KMI 素粒子宇宙起源研究機構
Kobayashi-Maskawa Institute for the Origin of Particles and the Universe

KMIIN - Kobayashi-Maskawa Institute Inauguration Conference
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Belle II

Super KEKB
Quest for BSM

Belle-II and SuperKEKB

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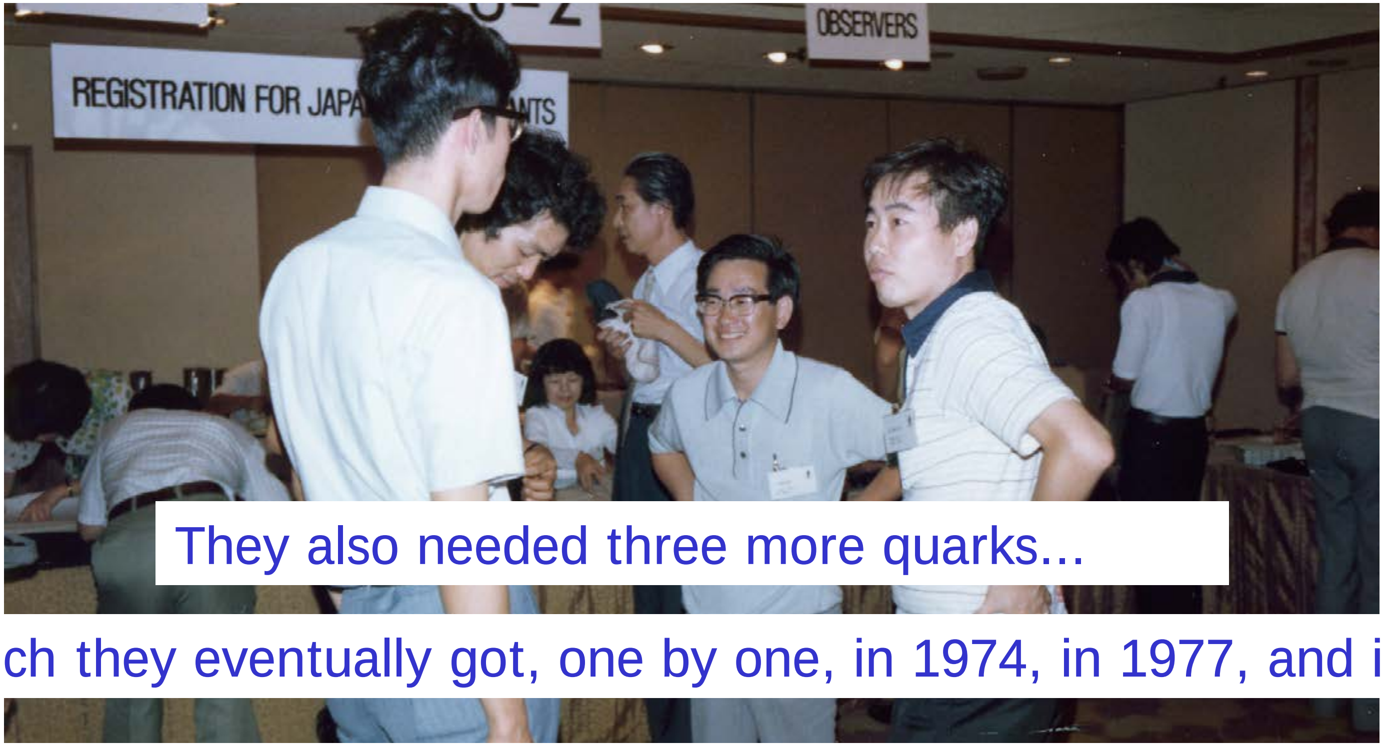
Contents

- Highlights from Belle (+ a little bit of history)
- Physics case for a super B factory
- Accellerator upgrade → SuperKEKB
- Detector upgrade → Belle-II
- Status and outlook

A little bit of history…

It all started when two young gentelmen of this University had a bright idea how CP violation - as observed in the kaon system - could be accommodated into the Standard Model.



They also needed three more quarks…

… which they eventually got, one by one, in 1974, in 1977, and in 1994.

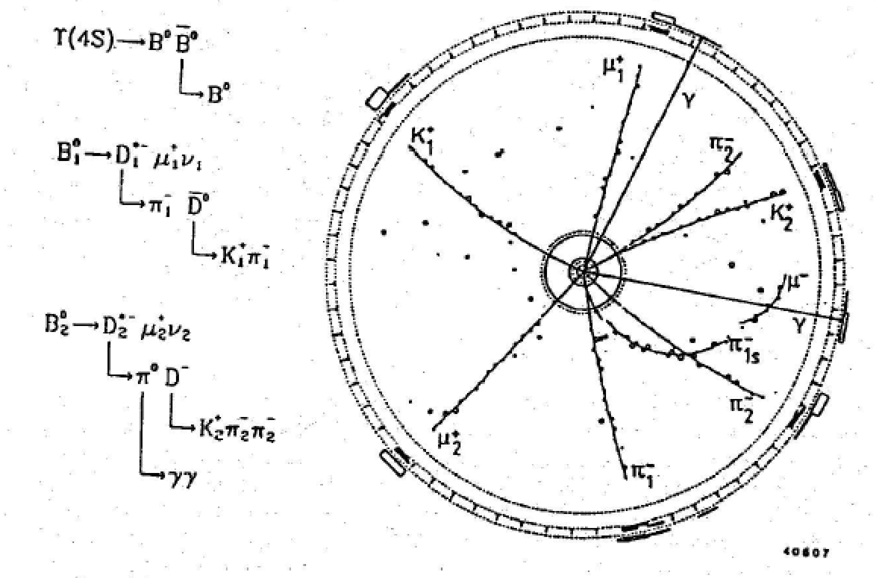
How to test the CP violation part of their theory?

Nature was kind, made sure there is enough mixing in the B meson system

→

Mixing in the B^0 system

1986: ARGUS discovers BB mixing: B^0 turns into anti-B^0



Reconstructed event with one B→anti-B

Integrated ϒ(4S) luminosity 1983-87:
103 pb^{-1} ~110,000 B pairs

(=1/7000 of the Belle data sample...)

Large mixing in the B^0 system →

→ top is very heavy

→ CP violation effects could be large in B decays

KM scheme predicted - among others – that CP violation in B→J/ψ K_S decays is related to the probability for the b→u transition!

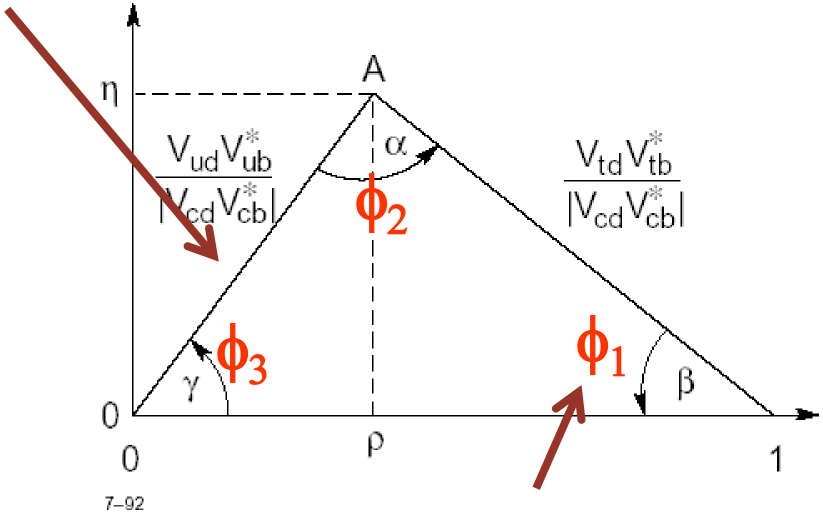
CKM matrix: determines charged weak interaction of quarks

Wolfenstein parametrisation: expand the CKM matrix in the parameter λ (=$\sin\theta_c$=0.22)

A, ρ and η: all of order one

$$V = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix} + O(\lambda^4)$$

from probability of b→u transitions



from CP violation in B→J/ψ K_S decays

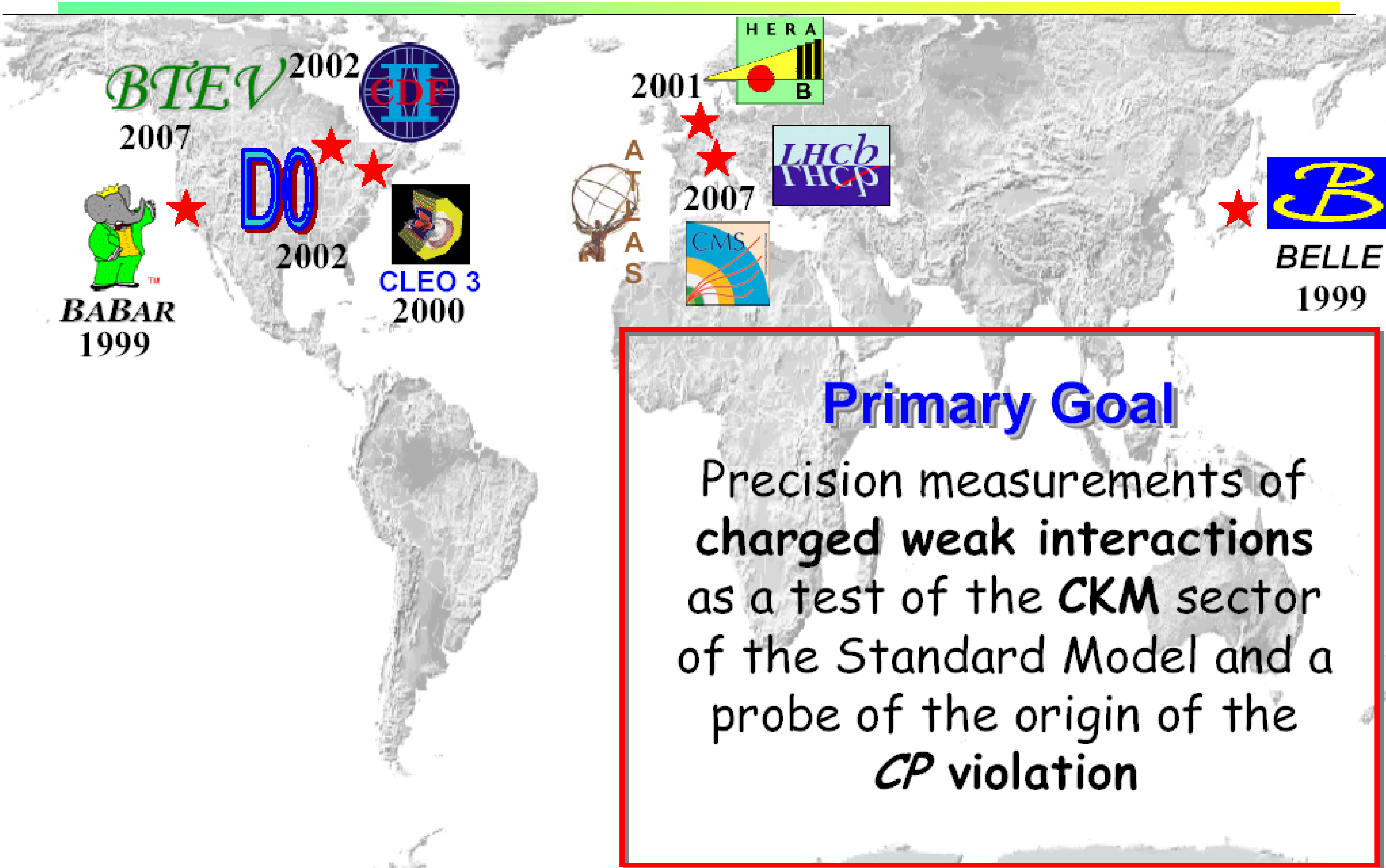
Unitarity condition:

$$V_{ud}V_{ub}{}^* + V_{cd}V_{cb}{}^* + V_{td}V_{tb}{}^* = 0$$

Goal: measure sides and angles in several different ways, check consistency →

Worldwide effort!

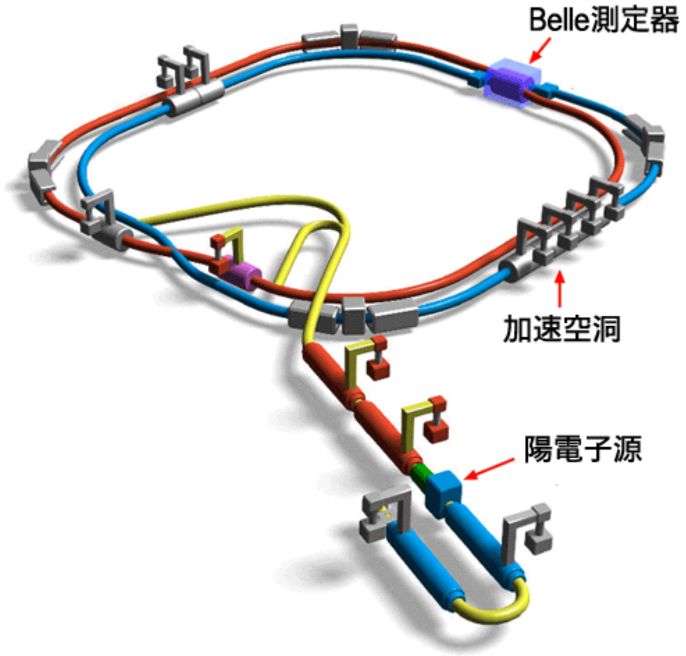
many experiments proposed around 1990, some approved, 2 succeeded...

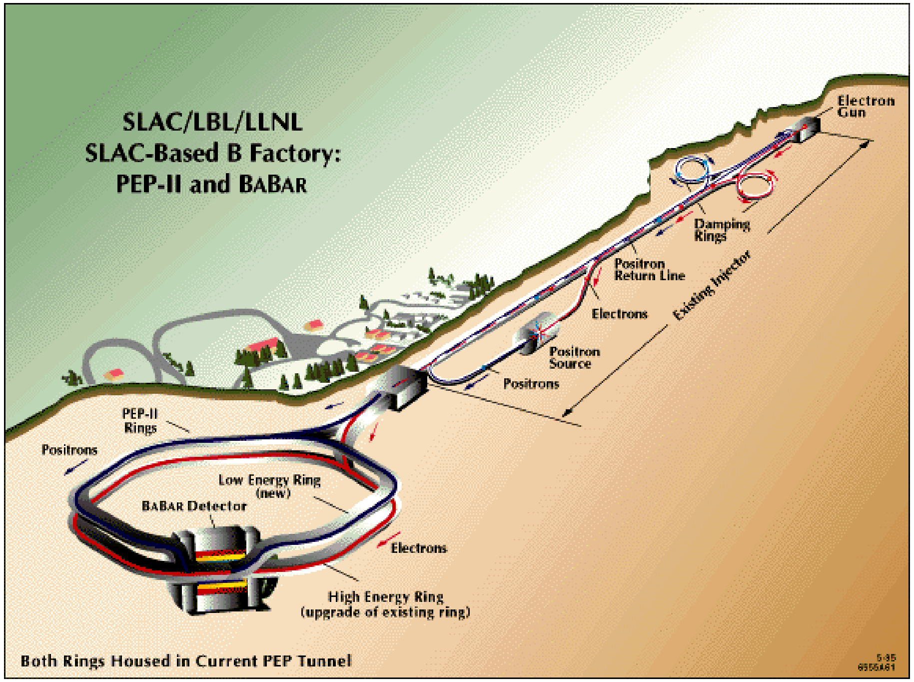


Primary Goal

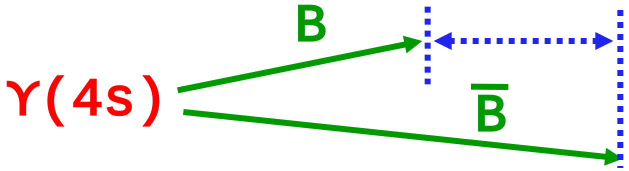
Precision measurements of **charged weak interactions** as a test of the **CKM** sector of the Standard Model and a probe of the origin of the ***CP*** **violation**

Asymmetric B factories





$\sqrt{s}$=10.58 GeV



$\Delta z \sim c\beta\gamma\tau_B$

$\sim 200\mu m$

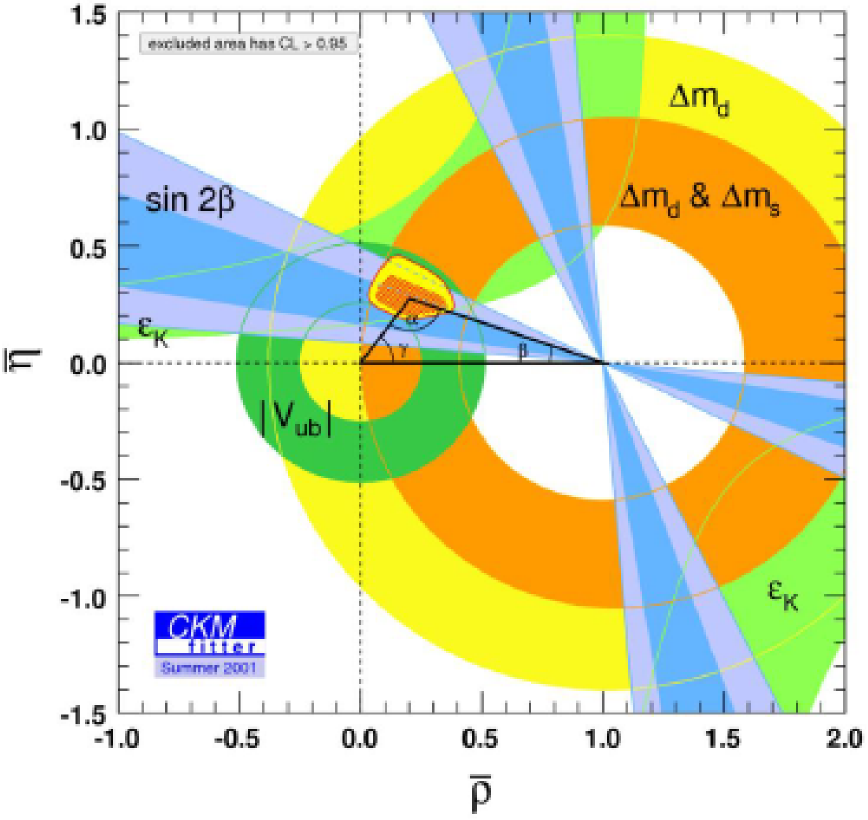
BaBar $p(e^-)=9$ GeV $p(e^+)=3.1$ GeV $\beta\gamma=0.56$

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

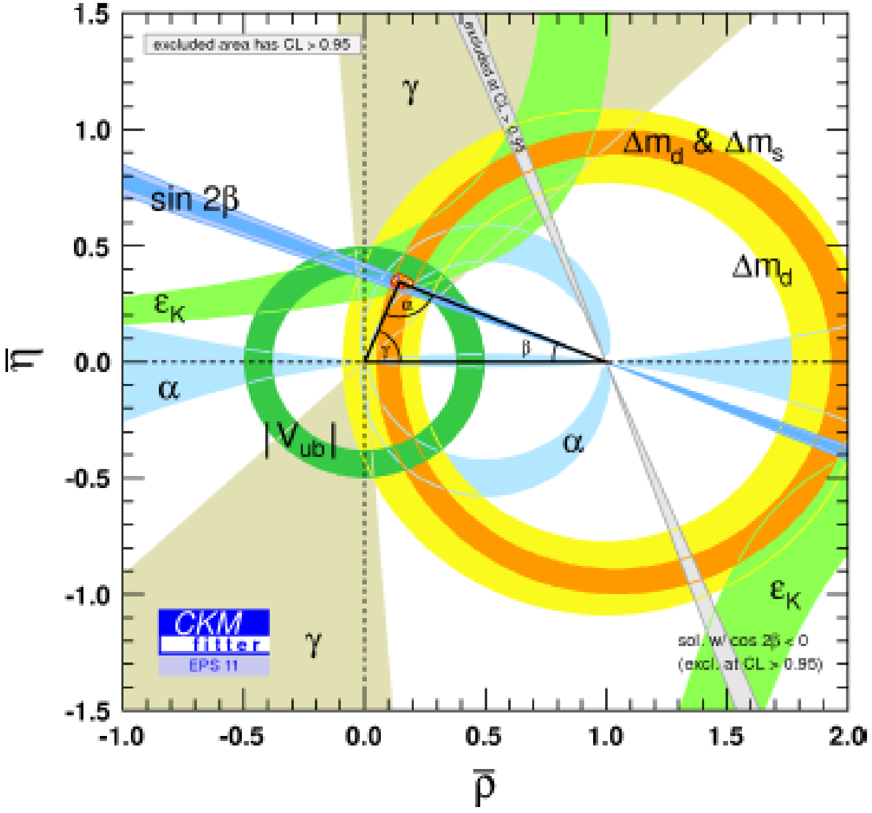
Unitarity triangle – 2011 vs 2001

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

EPS 2001



EPS 2011



Unitarity triangle – new/final measurements

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

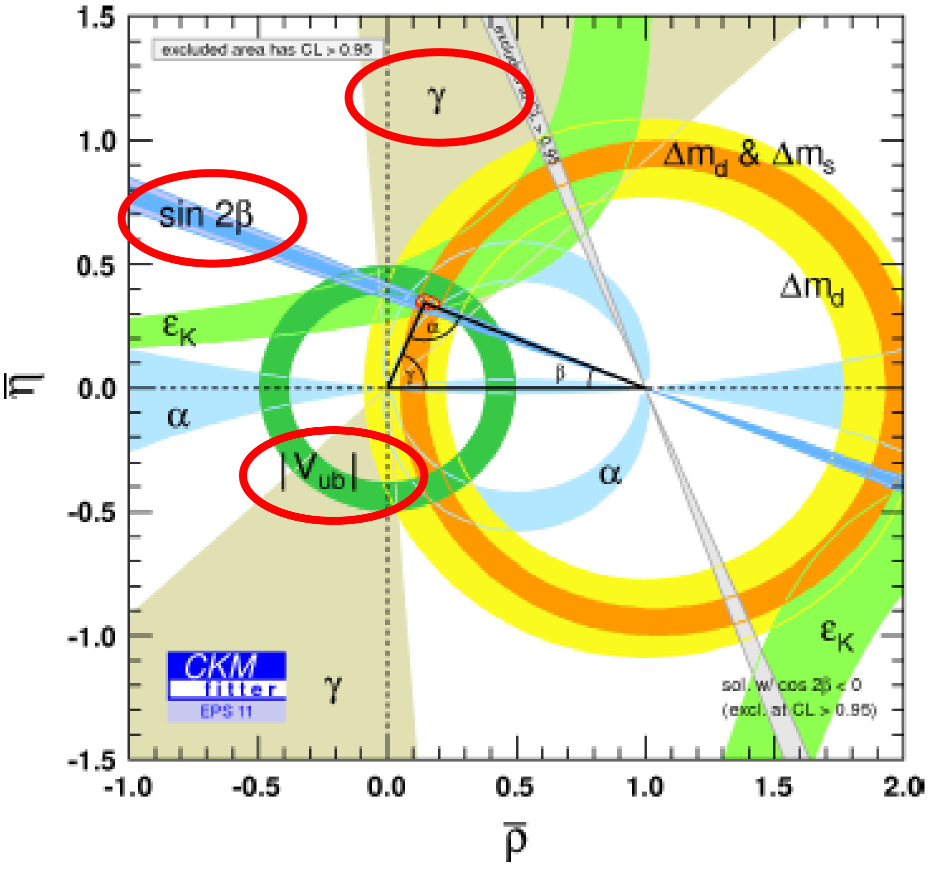
This summer:

Unitarity triangle:

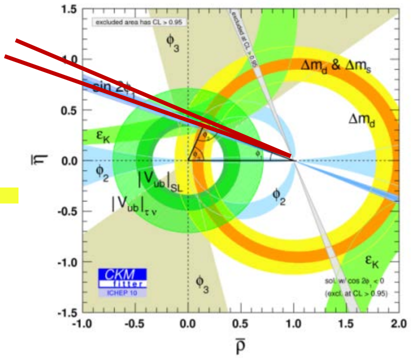
→ sin2ϕ_1 (=sin2β) : final measurement from Belle

→ ϕ_3 (=γ) new model-independent method

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



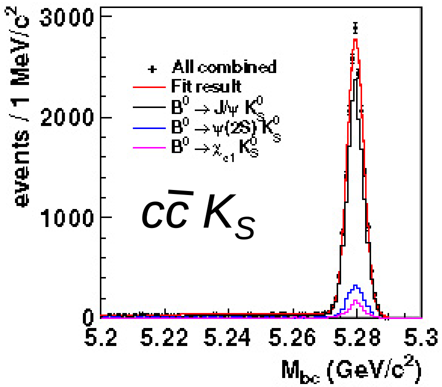
Final measurement of $\sin 2\phi_1$ (=$\sin 2\beta$)



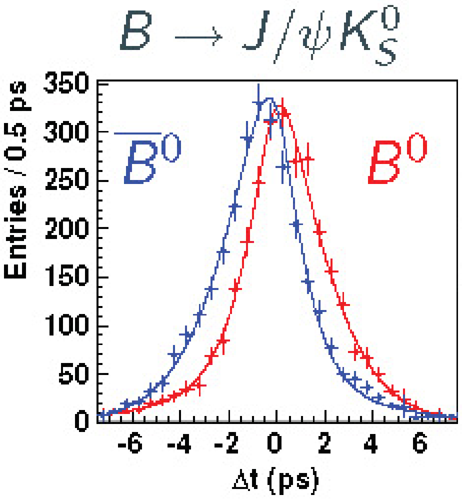
Belle, preliminary, 710 fb^{-1}

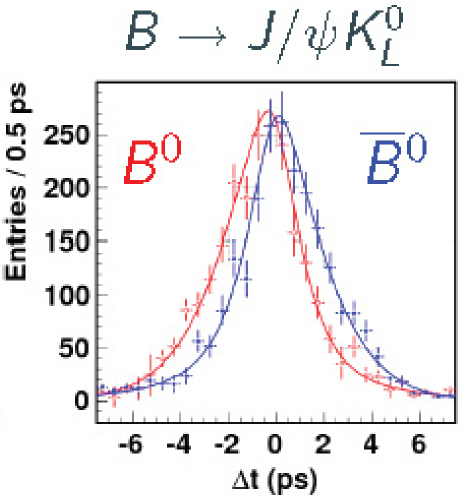
ϕ_1 from CP violation
measurements in $B^0 \to c\bar{c}\, K^0$

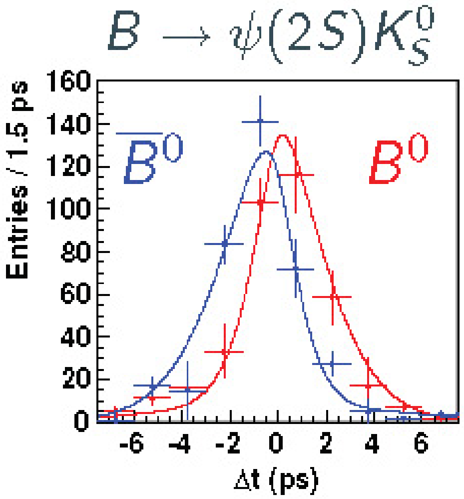
Improved tracking, more data
(50% more statistics than last result with 480 fb^{-1});
$c\bar{c} = J/\psi,\ \psi(2S),\ \chi_{c1}$ → 25k events

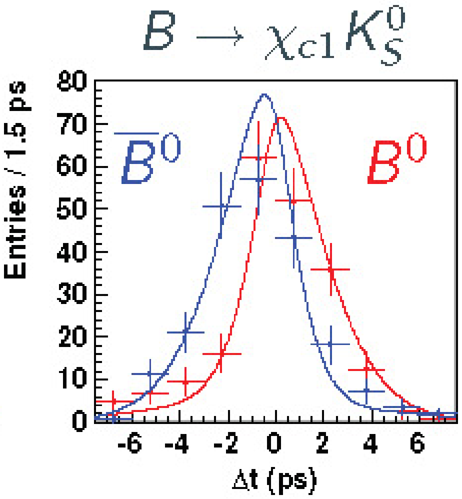


detector effects: wrong tagging, finite Δt resolution,
determined using control data samples









Final measurement of sin2ϕ_1 (=sin2β)

ϕ_1 from $B^0 \to c\bar{c}\, K^0$

Final result (preliminary) from Belle:

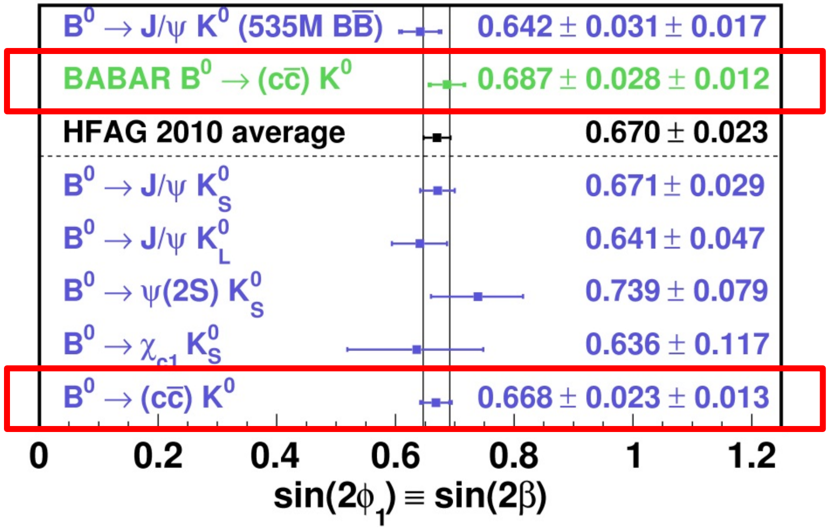
S= 0.668 ± 0.023 ± 0.013
A= 0.007 ± 0.016 ± 0.013

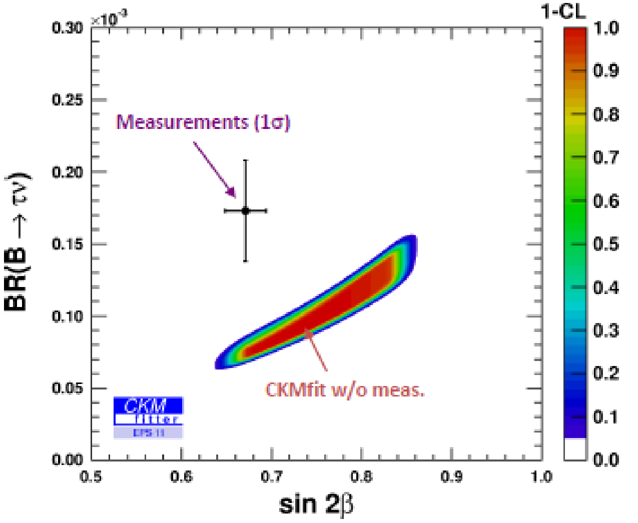
(SM: $S=\sin 2\phi_1$ (=sin2β), A=0)

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

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

Belle, preliminary, 710 fb^{-1}





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

SM: $b \to c\bar{c}d$, $S = \sin 2\phi_1$ ($= \sin 2\beta$), $A = 0$

B → D^+D^-

Belle preliminary

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

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

772×10^6 $B\bar{B}$ pairs

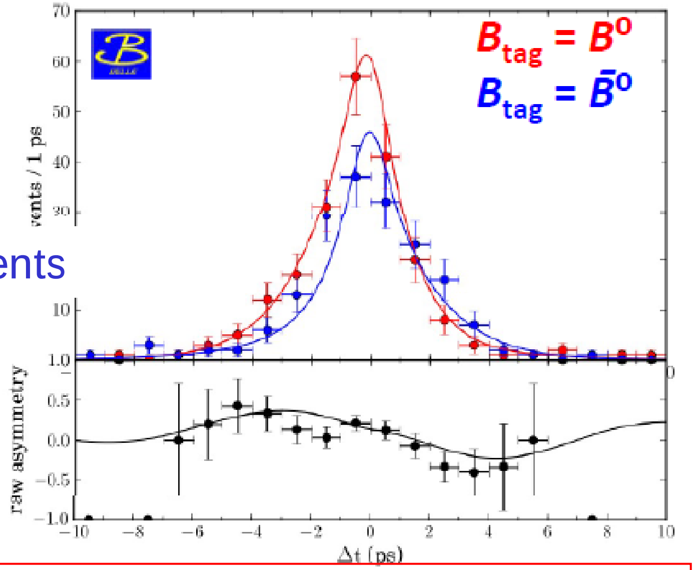
$B^0 \to (K^-\pi^+\pi^+)(K^+\pi^-\pi^-)$, $(K^-\pi^+\pi^+)(K_S\pi^0)$+c.c.

