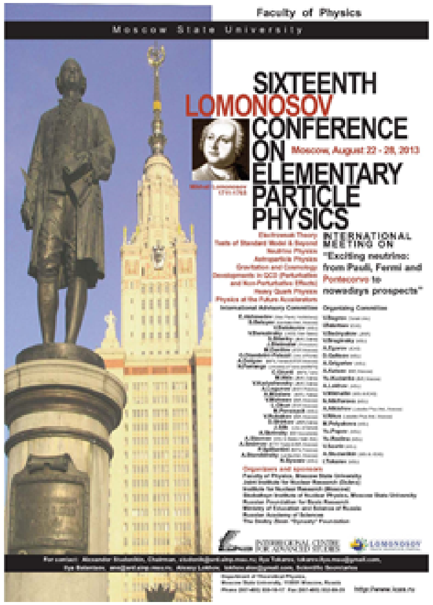

16th Lomonosov Conference on Elementary Particle Physics, Moscow, Aug. 22-28, 2013

The Belle II Experiment

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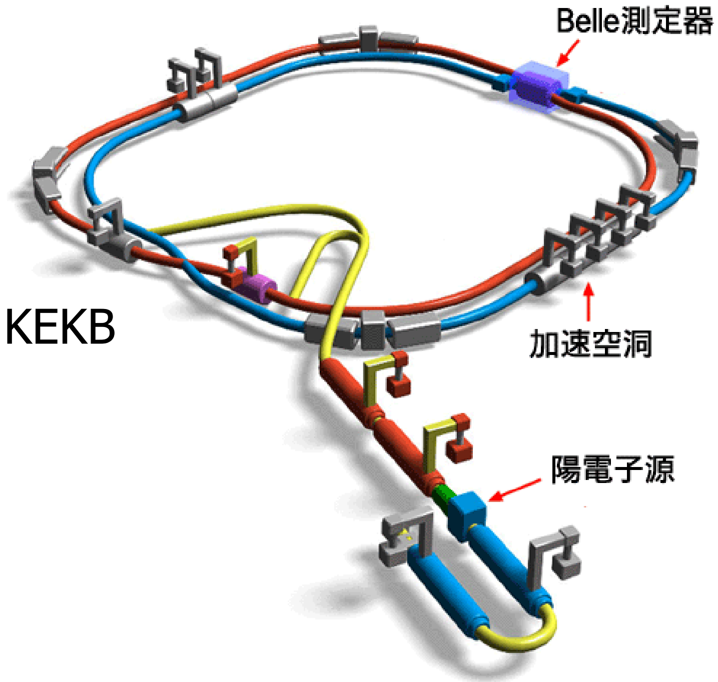
University of Ljubljana

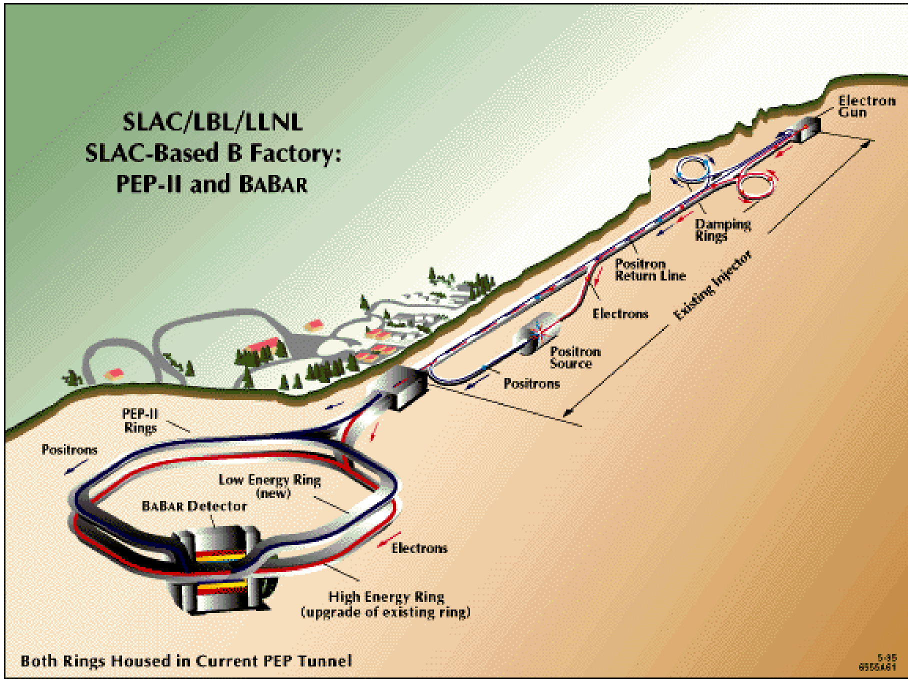
"Jožef Stefan" Institute

Contents

- Physics case for Belle II
- Accellerator – SuperKEKB
- Detector – Belle II
- Status and prospects

Flavour physics at the luminosity frontier with asymmetric B factories





$\sqrt{s}$=10.58 GeV

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

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

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

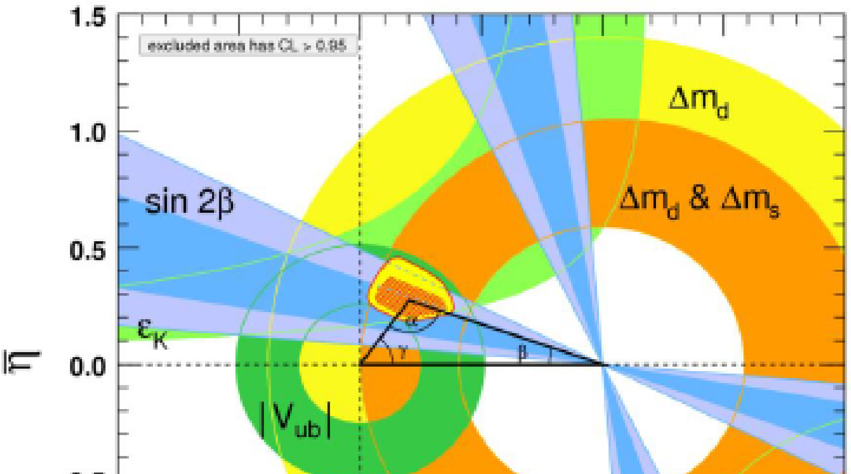
BaBar	$p(e^-)$=9 GeV	$p(e^+)$=3.1 GeV	$\beta\gamma$=0.56
Belle	$p(e^-)$=8 GeV	$p(e^+)$=3.5 GeV	$\beta\gamma$=0.42

To a large degree shaped flavour physics in the previous decade

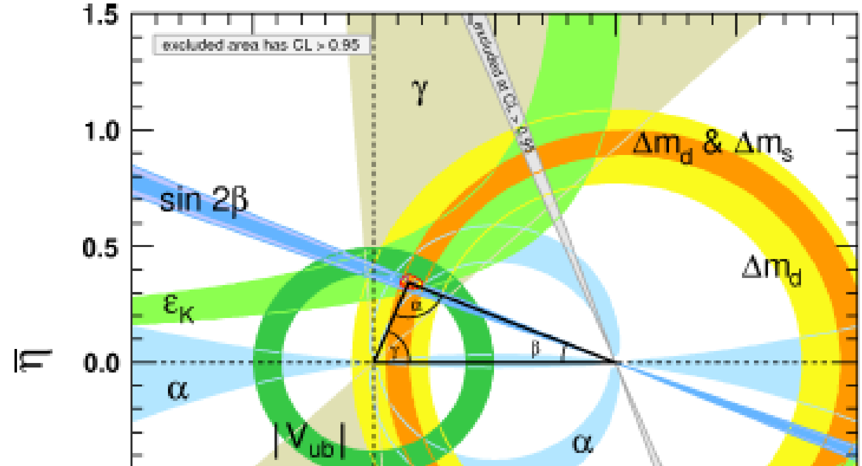
B factories: CP violation in the B system

CP violation in the B system: from the discovery (2001) to a precision measurement (2011).

EPS 2001



EPS 2011



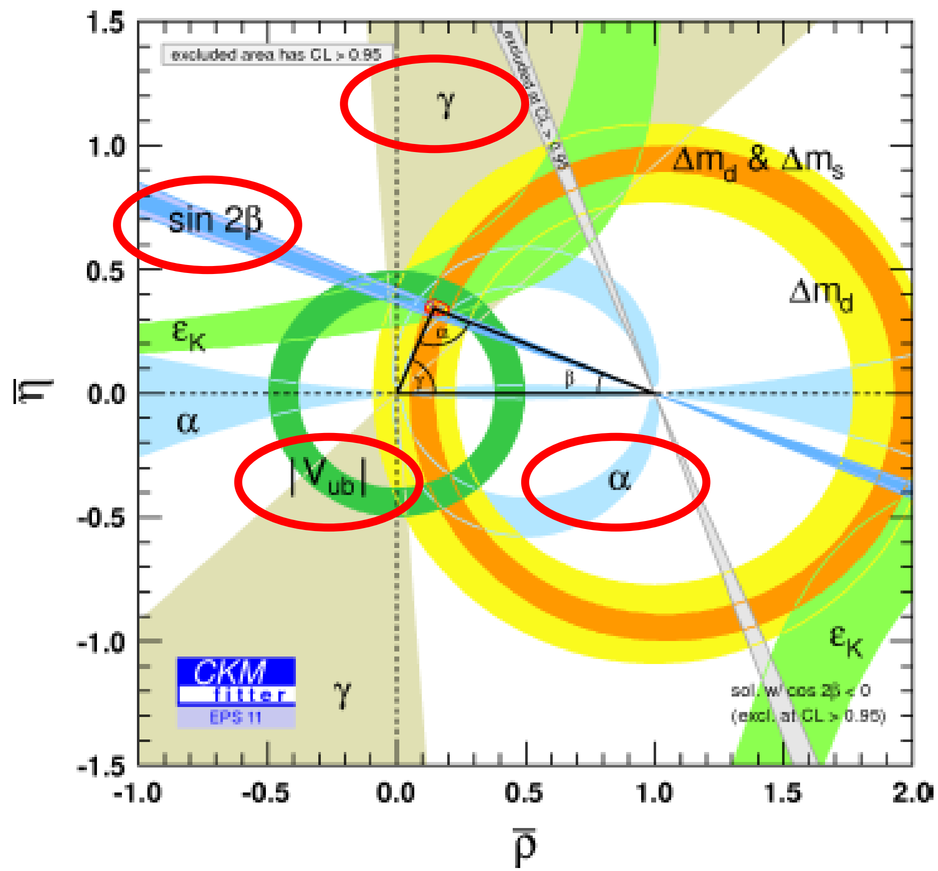
B factories: a success story

- 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 $b\rightarrow sl^+l^-$ has become a powerfull tool to search for physics beyond SM.
- Observation of D mixing
- Searches for rare τ decays
- Observation of new hadrons

Possible also because of unique capabilities of B factories: detection of neutrals, neutrinos, clean event environment.

Unitarity triangle – new measurements

Constraints from measurements of angles and sides of the unitarity triangle → Remarkable agreement, but still 10-20% NP allowed



Several very interesting recent results on angles and sides:

→ $\sin 2\phi_1$ ($=\sin 2\beta$)

→ ϕ_2 ($=\alpha$)

→ ϕ_3 ($=\gamma$)

→ $|V_{ub}|$

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

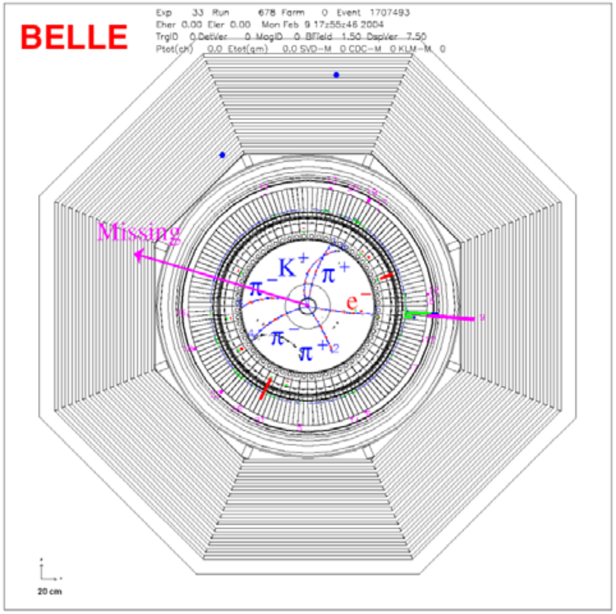
To observe a large ship far away one can either use **strong binoculars** or observe **carefully the direction and the speed of waves** produced by the vessel.

Energy frontier (LHC)

Luminosity frontier - (super) B factories

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 $\Upsilon(4S)$)

→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!)

→Well understood apparatus, with known systematics, checked on control channels

→ Talk by Leo Piilonen on recent results

Complementary to LHCb

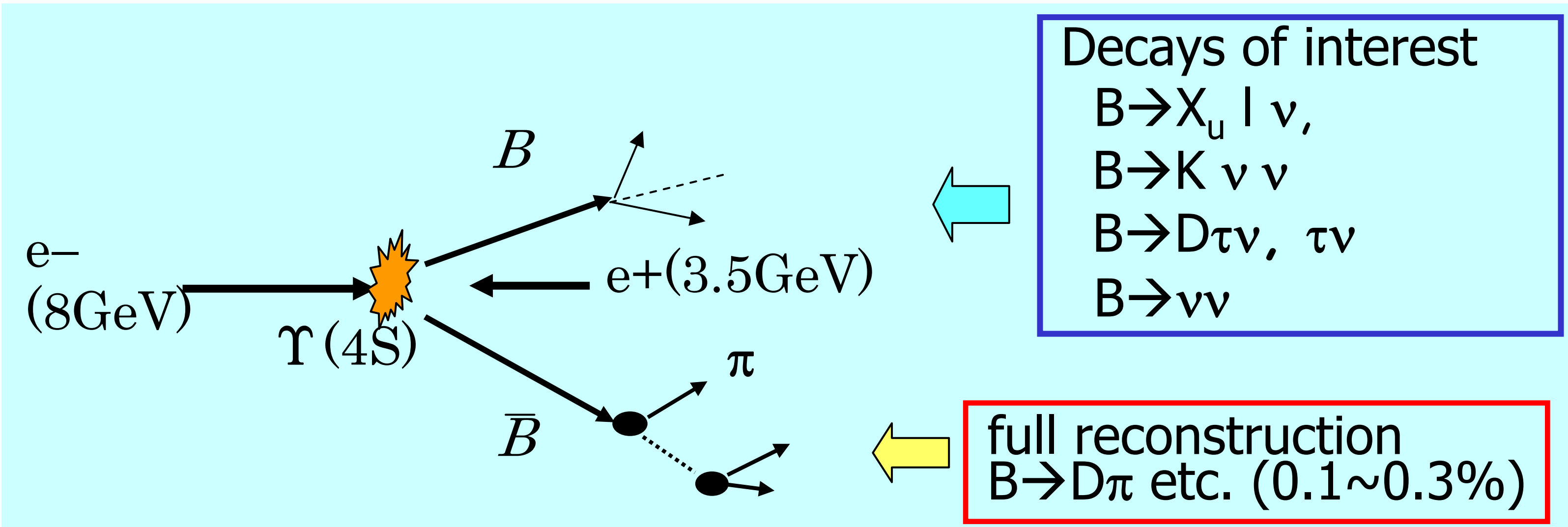
Observable	Expected th. accuracy	Expected exp. uncertainty	Facility
CKM matrix			
$\|V_{us}\|$ $[K \to \pi \ell \nu]$	**	0.1%	K-factory
$\|V_{cb}\|$ $[B \to X_c \ell \nu]$	**	1%	Belle II
$\|V_{ub}\|$ $[B_d \to \pi \ell \nu]$	*	4%	Belle II
$\sin(2\phi_1)$ $[c\bar{c}K_S^0]$	***	$8 \cdot 10^{-3}$	Belle II/LHCb
ϕ_2		1.5°	Belle II
ϕ_3	***	3°	LHCb
CPV			
$S(B_s \to \psi\phi)$	**	0.01	LHCb
$S(B_s \to \phi\phi)$	**	0.05	LHCb
$S(B_d \to \phi K)$	***	0.05	Belle II/LHCb
$S(B_d \to \eta' K)$	***	0.02	Belle II
$S(B_d \to K^*(\to K_S^0\pi^0)\gamma))$	***	0.03	Belle II
$S(B_s \to \phi\gamma))$	***	0.05	LHCb
$S(B_d \to \rho\gamma))$		0.15	Belle II
A_{SL}^d	***	0.001	LHCb
A_{SL}^s	***	0.001	LHCb
$A_{CP}(B_d \to s\gamma)$	*	0.005	Belle II
rare decays			
$\mathcal{B}(B \to \tau\nu)$	**	3%	Belle II
$\mathcal{B}(B \to D\tau\nu)$		3%	Belle II
$\mathcal{B}(B_d \to \mu\nu)$	**	6%	Belle II
$\mathcal{B}(B_s \to \mu\mu)$	***	10%	LHCb
zero of $A_{FB}(B \to K^*\mu\mu)$	**	0.05	LHCb
$\mathcal{B}(B \to K^{(*)}\nu\nu)$	***	30%	Belle II
$\mathcal{B}(B \to s\gamma)$		4%	Belle II
$\mathcal{B}(B_s \to \gamma\gamma)$		$0.25 \cdot 10^{-6}$	Belle II (with 5 ab^{-1})
$\mathcal{B}(K \to \pi\nu\nu)$	**	10%	K-factory
$\mathcal{B}(K \to e\pi\nu)/\mathcal{B}(K \to \mu\pi\nu)$	***	0.1%	K-factory
charm and τ			
$\mathcal{B}(\tau \to \mu\gamma)$	***	$3 \cdot 10^{-9}$	Belle II
$\|q/p\|_D$	***	0.03	Belle II
$arg(q/p)_D$	***	1.5°	Belle II

→Need both LHCb and super B factories to cover all aspects of precision flavour physics

- B. Golob, KEK FF Workshop, Feb. 2012

Power of e^+e^-, example: Full Reconstruction Method

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



→ Offline B meson beam!

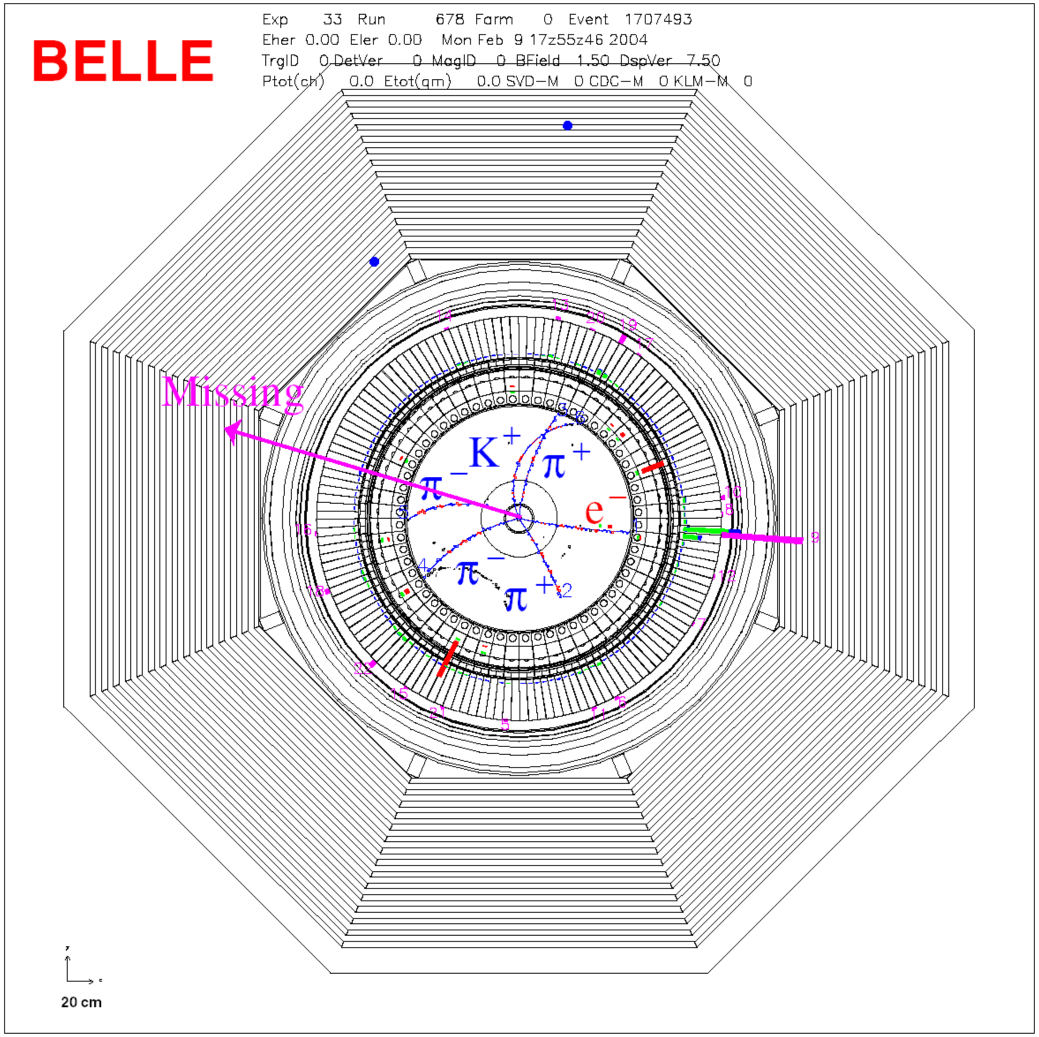
Powerful tool for B decays with several neutrinos in the final state

A modified version of this method can also be used for charm decays

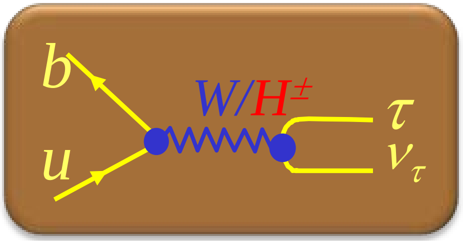
$B^- \rightarrow \tau^- \nu_\tau$

Example of a missing energy decay

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



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



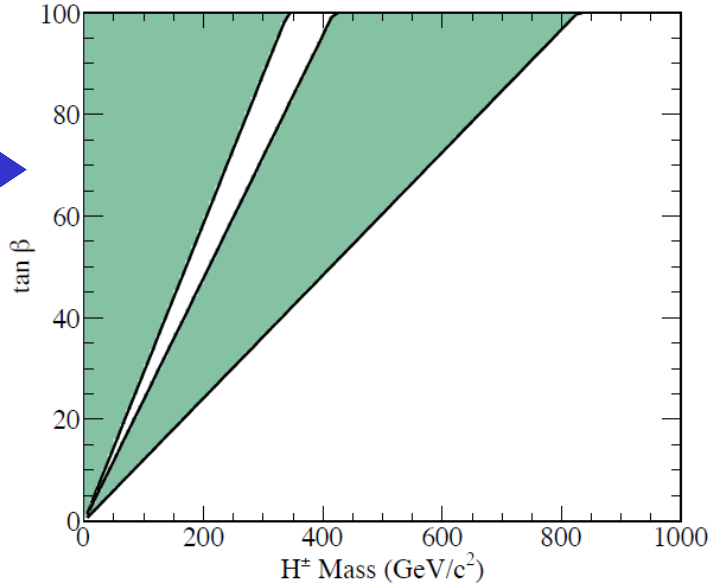
Measured value

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

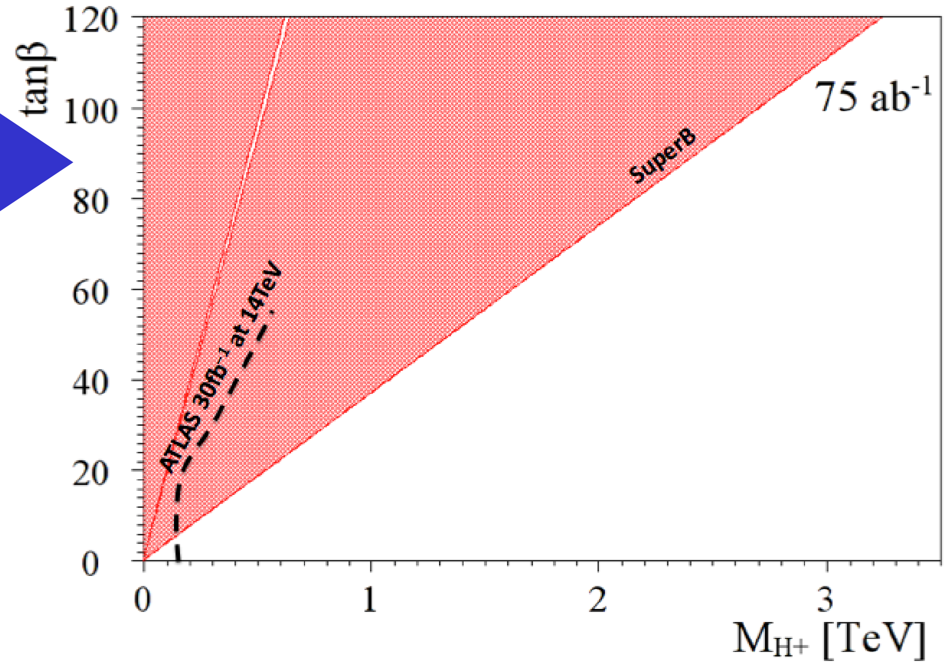
→ limit on charged Higgs mass vs. tanβ

(for type II 2HDM)

B factories: Exclusion plot

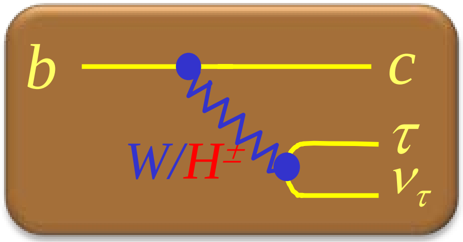


Super B factory: Discovery plot: very much competitive with LHC!



