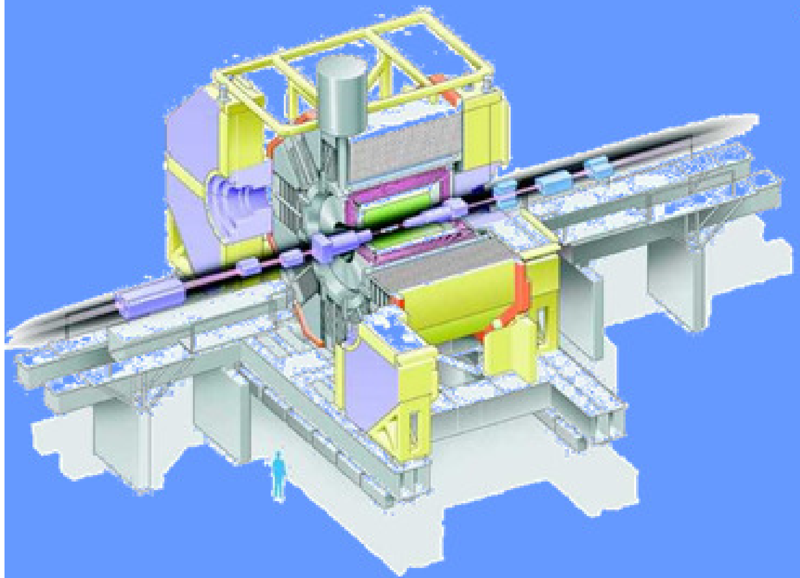
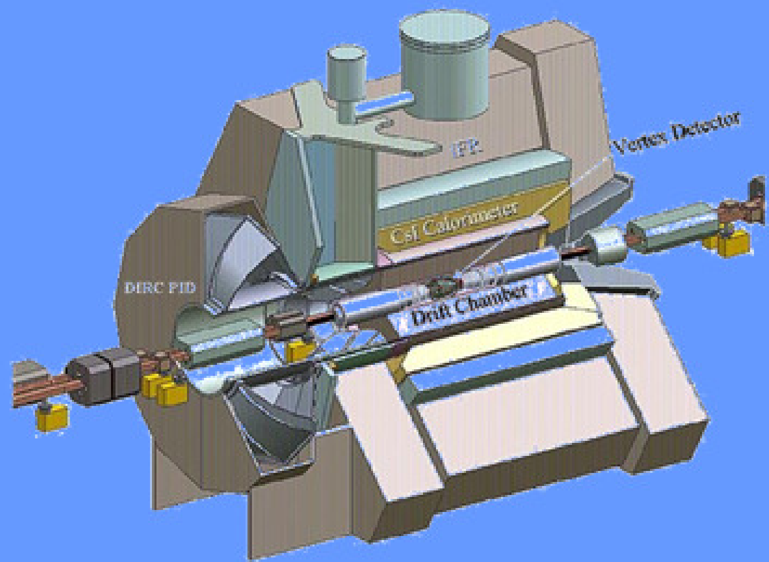
Recent results from B factories

A. Oyanguren
IFIC, UV-CSIC



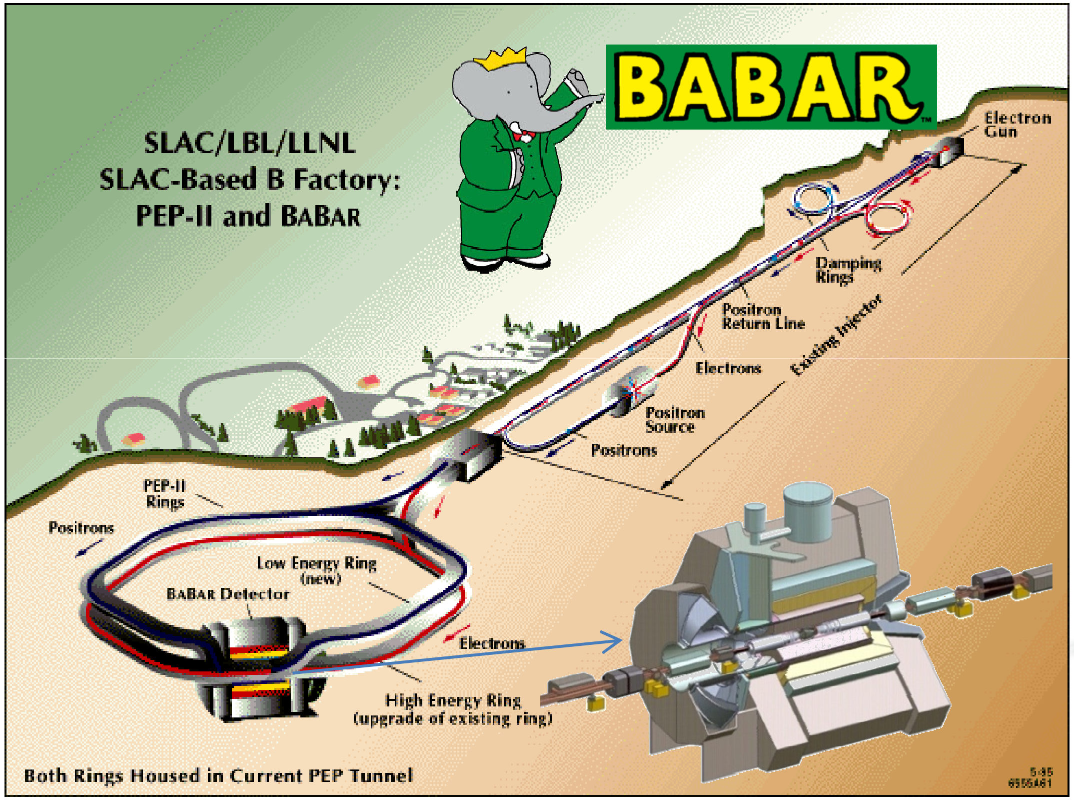


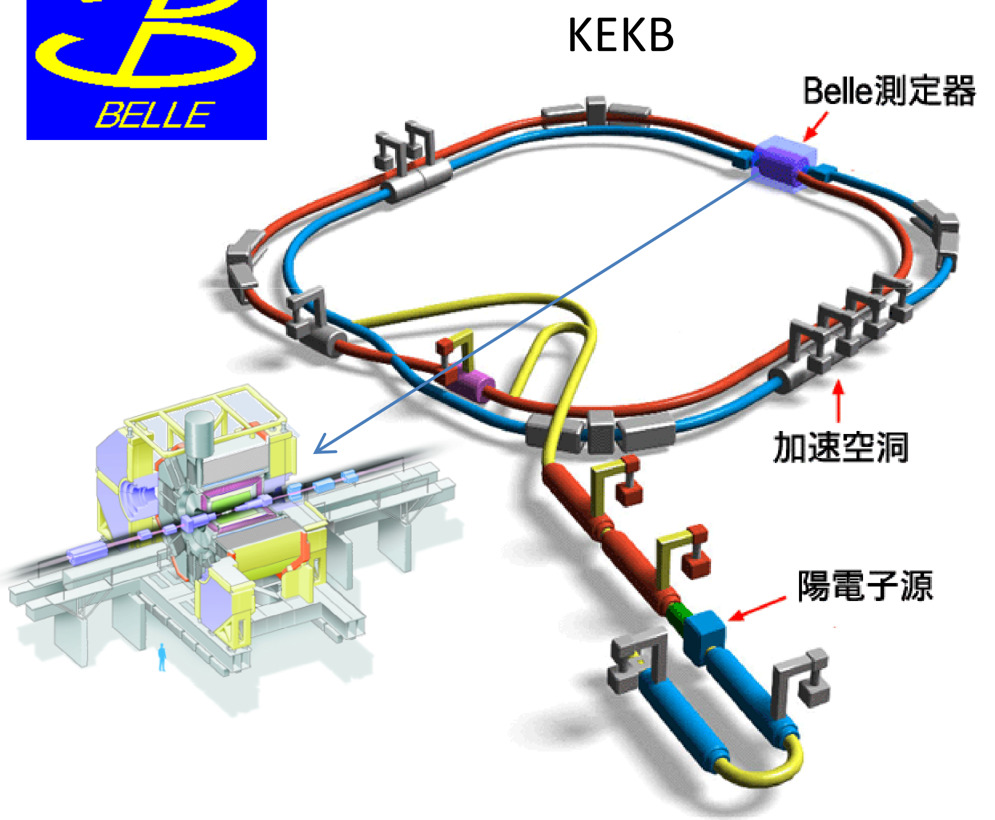
III Jornadas CPAN, Barcelona
2nd – 4th Nov. 2011

Outline

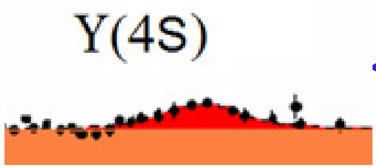
- B factories (Belle & BaBar)
- Leptonic decays: $B \to \tau\nu$, $D_s \to \ell\nu$
- Semileptonic decays: $B \to D^{(*)}\tau\nu$, V_{ub}, charm
- CPV (B, c and τ decays)
- Rare decays: $B \to s\gamma$, $B \to K\nu\nu$, $B \to \nu\nu$, $B \to \gamma\gamma$, $D \to \gamma\gamma$, $X_c \to h\ell\ell$
- Plans at Super Flavour Factories (Belle II & SuperB)

B factories





$\sqrt{s}=10.58$ GeV

e^+ →  ← e^-

$\Upsilon(4s)$ → B, $\bar{B}$

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

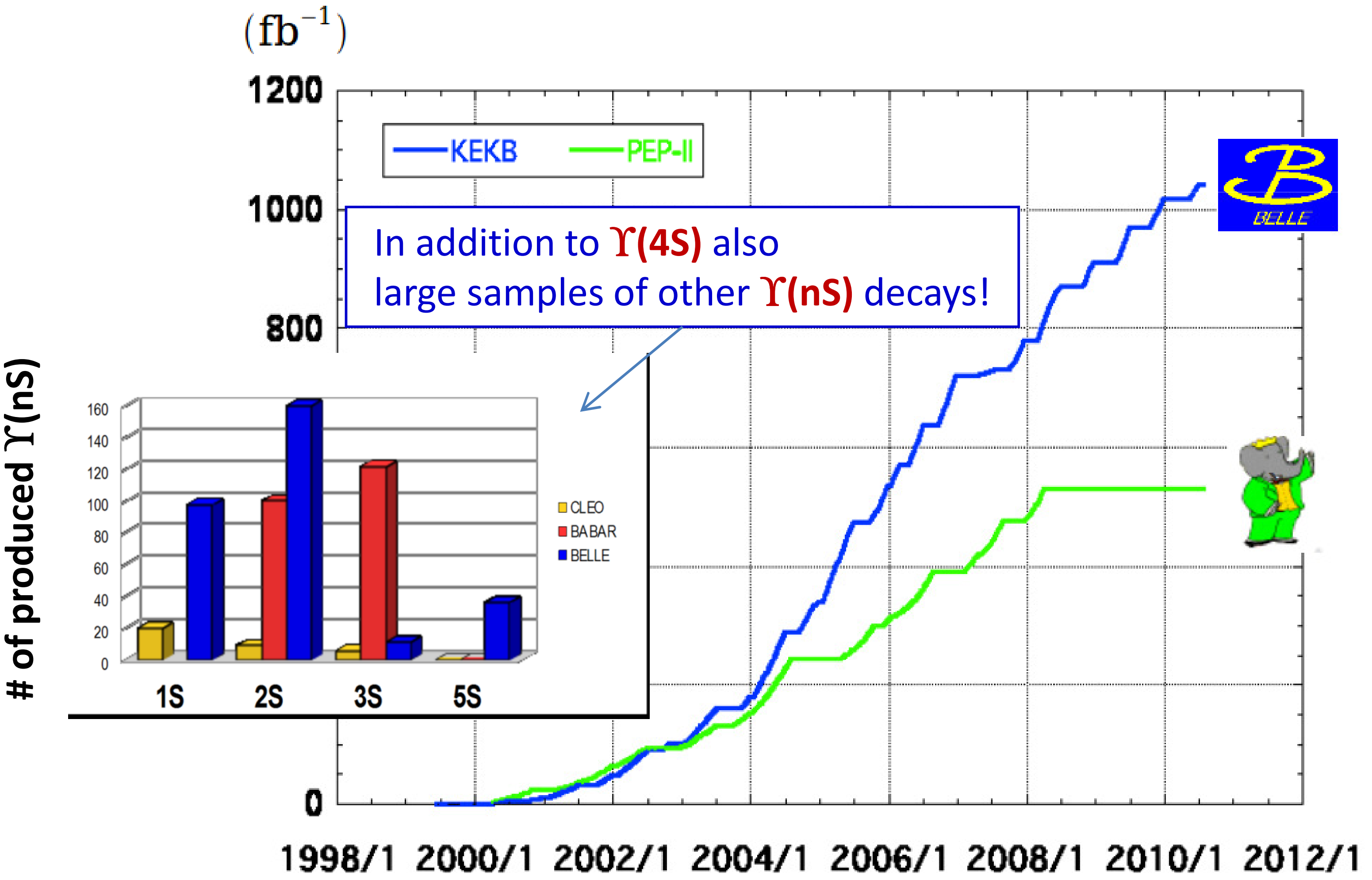
$\sim 200\mu m$

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

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

B factories

Integrated luminosity of B factories



> 1 ab^{-1}

On resonance:

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

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

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

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

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

Off reson./scan:

~ 100 fb^{-1}

~ 550 fb^{-1}

On resonance:

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

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

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

Off resonance:

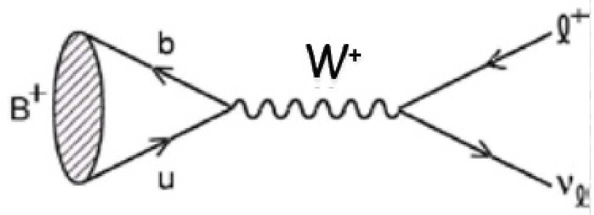
~ 54 fb^{-1}

Fantastic performance far beyond design values!

