B Physics Experimental Overview

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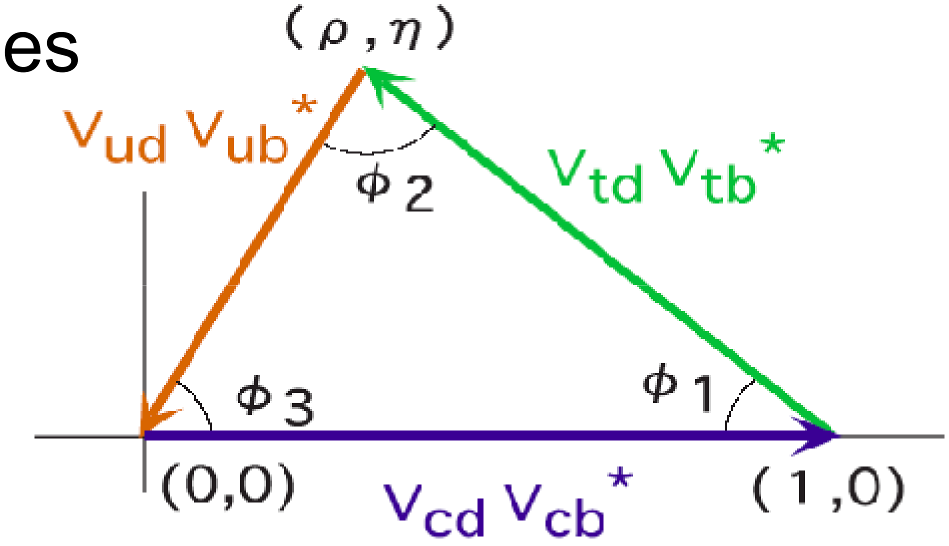
KEK

2010 LHC Days in Split

Oct 8, 2010

Contents

- Introduction of e^+e^- B factories
- CPV in $b \to s$ penguins
- $b \to s\gamma$ and $b \to s\ell\ell$
- Tauonic B decays
- Future Plan

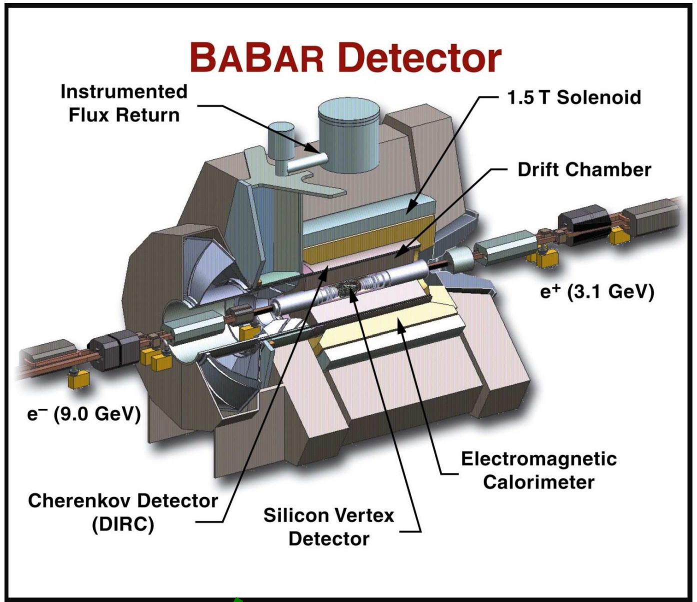


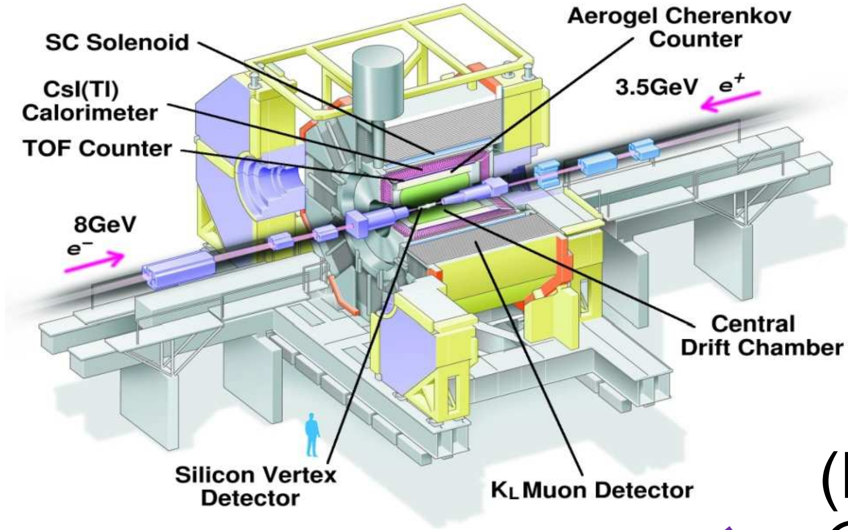
$\phi_1=\beta$, $\phi_2=\alpha$, $\phi_3=\gamma$

- My talk is focused on B physics from $\Upsilon(4S)$ at e^+e^- B factories.

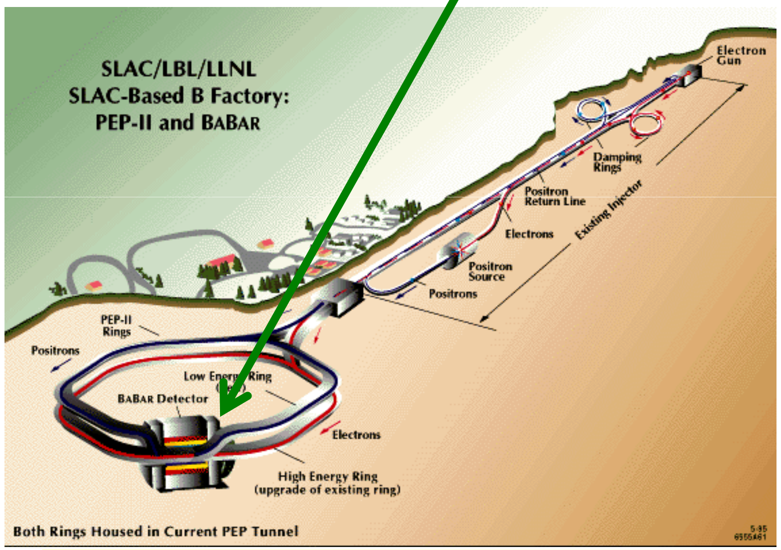
BaBar & Belle

BaBar
(PEP-II)
@ SLAC





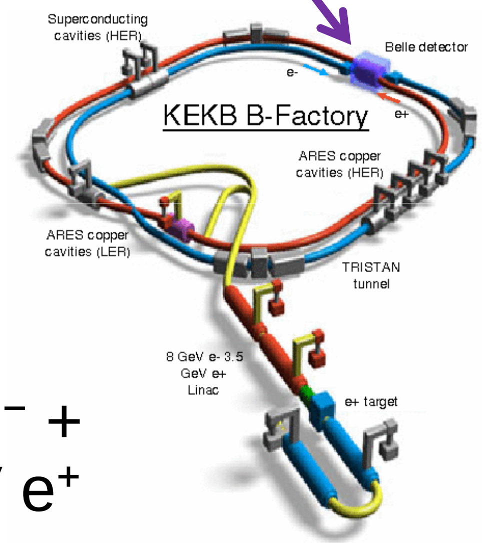
Belle
(KEKB)
@ KEK



3km Linac

9 GeV e⁻ +
3.1 GeV e⁺

3km ring

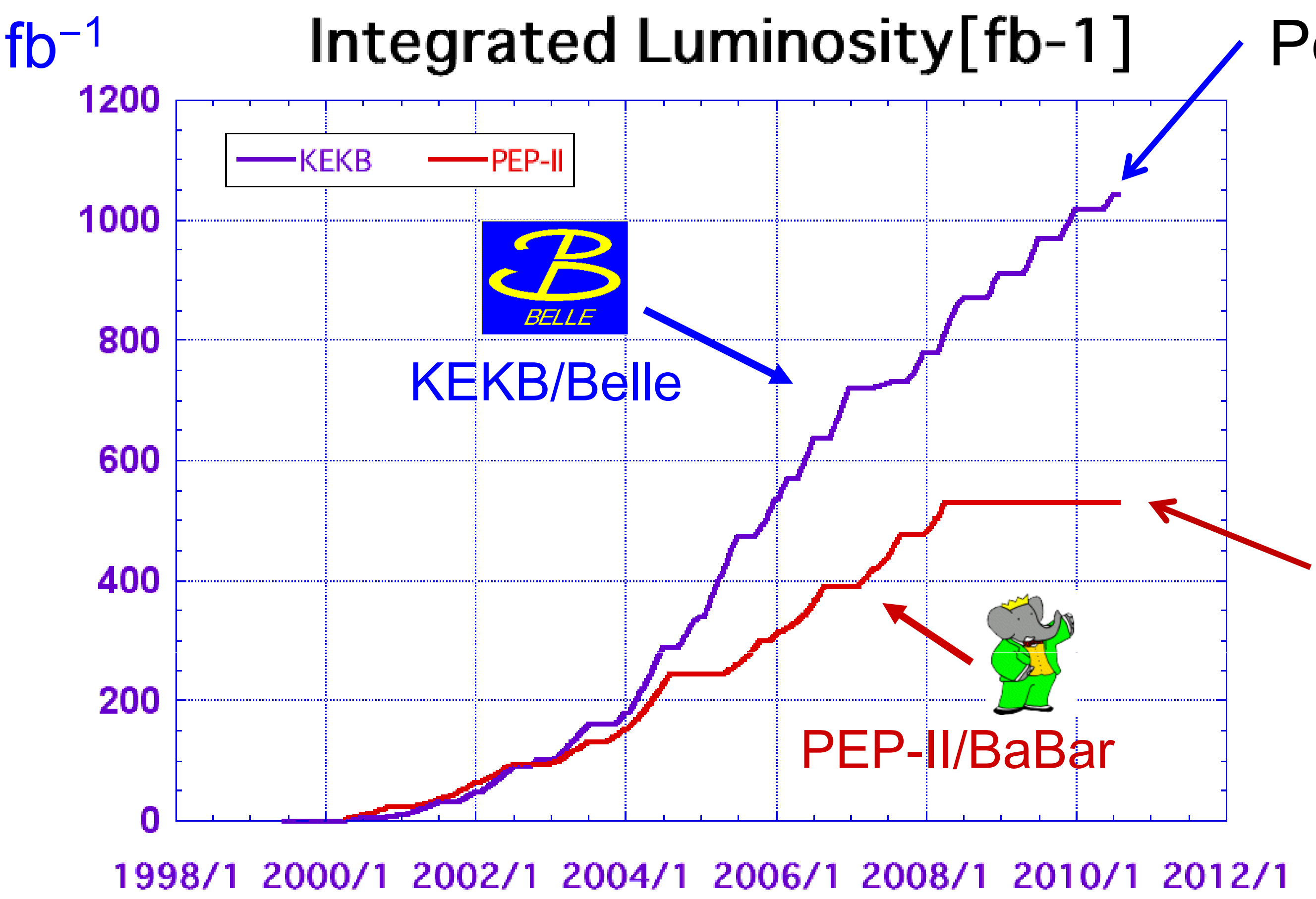


8 GeV e⁻ +
3.5 GeV e⁺

Luminosity

$e^+e^- \rightarrow \Upsilon(4S) \rightarrow B\bar{B}$ (1.1nb)

$1\ fb^{-1} \sim 10^6\ B\bar{B}$ @ $\Upsilon(4S)$



Total ~1020 fb^{-1}

Peak $2.11 \times 10^{34}\ cm^{-2}\ s^{-1}$

On resonance:

- $\Upsilon(5S)$: 121 fb^{-1} ← B_s
- $\Upsilon(4S)$: 711 fb^{-1}
- $\Upsilon(3S)$: 3 fb^{-1}
- $\Upsilon(2S)$: 24 fb^{-1}
- $\Upsilon(1S)$: 6 fb^{-1}

Off resonance, scan:

~ 100 fb^{-1}

Total 550 fb^{-1}

Peak $1.21 \times 10^{34}\ cm^{-2}\ s^{-1}$

On resonance:

- $\Upsilon(4S)$: 433 fb^{-1}
- $\Upsilon(3S)$: 30 fb^{-1}
- $\Upsilon(2S)$: 14 fb^{-1}

Off resonance:

~ 54 fb^{-1}

End of KEKB Operation

The operation of KEKB & Belle has ended on June 30, 2010.
⇒ Start of the upgrade to SuperKEKB & Belle II

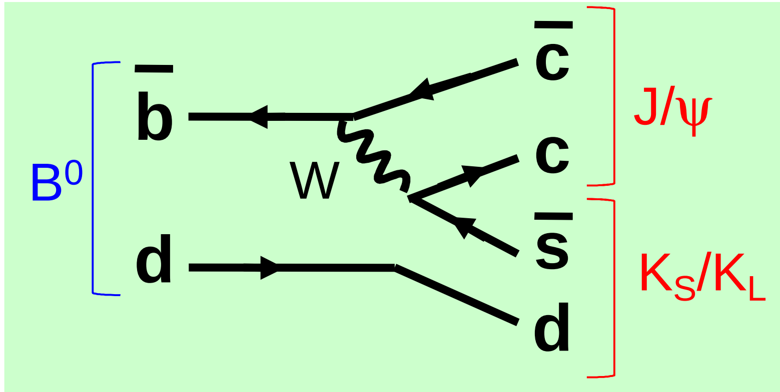
KEKB Control Room

Belle Control Room

BaBar (PEP II) ended the operation in 2008.

Measurement of $\sin 2\phi_1$

Golden mode: $\sin 2\phi_1$ with $B^0 \to J/\psi K^0$



$A_{CP}(\Delta t)$

$$= \frac{\Gamma(\overline{B}^0(\Delta t) \to f_{CP}) - \Gamma(B^0(\Delta t) \to f_{CP})}{\Gamma(\overline{B}^0(\Delta t) \to f_{CP}) + \Gamma(B^0(\Delta t) \to f_{CP})}$$

$$= S \sin(\Delta m \Delta t) + A \cos(\Delta m \Delta t)$$

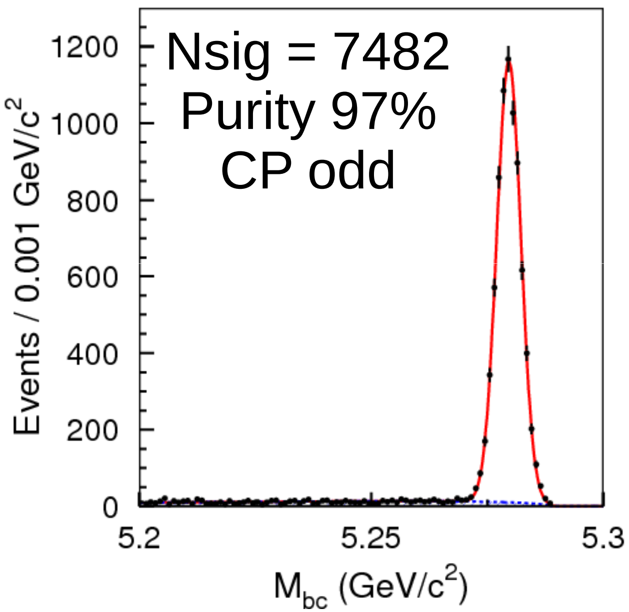
$S = -\xi \sin(2\phi_1)$

$A = 0$

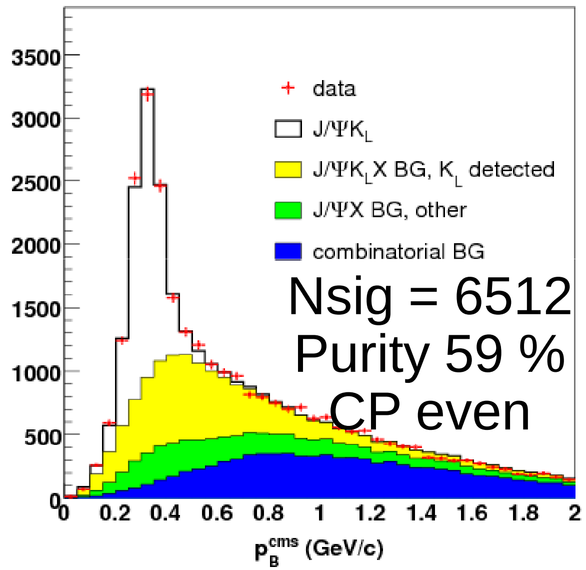
Signal Reconstruction:

535M $B\overline{B}$

$B^0 \to J/\psi K_S$



$B^0 \to J/\psi K_L$

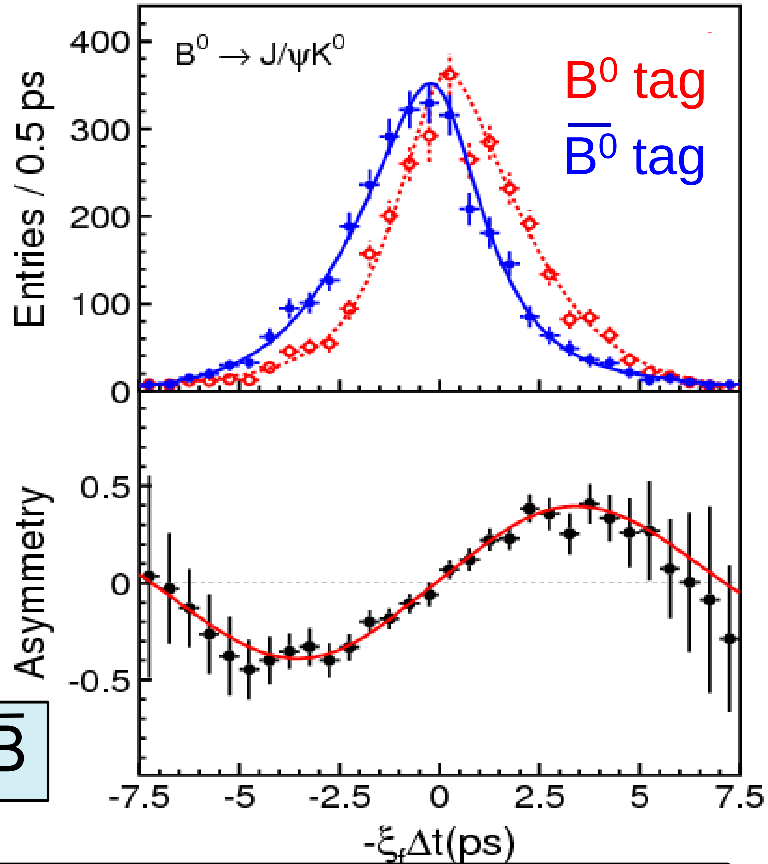


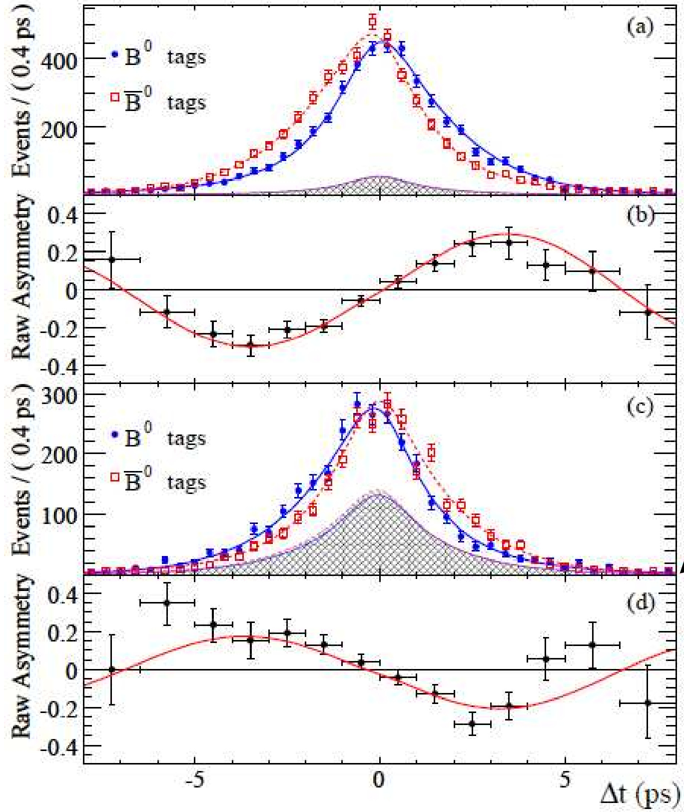
Measurement of $\sin 2\phi_1$

Sum of $J/\psi K_S$ and $J/\psi K_L$

[PRD98, 031802 (2007)]

535M $B\bar{B}$





$J/\Psi K_S$
$\Psi(2S) K_S$
$\chi_{c1} K_S$
$\eta_c K_S$

$J/\psi K_L$ [PRD79, 072009 (2009)]

465M $B\bar{B}$

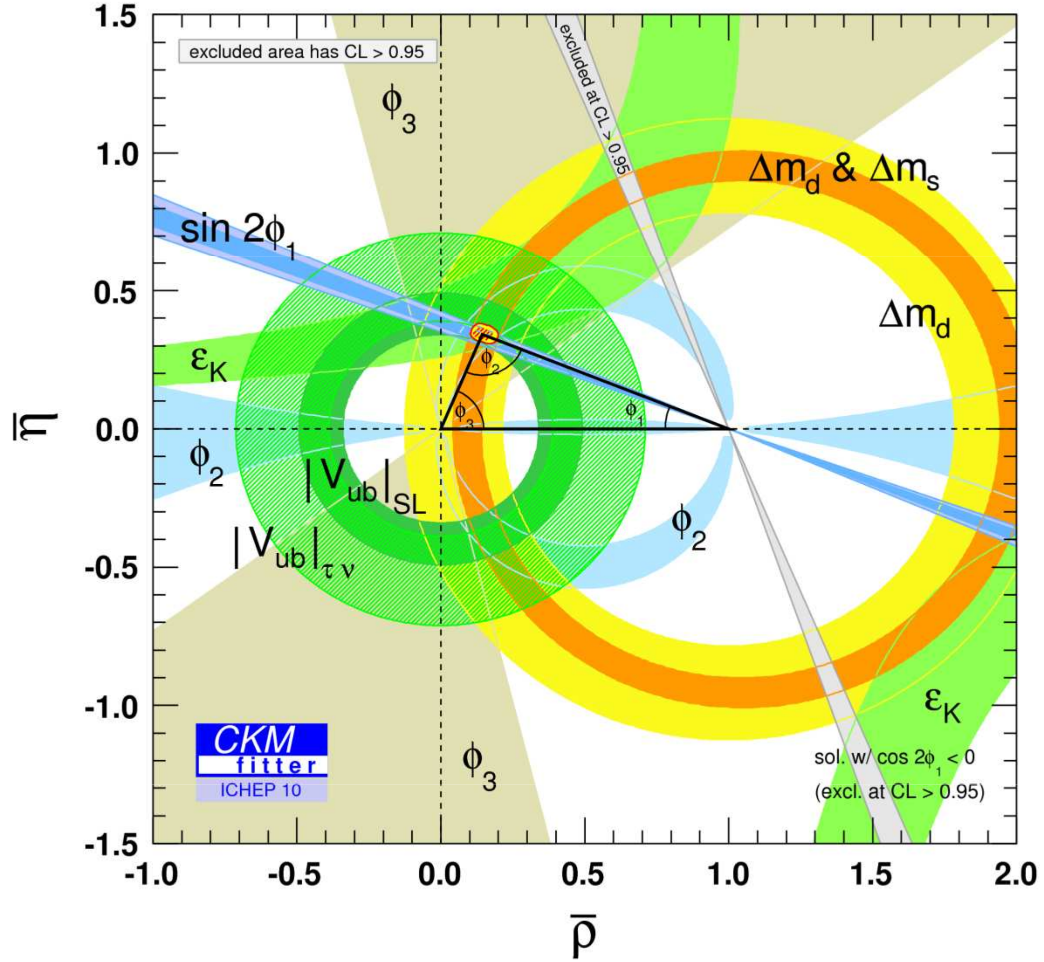
$\sin 2\phi_1 = 0.642 \pm 0.031 \pm 0.017$

$\sin 2\phi_1 = 0.687 \pm 0.028 \pm 0.012$

- Belle will soon provide a new result with the final sample (772M $B\bar{B}$).
  - ✓ Reprocessed data (high eff.) + inclusion of all ψ resonances.
  - ✓ Effectively ~ twice statistics. Expected $\sin 2\phi_1$ stat. error ~ 0.024.

Unitarity Triangle

Present constraints on UT.



Belle and BaBar confirmed

- CP Violation in the B meson system
- CKM mechanism as a source of the CP Violation.

