Portorož 2011
The Role of Heavy Fermions in Fundamental Physics
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Heavy Fermion Physics at Super Flavour Factories

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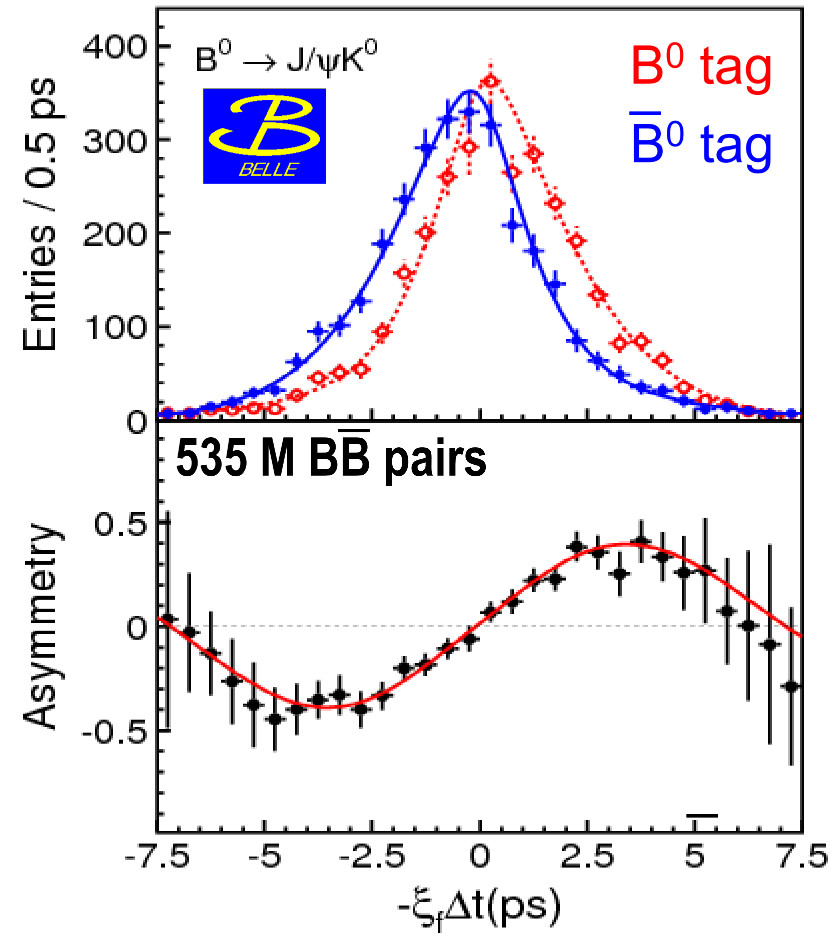
- Physics case for a Super B factory
- SuperKEKB/Belle-II@KEK and SuperB@Italy
- Accellerators
- Detectors
- Status and prospects of the projects
- Tau/charm factories

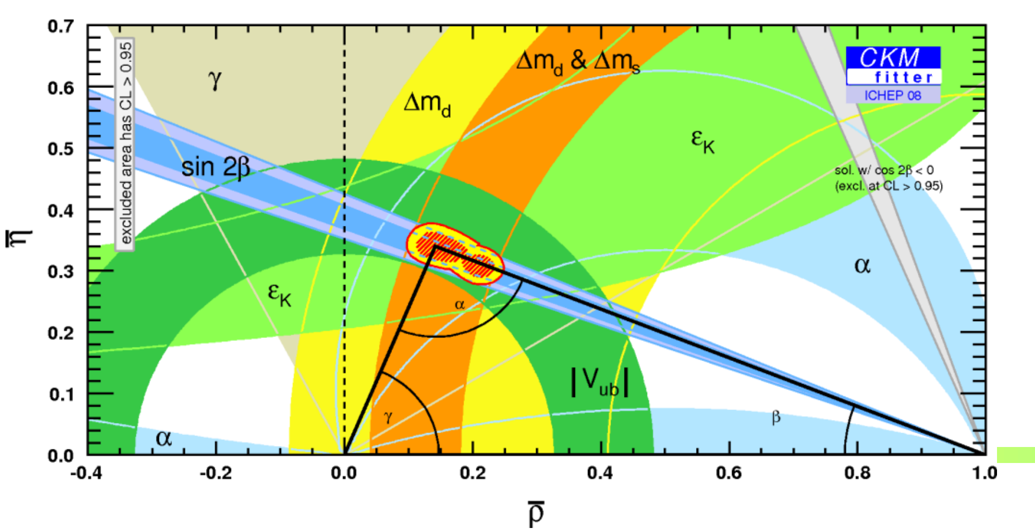
B factories: CP violation in the B system

CP violation in B system: from the discovery (2001) to a precision measurement (2006)

$\sin 2\phi_1 / \sin 2\beta$ from $b \rightarrow c\bar{c}s$

World average 2008:
$\sin 2\phi_1 = 0.681 \pm 0.025$



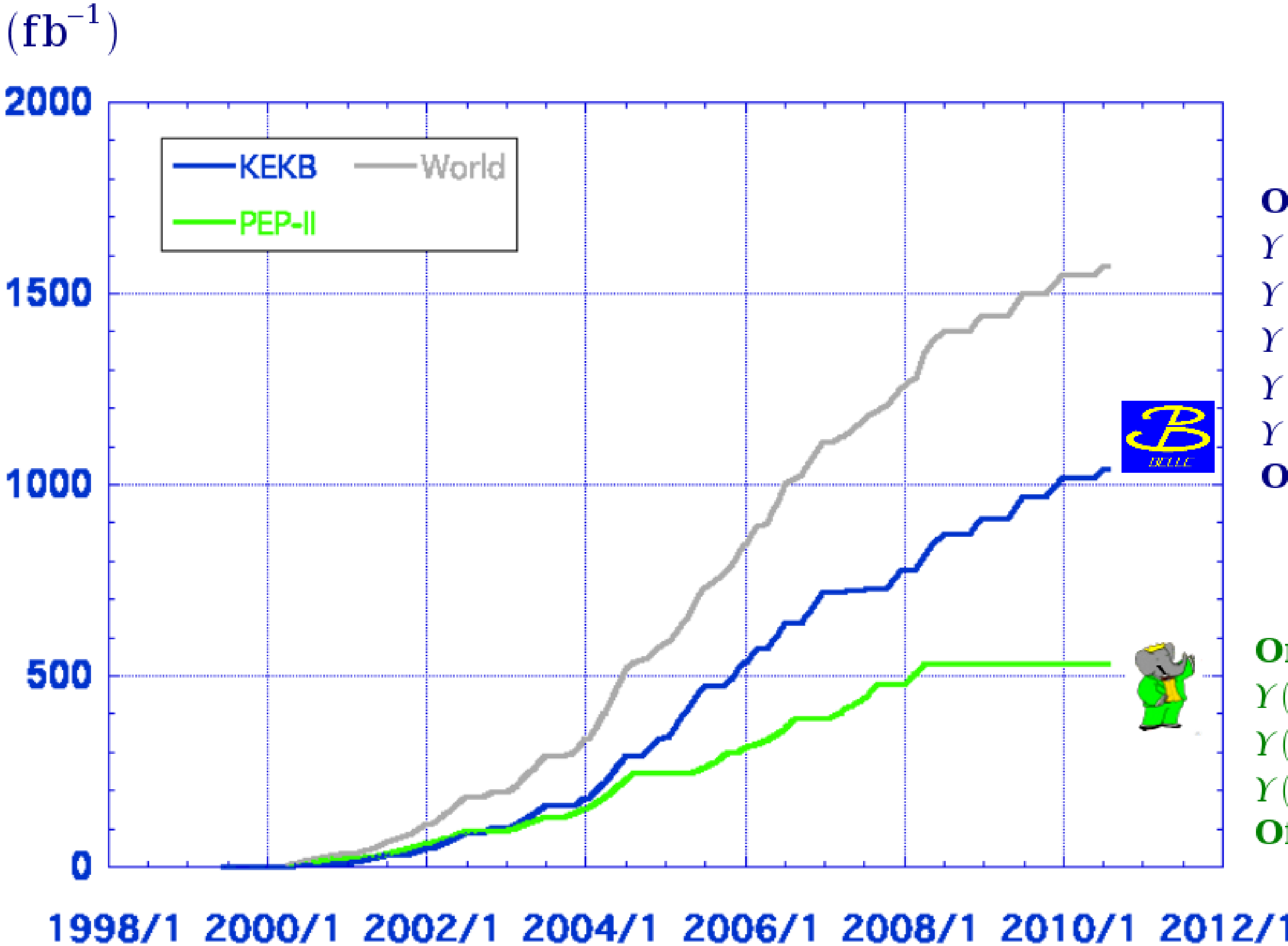


Constraints from measurements of angles and sides of the unitarity triangle → Remarkable agreement

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., $B \to \tau\nu$, $D\tau\nu$)
- $b \to s$ transitions: probe for new sources of CPV and constraints from the $b \to s\gamma$ branching fraction
- Forward-backward asymmetry (A_{FB}) in $b \to s l^+ l^-$ has become a powerfull tool to search for physics beyond SM.
- Observation of D mixing
- Searches for rare τ decays
- Observation of new hadrons

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:

$\sim 100\ fb^{-1}$

$\sim 550\ fb^{-1}$

On resonance:

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

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

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

Off resonance:

$\sim 54\ fb^{-1}$

Fantastic performance much beyond design values!

What next?

B factories → is SM with CKM right?

Next generation: Super B factories → in which way is the SM wrong?

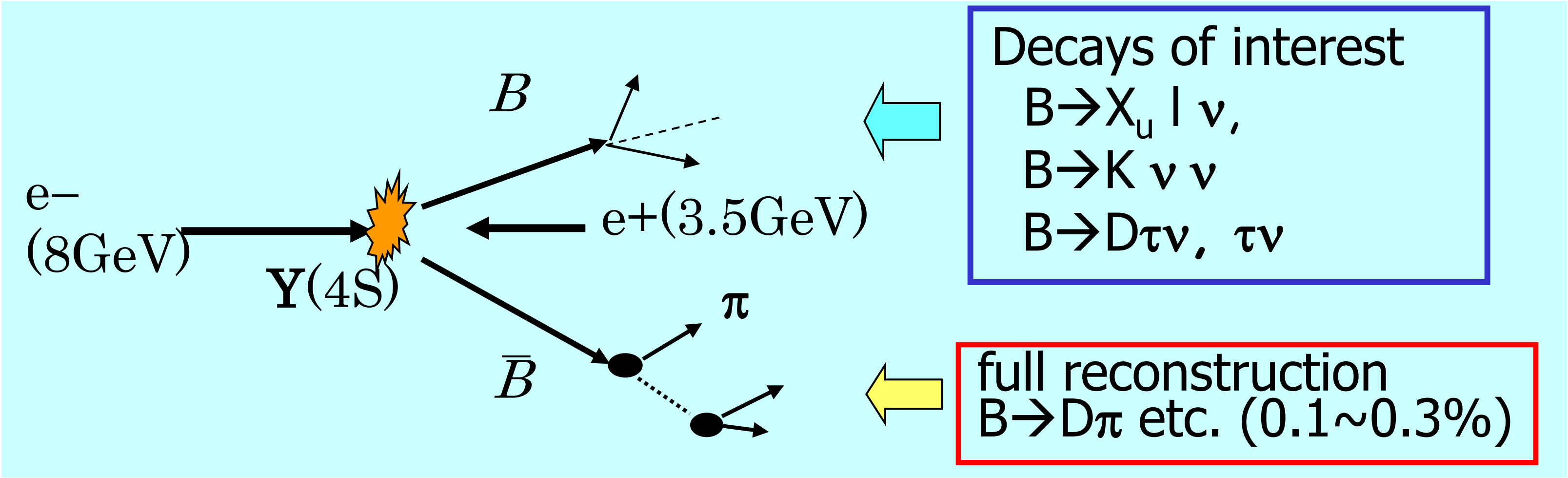
→ Need much more data (two orders!) because the SM worked so well until now → Super B factory

However: it will be a different world in four years, there will be 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

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

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

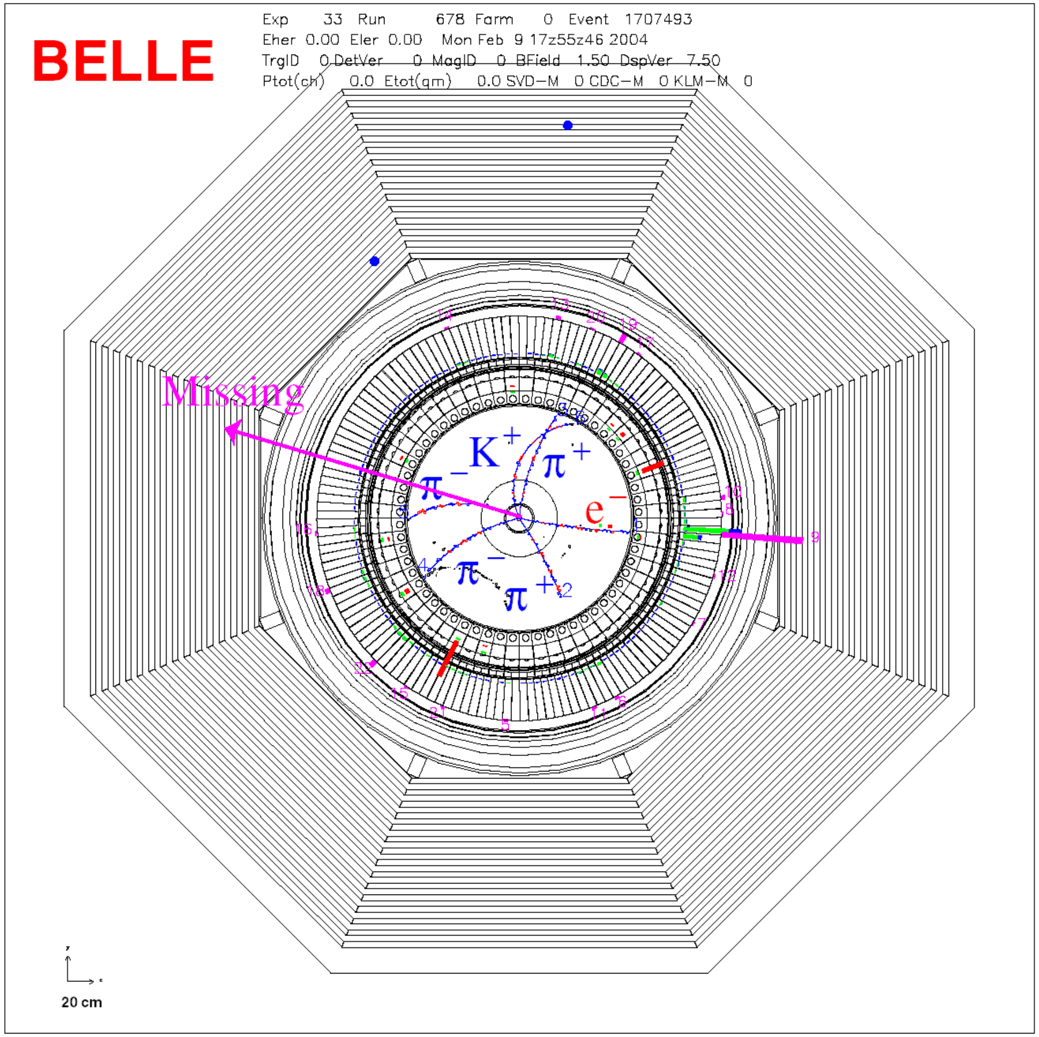


→ Offline B meson beam!

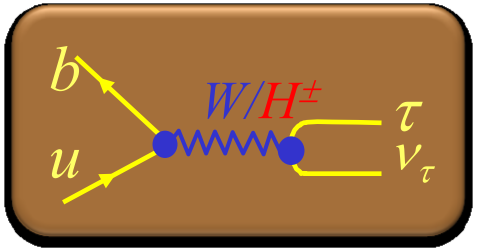
Powerful tool for B decays with neutrinos

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

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

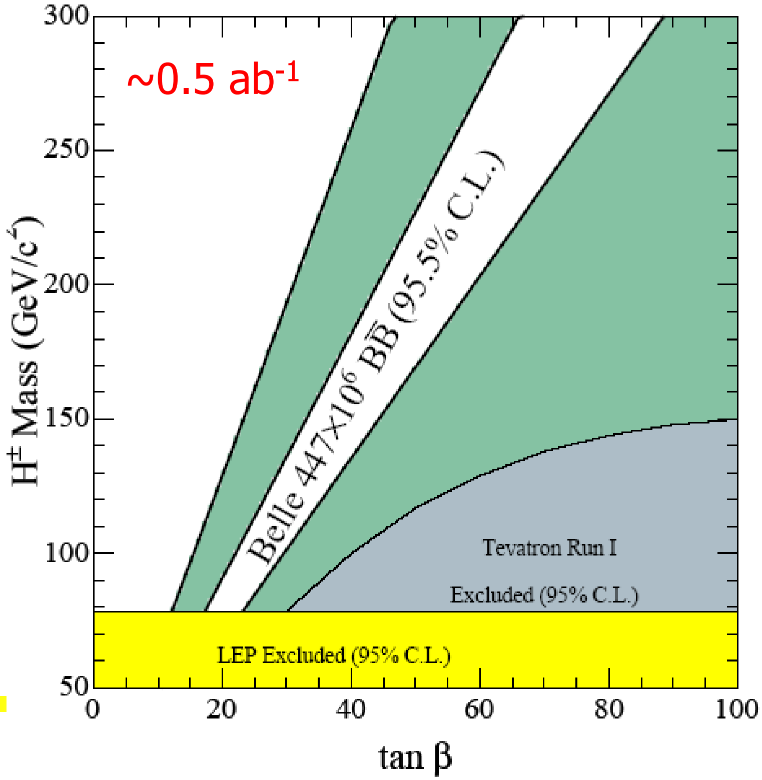


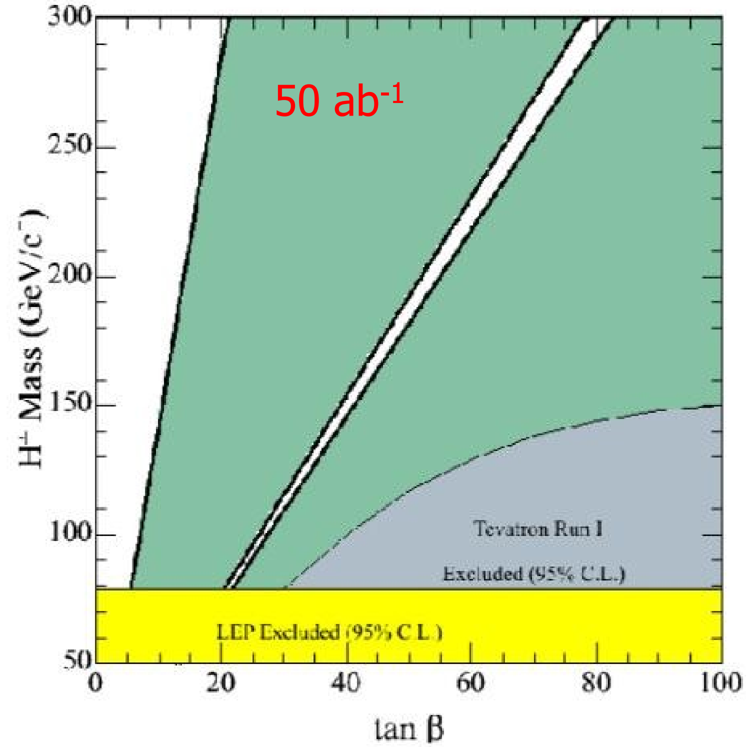
Charged Higgs limits from $B^- \to \tau^- \nu_\tau$



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

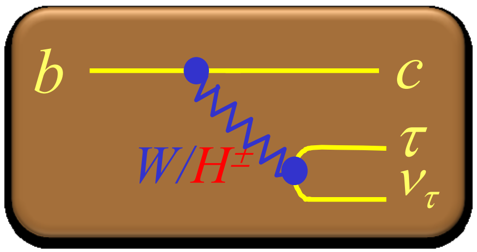
→ limit on charged Higgs mass vs. tanβ





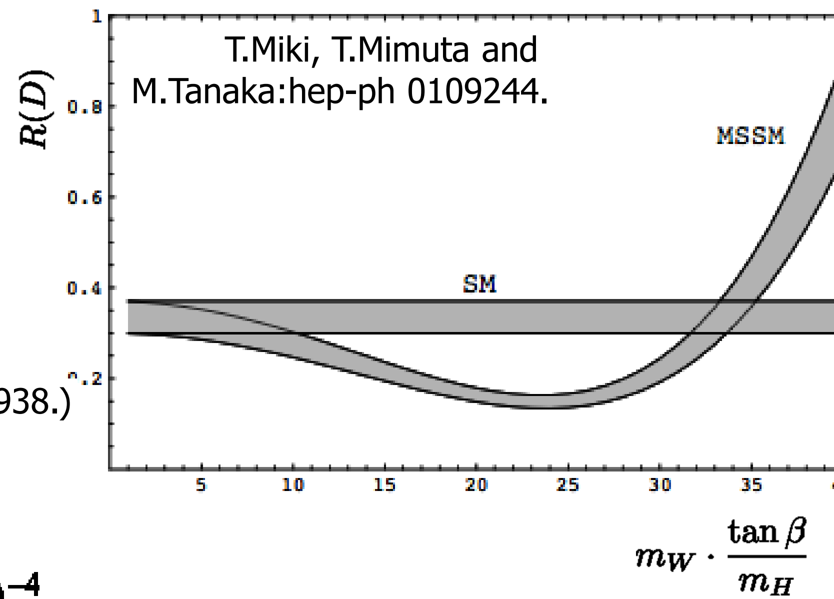
B→D$^{(*)}$τν

Semileptonic decay sensitive to charged Higgs



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

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



Compared to B→τν

1.Smaller theoretical uncertainty of R(D)

