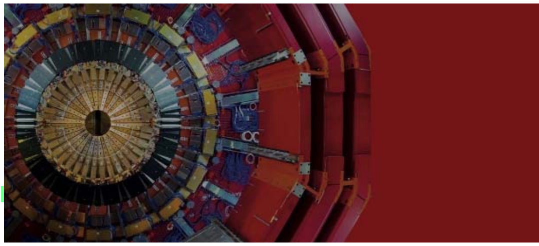

50 Jahre HEPHY
Meilensteine und zukünftige Herausforderungen der Teilchenphysik

Flavour Physics at Belle and Belle II

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Contents

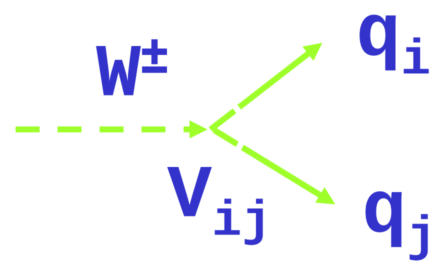
- Introduction with a little bit of history
- Belle: highlights
- Belle II: status and outlook

Flavour physics and CP violaton

Discovery of CP violation in $K_L \to \pi^+ \pi^-$ decays (Fitch, Cronin, 1964)

Kobayashi and Maskawa (1973): to accommodate CP violation into the Standard Model, need three quark generations, six quarks (at the time only three quarks were known...)

Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix

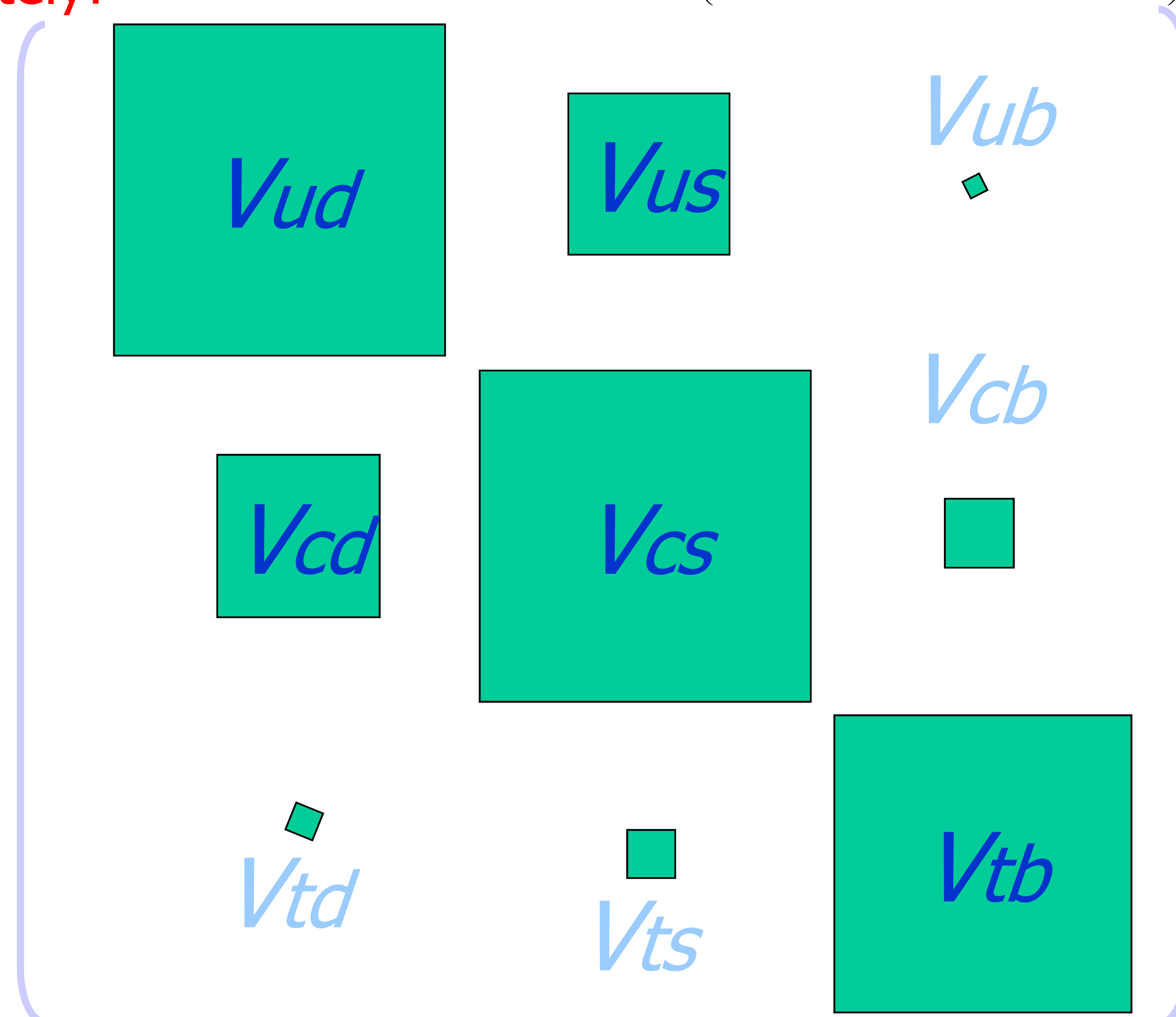


$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

SM: CP violation → CKM matrix has a non-trivial phase

→CKM: almost diagonal and real, but not completely!

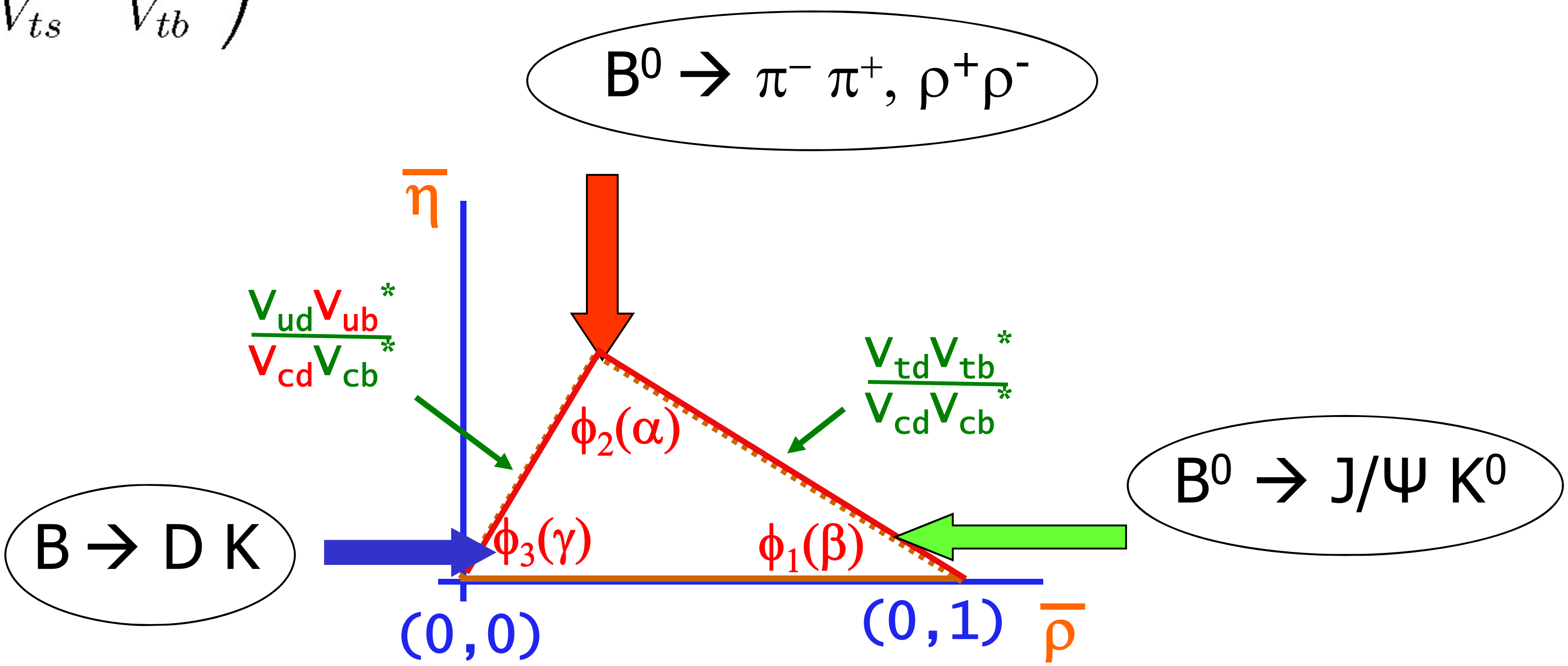
$$V = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4$$



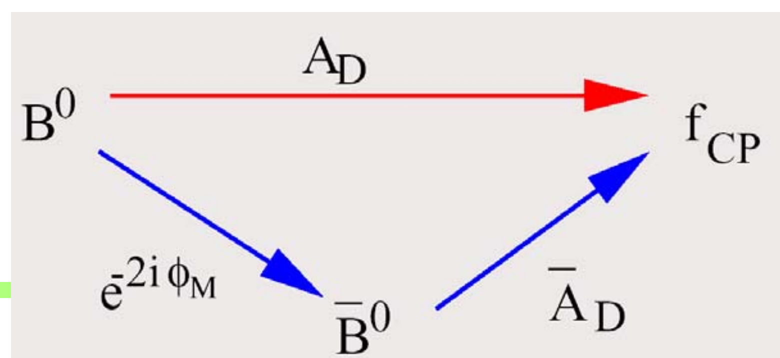
CP violation in the B system and unitarity triangle

$$\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix}$$

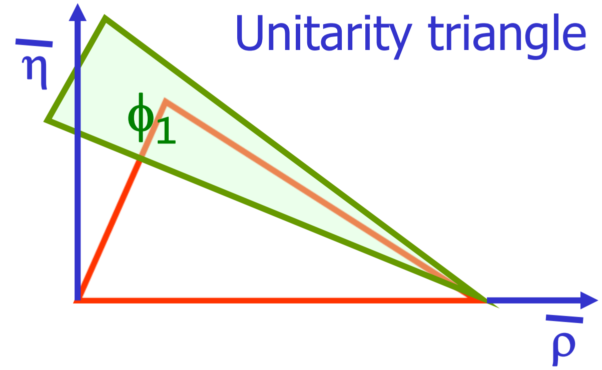
= unitary matrix → columns orthogonal
→ unitarity triagle



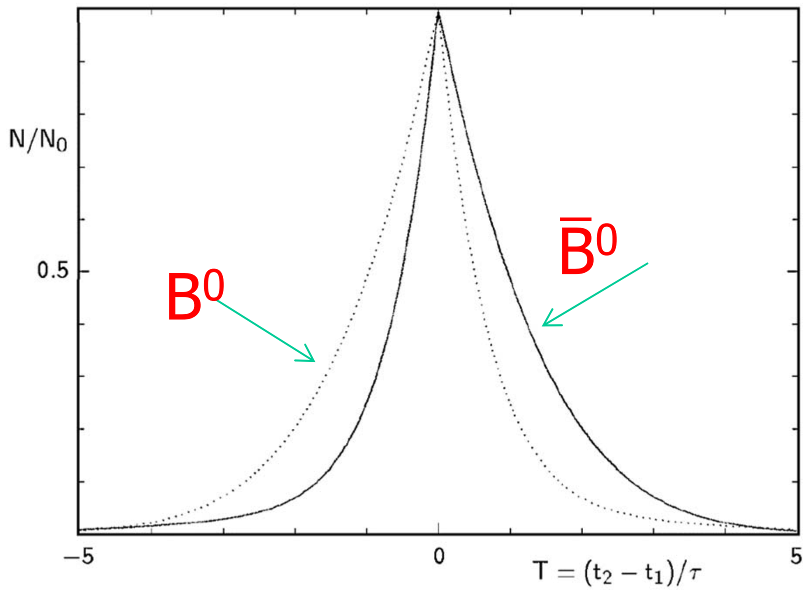
Angles: can be measured in
CP violation measurements

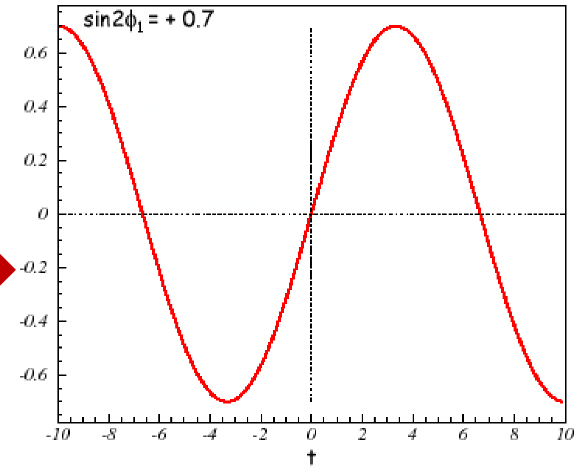


How to measure β/ϕ_1?



To determine the angle ϕ_1 of the unitarity triangle, we have to measure the time dependence of the difference in $\bar{B}^0 \rightarrow J/\Psi\ K_s$ and $B^0 \rightarrow J/\Psi\ K_s$ decays





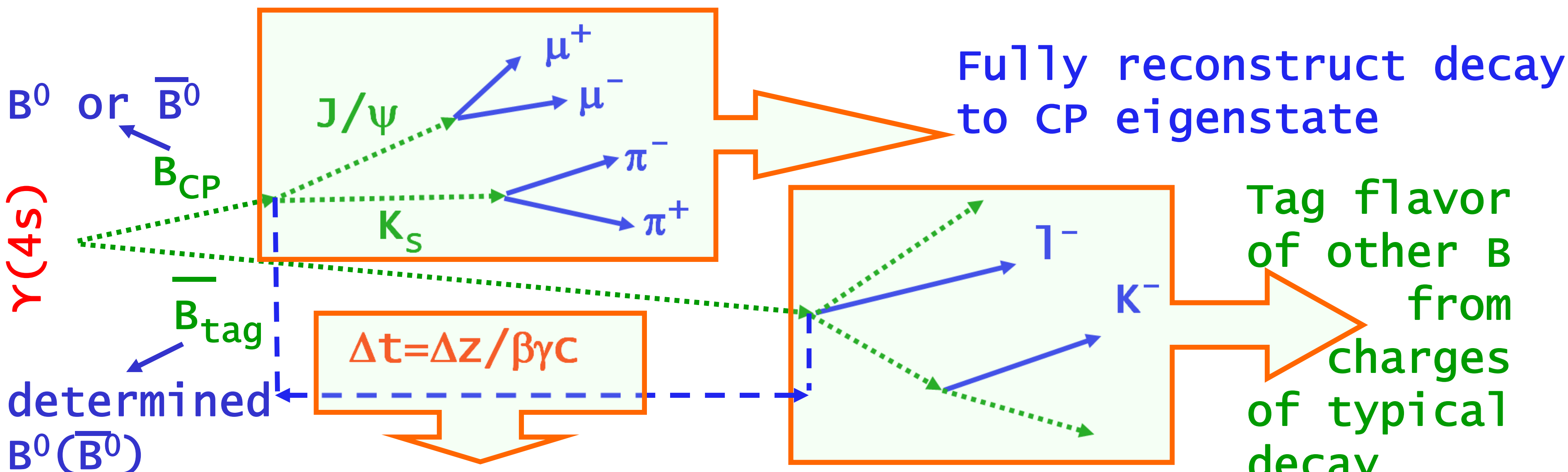
$$a_{f_{CP}} = -\frac{\Gamma(\overline{B}^0(t) \rightarrow f_{CP}) - \Gamma(B^0(t) \rightarrow f_{CP})}{\Gamma(\overline{B}^0(t) \rightarrow f_{CP}) + \Gamma(B^0(t) \rightarrow f_{CP})}$$

Time dependent decay rate difference - CP asymmetry:

$$a_{f_{CP}} = -\mathrm{Im}(\lambda_{f_{CP}})\sin(\Delta m t) = \sin 2\phi_1 \sin(\Delta m t)$$

CP violation measurement

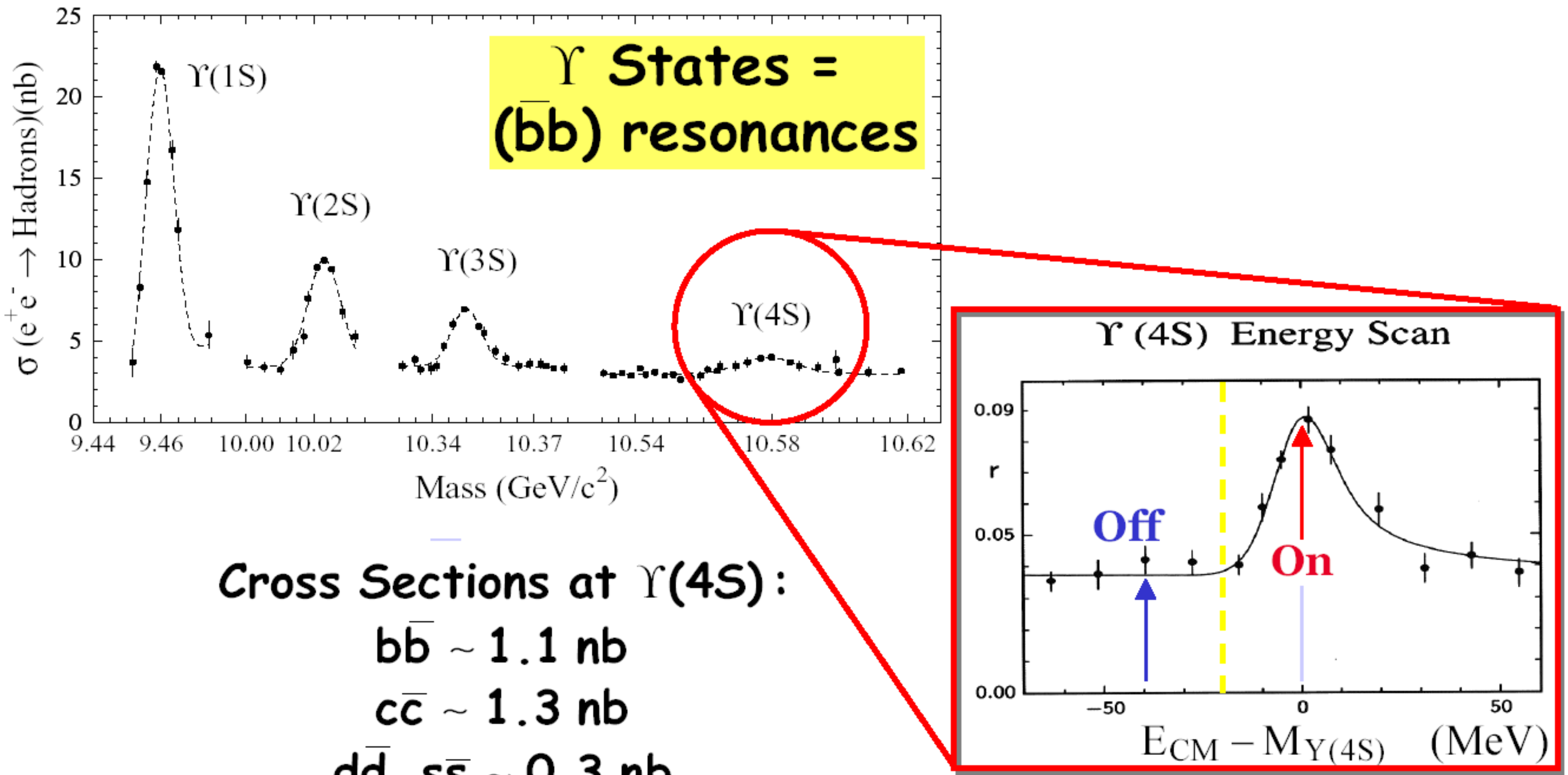
Measure the difference in time evolution in B^0 and anti-B^0 decays to a CP eigenstate



Determine time between decays

→ center-of-mass-system should be boosted!

B meson production at Υ(4s)



Cross Sections at Υ(4S):

