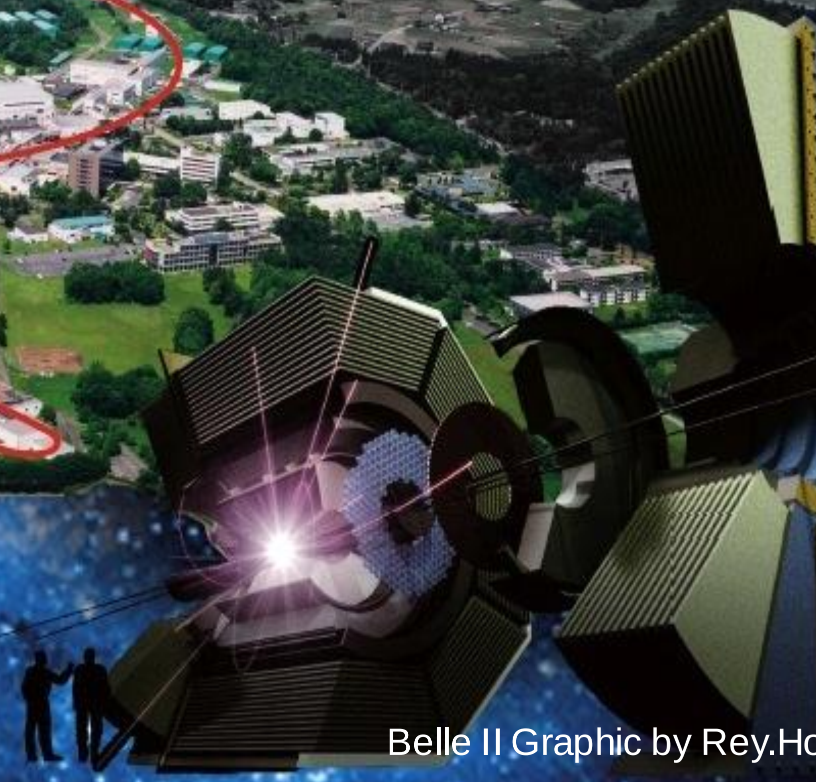
Status and Prospects of Super KEKB and Belle II

Zdenek Dolezal
Charles University in Prague
for Belle II

KEK
High Energy Accelerator Reseach Organization



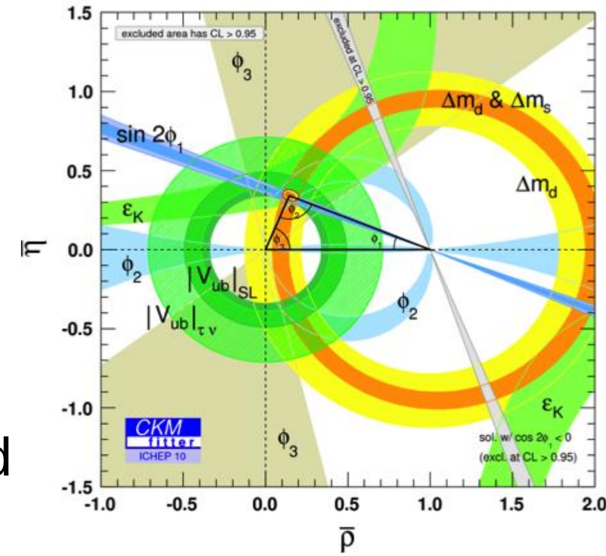
Belle II Graphic by Rey.Ho

Contents

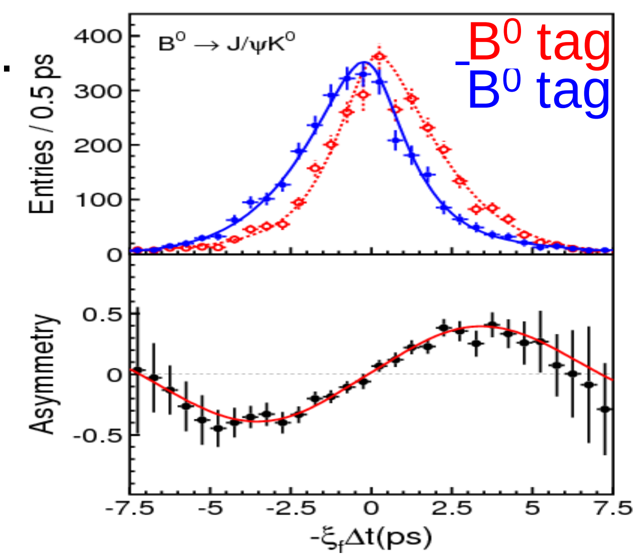
- Physics case for a Super B factory
- SuperKEKB/Belle-II@KEK
- Accellerator
- Detector
- Status and prospects of the project

B-factories: a success story

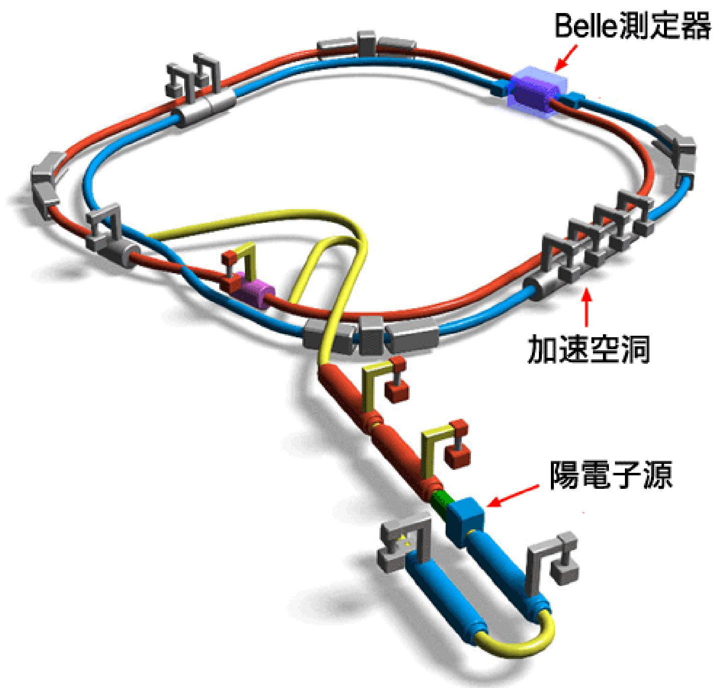
- Measurements of CKM matrix elements and angles of the unitarity triangle
- Observation of direct CP violation in B decays
- Measurements of rare decays (e.g., B→τν, Dτν)
- b→s transitions: probe for new sources of CPV and constraints from the b→sγ branching fraction

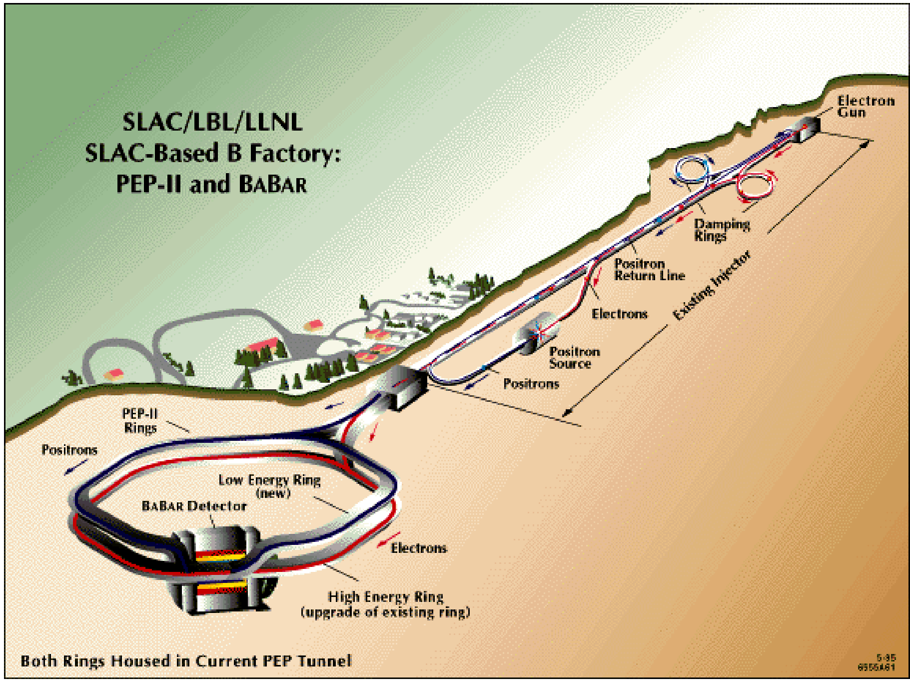


- Forward-backward asymmetry (A_{FB}) in b→sll has become a powerfull tool to search for physics beyond SM.
- Observation of D mixing
- Searches for rare τ decays
- Observation of new hadrons



Asymmetric B factories





$\sqrt{s}=10.58$ GeV

$e^+ \rightarrow \Upsilon(4s) \leftarrow e^-$

$\Upsilon(4s) \rightarrow B\,\bar{B}$

$\Delta z \sim c\beta\gamma\tau_B \sim 200\mu m$

BaBar	$p(e^-)=9$ GeV	$p(e^+)=3.1$ GeV	$\beta\gamma=0.56$
Belle	$p(e^-)=8$ GeV	$p(e^+)=3.5$ GeV	$\beta\gamma=0.42$
Belle II	$p(e^-)=7$ GeV	$p(e^+)=4$ GeV	$\beta\gamma=0.28$
SuperB	$p(e^-)=6.7$ GeV	$p(e^+)=4.2$ GeV	$\beta\gamma=0.23$

“Super” B Factory strategy

B factories → is SM with CKM right?

Super B factories → How is the SM wrong?

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

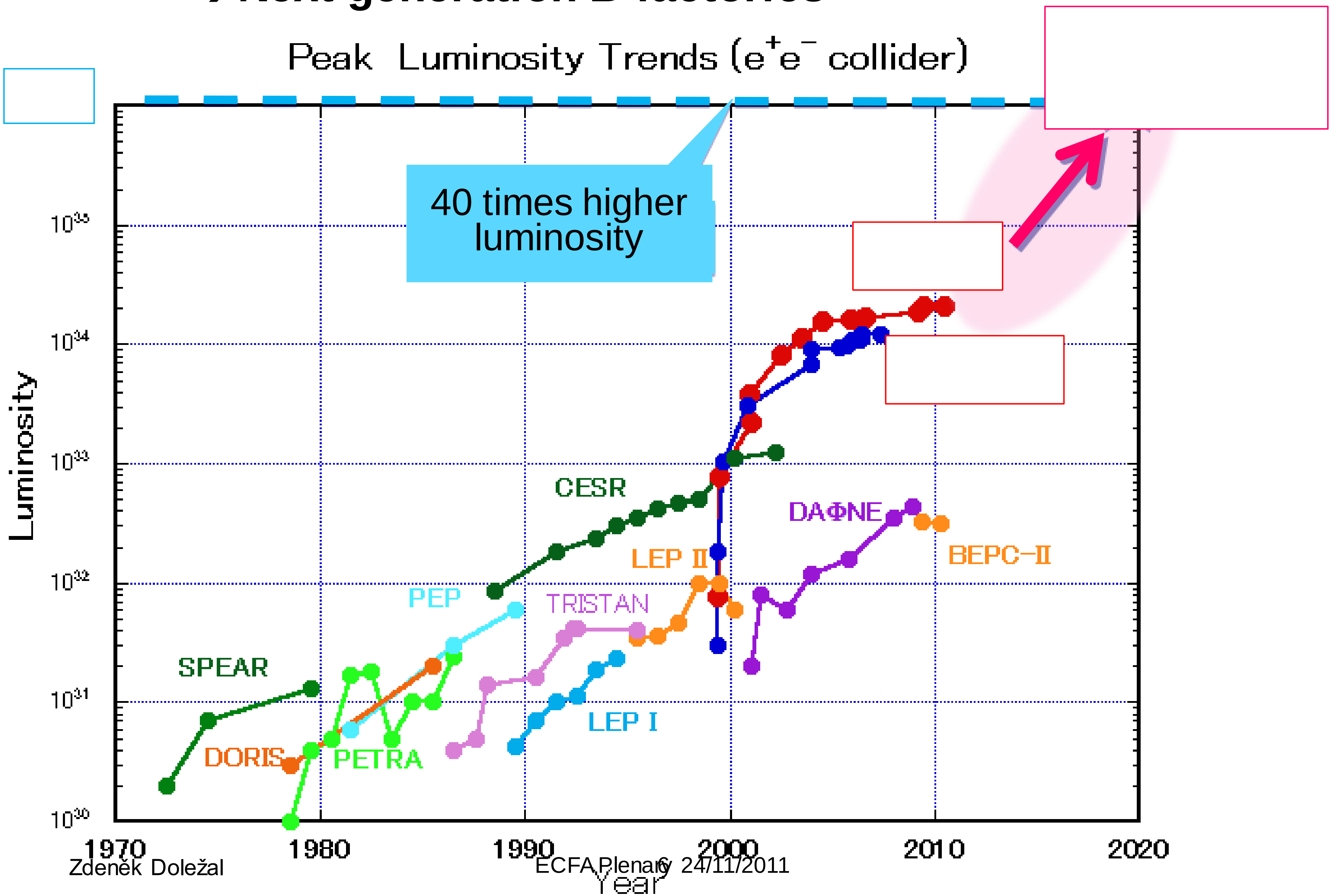
However: it will be a different world in four years, *there will be new knowledge from* LHCb, BESIII, ...

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

hep-ex

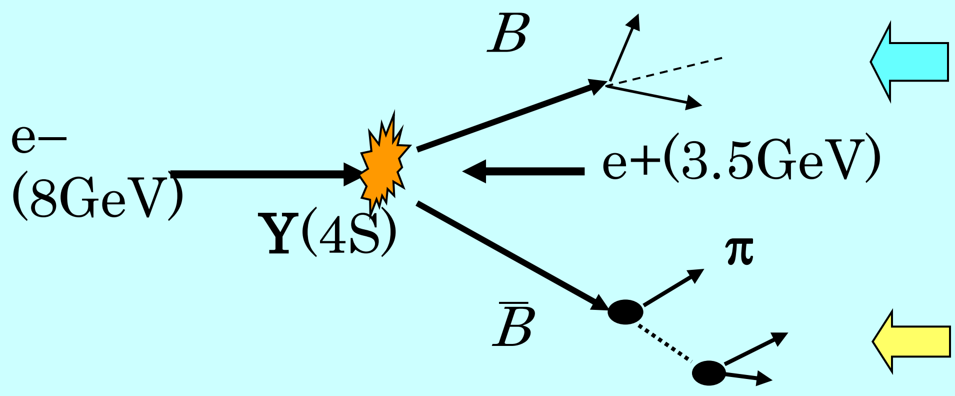
hep-ex

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



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



Decays of interest
B→X_u l ν,
B→K ν ν
B→Dτν, τν

full reconstruction
B→Dπ etc. (*neural net reconstruction*)

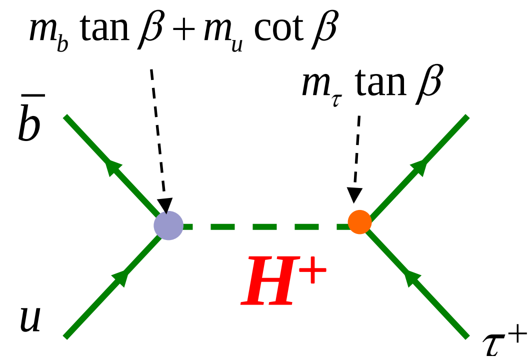
→ Offline B meson beam!

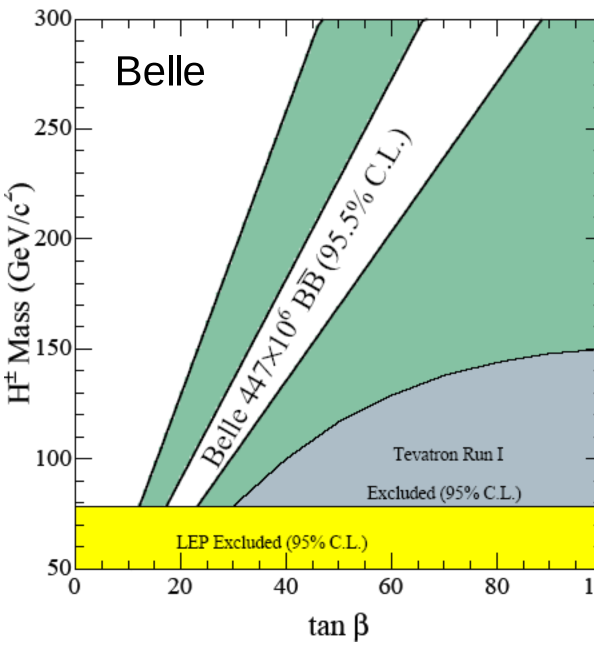
Powerful tool for B decays with neutrinos

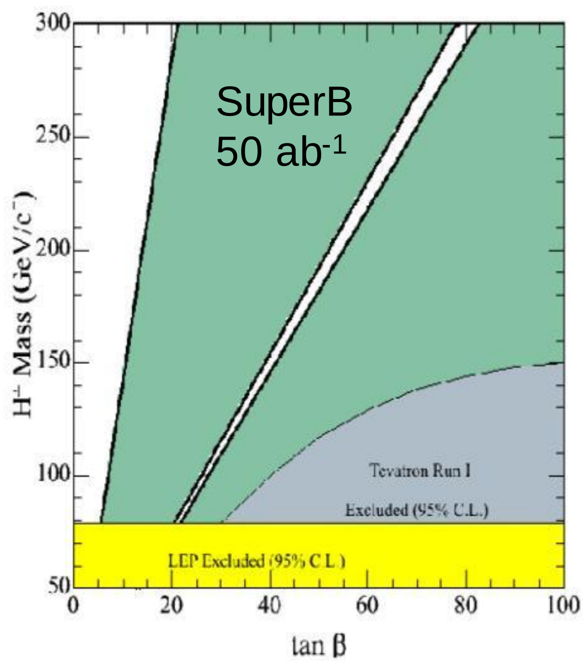
Charged Higgs limits from $B^- \rightarrow \tau^- \nu_\tau$

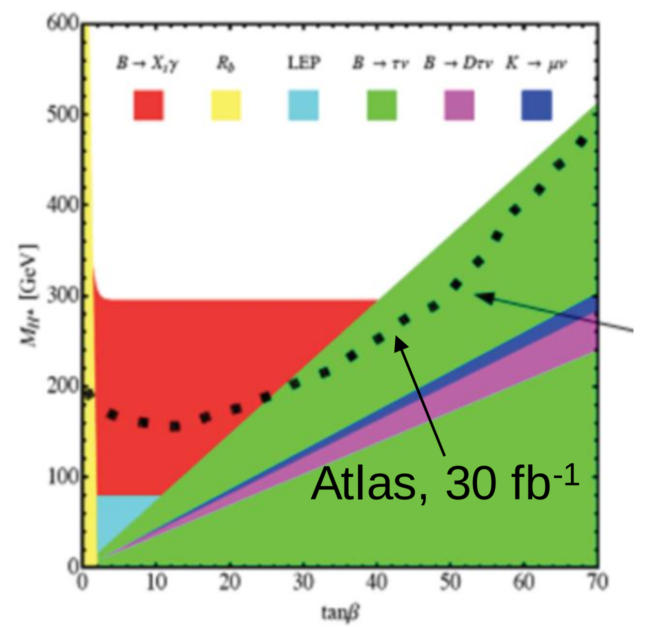
$$r_H = \frac{BF(B \to \tau\nu)}{BF(B \to \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

→ limit on charged Higgs mass vs. tanβ



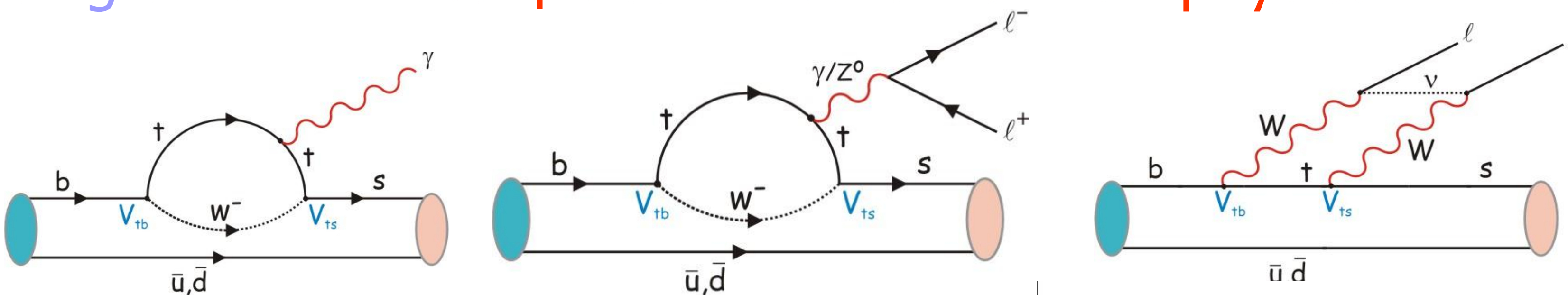






Why FCNC decays?

