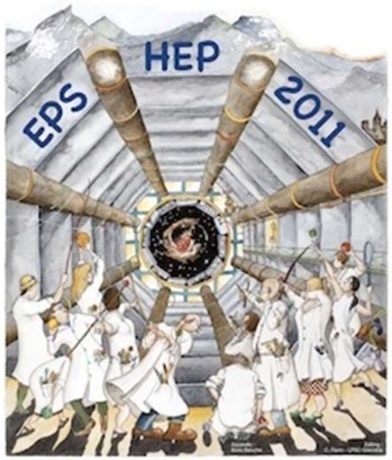


EPS HEP 2011, Grenoble, July 27, 2011

Flavour physics at the Intensity Frontier

Peter Križan

University of Ljubljana and J. Stefan Institute

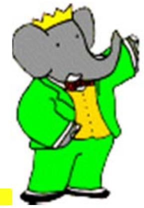
University of Ljubljana

"Jožef Stefan" Institute

Contents

- Unitarity triangle:
  - final value for $\sin 2\phi_1$ ($=\sin 2\beta$)
  - ϕ_3 ($=\gamma$) with a new method, ADS modes
  - sides: V_{ub} from exclusive and inclusive
- B decays: rare decays, direct CP violation, searches for CPT
- D: search for CP violation and rare decays
- τ decays (LFV → T. Mori, next talk)
- Physics at $\Upsilon(5s)$
  - $B_s \to J/\psi\, \pi\pi$
  - h_b and Z_b states
- X(3872) properties
- Plans for the future: Super B factories
- Summary and outlook

Talks at EPS HEP 2011: BaBar



D. Derkach	"Recent BABAR results on CP violation in B decays"
M. Franco Sevilla	"Semileptonic B and Charm Decays with BABAR"
A. Gaz	"Recent BABAR measurements of hadronic B branching fractions"
M. Martinelli	"Recent BABAR Charm Physics Results"
E.M.T. Puccio	"Charmless Hadronic B Decays with BABAR"
A. Adametz	"Recent BABAR Tau Physics Results"
A. Lusiani	"Searches for Light New Physics with BABAR"
E. Grauges	"Searches for Rare and Forbidden B and Charm Decays with BABAR"
A. Hafner	"Recent results on hadrons via Initial State radiation"
E. Guido	"Recent BABAR Studies of Bottomonium States"
	"Charmonium and Charmonium-like States with BABAR"

= 11 talks

Talks at EPS HEP 2011: Belle

T. Higuchi	"CPV and CPT in B decays at Belle"
J. Dalseno	"ϕ_2 and ϕ_3 measurements at Belle"
P. Chang	"Direct CPV and charmless B decays at Belle"
M.Z. Wang	"Other B decays at Belle"
R. Louvot	"B_s decays at Belle"
M. Starič	"$D_{(s)}^+$ decays and their CPV at Belle"
K. Hayasaka	"Rare tau decays at Belle"
P. Urquijo	"Exclusive (semi-)leptonic B meson decays at Belle"
A. Vinokurova	"Charmonium and X,Y,Z at Belle"
J. Wicht	"Observation of h_b and Z_b states at $\Upsilon(5S)$"
U. Tamponi	"$\Upsilon(2S)$ decays at Belle"
J. Rorie	"Search for a CP-odd light Higgs in $\Upsilon(1S)$ radiative decays at Belle"

= 12 talks

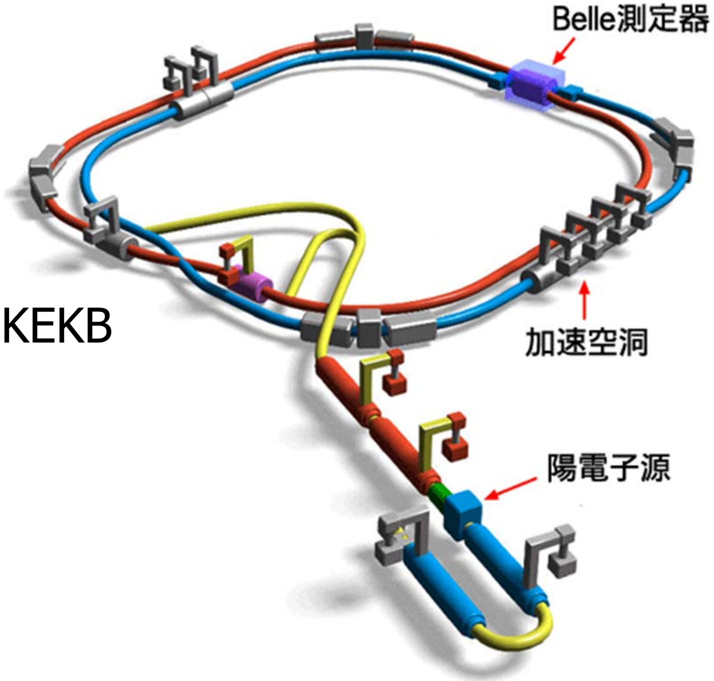
Talks at EPS HEP 2011: continued

Liaoyuan Dong	"Recent Results from BESIII"
E. Goudzovski	"Kaon physics at CERN: recent results"
C. Bloise	"Kaon physics at KLOE and KLOE-2 prospects"

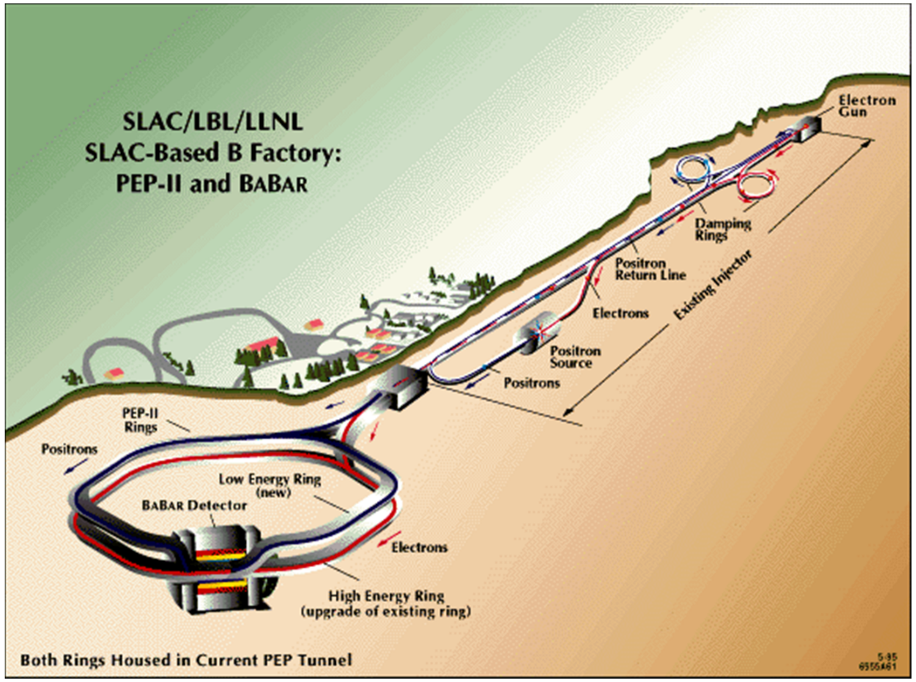
+ g-2 related talks by G. Venanzoni, T. Dimova, and S. Eidelman

In total 29 talks – impossible to cover all in 25 minutes...

Flavour physics at the luminosity frontier: asymmetric B factories



KEKB



$\sqrt{s}=10.58$ GeV

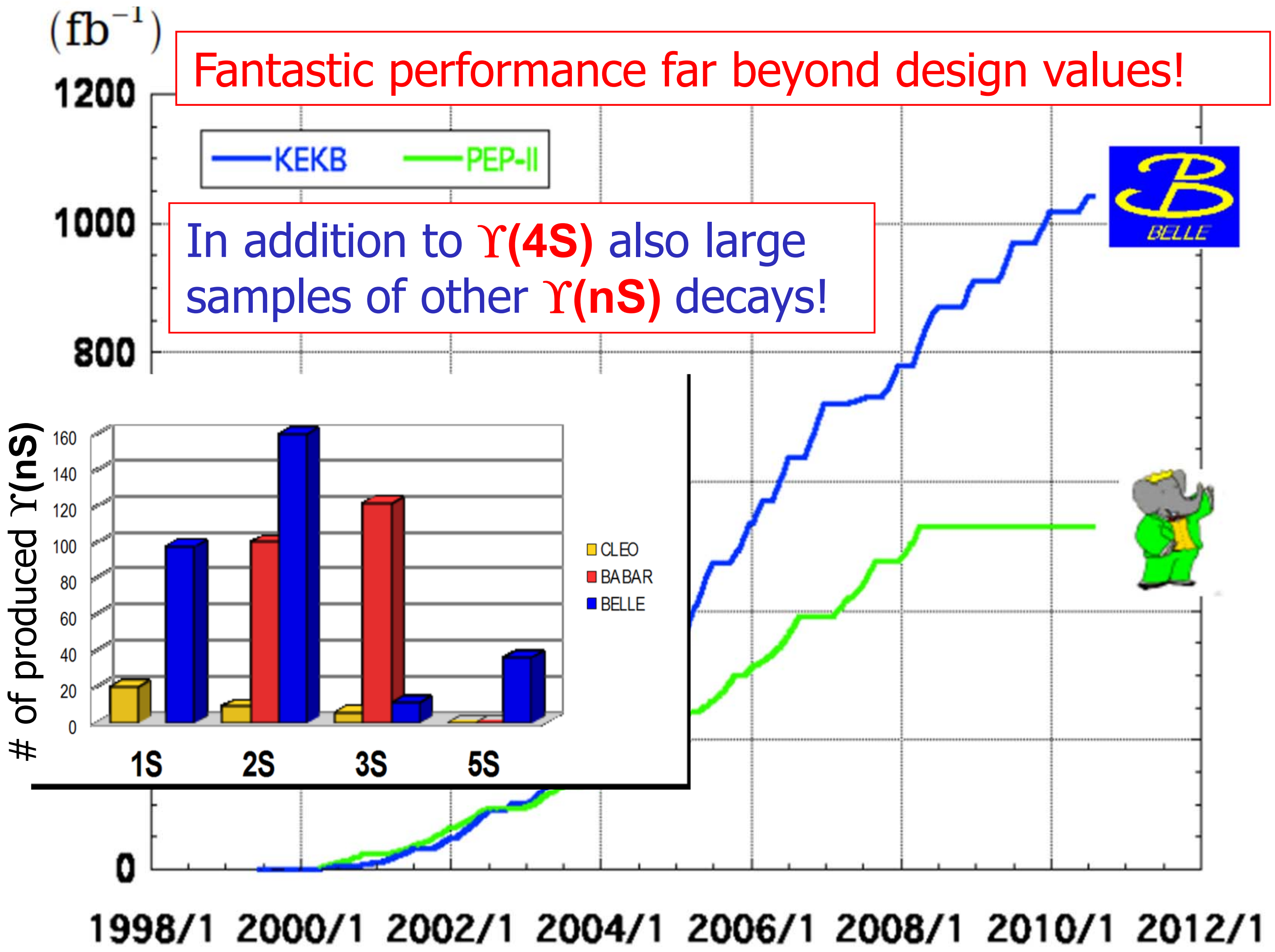
$e^+ \rightarrow \Upsilon(4s) \leftarrow e^-$

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

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

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

Integrated luminosity at B factories



> 1 ab^{-1}

On resonance:

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

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

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

$\Upsilon(2S)$: 25 fb^{-1}

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

Off reson./scan:

~ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

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

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

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

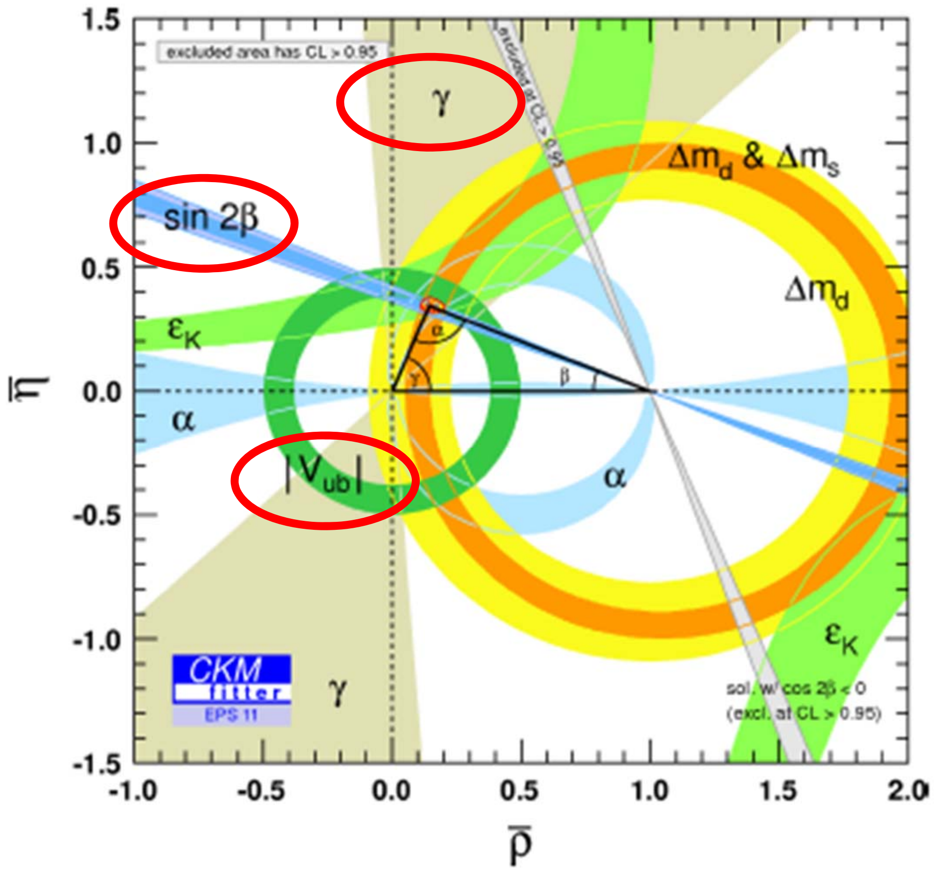
Off resonance:

~ 54 fb^{-1}

Unitarity triangle – new/final measurements

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

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



This conference

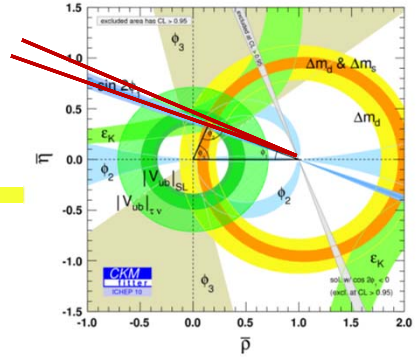
Unitarity triangle:

→ $\sin 2\phi_1$ (=$\sin 2\beta$) : final measurement from Belle

→ ϕ_3 (=γ) new model-independent method

→ $|V_{ub}|$ from exclusive and inclusive semileptonic decays

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



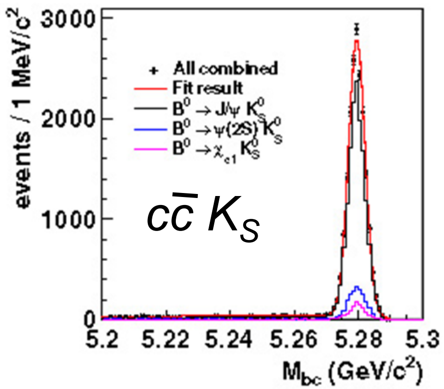
Belle, preliminary, 710 fb^{-1}

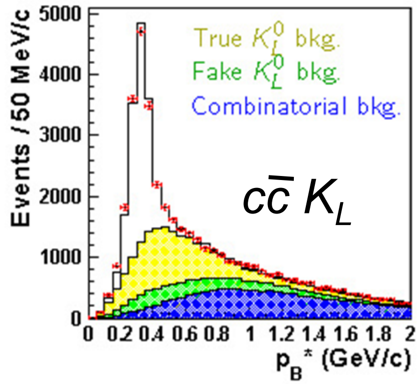
ϕ_1 from CP violation measurements in $B^0 \rightarrow c\bar{c}\,K^0$

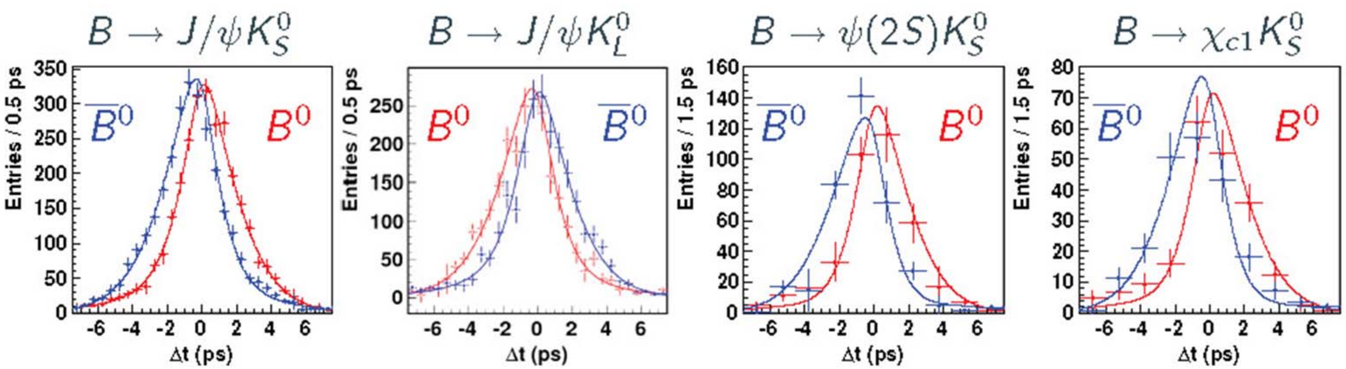
Improved tracking, more data
(50% more statistics than last result with 480 fb^{-1});
$c\bar{c}$ = J/ψ, $\psi(2S)$, χ_{c1} → 25k events

for K_L only cluster (direction) in ECL, KLM;
missing info from kinematic constraints;

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







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

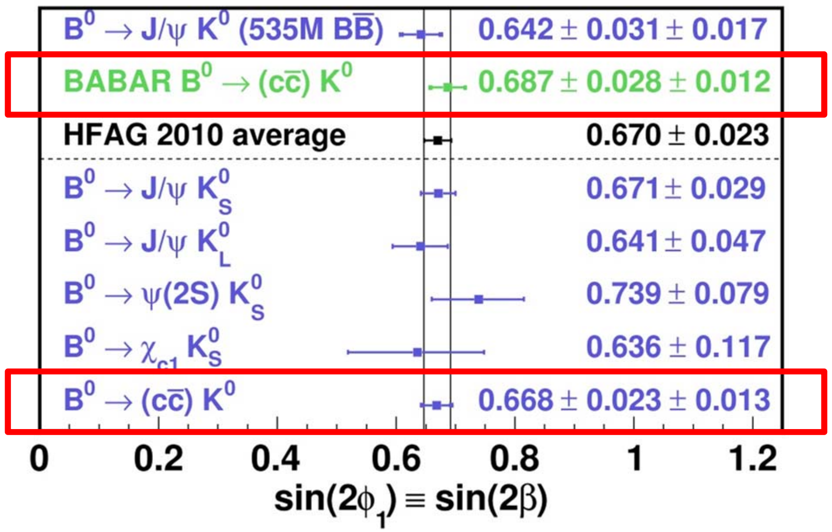
ϕ_1 from $B^0 \rightarrow c\bar{c}\, K^0$

Belle, preliminary, 710 fb^{-1}

→talk by T. Higuchi

Final result (preliminary) from Belle:

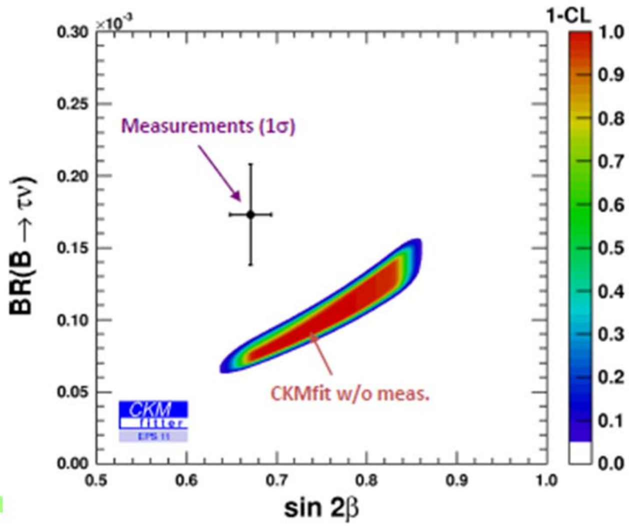
S= 0.668 ± 0.023 ± 0.013
A= 0.007 ± 0.016 ± 0.013



Still statistics limited, part of the syst. is statistics dominated!

Tension between $\mathcal{B}(B \rightarrow \tau\nu)$ and $\sin 2\phi_1$ (~2.5 σ) remains

→talk by V. Niess



CP violation in B → D^+D^- and $D^{*+}D^{*-}$

SM: b→ccd, S=sin2ϕ_1 (=sin2β), A=0

B → D^+D^-

Belle preliminary

$$S = -1.06 \pm 0.18 \pm 0.07$$

$$A = +0.43 \pm 0.16 \pm 0.04$$

772 x 10^6 $B\bar{B}$ pairs

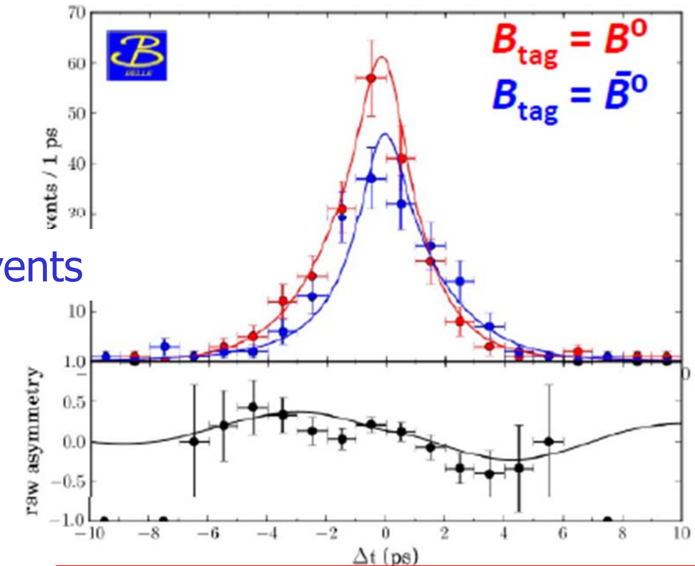
$B^0 \to (K^-\pi^+\pi^+)(K^+\pi^-\pi^-)$, $(K^-\pi^+\pi^+)(K_S\pi^0)$+c.c.

Previous measurement (535x10^6 $B\bar{B}$ pairs):

$$S = -1.13 \pm 0.37 \pm 0.09,$$

$$A = +0.91 \pm 0.23 \pm 0.06$$

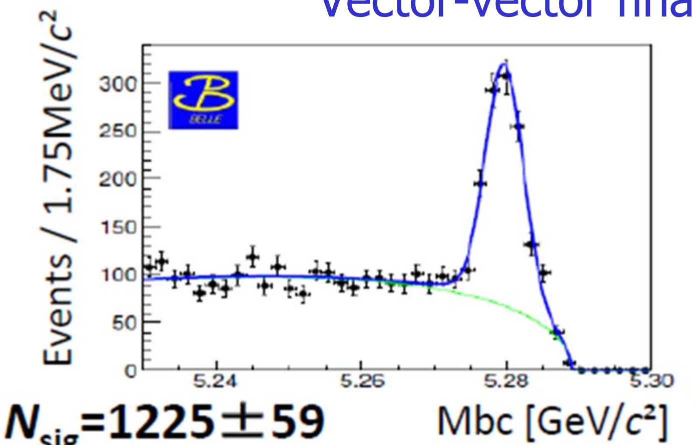
320 events



→ Large CP violation effects in many places!

B→$D^{*+}D^{*-}$

Vector-vector final state, need angular analysis for CPV measurement



N_{sig}=1225±59

1225 events, >2x increase in yield vs the 2009 paper

$$S = -0.79 \pm 0.13 \pm 0.03$$

$$A = +0.15 \pm 0.08 \pm 0.02$$

$$R_0 = 0.63 \pm 0.03 \pm 0.01$$

$$R_\perp = 0.14 \pm 0.02 \pm 0.01$$

772 x 10^6 $B\bar{B}$ pairs

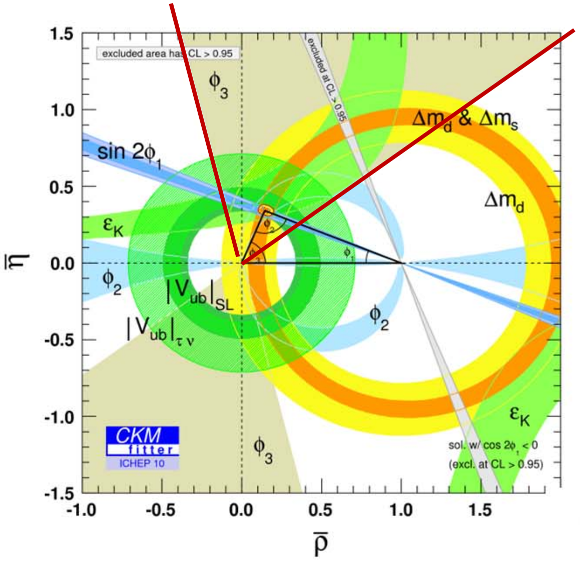
Belle preliminary

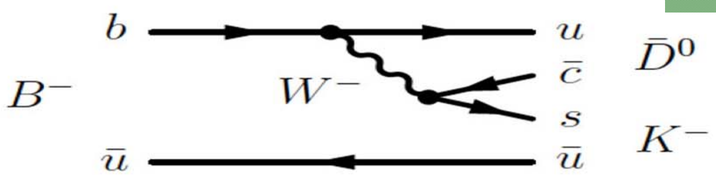
ϕ_3 (=γ) with Dalitz analysis

GGSZ method:

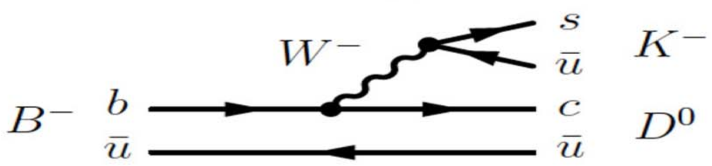
A. Giri et al., PRD68, 054018 (2003)

The best way to measure ϕ_3





Color+CKM suppressed



Favored

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

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

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

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

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

ϕ_3=(78 ± 12 ± 4 ± 9)°

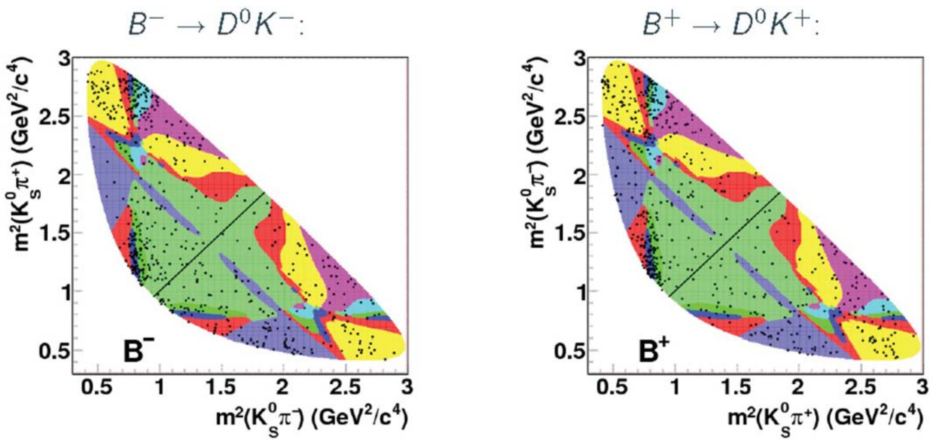
Belle, PRD81, 112002, (2010), 605 fb[-1]

ϕ_3=(68 ± 14 ± 4 ± 3)°

BaBar, PRL 105, 121801, (2010)

ϕ_3 (=γ) from model-independent/binned Dalitz method

GGSZ method: How to avoid the model dependence?
→ Suitably subdivide the Dalitz space into bins



$$M_i^\pm = h\{K_i + r_B^2 K_{-i} + 2\sqrt{K_i K_{-i}}(x_\pm c_i + y_\pm s_i)\}$$

$$x_\pm = r_B \cos(\delta_B \pm \phi_3) \quad y_\pm = r_B \sin(\delta_B \pm \phi_3)$$

M_i: # B decays in bins of D Dalitz plane, K_i: # D^0 ($\overline{D^0}$) decays in bins of D Dalitz plane ($D^* \to D\pi$), c_i, s_i: strong ph. difference between symm. Dalitz points ← Cleo, PRD82, 112006 (2010)

BELLE

Use only DK
N_{sig} = 1176 ± 43

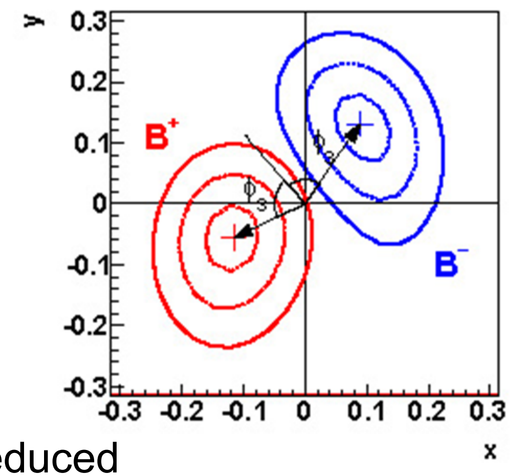
Belle, 710 fb^{-1}
arXiv:1106.4046

4-dim fit for signal yield (ΔE, M_{bc}, cosθ_{thrust}, $\mathcal{F}$);

ϕ_3=(77 ± 15 ± 4 ± 4)°

from c_i, s_i (statist.!)

