Physics Reach and Status of SuperKEKB/Belle II

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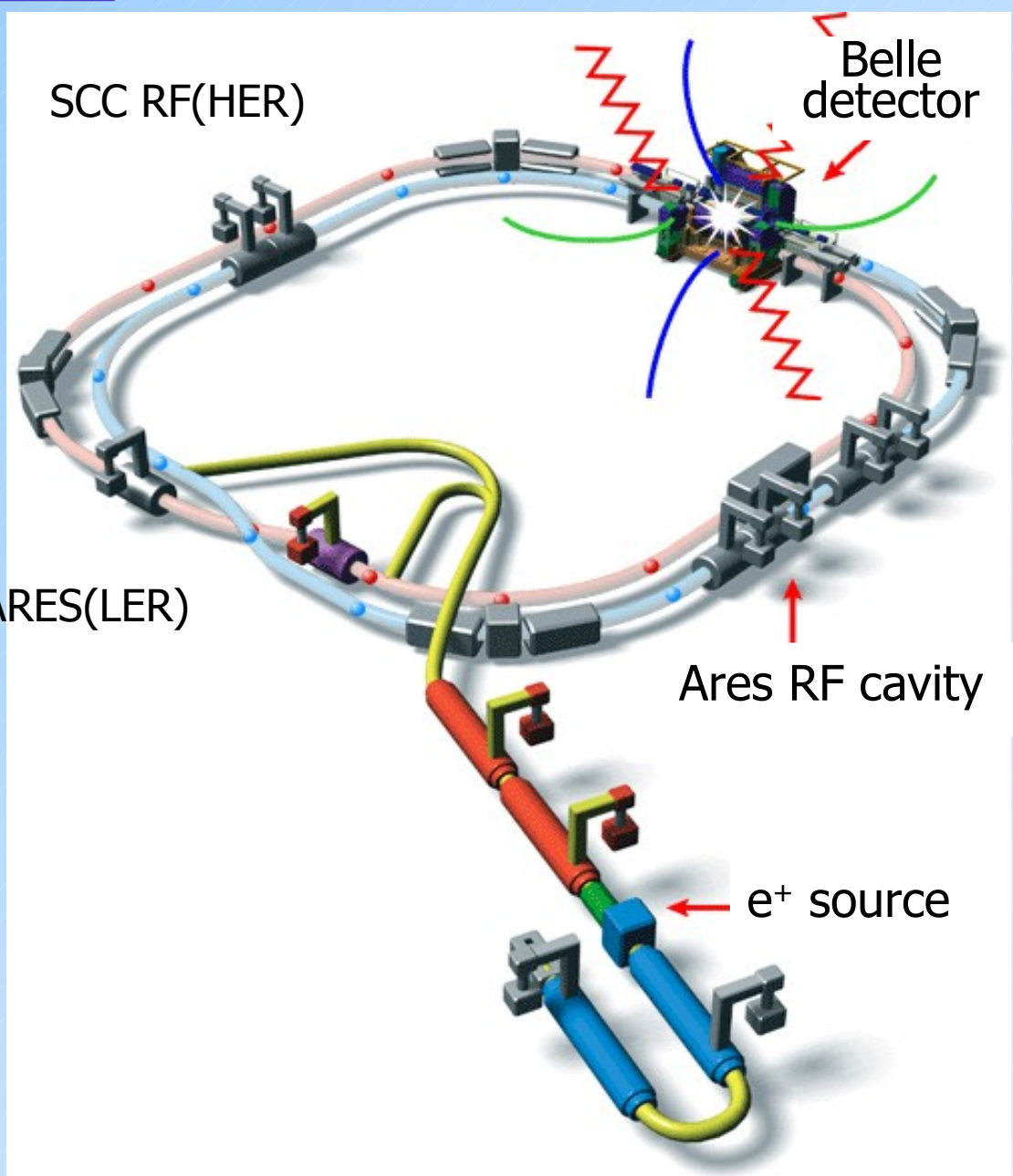
On behalf of the **Belle II Collaboration**

December 6 - 11, 2010
DISCRETE2010

Outline:

- KEKB/Belle – excellent starting point
- Physics motivation for upgrade
- KEKB → SuperKEKB upgrade
- Belle → Belle II upgrade
- Summary

KEKB operation



KEKB parameters:

HER: 8.0 GeV

LER: 3.5 GeV

crossing: 22 mrad

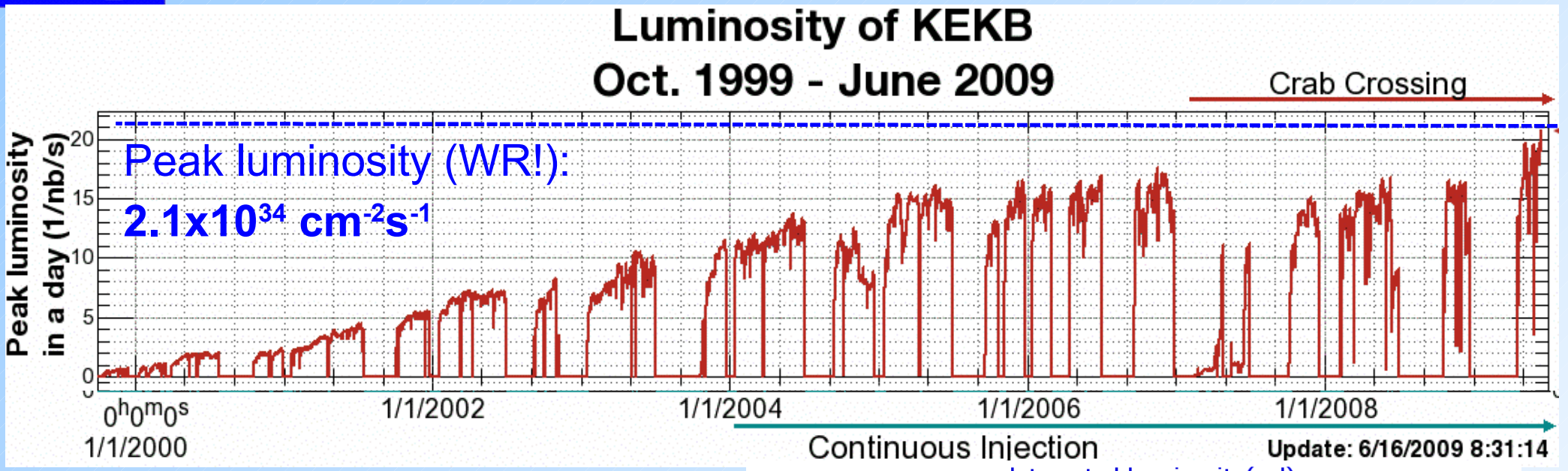
$$E_{CMS} = M(\Upsilon(4S))$$

$$\beta\gamma = 0.425$$

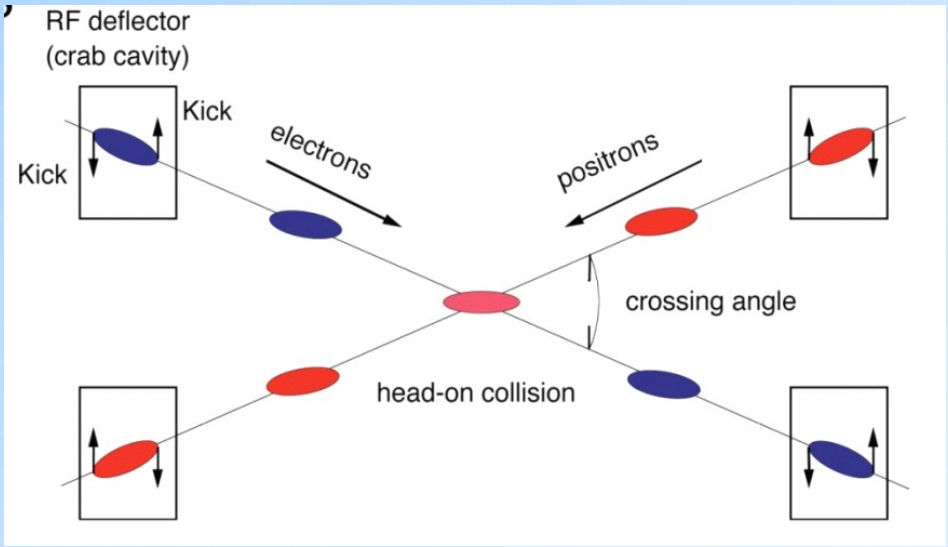
$$\int_{1999}^{2010} \mathcal{L}\,dt > 1\,ab^{-1}$$

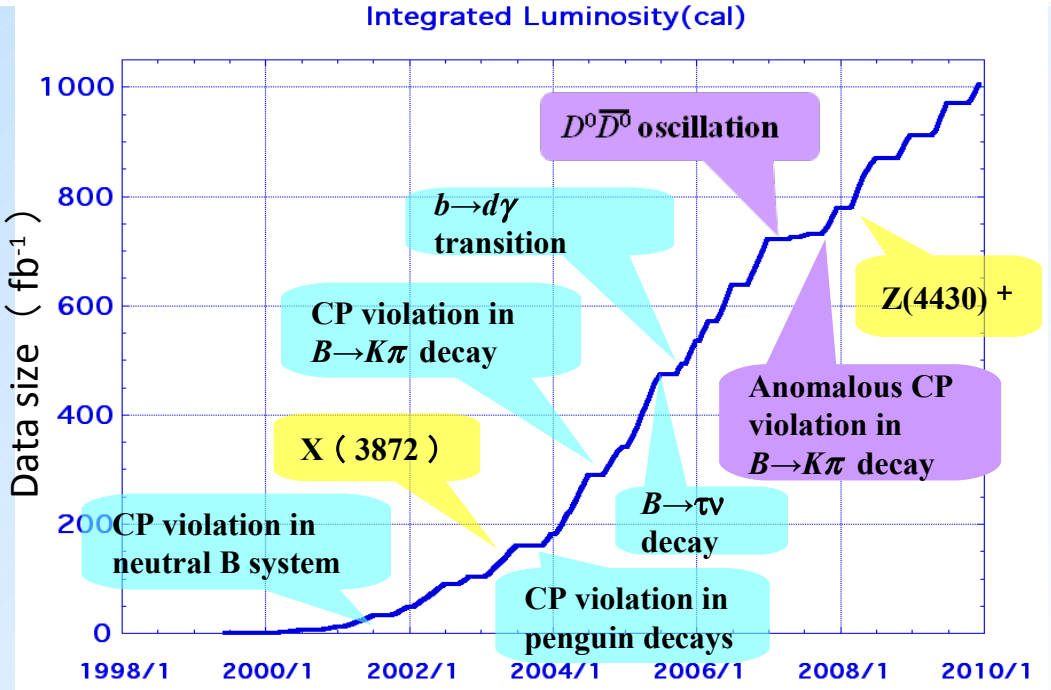
First physics run on June 2, 1999
Last physics run on June 30, 2010

KEKB/Belle time-line



Crab-crossing





Success of B-factories

- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decay modes (e.g., $B \to \tau\nu$, $D\tau\nu$)
- $b \to s$ transitions: probe for new sources of CPV and constraints from the $b \to s\gamma$ branching fraction
- Forward-backward asymmetry (AFB) in $b \to s\ell^+\ell^-$ has become a powerful tool to search for physics beyond SM.
- Evidence of D mixing
- Searches for rare τ decays
- Observation of new hadrons