$b\bar{b} \sim 1.1$ nb

$c\bar{c} \sim 1.3$ nb

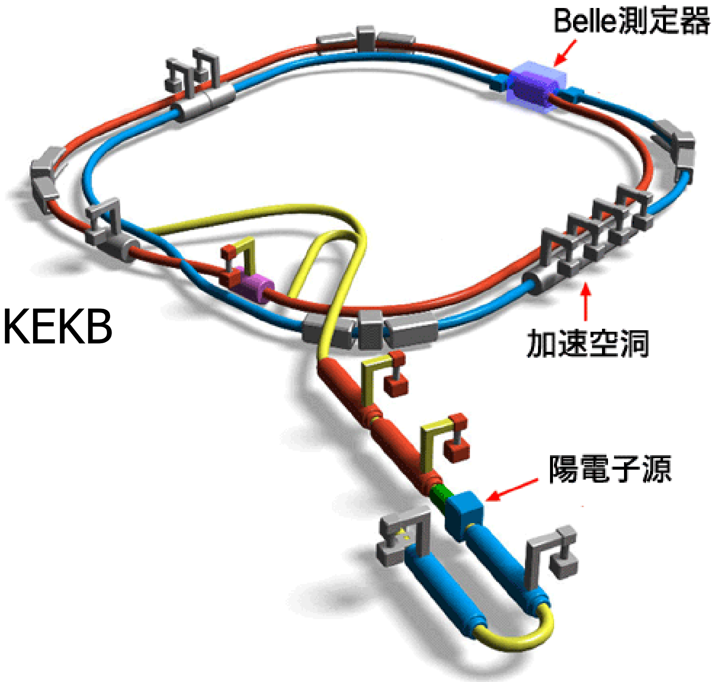
$d\bar{d}, s\bar{s} \sim 0.3$ nb

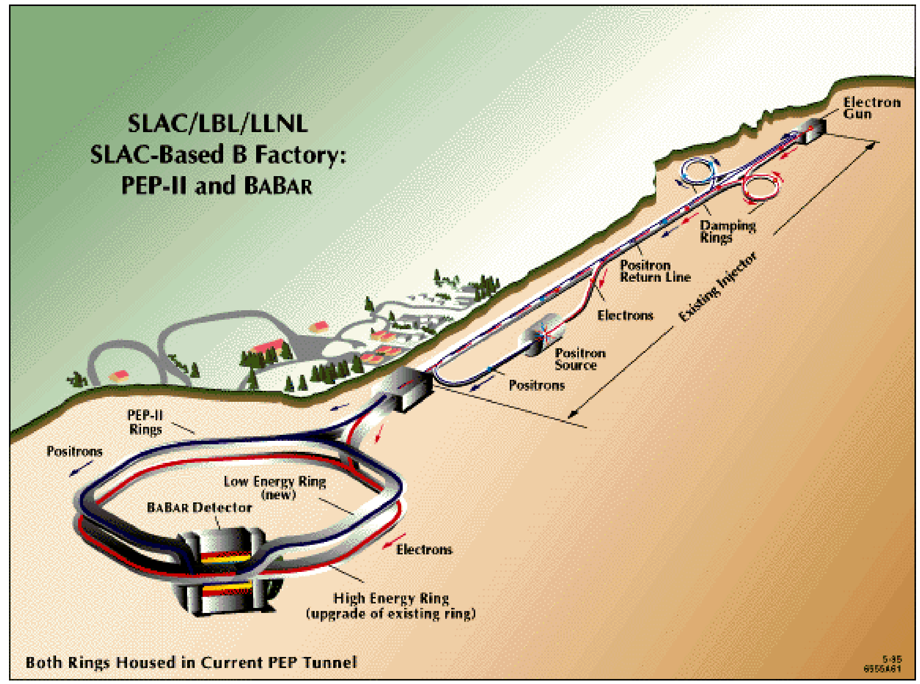
$u\bar{u} \sim 1.4$ nb

$e^+e^- \to \Upsilon(4S) \to B\bar{B}$

$L = 1$ state

Flavour physics at the luminosity frontier with asymmetric B factories





$\sqrt{s}=10.58$ GeV

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

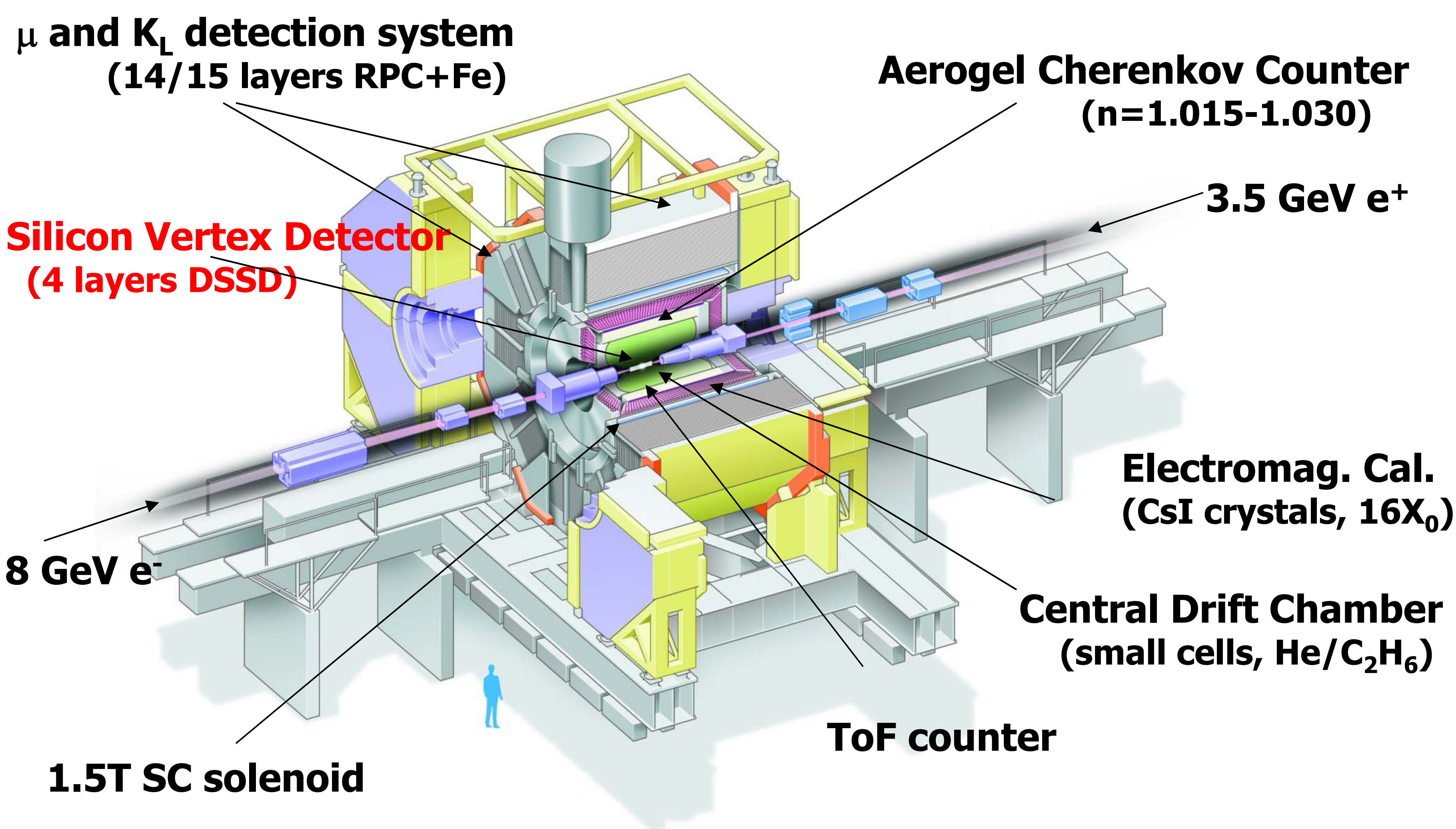
$\Upsilon(4s) \rightarrow B\,\bar{B}$

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

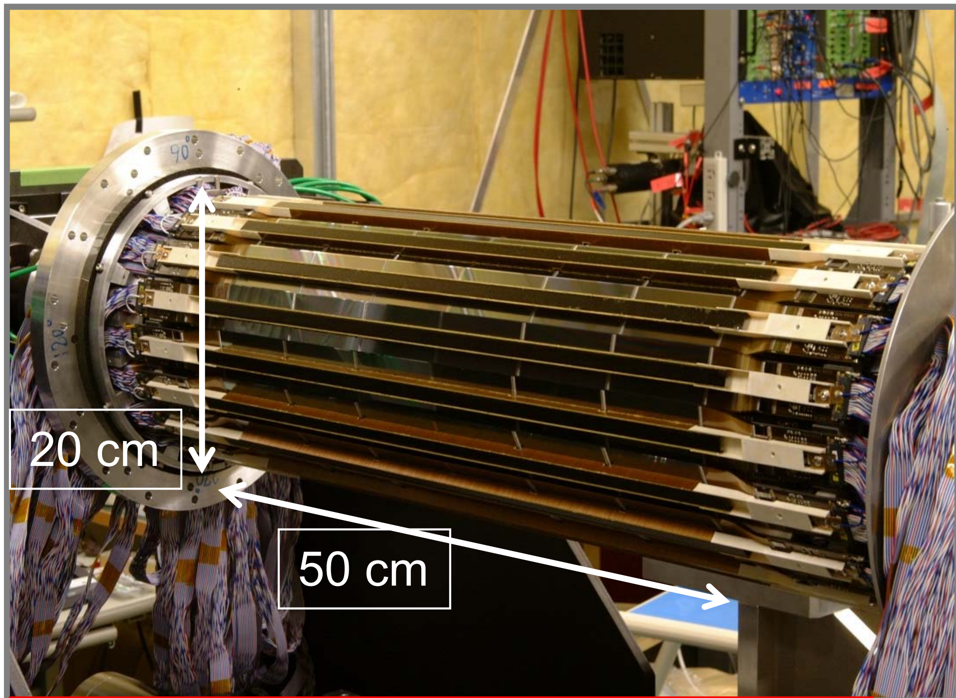
BaBar	$p(e^-)=9$ GeV	$p(e^+)=3.1$ GeV	$\beta\gamma=0.56$
Belle	$p(e^-)=8$ GeV	$p(e^+)=3.5$ GeV	$\beta\gamma=0.42$

To a large degree shaped flavour physics in the previous decade

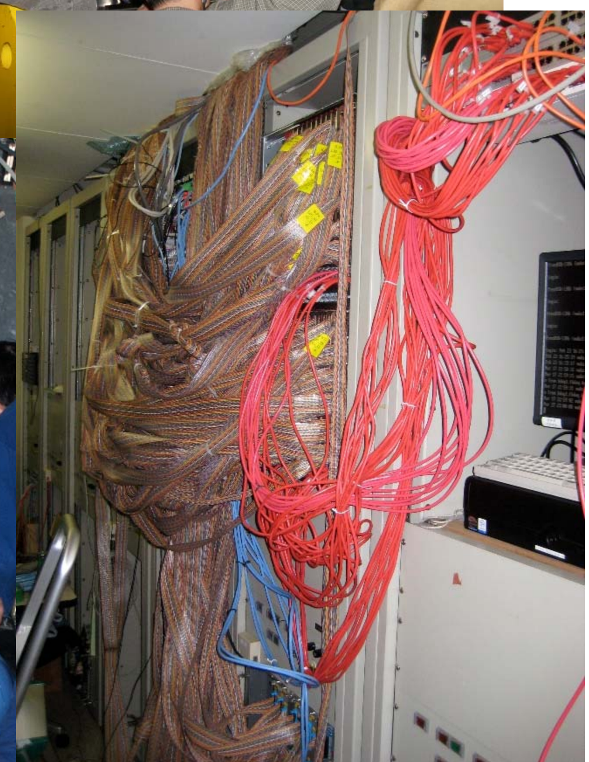
Belle spectrometer at KEK-B



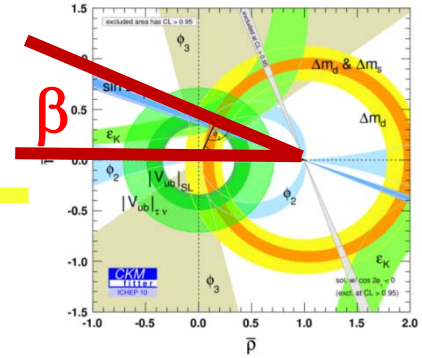
SVD: Silicon strip Vertex Detector



Read-out electronics: HEPHY

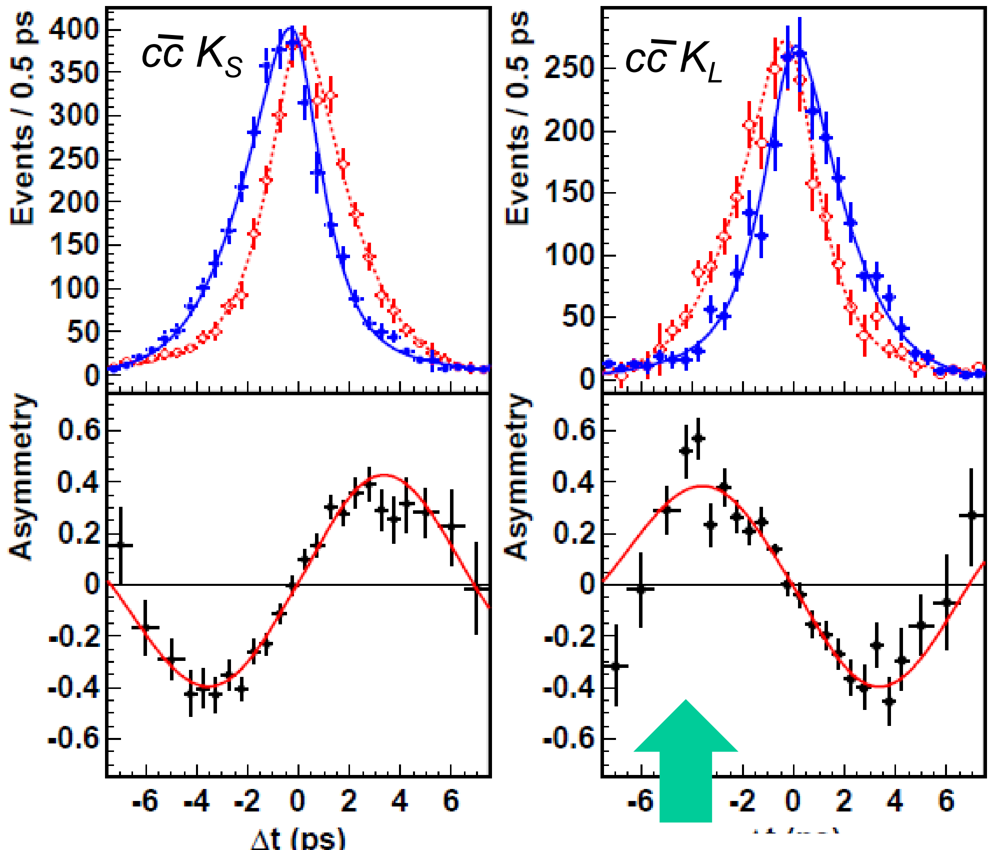


Final measurement of $\sin2\phi_1$ ($=\sin2\beta$)



ϕ_1 from CP violation measurements in $B^0 \to J/\psi K^0$

$$a_{f_{CP}} = -\mathrm{Im}(\lambda_{f_{CP}})\sin(\Delta m t) = \sin 2\phi_1 \sin(\Delta m t)$$



Opposite CP → sine wave with a flipped sign

$\sin2\phi_1$ ($=\sin2\beta$)

Belle:	0.668 ± 0.023 ± 0.012
BaBar:	0.687 ± 0.028 ± 0.012

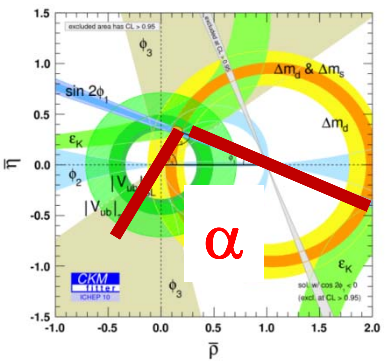
Belle, PRL 108, 171802 (2012)

BaBar, PRD 79, 072009 (2009)

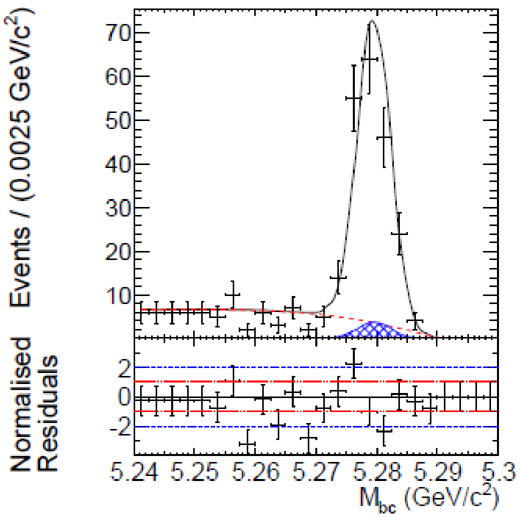
with a single experiment precision of ~4%!

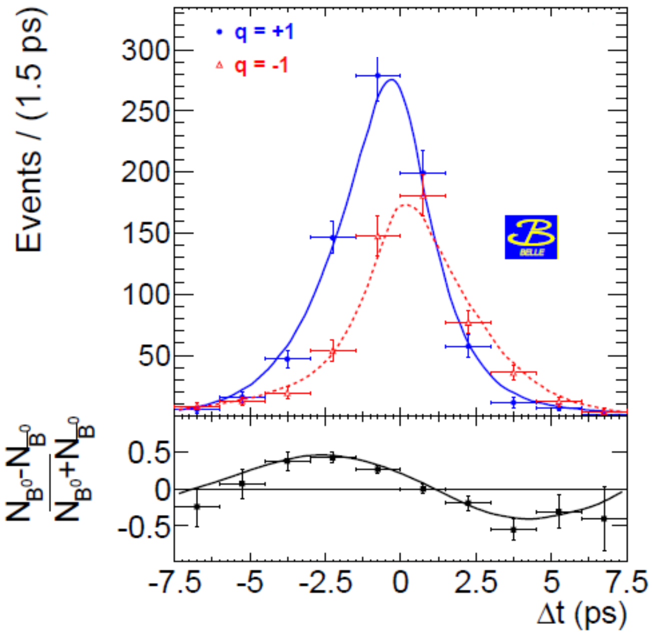
$\phi_1=\beta= (21.4\pm0.8)^0$

Final measurement of ϕ_2 (α) in B → $\pi^+\pi^-$ decays



ϕ_2 from CP violation measurements in $B^0 \to \pi^+\pi^-$



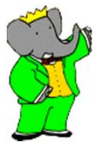


Belle, 710 fb^{-1}
PRD **88**, 092003 (2013)

$$a_{f_{CP}} = C\cos(\Delta m t) + S\sin(\Delta m t)$$

Belle, this measurement:
S = −0.64 ± 0.08 ± 0.03
C = −0.33 ± 0.06 ± 0.03

BaBar:
S = −0.68 ± 0.10 ± 0.03
C = −0.25 ± 0.08 ± 0.02

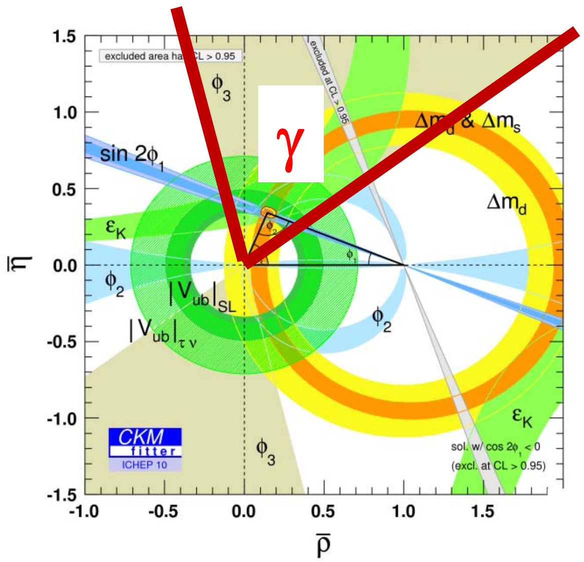


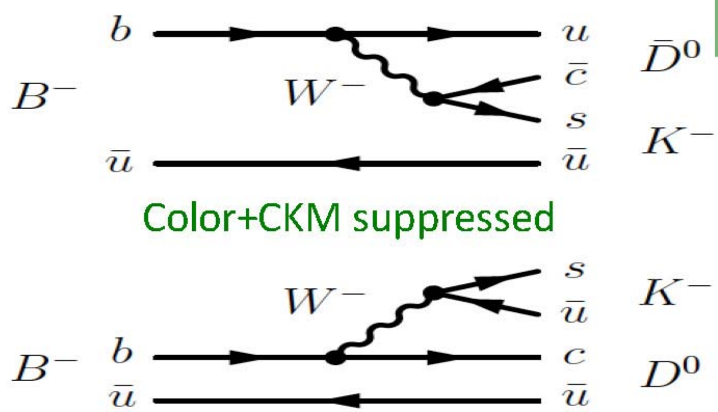
ϕ_3 (=γ) with Dalitz analysis

A. Giri et al., PRD68, 054018 (2003)
A. Bondar et al (Belle), Proc. BINP Meeting on Dalitz Analyses, 2002

GGSZ method:

The best way to measure ϕ_3





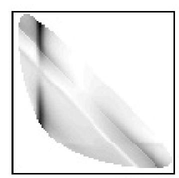
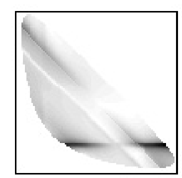
Color+CKM suppressed

Favored

$\overset{(-)}{D^0} \rightarrow K_S\pi^+\pi^-$

3-body $D^0 \rightarrow K_S\pi^+\pi^-$ Dalitz amplitude

$$|M_\pm(m_+^2, m_-^2)|^2 = |f_D(m_+^2, m_-^2) + re^{i\delta_B \pm i\phi_3} f_D(m_-^2, m_+^2)|^2$$

$= \Big|$  $+ re^{i\delta_B \pm i\phi_3}$  $\Big|^2$

Model dependent description of f_D using continuum D* data $\Rightarrow$ systematic uncertainty

ϕ_3=(78 ± 12 ± 4 ± 9)°

Belle, PRD81, 112002, (2010), 605 fb^{-1}

ϕ_3=(68 ± 14 ± 4 ± 3)°

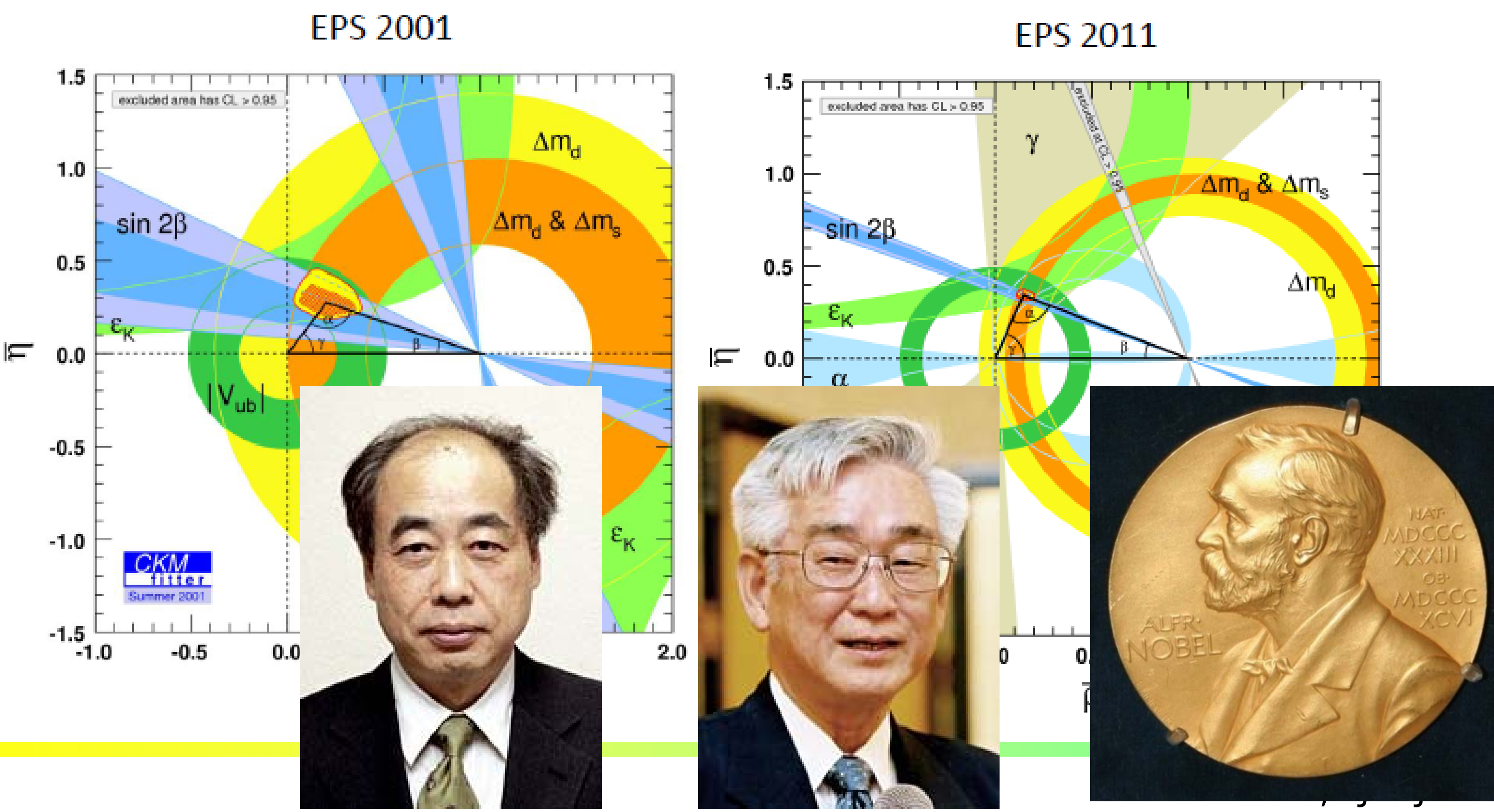
BaBar, PRL 105, 121801, (2010)

Unitarity triangle: progress

Measurements of the angles from discovery (2001) to a precision measurement (2011).

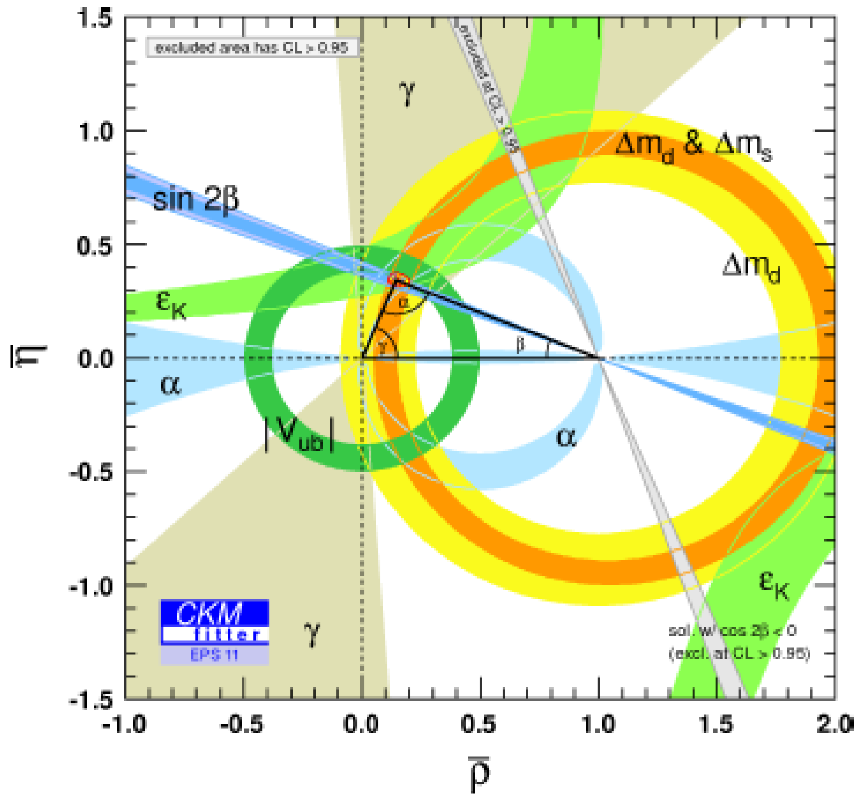
+ determination of the sides by measuring Vub and Vcb (C. Schwanda)

→ consistent picture



The unitarity triangle – status

Constraints from measurements of angles and sides of the unitarity triangle → remarkable agreement, but contributions of New Physics could be as high as 10-20%

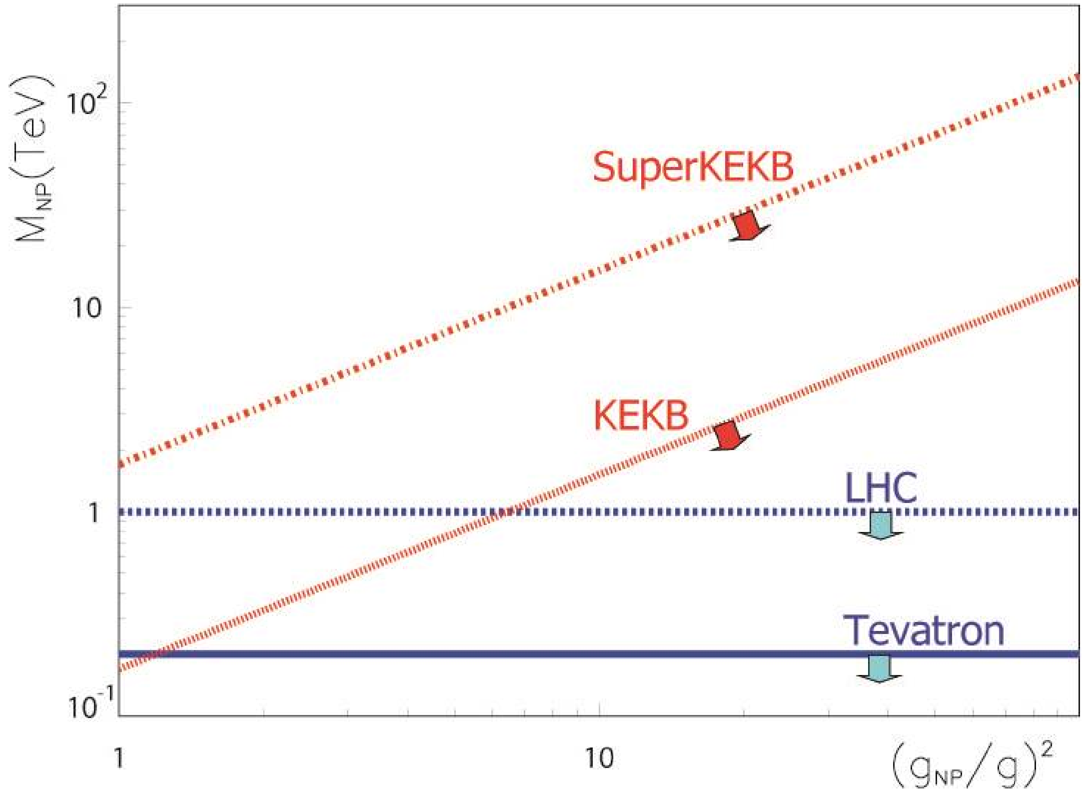


→investigate possible NP phenomena with precise measurements

→Intensity frontier

Intensity Frontier vs Energy Frontier

Reach in mass of New Physics particles



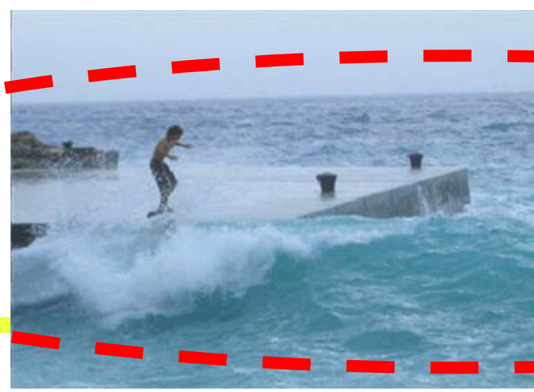
New Physics coupling vs standard model

→ A very interesting complementarity of the two approaches

Comparison of **energy** /**intensity** frontiers

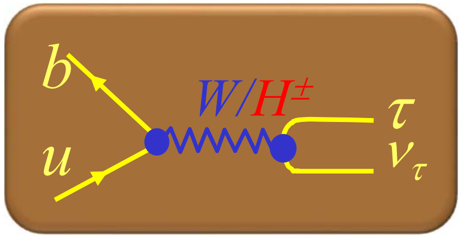
To observe a large ship far away one can either use **strong binoculars** or observe **carefully the direction and the speed of waves** produced by the vessel.