Flavour changing neutral current (FCNC) processes (like b→s, b→d) are forbidden at the tree level in the Standard Model. Proceed only at low rate via higher-order loop diagrams. Ideal place to search for new physics.

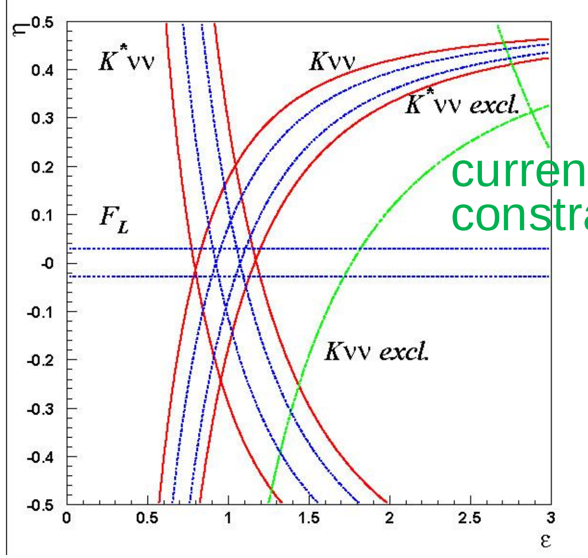


- $b \to s\gamma$, sll, $s\nu\nu$

example of constraints on right-handed currents with $B \to K^{(*)}\nu\nu$ with 50 ab^{-1}

$$\epsilon = \frac{\sqrt{|C_L^\nu|^2 + |C_R^\nu|^2}}{|(C_L^\nu)^{SM}|}$$

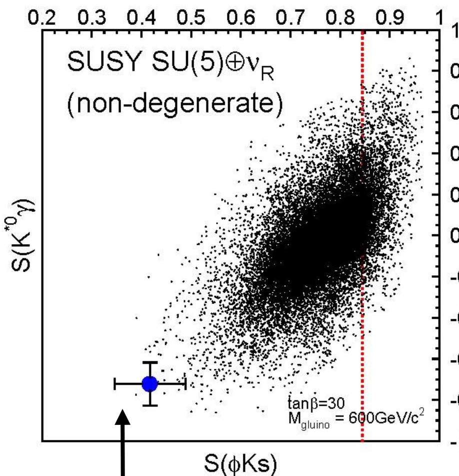
$$\eta = \frac{-\Re(C_L^\nu C_R^{\nu *})}{|C_L^\nu|^2 + |C_R^\nu|^2} .$$

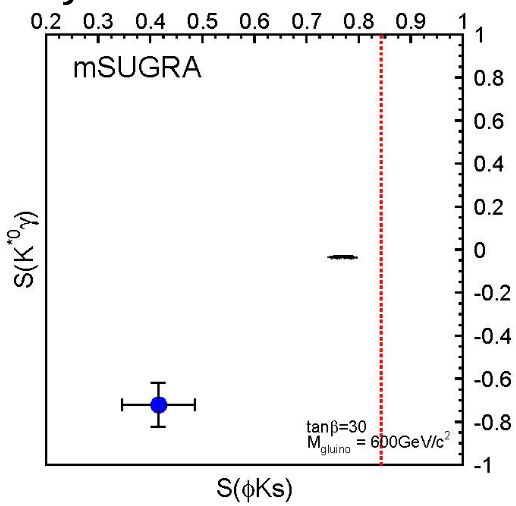


Why FCNC decays?

Correlations among various heavy flavor observables will be exploited to identify the nature of NP.

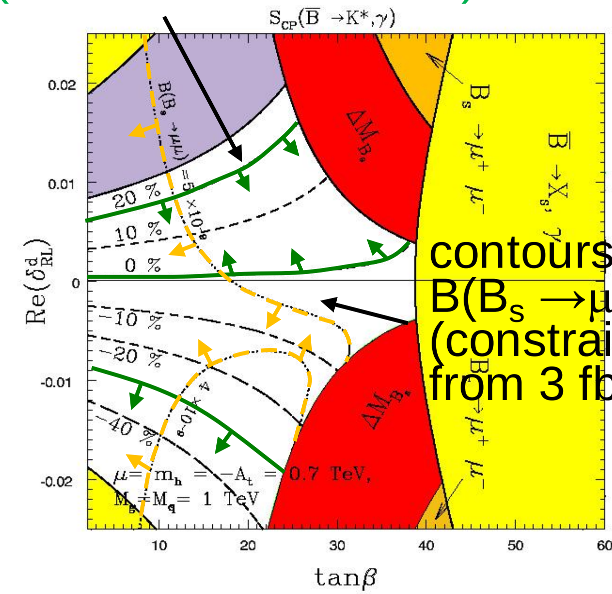
example of possible discrimination between grand unification theory with ν_R and minimal supergravity model





expected accuracy at Belle II with 5 ab^{-1}

contours of $S(K_S\pi^0\gamma)$ (constraint from 5 ab^{-1})



contours of $B(B_s\to\mu^+\mu^-)$ (constraint from 3 fb^{-1})

example of determination of mass insertions for squarks from the measurements of $S(K_s\pi^0\gamma)$ at Belle II and $B_s\to\mu^+\mu^-$ at LHCb.

Interpretations of possible NP contributions profits from complementarity of measurements at Belle II and LHCb.

Physics at a Super B Factory

- There is a good chance to see new phenomena;
  - **CPV in B or D decays from the new physics (non KM).**
  - **Lepton flavor violations in τ decays.**
- They will help to diagnose (if found) or constraint (if not found) new physics models.
- Even in the worst case scenario (MFV), Belle II measurements can search for effects of NP in the mass scale $\mathcal{O}$(1 TeV).
- **Physics motivation is independent of LHC.**
  - If LHC finds NP, precision flavor physics is compulsory to exploit its nature.
  - If LHC finds no NP, high statistics B/D/τ decays would be a unique way to search for the $\mathcal{O}$(1 TeV) (MFV) - $\mathcal{O}$(100 TeV) (enhanced flavor violating couplings) scale physics.

Full physics case of Belle II documented in arXiv:1002.5012

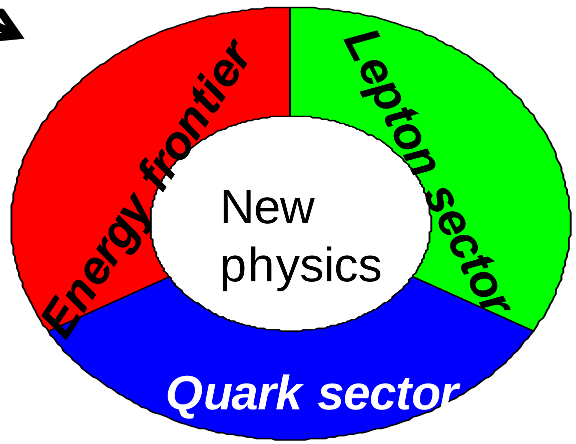
Super B factory: an important part of a broad unbiased approach to New Physics

ν experiments,
g_μ-2, $\mu \rightarrow e\gamma$, etc.

LHC, ILC

Mass spectrum, interactions

ν mass and mixing, CPV, and LFV

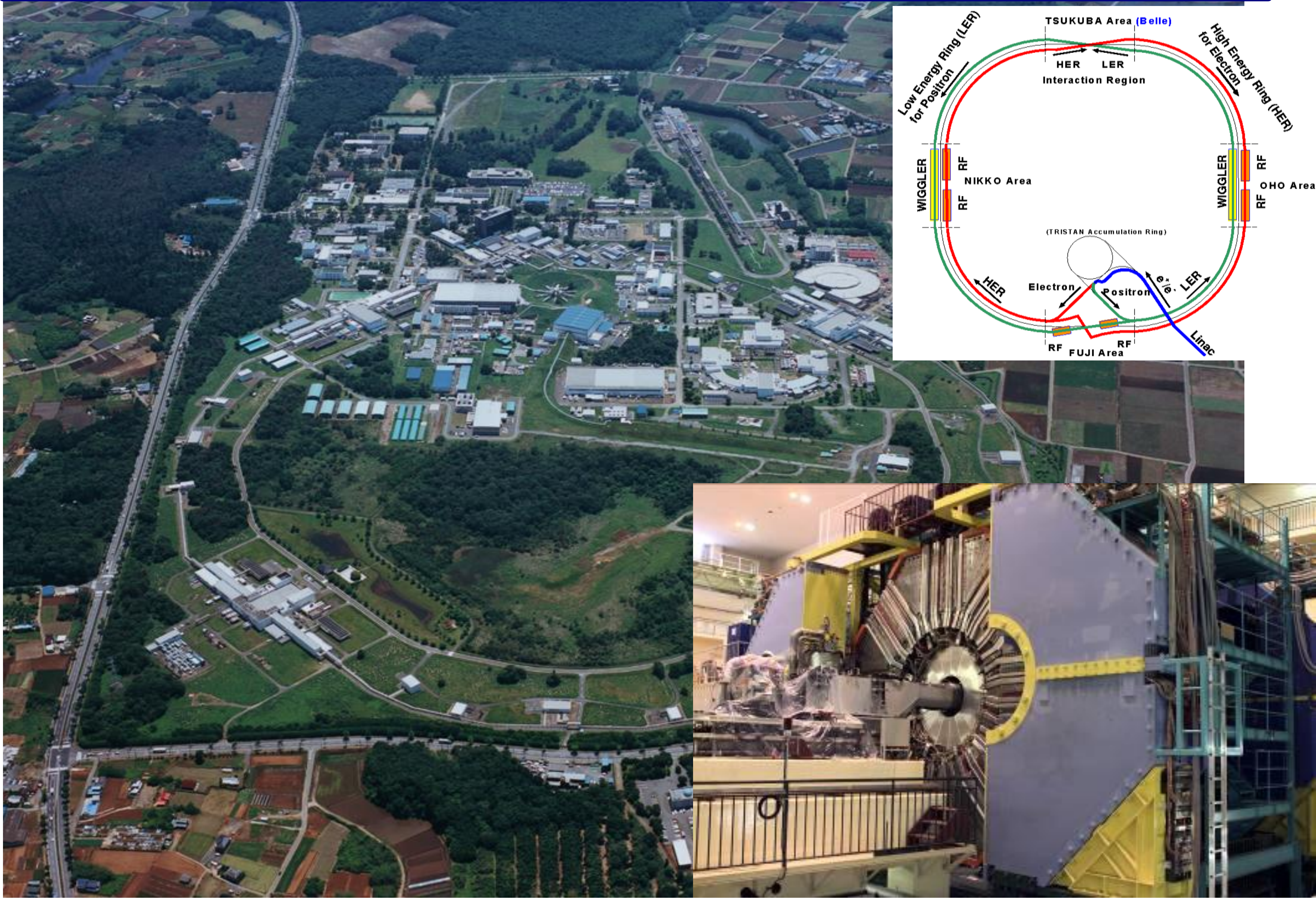


τ LFV,
τ CPV

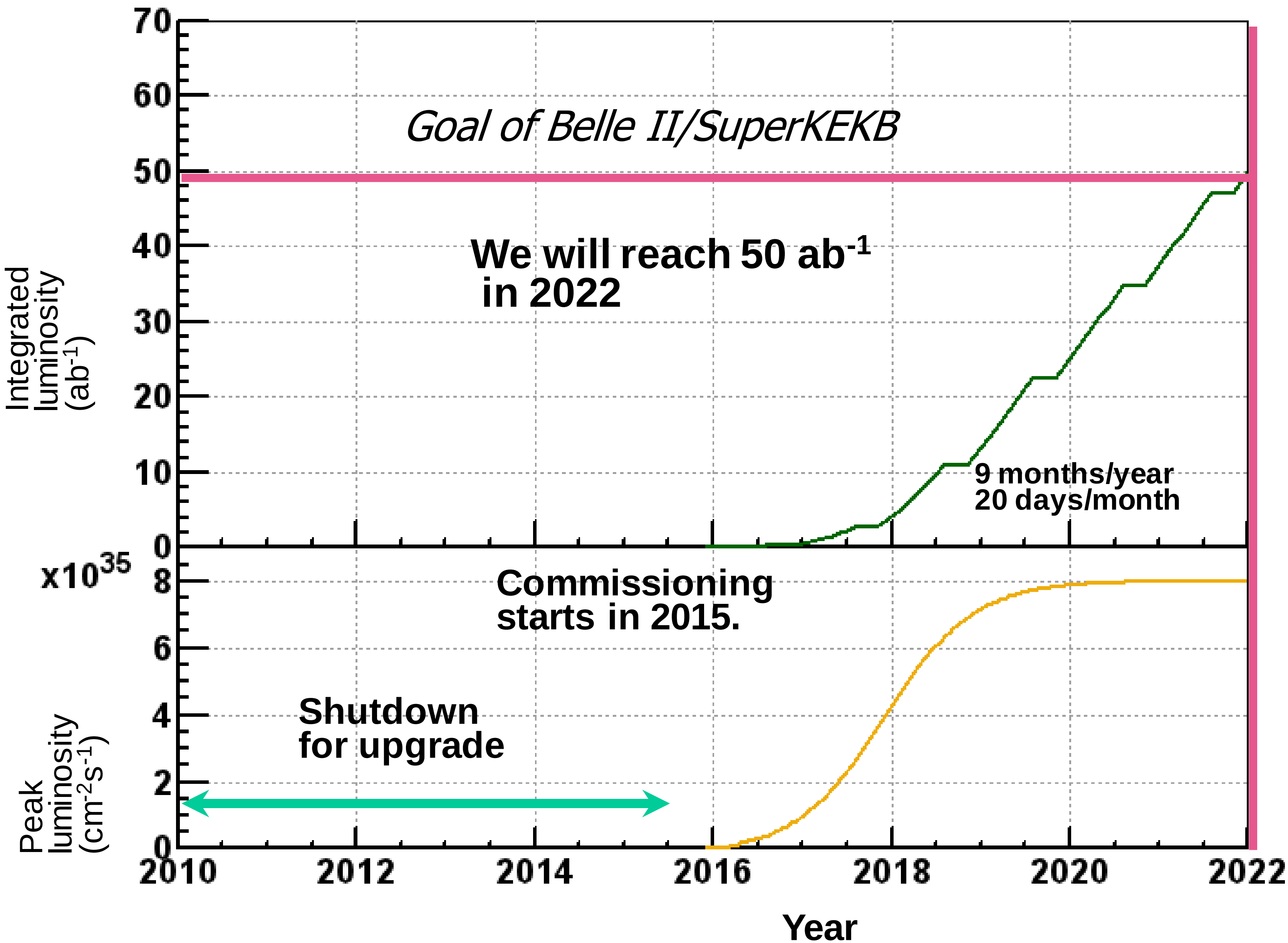
Flavor mixing,
CP phases

Super B factory,
LHCb, *K* experiments…

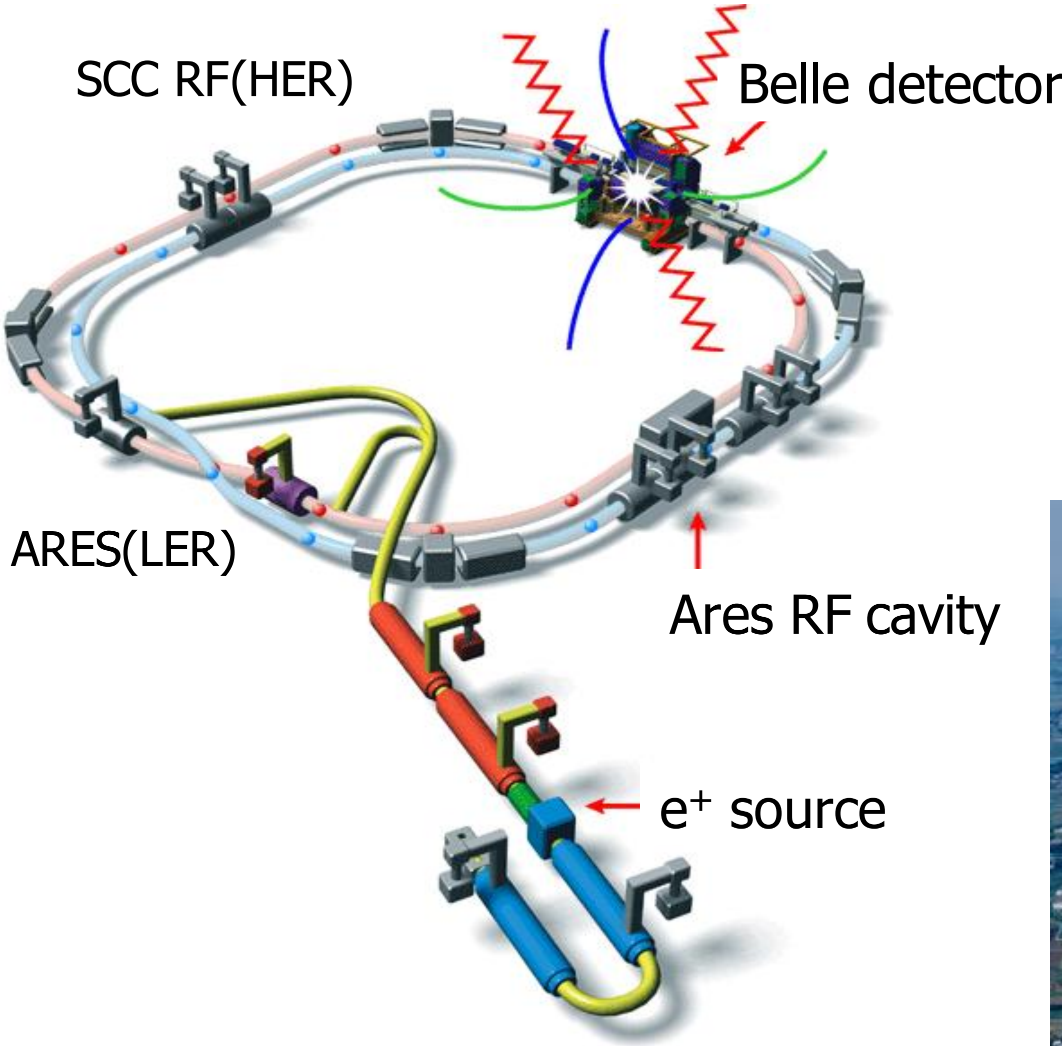
How to do it? Upgrade KEKB & Belle



Schedule (Beam starts in Fall 2014)



