KEK, SuperKEKB, Belle II

Journée Belle II, LAL Orsay

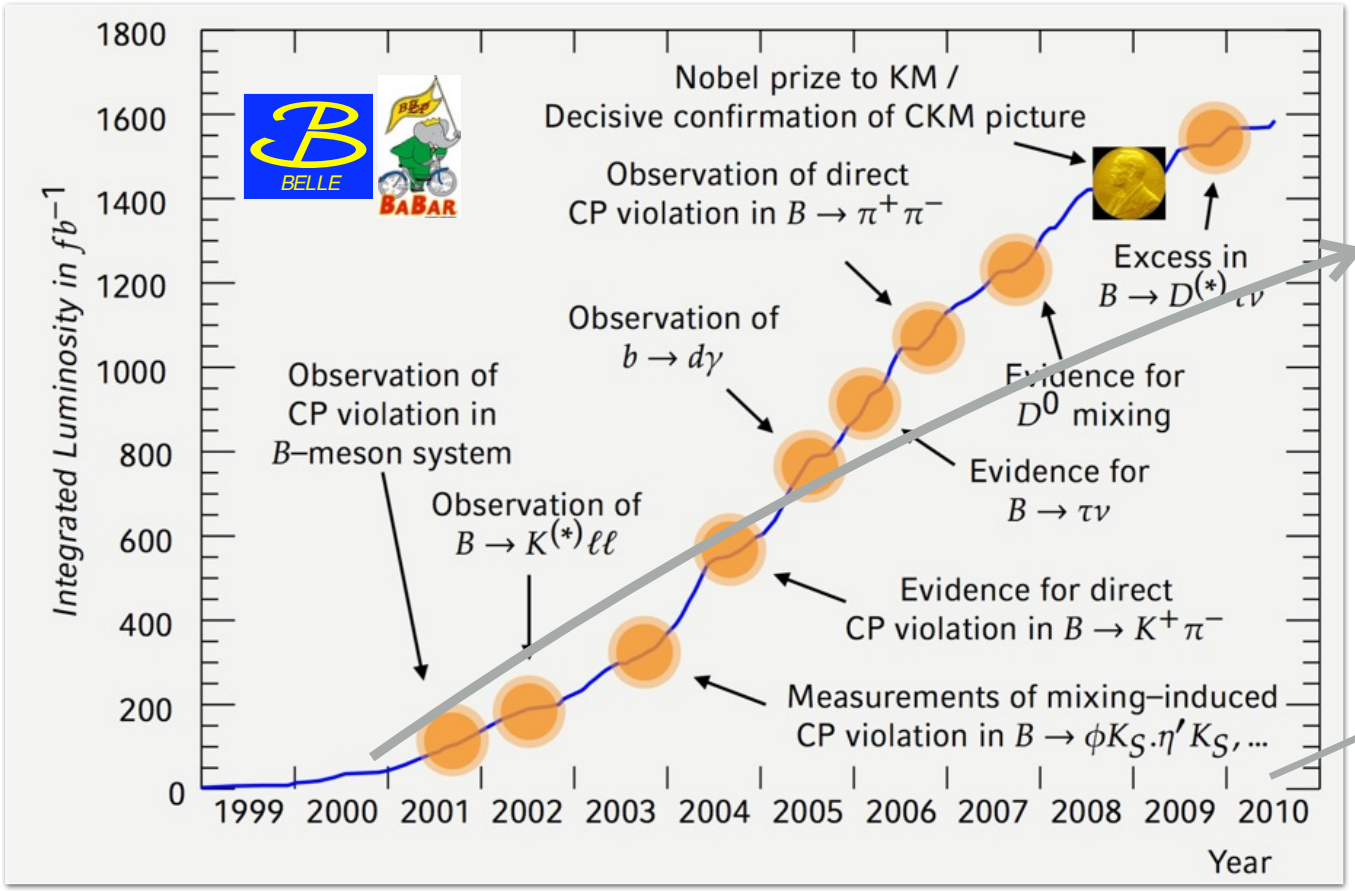
22 mars 2017

Francesco Forti, INFN and University, Pisa

Courtesy of A.Zupanc

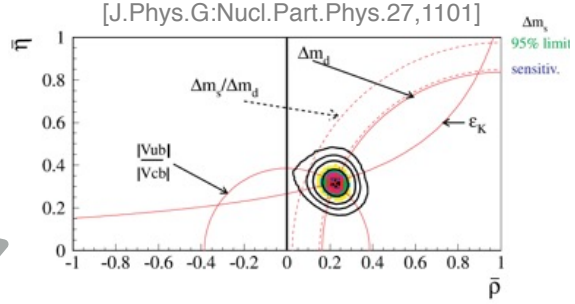
Asymmetric B factories: flavour physics at the intensity frontier

BaBar (PEPII@SLAC) and **Belle** (KEKB@KEK)



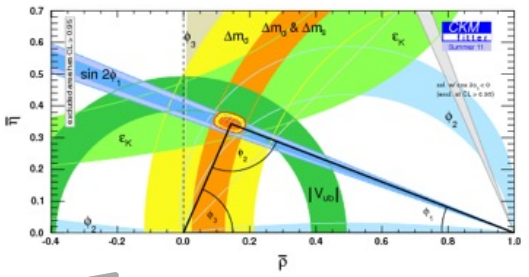
Unitarity Triangle @ 2000

[J.Phys.G:Nucl.Part.Phys.27,1101]



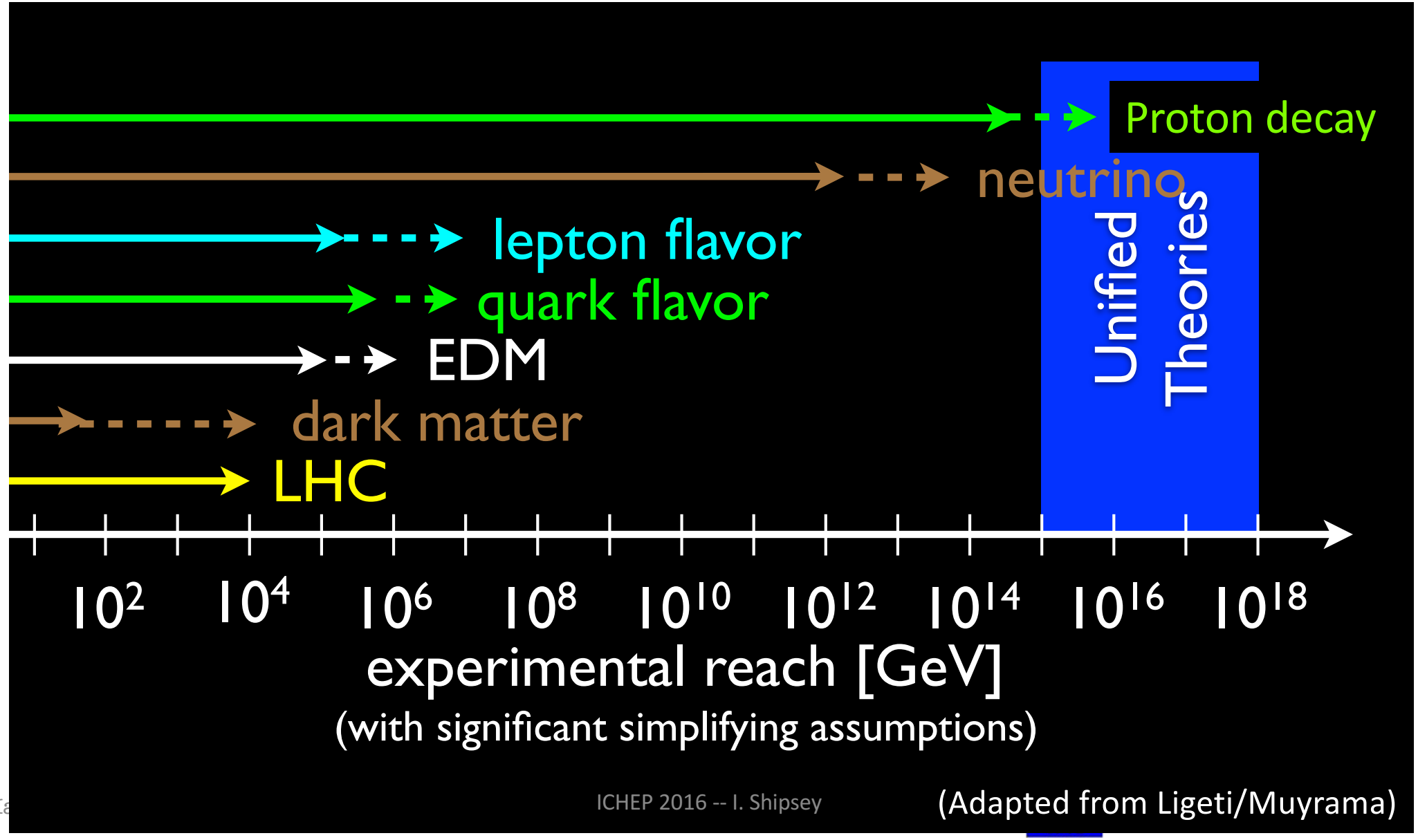
Unitarity Triangle @ 2011

[CKM fitter]



