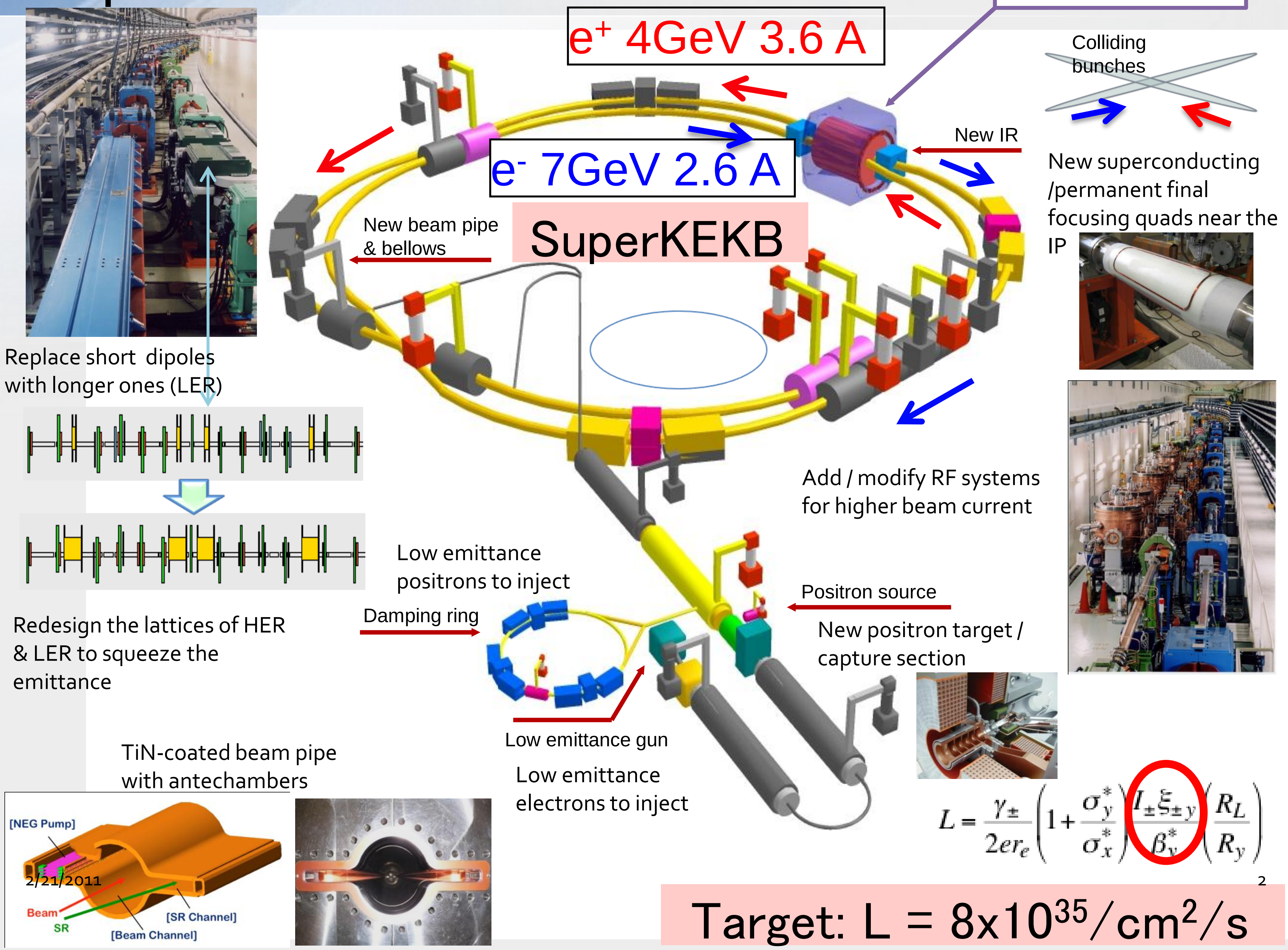
Belle II detector status

Yutaka Ushiroda (IPNS, KEK)
Joint Belle II & SuperB Background Meeting
Feb. 9, 2012

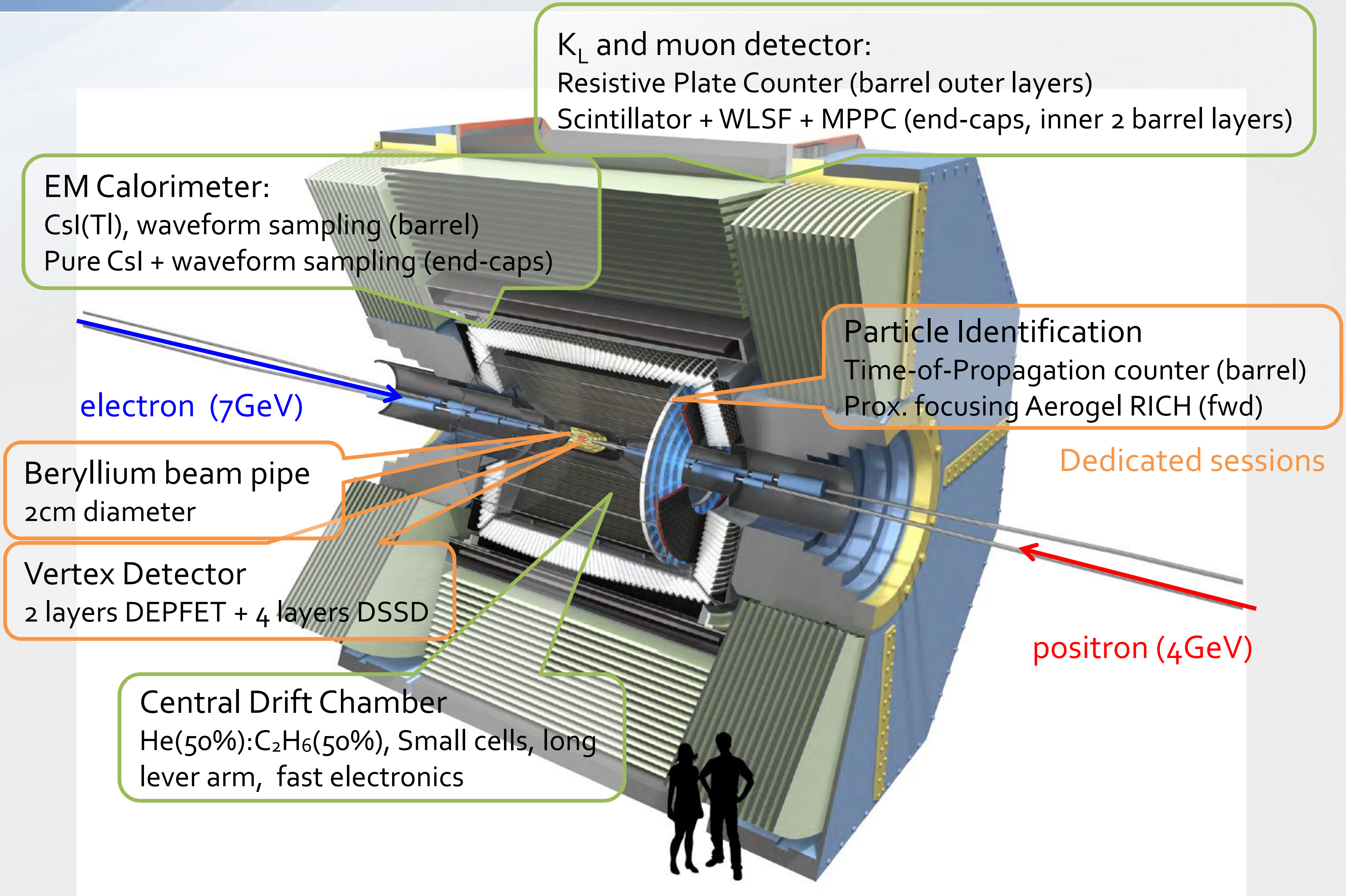
SuperKEKB and Belle II



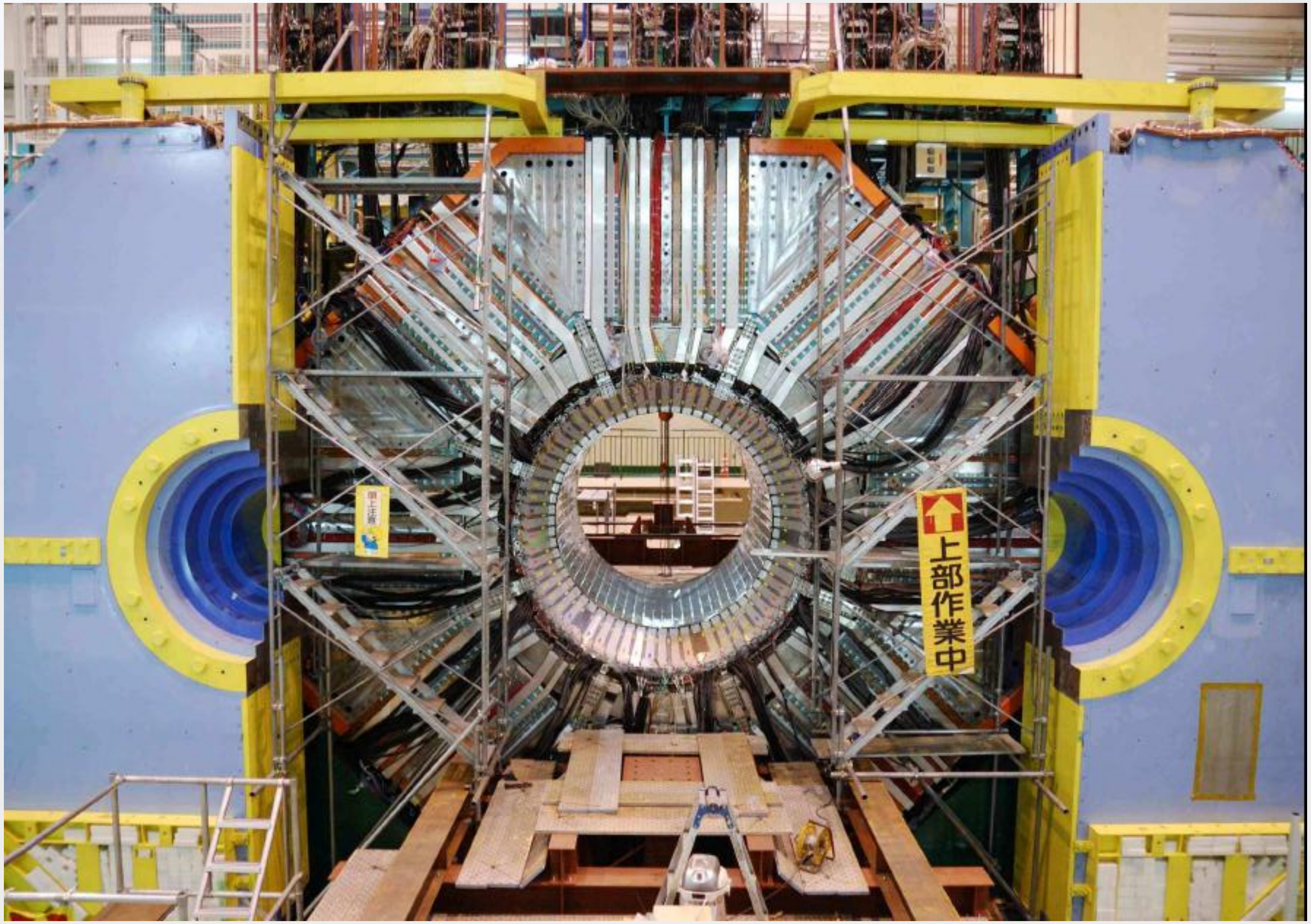
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

Target: L = $8\times10^{35}/cm^2/s$

Belle II Detector

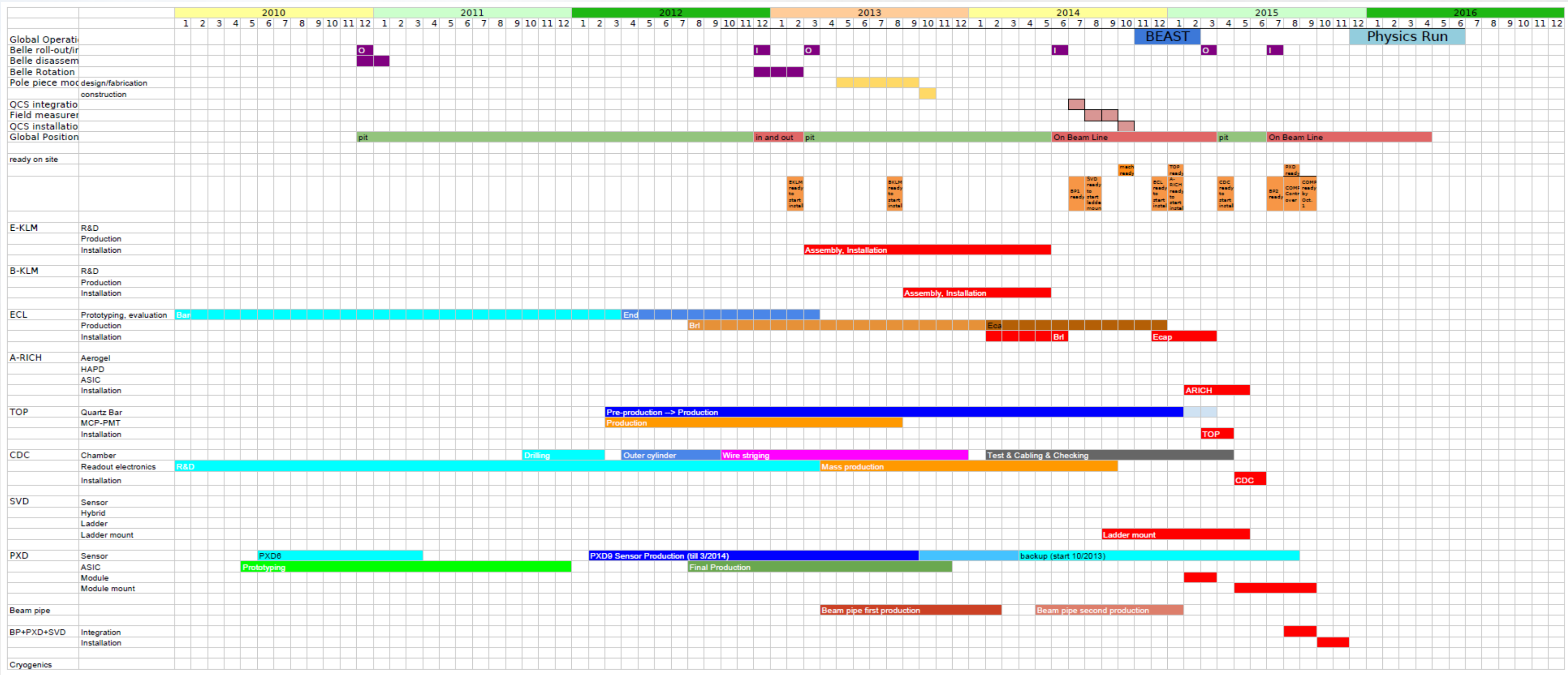


Status of Belle 1



Beam Pipe and Vertex Detector extraction: on Nov. 10, 2010
Belle Detector Roll-out: Dec. 9, 2010
End-caps, CDC, B-ACC, TOF extraction: in Jan. 2011

