

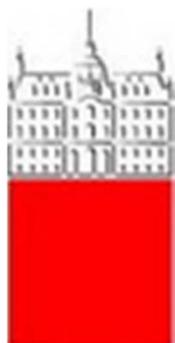


SuperKEKB and Belle-II

Peter Križan

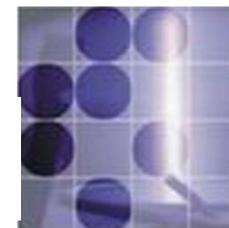
University of Ljubljana and J. Stefan Institute

XVII SuperB Workshop and Kick Off Meeting,
La Biodola, Isola d'Elba, May 30, 2011



**University
of Ljubljana**

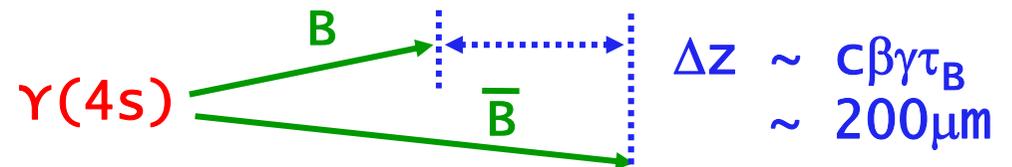
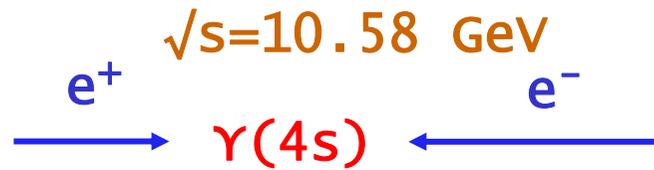
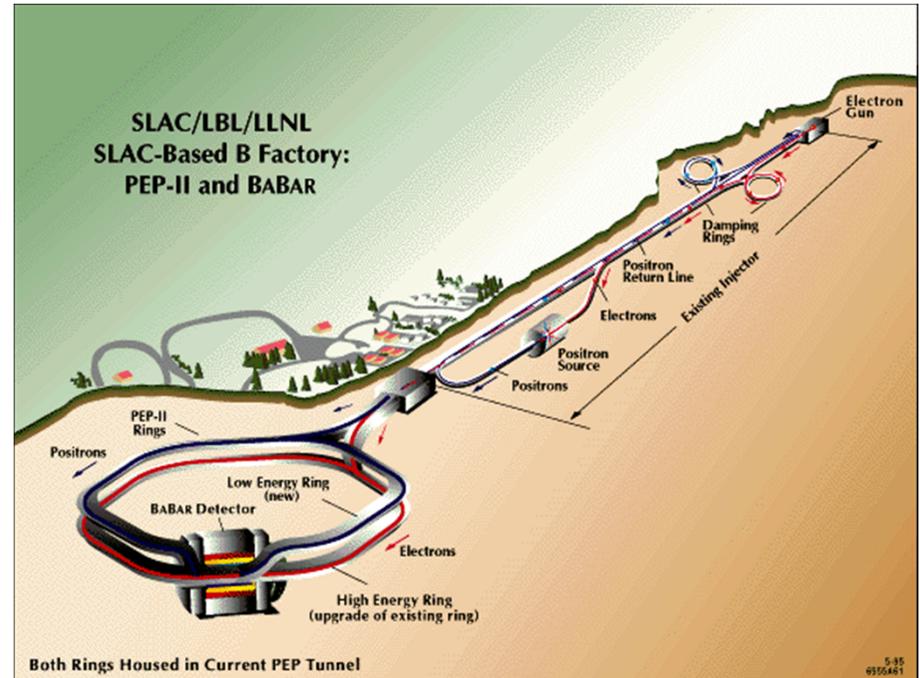
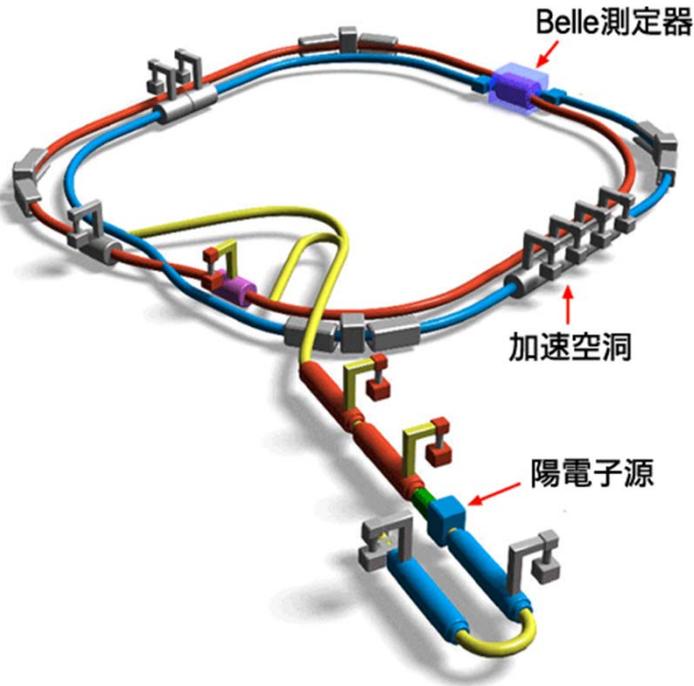
**"Jožef Stefan"
Institute**



Contents

- Physics case
- Accelerator upgrade → SuperKEKB
- Detector upgrade → Belle-II
- Project status
- Summary

Asymmetric B factories



BaBar $p(e^-) = 9 \text{ GeV}$ $p(e^+) = 3.1 \text{ GeV}$

$\beta\gamma = 0.56$

Belle $p(e^-) = 8 \text{ GeV}$ $p(e^+) = 3.5 \text{ GeV}$

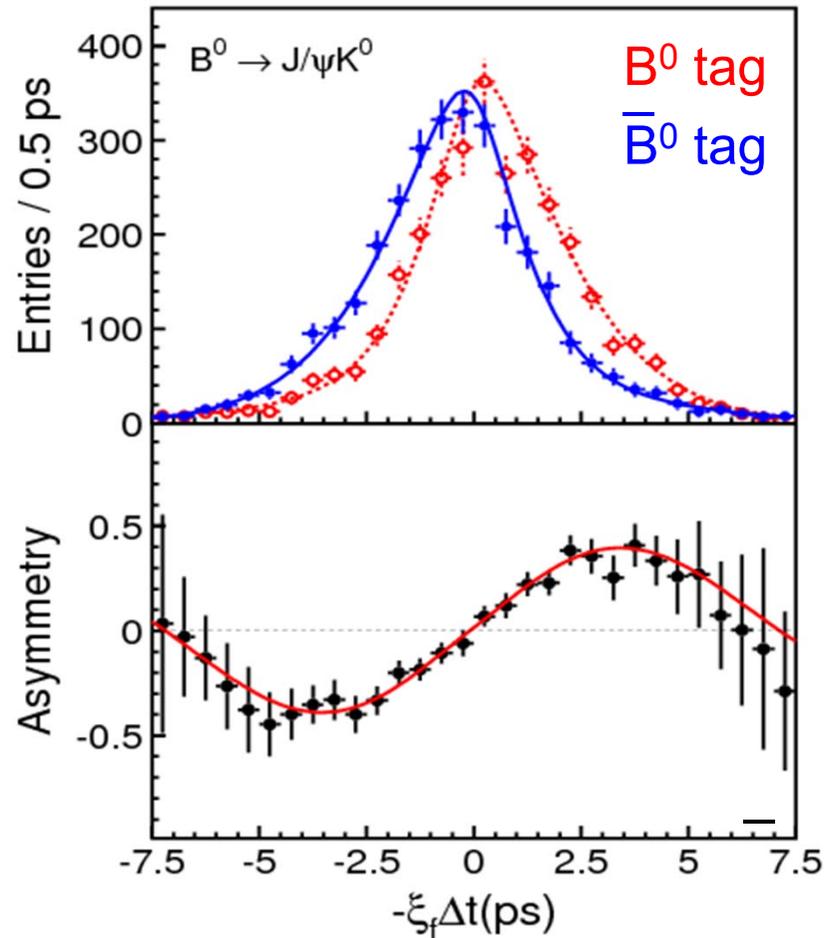
$\beta\gamma = 0.42$

Main motivation for B factories: measure CP violation in the B system

CP violation in B system:
from the **discovery**
(2001) to a **precision**
measurement (2006)

$\sin 2\phi_1 / \sin 2\beta$ from $b \rightarrow cc\bar{s}$

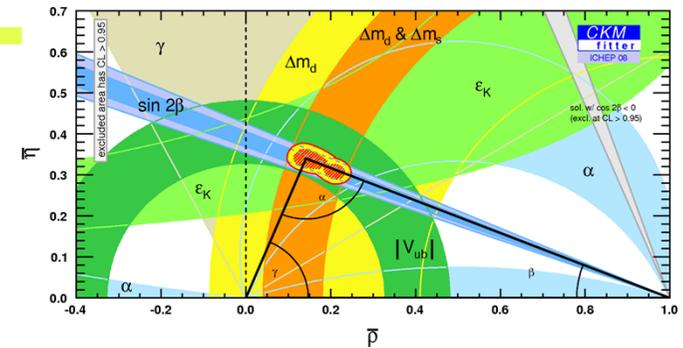
535 M $B\bar{B}$ pairs



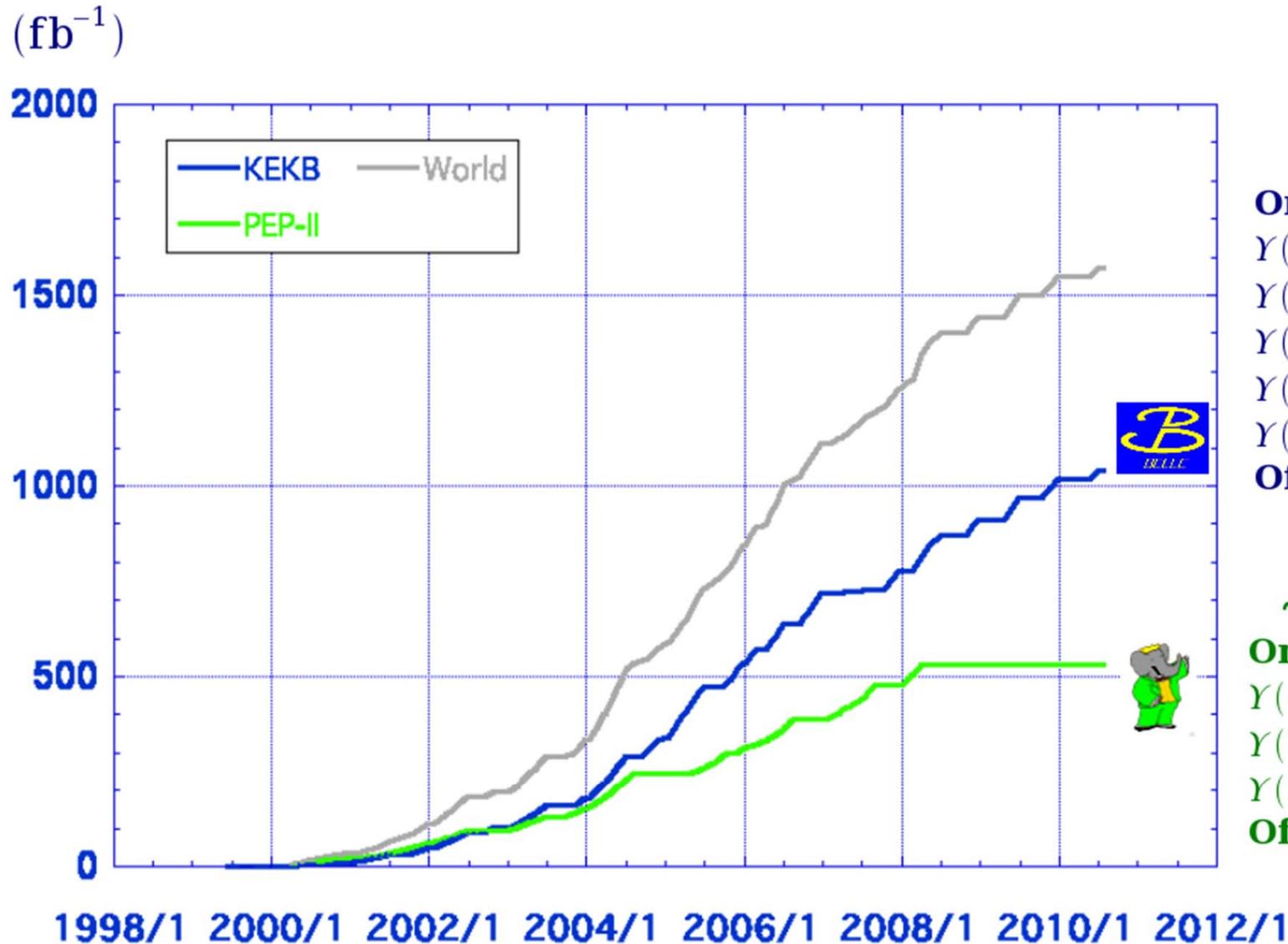
$$\sin 2\phi_1 = 0.642 \pm 0.031 \text{ (stat)} \pm 0.017 \text{ (syst)}$$

B factories: a success story

- 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., $B \rightarrow \tau \nu$, $D \tau \nu$)
- $b \rightarrow s$ transitions: probe for new sources of CPV and constraints from the $b \rightarrow s \gamma$ branching fraction
- Forward-backward asymmetry (A_{FB}) in $b \rightarrow s l^+ l^-$ has become a powerful tool to search for physics beyond SM.
- Observation of D mixing
- Searches for rare τ decays
- Observation of new hadrons



Luminosity at B factories



> 1 ab⁻¹
On resonance:
Y(5S): 121 fb⁻¹
Y(4S): 711 fb⁻¹
Y(3S): 3 fb⁻¹
Y(2S): 24 fb⁻¹
Y(1S): 6 fb⁻¹
Off reson./scan:
~ 100 fb⁻¹

~ 550 fb⁻¹
On resonance:
Y(4S): 433 fb⁻¹
Y(3S): 30 fb⁻¹
Y(2S): 14 fb⁻¹
Off resonance:
~ 54 fb⁻¹

Fantastic performance much beyond design values!

What next?

B factories → is SM with CKM right?

Next generation: Super B factories → in which way is the SM wrong?

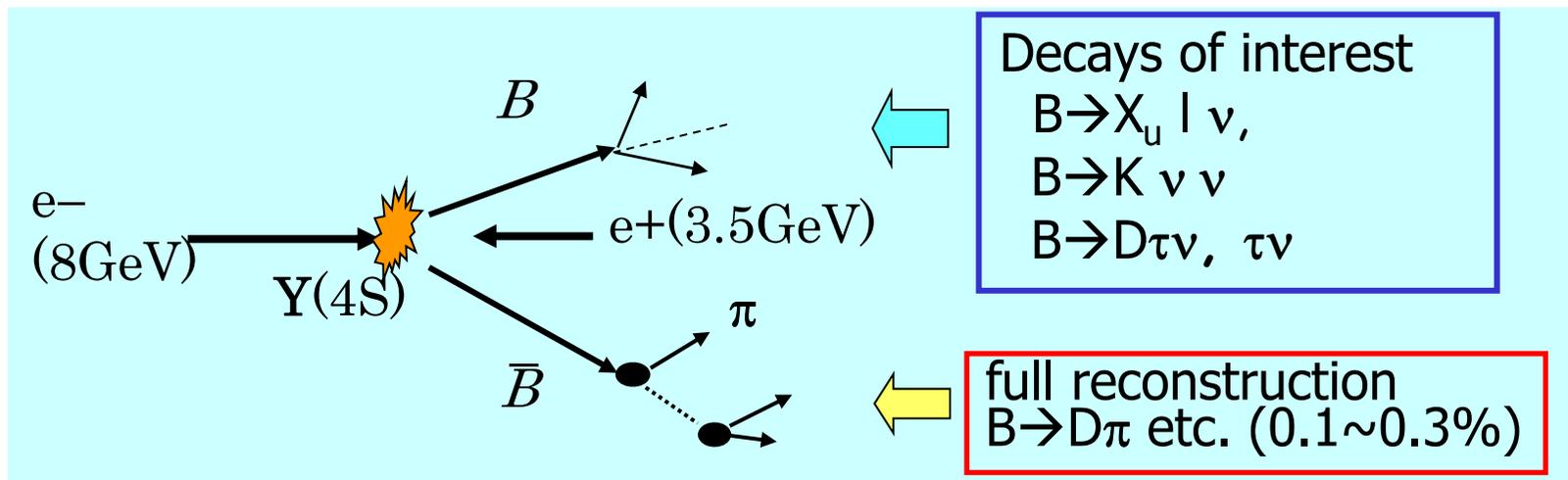
→ Need much more data (two orders!) because the SM worked so well until now → Super B factory

However: it will be a different world in four years, there will be serious competition from LHCb and BESIII

Still, e^+e^- machines running at (or near) $\Upsilon(4s)$ will have considerable advantages in several classes of measurements, and will be complementary in many more

Full Reconstruction Method

- Fully reconstruct one of the B's to
 - Tag B flavor/charge
 - Determine B momentum
 - Exclude decay products of one B from further analysis

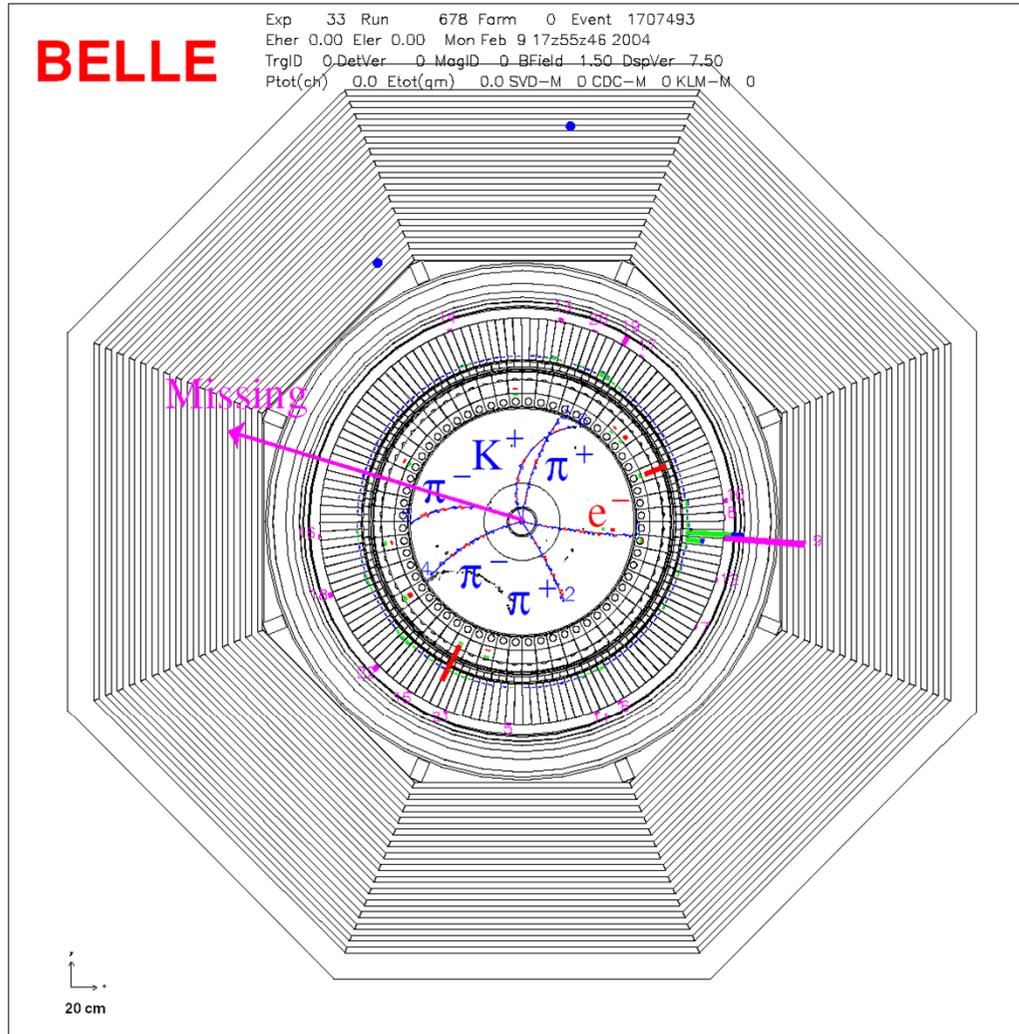


→ Offline B meson beam!

