Flavor Physics with the Belle Detector

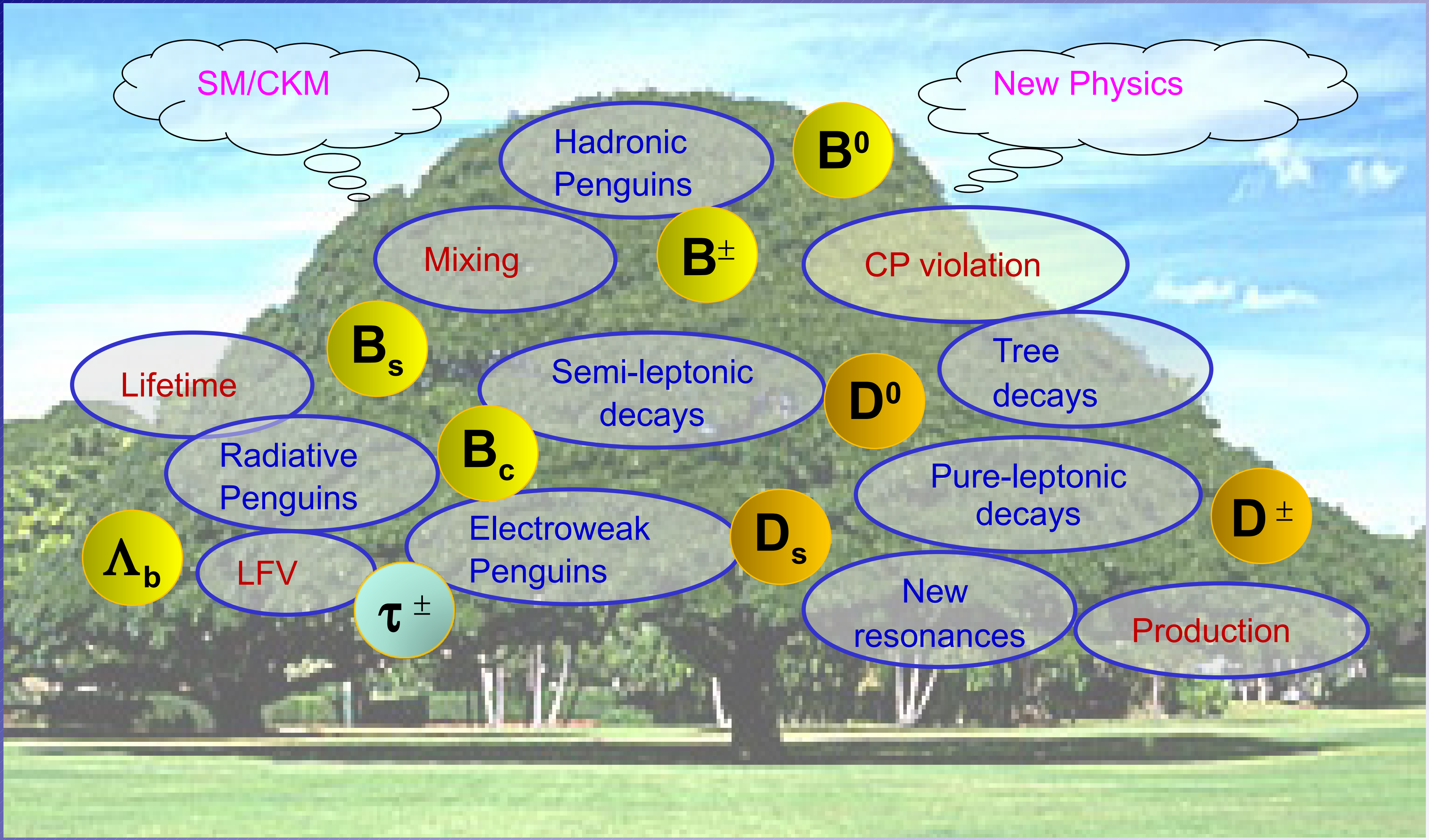
Ryosuke Itoh
KEK

La Thuile 2010

Les Rencontres de Physique de la Vallée d'Aoste

Feb.28-Mar.06, 2010

“Flavor Physics”



Outline

1. Introduction

2. Measurement of Unitarity Triangle: Updates
   - Update of ϕ_3 measurement with $B \to D^{(*)}K$ Dalitz
   - V_{cb} measurement using $B^+ \to D^* l \nu$
   - V_{ub} measurement using $B \to X_u l \nu$ with full recon tag

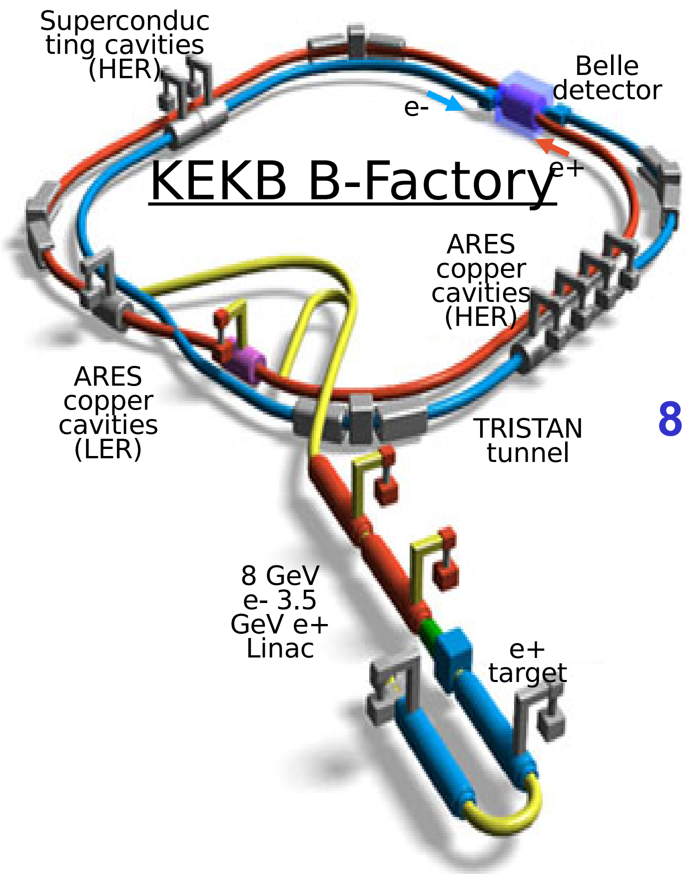
3. New results with $\Upsilon(5S)$
   - $B_s \to J/\psi\ \eta\ /\ \eta'$
   - $B_s \to D_s^* \pi\ /\ \rho$
   - $B_s \to h^+ h^-$

4. Summary

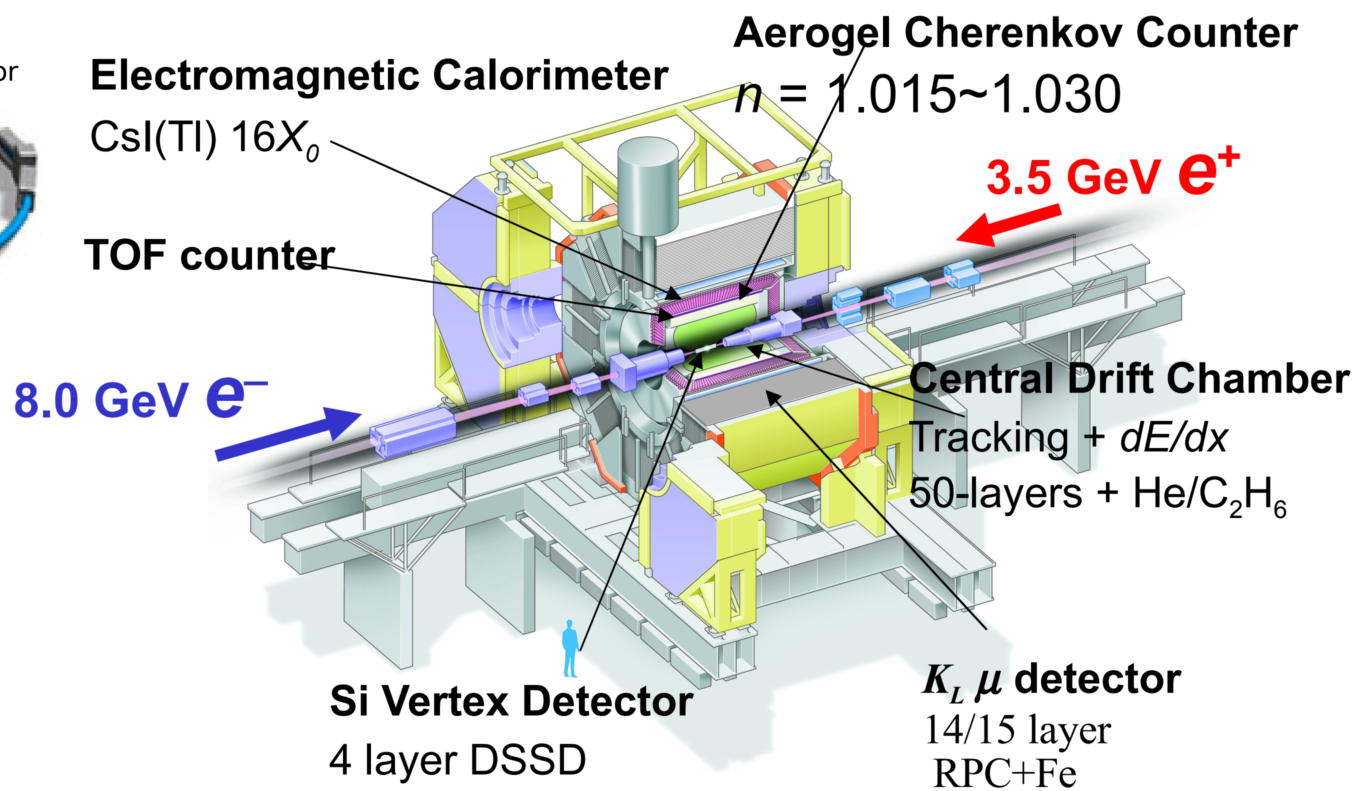
* Rare B decays will be covered by Kurtis Nishimura

1. Introduction

KEKB Accelerator

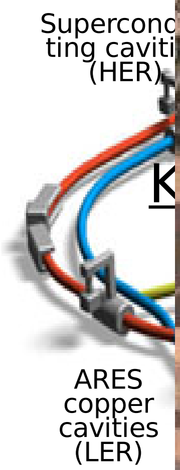


Belle Detector



2. Ex

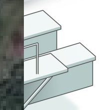
K



y Counter

)

ev e^+



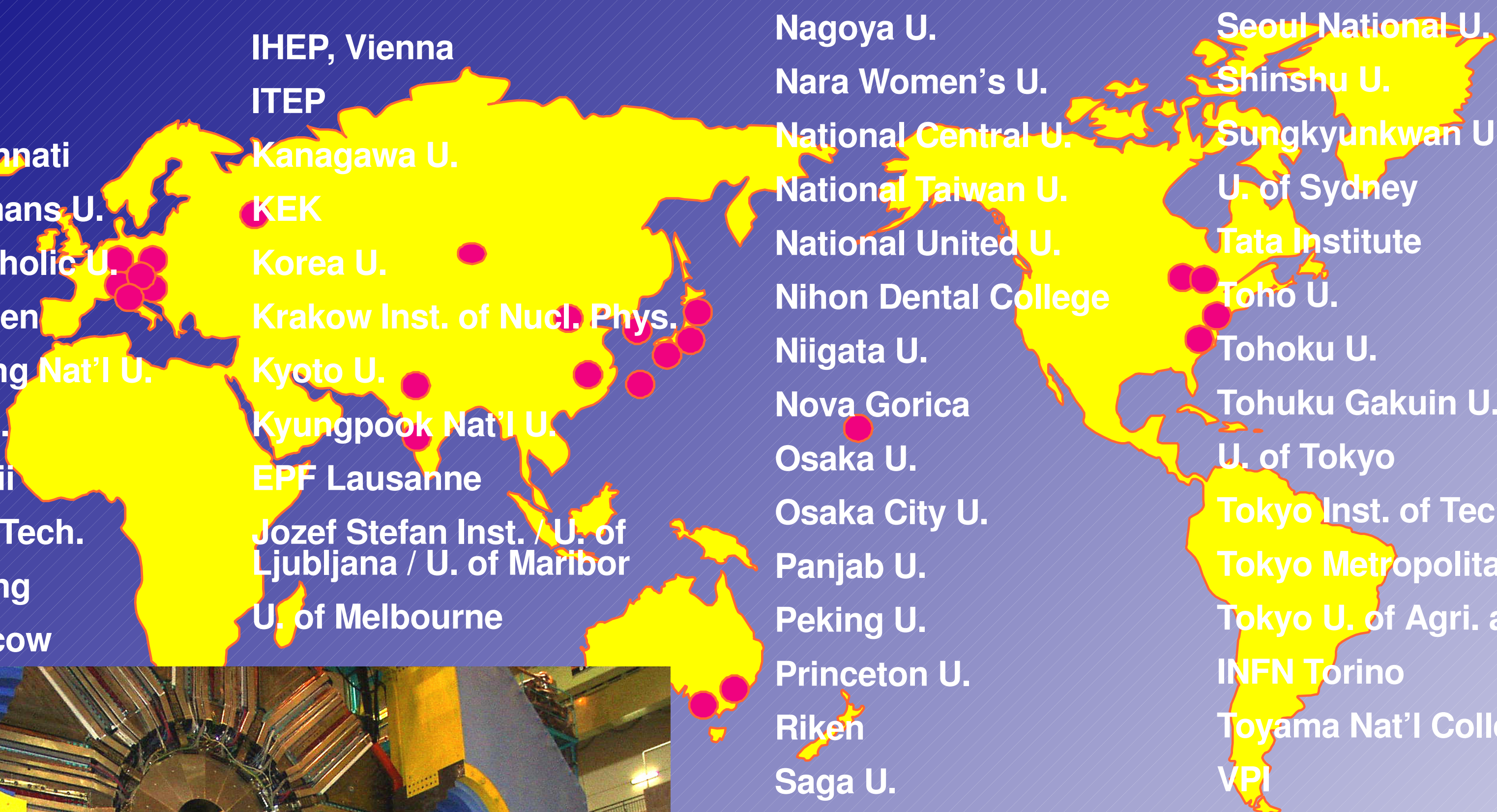
ift Chamber

dE/dx

- He/C_2H_6

ctor

Belle Collaboration



BINP
Chiba U.
U. of Cincinnati
Ewha Womans U.
Fu-Jen Catholic U.
U. of Giessen
Gyeongsang Nat'l U.
Hanyang U.
U. of Hawaii
Hiroshima Tech.
IHEP, Beijing
IHEP, Moscow

IHEP, Vienna
ITEP
Kanagawa U.
KEK
Korea U.
Krakow Inst. of Nucl. Phys.
Kyoto U.
Kyungpook Nat'l U.
EPF Lausanne
Jozef Stefan Inst. / U. of Ljubljana / U. of Maribor
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National Central U.
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National United U.
Nihon Dental College
Niigata U.
Nova Gorica
Osaka U.
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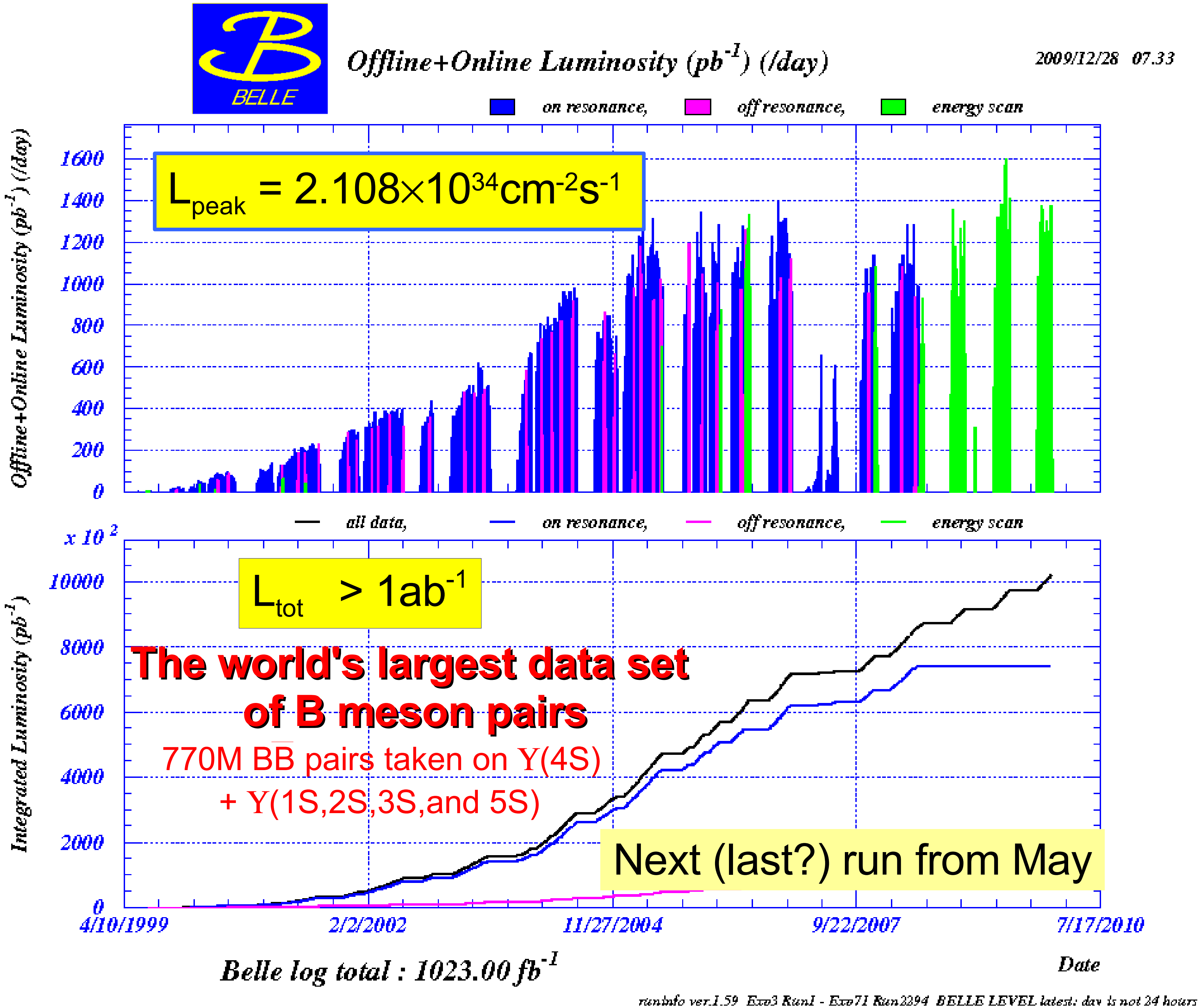
U. of Tokyo
Tokyo Inst. of Tech.
Tokyo Metropolitan U.
Tokyo U. of Agri. and Tech.
INFN Torino
Toyama Nat'l College
VPI
Yonsei U.

