From Strange, through Charm and Beauty, to the Top

A celebration of Svjetlana Fajfer's career

April 16, 2014, Jozef Stefan Institute

B Physics at B Factories in the LHC Era

Peter Križan

University of Ljubljana and J. Stefan Institute

University of Ljubljana

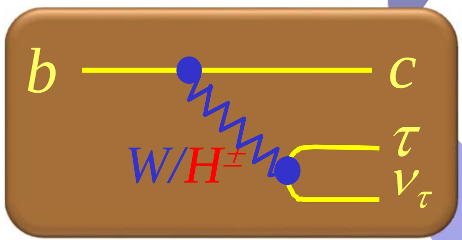
"Jožef Stefan" Institute

- Some recent results from B factories
- Towards a Super B factory
- Accellerator – SuperKEKB
- Detector – Belle II
- How does it relate to Svjetlana‵s work

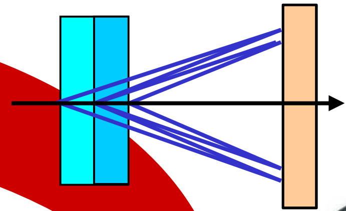
Experiment vs Theory

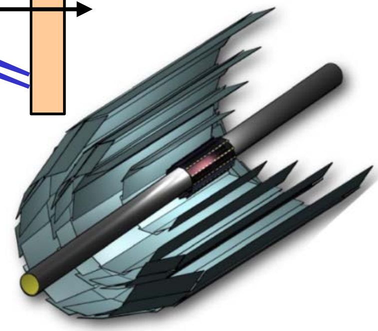
Experimentalists and theorists exchange notes, results, plans etc

$$(i\partial\!\!\!/ - m)\psi = 0$$



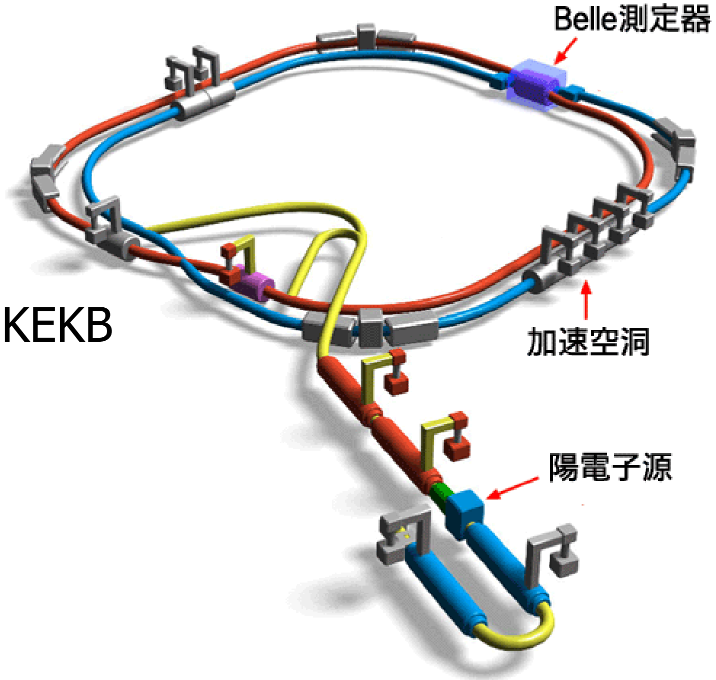
… neither species wants to know exactly what the others are doing while they do their own research on “dirty“ details…

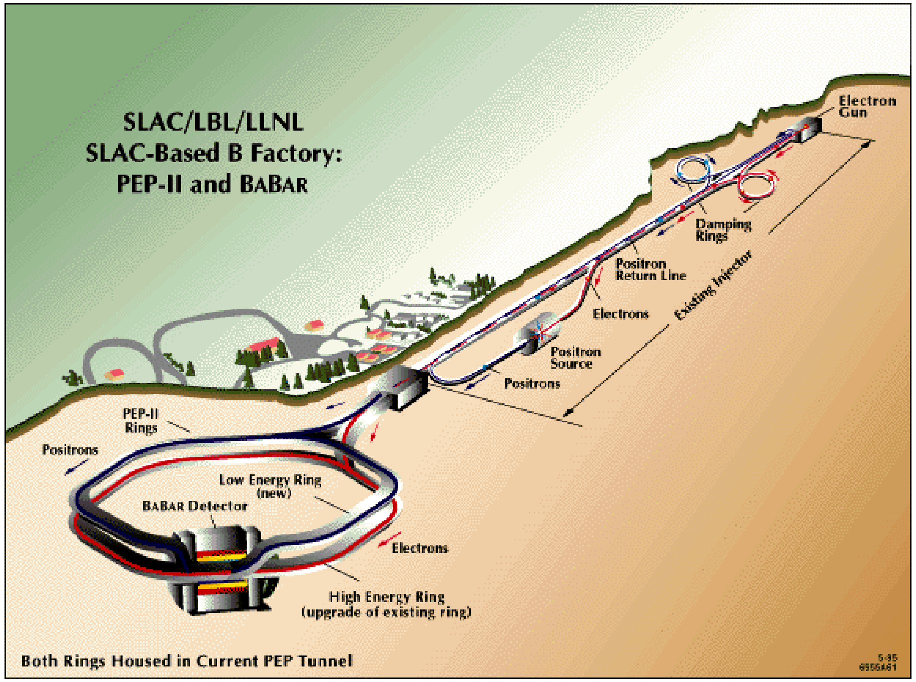




Experimentalists and theorists exchange notes, results, plans etc

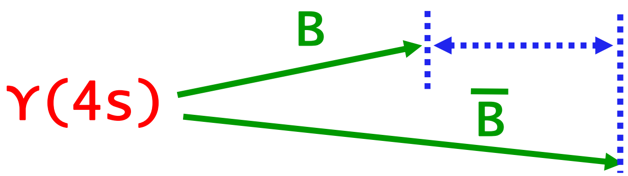
Flavour physics at the luminosity frontier with asymmetric B factories





$\sqrt{s}=10.58$ GeV

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



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

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

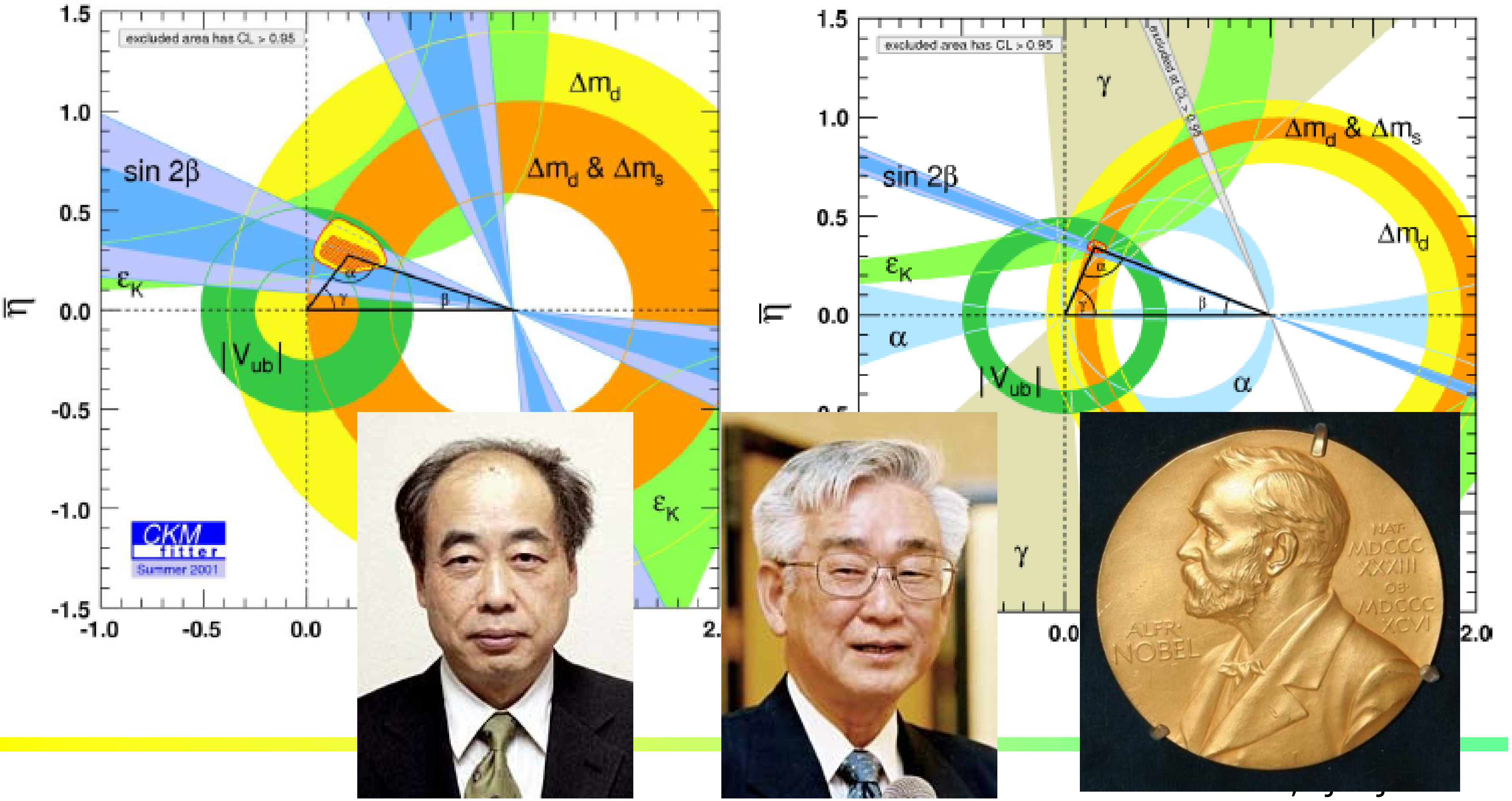
To a large degree shaped flavour physics in the previous decade

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



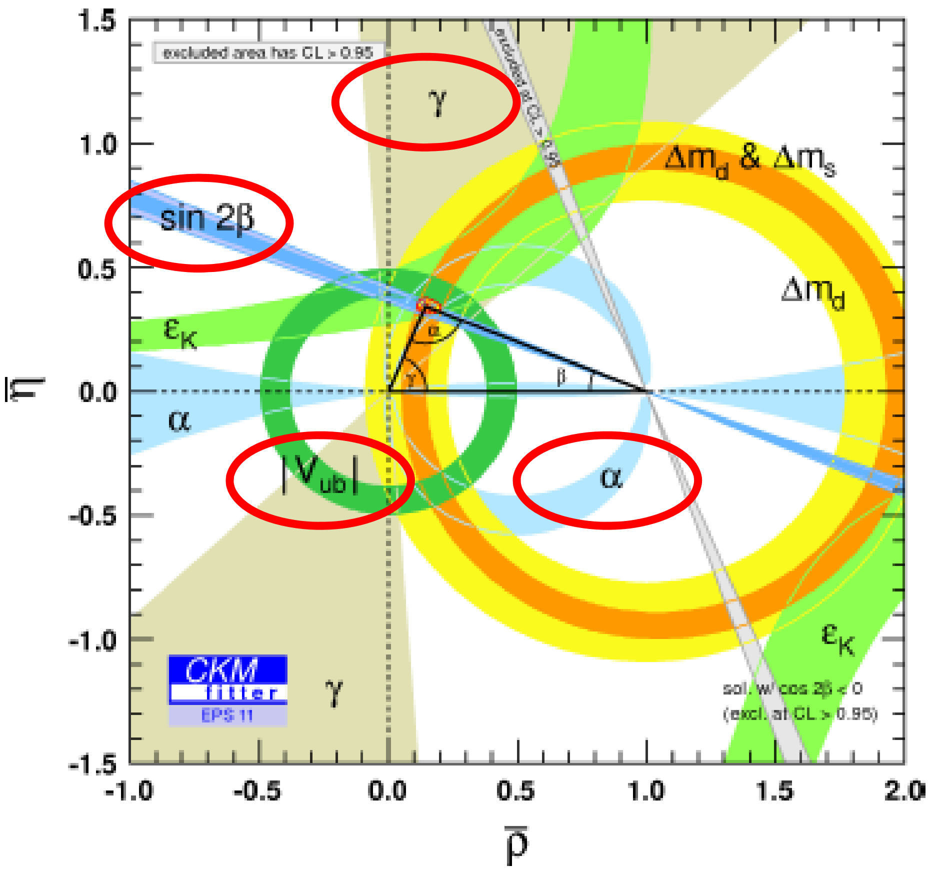
B factories: a success story

- 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, full solid angle coverage.

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:

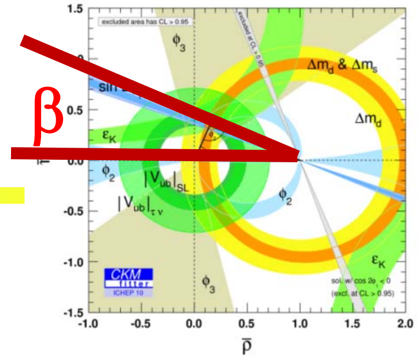
→ $\sin 2\phi_1$ ($=\sin 2\beta$)

→ ϕ_2 ($=\alpha$)

→ ϕ_3 ($=\gamma$)

→ $|V_{ub}|$

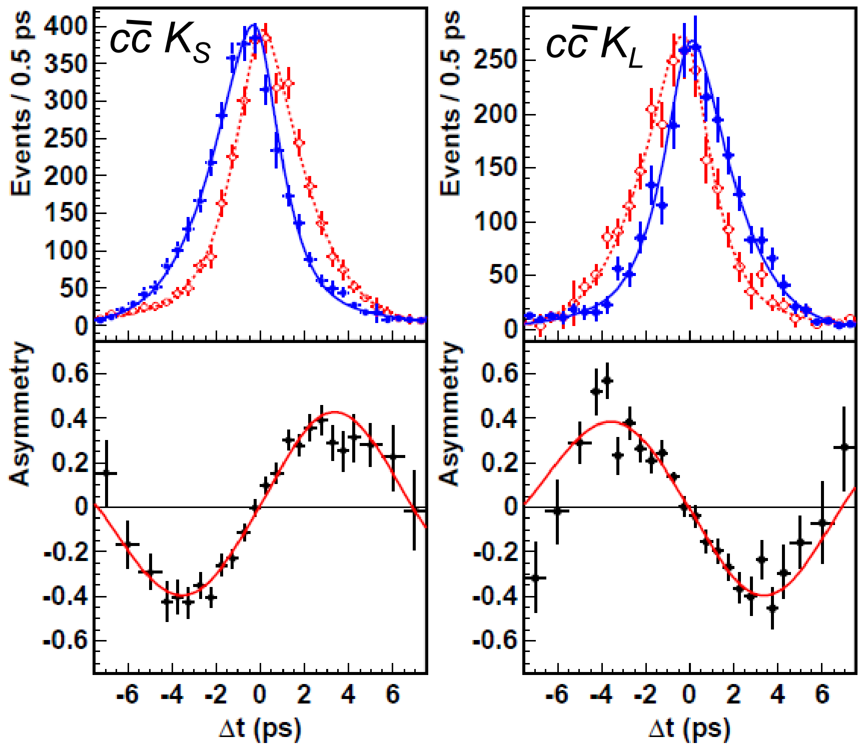
Final measurement of $\sin 2\phi_1$ (=$\sin 2\beta$)

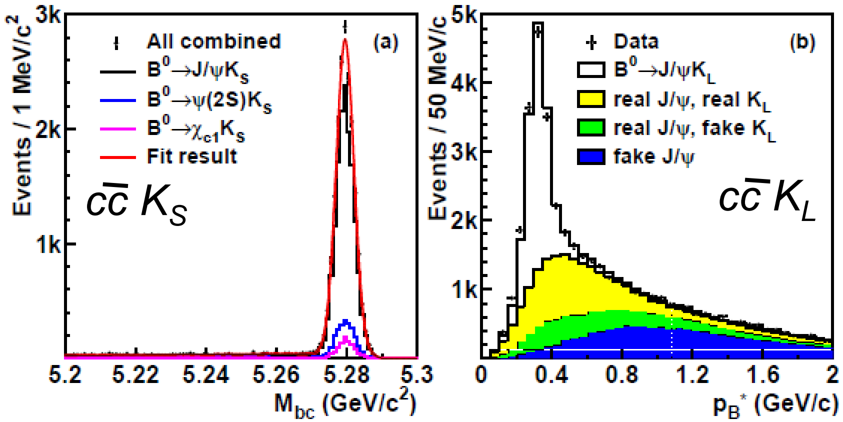


ϕ_1 from CP violation measurements in $B^0 \to c\bar{c}\, K^0$

Final measurement: with improved tracking, more data, improved systematics (50% more statistics than last result with 492 fb^{-1});
cc = J/ψ, $\psi(2S)$, χ_{c1} → 25k events

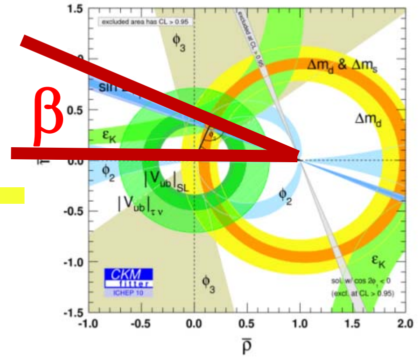
Detector effects: wrong tagging, finite Δt resolution → determined using control data samples





Belle, final, 710 fb^{-1}, PRL 108, 171802 (2012)

Final measurements of $\sin 2\phi_1$ ($=\sin 2\beta$)



ϕ_1 from $B^0 \to c\bar{c}\, K^0$

Final results for $\sin 2\phi_1$

Belle:	$0.668 \pm 0.023 \pm 0.012$
BaBar:	$0.687 \pm 0.028 \pm 0.012$

Belle, PRL 108, 171802 (2012)

BaBar, PRD 79, 072009 (2009)

with a single experiment precision of ~4%!

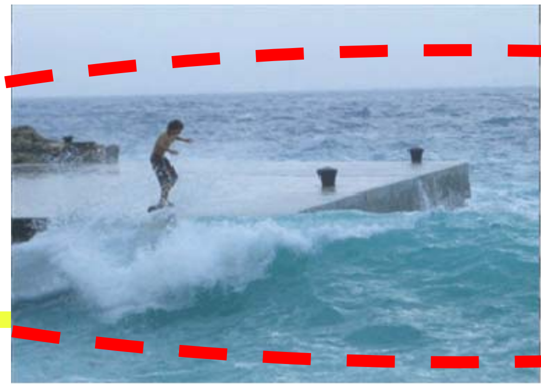
Comparison with LHCb:

- The power of tagging at B factories: 33% vs ~2-3% at LHCb
- LHCb: with 8k tagged $B_d \to J/\psi K_S$ events from 1/fb measured
  $\sin 2\beta = 0.73 \pm 0.07(\text{stat.}) \pm 0.04(\text{syst.})$
- Uncertainties at B factories - e.g., Belle final result
  $\sin 2\beta = 0.668 \pm 0.023(\text{stat.}) \pm 0.012(\text{syst.})$ - are 3x smaller than at LHCb

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.

