Recent Results from Belle

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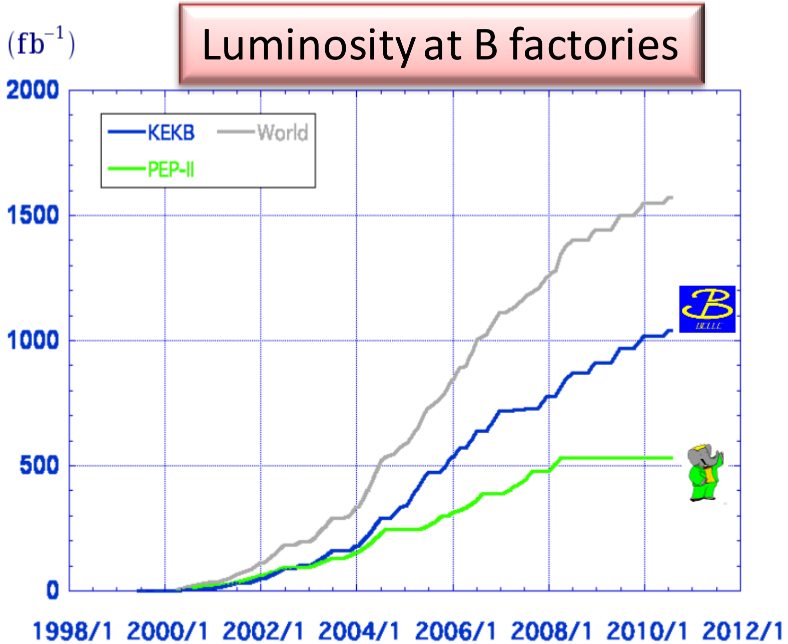
Outline

- Luminosity Record at Belle; Belle-II & super KEKB groundbreaking
- **Measurement for CKM UT sides $|V_{ub}|$ and $|V_{cb}|$; First Evidence for the Suppressed Decay : $B^- \to DK^-$ with $D \to K^+\pi^-$**
- **New Physics: CP violation in D and τ decays?**

Luminosity Record at B factories



"Last beam abort" ceremony on June 30, 2010

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}

Belle-II & super KEKB status at KEK, Japan

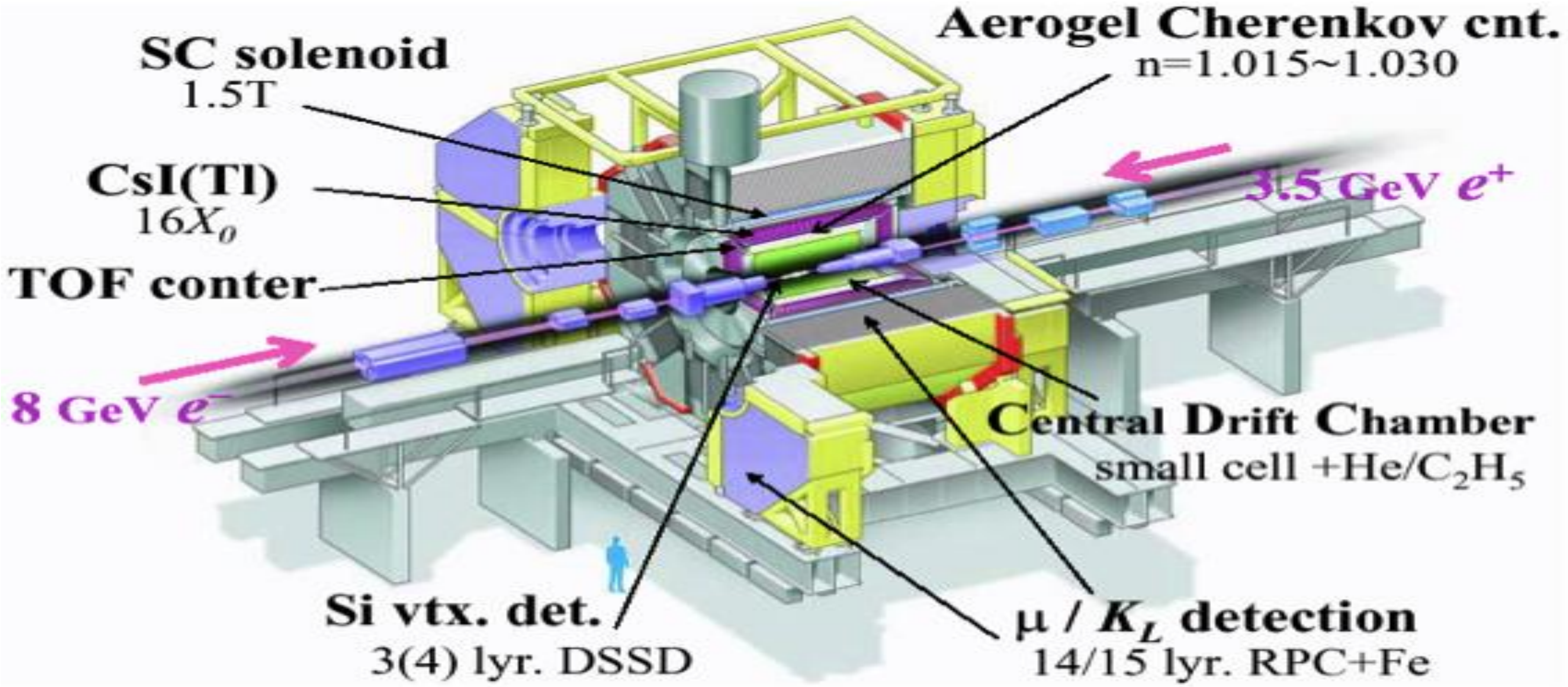
1. KEKB upgrade project was approved in 2010/Jun. A groundbreaking ceremony will be held on April 8, 2011.
2. Luminosity goal: 8 x 10^{35} $cm^{-2}s^{-1}$.
3. Plan of super KEKB: commission in 2014, reach the 50ab^{-1} in 2020~2021.
4. Please check Y. Horii's talk for more detail. (Mar.5)

International Commitment to Belle-II

Belle-II is now a collaboration of ~400 physicists from 57 institutions in 13 countries.

Belle detector

1. **Reprocessed data (tracking efficiency improvement).**
2. **Systematic improvement (using full data sample).**
3. **The tracking systematic goes from 1% to 0.35%.**



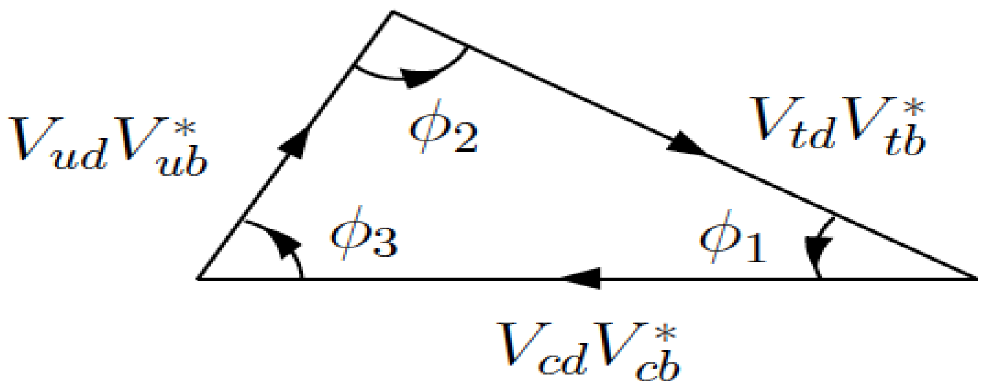
Unitarity Triangle (UT)

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

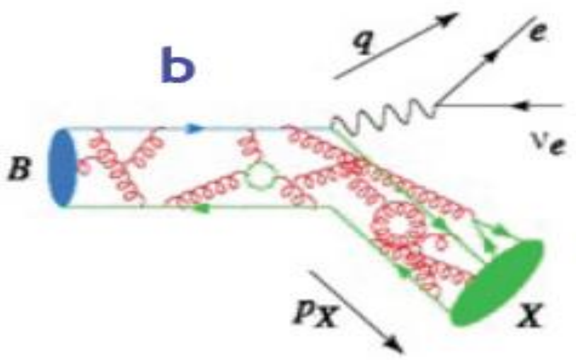
Weak eigenstates | CKM matrix | Mass eigenstates

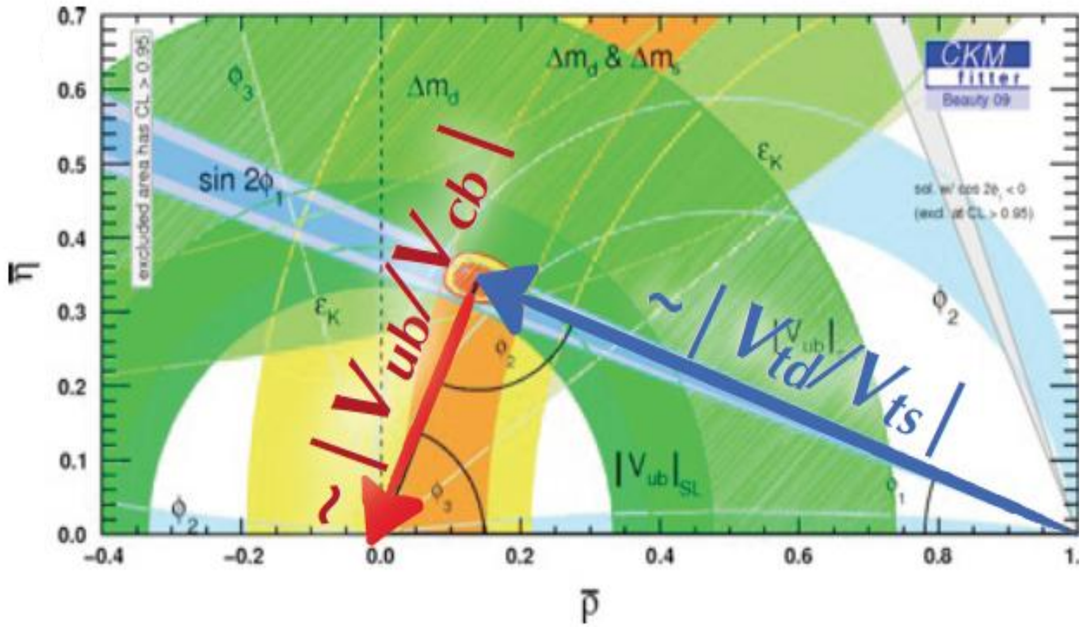
A **triangle** can be drawn using an **unitarity condition** of the CKM matrix