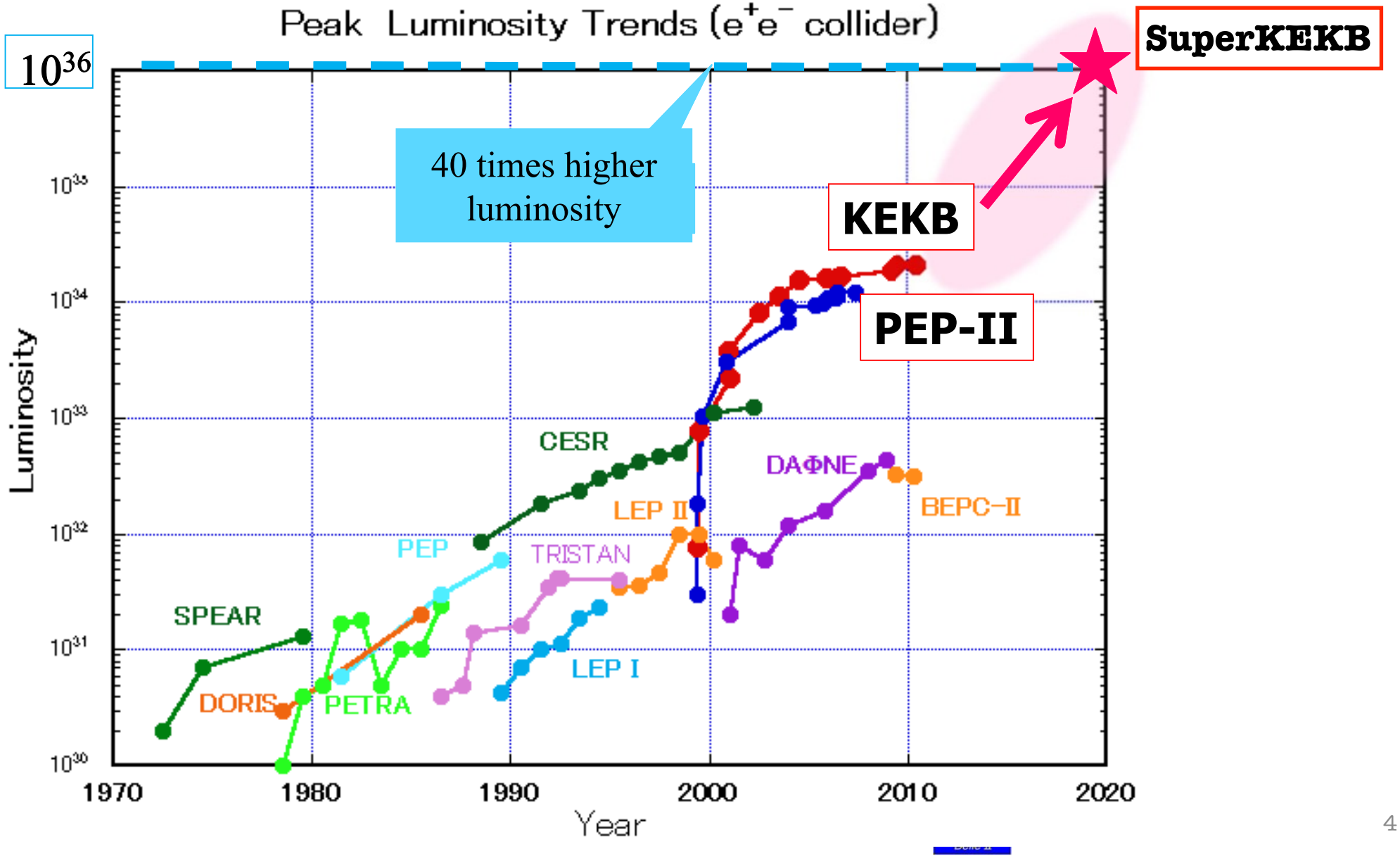
Confirmation of the Kobayashi-Maskawa mechanism of CPV.

The next decade: the power of quantum loops



(Adapted from Ligeti/Muyrama)

The intensity frontier



How to increase the luminosity?

Super KEKB Quest for BSM

Beam-beam parameter

Lorentz factor

Beam current

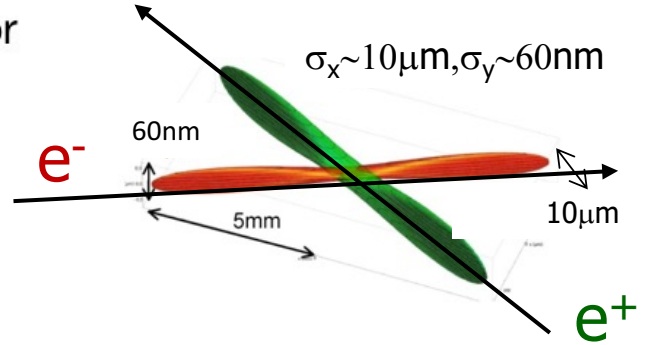
$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

Lumi. reduction factor
(crossing angle)&
Tune shift reduction factor
(hour glass effect)
0.8 - 1
(short bunch)

Classical electron radius

Beam size ratio@IP
1 - 2 % (flat beam)

Vertical beta function@IP



(1) Smaller β_y^*
(2) Increase beam currents
(3) Increase ξ_y

← **"Nano-Beam" scheme**

Collision with very small spot-size beams

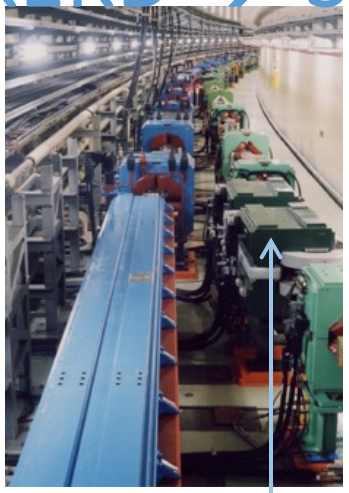
Invented by Pantaleo Raimondi for SuperB

SuperKEKB design parameters

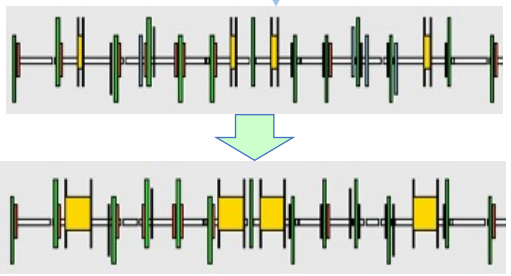
parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	ϕ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.37	0.40	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0881	0.0807	
Luminosity	L	2.1×10^{34}		8×10^{35}		$cm^{-2}s^{-1}$

- **Nano-beams and a factor of two more beam current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of short lifetime for the LER

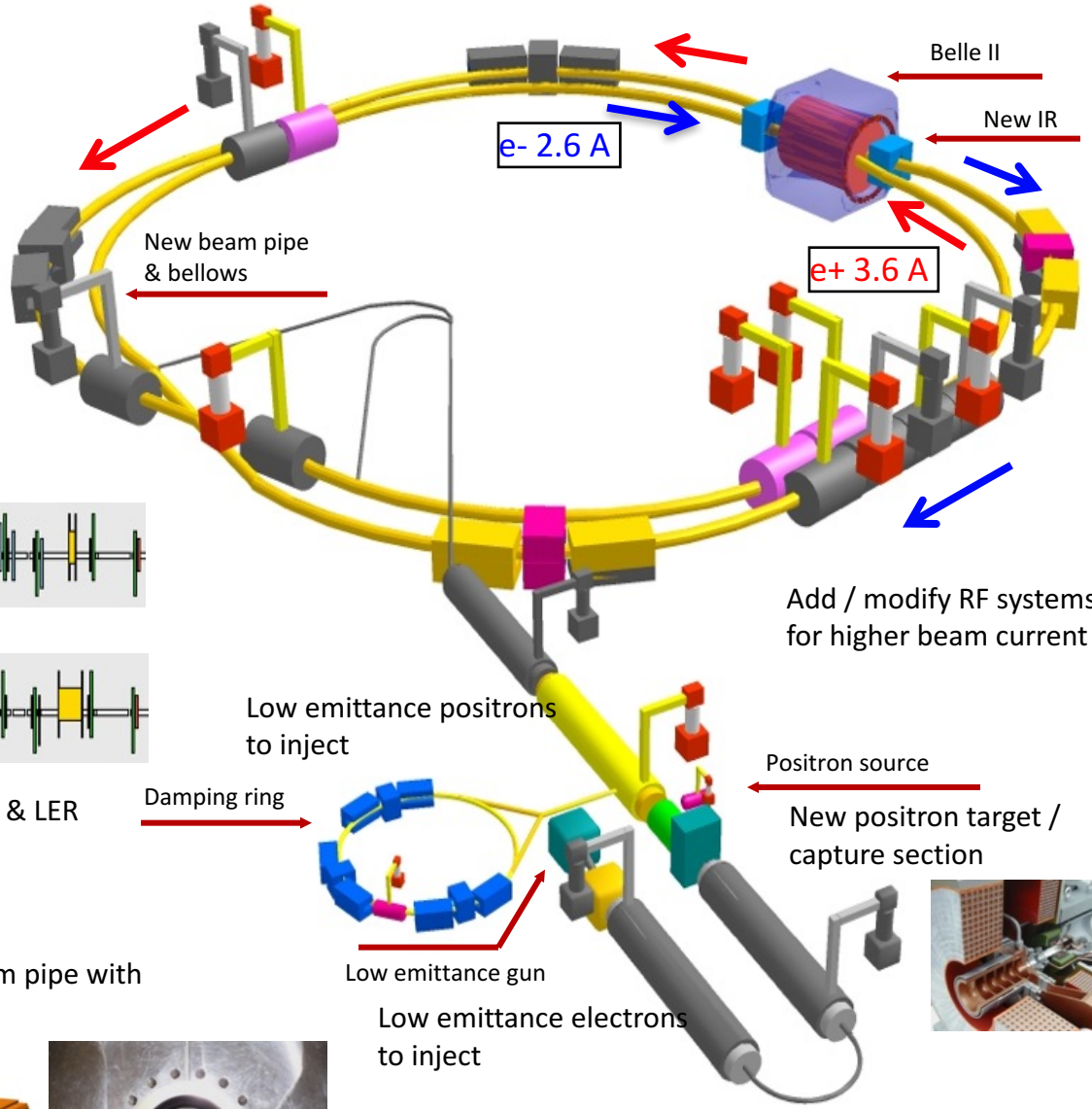
KEKB → SuperKEKB



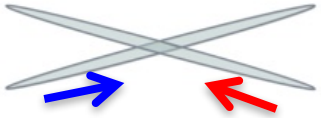
Replace short dipoles with longer ones (LER)



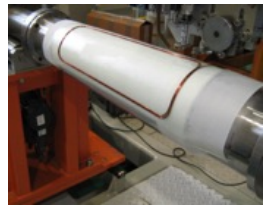
Redesign the lattices of HER & LER to squeeze the emittance



Colliding bunches



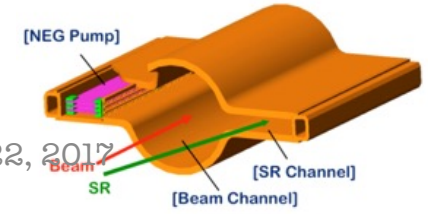
New superconducting /permanent final focusing quads near the IP