2008 Nobel Prize in Physics

Makoto Kobayashi

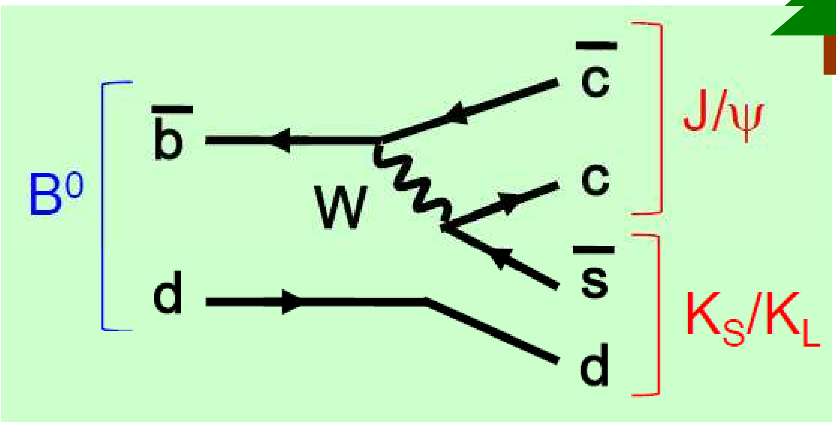
Toshihide Maskawa

Next target of B factories is the search and study of New Physics

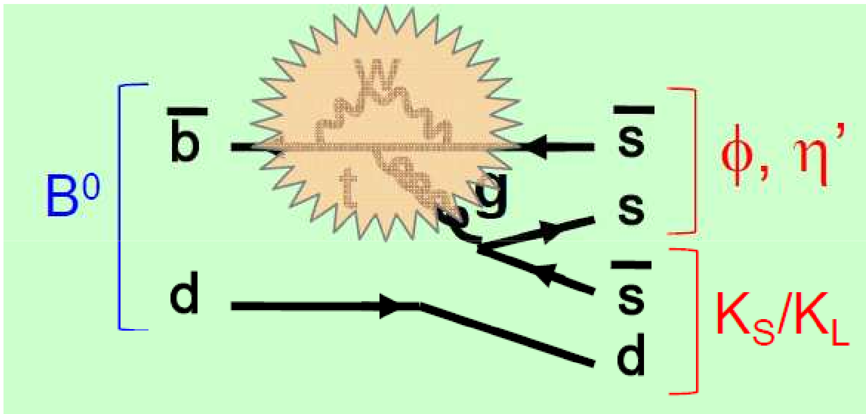
CP Violation in $b \to s$

CP Violation in b→s

$b \to c$ ($B \to J/\psi K^0$)



$b \to s$ ($B \to \phi K^0, \eta' K^0$)

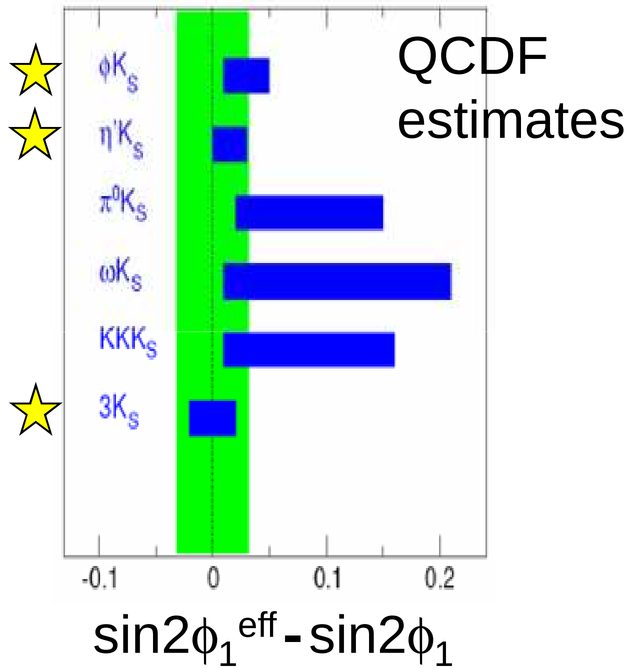


In the SM,

$S = -\xi \sin(2\phi_1)$

for $b \to s$ processes, but possible discrepancy due to non-SM contribution.

- The theoretical uncertainty (within SM) depends on the final states.
- $B \to K^0K^0K^0$, ϕK^0, $\eta' K^0$ are the cleanest modes (δS_{theory} ~a few %).

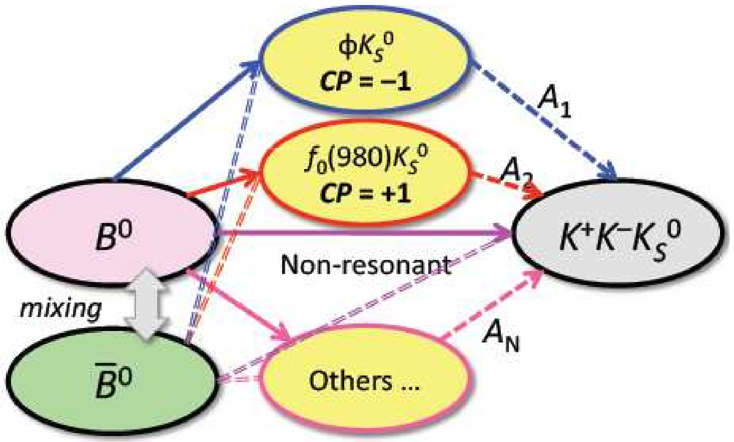


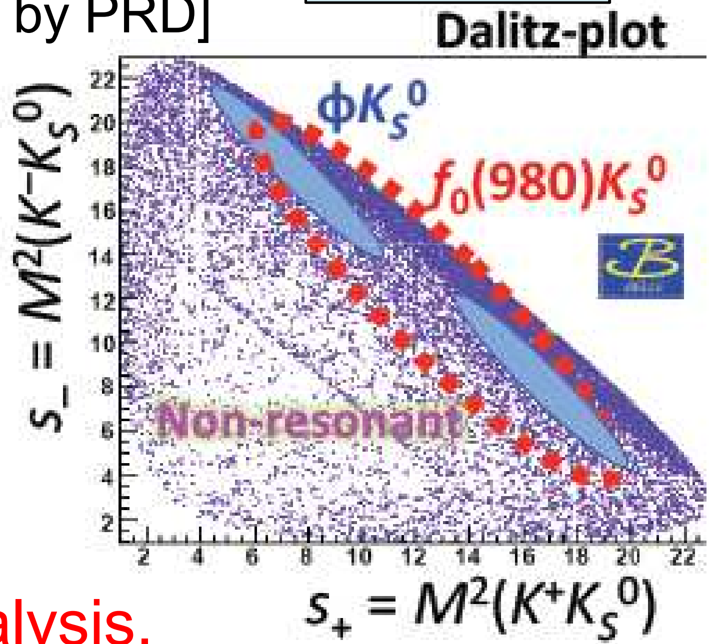
$B \to K^+K^-K_S$

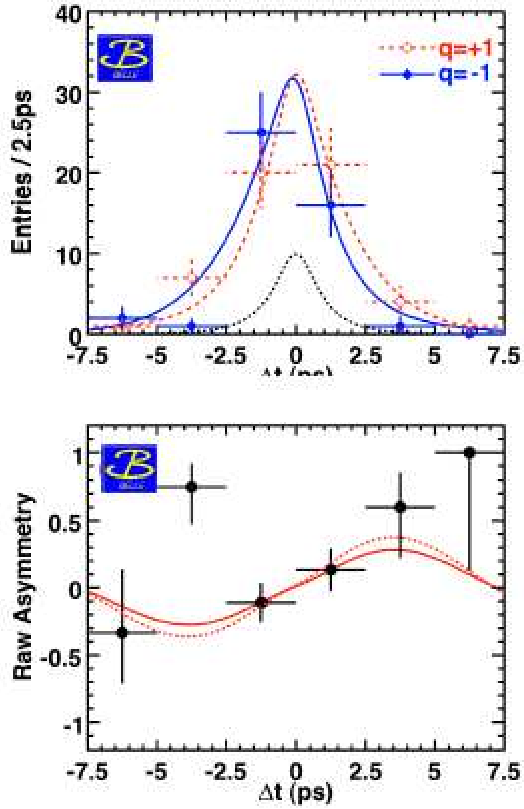
New Belle result on $B \to K^+K^-K_S$

[arXiv:1007.3848, accepted by PRD]

657M $B\bar{B}$







φ mass region

- Time dependent Dalitz analysis.
- Measure ϕ_1^{eff} associated with individual intermediate state.
- Multiple solutions; preferred one chosen with external information.

ϕK_S: $\phi_1^{eff} = (32.2 \pm 9.0 \pm 2.6 \pm 1.4)^\circ$

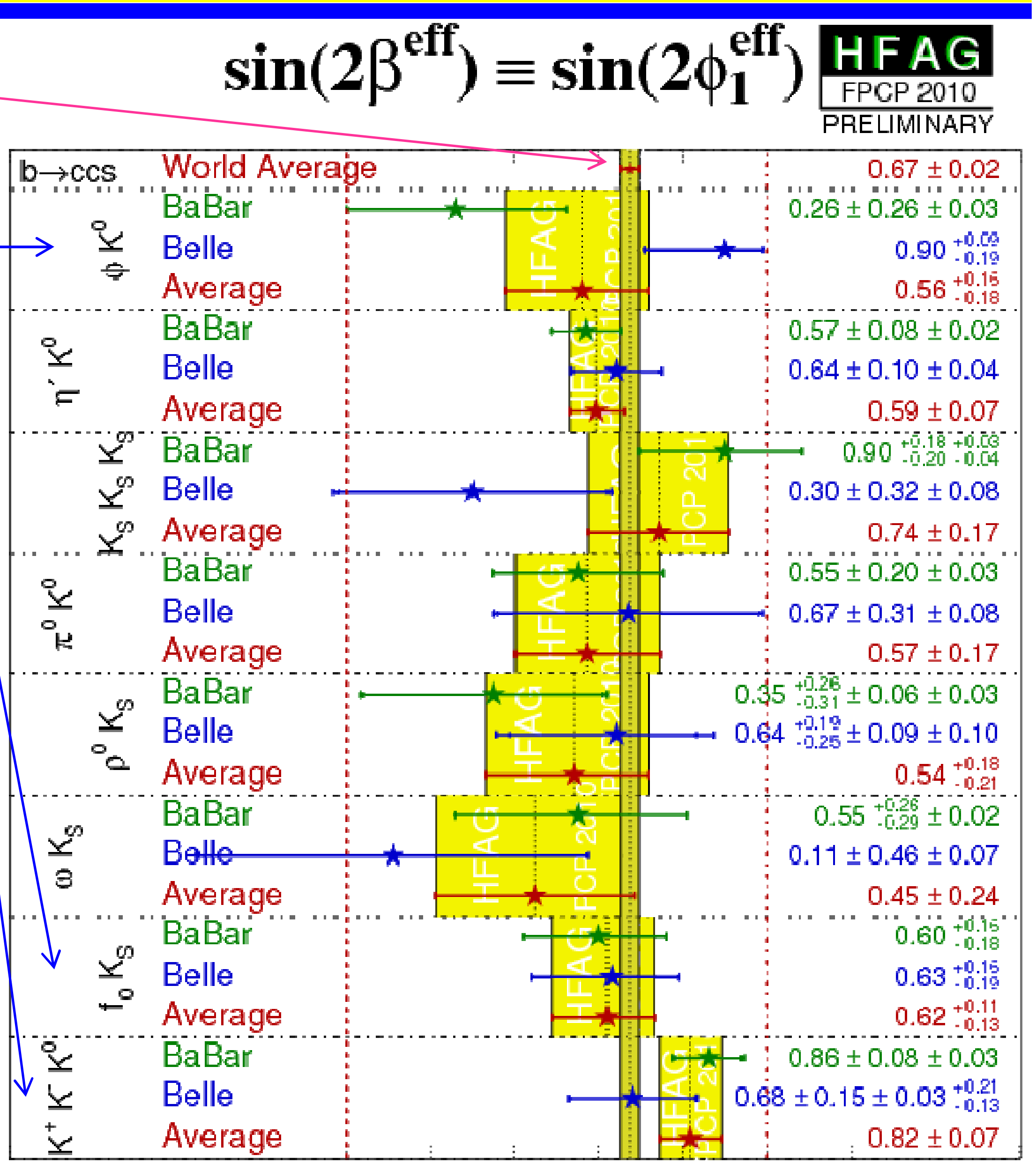
$f_0(890)K_S$: $\phi_1^{eff} = (31.3 \pm 9.0 \pm 3.4 \pm 4.0)^\circ$

$\phi_1 = (21.1 \pm 0.9)^\circ$

CP Violation in b→s

sin2ϕ_1 from b→ccs (reference)

new Belle result

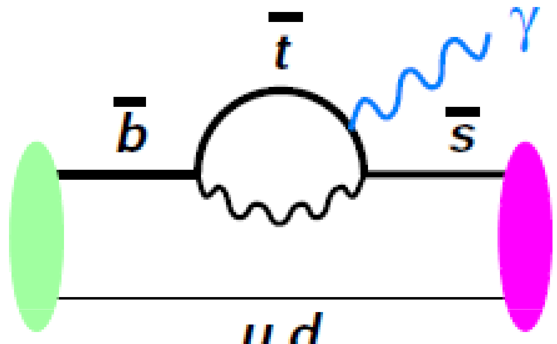


- Now in a good agreement with the SM.
- New CPV effect can be seen with much larger data (note: predicted $\delta\Delta\sin2\phi_1$~ O(%))

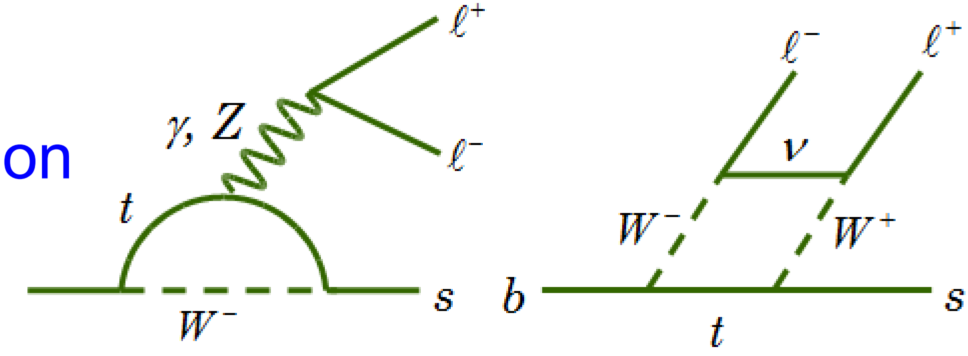
$b \to s\gamma$ and $b \to s\ell\ell$

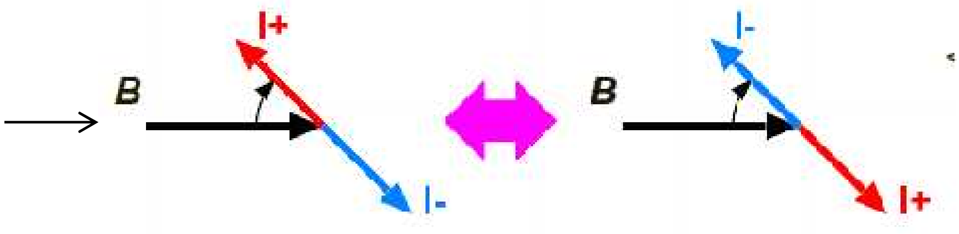
$b\to s\gamma$ and $b\to s\ell\ell$

- $b\to s(d)\gamma$, $b\to s\ell\ell$: FCNC process.
- Electroweak penguin (or box) diagram.
- Sensitive probe of New Physics.
- Limits on B.F. for $b\to s\gamma \Rightarrow$ constraints on charged Higgs mass.
- Charge asymmetry of $b\to s\gamma$.
  - ✓ $A_{CP}(B\to X_s\gamma) = 0.0042\,^{+0.0017}_{-0.0012}$
  - ✓ $A_{CP}(B\to X_s\gamma + X_d\gamma) = 0$
- $b\to s\ell\ell$ is sensitive to C_7, C_9, C_{10} Wilson Coefficient.
  - ✓ $b\to s\gamma$ is sensitive only to $|C_7|$.
  - ✓ Sign-flipped C_7 is allowed.
- Many observables in $b\to s\ell\ell$
  - ✓ Isospin asymmetry
  - ✓ Forward backward asymmetry.



$b\to s\gamma$ penguin

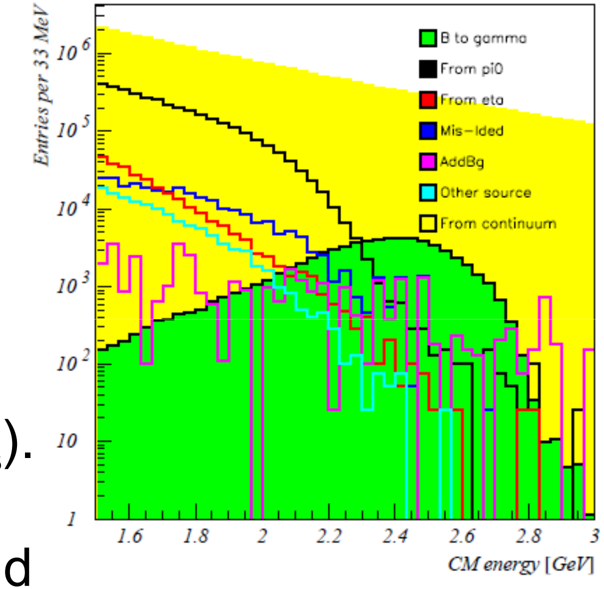




BF($B \to X_s\gamma$)

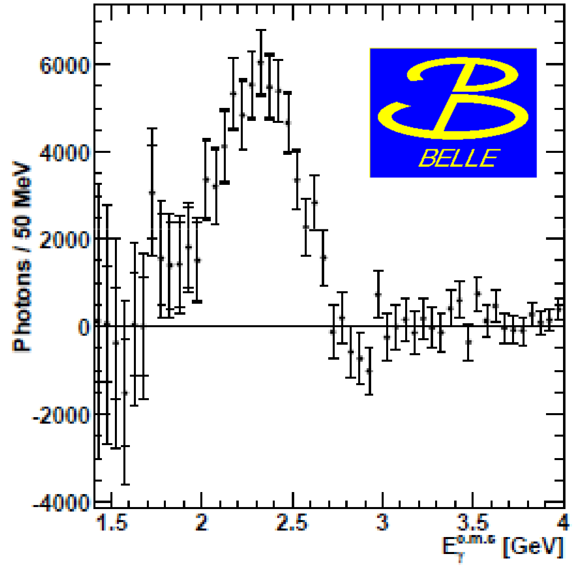
$b \to s\gamma$ ($B \to X_s\gamma$) Branching Fraction

- Most precise results are obtained with fully inclusive method.
  - ➢ Subtract the on-resonance photon energy spectrum by the continuum spectrum.
  - ➢ Measure at $E_\gamma > E_\gamma^{(min)}$. Need extrapolation.
  - ➢ Free from the model uncertainty of hadronic system (X_s).
  - ➢ Generally, has large backgrounds.
  - ➢ Lepton tag can be used for background suppression and flavor tagging.



$B(B \to X_s\gamma; E_\gamma > 1.7\text{GeV}) = (3.45 \pm 0.15 \pm 0.40) \times 10^{-4}$

[PRL 103, 241801(2009)]



$B(B \to X_s\gamma; E_\gamma > 1.6\text{GeV})$

$= (3.55 \pm 0.24 \pm 0.09) \times 10^{-4}$ [HFAG]

$= (3.15 \pm 0.23) \times 10^{-4}$ [theory, NNLO]

- 1.2σ difference.
- Constraint on NP: $M(H^+) > 295$ GeV @ 95% C.L.

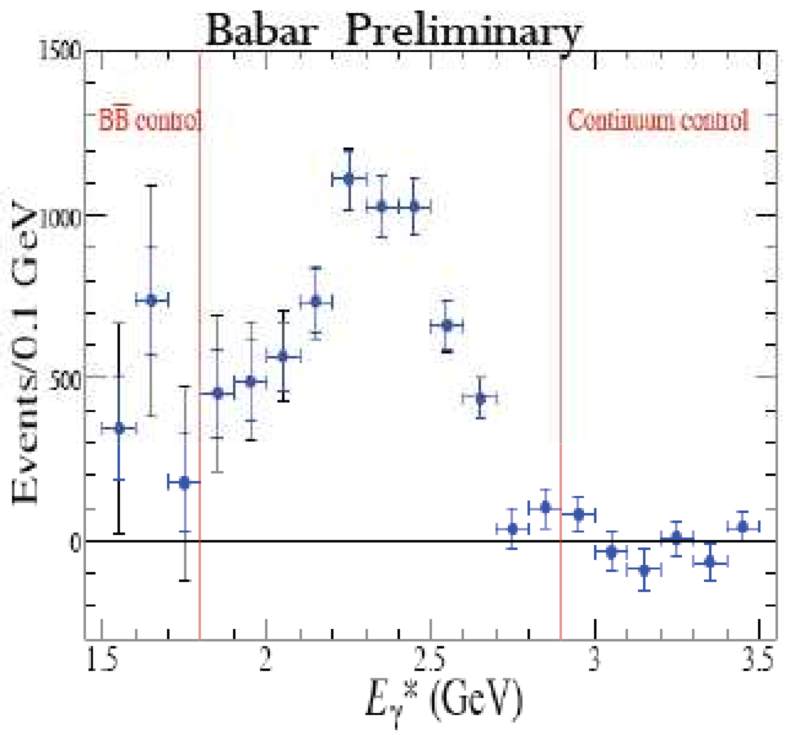
$A_{CP}(B \to X_{s/d}\gamma)$

New BaBar Measurement of CP asymmetry of $b \to s/d\gamma$.

- The flavor of B can be identified by the lepton from the other B.
  - ✓ Mistag rate $\omega \sim 13\%$.

$$A_{CP} = \frac{A_{CP}^{meas}}{1-2\omega}$$

	$\omega \pm \Delta\omega$
$B^0-\bar{B}^0$ oscillation	(0.1824±0.0024)/2
$B^0\bar{B}^0$:B^+B^-	0.000 ±0.0030
Non-direct-semileptonic	0.0318±0.0035
Fake ID	0.0073±0.0037
sum	0.131±0.0064



$N(l^+) = 2623 \pm 158$

$N(l^-) = 2397 \pm 151$

$A_{CP} = 0.056 \pm 0.060 \pm 0.018$

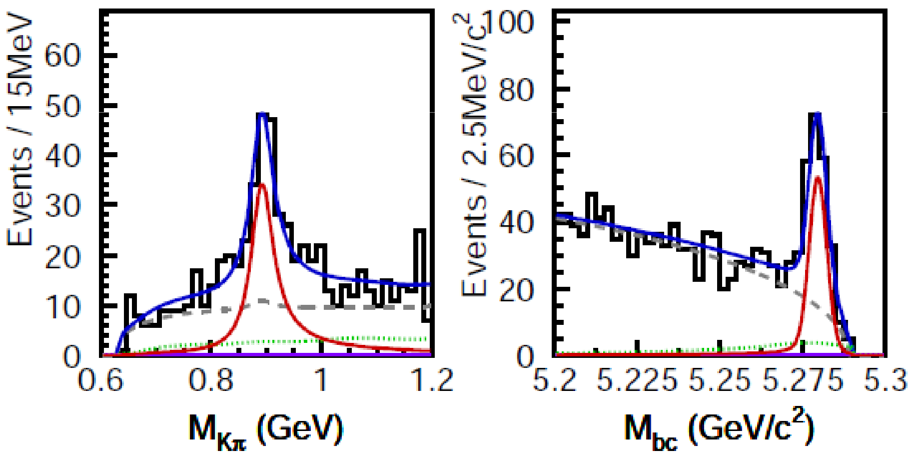
(null asymmetry)

[W. Wang @ CKM2010]

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

Analysis of $B \to K^{(*)}\ell\ell$ at Belle (similar at BaBar)

- Combine K or K* (from $K^+\pi^-$, $K_S\pi^+$, $K^+\pi^0$) with e/μ pair (l^+l^-).
- Bremsstrahlung photons (20-500MeV, <50mrad) from e recovered
- Dominant background: continuum and semileptonic B decays.
  - Suppress using event shape variables, missing mass etc.
- J/ψ (ψ') veto to remove $B \to J/\psi X$, $\psi' X$ events ($q^2 = M_{ll}^2$)
  - $8.68 < q^2 < 10.09$, $12.86 < q^2 < 14.18$ for muon pair
  - $8.11 < q^2 < 10.03$, $12.15 < q^2 < 14.11$ for electron pair
- Peaking background from $K^{(*)}\pi\pi$.
- M_{bc}-$M_{K\pi}$ 2d fit for K^*ll, M_{bc} 1d fit for Kll.

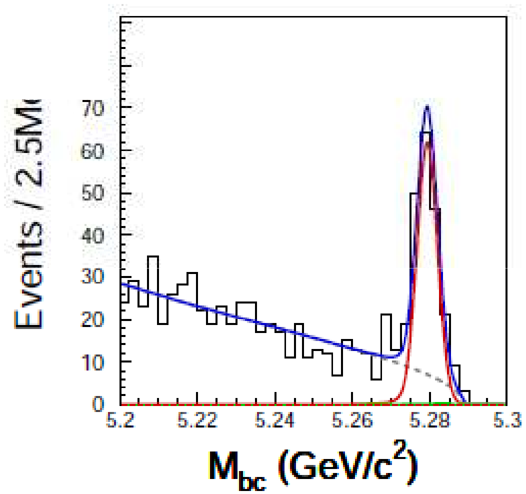


$K^*\ell\ell$

657M $B\bar{B}$

230 ± 24 events

$K\ell\ell$

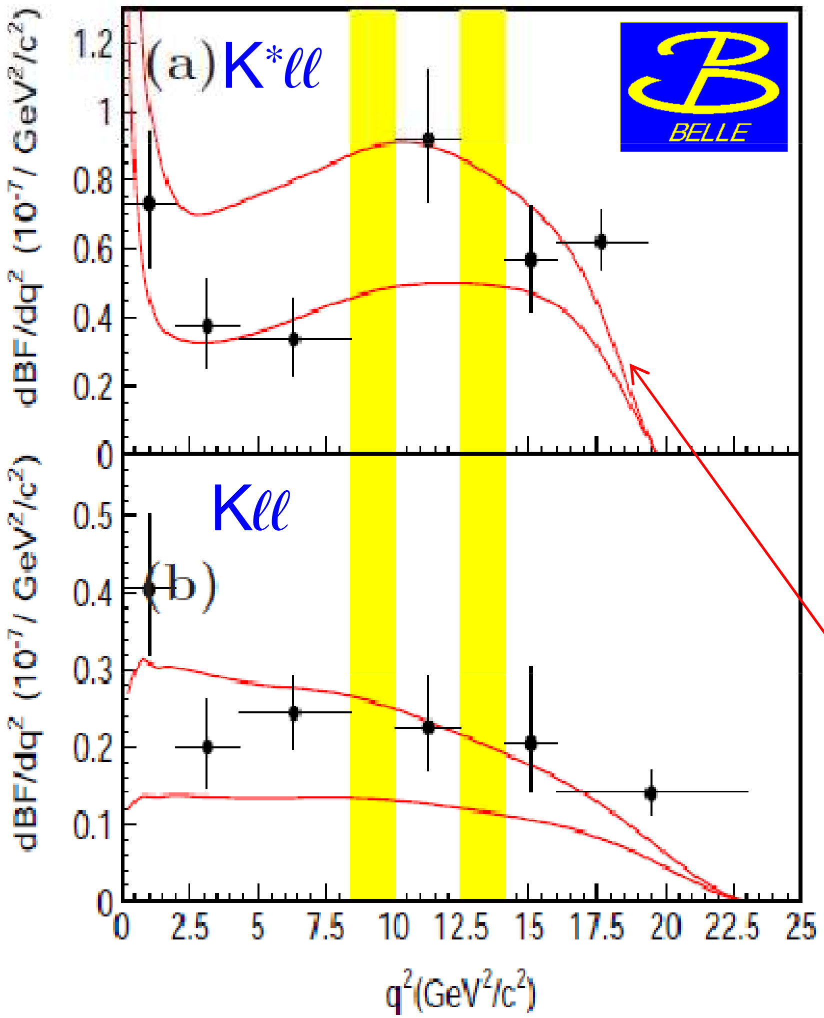


166 ± 15 events

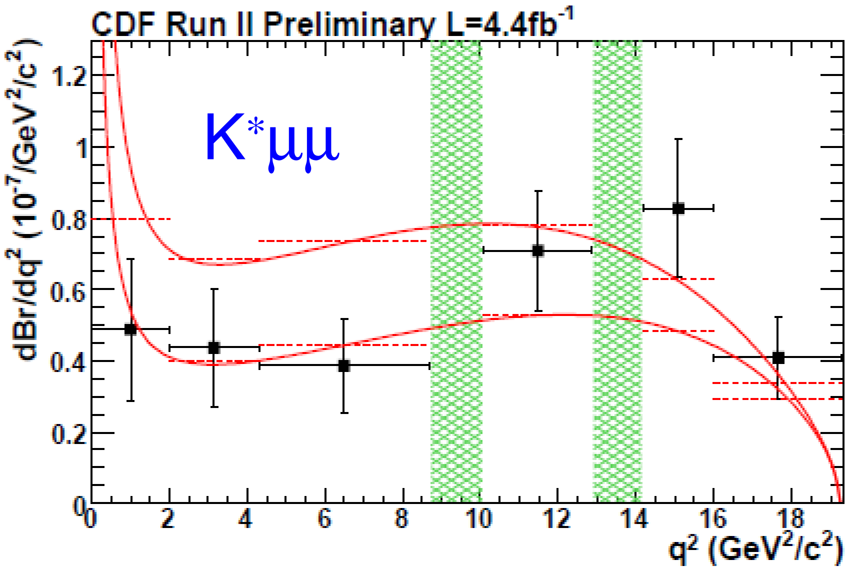
$B \to K^{(*)}\ell\ell$

Partial Branching Fraction (dBF/dq^2)

J/ψ, ψ(2S) veto



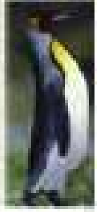
New result by CDF (with 4.4 fb^{-1})



- $K^{\pm}\mu^{\pm}\mu^{\mp}$, $K^{\pm}\pi^{\mp}\mu^{\pm}\mu^{\mp}$ only.

