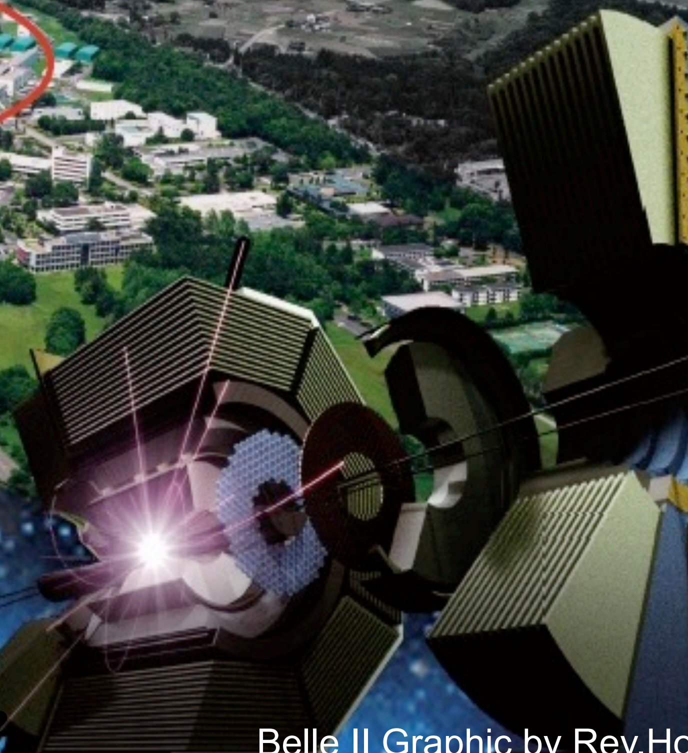
Status and Prospects of Super KEKB and Belle II

Zdenek Dolezal
Charles University in Prague
for Belle II



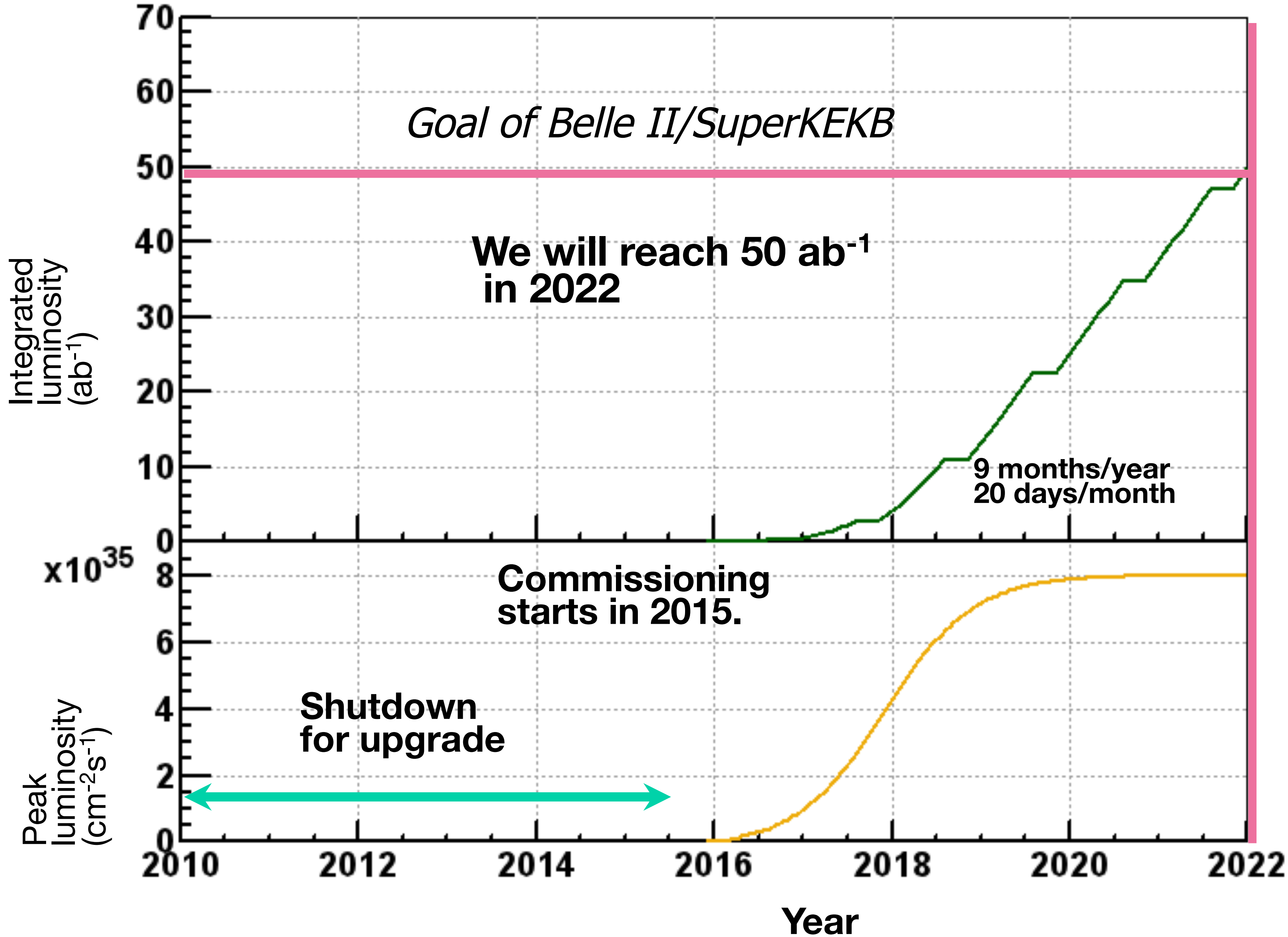
KEK
High Energy Accelerator Reseach Organization

Belle II Graphic by Rey.Ho

Contents

- Accellerator Progress
- Detector
- Computing
- Background
- Status and prospects of the project

Schedule (Beam starts in Fall 2014)



Super KEKB in nano-beam scheme

- To increase luminosity:

→ squeeze beams to nanometer scale and enlarge crossing angle (minimize β_y^*)

→ decrease beam emittance (keep current ξ_y)

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

I: beam current
β^*: trajectories envelope at IP
$\xi_y \propto \sqrt{(\beta_y^*/\varepsilon_y)}$ beam-beam parameter
ε: beam emittance
σ^*: beam size
$R_L, R_{\xi y}$: geometrical reduction factors (crossing angle, hourglass effect)

- Squeezing beams in stronger magnetic field saturated by hourglass effect → intersect bunches only at highly focused region

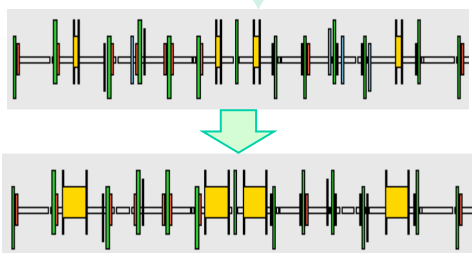
σ_x~100μm, σ_y~2μm ➡ **σ_x~10μm, σ_y~60nm**

Nano beam scheme: invented by Pantaleo Raimondi for the SuperB project.

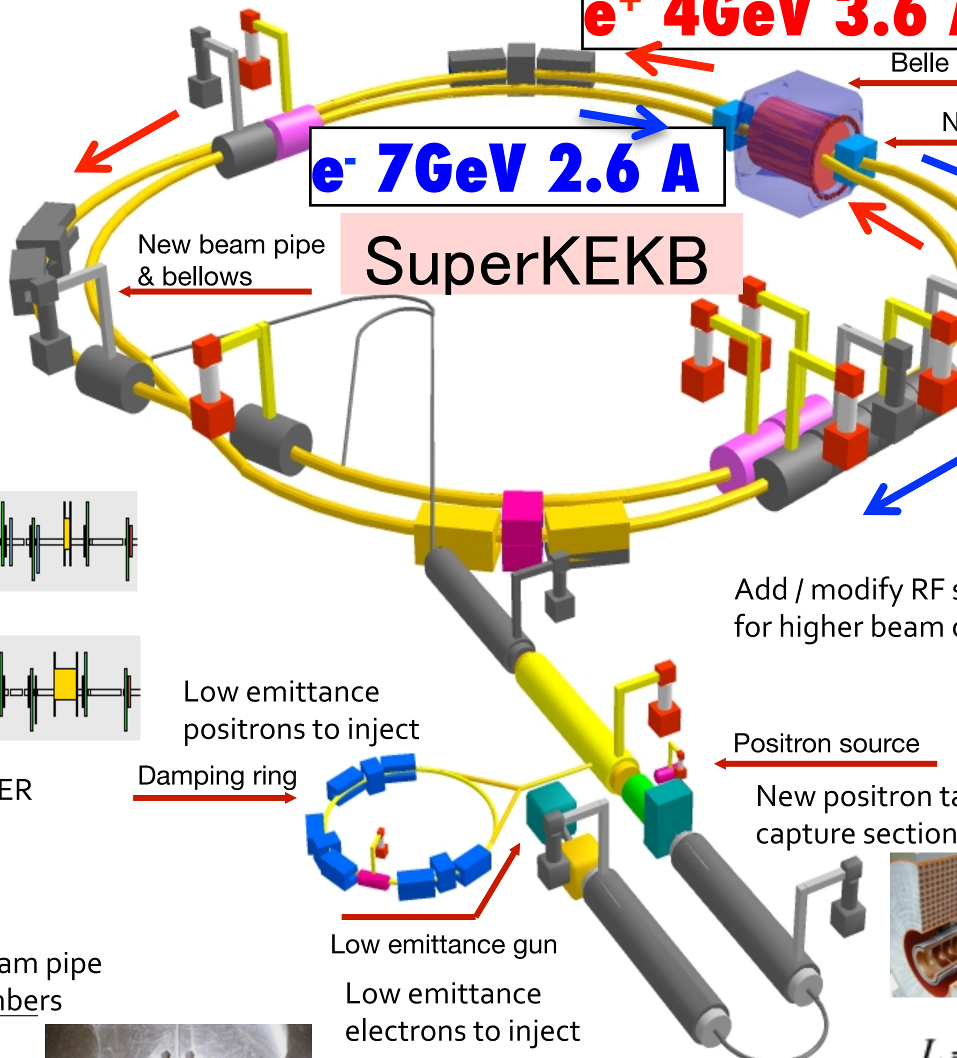
	E (GeV) LER/HER	β*$_y$ (mm) LER/HER	β*$_x$ (cm) LER/HER	ε$_x$ (nm) LER/HER	φ (mrad)	I (A) LER/HER	L (cm^{-2}s^{-1})
KEKB	3.5/8.0	5.9/5.9	120/120	18/24	11	1.6/1.2	2.1 x 10^{34}
SuperKEKB	4.0/7.0	0.27/0.41	3.2/2.4	3.1/2.4	41.5	3.6/2.6	80x10^{34}

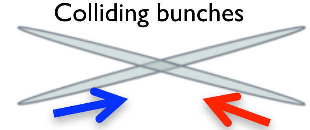
Super KEKB collider

Replace short dipoles with longer ones (LER)

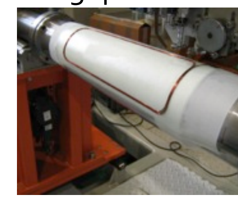


Redesign the lattices of HER & LER to squeeze the emittance



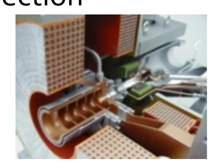


New superconducting / permanent final focusing quads near the IP

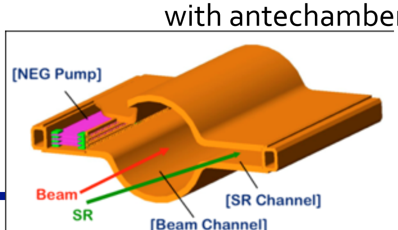


Add / modify RF systems for higher beam current

New positron target / capture section



TiN-coated beam pipe with antechambers

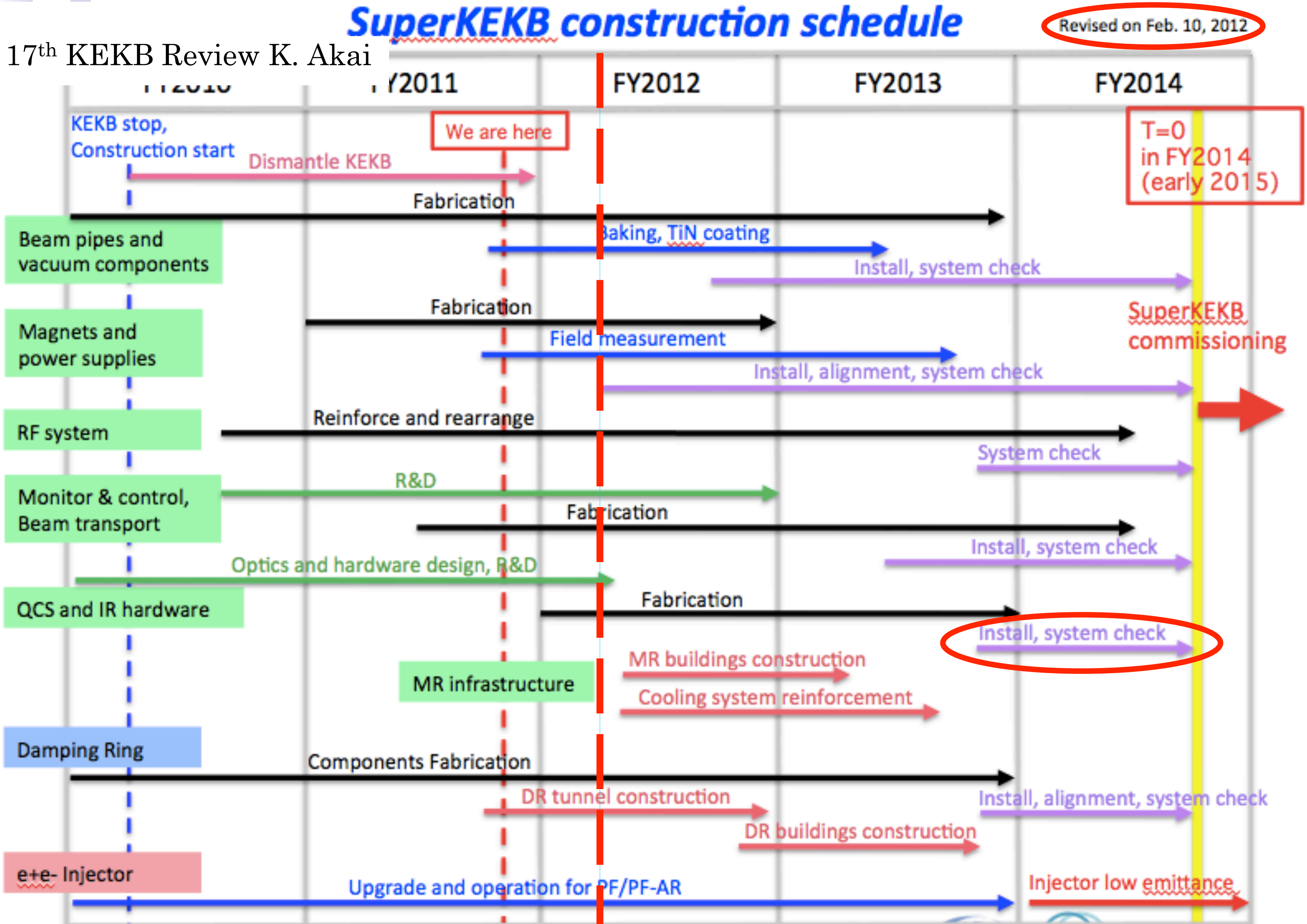


$$L = \frac{\gamma_{\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\frac{I_{\pm}\xi_{\pm y}}{\beta_y^*}\left(\frac{R_L}{R_y}\right)$$

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

17th KEKB Review K. Akai

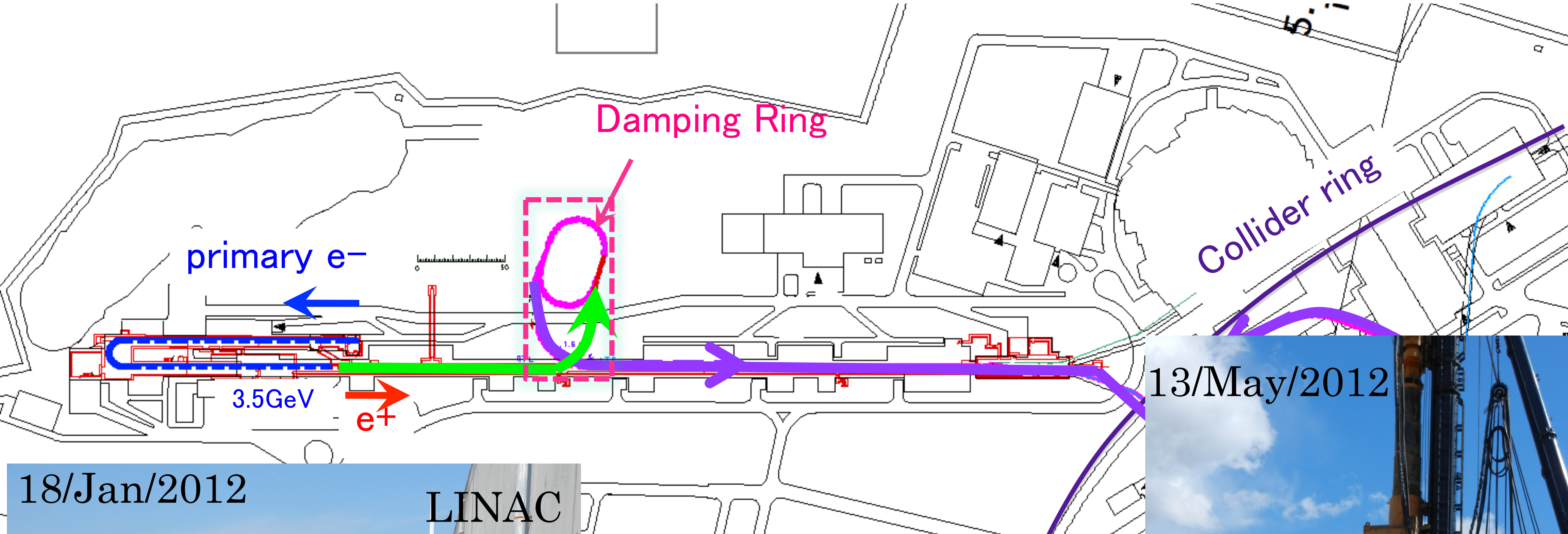
SuperKEKB construction schedule



The latest schedule about IR will be presented by the next Ohuchi-san's talk.

1st installation of the SuperKEKB magnet
Feb.7th 2012

Construction of Damping ring started !

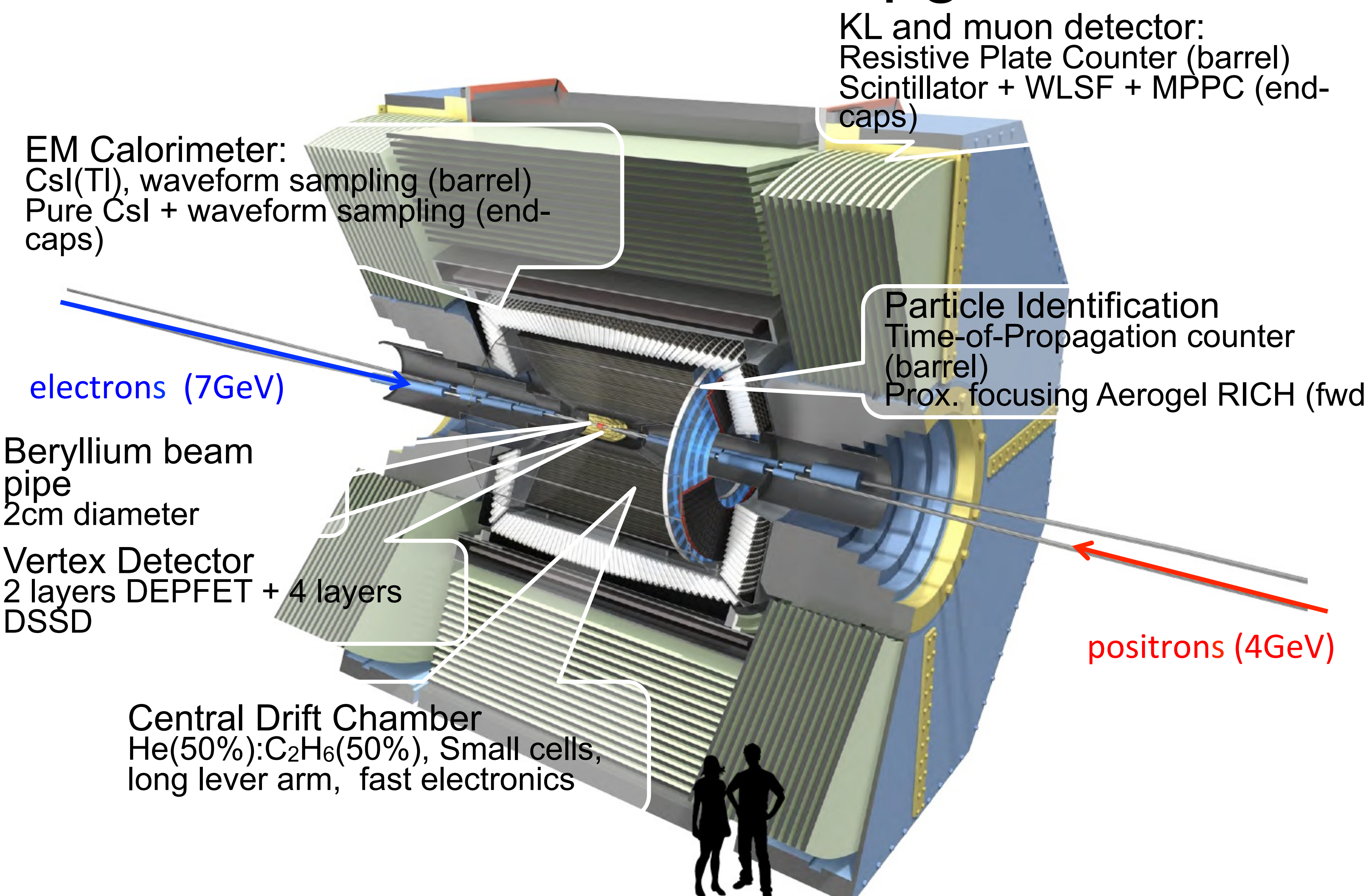


Accelerator status summary (K.Akai)

- The earthquake caused some delay and additional works for SuperKEKB construction, but we manage to recover to be in time for T=0.
- Design work and construction work are going on at the same time in consistent ways. But time limit for some critical designs will come soon.
- So far, budget is supplied as planned, except for the delay due to the earthquake.
- Shortage of human resources is getting better.
- Construction is well ongoing, prioritizing for T=0.