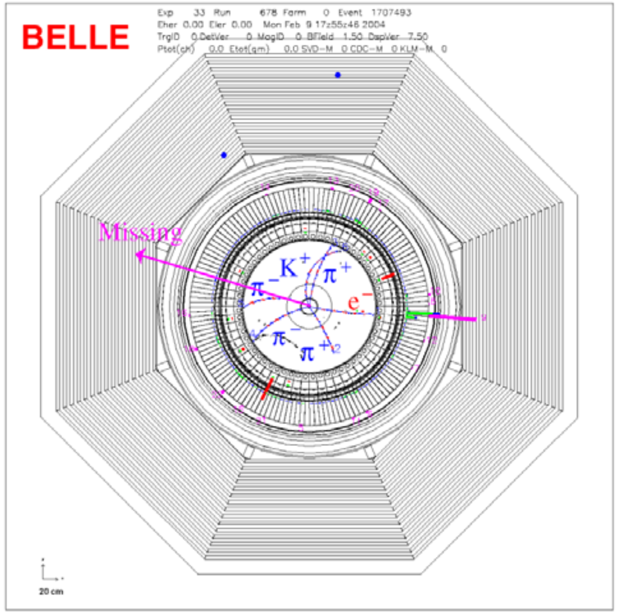
Energy frontier (LHC)



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

Complementary to LHCb

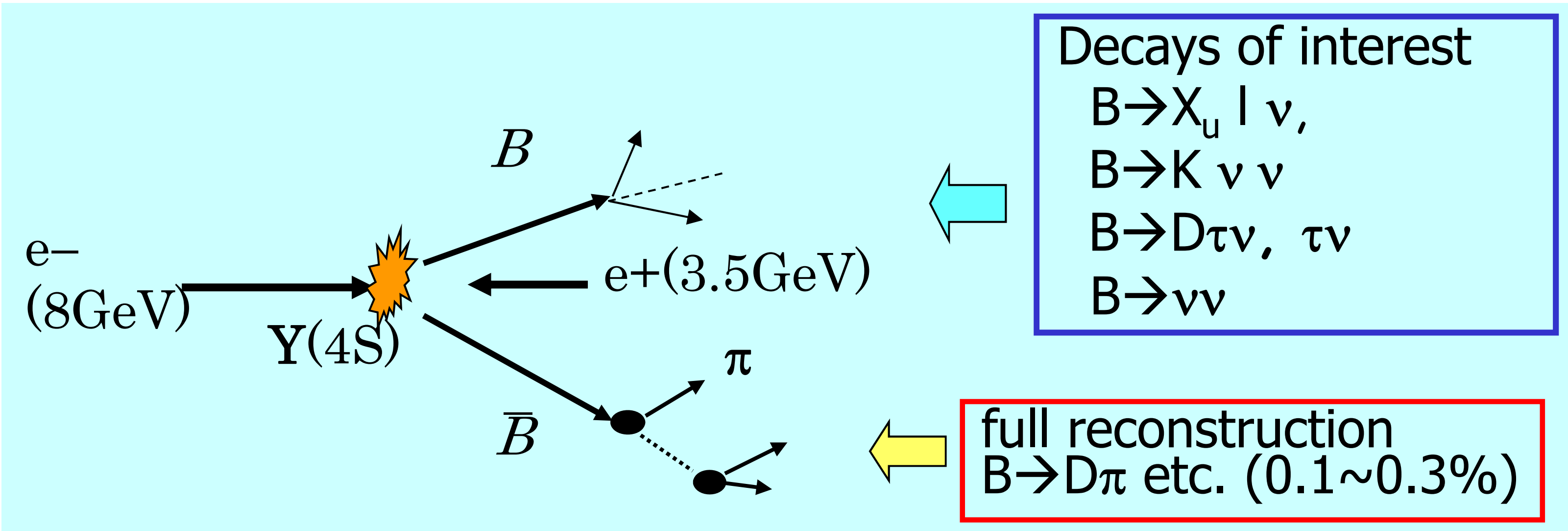
Observable	Expected th. accuracy	Expected exp. uncertainty	Facility
CKM matrix			
$\lvert V_{us}\rvert$ $[K \to \pi\ell\nu]$	**	0.1%	K-factory
$\lvert V_{cb}\rvert$ $[B \to X_c\ell\nu]$	**	1%	Belle II
$\lvert V_{ub}\rvert$ $[B_d \to \pi\ell\nu]$	*	4%	Belle II
$\sin(2\phi_1)$ $[c\bar{c}K_S^0]$	***	$8 \cdot 10^{-3}$	Belle II/LHCb
ϕ_2		1.5^o	Belle II
ϕ_3	***	3^o	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
$\lvert q/p\rvert_D$	***	0.03	Belle II
$arg(q/p)_D$	***	1.5^o	Belle II

→Need both LHCb and a super B factory 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!

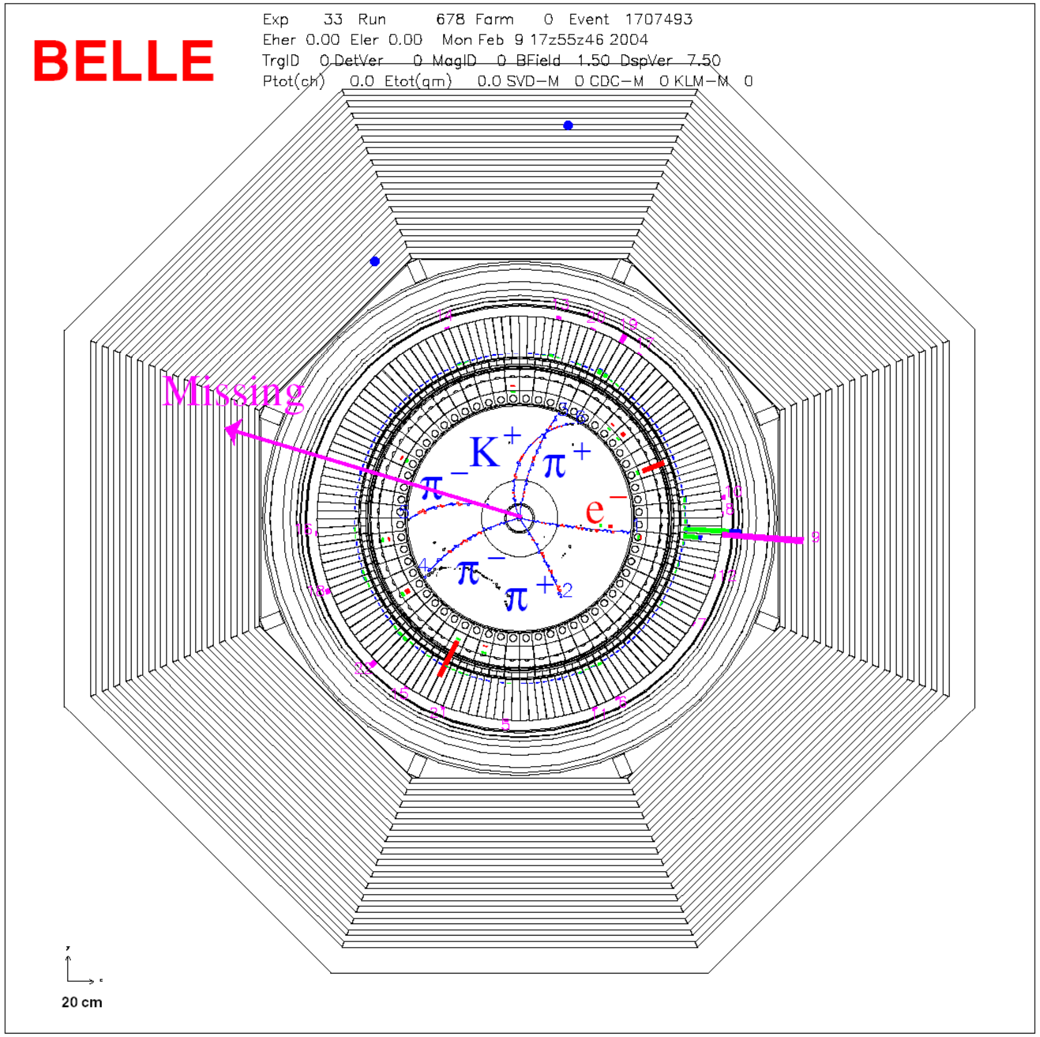
Powerful tool for B decays with several neutrinos in the final state

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

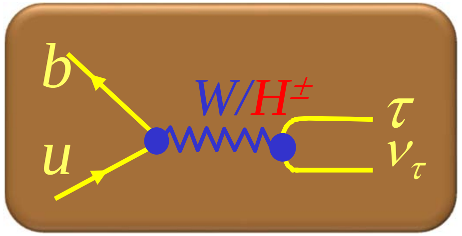
$B^- \rightarrow \tau^- \nu_\tau$

Example of a missing energy decay

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



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

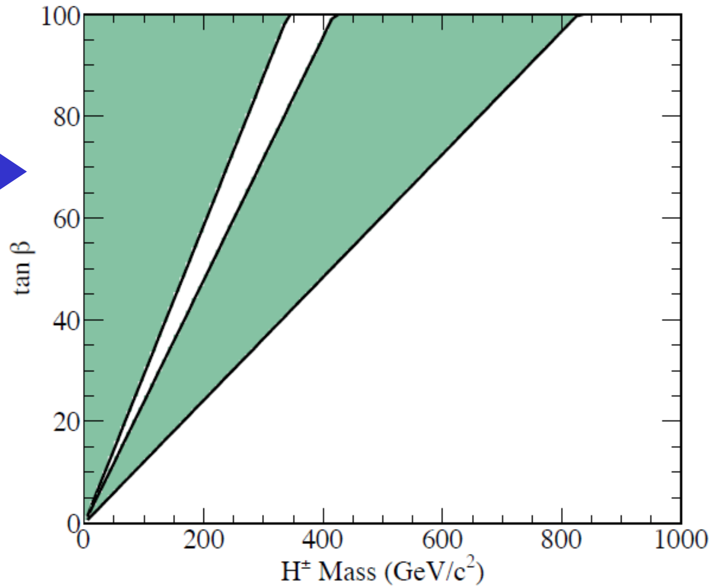


Measured value

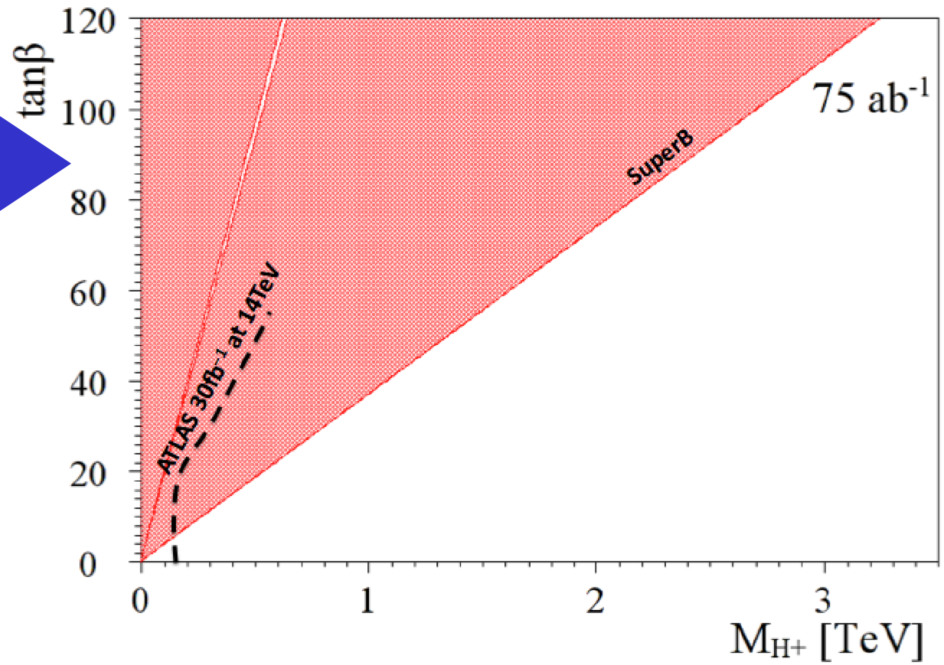
$$r_H = \frac{BF(B \to \tau\nu)}{BF(B \to \tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

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

B factories: Exclusion plot

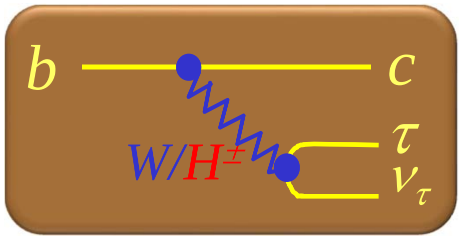


Super B factory: Discovery plot: very much competitive with LHC!



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

Semileptonic decay sensitive to charged Higgs



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

Kamenik, Mescia arXiv:0802.3790

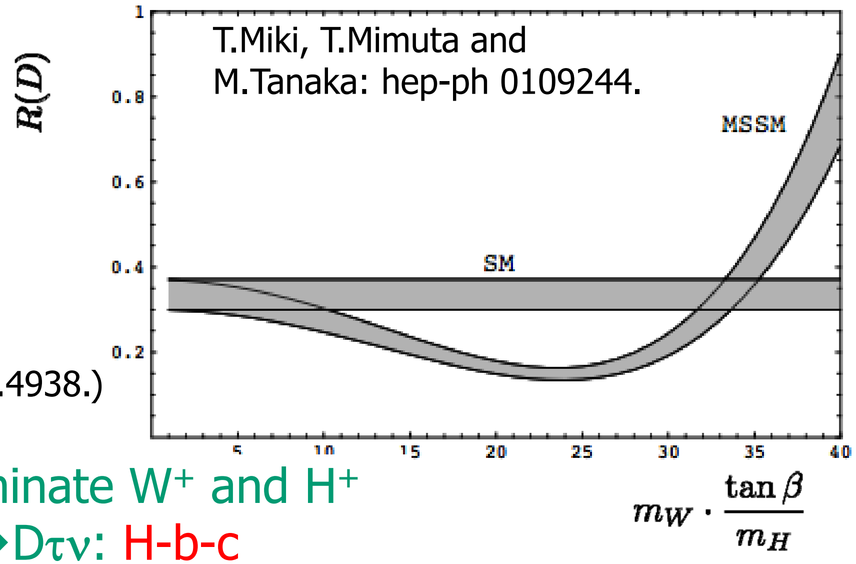
$$R(D) \equiv \frac{\mathcal{B}(B \to D\tau\nu)}{\mathcal{B}(B \to D\ell\nu)}$$

Complementary and competitive with $B \to \tau\nu$

1.Smaller theoretical uncertainty of R(D)

(For $B \to \tau\nu$,
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 $B \to \tau\nu$: H-b-u, $B \to D\tau\nu$: H-b-c

(LHC experiments sensitive to H-b-t)

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

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

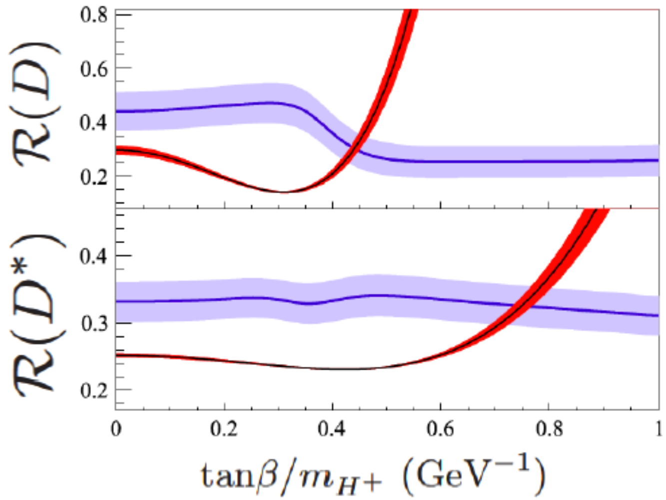
Exclusive hadron tag data

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

2.0σ   2.7σ

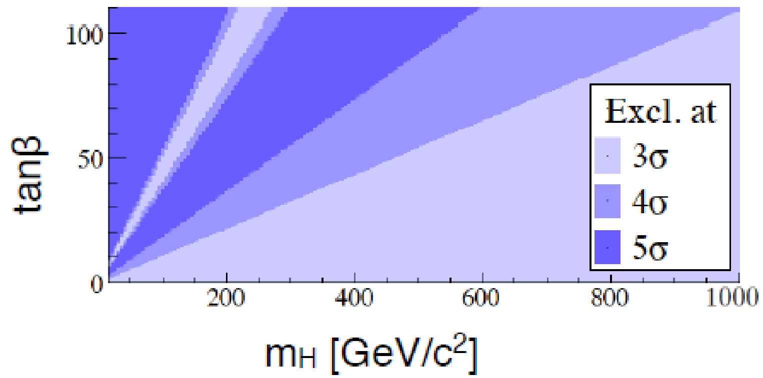
$$\mathcal{R}(D)_{\rm SM} = 0.297 \pm 0.017 \quad \mathcal{R}(D^*)_{\rm SM} = 0.252 \pm 0.003$$

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



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

→ Combined result: 3σ away from SM.

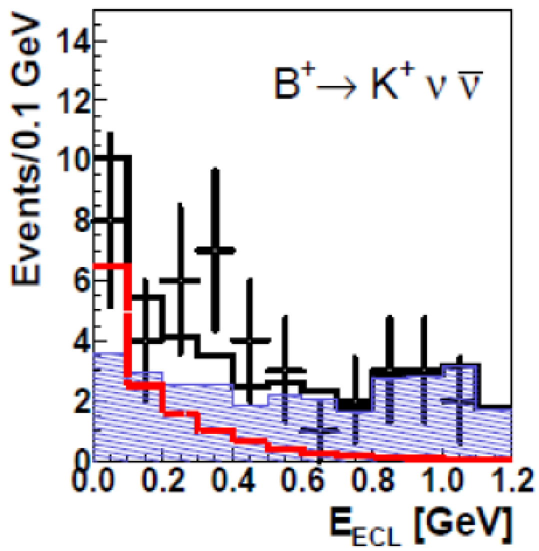


→ Combined result: Type II 2HDM excluded at 99.8% C.L. for any values of tanβ and charged Higgs mass

Five more recent papers by Svjetlana and colleagues on this topic!

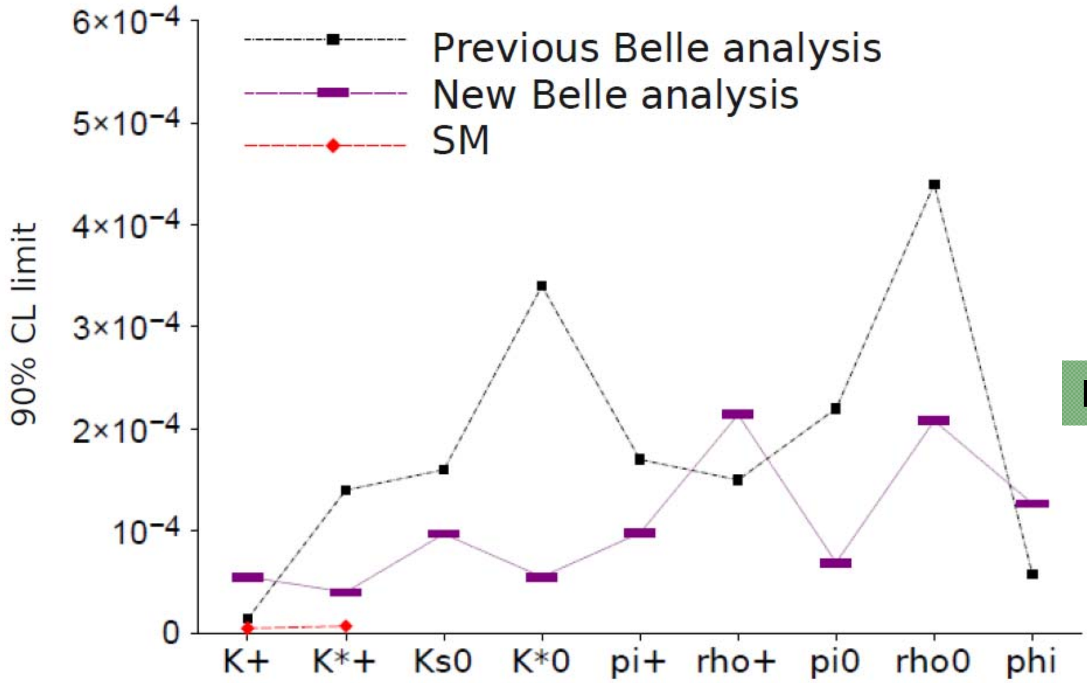
$B \to h\nu\bar{\nu}$ decays

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



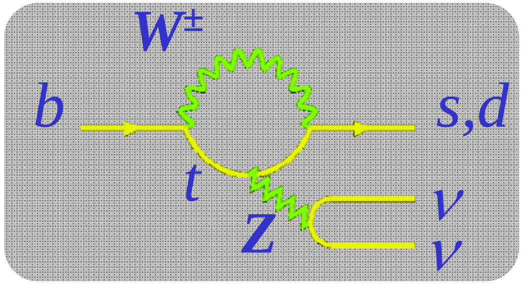
Belle, Phys. Rev. D 87, 111103(R) (2013)

