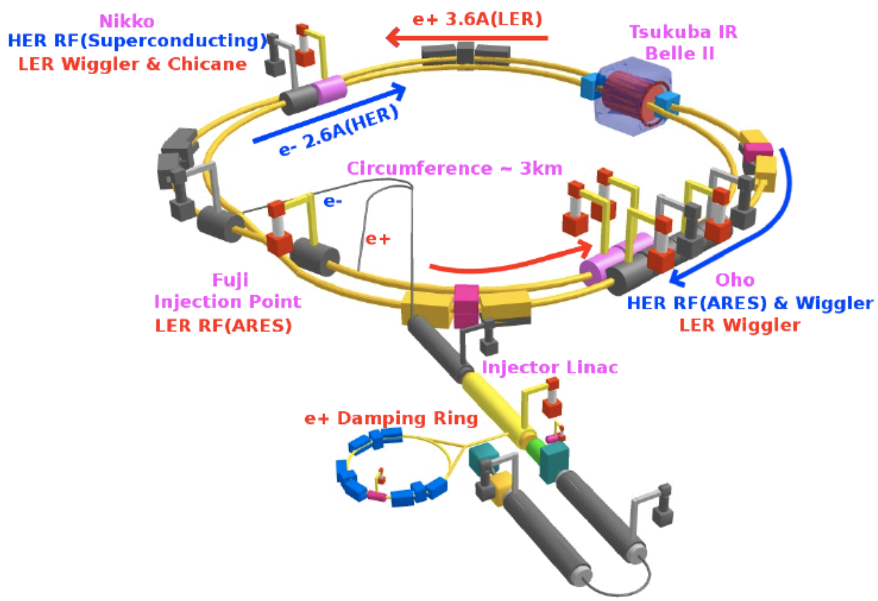
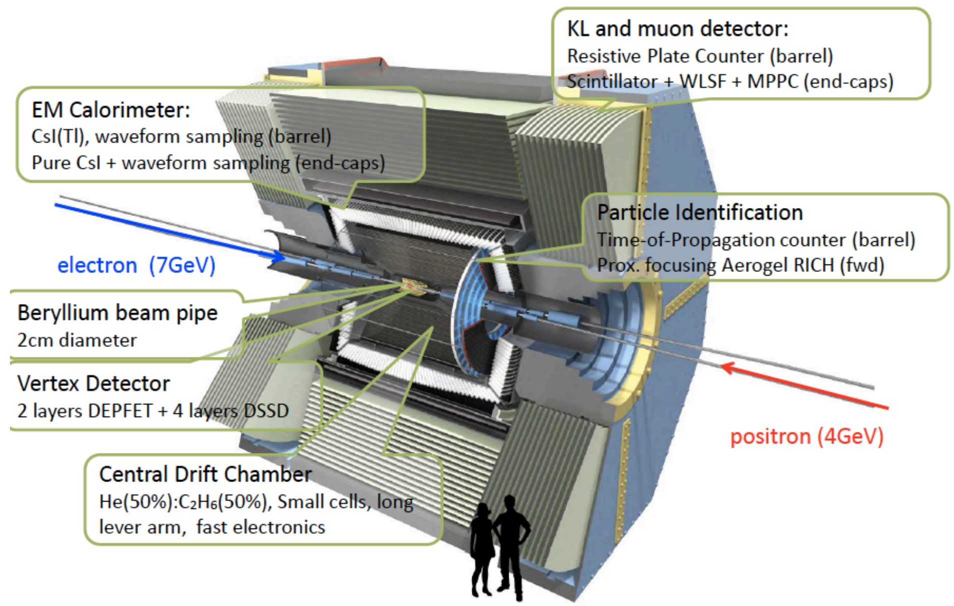
Overview of the SuperKEKB/Belle II Project

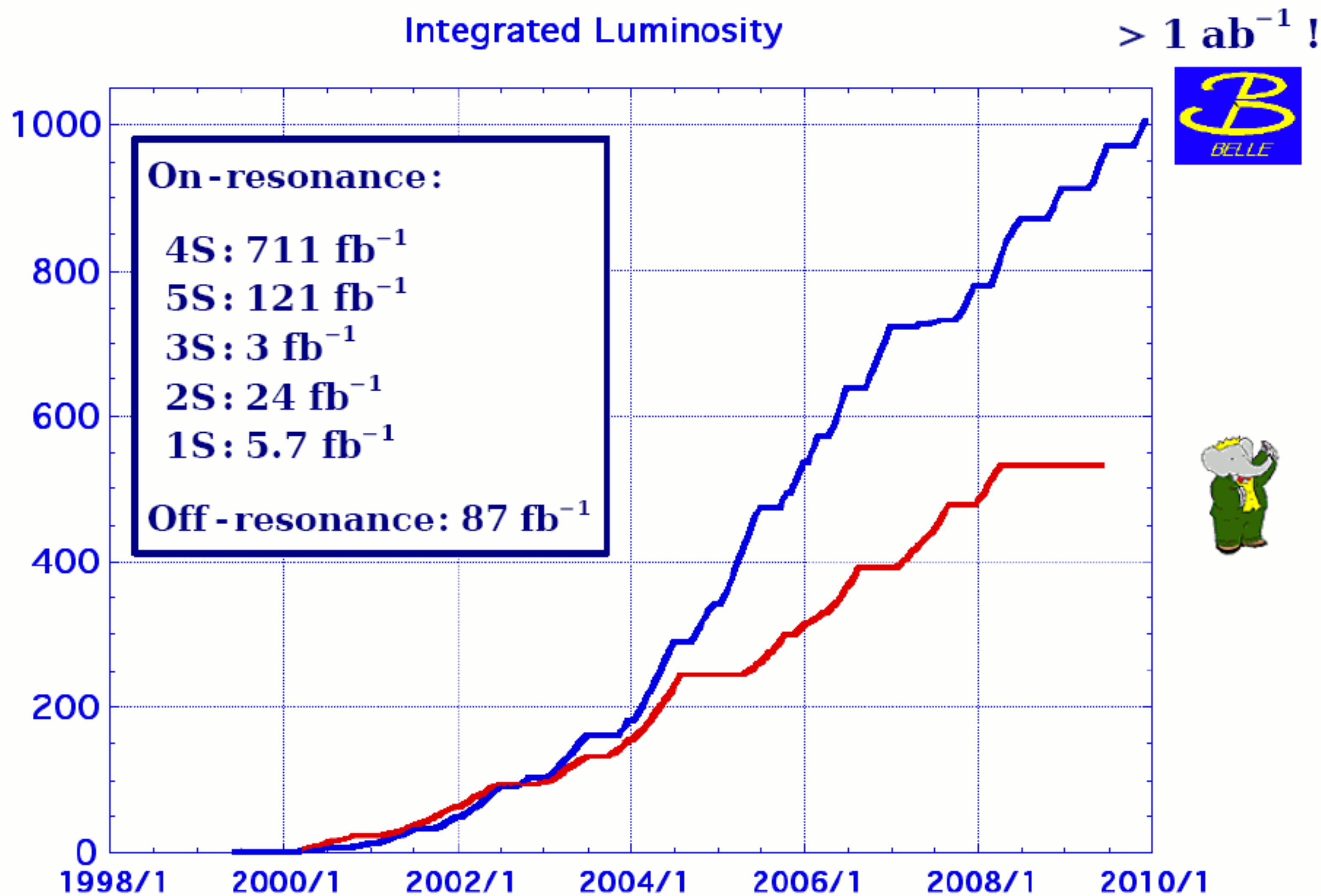
Tom Browder (University of Hawaii)





Intro, SuperKEKB, Belle II, Schedules

Belle/KEKB Integrated luminosity passed 1000 fb^{-1} (➔have to switch to new units, 1 ab^{-1})



Peak lumi record at KEKB: L=2.1 x $10^{34}/cm^2/sec$ with crab cavities [2]

Intense Analysis Phase: *Completed* ***reprocessing*** *Belle Datasets listed below* (units in fb^{-1})

- Upsilon(5S) 121.4 on-resonance (B_s physics)
- Upsilon(4S) 710.5 on-resonance/83.3 off

- Upsilon(1S) 5.7 on/1.8 off (100M 1S)
- Upsilon(2S) 24.1 on/1.7 off (159M 2S)
- Upsilon(3S) 2.95 on/0.248 off

Datasets in red are the world's *largest* samples

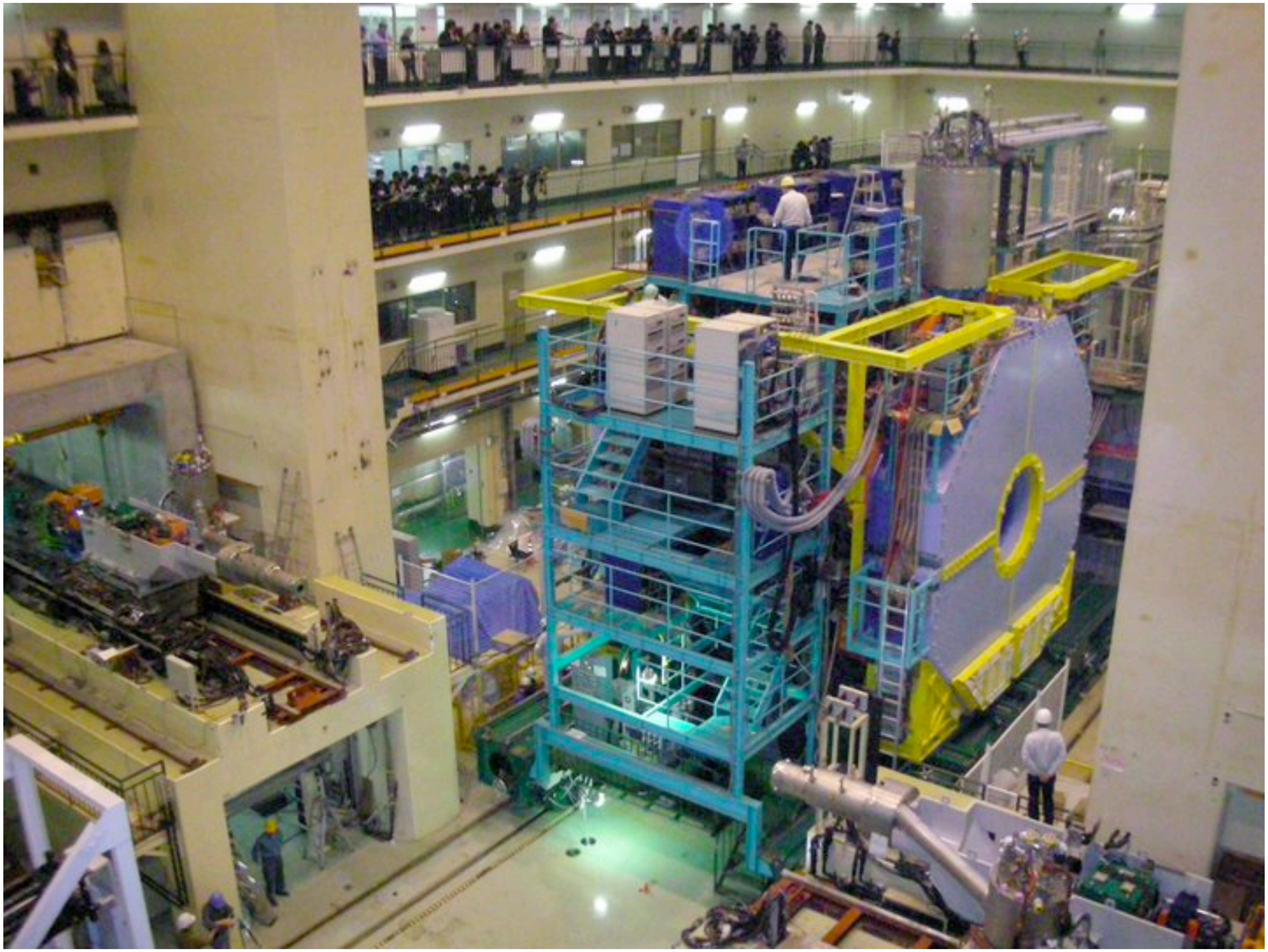
Last Belle data taking run in May-June 2010

KEKB Final Beam Abort Ceremony (June 30, 2010)

Belle実験グループ代表の一人、ハワイ大学のトム・ブラウダー教授は「11年前にKEKBとBelleが実験を開始したとき、世界最高のルミノシティを達成すると外部の人は予想していなかった。ここに至るまでの道のりは平坦ではなかったが、小林・益川両博士にノーベル賞をもたらしたB中間子のCP対称性の破れの確認など、世界各地の大学院生や研究者が数多くの論文を執筆するための重要なデータを得ることができた。これらのデータで得られた科学上の知見の大きさははかりしれない。」と述べました。

http://www.kek.jp/ja/news/topics/2010/KEKBfactory.html

Preparations begin for Belle-II



Belle Detector Roll-out (Dec, 2010)

Are we done ?

Из эффекта С. Окубо
При большой температуре
Для Вселенной сшита шуба
По ее кривой фигуре

НАРУШЕНИЕ *CP*-ИНВАРИАНТНОСТИ, *C*-АСИММЕТРИЯ И БАРИОННАЯ АСИММЕТРИЯ ВСЕЛЕННОЙ

А.Д.Сахаров

Теория расширяющейся Вселенной, предполагающая сверхплотное начальное состояние вещества, по-видимому, исключает возможность макроскопического разделения вещества и антивещества; поэтому следует

BAU: CKM mechanism still short by 10 orders of magnitude.

Why SFF(s) are so important.

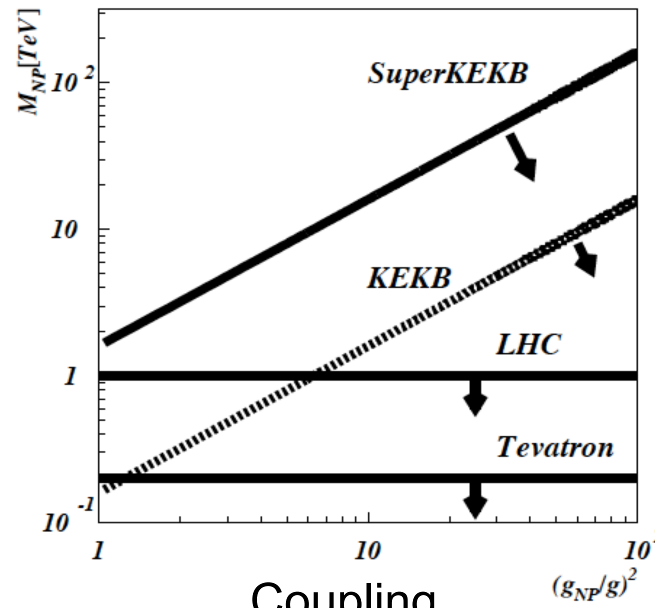
(*Sorry:* Bringing Torahs to Jerusalem)

A Super Flavor Factory (SFF) studies processes that are 1-loop in the SM but may be O(1) in NP : FCNC, mixing, CPV.

Current experimental bound is O(10-100) TeV depending on NP coupling. Thus if the LHC finds NP at O(1 TeV) it *must* have a non-trivial flavor structure.

Even if no new particles are found at the LHC, current SM couplings provide sensitivity to new particles at a SFF.

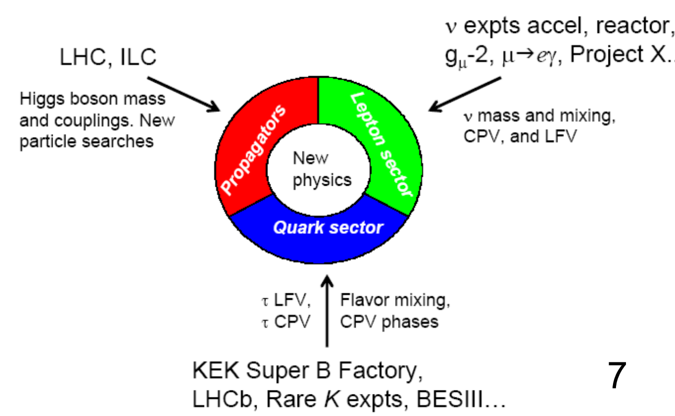
There must be new sources of CPV to explain the BAU (Baryon Asymmetry of the Universe)



Minimal Flavor Violating (MFV)

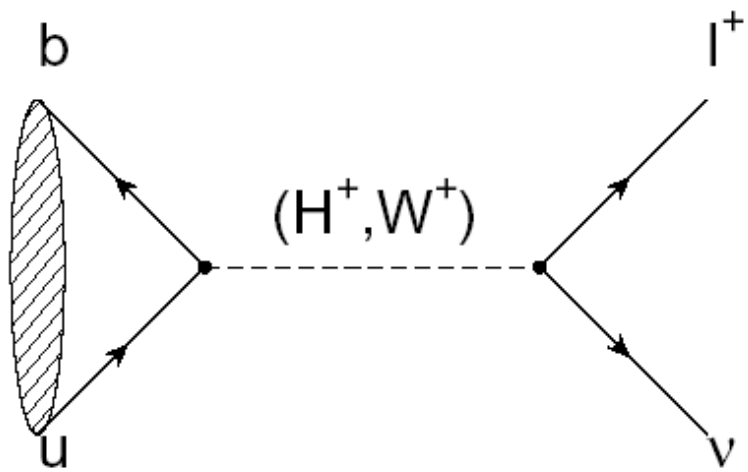
Enhanced Flavor coupling

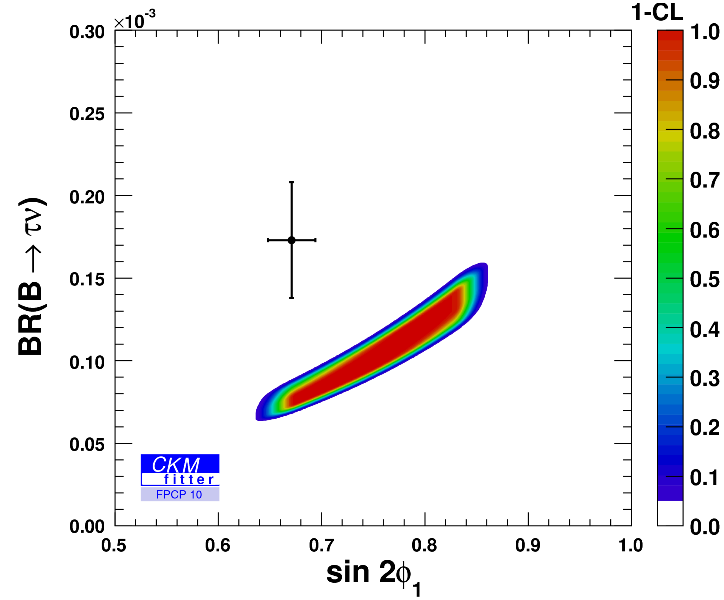
The Super B Factory is part of a Unified and Unbiased Attack on New Physics



$B^+ \rightarrow \tau^+ \upsilon_\tau$

(Example of a SFF decay with *Large* Missing Energy)





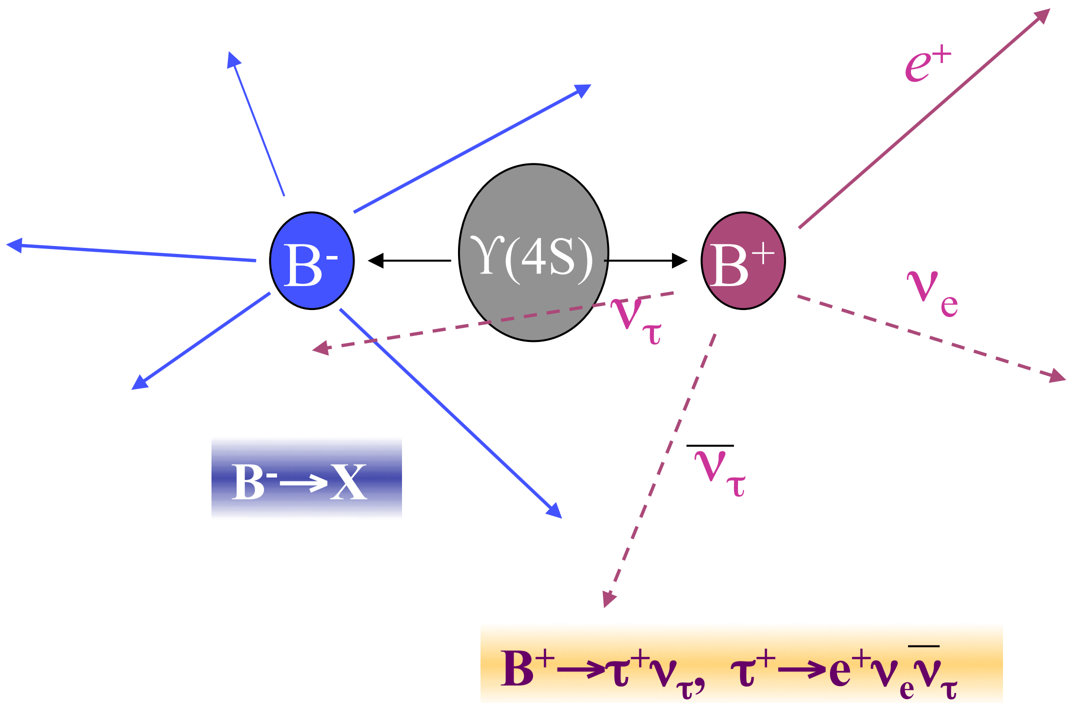
$$\mathcal{B}(B^+ \to \tau^+ \nu_\tau) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1 - \frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

Sensitivity to new physics from charged Higgs

The B meson decay constant, determined by the B wavefunction at the origin

($|V_{ub}|$ taken from indep. measurements.)