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 1999-2010
- Integrated lumi 1015/fb

Peak luminosity (WR!) :

2. 1 x 10^{34} $cm^{-2}s^{-1}$

Super KEKB in nano-beam scheme

- To increase luminosity:

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

→ decrease beam emittance (keep current ξ_y)

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

I: beam current

β*: trajectories envelope at IP

$\xi_y \propto \sqrt{(\beta_y^*/\varepsilon_y)}$ beam-beam parameter

ε: beam emittance

σ*: beam size

$R_L, R_{\xi y}$: geometrical reduction factors (crossing angle, hourglass effect)

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

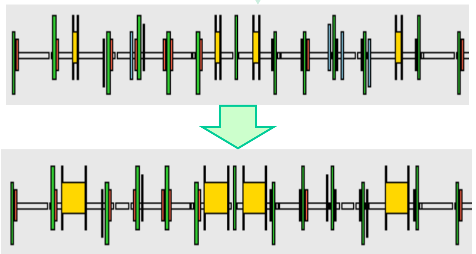
σ_x~100μm, σ_y~2μm ➡ **σ_x~10μm, σ_y~60nm**

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

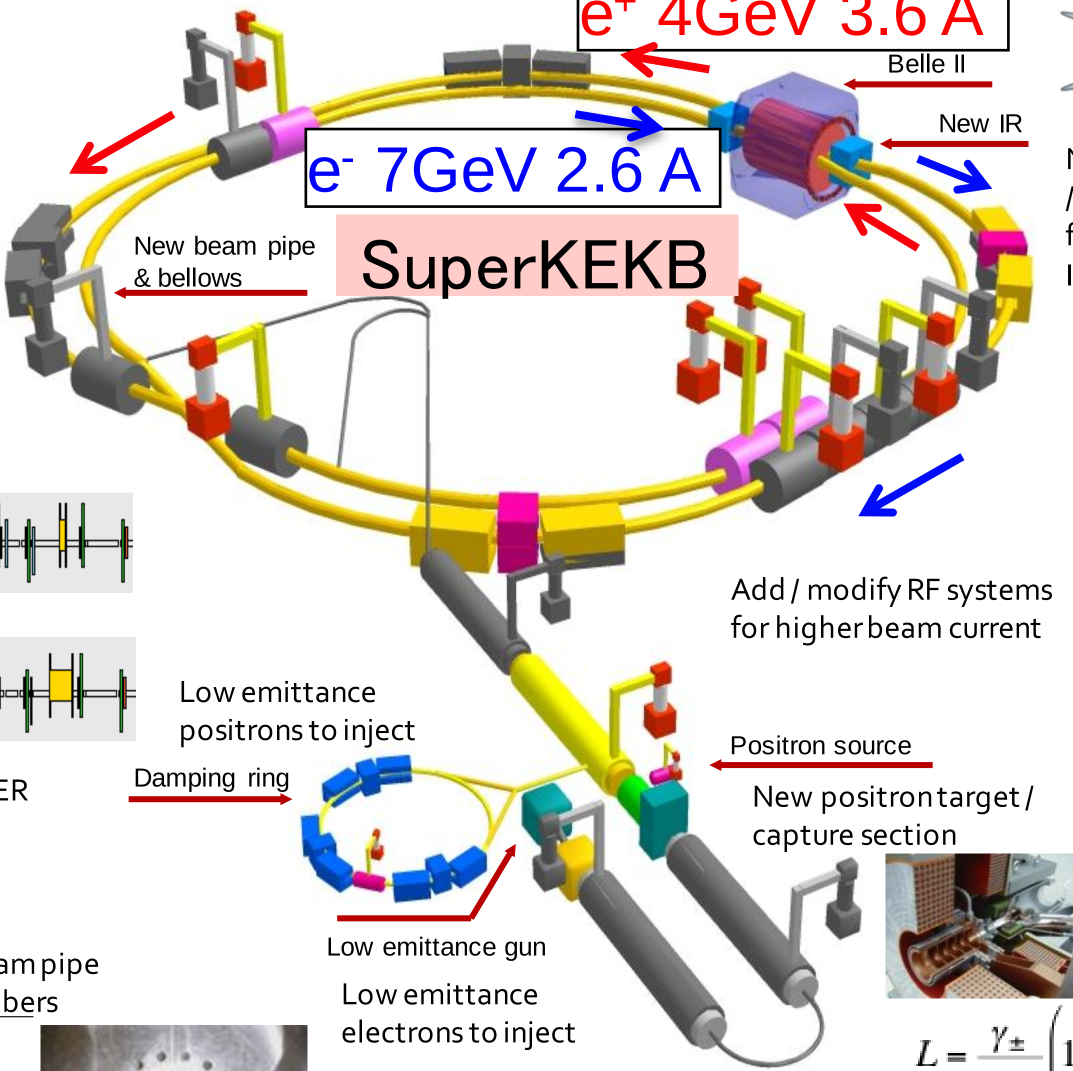
	E (GeV) LER/HER	β*y (mm) LER/HER	β*x (cm) LER/HER	εx (nm) LER/HER	φ (mrad)	I (A) LER/HER	L ($cm^{-2}s^{-1}$)
KEKB	3.5/8.0	5.9/5.9	120/120	18/24	11	1.6/1.2	2.1 x 10^{34}
SuperKEKB	4.0/7.0	0.27/0.41	3.2/2.5	3.2/1.7	41.5	3.6/2.6	80x10^{34}

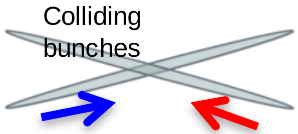
Super KEKB collider

Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance





New superconducting /permanent final focusing quads near the IP

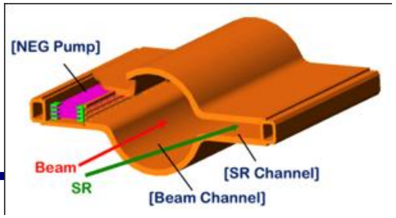
Add / modify RF systems for higher beam current

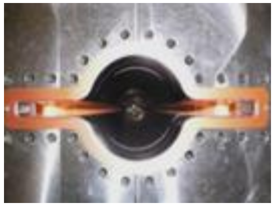
Low emittance positrons to inject

New positron target / capture section

Low emittance electrons to inject

TiN-coated beam pipe with antechambers





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

Target: L = 8×10^{35}/cm^2/s

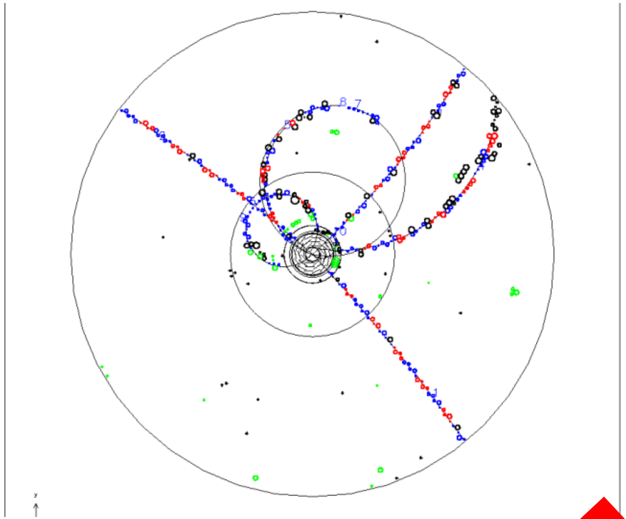
Requirements for the Belle II detector

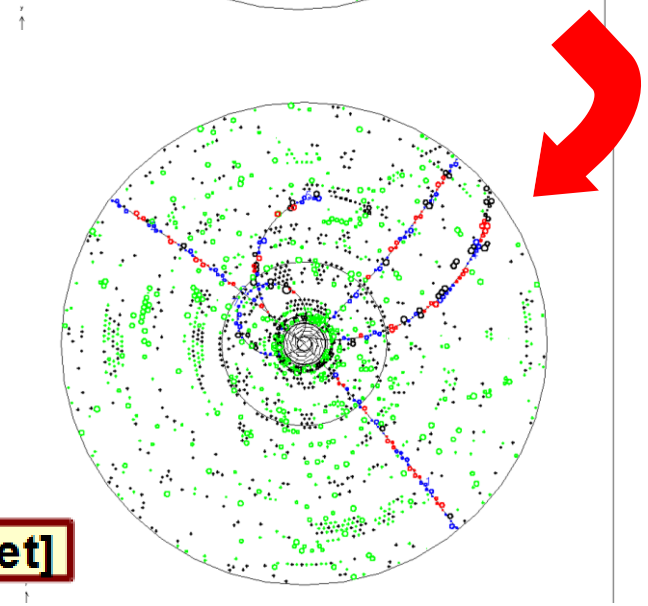
Critical issues at L= 8 x 10^{35}/cm^2/sec

