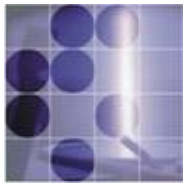
B Physics @ e^+e^-

Boštjan Golob
University of Ljubljana/Jožef Stefan Institute & Belle/Belle II Collaboration

University of Ljubljana



"Jožef Stefan" Institute

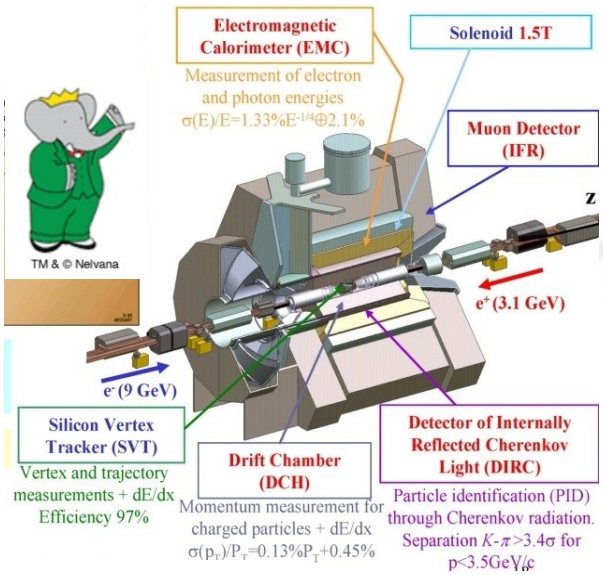
(proxy for Steven Robertson)

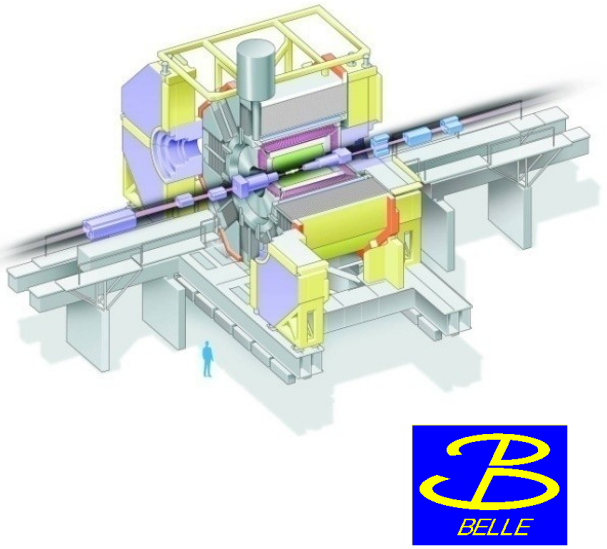
The Role of Heavy Fermions in Fundamental Physics, Portorož, April 11-14, 2011

B Physics @ e^+e^-

Some recent measurements:

- ϕ_1 update
- ϕ_3 Dalitz
- $b \to s(+d)\ \gamma$
- $B \to \tau\nu$





1999-2008
$\int \mathcal{L} dt \sim 530\ fb^{-1}$

1999-2010
$\int \mathcal{L} dt \sim 1020\ fb^{-1}$

on resonance production
$e^+e^- \to \Upsilon(4S) \to B^0\bar{B}^0, B^+B^-$
$\sigma(B\bar{B}) \approx 1.1$ nb (~$800 \cdot 10^6$ $B\bar{B}$ pairs)

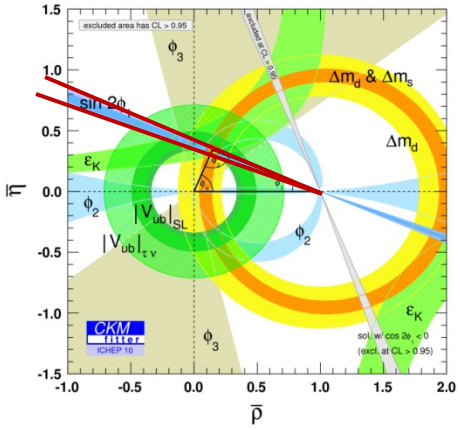
Belle status after the earthquake:

KEK official statement:
"As is now well known, Japan suffered a terrible earthquake and tsunami on March 11, which has caused tremendous damage, especially in the Tohoku area. Fortunately, all KEK personnel and users are safe and accounted for. The injection linac did suffer significant but manageable damage, and repairs are underway. The damage to the KEKB main rings appears to be less serious, though non-negligible. No serious damage has been reported so far at Belle. Further investigation is necessary. We would like to convey our deep appreciation to everyone for your generous expressions of concern and encouragement."

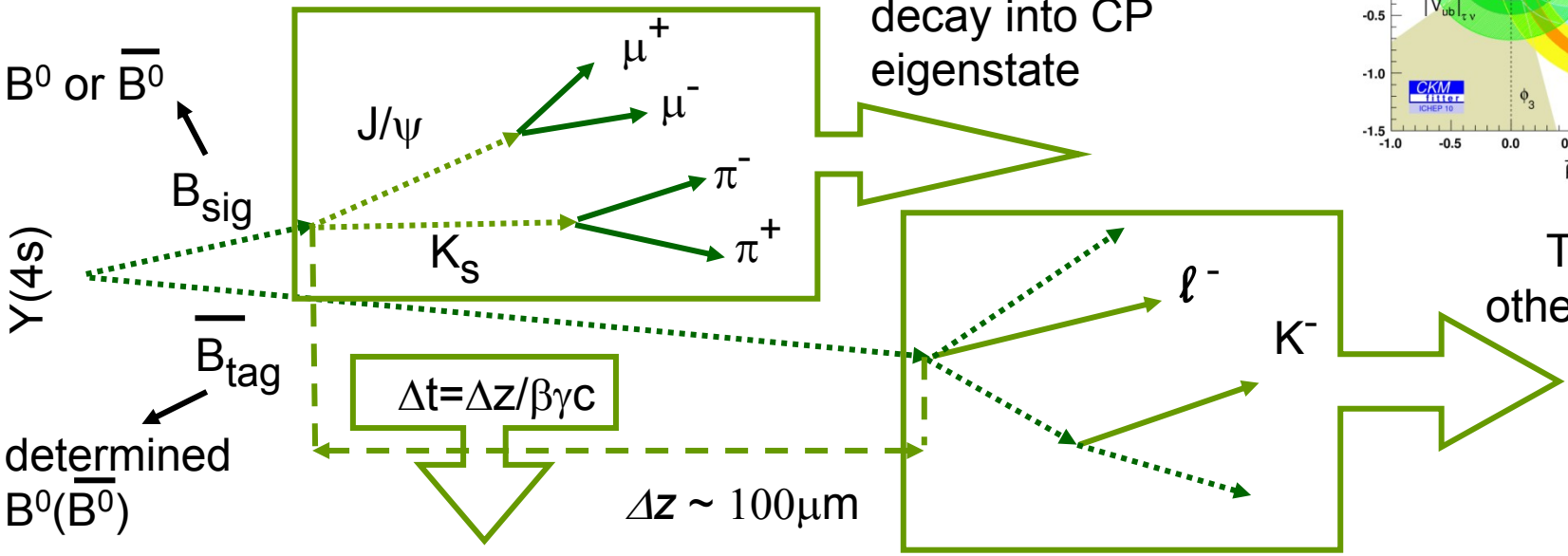
Most troublesome issue at the moment:

lack of electrical power, efforts going on to transfer data to locations other than KEK to assure the continuity of measurements (summer 2011 conferences)

ϕ_1 from $B^0 \to c\bar{c}\, K^0$



Method:



Fully reconstructed B decay into CP eigenstate

Tagging of other *B* flavor from the charge of typical decay products

Determination of the time between decays of two *B's*

$$p(\Delta t) = \frac{e^{|\Delta t|/\tau_{B^0}}}{4\tau_{B^0}} \{1 \pm [S_{f_{CP}} \sin(\Delta m_d \Delta t) + A_{f_{CP}} \cos(\Delta m_d \Delta t)]\}$$