Previous measurement (535×10^6 $B\bar{B}$ pairs):

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

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

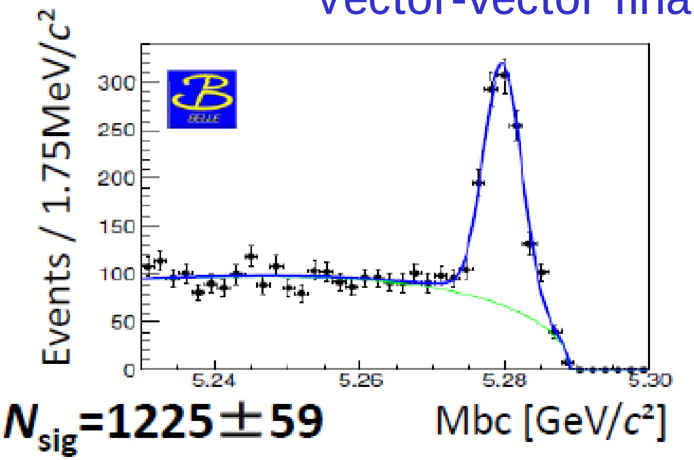
320 events



→ Large CP violation effects in many places in B decays!

B → $D^{*+}D^{*-}$

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



$N_{sig} = 1225 \pm 59$

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

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

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

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

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

772×10^6 $B\bar{B}$ pairs

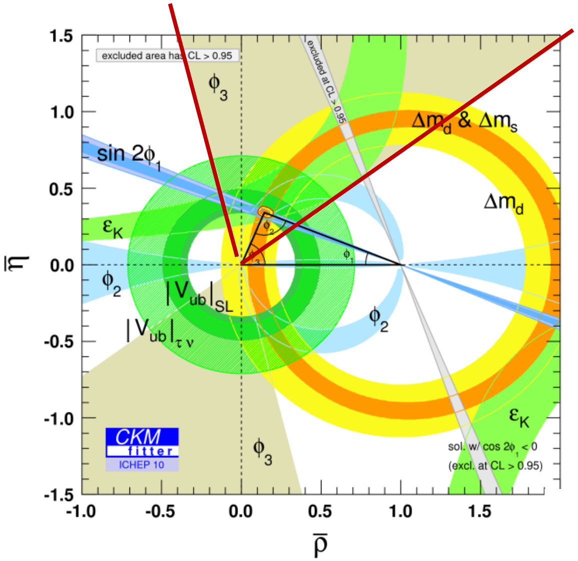
Belle preliminary

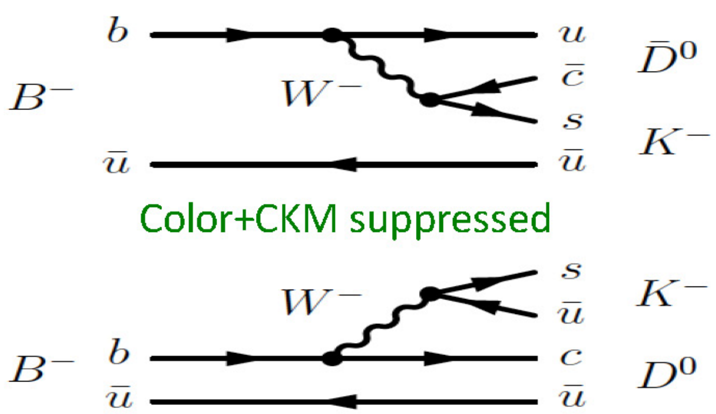
ϕ_3 (=γ) with Dalitz analysis

Dalitz method:

The best way to measure ϕ_3

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





Color+CKM suppressed

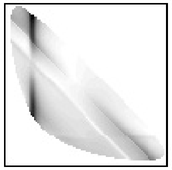
Favored

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

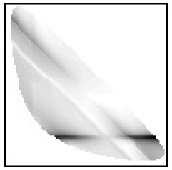
3-body $D^0 \to K_S\pi^+\pi^-$ Dalitz amplitude

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

$= \Big|$



$+ re^{i\delta_B \pm i\phi_3}$



$\Big|^2$

model dependent description of f_D using continuum D* data ⇒ 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)

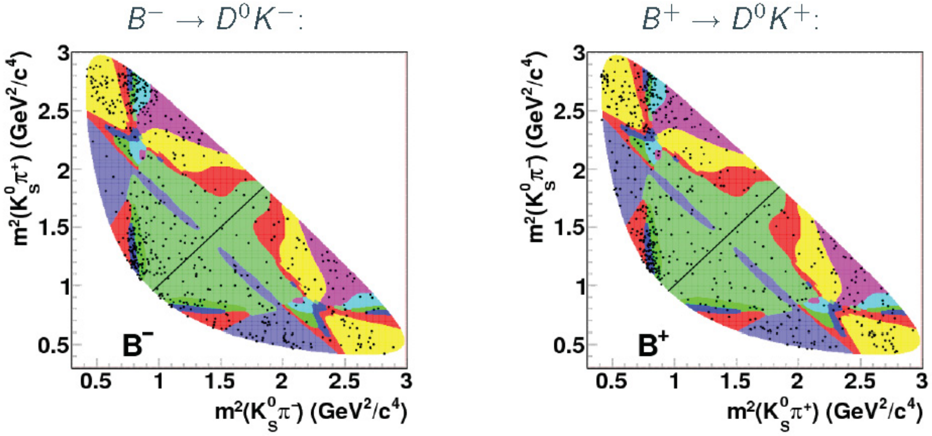
ϕ_3 (=γ) from model-independent/binned Dalitz method

Dalitz 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)

Use only DK

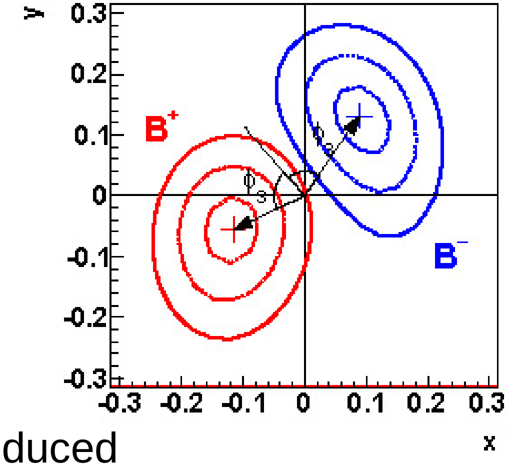
N_{sig} = 1176 ± 43

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

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

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

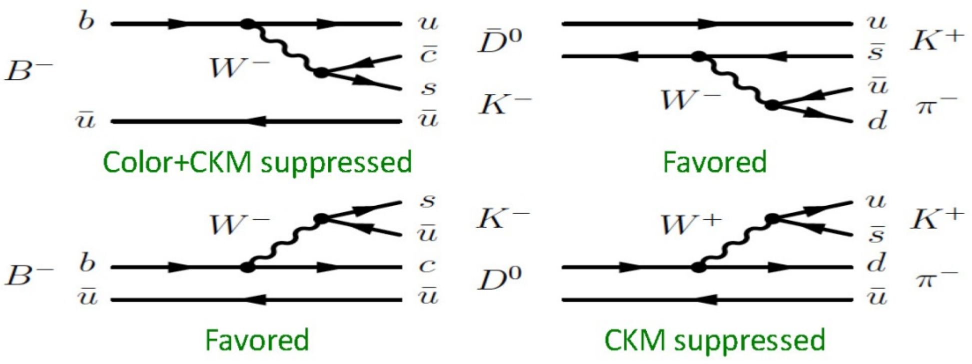
ϕ_3 with the ADS method

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

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

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

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



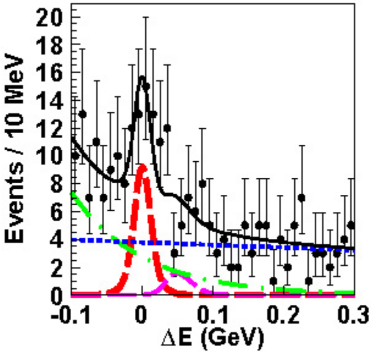
using additional input on r_B, r_D, ϕ_3 can be extracted in a model independ. manner

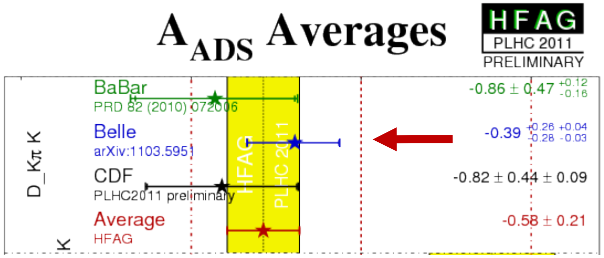
$$\mathcal{R}_{DK} = r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D) \cos\phi_3,$$
$$\mathcal{A}_{DK} = 2 r_B r_D \sin(\delta_B + \delta_D) \sin\phi_3 / \mathcal{R}_{DK},$$

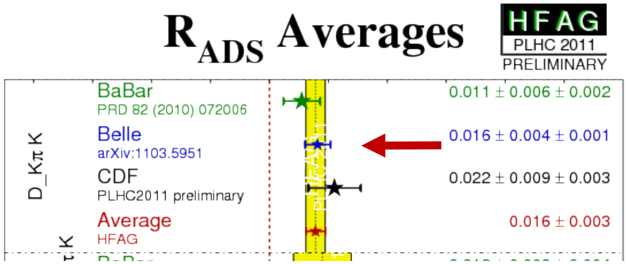
$R_{DK} = (1.63\,^{+0.44}_{-0.41}\,^{+0.07}_{-0.13}) \cdot 10^{-2}$
$A_{DK} = -0.39\,^{+0.26}_{-0.28}\,^{+0.04}_{-0.03}$

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

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

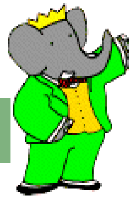






ADS can also be done in other channels: e.g.
B → D^0 K, D → K π π^0

BaBar, arXiv:1104:4472



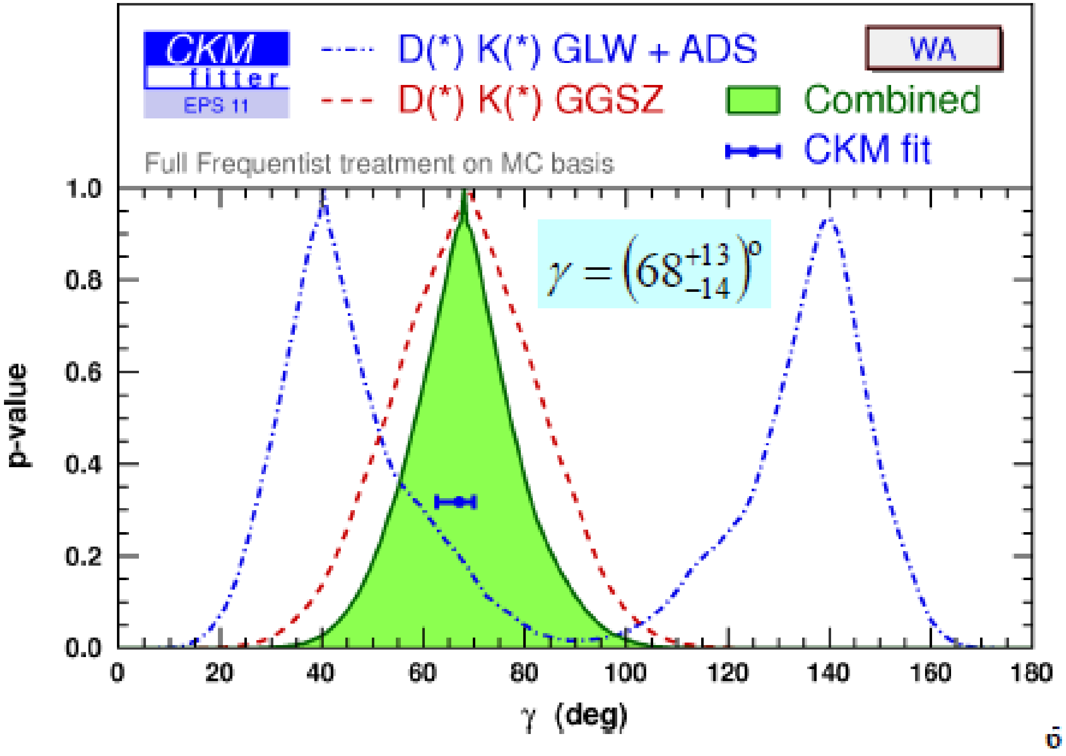
ϕ_3 measurement

Combined ϕ_3 value:

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

Note that B factories were not built to measure ϕ_3

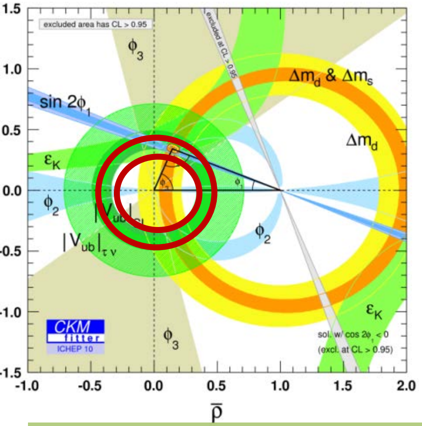
It turned out much better than planned!



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

Y. Horii (KMI) →poster at KMIIN

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



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

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

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

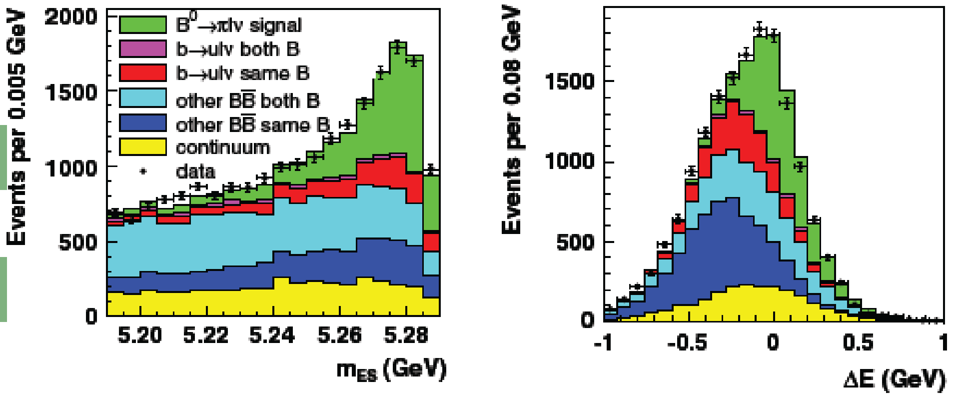
BaBar, PRD83, 032007 (2011)

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

BaBar, PRD83, 052011 (2011)

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

Belle, arXiv:1012:0090



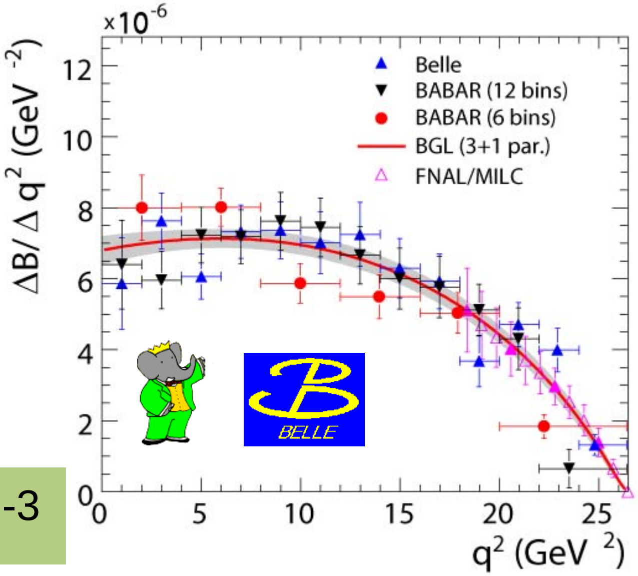
$|V_{ub}|$ extraction: fit data + LQCD points in

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

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

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

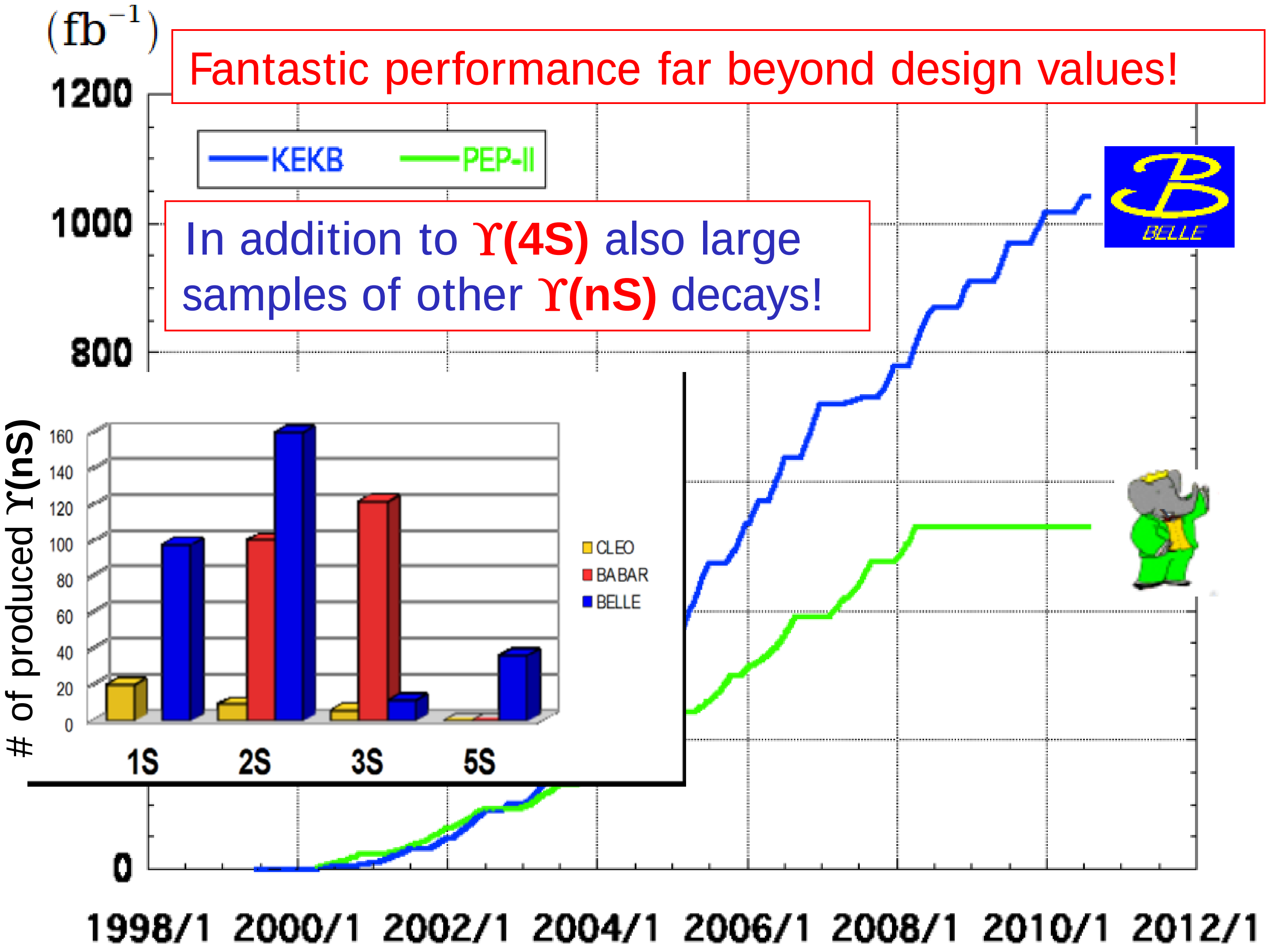
Belle + BaBar + FNAL/MILC $|V_{ub}| = (3.26 \pm 0.30)\cdot10^{-3}$



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

Integrated luminosity at B factories



Fantastic performance far beyond design values!

In addition to **Υ(4S)** also large samples of other **Υ(nS)** decays!

> 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}

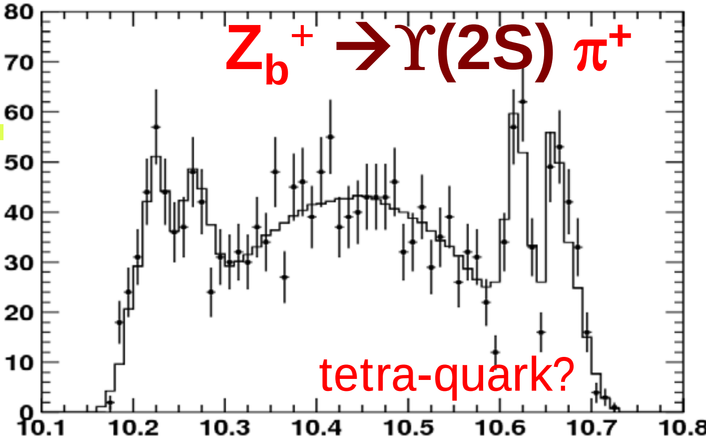
$\Upsilon(2S)$: 14 fb^{-1}

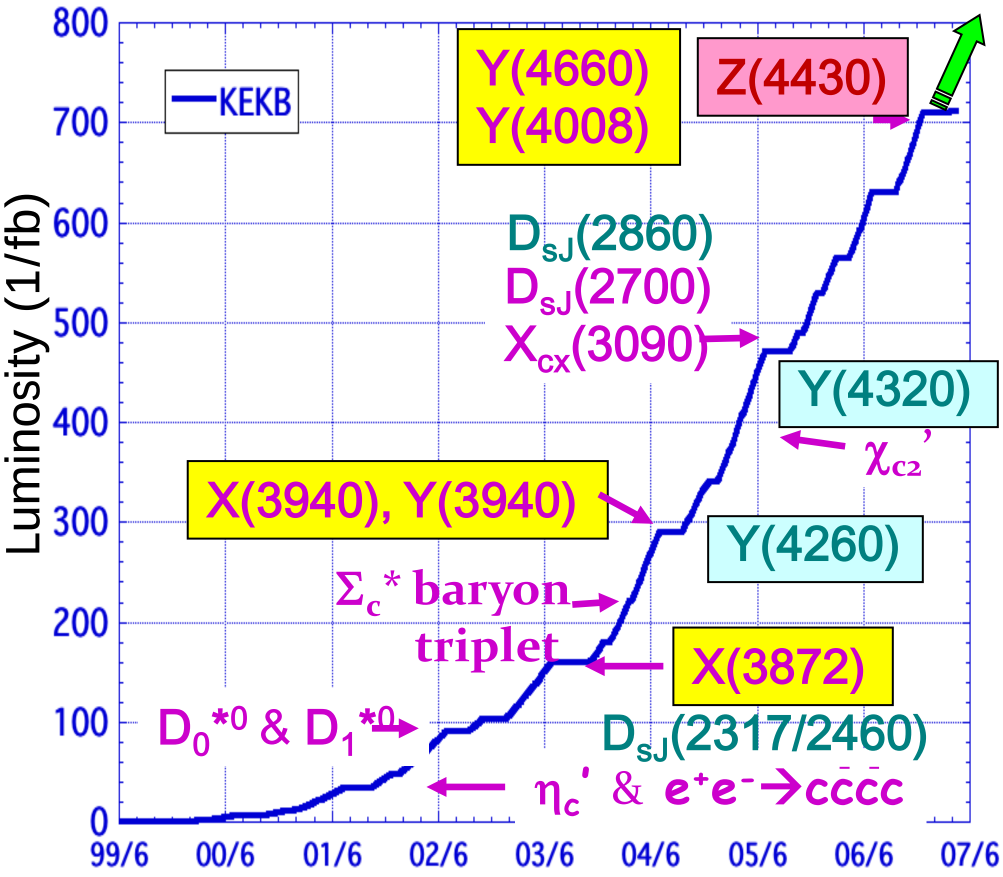
Off resonance:

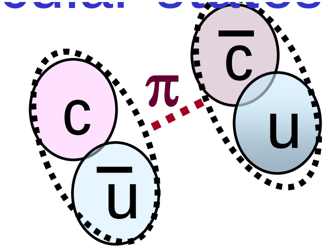
~ 54 fb^{-1}

New hadrons at B-factories

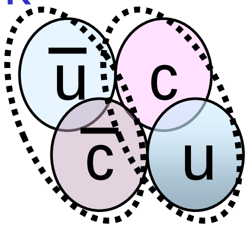
Discoveries of many new hadrons at B-factories
class of hadrons beyond the ordinary mesons.



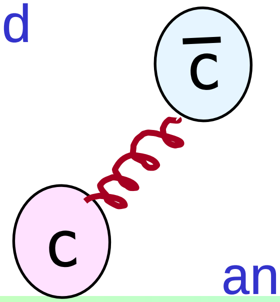




Tetra-quark



Hybrid



and more...

What next?

B factories → is SM with the KM scheme right?

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

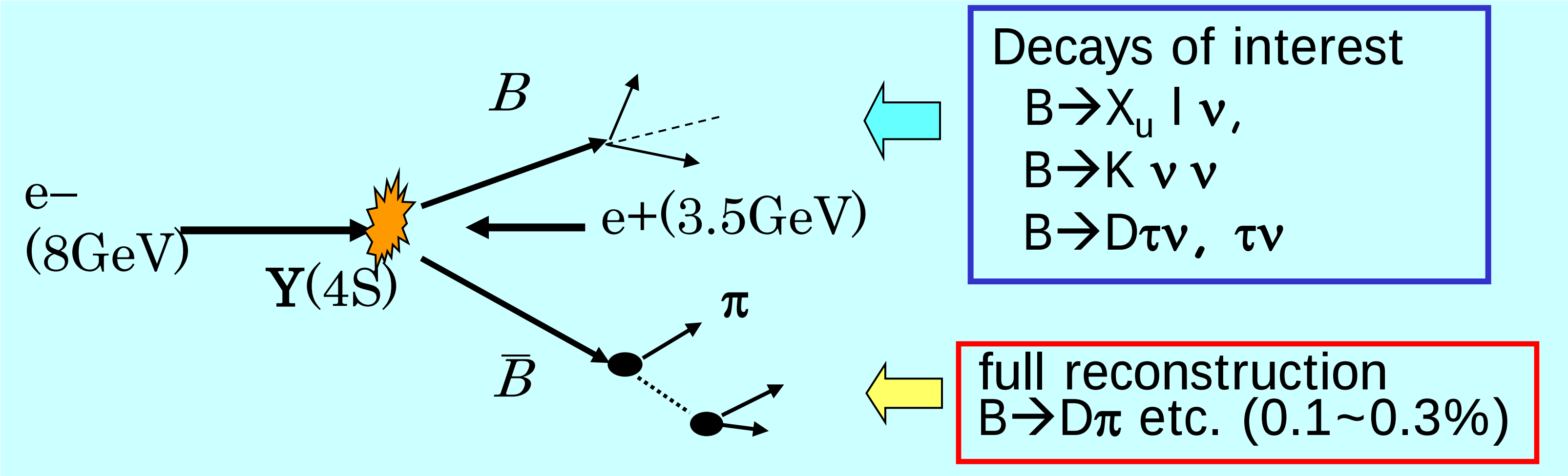
→ Need much more data (two orders!) because the SM worked so well until now → Super B factory

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) Y(4s) will have considerable advantages in several classes of measurements, and will be complementary in many more

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



Decays of interest
$B \to X_u\, l\, \nu$,
$B \to K\, \nu\, \nu$
$B \to D\tau\nu$, $\tau\nu$

full reconstruction
$B \to D\pi$ etc. (0.1~0.3%)

→ Offline B meson beam!