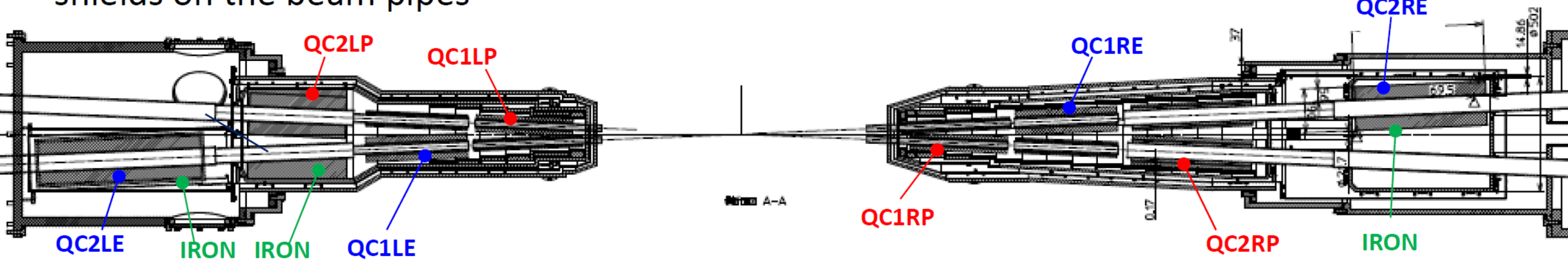
LER beam pipe production at BINP

Belle to Belle II Upgrade



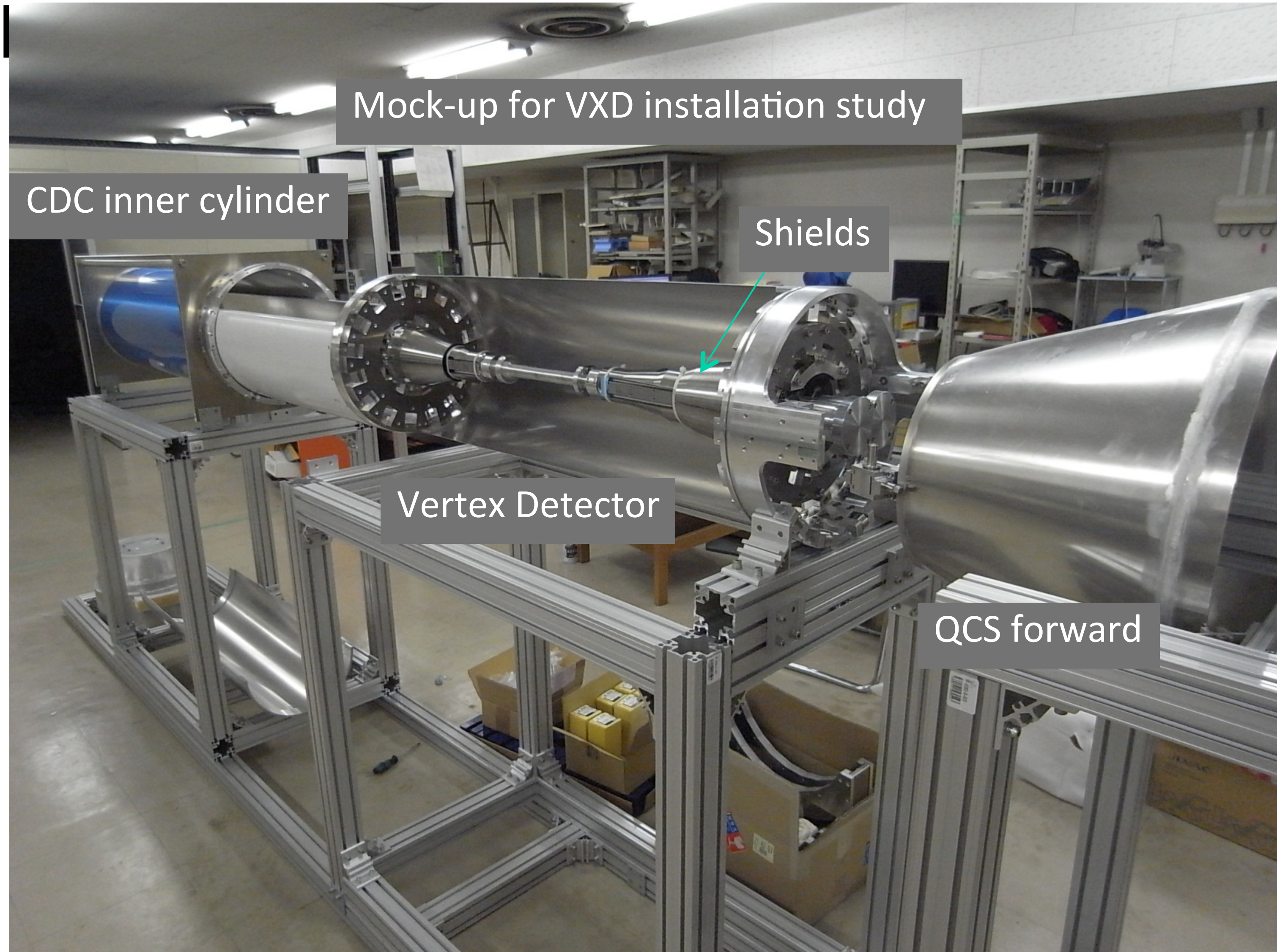
S.C. Magnets in SuperKEKB IR

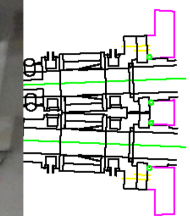
Design changes in the magnets: introducing iron yokes to the quadrupoles and magnetic shields on the beam pipes



	Integral field gradient, (T/m)·m Solenoid field, T	Position from IP, mm	Magnet type	Corrector	Leak field cancel coil
QC2RE	12.91 [34.9 T/m × 0.370m]	2925	S.C. + Iron Yoke	a_1, b_1, a_2, b_4	
QC2RP	10.92 [27.17 × 0.4135]	1925	S.C. + Iron Yoke	a_1, b_1, a_2, b_4	~~b_3, b_4, b_5, b_6~~
QC1RE	24.99 [66.22×0.3774]	1410	S.C. + Iron Yoke	a_1, b_1, a_2, b_4	~~b_3, b_4, b_5, b_6~~
QC1RP	22.43 [66.52×0.3372]	935	S.C.	a_1, b_1, a_2, b_4	b_3, b_4, b_5, b_6
QC1LP	22.91 [67.94×0.3372]	-935	S.C.	a_1, b_1, a_2, b_4	b_3, b_4, b_5, b_6
QC1LE	26.67 [70.68×0.3774]	-1410	S.C. + Iron Yoke	a_1, b_1, a_2, b_4	~~b_3, b_4, b_5, b_6~~
QC2LP	10.96 [27.15 × 0.4135]	-1925	S.C. + Iron Yoke	a_1, b_1, a_2, b_4	
QC2LE	14.13 [20.2×0.700]	-2700	S.C. + Iron Yoke	a_1, b_1, a_2, b_4	
ESR	4.3 T (max. field)		S.C. Solenoid		
ESR-add	0.3 T	Each beam	S.C. Solenoid + Iron Yoke		
ESL	4.7 T (max. field)		S.C. Solenoid		

IP Chamber



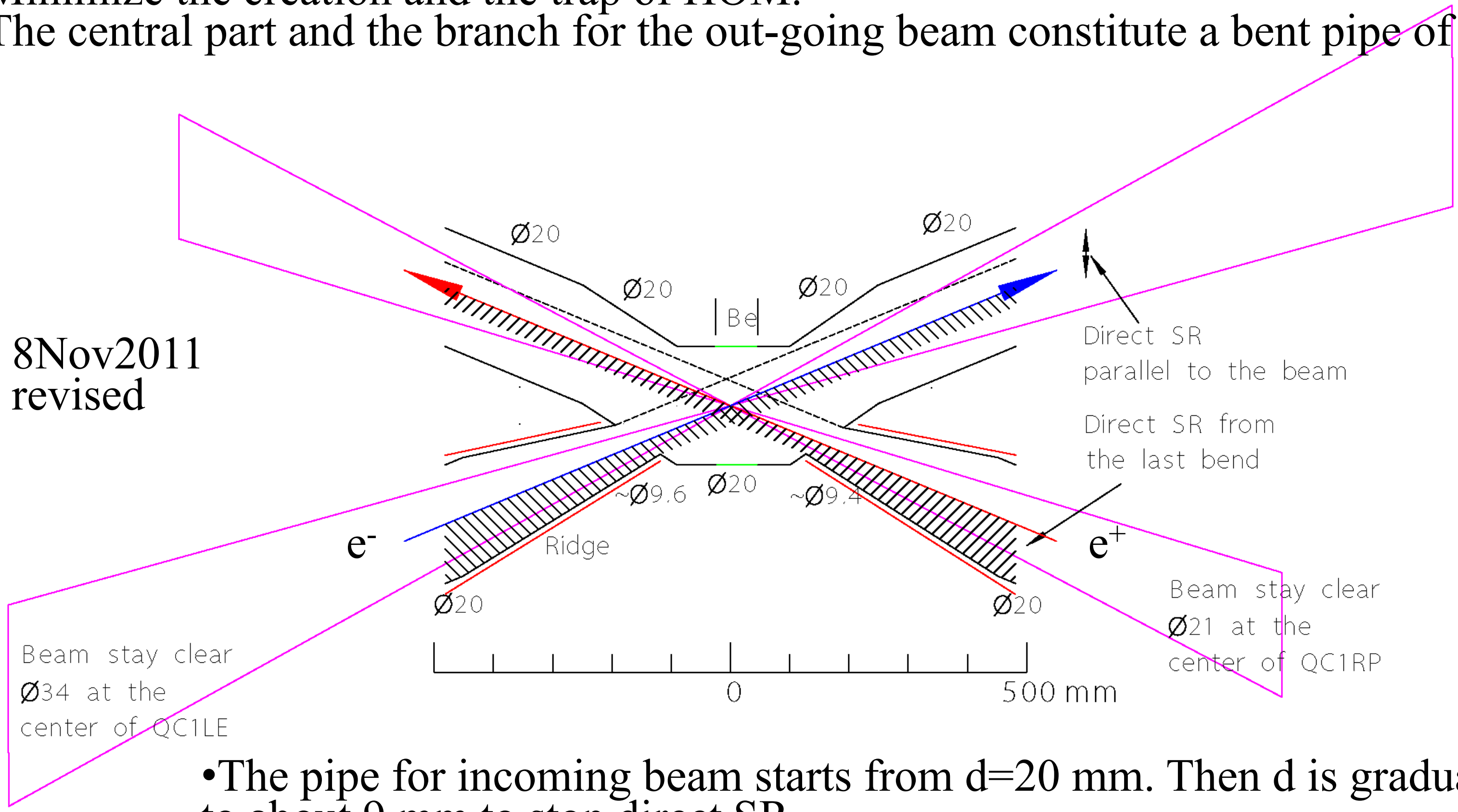


to by Satoh)

IP Chamber Design Features

- Minimize the creation and the trap of HOM.
- The central part and the branch for the out-going beam constitute a bent pipe of d=20mm.

8Nov2011
revised

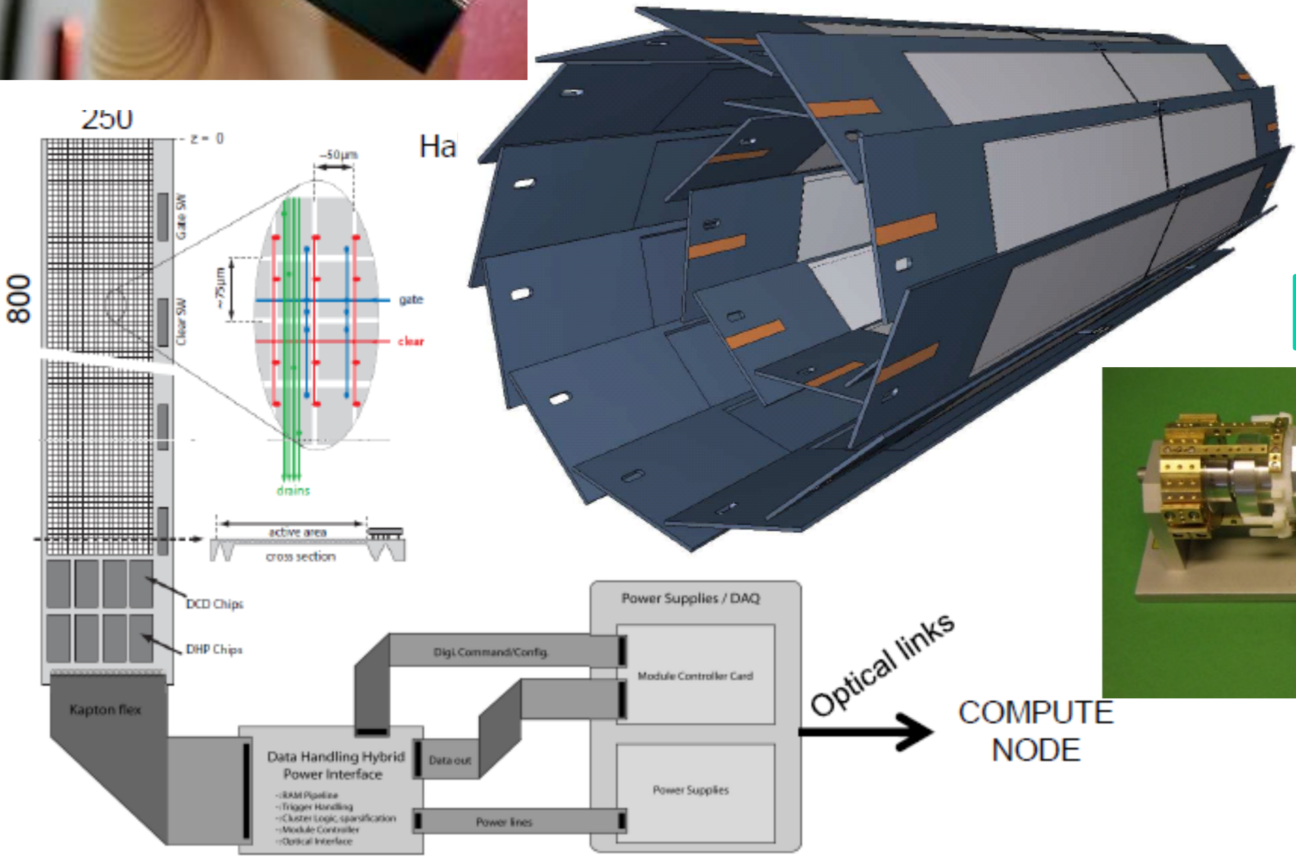


- The pipe for incoming beam starts from d=20 mm. Then d is gradually reduced to about 9 mm to stop direct SR.
- The inner surface of a pipe for incoming beam has ridges to prevent scattered light from hitting the central part.

Pixel vertex detector: DEPFET

	radius	pixel	thickness
Layer 1	r = 14mm	50x50μm^2	75μm(0.18%X0)
Layer 2	r = 22mm	50x75μm^2	75μm

total of 8 M pixels



Mechanical mockup

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

The ASICs are ready

The full-size close to final versions of the ASICs are designed, produced and tested.

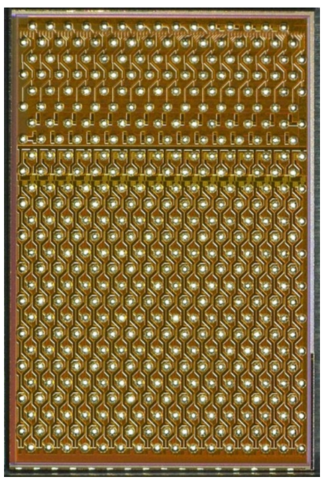
In general the chips seem to work fine

DCDBv2 (some excess noise is to be understood, but still better than v1)

SWITCHERBv1 and SWITCHERB18 (trade off   size <-> max. voltage swing)

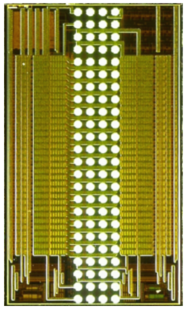
DHP02 (in 90nm IBM technology) NEW (but needs to be redesigned for TSMC 65nm)

Moreover – the layout of the module (the periphery (ASIC) part) has been done as well (Christian Kreidl)

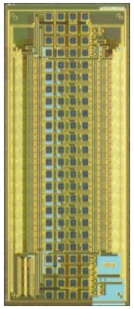


DCDBv2
180nm UMC

(Heidelberg)

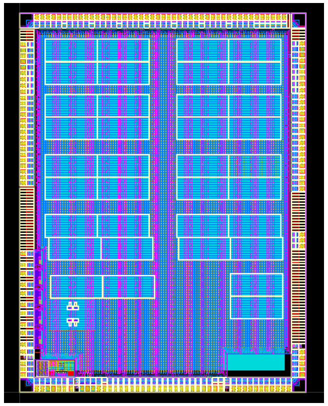


SWITCHERB
350nm HV AMS



SWITCHERB18
180nm HV AMS

(Heidelberg)

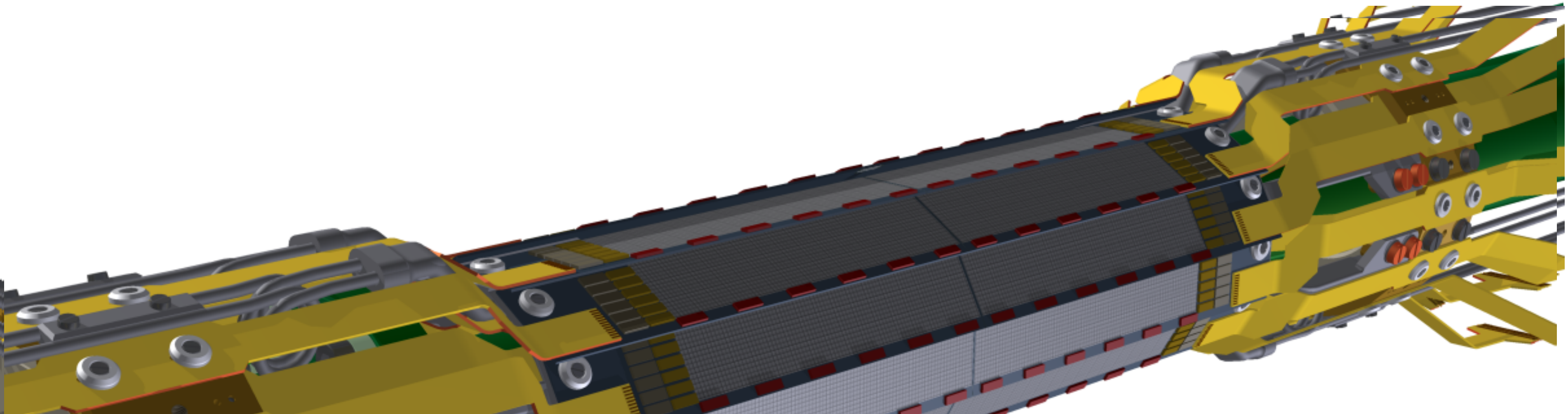


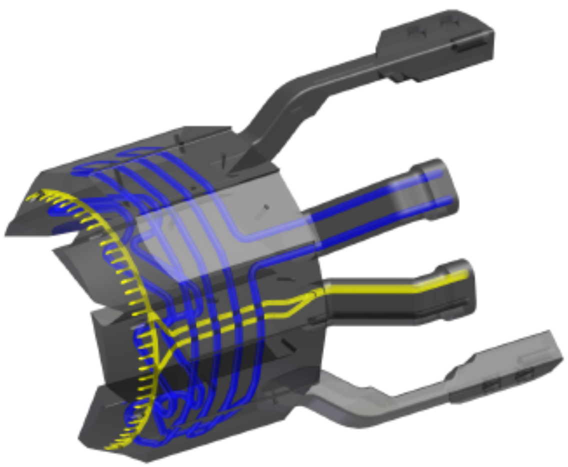
DHP0.2
90nm IBM

(Bonn with help from Barcelona)

Milestone!

Support

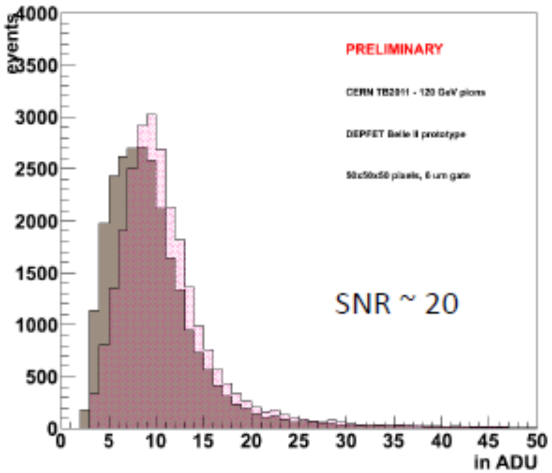




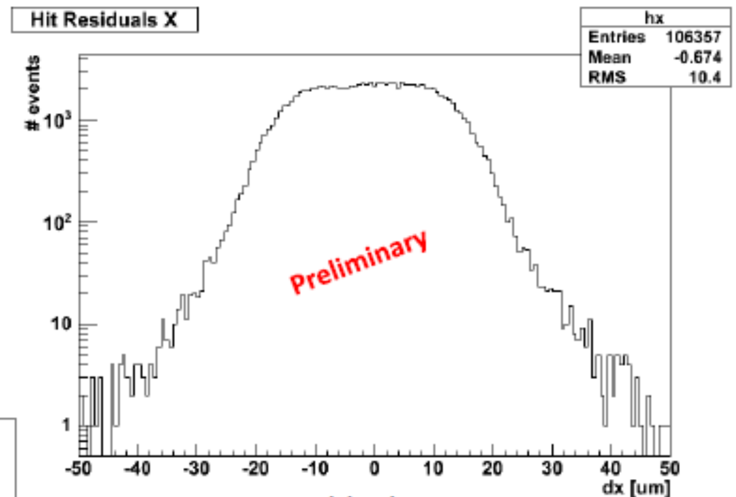
1) Beam pipe with PXD support
2) End flanges for module mounting an
3) Inner layer modules
4) Outer layer modules

PXD Test Beam: Results

Signal, residuals, efficiency

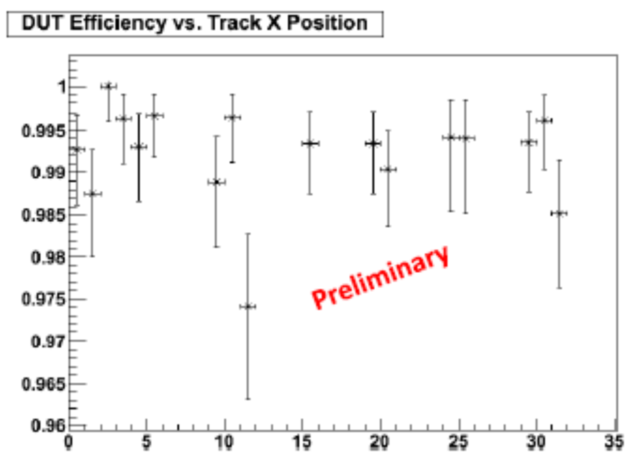


120 GeV pions at perpendicular incidence



CoG residuals ~ 10 μm

2 ADU seed cut, 1 ADU neighbor cut



Column hit efficiency >99%

cmarinas@uni-bonn.de

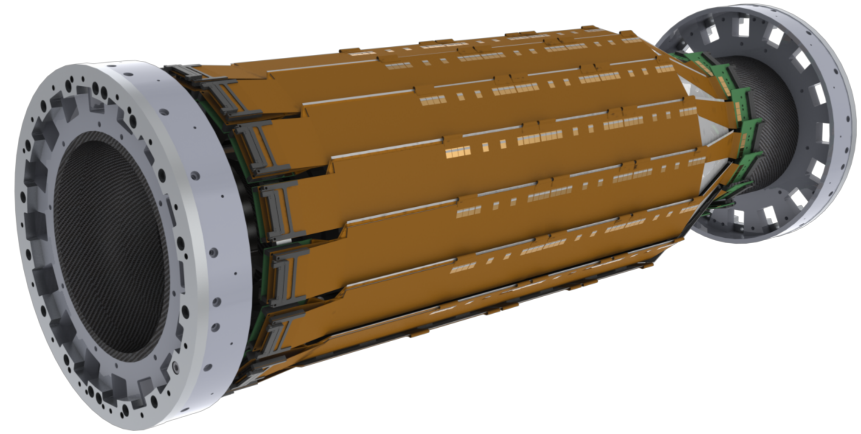
39

PXD status

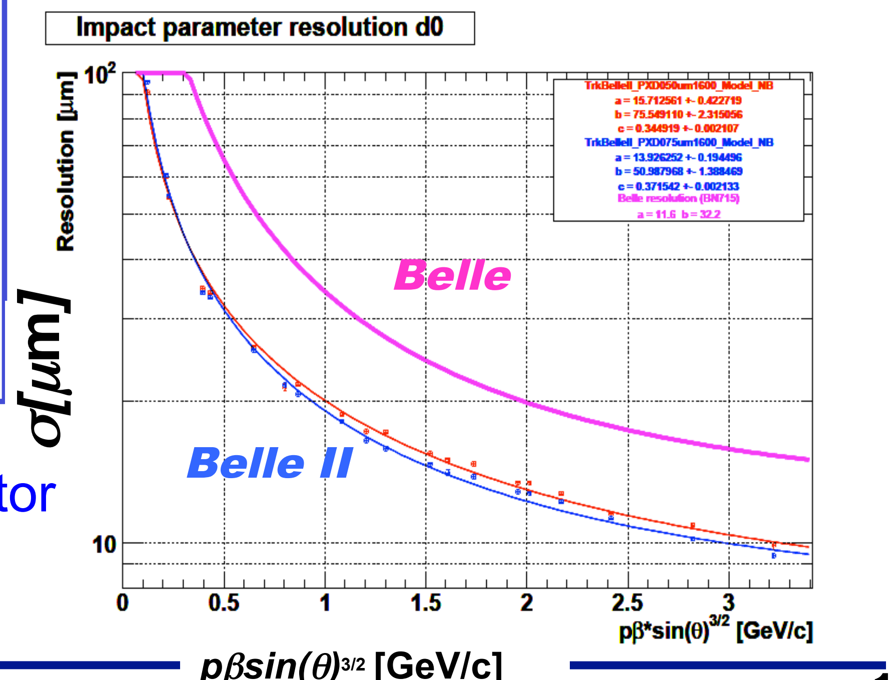
- Thin PXD6 matrices available and tested successfully in Lab and Beam Test.
- Yield initially low, reasons understood, process improved. Last wafers processed had >50% yield
- SOI procurement progressing, added a 2nd source, delivery of wafers imminent
- Have working prototypes of all ASICs (Milestone!) , work within specs (readout speed!)
- DHP needs to be converted from IBM 90nm (phased out by Mosis) to TSCM 65nm (testchip already working)
- We can blind the DEPFET against injection noise (tested both at lab and beam)
- Steady and significant progress of system issues:
  - CO2 and air cooling demonstrated.
  - driving of signal cables demonstrated.

SVD: double sided strips

		Belle II	Belle
Beam Pipe		r = 10 mm	15 mm
DEPFET			
	Layer 1	r = 14 mm	
	Layer 2	r = 22 mm	
DSSD			
	Layer 3	r = 38 mm	20 mm
	Layer 4	r = 80 mm	43.5 mm
	Layer 5	r = 105 mm	70 mm
	Layer 6	r = 135 mm	88 mm

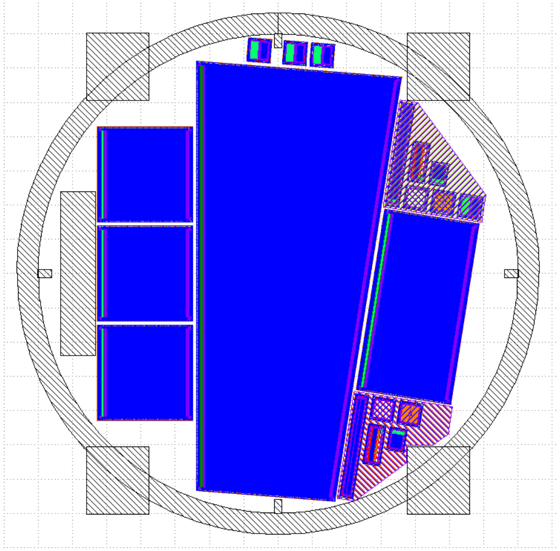


Less Coulomb Scattering & Pixel detector closer to the beam pipe improve the vertex resolution significantly.