$$S_{f_{CP}} = -\xi_{f_{CP}} \sin 2\phi_1$$

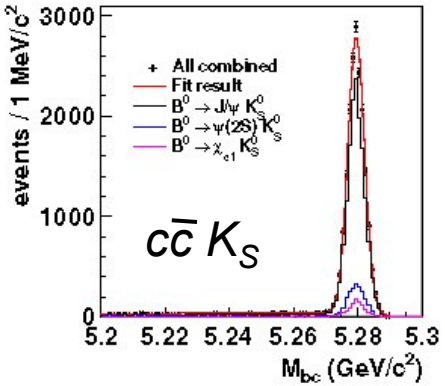
$$A_{f_{CP}} \simeq 0$$

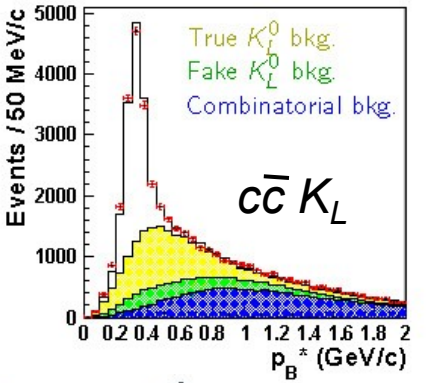
ϕ_1 from $B^0 \to c\bar{c}\, K^0$

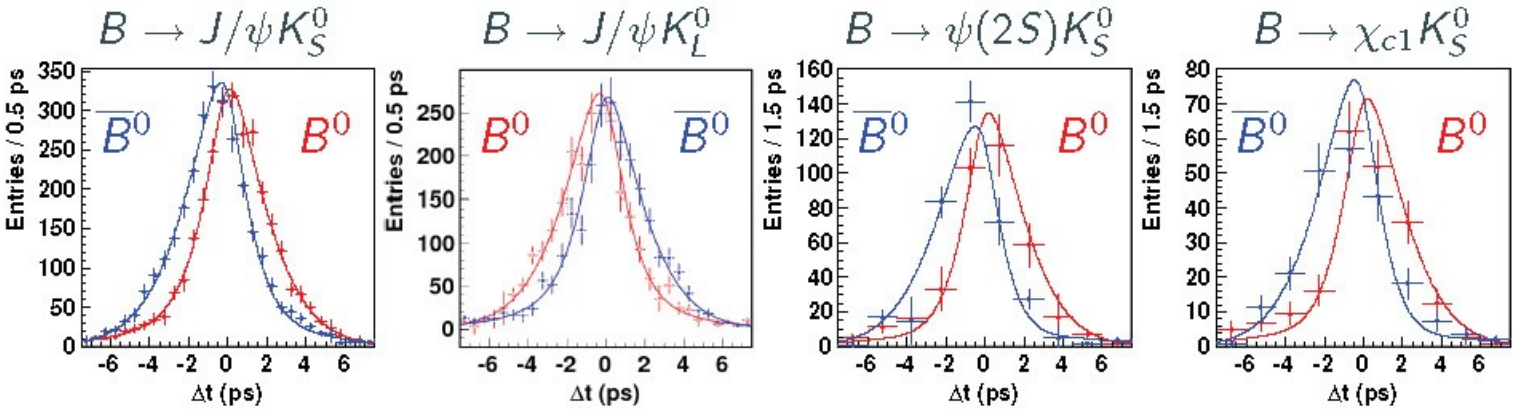
Belle, preliminary, 710 fb^{-1}

Improved tracking, more data
(50% more statistics than last result with 480 fb^{-1});
$c\bar{c}$ = J/ψ, $\psi(2S)$, χ_{c1}
for K_L only cluster (direction) in ECL, KLM;
missing info from kinematic constraints;

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





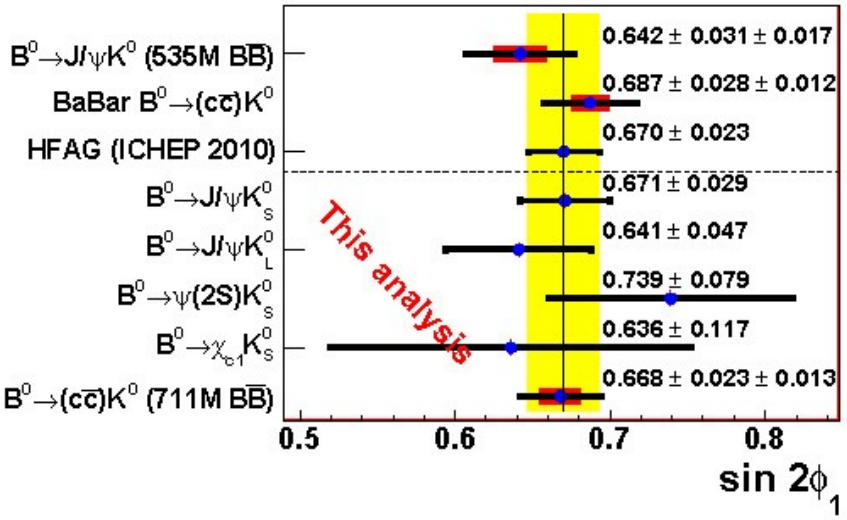


ϕ_1 from $B^0 \to c\bar{c}\, K^0$

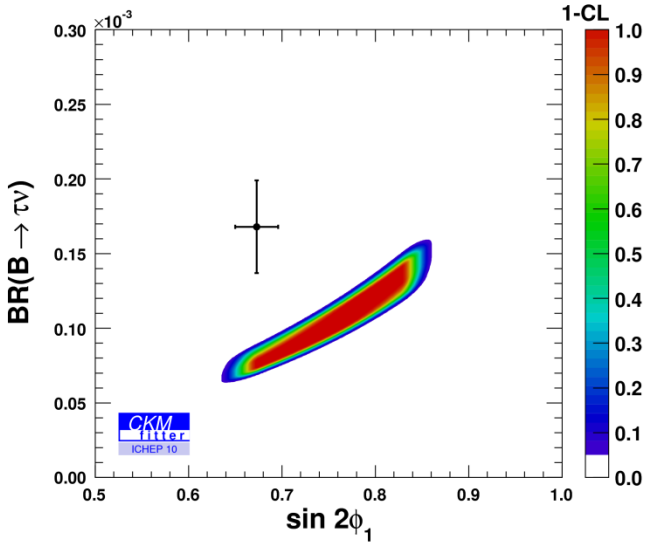
Belle, preliminary, 710 fb^{-1}

(Expected to be) final result from Belle:

$S = 0.668 \pm 0.023 \pm 0.013$
$A = 0.007 \pm 0.016 \pm 0.013$



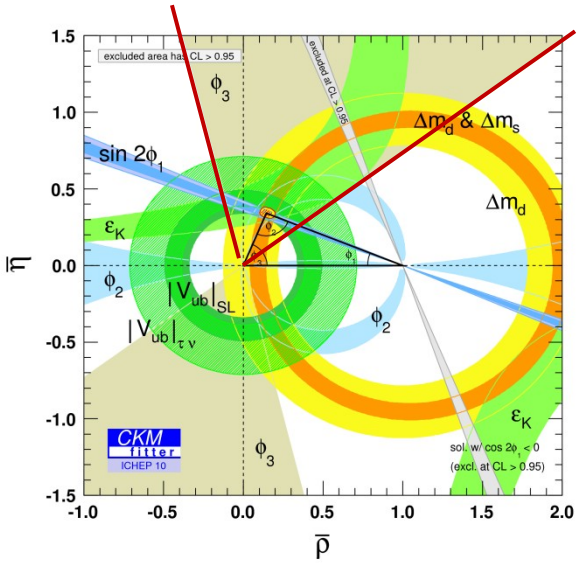
Tension between $\mathcal{B}(B \to \tau\nu)$ and $\sin 2\phi_1$ (2.8 σ) expected to be slightly decreased

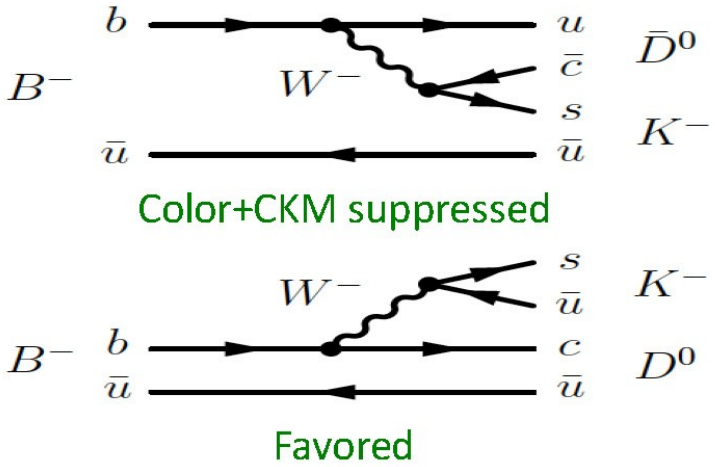


ϕ_3 Dalitz

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

GGSZ method





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

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

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

$$= \left| \quad + re^{i\delta_B \pm i\phi_3} \quad \right|^2$$

model dependent description of f_D

$\Rightarrow$

systematic uncertainty

$\phi_3 = (78 \pm 12 \pm 4 \pm 9)^\circ$

Belle, PRD81, 112002, (2010), 605 fb^{-1}

ϕ_3 Dalitz

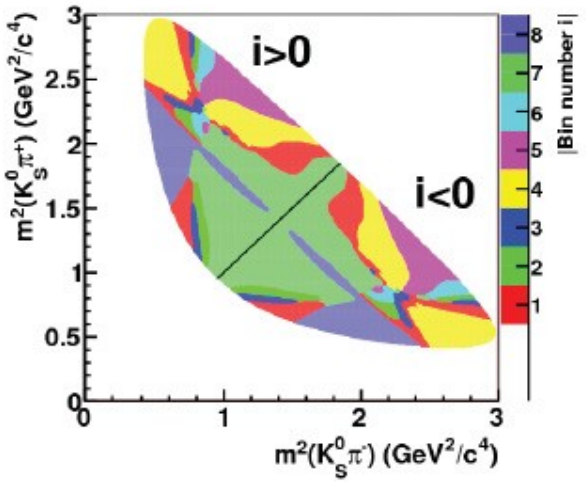
GGSZ method

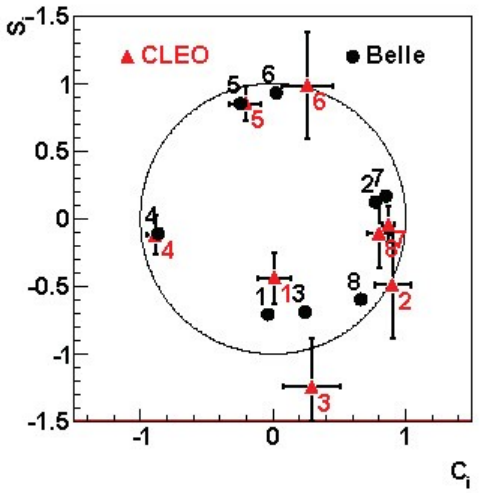
model independent measurement:

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

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

M_i: # B decays in bins of D Dalitz plane
K_i: # D^0 (D^0) decays in bins of D Dalitz plane ($D^* \to D\pi$)
c_i, s_i: strong phase difference between symmetric Dalitz points
$\Rightarrow$ measured by Cleo-c (BES III)





Cleo, PRD82, 112006, (2010)

ϕ_3 Dalitz

GGSZ method

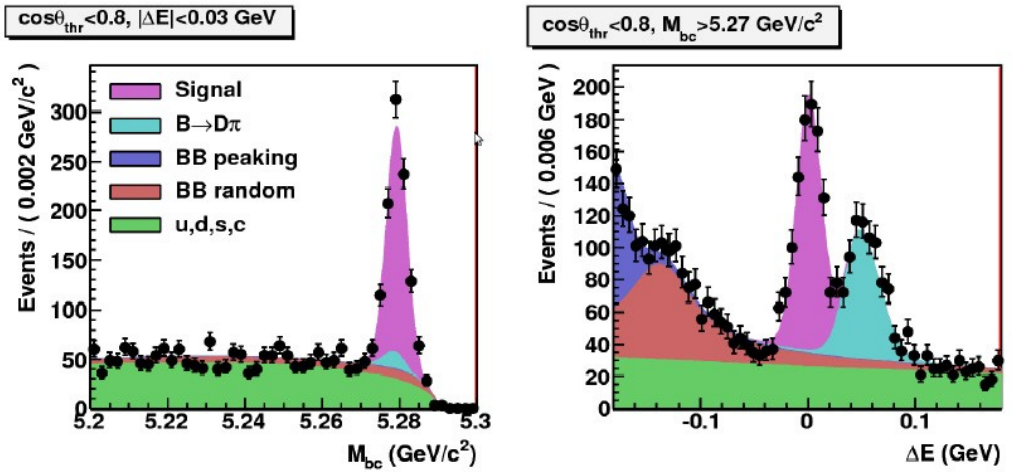
Belle, preliminary, 710 fb^{-1}

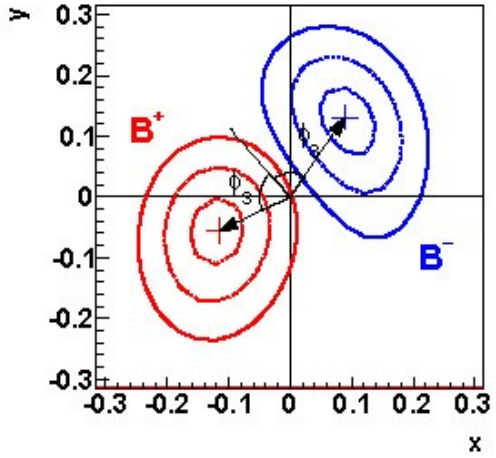
4-dim fit for signal yield (ΔE, M_{bc}, $\cos\theta_{thrust}$, $\mathcal{F}$);

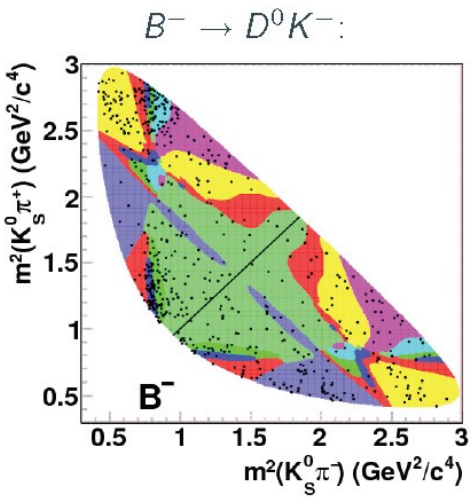
$\phi_3=(77 \pm 15 \pm 4 \pm 4)^o$

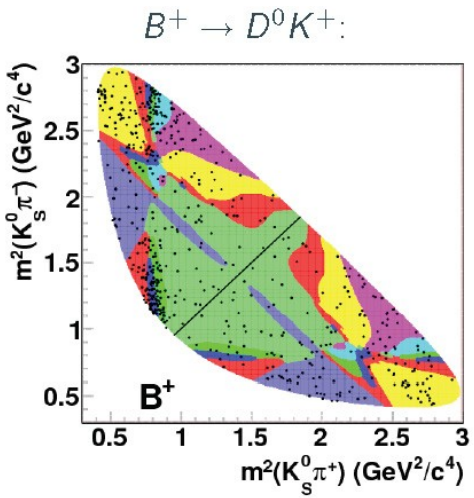
from c_i, s_i (statist.!)

$N_{sig} = 1176 \pm 43$









$b \to s\gamma$

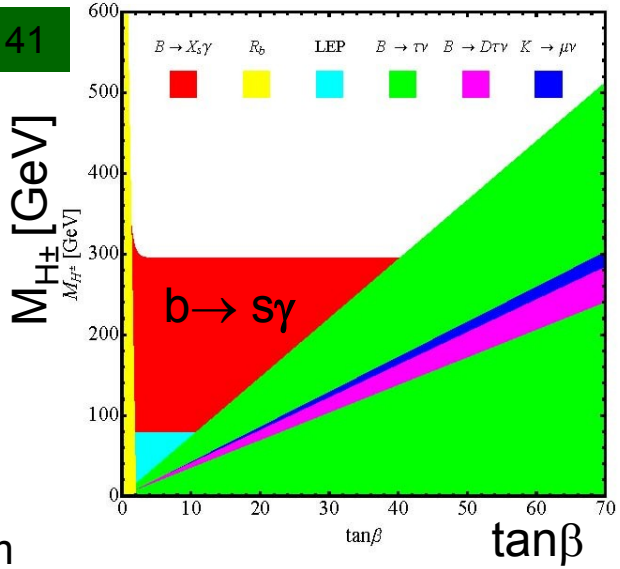
U. Haisch, arXiv:0805.2141

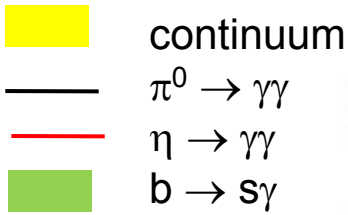
Inclusive $b \to s(+d)\gamma$

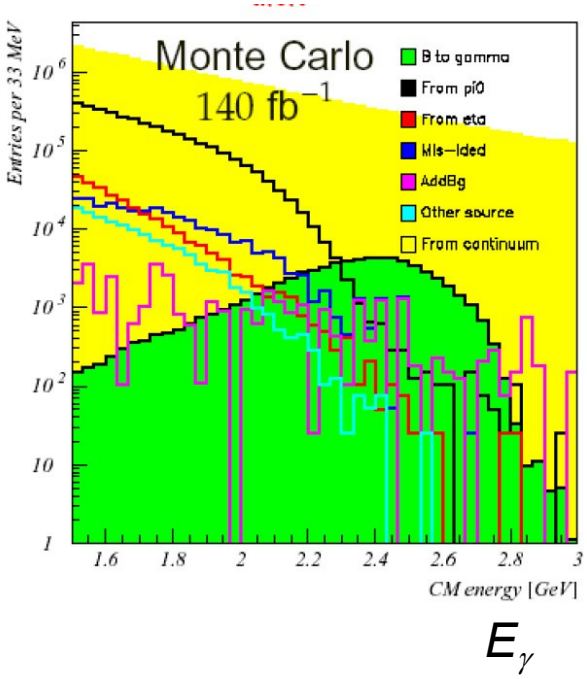
FCNC process;
sensitive to NP in loop;

