New Proposal
D_RD_16

Development of Advanced Monolithic Pixel Detector

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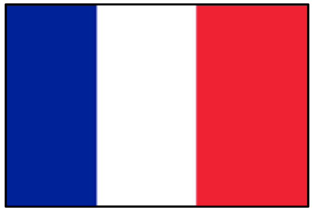
Collaboration Members



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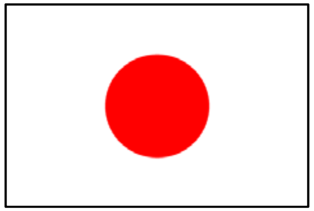

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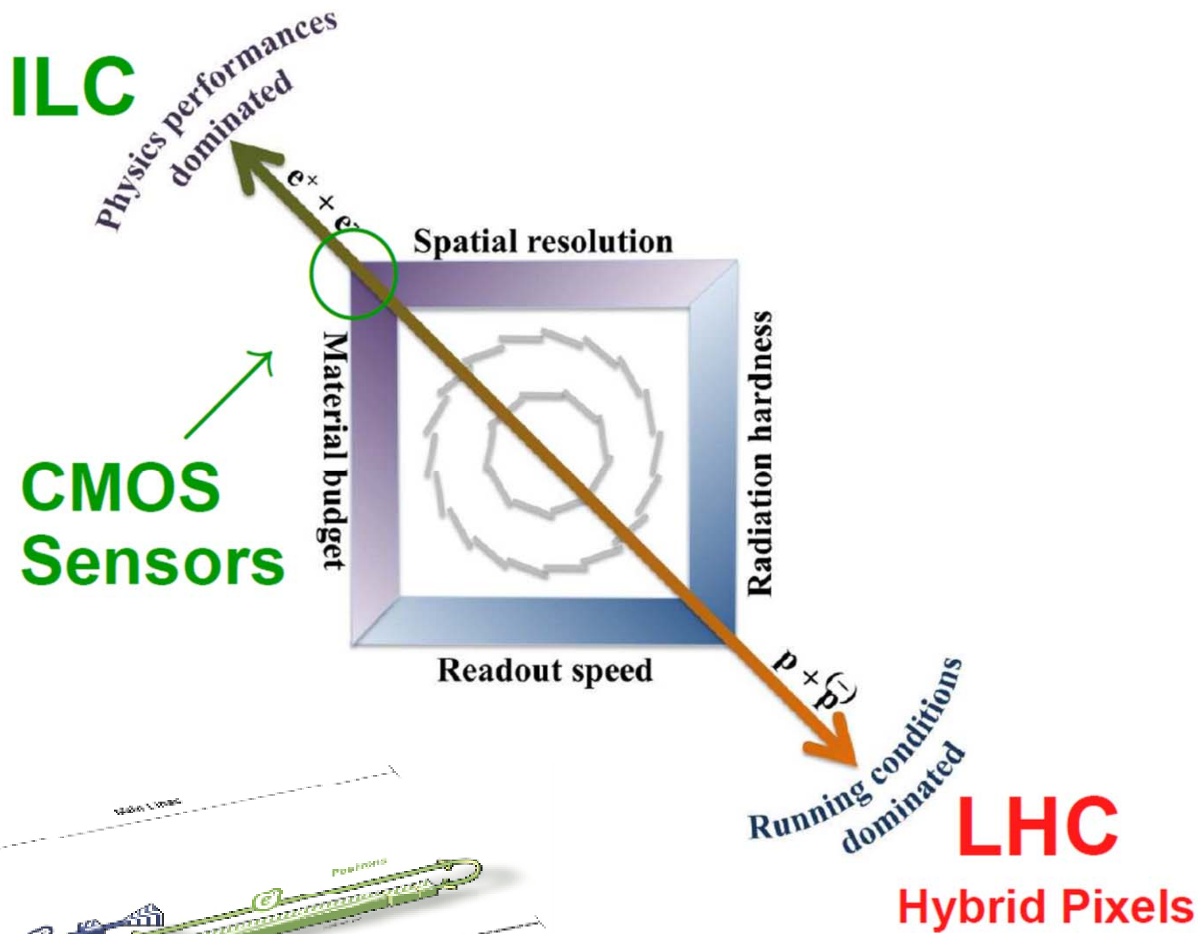
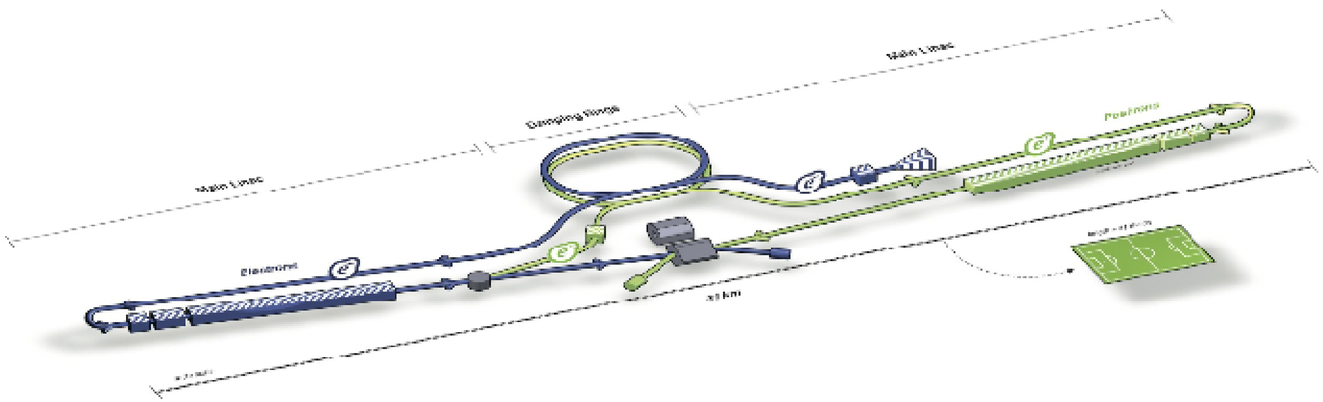
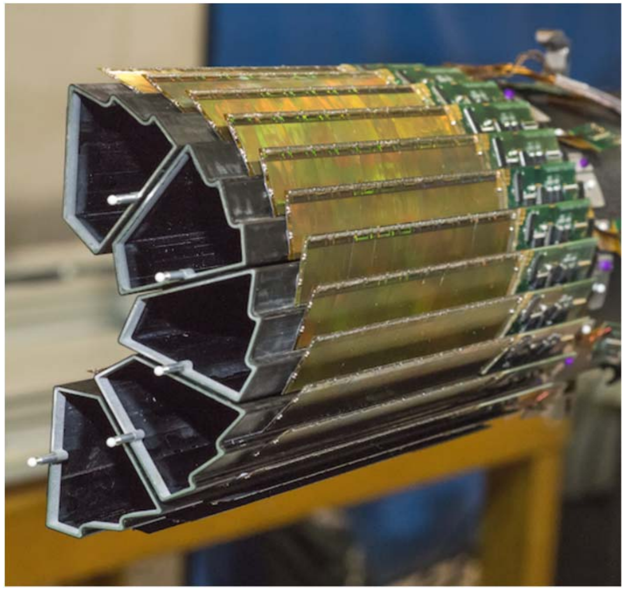
For Future High Energy Experiments such as ILC, High Precision Pixel Sensor is a Key Device.