Why measuring B->τν and related modes is non-trivial

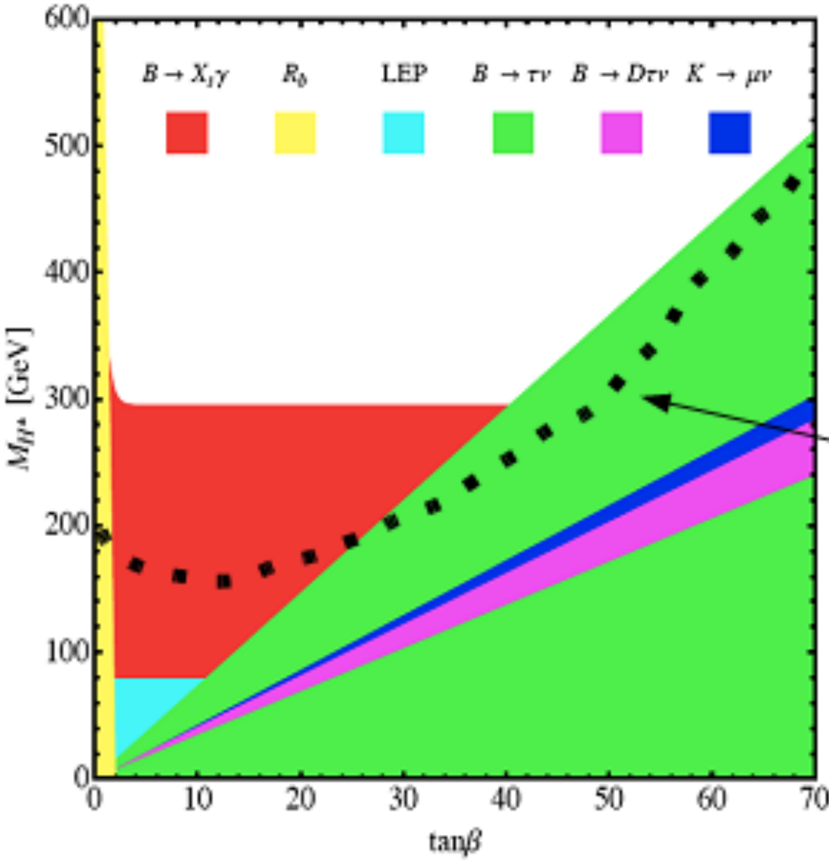


Most of the sensitivity is from tau modes with 1-prong

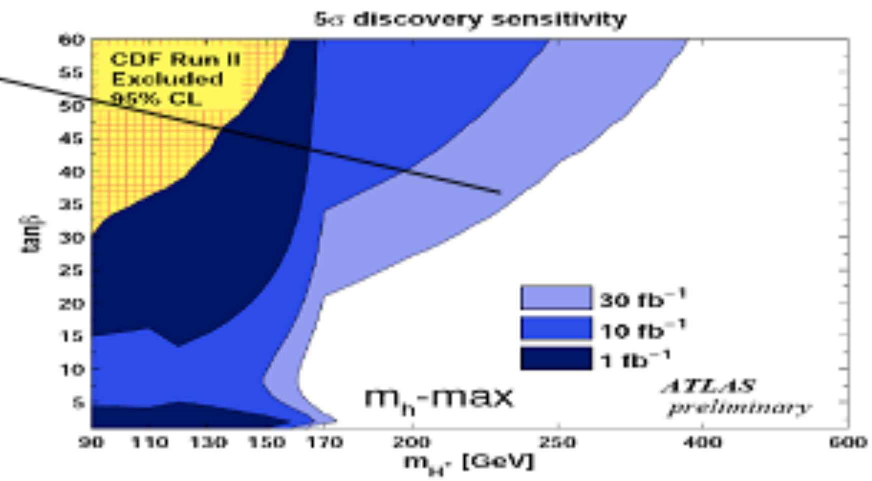
The experimental signature is rather difficult:
B decays to a single charged track + nothing

(This will be difficult at a hadron collider)

B Factories versus LHC (ATLAS) for the charged Higgs

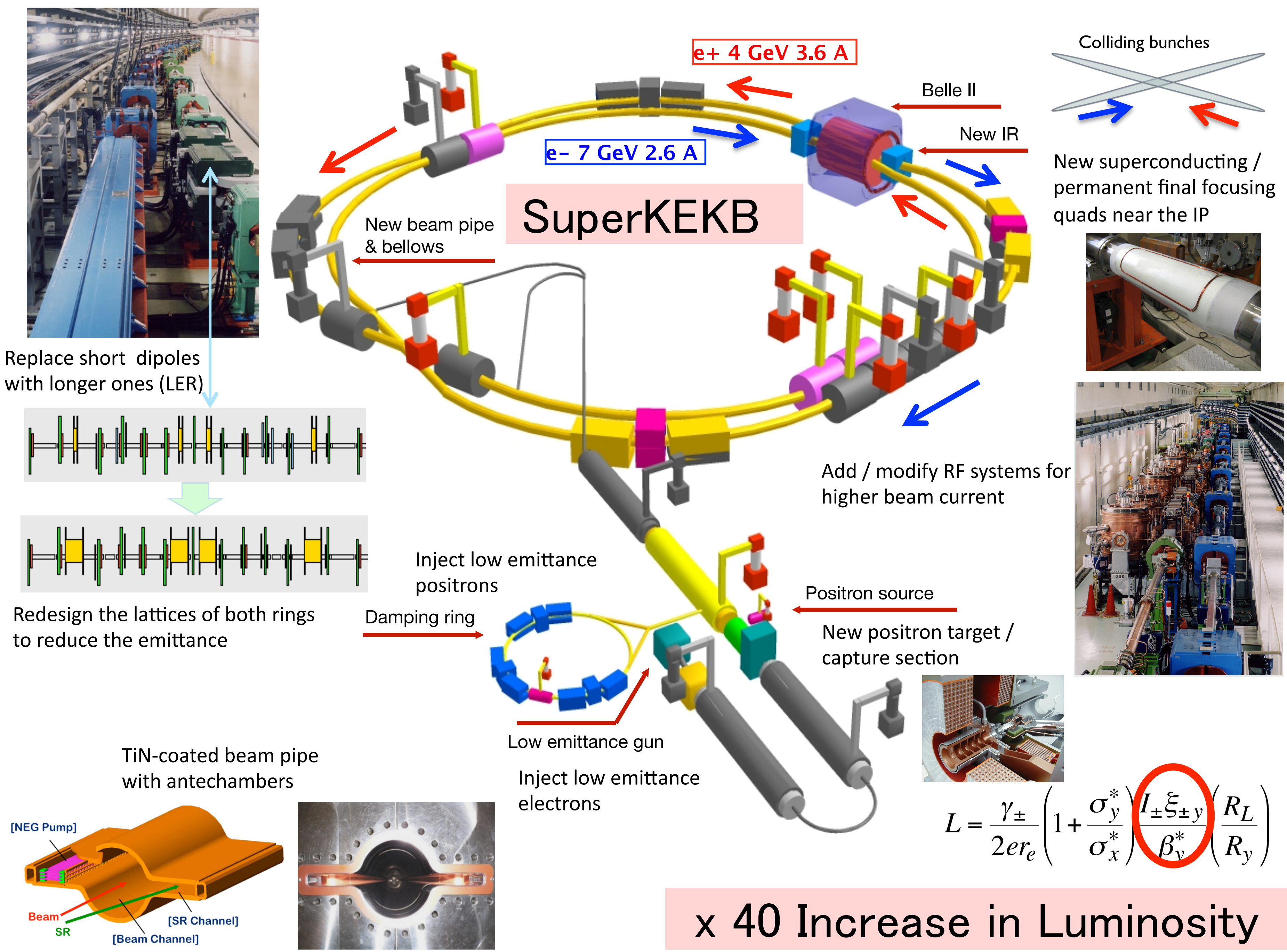


Current flavour constraints are already very competitive with LHC expected direct search sensitivity for charged Higgs



U. Haisch, hep-ph/0805.2141; ATLAS curve added by *Steve Robertson*

Also see (MSSM),D. Eriksson,F.Mahmoudi and 0.Stal



SuperKEKB
e+ 4 GeV 3.6 A
e− 7 GeV 2.6 A
Belle II
New IR
Colliding bunches
New superconducting / permanent final focusing quads near the IP
New beam pipe & bellows
Replace short dipoles with longer ones (LER)
Redesign the lattices of both rings to reduce the emittance
Add / modify RF systems for higher beam current
Inject low emittance positrons
Damping ring
Positron source
New positron target / capture section
Low emittance gun
Inject low emittance electrons
TiN-coated beam pipe with antechambers
[NEG Pump]
Beam
SR
[SR Channel]
[Beam Channel]
$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$
x 40 Increase in Luminosity

Comparison of Parameters for KEKB and SuperKEKB

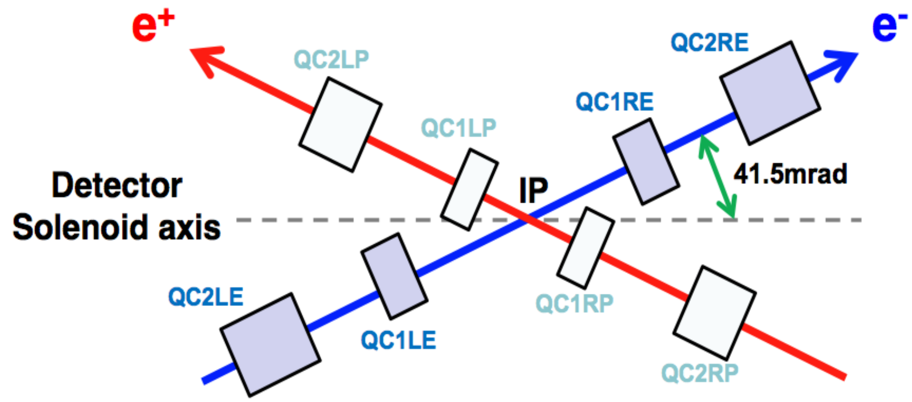
	KEKB Design	KEKB Achieved : with crab	SuperKEKB Nano-Beam
Energy (GeV) (LER/HER)	3.5/8.0	3.5/8.0	4.0/7.0
β_y^* (mm)	10/10	5.9/5.9	0.27/0.30
β_x^* (mm)	330/330	1200/1200	32/25
ε_x (nm)	18/18	18/24	3.2/5.3
$\varepsilon_y/\varepsilon_x$ (%)	1	0.85/0.64	0.27/0.24
σ_y(μm)	1.9	0.94	0.048/0.062
ξ_y	0.052	0.129/0.090	0.09/0.081
σ_z (mm)	4	6 - 7	6/5
I_{beam} (A)	2.6/1.1	1.64/1.19	3.6/2.6
$N_{bunches}$	5000	1584	2500
Luminosity (10^{34} cm^{-2} s^{-1})	1	2.11	80

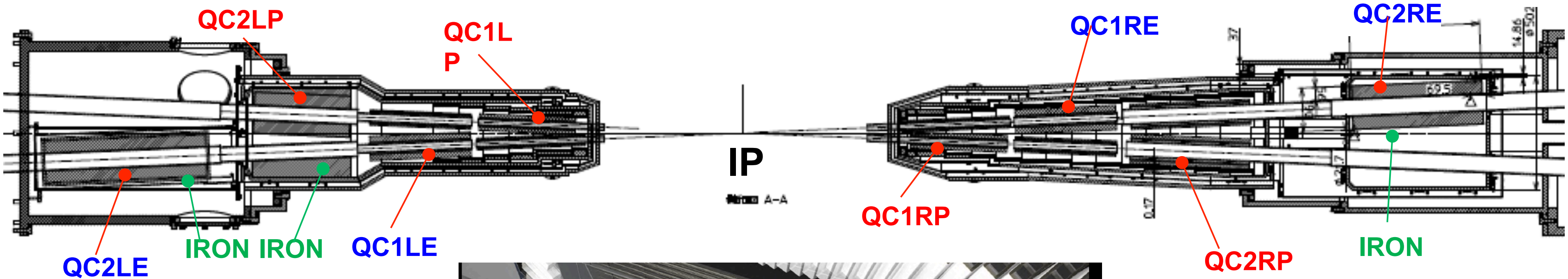
Update for Feb 2011, Accelerator Review Committee

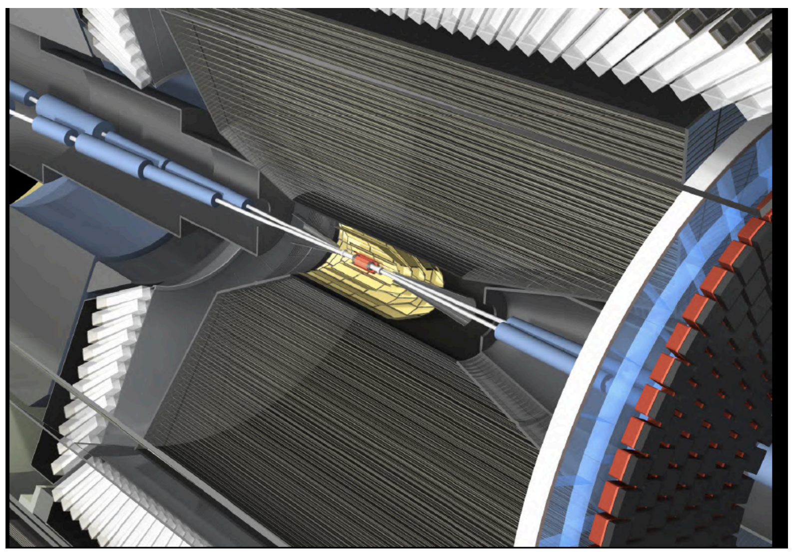
Y. Ohnishi et al.

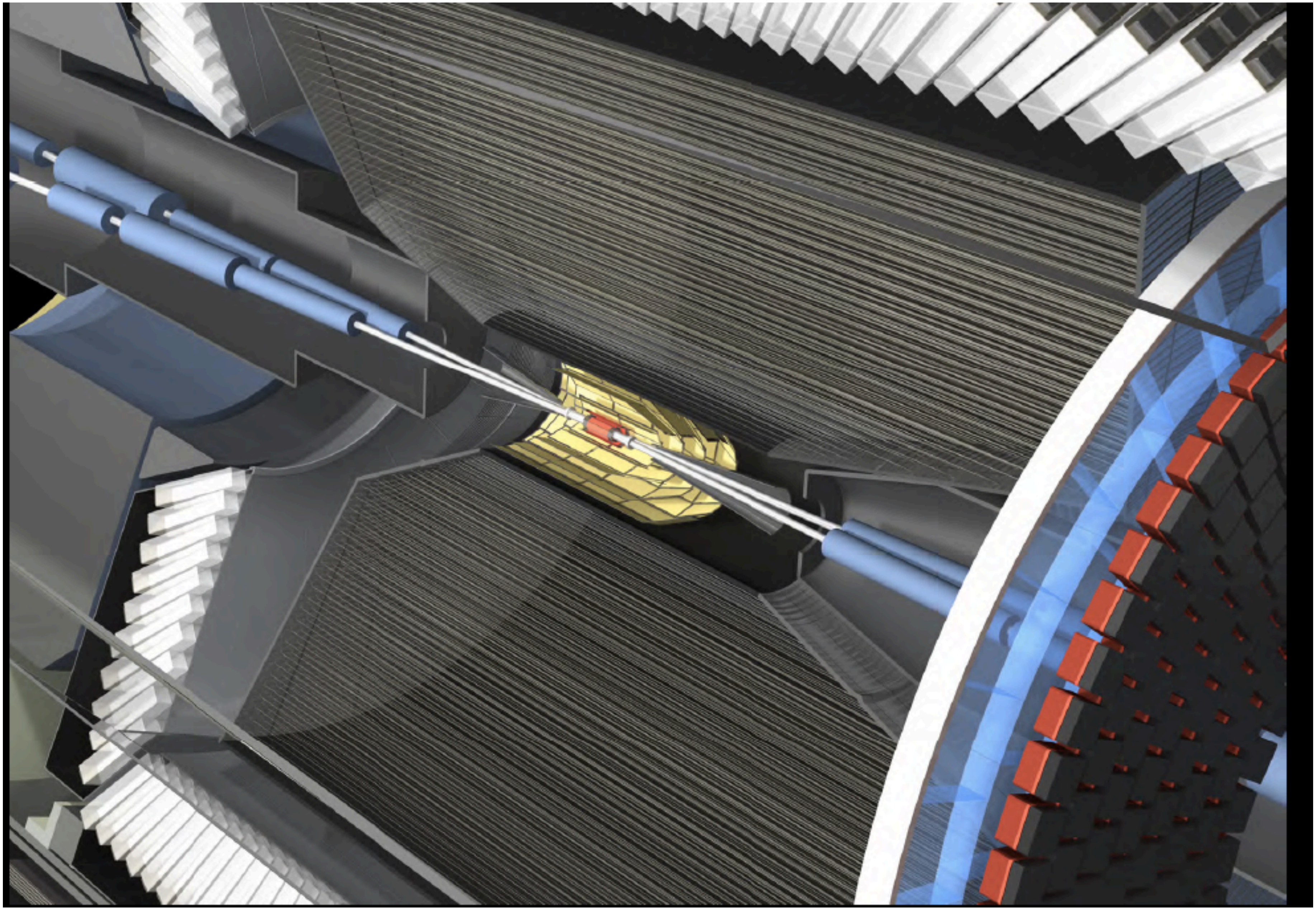
SuperKEKB/Belle II Interaction Region

Many new superconducting magnets at the IP; Belle detector currently aligned with LER will have to be *rotated*.

