SuperKEKB and SuperB: flavor physics

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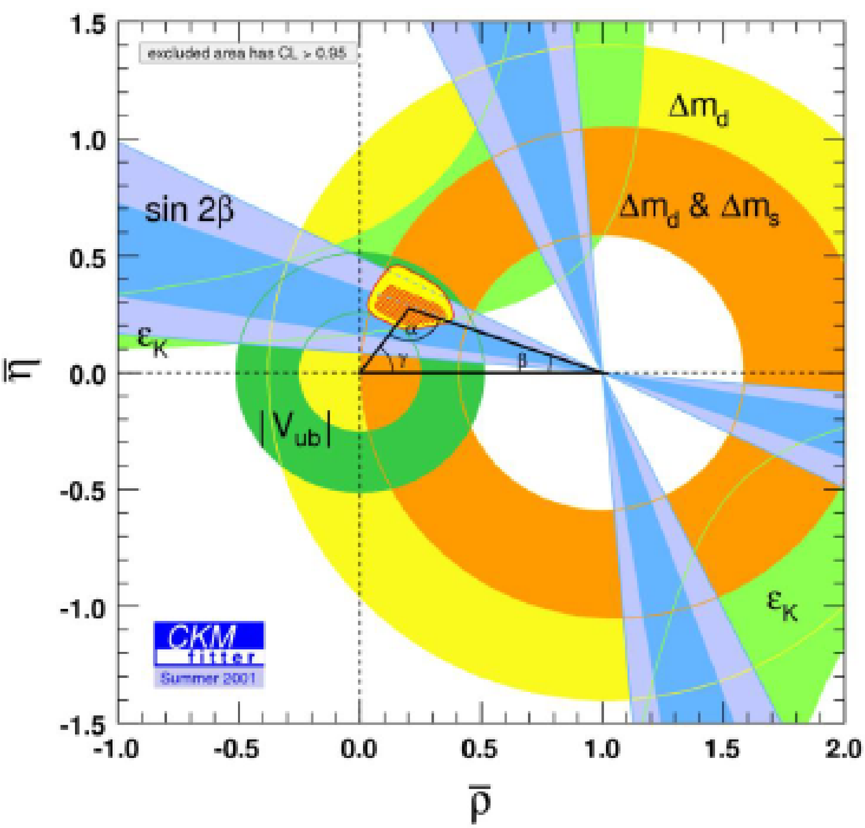
- Physics case for a Super B factory
- SuperKEKB/Belle-II@KEK and SuperB@Italy
- Accellerators
- Detectors
- Status and prospects of the projects

B factories: CP violation in the B system

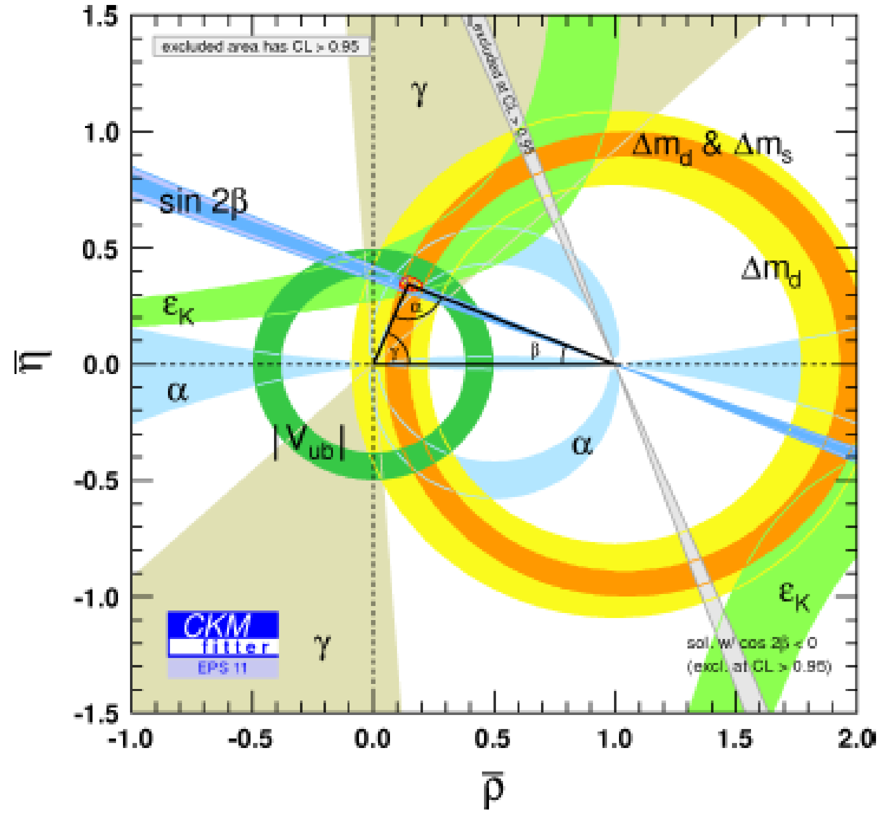
CP violation in the B system: from the discovery (2001) to a precision measurement (2011).

Unitarity triangle – 2011 vs 2001

EPS 2001



EPS 2011

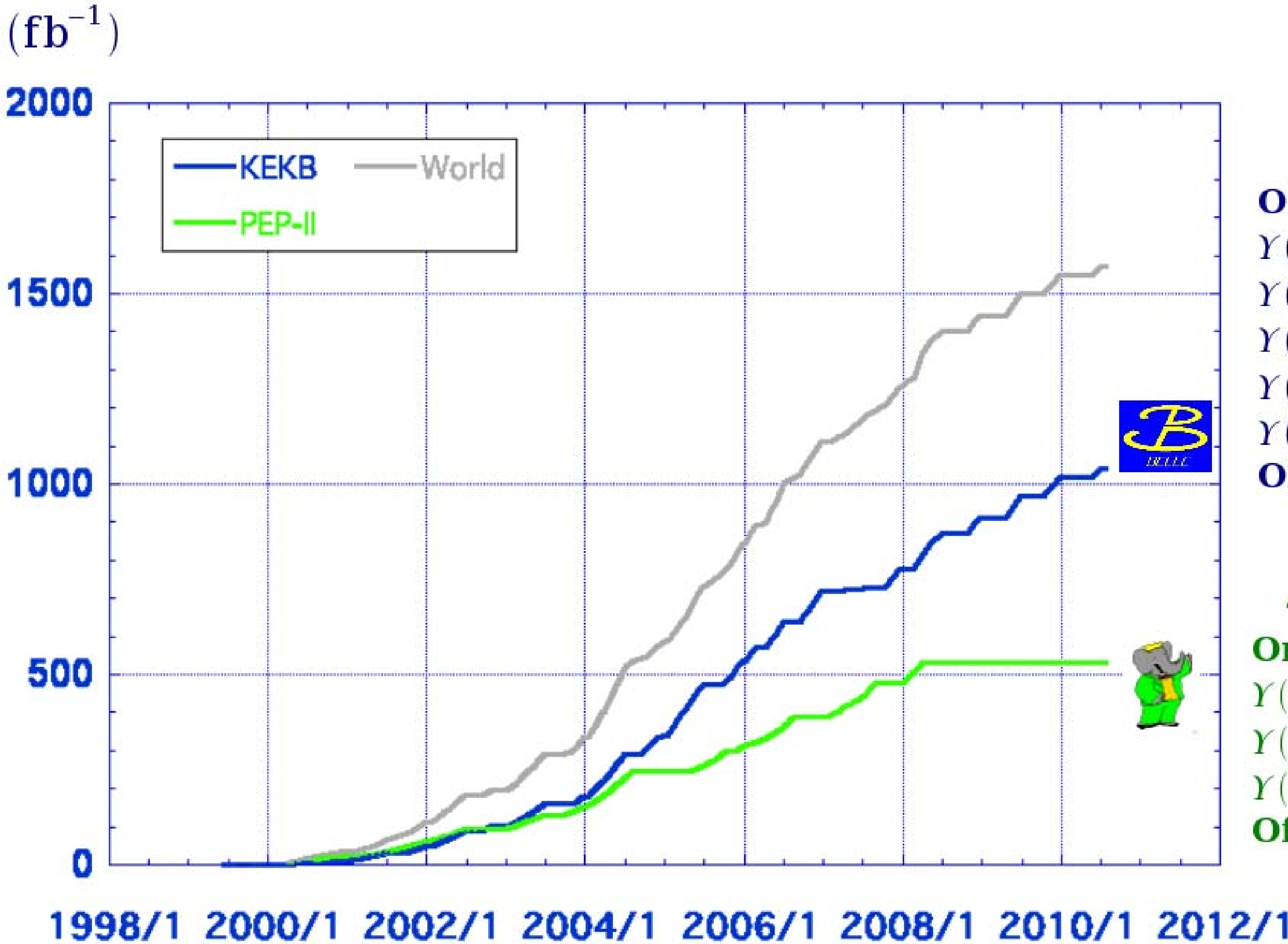


B factories: a success story

- 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.

Luminosity at B factories



> 1 ab^{-1}

On resonance:

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

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

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

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

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

Off reson./scan:

~ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

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

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

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

Off resonance:

~ 54 fb^{-1}

Fantastic performance much beyond design values!

What next?

Next generation: Super B factories → Looking for NP

→ Need much more data (two orders!)

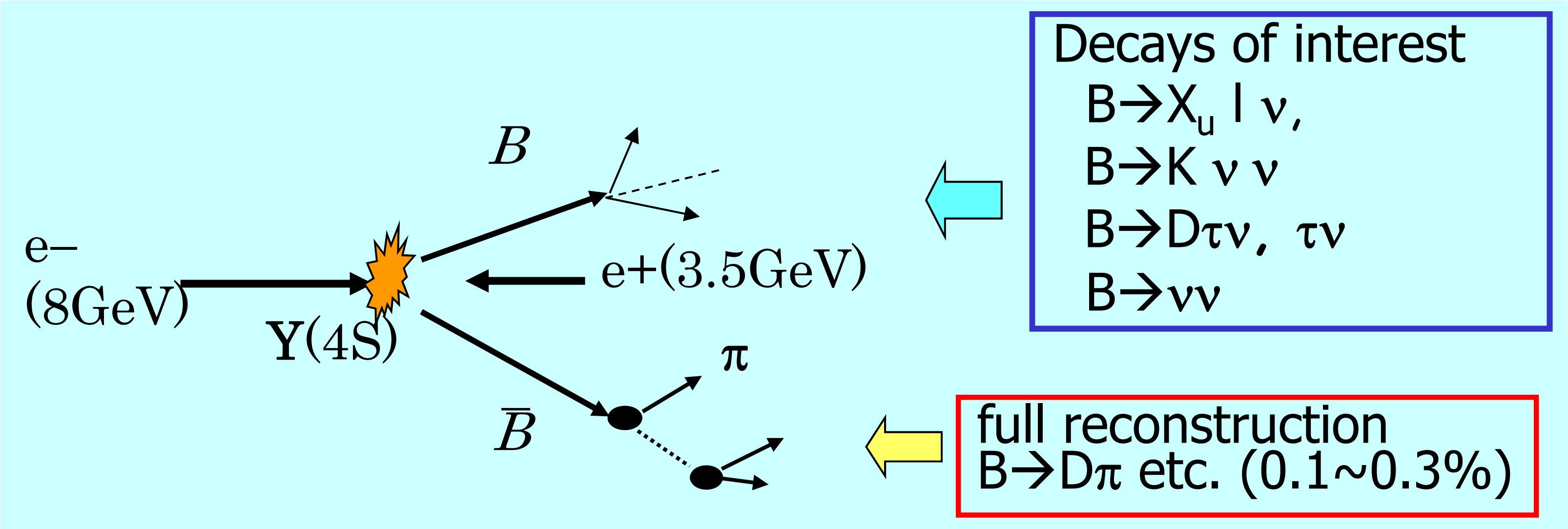
However: it will be a different world in four years, we will face a serious competition from LHCb and BESIII

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

Two projects: SuperKEKB+Belle-II in Japan, SuperB in Italy

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

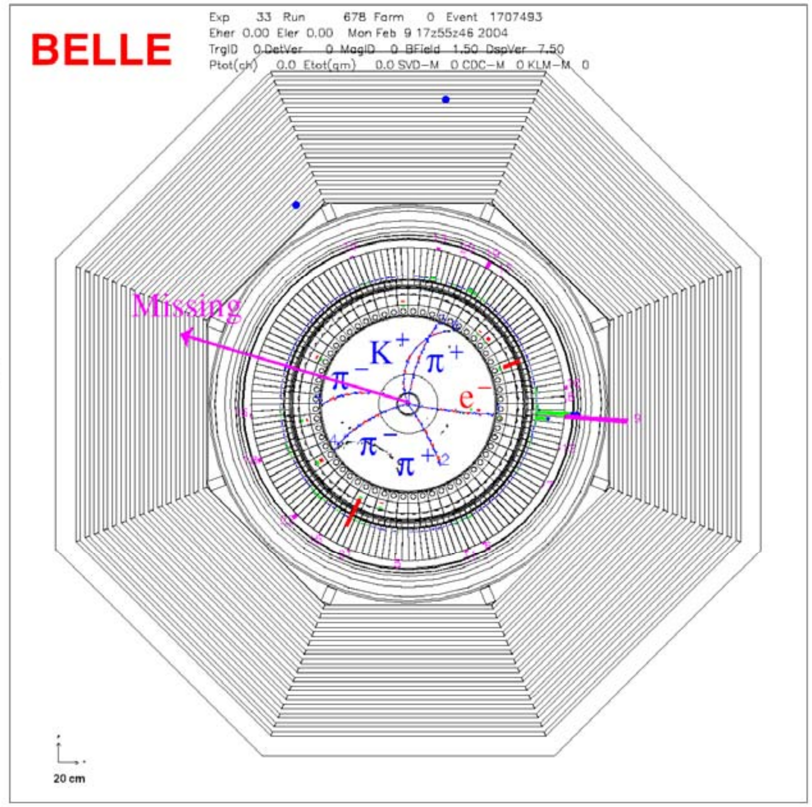


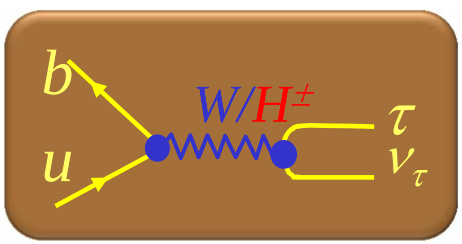
→ Offline B meson beam!

Powerful tool for B decays with neutrinos

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

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



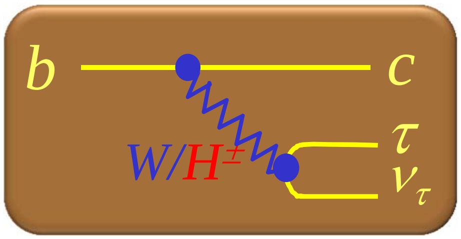


$$r_H = \frac{BF(B\to\tau\nu)}{BF(B\to\tau\nu)_{SM}} = \left(1 - \frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

→ limit on charged Higgs mass vs. tanβ

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

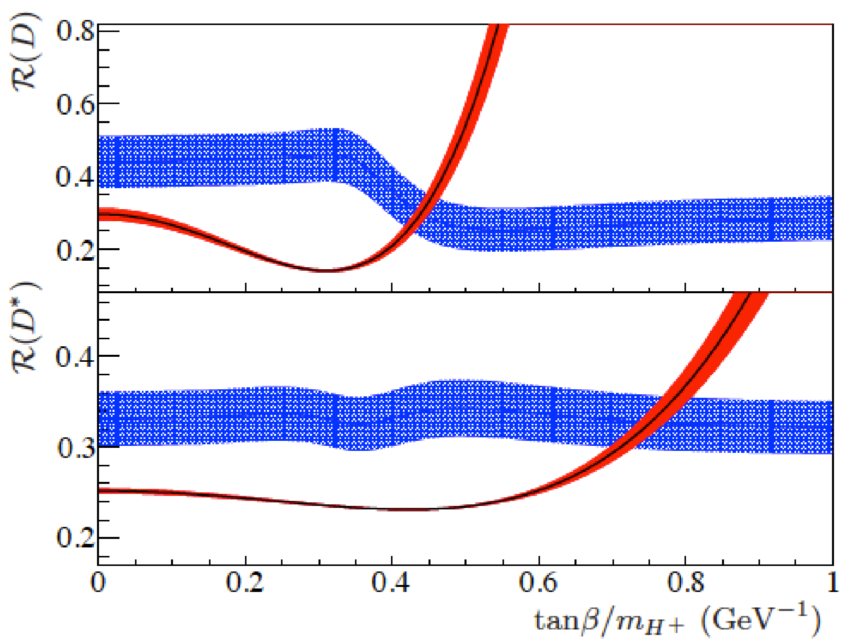
Semileptonic decay sensitive to charged Higgs



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

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

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)



N.B. BABAR sees a 3.4σ evidence for an excess of B → D(*)τν decays compared to SM expectations.