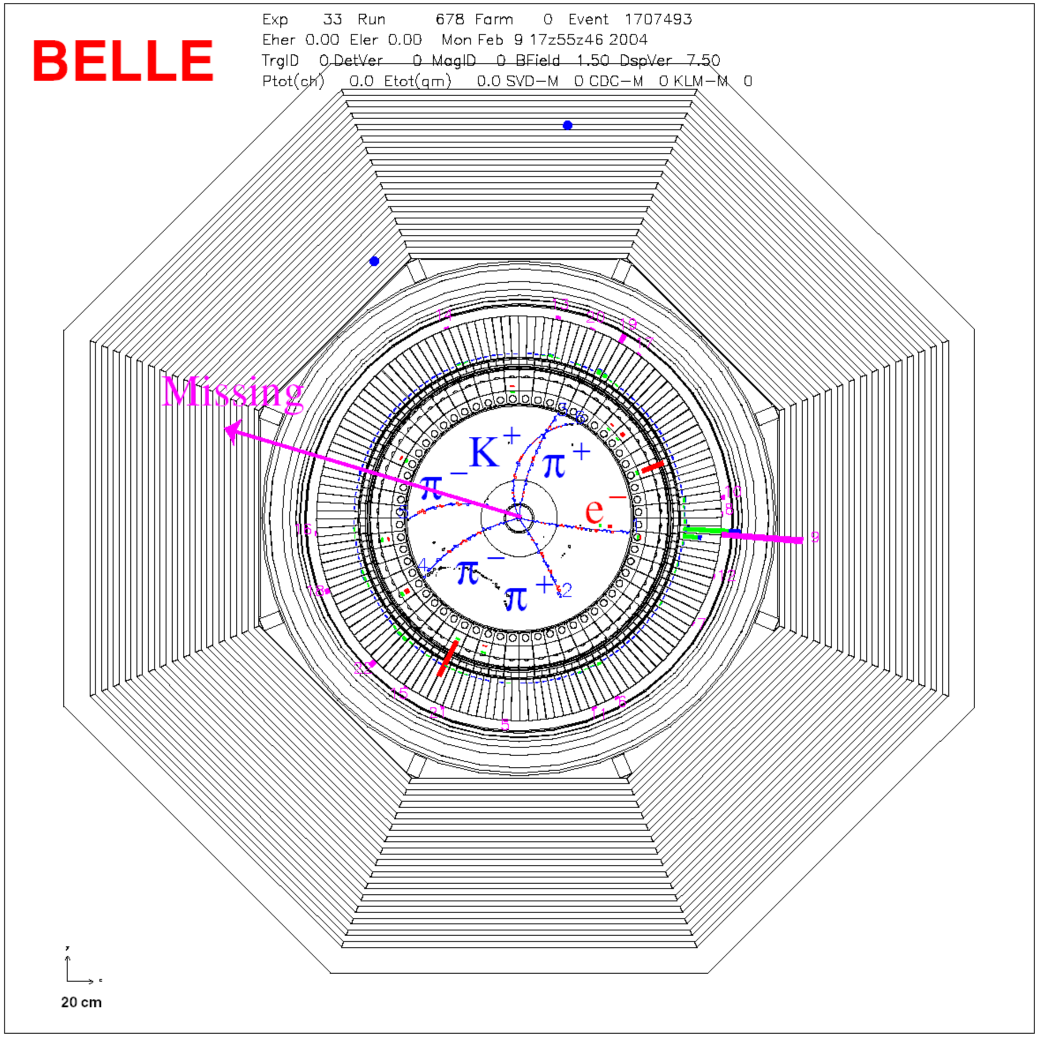
Powerful tool for B decays with neutrinos

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

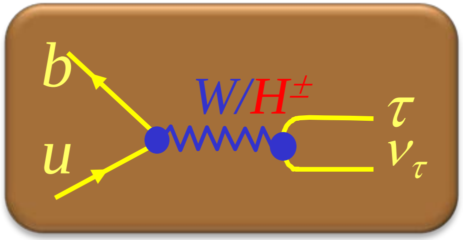
$$B^+ \to D^0\pi^+$$

$$(\to K\pi^-\pi^+\pi^-)$$

$$B^- \to \tau(\to e\nu\bar{\nu})\nu$$

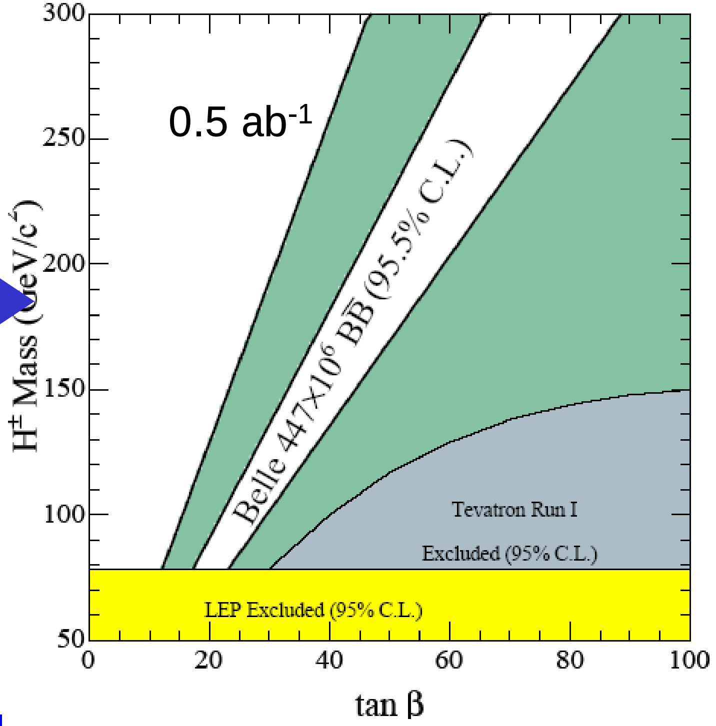


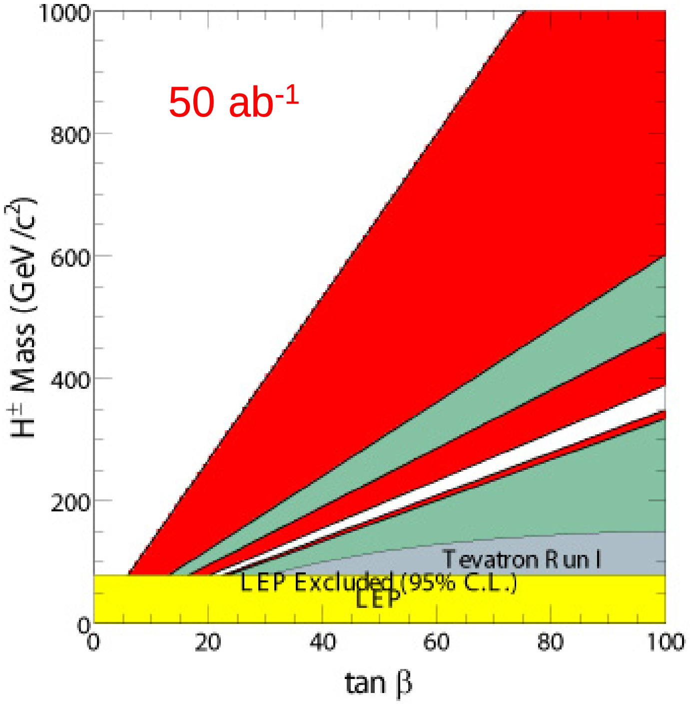
Charged Higgs limits from $B^- \to \tau^- \nu_\tau$



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

→ limit on charged Higgs mass vs. tanβ

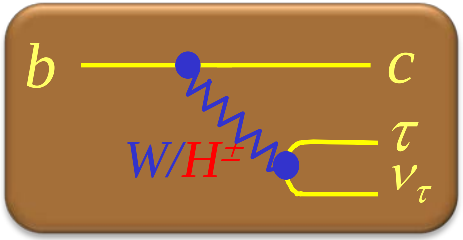




K. Ikado et al. (Belle), PRL 97 (2006) 251802

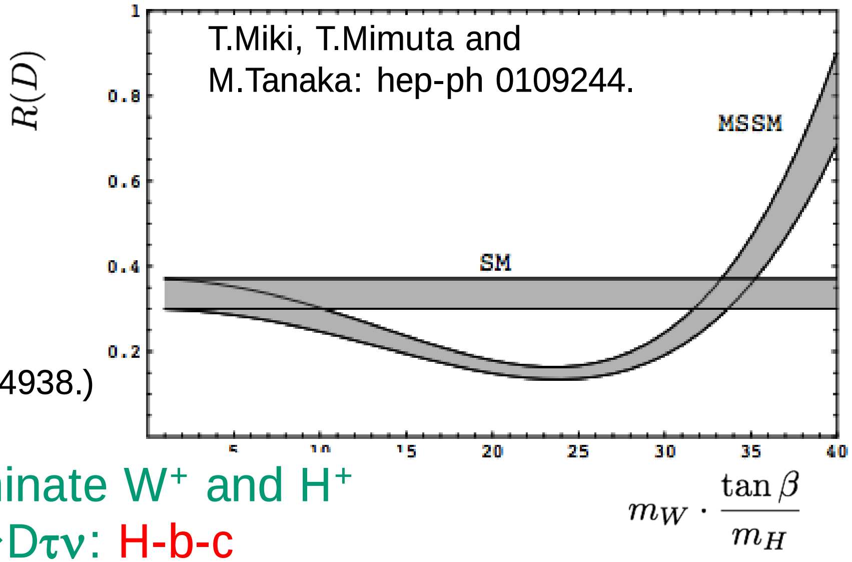
$B\rightarrow D^{(*)}\tau\nu$

Semileptonic decay sensitive to charged Higgs



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

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


T.Miki, T.Mimuta and M.Tanaka: hep-ph 0109244.

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

1.Smaller theoretical uncertainty of R(D)

(For $B\rightarrow\tau\nu$,
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 $B\rightarrow\tau\nu$: H-b-u, $B\rightarrow D\tau\nu$: H-b-c
(LHC experiments sensitive to H-b-t)

Advantage of B factories!

First observation of $B\rightarrow D^{*-}\tau\nu$ by Belle (2007)

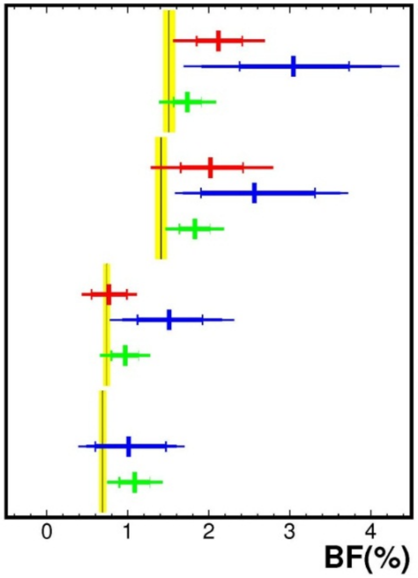
→ PRL 99, 191807 (2007)

B → $D^{(*)}\tau\nu$ decays

This summer: First 5σ observation (BaBar) of B → $D\tau\nu$ decays (exclusive hadron tag data)

Belle inclusive tag,
Belle exclusive tag,
Babar excusive tag
(summer 2011)
compared to the

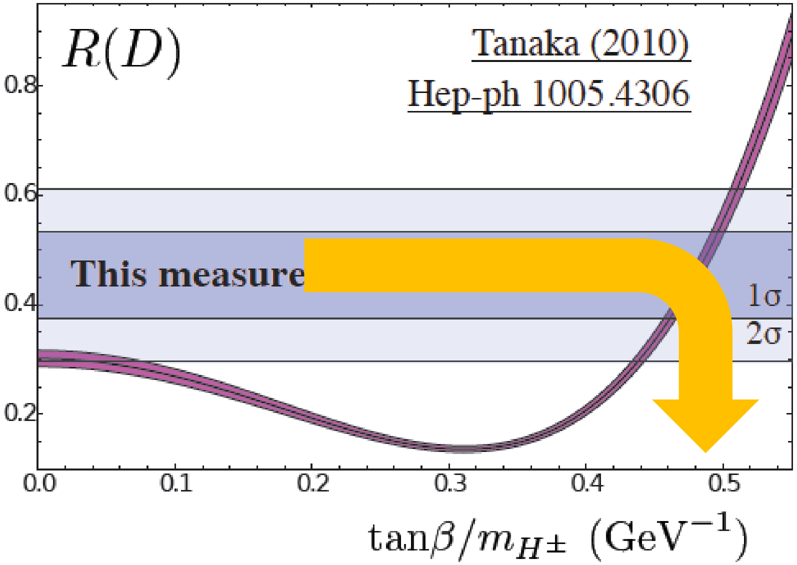
SM prediction



$B^+ \to \overline{D}^{*0}\tau^+\nu_\tau$	(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 than SM predictions →

→ A very interesting limit on charged Higgs



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

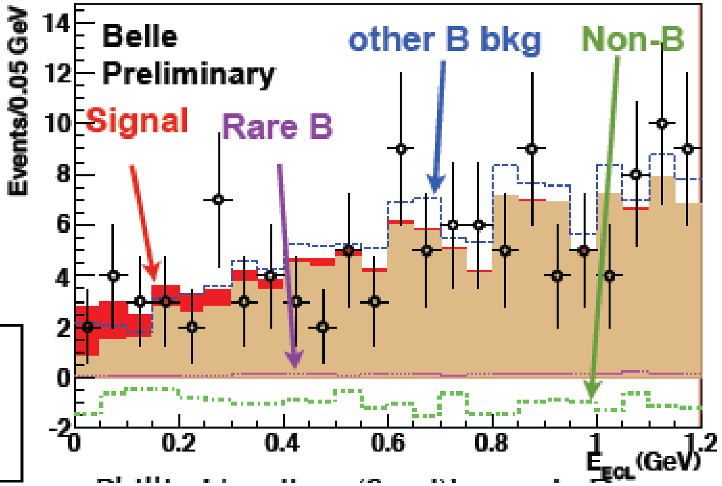
$B \rightarrow \nu\,\nu$ similar as $B \rightarrow \mu\,\mu$, a very sensitive channel to NP contributions

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

→ 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.



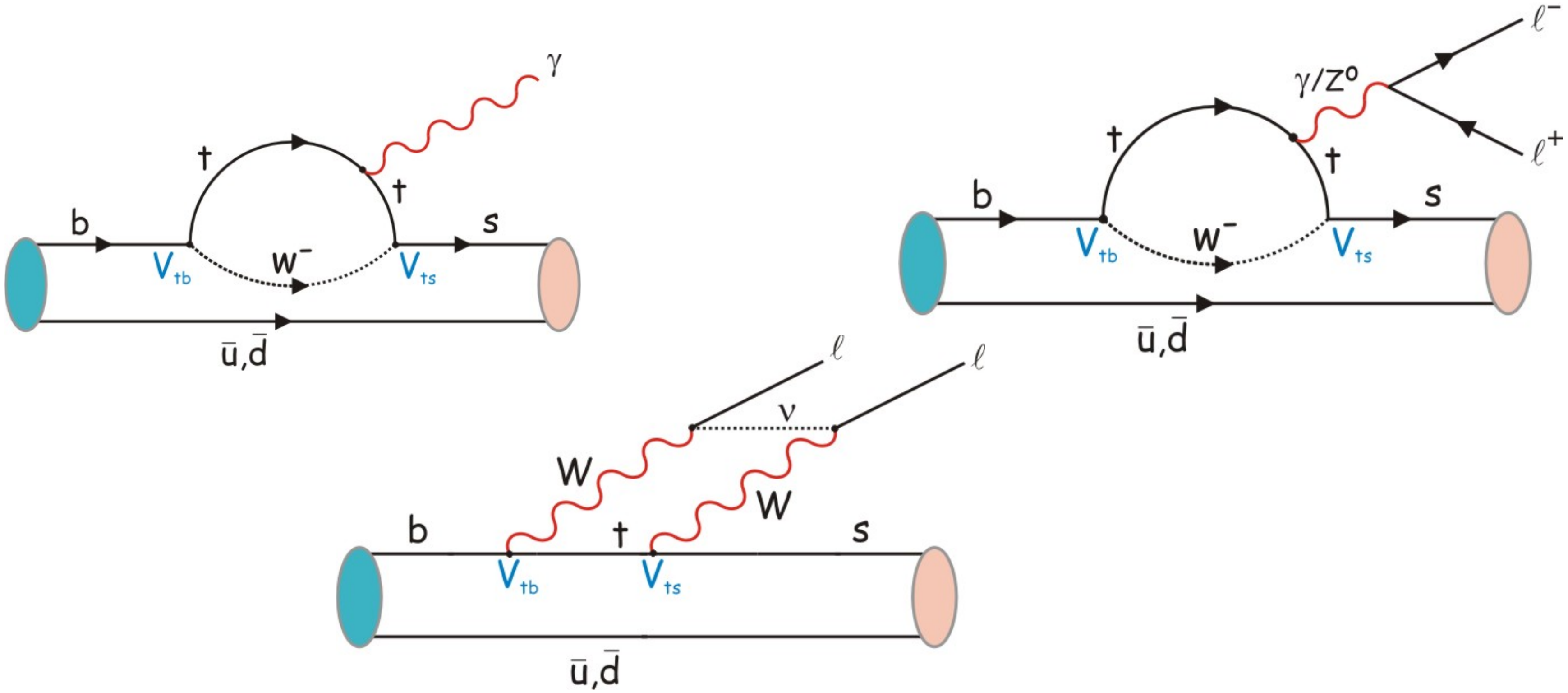
90% C.L. BR < 1.3 x 10^{-4}

Belle Preliminary 657M BBbar

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

Why FCNC decays?

Flavour changing neutral current (FCNC) processes (like b→s, b→d) are fobidden at the tree level in the Standard Model. Proceed only at low rate via higher-order loop diagrams. Ideal place to search for new physics.



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

arXiv:1002.5012

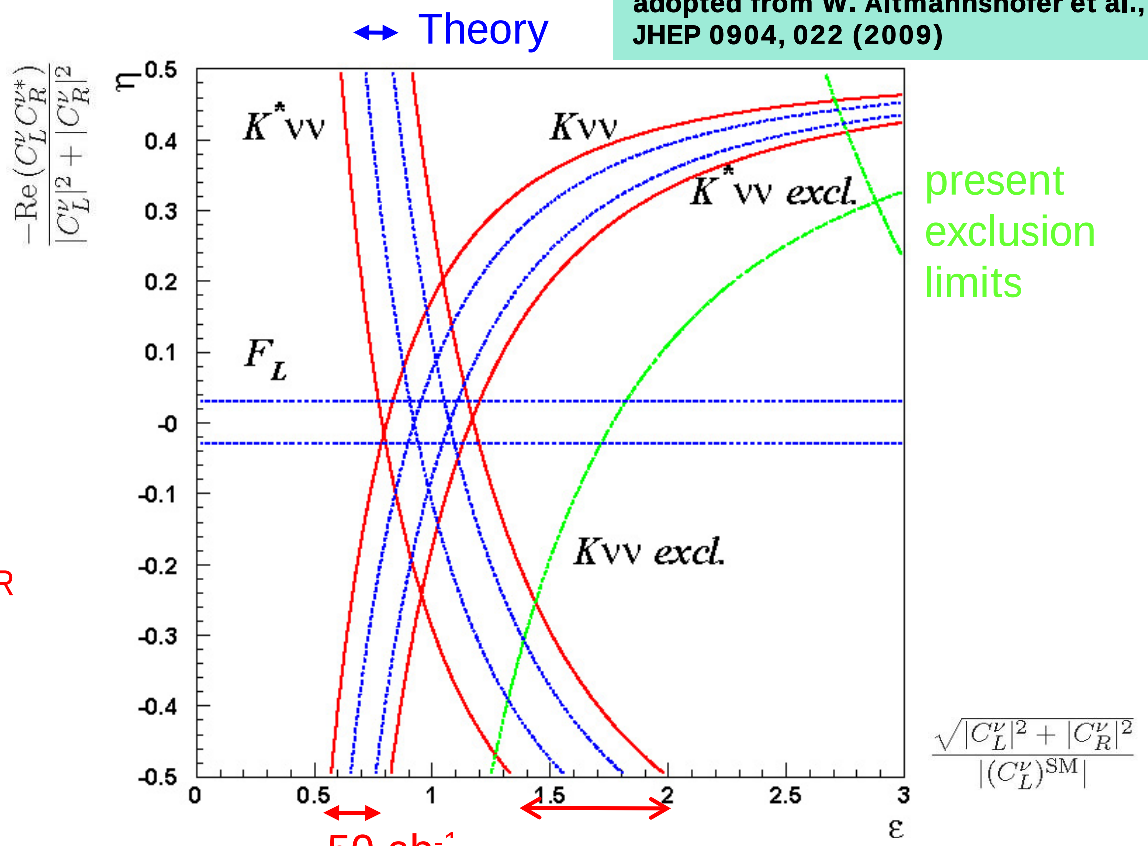
adopted from W. Altmannshofer et al., JHEP 0904, 022 (2009)

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

SM: penguin+box

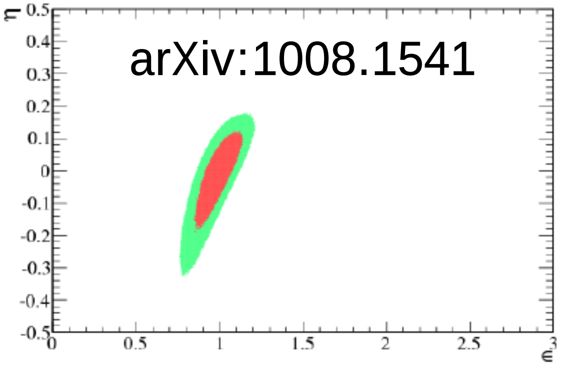
Look for departure from the expected value → information on couplings C^ν_R and C^ν_L compared to $(C^\nu_L)^{SM}$

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



present exclusion limits

50 ab^{-1}



arXiv:1008.1541

not possible @ LHCb

A difference in the direct violation of CP symmetry in B^+ and B^0 decays

nature International weekly journal of science

nature Vol 452|20 March 2008|doi:10.1038/nature06827

LETTERS

Difference in direct charge-parity violation between charged and neutral *B* meson decays

The Belle Collaboration*

CP asymmetry

$$\mathcal{A}_f = \frac{N(\overline{B} \to \bar{f}) - N(B \to f)}{N(\overline{B} \to \bar{f}) + N(B \to f)}$$

Difference between B^+ and B^0 decays

In SM expect $\mathcal{A}_{K^\pm\pi^\mp} \approx \mathcal{A}_{K^\pm\pi^0}$

Measure:

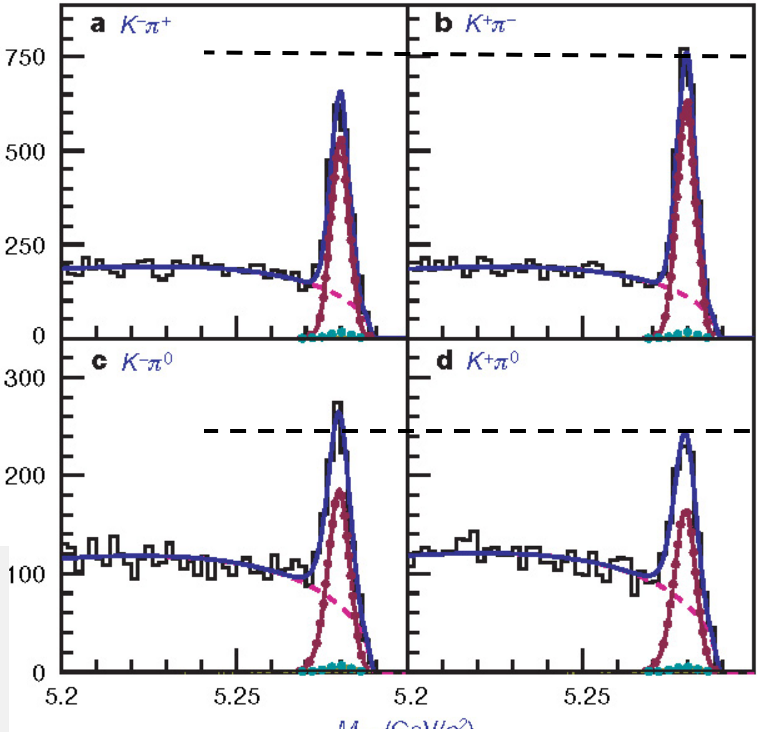
$$\mathcal{A}_{K^\pm\pi^\mp} = -0.094 \pm 0.018 \pm 0.008$$

$$\mathcal{A}_{K^\pm\pi^0} = +0.07 \pm 0.03 \pm 0.01$$

$$\Delta\mathcal{A} = +0.164 \pm 0.037$$

A problem for a SM explanation
(in particular when combined with other measurements)

A hint for new sources of CP violation?

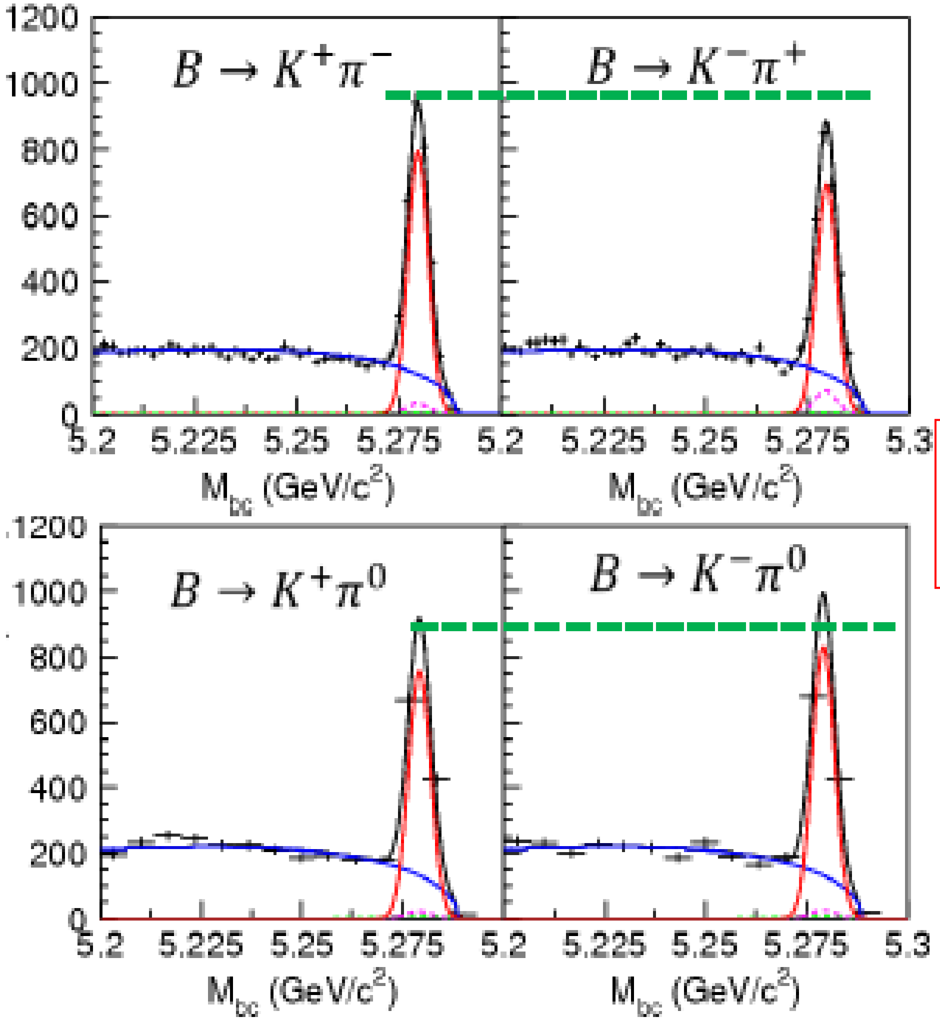


~1 in 10^5 B mesons decays in this decay mode

Belle, Nature 452, 332 (2008)

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

Update 2011



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

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:

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

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})

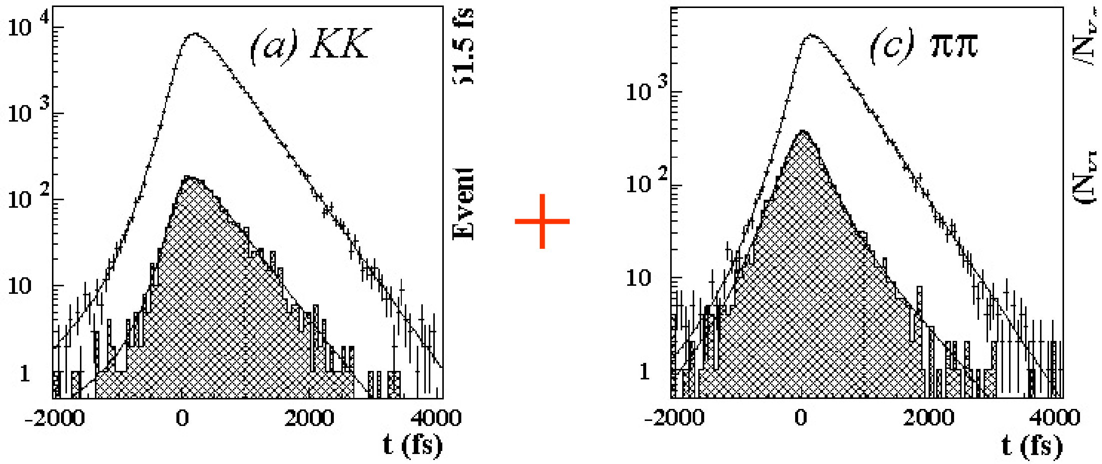
Main issues

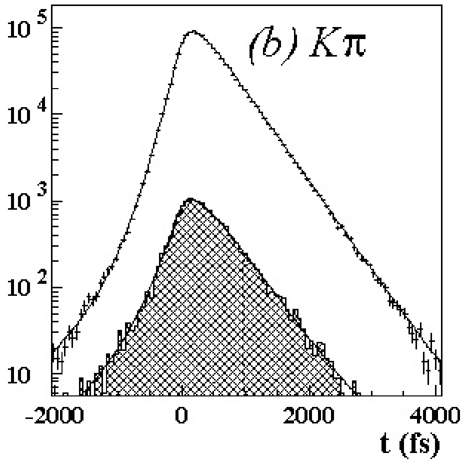
- Mixing and CP violation in charm
- Lepton flavour violation (LFV) in tau decays

→ Very sensitive to new physics effects!