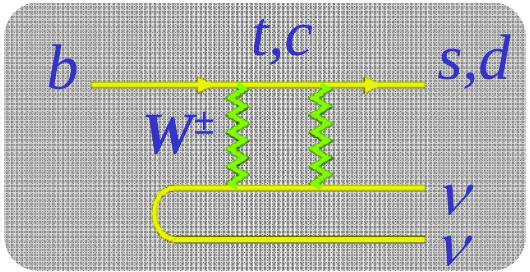
$B \to K^{(*)}\nu\bar{\nu}$

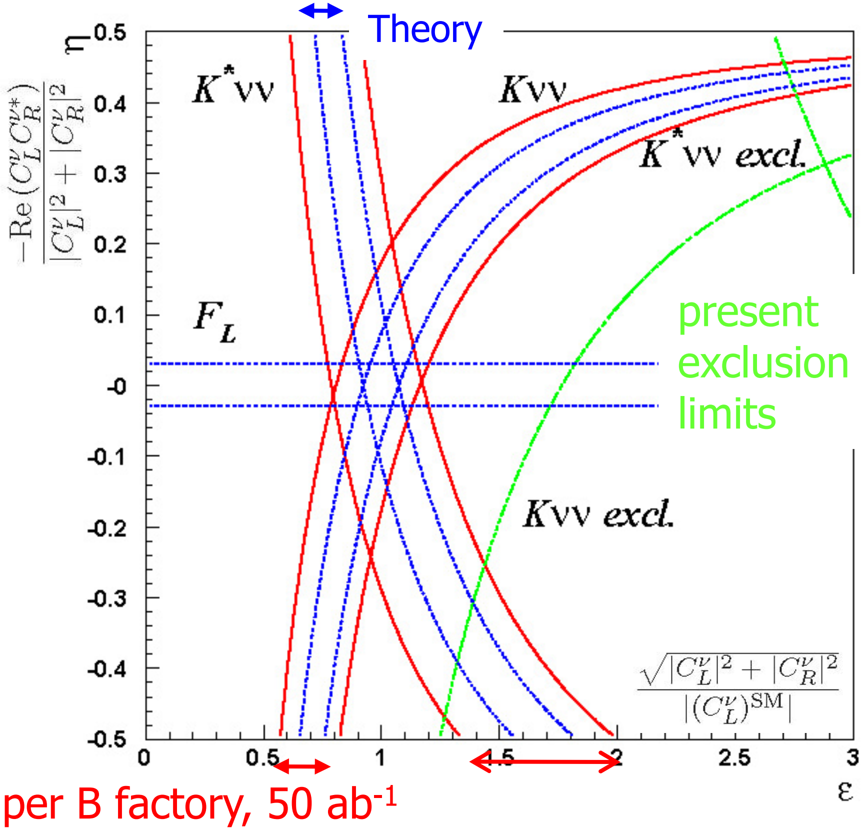
arXiv:1002.5012

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

SM: penguin + box diagrams



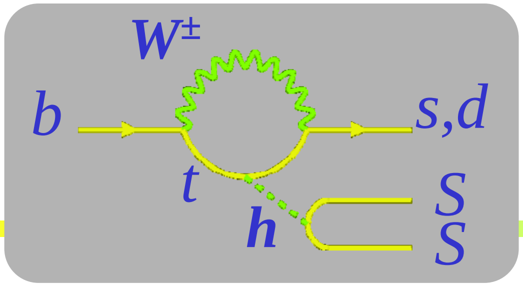


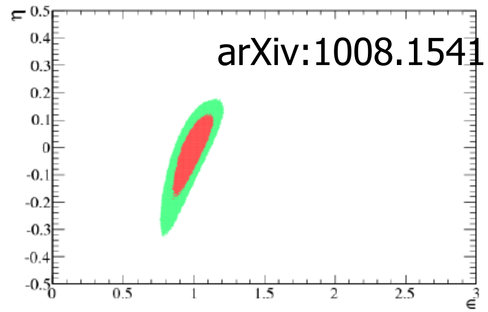


$B \to K\nu\nu,\ \mathcal{B} \sim 4{\cdot}10^{-6}$
$B \to K^*\nu\nu,\ \mathcal{B} \sim 6.8{\cdot}10^{-6}$

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.,



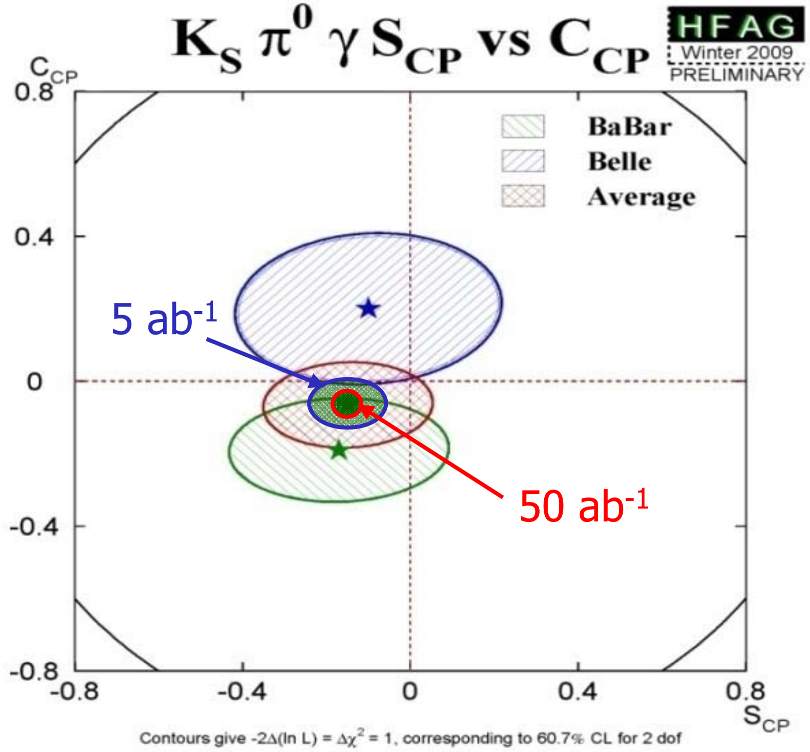


CP violation in B→$K_S\pi^0\gamma$

CP violation in B→$K_S\pi^0\gamma$ decays:
Search for right-handed currents

$B \to K^*\gamma$, $\mathcal{B}$ ~ 4.0·10^{-5}

δS ~0.2 (present)
→ ~a few % at 50 ab^{-1}



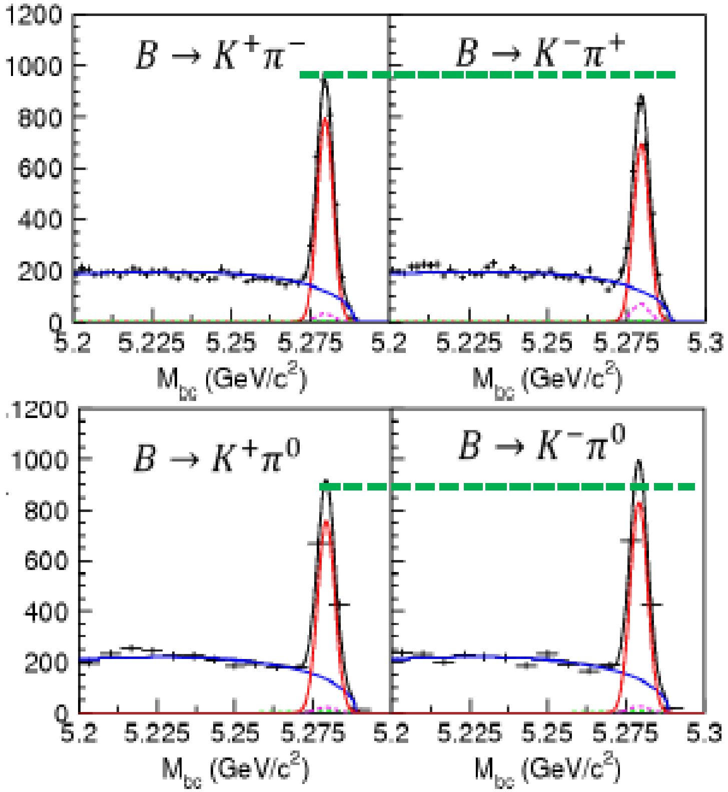
adopted from HFAG

not possible @ LHCb

Related to this: S. Fajfer, T.-N. Pham and N. Kosnik, On the Dalitz plot analysis of the B → $K\eta\gamma$ decays

Direct CP violation difference in $B \rightarrow K^+\pi^-$ and $K^+\pi^0$

2011 update



$\Delta A_{K\pi} = A_{CP}(K\pi^0) - A_{CP}(K\pi)$

Update of the 2008 result with the full data set and improved reconstruction - ~2x more data

$$A_{cp}(K^{\pm}\pi^0) = +0.043 \pm 0.024 \pm 0.002$$
$$A_{cp}(K^{\pm}\pi^{\mp}) = -0.069 \pm 0.014 \pm 0.007$$

$$\Delta A_{K\pi} = +0.112 \pm 0.028 \text{ @}4\sigma$$

Marko Petrič searches for CPV in $B \rightarrow K^+\pi^-\pi^0$

S. Fajfer, T.N. Pham, A. Prapotnik, Phys.Rev., CPV in $B \rightarrow K^+\pi^-\pi^+$, PRD70 (2004) 034033

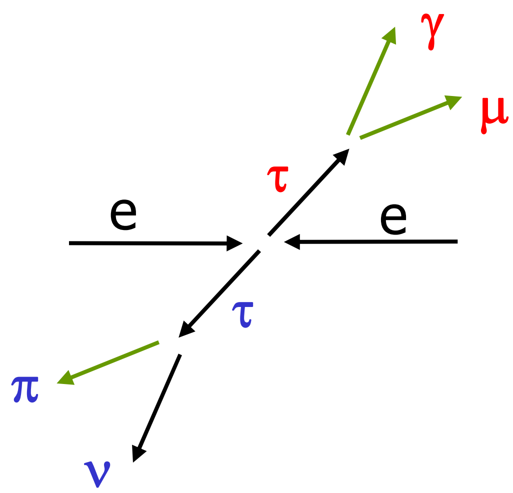
Charm and τ physics

B factories = charm and τ factories

For the experimental charm overview → Boštjan

Rare τ decays

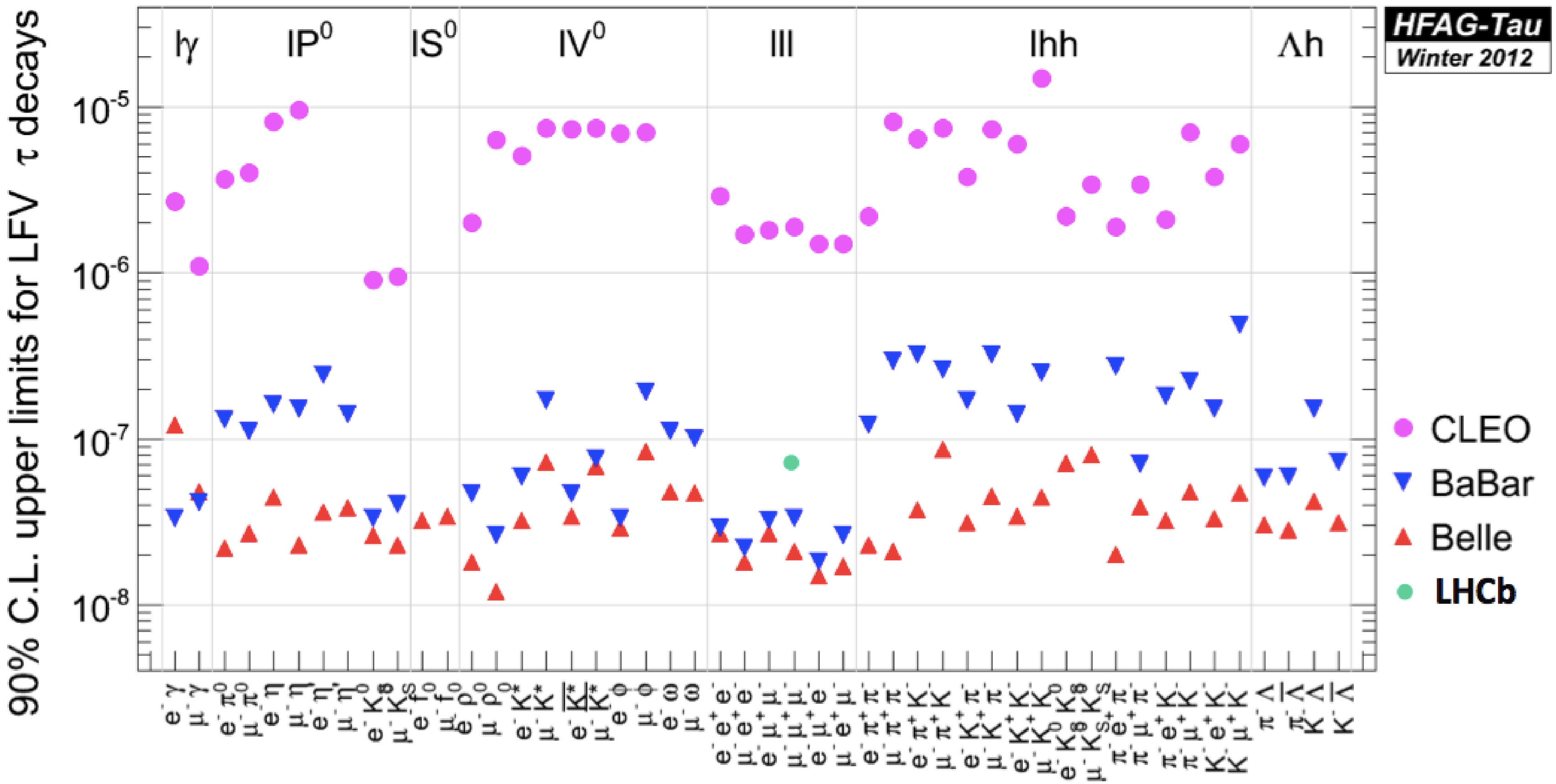
Example: lepton flavour violating decay $\tau \to \mu \gamma$



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

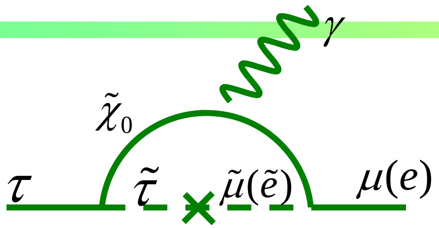
LFV in tau decays: present status

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



LFV and New Physics

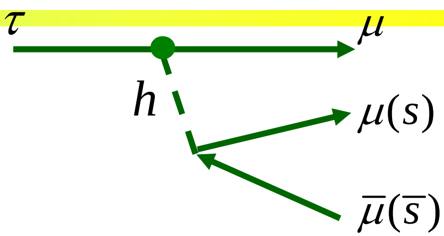
$\tau \to l\gamma$



- SUSY + Seasaw $(m^2_{\tilde{l}})_{23(13)}$
- Large LFV Br($\tau \to \mu\gamma$)=O($10^{-7\sim9}$)

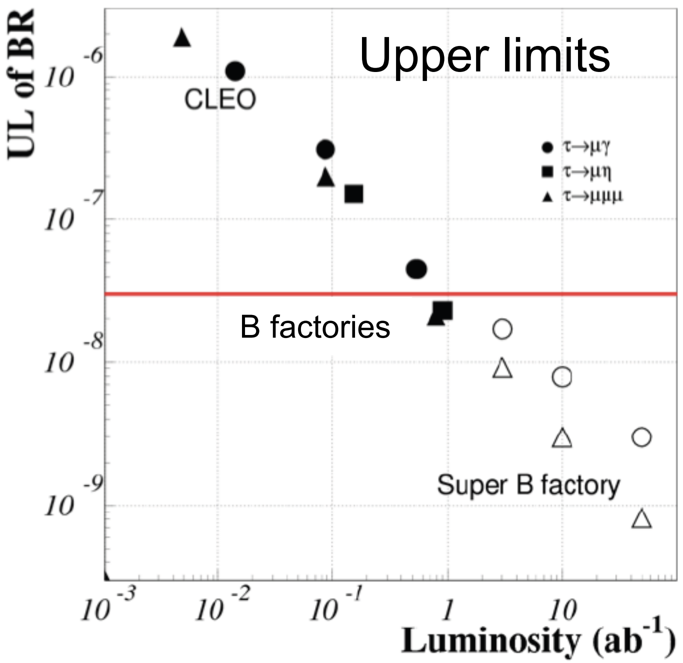
$$Br(\tau \to \mu\gamma) \simeq 10^{-6} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}}\right)\left(\frac{1TeV}{m_{SUSY}}\right)^4 \tan^2\beta$$

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



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

$$Br(\tau \to 3\mu) = 4\times10^{-7} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}}\right)\left(\frac{\tan\beta}{60}\right)^6\left(\frac{100GeV}{m_A}\right)^4$$



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

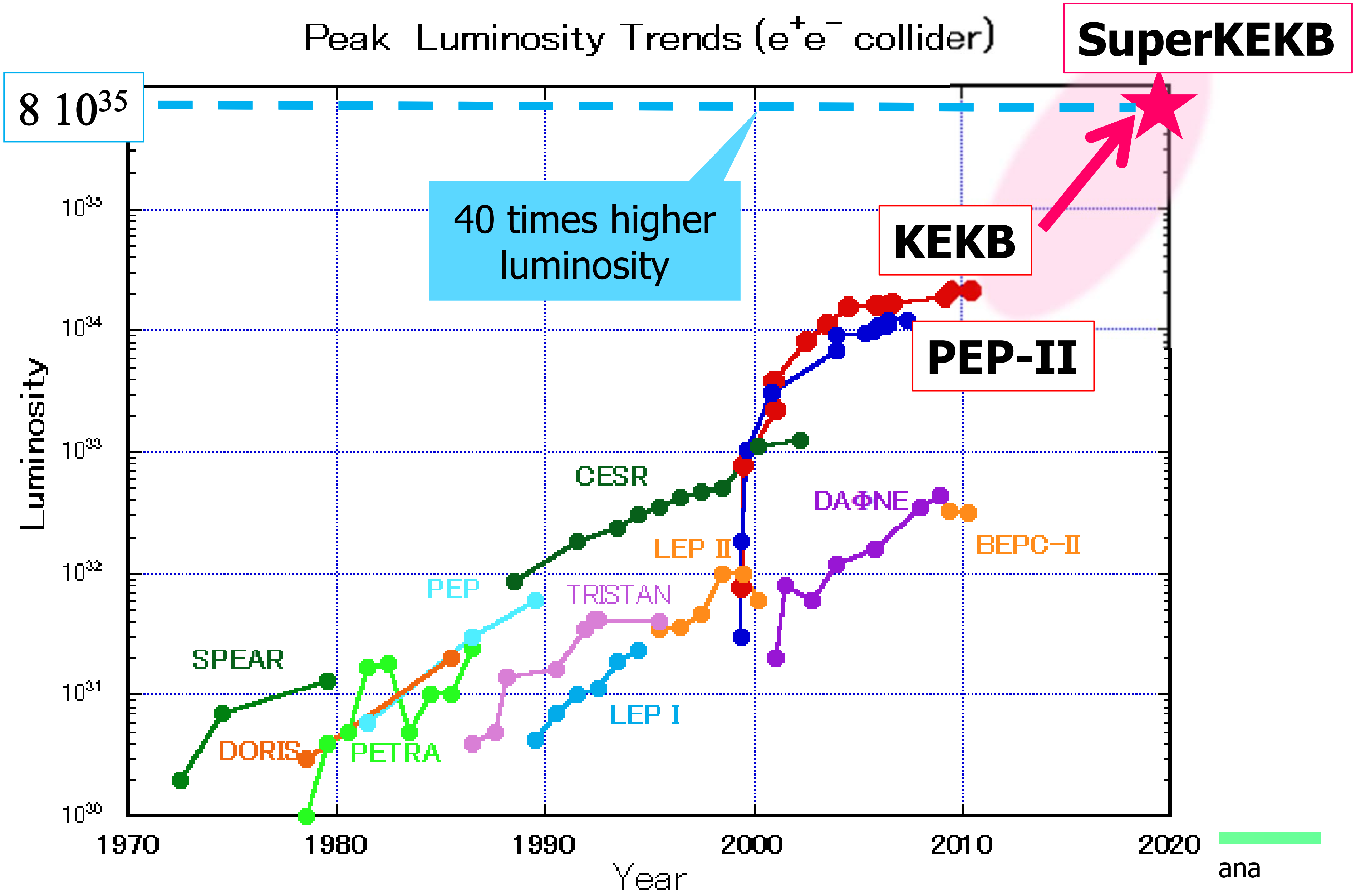
→ Need much more data (almost two orders!)