to be reduced with BESIII data



Important method upgrade for large event samples at LHCb and super B factories

→talk by J. Dalseno

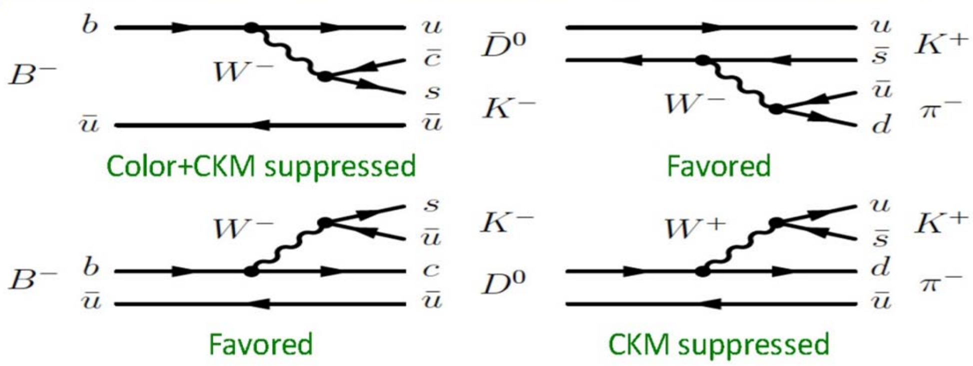
ϕ_3 with the ADS method

D. Atwood, I. Dunietz, A. Soni, PRL78, 3257 (1997)

$B^- \to [K^+\pi^-]_D K^-$ compared to
$B^- \to [K^-\pi^+]_D K^-$

$$\mathcal{R}_{DK} \equiv \frac{\mathcal{B}([K^+\pi^-]_D K^-) + \mathcal{B}([K^-\pi^+]_D K^+)}{\mathcal{B}([K^-\pi^+]_D K^-) + \mathcal{B}([K^+\pi^-]_D K^+)}$$

$$\mathcal{A}_{DK} \equiv \frac{\mathcal{B}([K^+\pi^-]_D K^-) - \mathcal{B}([K^-\pi^+]_D K^+)}{\mathcal{B}([K^+\pi^-]_D K^-) + \mathcal{B}([K^-\pi^+]_D K^+)}$$



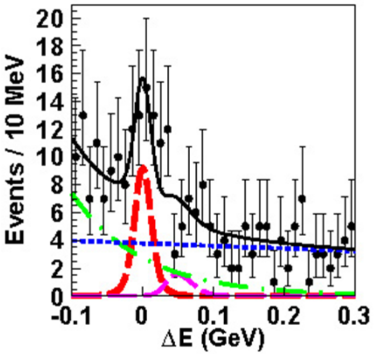
using additional input on r_B, r_D, ϕ_3 can be extracted in a model independ. manner

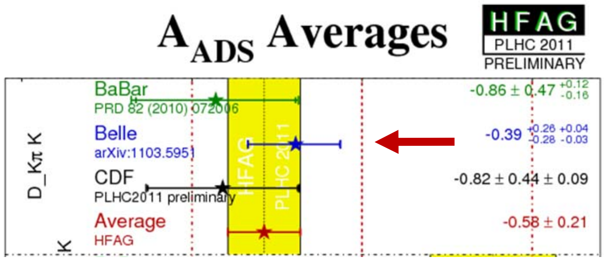
$$\mathcal{R}_{DK} = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D) \cos\phi_3,$$
$$\mathcal{A}_{DK} = 2 r_B r_D \sin(\delta_B + \delta_D) \sin\phi_3 / \mathcal{R}_{DK},$$

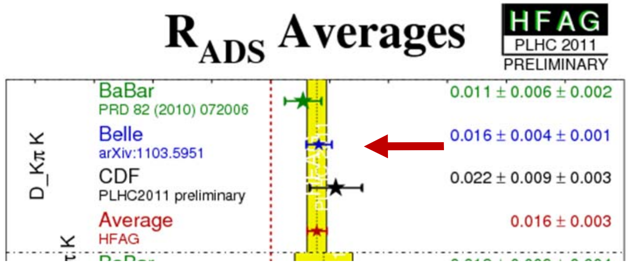
$R_{DK} = (1.63\,^{+0.44}_{-0.41}\,^{+0.07}_{-0.13}) \cdot 10^{-2}$
$A_{DK} = -0.39\,^{+0.26}_{-0.28}\,^{+0.04}_{-0.03}$

Belle, PRL 106, 231803 (2011)
arXiv:1103:5951, 710 fb^{-1}

$B^- \to [K^+\pi^-]_D K^-$
N_{sig}=56 ±15, 4.1 σ sign.,
first evidence







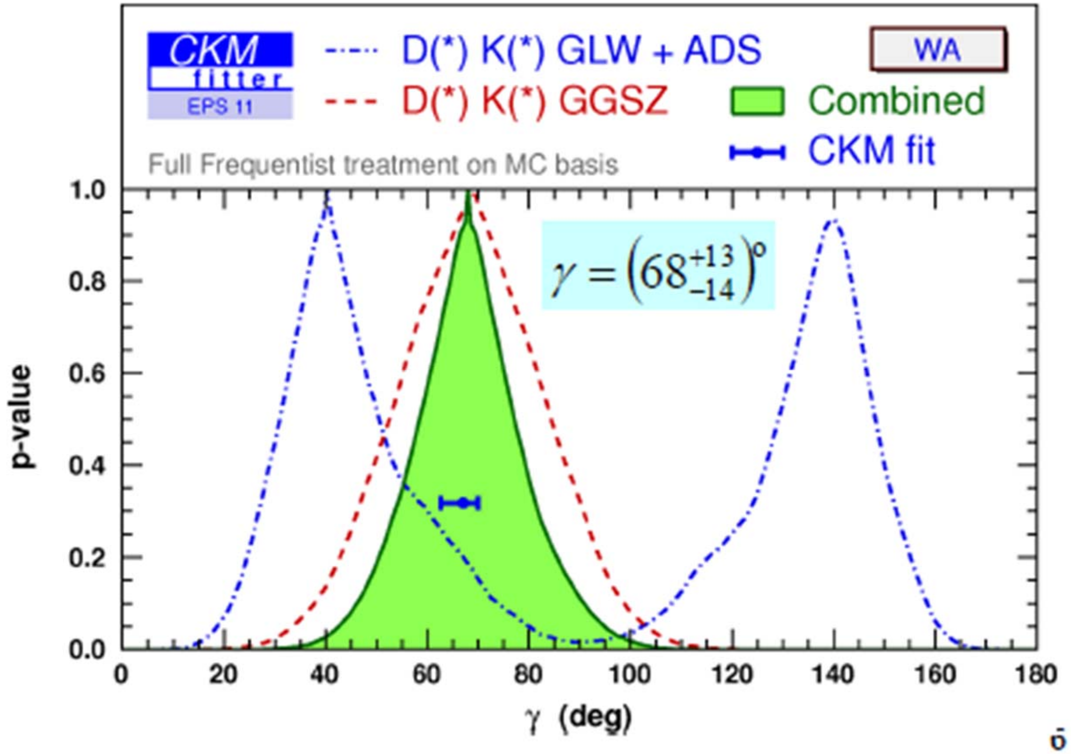
ADS can also be done in other channels: e.g.
B → D^0 K, D → K π π^0

BaBar, arXiv:1104:4472
→talk by D. Derkach

ϕ_3 measurement

Combined ϕ_3 value:

$\phi_3 = (68\ ^{+13}_{-14})$ degrees



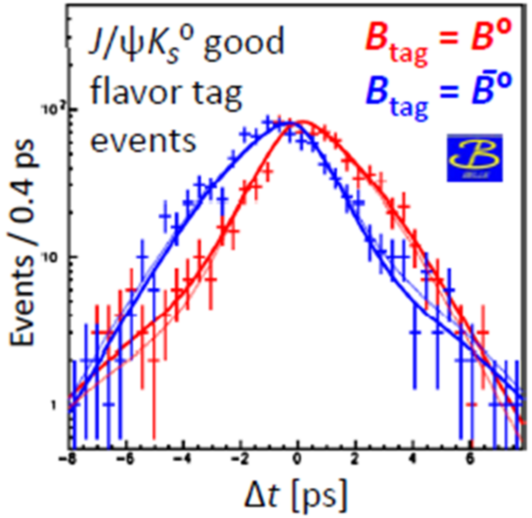
Note that B factories were not built to measure ϕ_3

It turned out much better than planned!

This is not the last word from B factories, analyses still to be finalized...

Search for CPT violation in B decays

Allow in addition to CP violation also for CPT violation in fitting the Δt distribution function (e.g. in $J/\psi\ K^0_S$ decays)
CPT-violating complex parameter: z
→ $Re(z) \neq 0$ and/or $Im(z) \neq 0$
→ CPT is violated.



Light lines indicate Re(z) = +0.2 Im(z) = +0.0 case.

Belle preliminary

$$\mathrm{Re}(z) = (+1.9 \pm 3.7 \pm 3.2) \times 10^{-2}$$

$$\mathrm{Im}(z) = (-5.7 \pm 3.3 \pm 6.0) \times 10^{-3}$$

$$\Delta\Gamma_d / \Gamma_d = (-1.7 \pm 1.8 \pm 1.1) \times 10^{-2}$$

535 x 10^6 $B\bar{B}$ pairs

Other parameters

$$\tau_{B^0} = 1.531 \pm 0.004 \quad \text{(ps)}$$

$$\tau_{B^+} = 1.639 \pm 0.006 \quad \text{(ps)}$$

$$\Delta m_d = 0.506 \pm 0.003 \quad (\mathrm{ps}^{-1})$$

$$|\lambda_{CP}| = 0.999 \pm 0.004$$

$$\arg(\eta_{CP}\lambda_{CP}) = -0.70 \pm 0.04$$

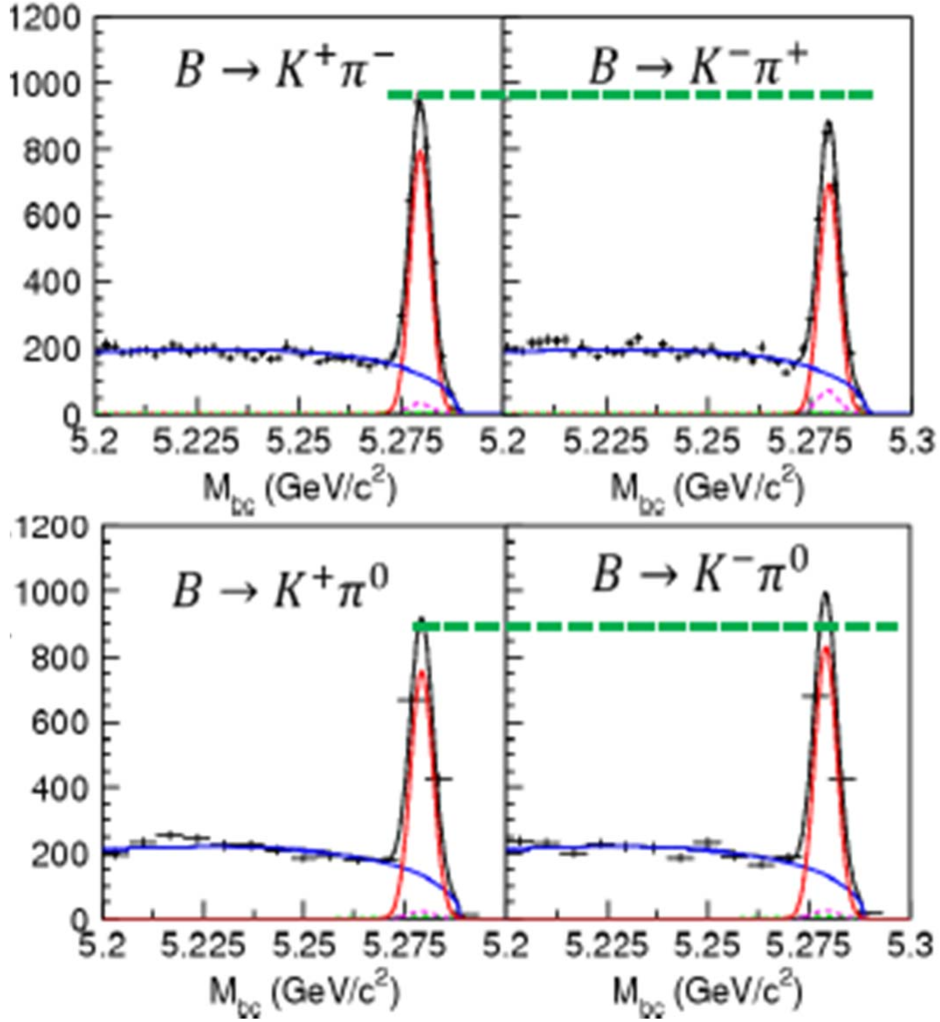
Above λ_{CP} corresponds to $S = +0.645$, which matches Belle's latest result, $S = +0.668 \pm 0.023 \pm 0.012$.

Best CPT violation measurement → no CPT violation in the B meson system

→talk by T. Higuchi

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

preliminary



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

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

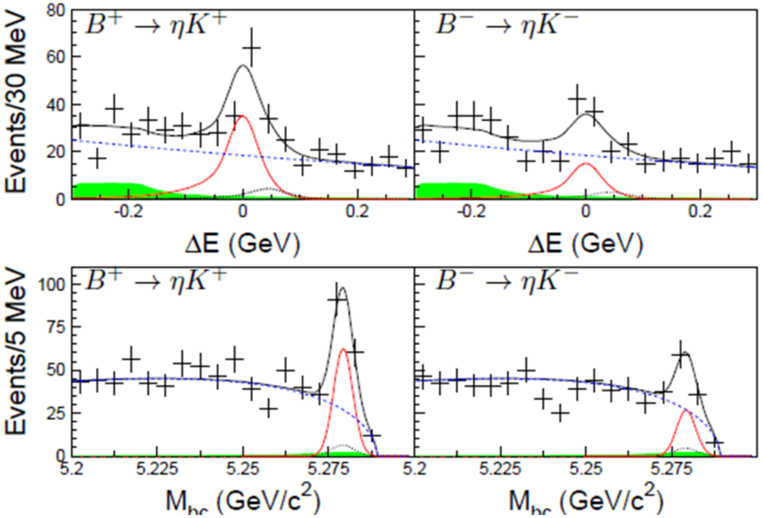
$$A_{cp}(K^\pm\pi^0) = +0.043 \pm 0.024 \pm 0.002$$
$$A_{cp}(K^\pm\pi^\mp) = -0.069 \pm 0.014 \pm 0.007$$

Belle preliminary:

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

→talk by P. Chang

Direct CP violation in B → ηK^+, $\eta\pi^+$



B → ηK^+

$A_{CP} = -0.38 \pm 0.10 \pm 0.01$ @3.8σ

In agreement with previous Belle and BaBar measurement,
$A_{CP} = -0.36 \pm 0.11 \pm 0.03$ @3.3σ

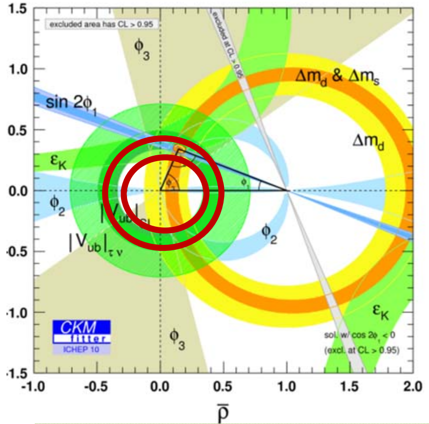
B → $\eta\pi^+$

$A_{CP} = -0.19 \pm 0.06 \pm 0.01$ @3.0σ

Tension between Belle and BaBar 2009 measurement remains
$A_{CP} = -0.03 \pm 0.09 \pm 0.03$