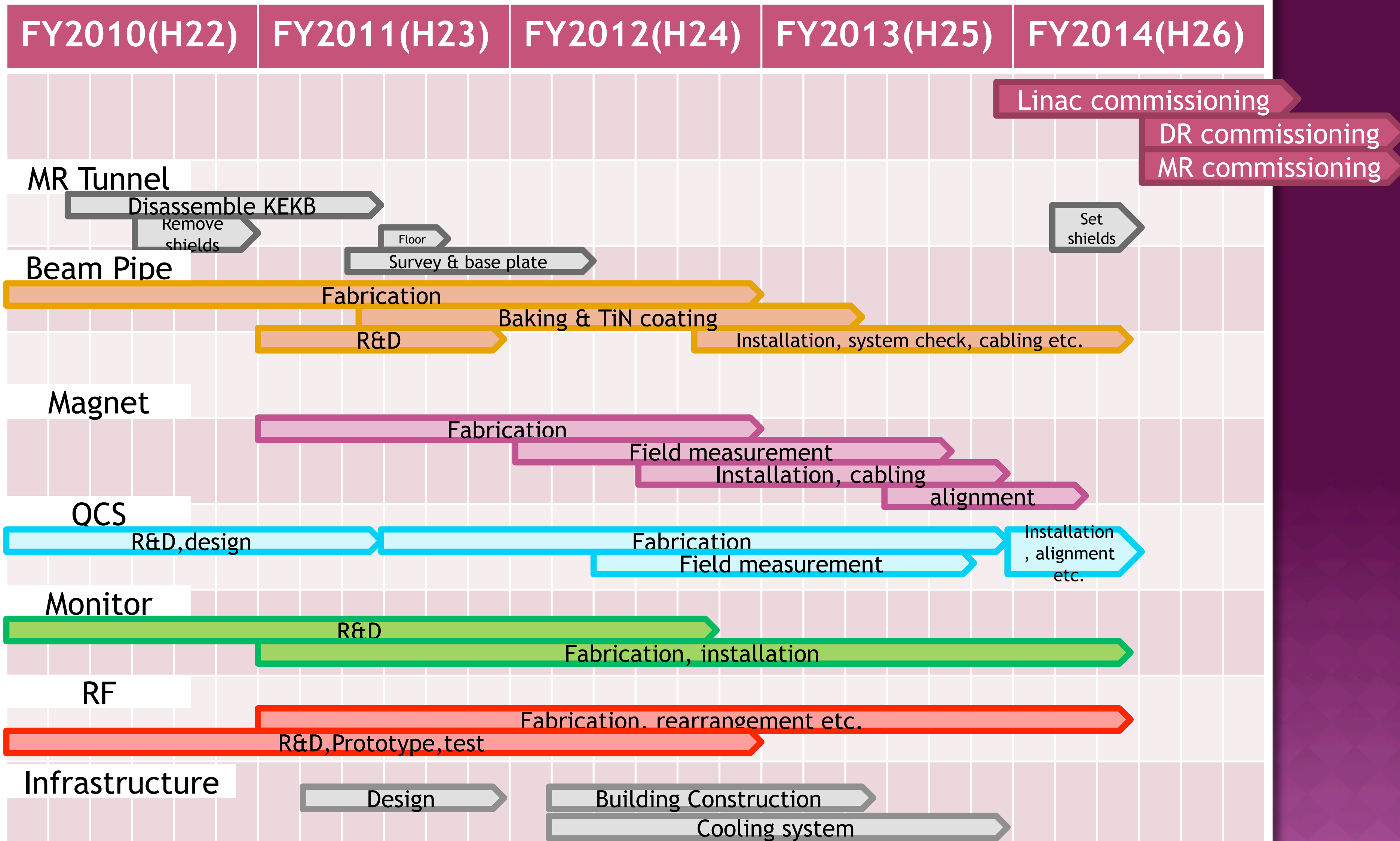




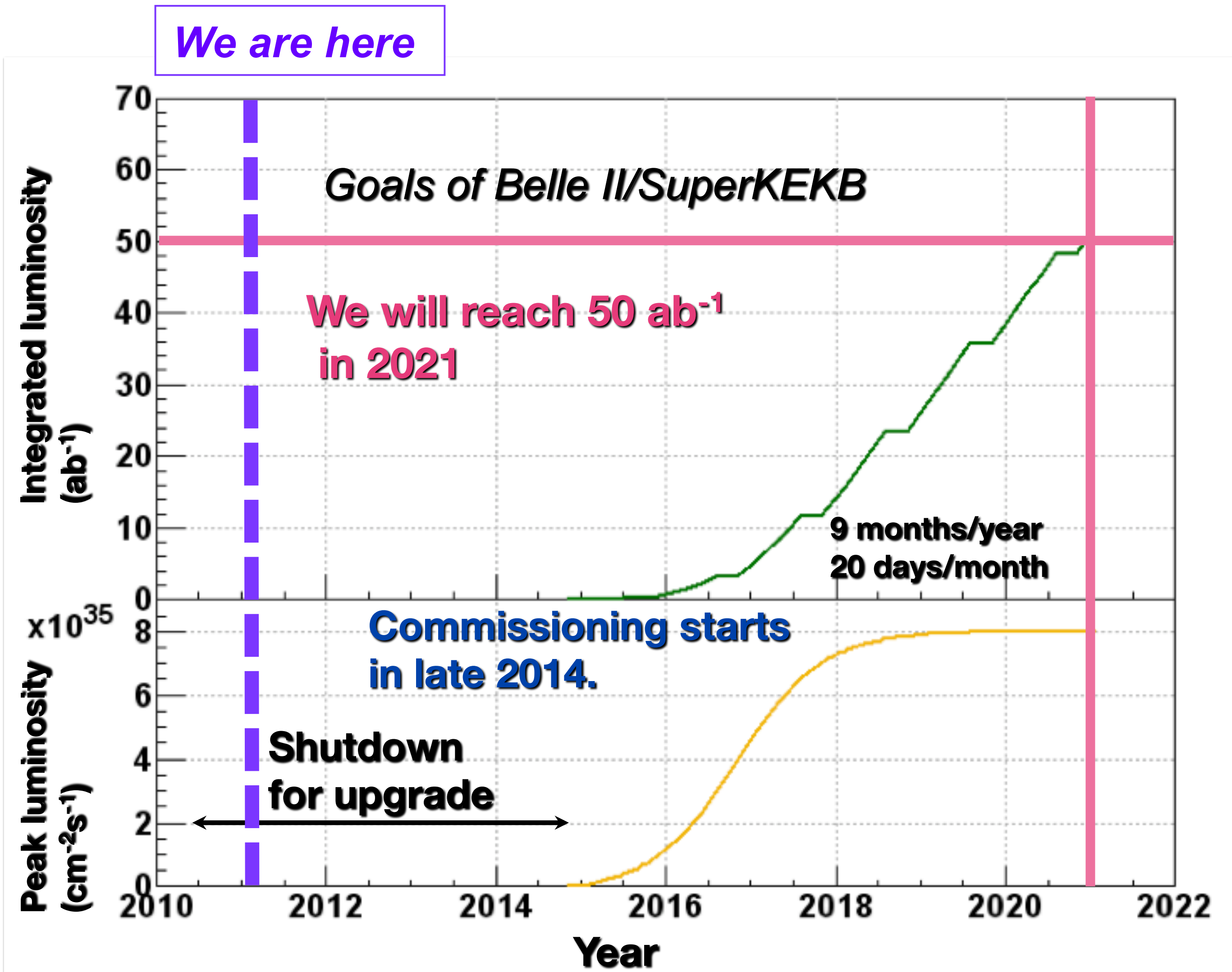




SuperKEKB Construction Schedule



SuperKEKB luminosity profile



Y. Ohnishi

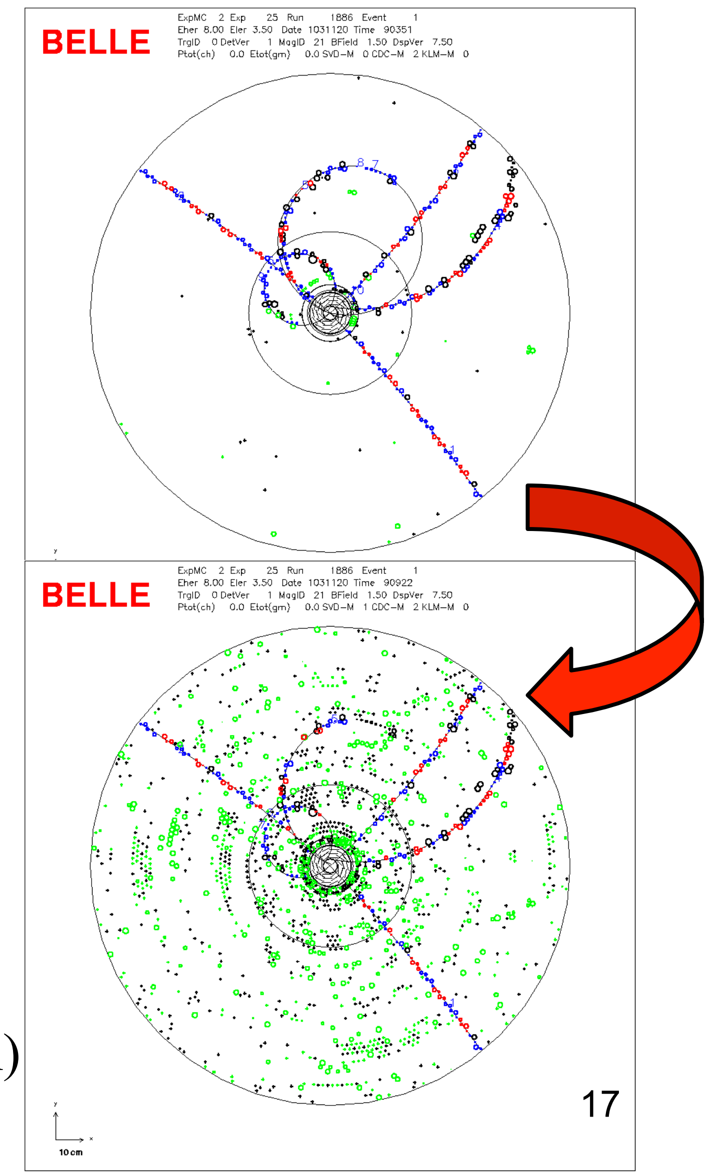
Features of Belle II detector@Super KEKB

High momentum PID with low fake rates to observe and study b$\rightarrow$s and b$\rightarrow$d *penguins* (a US contribution)

In contrast to LHCb, superb neutral detection capabilities.

e.g. $B \rightarrow K_S \pi^0 \gamma$ can be used to detect right-handed currents

Capable of observing rare "missing energy modes" such as $B \rightarrow K \nu \bar{\nu}$ with B tags. Hermeticity is critical.



Issues:

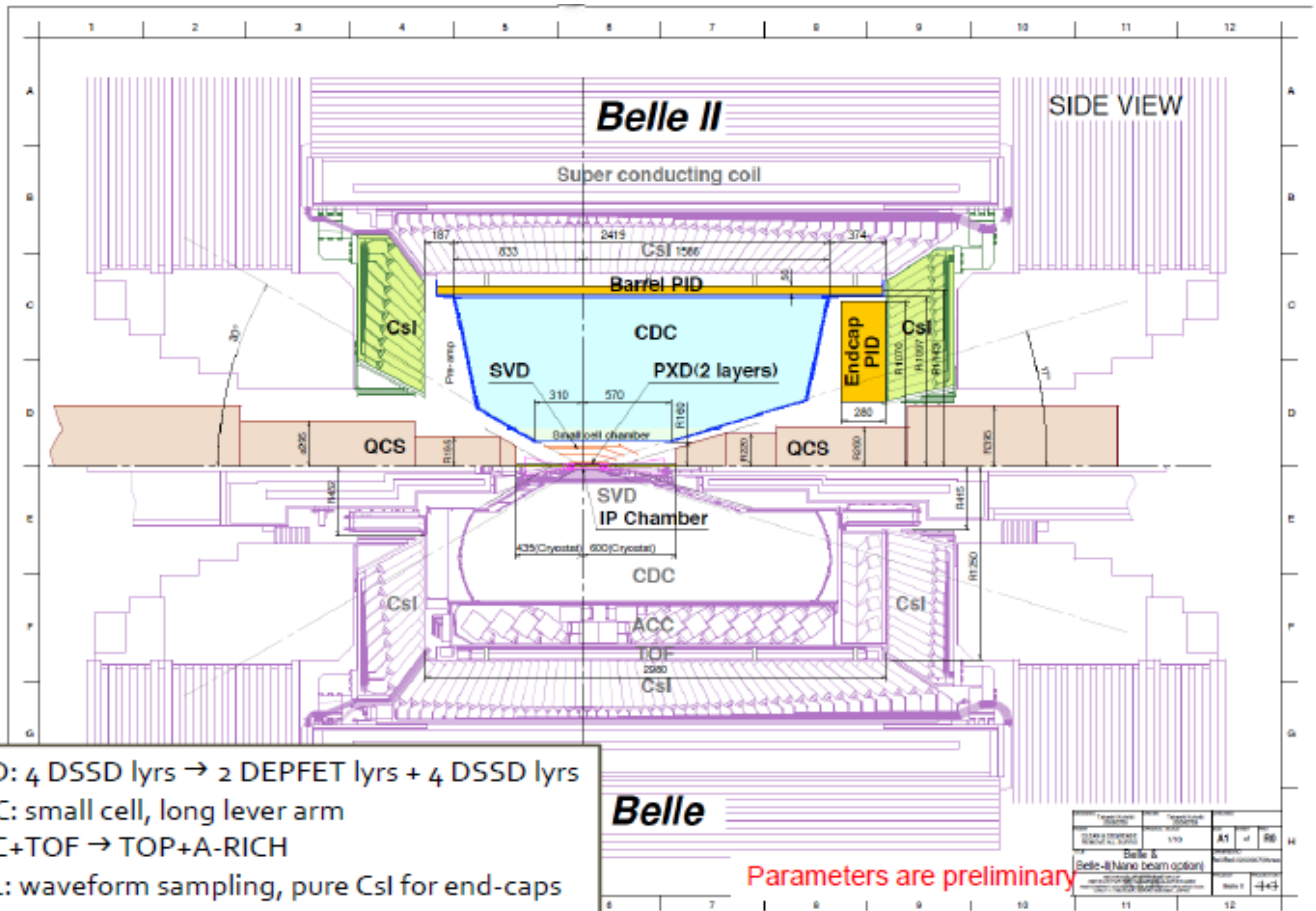
Higher background due to Touschek (~x 20)

Radiation damage and occupancy

Pixel detector (Germany, Czech Republic, Spain)

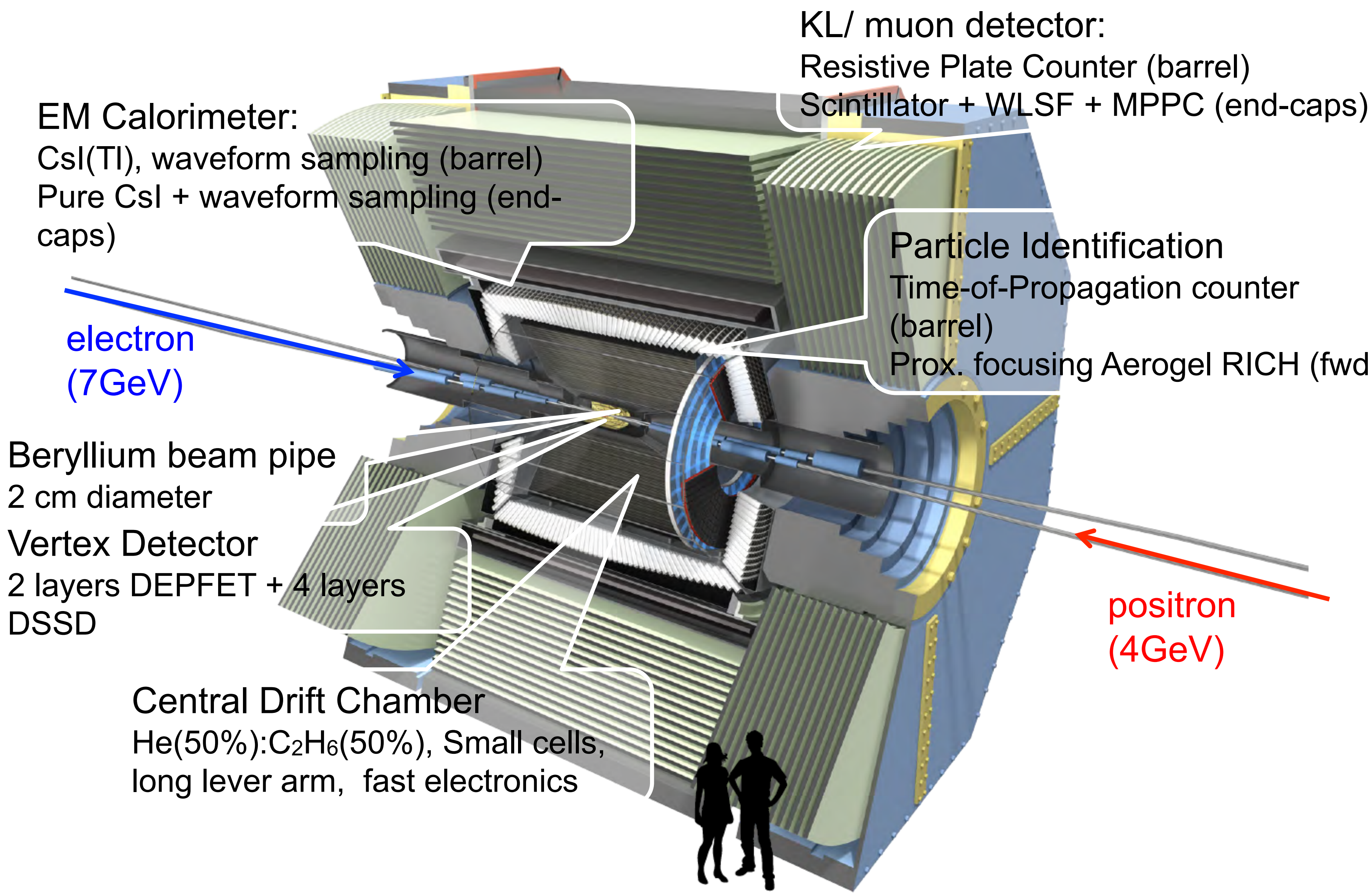
Higher event rate (x 50)

Belle II will re-use many components of the Belle detector

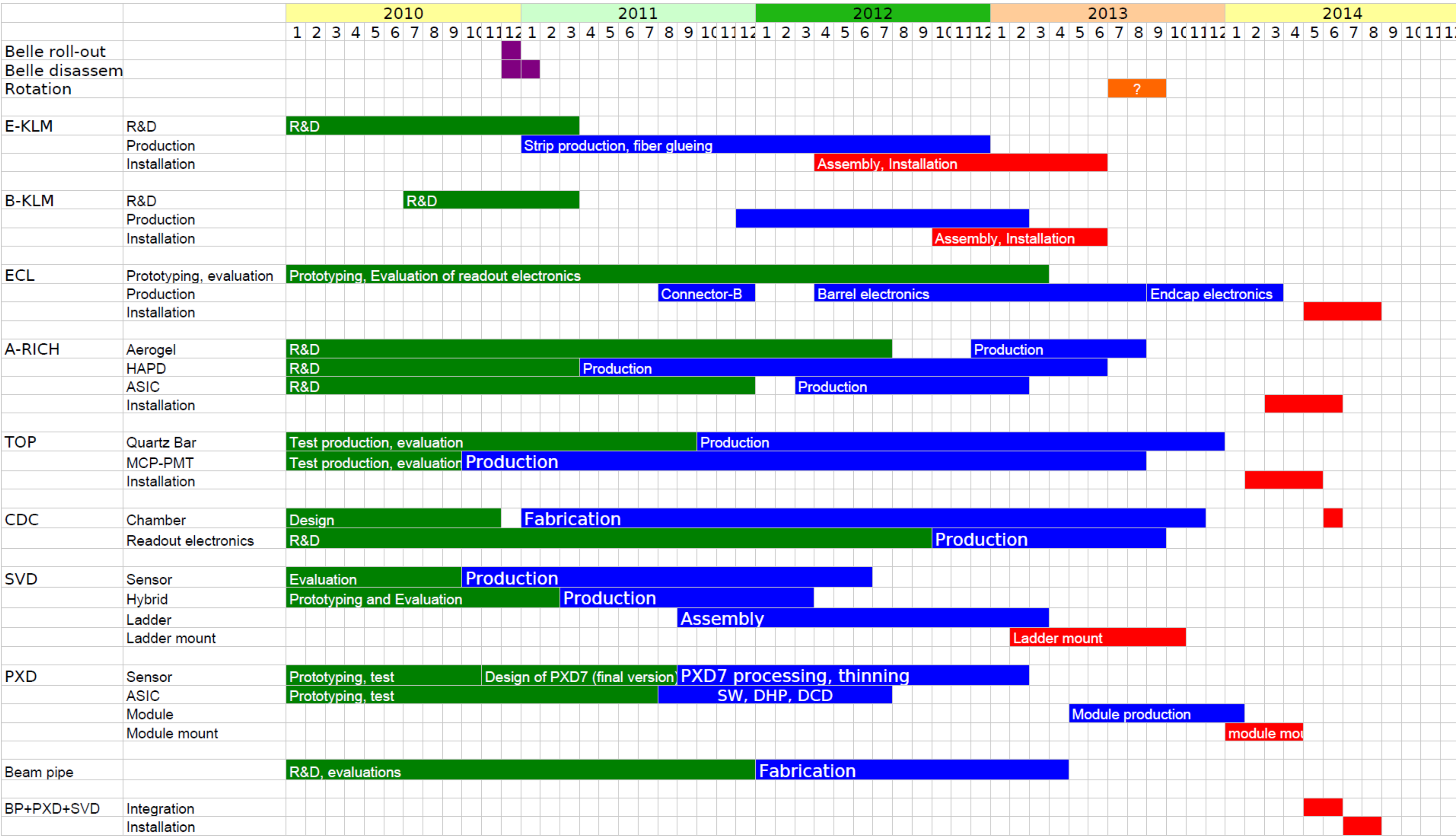


SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +MPPC (end-caps)