In addition: this result kills Type II 2HDM...

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

arXiv:1002.5012

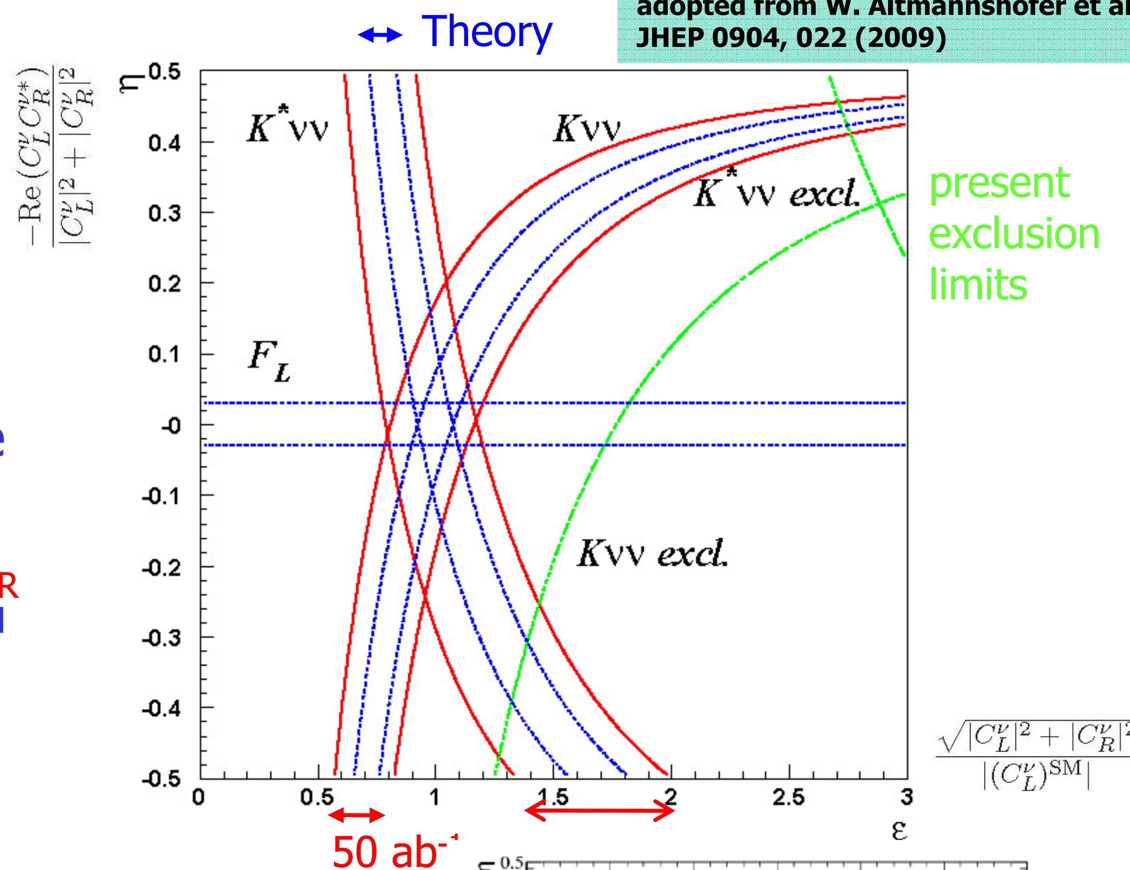
adopted from W. Altmannshofer et al., JHEP 0904, 022 (2009)

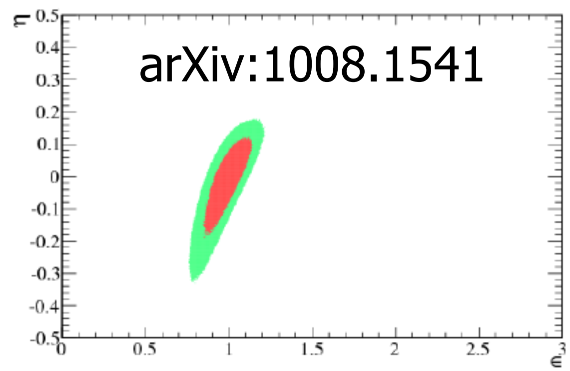
$B \to K\nu\nu$, $\mathcal{B} \sim 4 \cdot 10^{-6}$
$B \to K^*\nu\nu$, $\mathcal{B} \sim 6.8 \cdot 10^{-6}$

SM: penguin+box

Look for departure from the expected value → information on couplings C^{ν}_{R} and C^{ν}_{L} compared to $(C^{\nu}_{L})^{SM}$

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





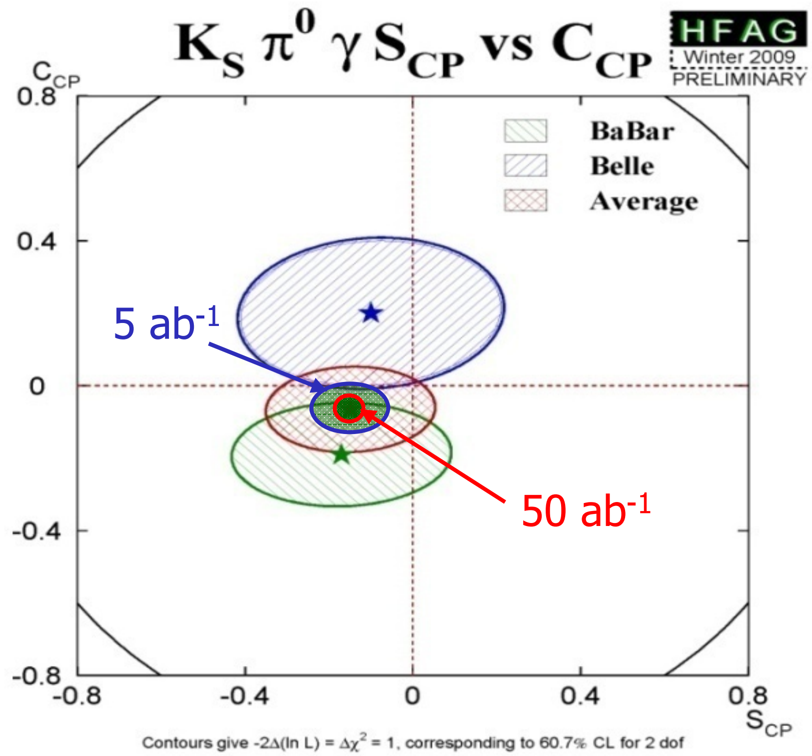
not possible @ LHCb

CP violation in B→$K_S\pi^0\gamma$

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

$B \rightarrow K^*\gamma$, $\mathcal{B} \sim 4.0 \cdot 10^{-5}$

$\delta S \sim 0.2$ (present)
→ ~a few % at 50 ab^{-1}

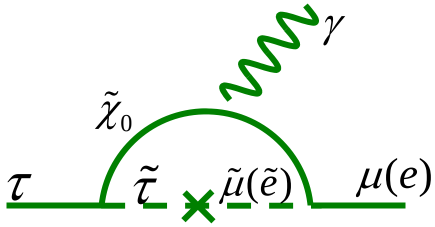


adopted from HFAG

not possible @ LHCb

τ physics: LFV and New Physics

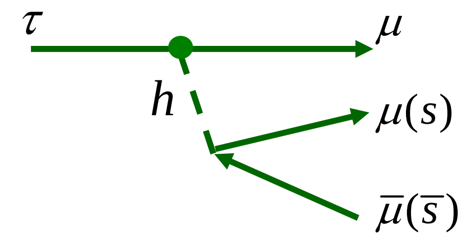
$\tau \to l\gamma$



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

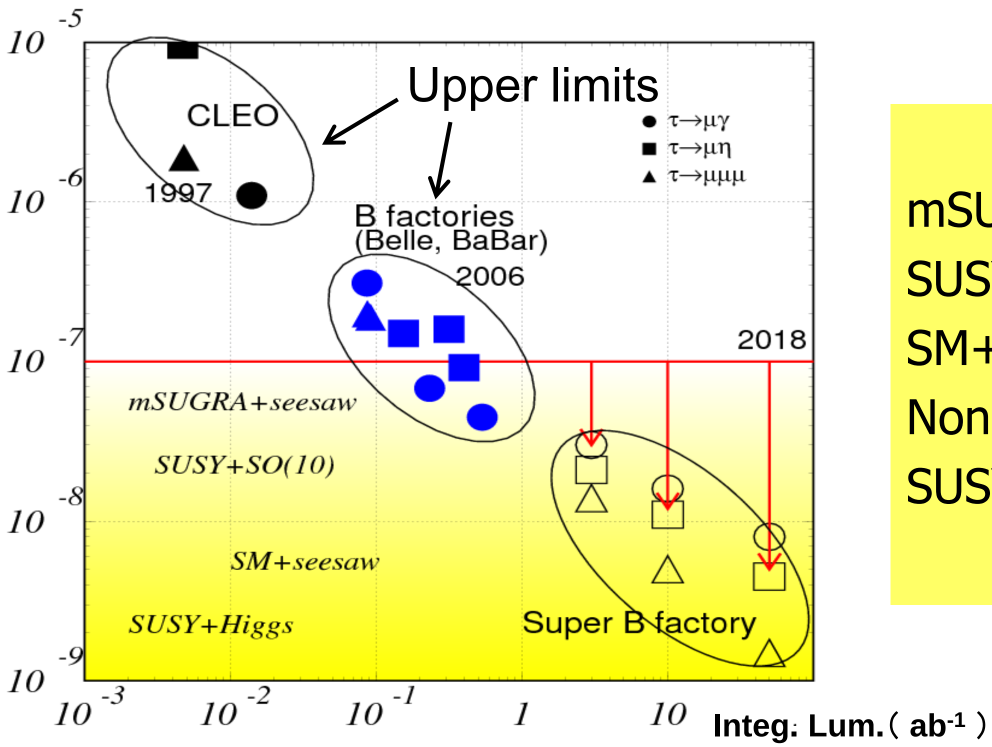
$$Br(\tau \to \mu\gamma) \simeq 10^{-6} \times \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}}\right)\left(\frac{1\,TeV}{m_{SUSY}}\right)^4 \tan^2\beta$$

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



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

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



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}

B Physics @ Y(4S)

Observable	B Factories (2 ab^{-1})	SuperB (75 ab^{-1})
$\sin(2\beta)$ $(J/\psi K^0)$	0.018	0.005 (†)
$\cos(2\beta)$ $(J/\psi K^{*0})$	0.30	0.05
$\sin(2\beta)$ (Dh^0)	0.10	0.02
$\cos(2\beta)$ (Dh^0)	0.20	0.04
$S(J/\psi\,\pi^0)$	0.10	0.02
$S(D^+D^-)$	0.20	0.03
$S(\phi K^0)$	0.13	0.02 (∗)
$S(\eta' K^0)$	0.05	0.01 (∗)
$S(K_S^0K_S^0K_S^0)$	0.15	0.02 (∗)
$S(K_S^0\pi^0)$	0.15	0.02 (∗)
$S(\omega K_S^0)$	0.17	0.03 (∗)
$S(f_0K_S^0)$	0.12	0.02 (∗)
γ $(B\to DK,\ D\to CP$ eigenstates)	$\sim 15^\circ$	2.5°
γ $(B\to DK,\ D\to$ suppressed states)	$\sim 12^\circ$	2.0°
γ $(B\to DK,\ D\to$ multibody states)	$\sim 9^\circ$	1.5°
γ $(B\to DK$, combined)	$\sim 6^\circ$	1–2°
α $(B\to\pi\pi)$	$\sim 16^\circ$	3°
α $(B\to\rho\rho)$	$\sim 7^\circ$	1–2° (∗)
α $(B\to\rho\pi)$	$\sim 12^\circ$	2°
α (combined)	$\sim 6^\circ$	1–2° (∗)
$2\beta+\gamma$ $(D^{(*)\pm}\pi^\mp,\ D^\pm K_S^0\pi^\mp)$	20°	5°

Observable	B Factories (2 ab^{-1})	SuperB (75 ab^{-1})
$\lvert V_{cb}\rvert$ (exclusive)	4% (∗)	1.0% (∗)
$\lvert V_{cb}\rvert$ (inclusive)	1% (∗)	0.5% (∗)
$\lvert V_{ub}\rvert$ (exclusive)	8% (∗)	3.0% (∗)
$\lvert V_{ub}\rvert$ (inclusive)	8% (∗)	2.0% (∗)
$\mathcal{B}(B\to\tau\nu)$	20%	4% (†)
$\mathcal{B}(B\to\mu\nu)$	visible	5%
$\mathcal{B}(B\to D\tau\nu)$	10%	2%
$\mathcal{B}(B\to\rho\gamma)$	15%	3% (†)
$\mathcal{B}(B\to\omega\gamma)$	30%	5%
$A_{CP}(B\to K^*\gamma)$	0.007 (†)	0.004 († ∗)
$A_{CP}(B\to\rho\gamma)$	~ 0.20	0.05
$A_{CP}(b\to s\gamma)$	0.012 (†)	0.004 (†)
$A_{CP}(b\to(s+d)\gamma)$	0.03	0.006 (†)
$S(K_S^0\pi^0\gamma)$	0.15	0.02 (∗)
$S(\rho^0\gamma)$	possible	0.10
$A_{CP}(B\to K^*\ell\ell)$	7%	1%
$A^{FB}(B\to K^*\ell\ell)s_0$	25%	9%
$A^{FB}(B\to X_s\ell\ell)s_0$	35%	5%
$\mathcal{B}(B\to K\nu\bar\nu)$	visible	20%
$\mathcal{B}(B\to\pi\nu\bar\nu)$	–	possible

M. Giorgi, ICHEP2010

Charm mixing and CP

Mode	Observable	$\Upsilon(4S)$ (75 ab^{-1})	$\psi(3770)$ (300 fb^{-1})
$D^0\to K^+\pi^-$	x'^2	3×10^{-5}	
	y'	7×10^{-4}	
$D^0\to K^+K^-$	y_{CP}	5×10^{-4}	
$D^0\to K_S^0\pi^+\pi^-$	x	4.9×10^{-4}	
	y	3.5×10^{-4}	
	$\lvert q/p\rvert$	3×10^{-2}	
	ϕ	2°	
$\psi(3770)\to D^0\overline{D}^0$	x^2		$(1-2)\times10^{-5}$
	y		$(1-2)\times10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

Charm FCNC

	Sensitivity
$D^0\to e^+e^-$, $D^0\to\mu^+\mu^-$	1×10^{-8}
$D^0\to\pi^0e^+e^-$, $D^0\to\pi^0\mu^+\mu^-$	2×10^{-8}
$D^0\to\eta e^+e^-$, $D^0\to\eta\mu^+\mu^-$	3×10^{-8}
$D^0\to K_S^0e^+e^-$, $D^0\to K_S^0\mu^+\mu^-$	3×10^{-8}
$D^+\to\pi^+e^+e^-$, $D^+\to\pi^+\mu^+\mu^-$	1×10^{-8}
$D^0\to e^\pm\mu^\mp$	1×10^{-8}
$D^+\to\pi^+e^\pm\mu^\mp$	1×10^{-8}
$D^0\to\pi^0e^\pm\mu^\mp$	2×10^{-8}
$D^0\to\eta e^\pm\mu^\mp$	3×10^{-8}
$D^0\to K_S^0e^\pm\mu^\mp$	3×10^{-8}
$D^+\to\pi^-e^+e^+$, $D^+\to K^-e^+e^+$	1×10^{-8}

τ Physics

	Sensitivity
$\mathcal{B}(\tau\to\mu\gamma)$	2×10^{-9}
$\mathcal{B}(\tau\to e\gamma)$	2×10^{-9}
$\mathcal{B}(\tau\to\mu\mu\mu)$	2×10^{-10}
$\mathcal{B}(\tau\to eee)$	2×10^{-10}
$\mathcal{B}(\tau\to\mu\eta)$	4×10^{-10}