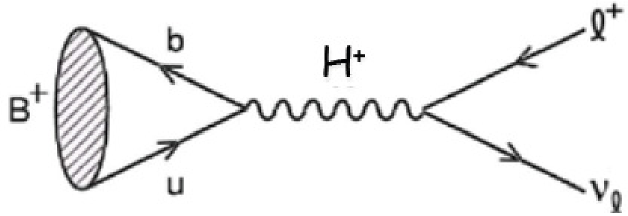
Leptonic decays

Motivation:

- **Weak annihilation processes (helicity suppressed) sensitive to New Physics effects**



- **$B \to \tau\nu$: a charged Higgs could enhance the SM branching fraction:**



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

From semileptonic decays:
$|V_{ub}|=(3.89 \pm 0.44) \times 10^{-3}$
[PDG 2010]

by:

$$\mathcal{B}(B^\pm \to \tau^\pm\nu) = B_{SM}(B^\pm \to \tau^\pm\nu) \times r_H$$

From Lattice QCD calculations:
$f_B = 191 \pm 3 \pm 13$ MeV
[Lenz et al., PRD 83, 036004 (2011)]

$$r_H = \left(1 - \frac{m_B^2}{m_{H^+}^2} \frac{\tan^2\beta}{1+\varepsilon_0 \tan\beta}\right)^2$$

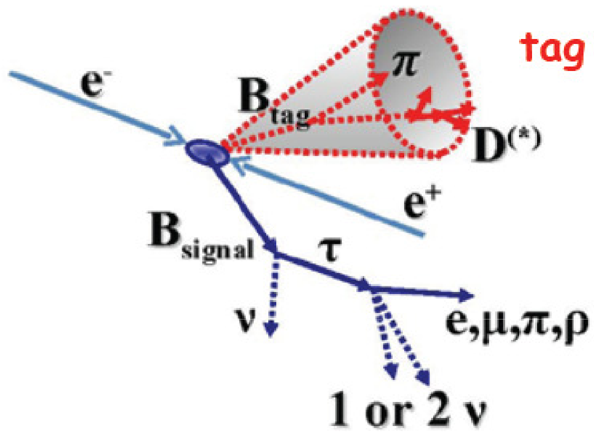
ε0 = radiative correction ~1%)

$$\mathcal{B}_{SM}(B^\pm \to \tau^\pm\nu) = (0.98 \pm 0.23_{V_{ub}} \pm 0.13_{f_B}) \times 10^{-4}$$

Leptonic decays

Experimental method:

→ Reconstruct one B meson in hadronic $B^{\pm} \to D^{(*)}X^{\pm}$ or $B^{\pm} \to J/\psi X^{\pm}$ decays (ε_{tag} ~1%)



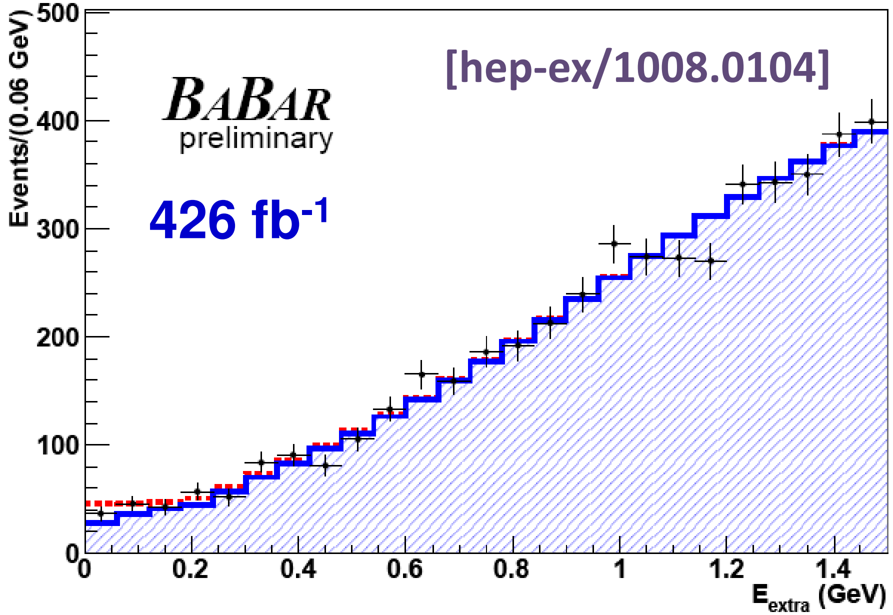
→ Look for signal in the recoil:
$\tau^{\pm} \to e^{\pm}\bar{\nu}\nu,\ \mu^{\pm}\bar{\nu}\nu,\ \pi^{\pm}\nu,\ \rho^{\pm}\nu$
using kinematical and event shape information

→ Look for extra energy E_{extra} = sum of neutral clusters in the ECM calorimeter

→ Study Extra using double tag events to control the bkg.

→ Extract $B \to \tau\nu$ from unbinned max. likelihood fit To E_{extra}: $\boxed{\mathcal{B}(B^{\pm} \to \tau^{\pm}\nu) = (1.8^{+0.57}_{-0.54} \pm 0.26) \times 10^{-4}}$

3.3σ significance



BaBar combined:

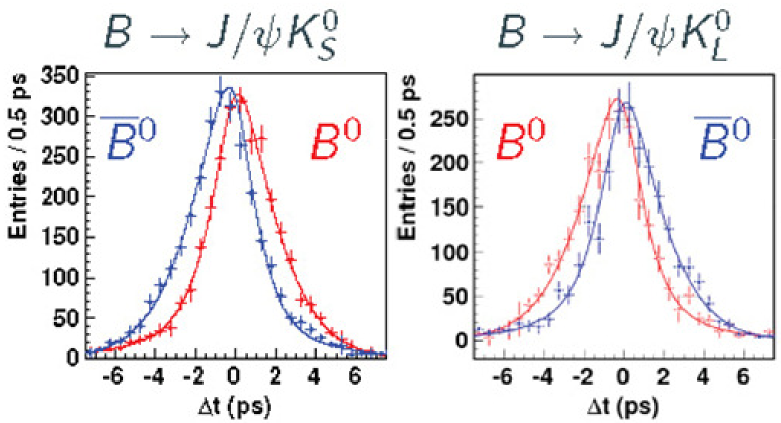
$$\boxed{\mathcal{B}(B^{\pm} \to \tau^{\pm}\nu) = (1.76 \pm 0.49) \times 10^{-4}}$$ [PRD 77, 011107 (2008)]

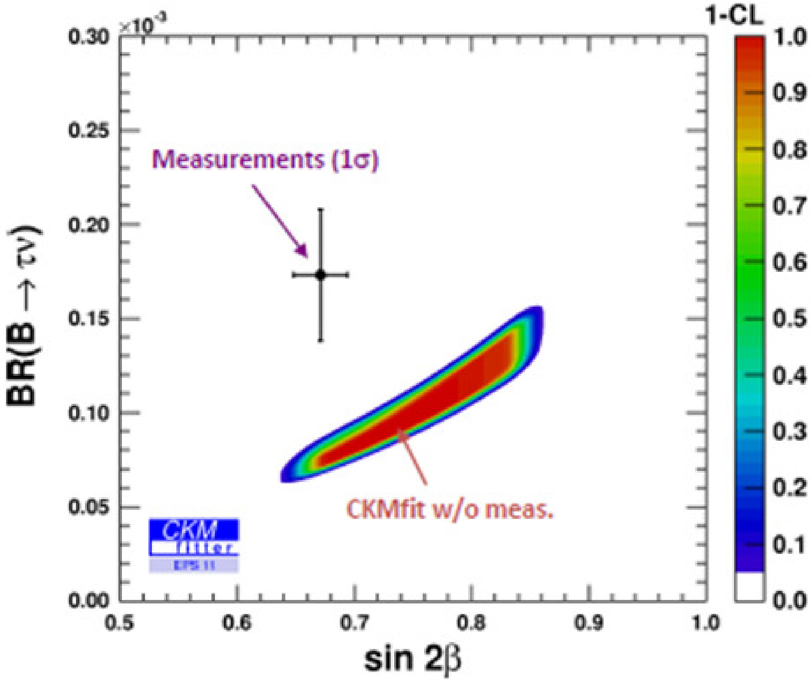
Belle: $$\boxed{\mathcal{B}(B^{\pm} \to \tau^{\pm}\nu) = (1.54^{+0.38+0.29}_{-0.37-0.31}) \times 10^{-4}}$$ [PRD 82, 071101 (2010)]

Leptonic decays

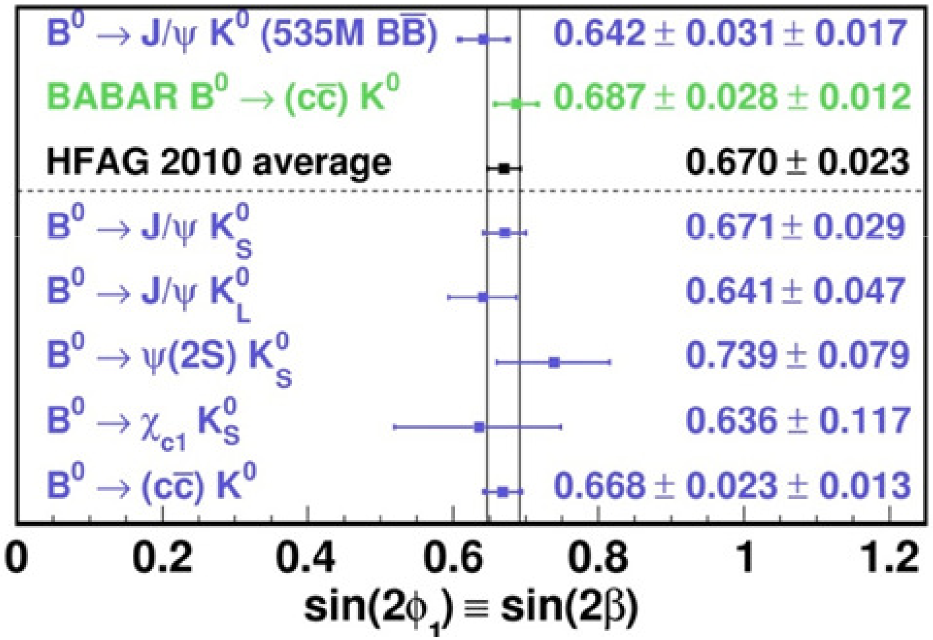
sin2β **from CP measurements in $B^0 \rightarrow cc\, K^0$**

Belle, preliminary, 710 fb^{-1}





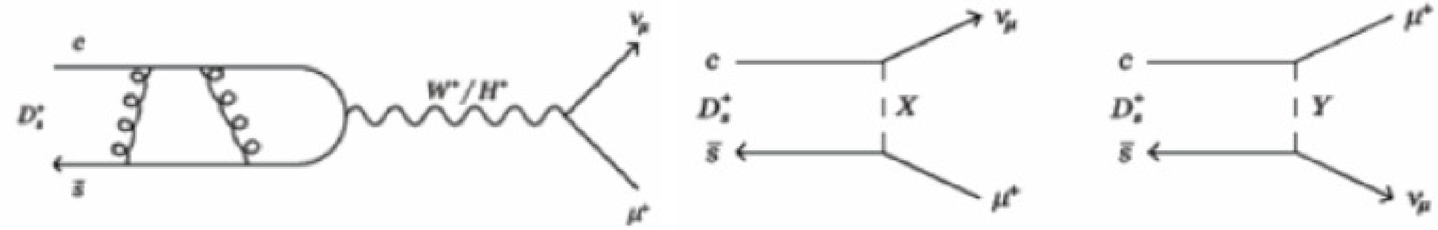
Final measurement of sin2β



Tension between B(*B*→ *τν*) and *sin2β* (~2.5σ) remains

Leptonic decays

- $D_s \to \ell\nu$ can also be enhanced by a charged Higgs or leptoquarks:

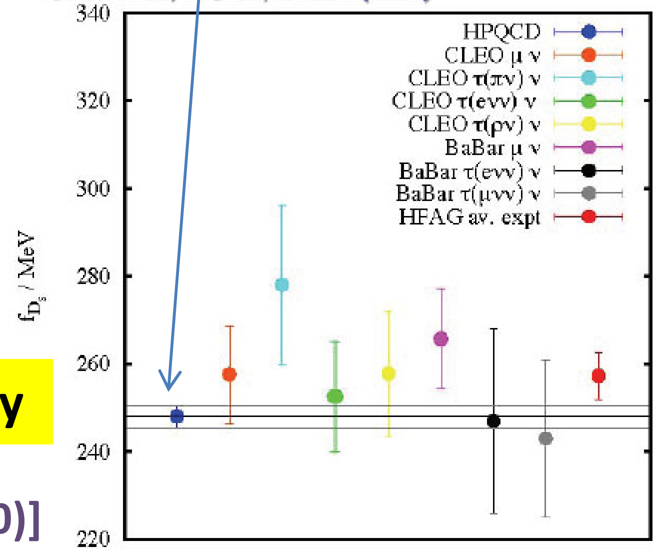


f_{D_s} calculated by LQCD with small error

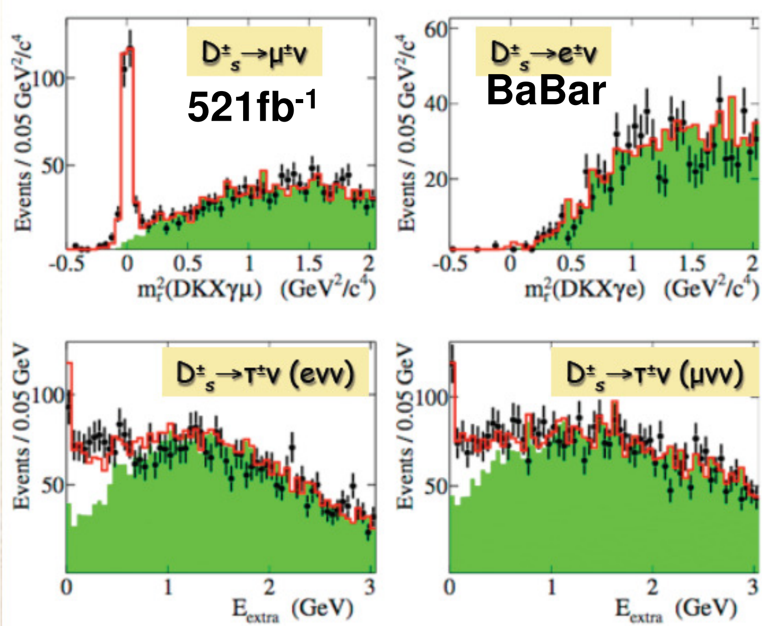
$f_{D_s} = (248.6 \pm 2.5)$ MeV

$$\mathcal{B}_{SM}(D_s \to \ell\nu) = \frac{G_F^2}{8\pi} m_{D_s} m_\ell^2 \left(1 - \frac{m_\ell^2}{m_{D_s}^2}\right)^2 f_{D_s}^2 |V_{cs}|^2 \tau_{D_s}$$

Davis et al., PRD 82, 114504 (2010)



- At BaBar $D_s \to e\nu, \mu\nu, \tau\nu$ measured from fully reconstructed events using the recoil mass and the E_{extra}

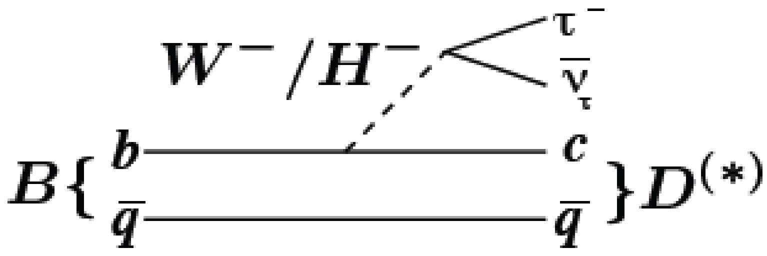


Agreement with theory

[PRD RC 82, 091103 (2010)]