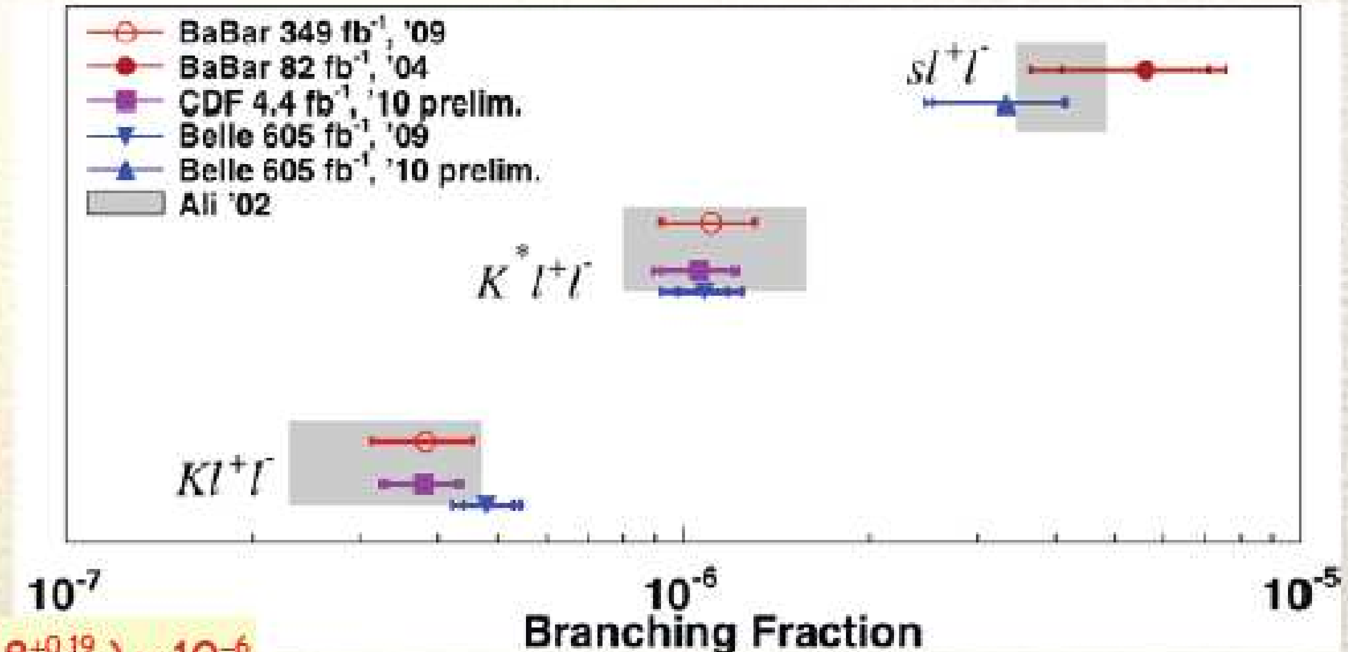
Theory (max. allowed region)

[A.Ali et al. PRD61, 074024 (2000), A.Ali et al. PRD66, 034002 (2006)]



$B \to K^{(*)} \ell^+ \ell^-$ Branching Fractions

- Total branching fractions of all 3 experiments are consistent with each other and the SM
- Belle updated $\mathcal{B}(B \to X_s \ell^+ \ell^-)$ using 605 fb^{-1}



new $\mathcal{B}(B \to X_s \ell^+ \ell^-) = (3.33 \pm 0.8^{+0.19}_{-0.24}) \times 10^{-6}$

Ali et al PRD 66, 034002 (2002)

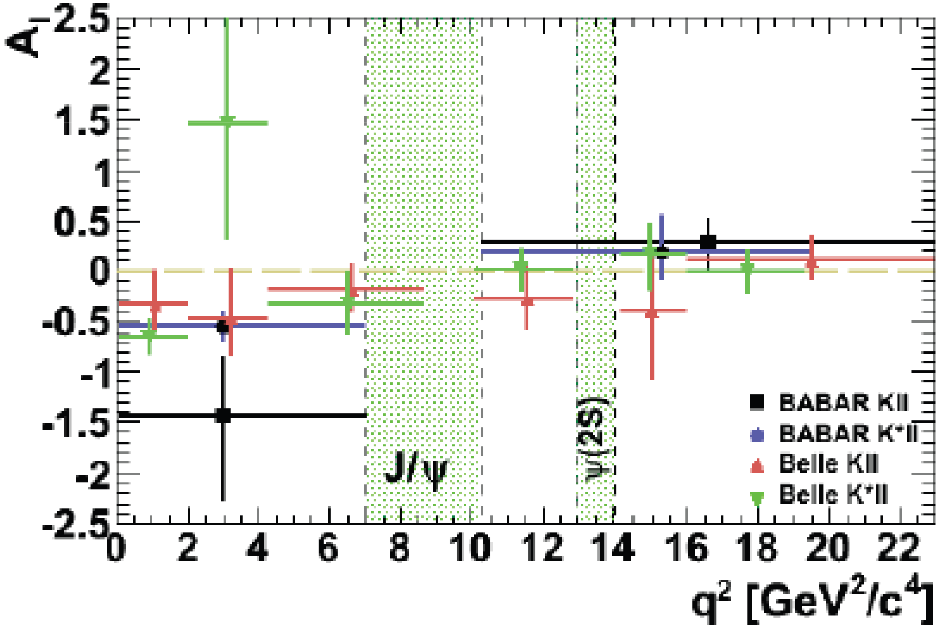
BABAR: PRL 102, 091803 (2009)
PRL 93,081862 (2004)
CDF: Note 10047 (2010)
Belle: PRL 103, 171801 (2009)
C.C.Ciang, ICHEP(2010)

- BABAR: $\mathcal{B}(B \to K \ell^+ \ell^-) = (0.394^{+0.073}_{-0.069} \pm 0.02) \times 10^{-6}$ $\mathcal{B}(B \to K^* \ell^+ \ell^-) = (1.11^{+0.19}_{-0.18} \pm 0.07) \times 10^{-6}$
- Belle: $\mathcal{B}(B \to K \ell^+ \ell^-) = (0.48^{+0.05}_{-0.04} \pm 0.03) \times 10^{-6}$ $\mathcal{B}(B \to K^* \ell^+ \ell^-) = (1.07^{+0.11}_{-0.10} \pm 0.09) \times 10^{-6}$
- CDF: new $\mathcal{B}(B^\pm \to K^\pm \mu^+ \mu^-) = (0.38^{+0.05}_{-0.05} \pm 0.03) \times 10^{-6}$ $\mathcal{B}(B^0 \to K^{*0} \mu^+ \mu^-) = (1.06^{+0.14}_{-0.14} \pm 0.09) \times 10^{-6}$

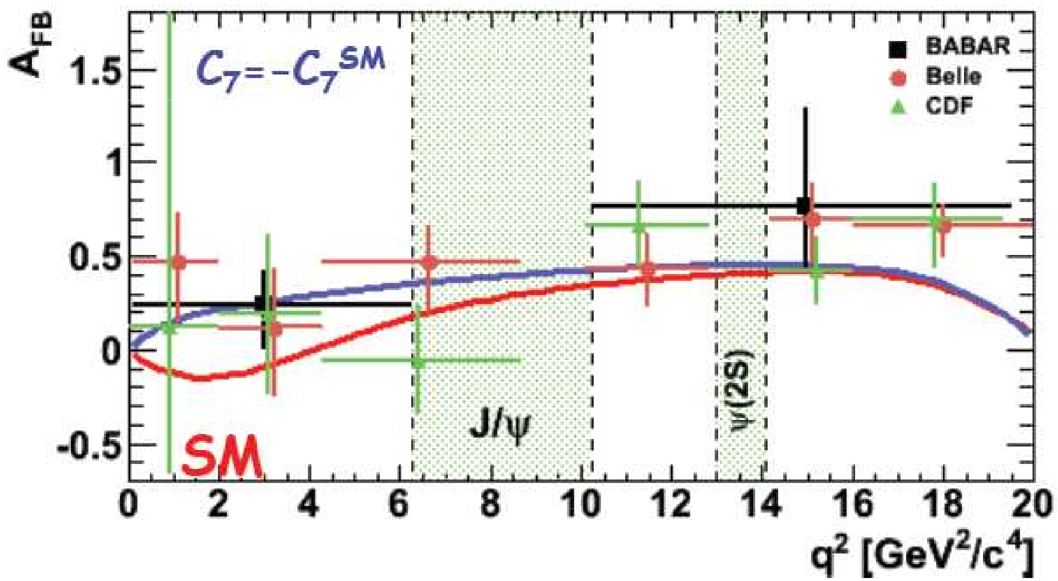
$B \to K^{(*)}\ell\ell$

Asymmetries: smaller theory errors.

Isospin asymmetry ($K^{(*)0}/K^{(*)+}$)



Forward-backward asymmetry



- BaBar found large A_I in low q^2 region (3.9σ).
- Belle's results are consistent with BaBar and SM.

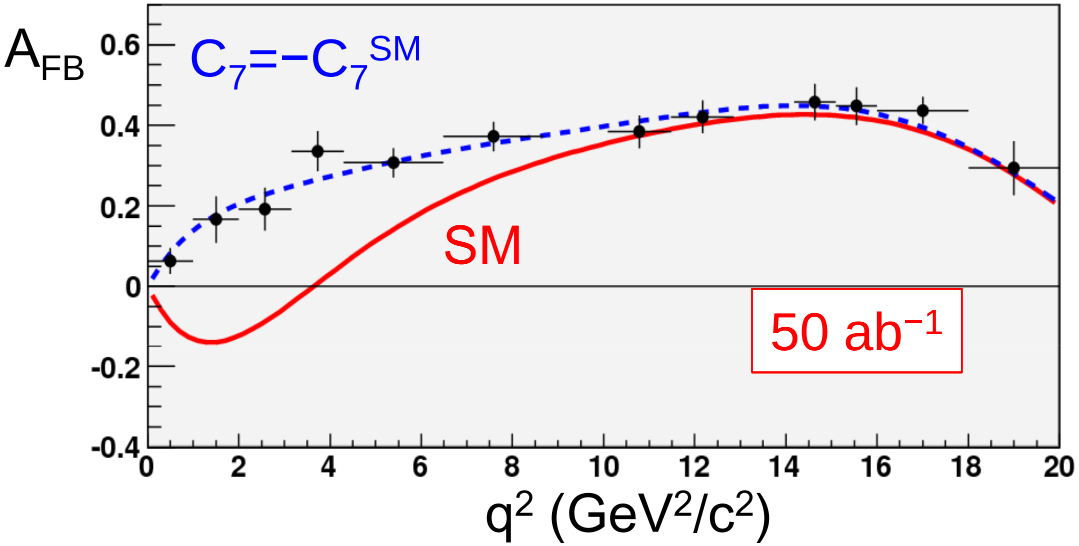
- All the three results are consistent with each other and SM-prediction.
- C_7 flipped scenario looks more favoured from A_{FB} distribution.

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

Future prospects:

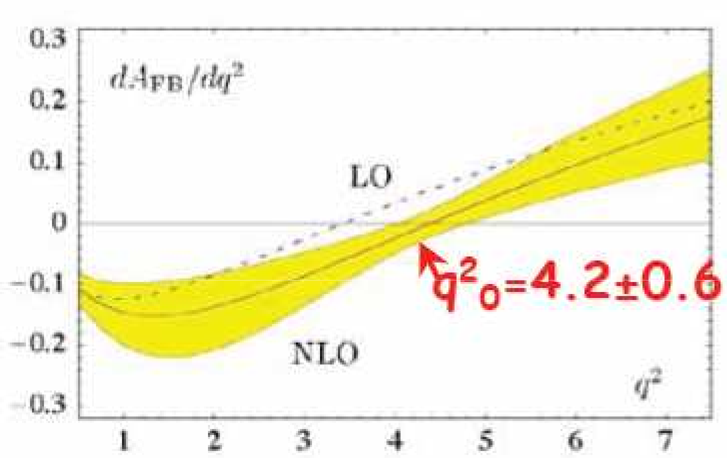
- One good benchmark is q_0^2 (zero crossing point): theoretically clean.
- Prospects @ LHC-b and super B factories.

LHCb 2 fb^{-1} : 13%
LHCb 100 fb^{-1} : 2%
Belle 50 ab^{-1} : 5%

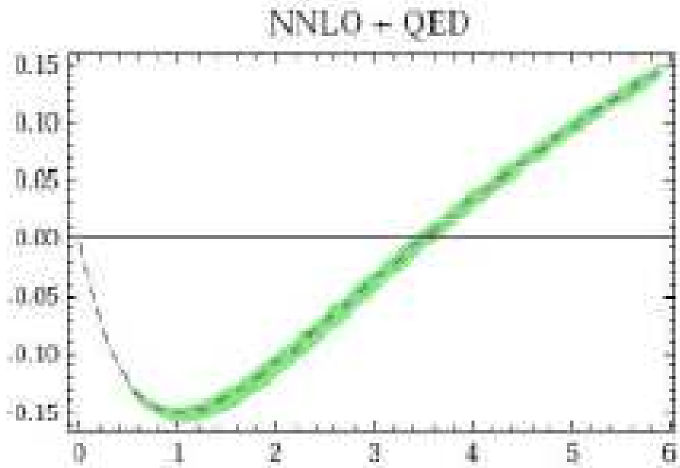


- Inclusive Xs is theoretically more clean: possible only in B factories.

$K^*\ell\ell$



$X_s\ell\ell$

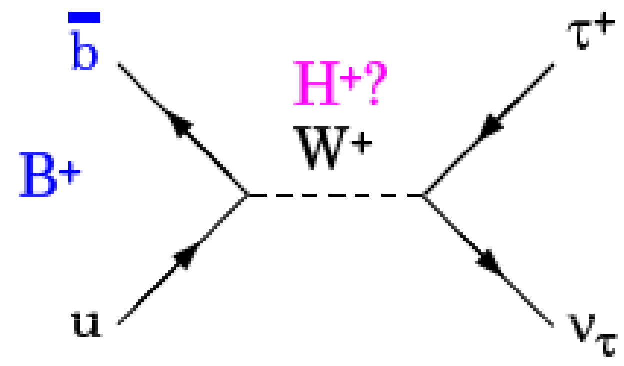


$q^2_0 = 3.5 \pm 0.1$ GeV^2

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

B→τν

- Possible contribution of charged Higgs (H^+) in tree level.
- In the SM: $\mathcal{B}(B\to\tau\nu_\tau) = (1.20 \pm 0.25)\times10^{-4}$



$$\mathcal{B}(B\to\tau\nu) = \frac{G_F^2 m_B}{8\pi} m_\tau^2 \left(1-\frac{m_\tau^2}{m_B^2}\right)^2 f_B^2 |V_{ub}|^2 \tau_B$$

$|V_{ub}|=(4.32\pm0.16\pm0.29)\times10^{-3}$ From inclusive semileptonic B decays HFAG ICHEP08

$f_B=190\pm13\text{MeV}$, From LQCD HPQCD arXiv:0902.1815

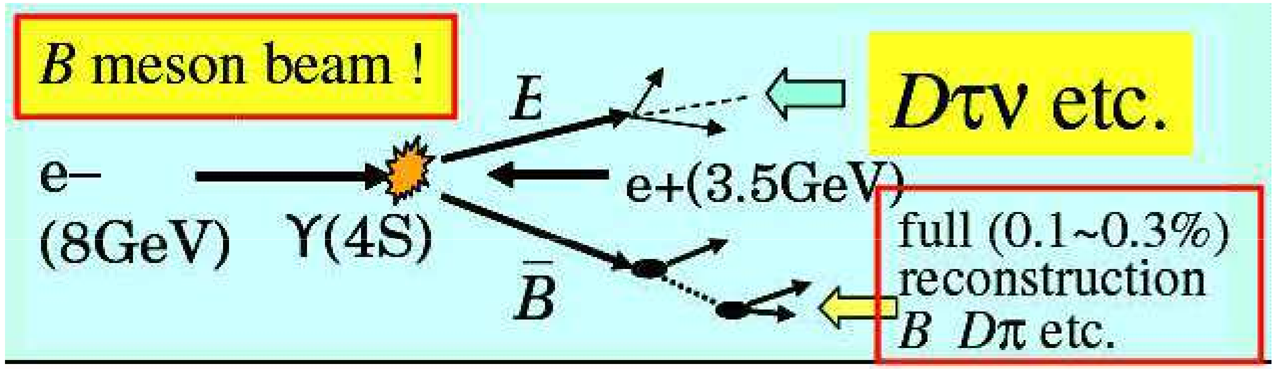
B decay constant ↔ Lattice QCD

However, experimentally very challenging due to more than 1 neutrino in the final state

$B^+ \to \tau^+\nu_\tau$

$\tau^+ \to e^+\nu_e\overline{\nu}_\tau$

$\to \pi^+\overline{\nu}_\tau$



Tag one of the B mesons
- Fully reconstruct using hadronic mode.
- Tag with B semi-leptonic decays.

B→τν

hadronic tags

449M $\bar{B}B$

$$BF(B\to\tau\nu)=[\mathbf{1.79}^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(syst)]\times10^{-4}$$

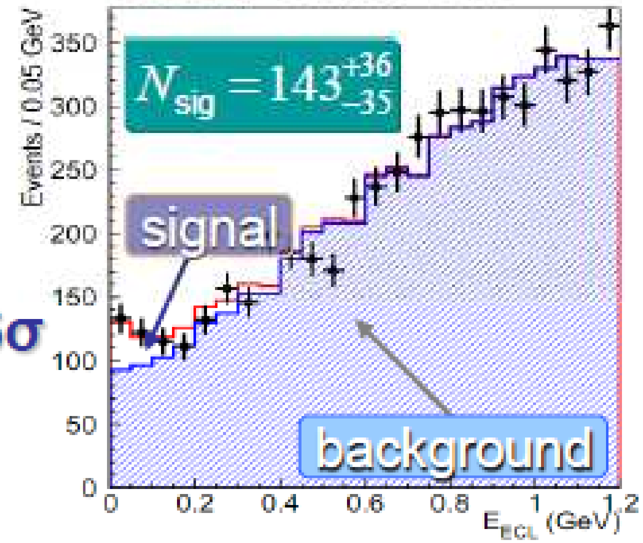
first evidence 3.5σ

↑ significance

Belle Collab., PRL **97**, 251802 (2006)

semileptonic tags

NEW 657M $\bar{B}B$



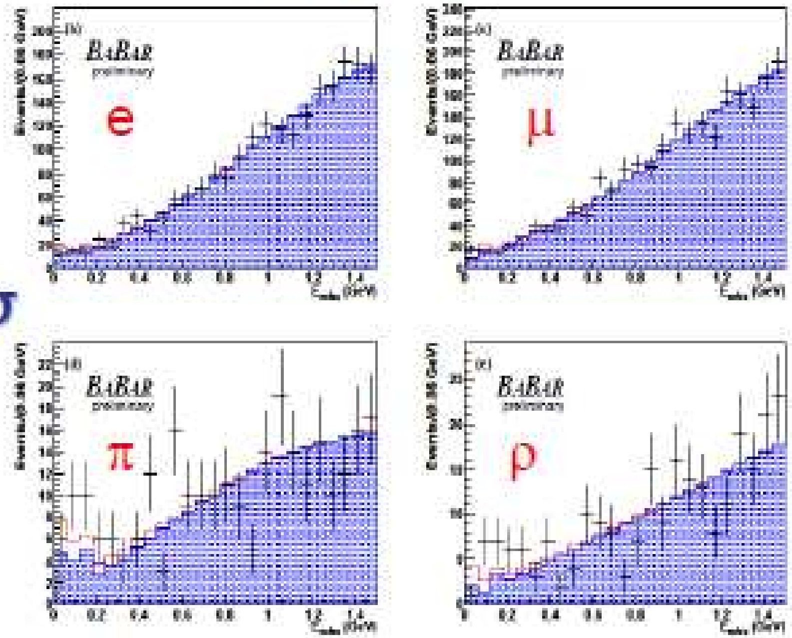
$$BF(B\to\tau\nu)=[\mathbf{1.54}^{+0.38}_{-0.37}(stat)^{+0.29}_{-0.31}(syst)]\times10^{-4}$$

Belle Collab., arXiv: 1006.4201 submitted to PRD-RC

hadronic tags

NEW, *preliminary*

468 M $\bar{B}B$



$$BF(B\to\tau\nu)=[\mathbf{1.80}^{+0.57}_{-0.54}(stat)\pm0.26]\times10^{-4}$$

BaBar Collab., arXiv: 1008.0104

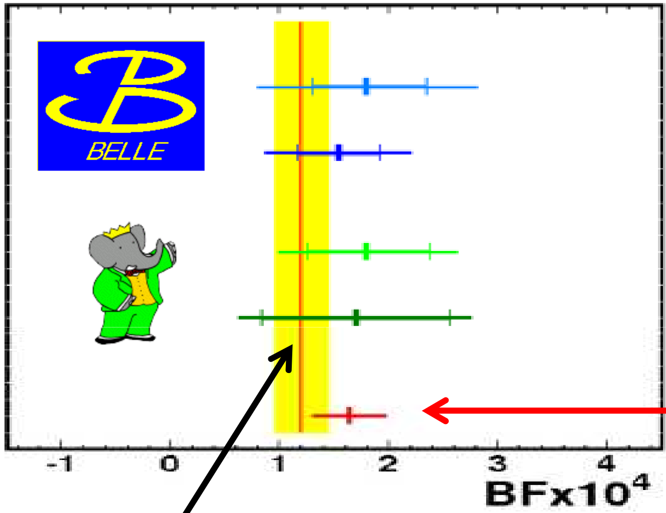
semileptonic tags

$$BF(B\to\tau\nu)=[\mathbf{1.7}\pm\mathbf{0.8}(stat)\pm0.2]\times10^{-4}$$ 2.3σ

BaBar Collab., PRD **81**, 051101 (2010)

slide from M.Rozanska
@Charged Higgs 2010

$B \to \tau\nu$



$[1.79^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(syst)]\times 10^{-4}$ hadronic tag

$[1.54^{+0.38}_{-0.37}(stat)^{+0.29}_{-0.31}(syst)]\times 10^{-4}$ semileptonic tag

$[1.80^{+0.57}_{-0.54}(stat)\pm 0.26(syst)]\times 10^{-4}$ hadronic tag

$[1.7\pm 0.8(stat)\pm 0.2(syst)]\times 10^{-4}$ semileptonic tag

HFAG $(1.64\pm0.39)\times10^{-4}$

Consistent with the SM: $(1.20 \pm 0.25)\times10^{-4}$

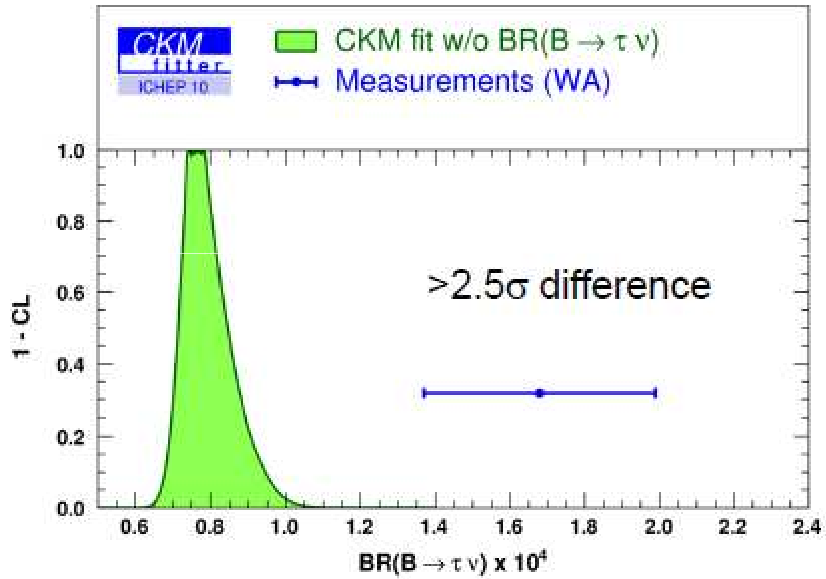
SM prediction

Alternative approach is to extract the B.F. from CKM fit (excluding direct meas.).