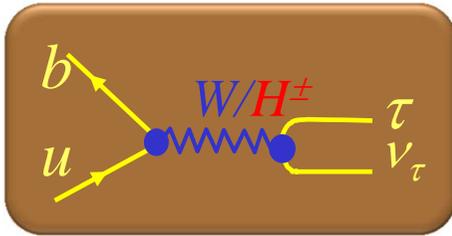
Powerful tool for B decays with neutrinos

Event candidate $B^- \rightarrow \tau^- \nu_\tau$

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

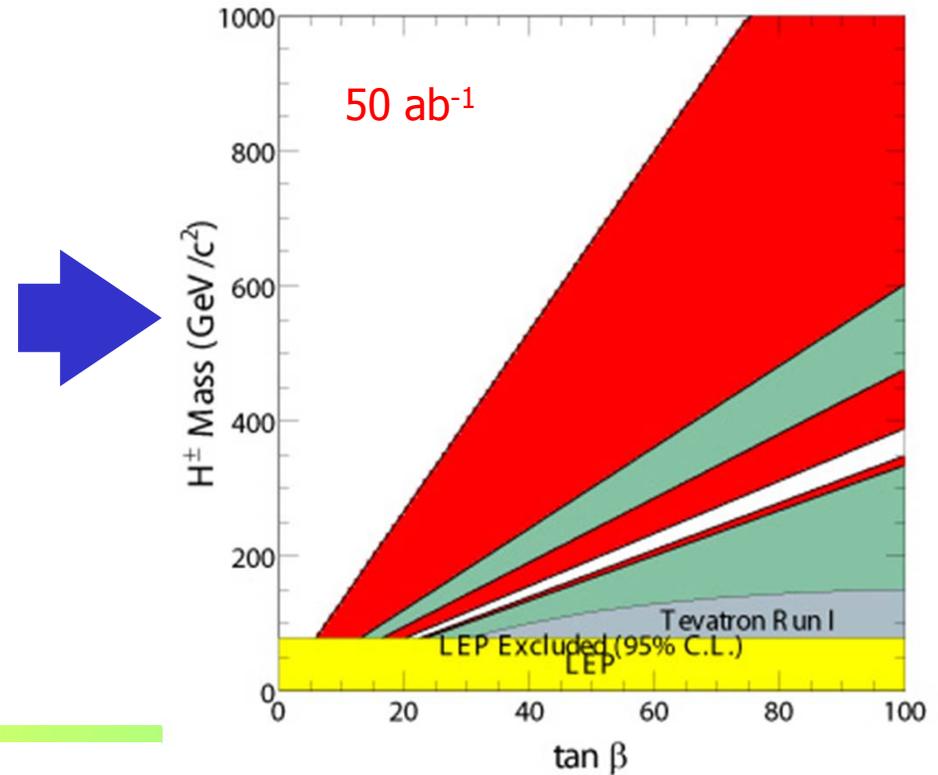
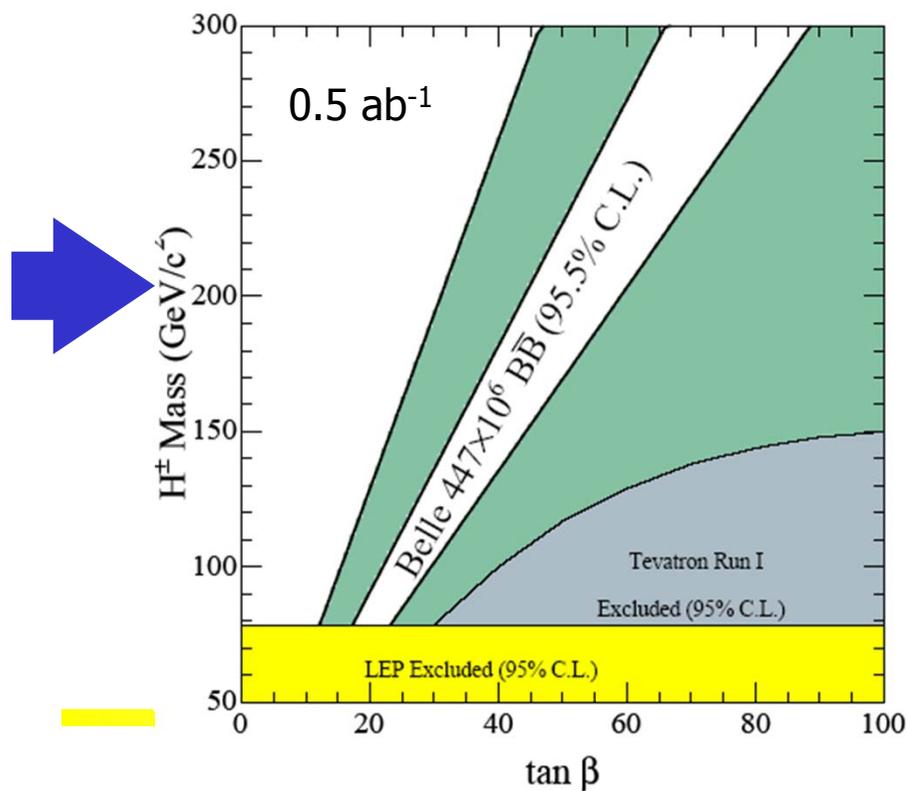


Charged Higgs limits from $B^- \rightarrow \tau^- \nu_\tau$



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

→ limit on charged Higgs mass vs. $\tan\beta$



$B \rightarrow K^{(*)} \nu \nu$

arXiv:1002.5012

adopted from W. Altmannshofer et al.,
JHEP 0904, 022 (2009)

$$B \rightarrow K \nu \nu, \mathcal{B} \sim 4 \cdot 10^{-6}$$

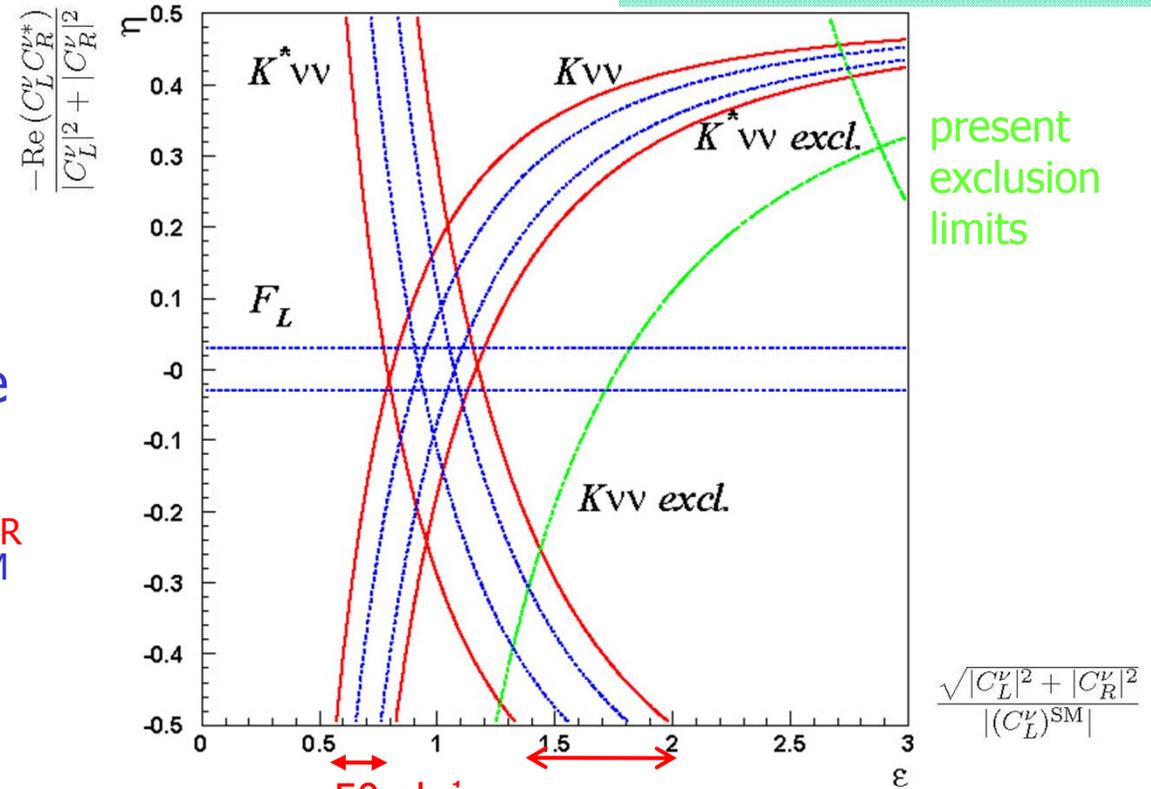
$$B \rightarrow K^* \nu \nu, \mathcal{B} \sim 6.8 \cdot 10^{-6}$$

SM: penguin+box

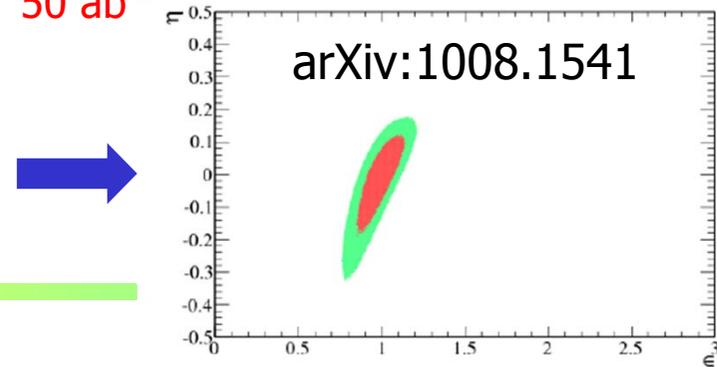
Look for departure from the expected value \rightarrow information on couplings C_R^ν and C_L^ν compared to $(C_L^\nu)^{\text{SM}}$

Again: fully reconstruct one of the B mesons, look for signal (+nothing else) in the rest of the event.

\leftrightarrow Theory

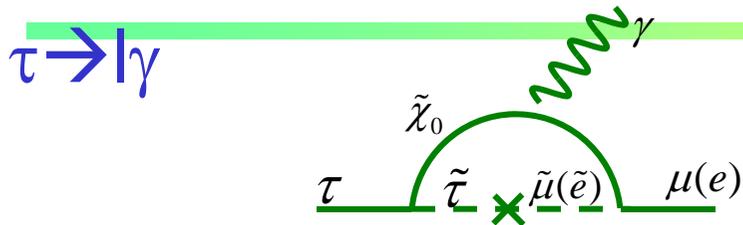


present exclusion limits



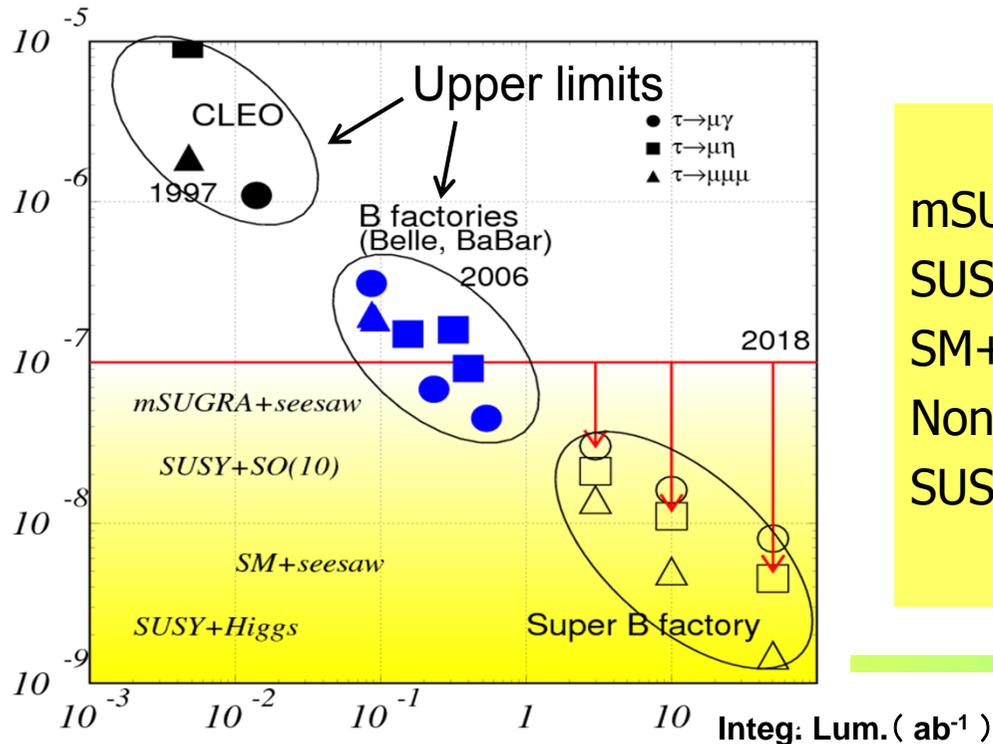
not possible @ LHCb

Lepton flavour violation and New Physics

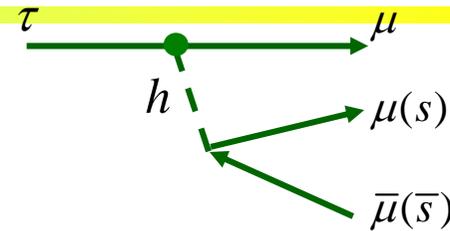


- SUSY + Seesaw $(m_{\tilde{l}}^2)_{23(13)}$
- Large LFV $Br(\tau \rightarrow \mu\gamma) = O(10^{-7 \sim 9})$

$$Br(\tau \rightarrow \mu\gamma) \approx 10^{-6} \times \left(\frac{(m_{\tilde{L}}^2)_{32}}{\bar{m}_{\tilde{L}}^2} \right) \left(\frac{1 \text{ TeV}}{m_{\text{SUSY}}} \right)^4 \tan^2 \beta$$



$\tau \rightarrow 3l, l\eta$



- Neutral Higgs mediated decay.
- Important when $M_{\text{SUSY}} \gg \text{EW scale}$.

$$Br(\tau \rightarrow 3\mu) =$$

$$4 \times 10^{-7} \times \left(\frac{(m_{\tilde{L}}^2)_{32}}{\bar{m}_{\tilde{L}}^2} \right) \left(\frac{\tan \beta}{60} \right)^6 \left(\frac{100 \text{ GeV}}{m_A} \right)^4$$

model	$Br(\tau \rightarrow \mu\gamma)$	$Br(\tau \rightarrow 3l)$
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}

B Physics @ Y(4S)

Observable	B Factories (2 ab ⁻¹)	SuperB (75 ab ⁻¹)	Observable	B Factories (2 ab ⁻¹)	SuperB (75 ab ⁻¹)
sin(2β) (J/ψ K ⁰)	0.018	0.005 (†)	V _{cb} (exclusive)	4% (*)	1.0% (*)
cos(2β) (J/ψ K ^{*0})	0.30	0.05	V _{cb} (inclusive)	1% (*)	0.5% (*)
sin(2β) (Dh ⁰)	0.10	0.02	V _{ub} (exclusive)	8% (*)	3.0% (*)
cos(2β) (Dh ⁰)	0.20	0.04	V _{ub} (inclusive)	8% (*)	2.0% (*)
S(J/ψ π ⁰)	0.10	0.02	$\mathcal{B}(B \rightarrow \tau\nu)$	20%	4% (†)
S(D ⁺ D ⁻)	0.20	0.03	$\mathcal{B}(B \rightarrow \mu\nu)$	visible	5%
S(φK ⁰)	0.13	0.02 (*)	$\mathcal{B}(B \rightarrow D\tau\nu)$	10%	2%
S(η'K ⁰)	0.05	0.01 (*)	$\mathcal{B}(B \rightarrow \rho\gamma)$	15%	3% (†)
S(K _s ⁰ K _s ⁰ K _s ⁰)	0.15	0.02 (*)	$\mathcal{B}(B \rightarrow \omega\gamma)$	30%	5%
S(K _s ⁰ π ⁰)	0.15	0.02 (*)	A _{CP} (B → K [*] γ)	0.007 (†)	0.004 († *)
S(ωK _s ⁰)	0.17	0.03 (*)	A _{CP} (B → ργ)	~ 0.20	0.05
S(f ₀ K _s ⁰)	0.12	0.02 (*)	A _{CP} (b → sγ)	0.012 (†)	0.004 (†)
γ (B → DK, D → CP eigenstates)	~ 15°	2.5°	A _{CP} (b → (s + d)γ)	0.03	0.006 (†)
γ (B → DK, D → suppressed states)	~ 12°	2.0°	S(K _s ⁰ π ⁰ γ)	0.15	0.02 (*)
γ (B → DK, D → multibody states)	~ 9°	1.5°	S(ρ ⁰ γ)	possible	0.10
γ (B → DK, combined)	~ 6°	1-2°	A _{CP} (B → K [*] ℓℓ)	7%	1%
α (B → ππ)	~ 16°	3°	A ^{FB} (B → K [*] ℓℓ) _{s0}	25%	9%
α (B → ρρ)	~ 7°	1-2° (*)	A ^{FB} (B → X _s ℓℓ) _{s0}	35%	5%
α (B → ρπ)	~ 12°	2°	$\mathcal{B}(B \rightarrow K\nu\bar{\nu})$	visible	20%
α (combined)	~ 6°	1-2° (*)	$\mathcal{B}(B \rightarrow \pi\nu\bar{\nu})$	-	possible
2β + γ (D ^{(*)±} π [∓] , D [±] K _s ⁰ π [∓])	20°	5°			

Charm mixing and CP

Mode	Observable	Υ(4S) (75 ab ⁻¹)	ψ(3770) (300 fb ⁻¹)
D ⁰ → K ⁺ π ⁻	x ²	3 × 10 ⁻⁵	
	y'	7 × 10 ⁻⁴	
D ⁰ → K ⁺ K ⁻	y _{CP}	5 × 10 ⁻⁴	
D ⁰ → K _S ⁰ π ⁺ π ⁻	x	4.9 × 10 ⁻⁴	
	y	3.5 × 10 ⁻⁴	
ψ(3770) → D ⁰ D ⁰	q/p	3 × 10 ⁻²	
	φ	2°	(1-2) × 10 ⁻⁵
	x ²		(1-2) × 10 ⁻³
	y		(1-2) × 10 ⁻³
	cos δ		(0.01-0.02)