Mode	$\mathcal{B}[10^{-3}]$	f_{D_s} [MeV]
$D_s^\pm \to e^\pm\nu$	<0.23@90%CL	-
$D_s^\pm \to \mu^\pm\nu$	6.02±0.38±0.34	265.7±8.4±7.7
$D_s^\pm \to \tau^\pm\nu$ ($\tau \to e\nu\bar{\nu}$)	50.7±5.2±6.8	247±13±17
$D_s^\pm \to \tau^\pm\nu$ ($\tau \to \mu\nu\bar{\nu}$)	49.1±4.7±5.4	243±12±14

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



Motivation:

- **Sensitive to charged-Higgs effects**
- **Involve form factors which can be measured in $B \to D^{(*)} e/\mu\nu$ decays**
- **Observables: R(D) and R(D*) ratios**

$$R(D^{(*)}) = \frac{\mathcal{B}\left(B \to D^{(*)}\tau\nu_\tau\right)}{\mathcal{B}\left(B \to D^{(*)}\ell\nu_\tau\right)}$$

- can be enhanced by the charged-Higgs ($\tan\beta/m_H$)
- several syst. and theo. uncertainties cancel out

SM predictions:

R(D) = 0.31 $\pm$ 0.02
R(D*) = 0.25 $\pm$ 0.02

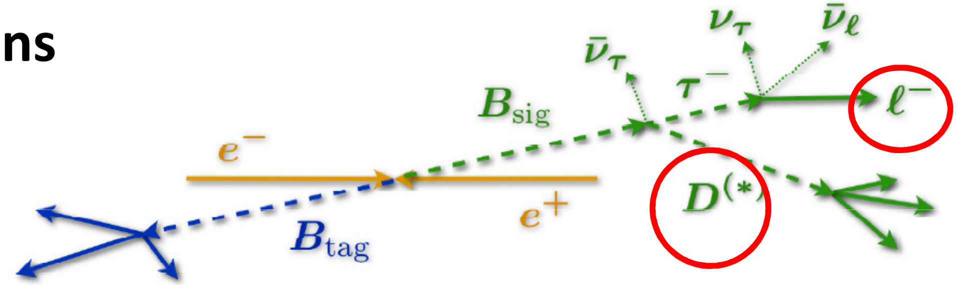
[Nierste, Trine, Westhoff PRD78 (08) 015066]

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

$\tau \to \mu\nu_\mu\nu_\tau$

$\tau \to e\nu_e\nu_\tau$

Experimental method:



- BaBar: Btag fully reconstructed into hadrons (Improved efficiencies (lepton and Btag))
- Bsig: $D^{(*)}$ and lepton (μ, e)
  - 4 signal samples: $(D^0, D^+, D^{*0}, D^{*+})\ell\nu$ (to extract $B \to D^{(*)}\tau\nu$)
  - 4 control samples: $(D^0, D^+, D^{*0}, D^{*+})\pi^0\ell\nu$ (to derive $D^{**}\ell\nu$ bkg)

$m_{miss}{}^2 = (p_{e+e-} - p_{Btag} - p_{D(*)} - p_\ell)^2$

- 2D unbinned ML fit $m_{miss}{}^2$-p^*_ℓ (3x4 par.)

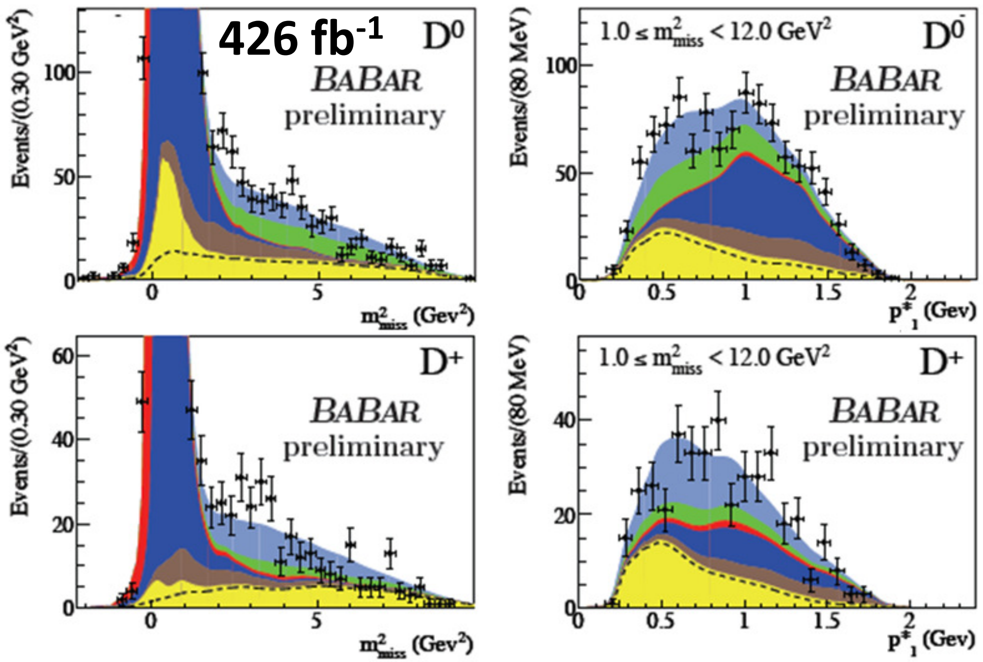
  Yields for:

  $B \to (D^0, D^+, D^{*0}, D^{*+})\tau\nu$

  $B \to (D^0, D^+, D^{*0}, D^{*+})\ell\nu$

  $B \to (D^0, D^+, D^{*0}, D^{*+})\pi^0\ell\nu$

  $\longrightarrow$ R(D) and R(D*)



Large signal significance (>5σ) for all channels

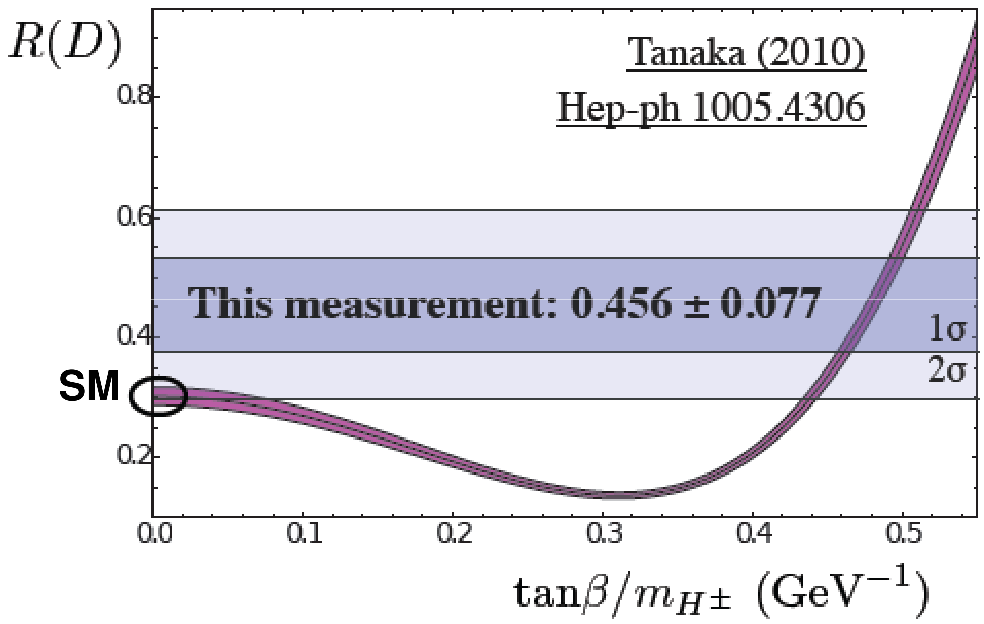
Semileptonic: $B \to D^{(*)}\tau\nu$

Results (preliminary):

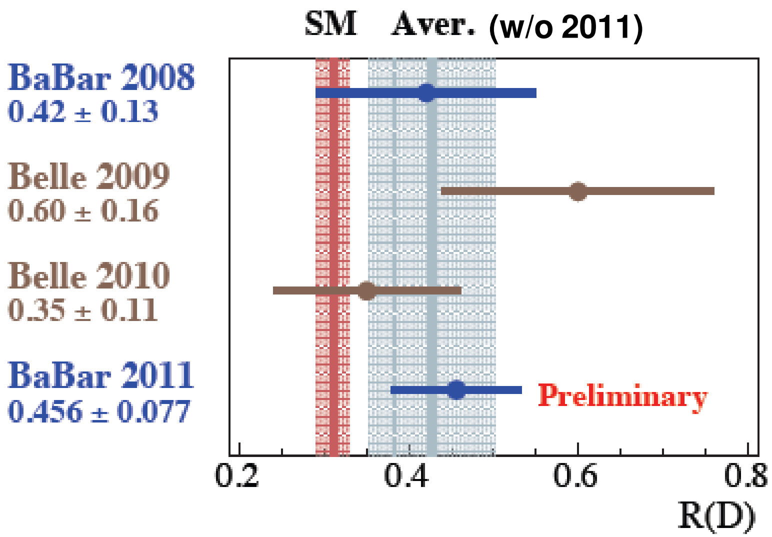
SM predictions:
R(D) = 0.31 ± 0.02
R(D*) = 0.25 ± 0.02

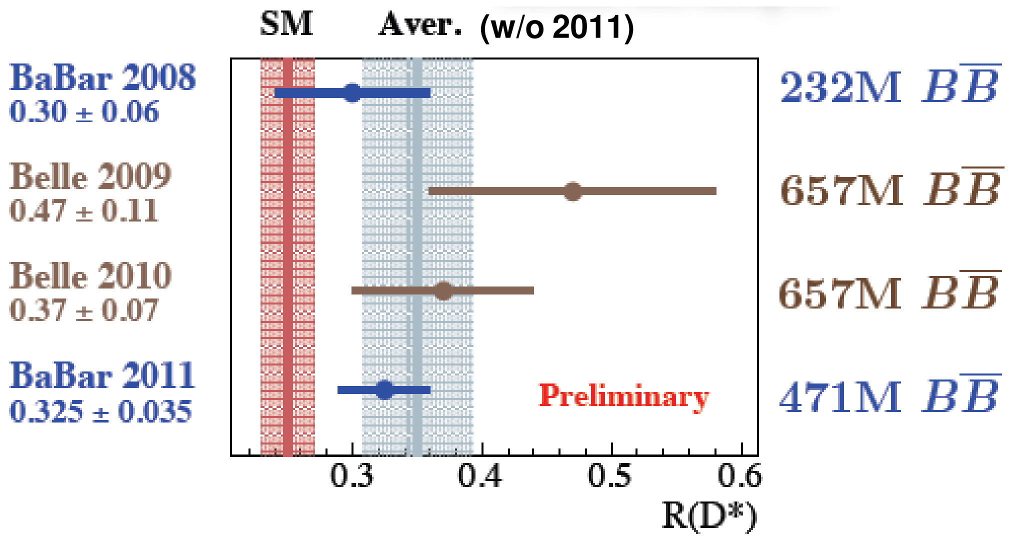
R(D) = 0.456 ± 0.053 ± 0.056
R(D*)= 0.325 ± 0.023 ± 0.027

1.8σ larger than SM prediction
→ favors large tanβ



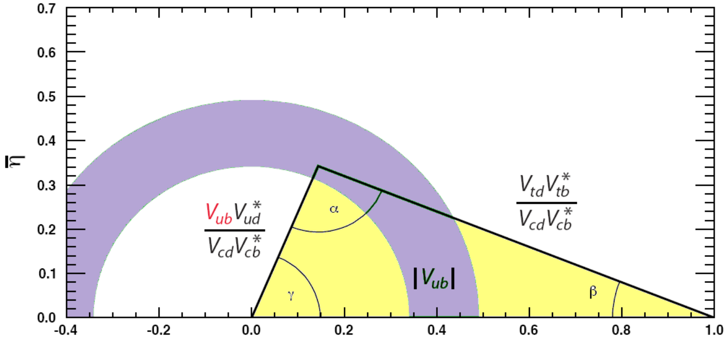
Comparison with previous results:



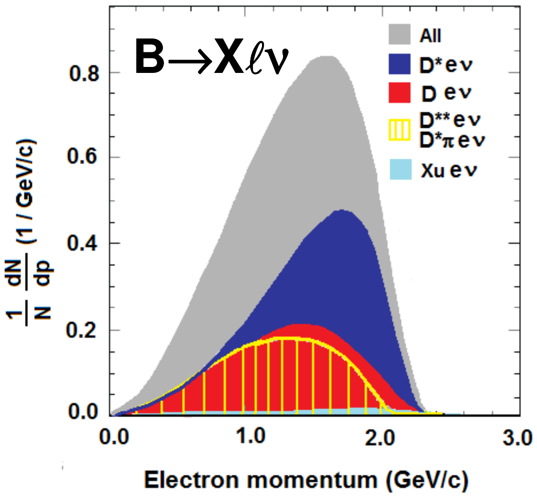


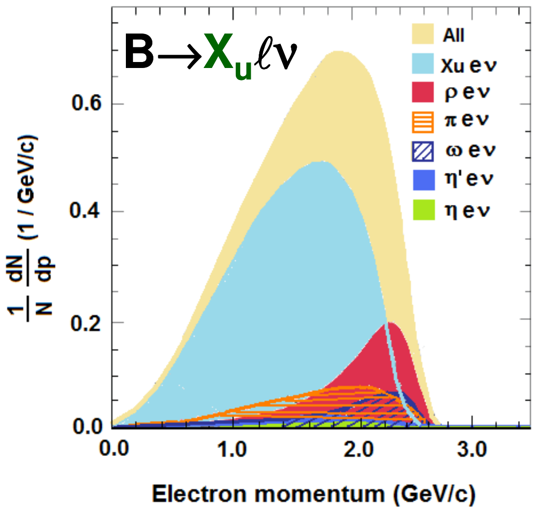
Semileptonic: V_{ub}

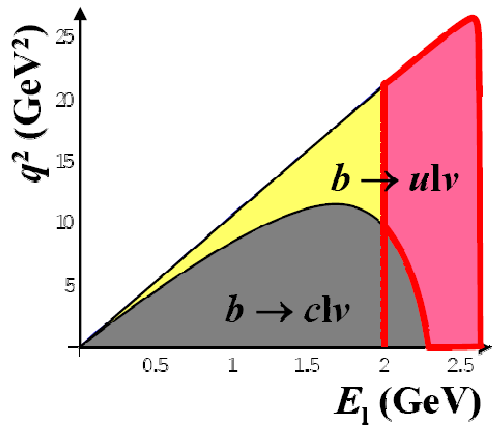
Motivation:



- Charmless semileptonic decays allow us to measure V_{ub} (upper UT vertex)
- Challenge: suppress charm background $B \to X\ell\nu = B \to X_c\ell\nu + \bar{B} \to X_u\ell\nu$ (50 : 1)