$BF(B\to\tau\nu)_{SM(CKM)} = [0.763^{+0.114}_{-0.061}]\times10^{-4}$ (CKMfitter)

$BF(B\to\tau\nu)_{SM(UT)} = [0.805\pm0.071]\times10^{-4}$ (UT fit)

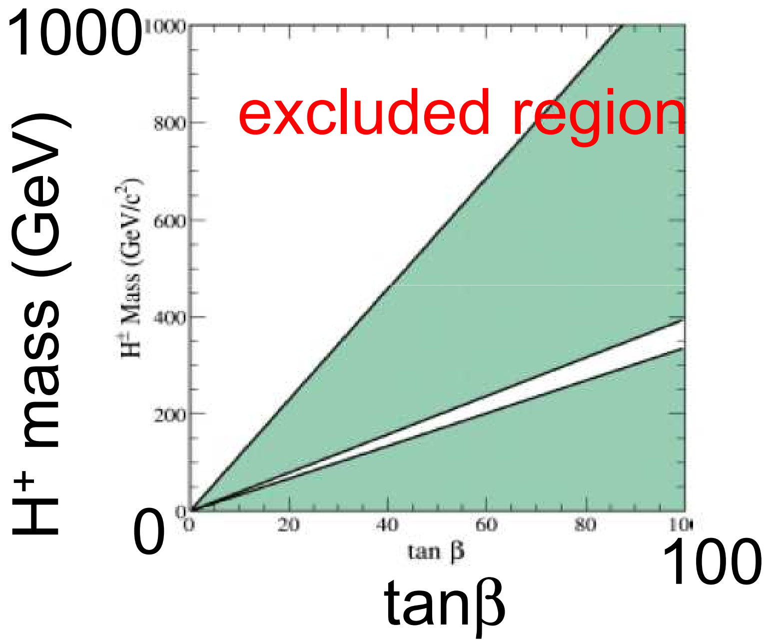
Tension!

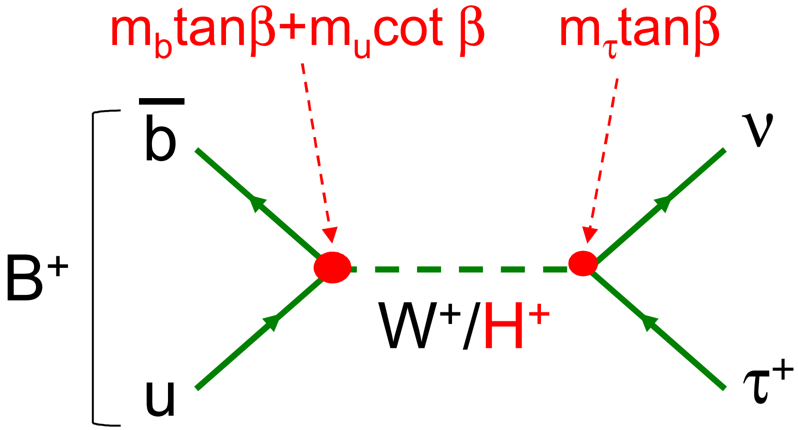


Limit to charged Higgs mass.

$$Br(B\to l\nu) = BR_{SM}\times\left(1-\tan^2\beta\frac{m_B^2}{m_H^2}\right)^2$$

(Type II '2HDM')

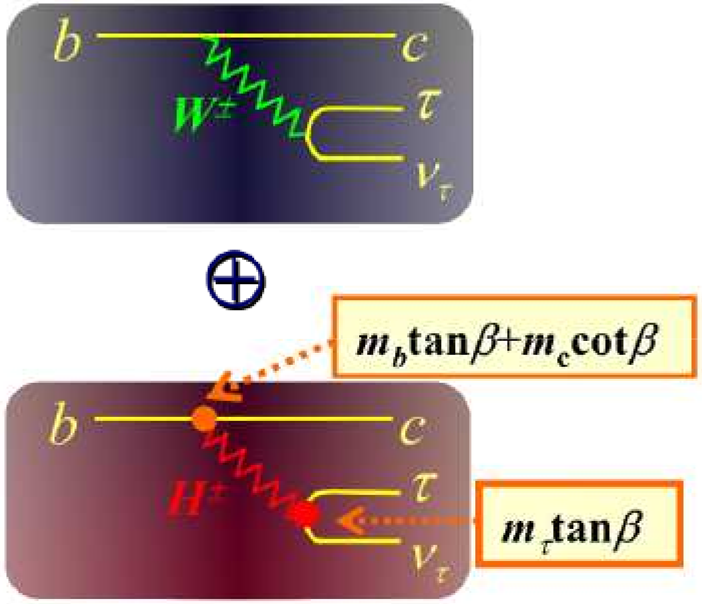




Unique opportunity to study b-H^+-u interaction

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

- Similar physics motivation to $B \to \tau\nu_\tau$, but
  - ✓ different theoretical uncertainty.
  - ✓ Study of b-H^+-c interaction.
- Similar analysis technique to $B \to \tau\nu_\tau$, but
  - ✓ More observables due to kinematical constraints.
  - ✓ Two ways of reconstruction: reconstruct tagged B first as $B \to \tau\nu_\tau$; or reconstruct signal first.
  - ✓ Simultaneous extractions of multiple modes due to self cross feed.
- Polarization sensitive to the NP.

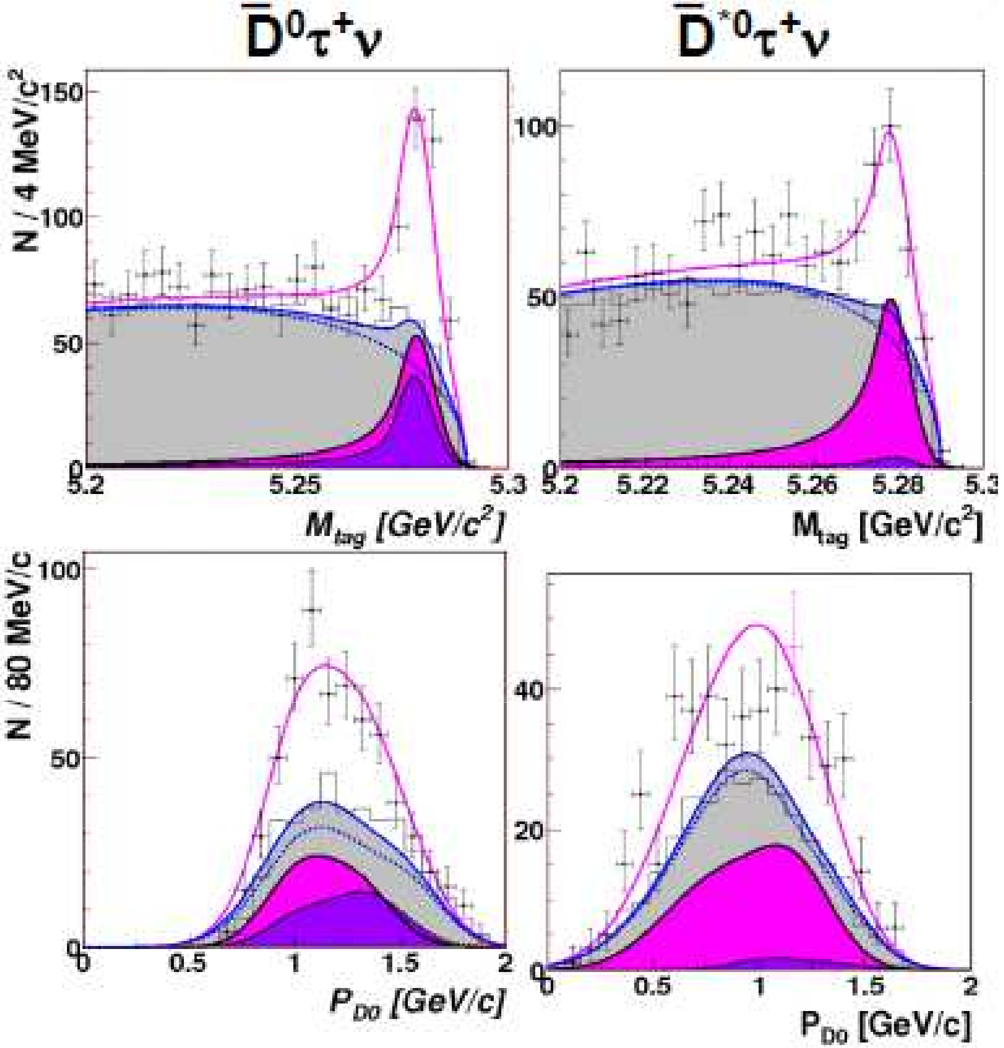


B→D$^{(*)}$τν

$\bar{D}^{*0}\tau^+\nu$ / $\bar{D}^{0}\tau^+\nu$ / background

657M $B\bar{B}$

[arXiv:1005.2302
to be published in PRD]



$$\mathcal{B}(B^+ \to \bar{D}^{*0}\tau^+\nu_\tau) = (2.12^{+0.28}_{-0.27}(\mathrm{stat}) \pm 0.29(\mathrm{syst}))\%$$

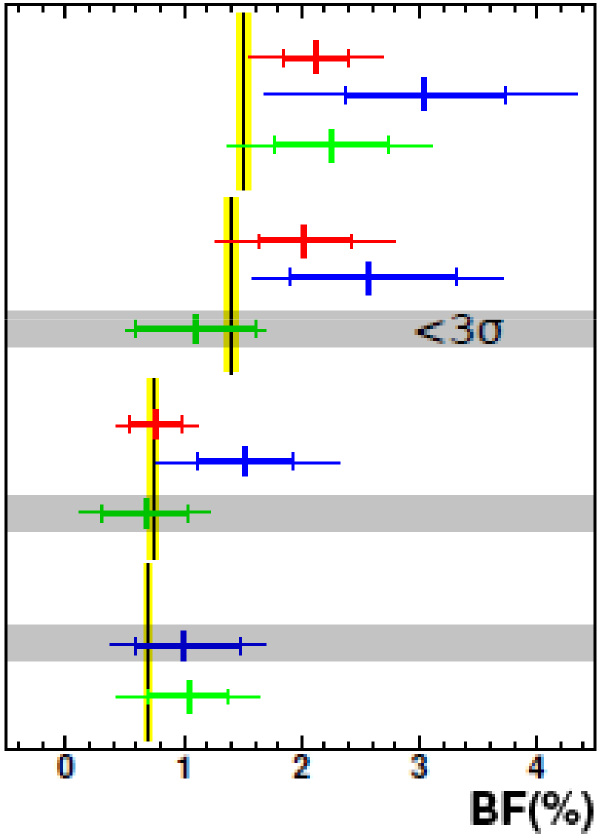
8.1σ

$$\mathcal{B}(B^+ \to \bar{D}^{0}\tau^+\nu_\tau) = (0.77 \pm 0.22(\mathrm{stat}) \pm 0.12(\mathrm{syst}))\%$$

3.5σ

first evidence

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



$B^+ \to \overline{D}^{*0} \tau^+ \nu_\tau$

- $[2.12^{+0.28}_{-0.27} \pm 0.29]\%$ 8.1σ
- $[3.04^{+0.69}_{-0.66}{}^{+0.40}_{-0.47}]\%$ 3.9σ
- $[2.25 \pm 0.48 \pm 0.22]\%$ 5.3σ

$B^0 \to D^{*-} \tau^+ \nu_\tau$

- $[2.02^{+0.40}_{-0.37} \pm 0.37]\%$ 5.2σ
- $[2.56^{+0.75}_{-0.66}{}^{+0.31}_{-0.22}]\%$ 4.7σ
- $[1.11 \pm 0.51 \pm 0.04]\%$ 2.7σ

$B^+ \to \overline{D}^{0} \tau^+ \nu_\tau$

- $[0.77 \pm 0.22 \pm 0.12]\%$ 3.5σ
- $[1.51^{+0.41}_{-0.39}{}^{+0.24}_{-0.19}]\%$ 3.8σ
- $[0.67 \pm 0.37 \pm 0.11]\%$ 1.8σ

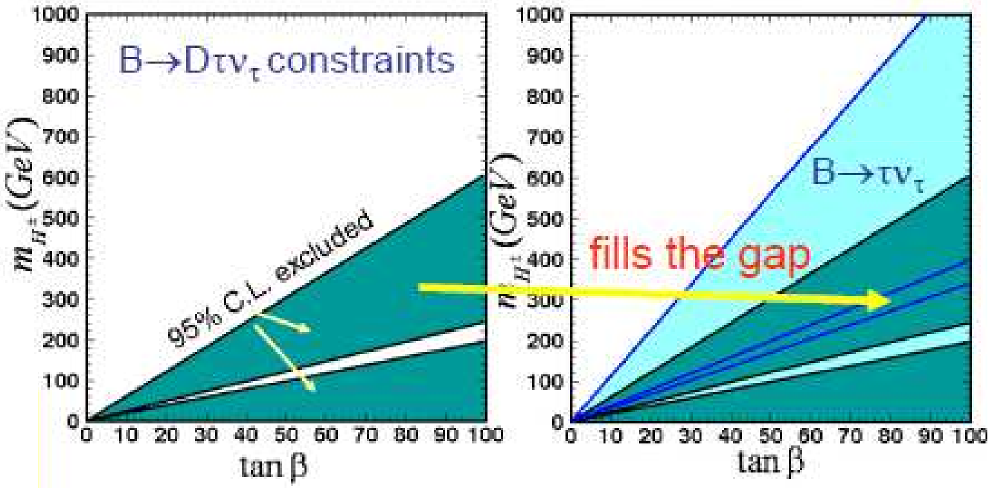
$B^0 \to D^{-} \tau^+ \nu_\tau$

- $[1.01^{+0.46}_{-0.41}{}^{+0.13}_{-0.11}]\%$ 2.6σ
- $[1.04 \pm 0.35 \pm 0.15]\%$ 3.3σ

– Belle inclusive B_{tag} [6]
– Belle exclusive B_{tag} [7]
– BaBar exclusive B_{tag} [8]
■ Standard Model [9]

All measurements are above (but also consistent with) the SM prediction.

Constraint on H^+



Other Missing Topics

- Measurement of CKM angle ϕ_2, ϕ_3.
- Measurement of |Vub| using B semileptonic decay.
- Time dependent CPV of $B \to K^*\gamma$ (Photon polarization).
- $B \to K\pi$ CP Asymmetry ($K\pi$ puzzle).
- ……
- τ decays (LFV)
- Charm physics: D^0-$\overline{D}^0$ mixing.
- Charmonium spectroscopy (exotic hadrons).
- ……
- Study of Bs decays by Belle using data at Υ(5S).
- Observation of η_b by BaBar using data at Υ(3S).
- …….
- Δm_s, $\Delta\Gamma_s$ from Tevatron.
- Search for $B_s \to \mu\mu$
- …….

Super B Factories

Super B Factories

- Although there exist interesting possible hints for the NP at the present B factories, all the results are consistent with the SM.
- NP should exist at the higher energy scale, possibly in TeV region considering the hierarchy problem → LHC will discover it.
- Super B factories can help the identification of the NP, i.e. whether it is SUSY or others, or how SUSY breaking occurs.

SUSY scenario →

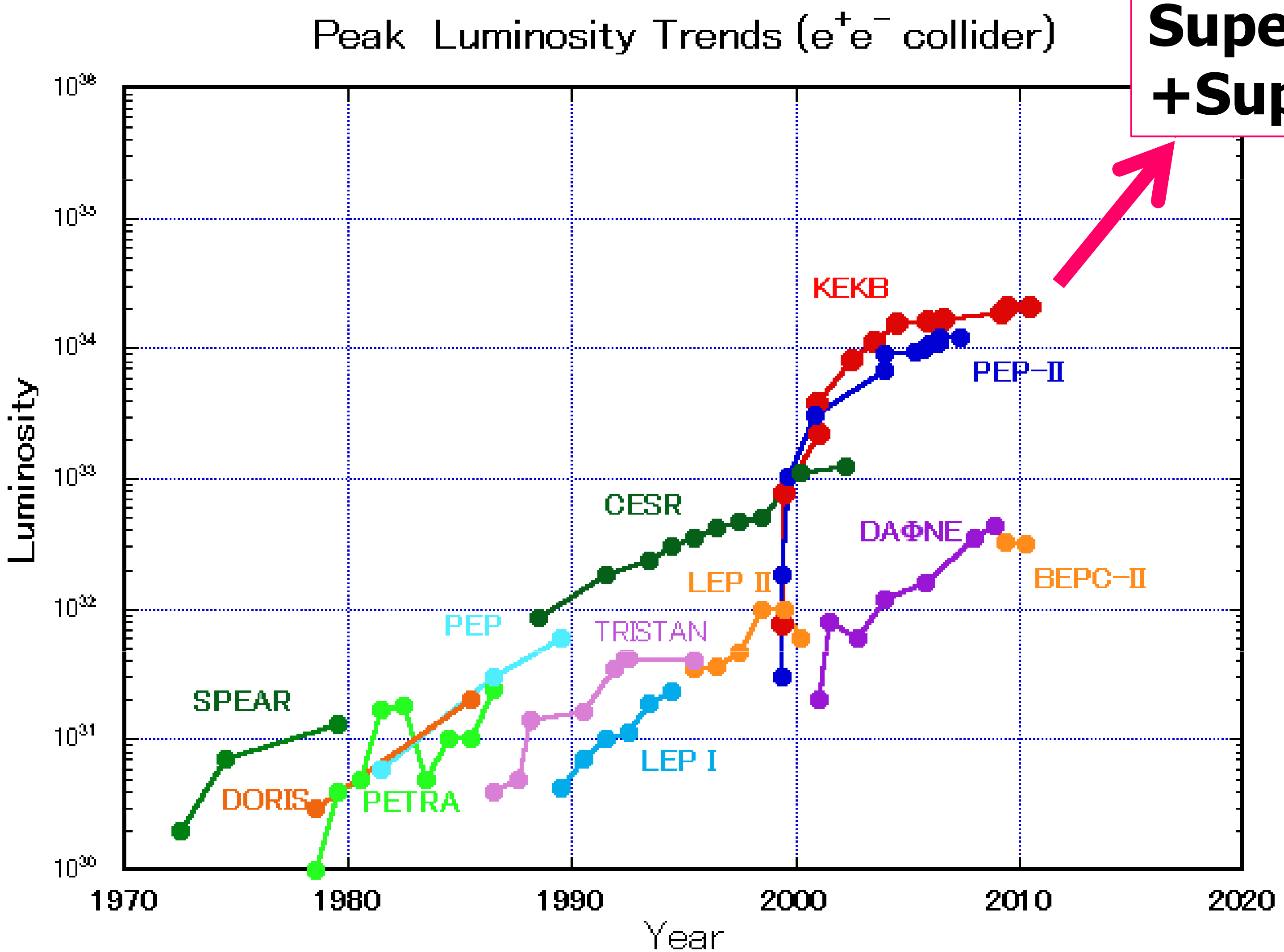
Observables @ Super B factories or other experiments ↓

	mSUGRA	MSSM+ν_R		SU(5)+ν_R		U(2) FS
		degenerate	non-degenerate	degenerate	non-degenerate	
$A_{CP}(s\gamma)$						✓
$S(K^*\gamma)$				✓	✓	✓
$S(\rho\gamma)$				✓	✓	✓
$S(\phi K_S)$				✓	✓	✓
$S(B_s \to J/\psi\ \phi)$				✓	✓	✓
$\mu \to e\gamma$		✓		✓	✓	?
$\tau \to \mu\gamma$		✓	✓	✓	✓	?
$\tau \to e\gamma$			✓		✓	?

[based on T.Goto et.al. PRD77, 095010(2008)]

Super B Factories

Increase the luminosity by ~2 orders of magnitudes!!



SuperKEKB
+SuperB

Japan (KEK)

Italy (INFN)

Target

SuperKEKB
$50\ ab^{-1}$
$8 \times 10^{35}\ cm^{-2}\ s^{-1}$

Super B
$75\ ab^{-1}$
$1 \times 10^{36}\ cm^{-2}\ s^{-1}$

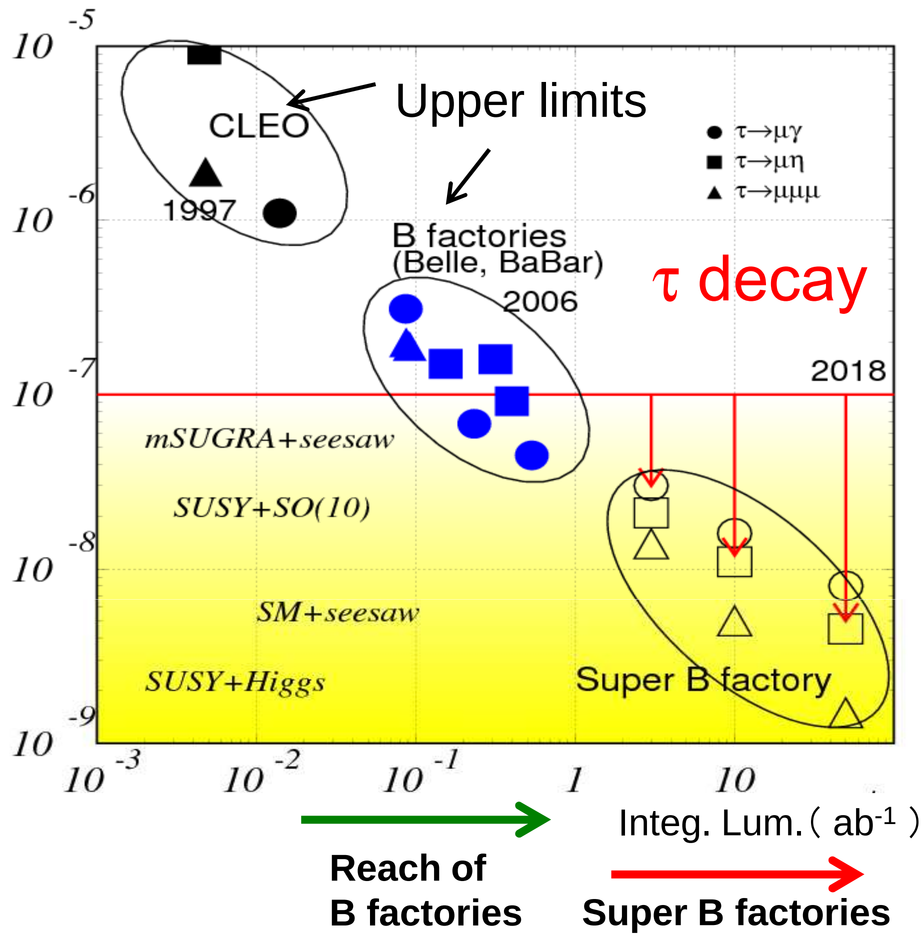
Physics with 50(75) ab^{-1}

Two recent publications:

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

In addition to the topics in this talk,

- Photon polarization of $B \to K^* \gamma$.
- $B \to K^{(*)} \nu\nu$.
- CPV in D.
- LFV in τ decay.
- …



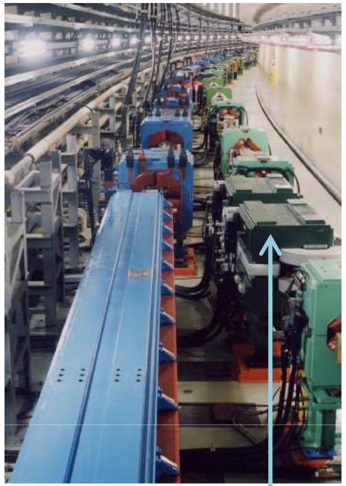
Nano Beam Scheme

	KEKB		SuperKEKB		SuperB		Units
	LER	HER	LER	HER	LER	HER	
Beam Energy	3.5	8	4	7	4.18	6.7	GeV
Half crossing angle	11		41.5		33		mrad
Beta func. @ IP (x/y)	1200 / 5.9		32 / 0.27	25 / 0.31	26 / 0.253	32 / 0.205	mm
Beam current	1.64	1.19	3.60	2.60	1.892	2.447	A
Luminosity [$\times 10^{34}$]	2.1		80		100		$cm^{-1}s^{-1}$

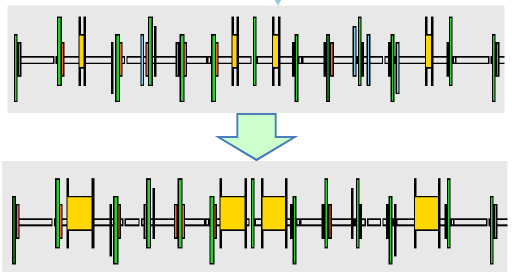
[detailed tables are in backup slides]

- Collision with very small spot-size beam.
- Increase beam current (moderately)
- Larger crossing angle.
- Change beam energy to symmetric side (to solve LER short lifetime).
- SuperB has plan to run at τ-charm threshold with ~ 10^{35} $cm^{-1}s^{-1}$

