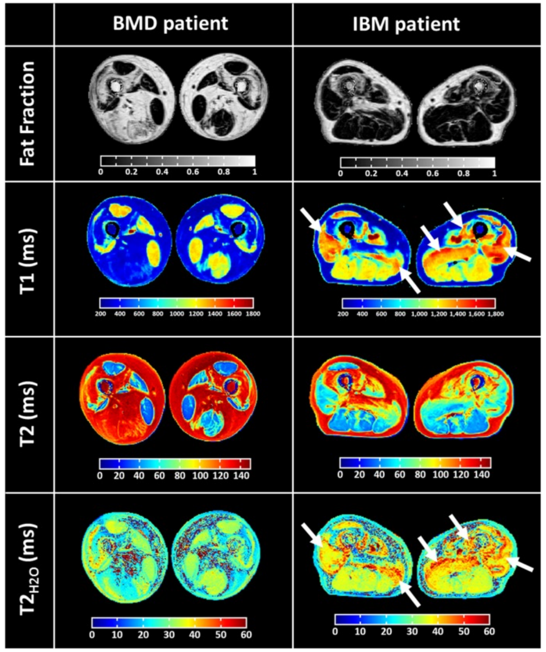
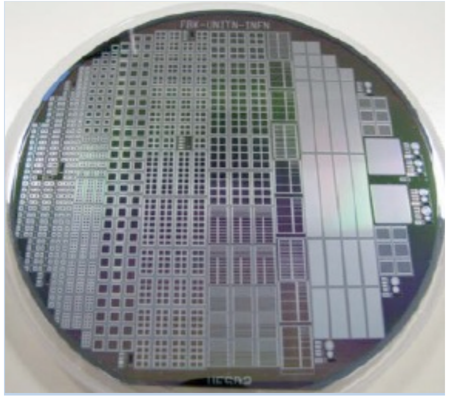
Istituto Nazionale di Fisica Nucleare

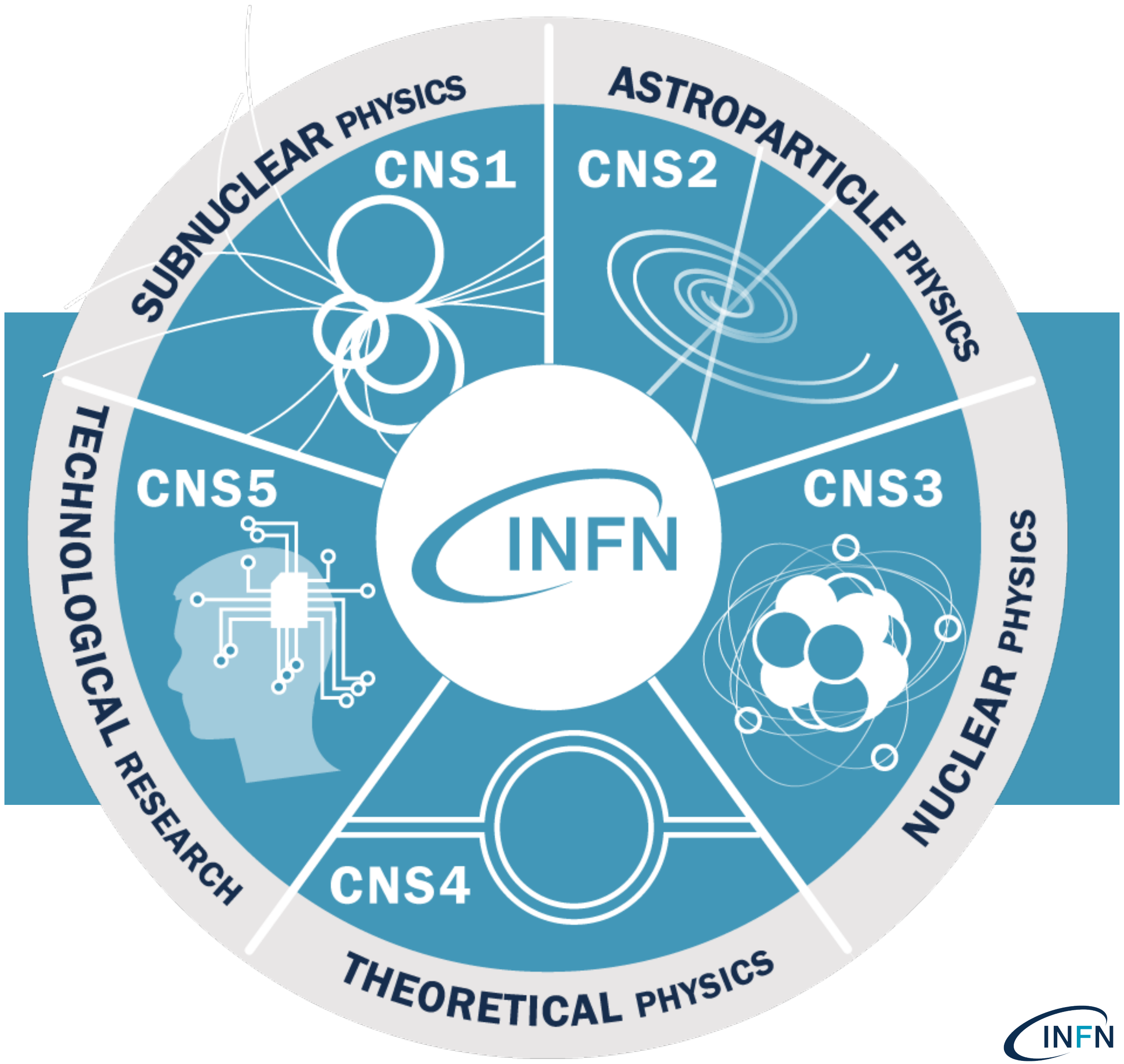


R&D on Detectors @INFN



Alberto Quaranta
President CSN5
University of Trento
INFN-TIFPA (Trento)

Scientific Commissions

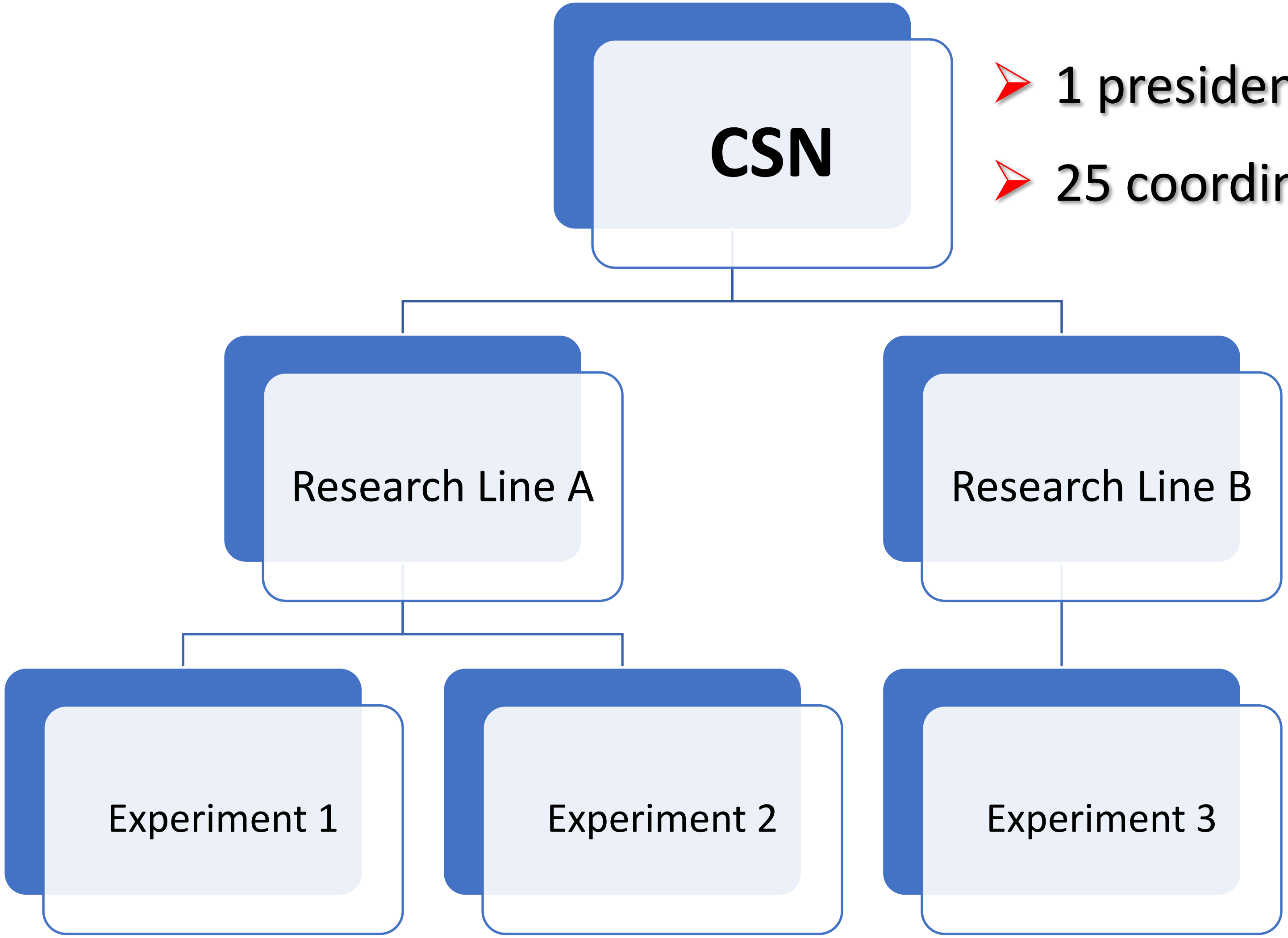


INFN

Role of Scientific Commissions

- They develop proposals for scientific programming and related financial estimates.
- They provide opinions on the scientific and technological aspects as well as opinions on the financial and organizational aspects of individual research proposals.
- They provide the evaluation and annual report of the activity carried out by each research initiative.
- They have its own fundings to distribute to the projects according with the decision of internal reviewers.

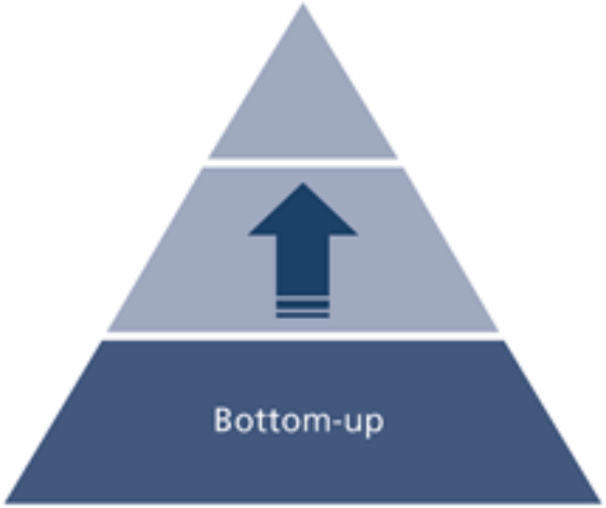
Structure



- 1 president.
- 25 coordinators.

Strategies

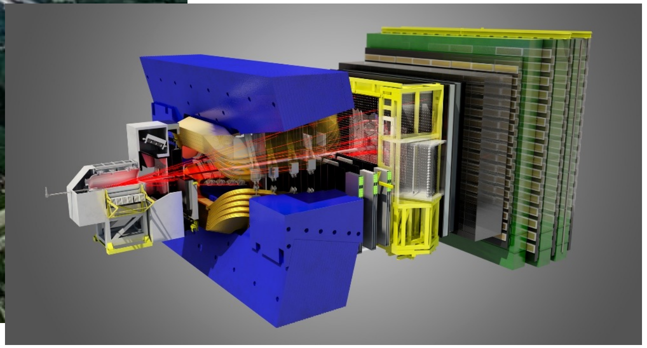
- Periodic meetings (2-4/y)
- Discussion about the approval and funding of new experiments/projects.
- Discussion about the state and the continuation of ongoing projects.
- Discussion about final reports of closing experiments.

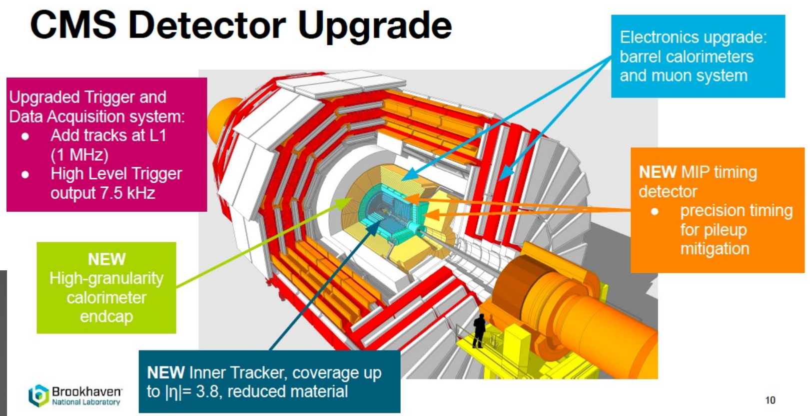


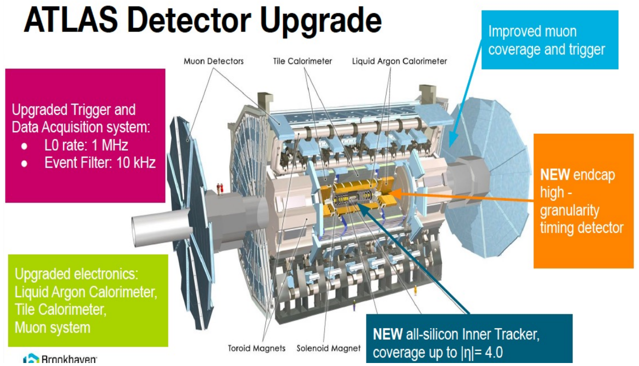
Selection and Reviewing

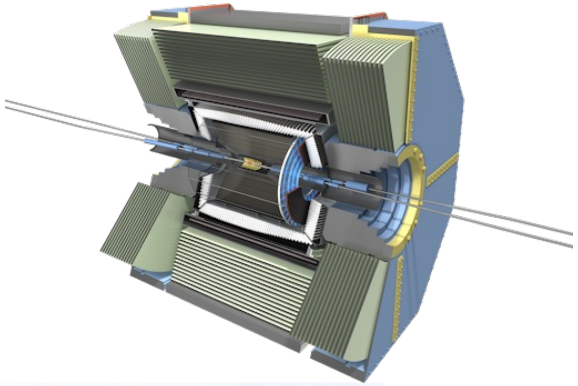
CSN1

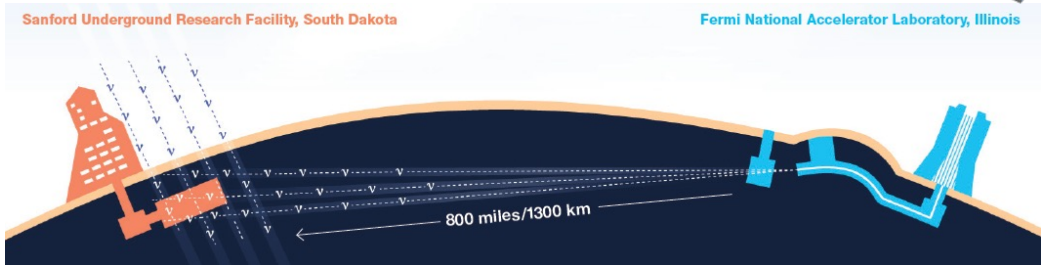
➢ President: Roberto Tenchini

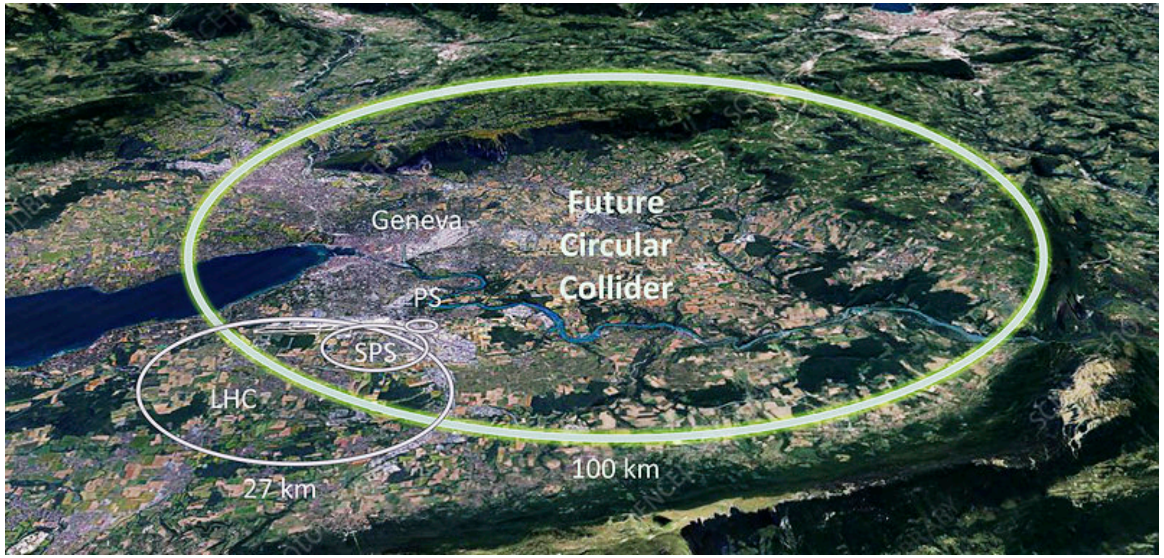












CSN1 Research Lines

Proton Structure
AMBER

Physics at Hadron Colliders
ATLAS
CMS
FASE2_ATLAS
FASE2_CMS
LHCf
SNDLHC

Heavy Flavour
BELLE2
BESIII
LHCb
NA62

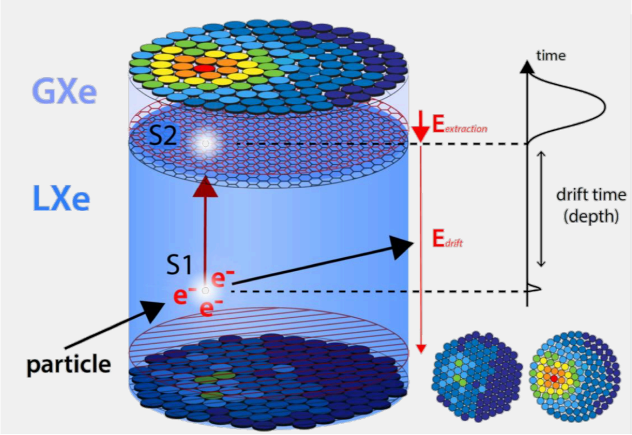
Charged Lepton Physics
GMINUS2
KLOE
LUXE
MEG
MUONE
PADME
PMU2E
UA9

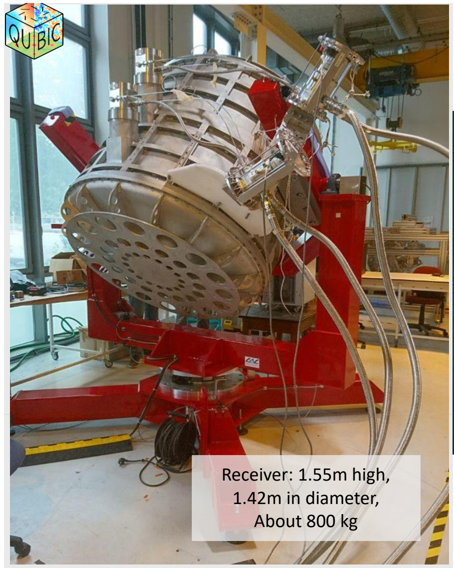
New Accelerators
IGNITE
RD_FCC
RD_MUCOL

Others
RD_FLAVOUR
SHADOWS
DUNE

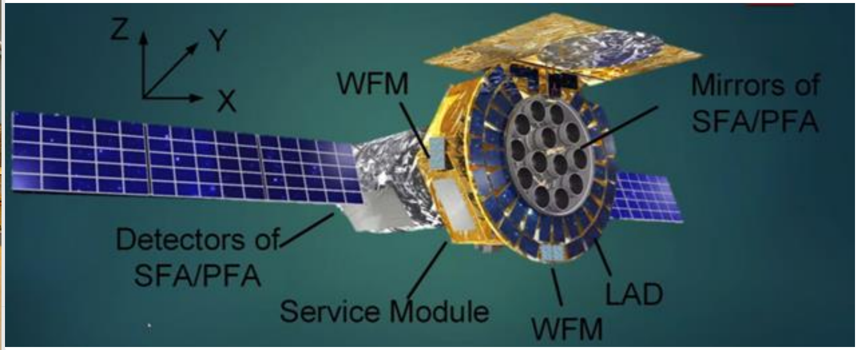
CSN2

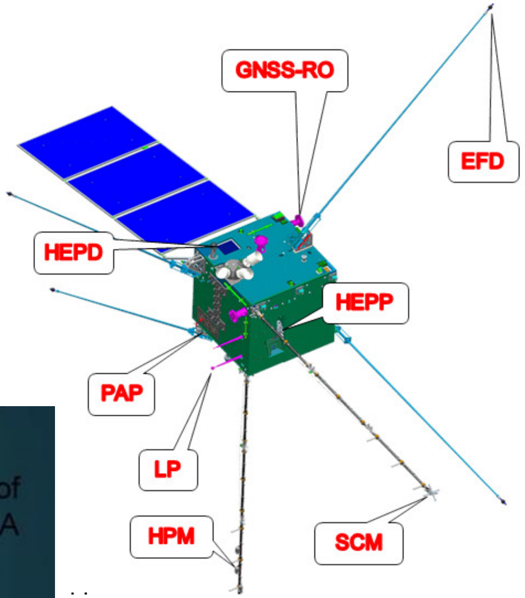
- President: Oliviero Cremonesi

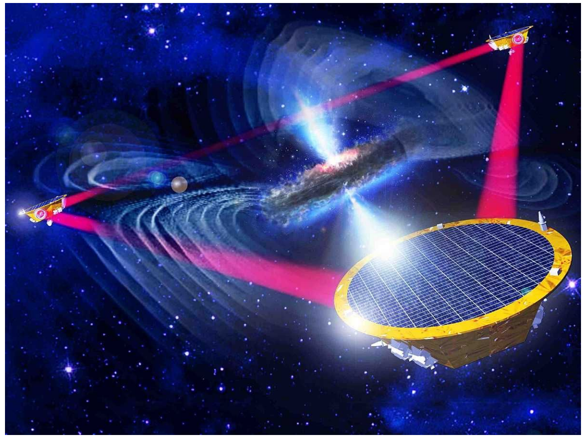


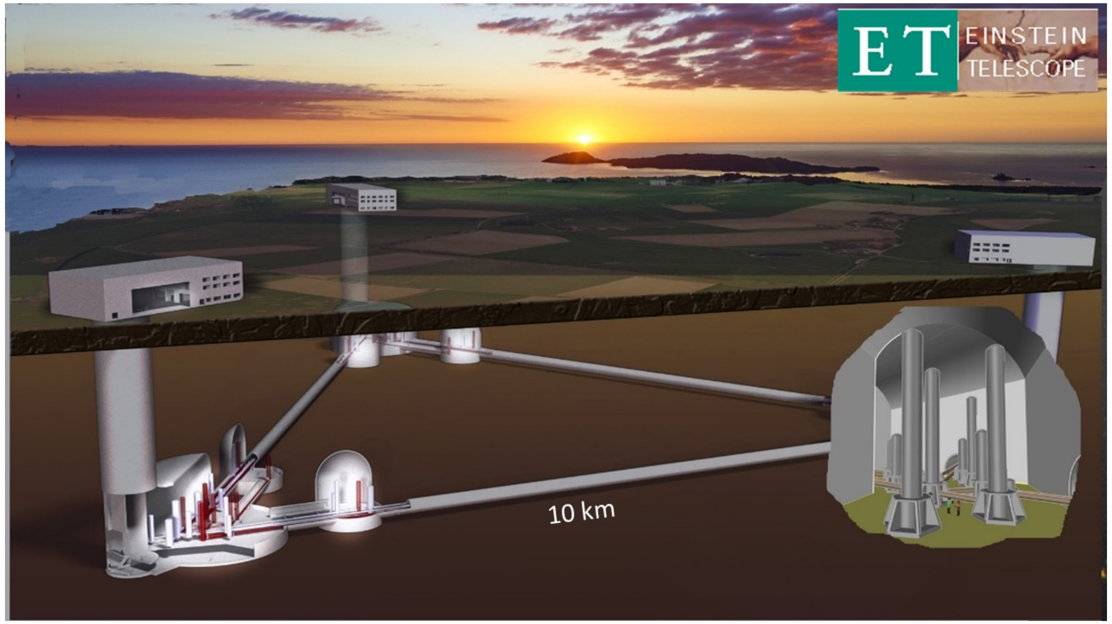


Receiver: 1.55m high,
1.42m in diameter,
About 800 kg









CSN2 Research Lines

Radiation from the Universe

AMS2
AUGER
CTA
FERMI
GAPS
HERD_DMP
KM3
LIMADOU_CSN2
LITEBIRD
LSPE
QUBIC
RESNOVA_CSN2
SPB2
SWGO
XRO

Gravitational Waves, General and Quantum Physics

ARCHIMEDES2
ET_ITALIA
GINGER
GRAFIQO
LISA
MEGANTE2
MOONLIGHT-2 S
ATOR_G
VIRGO

Dark Universe

BULLKID_DM
COSINUS_CSN2
CRESST
CYGNO
DAMA
DARKSIDE
EUCLID
NEWS
QUAX
SABRE
XENON

Neutrino Physics

CUORE_CUPID
ENUBET2
GERDA
HOLMES2
JUNO
KATRIN_TRISTAN
NUCLEUS
T2K

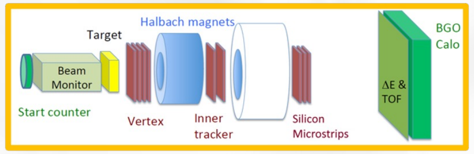
CSN3

➢ President: Paolo Giubellino

LUNA

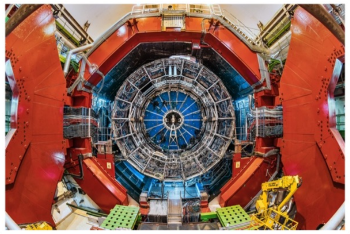
GAMMA

FOOT



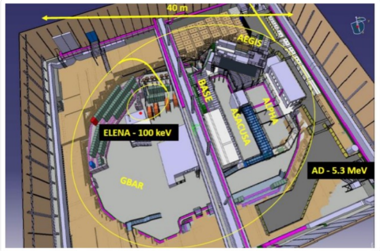
JLAB, MAMBO

ALICE



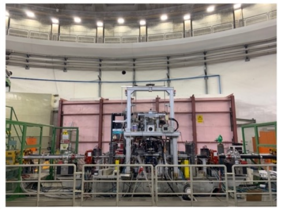
keV — **MeV** — **GeV** — **TeV**

E_{beam}

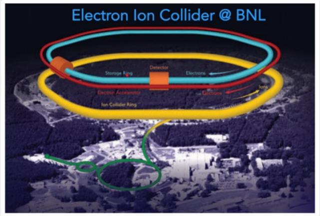


LEA

NUMEN, ASFIN2,NUCLEX, CHIRONE, FORTE…



SIDDHARTA, ULYSSES



EIC

JEDI

CSN3 Research Lines

PT Nuclear and Hdronic Matter
ALICE
NA60_PLUS

Nuclear Astrophysics
ASFIN2
ERNA2
LUNA3
N-TOF
PANDORA_GR3

Nuclear Structure and Reaction Dynamics
CHIRONE
FORTE
GAMMA
NUCLEX
NUMEN_GR3
PRISMA-PHYDES

Quark and Hadron Dynamics
EIC_NET
JLAB12
KAONNIS
MAMBO
REST
ULYSSES

Symmetries and Fundamental Interactions
FAMU
JEDI
LEA
VIP

Applications and Society Benefits
FOOT

CSN4

➢ President: Fulvio Piccinini

Strings and Field Theory

FLAG
GAGRA
GAST
GSS
NPQDC
QGSKY
SFT
ST&FI

Particle Physics Phenomenology

AMPLITUDES
APINE
ENP
LQCD123
PML4HEP
QCDLAT
QFT@COLLIDERS
SPIF
TPPC

Hadronic and Nuclear Physics

MONSTRE
NINPHA
NUCSYS
SIM

Mathematical Methods

BELL
DYNSYSMATH
GEOSYM_QFT
MMNLP
QUANTUM

Astroparticle Physics and Cosmology

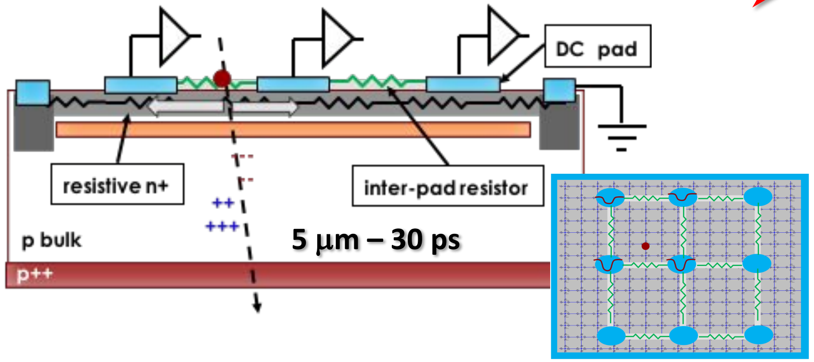
INDARK
NEUMATT
QUAGRAP
TASP
TEONGRAV

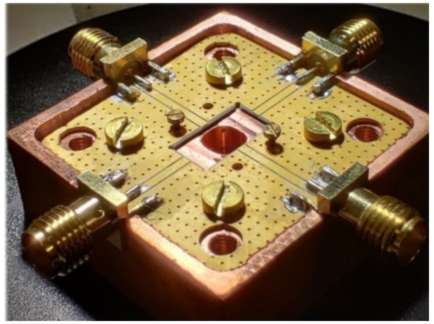
Statistical and Applied Field Theory

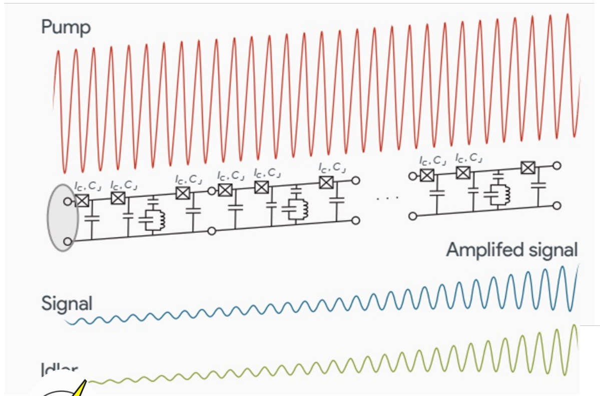
BIOPHYS
ENESMA
FIELDTURB
TIME2QUEST
LINCOLN

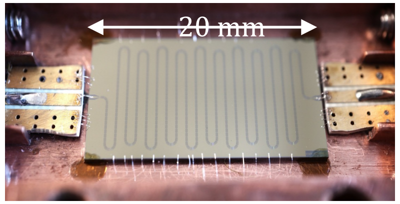
CSN5

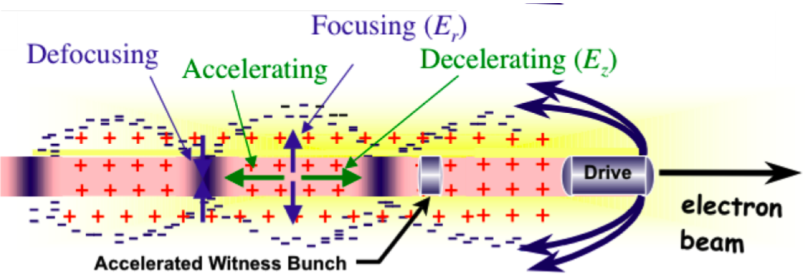
- President: Alberto Quaranta

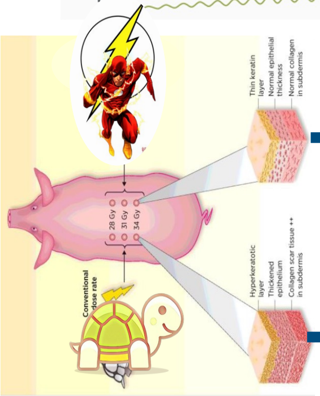




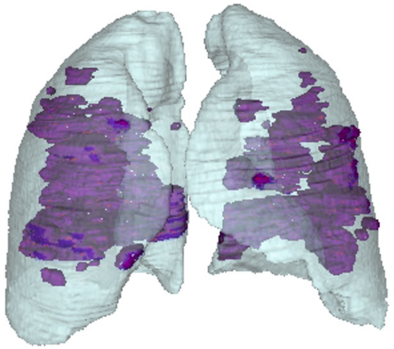


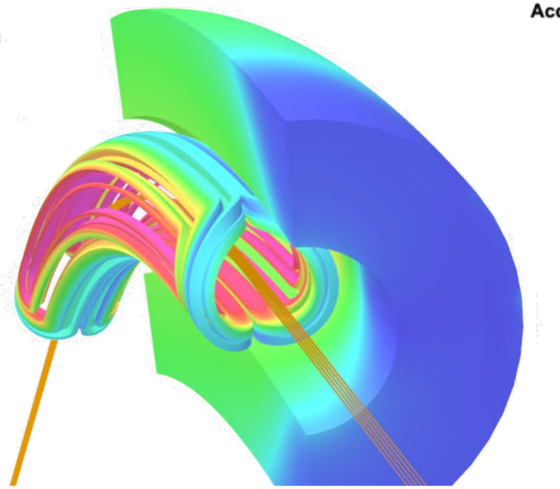


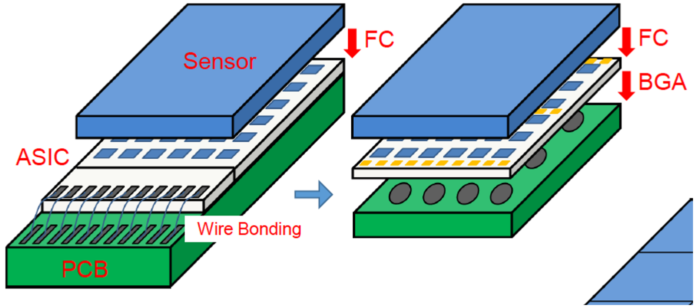




28 Gy 31Gy 34 Gy







CSN5 Research Lines

Accelerators

ALPHA_DTL_BETA
ASTRACT
CROWN
FUSION
HB2TF (CALL)
HISOL
HSMDIS
IONS
MICRON
PBT
PLASMA4BEAM2
SAMARA
SIG (CALL)
SL_BETATEST

Detectors, Computation and Electronics

4DSHARE
ADA_5D
ANNA
DARTWARS (CALL)
FEROCE
HASPIDE (CALL)
IBIS_NEXT
LITE-SPLD
MANIFOLD
MOONLIGHT
NGSA (CALL)
OPTIME
PHYDES
QUANTEP (CALL)
RD_PTOLEMY
RIPTIDE
SHINE
UNIDET
ACROMASS
ANEMONE
ASTAROTH
DIODE
GEANT4INFN
HIDRA2 (CALL)
IONOTRACK
MAG
uRTUBE (G)
N3G (CALL)
PRAD
OREO
PREDATOR (G)
QUB_IT
RHUM
ROUGE (G)
UTMOST

Interdisciplinary Research

ADMIRAL
ARES (G)
BEYOND (G)
BRAINSTAIN
CHNET_MAXI
DIDO (G)
EPISE
FRIDA (CALL)
MEDIPIX4
MIRO
NAMASSTE
PRAD
SAMADHA
SPHERE-X
SPOC
VI_HI
AI_INFN
ARTEMIS
BIOHOT
CHNET_BRONZE
CUPRUM_TTD
DISCOVER22
ETHIOPIA
HARDLIFE
MATHER3D
MUSICA (G)
NGSA (CALL)
RESILIENCE (G)
SEGNAR
SPHINX
T4QC
WIDMAPP

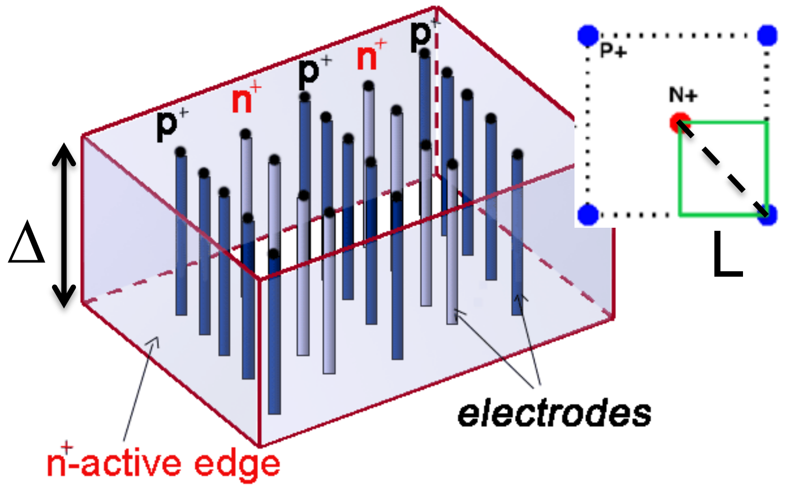
R&D @INFN on Detectors

- Activities developed and fundend by Scienfic Commissions.
- Expertise grown inside INFN.
- Over time, technological research has expanded beyond applications for high energies.
- Commission 5 devoted to R&D and «blue-sky» technologies.
- Interdisciplinary interests: e.d. medical physics, quantum technologies.