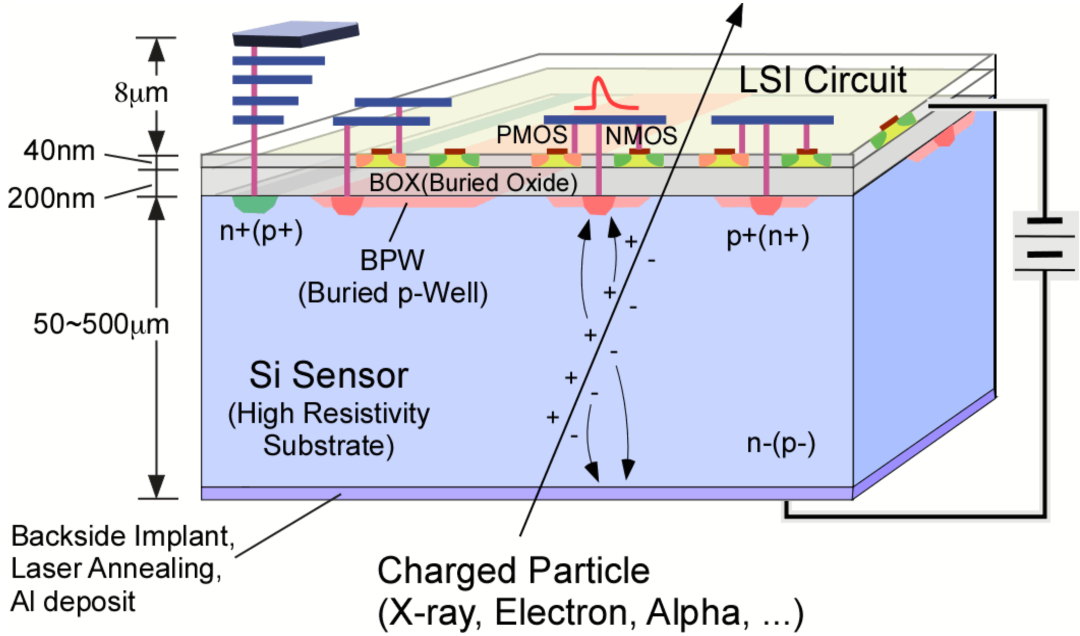
- Spatial Resolution < 3 μm
- Material budget ~ 0.1% X_0
- Bunch ID capability
- Multiple Buffers, fast Readout, …





Silicon Pixel Detector Activities in IPHC and KEK





- Long Experience in CMOS Pixel Sensors
- Used in STAR-PXL detector etc.

- Developed Advanced Silicon-On-Insulator (SOI) pixel process.
- Used as Vertex detector, X-ray detector etc.

CMOS Pixel Sensors (CPS): A Long Term R&D

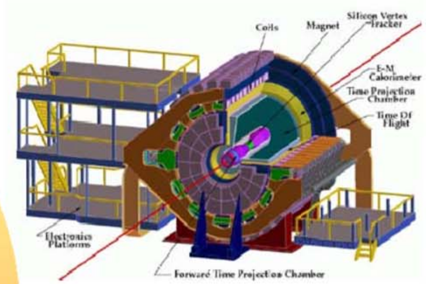
- ***Ultimate objective: ILC, with staged performances***
  - *CPS applied to other experiments with intermediate requirements*

EUDET 2006/2010

Beam Telescope

STAR 2013

Solenoidal Tracker at RHIC



EUDET (R&D for ILC, EU project)
STAR (Heavy Ion physics)
CBM (Heavy Ion physics)
ILC (Particle physics)
HadronPhysics2 (generic R&D, EU project)
AIDA (generic R&D, EU project)
FIRST (Hadron therapy)
ALICE/LHC (Heavy Ion physics)
EIC (Hadron physics)
CLIC (Particle physics)
BESIII (Particle physics)
...

ILC >2020

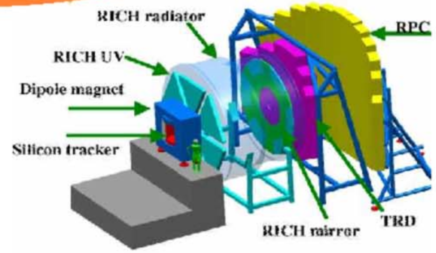
International Linear Collider

ALICE 2018

A Large Ion Collider Experiment

CBM >2018

Compressed Baryonic Matter



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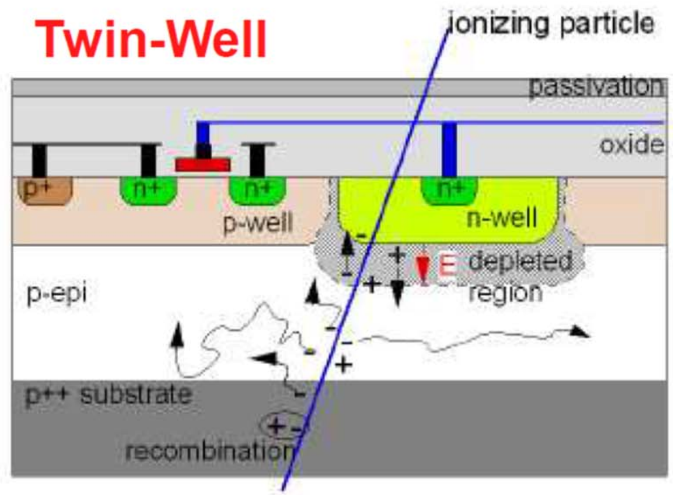
CMOS Pixel Sensors: Main Features

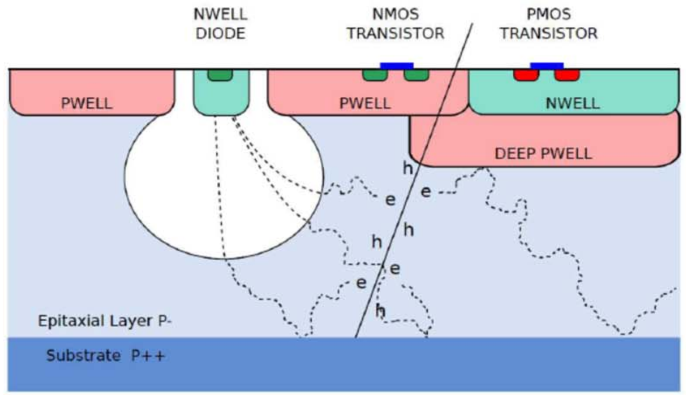
- **Prominent features of CMOS pixel sensors :**
  - high granularity $\Rrightarrow$ excellent (micronic) spatial resolution
  - signal generated in (very) thin (15-40 μm) epitaxial layer
    - $\hookrightarrow$ resistivity may be $\gg$ 1 k$\Omega \cdot cm$
  - signal processing μ-circuits integrated on sensor substrate
    - $\Rrightarrow$ impact on downstream electronics and syst. integration ($\Rrightarrow$ cost)

Twin-Well



- **CMOS pixel sensor technology has the highest potential :**

$\Rrightarrow$ R&D largely consists in trying to exploit potential at best
with accessible industrial processes
$\hookrightarrow$ manufacturing param. not optimised for particle detection:
wafer/EPI characteristics, feature size, N(ML), ...