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



Measurement of CKM UT sides





•Inclusive $|V_{ub}|$: $B \rightarrow X_u \, l \, \nu$

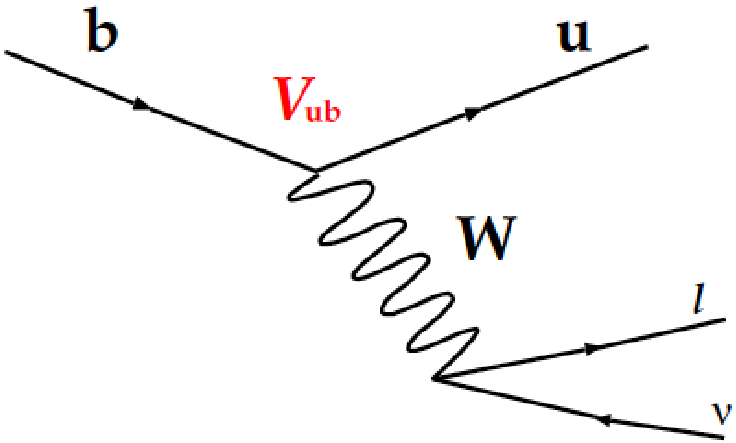
•Exclusive $|V_{ub}|$: $B \rightarrow \pi \, l \, \nu$

•Inclusive $|V_{cb}|$: $B \rightarrow X_c \, l \, \nu$

•Exclusive $|V_{cb}|$: $B \rightarrow D^* \, l \, \nu$

Inclusive decays: $b \rightarrow q \, l \, \nu$ Weak quark decay + QCD corrections	Exclusive decays: $B \rightarrow X_q \, l \, \nu$ Form factors, need lattice QCD

#1 Exclusive $|V_{ub}|$: $B^0 \rightarrow \pi^- l^+ \nu$



Here final state is $B^0 \rightarrow \pi^- l^+ \nu$, l=e,μ
Measurement is done with the equation,

$$\frac{d\Gamma(B \to \pi^- \ell^+ \nu)}{dq^2} = \frac{G_F^2}{192\pi^2 m_b^3} |V_{ub}|^2 \lambda(q^2)^{\frac{3}{2}} \left|f_+^\pi(q^2)\right|^2$$

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

Need extra input, determined by theorist

Basic parameters

- A charged pion and a lepton as a signal side
- missing 3 momentum

$$\vec{p_{\rm miss}} \equiv -\sum_i \vec{p_i}$$

- neutrino 4 momentum

$$p_\nu = (|\vec{p_{\rm miss}}|, \vec{p_{\rm miss}})$$

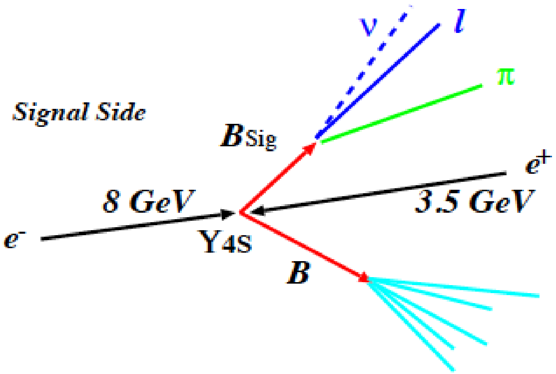
- Momentum transfer, q^2

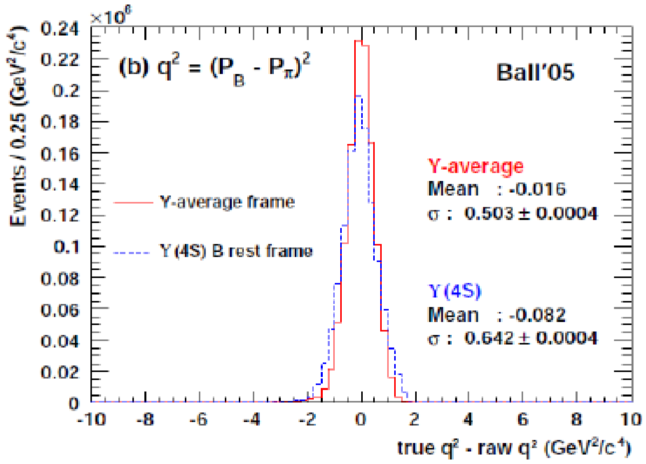
$$q^2 = (p_\ell + p_\nu)^2 = (p_{\rm B} - p_\pi)^2,$$

averaged over B direction ambiguity

- Estimate B yield by fitting distributions,

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



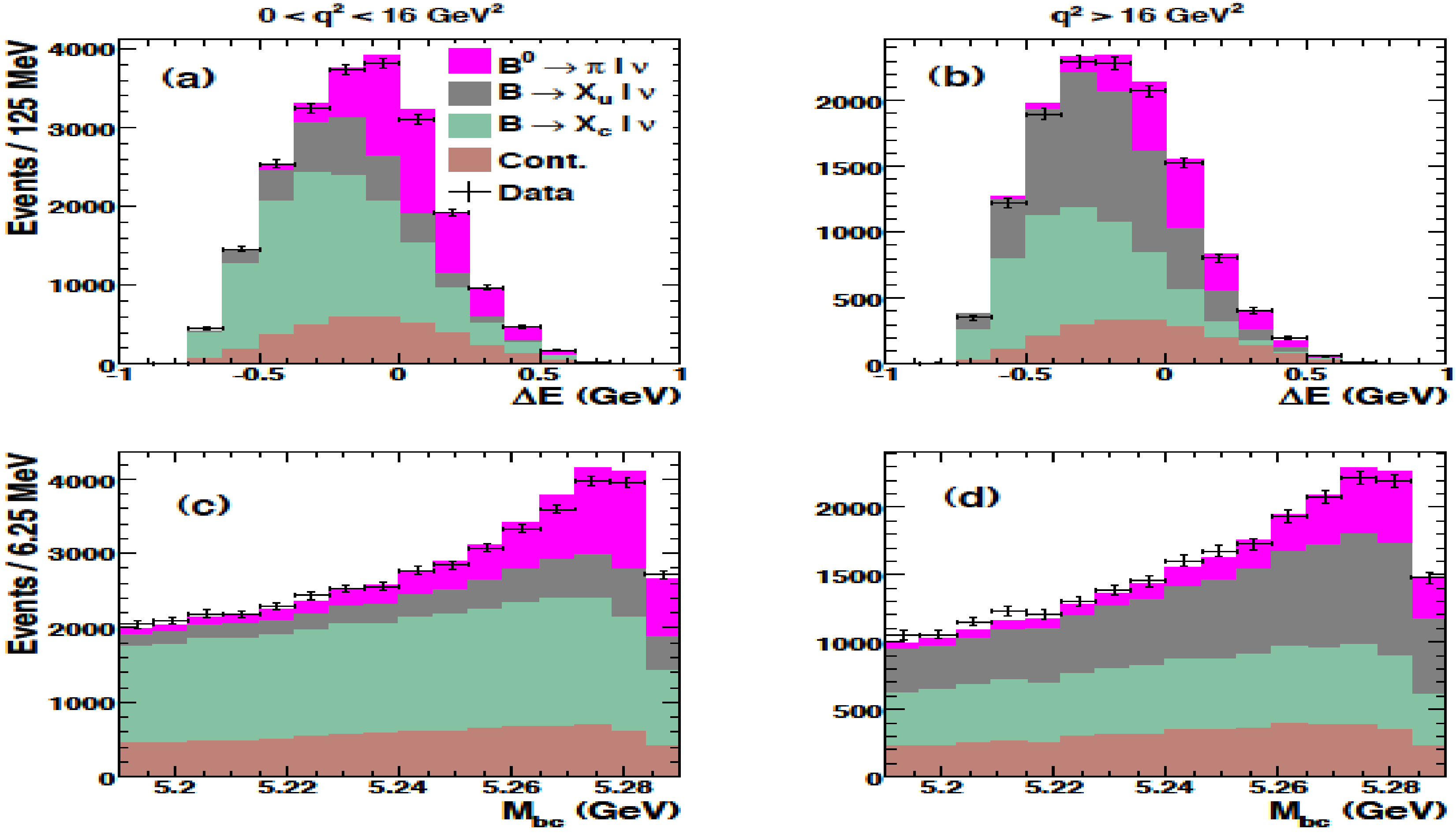


$\sigma_{q^2} \sim 0.5\ {\rm GeV}^2$

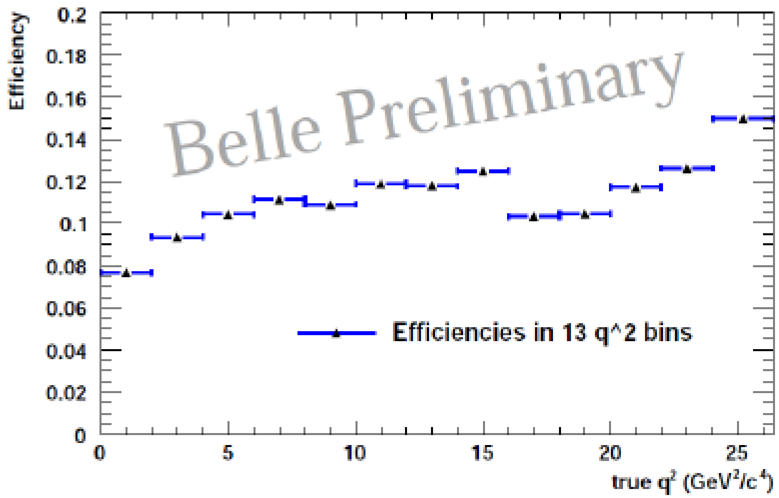
arXiv:1012.0090 Submitted to PRD(RC)

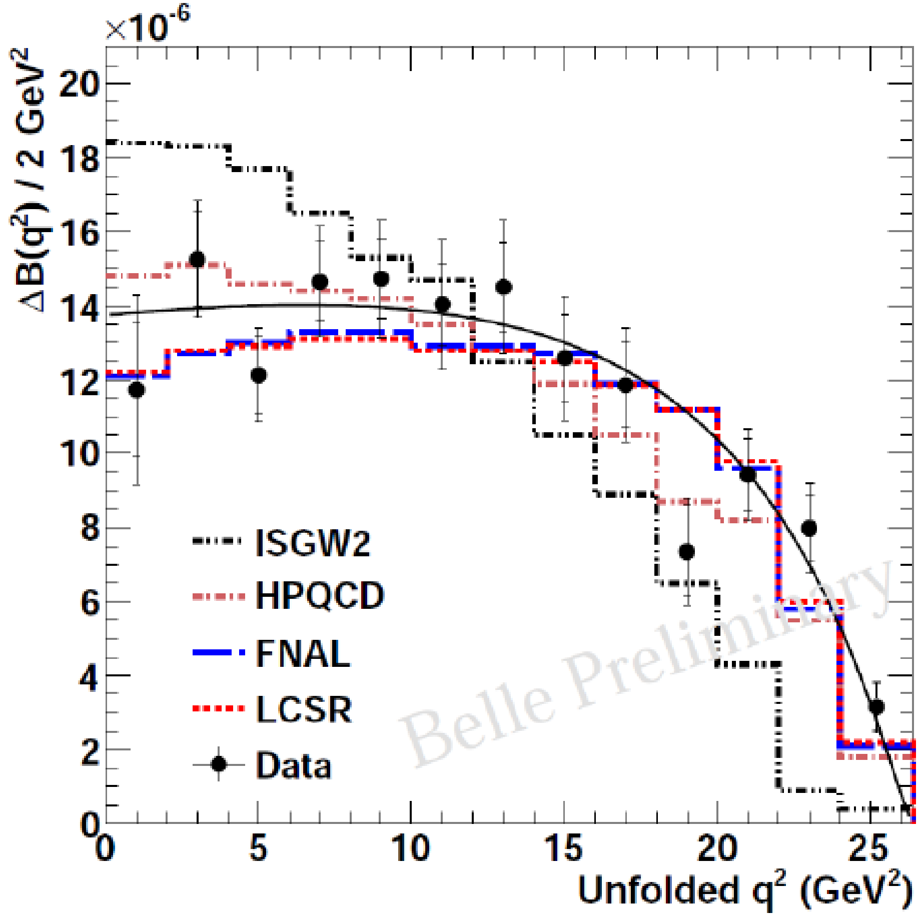
Yield extraction, ΔE-M_{bc} 2D Fit, $605 fb^{-1}$

$$\mathcal{B} = (1.49 \pm 0.04(\text{stat}) \pm 0.07(\text{syst})) \times 10^{-4}$$