15 countries

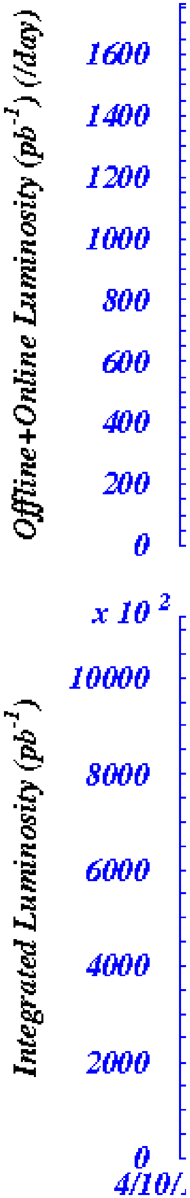
62 institutes

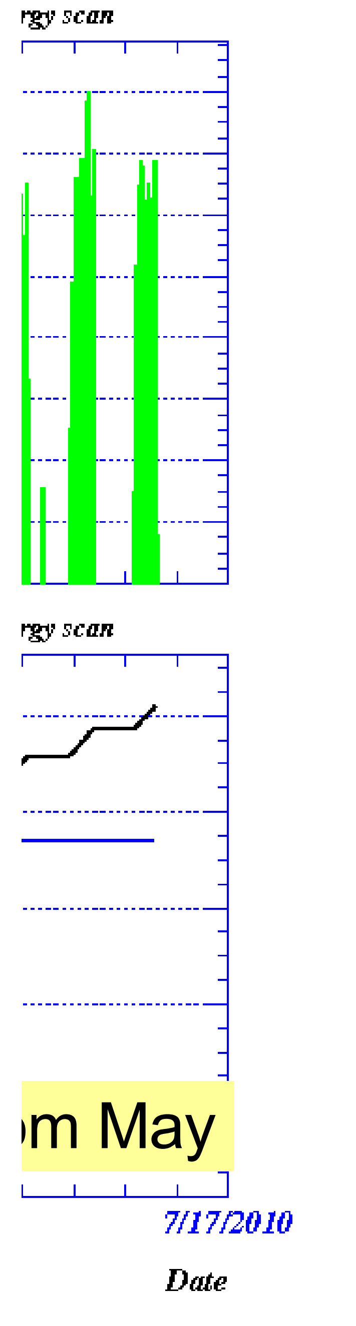
~400 collaborators



BELLE
Offline+Online Luminosity (pb-1) (/day)
2009/12/28 07.33
on resonance, off resonance, energy scan
Offline+Online Luminosity (pb-1) (/day)
1600
1400
1200
1000
800
600
400
200
0
Lpeak = 2.108×10^34cm^-2s^-1
all data, on resonance, off resonance, energy scan
x 10^2
10000
8000
6000
4000
2000
0
Integrated Luminosity (pb-1)
Ltot > 1ab-1
The world's largest data set
of B meson pairs
770M BB pairs taken on Υ(4S)
+ Υ(1S,2S,3S,and 5S)
Next (last?) run from May
4/10/1999
2/2/2002
11/27/2004
9/22/2007
7/17/2010
Date
Belle log total : 1023.00 fb-1
runinfo ver.1.59 Exp3 Run1 - Exp71 Run2394 BELLE LEVEL latest: day is not 24 hours

2009/12/28 07.33





KEKB・Belle 積分ルミノシティ1000fb^{-1}達成記念セレモニーを開催

2010年2月18日、KEK3号館セミナーホールにおいて、KEKB・Belle 積分ルミノシティ1000fb^{-1}達成記念セレモニーが開催されました。

セレモニーは約100名の来場者のもと、鈴木機構長による開会の挨拶で始まり、高谷浩樹文部科学省量子放射線研究推進室長、KEKBのレビュー委員会の委員長を務められたトーマス・ジェファーソン国立加速器施設のアンドリュー・ハットン博士、Belle PACの委員長を務められた中田達也欧州原子核合同研究機関（CERN）研究員による来賓挨拶、及び小林誠特別栄誉教授の挨拶があり、1000fb^{-1}達成のお祝いや次期計画であるスーパーKEKBへの期待のコメントなどが寄せられました。その後、生出勝宣加速器研究施設長と山内正則素粒子原子核研究所副所長の講演が行われ、最後にKEKBファクトリー実験を立ち上げた髙﨑史彦理事による「Bファクトリー計画の昔話」と題した講話が行われました。会場からも当時の思い出話が飛び交うなど、盛況のうちに幕を閉じました。

【関連サイト】 KEK:加速器研究施設のホームページ
KEKBのホームページ
Belleのホームページ

【関連記事】
- 05,02,24（トピックス記事）
  KEKBとBelleが一日積分ルミノシティの世界記録を更新
- 09,05,08（トピックス記事）
  クラブ空洞で新記録
- 09,06,18（News@KEK記事）
  KEKBの性能が設計値の２倍に ～クラブ空洞で新記録達成～
- 09,12,16（トピックス記事）
  KEKB/Belleが1000fb^{-1}蓄積達成

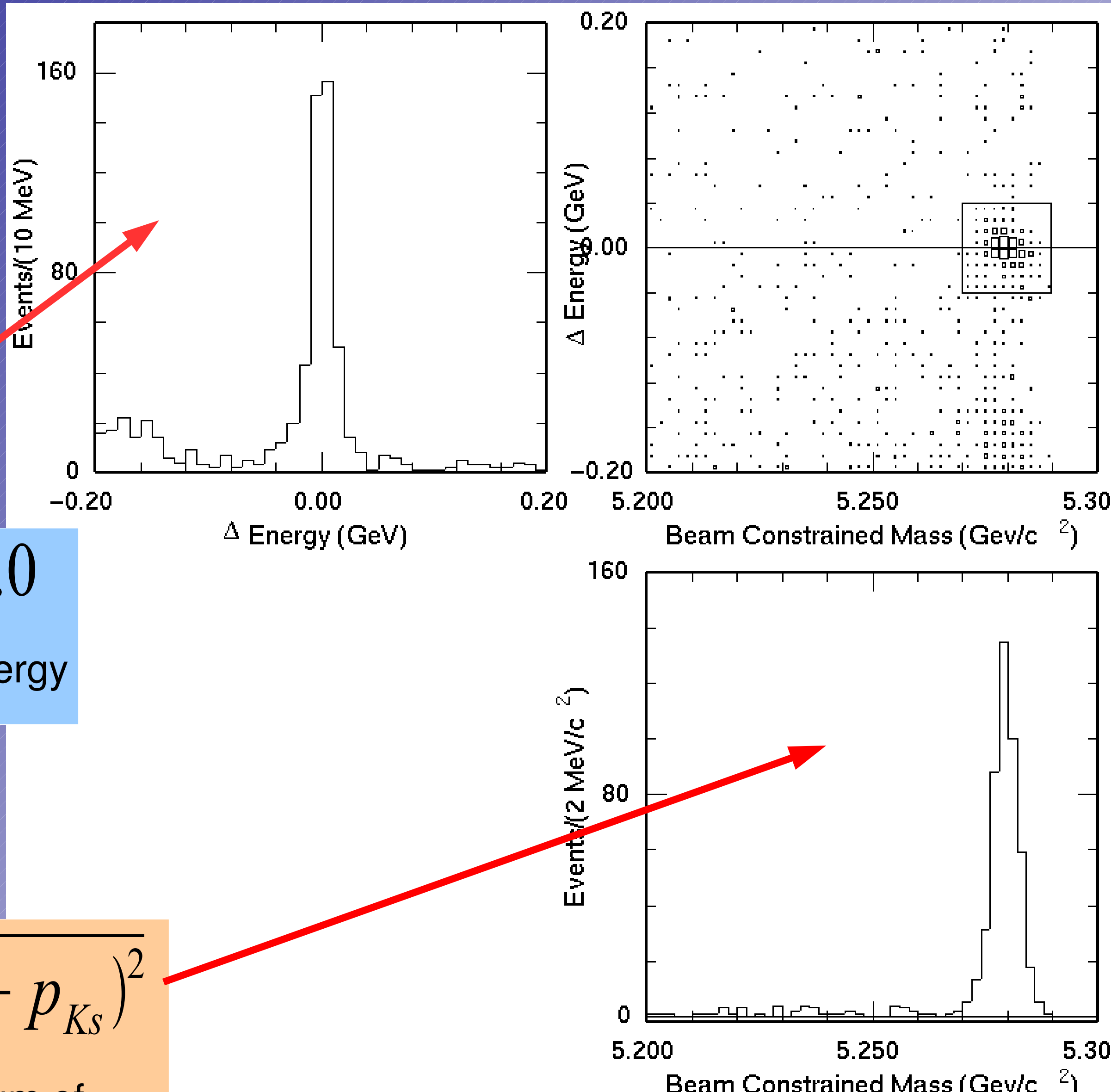

鈴木厚人機構長


小林誠特別栄誉教授


髙﨑史彦理事

Experimental Technique : Reconstruction of B meson

- B mesons are reconstructed from decay products by calculating invariant mass repeatedly.
- Signal is isolated using the kinematic constraints of production at threshold.



Energy difference:

$$\Delta E = (E_{J/\psi} + E_{Ks}) - E_{CM}/2.0$$

energy of B^0 candidate

expected energy of B^0

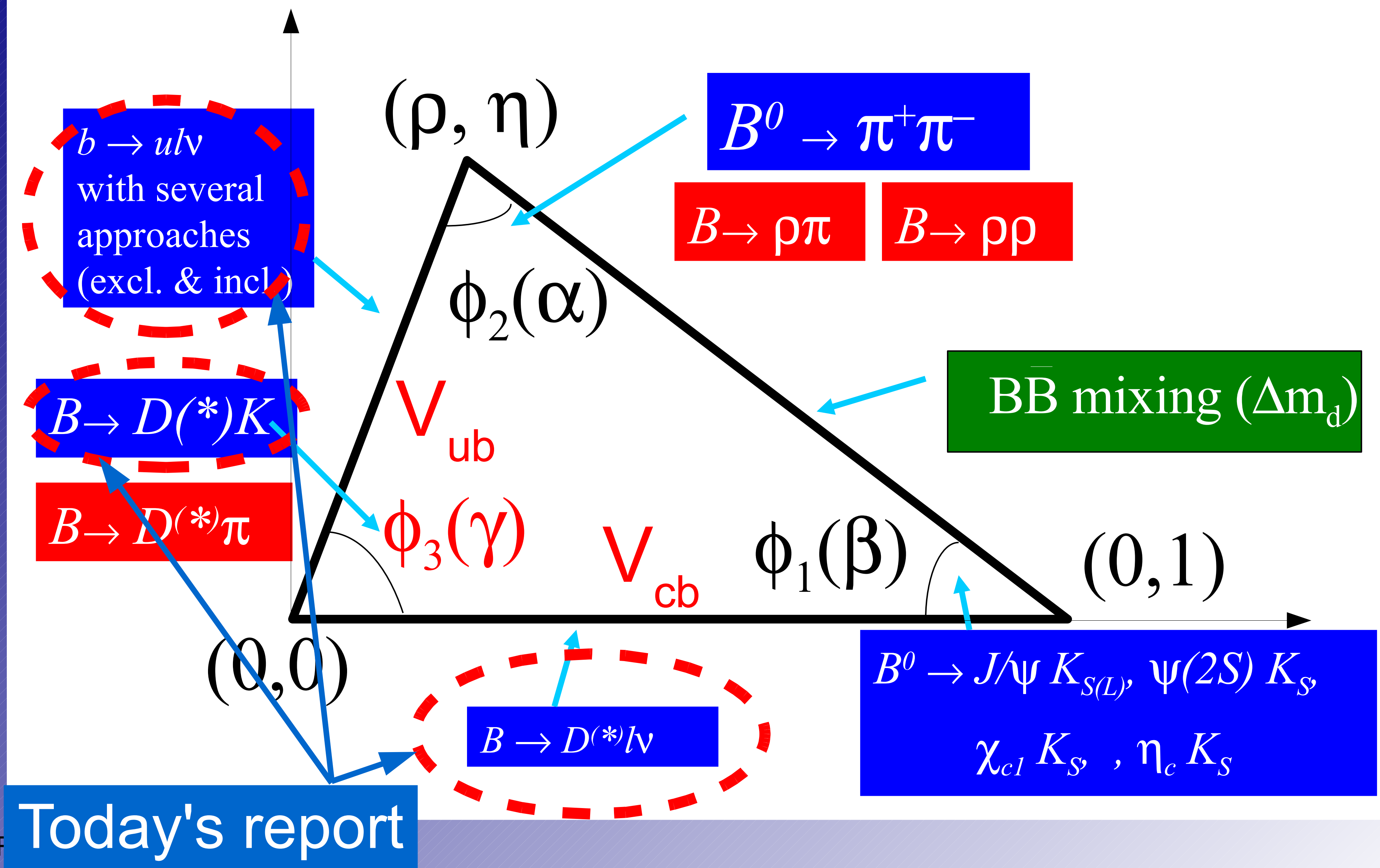
Beam Constrained Mass:

$$M_{bc} = \sqrt{(E_{CM}/2.0)^2 - (p_{J/\psi} + p_{Ks})^2}$$

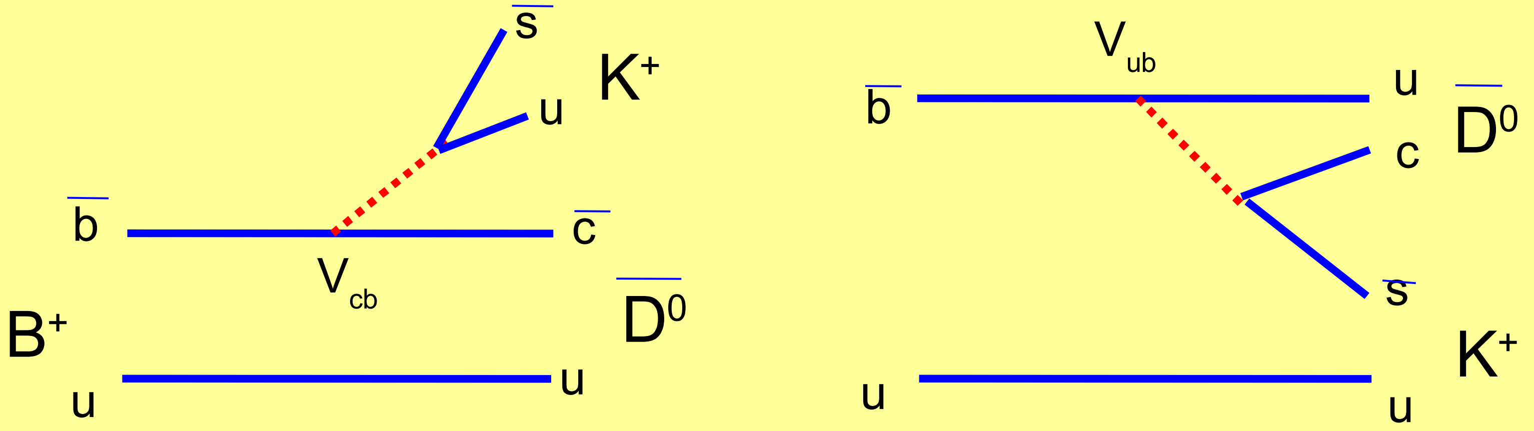
momentum of B^0 candidate

2. Measurement of Unitarity Triangle : Updates

$$V_{td}V_{tb}^{*}+V_{cd}V_{cb}^{*}+V_{ud}V_{ub}^{*}=1$$



1) Update of ϕ_3 measurement using $B^+ \to D^{(*)}K^+$ Dalitz analysis



* Use 3 body final state accessible to both D^0 and $\overline{D}^0$

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

Dalitz plot density: $|M|^2$

B^+: $M_+ = f(m_+^2, m_-^2) + re^{i\phi_3+i\delta} f(m_-^2, m_+^2)$, $r = \dfrac{A(suppressed)}{A(favoured)}$