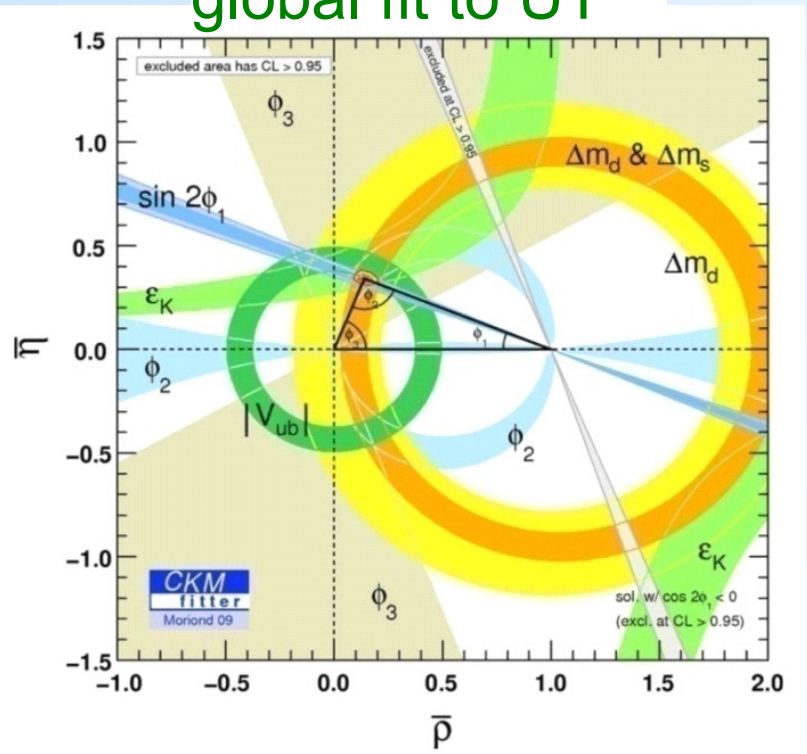
CKM mechanism confirmed at "1st order"

Small discrepancies exist → much more data needed (two orders) to investigate

→ Super B-factory

(complementary to LHC)

global fit to UT



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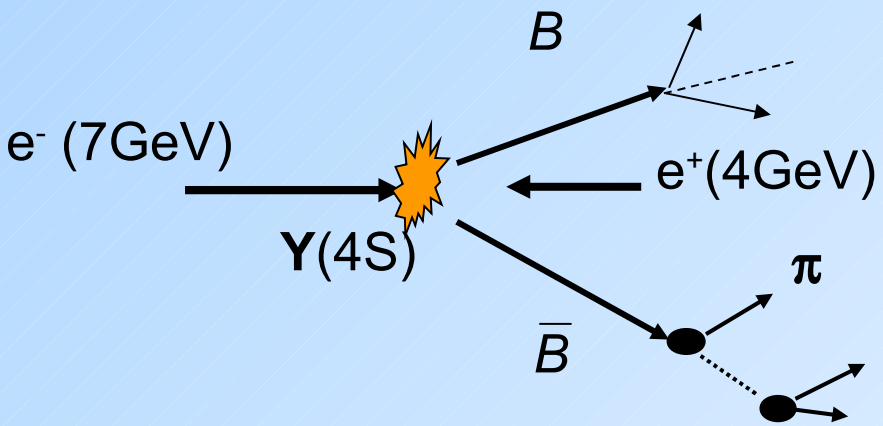
Advantage of e^+e^- - example: full reconstruction tag

Fully reconstruct one of the B's to:

- Tag B flavor/charge
- Determine B momentum
- Exclude decay products of one B from further analysis



Decays of interest
$B \to X_u \ell \nu$,
$B \to K \nu\nu$
$B \to D\tau\nu$, $\tau\nu$

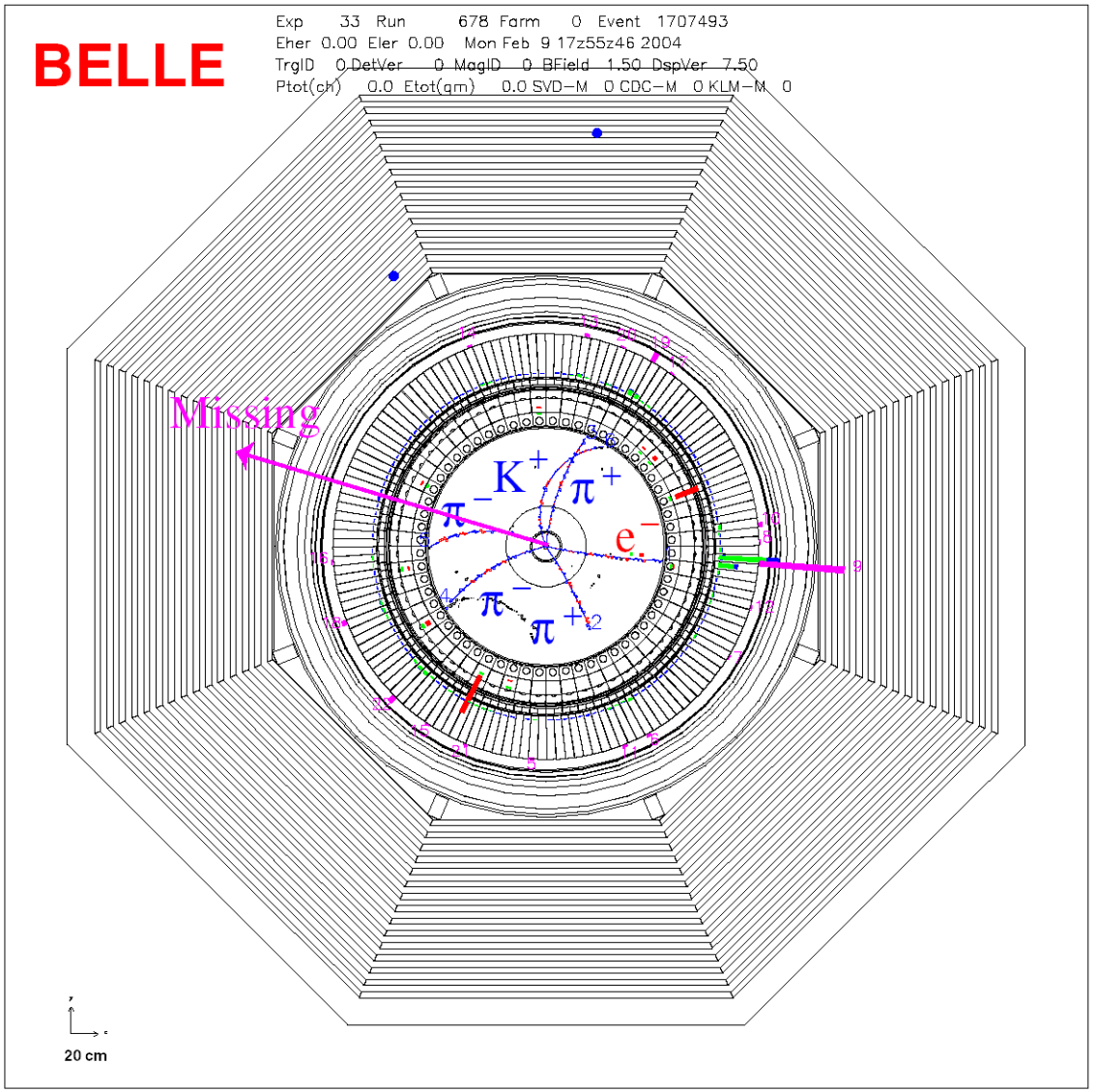
full reconstruction
$B \to D\pi$ etc. (0.3~0.6%)

„Offline B meson beam!"

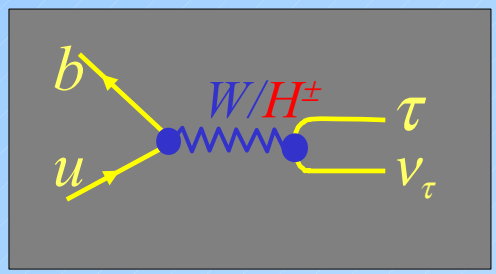
Powerful tool for B decays with neutrinos

Advantage of e^+e^- — example event

$$B^+ \to D^0\pi^+$$
$$(\to K\pi^-\pi^+\pi^-)$$
$$B^- \to \tau(\to e\nu\bar{\nu})\nu$$

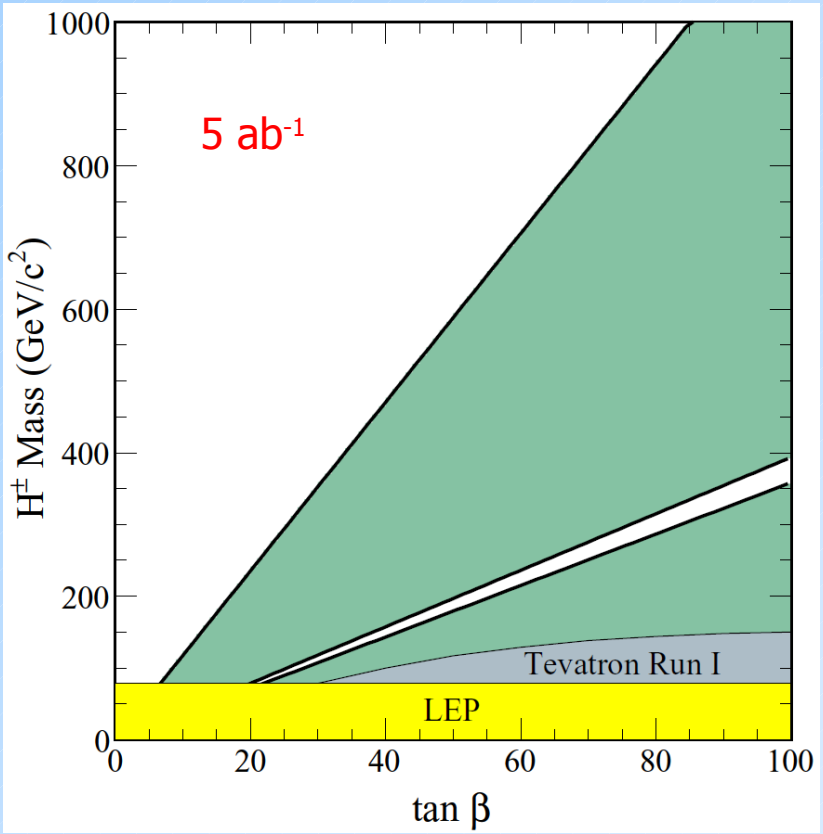


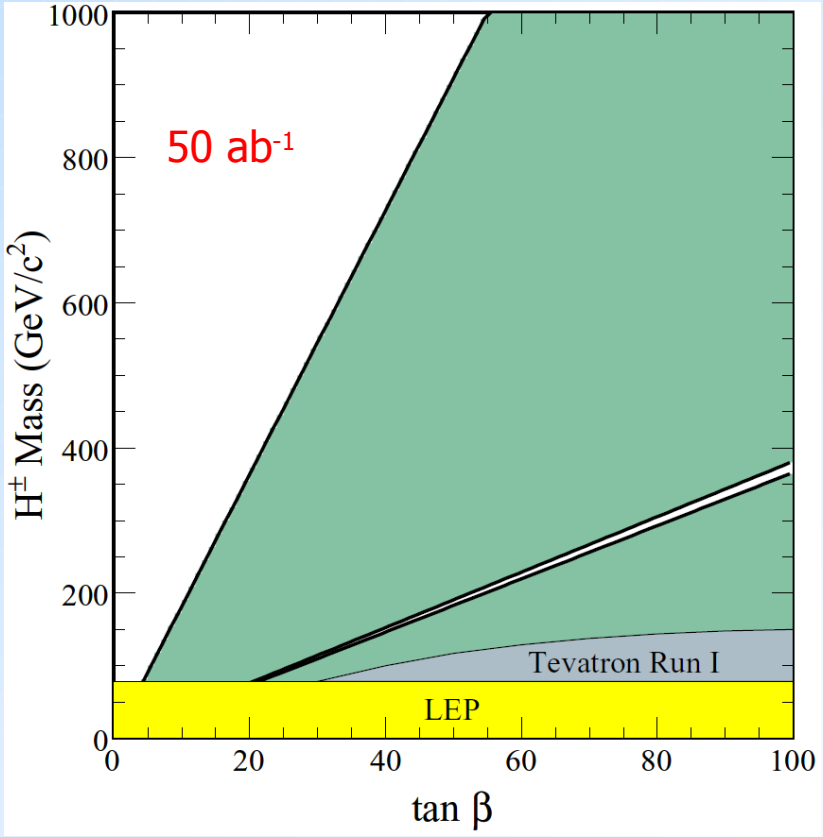
$B^- \to \tau\nu$ – charged higgs limits



