Belleの最新の物理結果

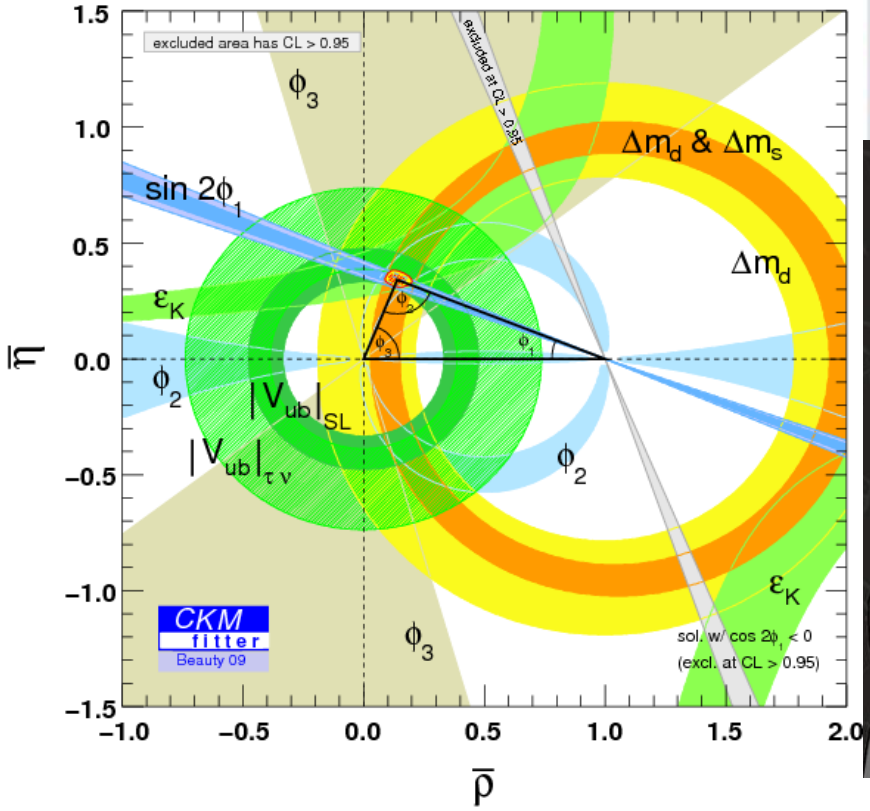
海野　祐士(Hanyang university)
Belle collaboration