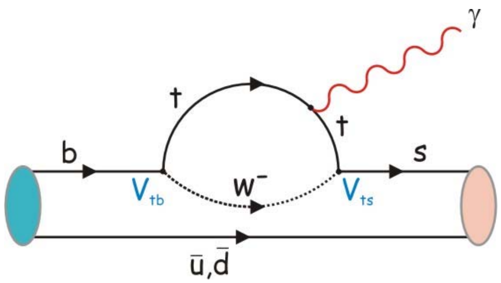
Energy frontier (LHC)

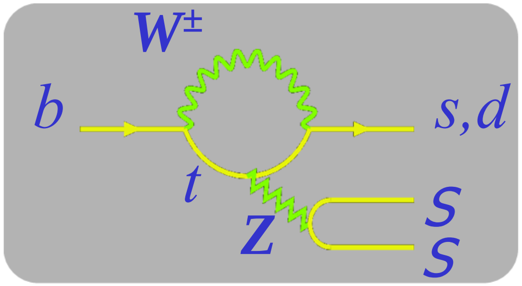


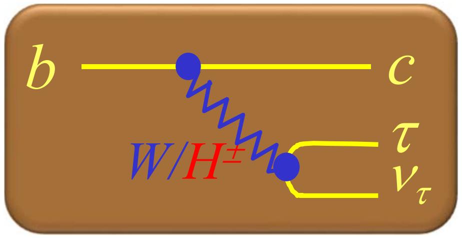
Luminosity frontier - (super) B factories

Rare B decays





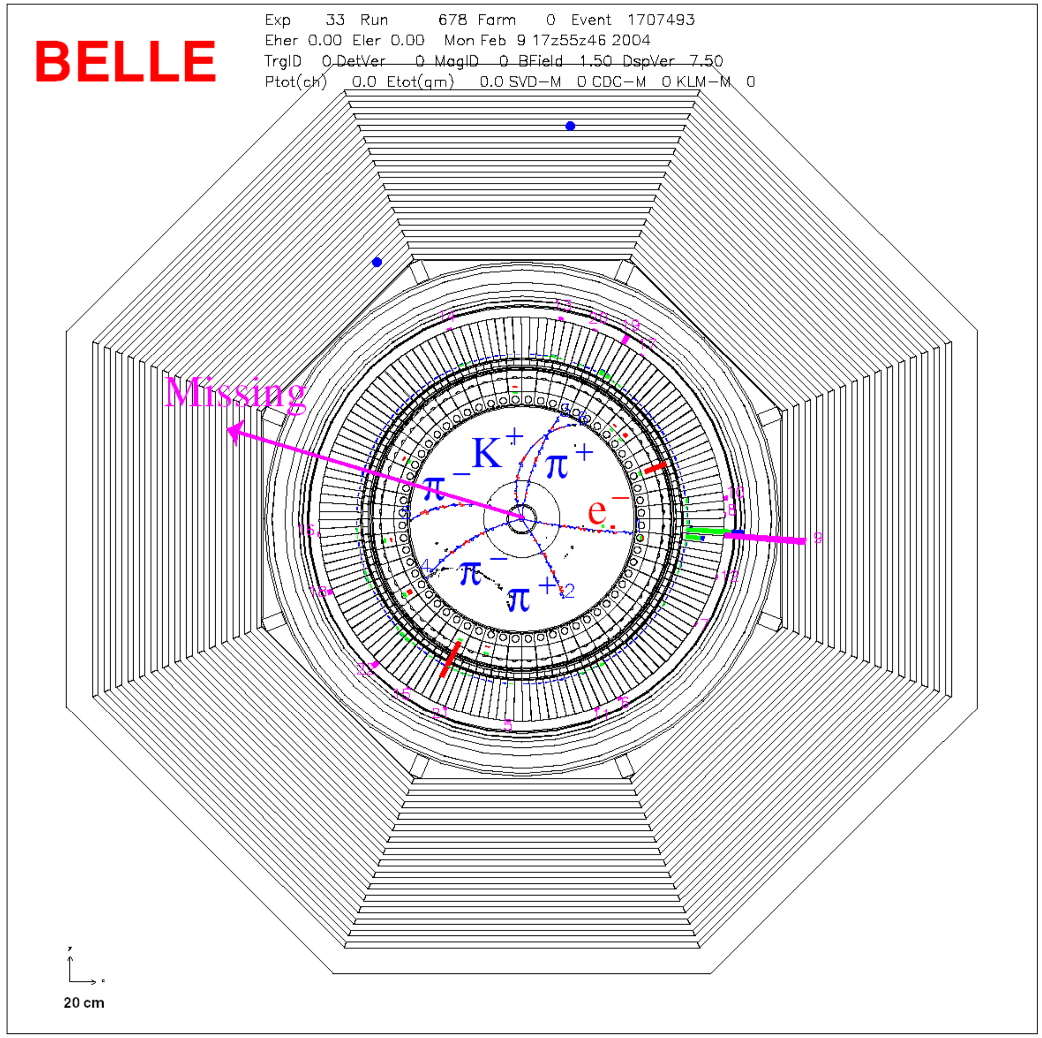




$B^- \rightarrow \tau^- \nu_\tau$

Example of a missing energy decay

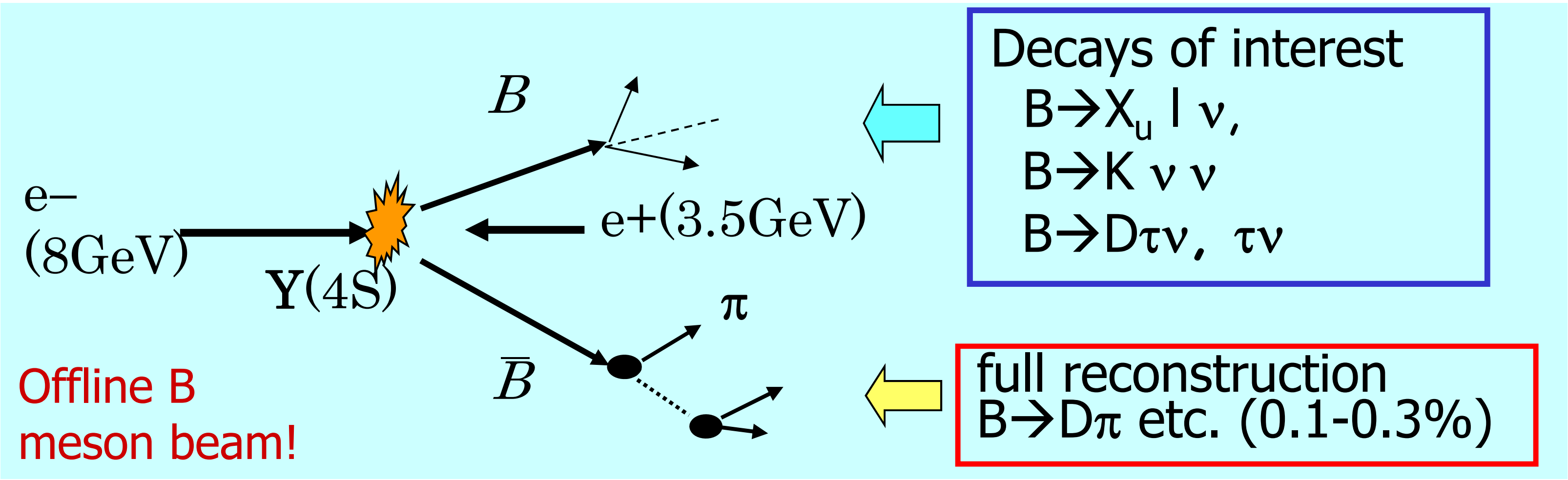
$$B^+ \longrightarrow D^0\pi^+$$
$$(\rightarrow K\pi^-\pi^+\pi^-)$$
$$B^- \rightarrow \tau(\rightarrow e\nu\bar{\nu})\nu$$



Full reconstruction tagging

Idea: fully reconstruct one of the B's to tag B flavor/charge, determine its momentum, and exclude decay products of this B from further analysis

(exactly two B's produced in Υ(4S) decays)



Powerful tool for B decays with neutrinos

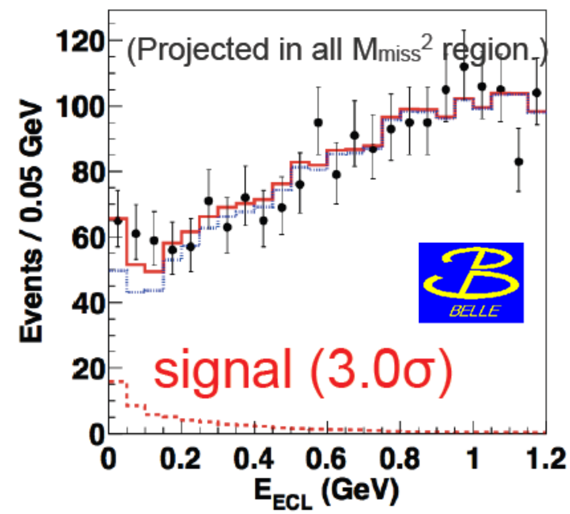
→unique feature at B factories

$B^- \to \tau^- \nu_\tau$

Method: tag one B with full reconstruction, look for the $B^- \to \tau^- \nu_\tau$ in the rest of the event.

Main discriminating variable on the signal side: remaining energy in the calorimeter, not associated with any charged track or photon

→ Signal at $E_{ECL} = 0$

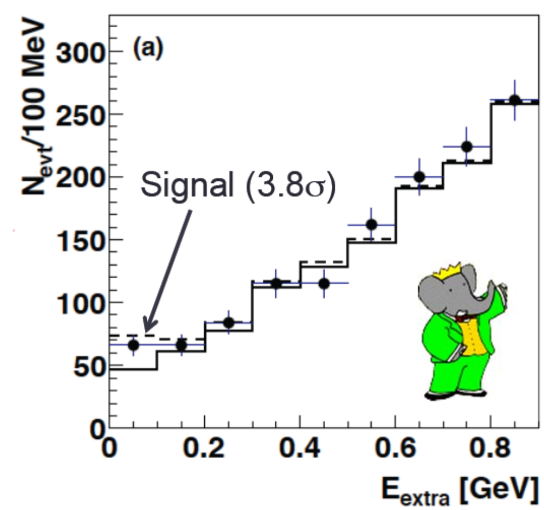


Belle $$Br(B \to \tau\nu) = [0.72\ ^{+0.27}_{-0.25} \pm 0.11] \times 10^{-4}$$

PRL 110, 131801 (2013)

BaBar $$Br(B \to \tau\nu) = [1.83\ ^{+0.53}_{-0.49} \pm 0.24] \times 10^{-4}$$

Phys. Rev. D 88, 031102(R) (2013)

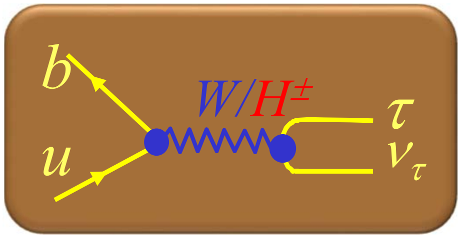


Combined

$$BF(B \to \tau\nu) = (1.15 \pm 0.23) \cdot 10^{-4}$$

$$r_H = \frac{BF(B \to \tau\nu)_{meas}}{BF(B \to \tau\nu)_{SM}} = 1.14 \pm 0.40$$

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

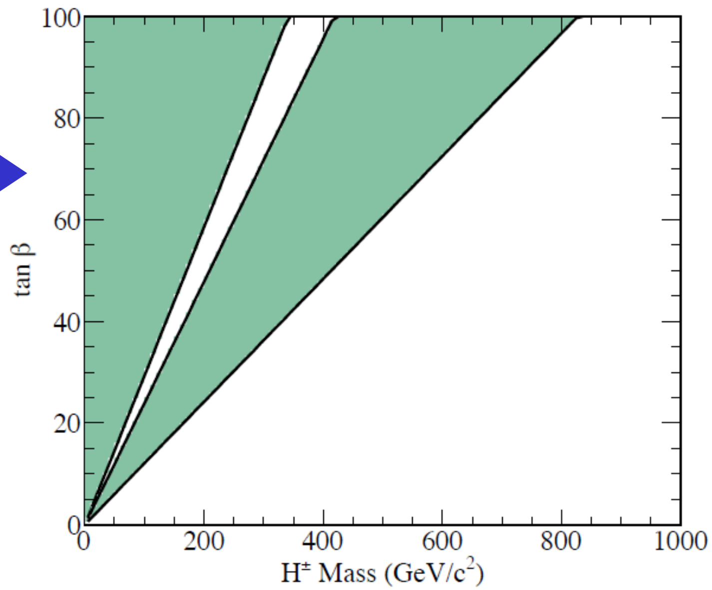


Measured value

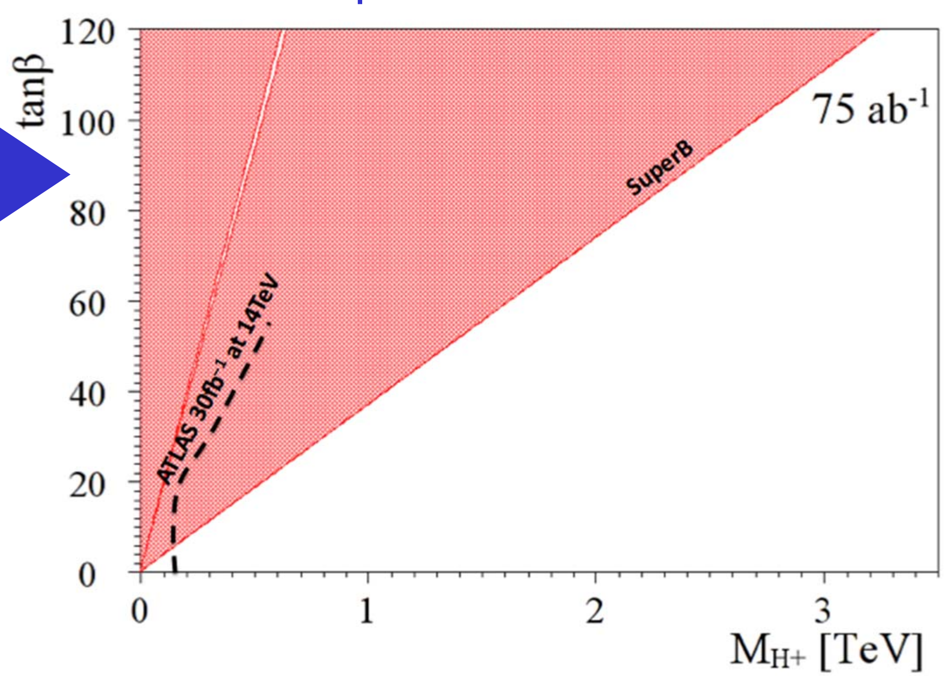
$$r_H = \frac{BF(B \to \tau\nu)}{BF(B \to \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

→ limit on charged Higgs mass vs. tanβ
(for type II 2HDM)

B factories: Exclusion plot



Super B factory: Discovery plot: very much competitive with LHC!



Charm and τ physics

B factories = charm and τ factories

Charm and τ can be found in any "Y(nS) samples"

→ the integrated luminosity of the samples used for charm and τ studies is larger than for the B physics studies (Belle ~ 1 ab^{-1}, BaBar ~0.550 ab^{-1})

→ This will of course remain true for the super B factory

A few examples of the strengths of B factories:

- CP violation in charm at B factories (and super B factories) →can measure CPV separately in individual decay channels, $\pi^+\pi^-$, K^+K^-, $K_S\pi$,...
- $D\bar{D}$ pairs produced with very few light hadrons
- Full reconstruction of events →

Rare charm decays: tag with the other D

Again make use of the hermeticity of the apparatus!

Example: leptonic decays of D_s

$$e^+e^- \to c\overline{c} \to \overline{D}_{\rm tag} K X_{\rm frag} D_s^{*+}$$

Method pioneered at HEPHY (L. Widhalm)

Recoil method in charm events:

- Reconstruct D_{tag} to tag charm, kaon to tag strangeness
- Additional light mesons (X_{frag}) can be produced in the fragmentation process (π, $\pi\pi$, ...)

2 step reconstruction:

- Inclusive reconstruction of D_s mesons for normalization (without any requirements upon D_s decay products)
- Within the inclusive D_s sample search for D_s decays
  - $D_s \to \mu\nu$: peak at $m_\nu^2 = 0$ in $M^2_{\rm miss}(D_{\rm tag} K X_{\rm frag} \gamma \mu)$
  - $D_s \to \tau\nu$: peak towards 0 in extra energy in calorimeter

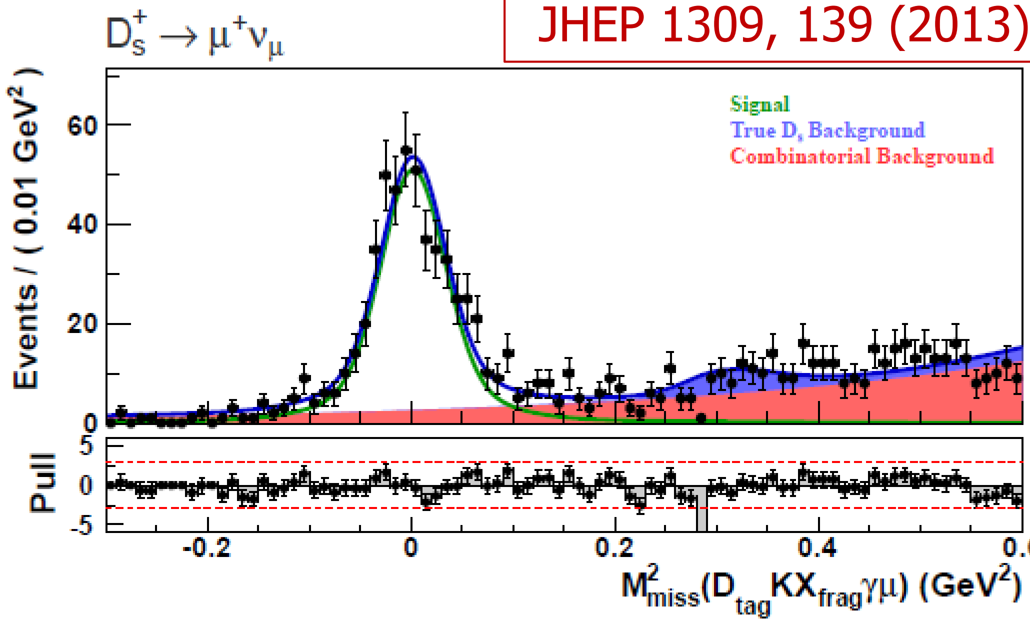
$D_s^+ \to \mu^+\nu_\mu$

Fit to the missing mass squared – $M^2_{\mathrm{miss}}(D_{\mathrm{tag}} K X_{\mathrm{frag}} \gamma \mu^\pm)$

JHEP 1309, 139 (2013)

Selection:

- $M_{\mathrm{miss}}(D_{\mathrm{tag}} K X_{\mathrm{frag}} \gamma)$ signal region
- 1 charged track pointing to the IP
- passing muon PID requirements



$$N^{\mathrm{excl}}_{D_s \to \mu\nu} = 489 \pm 26$$

Belle preliminary @ 913 fb^{-1}

$$\mathcal{B}(D_s^+ \to \mu^+\nu_\mu) = (0.528 \pm 0.028(\mathrm{stat.}) \pm 0.019(\mathrm{syst.}))\%$$

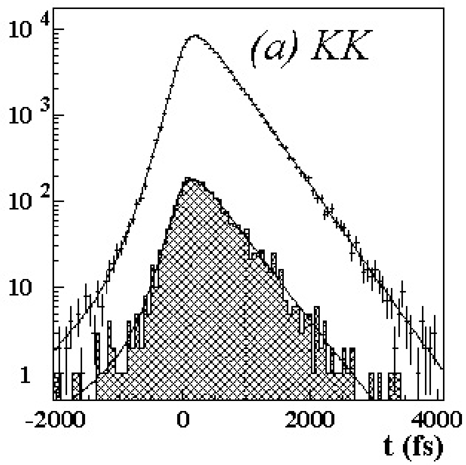
Most precise measurement up to date.