B^-: $M_- = f(m_-^2, m_+^2) + re^{-i\phi_3+i\delta} f(m_+^2, m_-^2)$

CPV: Asymmetry in Daltz dist. $m_+ = m(K_s\pi^+)$, $m_- = m(K_s\pi^-)$

$f(m_+^2, m_-^2)$: D^0 decay model

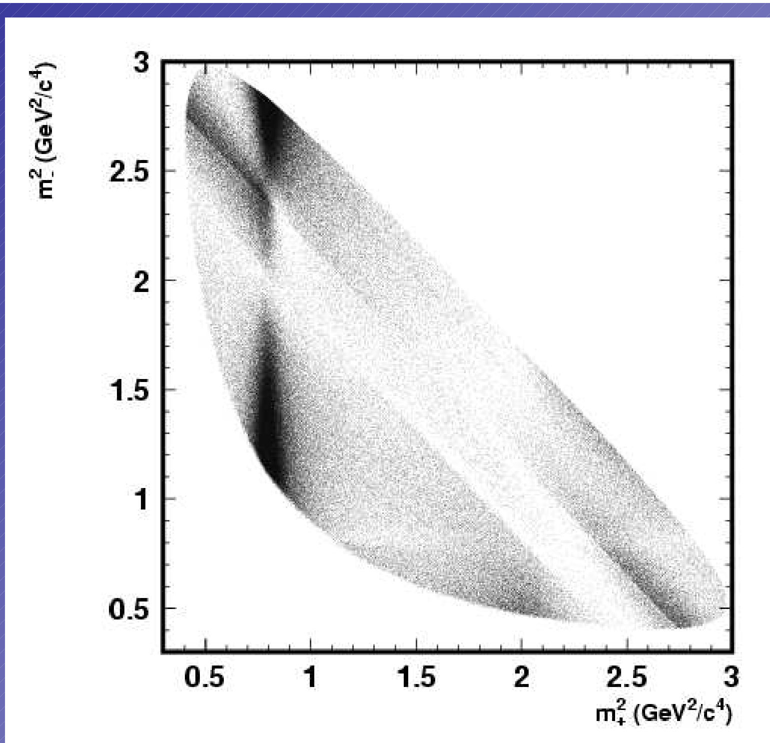
If f is known, all of r, δ, and ϕ_3 can be determined from the fit to the Dalitz plot. (proposed by A.Bondar in 2002, GGSZ paper in 2003)

New analysis with 605fb^{-1} data sample

Determination of D decay model f

* Use $D^0 \to K_s^0 \pi^+ \pi^-$ extracted from
  $D^{*\pm} \to D\pi^\pm$
* Fit with isobar model

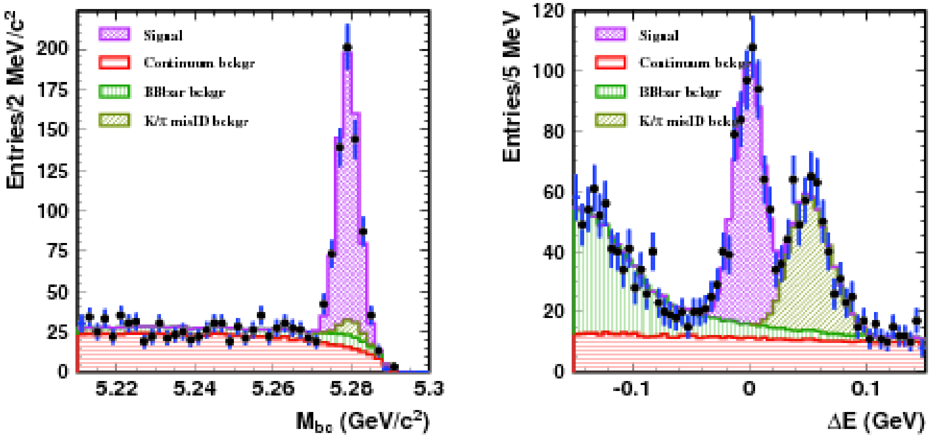
$$f(m_+^2, m_-^2) = \sum_{j=1}^{N} a_j e^{i\xi_j} A_j(m_+^2, m_-^2) + a_{NR} e^{i\xi_{NR}},$$



Intermediate state	Amplitude	Phase (°)
$K_S\sigma_1$	1.56 ± 0.06	214 ± 3
$K_S\rho^0$	1.0 (fixed)	0 (fixed)
$K_S\omega$	0.0343 ± 0.0008	112.0 ± 1.3
$K_S f_0(980)$	0.385 ± 0.006	207.3 ± 2.3
$K_S\sigma_2$	0.20 ± 0.02	212 ± 12
$K_S f_2(1270)$	1.44 ± 0.04	342.9 ± 1.7
$K_S f_0(1370)$	1.56 ± 0.12	110 ± 4
$K_S\rho^0(1450)$	0.49 ± 0.08	64 ± 11
$K^*(892)^+\pi^-$	1.638 ± 0.010	133.2 ± 0.4
$K^*(892)^-\pi^+$	0.149 ± 0.004	325.4 ± 1.3
$K^*(1410)^+\pi^-$	0.65 ± 0.05	120 ± 4
$K^*(1410)^-\pi^+$	0.42 ± 0.04	253 ± 5
$K_0^*(1430)^+\pi^-$	2.21 ± 0.04	358.9 ± 1.1
$K_0^*(1430)^-\pi^+$	0.36 ± 0.03	87 ± 4
$K_2^*(1430)^+\pi^-$	0.89 ± 0.03	314.8 ± 1.1
$K_2^*(1430)^-\pi^+$	0.23 ± 0.02	275 ± 6
$K^*(1680)^+\pi^-$	0.88 ± 0.27	82 ± 17
$K^*(1680)^-\pi^+$	2.1 ± 0.2	130 ± 6
non-resonant	2.7 ± 0.3	160 ± 5

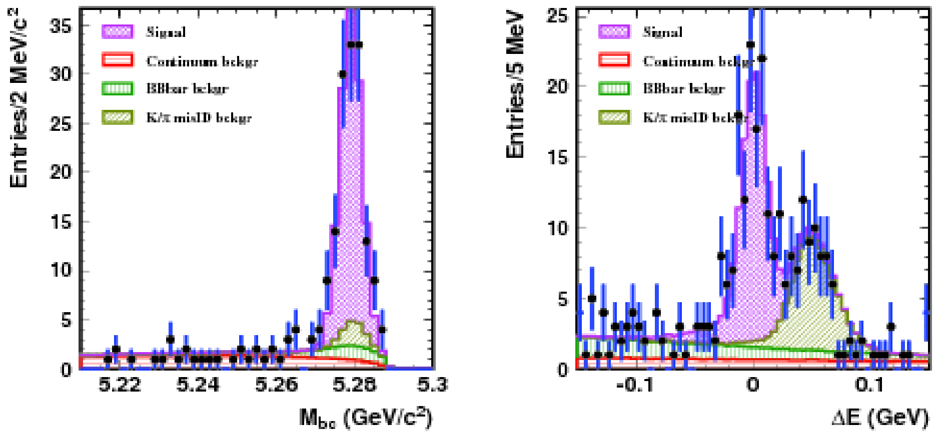
Event sample with 605fb^{-1}

$B^{\pm} \to DK^{\pm}$



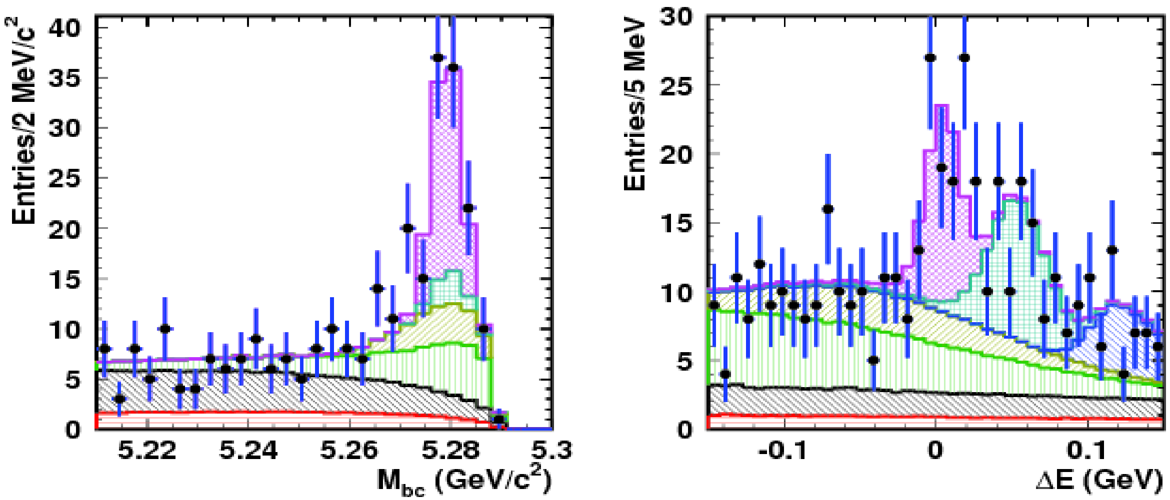
756 events (29% BG)

$B^{\pm} \to D^{*}K^{\pm},\ D^{*} \to D\pi^{0}$



149 events (20% BG)

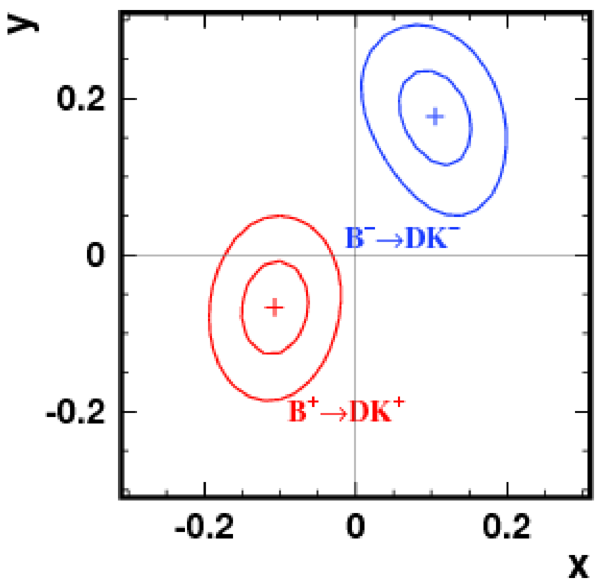
$B^{\pm} \to D^{*}K^{\pm},\ D^{*} \to D\gamma$ New!

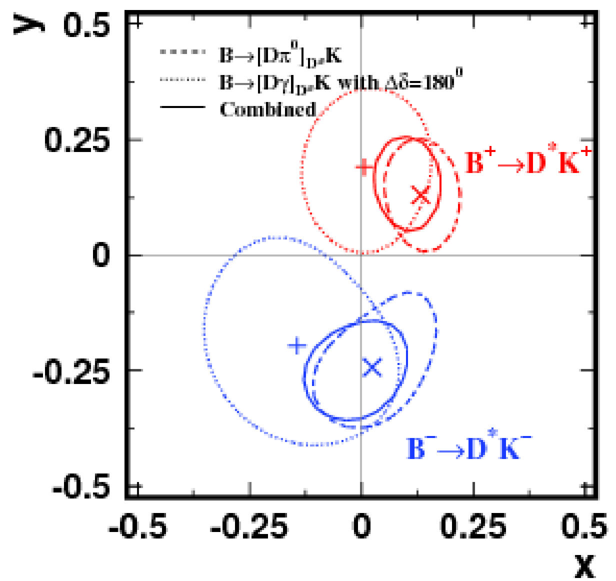


141 events (58% BG)

Fit to Dalitz (605fb^{-1})

Fit variables : $x_\pm = r_B \cos(\delta_B \pm \phi_3)$, $y_\pm = r_B \sin(\delta_B \pm \phi_3)$





$B^\pm \to DK^\pm$

$$\phi_3 = (80.8\ ^{+13.1}_{-14.8} \pm 5.0 \pm 8.9)^\circ$$
$$r_B = 0.161\ ^{+0.040}_{-0.038} \pm 0.011\ ^{+0.050}_{-0.010}$$
$$\delta_B = (137.4\ ^{+13.0}_{-15.7} \pm 4.0 \pm 22.9)^\circ$$

$B^\pm \to D^*K^\pm$

$$\phi_3 = (73.9\ ^{+18.9}_{-20.2} \pm 4.2 \pm 8.9)^\circ$$
$$r_B = 0.196\ ^{+0.073}_{-0.072} \pm 0.013\ ^{+0.062}_{-0.012}$$
$$\delta_B = (341.7\ ^{+18.6}_{-20.9} \pm 3.2 \pm 22.9)^\circ$$

ϕ_3(Dalitz) = $78.4^\circ\ ^{+10.8^\circ}_{-11.6^\circ} \pm 3.6^\circ(\text{syst}) \pm 8.9^\circ(\text{model})$

BELLE-CONF-0918
arXiv:0803.3375

CPV at 3.5σ!

World's most precise ϕ_3 measurement!

2) V_{cb} measurement using $B^+ \to \overline{D}^{*0} l^+ \nu$

- Previous V_{cb} measurements do not agree so well.

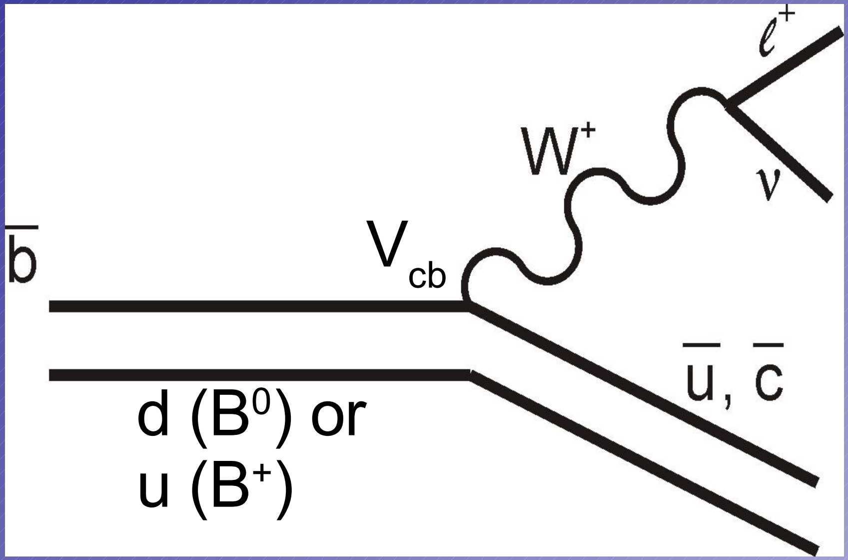
  <- *Some hidden systematics in the measurements is suspected.*

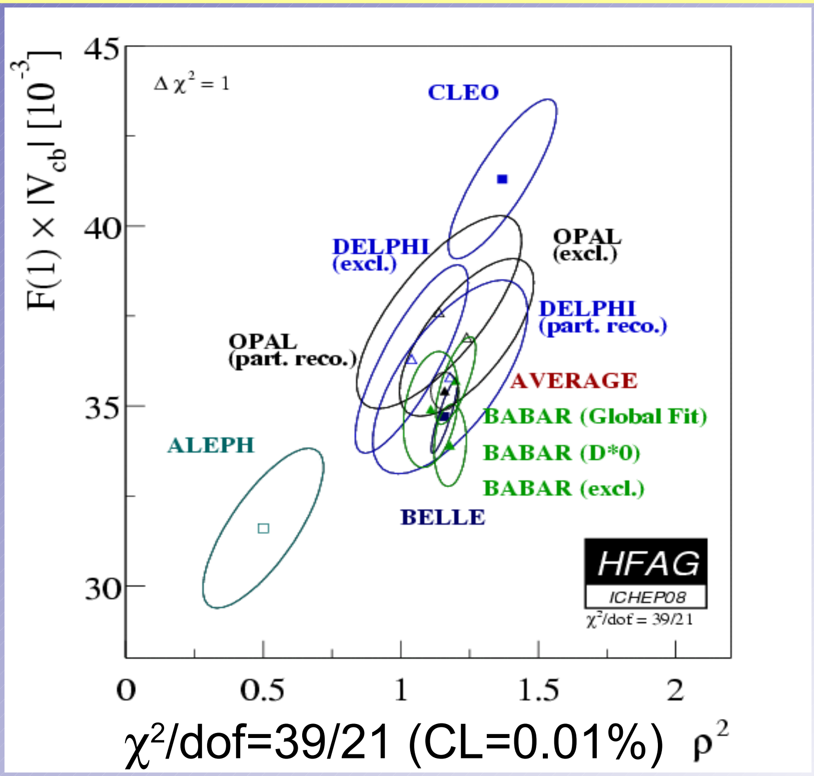
- Measurement of V_{cb} using $B^+ \to \overline{D}^{*0} l^+ \nu$ decay has different systematics from that of previous measurements using $B^0 \to D^{*-} l^+ \nu$.