Belle II Construction Schedule

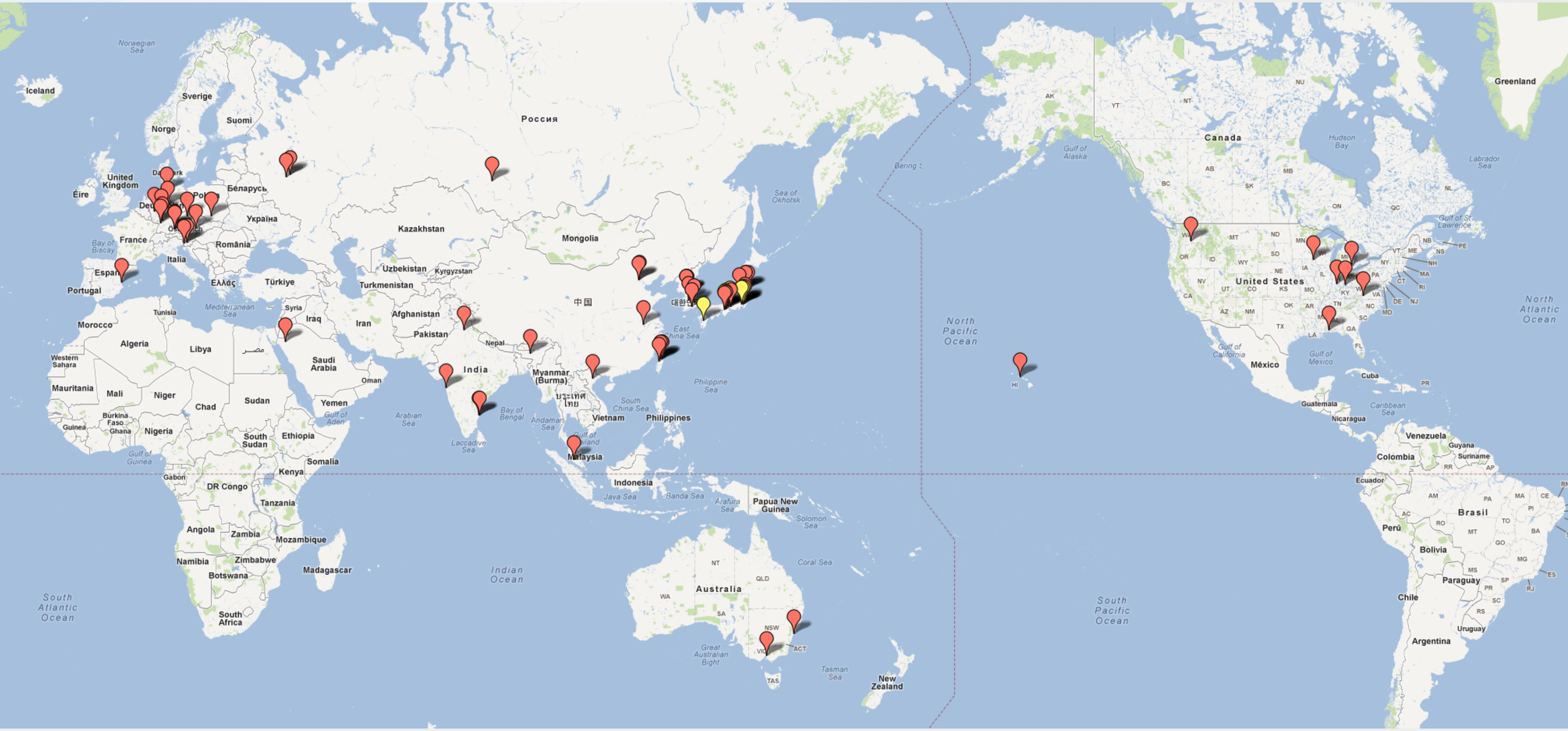


JFY2012 (April-March)
Belle rotation
Removal of cables

JFY2013
Installation of
KLM starts

JFY 2014
Machine operation starts
After machine commissioning, *inner* detectors are installed
Physics run starts in end of CY 2015

Belle II Collaboration



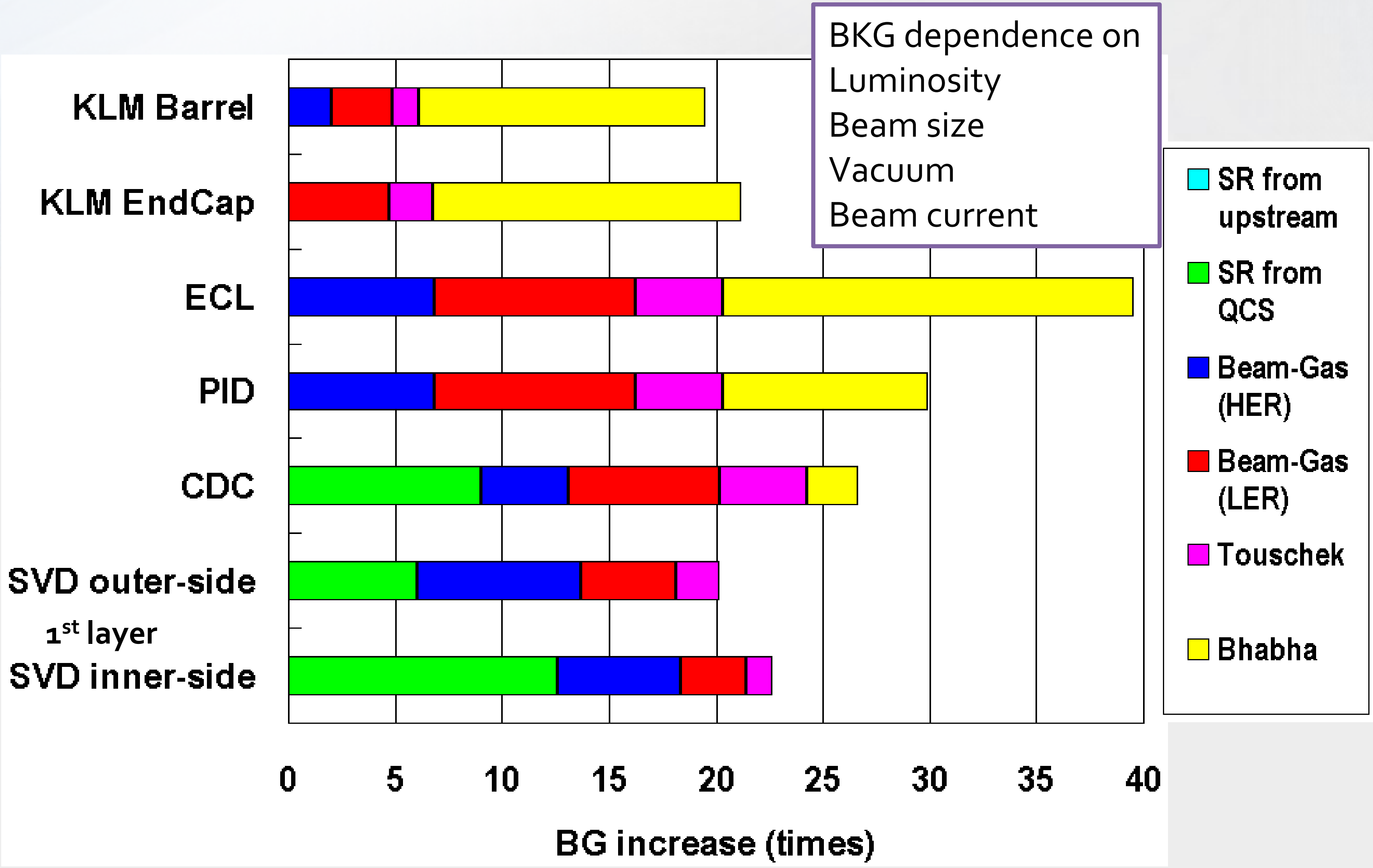
17 countries/regions, 62 institutes, ~400 collaborators (Jan. 2012)

Outline

- Introduction
- Early Estimations of Background Level
- Status of Detector Components
- Summary

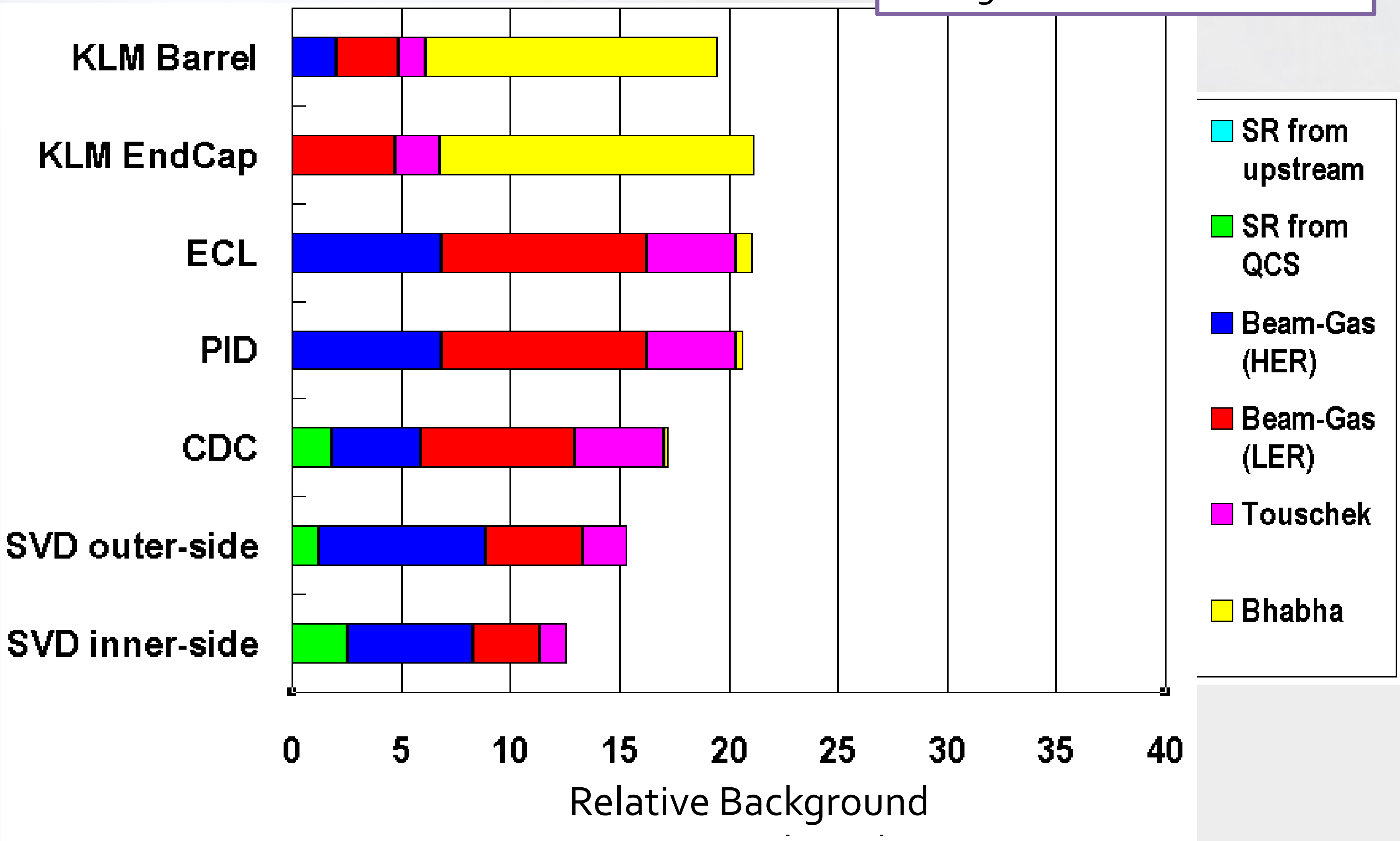
Early Estimations of Background Level

Beam Background Estimation (as of 2004; LoI)



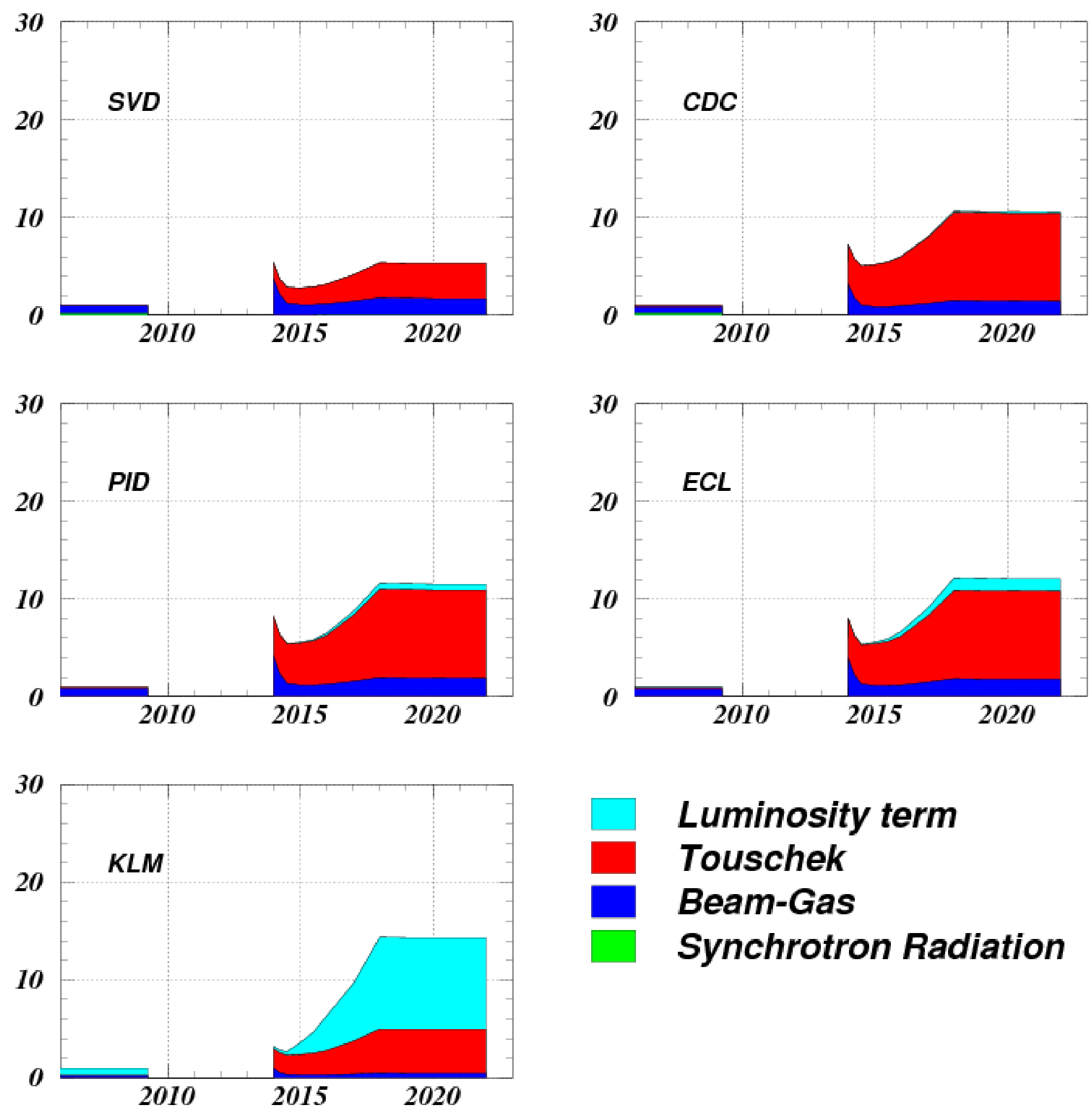
Beam Background Estimation (as of 2008)