Extract f_{D_s} :

$$f_{D_s} = \frac{1}{G_F m_\ell \left(1 - \frac{m_\ell^2}{M_{D_s}^2}\right) |V_{cs}|} \sqrt{\frac{8\pi \mathcal{B}(D_s \to \ell\nu_\ell)}{M_{D_s} \tau_{D_s}}}$$

Charm, last but not least:
discovery of D^0 mixing in K^+K^-, $\pi^+\pi^-$

Decay time distributions for KK, ππ, Kπ



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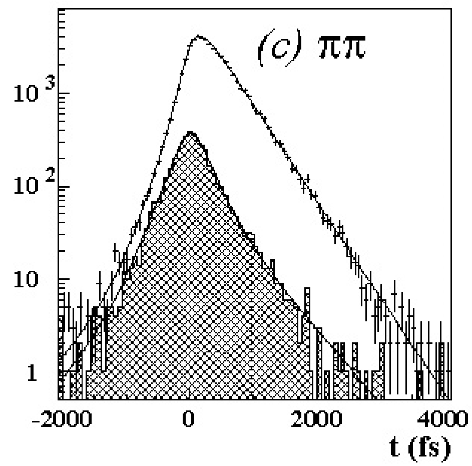
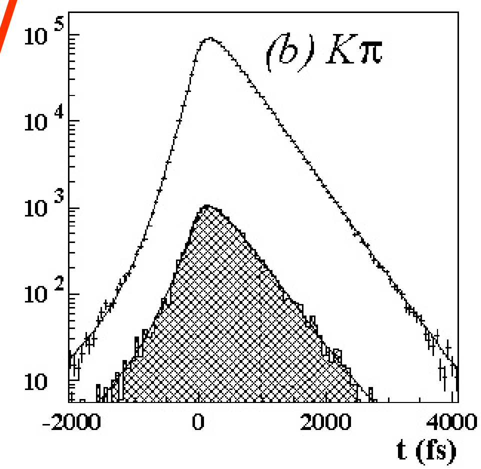
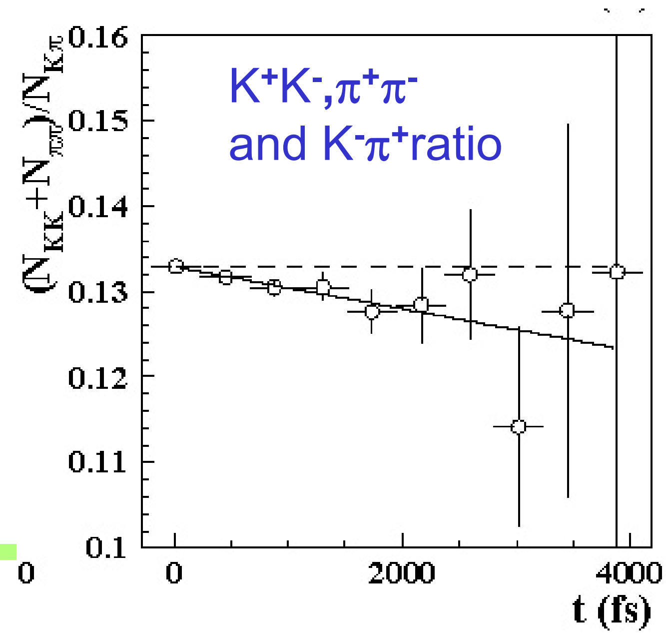




Mixing parameter

$$y_{CP} \equiv \frac{\tau(K^-\pi^+)}{\tau(K^-K^+)} - 1 \underset{no\ CPV}{=} y$$

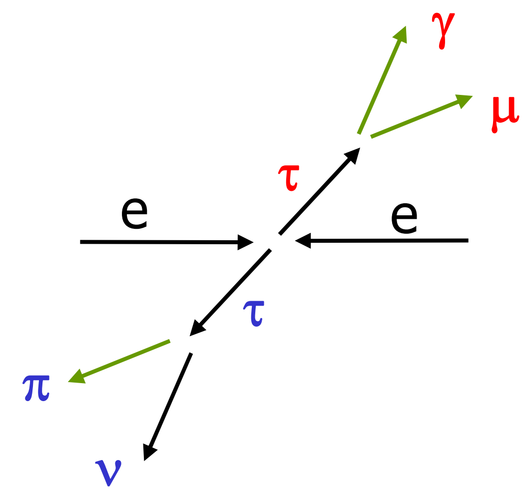
Difference of lifetimes
visually observable
in the ratio of the distributions →



PRL 98, 211803 (2007), 540fb^{-1}

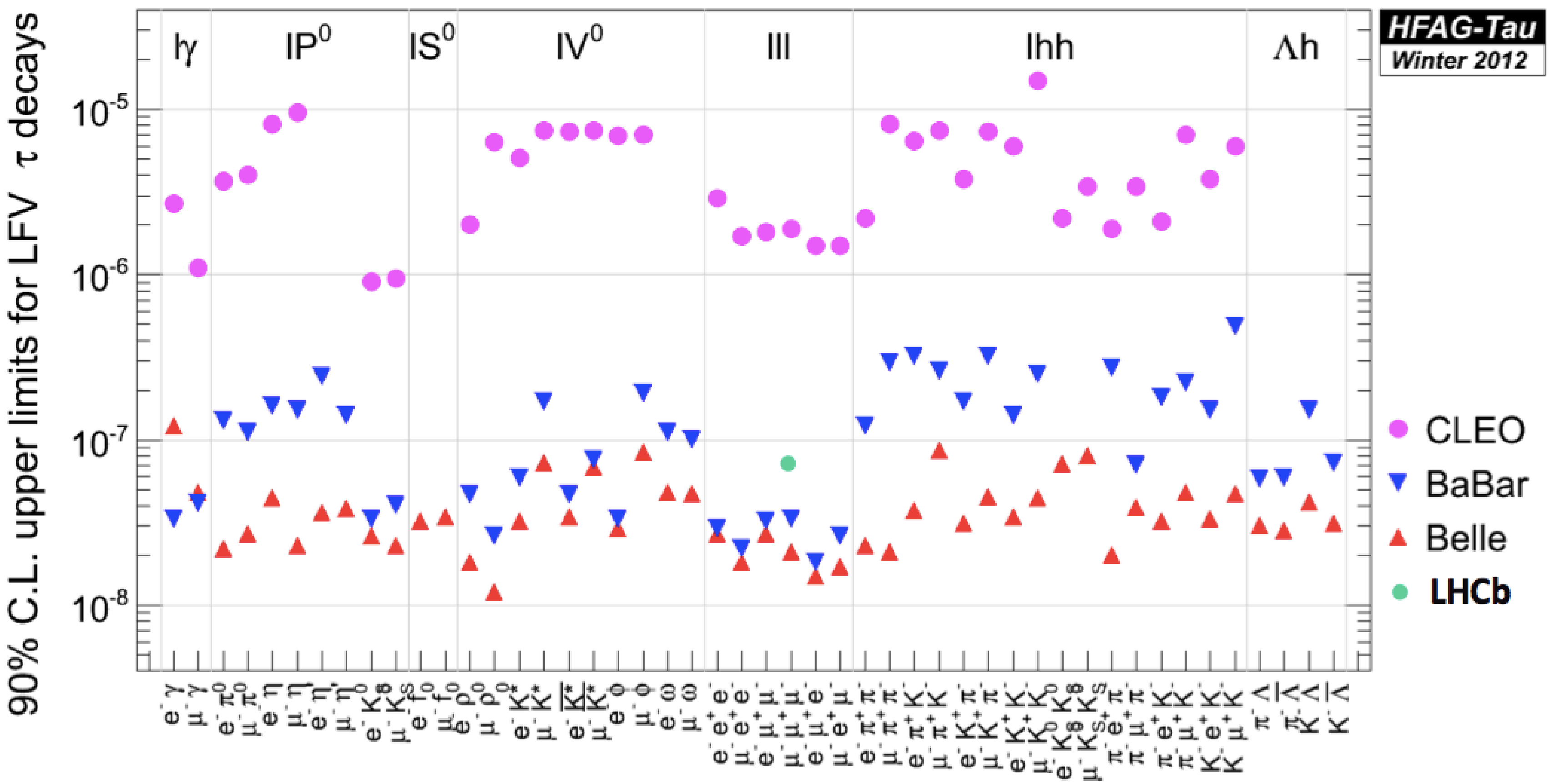
Rare τ decays

Example: lepton flavour violating decay $\tau \rightarrow \mu\,\gamma$



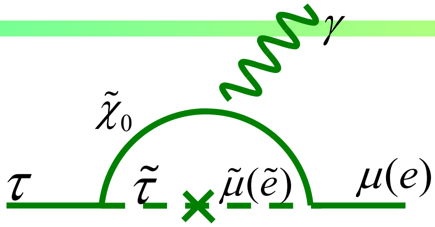
LFV in tau decays: present status

Lepton flavour violation (LFV) in tau decays: would be a clear sign of new physics



LFV and New Physics

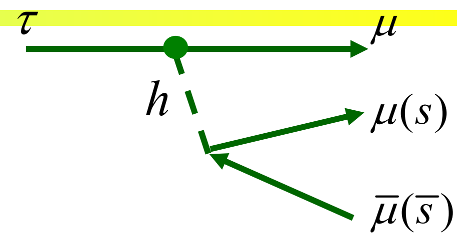
$\tau \rightarrow l\gamma$



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

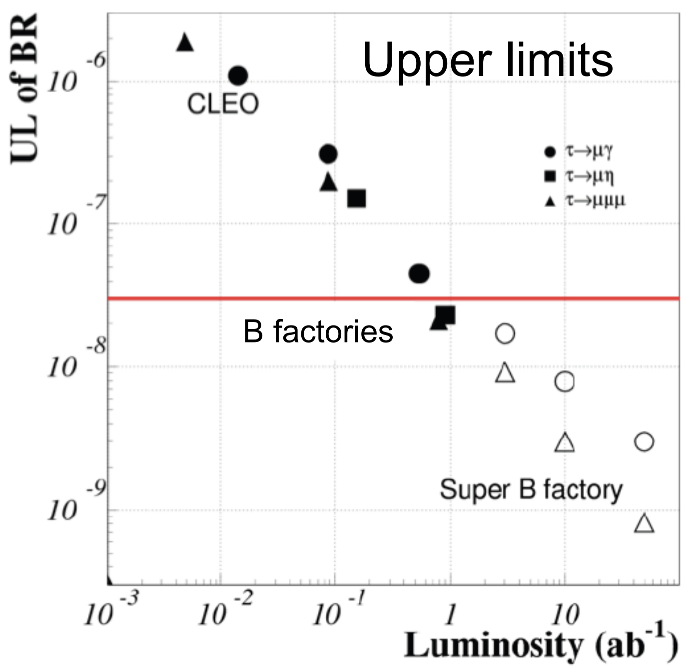
$$Br(\tau \rightarrow \mu\gamma) \simeq 10^{-6} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}}\right)\left(\frac{1\,TeV}{m_{SUSY}}\right)^4 \tan^2\beta$$

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



- Neutral Higgs mediated decay.
- Important when M_{SUSY} >> EW scale.

$$Br(\tau \rightarrow 3\mu) = 4\times 10^{-7} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}}\right)\left(\frac{\tan\beta}{60}\right)^6\left(\frac{100GeV}{m_A}\right)^4$$



Integ. Lum.(ab^{-1})

model	$Br(\tau\rightarrow\mu\gamma)$	$Br(\tau\rightarrow lll)$
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}

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 $b \rightarrow sl^+l^-$
- Observation of D mixing
- Searches for rare τ decays
- Discovery of exotic hadrons including charged charmonium- and bottomonium-like states

B factories remain competitive in many measurements because of their unique capabilities.

What next?

Next generation: Super B factories → Looking for NP

→ Need much more data (almost two orders!)

However: it will be a different world in three years, there is a hard competition from LHCb and BESIII

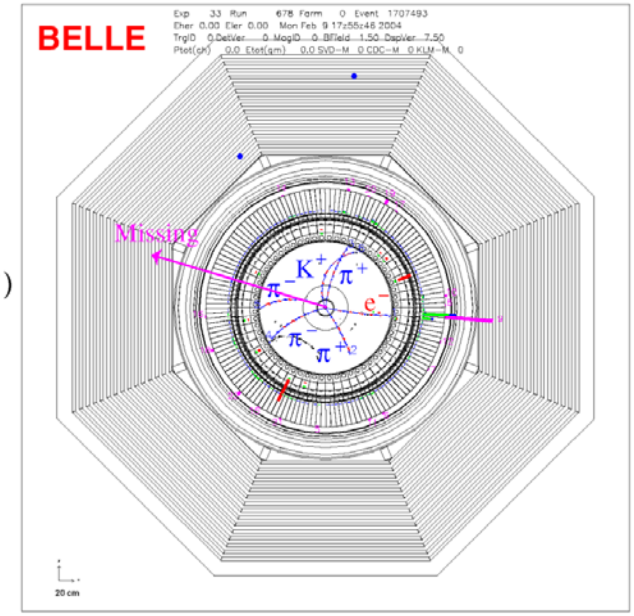
Still, e^+e^- machines running at (or near) Υ(4s) will have considerable advantages in several classes of measurements, and will be complementary in many more

→ Physics at Super B Factory, arXiv:1002.5012 (Belle II)

→ SuperB Progress Reports: Physics, arXiv:1008.1541 (SuperB)

Advantages of B factories in the LHC era

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



Unique capabilities of B factories:

→ Exactly two B mesons produced (at Υ(4S))

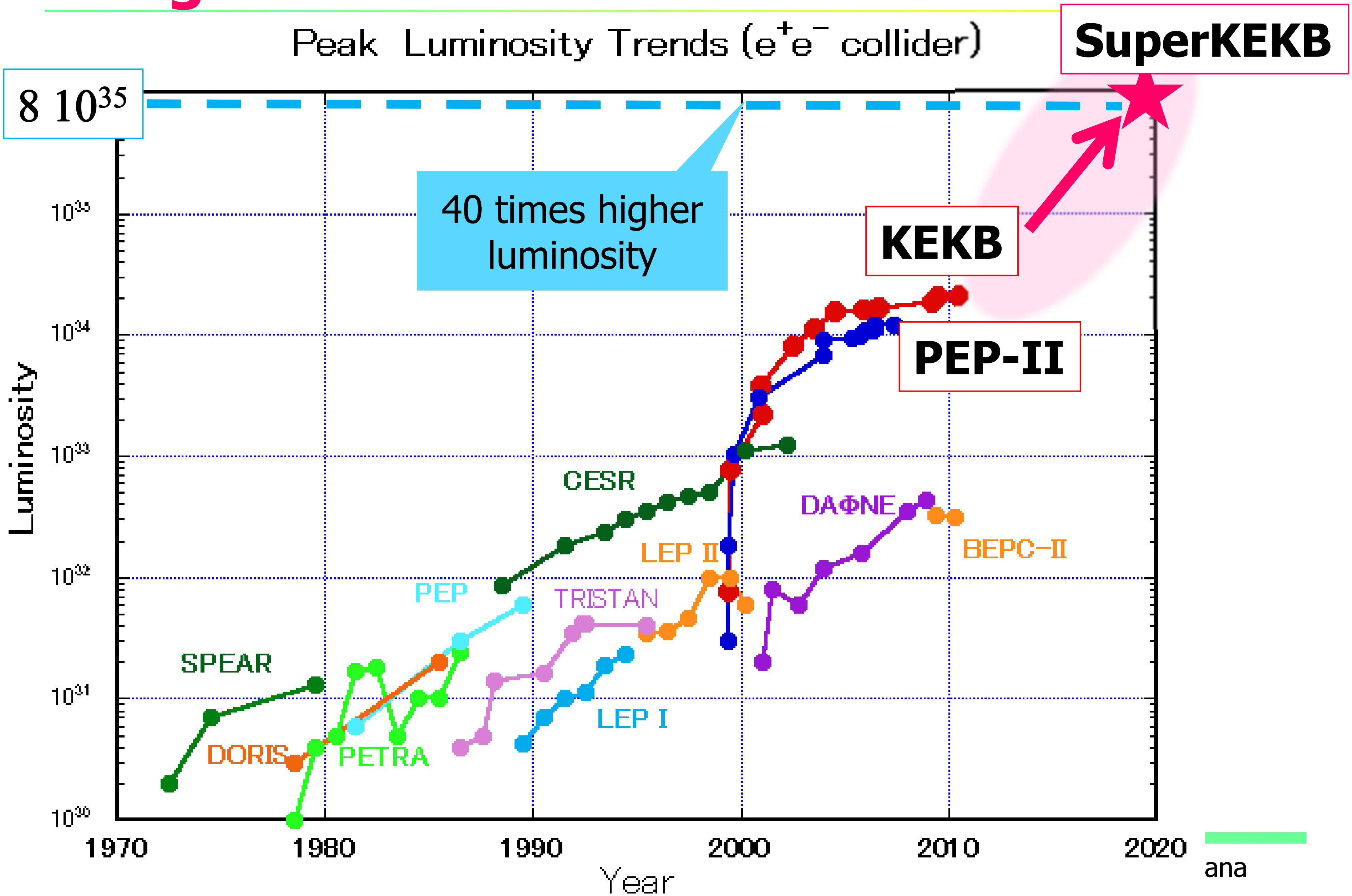
→ High flavour tagging efficiency

→ Detection of gammas, π^0s, K_Ls

→ Very clean detector environment (can observe decays with several neutrinos in the final state!)

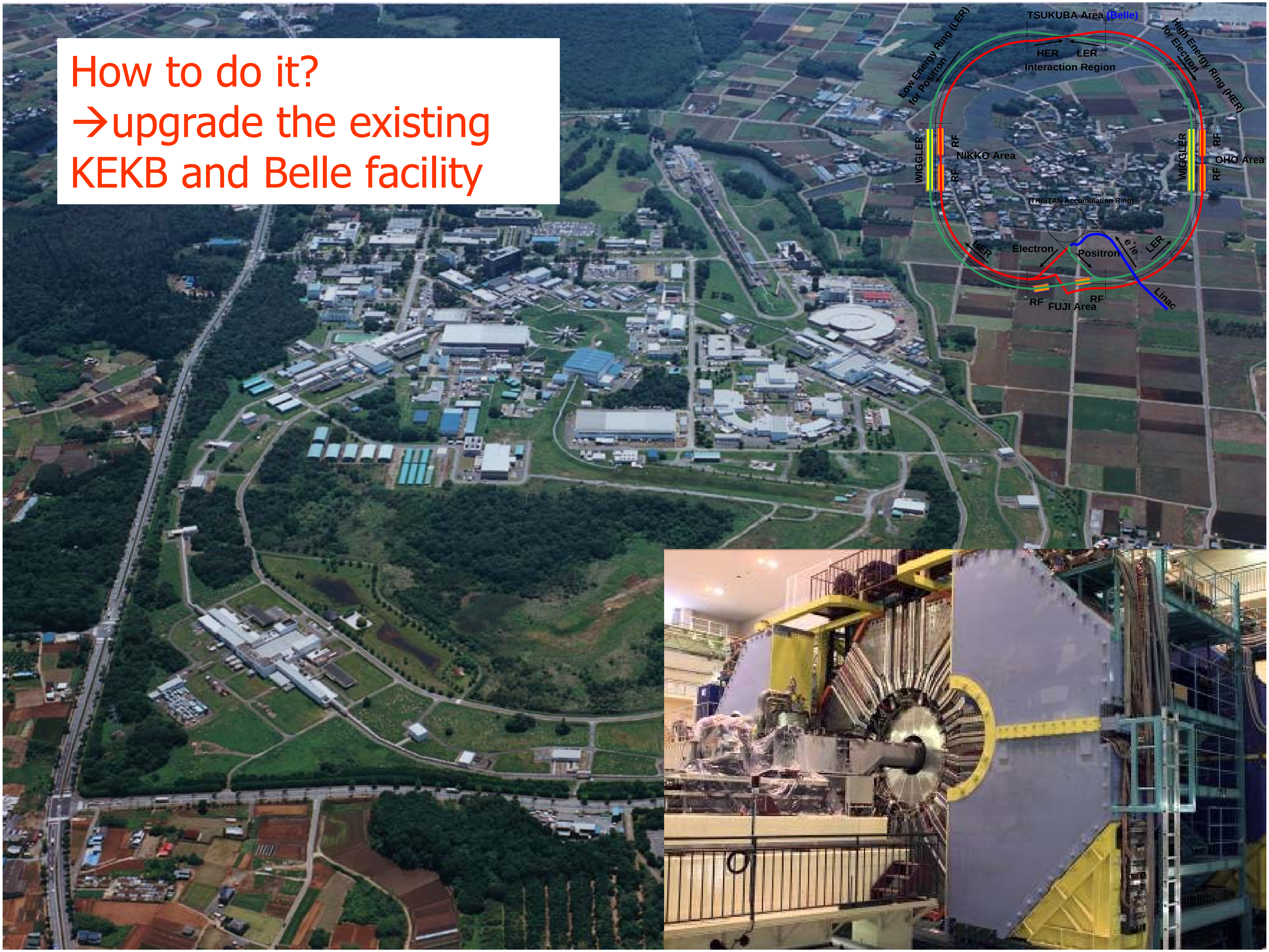
<u>However, need a two-orders-of-magnitude larger data sample!</u>

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



ana

How to do it?
→upgrade the existing KEKB and Belle facility



How to increase the luminosity?

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

(1) Smaller β_y^*
(2) Increase beam currents
(3) Increase ξ_y

"Nano-Beam" scheme

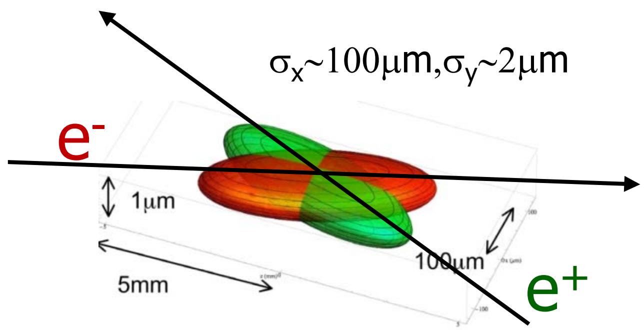
Collision with very small spot-size beams

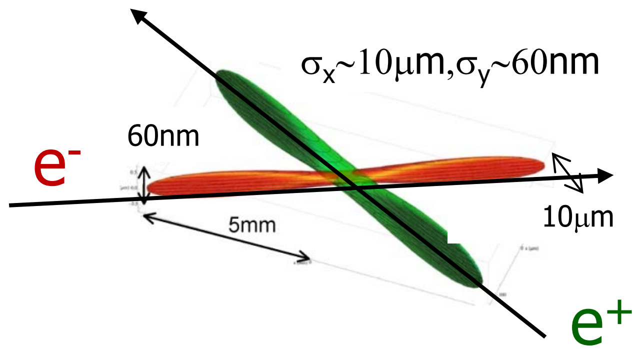
Invented by Pantaleo Raimondi for SuperB

How big is a nano-beam ?

How to go from an excellent accelerator with world record performance – KEKB – to a 40x times better, more intense facility?

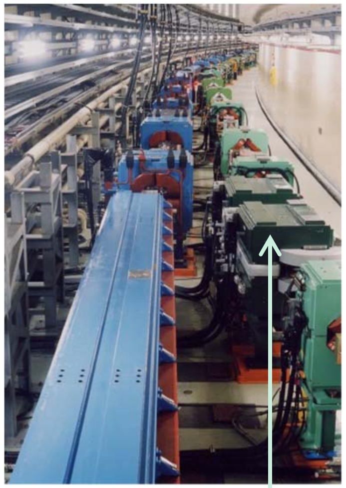
In KEKB, colliding electron and positron beams were already much thinner than a human hair...



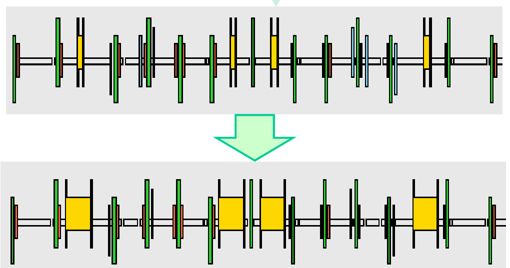


... For a 40x increase in intensity you have to make the beam as thin as a few x100 atomic layers!