  ** It does not rely on charged slow pion reconstruction*

  $D^{*0} \to D^0 \pi^0$ vs. $D^{*+} \to D^0 \pi^+$

  $\Rightarrow$ Good cross check of the measurement by $B^0 \to D^{*-} l^+ \nu$





Reconstruction (140fb^{-1})

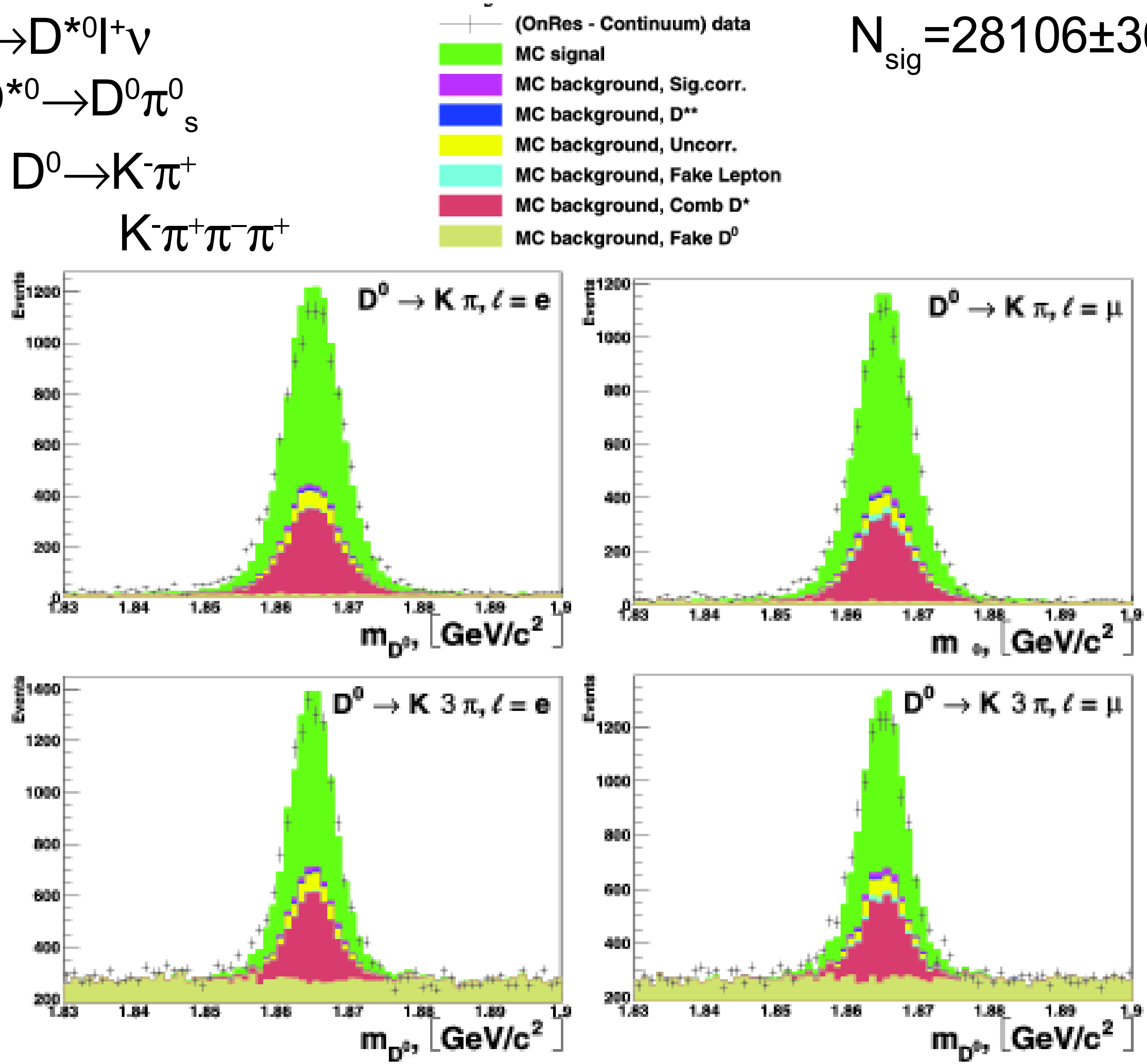
$B^+ \to D^{*0} l^+ \nu$

$D^{*0} \to D^0 \pi^0_s$

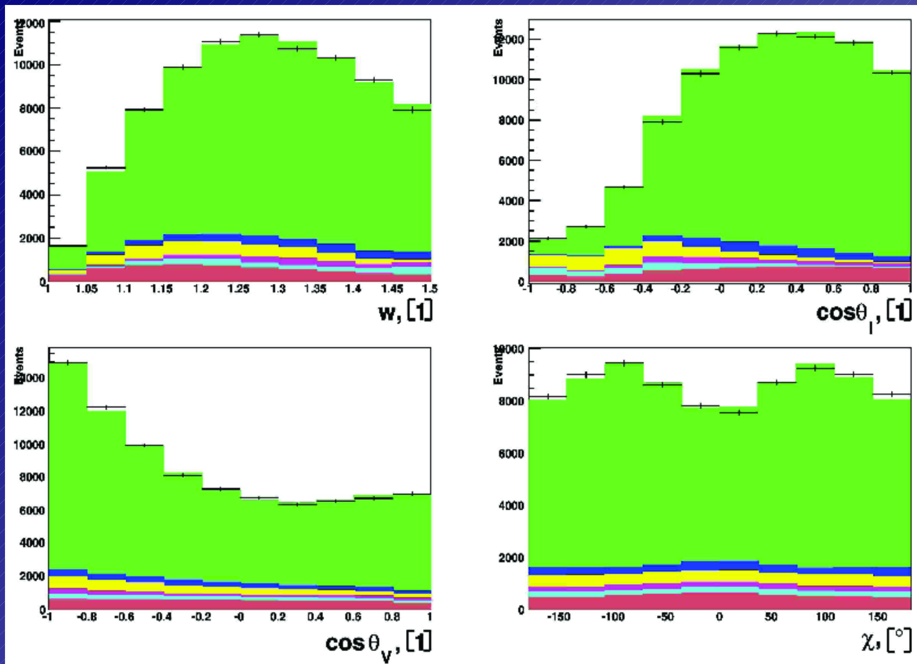
$D^0 \to K^- \pi^+$

$K^- \pi^+ \pi^- \pi^+$

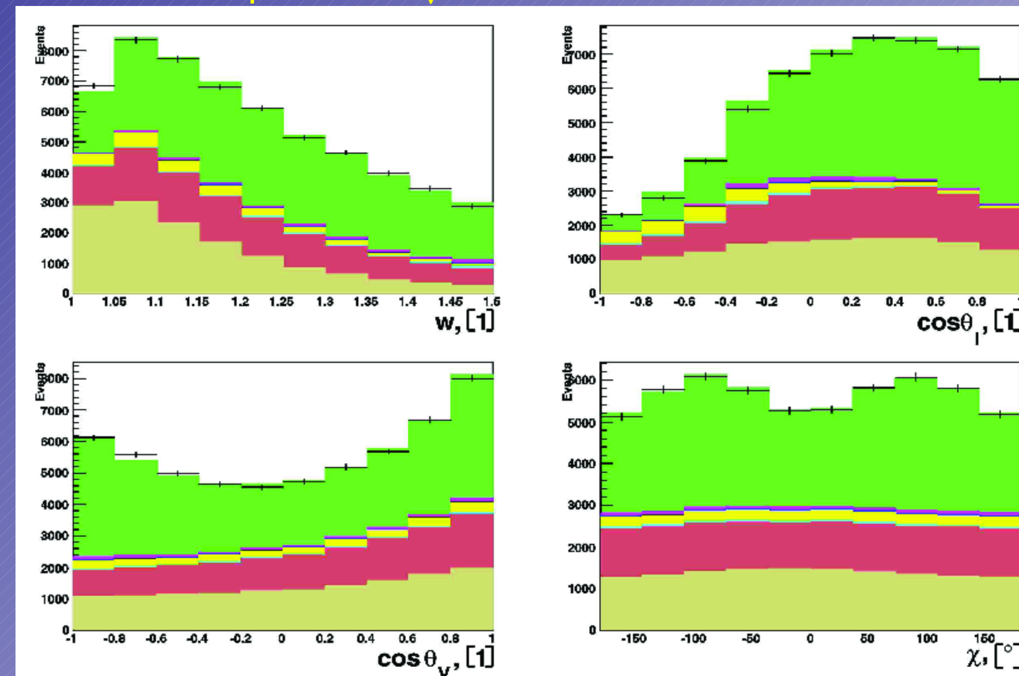
N_{sig}=28106±367 events



Distribution of 4 kinematic variables (w, $\cos\theta_l$, $\cos\theta_\nu$, χ)



B^0(ICHEP08)



B^+ (new)

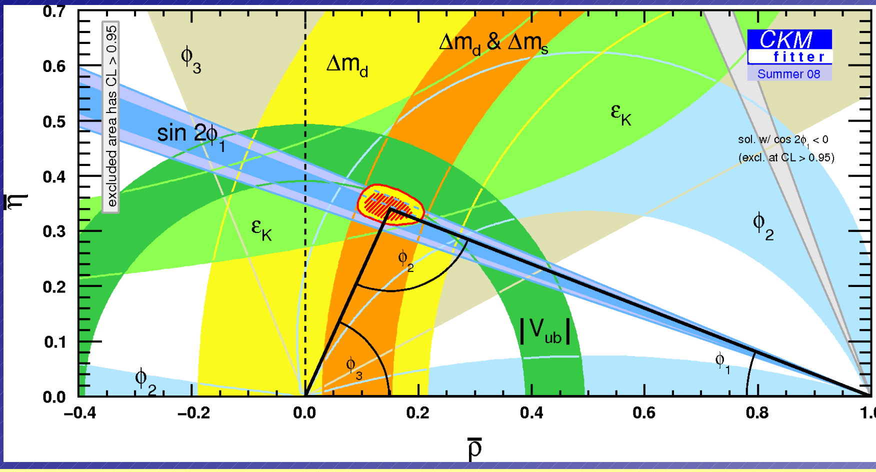
arXiv:0810.1657 arXiv:0910.3534

	$B^0 \to D^{*-}\ell\nu$	$B^+ \to \bar{D}^{*0}\ell\nu$
ρ^2	$1.293 \pm 0.045 \pm 0.029$	$1.376 \pm 0.074 \pm 0.056$
$R_1(1)$	$1.495 \pm 0.050 \pm 0.062$	$1.620 \pm 0.091 \pm 0.092$
$R_2(1)$	$0.844 \pm 0.034 \pm 0.019$	$0.805 \pm 0.064 \pm 0.036$
$R_{K3\pi/K\pi}$	2.153 ± 0.011	2.072 ± 0.023
$\mathcal{B}(B \to D^* \ell^+ \nu_\ell)$	$(4.42 \pm 0.03 \pm 0.25)\%$	$(4.84 \pm 0.04 \pm 0.56)\%$
$\mathcal{F}(1)\,\lvert V_{cb}\rvert \times 10^3$	$34.4 \pm 0.2 \pm 1.0$	$35.0 \pm 0.4 \pm 2.2$
χ^2/n.d.f.	138.8/155	187.8/155
P_{χ^2}	82.0%	3.7%

HFAG ave. of $F(1)|V_{cb}|$ by $B^0 \to D^* l \nu$ (FPCP09) : 35.49±0.52 (w/ old Belle value)

3) V_{ub} measurement using $B \to X_u l^+ \nu$ with "full-recon" tag

Some inconsistency between V_{ub} and $\sin 2\phi_1$ measurements



High precision measurement of V_{ub} is desired.

- Analysis using "full-recon" tag sample:

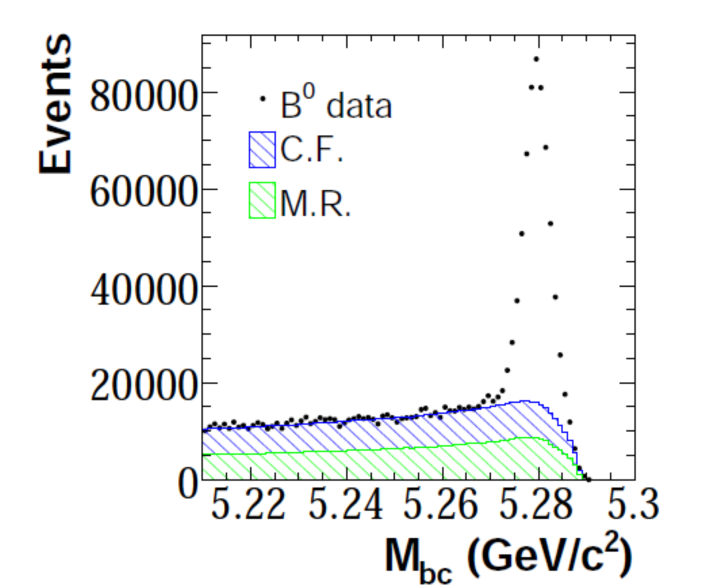
  "Reconstruct one B meson exclusively and analyze semi-leptonic decayof other B"

  * ~180 modes in total
  * High purity, but low efficiency

- Analysis with $605 fb^{-1}$ data set

  $5.27 < M_{bc} < 5.29 GeV/c^2$, $|\Delta E| < 0.05 GeV$

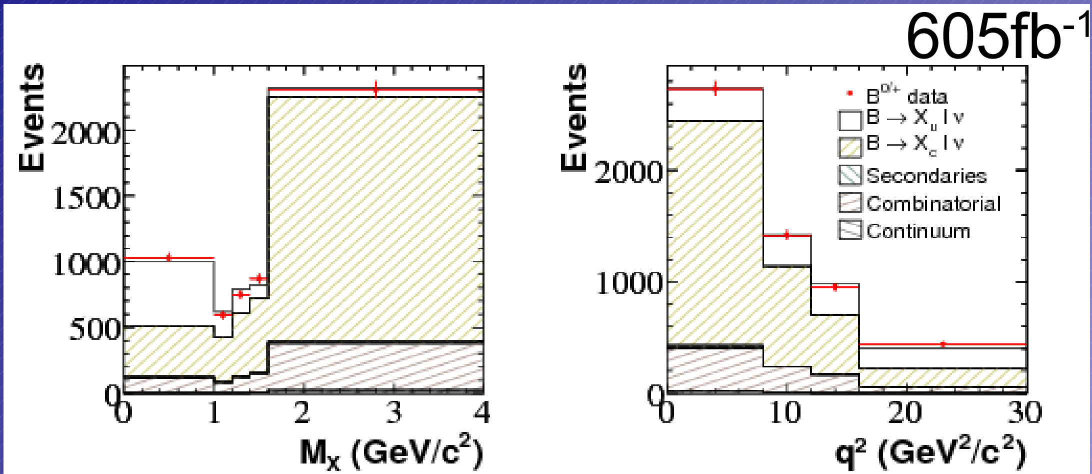
	eff. (%)	purity	N_{tag} ($\times 10^3$)
charged	0.29	0.25	689
neutral	0.28	0.30	479



Signal side

- 1 lepton with p_l^B>1GeV/c
- BG supression from b→c by “Boosted Decision Tree method” using 17 observables

  → ~90% phase space coverage! resulting in *a drastic reduction of theoretical uncertainty.*



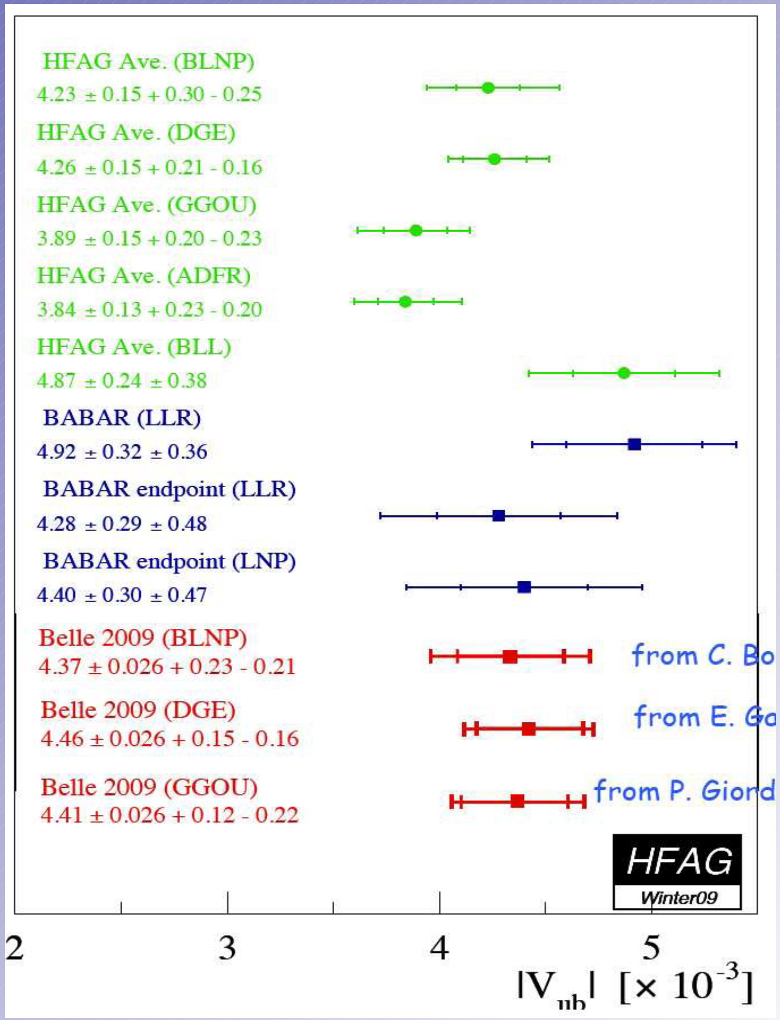
Partial branching fraction $\Delta B(B\to X_u l\nu)$

$\Delta B = (1.963\pm0.173\pm0.159)\times10^{-3}$

$|V_{ub}|=(4.37\pm0.26\pm0.23)\times10^{-3}$(BLNP)

$(4.46\pm0.26\pm0.16)\times10^{-3}$(DGE)

$(4.41\pm0.26^{+0.12}_{-0.22})\times10^{-3}$(GGOU)



 PRL 104, 021801 (2010)

Signal side

- 1 lepton with $p_l^B > 1 GeV/c$
- BG supression from b→c by “Boosted Decision Tree method” using 17 observables