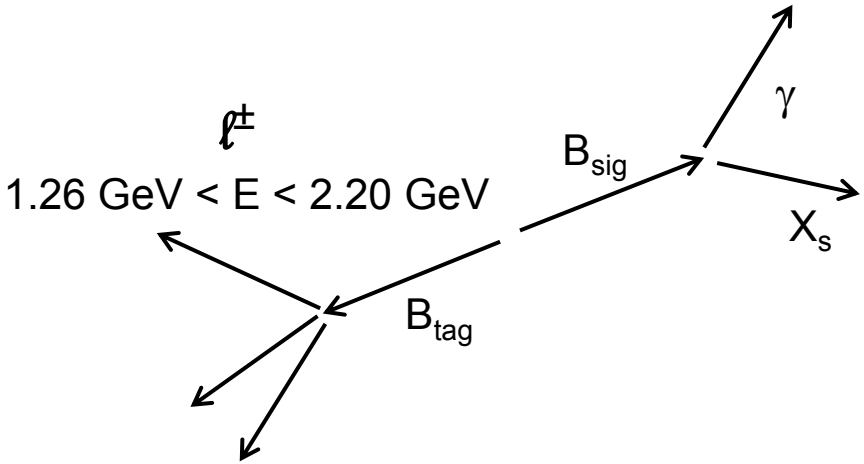
experimental challenge:
huge background

only γ reconstructed on signal side









$b \to s\gamma$

Inclusive $b \to s(+d)\gamma$

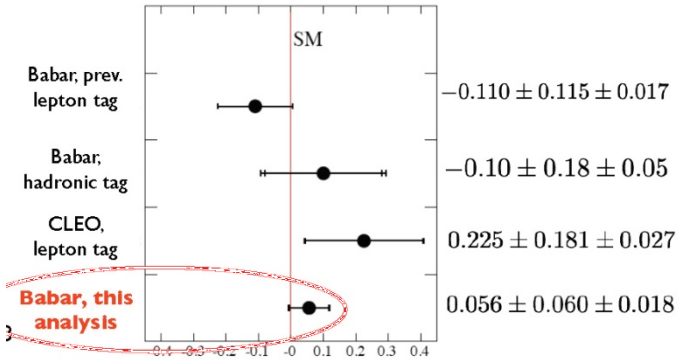
subtract scaled E_γ from off-resonance;

using semileptonic tagging $\Rightarrow A_{CP}$

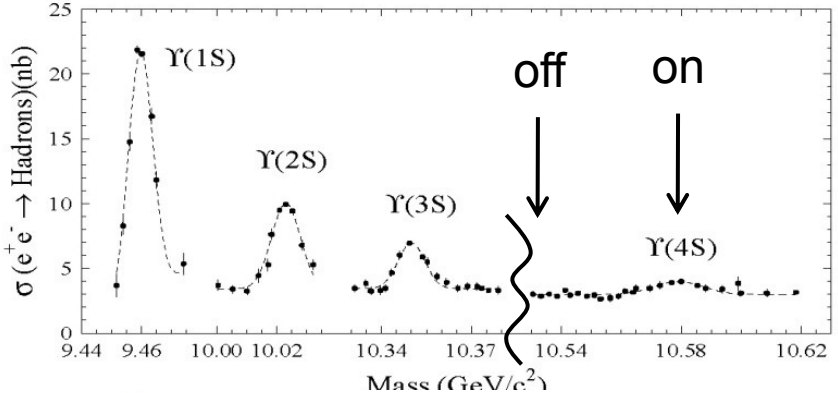
$$A_{CP} = \frac{\Gamma(b \to s\gamma + b \to d\gamma) - \Gamma(\bar{b} \to \bar{s}\gamma + \bar{b} \to \bar{d}\gamma)}{\Gamma(b \to s\gamma + b \to d\gamma) + \Gamma(\bar{b} \to \bar{s}\gamma + \bar{b} \to \bar{d}\gamma)}$$

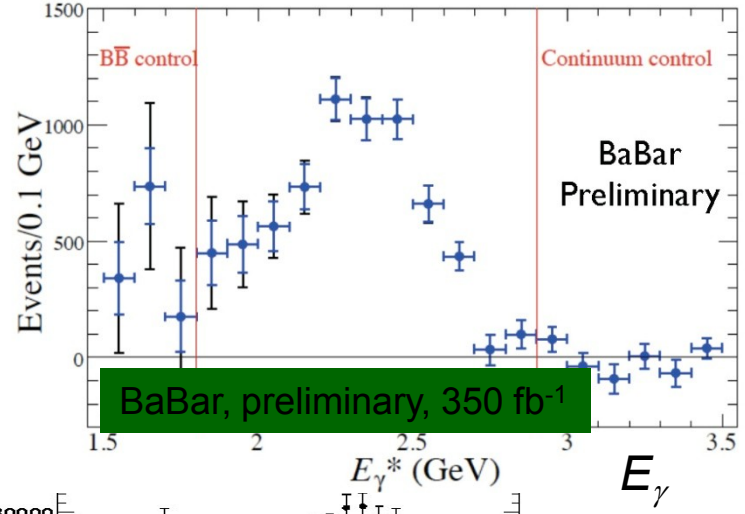
$$A_{CP}(B \to X_{s+d}\gamma) = O(m_s^2 / m_b^2) \sim 10^{-4}$$

A_{CP}=0.056 ± 0.060 ± 0.018

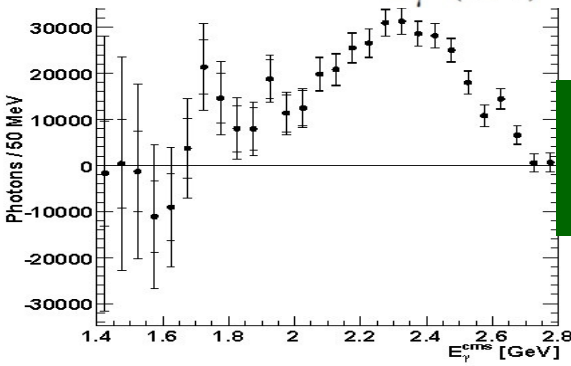


Belle: $b \to d\gamma$ subtracted



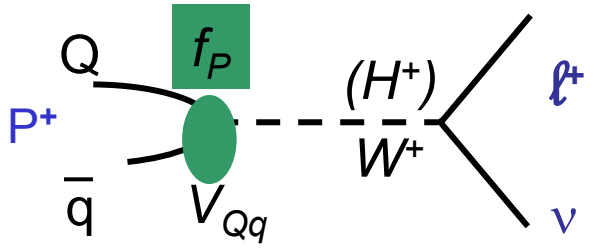


BaBar, preliminary, 350 fb^{-1}



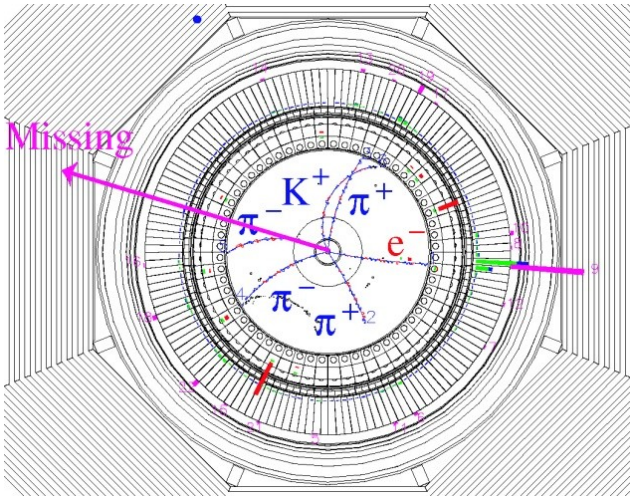
Belle, PRL103, 241801, (2008), 605 fb^{-1}

$B \to \tau\nu$



$B^+ \to \tau^+\nu$

fully (partially) reconstruct B_{tag};
search for 1/3 tracks from $B_{sig} \to \tau\nu$;
no additional energy in EM calorim.;
signal at E_{ECL}~0;



full B_{tag} reconstruction: hadronic tagging
partial B_{tag} reconstruction: semileptonic tagging

BaBar, arXiv: 1008.0104, 350 fb^{-1}

reconstruct. ε (hadronic tag, including $\tau\,\mathcal{B}$): $8 \cdot 10^{-4}$

Belle,PRD82, 071101 (2010), 605 fb^{-1}

reconstruct. ε (semileptonic tag, including $\tau\,\mathcal{B}$): $14 \cdot 10^{-4}$
new NN hadronic tag, ε increased by 80%

$B \to \tau\nu$

$B^+ \to \tau^+\nu$

result:

$\mathcal{B}(B^+ \to \tau^+\nu)=(1.80 \pm 0.56 \pm 0.26) \cdot 10^{-4}$

BaBar, arXiv: 1008.0104, 350 fb^{-1}

$\mathcal{B}(B^+ \to \tau^+\nu)=(1.65 \pm 0.38 \pm 0.36) \cdot 10^{-4}$

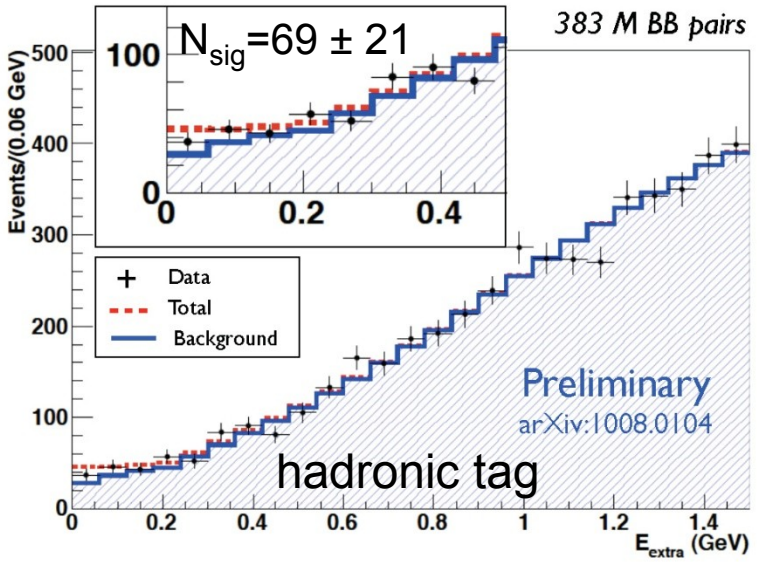
Belle,PRD82, 071101 (2010), 605 fb^{-1}

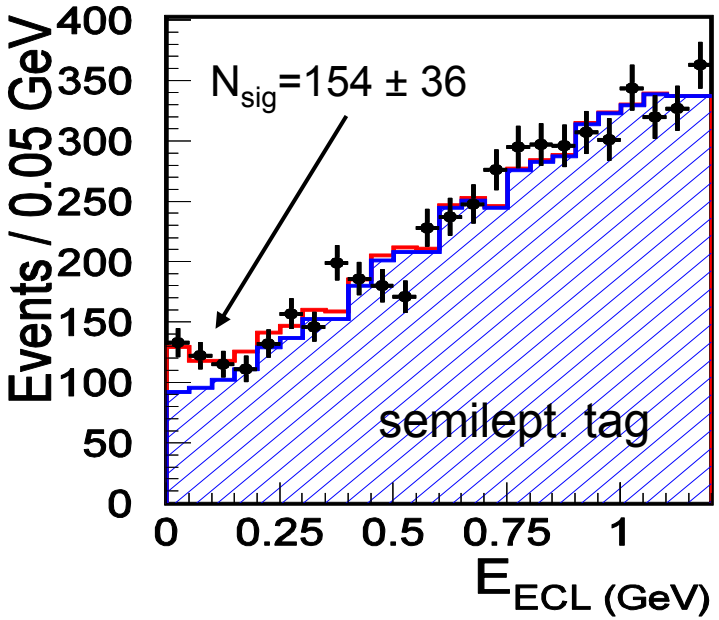
average, both tags (10^{-4})	
BaBar	1.76±0.49
Belle	1.54±0.48
HFAG	1.64±0.34

J. Walsh, Moriond EW 2011

$\mathcal{B}^{SM}(B^+ \to \tau^+\nu)=(1.20 \pm 0.20) \cdot 10^{-4}$

$$|V_{ub}| = (4.32 \pm 0.33) \times 10^{-4}$$
$$f_B = 190 \pm 13 \text{ MeV}$$
$$\tau_{B^+} = 1.638 \pm 0.011 \text{ ps}$$





Summary

- sin2ϕ_1 result from final data sample (1 ± 0.04 single meas.)
- ϕ_3 model independent determination (important for LHCb)
- many measurements being currently updated with final data sets

  $b \to s+d$ γ update (BaBar)

  $B \to \tau\, \nu$ (improved hadronic tag at Belle)
- expecting final results on modes to be fully exploited at Super B factories

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

Additional information

Int. luminosity

Belle

>1ab^{-1}

On resonance:

- Υ(5S): 121fb^{-1}
- Υ(4S): 711fb^{-1}
- Υ(3S): 3fb^{-1}
- Υ(2S): 24fb^{-1}
- Υ(1S): 6fb^{-1}

Offreson./scan:
~100fb^{-1}

BaBar

~550fb^{-1}

On resonance:

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

Offresonance:
~54fb^{-1}

System. error:

- vertexing: missalignment, IP profile
- tag-side interf.:

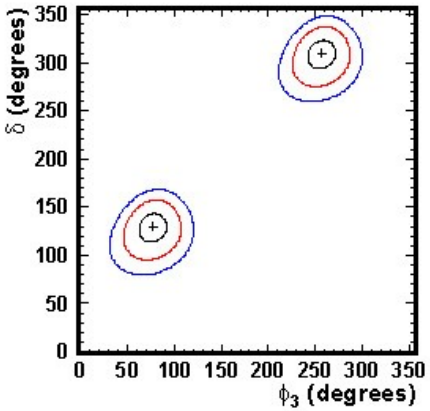
syst. from tag side interference: most of tagging from flavor specific final states, some contrib. from flavor non-specific (e.g. $D\pi$, CF/DCS); due to this Δt pdf is affected; can be checked with $B_{sig} \rightarrow D^* l \nu$ (no A_{CP}, effect tested on MC w/ and w/o B_{tag} interference)

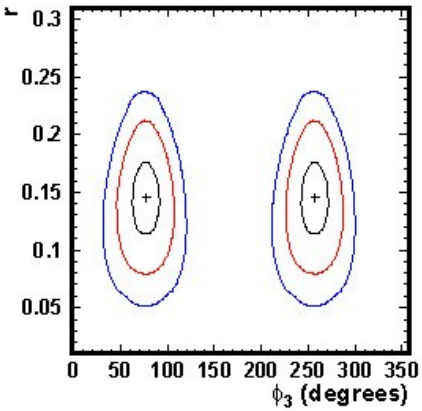
	ΔS	ΔA
Vertexing	$^{+0.008}_{-0.009}$	± 0.008
Flavor tagging	$^{+0.004}_{-0.003}$	± 0.003
Resolution function	± 0.007	± 0.001
Physics parameters	± 0.001	< 0.001
Fit bias	± 0.004	± 0.005
$J/\psi K^0_S$ signal fraction	± 0.002	± 0.001
$J/\psi K^0_L$ signal fraction	± 0.004	$^{+0.000}_{-0.002}$
$\psi(2S) K^0_S$ signal fraction	< 0.001	< 0.001
$\chi_{c1} K^0_S$ signal fraction	< 0.001	< 0.001
Background Δt	± 0.001	< 0.001
Tag-side interference	± 0.001	± 0.008
Total	± 0.013	± 0.013

ϕ_3 Dalitz

results:

$$\phi_3 = (77.3^{+15.1}_{-14.9} \pm 4.2 \pm 4.3)^\circ$$
$$r_B = 0.145 \pm 0.030 \pm 0.011 \pm 0.011$$
$$\delta_B = (129.9 \pm 15.0 \pm 3.9 \pm 4.7)^\circ$$





- main detector syst. from parametrization of signal, continuum and *BB* background

$b \to s\gamma$

- continuum subtraction:

$$N^{B\bar{B}}(E_\gamma^{CMS}) = N^{ON}(E_\gamma^{CMS}) - \alpha\, C_\varepsilon\, N^{OFF}(F_E E_\gamma^{CMS})$$

- A_{CP} as high as 10% in NP

Nucl.Phys.B704, 56, (2005)

α: lumin. ratio,
$\sqrt{s}$ dependence, ~8.8
C_ε: efficiency;
F_E: lower E_γ in off-data

-

- Control regions:
  - continuum: On-Off Data = -100±138 events
  - BB: 1252±272±841⇒ 1.4σ (assumes no signal, where expect 100-400 signal events in low-energy tail)
- A_{CP} is insensitive to photon energy cut: optimize ⇒ (2.1-2.8) GeV
- Yields:
  - N(l+) = 2623±158
  - N(l-) = 2397±151
- Account for mistag and bias:

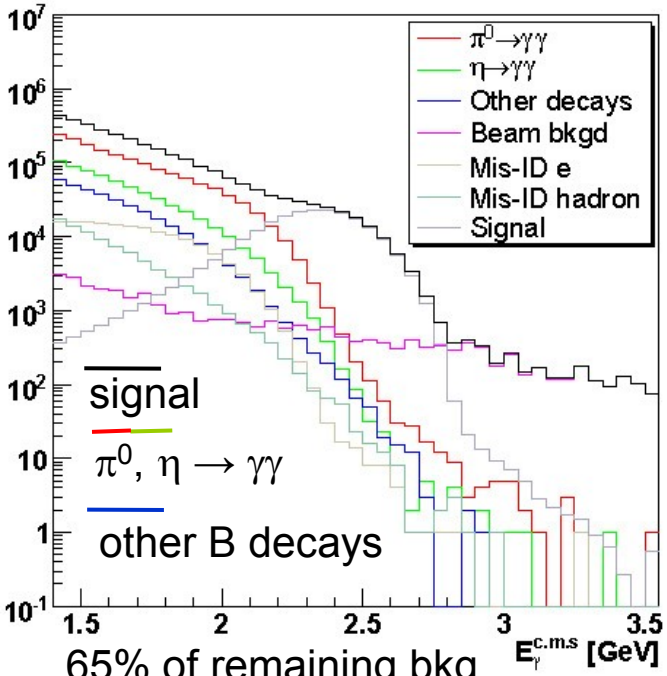
$$A_{CP} = \frac{A_{CP}^{meas}}{1-2\omega} + \Delta A_{CP}$$

J. Walsh, Moriond EW 2011

- after vetoing π^0, $\eta \to \gamma\gamma$:

Belle, PRL103, 241801, (2008), 605 fb^{-1}

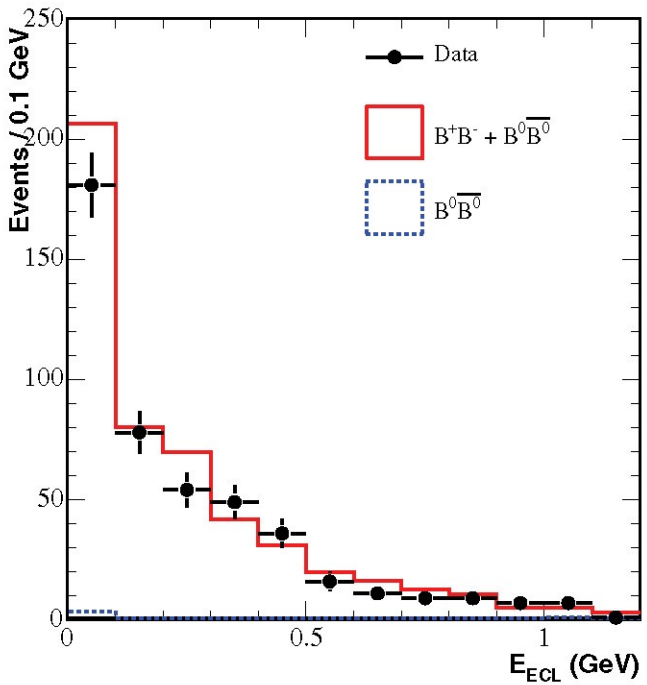
$$Br(B \to X_s\gamma; 1.7\,GeV < E_\gamma < 2.8\,GeV) = (3.47 \pm 0.15 \pm 0.40) \cdot 10^{-4}$$



65% of remaining bkg. from π^0, $\eta \to \gamma\gamma$

- system. error:
  background E_{ECL} shape (histogramed MC used for semil. tag analysis);
  continuum checked using off-resonance data (largest fract. of bkg. in semil. tag; for hadr. tag b $\to$u l ν also important);
  check of other important distributions with E_{ECL} sideband data;

- Check of E_{ECL}:
  double tagged decays,
  $B_{sig}^- \to D^{*0}\ell^-\nu$, $D^{*0} \to D^0\pi^0$



$B \to K \nu\nu$

$B \to h \nu\nu$

$B_{sig}B_{tag} \to (h\nu\nu)(X\ell\nu)$ semil. tag

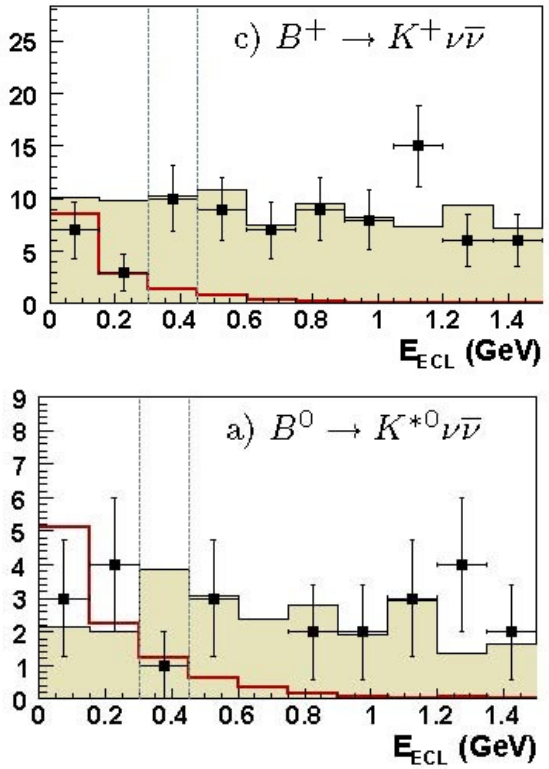
$\to (h\nu\nu)(X)$ hadr. tag

(BaBar: semil. tag only; additional bkg. suppresion with NN)

Belle, PRL99, 221802 (2007), 490 fb^{-1}

-- exp. signal (20xBr)

exp. bkg. (scaled to sideband)



90% C.L.UL's

SM

G. Buchalla et al., PRD63, 014015 (2001)

$\mathcal{B}(K^{*+}\nu\nu) < 1.4 \cdot 10^{-4}$

$\mathcal{B}(K^{*0}\nu\nu) < 3.4 \cdot 10^{-4}$ $\quad 1.3 \times 10^{-5}$

$\mathcal{B}(K^{+}\nu\nu) < 1.4 \cdot 10^{-5}$ $\quad 3.6 \times 10^{-6}$

$\mathcal{B}(K^{0}\nu\nu) < 1.6 \cdot 10^{-4}$

$\mathcal{B}(K^{+}\nu\nu) < 1.3 \cdot 10^{-5}$

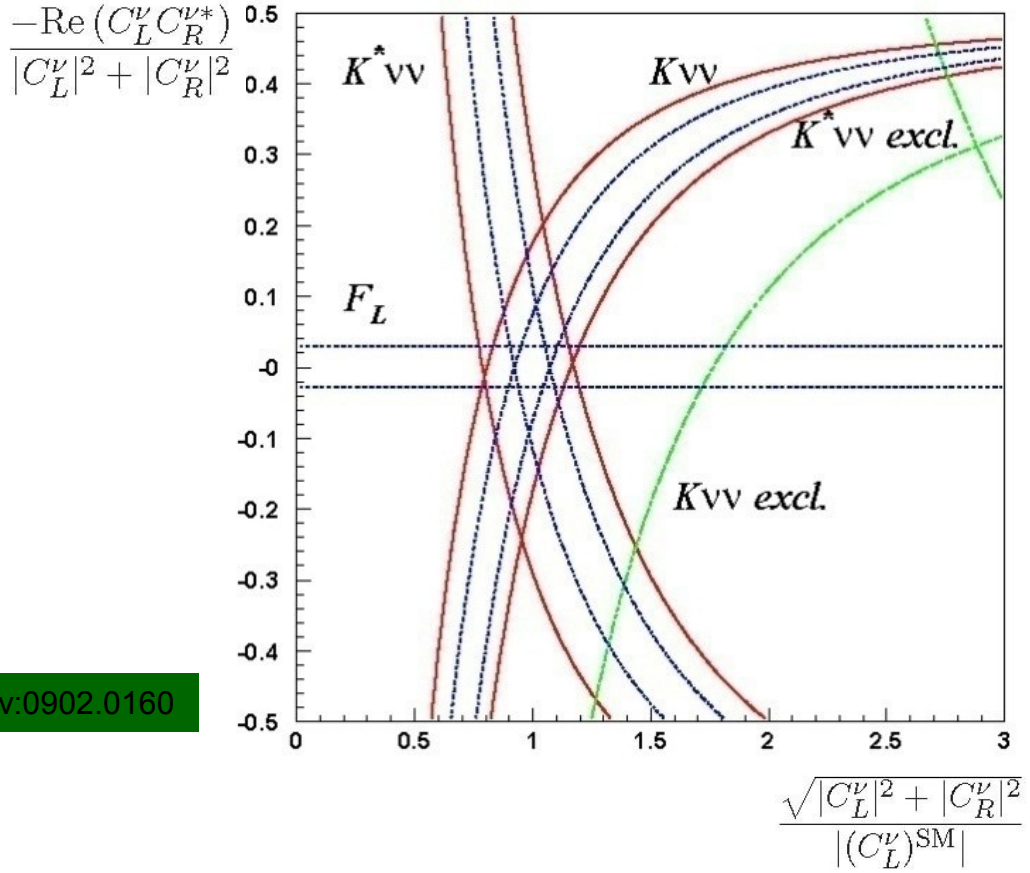
$\mathcal{B}(K^{0}\nu\nu) < 5.6 \cdot 10^{-5}$

Mode	N_{obs}	N_{obs} - N_{BG}
K^+	$19.4^{+4.4}_{-4.4}$	$1.8^{+6.2}_{-5.1}$
K^0	$6.1^{+4.0}_{-2.2}$	$2.2^{+4.1}_{-2.8}$
low-q^2 K^+	$19.4^{+4.4}_{-4.4}$	$1.8^{+6.2}_{-5.1}$
high-q^2 K^+	164^{+13}_{-13}	-23^{+49}_{-48}