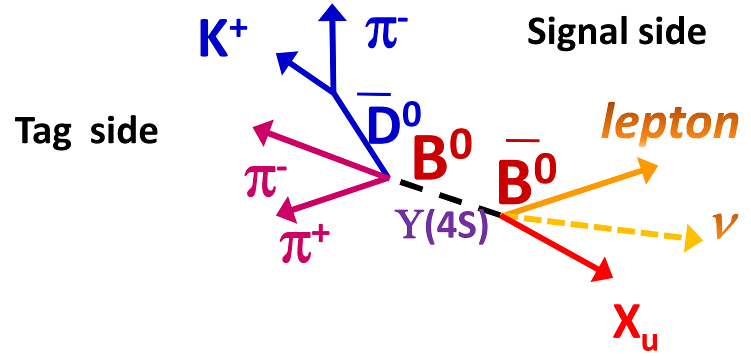
- Two different experimental methods:

 - **Inclusive:** high stat. but much bkg: use kinematic cuts: E_ℓ, q^2, M_X and $P_+ = E_X - |p_X|$
 Theory: Shape function from QCD
 - **Exclusive:** final meson (π,ρ,ω…): low stat. but better bkg rejection.
 Theory: Form factors from QCD

Semileptonic: $B \to X_u \ell \nu$

Experimental Method:

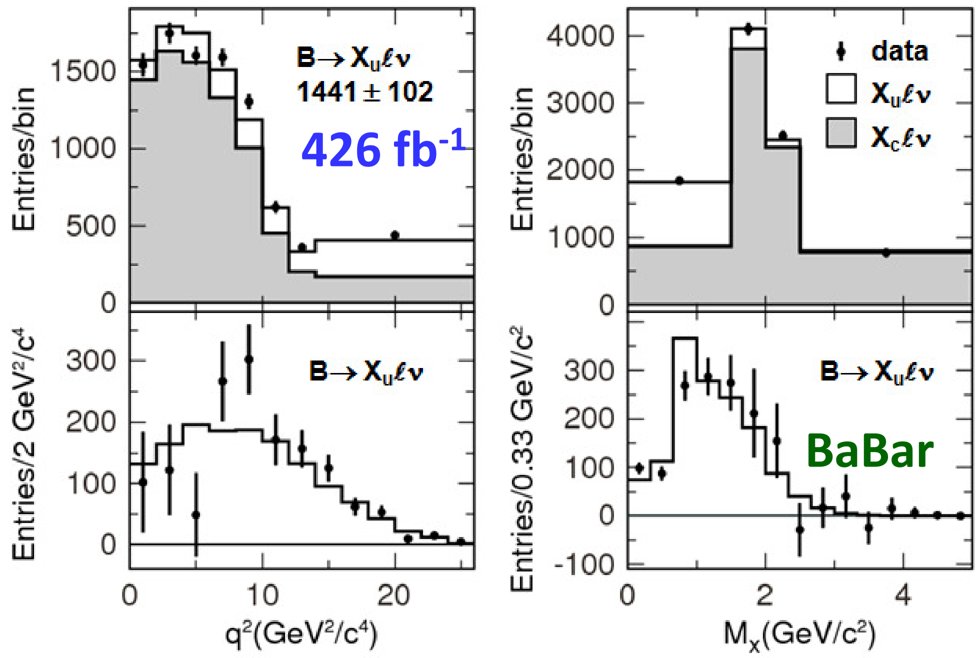
- At BaBar, Btag fully reconstructed hadronically (ε ~0.3-0.5%) + μ or e from the Bsig
- X_u from all remaining tracks and neutral clusters
- ν estimated from missing E and p
- Bkg suppression:
  - Combinatorial subtracted from m_{ES}
  - Charm: $B \to D^* \ell \nu$ partial reconstructed kaon veto, only 1 lepton $p_\ell^* > 1$ GeV



- Several PS regions, 2D fit for $\Delta B(B \to X_u \ell \nu)/B(B \to X \ell \nu)$ in q^2-M_x for $p_\ell^* > 1$GeV

$\to B \to X_c \ell \nu$ bkg and $B \to X_u \ell \nu$ signal yields

$\Delta B(B \to X_u \ell \nu) = 1.80\,(13)\,(15) \times 10^{-4}$



V_{ub} extraction:

$$|V_{ub}| = \sqrt{\frac{\Delta\mathcal{B}(\overline{B} \to X_u \ell \bar{\nu})}{\tau_B \cdot \Delta\Gamma_{\text{theory}}}}$$

BNLP: [Bosch *et al.* , PRD 72 (05) 073006]

DGE: [Andersen et al. , JHEP 0601 (06) 097]

GGOU: [Gambino et al., JHEP 0710 (07) 058]

ADFR: [Aglietti et al., EPJ. C 59 (09) 831]

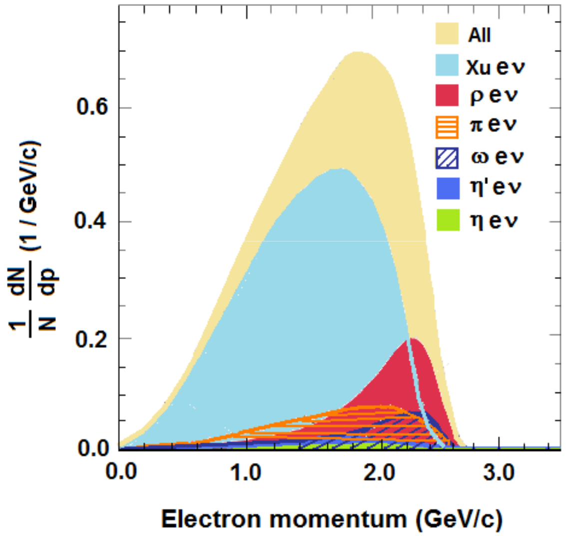
Average:

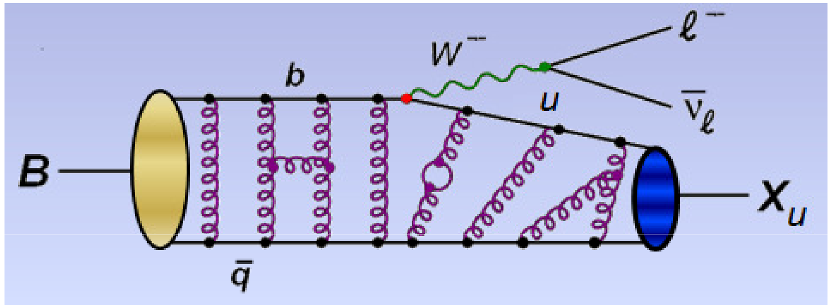
$|V_{ub}| = (4.31 \pm 0.25_{exp} \pm 0.16_{theo})10^{-3}$

[to be submitted to PRD]

Semileptonic: $B \to \pi \ell \nu$

- The exclusive B semileptonic decay rate is described as function of form factors:

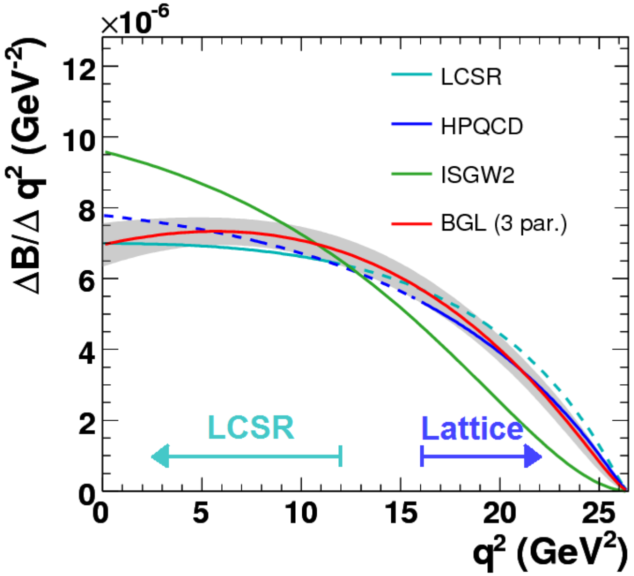


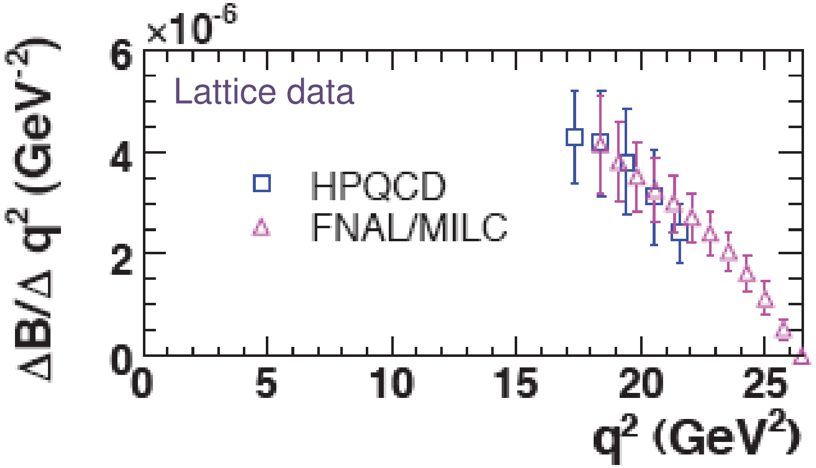


$= \pi, \eta, \eta', \rho, \omega$

$$\frac{d\Gamma(B \to \pi \ell \nu)}{dq^2} = \frac{G_F^2}{24\pi^3} |V_{ub}|^2 p_\pi^3 |f_+(q^2)|^2$$

QCD calculations:



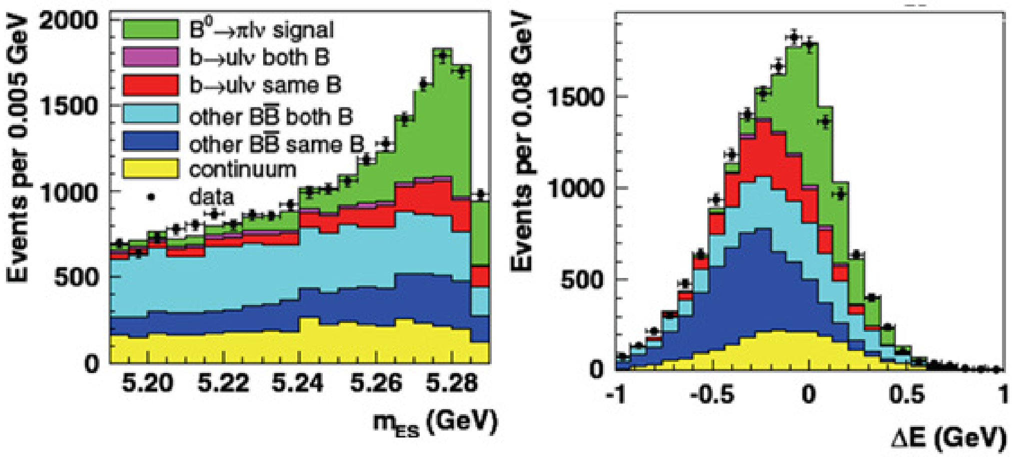


Semileptonic: $B \to \pi \ell \nu$

- BaBar, untagged analyses — PRD 83 (2011) 032007, PRD 83 (2011) 052011
- Loose ν reconstruction from full event
- Background suppression by cuts or Neural Net
- Fit using $\Delta E = (P_B P_{beams} - s/2)/\sqrt{2}$,

  $m_{ES} = [(s/2 + p_B p_{beams})^2 / E^2_{beams} - p^2_B]$ and

  $q^2 = (p_\ell + p_\nu)^2 = (p_B - p_\pi)^2$ **(in 12 or 6 bins)**



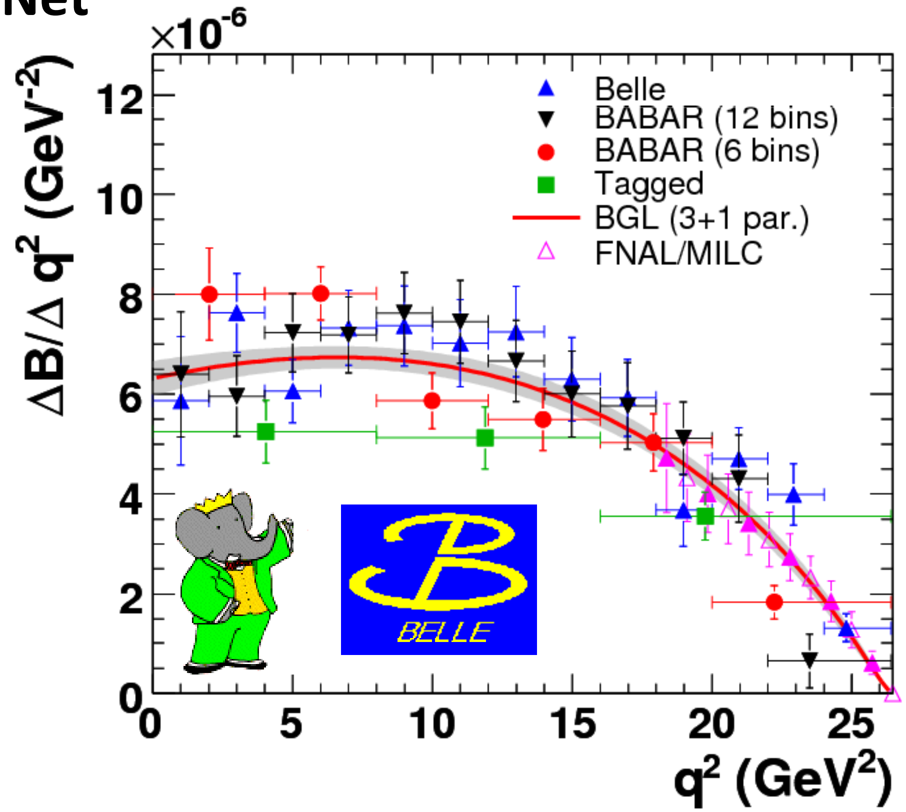
BaBar: $B(B \to \pi e \nu) = 1.42\ (5)\ (7) \times 10^{-4}$

$B(B \to \pi e \nu) = 1.41\ (5)\ (7) \times 10^{-4}$

Belle: $B(B \to \pi e \nu) = 1.49\ (4)\ (7) \times 10^{-4}$

[arXiv:1012:0090]

Fit to BaBar + Belle + LQCD



$|V_{ub}| = (3.19 \pm 0.14 \pm 0.27) \times 10^{-3}$

(V. Luth, J. Dingfelder)

Semileptonic: Vub

- **Exclusive:** $\boxed{|V_{ub}| = (3.19 \pm 0.14 \pm 0.27) \times 10^{-3}}$ (V. Luth, J. Dingfelder)

- **Inclusive:** $\boxed{|V_{ub}| = (4.34 \pm 0.13 \pm 0.15) \times 10^{-3}}$ (V. Luth, [NS61CH06-Luth])