B → $D^{(*)}\tau\nu$ decays

Semileptonic decay sensitive to charged Higgs



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

Kamenik, Mescia arXiv:0802.3790

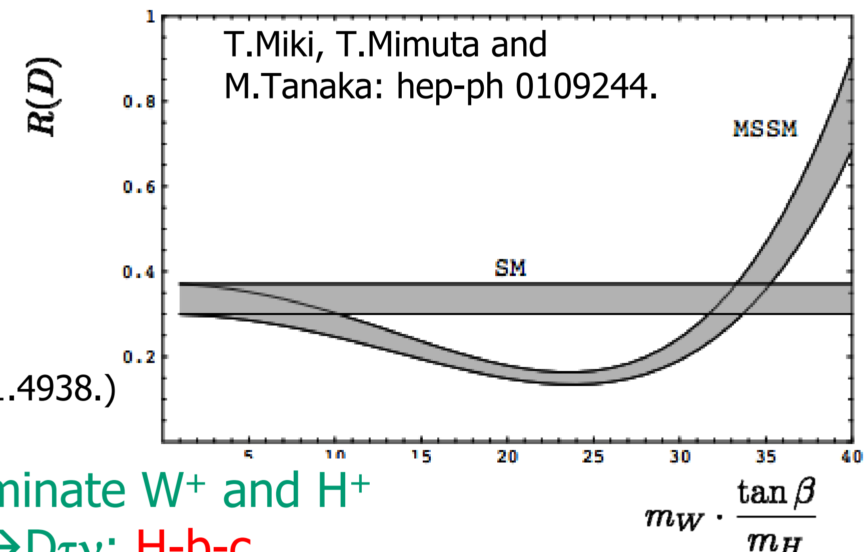
$$R(D) \equiv \frac{\mathcal{B}(B \to D\tau\nu)}{\mathcal{B}(B \to D\ell\nu)}$$

Complementary and competitive with B→τν

1.Smaller theoretical uncertainty of R(D)

(For B→τν,
There is O(10%) f_B uncertainty from lattice QCD)

2.Large Brs (~1%) in SM (Ulrich Nierste arXiv:0801.4938.)

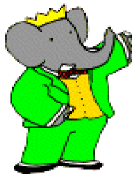


3. Differential distributions can be used to discriminate W^+ and H^+
4. Sensitive to different vertex B→τ ν: H-b-u, B→Dτν: H-b-c
(LHC experiments sensitive to H-b-t)

First observation of B → $D^{*-}\tau\nu$ by Belle (2007) → PRL 99, 191807 (2007)

$B \to D^{(*)} \tau\nu$ decays

Exclusive hadron tag data



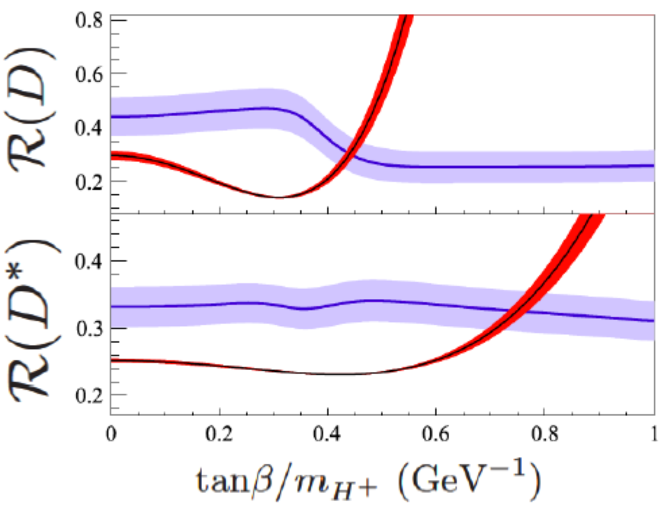
$$\mathcal{R}(D)_{\rm exp} = 0.440 \pm 0.072 \qquad \mathcal{R}(D^*)_{\rm exp} = 0.332 \pm 0.030$$

$\updownarrow$ 2.0σ $\qquad\qquad$ $\updownarrow$ 2.7σ

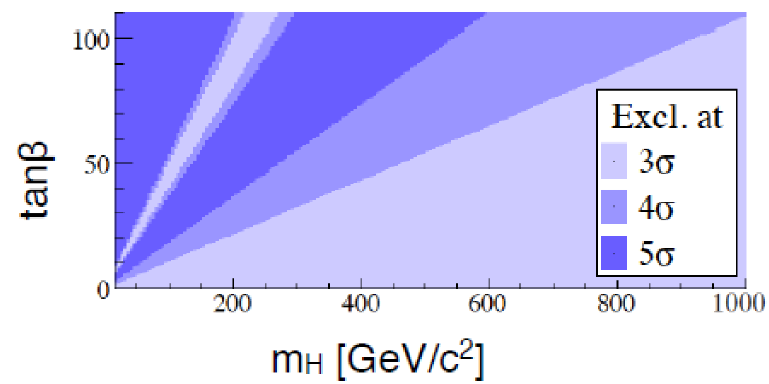
$$\mathcal{R}(D)_{\rm SM} = 0.297 \pm 0.017 \qquad \mathcal{R}(D^*)_{\rm SM} = 0.252 \pm 0.003$$

SM expectations in S. Fajfer, J. Kamenik, I. Nisandzic, PRD 85, 094025 (2012).

→ Combined result: 3σ away from SM.



Blue: this result, red: Type-II 2HDM.

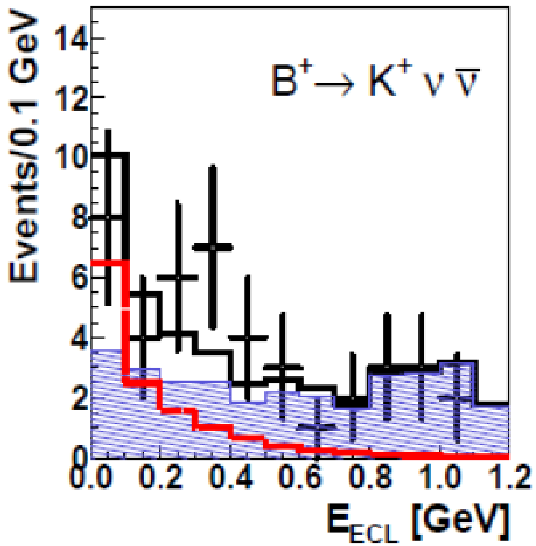


→ Combined result: Type II 2HDM excluded at 99.8% C.L. for any values of tanβ and charged Higgs mass

More discussion of the implications: in the BaBar report arXiv:1303.0571

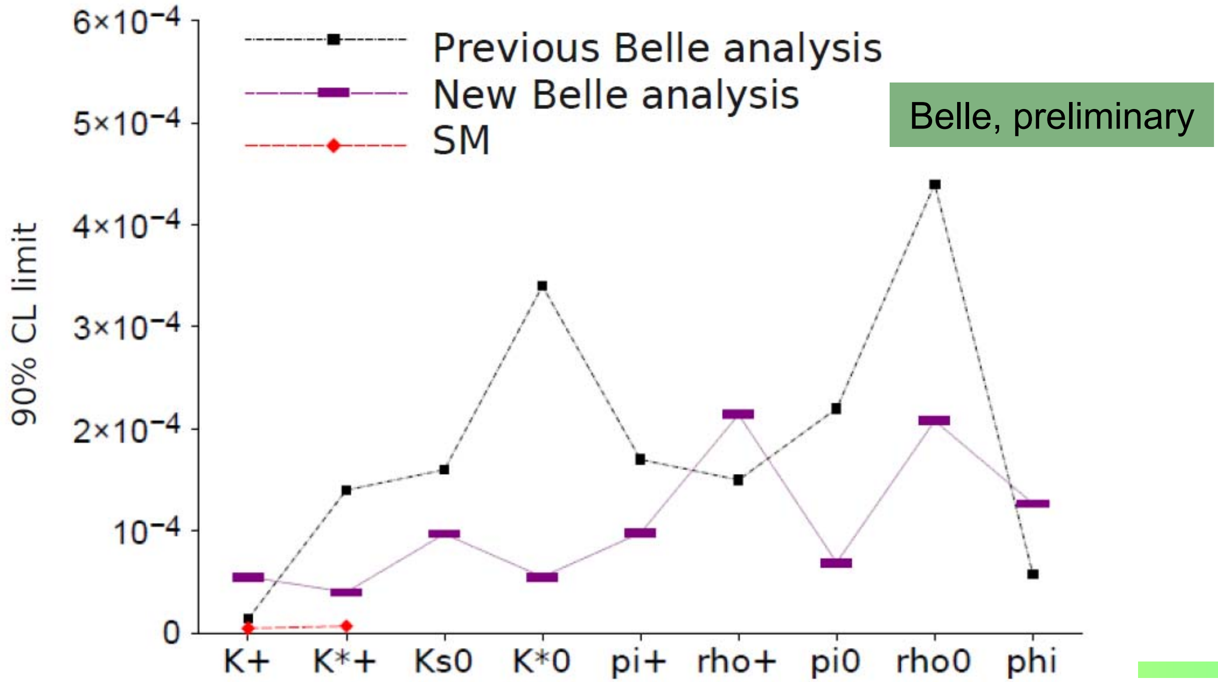
$B \to h\nu\bar{\nu}$ decays

Method: again tag one B with full reconstruction, search for signal in the remaining energy in the calorimeter, at $E_{ECL} = 0$



$$N_{Sig} = 13.3^{+7.4}_{-6.6}(stat) \pm 2.3(syst)$$
$$S_{stat+syst} = 2.0\sigma$$

Present status: recent update from Belle

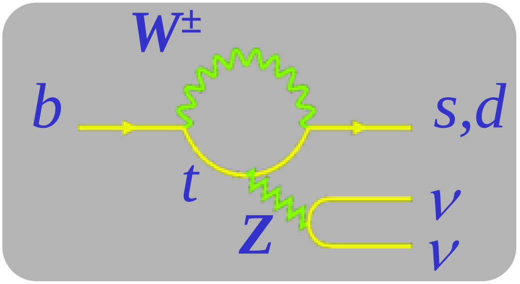


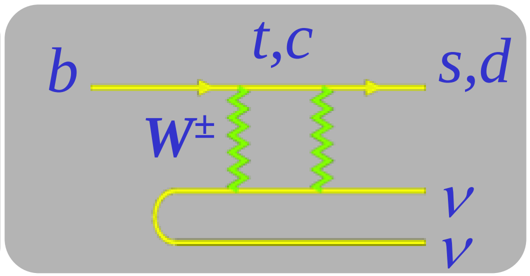
$B \to K^{(*)}\nu\bar{\nu}$

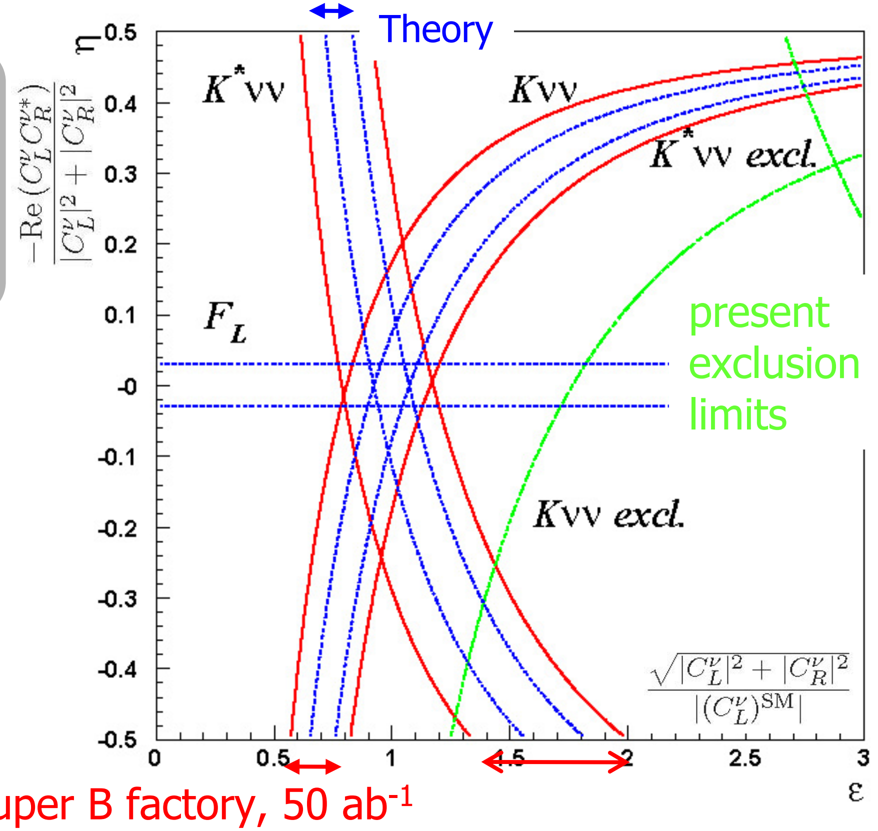
arXiv:1002.5012

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

SM: penguin + box diagrams



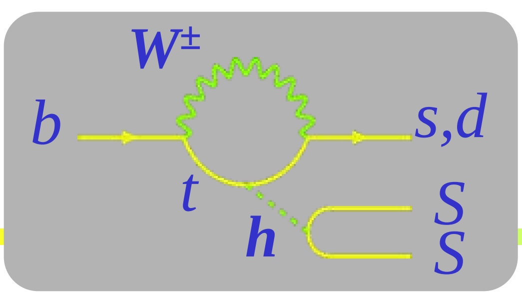


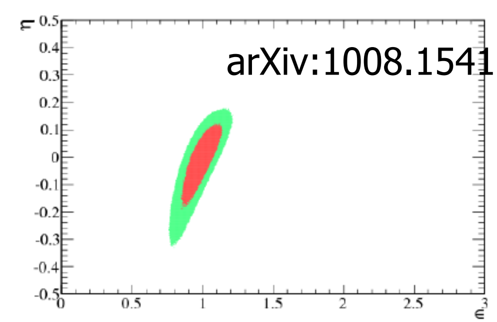


$B \to K\nu\nu$, $\mathcal{B} \sim 4{\cdot}10^{-6}$
$B \to K^*\nu\nu$, $\mathcal{B} \sim 6.8{\cdot}10^{-6}$

Look for deviations from the expected values → information on anomalous couplings C^ν_R and C^ν_L compared to $(C^\nu_L)^{SM}$

from, e.g.,





Charm and τ physics

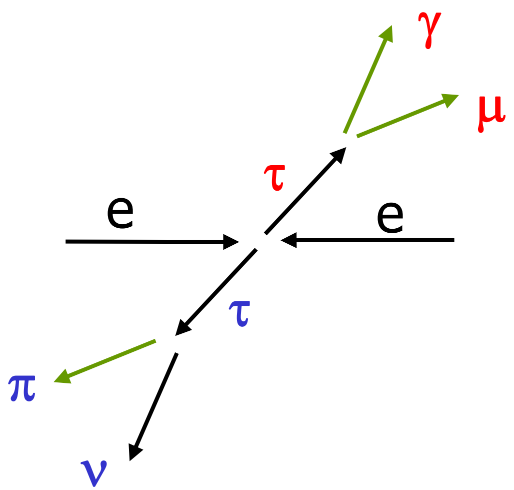
B factories = charm and τ factories

A few examples of the strengths of B factories:

- CP violation in charm at B factories (and super B factories) $\rightarrow$ 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, e.g. for $D^+ \rightarrow \mu^+\nu$ decays
- D mixing was discovered at Belle and BaBar

Rare τ decays

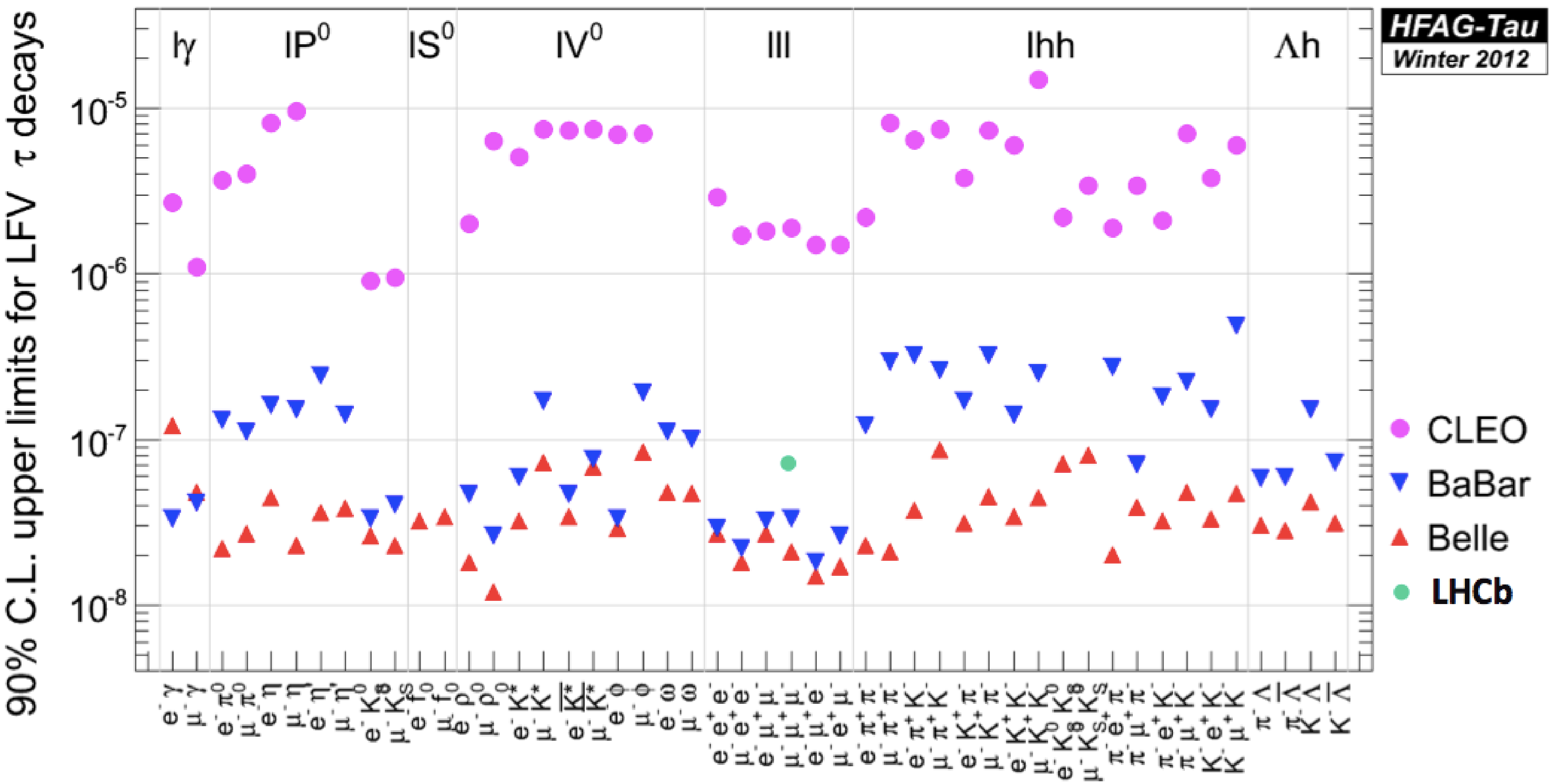
Example: lepton flavour violating decay $\tau \to \mu\,\gamma$



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

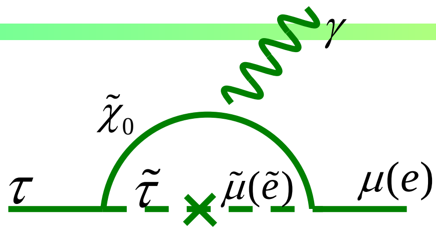
LFV in tau decays: present status

Lepton flavour violation (LFV) in tau decays: B factories reached upper limits of ~10^{-8}



LFV and New Physics

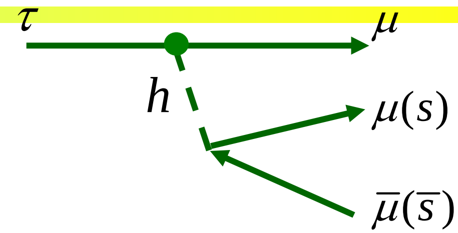
$\tau \to l\gamma$



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

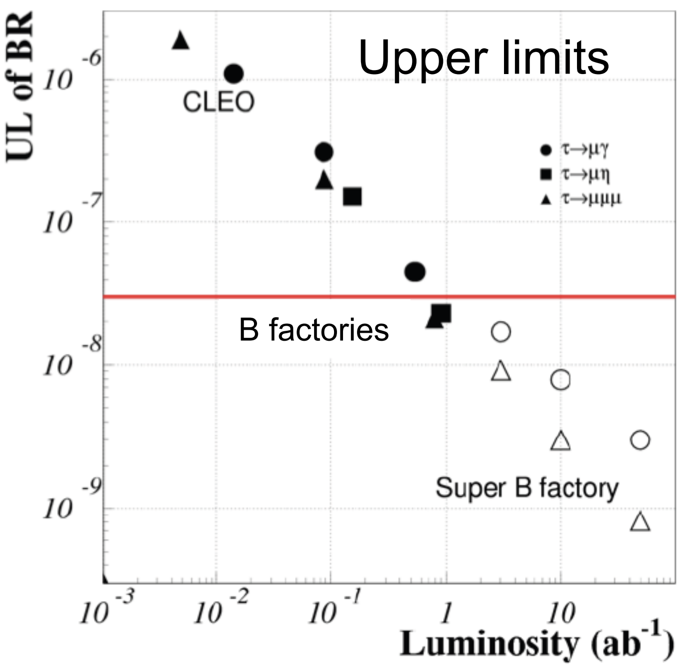
$$Br(\tau \to \mu\gamma) \simeq 10^{-6} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}} \right) \left(\frac{1\,TeV}{m_{SUSY}} \right)^4 \tan^2 \beta$$

$\tau \to 3l, l\eta$



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

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



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

What next?

Next generation: Super B factories → Looking for NP

→ Need much more data (almost two orders!)