Charm FCNC

Mode	Sensitivity
D ⁰ → e ⁺ e ⁻ , D ⁰ → μ ⁺ μ ⁻	1 × 10 ⁻⁸
D ⁰ → π ⁰ e ⁺ e ⁻ , D ⁰ → π ⁰ μ ⁺ μ ⁻	2 × 10 ⁻⁸
D ⁰ → ηe ⁺ e ⁻ , D ⁰ → ημ ⁺ μ ⁻	3 × 10 ⁻⁸
D ⁰ → K _S ⁰ e ⁺ e ⁻ , D ⁰ → K _S ⁰ μ ⁺ μ ⁻	3 × 10 ⁻⁸
D ⁺ → π ⁺ e ⁺ e ⁻ , D ⁺ → π ⁺ μ ⁺ μ ⁻	1 × 10 ⁻⁸
D ⁰ → e [±] μ [∓]	1 × 10 ⁻⁸
D ⁺ → π ⁺ e [±] μ [∓]	1 × 10 ⁻⁸
D ⁰ → π ⁰ e [±] μ [∓]	2 × 10 ⁻⁸
D ⁰ → ηe [±] μ [∓]	3 × 10 ⁻⁸
D ⁰ → K _S ⁰ e [±] μ [∓]	3 × 10 ⁻⁸
D ⁺ → π ⁻ e ⁺ e ⁺ , D ⁺ → K ⁻ e ⁺ e ⁺	1 × 10 ⁻⁸
D ⁺ → π ⁻ μ ⁺ μ ⁺ , D ⁺ → K ⁻ μ ⁺ μ ⁺	1 × 10 ⁻⁸
D ⁺ → π ⁻ e [±] μ [∓] , D ⁺ → K ⁻ e [±] μ [∓]	1 × 10 ⁻⁸

τ Physics

Sensitivity

$\mathcal{B}(\tau \rightarrow \mu\gamma)$	2 × 10 ⁻⁹
$\mathcal{B}(\tau \rightarrow e\gamma)$	2 × 10 ⁻⁹
$\mathcal{B}(\tau \rightarrow \mu\mu\mu)$	2 × 10 ⁻¹⁰
$\mathcal{B}(\tau \rightarrow eee)$	2 × 10 ⁻¹⁰
$\mathcal{B}(\tau \rightarrow \mu\eta)$	4 × 10 ⁻¹⁰
$\mathcal{B}(\tau \rightarrow e\eta)$	6 × 10 ⁻¹⁰
$\mathcal{B}(\tau \rightarrow \ell K_S^0)$	2 × 10 ⁻¹⁰

B_s Physics @ Y(5S)

Observable	Error with 1 ab ⁻¹	Error with 30 ab ⁻¹
ΔΓ	0.16 ps ⁻¹	0.03 ps ⁻¹
Γ	0.07 ps ⁻¹	0.01 ps ⁻¹
β _s from angular analysis	20°	8°
A _{SL}	0.006	0.004
A _{CH}	0.004	0.004
$\mathcal{B}(B_s \rightarrow \mu^+\mu^-)$	-	< 8 × 10 ⁻⁹
V _{td} /V _{ts}	0.08	0.017
$\mathcal{B}(B_s \rightarrow \gamma\gamma)$	38%	7%
β _s from J/ψφ	10°	3°
β _s from B _s → K ⁰ K ⁰	24°	11°

Physics at a Super B Factory

- There is a good chance to see new phenomena;
 - **CPV in B decays from the new physics (non KM).**
 - **Lepton flavor violations in τ decays.**
- They will help to diagnose (if found) or constrain (if not found) new physics models.
- $B \rightarrow \tau \nu$, $D \tau \nu$ can probe the charged Higgs in large $\tan\beta$ region.
- **Physics motivation is independent of LHC.**
 - If LHC finds NP, precision flavour physics is compulsory.
 - If LHC finds no NP, high statistics B/ τ decays would be a unique way to search for the $> \text{TeV}$ scale physics (=TeV scale in case of MFV).

There are many more topics: CPV in charm, new hadrons, ...

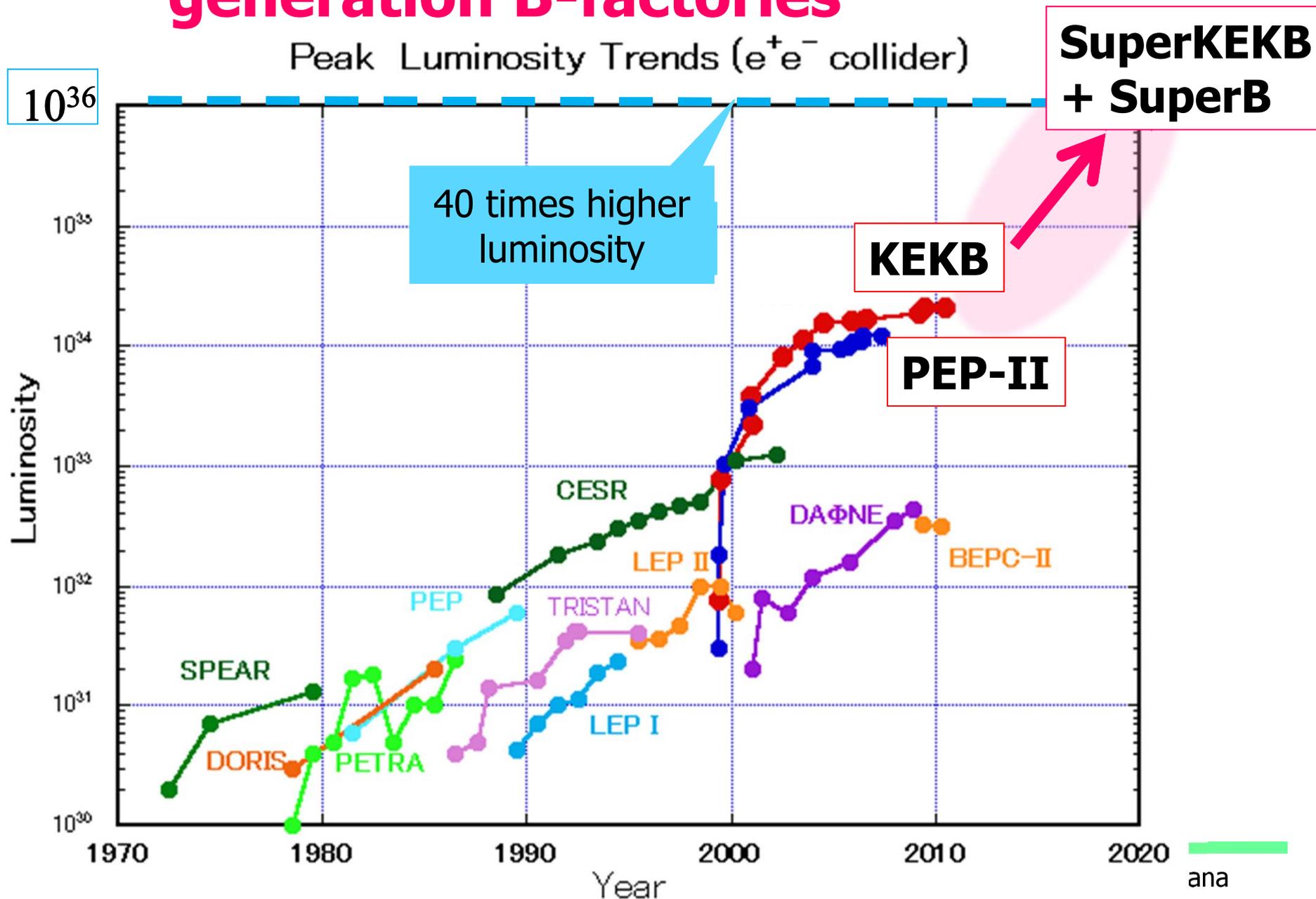
Recent update of the physics reach with 50 ab^{-1} (75 ab^{-1}):

Physics at Super B Factory (Belle II authors + guests) [hep-ex](#) > arXiv:1002.5012

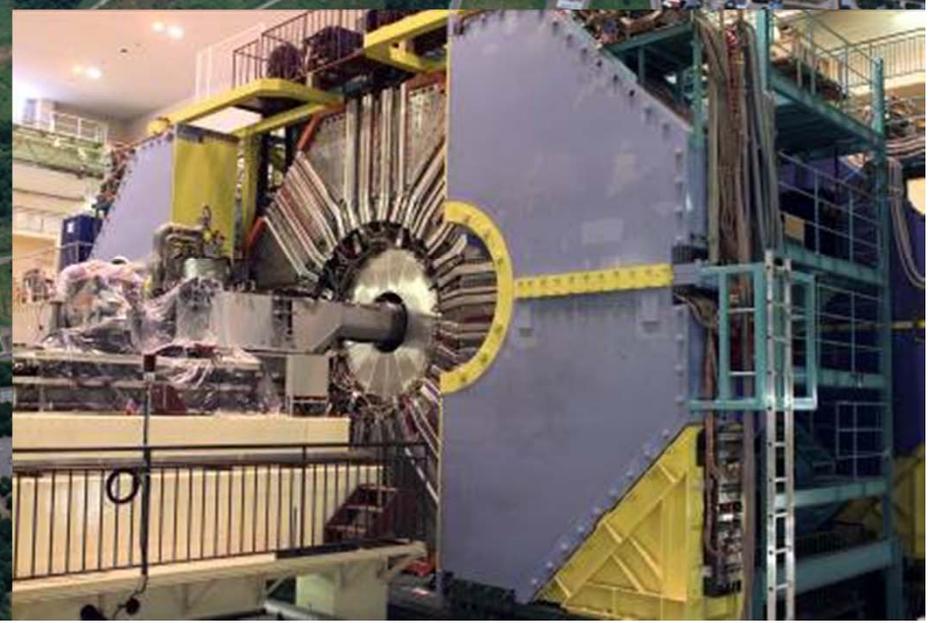
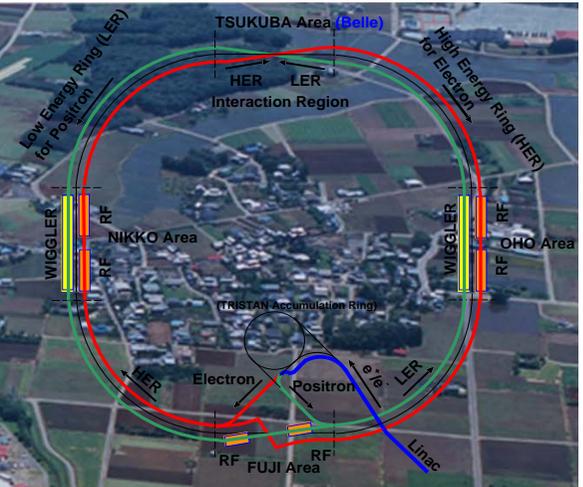
SuperB Progress Reports: Physics (SuperB authors + guests) [hep-ex](#) > arXiv:1008.1541

Accelerator

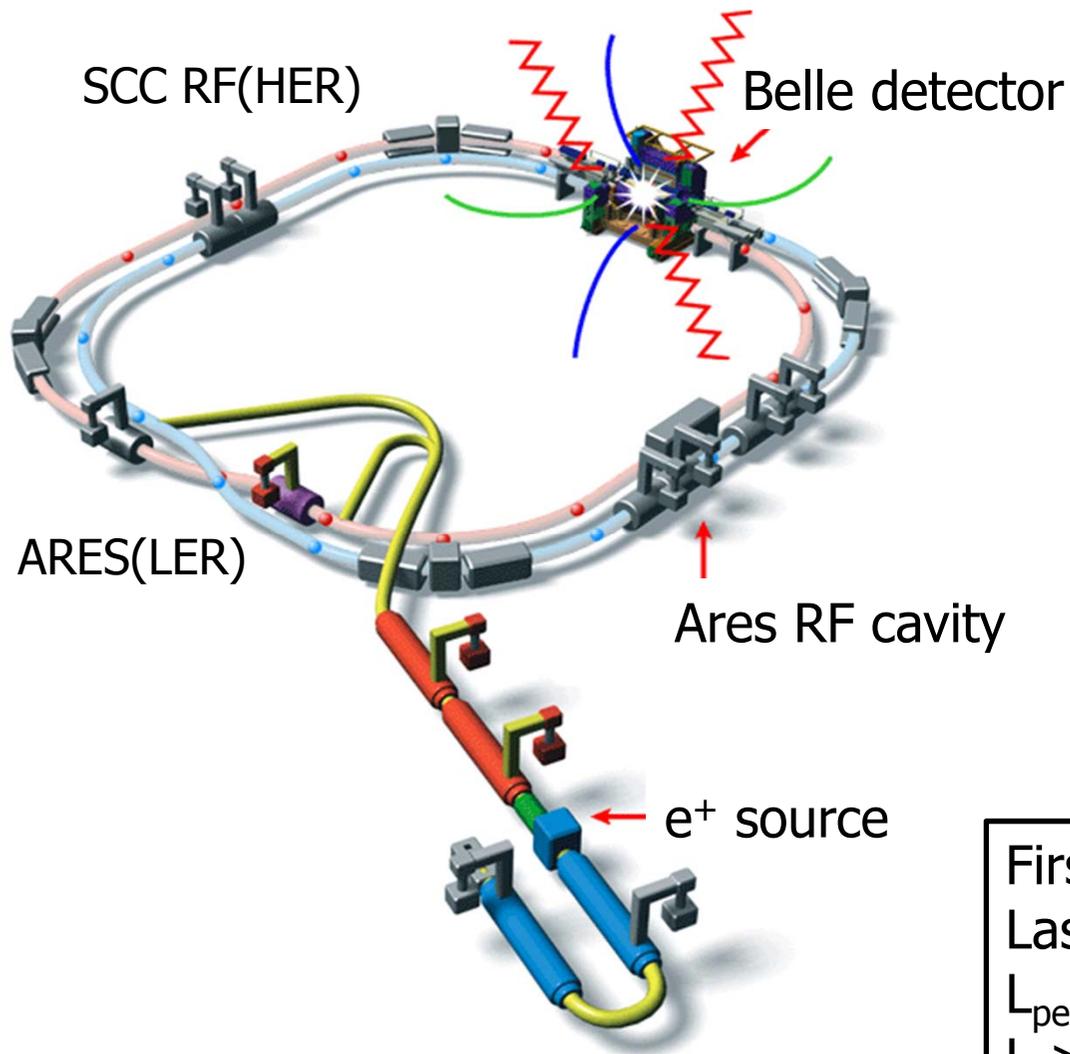
Need O(100x) more data → Next generation B-factories



How to do it?
→ upgrade KEKB and Belle



The KEKB Collider & Belle Detector



- e^- (8 GeV) on e^+ (3.5 GeV)
 - $\sqrt{s} \approx m_{\Upsilon(4S)}$
 - Lorentz boost: $\beta\gamma=0.425$
- 22 mrad crossing angle
- Operating since 1999

Peak luminosity (WR!) :
 $2.1 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$
=2x design value

First physics run on June 2, 1999
Last physics run on June 30, 2010
 $L_{\text{peak}} = 2.1 \times 10^{34} / \text{cm}^2 / \text{s}$
 $L > 1 \text{ ab}^{-1}$

The last beam abort of KEKB on June 30, 2010



→ Can start construction of SuperKEKB and Belle II

Strategies for increasing luminosity



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

Lorentz factor γ_{e^\pm}
 Beam current I_{e^\pm}
 Beam-beam parameter $\xi_y^{e^\pm}$
 Classical electron radius r_e
 Beam size ratio@IP $\frac{\sigma_y^*}{\sigma_x^*}$
 Vertical beta function@IP β_y^*
 Lumi. reduction factor (crossing angle) & Tune shift reduction factor (hour glass effect) $\frac{R_L}{R_{\xi_y}}$
 0.8 - 1 (short bunch)

- (1) Smaller β_y^***
 - (2) Increase beam currents**
 - (3) Increase ξ_y
- “Nano-Beam” scheme**

Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

Machine design parameters



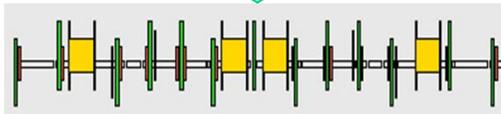
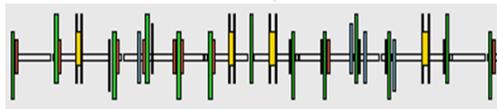
parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ϵ_x	18	24	3.2	4.3-4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	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}		$\text{cm}^{-2}\text{s}^{-1}$

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

KEKB to SuperKEKB

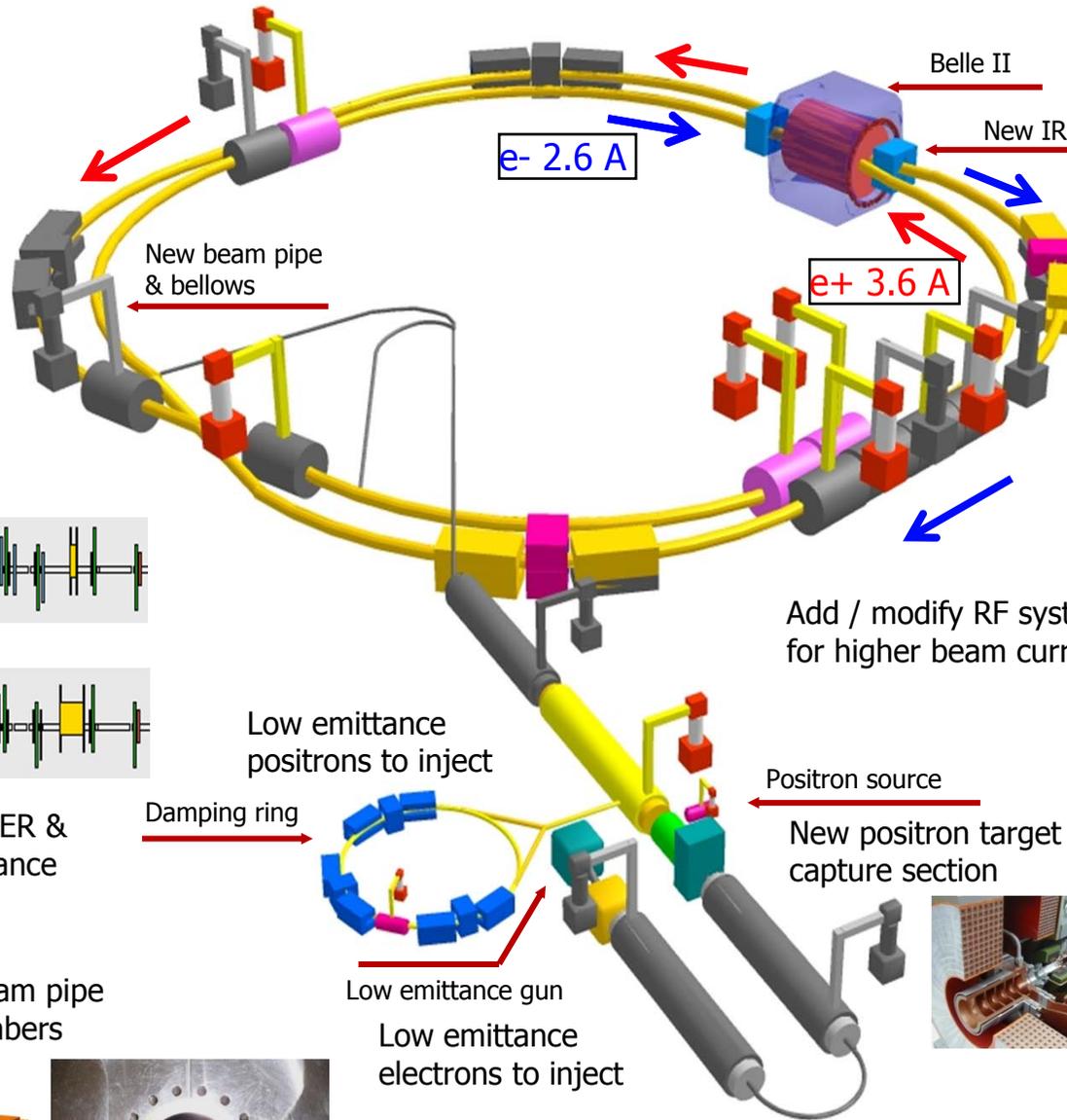
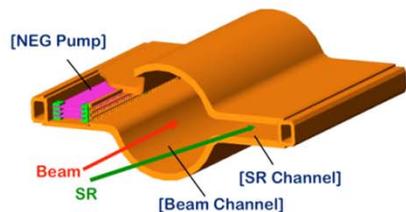