D^0 mixing in K^+K^-, $\pi^+\pi^-$

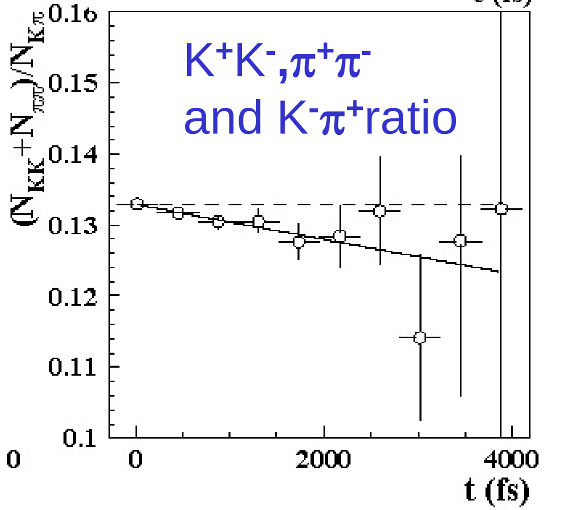
Decay time distributions for KK, ππ, Kπ





Difference of lifetimes visually observable in the ratio of the distributions →

Real fit: $y_{CP} = (1.31 \pm 0.32 \pm 0.25)$ %



K^+K^-,$\pi^+\pi^-$ and $K^-\pi^+$ratio

→ Observation of D mixing!

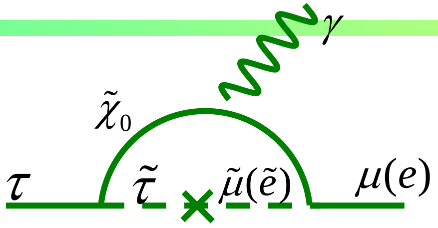
→ on a high side of SM predictions

M. Starič et al. (Belle), PRL 98 (2007) 211803

CP violation in the D system would be a clear sign of new physics

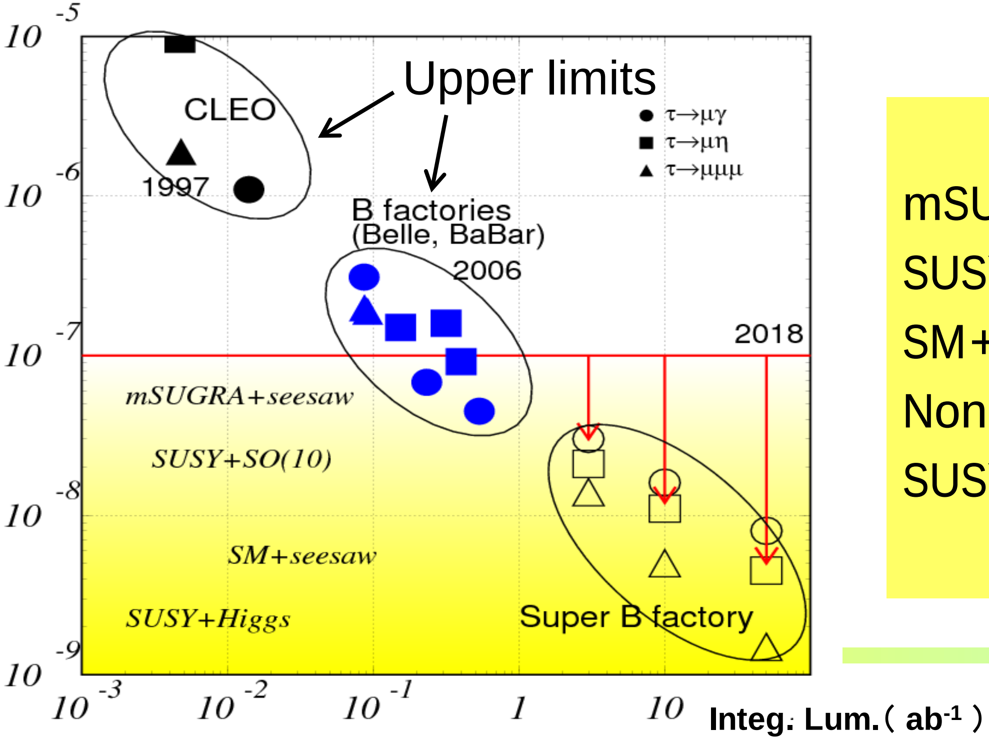
LFV and New Physics

τ→lγ

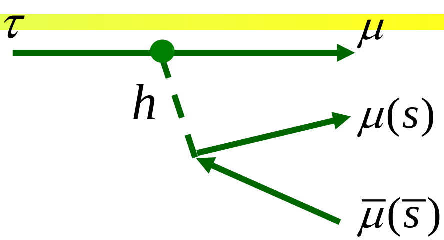


- SUSY + Seasaw $(m^2_{\tilde{l}})_{23(13)}$
- Large LFV Br(τ→μγ)=O(10$^{-7\sim9}$)

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



τ→3l,lη

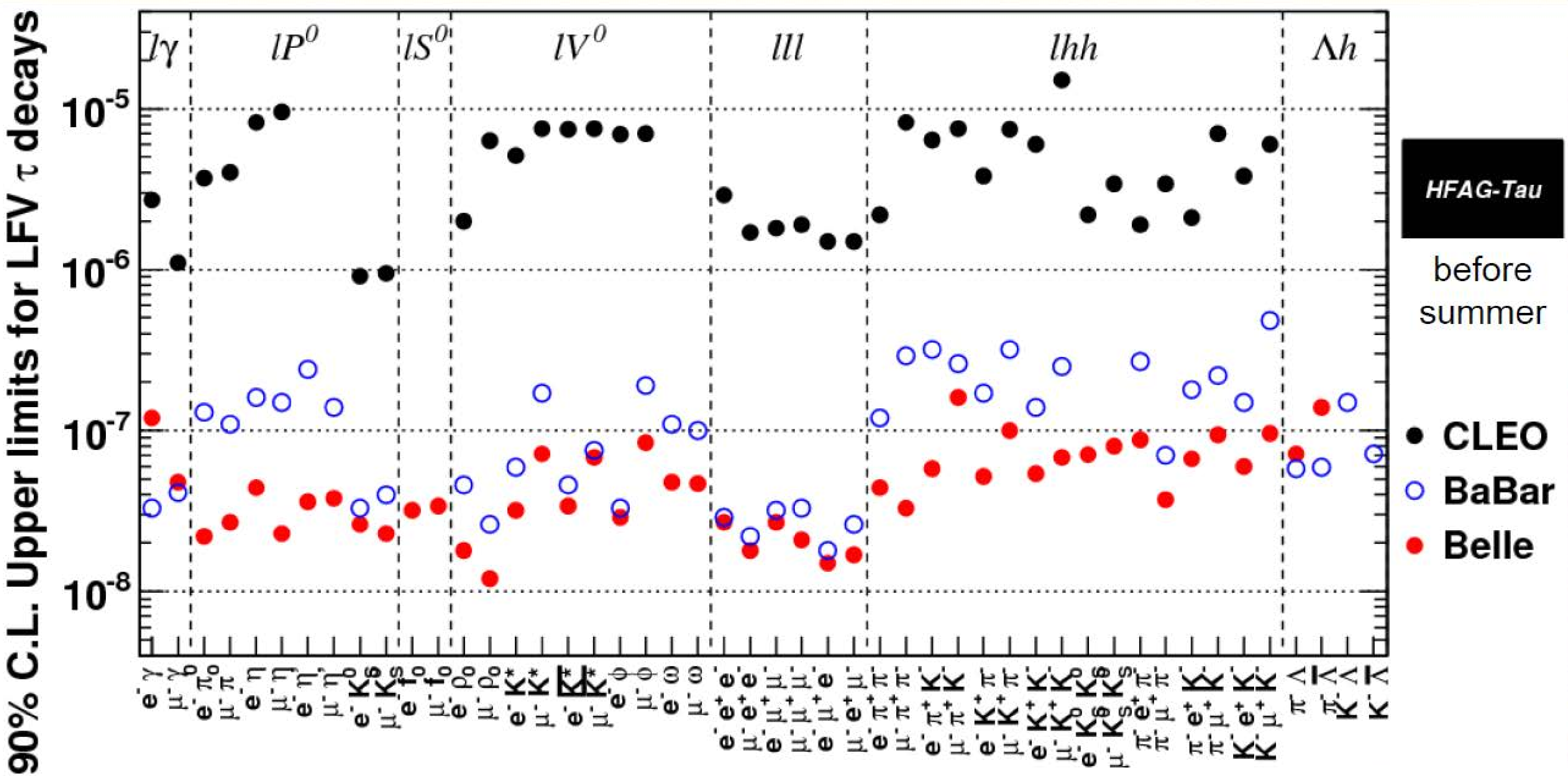


- Neutral Higgs mediated decay.
- Important when MSUSY >> EW scale.

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

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}

Upper Limits on τ LFV Decay

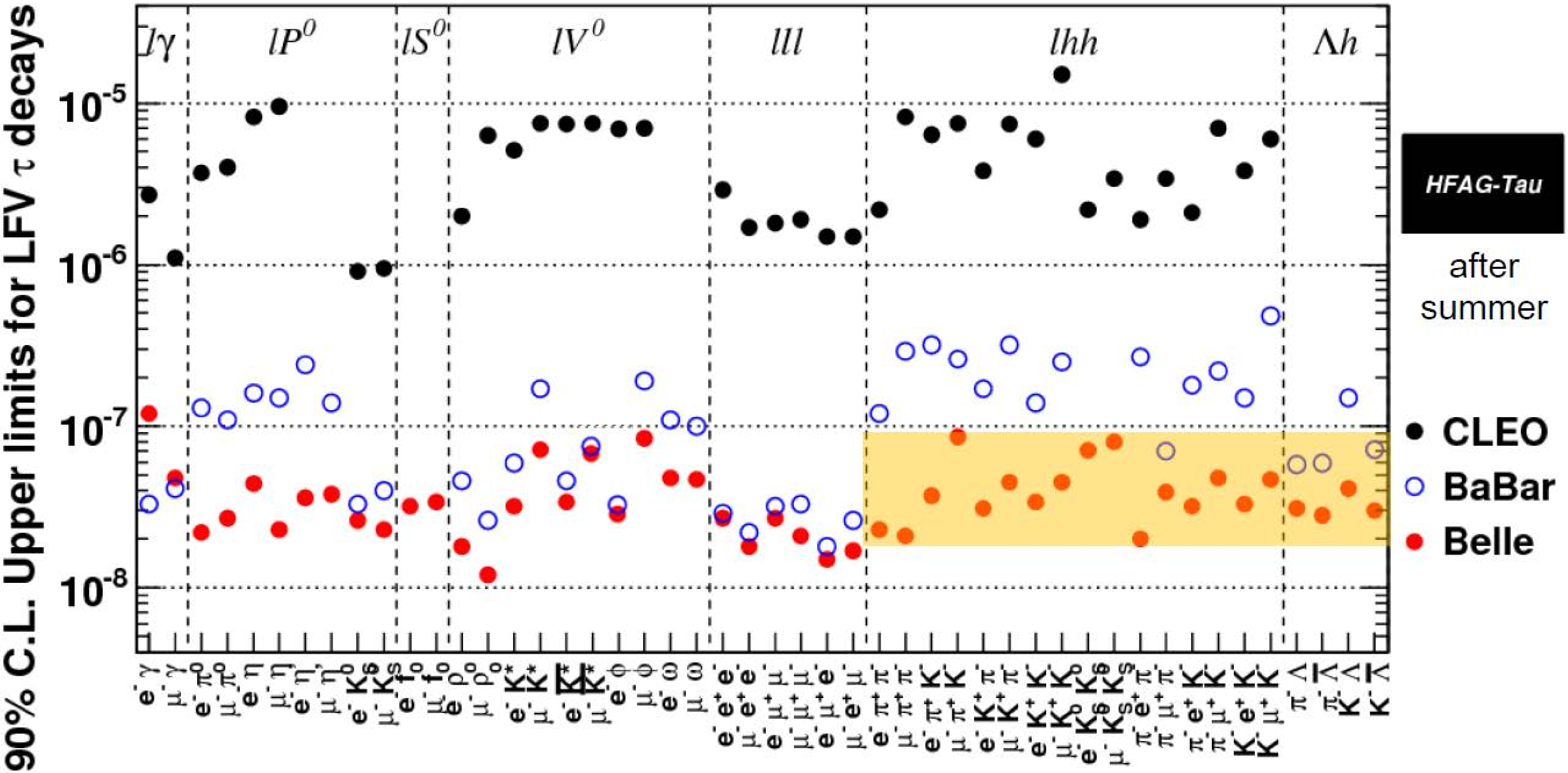


Lepton flavour violation (LFV) in tau decays: would be a clear sign of new physics →

$$Br(\tau \to \ell\gamma)_{SM} \propto \left(\frac{\delta m_\nu^2}{m_W^2}\right)^2 < 10^{-54}$$

K. Hayasaka, talk at PhiPsi11

New Upper Limits on τ LFV Decay



Reach upper limits around 10^{-8} ~100x more sensitive than CLEO

Update using full data samples will be finalized soon!

K. Hayasaka, talk at PhiPsi11 →poster at KMIIN

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)	$\sim 15°$	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%
$\mathcal{B}(B \to K\nu\overline{\nu})$	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		$(1-2) \times 10^{-5}$
	y		$(1-2) \times 10^{-3}$
	$\cos\delta$		$(0.01-0.02)$

Charm FCNC

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

	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}

$\mathrm{B_s}$ 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
$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	$< 8 \times 10^{-9}$
$\lvert V_{td}/V_{ts}\rvert$	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

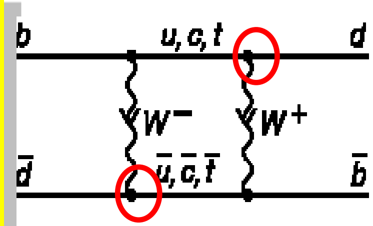
Physics at a Super B Factory

- 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→$\tau\nu$, D$\tau\nu$ can probe the charged Higgs in large tanβ 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).

Super B Factory Motivation 2

- Lessons from history: the top quark

<u>Physics of top quark</u>
First estimate of mass: BB mixing → ARGUS
Direct production, Mass, width etc. → CDF/D0
Off-diagonal couplings, phase → BaBar/Belle



$$V_{CKM} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ \boxed{V_{td}} & V_{ts} & V_{tb} \end{pmatrix}$$

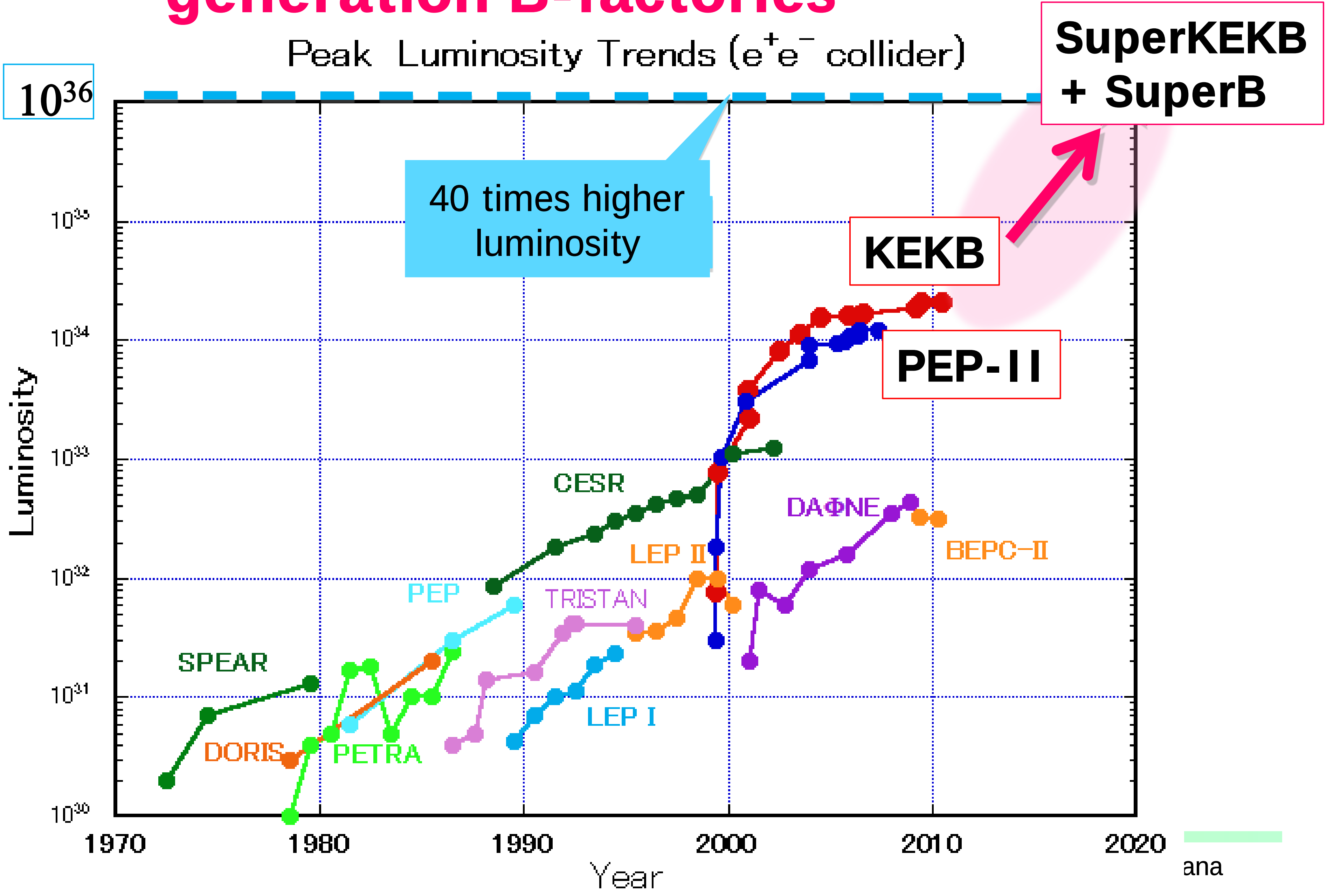
- Even before that: prediction of charm quark from the GIM mechanism, and its mass from K^0 mixing

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

Recent update of the physics reach with 50 ab^{-1} (75 ab^{-1}):
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

Accelerator

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



10^{36}

40 times higher luminosity

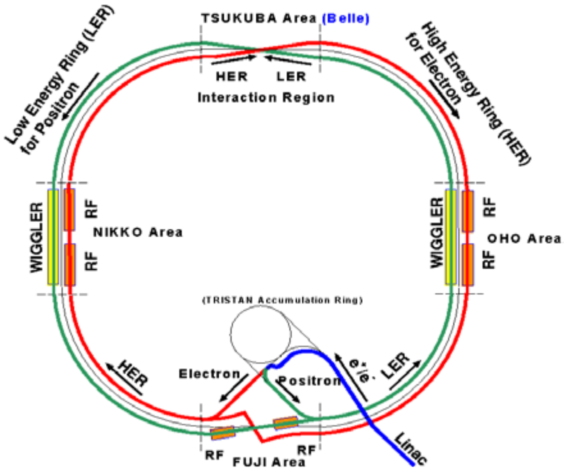
SuperKEKB + SuperB

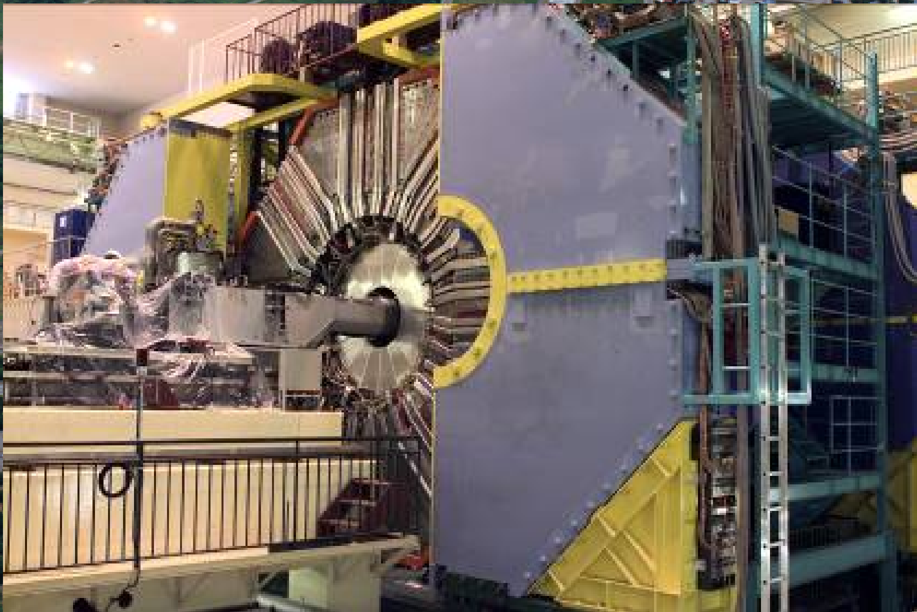
KEKB

PEP-II

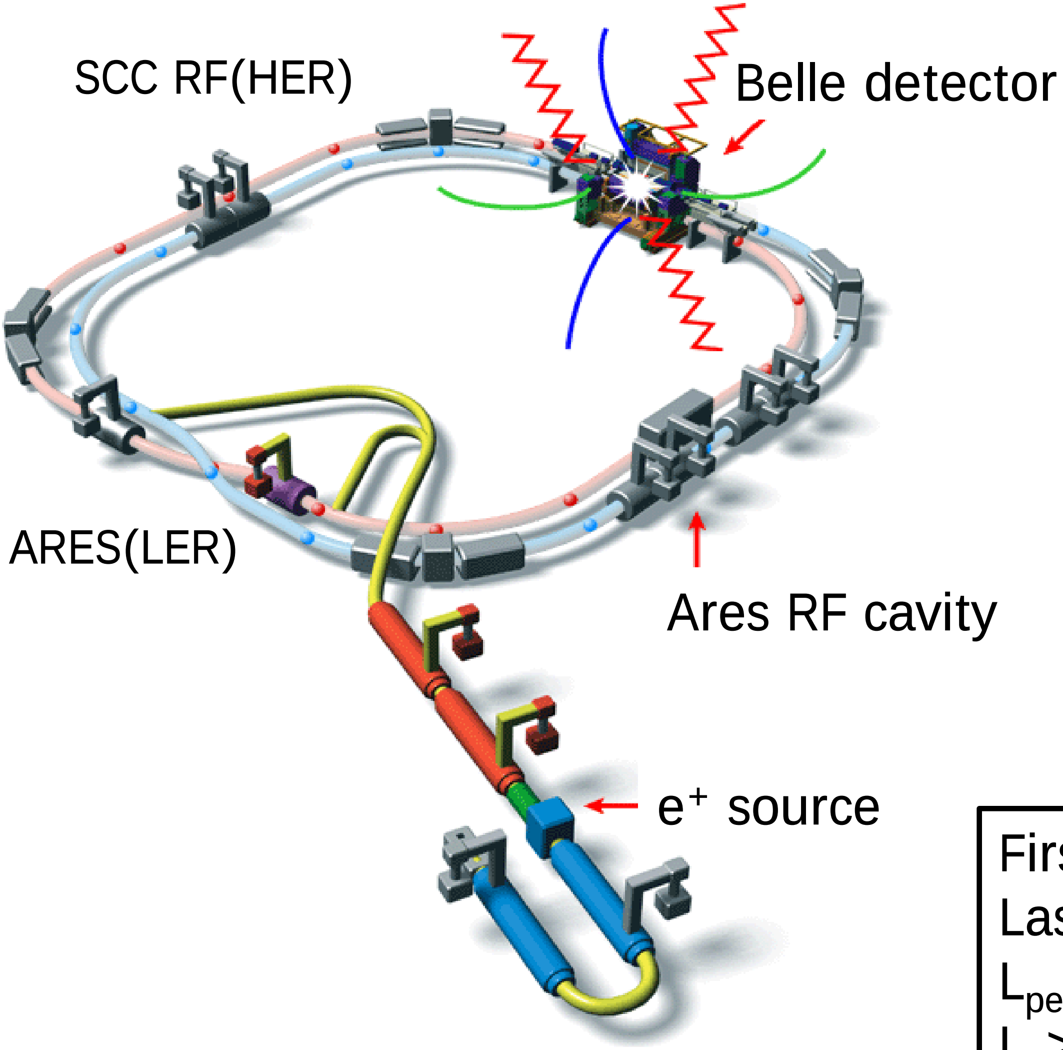
ana

How to do it?
→ upgrade KEKB and Belle





The KEKB Collider & Belle Detector



- e^- (8 GeV) on e^+(3.5 GeV)
  - $\sqrt{s} \approx m_{\Upsilon(4S)}$
  - Lorentz boost: $\beta\gamma=0.425$
- 22 mrad crossing angle
- Operating since 1999

Peak luminosity (WR!) :

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

=2x design value

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

The last beam abort of KEKB on June 30, 2010

→ Can start construction of SuperKEKB and Belle II

Strategies for increasing luminosity

Lorentz factor

Beam current

Beam-beam parameter

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

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

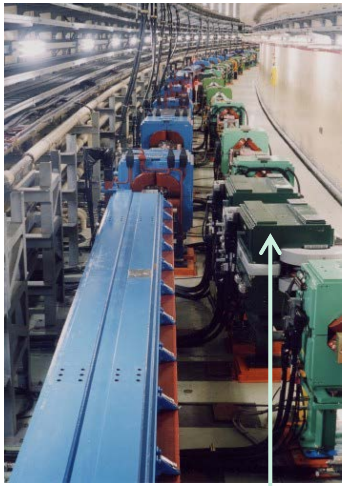
Invented by Pantaleo Raimondi for SuperB

Machine design parameters

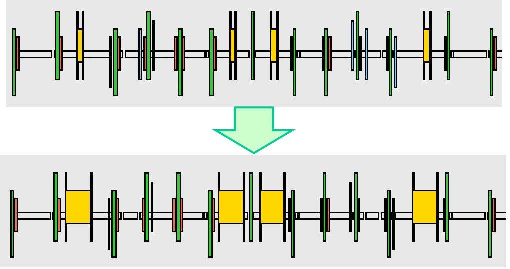
parameters		KEKB		**SuperKEKB**		units
		LER	HER	LER	HER	
Beam energy	E_b	3.5	8	4	7	GeV
Half crossing angle	φ	11		41.5		mrad
Horizontal emittance	ε_x	18	24	3.2	4.3-4.6	nm
Emittance ratio	κ	0.88	0.66	0.27	0.25	%
Beta functions at IP	β_x^*/β_y^*	1200/5.9		32/0.27	25/0.31	mm
Beam currents	I_b	1.64	1.19	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

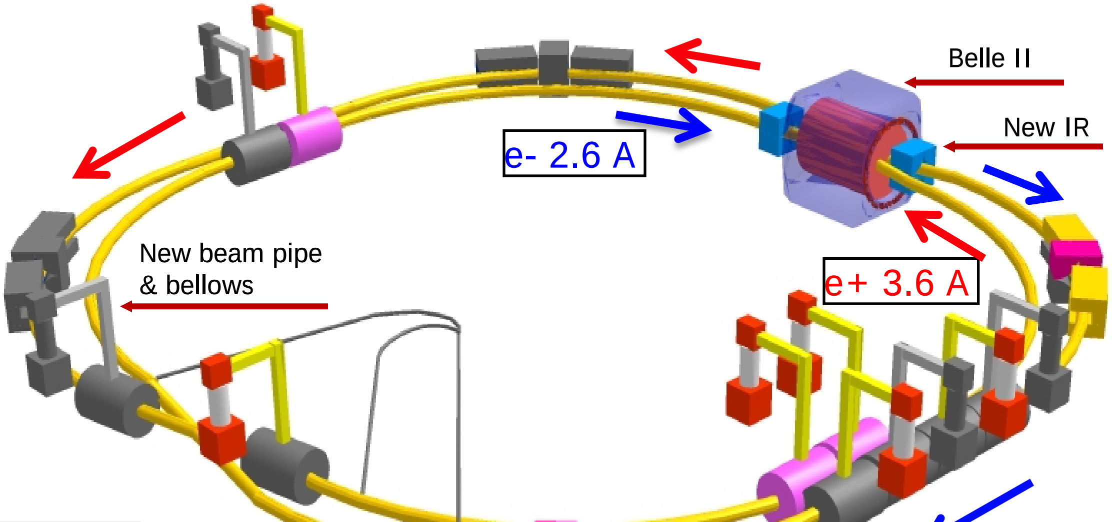
KEKB to SuperKEKB



Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance

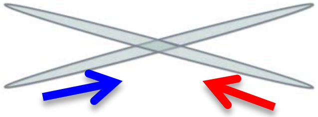


Belle II

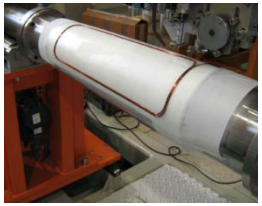
New IR

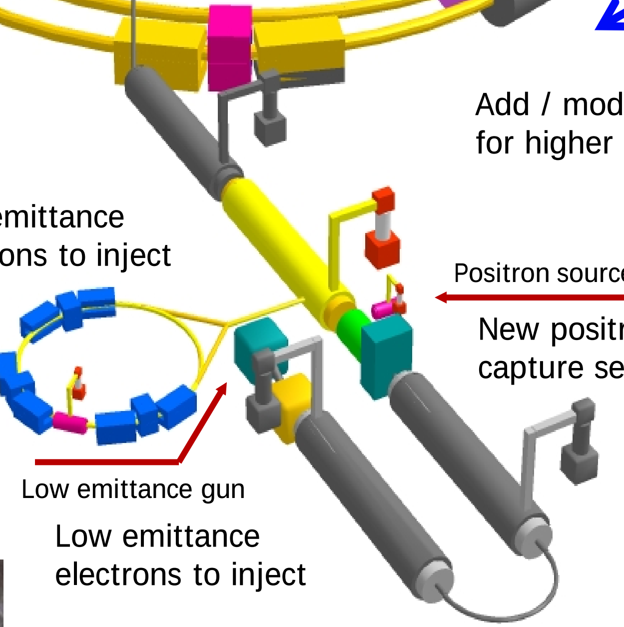
New beam pipe & bellows

Colliding bunches



New superconducting /permanent final focusing quads near the IP





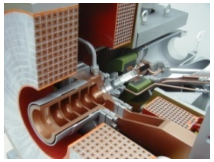
Add / modify RF systems for higher beam current