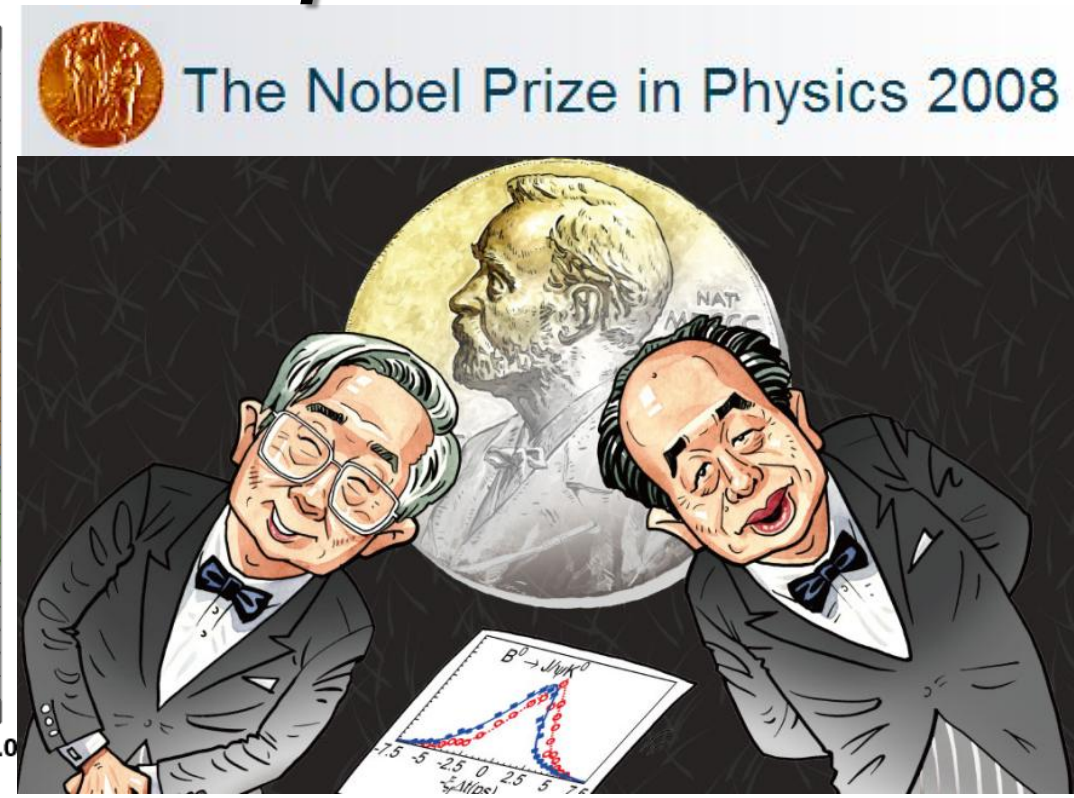
日本物理学会　第65回年次大会

2010年3月21日

Introduction

Belle results lead to Nobel prize to KM model



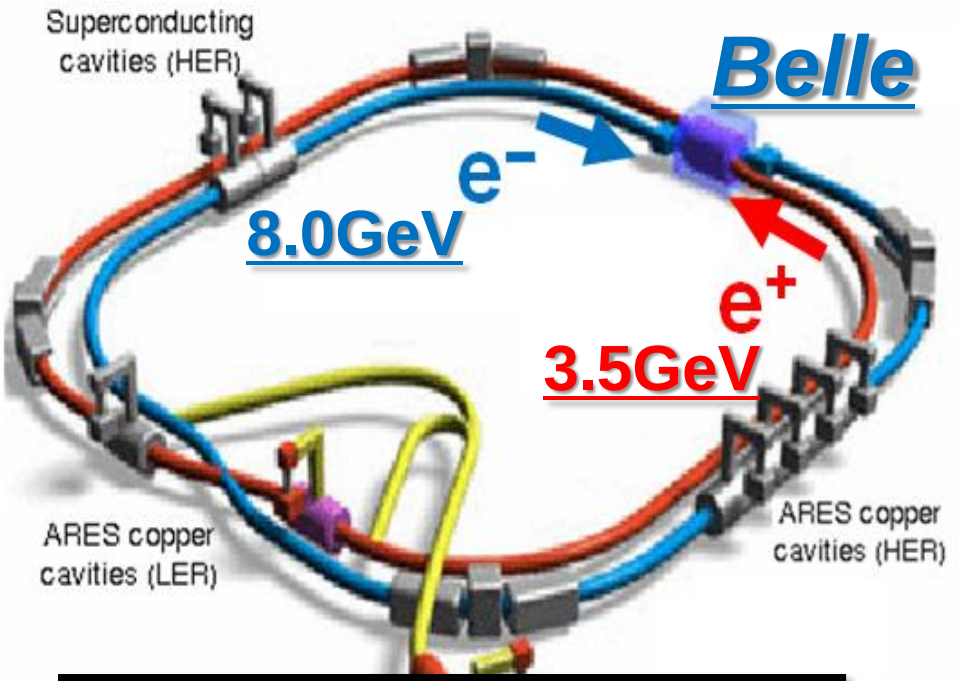


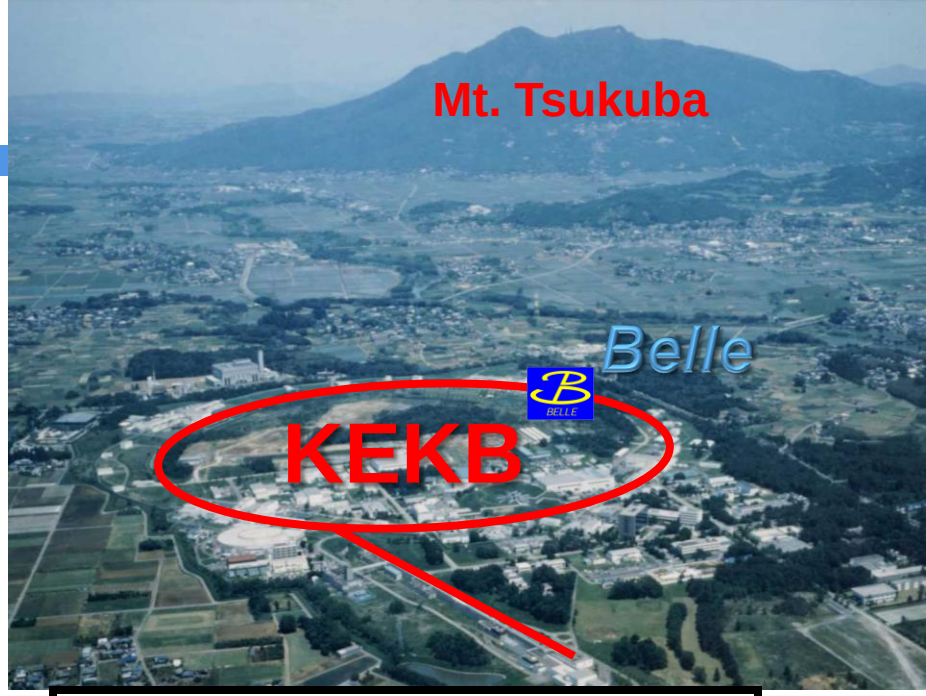
Extend and accelerate to search for new physics.
Many programs are running to find the effect of NP.

Outline

- Introduction
  - KEKB / Belle
- Constraints on NP
  - $B^+ \to D^{(*)0} \tau \nu$, $b \to s\gamma$, $b \to sll$,
  - $X(214)^0$, $D^0 \to l^+ l^-$
- Polarization puzzle in $B \to VV$
- Exploring B_s sector
  - $B_s \to D_s^* \pi/\rho$, $\Delta\Gamma_s/\Gamma_s$
- Summary