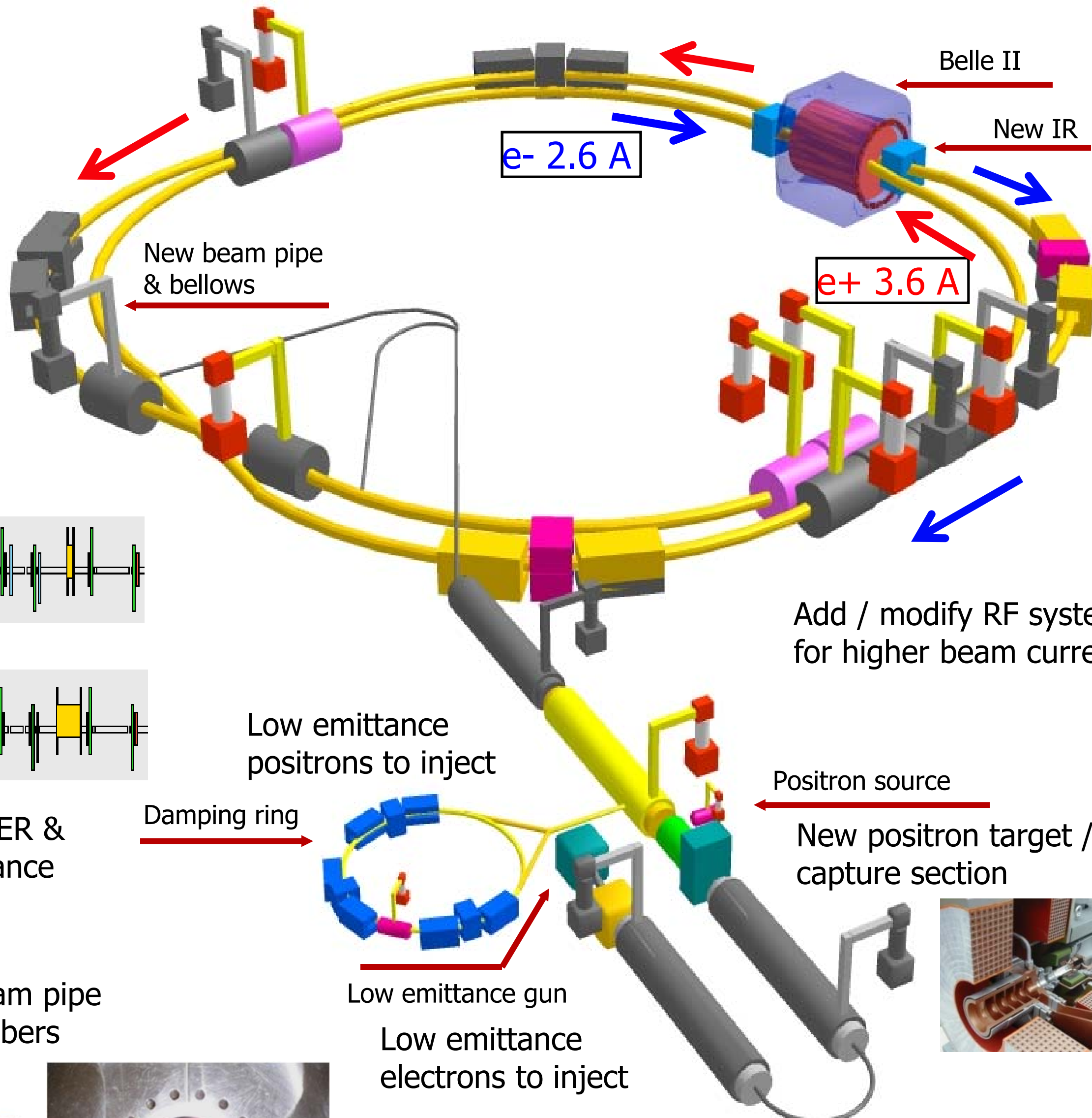
KEKB → SuperKEKB



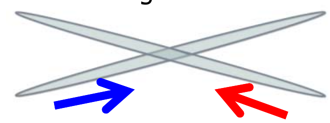
Replace short dipoles with longer ones (LER)



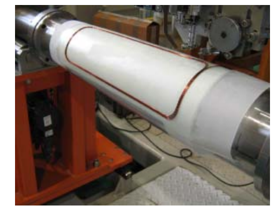
Redesign the lattices of HER & LER to squeeze the emittance



Colliding bunches



New superconducting /permanent final focusing quads near the IP



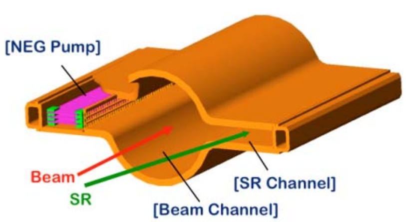
Add / modify RF systems for higher beam current

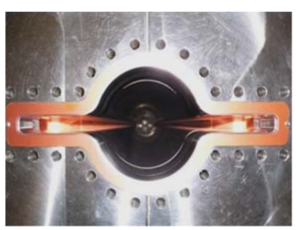
Low emittance positrons to inject

New positron target / capture section

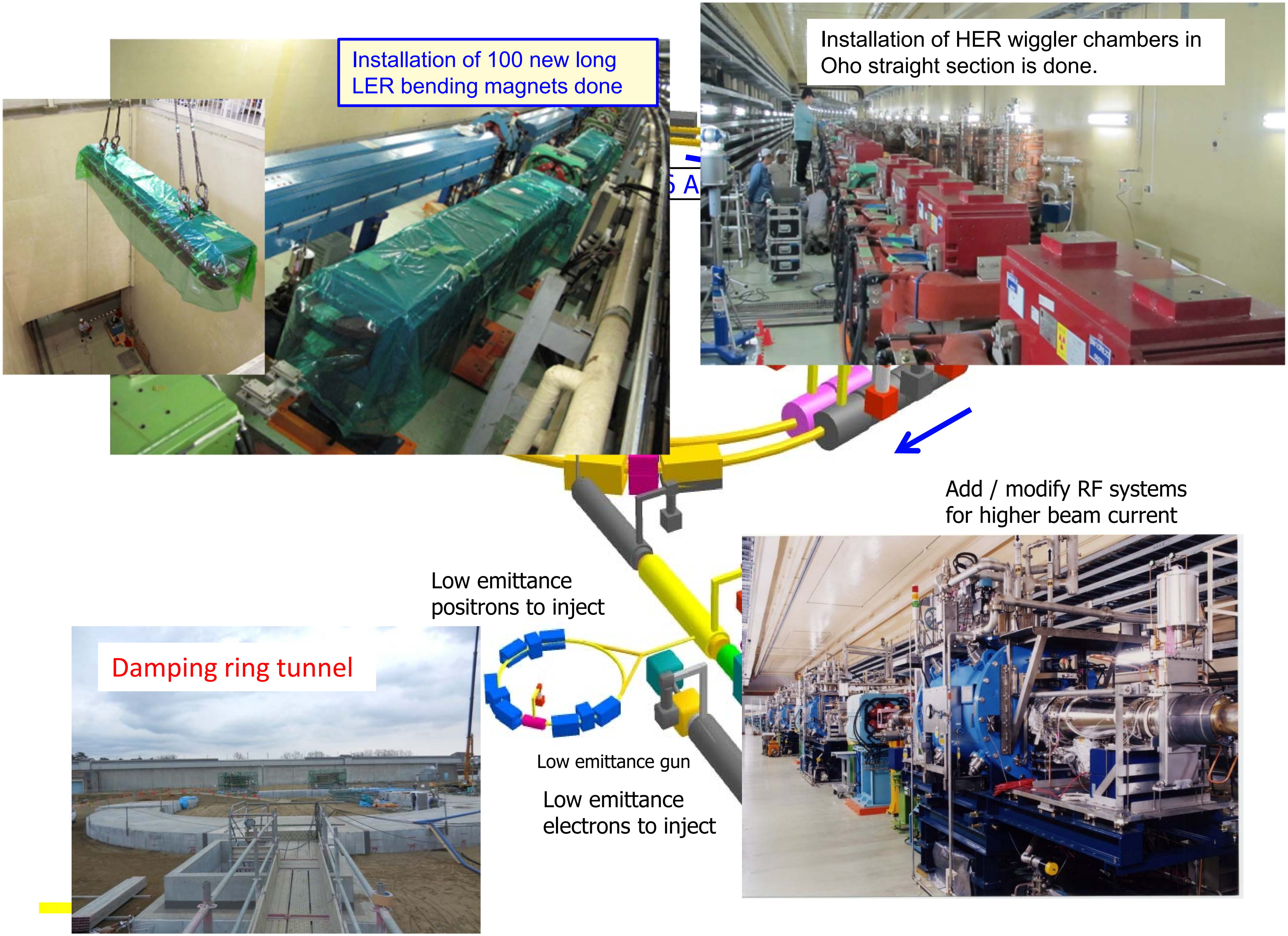
Low emittance electrons to inject

TiN-coated beam pipe with antechambers





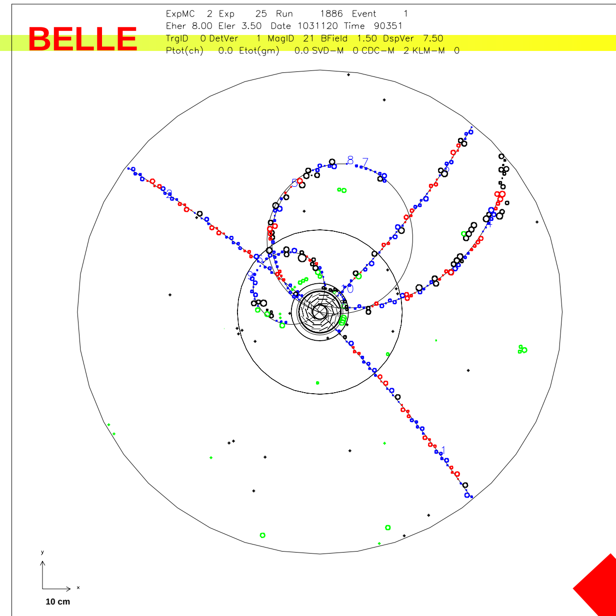
To get x40 higher luminosity

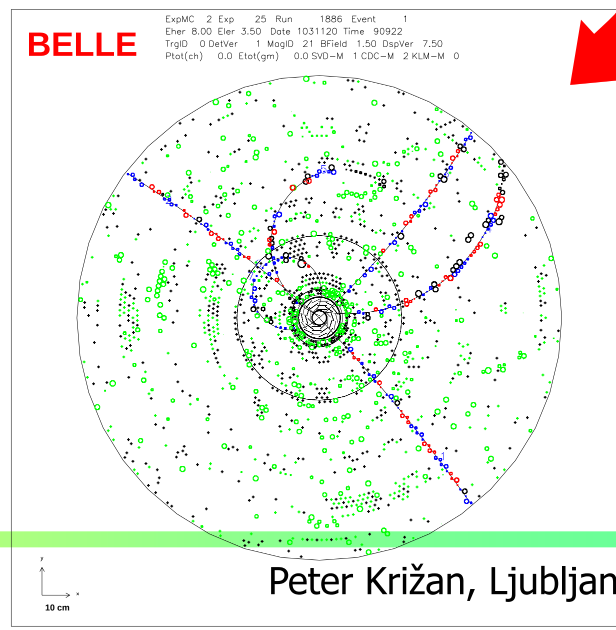

Installation of 100 new long LER bending magnets done
Installation of HER wiggler chambers in Oho straight section is done.
Add / modify RF systems for higher beam current
Low emittance positrons to inject
Damping ring tunnel
Low emittance gun
Low emittance electrons to inject

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
- **Require special features**
  - low *p* μ identification ← sμμ recon. eff.
  - hermeticity ← ν "reconstruction"



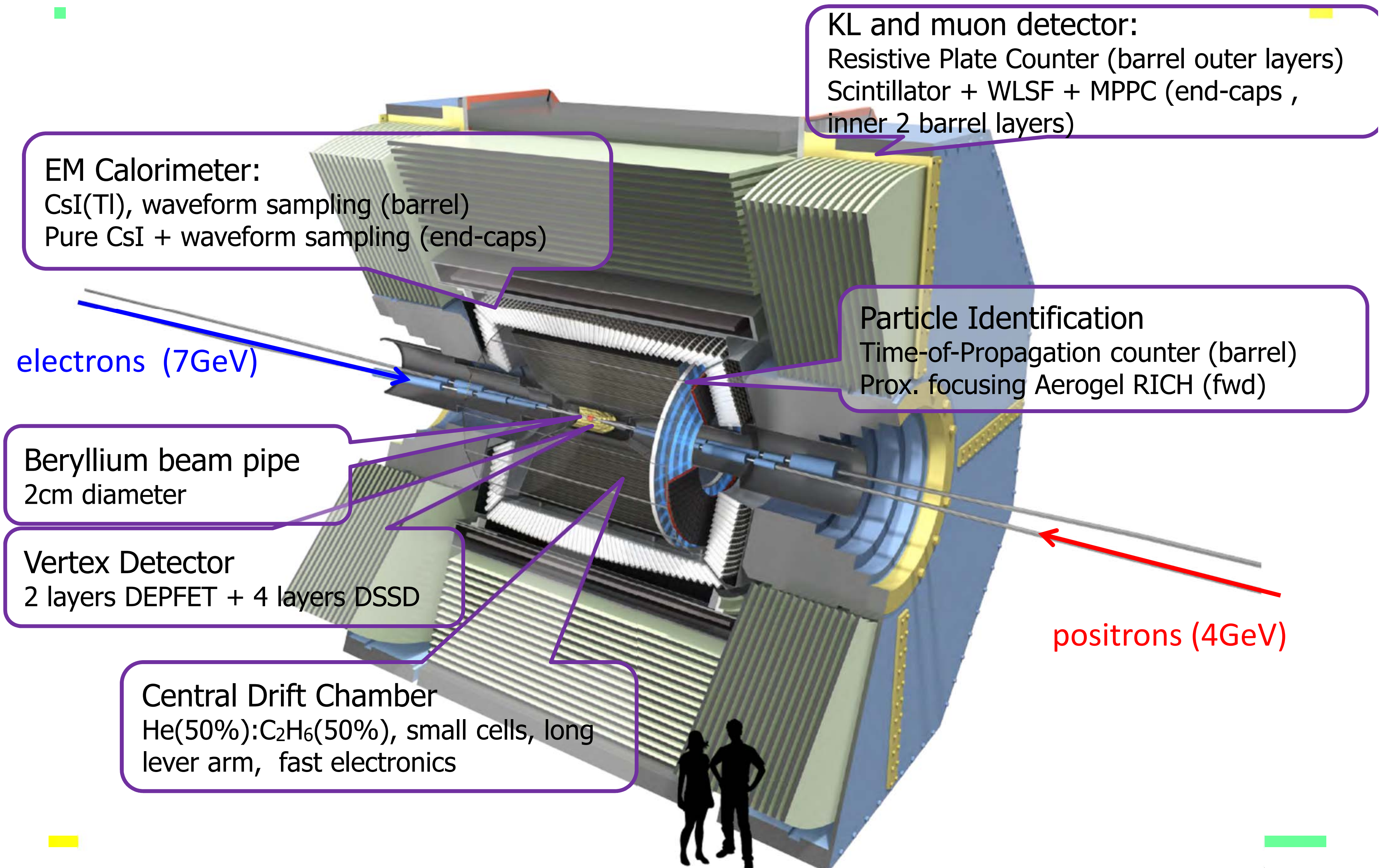


Solutions:

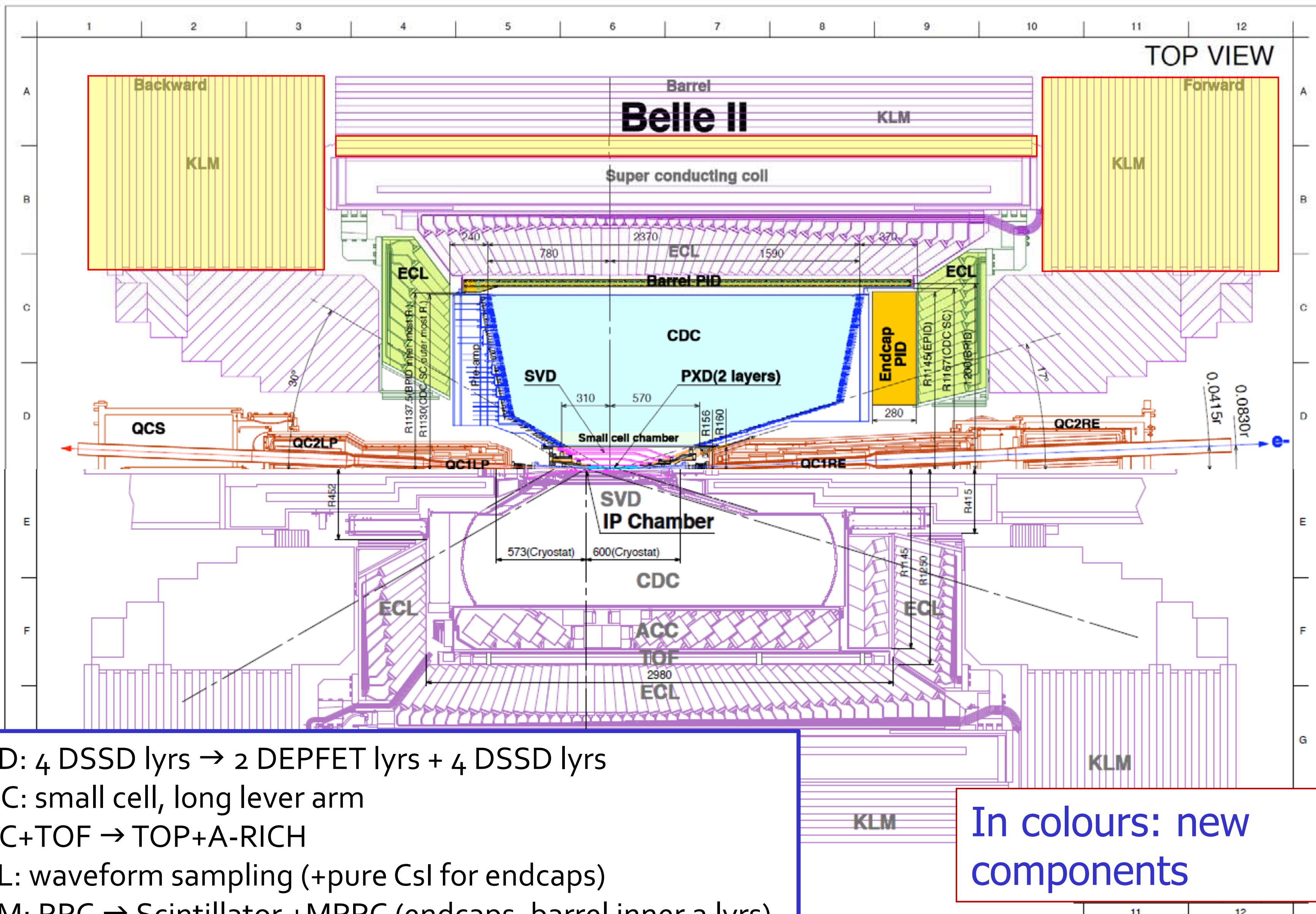
- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter crystals
- Faster readout electronics and computing system.

Belle II TDR, arxiv:1011.0352v1[physics.ins-det]

Belle II Detector



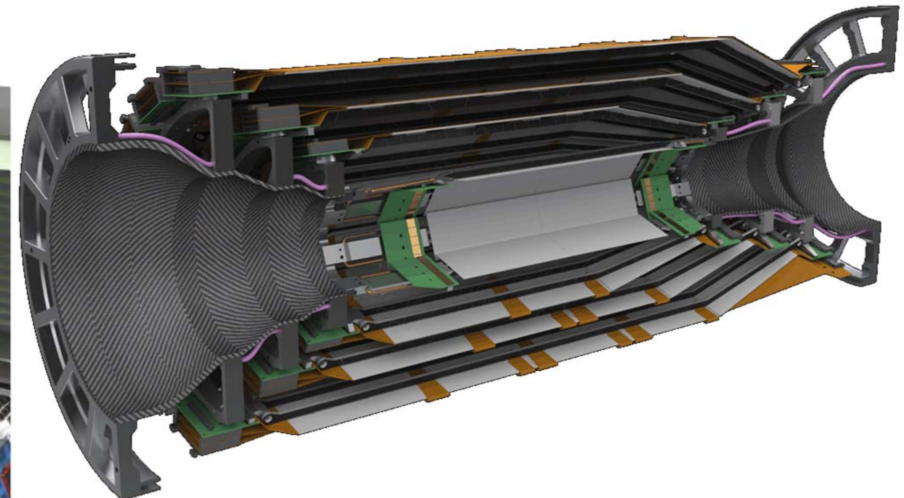
Belle II Detector (in comparison with Belle)

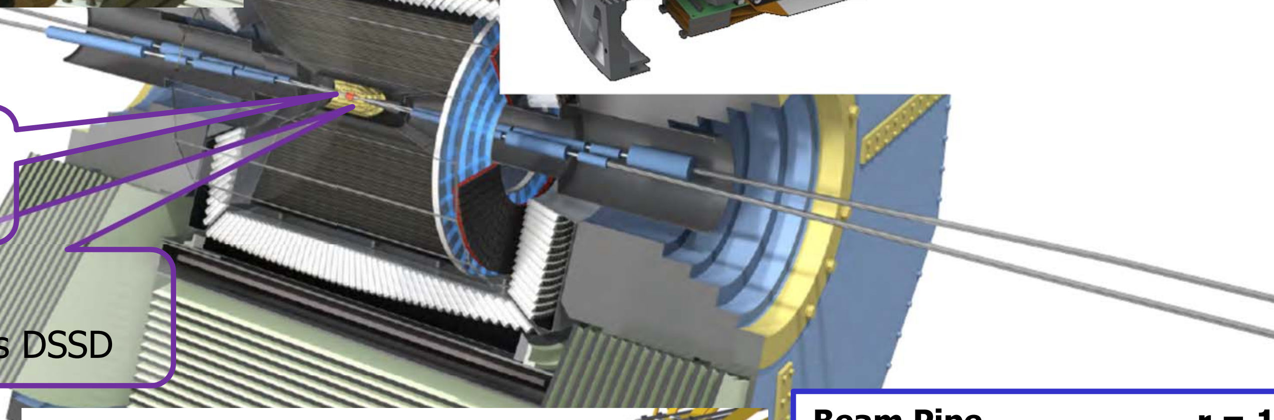


SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling (+pure CsI for endcaps)
KLM: RPC → Scintillator +MPPC (endcaps, barrel inner 2 lyrs)

In colours: new components

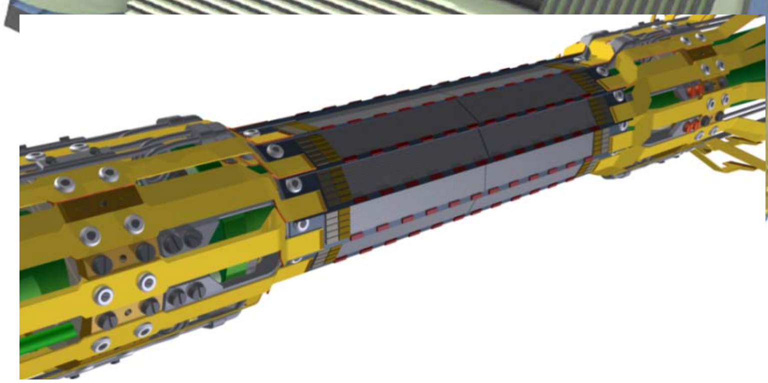
Belle II Detector – vertex region





Beryllium beam pipe
2cm diameter

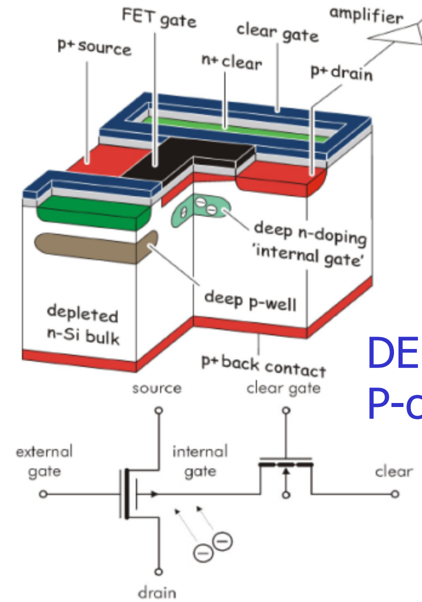
Vertex Detector
2 layers DEPFET + 4 layers DSSD



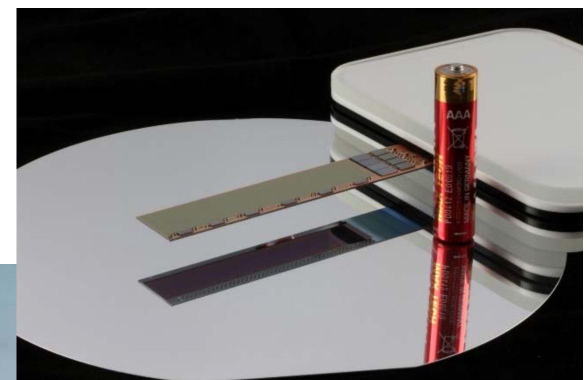
Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

Pixel detector: 2 layers of DEPFET sensors

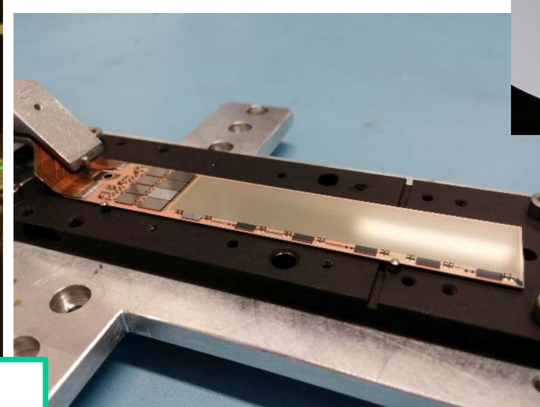
Mechanical mockup of the pixel detector



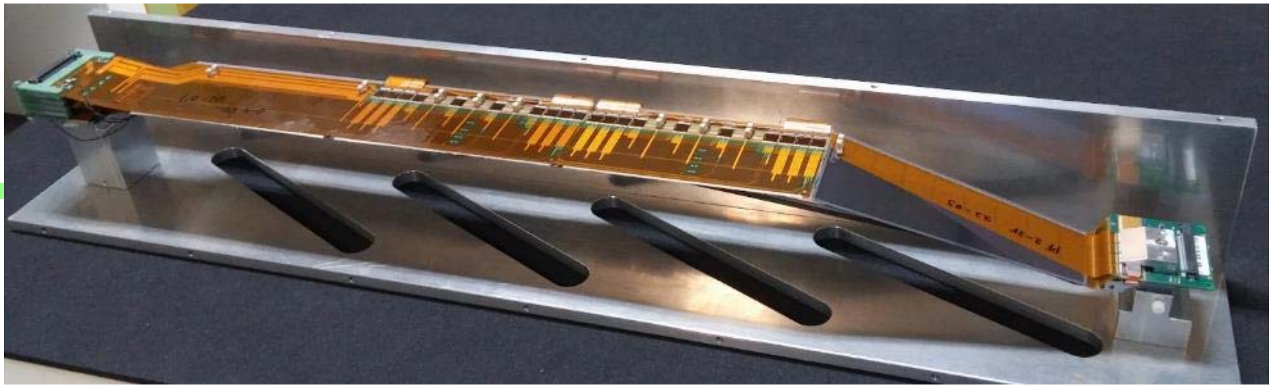
DEPFET sensor (Depleted P-channel FET)