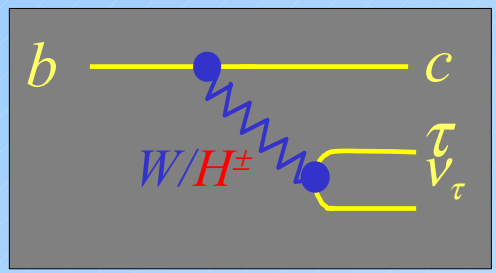
$$r_H = \frac{Br(B \to \tau\nu)}{Br(B \to \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)$$

→ limit on charged Higgs mass vs. tanβ





B → D(*)τν – sensitive to charged Higgs



Br of τ to μ,e could be reduced/enhanced significantly

$$R(D) \equiv \frac{Br(B \to D \tau \nu)}{Br(B \to D \ell \nu)}$$

Compared to B→τν

1.Smaller theoretical uncertainty of R(D)

For B→τν,

There is O(10%) f_B uncertainty from lattice QCD

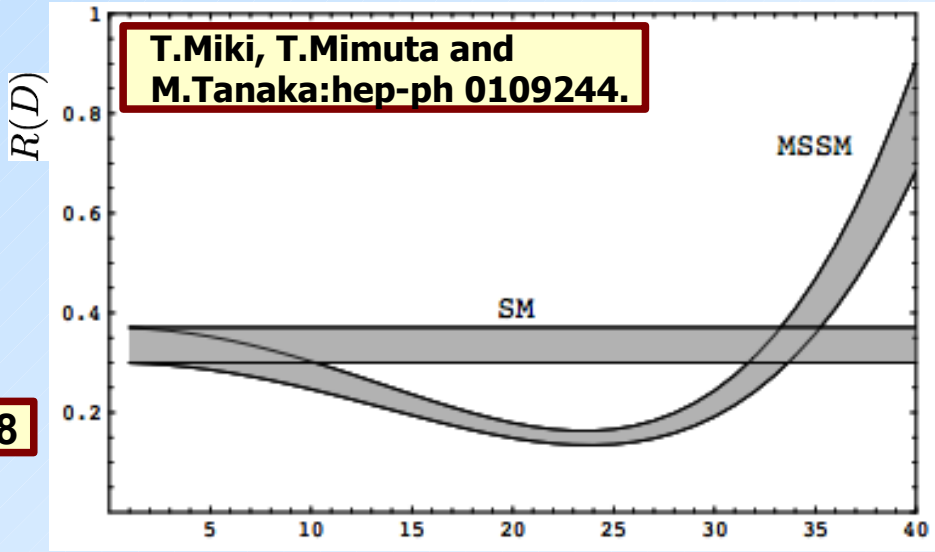
2.Large expected Br

Ulrich Nierste arXiv:0801.4938

$$\mathcal{B}(B^- \to D^0 \tau^- \bar{\nu}_\tau)^{SM} = (0.71 \pm 0.09)\%$$

$$\mathcal{B}(\bar{B}^0 \to D^+ \tau^- \bar{\nu}_\tau)^{SM} = (0.66 \pm 0.08)\%$$

$$\mathcal{B}(B \to \tau\nu) = [1.65^{+0.38}_{-0.37}(stat)^{+0.35}_{-0.37}(syst)] \times 10^{-4}$$



3. Differential distributions can be used to discriminate W^+ and H^+

4. Sensitive to different vertex B→τν: H-b-u, B→Dτν: H-b-c
(LHC experiments sensitive to H-b-t)

B → K*γ t-dependent CPV

$$P(B^0 \to f\,;\Delta t) = \frac{e^{-|\Delta t|/\tau}}{4\tau}\left[1 + S_{CP}^{f}\sin(\Delta m\,\Delta t) + A_{CP}^{f}\cos(\Delta m\,\Delta t)\right]$$

SM:

$$|S_{CP}^{K_S\pi^0\gamma}| \approx (2m_s/m_b)\sin 2\Phi_1 \approx 0.04$$

Left-Right Symmetric Models:

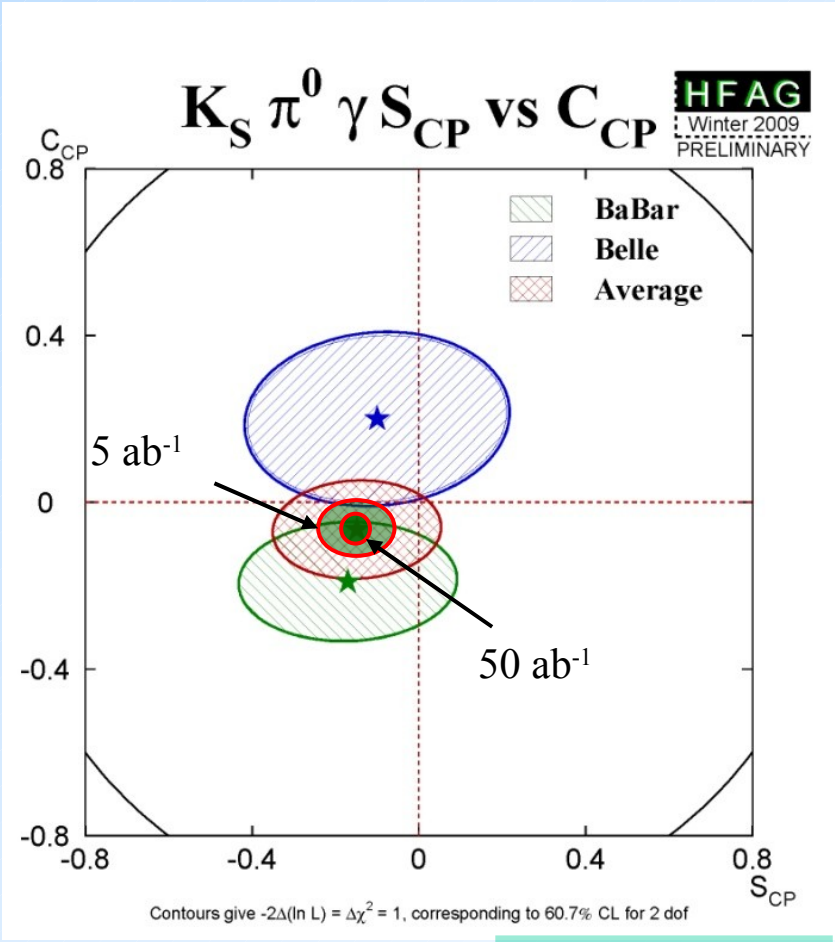
$$|S_{CP}^{K_S\pi^0\gamma}| \approx 0.67\cos 2\Phi_1 \approx 0.5$$

D. Atwood et al., PRL79, 185 (1997)

$$S_{CP}^{K_S\pi^0\gamma} = -0.15 \pm 0.20$$

$$A_{CP}^{K_S\pi^0\gamma} = -0.07 \pm 0.12$$

HFAG, Winter'09

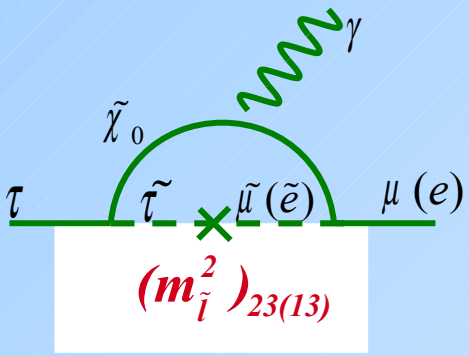


adopted from HFAG

$$\sigma(S_{CP}^{K_S\pi^0\gamma}) = \begin{array}{lll} 0.09 & @ & 5\text{ab}^{-1} \\ 0.03 & @ & 50\text{ab}^{-1} \end{array}$$ (~SM prediction)

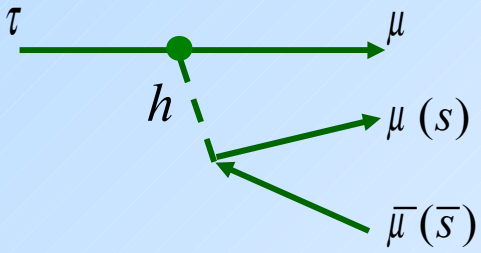
LFV and New Physics

$\tau \to \ell\gamma$



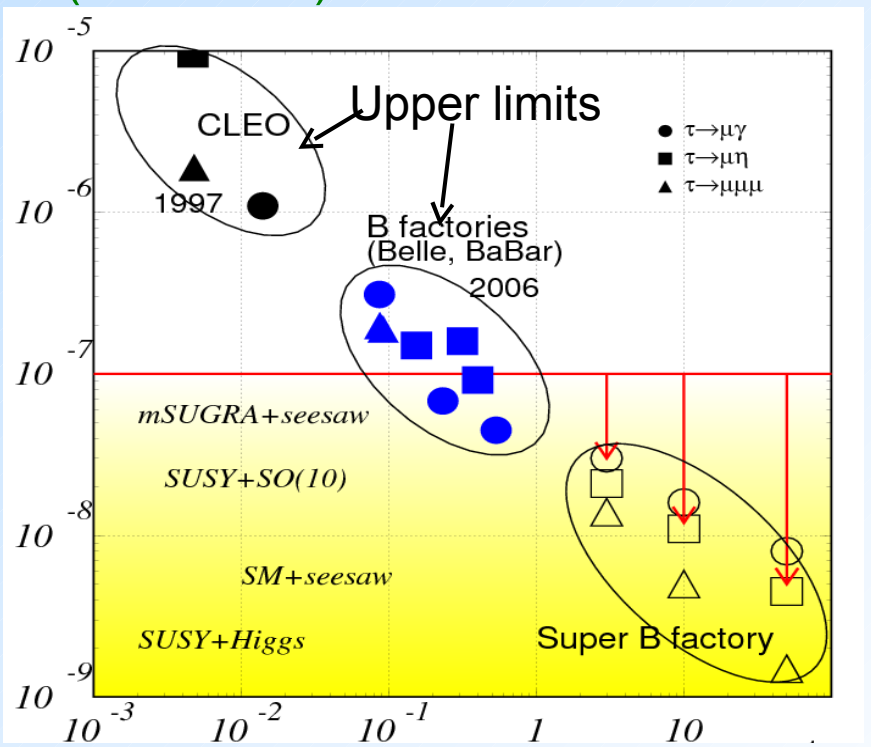
- SUSY + Seasaw
- Large LFV
- bkg. from ee→ ττγ (U.L. ∝ $1/\sqrt{\mathcal{L}}$)

$\tau \to 3\ell, \ell\eta$



- Neutral Higgs mediated decay.
- Important when MSUSY >> EW scale
- bkg. free (U.L. ∝ $1/\mathcal{L}$)

model	Br(τ→μγ)	Br(τ→ℓℓℓ)
mSUGRA+seesaw	10^{-7}	10^{-9}
SUSY+SO(10)	10^{-8}	10^{-10}
SM+seesaw	10^{-9}	10^{-10}
Non-Universal Z'	10^{-9}	10^{-8}
SUSY+Higgs	10^{-10}	10^{-7}



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SuperKEKB high luminosity strategy