BaBar, PRD82, 112002 (2010), 410 fb^{-1}

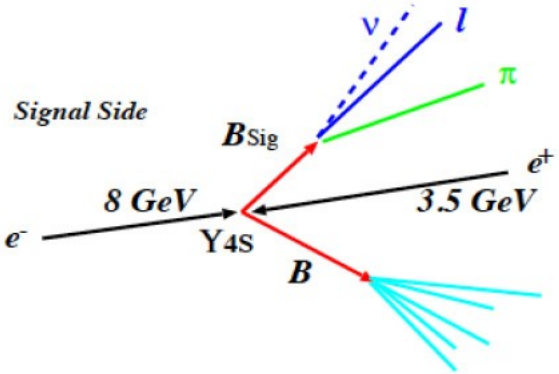
$B \to K \nu\nu$

$B \to h \nu\nu$



W. Altmannshofer et al., arXiv:0902.0160

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

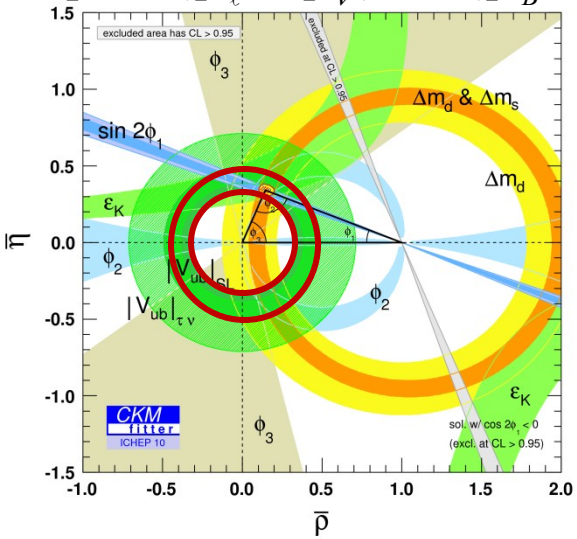


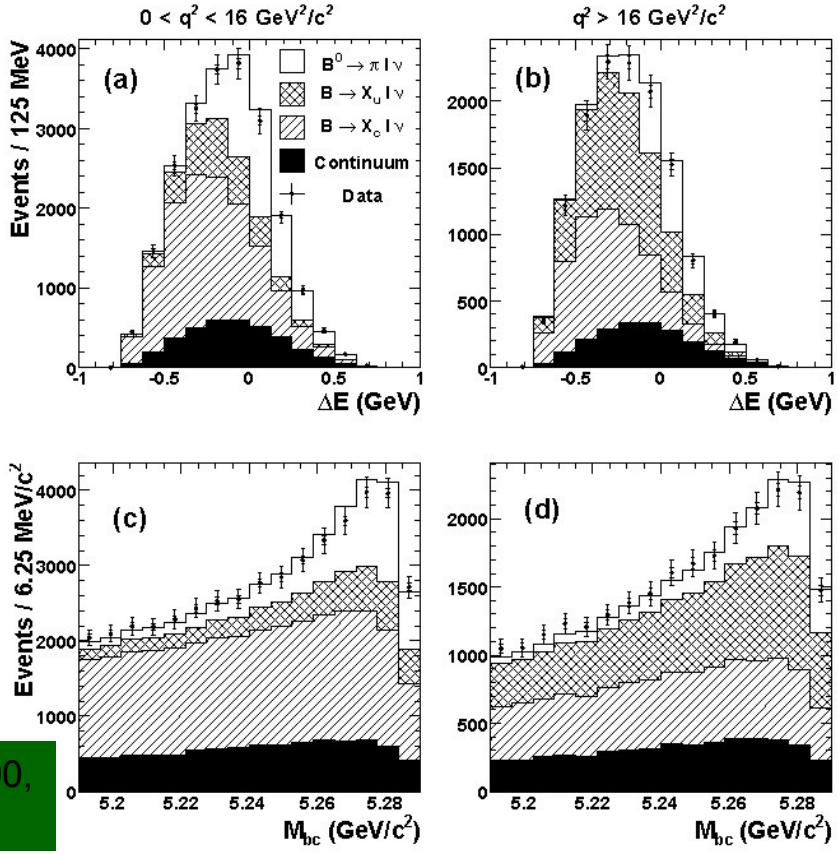
B reconstruction (CMS):

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

$$\vec{p}_{miss} = -\sum_{i \neq \pi,\ell} \vec{p}_i$$

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





Belle, arXiv:1012:0090, 605 fb^{-1}

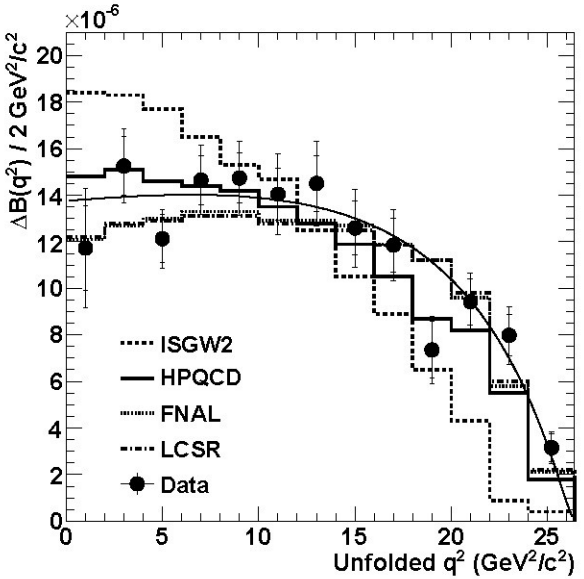
$|V_{ub}|$

Belle, arXiv:1012:0090, 605 fb^{-1}

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

2-dim (ΔE,M_{bc}) fit in bins of q^2:

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



model independent $|V_{ub}|$ determination:
$q^2 \to z(q^2)$;

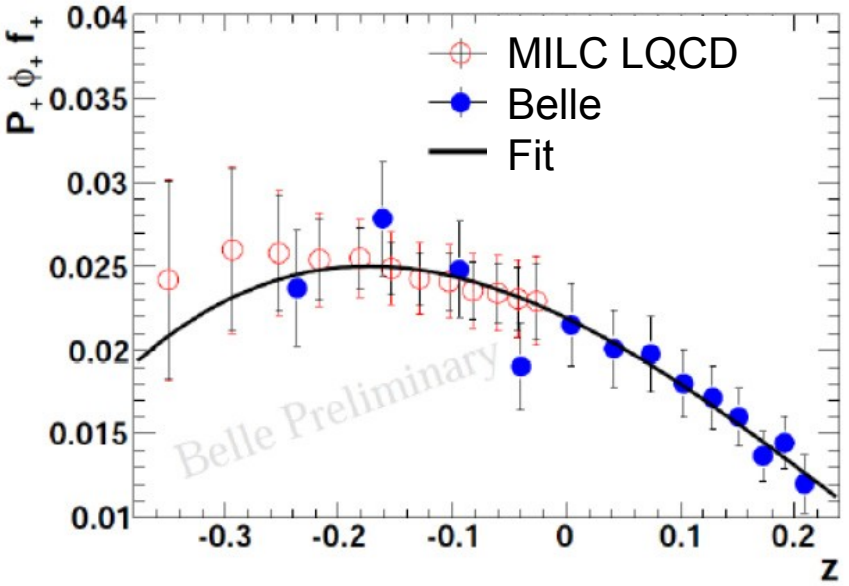
$$P_+\phi_+ f_+ = \sum_{i=0}^{\infty} a_i z^i$$

M.C. Arnesen et al., PRL95, 071802 (2005)

simultaneous fit to measured data and LQCD (i=0,1,2,3)

MILC Coll., PRD79, 054507 (2009)

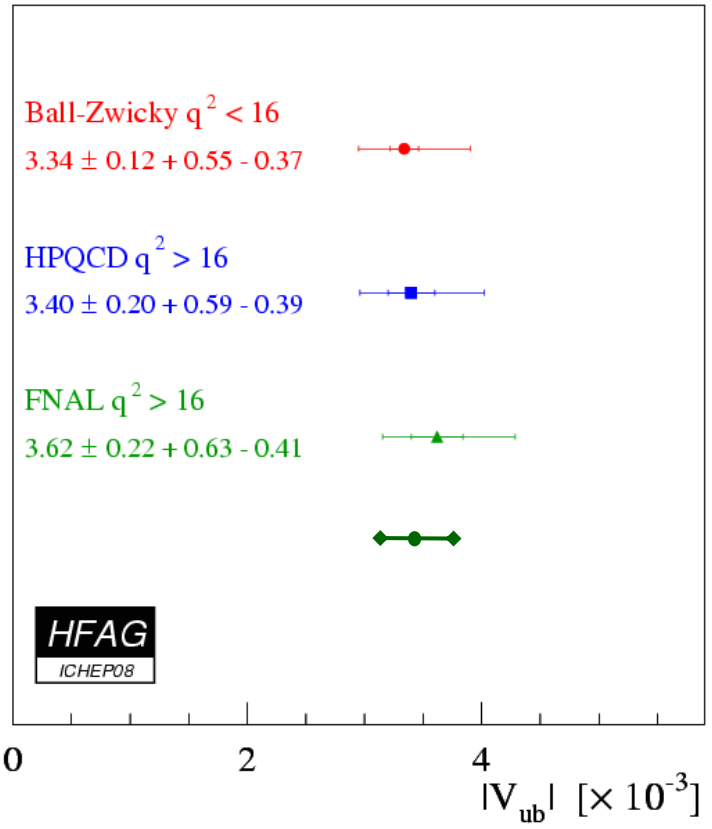
$|V_{ub}| = (3.43\pm0.33)\cdot10^{-3}$



$\mathcal{B}$ system. error:

- detector effects (tracking, PID eff.)
- continuum corr. (MC q^2 distr. compared to off-resonance data)
- ($\mathcal{B}$'s, f.f.'s)

$|V_{ub}|$ error:
- 3% $\mathcal{B}$ (data)
- 4% q^2 shape (data)
- 8% from th. normalization