+ Tungsten mask around QCS



20 times more background @ full I_{beam}

High current → nano beam



No reason to believe the accuracy is better than 100%
Still assume x20 BKG

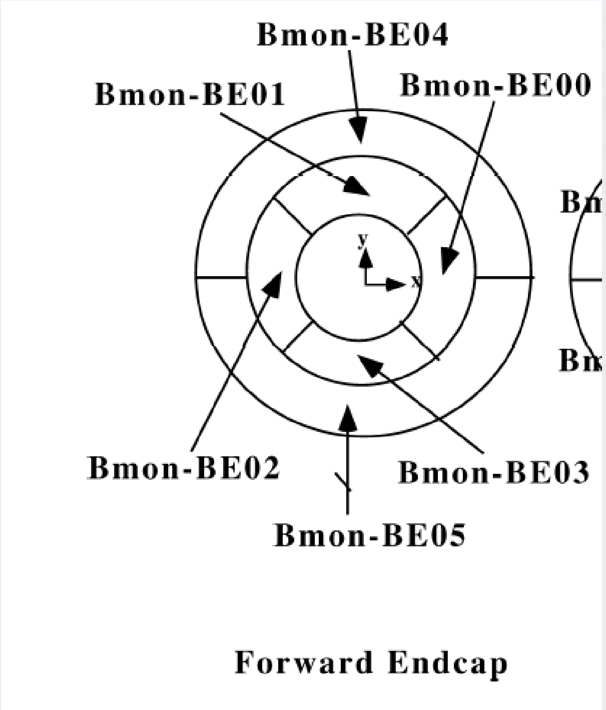
Detector Design

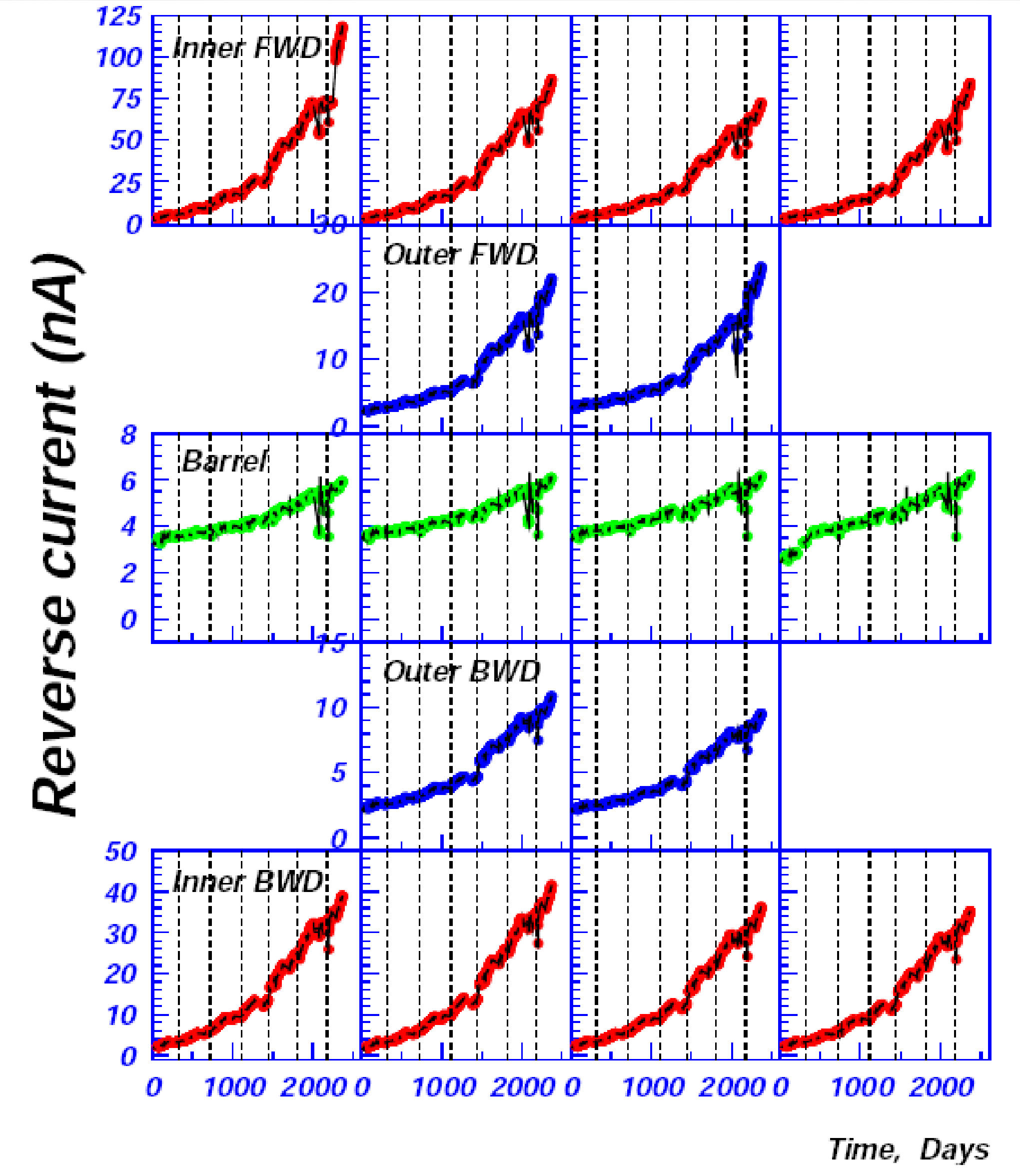
Beam Background Estimation (as of today)

- Simulation environment has been “established”
- Post-validate the background level

How many neutrons when x20?

Dark current of photodiodes of ECL
PD dark current increases by bulk damage
1nA ↔ 7×10^{8}n/cm^2

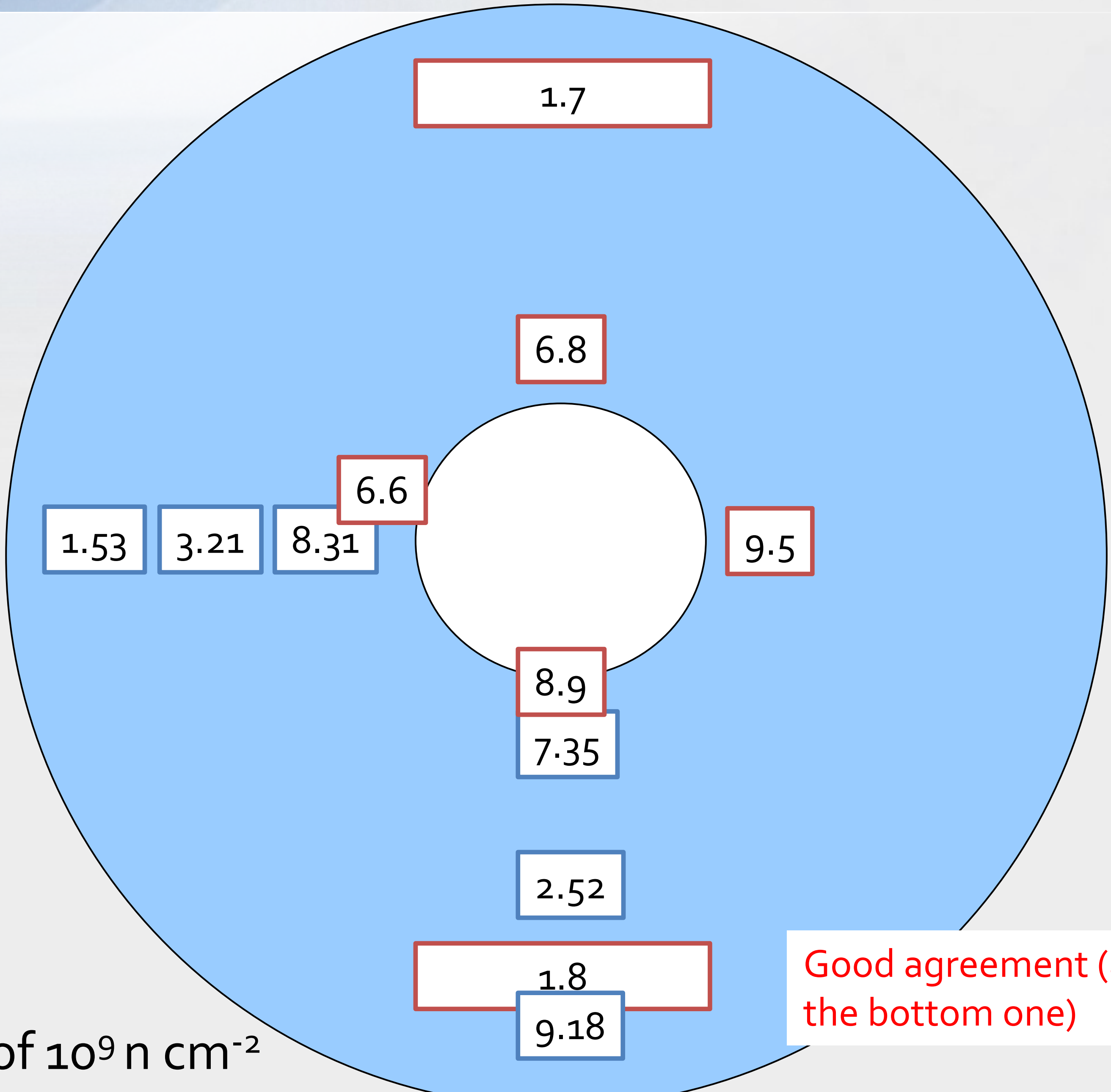




70nA per 10 Belle years
= 5×10^{10}n/cm^2
→ 10^{12}n/cm^2 per 10 Belle II years

A cross check

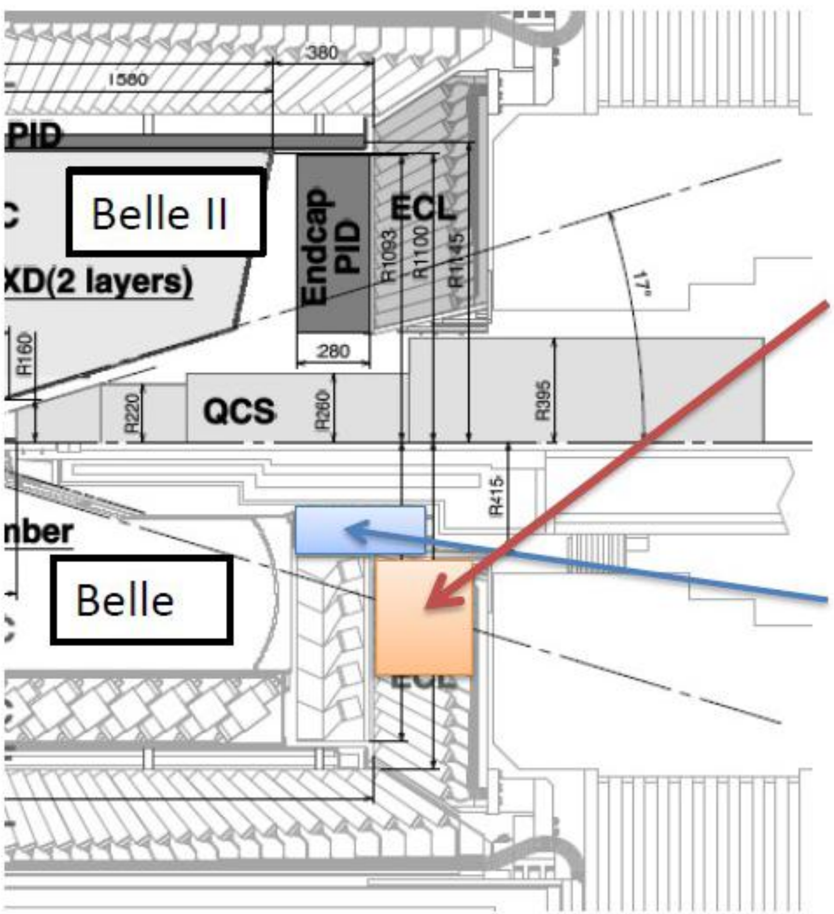
Si diodes (ELMA) installed in Feb. – Jun. 2008
(Int. L = 91/fb)



Good agreement (appart from the bottom one)

In unit of 10^9 n cm^{-2}

Ionization Dose



Extrapolation from measured dose around Belle ACC

→ To be updated with the Belle II full simulation.

- ECL Forward Inner

  2.4 Gy for 770fb-1 (CsI dose by PD current)

→ **60 Gy** (assumeing x20 BG)

- SVD Dock

  3.6 Gy for 70 fb-1 (by aminogray)

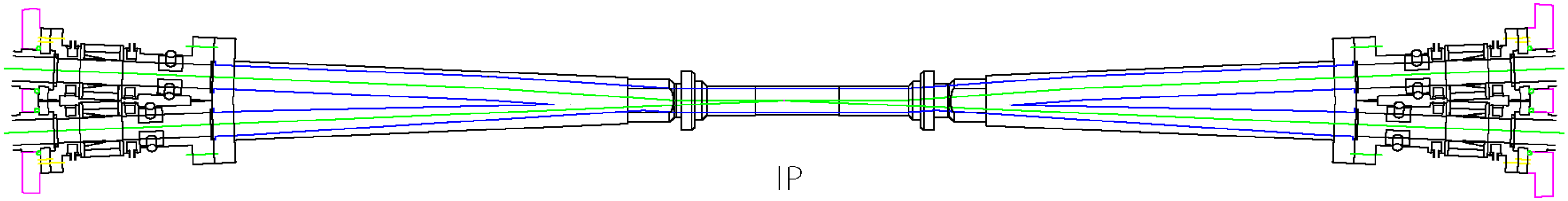
→ **1000 Gy** (assuming x20 BG)

Target for Belle II:
For most of HAPDs → 100Gy / 10 years
Inner most HAPDs → 1000Gy / 10 years

(1Gy = 100rad)

Status of Detector Components

1. IP Chamber
Mock-up

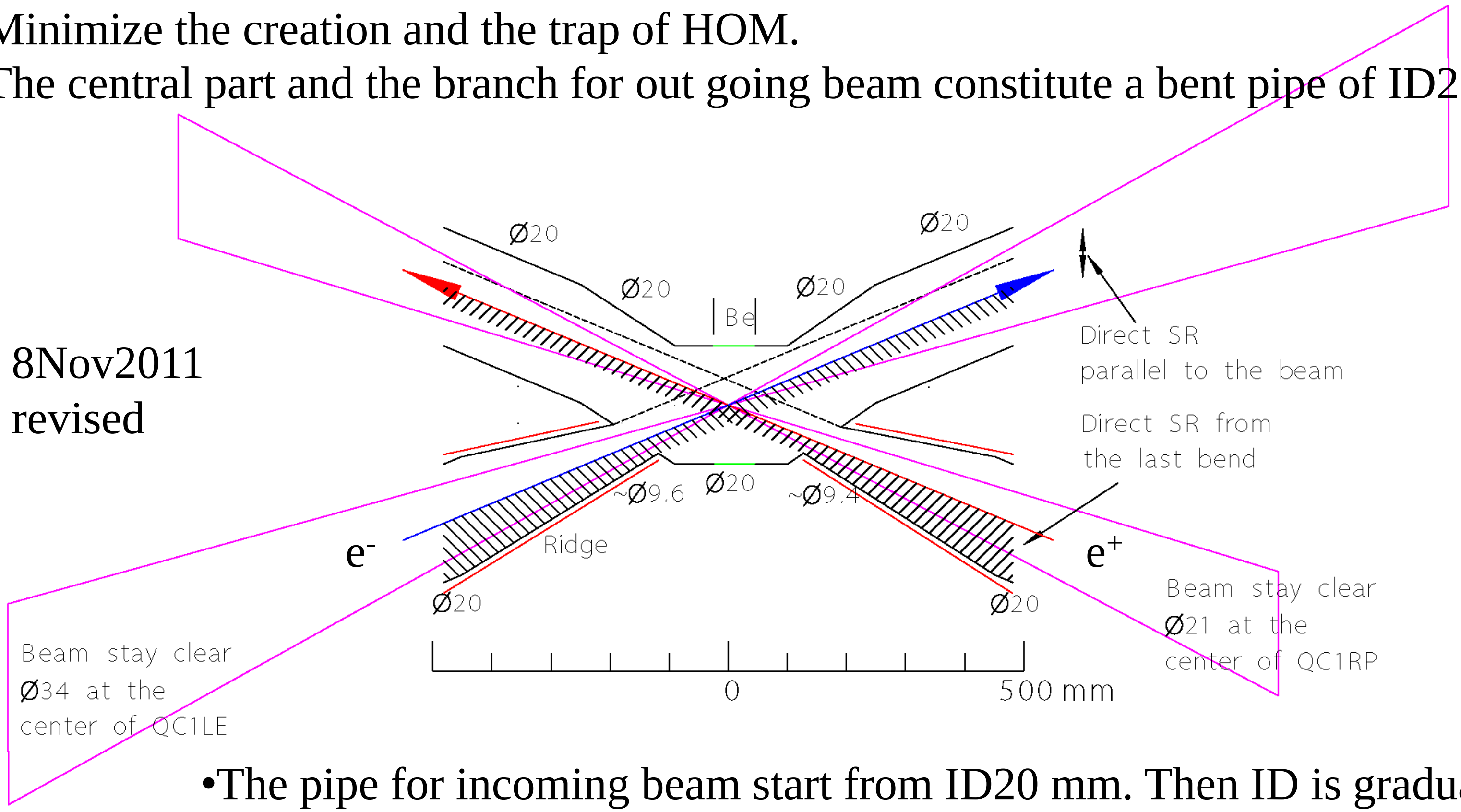


(Photo by Satoh)

1. IP Chamber Design Features

•Minimize the creation and the trap of HOM.
•The central part and the branch for out going beam constitute a bent pipe of ID20mm.

8Nov2011
revised

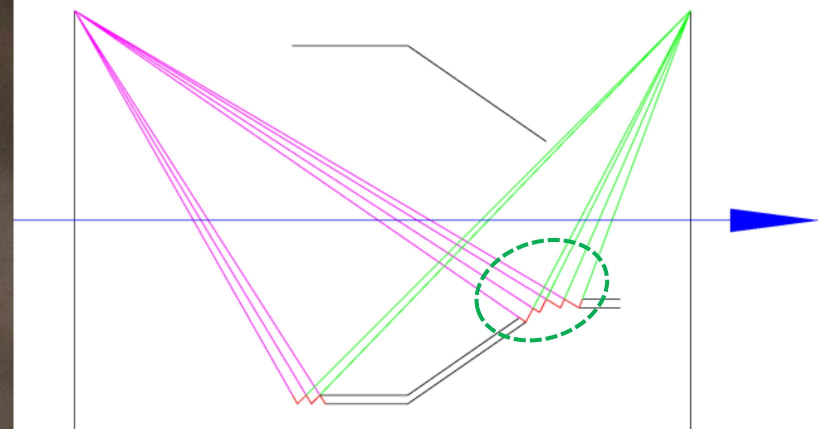


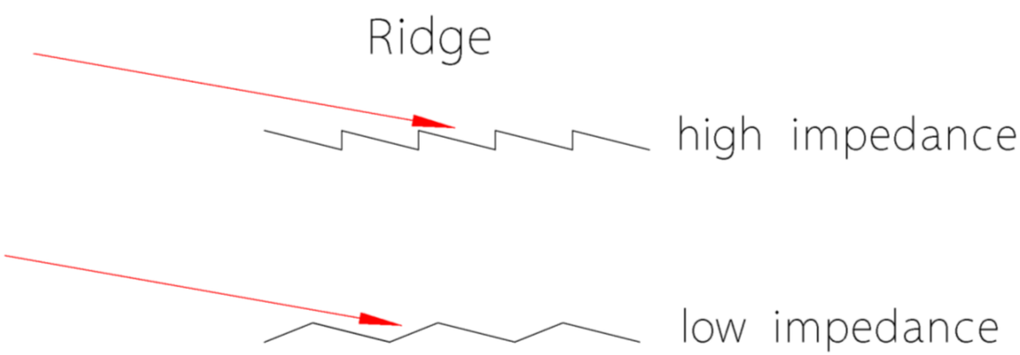
•The pipe for incoming beam start from ID20 mm. Then ID is gradually reduced to about 9 mm to stop direct SR.
•The inner surface of a pipe for incoming beam has ridges to prevent scattered light from hitting the central part.