Essential: neutral detection capabilities of B factories

$|V_{ub}|$ from $B^0 \rightarrow \pi^- \ell^+ \nu$ exclusive decays



Yield: 2d fit in $M_{bc}=M_{ES}$ and ΔE, bins of q^2

$$m_{bc} = \sqrt{E_{beam}^2 - |\vec{p_\pi} + \vec{p_\ell} + \vec{p_\nu}|^2}$$
$$\Delta E = E_{beam} - (E_\pi + E_\ell + E_\nu)$$

$\mathcal{B}=(1.41\pm0.05\pm0.07)\cdot10^{-4}$

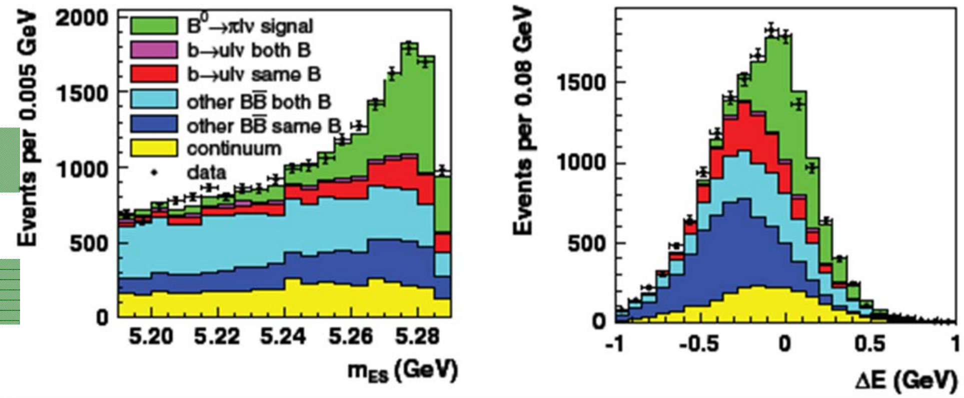
BaBar, PRD83, 032007 (2011)

$\mathcal{B}=(1.42\pm0.05\pm0.07)\cdot10^{-4}$

BaBar, PRD83, 052011 (2011)

$\mathcal{B}=(1.49\pm0.04\pm0.07)\cdot10^{-4}$

Belle, arXiv:1012:0090



→talks by P. Urquijo, M. Franco Sevilla

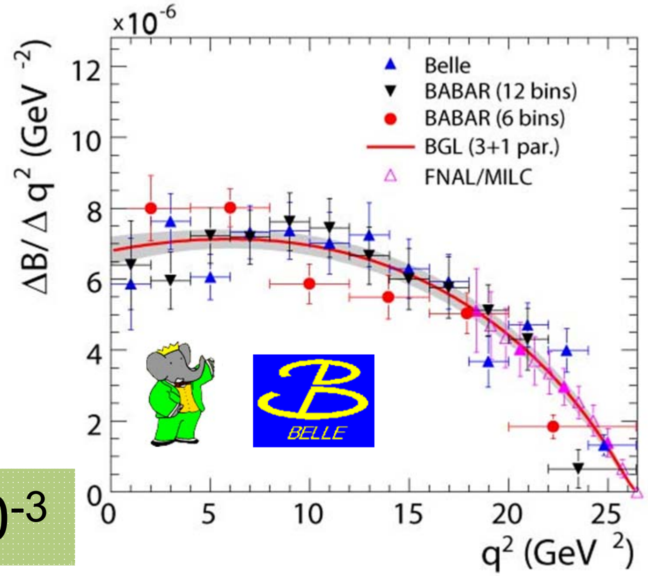
$|V_{ub}|$ extraction: fit data + LQCD points in

$$q^2 = (p_\ell + p_\nu)^2 = (p_B - p_\pi)^2$$

BaBar + FNAL/MILC $|V_{ub}| = (3.13\pm0.12\pm0.28)\cdot10^{-3}$

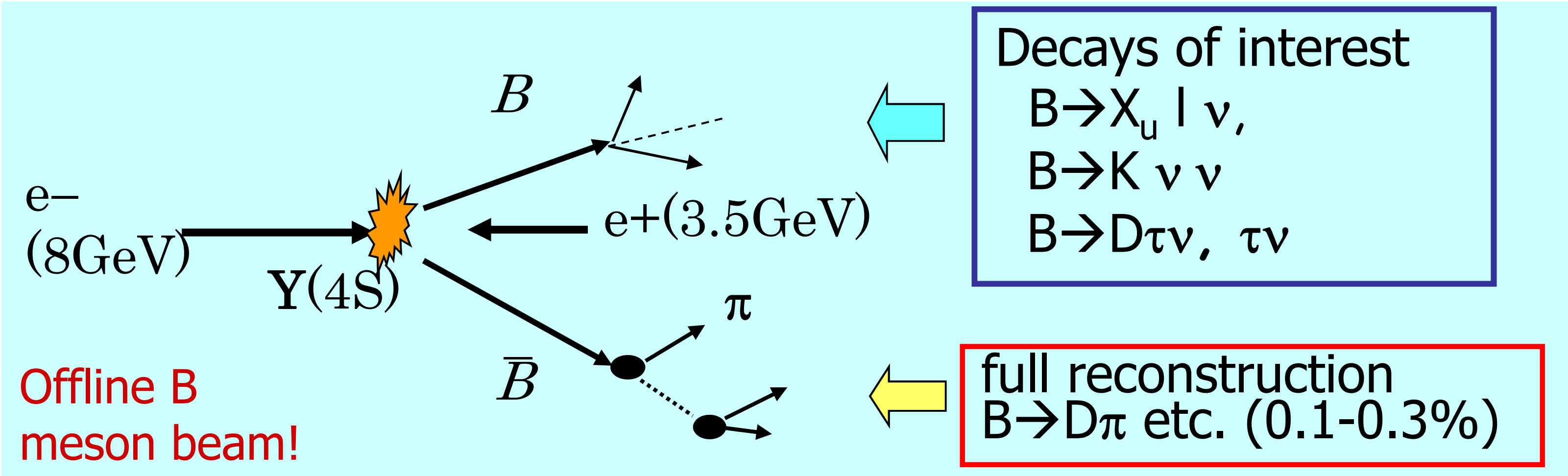
Belle + FNAL/MILC $|V_{ub}| = (3.43\pm0.33)\cdot10^{-3}$

Belle + BaBar + FNAL/MILC $|V_{ub}| = (3.26 \pm 0.30)\cdot10^{-3}$



$|V_{ub}|$ from inclusive decays

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

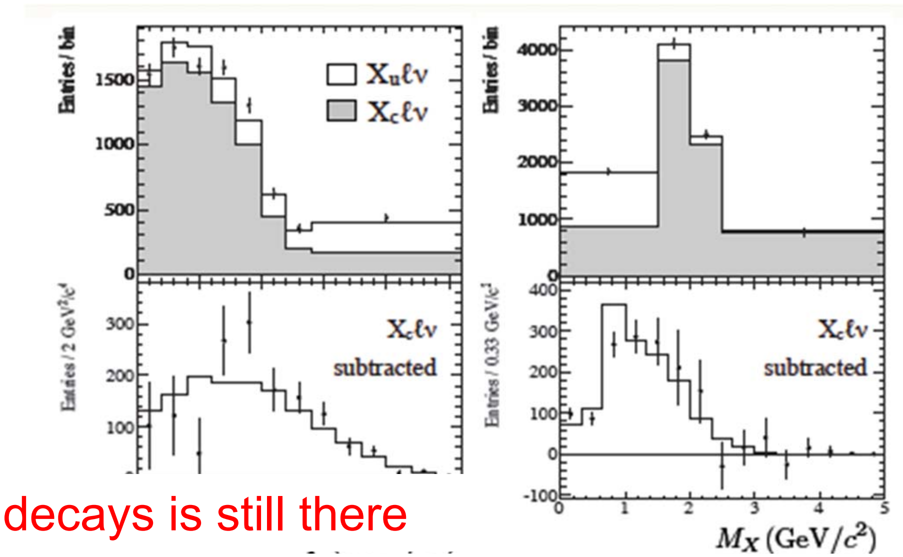


Powerful tool for B decays with neutrinos, used in several analyses in this talk
→unique feature at B factories

Use this method in an inclusive b→u measurement, K veto for b→c background reduction.

N_{sig} = 1441 ± 102

V_{ub}=(4.31±0.25±0.16)·10^{-3}



→ Tension between inclusive and exclusive decays is still there

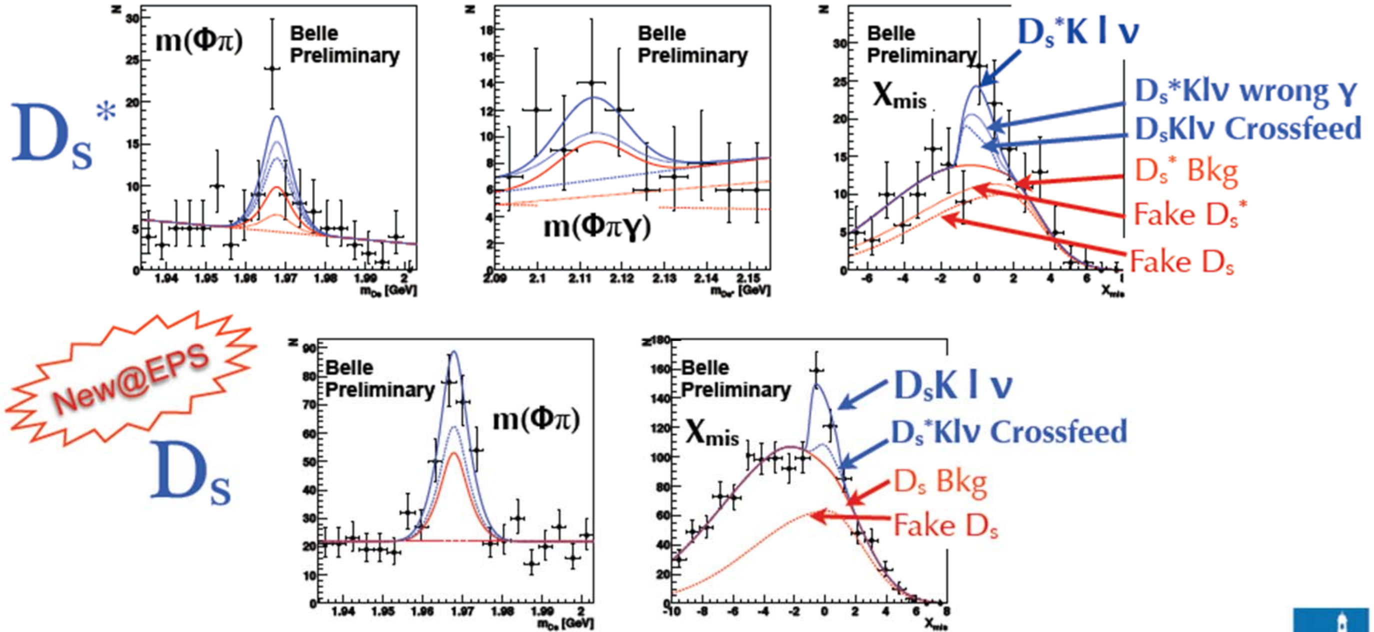
$B \to D_s^{(*)} K\, l\, \nu$

Search for missing exclusive modes in semileptonic B decays

arXiv:1012:4158

$B(D_s^{(*)} K\, l\, \nu) = (6.13 \pm 1.04\,(\mathrm{stat}) \pm 0.43(\mathrm{syst}) \pm 0.51(BR(D_s^*))) \cdot 10^{-4}$, $>5\sigma$

Disentangle $D_s\, K\, l\, \nu$ from $D_s^*\, K\, l\, \nu$:



ɔnic Decays at Belle, EPS2011 7

Mode	BR: Belle Preliminary
$D_s\, K\, l\, \nu$	$(3.0 \pm 1.2_{stat}{}^{+1.1}_{-0.8\ sys})10^{-4}$
$D_s^*\, K\, l\, \nu$	$(2.9 \pm 1.6_{stat}{}^{+1.1}_{-1.0\ sys})10^{-4}$
Combined	6 σ significance

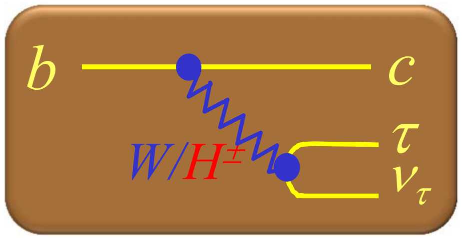
Consistent with BaBar combined fit

→talk by P. Urquijo

universitätbonn

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

Semileptonic decay sensitive to charged Higgs

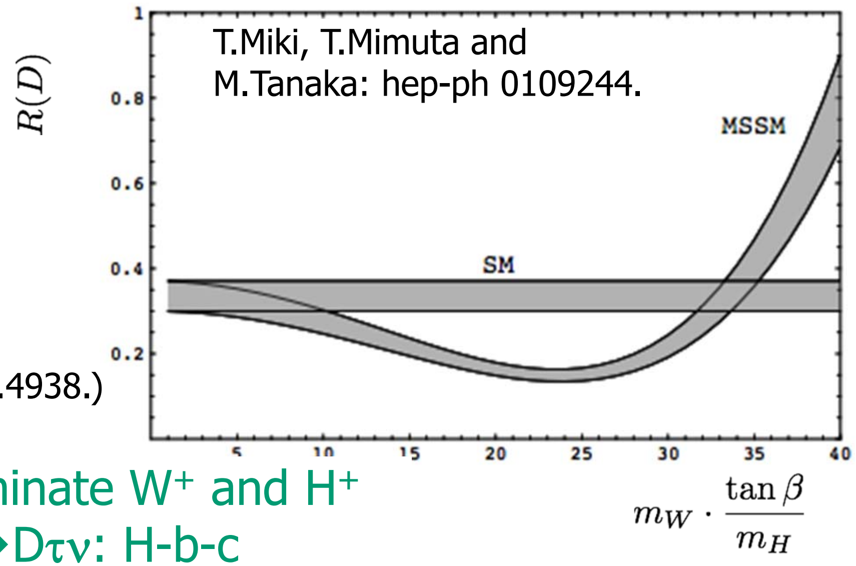


Ratio of τ to μ,e could be reduced/enhanced significantly

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

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)

Advantage of B factories!