Data compare with Models





- Efficiency calculated in each q^2 bin
- unfolded q^2 distribution
- ISGW2 disfavored

$|V_{ub}|$, uncertainty from Models

- V_{ub} can be extracted from the partial Branching Fraction,

$$|V_{ub}| = \sqrt{\Delta\mathcal{B}(q^2)/\tau_{B^0}\Delta\zeta},$$

where,
$\Delta\zeta$: form factor in corresponding q^2 range

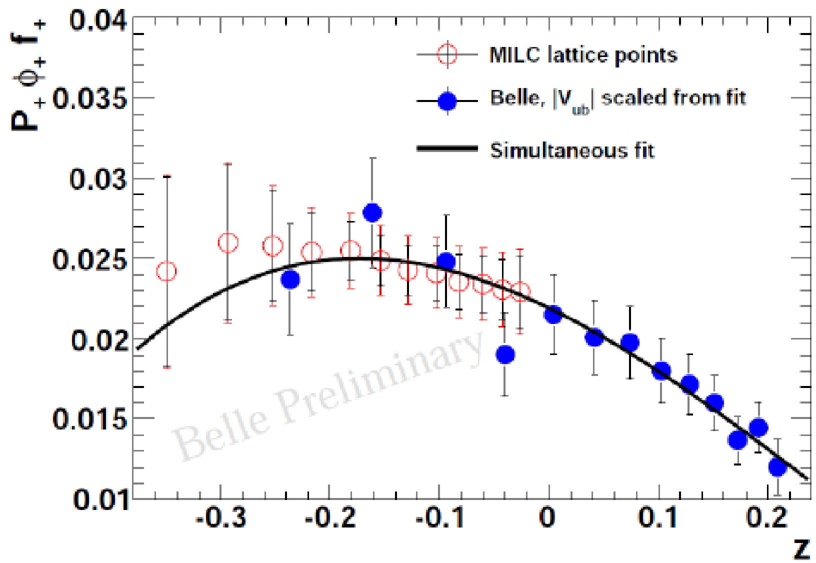
- Result

	q^2 (GeV^2)	$\Delta\zeta$ (ps^{-1})	$\lvert V_{ub}\rvert(10^{-3})$
HPQCD	> 16	2.07 ± 0.57	$3.55 \pm 0.09 \pm 0.09^{+0.62}_{-0.41}$
FNAL	> 16	1.83 ± 0.50	$3.78 \pm 0.10 \pm 0.10^{+0.65}_{-0.43}$
LCSR	< 16	5.4 ± 1.4	$3.64 \pm 0.06 \pm 0.09^{+0.60}_{-0.40}$
ISGW2	all	9.6 ± 4.8	$3.19 \pm 0.04 \pm 0.07^{+1.32}_{-0.59}$

- Form factor uncertainties largest contribution

$|V_{ub}|$, Belle data

- F.F. model independent V_{ub} extraction method (PRD79054507 (2009))
- $f(|V_{ub}|; f(z)) = f(|V_{ub}|; a_0 + a_1 z + a_2 z^2 + a_3 z^3)$
- $z = z(q^2)$
- simultaneous fit with
  - MILC lattice result,
  - Belle experimental result



arXiv:1012.0090
Submitted to PRD(RC)

$$|V_{ub}| = (3.43 \pm 0.33) \times 10^{-3}$$

(Stat. and syst. Errors combined)

#2 Exclusive $|V_{cb}|$: $B \rightarrow D^* l^+ \nu$

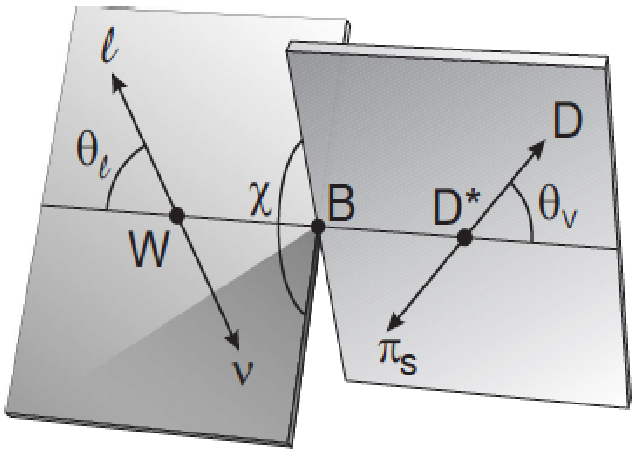
$$\frac{d\Gamma(B \to D^*\ell\nu)}{dw\,d\cos\theta_\ell\,d\cos\theta_V\,d\chi} = \frac{G_F^2}{48\pi^3}|V_{cb}|^2 m_{D^*}^3 (w^2-1)^{1/2} P(w)\mathcal{F}(w,\ldots)^2$$

$$\mathcal{F}(w) \Rightarrow \mathcal{F}(w, \cos\theta_\ell, \cos\theta_V, \chi, R_1, R_2, \rho^2)$$

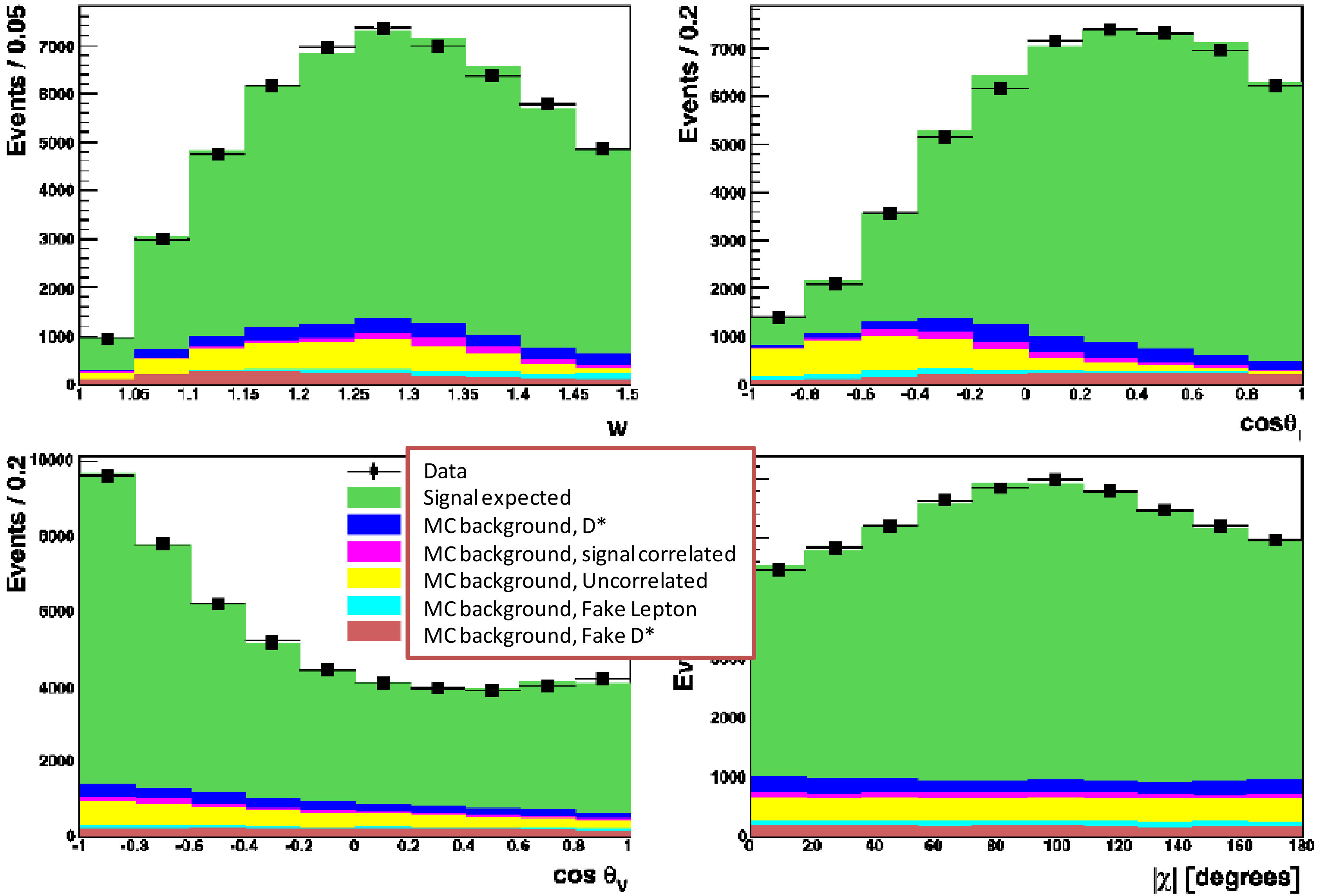
- Fit angular distributions, $\cos\theta_\ell, \cos\theta_V, \chi$ $\Rightarrow$ Form Factors R_1, R_2, ρ^2
- simultaneously fit w distribution to get $\mathcal{F}(1)|V_{cb}|$
- $|V_{cb}|$ is obtained with $\mathcal{F}(1)$ from FF calculation.