Ridge

Test fabrication of the low impedance ridge

Single scattered photon cannot enter the beryllium beam pipe

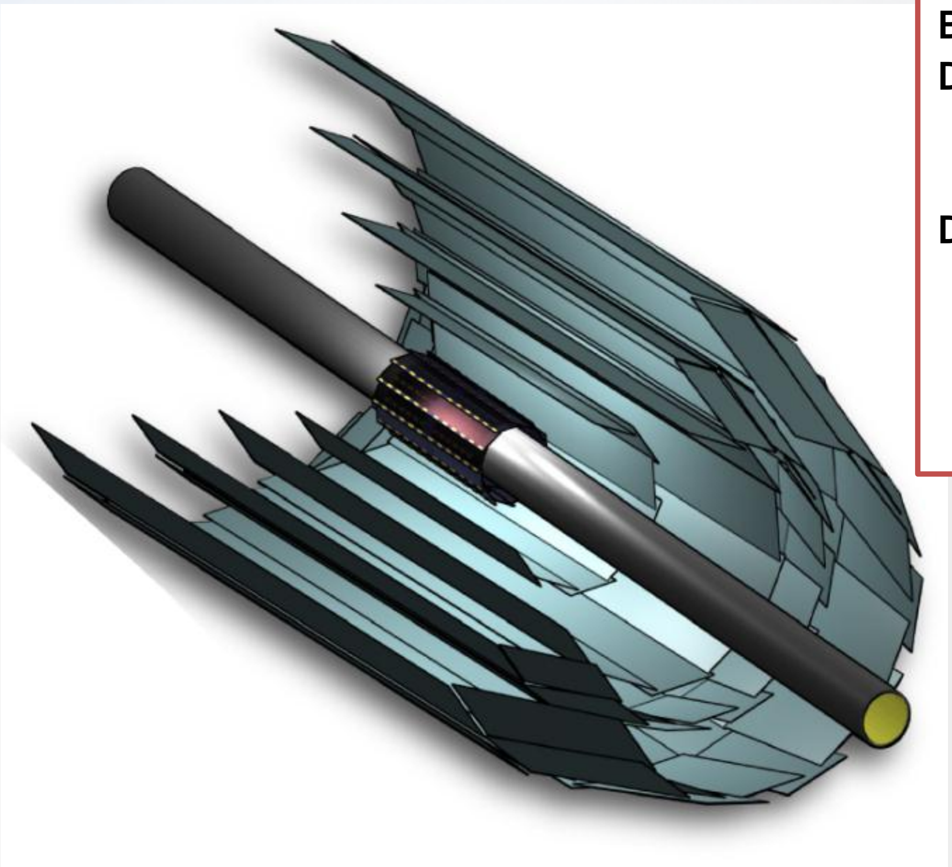




Low risk for multiply scattered photon to escape forward

Risk for multiply scattered photon to escape forward

Vertex Detector



		Belle II	Belle
Beam Pipe		r = 10mm	15mm
DEPFET			
	Layer 1	r = 14mm	
	Layer 2	r = 22mm	
DSSD			
	Layer 3	r = 38mm	20mm
	Layer 4	r = 80mm	43.5mm
	Layer 5	r = 115mm*	70mm
	Layer 6	r = 140mm*	88mm

*** final adjustment ongoing**

PXD (DEPFET)

Each pixel is a p-channel FET on a completely depleted bulk

A deep n-implant creates a potential minimum for electrons under the gate ("internal gate")

Signal electrons accumulate in the internal gate and modulate the transistor current (g_q ~ 400 pA/e$^-$)

Accumulated charge can be removed by a clear contact ("reset")

Fully depleted: => large signal, fast signal collection

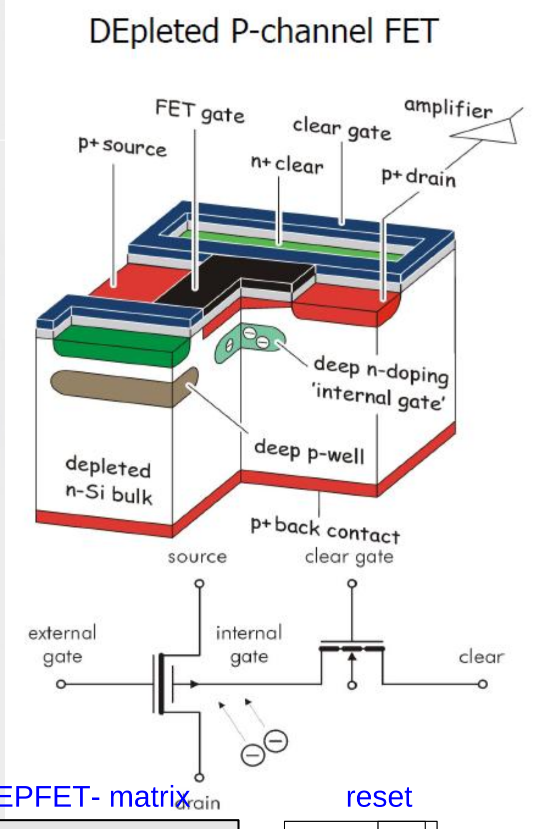
Low capacitance, internal amplification: => low noise

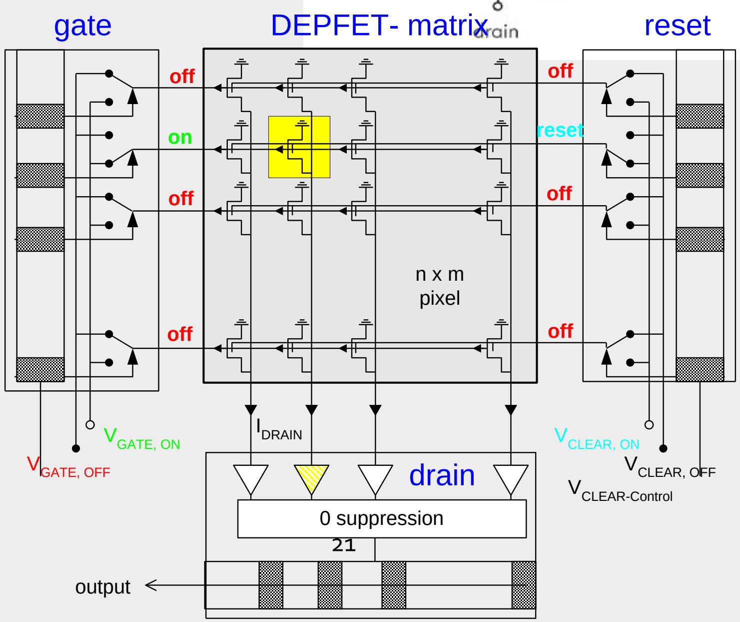
High S/N even for thin sensors (50µm)

Rolling shutter mode (column parallel) for matrix operation=>
20 µs frame readout time
=> Low power (only few lines powered)

Power consumption in sensitive area: 0.1W/cm²
=> air-cooling sufficient

DEPFET:
http://aldebaran.hll.mpg.de/twiki/bin/view/DEPFET/WebHome

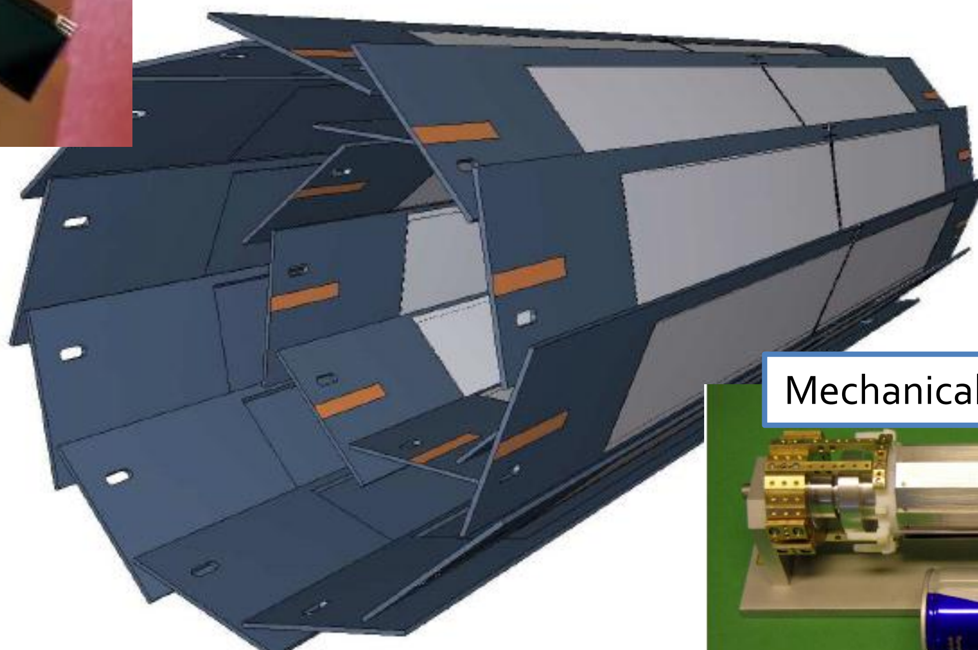


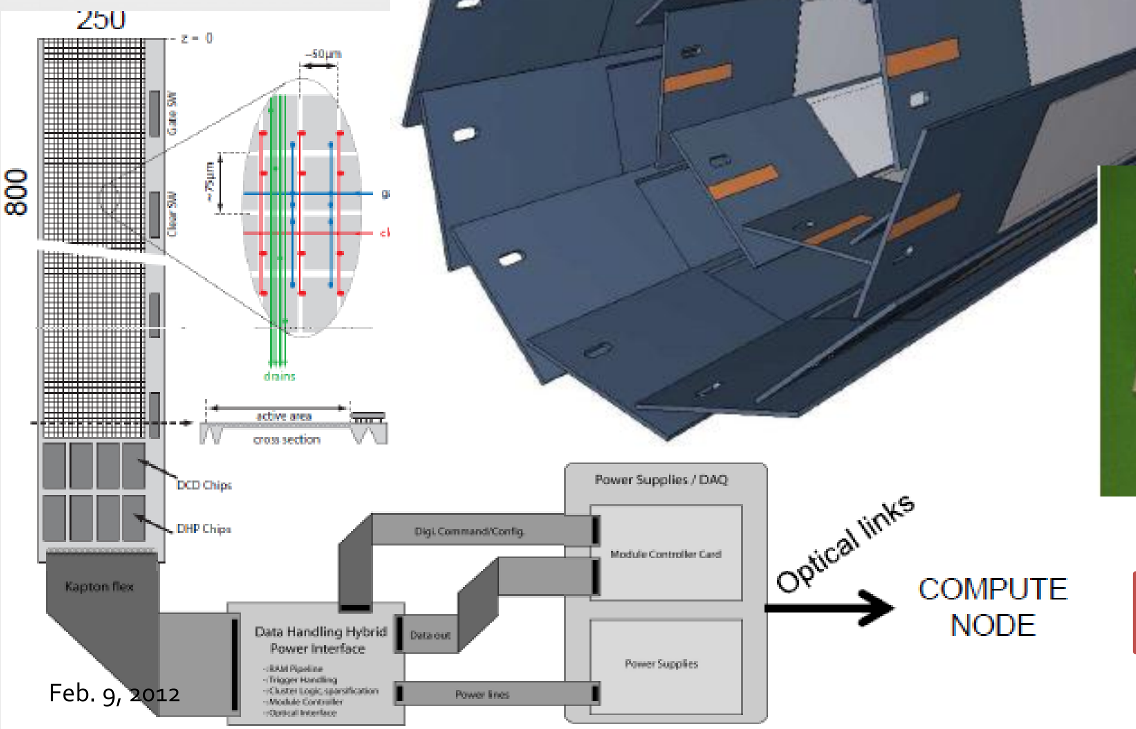


DEPFET for Belle II

Layer	radius (mm)	px size (μm²)	thickness (μm)	half ladder rows×cols	half ladder size (mm×mm)	#ladders
1	14	50x55	75	768×250	70×15	8
2	22	50x75	75	768×250	85×15	12