Replace short dipoles with longer ones (LER)

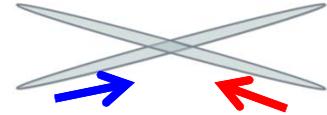


Redesign the lattices of HER & LER to squeeze the emittance

TiN-coated beam pipe with antechambers



Colliding bunches



New superconducting / permanent final focusing quads near the IP



To get x40 higher luminosity

Detector



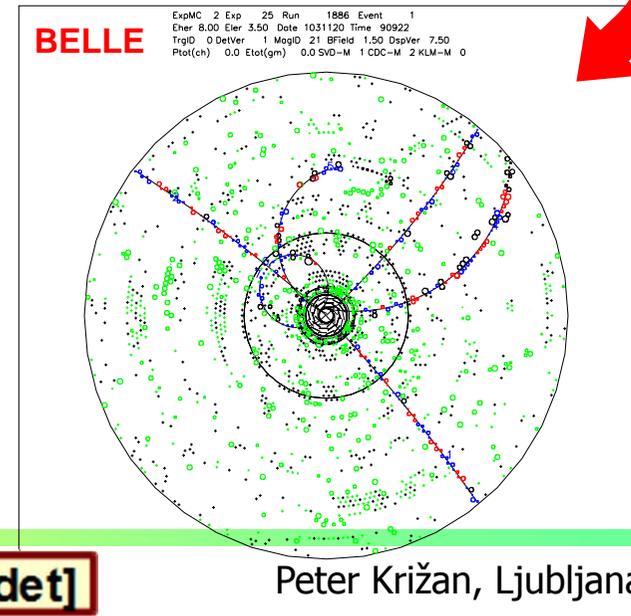
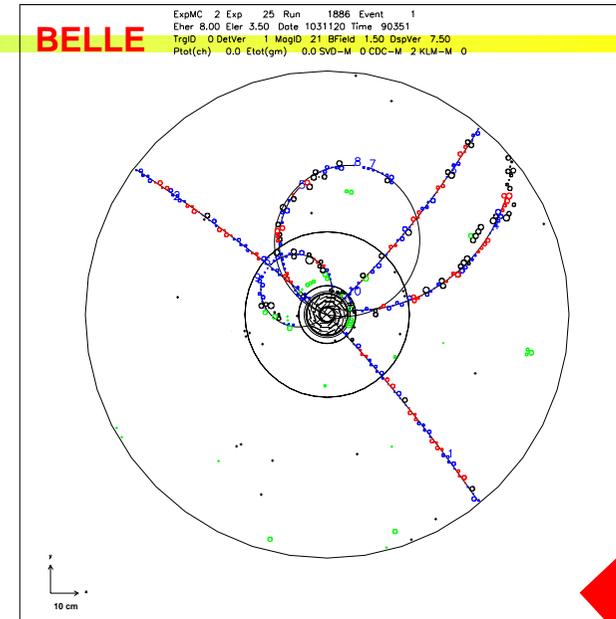
Requirements for the Belle II detector

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

- ▶ **Higher background ($\times 10\text{-}20$)**
 - radiation damage and occupancy
 - fake hits and pile-up noise in the EM
- ▶ **Higher event rate ($\times 10$)**
 - higher rate trigger, DAQ and computing
- ▶ **Require special features**
 - low $p \mu$ identification $\leftarrow s_{\mu\mu}$ recon. eff.
 - hermeticity $\leftarrow \nu$ "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 endcap calorimeter crystals
- ▶ Faster readout electronics and computing system.

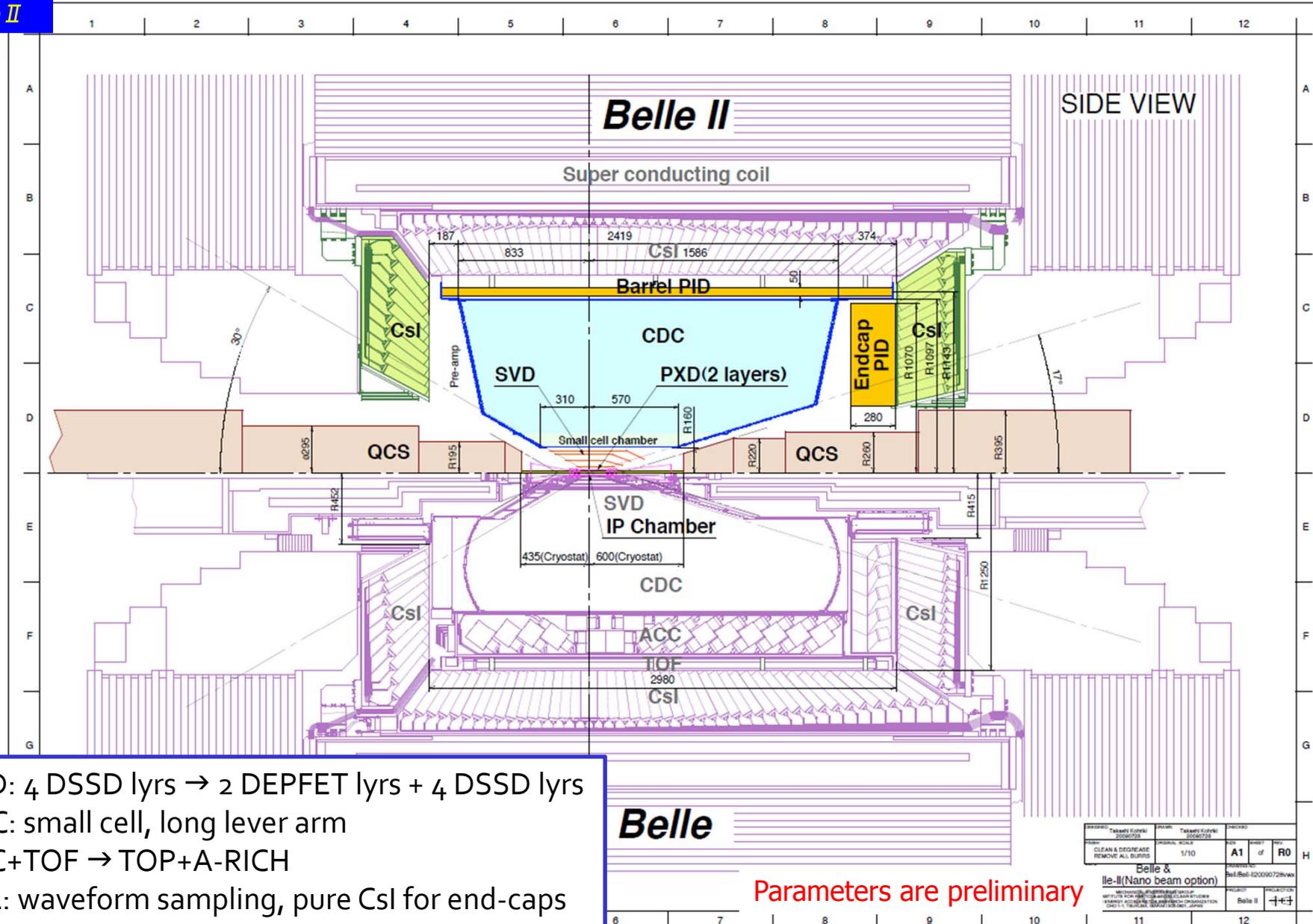


TDR published [arXiv:1011.0352v1](https://arxiv.org/abs/1011.0352v1) [physics.ins-det]

Peter Križan, Ljubljana



Belle II in comparison with Belle



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

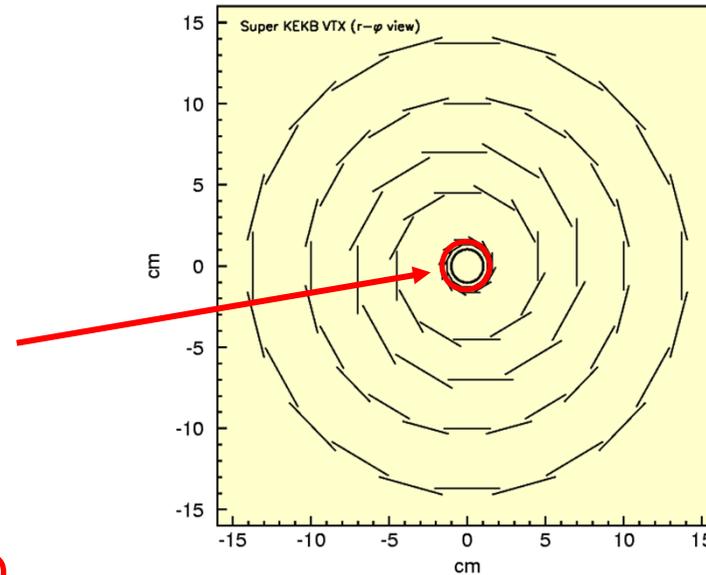
Belle

Parameters are preliminary

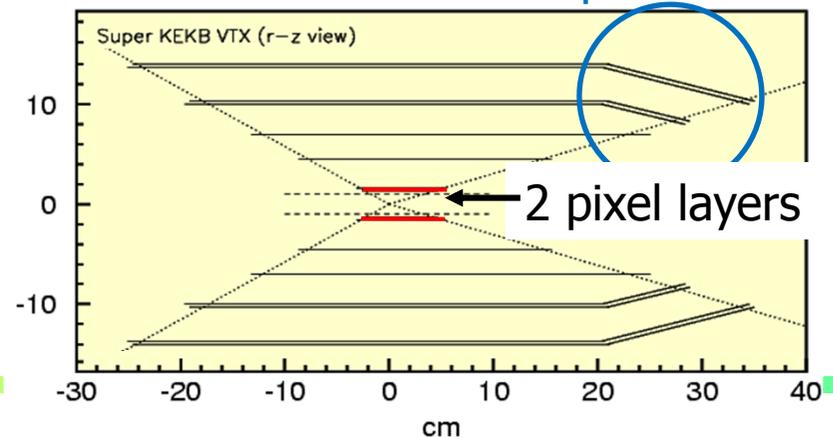
DESIGNED BY Takashi Kubota 20060728	APPROVED BY Takashi Kubota 20060728	REV A1	SHEET of	REV R0
CLEAN & DECREASE REMOVE ALL SURFES				
DATE: 2006/07/28				
PROJECT: Belle II (Nano beam option)				
PROJECT CODE: Belle II				

Vertex detector upgrade: PXD+SVD

- Configuration: 4 layers \rightarrow 6 layers (outer radius = 8cm \rightarrow 14cm)
 - More robust tracking
 - Higher Ks vertex reconstr. efficiency
- Inner radius: 1.5cm \rightarrow 1.3cm
 - Better vertex resolution
- Sensors of the two innermost layers L1+L2: **DEPFET Pixel sensors \rightarrow PXD**
- Layers 3-6: **normal double sided Si detector (DSSD) \rightarrow SVD**
- Strip readout chip: **VA1TA \rightarrow APV25**
 - Reduction of occupancy coming from beam background.
 - Pipeline readout to reduce dead time.



Slanted layers to keep the acceptance

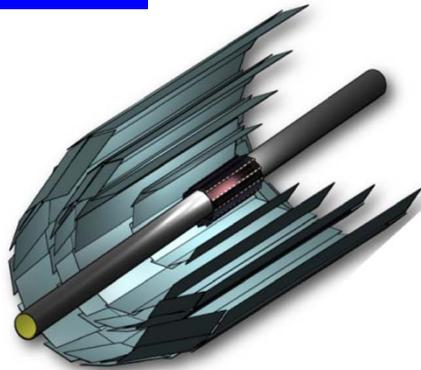




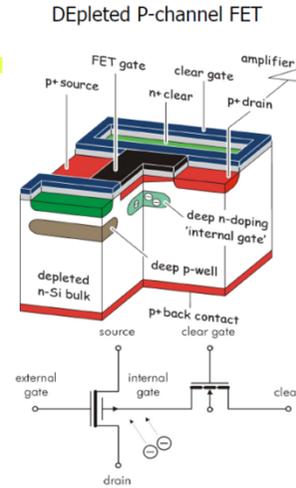
Vertex Detector

DEPFET:

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



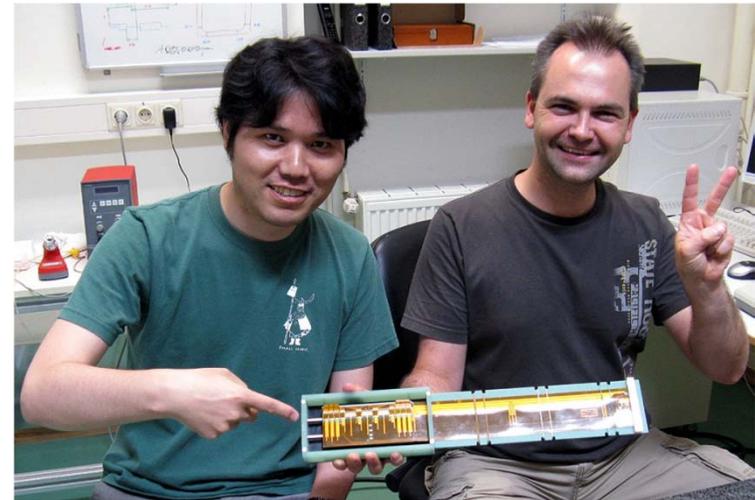
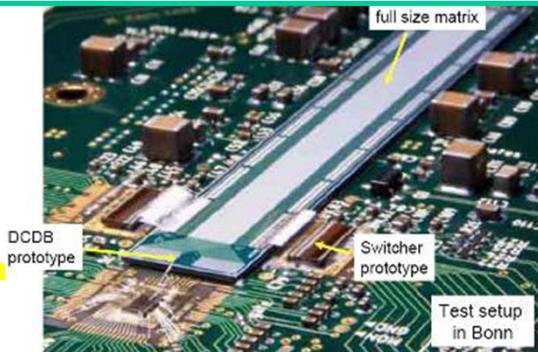
Beam Pipe	r = 10mm
DEPFET	
Layer 1	r = 14mm
Layer 2	r = 22mm
DSSD	
Layer 3	r = 38mm
Layer 4	r = 80mm
Layer 5	r = 115mm
Layer 6	r = 140mm



Mechanical mockup of pixel detector



Prototype DEPFET pixel sensor and readout



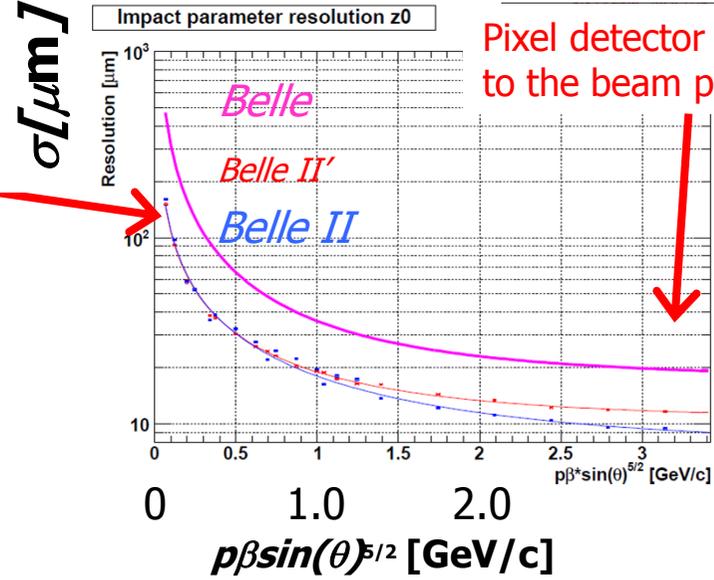
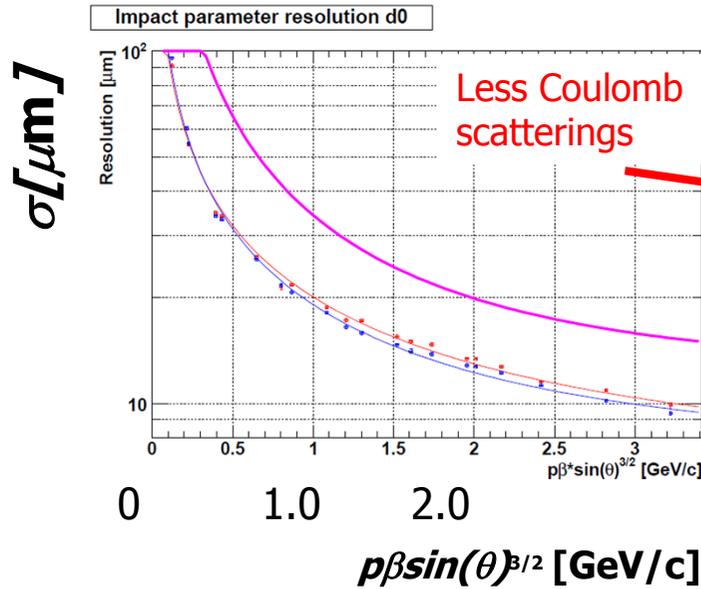
A prototype ladder using the first 6 inch DSSD from Hamamatsu has been assembled and tested.



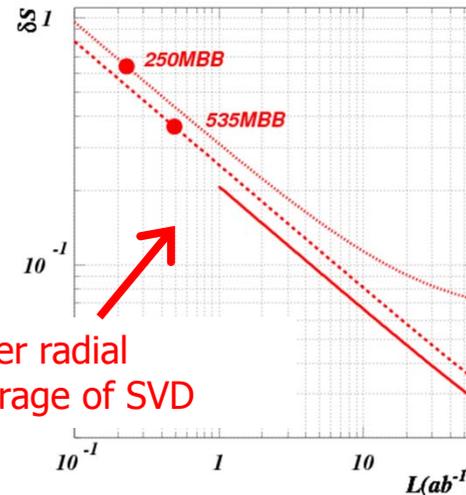
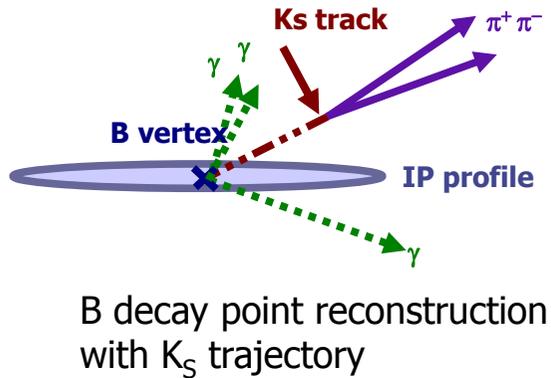
Expected performance

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

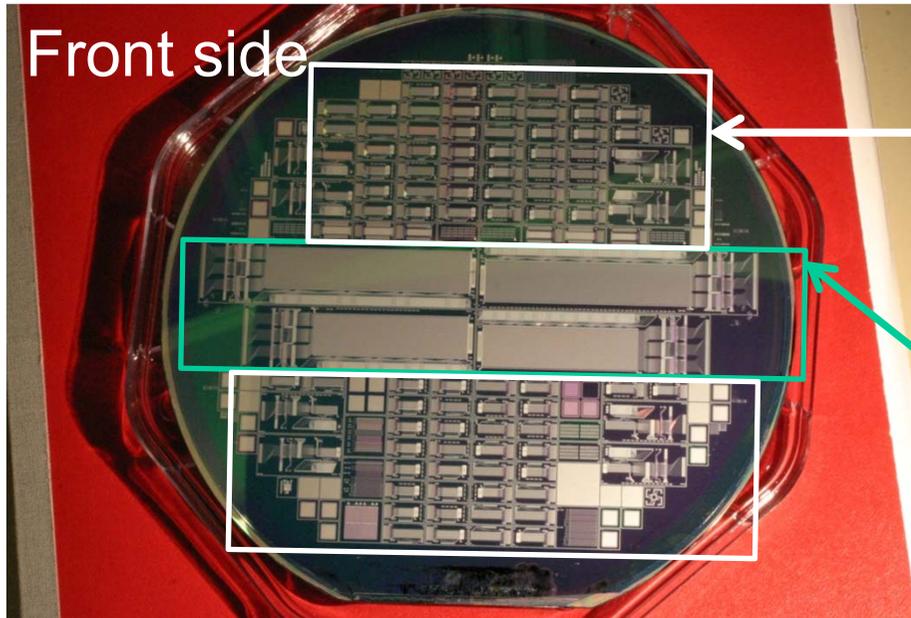
Significant improvement in IP resolution!