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

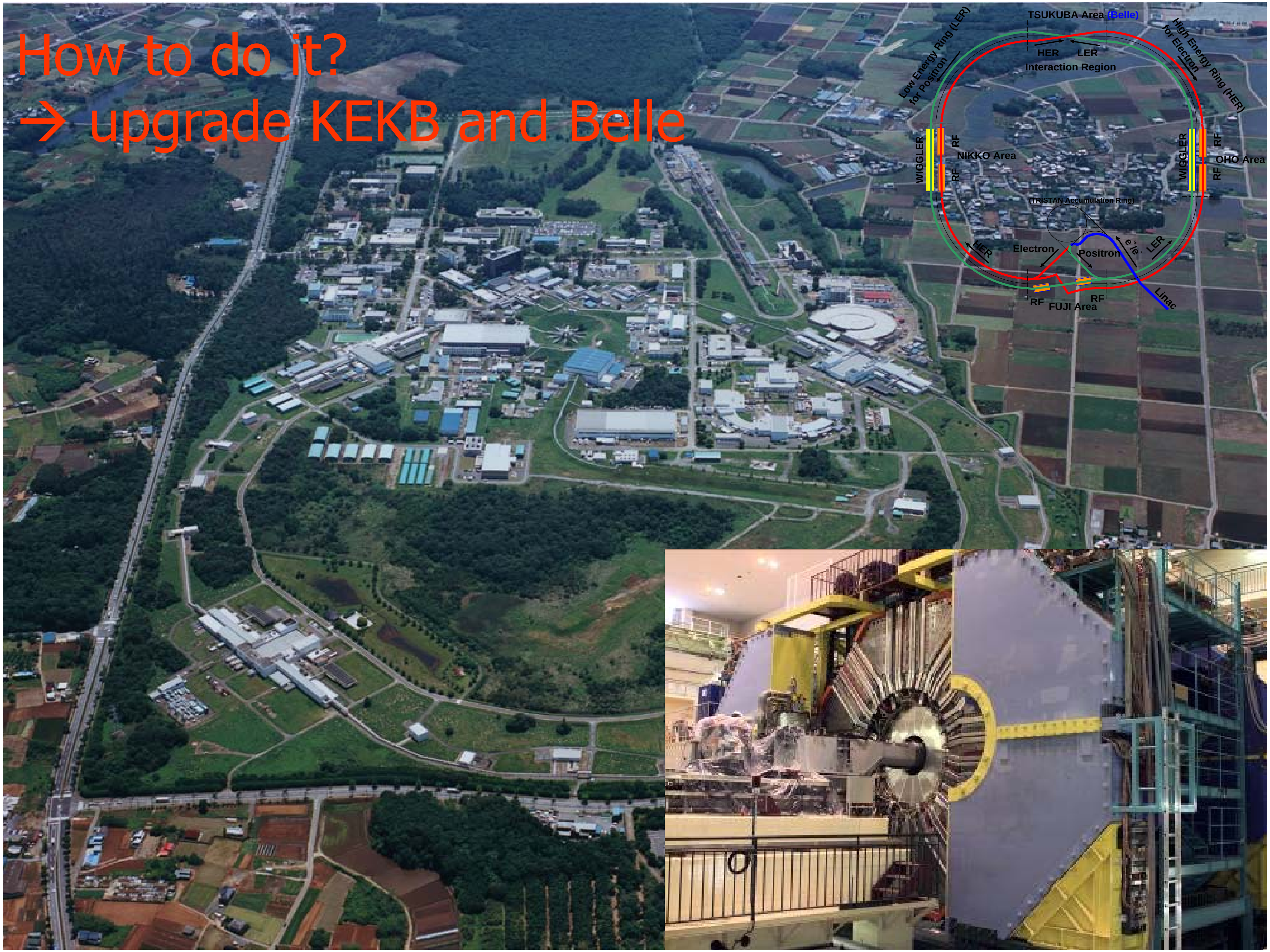
Still, e^+e^- machines running at (or near) Υ(4s) will have considerable advantages in several classes of measurements, and will be complementary in many more

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

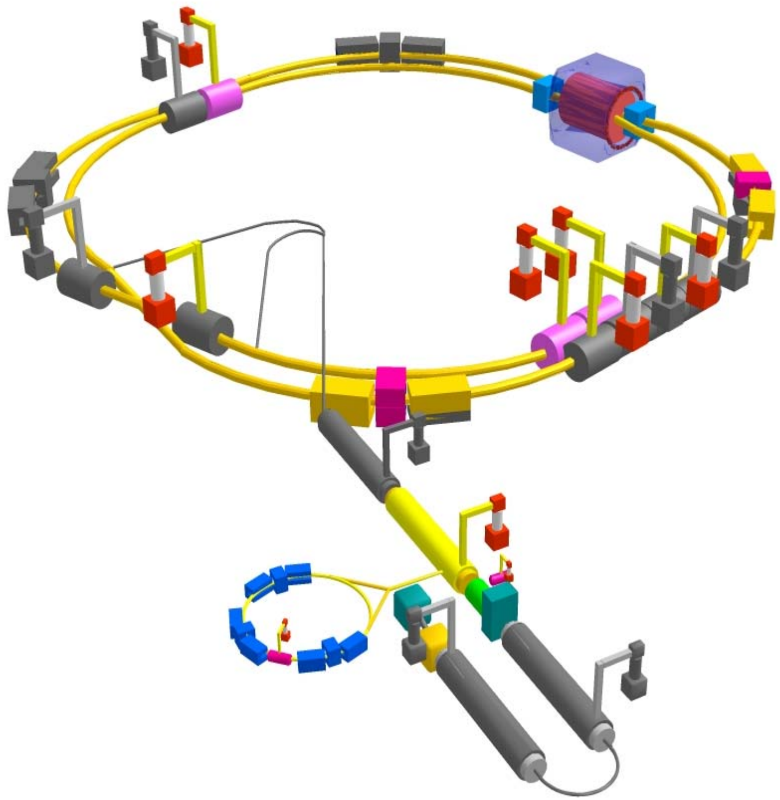
Need 50x more data →Next generation B-factories



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} = 2.1x10^{34}/cm^2/s
L > 1ab^{-1}

Strategies for increasing luminosity

Lorentz factor

Beam current

Beam-beam parameter

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

Classical electron radius

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

Vertical beta function@IP

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

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

"Nano-Beam" scheme

Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

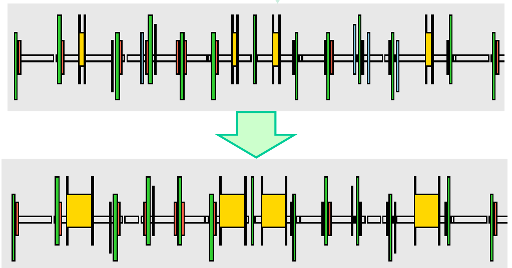
Machine design parameters

parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.6	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

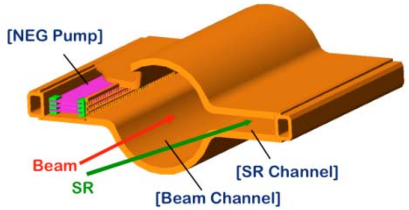
KEKB to SuperKEKB

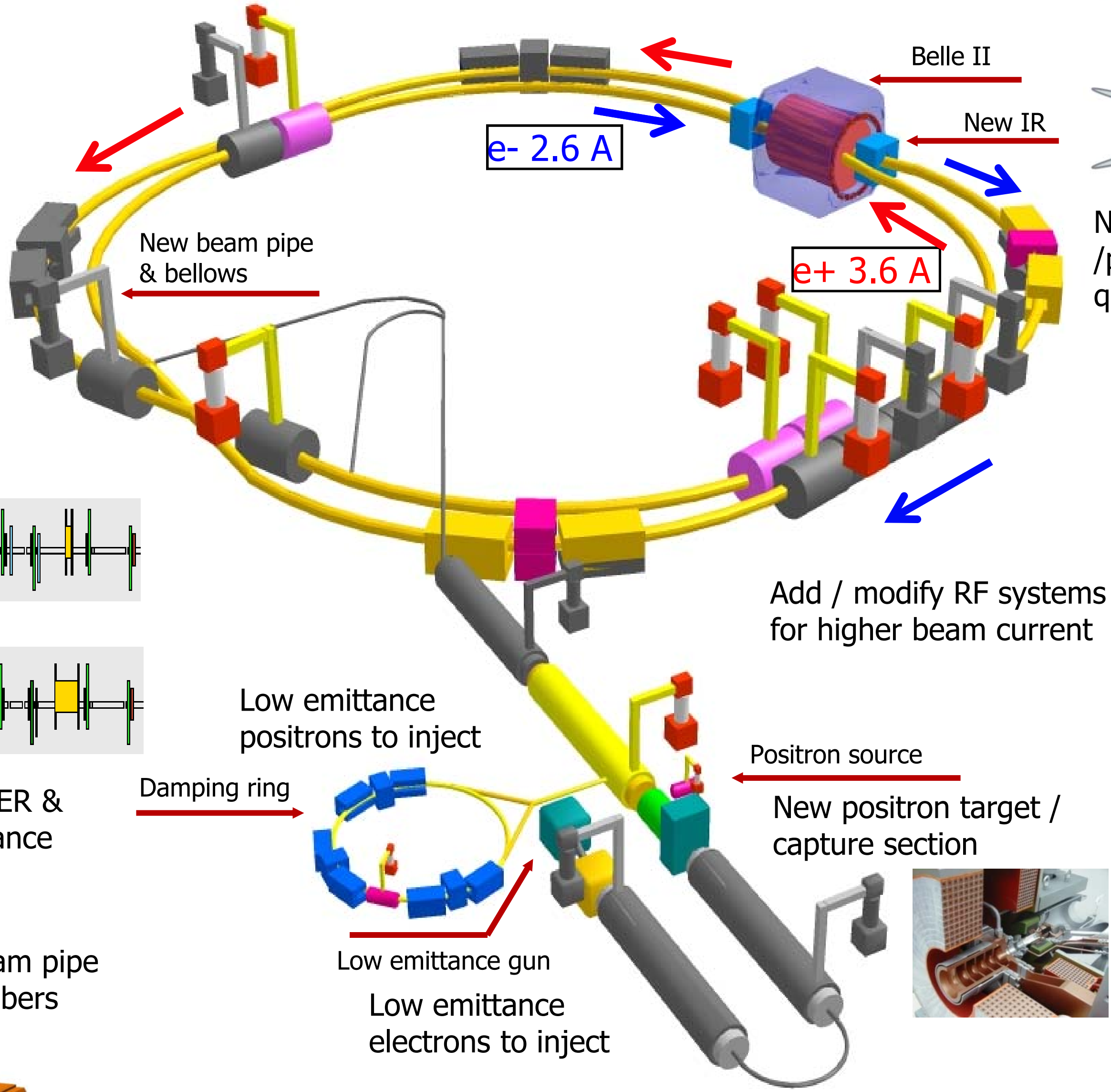
Replace short dipoles
with longer ones (LER)



Redesign the lattices of HER &
LER to squeeze the emittance

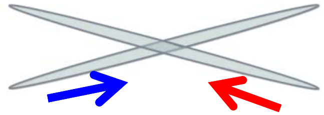
TiN-coated beam pipe
with antechambers



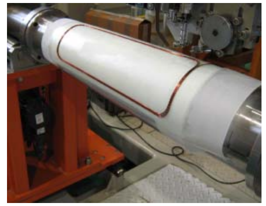


Low emittance
electrons to inject

Colliding bunches



New superconducting
/permanent final focusing
quads near the IP



Add / modify RF systems
for higher beam current

New positron target /
capture section

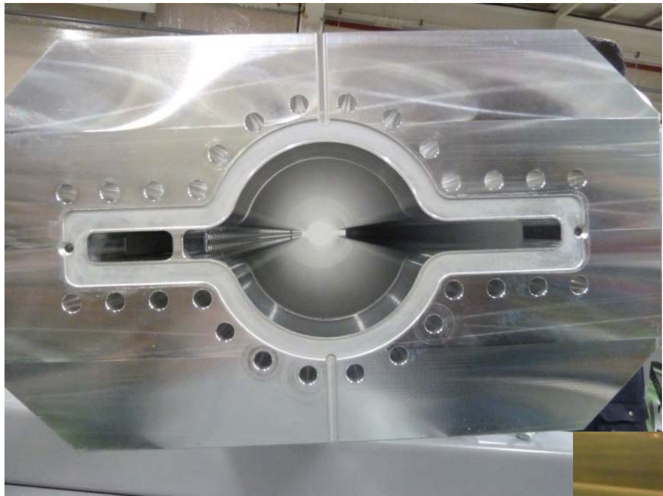
To obtain x40 higher luminosity

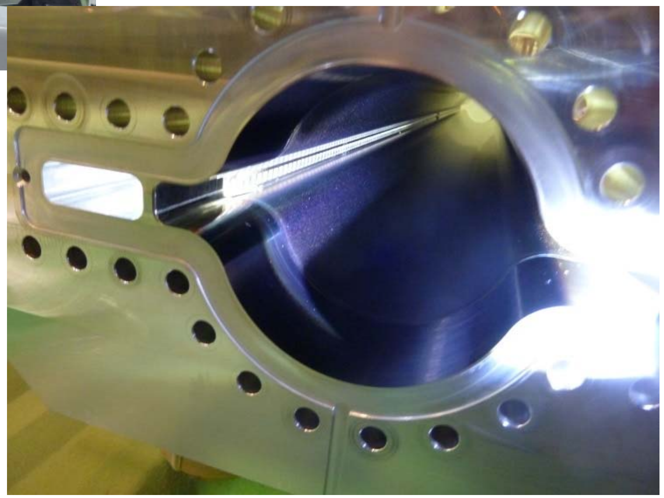
Entirely new LER beam pipe with ante-chamber and Ti-N coating

Beam pipe is made of aluminum.

Fabrication of the LER arc beam pipe section is completed

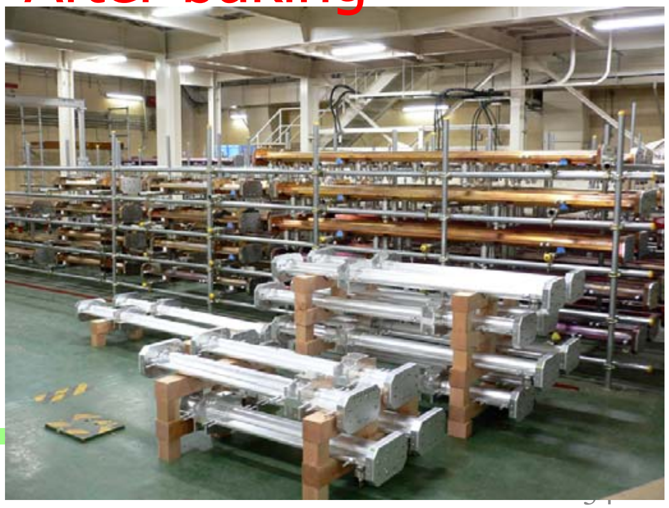
Al ante-chamber before coating





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

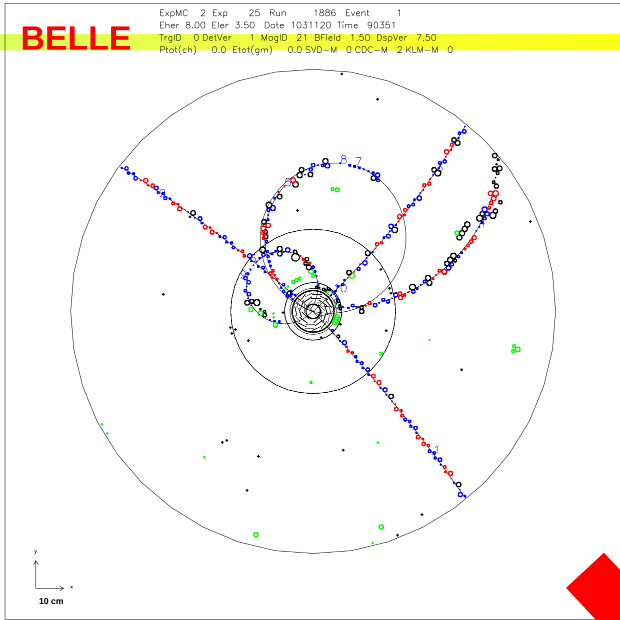
- Tunnel construction finished
- Construction of buildings for DR will start in April this year.
- Fabrication of accelerator components ongoing. Installation starts in 2014.
- DR commissioning will start in 2015.

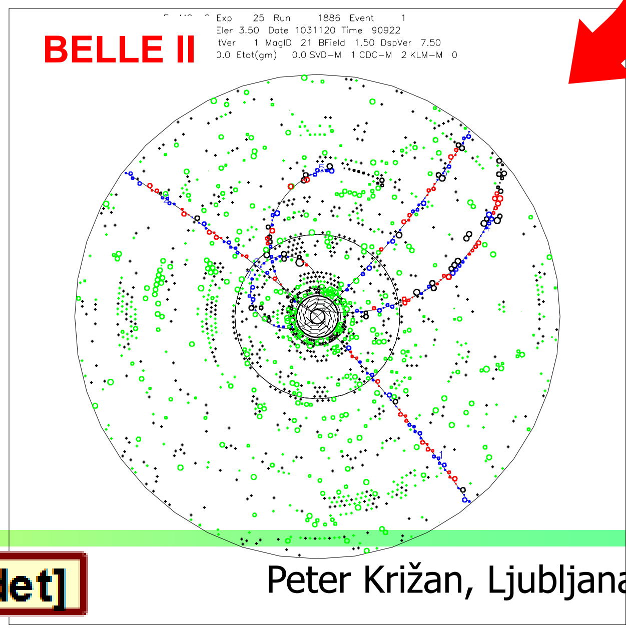
Inside DR tunnel

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 ← sμμ recon. eff.
  - hermeticity ← ν "reconstruction"



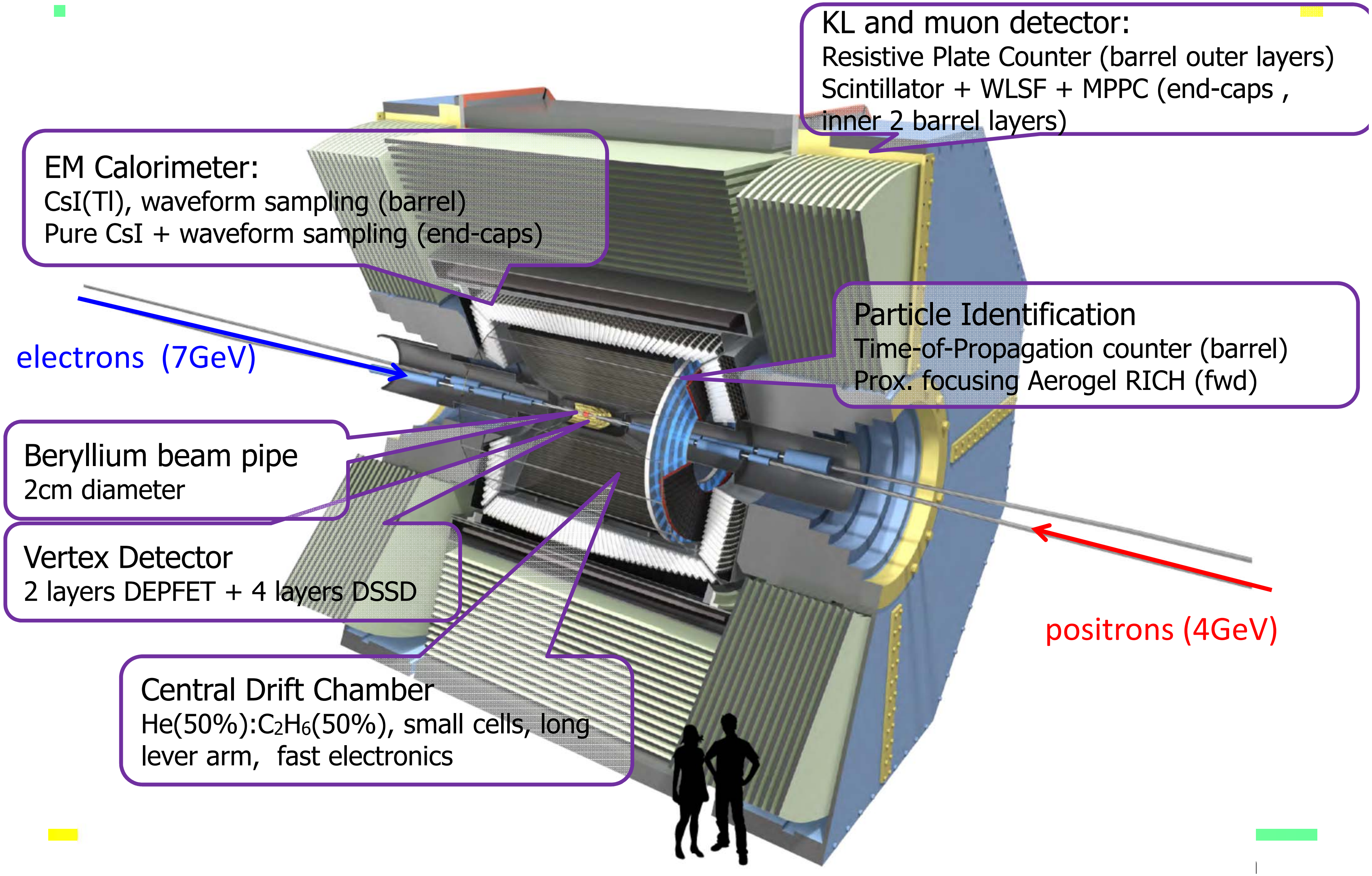


Have to employ and develop new technologies to make such an apparatus work!