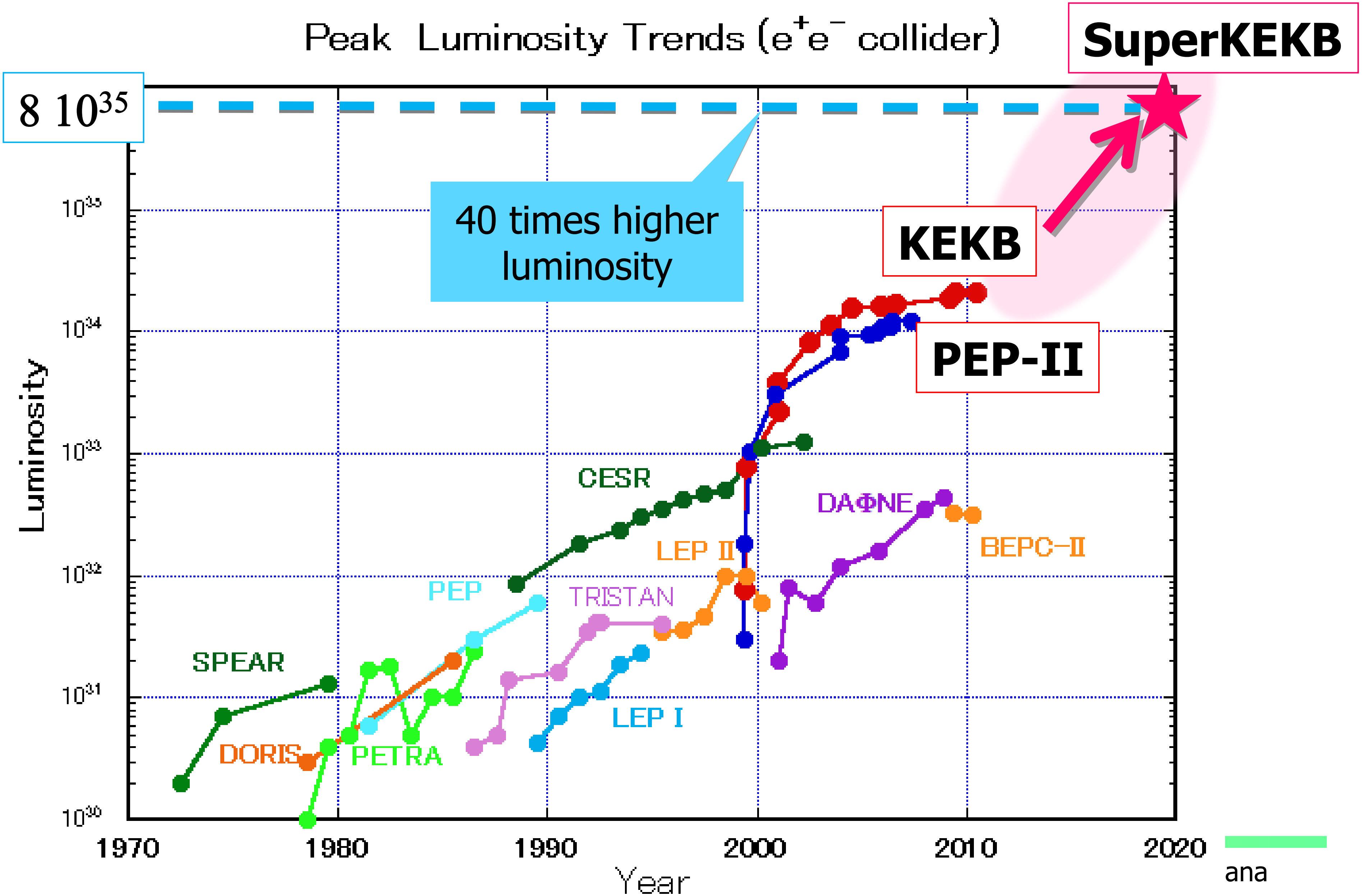
However: it will be a different world in four years, there is/will be serious competition from LHCb and BESIII

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

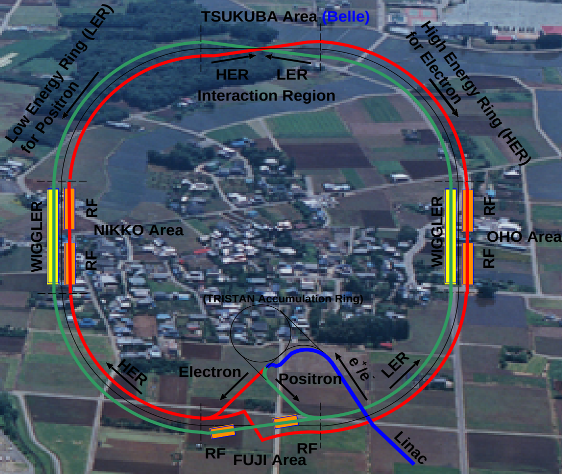
→ Physics at Super B Factory, arXiv:1002.5012 (Belle II)
→ SuperB Progress Reports: Physics, arXiv:1008.1541 (SuperB)

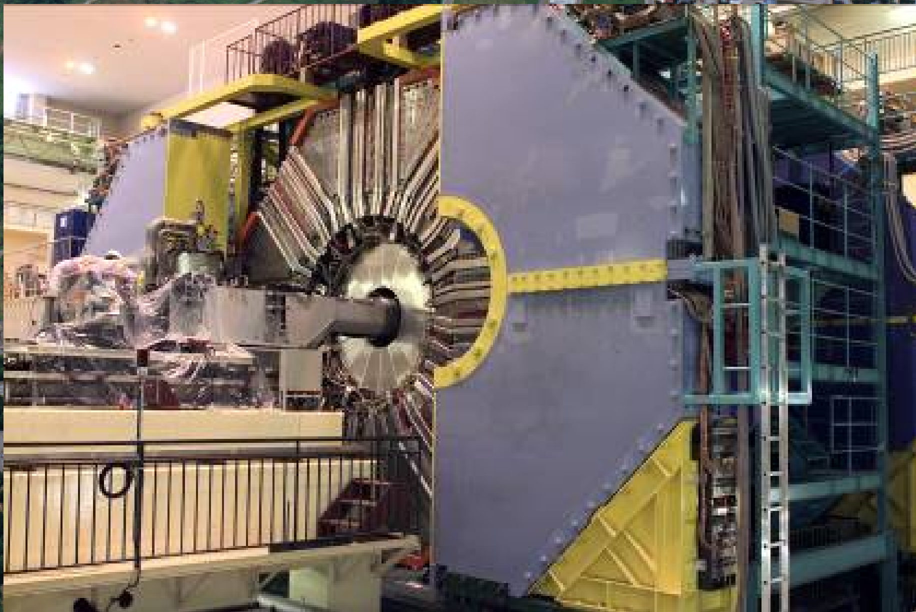
Accelerators

Need 50x more data →Next generation B-factories

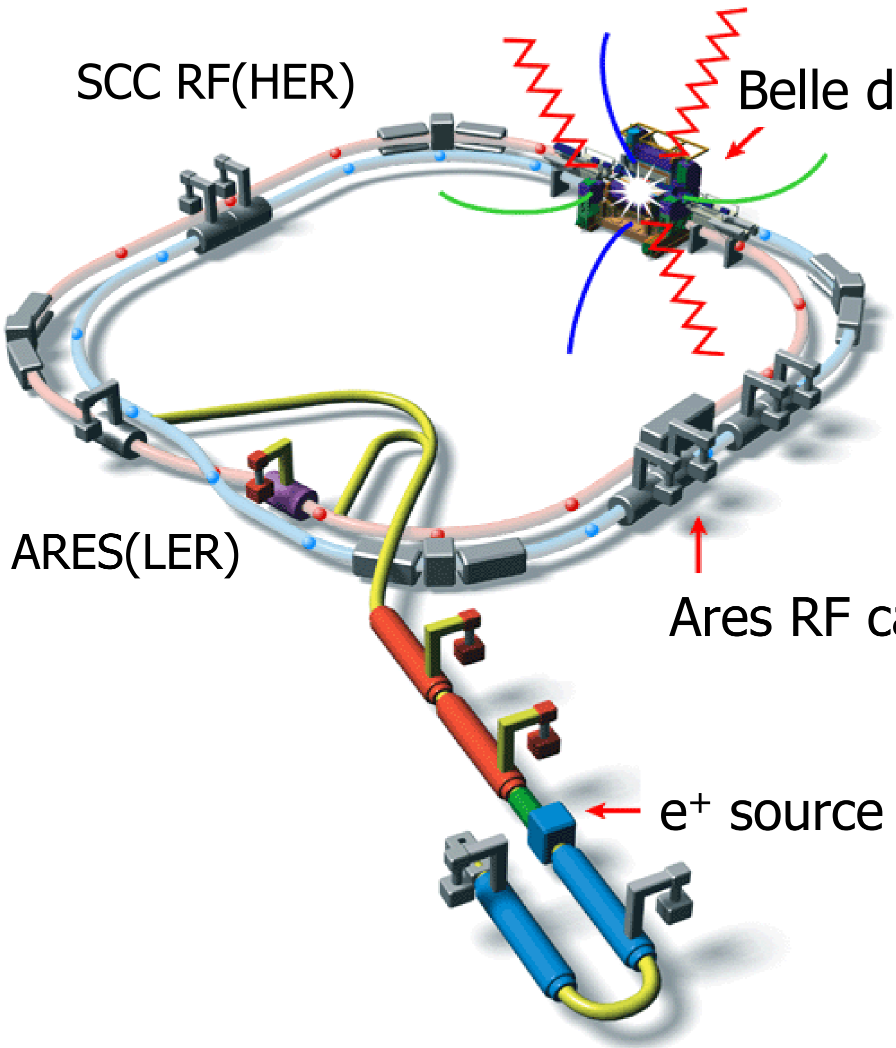


How to do it?
→ upgrade KEKB and Belle





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

=2x design value

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

Strategies for increasing 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

Machine design parameters

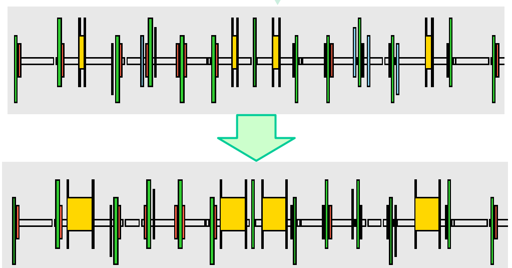
SuperKEKB
Quest for BSM

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	4.6	nm
Emittance ratio	κ	0.88	0.66	0.37	0.40	%
Beta functions at IP	β_x^* / β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0881	0.0807	
Luminosity	**L**	**2.1×10^{34}**		**8×10^{35}**		**$cm^{-2}s^{-1}$**

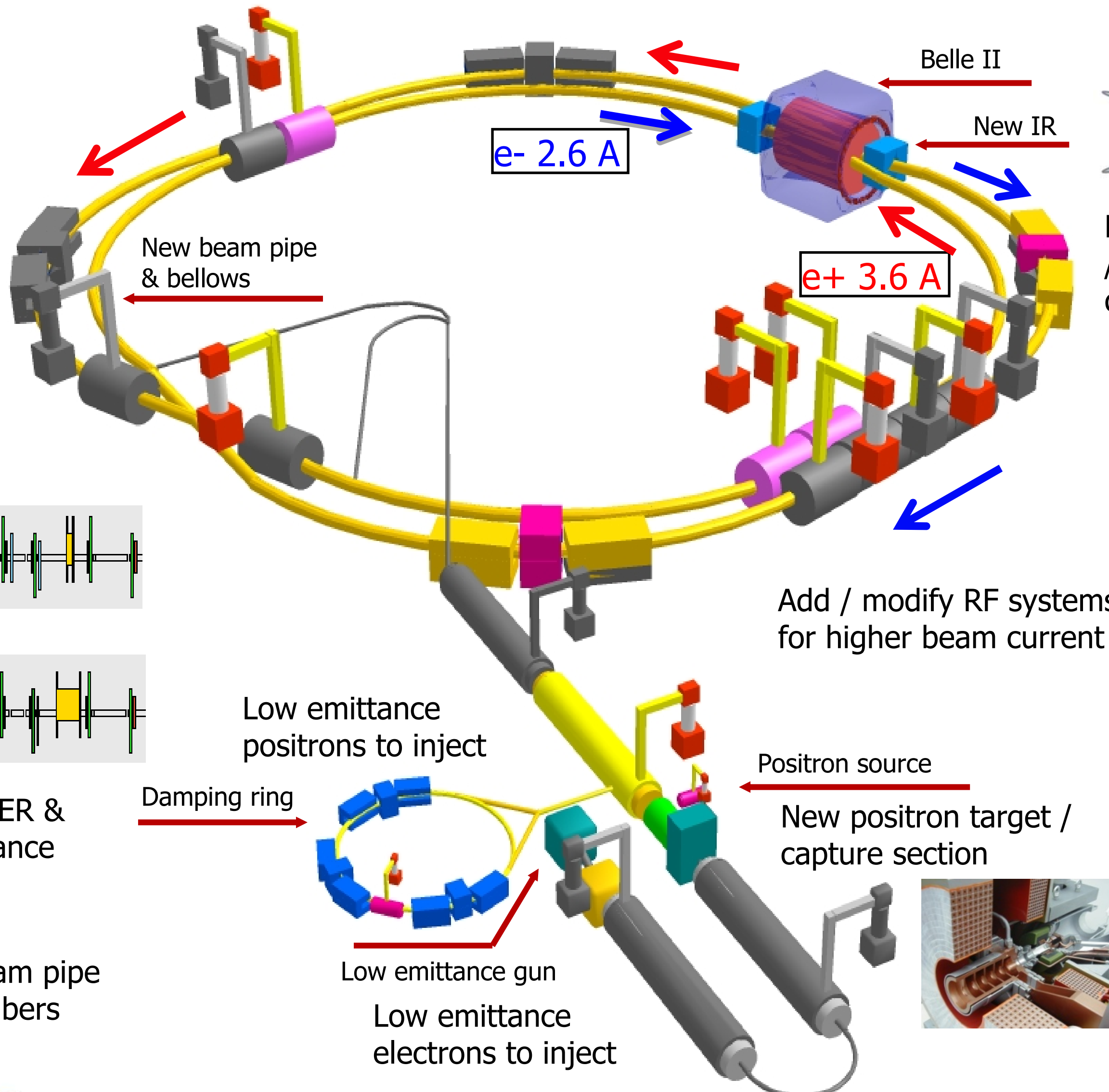
- **Nano-beams and a factor of two more beam current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of short lifetime for the LER

KEKB to SuperKEKB

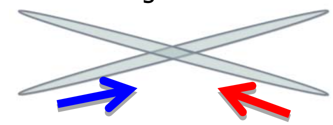
Replace short dipoles with longer ones (LER)



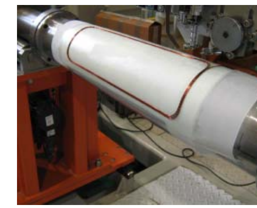
Redesign the lattices of HER & LER to squeeze the emittance



Colliding bunches



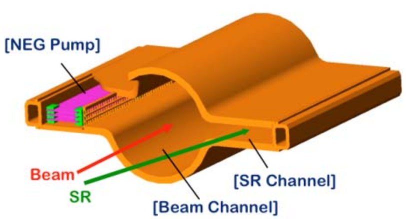
New superconducting /permanent final focusing quads near the IP



Add / modify RF systems for higher beam current

New positron target / capture section

TiN-coated beam pipe with antechambers



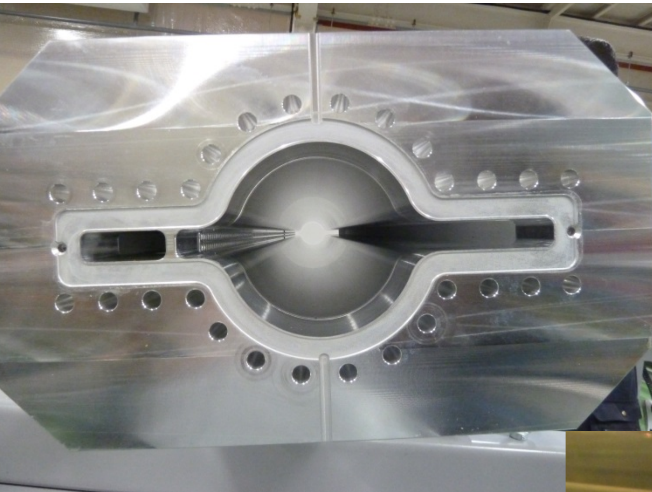
To obtain x40 higher luminosity

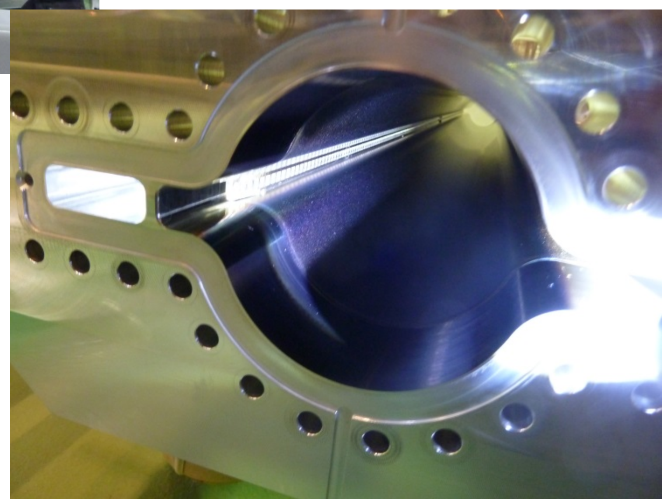
Entirely new LER beam pipe with ante-chamber and Ti-N coating

Beam pipe is made of aluminum.

Fabrication of the LER arc beam pipe section is completed

Al ante-chamber before coating





After TiN coating
before baking

After baking

All 100 4 m long dipole magnets have been successfully installed in the low energy ring (LER)!

Three magnets per day !

Installing the 4 m long LER dipole **over** the 6 m long HER dipole (remains in place).

Magnet installation

field measurement

move into tunnel

Installation of 100 new LER bending magnets done

carry on an air-pallet

carry over existing HER dipole

installation done

Damping ring construction: tunnel finished, spring 2013

- Tunnel construction finished
- Construction of buildings for DR will start in April this year.
- Fabrication of accelerator components ongoing. Installation starts in 2014.
- DR commissioning will start in 2015.

Inside DR tunnel

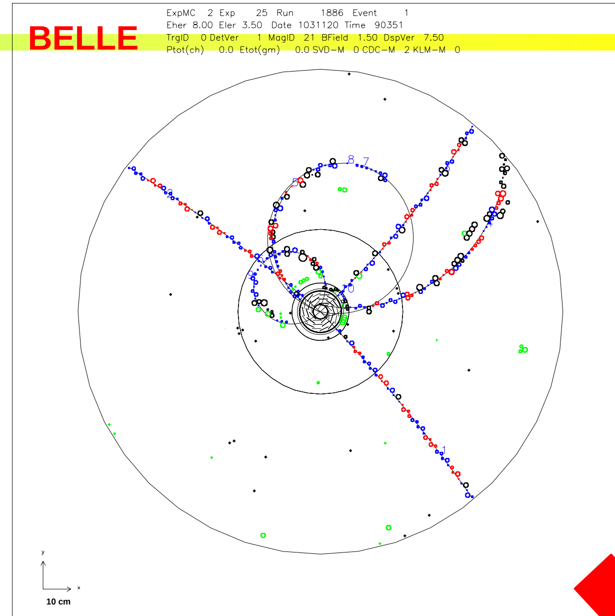
Now DR has been buried.

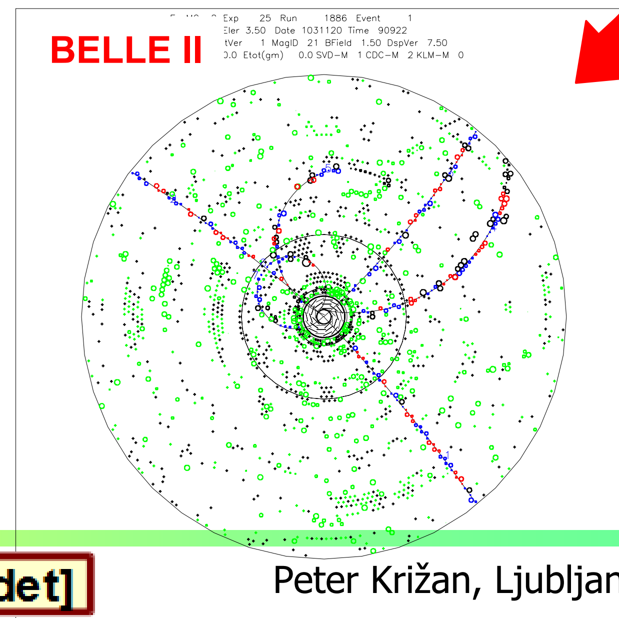
Detector

Need to build a new detector to handle higher backgrounds

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 ← $s\mu\mu$ recon. eff.
  - hermeticity ← ν "reconstruction"

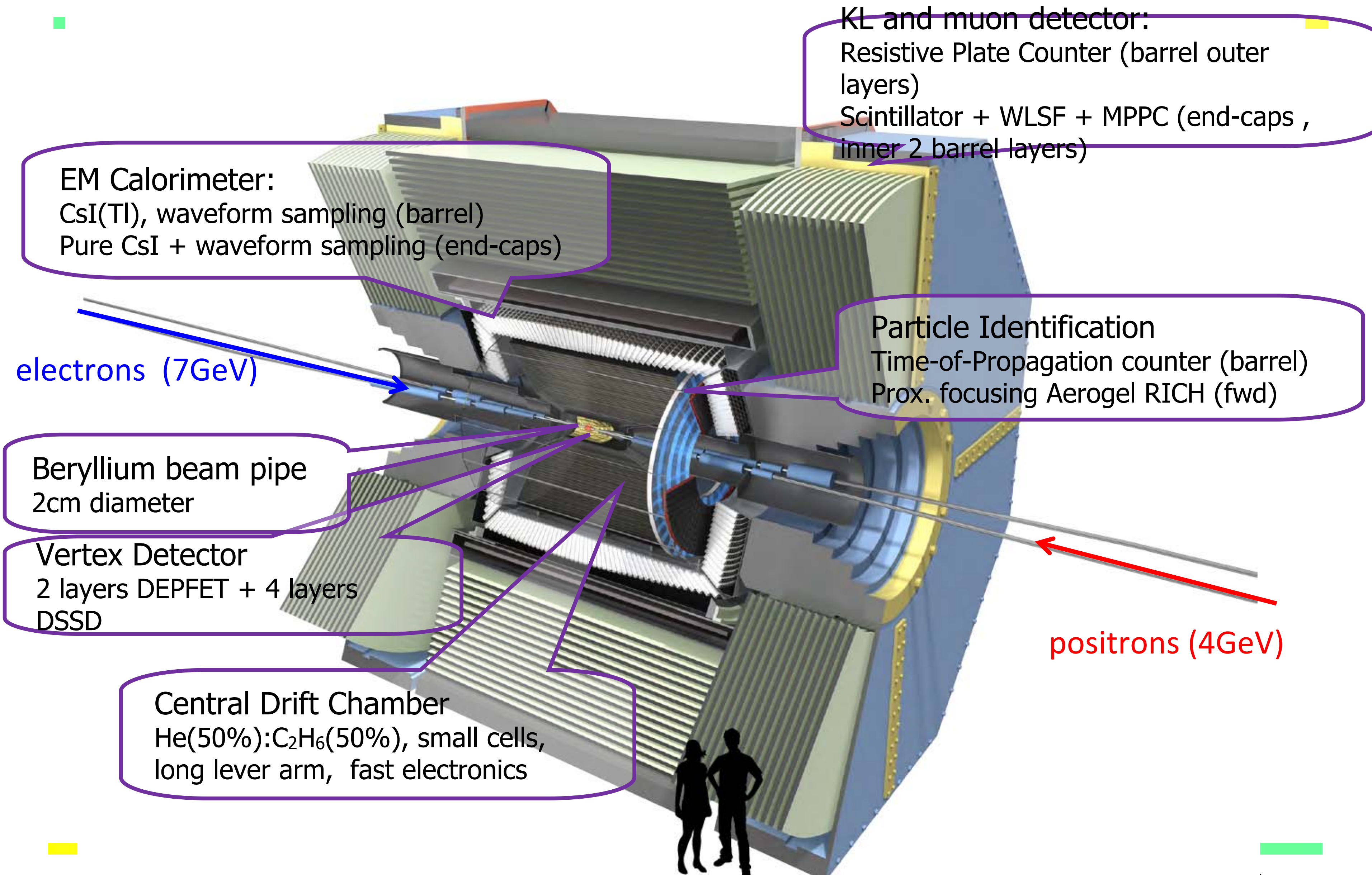




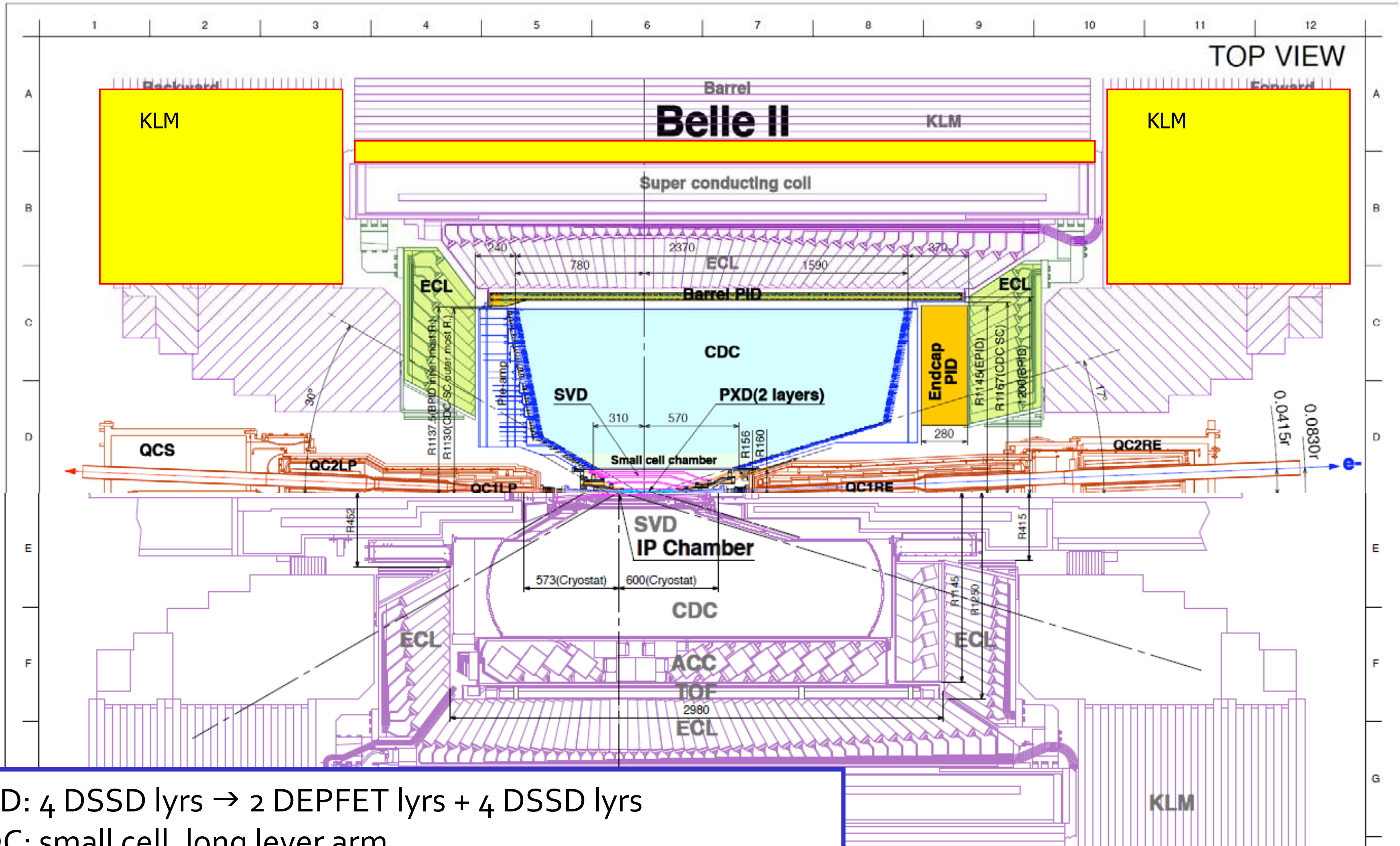
Have to employ and develop new technologies to make such an apparatus work! →