Belle II Detector

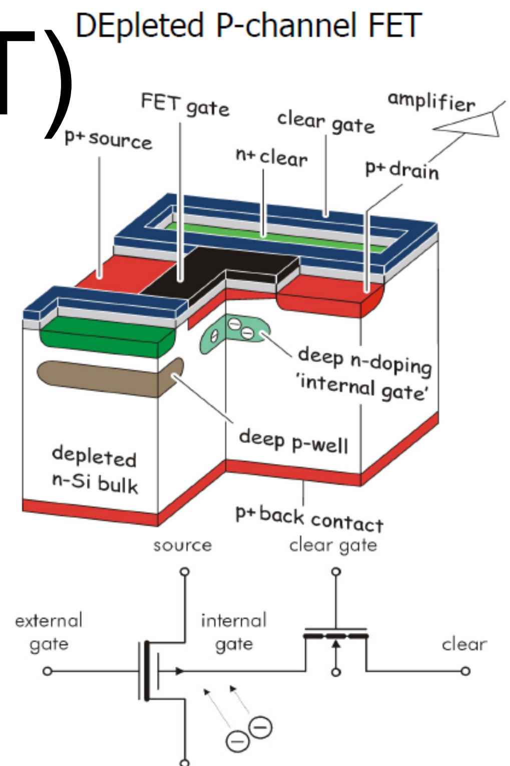


Belle II Construction Schedule



Designed to match the machine commissioning schedule and keep up with flavor physics at LHC

Pixel Detector (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$^-$)

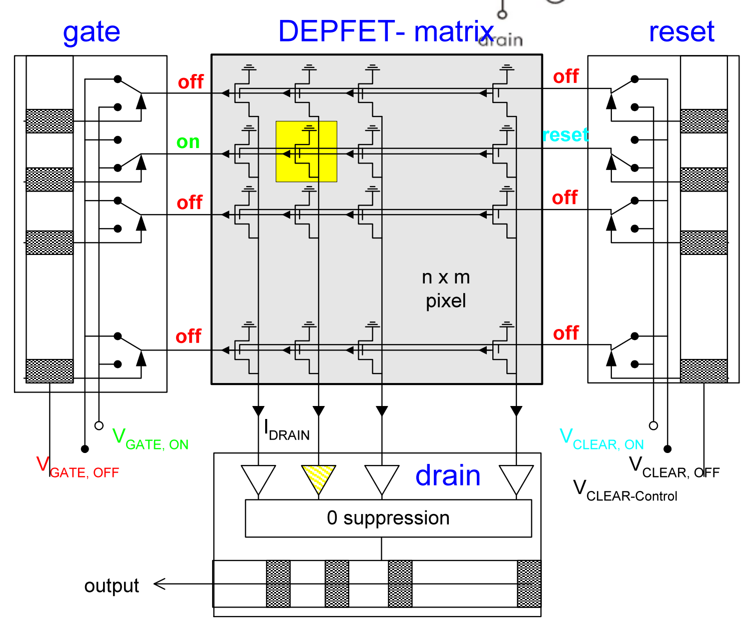
Accumulated charge can be removed by a clear contact (“reset”)

Fully depleted: => large signal, fast signal collection

Low capacitance, internal amplification: => low noise

High S/N even for thin sensors (50µm)

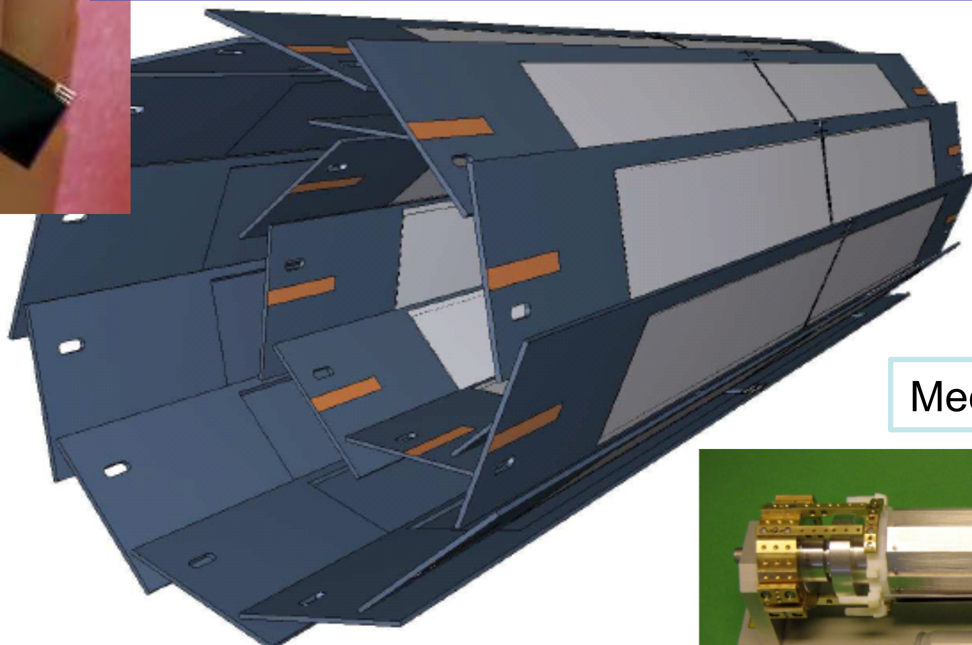
Rolling shutter mode (column parallel) for matrix operation
=> 20 µs frame readout time
=> Low power (only few lines powered)



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

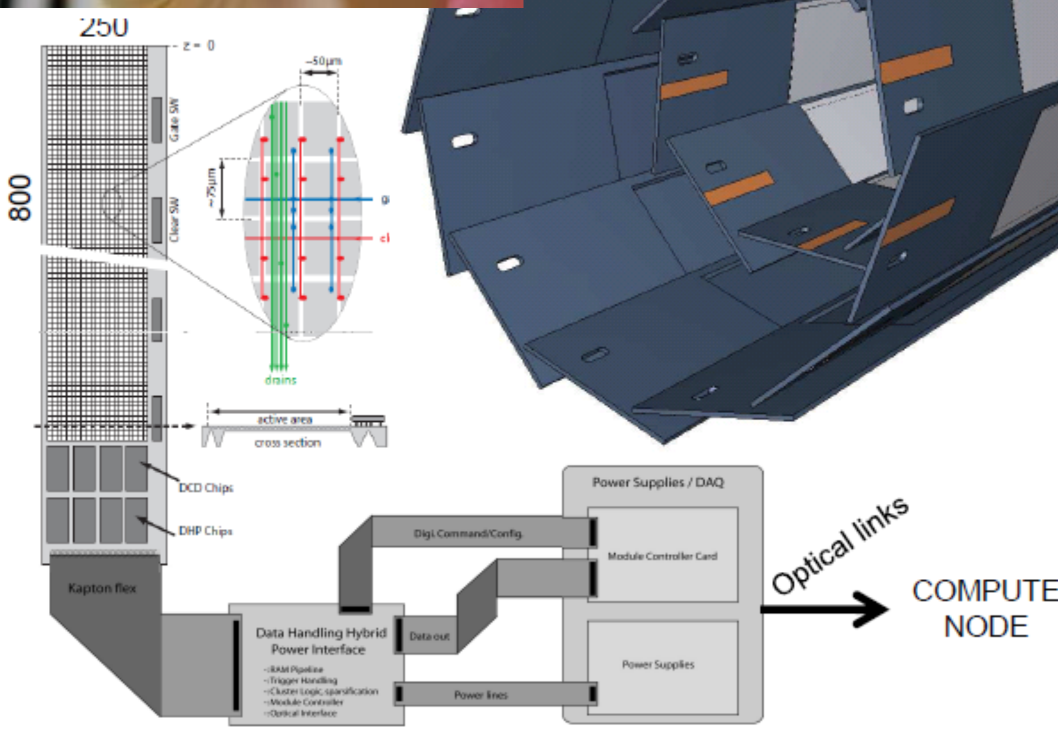
DEPFETs in Belle II

	radius	pixel	thickness
Layer 1	r = 14mm	50x50μm²	75μm(0.18%X0)
Layer 2	r = 22mm	50x75μm²	75μm



total of 8 M pixels

Mechanical mockup



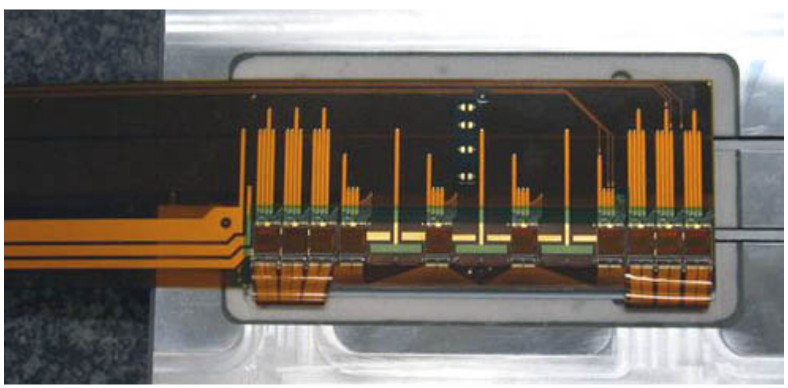
Power consumption in sensitive area: 0.1W/cm² => air-cooling sufficient

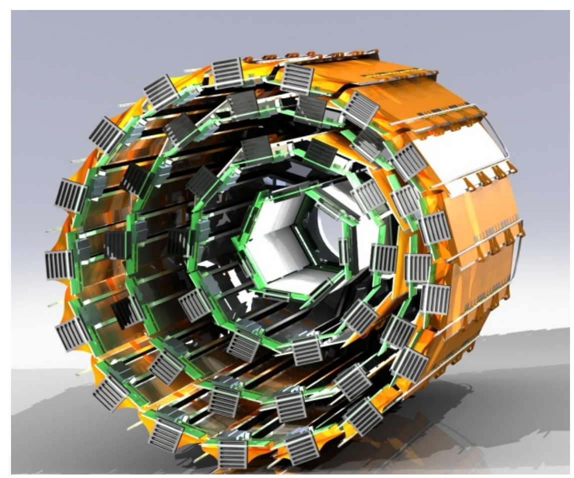
Vertex Detection via Pixels and DSSDs

Reduce beampipe radius. Try to buy back *time resolution* from smaller boost (7 x 4 GeV). Pixels needed for occupancy at small r.

		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

Double Sided Silicon Strips use thinned APV25 readout chip from CMS (100 μm; 0.55% X/layer)

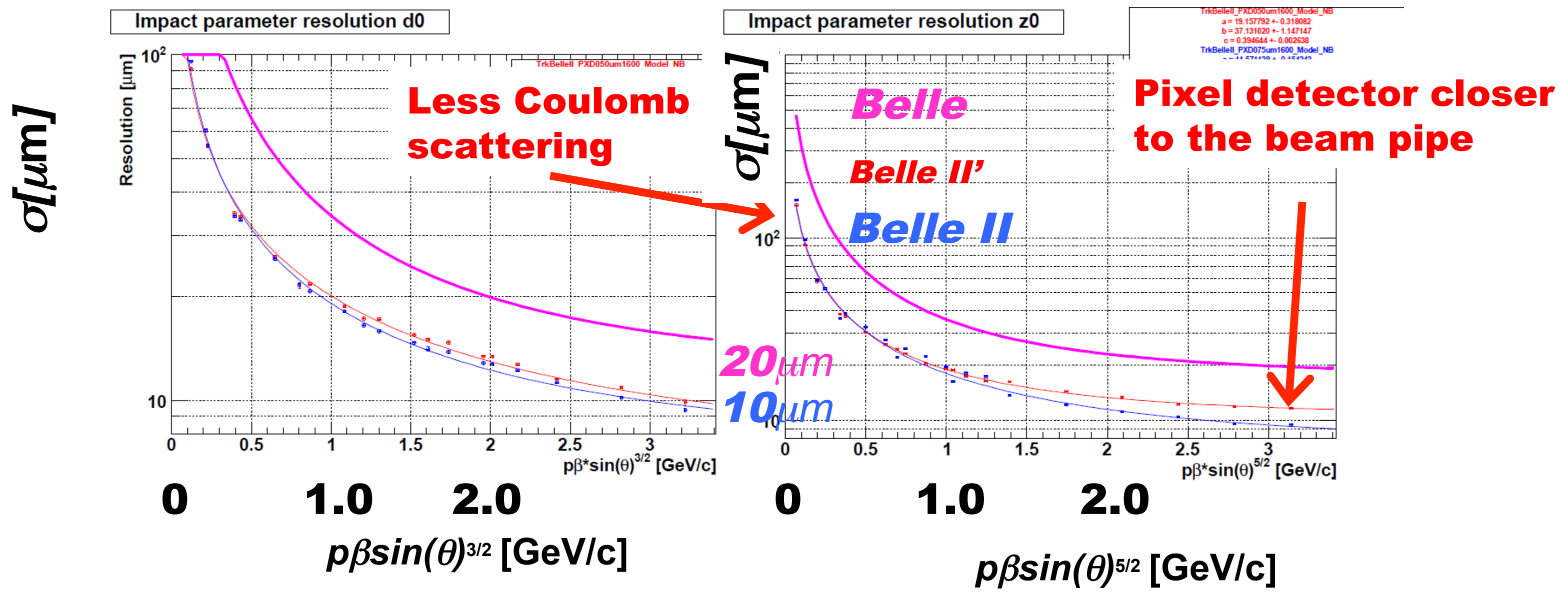




Belle II vertexing performance

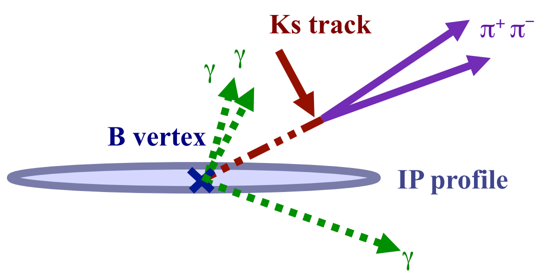
$$\sigma = a + \frac{b}{p\beta \sin^{\nu}\theta}$$

Significant improvement in IP resolution !

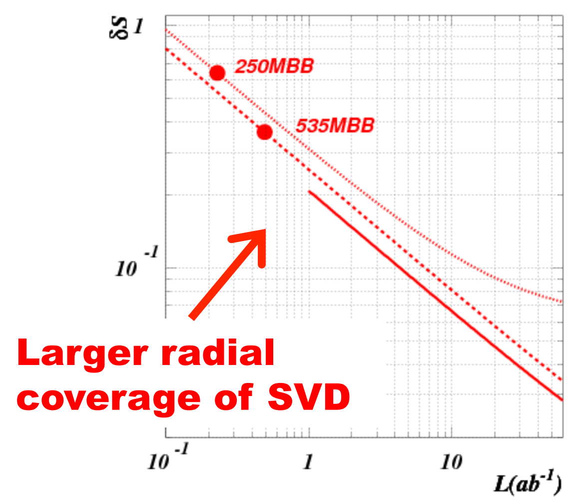


Significant improvement in $\delta S(K_S\pi^0\gamma)$

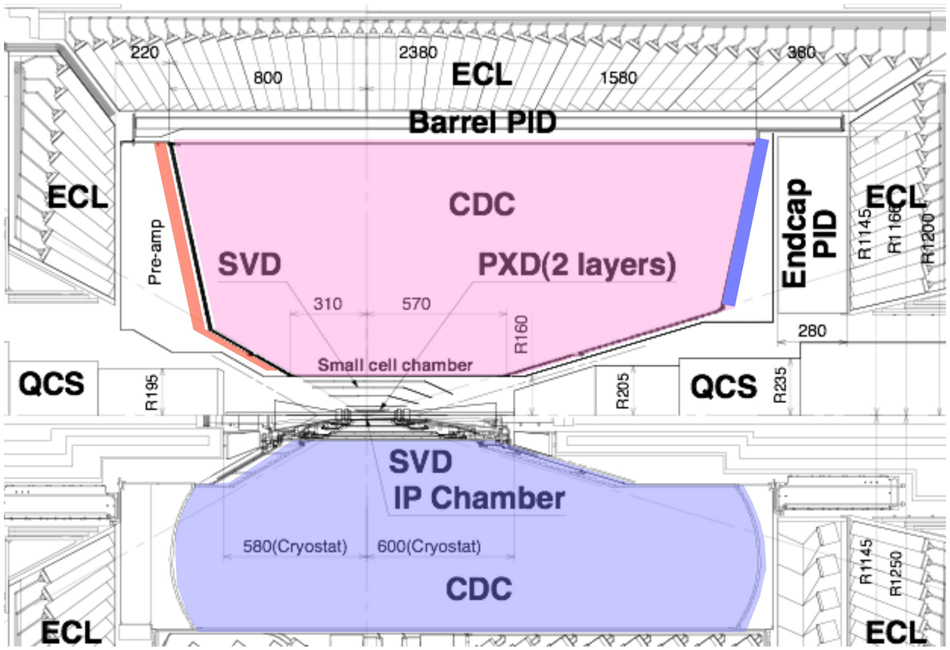
Right handed currents



B decay point reconstruction with K_S trajectory



Central Drift Chamber



	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 momentum resolution and dE/dx