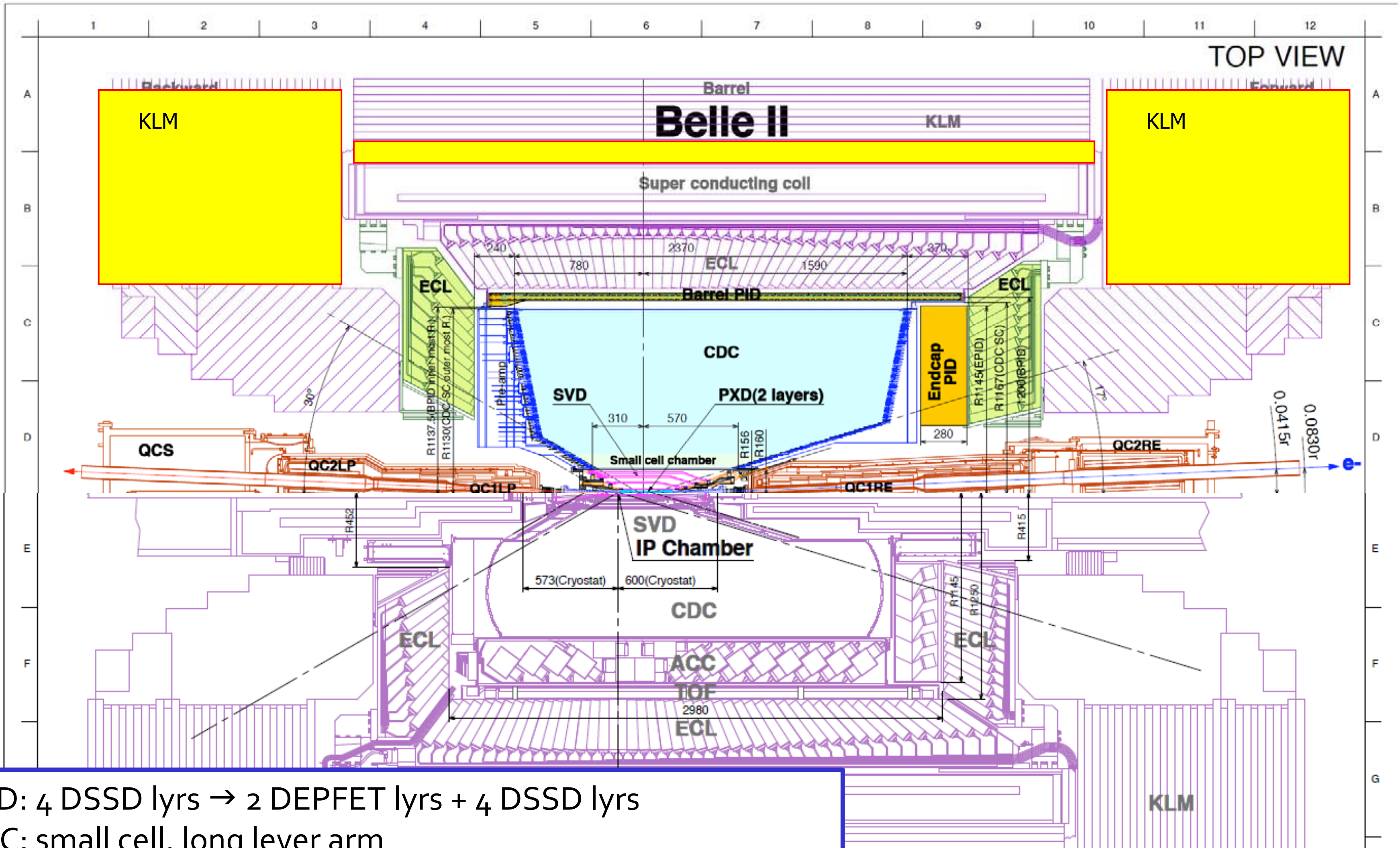
→

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

Belle II Detector



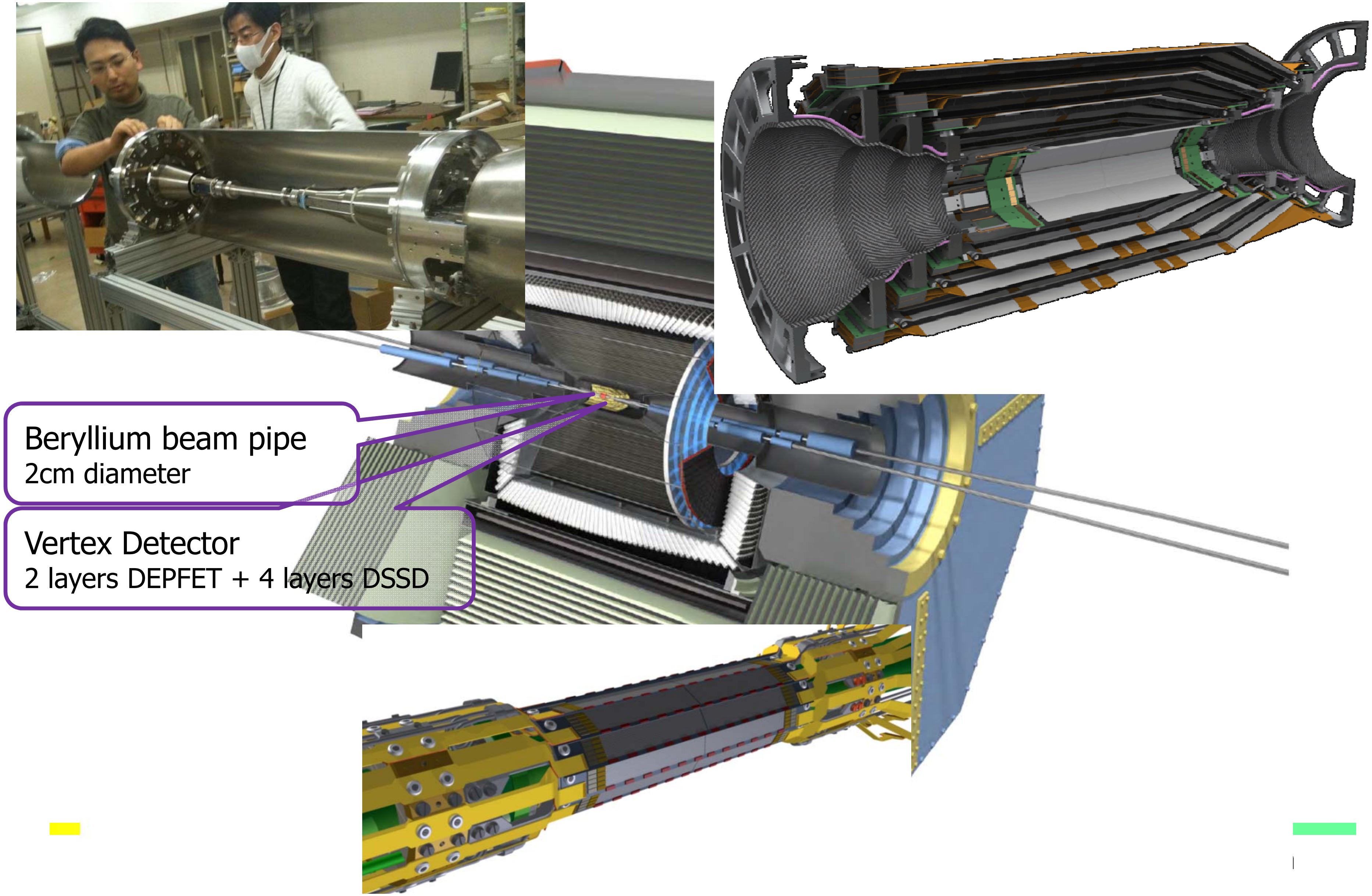
Belle II Detector (in comparison with Belle)



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)

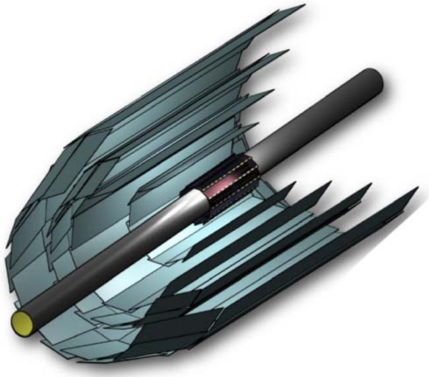
In colour: new or upgraded components

Belle II Detector – vertex region



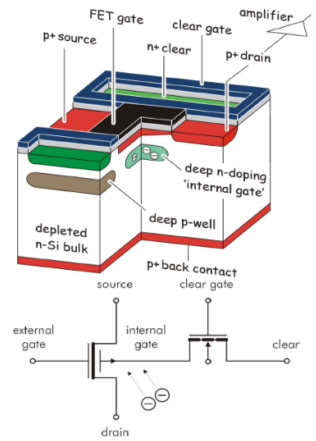
Vertex Detector

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

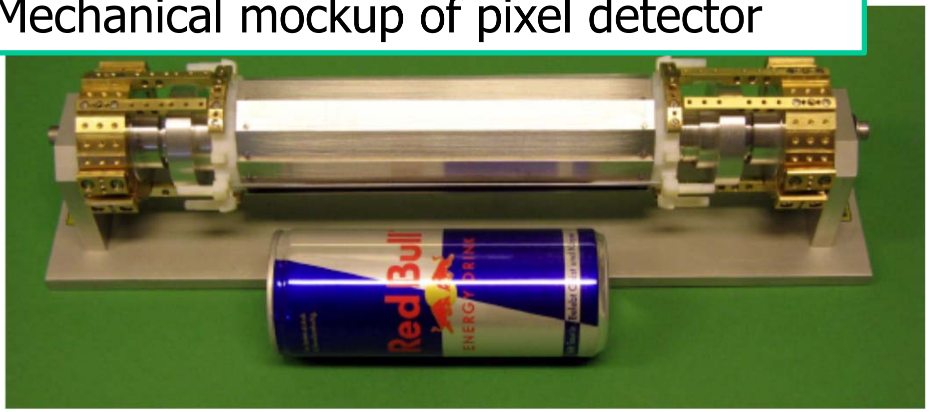


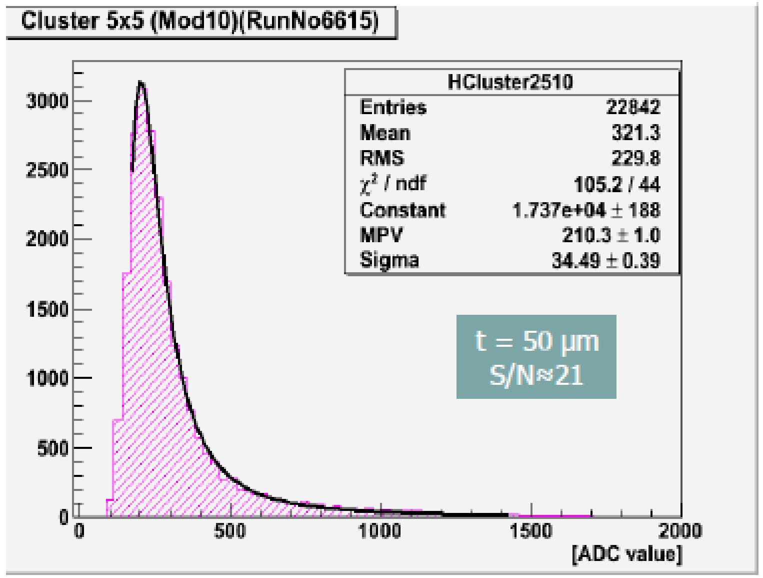
Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

DEpleted P-channel FET



Mechanical mockup of pixel detector

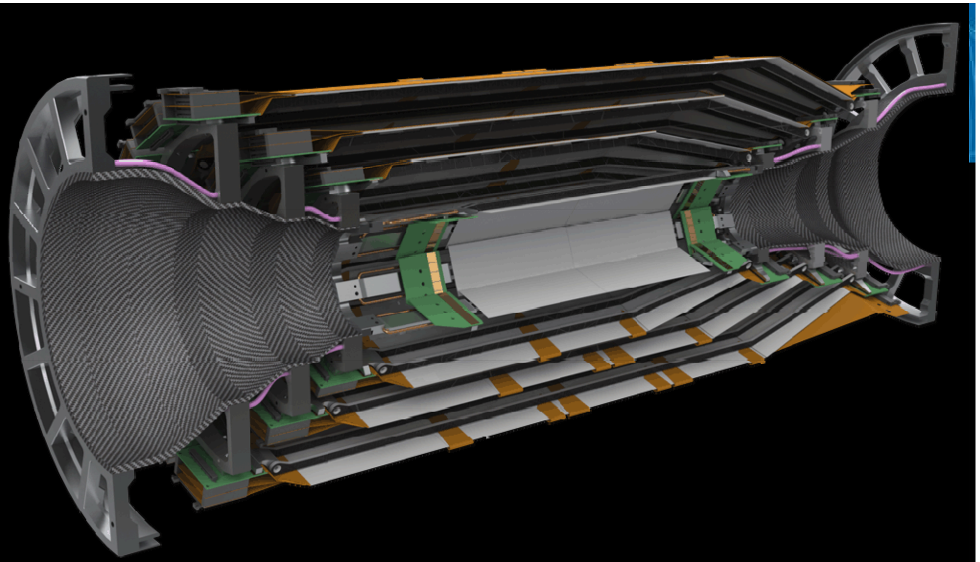


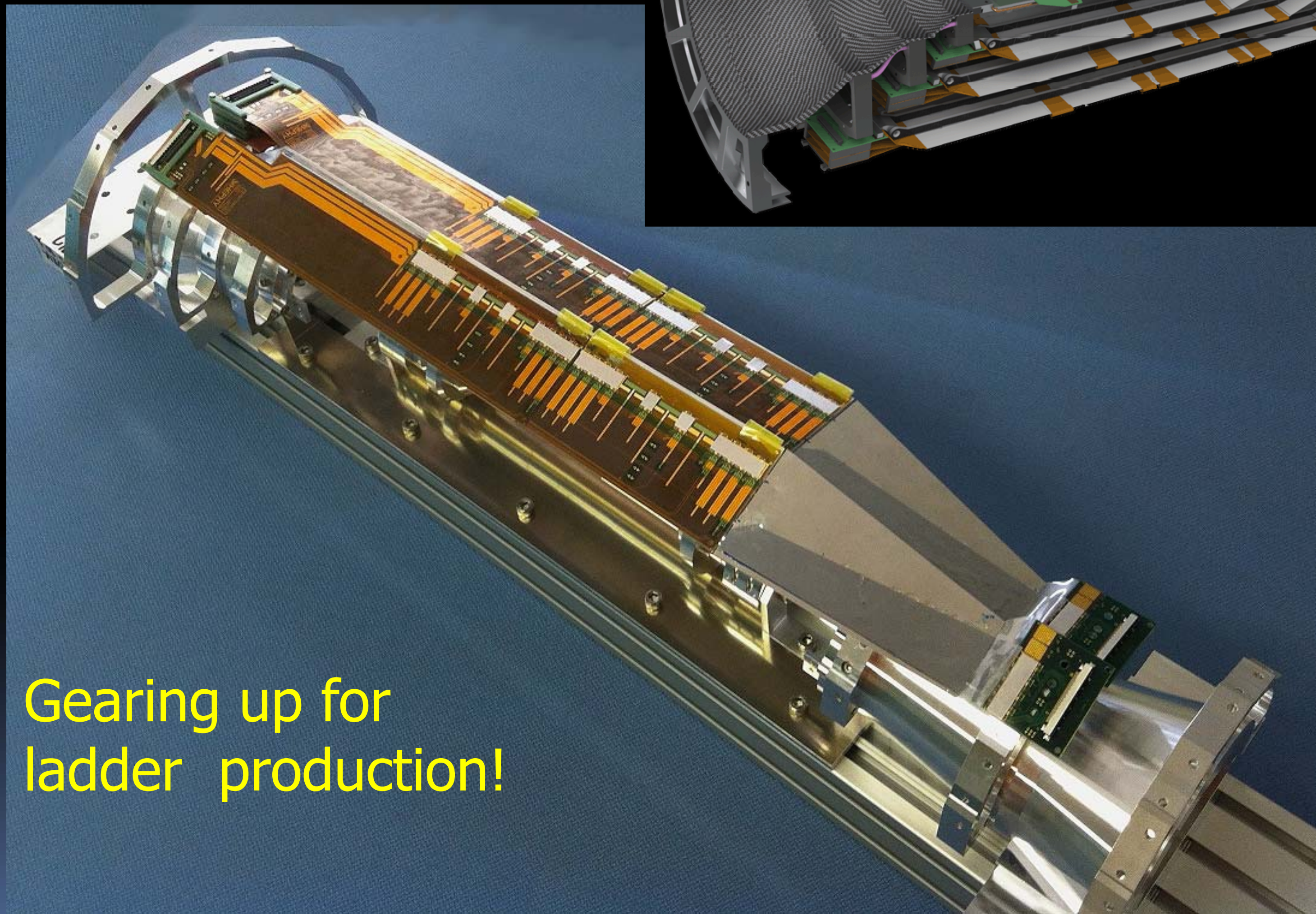


DEPFET pixel sensor

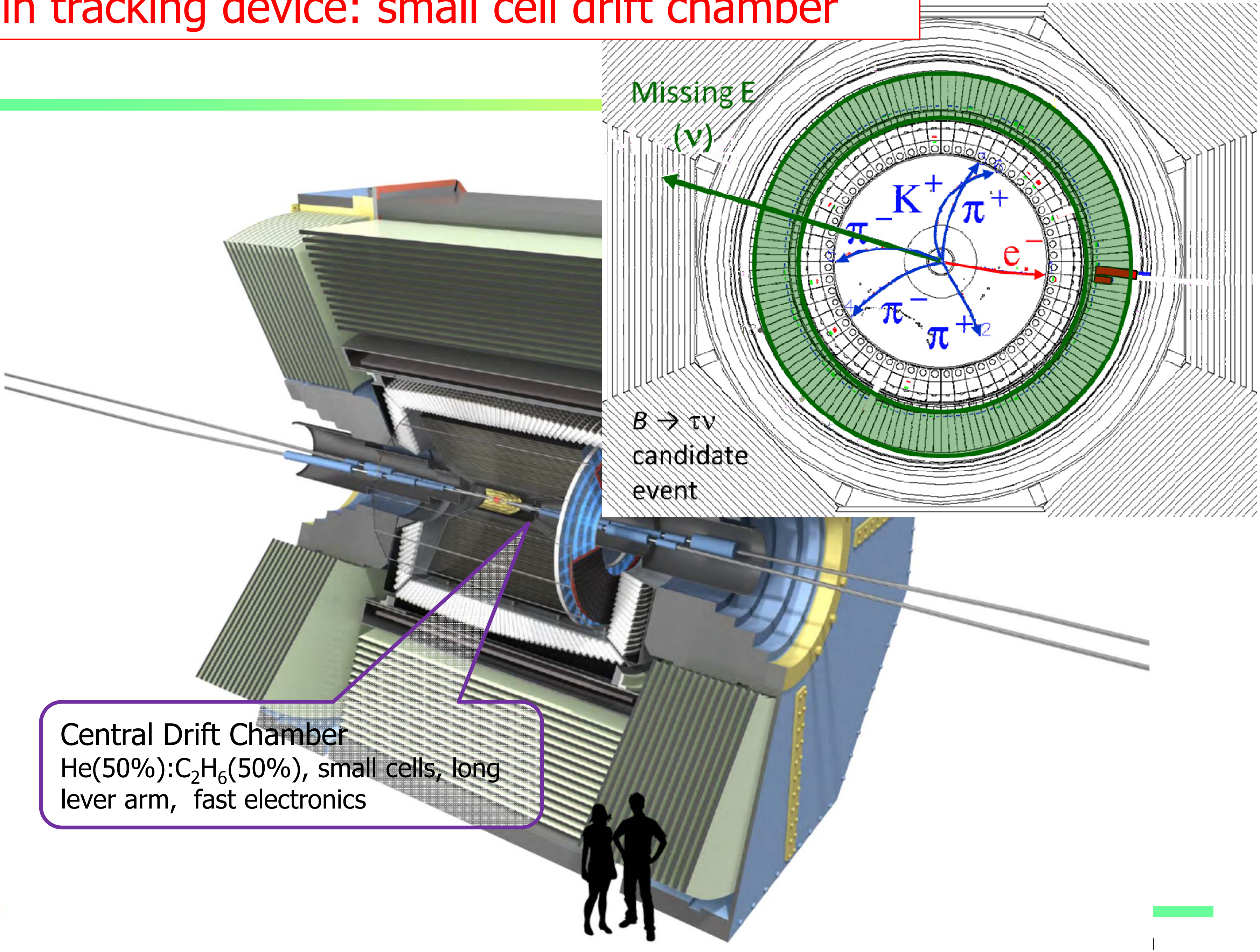
DEPFET sensor: very good S/N

SVD Mechanical Mockup

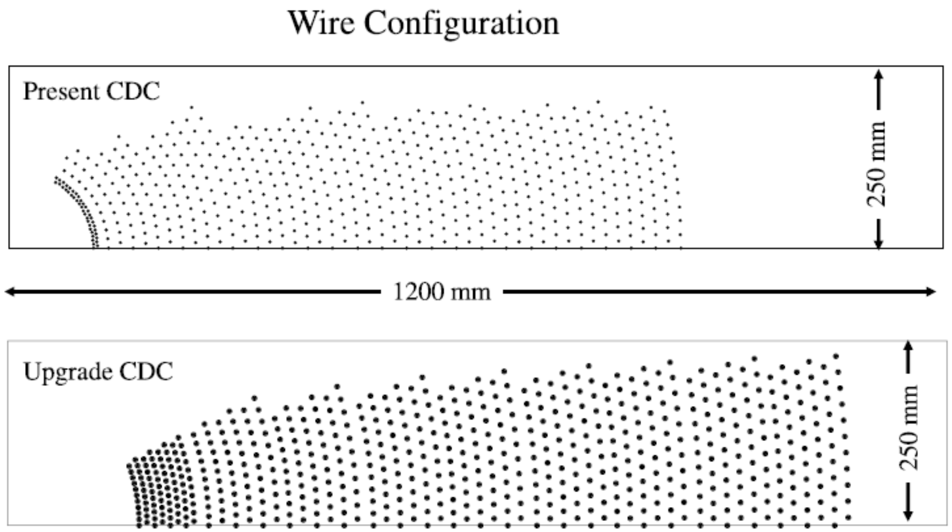




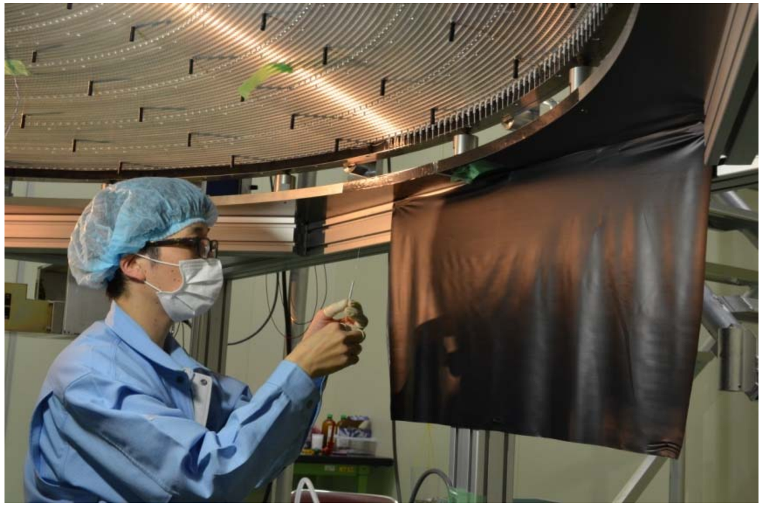
Main tracking device: small cell drift chamber



Belle II CDC



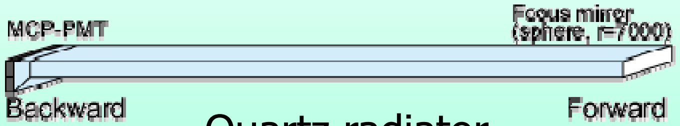
Much bigger than in Belle!