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

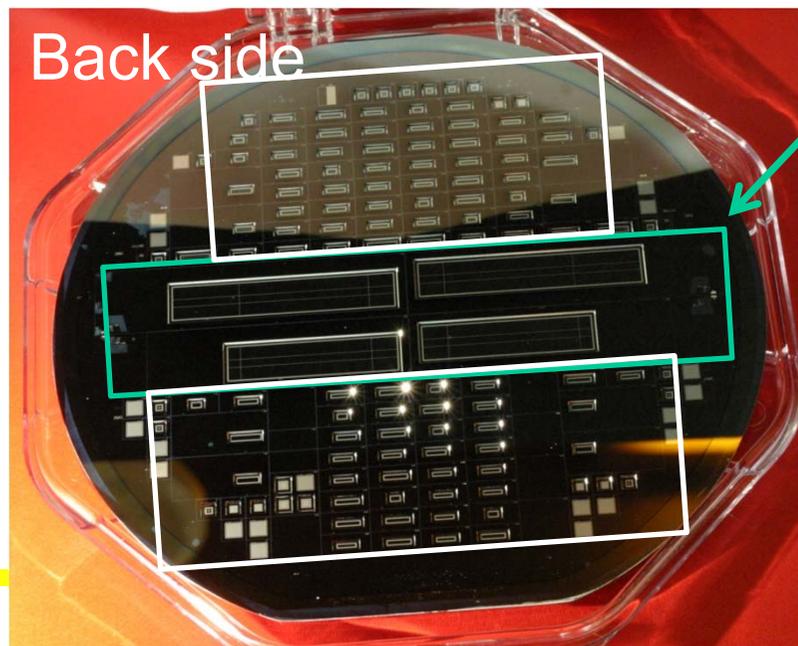


First measurements of thin DEPFETs

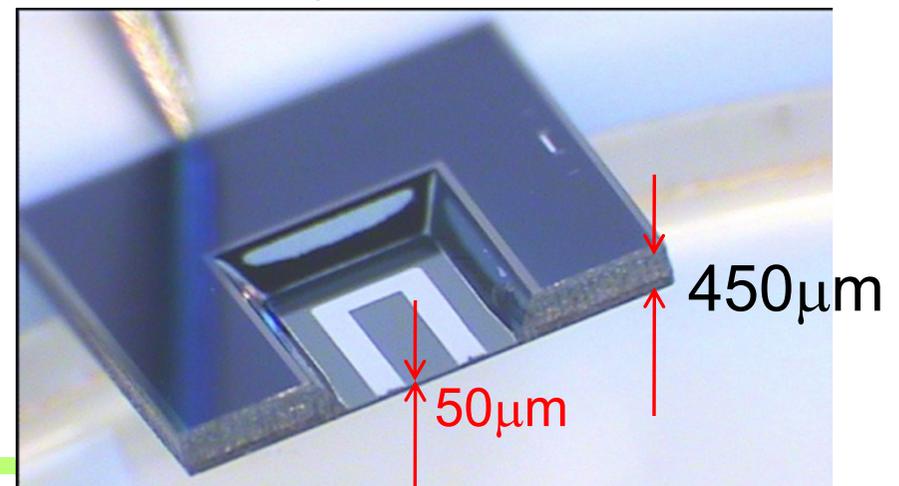


Small matrices 32x64 pixels,
different technology variations,
ASIC connection via wire bonding

Half ladders 768x120-160 pixels
(~ Belle II geometry)
ASIC connection via bump bonding



Cut through the matrix

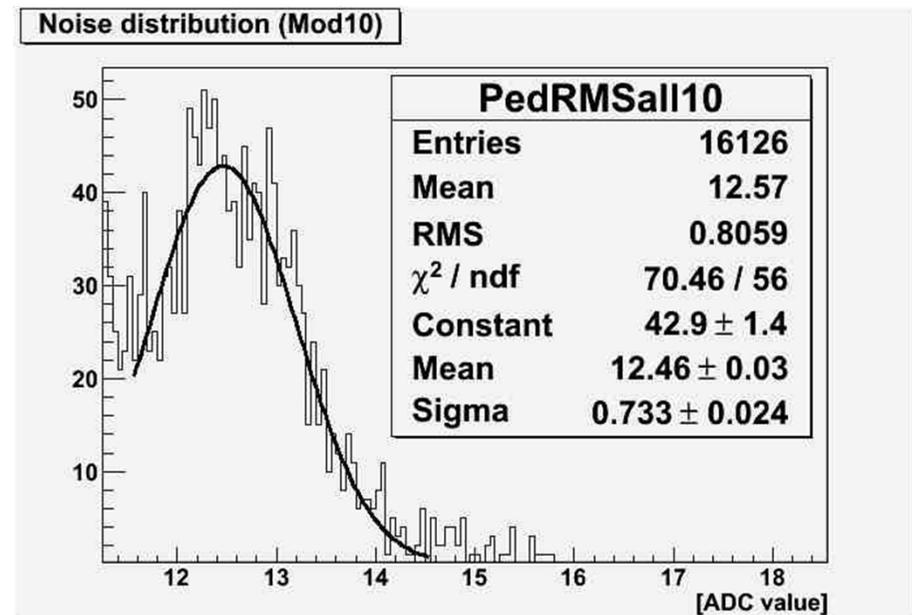
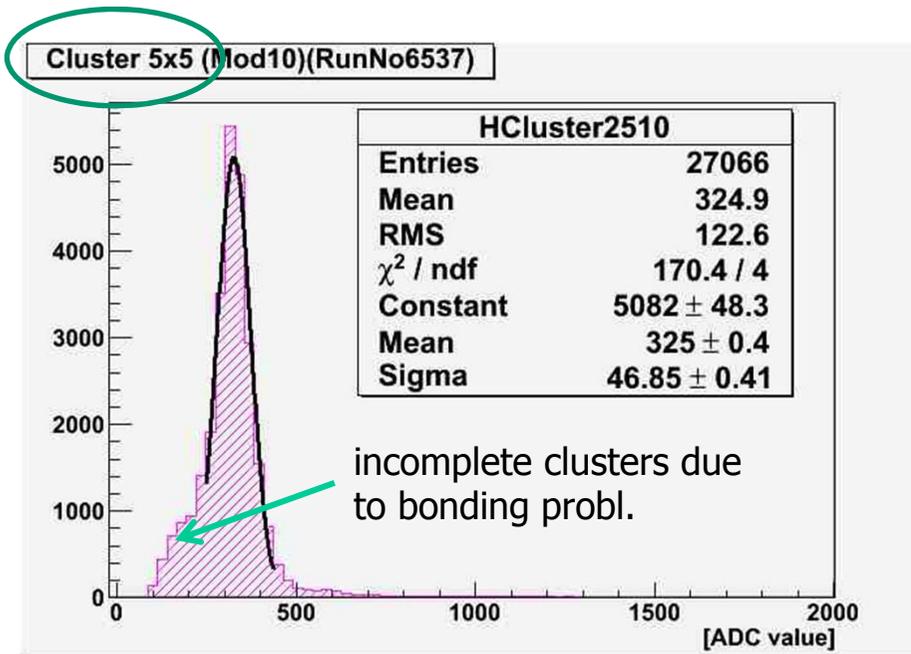


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First measurements of thin DEPFETs

Thin matrix: 32x64 pixels Belle II PXD design, pixel size 50 x 75 x 50 μm^3
(6 μm gate length)

irradiated with γ source



S/N = 26.08 at 22keV (^{109}Cd)

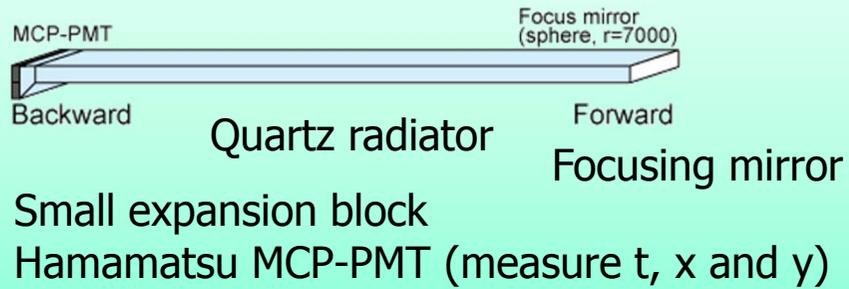
(22 keV \equiv 6100 e^- \sim mip in 75 μm)

readout of ASICs: CURO readout chip
(= system used in previous beam tests of thick DEPFET sensors
→ final read-out chip will have **2x smaller noise**)

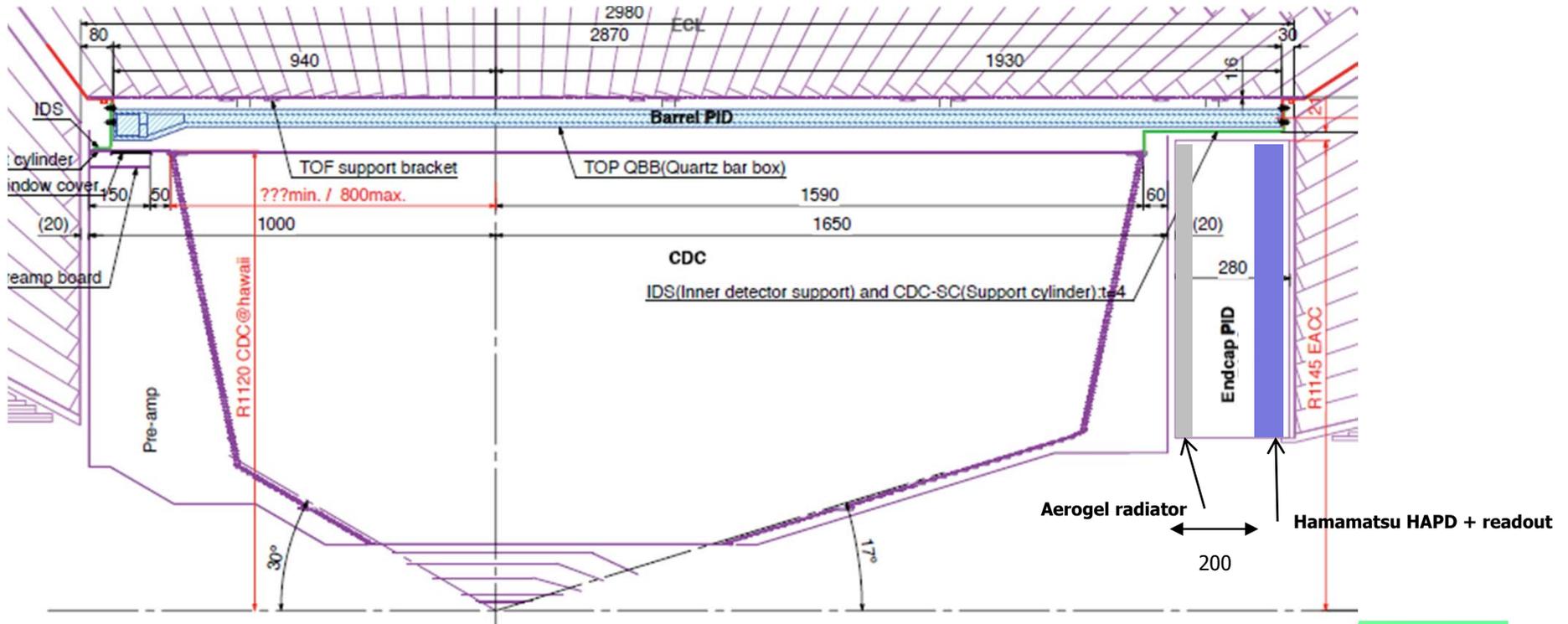
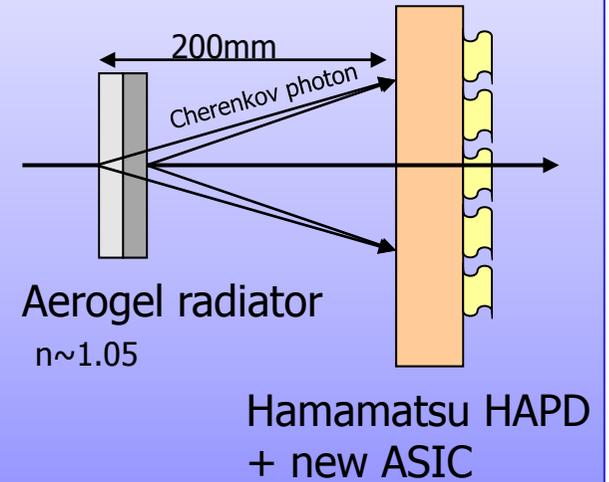


Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)

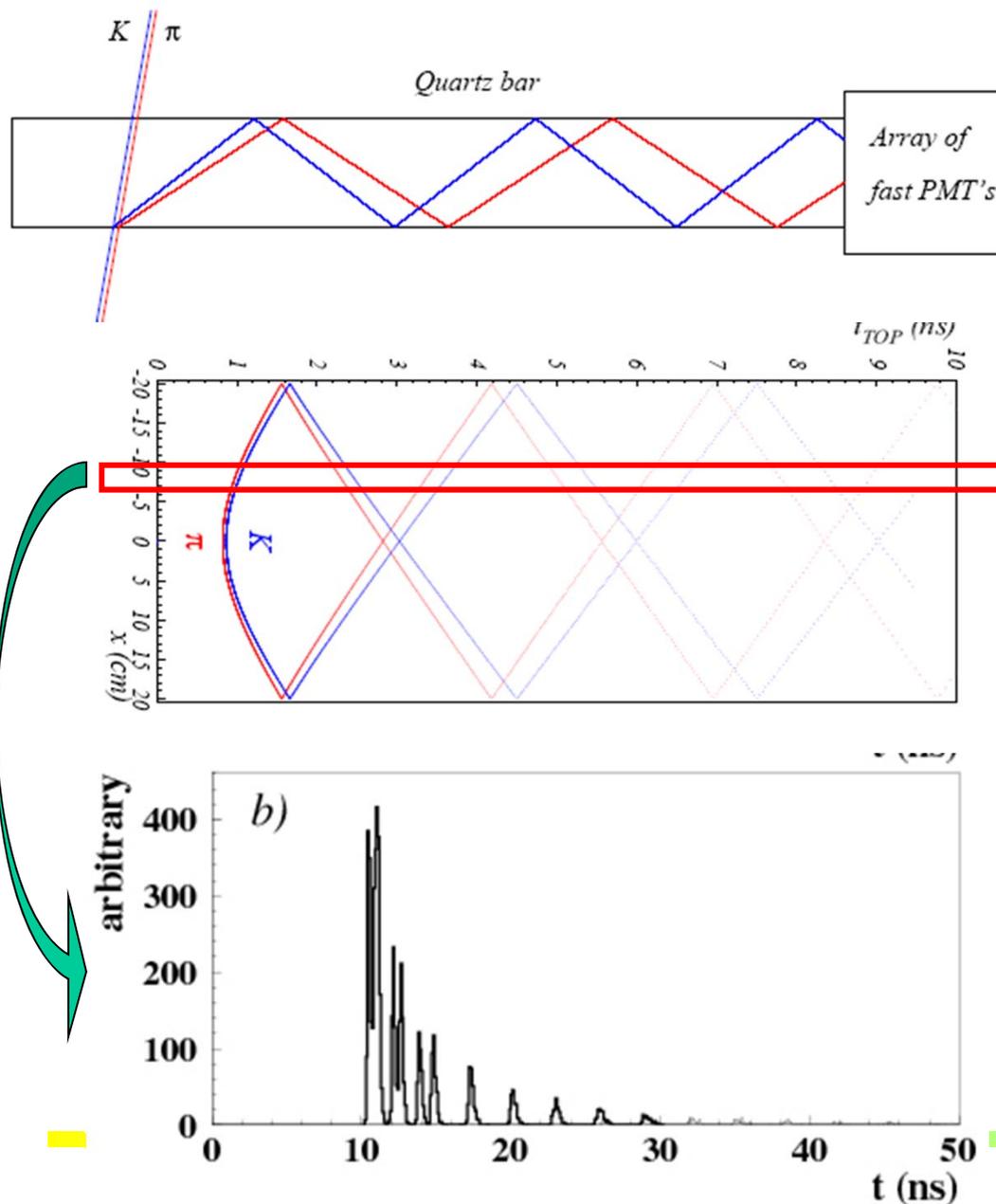


Endcap PID: Aerogel RICH (ARICH)



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Barrel PID: Time of propagation (TOP) counter



Pattern in the coordinate-time space ('ring') of a **pion** hitting a quartz bar with ~ 80 MAPMT channels

Time distribution of signals recorded by one of the PMT channels: different for π and K

Barrel PID: Time of propagation (TOP) counter

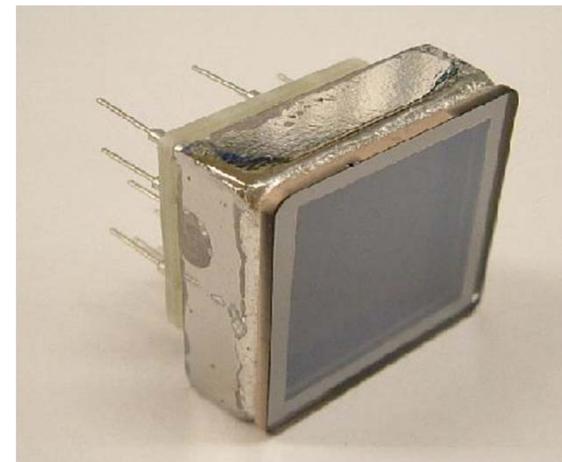


- Cherenkov ring imaging with precise time measurement.
- Reconstruct angle from two coordinates and the time of propagation of the photon
 - Quartz radiator ($\sim 2\text{cm}$)
 - Photon detector (MCP-PMT)
 - Good time resolution $\sim 40\text{ ps}$
 - Single photon sensitivity in 1.5 T