HEP Detectors

3D Sensors: a road from the idea to the application

- Gian Franco Dalla Betta – Trento



S. Parker et. al. NIMA 395 (1997) 328

Electrode distance (L) and active substrate thickness (Δ) are decoupled → L<<Δ by layout

High radiation hardness at relatively low voltage (power)
→ Main application in HEP

ADVANTAGES:

- Low depletion voltage (low power diss.)
- Short charge collection distance:
  - **Fast response**
  - **Tracking**
  - Less trapping probability after irr.
- Lateral drift → cell "shielding" effect:
  - Lower charge sharing
  - Low sensitivity to magnetic field
- Active edges

DISADVANTAGES:

- Non uniform spatial response (electrodes and low field regions).
- Higher capacitance with respect to planar (~3x for ~ 150 mm thickness).
- Complicated technology (cost, yield).

INFN 3D Sensor Developments with FBK (1)

➢ Gian Franco Dalla Betta – Trento

- INFN CSN5 TREDI (2005-2008)

→ Single-Type-Column (STC)

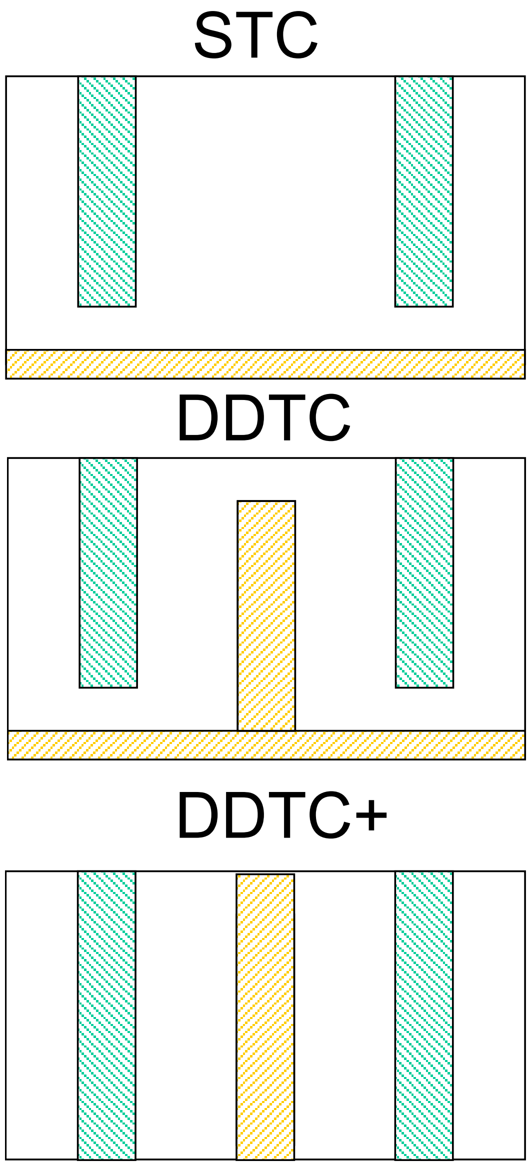
→ Double-Sided, Double-Type Column (DDTC)

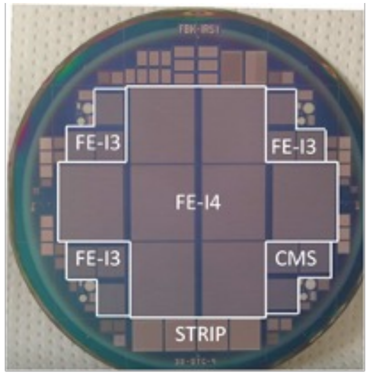
- INFN CSN5 TRIDEAS (2009-2012)

→ Double-Sided, Double-Type Passing Through Column (DDTC+)

- INFN CSN1 ATLAS (2010-2012)

→ Production for the ATLAS Insertable B-Layer using DDTC+ technology





Università degli Studi di Trento

INFN 3D Sensor Developments with FBK (2)

Istituto Nazionale di Fisica Nucleare

➢ Gian Franco Dalla Betta – Trento

- FBK upgrade of the clean room to 150 mm diameter wafers (2013)

- INFN CSN1 RD_FASE2 (2014-2017) + AIDA2020 (2015-2020)

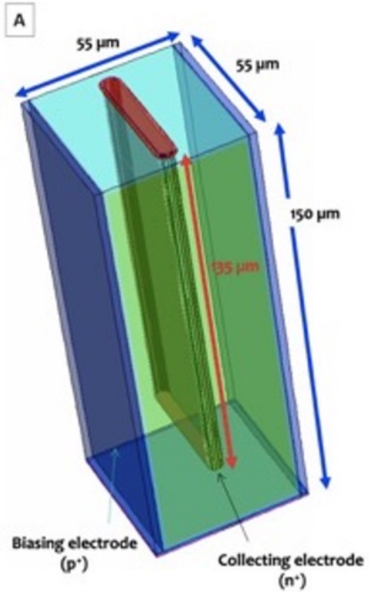
→ Joint ATLAS/CMS R&D for thin, small-pitch 3D pixels aimed at Phase2 upgrades

→ Due to small active thickness, single-sided technology with handle wafer while preserving back-side bias (Si-Si Direct Wafer Bonded substrates)

- INFN CSN1 RD_FASE_ATLAS and FASE2_CMS (2018-today)

→ Experiment-specific finalizations of 3D pixel developments

→ Currently in Production (for ATLAS ITk) and Pre-Production (for CMS)



- INFN CSN5 TIMESPOT (2018-2021) + AIDAInnova (2021-today)

→ Besides radiation hardness, 3D pixels also offer outstanding timing performance

→ Best results with trenched electrodes (~10 ps both before and after irradiation up to $2.5\times10^{16}\ n_{eq}/cm^2$) on test structures.

- INFN CSN1 LHCb (since 2022)

→ Aims at timing optimization with columnar 3D for LHCb VELO upgrade.

TimeSPOT

TIME and SPace real-time Operating Tracker

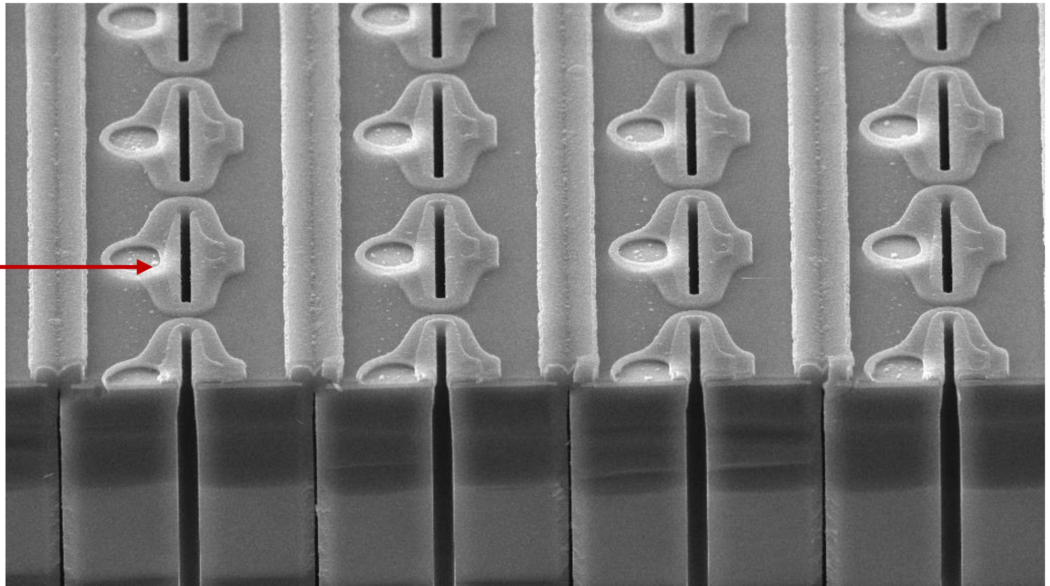
➢ Adriano Lai - Cagliari

Main target:

Develop and realize a demonstrator consisting of a complete yet simplified tracking **system**, integrating about 100-1000 read-out channels (pixels), satisfying the following characteristics:

- Space resolution: O (10 μm)
- Radiation hardness: > 10^{16} 1 MeV n_{eq}/cm^2 (sensors) and > 1 Grad (electronics)
- Time resolution: ≤ 50 ps per pixel (target ≈ 30 ps)
- Real time track reconstruction algorithms and fast read-out (data throughput > 10 TB/s)

TimeSPOT pixel
(size 55x55x150 μm³)
~2 fC MPV



trench electrodes:
SEM image from **TimeSPOT** production batch#2 (Dec 2020)

TimeSPOT

TIME and SPace real-time Operating Tracker

INFN

➢ Adriano Lai - Cagliari

Activities are organized in 6 work packages:

1. 3D silicon sensors: development and characterization (GF. Dalla Betta Trento)
2. 3D diamond sensors: development and characterization (S. Sciortino Firenze)
3. Design and test of pixel front-end (V. Liberali Milano)
4. Design and implementation of real-time tracking algorithms (N. Neri Milano)
5. Design and implementation of high speed readout boards (A. Gabrielli Bologna)
6. System integration and tests (A. Cardini Cagliari)

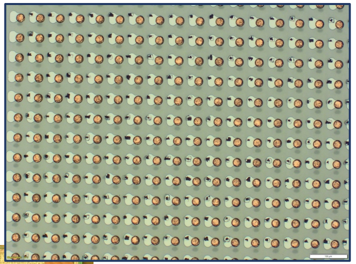
Sezioni INFN: Bologna, Cagliari, Genova, Ferrara, Firenze, Milano, Padova, Perugia, Torino, TIFPA. ≈ 60 heads, ~ 20 FTE. People from **LHCb, ATLAS, CMS + others**

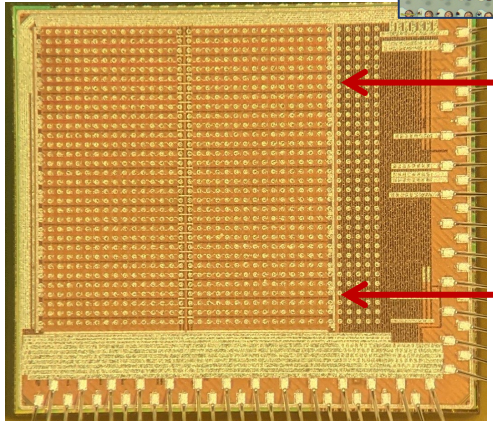
WP6: the Timespotter® demonstrator

A mini-tracker, under beam in summer-autumn 2022

➤ Adriano Lai - Cagliari

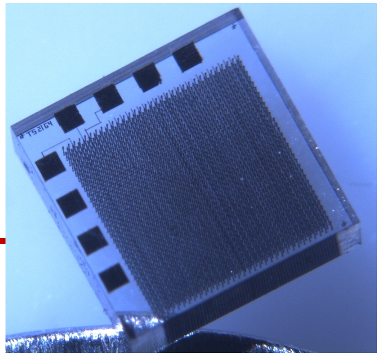
8 samples of each «flavour» are under preparation at IZM



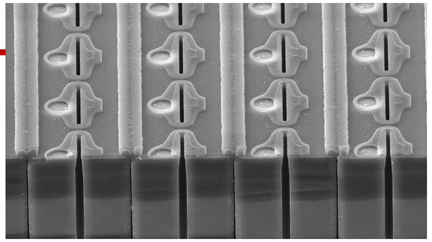


Under **Hybridization** @IZM (Delays!)

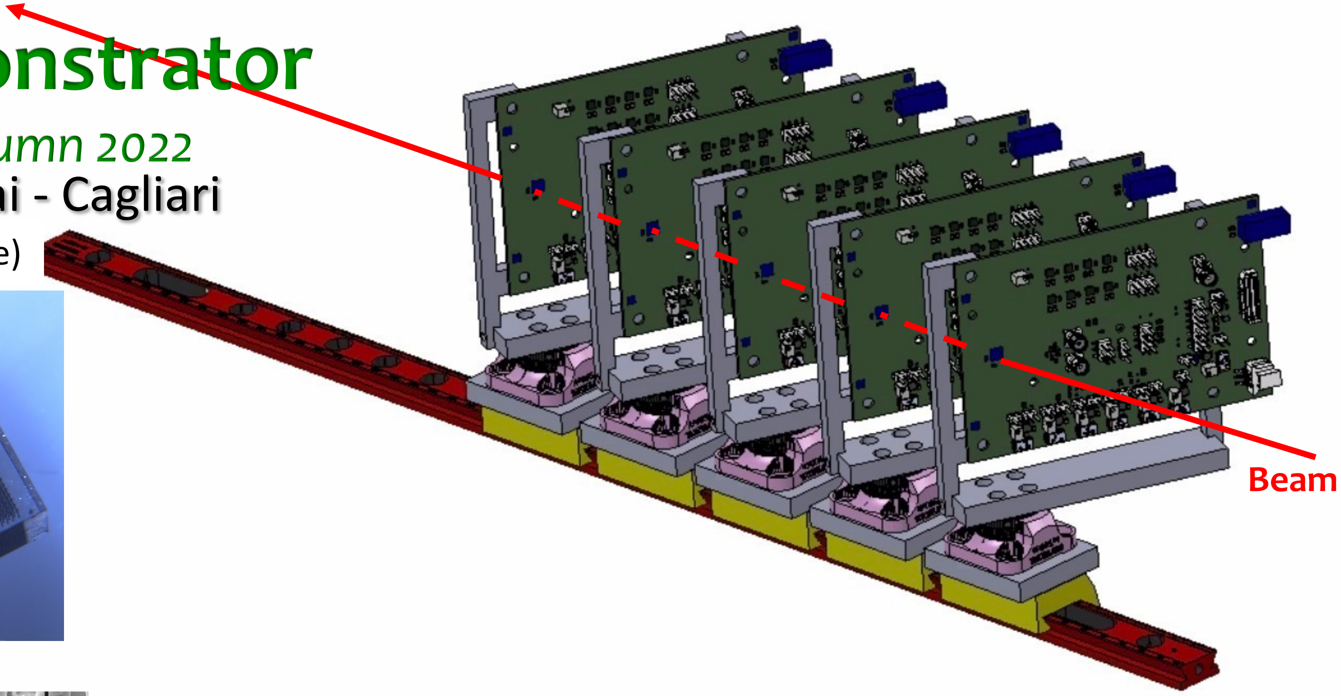
Diamond (Firenze)



32x32 matrix

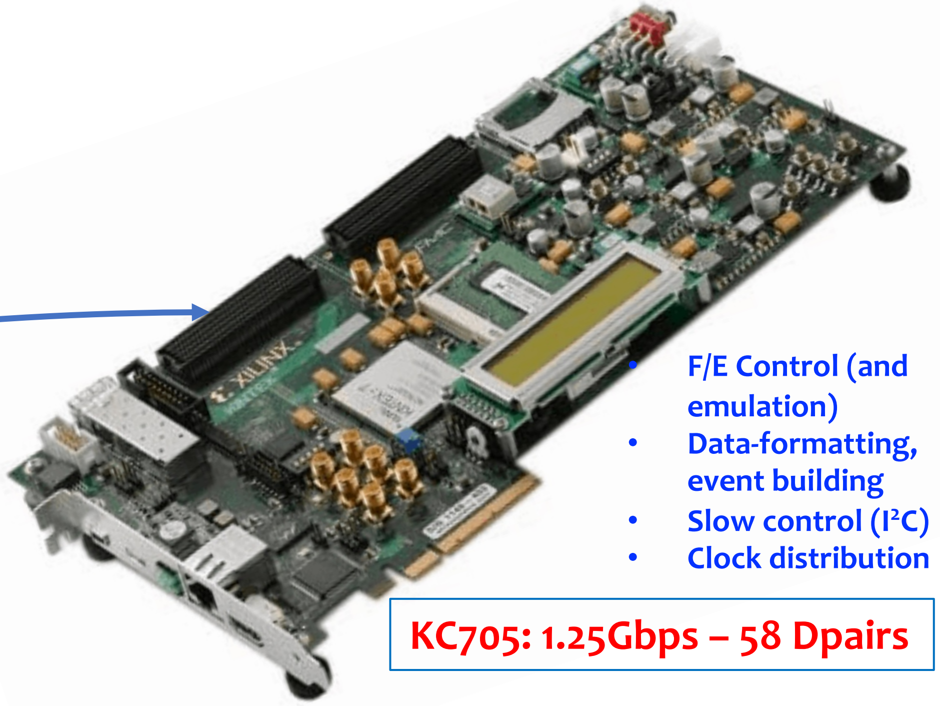


Silicon (FBK)



TS1-PCB 120x80 mm² (Cagliari, Milano, Torino)

Hi-speed, Hi-density Samtec twinax



- F/E Control (and emulation)
- Data-formatting, event building
- Slow control (I²C)
- Clock distribution

KC705: 1.25Gbps – 58 Dpairs

C. Cialdai, INFN Firenze

Falaphel

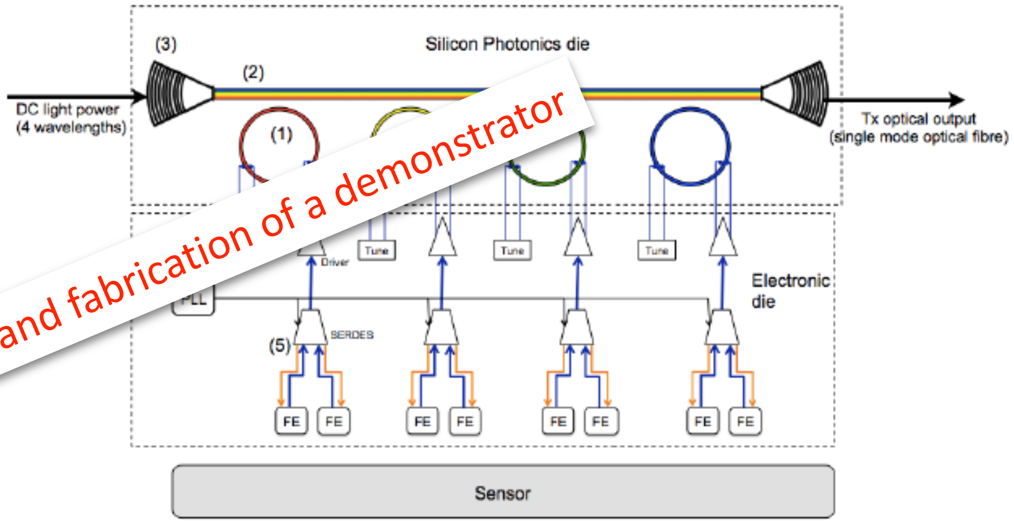
- Fabrizio Palla – Pisa

Hybrid integration of Silicon Photonics modulators with high-speed radiation hard (≥1 GRad) electronics in 28 nm **and front-end readout**

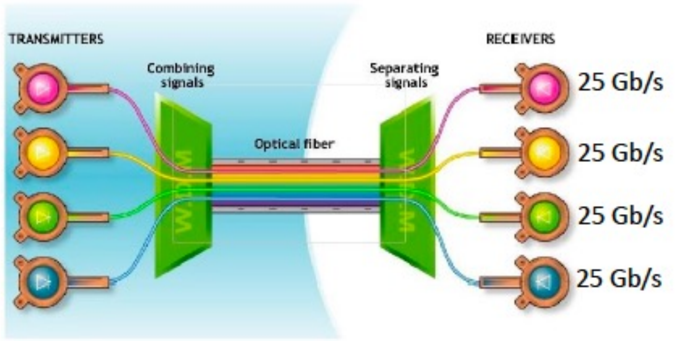
- Aggregated 100 Gb/s links using wavelength division multiplexing (4 wavelengths on a single optical fibre) and Integrated Front-End electronics

Table 1: Technology benchmarks and envisioned performance improvement with FALAPHEL

	State of the art – VCSEL+	This project (FALAPHEL)
Data rate	10 Gb/s	≥100 Gb/s
Radiation TID	200 Mrad (2 MGy)	≥1 Grad (10 MGy)
Total Fluence	10^{15}n/cm^2	>5 x 10^{16}n/cm^2



Design and fabrication of a demonstrator



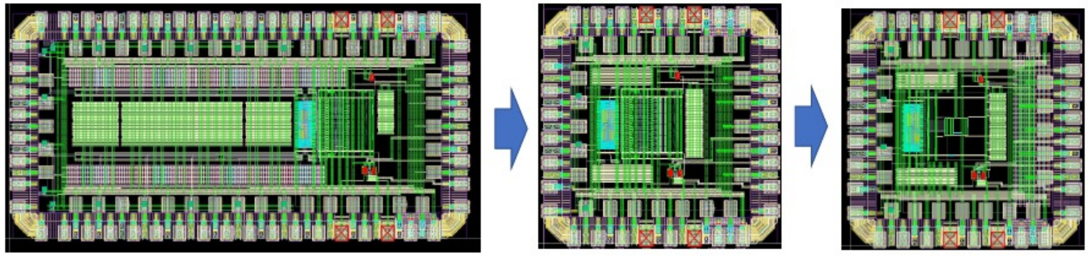
WDM allows to modulate different wavelengths sent over the same physical channel, instead of using multiple fibers for each communication

Falaphel

➢ Fabrizio Palla – Pisa

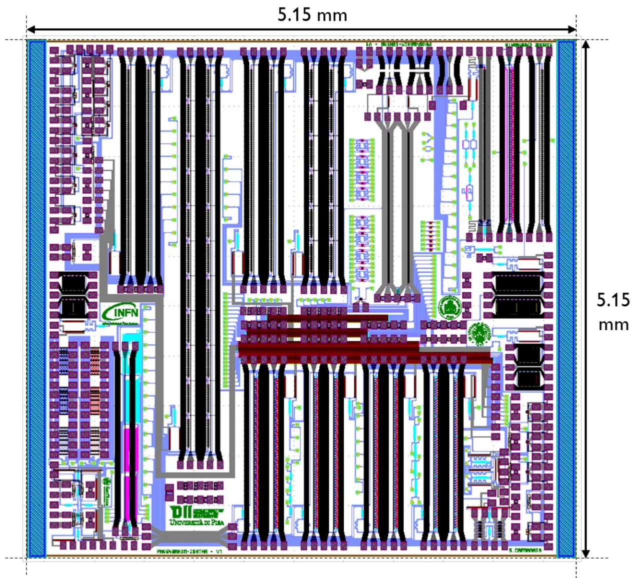
- Target data rate 10 Gb/s

20 Gb/s **20** Gb/s

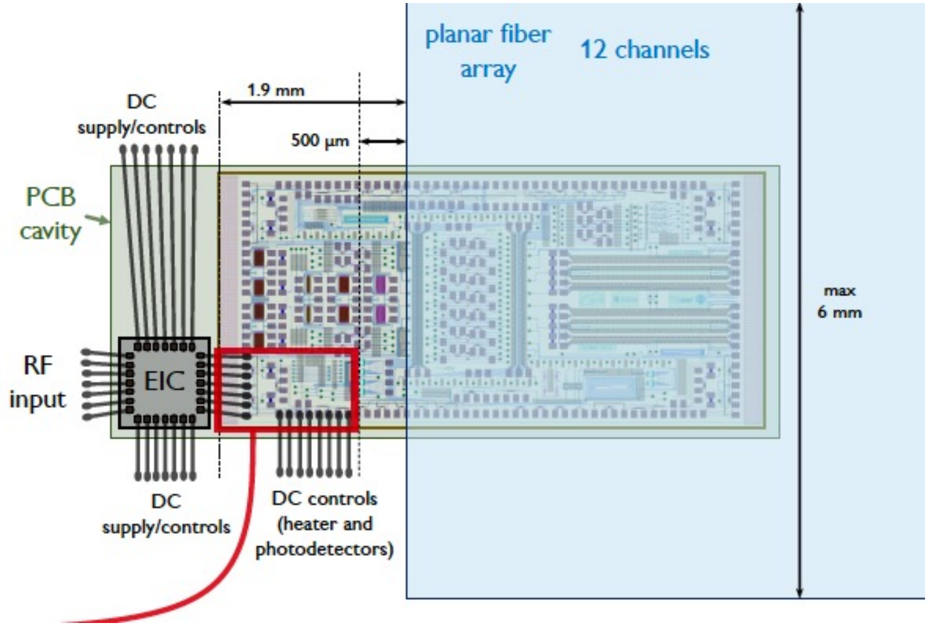


SER_V1 (SDR – CML) **SER_V2 (DDR – CML)** **SER_V3 (DDR – CMOS)**

28 nm HPC+ TSMC
Target data rate 25 Gb/s
TID 1 Grad

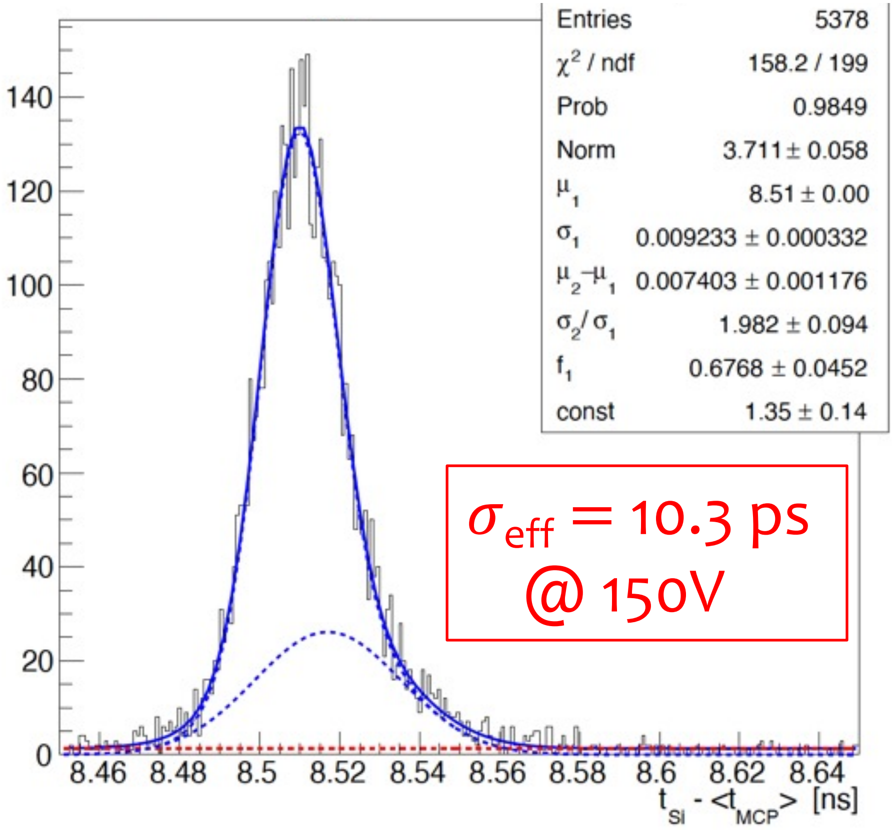


PICv1 SiPh Modulators for HEP
IMEC iSipp50G

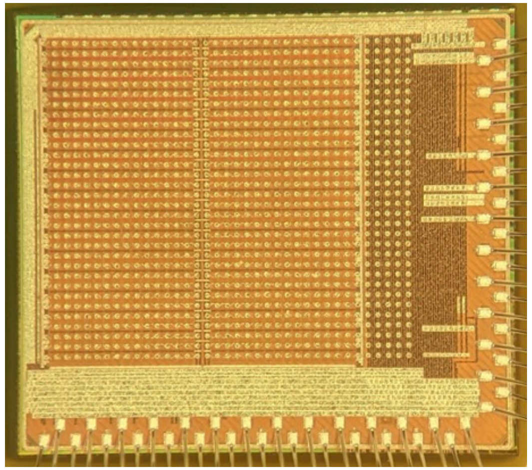


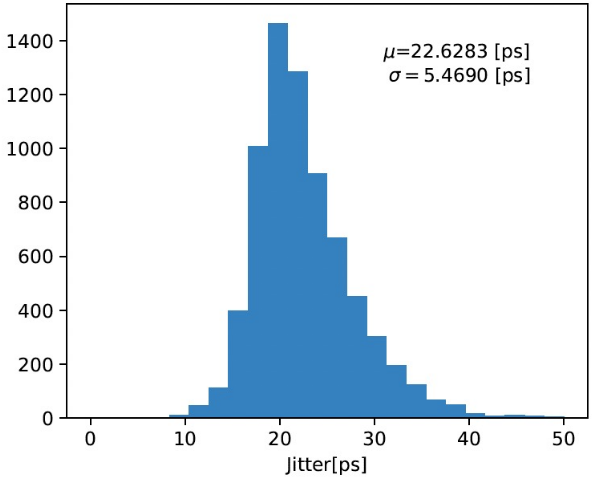
(starting) Results

Irradiated @ 2.5 10^{16} n_{eq}/cm^2 , α_{tilt} = 0°



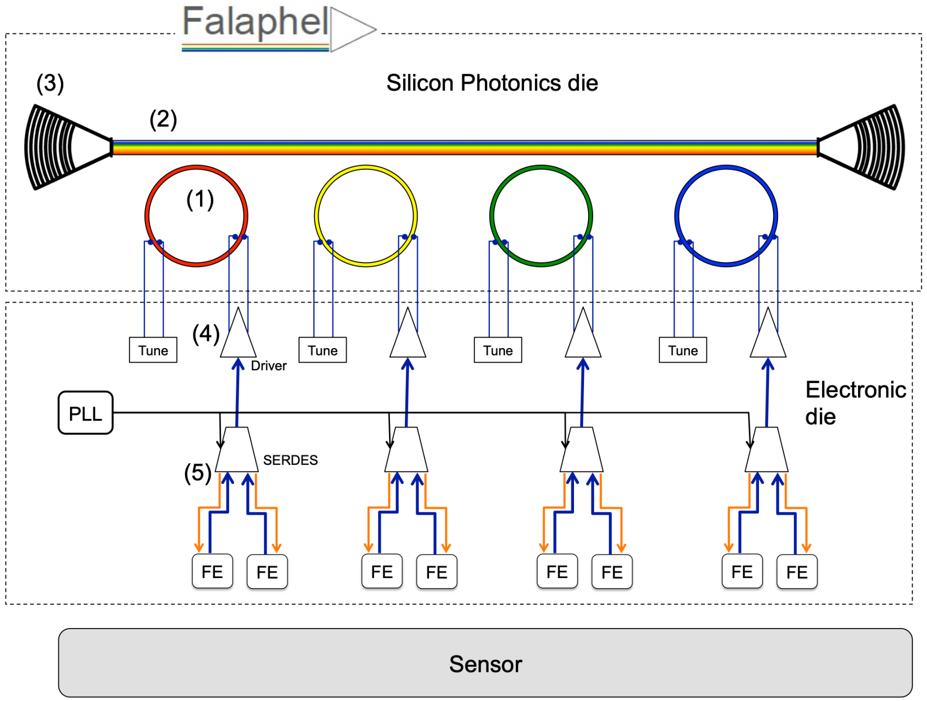
CMOS 28-nm Timespot1 ASIC

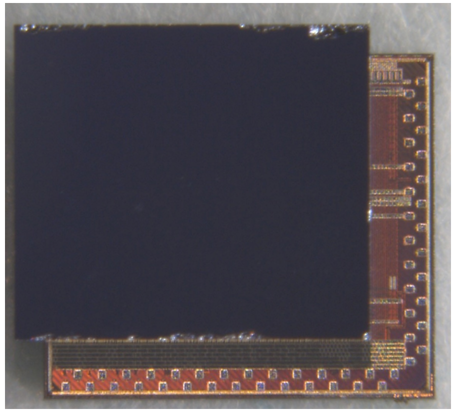




Distribution of the TA standard deviation across 1024 channels and 7 phases. Each point is computed from **100** repeated measurements.

Falaphel



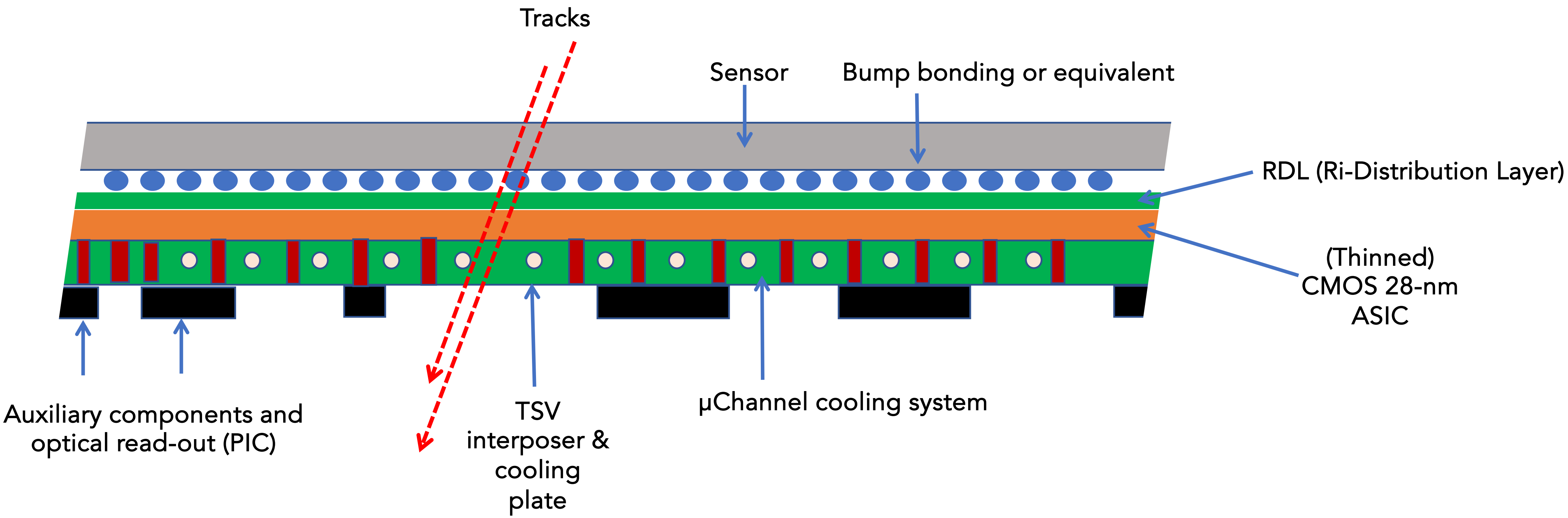


TimeSPOT
TIME and SPace real-time Operating Tracker

Scaltech28
28nm rad hardness

Vision/concept of a cut of the IGNITE system module

- Adriano Lai - Cagliari



Target deliverable of the IGNITE project:

- **A complete module (sensor, read-out ASIC, vertical IC, photonic circuit for data links, cooling system)**
- **The module development as a route to optimize material budget issues and High Density Interconnectivity between the device stages**
- **The whole thing below 0.8 (LHCb) ÷ 0.5 (NA62) % X_0**

Adriano Lai - Cagliari

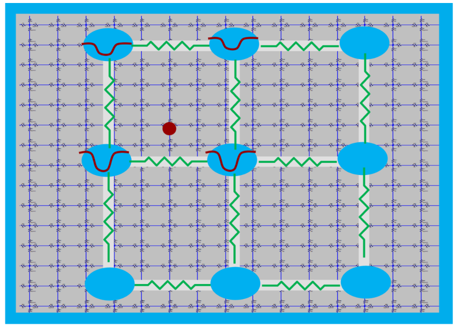
Status (4D-tracking)

	Status (4D-tracking)	Target
Space resolution (TimeSPOT)	$\sigma_s \approx 15$ µm (55 µm pitch)	$\sigma_s < 10$ µm (smaller pitch, clustering)
Time resolution (TimeSPOT)	$\sigma_t \approx 10$ ps (sensor only) $\sigma_t \approx 50$ ps (F/E + TDC only) $\sigma_t \approx 100$ ps (system)	$\sigma_t \approx 10$ ps (sensor only) $\sigma_t < 30$ ps (F/E + TDC only) $\sigma_t < 50$ ps (system)
Data Bandwidth (Falaphel)	BW ≈ 10 Gbps per chip BW ≈ 20 Gbps per Ser/Driver	BW ≈ 100 Gbps per chip (with data reduction on F/E) BW ≈ 25 Gbps per Ser/Driver
ASIC area size (TimeSPOT)	A ≈ 3 mm^2, not abuttable	A ≥ 2 cm^2, 3- or (preferably) 4-side abuttable
Power density (TimeSPOT)	P' ≈ 2 W/cm^2 (with timing) P' ≈ 1 W/cm^2 (without timing)	P' < 1.5 W/cm^2 (with timing) P' < 1 W/cm^2 (without timing)
Rate/pixel (TimeSPOT)	N/A	50 - 300 kHz (depending on pitch)
Rad hardness (TimeSPOT, ScalTech28)	$2.5\ 10^{16}$ 1 MeV $n_{eq}\ cm^{-2}$ (sensor) ≥ 1 Grad (CMOS 28nm estimate)	≈ 5 x 10^{16} 1 MeV $n_{eq}\ cm^{-2}$ (sensor) ≥ 1 Grad (CMOS 28nm estimate)

4DSHARE (CSN5)

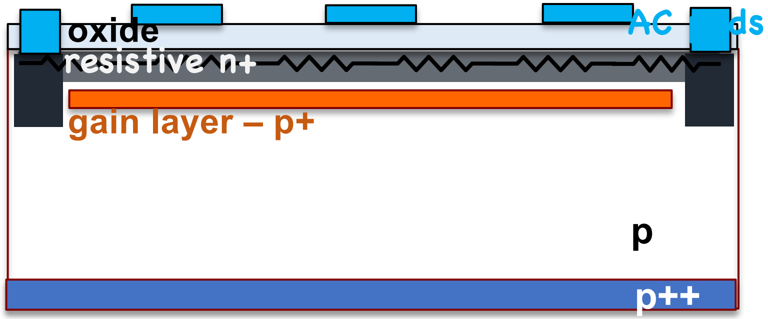
➤ Roberta Arcidiacono - Torino.