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

2.Large expected Br (Ulrich Nierste arXiv:0801.4938.)

$$\mathcal{B}(B^- \to D^0\tau^-\bar{\nu}_\tau)^{SM} = (0.71 \pm 0.09)\%$$

$$\mathcal{B}(\bar{B}^0 \to D^+\tau^-\bar{\nu}_\tau)^{SM} = (0.66 \pm 0.08)\%$$

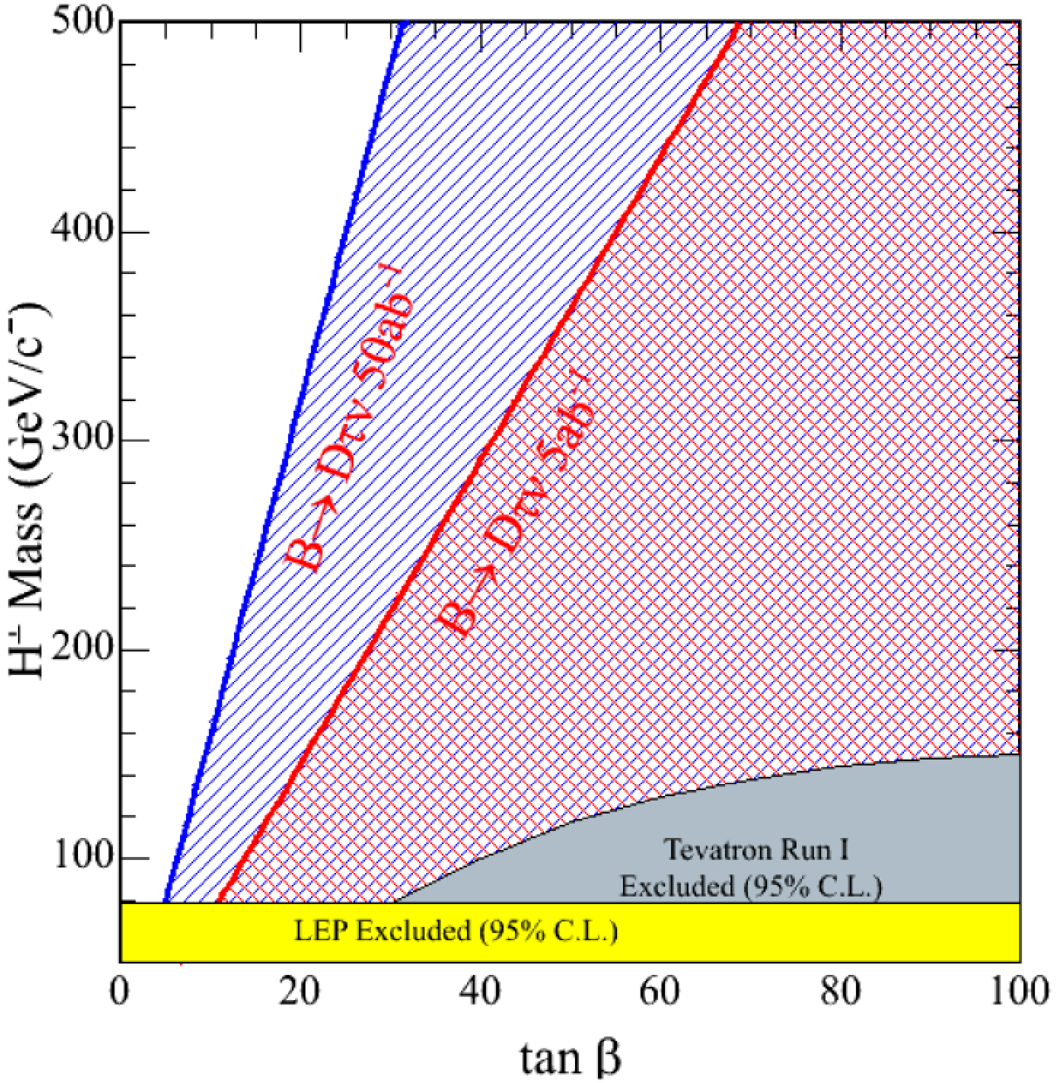
$$\mathcal{B}(B \to \tau\nu) = [1.65^{+0.38}_{-0.37}(stat)^{+0.35}_{-0.37}(syst)]\times 10^{-4}$$

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)

B→Dτν

Exclusion plots for
tanβ and H⁺ mass
for 5ab⁻¹ and 50ab⁻¹



B→D*τν – similar constraints on H⁺

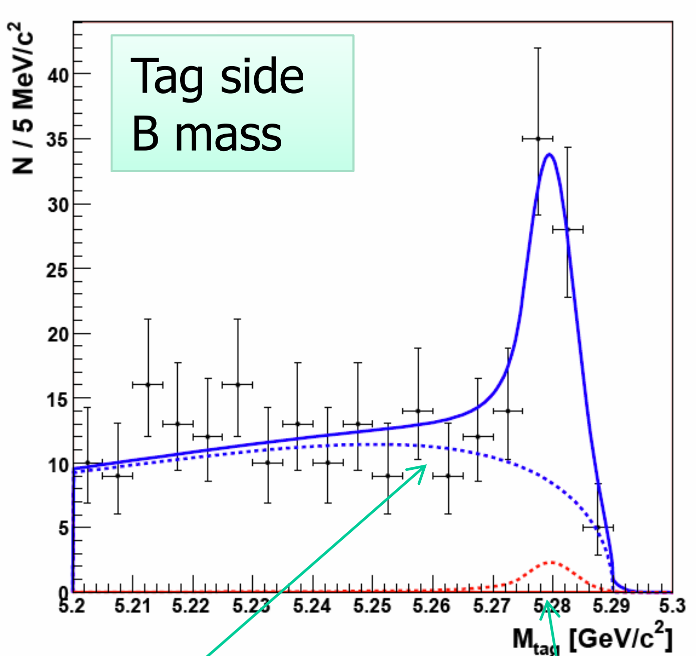
[PRL 99, 191807 (2007)]

535M $B\bar{B}$

FIRST OBSERVATION - 2007

$$BF(B^0 \to D^{*-}\tau^+\nu_\tau) = (2.02\,^{+0.40}_{-0.37}(stat) \pm 0.37(syst)) \times 10^{-2}$$

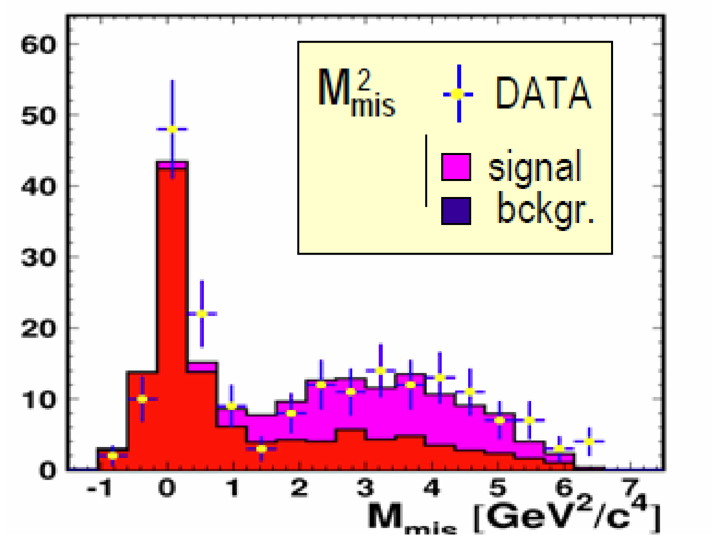
SIGNAL YIELD $N_s = 60\,^{+12}_{-11}$ 6.7σ (5.2σ with syst.)



combinatorial background

peaking background (D*⁻eν)

$$M^2_{mis} = (E_b - E_{D^{(*)}} - E_{l/h})^2 - (-\vec{p}_{tag} - \vec{p}_{D^{(*)}} - \vec{p}_{l/h})^2$$



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

arXiv:1002.5012

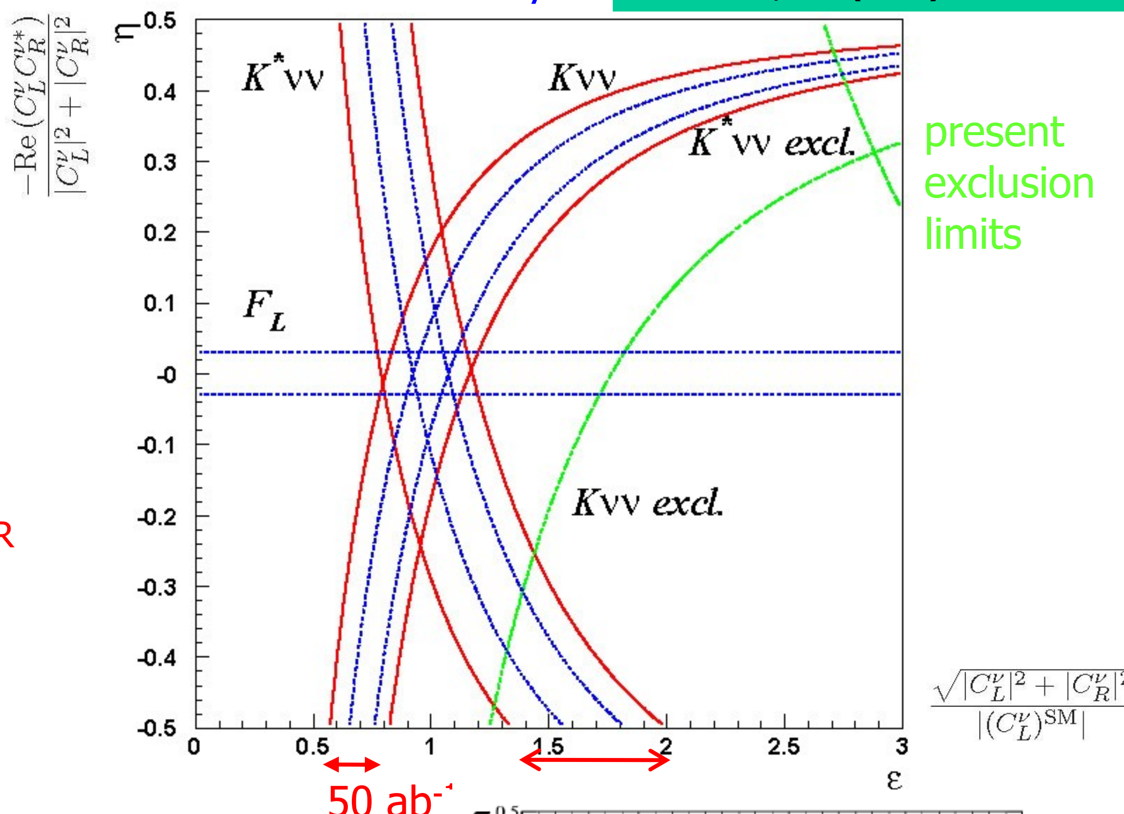
adopted from W. Altmannshofer et al., JHEP 0904, 022 (2009)

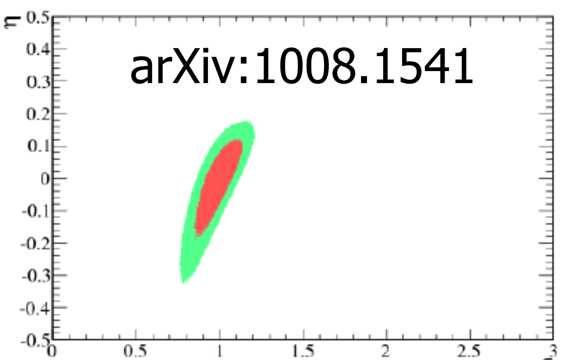
$B \to K\nu\nu$, $\mathcal{B} \sim 4 \cdot 10^{-6}$
$B \to K^*\nu\nu$, $\mathcal{B} \sim 6.8 \cdot 10^{-6}$

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 (+nothing else) in the rest of the event.





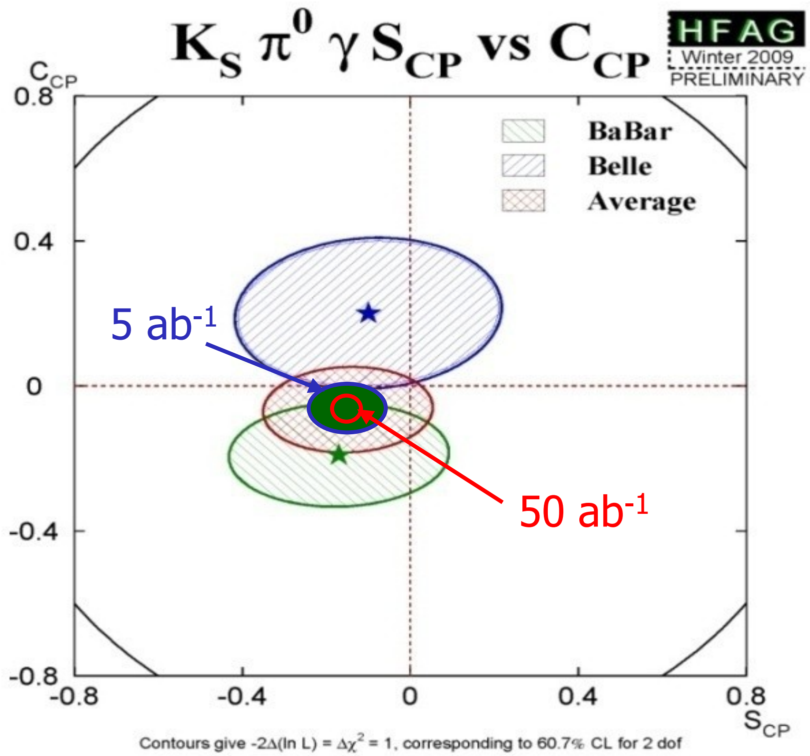
not possible @ LHCb

CP violation in B→$K_S\pi^0\gamma$

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

$B \to K^*\gamma$, $\mathcal{B}$ ~ $4.0\cdot10^{-5}$

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



adopted from HFAG

not possible @ LHCb

Charm mixing: expected sensitivities

Mixing parameters

HFAG χ^2 fit

Belle II, 50 ab^{-1}

$$x = (0.832 \pm 0.095)\%$$

$$y = (0.813 \pm 0.064)\%$$

$$\delta_{K\pi} = 24.6° \pm 4.9°$$

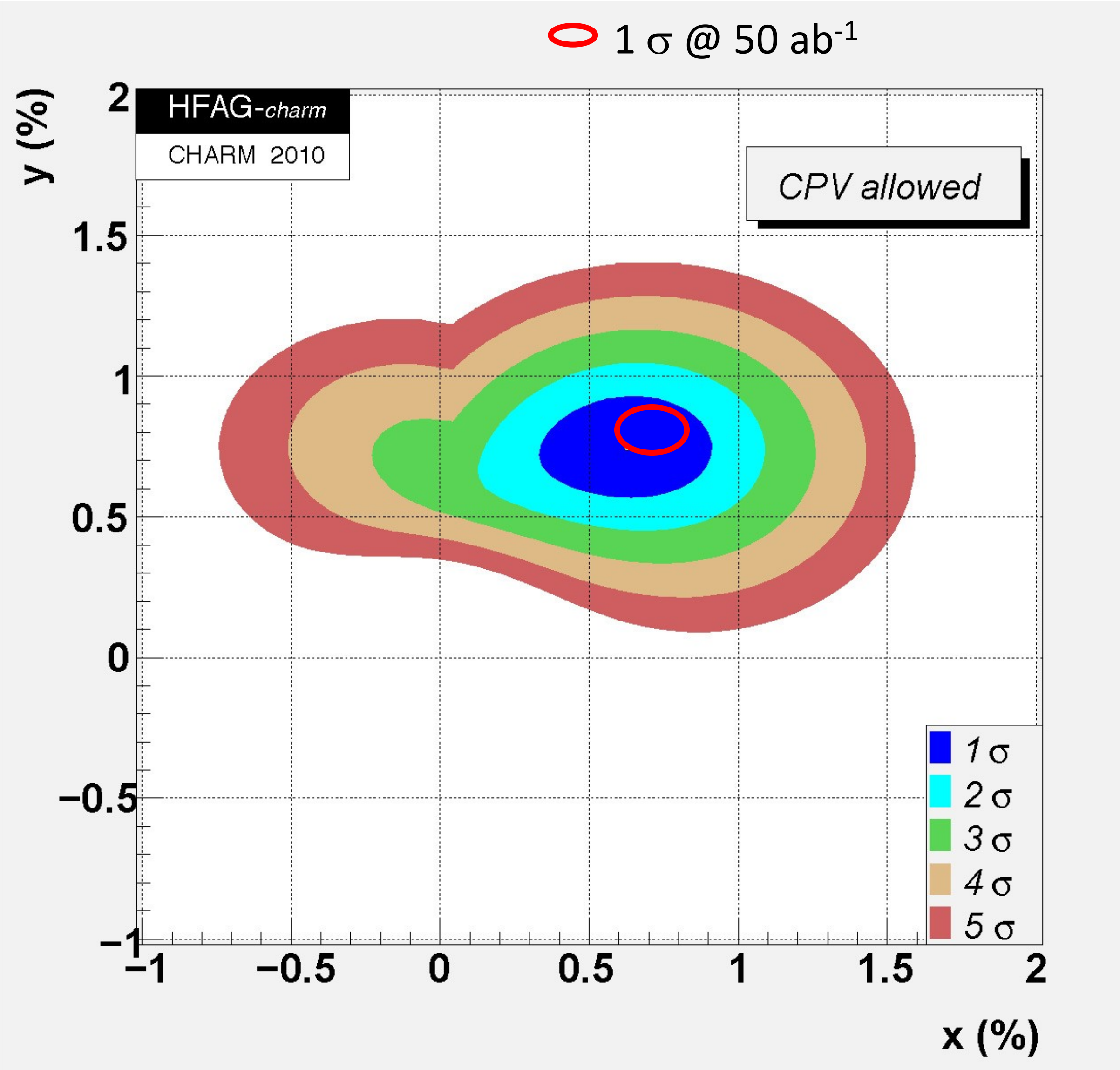
$$R_D = (0.336 \pm 0.003)\%$$

$$\frac{|q|}{|p|} = 0.894 \pm 0.054$$

$$\varphi = -0.004 \pm 0.049 \ rad$$

$$A_D = (-0.1 \pm 0.8)\%$$

only KK/ππ, Kπ and $K_s\pi\pi$ projected sensitivities included



Charm: expected sensitivities

CPV parameters

Belle II, 50 ab^{-1}

$$x = (0.832 \pm 0.095)\%$$

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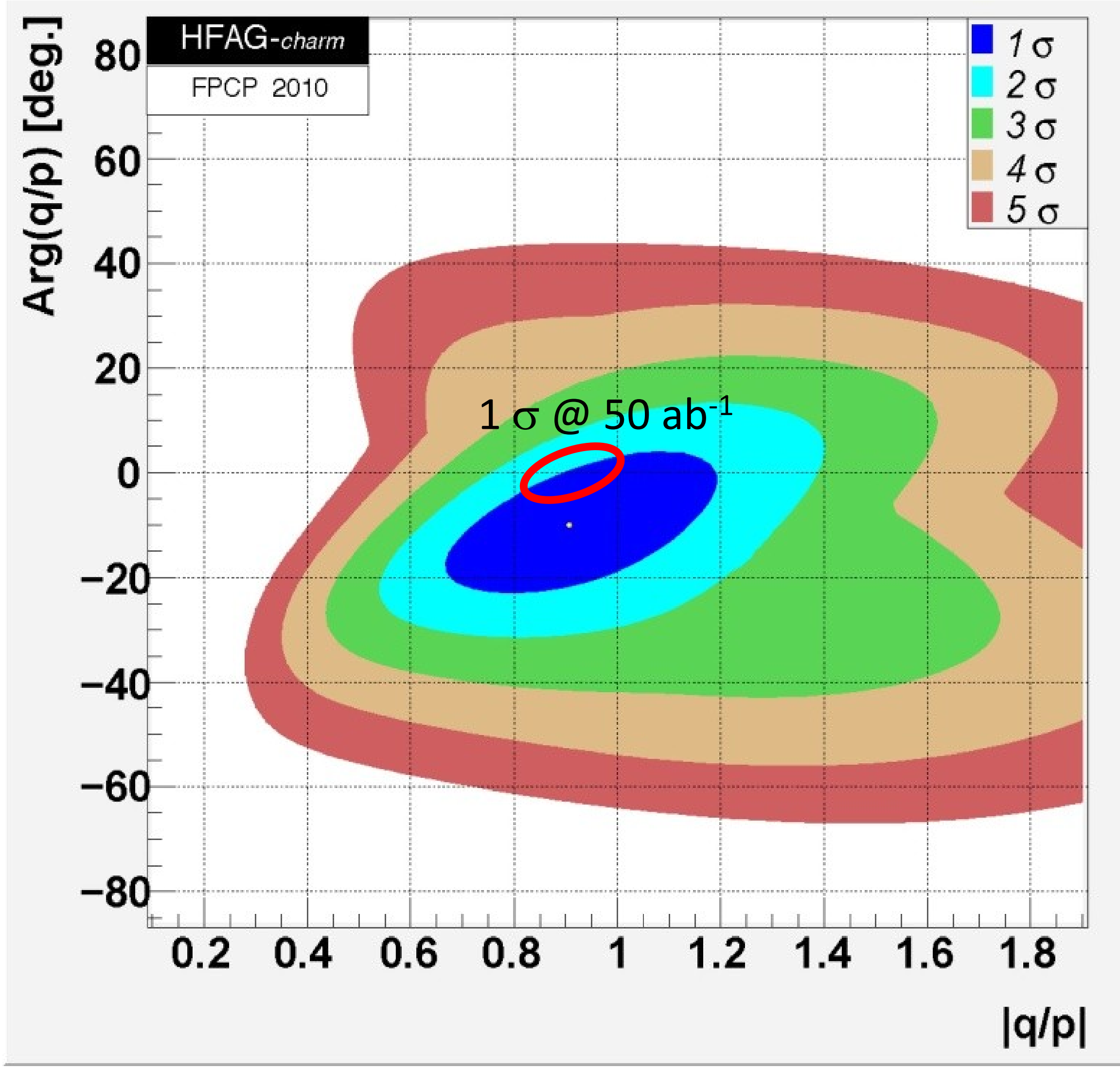
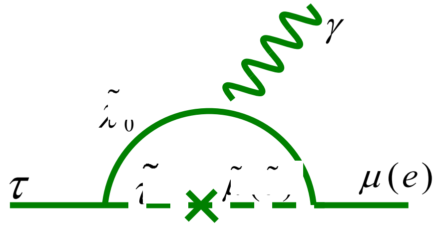