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



Belle 711fb^{-1} B→ D * $\ell\nu$ Analysis

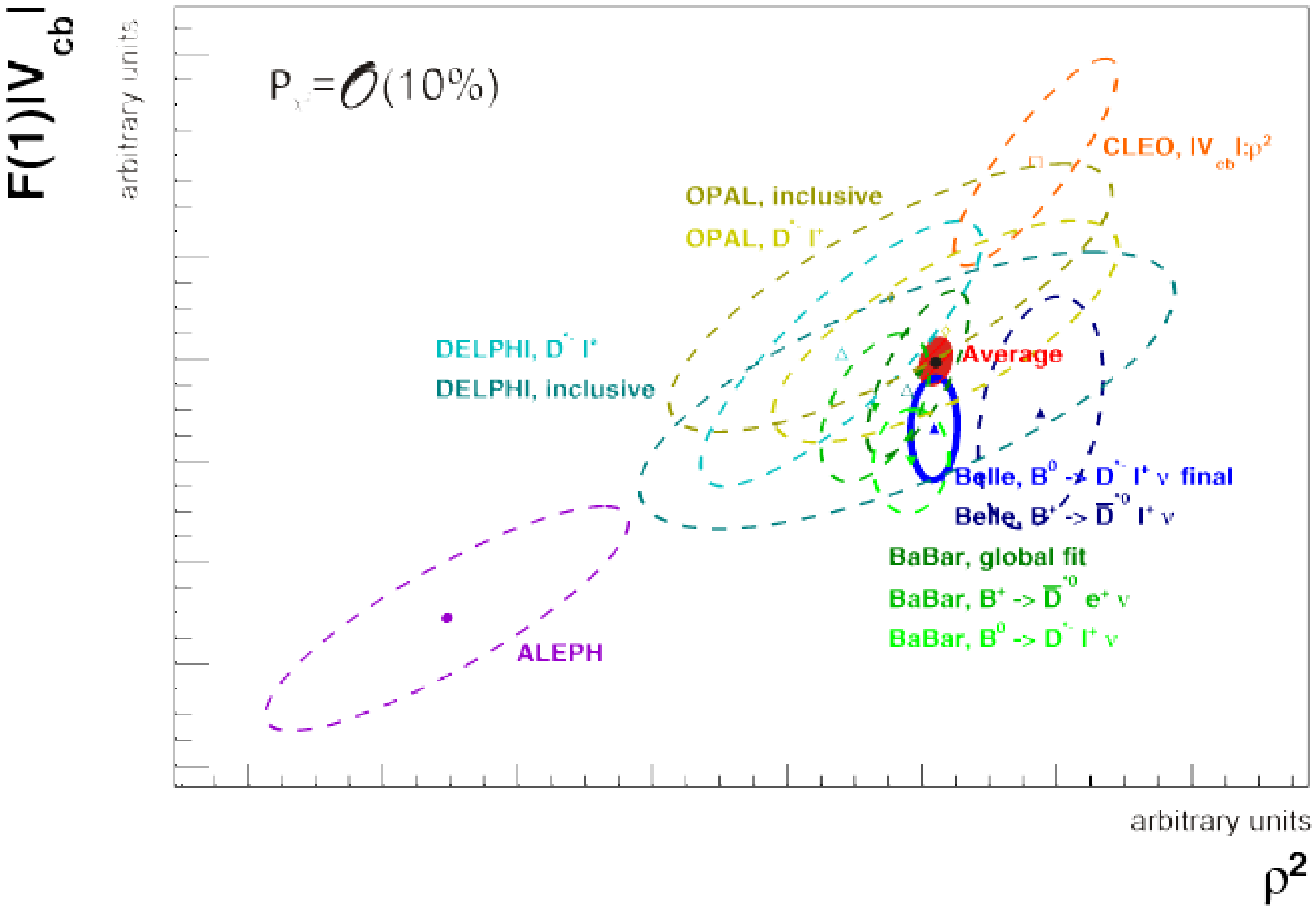


Exclusive B→ $D^*\ell\nu$ Results

PRD 82, 112007(2010)

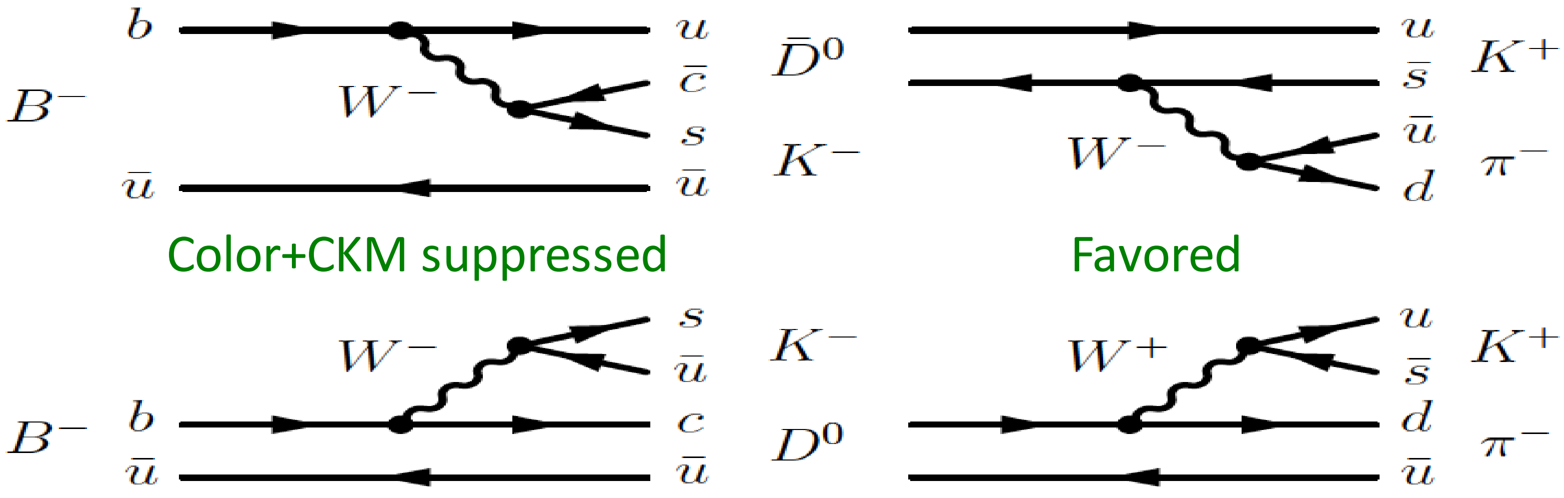
Belle		
	$B^+ \to \bar{D}^{*0}\ell\nu$	$B^0 \to D^{*-}\ell\nu$
$\mathcal{B}(B \to D^*\ell\nu)$	$(4.84 \pm 0.04 \pm 0.56)\%$	$(4.56 \pm 0.03 \pm 0.26)\%$
$\mathcal{F}(1)\|V_{cb}\| \times 10^3$	$35.0 \pm 0.4 \pm 2.2$	$34.5 \pm 0.2 \pm 1.0$
BaBar		
	$B^+ \to \bar{D}^{*0}\ell\nu$	$B^0 \to D^{*-}\ell\nu$
$\mathcal{B}(B \to D^*\ell\nu)$	$(5.56 \pm 0.08 \pm 0.41)\%$	$(4.69 \pm 0.04 \pm 0.34)\%$
$\mathcal{F}(1)\|V_{cb}\| \times 10^3$	$35.9 \pm 0.6 \pm 1.4$	$34.4 \pm 0.3 \pm 1.1$
	PRL100,231803(2008)	PRD77,032002(2008)
	Global $B \to \bar{D}X\ell\nu$	
$\mathcal{B}(B \to D^*\ell\nu)$	$(5.40 \pm 0.02 \pm 0.21)\%$	
$\mathcal{F}(1)\|V_{cb}\| \times 10^3$	$35.9 \pm 0.2 \pm 1.2$	
	PRD79, 012002(2009)	

World average



#3 First Evidence for the Suppressed Decay: $B^- \to DK^-$ with $D \to K^+\pi^-$

- Two diagrams exist for $B^- \to DK^-$, $D \to K^+\pi^-$.



Color+CKM suppressed — Favored

Favored — CKM suppressed

The two passes interfere, provide important information of ϕ_3.

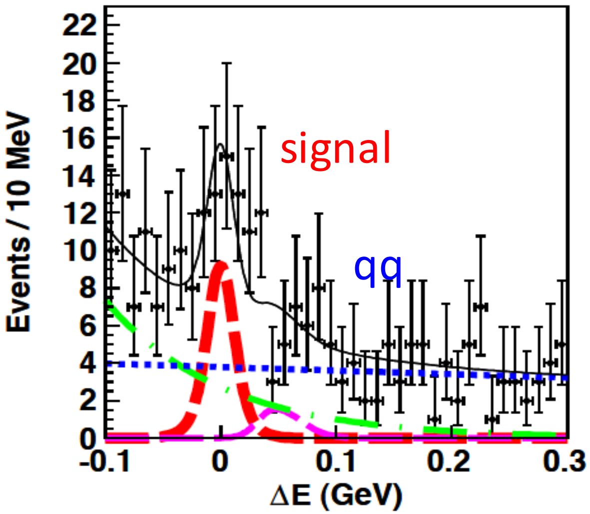
ADS, PRL78, 3257 (1997).

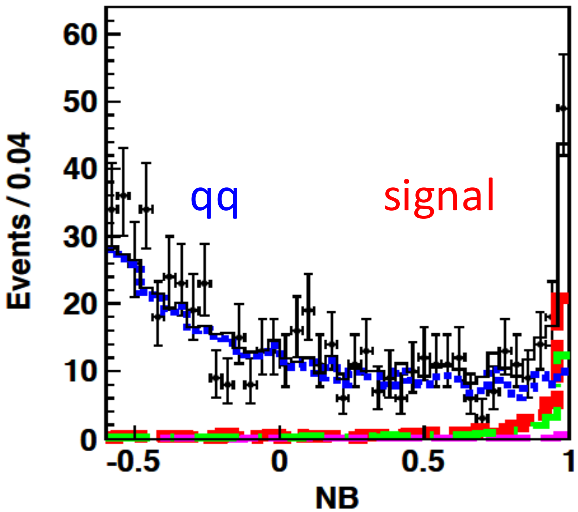
$r_{B(D)}$: ratio of the amplitudes of the two B(D) decays

$\delta_{B(D)}$: strong phase difference of the two B(D) decays

- By applying a 2-D fit on ΔE and NeuroBayes(NB), the first evidence of the signal is obtained with a significance of 4.1σ (including syst).

to be submitted to PRL





NB = a variable newly-introduced to discriminate between signal and BG from $e^+e^- \to qq$. (q = u, d, s, c.)