- The introduction of **internal moderate gain:**
  Low-Gain Avalanche Diode (LGAD)
  - It provides large signals with short rise time and low noise, ideal for timing
- **Intrinsic charge sharing:**

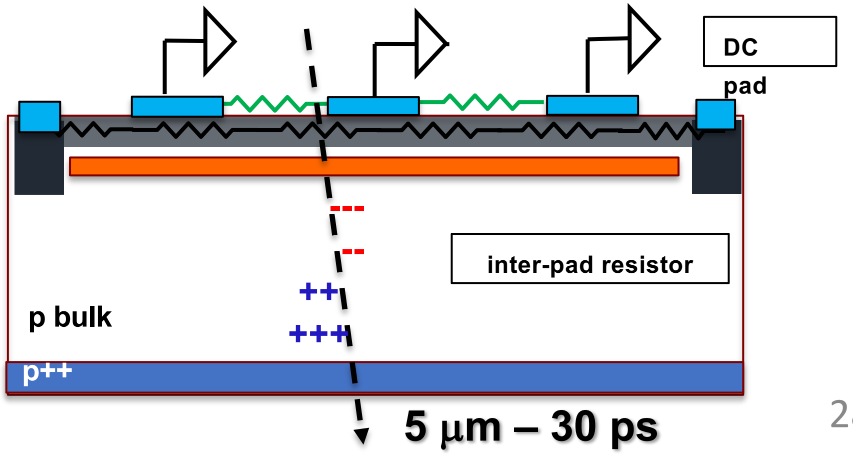


Resistive AC-coupled read-out LGAD (AC-LGAD or RSD)

- It provides intrinsic signal sharing, which is a **key ingredient to excellent spatial resolution using large pixels**
- **100% detector efficiency**, 100% Fill Factor, reduced material budget and **enhanced timing performance**
- the coordinates are reconstructed exploiting the charge sharing amongst neighboring electrodes
- State-of-the-art RSDs at gain = 30 achieve a spatial resolution of about 3-4% of the pitch size



- Oxide layer for AC-coupling is removed, **read-out electrodes implanted onto the resistive layer**
- Inter-pad resistors (or isolating trenches) added to create **a "cage" where the signal is confined**
- Signals are read out via the closest DC electrodes; leakage current removed at each electrodes

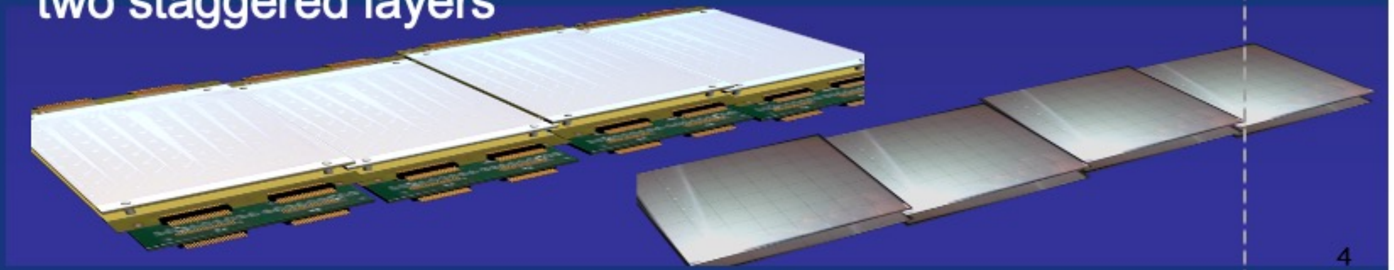


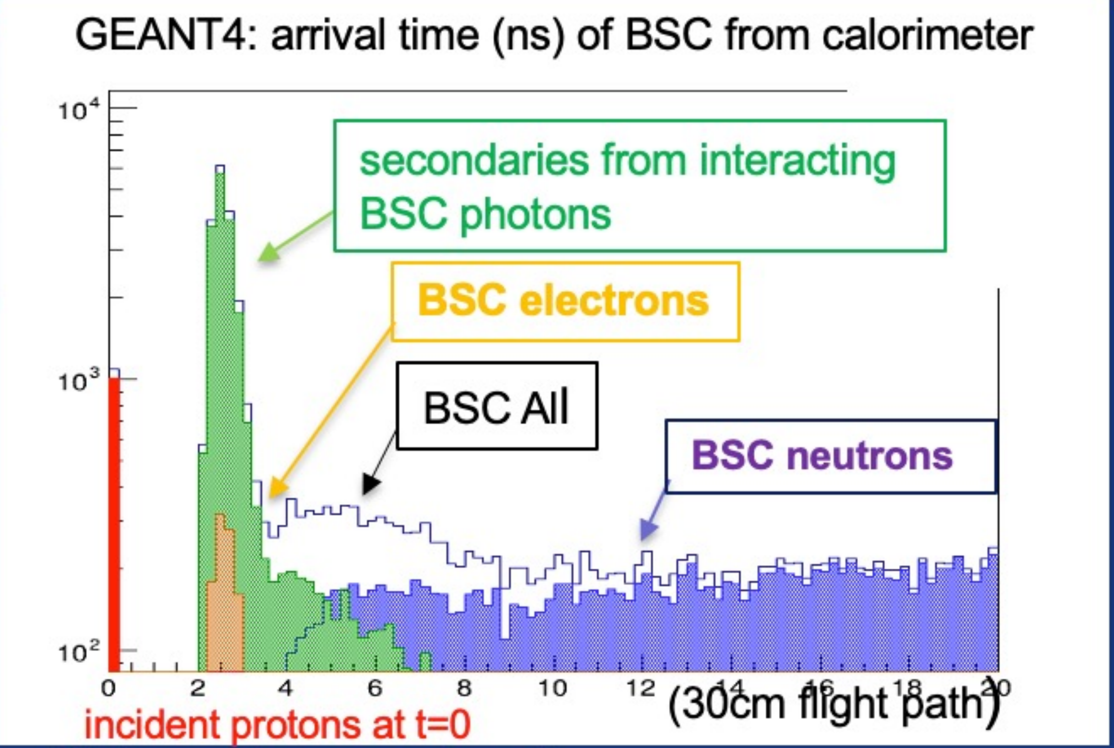
ADA_5D project — Charge & Timing 5D detector: x,y,z, charge, time

Development of a pixelated ToF detector with 100 ps time resolution (based on **LGAD** sensors) for the **rejection of Backscattering (BSC)** and the charge identification of CR elements with atomic number up to Z=30 in space experiments.

➢ Pier Simone Marrocchesi - Pisa.

two staggered layers





Charge measurement:

- large dynamic range > 1000 m.i.p.
- charge resolution for proton < 0.1

=> 200-300 μm thick sensors

Timing measurement:

- sub-ns resolution (e.g., for 20 cm flight path → 100 ps is required)

Space resolution and granularity:

- modest granularity (3mm x 3mm pixels) to cover large O(m^2) sensitive area

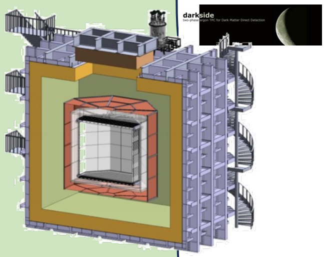
➤ Alessandro Montanari – Bologna

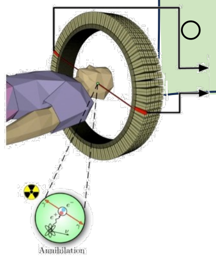
Main Features

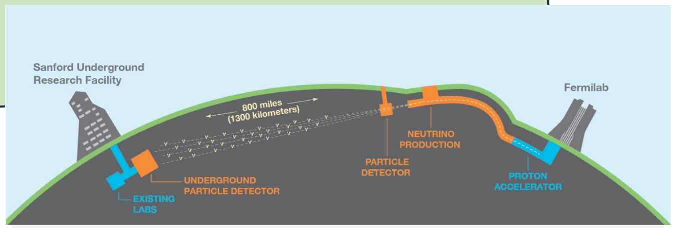
- Clear entrance window
  - ✓ Better Fill Factor
- Small SPAD sizes:
  - ✓ High Dynamic range
  - ✓ Better Radiation Tollerance
- All the contacts on one side:
  - ✓ Easy to couple Read Out Chip
- Improved VUV Photon Detection Efficiency

Applications

- Liquid Scintillators TPC (Argon, Xenon..)
- Imaging in Liquid Scintillators
- High radiation environments
- Cherenkov detectors
- High dynamic ranges Calorimeters
- TOF-PET

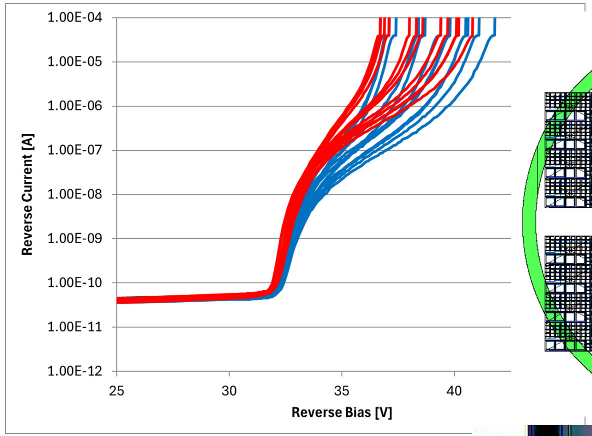


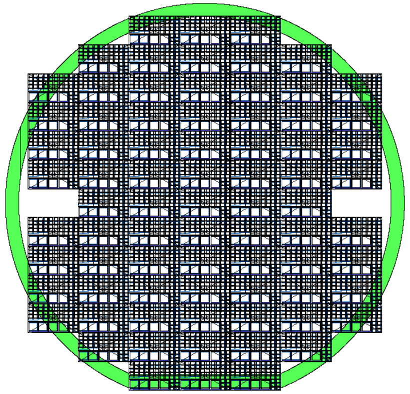


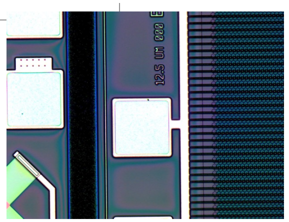


Main Technological Challenges

1. Design new cell (must limit Crosstalk, AfterPulse, Dark Count rate) DONE
2. Bulk removal (keeping flat surface: ‹ 1 μm)   DONE
3. Plasma doping on backside (dopant)
4. Laser annealing (activation of dopant)



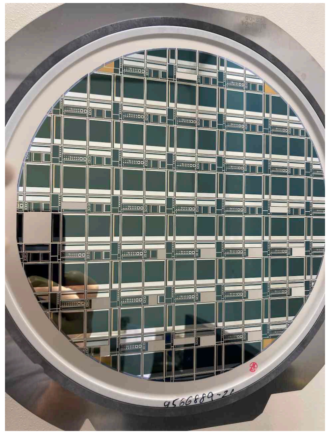




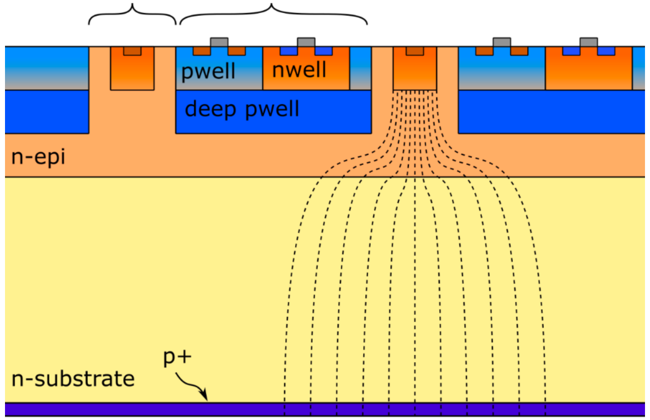
ARCADIA

Advanced Readout CMOS Architectures with Depleted Integrated sensor Arrays

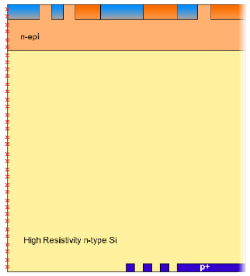
➤ Manuel Dionisio Da Rocha Rolo - Torino



- ARCADIA: customized 110nm CMOS sensor design and fabrication platform on LF11is technology
  - Sensor R&D and Technology, CMOS IP Design and Chip Integration, Data Acquisition
  - MD3: system-grade full-chip FDMAPS for Medical (pCT), Future Leptonic Colliders and Space Instruments
  - Scalable FDMAPS architecture with very low-power: **10 mW/cm²**
  - Fully-depleted monolithic active micro strips with fully-functional embedded readout electronics
  - Ongoing R&D for the implementation of monolithic CMOS sensors with gain layer for fast timing
  - Custom BSI process allow to develop fully-depleted thick sensors (400µm) for soft X-ray imaging

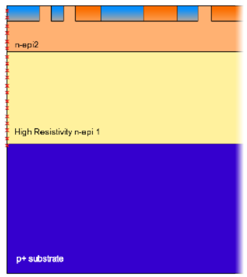


HR n+ Wafers with backside lithography

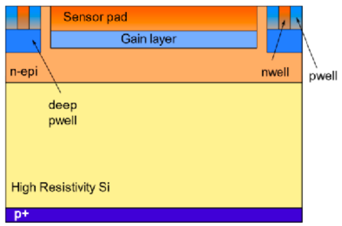


HR n+ Wafers without backside lithography

p+ Wafers with double epic

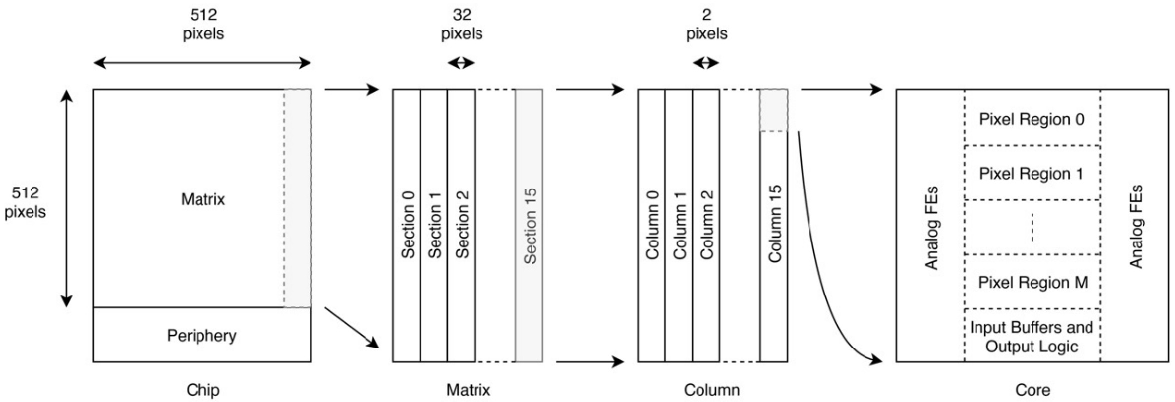


Wafer split with p-gain implant underneath the n+ collecting electrode



ARCADIA

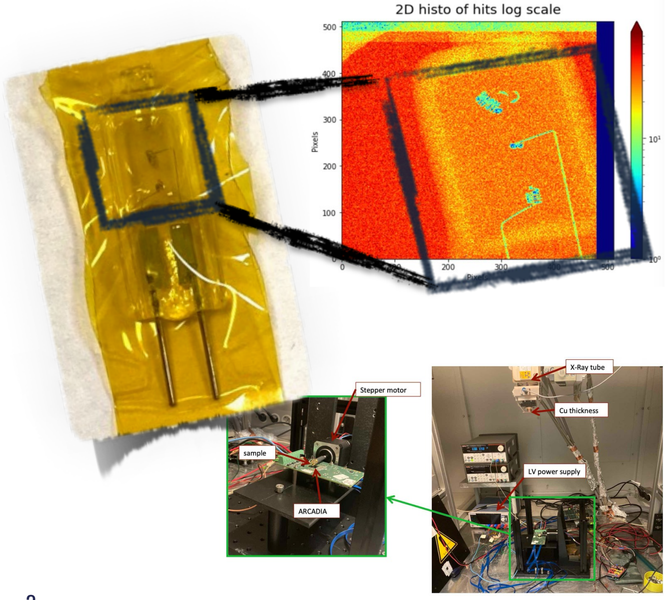
➢ Manuel Dionisio Da Rocha Rolo - Torino



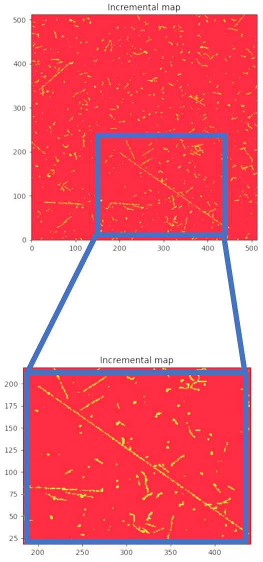
- Pixel size 25 µm x 25 µm, Matrix core 512 x 512
- 1.28 x 1.28 cm^2 silicon active area, "side-abuttable"
- Triggerless data-driven readout, clockless pixel matrix
- Event rate up to 100 MHz/cm^2)
  - High-rate operation (16 Tx)*: 17-30 mW/cm^2
  - Low-power operation (1 Tx): **10 mW/cm^2**

*configurable data transceiver driving strength

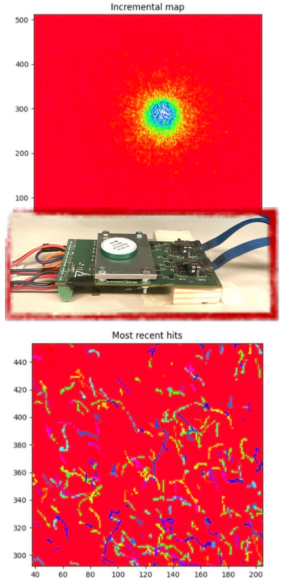
X-ray setup (2 mA, 40 kV) with W tube (8.40 - 9.67 keV)



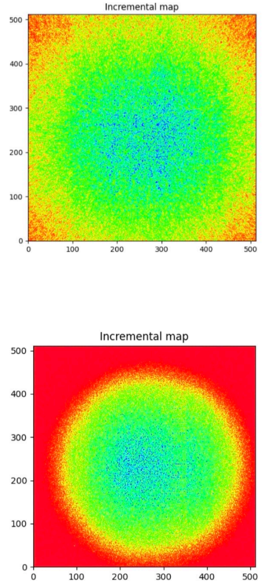
Cosmic rays (tilted sensor)



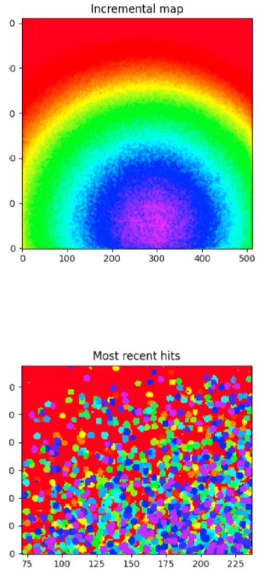
^{90}Sr (collimated 1mm)



^{90}Sr (uncollimated)



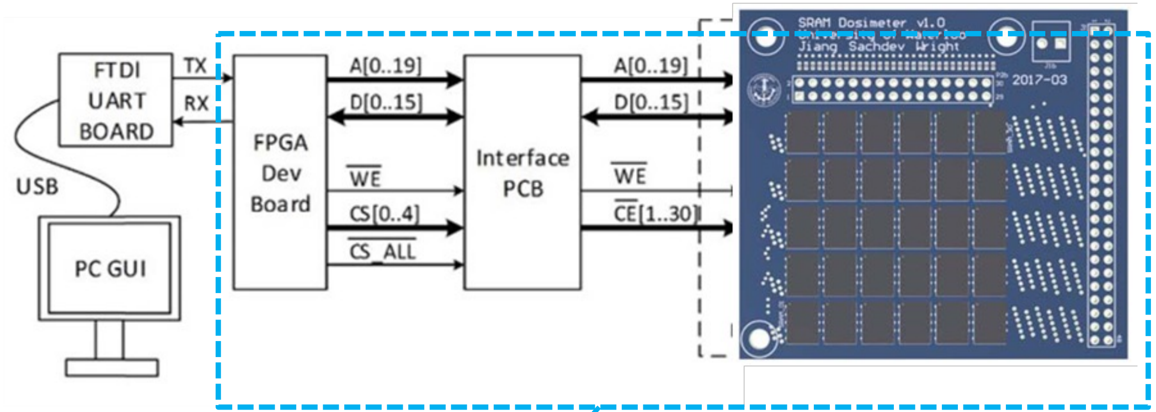
^{241}Am

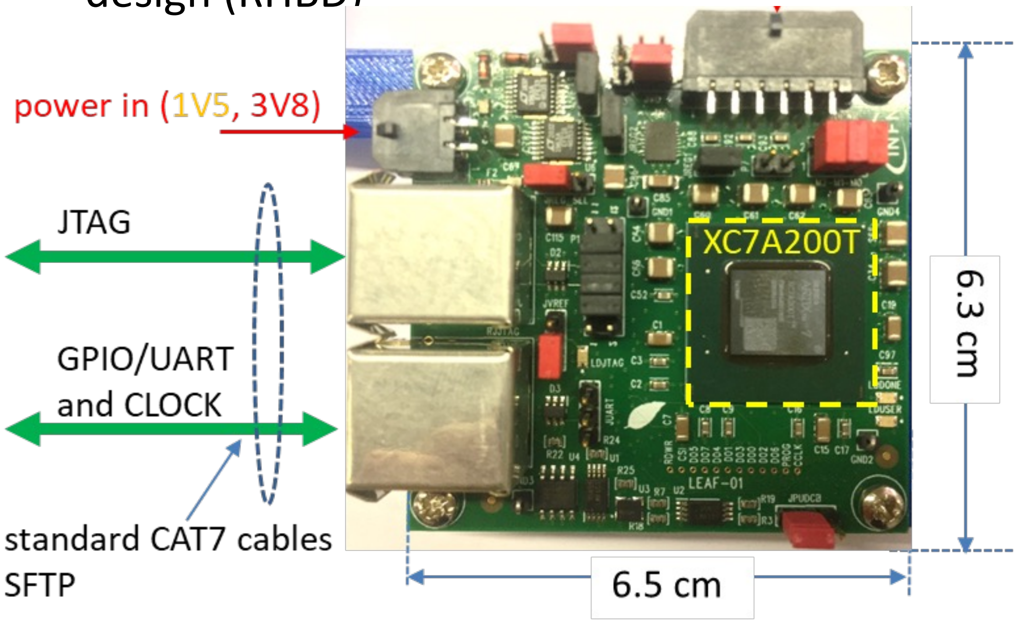


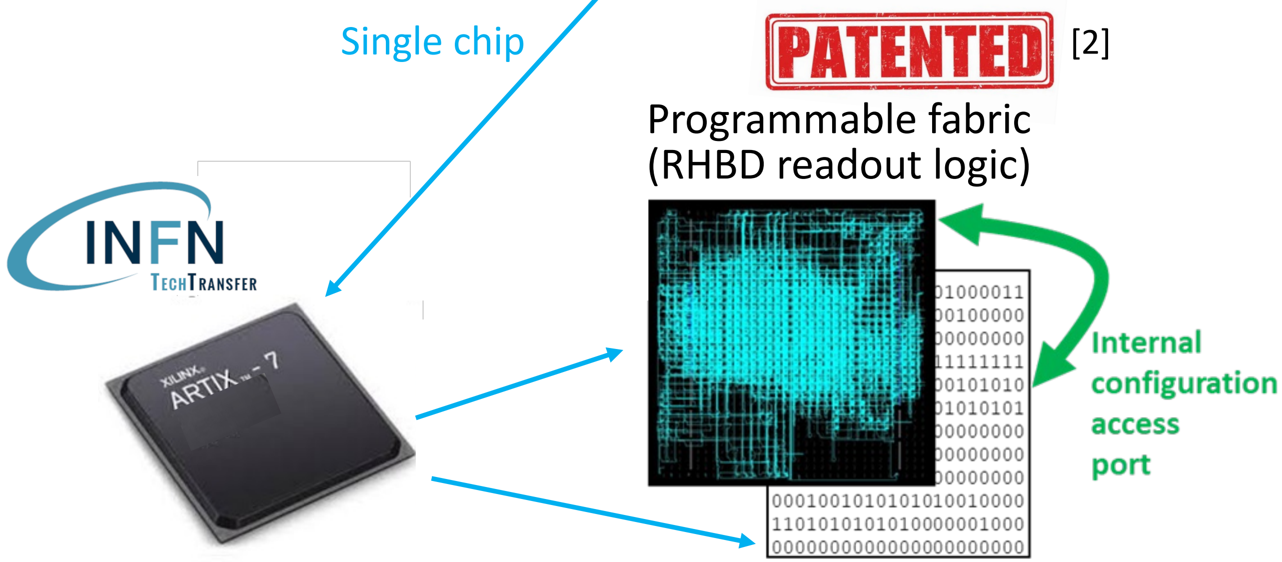
PHI - Programmable HIgh-energy-hadron fluence monitors

➤ Raffaele Giordano - Napoli

- PHI's idea: SRAM-based (Static Random Access Memory) FPGA as a compact hadron fluence counter
  - Configuration SRAM (CRAM) for sensing + programmable fabric for readout
- Compact and low-power (~0.7 W) system [1]
  - Only COTS components, radiation-hardened by design (RHBD)







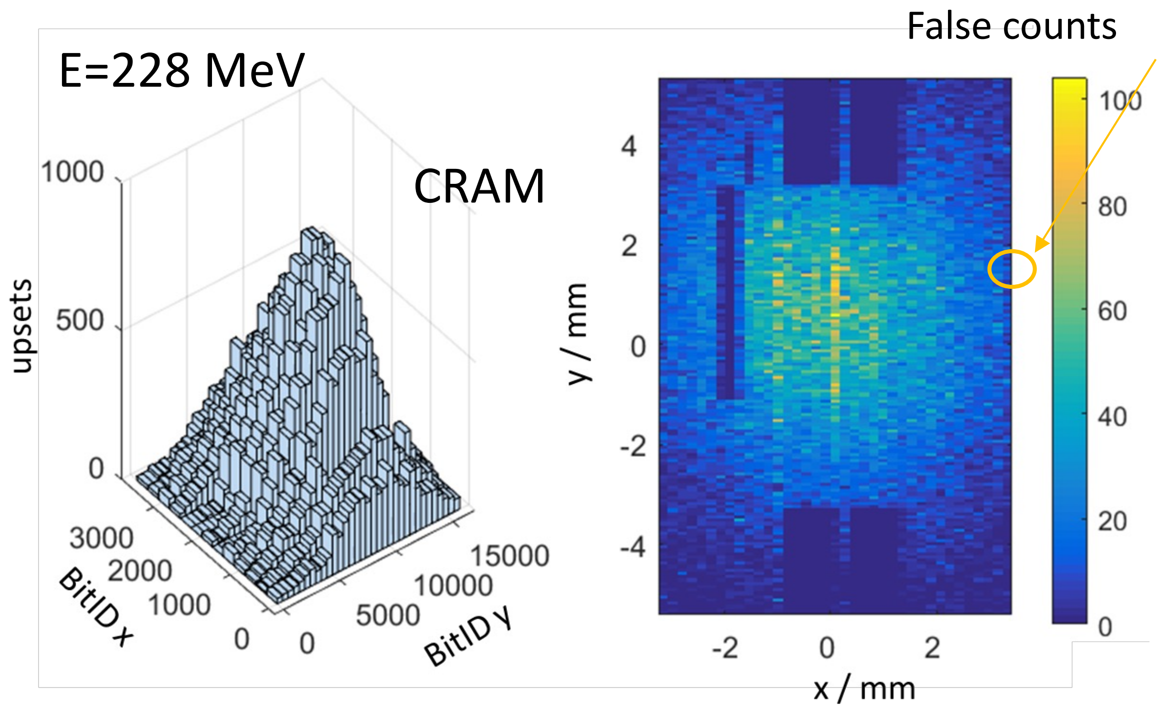
SRAM-based FPGA CMOS 28 nm

CRAM (59 Mb)

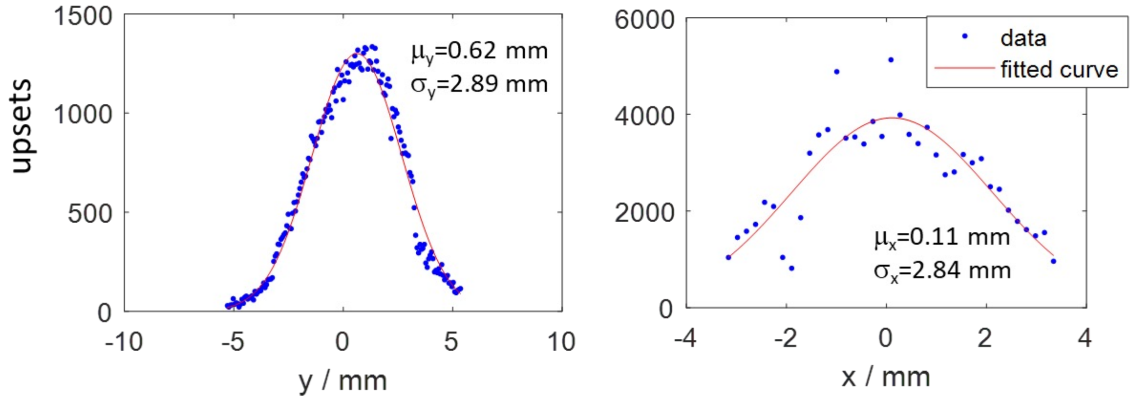
[1] R. Giordano et al., doi: 10.1109/TNS.2023.3265740
[2] PCT/IB2023/050417 filed on Jan. 18, 2023

PHI - Proton Beam Test Results

- Raffaele Giordano - Napoli



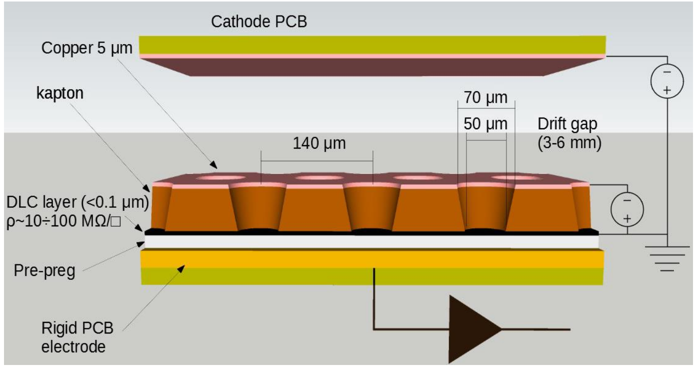
- σ(Energy, V_{DD}) monoenergetic protons, tunable energy in 70-228 MeV range
- Six samples tested, average
  - fluence $2.1 \cdot 10^{12}$ p/cm^2 per sample
  - flux $6.7 \cdot 10^{8}$ $p/(cm^2 s)$
- First usage of an FPGA to image a proton beam

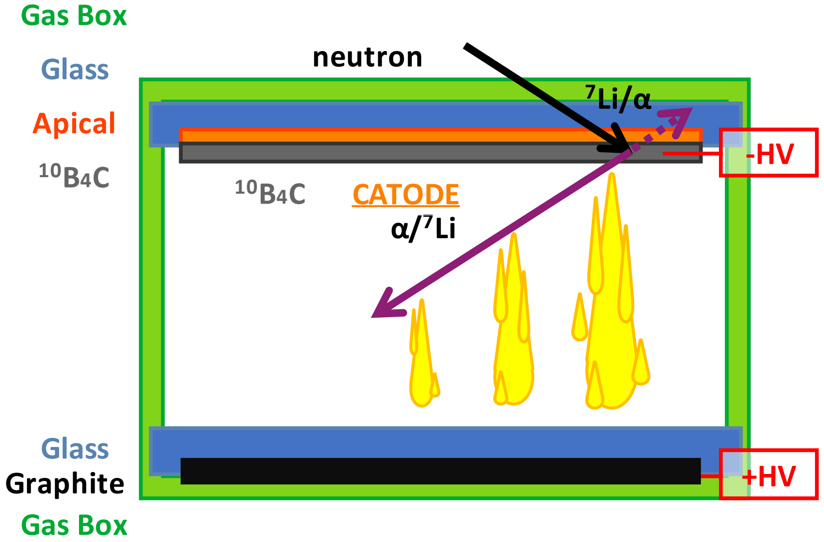


uRANIA-V

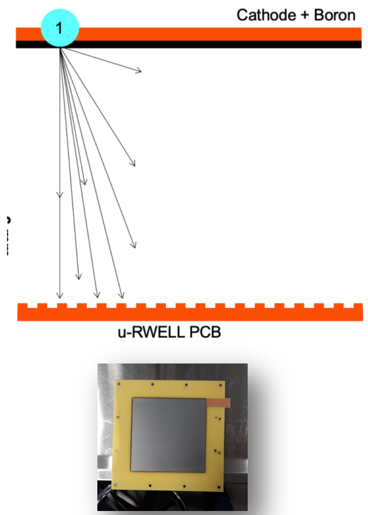
➢ Giovanni Bencivenni - LNF

Resistive Gaseous Detectors for thermal neutron detection

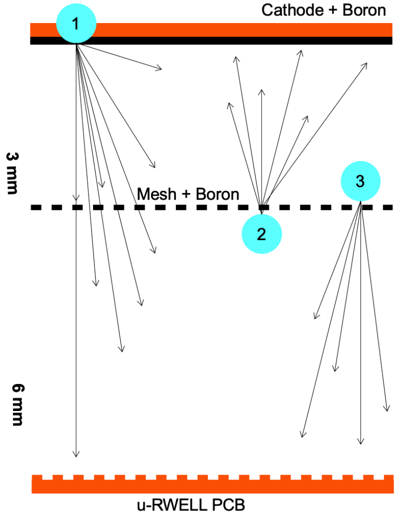


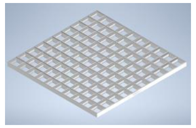


planar ^{10}B-cathode

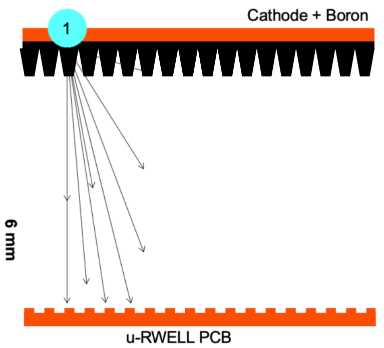


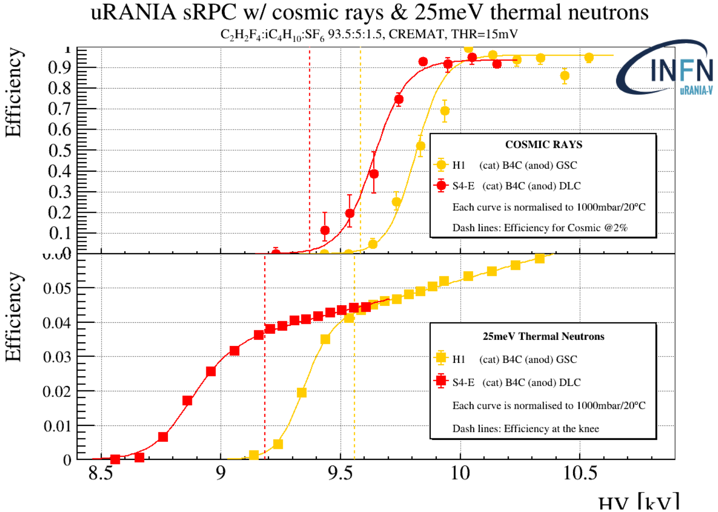
planar ^{10}B-cathode + ^{10}B-coated mesh