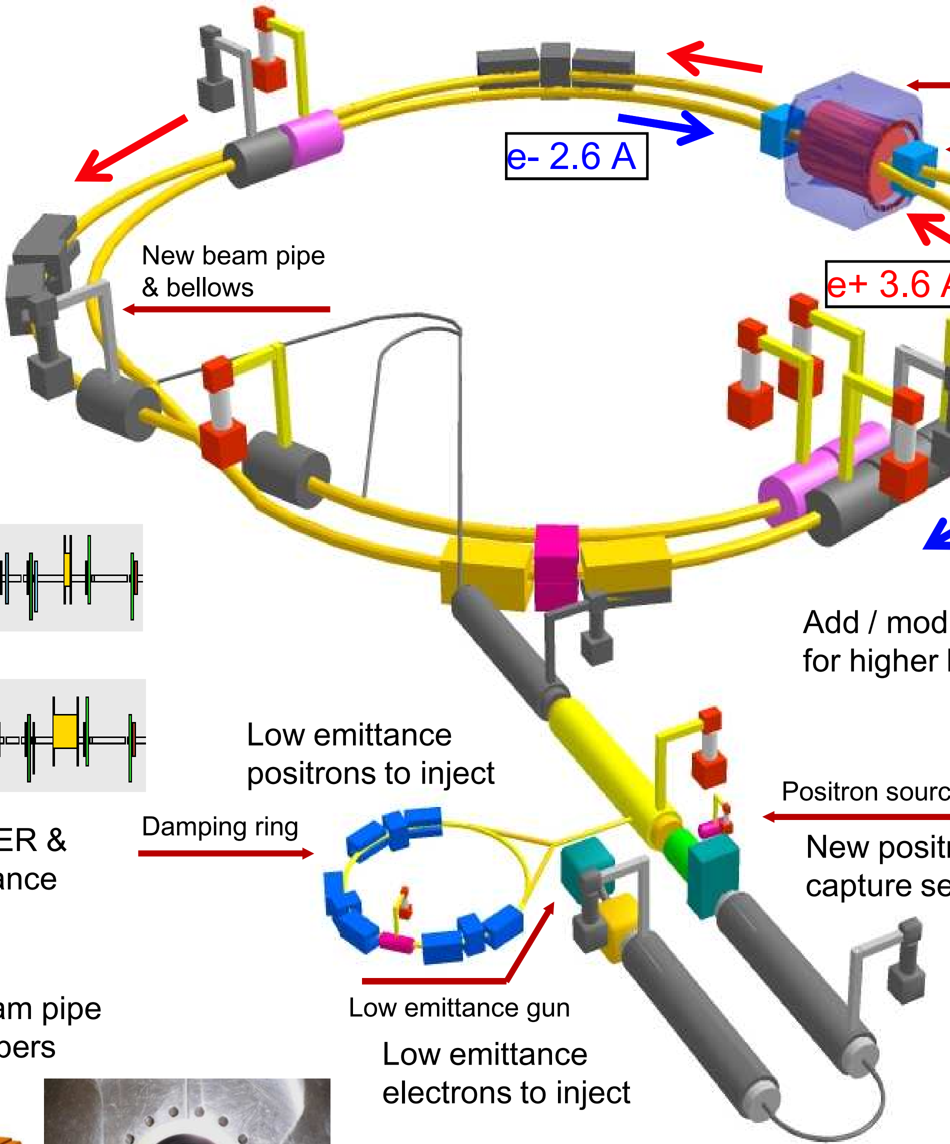
Upgrade to SuperKEKB



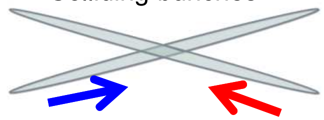
Replace short dipoles with longer ones (LER)



Redesign the lattices of HER & LER to squeeze the emittance



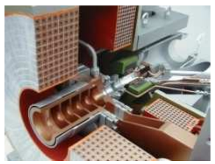
Colliding bunches



New superconducting /permanent final focusing quads near the IP

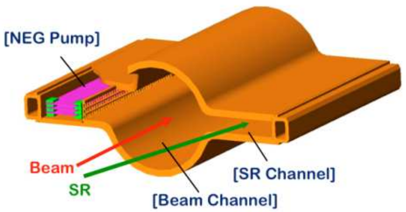
Add / modify RF systems for higher beam current

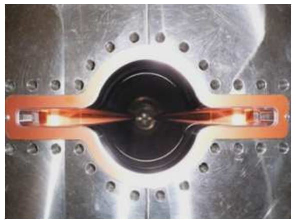
New positron target / capture section



Low emittance electrons to inject

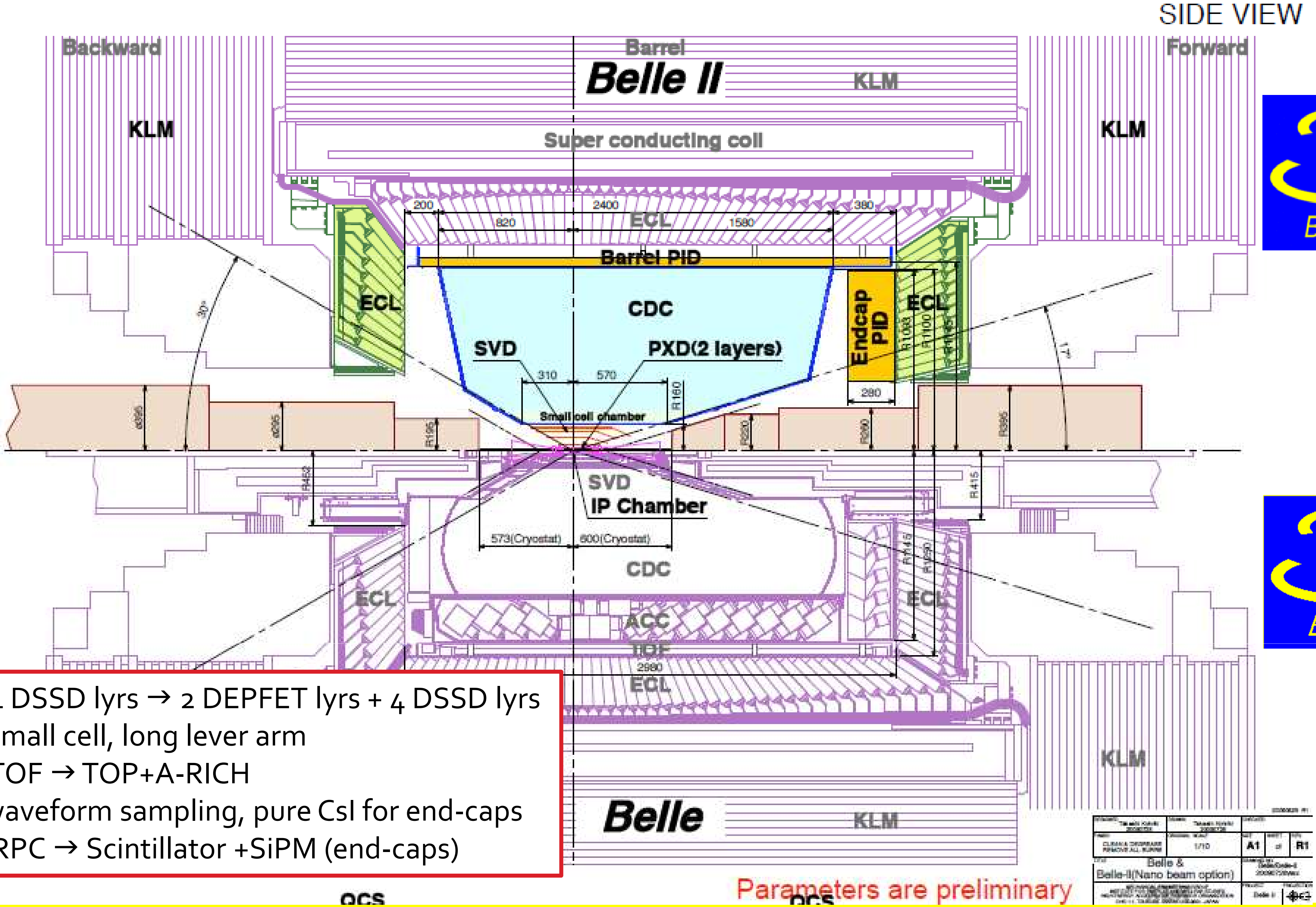
TiN-coated beam pipe with antechambers





To get x40 higher luminosity

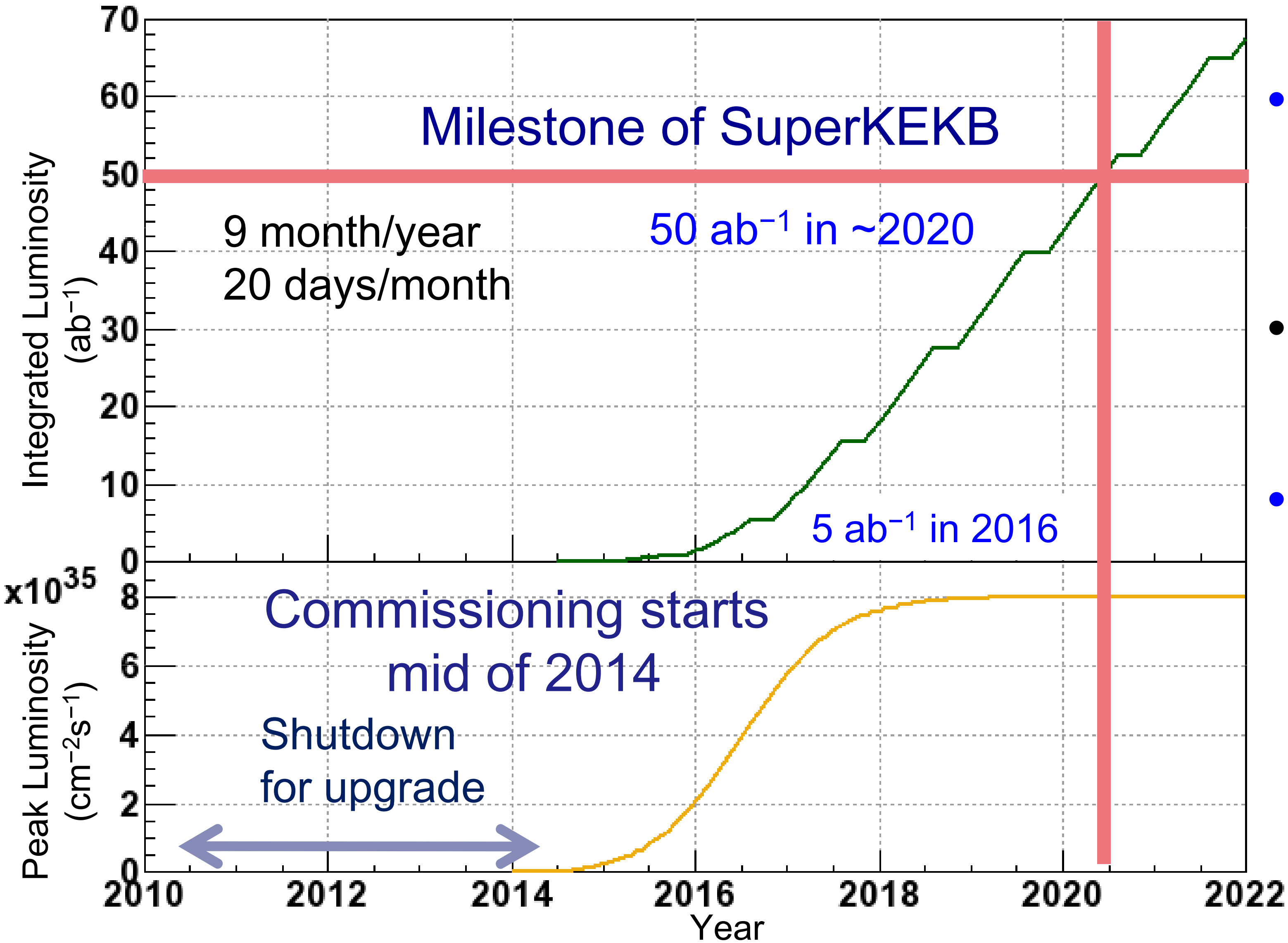
Belle II Detector



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)

SuperKEKB Schedule

SuperKEKB is approved!



- 10 billion yen (~90 million EUR) for machine.
- Continue efforts to obtain additional funds.
- Funds from several non-Japanese agencies.

Comparison with LHCb

	Belle	Belle II	Belle II	LHCb
	~ 0.5 ab^{-1}	5 ab^{-1}	50 ab^{-1}	10 fb^{-1} [5yrs]
$\Delta S(\phi K_S)$	0.22	0.073	0.029	0.14
$\Delta S(\eta' K_S)$	0.11	0.038	0.020	---
ϕ_s from $S(J/\psi\phi)$	---	---	---	0.01
$S(K^*\gamma)$	0.36	0.12	0.03	---
$S(\rho\gamma)$	0.68	0.22	0.08	---
$\Delta\mathcal{B}/\mathcal{B}(B \to \tau\nu)$	3.5σ	10%	3%	---
$B_s \to \mu\mu$	•	•	•	5σ @ 6 fb^{-1}
$\tau \to \mu\gamma$ [$\times 10^{-9}$]	<45	<30	<8	---
$\tau \to \mu\mu\mu$ [$\times 10^{-9}$]	<209	<10	<1	---
ϕ_2	11°	2°	1°	4.5°
ϕ_3	16°	6°	2°	2.4°

Advantage:

LHCb
- Modes where the final states are charged only.
- B_s
- B_c, Λ_b
- …..

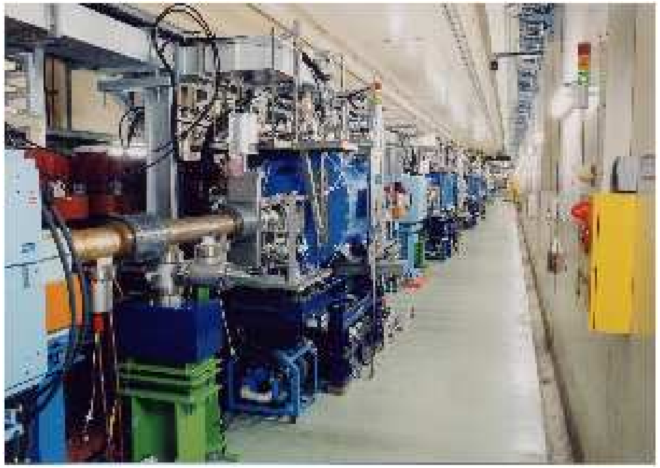
B factories
- Modes with γ, π^0 .
- Modes with ν .
- τ decays.
- K_S vertex.

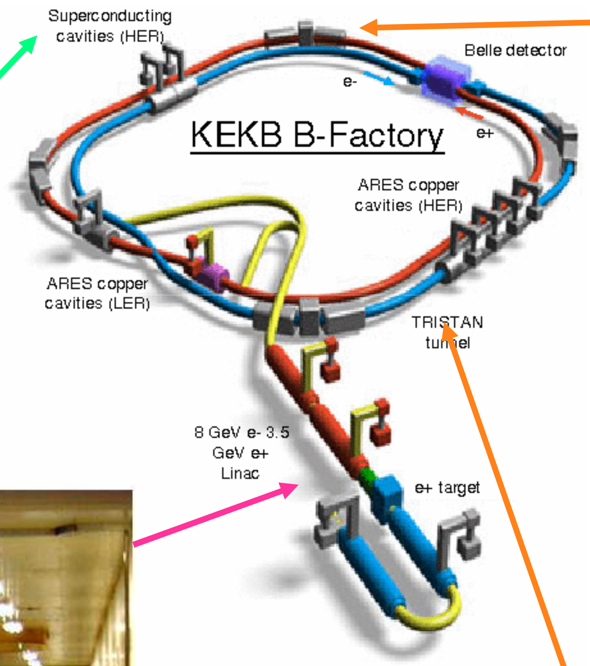
Summary

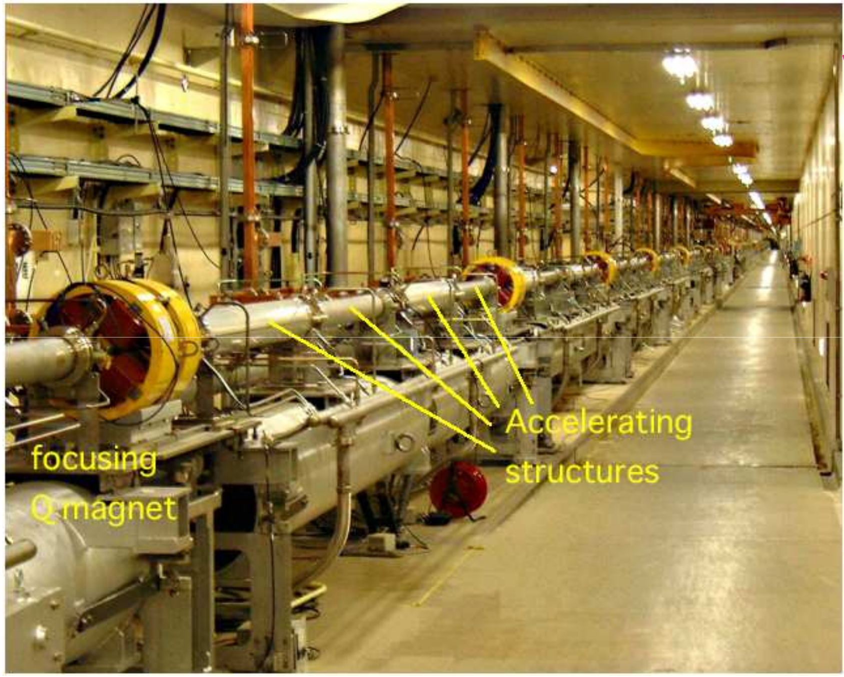
- BaBar/PEP-II and Belle/KEKB discovered the CP violation in B system, and confirmed the CKM mechanism.
  - ✓ The data taking finished.
- Focus on the search and study of the NP.
  - ✓ CPV in $b \rightarrow s$ penguins: now consistent with $\sin 2\phi_1$
  - ✓ $b \rightarrow s\gamma$ and $b \rightarrow s\ell\ell$: interesting results on A_{FB} for $K^*\ell\ell$.
  - ✓ Tauonic B decays: limit on charged Higgs mass.
  - ✓ And many other results.
- Now it is time to upgrade the B factories to “Super B factories”, which will provide ~2 orders of magnitude higher luminosity.
  - ✓ SuperKEKB (with BelleII detector) and SuperB.
- B factories have been leading and will continue to lead the flavour physics, which is complementary to the energy frontier experiments (LHC).

Backup

KEK




Superconducting cavities (HER)
Belle detector
e-
KEKB B-Factory
e+
ARES copper cavities (HER)
ARES copper cavities (LER)
TRISTAN tunnel
8 GeV e- 3.5 GeV e+ Linac
e+ target


Accelerating structures
focusing Q magnet

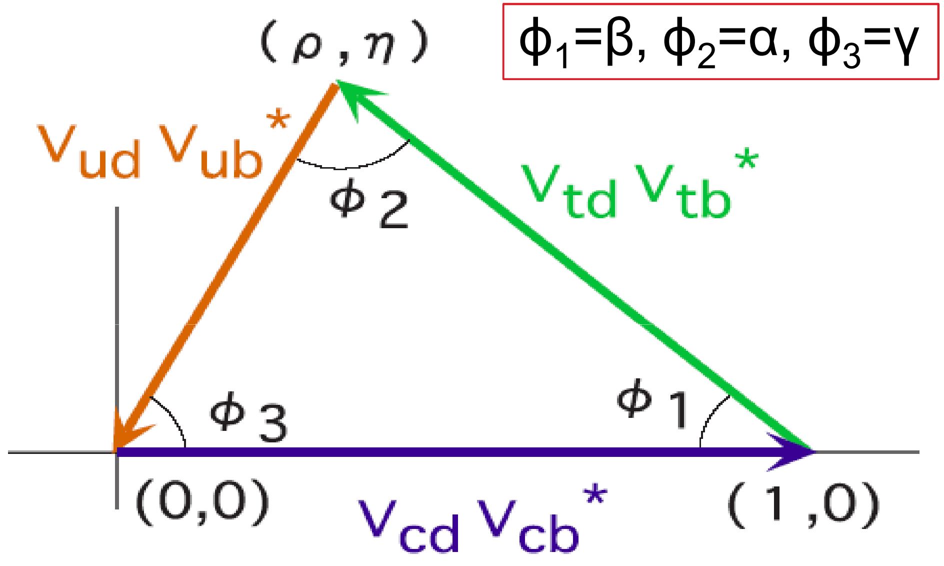
Unitarity Matrix

CKM matrix is unitary:

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

- This relation becomes a triangle in the complex plane = Unitarity Triangle
- Other triangles tend to be "collapsed".
- Non-zero ϕ_1 or ϕ_3
  = Complex phase in the CKM matrix
  = Strong support of KM mechanism.

$\phi_1=\beta,\ \phi_2=\alpha,\ \phi_3=\gamma$



$$V=\begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} = \begin{pmatrix} 1-\lambda^2/2 & \lambda & A\lambda^3(\rho-i\eta) \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

- Precise measurement of Unitarity Triangle is one of the main goal of B factory experiments.
- Various B decay modes can be used to measure the angles and sides of the triangle.

Nobel Prize

2008 Nobel Prize in Physics

Makoto Kobayashi
Toshihide Maskawa

for the discovery of the origin of the broken symmetry which predicts the existence of at least three families of quarks in nature

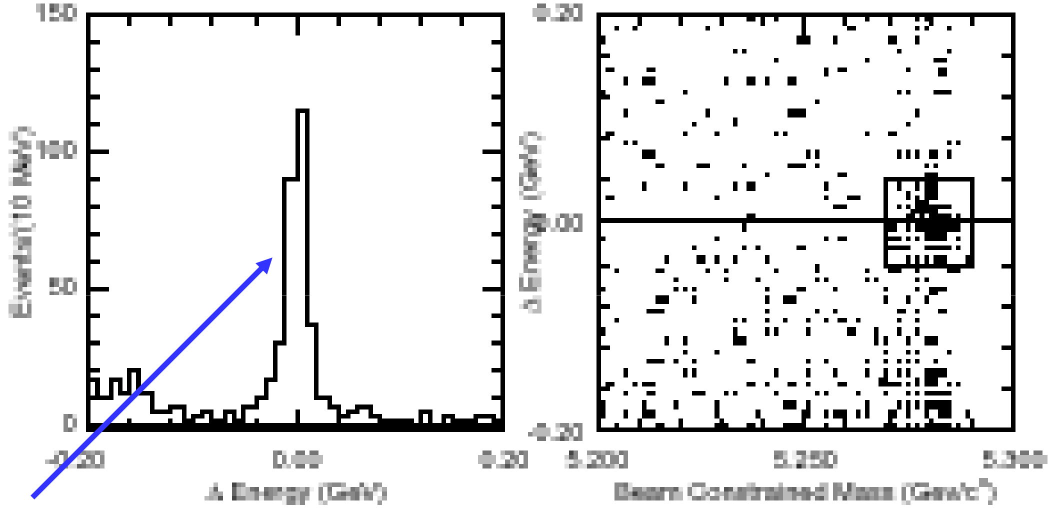
CP Violation

The spontaneous broken symmetries that Nambu studied, differ from the broken symmetries described by **Makoto Kobayashi** and **Toshihide Maskawa**. These spontaneous occurrences seem to have existed in nature since the very beginning of the universe and came as a complete surprise when they first appeared in particle experiments in 1964. It is only in recent years that scientists have come to fully confirm the explanations that Kobayashi and Maskawa made in 1972. It is for this work that they are now awarded the Nobel Prize in Physics. They explained broken symmetry within the framework of the Standard Model, but required that the Model be extended to three families of quarks. These predicted, hypothetical new quarks have recently appeared in physics experiments. As late as 2001, the two particle detectors BaBar at Stanford, USA and Belle at Tsukuba, Japan, both detected broken symmetries independently of each other. The results were exactly as Kobayashi and Maskawa had predicted almost three decades earlier.