total of 8 Mpx



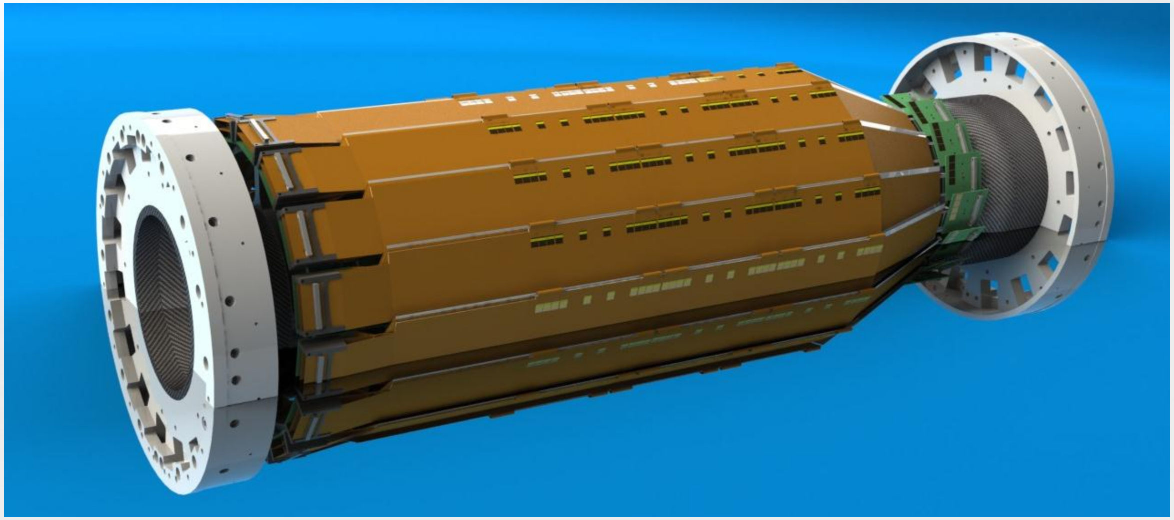


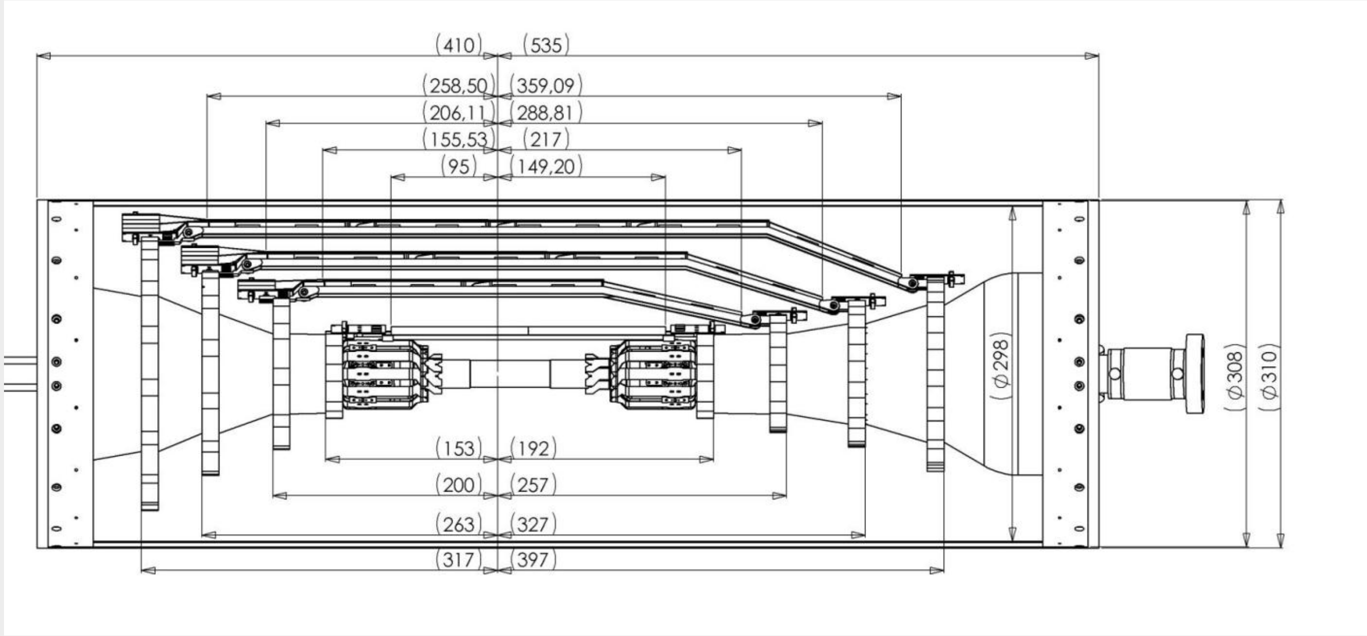
Mechanical mockup

To be ready by Aug. 2015 at KEK

SVD

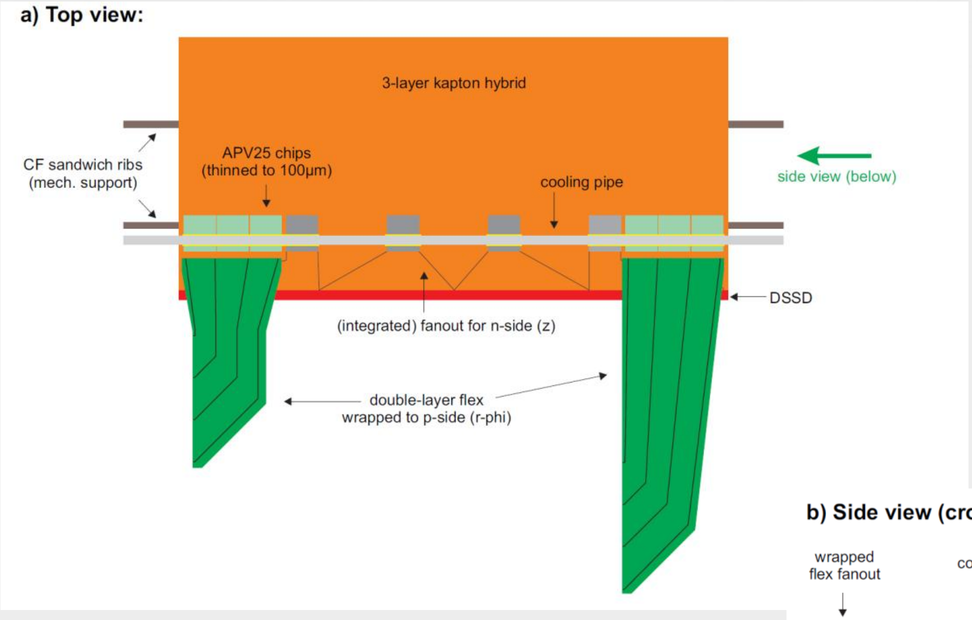
4 layers (r=38-140*mm)
HPK's rectangular DSSDs from 6" wafer for straight part
Micron's trapezoidal DSSDs for slanted part in the forward region

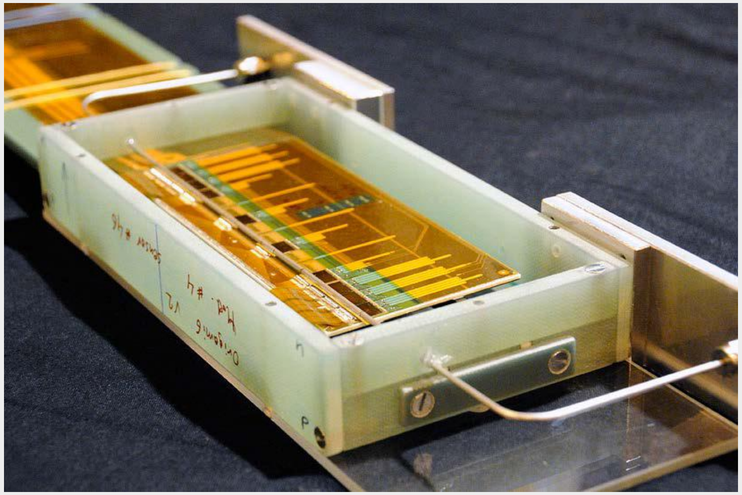


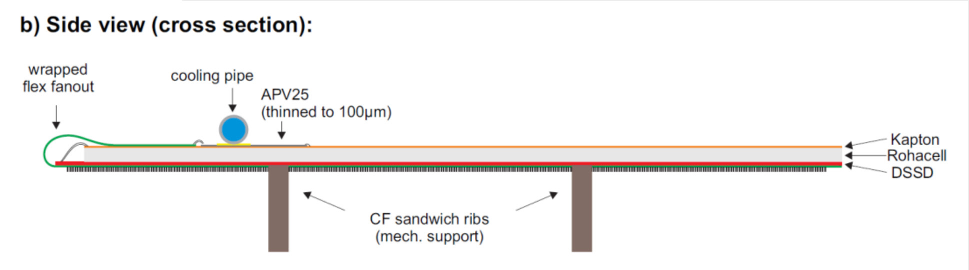


Readout ASIC chip on Sensor

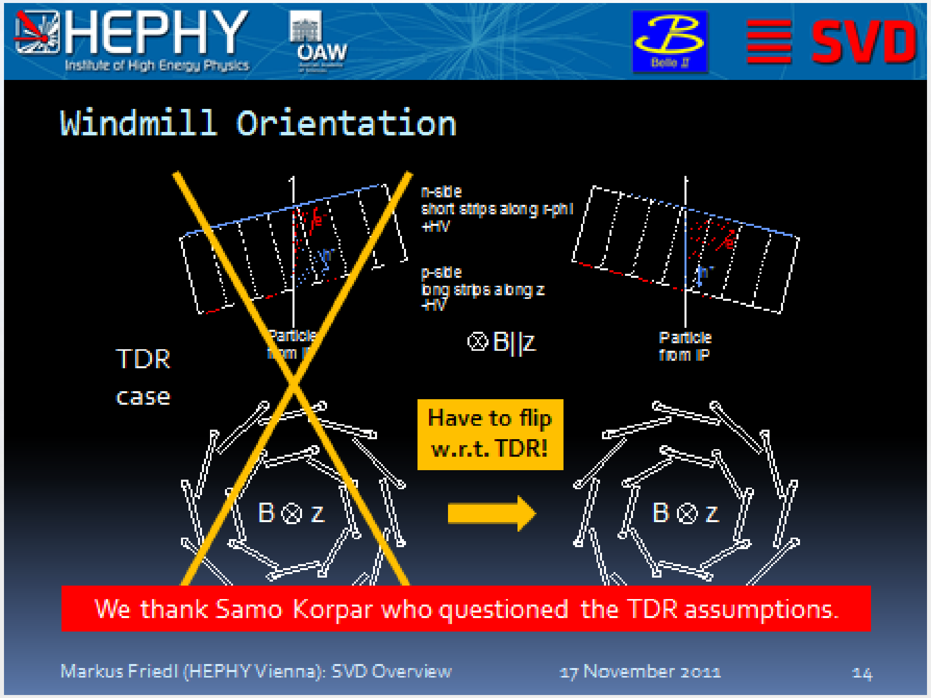
Fast shaping required (against high background)
APV25 (shaping time: 50ns, a bit too fast)
Capacitance too large to read out from the edge of half-ladder
→ chip on sensor
To reduce material in detector acceptance:
Thinning of APV25 (300μm→~100μm)
Chips on only one side to have single common cooling pipe



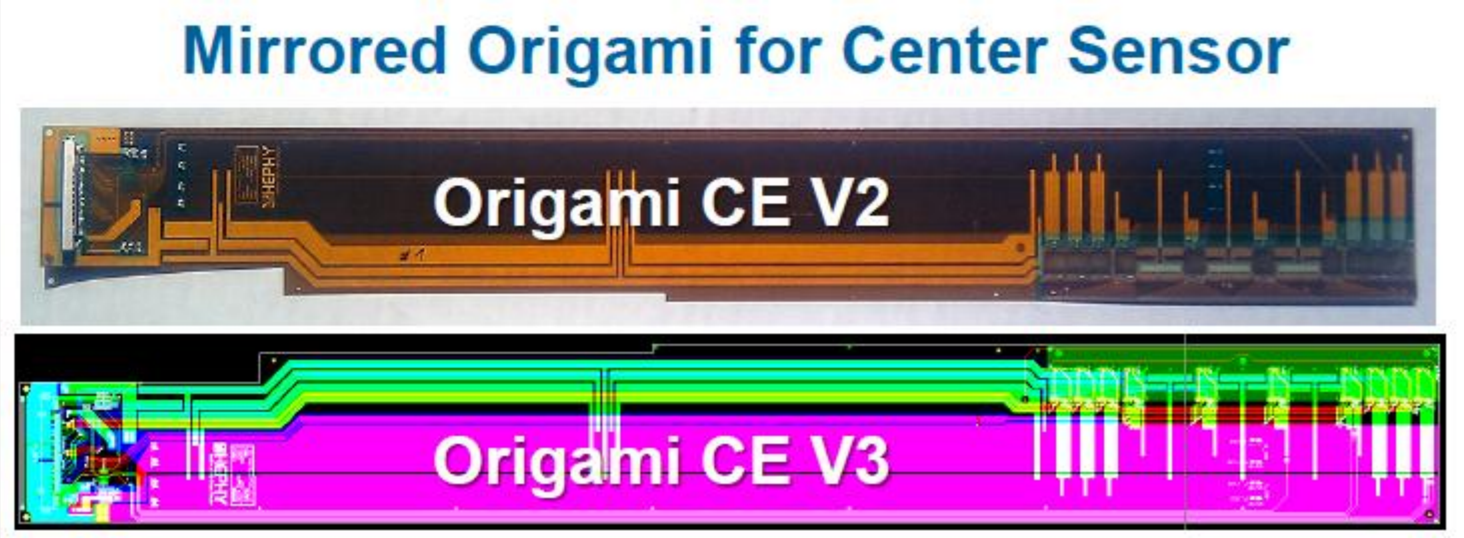




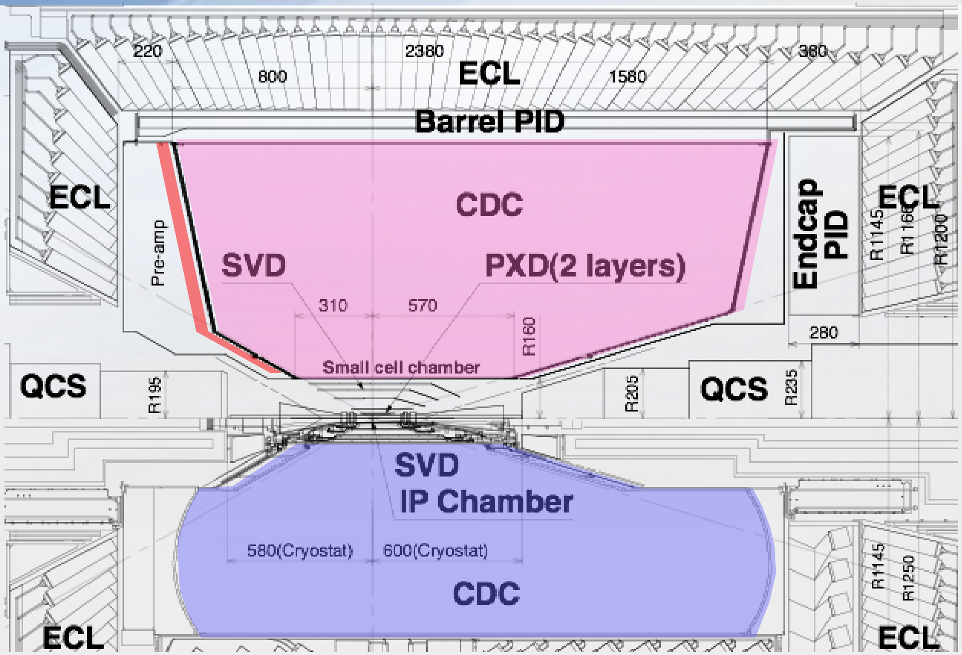
Errata



Windmill orientation is wrong in TDR
We mirror Origami
No technical difficulty in this change



Belle II CDC



	Belle	Belle II
inner most sense wire	r=88mm	r=168mm
outer most sense wire	r=863mm	r=1111.4mm
Number of layers	50	56
Total sense wires	8400	14336
Gas	He:C_2H_6	He:C_2H_6
sense wire	W(Φ30μm)	W(Φ30μm)
field wire	Al(Φ120μm)	Al(Φ120μm)