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

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

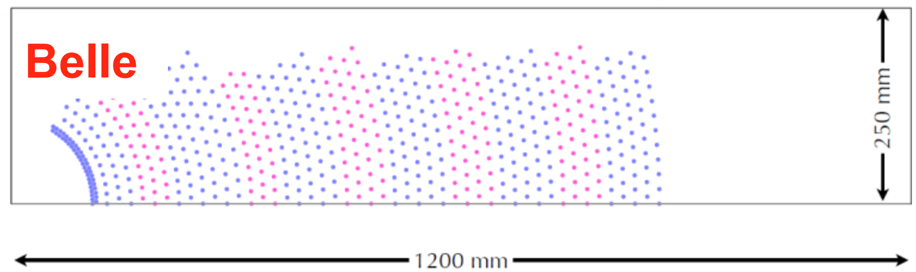
new readout system

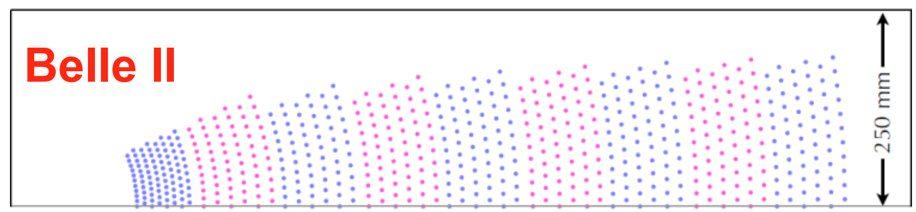
dead time 1-2μs → 200ns

small cell

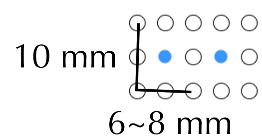
smaller hit rate for each wire

shorter maximum drift time

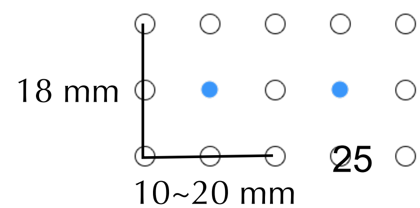




small cell

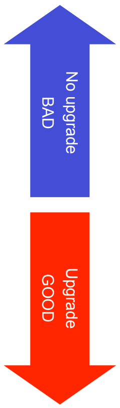


normal cell



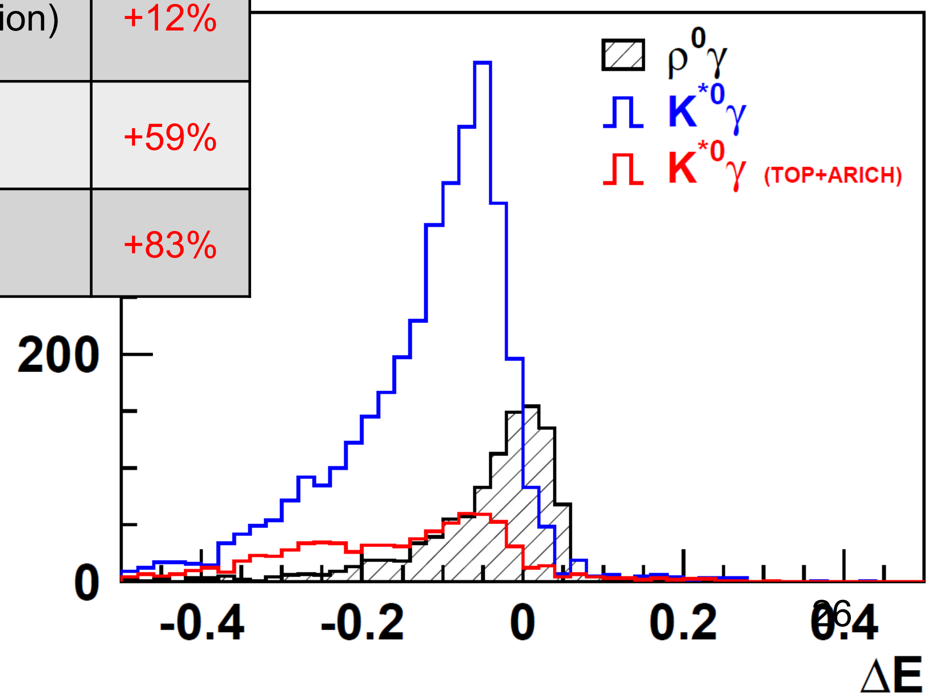
Improved PID Performance (Luminosity gain)

$B^0 \to \rho^0 \gamma$



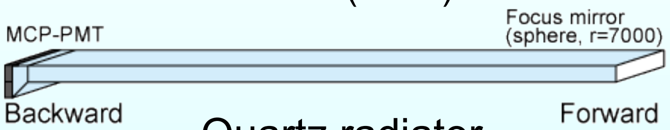
FWD \ BRL	ACC only	dE/dx only	As good as Belle	A-RICH
TOF, dE/dx NA	–74%	–69%	–68%	–62%
TOF NA	–41%	–35%	–32%	–22%
As good as Belle	–10%	–4%	0% (definition)	+12%
TOP opt.0	+27%	+33%	+40%	+59%
TOP opt.2	+45%	+51%	+60%	+83%

Improved b→d penguin physics reach with excellent PID detectors



Particle Identification in Belle II

Barrel PID: Time of Propagation Counter (iTOP)



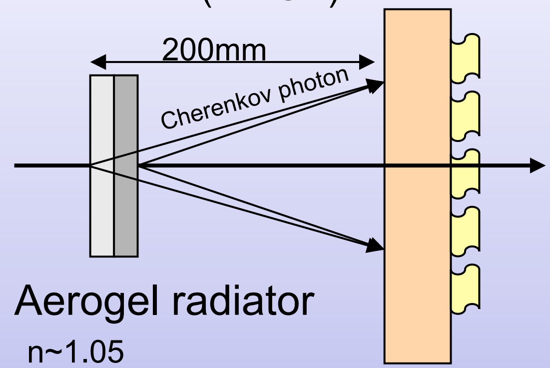
Quartz radiator

Focusing mirror

Small expansion block

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

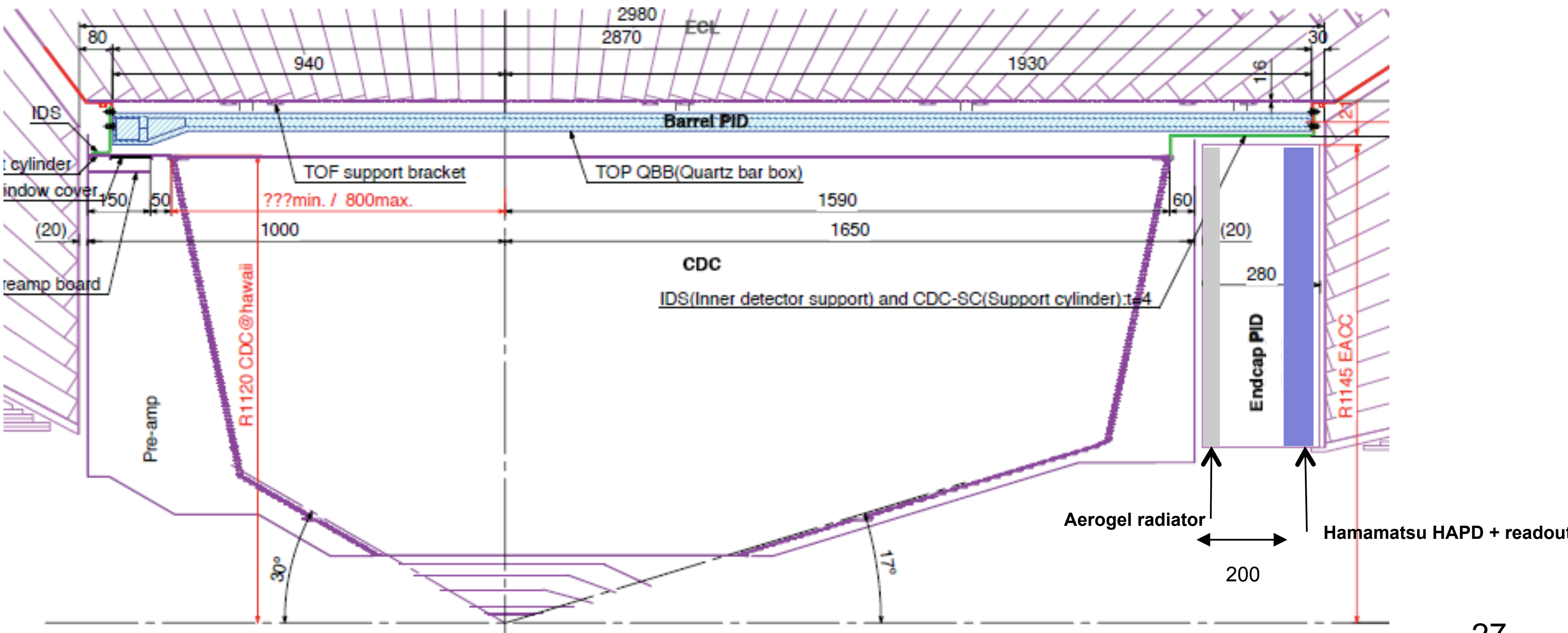
Endcap PID: Aerogel RICH (ARICH)



Aerogel radiator

n~1.05

Hamamatsu HAPD + new ASIC



Principle of Belle II barrel and endcap particle id

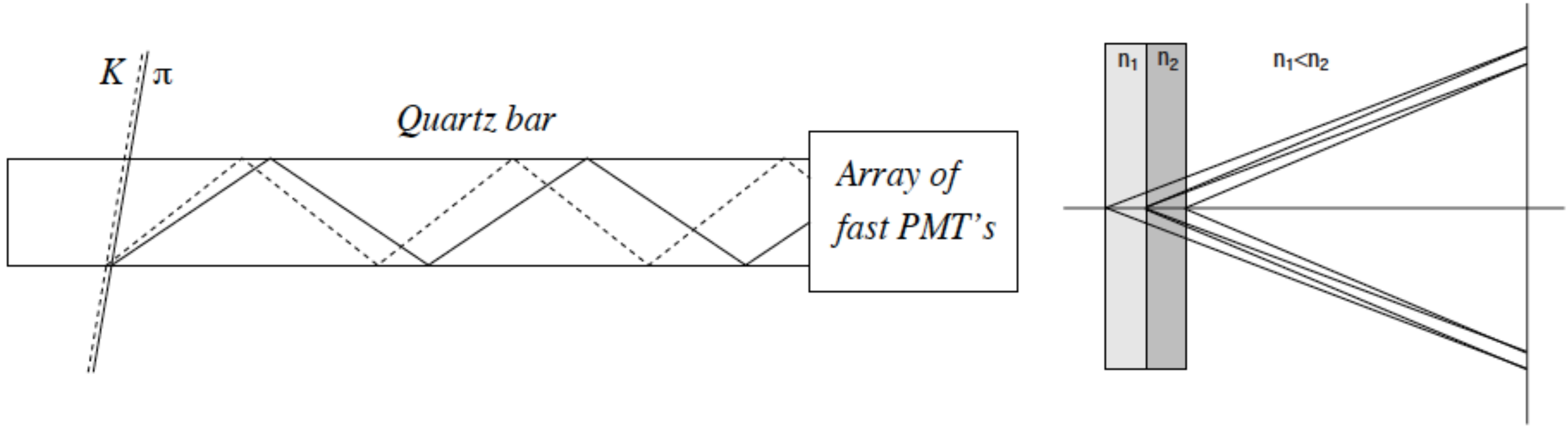
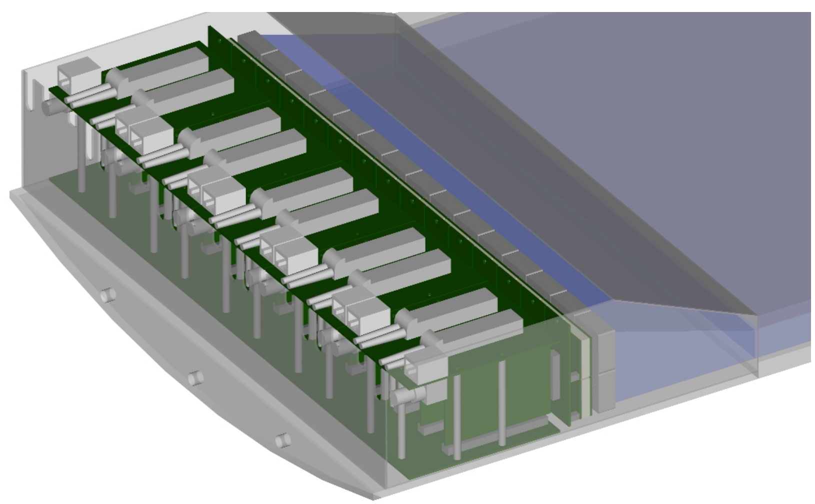


Figure 4: Belle-II PID systems: principle of operation of the TOP counter (left) and of the proximity focusing RICH with a nonhomogeneous aerogel radiator in the focusing configuration (right).

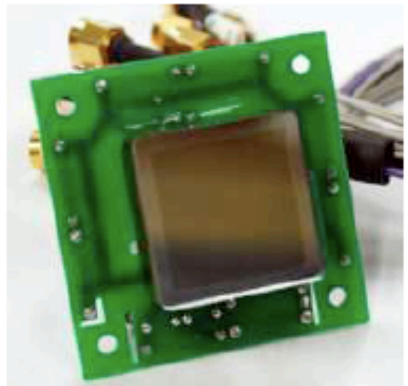


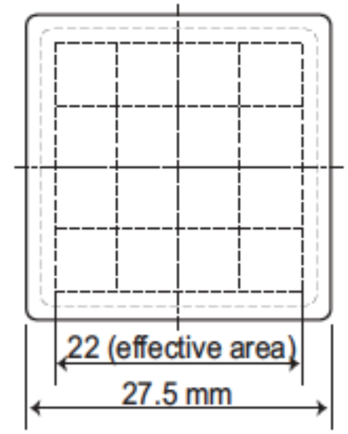
Readout electronics, wedge, and quartz bar

iTOP: Readout by fast pixelated PMTs

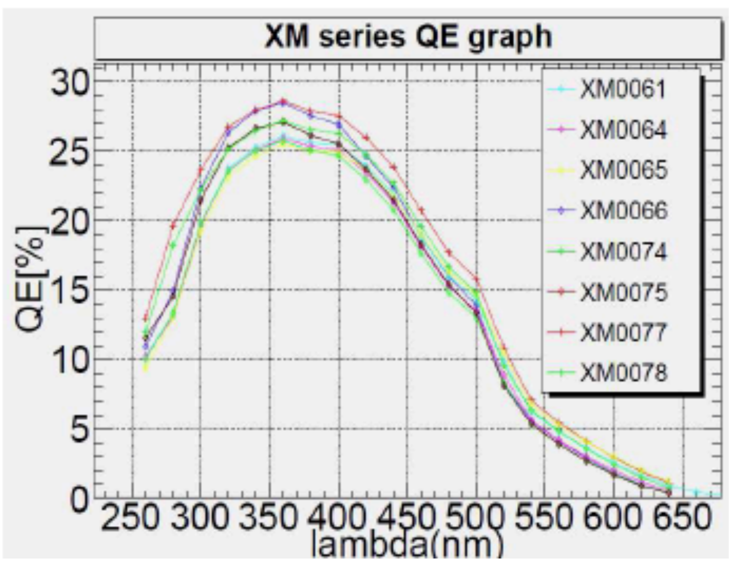
MCP-PMT: Hamamatsu SL-10

MCP-PMT with super bi-alkali photo-cathode, provided by HPK (QE ~28% for bi-alkali and 24% for multi-alkali)

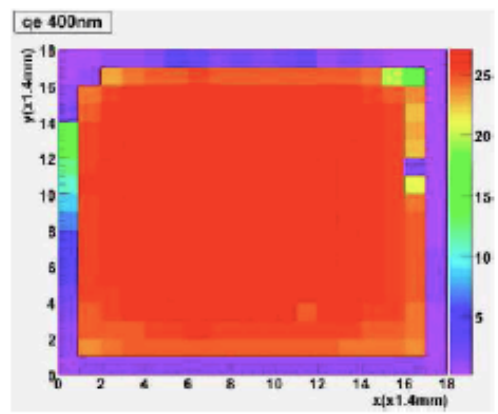




QE distributions for recent samples:



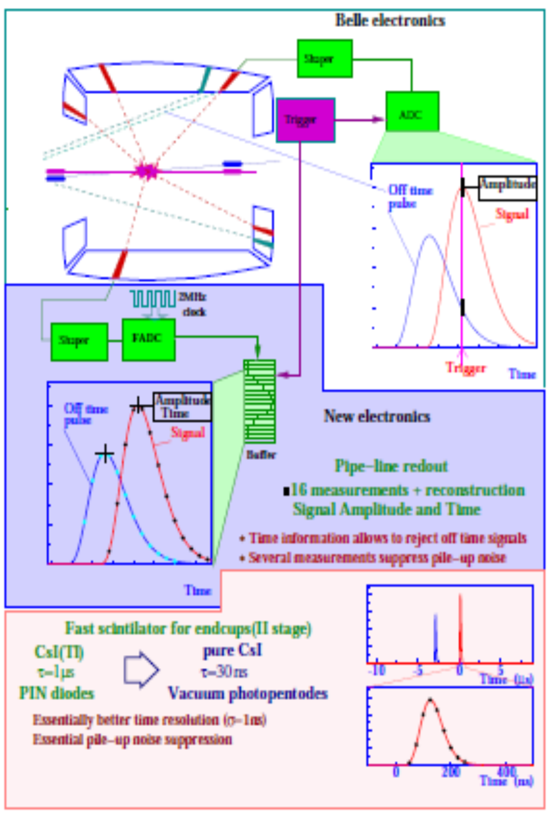
XM0061



ECL (Electromagnetic Crystal Calorimeter)

For t=0

1. Upgrade electronics to do waveform sampling & fitting
2. Upgrade endcap crystal (baseline option: pure CsI + photomultipliers); upgrade will have to be staged.



- Belle II can get advantage in π^0 and soft photon-detection efficiency and resolution in comparision with LHCb experiment
- Modify electronics for the barrel.
- Pipe-line readout with waveform analysis:
- 16 points within the signal are fitted by the signal function $F(t)$:

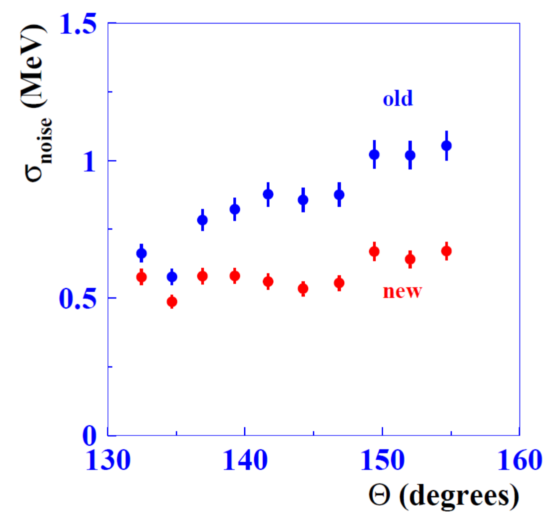
$$F(t) = A\ f(t - t_0)$$

A - amplitude of the signal and
t_0 – time of the signal,

$$\chi^2 = \sum (y_i - A\ f(t_i - t_0)) S^{-1}_{ij} (y_i - A\ f(t_i - t_0))$$

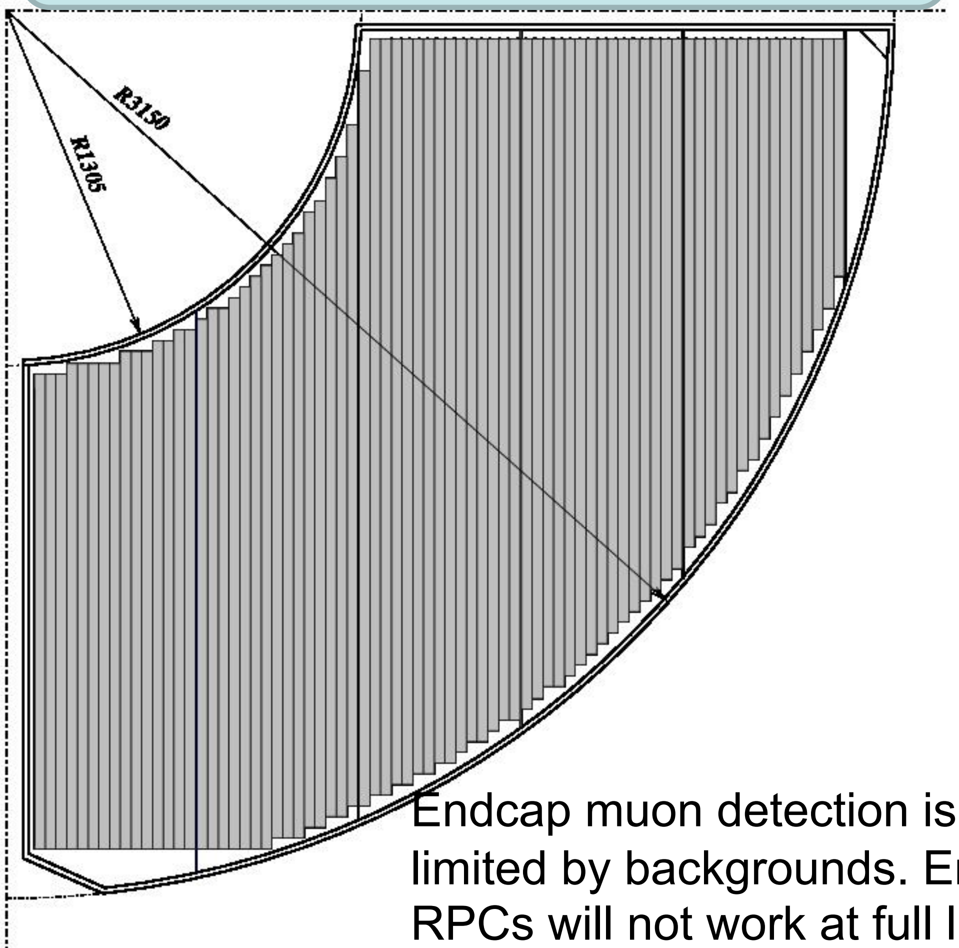
- Both amplitude and time information are reconstructed:
- Next stage: Replace the CsI(Tl) by the pure CsI crystals in endcaps.