Photon detector array

SL10 MCP-PMT

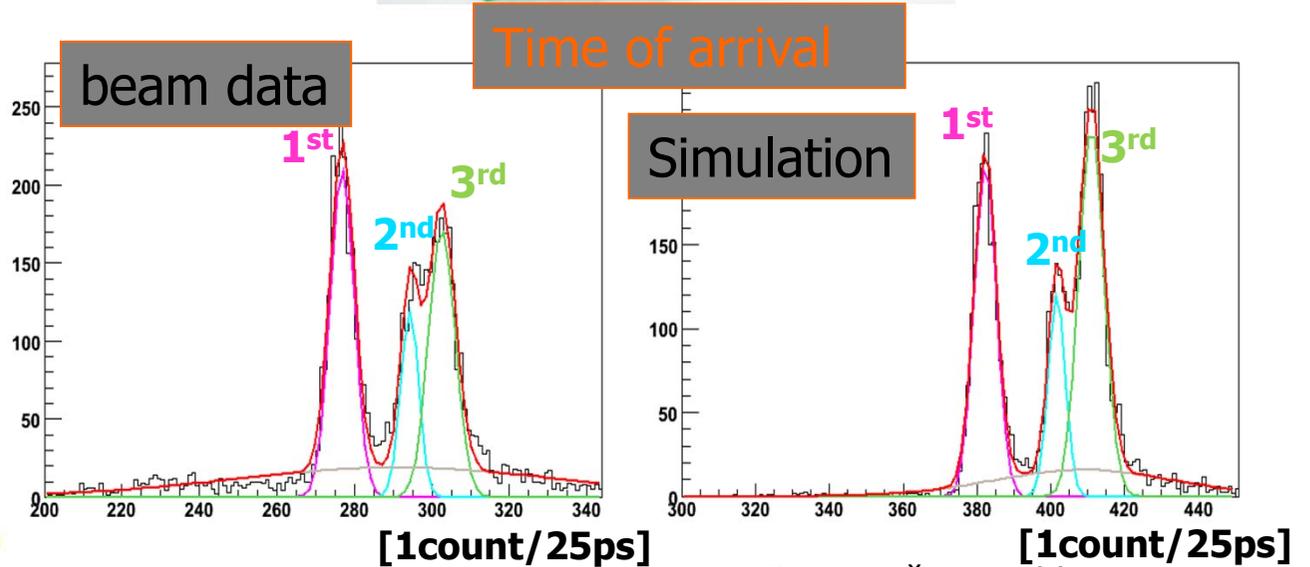
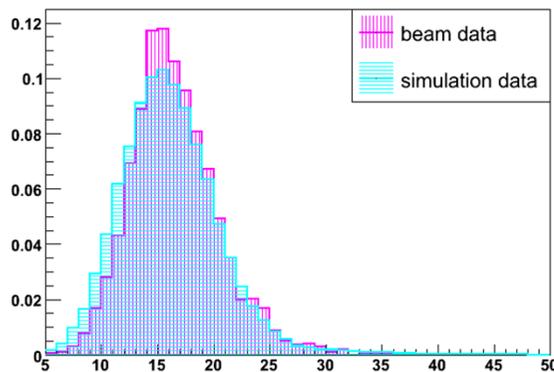
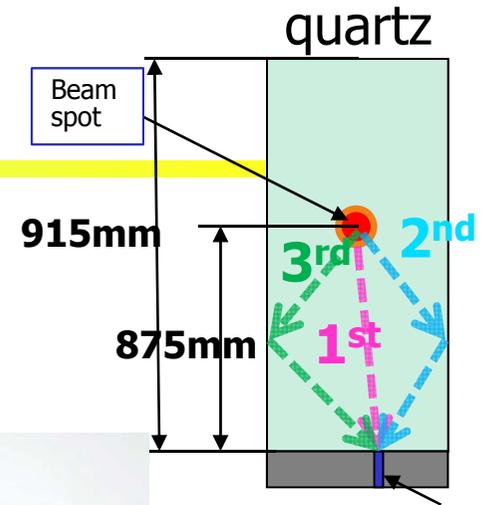


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TOP (Barrel PID)

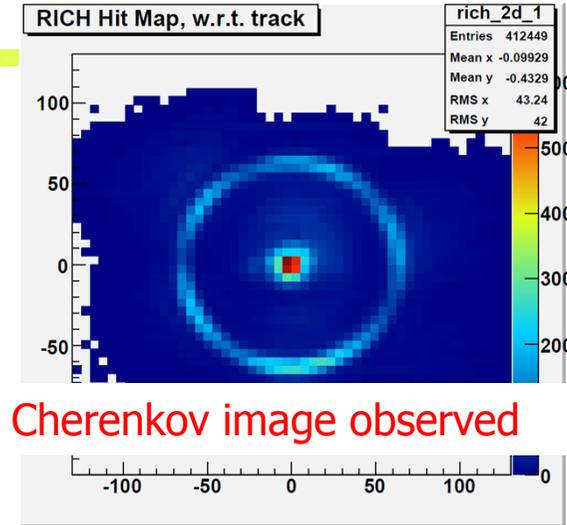
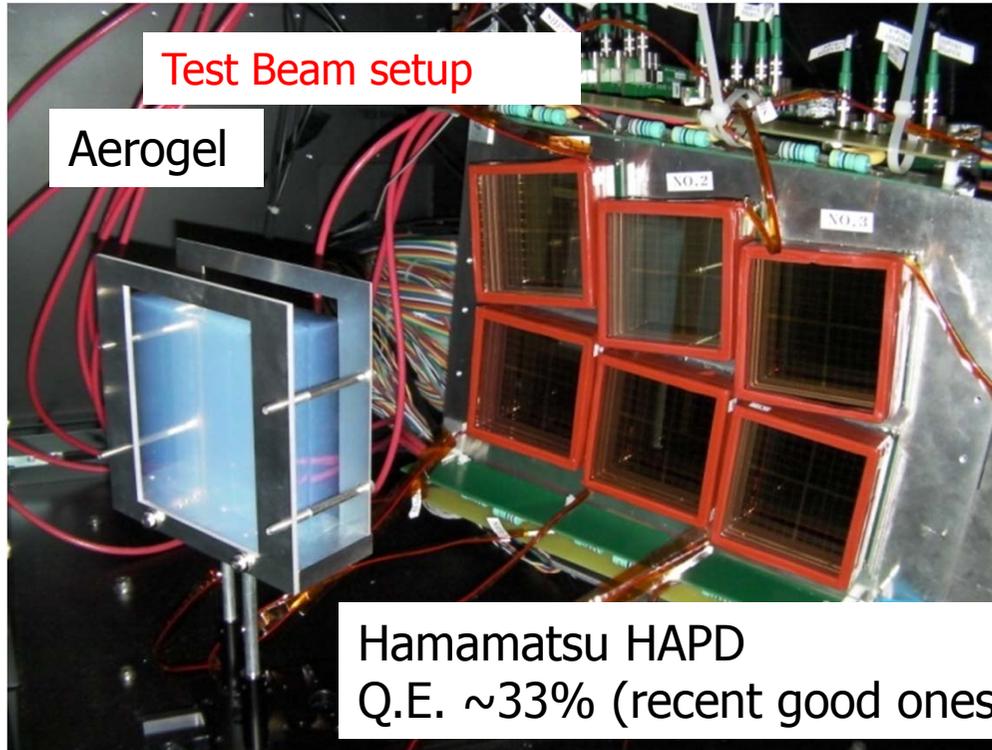
- Quartz radiator
 - 2.6m^L x 45cm^W x 2cm^T
 - Excellent surface accuracy
- MCP-PMT
 - Hamamatsu 16ch MCP-PMT
 - Good TTS (<35ps) & enough lifetime
 - Multialkali photo-cathode → SBA
- Beam test in 2009
 - # of photons consistent
 - Time resolution OK



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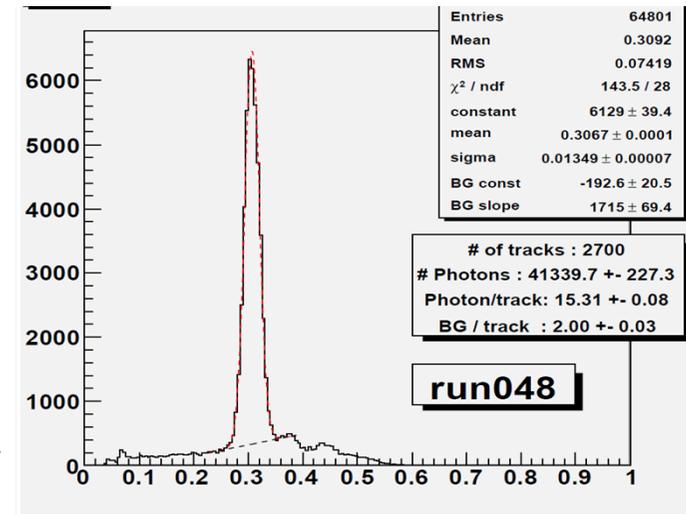


Aerogel RICH (endcap PID)



Clear Cherenkov image observed

Cherenkov angle distribution

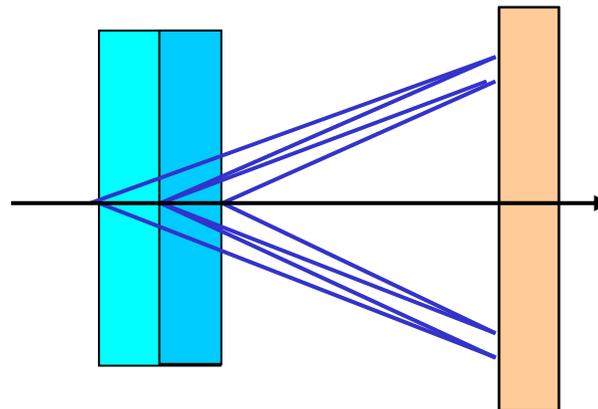


6.6 σ π/K at 4GeV/c !

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

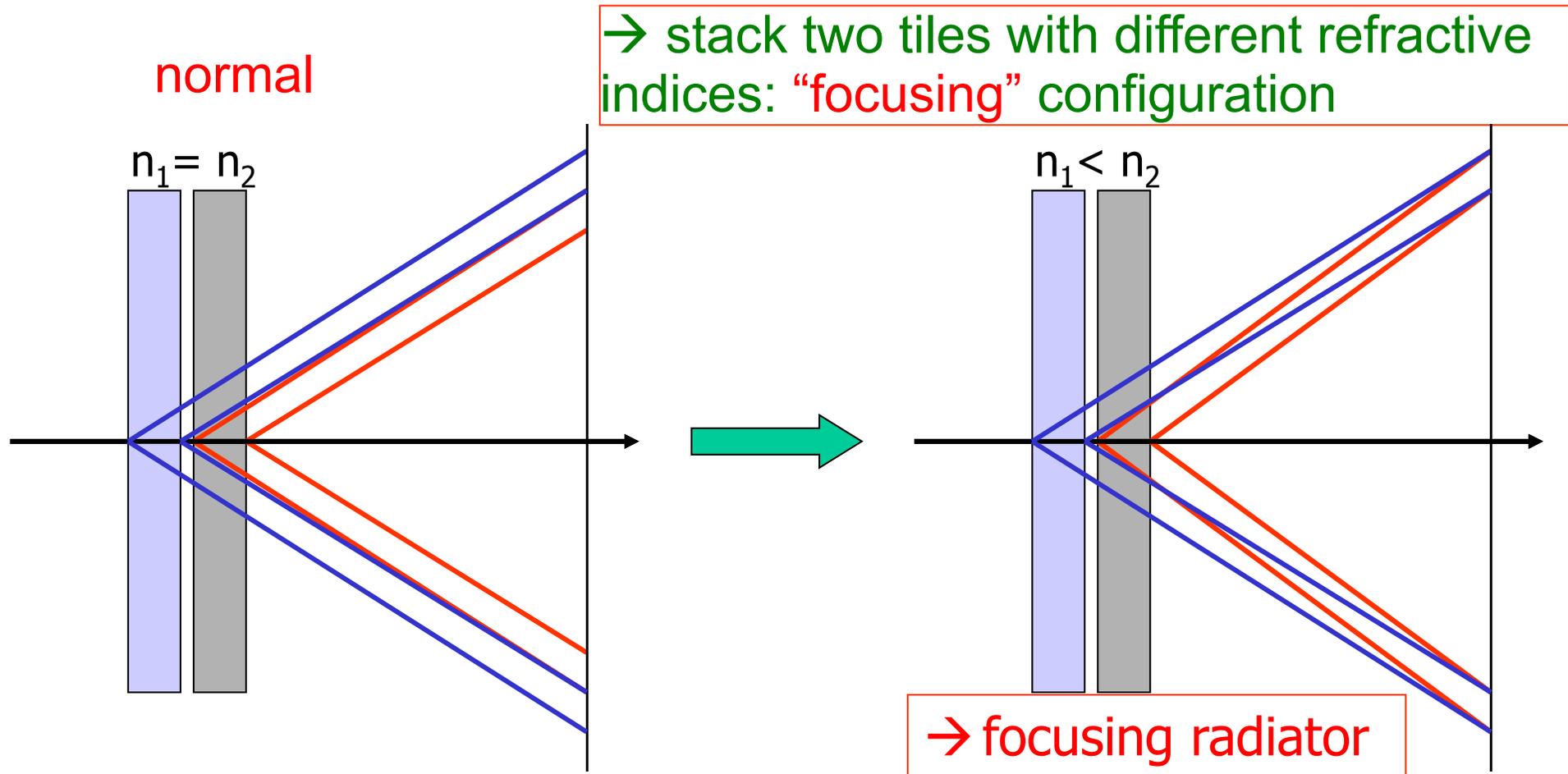
Employ multiple layers with different refractive indices → Cherenkov images from individual layers overlap on the photon detector.





Radiator with multiple refractive indices

How to increase the number of photons without degrading the resolution?

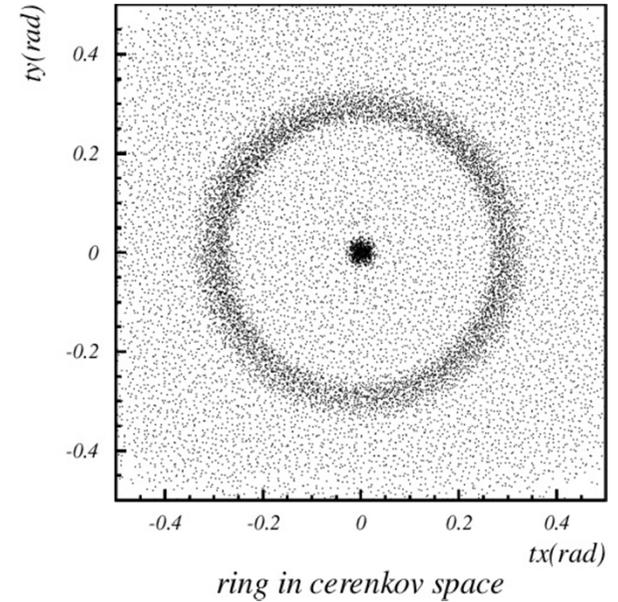
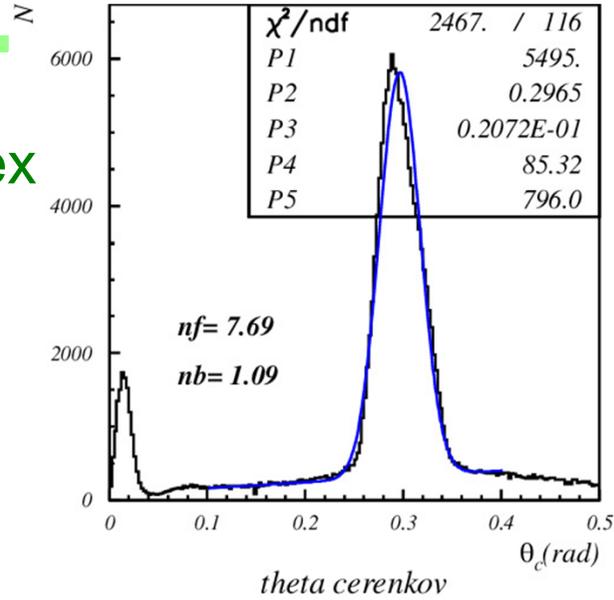
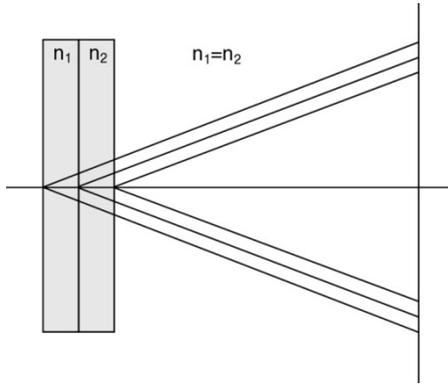


Such a configuration is only possible with aerogel (a form of Si_xO_y) – material with a tunable refractive index between 1.01 and 1.13.

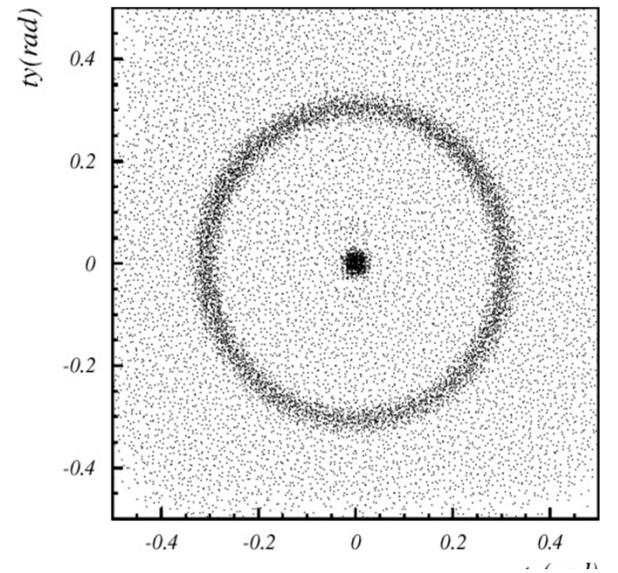
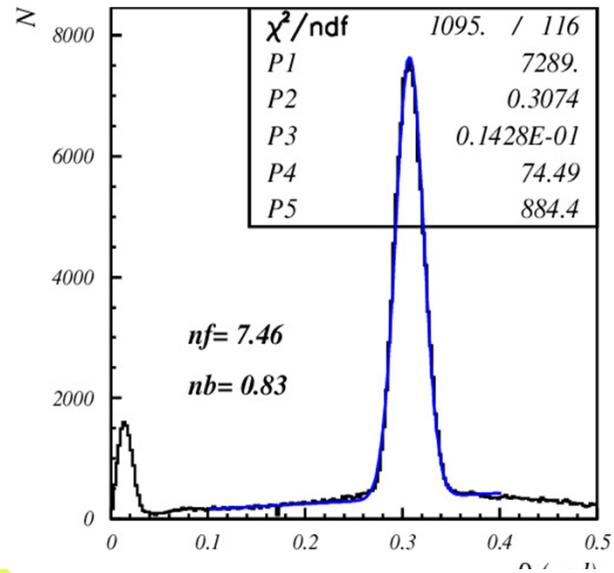
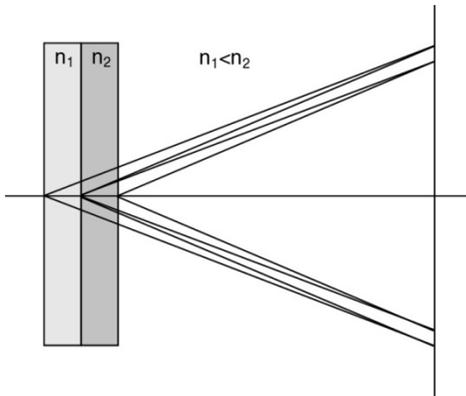