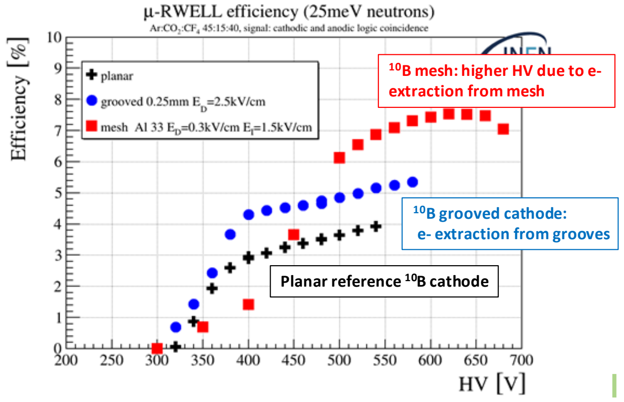




^{10}B-grooved cathode

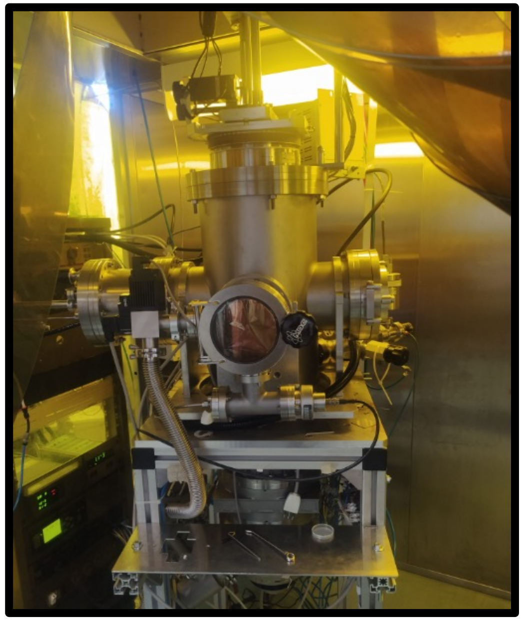


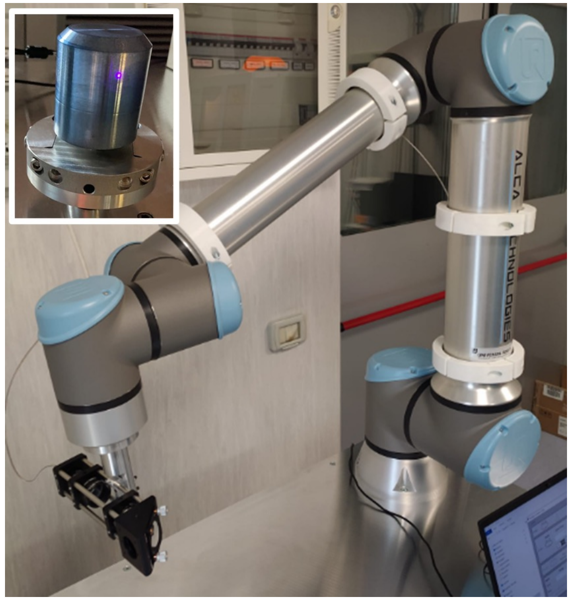


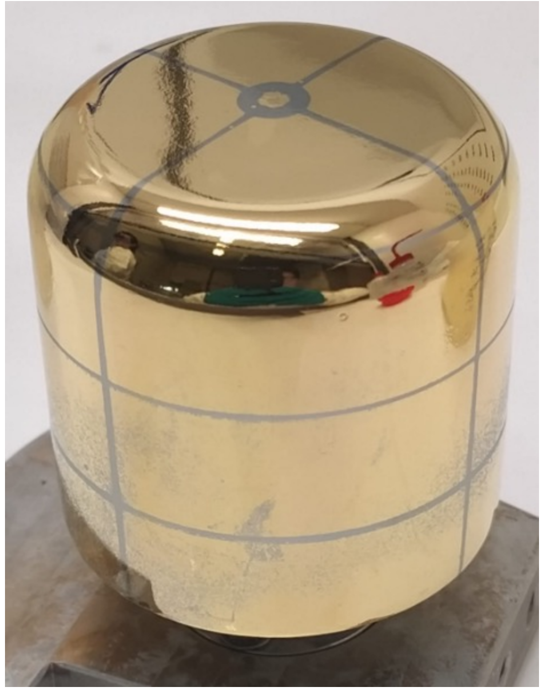


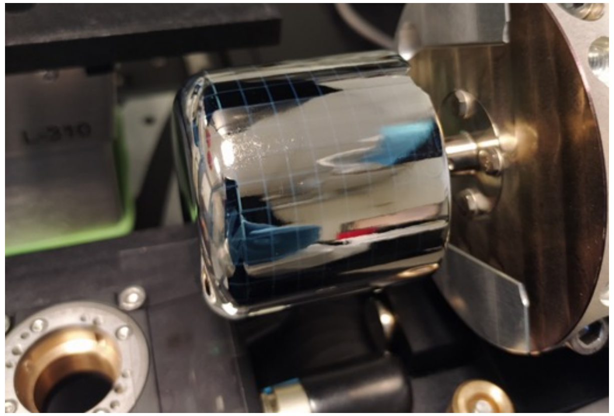
N3G: Next Generation Germanium Gamma detectors

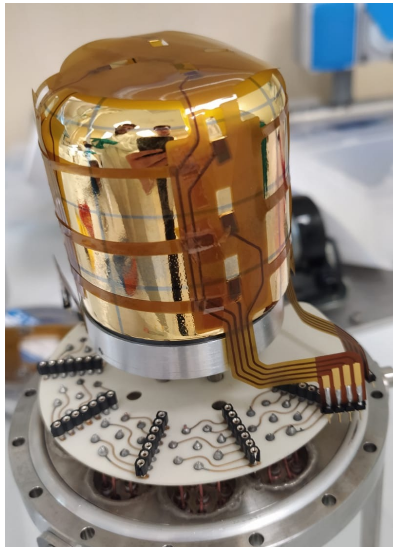
- Davide De Salvador – LNL

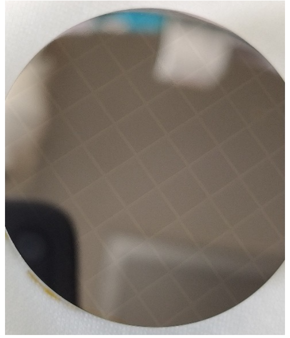


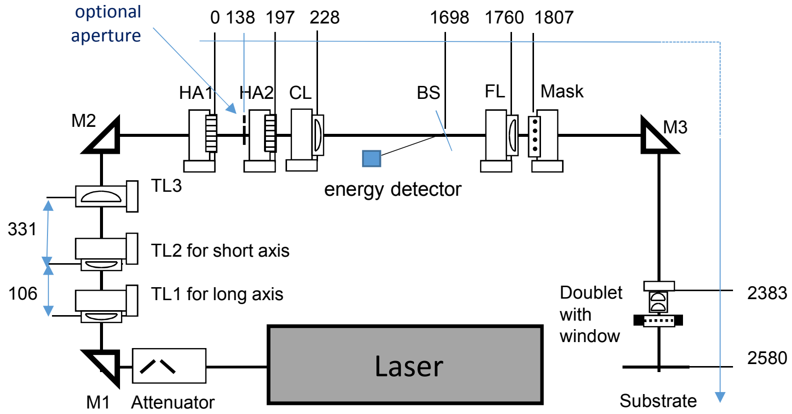






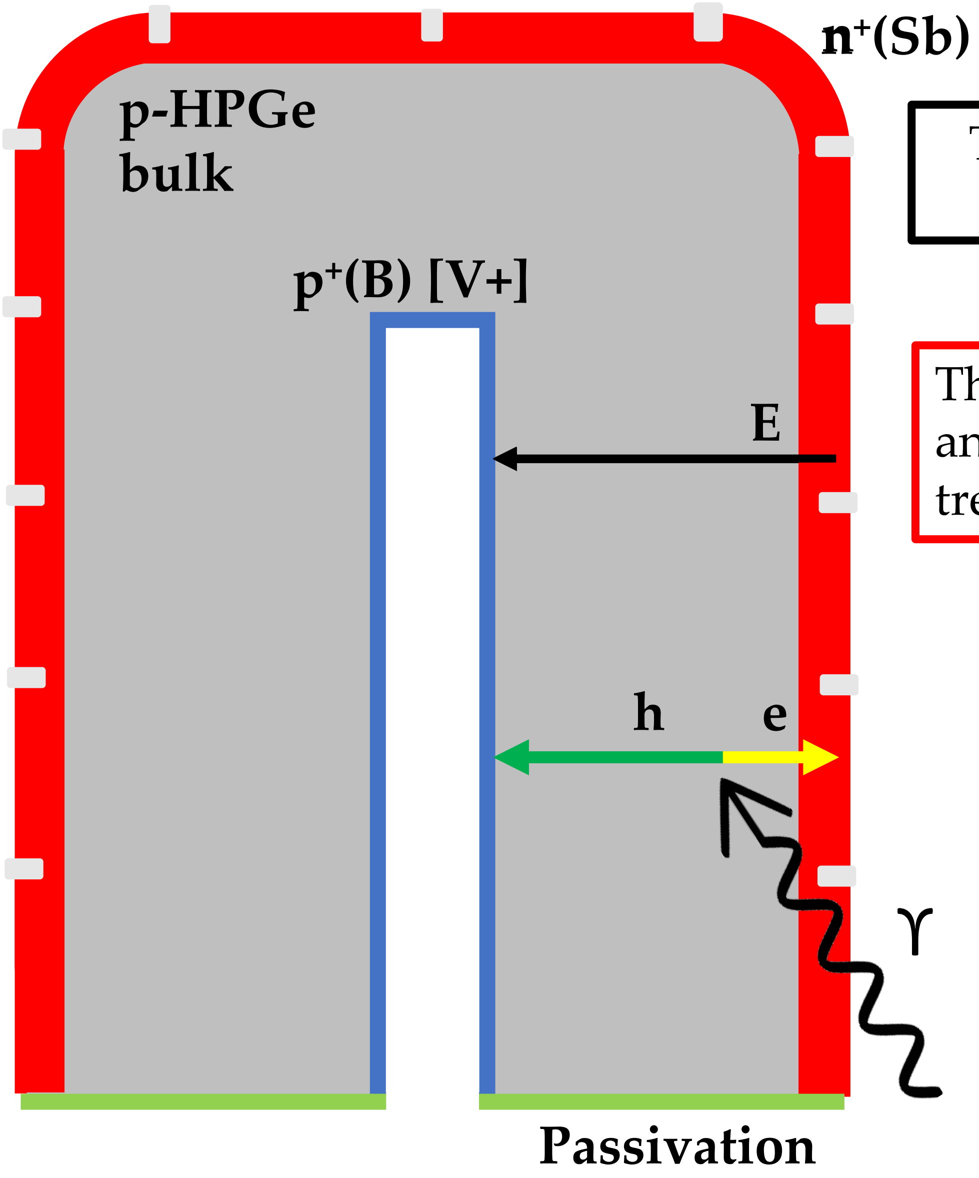






*Schematic coaxial segmented **p-type** detector*

- Davide De Salvador – LNL



The boron junction is thin, and easily segmentable

Polarity inversion demanded to test higher damage resistivity (hole trapping by neutron damage)

The lithium junction is thick and not stable under annealing treatments

Thin and thermally stable n-type dopants (**Pulsed Laser Melting**).

p-HPGe with segmentable n+ junction collecting electrons.

https://sd.fbk.eu/en/

➢ Maurizio Boscardin – FBK – Trento

Microfabrication Area
- Clean Room Detectors 700 m2; Class 10/100 0,8 um CMOS pilot line , fully equipped for device realization on 6-inch wafers
- Clean Room MEMS 500 m2 Class 100/1000

Testing Area 300 m2 manual and automatic parametric testing

Integration Area 100 m2 clean room Class 1000

3D Integration Laboratory equipped with Wafer Bonding/Debonding and Wager Grinding for back-side illuminated sensors and wafer-level integration

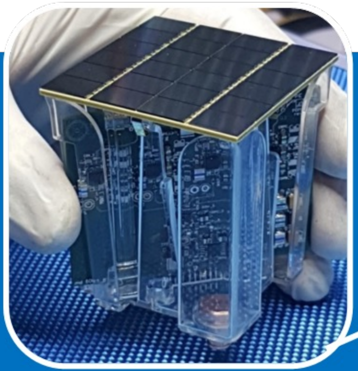
FBK-SD at a glance

~ 90 researchers
~ 30 technicians
~ 20 PhD students
~ 2000 sq metres labs

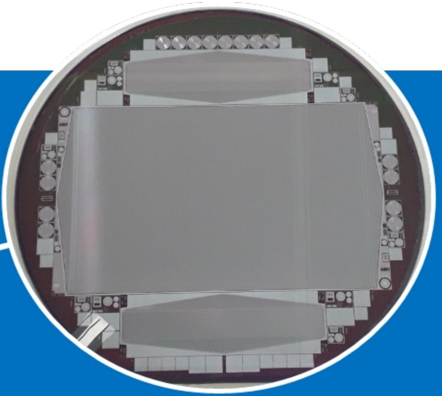
~9Meuro total budget
- ~50% from local government
- ~30% from competitive funds
- ~20% from directly commissioned activities

https://sd.fbk.eu/en/infrastructure/

➤ Maurizio Boscardin – FBK – Trento



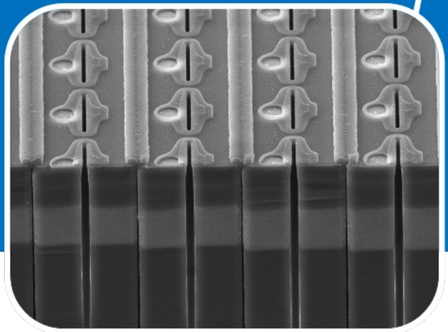
- Silicon Photomultipliers (SiPM)
- Silicon Drift Detectors (SDD)



SENSORS AND DEVICES
FONDAZIONE BRUNO KESSLER

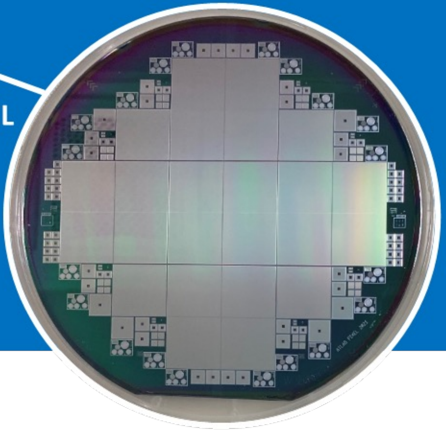
Custom Silicon Radiation Sensor Technologies

- Silicon 3D Detectors



- Low Gain Avalanche Diodes (LGADs)

- Strip & Pixel Detectors



Detectors for Space

SWEATERS

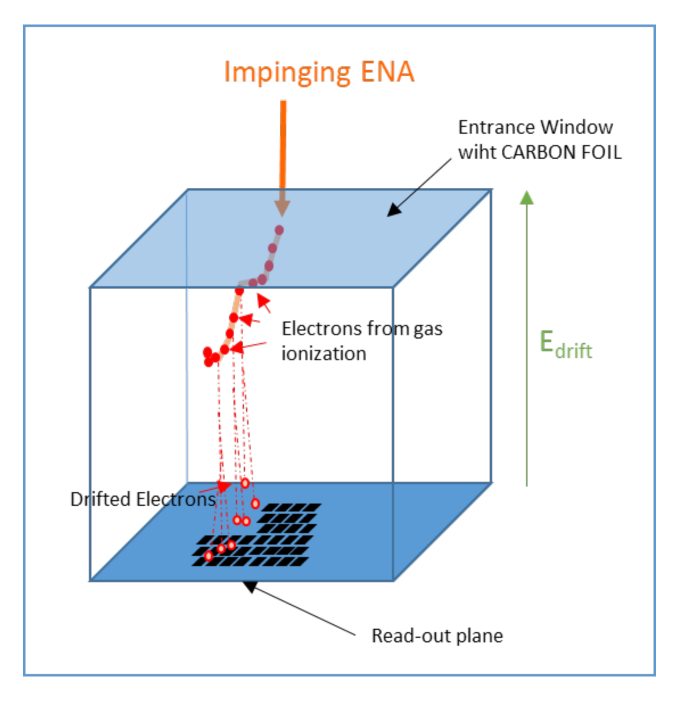
(Space WEAther Ena Radiation Sensor)

➢ Federico Pilo – Pisa

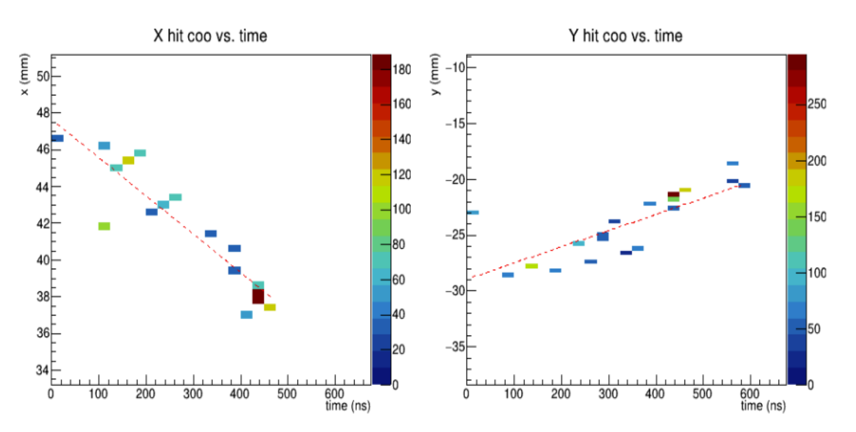
Development of an INNOVATIVE instrument to detect low energy atoms (1-100 keV), such as Energetic Neutral Atom (ENA) for Magnetospheric Imaging in Space

	Nice to have
Angular res.	5°x5°
Energy range	[1-100] keV
Energy resolution	20 %
Expected particle flux	10^2 - 10^5 $(cm^2\,s\,sr)^{-1}$
Mass channels	H, He, O discrimination

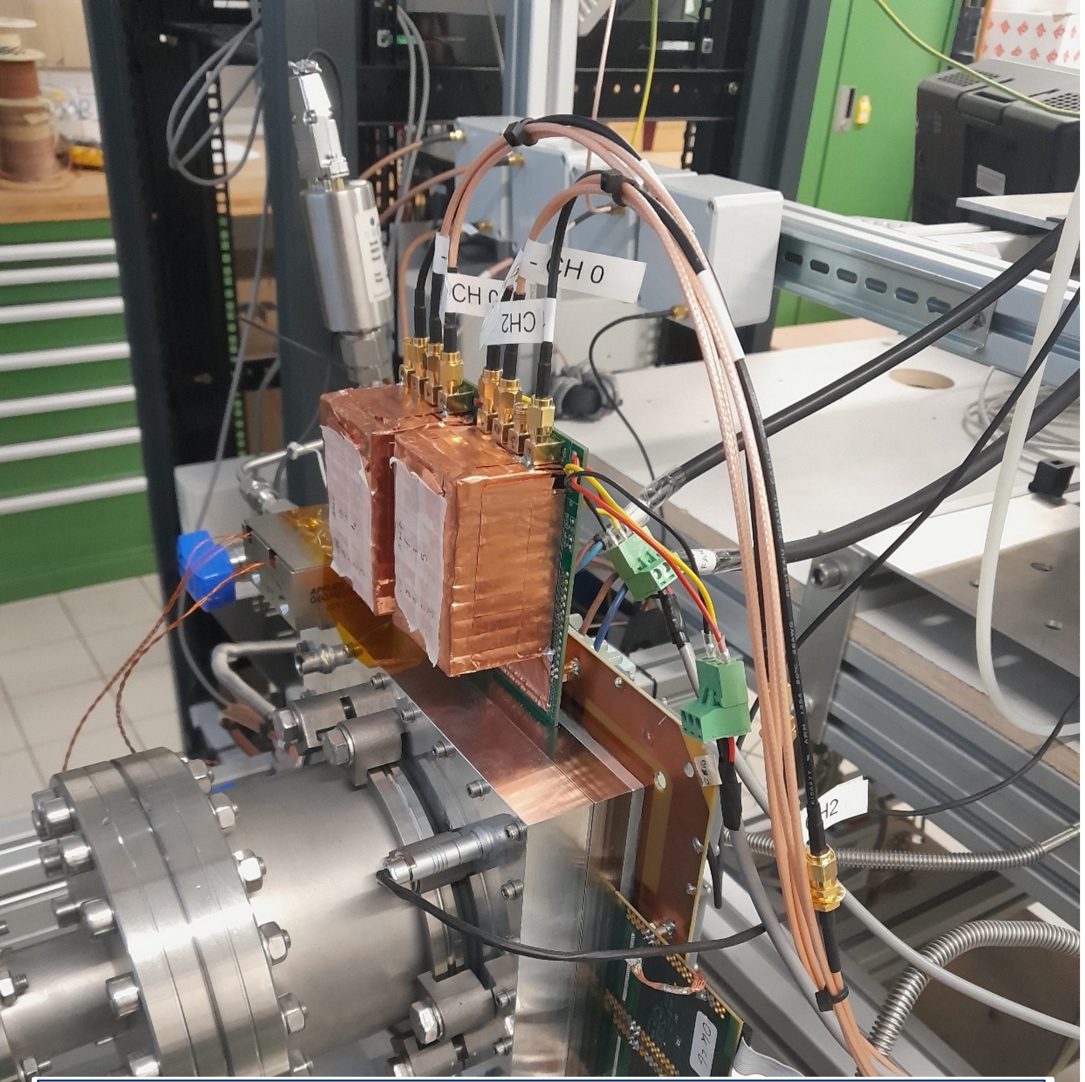
- **GOAL:** obtain global images of magnetosphere dynamics for possible Space Weather applications
- **HOW:** using a «gas calorimeter» based on Micro-Pattern Gas Detector (MPGD) technique and a read-out system able to provide a 3D track reconstruction of the particles
- Low-cost fabrication together with the robustness of the electrode materials of MPGD make it extremely attractive for harsh environment (like a space mission)



SWEATERS detector concept



Muon tracks at NTP in the SWEATERS detector. Clustering and µTPC tecniquies used for track reconstruction



SWEATERS
@ INFN CSN5

- Started on 01/2020
- 3 years

CSN5 Ricerca Tecnologica

SWEATERS ASI-INAF – Phase B

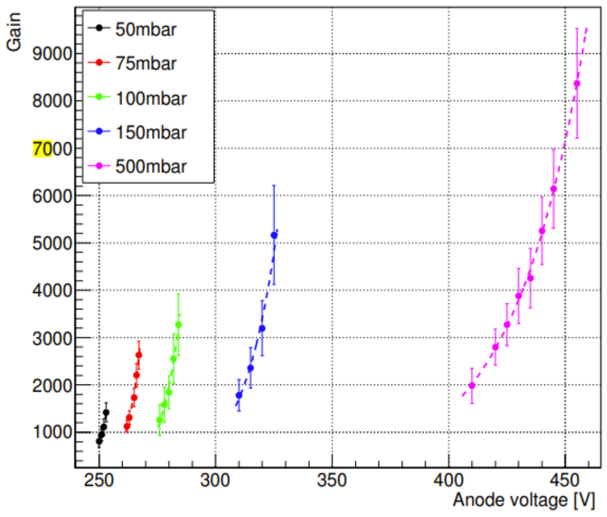
- **Started 04/2024**
- 3 years
- P.I.: INAF
- INFN responsible for gas detector and electronics R&D

SWEATERS - R&D status

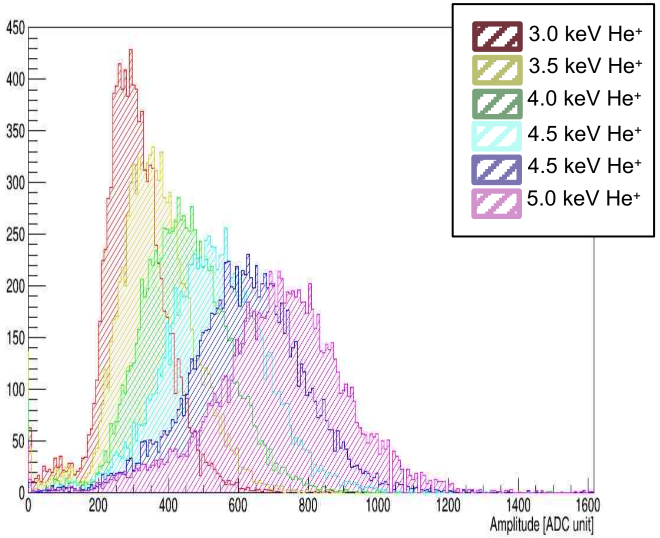
➤ Federico Pilo - Pisa

- ✓ The MPGD technology, specifically MICROMEGAS, has been selected: MICROMEGAS.
- ✓ It has been demonstrated that MICROMEGAS can operate effectively at low pressure levels, down to 50 mbar
- ✓ The detector can detect ionized atoms with energies below keV for light atoms
- ✓ Measurement of atom energies with adequate resolution has been achieved

❑ R&D efforts on the detector windows and direction reconstruction strategies are currently ongoing



SWEATERS MICROMEGAS amplification factor

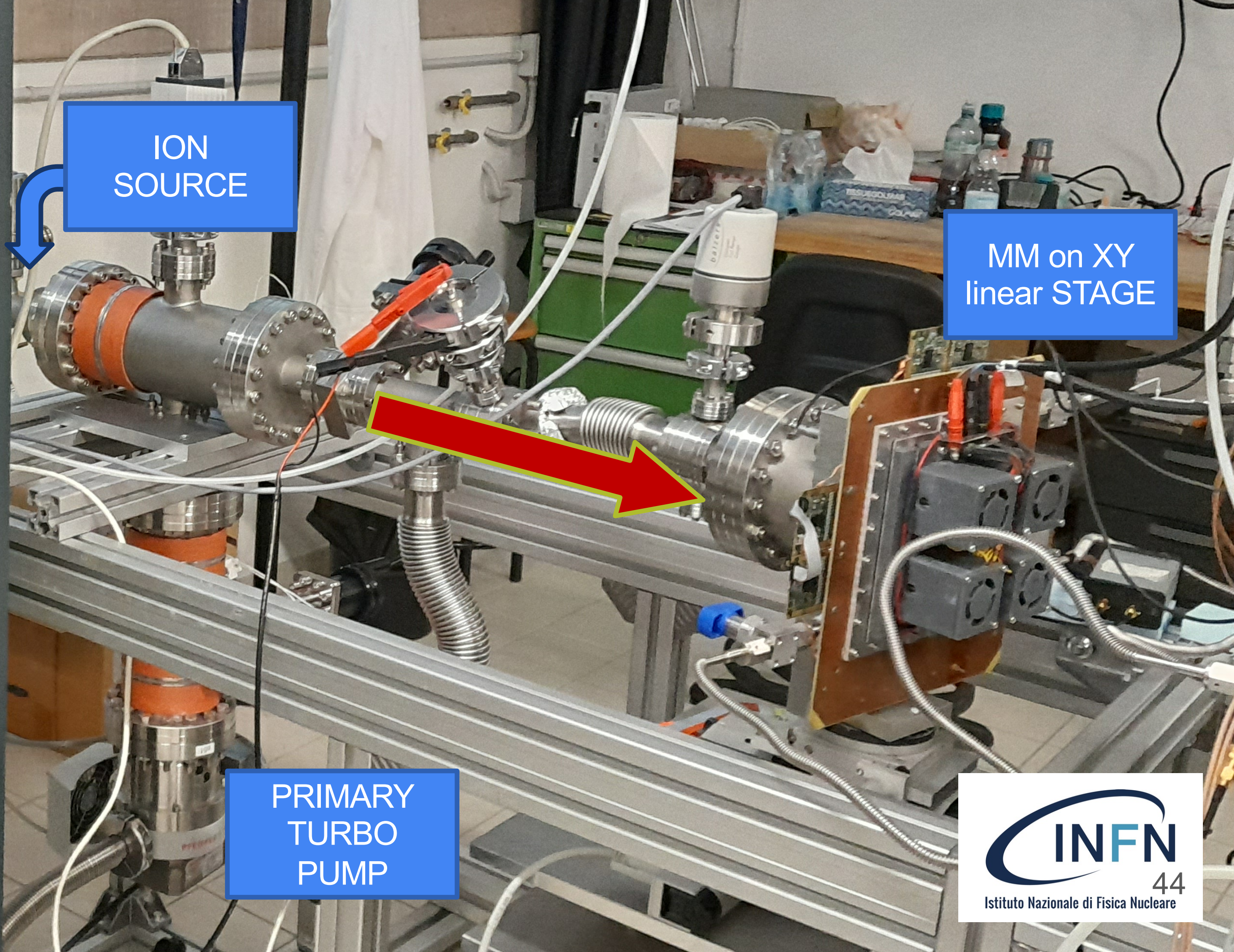


Monochromatic He energy reconstructed by SWEATERS at 100 mbar

Ion beam test facility @ INFN Pisa

A dedicated facility for SWEATERS and UTMOST programs

- H, He, N ion beams with energies up to 5 keV
- Space Environment Simulation and Calibration for the **SWEATERS** detectors (with Micro positioning stages and differential pumping)
- **UTMOST** ultra-thin membranes characterization with ions (transparency, charge state, angular scattering)



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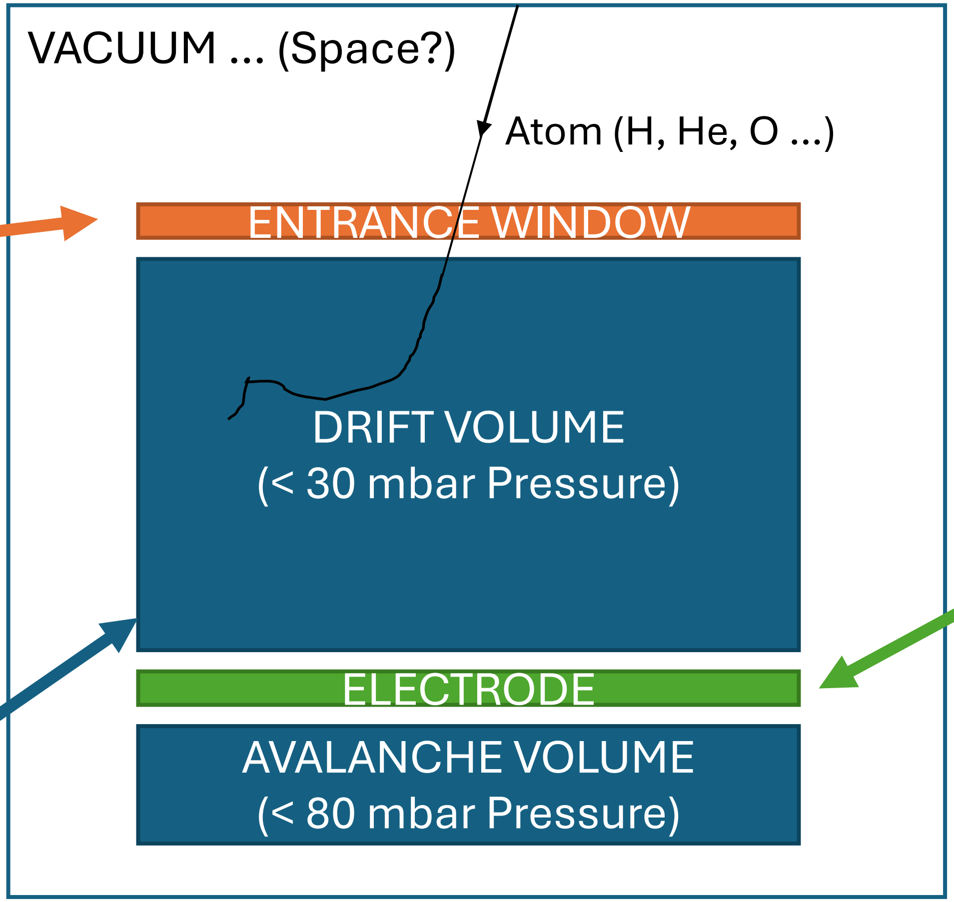
UTMOST

(**U**l**T**rathin **M**aterials f**O**r ga**S**eous de**T**ectors)

➢ Federico Pilo - Pisa

Integrating ultra-thin material-based technologies into a highly **INNOVATIVE GAS DETECTOR**

1. To create an entrance window for atoms with energies below 10 - 20 keV



2. To produce an ultra-thin electrode to maintain a pressure difference between the drift zone and the avalanche zone.

3. To combine the two technologies into a highly innovative gas detector based on MICROMEGAS technology

UTMOST – R&D Status

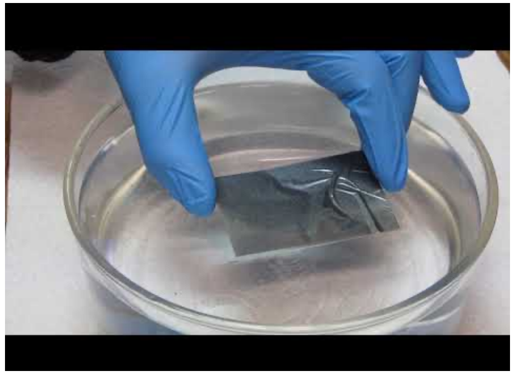
Started 2024, 3 years, CSN5 financed

- Federico Pilo - Pisa

UTMOST
UlTrathin Materials fOr gaSeous deTectors

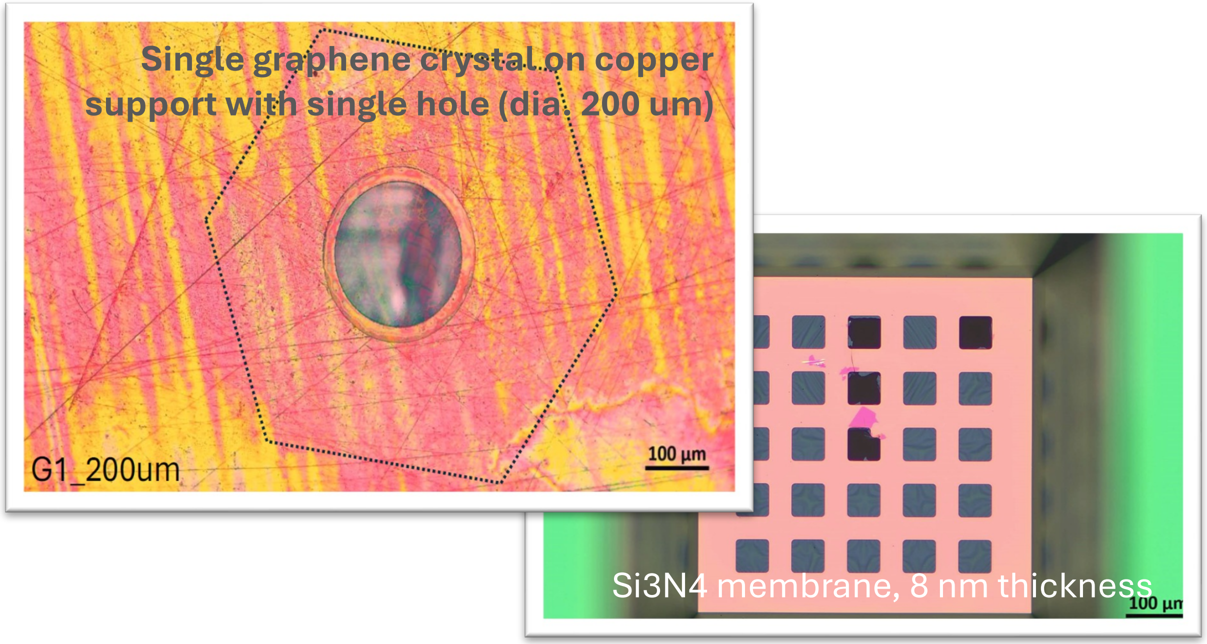
Studies on CARBON FOIL as Entrance Window

- Differential pressure test and optimization of mechnical support structures
- GOAL: > 100 mbar without any damage