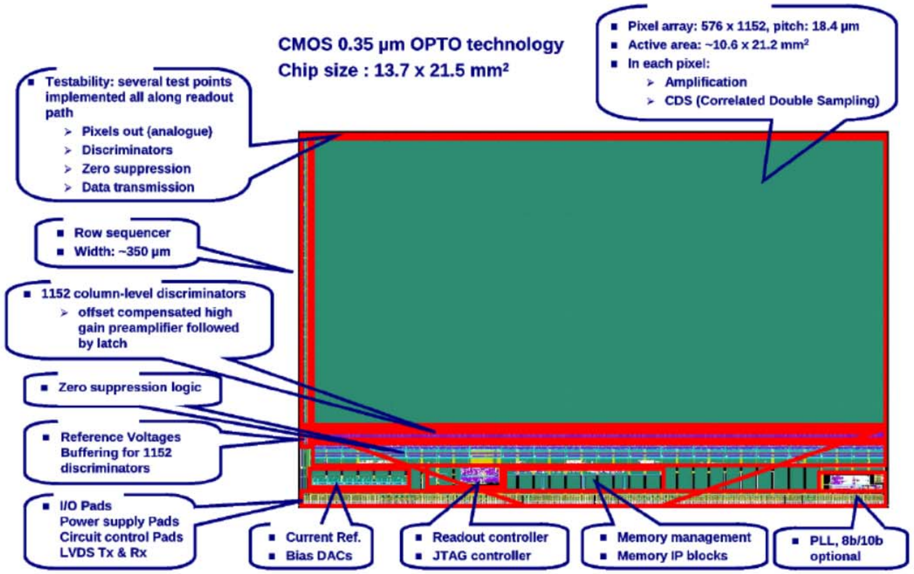
Quadruple-Well

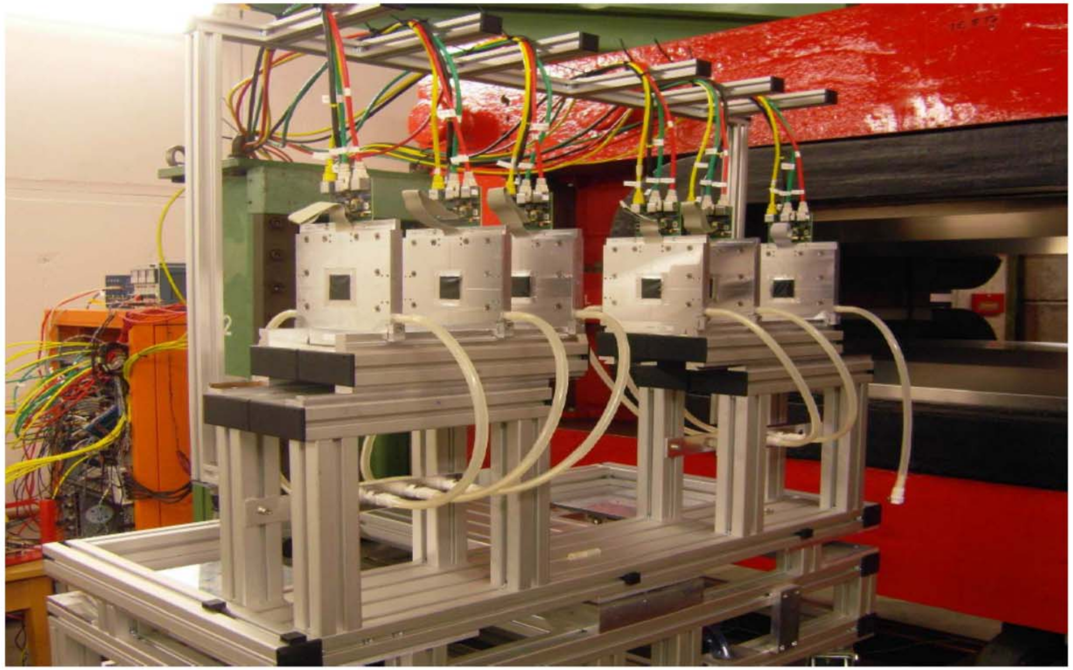
- **Read-out architectures :**
  - 1st generation : rolling shutter (synchronous) with analog pixel output (end-of-column discri.)
  - 2nd generation : rolling shutter (synchronous) with in-pixel discrimination
  - 3rd generation : data driven (asynchronous) with in-pixel discrimination
  - ...

Achievement: MIMOSA-26 & Beam Telescopes (EUDET, ...)

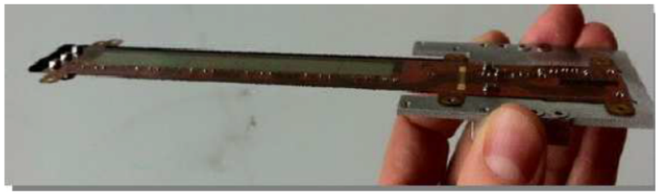
- **MIMOSA-26: 1st CPS combining all signal processing functionalities**

  $\sigma_{R\Phi,Z} \simeq$ **3.2** μm; **thickness** $\simeq$ **50** μm; **670,ooo pixels over 1x2 cm**^{2}; $> 10^6$ **part./cm**^{2}**/s**





- EUDET beam telescope ($\sim$ 10 copies worldwide), suited to electron beams $<$ 1 GeV (e.g. LNF)
- MIMOSA-26 equips numerous devices: FIRST (GSI), NA-61 & NA-63 (SPS), beam telescopes (FE-I4), vertex detector demonstrators (CBM, ...), etc.
- 2x6 MIMOSA-26 equip PLUME double-sided ladder $\rightarrowtail$ BEAST-II



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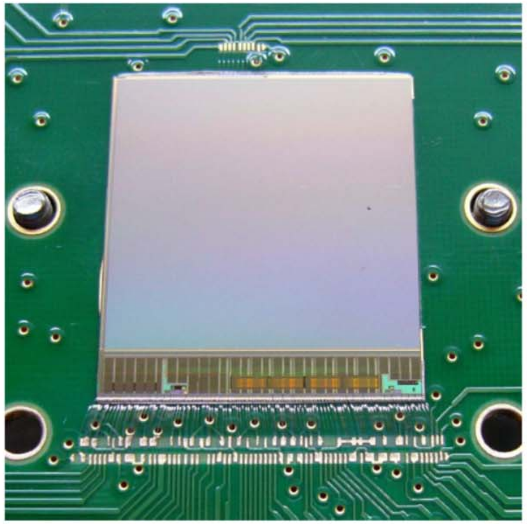
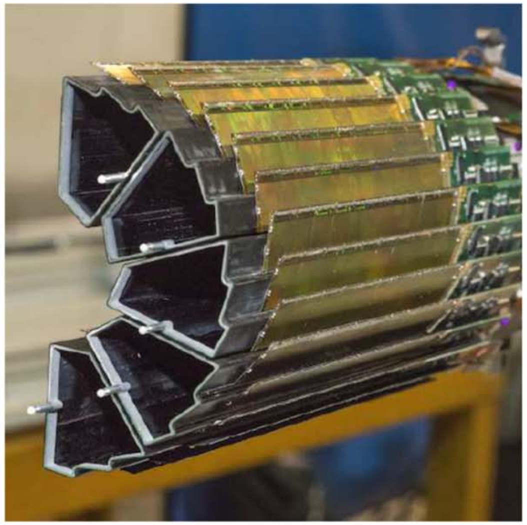
Achievement: MIMOSA-28 & STAR-PXL Detector (+ spin-offs)