B_s Physics @ Y(5S)

Observable	Error with 1 ab^{-1}	Error with 30 ab^{-1}
$\Delta\Gamma$	0.16 ps^{-1}	0.03 ps^{-1}
Γ	0.07 ps^{-1}	0.01 ps^{-1}
β_s from angular analysis	20°	8°
A_{SL}^s	0.006	0.004
A_{CH}	0.004	0.004
$\mathcal{B}(B_s\to\mu^+\mu^-)$	-	$<8\times10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	0.08	0.017
$\mathcal{B}(B_s\to\gamma\gamma)$	38%	7%

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

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

Physics at a Super B Factory

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

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

Complementary to LHCb

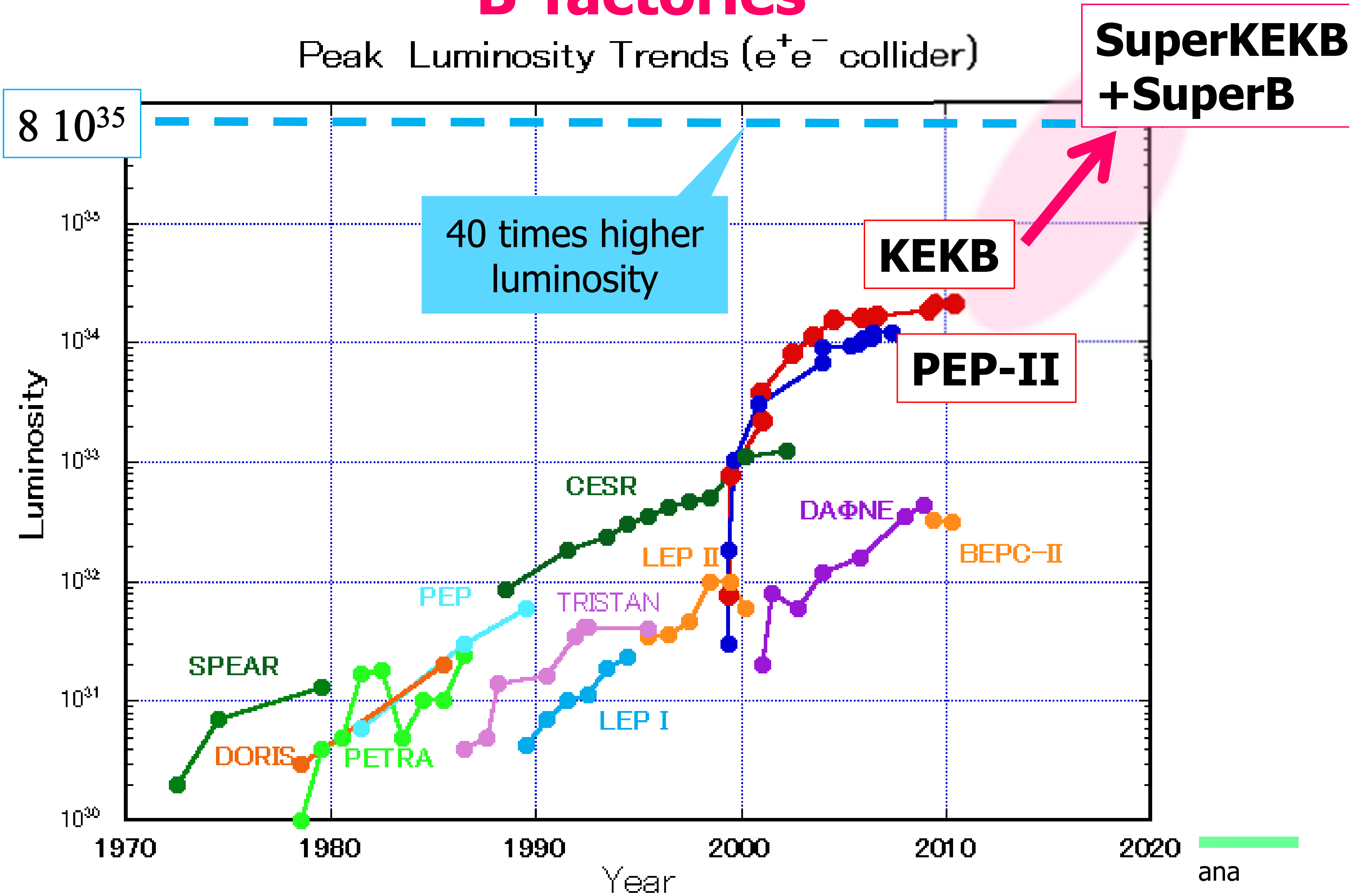
Observable	Expected th. accuracy	Expected exp. uncertainty	Facility
CKM matrix			
$\|V_{us}\|$ $[K \to \pi \ell \nu]$	**	0.1%	K-factory
$\|V_{cb}\|$ $[B \to X_c \ell \nu]$	**	1%	Belle II
$\|V_{ub}\|$ $[B_d \to \pi \ell \nu]$	*	4%	Belle II
$\sin(2\phi_1)$ $[c\bar{c}K_S^0$	***	$8 \cdot 10^{-3}$	Belle II/LHCb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

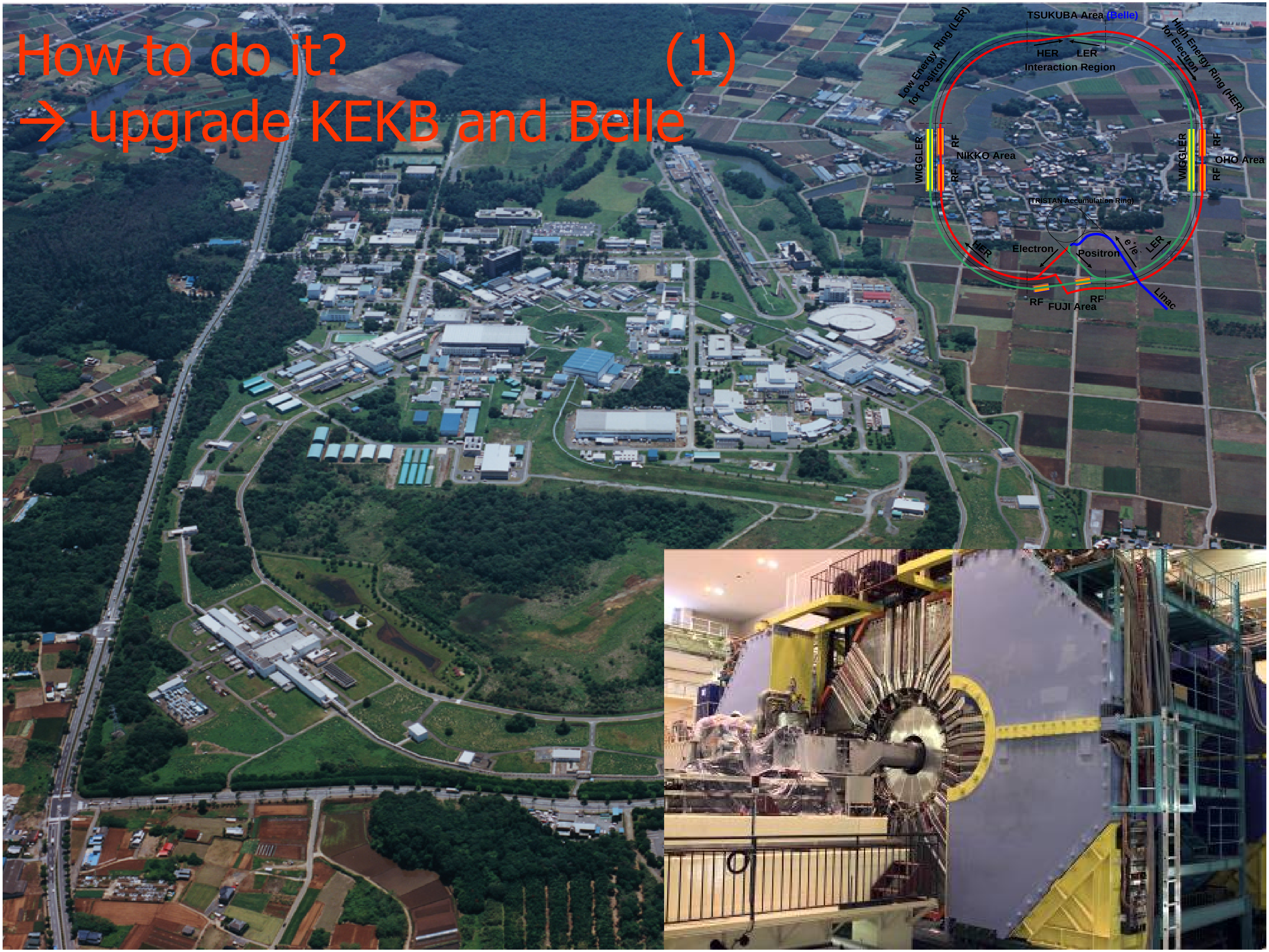
- B. Golob, KEK FF Workshop, Feb. 2012

Accelerators

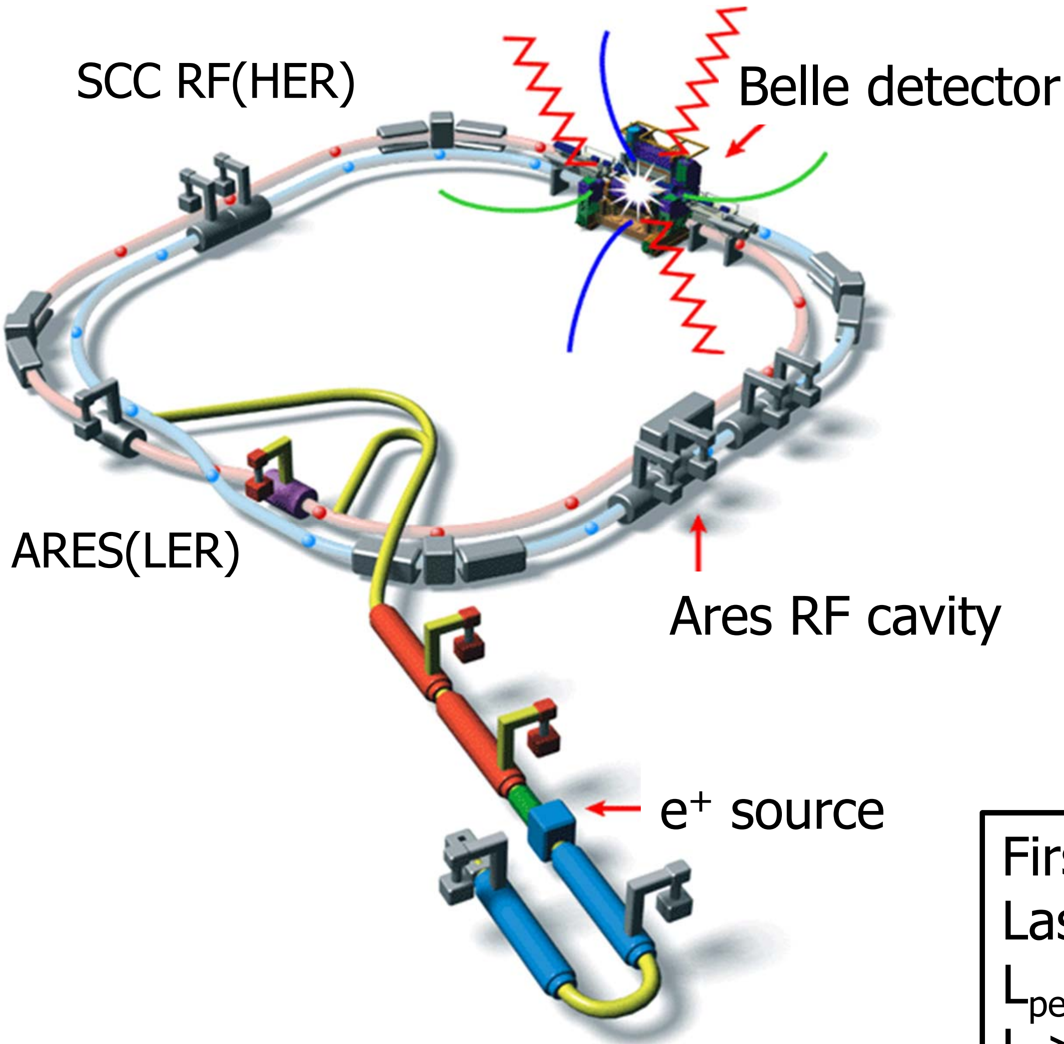
Need 50x more data →Next generation B-factories



How to do it? (1)
→ 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!) :

2.1×10^{34} cm^{-2}s^{-1}

=2x design value

First physics run on June 2, 1999
Last physics run on June 30, 2010
L_{peak} = 2.1×10^{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

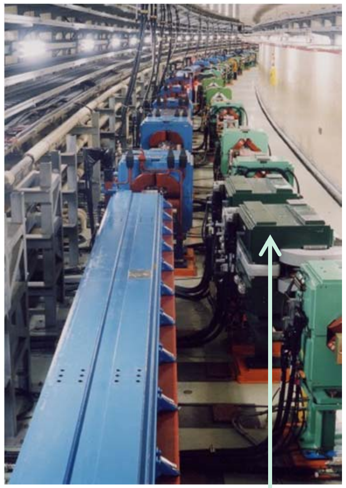
Invented by Pantaleo Raimondi for SuperB

Machine design parameters

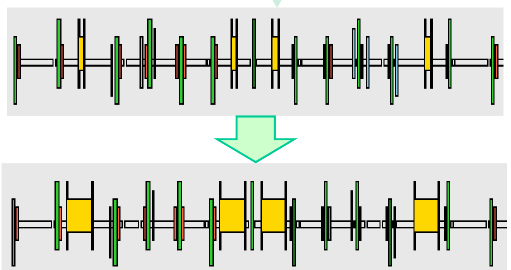
parameters		KEKB		**SuperKEKB**		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.6	nm
Emittance ratio	κ	0.88	0.66	0.37	0.40	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.30	mm
Beam currents	I_b	1.64	1.19	3.60	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

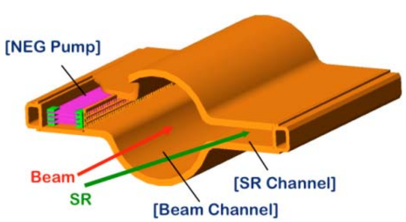


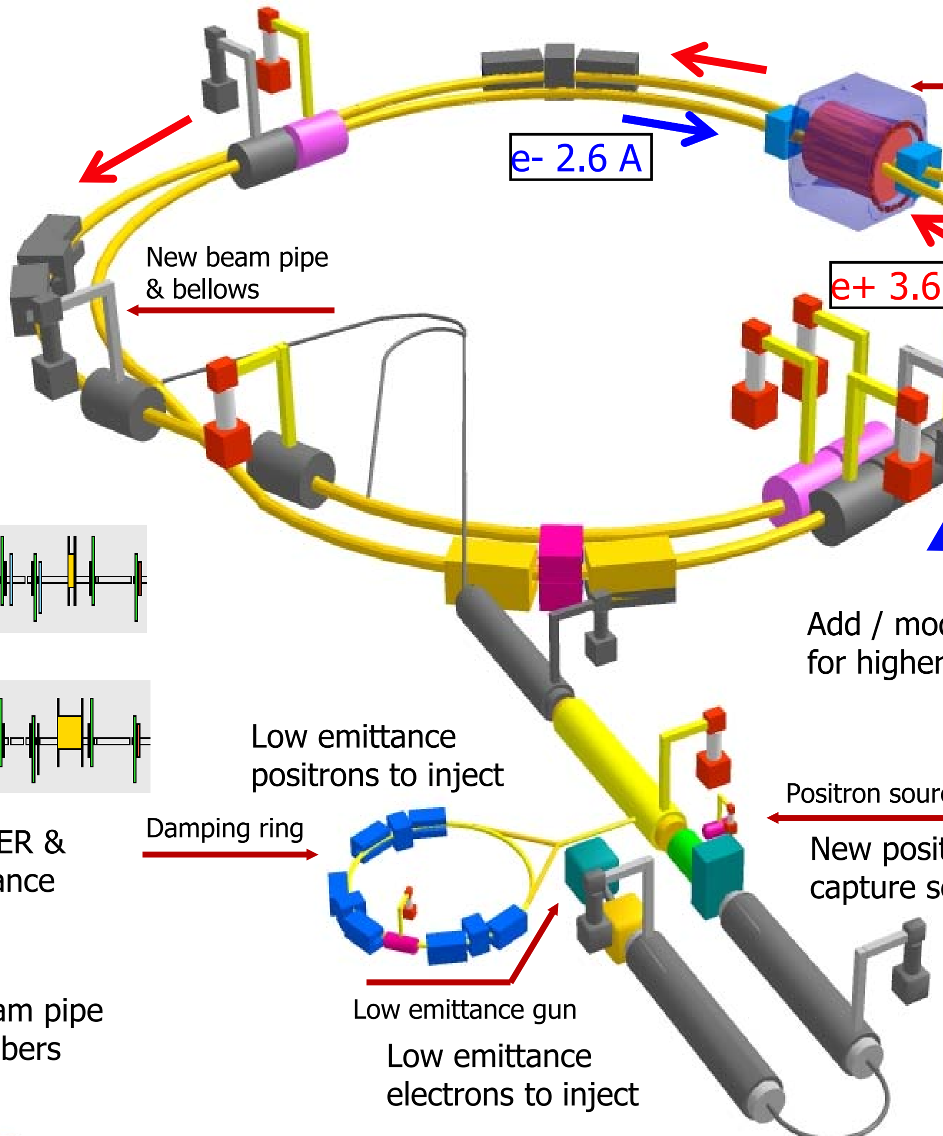
Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance

TiN-coated beam pipe with antechambers

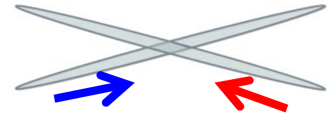




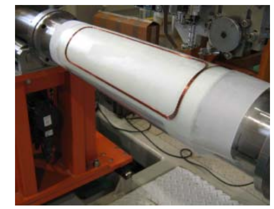
Low emittance positrons to inject

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

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

Three magnets per day !