Beam-beam parameter

Lorentz factor

Beam current

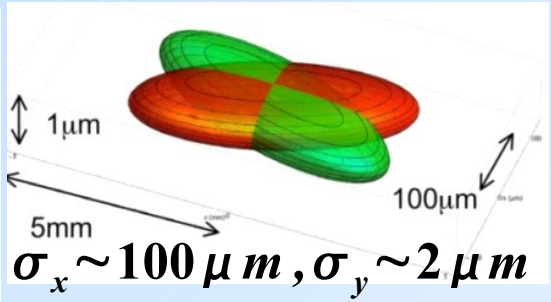
$$L = \frac{\gamma_{e\pm}}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_{e\pm}\xi_y^{e\pm}}{\beta_y^*}\right)\left(\frac{R_L}{R_{\xi_y}}\right)$$

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

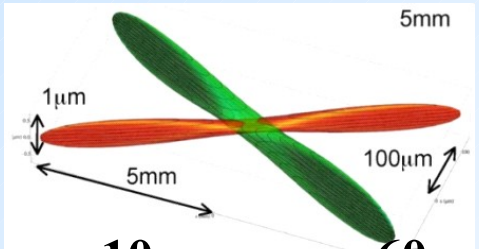
Classical electron radius

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

Vertical beta function@IP



$\sigma_x \sim 100\,\mu m, \sigma_y \sim 2\,\mu m$



$\sigma_x \sim 10\,\mu m, \sigma_y \sim 60\,nm$

- Smaller β_y^*
- Increase beam currents
- Keep ξ_y

"Nano-Beam" scheme

Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

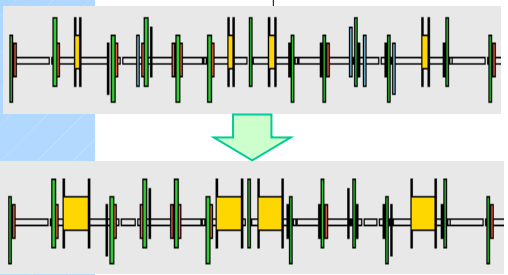
SuperKEKB machine design parameters

parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.3-4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0886	0.0830	
Luminosity	**L**	**2.1×10^{34}**		**8×10^{35}**		**$cm^{-2}s^{-1}$**

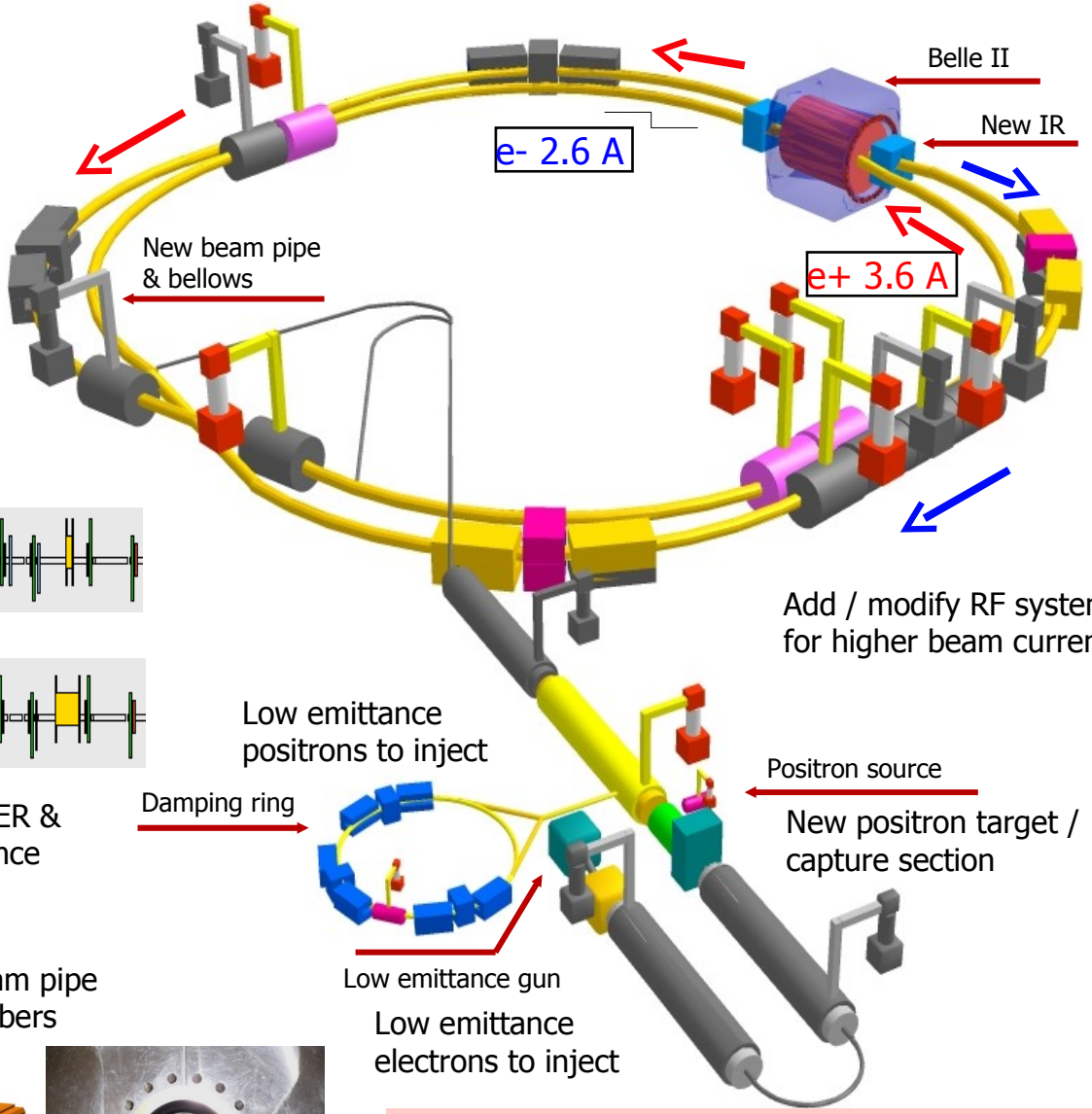
- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

KEKB upgrade to SuperKEKB

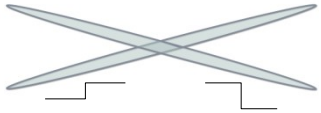
Replace short dipoles with longer ones (LER)



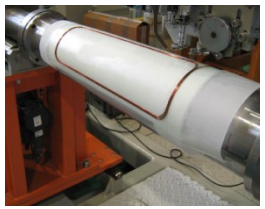
Redesign the lattices of HER & LER to squeeze the emitance



Colliding bunches



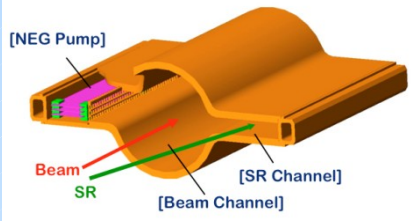
New superconducting /permanent final focusing quads near the IP

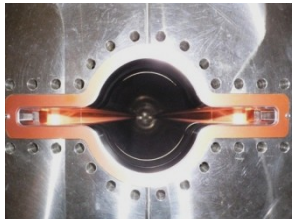


Add / modify RF systems for higher beam current

New positron target / capture section

TiN-coated beam pipe with antechambers





To get x40 higher luminosity → $8x10^{35}$ $cm^{-2}s^{-1}$

SuperKEKB - big step forward

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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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>Top >PressRelease >this page

last update: 10/06/23

Press Release

KEKB upgrade plan has been approved

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

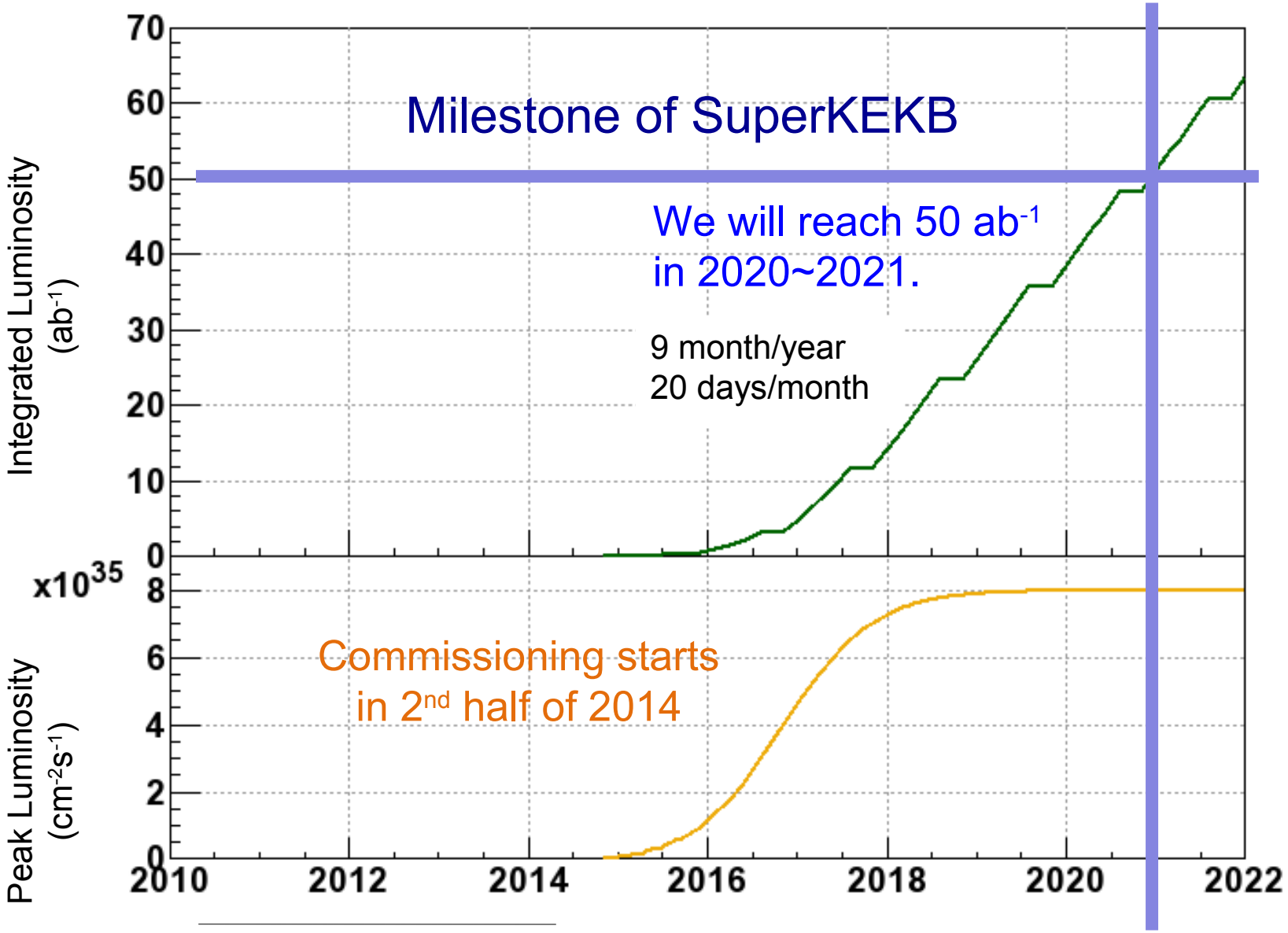
The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new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

Construction started !