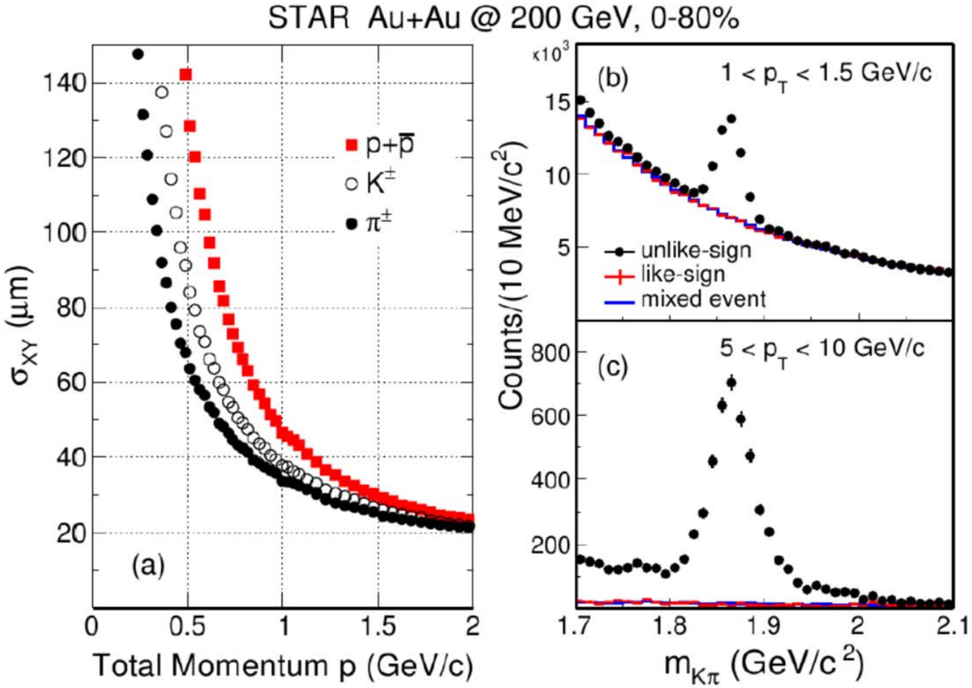
- MIMOSA-28: 1st CPS equipping a subatomic phys. experiment (STAR at RHIC/BNL)

  $\sigma_{R\Phi,Z} \simeq$ 3.7 μm; thickness $\simeq$ 50 μm; 970,ooo pixels over 2x2 cm^2; $> 10^6$ part./cm^2/s

3 data taking campaigns (2014–16) $\Rrightarrow$ state-of-the-art of the technology







- MIMOSA-28 equips numerous devices, e.g.:
  - AIDA BT: 4 millions of pixels per plane (4x4 cm^2, $< 0.1\%$ X_0)
  - BT part of LNF permanent infrastructure (450 MeV e^-)
  - telescope for hadrontherapy (GSI), etc.
  - demonstrator for inner tracker upgrade of BES-3 expt. at BEPC/IHEP

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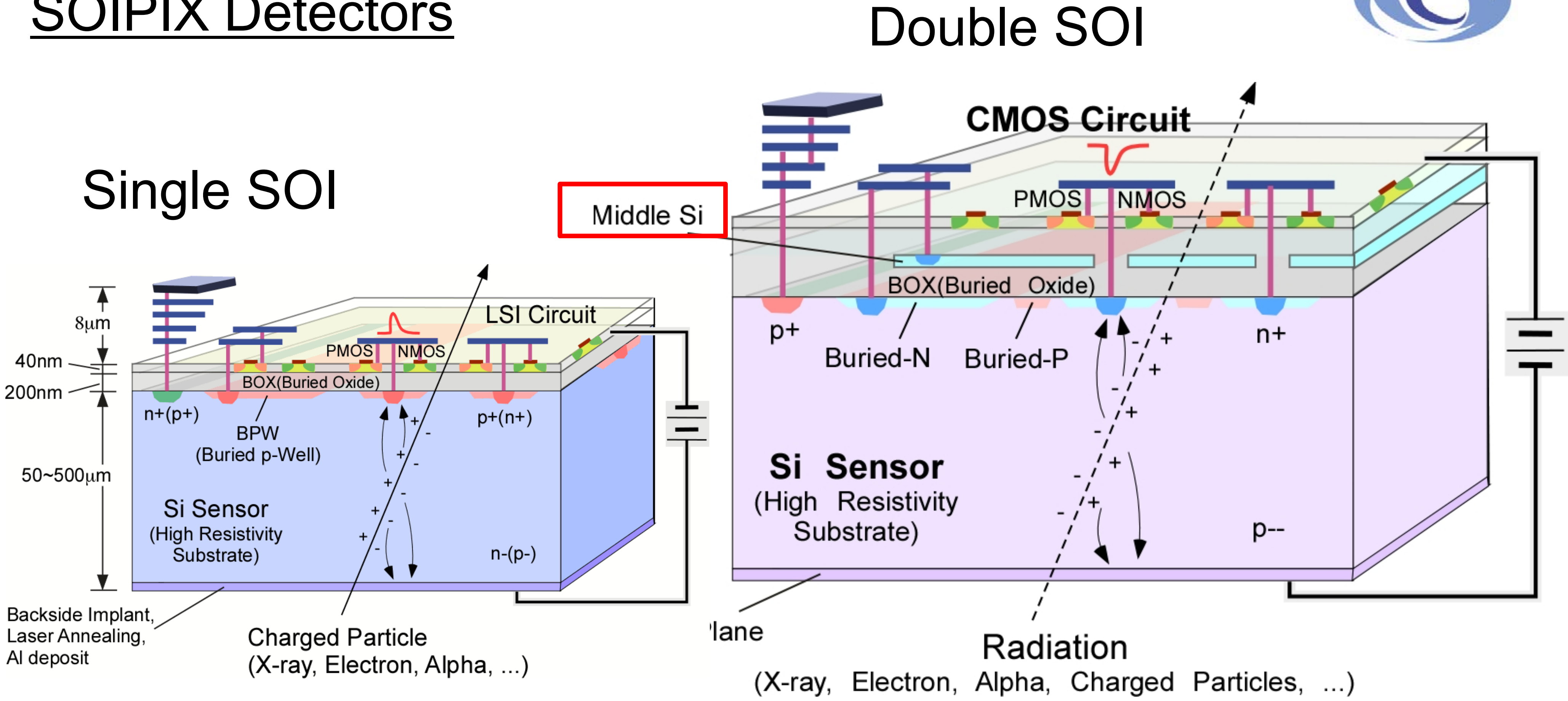
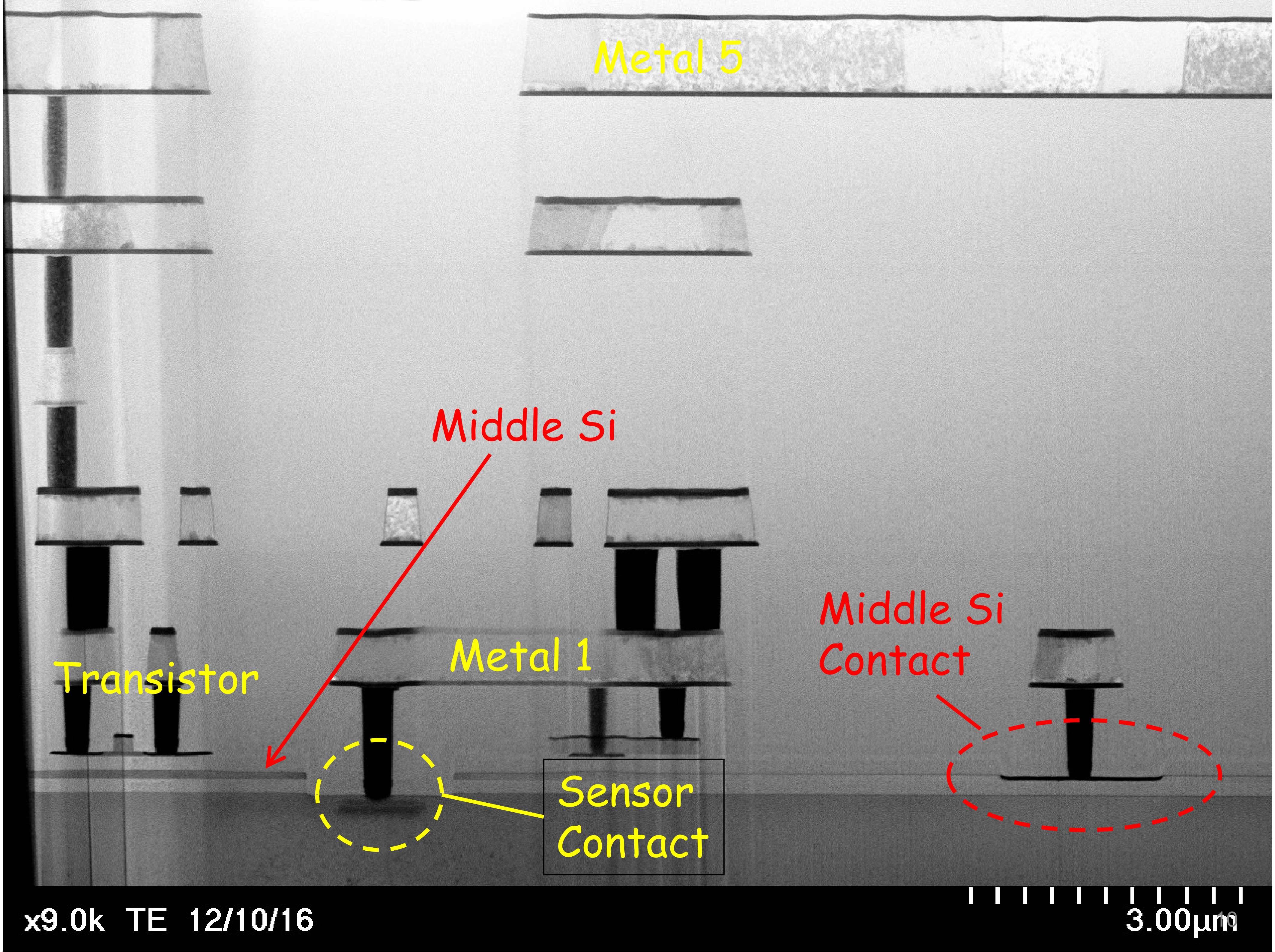
SOIPIX Detectors