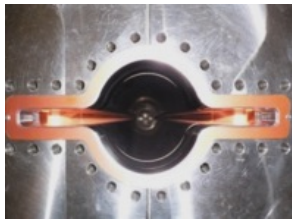


Add / modify RF systems for higher beam current

New positron target / capture section

TiN-coated beam pipe with antechambers



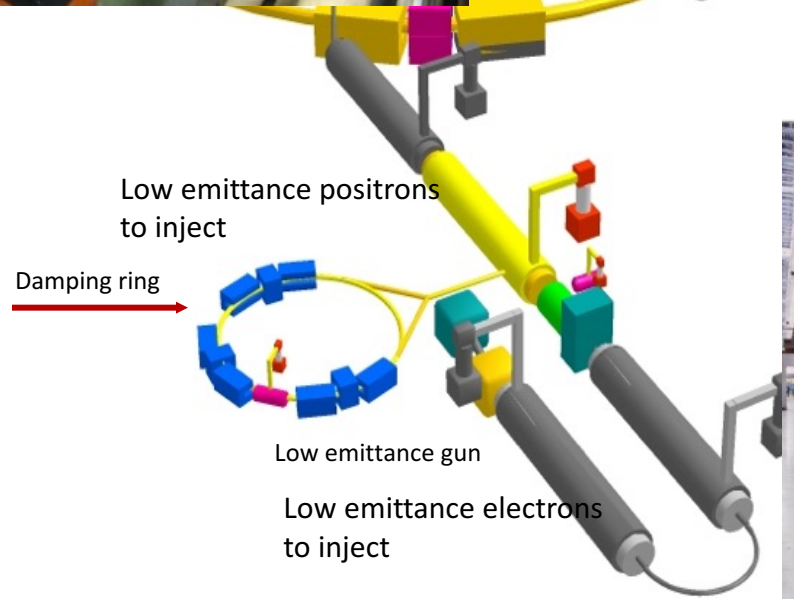


To get x40 higher luminosity

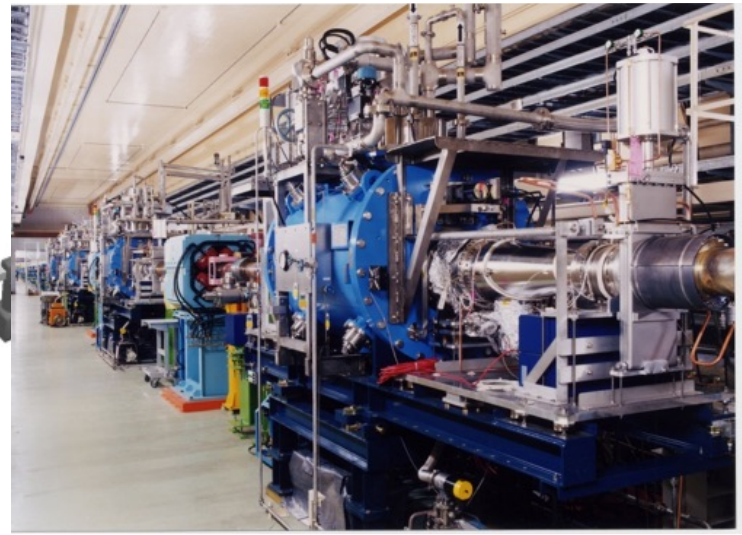
Installation of 100 new long LER bending magnets

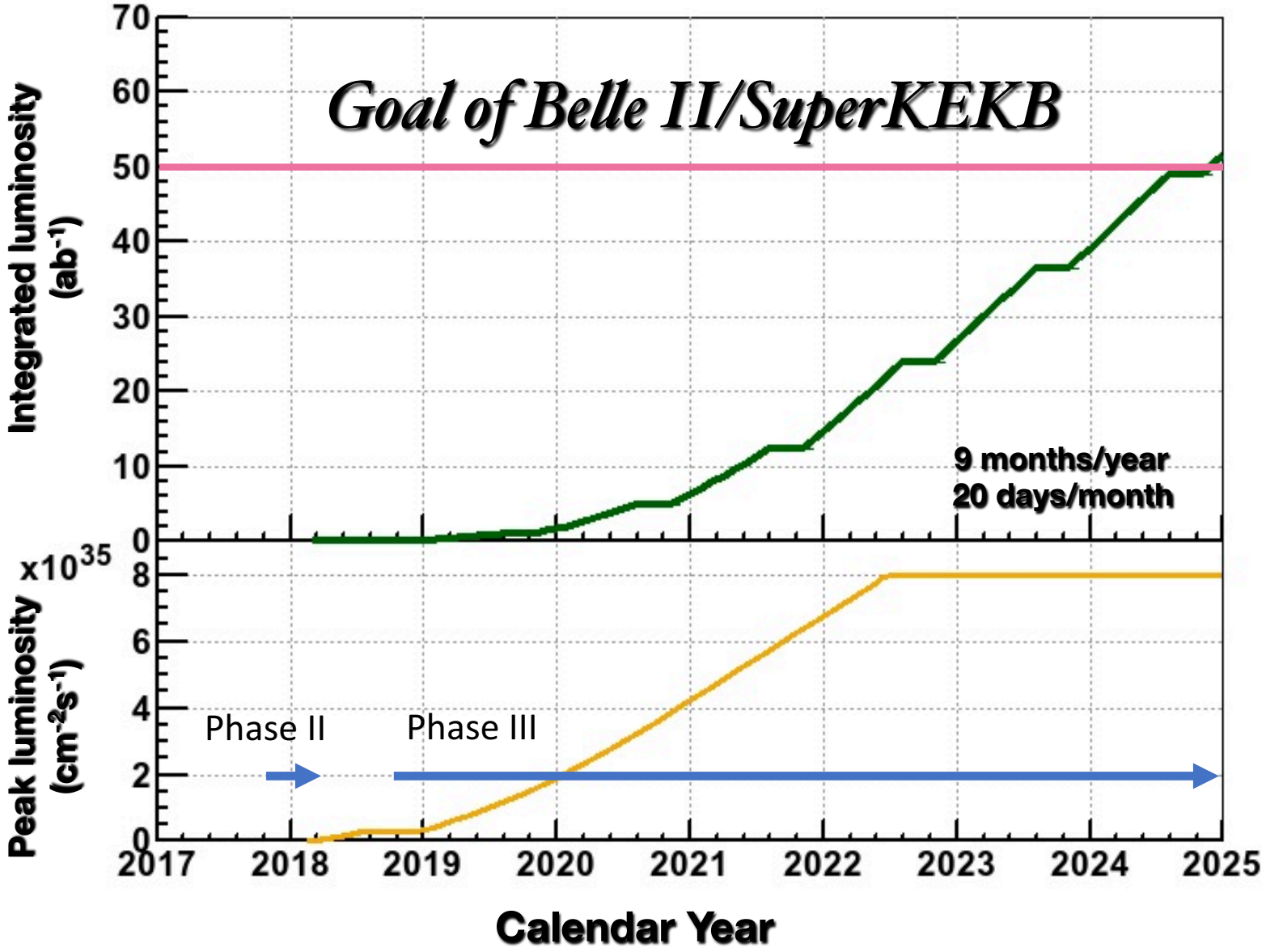
Installation of HER wiggler chambers

Damping ring tunnel



Add / modify RF systems for higher beam current





- Phase I (2016)
  - Circulated both beams but no collisions;
  - Tune accelerator optics, etc.; vacuum scrubbing
  - Beam Background studies with dedicated BEAST II/1 detector
- Phase II
  - First collisions
  - Beam Commissioning
  - Background measurements with BEAST II/2
  - Physics run with Belle II w/o VTX
    - on Y(4S) and Y(6S)
- Phase III
  - Physics run

Belle II Detector

K_L and muon detector:
Resistive Plate Counter (barrel outer layers)
Scintillator + WLSF + MPPC (end-caps, inner 2 barrel layers)

EM Calorimeter:
CsI(Tl), waveform sampling (baseline)
(opt.) Pure CsI for end-caps

Particle Identification
Time-of-Propagation counter (barrel)
Prox. focusing Aerogel RICH (fwd)

electron (7GeV)

Beryllium beam pipe
2cm diameter

Vertex Detector
2 layers DEPFET + 4 layers DSSD

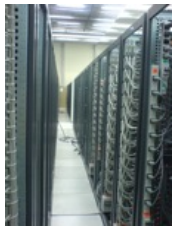
Central Drift Chamber
He(50%):C_2H_6(50%), Small cells, long lever arm, fast electronics

positron (4GeV)