Press release by the Royal Swedish Academy of Science

B Reconstruction

Utilize special kinematics at $\Upsilon(4S)$

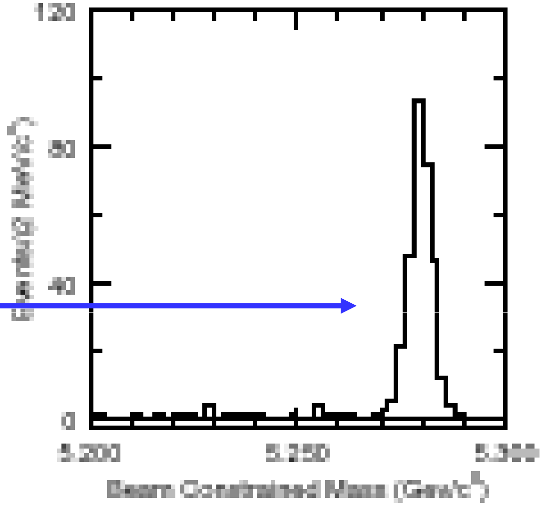


Energy difference:

$$\Delta E \equiv E_{J/\psi} + E_{K_S} - E_{CM}/2$$

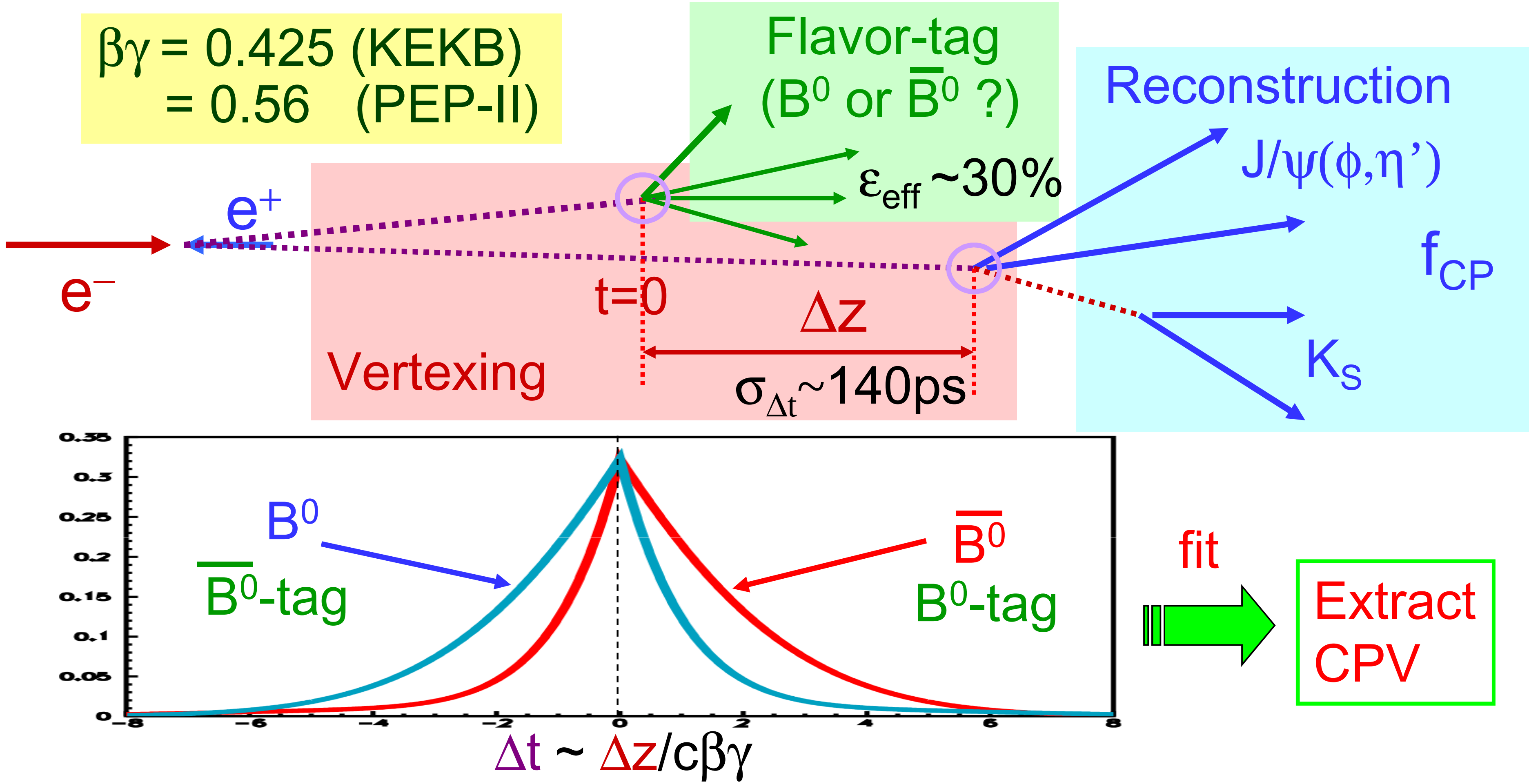
Beam-constrained mass:

$$M_{\rm bc} = \sqrt{(E_{CM}/2)^2 - (\vec{p}_{J/\psi} + \vec{p}_{K_S})^2}$$



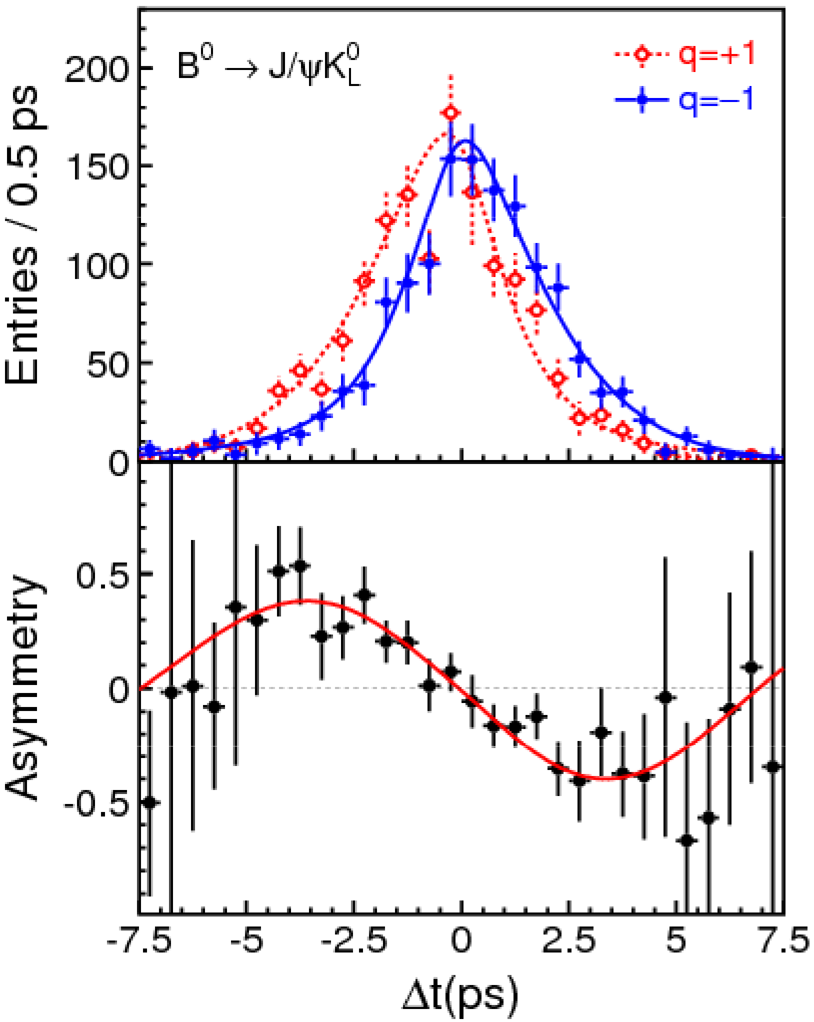
Asymmetric Collider

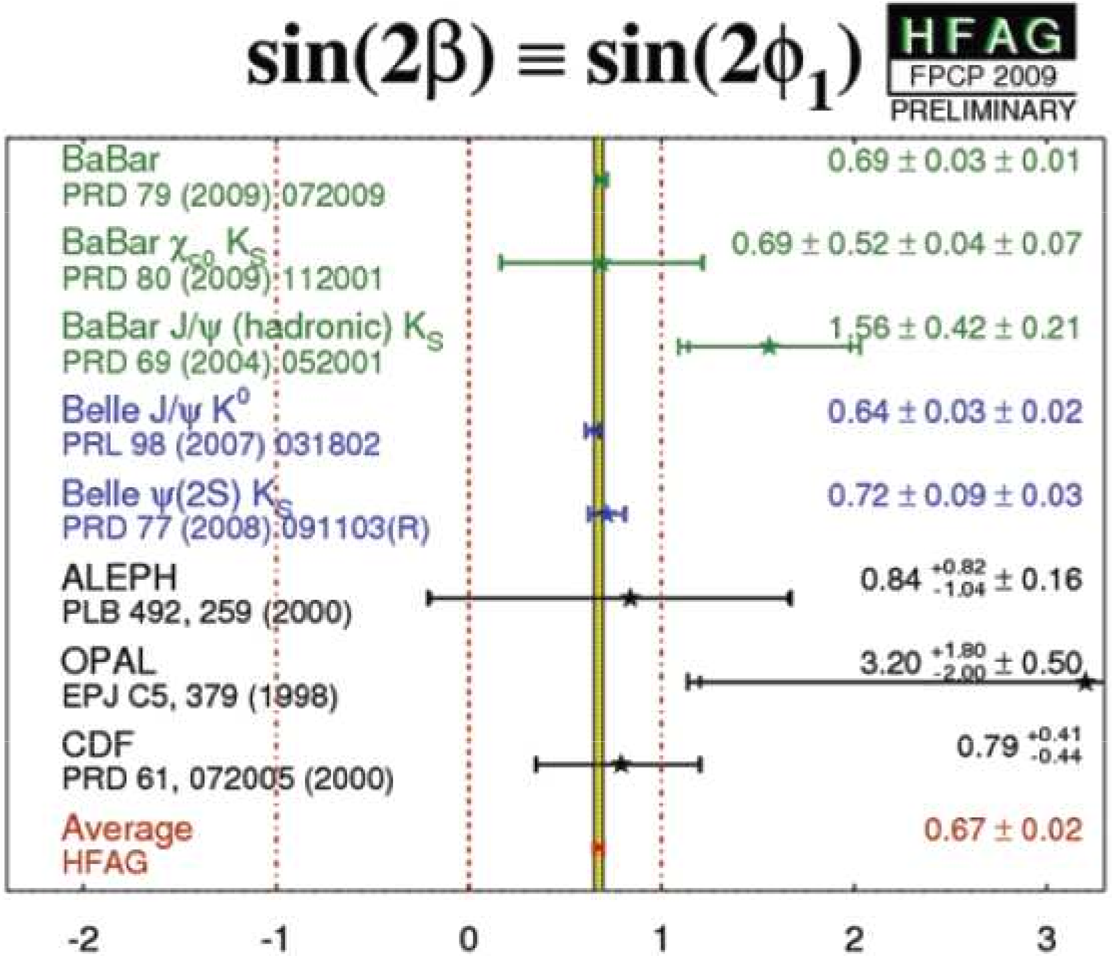
- Asymmetric energy to study time-dependent CP Violation (tCPV)
- Measure position instead of time (B lifetime ~1.6ps)



Measurement of sin2ϕ_1

Belle J/ψ K_L





$B \to X_s \gamma$

Three methods for inclusive analysis for $B \to X_s \gamma$.

Fully inclusive

- Subtract the on-resonance photon energy spectrum by the continuum spectrum.
- Free from the model uncertainty of hadronic system (X_s).
- Generally, has large backgrounds.
- Lepton tag is sometimes used for background suppression and flavor tagging.

Sum of exclusive modes (semi-inclusive; pseudo-reconstruction).

- Reconstruct hadronic system (X_s) as a sum of exclusive modes.
- Signal is cleaner than using the fully inclusive method.
- Model uncertainty of hadronic system; missing modes.
- Separation of X_s and X_d.

Recoil tag (full reconstruction).

- Fully reconstruct the other side B.
- Very low efficiency (<1%), but very clean (continuum bkg becomes negligible).
- Measurement in B frame. Access to flavor information etc.

$B \to X_s \gamma$

Status of $\mathcal{B}(B \to X_s \gamma)$

Mode	$\mathcal{B}$	E_{min}	$\mathcal{B}(E_\gamma > E_{min})$	$\mathcal{B}^{cnv}(E_\gamma > 1.6)$
CLEO Inc. [3]	$321 \pm 43 \pm 27^{+18}_{-10}$	2.0	$306 \pm 41 \pm 26$	$327 \pm 44 \pm 28 \pm 6$
Belle Semi.[4]	$336 \pm 53 \pm 42^{+50}_{-54}$	2.24	–	$369 \pm 58 \pm 46^{+56}_{-60}$
BABAR Semi.[6]	$335 \pm 19^{+56+4}_{-41-9}$	1.9	$327 \pm 18^{+55+4}_{-40-9}$	$349 \pm 20^{+59+4}_{-46-3}$
BABAR Inc. [7]	–	1.9	$367 \pm 29 \pm 34 \pm 29$	$390 \pm 31 \pm 47 \pm 4$
BABAR Full [8]	$391 \pm 91 \pm 64$	1.9	$366 \pm 85 \pm 60$	$389 \pm 91 \pm 64 \pm 4$
Belle Inc.[5]	–	1.7	$345 \pm 15 \pm 40$	$347 \pm 15 \pm 40 \pm 1$
Average				$355 \pm 24 \pm 9$

fully inclusive (CLEO Inc., *BABAR* Inc., Belle Inc.)

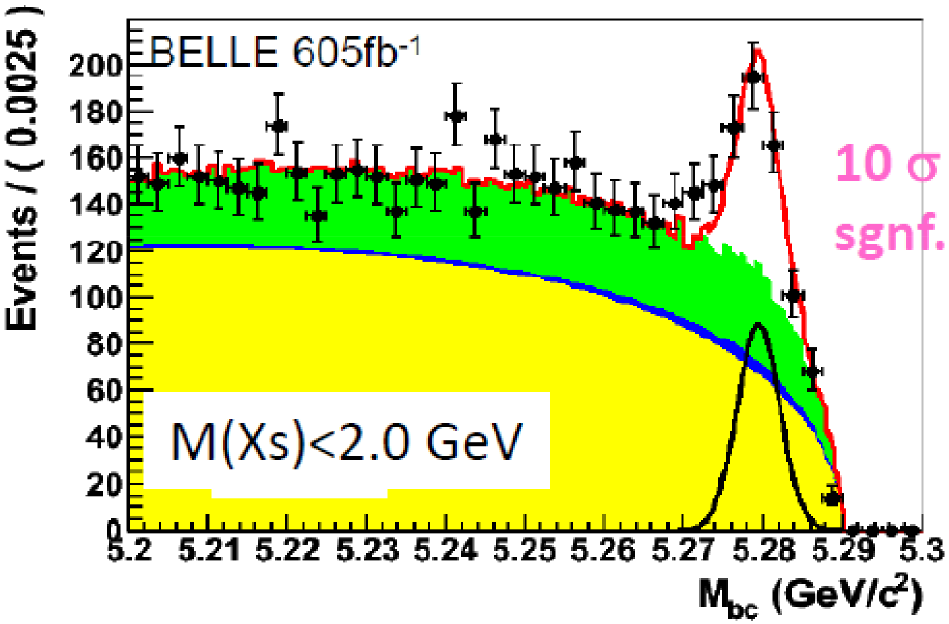
sum of exclusive (Belle Semi., *BABAR* Semi.)

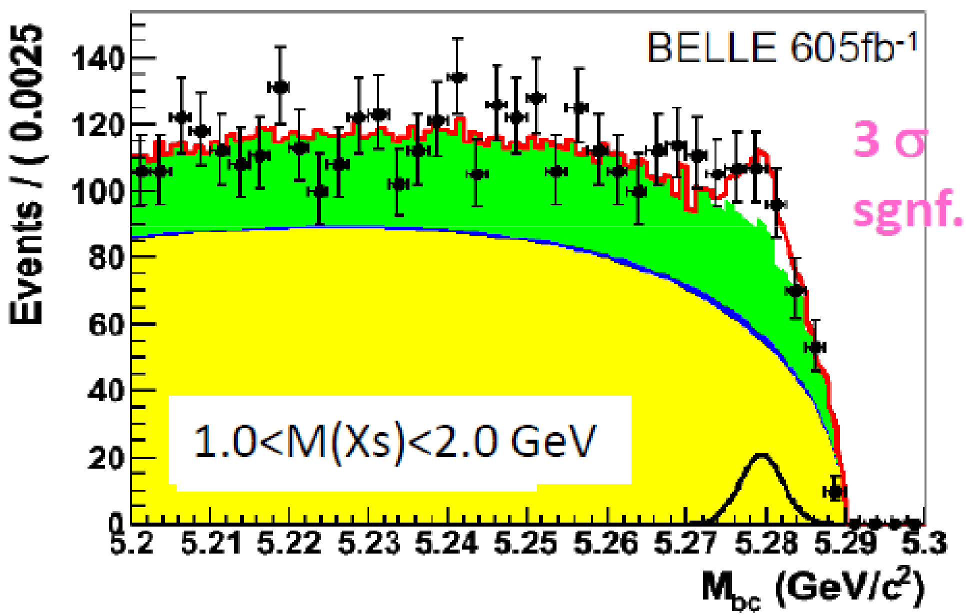
recoil tag (*BABAR* Full)

c.f.) theory $\mathcal{B}(B \to X_s \gamma) = (3.15 \pm 0.23) \times 10^{-4}$

Belle 605 fb^{-1} result

[LP09]





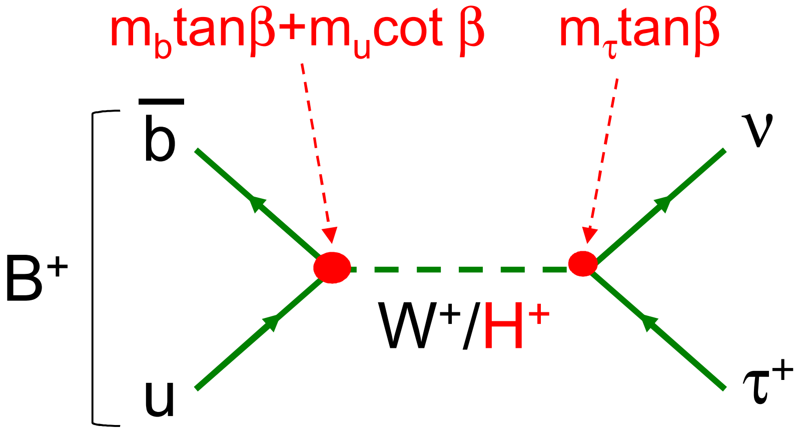
238.3 ± 26.4 ± 2.3 events

$$\mathcal{B}(B \to X_s \ell^+ \ell^-) = (3.33 \pm 0.80 \,^{+0.19}_{-0.24}) \times 10^{-6}$$

c.f.) SM (Ali et al): $\mathcal{B}_{\rm SM} = (4.2 \pm 0.7) \times 10^{-6}$

C_7 sign-flip (Gambino et al): $\mathcal{B}_{C_7>0} = (8.8 \pm 1.0) \times 10^{-6}$

$B\to\tau\nu$



$$\mathcal{B}(B\to\tau\nu)=\mathcal{B}(B\to\tau\nu)_{\rm SM}\times r_H$$

$$r_H=\left(1-\frac{m_B^2}{m_H^2}\tan^2\beta\right)^2$$

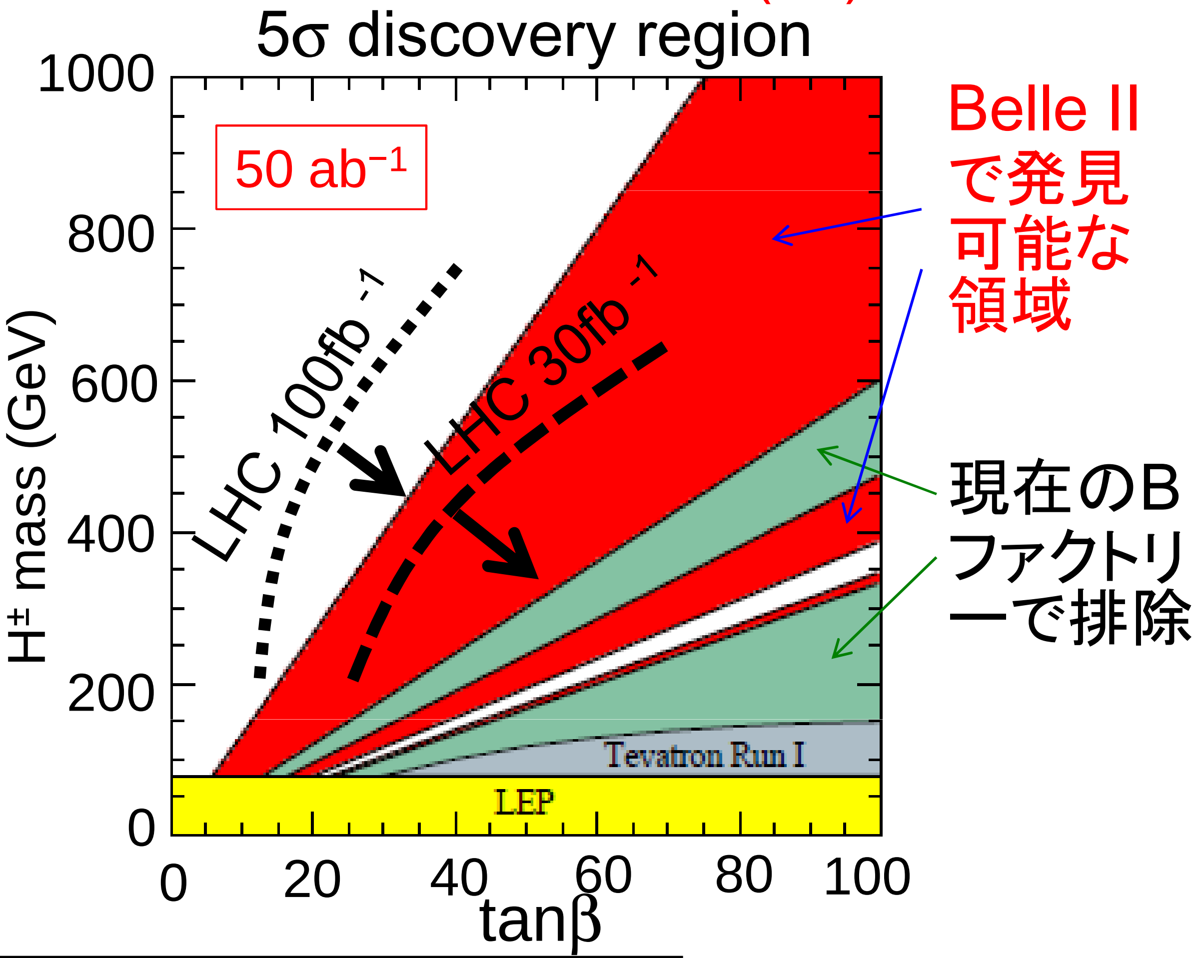
$B(B\to\tau\nu) = (1.53\pm0.33)\times10^{-4}$

[ICHEP2008]

σ ~ 2% @50 ab^{-1}

f_B と $|V_{ub}|$ の誤差を数%まで減らすことが重要（右図はともに 2.5% を仮定）

- 標準模型では W-消滅過程
- SUSYでは荷電ヒッグス(H^+)の寄与



b-H^+-u 結合を測定する唯一の手段

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

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

SM: penguin+box

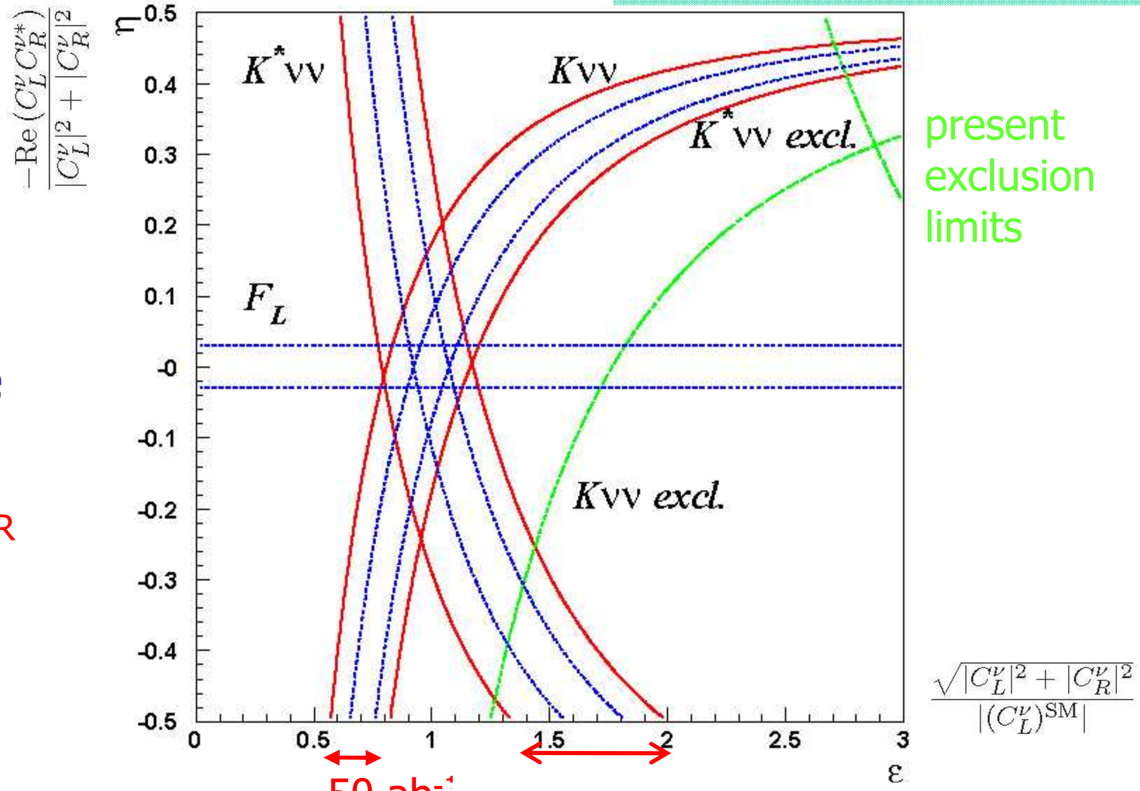
Look for departure from the expected value → information on couplings C^ν_R and C^ν_L compared to $(C^\nu_L)^{SM}$