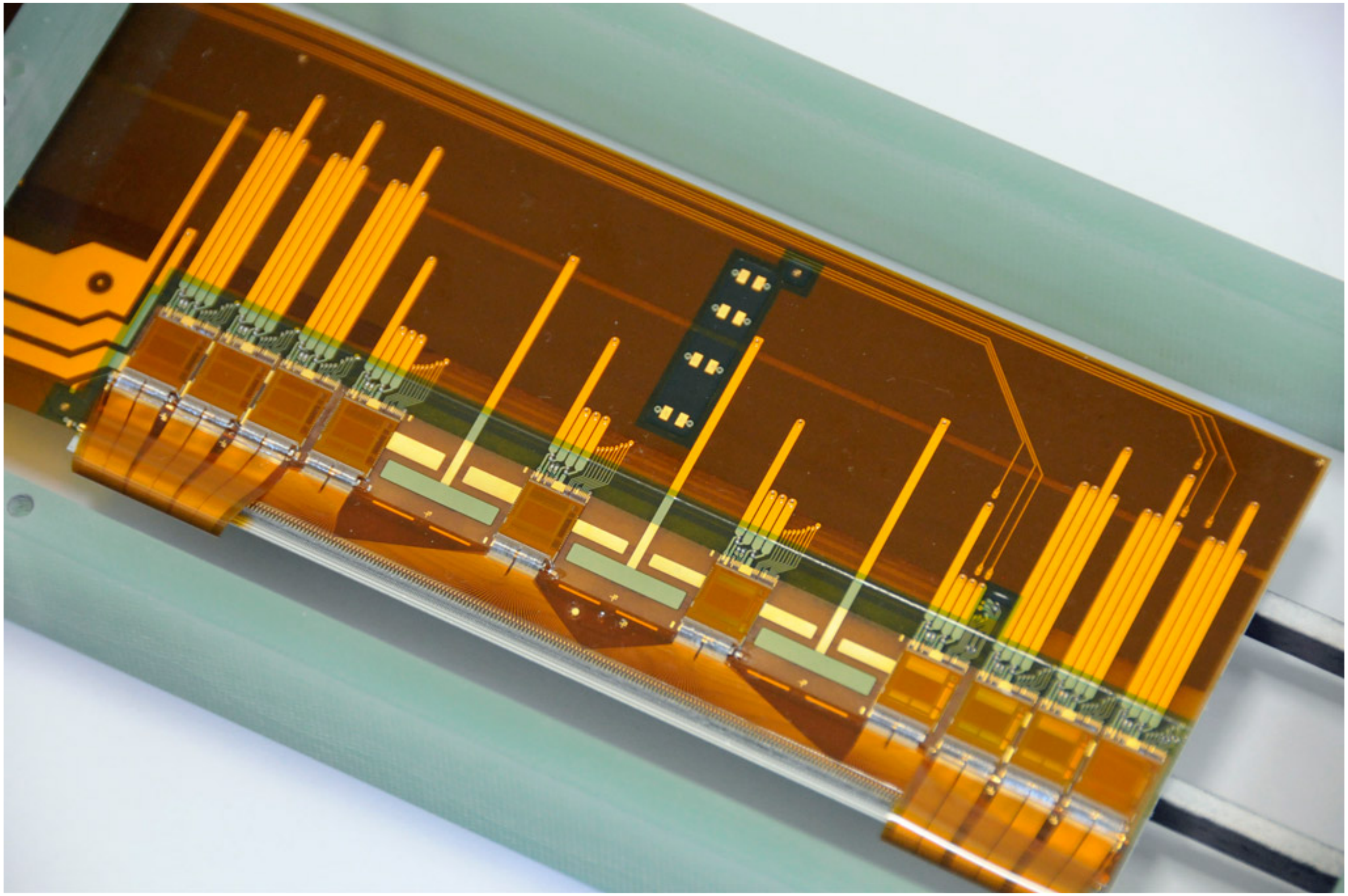


SVD: DSSD

- Micron DSSD sensor:
  - After careful (and long) verification of design in Micron, the production started.
  - Prototype sensors will arrive to Vienna in July.
- HPK DSSD sensors
  - About 40 DSSD will be delivered in March.
  - HPK kindly agreed to supply a 2cmx2cm DSSD from each wafer.
- Baby sensors
  - Quality control of product.
  - Useful for basic parameter measurement.
  - We do not have to ruin full size sensors for radiation damage test.

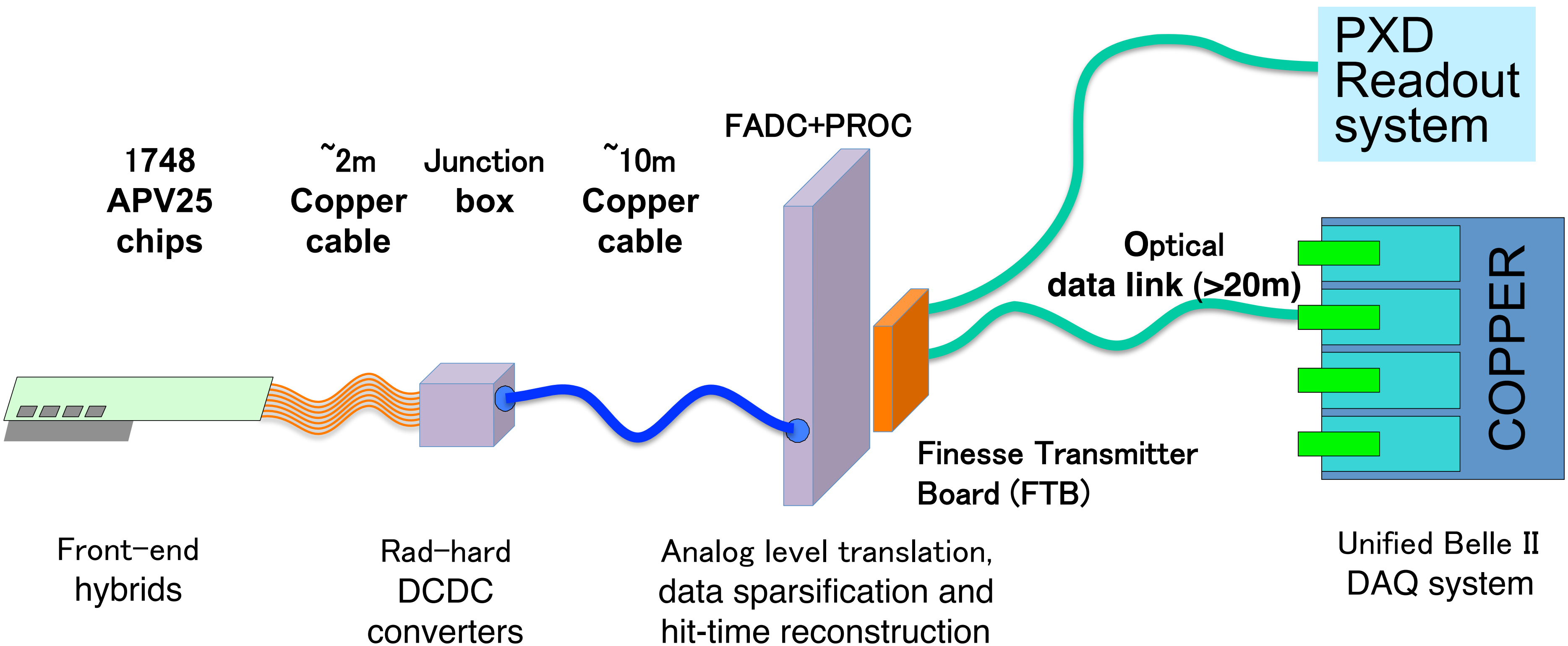


SVD: Origami Module with 6” HPK DSSD



SVD: Readout Chain Overview

- APV25 data is through 12 m long copper cable to FADCs.
- Zero suppression and hit time finding by FADC firmware
- FTB to COPPER readout system



SVD Summary

- Mechanics / structure solved
- Cooling: now working on the details of CO_2 distribution and thermal transfer to APV chips
- Sensors: New wedge shaped sensors (for slanted part) now being fabricated at Micron, expected back in early July
- Origami: in June, a 2-sensor Origami ladder will be built at IPMU (Tokyo University) together with HEPHY and Tata people.
- Electronics readout: Continuously working on various parts, some circuits already prototyped and tested (analog and digital level translation), others in production (edge hybrids, Junction box boards)
- Software: simulation, online & offline all started
- Beam test & irradiation in October 2012
- Series ladder production will start in May 2013 (according to the schedule)

Central Drift Chamber

longer lever arm

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

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

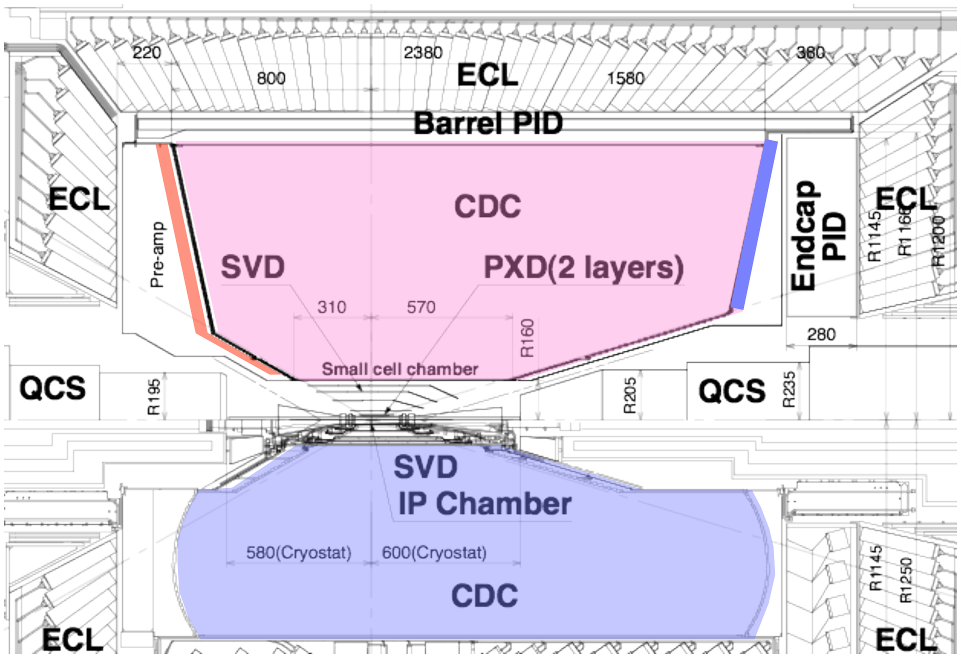
new readout system

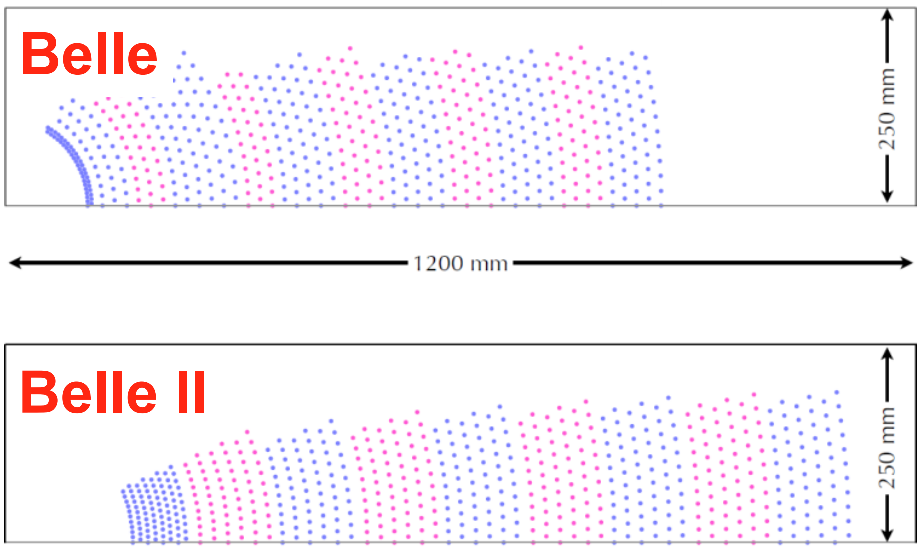
dead time 1-2μs → 200ns

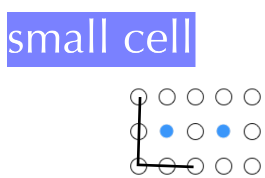
small cell

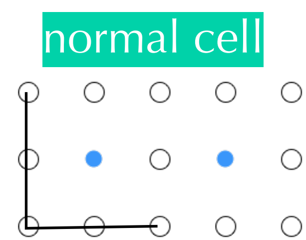
smaller hit rate for each wire

shorter maximum drift time



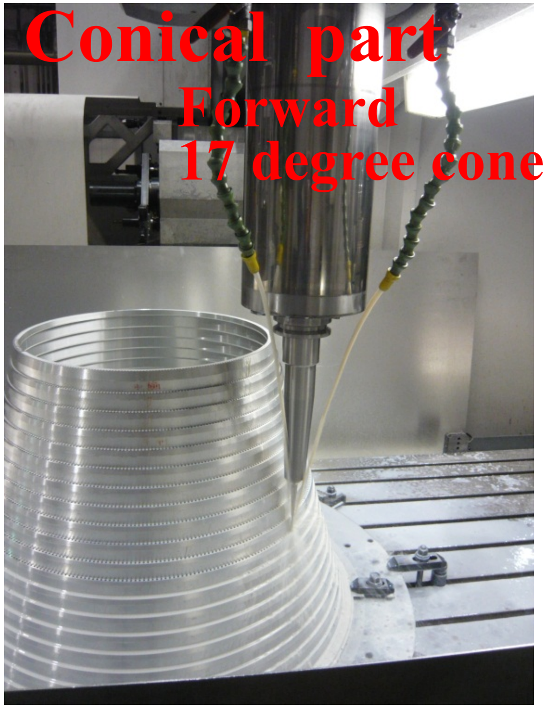






	Belle	Belle II
inner most sense wire	r=88mm	r=168mm
outer most sense wire	r=863mm	r=1111.4mm
Number of layers	50	56
Total sense wires	8400	14336
Gas	He:C_2H_6	He:C_2H_6
sense wire	W(Φ30μm)	W(Φ30μm)
field wire	Al(Φ120μm)	Al(Φ120μm)

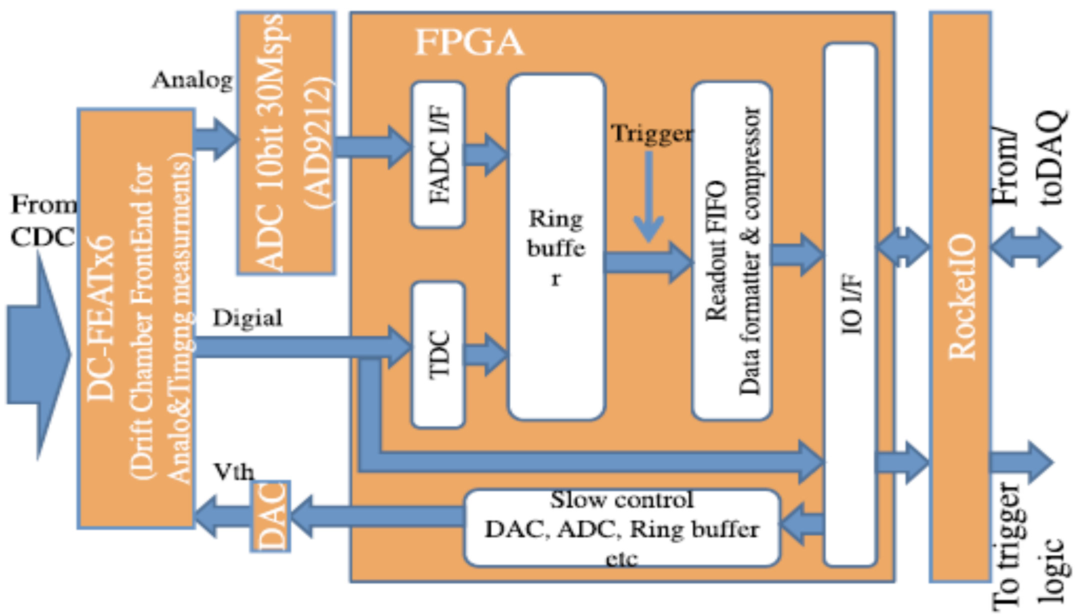
CDC endplate drilling

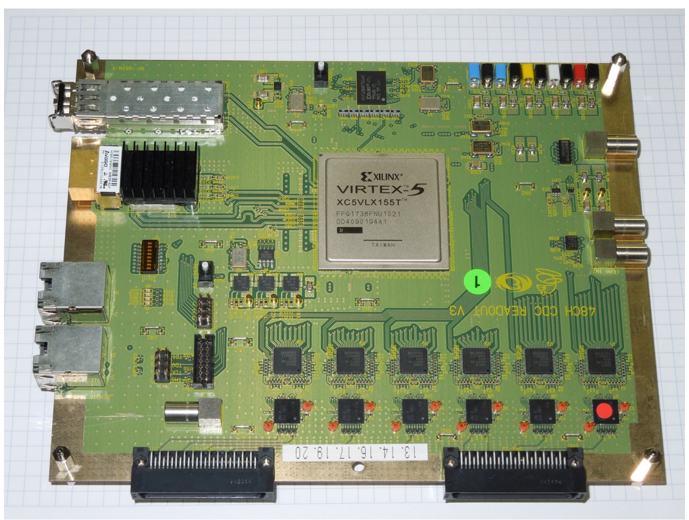


Shaping and drilling were done without serious troubles.
There is no drill breaking.

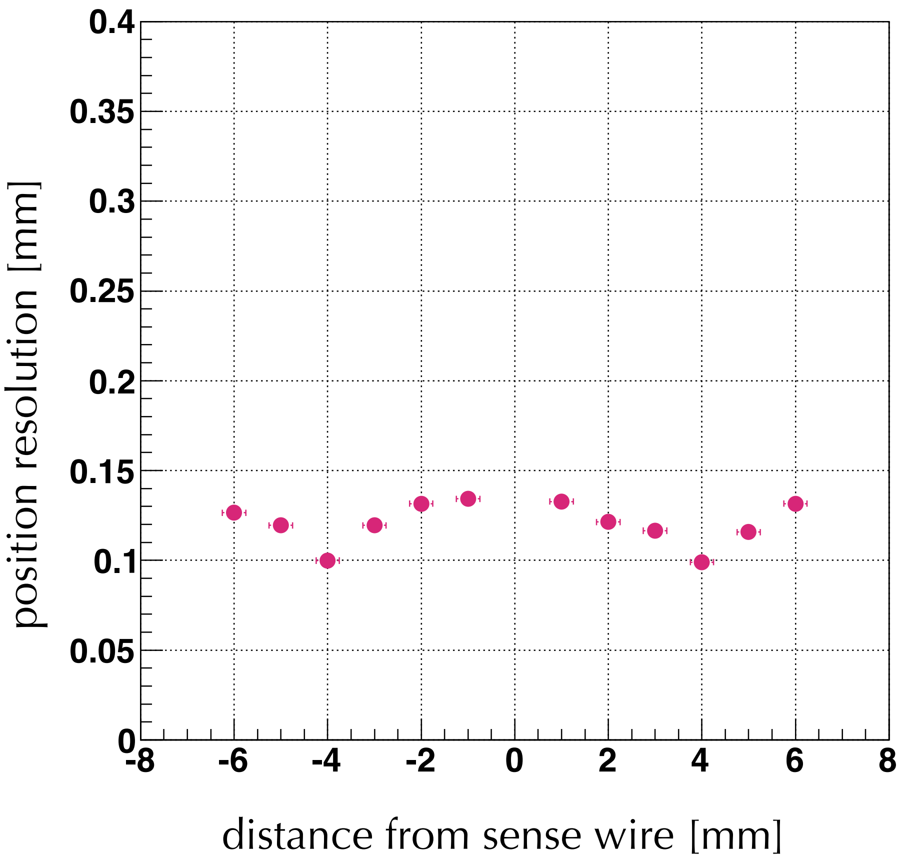
Central Drift Chamber Readout

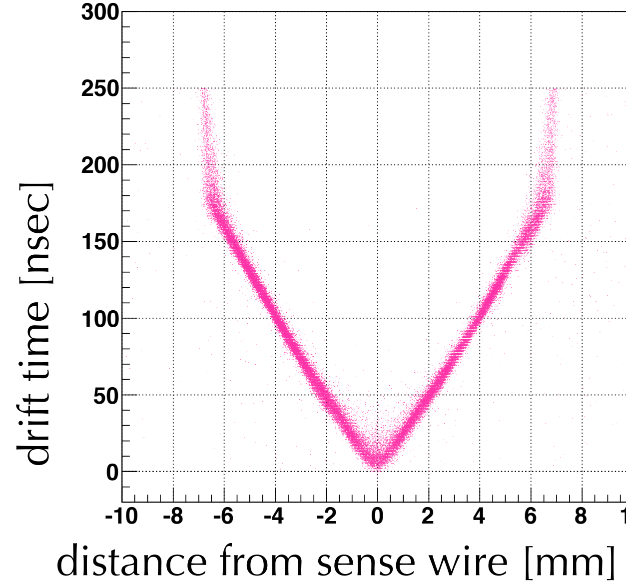
- New electronics has been designed and tested
- The drift time is measured with an FPGA-based TDC
- A slow FADC (around 30MSa/s) measures the signal charge.

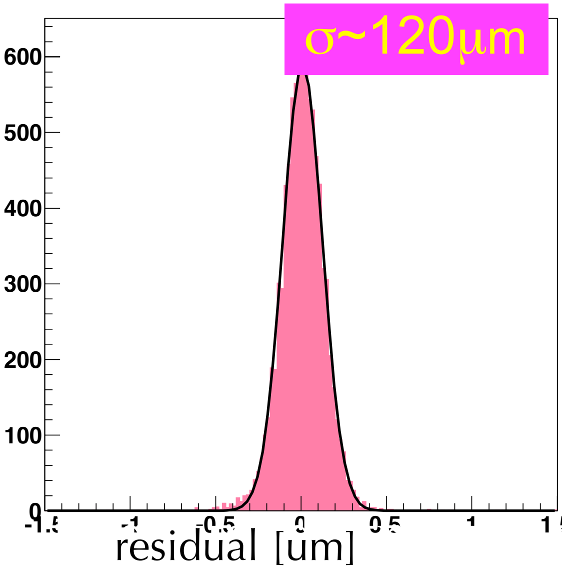




CDC Test beam Results from 2011



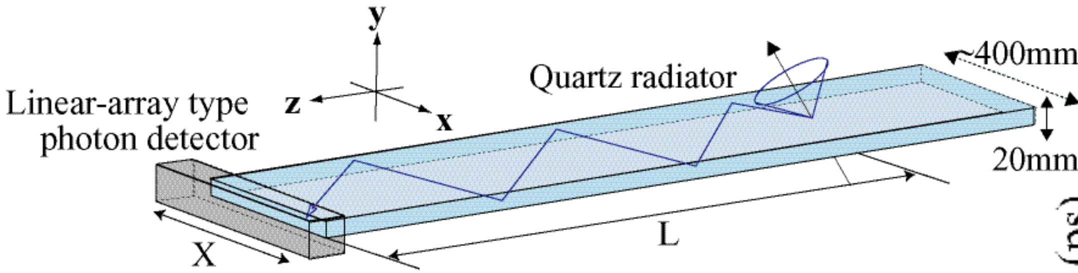




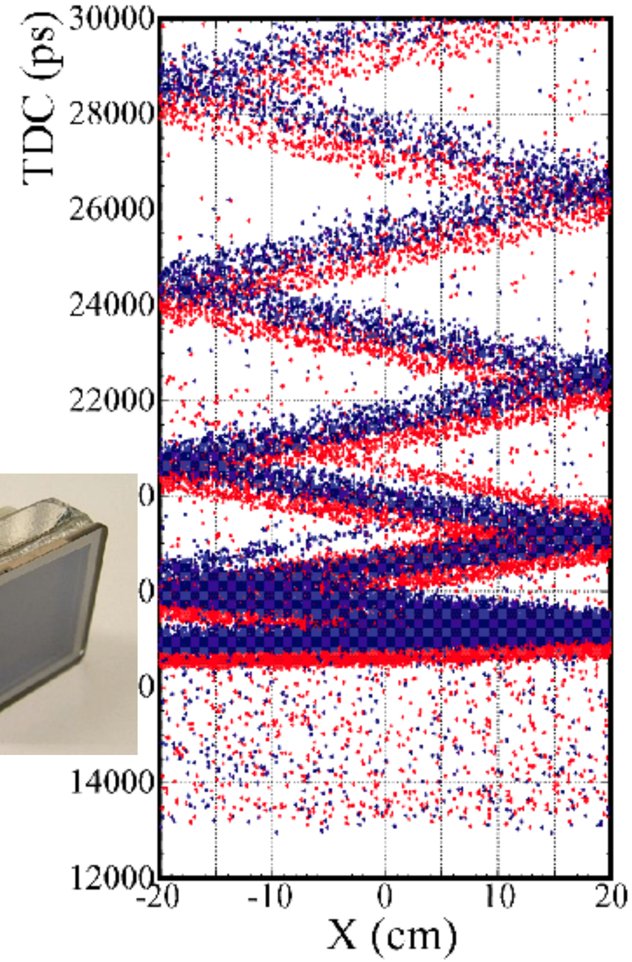
CDC Summary

- Fabrication of six endplates almost done successfully.
- Fabrication of outer cylinder started and it will be delivered by Sep 2012. Then, we can meet the installation schedule (May in 2015)
- Wire stringing will start in 2012
- New ASIC works fine.
  - Mass production already finished.
  - Quality check started in NTU
- New 48ch readout board (Ver.3) basically works fine.
  - More tests will be done in 2012.
    - Radiation hardness of optical transceivers (DAQ,TRG talks)
  - Mass production will be done in 2013 (and 2014).