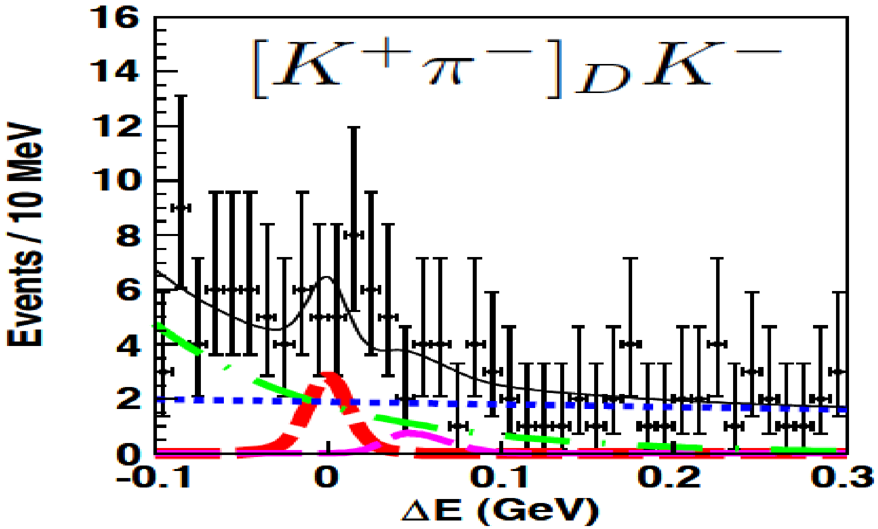
- From the obtained yield, we evaluate

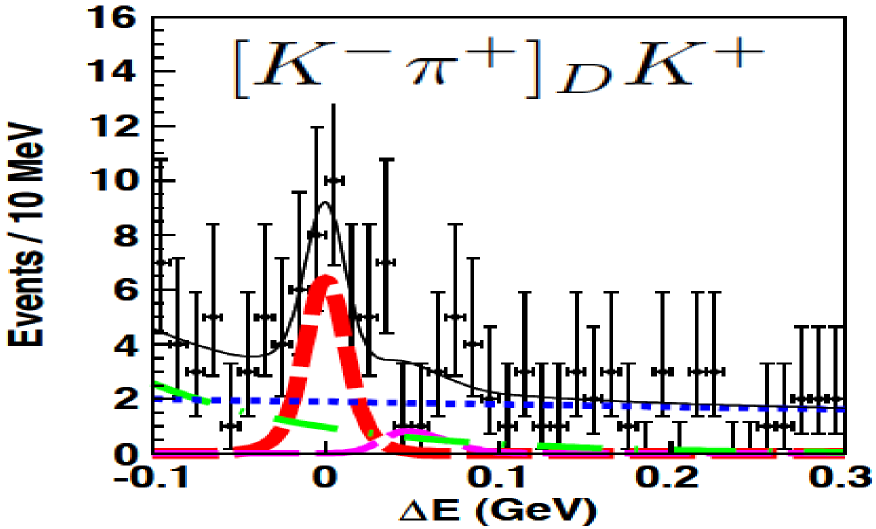
Calibration mode

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

$$= [1.63^{+0.44}_{-0.41}(\mathrm{stat})^{+0.07}_{-0.13}(\mathrm{syst})] \times 10^{-2}$$

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





We also obtain the CP asymmetry as

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

$$= -0.39^{+0.26}_{-0.28}(\mathrm{stat})^{+0.04}_{-0.03}(\mathrm{syst})$$

which is related to ϕ_3 as

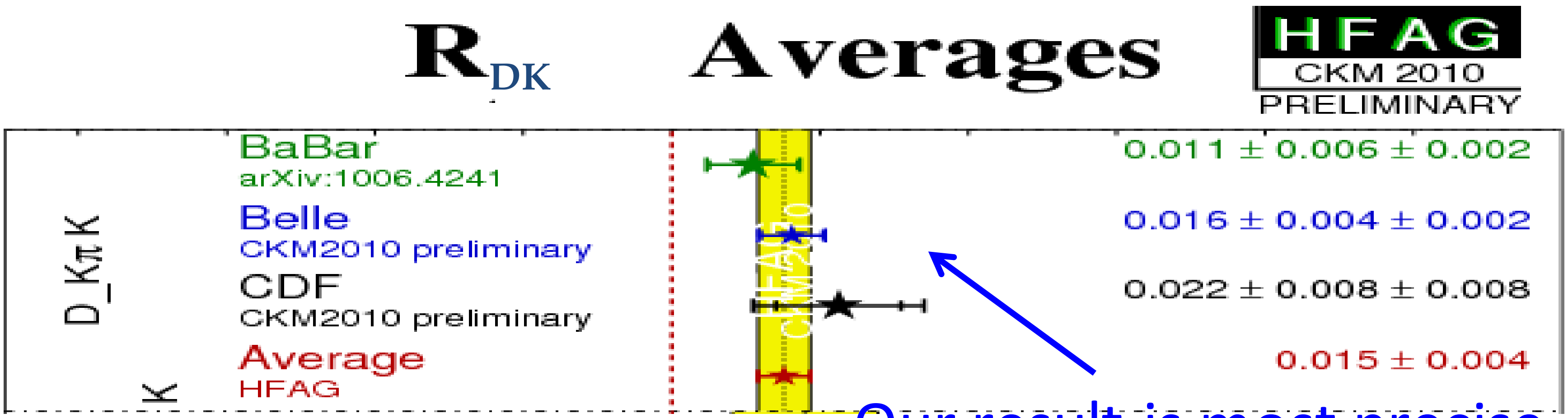
$$\mathcal{A}_{DK} = 2 r_B r_D \sin(\delta_B + \delta_D) \sin \phi_3 / \mathcal{R}_{DK}$$

Our result of A_{DK} is also the most precise.

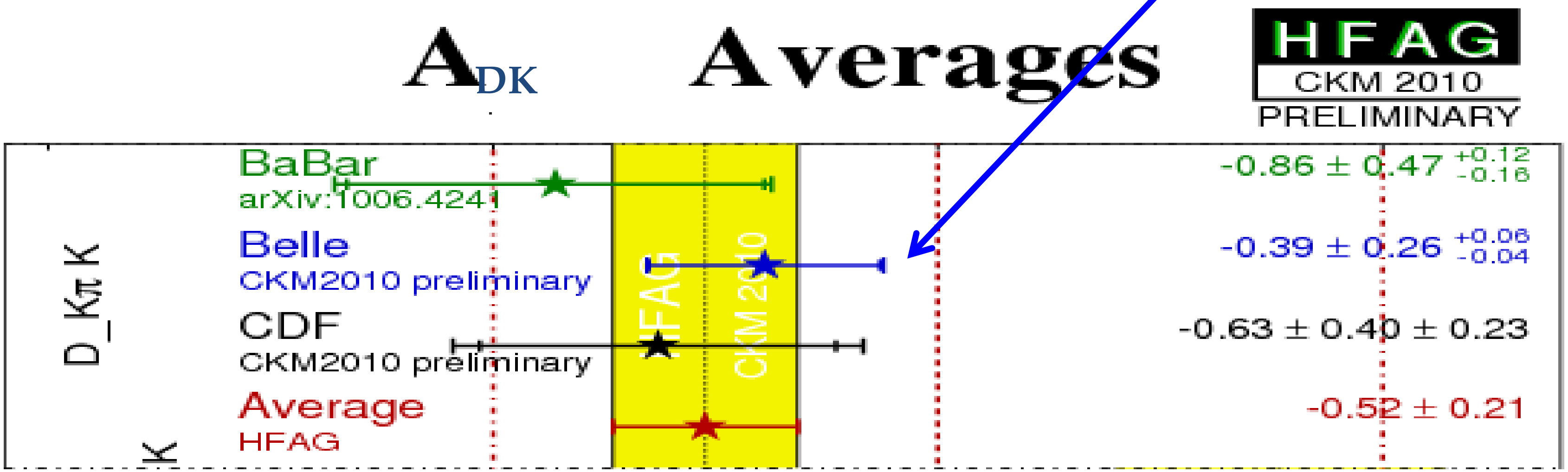
The ϕ_3 can be extracted from the simultaneous fit using R_{DK}, A_{DK}, and other observables for $B^- \rightarrow D_{CP} K^-$

Submit to PRL soon

Compared with previous results



Our result is most precise.



Can we find CP Violation in D decays?

- Searches for direct CP violation performed in total over 30 D^0, D^+ and D_s^+ decay modes in past 15 years
  - $\hookrightarrow$ Belle, BaBar, Cleo, CDF, FOCUS, E796, E687
- No evidence for CP violation found so far
  - $\hookrightarrow$ Sensitivity is in some cases reaching 0.2%
- Measurements statistical limited
  - $\hookrightarrow$ All measurements can be significantly improved!

$D^0 \to$	A_{CP} [%]	$D^+ \to$	A_{CP} [%]	$D_s^+ \to$	A_{CP} [%]
K^+K^-	-0.16 ± 0.23	$K_S^0\pi^+$	-0.72 ± 0.26	$K_S^0K^+$	-0.28 ± 0.41
$\pi^+\pi^-$	$+0.22 \pm 0.37$	$K_S^0K^+$	-0.09 ± 0.63	$K_S^0\pi^+$	$+6.5 \pm 2.5$
$\pi^+\pi^-\pi^0$	-0.23 ± 0.42	$K^+K^-\pi^+$	$+0.39 \pm 0.61$	$K^+K^-\pi^+$	$+0.3 \pm 1.4$
$K^-\pi^+\pi^0$	$+0.16 \pm 0.89$	$K^-\pi^+\pi^+$	-0.5 ± 1.0	$\pi^+\pi^-\pi^+$	$+2.0 \pm 4.7$
$K_S^0\pi^0$	$+0.10 \pm 1.3$	$K^-\pi^+\pi^+$	-0.5 ± 1.0	$K^+\pi^-\pi^+$	$+11.2 \pm 7.1$
$K^+K^-\pi^0$	$+1.00 \pm 1.7$	$K_S^0\pi^+\pi^0$	$+0.3 \pm 0.9$	$\pi^+\eta$	-8.2 ± 5.3
$\pi^0\pi^0$	$+0.10 \pm 4.8$	$\pi^+\pi^-\pi^+$	-1.7 ± 4.2	$\pi^+\eta'$	-5.5 ± 3.9
$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$	$\vdots$

How?

Key is to distinguish possible *CPV* asymmetry from detector effects and production asymmetry in reconstructed asymmetry

$$A^{\rm reco} = \frac{N_D^{\rm reco} - N_{\overline{D}}^{\rm reco}}{N_D^{\rm reco} + N_{\overline{D}}^{\rm reco}}$$

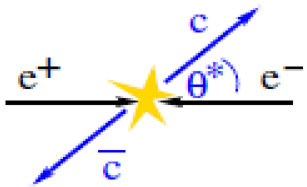
$$N_D^{\rm reco} = N_D^{\rm prod} \cdot \mathcal{B}(D \to f) \cdot \varepsilon_f \implies \text{if } A_i \ll 1 \implies \boxed{\mathbf{A}^{\rm reco} = \mathbf{A}_{\rm FB}^{\rm D} + \mathbf{A}_{\rm CP}^{\rm f} + \mathbf{A}_{\epsilon}^{\rm f}}$$

$\mathbf{A}_{\rm CP}$
CP asymmetry

independent of any kinematic variable

$\mathbf{A}_{\rm FB}$
Production asymmetry

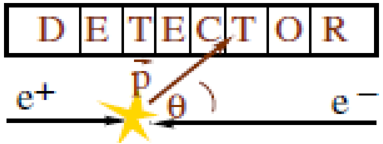
due to γ/Z interference in $e^+e^- \to c\overline{c}$ (only at e^+e^- coll.)



(anti-symmetric in $cos\theta_D^*$)

$\mathbf{A}_{\epsilon}^{\rm f}$
Reconstruction asymmetry

$h^{\pm}$ reconstruction efficiency asymmetry



$(p^{\rm lab},\ cos\theta^{\rm lab})$

In order to control systematics $\mathbf{A_i}$'s are estimated on real data sample!