→ ~90% phase space coverage! resulting in
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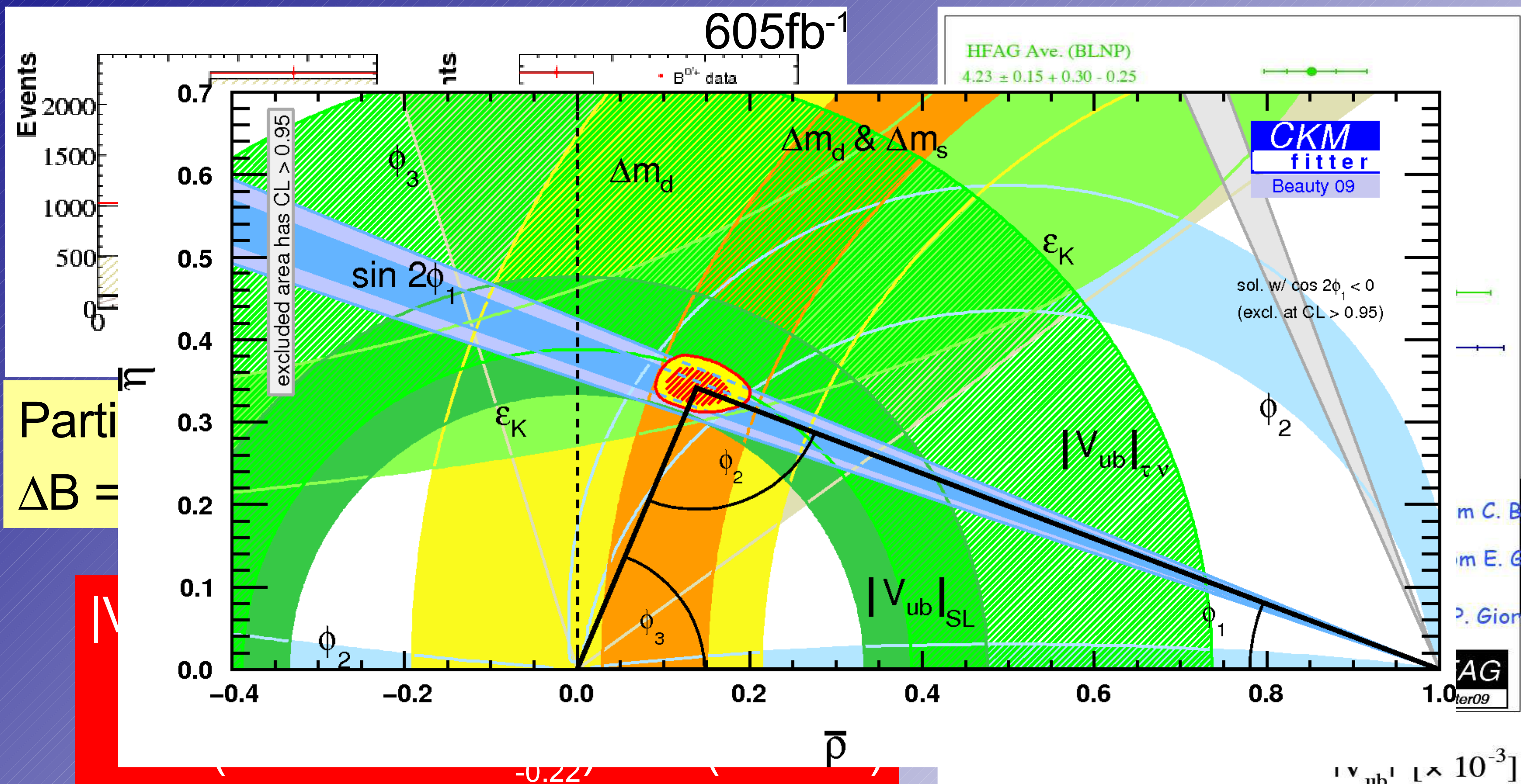
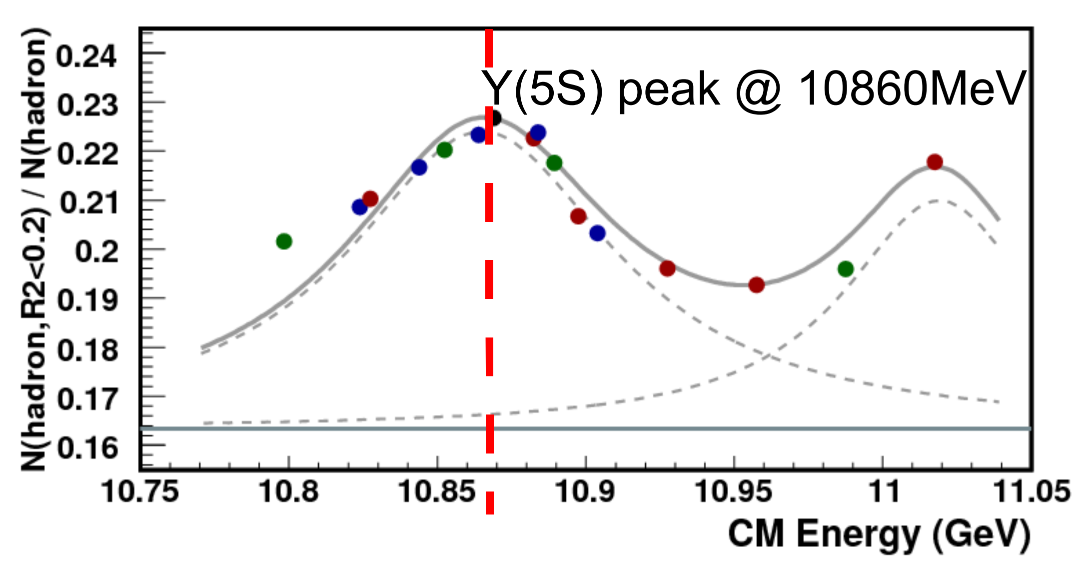


 PRL 104, 021801 (2010)

3. New Results with Υ(5S)

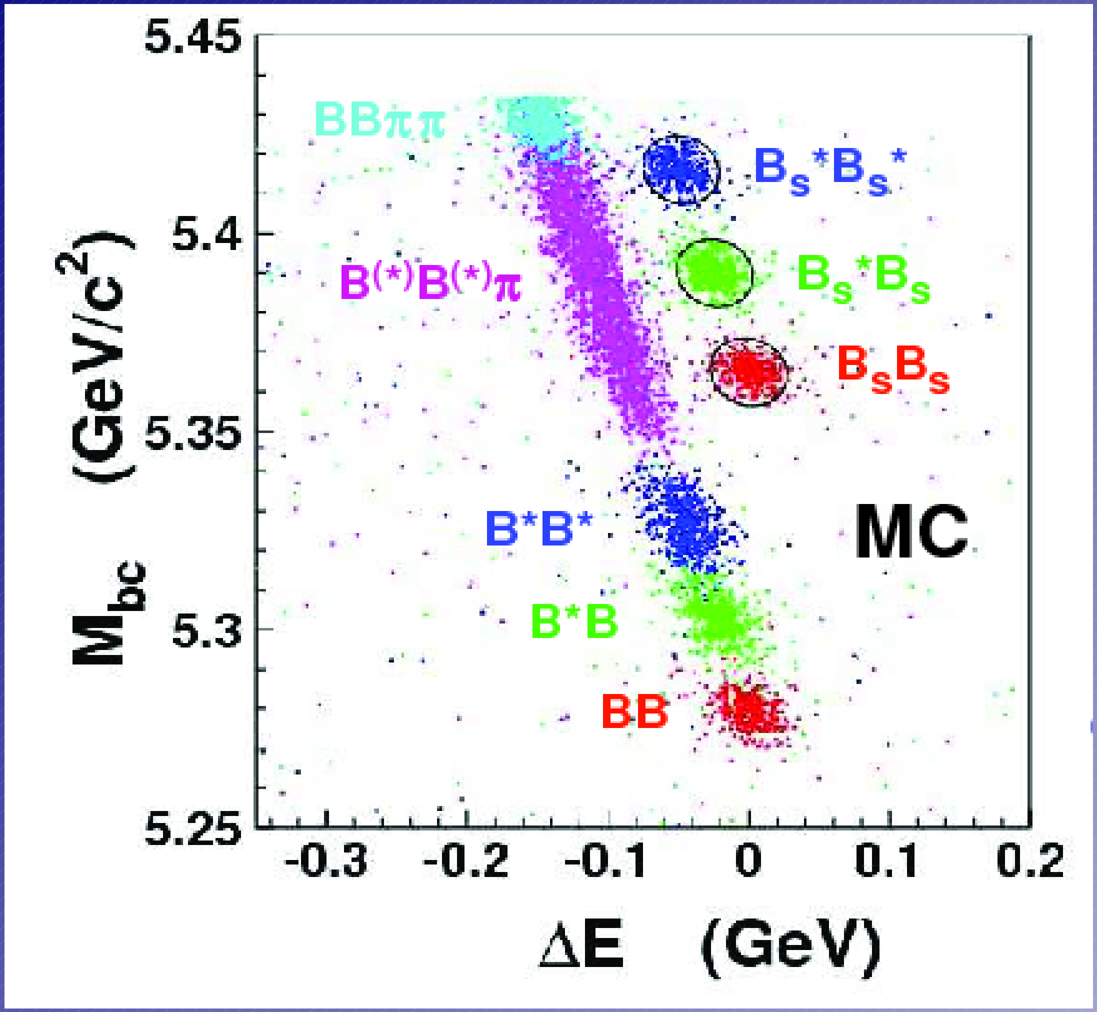
- Belle has been taking data on Υ(5S) peak.
- Data sample of ~120 fb^{-1} is already in hand.
  - * 2005: 1.86fb^{-1}
  - * 2006: 21.7fb^{-1}
  - * 2008: ~28fb^{-1}
  - * 2009: ~70fb^{-1}
- Rich B_s physics
- Final goal:
  $\Delta\Gamma_s/\Gamma_s$ measurement for CPV search.
  ($\sigma(\Delta\Gamma_s/\Gamma_s)$~15% with ~500 CP eigenstates)
- Today's results are based on 23.6fb^{-1} data set.

Belle scan (2005-2007)



$e^+e^- \to \Upsilon(5S)$
$\to B^{(*)}B^{(*)} (\pi)(\pi)$
$\to B_s^{(*)}B_s^{(*)}$
……

Signature of B_s production



MC: $B_s \to D_s^- \pi^+$ and
$B^0 \to D^- \pi^+$

$e^+e^- \to \Upsilon(5S)$
$\to B_{(s)}^{(*)} B_{(s)}^{(*)} (\pi)(\pi)$
where
$B_{(s)}^* \to B\gamma$

* B energy and momentum are reconstructed.
* The radiative γ is not reconstructed (too soft).

1) Observation of $B_s \to J/\psi\eta$ and evidence of $B_s \to J/\psi\eta'$ (arXiv:0912.1434)

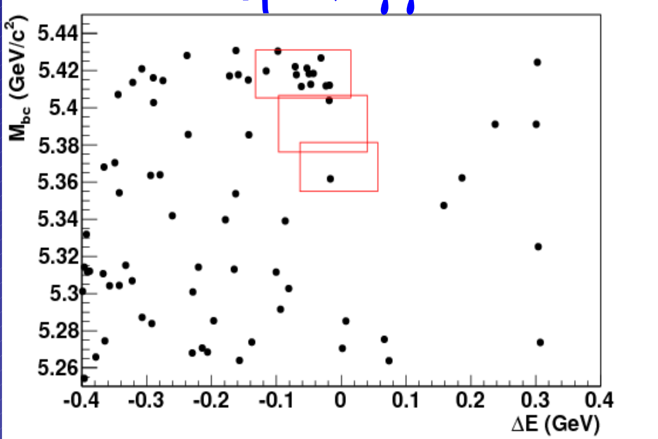
$B_s \to J/\psi\eta(')$ decay is a CP eigenstate whose time distribution can be used to measure the B_s^0 width difference $\Delta\Gamma_s$ for CPV search.

a) $B_s \to J/\psi\eta$

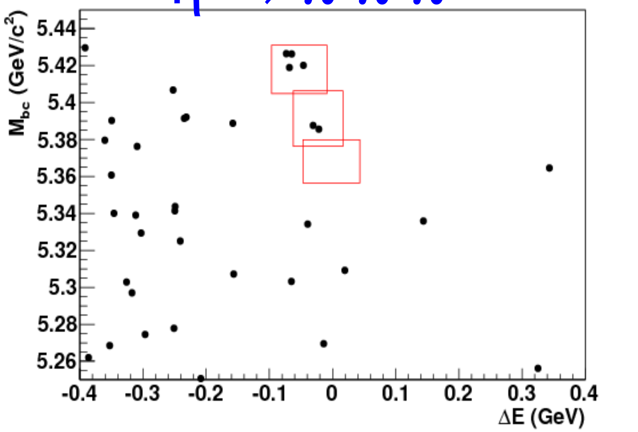
Reconstruction

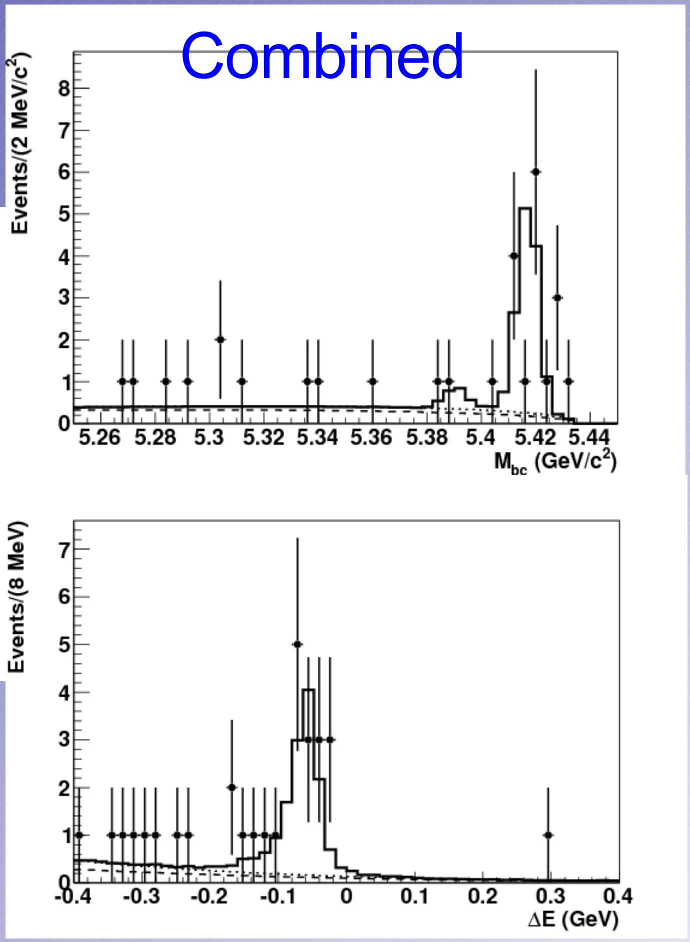
$J/\psi \to e^+e^-$ and $\mu^+\mu^-$
$\eta \to \gamma\gamma$ and $\pi^+\pi^-\pi^0$

$\eta \to \gamma\gamma$



$\eta \to \pi^+\pi^-\pi^0$





~15±4 events in $B_s^*B_s^*$ (7.3σ)

First Observation!

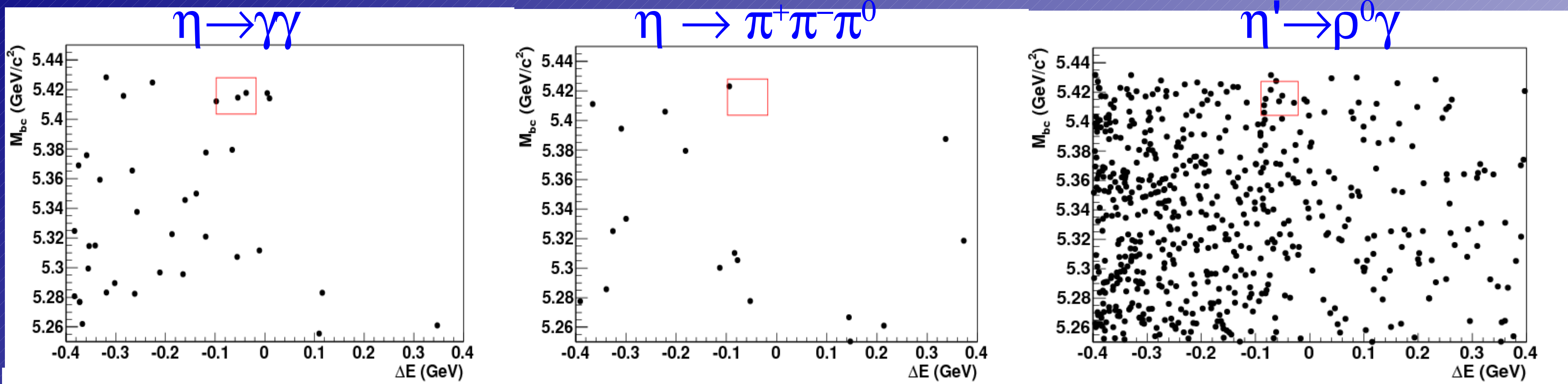
$Br(B_s \to J/\psi\,\eta) = (3.3 \pm 0.9(stat) \pm 0.3(sys) \pm 0.4(f_s)) \times 10^{-4}$