τ physics: LFV and New Physics

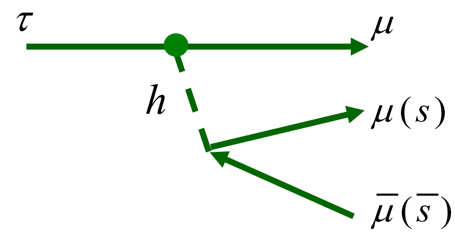
τ→lγ



- SUSY + Seasaw
- Large LFV Br(τ→μγ)=O(10$^{-7\sim9}$)

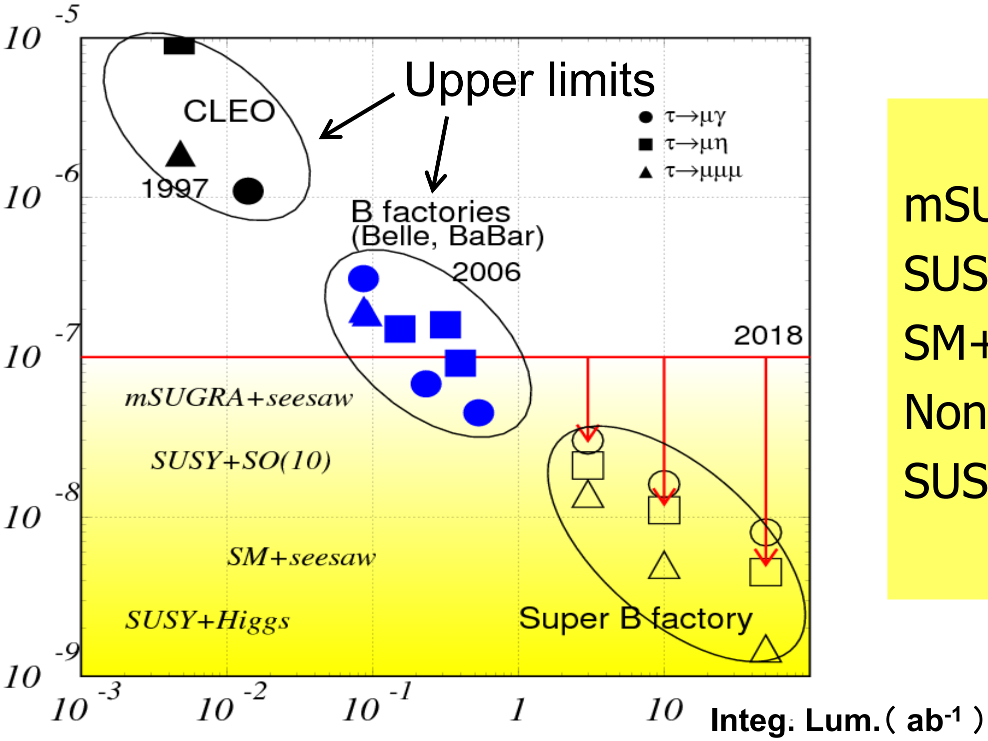
$$Br(\tau \to \mu\gamma) \simeq \left(\frac{(m^2_{\tilde{L}})_{32}}{\bar{m}^2_{\tilde{L}}}\right)^2 \left(\frac{1\,TeV}{m_{SUSY}}\right)^4 \tan^2\beta$$

τ→3l,lη



- Neutral Higgs mediated decay.
- Important when MSUSY >> EW scale.

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



model	Br(τ→μγ)	Br(τ→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})	Super$B$ (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 (∗)
$S(K^0_S K^0_S K^0_S)$	0.15	0.02 (∗)
$S(K^0_S \pi^0)$	0.15	0.02 (∗)
$S(\omega K^0_S)$	0.17	0.03 (∗)
$S(f_0 K^0_S)$	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° (∗)
$2\beta+\gamma$ $(D^{(*)\pm}\pi^\mp,\ D^\pm K^0_S\pi^\mp)$	20°	5°

Observable	B Factories (2 ab^{-1})	Super$B$ (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 (†)
$S(K^0_S\pi^0\gamma)$	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

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}	
$D^0\to K^0_S\pi^+\pi^-$	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

Mode	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}
$D^0\to K^0_S e^+e^-$, $D^0\to K^0_S\mu^+\mu^-$	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}
$D^0\to K^0_S e^\pm\mu^\mp$	3×10^{-8}
$D^+\to\pi^-e^+e^+$, $D^+\to K^-e^+e^+$	1×10^{-8}
$D^+\to\pi^-\mu^+\mu^+$, $D^+\to K^-\mu^+\mu^+$	1×10^{-8}
$D^+\to\pi^-e^\pm\mu^\mp$, $D^+\to K^-e^\pm\mu^\mp$	1×10^{-8}

τ Physics

Mode	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}
$\mathcal{B}(\tau\to e\eta)$	6×10^{-10}
$\mathcal{B}(\tau\to\ell K^0_S)$	2×10^{-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^s_{SL}	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%
β_s from $J/\psi\phi$	10°	3°
β_s from $B_s\to K^0\bar K^0$	24°	11°

M. Giorgi, ICHEP2010

Physics with 50ab^{-1} / 75ab^{-1}

→Two publications:

- Physics at Super B Factory (Belle II authors + guests)

hep-ex > arXiv:1002.5012

- SuperB Progress Reports: Physics (SuperB authors + guests)

hep-ex > arXiv:1008.1541

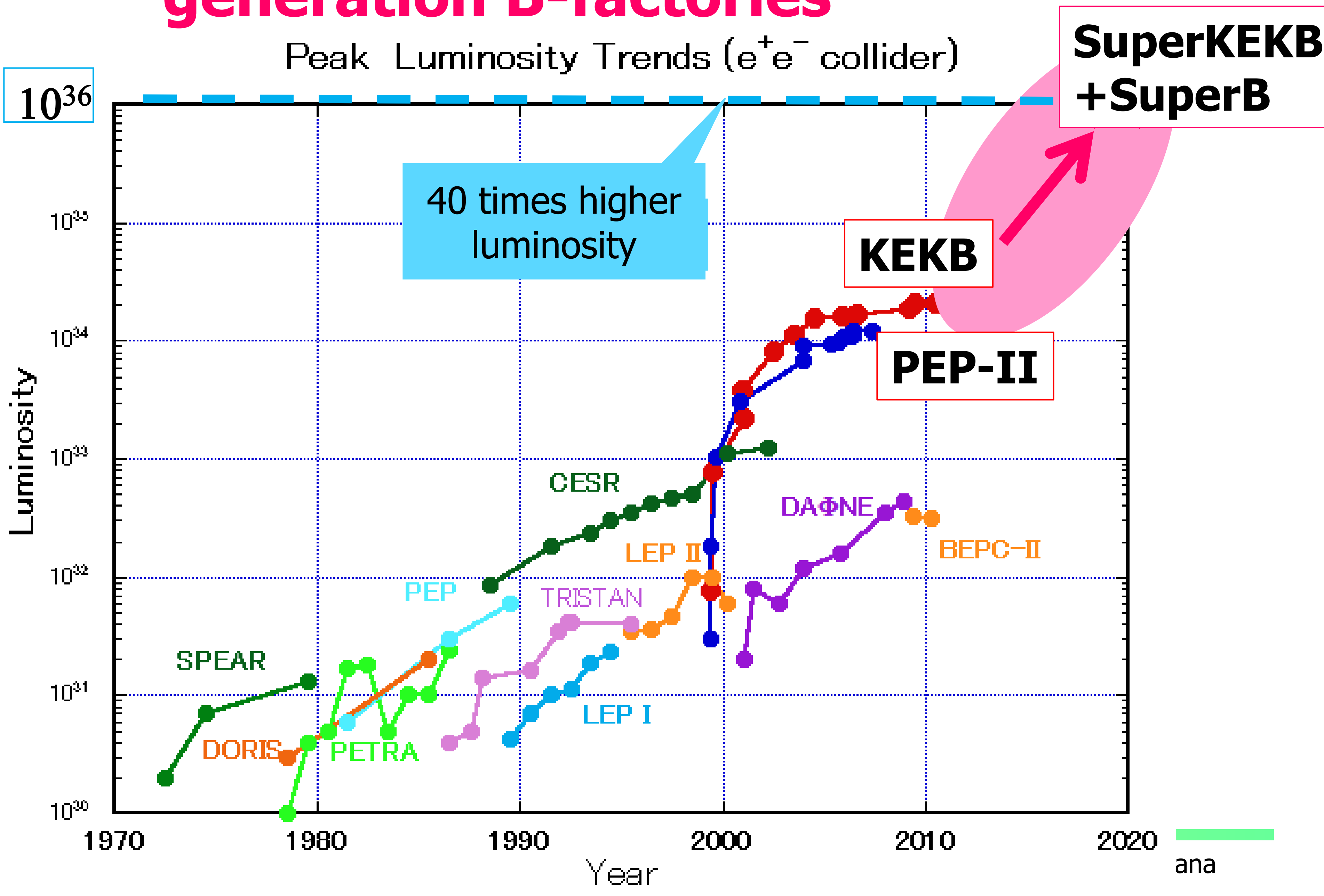
Physics at a Super B Factory

- 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).

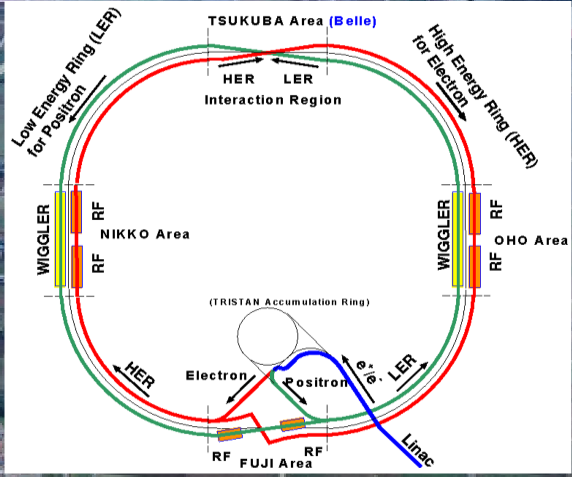
There are many more topics: CPV in charm, new hadrons, …

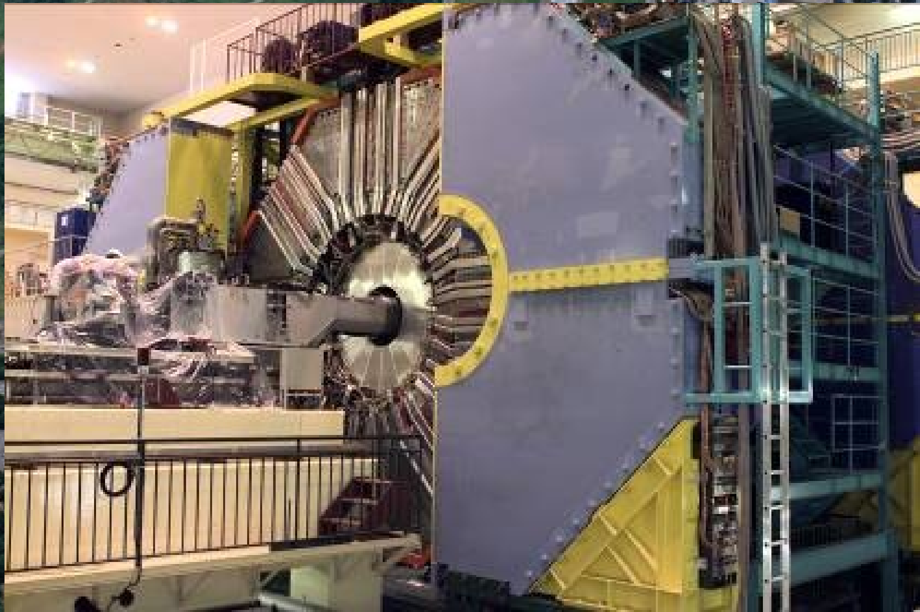
Accelerators

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

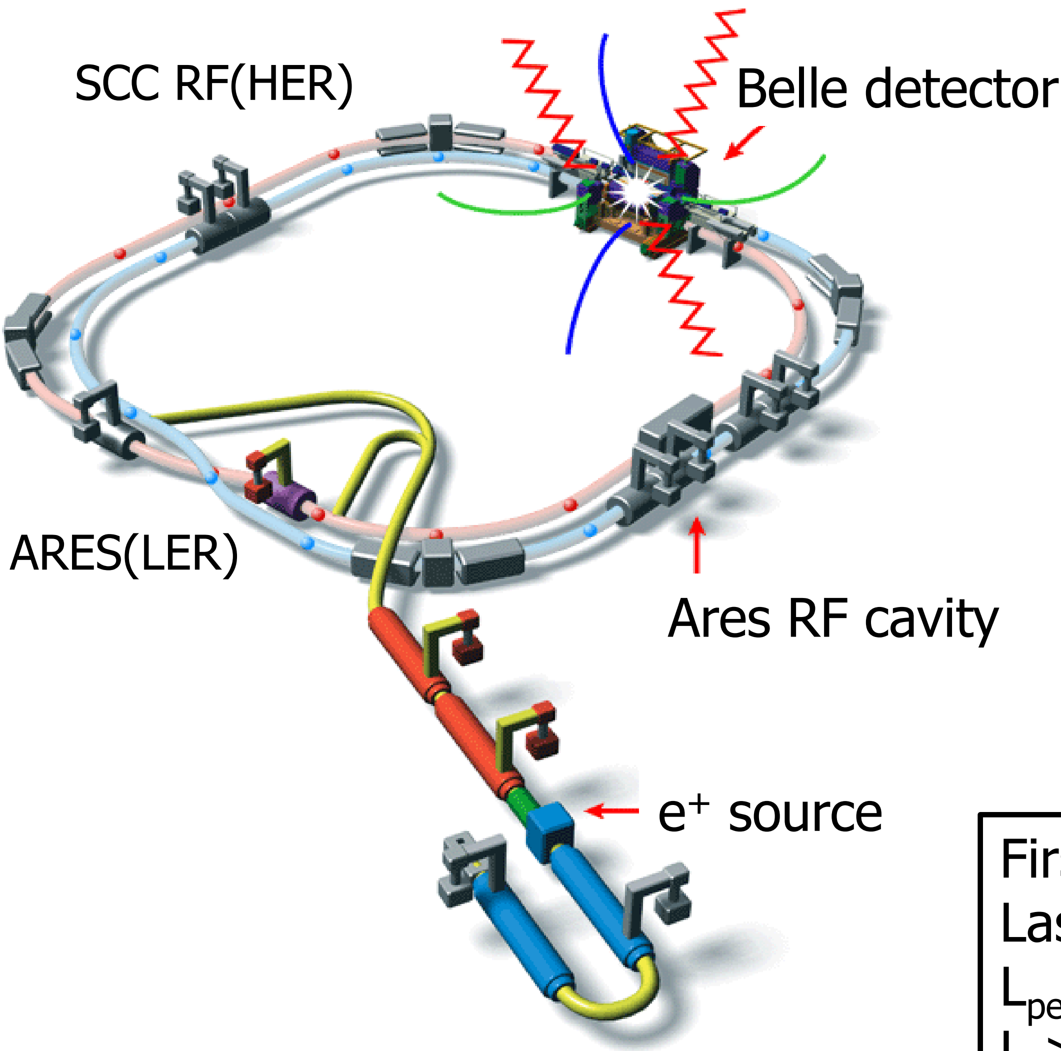


How to do it?
→ upgrade KEKB and Belle





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!) :

2.1×10^{34} cm^{-2}s^{-1}

=2x design value

First physics run on June 2, 1999
Last physics run on June 30, 2010
$L_{peak} = 2.1\times10^{34}/cm^2/s$
$L > 1ab^{-1}$

The last beam abort of KEKB on June 30, 2010

→ Can start construction of SuperKEKB and Belle II

Strategies for increasing luminosity

Super KEKB Quest for BSM

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

Lorentz factor

Beam current

Beam-beam parameter

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

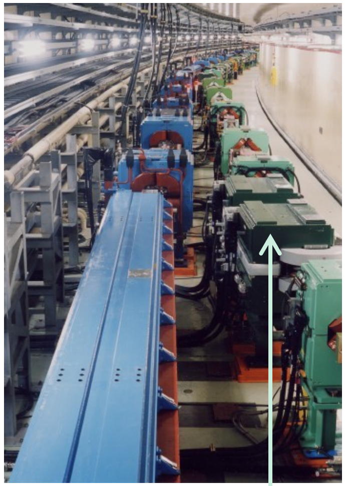
Invented by Pantaleo Raimondi for SuperB

Machine design parameters

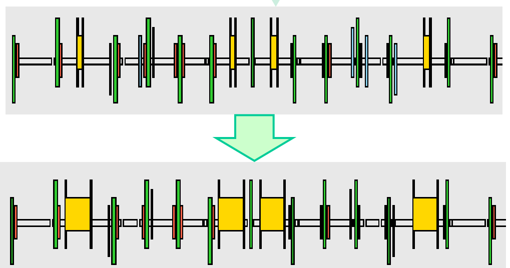
parameters		KEKB		SuperKEKB		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	5.0	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	3.60	2.60	A
beam-beam parameter	ξ_y	0.129	0.090	0.0886	0.0830	
Luminosity	**L**	**2.1×10^{34}**		**8×10^{35}**		$cm^{-2}s^{-1}$

- **Small beam size & high current** to increase luminosity
- **Large crossing angle**
- **Change beam energies** to solve the problem of LER short lifetime