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

Belle II Detector



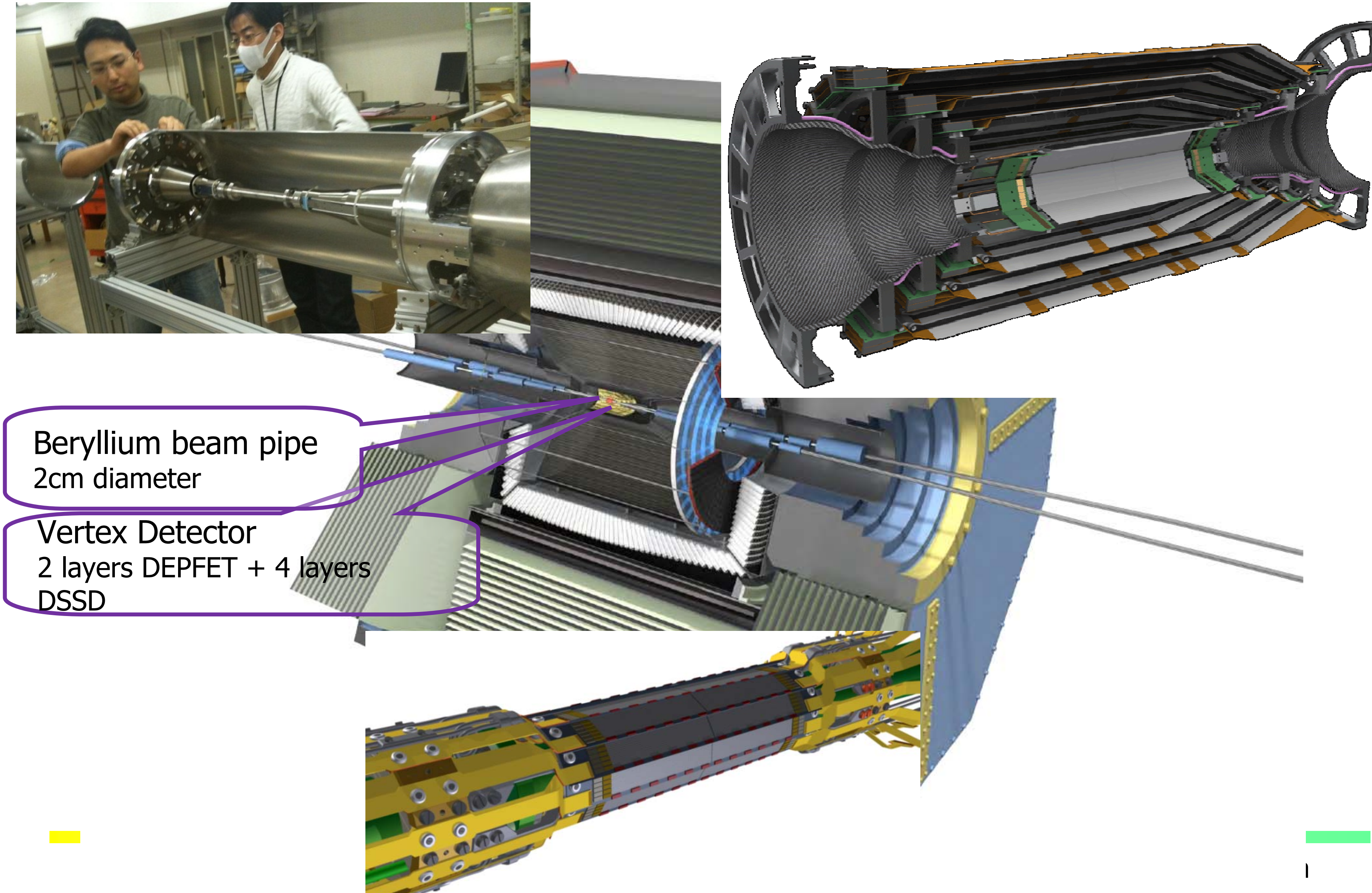
Belle II Detector (in comparison with Belle)



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)

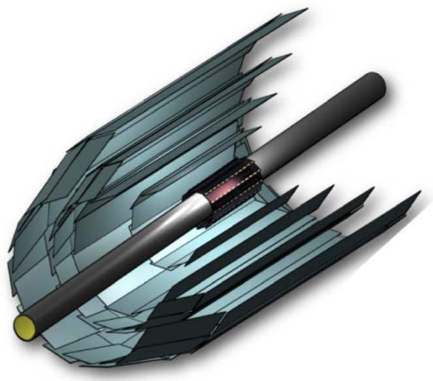
In colour: new or upgarded components

Belle II Detector – vertex region



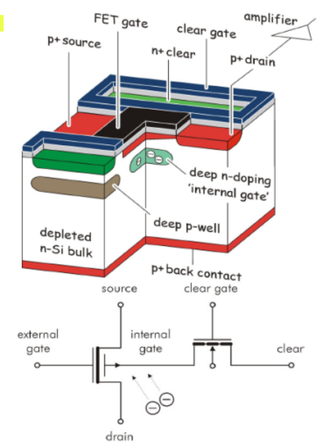
Vertex Detector

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



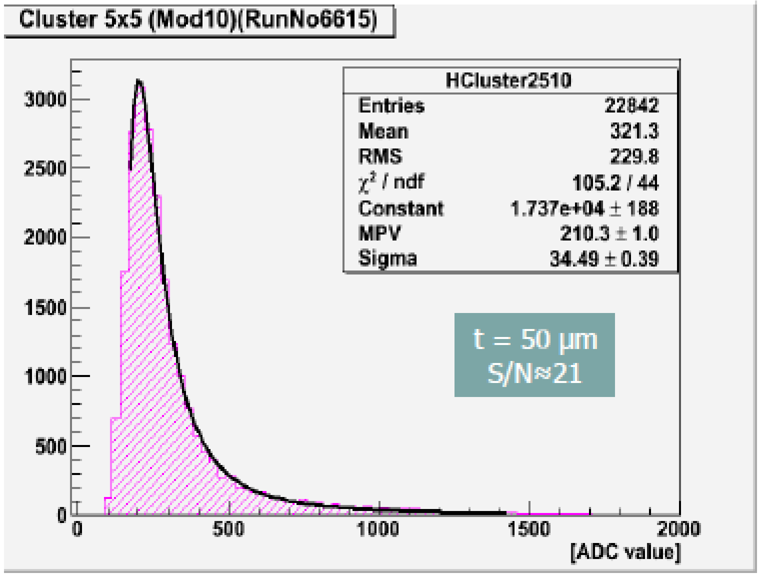
Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

DEpleted P-channel FET



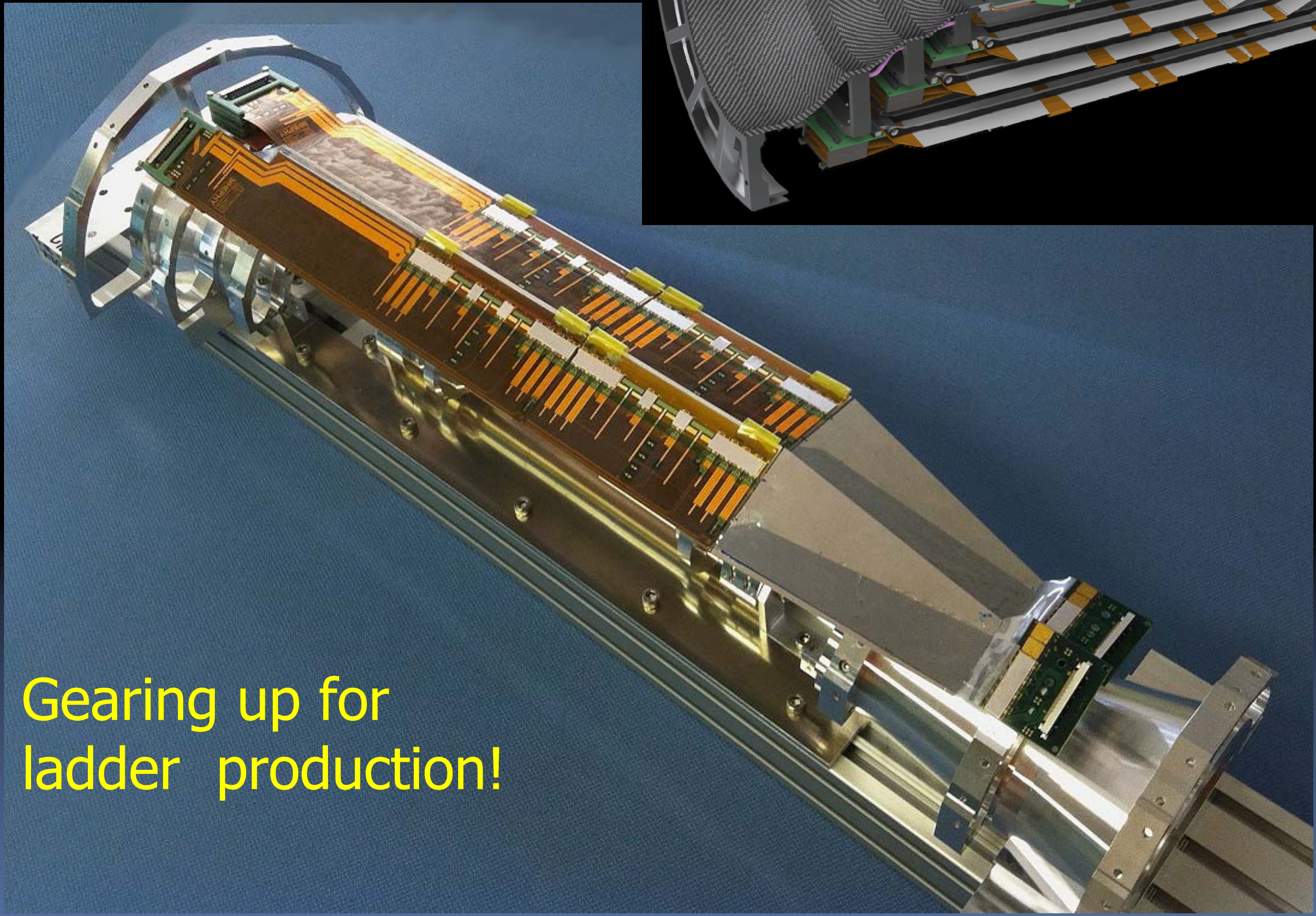
Mechanical mockup of pixel detector

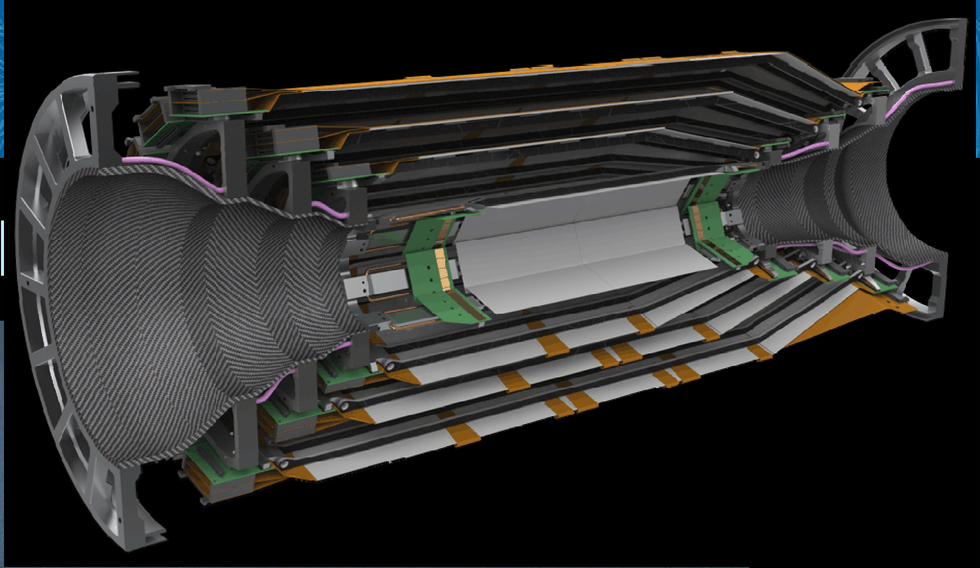
DEPFET pixel sensor



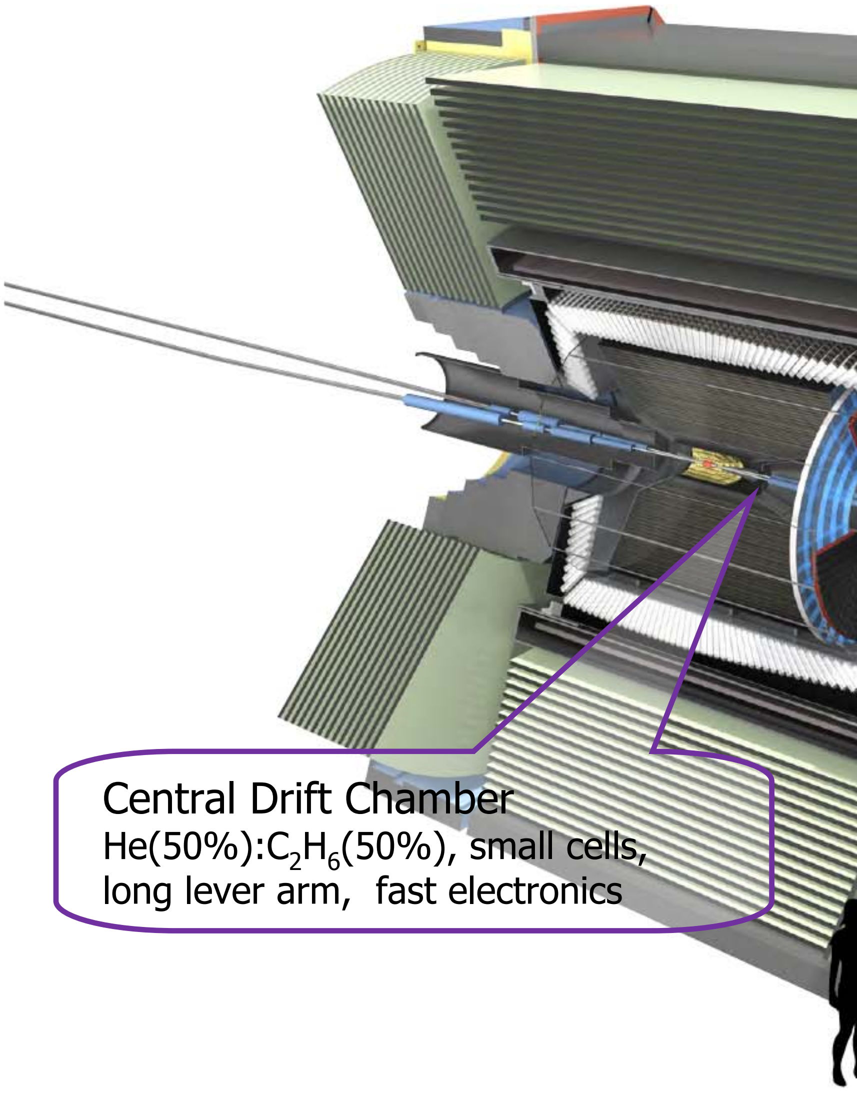
DEPFET sensor: very good S/N

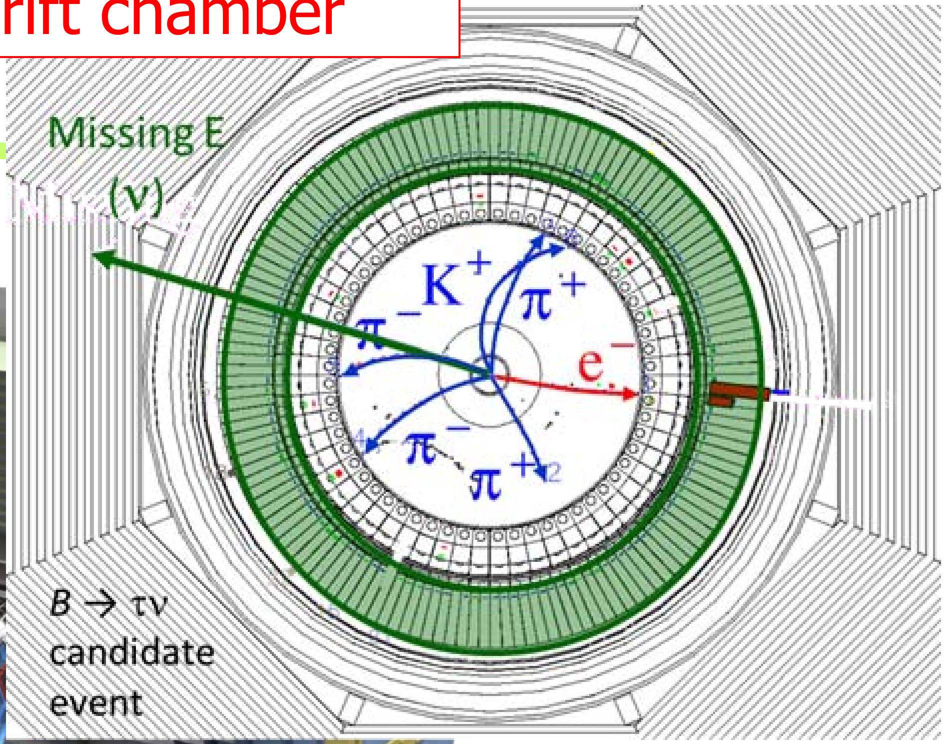
SVD Mechanical Mockup



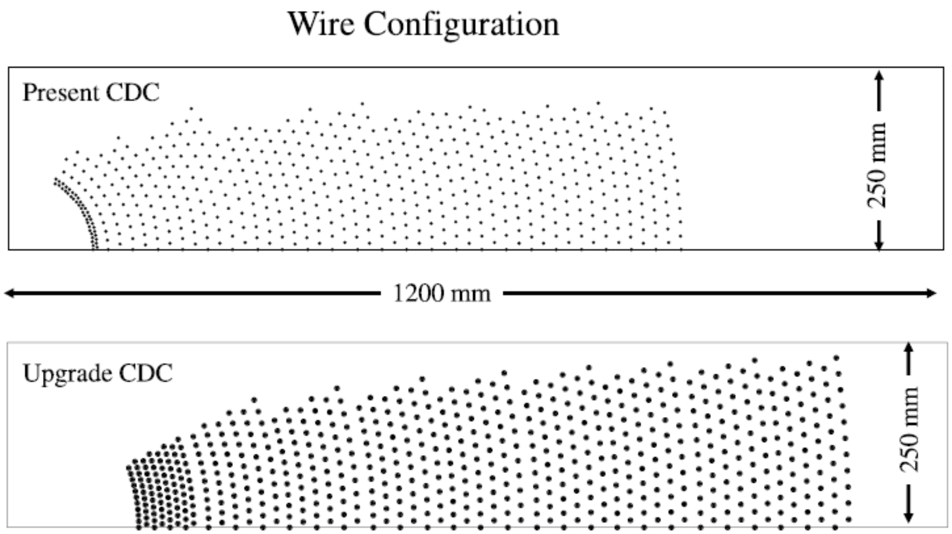


Main tracking device: small cell drift chamber

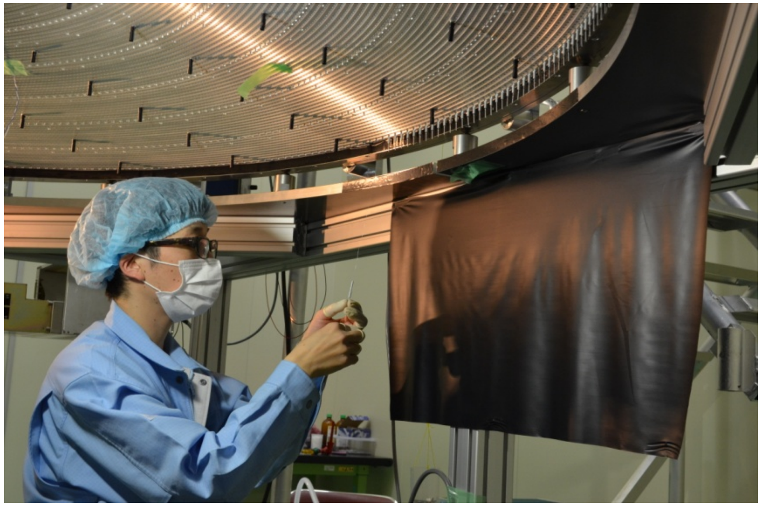




Belle II CDC



Much bigger than in Belle!

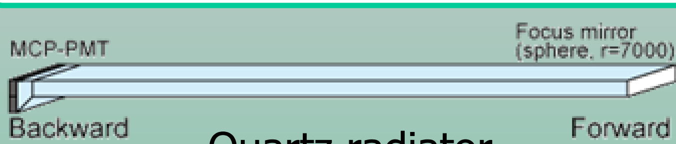


Wire stringing in a clean room

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

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



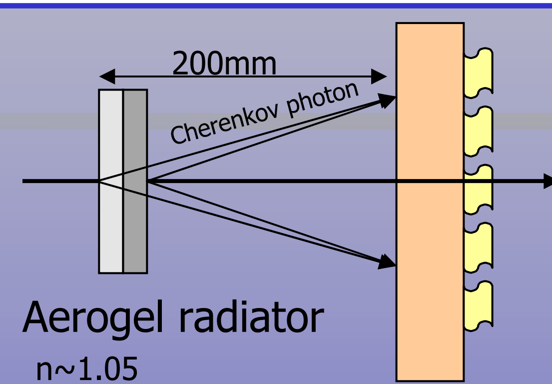
Quartz radiator

Focusing mirror

Small expansion block

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

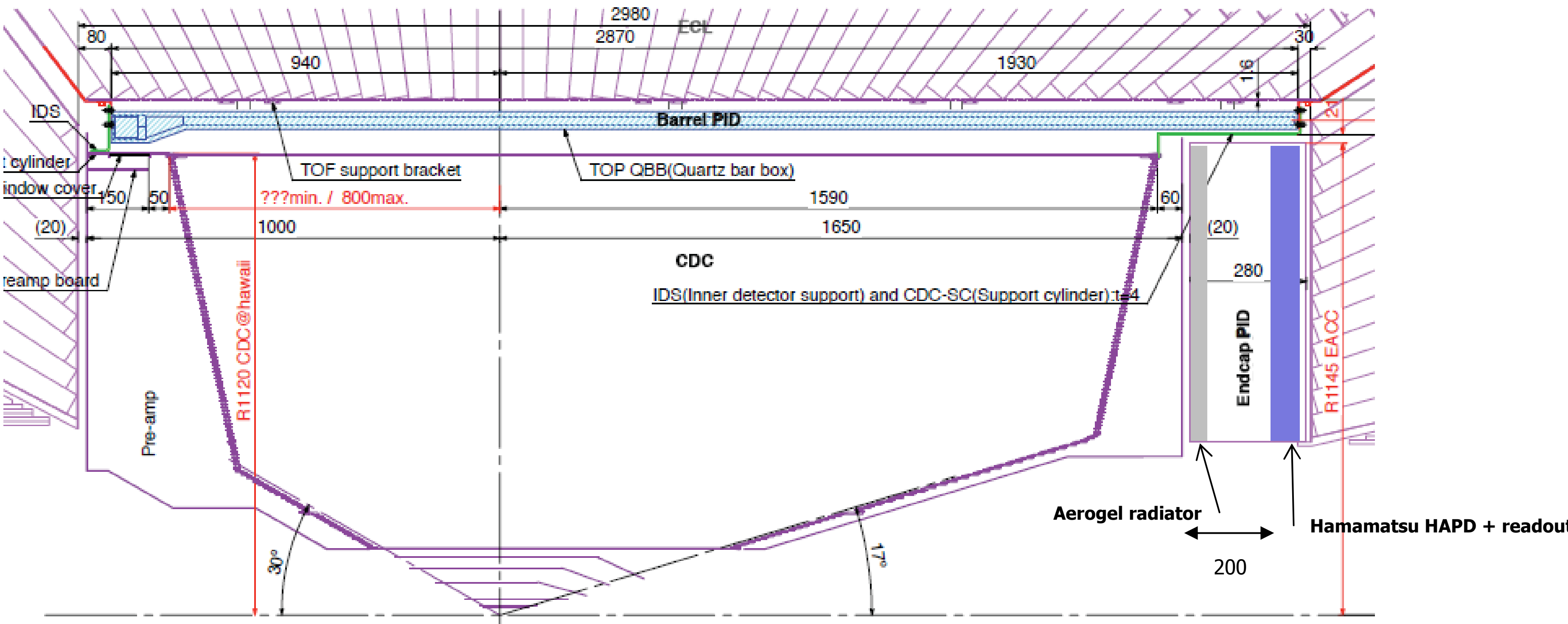
Endcap PID: Aerogel RICH (ARICH)