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

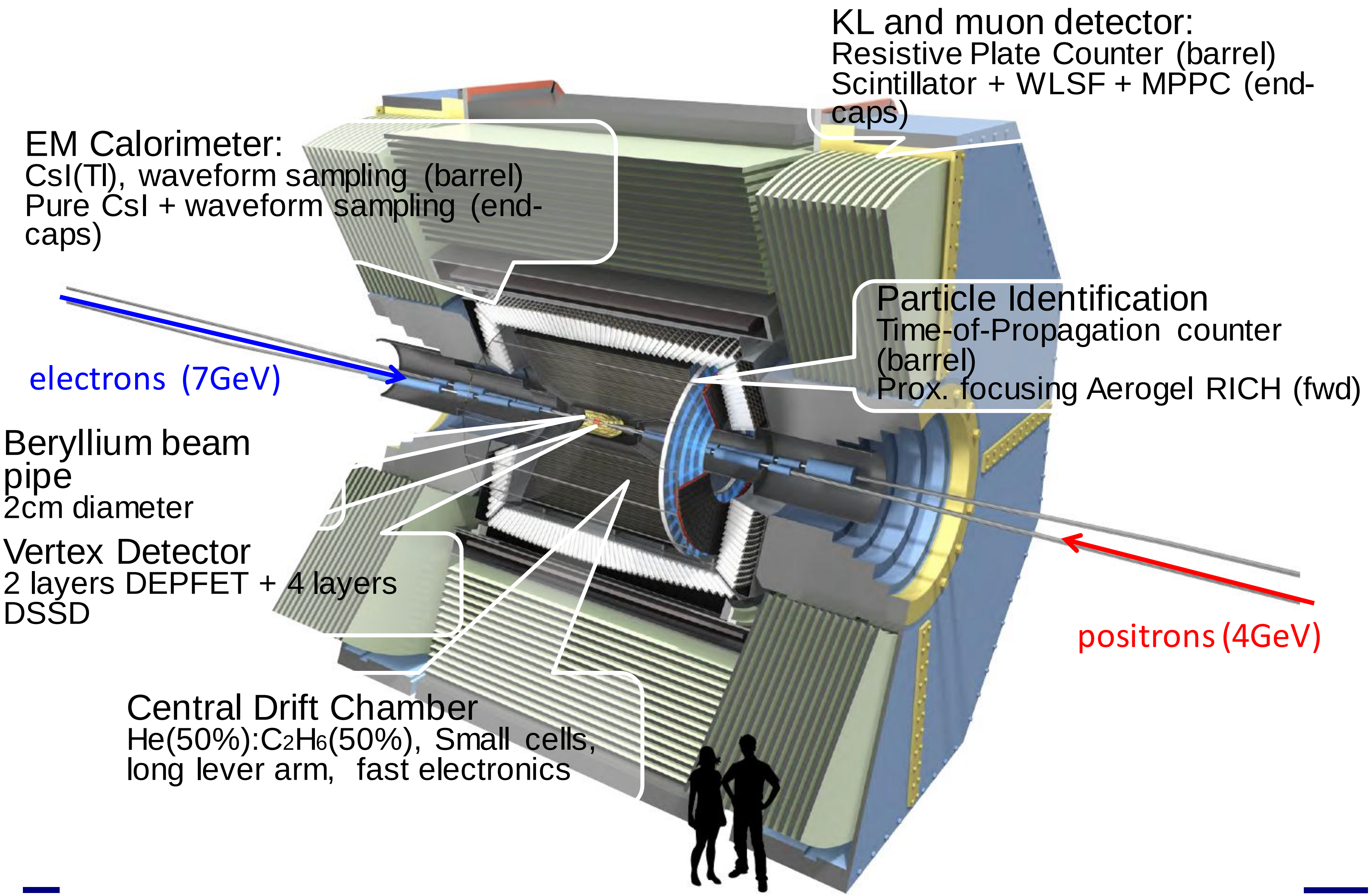
Result: significant upgrade

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



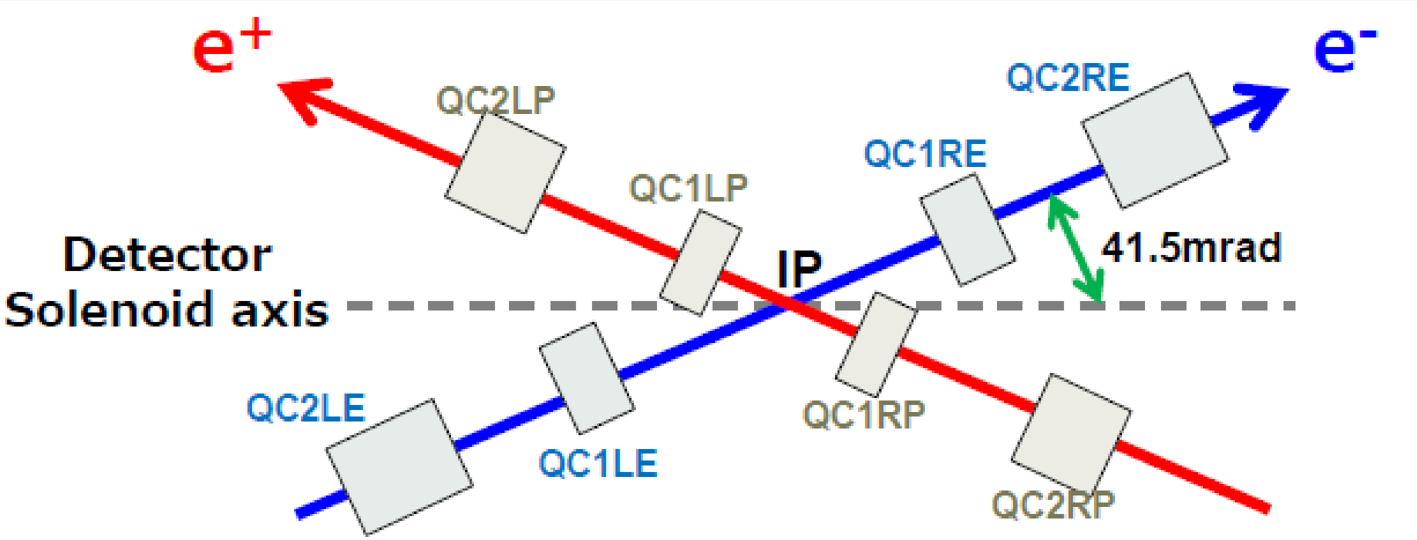


Belle to Belle II Upgrade



Interaction Region Design

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

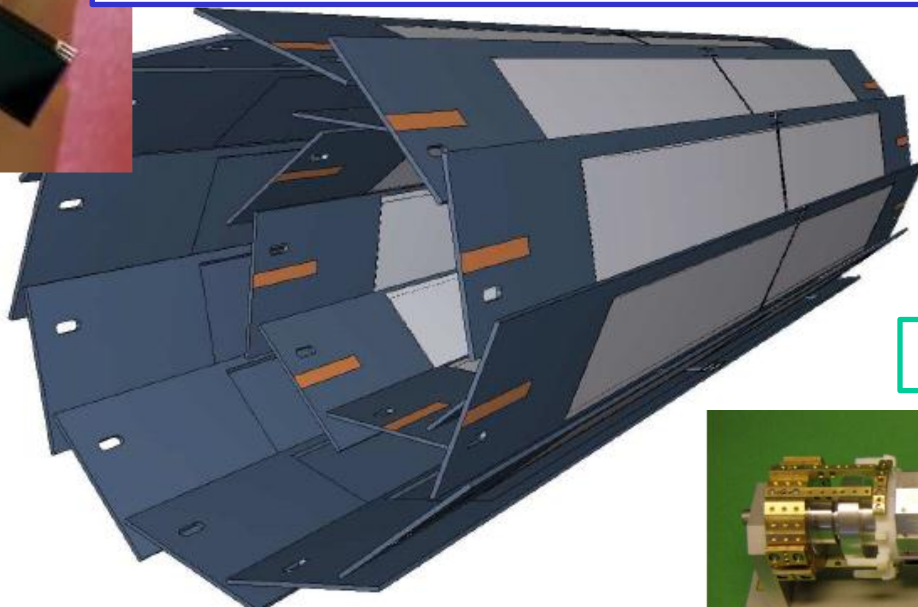


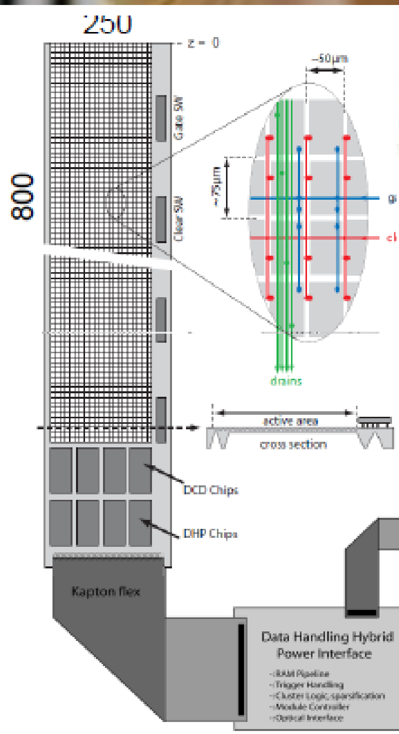
N.Ohuchi

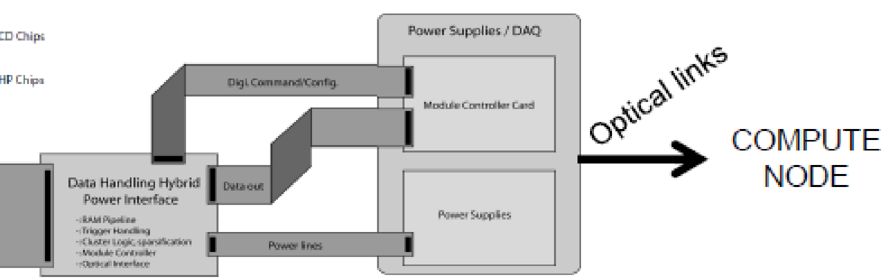
Pixel vertex detector: DEPFET

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

total of 8 M pixels





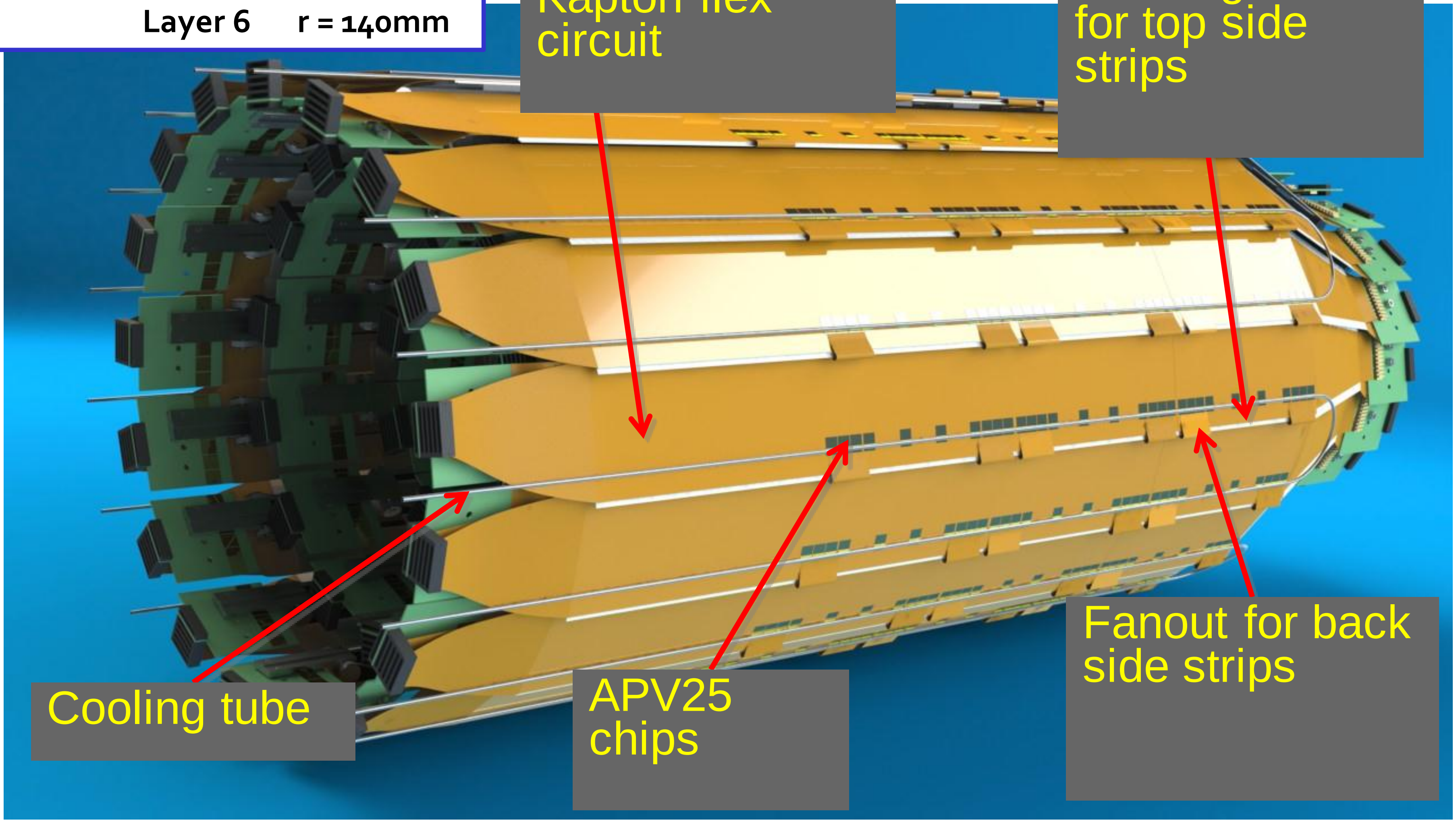


Mechanical mockup

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

Silicon Vertex Detector

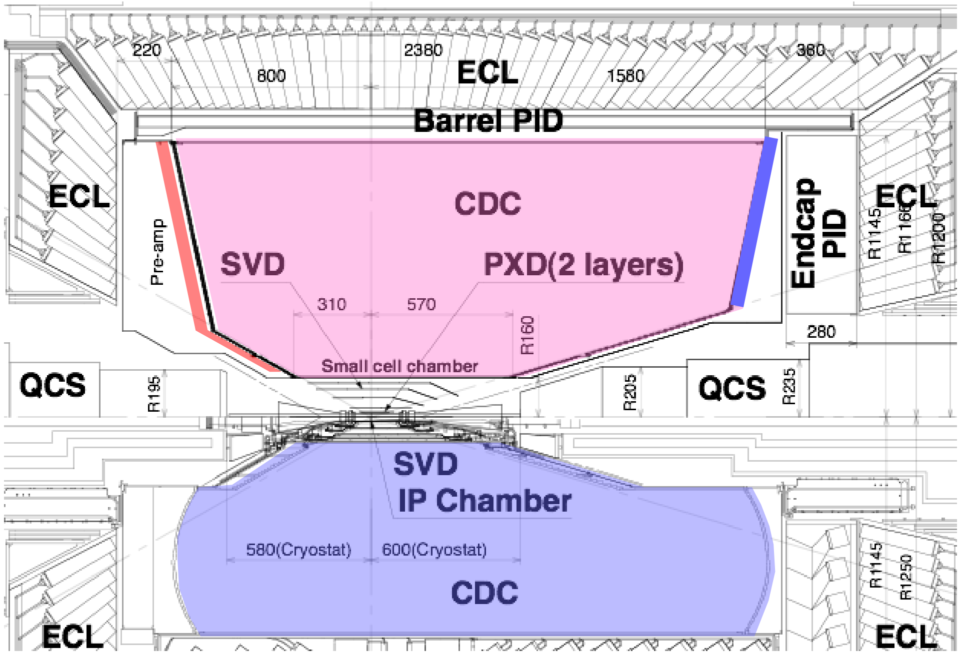
DSSD	Layer 3	r = 38mm
	Layer 4	r = 80mm
	Layer 5	r = 115mm
	Layer 6	r = 140mm



Central Drift Chamber

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

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



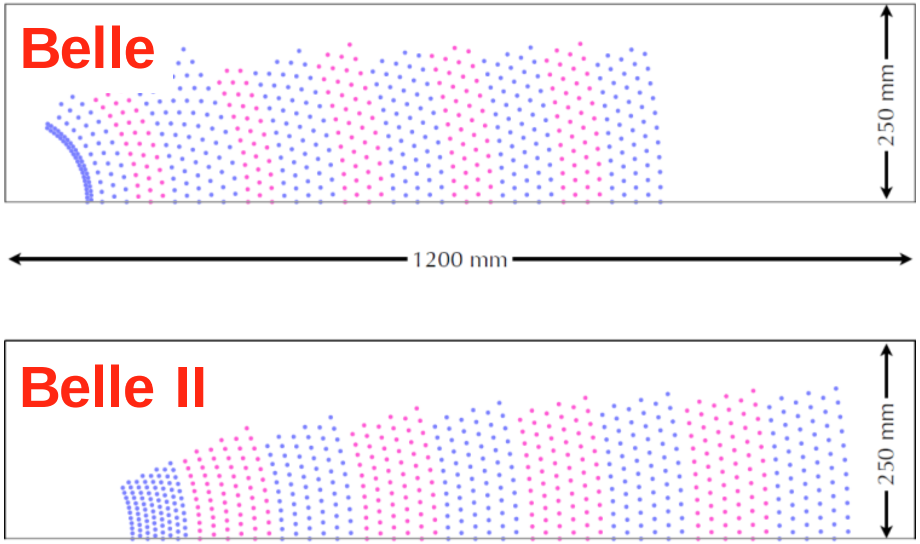
new readout system

dead time 1-2μs → 200ns

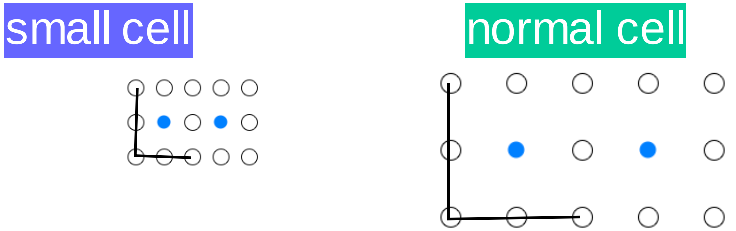
small cell

smaller hit rate for each wire

shorter maximum drift time

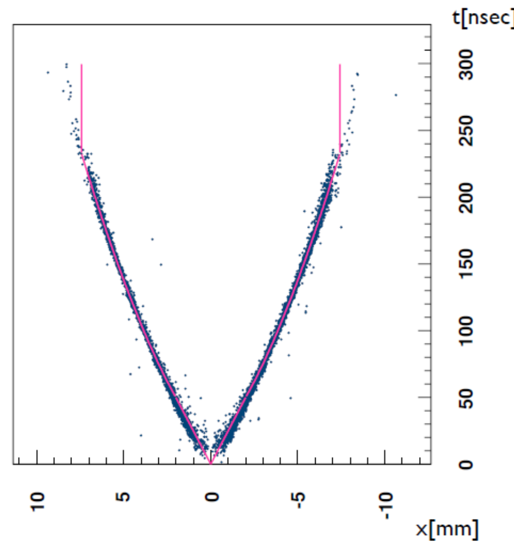


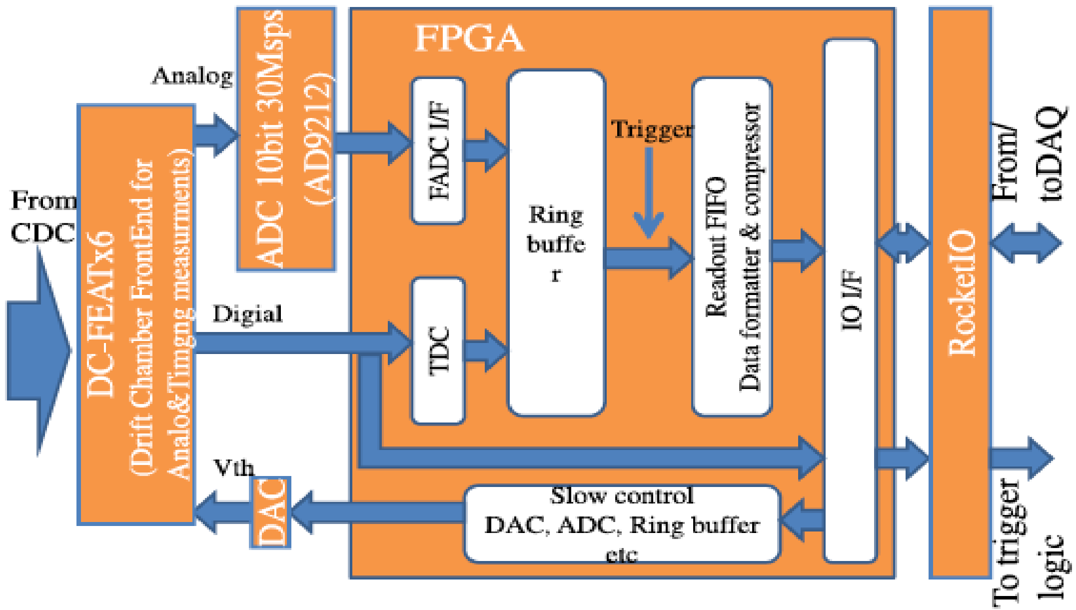
	Belle	Belle II
inner most sense wire	r=88mm	r=168mm
outer most sense wire	r=863mm	r=1111.4mm
Number of layers	50	56
Total sense wires	8400	14336
Gas	He:C_2H_6	He:C_2H_6
sense wire	W(Φ30μm)	W(Φ30μm)
field wire	Al(Φ120μm)	Al(Φ120μm)

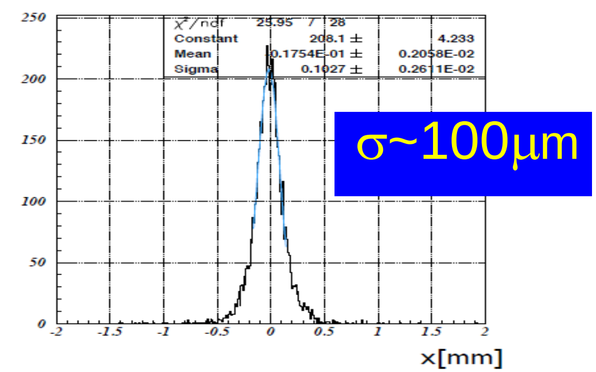


Central Drift Chamber Readout

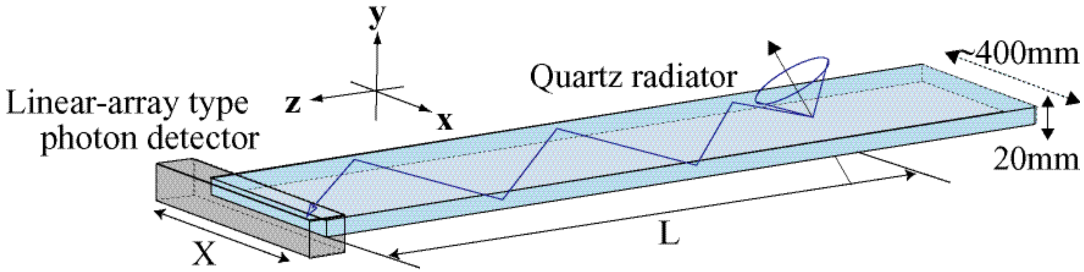
- New electronics has been designed and tested
- The drift time is measured with an FPGA-based TDC
- A slow FADC (around 30MSa/s) measures the signal charge.



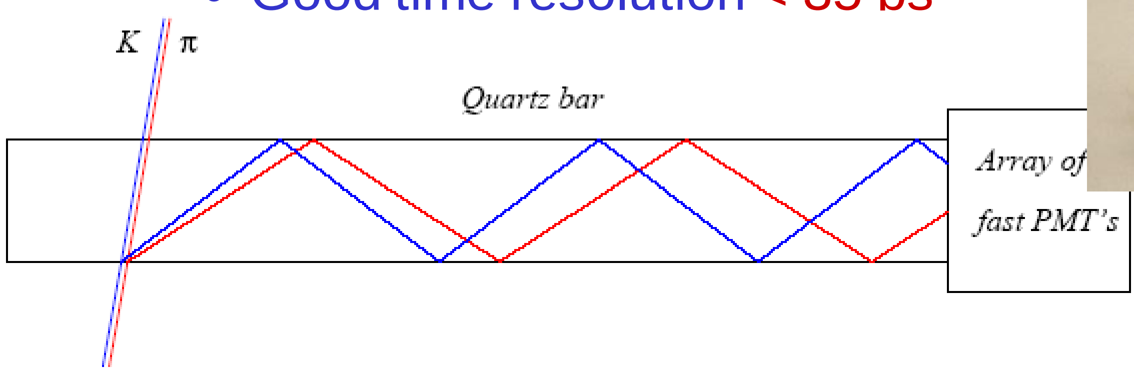


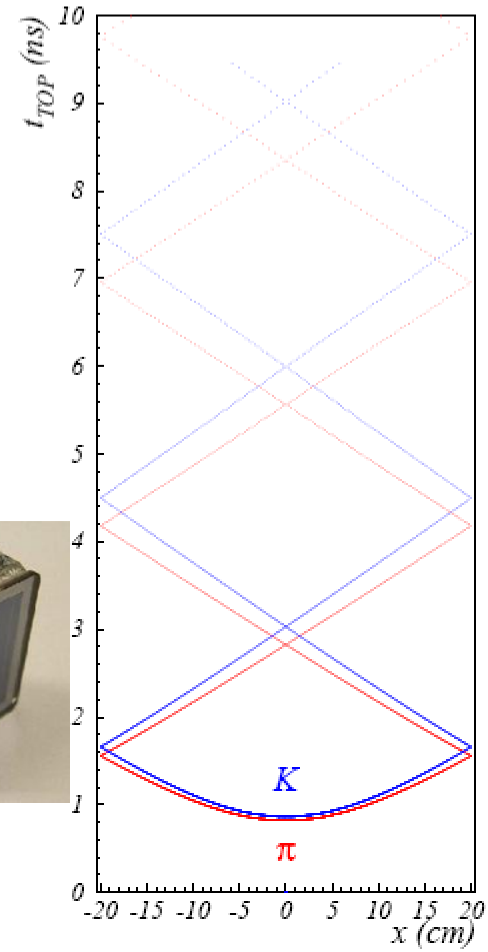


Barrel PID: Time of propagation (TOP) counter



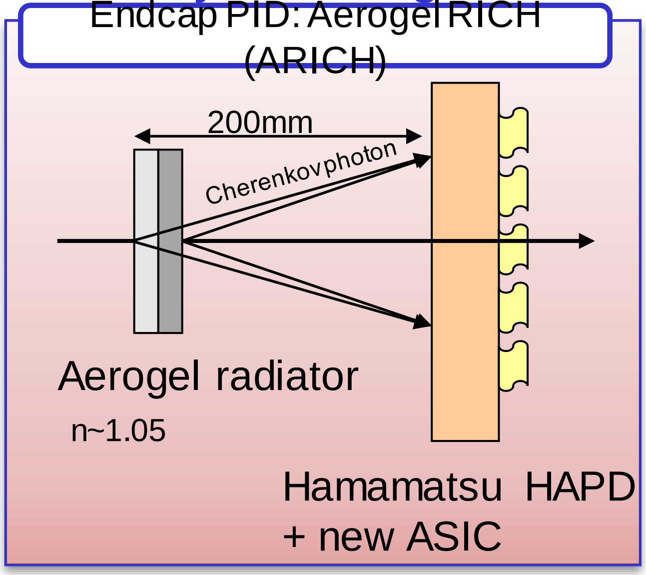
- Cherenkov ring imaging with precise time measurement.
- Reconstruct angle from one coordinate and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT Hamamatsu 16ch MCP-PMT)
    - Good time resolution < 35 ps