Inclusive $|V_{ub}| \neq$ Exclusive $|V_{ub}|$

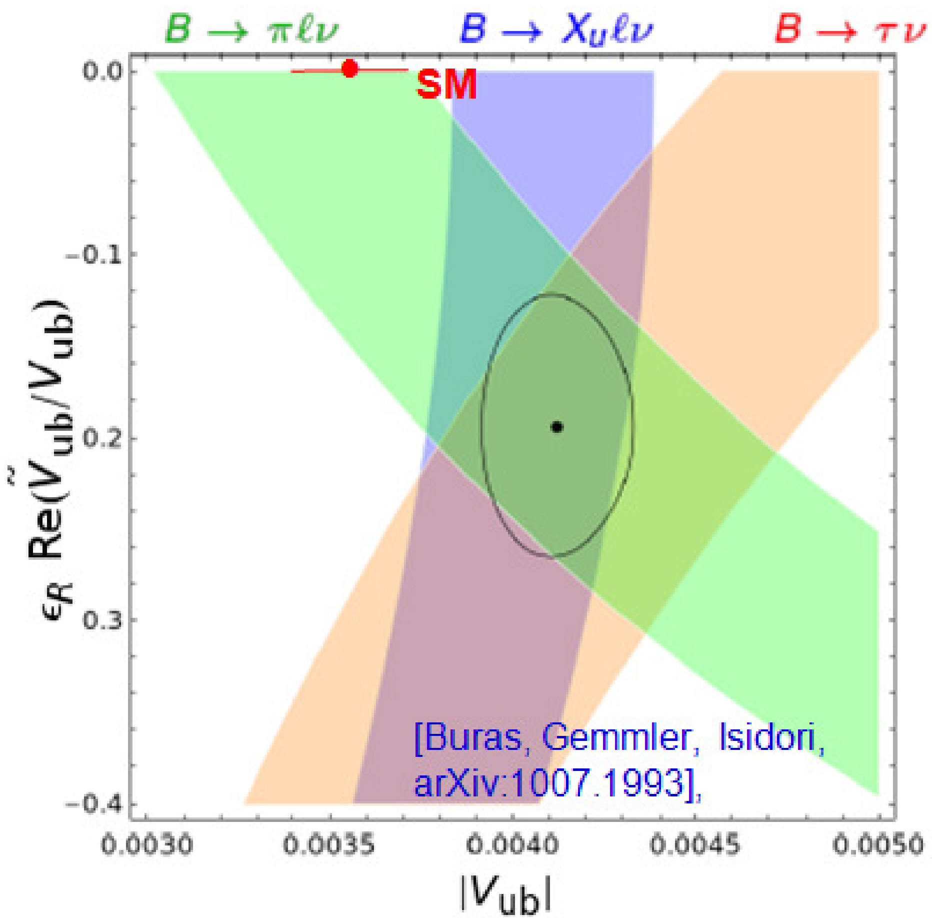
>2σ difference since many years ago

and V_{ub} from $B \rightarrow \tau\nu$ larger than for $B \rightarrow \pi\ell\nu$

New Physics contribution?

(RH currents modification)

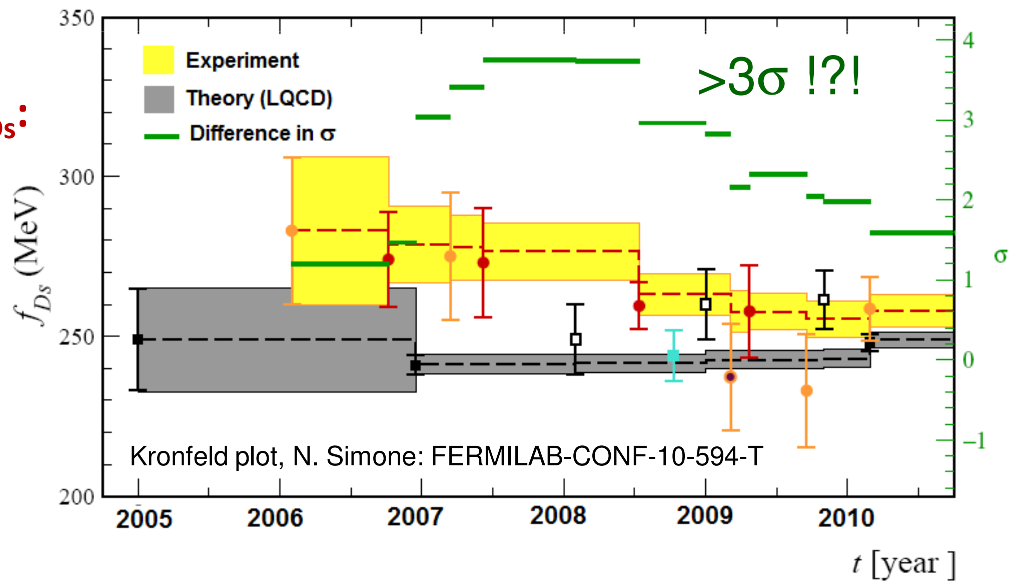
$$|V_{ub}|_{B\to X_u\ell\nu} \longrightarrow \sqrt{|V_{ub}|^2 + \epsilon_R^2\,|\widetilde{V}_{ub}|^2}$$
$$|V_{ub}|_{B\to \pi\ell\nu} \longrightarrow |V_{ub} + \epsilon_R\,\widetilde{V}_{ub}|$$
$$|V_{ub}|_{B\to \tau\nu} \longrightarrow |V_{ub} - \epsilon_R\,\widetilde{V}_{ub}|$$



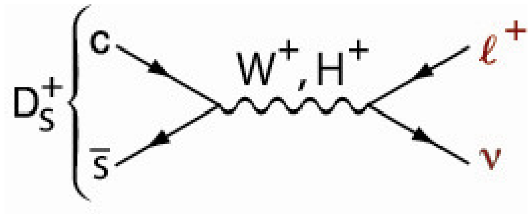
Semileptonic: charm

- Charm semileptonic decays allow to measure form factors in the charm sector, validating LQCD methods
  - $\longrightarrow$ increase theory precision involving B decays
  - $\longrightarrow$ trust LQCD calculations ensuring possible New Physics signs

Example: the leptonic constant f_{Ds}:



f_{Ds} puzzle:
exp $\neq$ theo$\longrightarrow$ contribution from a charged Higgs?



- Several charm semileptonic channels have been studied at BaBar from $e^+e^- \longrightarrow cc$ using a partial reconstruction technique:

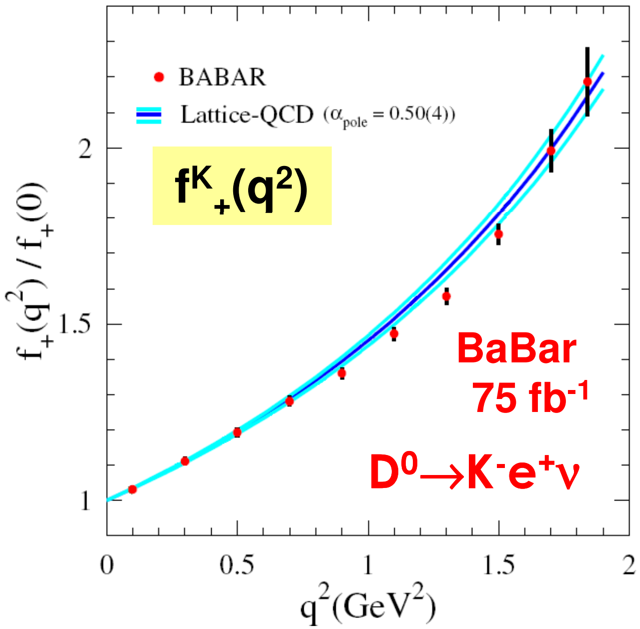
$D\rightarrow Ke\nu$, $D_s\rightarrow KKe\nu$, $D^+\rightarrow K\pi e\nu$ published
$D\rightarrow \pi e\nu$ (soon)
$\longrightarrow$ can be related to $B\rightarrow \pi e\nu$ $\longrightarrow$ access to V_{ub}

$$\left.\frac{d\Gamma(B\to\pi e\bar{\nu}_e)/dw}{d\Gamma(D\to\pi e\bar{\nu}_e)/dw}\right|_{\text{same } w} = \left|\frac{V_{ub}}{V_{cd}}\right|^2 \left(\frac{M_B}{M_D}\right)\left|\frac{f_+^{B\to\pi}}{f_+^{D\to\pi}}\right|^2$$

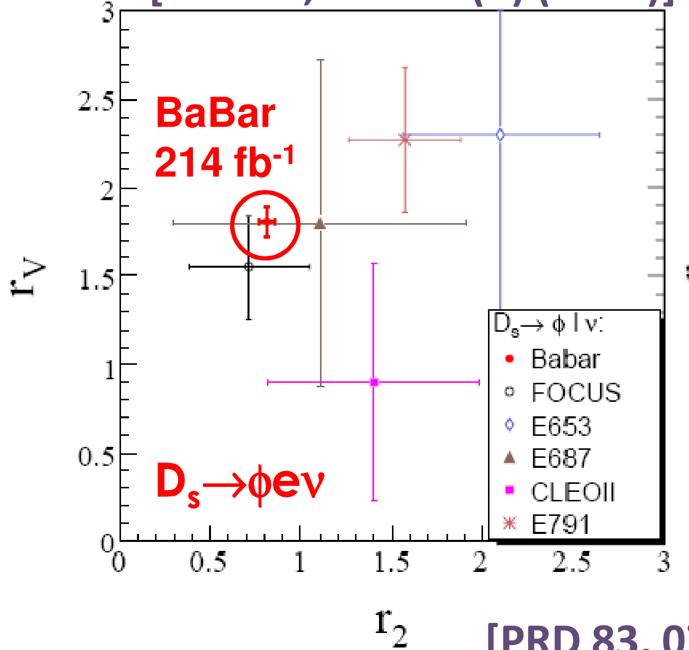
Semileptonic: charm

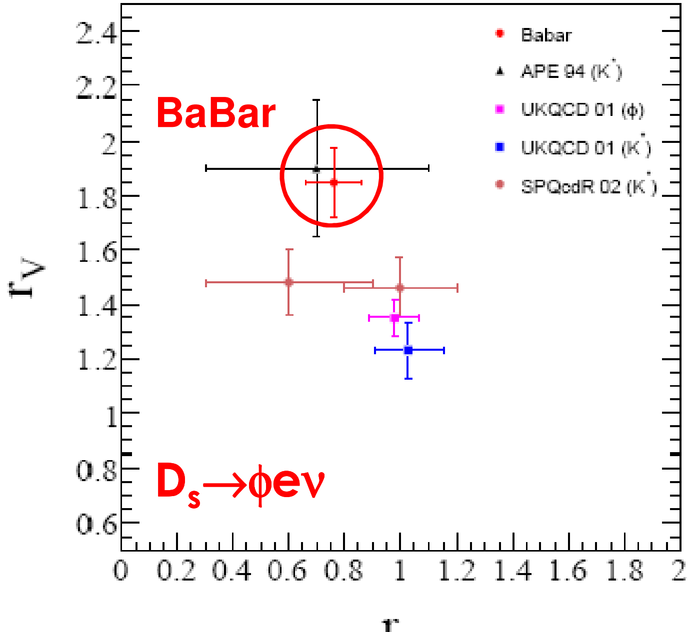
- Quite precise form factor measurements from BaBar→ need LQCD improvements

[PRD 76, 052005 (2007)]

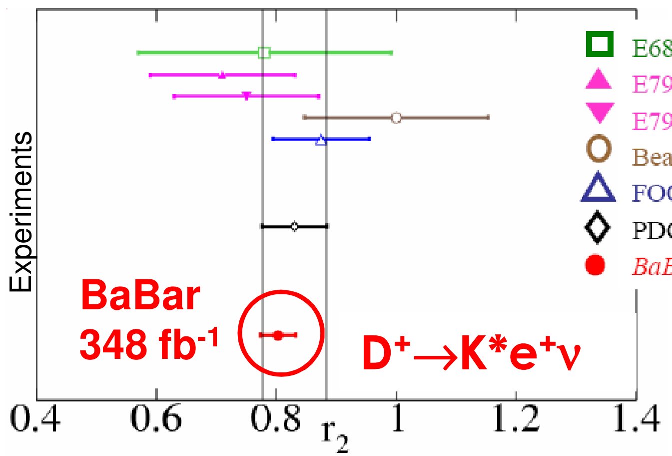


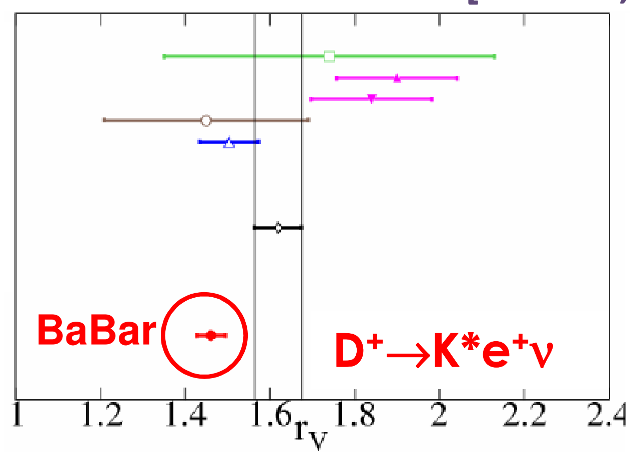
[PRD 78, 051101(R) (2008)]

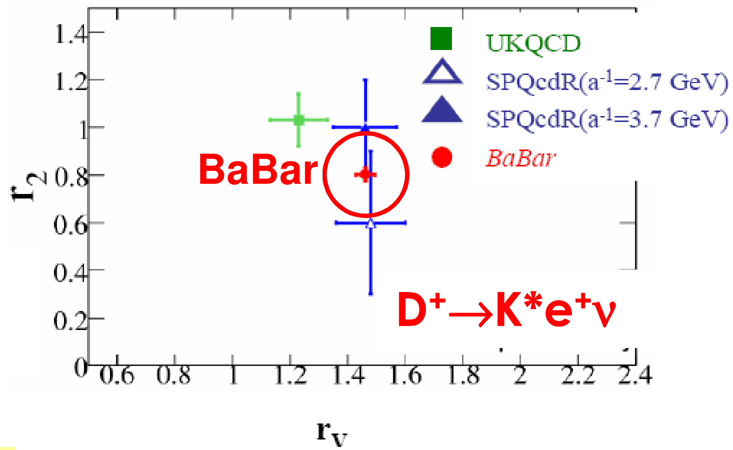




[PRD 83, 072001 (2011)]