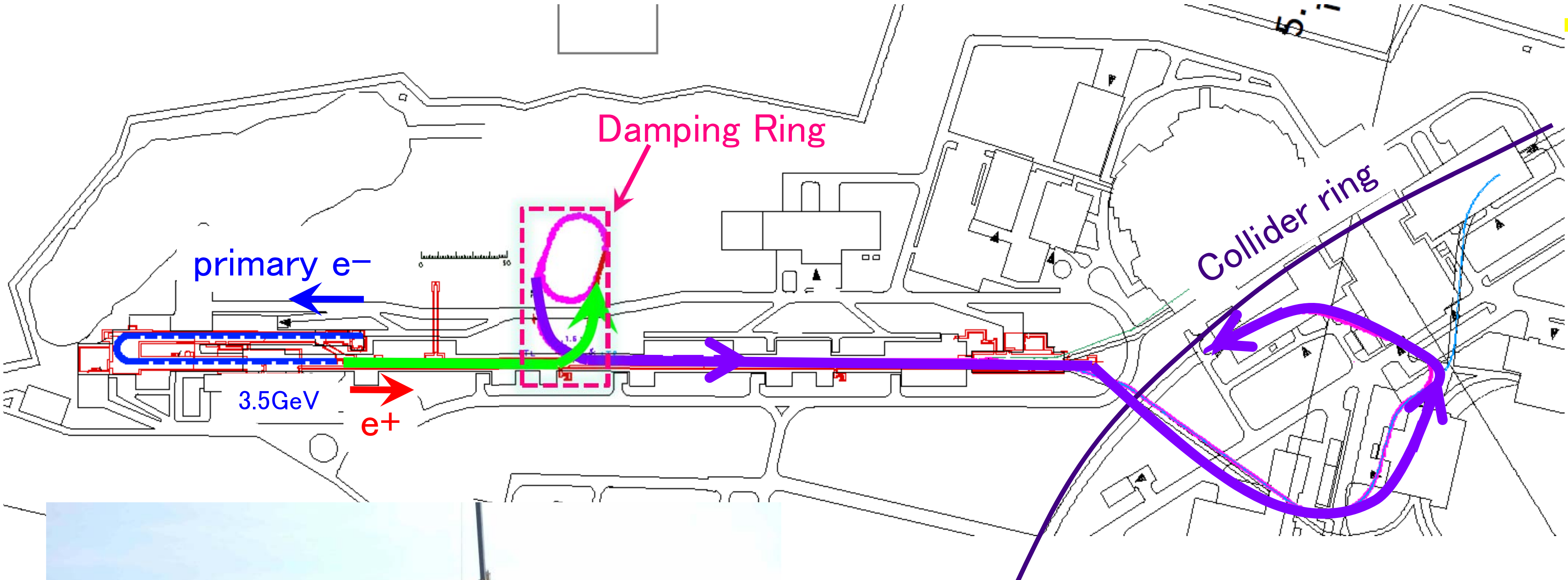
Installing the 4 m long LER dipole **over** the 6 m long HER dipole (remains in place).

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

Damping ring: construction started in Jan 2012



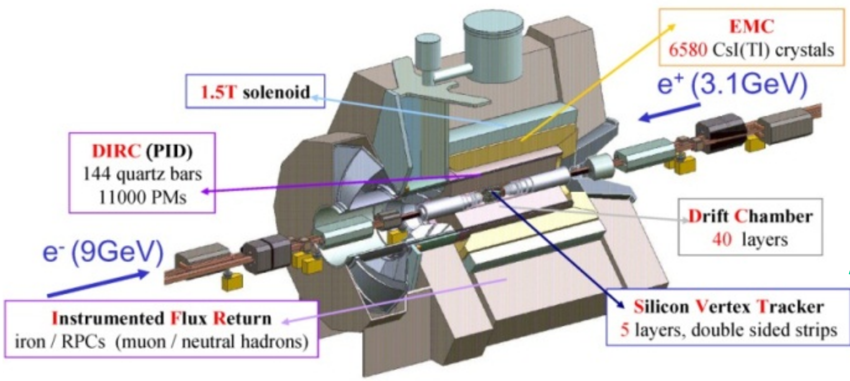
- Fabrication of accelerator components ongoing.
- Buildings will be constructed in JFY2012-13 after the tunnel is completed
- Damping ring will be completed by the end of JFY2014.

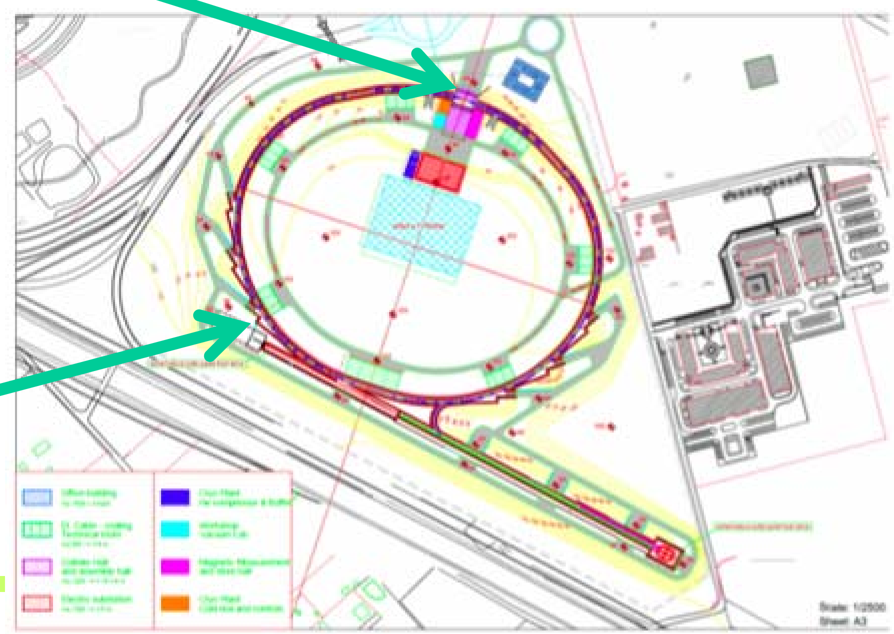
How to do it? (2)

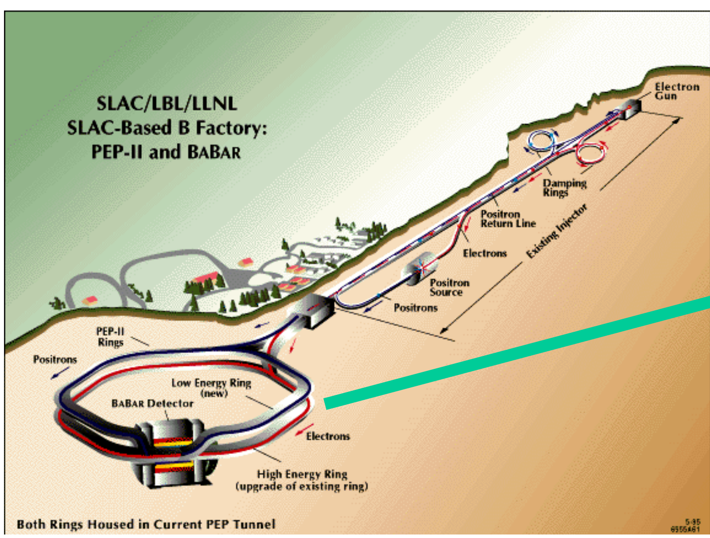
→ Construct a new tunnel near Frascati, Italy

→ Move magnets from PEP-II

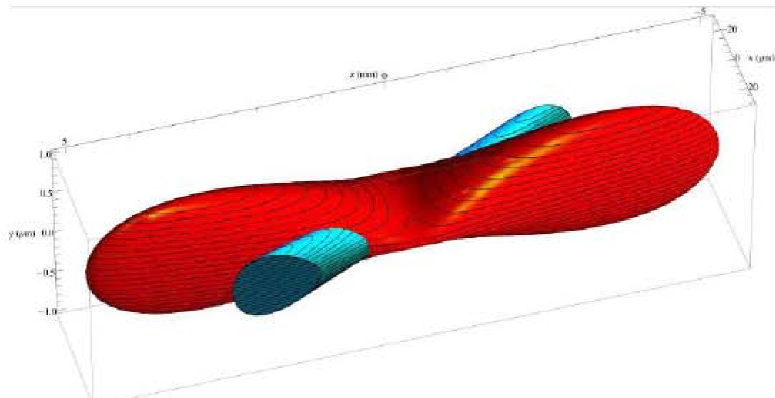
→ Move BaBar, upgrade



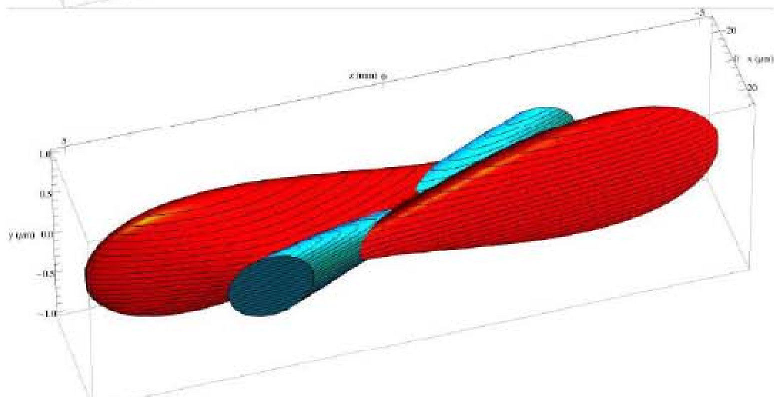




Nano-beam collisions with crab waist



Without
Crab-sextupoles



With
Crab-sextupoles

All particles from both beams collide in the minimum β_y region, with a net luminosity gain

Crab waist scheme: successfully tested in the DAΦNE ring

Parameters for 1×10^{36} Lumi (max 4×10^{36})

		Base Line		Low Emittance		High Current		Tau/Charm (prelim.)	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	cm^{-2} s^{-1}	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.899	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.166
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

Tau/charm threshold running at 10^{35}

Baseline + other 2 options:
- Lower y-emittance
- Higher currents (twice bunches)

Baseline:
- Higher emittance due to IBS
- Asymmetric beam currents

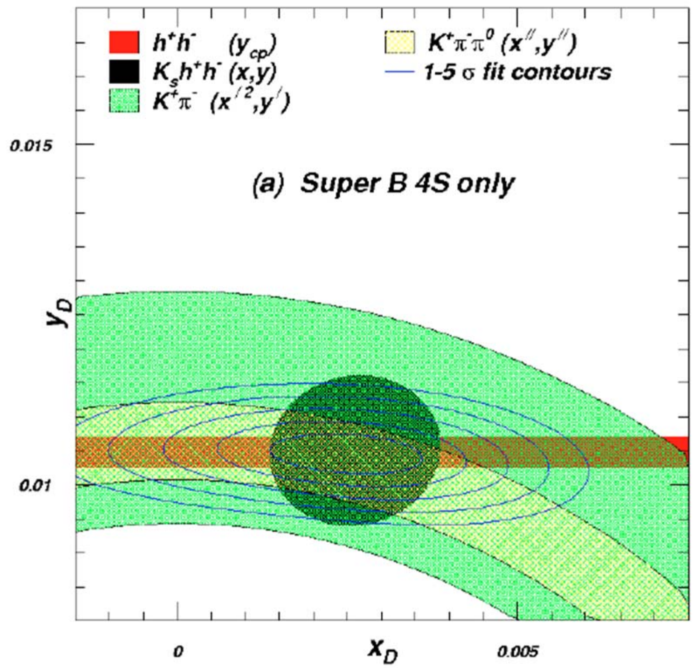
RF power includes SR and HOM

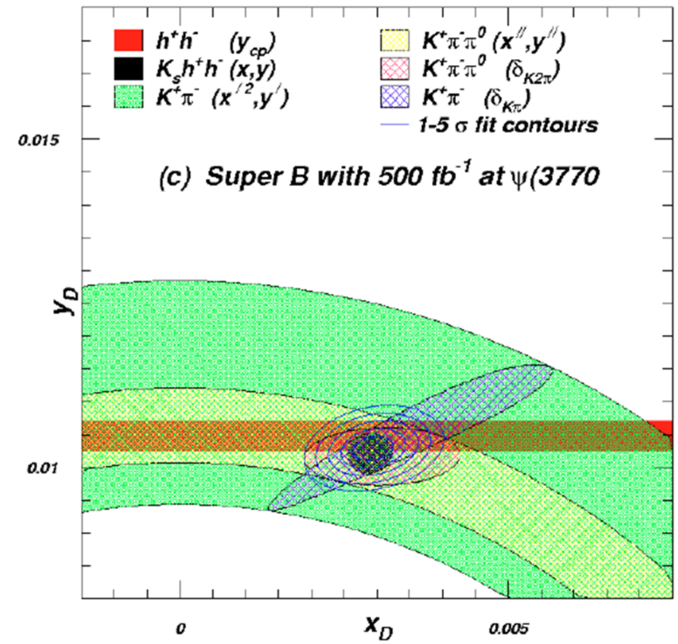
M. Giorgi, ICHEP2010

Interest of running at charm threshold

Decays of $\psi(3770) \rightarrow D^0 D^0$ produce coherent $(C=-1)$ pairs of D^0's.