One module of new electronics tested in Belle



KLM: K_L&Muon detector

RPC → Scintillator (Endcap)
also inner 1,2, or 3 layers of Barrel(TBD)

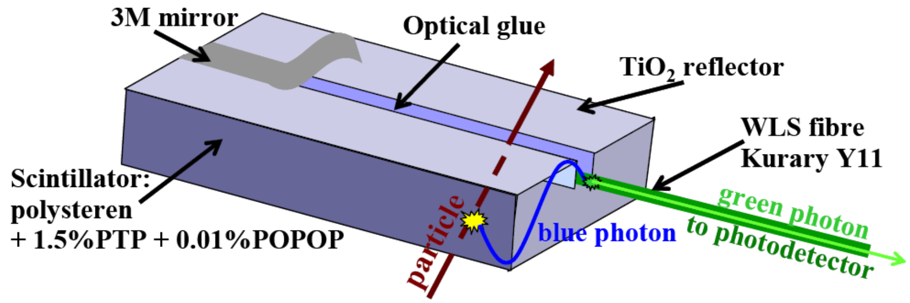


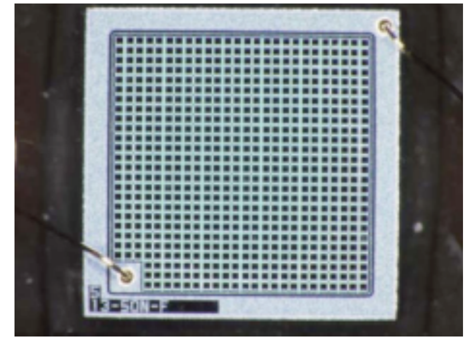
Endcap muon detection is already limited by backgrounds. Endcap RPCs will not work at full luminosity and higher backgrounds. Inner barrel is *marginal.*

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

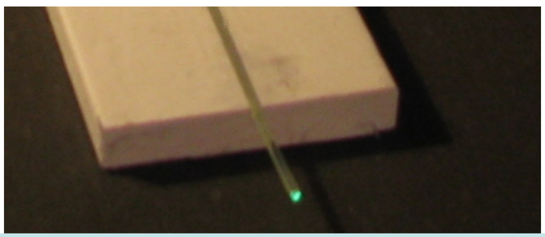
Anatomy of Belle II scintillator strip





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

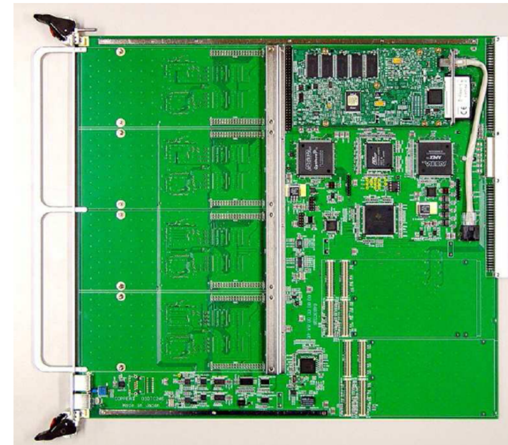
fiber: Kuraray Y11 MC



Scintillator bar: Vladimir (Russia)
(used in T2K ND)

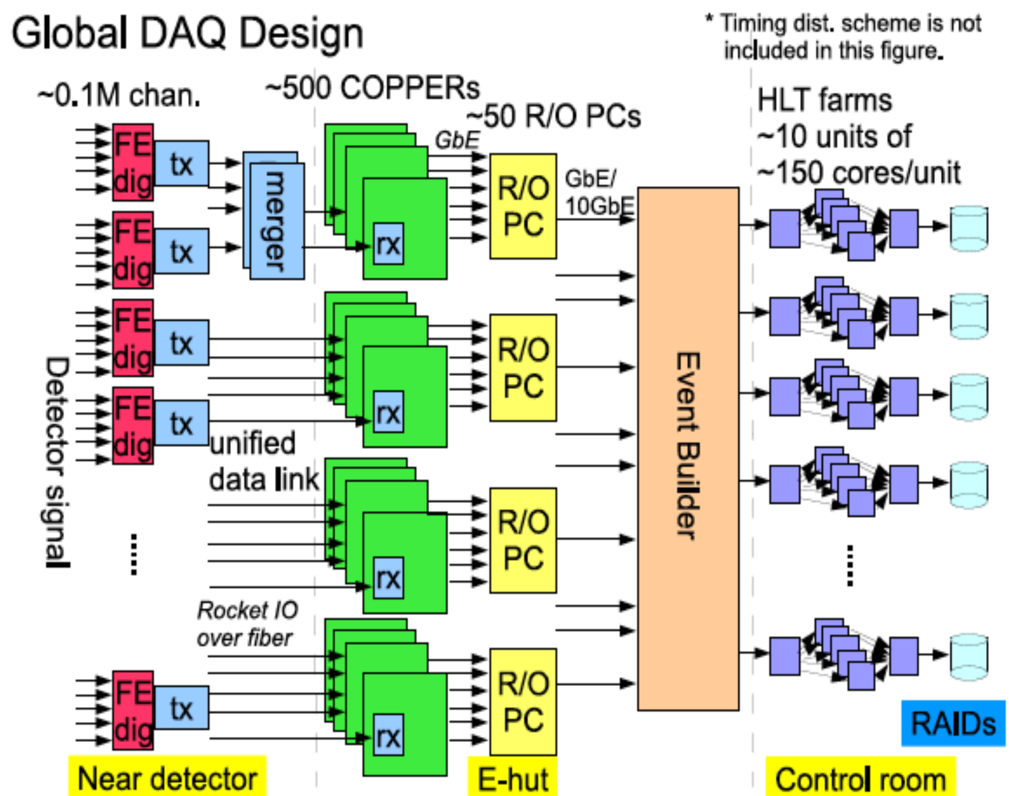
Mechanical mockup at
ITEP Moscow

DAQ Overview (*no time for details*)



- At full luminosity, the data rate is 600 MB/sec.
- A high performance DAQ system is being designed by KEK and IHEP Beijing

		Belle	Belle II
Level 1 Trigger	Trigger rate (kHz)	0.3-0.5	20-30
	Event size (kBytes)	40	300
	Data rate (MB/s)	20	6000
High Level Trigger	Reduction	1/ 2	1/10
	Storage Bandwidth (MB/s)	20	600



SuperKEKB/BelleII Status

- 5.8 oku yen (M$) for Damping Ring (FY2010)
- 100 oku yen (M$) for machine: Very Advanced Research Support Program (preliminary approval);
- + ~60 oku-yen/year for three years
- KEKB operation terminated in July 2010
- Jan-March 2011 : *full approval* by the Diet and Japanese government
- 2010-2013: construction, installation
- End of 2014: accl. commissioning

一般向けページ >> 研究者向けページ >> English Pages >>

Press Release

大学共同利用機関法人 KEK 高エネルギー加速器研究機構

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last update: 10/06/23

Press Release

KEKB upgrade plan has been approved

June 23, 2010
High Energy Accelerator Research Organization (KEK)

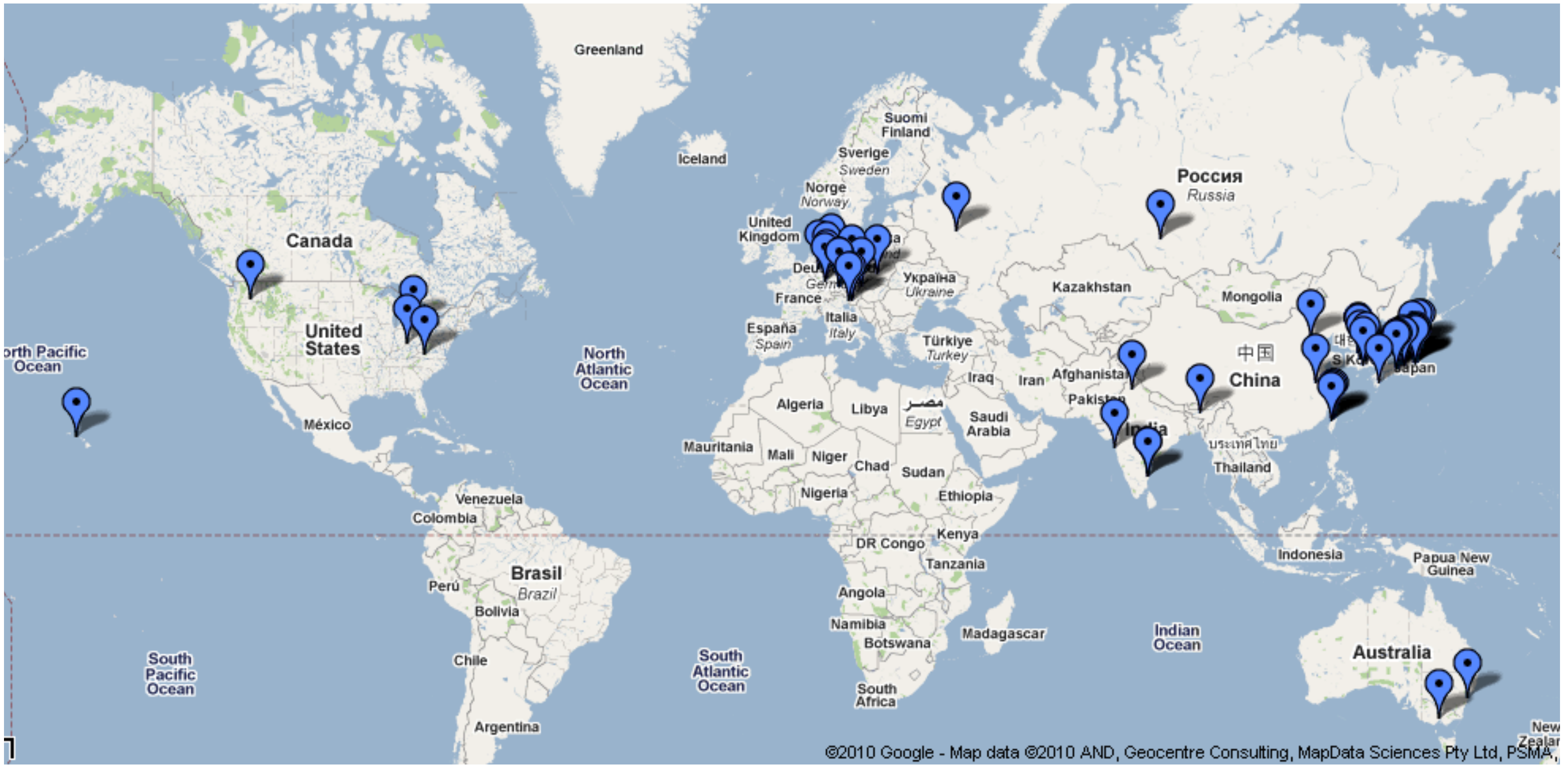
The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government.

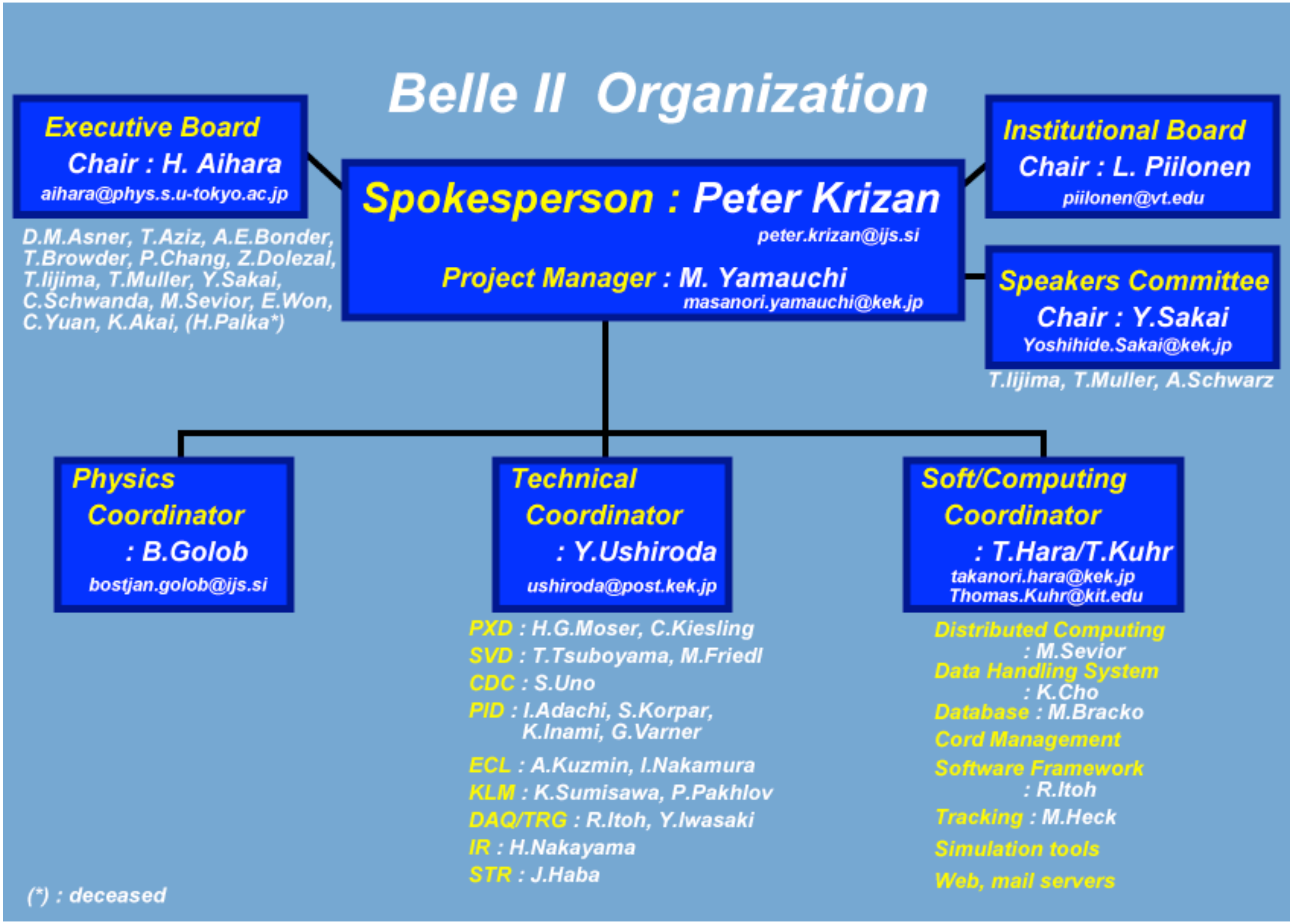
"We are delighted to hear this news," says Masanori Yamauchi, former spokesperson for the Belle experiment and currently a deputy director of the Institute of Particle and Nuclear Studies of KEK. "This three- year upgrade plan allows the Belle experiment to study the physics from decays of heavy flavor particles with an unprecedented precision. It means that KEK in Japan is launching a renewed research program in search for new physics by using a technique which is complementary to what is employed at LHC at CERN."

[Media Contact] Youhei Morita,
Head of Public Relations Office, KEK
tel. +81-29-879-6047

| proffice@kek.jp | Copyright | Send Question

Belle II Overview in GOOGLE Maps




Belle II Organization
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aihara@phys.s.u-tokyo.ac.jp
D.M.Asner, T.Aziz, A.E.Bonder,
T.Browder, P.Chang, Z.Dolezal,
T.Iijima, T.Muller, Y.Sakai,
C.Schwanda, M.Sevior, E.Won,
C.Yuan, K.Akai, (H.Palka*)
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SVD : T.Tsuboyama, M.Friedl
CDC : S.Uno
PID : I.Adachi, S.Korpar,
K.Inami, G.Varner
ECL : A.Kuzmin, I.Nakamura
KLM : K.Sumisawa, P.Pakhlov
DAQ/TRG : R.Itoh, Y.Iwasaki
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Data Handling System
: K.Cho
Database : M.Bracko
Cord Management
Software Framework
: R.Itoh
Tracking : M.Heck
Simulation tools
Web, mail servers
(*) : deceased

KEK is moving ahead with a Super B Factory. SuperKEKB starts in late 2014 with an international detector collaboration (Belle-II). The project is approved. The laboratory and manpower are already in place; many nations have already committed; the funding is more or less assembled. KEKB and Belle have a track record of exceeding expectations.

The project is designed to discover new FCNC and new sources of CPV. The physics program is deep, broad and should help elucidate new physics found at the LHC.