$A_1(q^2)$, $A_2(q^2)$, $V(q^2)$→ $r_2=A_2(0)/A_1(0)$ $r_V=V(0)/A_1(0)$

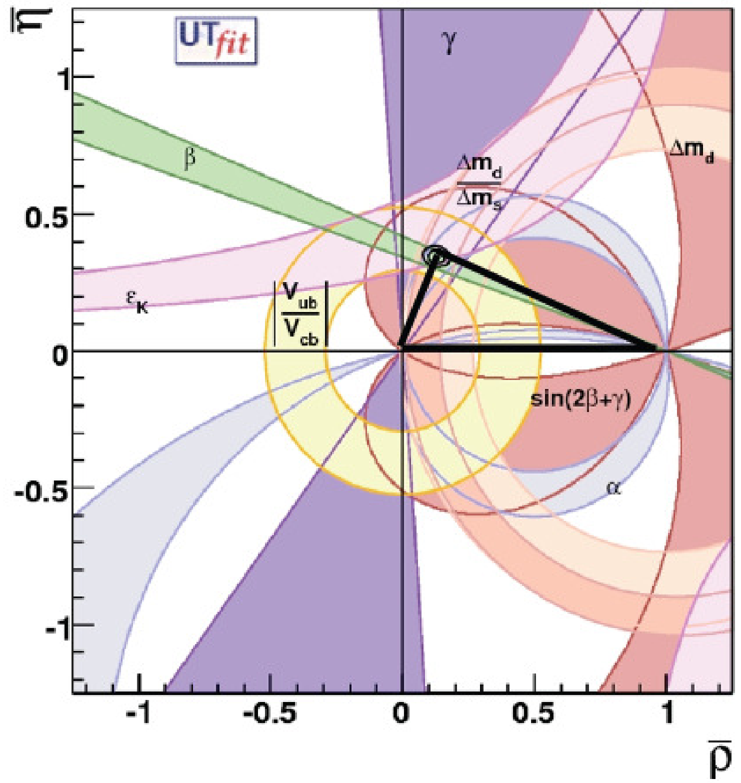
CP Violation

Motivation:

- **In the SM CPV arises from the not vanishing phase of the CKM matrix**
- **CPV well established from B decays**
  $\rightarrow$ dominant CKM mechanism
- **New Physics can induce additional FCNC and CP-violating phases**
- **Many observations of CPV processes in the last decade in the beauty and strange sectors**
  $\rightarrow$ Overall consistency with SM predictions
- **No observation yet of CPV effects in the charm sector**
- **No observation yet of CPV effects in the lepton sector**

The CKM matrix

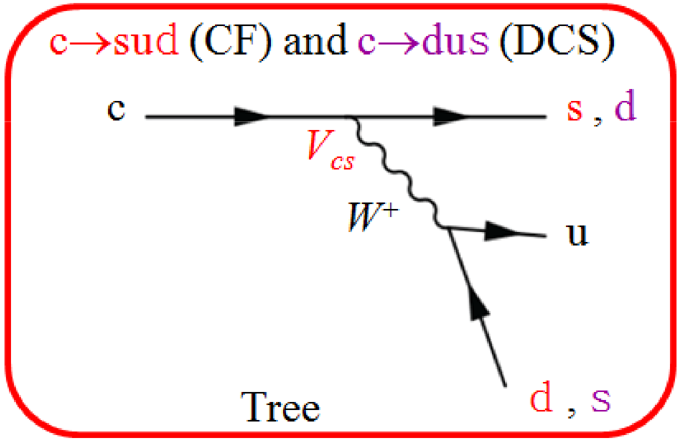
$$
\begin{array}{cc}
 & \begin{array}{ccc} \quad d \quad & \quad s \quad & \quad b \quad \end{array} \\
\begin{array}{c} u \\ c \\ t \end{array} &
\begin{pmatrix}
1-\frac{1}{2}\lambda^2 & \lambda & A\lambda^3(1-\rho-i\eta) \\
-\lambda & 1-\frac{1}{2}\lambda^2 & A\lambda^2 \\
A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1
\end{pmatrix}
\end{array}
$$

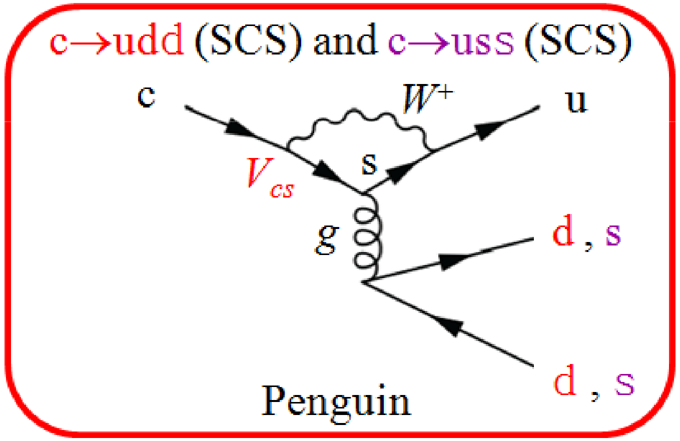


CP Violation in D decays

Motivation:

- **Direct CP violation in D decays arises through interference between:**





- **In the SM is CKM suppressed O(10^{-3}) or less:** $V_{cs} \rightarrow 1-\frac{1}{2}\lambda^2 - \boxed{i\eta A^2\lambda^4}$

- **New Physics can increase or reduce the effect:**
  - e.g. additional CP phase from charged Higgs boson

[PRD 75, 036008 (2007)]
[hep-ph/0104008 (2001)]
[PRD 51, 003478 (1995)]

- **SCS decays are more likely to show the effect if present**

- **Current experimental sensitivity O(10^{-3})**

CP Violation in D decays

Experimental method:

- Due to CPV in mixing in the kaon sector, the direct CP asymmetry for $D^+ \rightarrow K_s \pi^+$

$$A_{CP} = \frac{\Gamma(D^+ \rightarrow \pi^+ K_s^0) - \Gamma(D^- \rightarrow \pi^- K_s^0)}{\Gamma(D^+ \rightarrow \pi^+ K_s^0) + \Gamma(D^- \rightarrow \pi^- K_s^0)}$$

is expected to be [hep-ph/0104008 (2001)]

$A_{CP} = -(0.332 \pm 0.006)\%$

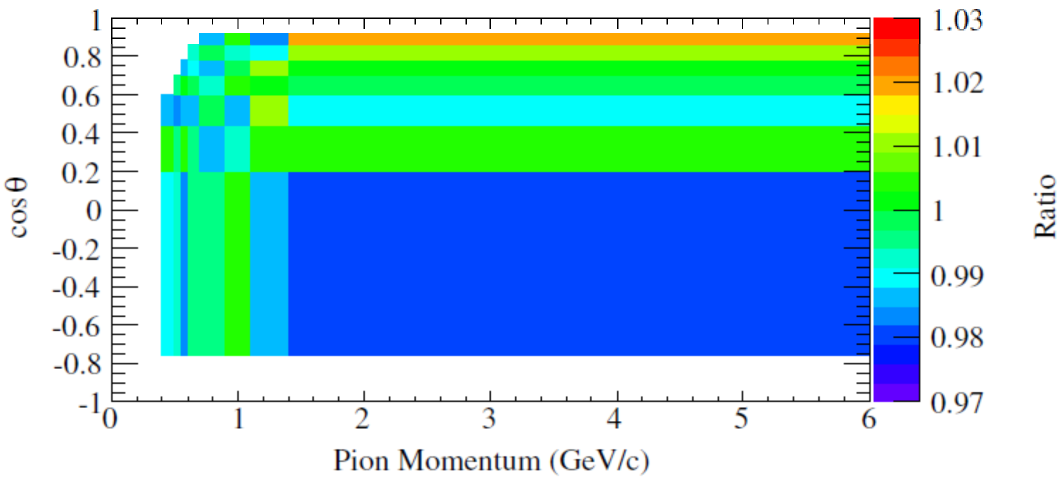
- At BaBar: signal yields from likelihood fit to $m(\pi^+ K^0_s)$, with selection based on a Boosted Decision Tree with 7 variables: $\tau_T(D^\pm)$, $L_T(D^\pm)$, $p^*(D^\pm)$, $p(K^0_S)$, $p_T(K^0_S)$, $p(\pi^\pm)$, $p_T(\pi^\pm)$
- 807K $D^\pm$ signal events
- Measure

$$A = \frac{N_{D^+} - N_{D^-}}{N_{D^+} + N_{D^-}} = A_{CP} + \boxed{A_{FB}} + \boxed{A_\varepsilon}$$

Forward-Backward asymmetry

Detector charge asymmetry

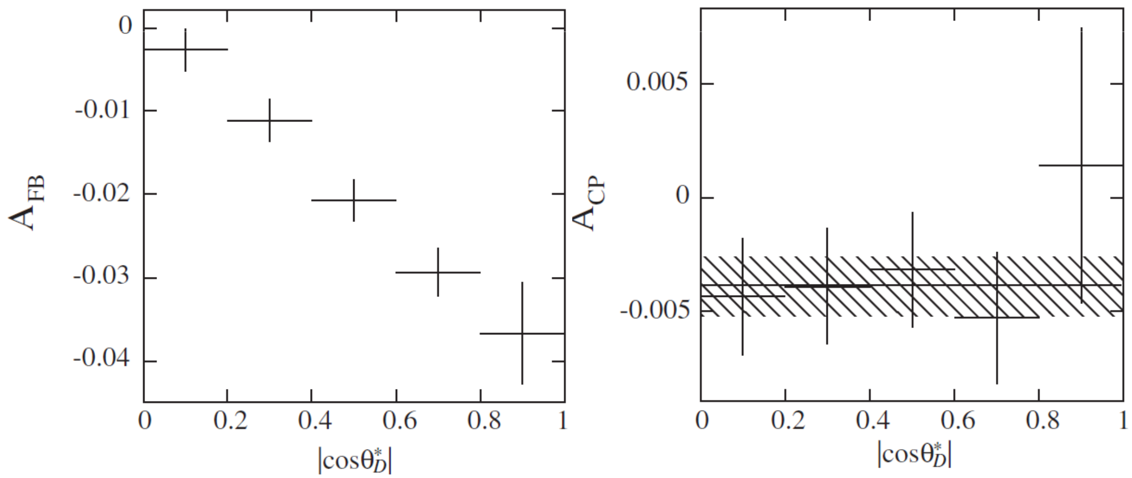
- Data-driven method to correct for A_ε
  - Use tracks from $e^+e^- \rightarrow \Upsilon(4S) \rightarrow BB$ decays (isotropic in rest frame) to map the ratio of π^+/π^- detection efficiencies
  - Offset on $A_{CP} \approx +0.05\%$



CP Violation in D decays

- Use data-driven method to extract A_{FB}, and A_{CP} in bins of polar angle

$$A_{FB}(|\cos\theta_D^*|) = \frac{A(+|\cos\theta_D^*|) - A(-|\cos\theta_D^*|)}{2} \qquad A_{CP}(|\cos\theta_D^*|) = \frac{A(+|\cos\theta_D^*|) + A(-|\cos\theta_D^*|)}{2}$$



$D^+ \rightarrow K_s \pi^+$

$$A_{CP} = (-0.44 \pm 0.13 \pm 0.10)\%$$

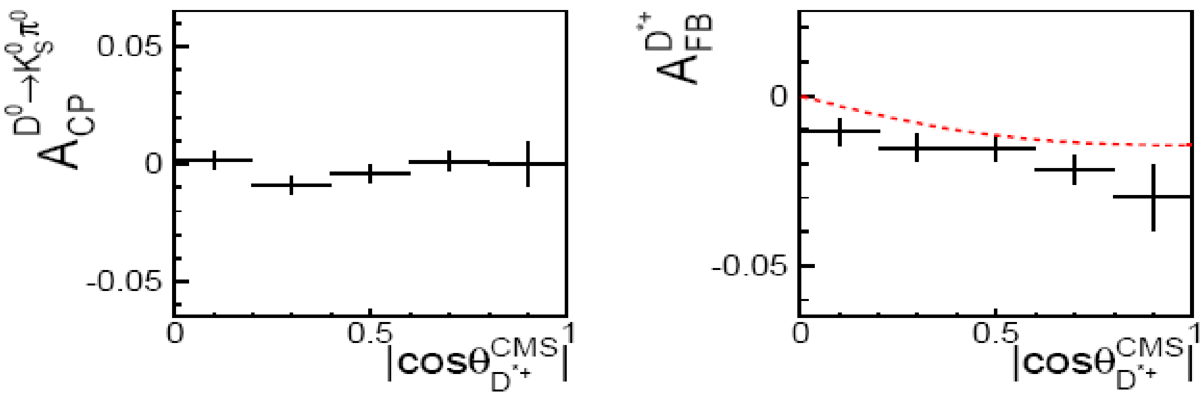
[PRD 83, 071103(R) (2011)]

Consistent with SM (-0.332±0.006)%

- At Belle $D^0 \rightarrow K_S\,\pi^0$, tag D flavour with the D* decay

$A_{CP} = (-0.28 \pm 0.19 \pm 0.10)\%$

[PRL 106, 211801 (2011)]



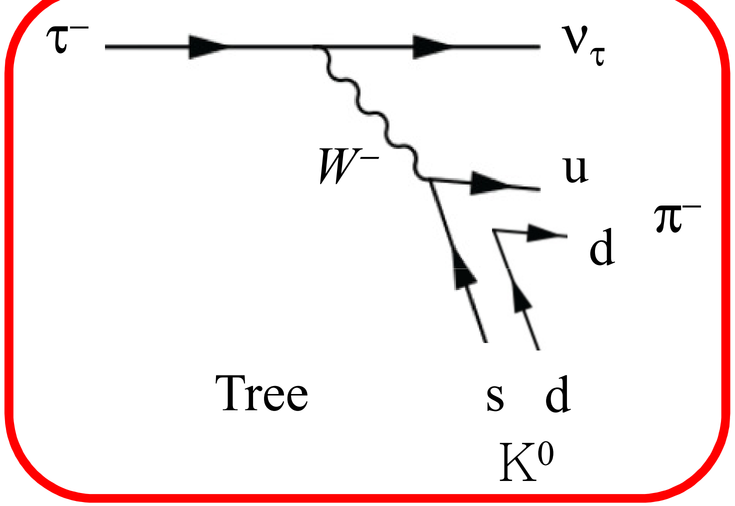
CP Violation in $\tau \to \pi K_s \nu$

Motivation:

- **CP violation not yet observed in the lepton sector**
- **Search for direct CP violation in tau decays: $\tau^- \to \pi^- K_s \nu_\tau$**

$\rightarrow$ **within the SM, due to the K_s presence, the asymmetry:**

$$A_{CP} = \frac{\Gamma(\tau^+ \to \pi^+ K_s^0 \bar{\nu}_\tau) - \Gamma(\tau^- \to \pi^- K_s^0 \nu_\tau)}{\Gamma(\tau^+ \to \pi^+ K_s^0 \bar{\nu}_\tau) + \Gamma(\tau^- \to \pi^- K_s^0 \nu_\tau)}$$



is expected to be $A^{SM}_{CP} = (0.332 \pm 0.006)\%$ [Bigi and Sanda, PLB 625, 47 (2005)]

(same argument than for $D \to K_s \pi$ decays)

$\rightarrow$ **A deviation of the measured A_{CP} from A_{CP}^{SM} would be a hint of New Physics**

- **e.g. an additional CP violating phase from an exotic charged Higgs boson**

[PLB 398, 407 (1997)]

Can consider $\tau^- \to \pi^- K_s (>=0\pi^0) \nu_\tau$ since π^0s are not expected to change the asymmetry