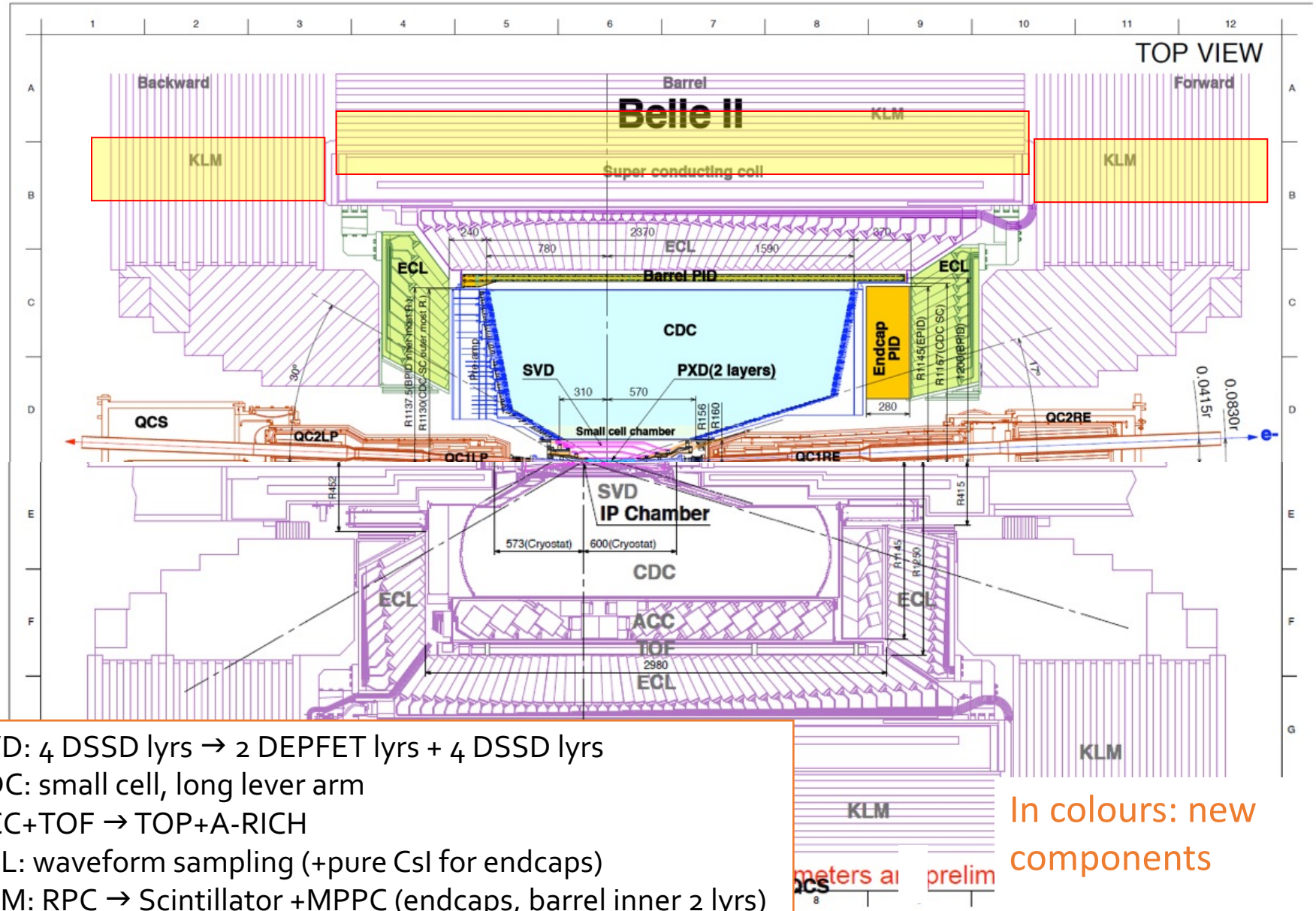
COMPUTING

0110001

Lots of Data



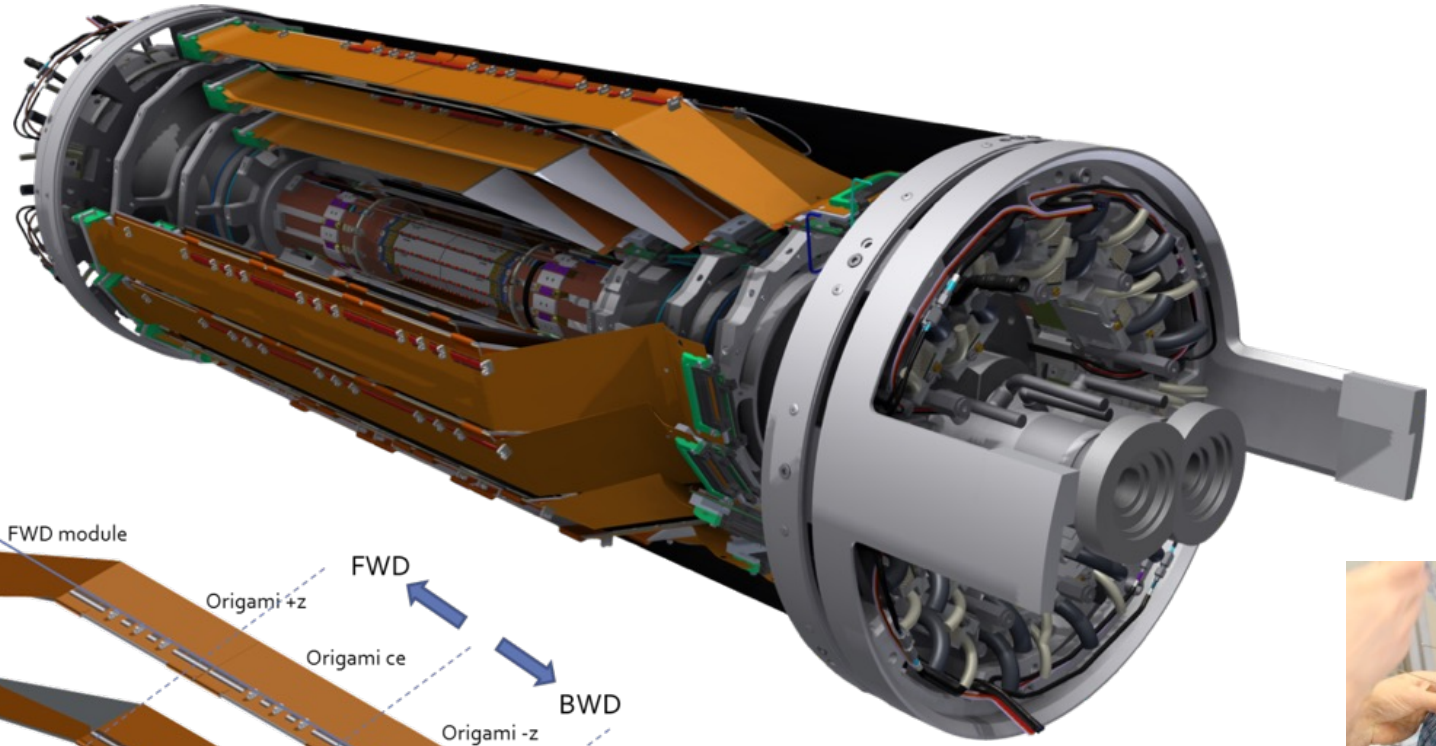
Belle II Detector (in comparison with Belle)

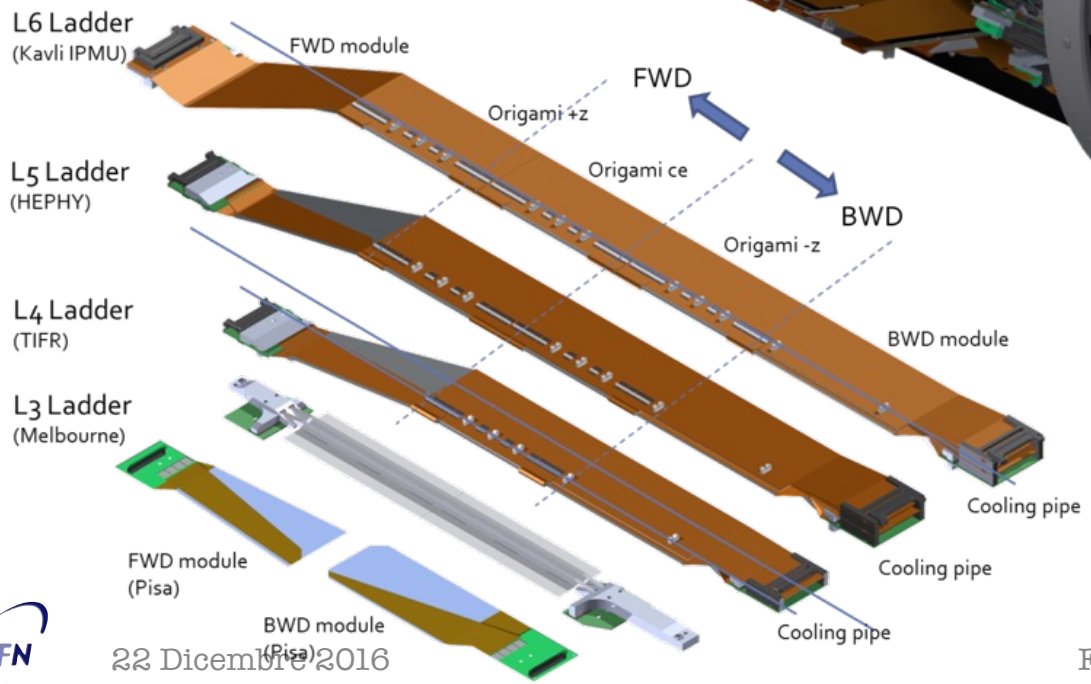


SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling (+pure CsI for endcaps)
KLM: RPC → Scintillator +MPPC (endcaps, barrel inner 2 lyrs)