Low emittance positrons to inject

Damping ring

Positron source

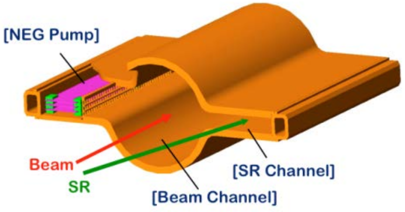
New positron target / capture section

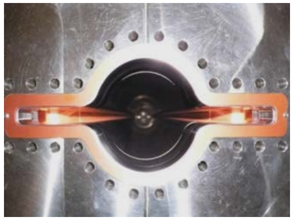


Low emittance gun

Low emittance electrons to inject

TiN-coated beam pipe with antechambers





To get x40 higher luminosity

Detector

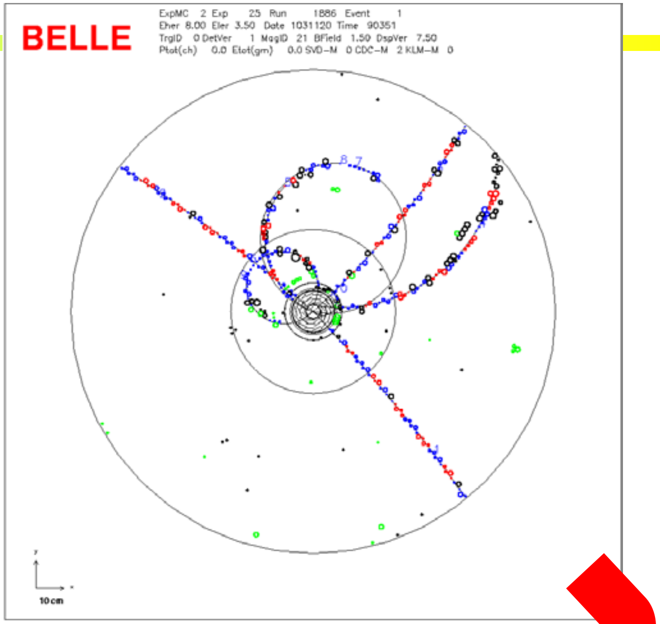
Requirements for the Belle II detector

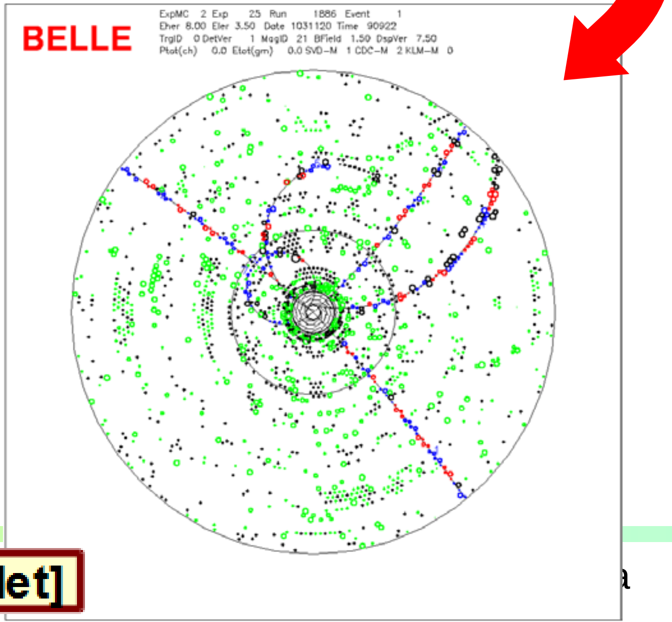
Critical issues at L= 8 x 10^{35}/cm^2/sec

- **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 ← sμμ recon. eff.
  - hermeticity ← ν “reconstruction”

Solutions:

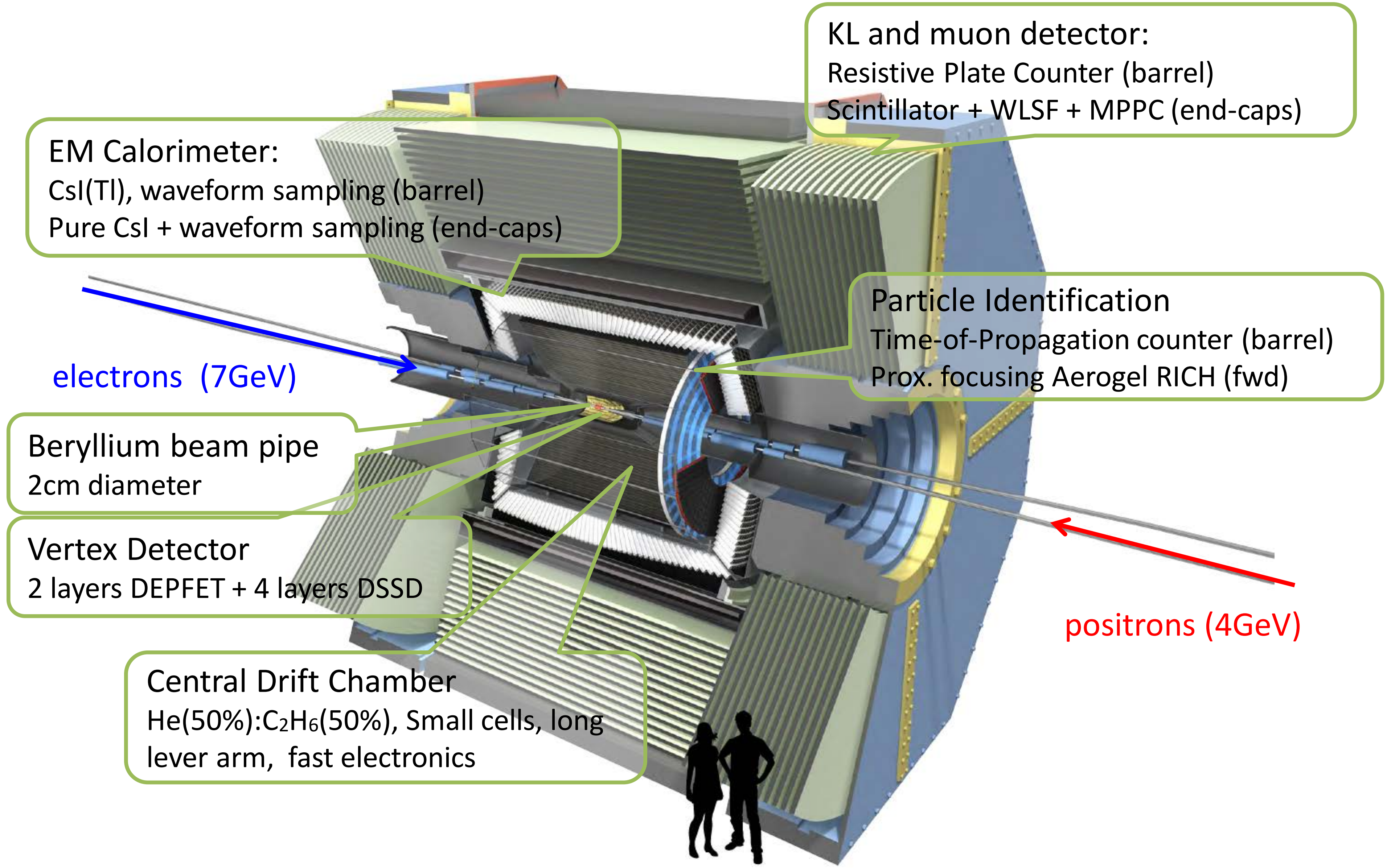
- Replace inner layers of the vertex detector with a pixel detector.
- Replace inner part of the central tracker with a silicon strip detector.
- Better particle identification device
- Replace endcap calorimeter crystals
- Faster readout electronics and computing system.





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

Belle II Detector



KL and muon detector:
Resistive Plate Counter (barrel)
Scintillator + WLSF + MPPC (end-caps)

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

Particle Identification
Time-of-Propagation counter (barrel)
Prox. focusing Aerogel RICH (fwd)

electrons (7GeV)

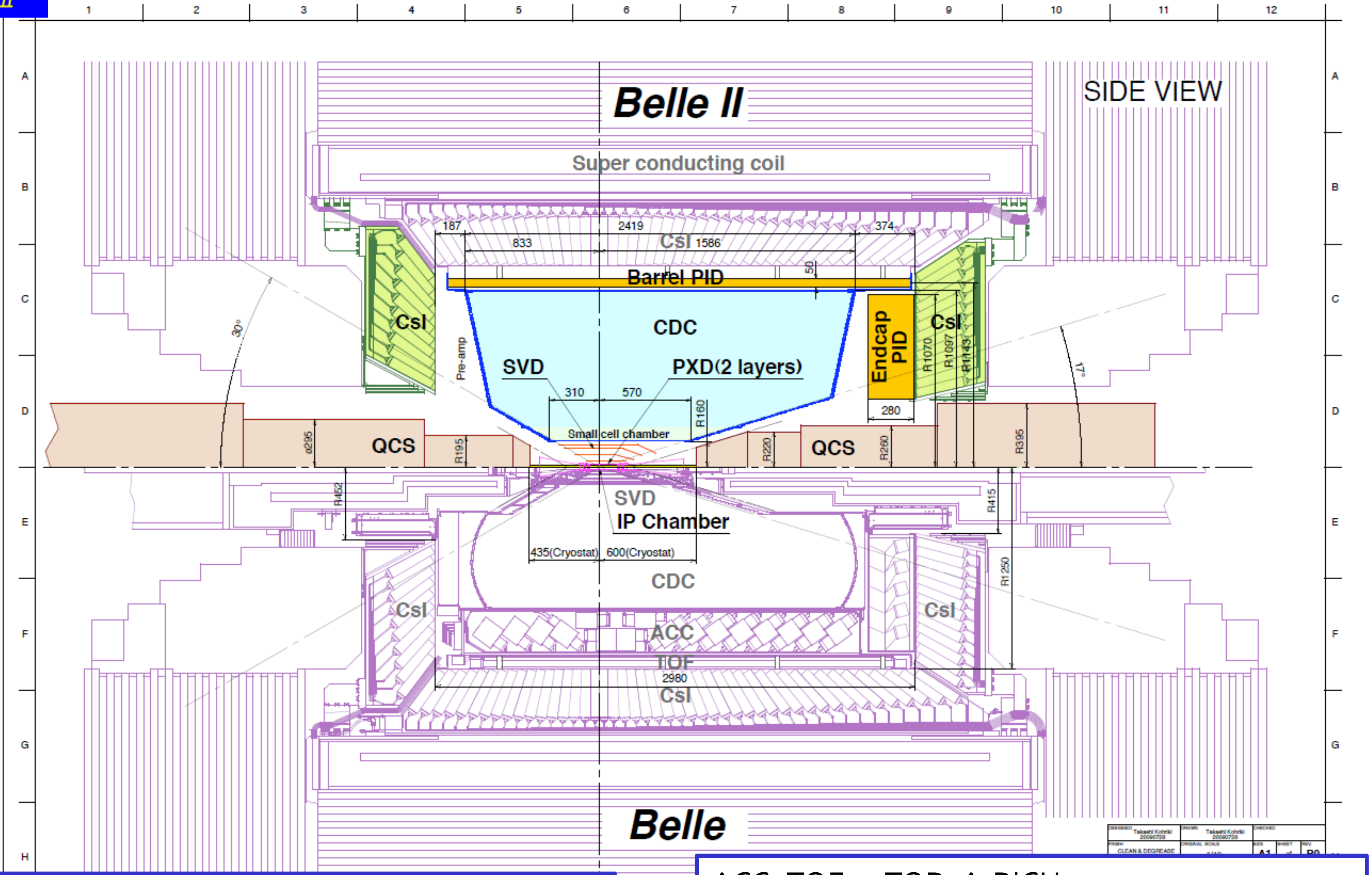
Beryllium beam pipe
2cm diameter

Vertex Detector
2 layers DEPFET + 4 layers DSSD

positrons (4GeV)

Central Drift Chamber
He(50%):C_2H_6(50%), Small cells, long lever arm, fast electronics

Belle II (top) compared with Belle (bottom)

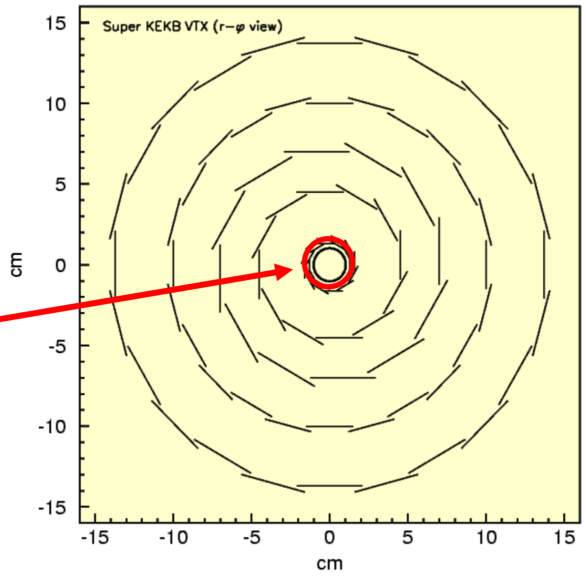


SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm

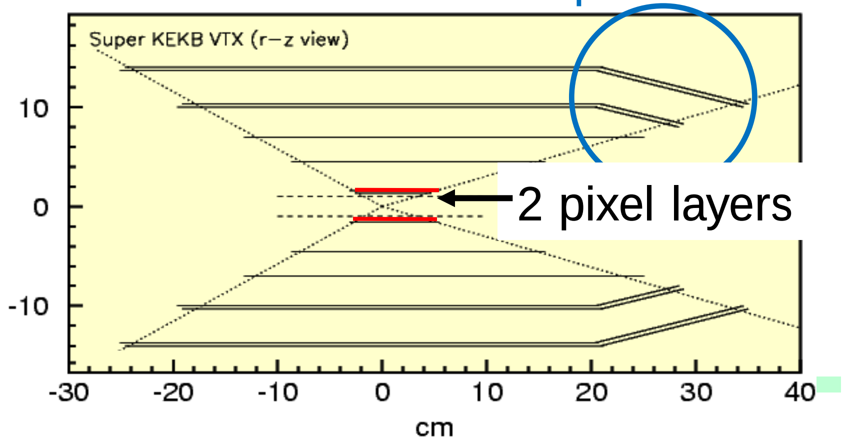
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +SiPM (end-caps)

Vertex detector upgrade: PXD+SVD

- Configuration: 4 layers → 6 layers (outer radius = 8cm→14cm)
  - More robust tracking
  - Higher K_S vertex reconstr. efficiency
- Inner radius: 1.5cm → 1.3cm
  - Better vertex resolution
- Sensors of the two innermost layers L1+L2: DEPFET Pixel sensors →PXD
- Layers 3-6: normal double sided Si detector (DSSD) →SVD
- Strip readout chip: VA1TA → APV25
  - Reduction of occupancy coming from beam background.
  - Pipeline readout to reduce dead time.



Slanted layers to keep the acceptance

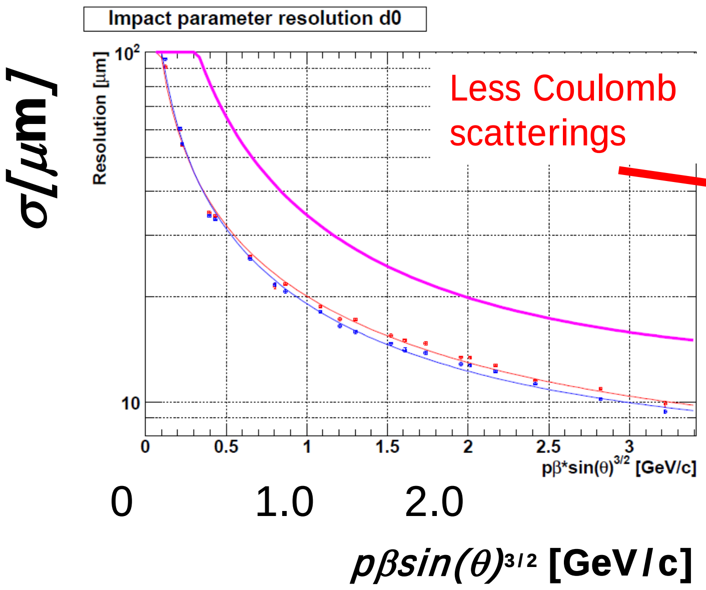


2 pixel layers

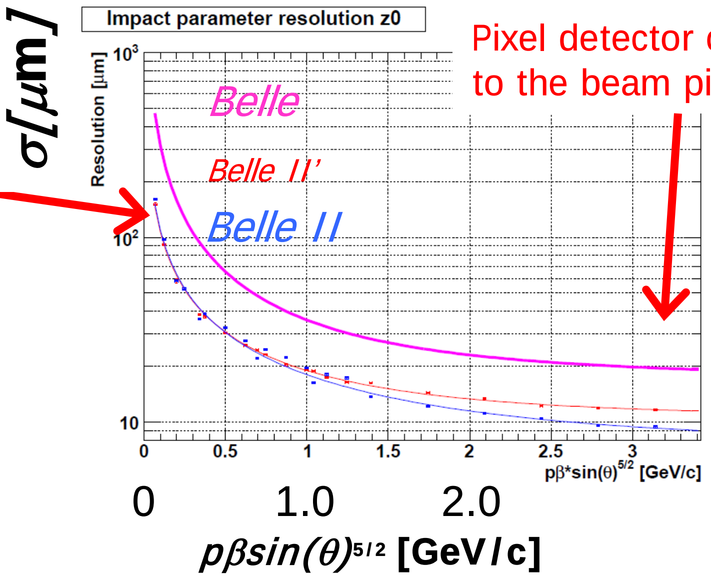
Expected performance

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

Significant improvement in IP resolution!

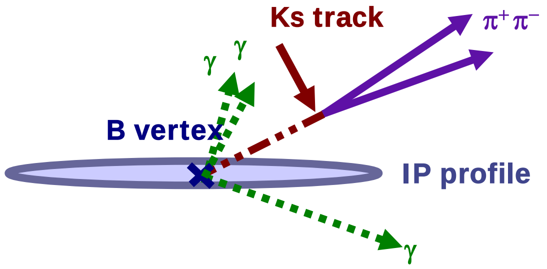


Less Coulomb scatterings

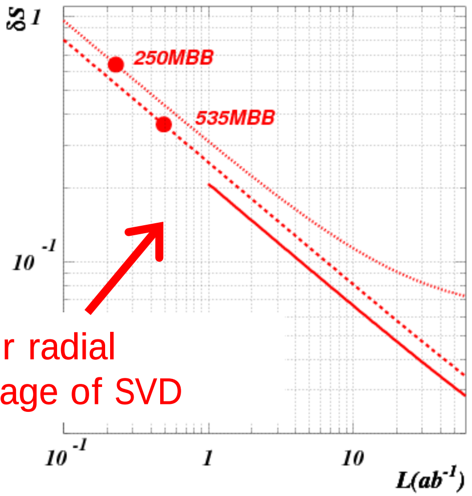


Pixel detector close to the beam pipe

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



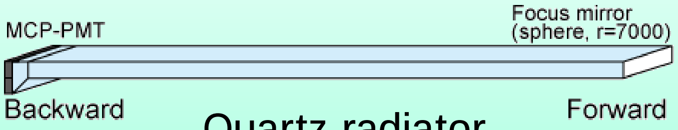
B decay point reconstruction with K_S trajectory



Larger radial coverage of SVD

Particle Identification Devices

Barrel PID: Time of Propagation Counter (TOP)



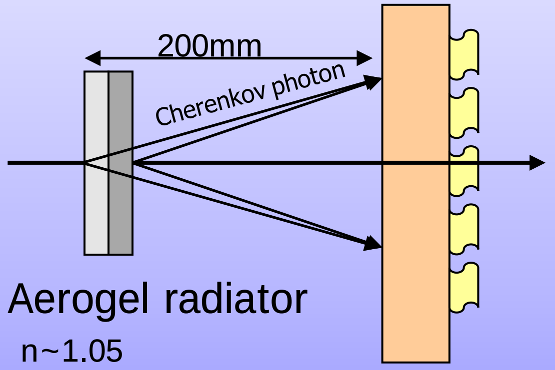
Quartz radiator

Focusing mirror

Small expansion block

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

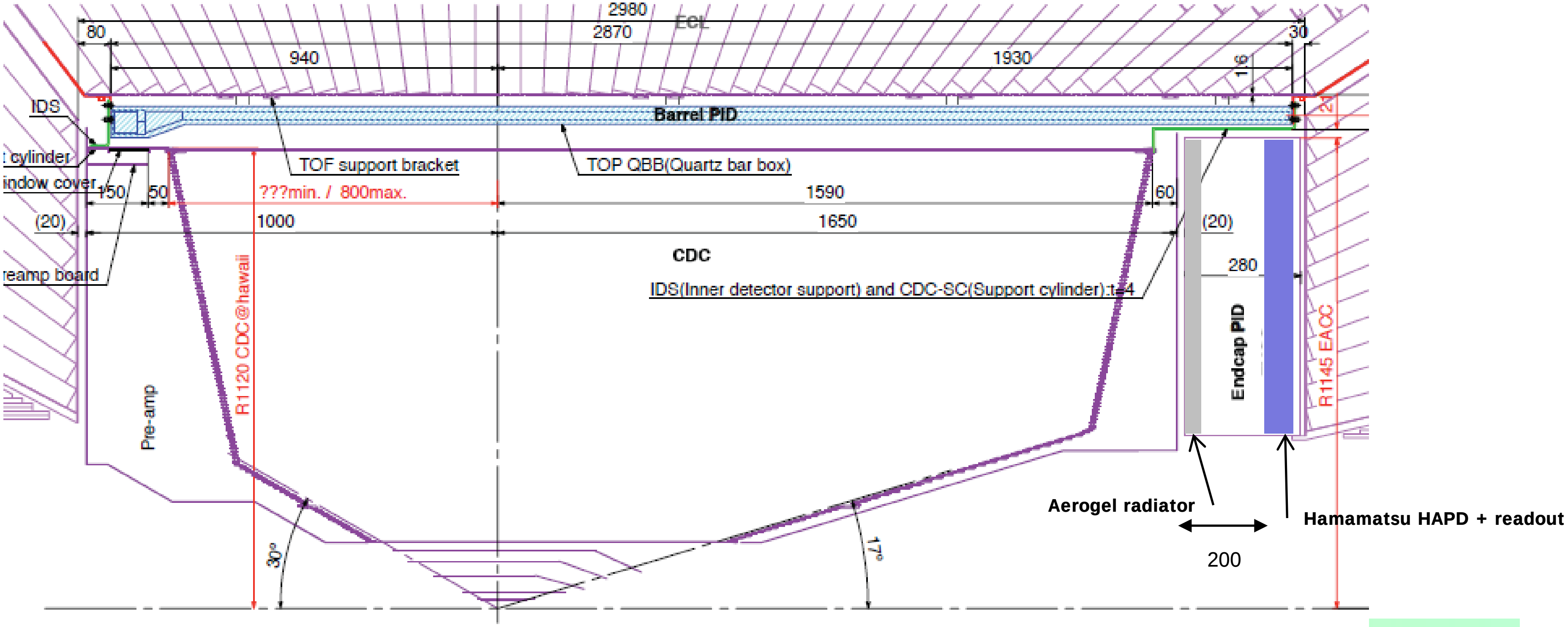
Endcap PID: Aerogel RICH (ARICH)



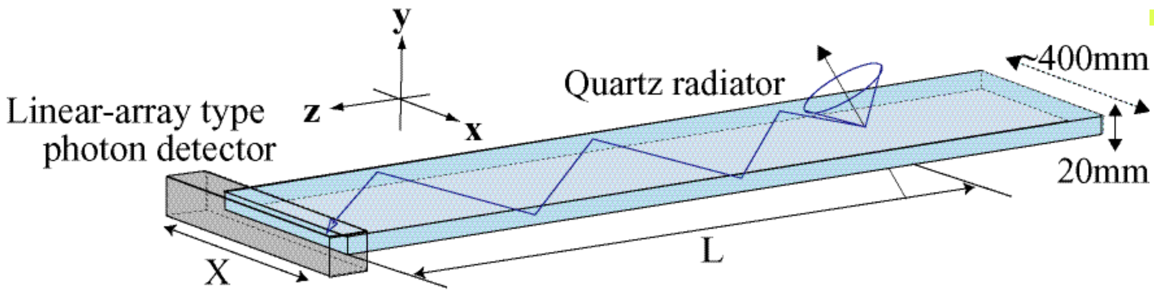
Aerogel radiator

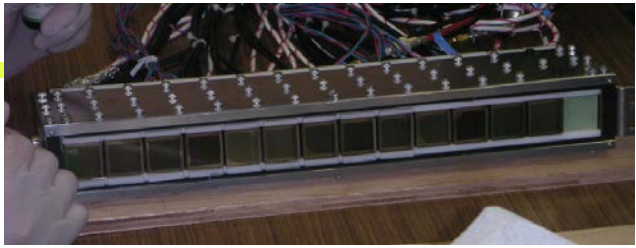
n~1.05

Hamamatsu HAPD
+ new ASIC

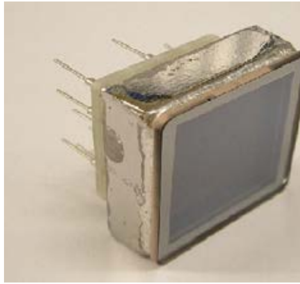


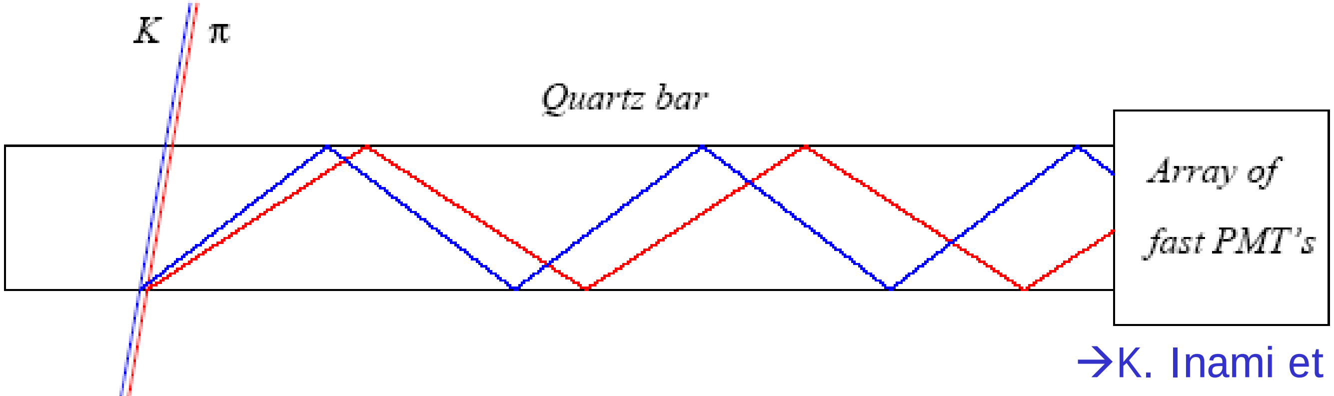
Barrel PID: Time of propagation (TOP) counter

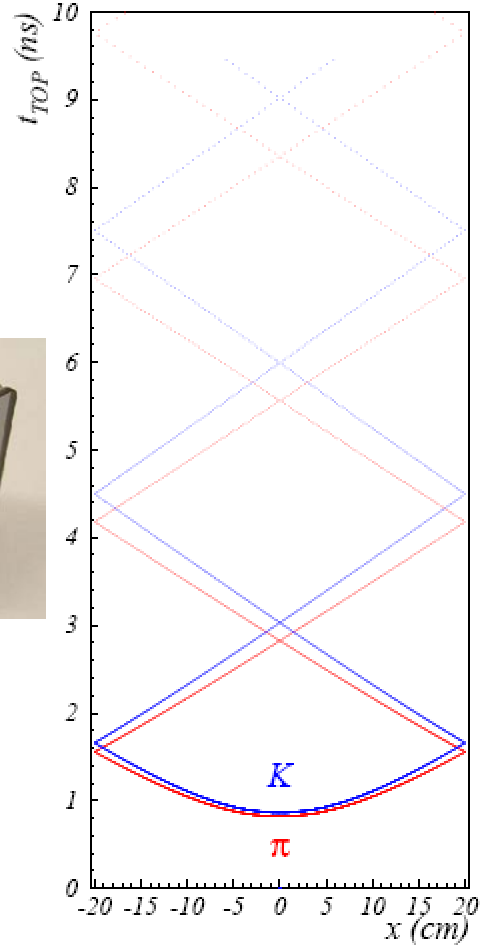




- Cherenkov ring imaging with precise time measurement.
- Reconstruct angle from two coordinates and the time of propagation of the photon
  - Quartz radiator (2cm)
  - Photon detector (MCP-PMT)
    - Good time resolution ~ 40 ps
    - Single photon sensitivity in 1.5