Method

Developed methods for measuring recon. asym. of $\pi^{\pm}_{\rm slow}$, $\pi^{\pm}$ and $K^{\pm}$

- $\pi^{+}_{\rm slow}$ from $D^{*+} \to D^0\pi^+$ decays
  $\hookrightarrow$ Using tagged and untagged samples of $D^0 \to K^-\pi^+$ decays
  $$A^{\pi_{\rm slow}}(p_{\pi_{\rm slow}}, cos\theta_{\pi_{\rm slow}}) \approx (+0.14 \pm 0.07)\%$$
- $\pi^{\pm}$

  charge of slow pion gives flavour of D0

  $\hookrightarrow$ Using $D_s^+ \to \phi\pi^+$ decays
  $$[A_{FB} + A^{\pi}](cos\theta^*_D, p_\pi, cos\theta_\pi) \approx (-0.3 \pm 0.2)\%$$
- $K^{\pm}$
  $\hookrightarrow$ Using $D_s^+ \to \phi\pi^+$ and $D^0 \to K^-\pi^+$ decays
  $$A^K(p_K, cos\theta_K) \approx (-0.4 \pm 0.2)\%$$

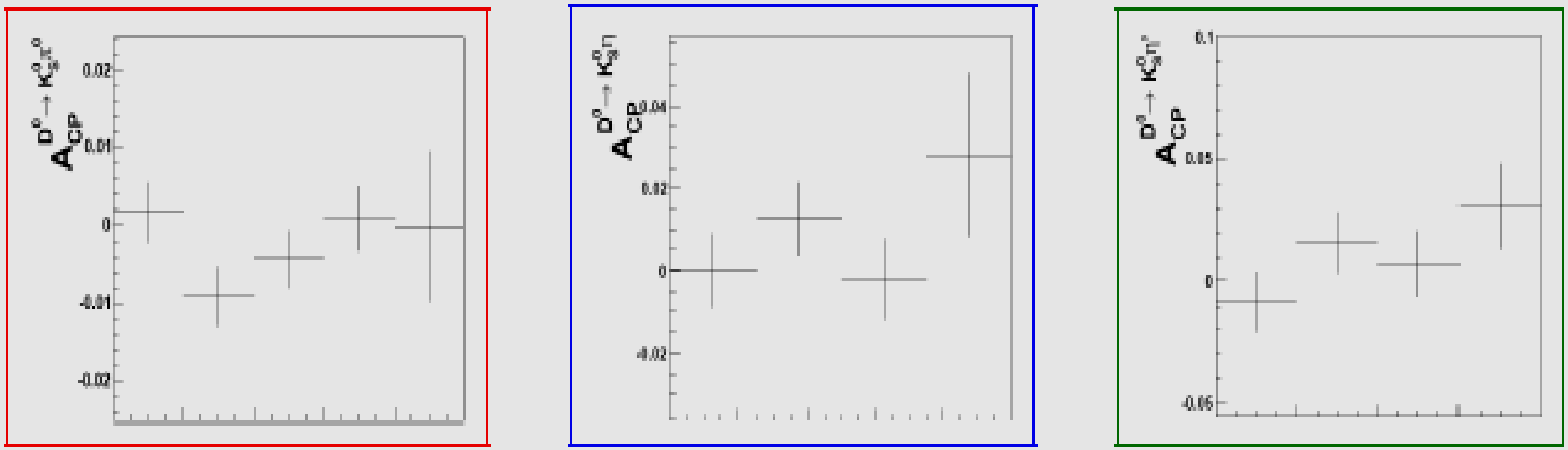
Need to make assumptions:

1. No CP violation in Cabbibo favored decays
2. Forward-backward asymmetry the same for all charm meson species

#4 A_{CP} of $D^0 \to K_s^0 P^0 (P^0 = \pi^0, \eta, \eta')$

791fb^{-1}
arXiv:1102.0888
Submitted to PRL

- A_{CP} in $D^0 \to K_S^0 \pi^0$, $D^0 \to K_S^0 \eta (\star)$ and $D^0 \to K_S^0 \eta' (\star)$ $\star$ – first measurement



$A_{CP} = (-0.28 \pm 0.19 \pm 0.10)\%$ $(+0.54 \pm 0.51 \pm 0.13)\%$ $(+0.90 \pm 0.67 \pm 0.15)\%$

#4 A_{CP} of $D^0 \rightarrow K_s^0(\pi^0, \eta, \eta')$

Decay	Lumi	A_{CP} [%]
$D^+ \rightarrow \eta\pi^+$	955 fb^{-1}	$+1.62 \pm 1.14 \pm 0.15$
$D^+ \rightarrow \eta'\pi^+$	955 fb^{-1}	$-0.12 \pm 1.13 \pm 0.18$
$D^+ \rightarrow \varphi\pi^+$	955 fb^{-1}	$+0.51 \pm 0.28 \pm 0.05$
$D^0 \rightarrow K_s\pi^0$	790 fb^{-1}	$-0.28 \pm 0.19 \pm 0.10$
$D^0 \rightarrow K_s\eta$	790 fb^{-1}	$+0.54 \pm 0.51 \pm 0.16$
$D^0 \rightarrow K_s\eta'$	790 fb^{-1}	$+0.98 \pm 0.67 \pm 0.14$
$D^+ \rightarrow K_s\pi^+$	673 fb^{-1}	$-0.71 \pm 0.19 \pm 0.20$
$D_s^+ \rightarrow K_s\pi^+$	673 fb^{-1}	$+5.45 \pm 2.50 \pm 0.33$
$D^+ \rightarrow K_sK^+$	673 fb^{-1}	$-0.16 \pm 0.58 \pm 0.25$
$D_s^+ \rightarrow K_sK^+$	673 fb^{-1}	$+0.12 \pm 0.36 \pm 0.22$
$D^0 \rightarrow K^+K^-$	540 fb^{-1}	$-0.43 \pm 0.30 \pm 0.11$
$D^0 \rightarrow \pi^+\pi^-$	540 fb^{-1}	$+0.43 \pm 0.52 \pm 0.12$

Most sensitive CP measurement in charmed particle sector (up to date)

First measurement

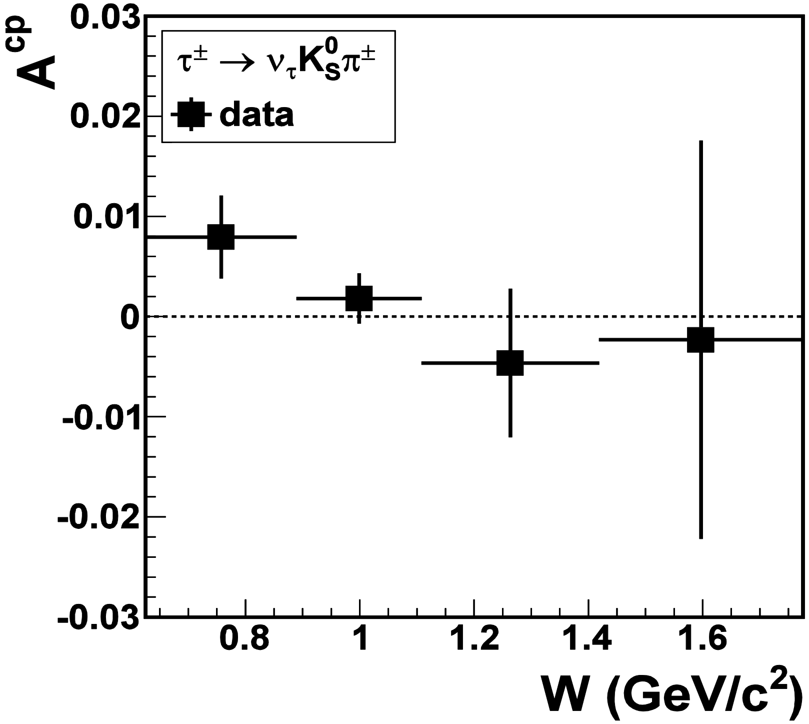
Results:

1. **Consistent with the SM**
2. **Most stringent constraints**

Can we find **CP violation in τ^- decays?**

- CP violation has only been observed **in meson system**. How about in the **leptonic sector**?
- Its discovery would be clear evidence for **New Physics (NP)!**
- Previously published paper is by **CLEO** collaboration, **13.3fb^{-1}**.

CP violation results in $\tau^- \rightarrow K_s \pi^- \nu_\tau$

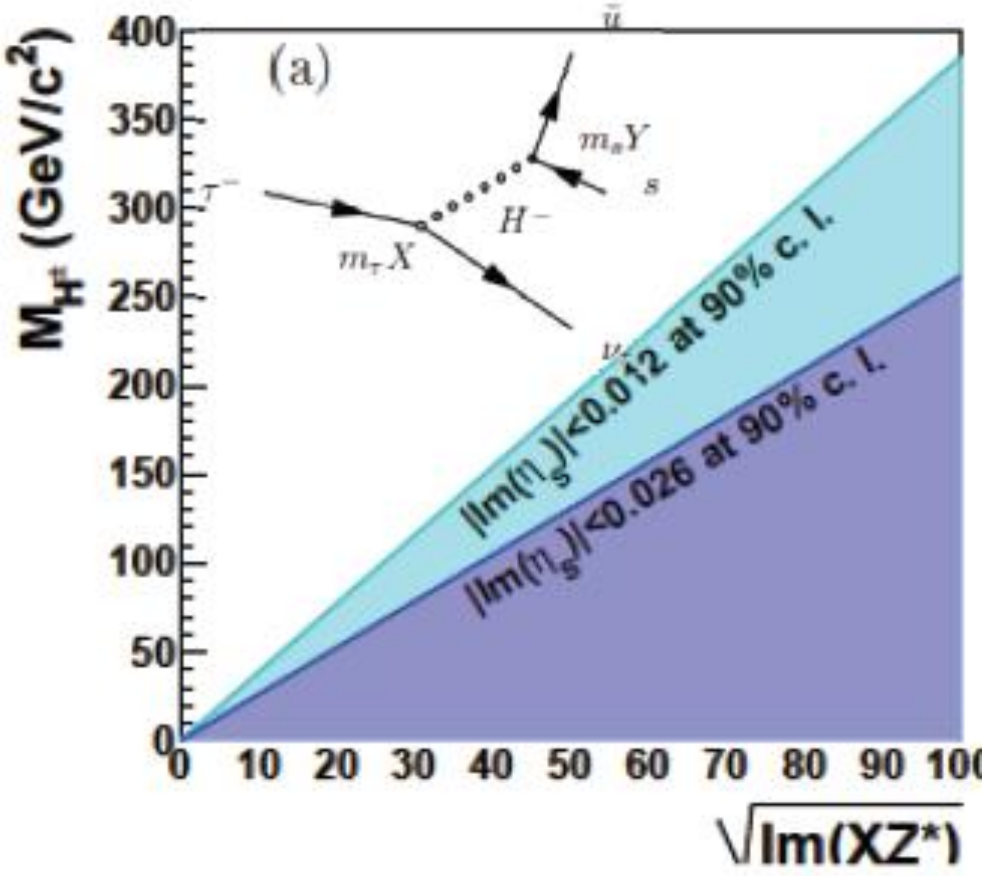


$699 fb^{-1}$ arXiv:1101.0349
submitted to PRL

Results:

1. **No significant CP asymmetry has been observed.**
2. **$|Im(\eta_s)| < (0.012\text{-}0.026)$ at 90 %C.L.**
3. **One order of magnitude more restrictive than the previous CLEO results $|Im\ \eta_s| < 0.19$**