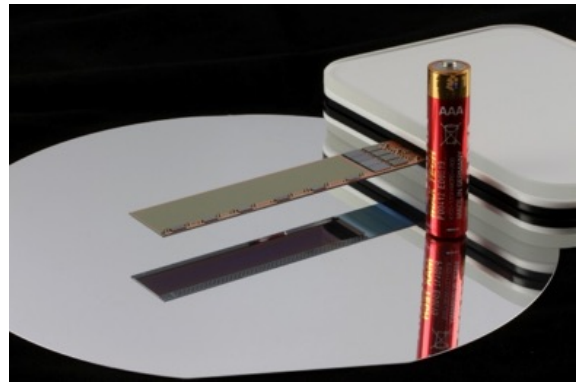
In colours: new components

Vertex Detector

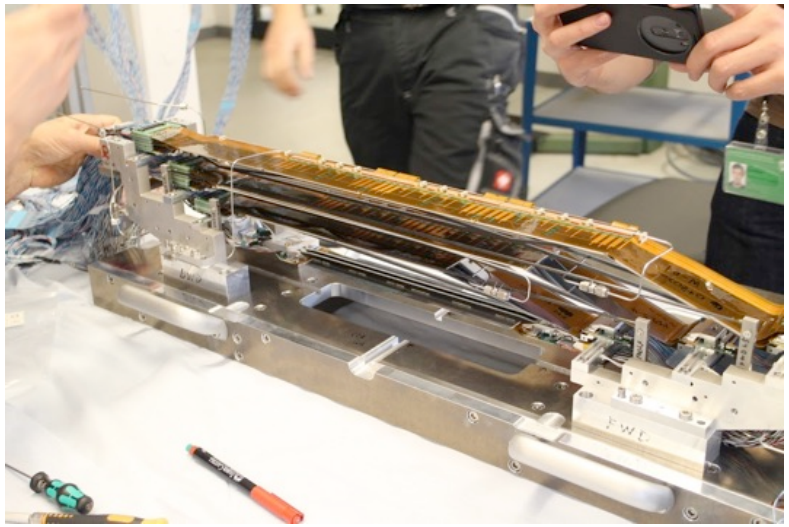




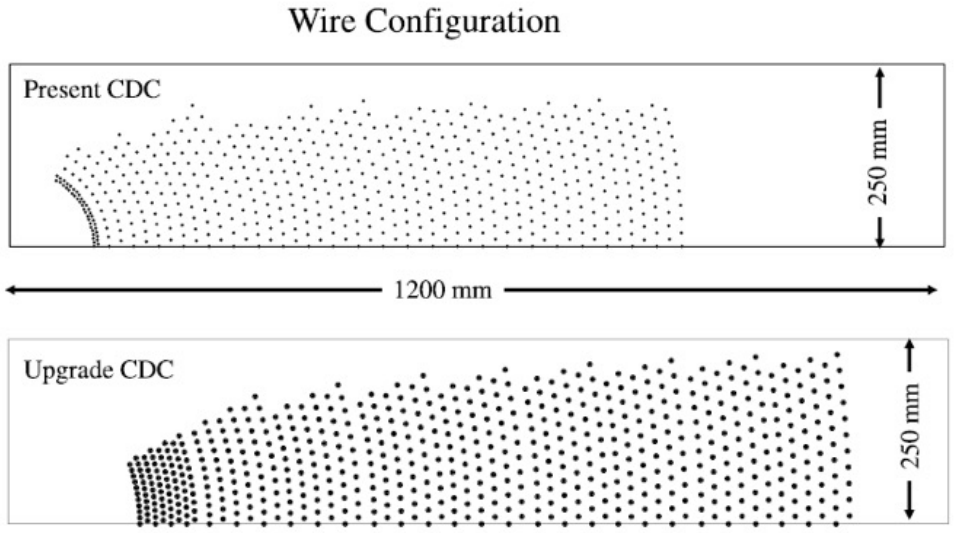
First pixel sensor



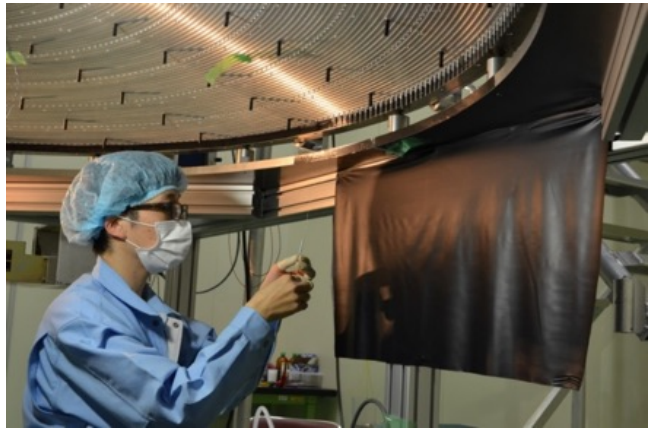
An VXD Slice tested in DESY



Belle II CDC

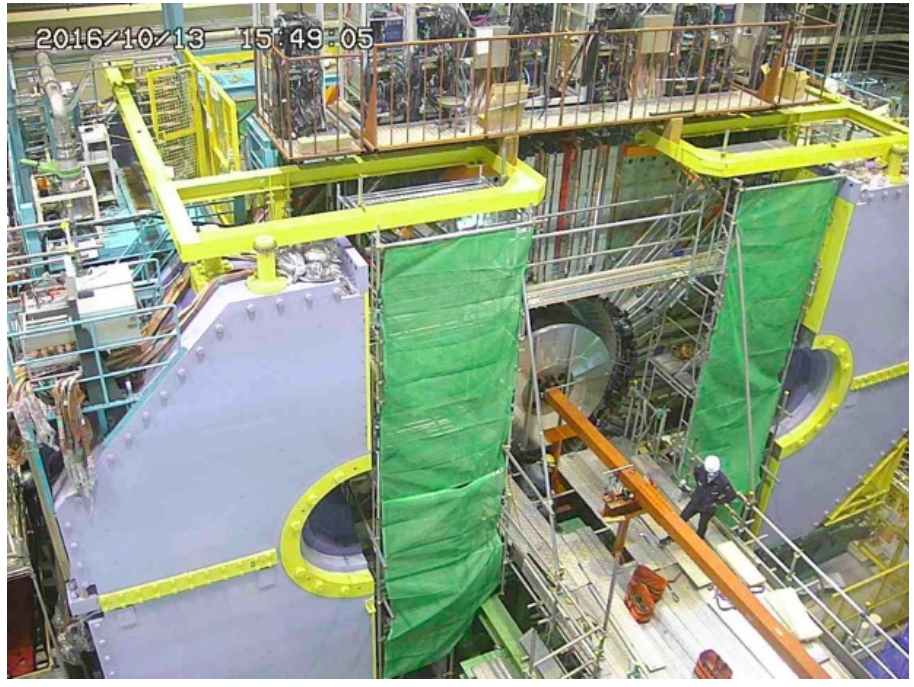


Much bigger than in Belle!



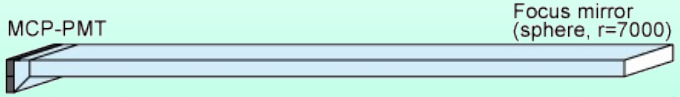
Wire stringing in a clean room

- thousands of wires,
- 1 year of work...



Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



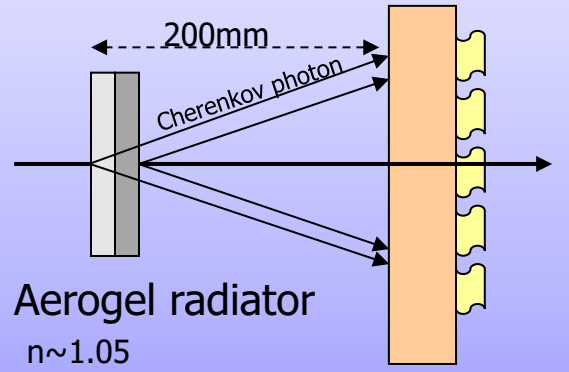
Quartz radiator

Focusing mirror

Small expansion block

Hamamatsu MCP-PMT (measure t, x and y)

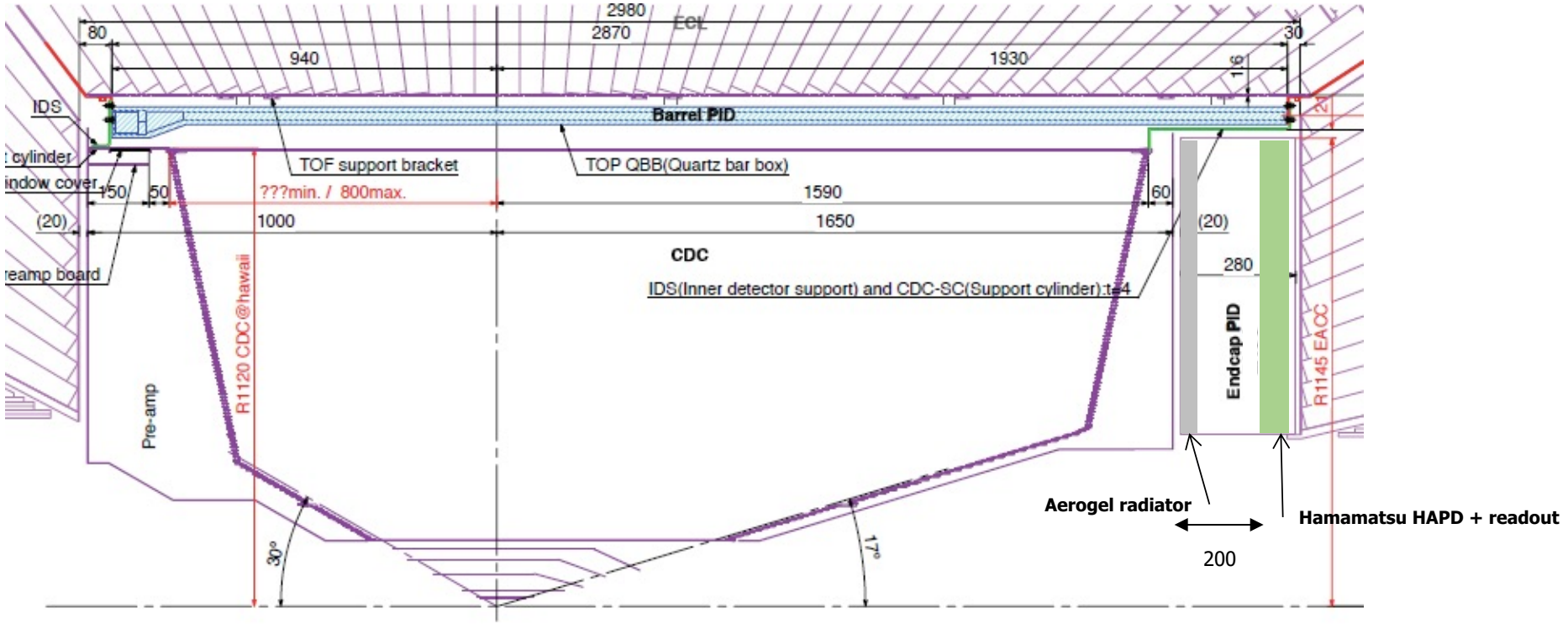
Endcap PID: Aerogel RICH (ARICH)