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

arXiv:1002.5012

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

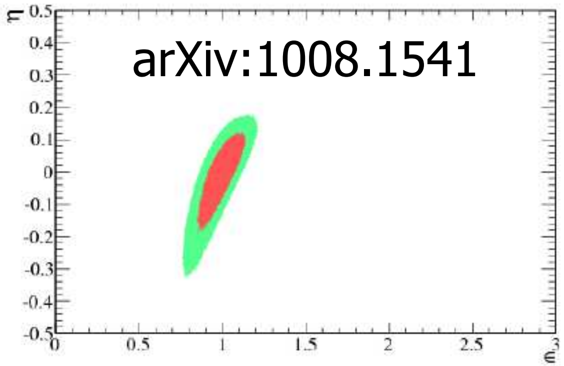
↔ Theory



present exclusion limits

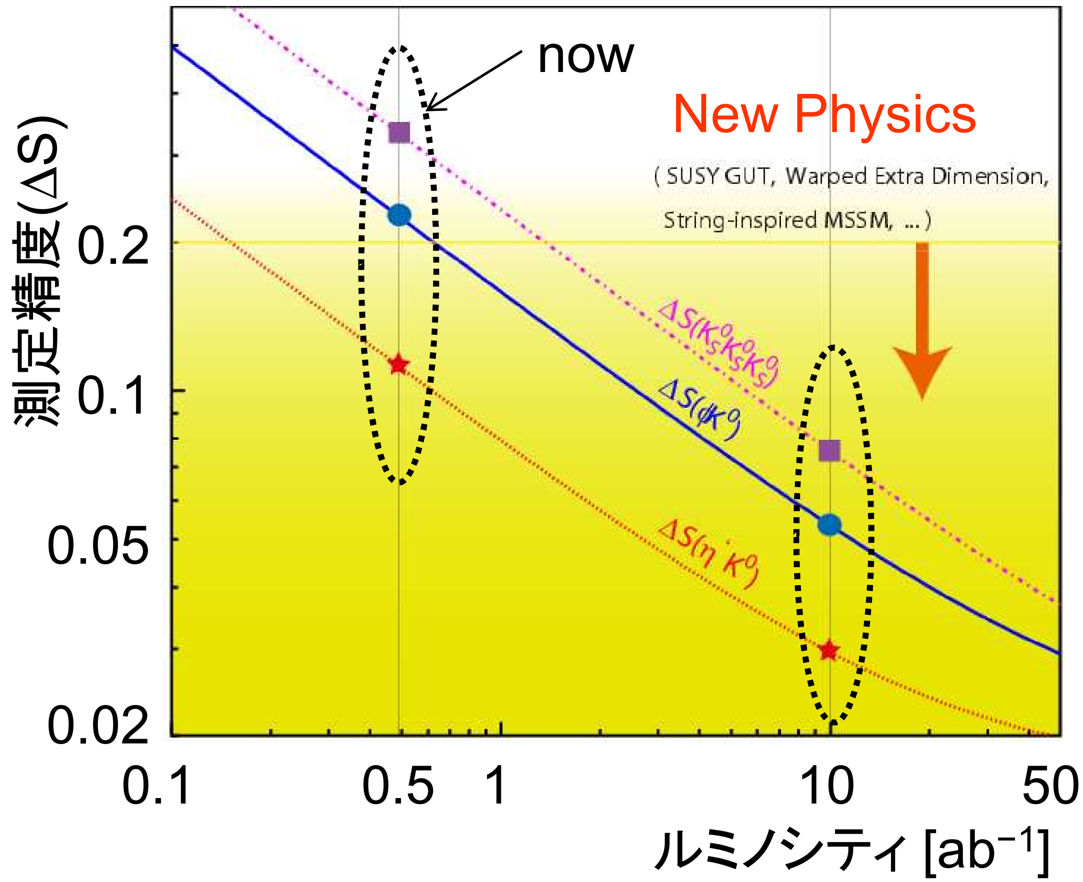
50 ab^{-1}

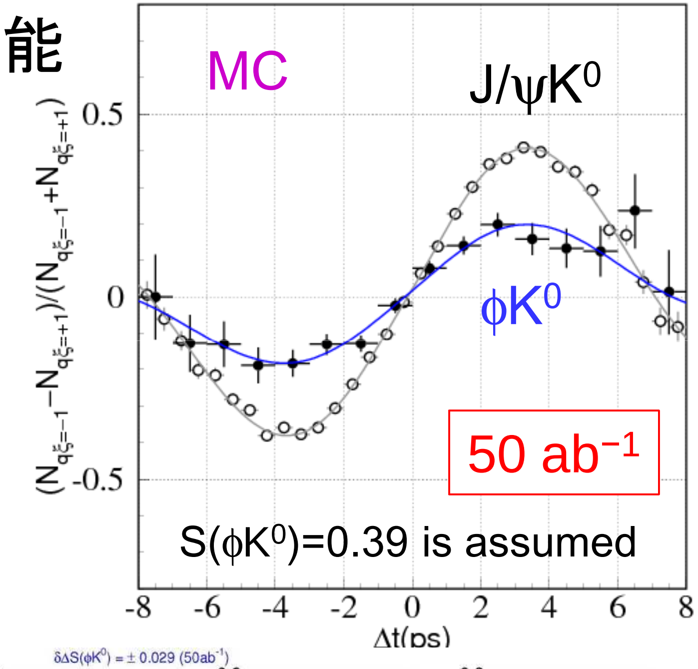
arXiv:1008.1541

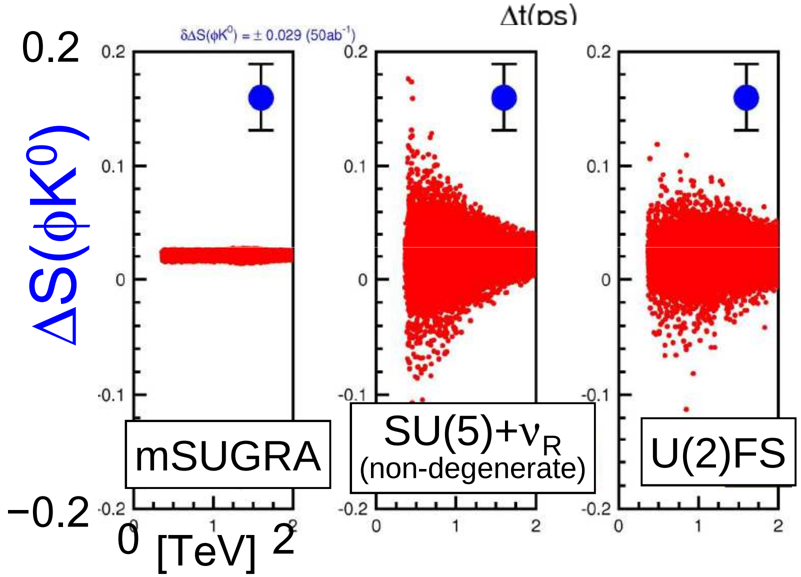


CP Violation in b→s

10-50 ab^{-1} のデータで O(0.01) の精度で測定可能





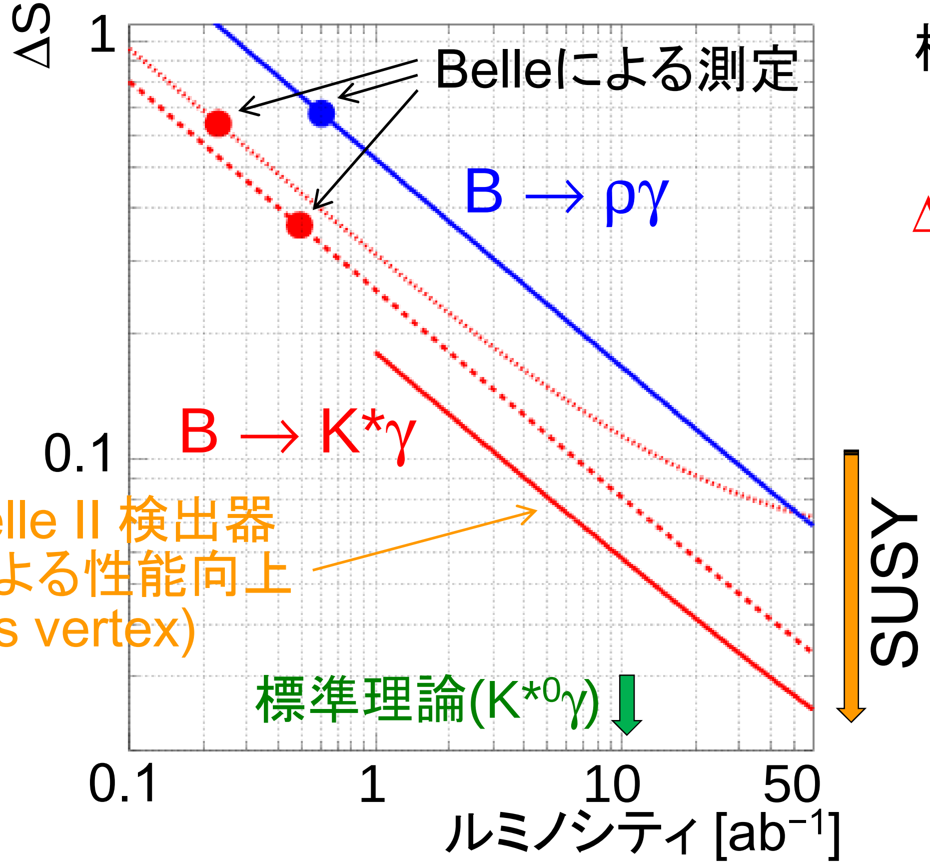


SUSYの模型の識別に用いる情報の一つとして有用

Photon Helicity in b→s(d)γ

- 標準模型では、電弱相互作用は左巻きに作用
  - ✓b→s(d)γ 過程からの光子はほぼ左巻き
- 右巻きのカレントは新物理の信号
  - ✓time-dependent CPV が起こる

Possible deviation from SM
O(1): Warped extra dim.
O(1): L-R symmetric model
O(0.1): SUSY SU(5)

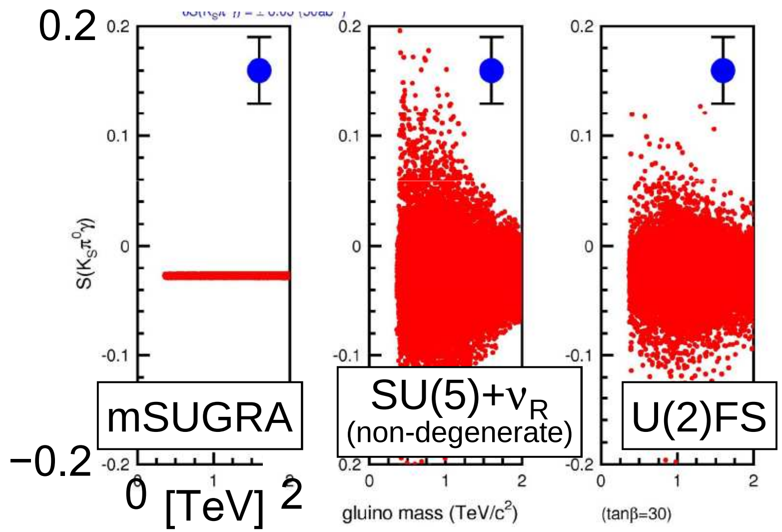


標準理論では

$|S(K^{*0}\gamma)| < 0.02,\ \ S(\rho^0\gamma) \sim 0$

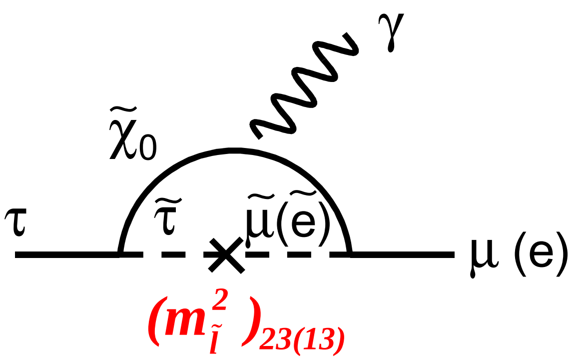
$\Delta S(K^{*0}\gamma) = 0.027$ @ 50 ab^{-1}

$\Delta S(\rho^0\gamma) = 0.075$ @ 50 ab^{-1}



τ LFV

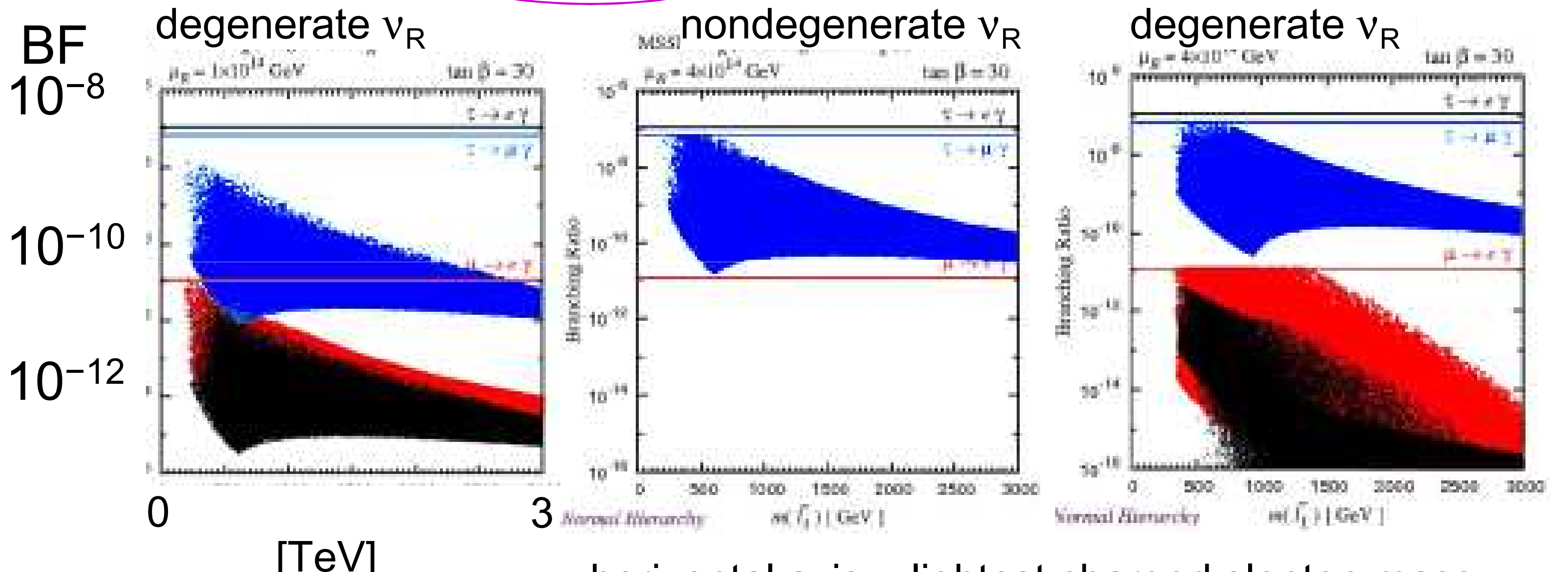
- レプトンフレーバーの破れ(LFV):標準模型では禁止
- 多くの新物理モデルでは予言されている
- Bファクトリーでは、大量の τ 対が作られる
  (τ ファクトリー)。
- τ の崩壊:第3世代と第2(1)世代の混合



クォークセクターには新物理の効果があまり現れないモデル

MSSM + ν_R

SU(5) + ν_R



$\tau \to \mu\gamma$
$\tau \to e\gamma$
$\mu \to e\gamma$

horizontal axis = lightest charged slepton mass

Nano Beam Scheme

Beam-beam parameter

Lorentz factor

Beam current

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

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

Classical electron radius

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

Vertical beta function@IP

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

"Nano-Beam" scheme

Collision with very small spot-size beams

Invented by Pantaleo Raimondi for SuperB

SuperKEKB

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

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

M. Iwasaki, ICHEP2010

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

		Base Line		Low Emittance		High Current		Tau/Charm (prelim.)	
Parameter	Units	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)	HER (e+)	LER (e-)
LUMINOSITY	cm^{-2} s^{-1}	1.00E+36		1.00E+36		1.00E+36		1.00E+35	
Energy	GeV	6.7	4.18	6.7	4.18	6.7	4.18	2.58	1.61
Circumference	m	1258.4		1258.4		1258.4		1258.4	
X-Angle (full)	mrad	66		66		66		66	
Piwinski angle	rad	22.88	18.60	32.36	26.30	14.43	11.74	8.80	7.15
β_x @ IP	cm	2.6	3.2	2.6	3.2	5.06	6.22	6.76	8.32
β_y @ IP	cm	0.0253	0.0205	0.0179	0.0145	0.0292	0.0237	0.0658	0.0533
Coupling (full current)	%	0.25	0.25	0.25	0.25	0.5	0.5	0.25	0.25
ε_x (without IBS)	nm	1.97	1.82	1.00	0.91	1.97	1.82	1.97	1.82
ε_x (with IBS)	nm	2.00	2.46	1.00	1.23	2.00	2.46	5.20	6.4
ε_y	pm	5	6.15	2.5	3.075	10	12.3	13	16
σ_x @ IP	μm	7.211	8.872	5.099	6.274	10.060	12.370	18.749	23.076
σ_y @ IP	μm	0.036	0.036	0.021	0.021	0.054	0.054	0.092	0.092
Σ_x	μm	11.433		8.085		15.944		29.732	
Σ_y	μm	0.050		0.030		0.076		0.131	
σ_L (0 current)	mm	4.69	4.29	4.73	4.34	4.03	3.65	4.75	4.36
σ_L (full current)	mm	5	5	5	5	4.4	4.4	5	5
Beam current	mA	1892	2447	1460	1888	3094	4000	1365	1766
Buckets distance	#	2		2		1		1	
Ion gap	%	2		2		2		2	
RF frequency	Hz	4.76E+08		4.76E+08		4.76E+08		4.76E+08	
Harmonic number		1998		1998		1998		1998	
Number of bunches		978		978		1956		1956	
N. Particle/bunch		5.08E+10	6.56E+10	3.92E+10	5.06E+10	4.15E+10	5.36E+10	1.83E+10	2.37E+10
Tune shift x		0.0021	0.0033	0.0017	0.0025	0.0044	0.0067	0.0052	0.0080
Tune shift y		0.0970	0.0971	0.0891	0.0892	0.0684	0.0687	0.0909	0.0910
Long. damping time	msec	13.4	20.3	13.4	20.3	13.4	20.3	26.8	40.6
Energy Loss/turn	MeV	2.11	0.865	2.11	0.865	2.11	0.865	0.4	0.166
σ_E (full current)	dE/E	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.43E-04	7.34E-04	6.94E-04	7.34E-04
CM σ_E	dE/E	5.00E-04		5.00E-04		5.00E-04		5.26E-04	
Total lifetime	min	4.23	4.48	3.05	3.00	7.08	7.73	11.41	6.79
Total RF Power	MW	17.08		12.72		30.48		3.11	

Tau/charm threshold running at 10^{35}

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

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

RF power includes SR and HOM

M. Giorgi, ICHEP2010

Interest of running @ threshold

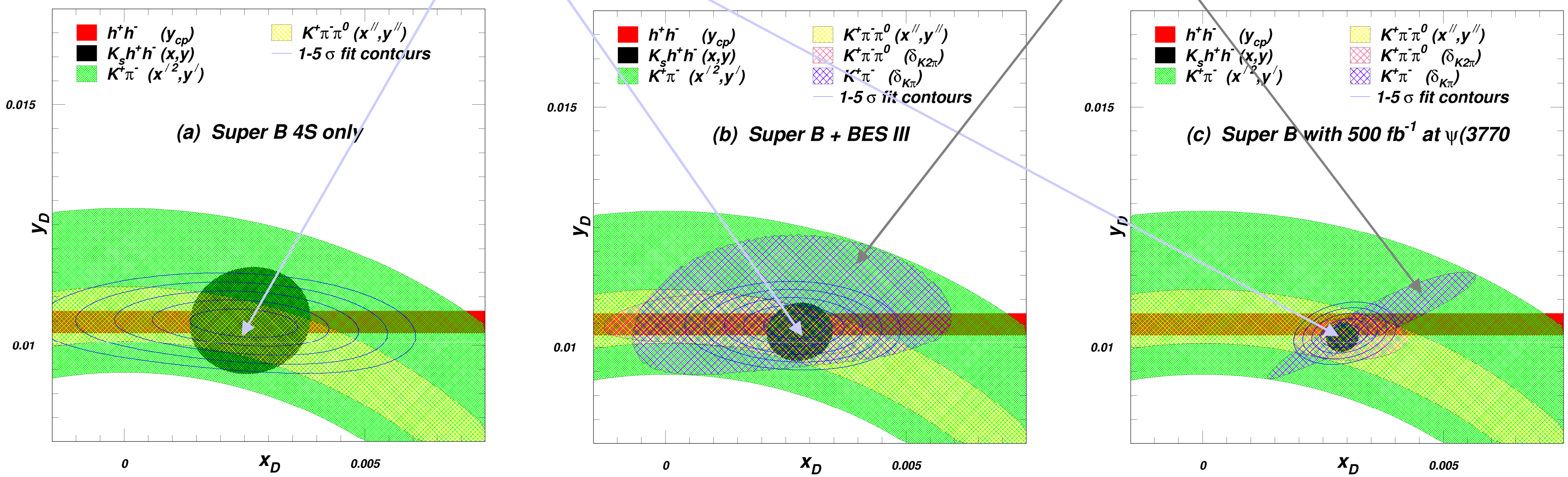
M. Giorgi, ICHEP2010

500/fb at $\psi(3770)$

Decays of $\psi(3770) \rightarrow D^0 D^0$ produce coherent *(C=-1)* pairs of D^0's. Quantum correlations in their subsequent decays allow measurements of strong phases

- Required for improved measurement of CKM γ
- Also required for D^0 mixing studies

- Dalitz plot model uncertainty shrinks
- Information on overall strong phase is added



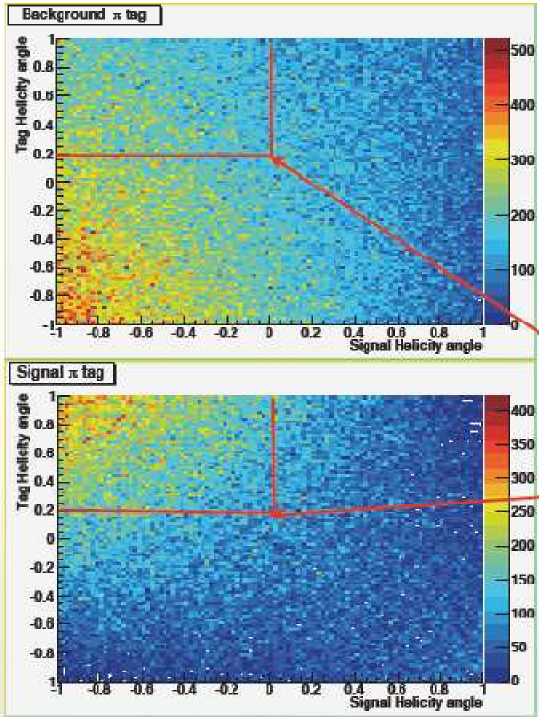
Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K^+\pi^-}$	$\delta^\circ_{K^+\pi^-\pi^0}$
(b)	$xxx^{+0.72}_{-0.75}$	$xxx \pm 0.19$	$xxx^{+3.7}_{-3.4}$	$xxx^{+4.6}_{-4.5}$
Stat.	(0.18)	(0.11)	(1.3)	(2.9)

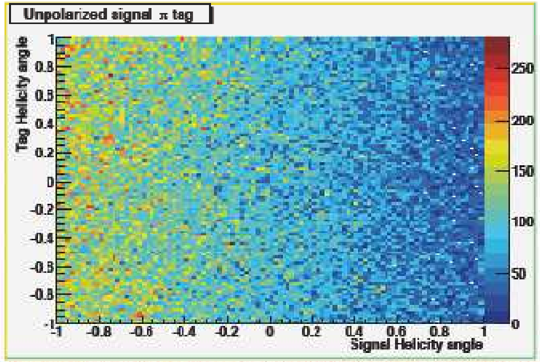
Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K^+\pi^-}$	$\delta^\circ_{K^+\pi^-\pi^0}$
(c)	$xxx \pm 0.42$	$xxx \pm 0.17$	$xxx \pm 2.2$	$xxx^{+3.3}_{-3.4}$
Stat.	(0.18)	(0.11)	(1.3)	(2.7)

Fit	$x \times 10^3$	$y \times 10^3$	$\delta^\circ_{K^+\pi^-}$	$\delta^\circ_{K^+\pi^-\pi^0}$
(d)	$xxx \pm 0.20$	$xxx \pm 0.12$	$xxx \pm 1.0$	$xxx \pm 1.1$
Stat.	(0.17)	(0.10)	(0.9)	(1.1)

Uncertainty in x_D improves more than that of y_D

Polarized beam helps to reduce irreducible background in tau decays

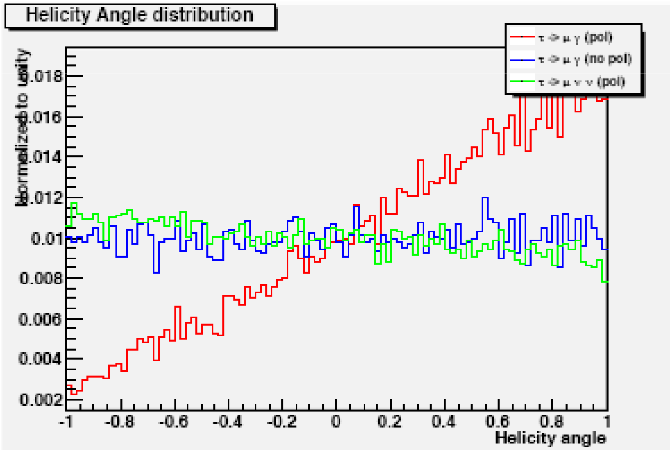




75 ab^{-1}

arXiv:1008.1541v1 [hep-ex]

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



$B(\tau \to \mu\gamma)$ $2\times 10-9$

$B(\tau \to e\,\gamma)$ $2\times 10-9$

→

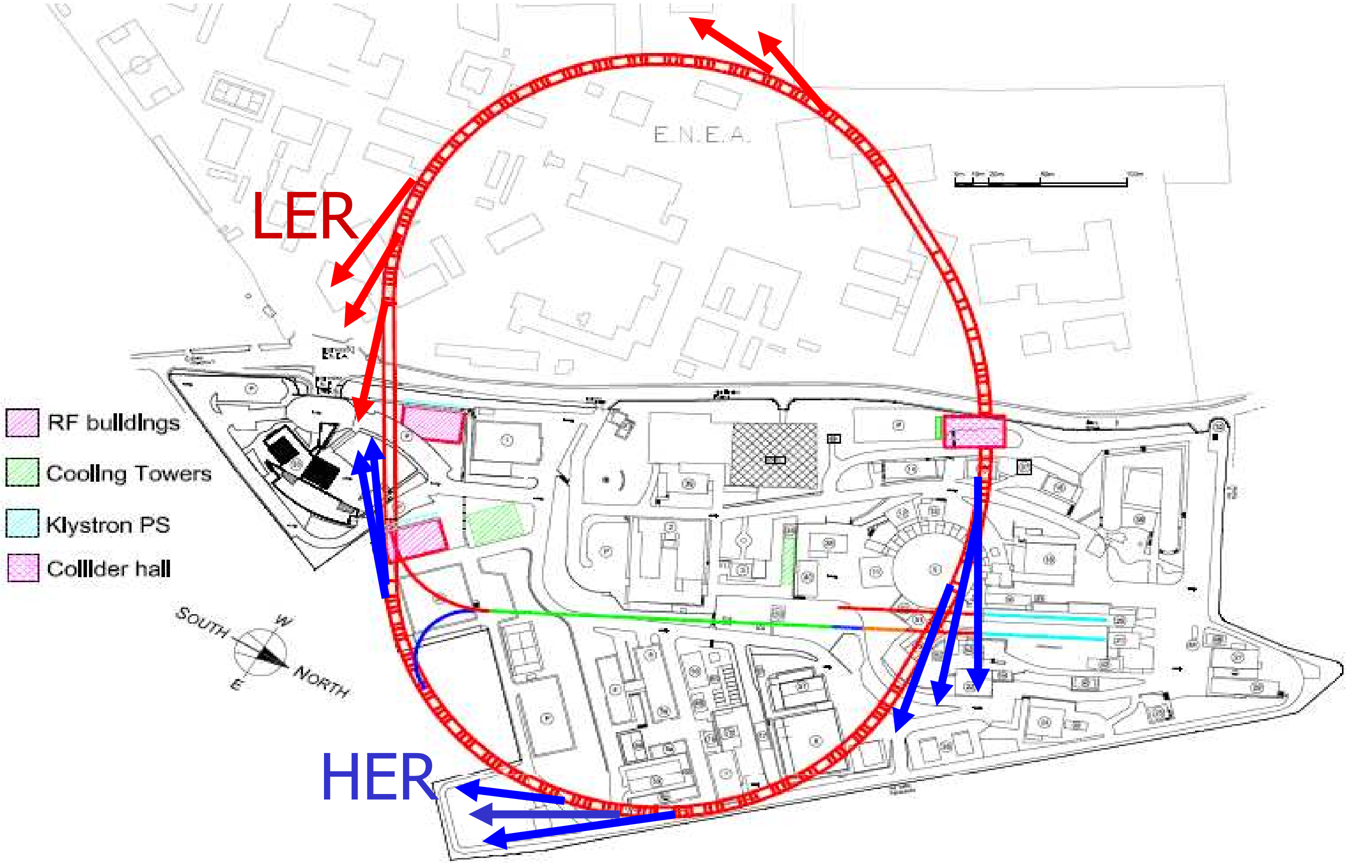
$B(\tau \to \mu\gamma)$ $1\times 10-9$

$B(\tau \to e\,\gamma)$ $1\times 10-9$

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

M. Giorgi, ICHEP2010

Machine layout with Photon Beam Lines



No impediment caused by the photon operation is seen so far to prevent design operations of SuperB for HEP.