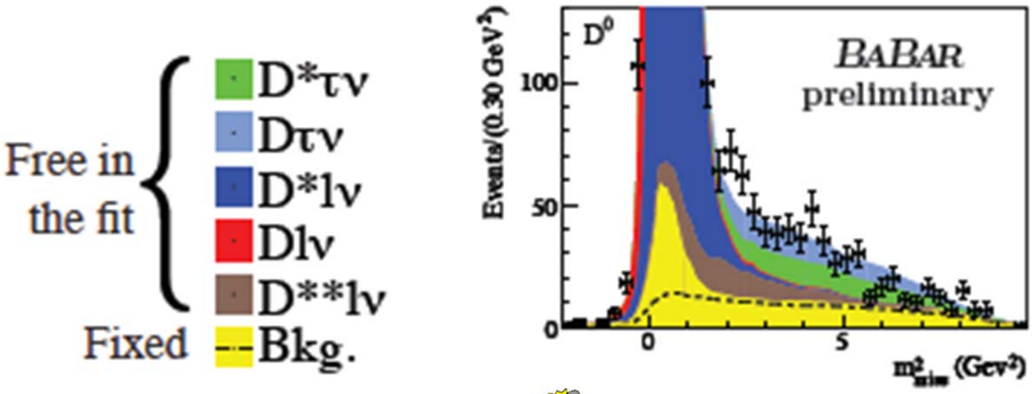
First observation of $B \to D^{*-}\tau\nu$ by Belle (2007) → PRL 99, 191807 (2007)

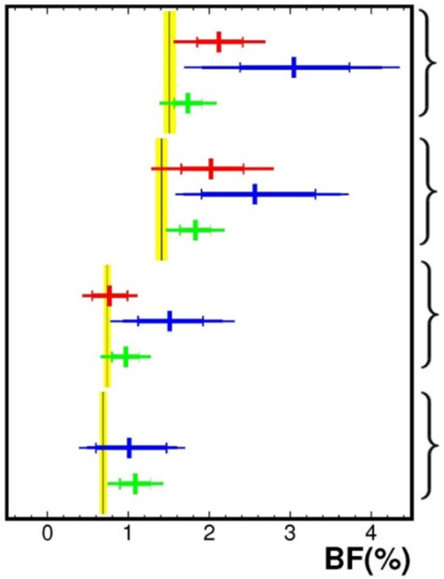
B → D$^{(*)}\tau\nu$ decays

→talk by M. Franco Sevilla

This conference: First 5σ observation of B → Dτν decays

Exclusive hadron tag data





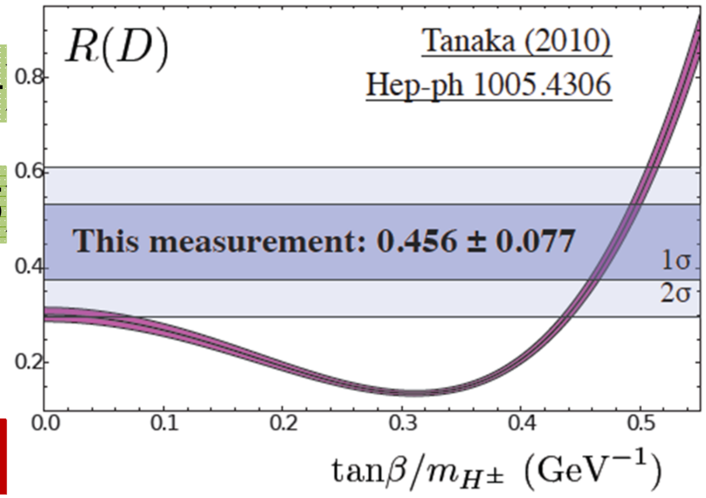
$B^+ \to \overline{D}^{*0}\tau^+\nu_\tau$ (1.73±0.17±0.18)%

$B^0 \to D^{*-}\tau^+\nu_\tau$ (1.82±0.19±0.17)%

$B^+ \to \overline{D}^{0}\tau^+\nu_\tau$ (0.96±0.17±0.14

$B^0 \to D^{-}\tau^+\nu_\tau$ (1.08±0.19±0.15

All values higher then SM predictions →



Belle inclusive tag, Belle exclusive tag, Babar excusive tag (this conference) compared to the SM prediction

$B \rightarrow \nu\,\nu$ decay

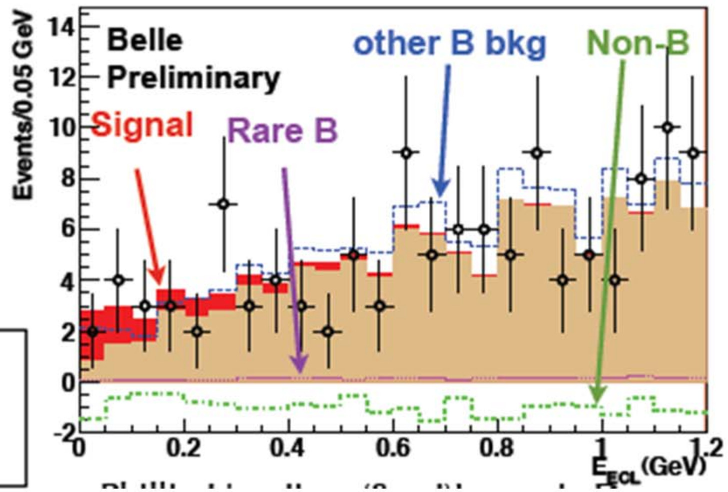
$B \rightarrow \nu\,\nu$ similar as $B \rightarrow \mu\,\mu$ a very sensitive channel to NP contributions

Even more strongly helicity suppressed by $\sim(m_\nu/m_B)^2$

$\rightarrow$ Any signal = NP

Unique feature at B factories: use tagged sample with fully reconstructed B decays on one side, require no signal from the other B.

Use rest energy in the calorimeter and angular distribution as the fit variables.



90% C.L. BR < 1.3 x 10^{-4}

Belle Preliminary 657M BBbar

c.f. (Babar) BR < 2.2 x 10^{-4}

$\rightarrow$talk by P. Urquijo

Charm and τ physics

B factories = charm and τ factories

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

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

Charm and τ results: mainly on CP violation searches and rare decays

τ: lepton flavour violation → next talk (T. Mori)

CP violation searches in D decays

Very small in SM, decay rate asymmetry A_{CP} O(0.1%), with NP up to O(1%)

Search for CPV in $D^+_{(s)} \to \phi\,\pi^+$, measure difference of A_{rec} for $D^+ \to \phi\,\pi^+$ and $D^+_s \to \phi\,\pi^+$ decays in bins of $\cos\Theta^*$, p_π, $\cos\Theta_\pi$

$$\Delta A_{rec}(\cos\theta^*, p_\pi, \cos\theta_\pi) = \Delta A_{CP} + \Delta A_{FB}(\cos\theta^*)$$

$\to$ odd in $\cos\Theta^*$

No CPV expected in the $D^+_s \to \phi\,\pi^+$ (Cabbibo favoured decay)

$$\to \quad A_{CP}^{D^+\to\phi\pi^+} = (+0.51 \pm 0.28 \pm 0.05)\%$$

$\to$talk by M. Starič

$D^+ \to K^0_S\,\pi^+$ $\boxed{A_{CP} = (-0.44 \pm 0.13 \pm 0.10)\%}$

$\to$talk by M. Martinelli

Contribution from CPV in K^0_S =-(0.332 +-0.006)%

PRD83, 071103(R) (2011)

$D^0 \to K^0_S\,\pi^0$, tag D flavour with the D* decay

$$\boxed{D^0 \to K^0_s\pi^0 \quad -0.28 \pm 0.19 \pm 0.10}$$

PRL106, 211801 (2011)

Contribution from CPV in K^0_S =-(0.332 +-0.006)%

Assuming no direct CP in this decay$\to$

$$a^{\mathrm{ind}} = A_{CP}^{K^0_s\pi^0} - A_{CP}^{K^0} = (+0.05 \pm 0.19 \pm 0.10)\%$$

D decays: CP violation searches and rare decays

T-odd correlations in $D^+ \to K_s h^+h^-h^+$.

Final state interactions: their effect can be eliminated in the difference $A_T(D^+)$ - $A_T(D^-)$. Result: consistent with 0

$$\mathcal{A}_T(D^+) = (-12.0 \pm 10.0_{\text{stat}} \pm 4.6_{\text{syst}}) \times 10^{-3}$$
$$\mathcal{A}_T(D_s^+) = (-13.6 \pm 7.7_{\text{stat}} \pm 3.4_{\text{syst}}) \times 10^{-3}$$

→ paper submitted
→talk by M. Martinelli

$D \to \gamma\gamma$

$B(D \to \gamma\gamma) < 2.4\ 10^{-6}$, 10x improvement vs PDG value

NP estimates
Singer, Fajfer, Zupan, PRD64, 074008 (2011)

→talk by E. Grauges

$X_c \to h\, l^+l^-$ heavily suppressed, SM~10^{-8}, NP could enhance it to 10^{-6} -10^{-5}

Influence of resonances in the final state excluded by a veto on ϕ mass.

Upper limits depend on the final state, typically 10^{-6} -10^{-5}

B_s decays: use 121 fb^{-1} of $\Upsilon(5S)$ data

Data taking at $\Upsilon(5S)$, initial motivation: study B_s decays

First 21 fb^{-1}: used to measure $B_s \to D_s^{(*)}\pi$, $D_s^{(*)}\rho$, $D_s^{(*)}D_s^{(*)}$,
B_s and B_s^* mass, world's best measurement

121 fb^{-1} of $\Upsilon(5S)$ $\to$ 15M B_s decays: clean sample

$\to$Observation of the first baryonic B_s decay to $\Lambda_c \Lambda \pi$

$\to$CP eigenstates:

- $B_s \to J/\psi\, f_0$, $J/\psi\, f_0(1370)$
- $B_s \to J/\psi\, \eta$, $J/\psi\, \eta$\` (almost ready...)

$\to$talk by R. Louvot

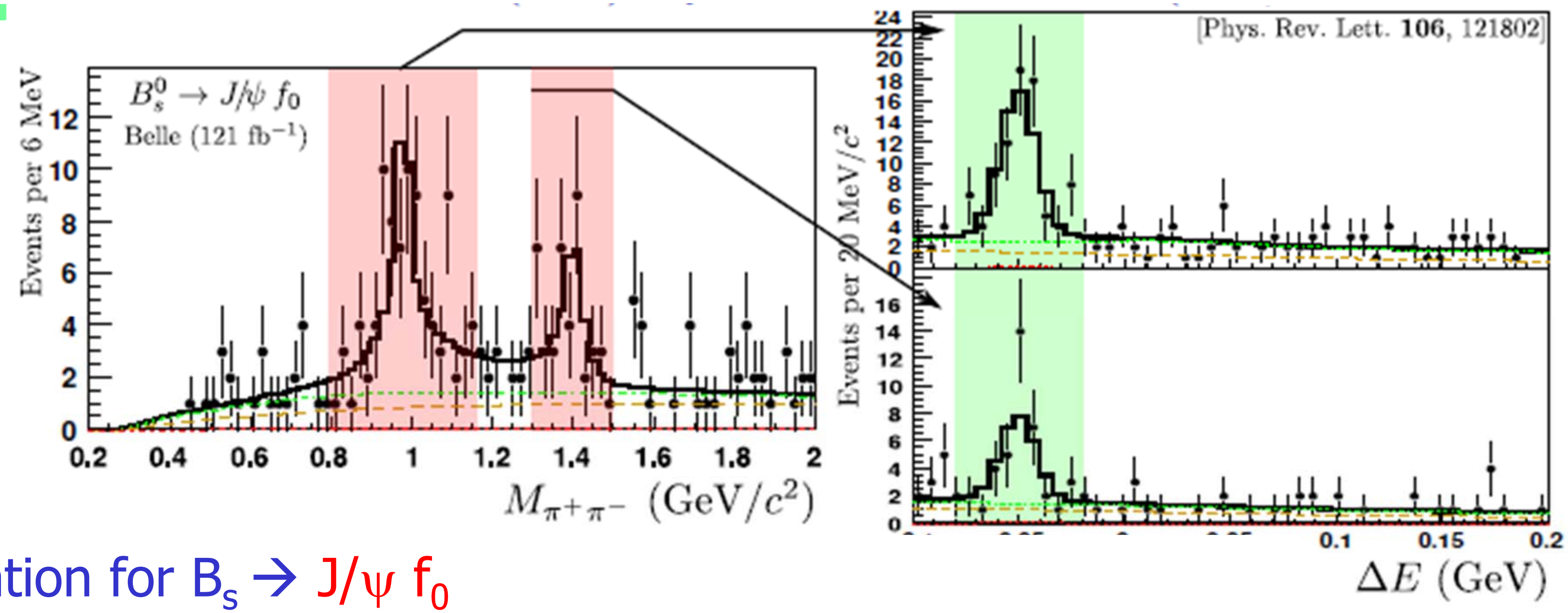
Measure $\sin 2\phi_1$ in Y(5S) $\to$ B B π decays

$\Upsilon(5S)$ is a puzzling object...

$\to$Complementary to B_s studies at hadron machines because of neutral and neutrino detection capabilities

$B_s \to J/\psi\ f_0$, $J/\psi\ f_0(1370)$

→talk by R. Louvot



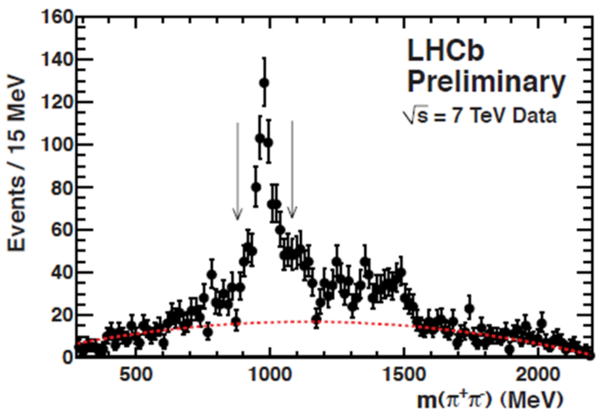
Observation for $B_s \to$ $J/\psi\ f_0$

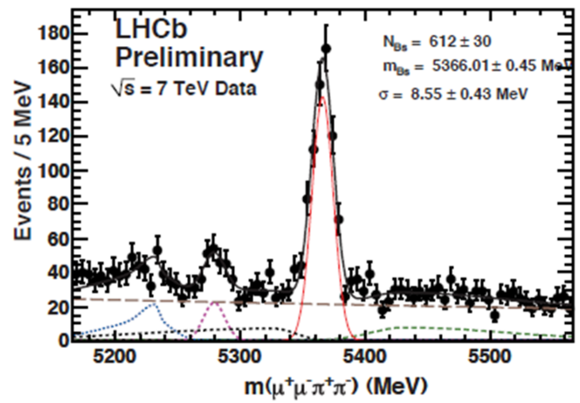
First evidence of $B_s \to$ $J/\psi\ f_0(1370)$

LHCb EPS11

results →

(talk M. Artuso)





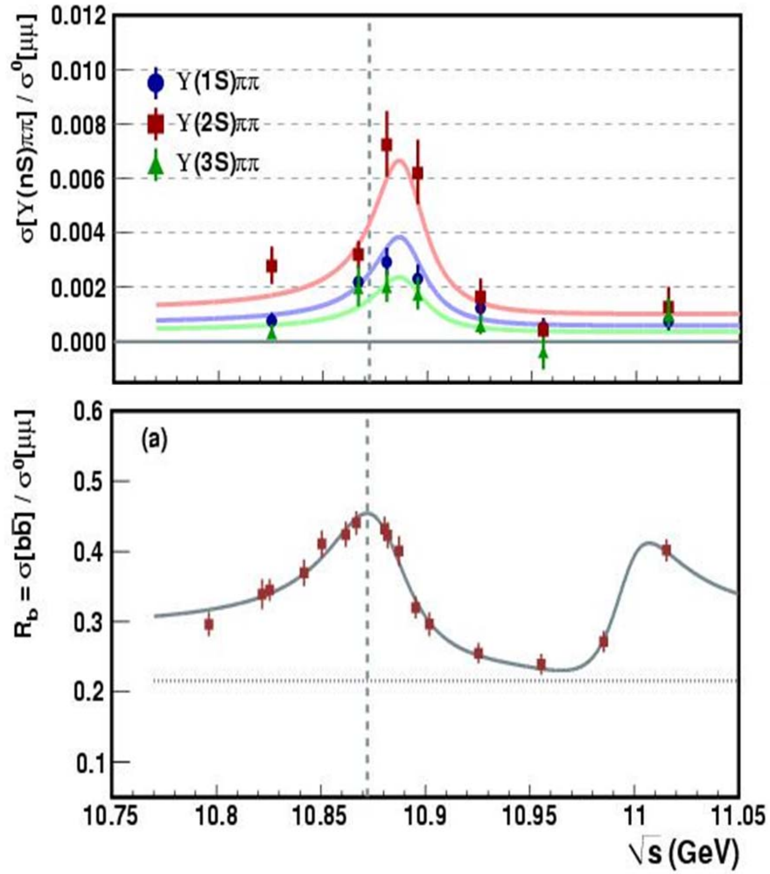
Puzzles of Υ(5S) decays

PRL100,112001(2008)