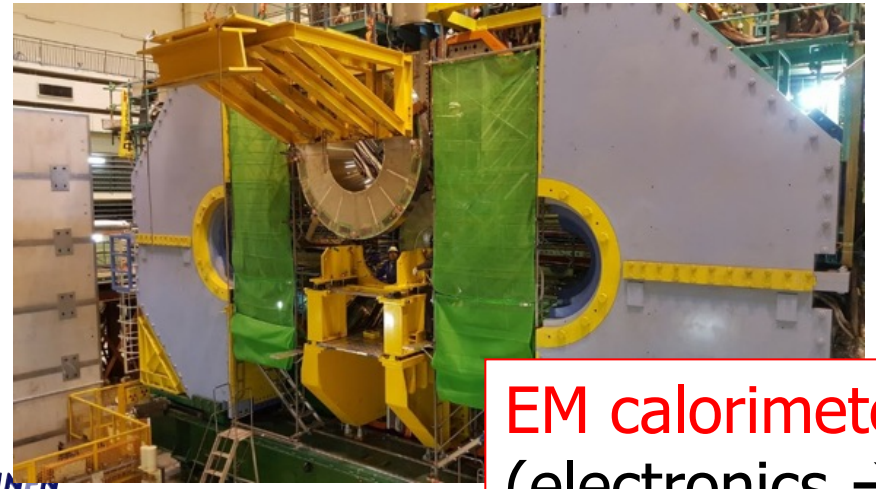
Aerogel radiator

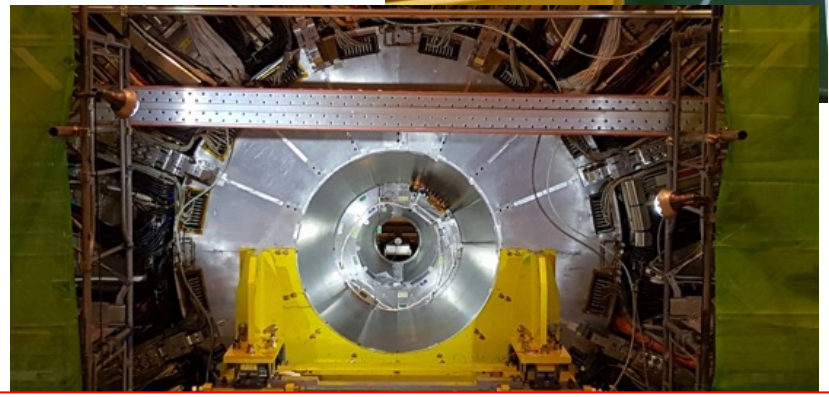
n~1.05

Hamamatsu HAPD



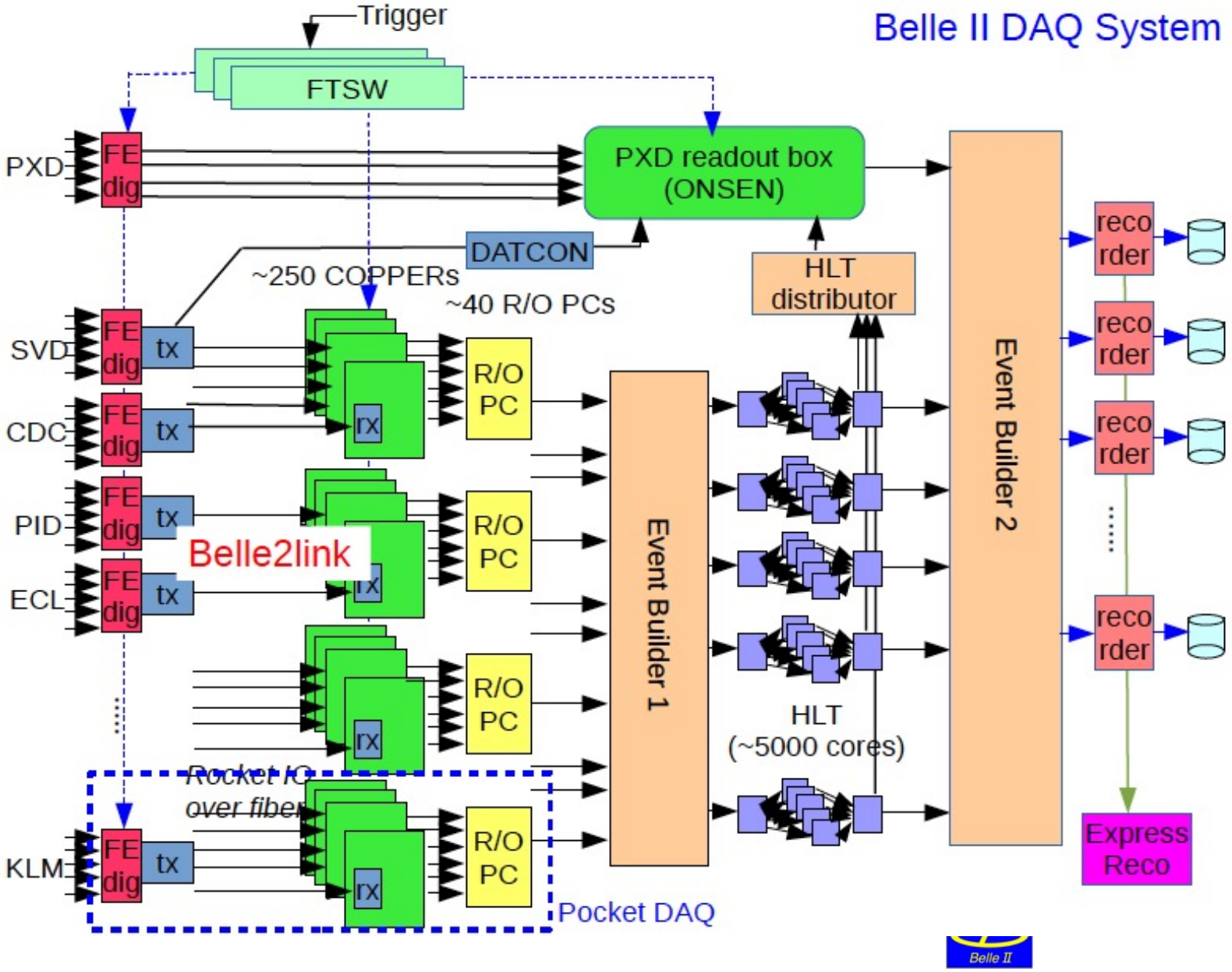
ECL Endcap installation





EM calorimeter: upgrade needed because of higher rates (electronics → waveform sampling) and radiation load