M. Giorgi, ICHEP2010

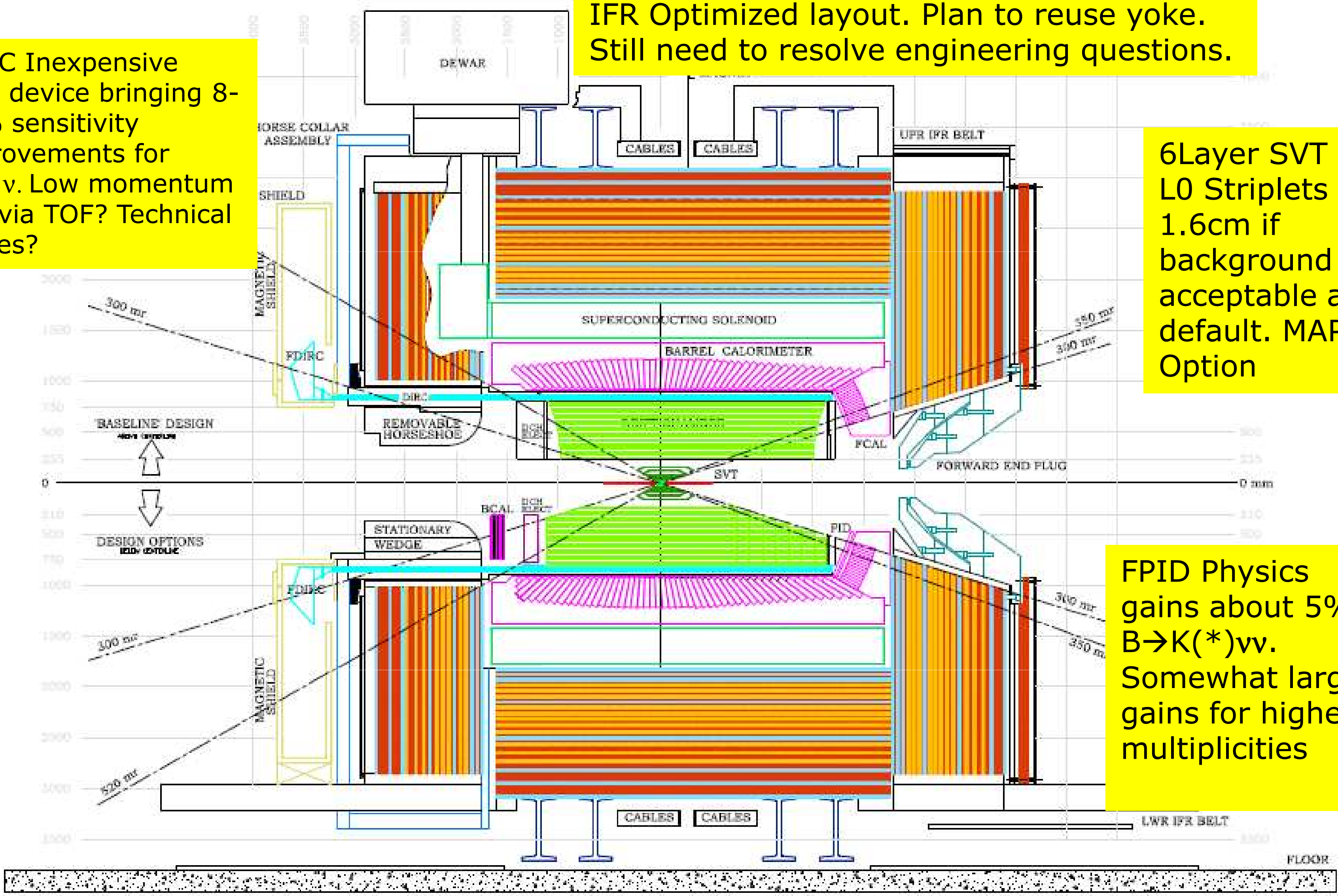
SuperB Detector (with options)

BEMC Inexpensive Veto device bringing 8-10% sensitivity improvements for B→τ ν. 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→K(*)νν. Somewhat larger gains for higher multiplicities



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Towards green light

- The project is the first “flagship project” of the new national research plan
- The project has been mentioned as a reciprocity condition in a Russian-Italian agreement on ignitor (nuclear fusion)

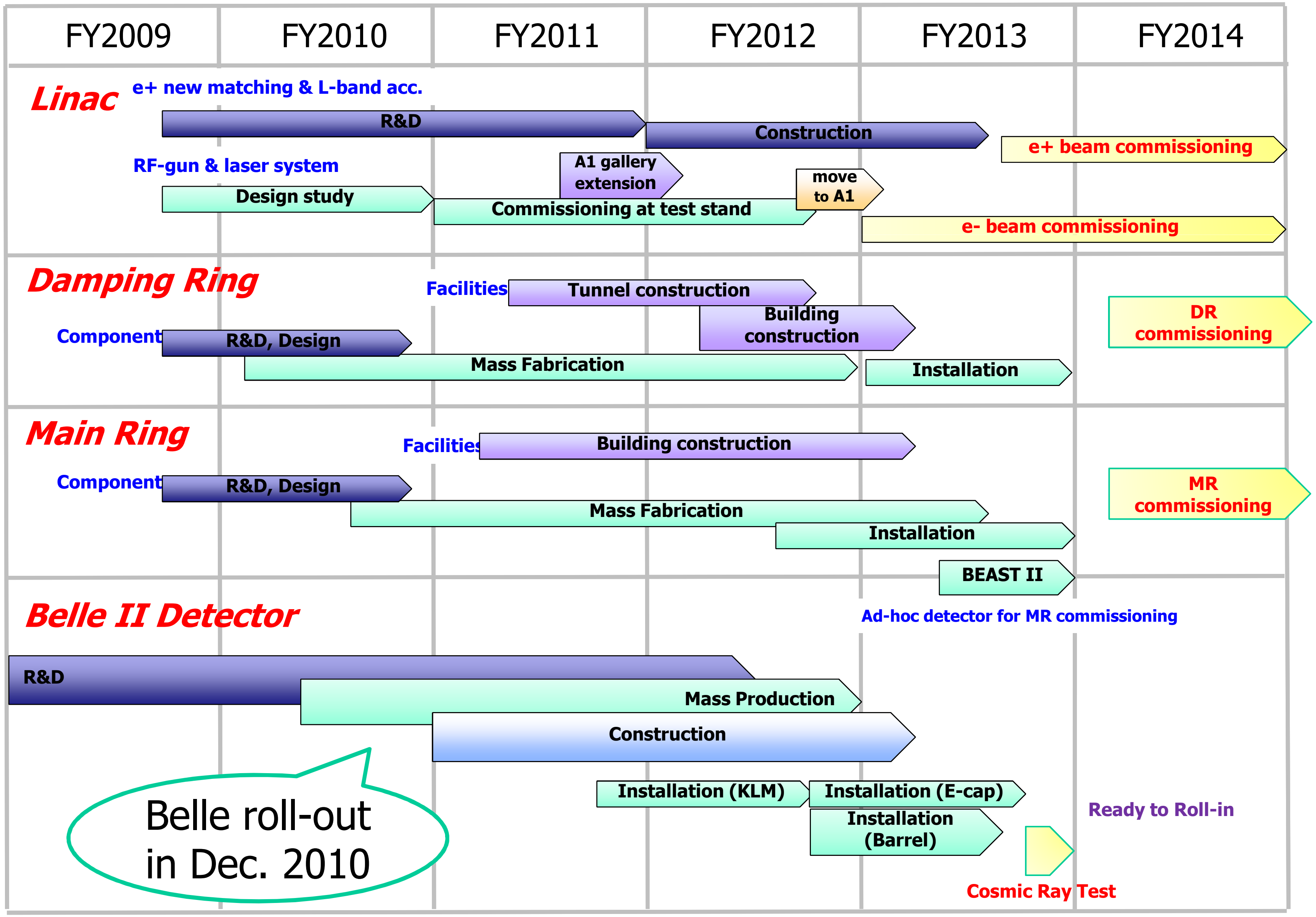
•A formal commitment with INFN for the project with the declaration of some available budget in the current year is expected.

•This commitment will set the start of the project.

M. Giorgi, ICHEP2010

Construction Schedule of SuperKEKB/Belle II

Jun. 24, 2010



SuperKEKB: Major items for upgrade

- New Ante-chamber beam pipes

Mitigation techniques for suppression of the electron cloud.

- New IR design

New superconducting/permanent magnets around IP.

Optimization of the compensation solenoid.

Local chromaticity correction sections for both rings.

- New low emittance optics for both e^+e^- rings

Replace dipoles & change the wiggler layout for positron ring

- New low emittance beam injections

New damping ring and target for positrons / New RF gun for electrons

- Higher beam currents

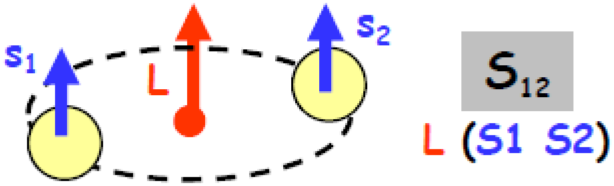
Add / modify the RF systems

- Precise beam diagnostics and tunings

More precise magnet setting ⇔ power supplies.

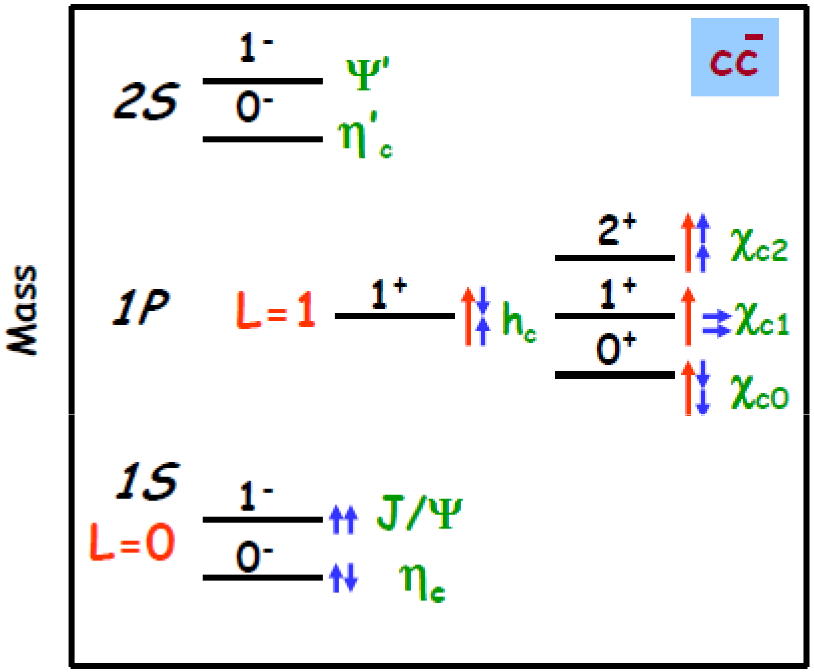
M. Iwasaki, ICHEP2010

Charmonium spectroscopy



Potential models, energy splitting

Energy splitting: singlet and triplet.

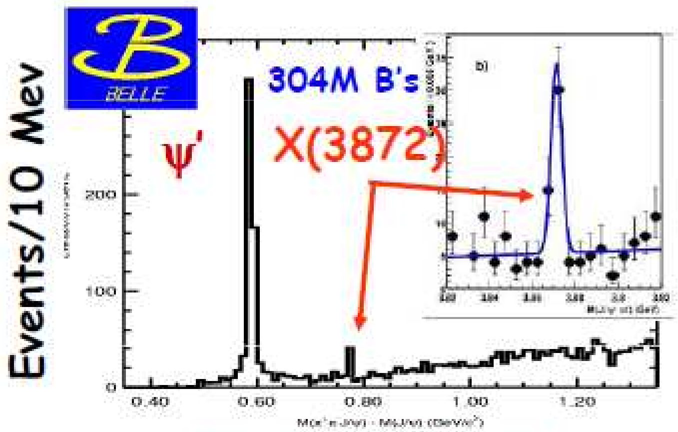


Potential models predict masses of conventional states with fixed quantum numbers.

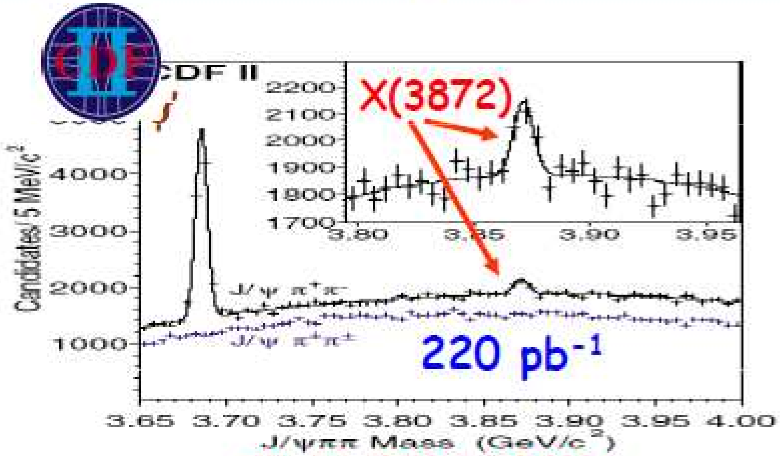
Generally, accuracy of mass predictions should not exceed few tens of MeV/c^2.

$X(3872) \to J/\psi\ \pi^+\pi^-$ decay

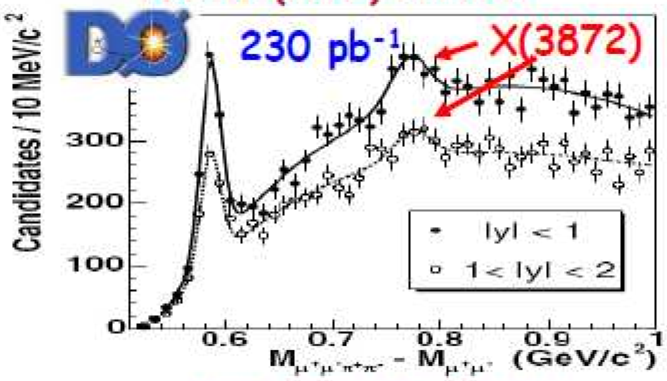
First observed by Belle in $B^\pm \to K^\pm (J/\psi\pi^+\pi^-)$. Then confirmed by CDF, D0 and BaBar.



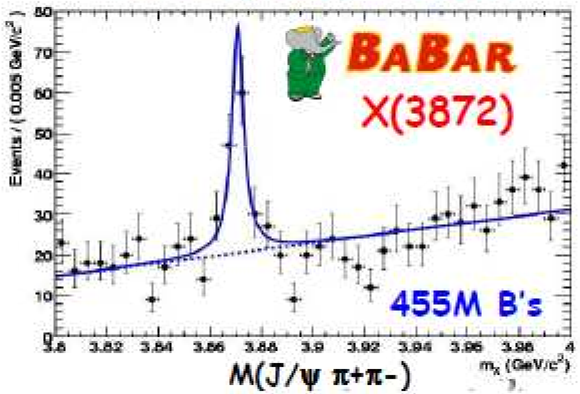
PRL 91 (2003) 262001



PRL 93 (2004) 072001

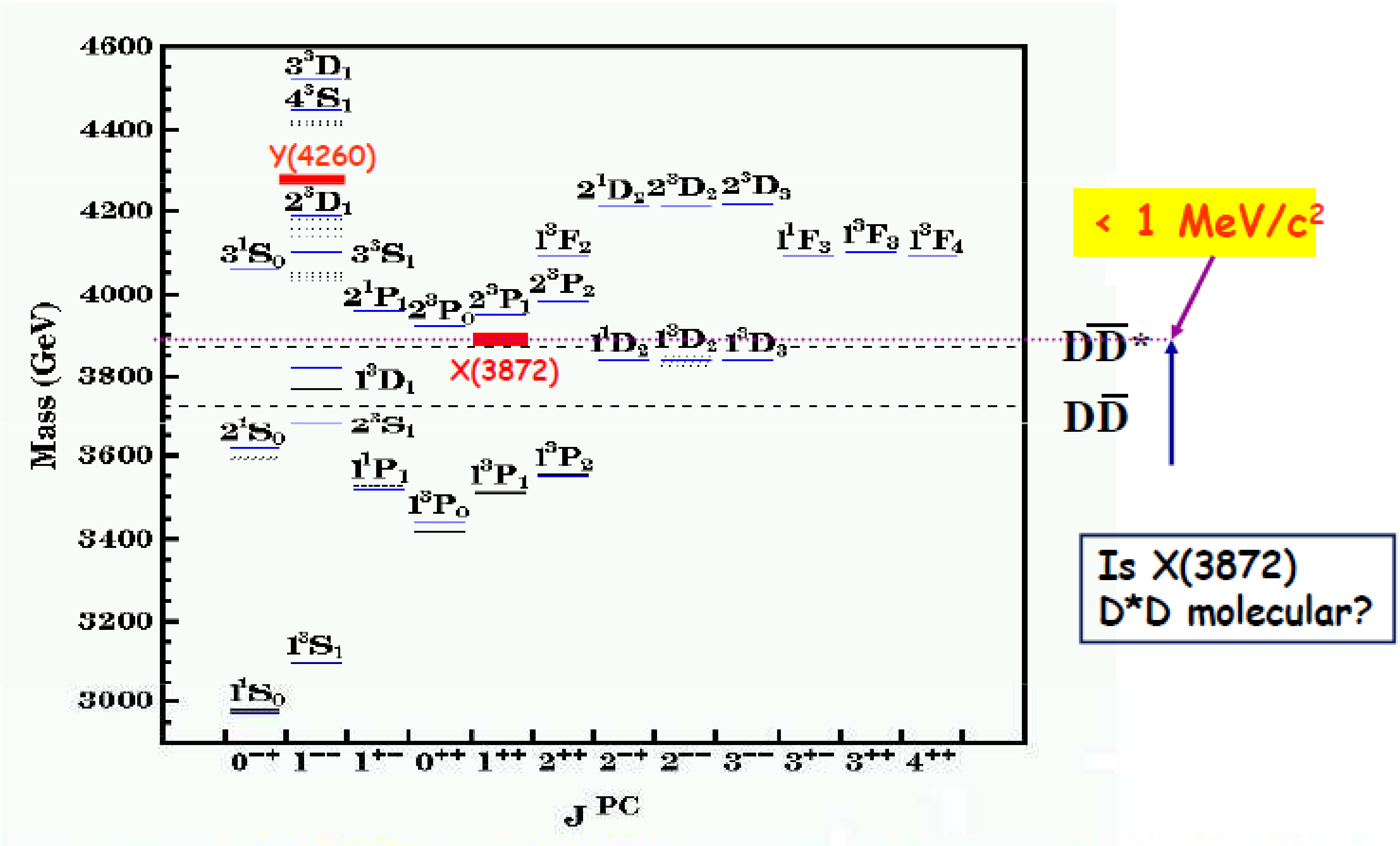


PRL 93 (2004) 162002



PRD 77 (2008) 111101

X(3872) interpretation ?



Is X(3872) D*D molecular?

Interpretations of X(3872) and X(4260) are unclear. Most popular for X(3872) is molecular interpretation (X(3872)-> $J/\psi\,\gamma$ branching fraction is small for 1++ χ'_{c1}).

Conventional and unconventional mesons

1. Conventional quark-antiquark mesons ($q\bar{q}$).
2. Glueballs (gg, ggg). Lightest glueballs $J^{PC} = 0^{++}$ and 2^{++}.
3. Hybrid mesons ($q\bar{q}g$). Ground states $J^{PC} = 0^{-+}, 1^{-+}, 1^{--}, 2^{-+}$.
4. Tetraquarks ($q\bar{q}q\bar{q}$). Large binding energy. Non-$\bar{q}q$ flavor?
5. Molecular states ($q\bar{q}$ $\bar{q}q$). Small binding energy. Deuteron-like.
6. Mixture of these states. Small admixture of exotic state.

Exotic states can be separated using information on masses, widths, quantum numbers, production and decay modes (rates).

Theoretical calculations, potential models, lattice calculations.

Experimental results on X(3872)

1. Bound state scenario supported by: $\dfrac{BR(X \to \overline{D^0} D^{*0})}{BR(X \to J/\psi\, \pi\pi)} \simeq 10$

2. CDF angular analysis: $J^{PC} = 1^{++}, 2^{-+}$ favored

3. Large isospin violation: $\dfrac{BR(X \to J/\psi \pi^+ \pi^- \pi^0)}{BR(X \to J/\psi\, \pi^+ \pi^-)} = 1.0 \pm 0.4 \pm 0.3$

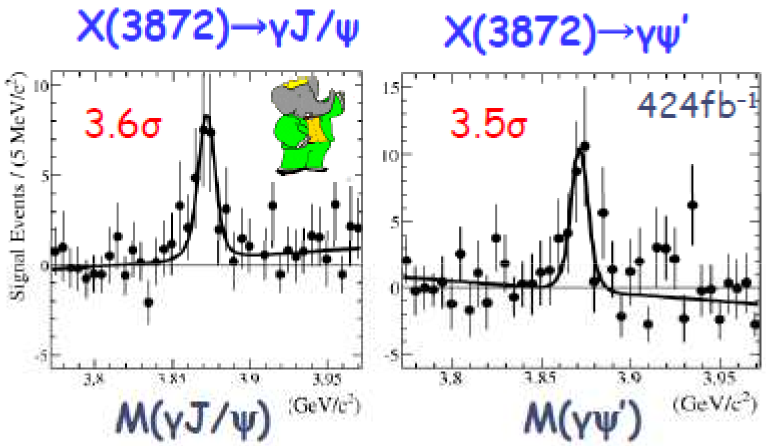
4. Radiative decays are important to test molecular interpretation.
   E. S. Swanson, Phys. Rept. 429, 243 (2006) : $\dfrac{BR(X \to \gamma\psi')}{BR(X \to \gamma J/\psi)} < 0.01$ for molecular

Belle, 256 fb^{-1} (hep-ex/0505037)

$$BR(B^+ \to X(3872) K^+) \times BR(X \to \gamma J/\psi) = (1.8 \pm 0.6 \pm 0.1) \times 10^{-6}$$

BaBar (2009)

$$\frac{BR(X \to \gamma\psi')}{BR(X \to \gamma J/\psi)} = 3.5 \pm 1.4$$



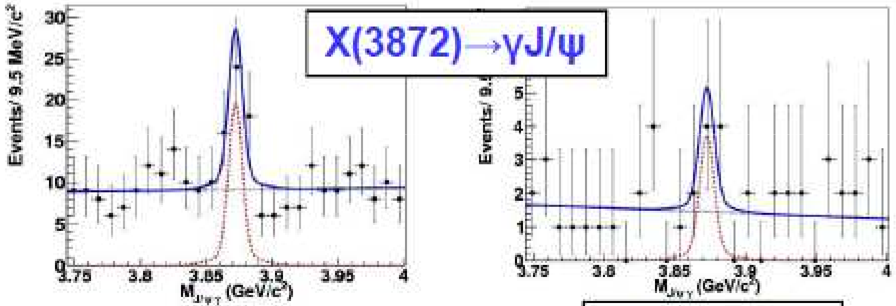
PRL102, 132001 (2009)

The BaBar result seems to be serious problem for molecular interpretation.

Belle results on radiative X(3872) decays

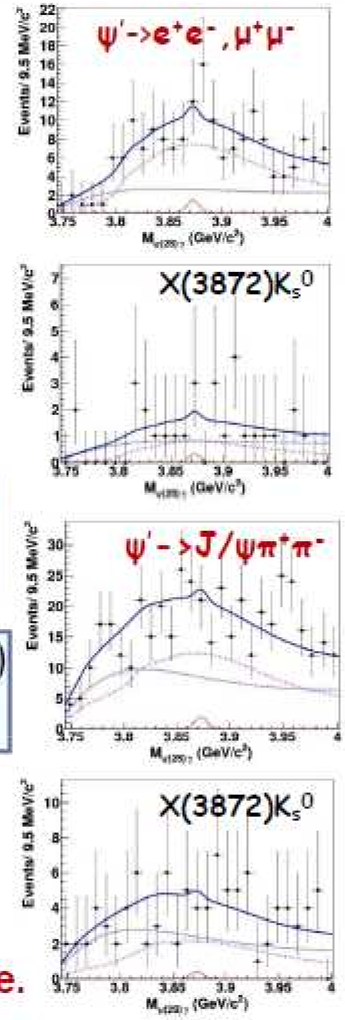
Belle preliminary, ICHEP10 772 x 10^6 $B\bar{B}$ pairs

X(3872)→γJ/ψ



B⁺->X(3872)K⁺ B⁰->X(3872)K_S^0

X(3872)→γψ'



$$BR(B^+ \to X(3872)K^+) \times BR(X \to \gamma J/\psi) = (1.78 \pm 0.46 \pm 0.12) \times 10^{-6}$$

$$BR(B^0 \to X(3872)K^0) \times BR(X \to \gamma J/\psi) < 2.4 \times 10^{-6} \text{ @90\%CL}$$

$$BR(B^+ \to X(3872)K^+) \times BR(X \to \psi'\gamma) < 3.4 \times 10^{-6} \text{ @90\%CL}$$

$$BR(B^0 \to X(3872)K^0) \times BR(X \to \psi'\gamma) < 6.6 \times 10^{-6} \text{ @90\%CL}$$

$$\frac{BR(X \to \psi'\gamma)}{BR(X \to J/\psi\gamma)} < 2.1 \text{ @90\%CL}$$

No X -> ψ' γ signal was observed by Belle. Upper limit is smaller than BaBar ratio. However uncertainties are too large to conclude.

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