Focusing configuration – data

4cm aerogel single index



2+2cm aerogel

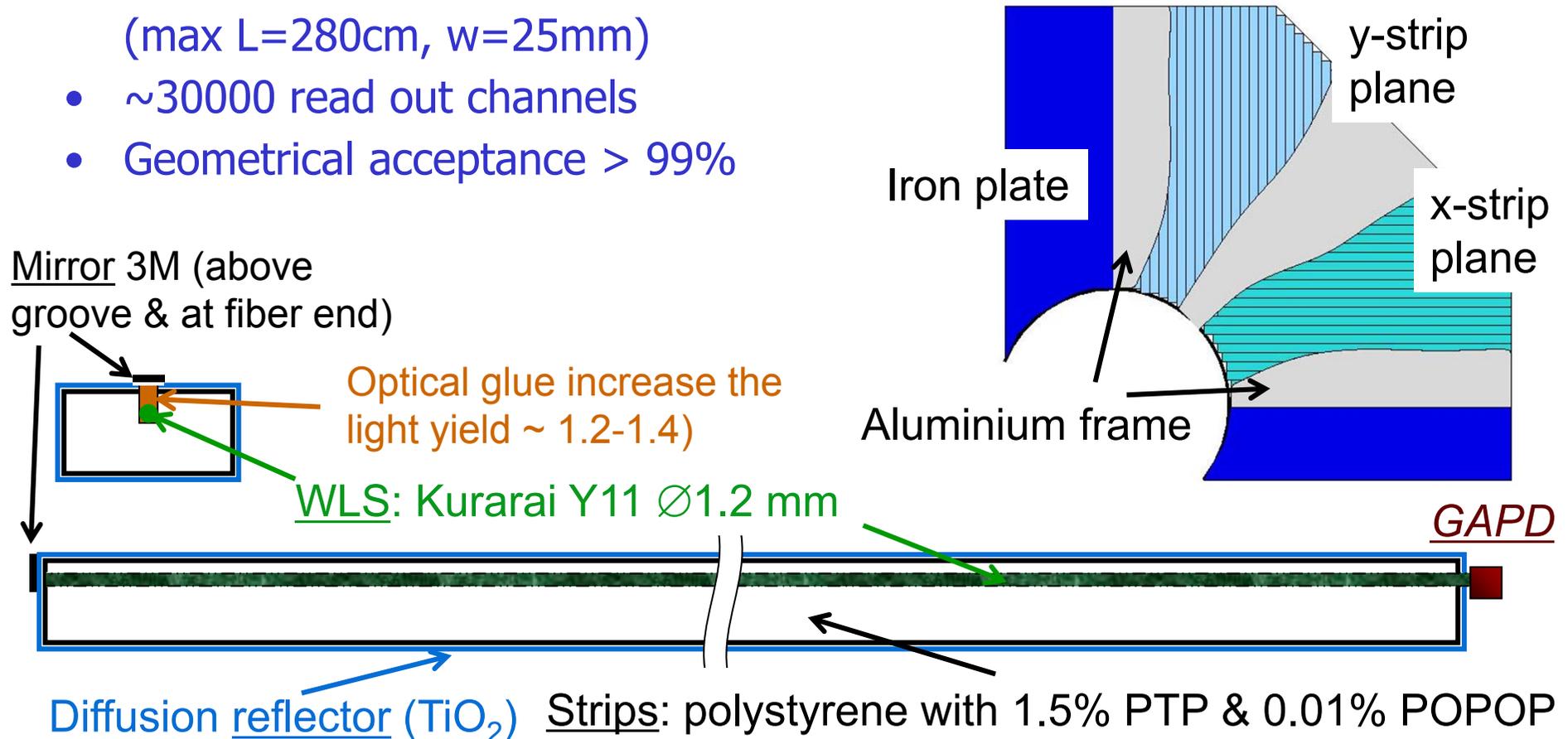


→ NIM A548 (2005) 383

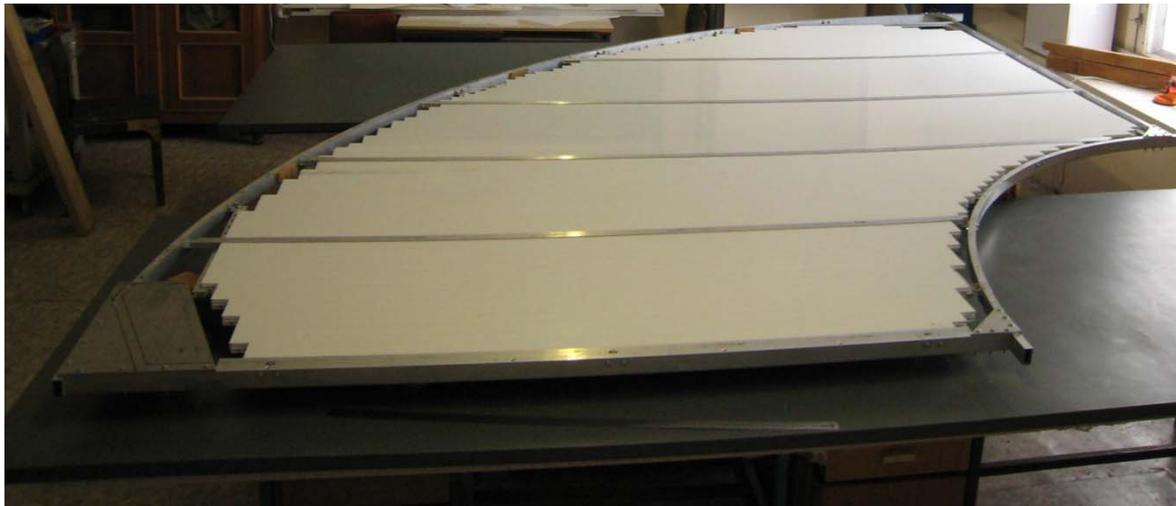
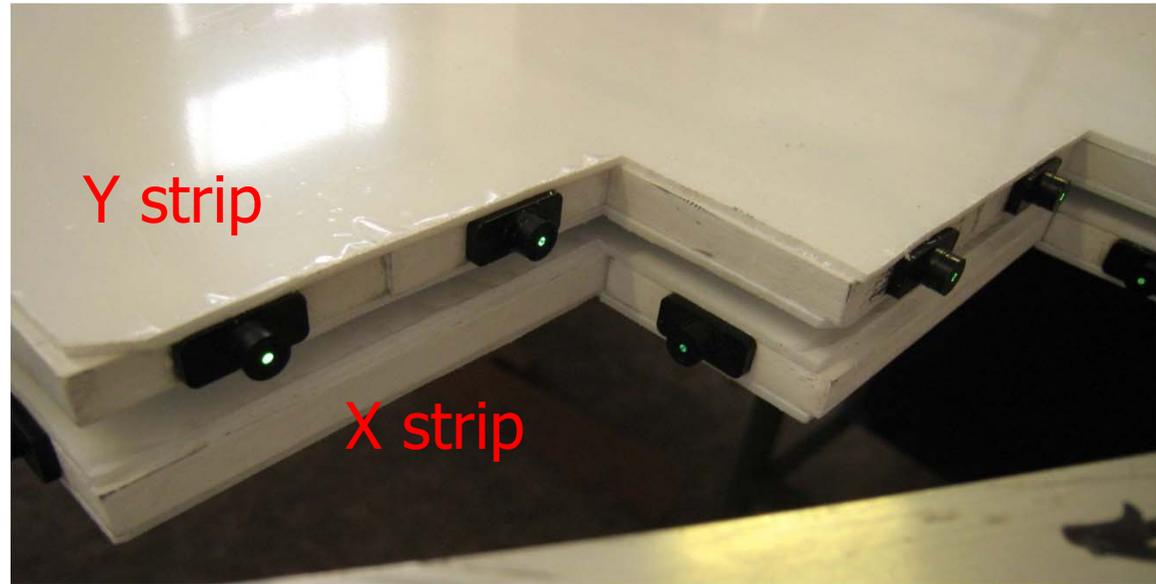
KLM upgrade in the endcaps

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 90° sector (max $L=280\text{cm}$, $w=25\text{mm}$)
- ~ 30000 read out channels
- Geometrical acceptance $> 99\%$



KLM upgrade in the endcaps

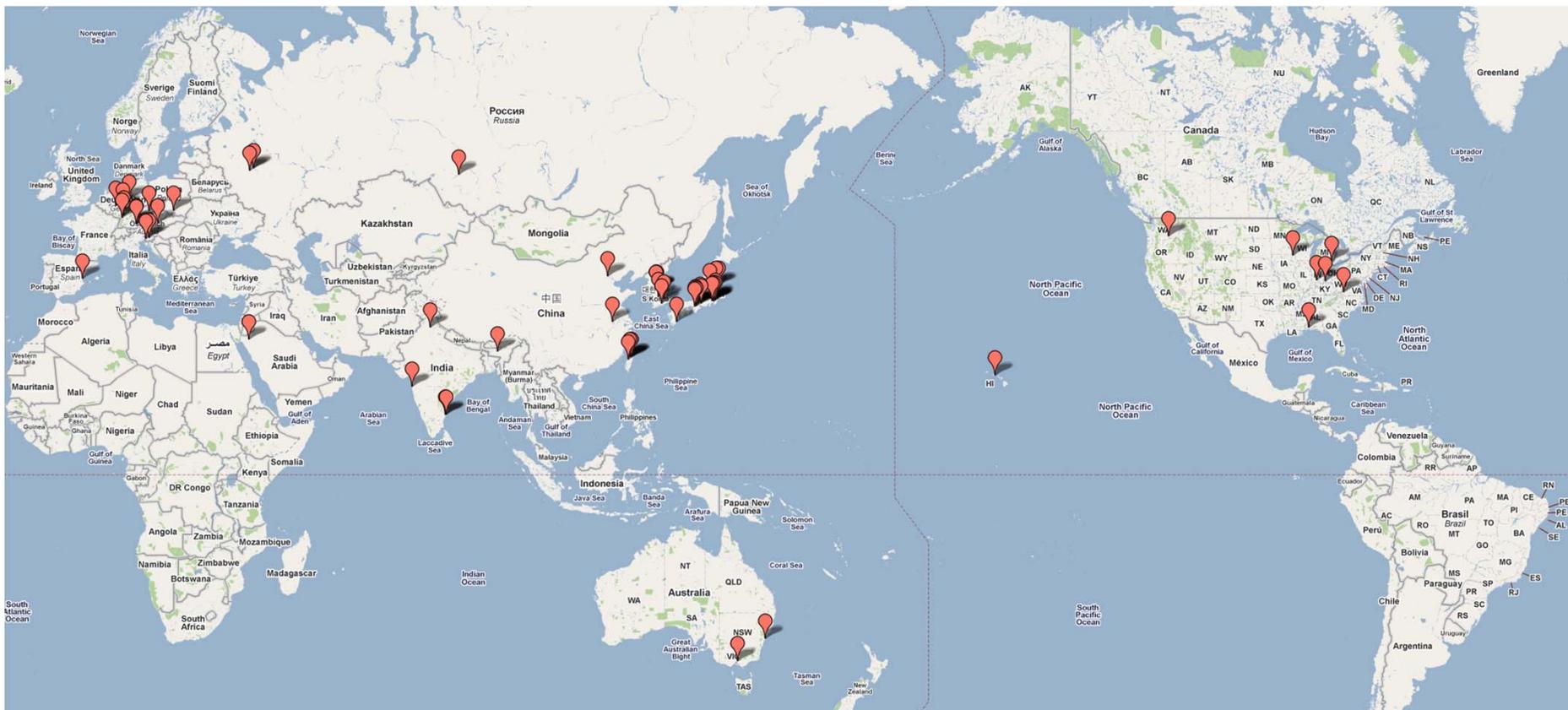


$\frac{1}{4}$ of one layer
produced at ITEP,
tested, sent to KEK

Status of the project



Belle II Collaboration



15 countries, ~60 institutions

~400 collaborators



European groups of Belle-II

- Austria: HEPHY (Vienna)
- Czech republic: Charles University in Prague
- Germany: U. Bonn, U. Giessen, U. Goettingen, U. Heidelberg, KIT Karlsruhe, LMU Munich, MPI Munich, TU Munich
- Poland: INP Krakow
- Russia: ITEP (Moscow), BINP (Novosibirsk), IHEP (Protvino)
- Slovenia: J. Stefan Institute (Ljubljana), U. Ljubljana, U. Maribor and U. Nova Gorica
- Spain: U. Valencia

→A sizeable fraction of the collaboration:
in total ~140 collaborators out of ~400!



SuperKEKB/Belle II funding Status

KEKB upgrade has been approved

- 5.8 oku yen (~MUSD) for Damping Ring (FY2010)
- 100 oku yen for machine -- Very Advanced Research Support Program (FY2010-2012)
- Full approval by the Japanese government by December 2010; the project is in the JFY2011 budget as approved by the Japanese Diet end of March 2011

Several non-Japanese funding agencies have also **already allocated sizable funds** for the upgrade.

→ construction started!



KEKB upgrade plan has been approved

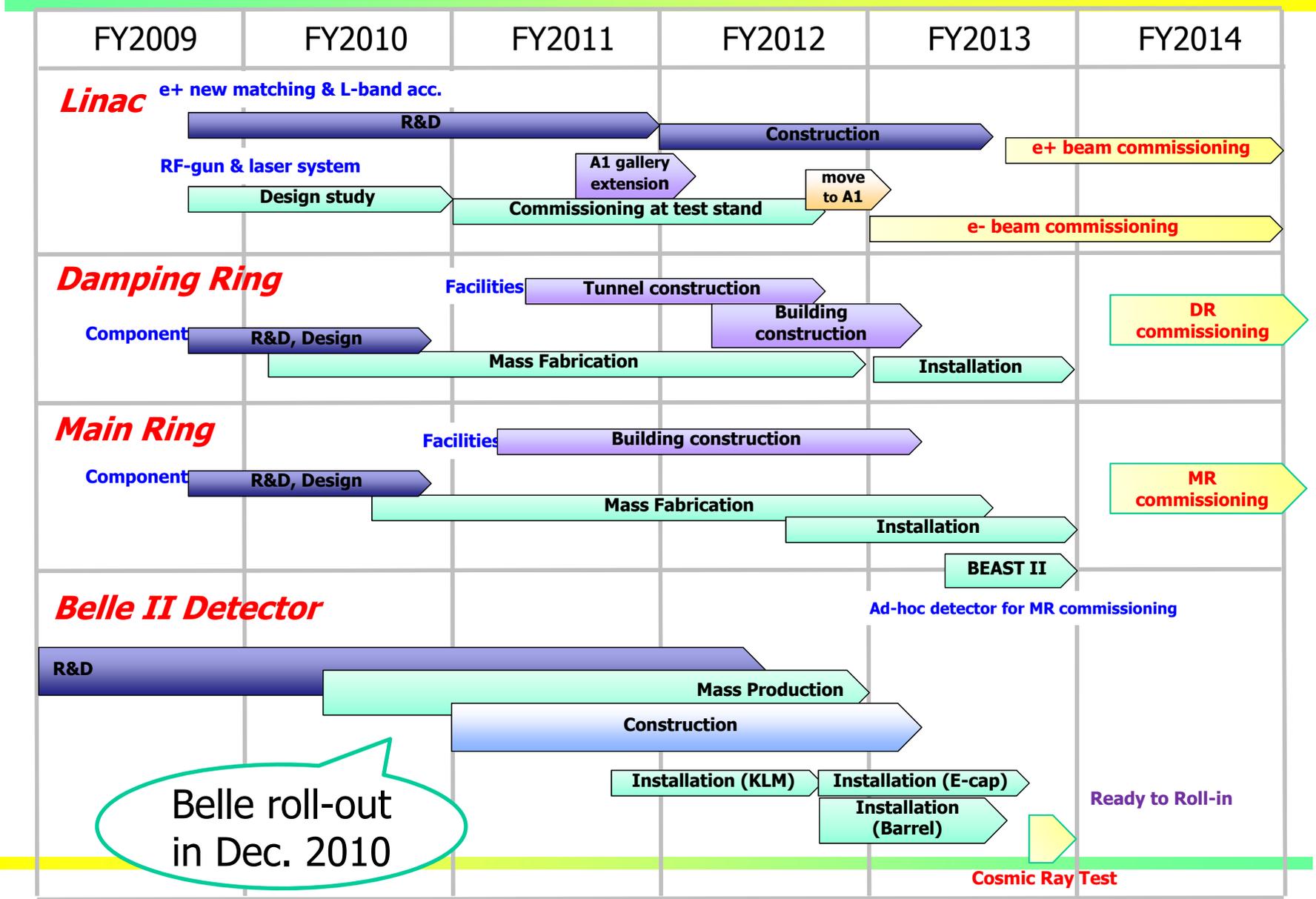
June 23, 2010
High Energy Accelerator Research Organization (KEK)

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 Schedule of SuperKEKB/Belle II



Belle roll-out in Dec. 2010



Early November: taking out the SVD2 – vertex detector

Next step: central drift chamber was taken out and...

Belle was rolled out in December to the parking position – waiting for the assembly to start...

KEKB/Belle status: official statement

„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 KEBB 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.”

KEKB/Belle status

Fortunately enough:

- KEBB stopped operation in July 2010, and the low energy ring was to a large extent disassembled
- Belle was rolled out to the parking position in December.

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

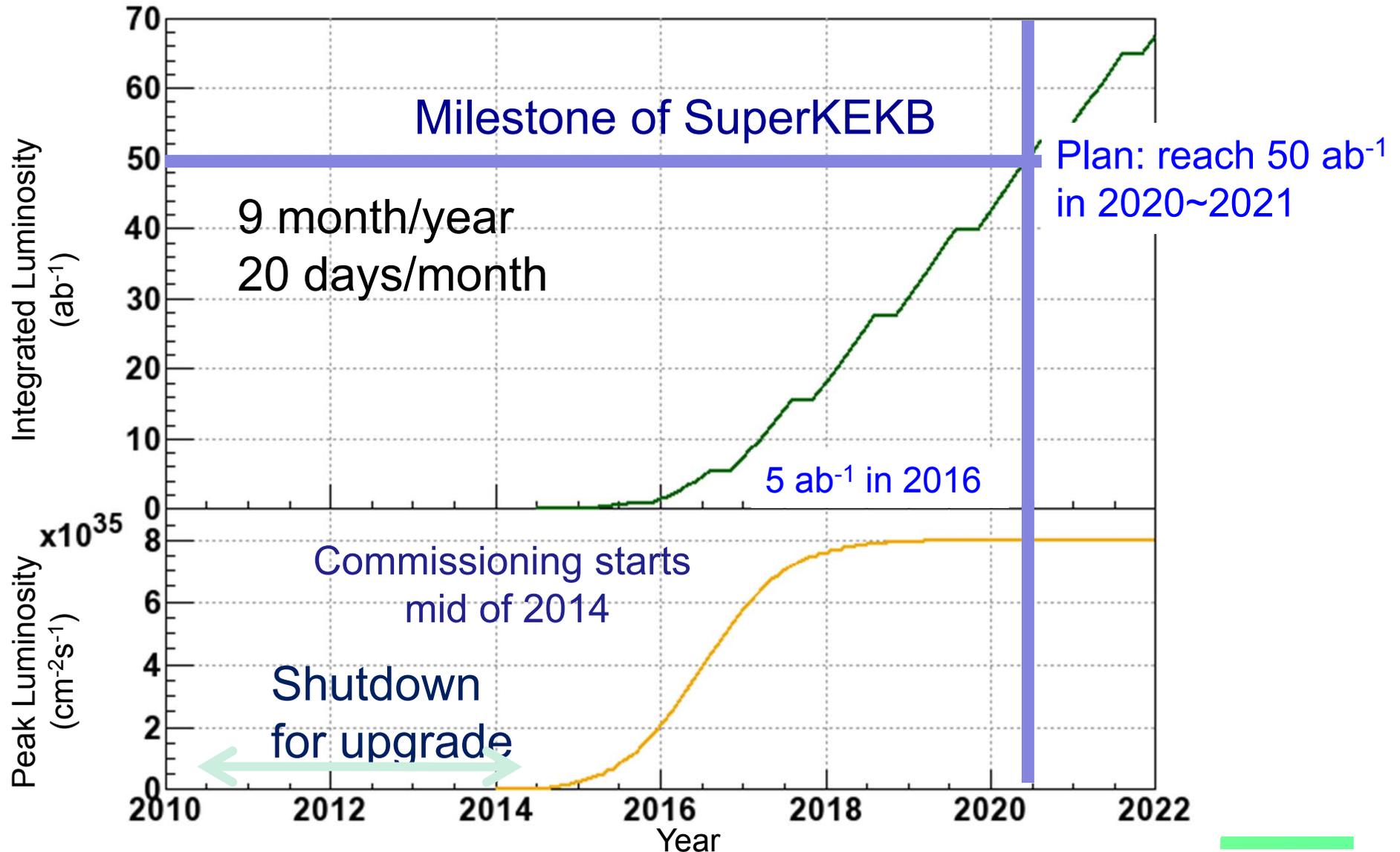


We are checking the functionality of the Belle spectrometer (in particular the CsI calorimeter), so far all OK in LED and cosmic ray tests!