Backup Slides

On the Impact of the Earthquake (message from KEK management)

- As is now well known, Japan suffered a terrible earthquake and tsunami on March 11, which has caused tremendous damage, especially in the Tohoku area. Fortunately, all KEK personnel and users are safe and accounted for. The injection linac did suffer significant but manageable damage, and repairs are underway. The damage to the KEKB main rings appears to be less serious, though non-negligible. No serious damage has been reported so far at Belle. Further investigation is necessary. We would like to convey our deep appreciation to everyone for your generous expressions of concern and encouragement.
- No significant delay expected for SuperKEKB construction (damping ring construction schedule may slip ~1-2 months)

The Belle II Collaboration

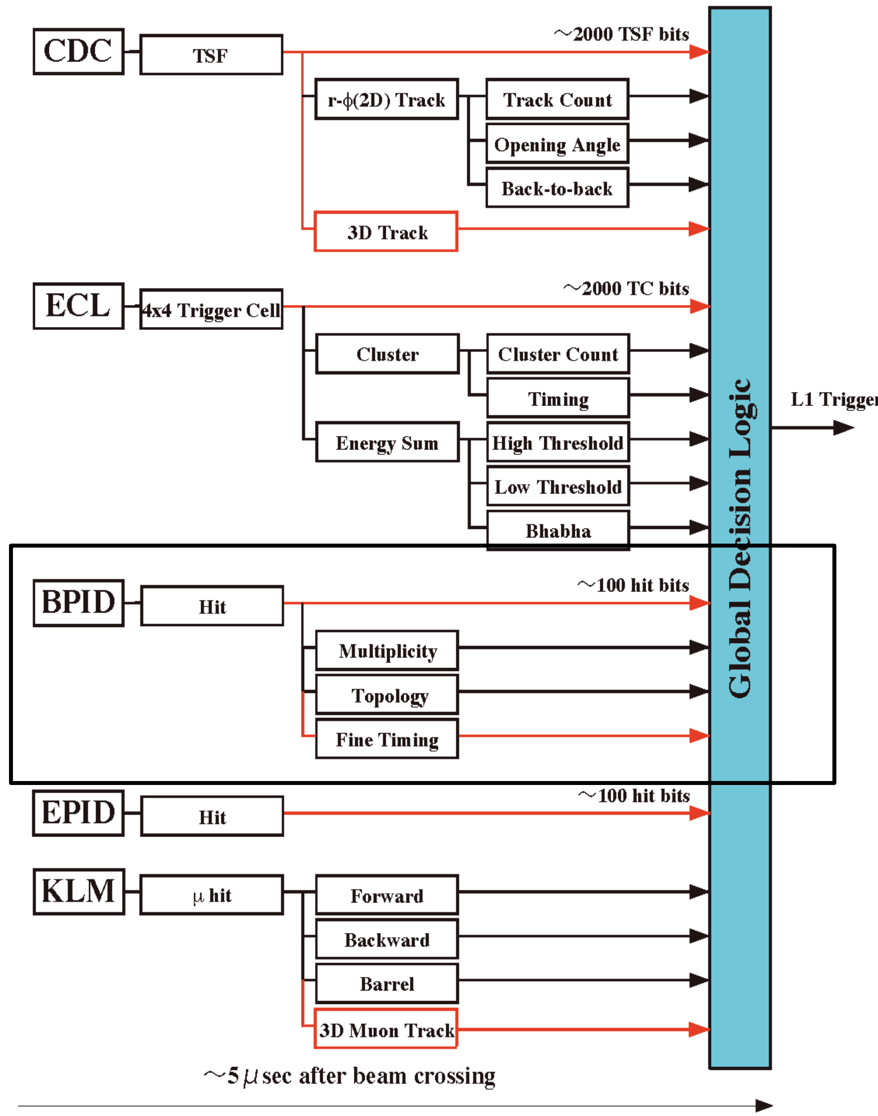
Technical Design Report (TDR)

- arXiv:1011.0352: http://arxiv.org/abs/1011.0352
- KEK Report 2010-1: http://www-lib.kek.jp/cgi-bin/kiss_prepri.v8?KN=201024001&OF=8.
- Belle II web page: http://b2comp.kek.jp/~twiki/pub/Organization/B2TDR/B2TDR.pdf

Reviewed by BPAC external review at two special meetings in May 2010 and in Nov. 2010, hardcopies printed in Nov.

Trigger Overview

- The luminosity will be 40 times larger than in Belle
- Physics event rate will be 10 kHz at $8x10^{35}/cm^2/s$.
- The BPID (a.k.a iTOP) will provide a fast trigger signal.



Lum ($cm^{-2}s^{-1}$)	Lum. Comp.	N/S=~0.5		N/S=~6	
		BG	Total	BG	Total
$1x10^{34}$	190 Hz	100 Hz	290 Hz	1100 Hz	1300 Hz
$1x10^{35}$	1.9 kHz	1.0 kHz	2.9 kHz	11 kHz	13 kHz
$8x10^{35}$	7.2 kHz	8 kHz	23 kHz	88 kHz	95 kHz

Belle II/ LHCb comparisons (part I)

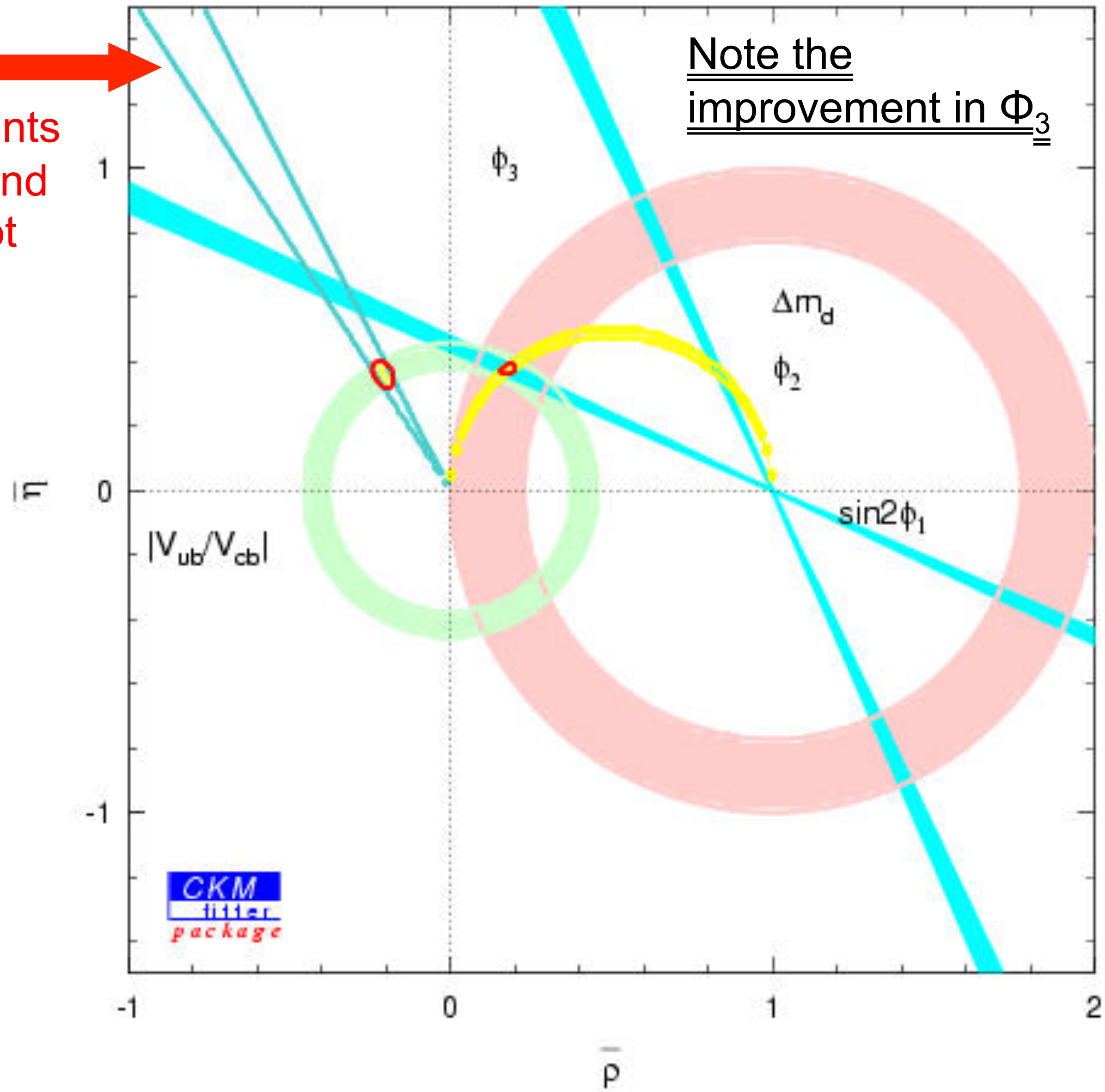
Observable	Belle 2006 ($\sim$0.5 ab^{-1})	Belle II/SuperKEKB (5 ab^{-1})	(50 ab^{-1})	LHCb† (2 fb^{-1})	(10 fb^{-1})
Hadronic $b \to s$ transitions					
$\Delta\mathcal{S}_{\phi K^0}$	0.22	0.073	0.029		0.14
$\Delta\mathcal{S}_{\eta' K^0}$	0.11	0.038	0.020		
$\Delta\mathcal{S}_{K^0_S K^0_S K^0_S}$	0.33	0.105	0.037	-	-
$\Delta\mathcal{A}_{\pi^0 K^0_S}$	0.15	0.072	0.042	-	-
$\mathcal{A}_{\phi\phi K^+}$	0.17	0.05	0.014		
$\phi_1^{eff}(\phi K_S)$ Dalitz		3.3°	1.5°		
Radiative/electroweak $b \to s$ transitions					
$\mathcal{S}_{K^0_S \pi^0 \gamma}$	0.32	0.10	0.03	-	-
$\mathcal{B}(B \to X_s\gamma)$	13%	7%	6%	-	-
$A_{CP}(B \to X_s\gamma)$	0.058	0.01	0.005	-	-
C_9 from $A_{FB}(B \to K^*\ell^+\ell^-)$	-	11%	4%		
C_{10} from $A_{FB}(B \to K^*\ell^+\ell^-)$	-	13%	4%		
C_7/C_9 from $A_{FB}(B \to K^*\ell^+\ell^-)$	-		5%		7%
R_K		0.07	0.02		0.043
$\mathcal{B}(B^+ \to K^+\nu\nu)$	$^{\dagger\dagger} < 3\ \mathcal{B}_{\rm SM}$		30%	-	-
$\mathcal{B}(B^0 \to K^{*0}\nu\bar{\nu})$	$^{\dagger\dagger} < 40\ \mathcal{B}_{\rm SM}$		35%	-	-
Radiative/electroweak $b \to d$ transitions					
$\mathcal{S}_{\rho\gamma}$	-	0.3	0.15		
$\mathcal{B}(B \to X_d\gamma)$	-	24% (syst.)		-	-

Belle II/ LHCb comparisons (part II)

Observable	Belle 2006 (~0.5 ab^{-1})	Belle II/SuperKEKB (5 ab^{-1})	Belle II/SuperKEKB (50 ab^{-1})	LHCb† (2 fb^{-1})	LHCb† (10 fb^{-1})
Leptonic/semileptonic B decays					
$\mathcal{B}(B^+ \to \tau^+\nu)$	3.5σ	10%	3%	-	-
$\mathcal{B}(B^+ \to \mu^+\nu)$	†† $< 2.4\mathcal{B}_{\rm SM}$	4.3 ab^{-1} for 5σ discovery		-	-
$\mathcal{B}(B^+ \to D\tau\nu)$	-	8%	3%	-	-
$\mathcal{B}(B^0 \to D\tau\nu)$	-	30%	10%	-	-
LFV in τ decays (U.L. at 90% C.L.)					
$\mathcal{B}(\tau \to \mu\gamma)$ $[10^{-9}]$	45	10	5	-	-
$\mathcal{B}(\tau \to \mu\eta)$ $[10^{-9}]$	65	5	2	-	-
$\mathcal{B}(\tau \to \mu\mu\mu)$ $[10^{-9}]$	21	3	1	-	-
Unitarity triangle parameters					
$\sin 2\phi_1$	0.026	0.016	0.012	~0.02	~0.01
ϕ_2 $(\pi\pi)$	11°	10°	3°	-	-
ϕ_2 $(\rho\pi)$	$68° < \phi_2 < 95°$	3°	1.5°	10°	4.5°
ϕ_2 $(\rho\rho)$	$62° < \phi_2 < 107°$	3°	1.5°	-	-
ϕ_2 (combined)		2°	$\lesssim 1°$	10°	4.5°
ϕ_3 $(D^{(*)}K^{(*)})$ (Dalitz mod. ind.)	20°	7°	2°	8°	
ϕ_3 $(DK^{(*)})$ (ADS+GLW)	-	16°	5°	5-15°	
ϕ_3 $(D^{(*)}\pi)$	-	18°	6°		
ϕ_3 (combined)		6°	1.5°	4.2°	2.4°
$\lvert V_{ub}\rvert$ (inclusive)	6%	5%	3%	-	-
$\lvert V_{ub}\rvert$ (exclusive)	15%	12% (LQCD)	5% (LQCD)	-	-
$\bar{\rho}$	20.0%		3.4%		
$\bar{\eta}$	15.7%		1.7%		

New Physics might appear like this @50 ab^{-1}

NB Constraints from trees and boxes do not agree



This would indicate that there is a NP phase in b→d

50 ab^{-1}

Super B Factory vs current sensitivities

Hard to condense all the NP observables into one sound bite……

Observable	SFF sensitivity	Current sensitivity
$\sin(2\beta)$ $(J/\psi K^0)$	0.005-0.012	0.01
γ (DK)	1–2°	$\sim$ 31° (CKMFitter)
α $(\pi\pi, \rho\pi, \rho\rho)$	1–2°	$\sim$ 15° (CKMFitter)
$\lvert V_{ub}\rvert$(excl)	3-5%	$\sim$ 18% (PDG review)
$\lvert V_{ub}\rvert$(incl)	2-6%	$\sim 8(PDGreview)\%$
$\bar{\rho}$	1.7-3.4%	$^{+20\%}_{-12\%}$
$\bar{\eta}$	0.7-1.7%	$\pm$4.6%
$S(\phi K^0)$	0.02-0.03	0.17
$S(\eta' K^0$	0.01-0.02	0.07
$\mathcal{B}(B \to \tau\nu)$	$3-4\%$	30%
$\mathcal{B}(B \to \mu\nu)$	$5-6\%$	not measured
$\mathcal{B}(B \to D\tau\nu)$	$2-2.5\%$	31%
$\mathcal{B}(B \to \rho\gamma)/\mathcal{B}(B \to K^*\gamma)$	3-4%	16%
$A_{CP}(b \to s\gamma)$	0.004-0.005	0.037
$A_{CP}(b \to s\gamma + d\gamma)$	0.01	0.12
$S(K_S\pi^0\gamma)$	0.02-0.03	0.24
$S(\rho^0\gamma)$	0.08-0.12	0.67
$A^{FB}(B \to K^*\ell^+\ell^-)_{s0}$	4-6%	not measured
$\mathcal{B}(B \to K\nu\bar{\nu})$	16-20%	not measured
$\mathcal{B}(B \to s\ell^+\ell^-)_{s0}$		
$\mathcal{B}(B \to d\ell^+\ell^-)_{s0}$		not measured
ϕ_D (NP phase)	$\pm(1-2)°$	$\sim \pm 20°$
$\mathcal{B}(\tau \to \mu\gamma)$	$(2-8) \times 10^{-9}$	not seen, $< 5.0 \times 10^{-8}$
$\mathcal{B}(\tau \to \mu\mu\mu)$	$(0.2-1) \times 10^{-9}$	not seen, $< (2-4) \times 10^{-8}$
$\mathcal{B}(\tau \to \mu\eta)$	$(0.4-4) \times 10^{-9}$	not seen, $< 5.1 \times 10^{-8}$

(50-75 ab^{-1} compared to current 1 ab^{-1})

From TEB et al., hep-ph/0710.3799 and RMP 81, 2009

Why a flavor factory is so important:

- *A flavor factory studies processes that occur at 1-loop in the SM but may be O(1) in NP: FCNC, neutral meson mixing, CP violation. These loops probe energy scales that cannot be accessed directly (even at the LHC).*
- *Current experimental bounds NP scale is 10-100 TeV; thus, if the LHC finds NP at O(1) TeV, it must have a nontrivial flavor/phase structure*
- *Even if no new sources of CPV or flavor violation, current SM couplings are sufficient to provide sensitivity to new particles at a super flavor factory*
- *SM CP violation is insufficient to account for baryogenesis of matter-dominated universe; must be other sources of CPV*
- *If supersymmetry is found at the LHC, a crucial question will be: how is it broken. By studying flavor couplings, a flavor factory can address this.*

A (super) flavor factory searches for NP by phases, CP asymmetries, inclusive decay processes, rare leptonic decays, absolute branching fractions. There is a wide range of observables. These are complementary to the LHC Atlas and CMS experiments, which will search for NP via direct new particle production at high-p_T.

The most compelling hint for new physics in the weak interaction is the BAU

$$\boxed{\frac{n_{\mathcal{B}}}{n_\gamma} = (5.1^{+0.3}_{-0.2})\times 10^{-10}}$$ WMAP

$$\boxed{\mathrm{KM} \sim 10^{-20}}$$

Too small by 10 orders of magnitude in the SM

Why? Jarlskog Invariant in the SM (only 3 generations in KM)

$$J = (m_t^2 - m_u^2)(m_t^2 - m_c^2)(m_c^2 - m_u^2)(m_b^2 - m_d^2)(m_b^2 - m_s^2)(m_s^2 - m_d^2)\,A$$

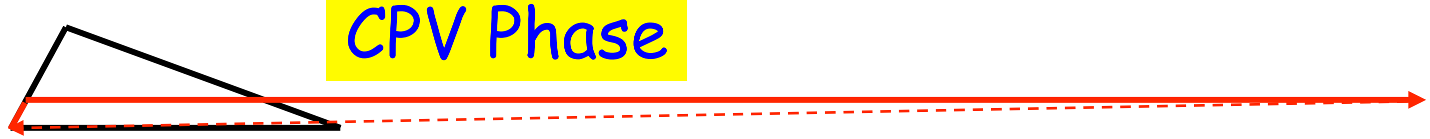
Normalize by T ~ 100 GeV ⇒ $\boxed{J/T^{12} \sim 10^{-20}}$

Mass factors in J too small !

in SM

$A \sim 3\times 10^{-5}$ is common (unique) area of triangle

CPV Phase



Credit: W.S. (George) Hou

Some <u>popular</u> theoretical solutions to this BAU problem and their experimental implications:

<u>Leptogenesis:</u> requires M~O(10^{10} GeV) RH neutrinos AND CP violation in the neutrino sector.

May produce lepton flavor violation such as $\tau \rightarrow \mu\gamma$ (or $\mu \rightarrow e$ conversion)

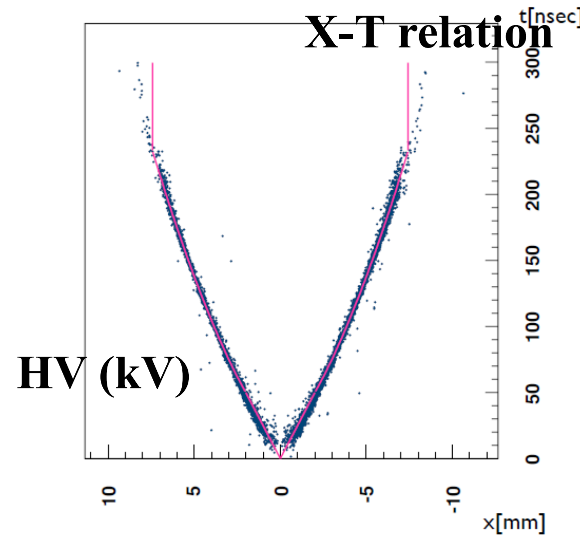
<u>"Enhanced Baryogenesis":</u> add massive 4th generation quarks (e.g. Hou, Soni et al) or add new SUSY particles in the MSSM (light scalars e.g. stop). Both will lead to new CPV phases.

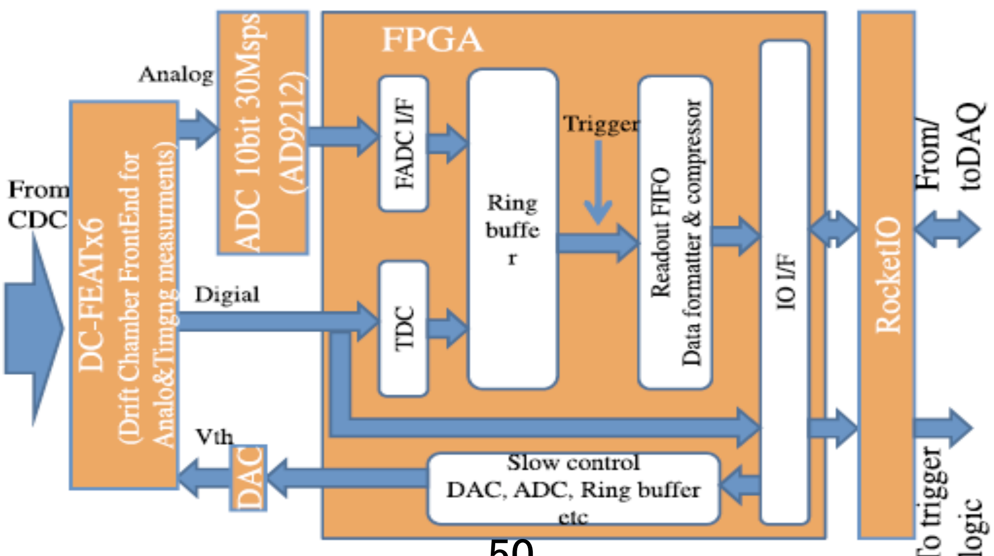
Phases in $b \rightarrow s$ or $b \rightarrow d$ mixing, anomalous EW penguins (K π puzzle), B_s mixing etc..