Results in $\tau^- \to K_s \pi^- \nu_\tau$: set M_H limit



- $|Im(\eta_s)| < (0.012\text{-}0.026)$ at 90 %C.L.
- = Limits for multi Higgs Doublet Model
- X, Z: complex coupling for Higgs
- M_H: lightest charged Higgs mass

Summary

- Updated results using exclusive decays:

$B^0 \to \pi^- l^+ \nu$

$$\mathcal{B} = (1.49 \pm 0.04(\text{stat}) \pm 0.07(\text{syst})) \times 10^{-4}$$

$$|V_{ub}| = (3.43 \pm 0.33) \times 10^{-3}$$

$B \to D^* l^+ \nu$

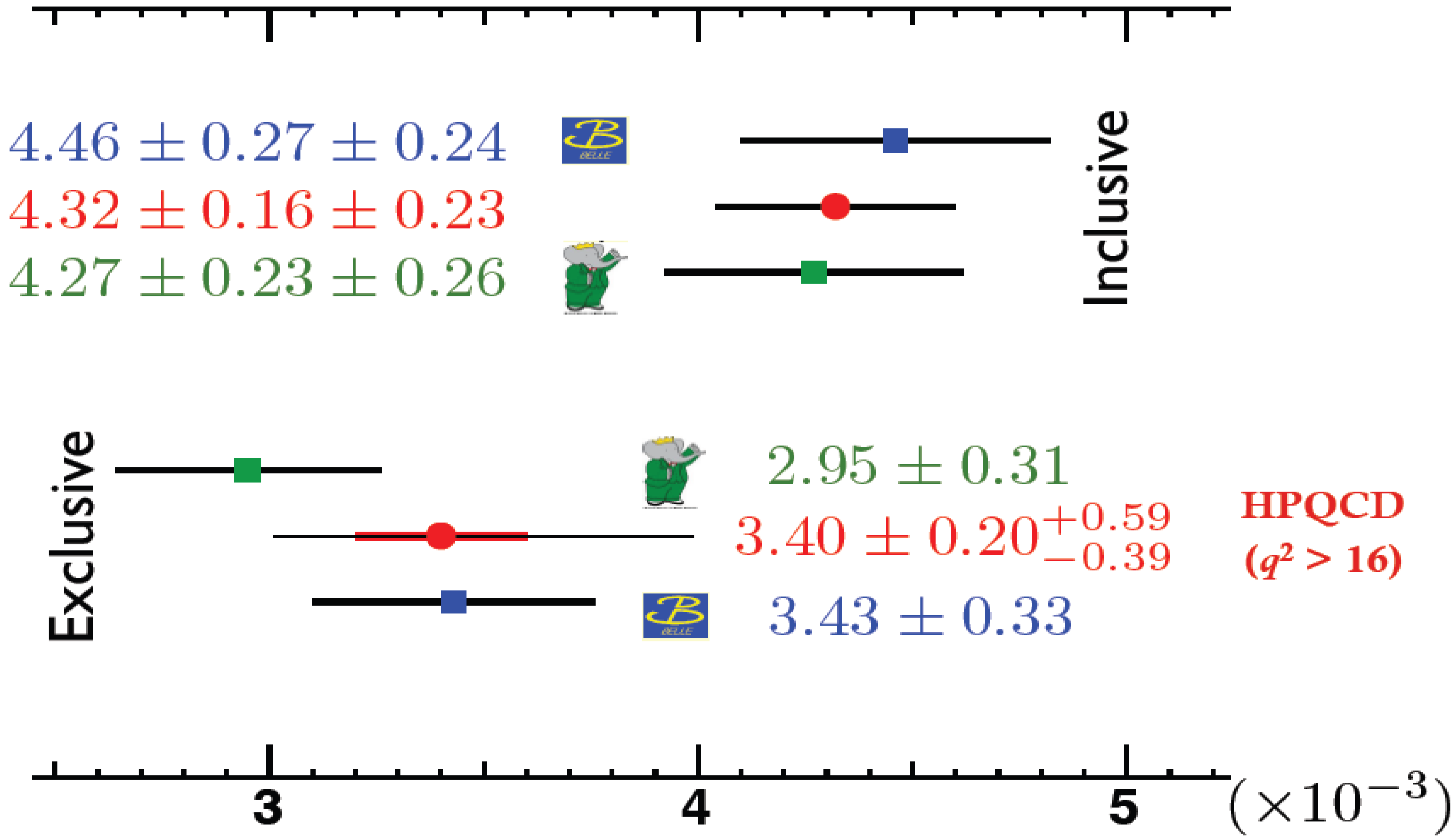
	$B^+ \to \bar{D}^{*0} \ell \nu$	$B^0 \to D^{*-} \ell \nu$
$\mathcal{B}(B \to D^* \ell \nu)$	$(4.84 \pm 0.04 \pm 0.56)\%$	$(4.56 \pm 0.03 \pm 0.26)\%$
$\mathcal{F}(1)\|V_{cb}\| \times 10^3$	$35.0 \pm 0.4 \pm 2.2$	$34.5 \pm 0.2 \pm 1.0$

Summary

- **First Evidence (4.1σ) for the Suppressed Decay**: **$B^- \rightarrow DK^-$ with $D \rightarrow K^+\pi^-$. We obtain the most precise R_{DK} and A_{DK} value.** The ϕ_3 can be extracted later.
- New Physics not found:
  - **A_{CP} of $D^0 \rightarrow K_s^0 P^0 (P^0 = \pi^0, \eta, \eta')$**
  - **CP violation in $\tau^- \rightarrow K_s \pi^- \nu_\tau$ decays**

Thank you~

$|V_{ub}|$ Summary



4.46 ± 0.27 ± 0.24
4.32 ± 0.16 ± 0.23
4.27 ± 0.23 ± 0.26
Inclusive
Exclusive
2.95 ± 0.31
3.40 ± 0.20 +0.59 −0.39
HPQCD
(q² > 16)
3.43 ± 0.33
3
4
5
(×10⁻³)

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- Cord Management
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#3 ϕ_3 using ADS method: $B^- \rightarrow DK^-$ with $D \rightarrow K^+\pi^-$

to be submitted to PRL

Model independent ϕ_3 from $B^- \rightarrow DK^-$, $D \rightarrow K_S\pi^+\pi^-$ Dalitz

Previous analysis using 605M BB has large Dalitz model syst.

$$\phi_3 = 78.4^{\circ}{}^{+10.8^{\circ}}_{-11.6^{\circ}} \pm 3.6^{\circ}(\mathrm{syst}) \pm 8.9^{\circ}(\mathrm{model})$$

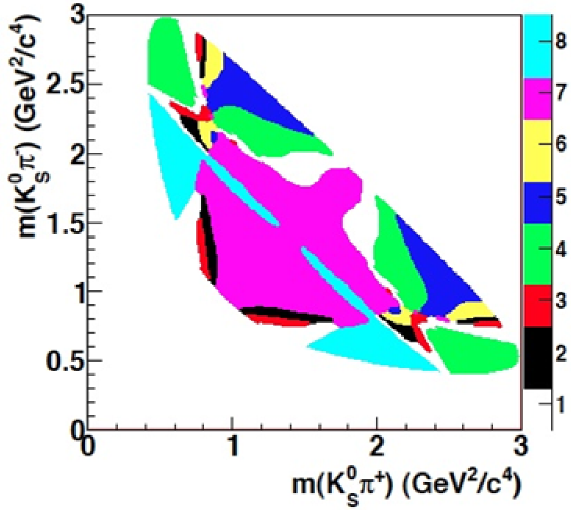
In current analysis

- full Belle data set is used (771M)
- more sophisticated 4D fit instead of 2D (inc. $\cos\theta_{thr}$ & cont. suppr. F)
- CLEO input parameters c_i & s_i are used to fit Dalitz plot:

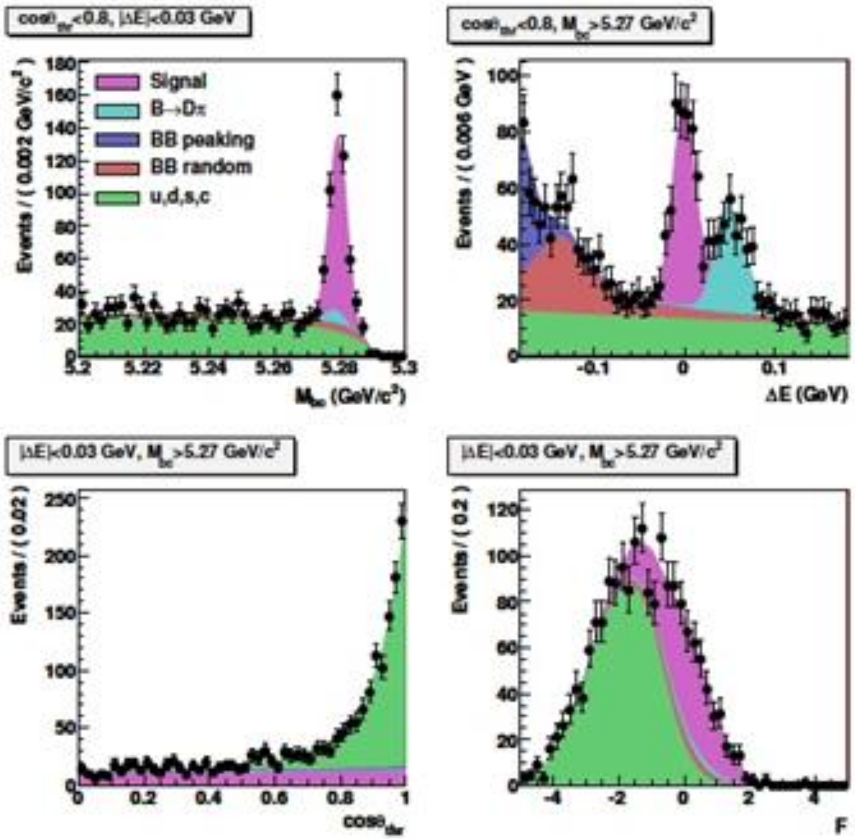
$$M_i^{\pm} = h\{K_i + r_B^2 K_{-i} + 2\sqrt{K_i K_{-i}}(x_{\pm}c_i + y_{\pm}s_i)\}$$