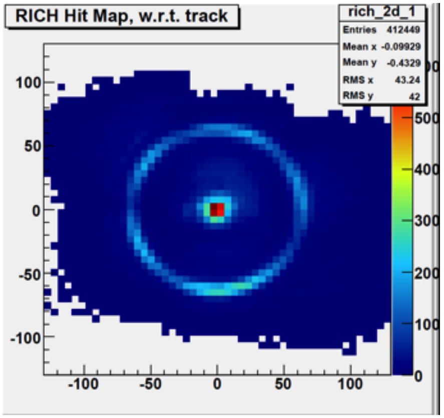


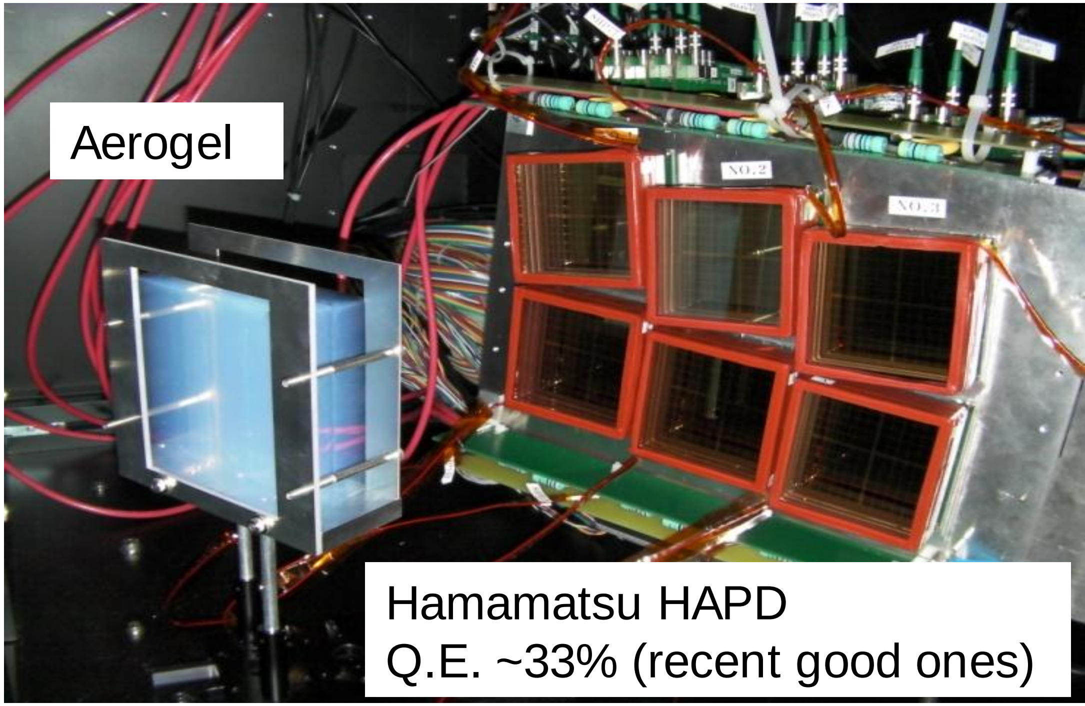
End-cap PID: Aerogel RICH

- Proximity focusing RICH with aerogel radiator



Test Beam setup



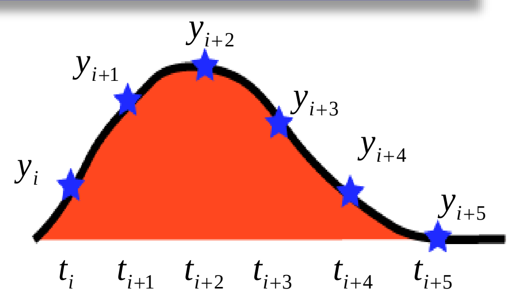


Clear Cherenkov image observed

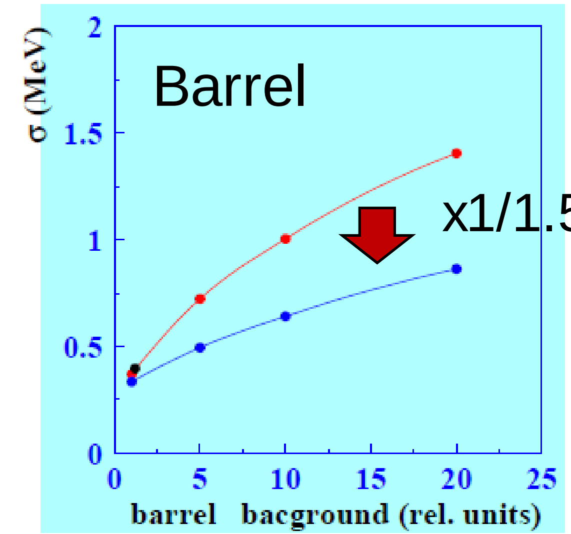
ECL Upprade

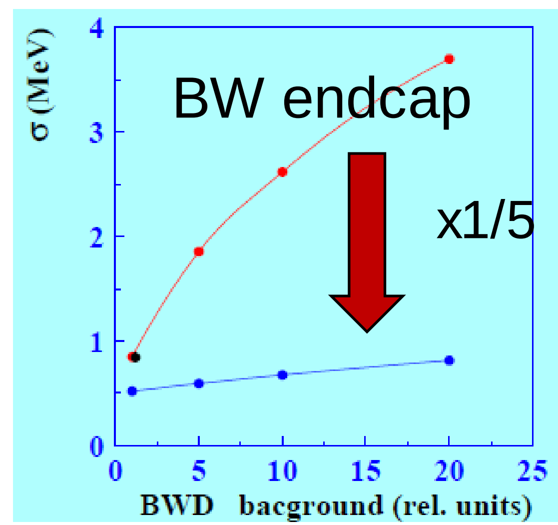
- Increase of dark currents due to neutron flux
- Fake clusters & pile-up noise

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



Pure CsI & photopentods

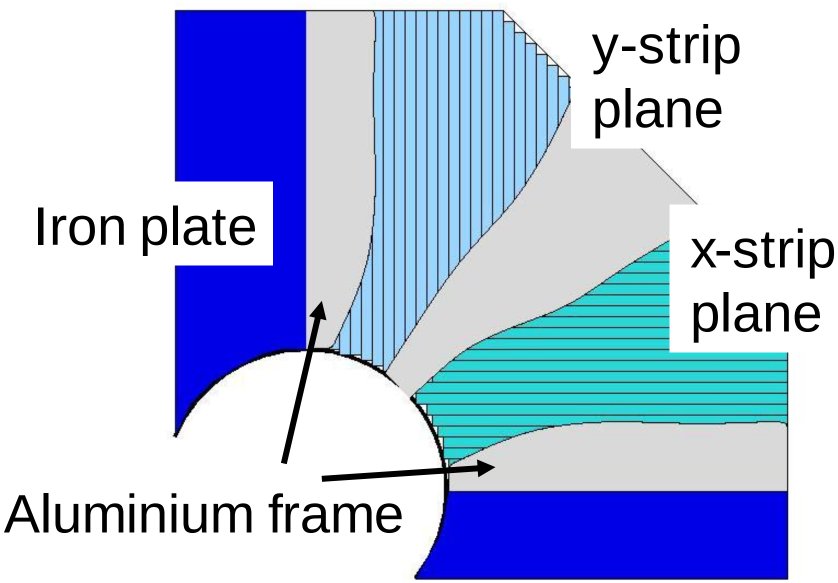




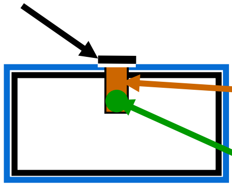
KLM upgrade

Scintillator-based KLM (endcap)

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



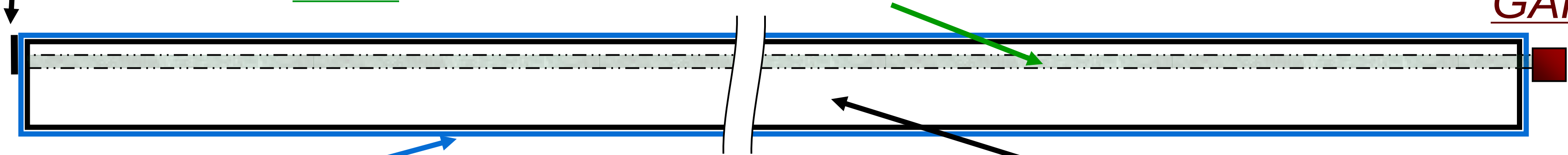
Mirror 3M (above groove & at fiber end)



Optical glue increase the light yield ~ 1.2-1.4

WLS: Kurarai Y11 ∅1.2 mm

GAPD



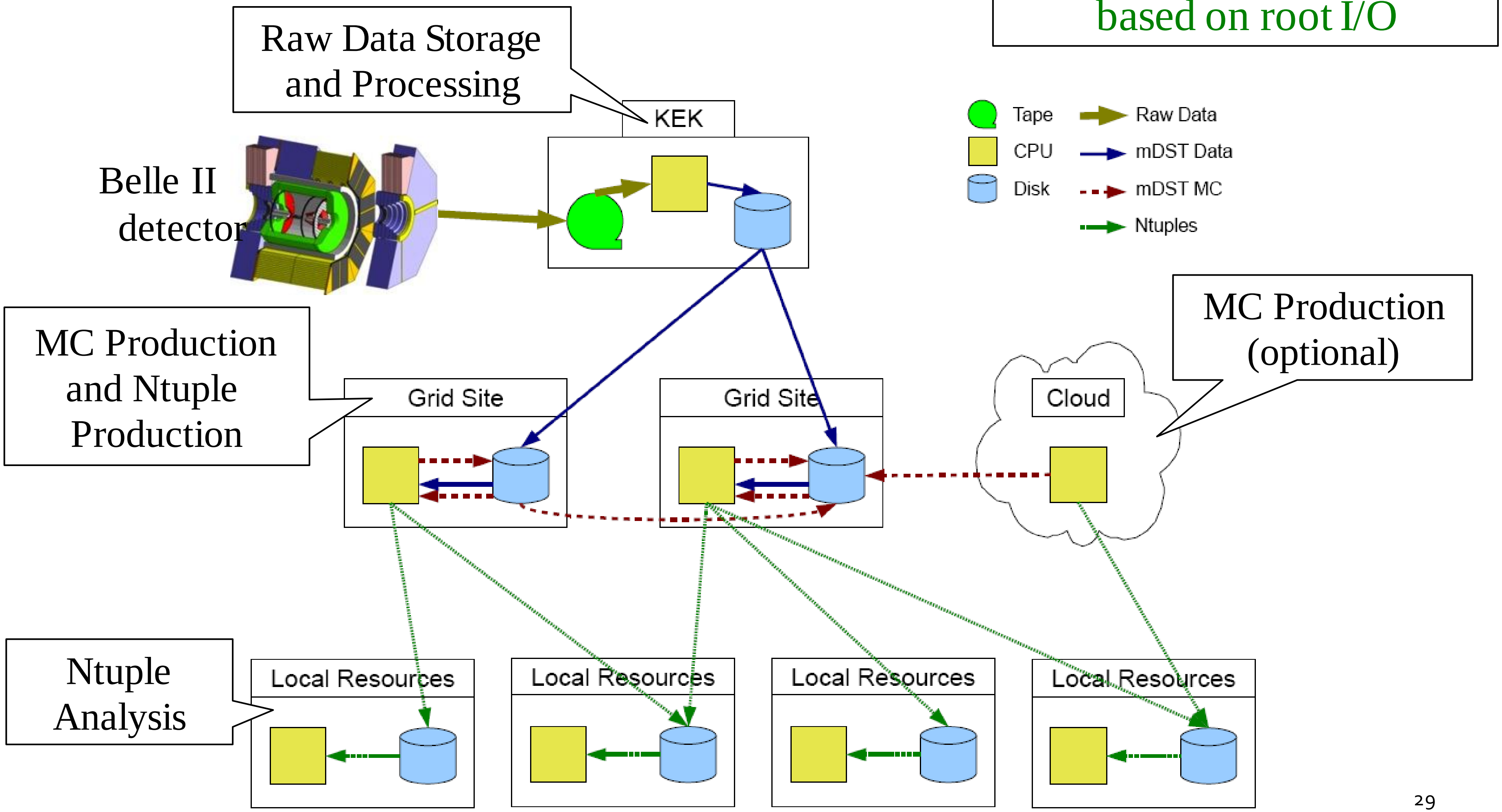
Diffusion reflector (TiO_2)

Strips: polystyrene with 1.5% PTP & 0.01% POPOP

Belle II Computing Model

Grid-based Distributed Computing

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



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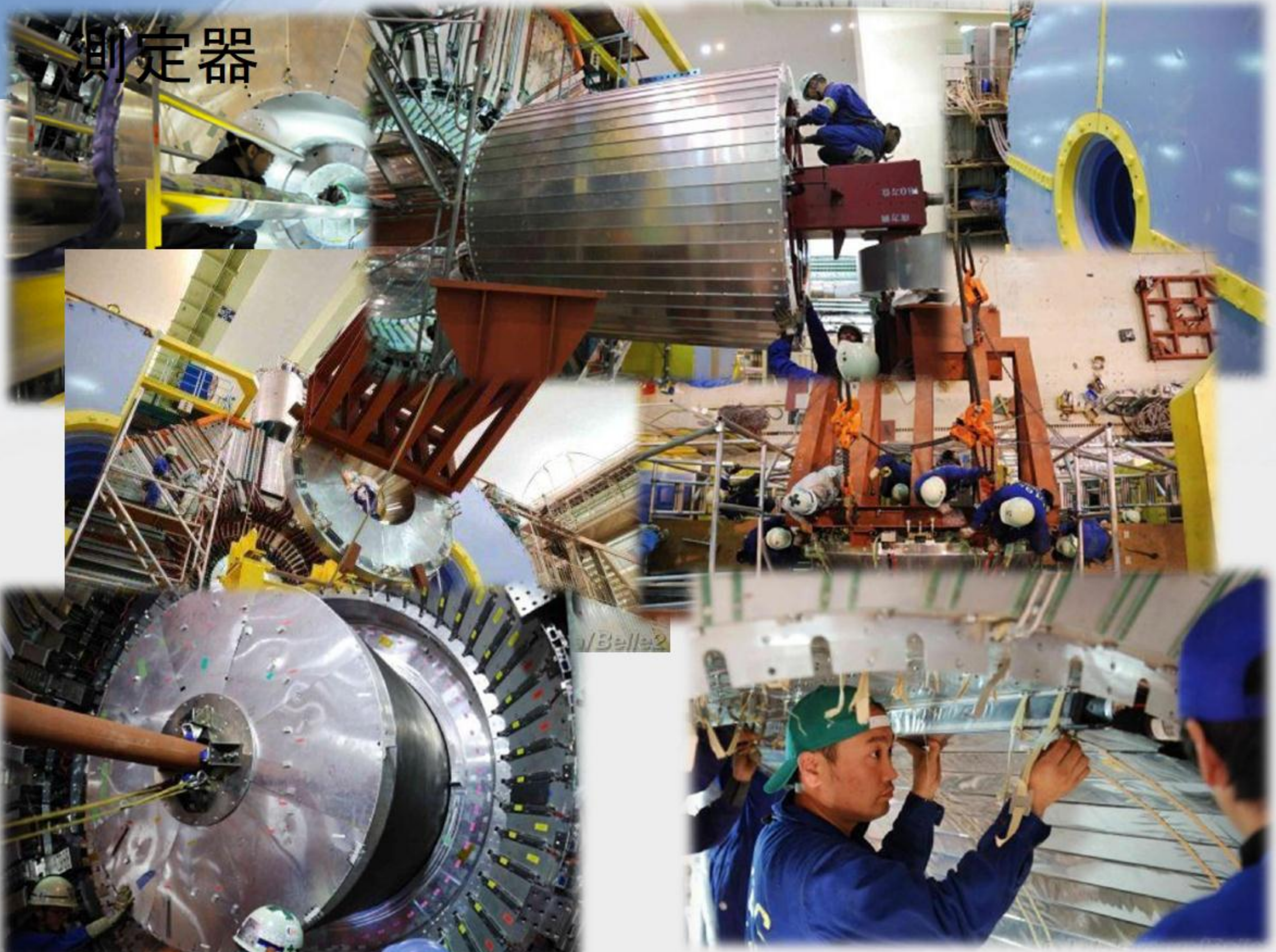
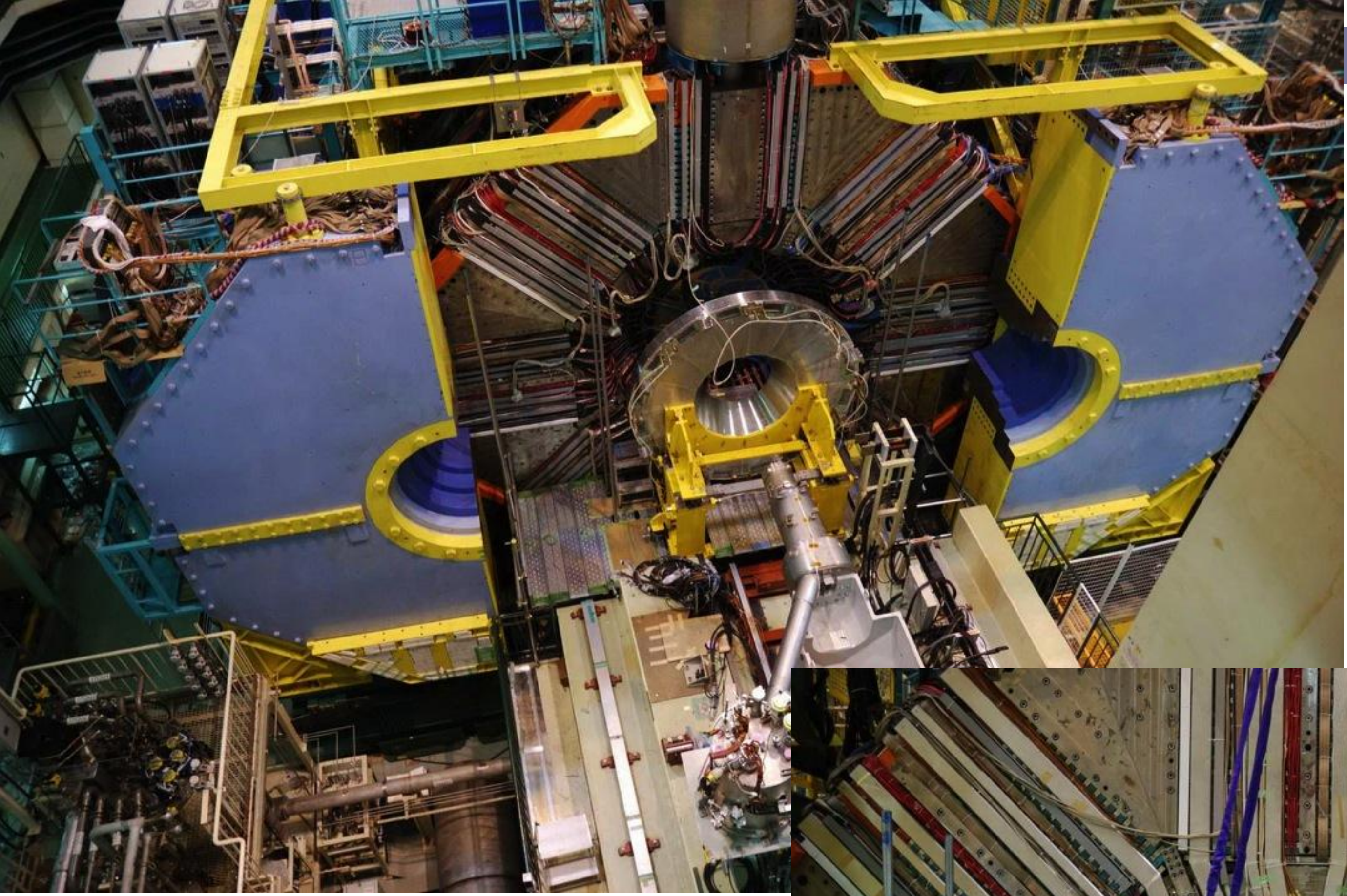
KEKB being disassembled after 11 years of successful run