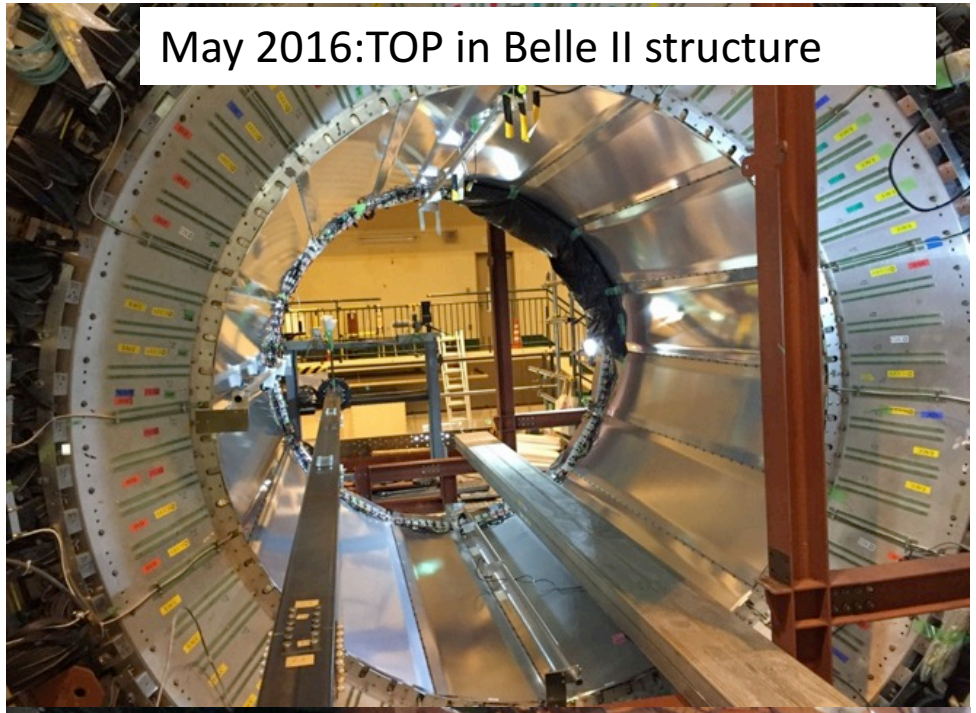
Trigger, DAQ and readout



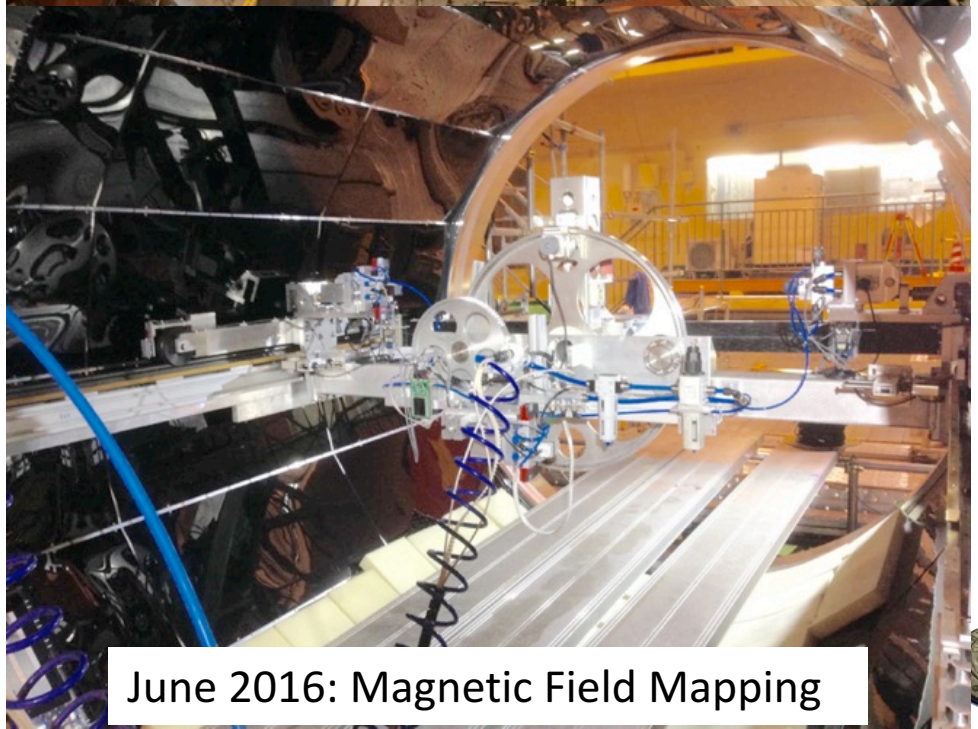
Tsukuba Hall

Oct 2016: Central Drift Chamber inside Belle II

Feb 2017: Final Focus installation



May 2016:TOP in Belle II structure

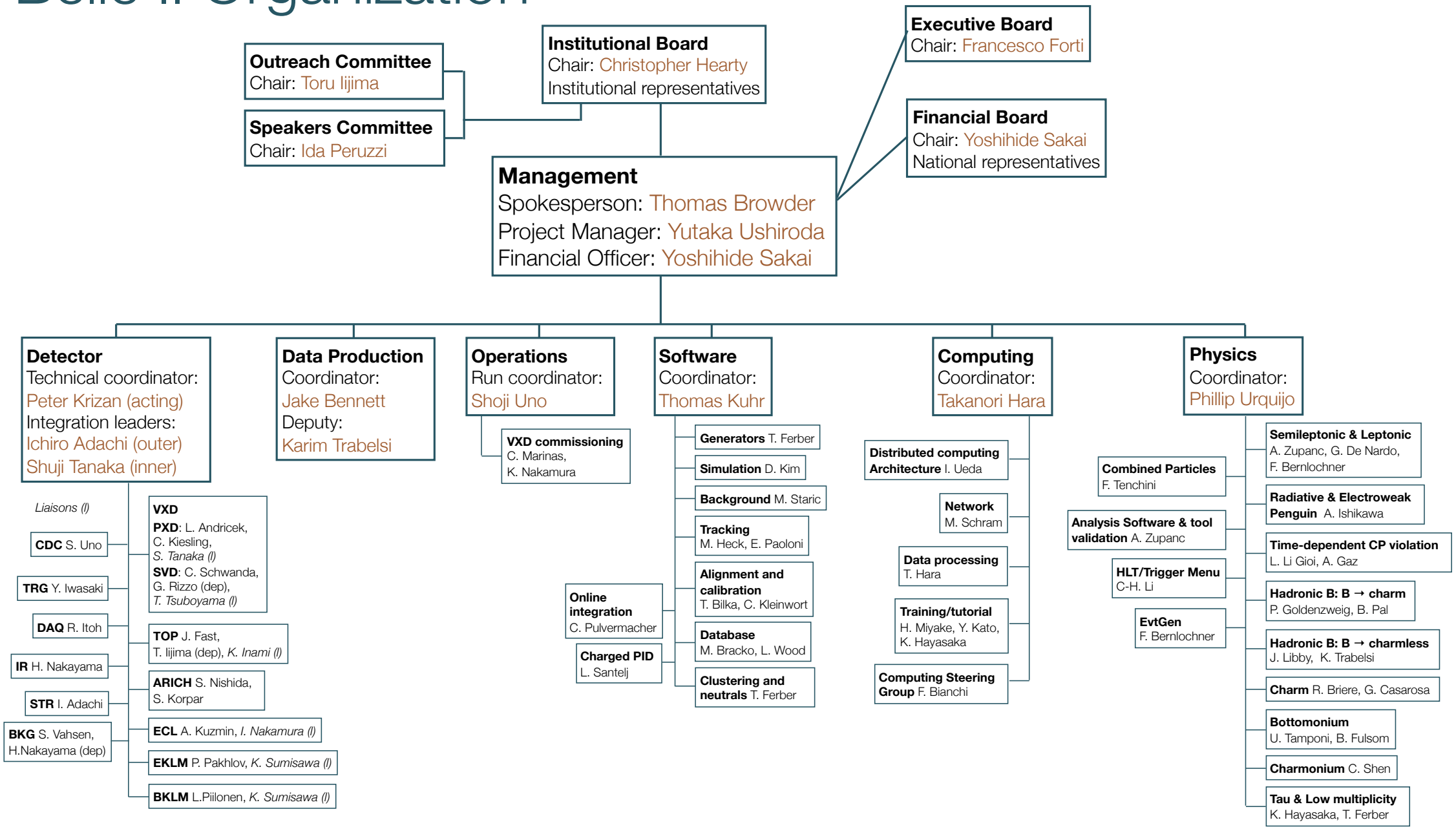


June 2016: Magnetic Field Mapping

Belle II Collaboration

>700 members,
101 institutions,
23 countries

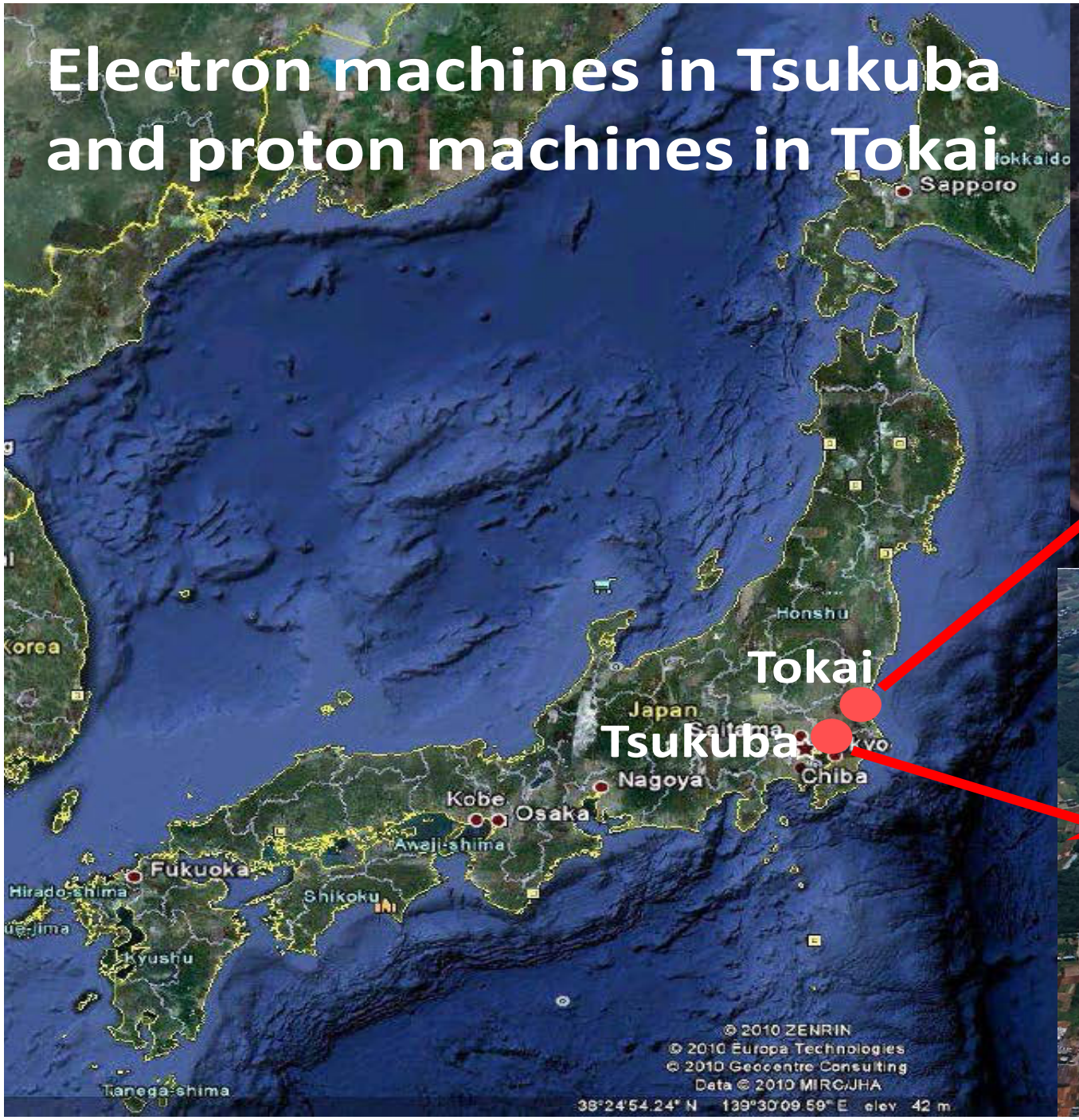
Belle II Organization

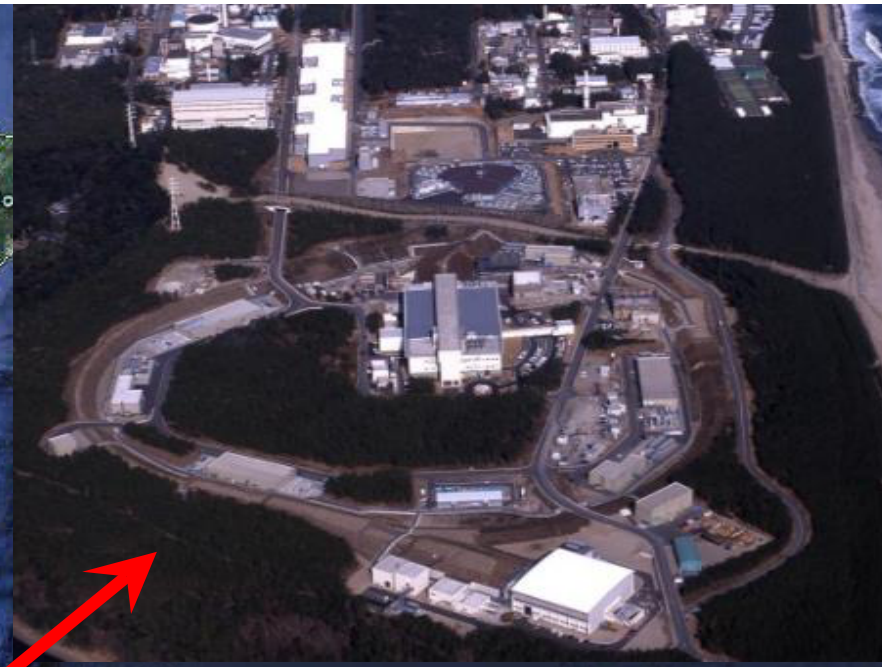


KEK Inter-University Research Institute Corporation
High Energy Accelerator Research Organization

- 1971: **National Laboratory for High Energy Physics (KEK) was established.**
- 1976: The proton synchrotron (PS) produced an 8 GeV beam as designed. The PS achieved 12 GeV.
- 1978: The Booster Synchrotron Utilization Facility and a Photon Factory (PF) were founded.
- 1982: The PF succeeded in storing a 2.5 GeV electron beam.
- 1984: The Transposable Ring Intersecting Storage Accelerator in Nippon (TRISTAN) Accumulation Ring (AR) accelerated an electron beam to 6.5 GeV.
- 1985: The AR accelerated a positron beam to 5 GeV.
- 1986: The TRISTAN Main Ring (MR) accelerated both electron and positron beams to 25.5 GeV.
- 1988: The MR energy was upgraded to 30 GeV with the help of superconducting accelerating cavities.
- 1989: Accelerator and Synchrotron Radiation Science departments were established in the Graduate University for Advanced Studies.
- 1994: KEKB B-factory construction began.
- 1995: TRISTAN experiments finished.
- 1997: **The High Energy Accelerator Research Organization was established.**
- 1998: First beam storage at KEKB (KEK B-factory) ring.
- 1999: The Long-baseline Neutrino Oscillation experiment (K2K) began. The Belle experiment at the KEKB began operation.
- 2001: Construction of High Intensity Proton Accelerators (J-PARC) started.
- 2004: Became the Inter-University Research Institute Corporation High Energy Accelerator Research Organization. K2K experiment ended.
- 2005: Tokai Campus was opened. Experiments at PS ended.
- 2006: J-PARC Center was established.
- 2008: Prof. Makoto Kobayashi won the 2008 Nobel Prize in Physics.
- 2009: J-PARC construction was completed.
- 2016: First turns and successful storage of beams in the SuperKEKB electron and positron rings[3]

Electron machines in Tsukuba and proton machines in Tokai

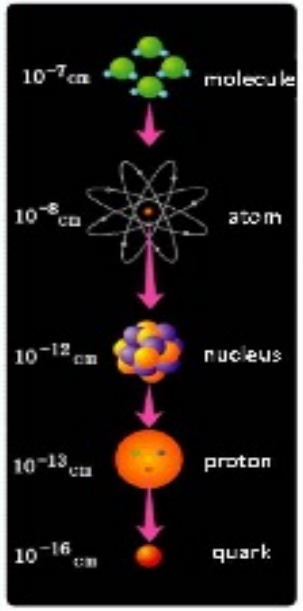


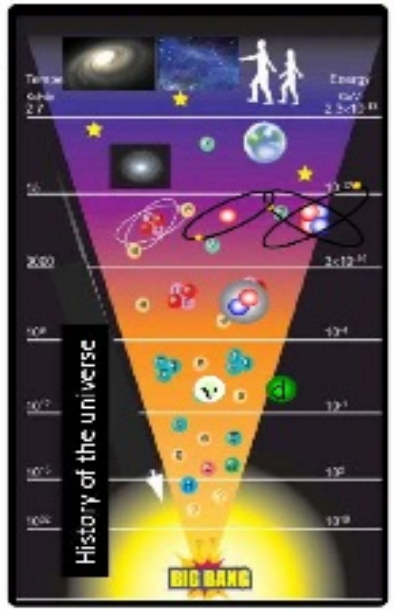


KEK
High Energy Accelerator Research Organization

Diversity in accelerator based sciences

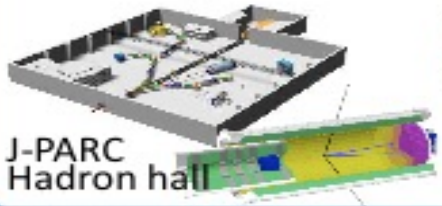
Pursuing fundamental laws of nature





T2K neutrino exp.