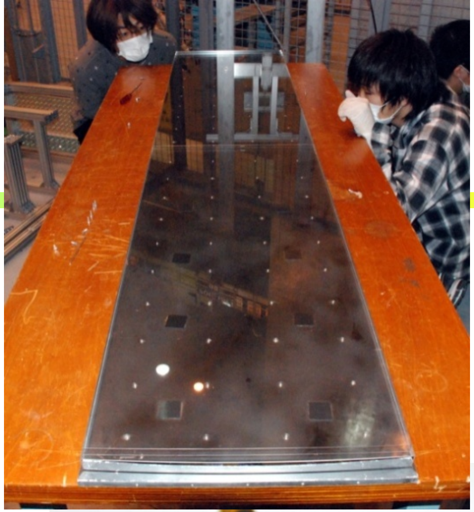


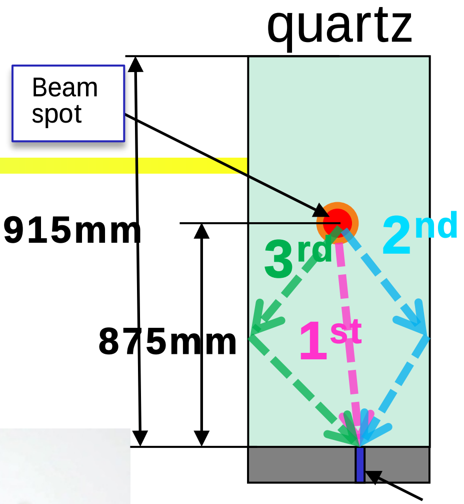


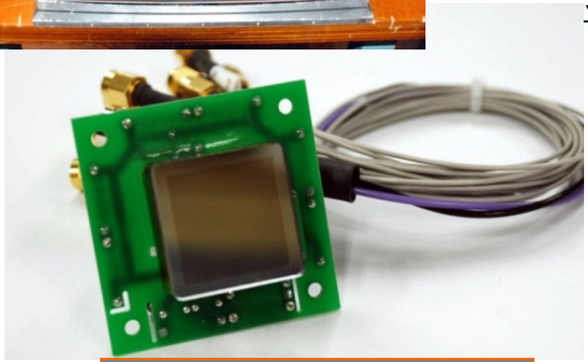
→K. Inami et al., NIM A639 (2011) 298

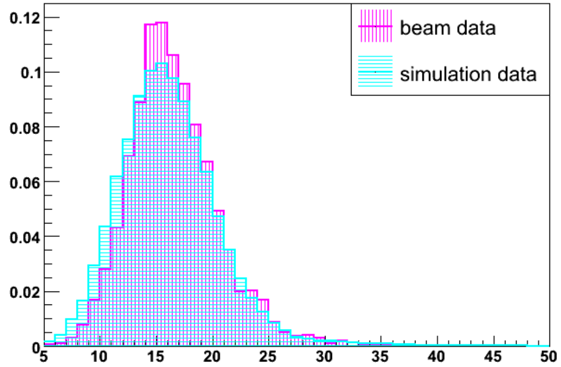
TOP (Barrel PID)

- 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

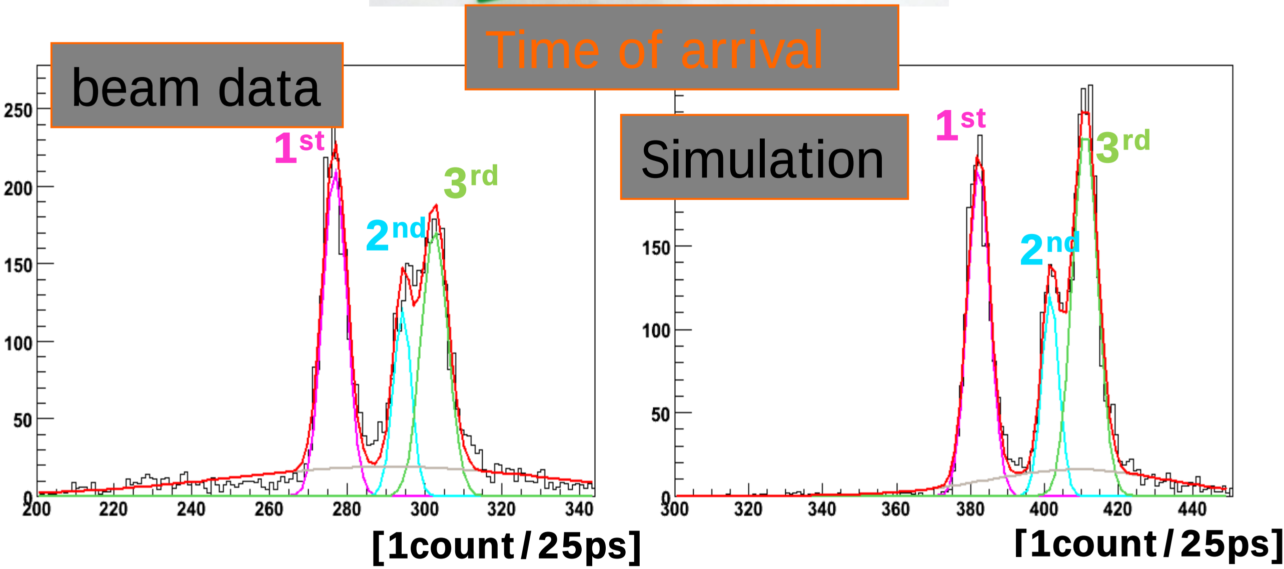






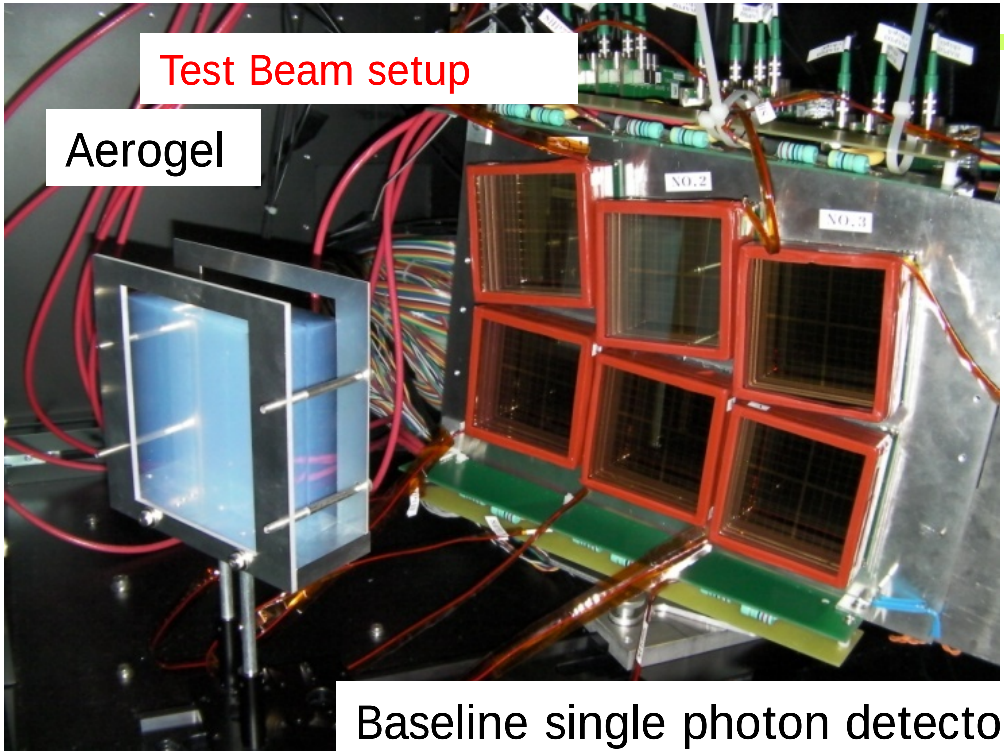


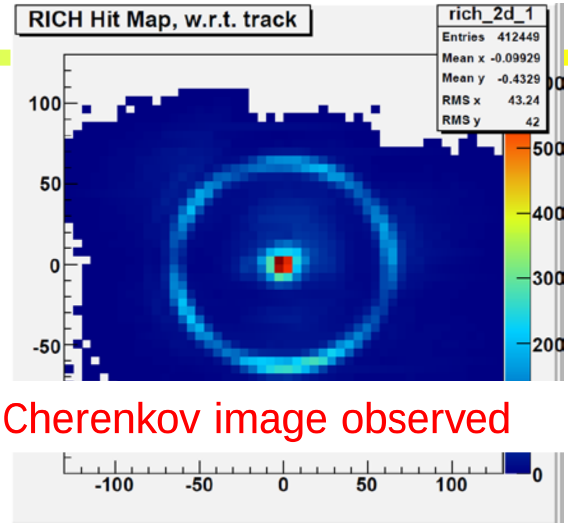
# of photons



→two posters

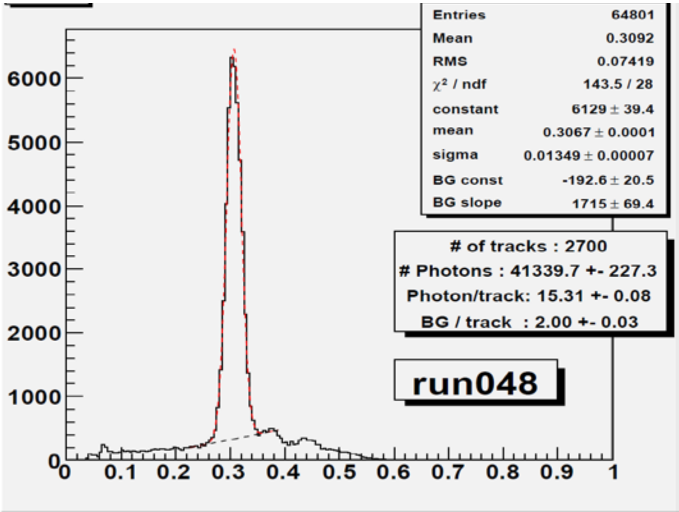
Aerogel RICH (endcap PID)



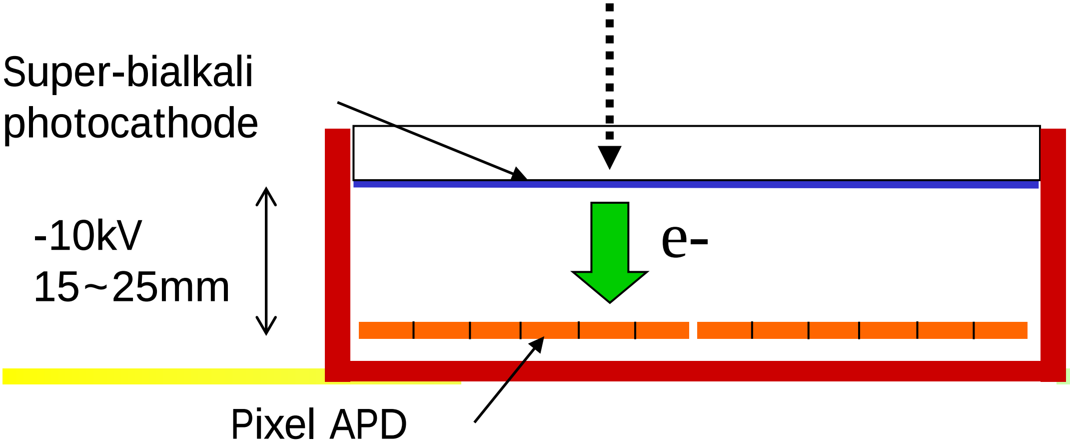


Clear Cherenkov image observed

Cherenkov angle distribution



Baseline single photon detector for 1.5 T: Hamamatsu HAPD



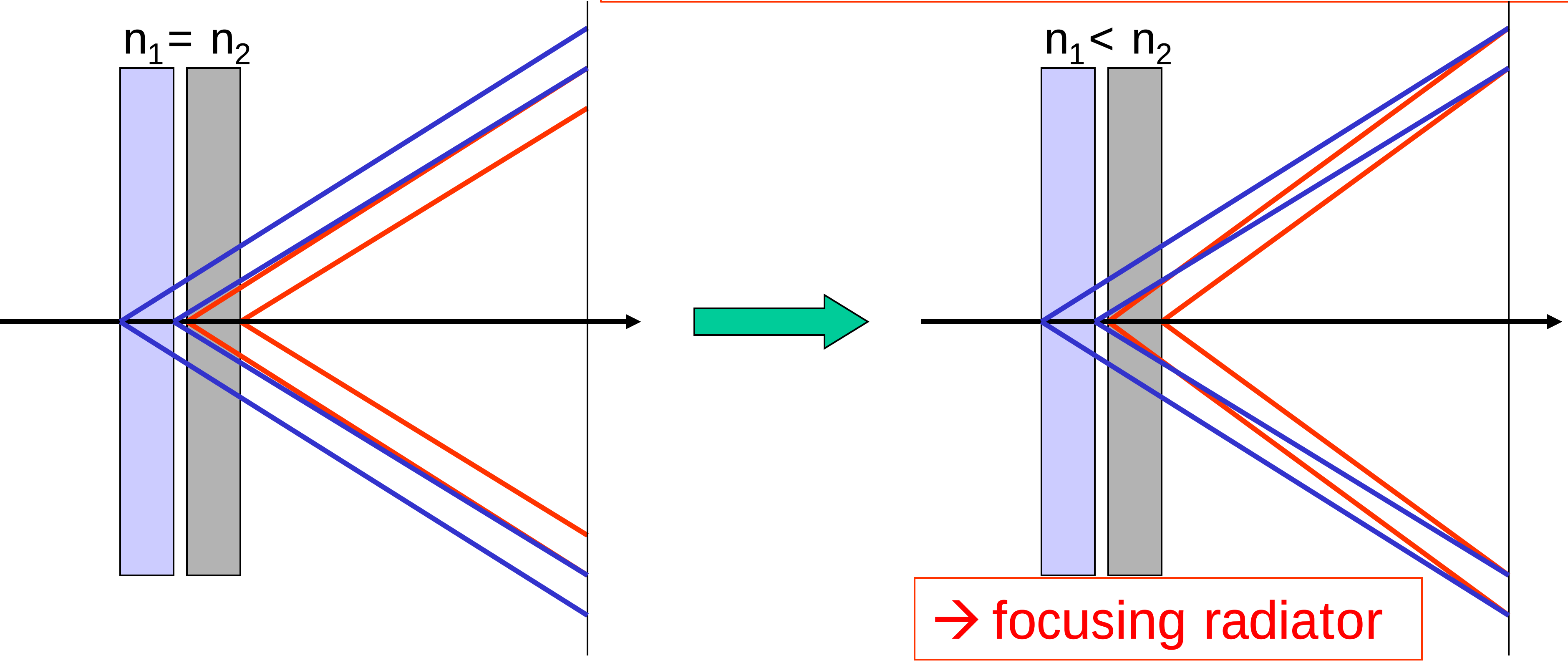
6.6 σ π/K at 4GeV/c !

Radiator with multiple refractive indices

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

normal

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

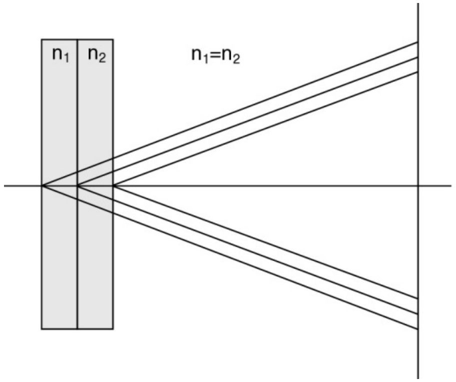


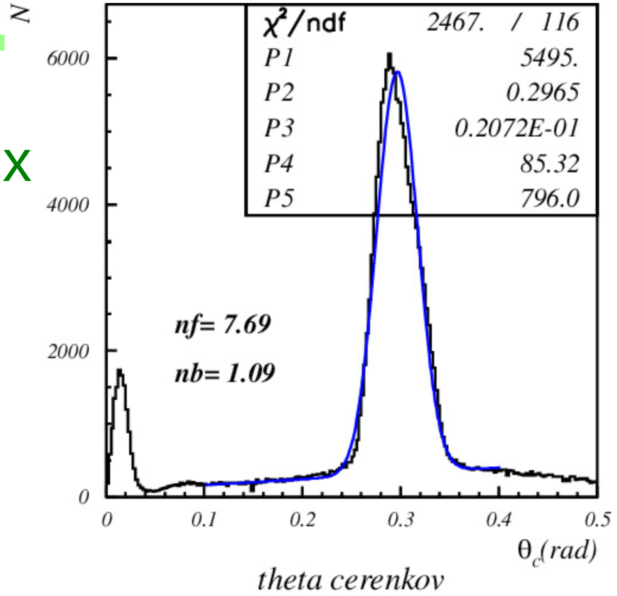
→ focusing radiator

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.

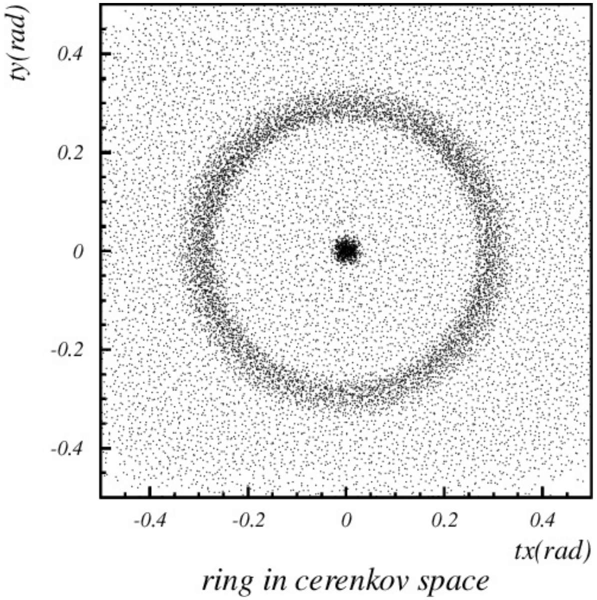
Focusing configuration – data

4cm aerogel single index



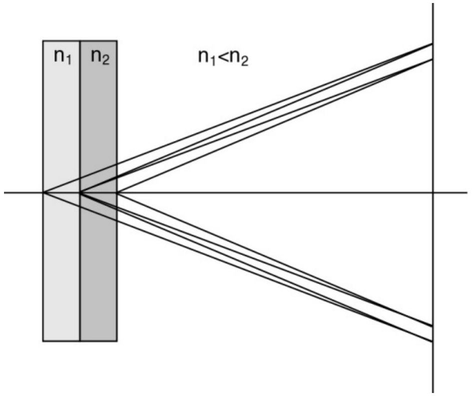


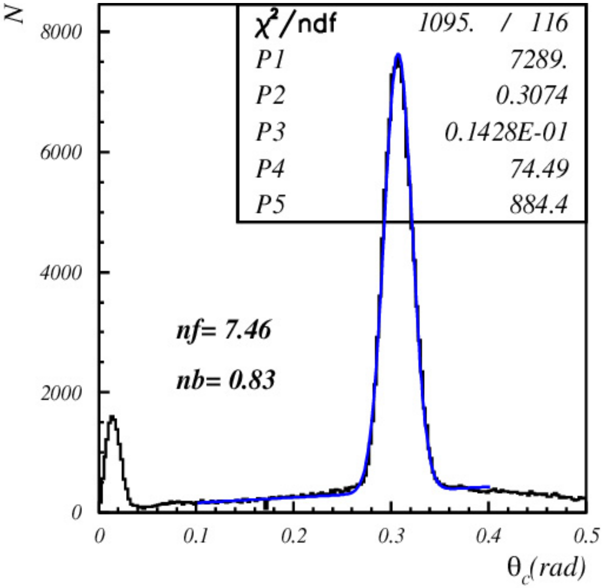
theta cerenkov

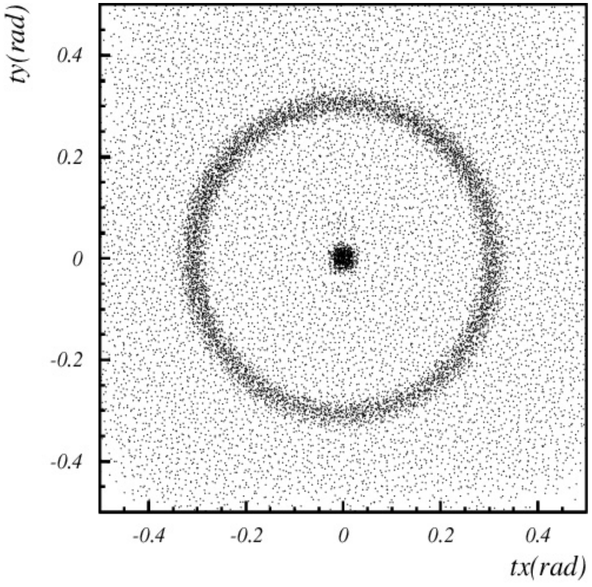


ring in cerenkov space

2+2cm aerogel





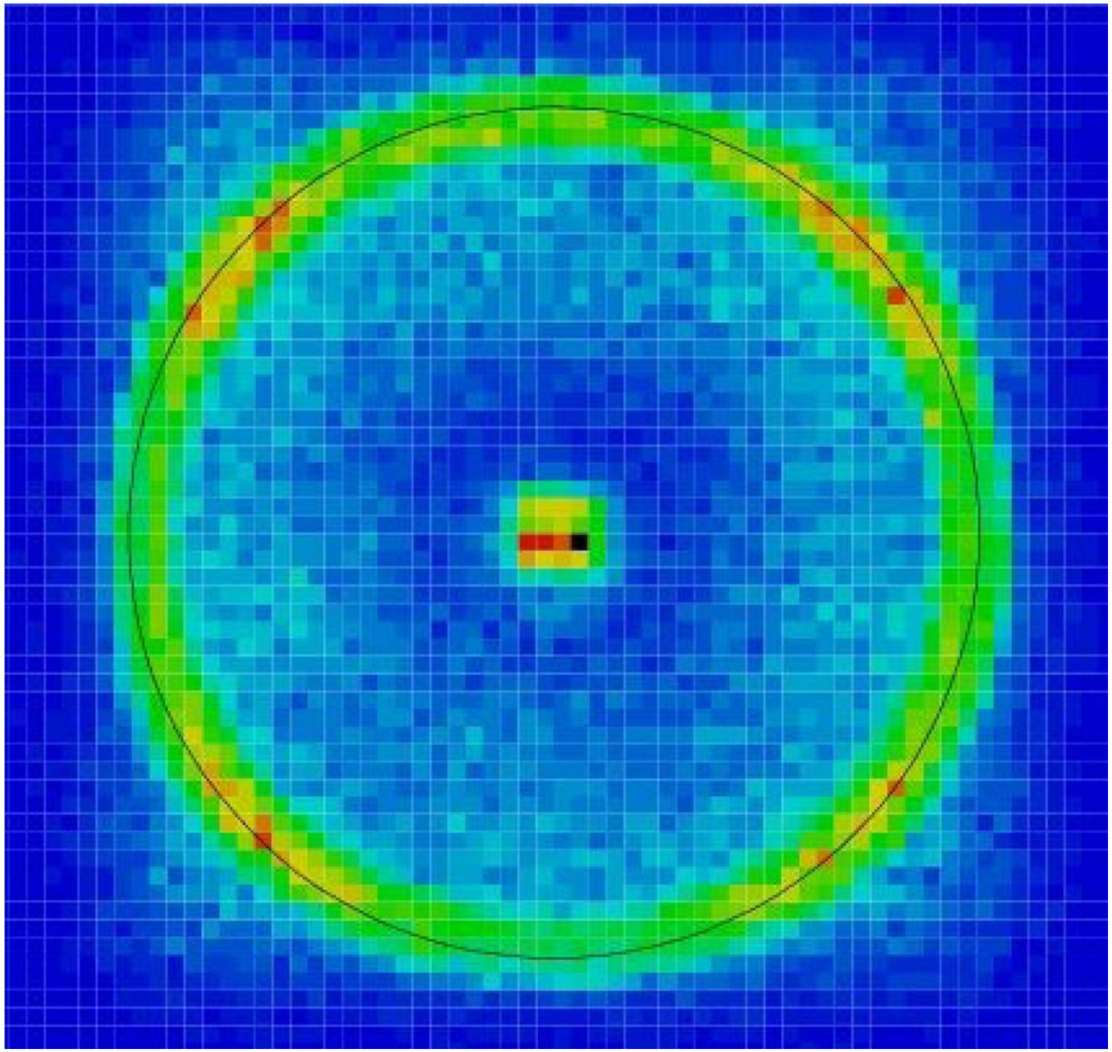


→T. Iijima, S. Korpar et al., NIM A548 (2005) 383

Another candidate: SiPM

Another sensor candidate: SiPMs (G-PAD), easy to handle, but never before used for single photon detection (high dark count rate with single photon pulse height) → use a narrow time window and light concentrators

Cherenkov ring with SiPMs



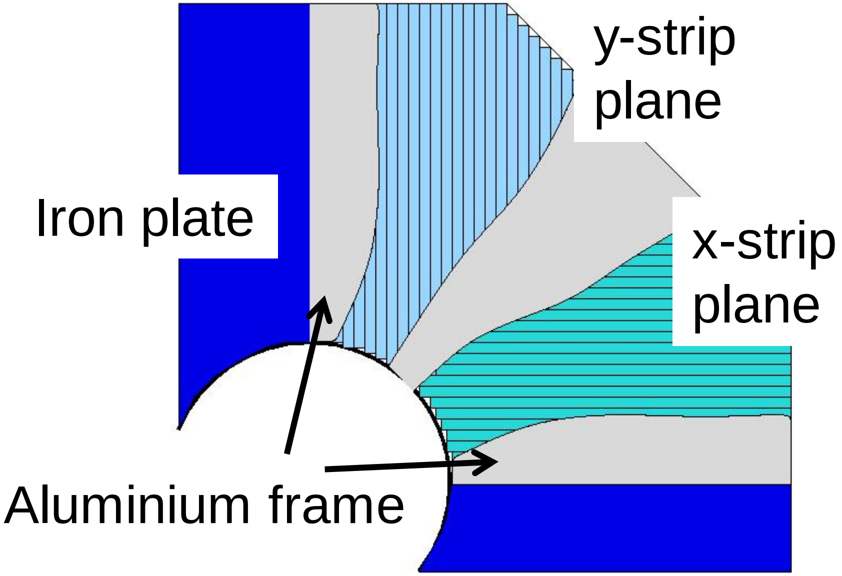
First successful use of SiPMs as single photon detectors in a RICH counter!