	Γ(MeV)
$\Upsilon(5S) \to \Upsilon(1S)\pi^+\pi^-$	$0.59 \pm 0.04 \pm 0.09$
$\Upsilon(5S) \to \Upsilon(2S)\pi^+\pi^-$	$0.85 \pm 0.07 \pm 0.16$
$\Upsilon(5S) \to \Upsilon(3S)\pi^+\pi^-$	$0.52^{+0.20}_{-0.17} \pm 0.10$
$\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$	0.0060
$\Upsilon(3S) \to \Upsilon(1S)\pi^+\pi^-$	0.0009
$\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-$	0.0019

10^2

PRD82,091106R(2010)



(1) Rescattering Υ(5S)$\to$BB$\pi\pi\to\Upsilon$(nS)$\pi\pi$

Simonov JETP Lett 87,147(2008)

(2) Exotic resonance Y_b near Υ(5S)

analogue of Y(4260) resonance

with anomalous Γ(J/ψ $\pi^+\pi^-$)

Dedicated energy scan $\Rightarrow$

shapes of R_b and $\sigma(\Upsilon\pi\pi)$ different (2σ)

Υ(5S) is very interesting and not yet understood

Search for $h_b(nP)$ in $\Upsilon(5S)$ decays

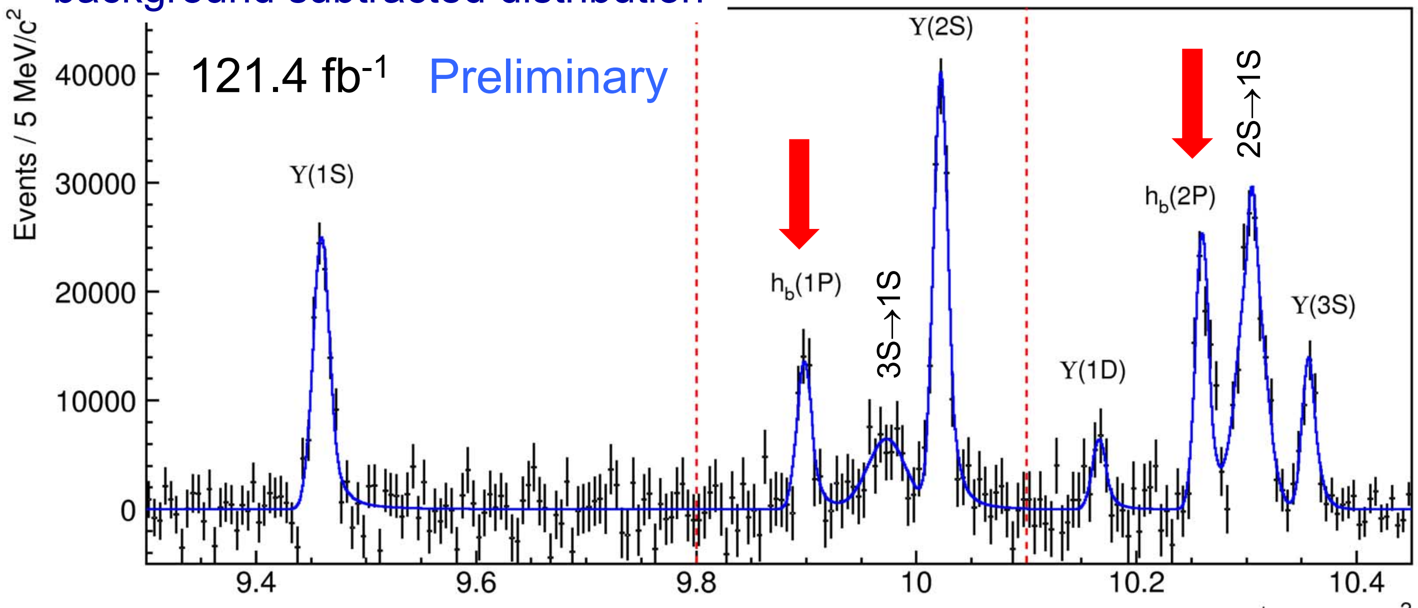
$h_b(nP)$: $(b\bar{b})$, S=0, L=1, $J^{PC}=1^{+-}$

Evidence from BaBar $\Upsilon(3S) \to \pi^0 h_b(1P) \to \pi^0 \gamma \eta_b(1S)$ arXiv:1102.4565

Search for signal $\boxed{\Upsilon(5S)} \to h_b(nP) \boxed{\pi^+\pi^-}$ ← Only two charged pions used

$$M_{hb(nP)} = \sqrt{(P_{\Upsilon(5S)} - P_{\pi+\pi-})^2} \equiv MM(\pi+\pi-)$$

background subtracted distribution



Significance
w/ systematics

$h_b(1P)$ 5.5σ
$h_b(2P)$ 11.2σ

arXiv:1103.3419

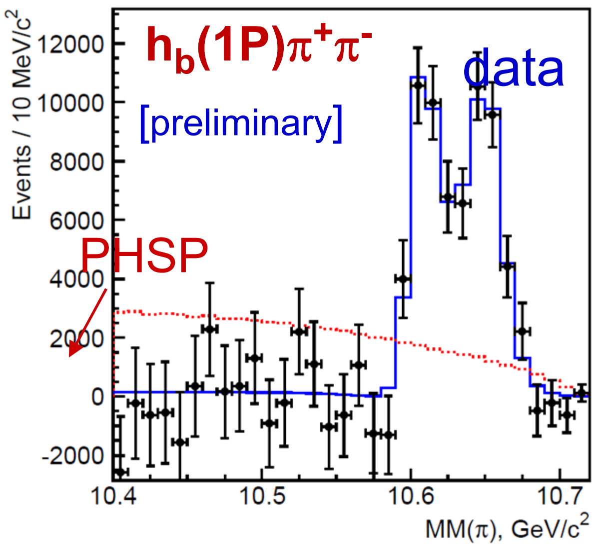
→talk by J. Wicht

h_b production is enhanced (despite of spin flip between Y(5S) and h_b)
→ the mechanism of production is exotic

Resonant substructure in $\Upsilon(5S) \to h_b(nP)\,\pi^+\pi^-$

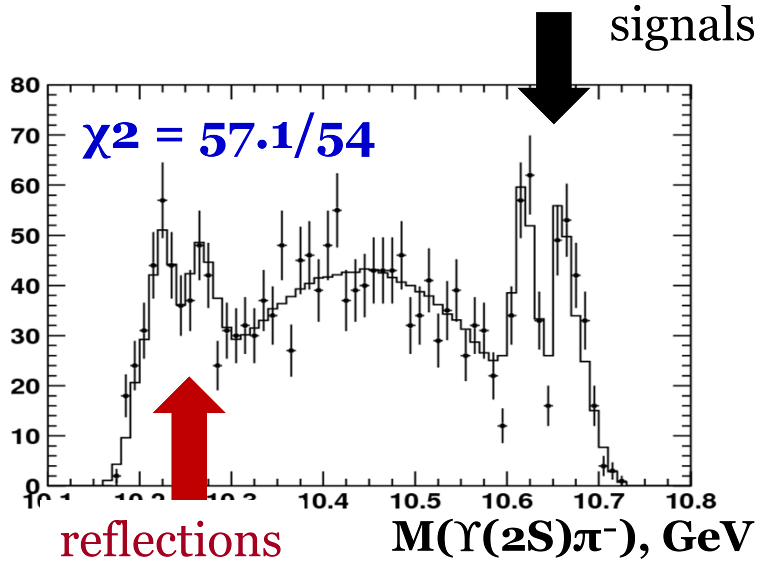
Look at $M(h_b\pi^+) = MM(\pi^-)$

measure $\Upsilon(5S)\to h_b\pi\pi$ yield in bins of $MM(\pi)$



Exclusive searches:

Observed in $\Upsilon(5S) \to$ **$\Upsilon(1S)$** π+π-, **$\Upsilon(2S)$** π+π- and **$\Upsilon(3S)$** π+π-



$Z_b(10610)$ — $M = 10608.1 \pm 1.7$ MeV, $\Gamma = 15.5 \pm 2.4$ MeV

$Z_b(10650)$ — $M = 10653.3 \pm 1.5$ MeV, $\Gamma = 14.0 \pm 2.8$ MeV

Seen in 5 different final states, parameters are consistent

$J^P=1^+$ in agreement with data; other J^P are disfavored

→ What is the nature of Z_b^+? Molecules, tetraquarks, cusps, ... ?

X(3872) properties

X(3872) First observed by Belle in 2003 in B→K X, X → $J/\psi\ \pi^+\pi^-$.

Mass is close to the (D^0+D^{*0}) threshold. Width is less than experimental resolution. Confirmed by BaBar, CDF, D0, LHCb, CMS. Nature not known.

New results, full Belle data sample:

X → $J/\psi\ \pi^+\pi^-$:

arXiv:1105.0177

X in $B^0 \to K^0$ X and $B^+ \to K^+$ X is the same particle,

$\Delta M = (-0.69 \pm 0.97 \pm 0.19)$ MeV

1^{++} and 2^{-+} hypotheses are both possible

arXiv:1107.0163

X(3872) radiative decays:

$\mathcal{B}(X \to \psi' \gamma) / \mathcal{B}(X \to J/\psi\ \gamma) < 2.1$ (90% CL)

(In the molecular model of X, $\mathcal{B}(X \to \psi' \gamma$ is highly suppressed compared to $\mathcal{B}(X \to J/\psi\ \gamma)$

→talk by A. Vinokurova

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 $b \to sl^+l^-$ 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.

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, 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

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

M. Giorgi, ICHEP2010

B Physics @ Υ(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)	$\sim 15°$	2.5°
γ $(B\to DK,\ D\to$ suppressed states)	$\sim 12°$	2.0°
γ $(B\to DK,\ D\to$ multibody states)	$\sim 9°$	1.5°
γ $(B\to DK$, combined)	$\sim 6°$	1–2°
α $(B\to\pi\pi)$	$\sim 16°$	3°
α $(B\to\rho\rho)$	$\sim 7°$	1–2° (∗)
α $(B\to\rho\pi)$	$\sim 12°$	2°
α (combined)	$\sim 6°$	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

	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}
$D^0\to K^0_Se^+e^-$, $D^0\to K^0_S\mu^+\mu^-$	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}
$D^0\to K^0_Se^\pm\mu^\mp$	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

	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}

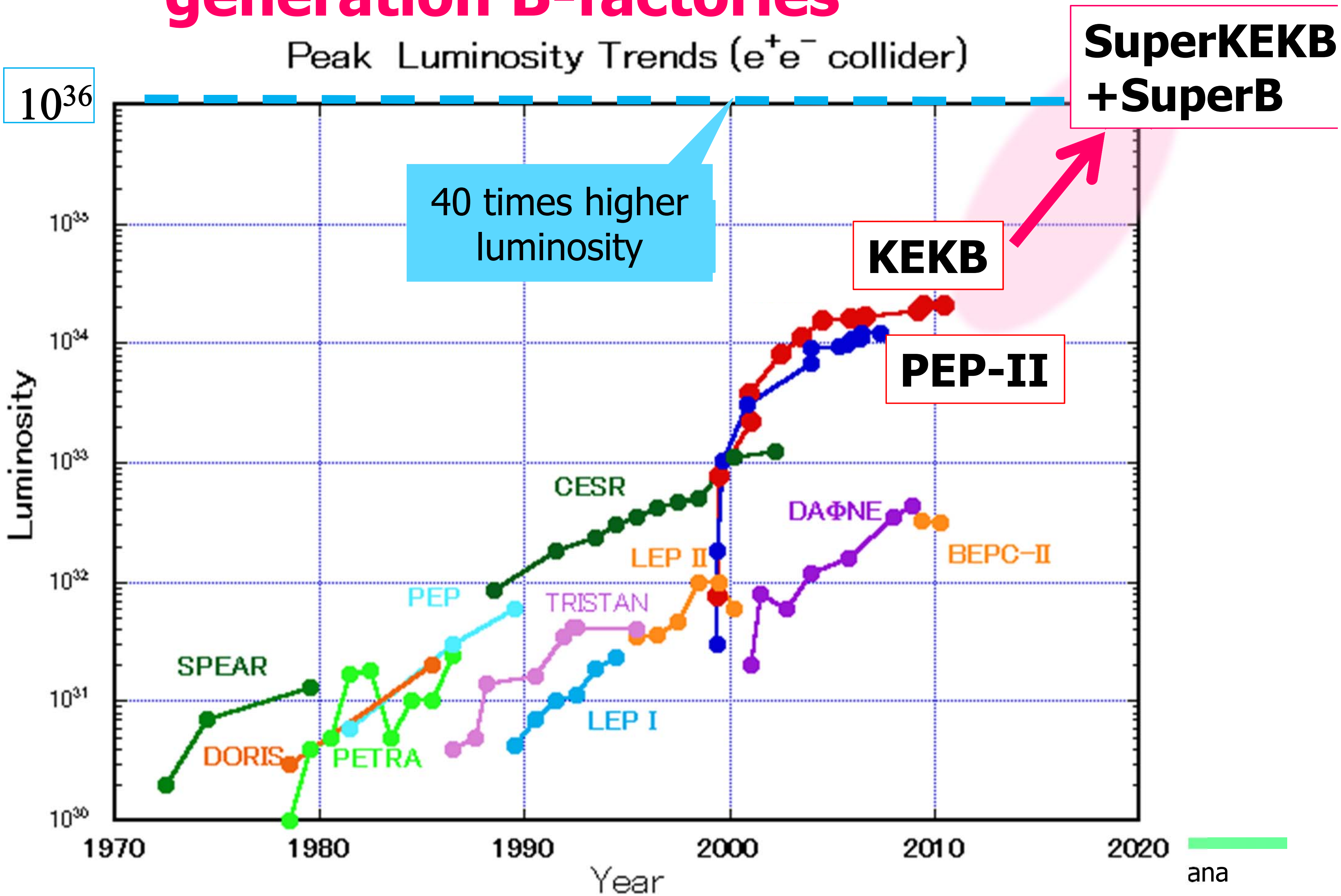
B_s Physics @ Υ(5S)

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°
$A^s_{\rm SL}$	0.006	0.004
$A_{\rm CH}$	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°