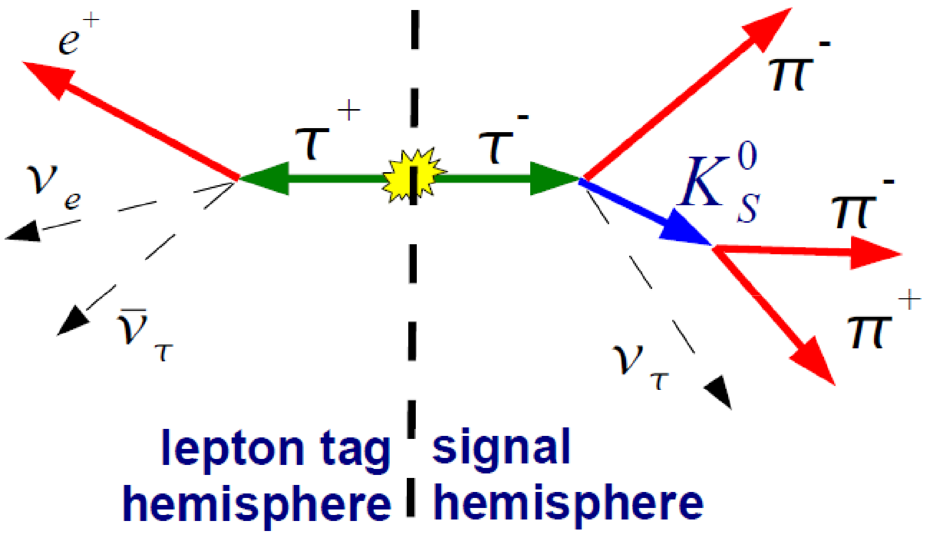
CP Violation in $\tau \to \pi K_s \nu$

Experimental method:

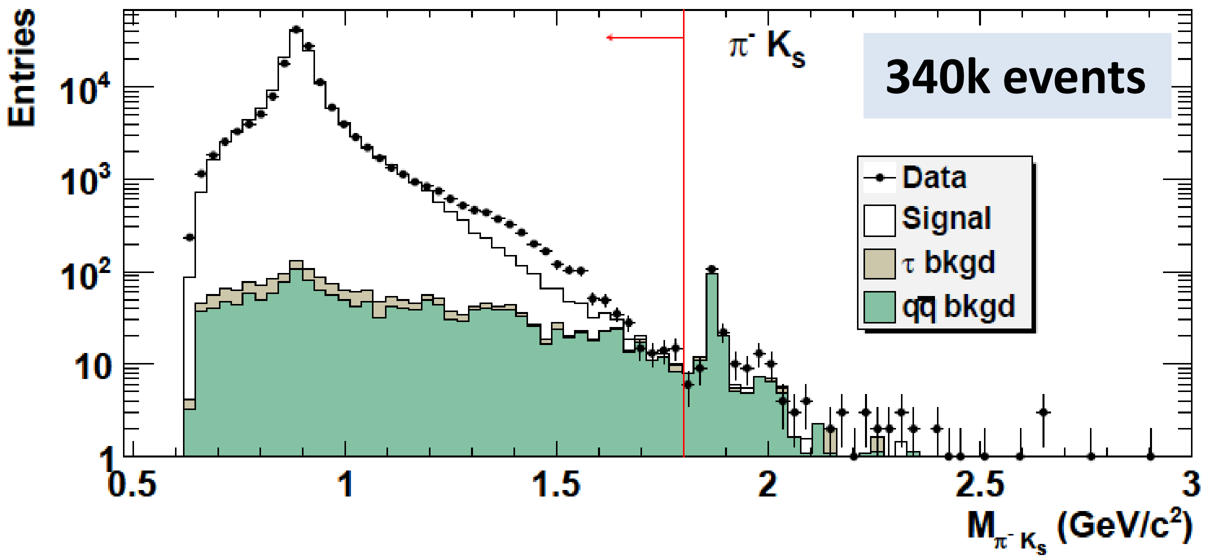
- Reconstruct from continuum $\tau^- \to \pi^- K_s (>=0\pi^0) \nu_\tau$ (up to $3\pi^0_s$)
- Electron and muon tags with $p_\ell^* > 4$ GeV (reduce bkg from non-τ-pairs)
- Reconstructed hadronic mass < 1.8 GeV (rejects qq bkg)
- Remaining background further reduced using information of:

  $\rightarrow$ $q\bar{q}$ events: visible energy, number of neutral clusters, thrust, total transverse momentum

  $\rightarrow$ Fake K^0_s: displaced vertex, invariant mass, momentum and polar angle of the K^0_s candidate



Invariant mass of the hadronic final state ($0\pi^0_s$)



CP Violation in $\tau \rightarrow \pi K_s \nu$

Experimental method:

- Measured raw A_{CP} value (after subtraction of qq background and non-$K^0{}_s\tau$ decays) has to be corrected by:
  - Different nuclear reaction cross-section of K^0 and $\overline{K^0}$ with material detector
    - (0.14±0.03)% for e-tag, (0.14±0.02)% for μ-tag
    - Errors include uncertainties from kaon-nucleon cross-sections and isospin
  - Dilution from background modes including $K^0{}_s$

Source	Fraction e-tag (%)	Fraction μ-tag (%)	SM expected A_{CP}
$\tau^- \rightarrow \pi^- K^0{}_S(\geq 0\pi^0)\nu_\tau$	78.4 ± 4.0	77.4 ± 4.0	(0.33±0.01)%
$\tau^- \rightarrow K^- K^0{}_S(\geq 0\pi^0)\nu_\tau$	4.2 ± 0.3	4.0 ± 0.3	(−0.33±0.01)%
$\tau^- \rightarrow \pi^- K^0 K^0(\geq 0\pi^0)\nu_\tau$	15.6 ± 3.7	15.7 ± 3.7	0

- Result: [Preliminary, submitted to PRD-RC arXiv:1109.1527]

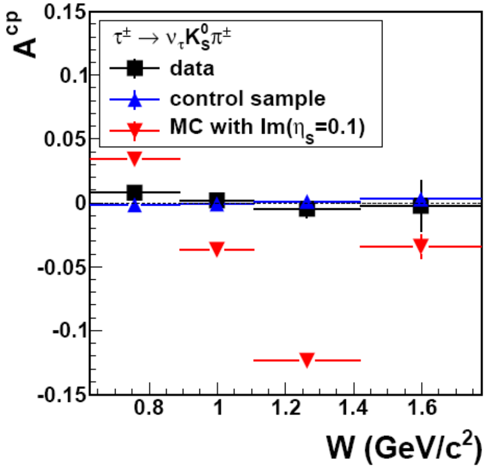
$$\boxed{A_{CP} = (-0.45 \pm 0.24 \pm 0.11)\%}$$

≈3σ from the SM prediction

Belle:

No significant CP asymmetry O(10^{-3})

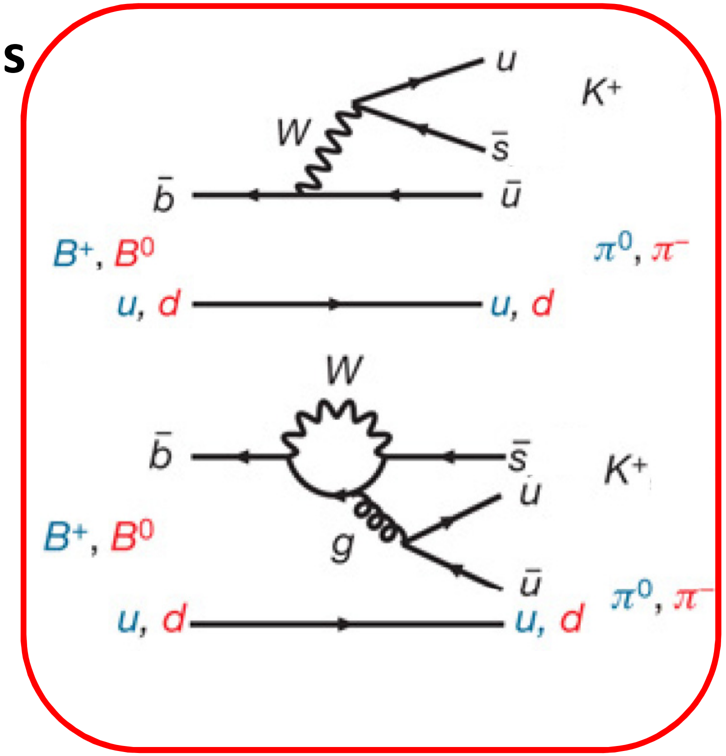
[PRL107:131801,2011]



CP Violation in B$\not\to$c decays

Motivation:

- Many such decays are dominated by b→s penguins
  - Tree amplitudes subdominant in SM
  - Time-dependence and FSI (intermediate states) allow to measure the CKM angles
- New Physics can change CP asymmetries, BRs and polarizations in B→VV decays

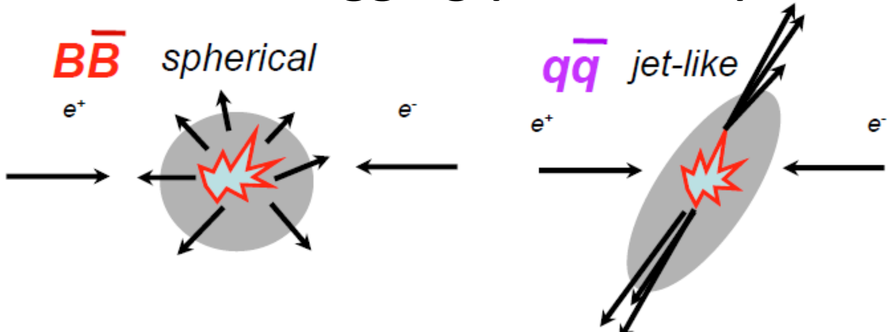


Experimental method:

- Use kinematic constraints from beam energies

$$m_{ES} = \sqrt{\left(\sqrt{s}/2\right)^2 - p_B^{*2}} \qquad \Delta E = E_B^* - \sqrt{s}/2$$

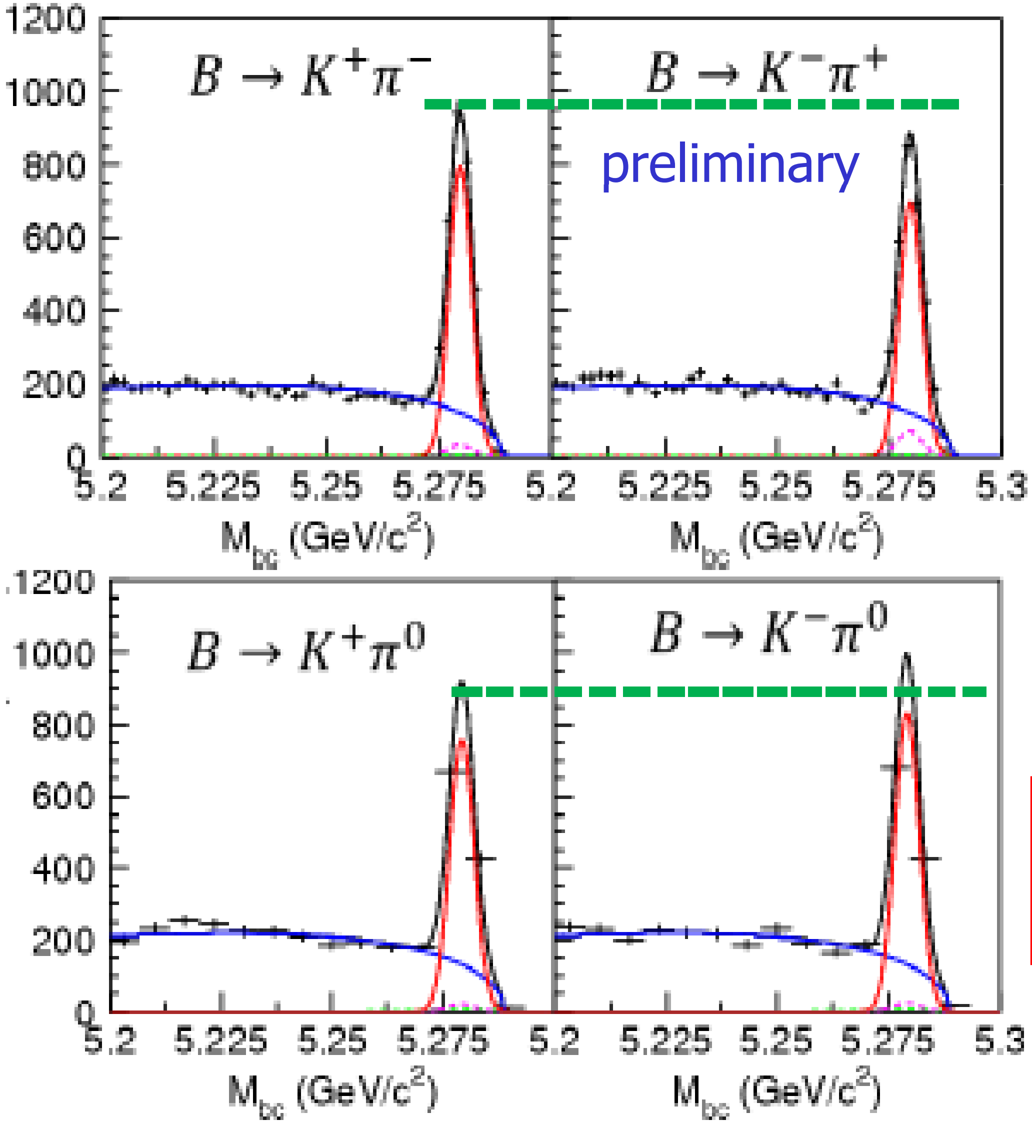
- Event shape variables combined into a linear (Fisher) or non linear (NN) combination. Tagging (other "B") information often used



Apply selection to reject continuum as variable in ML fit

CP Violation in $B \not\to c$ decays

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



$\Delta A_{K\pi} = A_{CP}(K\pi^0) - A_{CP}(K\pi)$
expected to be ~0 in the SM

Update the 2008 result with the full data set and improved reconstruction - ~2x more data 772 M $B\bar{B}$

Belle preliminary:

$\Delta A_{K\pi}$ = +0.112 ± 0.028 @4σ

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

World Average: $\Delta A_{K\pi}$= +0.121 ±0.022 @5.5σ

CP Violation in B$\not\to$c decays

- **Direct CP violation difference in $B^0 \to K^+\pi^-\pi^0$ and $B^+ \to K^+\pi^0\pi^0$ at BaBar**
  - Perform ML fit with m_{ES} and NN, and for $K^+\pi^-\pi^0$ only, also ΔE and Dalitz plot

454×10^6 BB pairs

→ **For $B^0 \to K^+\pi^-\pi^0$**

[PRD 83, 112010 (2011)]