Aerogel radiator

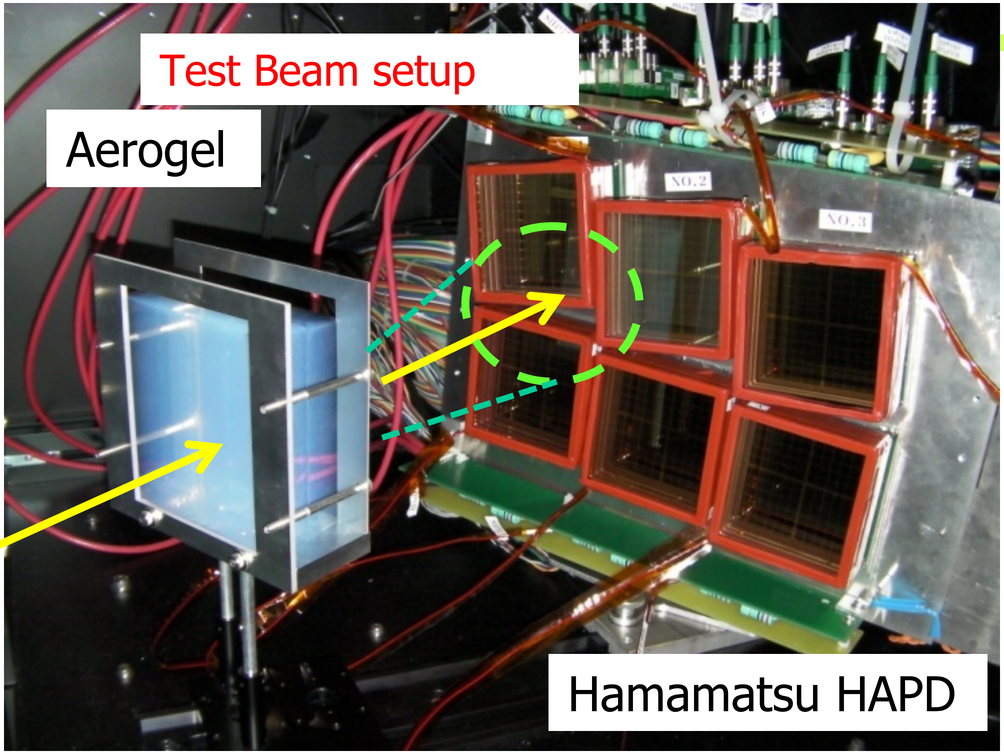
n~1.05

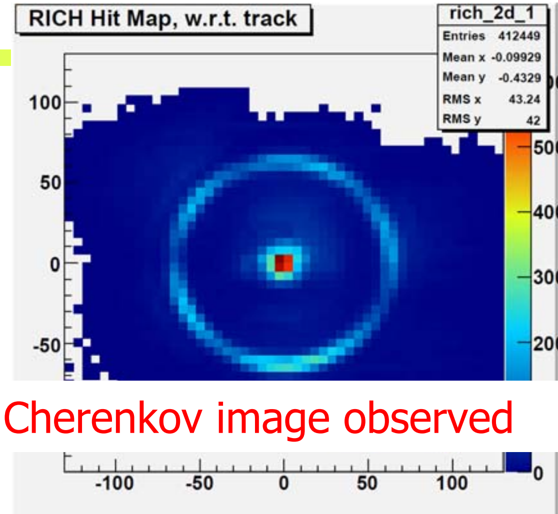
Hamamatsu HAPD
+ new ASIC



Peter Križan, Ljubljana

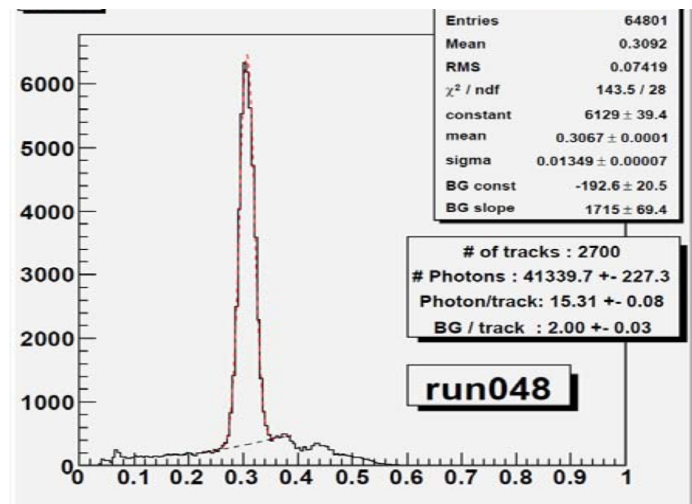
Aerogel RICH (endcap PID)





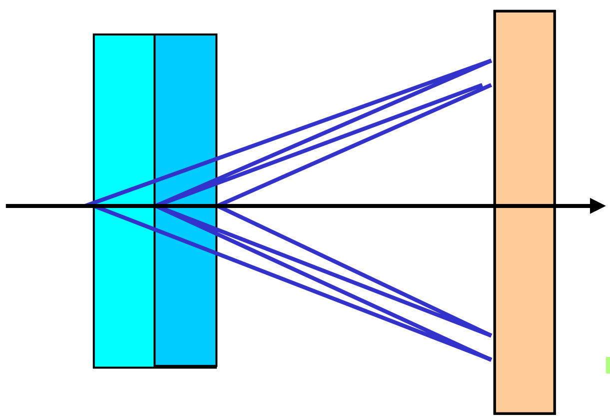
Clear Cherenkov image observed

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.

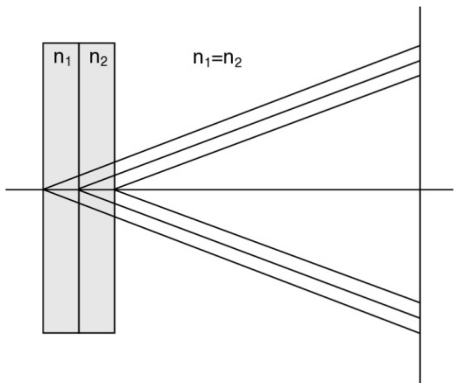


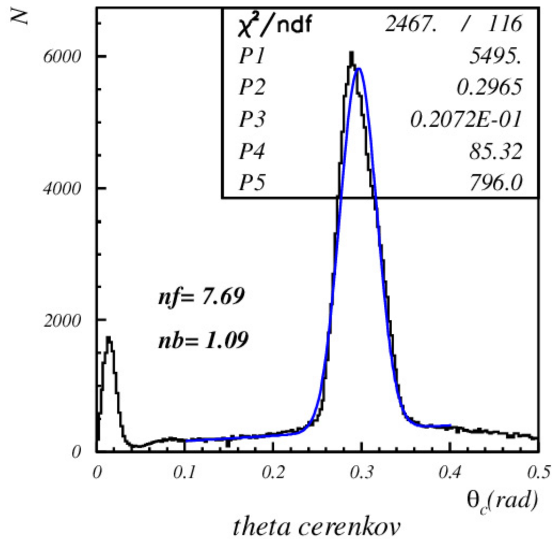
6.6 σ π/K at 4GeV/c !

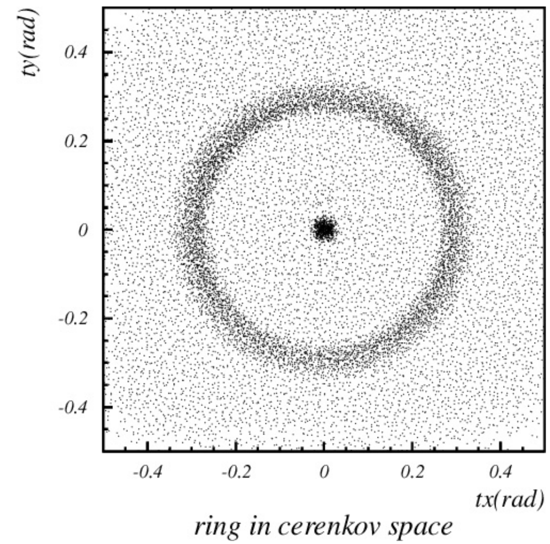
RICH with a focusing radiator

Increases the number of photons without degrading the resolution

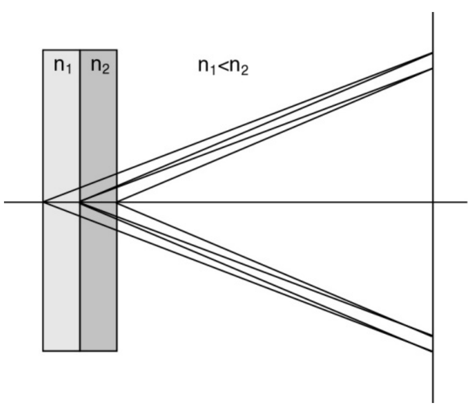
4cm aerogel single index

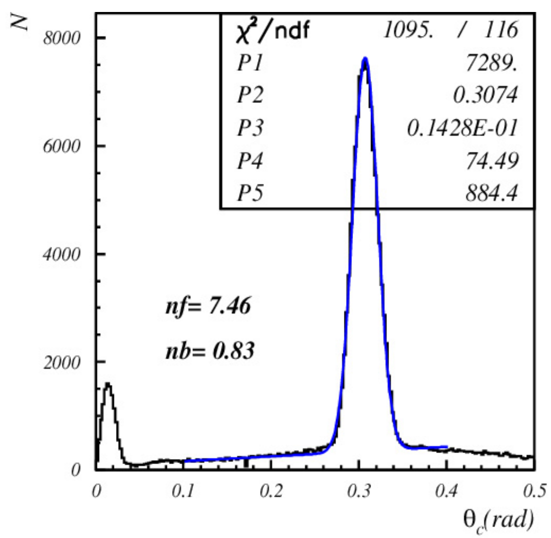


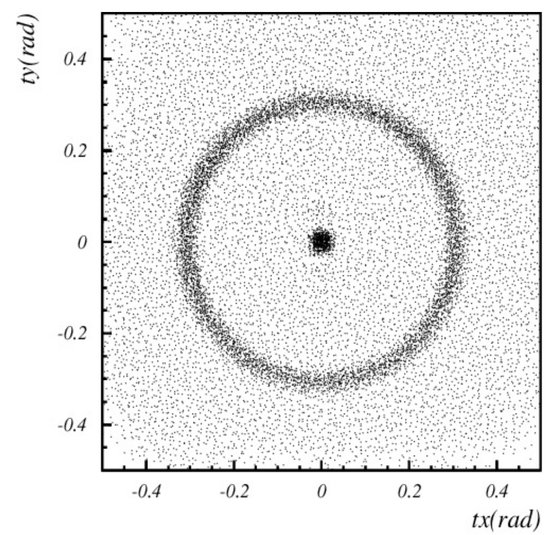




2+2cm aerogel







→NIM A548 (2005) 383

Particle Identification Devices

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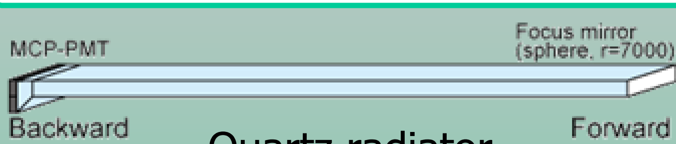


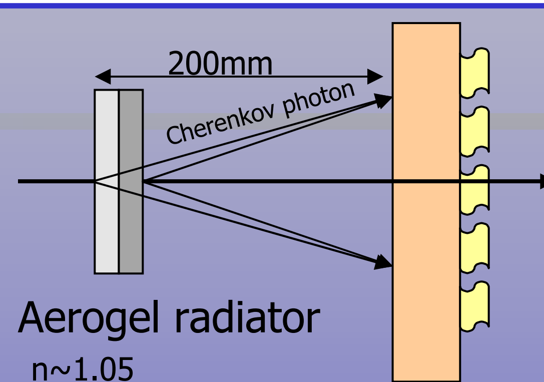
Quartz radiator

Focusing mirror

Small expansion block

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

Endcap PID: Aerogel RICH (ARICH)

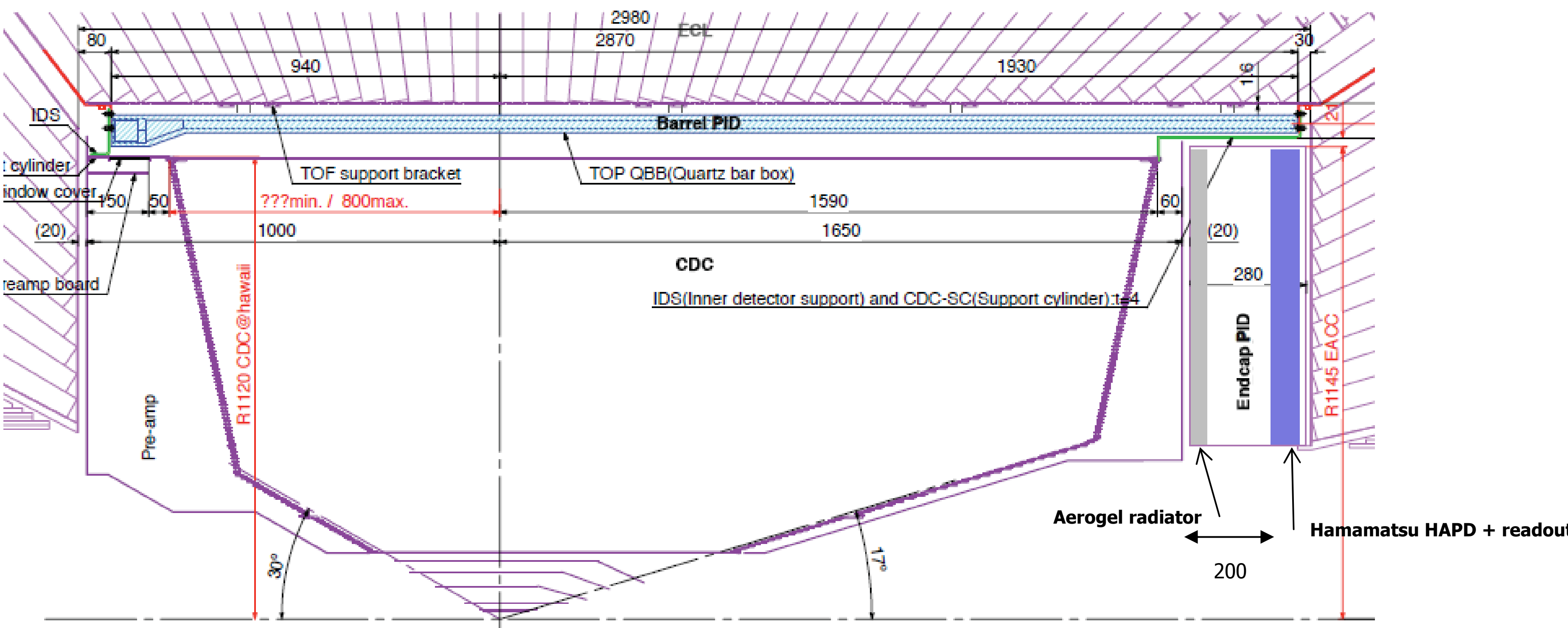


Aerogel radiator

n~1.05

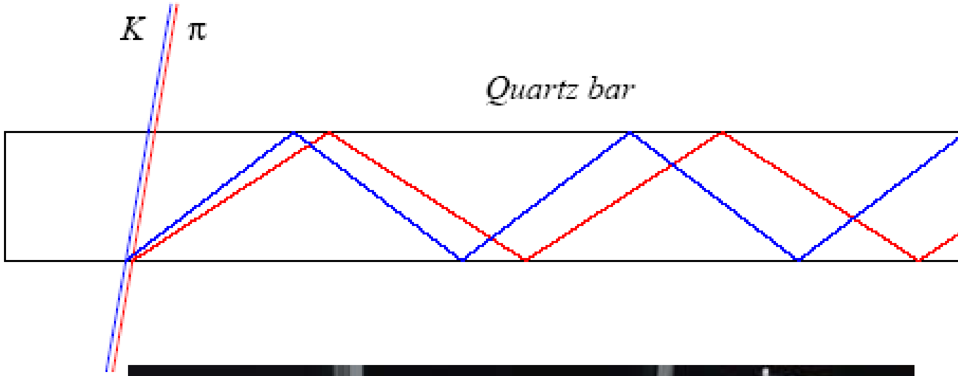
Hamamatsu HAPD

+ new ASIC



Peter Križan, Ljubljana

Barrel PID: Time of propagation (TOP) counter

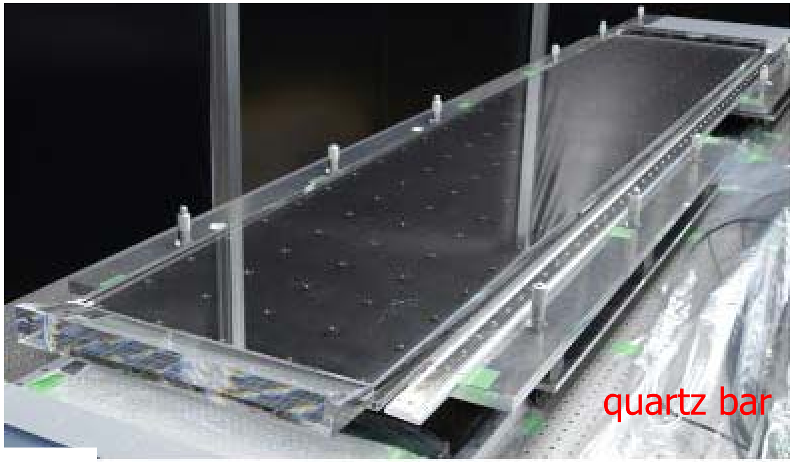


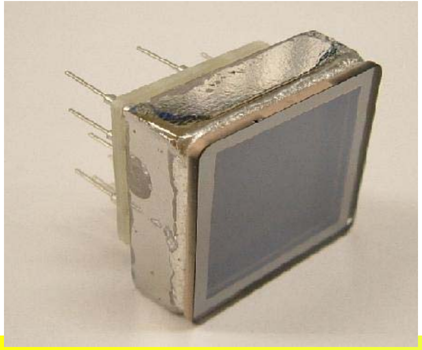
Cherenkov ring imaging with precise time measurement.

Device uses internal reflection of Cerenkov ring images from quartz like the BaBar DIRC

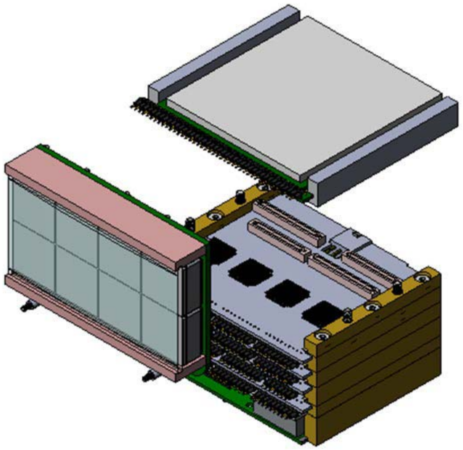
Reconstruct Cherenkov angle from two hit coordinates and the time of propagation of the photon

- Quartz radiator (2cm)
- Photon detector (MCP-PMT)
  - Excellent time resolution ~40 ps
  - Single photon sensitivity in 1.5 T
- Fast read-out electronics

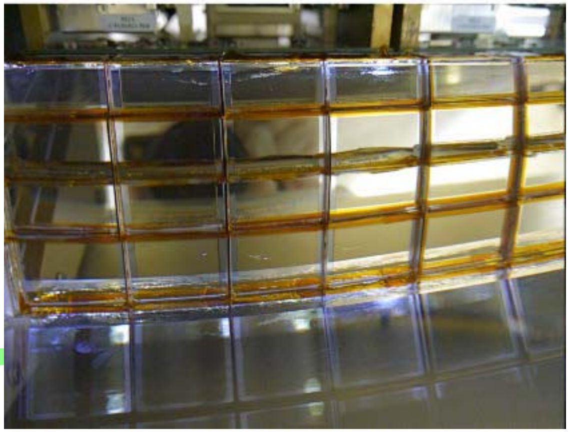




Hamamatsu SL10 MCP PMT

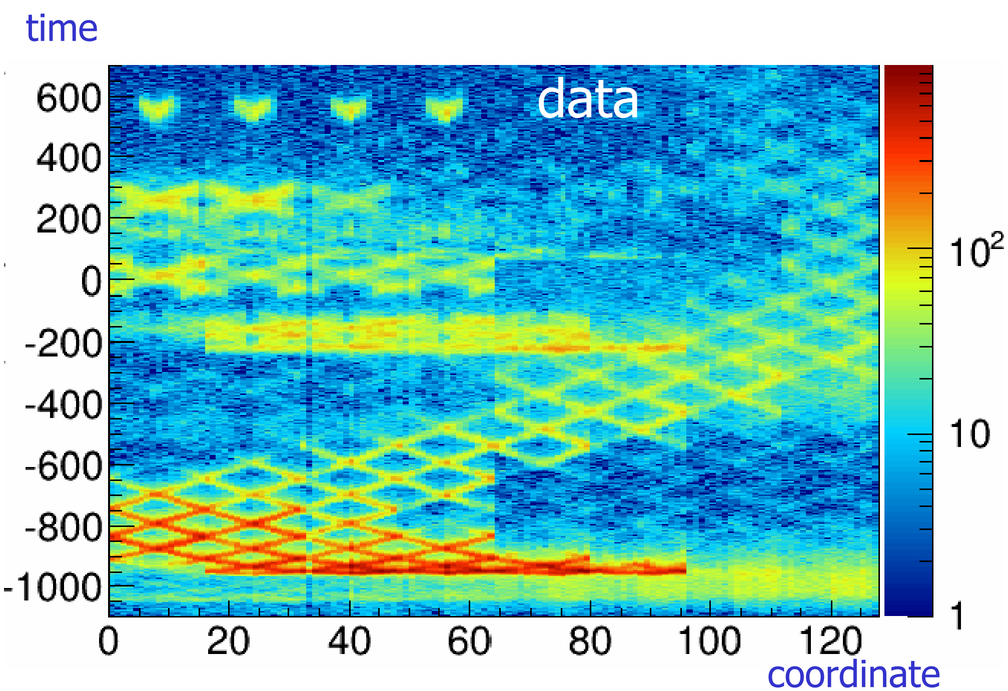


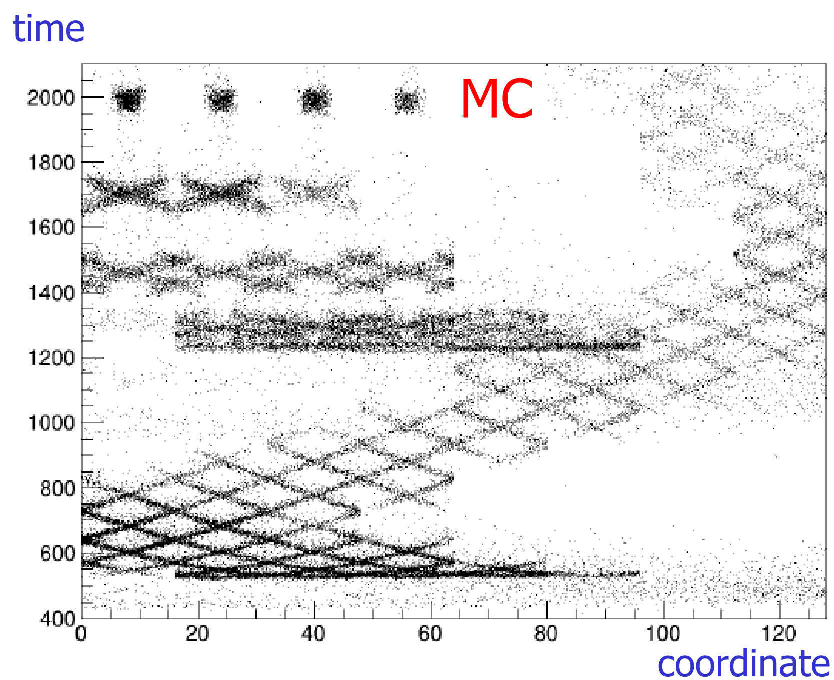
8 PMTs with read-out electronics



TOP image

Pattern in the coordinate-time space ('ring') – different for kaons and pions.

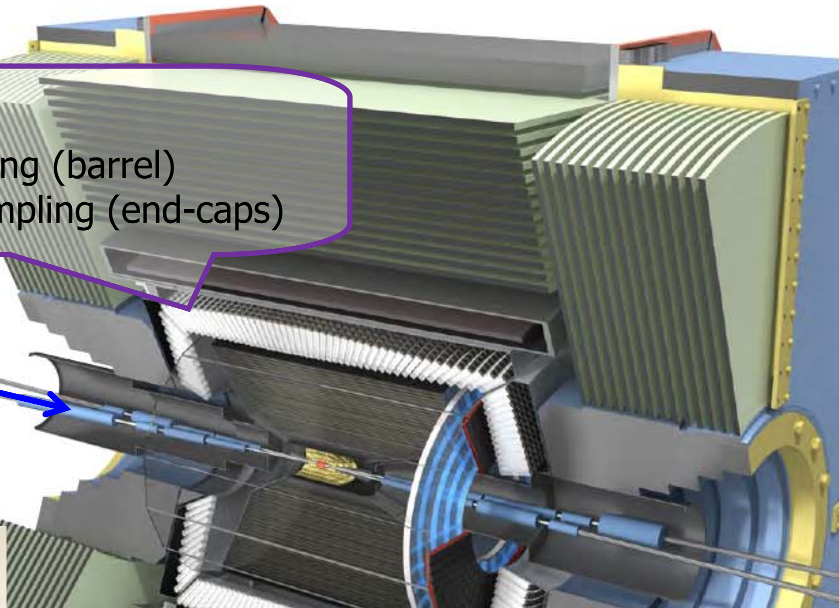


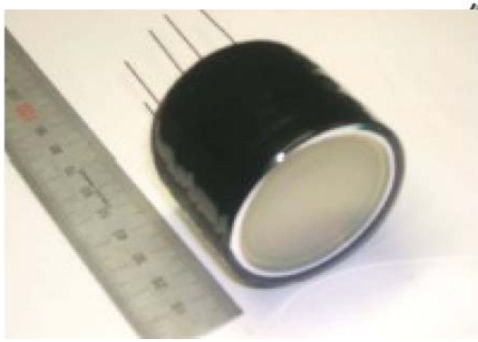


Excellent agreement between beam test data and MC simulated patterns.