longer lever arm

improve resolution of momentum and dE/dx

$$\sigma_{P_t}/P_t = 0.19 P_t \oplus 0.30/\beta$$

$$\sigma_{P_t}/P_t = 0.11 P_t \oplus 0.30/\beta$$

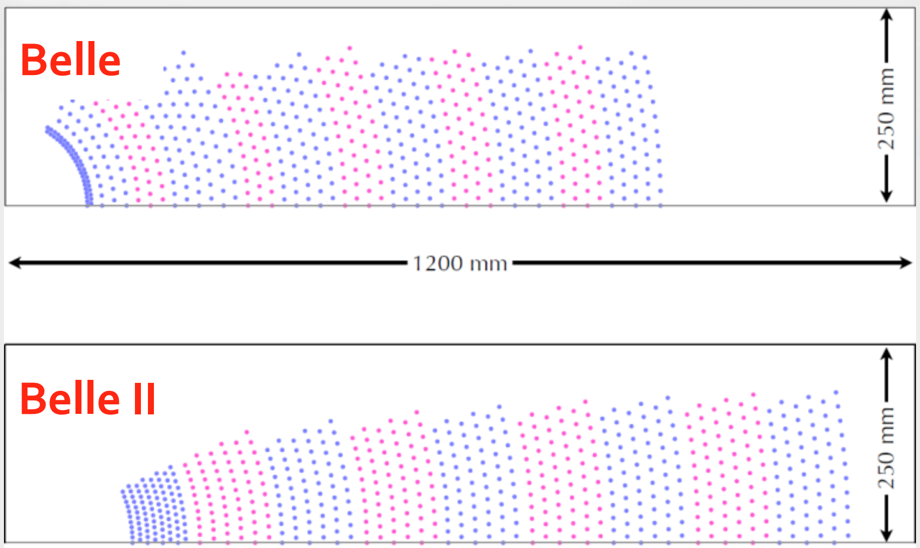
new readout system

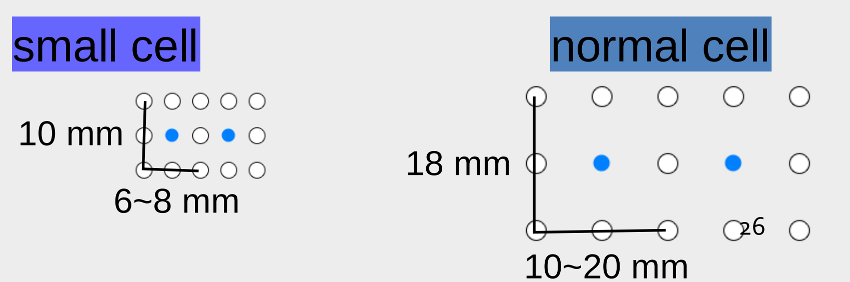
dead time 1-2μs → 200ns

small cell

smaller hit rate for each wire

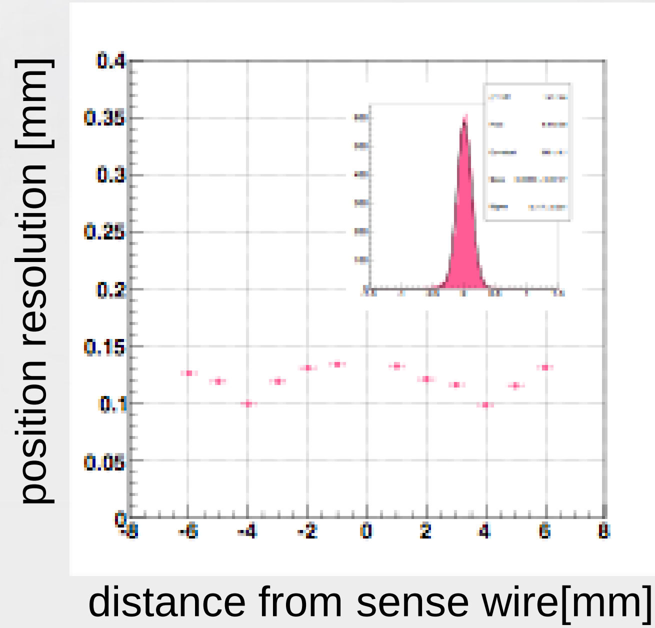
shorter maximum drift time





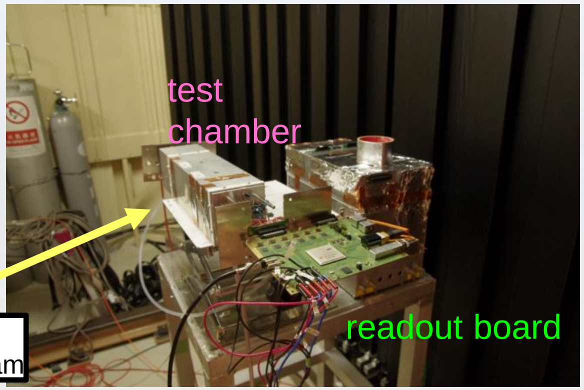
CDC readout electronics

typical position resolution
100−120um



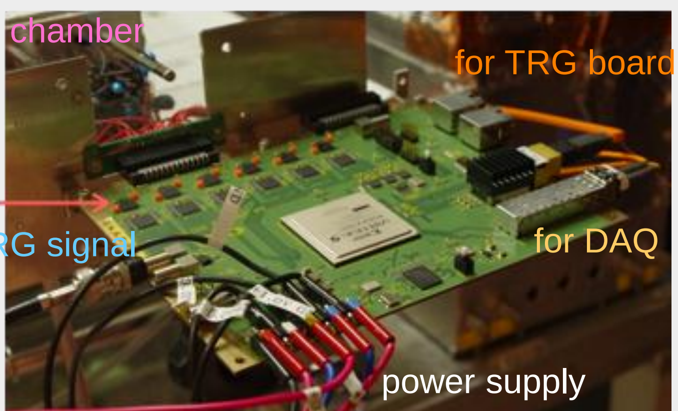
beam test @LEPS beam line in Spring-8

He:C_2H_6
(50:50) gas

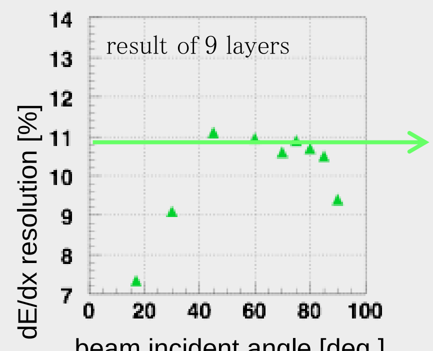


48ch/board
Size : 190mm x 150mm
Weight : 240g

CDC readout board Version 3



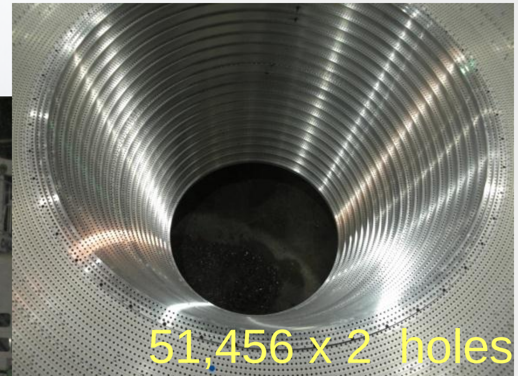
expected dE/dx resolution at Belle II CDC (56layers) ~ 5%

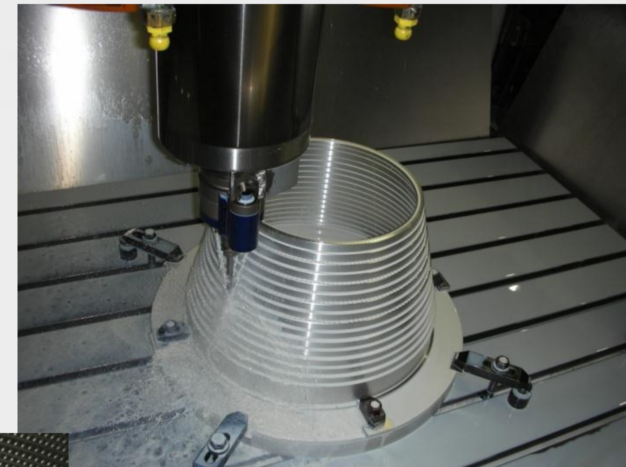


Mass production
ASD chip : going on
Board : 2013-2014

CDC structure

Feb. 3, 2012





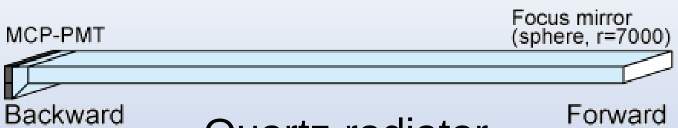
Small cell part being drilled

Main and conical endplates have been completed

Wire stringing ; Autumn, 2012 - Winter, 2013

Ring-imaging Cherenkov detectors

Barrel PID: Time of Propagation Counter (TOP)



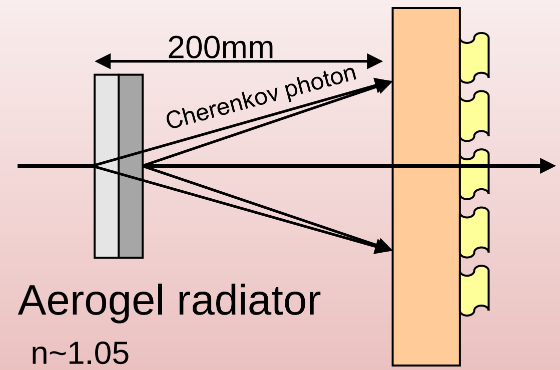
Quartz radiator

Focusing mirror

Small expansion block

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

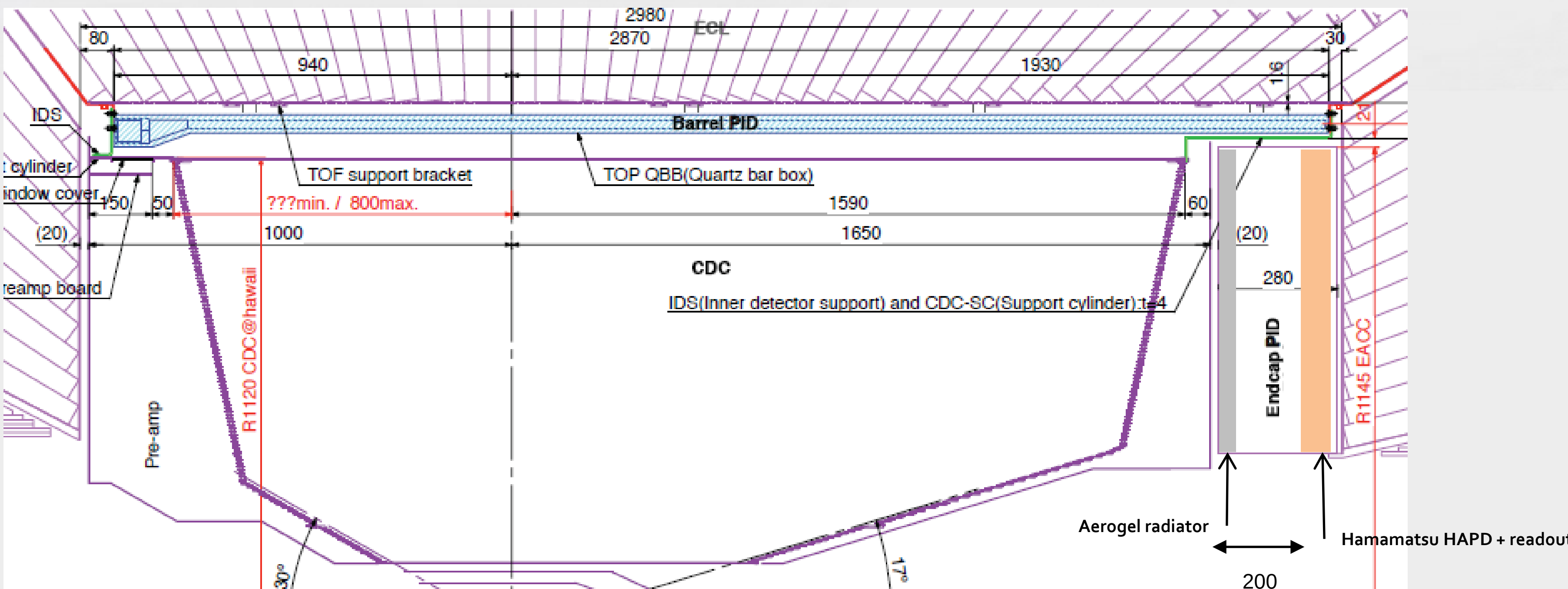
Endcap PID: Aerogel RICH (ARICH)



Aerogel radiator

n~1.05

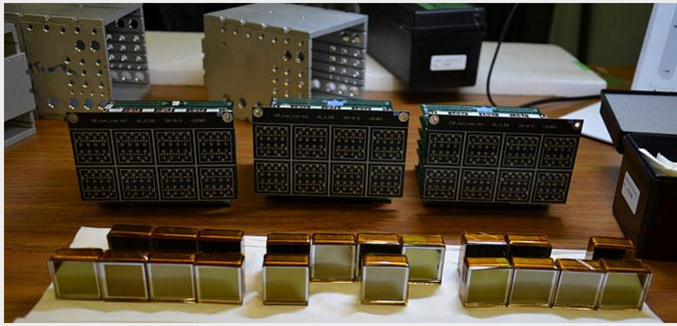
Hamamatsu HAPD
+ new ASIC

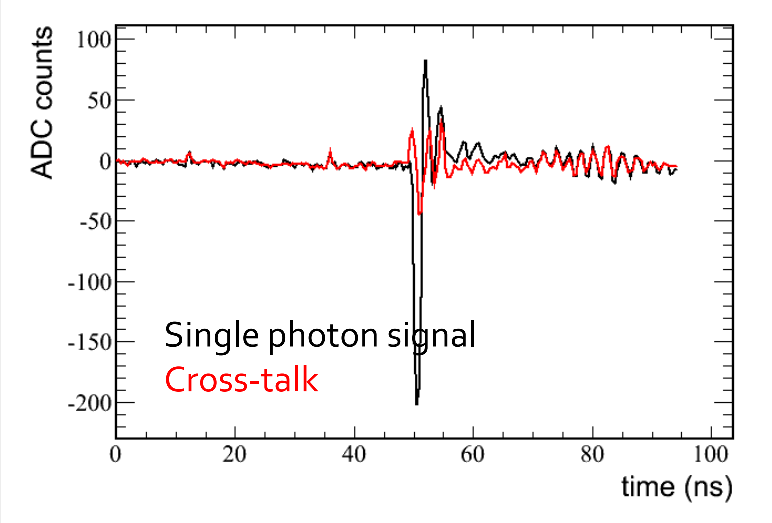


Target: 4σ π/K separation @ 4GeV

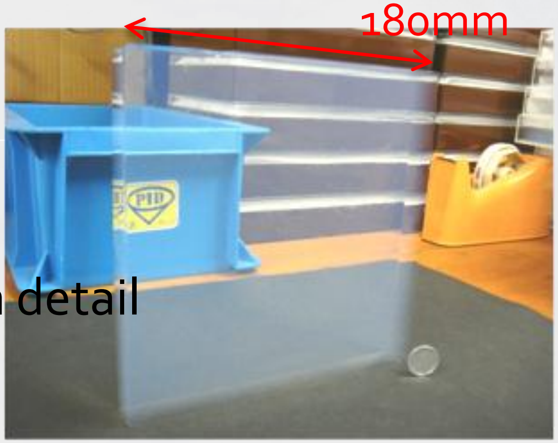
TOP status

- Quartz radiator
  - (Almost) full size quartz radiator is prepared.
    - Two quartz bars and mirror is glued successfully.
  - Support box is produced and tested.
- Readout block
  - New ASIC for high speed waveform readout is tested with MCP-PMTs and outputs single photon pulse.
- Beam test
  - Performed with 120GeV proton at FTBF in Dec.-Jan.
    - data analysis going on.



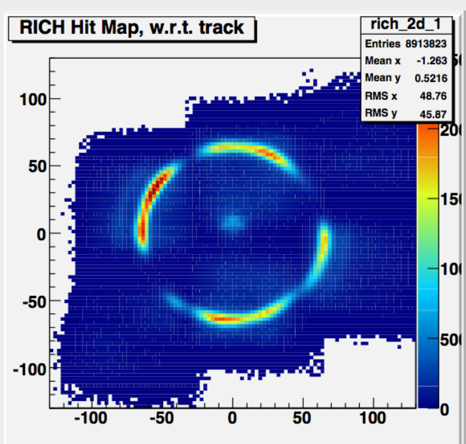


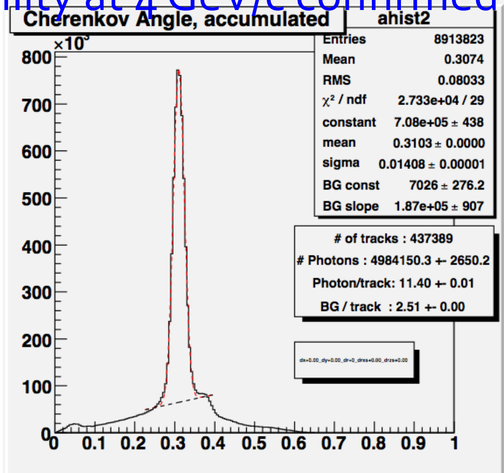
ARICH status

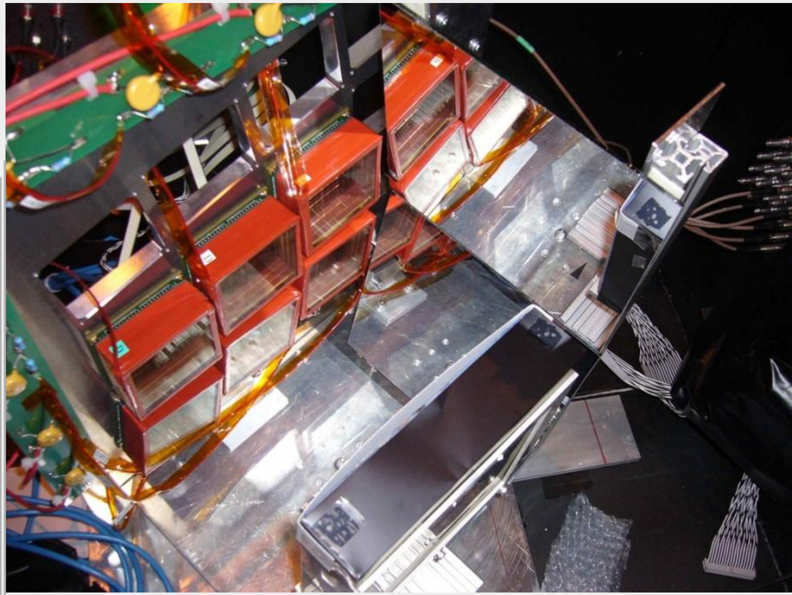


- HAPD
  - Ionization damage to APDs has been studied in detail
  - New ionization-tolerant APD is being tested
- Aerogel radiator
  - Aerogel tile with real size was fabricated
  - Further studies are going on
- Test beam experiment carried out on at CERN September 2011
  - Final geometry of HAPD arrays
  - Mirror introduced

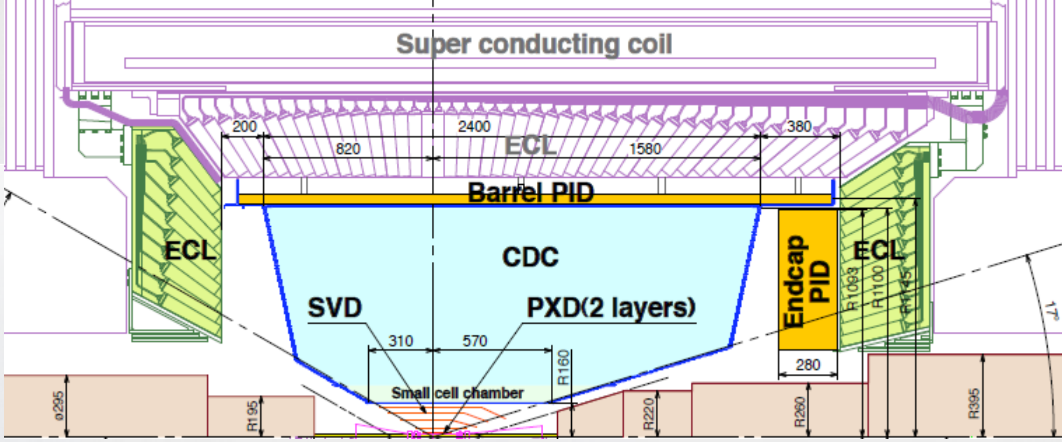
5.5 σ K & π separation capability at 4 GeV/c confirmed