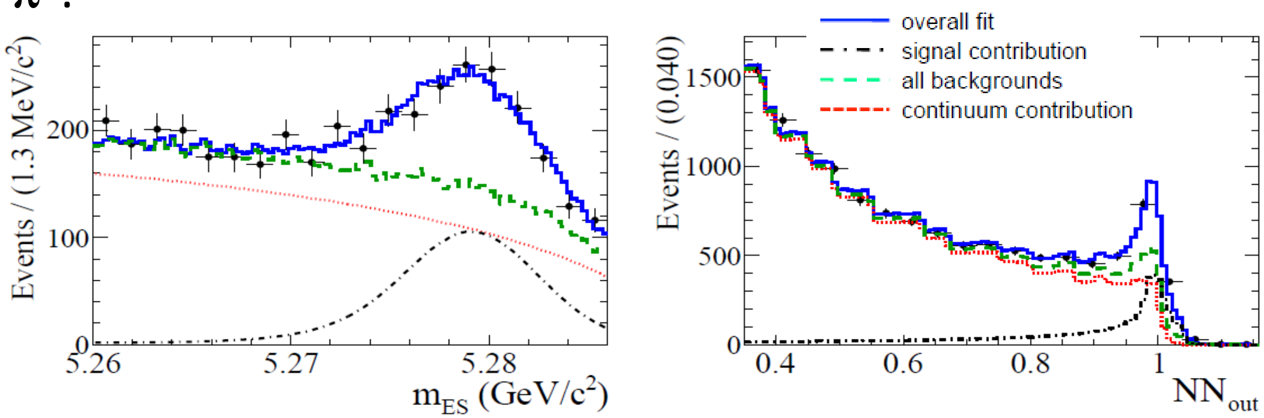
- $BF(B^0 \to K^+\pi^-\pi^0) = (38.5 \pm 1.0 \pm 3.9)\times10^{-6}$
- $A_{CP}(K^{*+}\pi^-) = -0.29 \pm 0.11 \pm 0.02$
- When combined with $B^0 \to K_s\pi^+\pi^-$:

3.1σ evidence for direct CPV

$A_{CP}(K^{*+}\pi^-) = -0.24 \pm 0.07 \pm 0.02$

→ **For $B^+ \to K^+\pi^0\pi^0$**

- **First inclusive measurement**
- Measure resonances in a two-body fashion
- **10 σ significance**



Decay	N_{signal}	BF($\times10^{-6}$)	A_{CP}
$B^+ \to K^+\pi^0\pi^0$	7427±518	16.2±1.2±1.5	−0.06±0.06±0.04
$B^+ \to K^{*+}\pi^0$	1078±197	8.2±1.5±1.1	−0.06±0.24±0.04
$B^+ \to f_0(\to\pi^0\pi^0)K^+$	1186±241	2.8±0.6±0.5	+0.18±0.18±0.04
$B^+ \to \chi_{c0}K^+$	245±105	182±78±32±8	−0.96±0.37±0.04

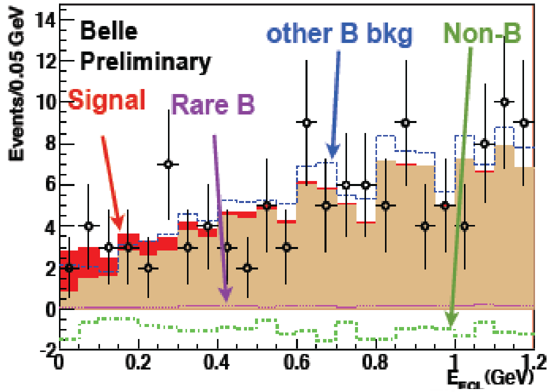
471×10^6 BB pairs

$A_{CP}(K^{*+}\pi^0) = -0.06 \pm 0.24 \pm 0.04$

Preliminary

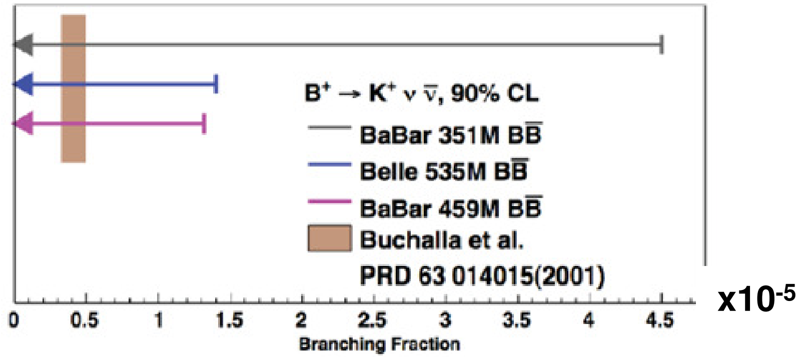
Rare decays

- Rare processes are quite sensitive to New Physics effects



- $B\rightarrow\nu\nu$: Belle: fully reco tag + nothing on the signal side
  BR< 1.3 x 10^{-4} @ 90% CL (BaBar: BR< 2.2 x 10^{-4})

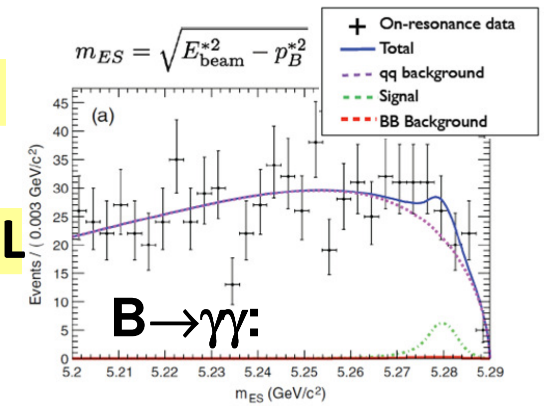
- $B\rightarrow K\nu\nu$: BaBar: semileptonic tag + K and 2ν on the signal side [PRD 82, 112002 (2010)]

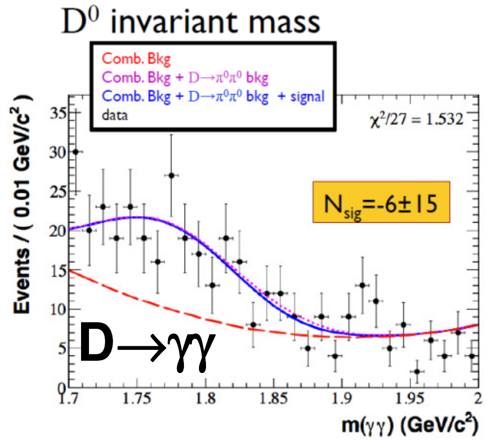


- $B\rightarrow(s+d)\gamma$: BaBar: semileptonic tag + 1 γ on the signal side: A_{CP} = 0.056 ± 0.060 ± 0.018 (≅ SM)

- $B\rightarrow\gamma\gamma$: BaBar: Upper Limit lowered by a factor 2: BR< 3.2 x 10^{-7} @ 90% CL

- $D\rightarrow\gamma\gamma$: BaBar: BR< 2.4 x 10^{-6} @ 90% CL



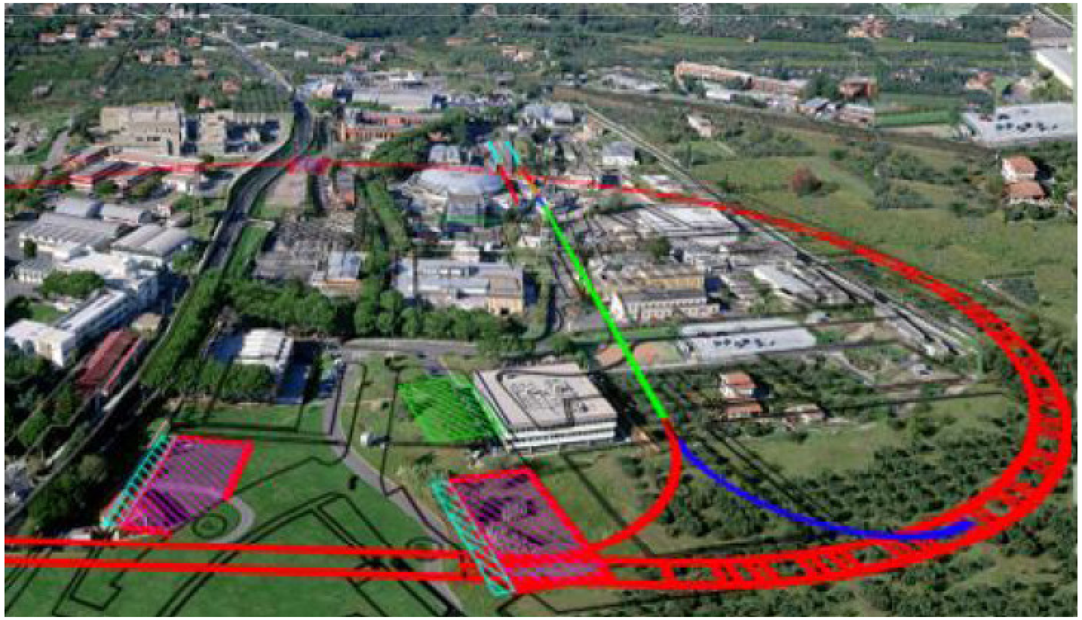


- Most of LFV and LNV $X_c\rightarrow h\ell\ell$ BF ULs down by 1 order of magnitude (10^{-6})

Future: SuperB, Belle-II

- Two new facilities aiming to find New Physics at the TeV scale with an integrated luminosity of 50-75 ab^{-1} around 2020

SuperB, Frascati (Italy)



Belle-II, Tsukuba (Japan)

- Approved, build a new tunnel, new machine reusing and upgrading PEP-II and BaBar, quickly ramping up

- Approved, major upgrade at KEK in 2010-14. SuperKEKB+Belle II, construction started , data taking in 2016

Future: SuperB, Belle-II

τ **Physics**:

B($\tau \to \ell\gamma$) ~ 10^{-9}

B($\tau \to \ell\ell\ell$)~10^{-10}

B($\tau \to \ell h$)~10^{-10}

Charm Physics:

CP parameters: ($K\pi$) (~10^{-5})

FCNC: D$\to$(h)$\ell\ell$ (~10^{-8})

B Physics:

B$\to K\nu\nu$ (~20%)

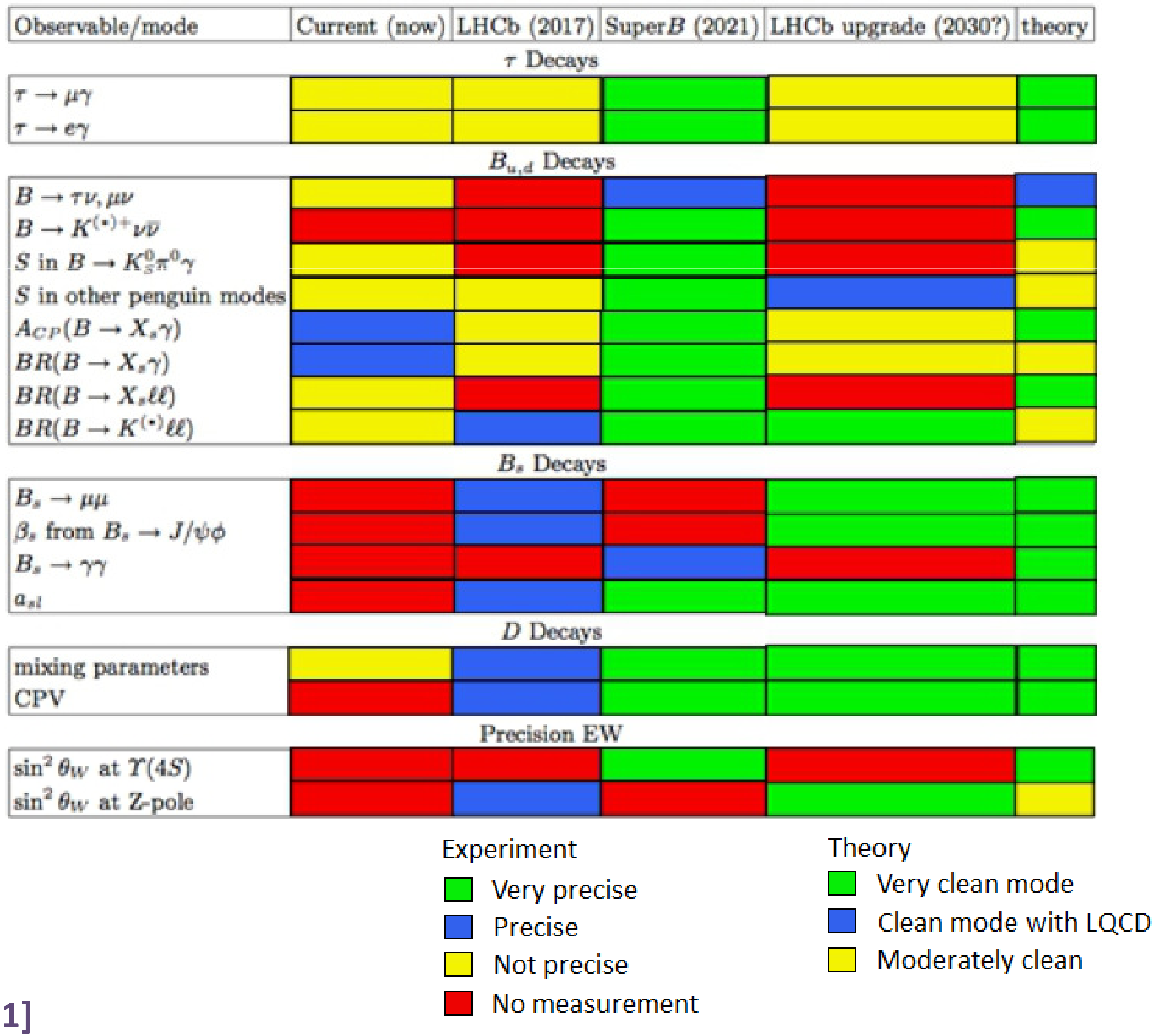
B$\to\tau\nu$ (~ 4%)

B$\to\mu\nu$ (~ 5%),

B$\to D\tau\nu$ (~ 2%)

A_{CP}(b$\to$sγ) (~ 0.002)

V_{ub} (~ 2%)



[SuperB, arXiv:1008.1541]

Summary

- $B \to \tau\nu$ Larger than SM prediction: 2.5σ from $\sin 2\beta$
- $B \to D^{(*)}\tau\nu$ $B \to D^0\tau\nu$ and $B \to D^+\tau\nu$ more than 5σ significance
  $R(D^{(*)})$ exceed by 1.8 σ the SM values
- V_{ub} $|V_{ub}|_{excl.} = (3.19 \pm 0.14 \pm 0.27) \times 10^{-3}$
  $|V_{ub}|_{incl.} = (4.34 \pm 0.13 \pm 0.15) \times 10^{-3}$ More than 3σ difference
- $\Delta A_{CPK\pi}$ $\neq 0$ with with more than 5σ significance
- CPV in $\tau^- \to \pi^- K_s \nu_\tau$ A_{CP} at 3σ from SM prediction at BaBar
- Many other improved results on CP asymmetries, BRs, Upper Limits for rare decays, charm decay constants, form factors, spectroscopy…

- Waiting exciting results from LHCb ⊕ the new generation of flavour facilities: SuperB & Belle-II