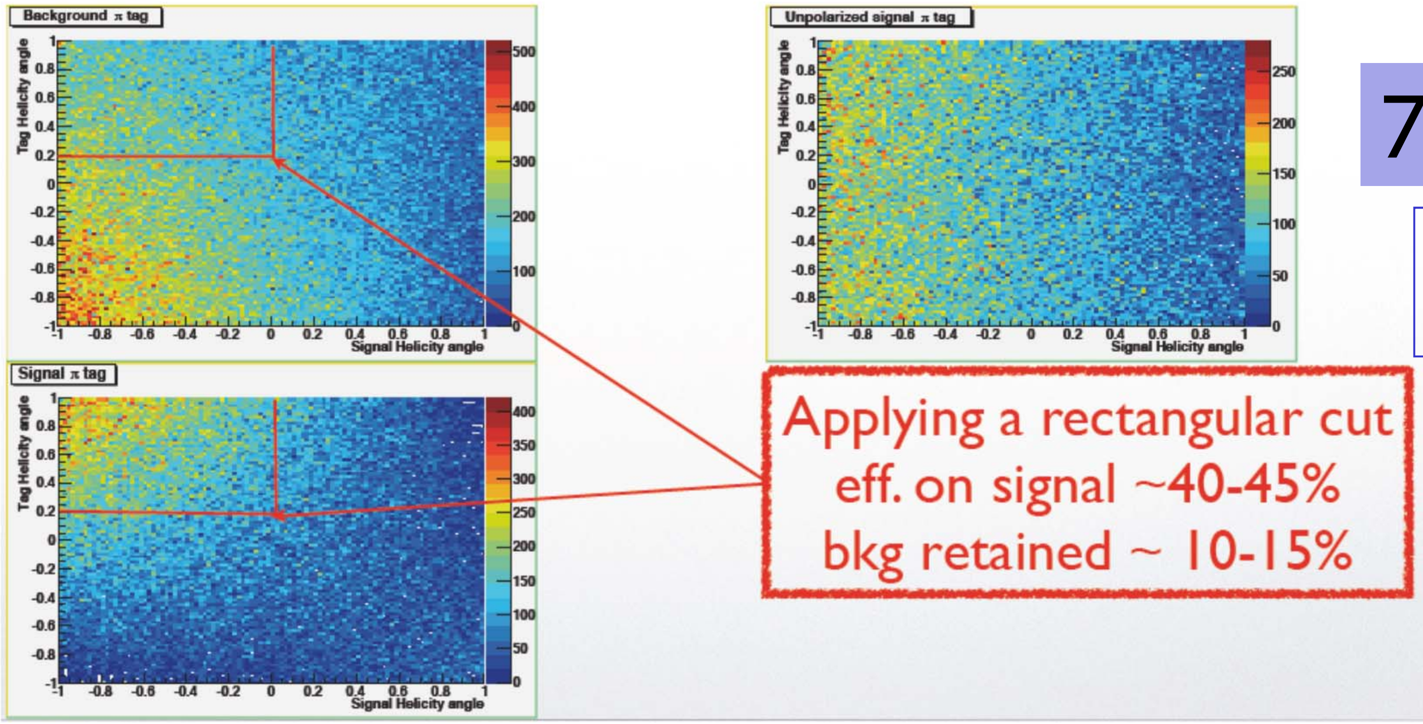
- 3 months of running will give $500 fb^{-1}$: 50x BES-III





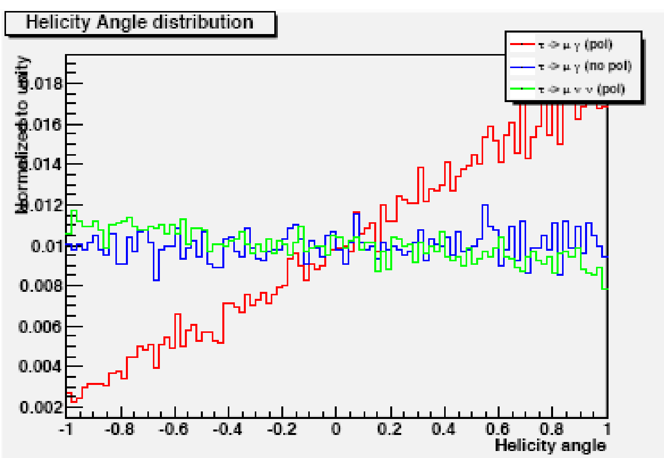
- Precision charm mixing,
- CPT Violation, rare decays, CPV using quantum correlations, decay constants, ...

Polarized beam helps to reduce irreducible background in tau decays (e.g. $\tau \rightarrow \mu\gamma$)



75 ab^{-1}

arXiv:1008.1541v1 [hep-ex]



$B(\tau \rightarrow \mu\gamma)$ $2\ 10^{-9}$	$B(\tau \rightarrow \mu\gamma)$ $1\ 10^{-9}$
$B(\tau \rightarrow \mathbf{e}\gamma)$ $2\ 10^{-9}$	$B(\tau \rightarrow \mathbf{e}\gamma)$ $1\ 10^{-9}$

Sensitivity improves at least by a factor 2.
Equivalent to a factor 4 increase in luminosity.

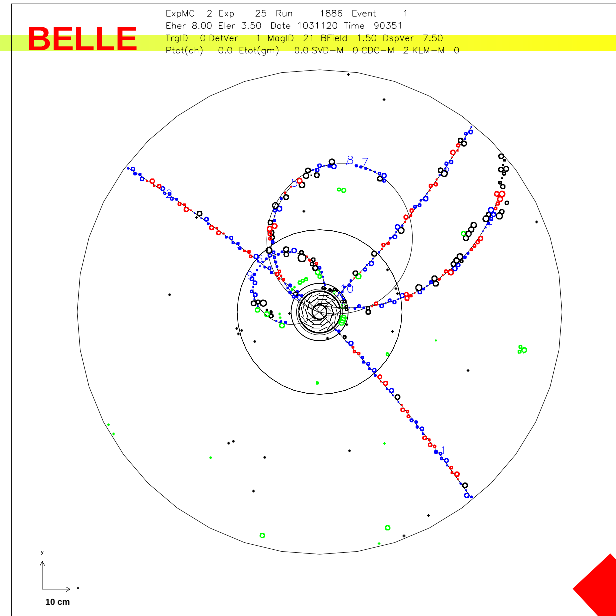
M. Giorgi, ICHEP2010

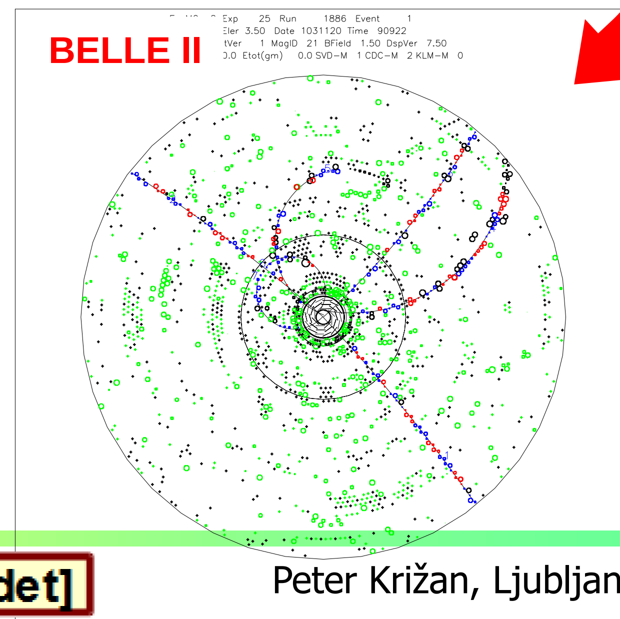
Detectors

Need to build a new detector to handle higher backgrounds

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

- **Higher background ($\times$10-20)**
  - radiation damage and occupancy
  - fake hits and pile-up noise in the EM
- **Higher event rate ($\times$10)**
  - higher rate trigger, DAQ and computing
- **Require special features**
  - low p μ identification $\leftarrow$ $s\mu\mu$ recon. eff.
  - hermeticity $\leftarrow$ ν "reconstruction"



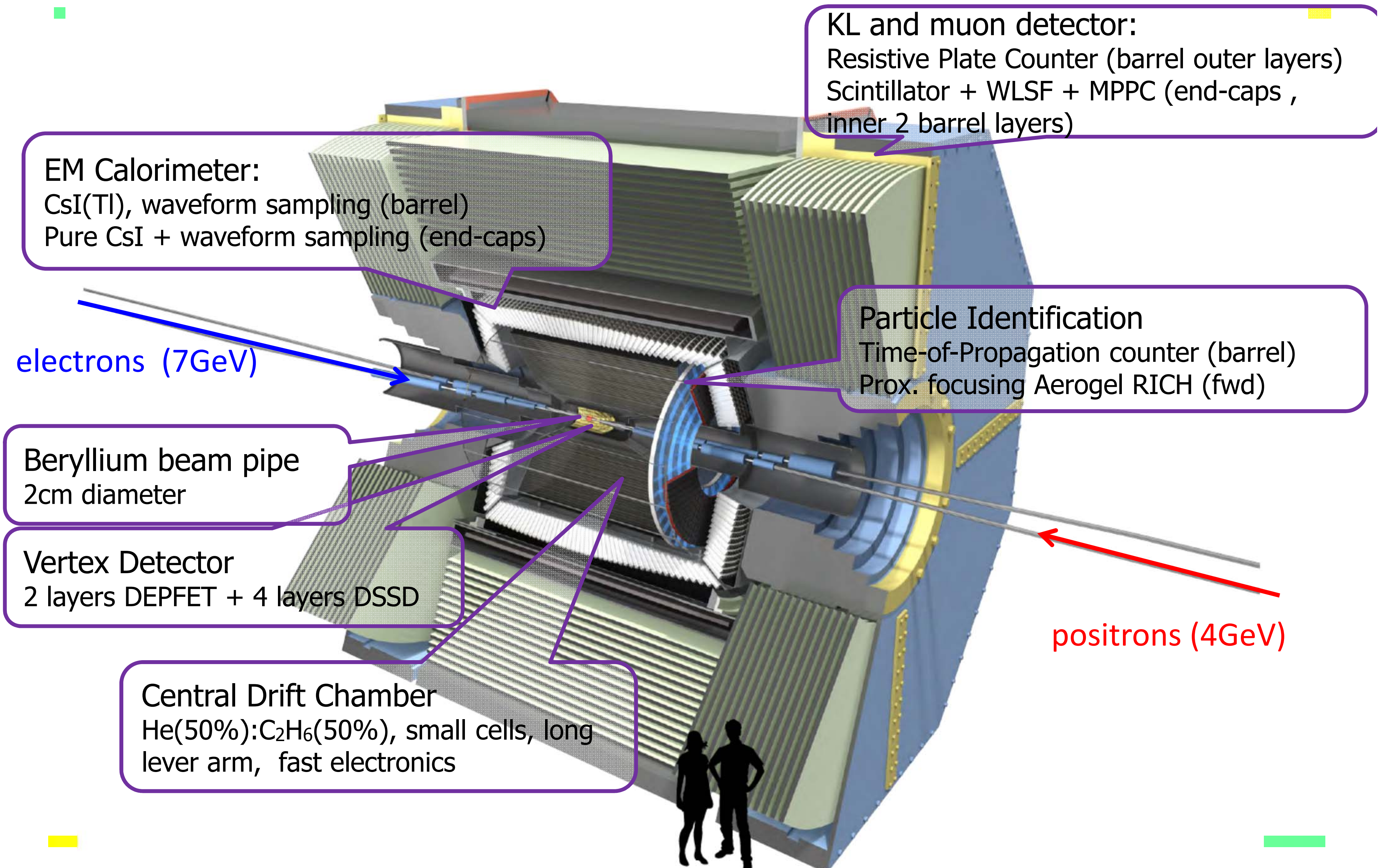


Have to employ and develop new technologies to make such an apparatus work!

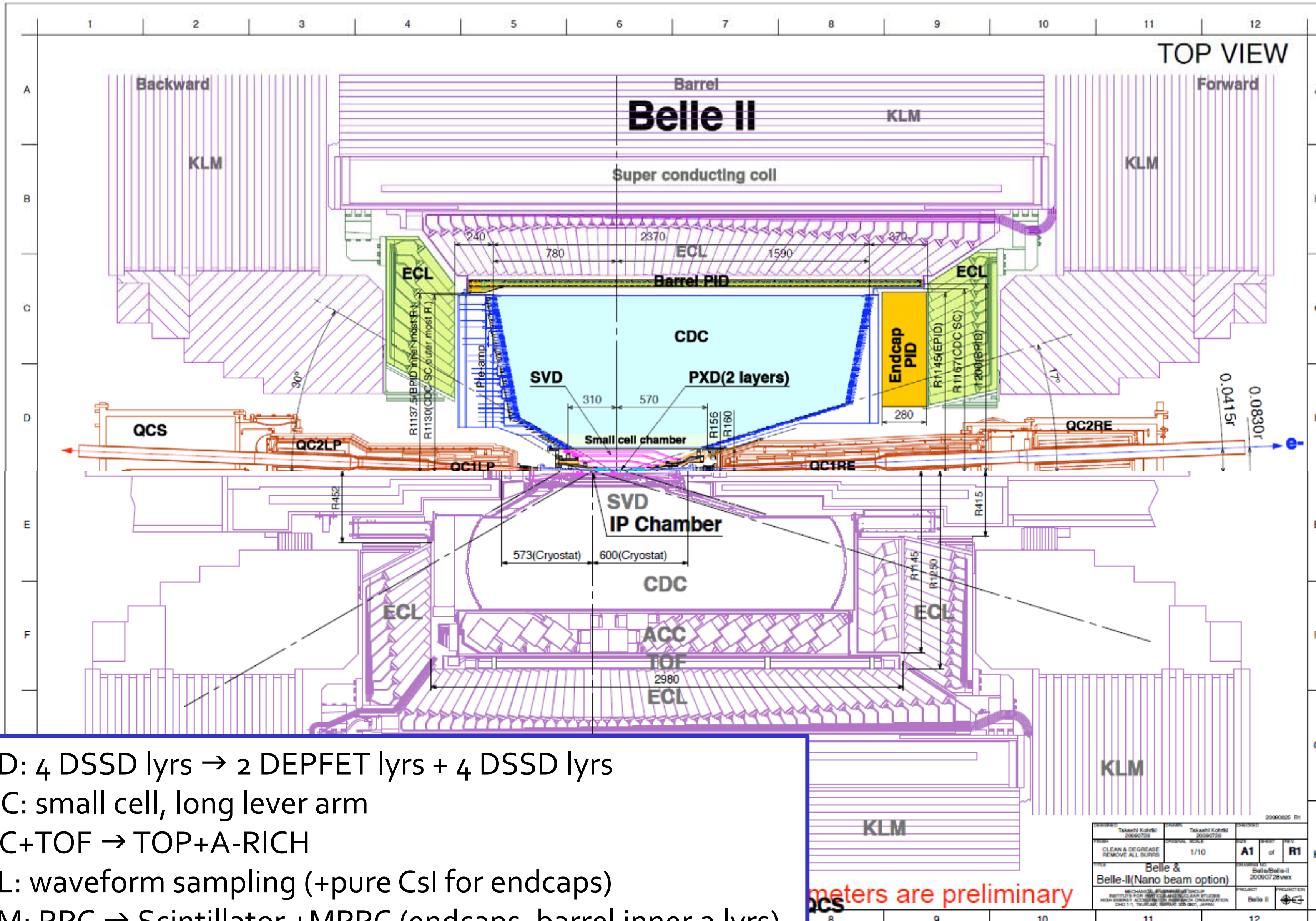
$\rightarrow$

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

Belle II Detector

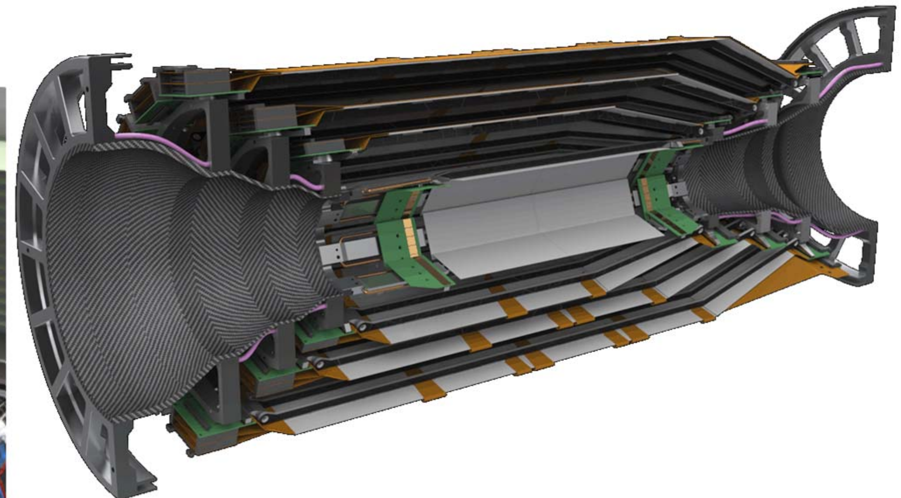


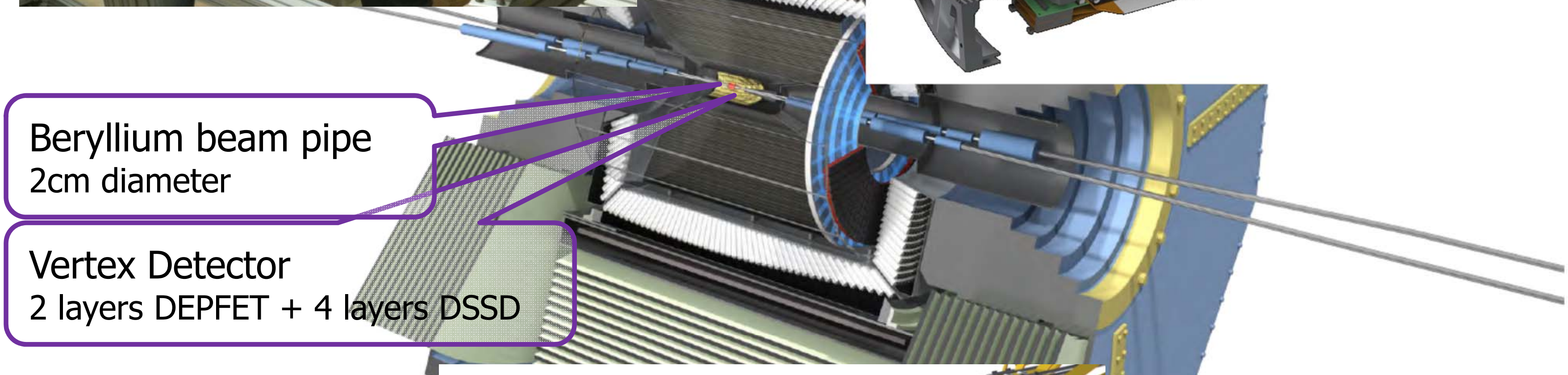
Belle II Detector (in comparison with Belle)