Wire stringing in a clean room
- thousands of wires,
- 1 year of work...

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



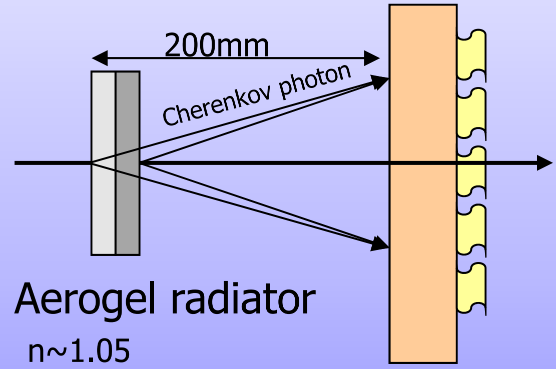
Quartz radiator

Focusing mirror

Small expansion block

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

Endcap PID: Aerogel RICH (ARICH)

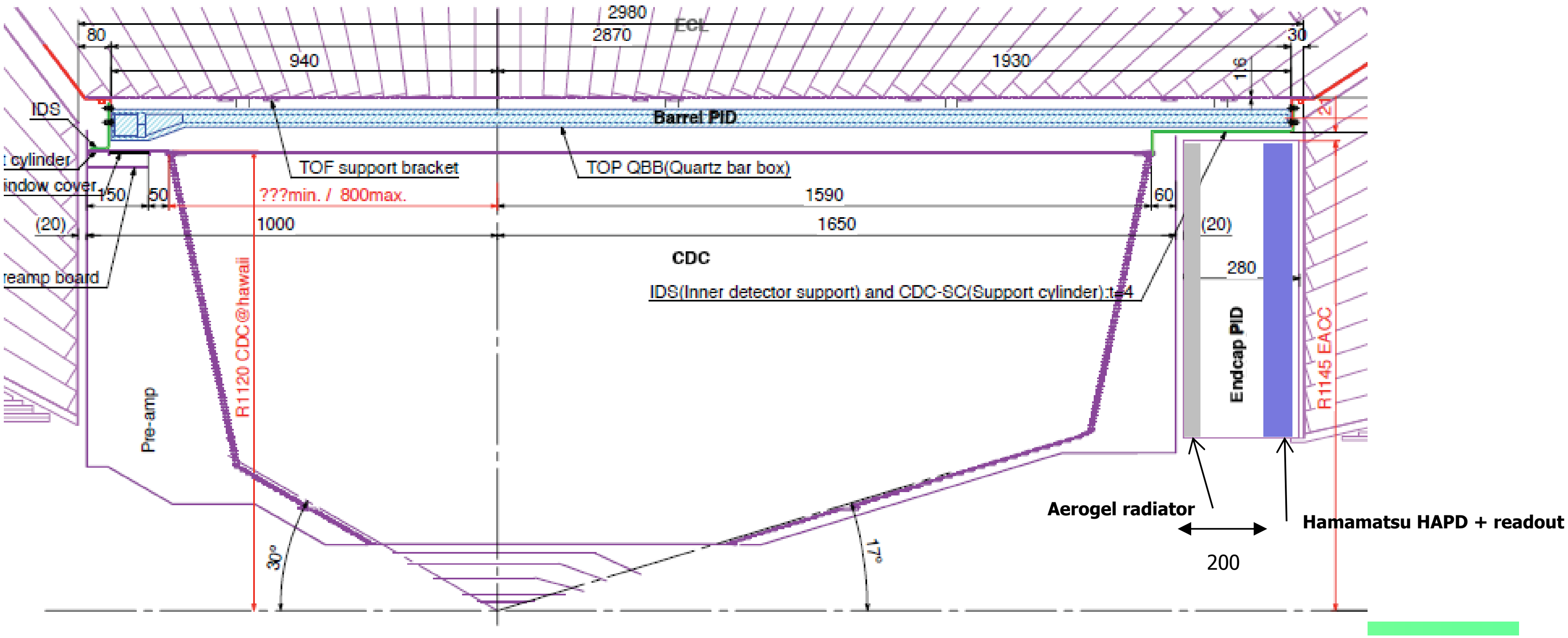


Aerogel radiator

n~1.05

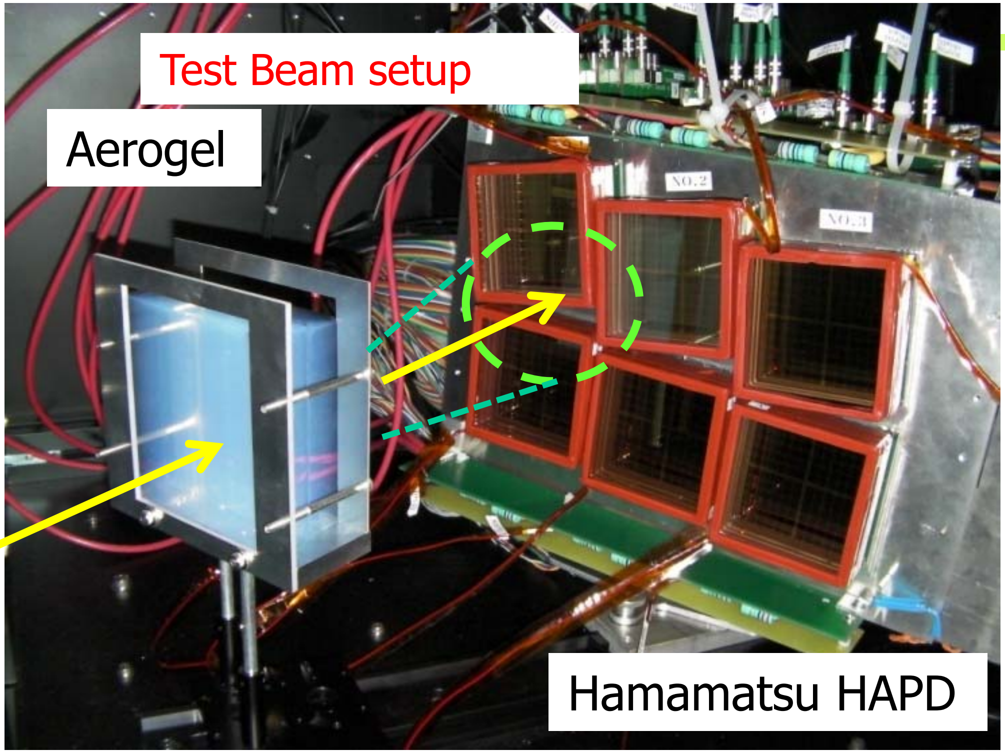
Hamamatsu HAPD

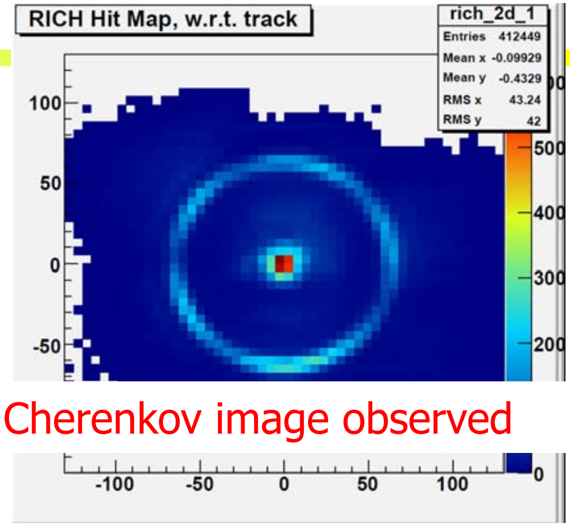
+ new ASIC



Peter Križan, Ljubljana

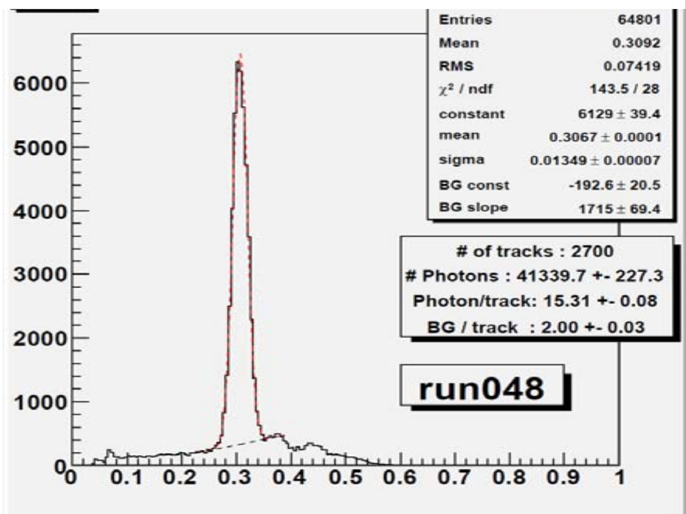
Aerogel RICH (endcap PID)





Clear Cherenkov image observed

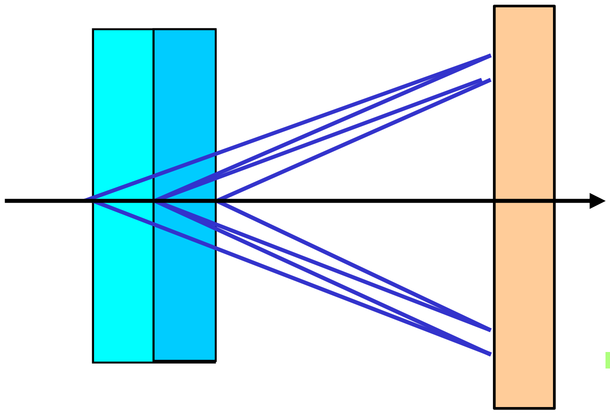
Cherenkov angle distribution



6.6 σ π/K at 4GeV/c !

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

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

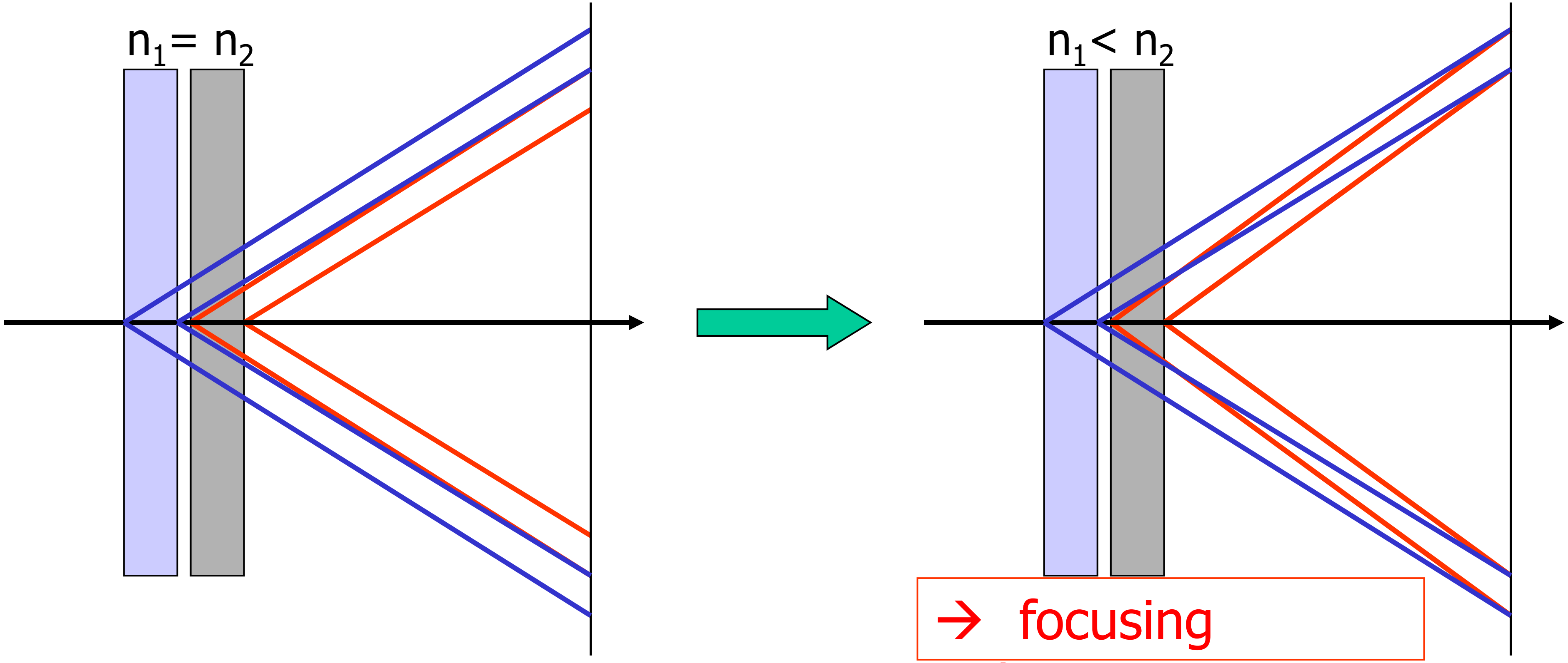


Radiator with multiple refractive indices

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

normal

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



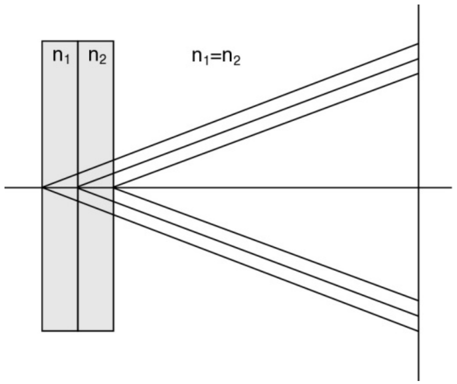
→ focusing

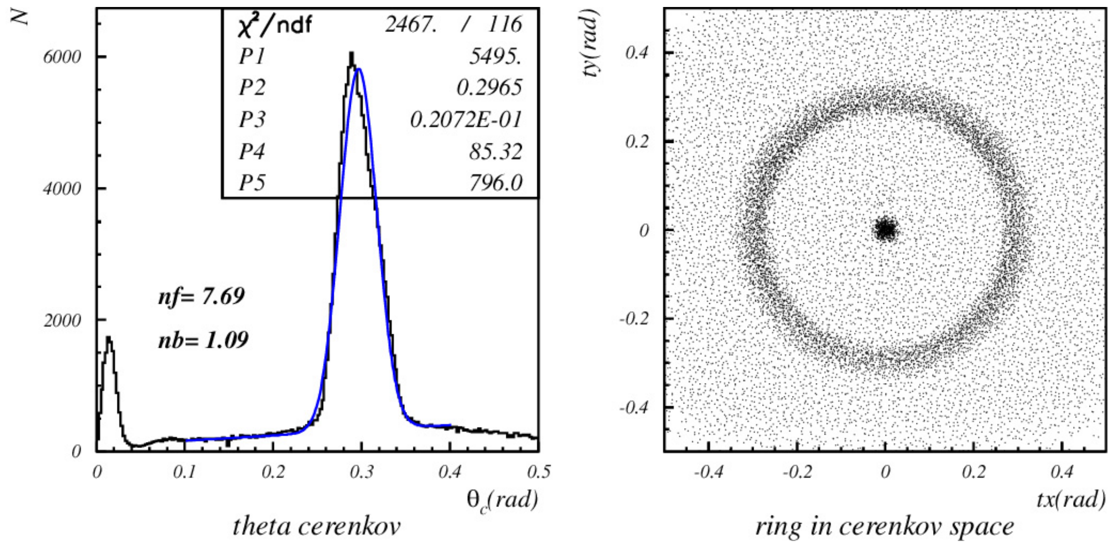
Such a configuration is only possible with aerogel (a form of Si_xO_y) – material with a tunable refractive index between 1.01 and 1.13.

RICH with a focusing radiator

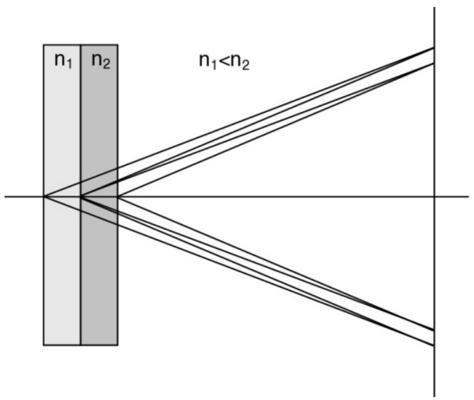
Increases the number of photons without degrading the resolution