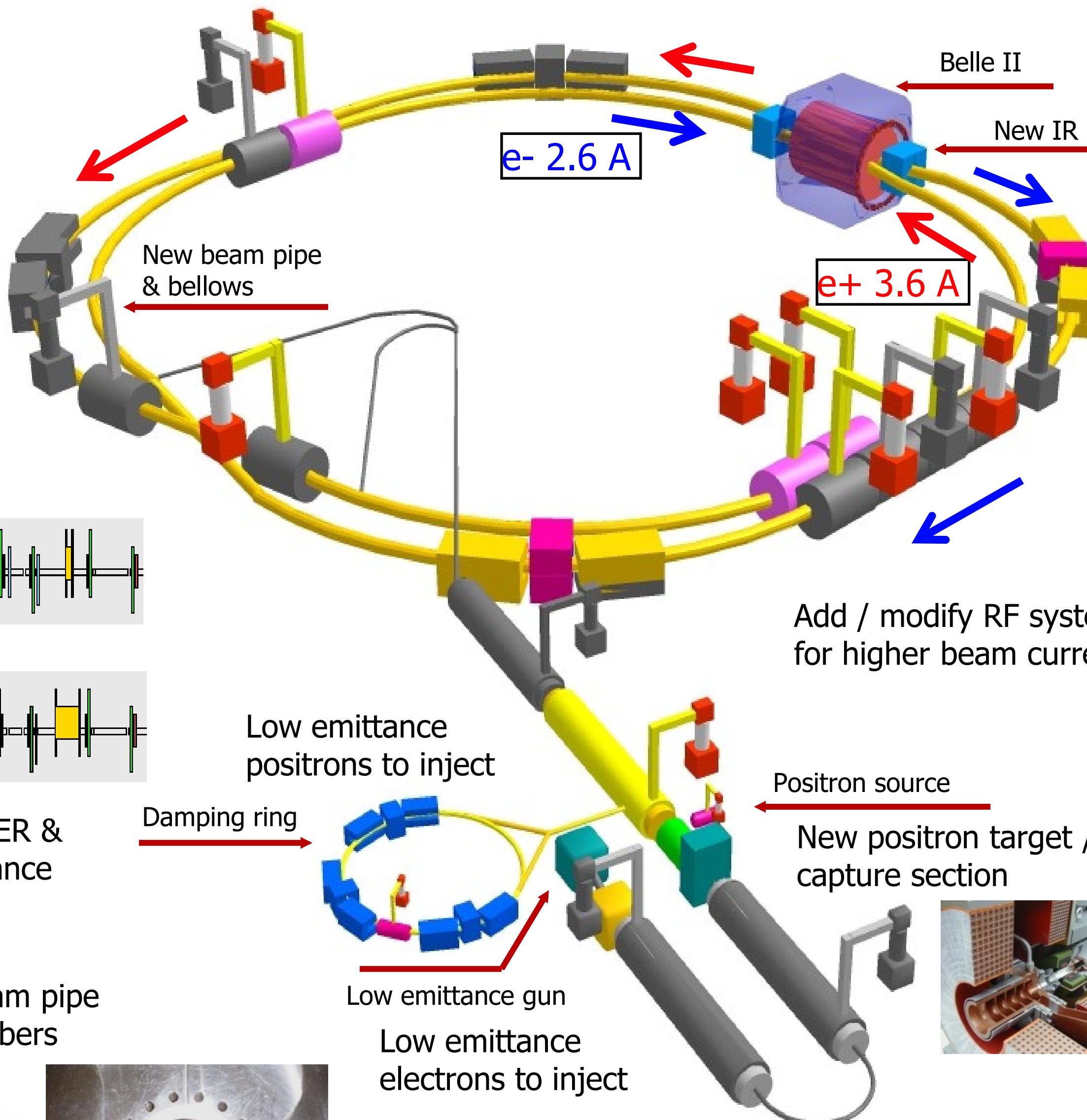
KEKB to SuperKEKB



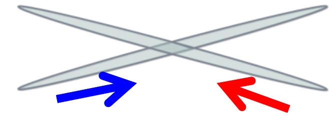
Replace short dipoles with longer ones (LER)



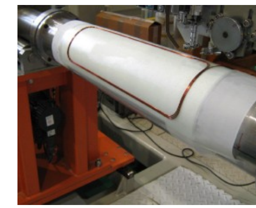
Redesign the lattices of HER & LER to squeeze the emittance



Colliding bunches



New superconducting /permanent final focusing quads near the IP



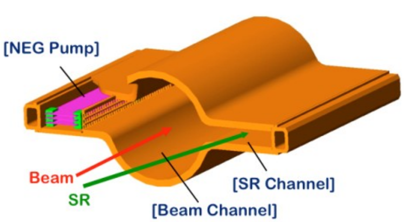
Add / modify RF systems for higher beam current

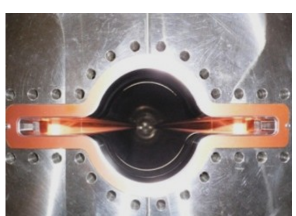
Low emittance positrons to inject

New positron target / capture section

Low emittance electrons to inject

TiN-coated beam pipe with antechambers





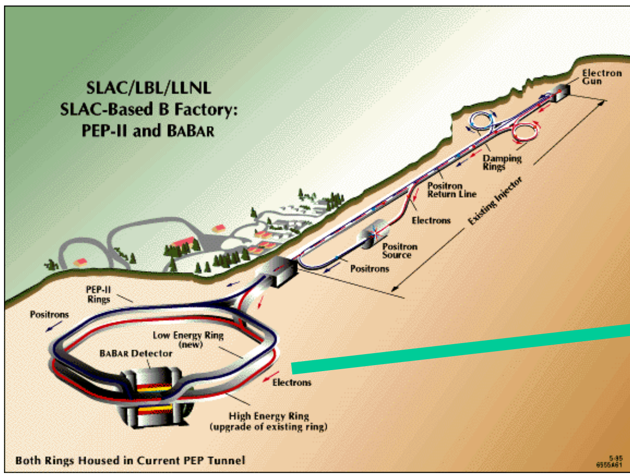
To get x40 higher luminosity

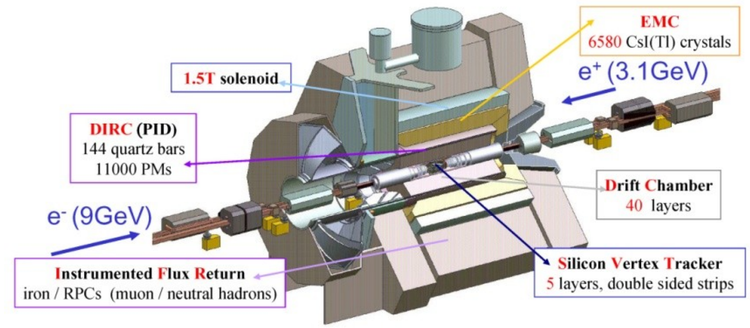
How to do it? (2)

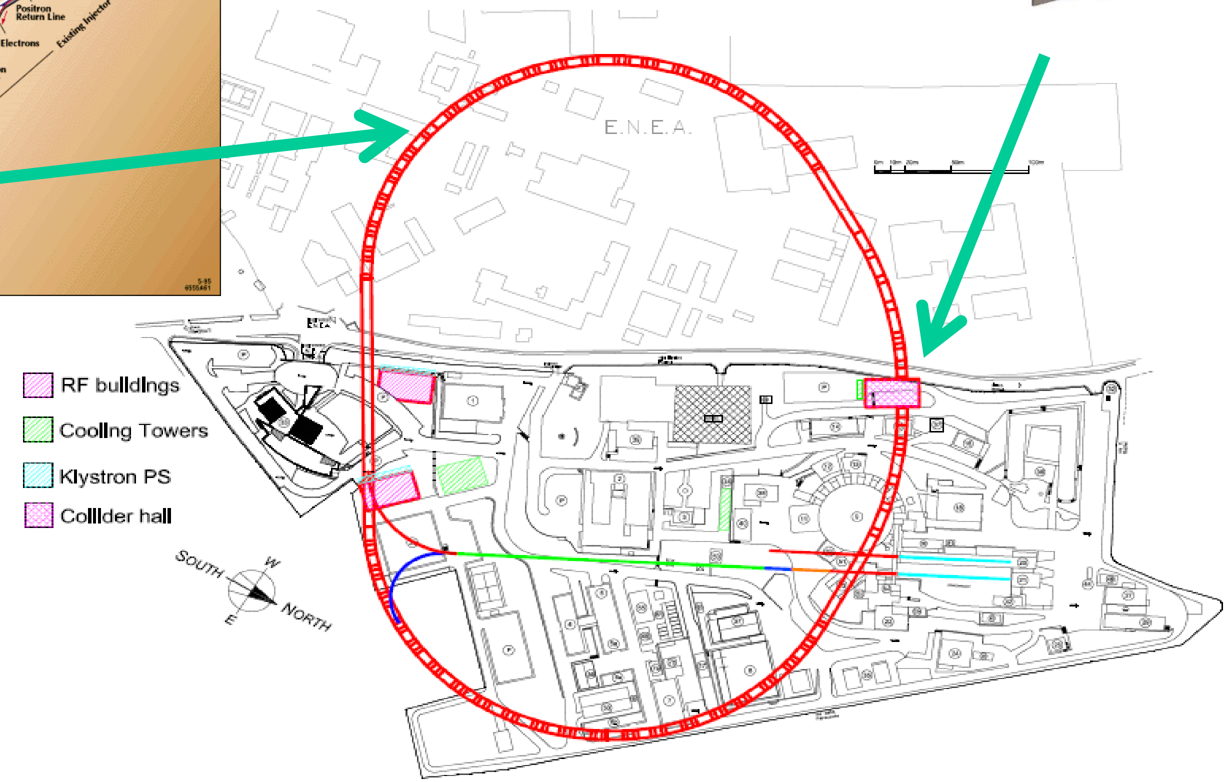
→ Construct a new tunnel in Italy

→ Move magnets from PEP-II

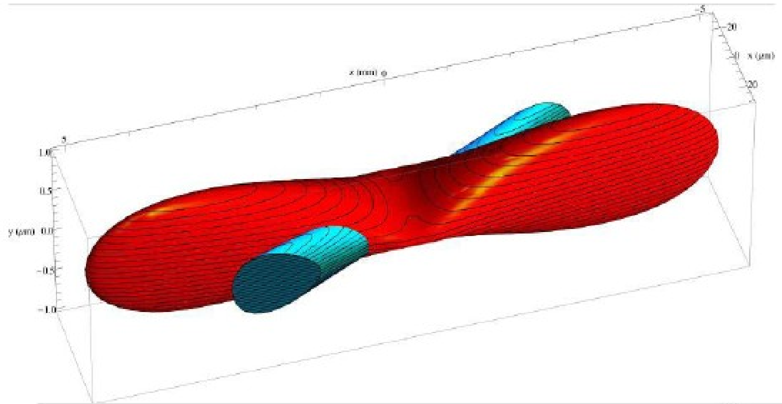
→ Move BaBar, upgrade



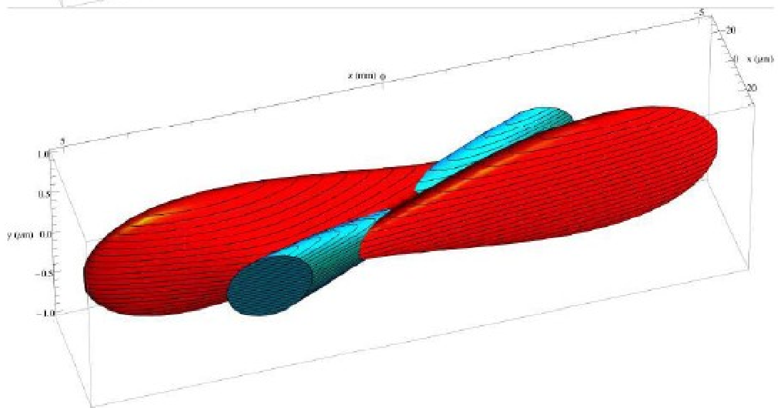




Nano-beam collisions with crab waist



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	5.099	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

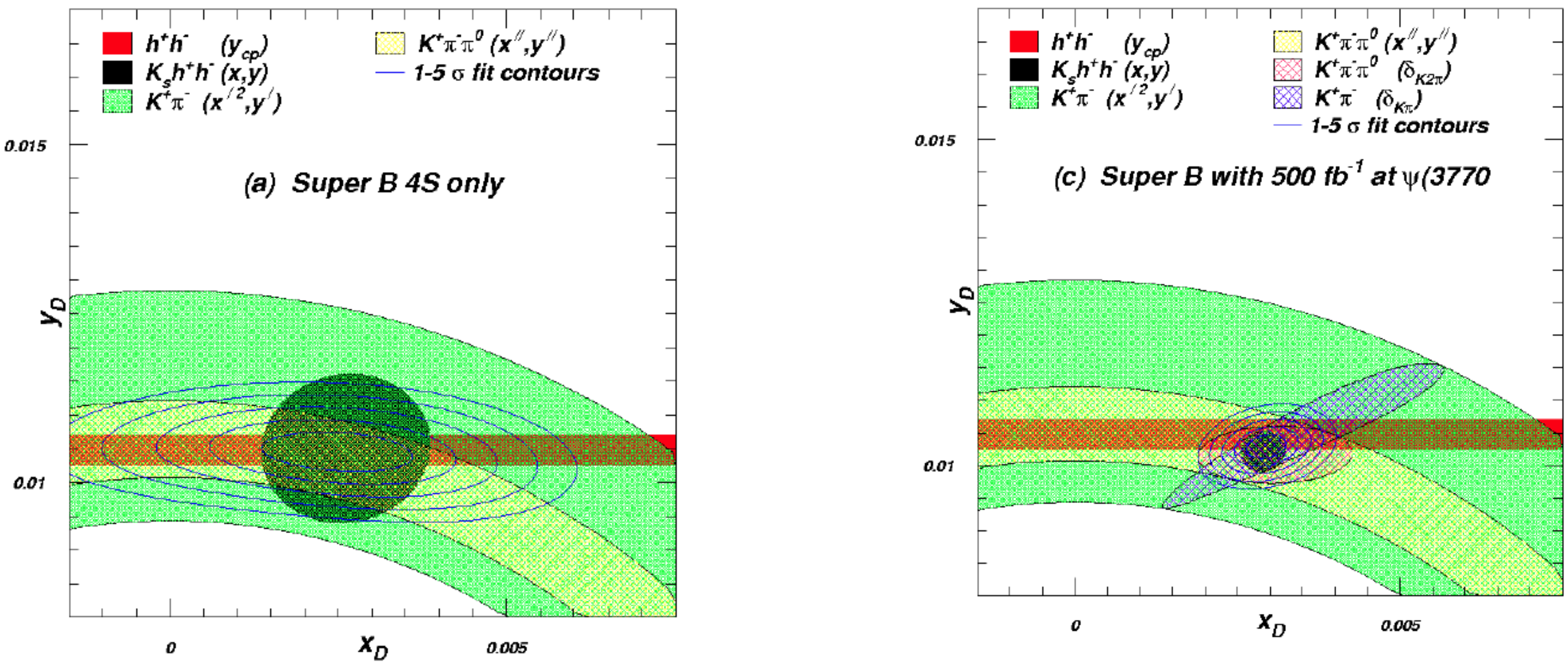
RF power includes SR and HOM

M. Giorgi, ICHEP2010

Interest of running at charm threshold

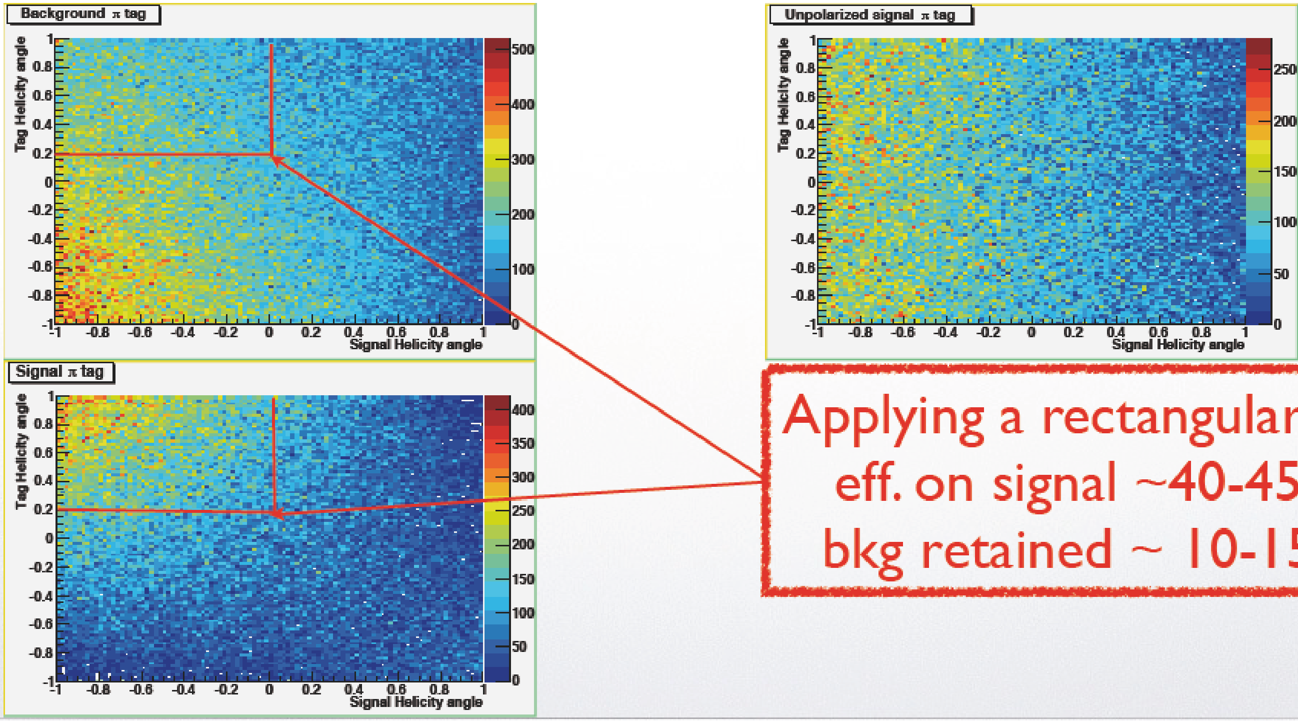
Decays of $\psi(3770) \rightarrow D^0\bar{D}^0$ produce coherent $(C=-1)$ pairs of D^0's.

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



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

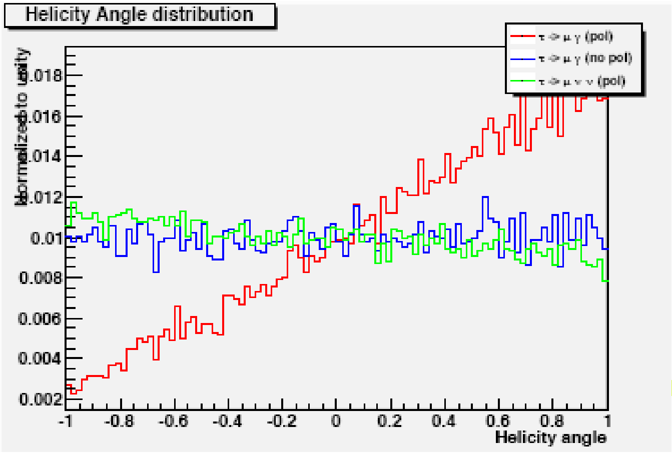
Polarized beam helps to reduce irreducible background in tau decays (e.g. $\tau \to \mu\gamma$)



75 ab^{-1}

arXiv:1008.1541v1 [hep-ex]

Applying a rectangular cut
eff. on signal ~40-45%
bkg retained ~ 10-15%

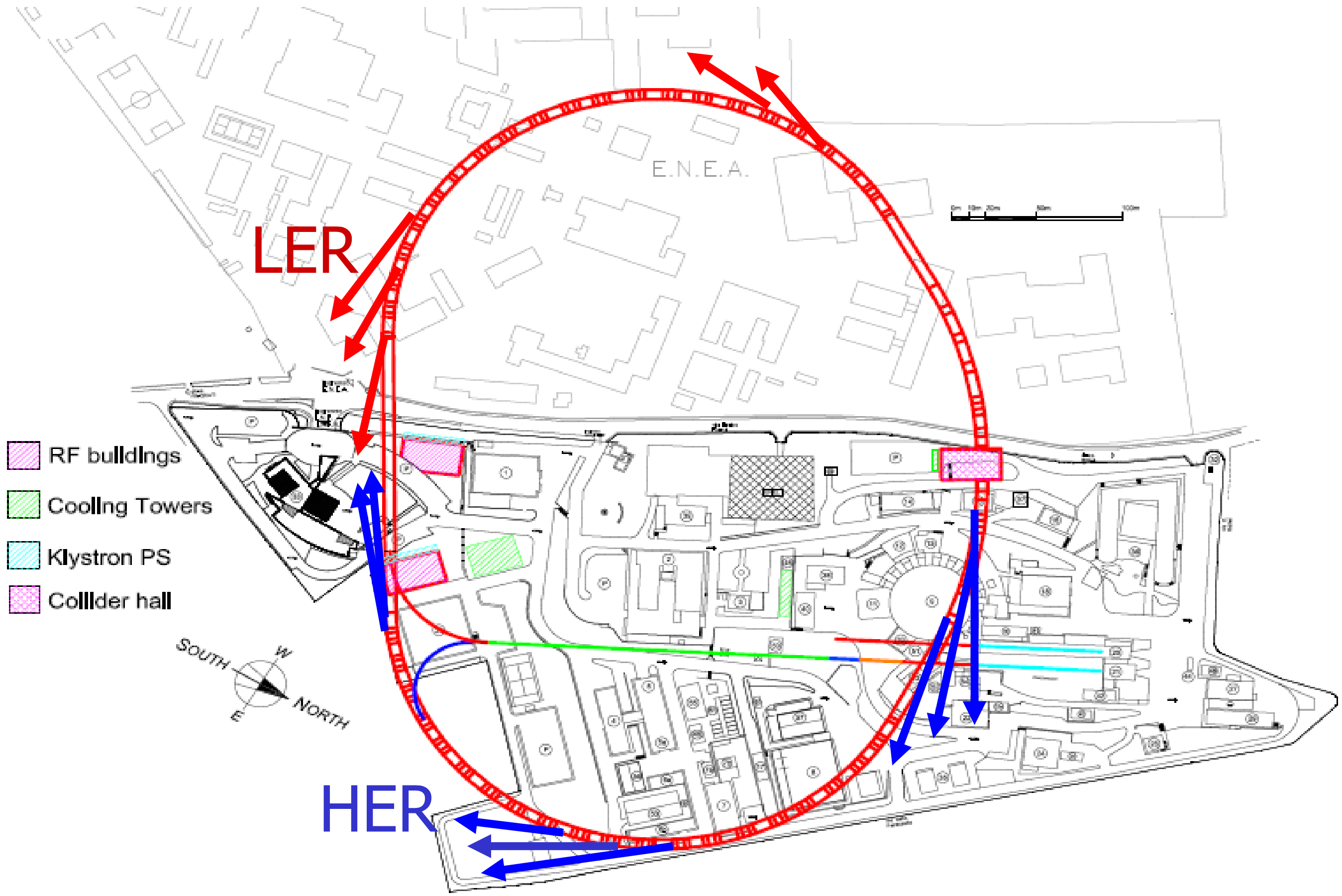


Before		After	
$B(\tau\to\mu\gamma)$	$2\ 10^{-9}$	$B(\tau\to\mu\gamma)$	$1\ 10^{-9}$
$B(\tau\to e\gamma)$	$2\ 10^{-9}$	$B(\tau\to e\gamma)$	$1\ 10^{-9}$

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

M. Giorgi, ICHEP2010

Machine layout



Polarization (80%) is understood and feasible.
Parameter flexibility allows 10^{36} peak lumi without stressing limits!