The lab (Tsukuba campus) has to a large extent recovered from the earthquake, back to normal operation – including the power supply for the computing center for Belle data analysis for summer conferences...



Luminosity upgrade projection



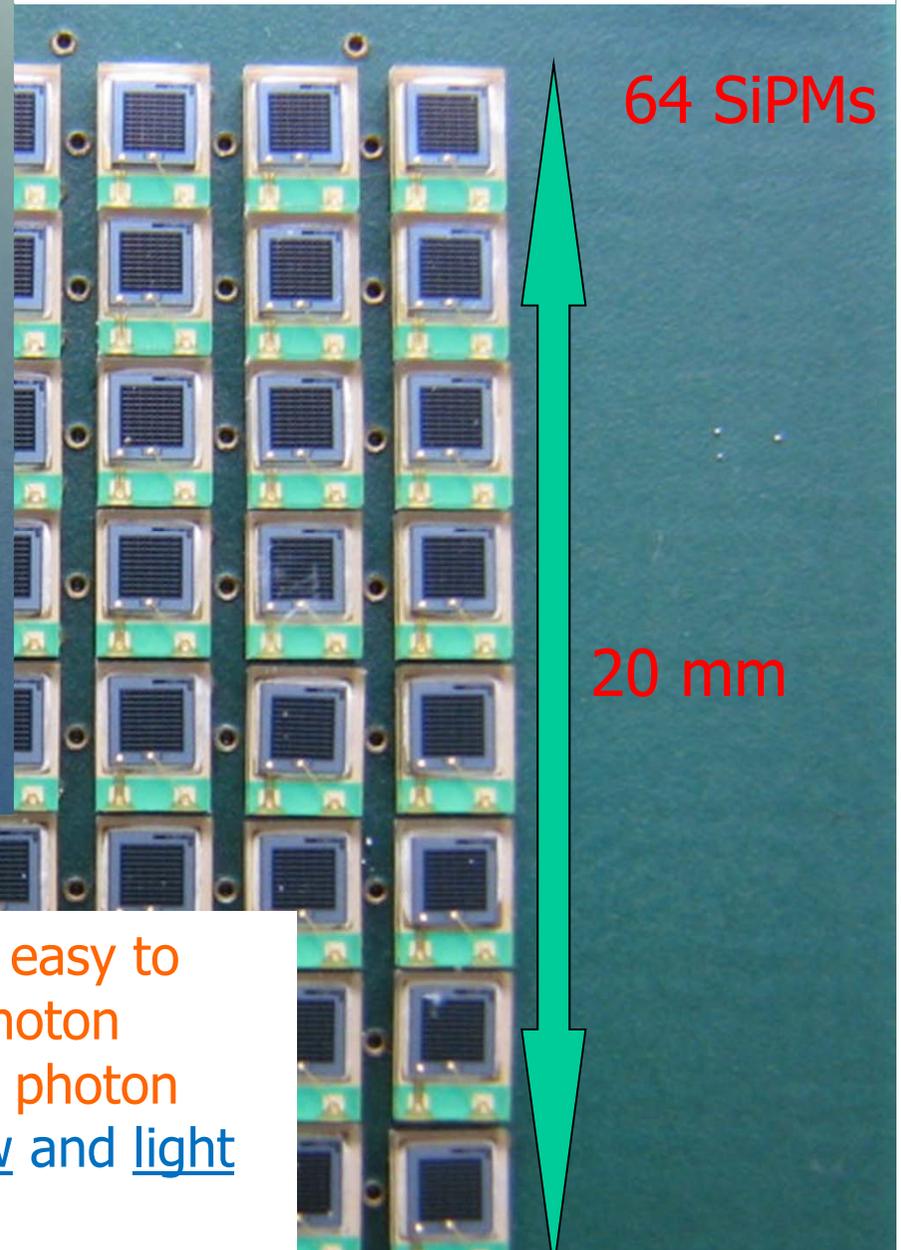
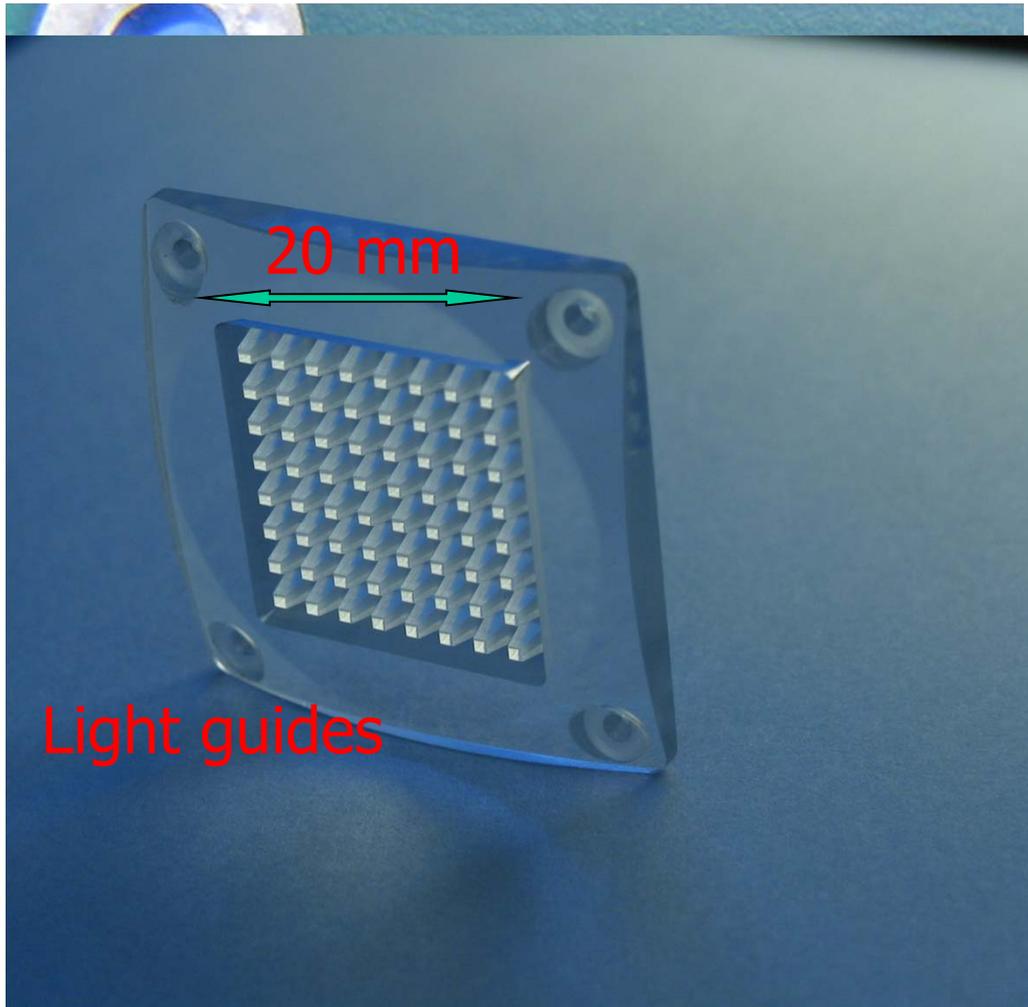
Summary

- B factories have proven to be an excellent tool for flavour physics, with **reliable long term** operation, constant **improvement** of the performance, **achieving and surpassing** design performance
- Major upgrade is under way at KEK in 2010-14 → SuperKEKB+Belle II, **L x40, construction started**
- Physics reach updates available
- Expect a new, exciting era of discoveries, complementary to the LHC
- Expect a good collaboration and competition with SuperB!



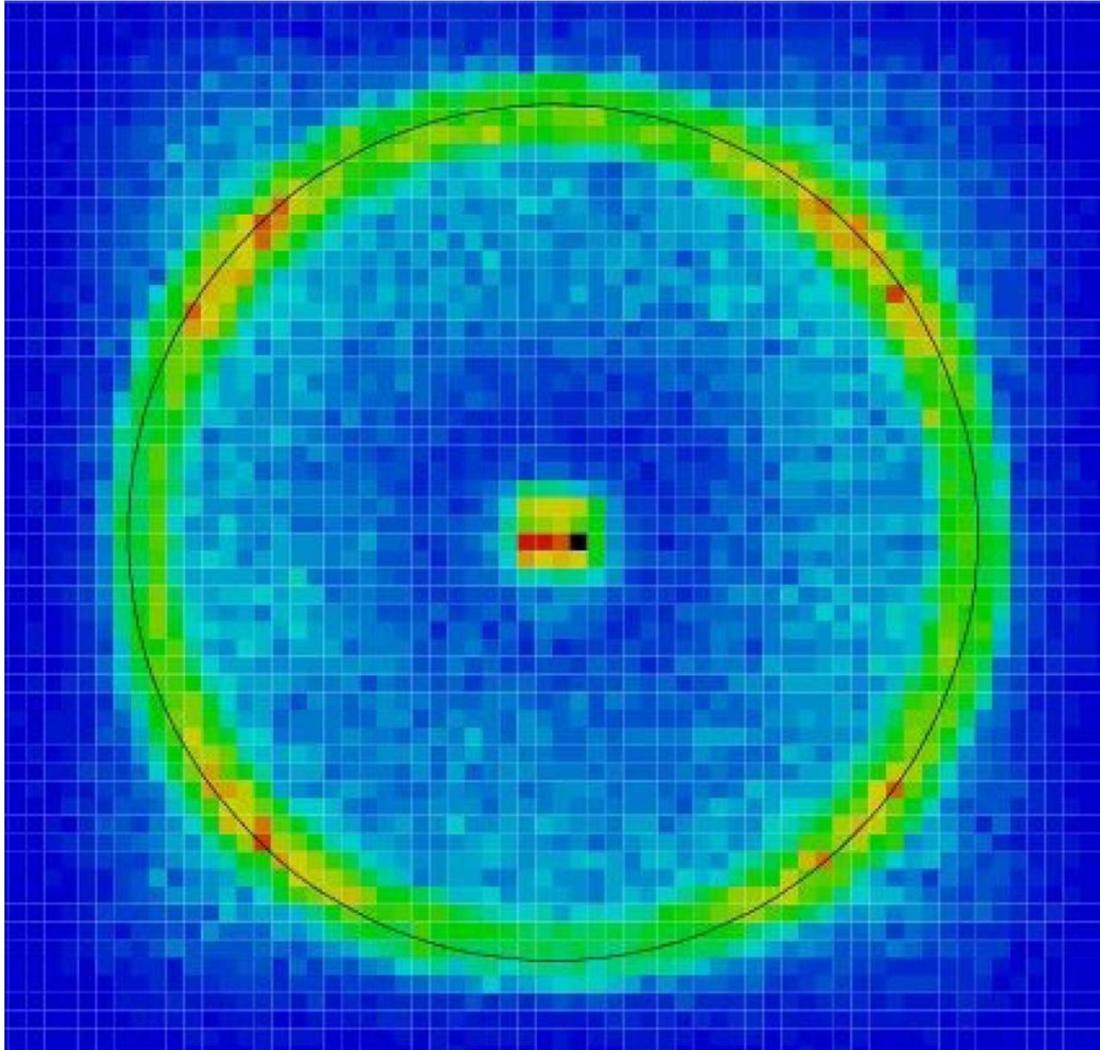
Back-up slides

Another candidate: SiPM



Another sensor candidate: SiPMs (G-PAD), easy to handle, but never before used for single photon detection (high dark count rate with single photon pulse height) → use a narrow time window and light concentrators

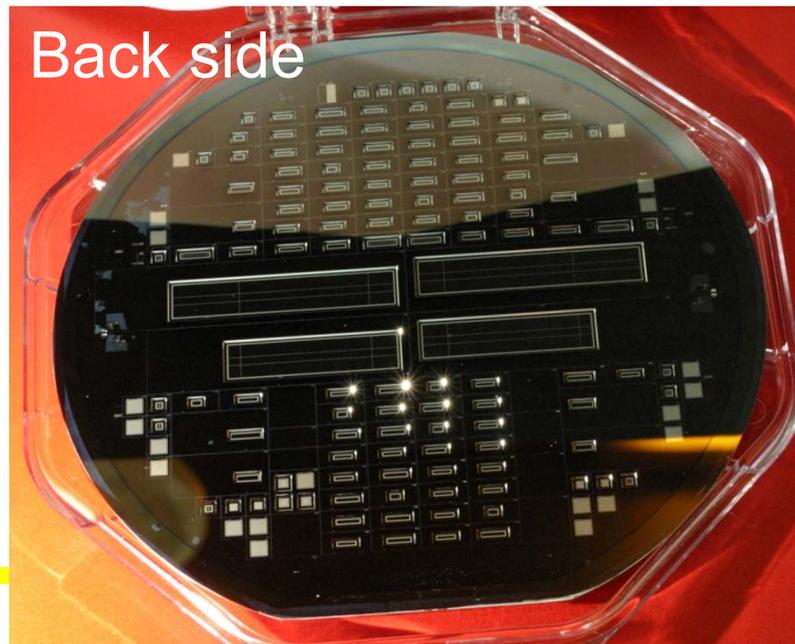
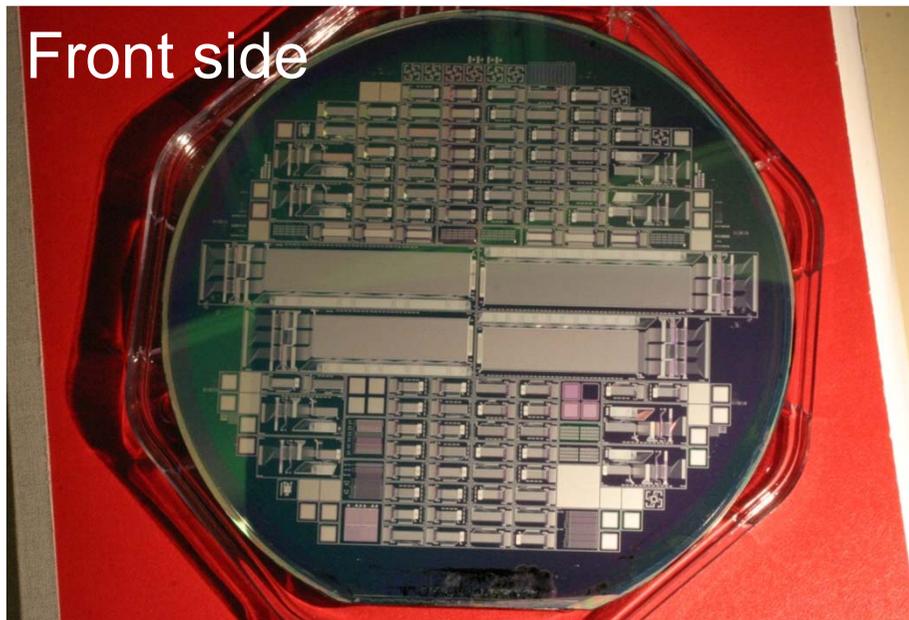
Cherenkov ring with SiPMs



First successful use of SiPMs as single photon detectors in a RICH counter!

NIM A594 (2008) 13

First measurements of thin DEPFETs



PXD6 test production:

150 mm wafers with active pixel sensors

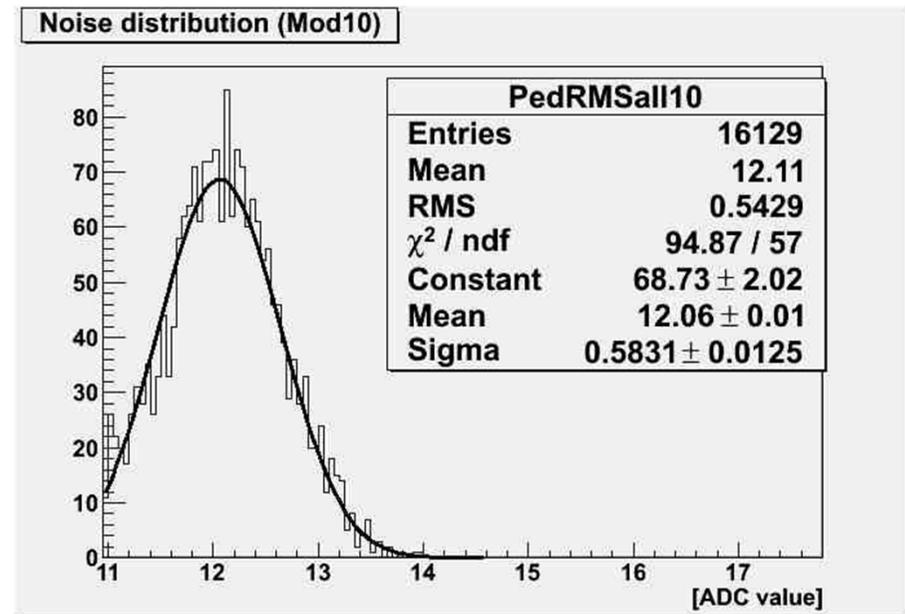
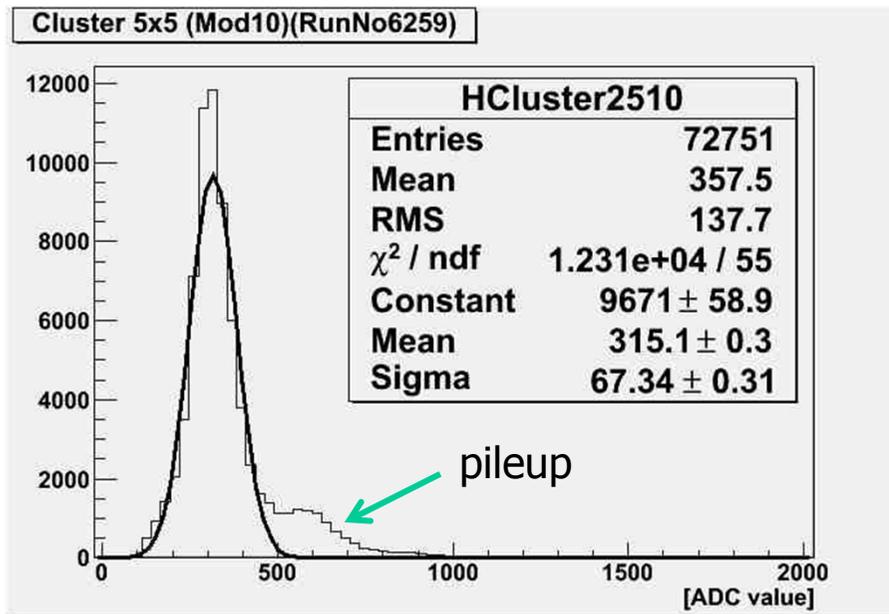
DEPFET:

highly specialized MOS technology, including two polysilicon and two metal layers, combined with a unique thinning technology (down to 50 μm).

fully depleted bulk,
high signal/noise ratio

First measurements of thin DEPFETs

Thick matrix: 32x64 pixels Belle II PXD design, pixel size 50 x 75 x 450 μm^3
(6 μm gate length)
(for reference)



S/N = 26.12 at 22keV (^{109}Cd)

(S/N independent of thickness under γ irradiation!)

readout of ASICs: CURO readout chip

this chip has ~ twice the noise of final DCD chip: S/N will get better

Machine design parameters



	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
ϵ_y/ϵ_x (%)	1	0.85/0.64	0.27/0.24
σ_y (μm)	1.9	0.94	0.048/0.062
ξ_{ζ_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 ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)	1	2.11	80

IR layout

- ◆ 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