SuperKEKB luminosity time-line



Belle II detector requirements

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

Higher background (x10-20):

- radiation damage and occupancy
- fake hits and pile-up noise in the EM

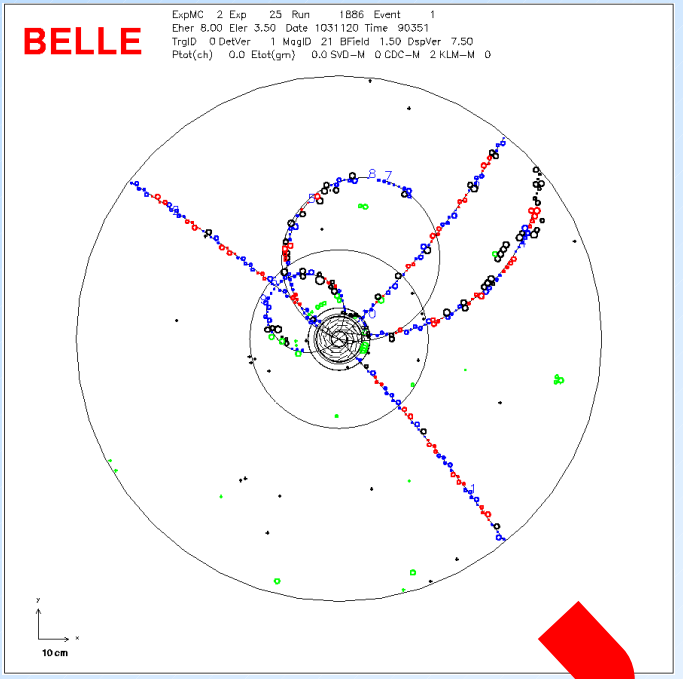
Higher L1 trigger rate (~ 0.5kHz→20kHz):

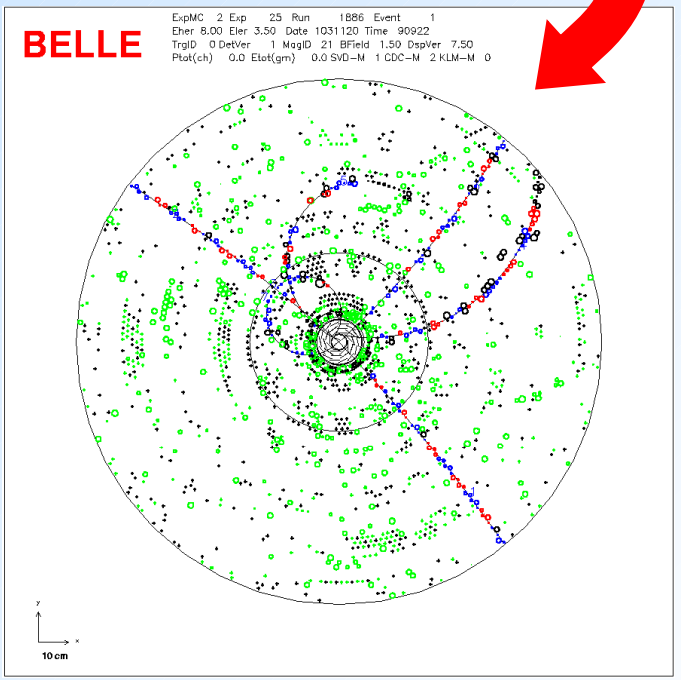
- higher rate trigger, DAQ and computing

Require special features:

low momentum μ identification ← sμμ recon. eff.

hermeticity ← ν "reconstruction"



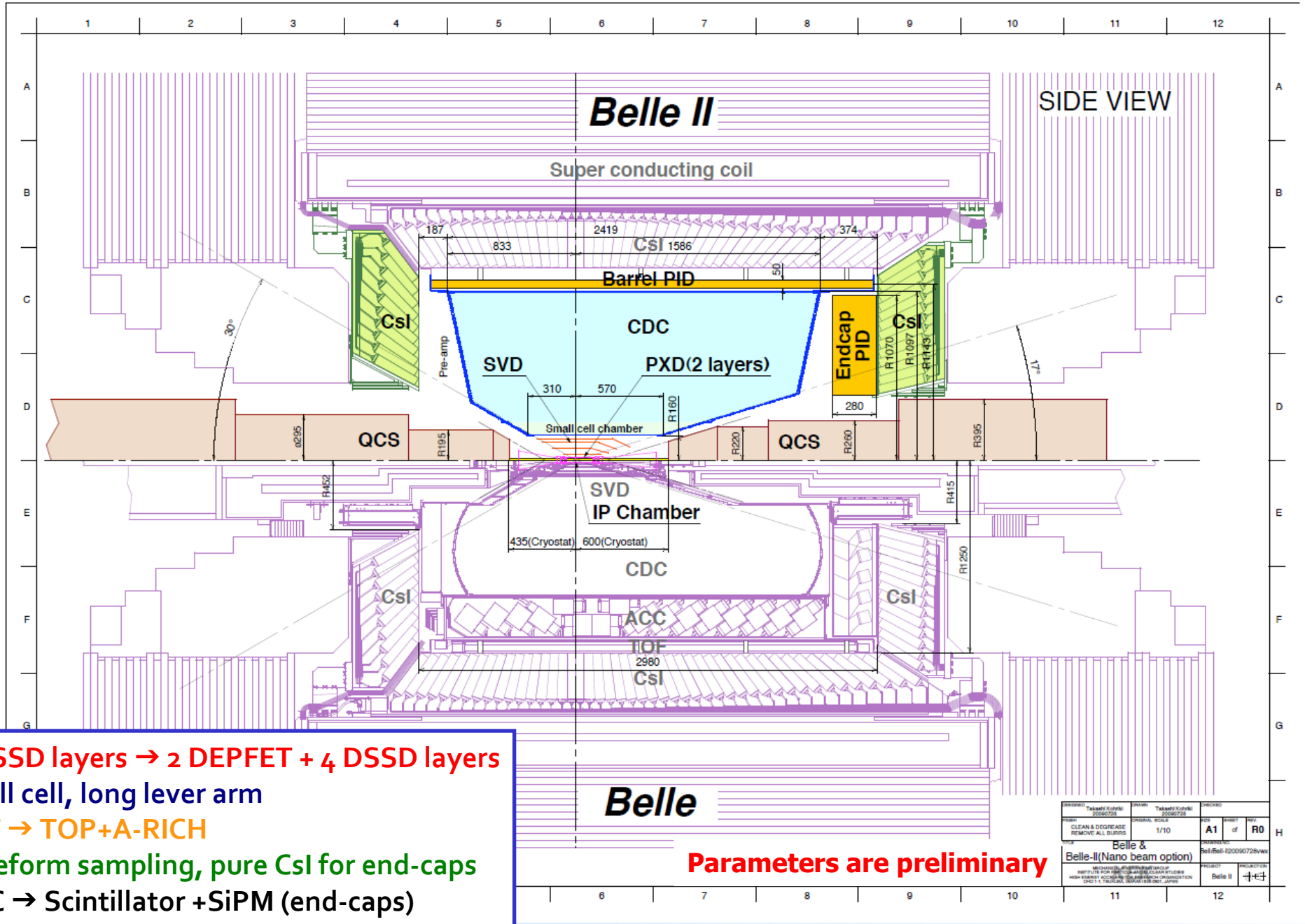


Solutions:

- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace end-cap calorimeter crystals and electronics
- Faster readout electronics and computing system.

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

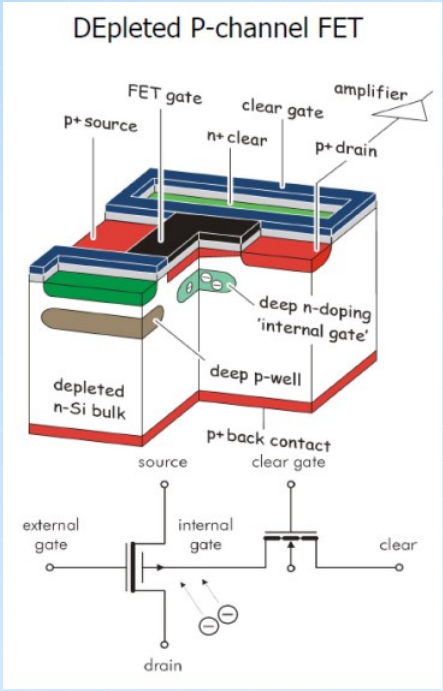
Belle II: an upgrade of Belle



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

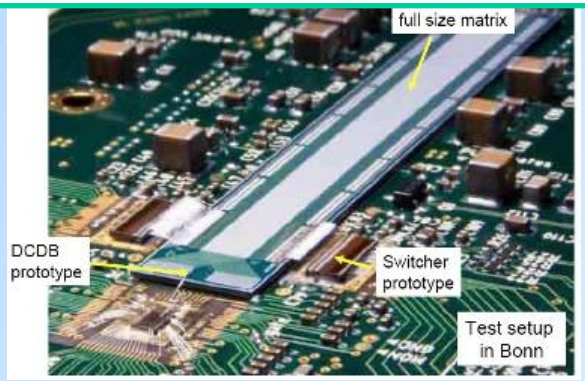
Vertex detector (PXD+SVD)

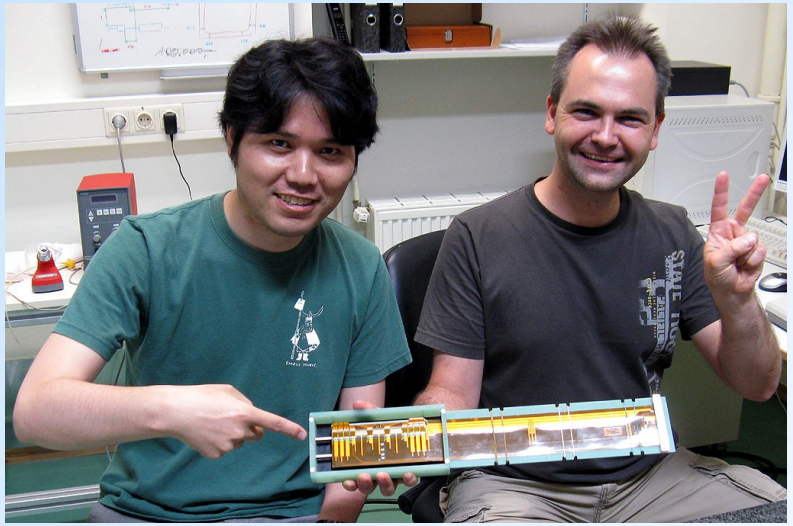
Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**



Mechanical mockup of pixel detector

Prototype DEPFET pixel sensor and readout

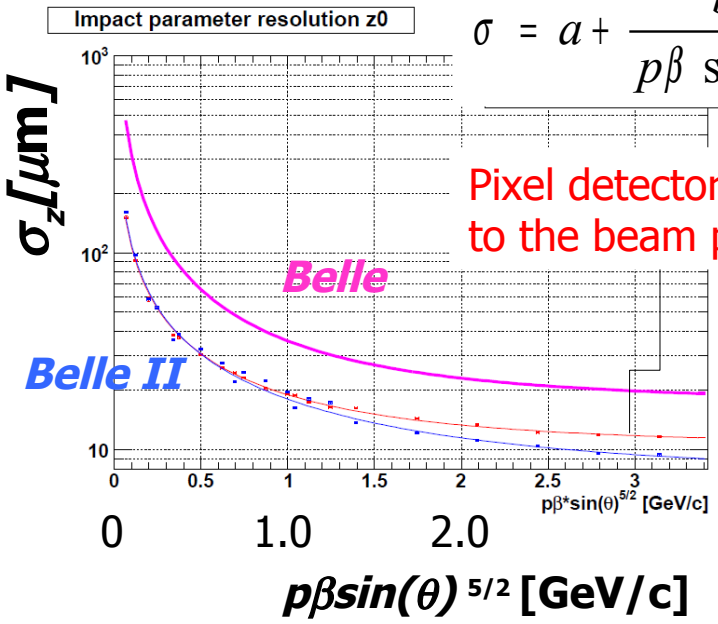




A prototype ladder using the first 6 inch DSSD from Hamamatsu has been assembled and tested.

Vertexing performance and K_s efficiency

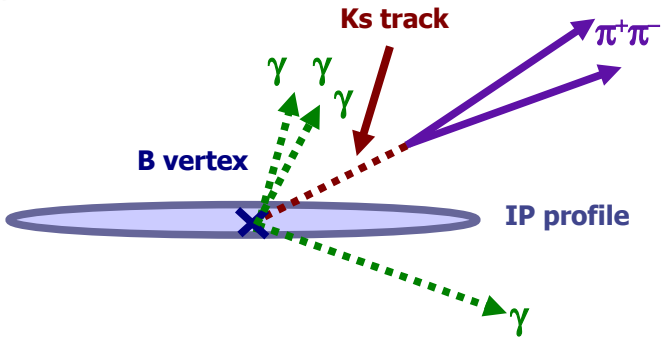
Significant improvement in IP resolution!