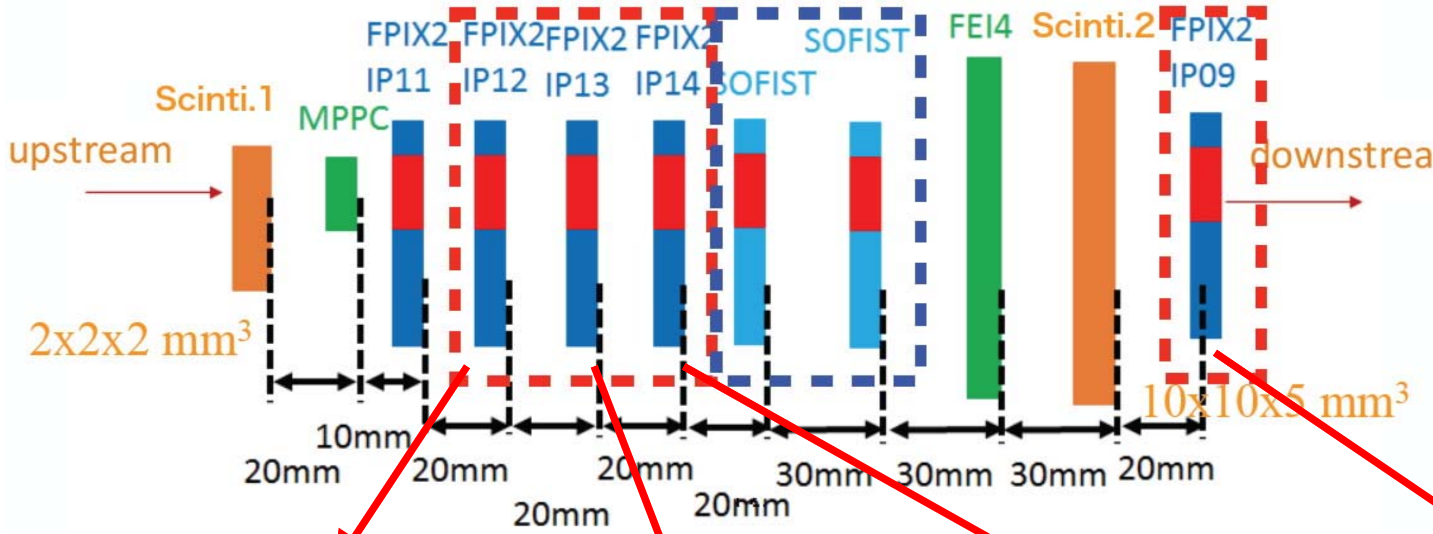
Double SOI Detector
- Middle Si layer shields coupling between sensor and circuit.
- It also compensate E-field generated by radiation trapped hole.
- Good for Complex function and Counting-type sensor.
- Can be used in High radiation environment.



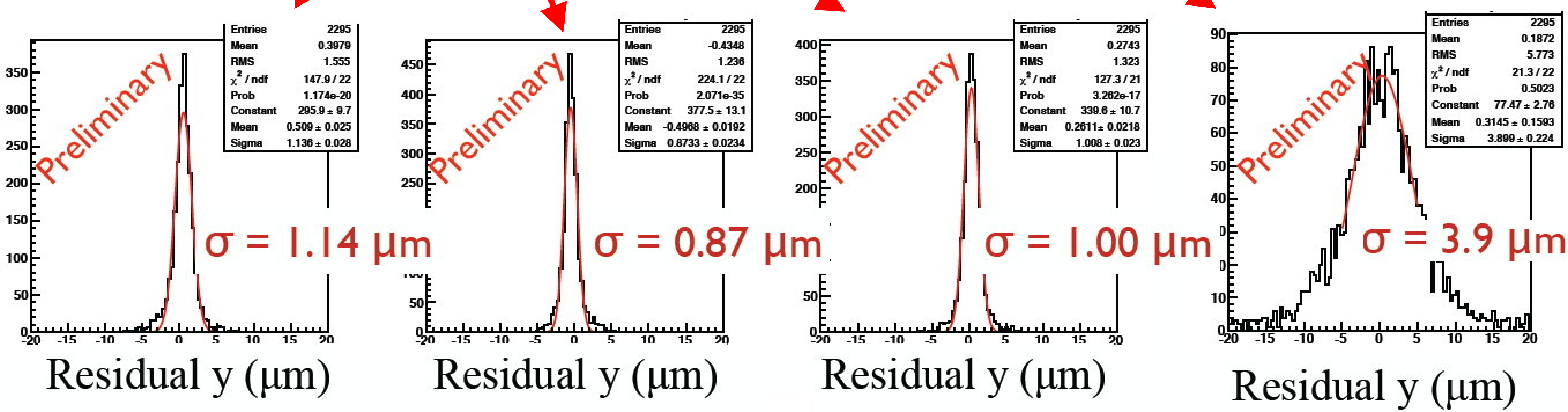
Metal 5
Middle Si
Middle Si Contact
Metal 1
Transistor
Sensor Contact
x9.0k TE 12/10/16
3.00μm