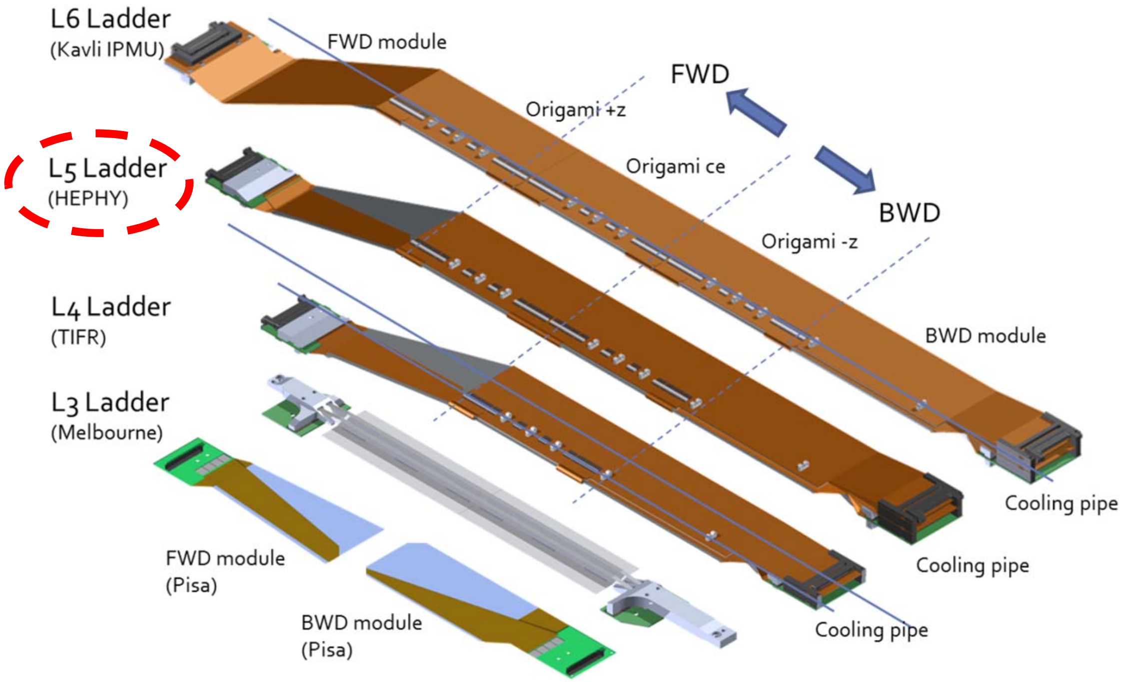
First laser light observed with the full size sensor



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

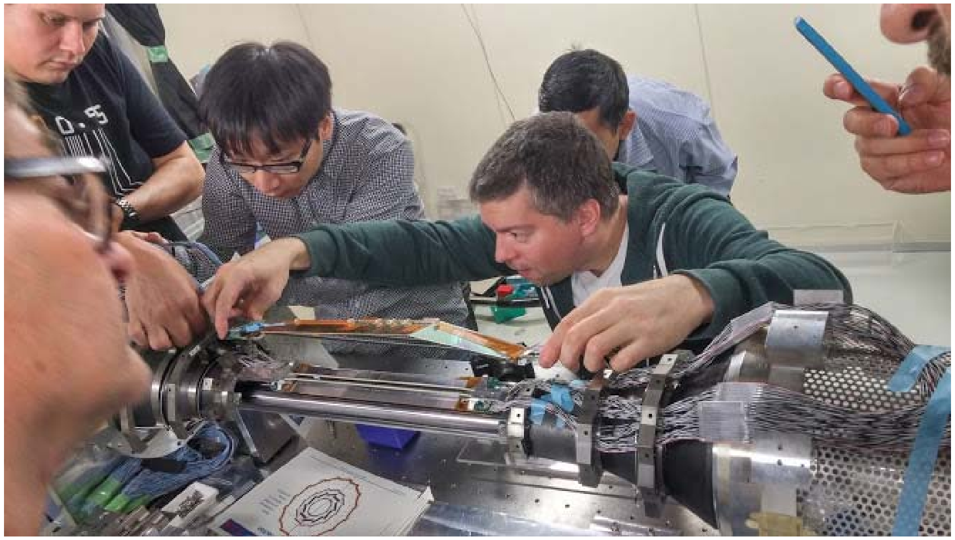


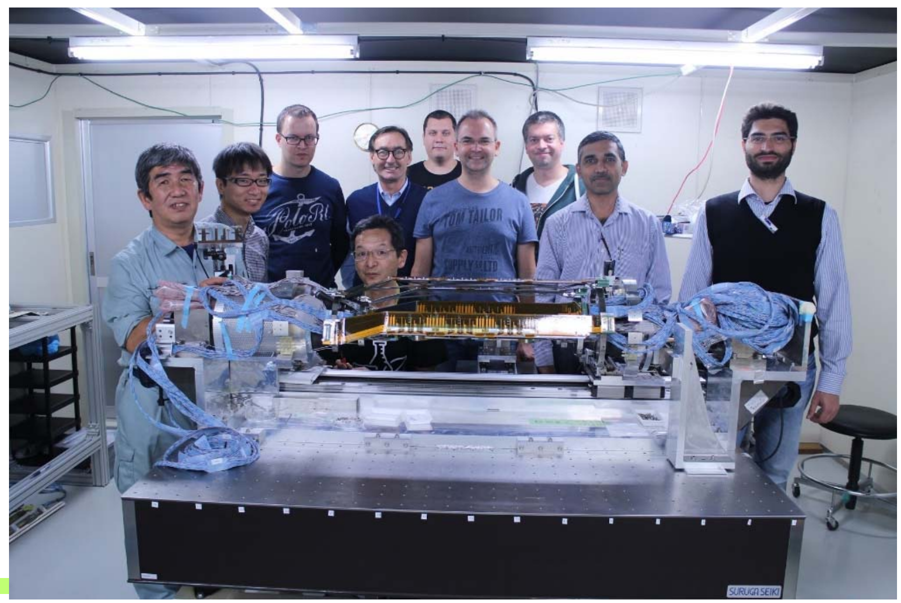
SVD: four layers of double-sided silicon microstrip detectors.



Production well under way!

Making of the SVD





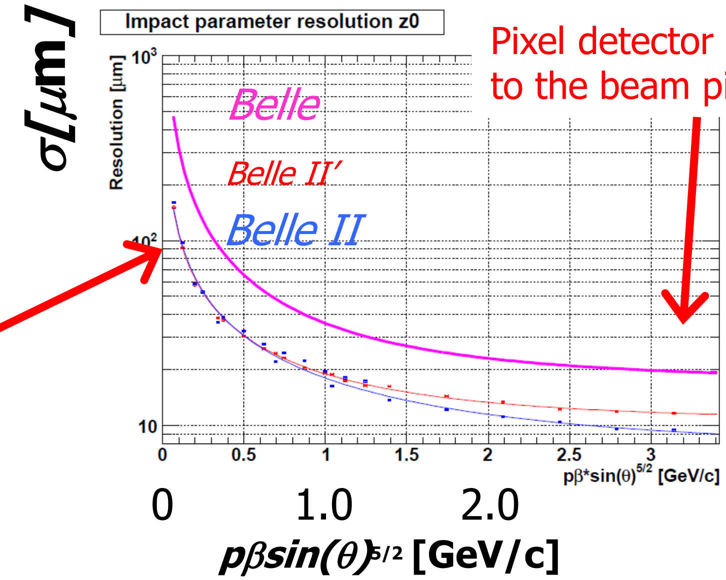
Peter Križan, Ljubljana

Expected performance

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

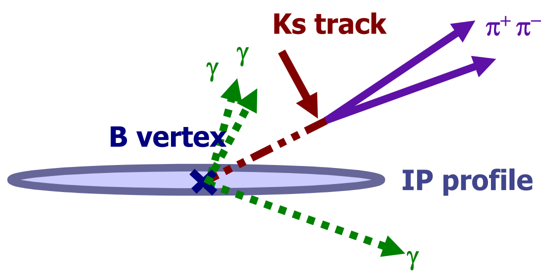
Significant improvement in vertex resolution!

Less Coulomb scattering

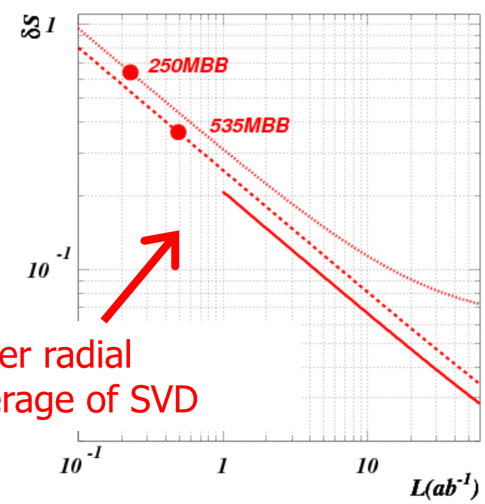


Pixel detector close to the beam pipe

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

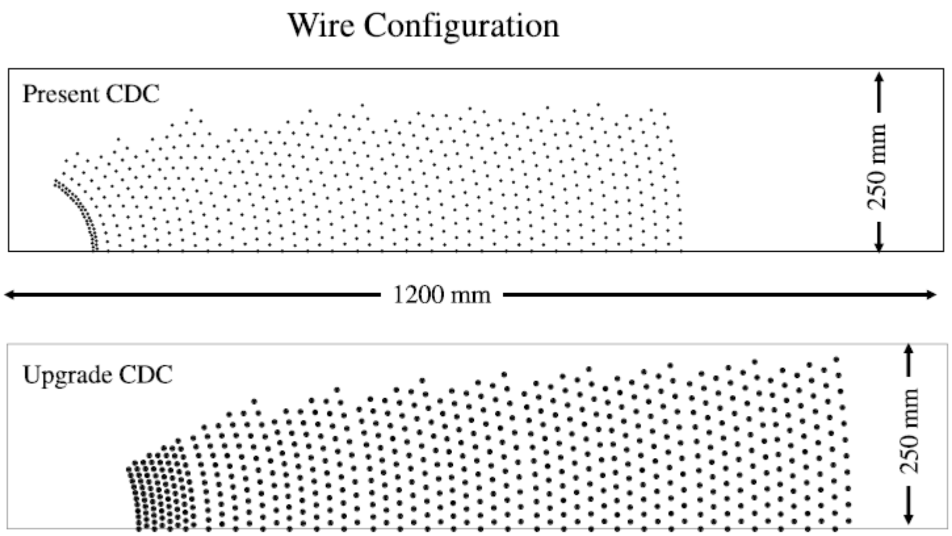


B decay point reconstruction with K_S trajectory

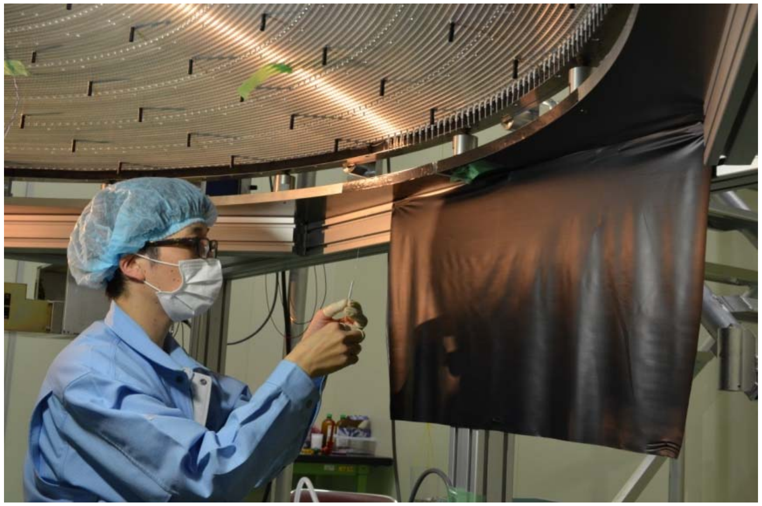


Larger radial coverage of SVD

Belle II CDC



Much bigger than in Belle!

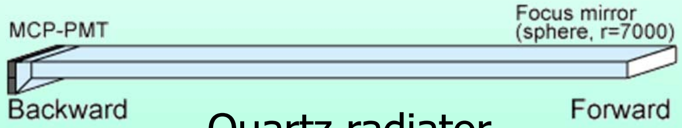


Wire stringing in a clean room

- thousands of wires,
- 1 year of work...

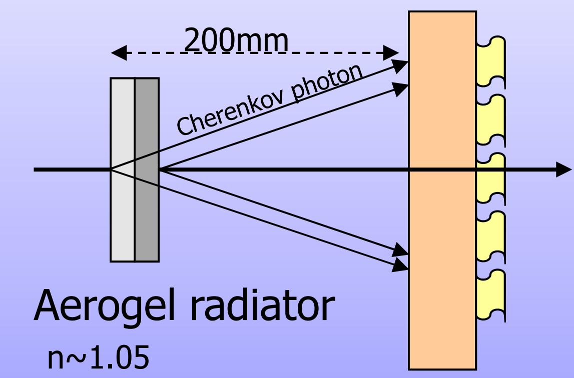
Particle Identification Devices

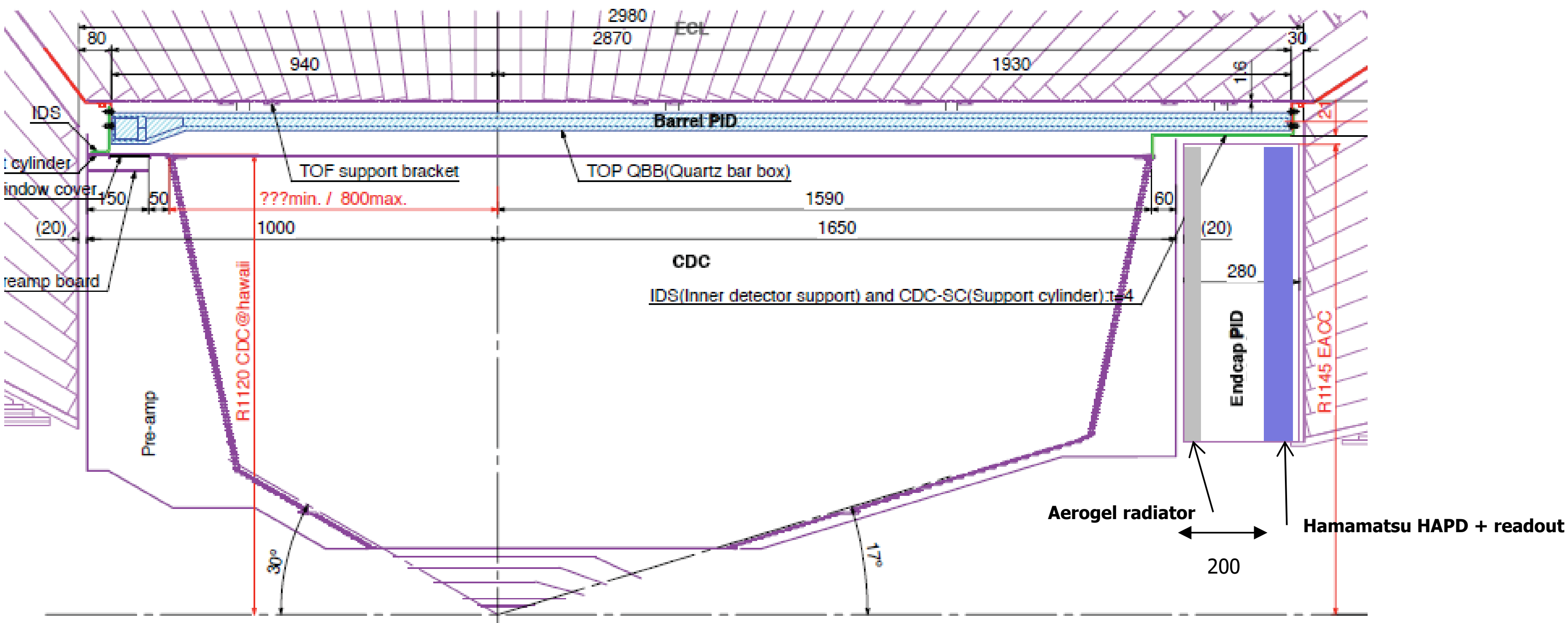
Barrel PID: Time of Propagation Counter (TOP)



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

Endcap PID: Aerogel RICH (ARICH)





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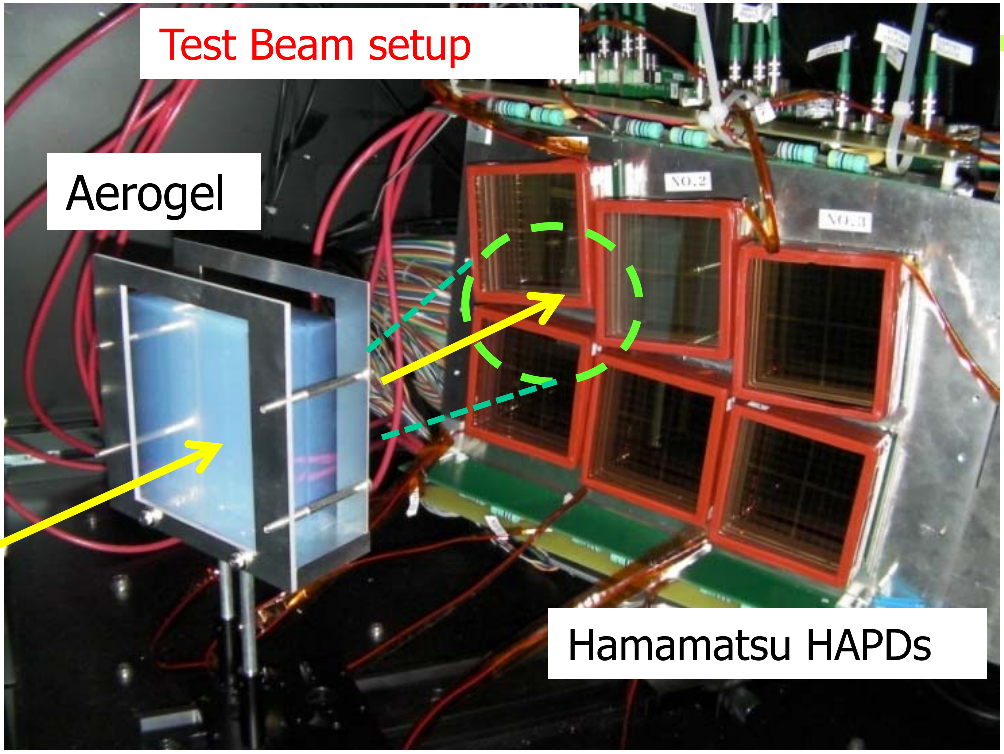
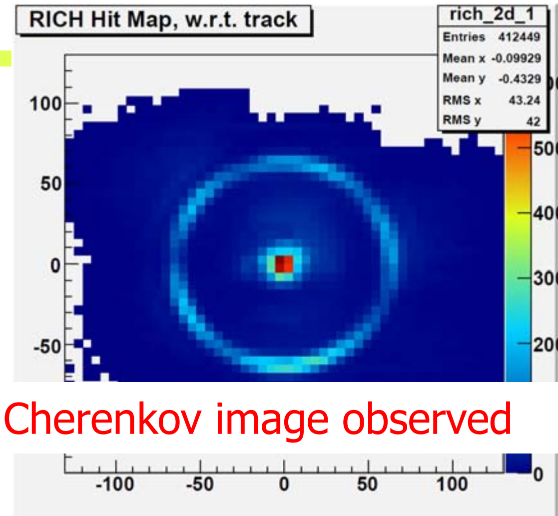
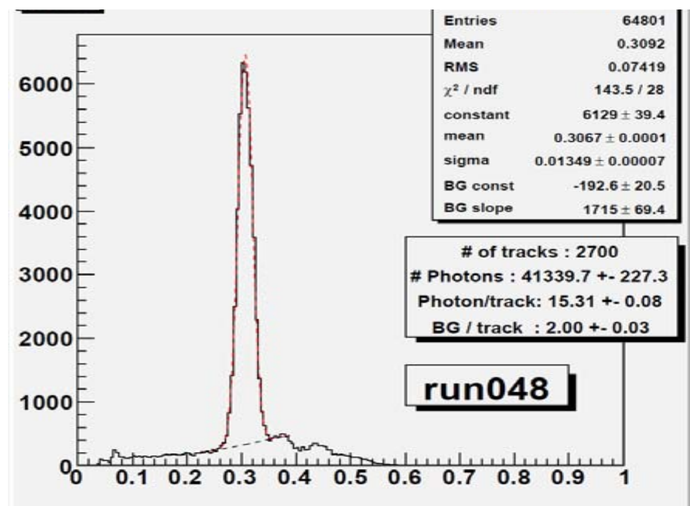
Aerogel RICH (endcap PID)





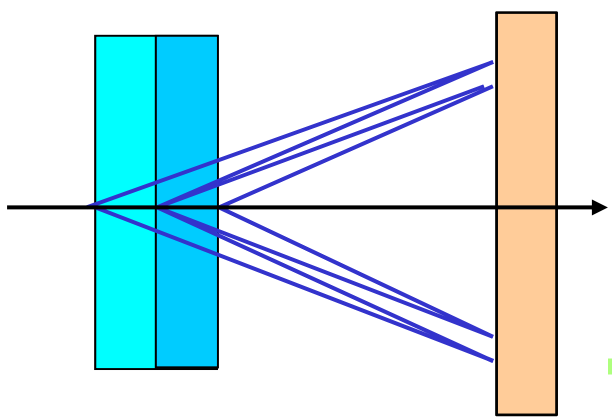
Clear Cherenkov image observed

Cherenkov angle distribution



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 !

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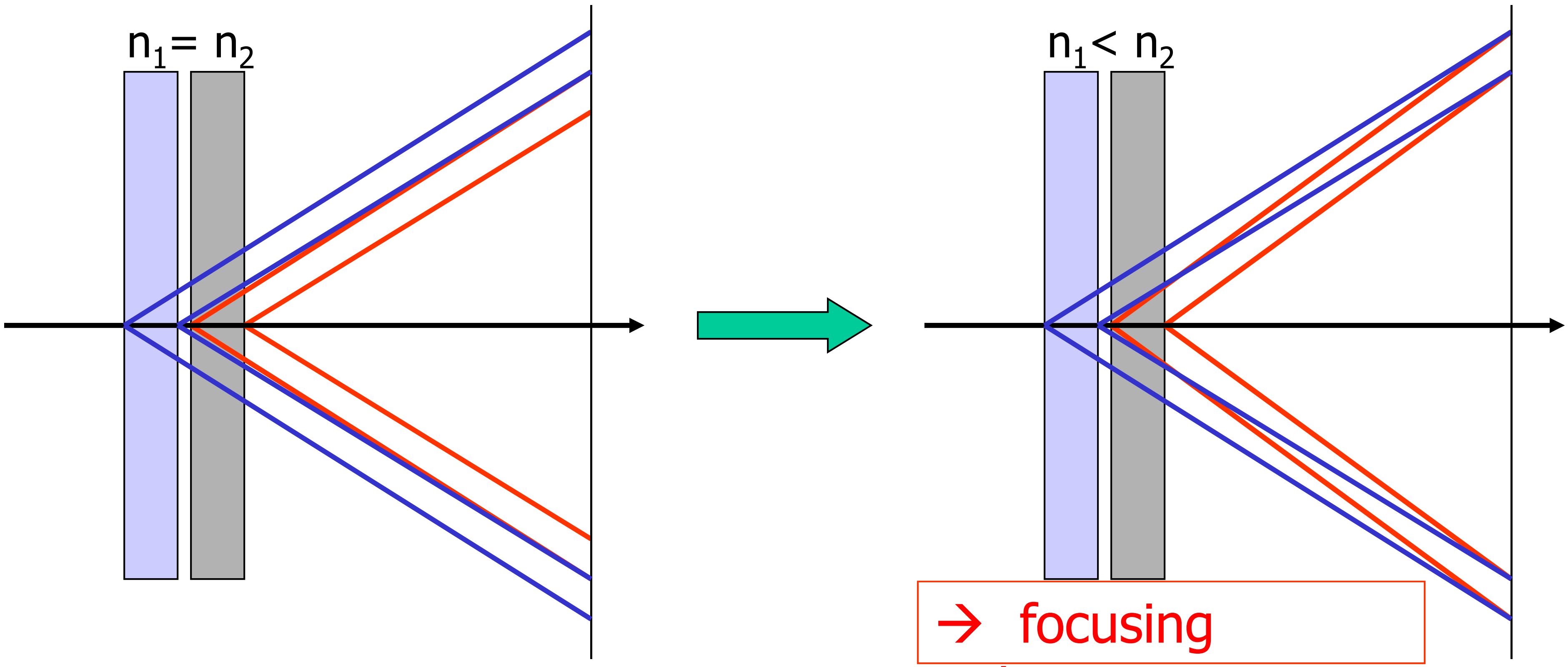
Radiator with multiple refractive indices

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

normal

→ stack two tiles with different refractive indices: "focusing" configuration

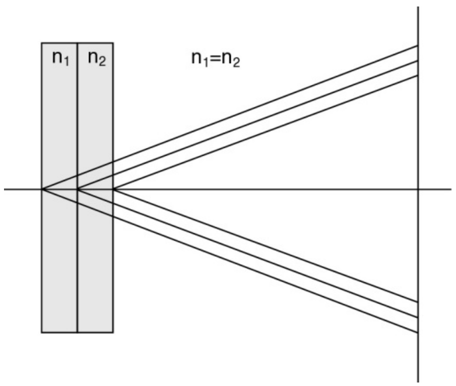


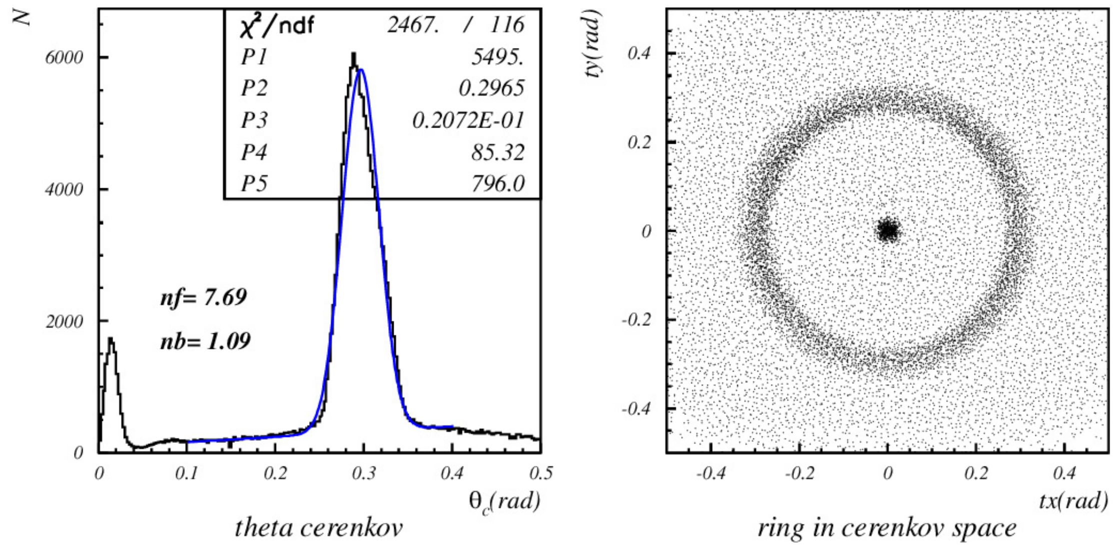
Such a configuration is only possible with aerogel (a form of Si_xO_y) – material with a tunable refractive index between 1.01 and 1.13.