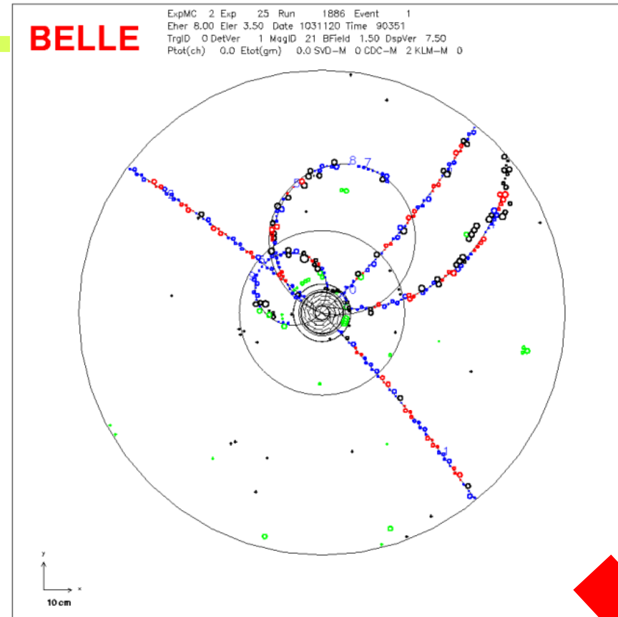
The operation of synchrotron lines and HEP operation seem to be compatible within the same machine.

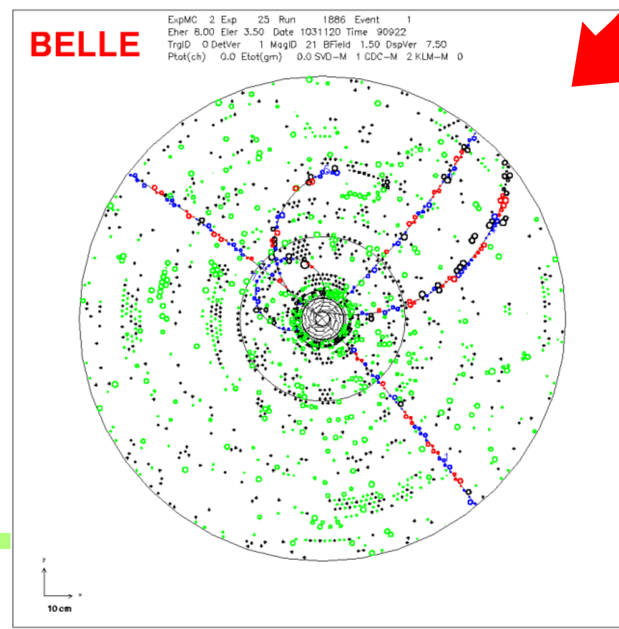
Detectors

Requirements for the Belle II detector

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"

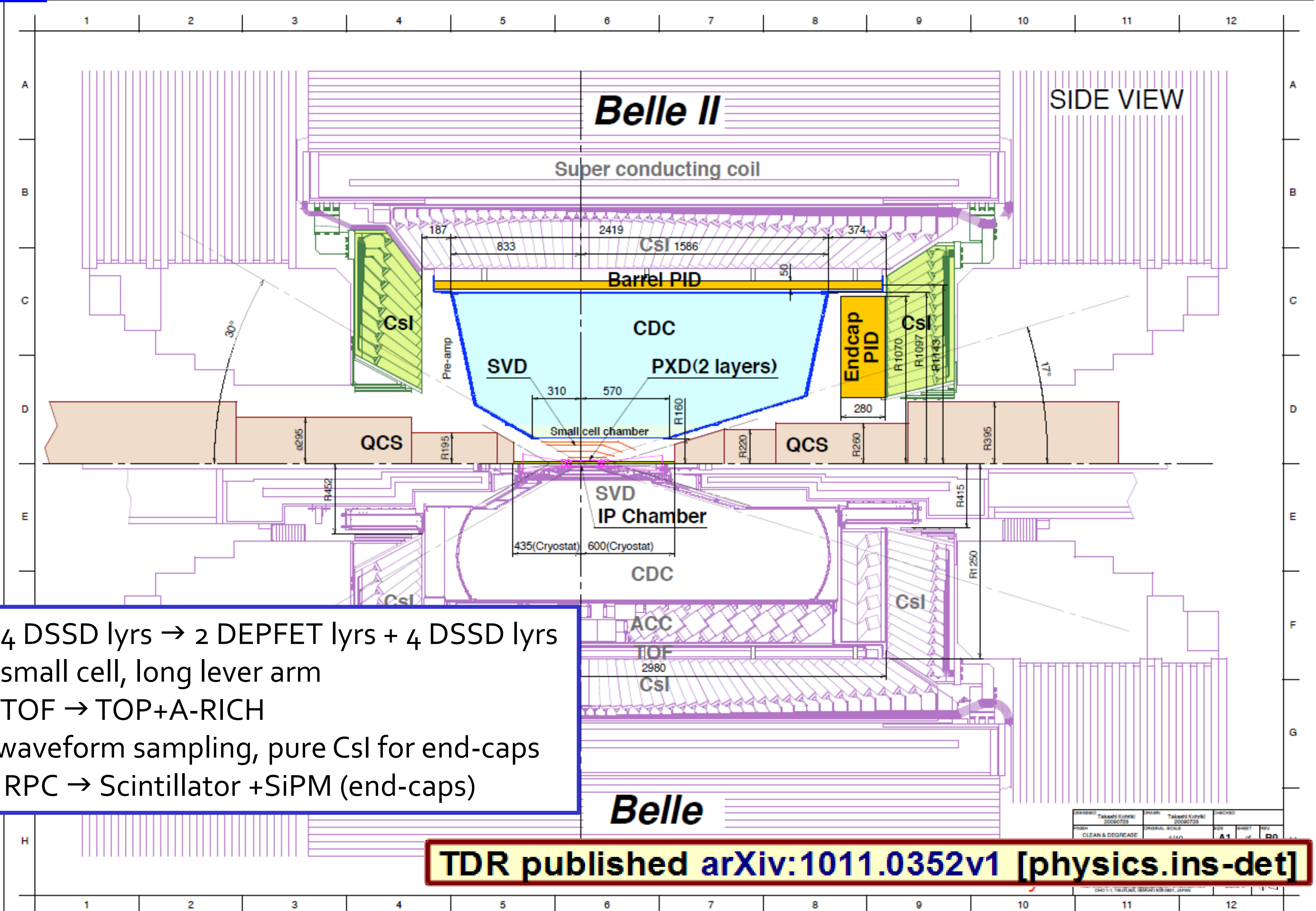




Solutions:
- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter crystals
- Faster readout electronics and computing system.

Very similar reasoning also for SuperB

Belle II in comparison with Belle

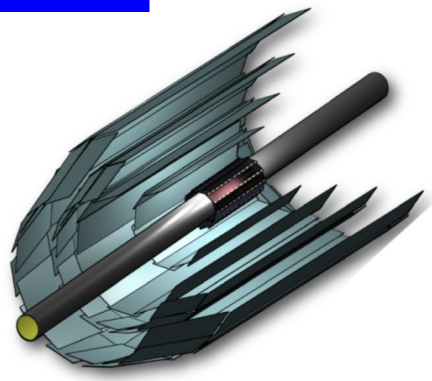


SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +SiPM (end-caps)

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

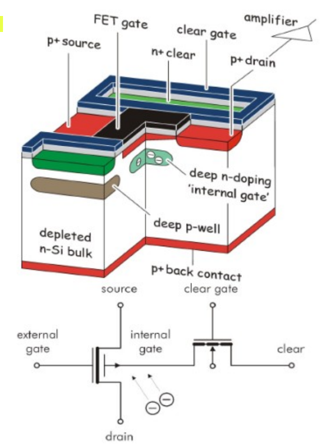
Vertex Detector

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

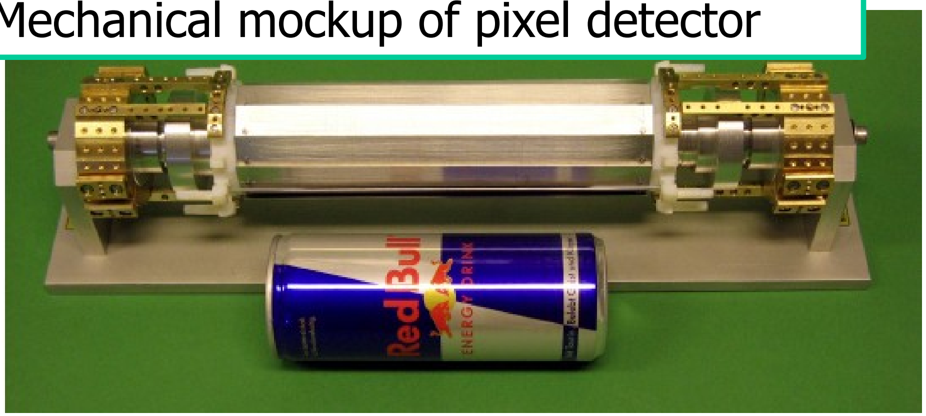


Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

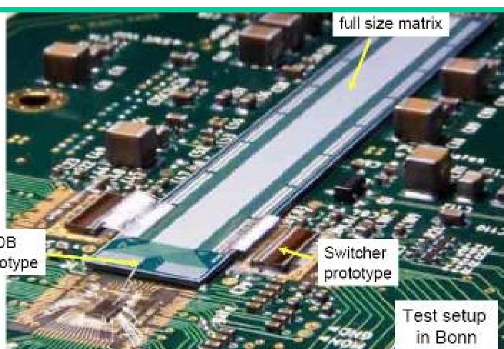
DEpleted P-channel FET

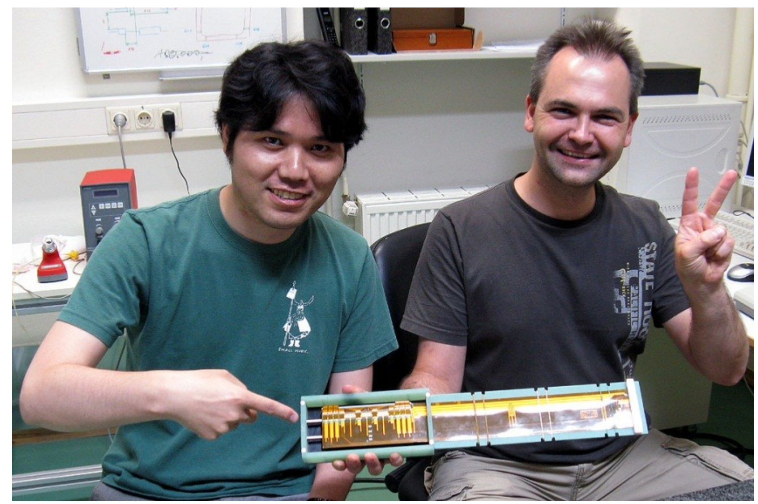


Mechanical mockup of pixel detector



Prototype DEPFET pixel sensor and readout



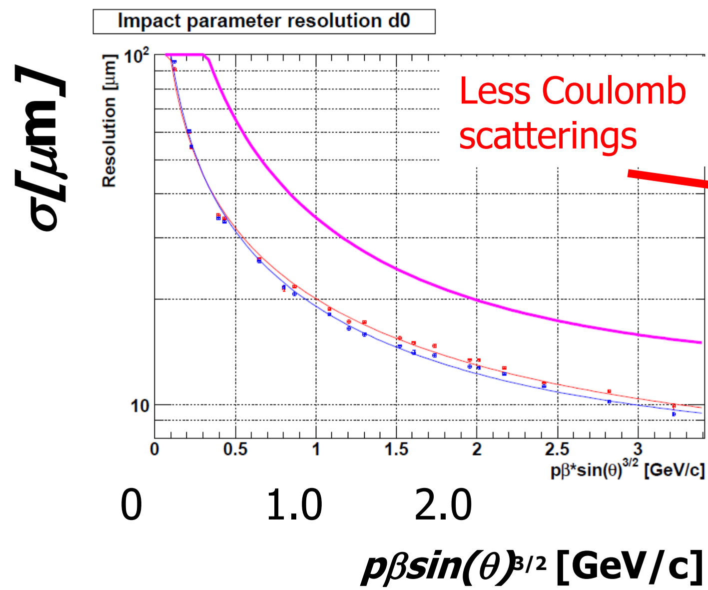


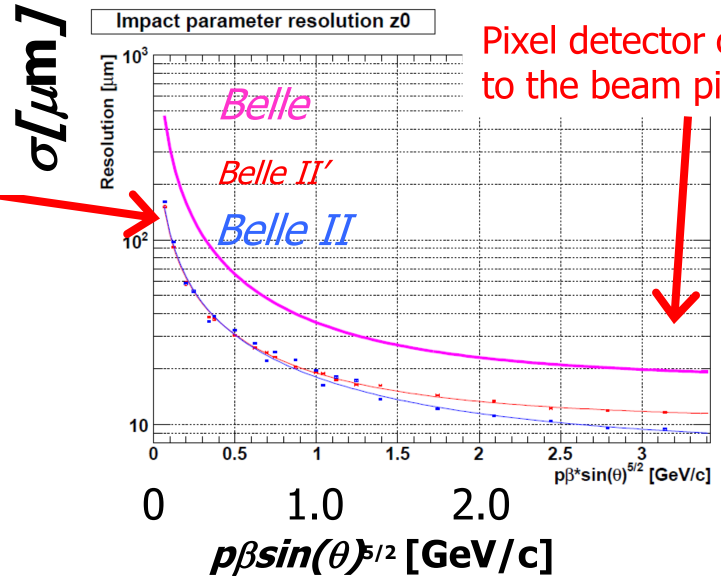
A prototype ladder using the first 6 inch DSSD from Hamamatsu has been assembled and tested.

Expected performance

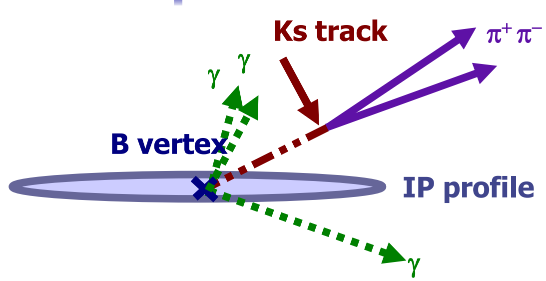
$$\sigma = a + \frac{b}{p\beta \sin^{\nu}\theta}$$

Significant improvement in IP resolution!

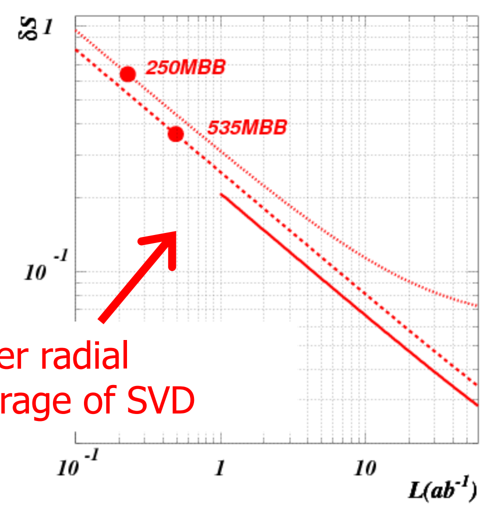




Significant improvement in $\delta S(K_S\pi^0\gamma)$



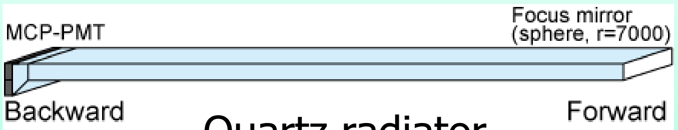
B decay point reconstruction with K_S trajectory



Larger radial coverage of SVD

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



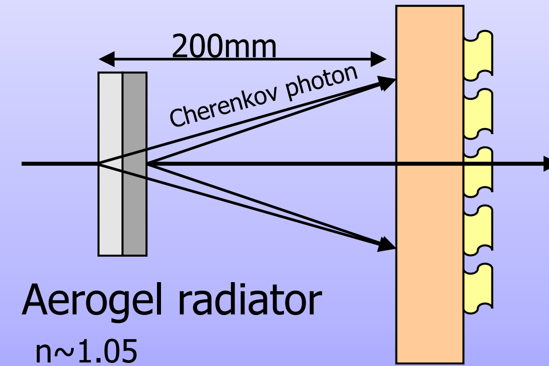
Quartz radiator

Focusing mirror

Small expansion block

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

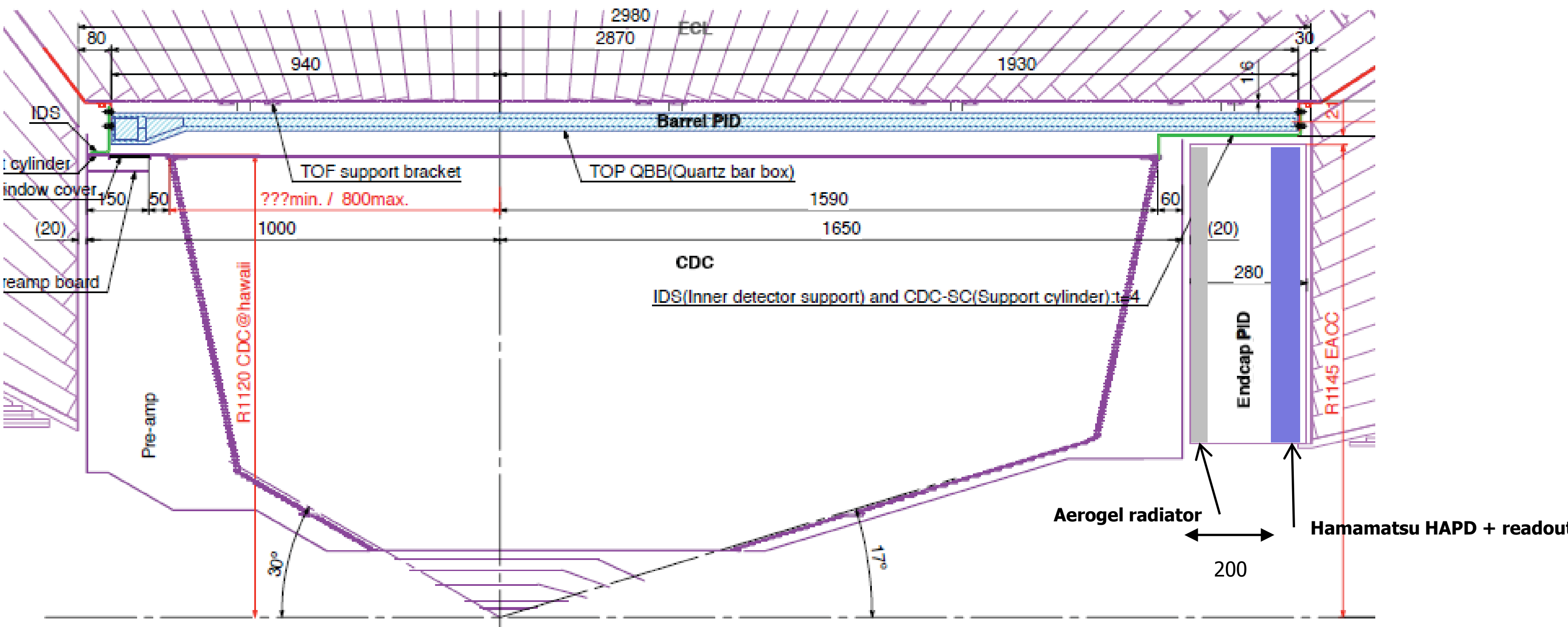
Endcap PID: Aerogel RICH (ARICH)