120GeV/c Proton Beam test at FNAL

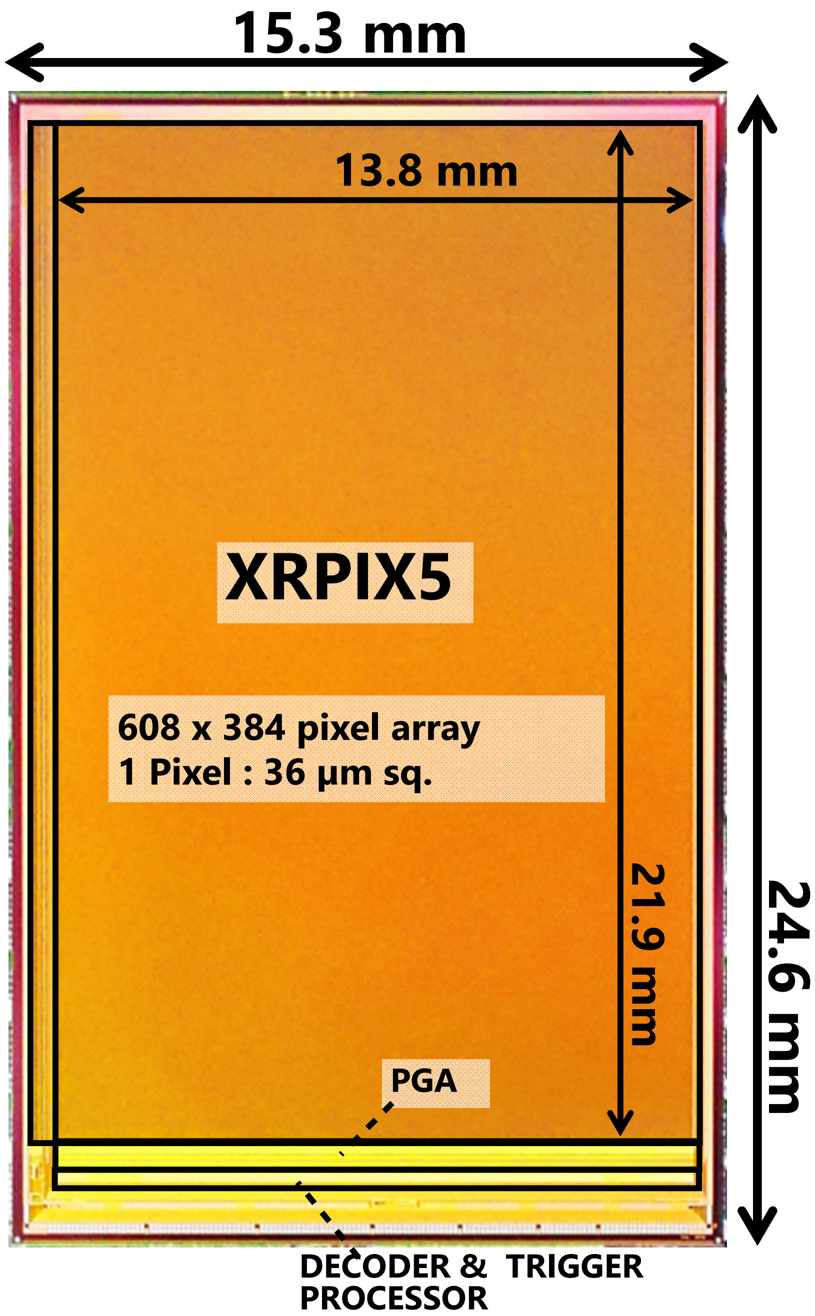
FPIX2 (8 μm pixel) x 4
SOFIST_v1 (20 μm pixel) x 2