Focusing configuration – data

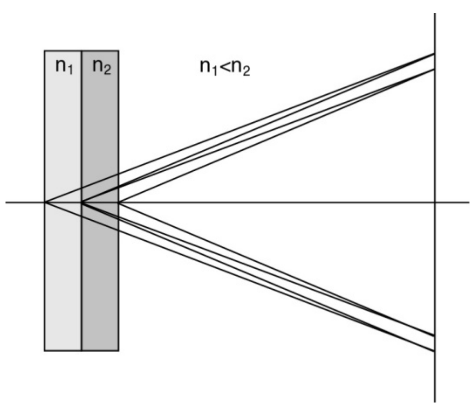
Increases the number of photons without degrading the resolution

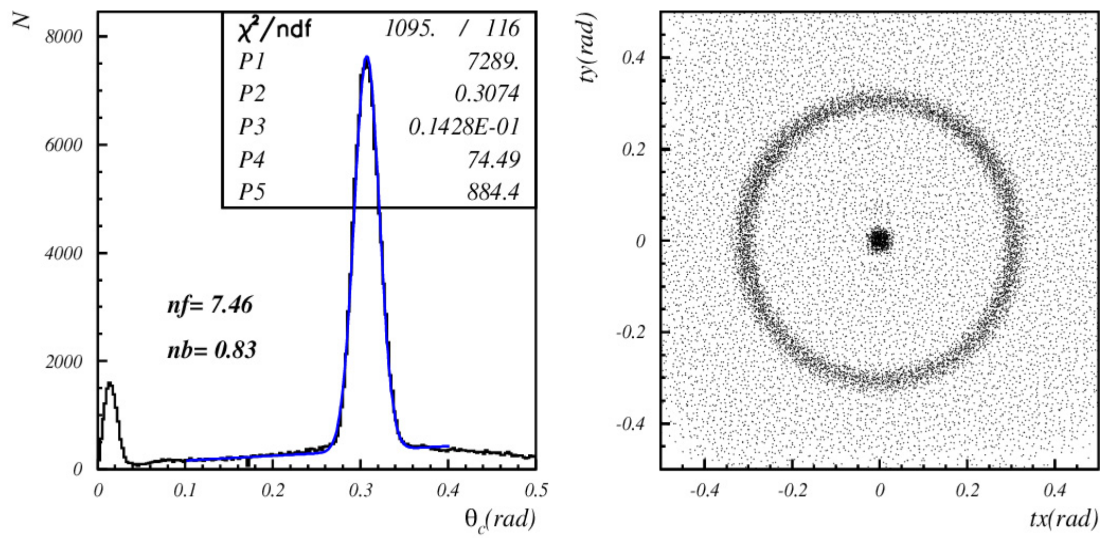
4cm aerogel single index





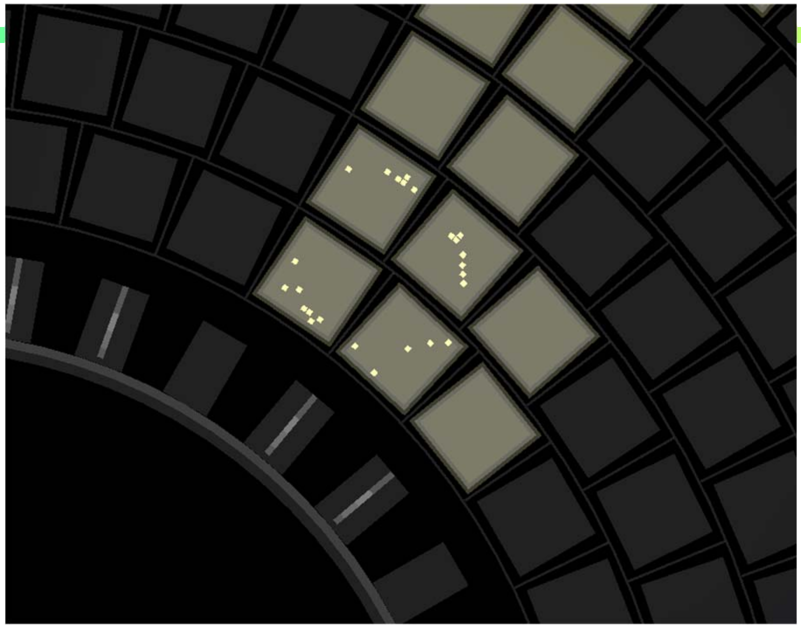
2+2cm aerogel

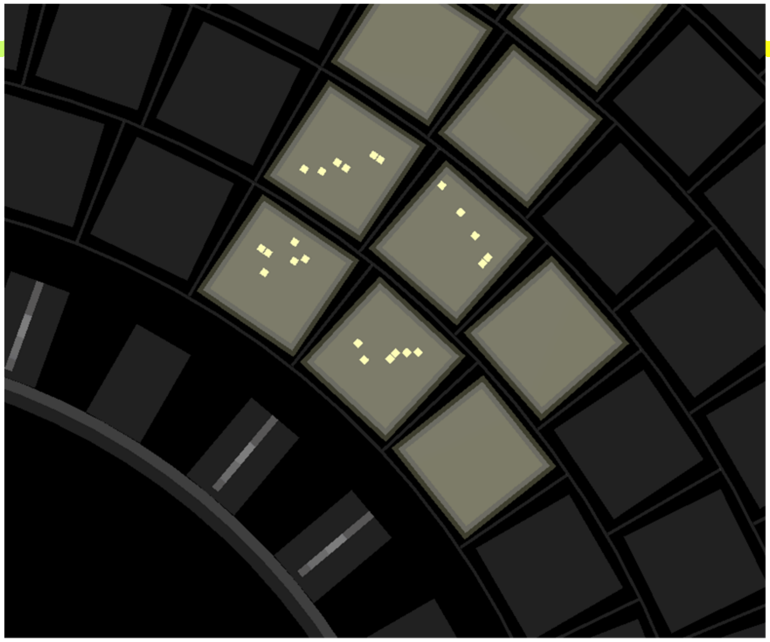


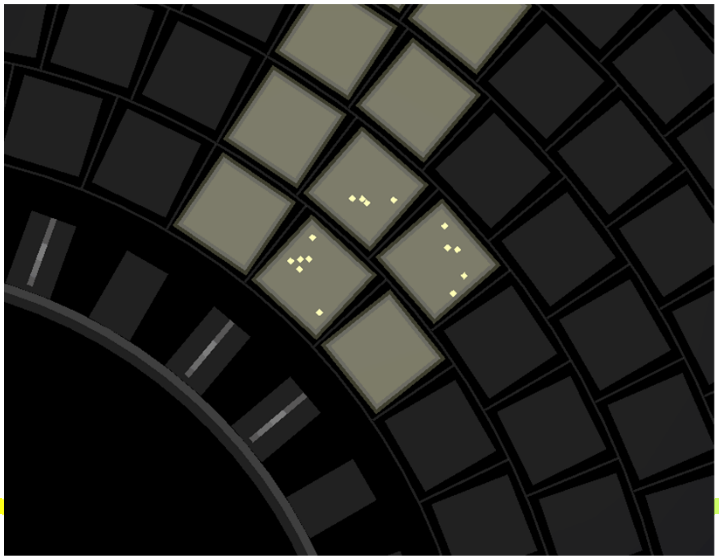


→NIM A548 (2005) 383

ARICH: Rings from cosmic ray muons



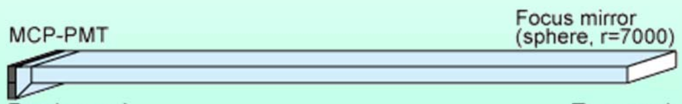




One sector of the ARICH has been instrumented.

Cherenkov detectors

Barrel PID: Time of Propagation Counter (TOP)



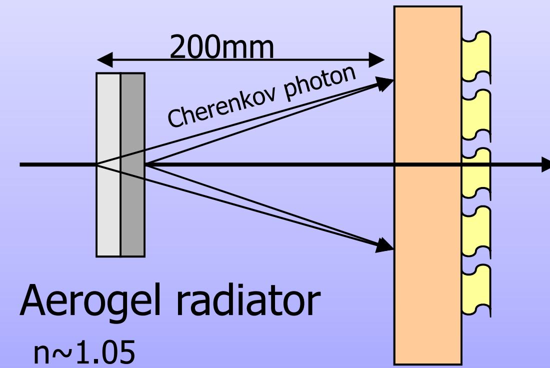
Quartz radiator

Focusing mirror

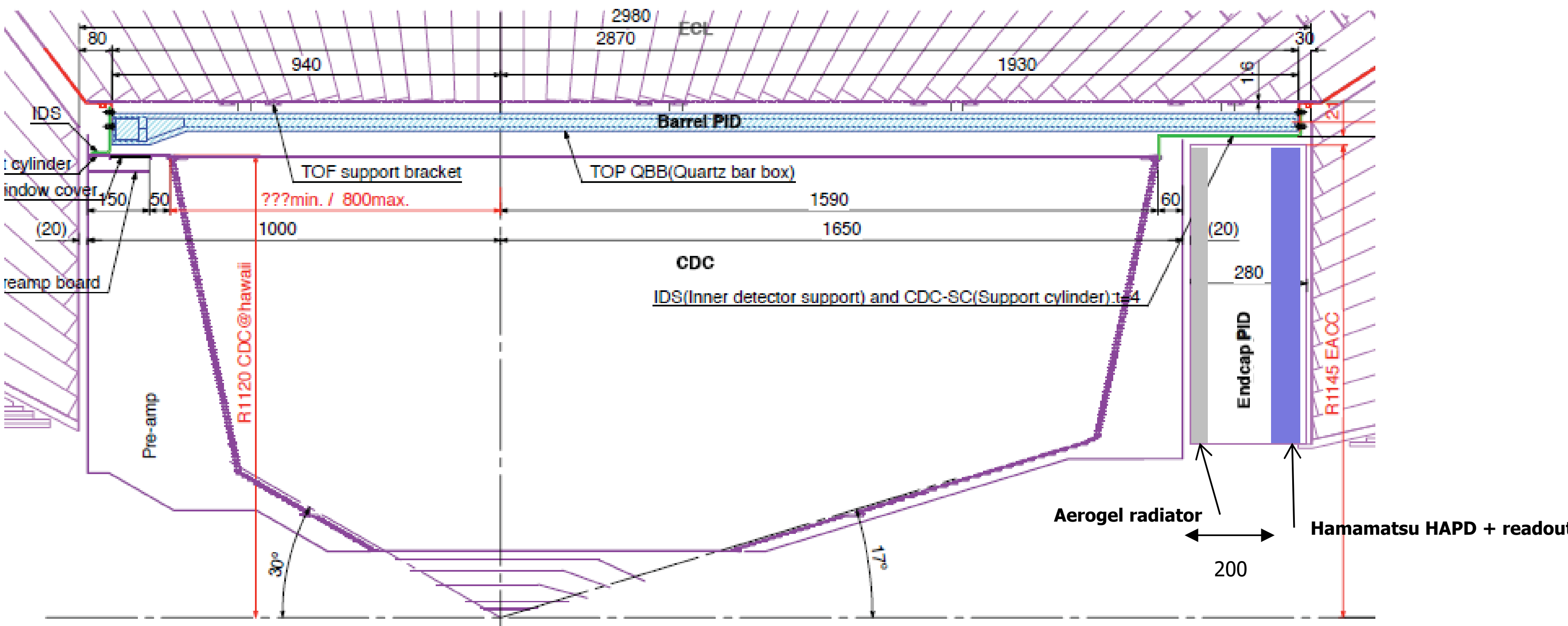
Small expansion block

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

Endcap PID: Aerogel RICH (ARICH)

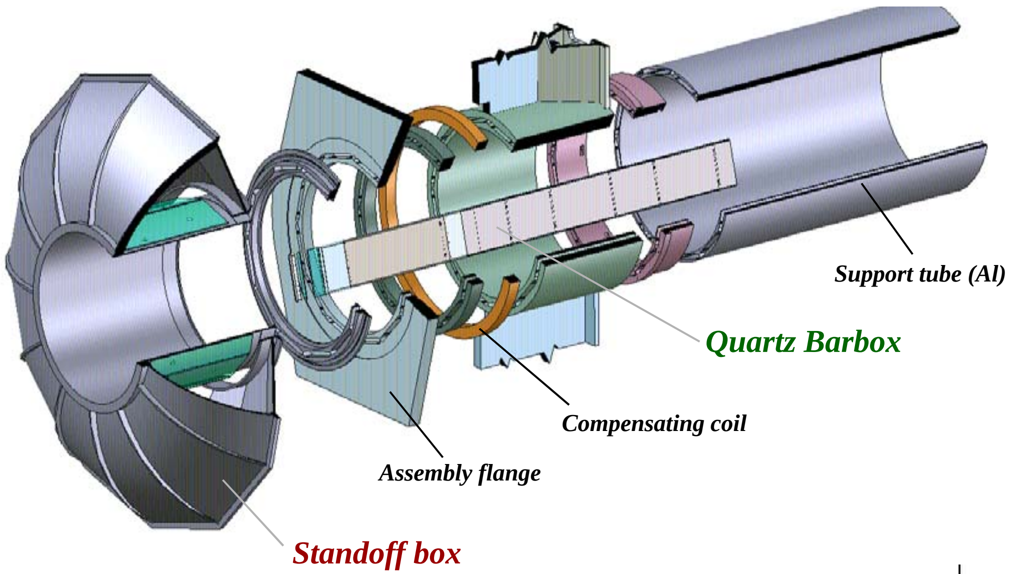


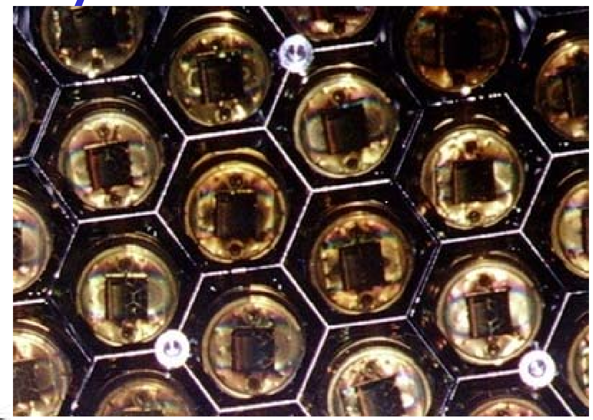
Hamamatsu HAPD
+ new ASIC

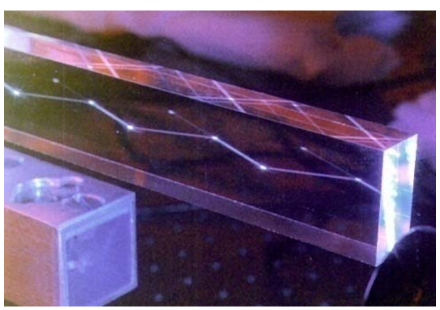


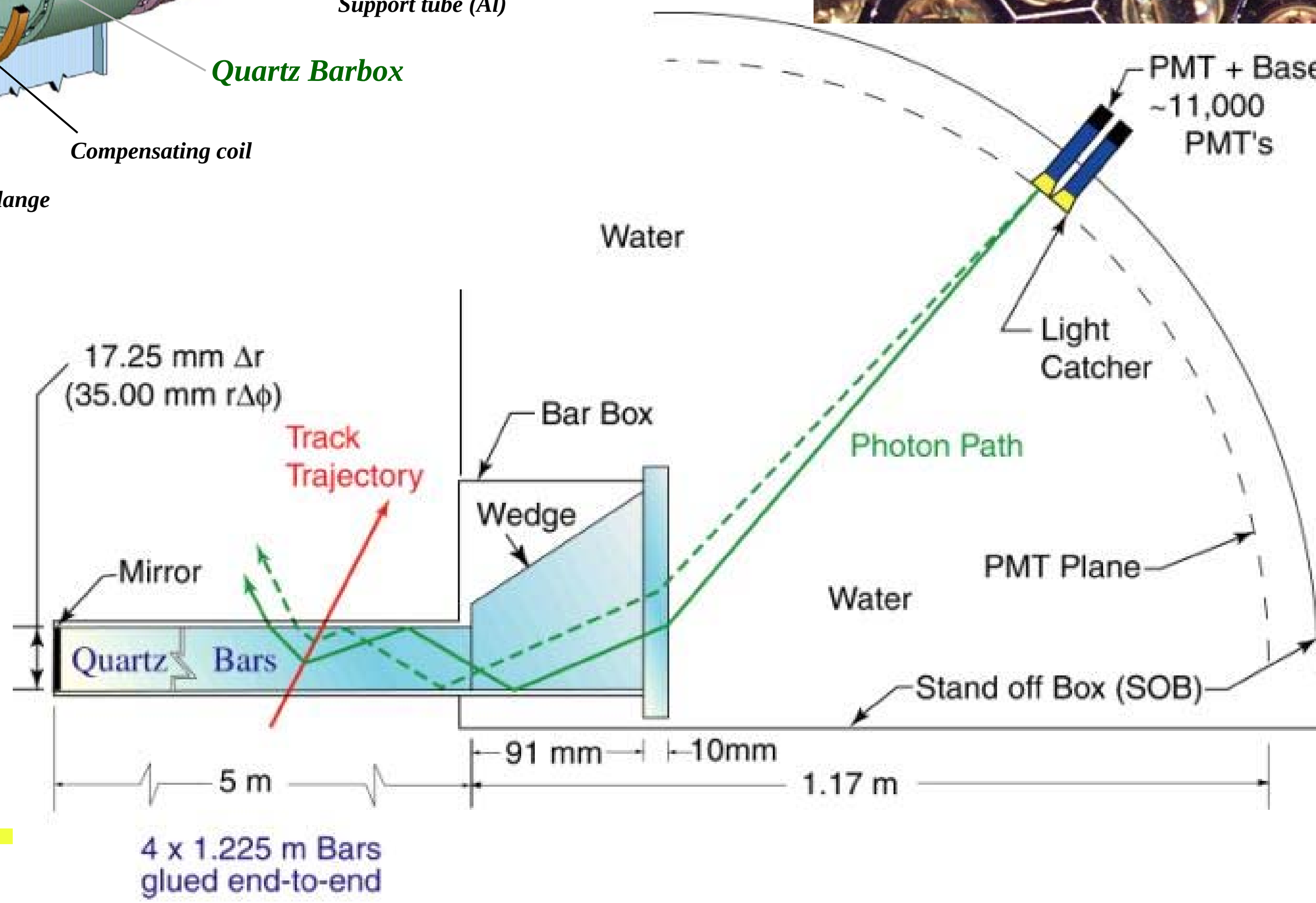
Peter Križan, Ljubljana

DIRC (@BaBar) - detector of internally reflected Cherenkov light

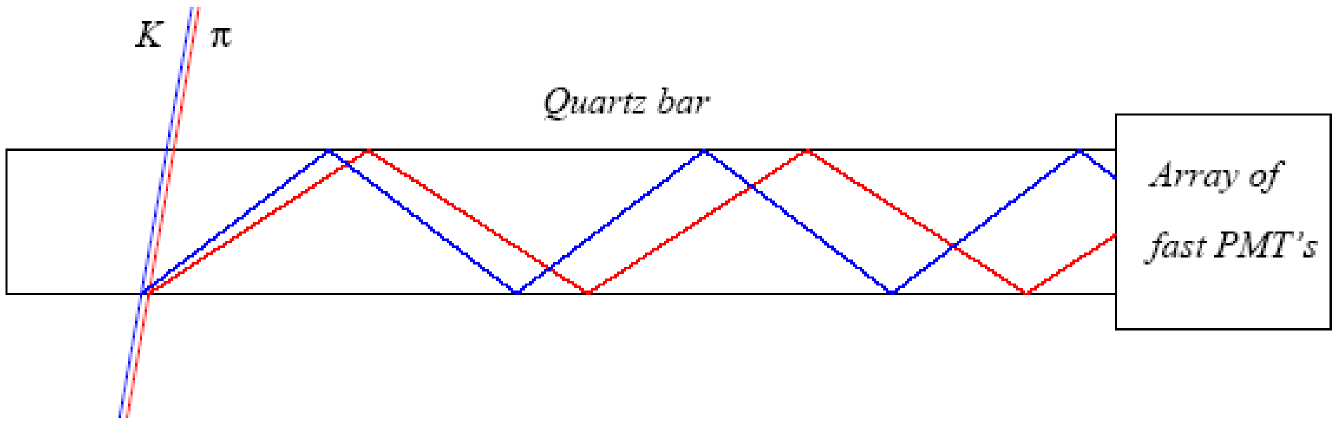


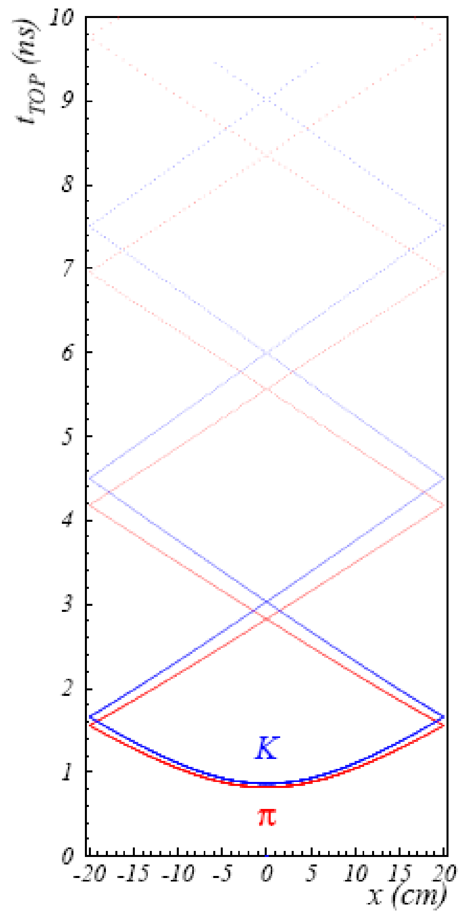






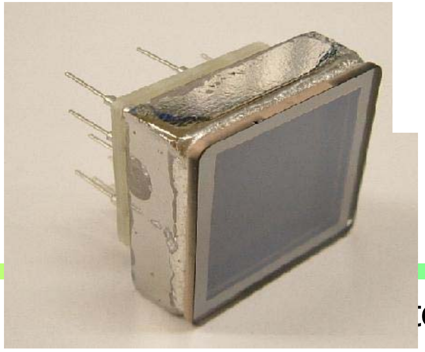
Belle II Barrel PID: Time of propagation (TOP) counter



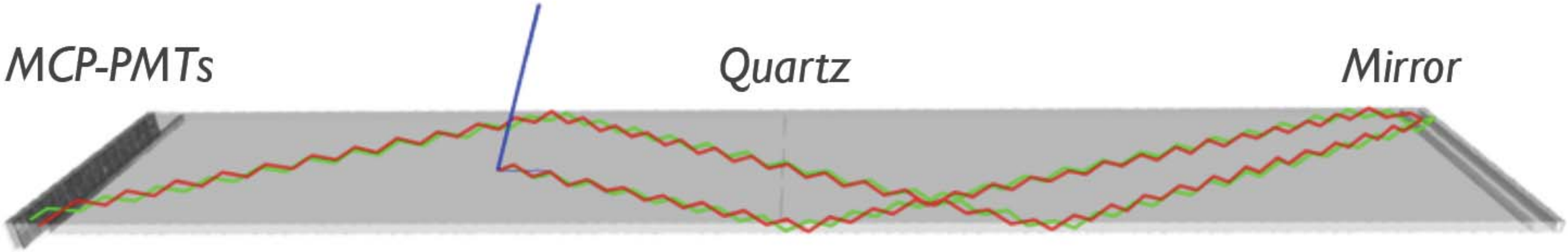


- Cherenkov ring imaging with precise time measurement.
- Uses internal reflection of Cherenkov ring images from quartz like the BaBar DIRC.
- Reconstruct Cherenkov angle from two hit coordinates and