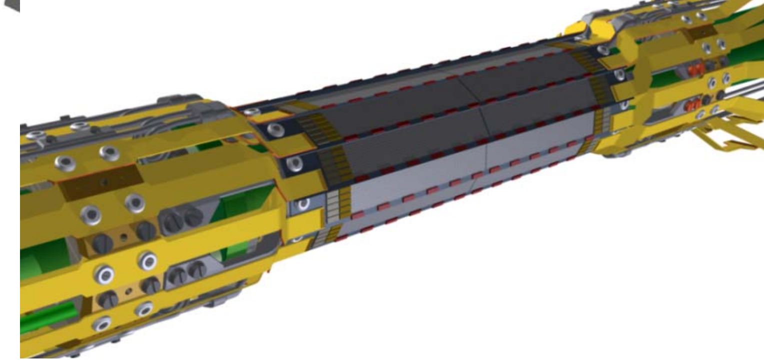


SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling (+pure CsI for endcaps)
KLM: RPC → Scintillator +MPPC (endcaps, barrel inner 2 lyrs)

Belle II Detector – vertex region

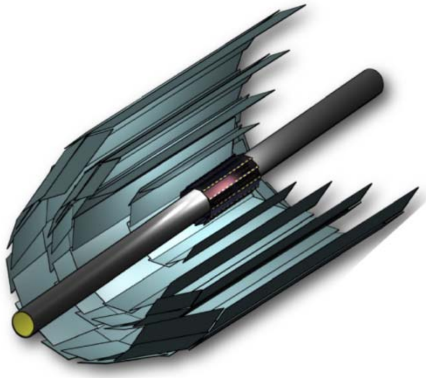






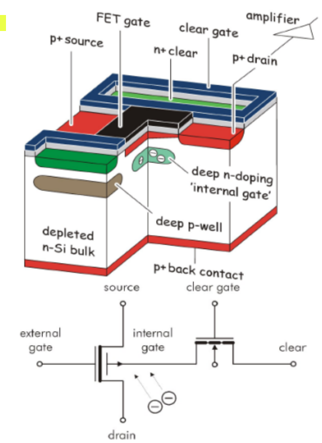
Vertex Detector

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

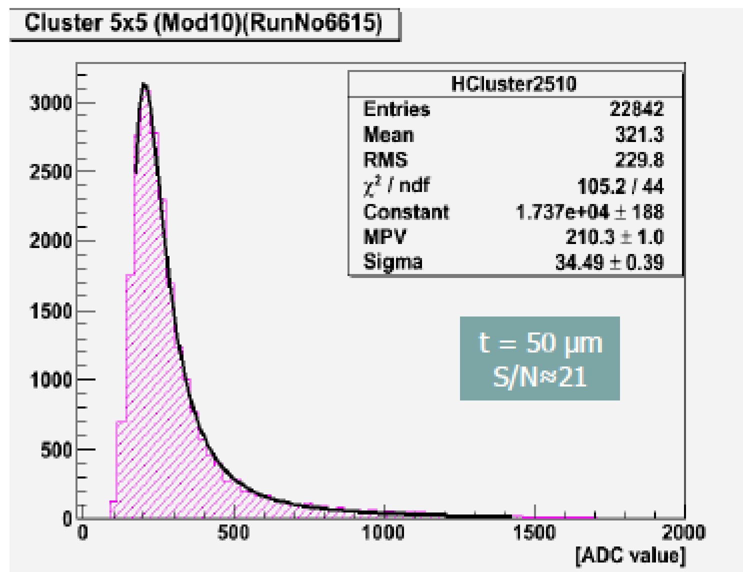


Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

DEpleted P-channel FET



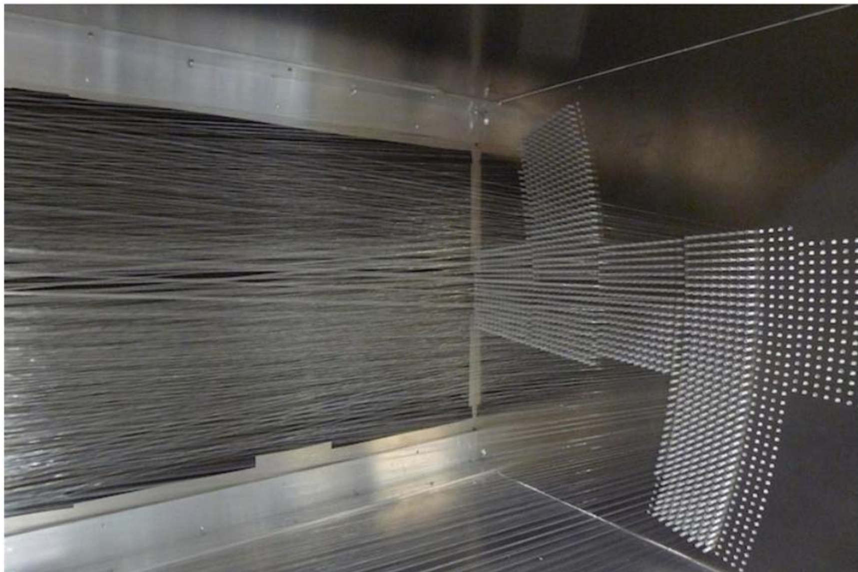
Mechanical mockup of pixel detector

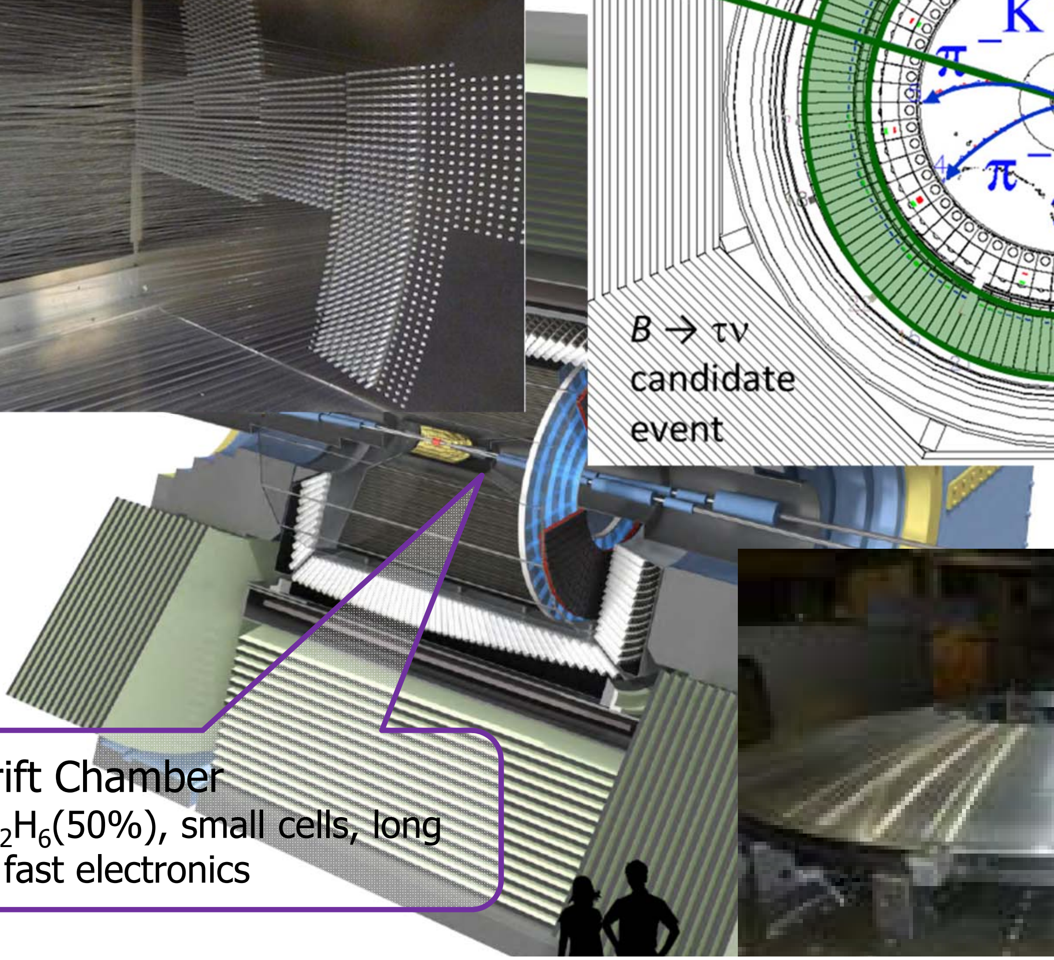


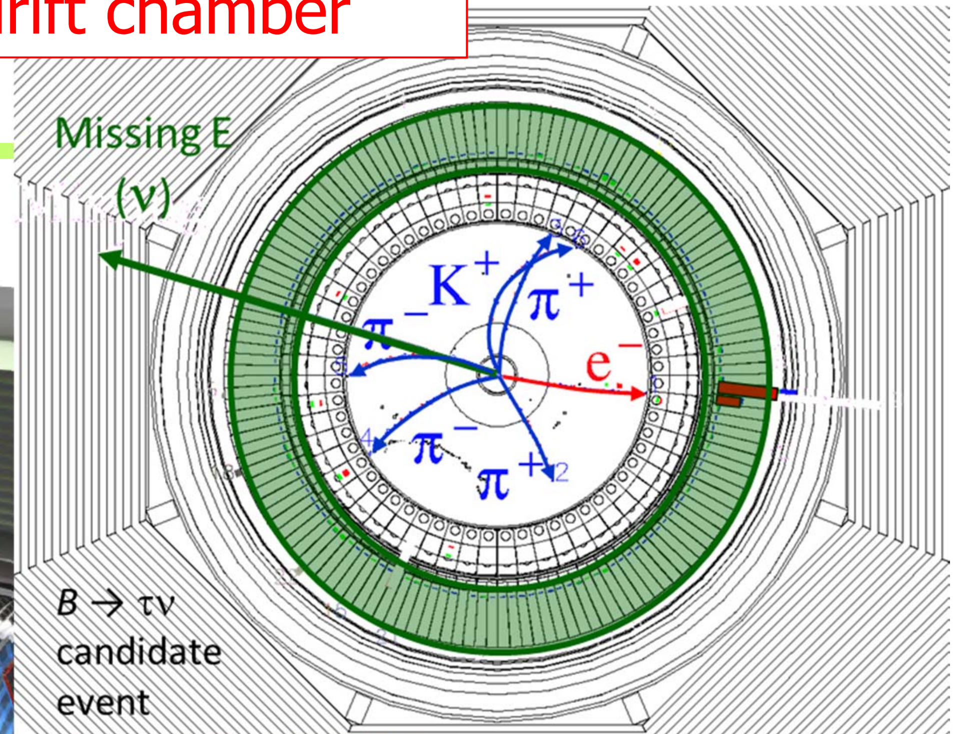
DEPFET pixel sensor

DEPFET sensor: very good S/N

Main tracking device: small cell drift chamber



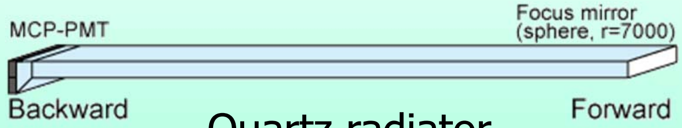




Endplates of the drift chamber have been fabricated, main cillinder to be delivered this month

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



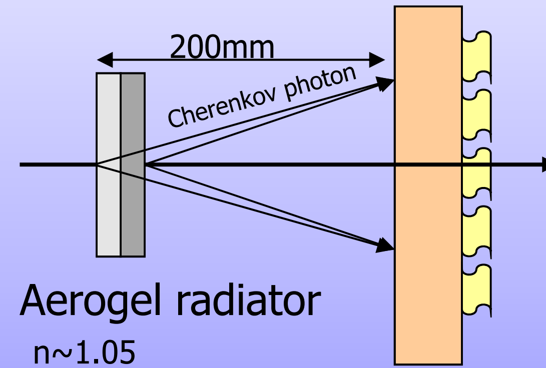
Quartz radiator

Focusing mirror

Small expansion block

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

Endcap PID: Aerogel RICH (ARICH)