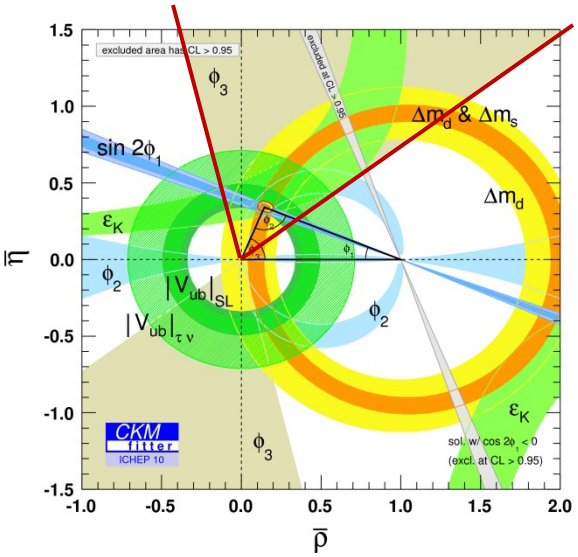


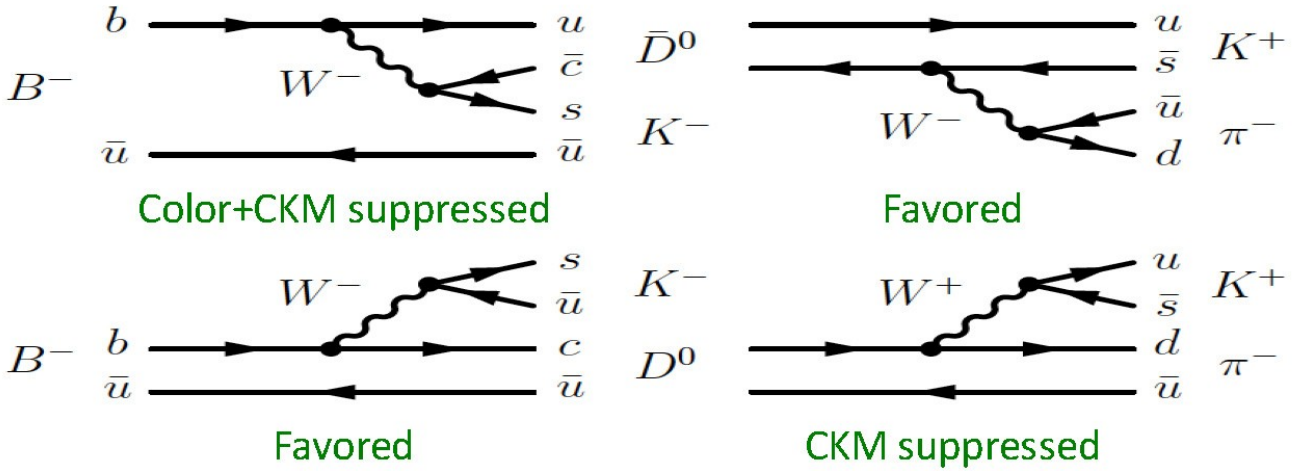
HFAG

ϕ_3 ADS

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

ADS method





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

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

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

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

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

ϕ_3 ADS

Belle, arXiv:1103:5951, 710 fb^{-1}

ADS method

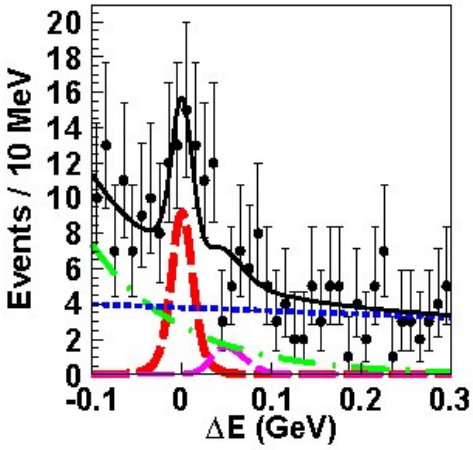
signal isolation: ΔE, NB
(NeuroBayes neural net)

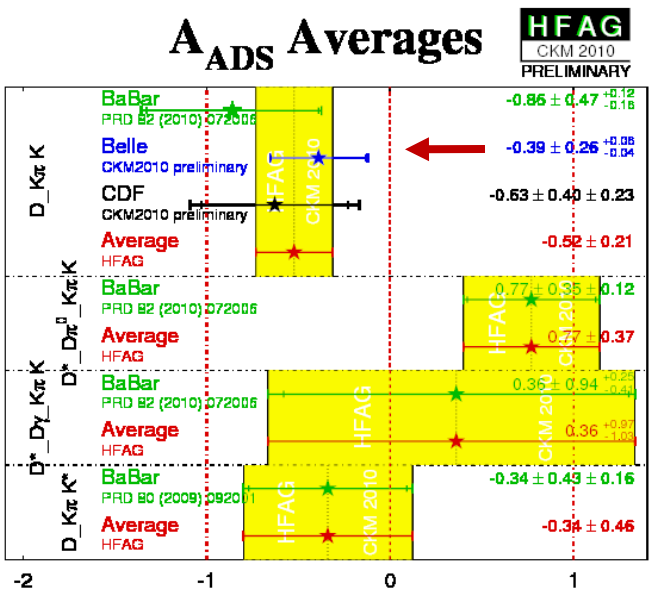
$R_{DK}=(1.63\ ^{+0.44}_{-0.41}\ ^{+0.07}_{-0.13})\cdot 10^{-2}$
$A_{DK}= -0.39\ ^{+0.26}_{-0.28}\ ^{+0.04}_{-0.03}$

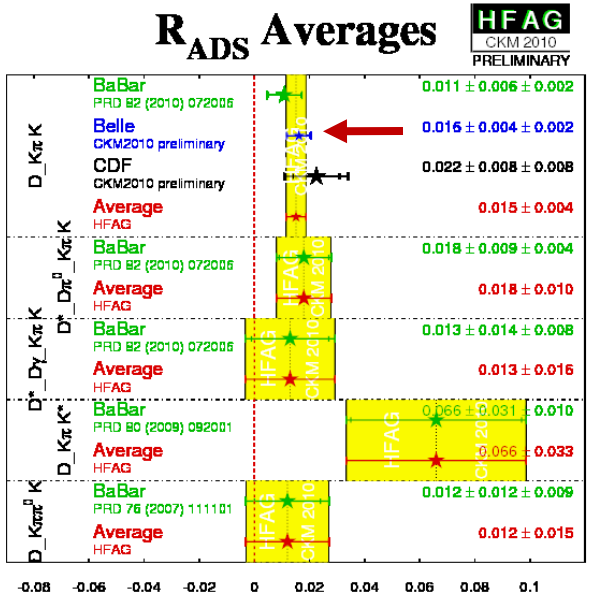
N_{sig}=56 ±15

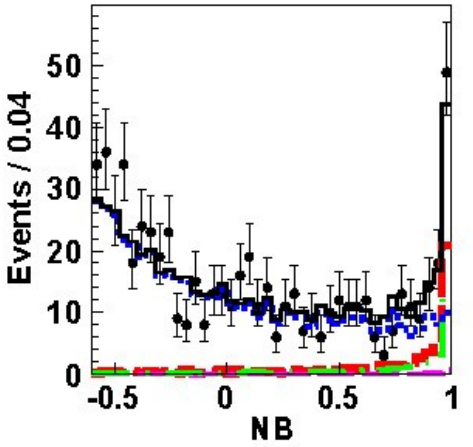
sign.: 4.1 σ

first evidence





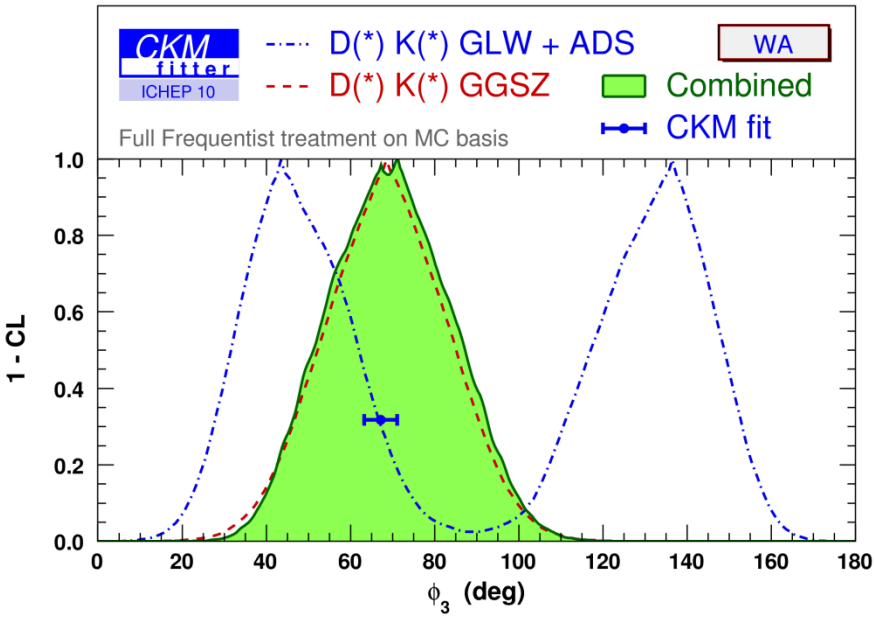




ϕ_3 ADS

system. error:

- peaking backgrounds ($[K^+\pi^-]_D\pi^-$)



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