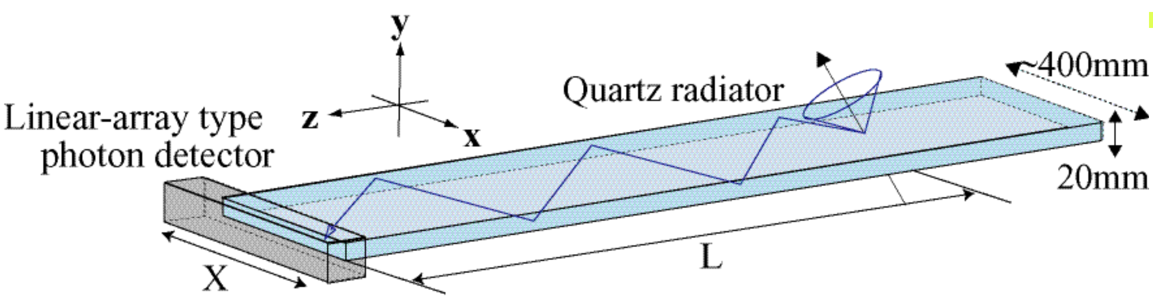
Aerogel radiator

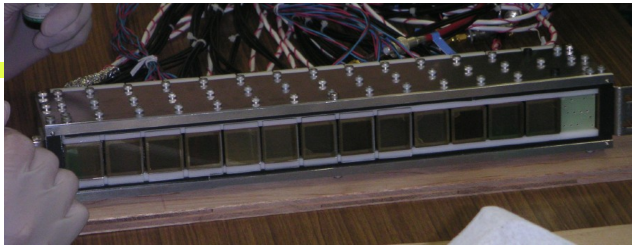
n~1.05

Hamamatsu HAPD
+ new ASIC

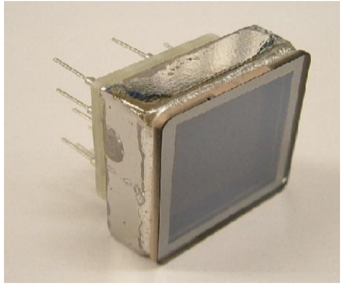


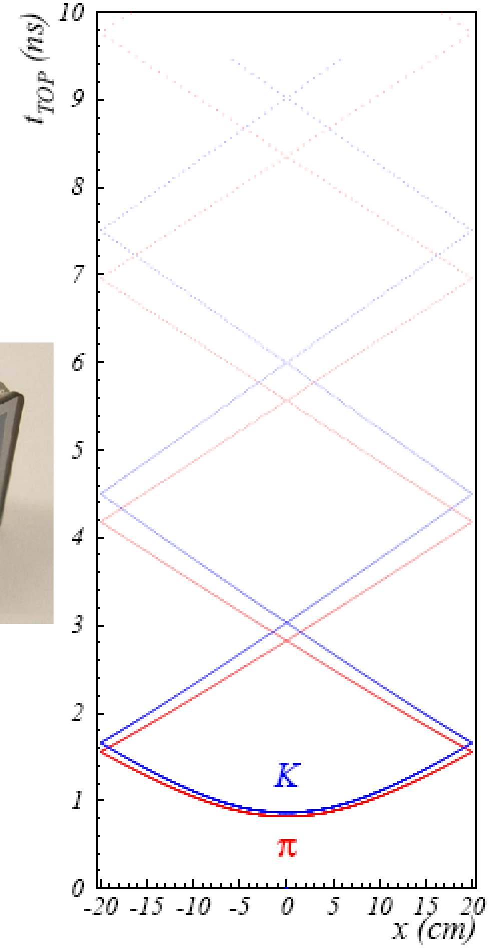
Barrel PID: Time of propagation (TOP) counter

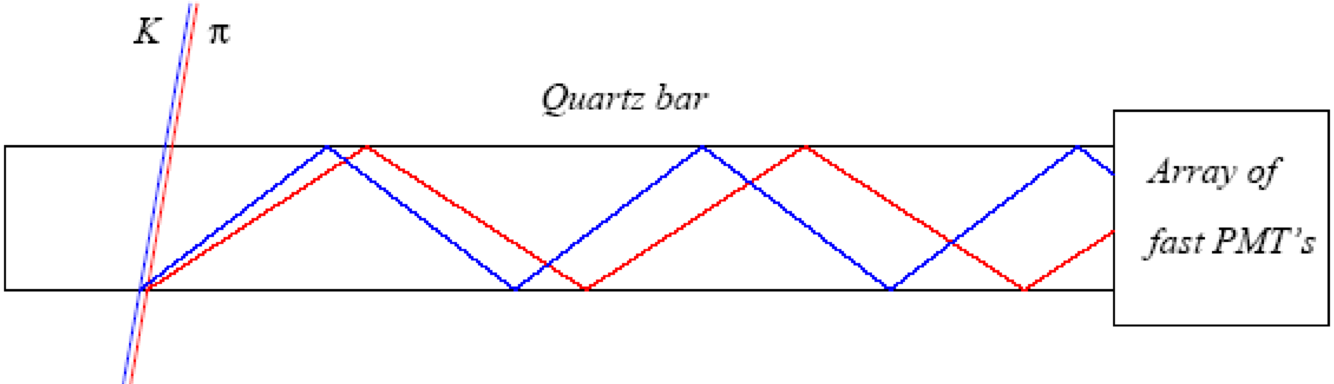




- Cherenkov ring imaging with precise time measurement.
- Reconstruct angle from two coordinates and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT)
    - Good time resolution ~ 40 ps
    - Single photon sensitivity in 1.5

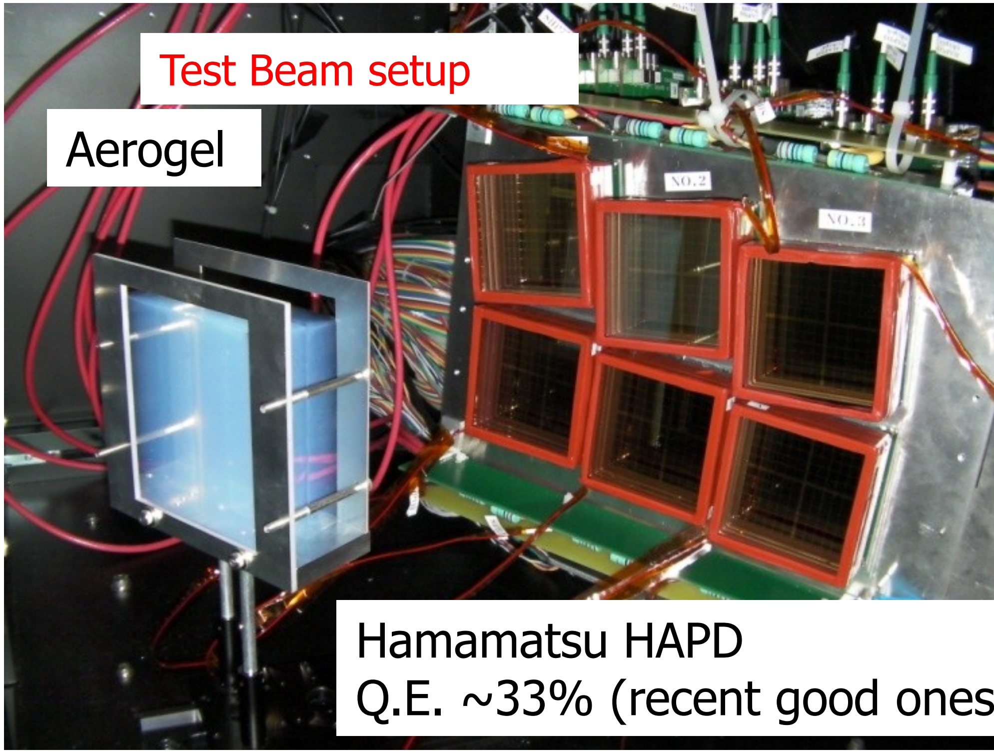


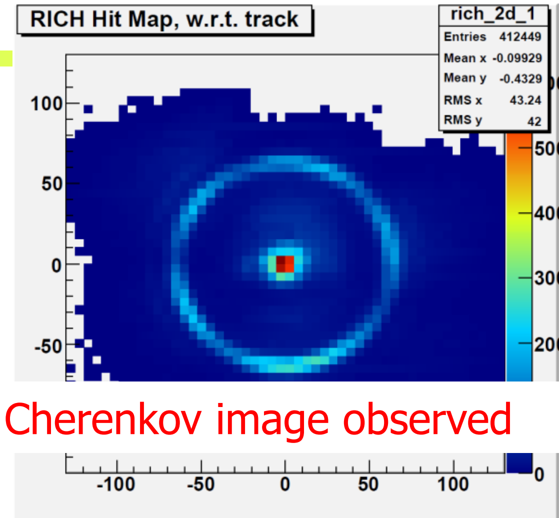




Peter Križan, Ljubljana

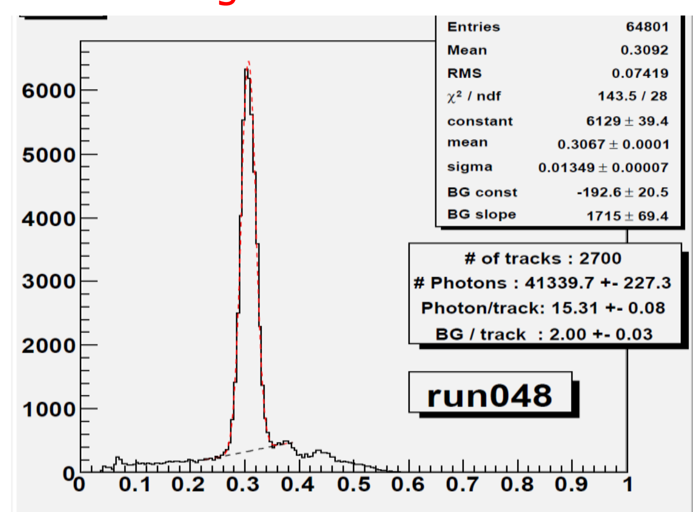
Aerogel RICH (endcap PID)





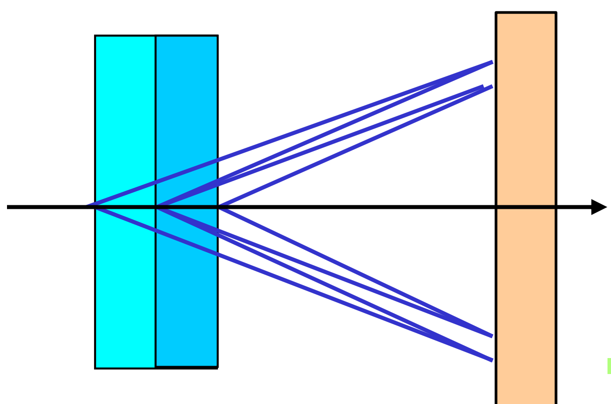
Clear Cherenkov image observed

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 !

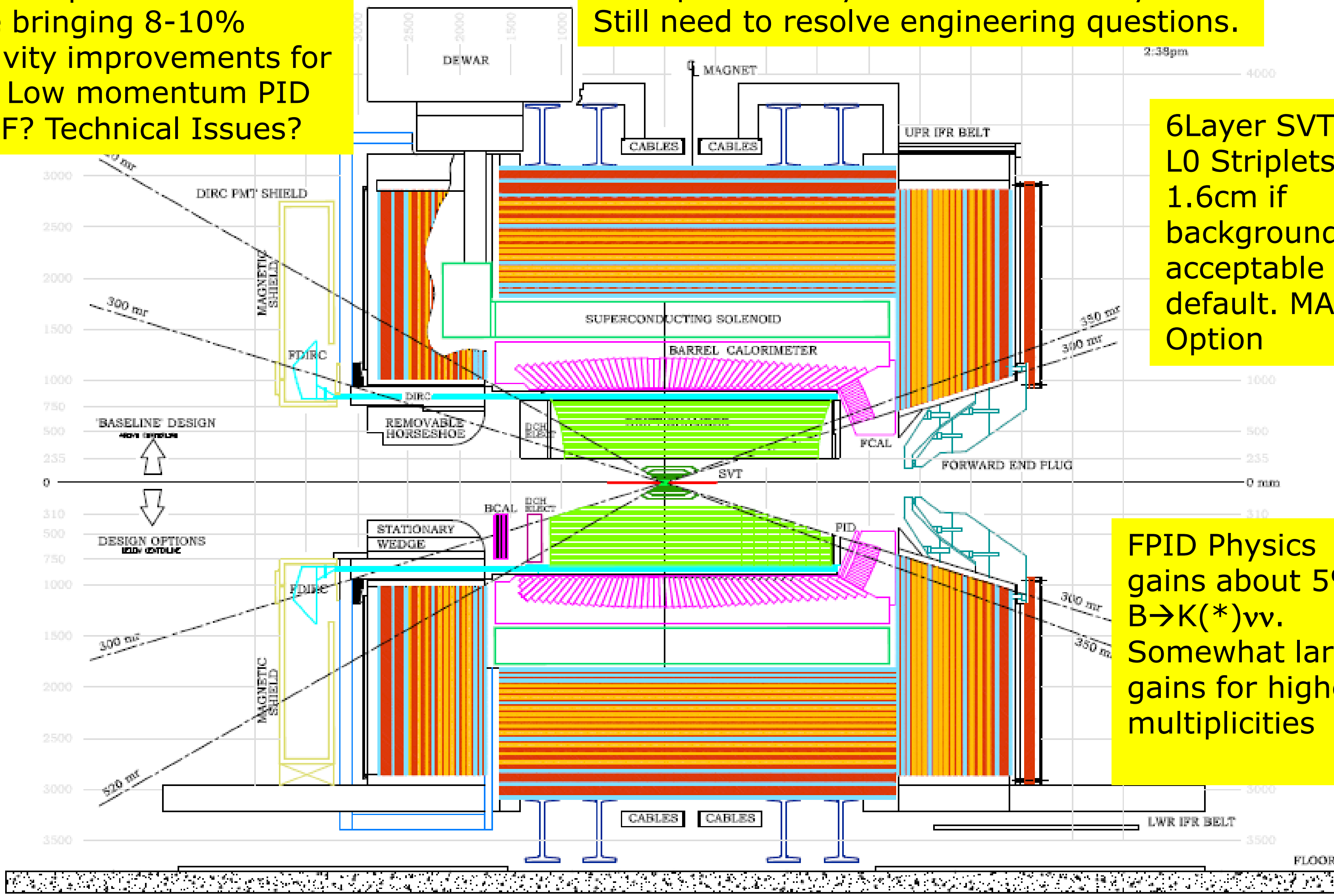
Peter Križan, Ljubljana

SuperB Detector (with options)

BEMC Inexpensive Veto device bringing 8-10% sensitivity improvements for $B \rightarrow \tau \nu$. Low momentum PID via TOF? Technical Issues?

IFR Optimized layout. Plan to reuse yoke. Still need to resolve engineering questions.

6Layer SVT L0 Striplets @ 1.6cm if background is acceptable as default. MAPS Option



FPID Physics gains about 5% in $B \rightarrow K(*)\nu\nu$. Somewhat larger gains for higher multiplicities

M. Giorgi, ICHEP2010

Status of the projects

Belle II Collaboration

13 countries/regions, 54 institutes

300 collaborators, >100 from Europe

SuperKEKB/Belle II funding Status

KEKB upgrade has been approved

- 5.8 oku yen (~MUSD) for Damping Ring (FY2010)
- 100 oku yen for machine -- Very Advanced Research Support Program (FY2010-2012)
- Full approval by the Japanese government by December 2010; the project is in the JFY2011 budget as approved by the Japanese Diet end of March 2011


一般向けページ >> 研究者向けページ >> English Pages >>

Press Release

大学共同利用機関法人 KEK 高エネルギー加速器研究機構

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last update: 10/06/23

Press Release

KEKB upgrade plan has been approved

June 23, 2010
High Energy Accelerator Research Organization (KEK)

The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government.

"We are delighted to hear this news," says Masanori Yamauchi, former spokesperson for the Belle experiment and currently a deputy director of the Institute of Particle and Nuclear Studies of KEK. "This three- year upgrade plan allows the Belle experiment to study the physics from decays of heavy flavor particles with an unprecedented precision. It means that KEK in Japan is launching a renewed research program in search for new physics by using a technique which is complementary to what is employed at LHC at CERN."

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Head of Public Relations Office, KEK
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1-1 Oho, Tsukuba, Ibaraki 305-0801 Japan

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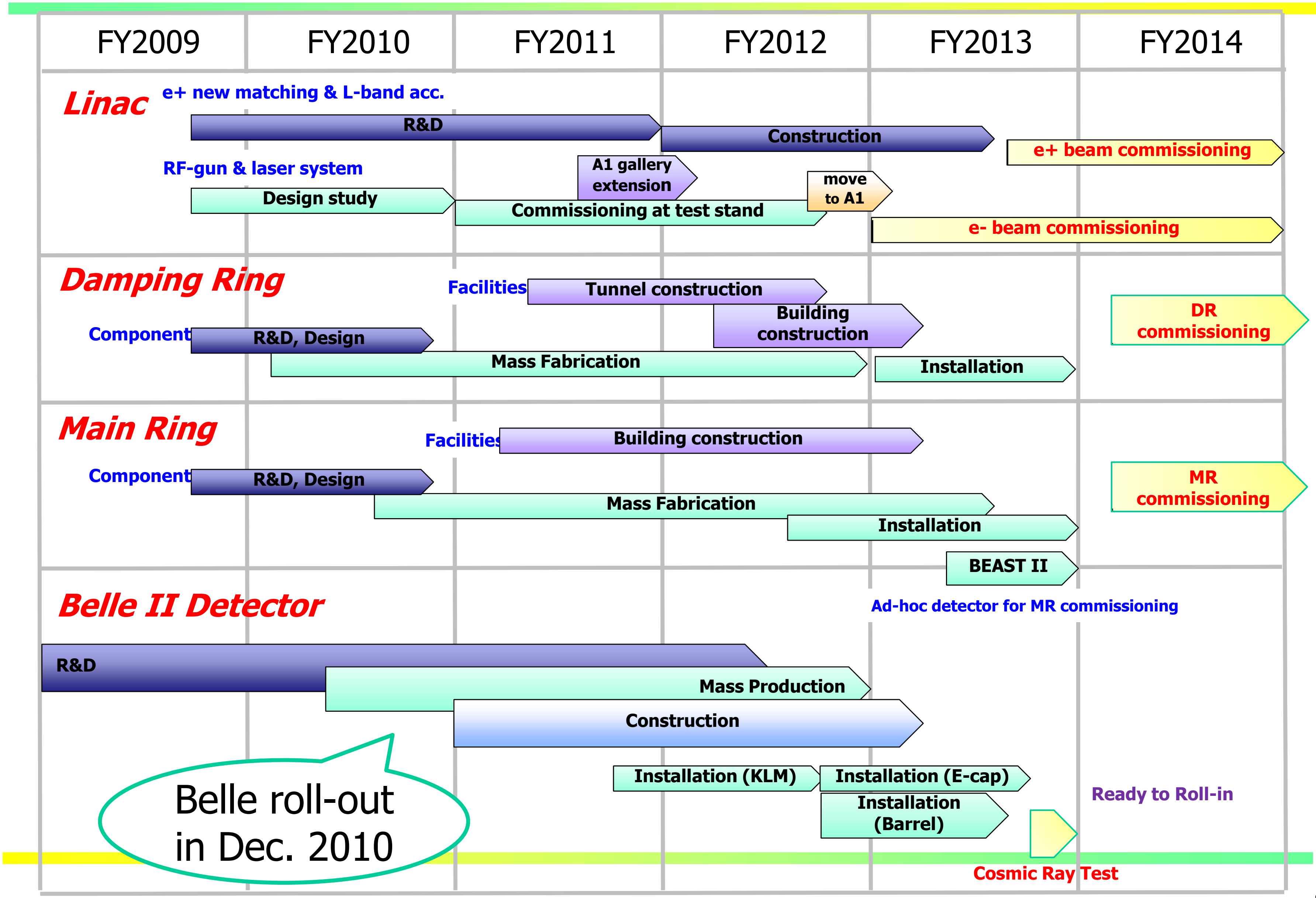
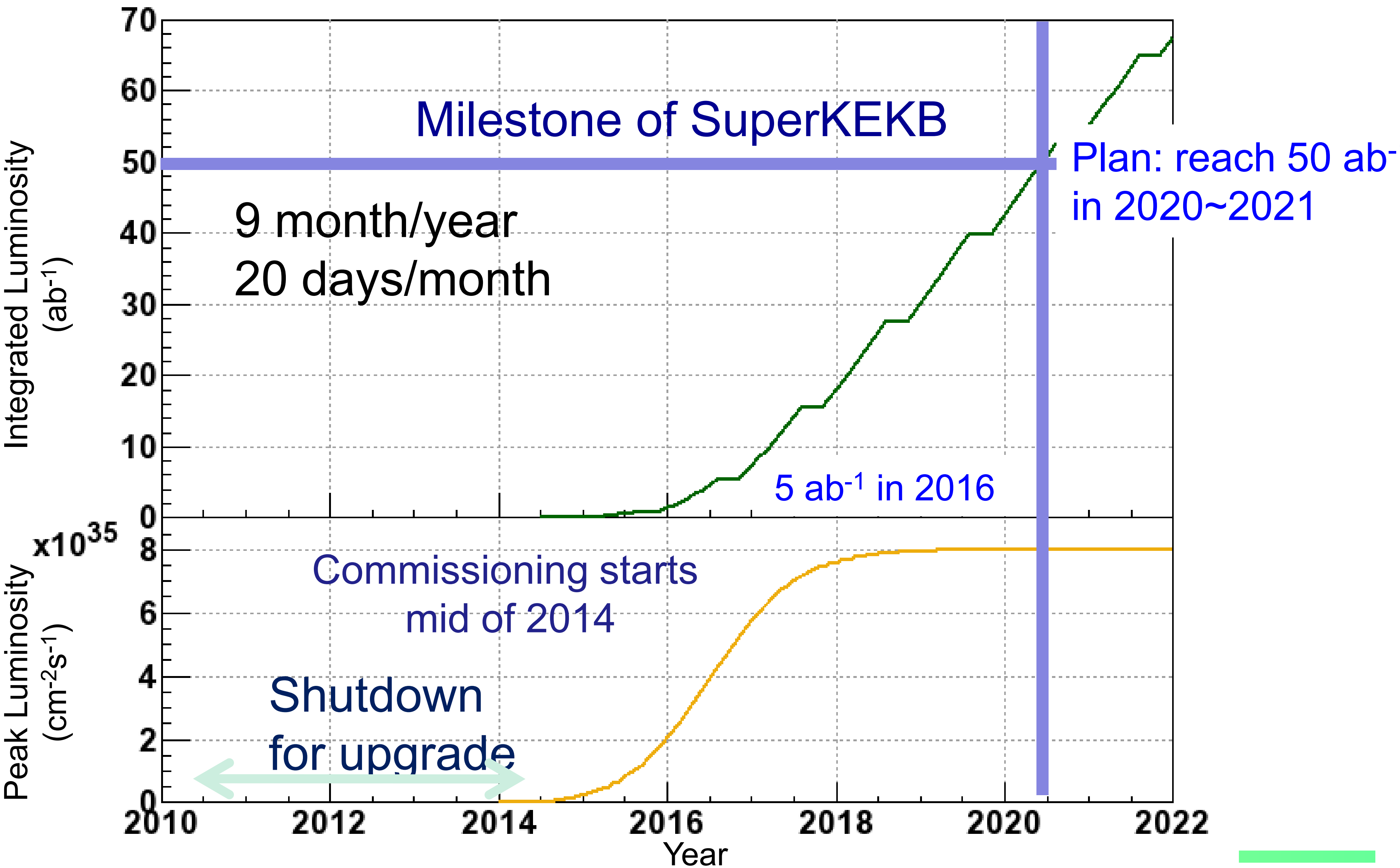
Several non-Japanese funding agencies have also already allocated sizable funds for the upgrade.