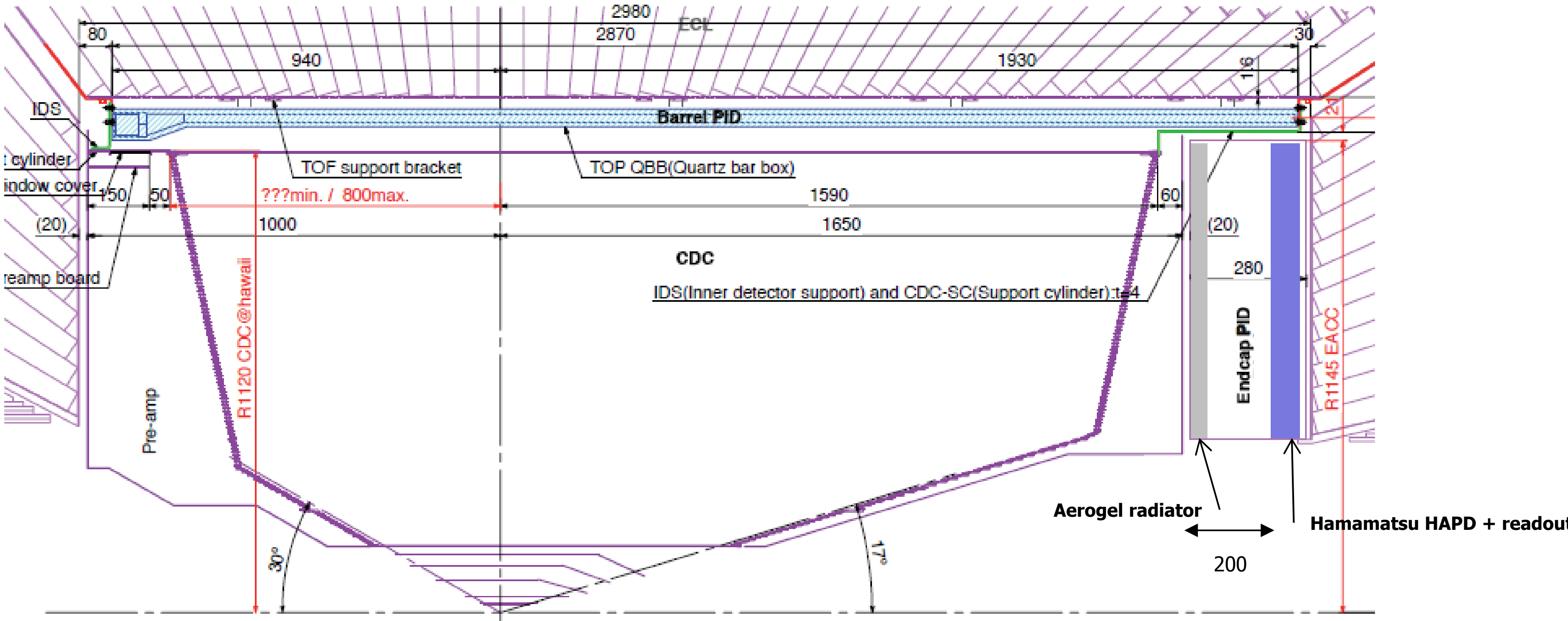


Aerogel radiator

n~1.05

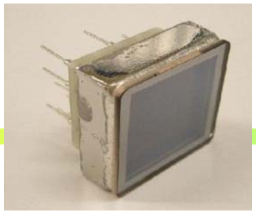
Hamamatsu HAPD

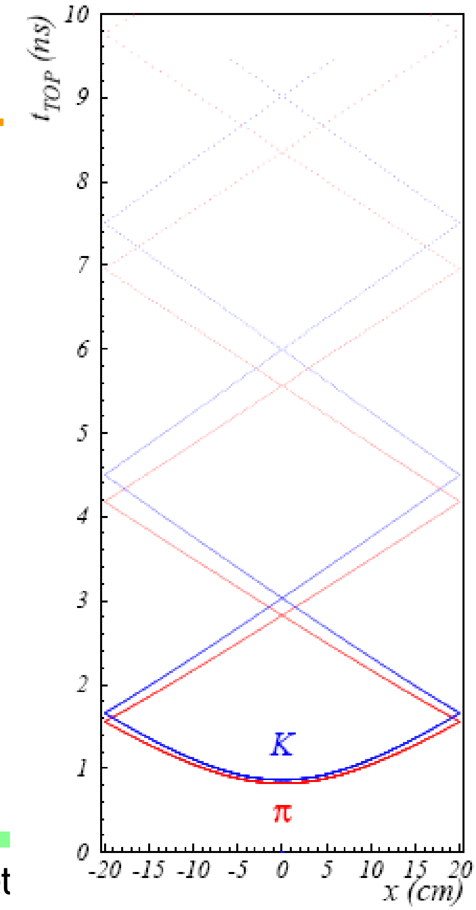
+ new ASIC



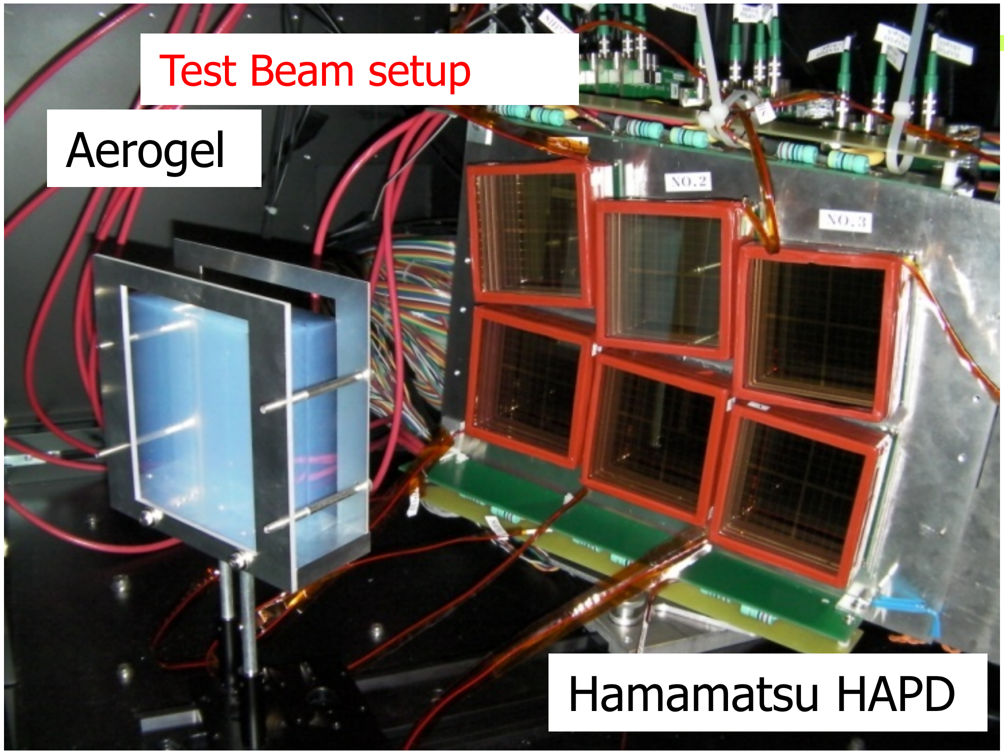
Barrel PID: Time of propagation (TOP) counter

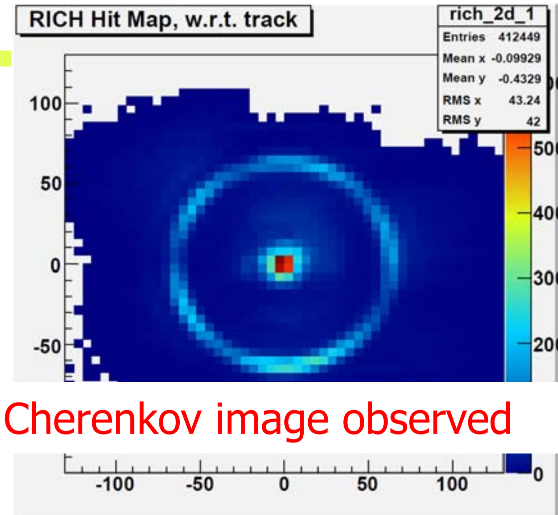
- Cherenkov ring imaging with precise time measurement.
- Device uses internal reflection of Cerenkov ring images from quartz like the BaBar DIRC
- Reconstruct Cherenkov angle from two hit coordinates and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT)
    - Good time resolution ~ 40 ps
    - Single photon sensitivity in 1.5 T field
    - Hamamatsu SL10





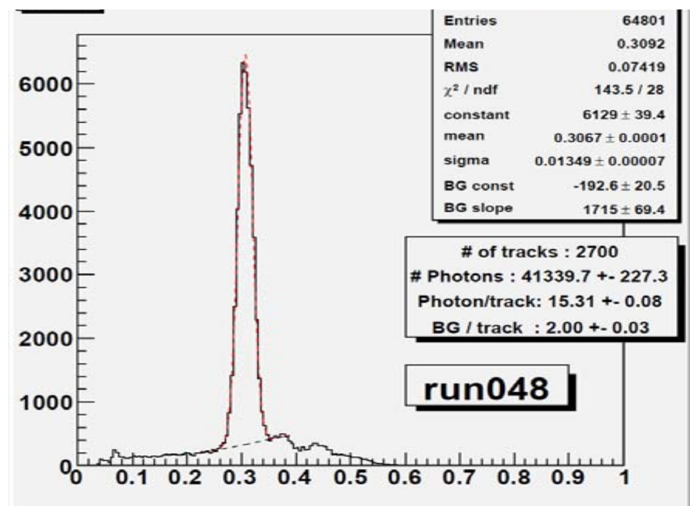
Aerogel RICH (endcap PID)



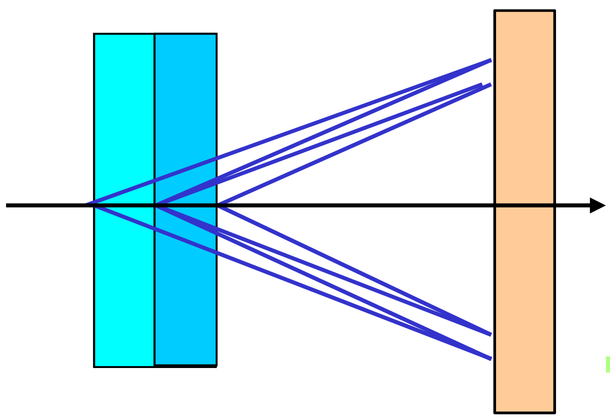


Clear Cherenkov image observed

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.

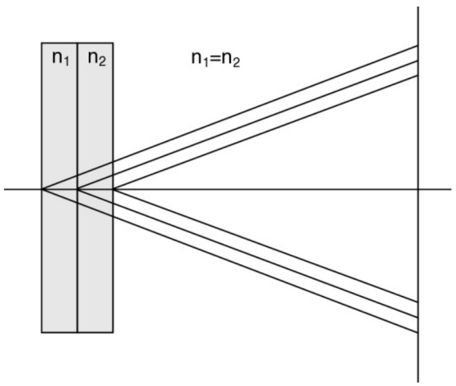
6.6 σ π/K at 4GeV/c !

Peter Križan, Ljubljana

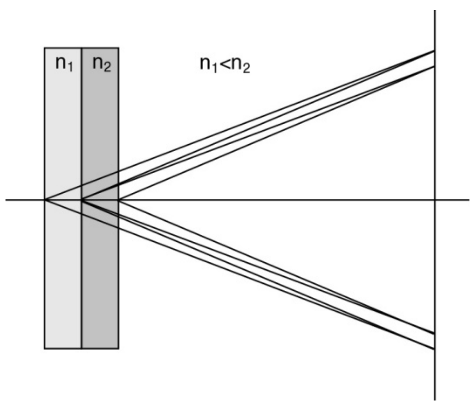
RICH with a focusing radiator

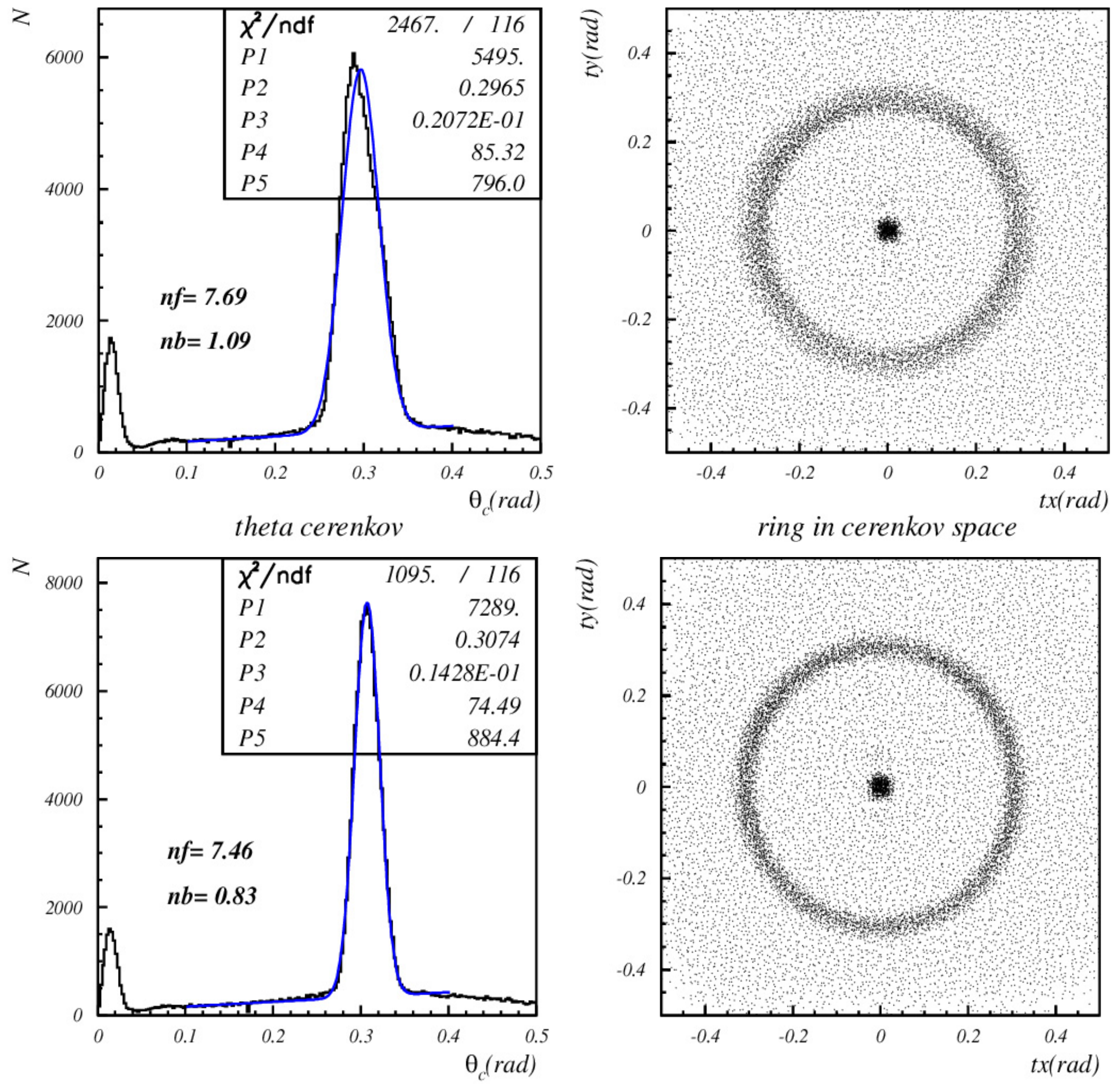
Increases the number of photons without degrading the resolution