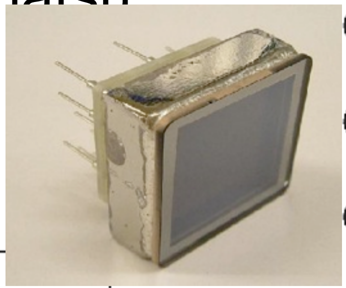
Barrel PID: Time of propagation (TOP) counter

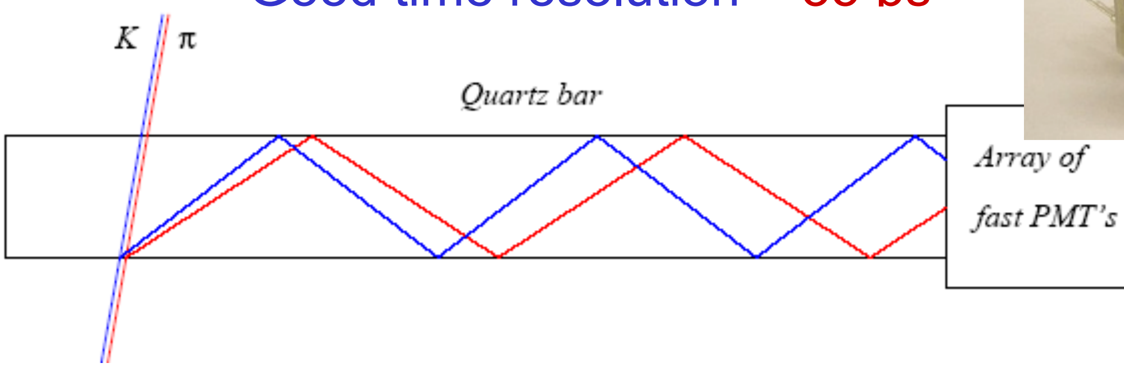


Simulation
2GeV/c, θ=90 deg



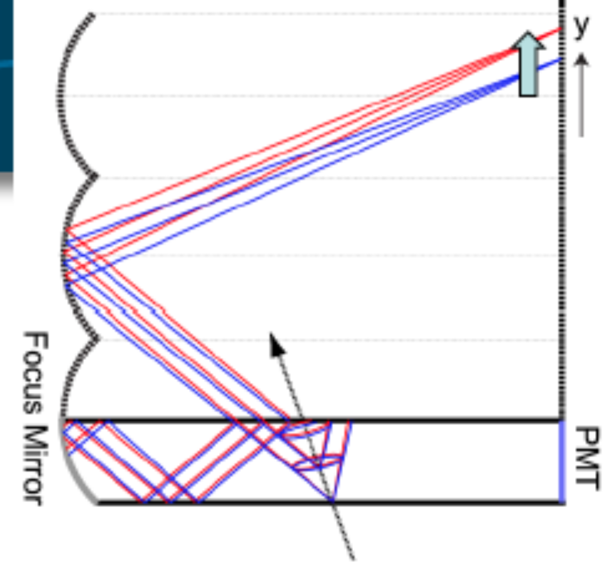
- Cherenkov ring imaging with precise time measurement.
- Reconstruct angle from one coordinate and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT Hamamatsu 16ch MCP-PMT)
    - Good time resolution < 35 ps

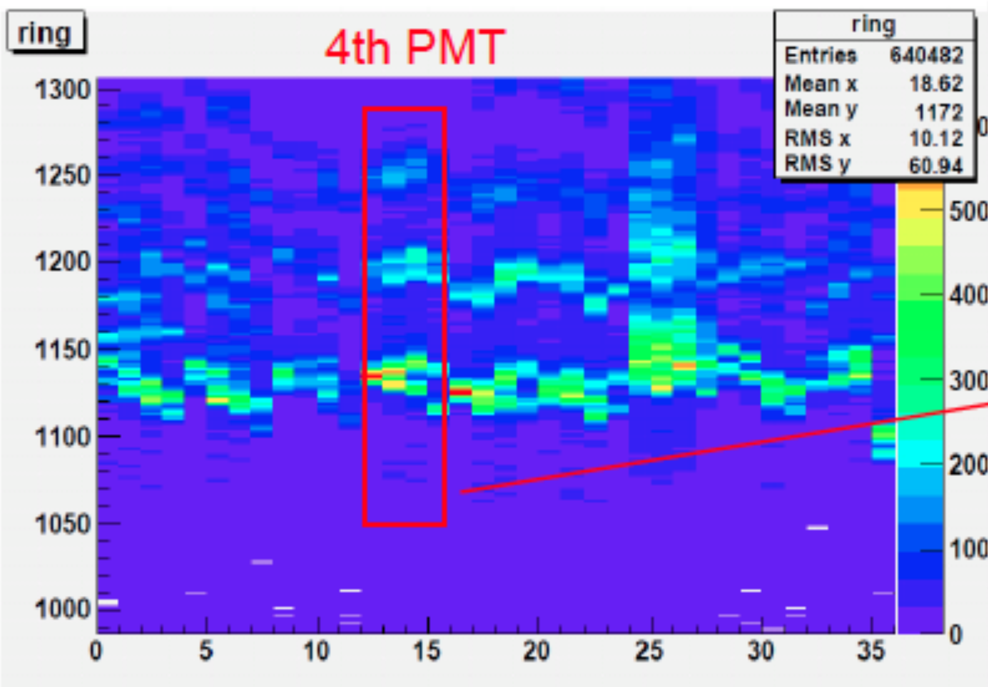


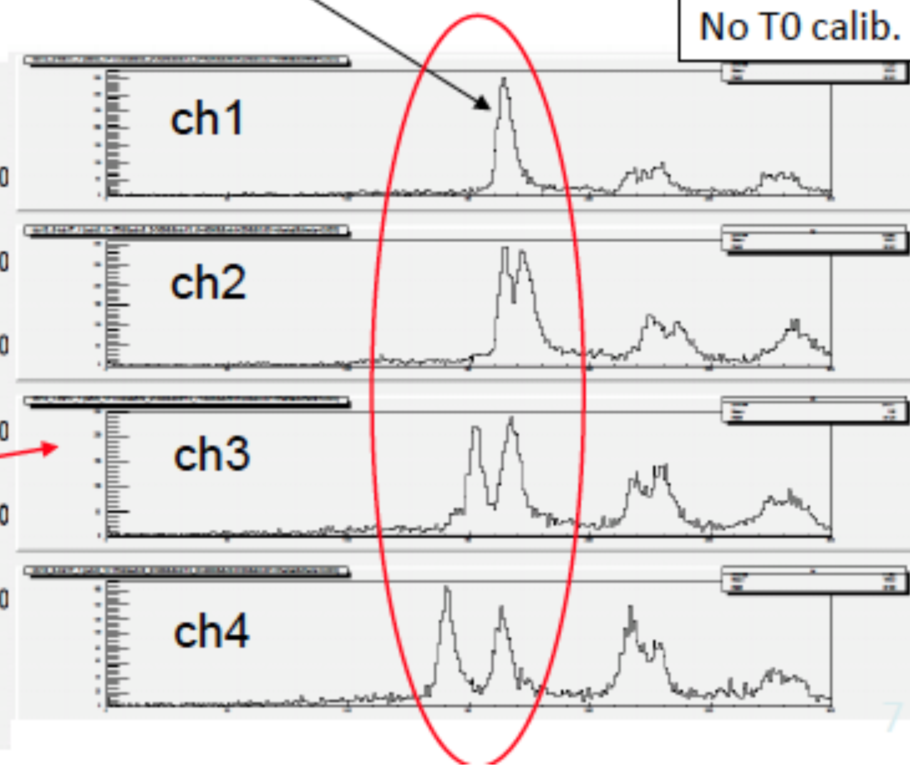


Ring image

- Complicated ring image as expected
- Expected time distribution along y-channel
- Good time resolution : ~95ps
  - By simulation: ~103ps
  - Without focus system, resolution is ~170ps for 2900mm propagation.





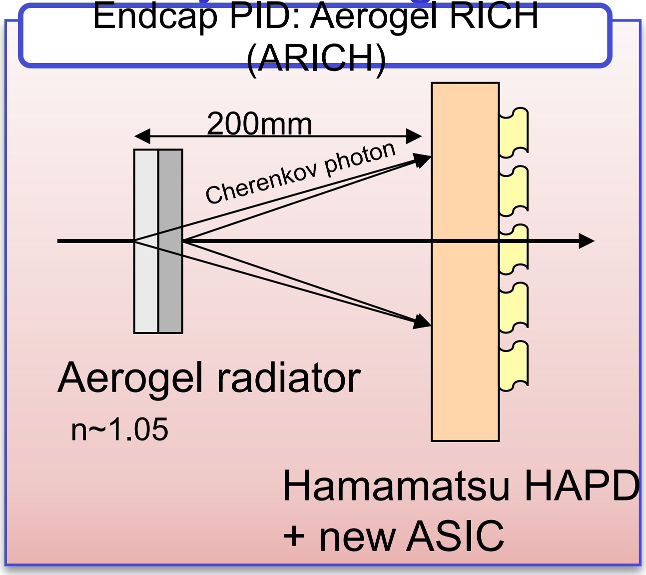


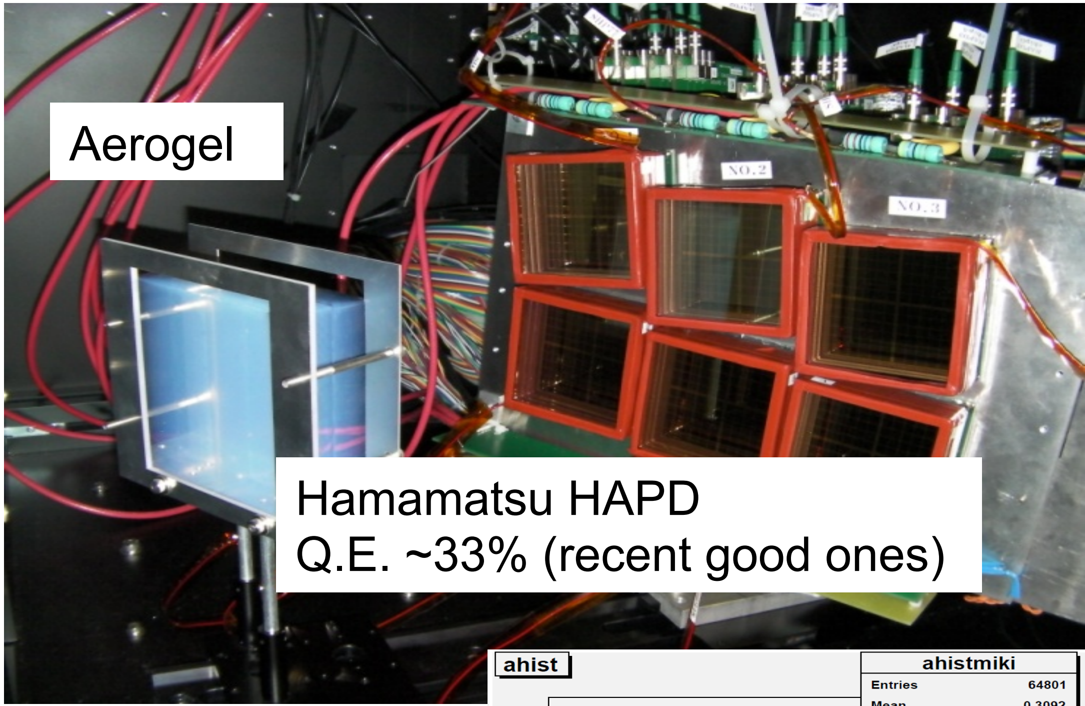
Barrel PID Summary

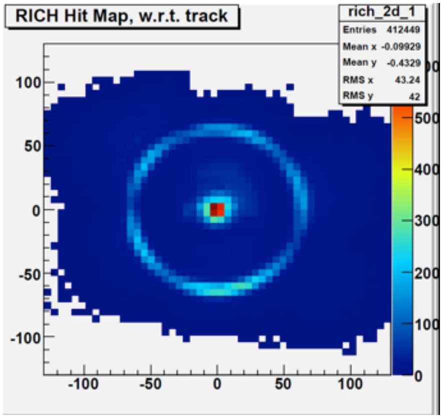
- Quartz radiator
  - (Almost) full size quartz radiator is prepared.
    - Two quartz bars and mirror were glued successfully.
  - Support box is produced and tested.
- Readout block
  - New ASIC for high speed waveform readout is tested with MCP-PMTs and outputs single photon pulses.
- Beam test
 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

End-cap PID: Aerogel RICH

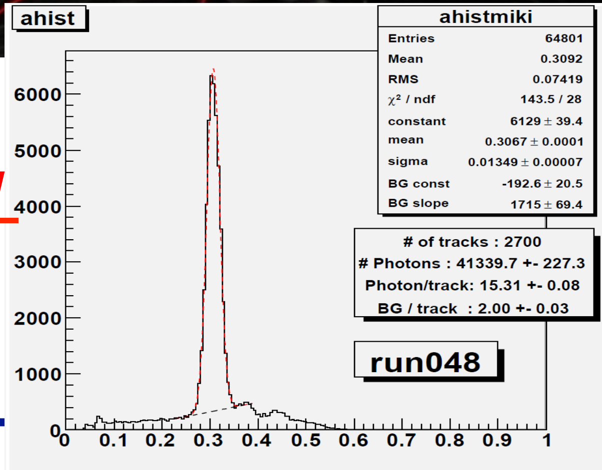
- Proximity focusing RICH with aerogel radiator   Test Beam setup







6.6 σ π/K at 4GeV/c !



Clear Cherenkov image observed

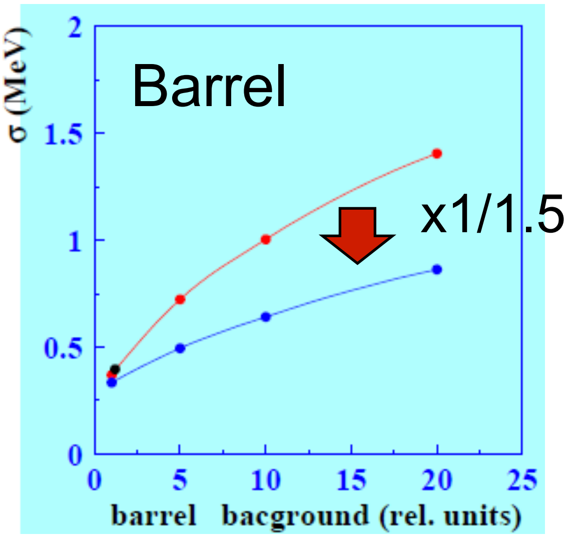
E-PID summary

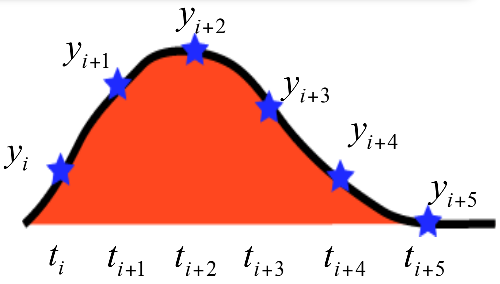
- Aerogel:
  - Ready to start production of normal aerogel radiator with refractive indices 1.045, 1.055. Production of large pin-drying aerogel tiles with higher refractive index still under study.
- HAPD:
  - Degradation of APD performance during gamma irradiation understood and new HAPD samples produced.
  - Tests of new samples is ongoing and the decision on final HAPD parameters in September.
- Electronics:
  - Close to final prototype of FE board with SA02 ASICs successfully tested with small ARICH prototype in the beam tests.
  - Samples of final version of ASICs (SA03) successfully tested and new FE board is in production.
  - Tests of the merger board prototype are ongoing.

ECL Upgrade

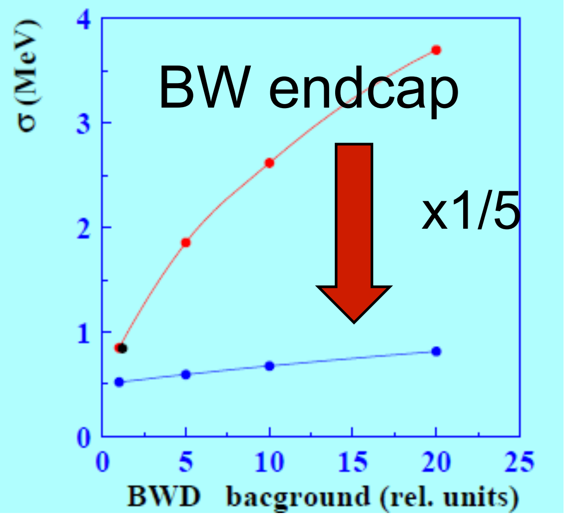
- Increase of dark currents due to neutron flux
- Fake clusters & pile-up noise

- Barrel:
  0.5μs shaping + 2MHz w.f. sampling.
- Endcap (may have to be staged):
  pure CsI + photopentodes
  30ns shaping + 43MHz w.f. sampling





Pure CsI & photopentods



ECL Status

Barrel electronics modification:

- Barrel Shaper DSP modules mass production is started this year(100 of 450). The bidding procedure is going on.
- Endcap version of Shaper DSP module design is prepared.
- Collector module: second version has been produced. Belle2link will be tested in August.
- VME crate design is to be finished this year.

ECL Status (cont'd)

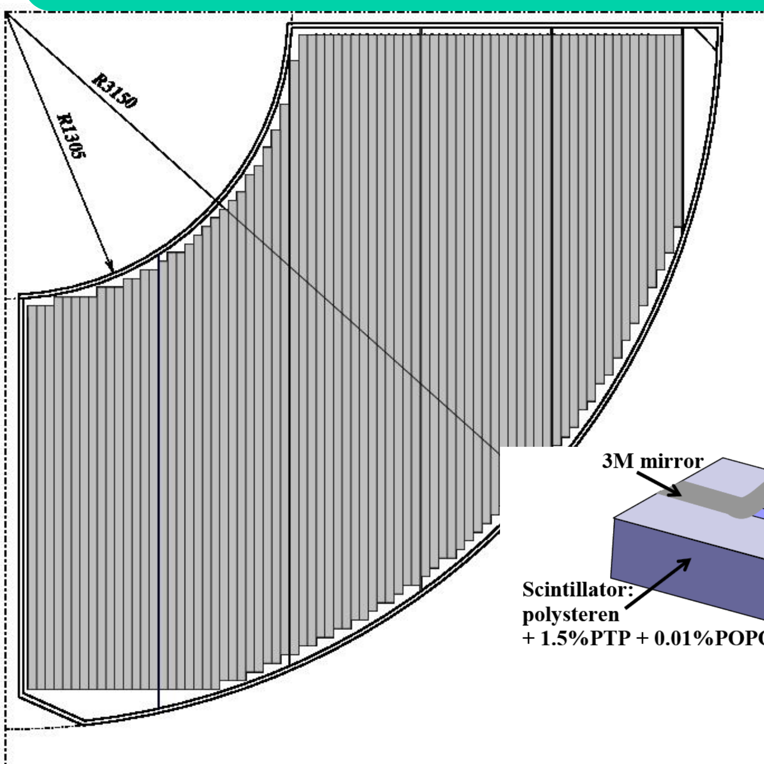
Crystal counter status:

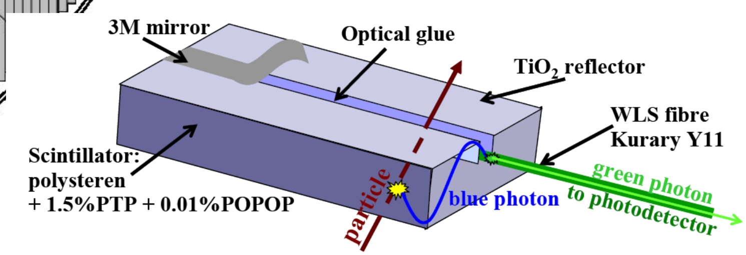
- The test bench for test of the barrel counters with cosmic was prepared.It based on the
- 1 VME crate with 12 SHaper_DSP modules, collector and fam module
- and allows to test 184 counters by once.
- The test of the counters is going on. Half of the counters has been tested. Will be finished in July.

- R&D with pure CSI option for endcaps is going on.
- Pure CsI+PP option has been tested.
- Pure CsI+APD is tested.
- Radiation hardness of Pure CsI crystals is going on.

KLM: K_L & Muon detector

RPC → Scintillator (Endcap)
also inner 3 layers of Barrel(TBD)





Endcap muon detecton is already limited by backgrounds. Endcap RPCs will not work at full luminosity and higher backgrounds. Inner barrel is *marginal.*

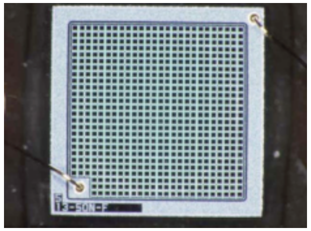
LAYOUT

- **One layer: 75 strips (4 cm width)/sector**
- **5 segments**
  1 segment = 15strips
- **Two orthogonal layer = superlayer**
- **F&B endcap KLM:**
  - **Total area ~1400 m^2**
  - **16800 strips**
  - **the longest strip 2.8 m; the shortest 0.6 m**

WLS fiber in each strip

Hamamatsu MPPC at one fiber end

mirrored far fiber end



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

Test mass production @ ITEP

- ~150 long strips produced to check all operations
- On line test of the quality of production: performance is more stable than with manual operations

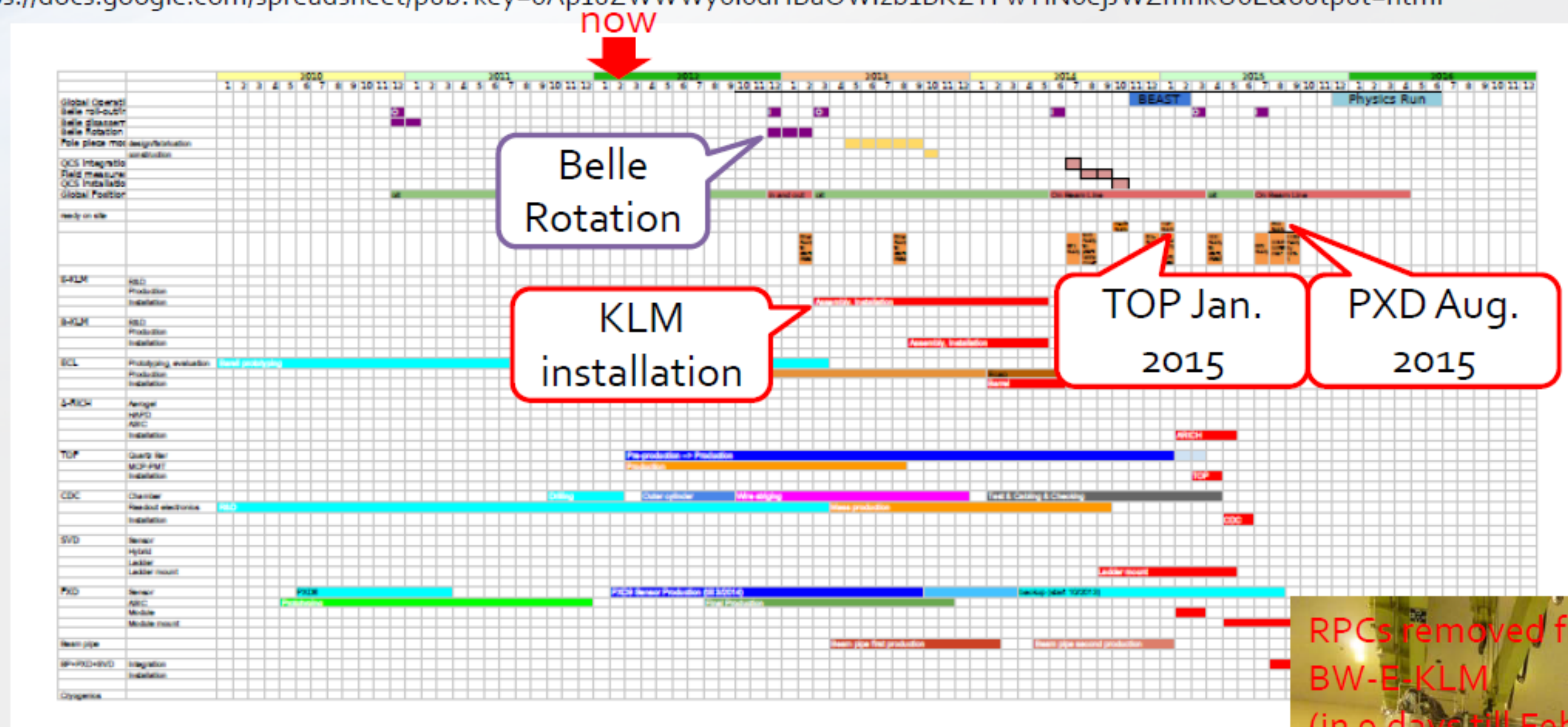
- according to estimates ½ of the sector should be produced in one day:
  - preparation of fiber (100 at once) – 1 people
  - 80 strips (2-3 people)
  - cosmics test
  - 5 segments at 5 tables (2-3 people)
- need 230 workdays to produce whole detector

KLM status

- Test module for endcap was built at KEK in July 2011.
- Radiation-hardness tests have been conducted in proton beam at ITEP for SiPMs, preamps, and preamp carrier cards. All will survive for at least a decade of Belle II operation at full luminosity.
- Light-collection efficiency is improved by 40% by protruding the wavelength-shifting fiber 200 microns closer to the SiPM
- Quality test stand has been developed at ITEP.
- Mass-production test procedures have been tested at ITEP.
- Most of raw material is now at ITEP or will be delivered soon.