ECL upgrade

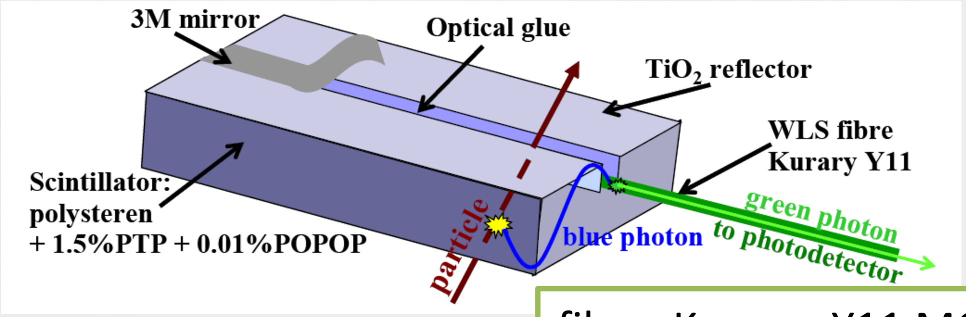


- Electronics upgrade for CsI(Tl)
  - 12 final prototype will be in hand (March 2012)
  - ~100/~600 boards in JFY2012
- Pure CsI for endcaps*
  - Test production going on
  - Photodetector to be determined
    - Photo-pentrode
    - APD

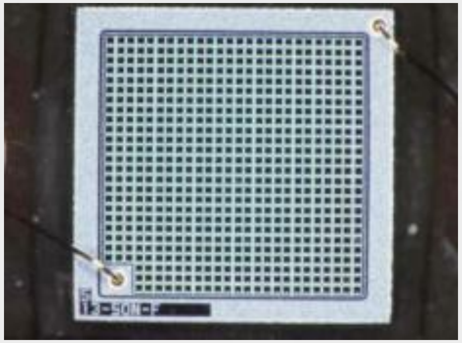
*if funding allows

KLM

RPC → Scintillator bar + MPPC for endcap
and innermost n layers in barrel



fiber: Kuraray Y11 MC



MPPC: Hamamatsu
1.3×1.3 mm 667 pixels
(used in T2K ND)

Neutron rates on BKLM

Simulation

LER Touschek only

Layer	Neutron flux (Hz/cm^2)	Hit rate (Hz/cm^2)	Efficiency
0	2407	17.3	0.13
1	1762	12.7	0.36
2	1221	8.8	0.55
3	785	5.6	0.71
4	504	3.6	0.81
5	293	2.1	0.89

Hit rate (Hz/cm^2)	Efficiency
—	1.00
—	1.00
2.3	0.88
1.4	0.92
1.0	0.94
0.6	0.96

Extrapolation

		ext.	replace L00	replace L00/01	twice rate
L00	rate(Hz/cm^2)	7.5	7.5	7.5	15
	eff.	0.38	1	1	1
L01	rate(Hz/cm^2)	4	2.7	2.7	5.4
	eff.	0.67	0.78	1	1
L02	rate(Hz/cm^2)	2	1.3	0.9	1.8
	eff.	0.83	0.89	0.93	0.85

replaced by scintillator

Estimated neutron rates on BKLM roughly matches to the extrapolation from KEKB data; still acceptable after replacing 2 inner layers. Neutrons from radiative Bhabha to be checked.

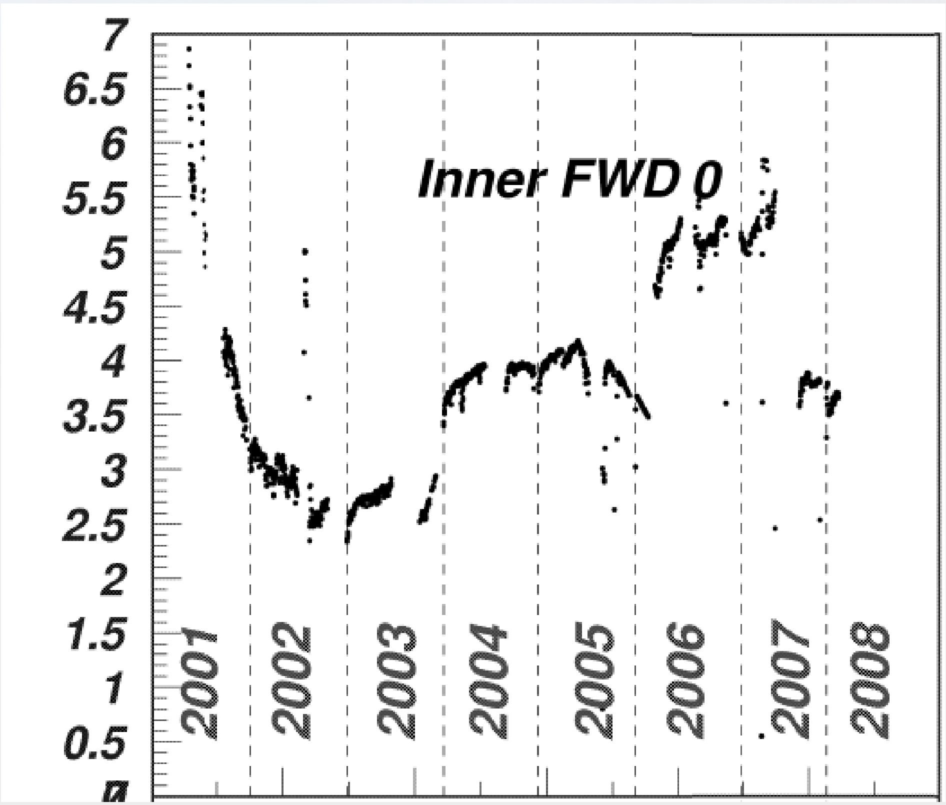
Summary

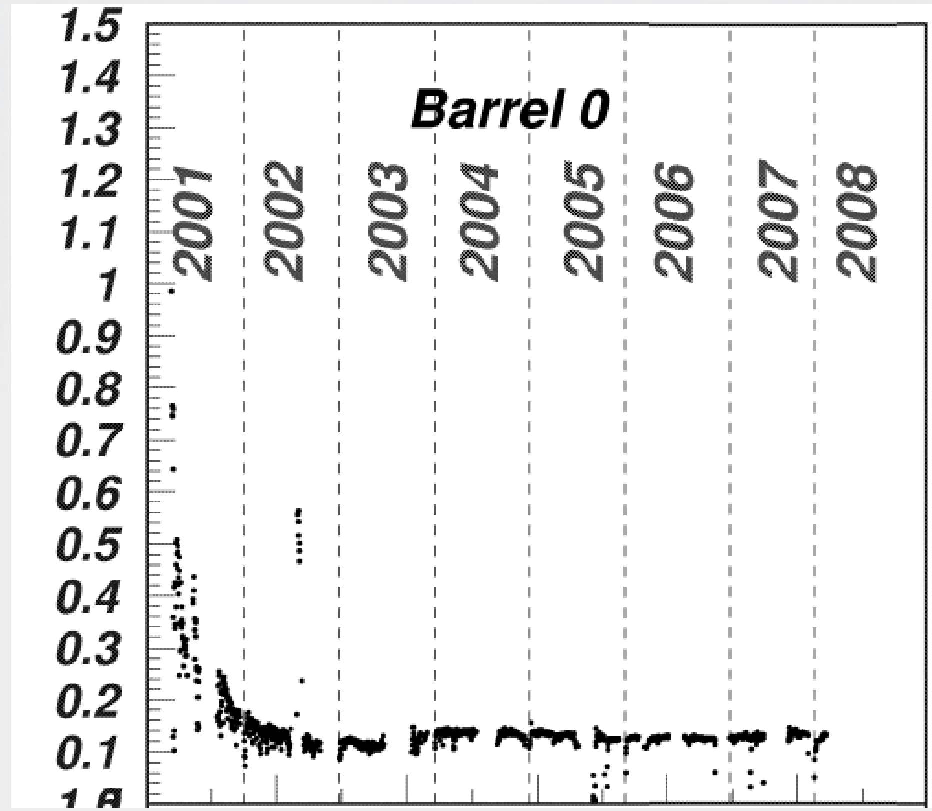
- Belle 1 disassembly has been completed (except KLM)
- Belle II full-fledged physics run starts in 2015 (target)
- Detector design was started assuming 20 times more background (the best knowledge at that time based on extrapolation)
  - 10^{12}n/cm2/10 years@endcap
  - 100-1000Gy/10 years @endcap
- Background simulation studies post-validate the extrapolations
- Detector development/production extensively going on

Backup

Dark current increase

ΔI_{bias} / (Integrated beam current)



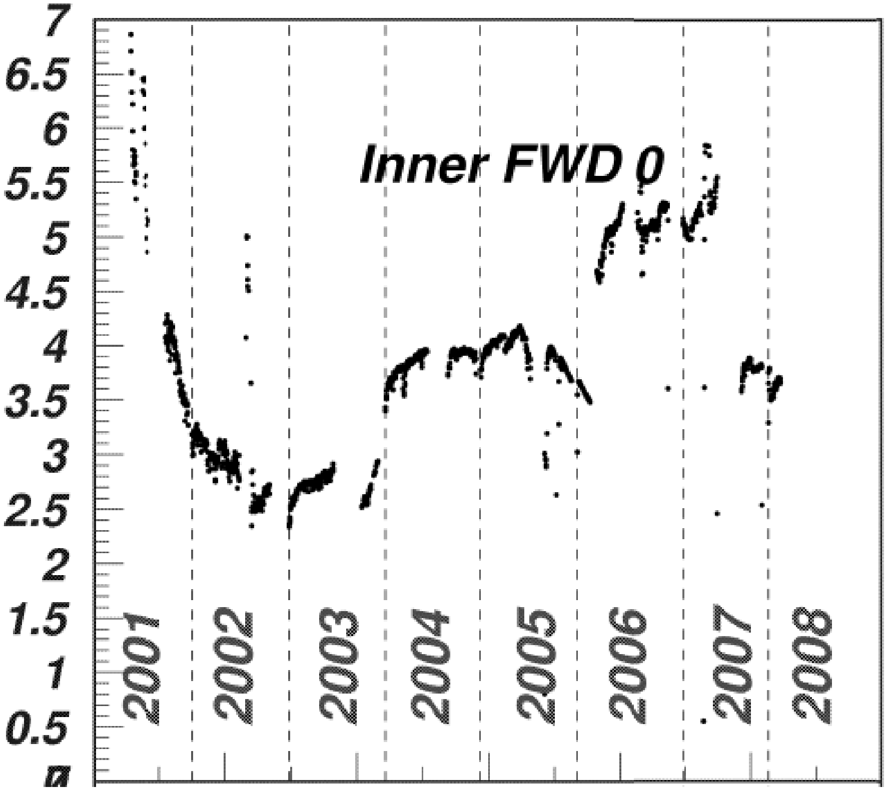


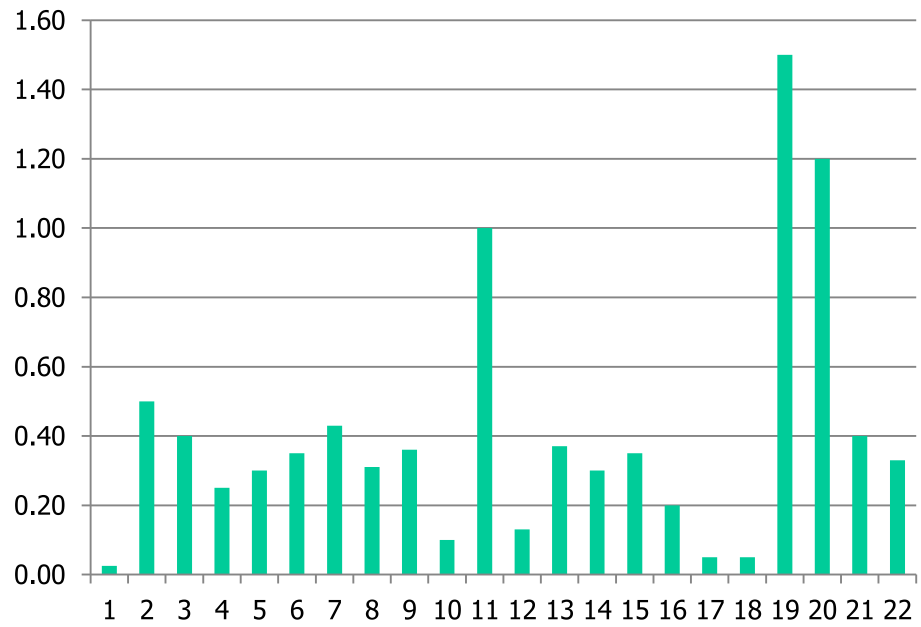
Inner forward region

Typical barrel region

Bias current increase

Inner forward region



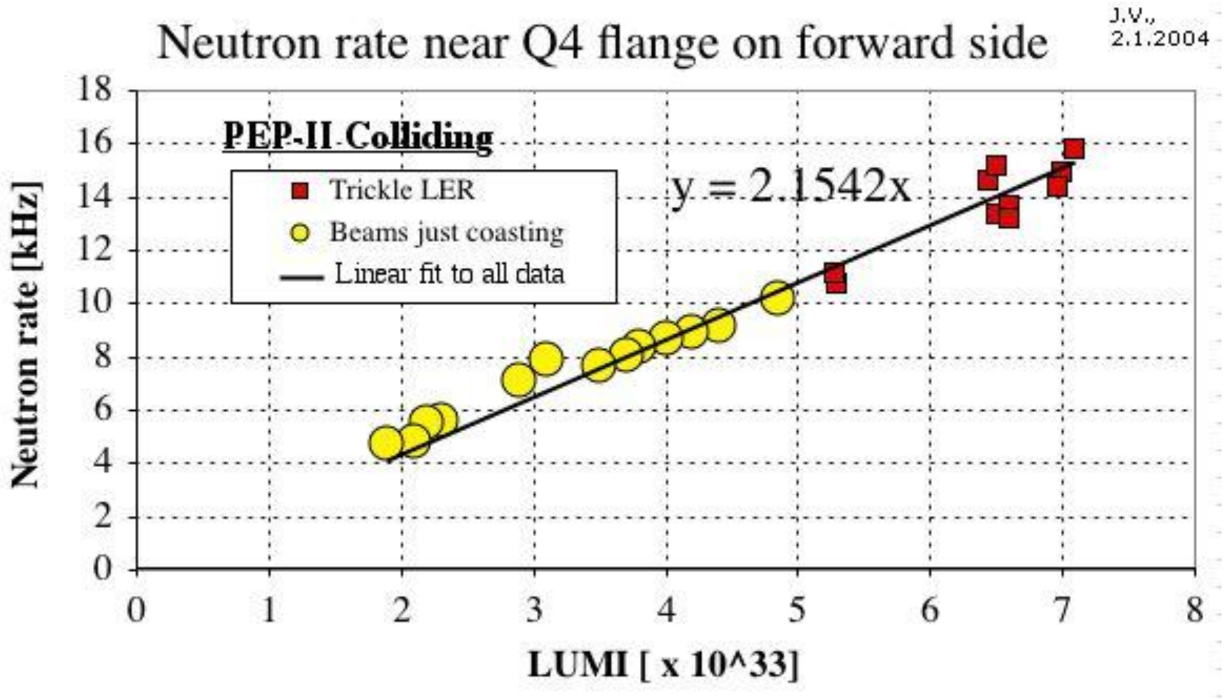


ΔI_{bias} normalized to integrated beam current

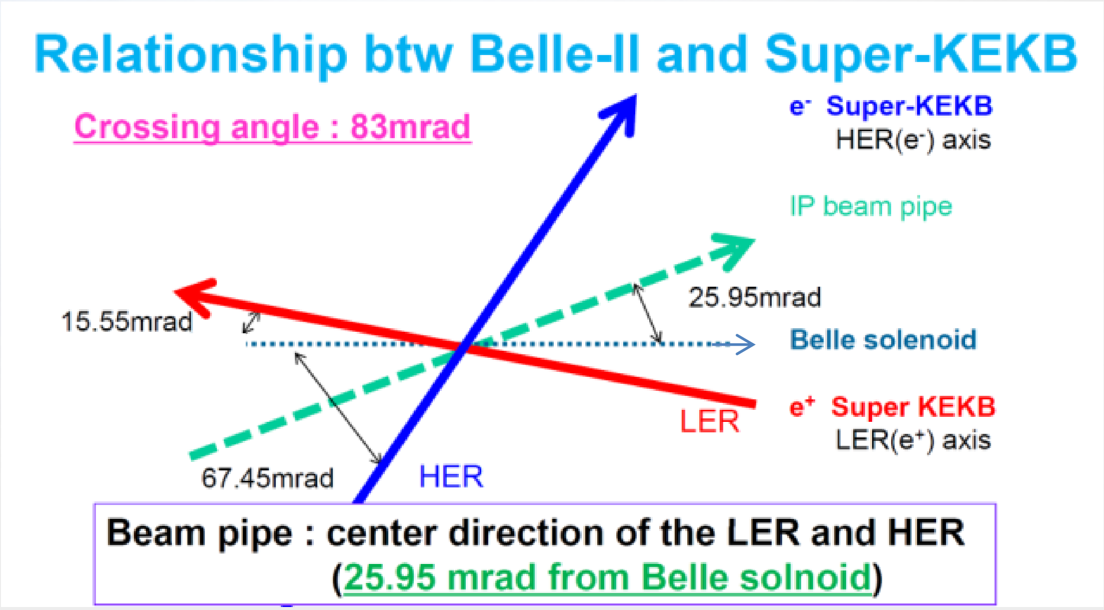
ΔI_{bias} normalized to integrated luminosity for different run periods

Neutron fluence – how to extrapolate?