測定器





Belle is also being disassembled to revive as Belle-II.

The Earthquake

As is 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 were safe. 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.

KEKB/Belle status

Fortunately enough:

- KEKB stopped operation in July 2010, and the low energy ring was to a large extent disassembled
- Belle was rolled out in its parked position

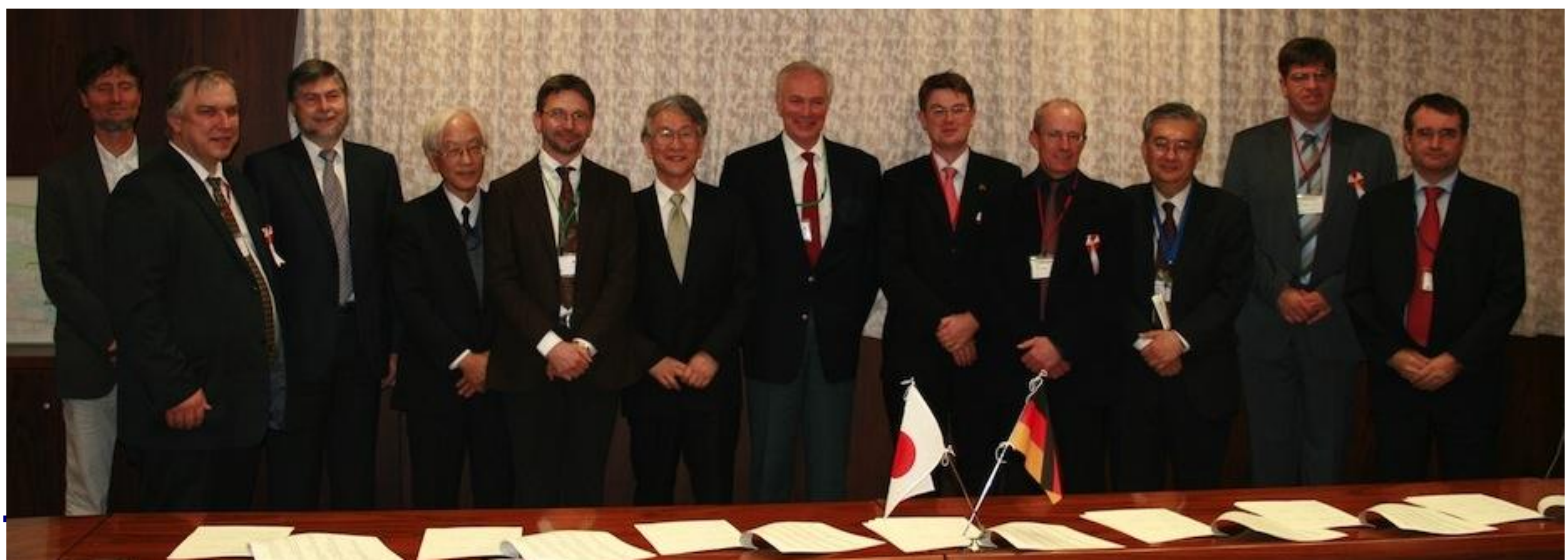
The 1400 tons of Belle moved by ~6cm (most probably by 20cm in one direction, and 14cm back)...

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

The lab (Tsukuba campus) has to a large extent recovered from the earthquake, back to normal operation – very little impact on the upgrade schedule

SuperKEKB/Belle II Funding Status

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



The Belle II Collaboration

A very strong group of ~400 highly motivated scientists!

Next open general meetings: KEK March 14-17 2012
Bad Aibling (Bavaria) July 26-29 2012

Belle II Collaboration (Europe)

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

Summary

- SuperKEKB/Belle II aims for (discovering and) understanding the New Physics.
- Target luminosity of SuperKEKB is $8x10^{35}/cm^2/s$, will provide $50ab^{-1}$ by 2021-2022.
- Belle II gives similar or better performance than Belle even under higher beam background.
- Project has been approved by Japanese Government. KEKB/Belle operation has been terminated and construction started.
- Next collaboration meeting: 14-17 March 2012 @KEK, still open to everyone. New collaborators welcome!
- Project officially started with the Groundbreaking ceremony last week

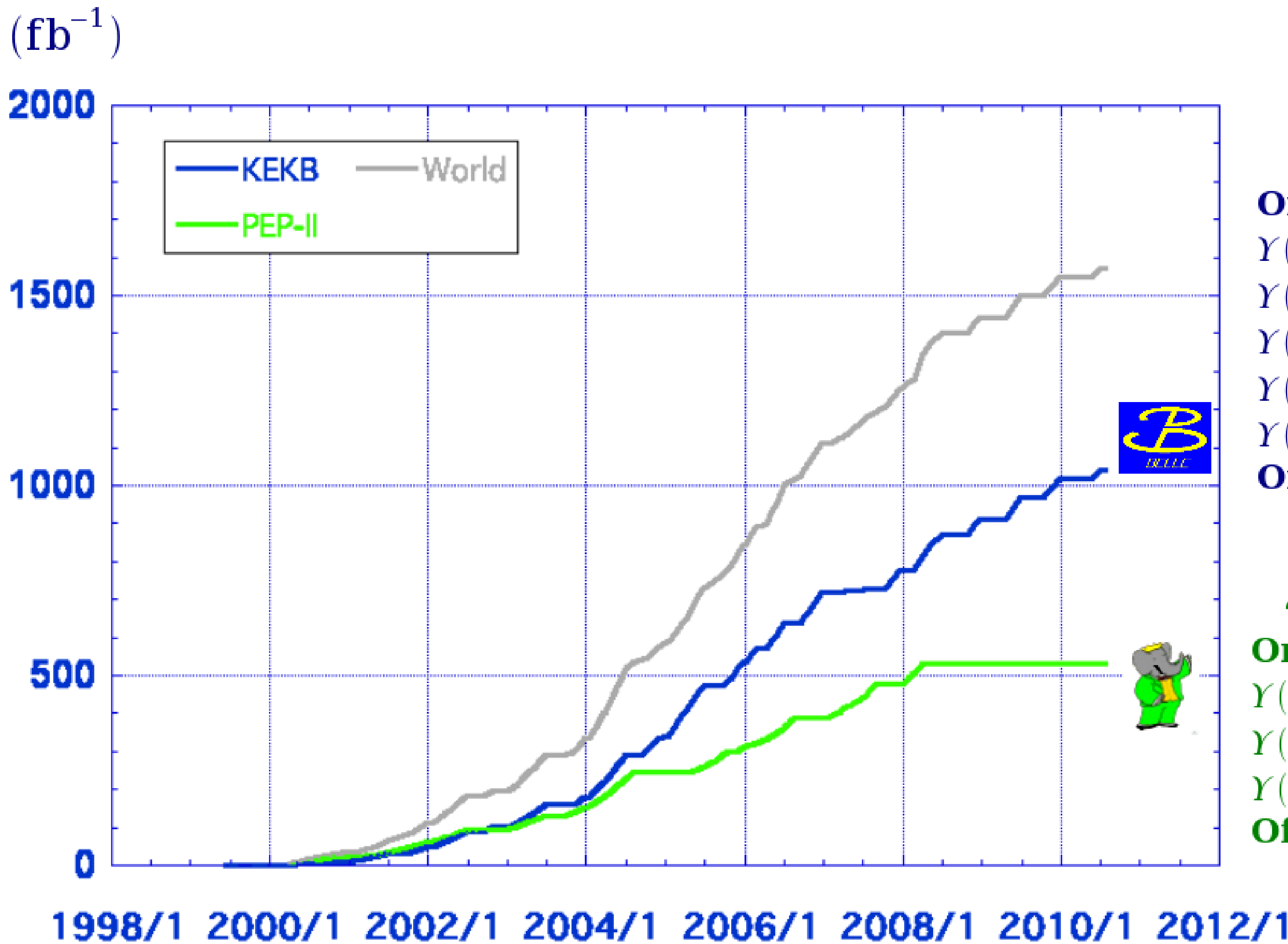
Groundbreaking ceremony Nov 18 2011, KEK

Many thanks to CERN DG for his nice words!

Groundbreaking ceremony Nov 18 2011, KEK

Backup

Luminosity at the B Factories



> 1 ab^{-1}

On resonance:

$\Upsilon(5S)$: 121 fb^{-1}

$\Upsilon(4S)$: 711 fb^{-1}

$\Upsilon(3S)$: 3 fb^{-1}

$\Upsilon(2S)$: 24 fb^{-1}

$\Upsilon(1S)$: 6 fb^{-1}

Off reson./scan:

~ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

$\Upsilon(4S)$: 433 fb^{-1}

$\Upsilon(3S)$: 30 fb^{-1}

$\Upsilon(2S)$: 14 fb^{-1}

Off resonance:

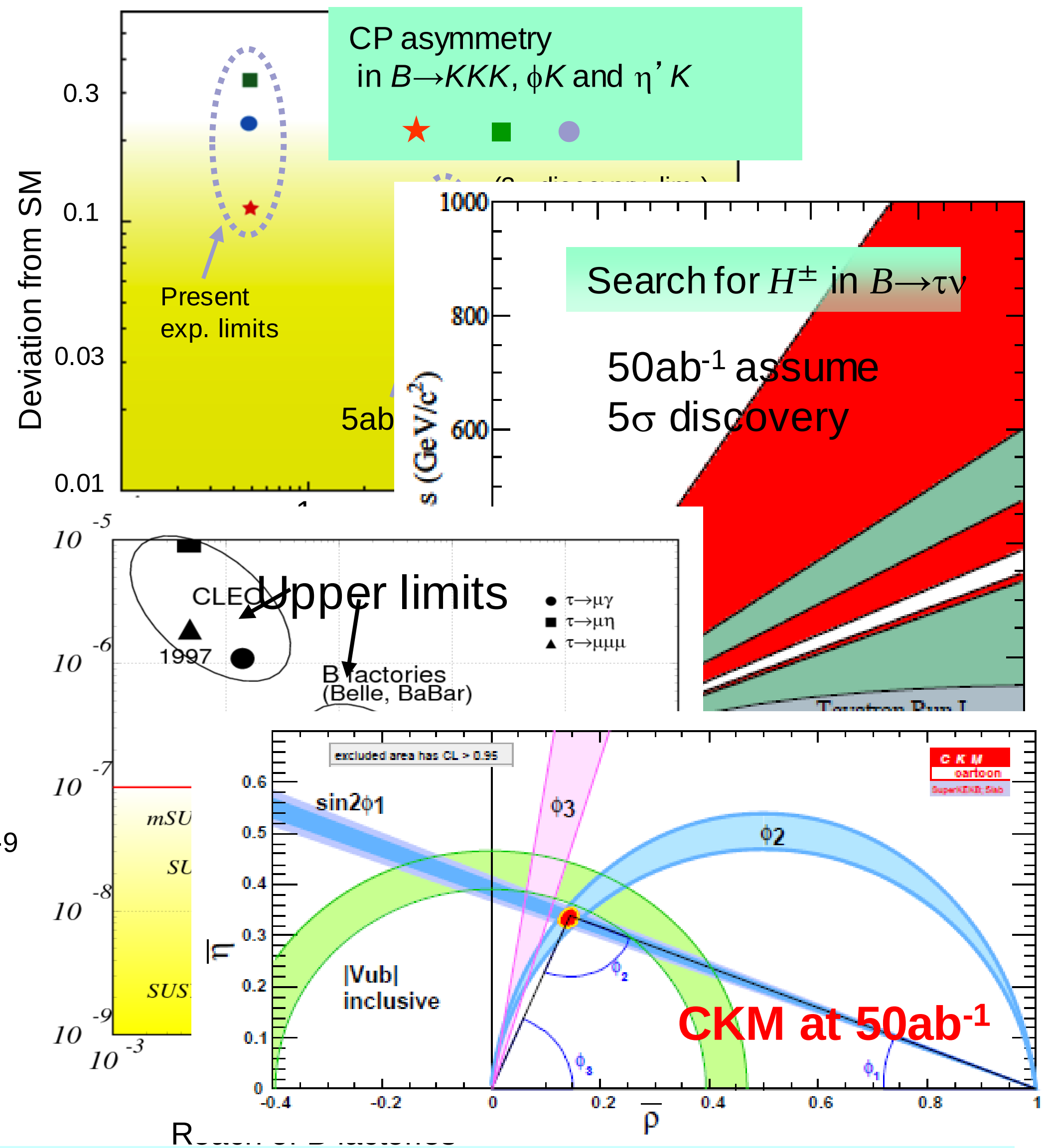
~ 54 fb^{-1}

Fantastic performance much beyond design values!

Physics reach at a Super KEKB/Belle

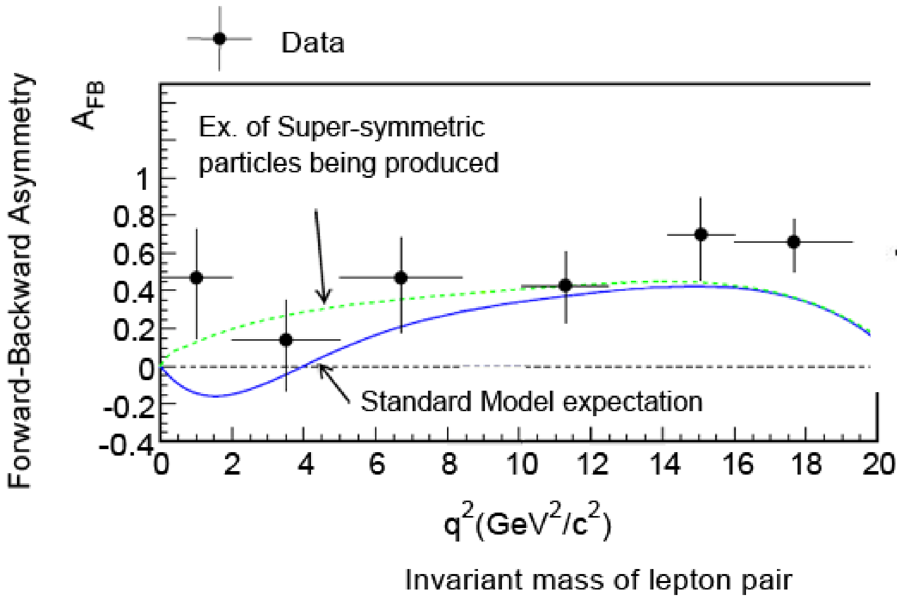
	Belle' 06 (~0.5ab^{-1})	5ab^{-1}	50ab^{-1}
$\Delta S(\phi K^0)$	0.22	0.073	0.029
$\Delta S(\eta' K^0)$	0.11	0.038	0.020
$\Delta S(K_S K_S K_S)$	0.33	0.105	0.037
$\Delta S(K_S \pi^0 \gamma)$	0.32	0.10	0.03
$Br(X_s\gamma)$	13%		
$A_{CP}(X_s\gamma)$	0.058	0.01	0.005
C_9 [$A_{FB}(K^*ll)$]	---	11%	4%
C_{10}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

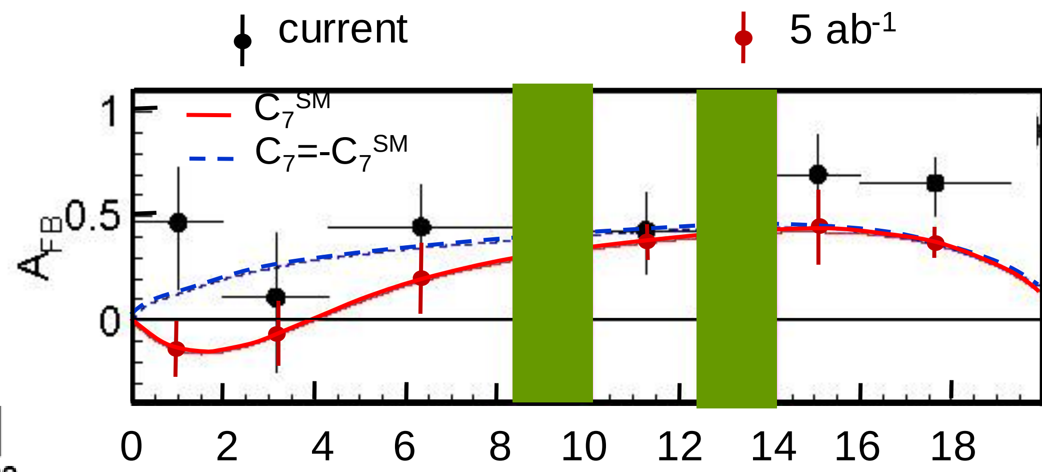
τ upper limits: X10^{-9}



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

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





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

Strong competition from LHCb and ATLAS/CMS

Comparison with the LHCb

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

Complementary!!