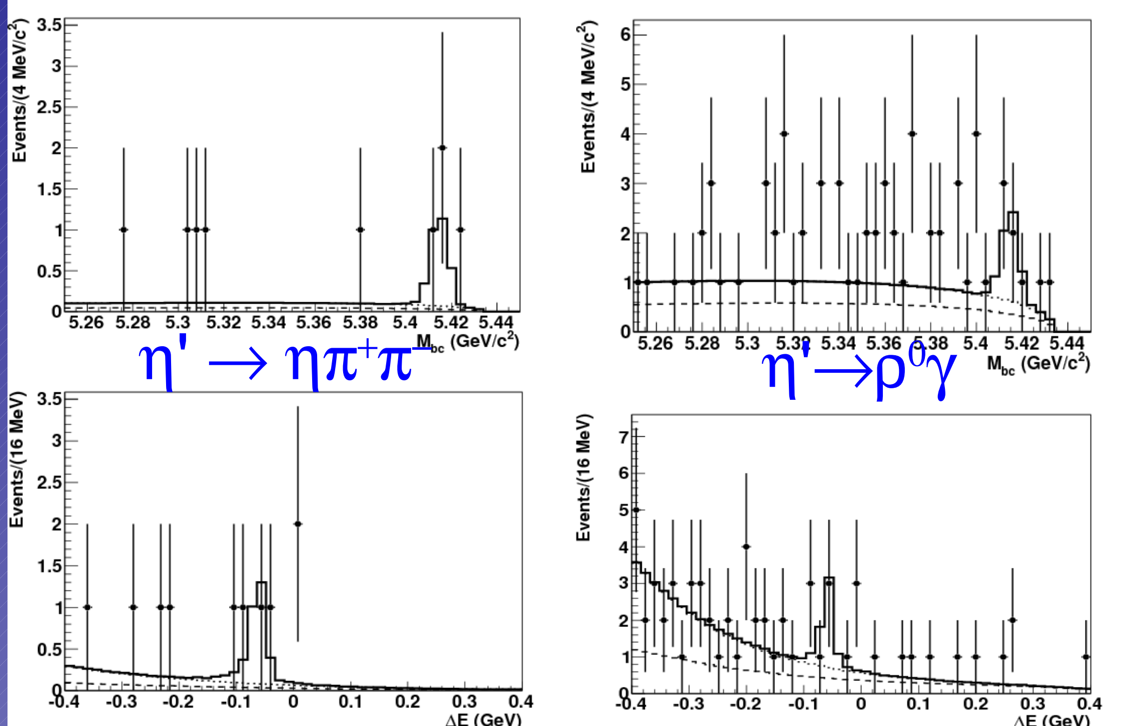
f_s: B_s meson fraction in $\Upsilon(5S)$ decay = $(19.5^{+3.0}_{-2.3})$% (Belle+CLEO)

b) $B \to J/\psi\eta'$

Reconstruction:

$J/\psi \to e^+e^-$ and $\mu^+\mu^-$
$\eta' \to \eta\pi^+\pi^-(\eta \to \gamma\gamma$ and $\pi^+\pi^-\pi^0);\rho^0\gamma$





11±5 events in $B_s^*B_s^*$ (3.8σ)

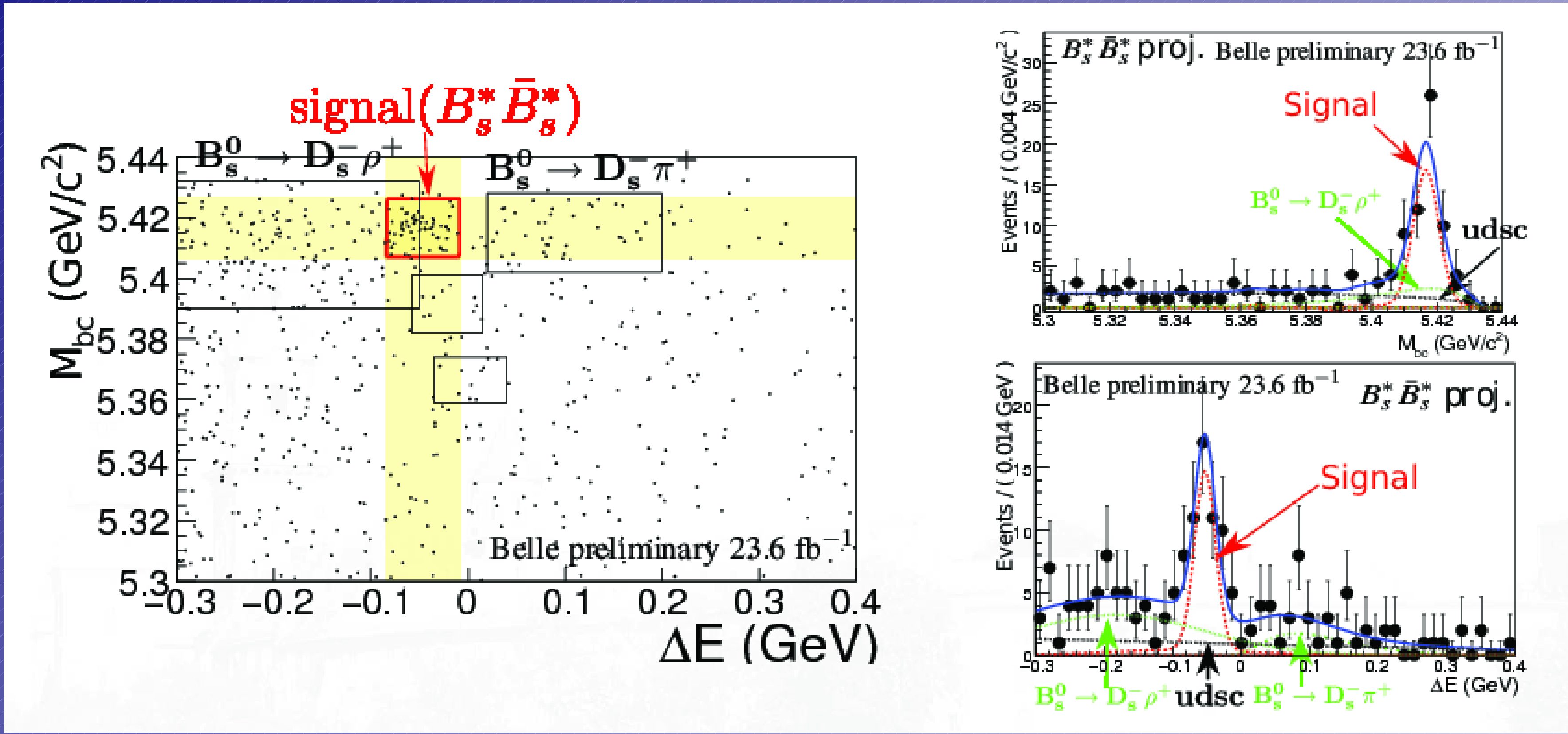
First Evidence!

$$Br(B_s \to J/\psi\,\eta') = (3.1 \pm 1.2(stat)^{+0.5}_{-0.6}(sys) \pm 0.38(f_s)) \times 10^{-4}$$

2) Observations of $B_s \to D_s^{*-}\pi^+$ and $B_s \to D_s^{(*)-}\rho^+$: CF decays

* Important for the measurement of f_s (B_s fraction in Y(5S) decay)

a) $B_s \to D_s^{*-}\pi^+$



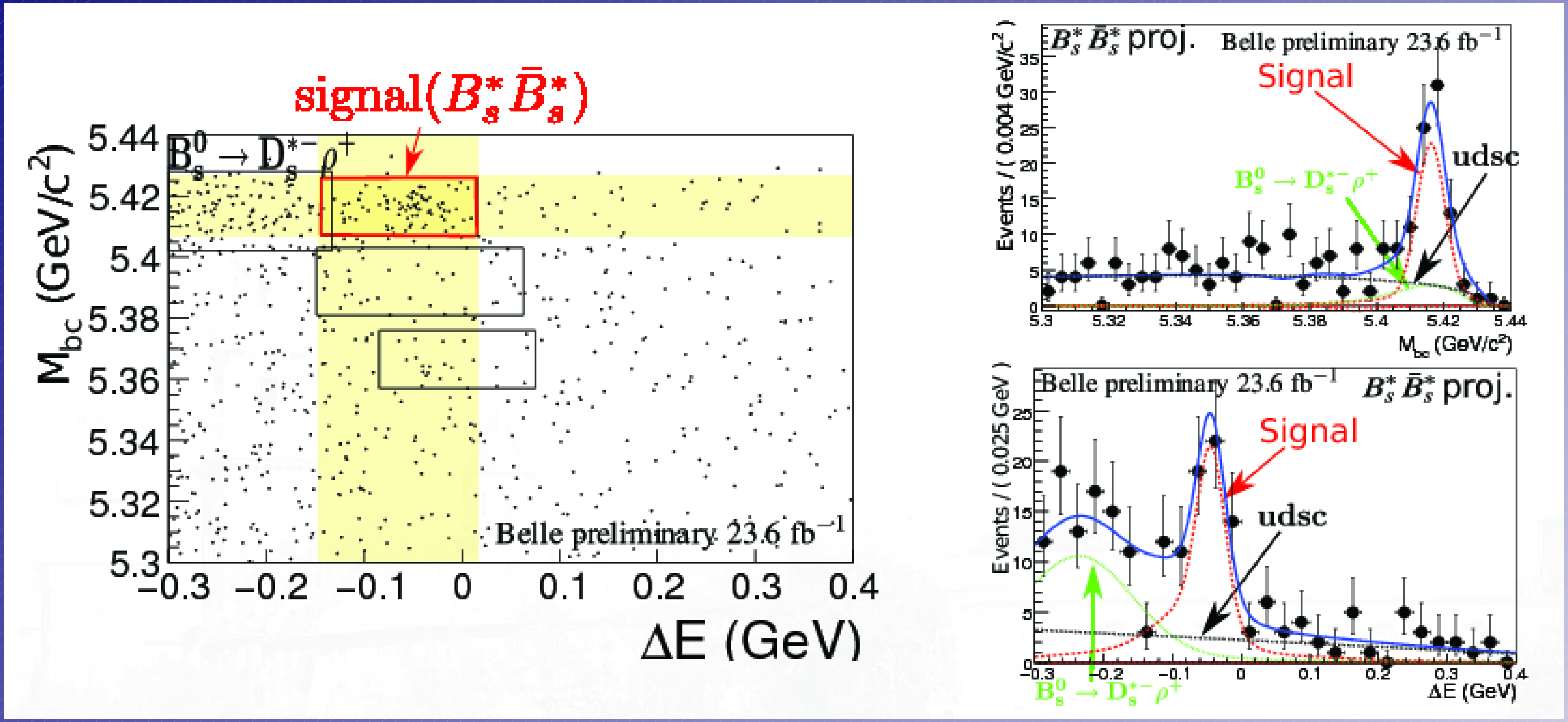
$N_{sig} = 53.4^{+10.3}_{-0.4}$(stat)$^{+2.4}_{-2.6}$(fit) events

⇒ 8.4 σ : first observation

preliminary

$Br(B_s \to D_s^{*-}\pi^+) = (2.4^{+0.5}_{-0.4}(stat) \pm 0.3(sys) \pm 0.4(f_s)) \times 10^{-3}$

b) $B_s \to D_s^- \rho^+$



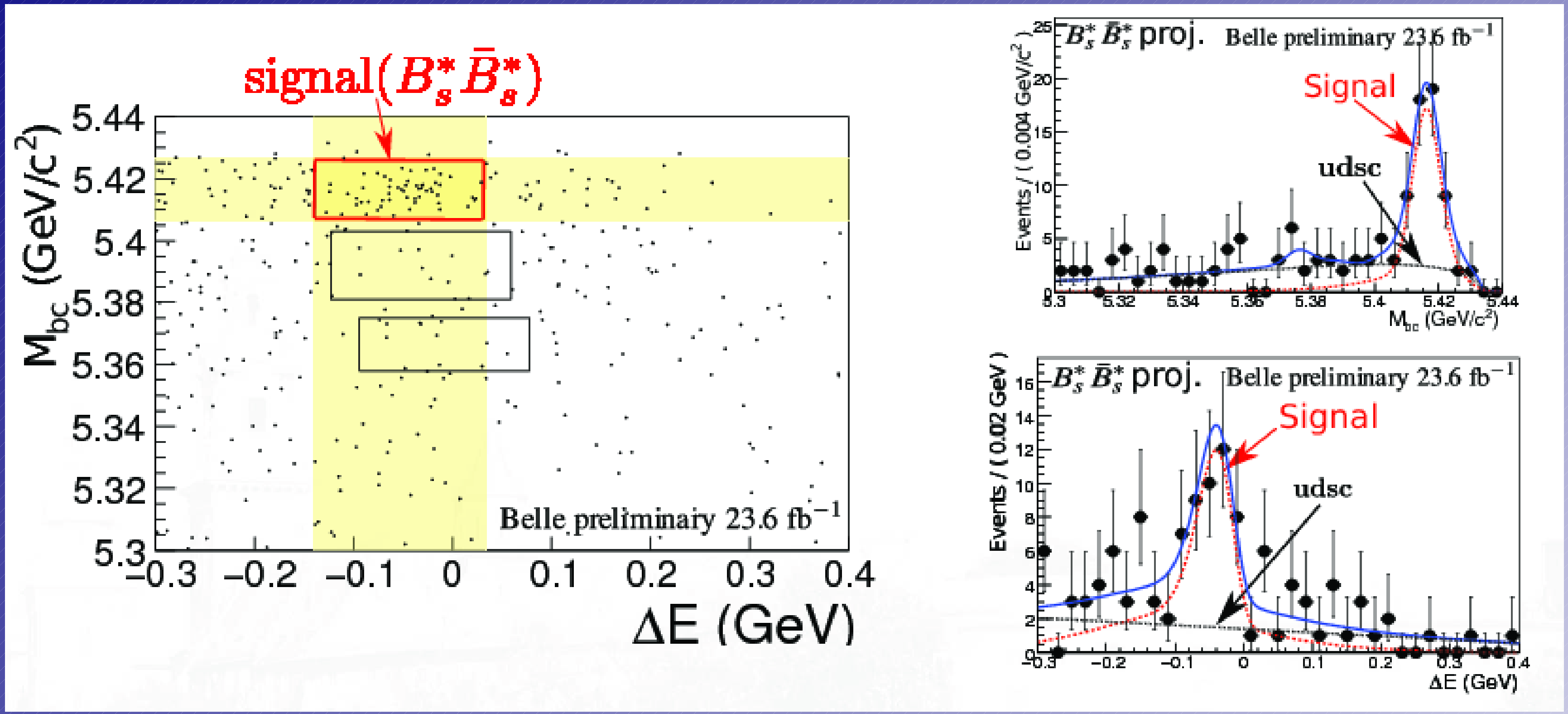
$N_{sig} = 87.1^{+13.9}_{-12.4}(stat)^{+4.0}_{-4.2}(fit)$ events

$\Rightarrow$ 10.1 σ : first observation

preliminary

$Br(B_s \to D_s^- \rho^+) = (8.5^{+1.3}_{-1.2}(stat) \pm 1.1(sys) \pm 1.3(f_s)) \times 10^{-3}$

c) $B_s \to D_s^{*-}\rho^+$



$N_{sig} = 73.7^{+13.5}_{-12.4}$(stat)±3.7(fit) events

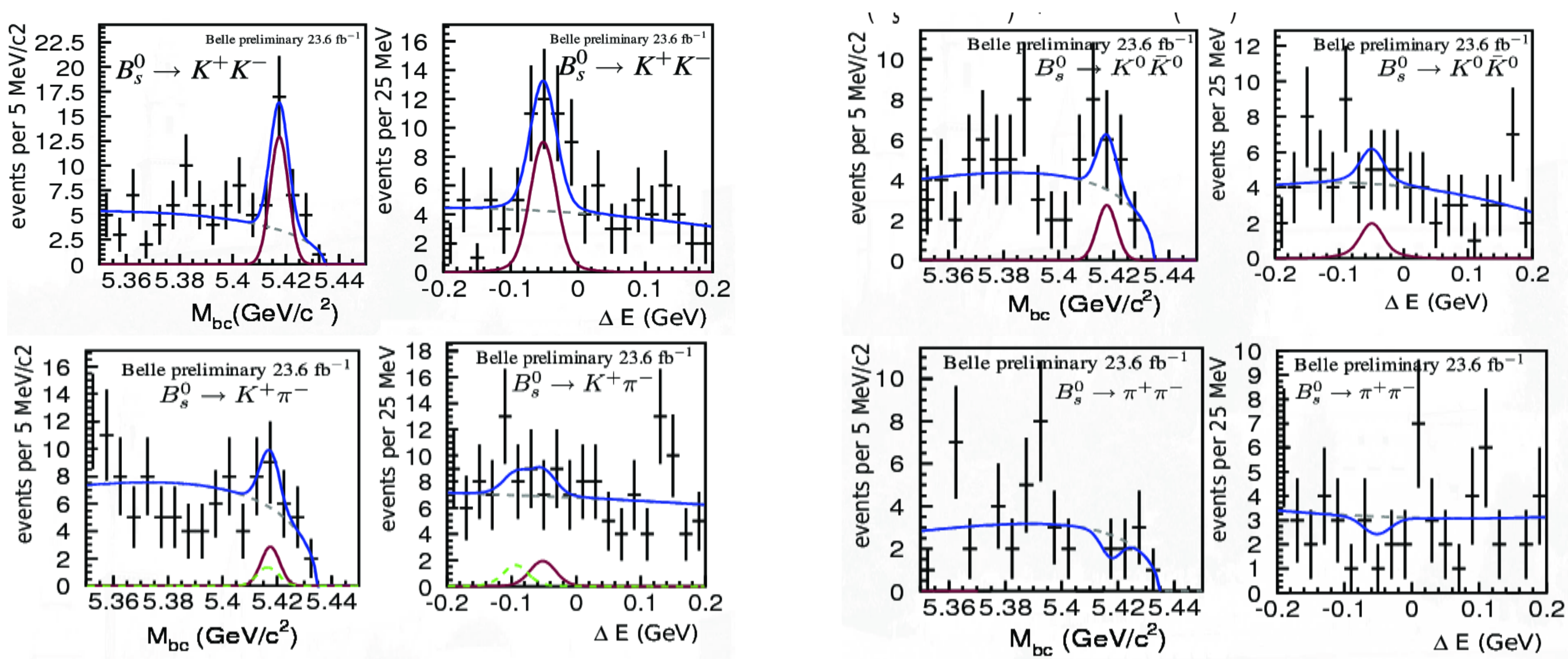
⇒ 8.6 σ : first observation

preliminary

$Br(B_s \to D_s^{*-}\rho^+) = (13.0^{+2.3}_{-2.1}(stat) \pm 1.7(sys) \pm 1.7(pol.) \pm 1.3(f_s)) \times 10^{-3}$

3) Study of $B_s^0 \to hh$

* May be sensitive to NP (KK) <- London and Matias, PRD 70, 031502
* Possibility of ϕ_3 measurement (KK/ππ) <- Fleischer, PLB 459, 306
* CP eigenstates (KK, ππ)



$$\mathcal{B}(B_s^0 \to K^+K^-) = (3.8^{+1.0}_{-0.9} \pm 0.7) \times 10^{-5}$$
$$\mathcal{B}(B_s^0 \to \pi^+\pi^-) < 1.2 \times 10^{-5} \text{ (90\% C.L.)}$$
$$\mathcal{B}(B_s^0 \to K^0\bar{K}^0) < 3.3 \times 10^{-5} \text{ (90\% C.L.)}$$
$$\mathcal{B}(B_s^0 \to K^+\pi^-) < 2.6 \times 10^{-5} \text{ (90\% C.L.)}$$

preliminary

4. Summary

- Belle has accumulated a data set of $1ab^{-1}$ luminosity and various analyses are in progress.