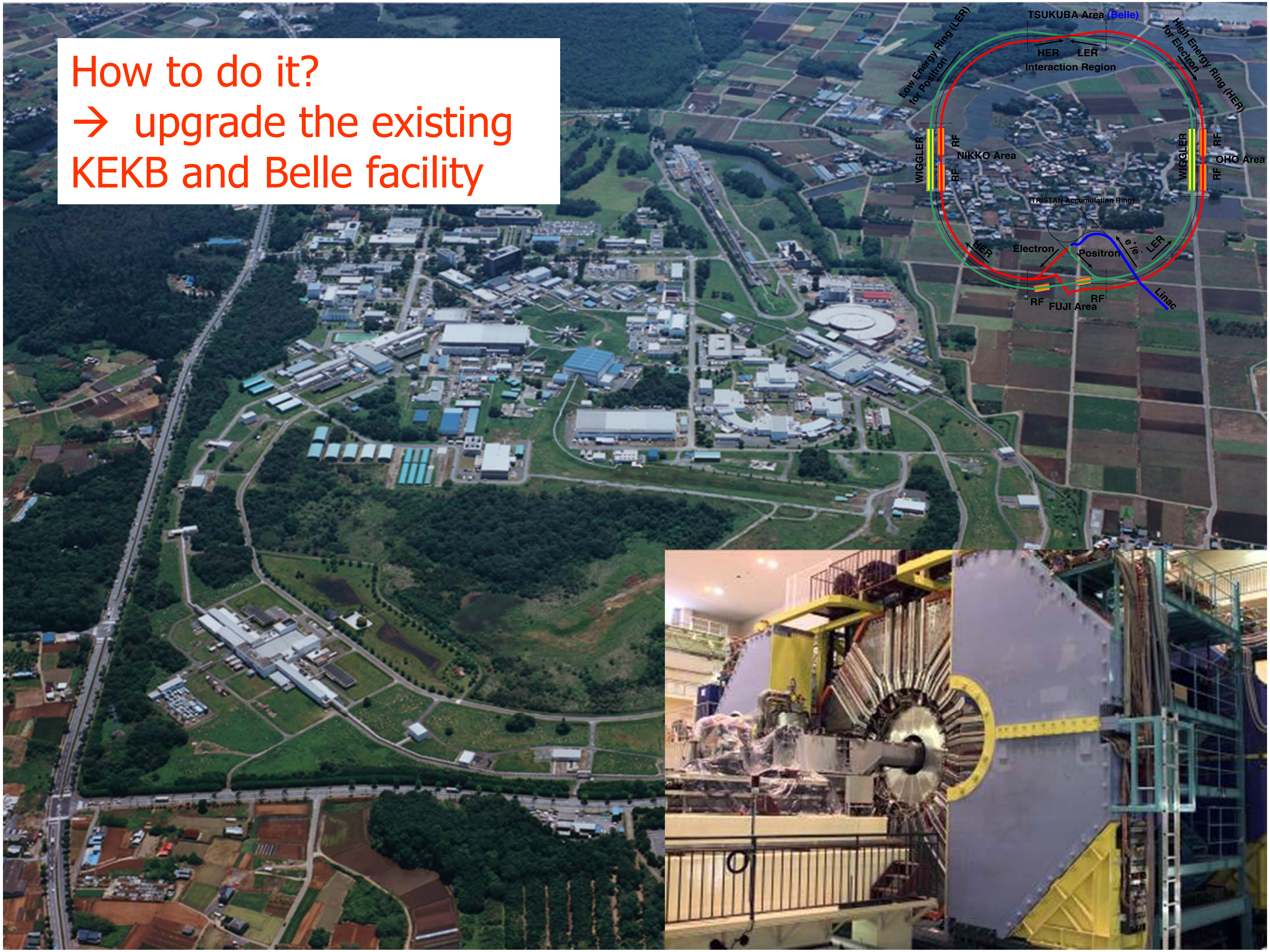
→ Physics at Super B Factory, arXiv:1002.5012 (Belle II)

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

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



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



How to increase the luminosity?

Beam-beam parameter

Lorentz factor

Beam current

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

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

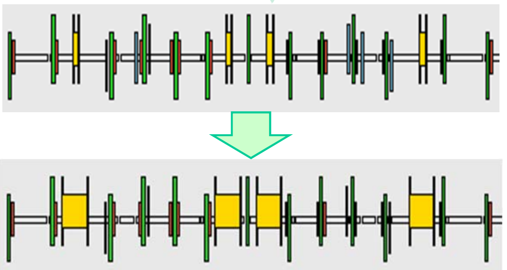
"Nano-Beam" scheme

Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

KEKB → SuperKEKB

Replace short dipoles with longer ones (LER)

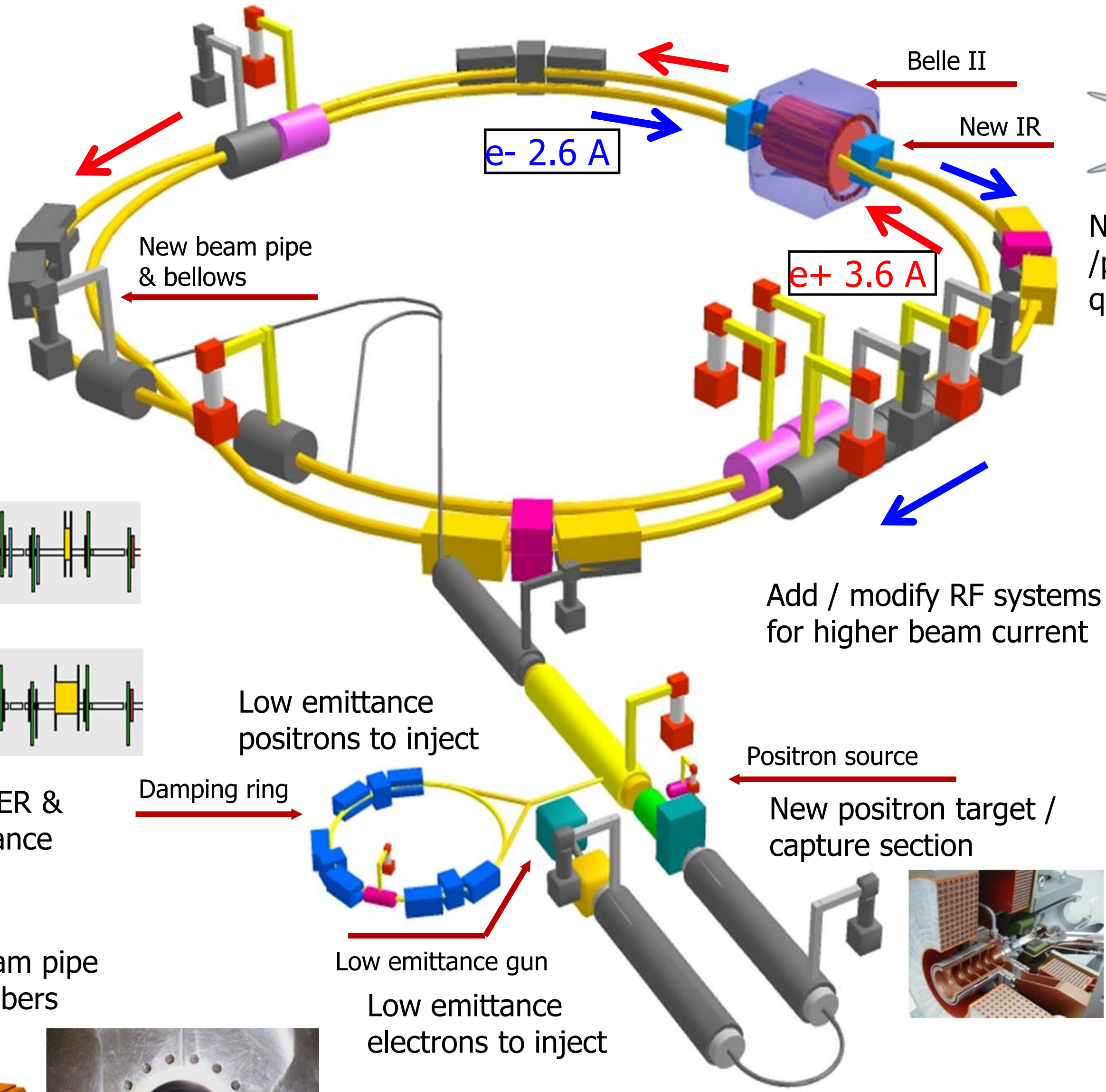


Redesign the lattices of HER & LER to squeeze the emittance

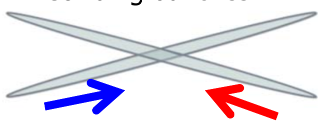
New beam pipe & bellows

Belle II

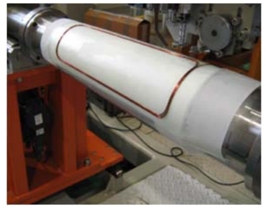
New IR



Colliding bunches



New superconducting /permanent final focusing quads near the IP



Add / modify RF systems for higher beam current

Low emittance positrons to inject

Damping ring

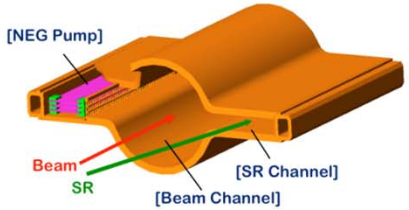
Positron source

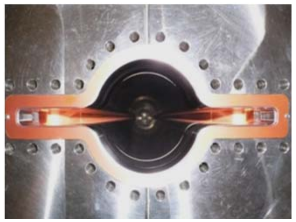
New positron target / capture section

Low emittance gun

Low emittance electrons to inject

TiN-coated beam pipe with antechambers



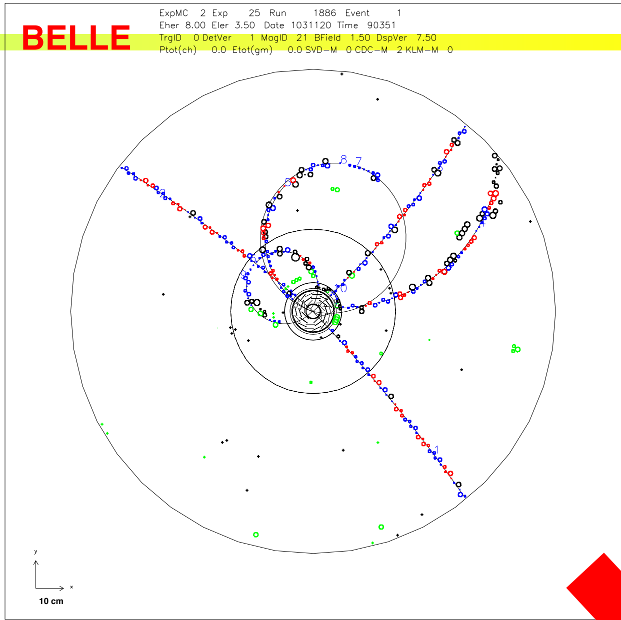


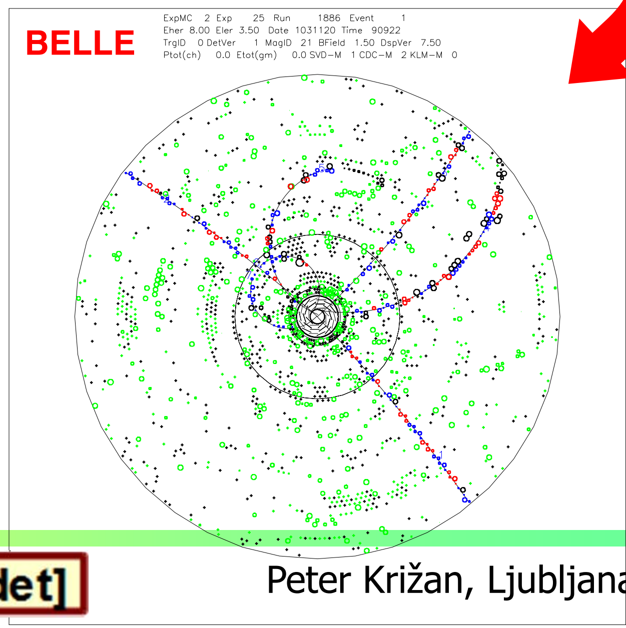
To get x40 higher luminosity

Requirements for the Belle II detector

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

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

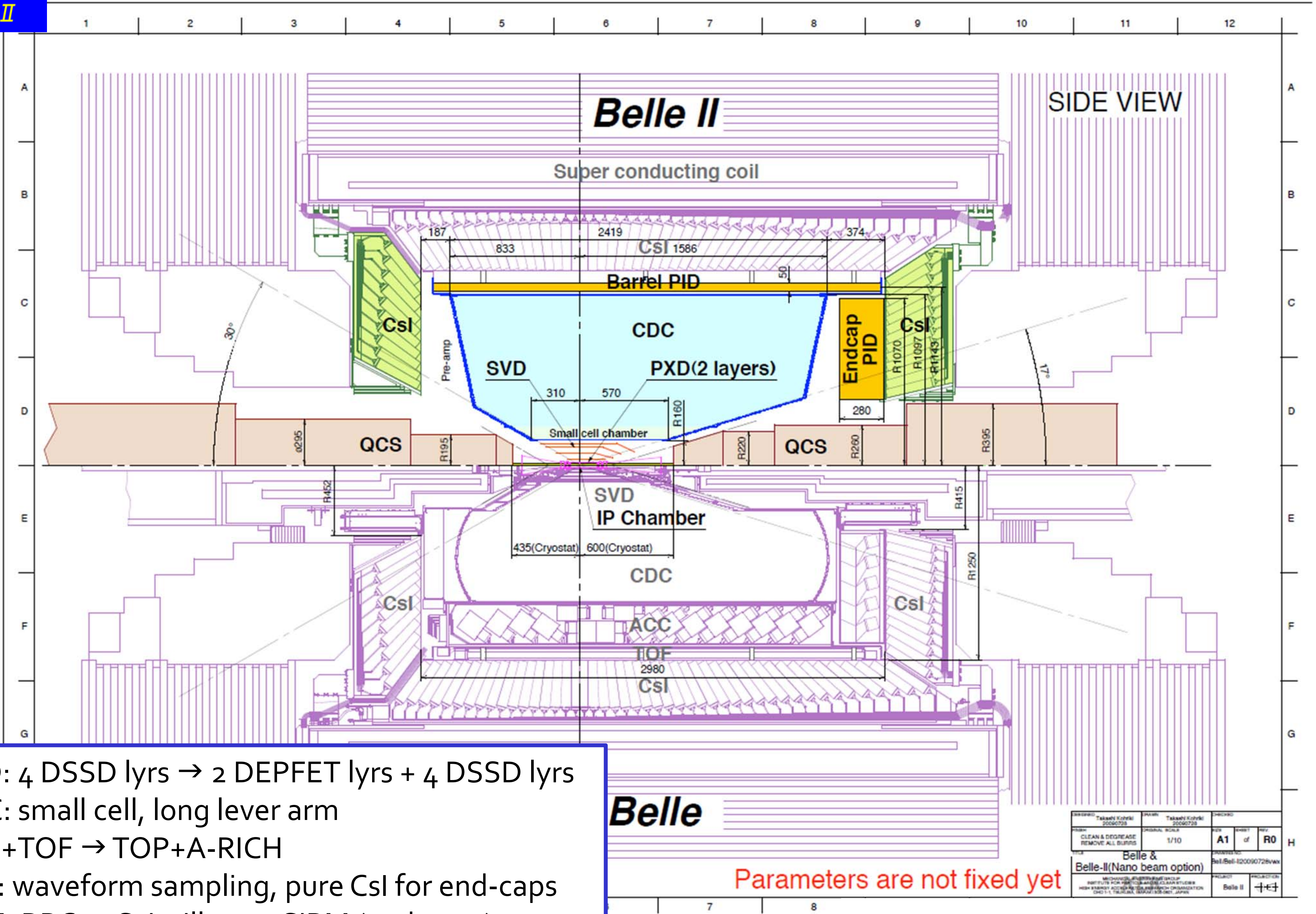




Solutions:
- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter crystals
- Faster readout electronics and computing system.