Belle II Construction Schedule

https://docs.google.com/spreadsheet/pub?key=0Ap1uZWWWy6IodHBaOWIzb1BKZTFwYlN0ejJWZmhkU0E&output=html

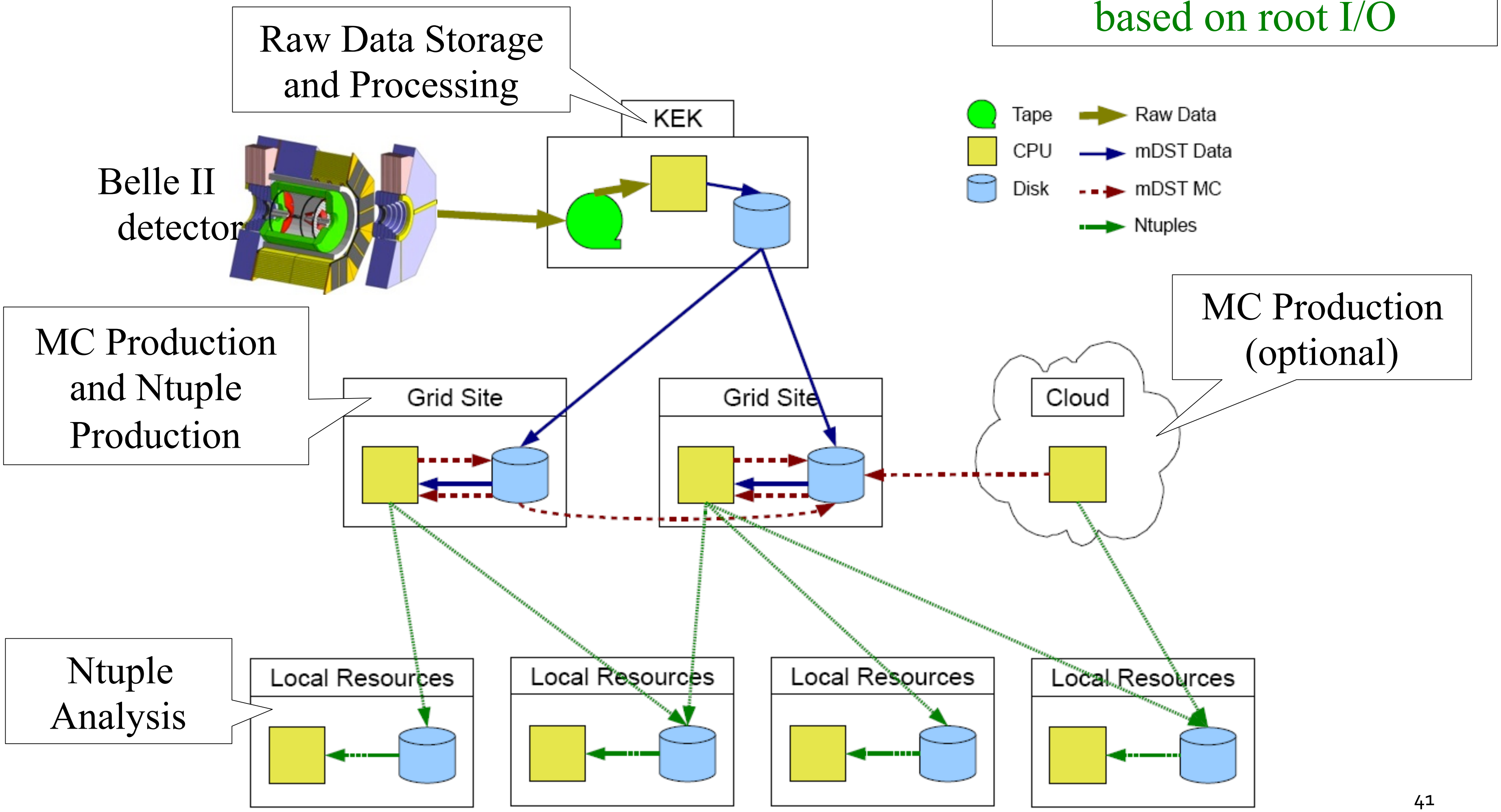


Detector rotation in the end of JFY2012 (Dec/Jan – Feb./Mar.)
KLM installation starts right after that (Mar./Apr. –)
TOP should be ready at KEK in Jan. 2015
PXD should be ready at KEK in Aug. 2015
(three on critical path)

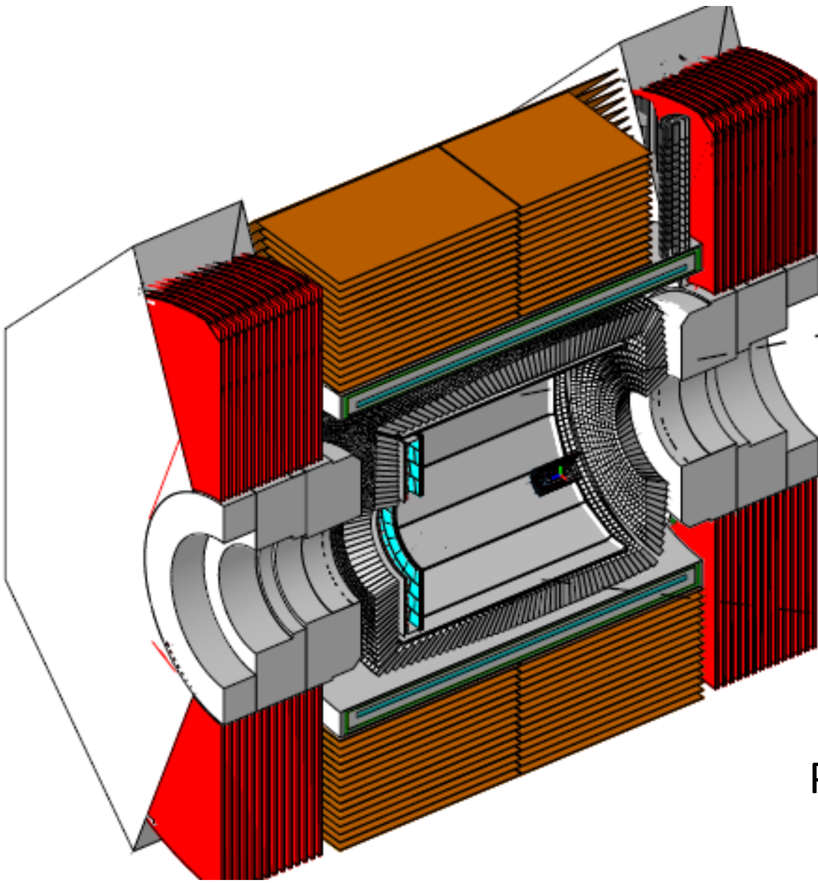
Belle II Computing Model

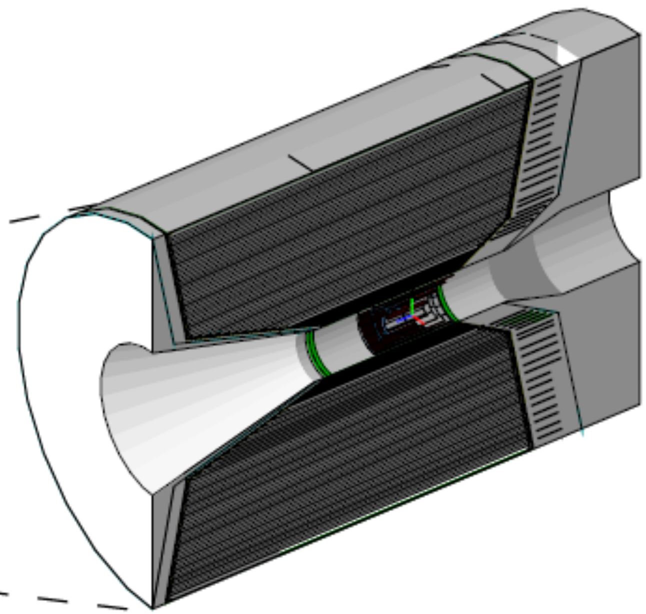
Grid-based Distributed Computing

Common framework for DAQ and offline basf2 based on root I/O

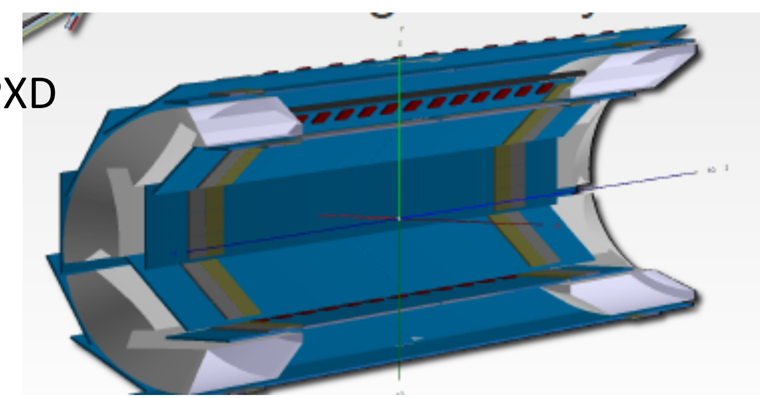


Whole geometry ready in GEANT4





PXD



Elements outside detector (|s|>4m) are not yet implemented (bending magnets, concrete shield etc…)

Hiroyuki Nakayama (KEK)

Physics studies

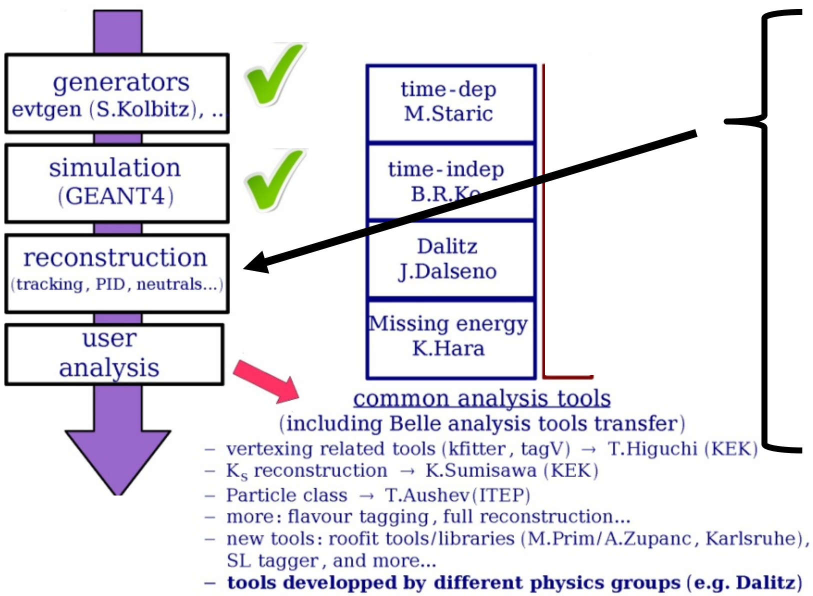
ProtoPhysics groups

t-independent methods, B.R. Ko
t-dependent methods, M. Starič
Dalitz methods, J.Dalseno
***E_{miss}* methods**, K. Hara

Aim of ProtoPhysics groups:

"*preparation, development and tests of Full simulation and reconstruction tools,*

...choosing, preparing and studying benchmark physics modes for estimating the performance of the detector using simulation"



Simplified tracking (CDC on)ly)
need PXD, SVD

TOP&ARICH reco
(not with track fitter output yet)

ECL (need for fullrecon, Belle algorithm, no t info)
KLM (track extrapol., μ id, no K_L)

preparing full analysis chain to be at Belle II

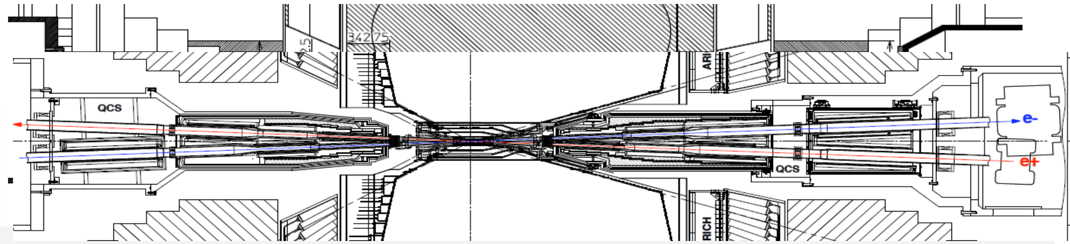
Background estimation status

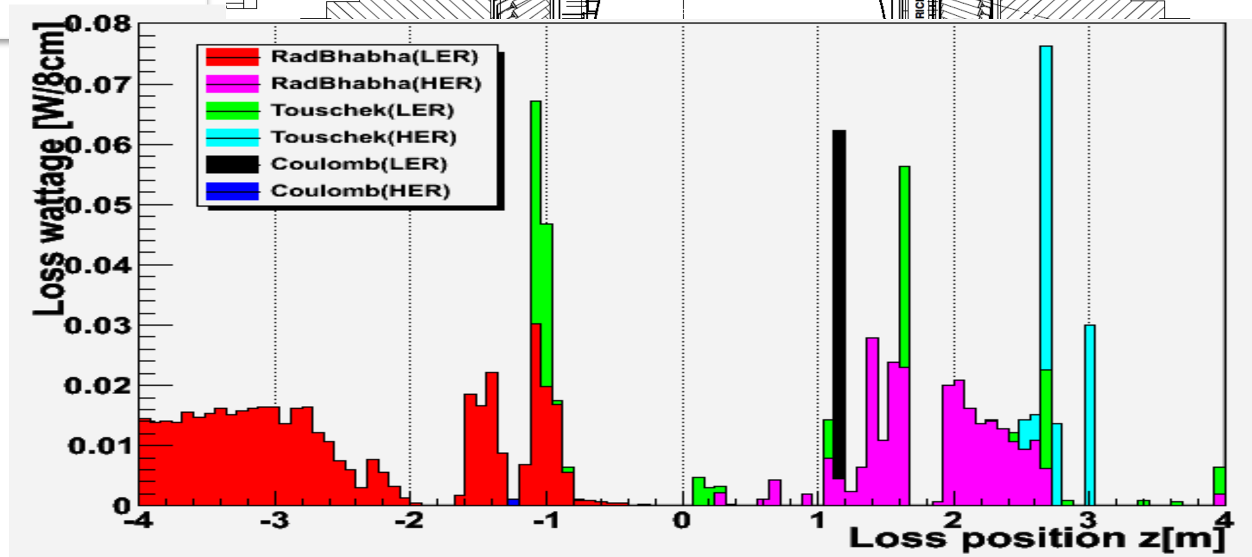
- Touschek: expected to be severe in nano-beam scheme, but can be reduced by horizontal and vertical collimators.
- Beam-gas Coulomb: Also severe with thinner IR beam pipe and larger maximum by(~4000m), but can be reduced by narrow (few mm) vertical collimator, without losing beam stability if placed at small βy.
- Radiative Bhabha: $e^{+/-}$ with large ΔE after RBB process can be lost inside the detector and become considerable BG
- Synchrotron Radiation: tolerable (negligible SR hit rate on Be pipe thanks to the collimation on incoming beam pipe)
- 2-photon: tolerable (discrepancy between SuperB's estimation disappeared during the discussion at Joint BG workshop)
- Beam-gas brems, beam-beam kick, etc…

Total BG (for IPAC2012)

Ver. 2012.5.18

Loss wattage
= loss rate
 * energy of loss particle





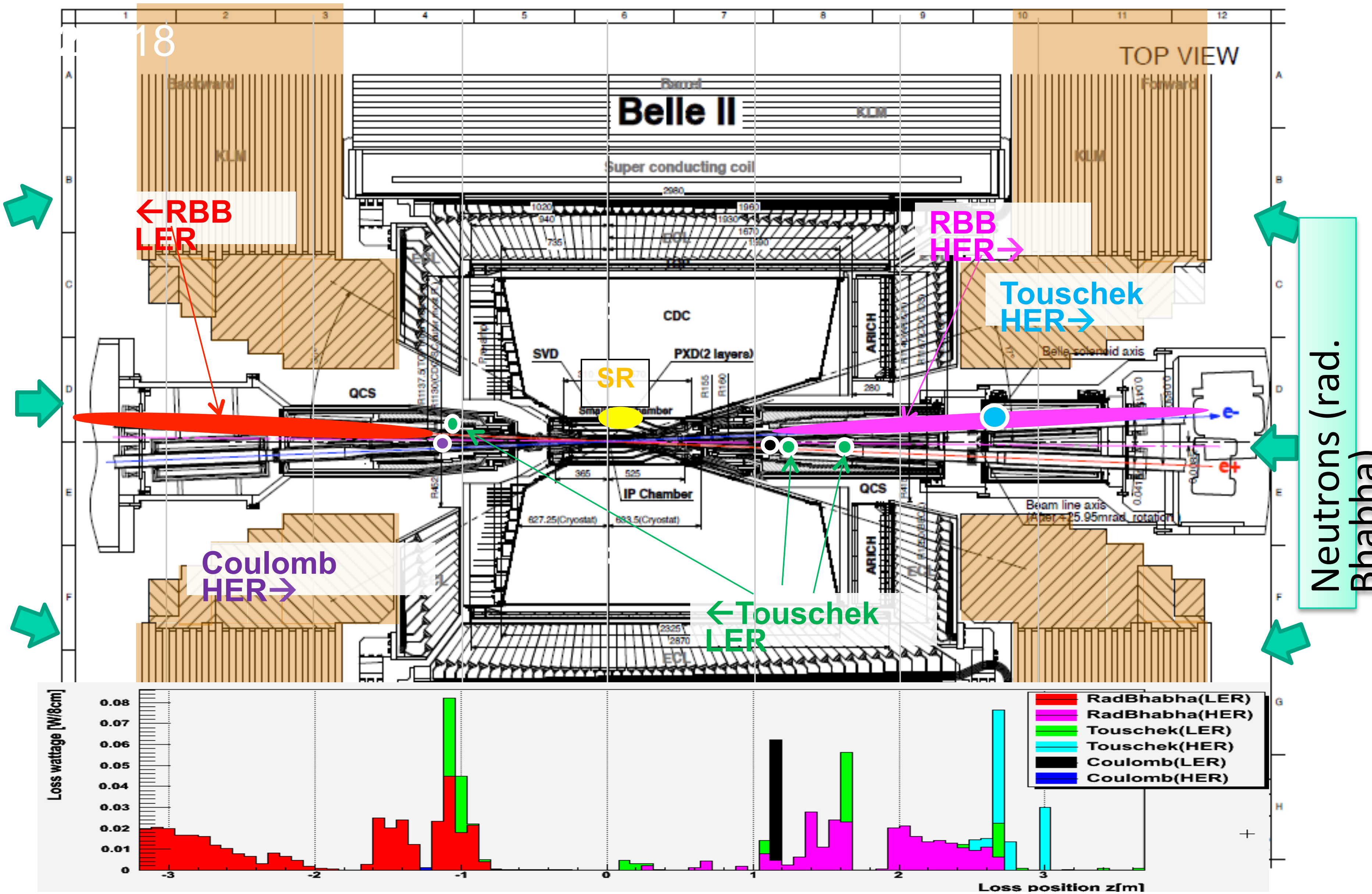
HER
(e-)

LER
(e+)

	LER (4GeV e+)	HER (7GeV e-)
Rad. Bhabha	0.45 W (eff. 0.7GHz)	0.25W (eff. 0.22GHz)
Touschek	0.14 W (0.22GHz)	0.11 W (0.10 GHz)
Coulomb	0.06 W (0.09GHz)	0.001W (0.001GHz)

1GeV , 1GHz
= 0.16W

Background picture



Impact on detector

- GEANT4-based full-simulation performed
  - Detector performance are studied
    - PXD/SVD occupancy, CDC hit rate, PID performance, etc..
  - Radiation dose, neutron rate
    - Readout boards, Si devices, ECL crystals, etc..
- Some sub-detectors require further mitigation
  - Thick tungsten shield inside final Q cryostat
    - To mitigate TOP PMT photocathode aging, CDC hit rate, etc..
  - Additional neutron shield
    - To protect CDC electronics board, ARICH HAPD, etc..

SuperKEKB/Belle II Funding Status

- Accelerator upgrade + 50% of the detector - ca *320 M€* approved in March 2011
- Funding of the contribution to the remaining 50% of the detector – ca *20 M€* - in many other countries approved or on the way
- First MoU between German FAs and KEK signed in 2011, others to follow

The Belle II Collaboration

A very strong group of ~400 highly motivated scientists!

Next open general meetings:
Bad Aibling (Bavaria) July 26-29 KEK November 12-15 2012

Summary

- SuperKEKB/Belle II aims for (discovering and) understanding the New Physics.
- Target luminosity of SuperKEKB is $8x10^{35}/cm^2/s$, will provide $50ab^{-1}$ by 2021-2022.
- Belle II gives similar or better performance than Belle even under higher beam background.
- Project has been approved by Japanese Government and started. KEKB/Belle operation has been terminated and construction started.
- Next collaboration meeting: Bavaria July 26-29, still open to everyone. New collaborators welcome!
- Accelerator upgrade well underway
- Detector: Moving from the design phase into production for many components
- Looking forward to a friendly competition with a second Super-flavour

Backup

Machine parameters

Y. Ohnishi

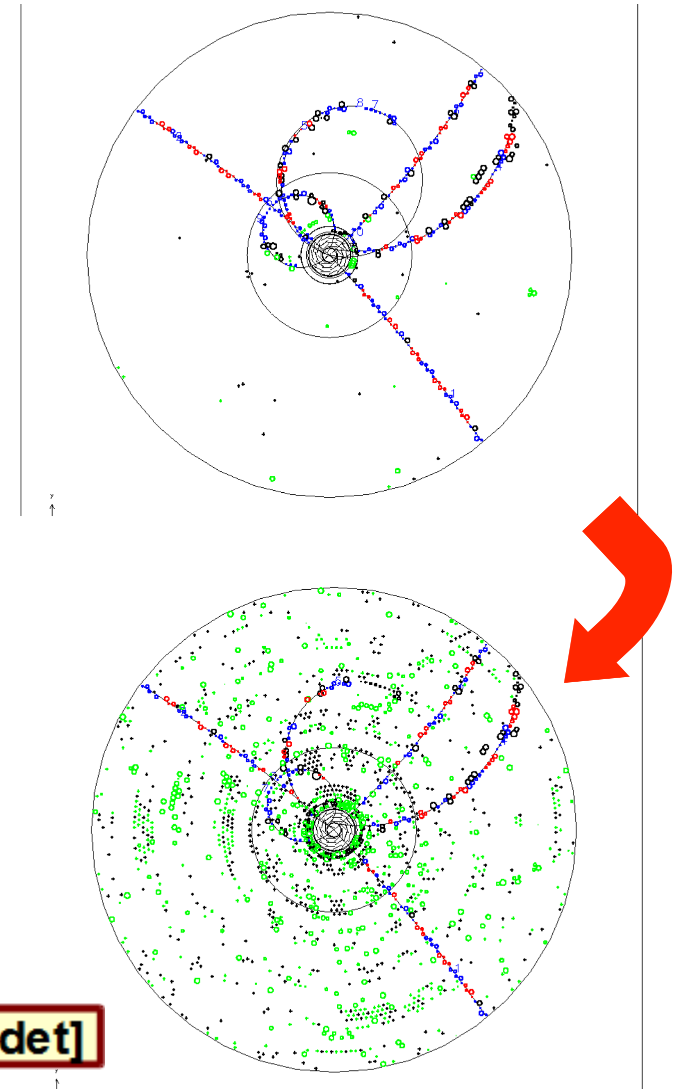
2011/July/20	LER	HER	unit	
E	4.000	7.007	GeV	
I	3.6	2.6	A	
Number of bunches	2,500			
Bunch Current	1.44	1.04	mA	
Circumference	3,016.315		m	
$\varepsilon_x/\varepsilon_y$	3.2(1.9)/8.64(2.8)	4.6(4.4)/11.5(1.5)	nm/pm	():zero current
Coupling	0.27	0.28		includes beam-beam
β_x^*/β_y^*	32/0.27	25/0.30	mm	
Crossing angle	83		mrad	
α_p	3.25×10^{-4}	4.55×10^{-4}		
σ_δ	$8.08(7.73)\times10^{-4}$	$6.37(6.31)\times10^{-4}$		():zero current
V_c	9.4	15.0	MV	
σ_z	6.0(5.0)	5(4.9)	mm	():zero current
ν_s	-0.0247	-0.0280		
ν_x/ν_y	44.53/44.57	45.53/43.57		
U_0	1.87	2.43	MeV	
$\tau_{x,y}/\tau_s$	43.1/21.6	58.0/29.0	msec	
ξ_x/ξ_y	0.0028/0.0881	0.0012/0.0807		
Luminosity	8×10^{35}		$cm^{-2}s^{-1}$	

Feb. 26, 2012 K. Akai (KEK), SuperKEKB Status, presented at the 6th Belle PAC 15

Requirements for the Belle II detector

Critical issues at L= 8 x $10^{35}/cm^2/sec$

- **Higher background ($\times$10-20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate ($\times$10)**
  - higher rate trigger, DAQ and computing
- **Special features required**
  - low *p* μ identification $\leftarrow$ s$\mu\mu$ recon. eff.
  - hermeticity $\leftarrow$ ν "reconstruction"



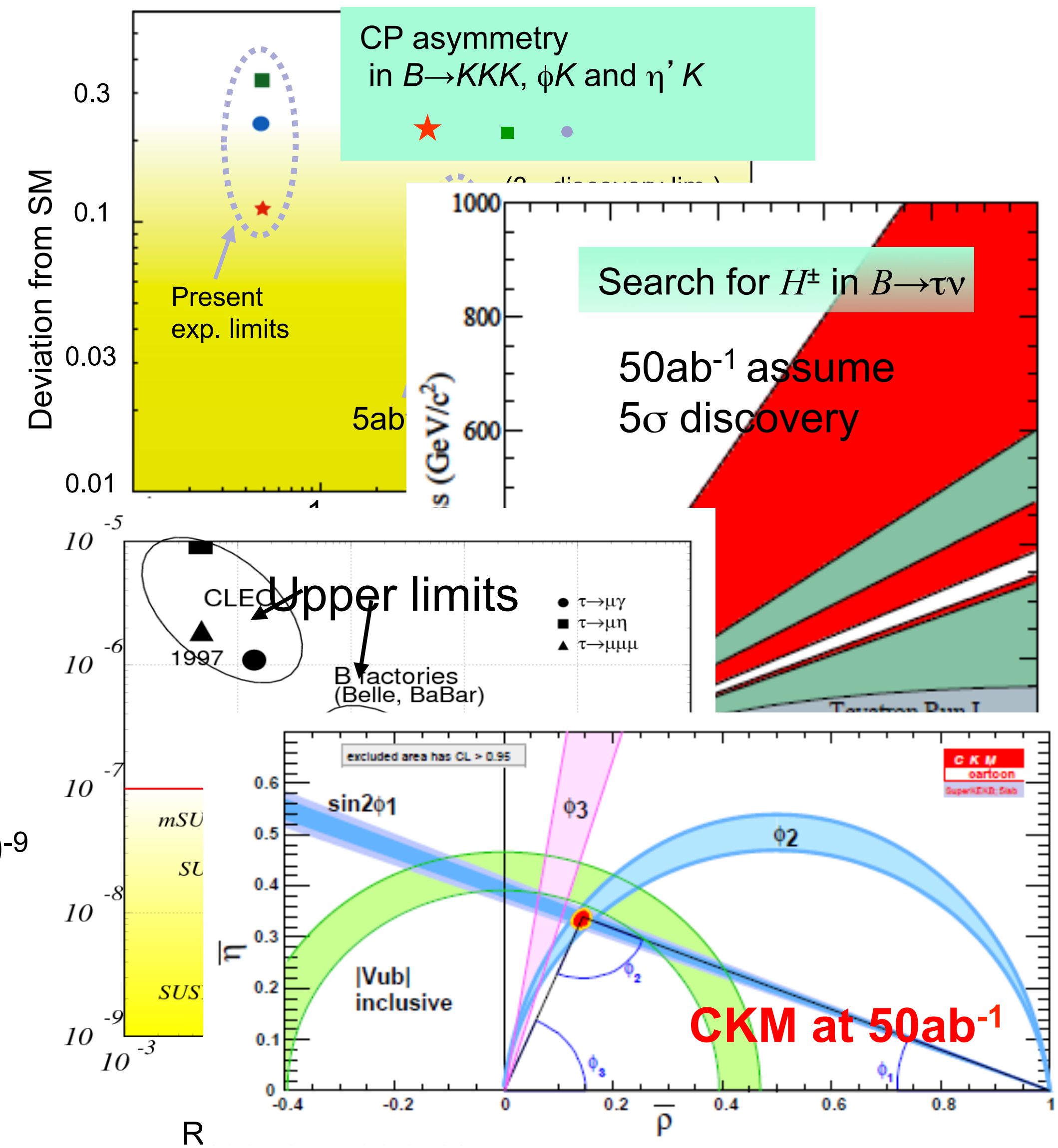
Result: significant upgrade

TDR published arXiv:1011.0352v1 [physics.ins-det]