Studies on GRAPHENE and Si3N4 FOILS for the Ultra-thin Electrode

- Electron transparency test
- GOAL: >50% even for energies of a few eV



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iit GRAPHENE
ISTITUTO ITALIANO DI TECNOLOGIA
GRAPHENE LABS

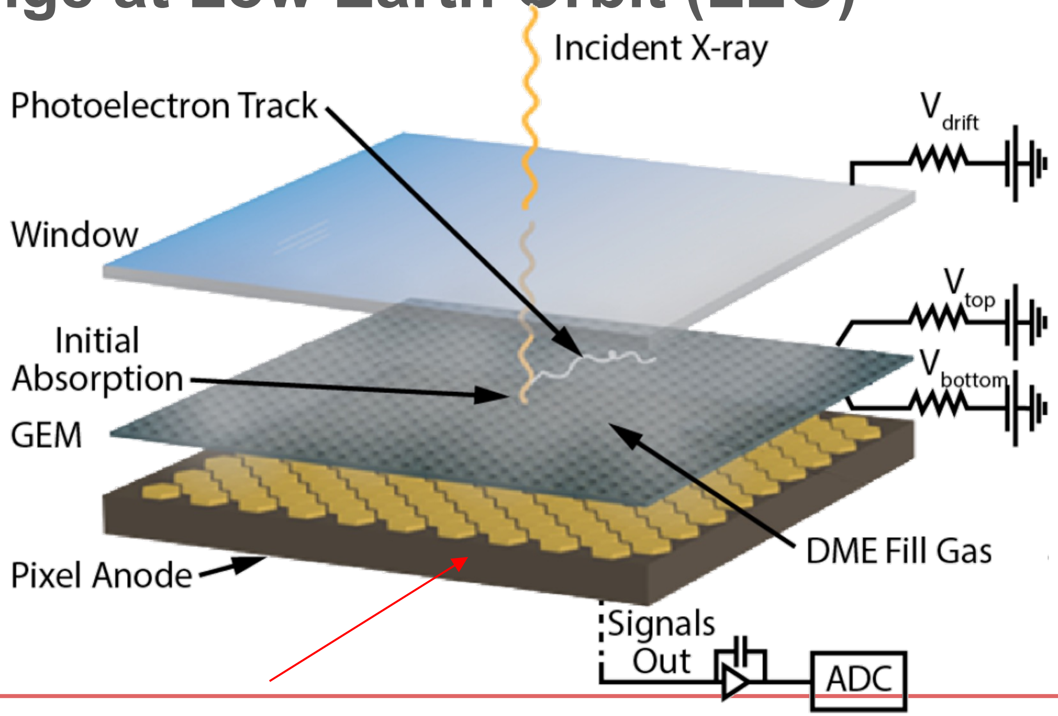
ROMA TRE
UNIVERSITÀ DEGLI STUDI

A long history of X-rays detectors

- Massimo Minuti - Pisa

from a first step in CSN5 … to the IXPE mission in orbit

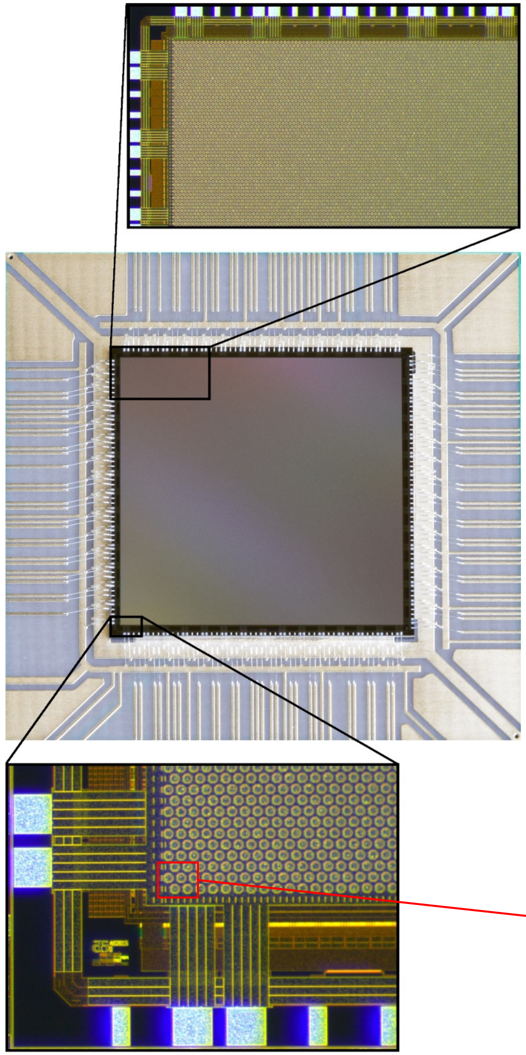
X-ray energy, polarimetry and timing measurement in the 2-8 keV energy range at Low Earth Orbit (LEO)

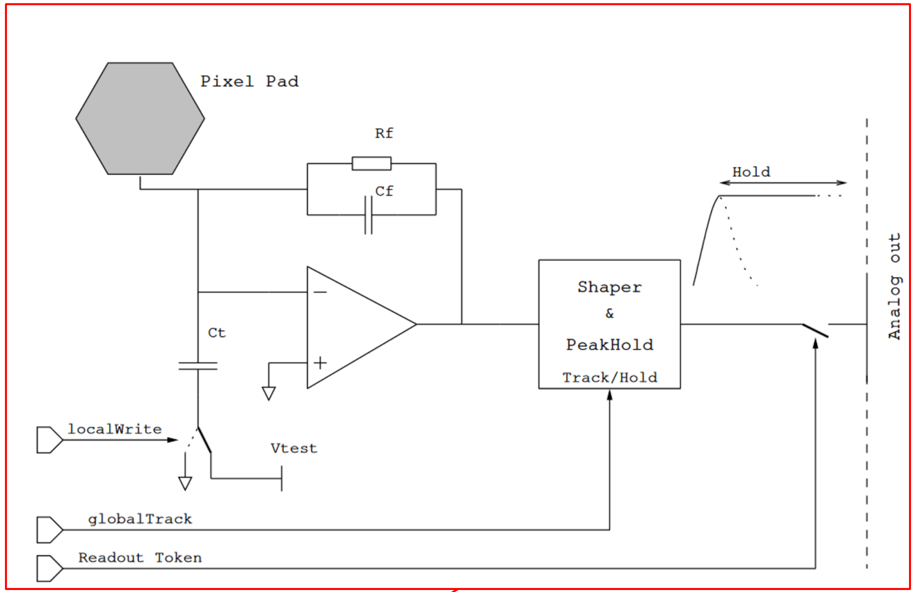


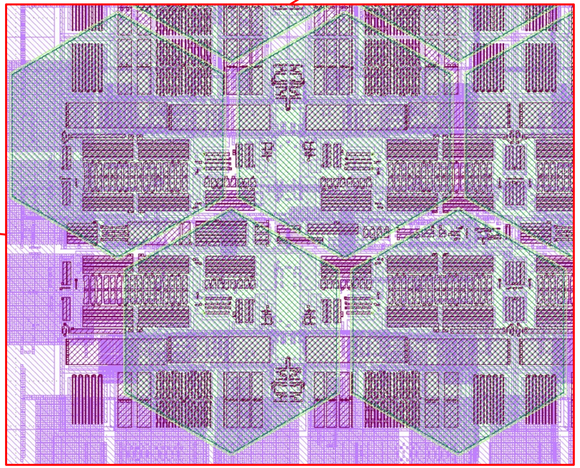
Large area full-custom 180nm CMOS readout ASIC (XPOL)

A long history of X-rays detectors

The XPOL readout chip







- Massimo Minuti - Pisa

Technology	180nm CMOS
Active Area	15.2 X 15.2 mm^2
Number of pixels	107.008 (304 X 352)
Physical pitch	50 um
Shaping time	1us
Pixel Noise (ENC)	30 e-
Full scale linear range (FSLR)	30 ke-
Minimum trigger threshold	150 e-
Maximum Readout Freq.	20MHz

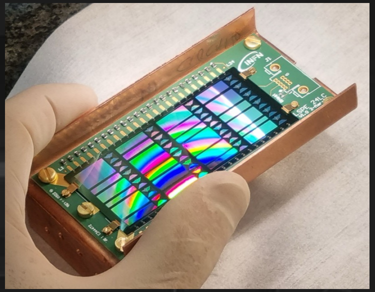
Self triggering, event-driven analog readout.

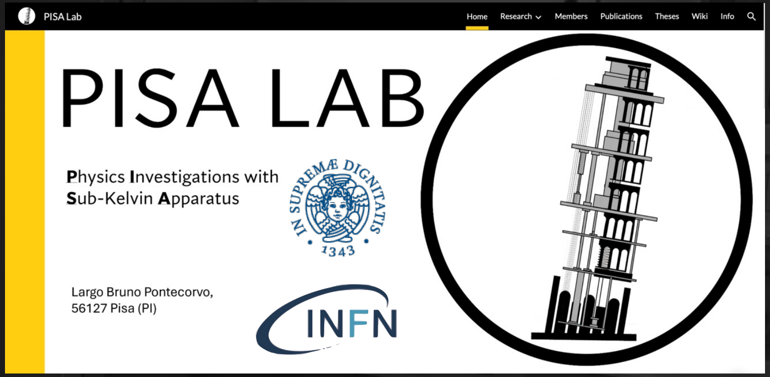
Position, Energy and Time of Arrival in one shot!

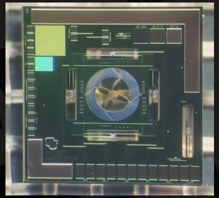
Cryogenic detectors development and test

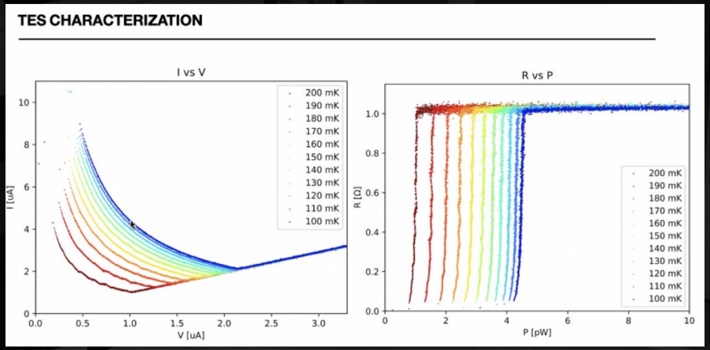
INFN Pisa and Physics Department

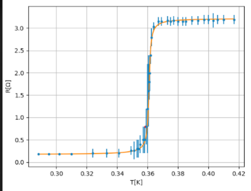
- 50 m^2 ISO7 cleanroom (classe 10000) + sub-Kelvin test facilities
  - spin coater, optical lithography (also maskless) thermal evaporation, RIE
  - 3-He sorption fridge, 1 dry dilution fridge + 1 being procured
- KIDs for dark matter, TESs for particle physics and Cosmic Microwave Background, superconducting QuBITs, parametric amplifiers, Rydberg atoms
- Readout electronics, SQUID tests, cryogenic LC filters, multiplexing
- Tests with optical and radioactive sources
- Synergistic activity b/w HEP, solid state research and teaching

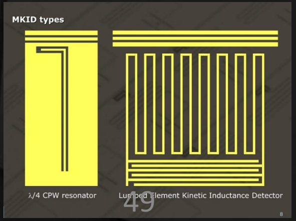










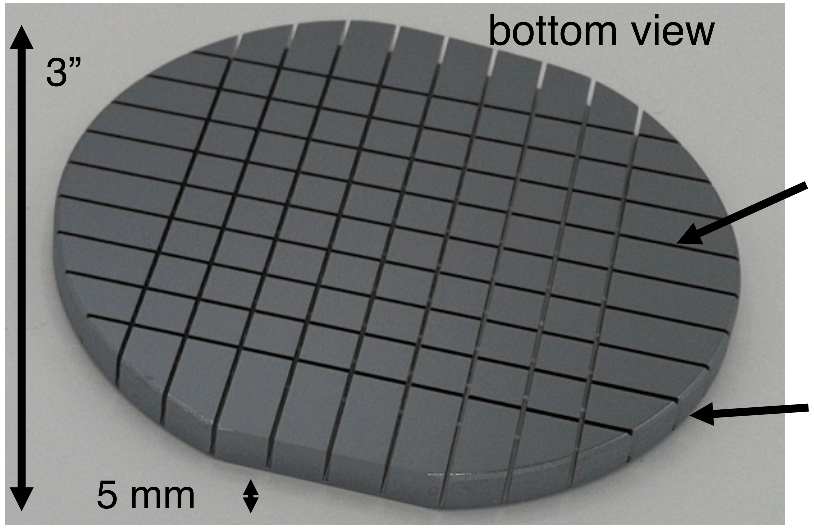


BULLKID: BULky and Low-threshold Kinetic Inductance Detector

- ***Goal:*** development of a monolithic multipixel array of phonon detectors for Coherent Neutrino Scattering and light WIMP-like particle
- **Method:** Implementation through carving on a thick Si wafer of dices, sensed by phonon-mediated KIDs.
- Variation of the kinetic inductance in superconductors to detect dark matter
- Large mass detectors with natural multiplexing readout
- Each channel includes a LC resonator tuned at different frequency.

➤ Angelo Cruciani – Roma

Carving of dices in a thick silicon wafer

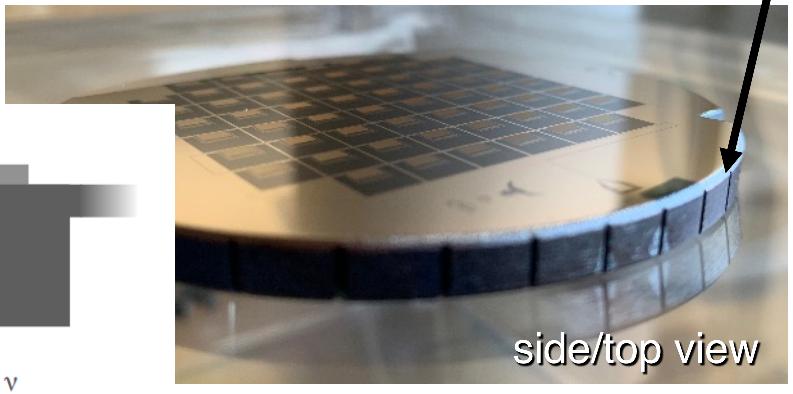


➤ Andrea Mazzolari Ferrara

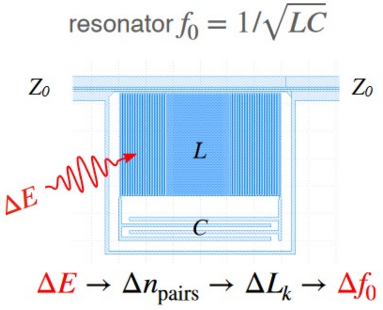
4.5 mm deep grooves
- 6 mm pitch
- chemical etching

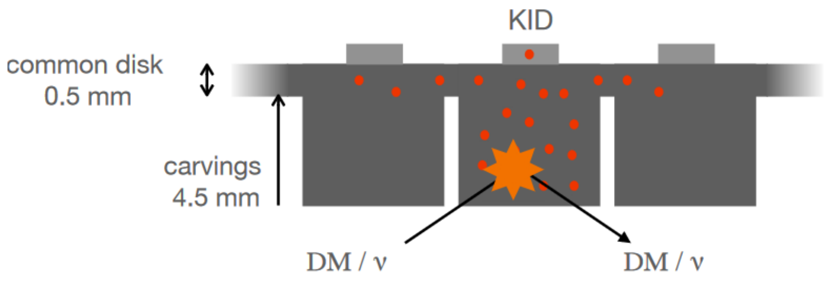
0.5 mm thick common disk:
- holds the structure
- hosts the KIDs

Lithography of multiplexed KID array



KID array
- 60 nm aluminum film
- 60 KIDs lithography





BULLKID: BULky and Low-threshold Kinetic Inductance Detector

➤ Angelo Cruciani – Roma

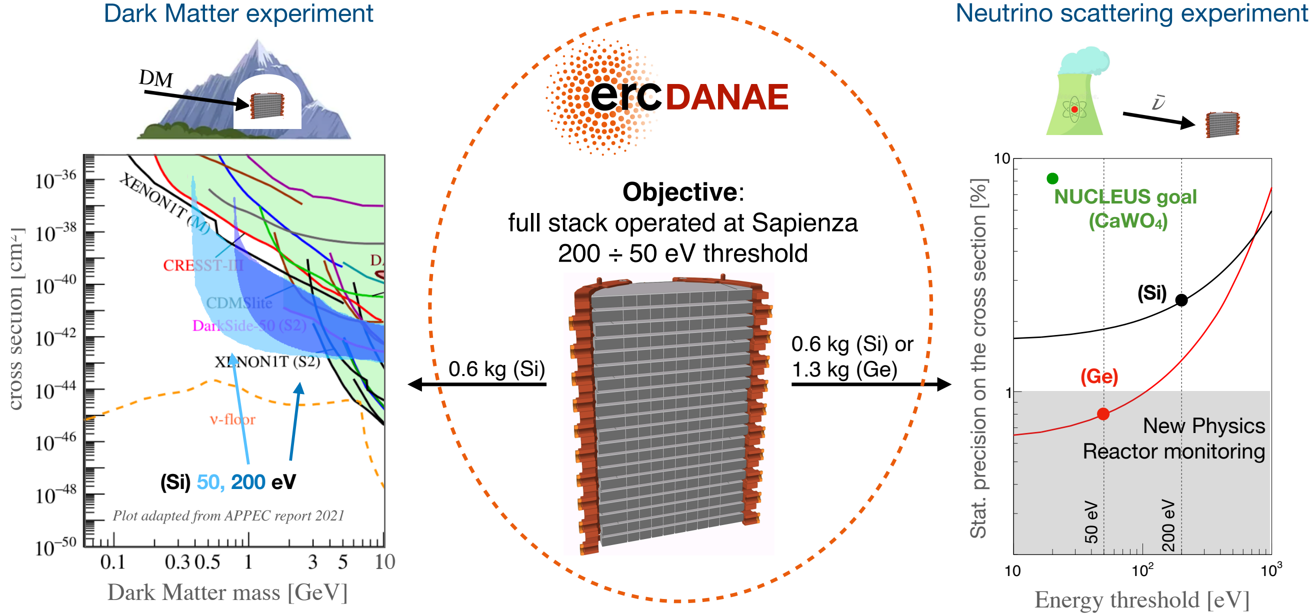
- ***Achievment:***
- developed a 60 pixel array with energy threshold of 160 eV
- Single pixel does not exhibit excess down to the threshold
- **Timeline**

2019-23: R&D supported by INFN and Sapienza

2023: Awarded with a CoG ERC (HI: Sapienza, Ben: INFN, CNRS)

2024 -: Started experiment (INFN, CNRS, KIT, UNAM) for the search of light WIMP-like particles at Gran Sasso.

Relationship of DANAE to other projects



Quantum Sensors

DARTWARS

Detector Array Readout with Traveling Wave AmplifieRS

INFN Istituto Nazionale di Fisica Nucleare

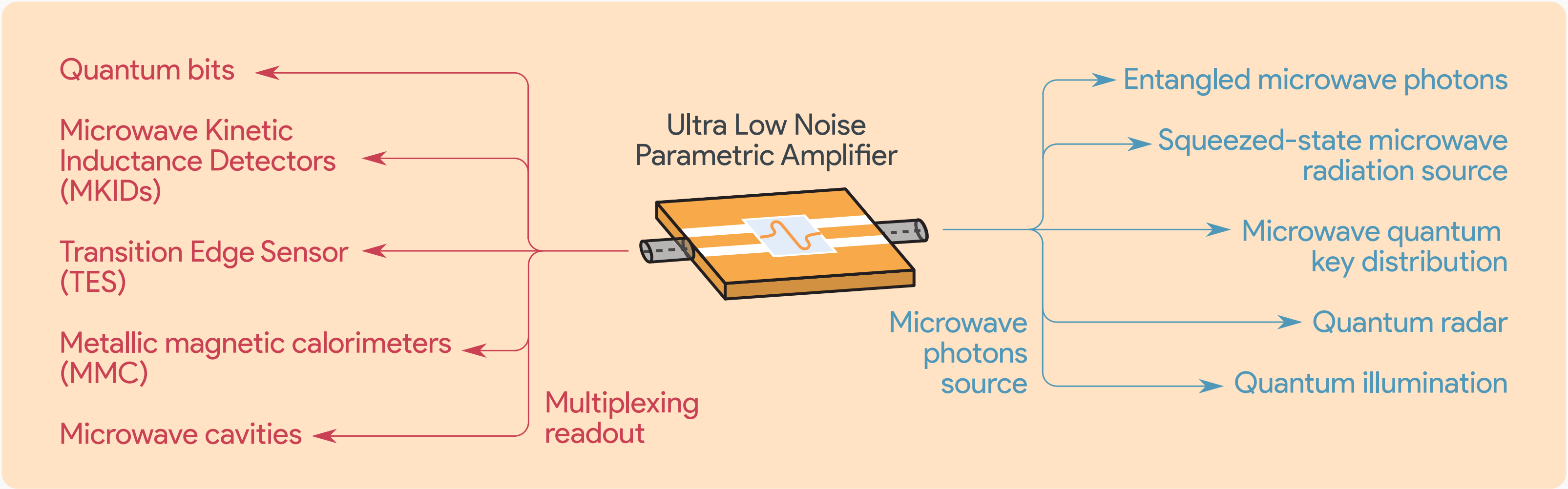
CSN5 Technological research

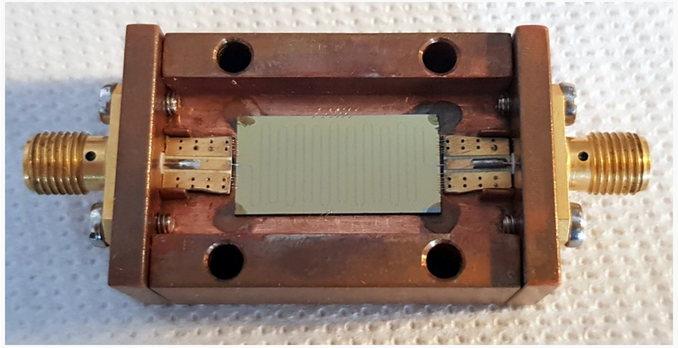
UNIVERSITA' DEGLI STUDI DI MILANO BICOCCA

➤ Andrea Giachero
Milano Bicocca

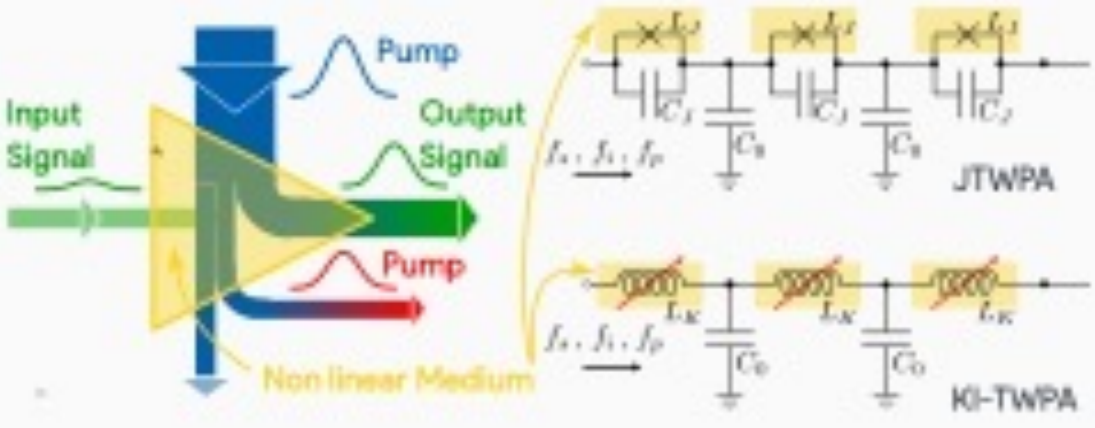
Development of high performing parametric amplifiers following two different promising approaches (KI-TWPA, JTWPA) and exploring new design solutions, new materials and advanced fabrication processes;

Readout demonstration of various detectors/components (TESs, MKIDs, microwave cavities and qubits) with improved performances due to a parametric amplification with a noise at the quantum level



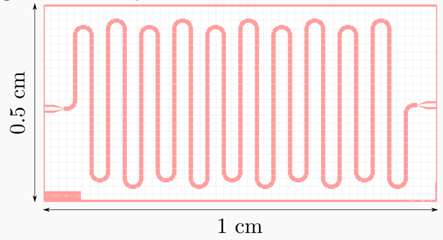


KI-TWPA - design L1 - version 1, 2023



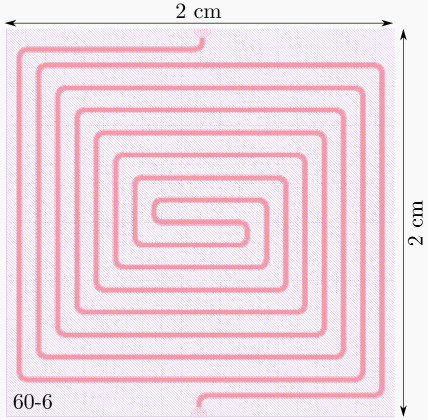
➤ **Andrea Giachero**
Milano Bicocca

Design L1: 553 super-cells (*half-size*)

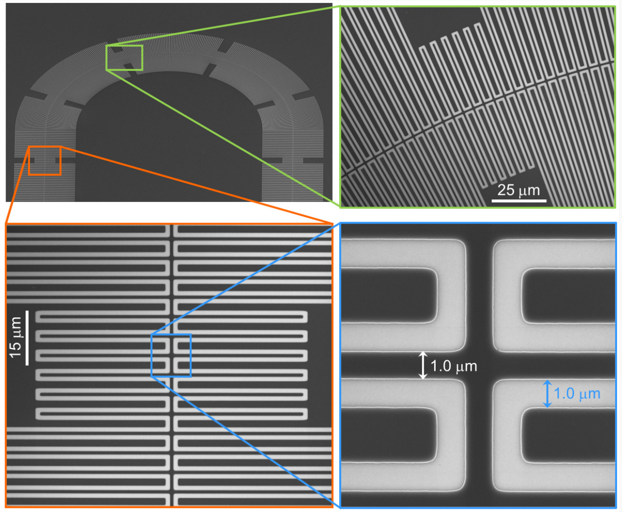


Expected gain
G = 10 dB

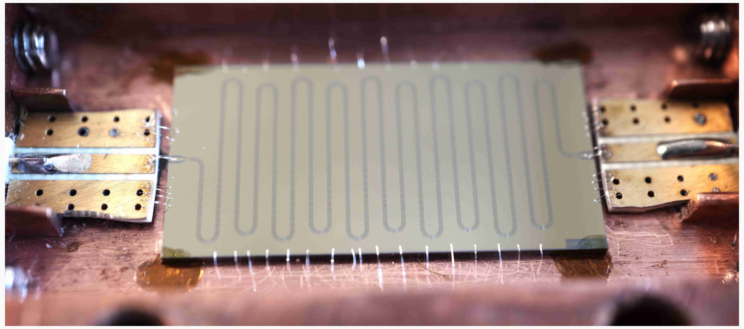
Design L2: 1000 super-cells (*full-size*)



Expected gain
G = 20-30 dB



SEM pictures of the fabricated KI-TWPA.



KITWPA in the copper box

- The first KI-TWPA prototype based on the preliminary *half-size* layout L1 has been produced early in 2023;
- Device composed of 523 *super-cells* with a length of about 17 cm. Gain expected in the (7–11) dB range;
- Characterization results from these preliminary amplifiers are be crucial in refining the final design;

Qub-IT

➤ Claudio Gatti - LNF

Main Objective:

Realization of an itinerant single-photon counter that surpasses present devices in terms of efficiency and low dark-count rates by exploiting repeated QND measurements of a single photon and entanglement in multiple qubits.

Specific Objectives:

1. Design and simulation of SC qubits coupled to resonators
2. Fabrication of circuits with SC qubits
3. Single-shot measurement of SC qubits with quantum amplifier
4. Control of SC qubits with FPGA board
5. Quantum sensing experiments with entangled qubits

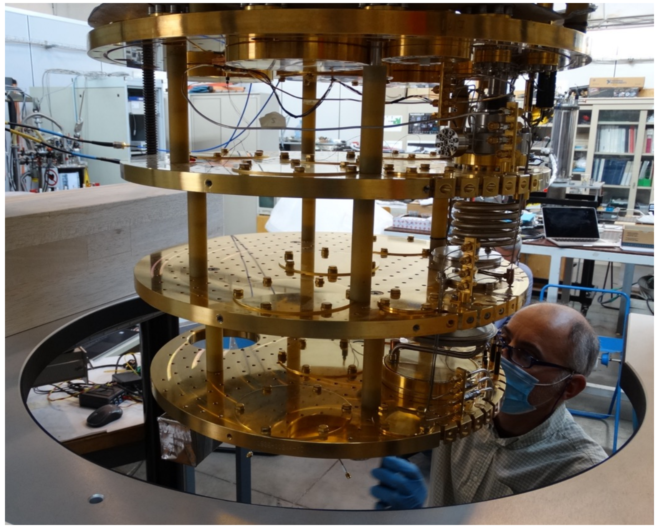
Synergies with:

SQMS – SUPERCONDUCTING QUANTUM MATERIALS & SYSTEMS CENTER

NQSTI – National Quantum Science and Technology Institute

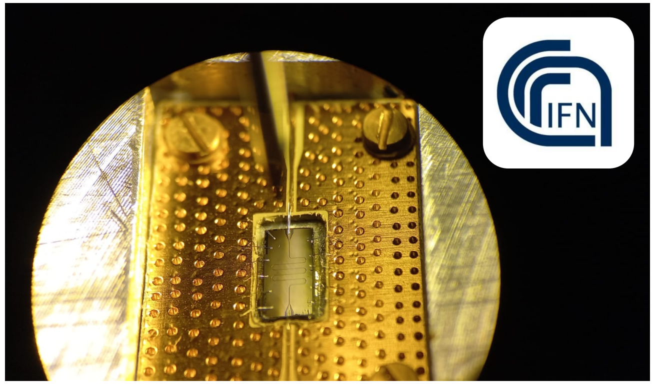
ICSC – Centro Nazionale di Ricerca in HPC, Big Data and Quantum Computing

Cryogenic measurements

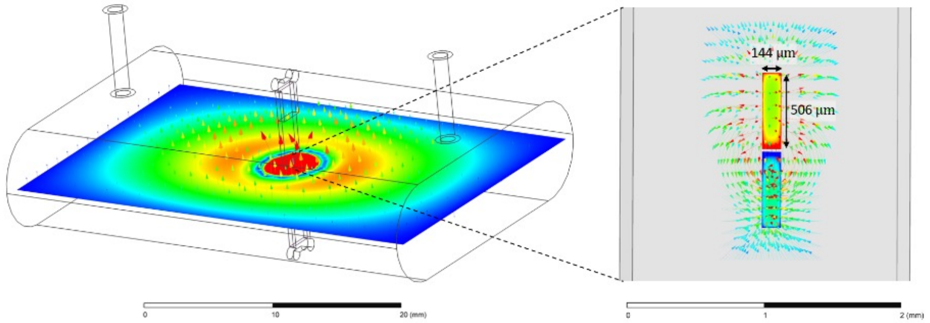


Quantum Amplifiers

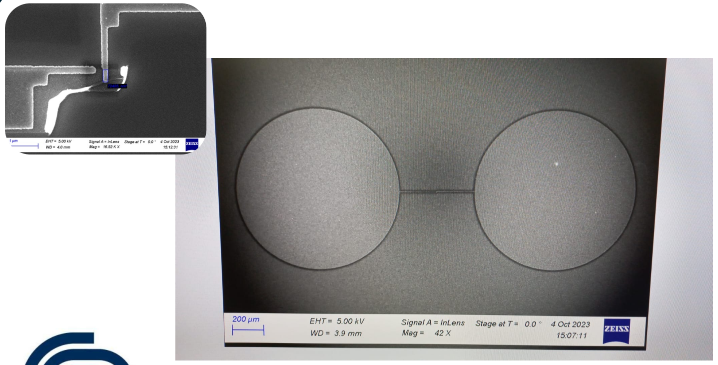
Superconducting circuits



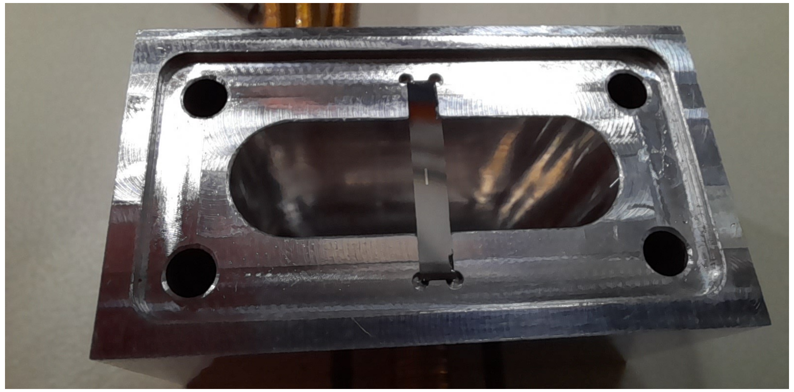
Superconducting Qubits in a 3D Cavity



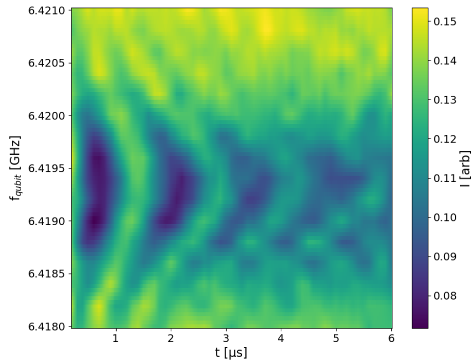
Design and simulation of qubit in 3D cavity



3D Qubit fabrication within the Collaboration



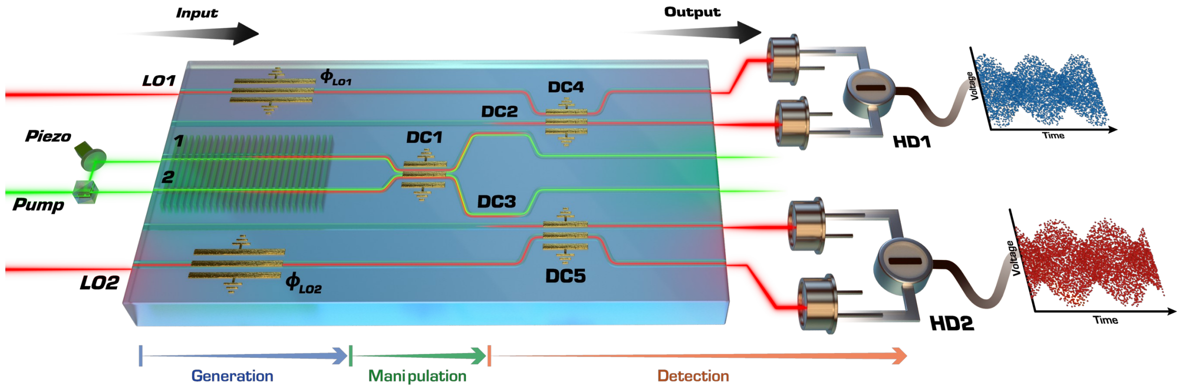
Qubit in 3D cavity from external collaborations



Qubit characterization

Appl. Sci. 2024, 14, 1478.

UNIDET: UNIversal DETector for Quantum Light



- Mirko Lobino – Trento

M. Lobino et al., **Integrated photonic platform for quantum information with continuous variables**,
DOI: 10.1126/sciadv.aat9331

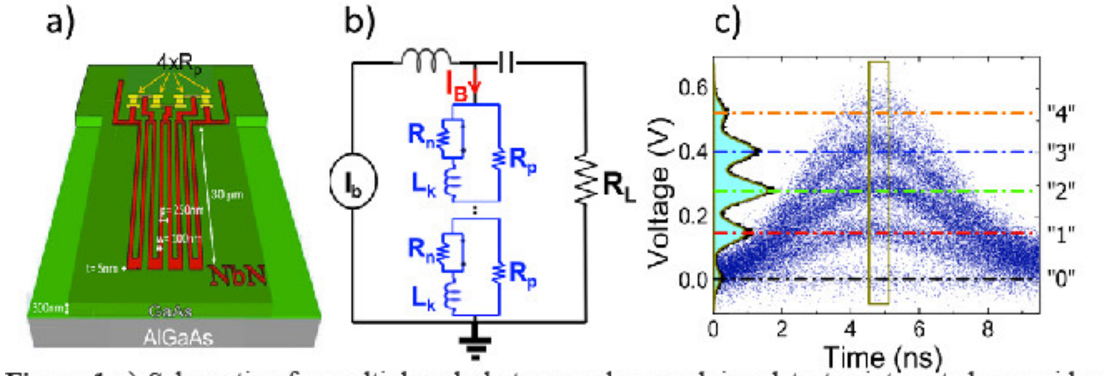


Figure 1 a) Schematic of a multiplexed photon number resolving detector integrated on a ridge GaAs waveguide, developed using a series connection of four pixel SNSPD and b) its equivalent electric circuit, which includes the amplifier input impedance R_L. c) Pulse height corresponding to the number of absorbed photons [25].