SuperKEKB and Belle II



COMET

J-PARC Hadron hall

Basic science

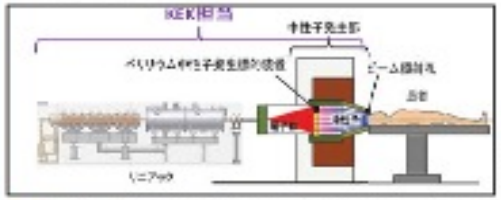
Material science and its applications

Accelerators

Technical development and its applications

Superconducting accelerator

Energy recovery linac

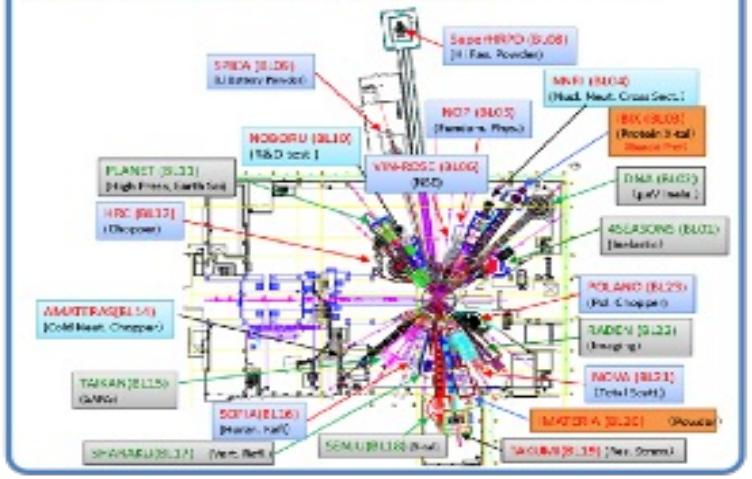


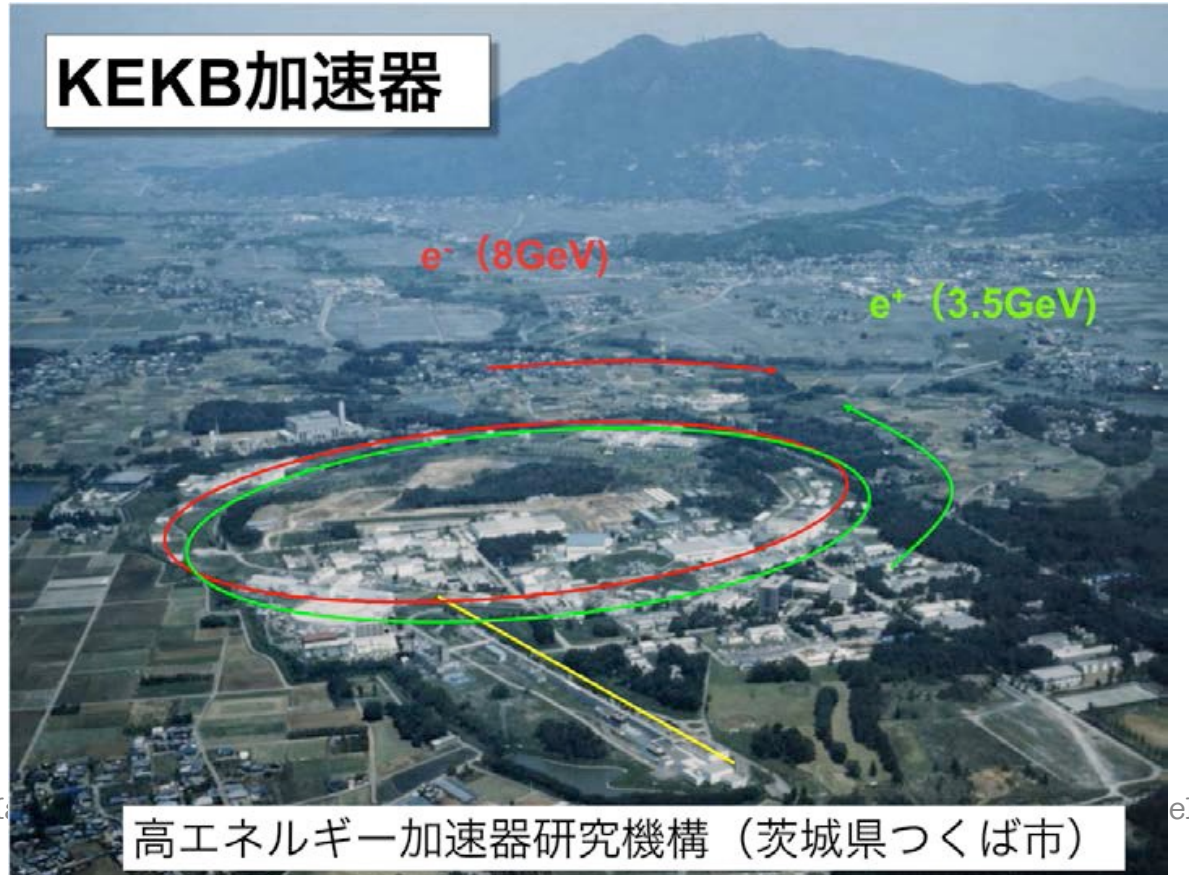
Accelerator-based BNCT

Pursuing origin of function in materials

Photon factory X-ray as a probe

J-PARC MLF neutron and μ as a probe

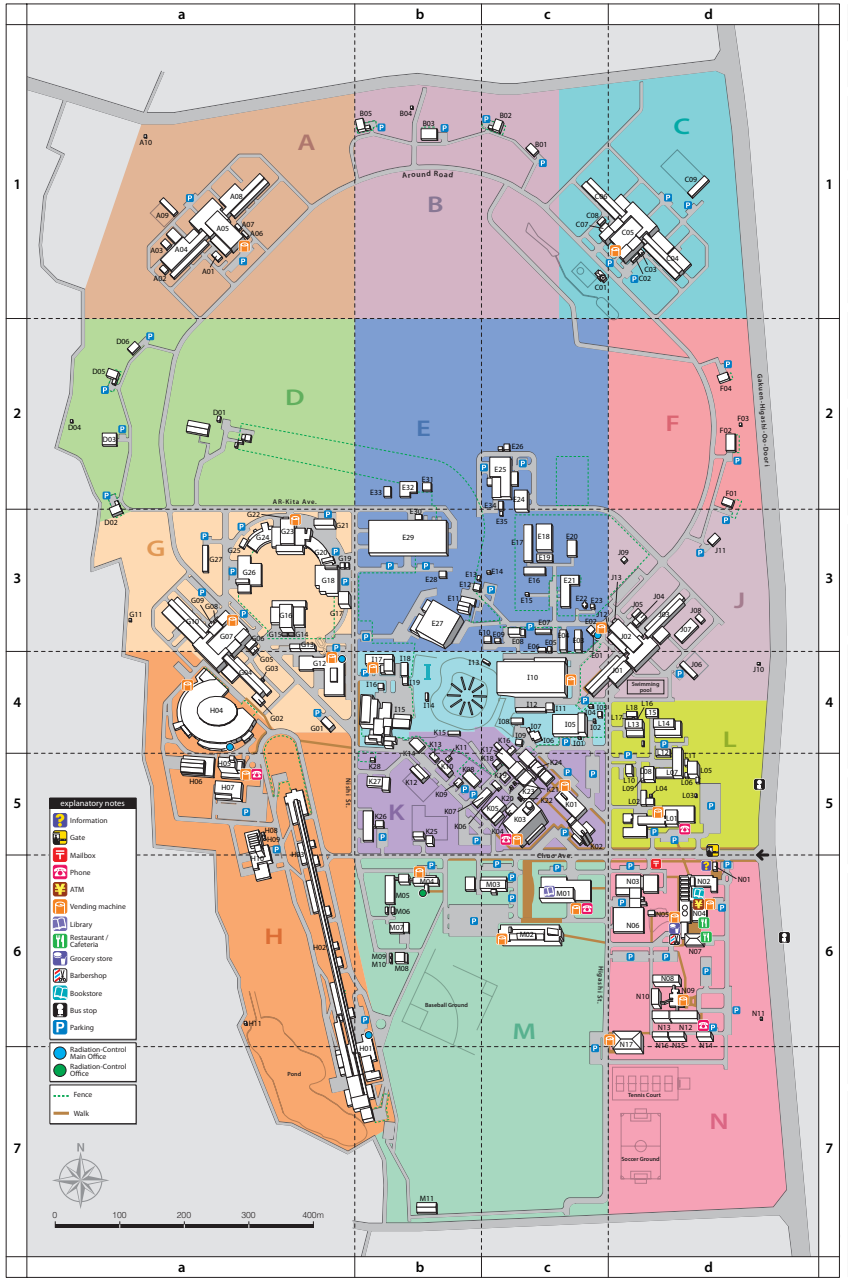




Inter-University Research Institute Corporation

KEK Campus Map

HIGH ENERGY ACCELERATOR RESEARCH ORGANIZATION



ZONE-A		
No.	Address	Name
A05	a-1	KEKB Nikko Lab.

ZONE-C		
No.	Address	Name
C05	d-1	KEKB Tsukuba Lab.

ZONE-E		
No.	Address	Name
E21	c-3	Radioisotope Lab.
E25	c-2	Superconducting RF Test Facility
E27	b-3	PS North Experiment Hall
E29	b-3	Accelerator Test Facility

ZONE-G		
No.	Address	Name
G07	a-3	KEKB Fuji Lab.
G12	a-4	KEKB Control Bldg.
G16	a-3	PF-AR South Lab.
G18	a-3	PF-AR East Lab.
G20	a-3	PF-AR North East Lab.
G23	a-3	PF-AR North Lab.
G24	a-3	PF-AR North West Lab.
G26	a-3	PF-AR West Lab.

ZONE-H		
No.	Address	Name
H01	b-7	Electron Linac Control Bldg.
H02	a-5,6,7	Electron Linac
H04	a-4	PF Light Source Bldg.
H05	a-5	PF Main Bldg.
H07	a-5	PF Lab.

ZONE-I		
No.	Address	Name
I10	c-4	PS East Exp. Hall
I15	b-4	Advanced Instrumentation Lab.(1)
I17	b-4	Advanced Instrumentation Lab.(2)

ZONE-J		
No.	Address	Name
J02	d-3	KEKB Oho Lab.

ZONE-K		
No.	Address	Name
K01	c-5	Ichi-Go-Kan Bldg.
K02	c-5	Ni-Go-Kan Bldg.
K03	c-5	San-Go-Kan Bldg.
K14	b-4	Proton Beam Application Bldg.
K23	c-5	PS North Lab.
K24	c-5	PS Lab.
K26	b-5	Structural Biology Bldg.

ZONE-L		
No.	Address	Name
L01	d-5	Administration Bldg.
L05	d-5	Cryogenics Bldg. No.4
L07	d-5	Cryogenics Bldg. No.2
L08	d-5	Cryogenics Bldg. No.3
L10	d-5	Cryogenics Bldg. No.1
L13	d-4	Machine Shop Bldg. No.1
L14	d-4	Machine Shop Bldg. No.2
L15	d-4	Machine Shop Bldg. No.3

ZONE-M		
No.	Address	Name
M01	c-6	Kenkyu Honkan Bldg.
M02	c-6	Yon-Go-Kan Bldg.
M03	c-6	Cryogenics and Vacuum Lab.
M04	b-6	Radiation Contol
M05	b-6	Chemistry Lab.

ZONE-N		
No.	Address	Name
N01	d-6	Information Center
N02	d-6	KEK Interenational Center
N03	d-6	Computer North Bldg.
N04	d-6	Cafeteria
N06	d-6	Computer South Bldg.
N07	d-6	Employee's Center
N08	d-6	Dormitory No.2
N09	d-6	Dormitory Commons
N10	d-6	Dormitory No.3
N12	d-6	Dormitory No.1
N13	d-6	Dormitory No.4
N14	d-6	Guest House A
N15	d-6	Guest House B
N16	d-6	Guest House C
N17	d-6	Gymnasium

No.	Address	Name
N02	d-6	Bookstore
N04	d-6	Cafeteria
M01	c-6	KEK Communication Plaza
N07	d-6	Grocery/Restaurant/Barbershop
N17	d-6	Gymnasium
N01	d-6	Information / Emergency Center
M01	c-6	Library
I15	b-4	Medical Help
M04	b-6	Radiation Control Office
N02	d-6	Lost Office
–	d-4	Swimming pool
–	b-6	Baseball Ground
–	d-7	Tennis Court