Physics reach at a Super KEKB/Belle

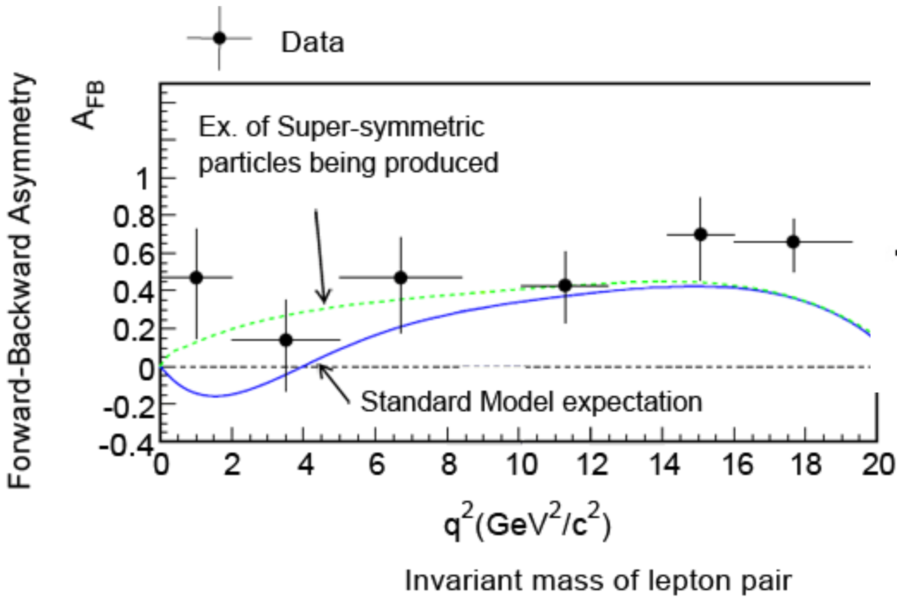
	Belle'06 (~$0.5ab^{-1}$)	$5ab^{-1}$	$50ab^{-1}$
$\Delta S(\phi K^0)$	0.22	0.073	0.029
$\Delta S(\eta' K^0)$	0.11	0.038	0.020
$\Delta S(K_S K_S K_S)$	0.33	0.105	0.037
$\Delta S(K_S \pi^0 \gamma)$	0.32	0.10	0.03
$Br(X_s \gamma)$	13%		
$A_{CP}(X_s \gamma)$	0.058	0.01	0.005
C_9 [$A_{FB}(K^*ll)$]	---	11%	4%
C_{10} [$A_{FB}(K^*ll)$]	---	13%	4%
$Br(B^+ \to K^+ \nu\nu)$	<9Br(SM)	$33ab^{-1}$ for 5σ discovery	
$Br(B^+ \to \tau\nu)$	3.5σ	10%	3%
$Br(B^+ \to \mu\nu)$	<2.4Br(SM)	$4.3ab^{-1}$ for 5σ discovery	
$Br(B^+ \to D\tau\nu)$	---	7.9%	2.5%
$Br(\tau \to \mu\gamma)$	<45	<30	<8
$Br(\tau \to \mu\eta)$	<65	<20	<4
$Br(\tau \to 3\mu)$	<209	<10	<1
$\Delta\sin 2\phi_1$	0.026	0.016	0.012
$\Delta\Phi_2$ ($\rho\pi$)	68°—95°	3°	1°
$\Delta\Phi_3$(Dalitz)	20°	7°	2.5°
ΔV_{ub} (incl.)	7.3%	6.6%	6.1%

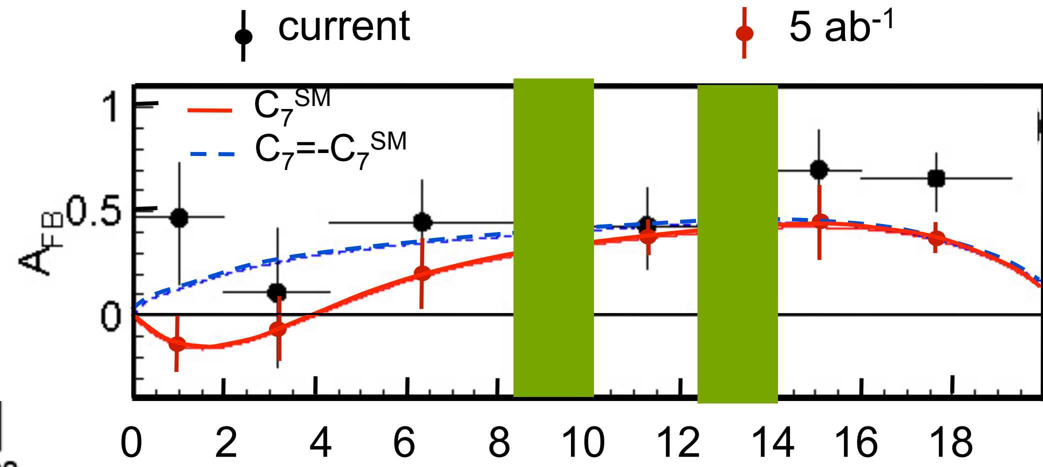
$\}$ X10^{-9} (for the τ rows)



Physics at Super B Factory [hep-ex/0406071]   Currently being updated.

$A_{FB}(B \rightarrow K^* l^+ l^-)[q^2]$ at a Super B Factory





- Zero-crossing q^2 for A_{FB} will be determined with a 5% error with 50ab^{-1}.

Strong competition from LHCb and ATLAS/CMS

Comparison with the LHCb

e^+e^- has advantages in…	LHCb has advantages in…
CPV in $B \to \phi K_S$, $\eta' K_S$,…	CPV in $B \to J/\psi K_S$
CPV in $B \to K_S \pi^0 \gamma$	Most of B decays not including ν or γ
$B \to K\nu\nu$, $\tau\nu$, $D^{(*)}\tau\nu$	Time dependent measurements of B_S
Inclusive $b \to s\mu\mu$, *see*	$B_{(s,d)} \to \mu\mu$
$\tau \to \mu\gamma$ and other LFV	B_c and bottomed baryons
$D^0\overline{D^0}$ mixing	

Complementary!!

Luminosity gain and upgrade items (preliminary)

3 years shutdown

Item	Gain	Purpose
beam pipe	x 1.5	high current, short bunch, electron cloud
IR($\beta^*_{x/y}$=20cm/3 mm)	x 1.5	small beam size at IP
low emittance(12 nm) & $\nu_x \rightarrow 0.5$	x 1.3	mitigate nonlinear effects with beam-beam
crab crossing	x 2	mitigate nonlinear effects with beam-beam
RF/infrastructure	x 3	high current
DR/e^+ source	x 1.5	low β^* injection, improve e^+ injection
charge switch	x ?	electron cloud, lower e^+ current

Major KEKB components

Item	Object	Oku-yen ~1.0 M$	Luminosity
New beam pipes	Enable high current Reduce e-cloud	178 (incl. BPM, magnets, etc.)	x 1.5
New IR	Small β^*	31	x 2
e+ Damping Ring	Allow injection with small increase e+ capture	40 incl. linac upgrade	if not, x 0.75
More RF and cooling systems	High current	179 (incl. facilities)	x 3
Crab Cavities	Higher beam-beam param.	15	x (2 – 4)

Items are interrelated.

- **Tunnel already exists.**
- **Most of the components (magnets, klystrons, etc.) will be re-used.**

Upgrade from KEKB to SuperKEKB

- smaller beam size, more current
  → x40 higher luminosity

Machine parameter	HER (KEKB)	LER (KEKB)	HER (SuperKEKB)	LER (SuperKEKB)
Vertical beam size	0.94μm	0.94μm	59nm	59nm
Beam current(mA)	1188	1637	2600	3600
luminosity($cm^{-2}s^{-1}$)	2.1×10^{34}		8×10^{35}	

Introduction: background sources

- **Touschek effect ($\propto I \times E^{-3}$)**
  - Intra-bunch scattering → energy increase & decrease
  - Significant in low energy ring (LER)
- **Beam-gas scattering ($\propto P \times I$)**
  - Collision with remaining gas
  - Type 1: Coulomb scattering → direction change
  - Type 2: Bremsstrahlung → energy decrease
- **Synchrotron Radiation ($\propto E^2 \times B^2$)**
  - Type 1: Upstream (SR hit Be beam pipe directly)
  - Type 2: Backscatter (SR hit downward beam pipe, then reflected back to IP)
- **Radiative Bhabha, other QED process ($\propto L$)**
  - Type 1: radiated gamma + magnet Fe → neutron, main bkg source for KLM
  - Type 2: e+,e- lose energy→off-trajectry→ hit downward beam pipe → shower
- **Beam-beam effect**
  - Injected particles with a large horizontal oscillation (due to injection error) may be lost

BG estimation at SuperKEKB

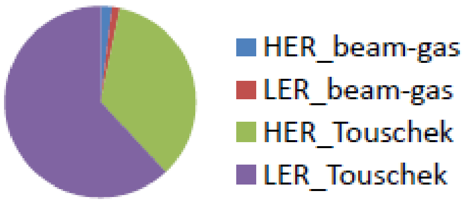
Assumptions:

- Use $\tau_{Touschek}$ from optics simulation: 8.7min(LER), 15.3min(HER)
- Use same $\tau_{beam\text{-}gas}$ from KEKB machine study: 800min(LER), 3400min(HER)
- Use same $k_{Touchek}$, $k_{beam\text{-}gas}$ from KEKB machine study

CDC 400+-40 uA (cf. ~20uA@2003)

→ ~120 kHz/wire or less at layer 6 or outer

CDC



LER/total: 60~70%,
Touschek/total: >90%

ECL 60+-5 GeV/event

→ wave form fitting (x1/7) → ~9 GeV/event

SVD 6000+-600 event/trigger

→ shorter integration time (2μs→75ns)

→ ~400 event/trigger, occupancy: 2.7%+-0.3% <10% (SVD2)

PXD (estimated from SVD)

→ 3.2M pixels in 1st layer, shaping time: 20μs

→ Occupancy = 1.5±0.1%

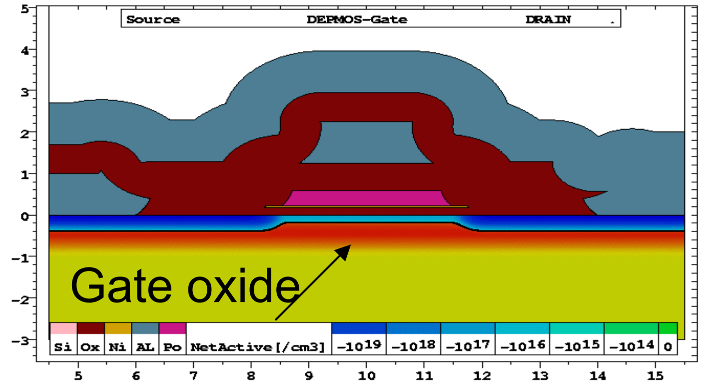
(not including low-pt tracks or <few keV gammas)

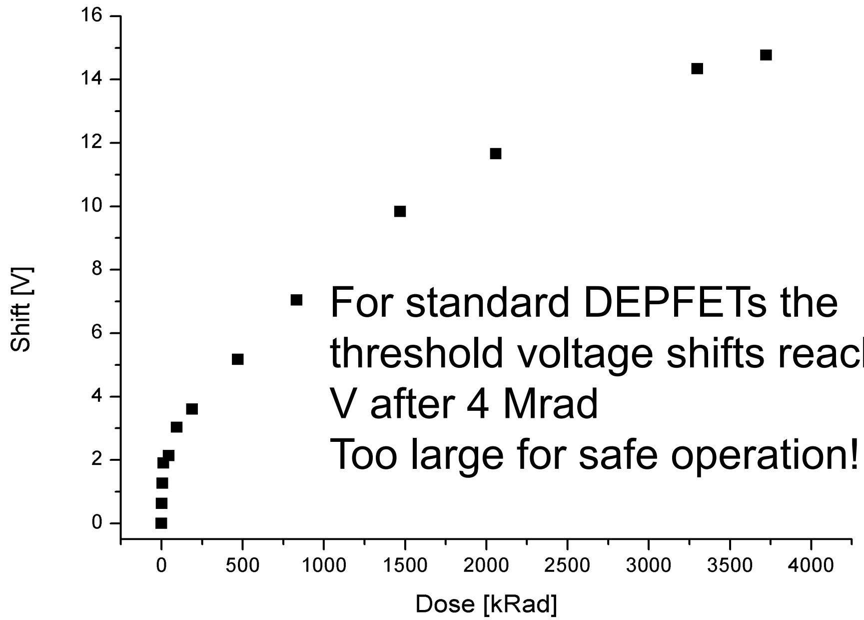
PXD 1st: 14mm
SVD2 1st : 30mm

SR, Rad.Bhabha, beam-beam BG are not included

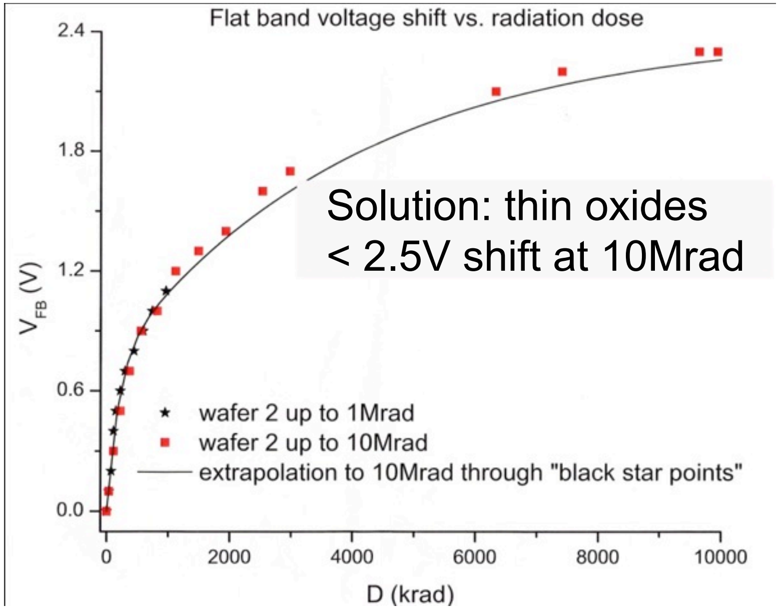
DEPFET Radiation Damage

DEPFET based on a MOS structure problem with ionizing radiation:
Creation of fixed (positive) charges in the oxide layer and at the interface
Attracts electrons at the Si/SiO_2 interface
Need more negative gate voltages to compensate
=> Shift of transistor threshold





- For standard DEPFETs the threshold voltage shifts reach 14 V after 4 Mrad
Too large for safe operation!



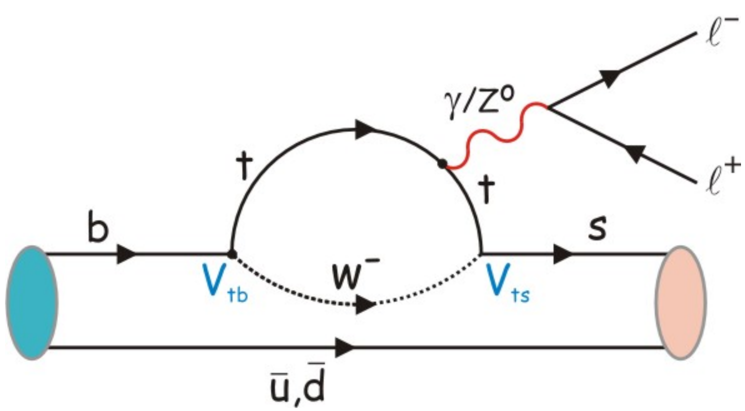
Solution: thin oxides
< 2.5V shift at 10Mrad

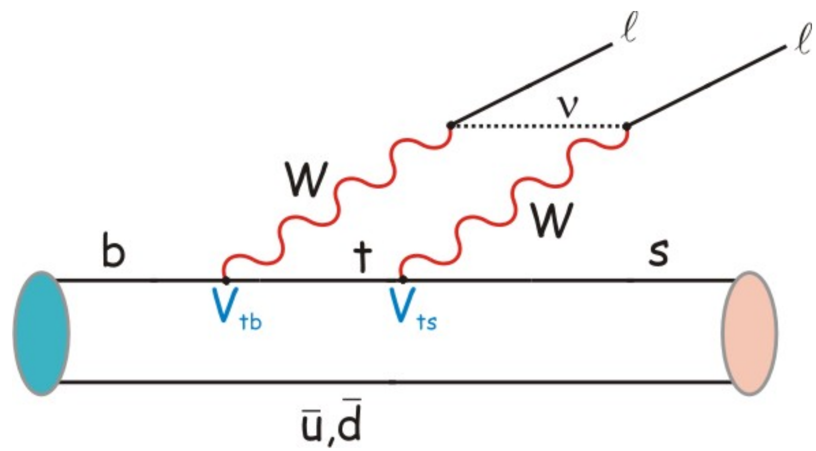
62

Belle II basic parameters (TDR)

Component	Type	Configuration	Readout	Performance
Beam pipe	Beryllium double-wall	Cylindrical, inner radius 10 mm, 10 μm Au, 0.6 mm Be, 1 mm coolant (paraffin), 0.4 mm Be		impact parameter resolution $\sigma_{z0} \sim 20\ \mu$m (PXD and SVD)
PXD	Silicon pixel (DEPFET)	Sensor size: 15×100 (120) mm^2 pixel size: 50×50 (75) μm^2 2 layers: 8 (12) sensors	10 M	
SVD	Double sided Silicon strip	Sensors: rectangular and trapezoidal Strip pitch: 50(p)/160(n) - 75(p)/240(n) μm 4 layers: 16/30/56/85 sensors	245 k	
CDC	Small cell drift chamber	56 layers, 32 axial, 24 stereo r = 16 - 112 cm - 83 $\leq z \leq$ 159 cm	14 k	$\sigma_{r\phi} = 100\ \mu$m, $\sigma_z = 2$ mm $\sigma_{p_t}/p_t = \sqrt{(0.2\% p_t)^2 + (0.3\%/\beta)^2}$ $\sigma_{p_t}/p_t = \sqrt{(0.1\% p_t)^2 + (0.3\%/\beta)^2}$ (with SVD) $\sigma_{dE/dx} = 5\%$
TOP	RICH with quartz radiator	16 segments in ϕ at $r \sim 120$ cm 275 cm long, 2 cm thick quartz bars with 4x4 channel MCP PMTs	8 k	$N_{p.e.} \sim 20$, $\sigma_t = 40$ ps K/π separation : efficiency > 99% at < 0.5% pion fake prob. for $B \to \rho\gamma$ decays
ARICH	RICH with aerogel radiator	4 cm thick focusing radiator and HAPD photodetectors for the forward end-cap	78 k	$N_{p.e.} \sim 13$ K/π separation at 4 GeV/c: efficiency 96% at 1% pion fake prob.
ECL	CsI(Tl) (Towered structure)	Barrel: r = 125 - 162 cm End-cap: z = -102 cm and +196 cm	6624 1152 (F) 960 (B)	$\frac{\sigma E}{E} = \frac{0.2\%}{E} \oplus \frac{1.6\%}{\sqrt[4]{E}} \oplus 1.2\%$ $\sigma_{pos} = 0.5\ \mathrm{cm}/\sqrt{E}$ (E in GeV)
KLM	barrel: RPCs end-caps: scintillator strips	14 layers (5 cm Fe + 4 cm gap) 2 RPCs in each gap 14 layers of $(7-10) \times 40$ mm^2 strips read out with WLS and G-APDs	θ: 16 k, ϕ: 16 k 17 k	$\Delta\phi = \Delta\theta = 20$ mradian for K_L ~ 1 % hadron fake for muons $\Delta\phi = \Delta\theta = 10$ mradian for K_L $\sigma_p/p = 18\%$ for 1 GeV/c K_L

Another FCNC decay: $B \rightarrow K^* l^+ l^-$





$b \rightarrow s\, l^+l^-$ was first measured in $B \rightarrow K\, l^+l^-$ by Belle (2001).

Important for further searches for the physics beyond SM

Particularly sensitive: backward-forward asymmetry in $K^*\, l^+l$

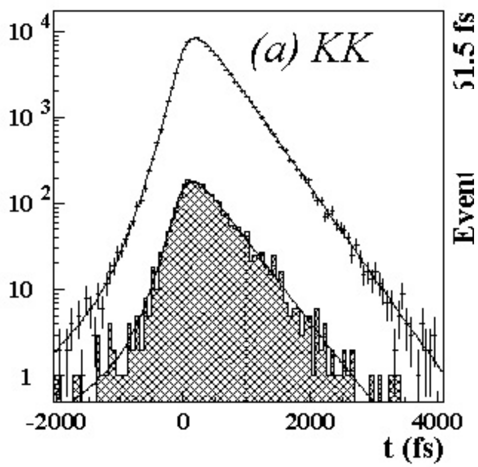
$$A_{FB} \propto \Re\left[C_{10}^*\left(sC_9^{eff}(s) + r(s)C_7\right)\right]$$

C_i : Wilson coefficients, abs. value of C_7 from $b \rightarrow s\gamma$

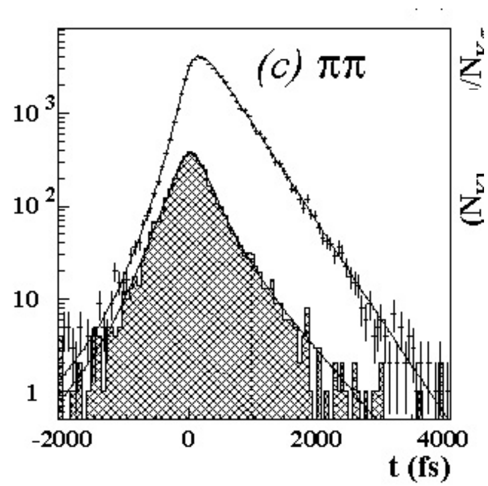
s=lepton pair mass squared

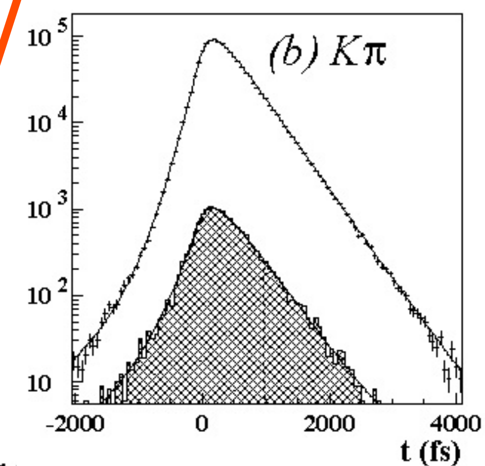
D^0 mixing in K^+K^-, $\pi^+\pi^-$

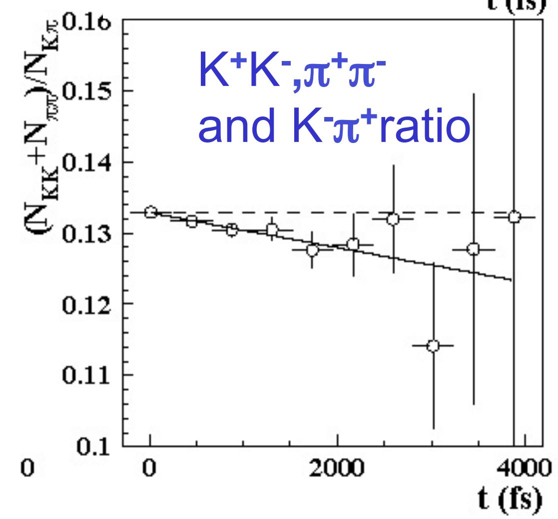
Decay time distributions for KK, ππ, Kπ



+







K^+K^-,$\pi^+\pi^-$ and $K^-\pi^+$ratio

Difference of lifetimes visually observable

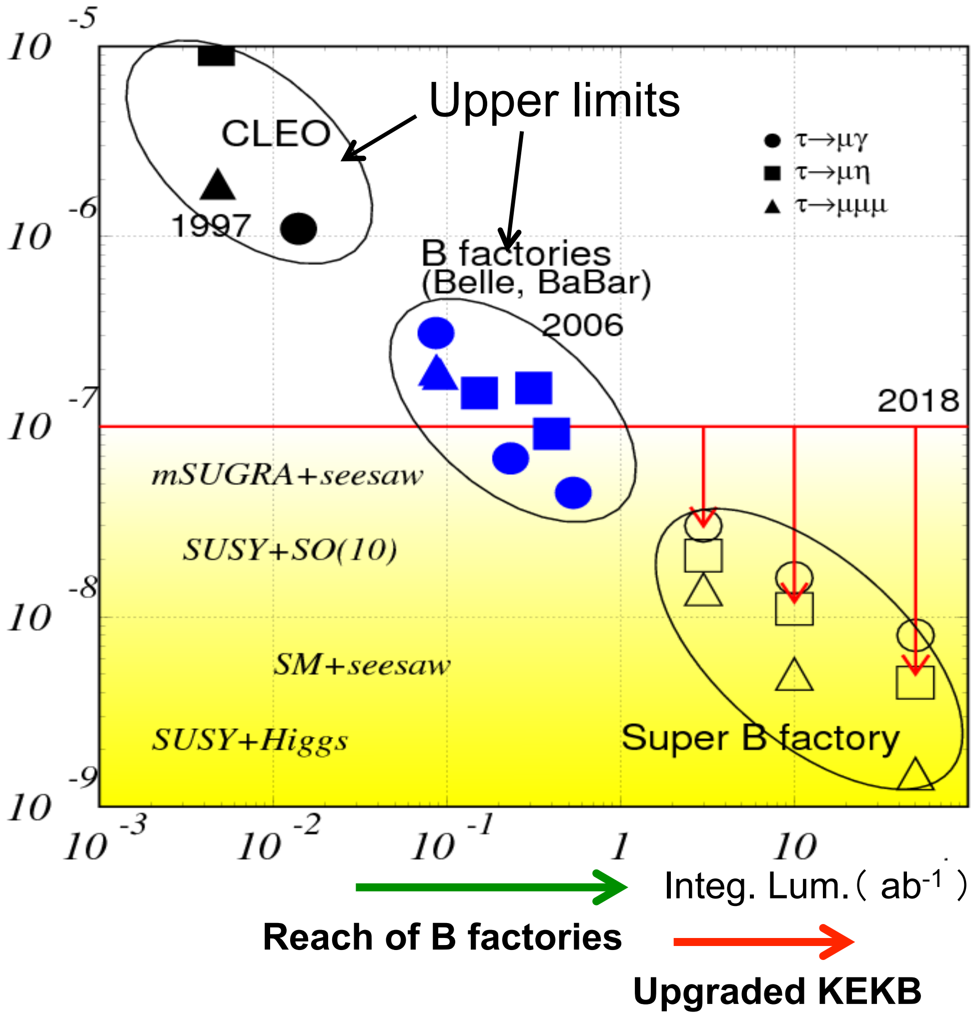
in the ratio of the distributions →

Real fit: $y_{CP} = (1.31 \pm 0.32 \pm 0.25)$ %

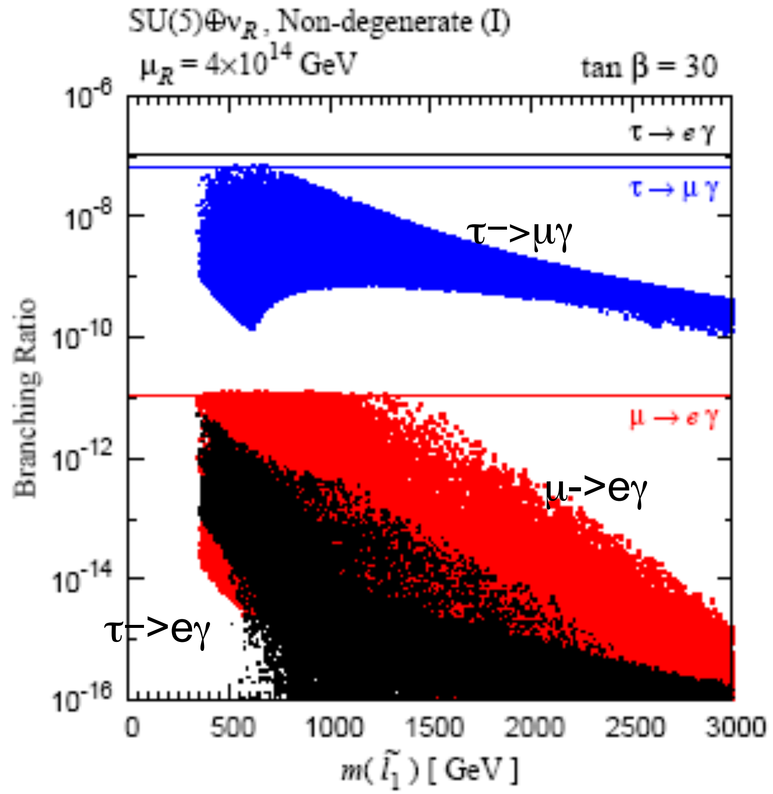
An observation of CP violations would be a clear sign of new physics

Precision measurements of τ decays

LF violating τ decay?