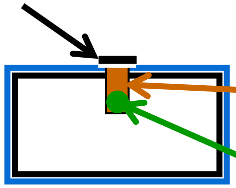
Korpar et al., NIM A594 (2008) 13

KLM upgrade in the endcaps

Scintillator-based KLM (endcap)

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

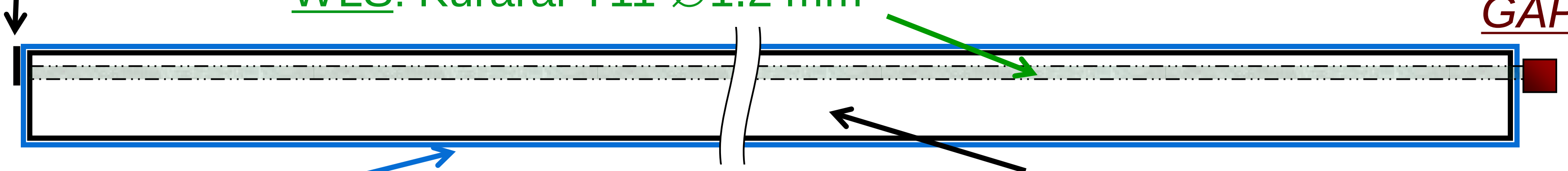




Mirror 3M (above groove & at fiber end)

Optical glue increase the light yield ~ 1.2-1.4)

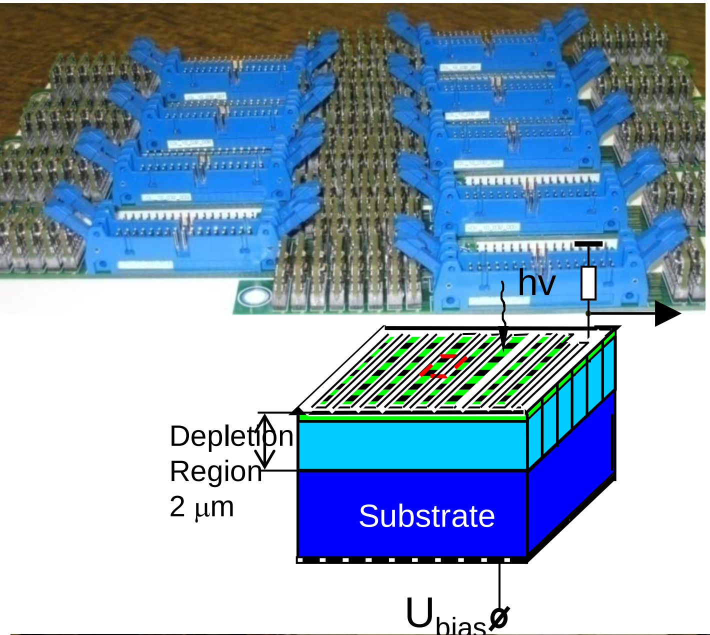
WLS: Kurarai Y11 ∅1.2 mm

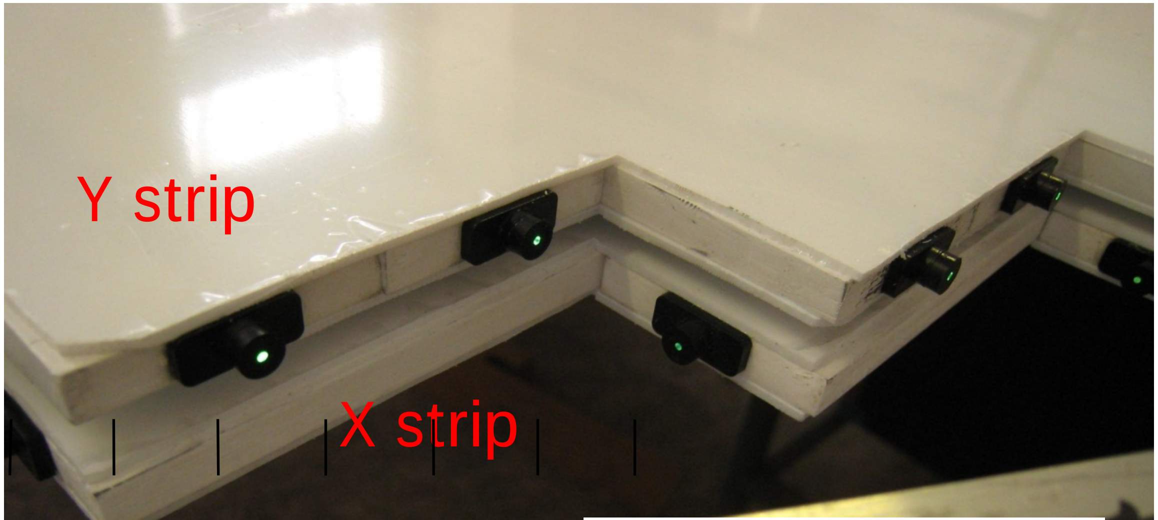


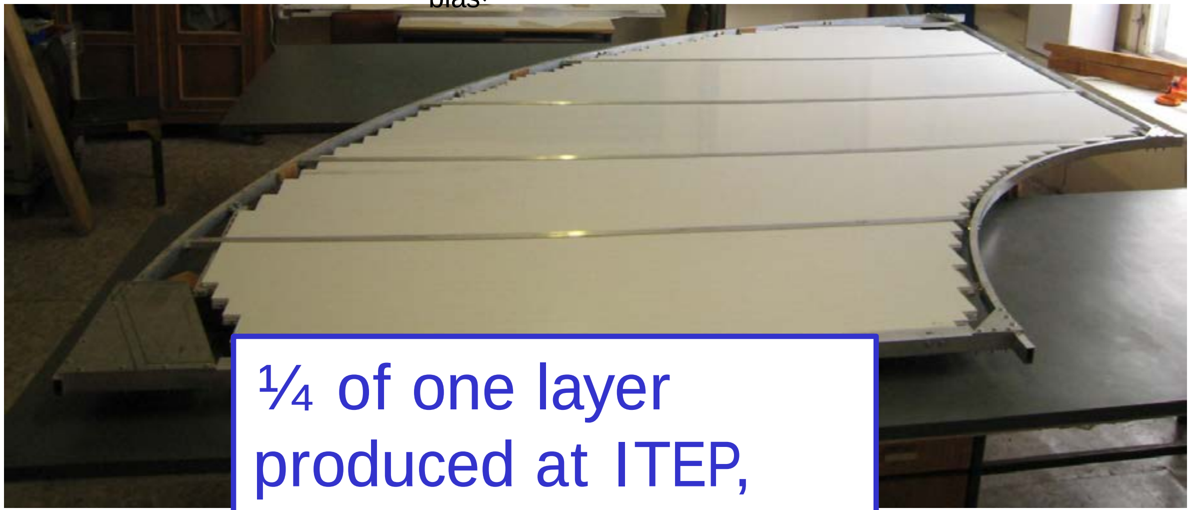
Diffusion reflector (TiO_2)

Strips: polystyrene with 1.5% PTP & 0.01% POPOP

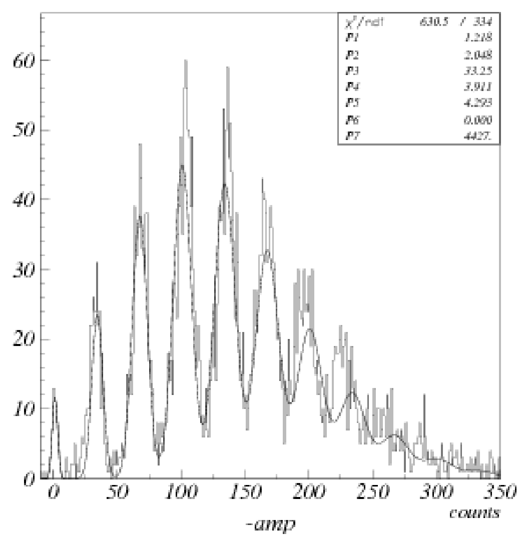
Endcap KLM upgrade







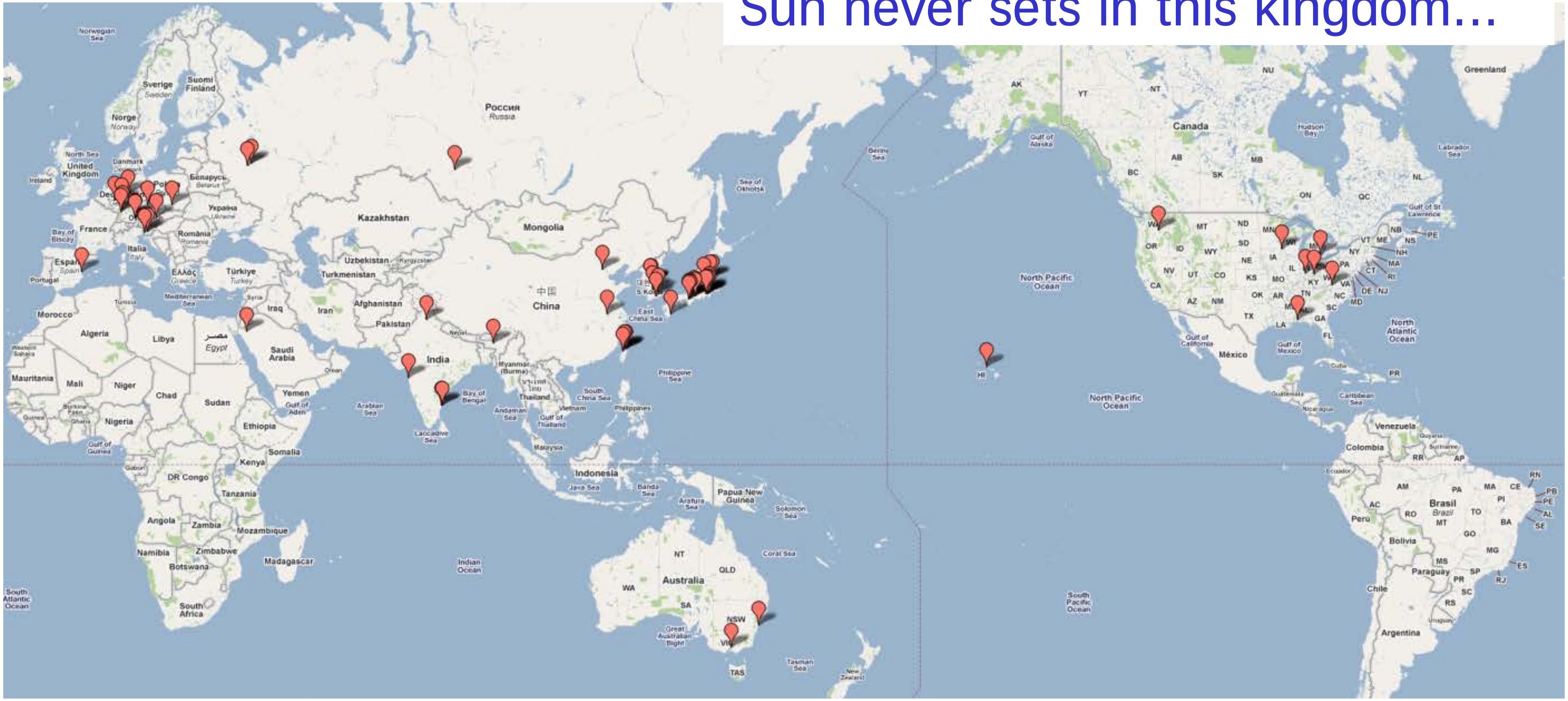
¼ of one layer produced at ITEP, tested, sent to KEK



Single p.e. resolution with TARGET WFS ASIC readout

Status of the project

Belle II Collaboration



Sun never sets in this kingdom…

15 countries/regions, ~60 institutions, ~400 collaborators

SuperKEKB/Belle II Status

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.

→construction started in 2010!

KEKB/Belle status after the earthquake

Fortunately enough:

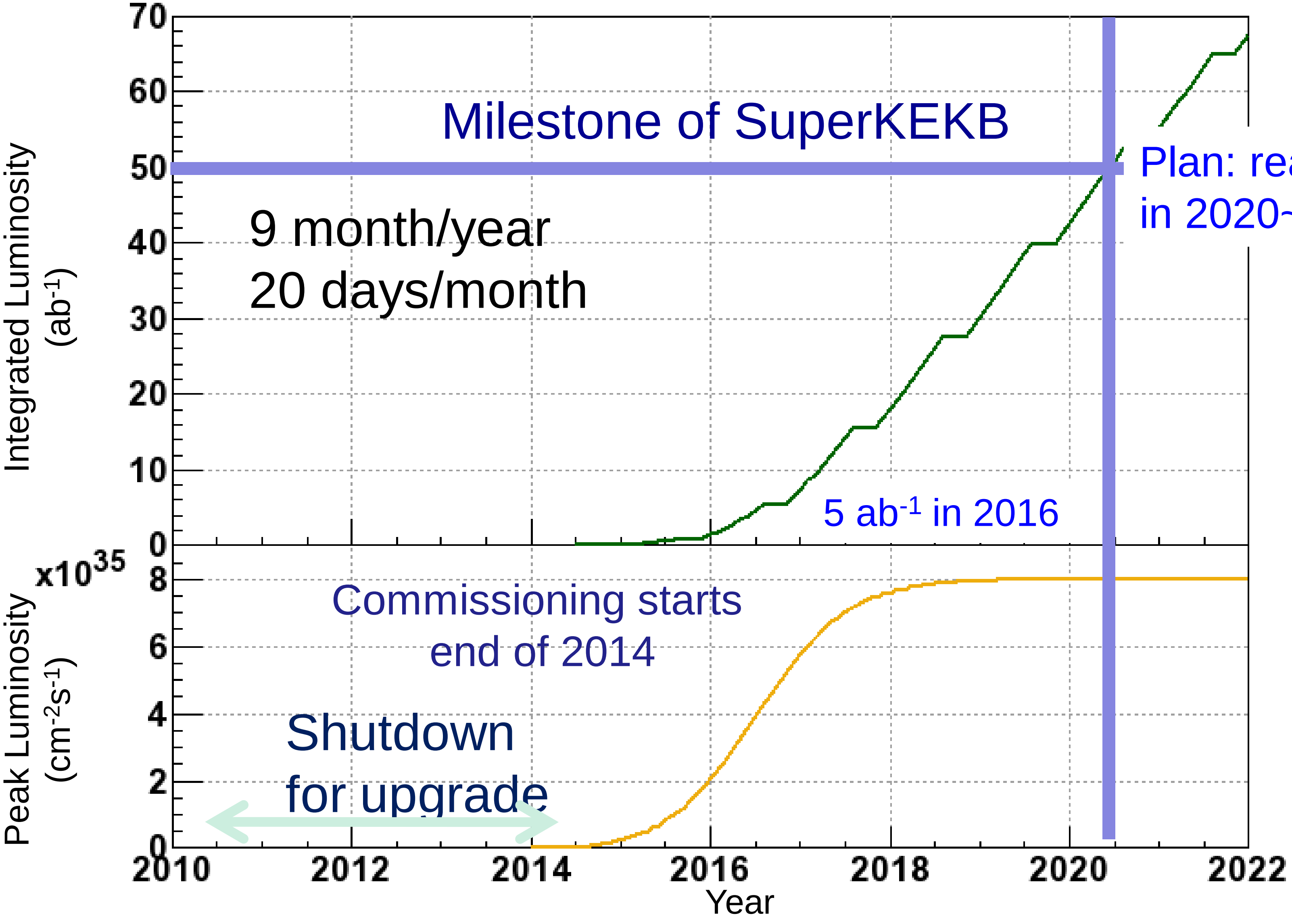
- KEKB stopped operation in July 2010, and the low energy ring was to a large extent disassembled
- Belle was rolled out to the parking position in December 2010.

The 1400 tons of Belle moved by ~6cm (most probably by 20cm in one direction, and 14cm back)…

We are checking the functionality of the Belle spectrometer (in particular the CsI calorimeter), so far all OK in LED and cosmic ray tests!

The lab has recovered from the earthquake, back to normal operation since early summer.

Luminosity upgrade projection



Milestone of SuperKEKB

Plan: reach 50 ab^{-1} in 2020~2021

9 month/year
20 days/month

5 ab^{-1} in 2016

Commissioning starts end of 2014

Shutdown for upgrade

Peter Križan, Ljubljana

Summary

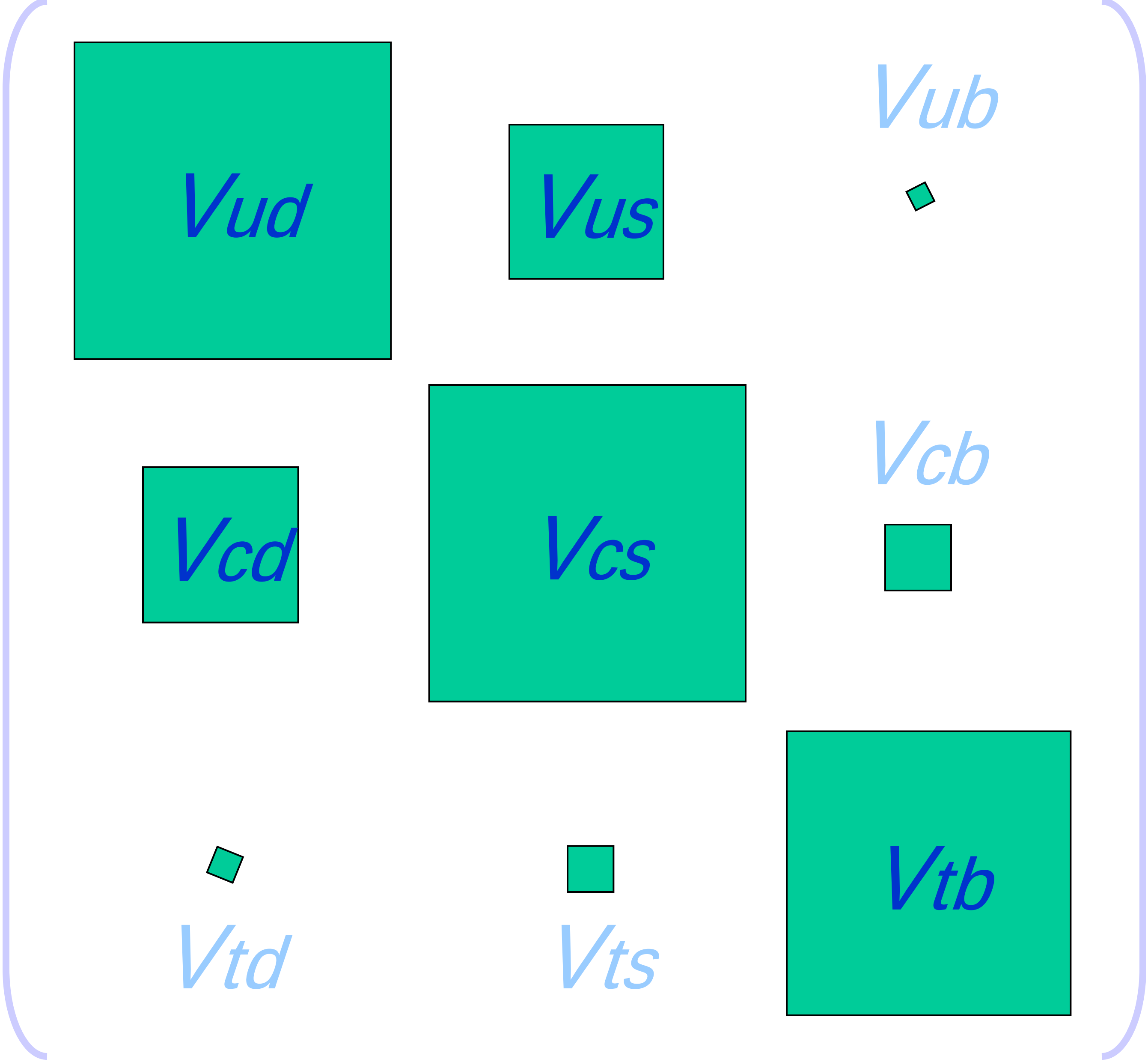
- B factories have proven to be an excellent tool for flavour physics, with reliable long term operation, constant improvement of the performance, achieving and surpasing design perfomance
- Major upgrade at KEK in 2010-15 → SuperKEKB+Belle II, L x40, construction started
- Physics reach updates available
- Expect a new, exciting era of discoveries, complementary to the LHC

- U. Nagoya has been playing an important role in this effort, and we are looking forward to a strong contribution from KMI!

Back-up slides

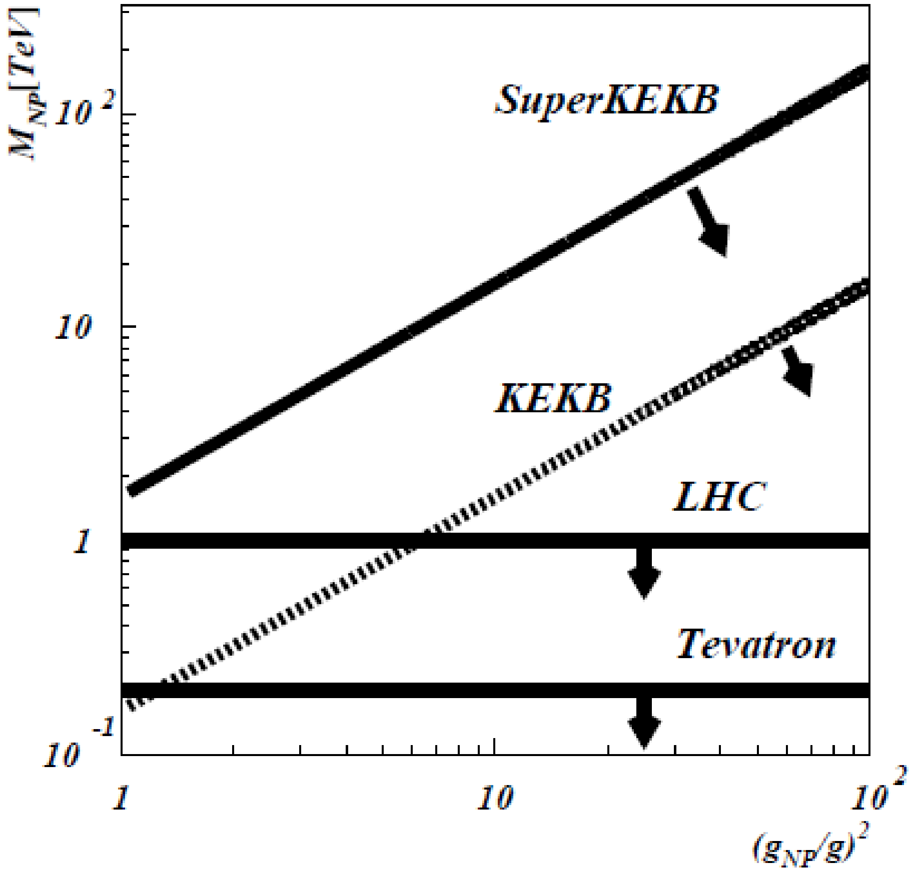
CKM: almost a diagonal matrix, but not completely

CKM: almost real, but not completely!



NP physics reach

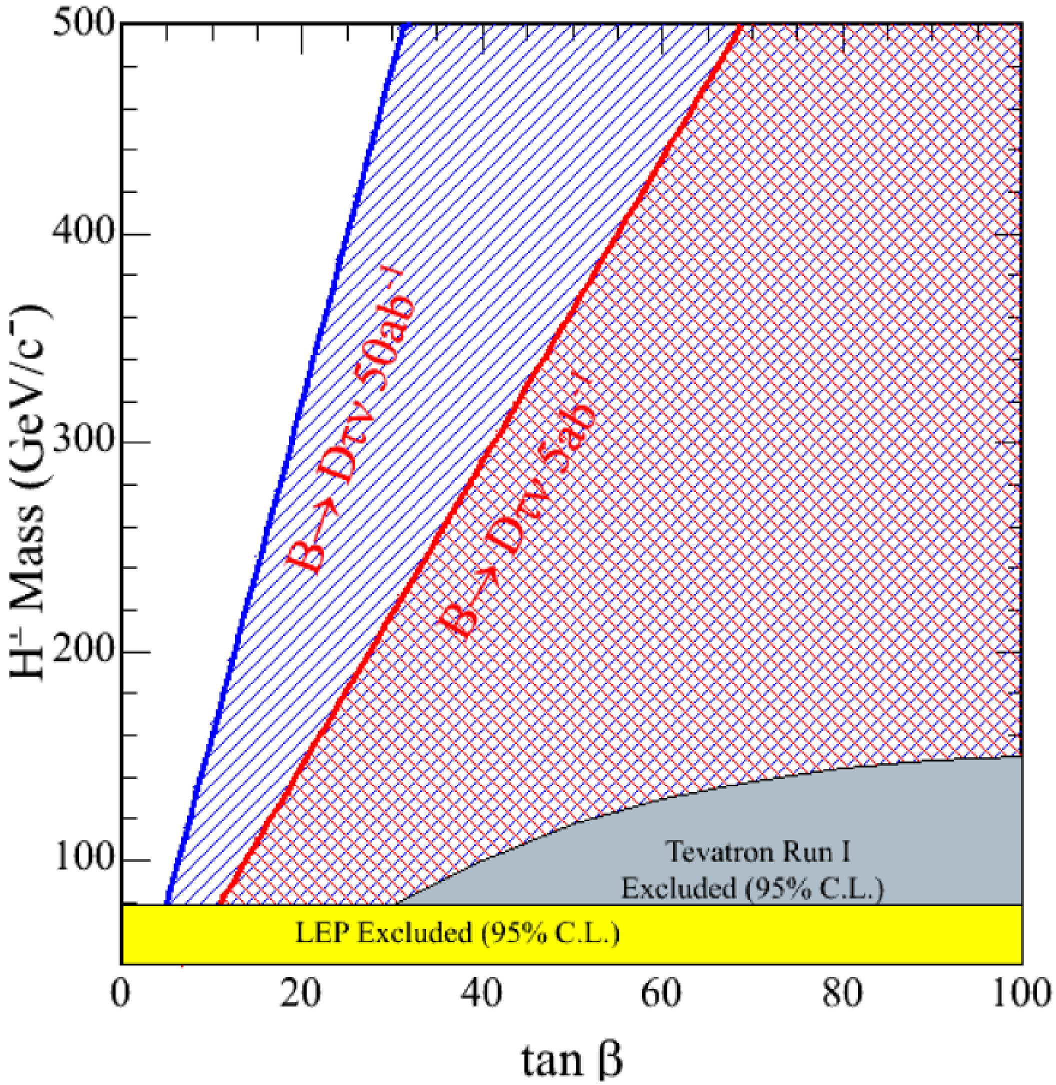
NP mass scale (TeV)



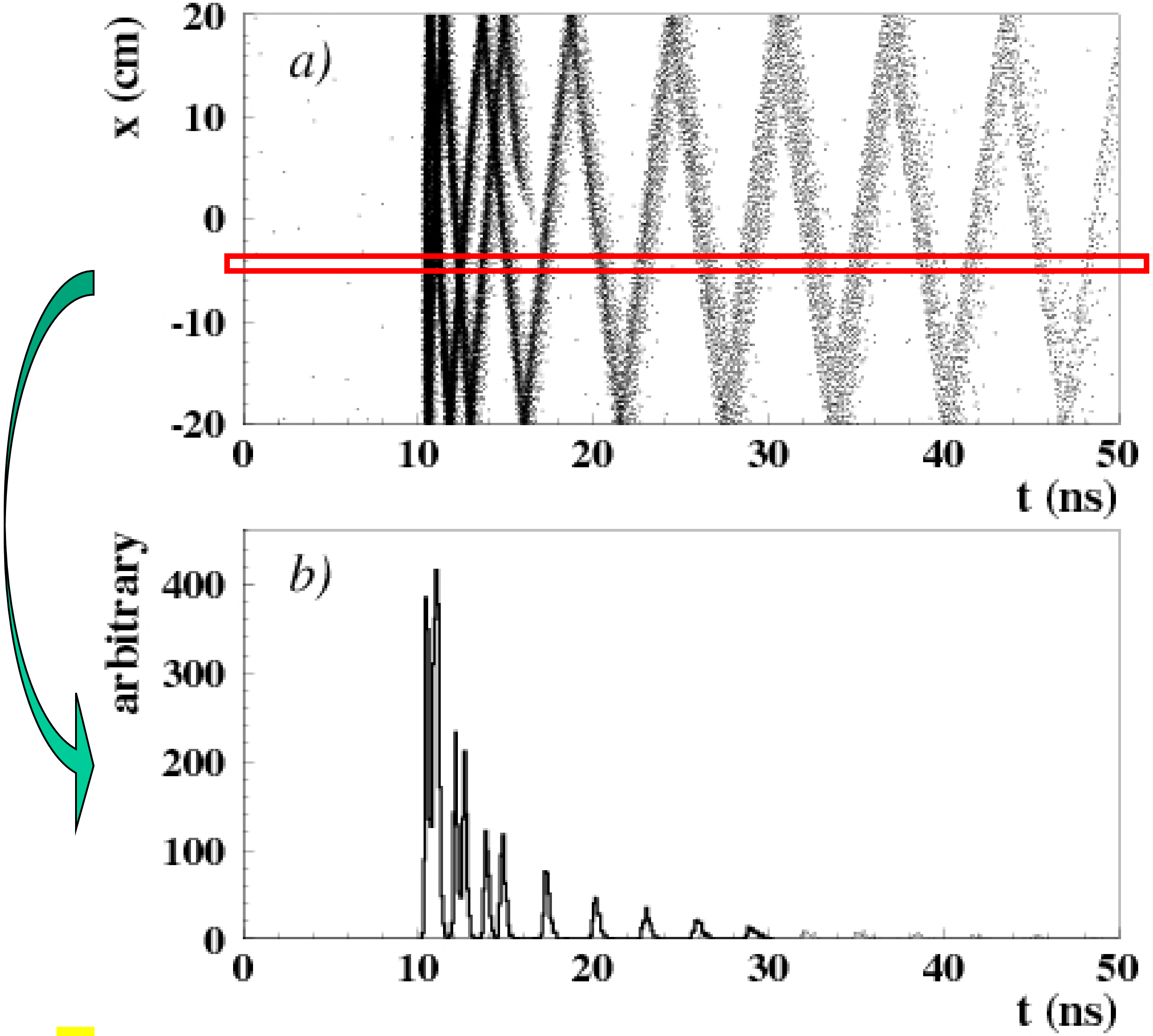
NP coupling

B→Dτν

Exclusion plots for
tanβ and H^+ mass
for 5ab^{-1} and 50ab^{-1}



TOP image



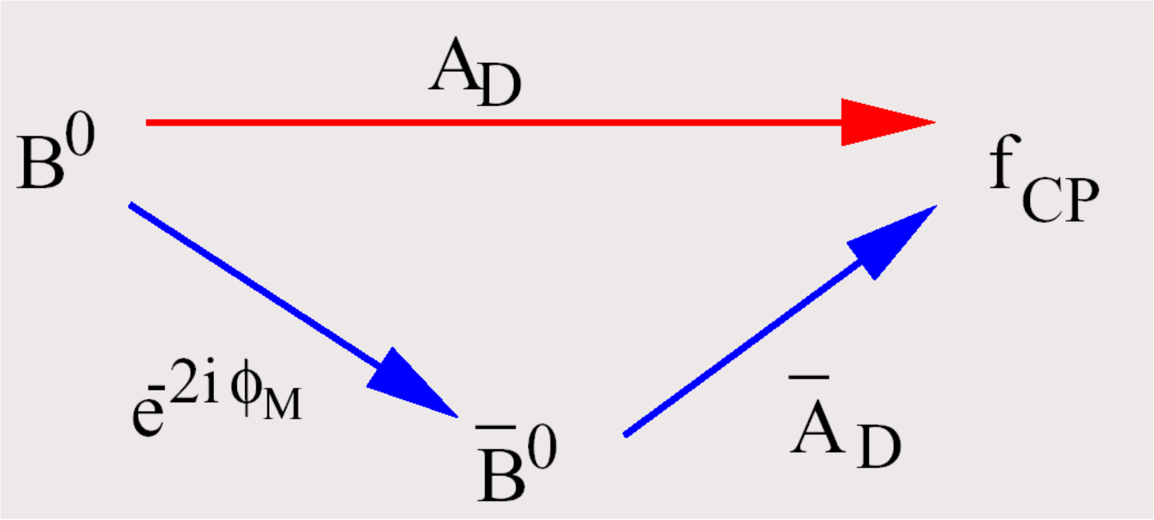
Pattern in the coordinate-time space (‘ring’) of a pion hitting a quartz bar with ~80 MAPMT channels

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

CP violation in the interference between decays with and without mixing

CP violation in the interference between mixing and decay to a state accessible in both B^0 and anti-B^0 decays