- Update of ϕ_3 measured using Dalitz:

$$78.4^\circ {}^{+10.8^\circ}_{-11.6^\circ} \pm 3.6^\circ(\text{syst}) \pm 8.9^\circ(\text{model})$$

→ World's most precise measurement of ϕ_3

- New V_{cb} measurement using $B^+ \to \bar{D}^* l^+ \nu$:

$$F(1)|V_{cb}| = (35.0 \pm 0.4 \pm 2.2) \times 10^{-3}$$

→ Consistent with previous measurement using $B^0 \to D^{*-} l^+ \nu$

- New V_{ub} measurement using $B \to X_u l^+ \nu$ with full recon tag.

→ 90% phase space coverage → drastic reduction of theoretical uncertainty

- New observations and studies in B_s decays from $\Upsilon(5S)$:

  $J/\psi\eta(')$, $D_s^{*-}\pi^+$, $D_s^{(*)-}\rho^+$, and h^+h^-.

  → aiming at $\Delta\Gamma_s/\Gamma_s$ measurement ($\sigma(\Delta\Gamma_s/\Gamma_s)$ ~15% with a full Y(5S) data set) .

- Many new results will come out with a full data set of 1 ab^{-1}.
  Belle's "Intense Analysis Phase" before SuperKEKB.

Backup Slides

Summary of Belle Datasets (now ready for analysis, units fb^{-1})

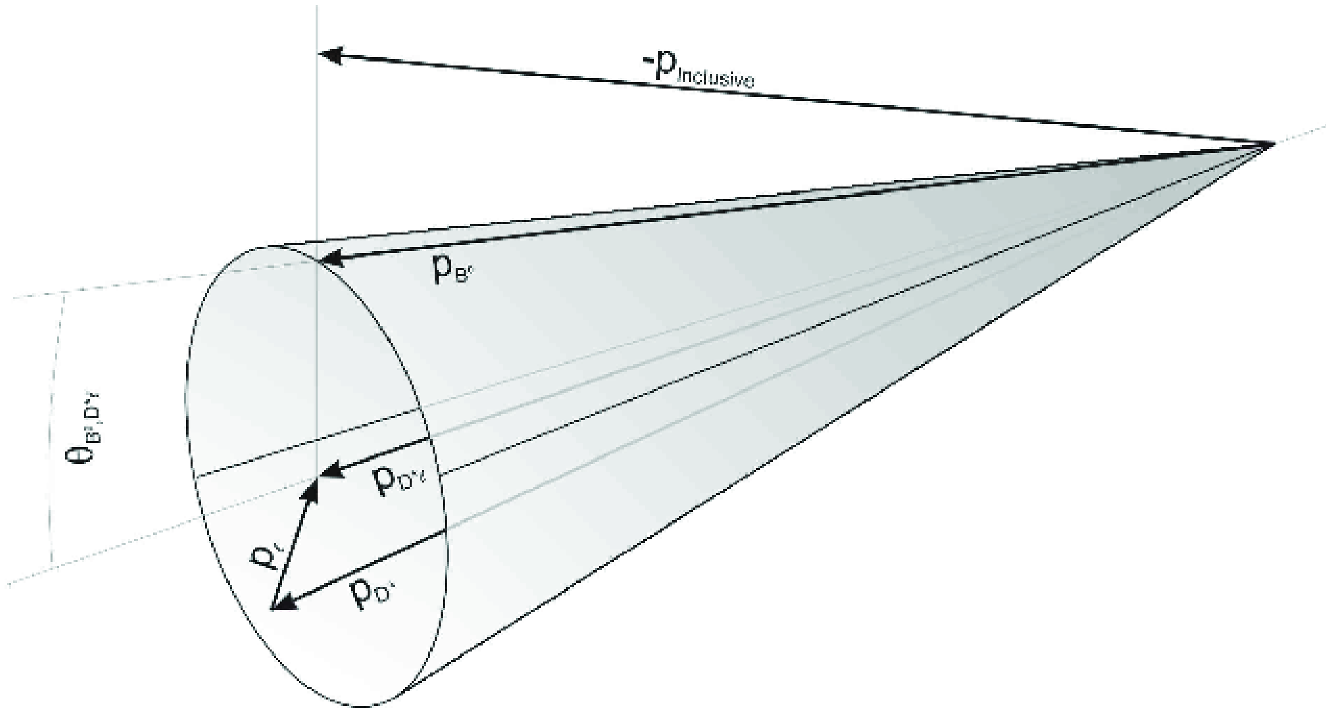
- Upsilon(5S) 120.6 on-resonance
- Upsilon(4S) 710.5 on-resonance/83.3 off

- Upsilon(1S) 5.7 on/1.8 off (100M 1S)
- Upsilon(2S) 24.1 on/1.7 off (159M 2S)
- Upsilon(3S) 2.95 on/0.248 off

Datasets in red are the world's largest samples

SVD: 3 layer config used for 140.9 on/15.6 off of 4S sample

Best B^+ candidate - B rest frame

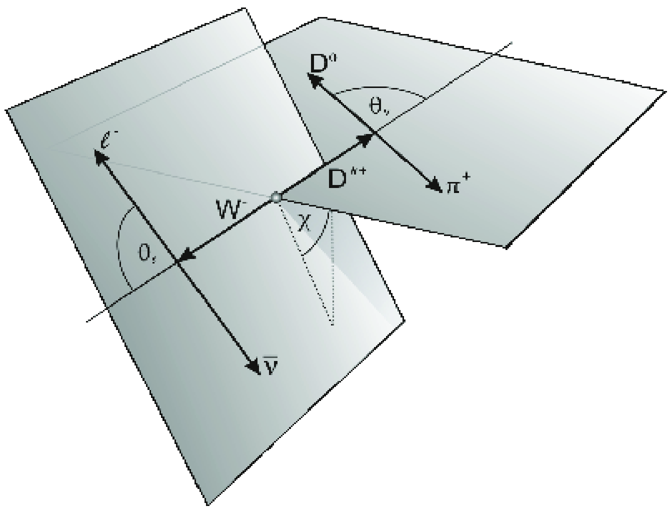


- B^+ momentum constrained by reconstructed kinematics
- Choose best B^+ candidate using remaining event ("$\vec{p}_{\text{inclusive}}$")
- Resolutions are as good as in B^0 case

Observables

Kinematic variables

- $w = \frac{p_B^{\mu} \cdot p_{D^*,\mu}}{m_{B^0}\, m_{D^*}} = a + b\, q^2$
- $\cos\theta_\ell$, $\cos\theta_V$, χ



Differential decay width

$$\frac{d^4\Gamma(B \to D^* \ell^+ \nu_\ell)}{dw\, d(\cos\theta_\ell)\, d(\cos\theta_V)\, d\chi}$$

$$= \frac{6 m_B m_{D^*}^2}{8(4\pi)^4} \sqrt{w^2 - 1}(1 - 2wr + r^2) G_F^2 |V_{cb}|^2$$

$$\times \{(1 - \cos\theta_\ell)^2 \sin^2\theta_V H_+^2(w)$$

$$+ (1 + \cos\theta_\ell)^2 \sin^2\theta_V H_-^2(w)$$

$$+ 4 \sin^2\theta_\ell \cos^2\theta_V H_0^2(w)$$

$$- 2 \sin^2\theta_\ell \sin^2\theta_V \cos 2\chi H_+(w) H_-(w)$$

$$- 4 \sin\theta_\ell (1 - \cos\theta_\ell) \sin\theta_V \cos\theta_V \cos\chi H_+(w) H_0(w)$$

$$+ 4 \sin\theta_\ell (1 + \cos\theta_\ell) \sin\theta_V \cos\theta_V \cos\chi H_-(w) H_0(w)\}$$

- Aside from masses etc. identical for B^0 and B^+

$$\frac{d\Gamma}{dw} = \frac{G_F^2}{48\pi^3} m_{D^{*0}}^3 (m_B - m_{D^{*0}})^2 \mathcal{G}(w) \mathcal{F}^2(w) |V_{cb}|^2$$

$\mathcal{F}(1)|V_{cb}|$ and FF parameters ρ^2, $R_1(1)$, $R_2(2)$

$F(1)|V_{cb}|$: Comparison with other measurements

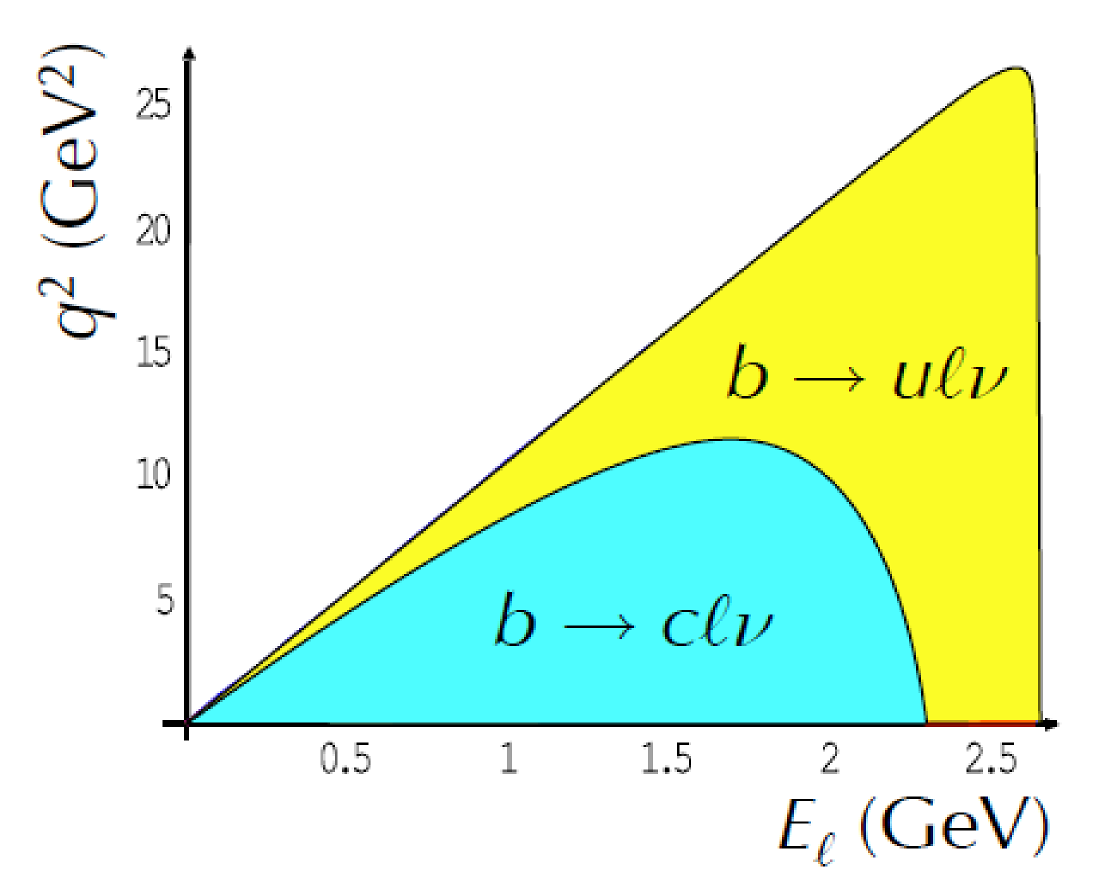
	this result	Belle B^0 (BN 1054, preliminary)
$\mathcal{F}_1\|V_{cb}\| \times 10^3$	$35.0 \pm 0.4 \pm 2.2$	$34.4 \pm 0.2 \pm 1.0$
ρ^2	$1.376 \pm 0.074 \pm 0.056$	$1.293 \pm 0.045 \pm 0.029$
$R_1(1)$	$1.620 \pm 0.091 \pm 0.093$	$1.495 \pm 0.050 \pm 0.062$
$R_2(1)$	$0.805 \pm 0.064 \pm 0.037$	$0.844 \pm 0.034 \pm 0.019$

	BaBar B^0 [3]	Babar B^+ [4]
$\mathcal{F}_1\|V_{cb}\| \times 10^3$	$34.4 \pm 0.3 \pm 1.2$	$35.9 \pm 0.6 \pm 1.4$
ρ^2	$1.191 \pm 0.048 \pm 0.028$	$1.16 \pm 0.06 \pm 0.08$
$R_1(1)$	$1.429 \pm 0.061 \pm 0.044$	-
$R_2(1)$	$0.827 \pm 0.038 \pm 0.022$	-

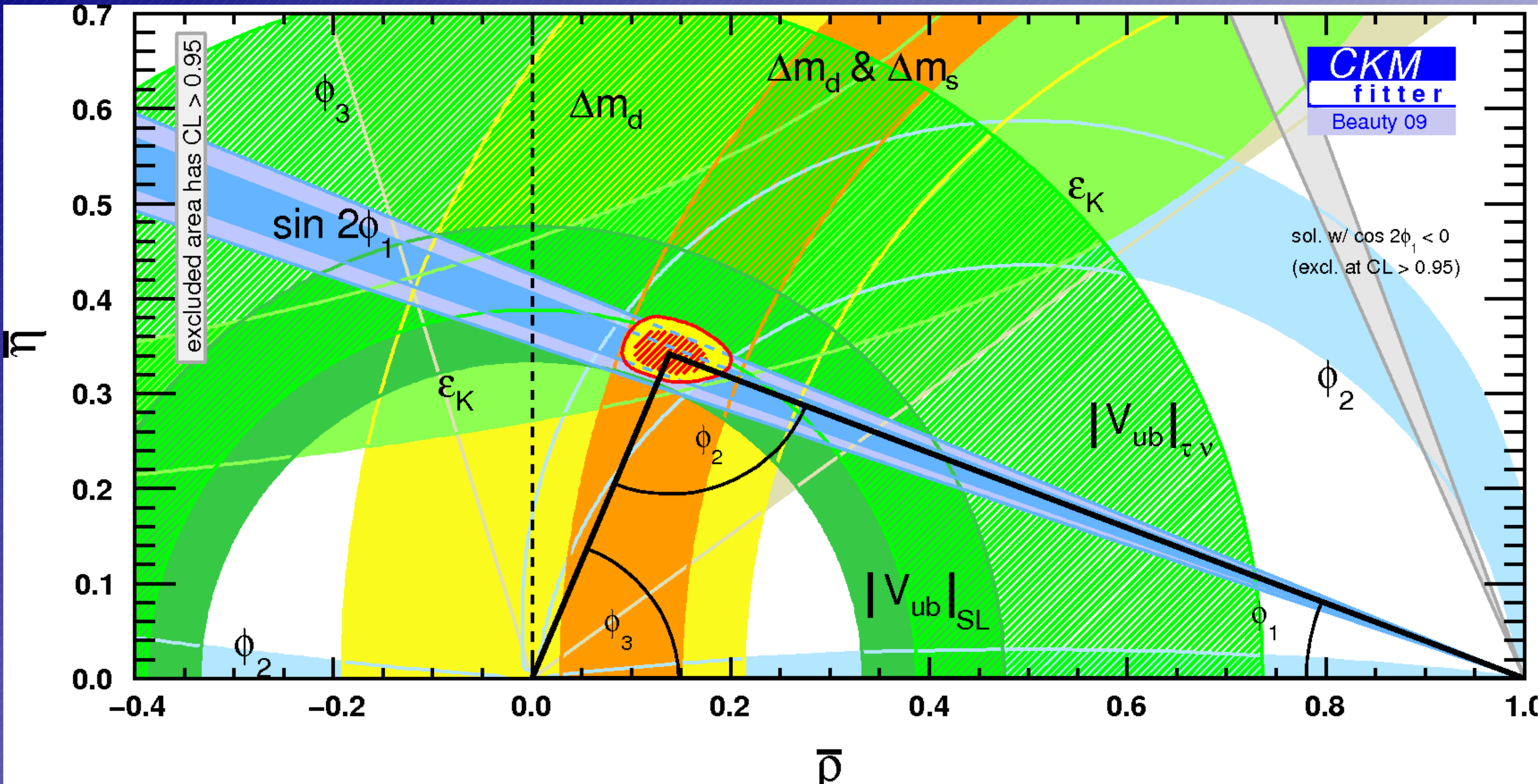
	CLEO	ARGUS	Babar tagged	Babar global fit
$\mathcal{B}(B^+)[\%]$	$6.6 \pm 0.2 \pm 0.4$	$6.1 \pm 1.4 \pm 1.0$	$5.71 \pm 0.15 \pm 0.30$	$5.37 \pm 0.02 \pm 0.21$

	Babar untagged (%)	our B^+ fit	our B^0 fit (assuming equal width)
$\mathcal{B}(B^+)[\%]$	$5.31 \pm 0.08 \pm 0.40$	$4.84 \pm 0.04 \pm 0.57\%$	$(4.73 \pm 0.04 \pm 0.28) \times \tau_{B^0}/\tau_{B^+}$

Phase space vs. lepton energy of $b \to ul\nu$ and $cl\nu$

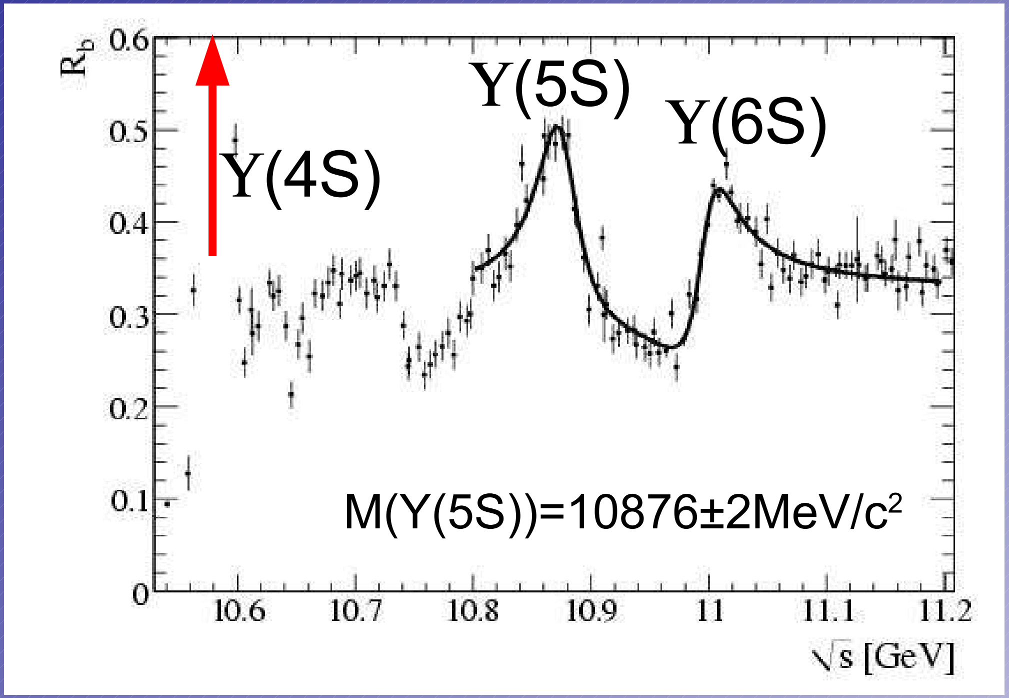


Constraint on unitarity triangle as of 2009



Energy scan by BaBar

BaBar PRL102, 012001 (2009)



Comparison with Fermilab B_s studies.