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

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)

Y. Ushiroda, ICHEP2010

SuperKEKB/Belle II Status

Belle II Collaboration

15 countries, ~60 institutions, 400 collaborators

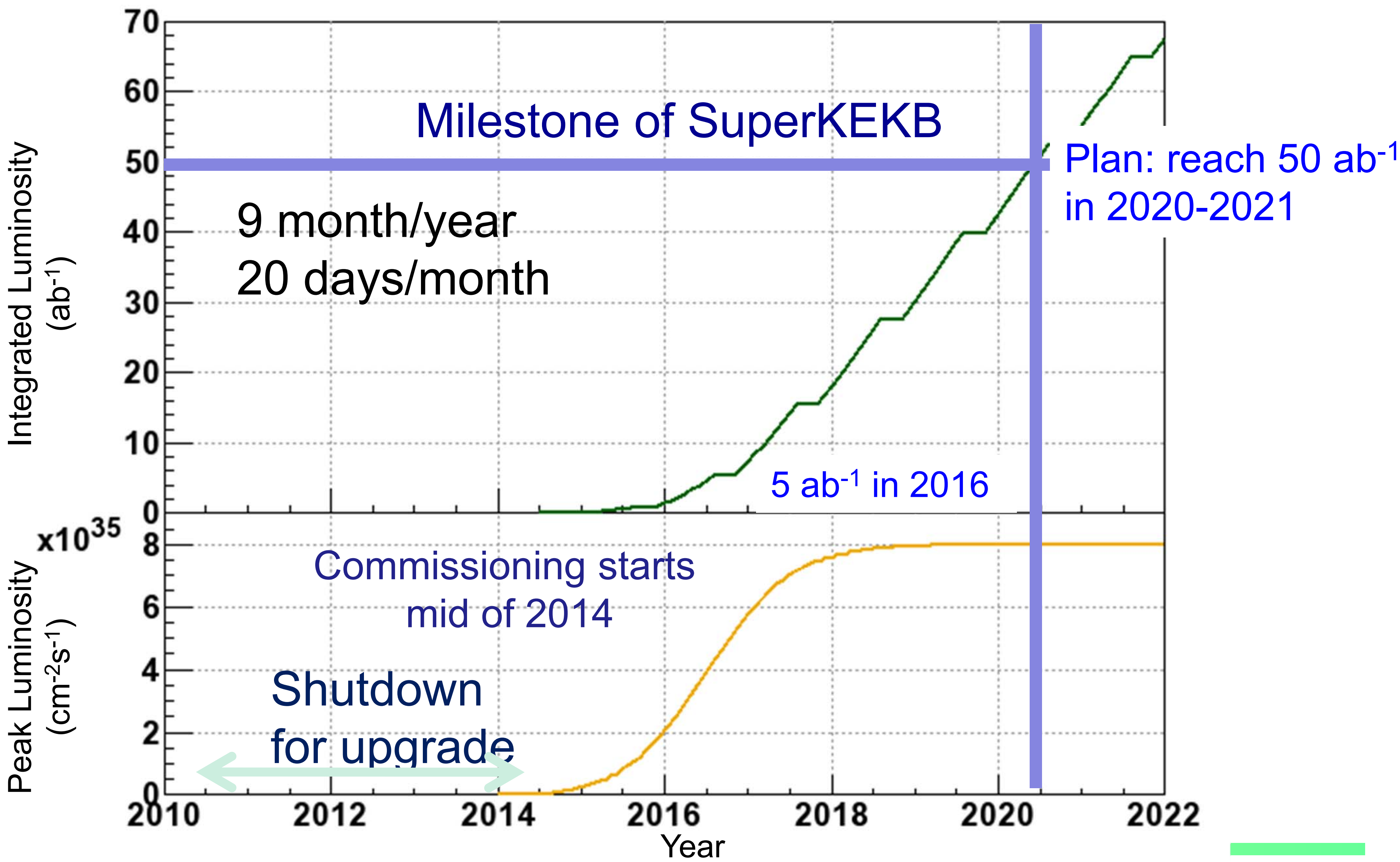
→ ~150 from Europe

→construction started in 2010!

Funding

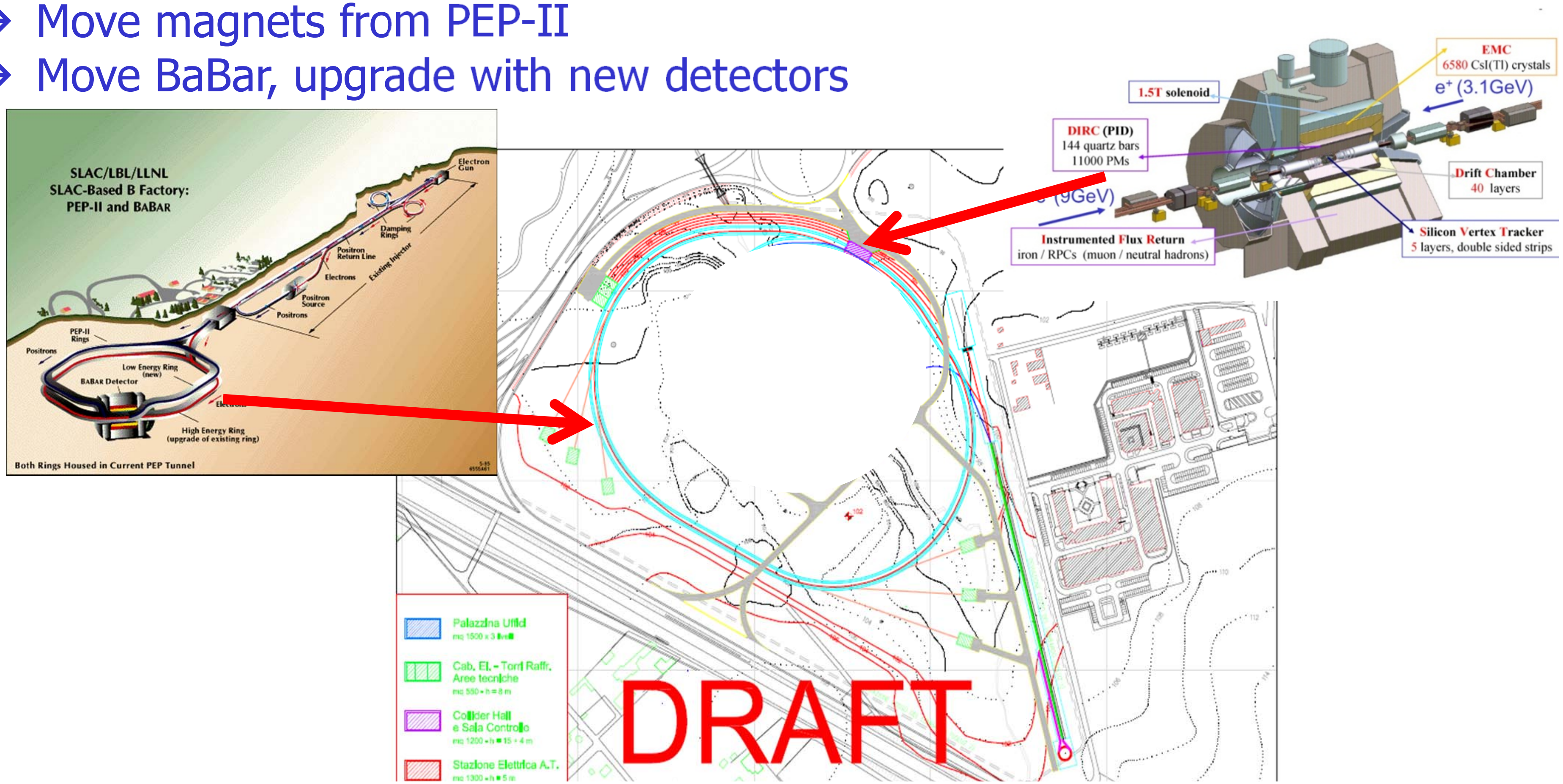
- ~100 MUS for machine -- Very Advanced Research Support Program (FY2010-2012)
- Full approval by the Japanese government in December 2010; the project is in the JFY2011 budget as approved by the Japanese Diet end of March 2011
- Most of non-Japanese funding agencies have also already allocated sizable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

Luminosity upgrade projection



Super B factory in Italy: SuperB

Construct a new tunnel in Tor Vergata U. near Frascati
→ Move magnets from PEP-II
→ Move BaBar, upgrade with new detectors



Features:

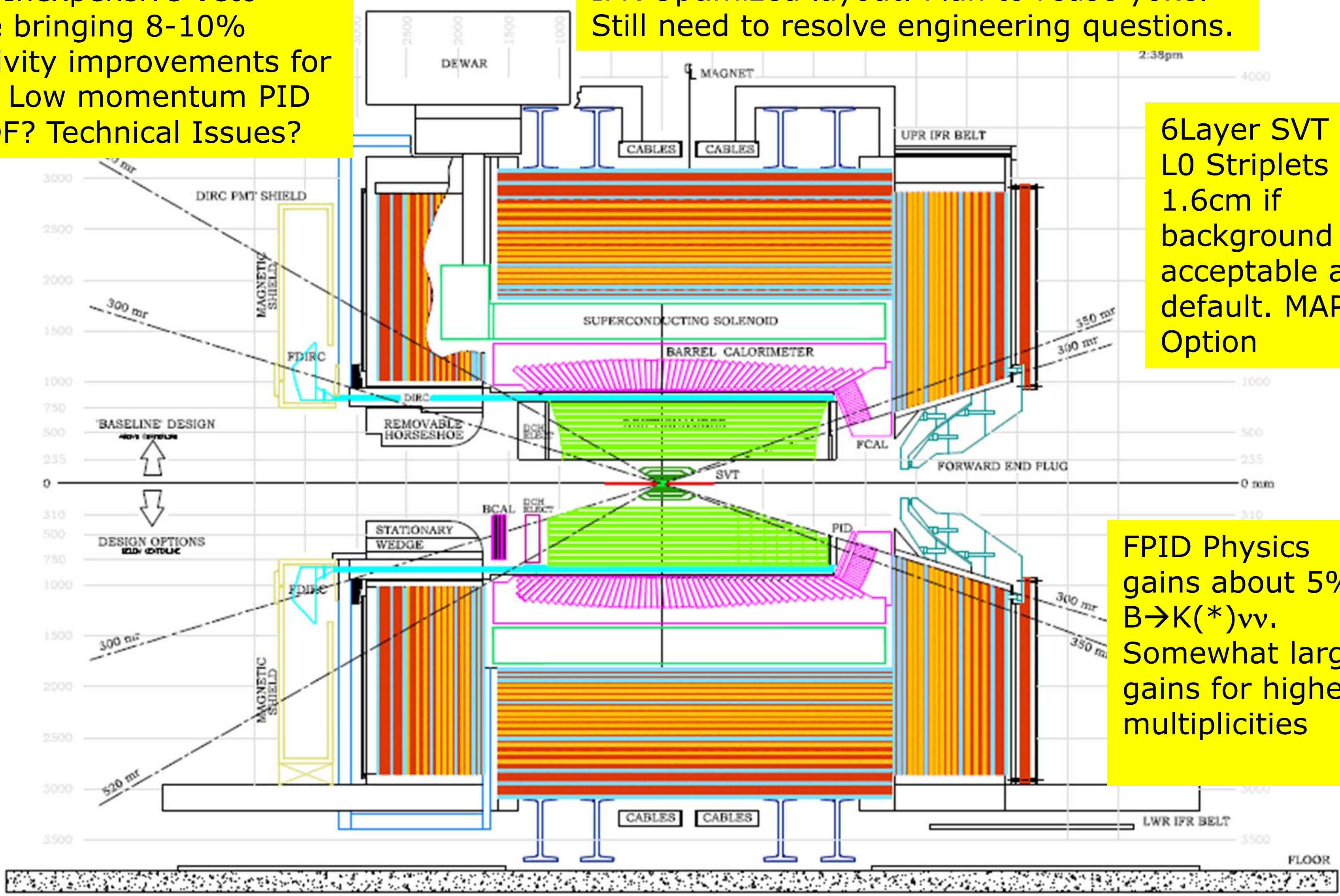
- use nano beams with crab waist scheme: successfully tested at DAΦNE
- run at charm threshold
- polarized e beam

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

SuperB Status

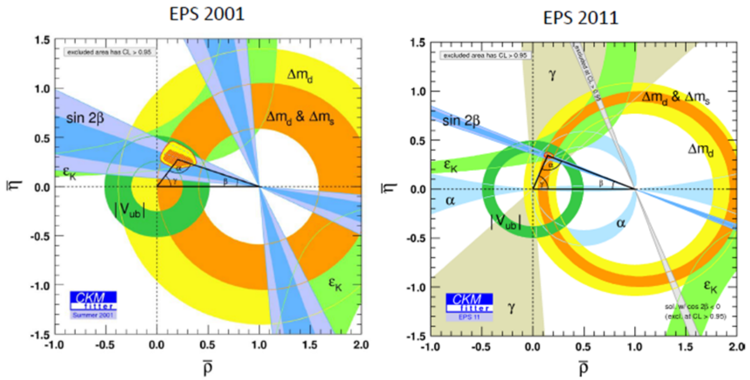
- SuperB has been approved as the first in a list of 14 Italian "flagship" projects within the new national research plan.
- The national research plan has been endorsed by "CIPE" (the institution responsible for infrastructure long term plans)
- A financial allocation of 250 Million Euros in about five years has been approved for the "superb flavour factory"
- At the end of 2010 an initial sum of 19 MEuros has been allocated
- A sum of the order of 50 MEUR is expected for 2011 budget

From a talk by Roberto Petronzio at the XVII SuperB Workshop and Kick Off Meeting - La Biodola (Isola d'Elba) Italy, May 30, 2011

Summary 1

- $\sin 2\phi_1$ result from final data sample (4% error from a single meas.)
- Model independent determination of ϕ_3 (important for LHCb)
- Interesting phenomena observed at Y(5S)
- New BaBar results on $B \rightarrow D^{(*)}\tau\nu$ decays – all above SM
- Analyses using hadronic tag at Belle: much improved eff. X2, important for $B \rightarrow D^{(*)}\tau\nu$, $B \rightarrow \tau\nu$, $B \rightarrow K\nu\nu$, exclusive $b \rightarrow u$.
- Many measurements being currently updated with final data sets
- Soon expected: BaBar $b \rightarrow s+d\ \gamma$, Belle: final measurement of ϕ_2 in $B \rightarrow \pi^+ \pi^-$, measurement of ϕ_2 in $B \rightarrow a_1 \pi$, $B \rightarrow \pi^0\pi^0$, $\rho^0\rho^0$
- Concentrate on measurements that use the unique capabilities of B factories

Summary 2



- B factories have proven to be an excellent tool for flavour physics, with reliable long term operation, constant improvement of the performance, achieving and surpassing design perfomance
- Major upgrade at KEK in 2010-14 → SuperKEKB+Belle II, L x40, construction started
- SuperB near Frascati: build a new tunnel, reuse (+ugrade) PEP-II and BaBar, approved, ramping up
- Tau/charm factories, BESIII and the new ones - e.g. at BINP, will play an important role in the searches for NP
- Expect a new, exciting era of discoveries, complementary to the LHC

Belle II

Super KEKB
uest for BSM

SuperB