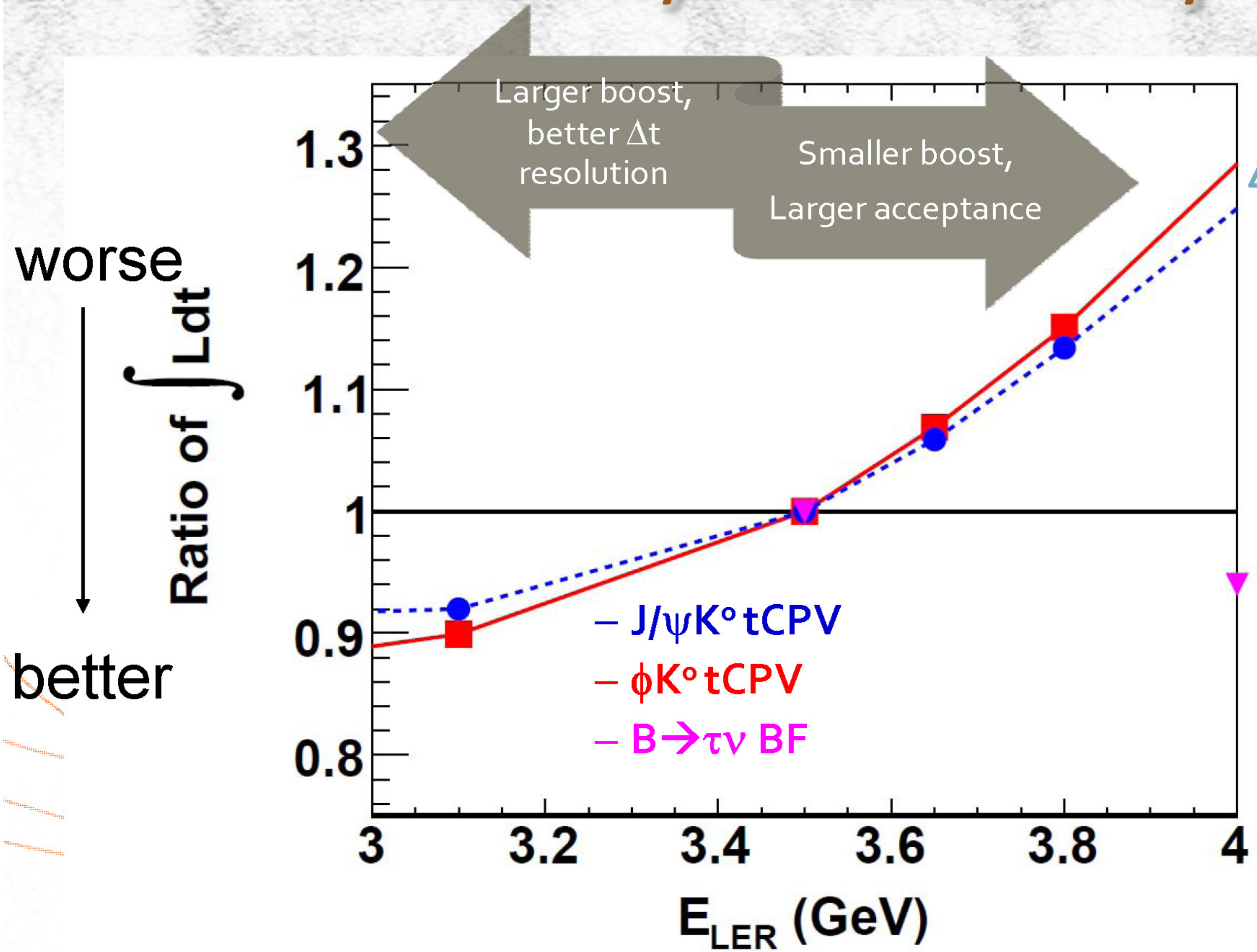


Theoretical predictions compared to present experimental limits



T.Goto et al., 2007

Beam Energy Asymmetry and Physics Sensitivity



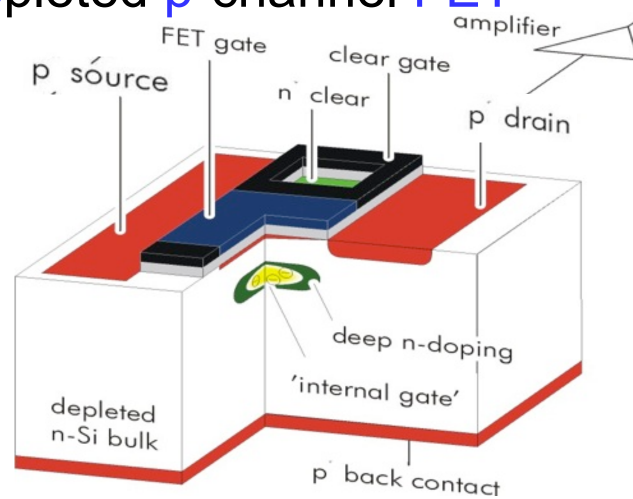
25% more Luminosity needed for the same sensitivity.

6% less Luminosity needed for the same sensitivity.

DEPFET Principle

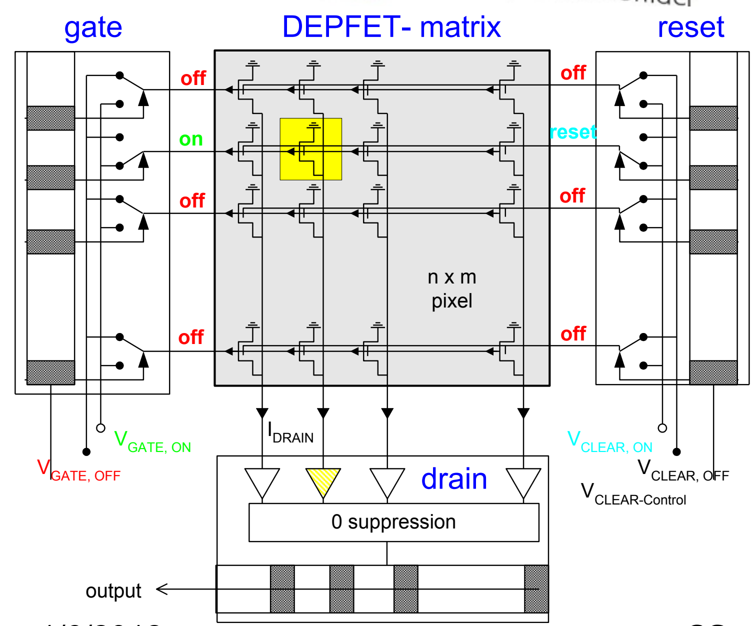
•p-channel FET on a completely depleted bulk
•A deep n-implant creates a potential minimum for electrons under the gate
•("internal gate")
•Signal electrons accumulate in the internal gate and modulate the transistor current (g_q ~ 400 pA/e$^-$)
•Accumulated charge can be removed by a clear contact ("reset")
•Invented in MPI Munich

Depleted p-channel FET



Fully depleted:
→ large signal, fast signal collection
Low capacitance, internal amplification → low noise

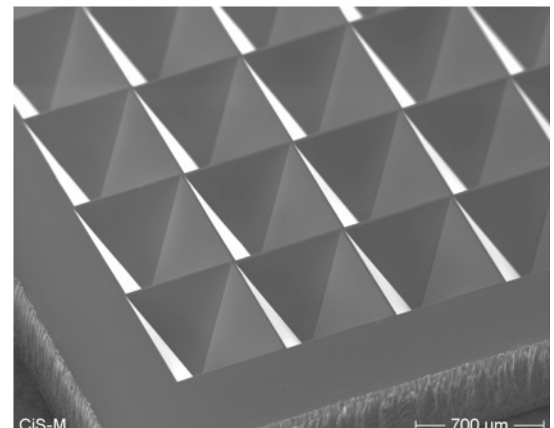
Transistor on only during readout: low power
Complete clear → no reset noise

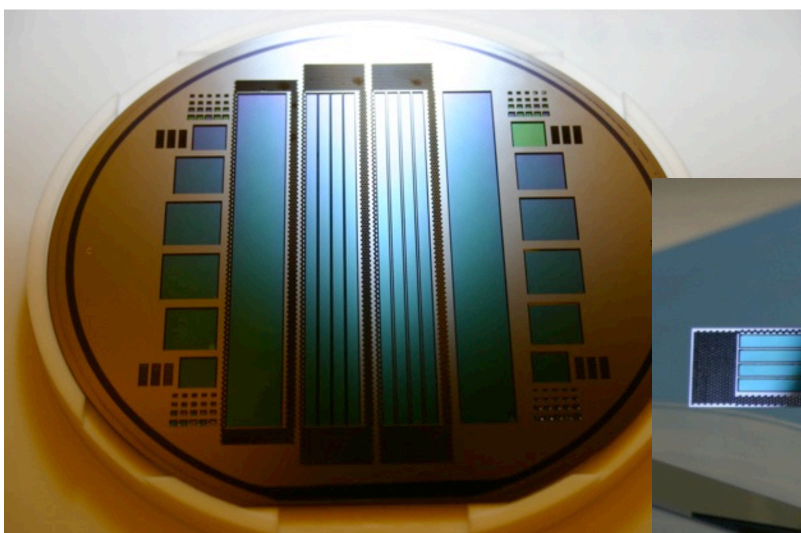


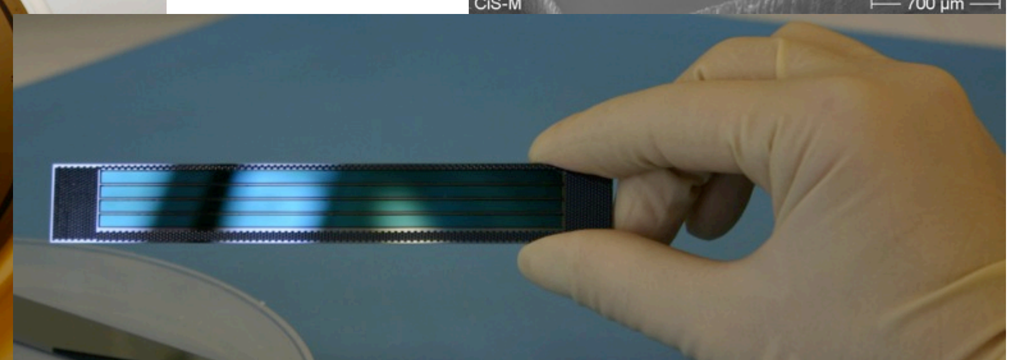
Thinning Technology

1. implant backside on sensor wafer
2. bond sensor wafer to handle wafer
3. thin sensor side to desired thickness
4. process DEPFETs on top
5. structure resist, etch backside up to oxide/implant

- Sensor wafer bonded on “handle” wafer.
- Rigid frame for handling and mechanical stiffness
- 50 μm thickness produced
- Samples of 10x1.3 cm^2 & frame of 1 & 3 mm width
- Electrical properties ok (diodes)







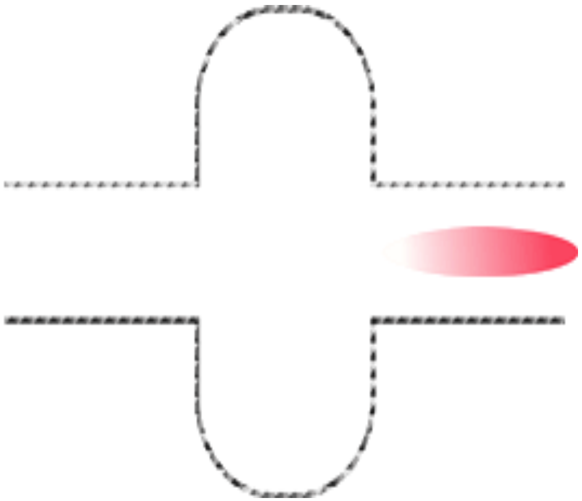
European groups of Belle-II

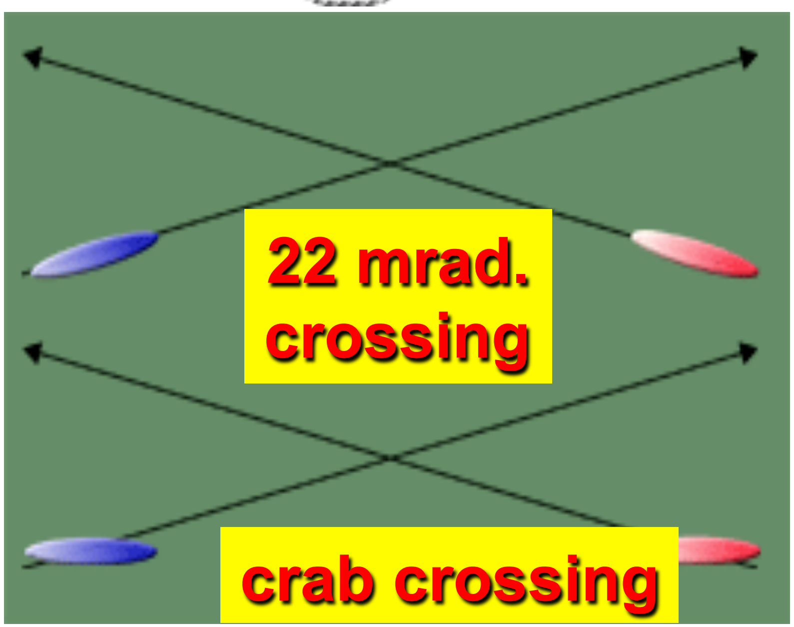
The European groups have major responsibilities in some essential detector systems:

- Pixel vertex detector (DEPFET)
- Silicon strip vertex detector
- Particle identification systems (endcap Aerogel RICH, barrel Time-of-Propagation counter)
- Electromagnetic calorimeter
- Muon detector based on scintilator strips

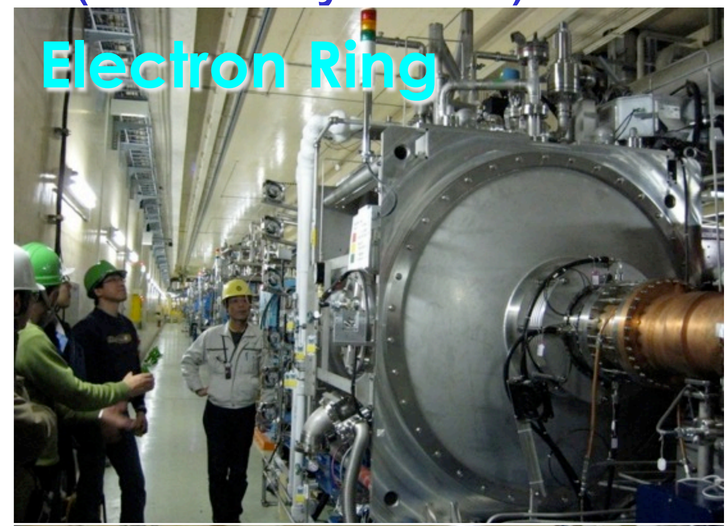
They are also contributing substantially to the computing and software, as well as to the set-up of the physics program.

The key factor in KEKB performance: crab cavity





Installed in the KEKB tunnel
(February 2007)

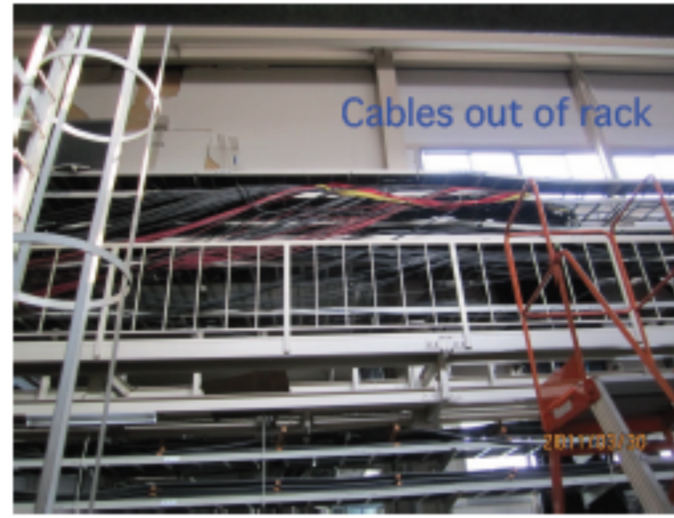


SuperKEKB parameters compared with SuperB

		SuperB (Baseline)		SuperKEKB	
Parameter	units	HER (e+)	LER (e-)	HER (e-)	LER (e+)
Circumference	m	1258.4		3016.3	
Energy	GeV	6.7	4.18	7	4
X angle (full)	mrad	66		83	
β_x at IP	cm	2.6	3.2	2.4	3.2
β_y at IP	cm	0.0252	0.0206	0.041	0.027
ε_x	nm	2.0	2.41	2.4	3.1
Emittance ratio	%	0.25	0.25	0.35	0.40
σ_z (full)	mm	5	5	5	6
I	mA	1892	2410	2620	3600
σ_x at IP	μm	7.211	8.782	7.75	10.2
σ_y at IP	μm	0.035	0.035	0.059	0.059
ξ_x		0.0021	0.0033	0.0028	0.0028
ξ_y		0.0978	0.0978	0.0875	0.09
Luminosity	$cm^{-2}\ s^{-1}$	1×10^{36}		0.8×10^{36}	

Next Generation

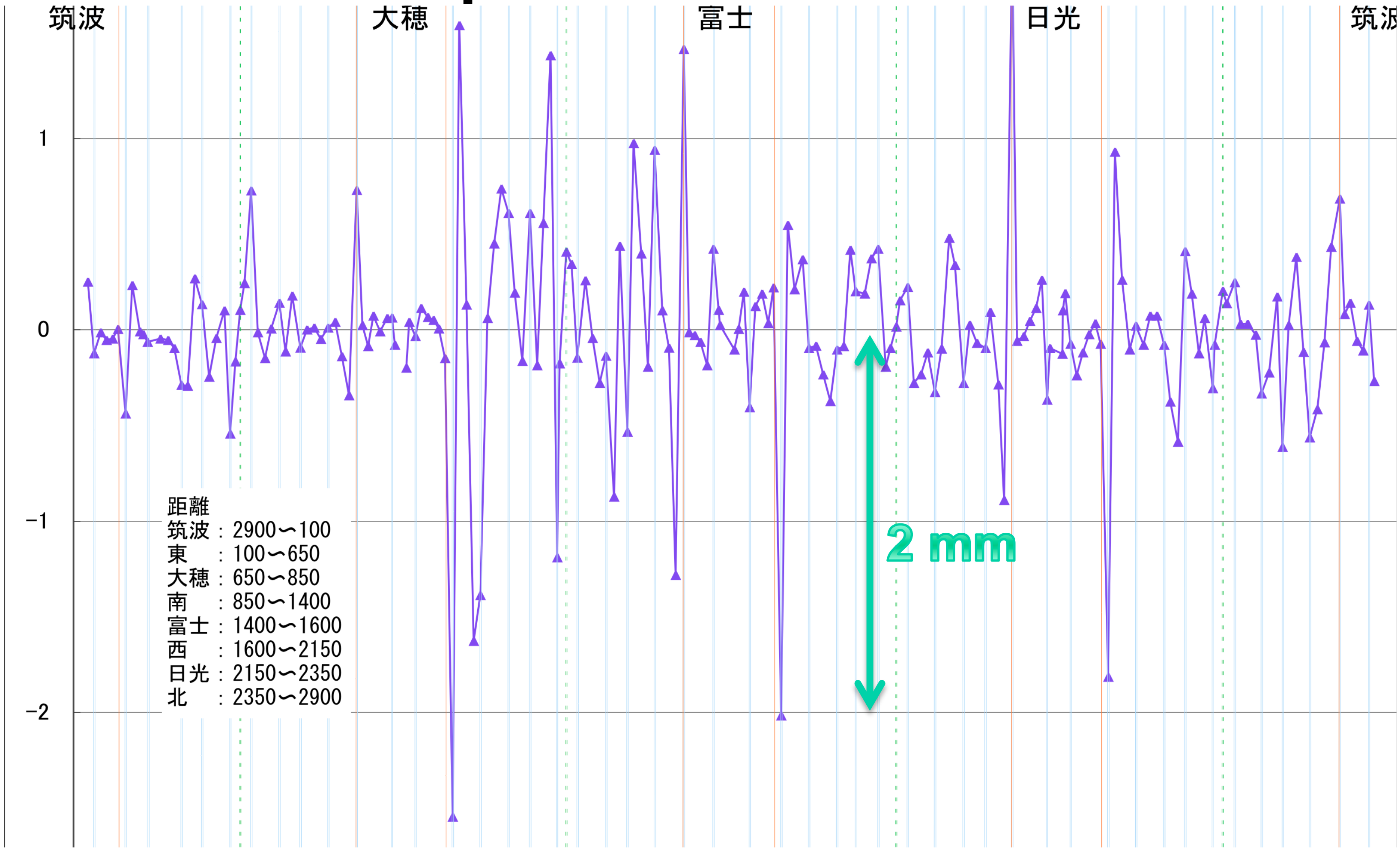
D5 power supply building



Panels and floor in the control room

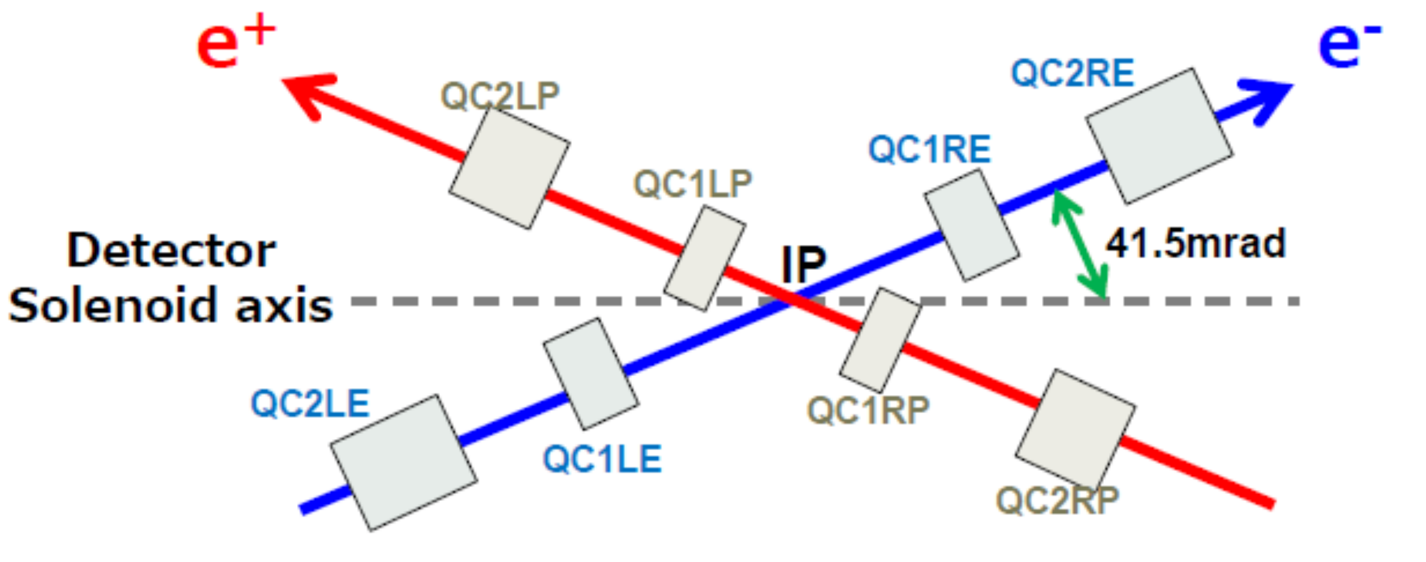
The 1400 tons of Belle moved by ~6cm (most probably by 20cm in one direction, and 14cm back)...