EM calorimeter: upgrade needede because of higher rates (barrel: electronics, endcap: electronics and CsI(Tl) → pure CsI) and radiation load (endcap: CsI(Tl) → pure CsI)

EM Calorimeter:
CsI(Tl), waveform sampling (barrel)
Pure CsI + waveform sampling (end-caps)

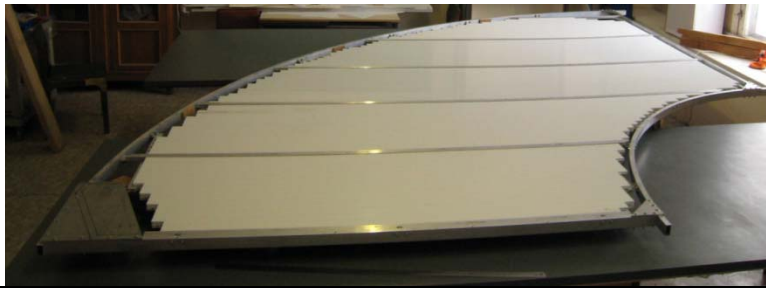


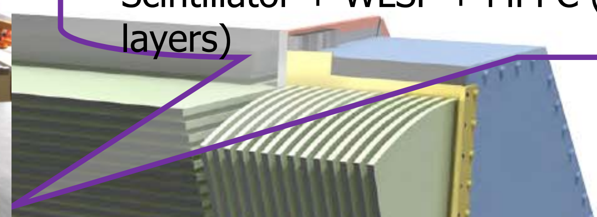


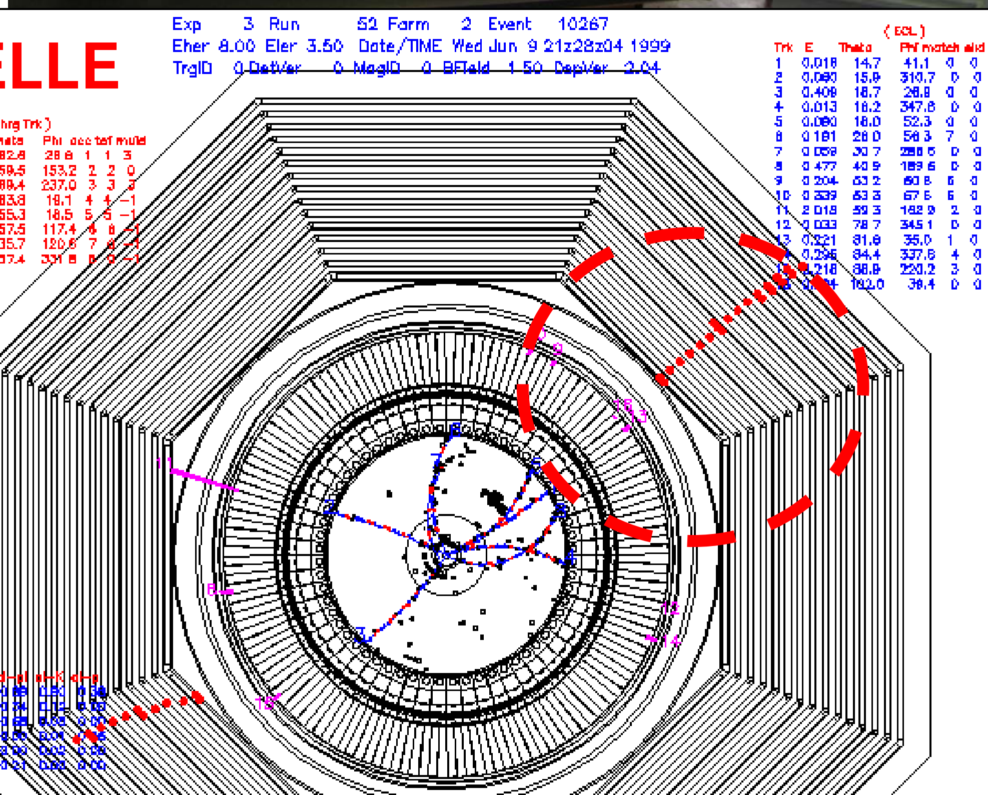
Upgrade to pure CsI: a major collaborative effort of Russia, Japan, Canada, Italy, Ukraine

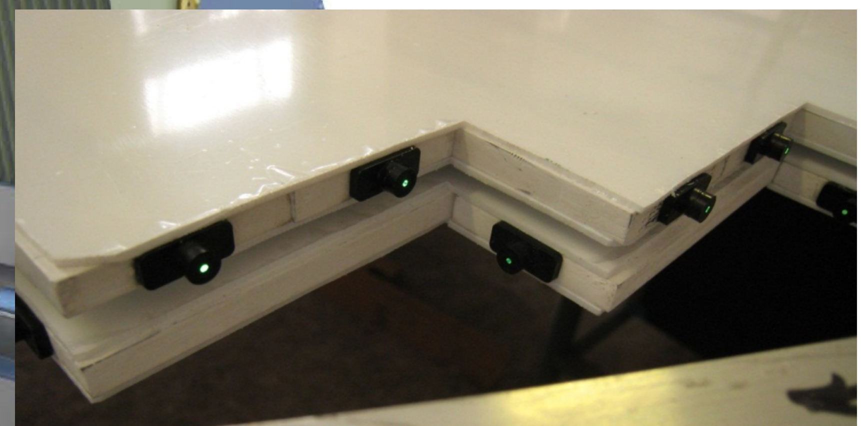
Detection of muons and K_Ls: a sizable part of the present RPC system have to be replaced to handle higher backgrounds (mainly from neutrons).

K_L and muon detector:
Resistive Plate Counter (barrel)
Scintillator + WLSF + MPPC (end-caps + barrel 2 inner layers)





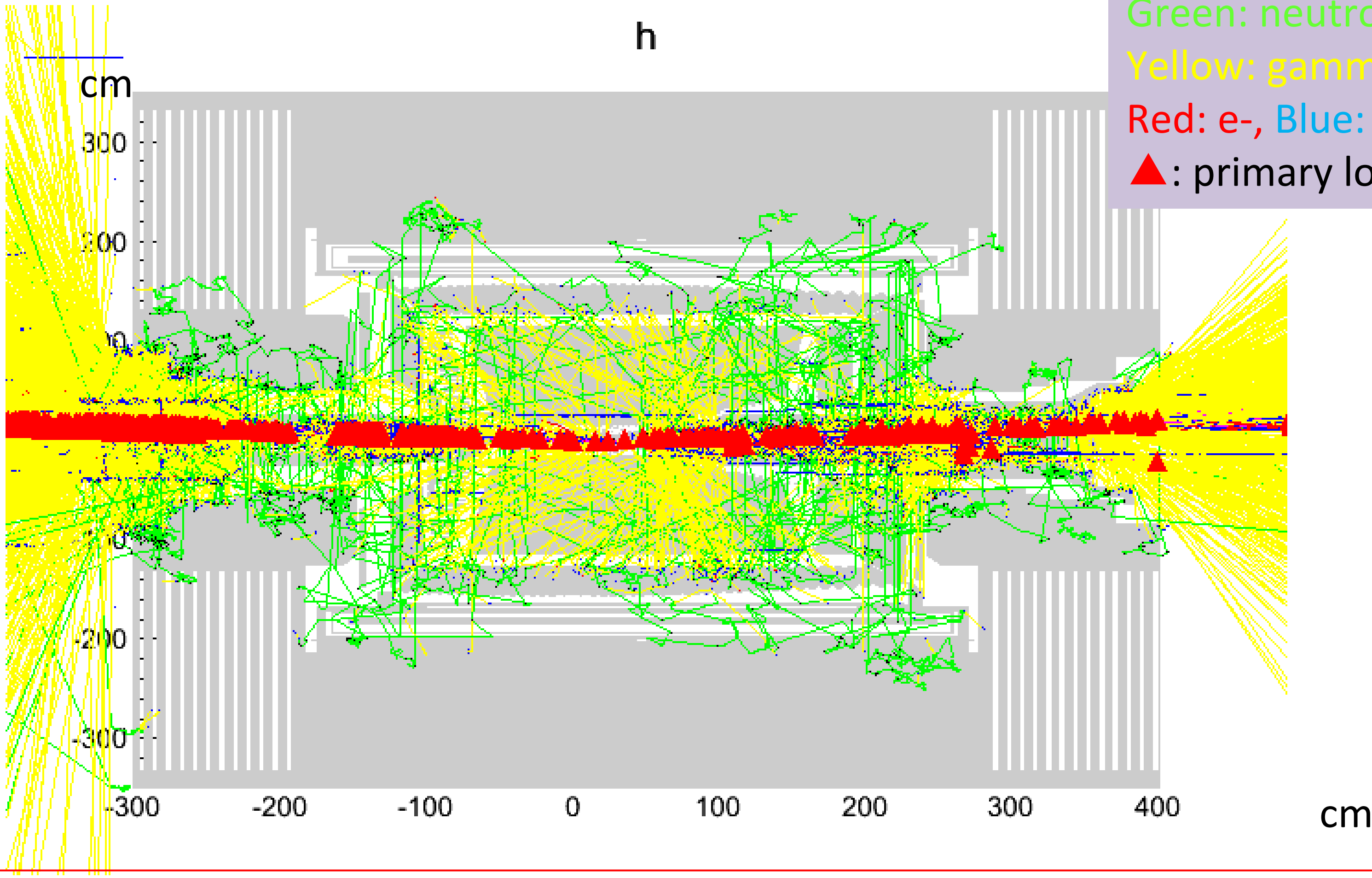




Expected to improve K_L and muon detection efficiency beyond Belle performance.

Background event display

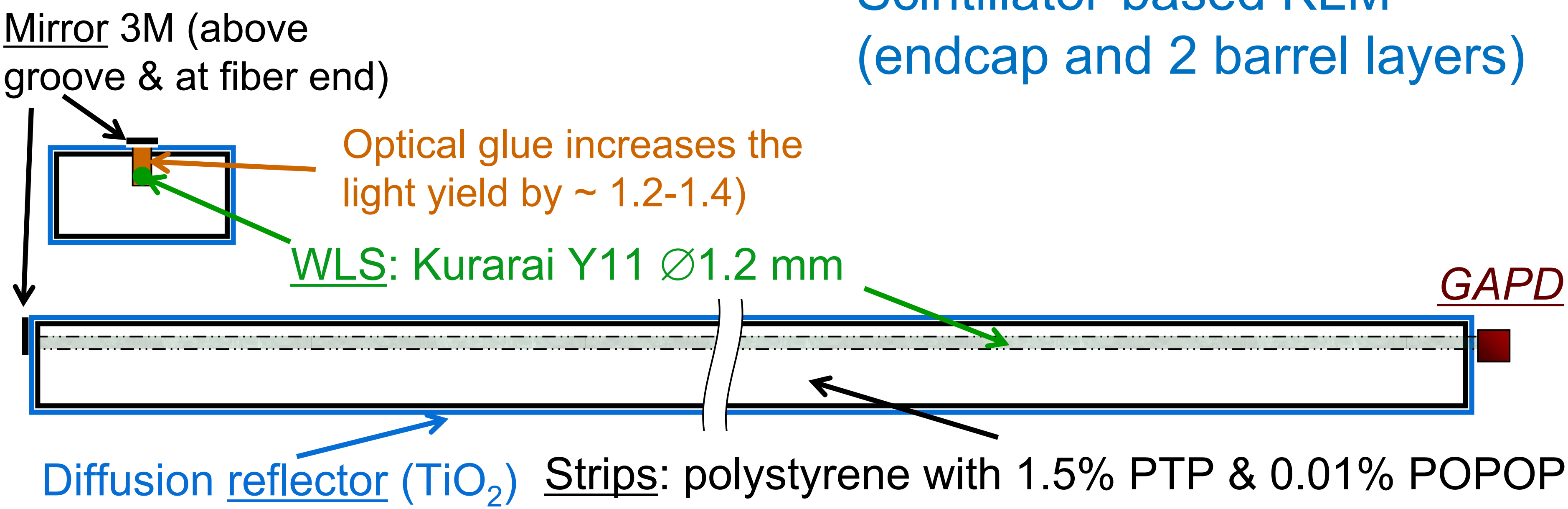
100ns, shown E>1MeV
Green: neutrons
Yellow: gammas
Red: e-, Blue: e+
▲: primary loss position



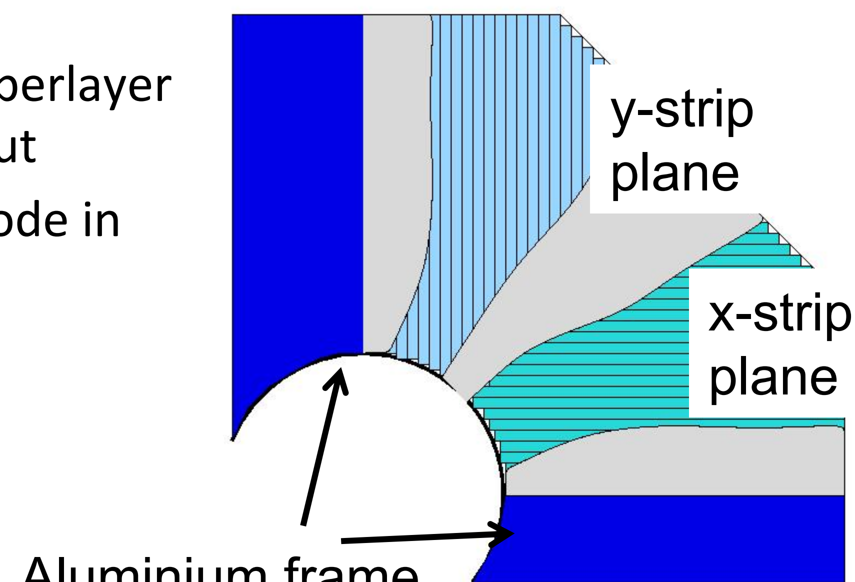
Neutrons: background hits in the muon and KL detection system (KLM) → reduce the efficiency of muon and KL detection → replace RPCs in the endcaps and 2 barrel layers.

Muon detection system upgrade

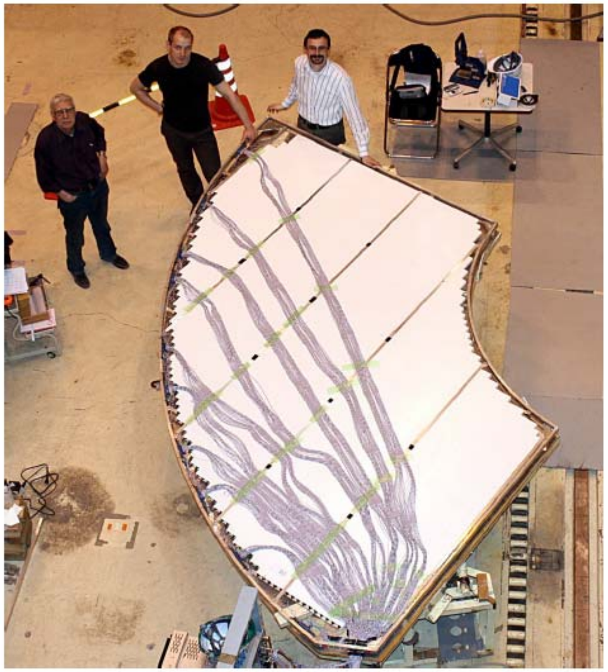
Scintillator-based KLM (endcap and 2 barrel layers)



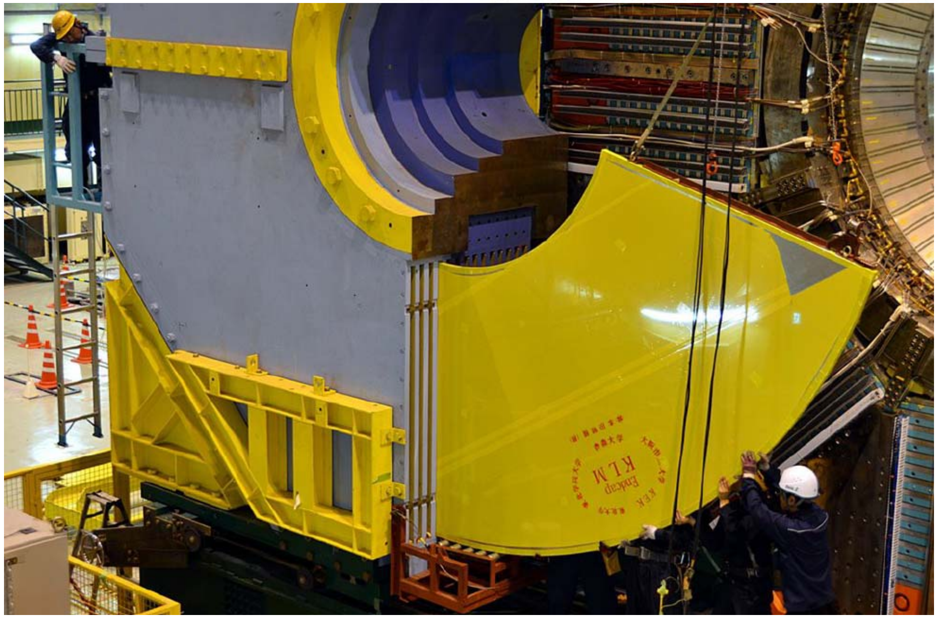
- Two independent (x and y) layers in one superlayer made of orthogonal strips with WLS read out
- Photo-detector = SiPM (avalanche photodiode in Geiger mode)
- ~120 strips in one 90º sector (max L=280cm, w=25mm)
- ~30000 read out channels
- Geometrical acceptance > 99%



Muon detection system upgrade



Scintillator-based KLM:
•design and construction of modules at ITEP, Moscow
•installation of final modules in the Belle II detector – the first Belle II component to be ready!



Status of the project

The Belle II Collaboration

A very strong group of 560 highly motivated scientists!

SuperKEKB/Belle II Status

Funding

- ~100 MUS for machine approved in 2009 -- Very Advanced Research Support Program (FY2010-2012)
- Full approval by the Japanese government in December 2010; the project was finally in the JFY2011 budget as approved by the Japanese Diet end of March 2011
- Most of non-Japanese funding agencies have also already allocated sizable funds for the upgrade of the detector.

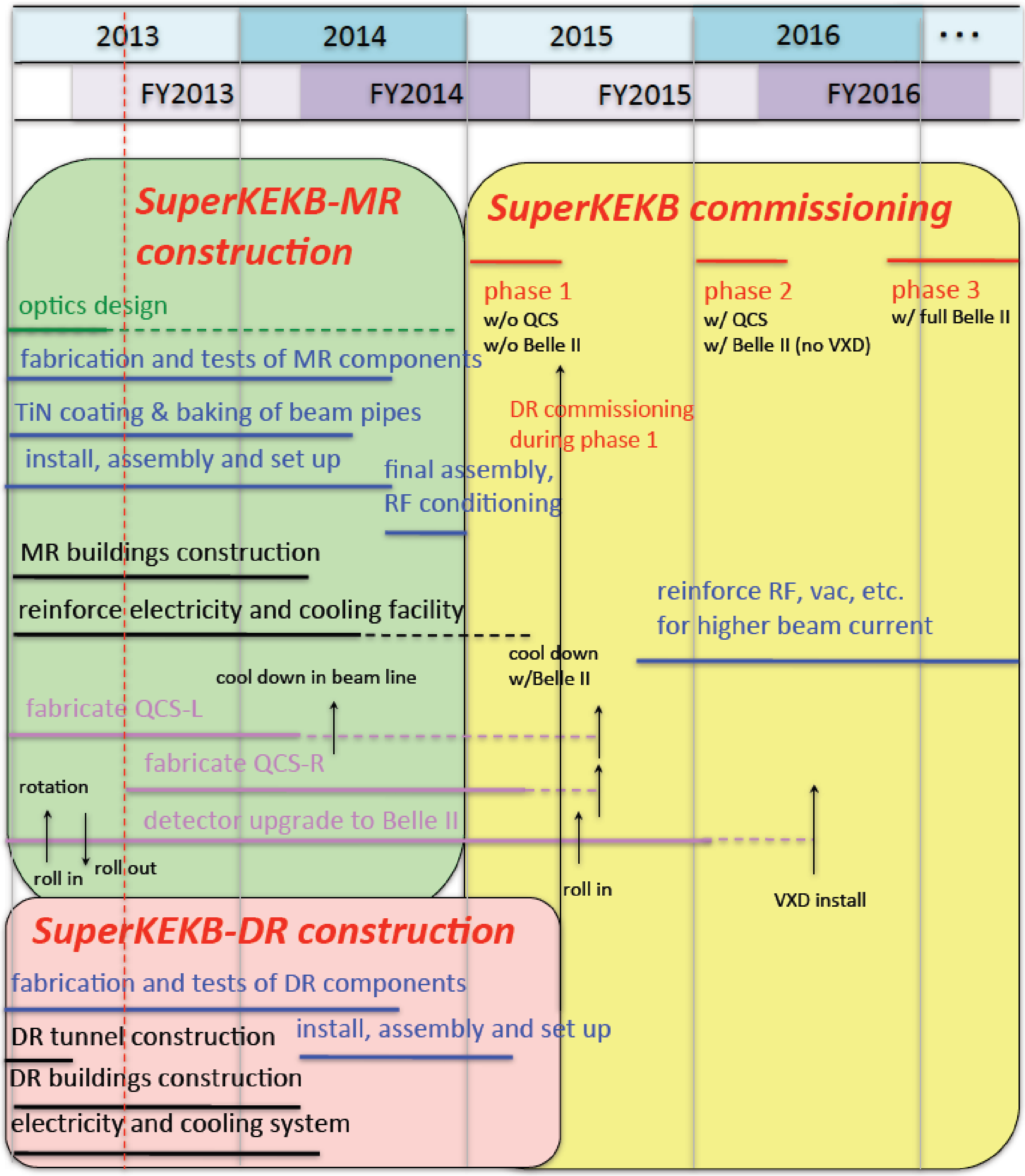
→construction started in 2010!

Ground breaking ceremony in November 2011

SuperKEKB and Belle II construction proceeds according to the schedule.

The Italian super B factory project (SuperB) was unfortunately canceled, several of the former SuperB collaborators have joined Belle II.