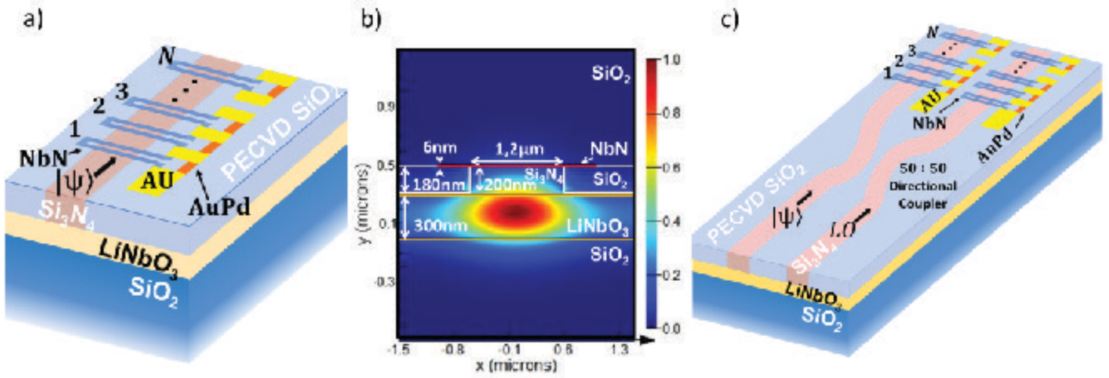


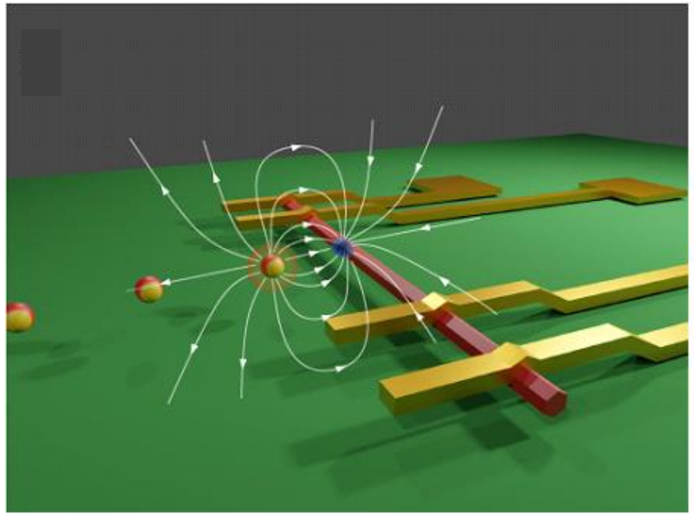
Figure 2 a) Schematic of the integrated PNR to develop in this project showing a series of N pixels composed by a NbN nanowire (80 nm width) and an AuPd on-chip parallel resistance (Rp=20 Ω value). b) Field intensity for the first TE mode propagating in the waveguide where the light absorption in each NbN nanowire element is at 3.4%. c) Schematic of the hybrid detector.

- ✓ Realization of an integrated detector for both single photon number resolving detection and homodyne mesurements.
- ✓ Base for the realization of a complete integrated structure for quantum computing.
- ✓ Several photon number integrated detectors are the basis for a fully integrated quantum computer.
- ✓ Homodying can be used for innovative techniques for the generation of quantum numbers.

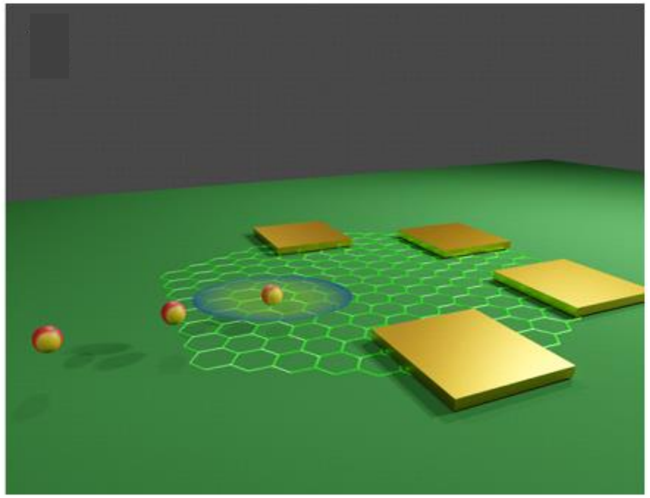
Multidimensional nANodevice archItectures For lOw-perturbation singLe-ion Detection (MANIFOLD)

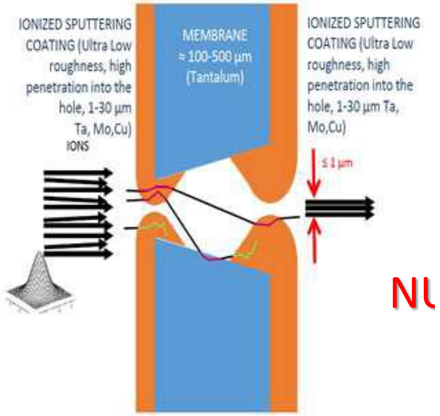
➢ Francesco Rossella - Pavia

nanotubes or nanowires



2D crystals





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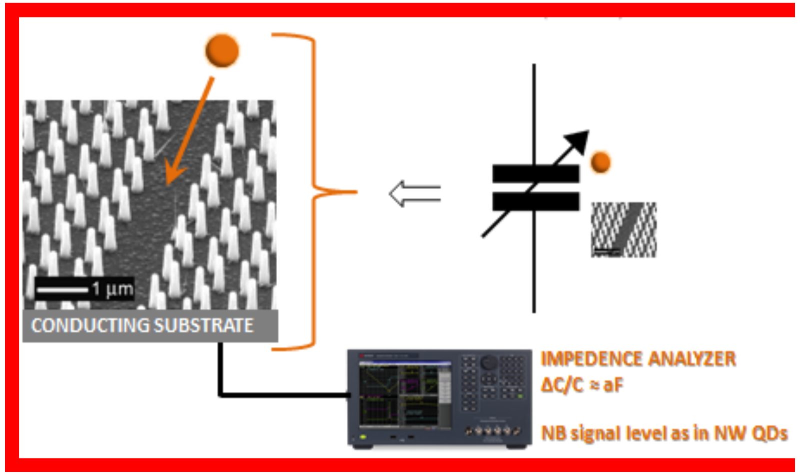


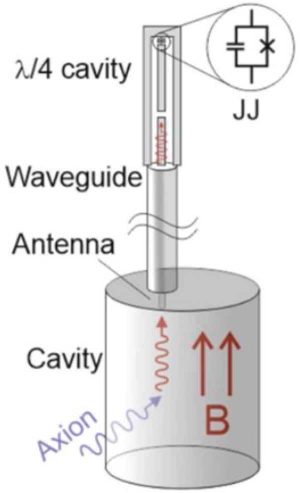
Istituto Nazionale di Fisica Nucleare

Resilience

➤ Alessandro D'Elia - LNF

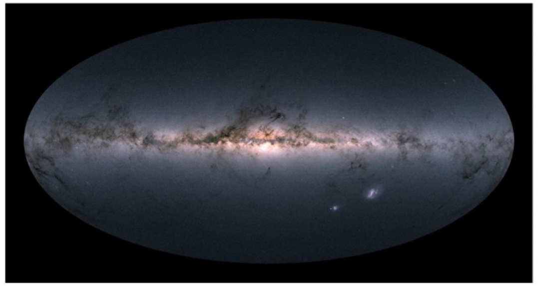
Magnetic field resilient microwave single photon detector based on van der Waals Josephson junctions

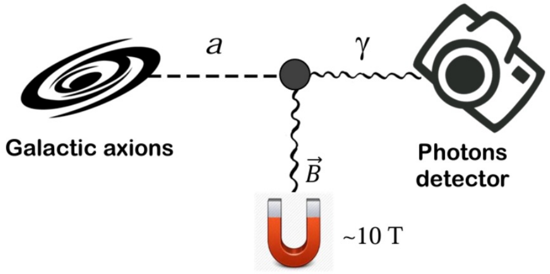
JJ as microwave single photon detector



- *Fabrication of $NbSe_2$ JJ with controllable thickness (electrodes and insulating layer)*
- $NbSe_2$ JJ electrical characterization at cryogenic temperature and in presence of strong magnetic field
- Test of $NbSe_2$ JJ as microwave single photon detector (operating in a 9 T Magnetic field)

Axions as dark matter





Background

- Axions and the necessity for single microwave photon detector
- Josephson junctions
- Current limitations of JJ

Proposal

- vdW materials as platform for quantum technologies
- $NbSe_2$ junctions to overcome the limitations
- Timetable, team composition and budget required

Superconducting Quantum Devices & Experiments at FBK

FONDAZIONE BRUNO KESSLER

➤ Federica Mantegazzini – FBK – Trento

Goal: Development of superconducting quantum circuits

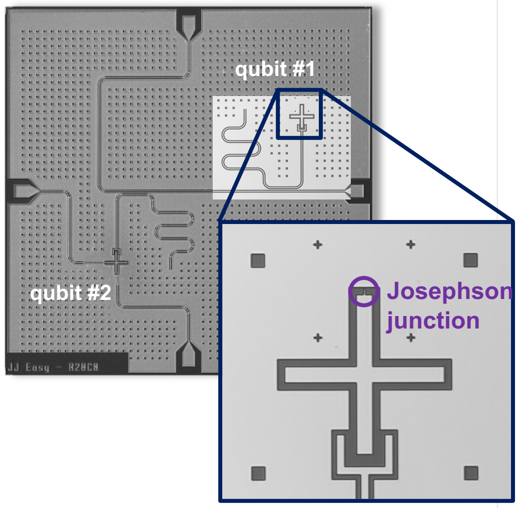
- Josephson junctions (Al/AlOx/Al & other materials)
- Quantum-limited amplifiers (TWPAs, JPAs)
- Qubits (transmons)

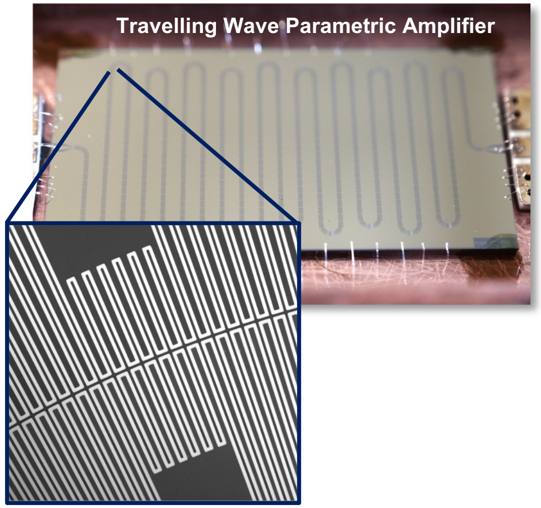
Activities: Design, simulations, microfabrication, optimisation of cryogenic set-ups, cryogenic measurements, final experiments

Facilities:

- State-of-the-art microfabrication/packaging cleanrooms
- Analysis/characterisation tools (SEM/EDX/EDS, AFM, TOF-SIMS, XPS, …)
- Cryogenic laboratory (T_b = 10 mK) *under construction*

Applications: Quantum sensing, cQED experiments, cryogenic detectors





Projects:

NQSTI National Quantum Science and Technology Institute

QU- PILOT

Hy-QMS

DARTWARS

MiSS

Qub-IT

INFN

CSN5 Ricerca Tecnologica

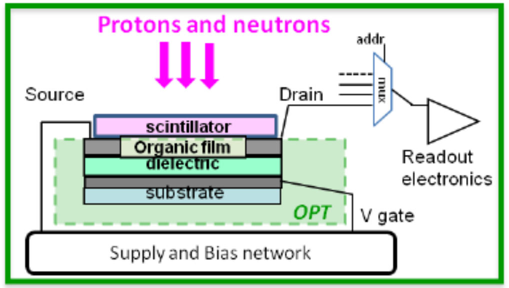
Italia domani

Ministero degli Affari Esteri e della Cooperazione Internazionale

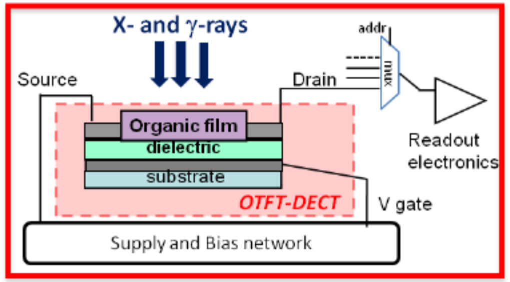
Flexible and Organic Detectors

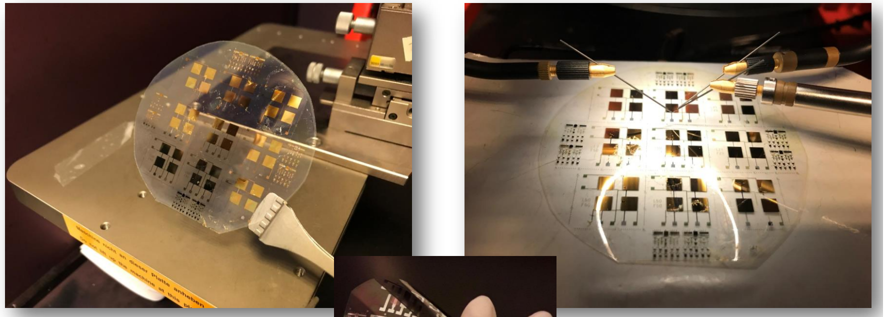
- Beatrice Fraboni
  Bologna

INDIRECT DETECTING SINGLE PIXEL (NEPRO)

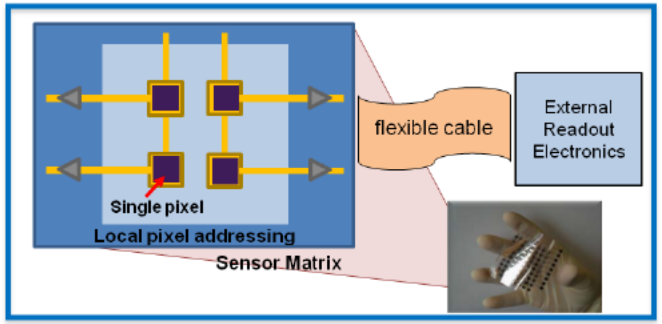


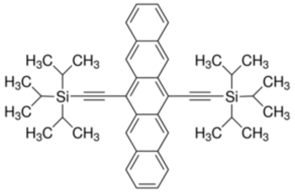
DIRECT DETECTING SINGLE PIXEL (PHOX)

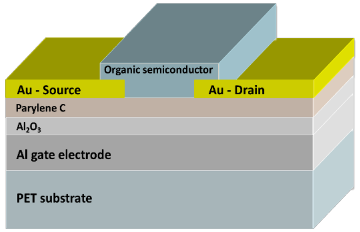




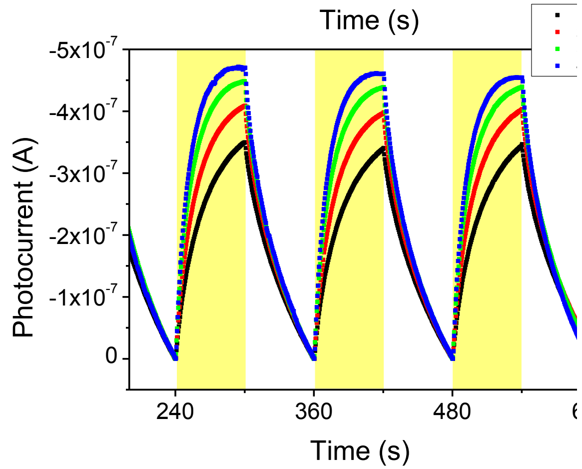
FULLY INTEGRATED FLEXIBLE DETECTING SYSTEM

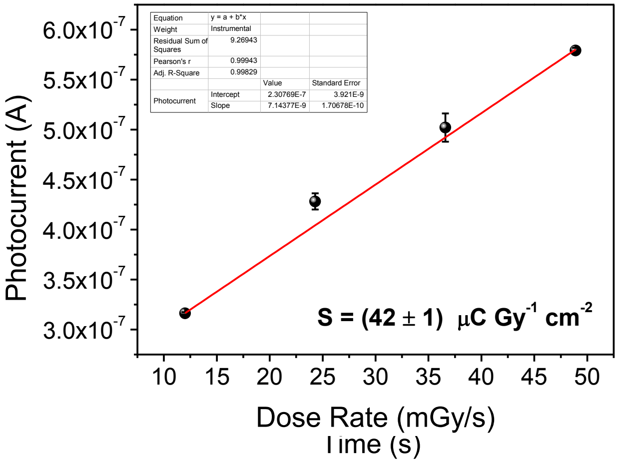


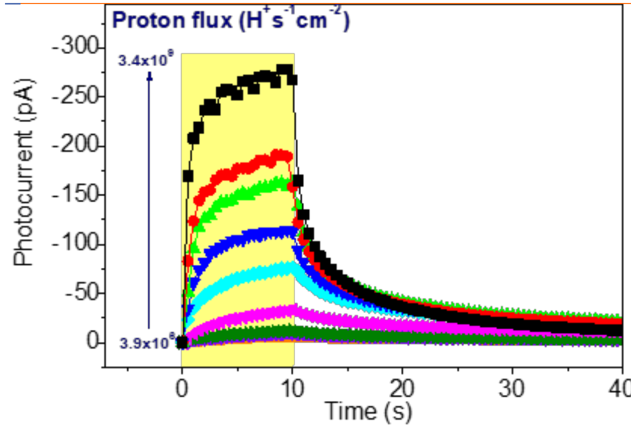


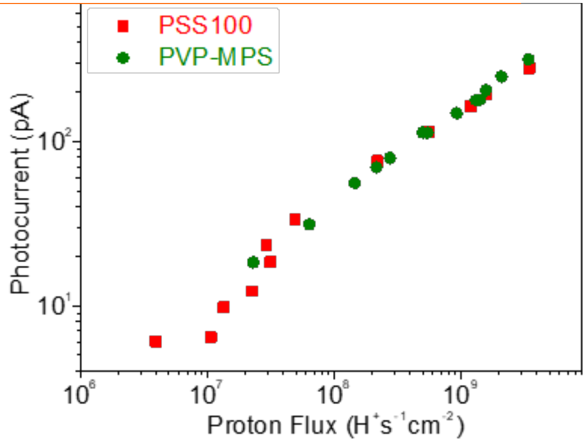


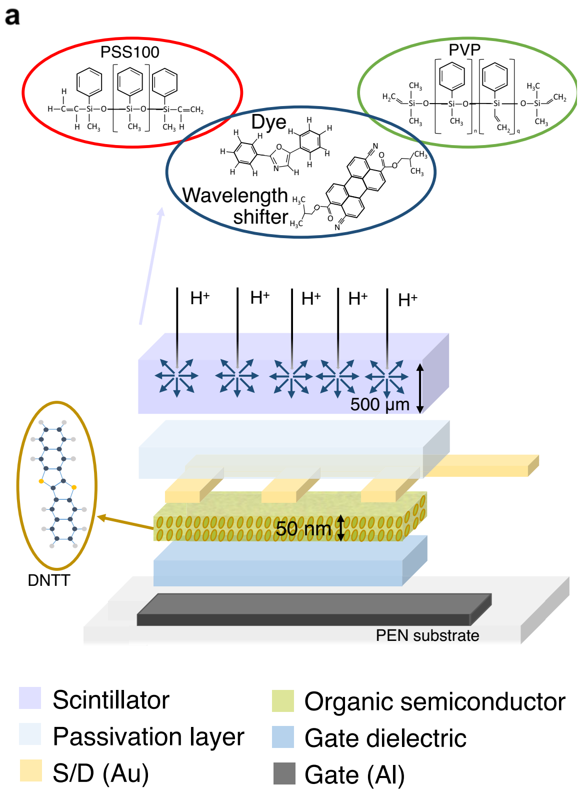
➤ Beatrice Fraboni
Bologna

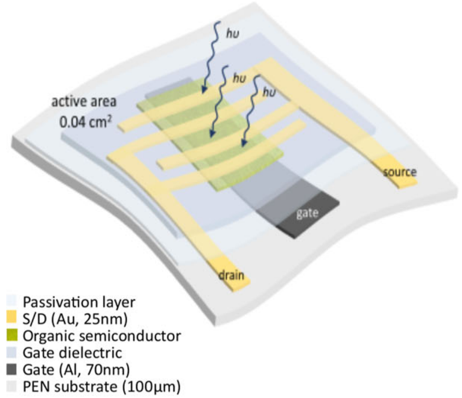


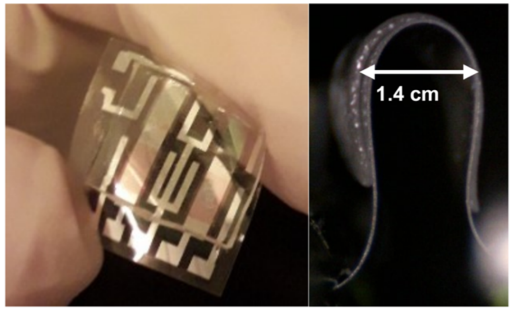










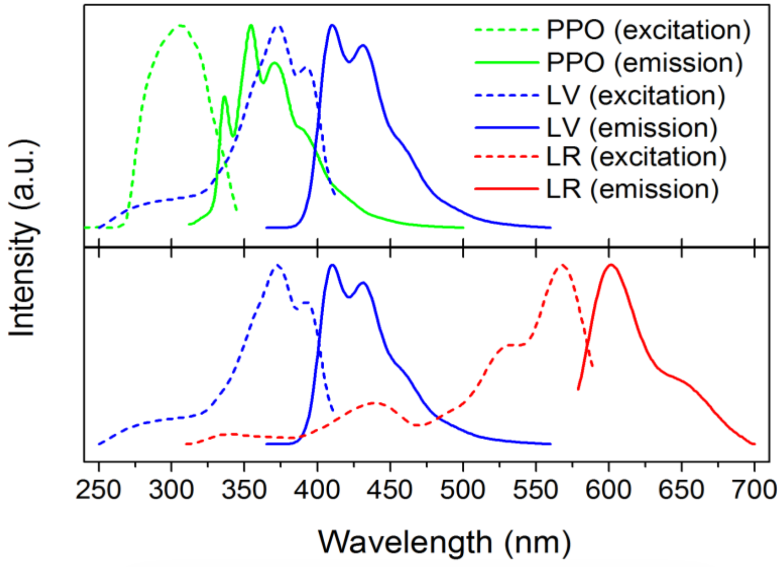


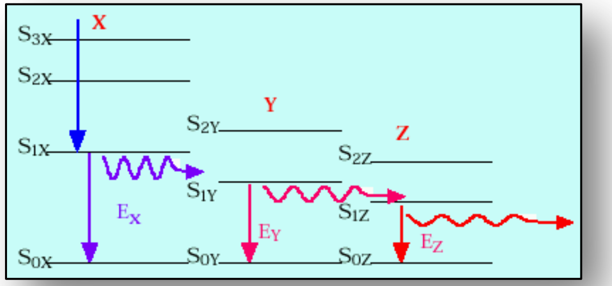
Polysiloxane scintillators

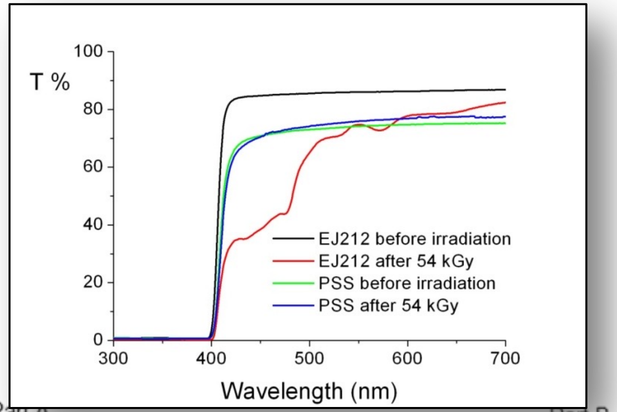
➢ Sara Carturan – LNL

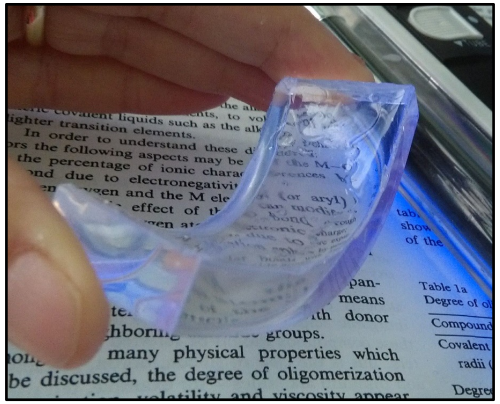
Polysiloxane scintillators peculiar features

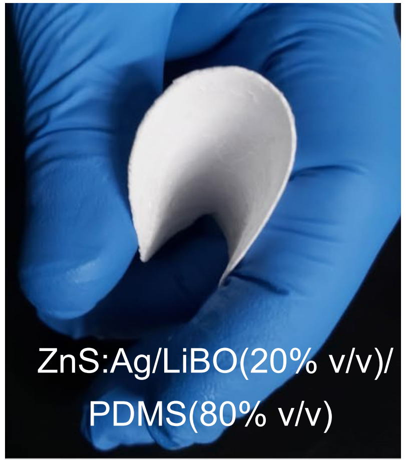
- ➢ Transparency
- ➢ Flexibility
- ➢ Radiation hardness
- ➢ Thermal resistance

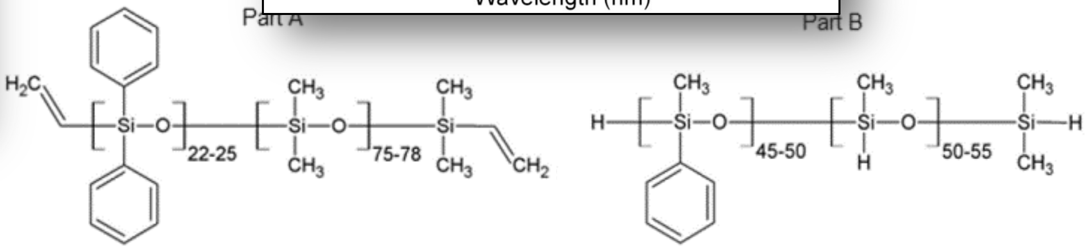


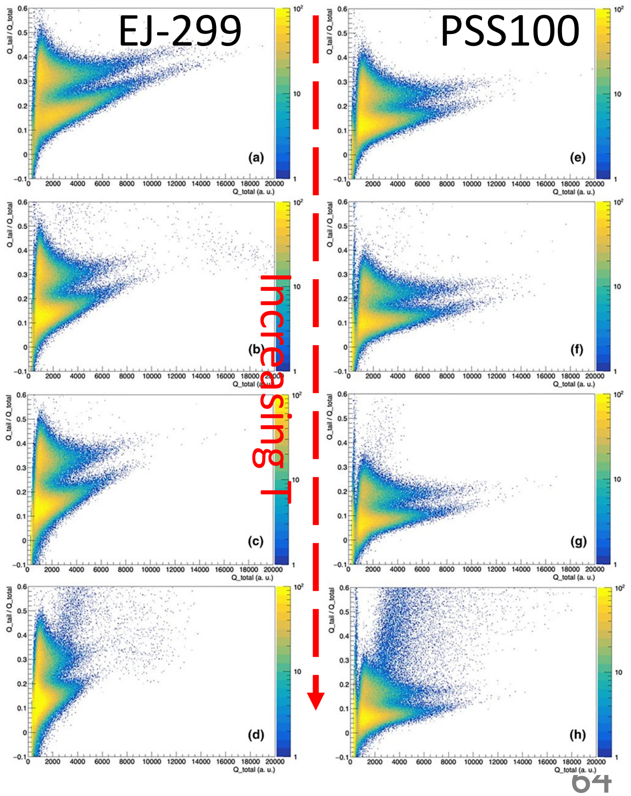










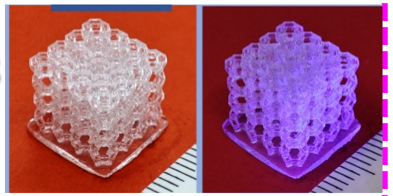


SHINE

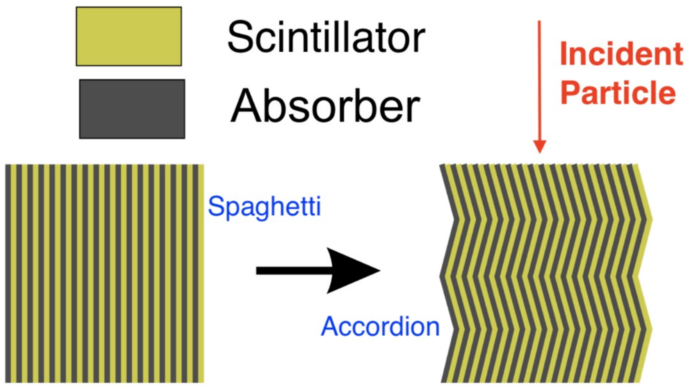
➢ Anna Paola Caricato – Lecce

Plastic Scintillators PHantom vIa additive maNufacturing tEchniques

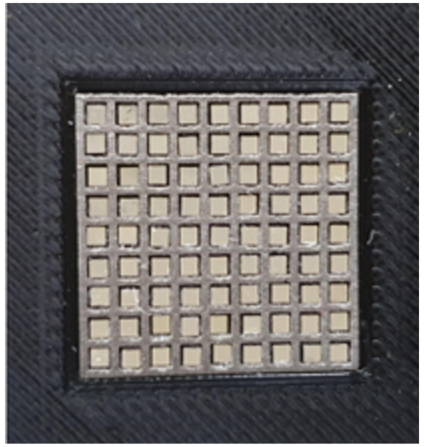
3D printed scintillators

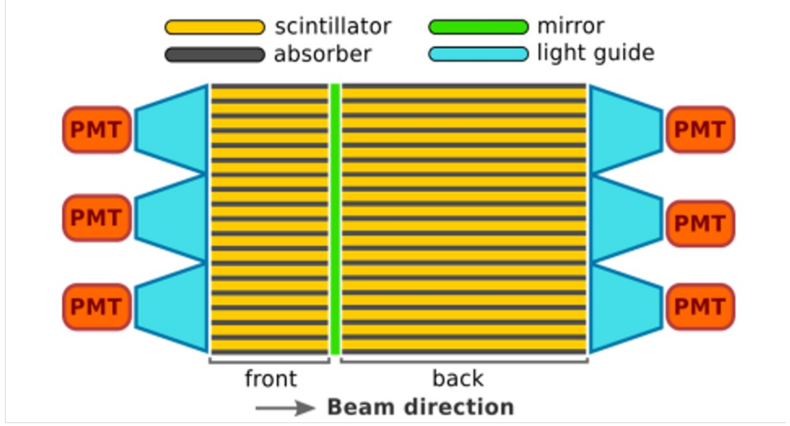


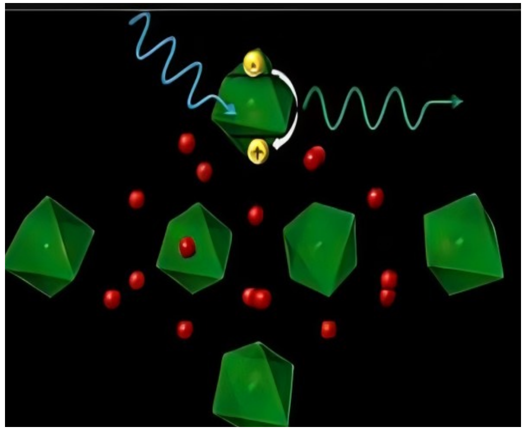
- UV curable siloxane through sol-gel chemistry
- Assessed formulations as for light yield and printability



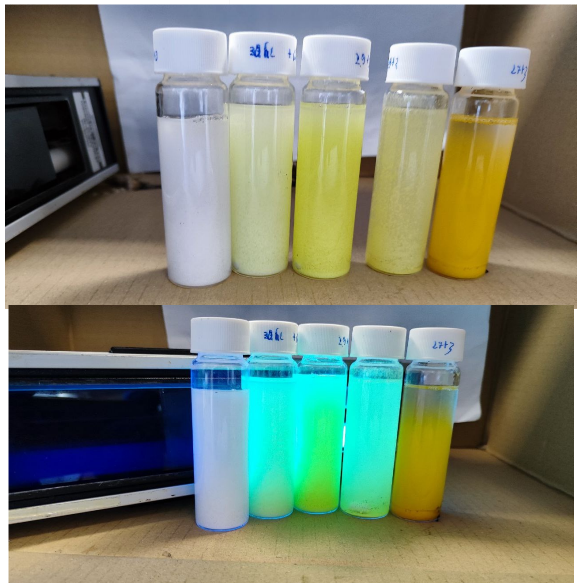
Tomorrow (SPACAL modules)







Cs_4PbBr_6



ANEMONE
hAdroN bEam MONitoring by pErovskite based detectors

MAIN AIM:

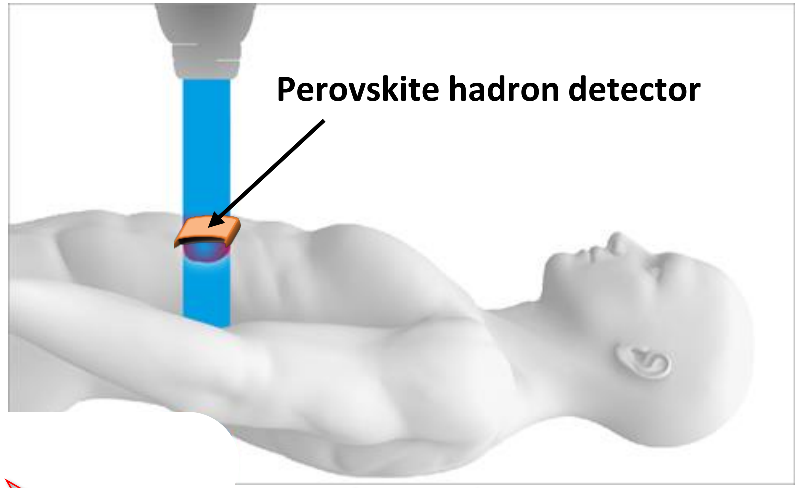
Development of **the first PEROVSKITE (Hybrid and Inorganic) film-based real-time direct detector for PROTONS and IONS**, as **beam monitor** for **hadron therapy** and as beam test tool for high-energy experiments, realized on flexible substrate.

OBJECTIVES:

i) **Unravel the interaction of charged particles** with nanostructured **hybrid and inorganic perovskite** films to design novel detectors.

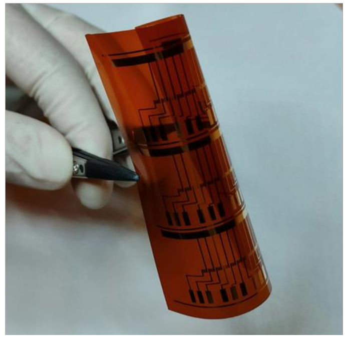
ii) **Design and optimization** of the most performing PVK-based active layer (hybrid and inorganic) and detector layout for hadron detection.

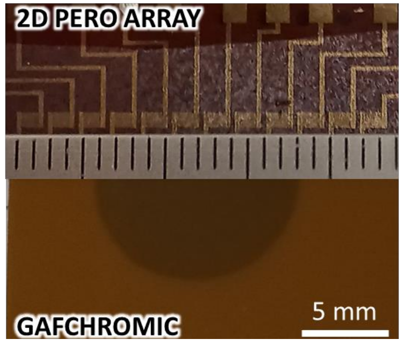
iii) **Test under relevant proton/ion irradiation and dosimetric characterization** for beam monitoring application during hadrontherapy treatments.

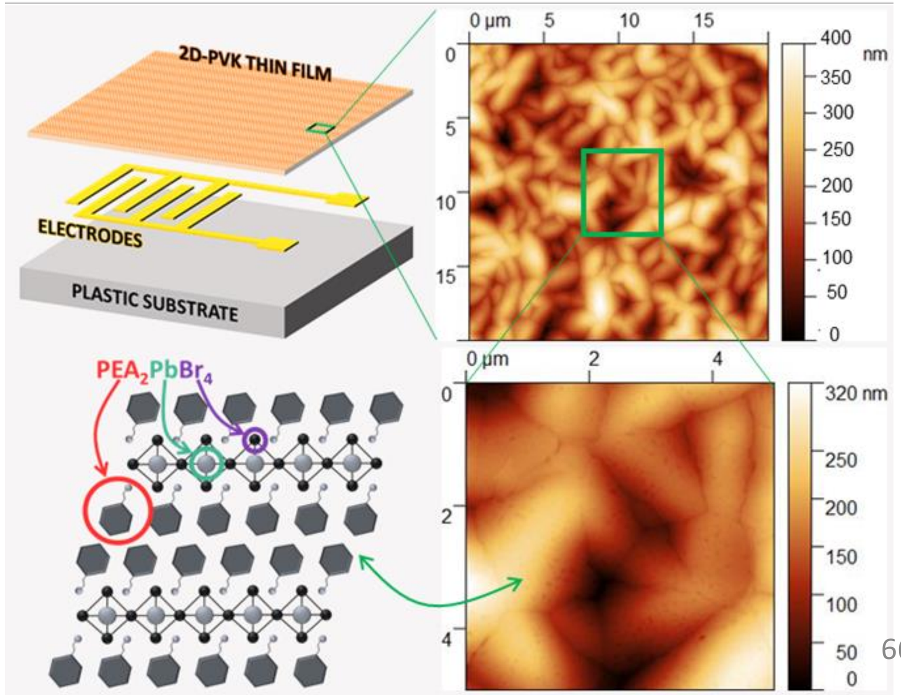


➢ Laura Basiricò - Bologna

Solution grown 2D perovskites on Kapton **flexible substrate**







➤ Ilaria Fratelli - Bologna

BEYOND

– flexiBlE hYbrid neutrON Detectors –

Grant for young reasearchers funded by CSN5 – INFN

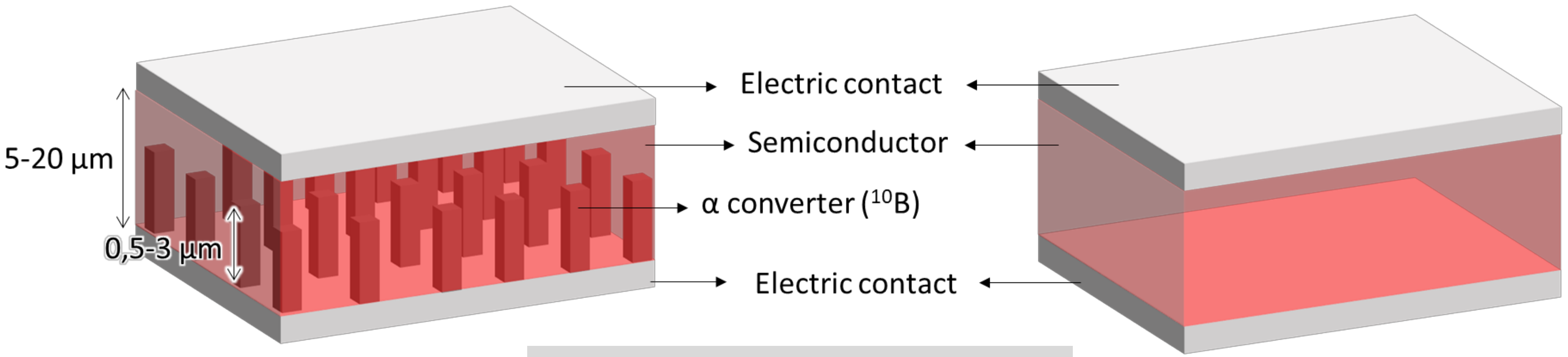
GOALS

fabrication and characterization of flexible and large-area detectors for thermal and fast neutrons based on hybrid halide perovskites and organic polymers.