KEKB accelerator



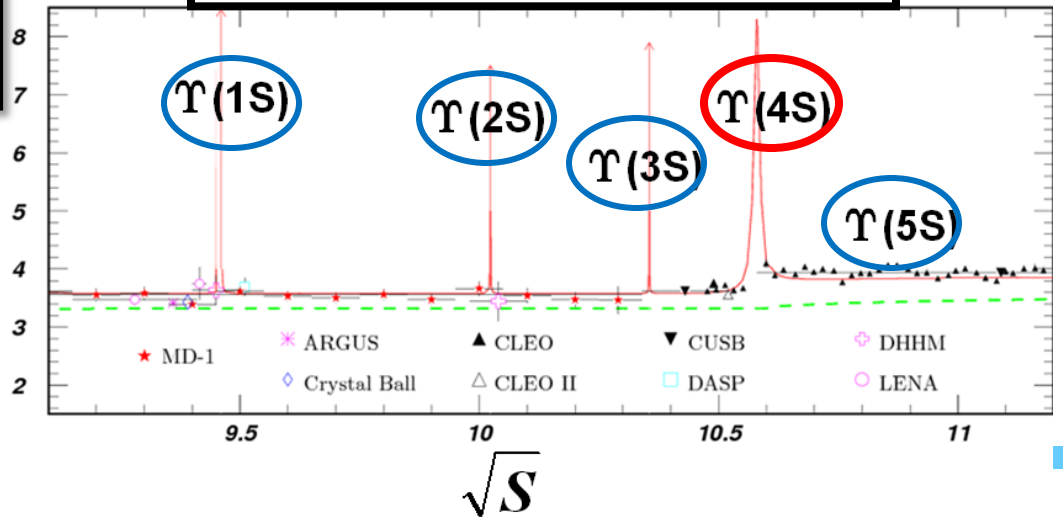


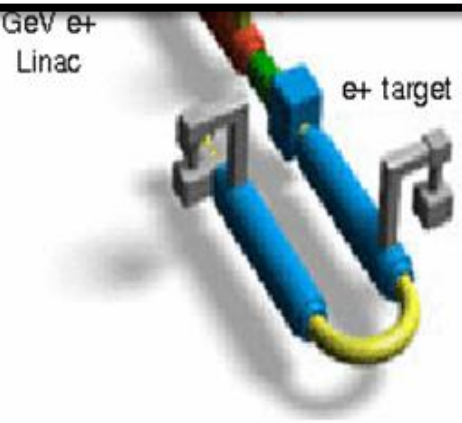
World record luminosity

$L_{peak} = 2.1 \times 10^{34}\ cm^{-2}s^{-1}$