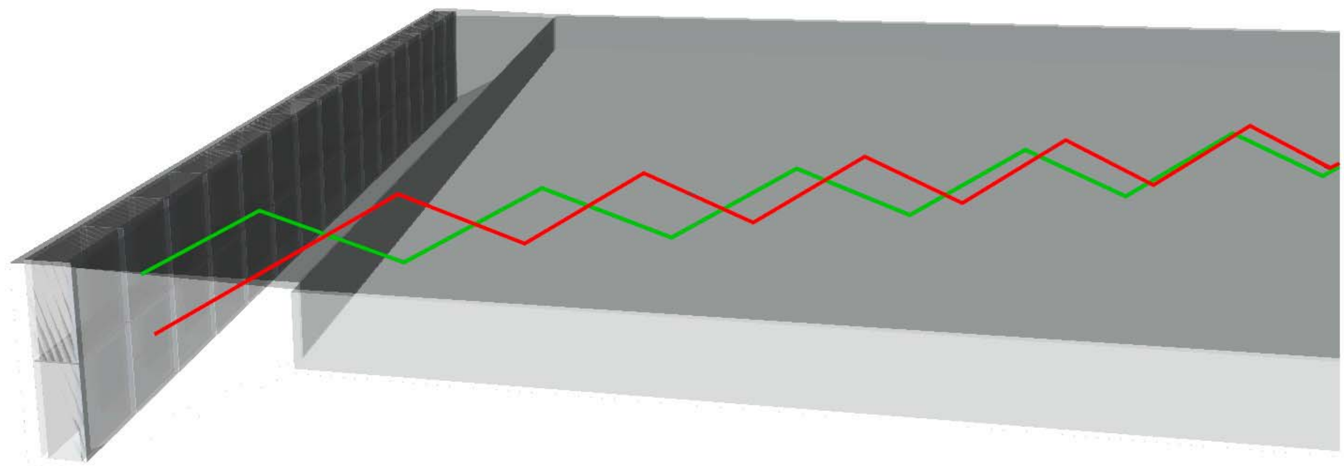
the time of propagation of the photon
  - Quartz radiator (2cm thick)
  - Photon detector (MCP-PMT)
    - Excellent time resolution ~ 40 ps
    - Single photon sensitivity in 1.5



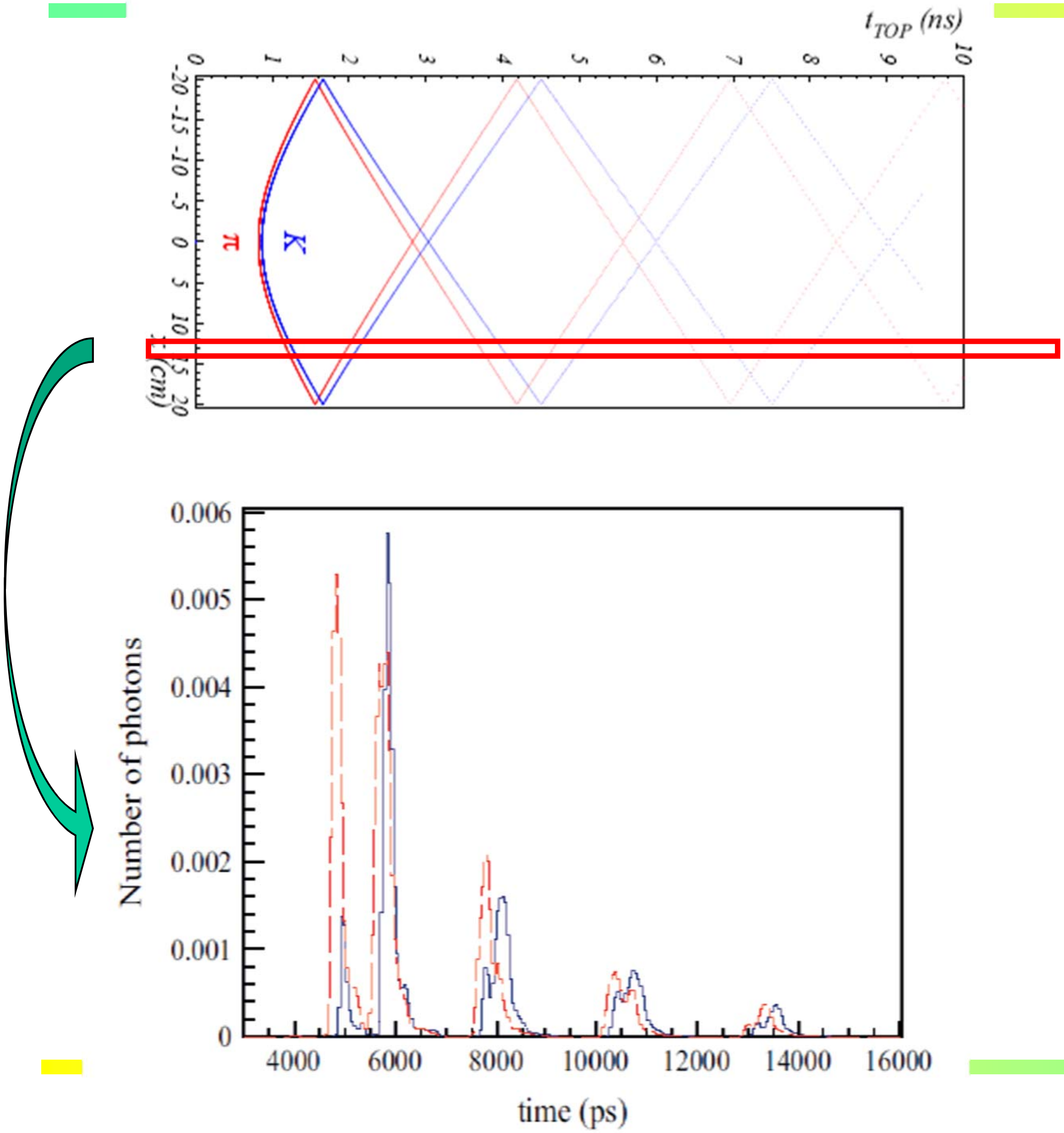
Barrel PID: Time of propagation (TOP) counter



Example of Cherenkov-photon paths for 2 GeV/c $\pi^{\pm}$ and $K^{\pm}$.



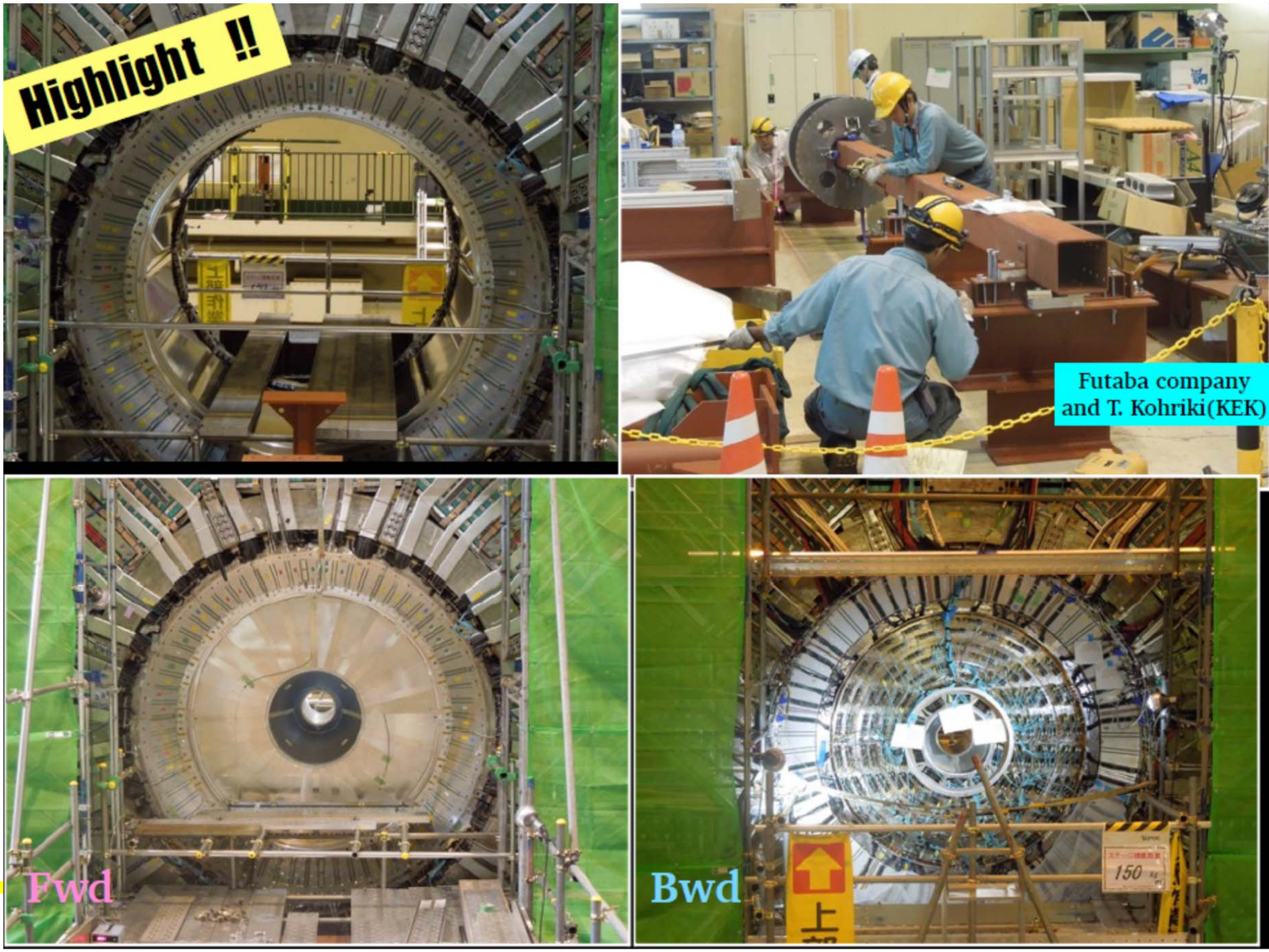
TOP image



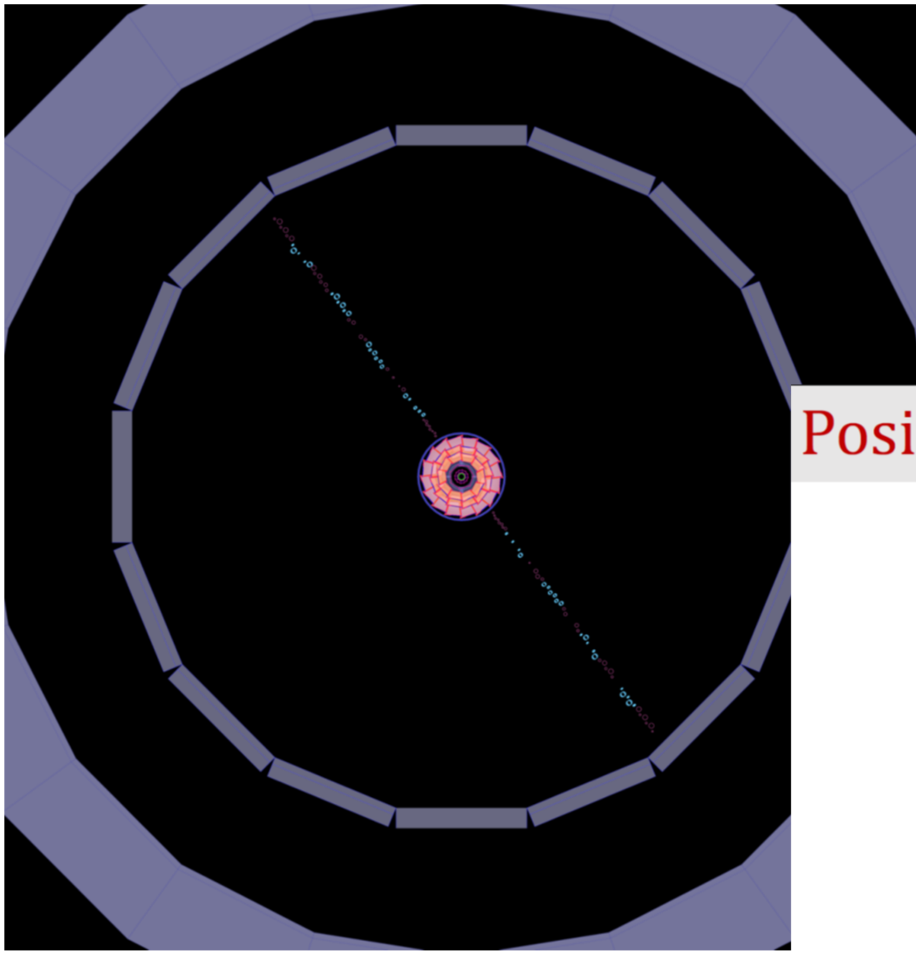
Pattern in the coordinate-time space ('ring') of a pion hitting a quartz bar with ~80 MAPMT channels

Time distribution of signals recorded by one of the PMT channels: different for π and K (~shifted in time)

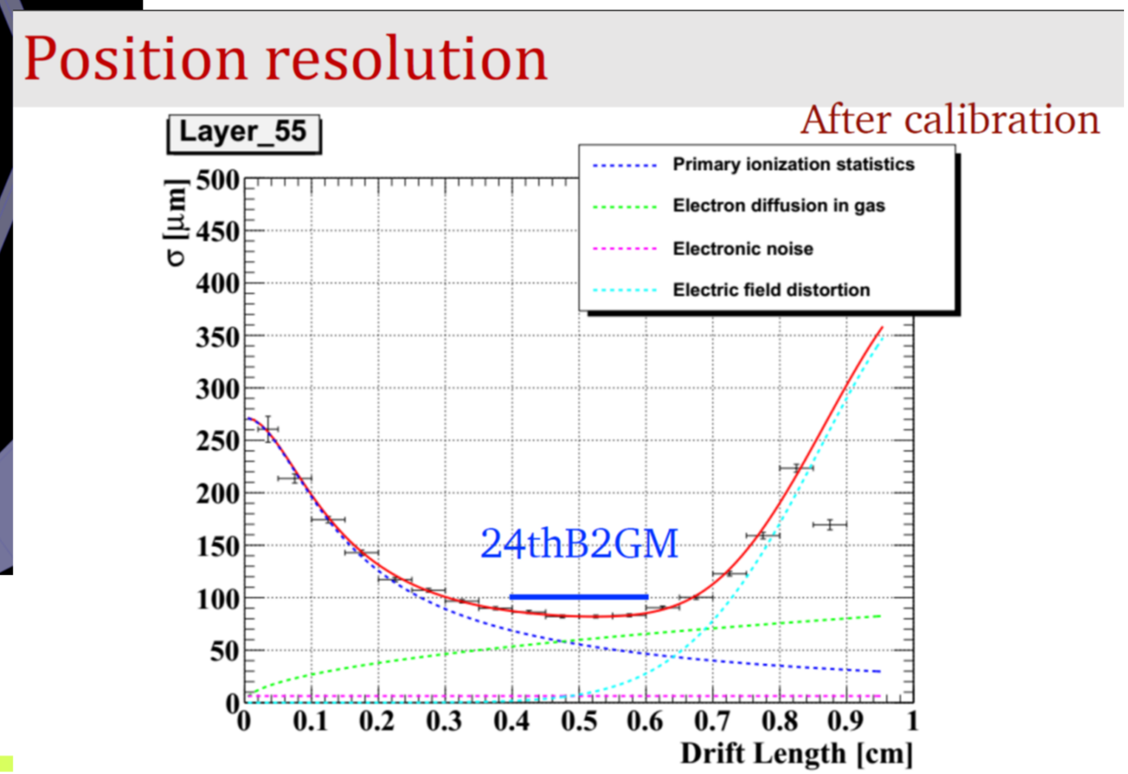
TOP and CDC: installed, cabling of CDC almost finished



CDC, stand-alone cosmic test in spring



Excellent performance!



Position resolution at good region: 80-150μm, it depends on layer.

VXD (= PXD + SVD) Interaction Region Components

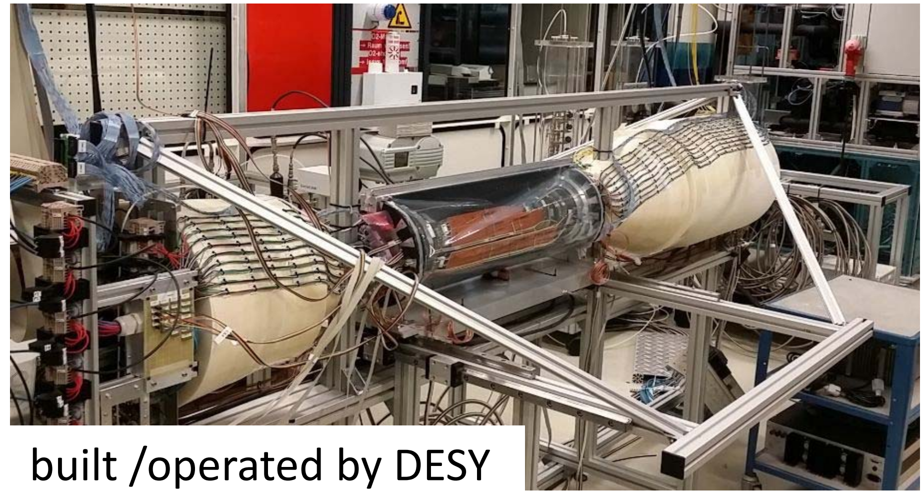
2-phase CO_2 cooling unit („IBBelle“)

built at MPI in collaboration with CERN / Nikhef (~same as ATLAS unit)

Cooling power > 2 kW fully comissioned at MPI (needed for PXD/SVD : 360/750 W)

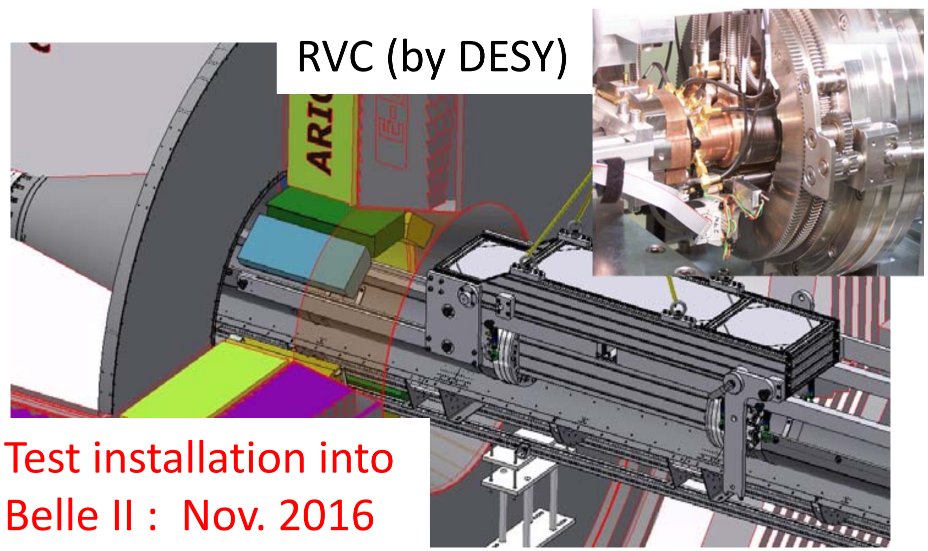
IBBelle has arrived at KEK on Oct. 20

VXD thermal management mockup for CO2 cooling studies: original sizes and materials



built /operated by DESY

VXD installation into Belle (design by MPI)



RVC (by DESY)

Test installation into Belle II : Nov. 2016

SuperKEKB/Belle II Status

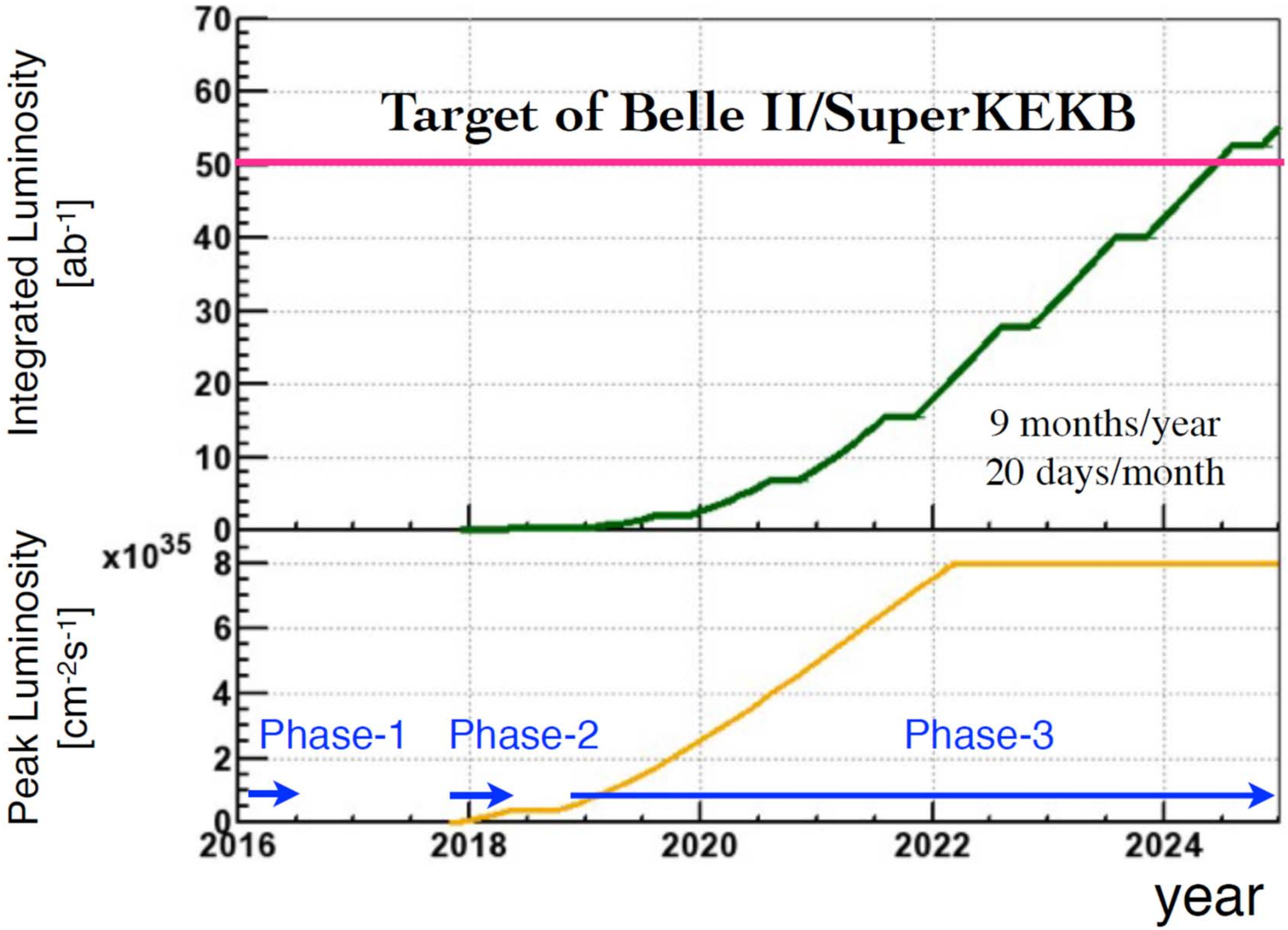
- Commisioning (Phase 1) of the main ring (without final quads) successfully carried out from Feb 1, 2016 – end of June! Interaction point detector: instead of Belle II, a commissioning detector – Beast II.

- Add final quads in until end of 2016
- Belle II: installation of outer detectors: early summer – december 2016
- Belle II (without the vertex detector) roll in March 2017, cosmic rays
- Phase 2 commissioning Nov 2017 – spring 2018 (+ first physics runs)
- Install vertex detector summer 2018
- Full detector operation by the end 2018 (Phase 3)

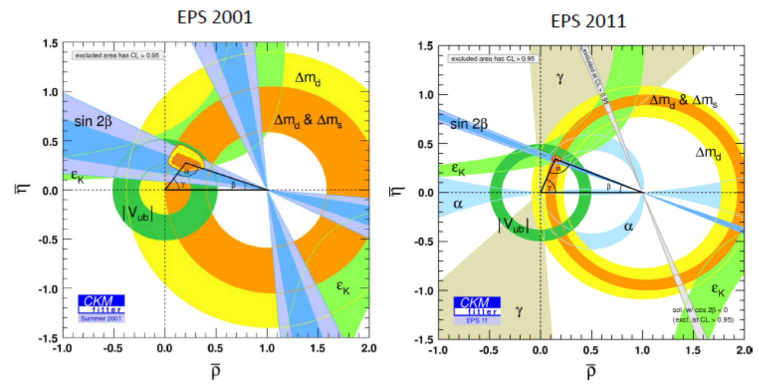
The Belle II Collaboration

A very strong group of ~650 highly motivated scientists!

SuperKEKB luminosity projection



Summary



- Physics of B mesons has contributed substantially to our present understanding of elementary particles and their interactions
- B factories have proven to be an excellent tool for flavour physics as well for searches for new hadronic states, with reliable long term operation, constant improvement of the performance, achieving and surpassing design performance
- Super B factory at KEK under construction → SuperKEKB+Belle II, L x40, construction at full speed
- Expect a new, exciting era of discoveries, and a friendly competition and complementarity of Belle II, LHCb and BESIII
- A lot of interesting challenges and discoveries for HEPHY!