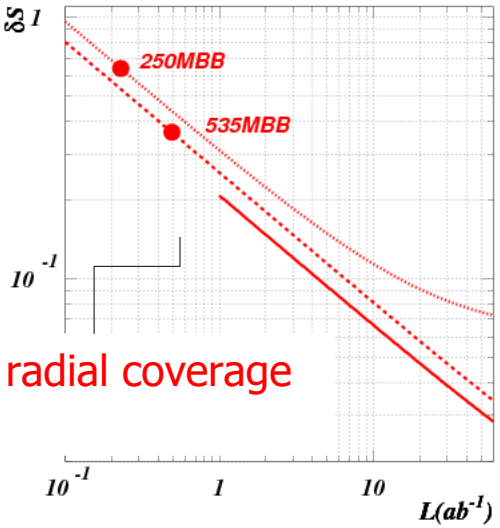
$$\sigma = a + \frac{b}{p\beta \sin^{\nu}\theta}$$

Pixel detector close to the beam pipe

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

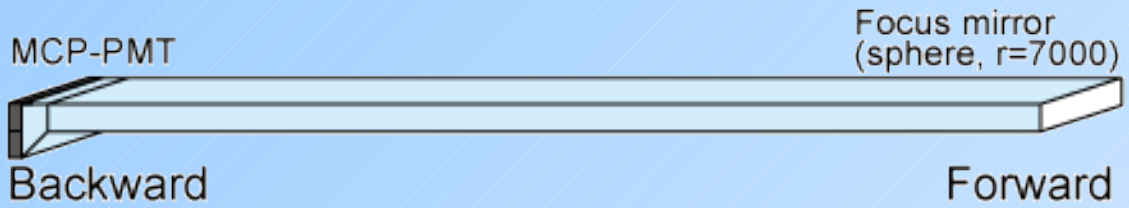


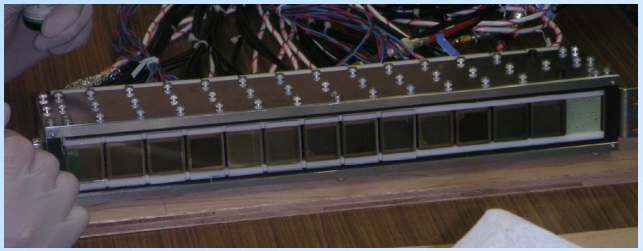
B decay point reconstruction with K_S trajectory



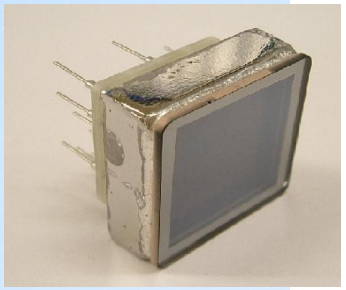
Larger radial coverage of SVD

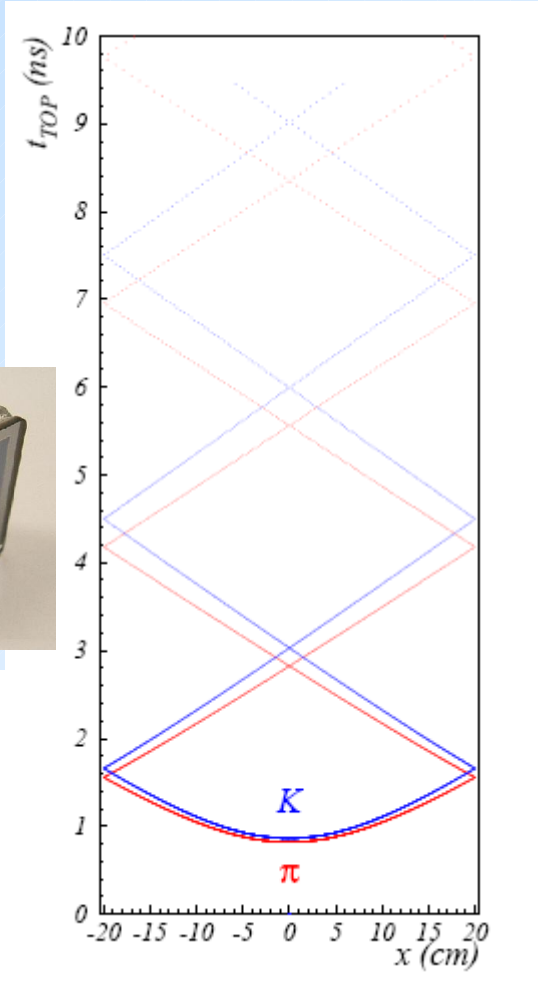
Barrel PID - TOP counter

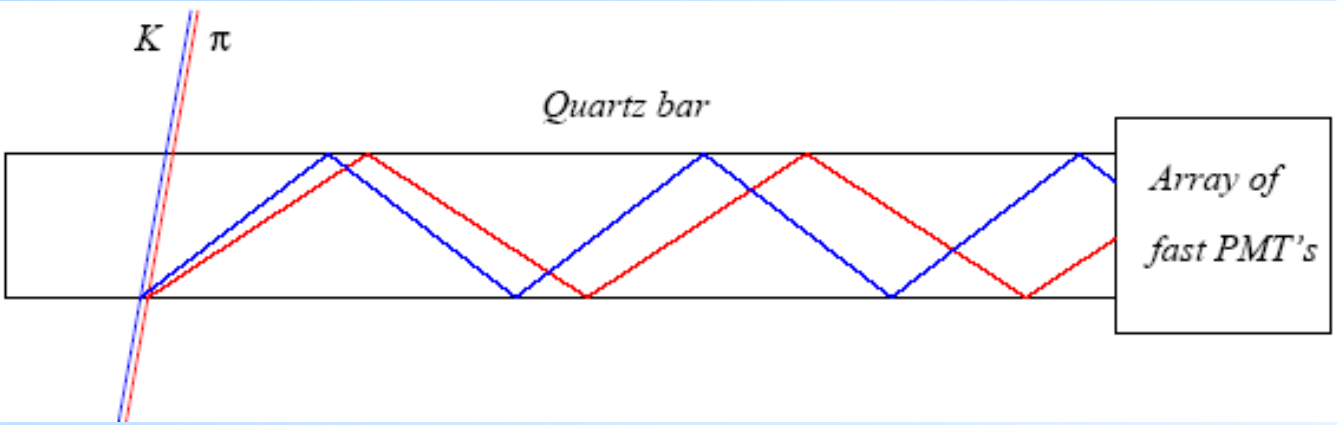




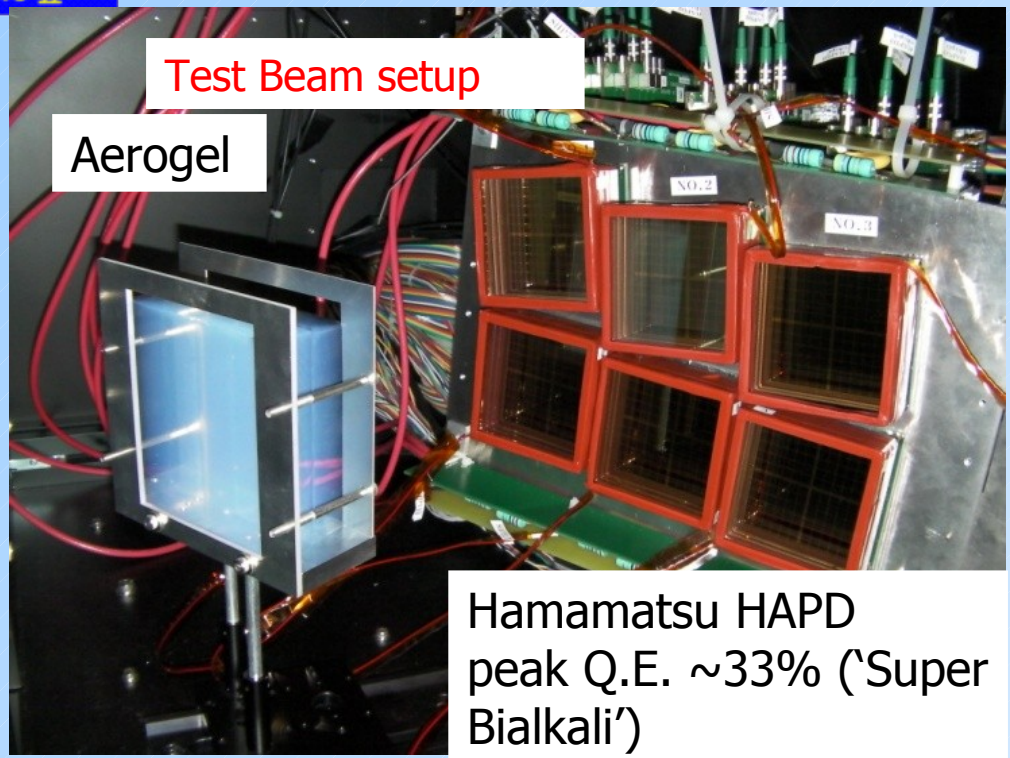
- Cherenkov ring imaging with precise time measurement. (DIRC based)
- Reconstruct angle from two coordinates and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT)
    - Good time resolution ~ 40 ps
    - Single photon sensitivity in 1.5 T
    - Wave-form sampling read-out



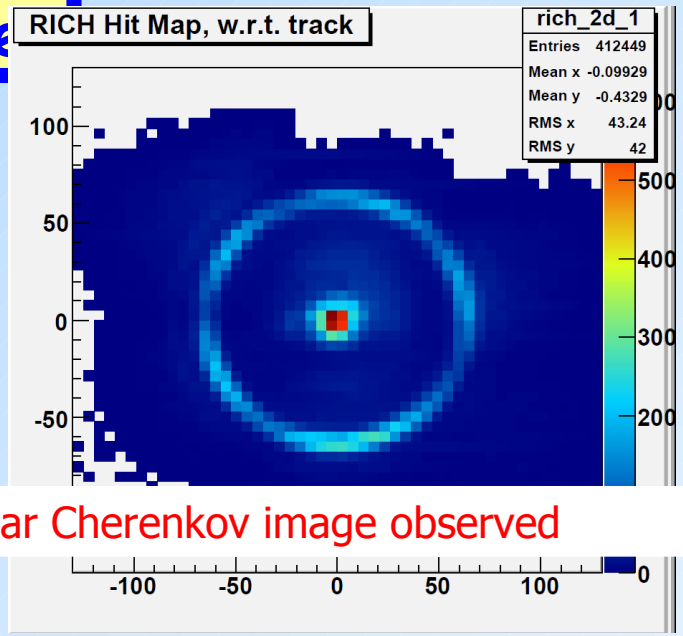




End-cap PID – aerogel RICH counte

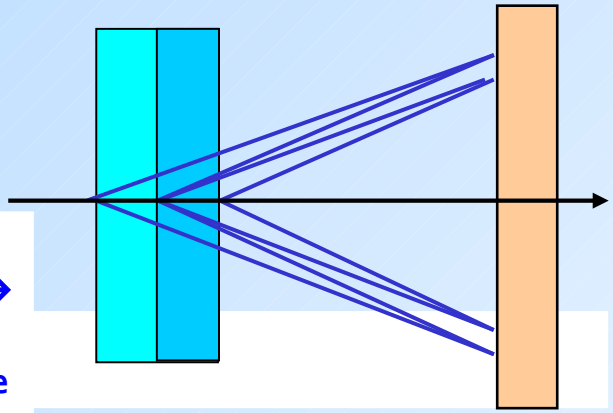


Hamamatsu HAPD peak Q.E. ~33% ('Super Bialkali')