Luminosity gain and upgrade items (preliminary)

3 years shutdown

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

Major KEKB components

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

Items are interrelated.

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

Upgrade from KEKB to SuperKEKB

- smaller beam size, more current
  → x40 higher luminosity

Machine parameter	HER (KEKB)	LER (KEKB)	HER (SuperKEKB)	LER (SuperKEKB)
Vertical beam size	0.94μm	0.94μm	59nm	59nm
Beam current(mA)	1188	1637	2600	3600
luminosity($cm^{-2}s^{-1}$)	$2.1x10^{34}$		$8x10^{35}$	

Introduction: background sources

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

BG estimation at SuperKEKB

Assumptions:

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

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

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

ECL 60+-5 GeV/event

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

SVD 6000+-600 event/trigger

→ shorter integration time (2μs→75ns)

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

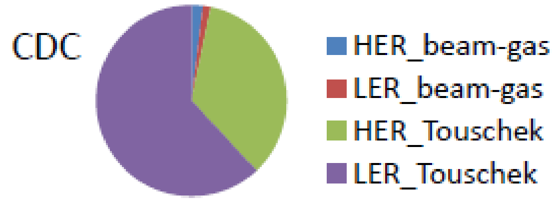
PXD (estimated from SVD)

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

→ Occupancy = 1.5±0.1%

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

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

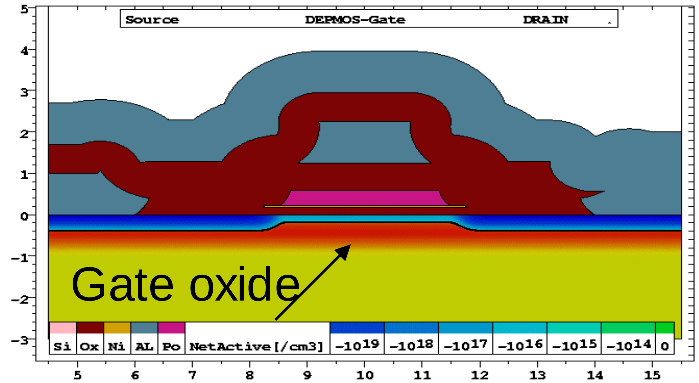


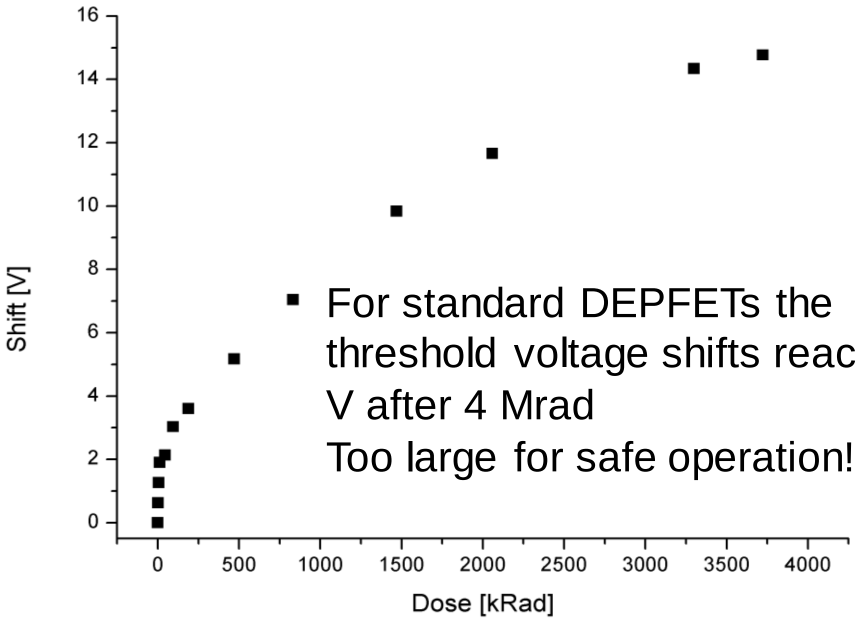
LER/total: 60~70%,
Touschek/total: >90%

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

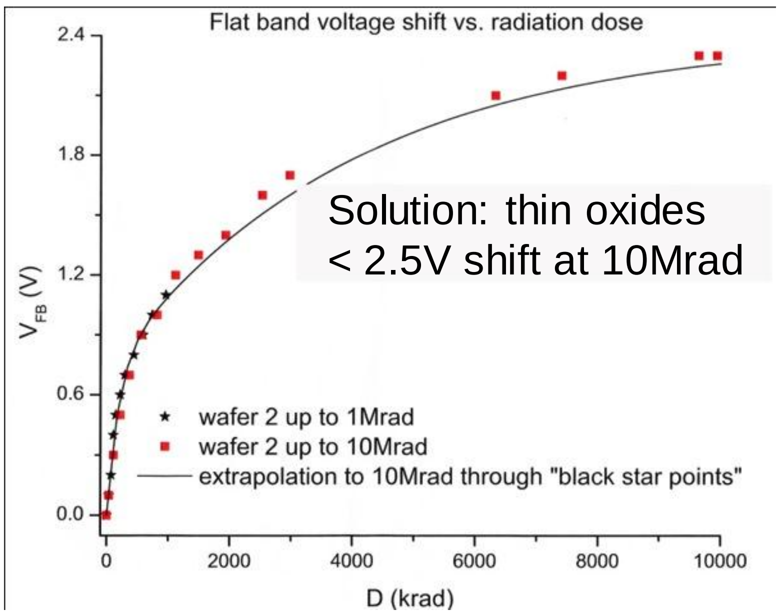
DEPFET Radiation Damage

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





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

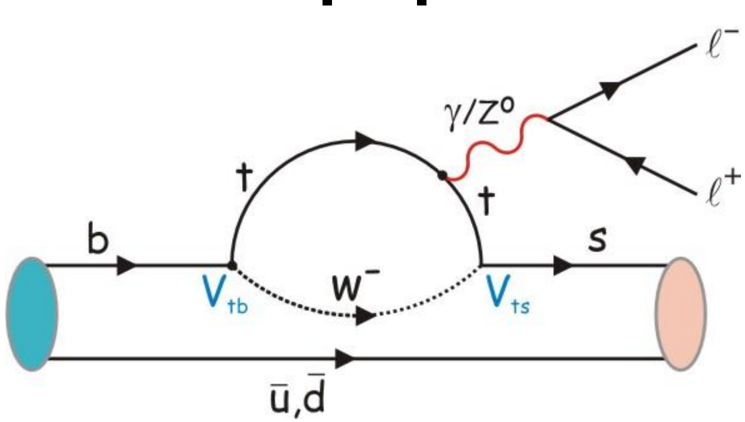


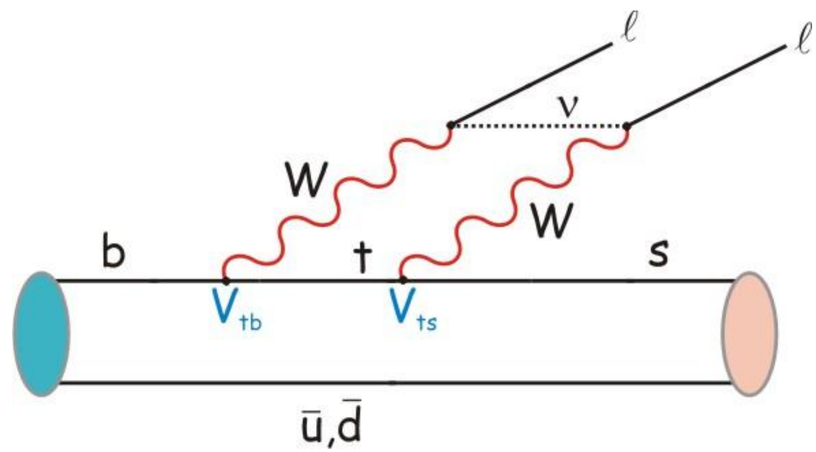
Solution: thin oxides
< 2.5V shift at 10Mrad

Belle II basic parameters (TDR)

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

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





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

Important for further searches for the physics beyond SM

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

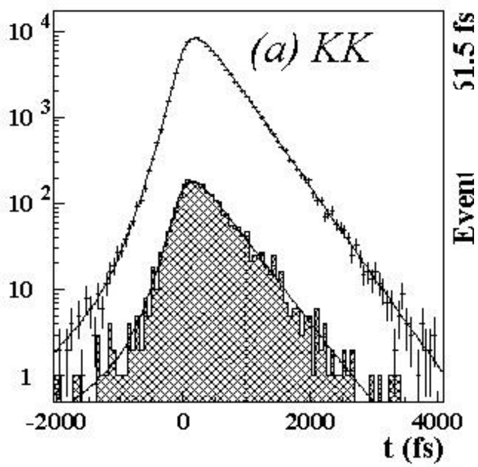
$$A_{FB} \propto \Re\left[C_{10}^{*} (sC_9^{eff}(s) + r(s)C_7) \right]$$

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

s=lepton pair mass squared

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

Decay time distributions for KK, ππ, Kπ



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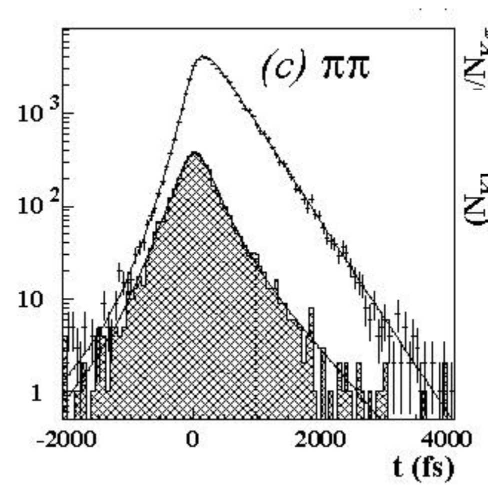
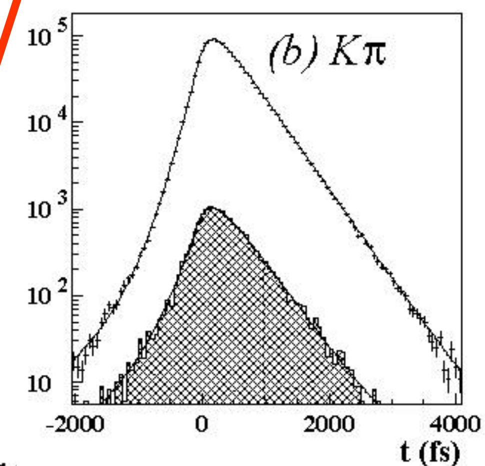
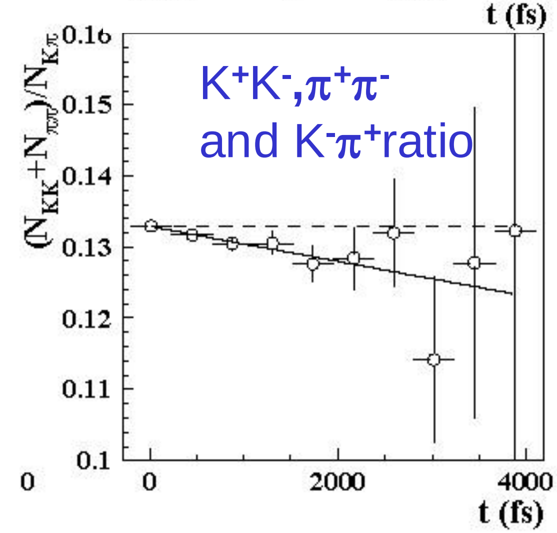




Difference of lifetimes
visually observable
in the ratio of the distributions →

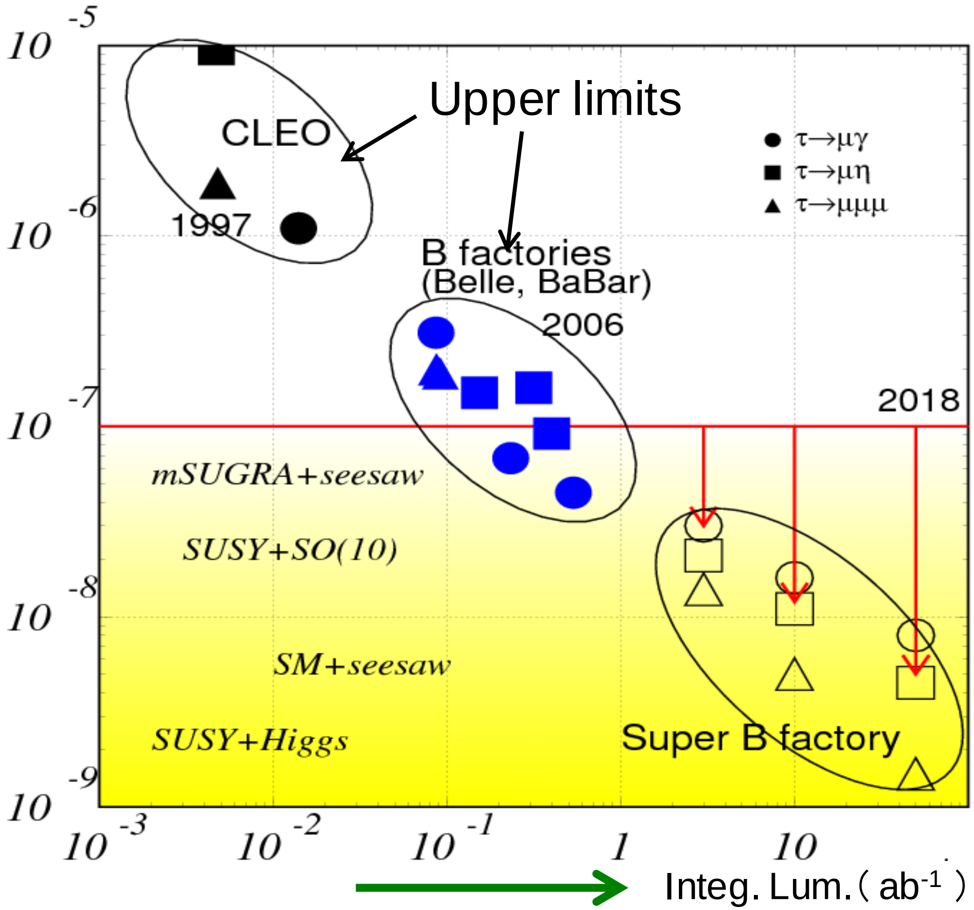
Real fit: $y_{CP} = (1.31 \pm 0.32 \pm 0.25)\%$



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

Precision measurements of τ decays

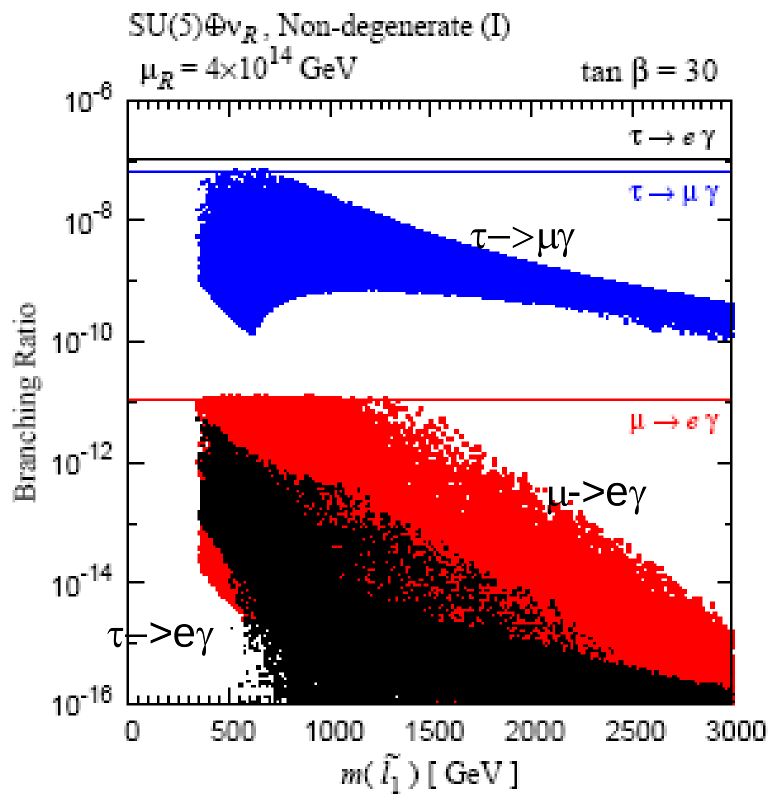
LF violating τ decay?