4cm aerogel single index



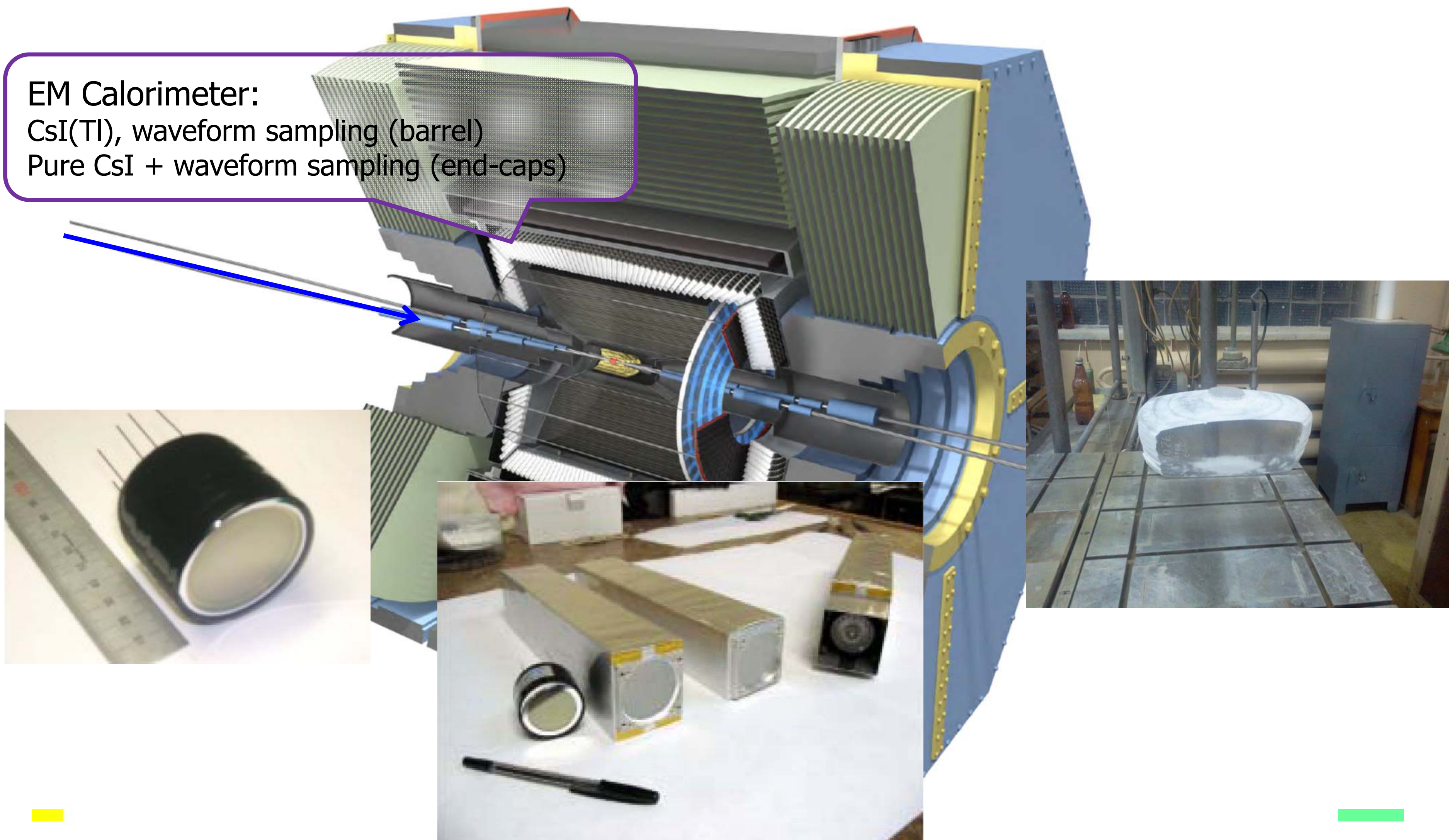
2+2cm aerogel





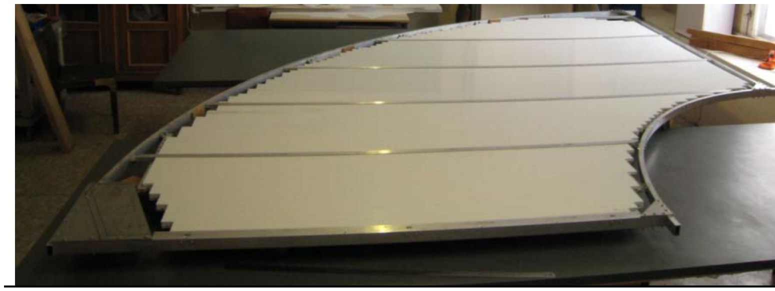
→NIM A548 (2005) 383

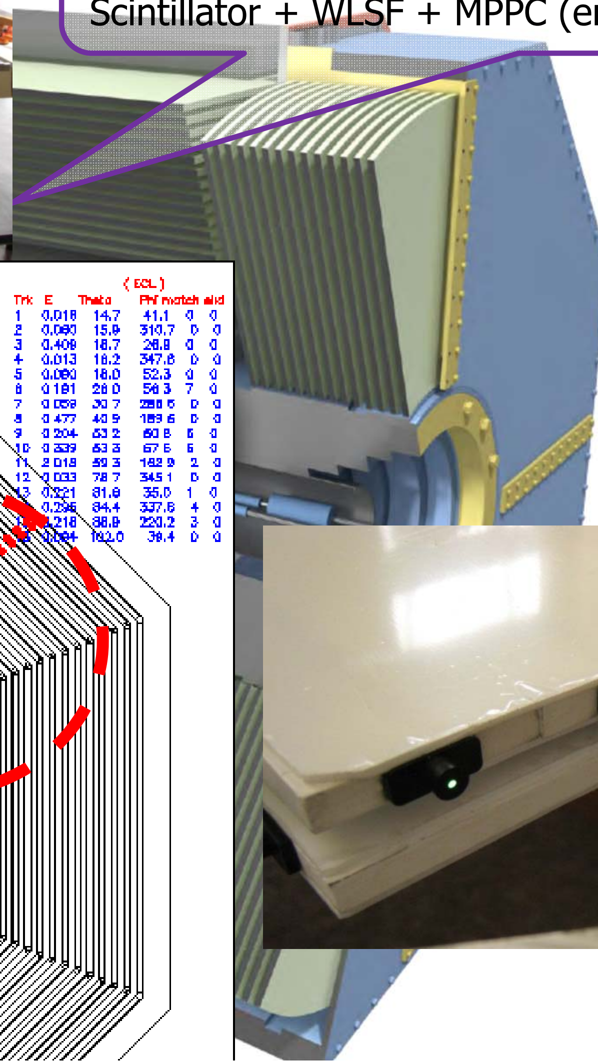
EM calorimeter: upgrade needede because of higher rates (barrel: electronics, endcap: electronics and CsI(Tl) → pure CsI) and radiation load (endcap: CsI(Tl) → pure CsI)

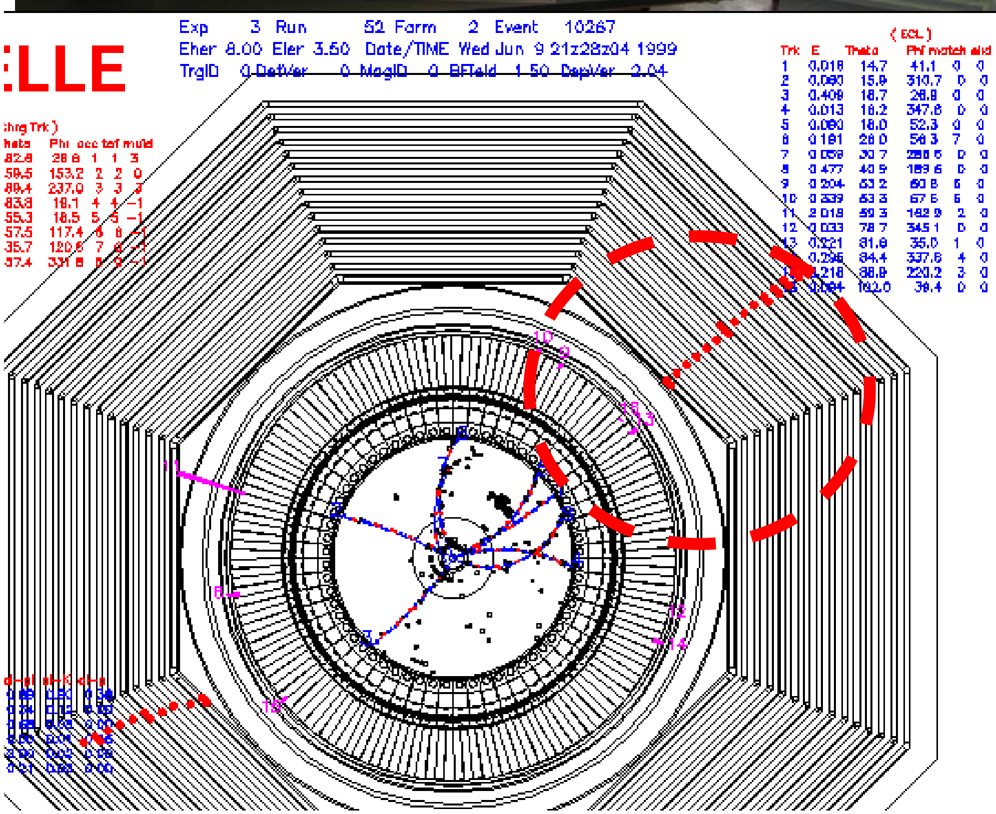


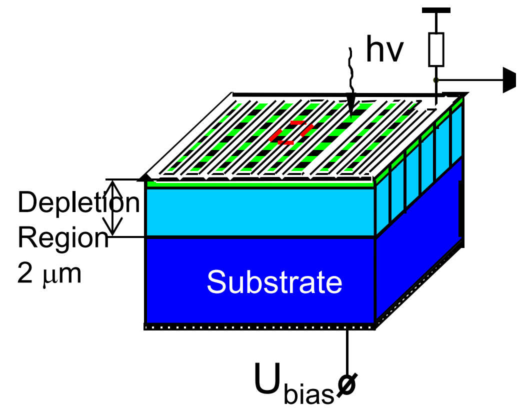
Detection of muons and KLs: Parts of the present RPC system have to be replaced to handle higher backgrounds (mainly from neutrons).

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



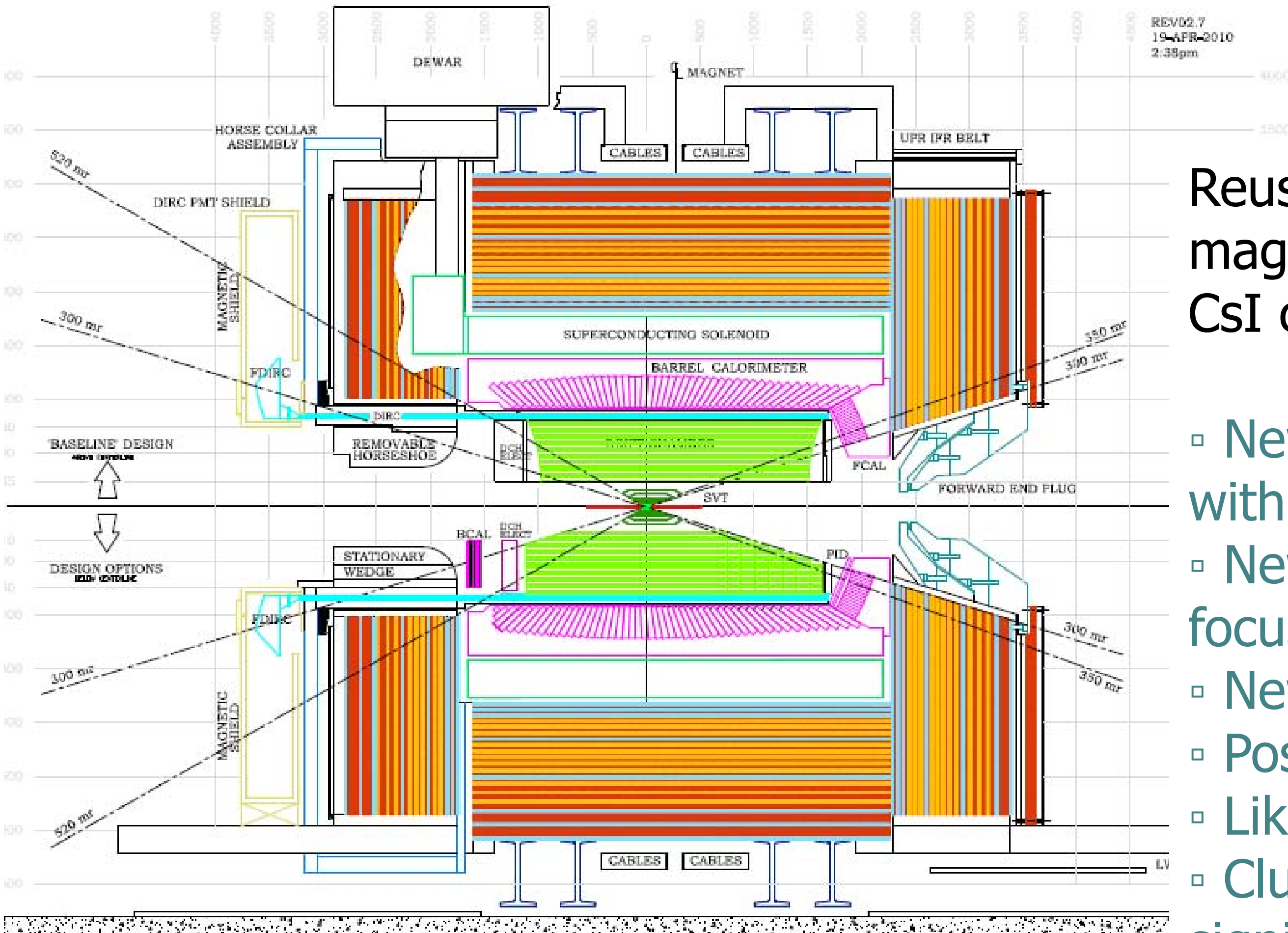






ljana

SuperB Detector



Reuse BaBar components: magnet, DIRC bars, barrel CsI calorimeter.

- New silicon; add Layer 0 with smaller beam pipe
- New way to read out DIRC: focusing DIRC
- New forward calorimeter
- Possible forward PID
- Likely backward EMC
- Cluster counting in DC: significant improvement of dE/dx resolution

Status of the projects

The Belle II Collaboration

A very strong group of ~400 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.

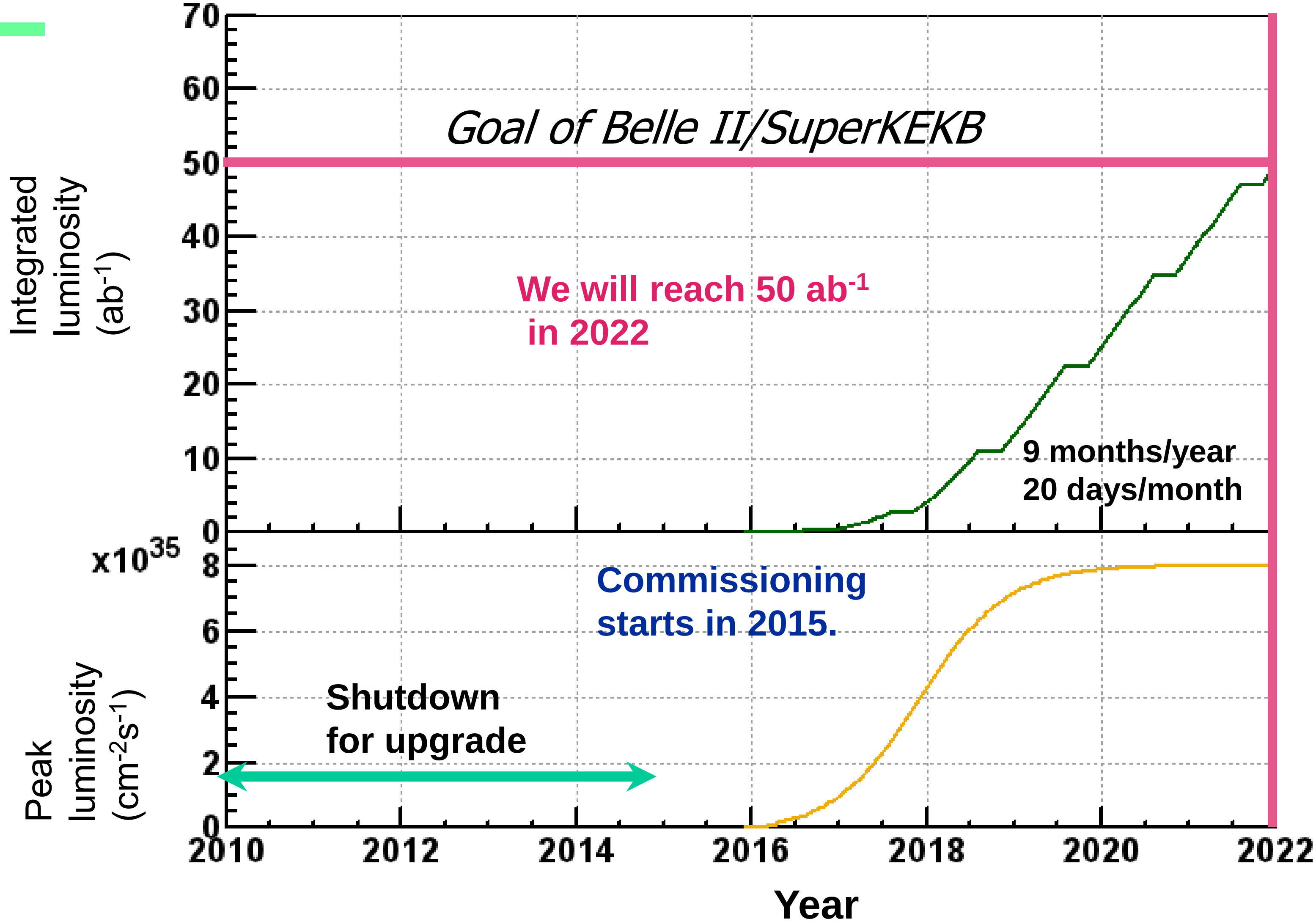
→construction started in 2010!

Fortunately little damage during the March 2011 earthquake → no delay

Ground breaking ceremony in November 2011

SuperKEKB and Belle II construction proceeds according to the schedule.

Schedule



The schedule is likely to shift by a few months because of a new construction/commissioning strategy for the final quads.

SuperB Status

SuperB approved as the first in a list of 14 “flagship” projects within the Italian National Research Plan

- National Research Plan endorsed by “CIPE” (institution responsible for infrastructure long term plans)
- A financial allocation of 256M EUR over six years approved for the “SuperB Flavour Factory” (total cost and request ~twice that, assuming PEP-II equipment re-use)
- Cabibbo Lab created on Oct 7 , 2011

▫ Major step forward: first major particle physics accelerator lab to be created in a generation

▫ legal structure needed in order to spend funds, sign MOUs

▫ MOUs with various institutions and labs completed or nearing completion - most recently completed MOU with Budker Institute

SuperB Status and Plan

- SuperB Collaboration formally in place since March 2012
- Cabibbo Lab management in place April 2012
- First hires in May/June 2012
- International Review Committee set up by Italian Ministry of Science (MIUR) to examine the Cost and Schedule of the SuperB project
- Report of the committee expected this autumn
- Ministerial review for all Flagship projects in autumn 2012, SuperB review on Nov. 19-20.

Plan:

- Machine and Detector TDR end 2012
- Start civil engineering 2013
- Start machine installation early 2014
- First collisions 2018

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 2010-14 → SuperKEKB+Belle II, L x40, construction started, final approval by the Japanese government end of 2010, included in the JFY2011 budget
- SuperB in Italy: build a new tunnel, reuse (+ugrade) PEP-II and BaBar, approval by INFN end of 2010
- Physics reach updates available
- Expect a new, exciting era of discoveries, complementary to the LHC