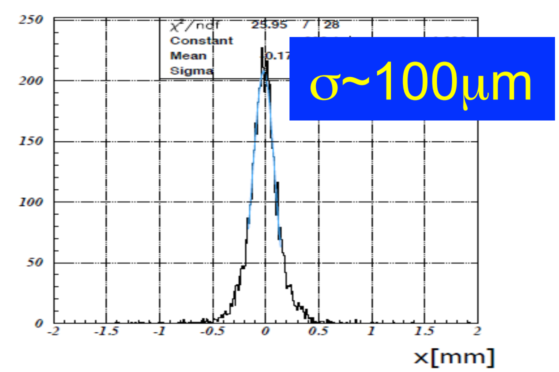
Looking for low energy echoes of the primordial *CP violation produced at energy scales that are beyond the reach of accelerators*

Central Drift chamber

- The new electronics has been designed and tested.
- The drift time is measured with a TDC built-in in an FPGA.
- A slow FADC (around 30MHz) measures the signal charge.

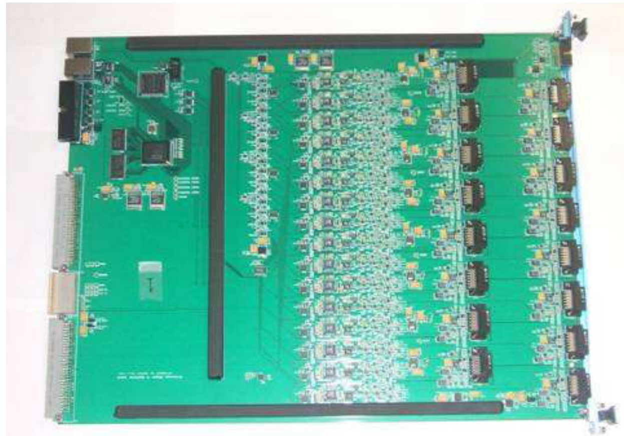






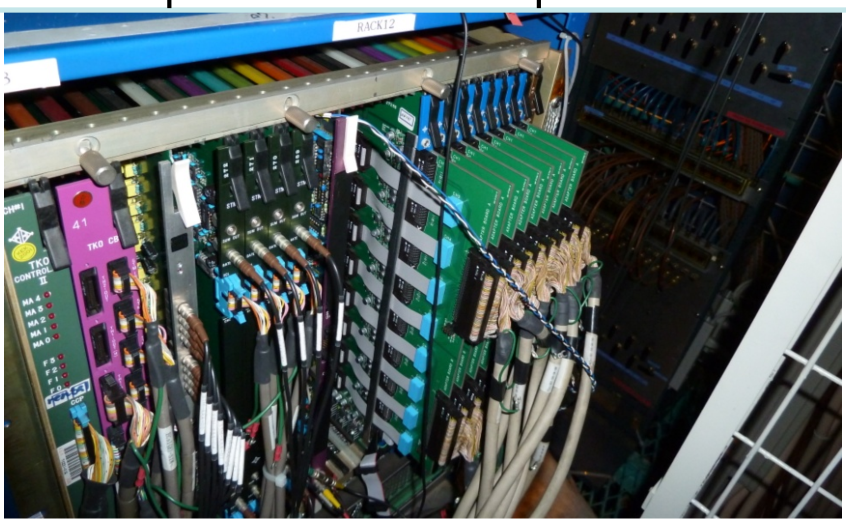
Residual distribution

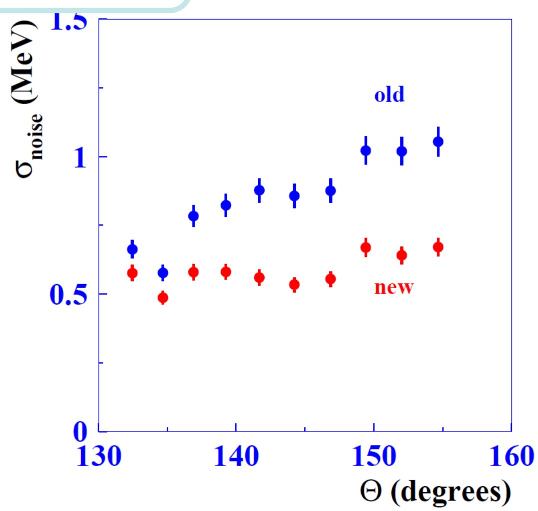
New Belle II ECL readout electronics



Ready for mass production

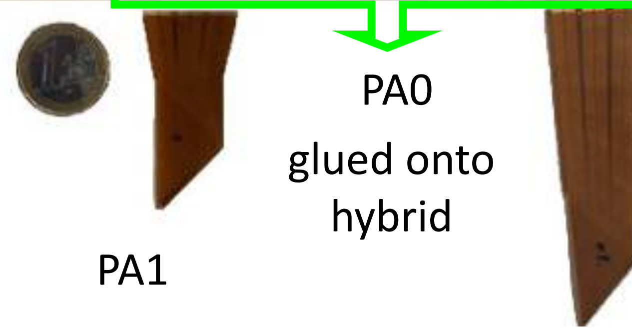
One of older versions has been installed in Belle to readout part of the end cap in 2008. Tested OK.





APV25 readout chip adapted to Belle-II

- Origami PCB
  - 3-layer design
  - 237µm thick (nominal)
- PA0, PA1 and PA2
  - 2-layer design
  - 145µm thick (nominal)



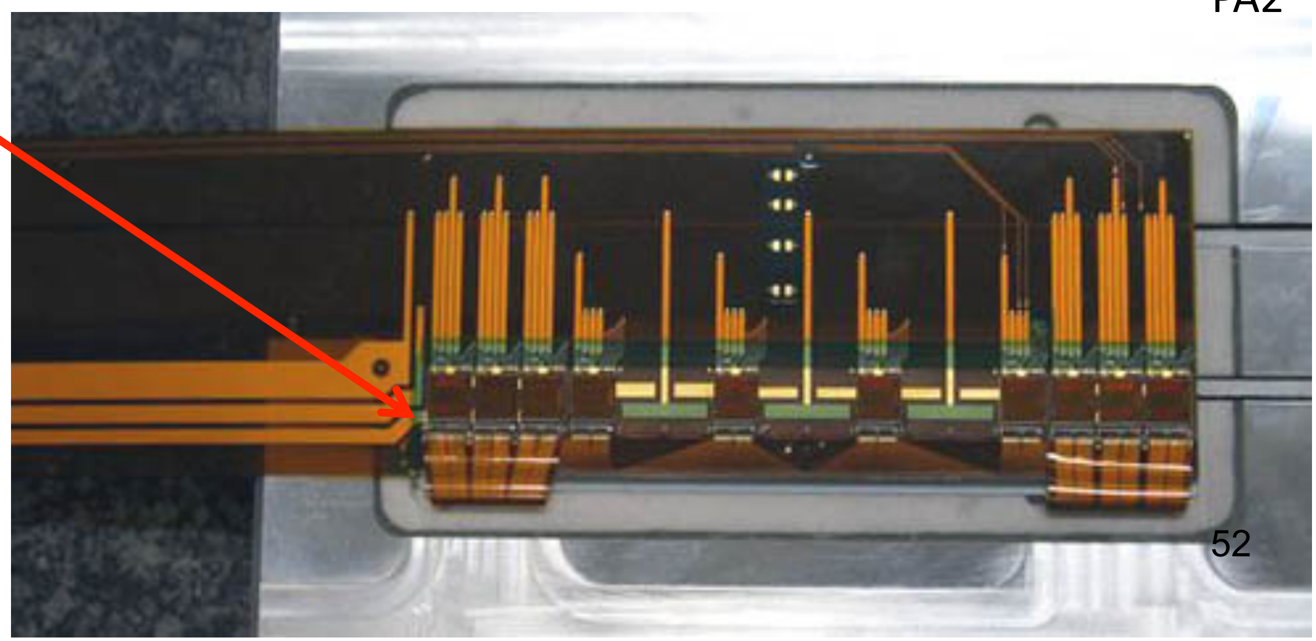
PA0
glued onto hybrid

PA1

PA2

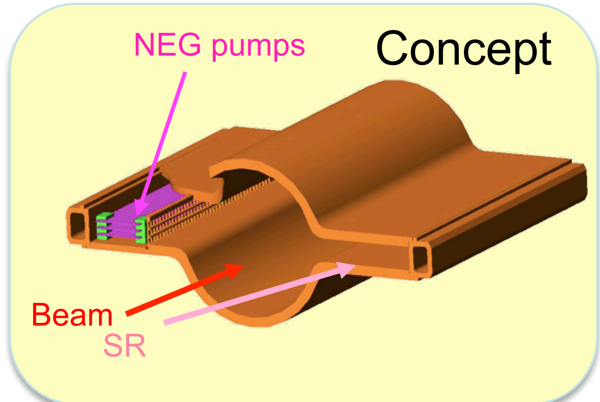
Thinned APV25 (300µm→~100µm)

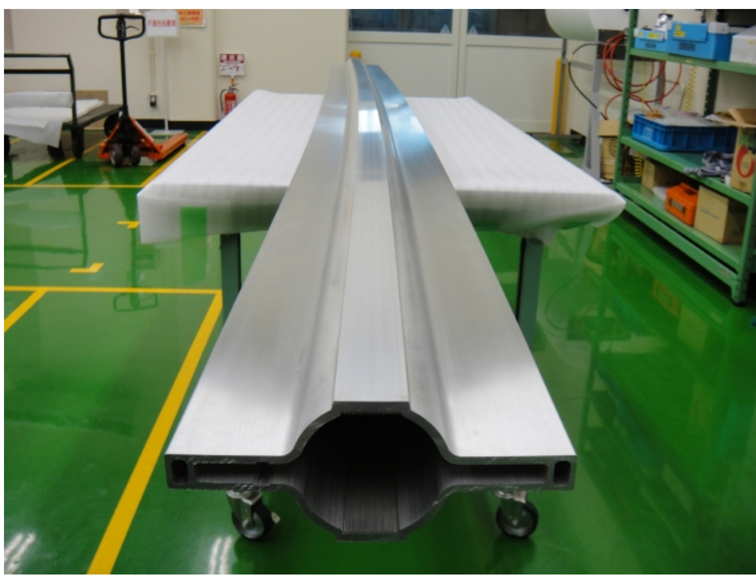
~0.55%X_0/layer



Ante-chamber type beam pipe for LER

- **Structure**
  - SR from beam is handled in the ante-chamber.
  - NEG pumps in the ante-chamber.
  - TiN coating inside.
- **Features**
  - **Suppress electron clouds.**
  - Reduce beam impedance.
  - Reduce SR power density at the wall.
- **Materials Used**
  - Copper in wiggler magnet section.
  - Aluminum alloy in arc sections (reduce cost and manufacturing time).

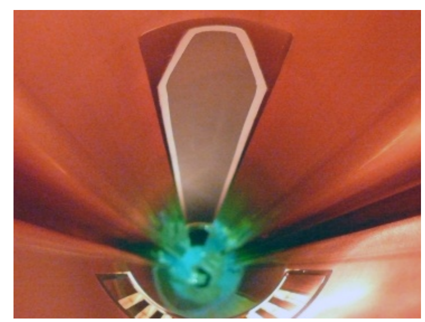




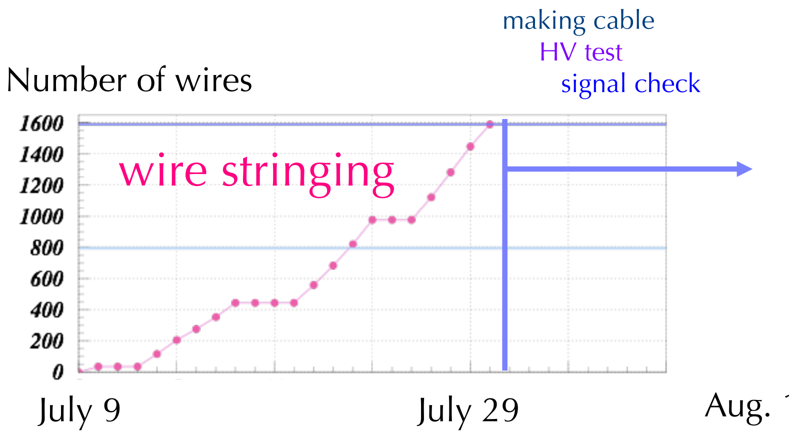
Arc section (aluminum)

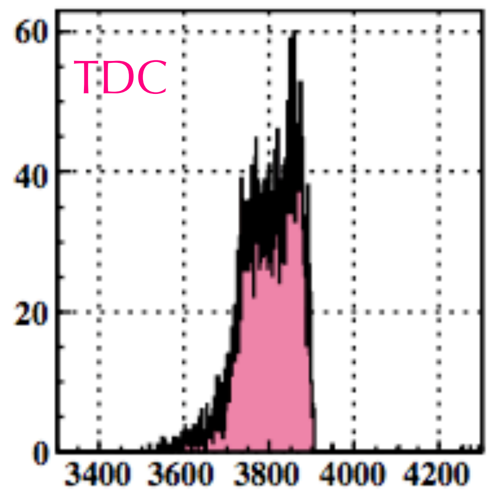
Wiggler section (copper)

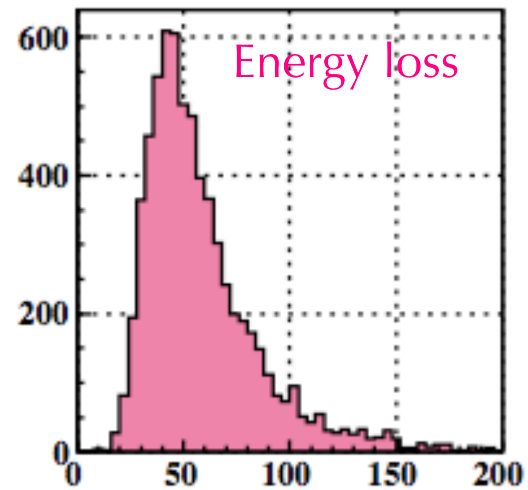
Inside view (clearing electrode for wiggler section)



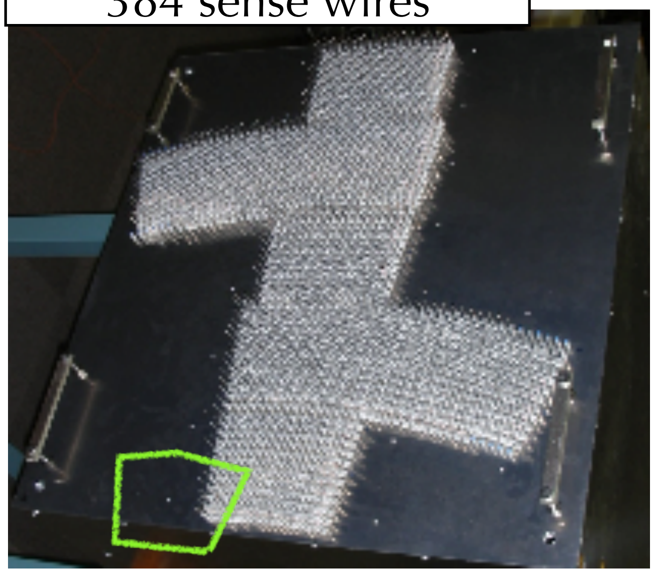
Test chamber measurements (electronics, trigger)

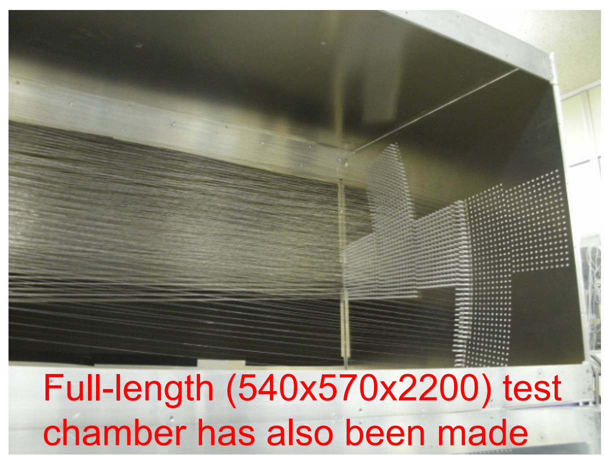


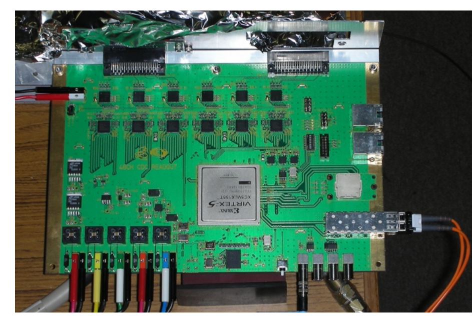




1205 field wires
384 sense wires



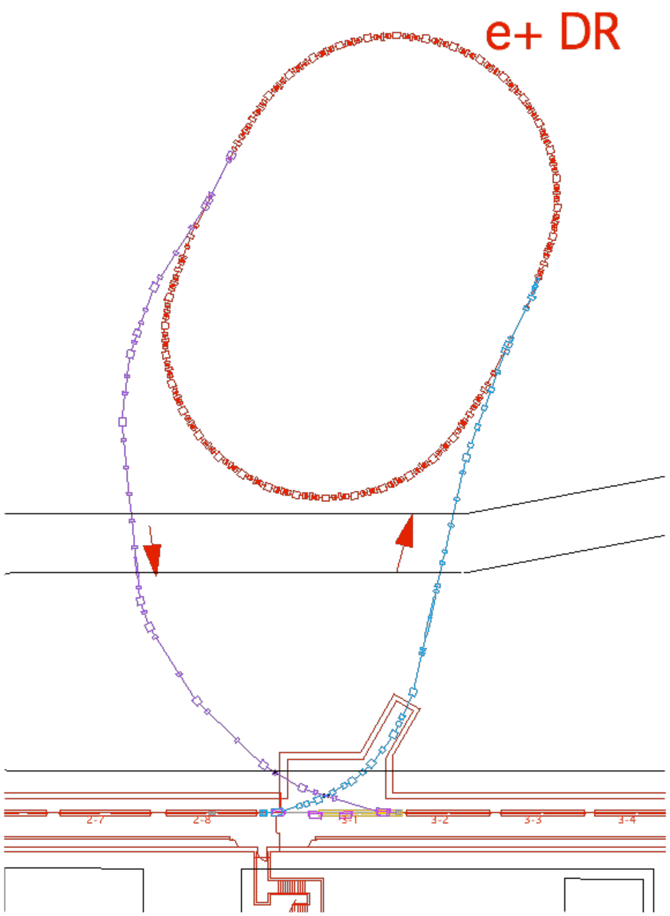




FADC board

New positron damping ring

a positron damping ring
for very low emittance beam injection



Beam energy (GeV)	1.1		
Circumference (m)	135		
# of train	2		
# of bunches/train	2		
Maximum stored current (mA)	70.8		
Horizontal damping time (ms)	11		
Injected-beam emittance (μm)	1.7		
Emittance @ extraction (H/V) (nm)	42.5 / 2.07		
Cavity voltage (Vc) (MV)	0.5	1.0	1.4
Bunch length (mm)	11.1	7.7	6.5
Momentum compaction (α)	0.0141		
Energy spread (%)	0.055		

Electron cloud will be mitigated by TiN coated ante-chambers and solenoid windings.
➔Fabrication of magnets started in JFY2010.

SuperKEKB and Belle-II

(A Super Flavor Factory starting in fall 2014: B, charm and tau etc..)

Gelato at *Tsukuba Express* stop near Asakusa

Belle II Construction Schedule (outer enlarged)