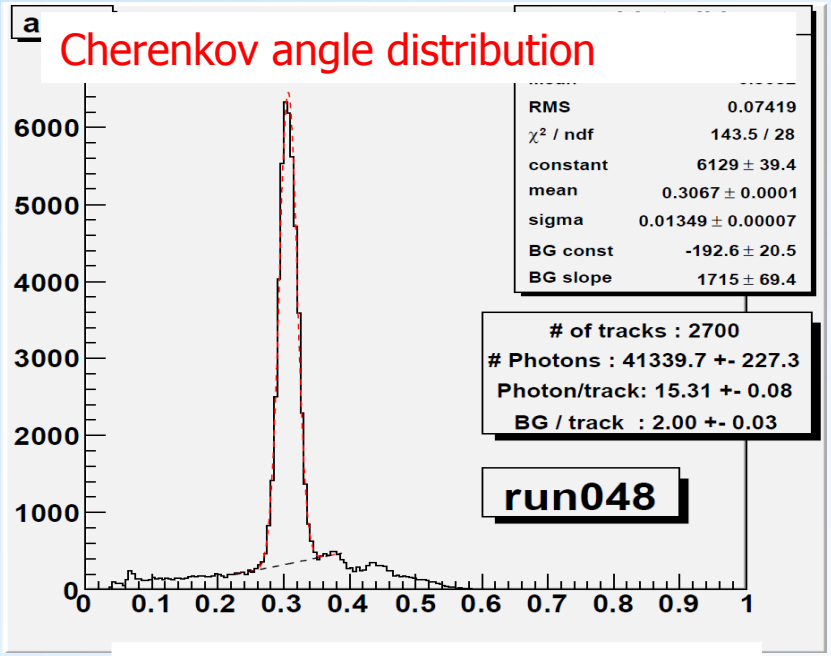


Clear Cherenkov image observed

RICH with a novel "focusing" radiator – a two layer radiator



Employ multiple layers with different refractive indices → Cherenkov images from individual layers overlap on the photon detector.



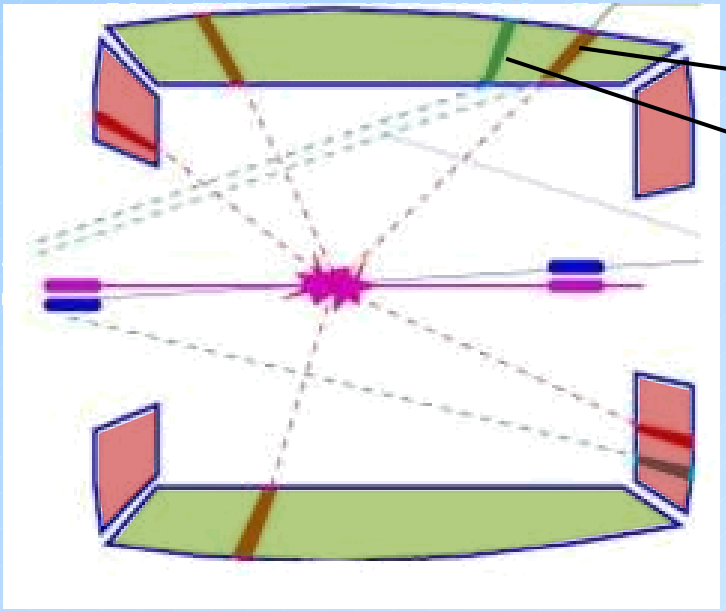
6.6 σ π/K at 4GeV/c !

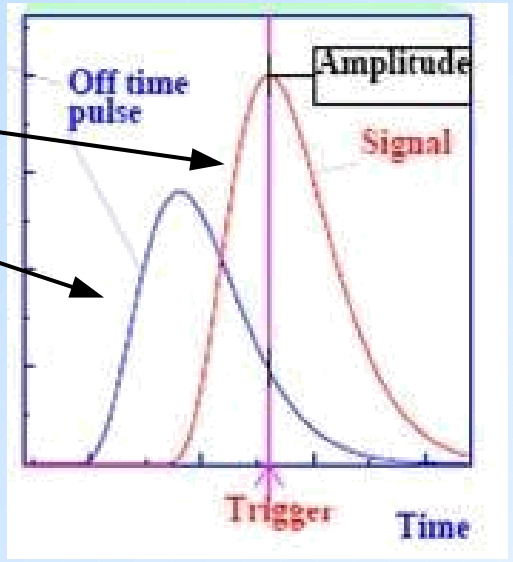
Samo Korpar
University of Maribor and Jožef Stefan Institute

ECL calorimeter

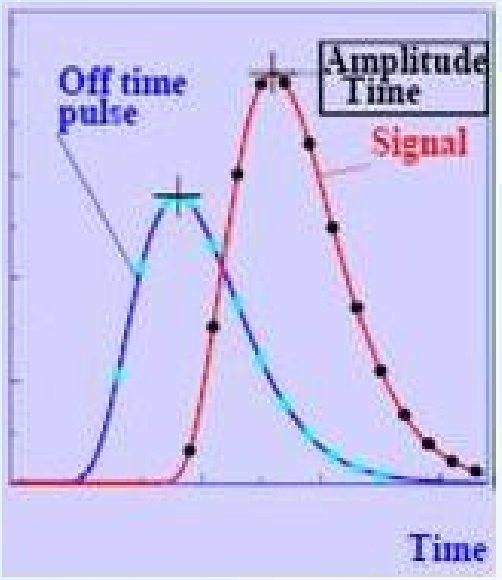
currently only
amplitude measured

wave form sampling:





new electronics:
16 meas. of time and amplitude;
fake clusters suppressed by 7x;



end-caps:

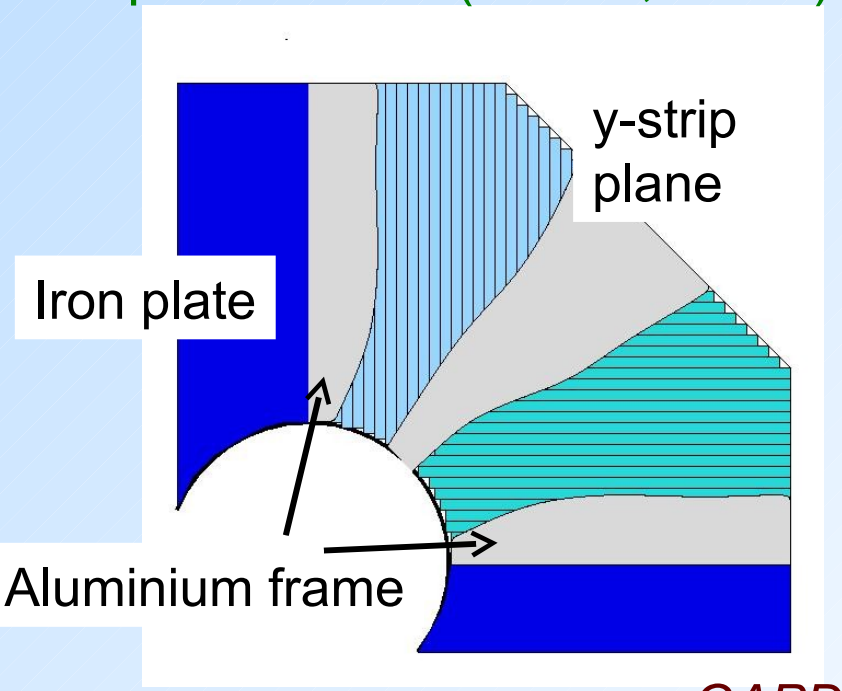
replace CsI(Tl) with pure CsI (partially)

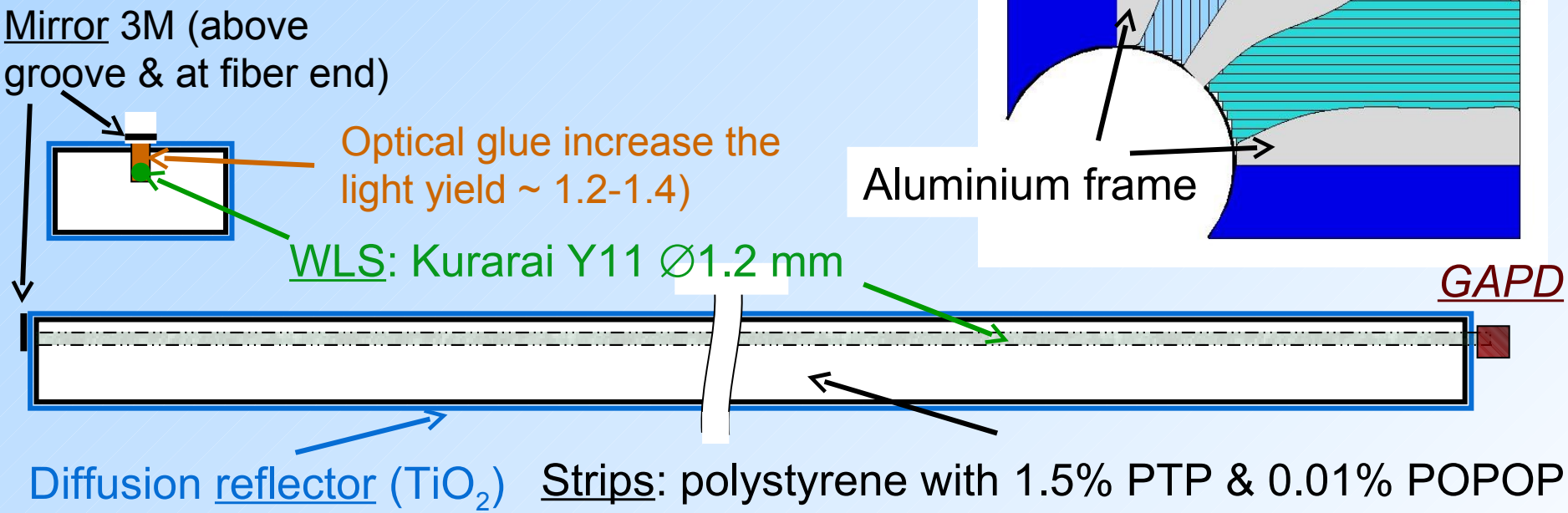
expected performance
@ 10x bkg.
~ 5%-10% lower ε

End-cap KLM upgrade

Scintillator-based KLM (endcap)