Belle: looks more like with currents
BaBar: with lumi
Super B factory: somewhere in between? Where? What are the coeffcients?



Detector Rotation



Contacting with several companies (general contractors/shipbuilding industry/...)
Quotation(s) by March 2012
April 2012 – February 2013 for rotation (but will only need a few months)

Machine people will state that they give up finding smart optics which works out without Belle rotation by the time we contract (late spring in 2012).

TRG Status and Schedule

Date	2011				2012				2013				2014				2015				Status
	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	3	6	9	12	
CDC TRG Hardwares																					
UT3	Prototype γ (3)				Production (25)																OK
TRG Data Merger Proto-type				Prototype (3)				Production (40)													OK
Partial System Test		FE - Mgr - TSF - Trker																			OK
Installation & Commissioning																					
Operation																					
ECL TRG Hardwares																					
SH-DSP			Proto.3			Production (576)															OK
FAM				Proto.3			Production (52)														OK
TMM					Proto.3		Production (5)														OK
ETM					Proto.3		Production (51)														OK
Installation & Commissioning																					
Operation																					
TOP TRG Hardwares																					
TRG_FIN	Proto. 3									Production (12)											OK
KLM TRG																					
Design																					Delayed
Production																					
Installation & Commissioning																					
Operation																					
GDL																					
Partial System Test																					
Installation & Commissioning																					
Operation																					

UT3-β shown in Feb. 2010
24 RocketIO (GTX, 6.25Gbps)
FPGA: Xilinx XC6VLX240T

UT3-γ w/o front panel
3 boards 1 set:
- main board (center): 24 RocketIO (GTH, 11Gbps) ch
- 40ch RocketIO extension board (right)
- Universal I/O board (left): NIM, Belle2link, LVDS I/O

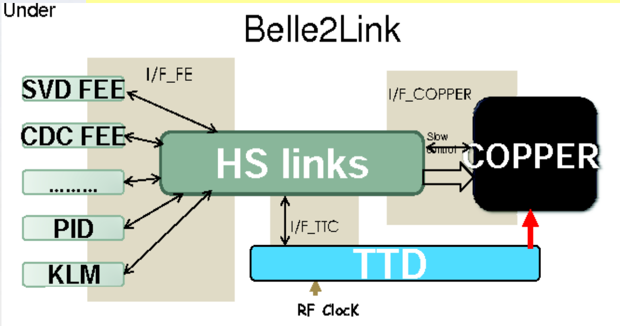
FPGA: Xilinx XC6VHX380T or 565T

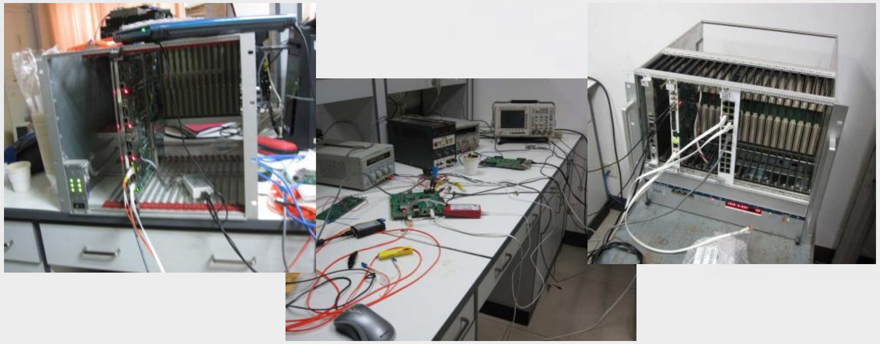
DAQ status

1) DAQ↔Detector FEE I/F

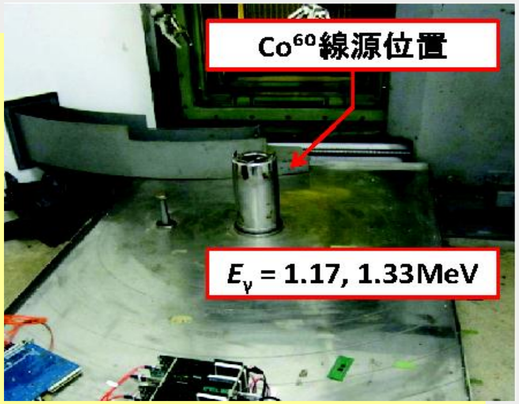
* Trigger timing distribution logic + Belle2link

- Prototype production and test were completed
- “System tests” with each detector FEE is going on (CDC, ECL, SVD, A-RICH, TOP, KLM, …)





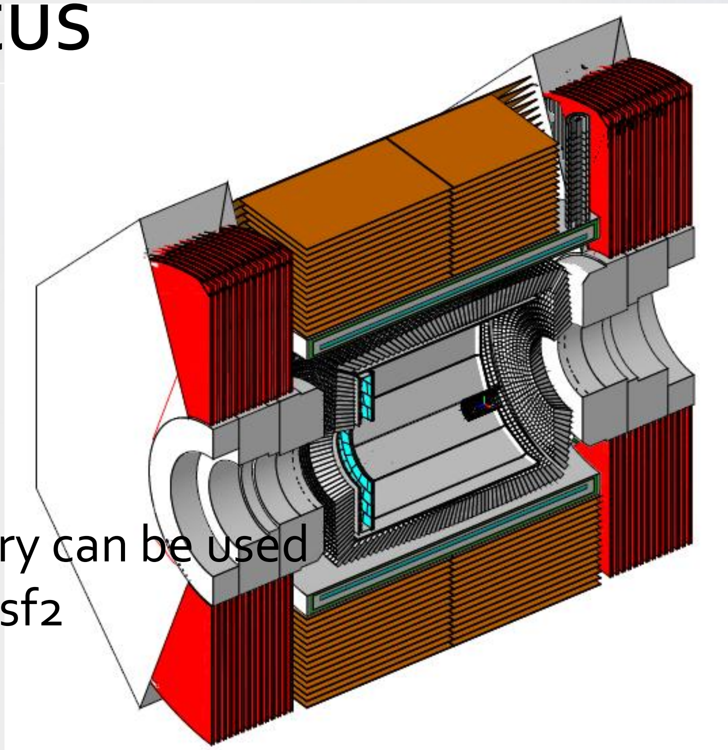
2) Radiation test of FEE I/F in neutron and γ-ray sources

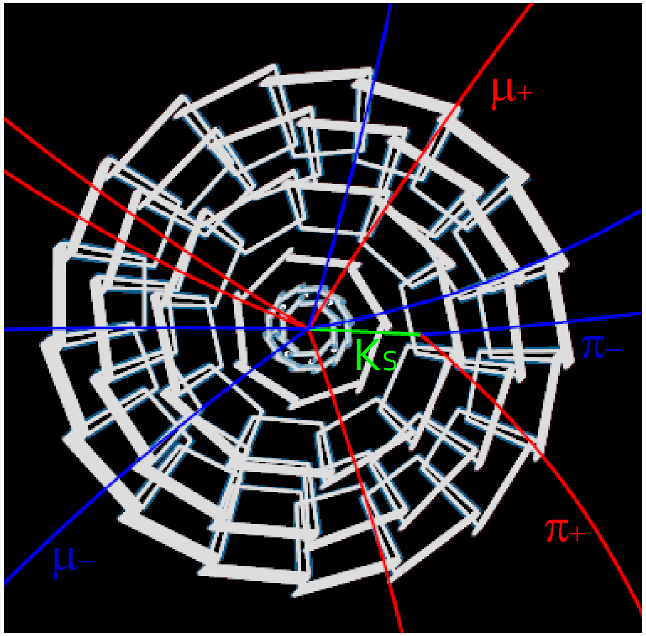


* No fatal damage was observed in the neutron irradiation so far.
* Damage was observed in the optical transceiver with a γ-ray irradiation of ~300 Gy (eqiv. ~3 year Belle II operation)
  → looking for better product.
* FPGA (Virtex5) survived with an 8kGy irr. → OK
* Voltage regulator : tolerance was largely different among products. but should be OK.

Software development status

- Geometry: TGeo → G4
  - TGeo does not support
    volume properties (e.g. opitcal surface)
    geometrical shapes fully available in G4
  - start converting all related packages
- Framework:
  - basf2 was updated so that the new geometry can be used
  - parallel process is being tested with new basf2





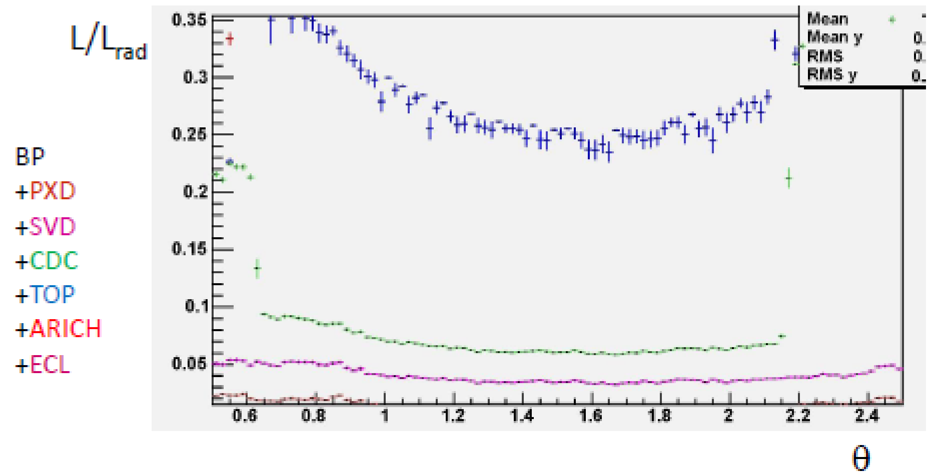
- Simulation: all detector geometry were rewritten.
- Generators
  - EvtGen is being implemented in new basf2
- Track finding/fitting: updating for new basf2
  - Conformal, Hough, Cell-automaton, etc.
- Vertexing : RAVE could be used
- Belle legacy tools should be migrated to basf2
- still so many things : event display, digitization,
  clustering, particle ID, data model, ...

Material amount

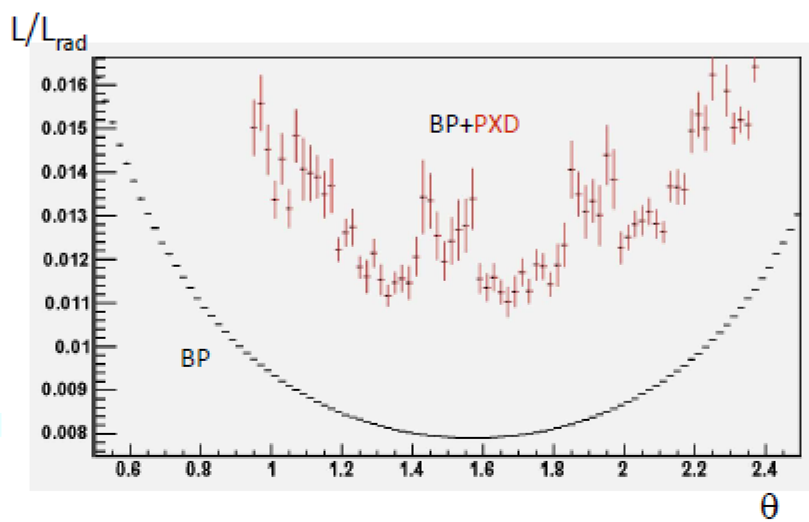
in term of radiation lengths

neutral particle
("geantino")

Belle II Geant4 simulation,
version October 27th 2011



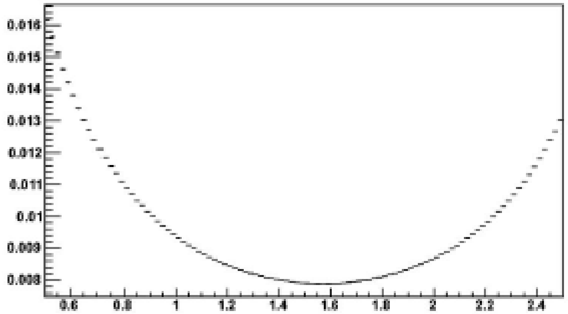
"track->GetMaterial()->GetRadlen();"
returns radiation length of the material;

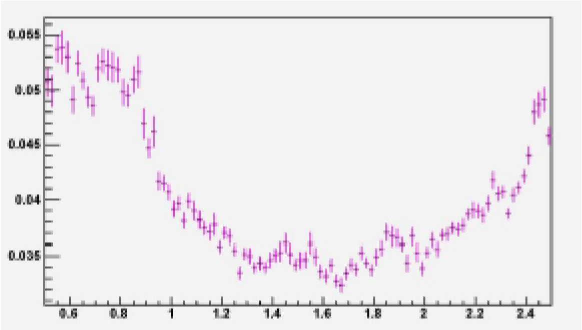


examples:

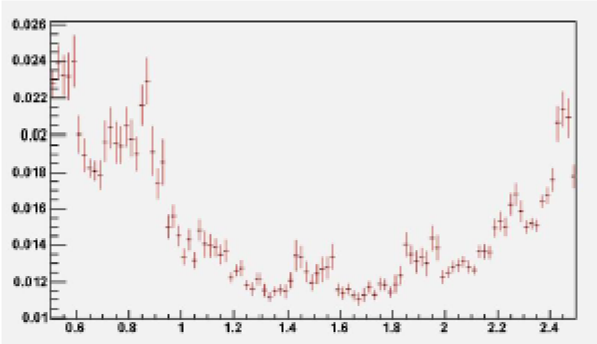
material	X_0 (*) (g/cm^2)	Geant4 (g/cm^2)
Au	6.46	6.452
Si	21.82	21.82

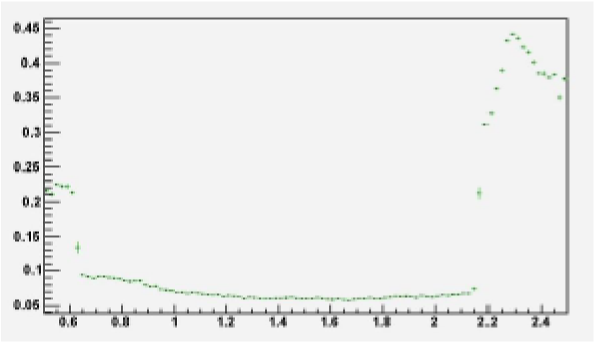
(*) http://cdsweb.cern.ch/record/1279627/files/PH-EP-Tech-Note-2010-013.pdf

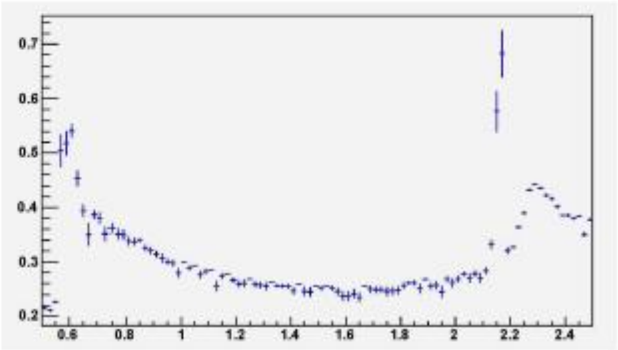


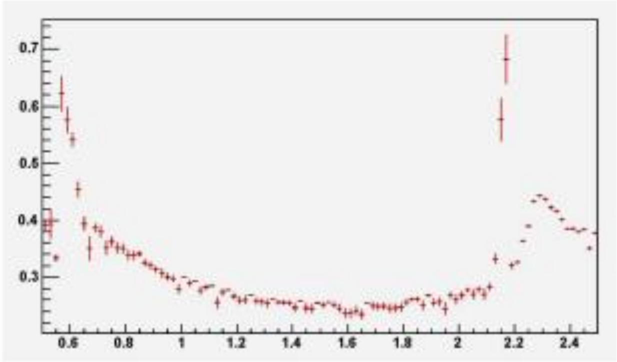


BP
+PXD
+SVD
+CDC
+TOP
+ARICH
+ECL









BP
+PXD
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