Reach of B factories

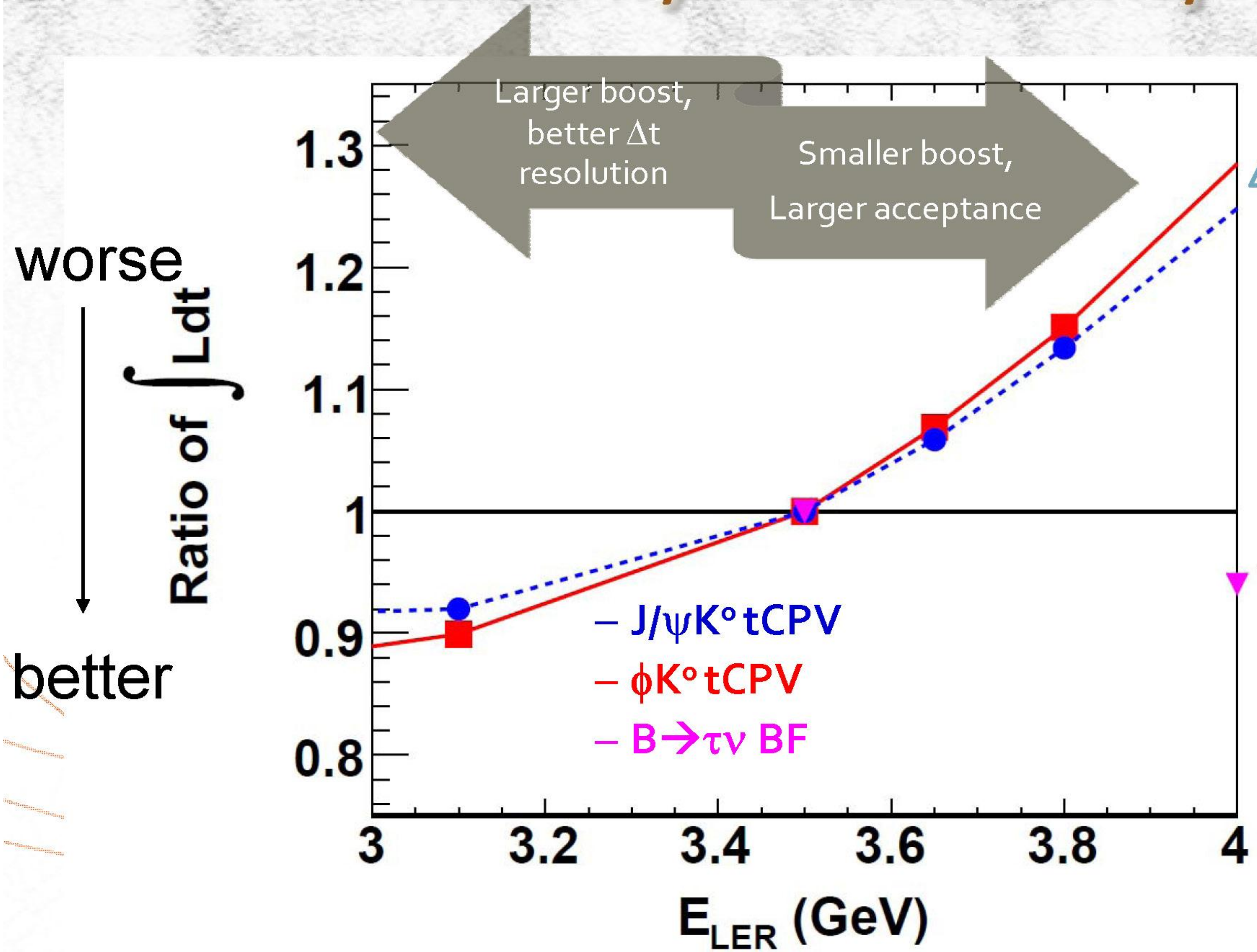
Upgraded KEKB

Theoretical predictions compared to present experimental limits



T.Goto et al., 2007

Beam Energy Asymmetry and Physics Sensitivity



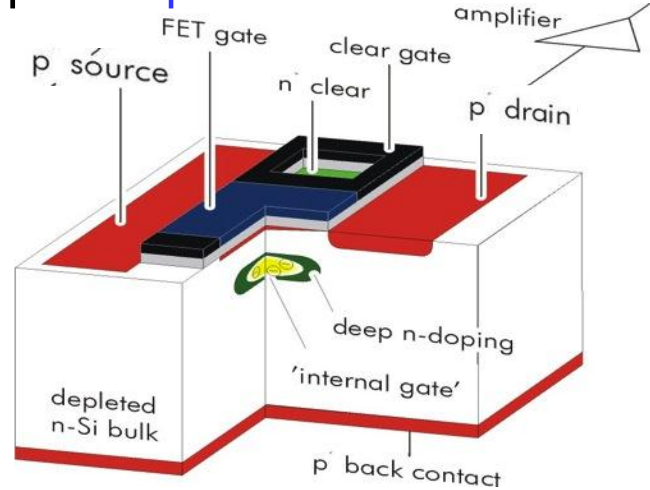
25% more Luminosity needed for the same sensitivity.

6% less Luminosity needed for the same sensitivity.

DEPFET Principle

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

Depleted p-channel FET



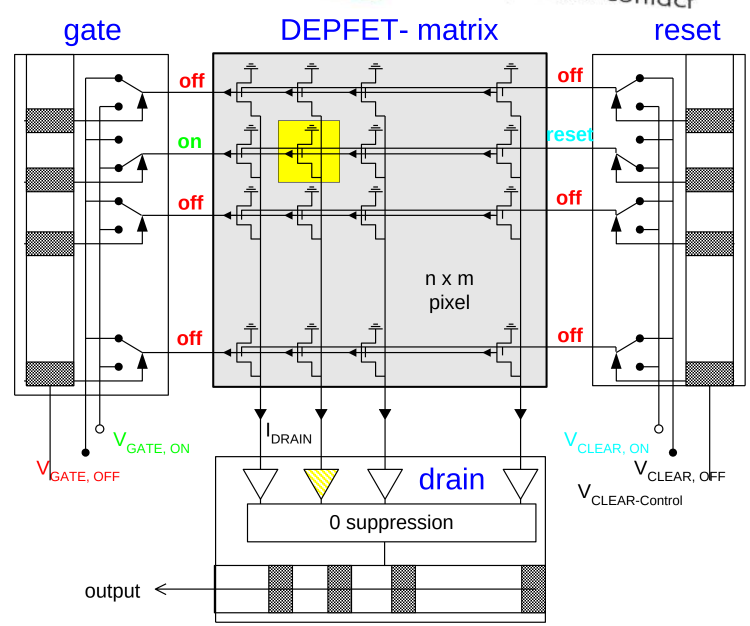
Fully depleted:

→ large signal, fast signal collection

Low capacitance, internal amplification → low noise

Transistor on only during readout: low power

Complete clear → no reset noise



Neutron flux

1MeV equivalent rate

1 year = 10^7 sec

	Region	Simulation (Touschek BG)	Assumption used for R&D	Life time by irradiation test based on the assumption
PXD	Sensors, readout	2×10^{11}/cm2/year (+0.7×10^{11} from 2-photon)	10^{12} /cm2/year	OK for at least 10 years (10^{13} n/cm2)
SVD	Sensors, chips	3 x 10^{11}/cm2/year	-	Should be OK (tested in ATLAS/CMS)
TOP	Readout electronics	~ 5×10^{10}/cm2/year	10^{11} /cm2/year	To be tested
ARICH	HAPD/ASIC	~7×10^{10}/cm2/year	10^{11} /cm2/year	OK for at least 4 years
ECL	Diodes	~8×10^{10}/cm2/year	10^{11} /cm2/year	OK for at least 40 years
EKLM	SiPMs	<2×10^{8}/cm2/year - upper limit since observed no hits - not including neutrons which travel more than 10us	10^{9}/cm2/year	OK for at least 10 years
BKLM	SiPMs	2~8×10^{9}/cm2/year	2×10^{10}/cm2/year	OK for at least 10 years

Neutron flux on CDC readout board is rather small, since boards are located on backward side and Touschek loss position is on forward side. It might increase (by order) including other BG sources which are lost on backward side.

Radiation dose

1 year = 10^7 sec

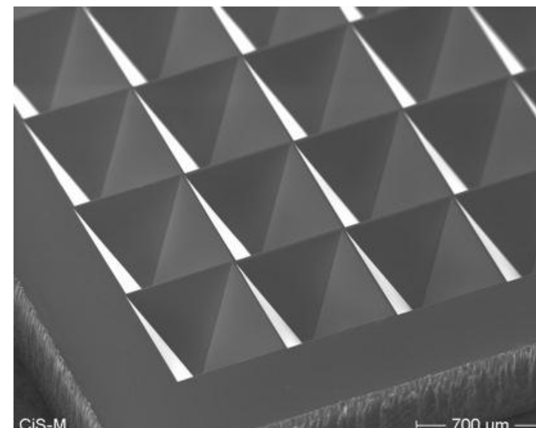
	Region	Simulation (Touschek BG)	Assumption used for R&D	Life time by irradiation test based on the assumption
PXD	DCD, DHP, switchers	~2 Gy/year (+2 Gy/y from 2-photon)	10,000 Gy/year (conservative)	OK up to at least 10 years
SVD	APV	3.5 Gy/year	-	Much more than 100Gy
TOP	Readout electronics	~10 Gy/year	100 Gy/year	OK up to at least 10 years
ARICH	PCB,APDs	~10 Gy /year	100 Gy/year	OK up to at least 10 years
ECL	Crystals	~8 Gy/year	40 Gy/year	OK up to at least 10 years

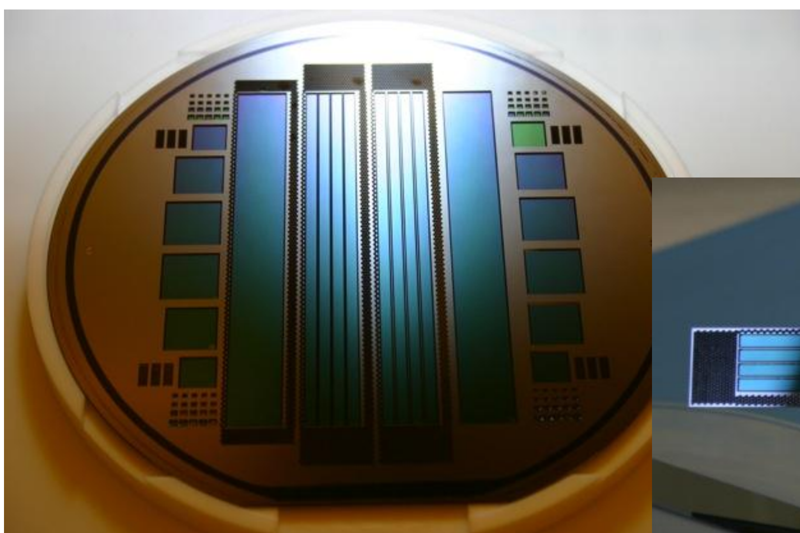
Impact from Touschek BG is tolerable in terms of neutron/radiation dose.
Next step is to see the impact from other BG sources, such as beam-gas BG, radiative Bhabha BG, SR, etc..

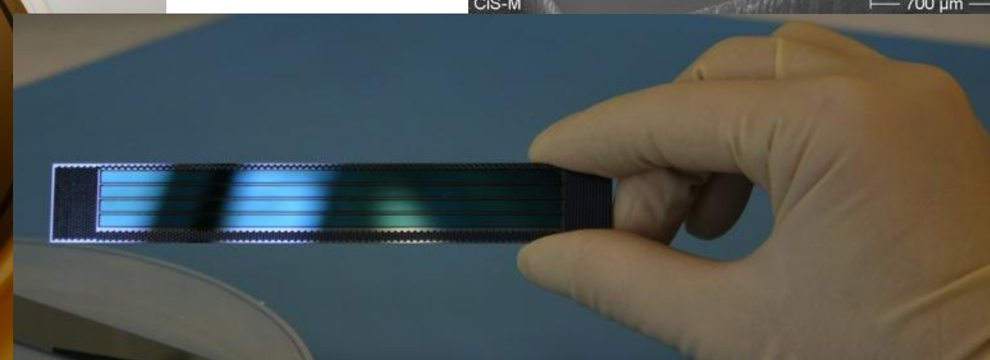
Thinning Technology

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

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

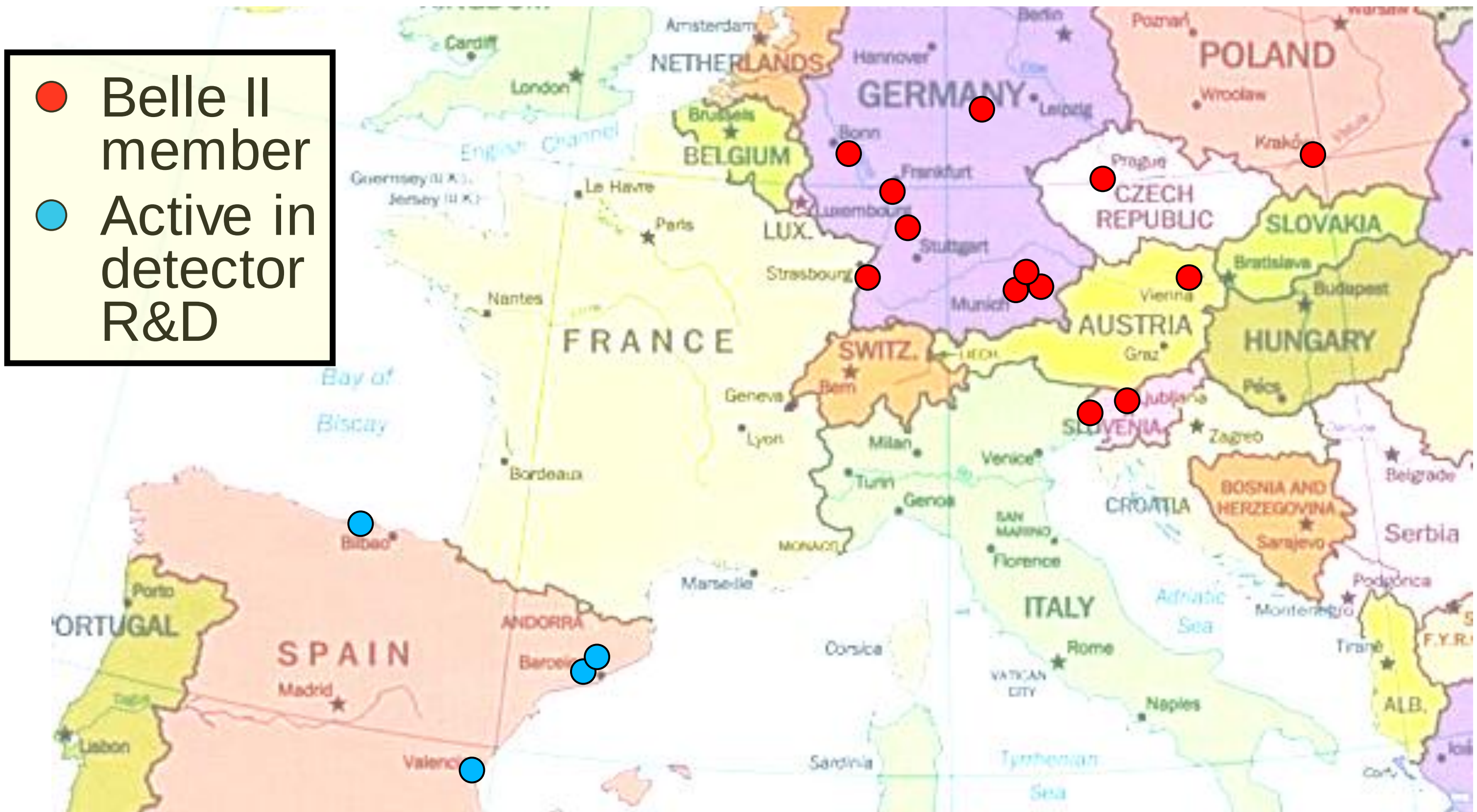






New Collaboration (Belle II)

- Belle II is a new international collaboration
  - Significant European participation + funding (A, CZ, D, PL, RUS, SLO)
  - Spokesperson P. Križan, Ljubljana



Detector	Proposed budget (Sep. 2010)	Possible reduction	Assumed in-kind contributions	Budget requested to KEK
IR	94	19	0	76
PXD	~€3.5M		~€3.5M (DEPFET Collab.)	0
SVD	500	130	100 (Vienna)	270
CDC	358	11	30 (NTU)	317
BPID	878		508 (US) 120 (Nagoya)	250
EPID	599	100	120 (Ljubljana)	379
ECL	327	0	0	327
KLM	165	0	35 (ITEP) 50 (VPI)	80
Trigger	107	0	36 (NTU)	71
DAQ	411	0	50 (IHEP, Korea U., Giessen)	361
Computing	N/A	0	N/A	N/A
Structure	336	0	0	336
Total	4125	260	1399	2467

Only for barrel
Need extra fun
for endcap ECL

Belle-II Collaboration

New collaboration (Belle-II) officially formed

- 13 countries/region, 43 institutes, ~300 members

Separate group/organization from Belle

Executive Board (Chair: H. Aihara)

Spokesperson: P. Križan
Project manager: M. Yamauchi

Institutional Board (Chair: E. Won)

Physics coordinators:
B. Golob / K. Trabelsi

Technical coordinator: Y. Ushiroda

Software /computing coordinators: T. Hara / T. Kuhr

2010.11: 7th Open Collaboration Meeting

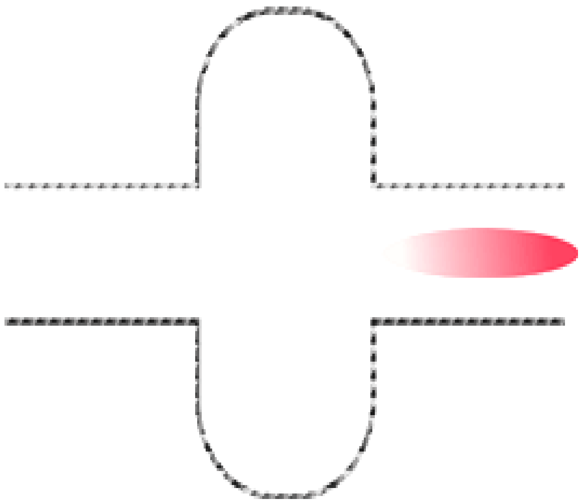
European groups of Belle-II

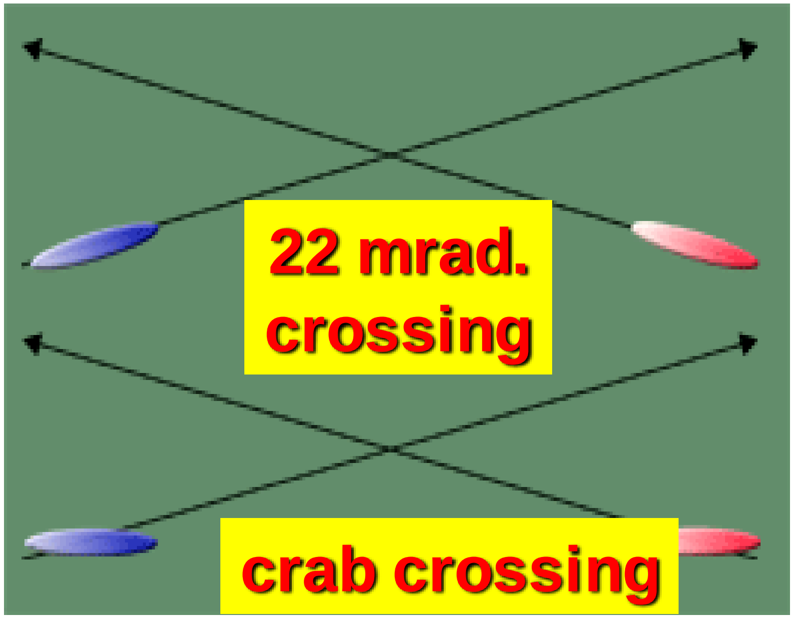
The European groups have major responsibilities in some essential detector systems:

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

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

The key factor in KEKB performance: crab cavity





Installed in the KEKB tunnel
(February 2007)

Belle to Belle II Upgrade

TDR: KEK Report 2010-1