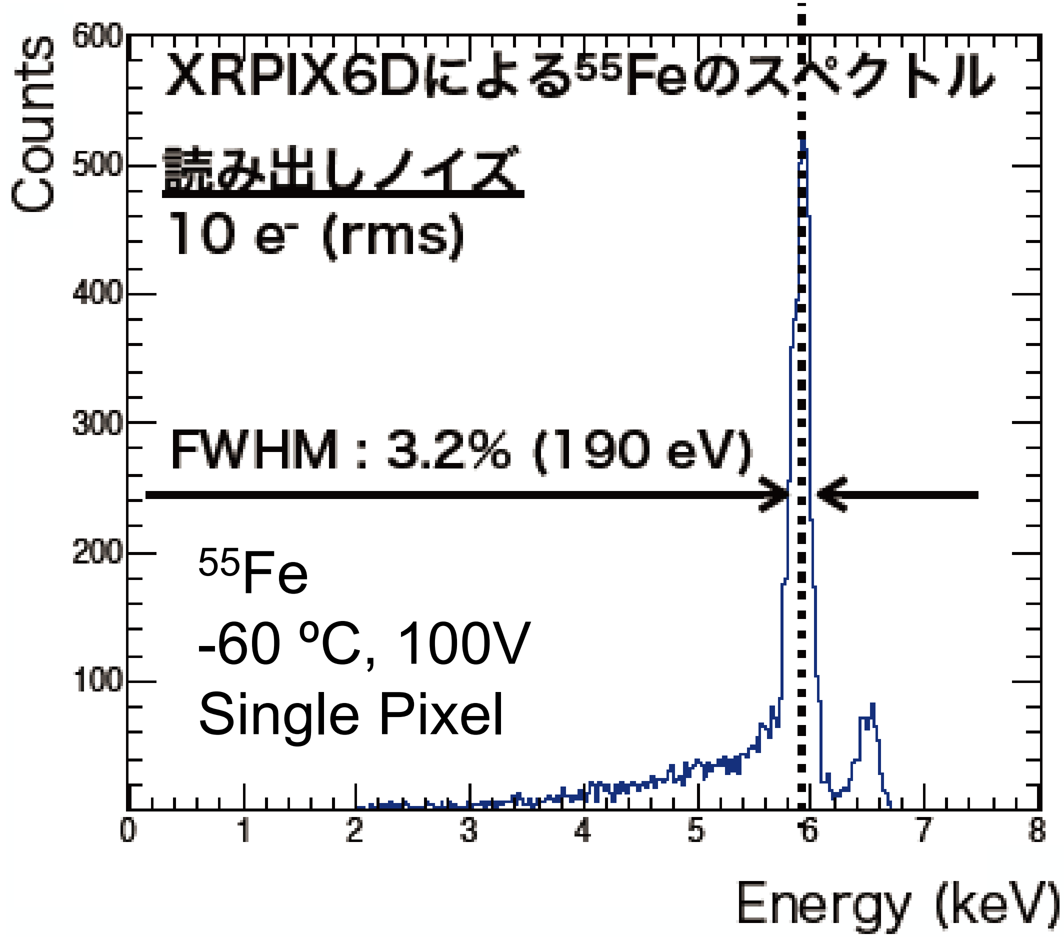
FPIX2
Position Resolution
~0.7 μm



XRPIX: Event Driven X-ray Astronomy Detector

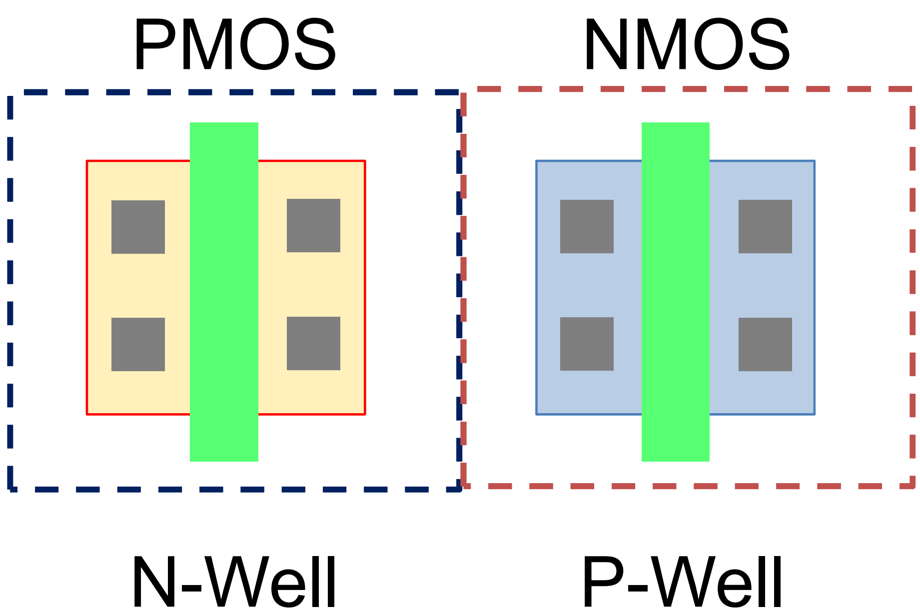


- Chip size : 24.6 mm x 15.3 mm
- Pixel size : 36 μm sq.
- # of pixel : 608 x 384 (= ~233k)
- Thickness of sensor layer : 310 μm (CZ wafer)
  500 μm (FZ wafer)

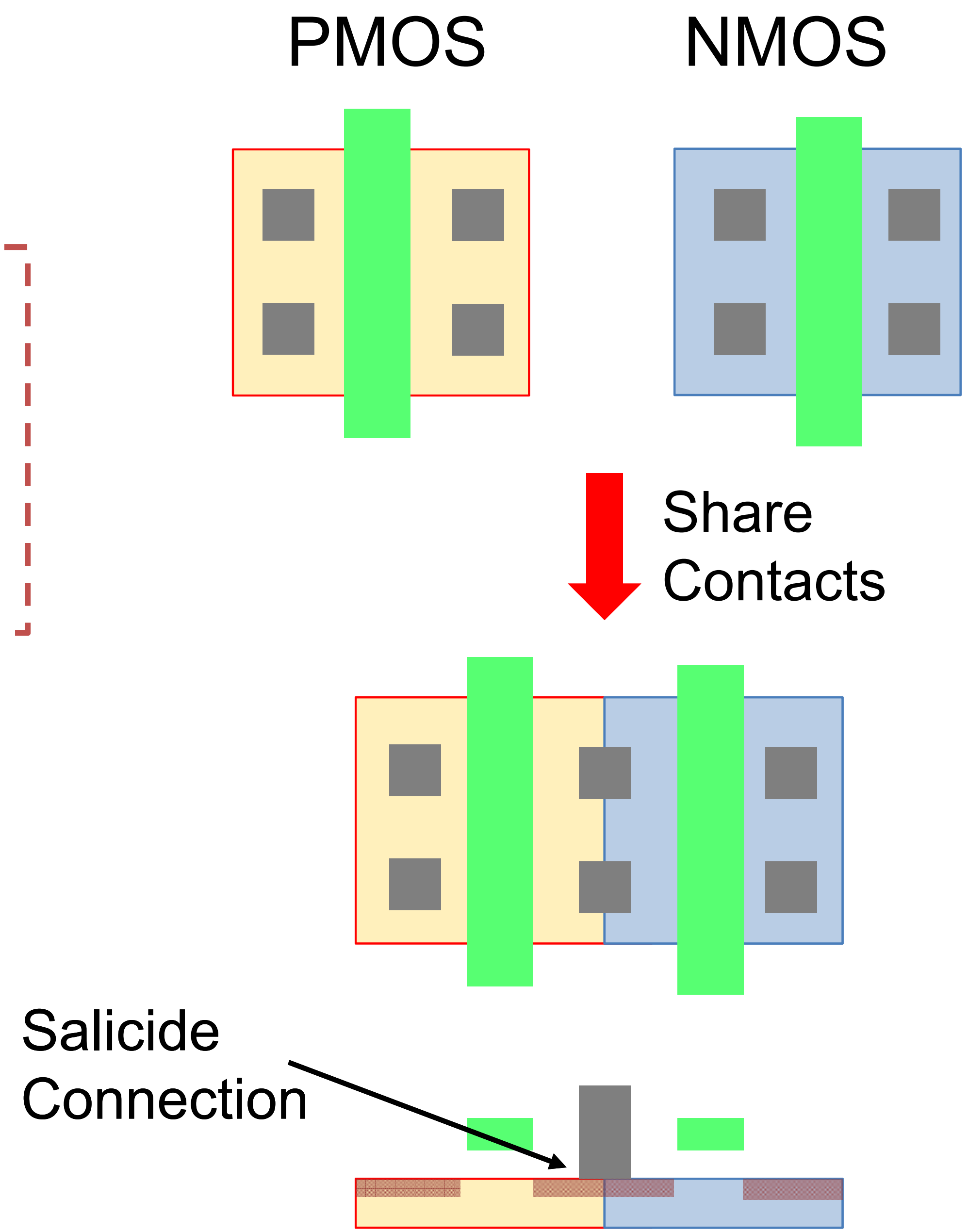


Layout Shrink（Active Merge)