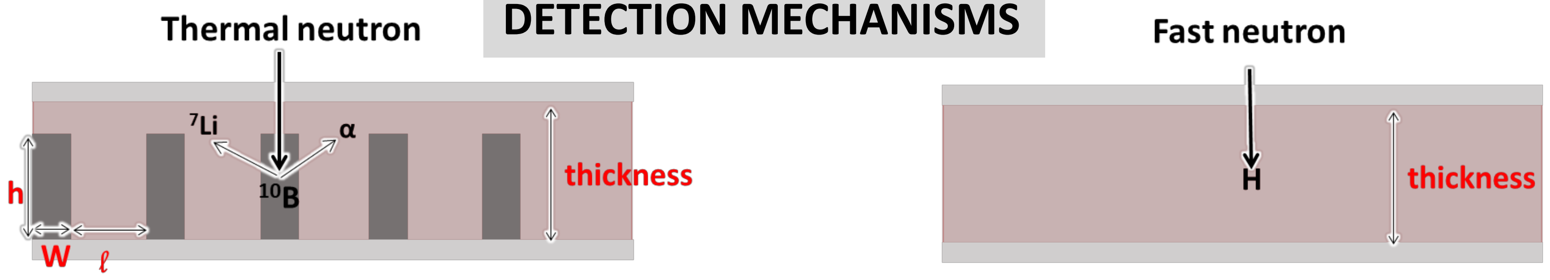
For the detection of thermal neutrons we will exploit the coupling with 3D microstructures of ^{10}B, while the detection of fast neutrons will be based on the intinsically high density of H atoms.

TND DETECTION OF THERMAL and EPITHERMAL NEUTRONS

FND DETECTION OF FAST NEUTRONS

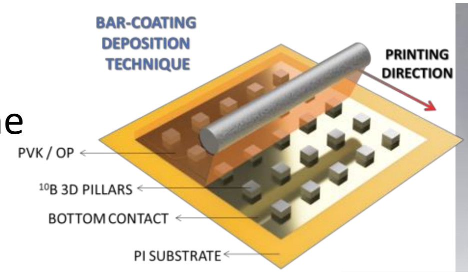


DETECTION MECHANISMS

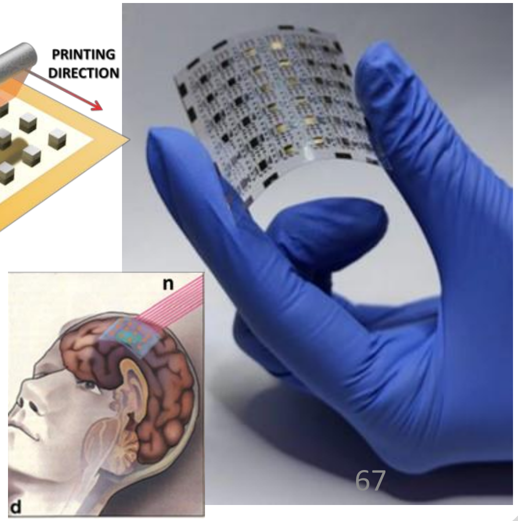


ADVANTAGES

The main advantage offered by BEYOND is the possibility of deposit the semiconductor (polymer or perovskite) from solution **by low-cost, low-tech and low-temperature deposition techniques easy-scalable onto large and flexible surfaces.**

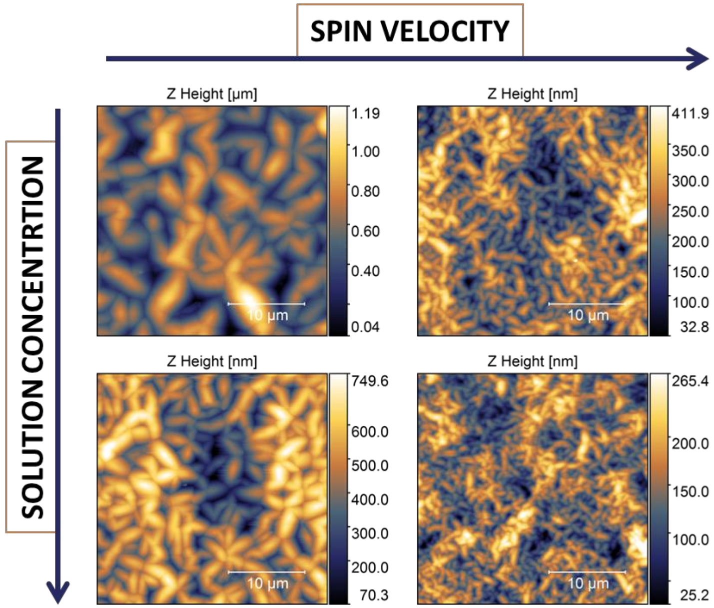


→ **WEREABLE, REAL-TIME and IN-LINE PERSONAL DOSIMETERS**



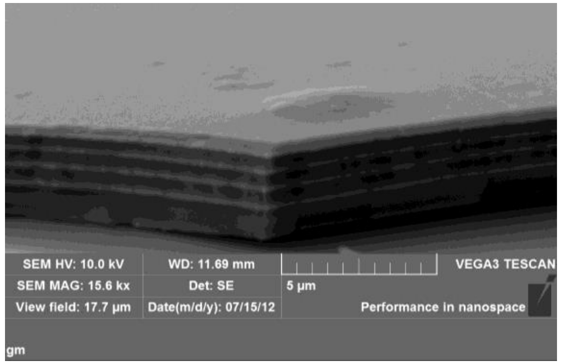
Ilaria Fratelli - Bologna

2D HYBRID PEROVSKITE deposition optimization



Tuning of the morphology and semiconductor thickness by varying the deposition parameters

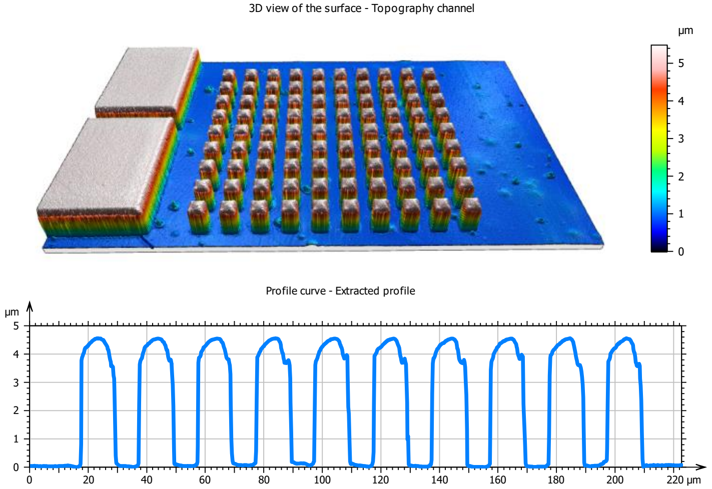
α-converter DEPOSITION



^{10}B/Ti multilayer deposition by RF magnetron sputtering

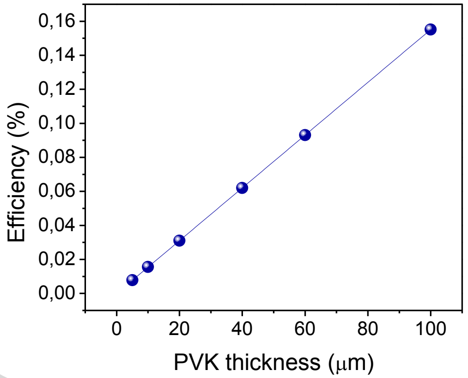
3D PILLARS micropatterning

by photolithography technique



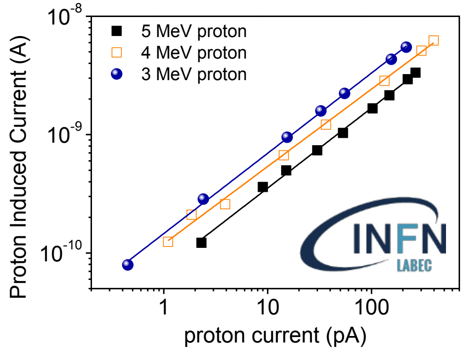
MONTE CARLO simulation (Geant4)

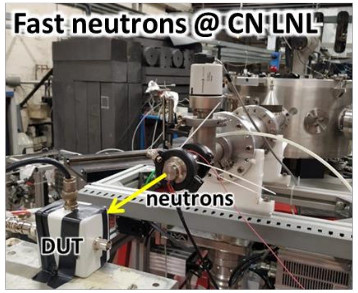
Calculation of the Neutron detection efficiency varying the perovskite thickness

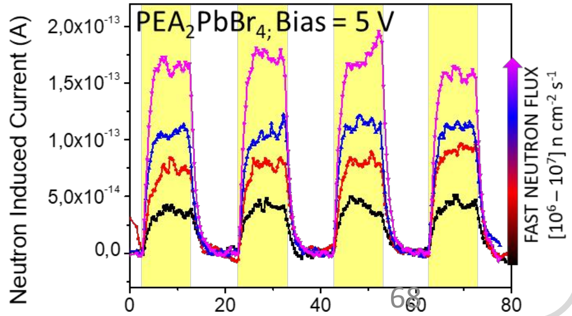


TEST under NEUTRONS and other RADIATION

Detection response under protons and fast neutrons





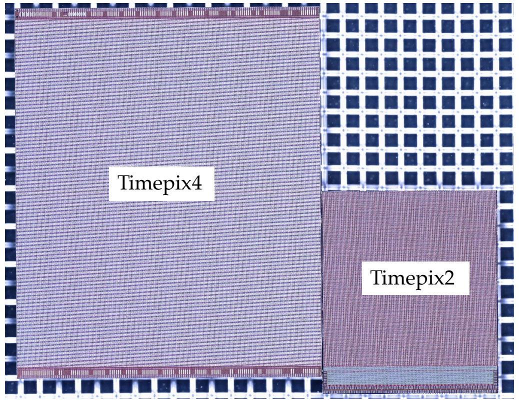


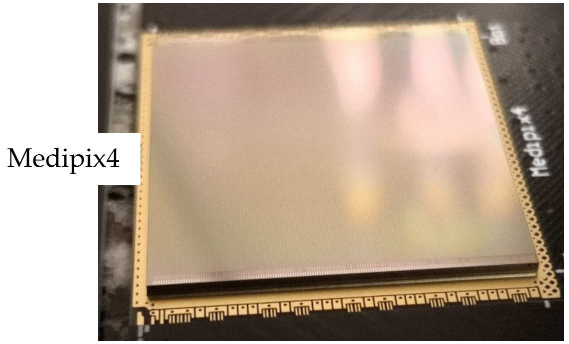
Detectors for Medical Applications

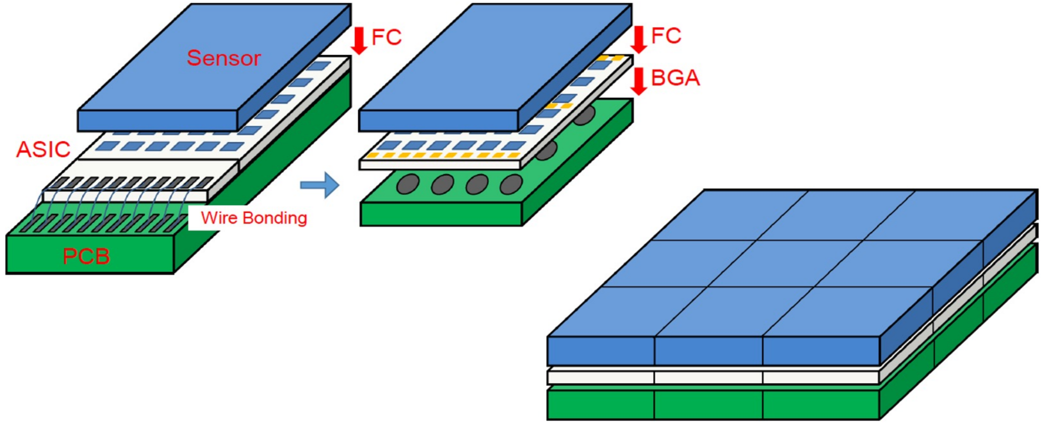
MEDIPIX4

➤ Massimiliano Fiorini – Ferrara

- Medipix4 international Collaboration based at CERN
  - 20 members, 2 ASICs
  - INFN joined in 2020
- Scientific goals: development of hybrid pixel detector ASICs
  - 2 ASICs for 4-side buttable large pixel detectors thanks to vertical integration (Through Silicon Via)
    - Spectroscopic X-ray imaging at rates compatible with medical CT scans (**Medipix4**)
    - Single-threshold particle tracking detector chip with improved energy and time resolution and data-driven architecture (**Timepix4**)

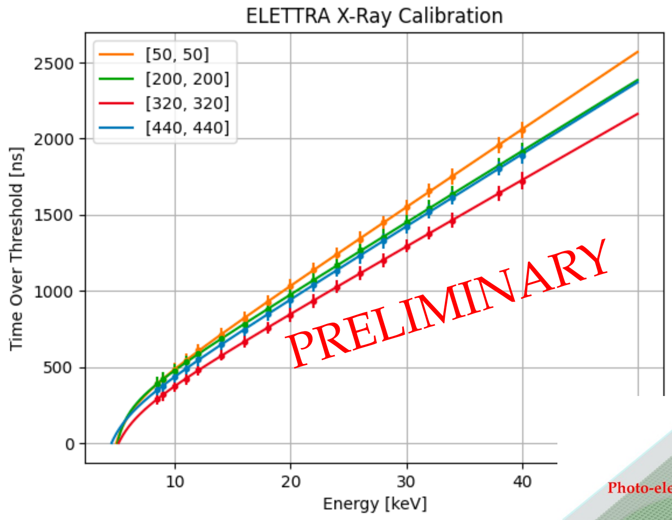


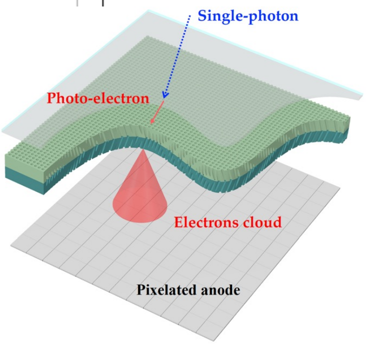




MEDIPIX4

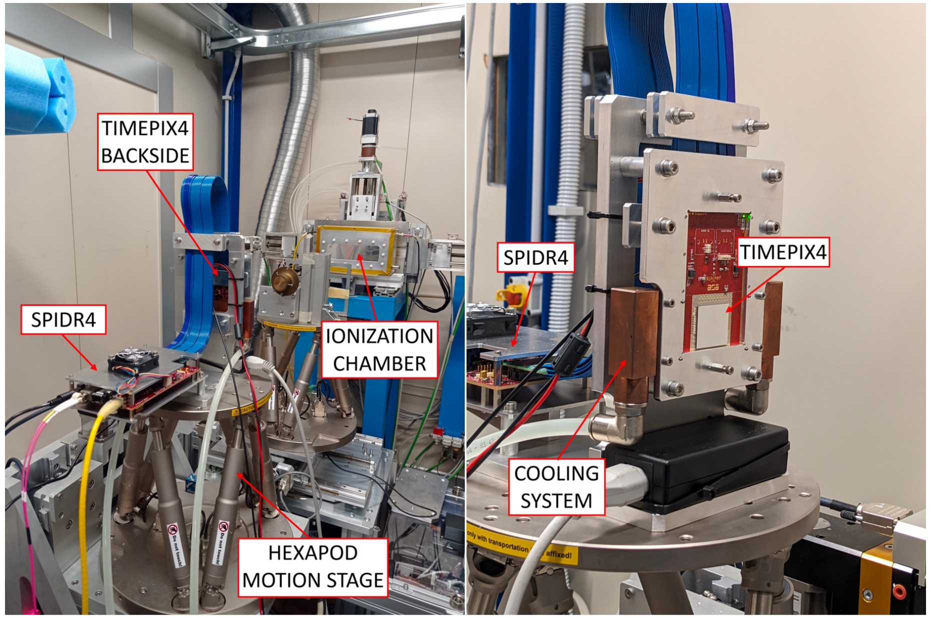
- Main interest of INFN groups:
  - Medical imaging, nuclear medicine, dosimetry, particles tracking
  - Visible photon detector (ERC-funded 4DPHOTON project) with excellent timing and position resolutions.





Massimiliano Fiorini (Ferrara

European Research Council



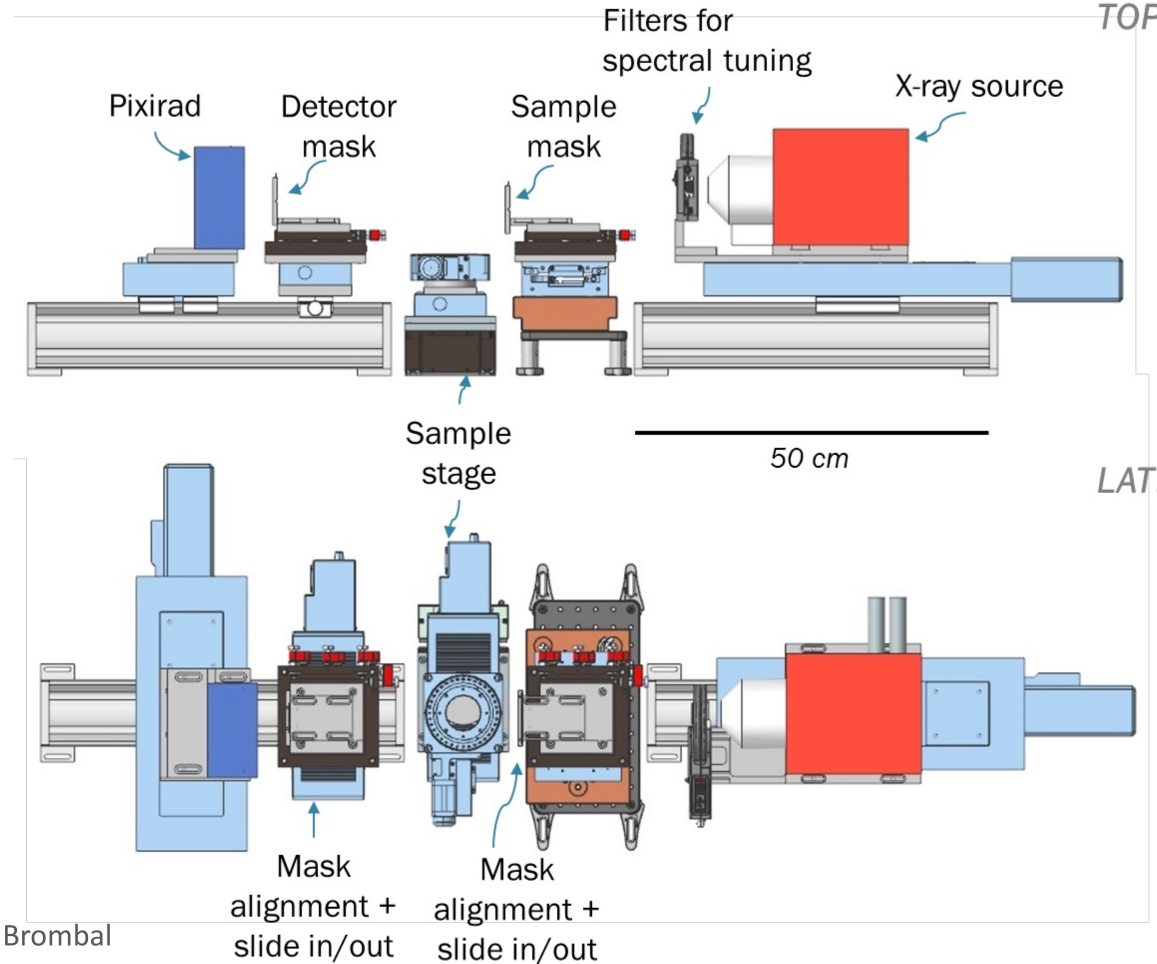
Measurement setup in Elettra Synchrotron (October 2023)

Medipix Collaboration Meeting in Ferrara (June 2022)

SYSTEM CHARACTERIZATION - PEPI Laboratory

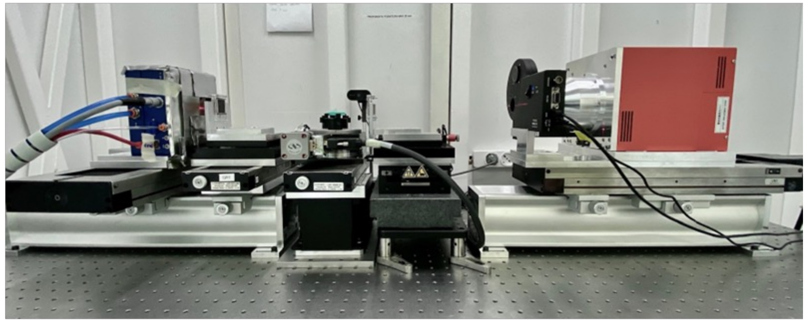
PEPI laboratory is a new multimodal X-ray imaging setup integrating 2 cutting edge technologies: 1. A Chromatic High-Z detector (Pixirad-PixieIII) and 2. Phase contrast imaging through the propagation-based and edge-illumination techniques

PEPI is a project funded by the *Young researchers grant* programme – CSN5 – INFN

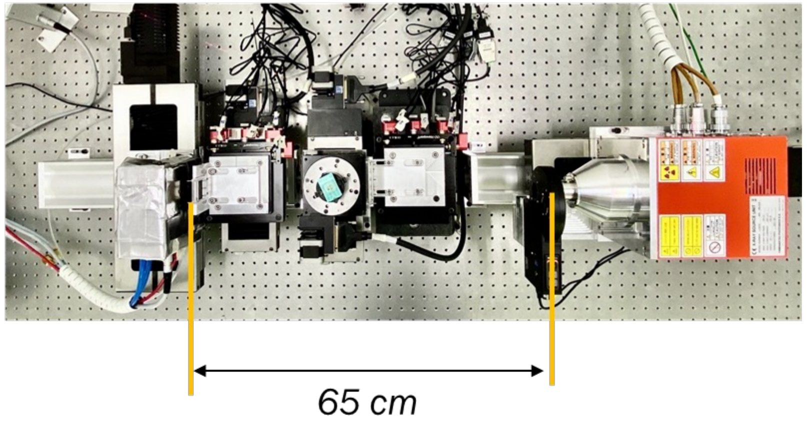


TOP VIEW

➤ **Luca Brombal – Trieste**



LATERAL VIEW



P hoton-counting
E dge-illumination
P hase-contrast
I maging

Brombal, Luca, et al. *Scientific Reports* 13.1 (2023): 4206.

L. Brombal

INFN

R&D on primary beam monitors and Prompt Gamma Timing for particle therapy (MERLINO&SIG)

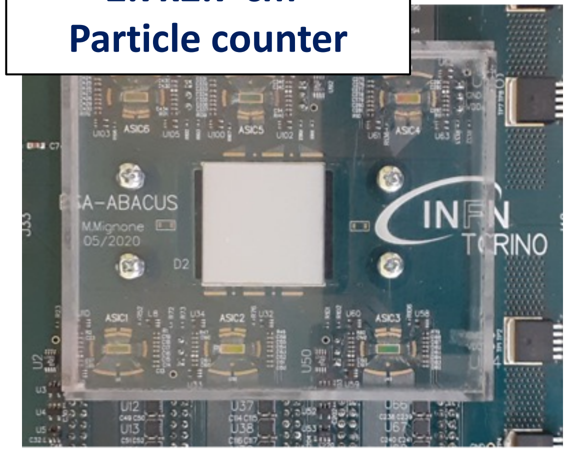
CSN5 Ricerca Tecnologica

Superconducting Ion Gantry

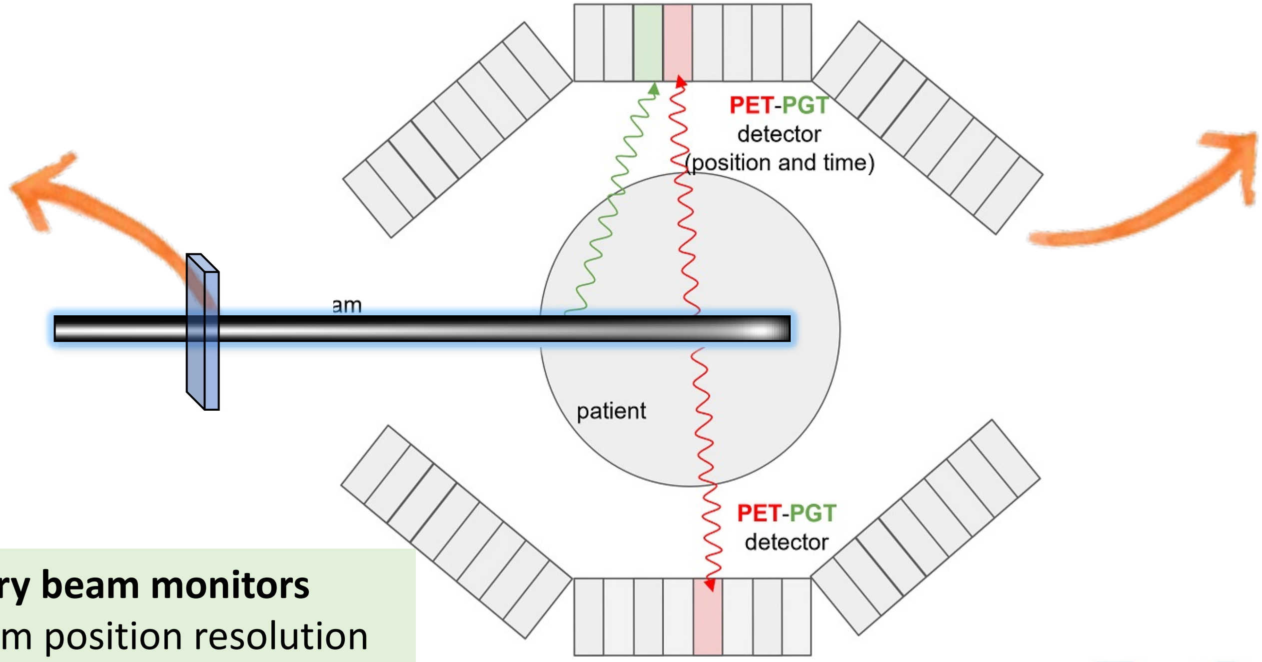
INFN-To expertise: Detectors for Medical applications → proton and ion therapy

SIG aims at exploiting **thin silicon sensors** and **picoTDC technologies** for **single particle tracking** up to clinical beam intensity (**10^8 part/cm^{2}s**) to
 (1) overcome the low sensitivity of ionization chamber and allow fast scanning;
 (2) provide trigger for range verification system based on **Prompt Gamma Timing (PGT).**

2.7x2.7 cm^2
Particle counter

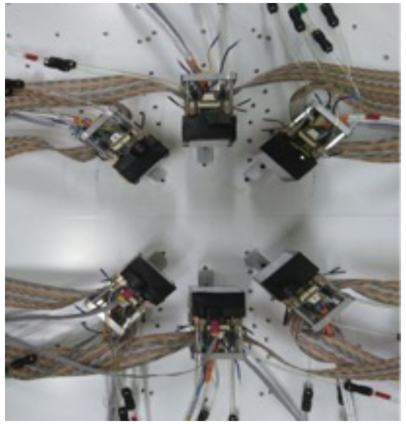


BEAM MONITOR
Thin LGAD and PIN strip sensors



Primary beam monitors
< 50 μm position resolution
< 20 ps time resolution

PET-PGT DETECTORs
LFS + SiPM read out
by INFN-TOFPET2 ASICs



➢ Simona Giordanengo - Torino

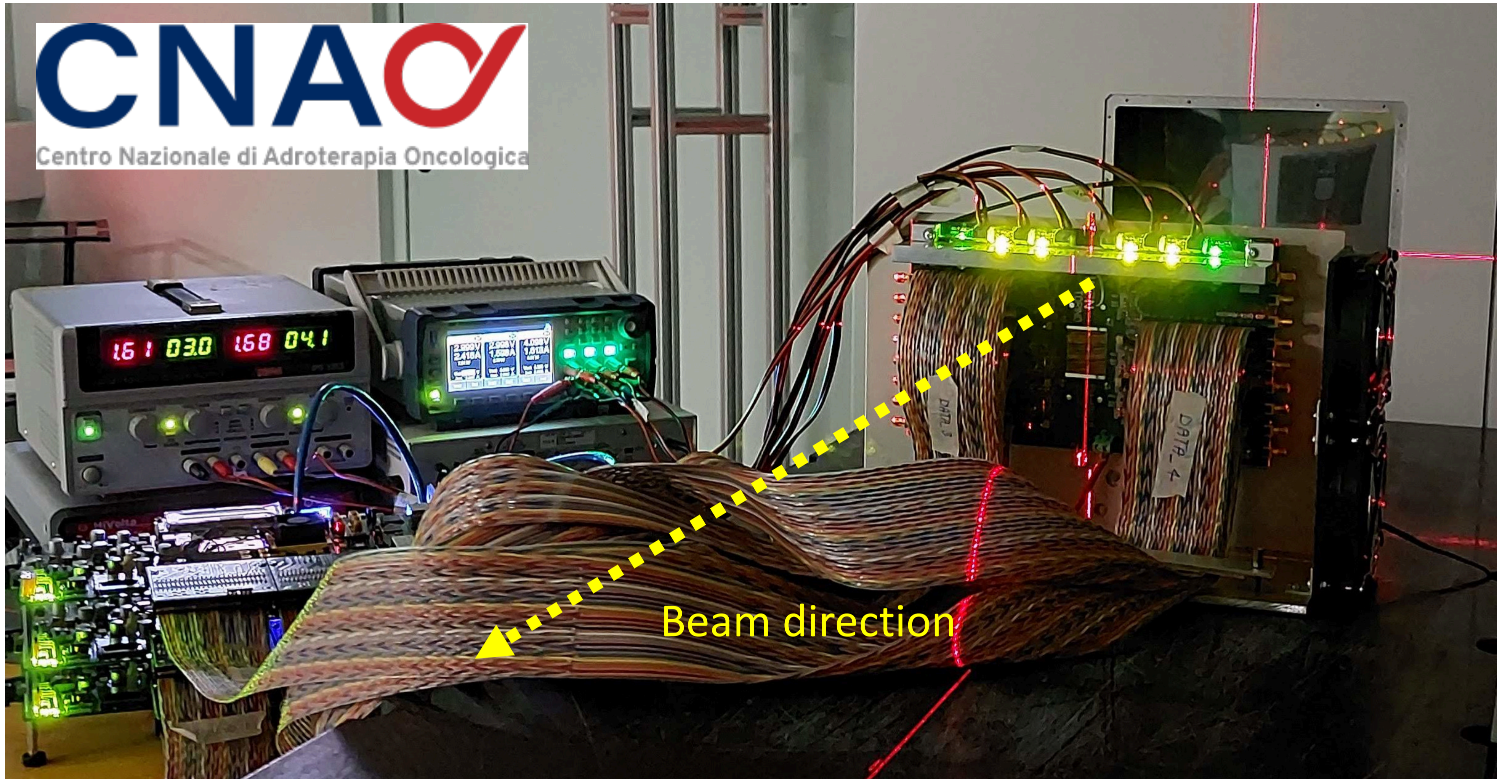
FONDAZIONE BRUNO KESSLER
CNAO Centro Nazionale di Adroterapia Oncologica
INFN TORINO Istituto Nazionale di Fisica Nucleare Sezione di Torino

R&D on primary beam monitors for ion therapy (SIG project)

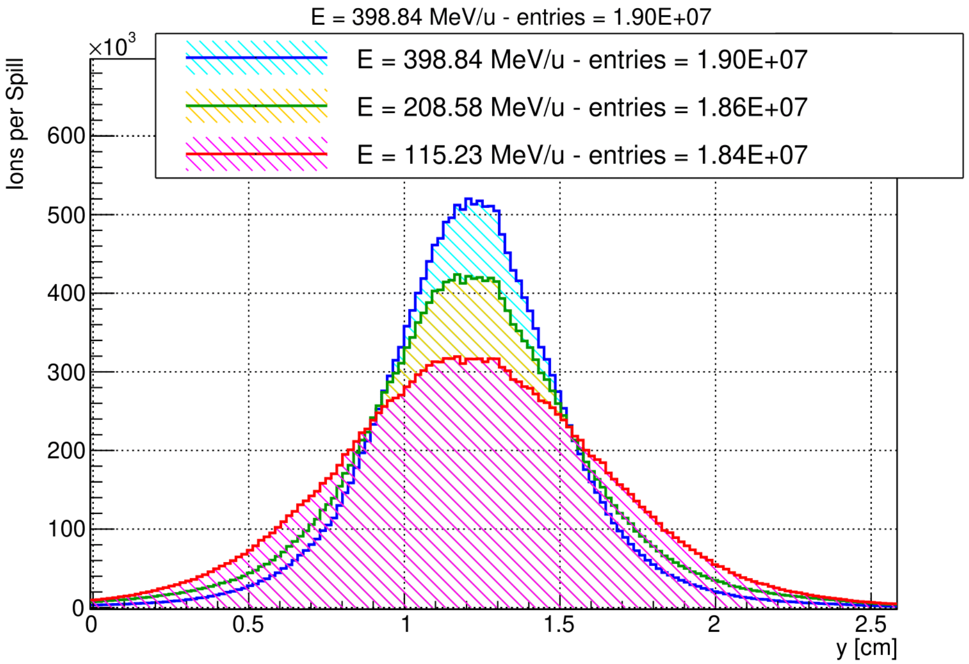
Superconducting Ion Gantry

➢ Simona Giordanengo - Torino

Example of carbon ions counter test at CNAO (Pavia, Italy)



Carbon Ions beam profiles at
3 monoenergetic beam energies



Optimized DAQ based on **CAEN picoTDC** for time measurement of single primary particle with ~ 1 ps bin

Sensors, ASIC and DAQ system designed and developed at INFN

R&D on beam monitors for FLASH therapy and minibeams

FRIDA&MIRO

- Anna Vignati – Torino
- Roberto Sacchi - Torino

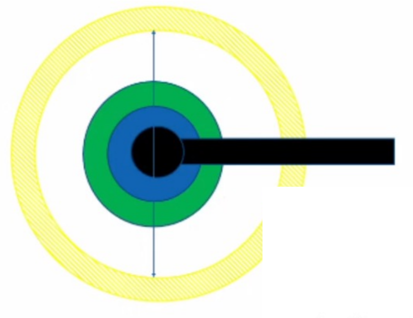
MIRO (Minibeam Radiotherapy)
Francesco Romano Catania

FRIDA
Alessio Sarti
Roma

CSN5 Ricerca Tecnologica

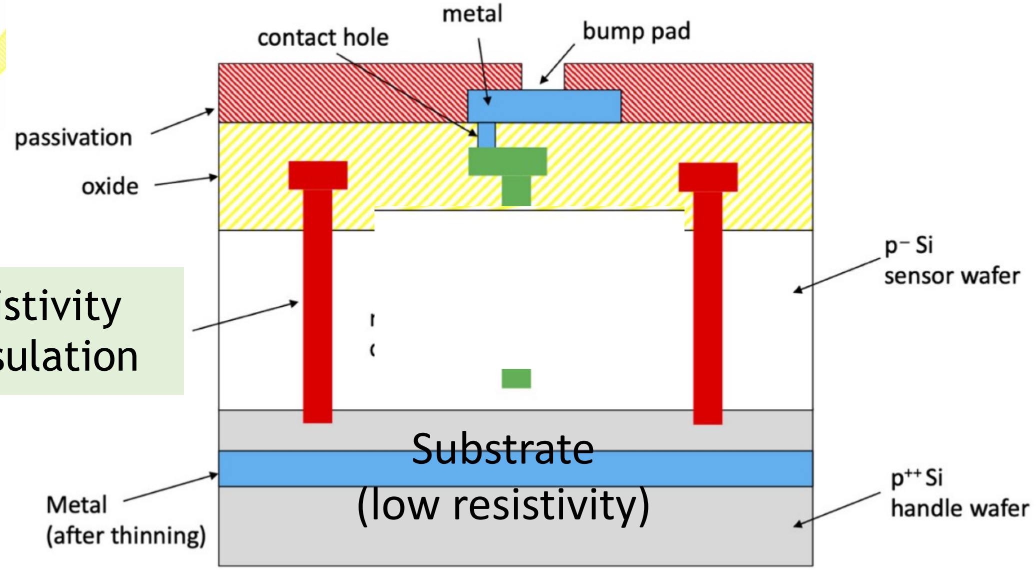
FRIDA aims at exploting **thin silicon sensors** for beam monitoring of Ultra High Dose Rate beams needed for FLASH therapy

MIRO aims at exploiting **new silicon sensors** for **monitoring minibeams**



Top View

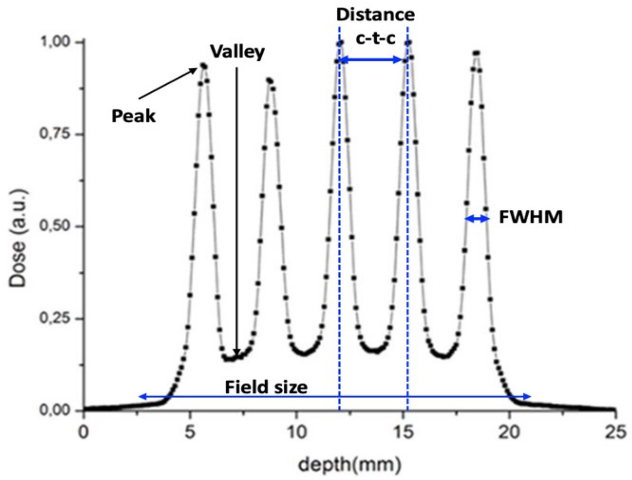
High Resistivity Trench Insulation



Side View

Vbias contact

Modified from: Dalla Betta, G. F., & Ye, J. (2023). Silicon radiation detector technologies: From planar to 3D. Chips, 2(2), 83-101.