- There are several advantages in Υ(5S) running, comparing with hadron-hadron colliders (in particular with CDF and D0):

  1) "Model independent" branching fraction measurements.
  2) Measurement of decay modes with γ, π^0 and η in final state ($D_s^+ \rho^-$).
  3) No trigger problems for multiparticle final states (like $D_s^+ D_s^-$).
  4) Inclusive measurements (inclusive photon spectrum, semileptonic *BF*).
  5) Partial reconstruction (*Bf* ($D_s^+ l^- \nu$) using "missing-mass" method).

- There are also disadvantages:

  1) We have to choose between running at Υ(4S) or Υ(5S).
  2) Number of B_s is smaller than in Fermilab experiments.
  3) Vertex resolution is not good enough to measure B_s mixing (?).

What we can do with more Y(5S)

1) Search for new CPV in $B_s \to$CP-specific modes

($J/\psi\ \phi$, $D_s^* D_s^*$, $J/\phi\ \eta'$,K^+K^-,$D^0_{CP}K^0$)

- SM predicts CP conservation in these modes in contrast to $B_d \to J/\psi\ K^0(K^{*0})$ since CP-violating CKM elements (V_{td},V_{ub}) are not included in the decay amplitude.
- CPV can be searched for by measuring $\Delta\Gamma_s/\Gamma_s$ in these decays.
- Analysis method: time-dependent analysis

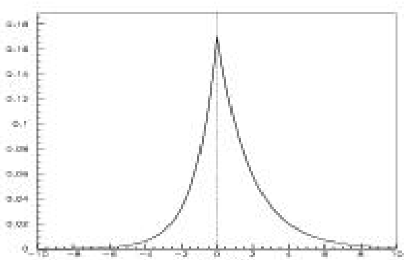
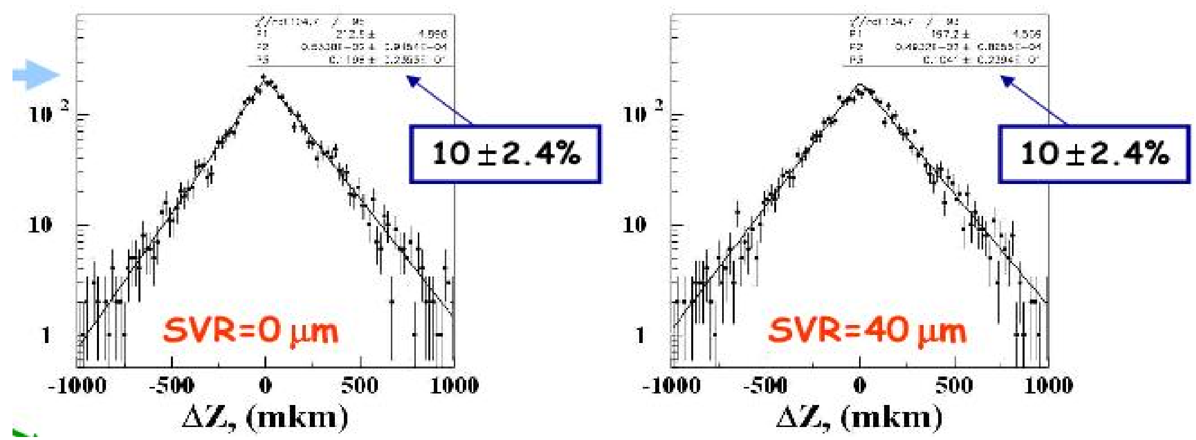


図 2: $\Delta\Gamma_s/\Gamma_s = +0.2$、$\eta_{CP} = +1$ の場合の Δt 分布。



* SVD resolution is not critical in contrast to the mixing measurement

Expected event yields: ~ 500 events in total with 100/fb

$\to \sigma(\Delta\Gamma_s/\Gamma_s)$ ~ 15%

Motivation for $B_s \to D_s^{*-}\pi^+$ and $B_s \to D_s^{(*)-}\rho^+$

- B_s decay into CKM favored modes provides useful information for the study of B_s property.

- Also useful to measure f_s (fraction of B_s produced in Υ(5S) decay)

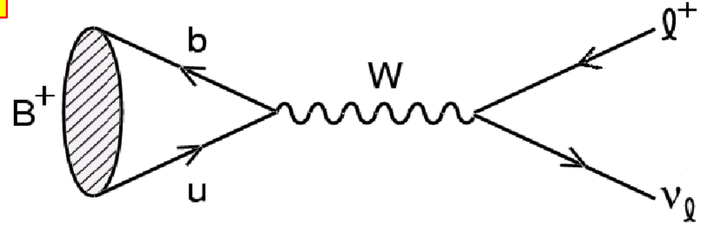
- Our recent publication (PRL 102, 021801 (2010)) already reported the results for $B_s \to D_s^-\pi^+$
  -> World's most precise mearements of Br and m(B_s*).

- But the statistics was limited to only ~160 events.

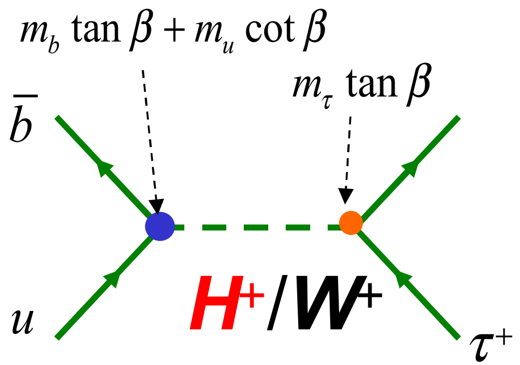
- New analyses for $D_s^{*-}\pi^+$ and $D_s^{(*)-}\rho^+$ are made for the improvement.

$B \to \tau\nu$

SM



NP



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

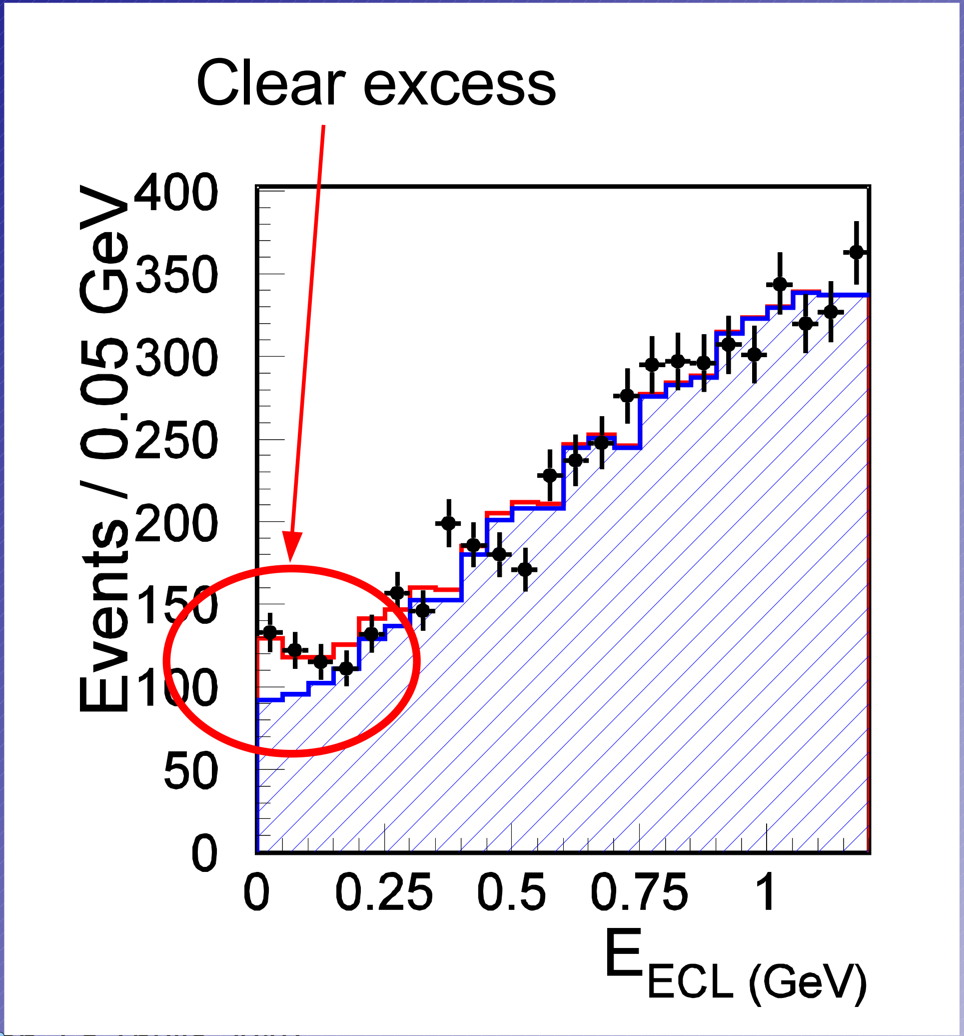
$$r_H = \left(1 - \frac{m_B^2}{m_H^2} \tan^2\beta\right)^2$$

$Br = Br_{SM} \times r_H$

* In the framework of Standard Model, the decay is useful for the determination of V_{ub} and f_B
* Also sensitive to New Physics!
  - The existence of charged Higgs can modify SM branching fraction

Results with 605fb^{-1}

- Signal is identified by looking at the energy clusters in the calorimeter (ECL) which are associated with neither signal nor tag B meson decay products.
  * No energy deposit is expected in signal events.



Semi-leptonic tag only

ArXiv:0809.3834

$N_{sig} = 154^{+36}_{-35}(stat)^{+20}_{-22}(syst)$

@ 3.8σ (4.7σ w/o syst.) significance

$Br(B \to \tau\nu) = (1.65^{+0.38}_{-0.37}\ {}^{+0.35}_{-0.37}) \times 10^{-4}$

Previous Belle result with 449M events

$Br = 1.79^{+0.56}_{-0.49}(stat)^{+0.46}_{-0.51}(syst)$

Belle measurement of Br(B→τν)

$$\mathcal{B}(B \to \tau\nu) = (1.65^{+0.38+0.35}_{-0.37-0.37}) \times 10^{-4}$$

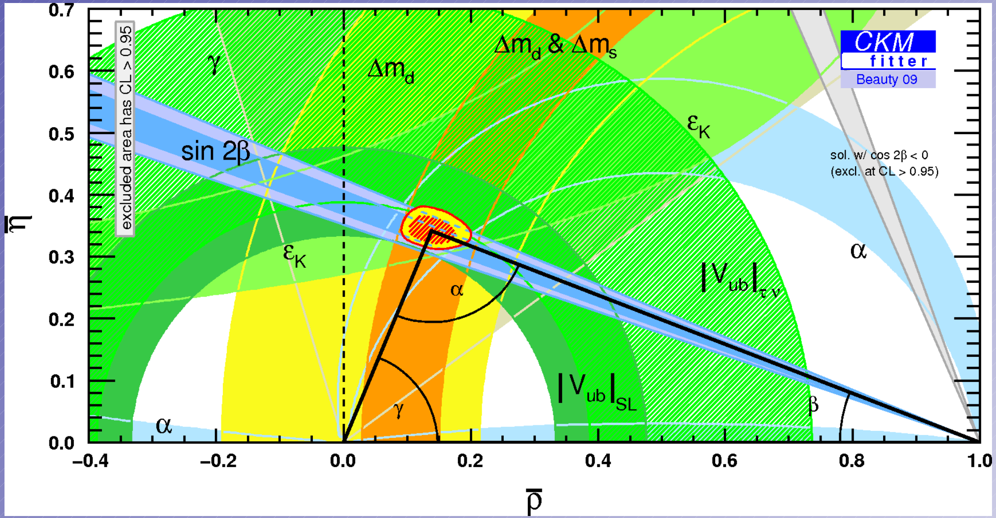
$$B(B \to \tau\nu)_{Belle+BaBar} = (1.73 \pm 0.35) \times 10^{-4}$$

$$B(B \to \tau\nu)_{CKMfitter} = (0.79^{+0.16}_{-0.10}) \times 10^{-4}$$

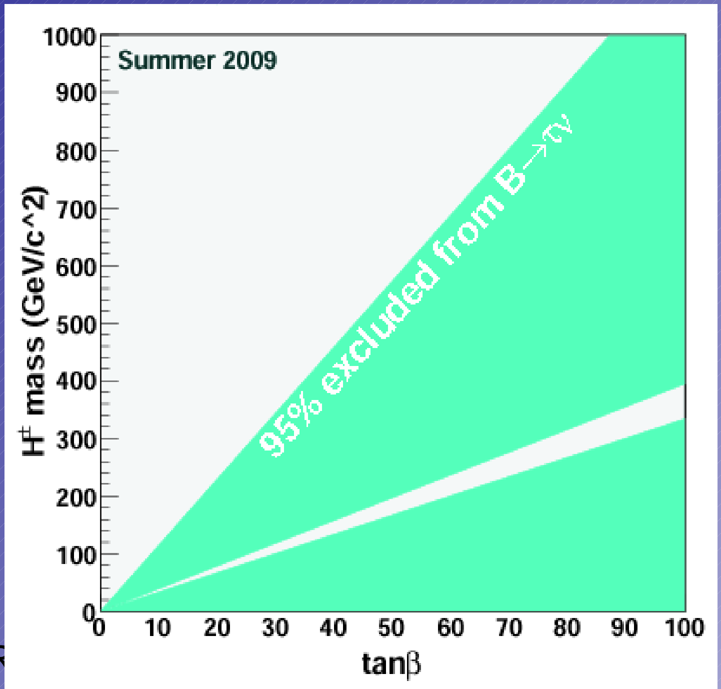
$$Br(B \to \tau\nu) = Br_{SM}(B \to \tau\nu) \times r_H$$

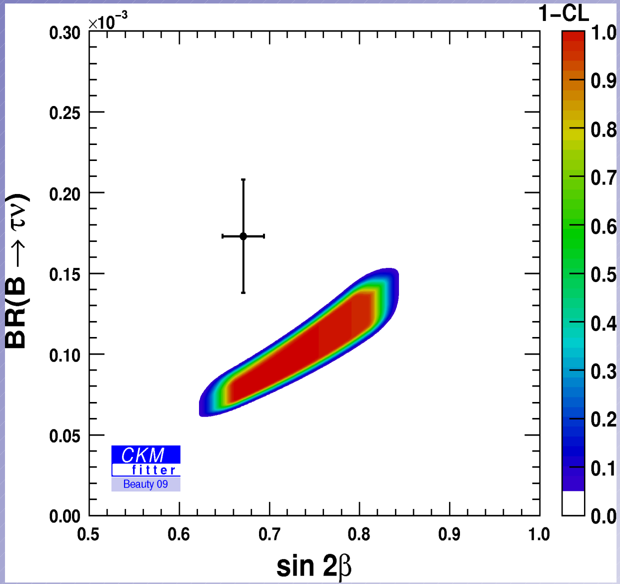
$$r_H = \left(1 - \frac{m_B^2}{m_H^2} \tan^2\beta\right)^2$$

$$B(B \to \tau\nu)_{SM} = (1.20 \pm 0.25) \times 10^{-4}$$



Constraint on Higgs Mass





2.4σ discrepancy!!