SuperKEKB/Belle II Schedule

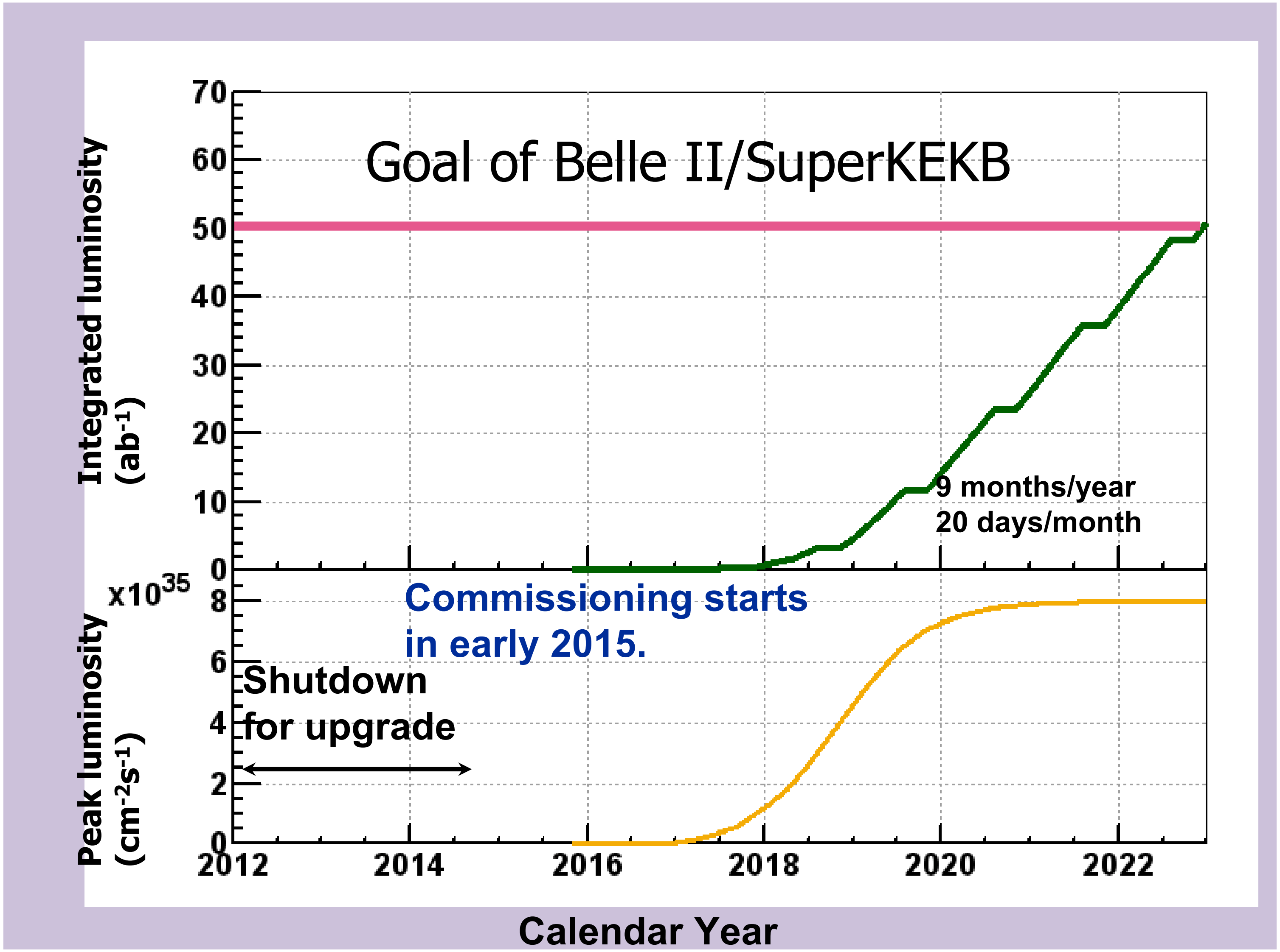


K. Akai

Commissioning in three phases:

– Phase 1: w/o final quads, w/o Belle II
  - basic machine tuning
  - low emittance beam tuning
  - vacuum scrubbing
    – At least one month at beam currents of 0.5~1A.
  - Damping ring commissioning
– Phase 2: with final quads and Belle II, but no VXD
  - low beta* beam tuning
  - small x-y coupling tuning
  - collision tuning
  - study beam background
    – careful checks beam background before VXD installation.
– Phase 3: with QCS and full Belle II
  - physics run
  - luminosity increase

SuperKEKB luminosity projection



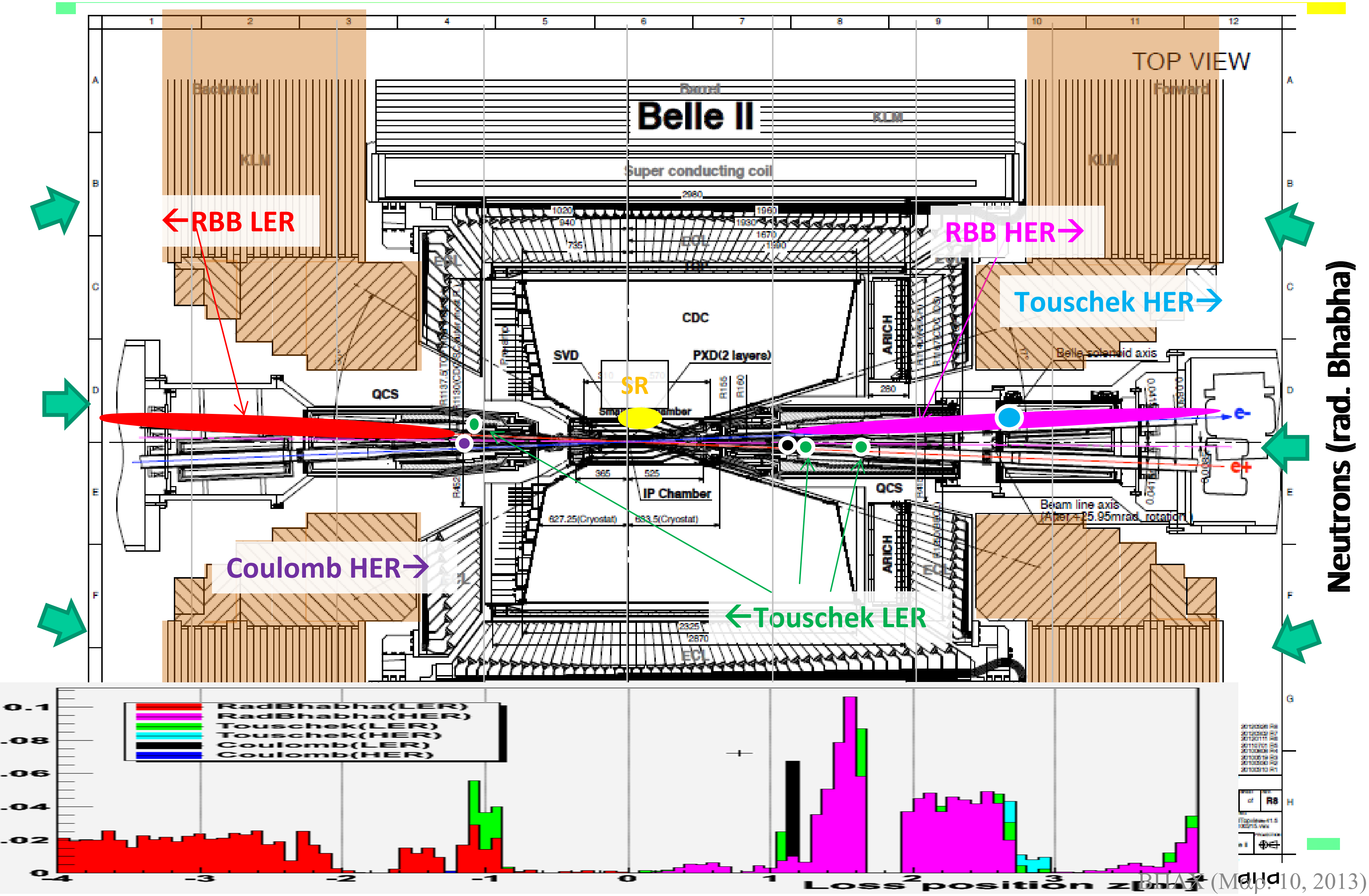
Summary

- B factories have proven to be an excellent tool for flavour physics, with reliable long term operation, constant improvement of the performance, achieving and surpasing design values →talk by Leo Piilonen
- Major upgrade at KEK in 2010-15 → SuperKEKB+Belle II, L x40, final approval by the Japanese government end of 2010, construction proceeds at full speed
- Funding also secured by collaborating countries
- Physics reach updates available
- Expect a new, exciting era of discoveries, complementary to the LHC

Additional slides

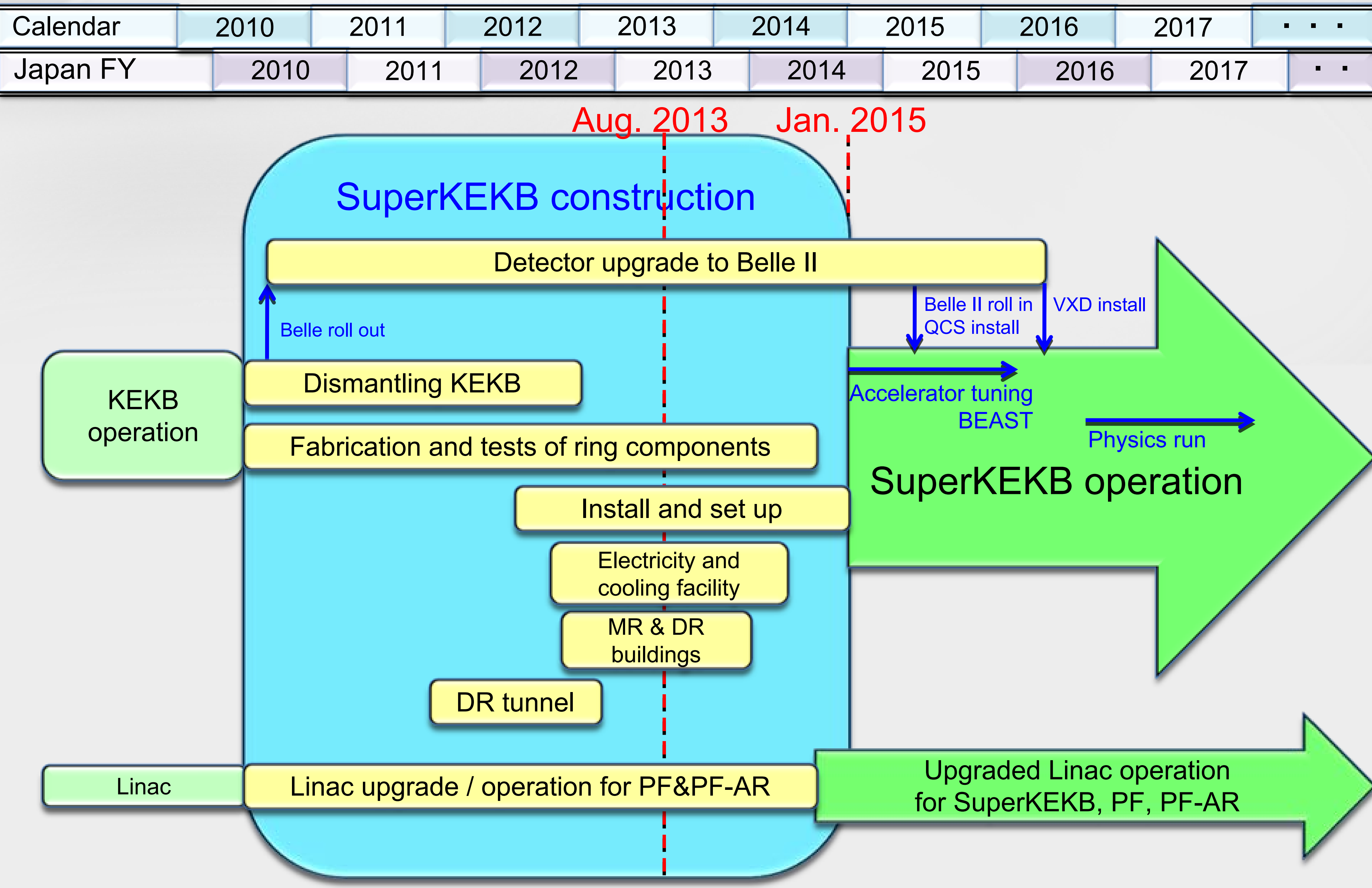
Backgrounds

Ver. 2013.3.4



BEAST (Mar. 10, 2013)

SuperKEKB/Belle II schedule



SuperKEKB Commissioning Scenario

Commissioning in three phases:

- Phase 1: w/o final quads, w/o Belle II
  - basic machine tuning
  - low emittance beam tuning
  - vacuum scrubbing
    - At least one month at beam currents of 0.5~1A.
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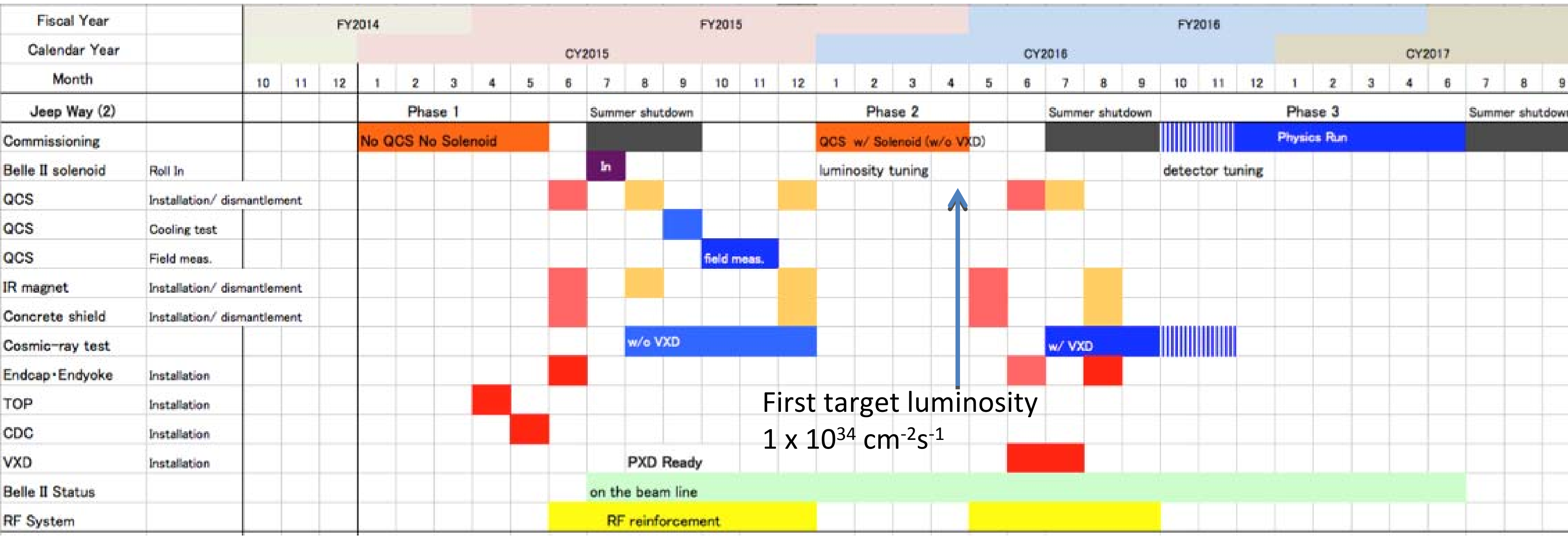
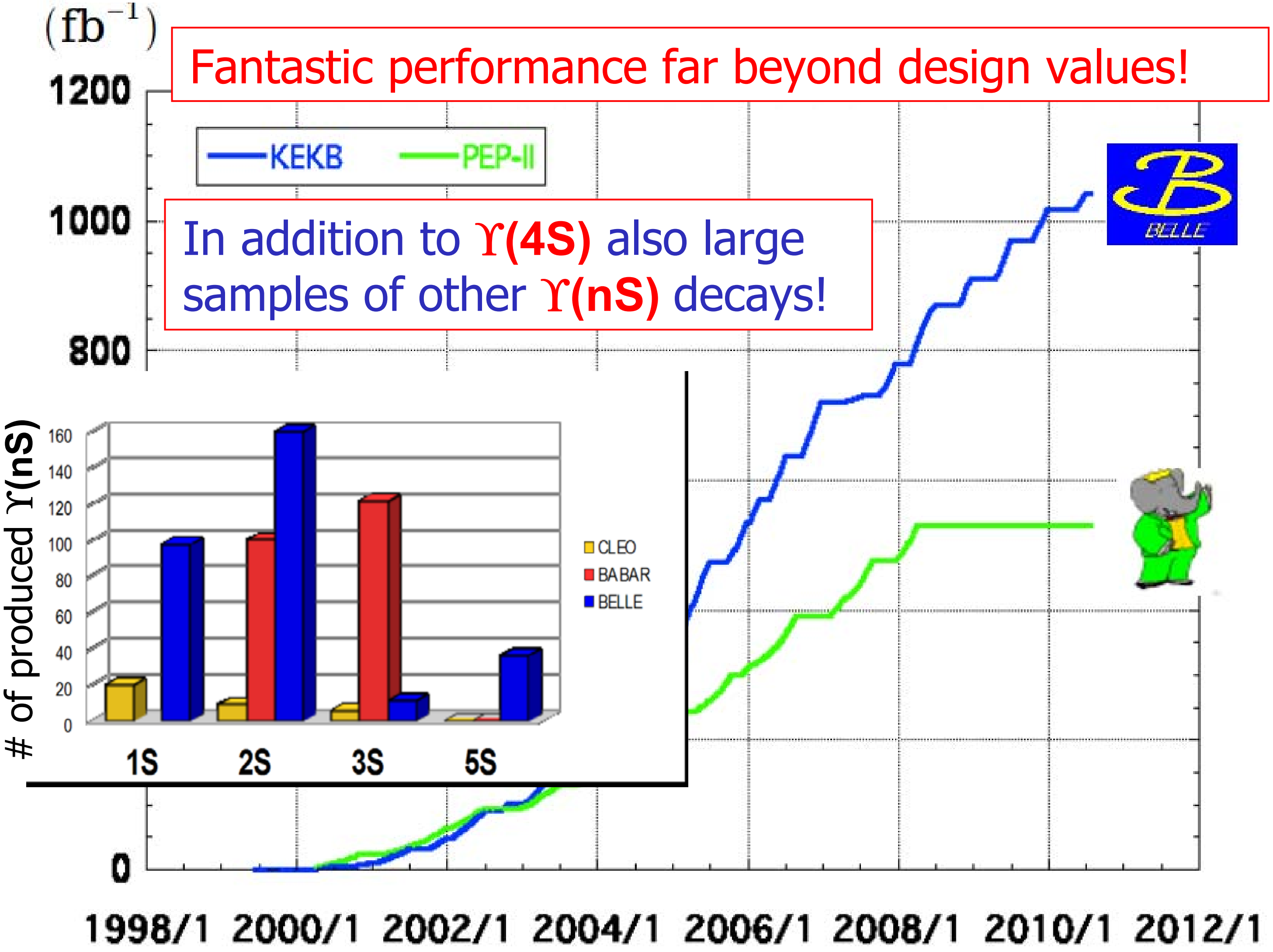
  - study beam background
    - careful checks beam background before VXD installation.
- Phase 3: with QCS and full Belle II
  - physics run
  - luminosity increase

Commissioning schedule



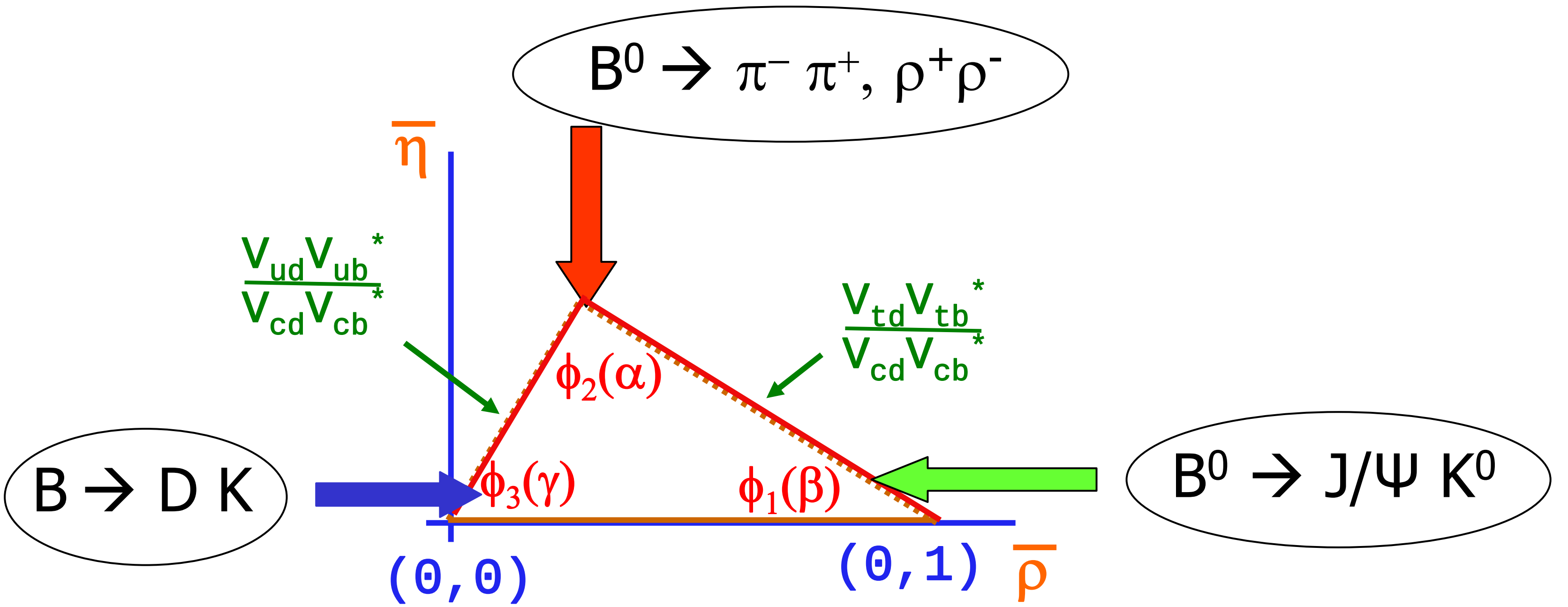
Integrated luminosity at B factories



> 1 ab^{-1}
On resonance:
$\Upsilon(5S)$: 121 fb^{-1}
$\Upsilon(4S)$: 711 fb^{-1}
$\Upsilon(3S)$: 3 fb^{-1}
$\Upsilon(2S)$: 25 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}

CP violation in the B system and unitarity triangle

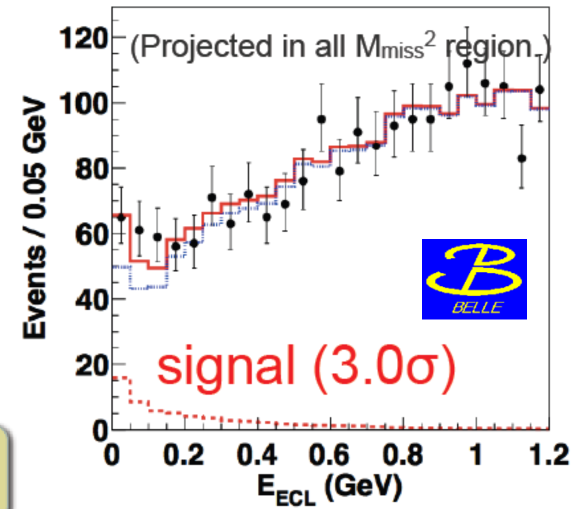


$B^- \rightarrow \tau^- \nu_\tau$

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

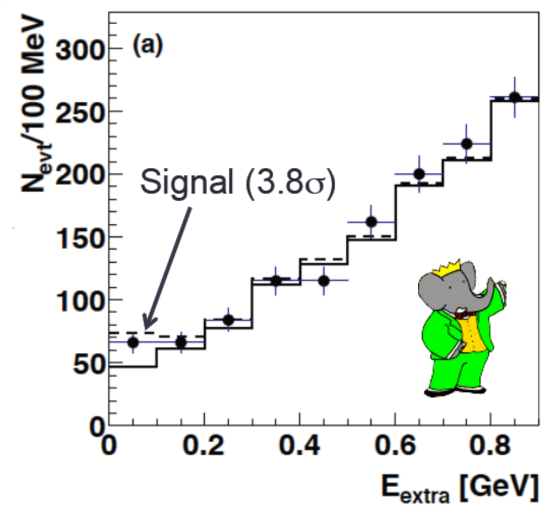
Main discriminating variable on the signal side: remaining energy in the calorimeter, not associated with any charged track or photon

→ Signal at $E_{ECL} = 0$



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

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



All measurements combined

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

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

Rare charm decays: tag with the other D

Again make use of the hermeticity of the apparatus!

Example: leptonic decays of D_s

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

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:

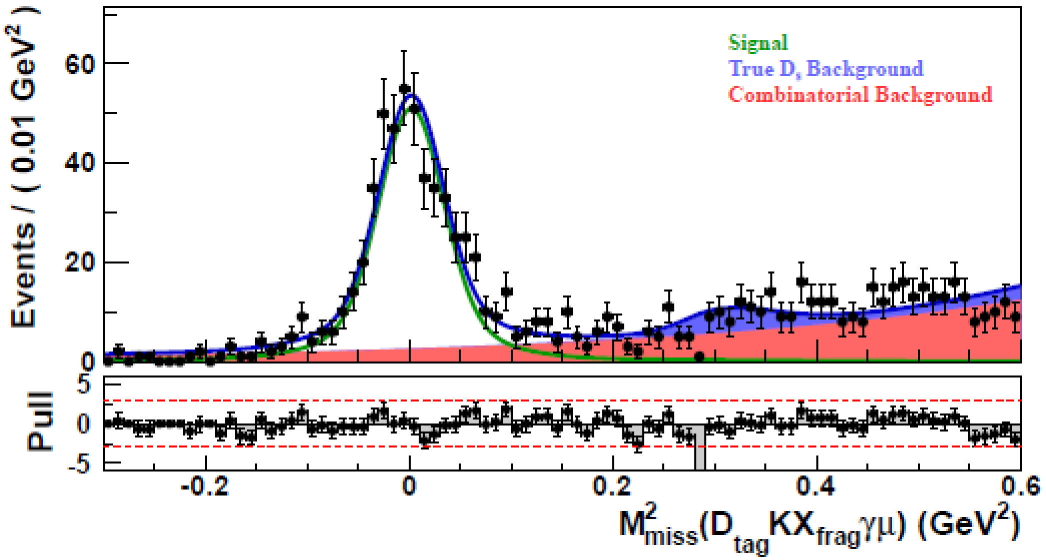
- Inclusive reconstruction of D_s mesons for normalization (without any requirements upon D_s decay products)
- Within the inclusive D_s sample search for D_s decays
  - $D_s \to \mu\nu$: peak at $m_\nu^2 = 0$ in $M^2_{\rm miss}(D_{\rm tag}KX_{\rm frag}\gamma\mu)$
  - $D_s \to \tau\nu$: peak towards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

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

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

Selection:

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



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

Belle, arxiv:1301.7218

Belle preliminary @ 913 fb^{-1}

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

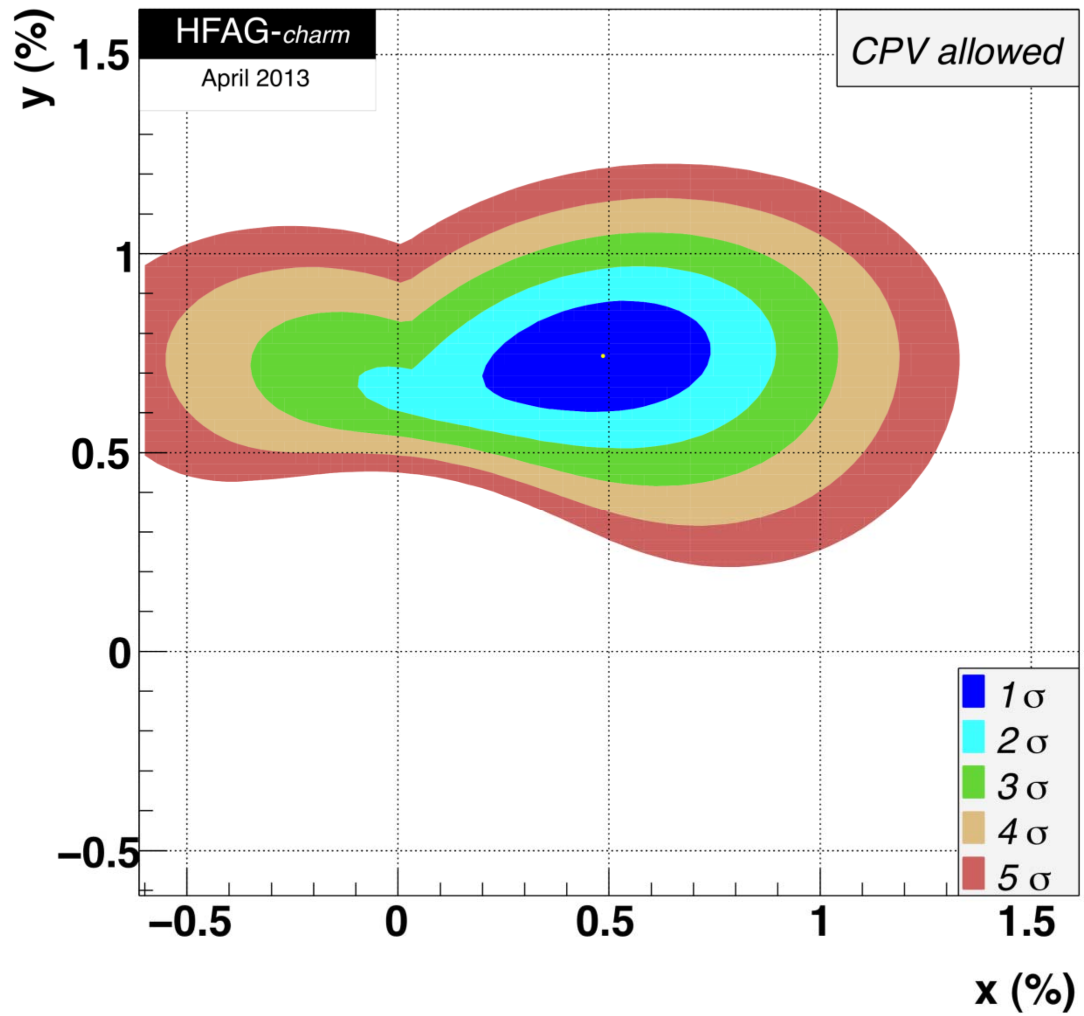
Most precise measurement up to date.