Key features:

- Precise definition of the active volume
- Optimal insulation from surrounding sensors
- Small sensor size for high resolution measurements on single minibeam

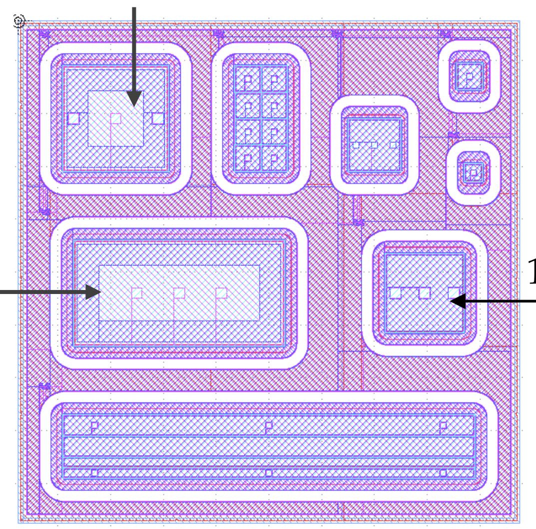
UNIVERSITAS STUDII TAURINENSIS 1404 · FONDAZIONE BRUNO KESSLER · INFN TORINO Istituto Nazionale di Fisica Nucleare Sezione di Torino

PiN planar silicon sensor for Ultra High Dose Rate beams

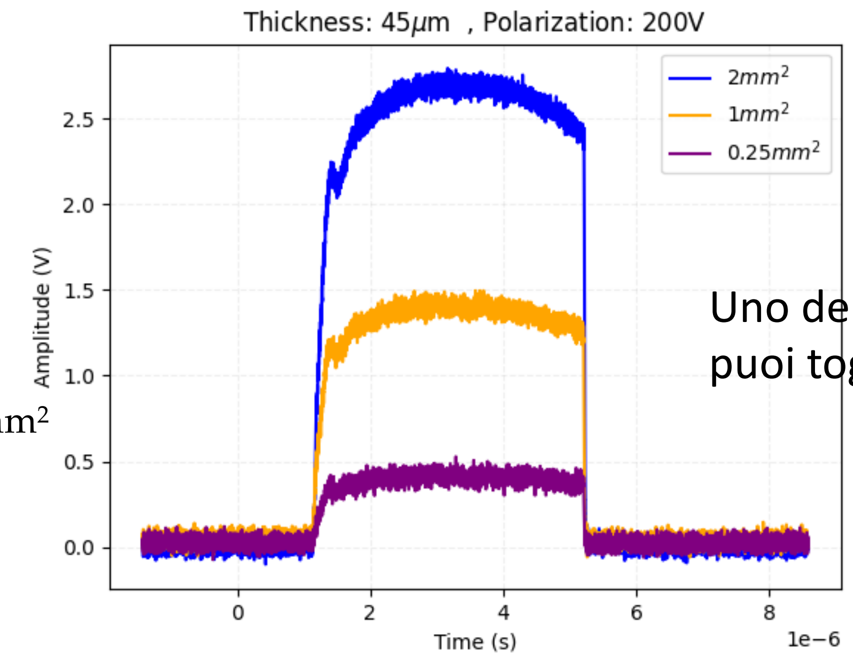
Tests at 9 MeV UHDR electrons @ CPFR EF in Pisa

Sensors, ASIC and DAQ system designed and developed within INFN projects

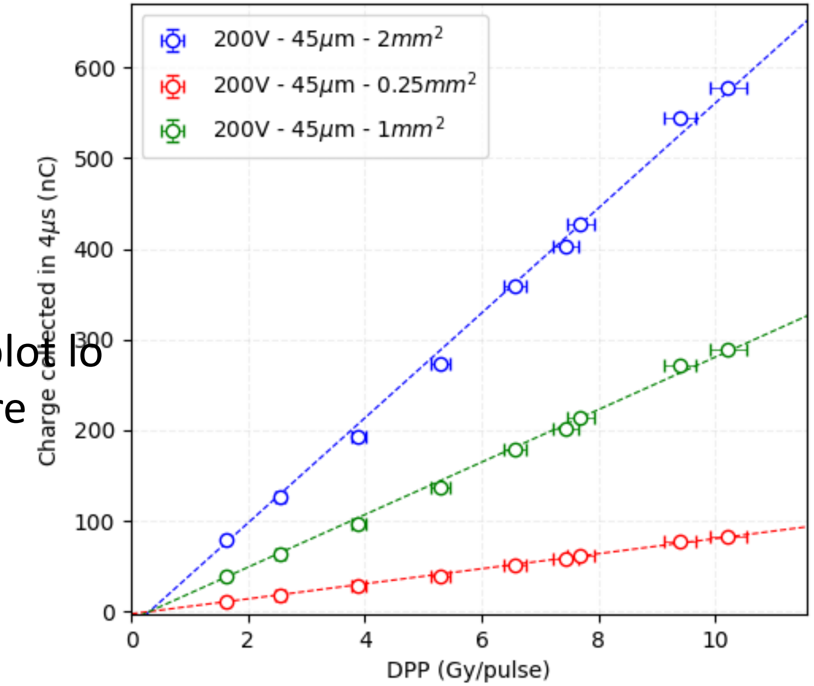
- **3 pad sensors (pin) [eXFlu]**
- Areas 2/1/0.25 mm^2, active thickness **45/30 μm**, total thickness 615 μm)



Sensors with different areas and thicknesses *developed in collaboration with INFN-**ExFLU** project*



Uno dei 2 plot lo puoi togliere



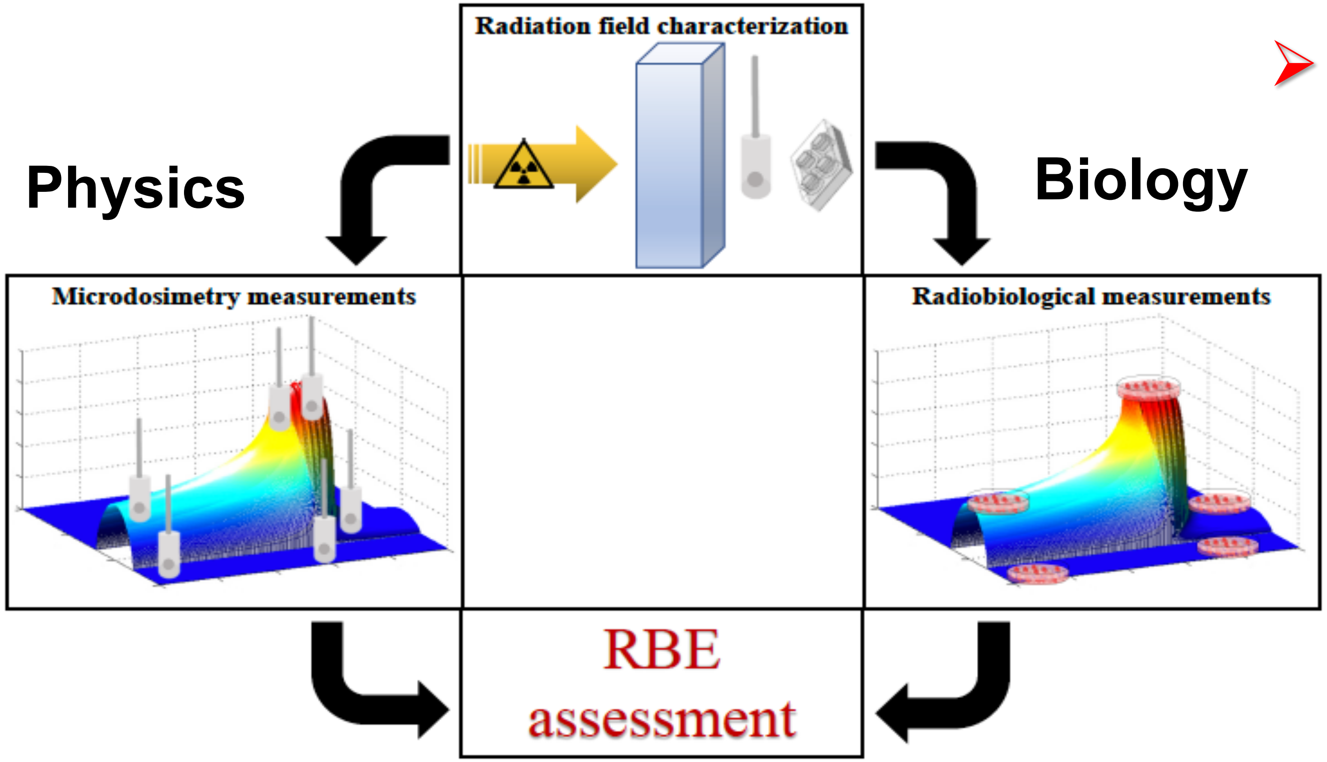
➢ Valentina Sola - Torino

MICROBE_IT: MICROdosimetry-based assessment of Biological Effectiveness in Ion Therapy goal

Field of research: particle therapy for cancer treatment

Outcome: GSM^2 (Generalized Stochastic Microdosimetric Model) for predicting cell survival and RBE (relative biological effectiveness)

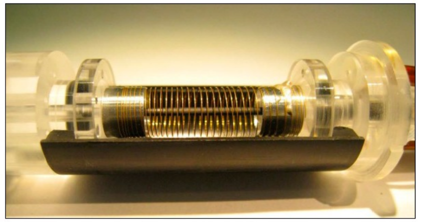
Goal: improve treatment planning effectiveness, and decrease normal tissue toxicity.



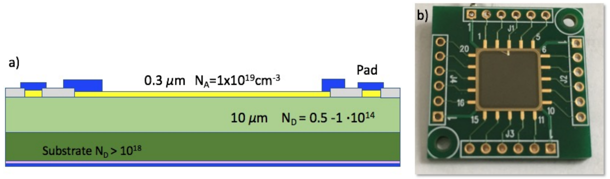
- Chiara La Tessa - Trento

MICROBE_IT: MICROdosimetry-based assessment of Biological Effectiveness in Ion Therapy goal

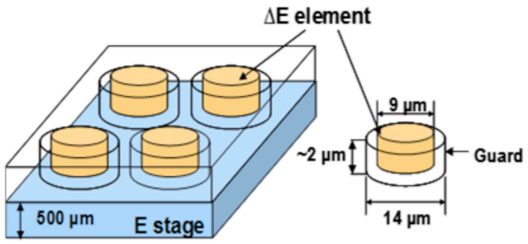
µicrobe_IT



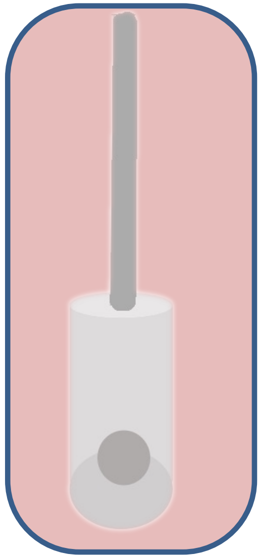
Mini-TEPC



Micro Plus probe

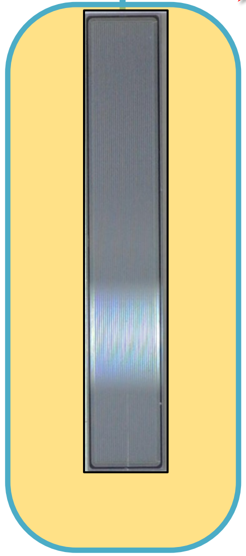


Silicon telescope



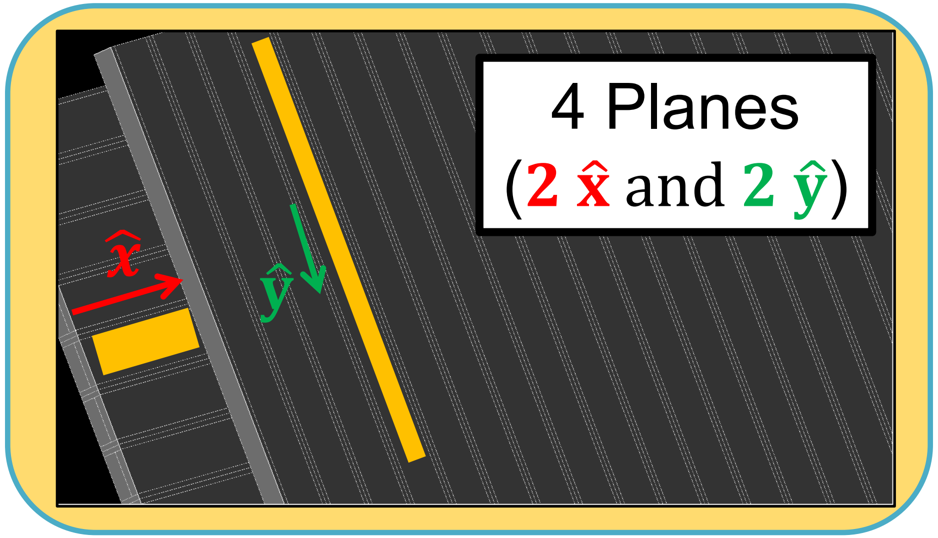
TEPC

+



LGADs

➤ Chiara La Tessa - Trento

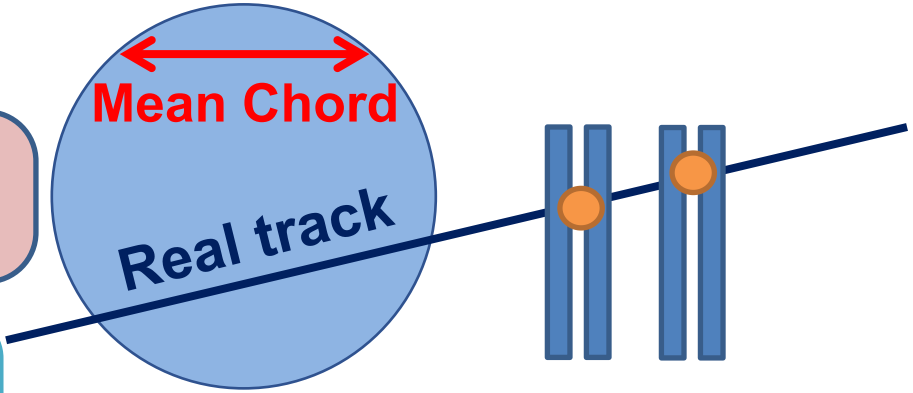


NEW

$$= \frac{\varepsilon}{RTL}$$

Energy deposition of all particles traversing the TEPC

Real track length of particles provided by the LGADs

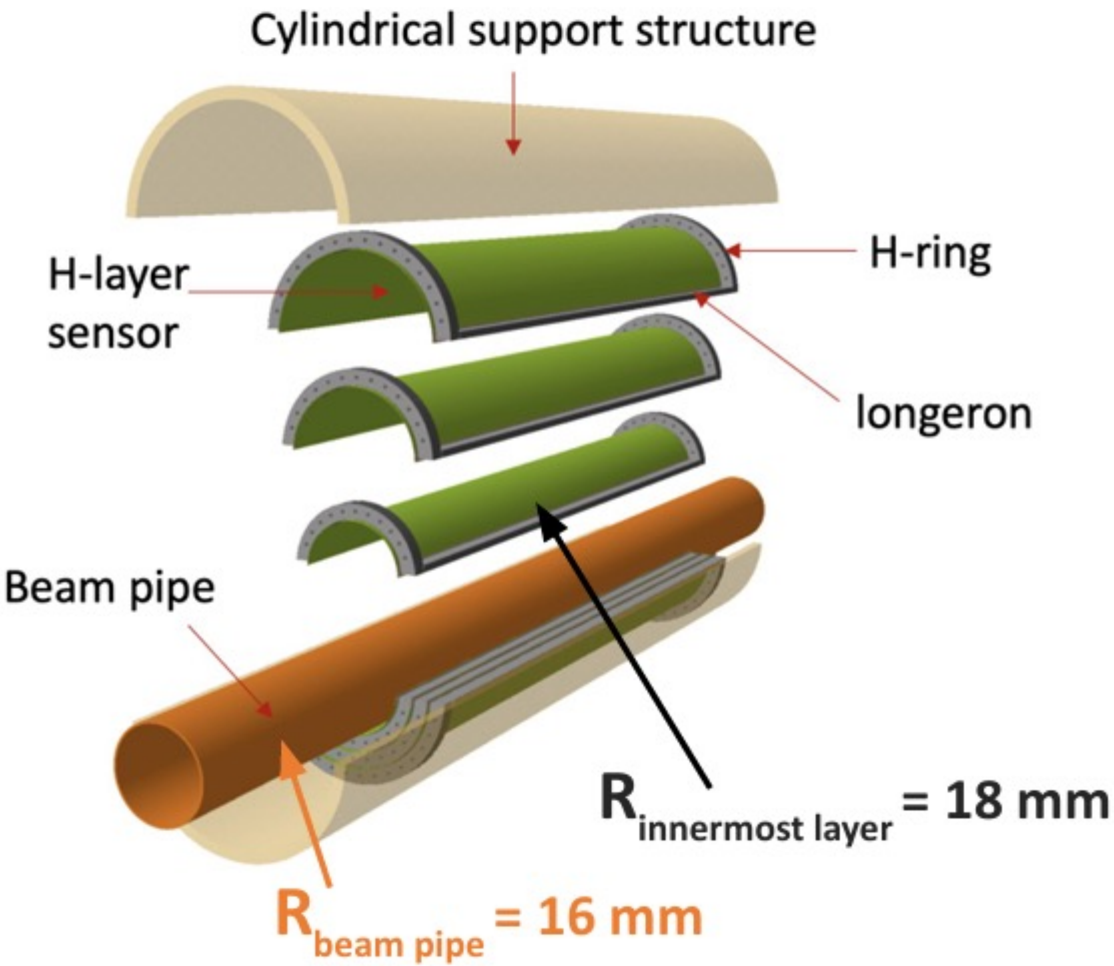


Large Detectors

The ITS3 - a bent vertex detector

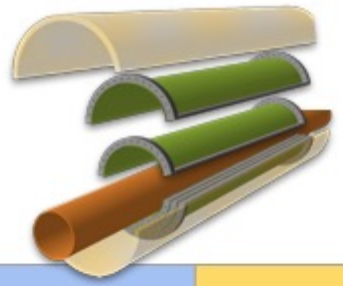
- Ready for LHC RUN 4 - mounted during LS3
- Built using **wafer-scale MAPS sensors**, fabricated using **stitching**
- **Thinned ≤ 50 μm,** when Si is **flexible**
- Mechanically held in place thanks to carbon foam ribs
- **Bent** to the target radius (18 mm, **closer** to the Interaction Point thanks to the new beam-pipe at 16 mm)
- Better tracking efficiency, less power consumption
- ITS3 will replace 3 innermost ALICE Inner Tracking System 2 (ITS2) layers with only **6 sensors** 26 cm long

The ITS3 structure



ITS3 roadmap

ALICE



LS2		RUN3				LS3			RUN4				LS4	
2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034
	MLR1		ER1	ER2 + ER3										

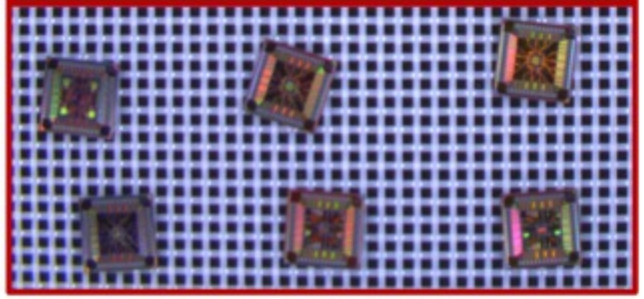
ITS3 (2021–2025)

You are **here**

Multi Layer Reticle 1 (MLR1)

First submission using a new CMOS TPSCo* 65 nm technology

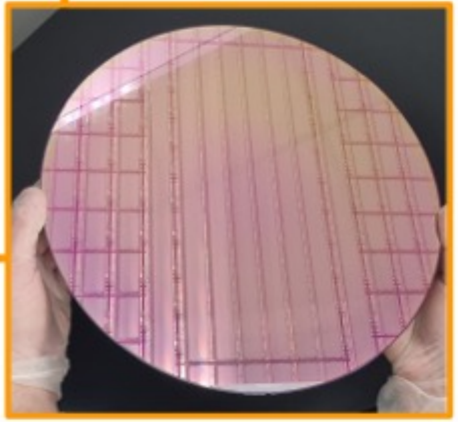
- Many prototypes
- Aim: technology qualification
- Small scale sensors



Engineering Run 1 (ER1)

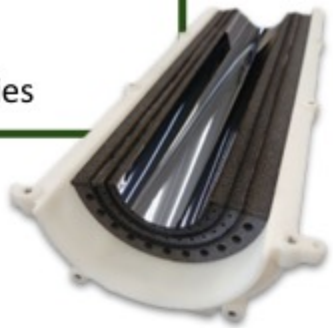
First stitched (wafer-scale) prototype

- 1D stitching
- First working stitching prototype in HEP
- First tests in 2023, July



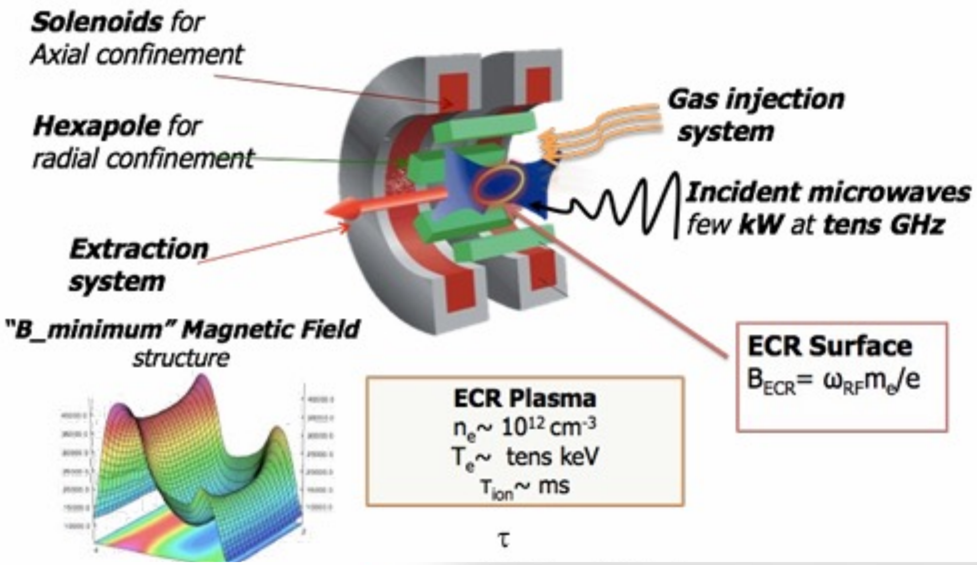
Engineering Run 2 (full sensor) + Engineering Run 3 (final sensor)

- 2D stitching
- **final size** sensor studies

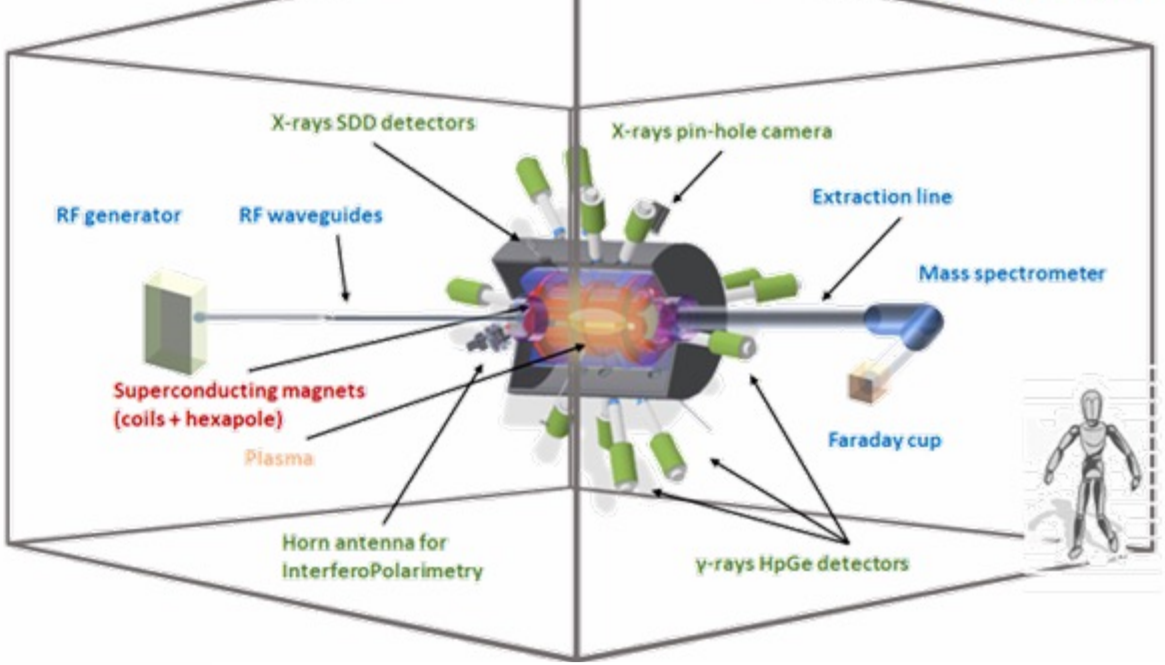


*Tower Partner Semiconductor Co.

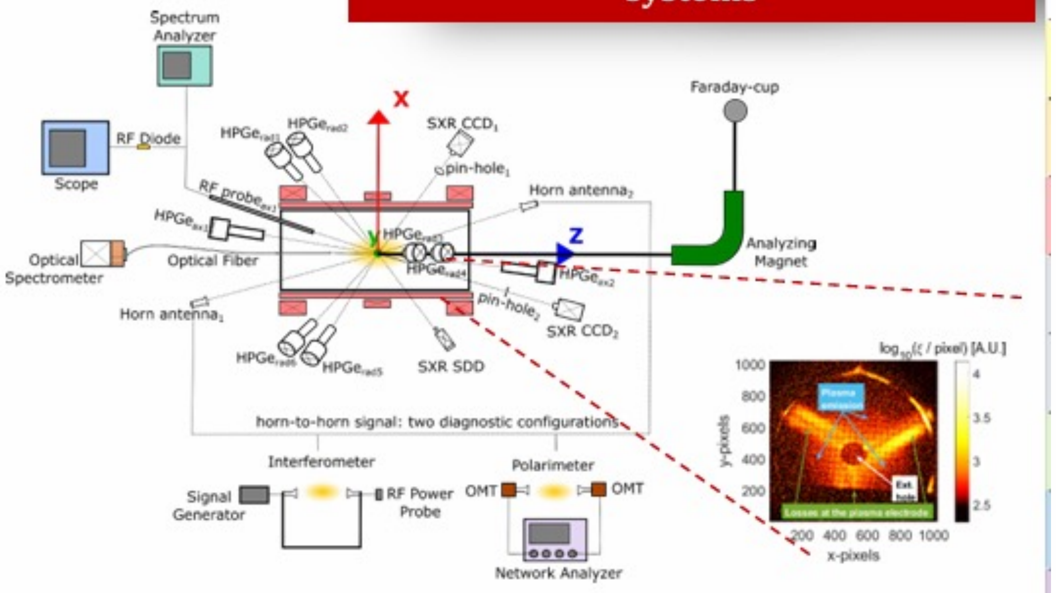
PANDORA: A New ECRIT – ECR Ion Trap for β-decay measurements in plasmas



Magnetic traps for hot plasmas excited by e.m. waves



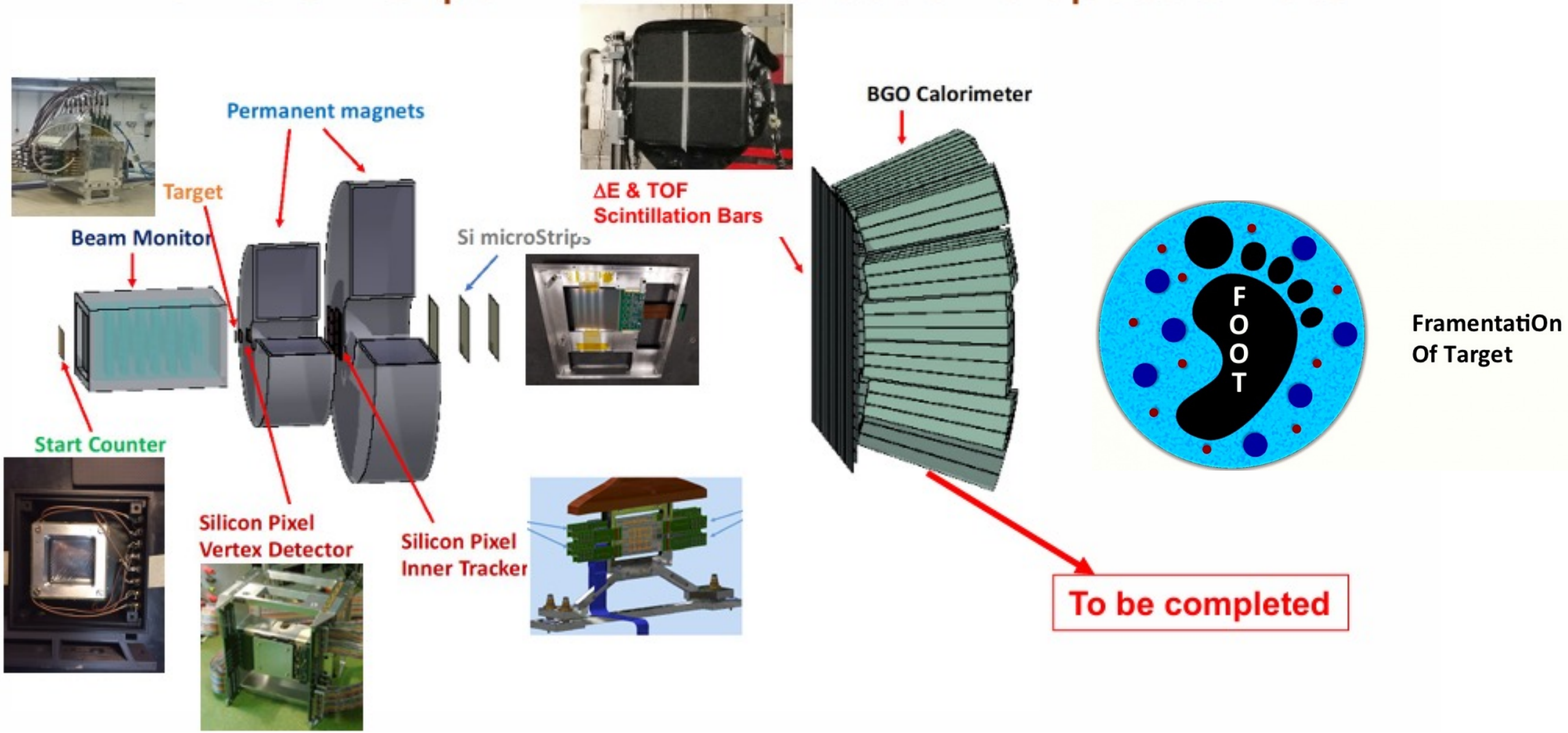
PANDORA plasma multidiagnostics systems



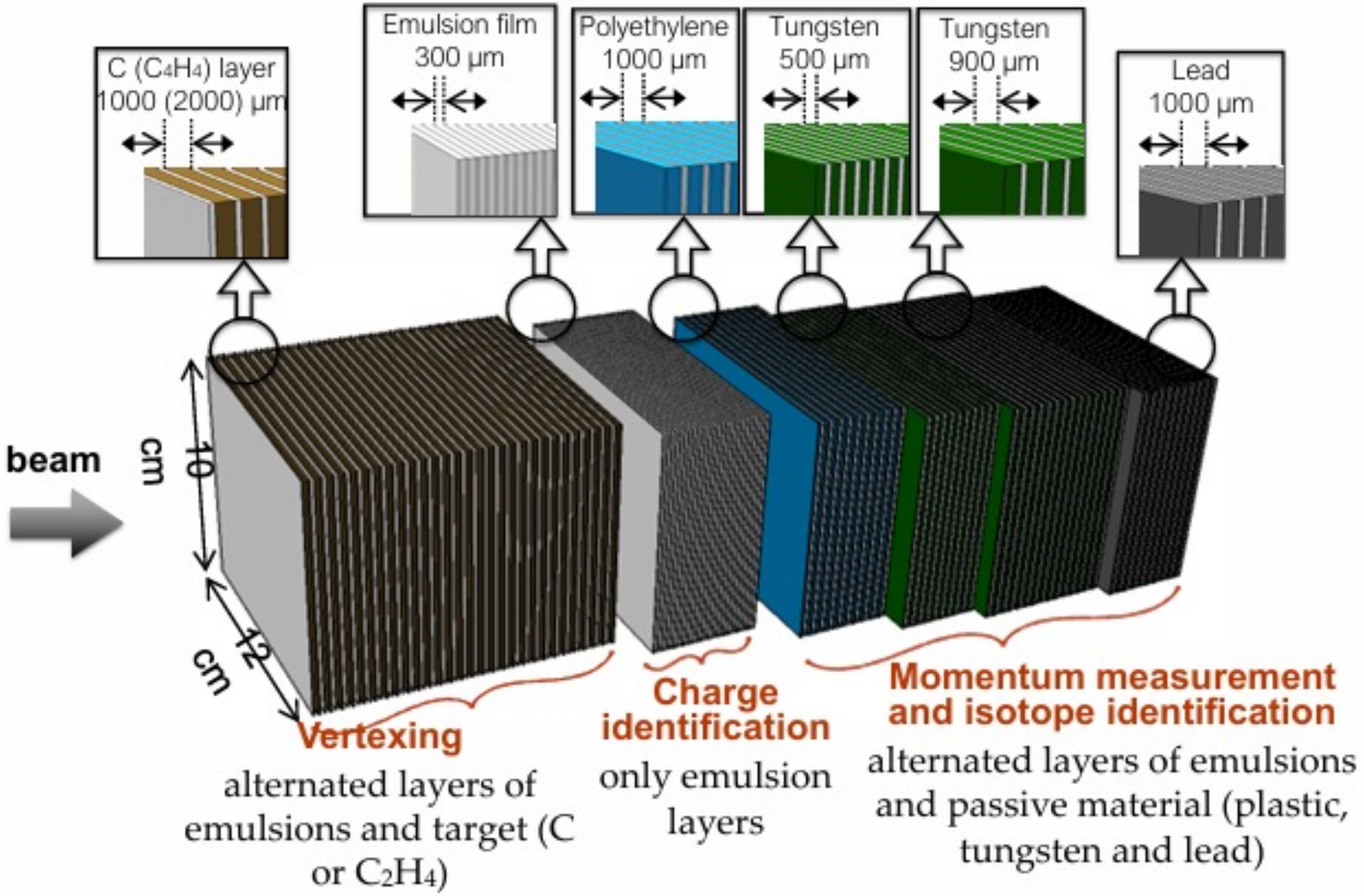
PANDORA Plasma Diagnostics

- 14 HPGe detectors
- new high performances X-ray CCD camera

The FOOT experiment: the electronic spectrometer



The FOOT experiment: the emulsion spectrometer



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