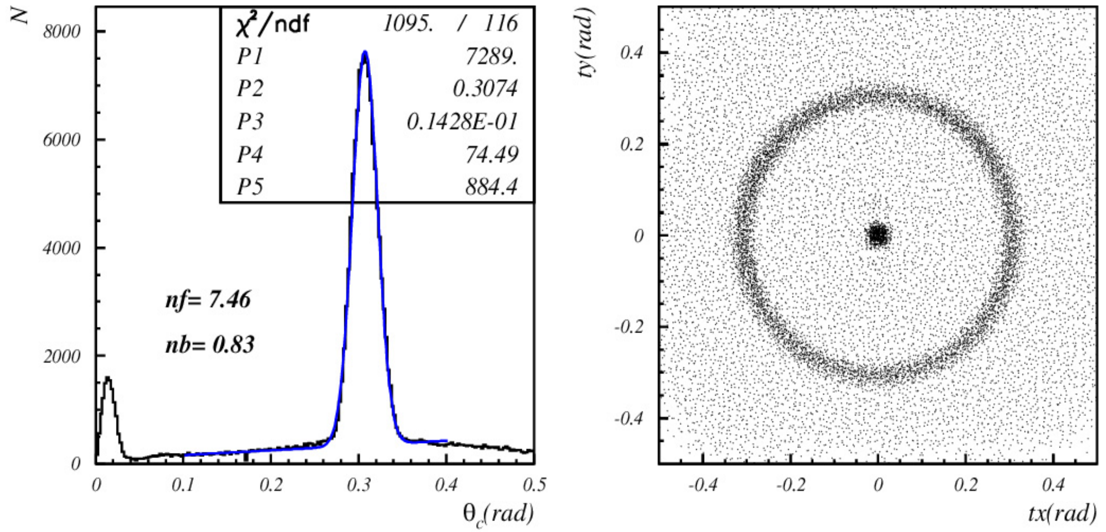
4cm aerogel single index





2+2cm aerogel

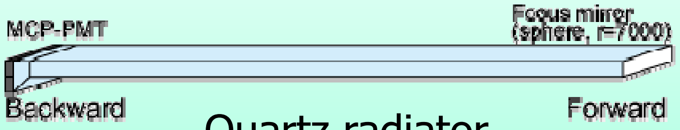




→NIM A548 (2005) 383

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



Quartz radiator

Focusing mirror

Small expansion block

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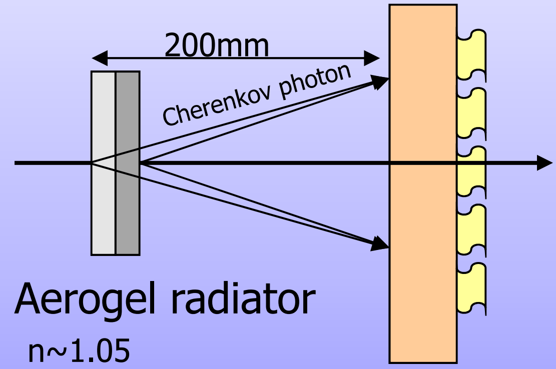
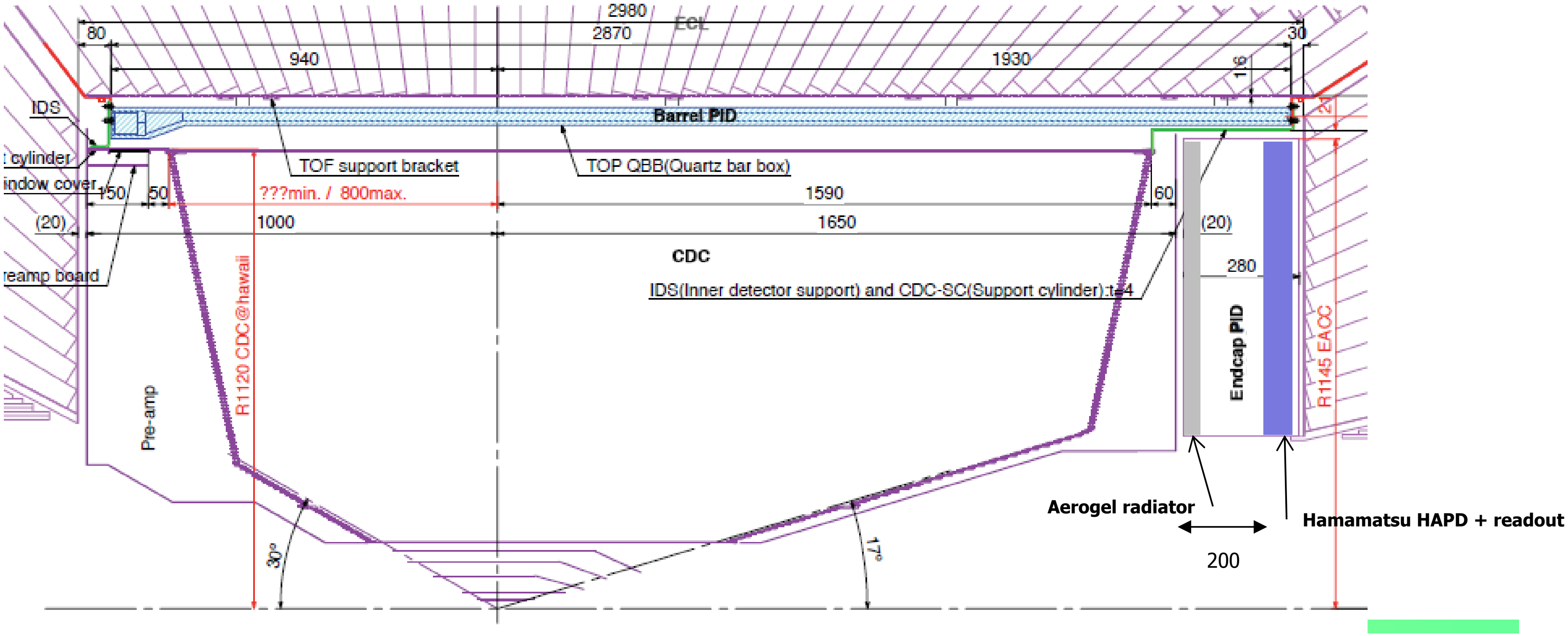
Endcap PID: Aerogel RICH (ARICH)



Aerogel radiator

n~1.05

Hamamatsu HAPD
+ new ASIC



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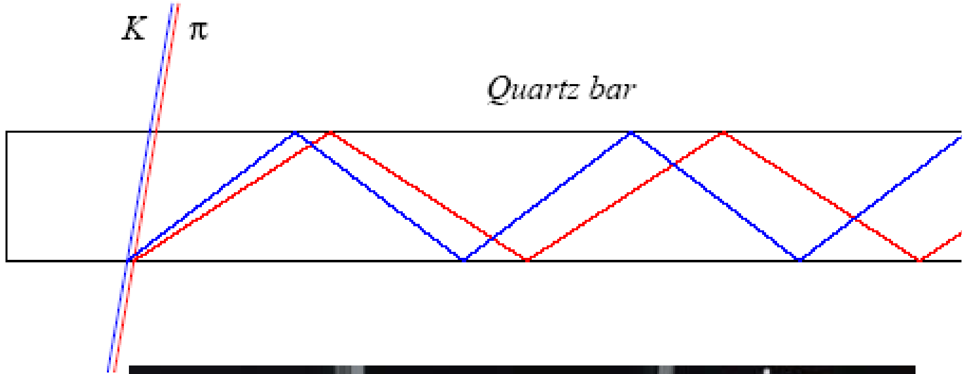
Barrel PID: Time of propagation (TOP) counter

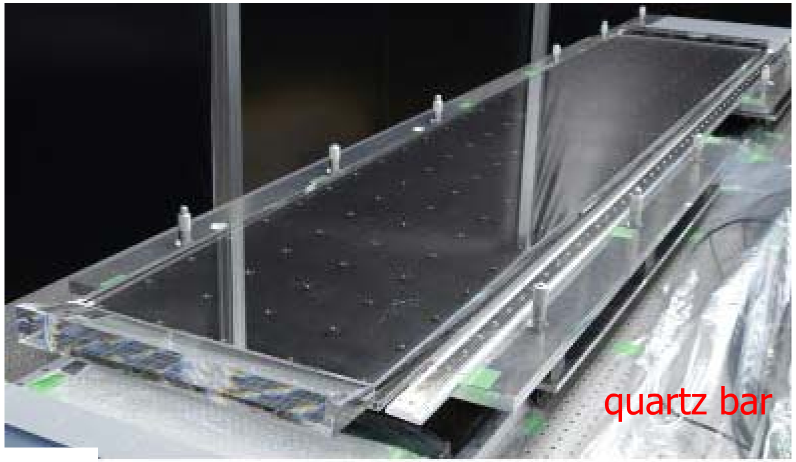
Cherenkov ring imaging with precise time measurement.

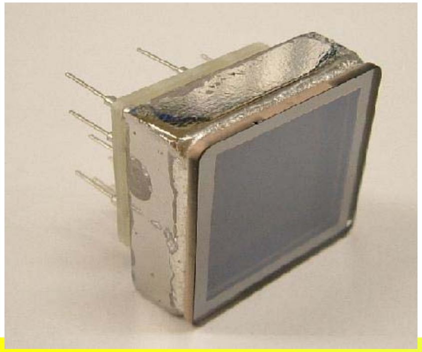
Device uses internal reflection of Cerenkov ring images from quartz like the BaBar DIRC

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

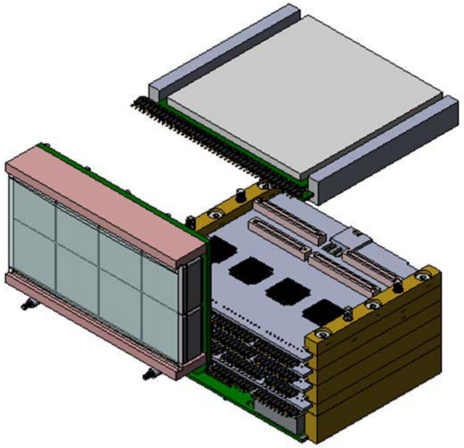
- Quartz radiator (2cm)
- Photon detector (MCP-PMT)
  - Excellent time resolution ~40 ps
  - Single photon sensitivity in 1.5 T
- Fast read-out electronics



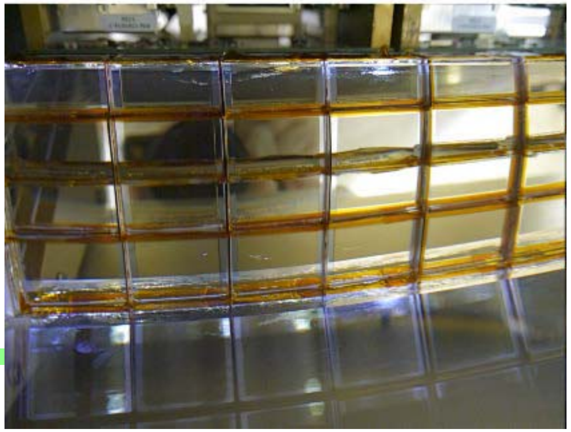




Hamamatsu SL10 MCP PMT

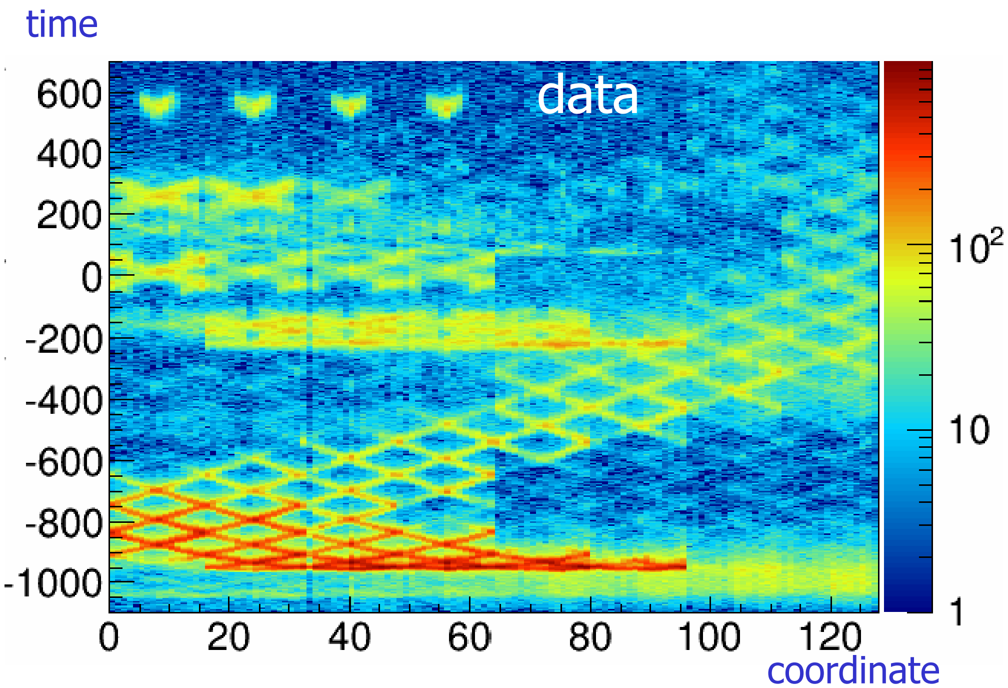


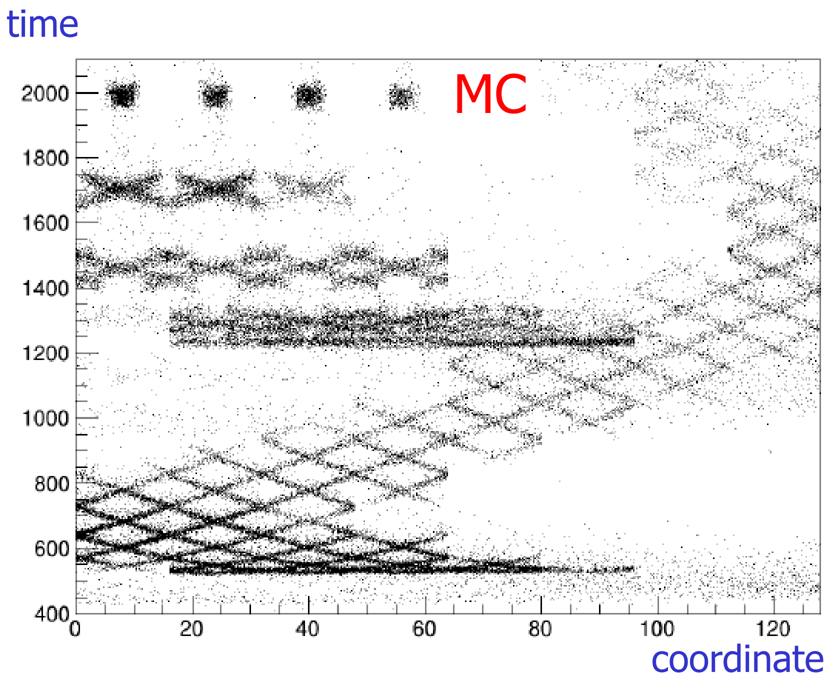
8 PMTs with read-out electronics



TOP image

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



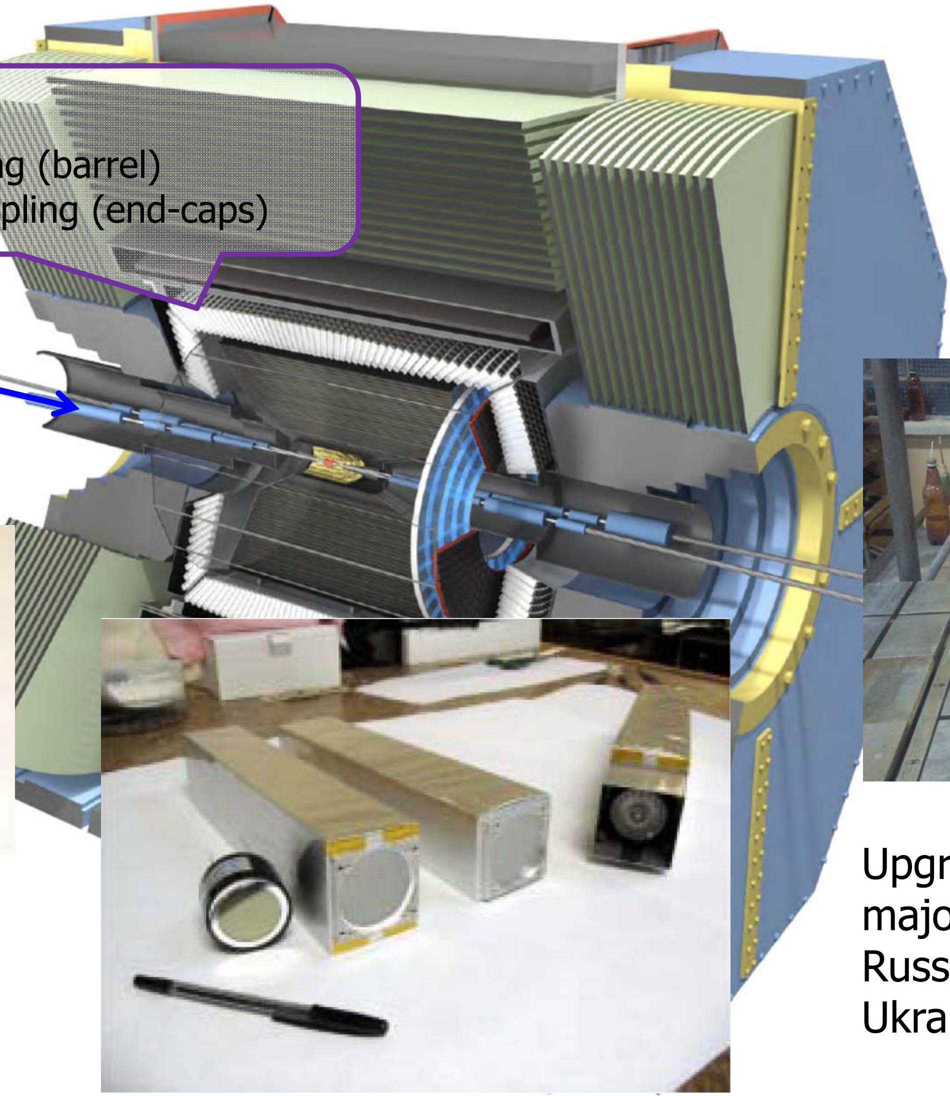


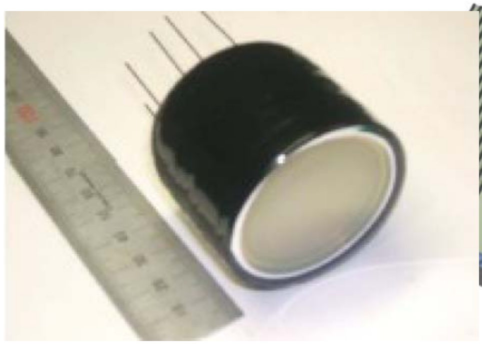
Excellent agreement between beam test data and MC simulated patterns.

Marko Starič: likelihood functions can be derived analytically!

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)

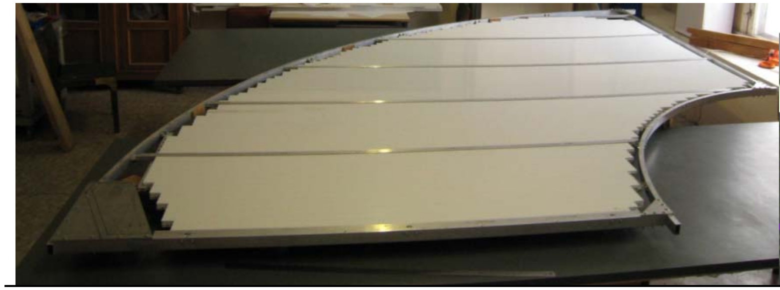


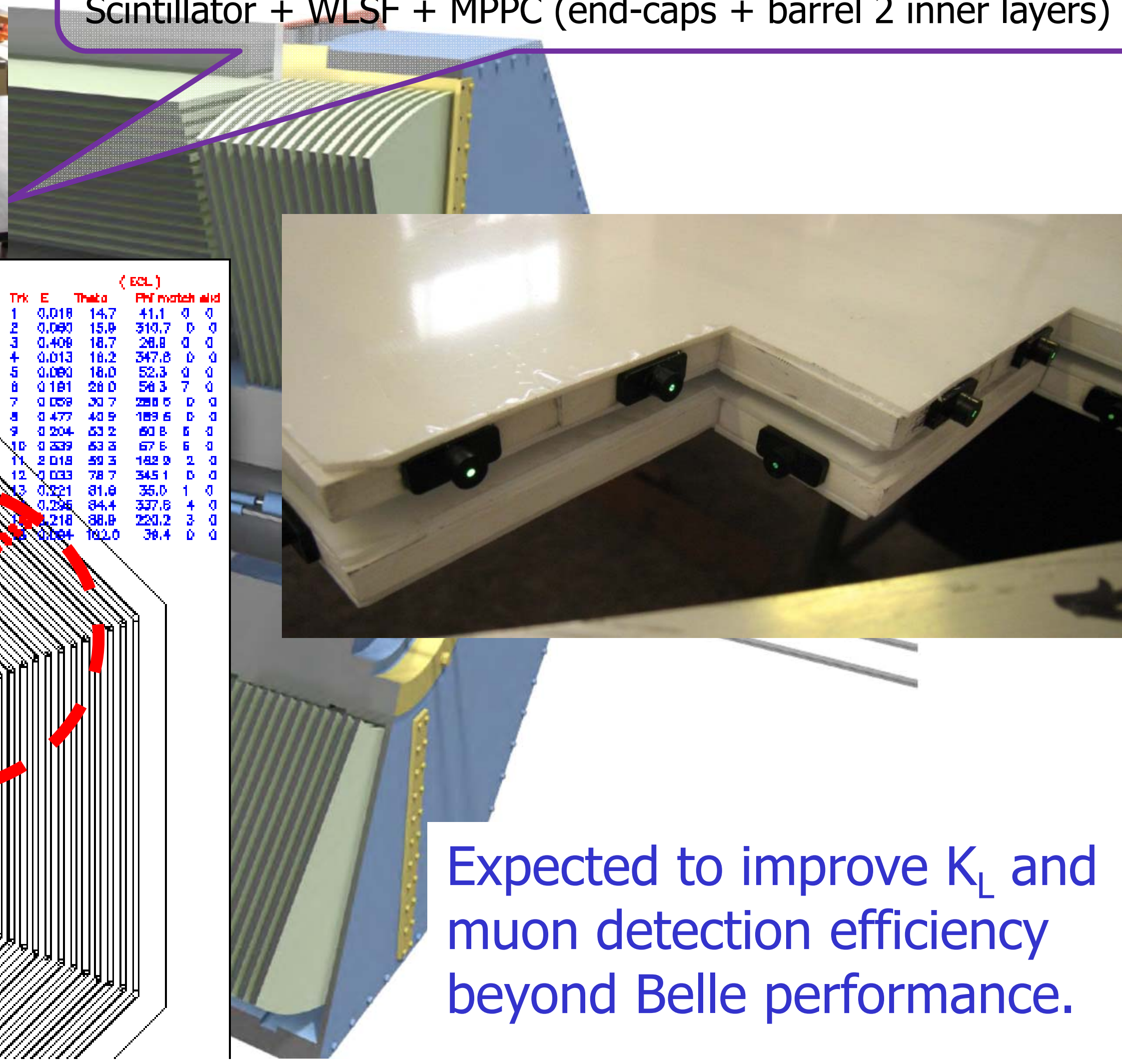


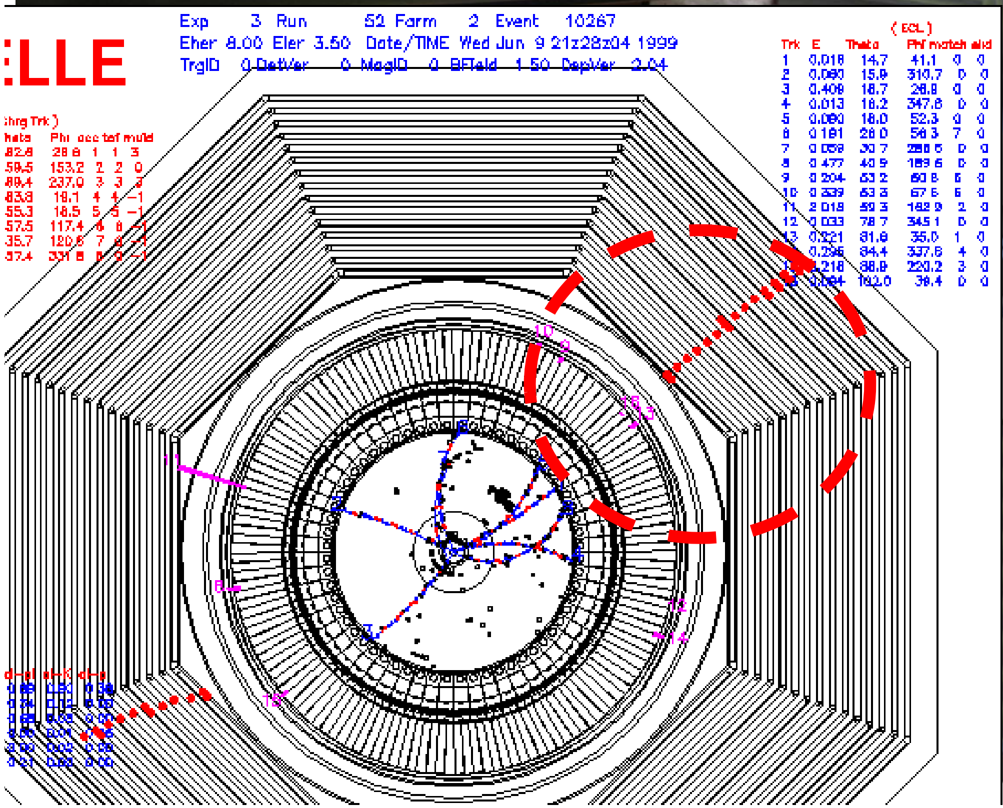
Upgrade to pure CsI: a major collaborative effort of Russia, Japan, Canada, Italy, Ukraine