Bulk CMOS



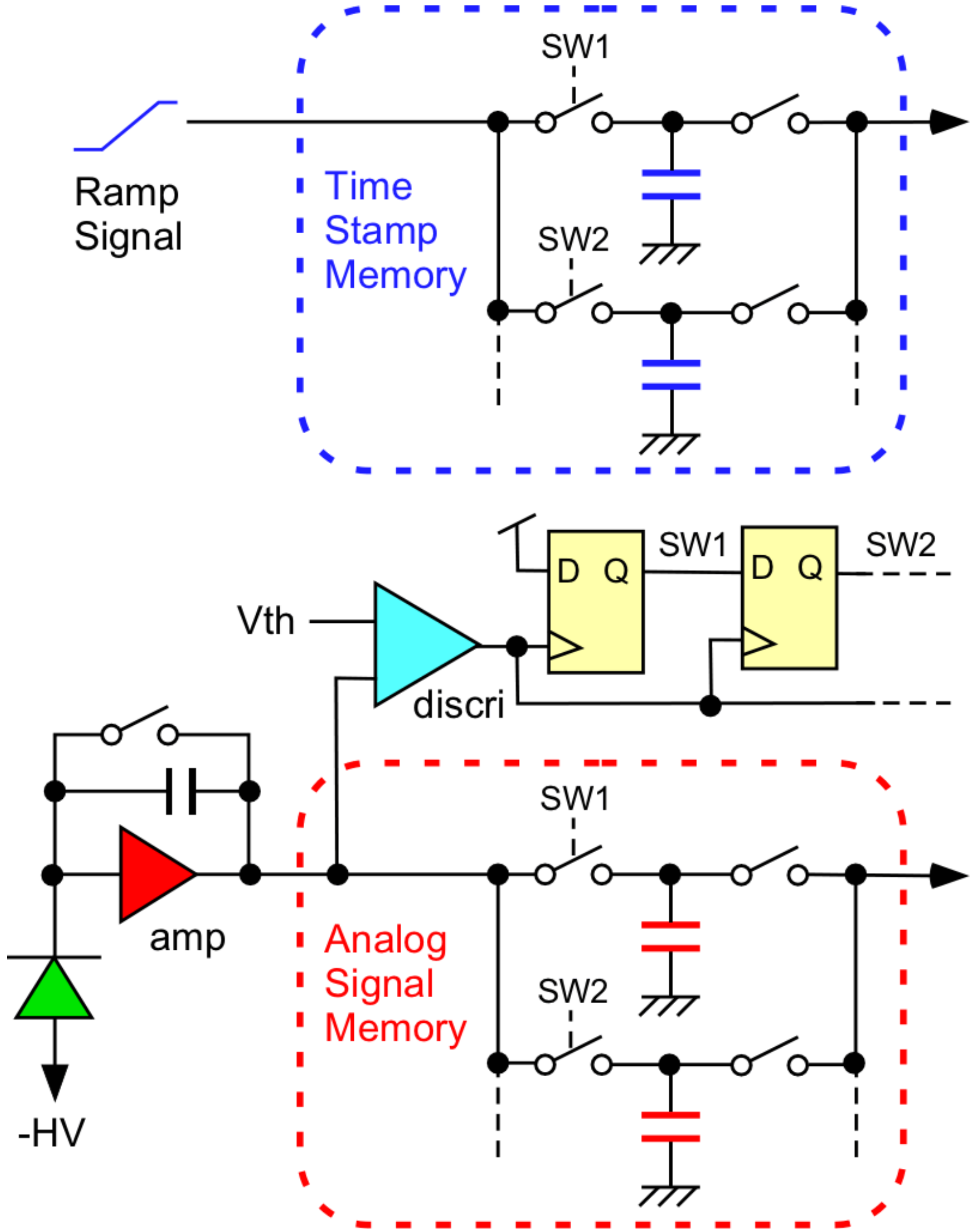
SOI



In the SOI process, it is possible to merge NMOS & PMOS Active region and share contacts.

ILC Vertex Detector R&D : SOFIST

(SOI sensor for Fine measurement of Space & Time)

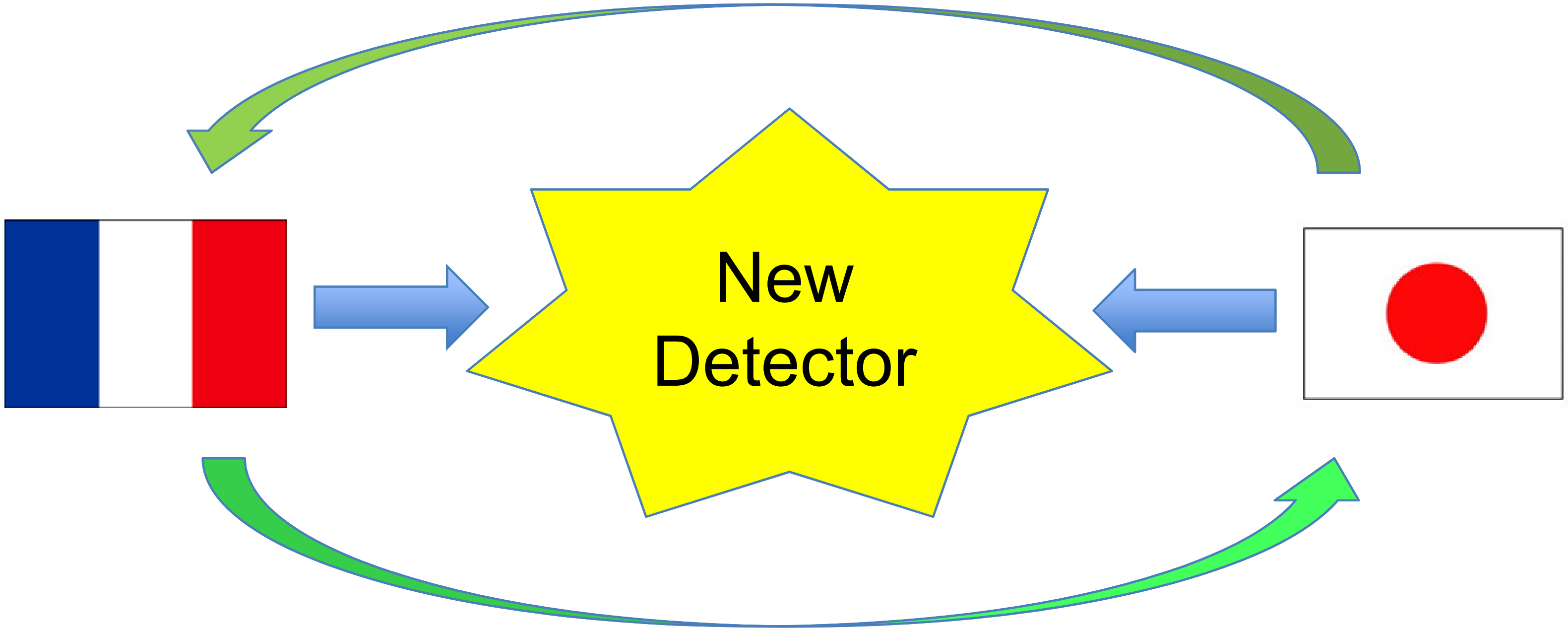


Test Chip Spec.

- Chip size: 2.9 × 2.9 mm2
- Substrate (FZ n-type, 2 kΩ•cm)
- Pixel size: 20~25 μm
- No. of Pixel: 50 × 50 pixels
- Gain: 32 mV/ke- (@Cf=5fF)
- Analog signal memories: 2 for signal or 2 for time
- Column-ADC: 8 bit
- Zero Suppression Logic

Exchange Researchers and Utilize Both Resources Through TYL-FJPPL

Learn Detector Design etc.
Joint Beam Test, …



Learn SOI pixel design
Use SOI process, …

Summary

- IPHC group has long history in developing CMOS Pixel Sensors (CPS), and build CPS detectors for many experiments.
- Japanese group has developed SOI pixel process. It showed high performance in position resolution, energy resolution, pixel size, radiation tolerance etc., which are necessary in future experiments.
- In collaboration of these two groups, large synergy will be expected.