→construction started!

Construction Schedule of SuperKEKB/Belle II



Luminosity upgrade projection



KEKB/Belle status: official statement

As is now well known, Japan suffered a terrible earthquake and tsunami on March 11, which has caused tremendous damage, especially in the Tohoku area. Fortunately, all KEK personnel and users are safe and accounted for.

The injection linac did suffer significant but manageable damage, and repairs are underway. The damage to the KEKB main rings appears to be less serious, though non-negligible. No serious damage has been reported so far at Belle. Further investigation is necessary.

We would like to convey our deep appreciation to everyone for your generous expressions of concern and encouragement.

KEKB/Belle status

Fortunately enough:

- KEKB stopped operation in July 2010, and was already to a large extent disassembled before the earthquake
- Belle was rolled out to the parking position in December.

We will check the functionality of the calorimeter in the next months (channel by channel...)

SuperB Status

- SuperB in April 2010 on the list of the Italian National Research Plan (PNR) Flagship Projects
  - Cooperation of INFN and IIT (Italian Institute of Technology): HEP experiment and light source
- In December 2010 first funding of 19M€ as the first part of a pluriennal funding plan
  - Internal to Ministry of Research
- In April 2011 approval of the PNR by CIPE, including 250M€ for SuperB.
  - CIPE is the inter-ministerial committe for economic planning

SuperB Funding in INFN 3-year plan

Componenti Super B	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
Sviluppo Acceleratore (130 M€) Costruzione infrastrutture, Sviluppo damping rings, Sviluppo transfer lines, Messa in funzione linac, Damping lines transfer lines, Costruzione facility end-user	20	50	60							
Sviluppo Centri Calcolo (43 M€) Sviluppo progettazione costruzione centro di calcolo per analisi dati	5	15	23							
Completamento Acceleratore (126 M€) Installazione componenti negli archi acceleratore, Installazione zona di interazione, Messa in funzione acceleratore				42	42	42				
Utilizzo installazione (80 M€) Costi operazione e manutenzione acceleratore							20	20	20	20
Totale Infrastrutture tecniche (379 M€)	25	65	83	42	42	42	20	20	20	20
Overheads INFN (34.3 M€ equivalente al 9%)	2.3	5.9	7.5	3.8	3.8	3.8	1.8	1.8	1.8	1.8
Cofinanziamento INFN (150 M€)	15	15	15	15	15	15	15	15	15	15
Costo Totale del progetto (563.3 M€)	42.3	85.9	105.5	60.8	60.8	60.8	36.8	36.8	36.8	36.8

Funding for
- Accelerator
- Infrastructure
- Computing

Detector funding inside ordinary funding agency budget.

In addition, we re-use parts of PEP-II and Babar, for a value of about 135M€

IIT contribution (100M?) in addition, mainly for synchrotron light lines construction.

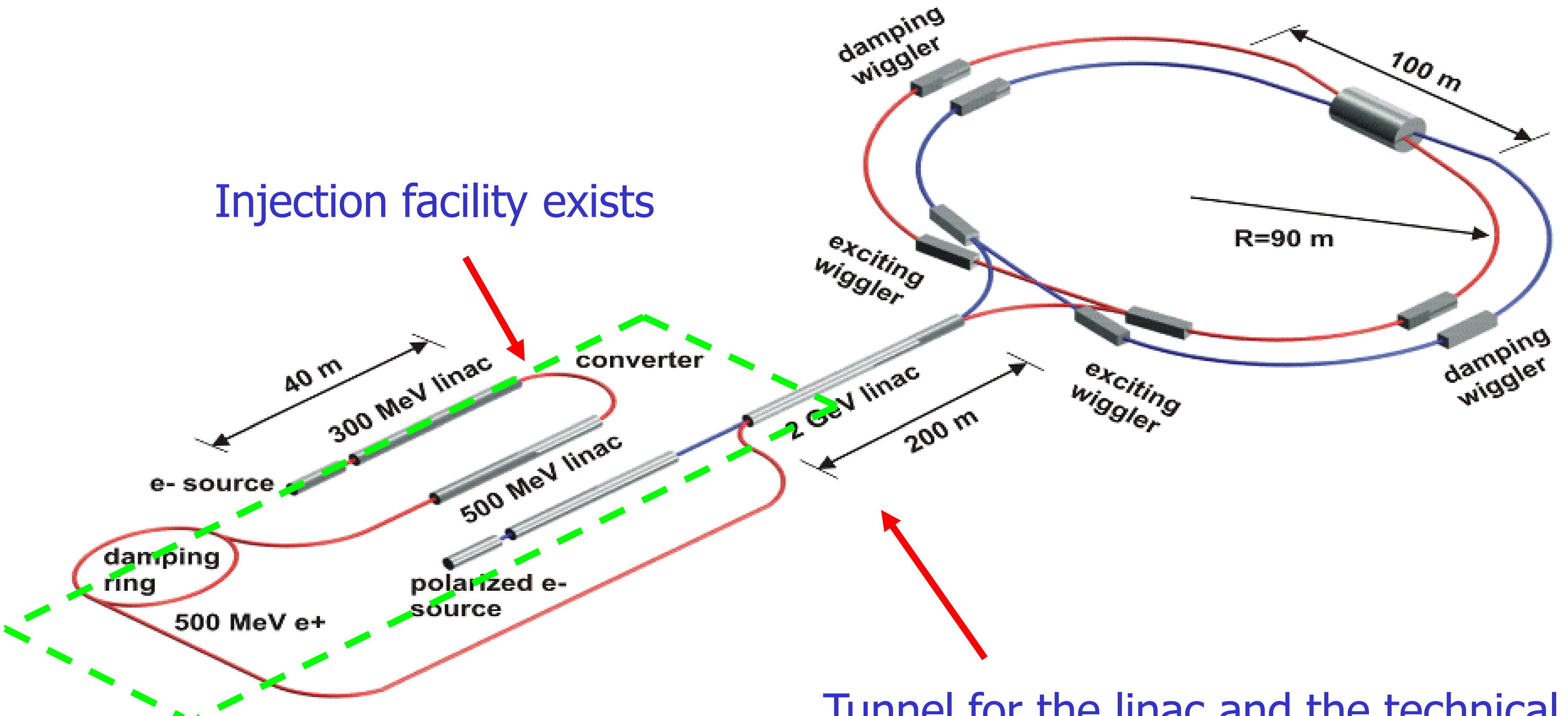
Next steps and timeline

- Choose the site asap! Foreseen end of May 2011.
  - The preferred site is Tor Vergata close to LNF
- Complete the Technical Design Report
  - End of 2011/Mid 2012
- Prepare the transition from TDR Phase to Construction
  - Collaboration will start formally forming at the Elba meeting, May 2011
- Start recruitment for the construction: mainly accelerator physicists and engineers
- Completion of construction foreseen in 2015/16.

τ-charm factory

Layout of the Novosibirsk c/τ factory

Injection facility exists



Tunnel for the linac and the technical straight section of the factory is ready

Physics at τ-charm factory

- Precision charm physics
  - Precision charm$\rightarrow$ precision CKM (strong phases, f_D, f_{Ds} ...)
  - High sensitivity search for rare processes (rare D & Λ_c decays, CPV, mixing)
- Precision τ-physics with polarized beams
  - Lepton universality, Lorentz structure of τ-decay…
  - CPV
  - LFV decays
  - Second class currents
- High statistic spectroscopy and search for exotics
  - Charm and charmonium spectroscopy
  - Light hadron spectroscopy in charmonium decays ($N_{J/\psi}$~10^{12})

Super τ charm factory

Mixing parameters @ charm factory (threshold)
of lower accuracy than @ B factory
(unless t-dependent meas. with asymmetric collider);

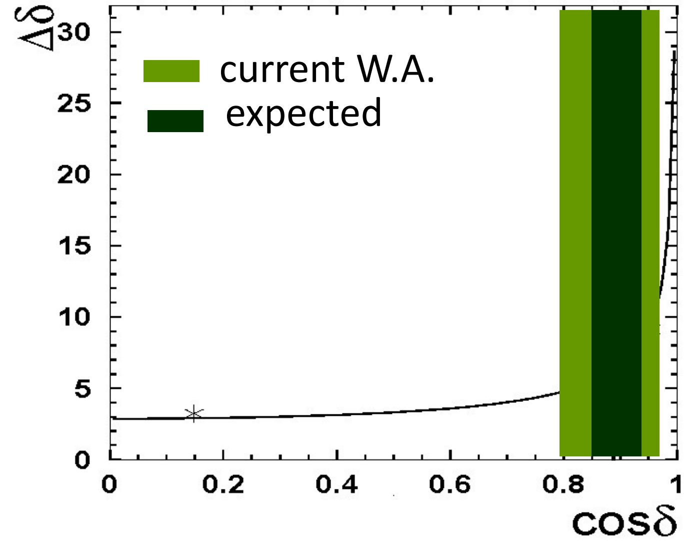
Various options for CPV measurements
several competitive or better, and complementary to B-factory
(including $D^0 D^0$ with C=+1);
many other possibilities
(Dalitz studies, triple product correlations, T-odd moments, ...)

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, government in April 2011
- Physics reach updates available
- c/tau factory with high luminosity and longitudinal polarization could provide complementary opportunities for tests of the Standard Model
- Expect a new, exciting era of discoveries, complementary to the LHC

Additional slides

BES III, arXiv:0809.1869



Charm-factories

$20\ \text{fb}^{-1}$: $\sigma(R_M) \sim 1 \cdot 10^{-4}$

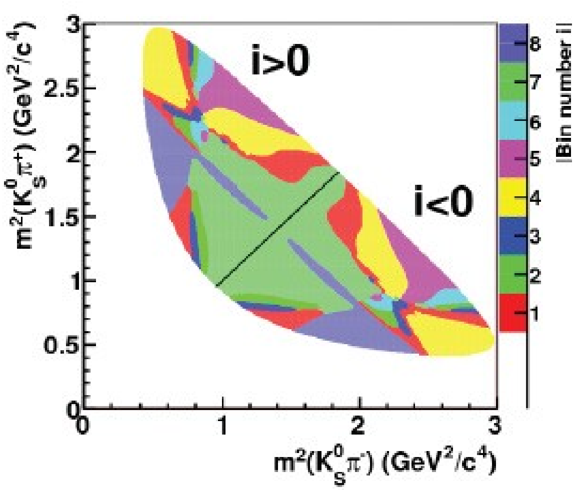
(from $\psi(3770) \to K^-\pi^+, K^-\pi^+$)

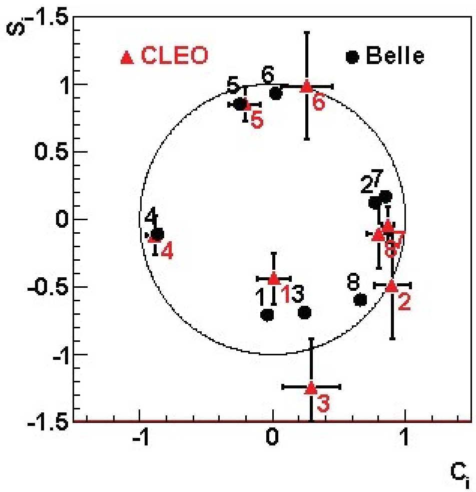
(n.b.: $R_M \sim 1 \cdot 10^{-4}$);

$\sigma(y) \sim 0.3\%$

$\sigma(\cos\delta) \sim 0.04$

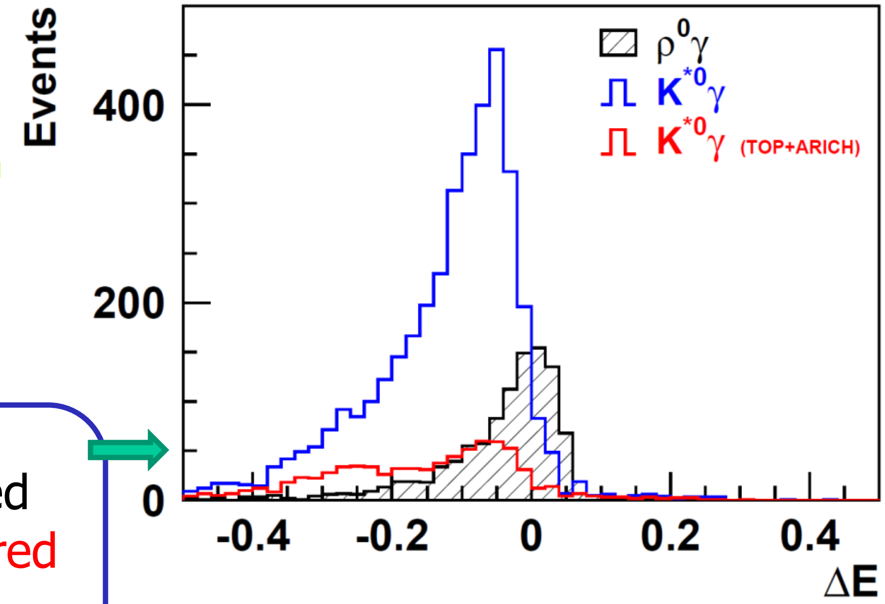
important contribution in measurements
of strong phase difference over Dalitz plane for multi-body decays;
e.g. $D^0 \to K_S\pi^+\pi^-$ model independent (more accurate) measurement of ϕ_3





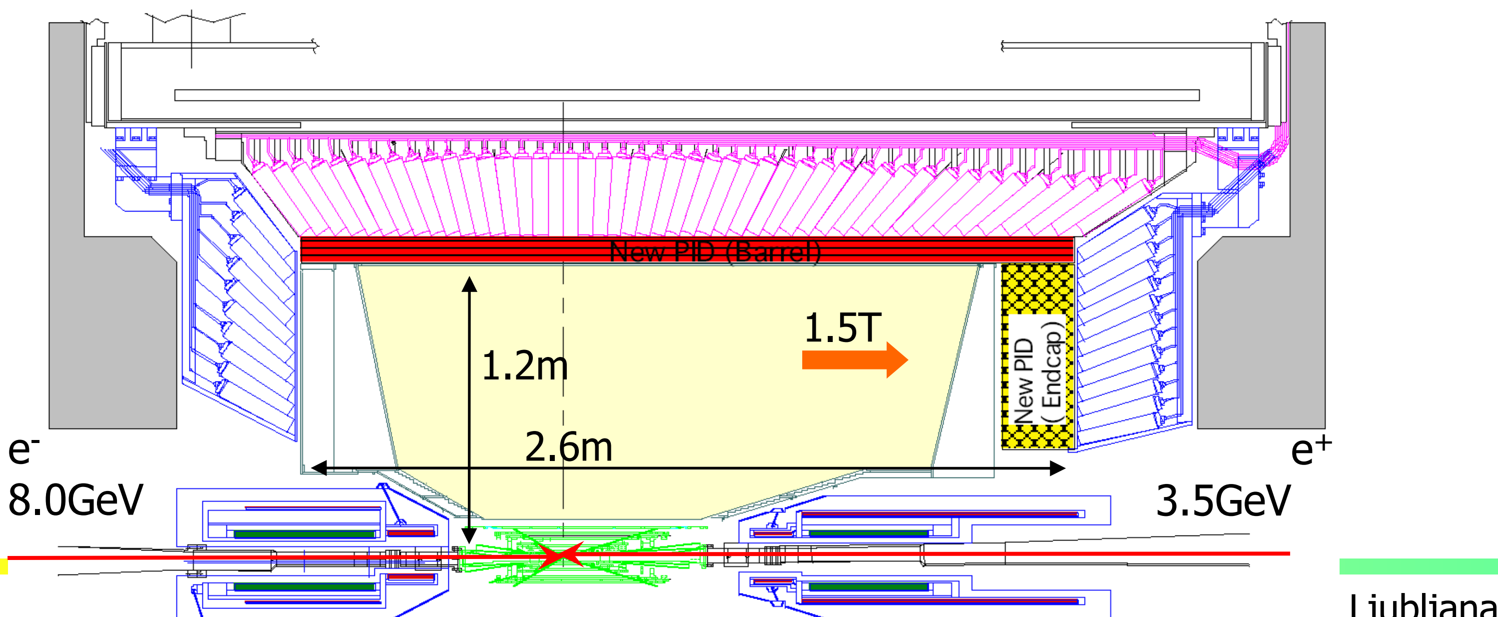
Cleo, PRD82, 112006, (2010)

- Barrel: TOP counter
- End cap: Aerogel RICH



Expected impact, example B→K*γ: background reduced from blue (present Belle) to red

→Up to 80% gain in sensitivity

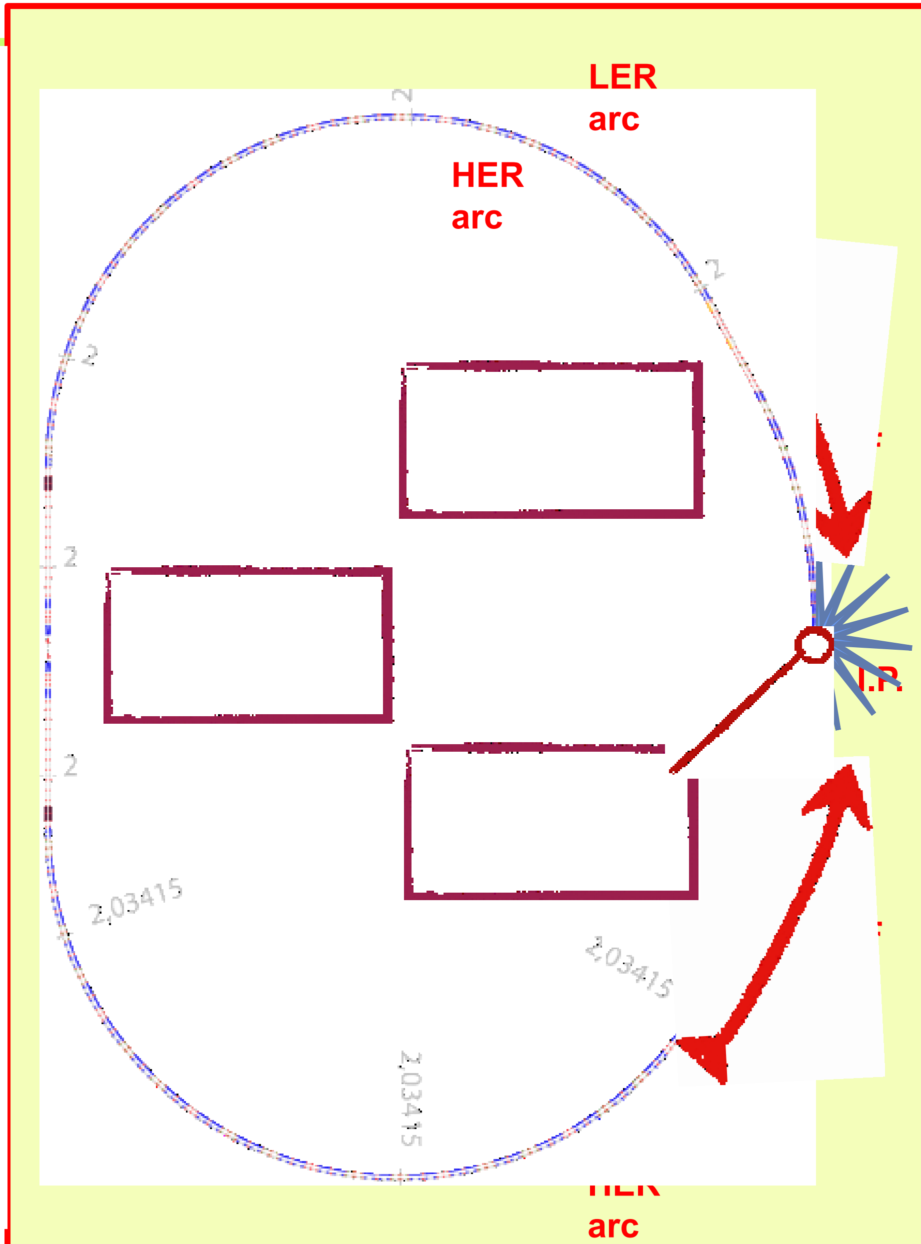


Ljubljana

SuperB Parameters

		Base Line		Low Emittance		High Current		Tau-charm	
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	
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
Emittance x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
Emittance y	pm	5	6.15	2.5	3.075	10	12.3	13	16
Bunch length (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	MHz	476.		476.		476.		476.	
Revolution frequency	MHz	0.238		0.238		0.238		0.238	
Harmonic number	#	1998		1998		1998		1998	
Number of bunches	#	978		978		1956		1956	
N. Particle/bunch (10^{10})	#	5.08	6.56	3.92	5.06	4.15	5.36	1.83	2.37
σ_x effective	μm	165.22	165.30	165.22	165.30	145.60	145.78	166.12	166.67
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.0254	0.092	0.092
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
Σ_x effective	μm	233.35		233.35		205.34		233.35	
Σ_y	μm	0.050		0.030		0.076		0.131	
Hourglass reduction factor		0.950		0.950		0.950		0.950	
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.097	0.097	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Longitudinal 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	0.17
Momentum compaction (10^{-4})		4.36	4.05	4.36	4.05	4.36	4.05	4.36	4.05
Energy spread (10^{-4}) (full current)	dE/E	6.43	7.34	6.43	7.34	6.43	7.34	6.43	7.34
CM energy spread (10^{-4})	dE/E	5.0		5.0		5.0		5.0	
Total lifetime	min	4.23	4.48	3.05	3	7.08	7.73	11.4	6.8
Total RF Wall Plug Power	MW	16.38		12.37		28.83		2.81	