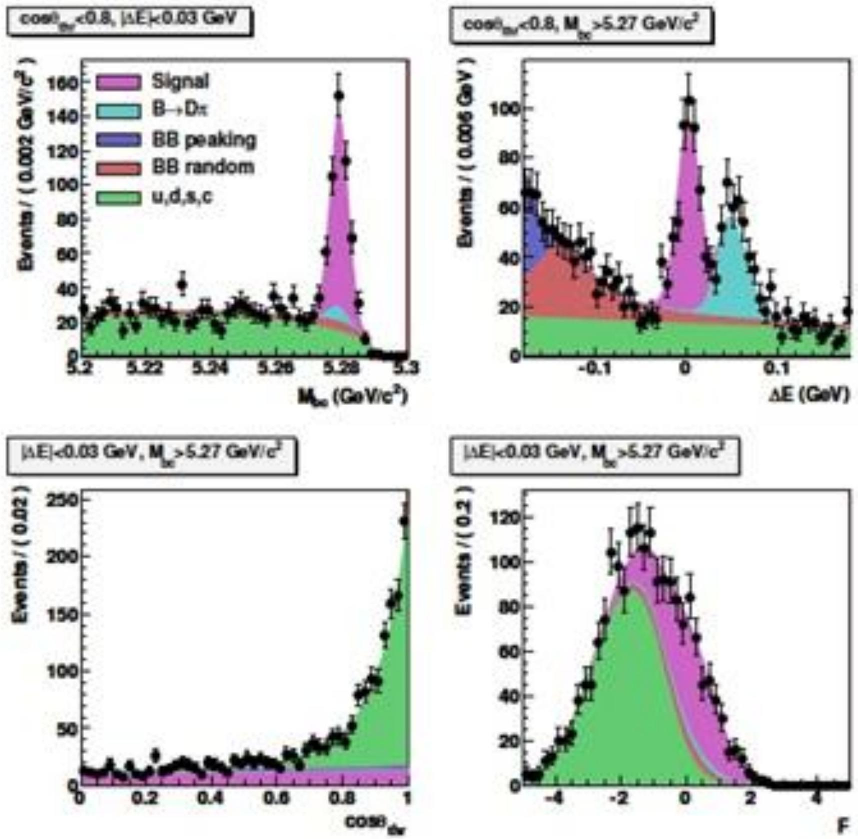
$$x_{\pm} = r_B \cos(\delta_B \pm \phi_3) \quad y_{\pm} = r_B \sin(\delta_B \pm \phi_3)$$

Dalitz plot binning is optimized for ϕ_3 measurement:
checked using control sample of $B \rightarrow D\pi$ that it gives additional ~10% improvement in x precision



#3 ϕ_3 using ADS method: Result





$B^- \to DK^-$

574.9 ± 29.9 events

$B^+ \to DK^+$

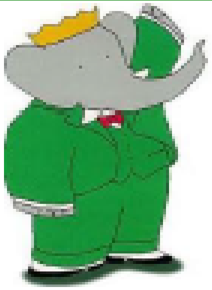
601.6 ± 30.8 events

Available charm samples

Diverse exp. conditions!

B-factories:

- continuum production @ $\Upsilon(4S)$: $\sigma(c\bar{c}) \approx 1.3$ nb
- Belle: $\sim 1.3 \cdot 10^9$ $c\bar{c}$ pairs
- Babar: $\sim 0.7 \cdot 10^9$ $c\bar{c}$ pairs

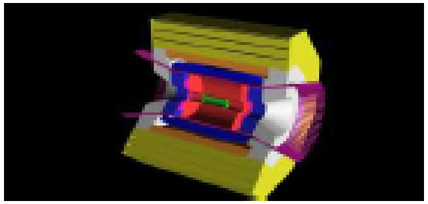


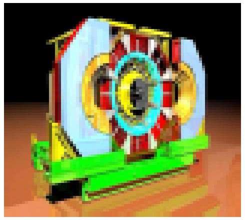
Tevatron:

- $p\bar{p}$ @ ~ 2 TeV
- CDF: $\sim 70 \cdot 10^9$ D^0's

Charm factories:

- $\psi(3770) \to D^0\overline{D^0}$, D^+D^-
- CLEO: $\sim 2.8 \cdot 10^6$ $D^0\overline{D}^0$ pairs
- BESIII: $\sim 3.4 \cdot 10^6$ $D^0\overline{D}^0$ pairs





LHC:

- pp @ 7 TeV
- LHCb: *has only started*

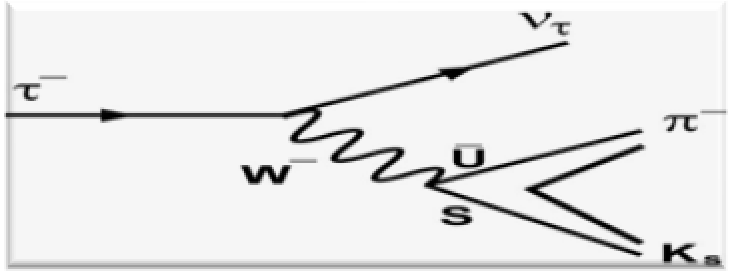
Two source of CP asymmetries in $\tau^- \rightarrow K_s \pi^- \nu_\tau$

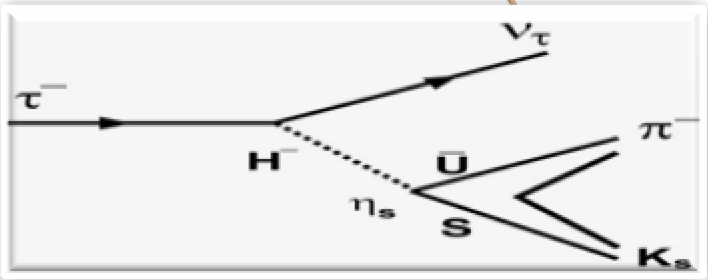
- CP Asymmetry from known physics (Bigi, Sanda . 2005)

$$\frac{\Gamma(\tau^+ \rightarrow Ks\pi^+\nu_\tau) - \Gamma(\tau^- \rightarrow Ks\pi^-\nu_\tau)}{\Gamma(\tau^+ \rightarrow Ks\pi^+\nu_\tau) + \Gamma(\tau^- \rightarrow Ks\pi^-\nu_\tau)} = 3.3 \times 10^{-3}$$

- CP Asymmetry in the final state distribution (Kuhn, Mirkes 1993).

Possible two Models: (1)general two Higgs doublet model (2HDM), (2)Multi-Higgs-Doublet Model (MHDM)





R_{DK}: ratio of the suppressed mode to the calibration mode

A_{DK}: CP asymmetry for the suppressed mode

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

Calibration mode

$$= r_B^2 + r_D^2 + 2 r_B r_D \cos(\delta_B + \delta_D) \cos\phi_3,$$

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

$$= 2 r_B r_D \sin(\delta_B + \delta_D) \sin\phi_3 / R_{DK}.$$

$[f]_D$: f originates from D.

$$r_B = \left| \frac{A(B^- \to \bar{D}^0 K^-)}{A(B^- \to D^0 K^-)} \right| \quad \delta_B = \delta(B^- \to \bar{D}^0 K^-) - \delta(B^- \to D^0 K^-)$$

$$r_D = \left| \frac{A(D^0 \to K^+\pi^-)}{A(\bar{D}^0 \to K^+\pi^-)} \right| \quad \delta_D = \delta(\bar{D}^0 \to K^+\pi^-) - \delta(D^0 \to K^+\pi^-)$$

Motivation

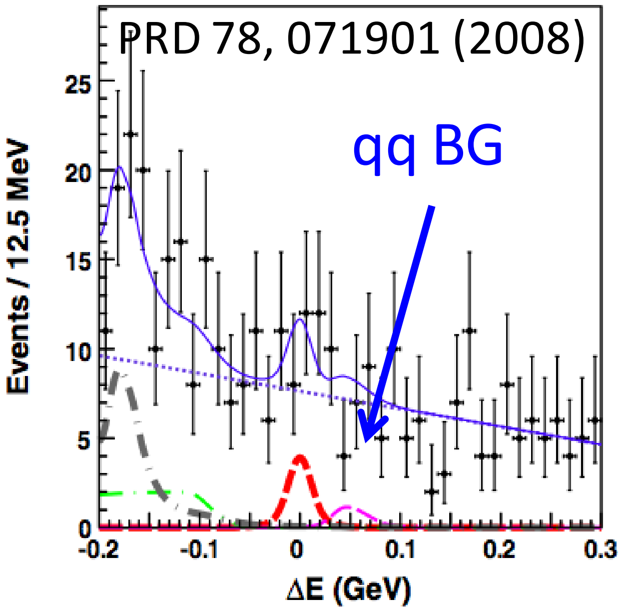
– Most precise measurement of ϕ_3 at Belle is obtained from the decay $B^- \to DK^-$, $D \to K_S\pi^+\pi^-$ as

$$\phi_3 = 78.4^\circ \ {}^{+10.8^\circ}_{-11.6^\circ} \pm 3.6^\circ(\mathrm{syst}) \underline{\pm 8.9^\circ(\mathrm{model})}$$

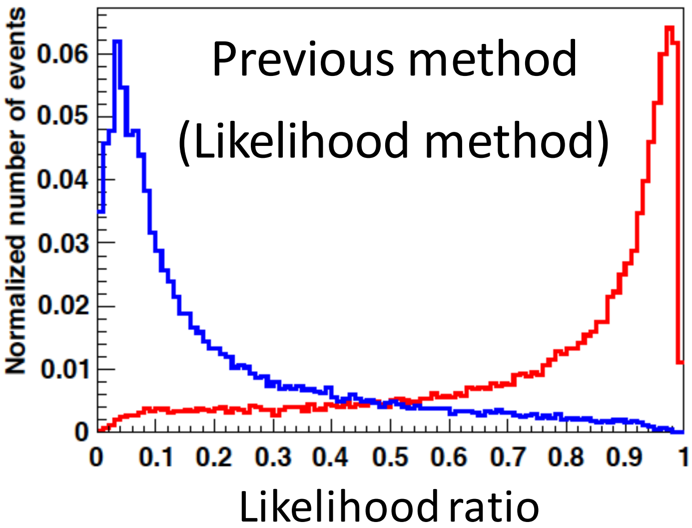
Nontrivial model uncertainties exist in the three-body D decay.

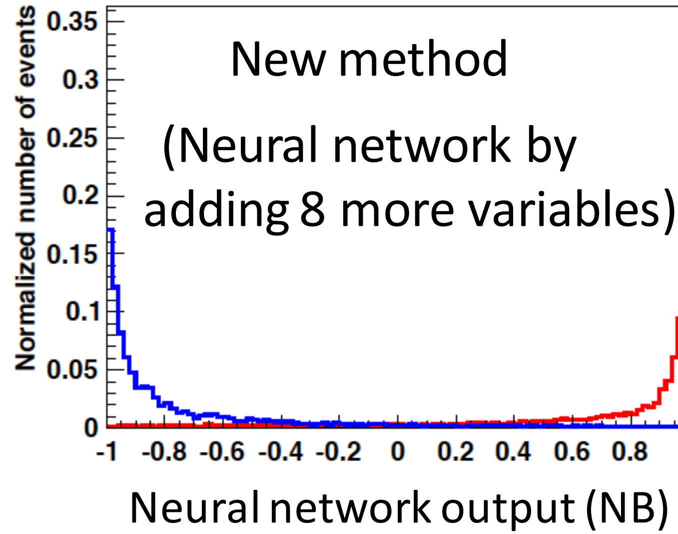
– One of model-independent method is "ADS" method, which employs $B^- \to DK^-$, $D \to K^+\pi^-$.

– No significant signal is obtained in the previous analysis, since BG from $e^+e^- \to qq$ (q=u,d,s,c) is large…



- We introduce new technique to discriminate the signal and qq BG:





- By applying a 2-D fit on ΔE and NB, we obtain the first evidence of the signal (4.1σ including syst).