Extract f_{D_s} :

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

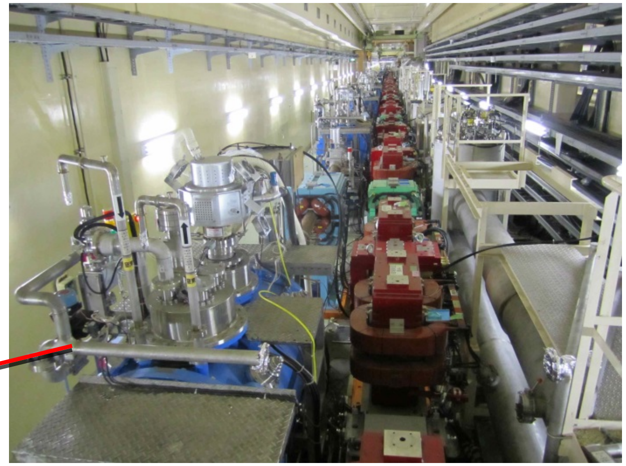
Charm: last but not least…

D mixing was discovered at Belle and BaBar…



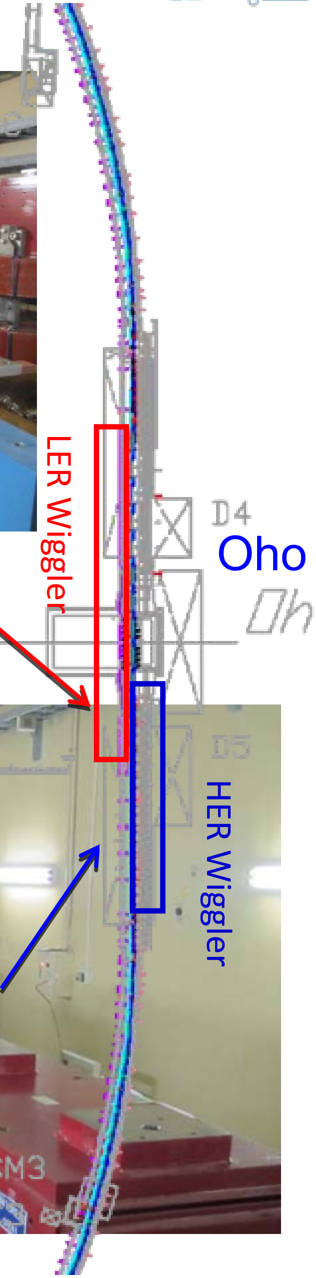
… and there remains a lot for us to do in the era of super B factories.

Wiggler sections

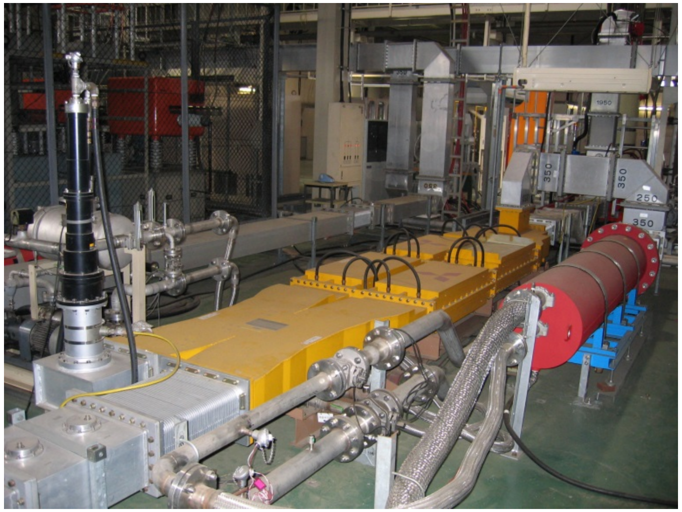


Installation of LER wiggler chambers in Nikko and Oho straight sections will be completed in March.

Installation of HER wiggler chambers in Oho straight section is done.

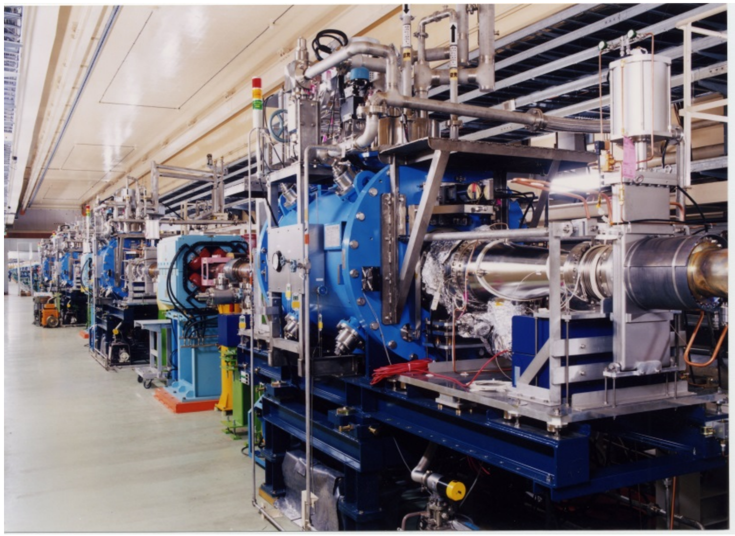


Upgrade of RF system to cope with twice beam currents and 2.5 times beam power



RF high power system

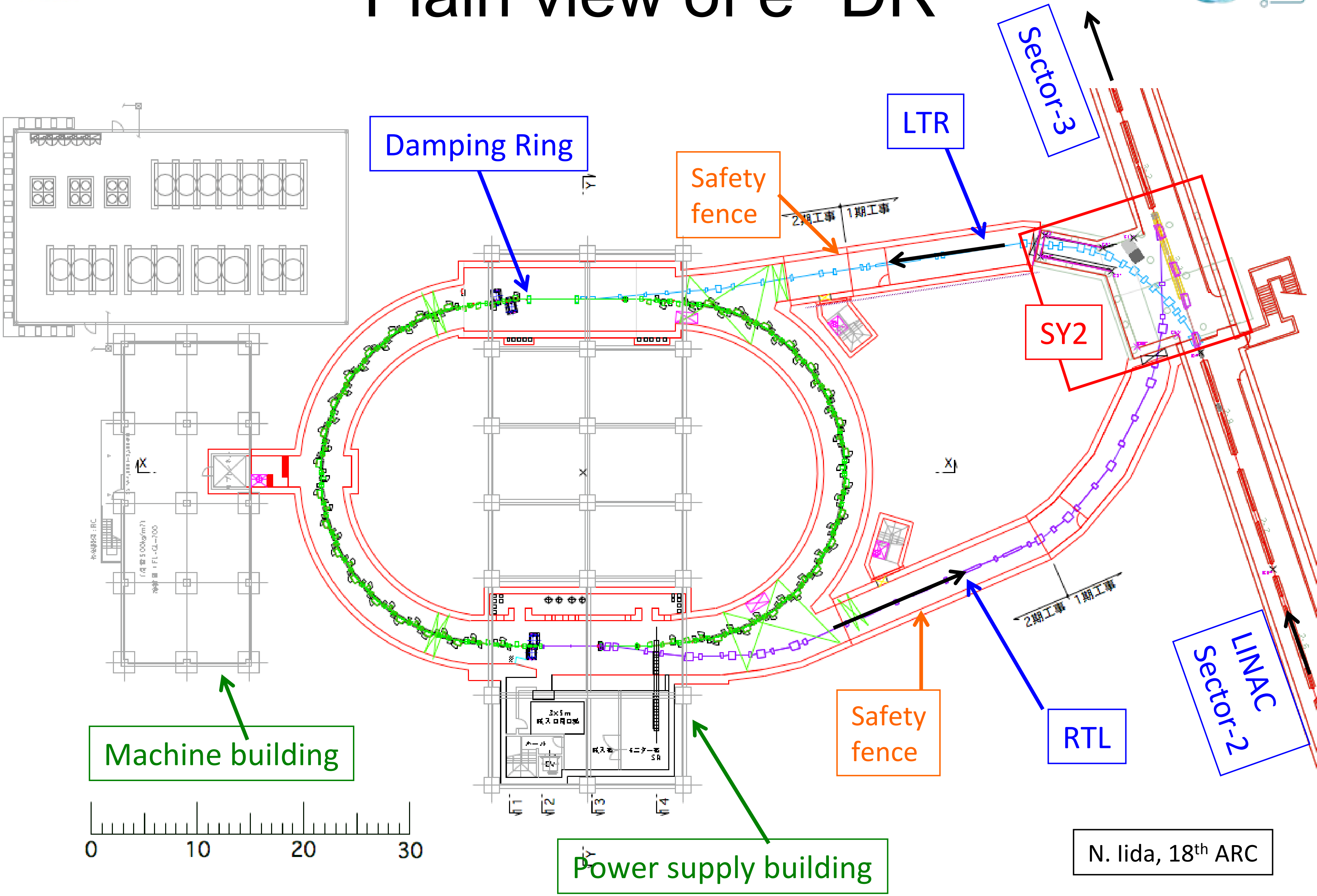
1.2MW CW kystron



Superconducting cavities

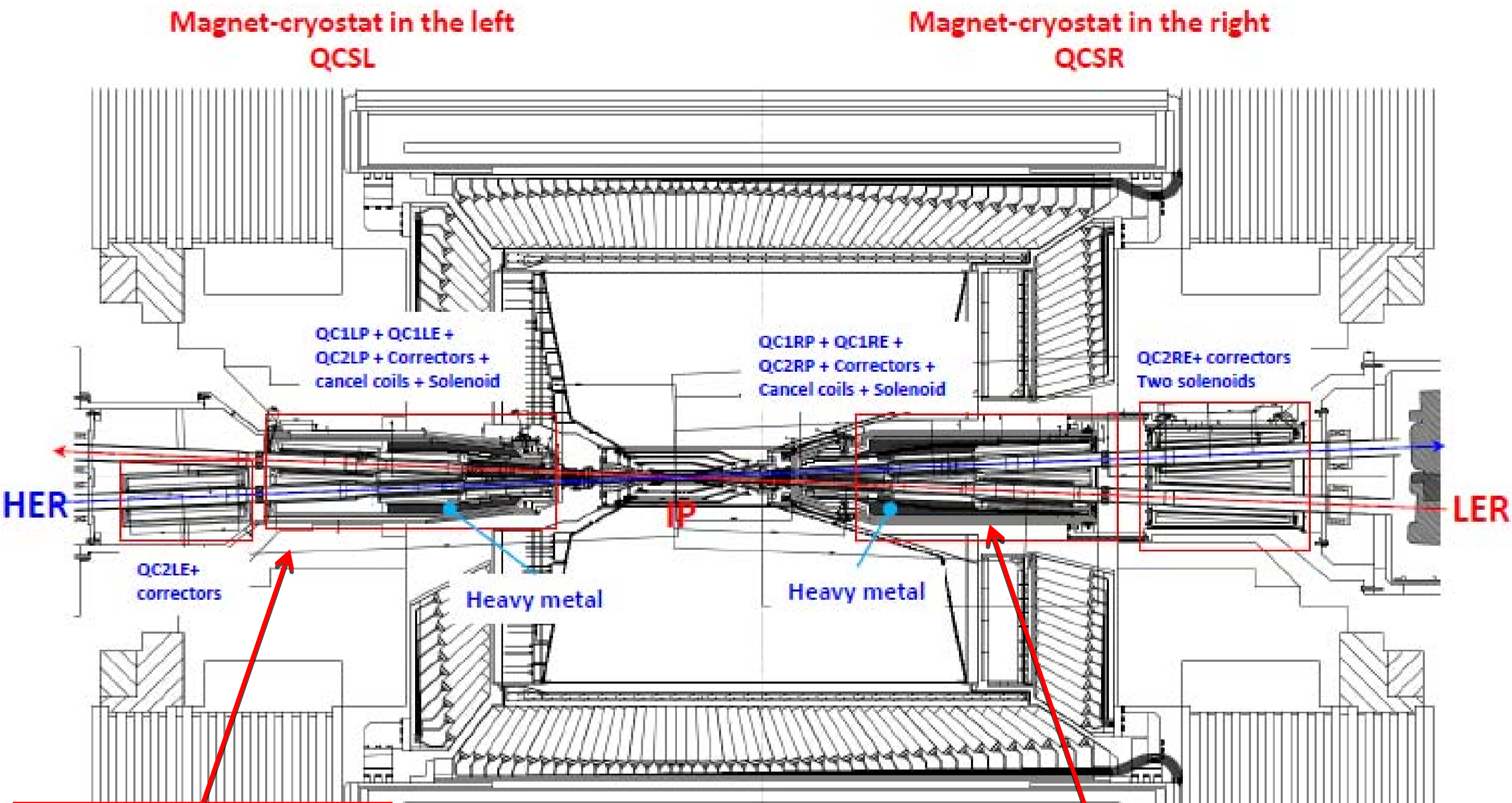
Six ARES cavities in D5 moved from HER to LER. HER wiggler magnets were installed close to the ARES.

Plain view of e^+ DR



N. Iida, 18th ARC

IR magnets overview



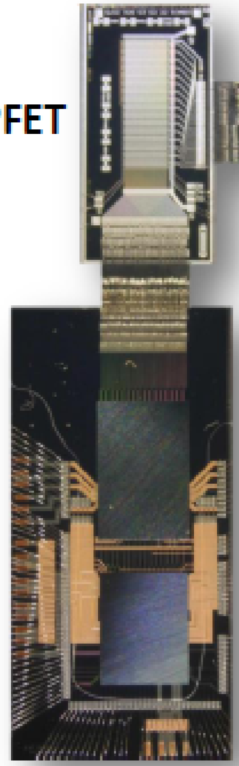
in production

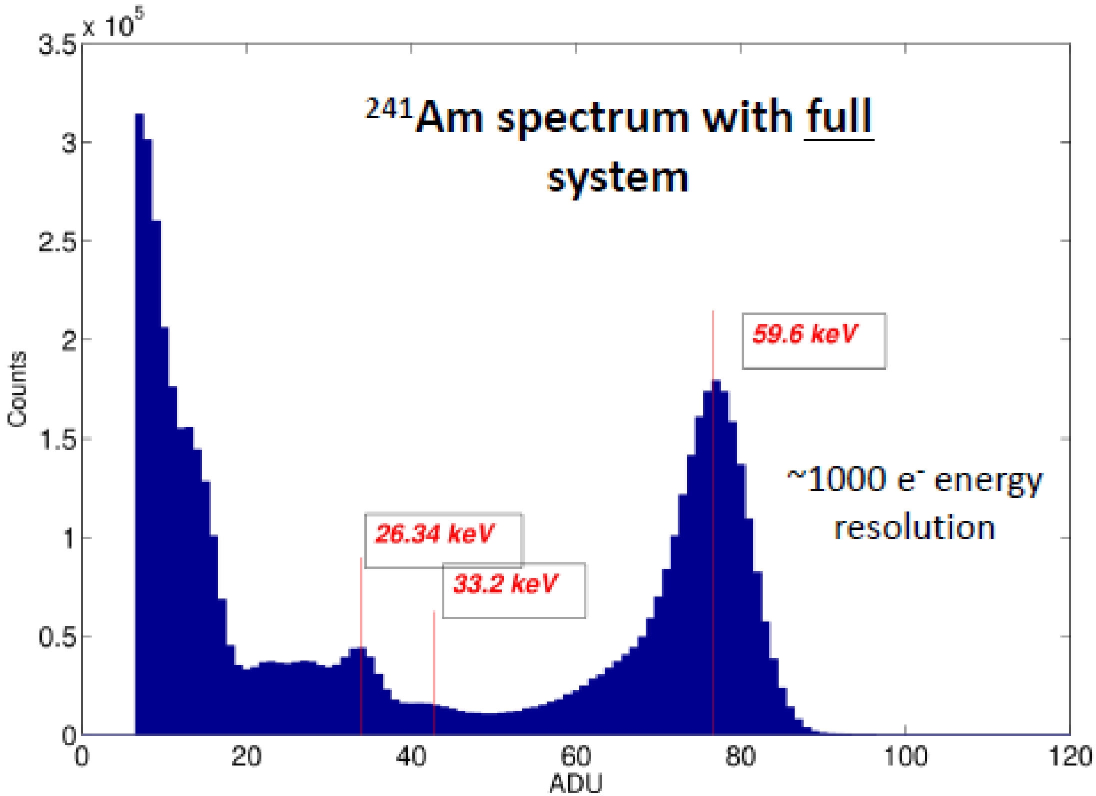
in production

PXD: test of the full read-out chain

- All the ASICs + Belle II DEPFET working together
- Trigger-less zero suppression readout

Carlos Marinas, Bonn





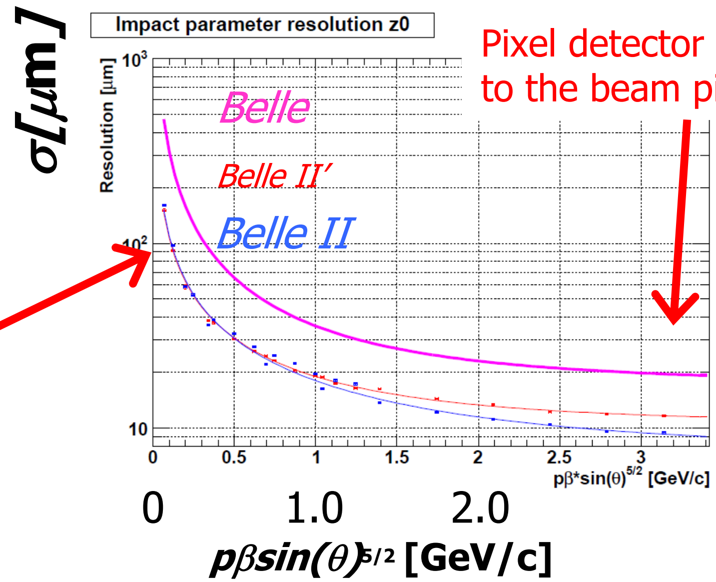
Expected performance

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

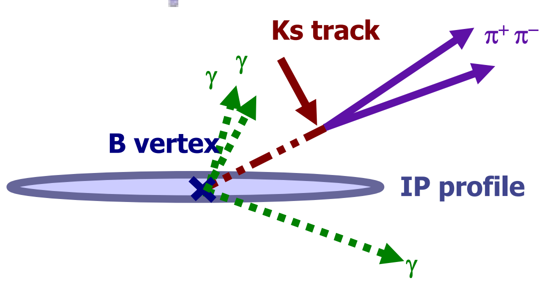
Significant improvement in vertex resolution!

Pixel detector close to the beam pipe

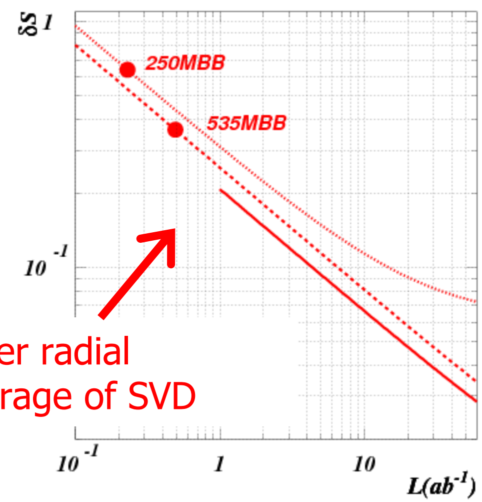
Less Coulomb scattering



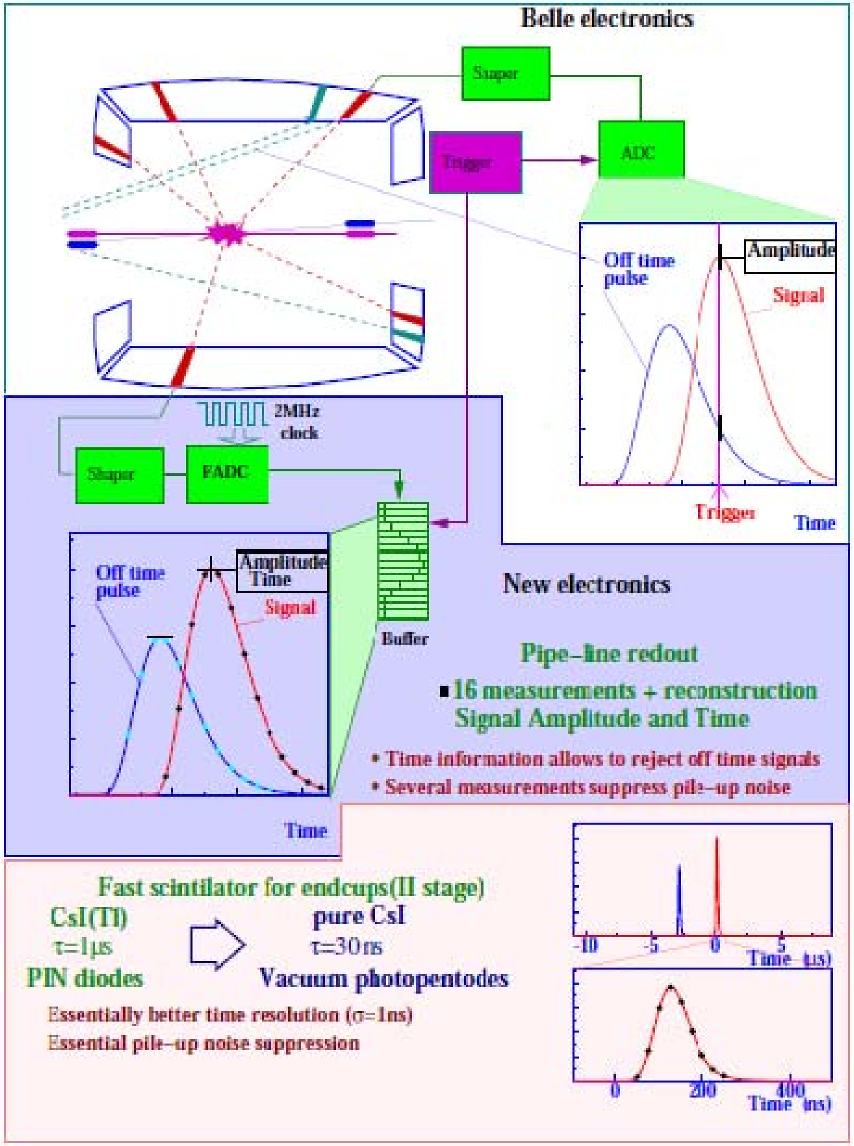
Significant improvement in $\delta S(K_S\pi^0\gamma)$



B decay point reconstruction with K_S trajectory



Larger radial coverage of SVD



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

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

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

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

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