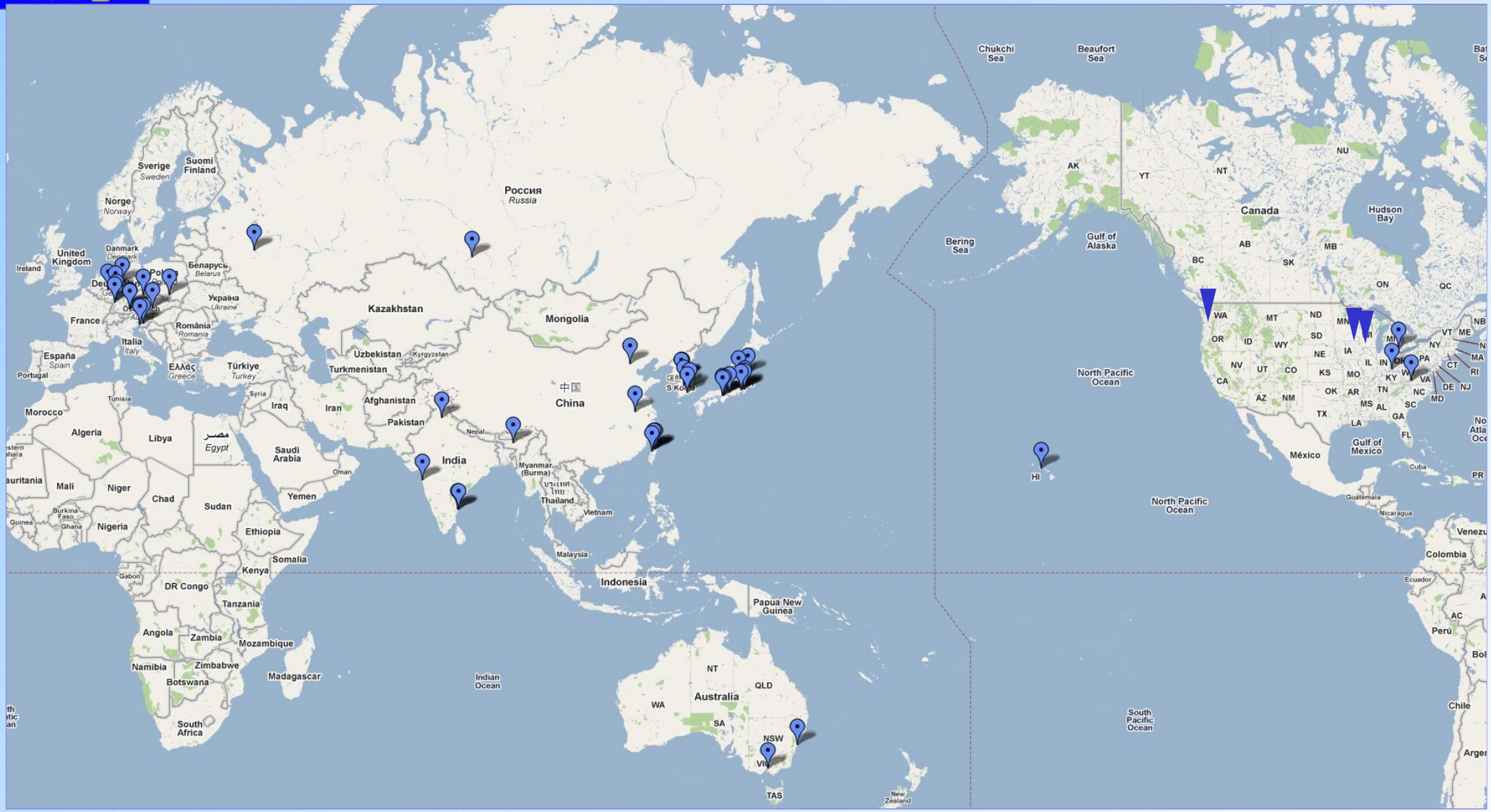
- Two independent (x and y) layers in one super-layer made of orthogonal strips with WLS read out
- Photo-detector = Geiger mode avalanche photo-diode (GAPD, SiPM)
- ~120 strips in one 90º sector (max L=280cm, w=25mm)
- ~30000 read out channels
- Geometrical acceptance > 99%





Belle II collaboration

http://belle2.kek.jp



13 countries/regions, ~60 institutions, ~350 collaborators

Summary

- KEKB/Belle have proven to be an excellent instruments to study flavor physics, with reliable long term operation, constant improvement of the performance and achieving and surpassing design performance
- Major upgrade at KEK in 2010-14 → SuperKEKB+Belle II, L x 40, construction started
- Physics reach updates available

  arXiv:1002.5012 (http://belle2.kek.jp/physics.html)
- Technical design report published

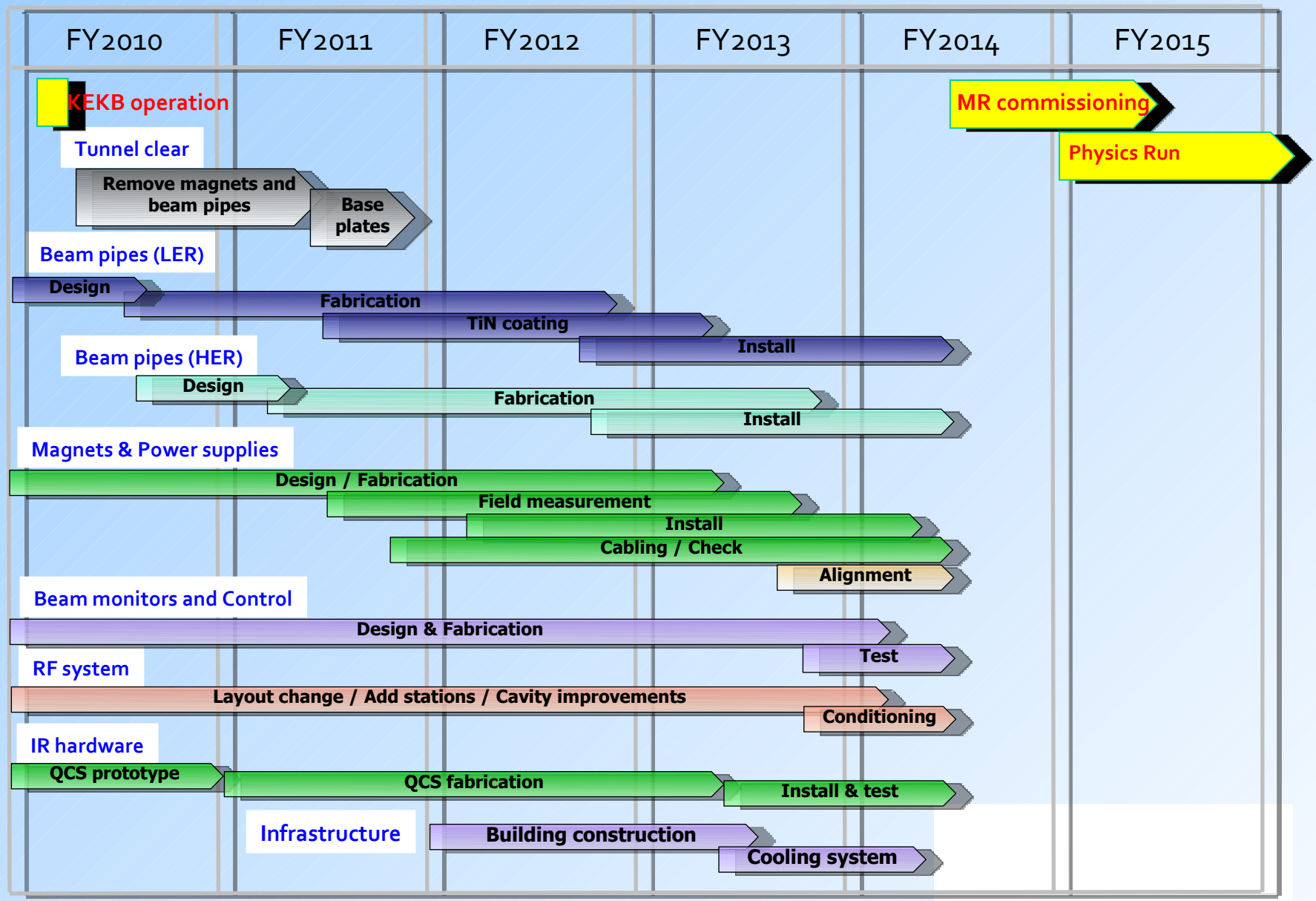
  TDR published arXiv:1011.0352v1 [physics.ins-det]

Expect a new, exciting era of discoveries, complementary to the LHC

BACKUP SLIDES

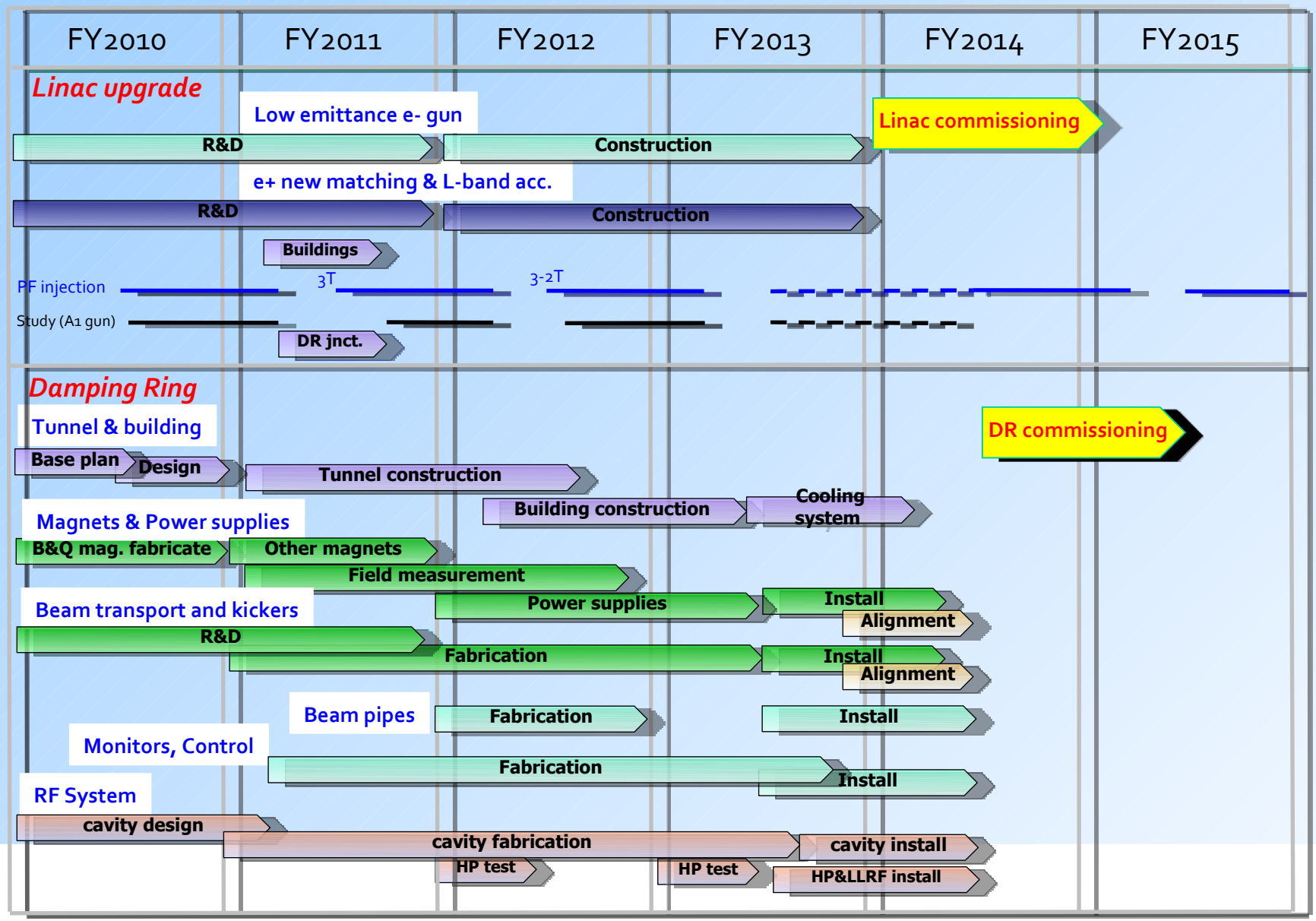
SuperKEKB Main Ring schedule

Oct. 20, 2010



Linac upgrade and DR construction schedule

Oct. 20, 2010



Installation Schedule of Belle II

		2010												2011											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Belle roll-out	Dec. 2010																								
Belle disassemble	Jan. - Mar. 2011																								
Rotation	Jul. - Sep. 2013																								
Installation of E-KLM	Apr. - Jun. 2013																								
Installation of B-KLM	Oct. - Jun. 2013																								
Installation of ECL	May - Aug. 2014																								
Installation of A-RICH	Mar. - Jun. 2014																								
Installation of Endcaps	Sep. 2014																								
Installation of TOP	Feb. - May 2014																								
Installation of CDC	Jun. 2014																								
ladder mounting of PXD	May 2014																								
ladder mounting of SVD	Jun. 2014																								
Installation of VXD	Jul. - Aug. 2014																								

		2012												2013												2014											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Belle roll-out	Dec. 2010																																				
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