For example: a CP eigenstate f_{CP} like $\pi^+ \pi^-$ or $J/\psi\, K_S$

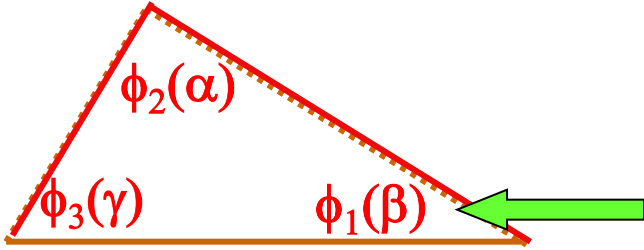


Decay rate asymmetry

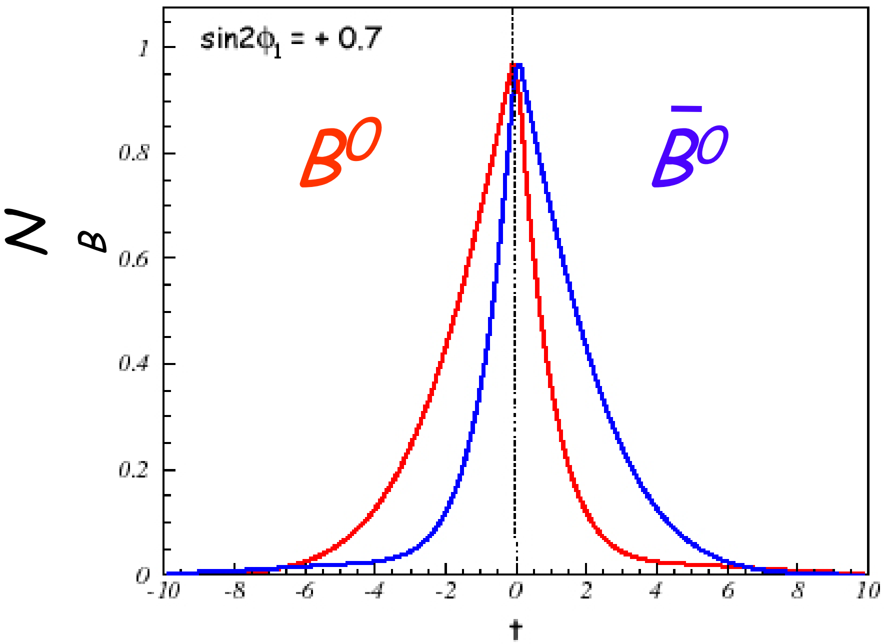
$$\boxed{a_{f_{CP}} = -\mathrm{Im}(\lambda)\sin(\Delta m t)}$$

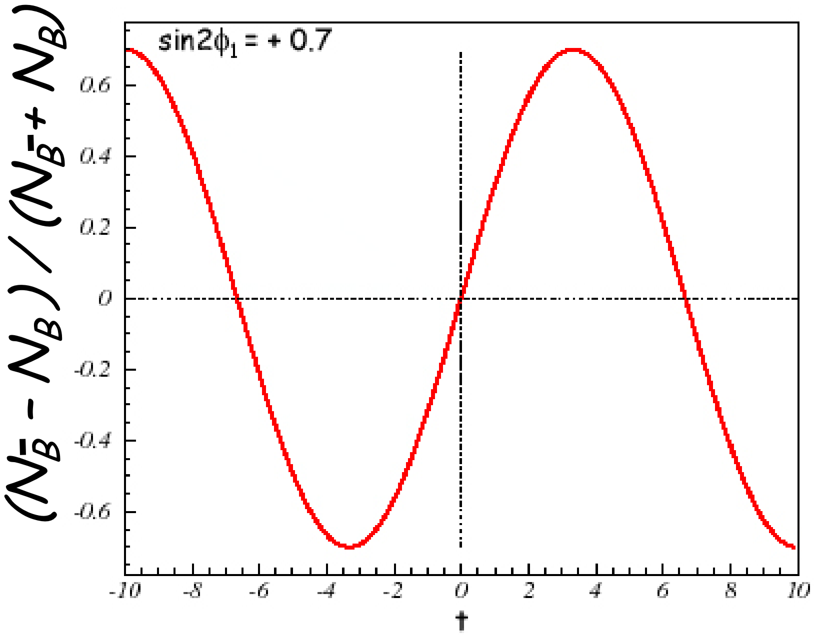
If $|\lambda| = 1$

For $J/\psi\, K_S$ $$\mathrm{Im}(\lambda) = \sin 2\phi_1$$



CP Violation in B decays to CP eigenstates f_{CP}

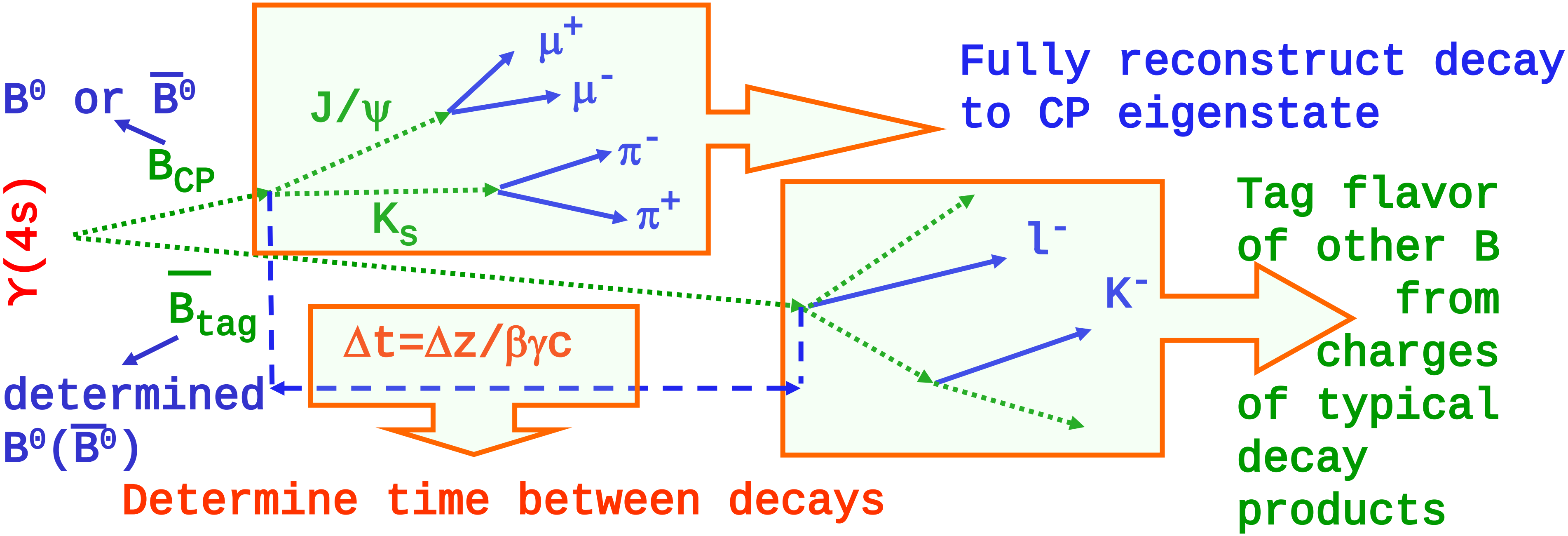




$$A_{CP}(t) = \frac{\Gamma(\overline{B}^0(t) \to f_{CP}) - \Gamma(B^0(t) \to f_{CP})}{\Gamma(\overline{B}^0(t) \to f_{CP}) + \Gamma(B^0(t) \to f_{CP})} = -\boxed{\xi_f} \sin 2\phi_1 \sin \Delta m_B t$$

$\xi_f = \pm 1$ **for** $CP = \pm 1$

Principle of measurement



Fully reconstruct decay to CP eigenstate

Tag flavor of other B from charges of typical decay products

determined $B^0(\bar{B}^0)$

$\Delta t=\Delta z/\beta\gamma c$

Determine time between decays

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

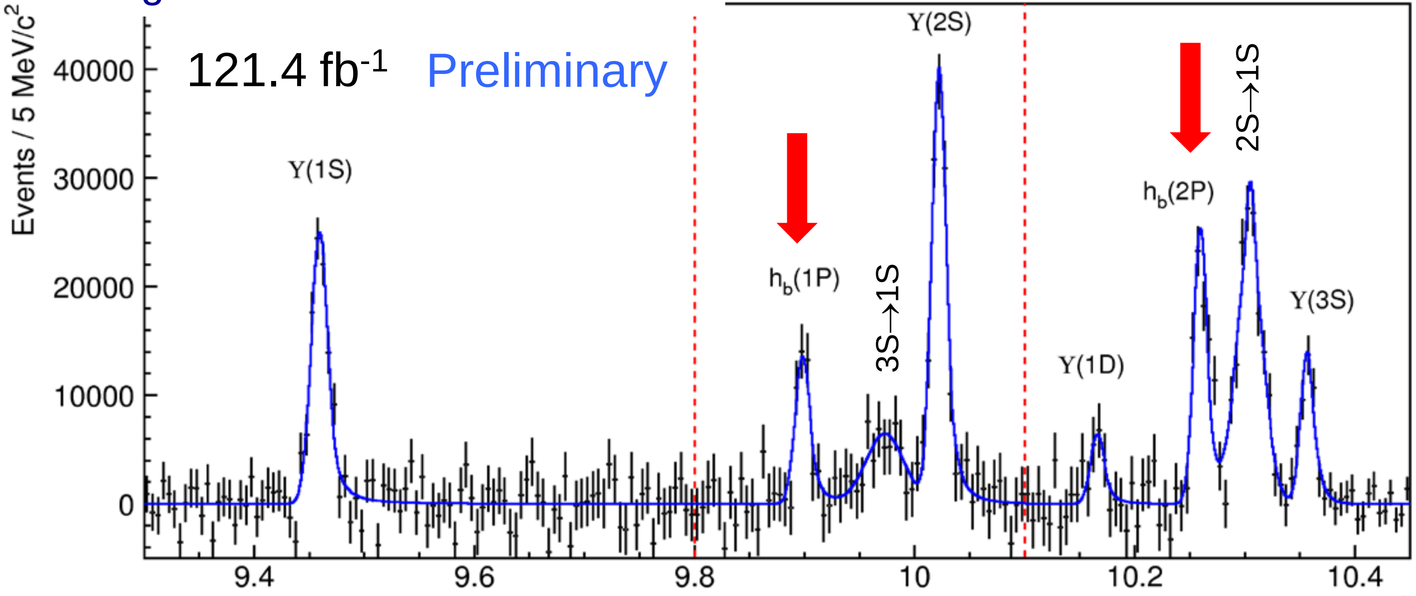
$h_b(nP)$: $(b\bar{b})$, $S=0$, $L=1$, $J^{PC}=1^{+-}$

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

Search for signal $\boxed{\Upsilon(5S)} \rightarrow h_b(nP) \boxed{\pi^+\pi^-}$ ← 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

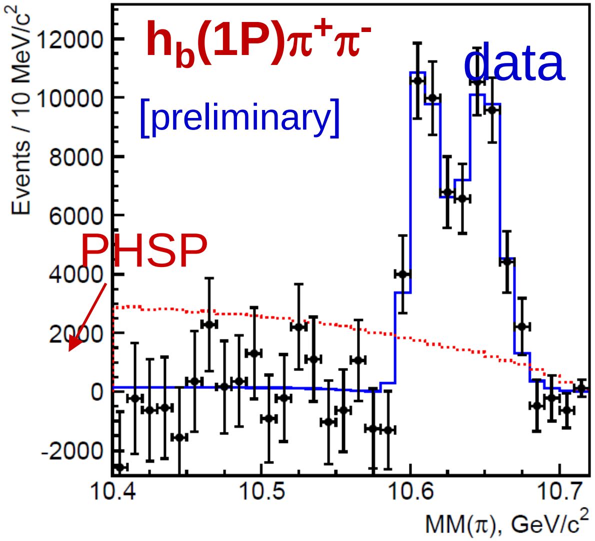
→talk by J. Wicht

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

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

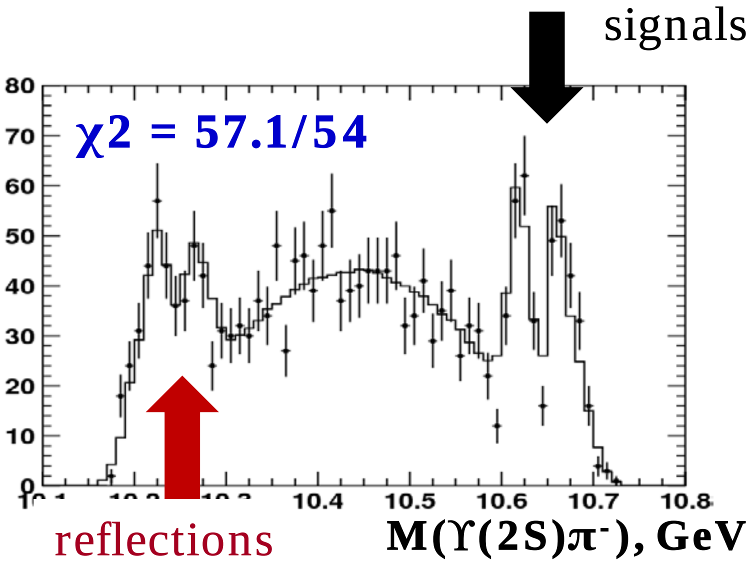
Look at $M(h_b\pi^+) = MM(\pi^-)$

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



Exclusive searches:

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



$Z_b(10610)$ $M = 10608.1 \pm 1.7$ 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

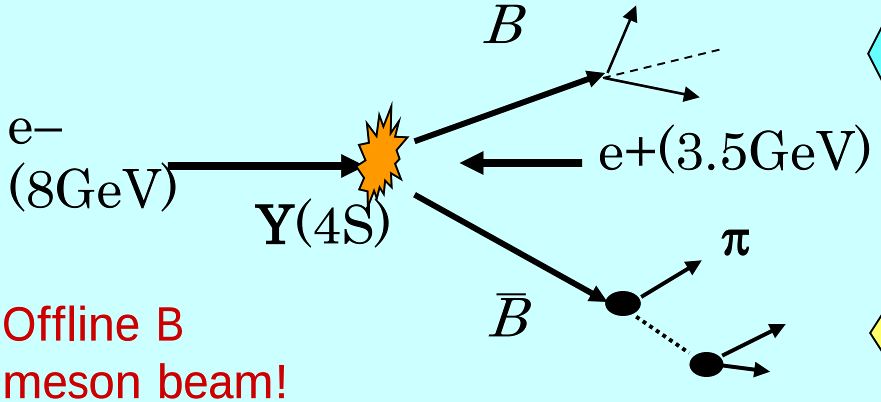
Seen in 5 different final states,
parameters are consistent

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

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

$|V_{ub}|$ 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



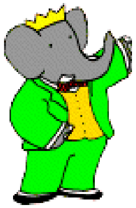
Offline B meson beam!

Decays of interest
- $B \to X_u\, l\, \nu$,
- $B \to K\, \nu\, \nu$
- $B \to D\tau\nu$, $\tau\nu$

full reconstruction
$B \to D\pi$ etc. (0.1-0.3%)

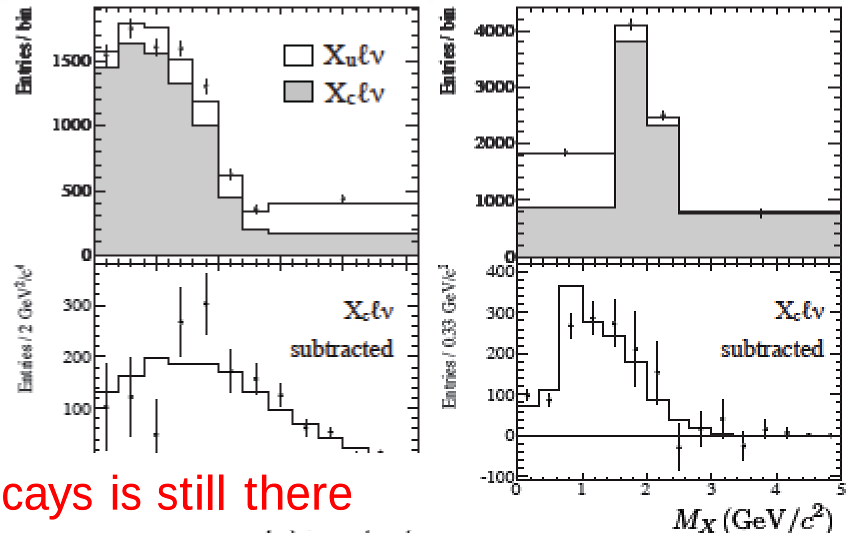
Powerful tool for B decays with neutrinos, used in several analyses in this talk
→unique feature at B factories

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



N_{sig} = *1441* ± 102

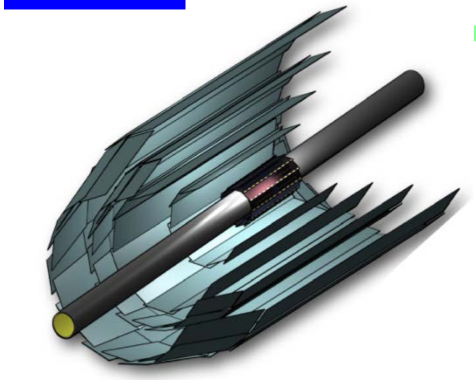
$V_{ub}=(4.31\pm0.25\pm0.16)\cdot10^{-3}$



→ Tension between inclusive and exclusive decays is still there

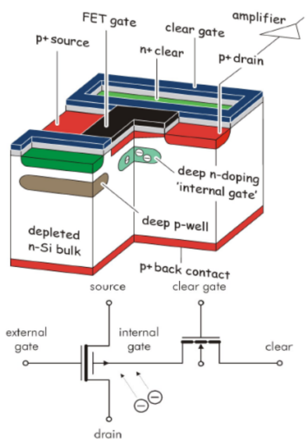
Vertex Detector

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

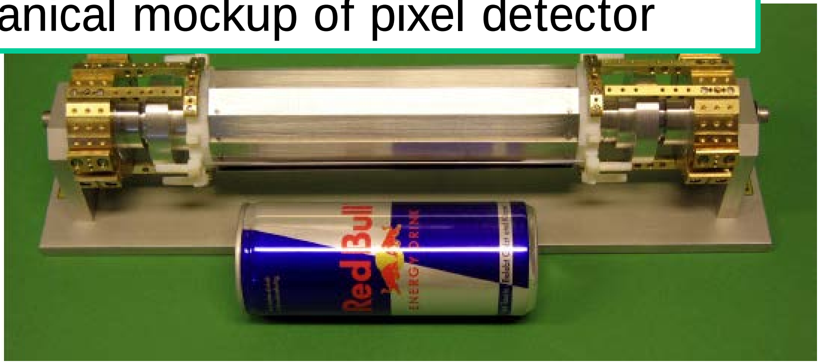


Beam Pipe		**r = 10mm**
DEPFET		
	Layer 1	**r = 14mm**
	Layer 2	**r = 22mm**
DSSD		
	Layer 3	**r = 38mm**
	Layer 4	**r = 80mm**
	Layer 5	**r = 115mm**
	Layer 6	**r = 140mm**

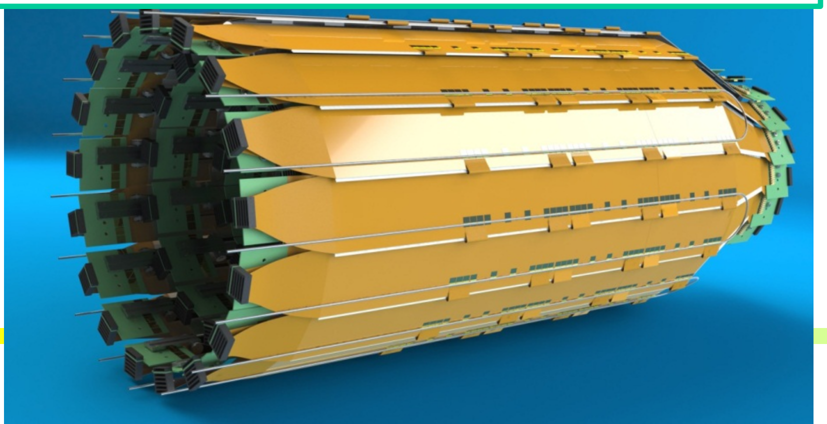
DEpleted P-channel FET

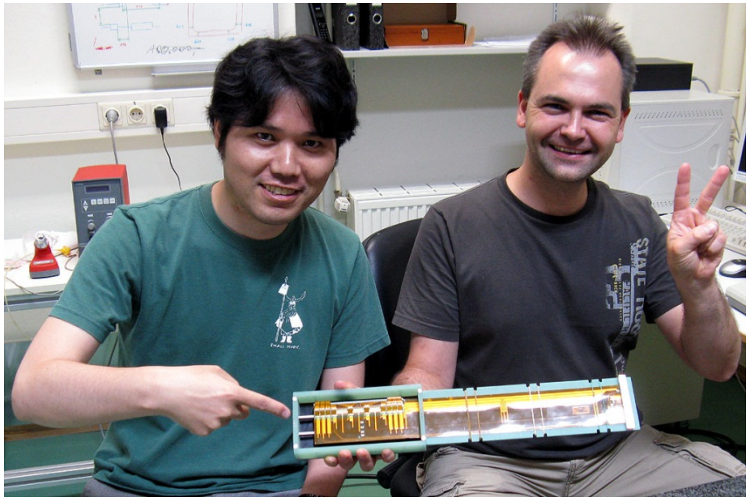


Mechanical mockup of pixel detector



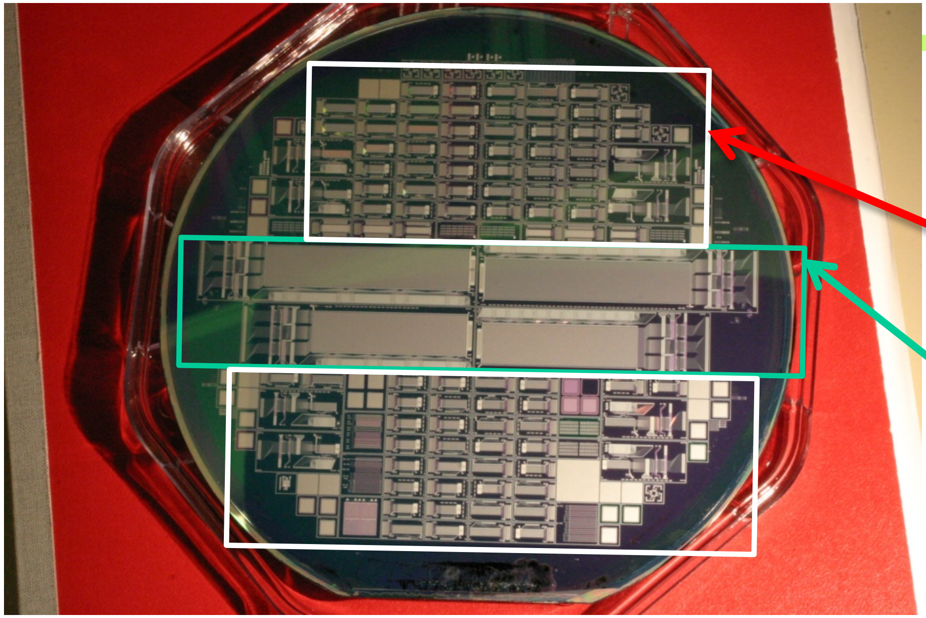
Silicon strip vertex detector





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

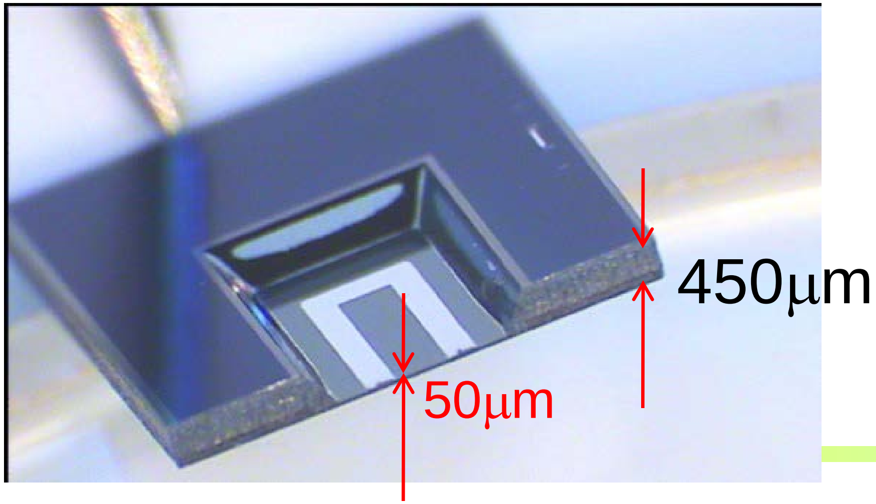
First measurements of thin DEPFETs

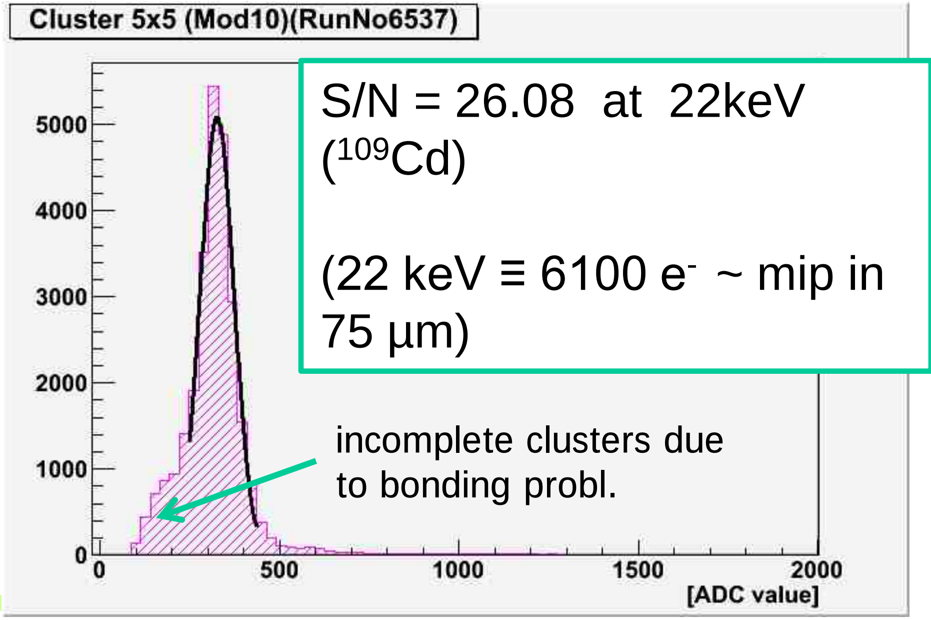


Small matrices 32x64 pixels, different technology variations, ASIC connection via wire bonding

Half ladders 768x120-160 pixels (~ Belle II geometry) ASIC connection via bump bonding

Cut through the matrix



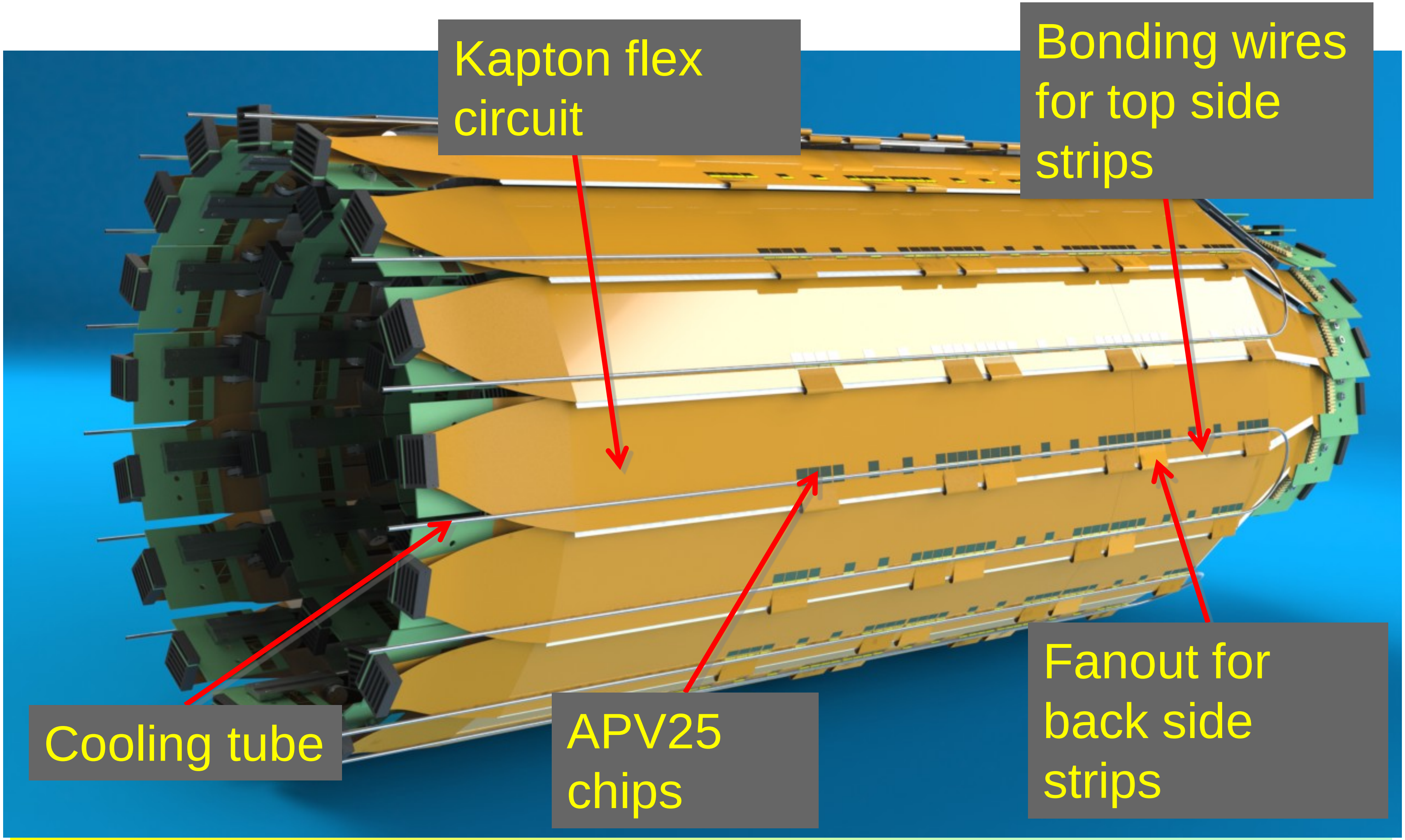


S/N = 26.08 at 22keV (^{109}Cd)

(22 keV ≡ 6100 e^- ~ mip in 75 µm)

incomplete clusters due to bonding probl.

Silicon Vertex Detector



Kapton flex circuit

Bonding wires for top side strips

Cooling tube

APV25 chips

Fanout for back side strips