SuperB Collider Progress Report



Background Issue: sources

	Cross section	Evt/bunch xing	Rate
Beam Strahlung	~340 mbarn (Eγ/Ebeam > 1%)	~850	0.3THz
e^+e^- pair production	~7.3 mbarn	~18	7GHz
e^+e^- pair (seen by L0 @ 1.5 cm)	~0.07 mbarn	~0.2	70 MHz
Elastic Bhabha	$O(10^{-4})$ mbarn (Det. acceptance)	~250/Million	100KHz
Y(4S)	$O(10^{-6})$ mbarn	~2.5/Million	1 KHz
	Loss rate	Loss/bunch pass	Rate
Touschek (LER)	4.1kHz / bunch (+/- 2 m from IP)	~3/100	~5 MHz

Two colliding beams :
- radiative Bhabha → *dominant effect on lifetime*
- e+e- e+e- production → *important source for SVT layer-0*

Single beam :
- synchrotron radiation → *strictly connected to IR design*
- Touschek → *negligible in BaBar, important in SuperB*
- beam-gas
- intra-beam scattering

Collimators, dynamic aperture and energy acceptance optimization solve the problem of Touschek background in LER

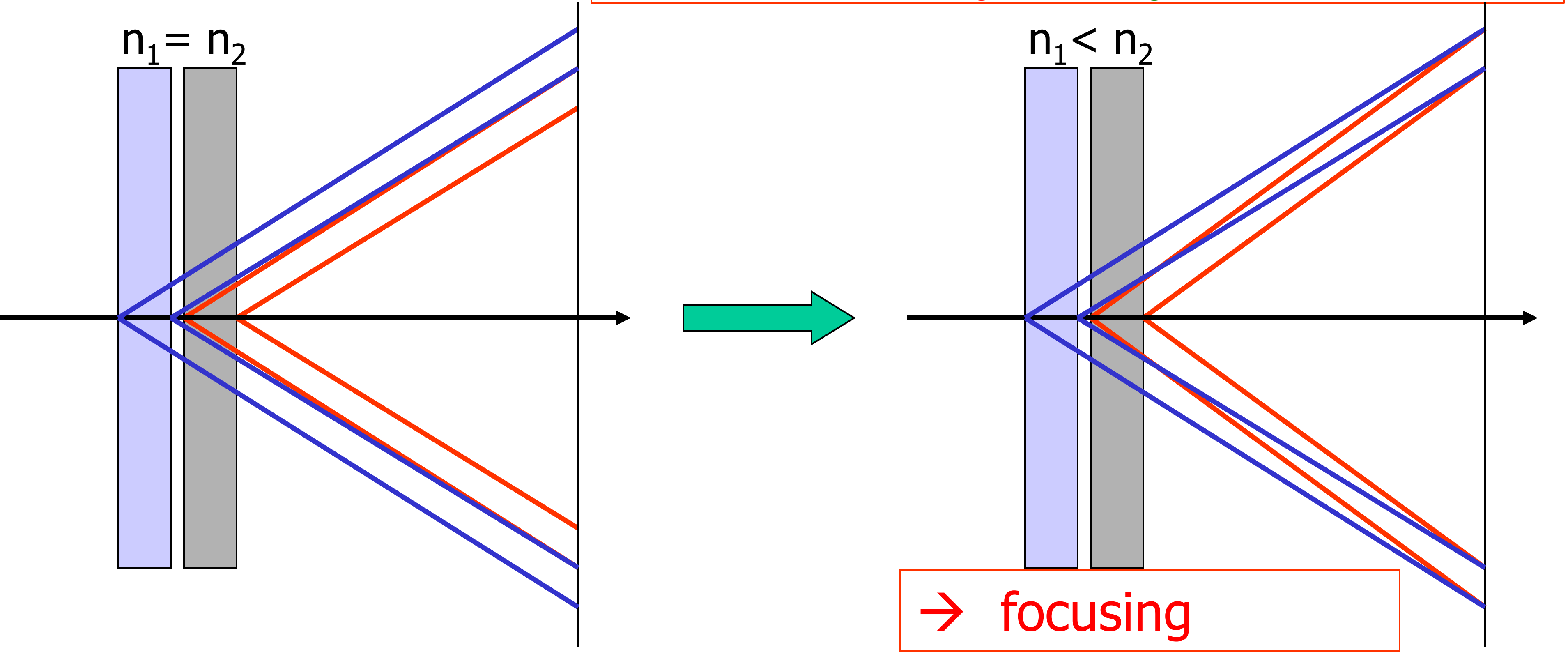
M. Giorgi, ICHEP2010

Radiator with multiple refractive indices

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

→ stack two tiles with different refractive indices: “focusing” configuration

normal

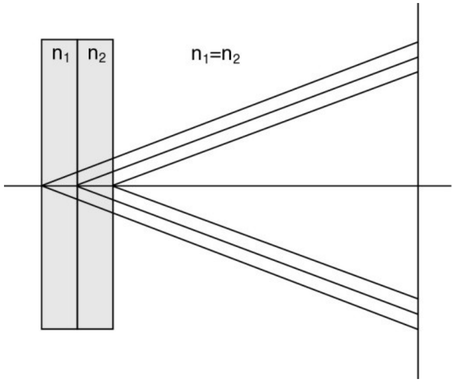


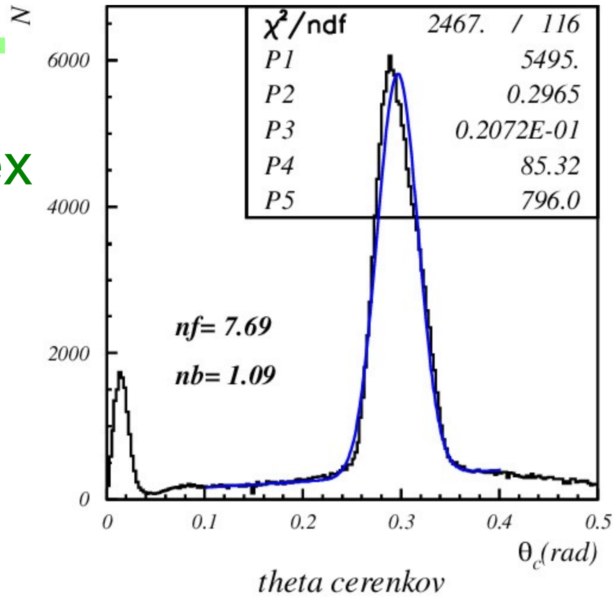
→ focusing

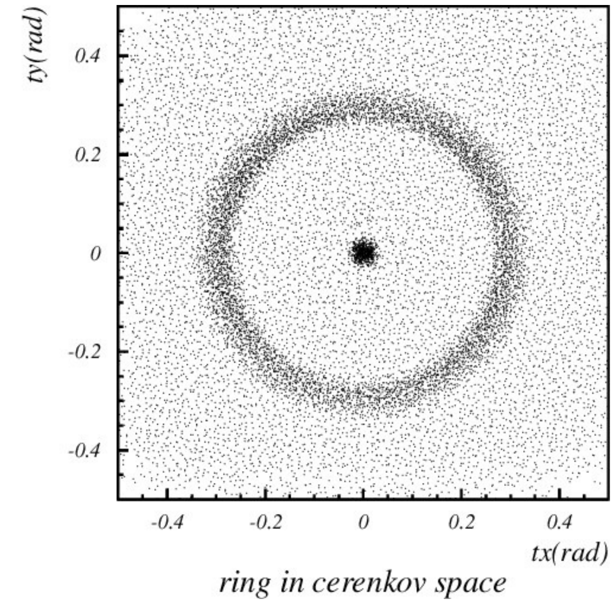
Such a configuration is only possible with aerogel (a form of Si_xO_y) – material with a tunable refractive index between 1.01 and 1.13.

Focusing configuration – data

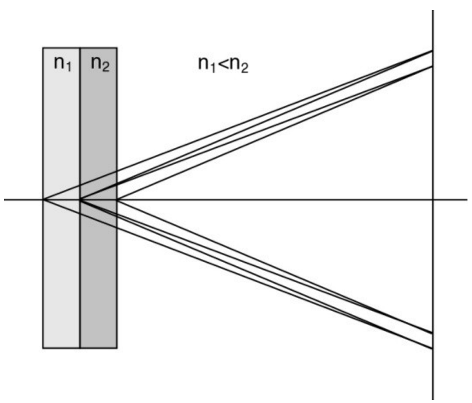
4cm aerogel single index

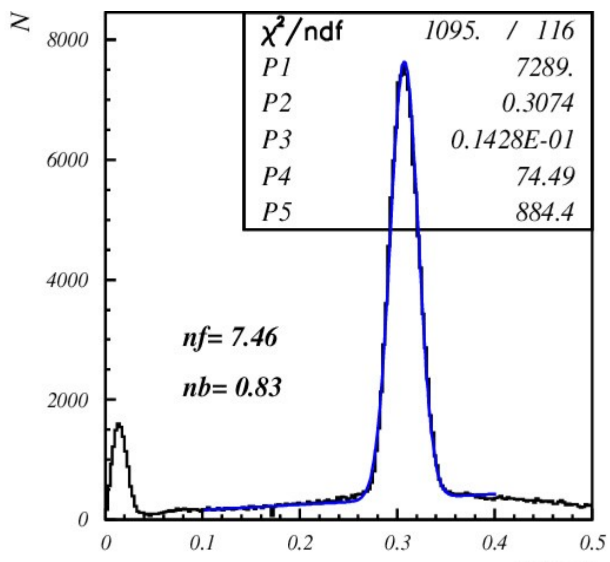


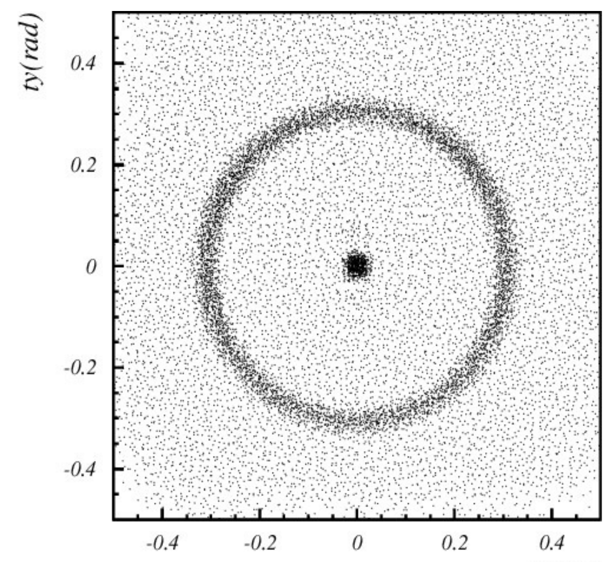




2+2cm aerogel



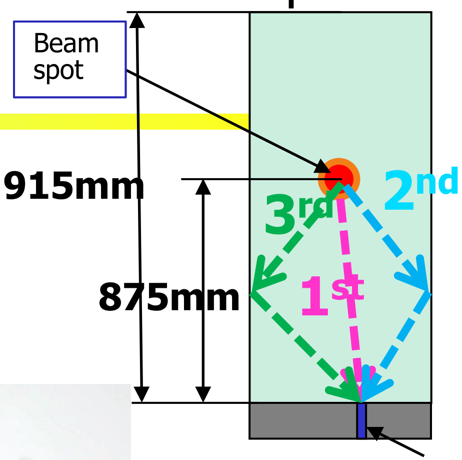


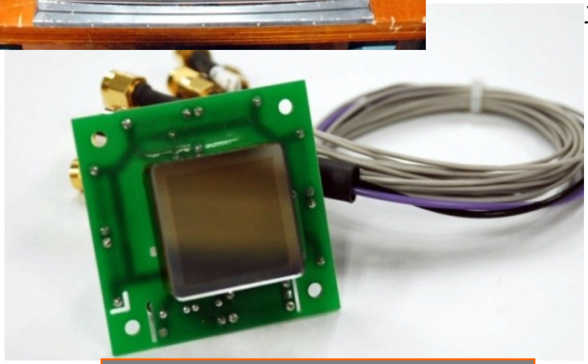


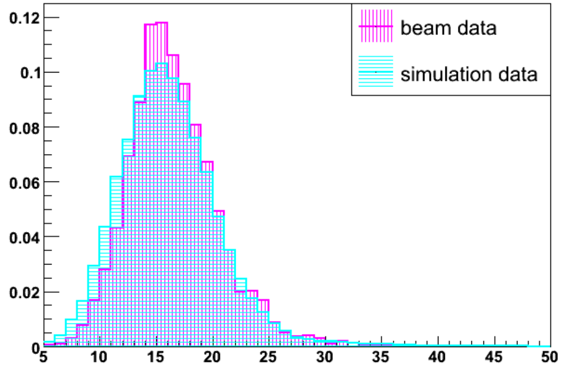
→NIM A548 (2005) 383

TOP (Barrel PID)

- Quartz radiator
  - 2.6m^L x 45cm^W x 2cm^T
  - Excellent surface accuracy
- MCP-PMT
  - Hamamatsu 16ch MCP-PMT
    - Good TTS (<35ps) & enough lifetime
    - Multialkali photo-cathode → SBA
- Beam test in 2009
  - # of photons consistent
  - Time resolution OK

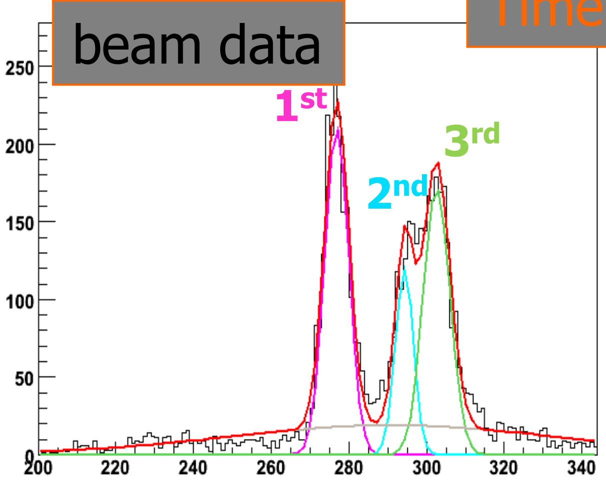


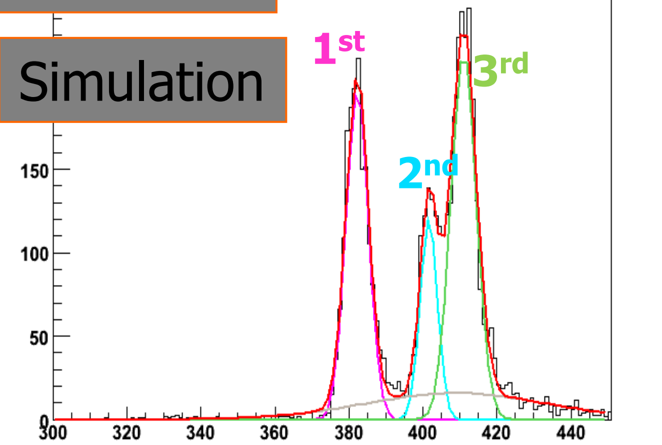




# of photons

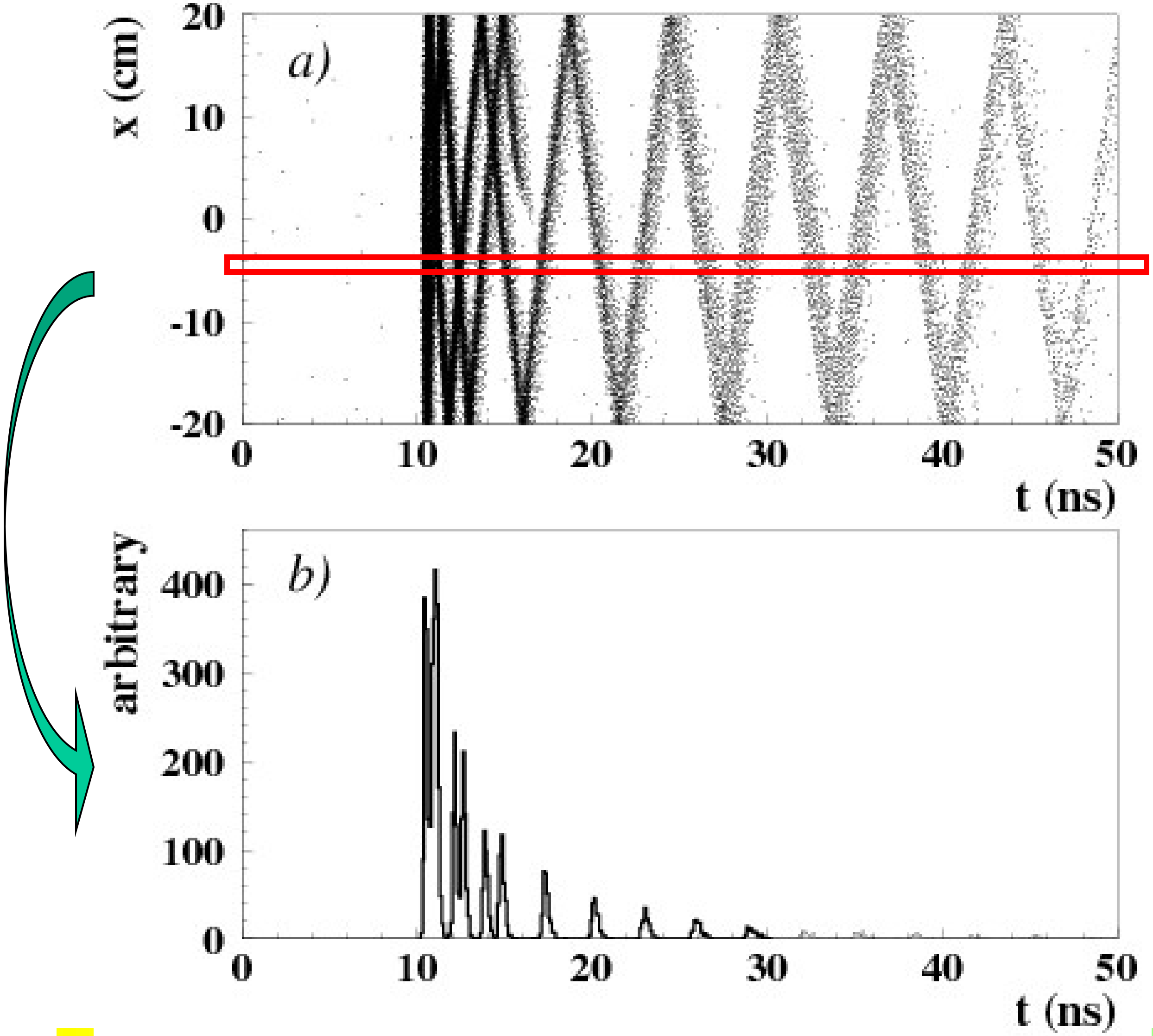
Time of arrival





Peter Križan, Ljubljana

TOP image



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

Time distribution of signals recorded by one of the PMT channels: different for π and K