KEKB magnets displacement after the quake in March 2011



Belle to Belle II Upgrade

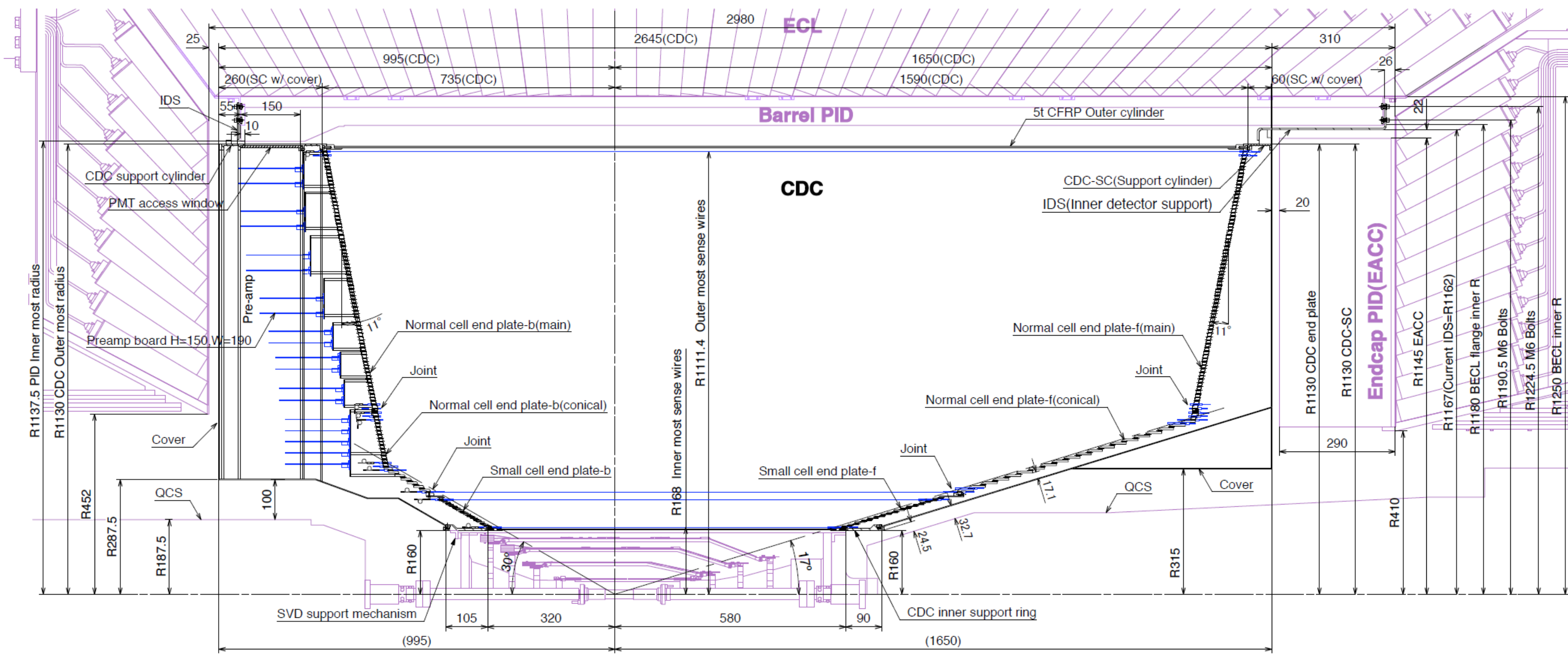
- New final focusing system based on the nano-beam scheme has been designed.
  - Consists of **8 superconducting magnets**
  - Final focusing Q-magnets **for each beam**
  - **Crossing angle 83 mrad** to bring the FF magnets closer to IP



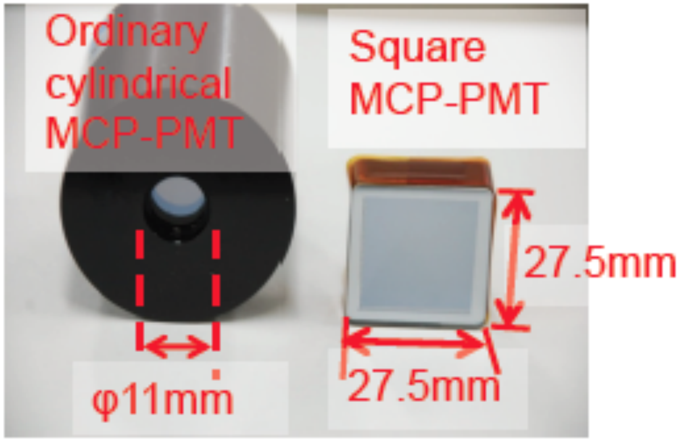
N.Ohuchi

Main Features

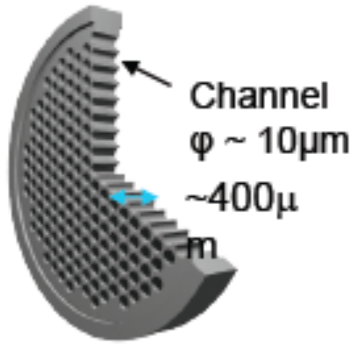
- **Larger outer radius thanks to a compact BPID**
- **Larger inner radius to make SVD space more and to avoid high radiation region**
- Conical endplates will be machined to meet final focusing magnets.
- A small cell chamber will be installed as same as the Belle CDC.
- **New compact electronics boards are located near backward end plate.**
- **3D charged trigger scheme will be adopted.**



Square-shaped MCP-PMT: SL10

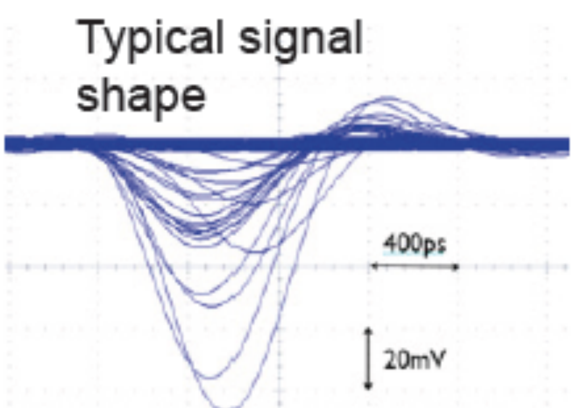


Co-development with Hamamatsu Photonics K.K.

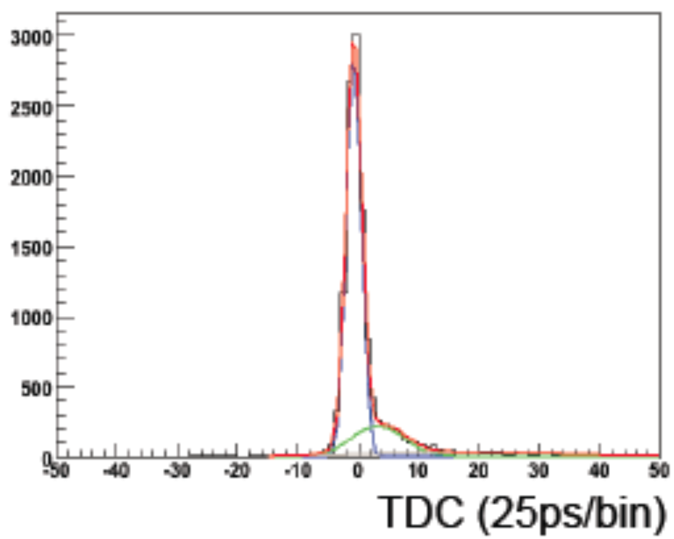


MCP(Micro channel plate)

Catalog spec	
Photo-cathode	Multi-alkali / Super bi-alkali
MCP Channel φ	10μm
MCP bias angle	13°
MCP thickness	400μm
MCP layers	2
Al protection layer	On 2nd MCP
Anode channels	1×4 / 4×4
Sensitive region	64%
HV	~ 3000 – 3500 V



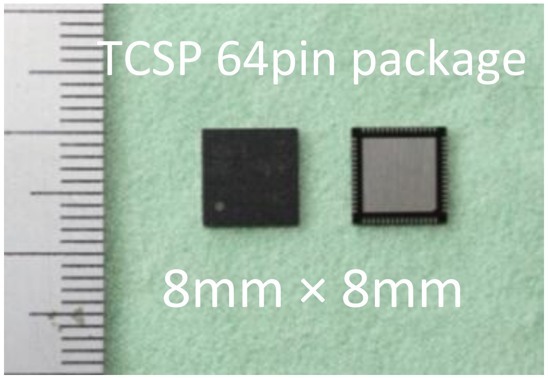
σ=34.2±0.4ps



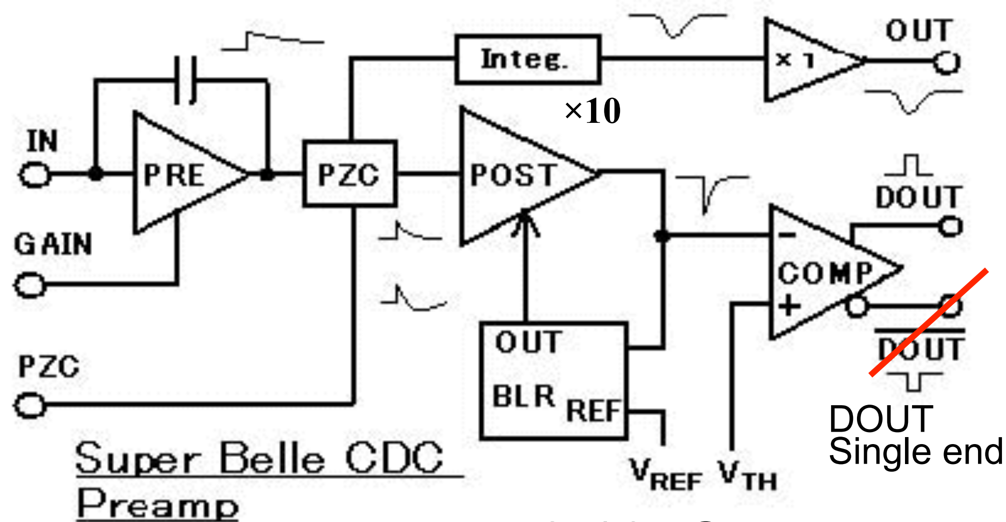
- Large effective area
- Position information
- Single photon detection
- Fast raise time: ~400ps
- Gain: >$1x10^6$ at B=1.5T
- T.T.S.(single photon): ~35ps at B=1.5T

ASIC

Amp-Shaper-Discriminator (ASD) chip



Level shift
to match FADC input

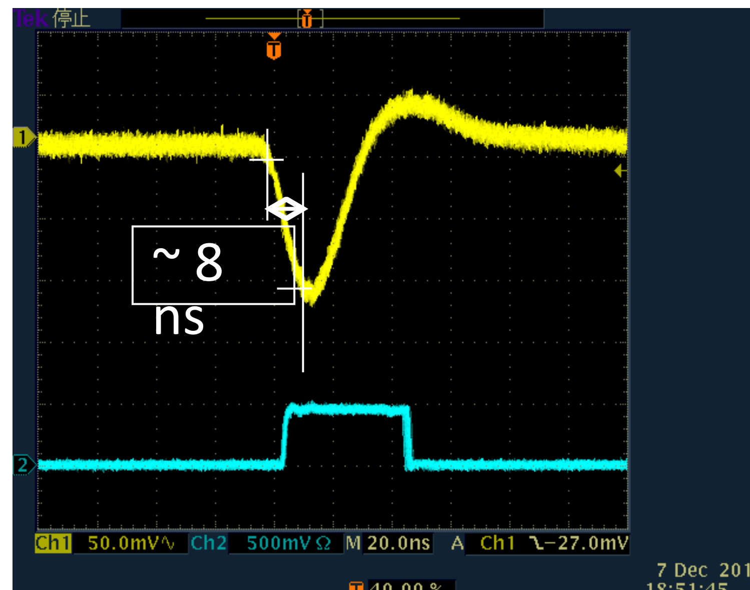


DOUT
Single end

Input : 0.13pC

Specifications

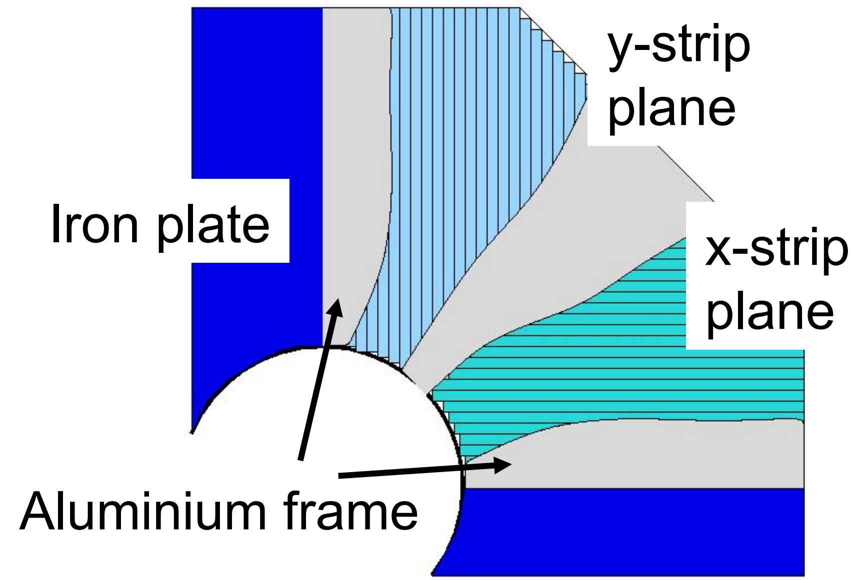
Parameter	Value
# of Chs.	8
Analog gain	-1.1V/pC
Peaking time	8 ns
Noise	4000 e @Cd=20 pF
Power	+5V, +3.3V
Power consumption	34mW/ch
Process	BiCMOS 0.8 μm

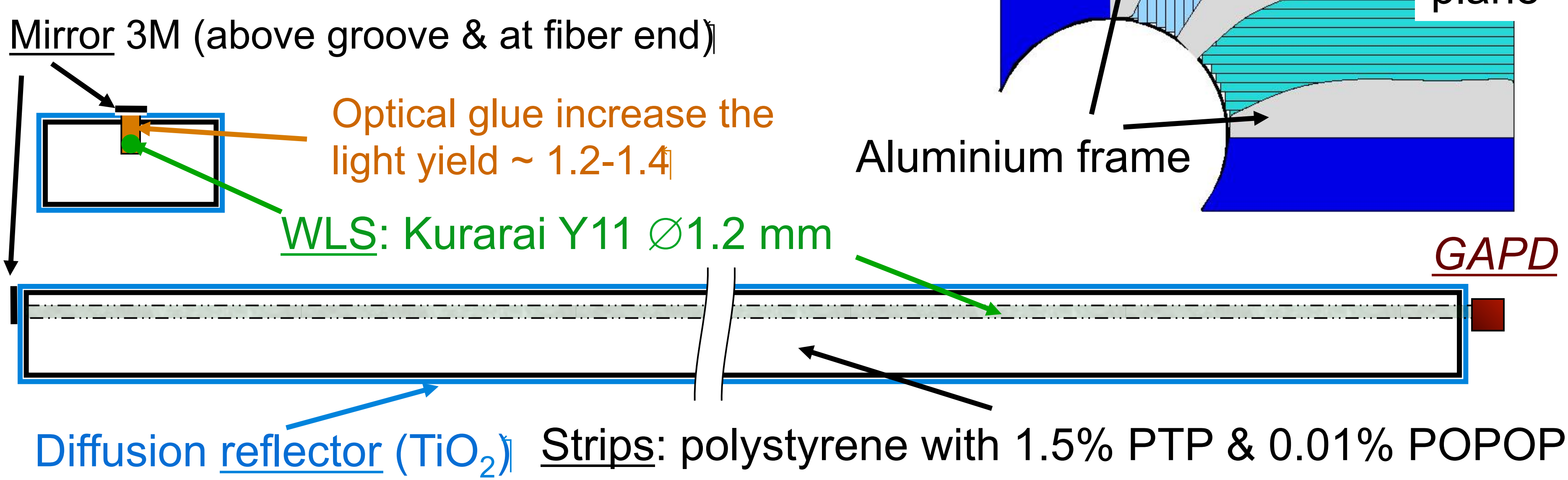


KLM upgrade

Scintillator-based KLM (endcap)

- Two independent (x and y) layers in one superlayer made of orthogonal strips with WLS read out
- Photo-detector = avalanche photodiode in Geiger mode (SiPM)
- ~120 strips in one 90º sector (max L=280cm, w=25mm)
- ~30000 read out channels
- Geometrical acceptance > 99%





Neutron rates on BKLM

LER Touschek only

Simulation

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

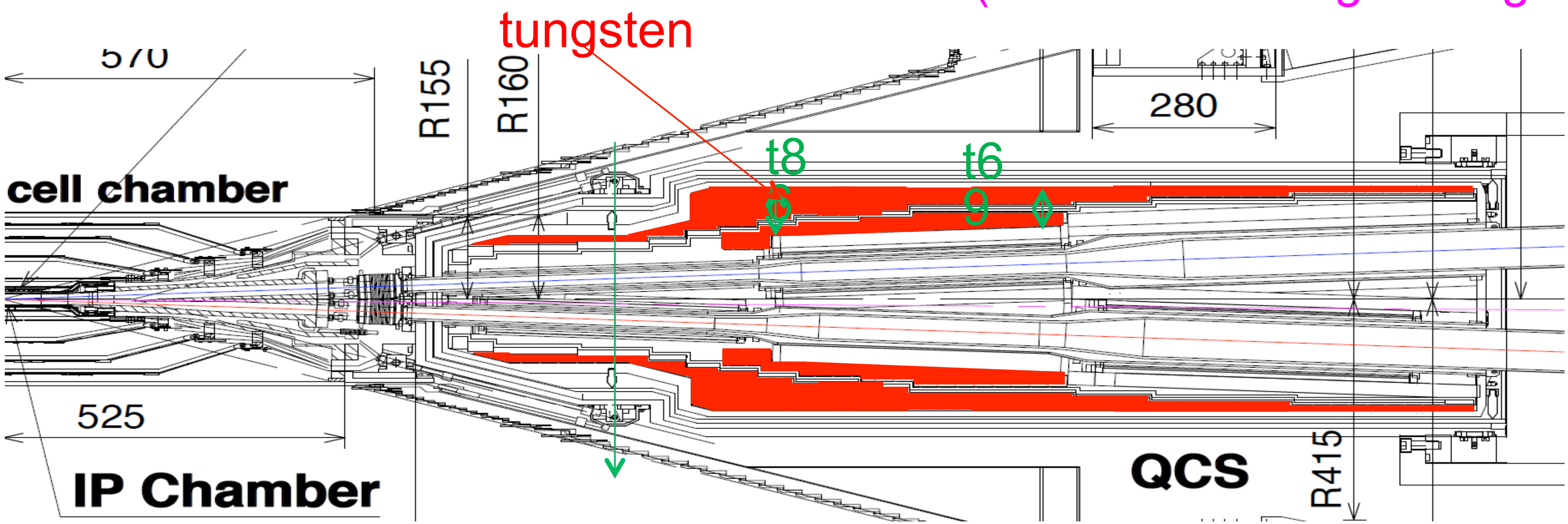
replaced by scintillator

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

2011/11/11

Latest final Q-magnet design

(a concrete design being ass



Neutron flux

1MeV equivalent rate

1 year = 10^7 sec

	Region	Simulation [x10^{11} eqn/cm^2/ year]	R&D assumption [x10^{11} eqn/cm^2/ year]	Current tolerance
PXD	DHP,DCD, Swithers	1	10	OK up to 100x10^{11} eqn/cm^2
SVD	Sensors, chips	10	-	Should be OK, irradiation test ongoing
CDC	Readout Boards	4	1	Tested up to 10x10^{11} eqn/cm2
TOP	Readout electronics	0.35	1	Tested up to 10x10^{11} eqn/cm2 ASIC not tested yet
ARIC H	HAPD	2.5 (inner rings)	0.4	Tested up to 4x10^{11} eqn/cm2 Start to see degradation
ECL	Crystals	2.5	10	OK up to 100x10^{11} eqn/cm2 (by Kuzmin)
ECL	Diodes	1.8 (f-endcap)	1	OK up to 10x10^{11} eqn/cm2 (by Kuzmin, dark current increased
BKLM	SiPMs	0.04	-	

Radiation dose

1 year = 10^7 sec

	Region	Simulation [Gy/year]	R&D assumption [Gy/year]	Current tolerance
PXD	Sensor	19k	>19k	Tested up to 100kGy(=10Mrad) 200kGy would be also OK
SVD	APV	3k	10k	OK up to 100kGy (by Peter)
CDC	Readout boards	80	100	Tested up to 1000Gy New SFP survive w/o communication
TOP	Readout electronics	7	30	Tested up to 300Gy for FPGA and optical transceiver/fiber, ASIC not tested yet
ARICH	HAPDs	50	100	APD tested up to 1000Gy
ECL	Crystals	41 (fwd-endcap)	10	OK up to 100Gy (by Kuzmin) (TDR said 36Gy)
ECL	Diodes	35 (fwd-endcap)	70	OK up to 700Gy (by Kuzmin)
BKLM	SiPM	Safe (Piilonen)	-	-

Detector performance

	Simulation	Requirement
PXD occupancy	**0.64%** (2-photon) + **0.15%** (Touschek LER)	< 3%
SVD occupancy	~4% (z) / 7% (r-phi) assuming 5000e- threshold and 50ns shaping time	< ~10%
CDC hit rate	280kHz/wire	< 200kHz/wire
TOP K/pi separation	K/pi separation remains good	
TOP photo-cathode aging	Photoelectron flux: 20MHz/PMT	<1MHz/PMT
ECL	16 fake clusters in 100ns time window 11 MeV pile up noise in f-endcap	Belle1: 6 fake clusters Belle1: 0.8 MeV pile up
BKLM	Need to replace layer 0 and 1 with scintillator. It also recovers efficiency of layer 2 (0.66->0.91), layer 3(0.78->0.94)	
EKLM	Strip occupancy: 20kHz	< 200KHz

Belle II Collaboration (Europe)

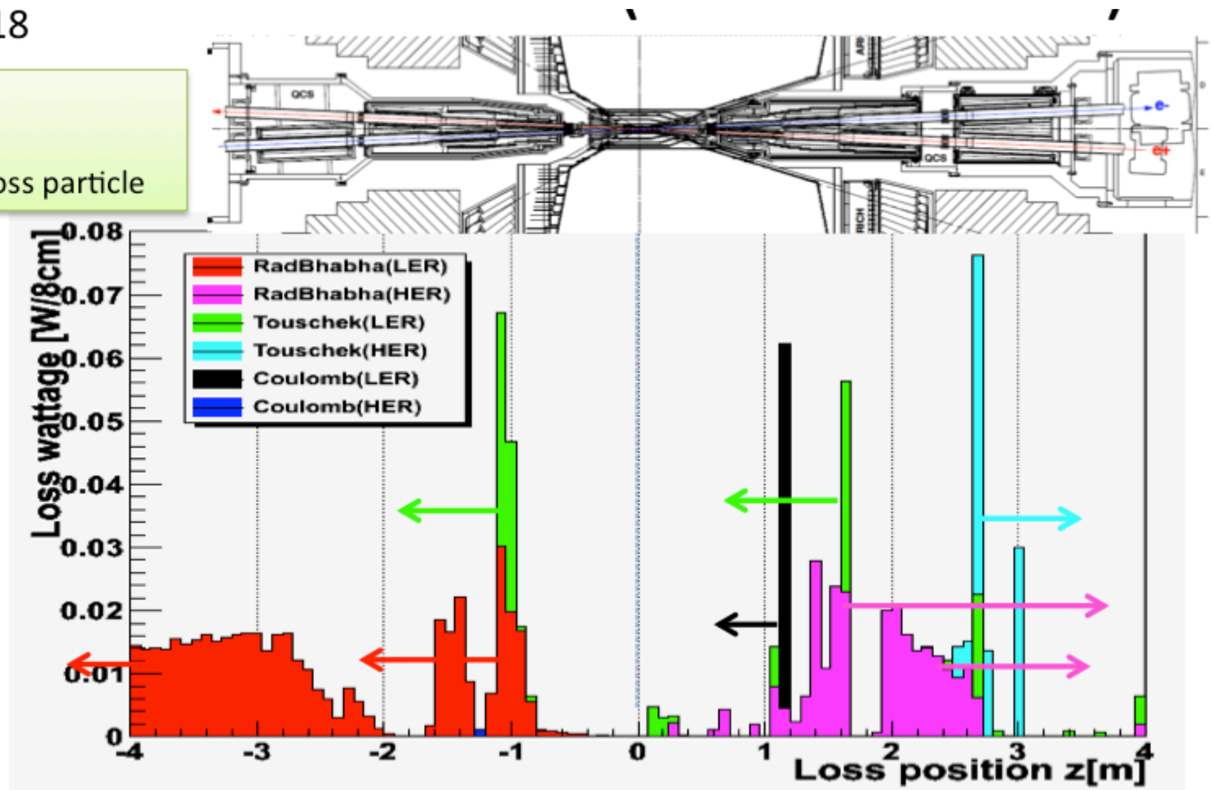
- Significant European participation + funding
- 19 institutes with ca 130 physicists (A, CZ, D, E, PL, RUS, SLO)
- Spokesperson P. Križan, Ljubljana
- CERN Recognized Experiment RE20

Total background

Ver. 2012.5.18

Loss wattage
= loss rate
  * energy of loss particle

HER
(e-)



LER
(e+)

	LER (4GeV e+)	HER (7GeV e-)
Rad. Bhabha	0.45 W (eff. 0.7GHz)	0.25W (eff. 0.22GHz)
Touschek	0.14 W (0.22GHz)	0.11 W (0.10 GHz)
Coulomb	0.06 W (0.09GHz)	0.001W (0.001GHz)

1GeV ,1GHz
= 0.16W