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)

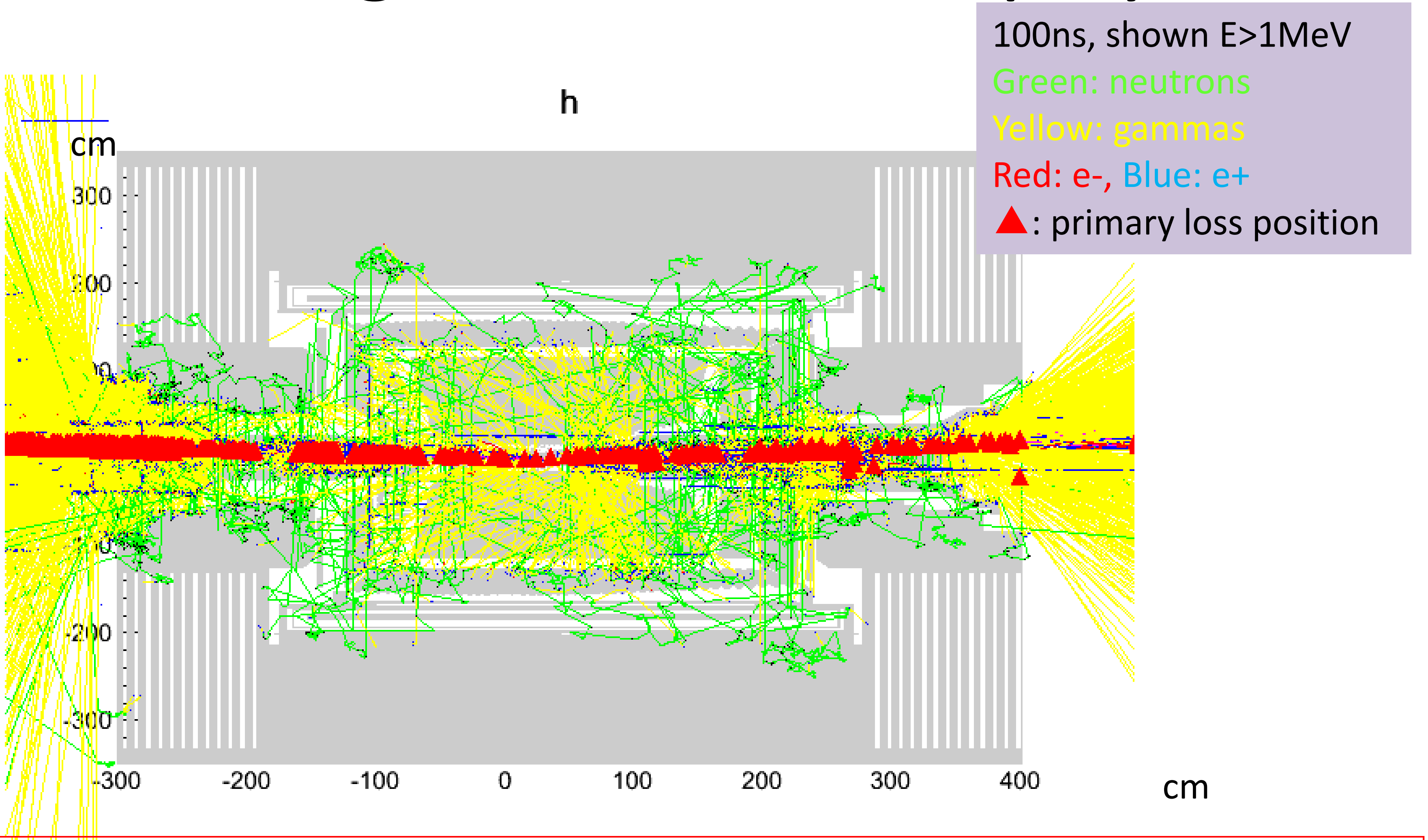






Expected to improve K_L and muon detection efficiency beyond Belle performance.

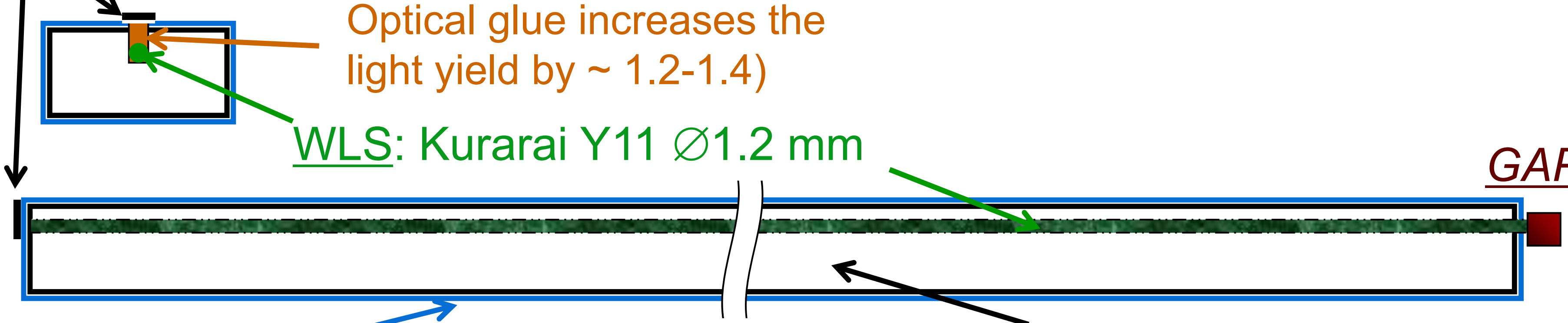
Background event display



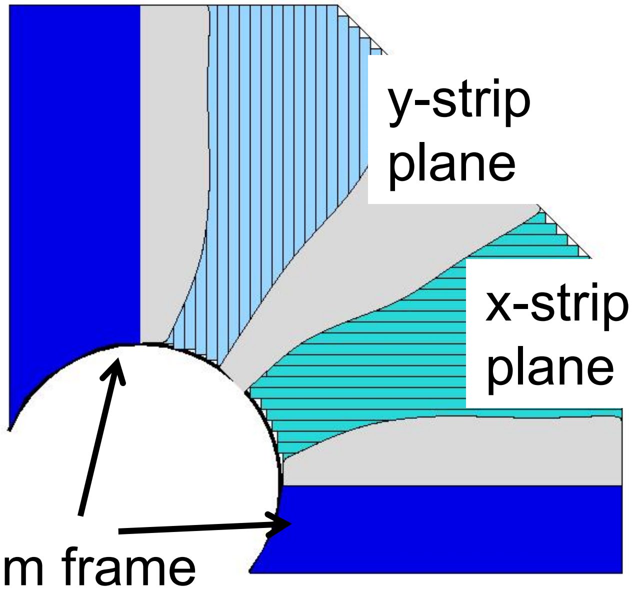
Neutrons: background hits in the muon and KL detection system (KLM) → reduce the efficiency of muon and KL detection → replace RPCs in the endcaps and 2 barrel layers.

Muon detection system upgrade

Scintillator-based KLM (endcap and 2 barrel layers)



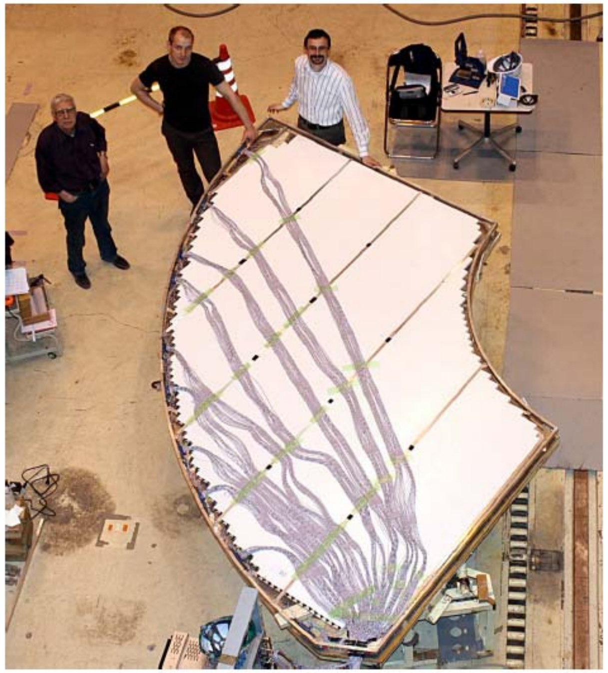
- Two independent (x and y) layers in one superlayer made of orthogonal strips with WLS read out
- Photo-detector = SiPM (avalanche photodiode in Geiger mode)
- ~120 strips in one 90º sector (max L=280cm, w=25mm)
- ~30000 read out channels
- Geometrical acceptance > 99%

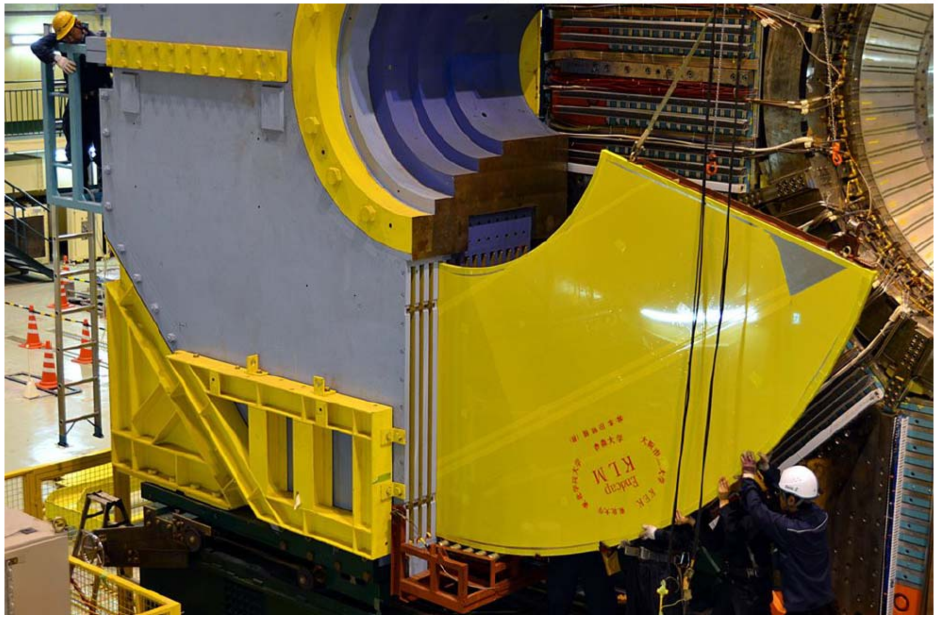


Muon detection system upgrade

Scintillator-based KLM:

- installation of final modules in the Belle II detector – the first Belle II component to be ready!





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.

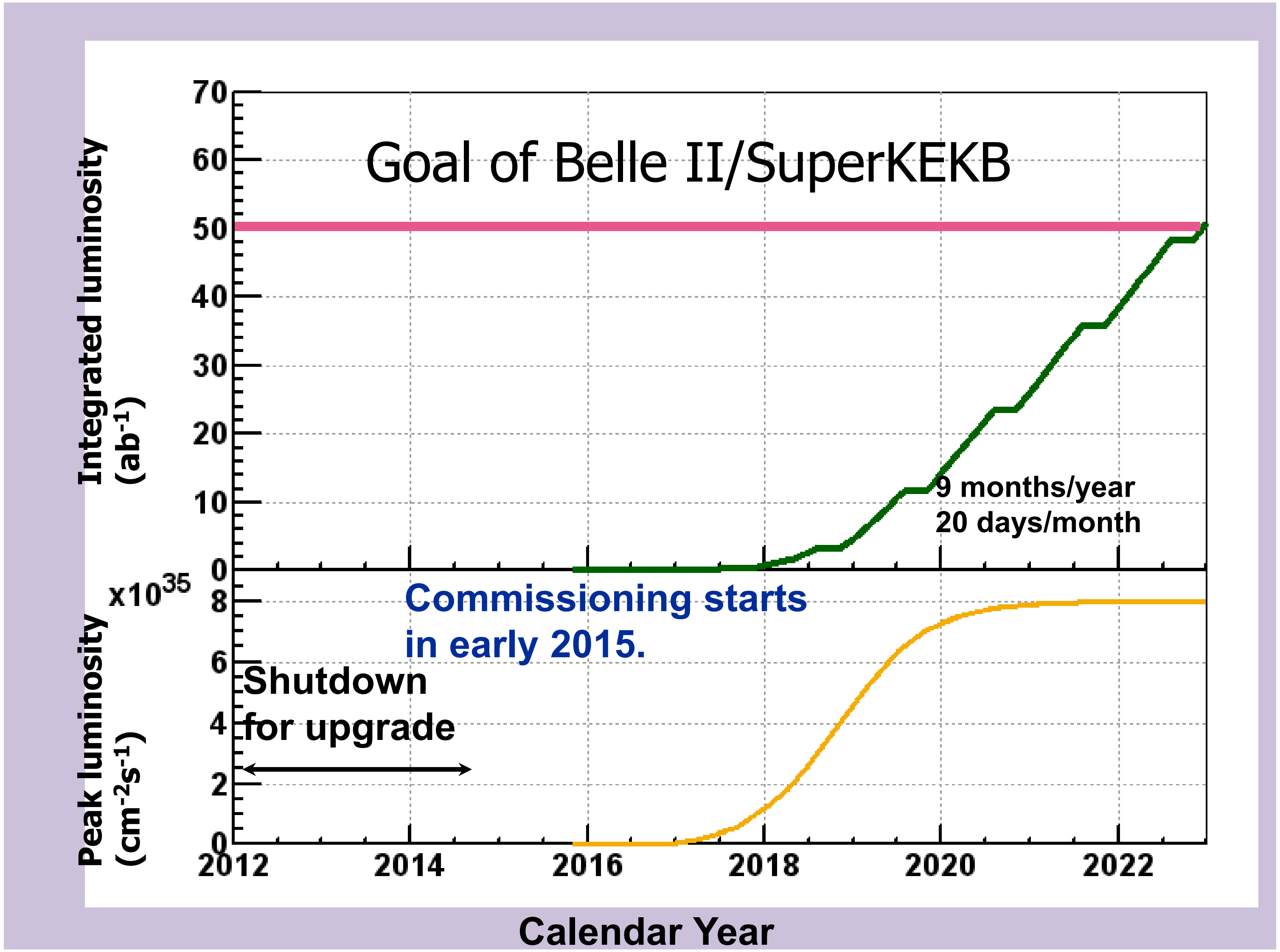
→construction started in 2010!

Ground breaking ceremony in November 2011

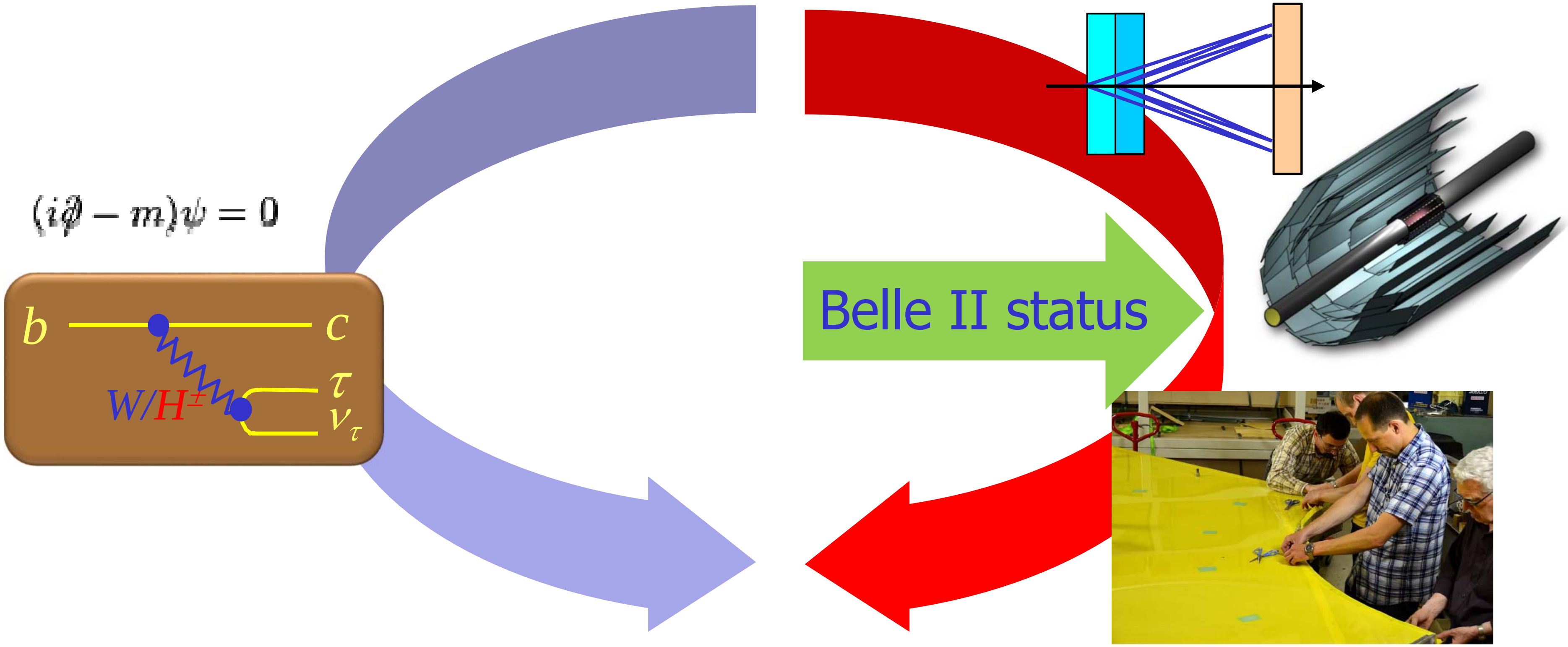
SuperKEKB and Belle II construction proceeds according to the schedule.

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

SuperKEKB luminosity projection



Experiment vs Theory, continued



We are very much looking forward to the time when we will be able again to exchange notes, results, plans etc with Svjetlana et al

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
- Major upgrade at KEK in 2010-15 → SuperKEKB+Belle II, L x40, construction proceeds at full speed
- Expect a new, exciting era of discoveries, complementary to the LHC
- Expect a lively exchange of ideas with theorists, in particular with Svjetlana, Jure, Jernej, Saša, and the new forces from her group

Summary

- 20++ years ago Ljubljana was not the same place for particle physics (not only were we 20++ years younger…)
- There was a strong experimental flavour physics group at ARGUS, CPLEAR, DELPHI and HERA-B, while theory was QCD oriented – it makes a huge difference if you have to go to a conference to get feedback or ideas or email a theorist you do not know so well, rather than walking down the corridor and knock on the door…
- With Svjetlana‘s arrival things started to change, and the group that formed around her proved to be a wonderful source of ideas and feedback
- I am looking forward to a continuation of the intellectual exchange in the years to come!