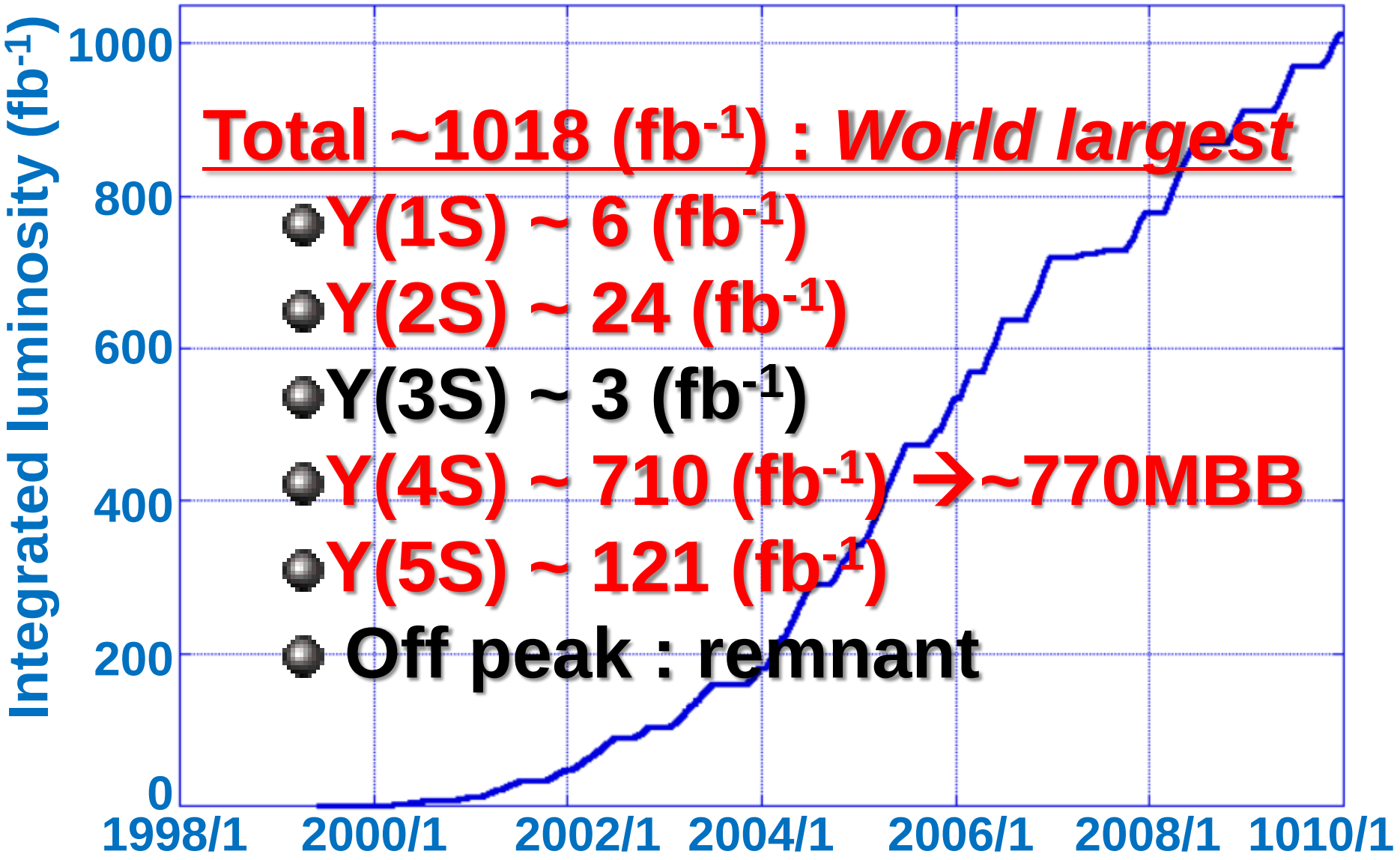
$$E_{CM} = 10.58\ GeV$$

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

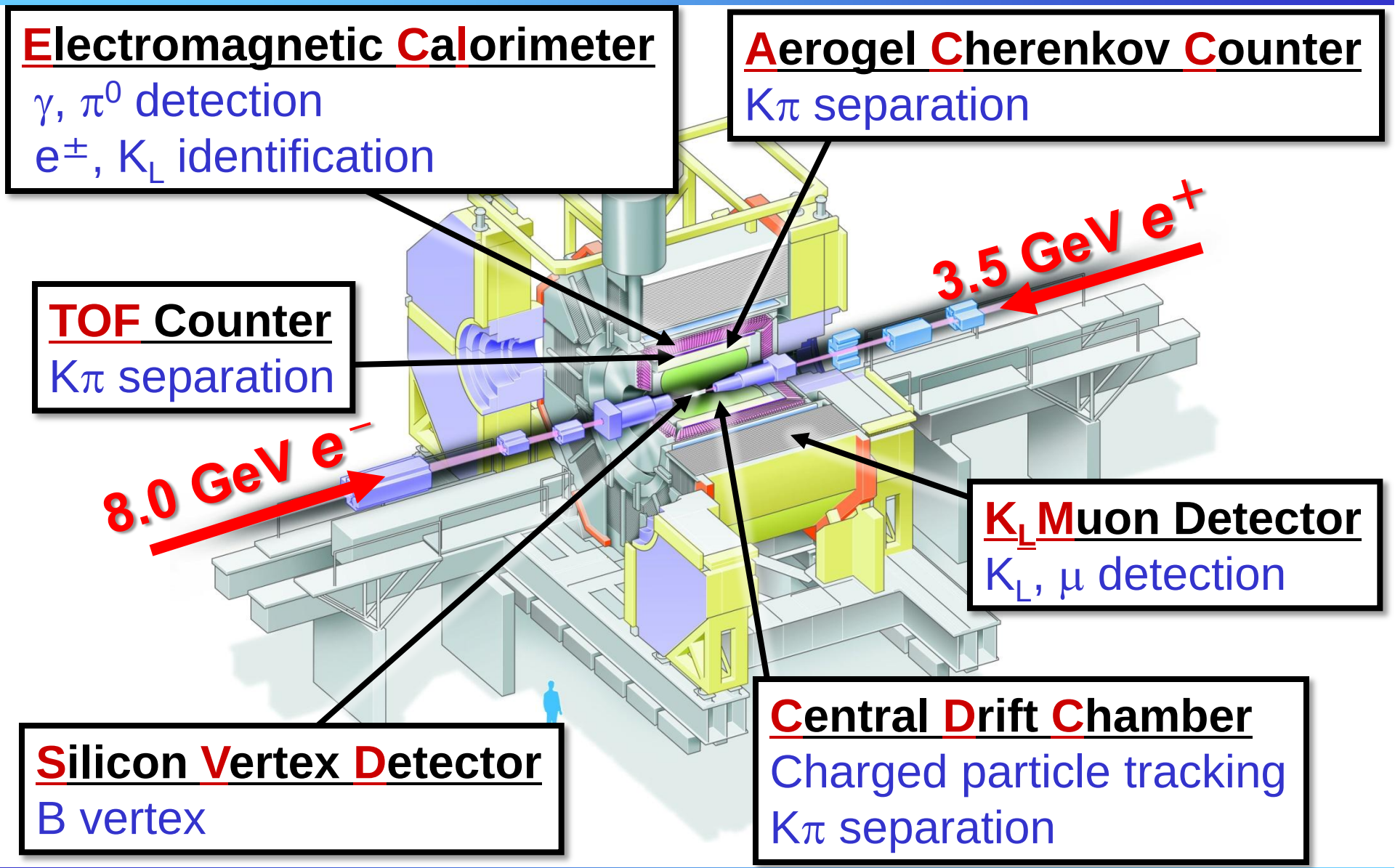




Integrated luminosity

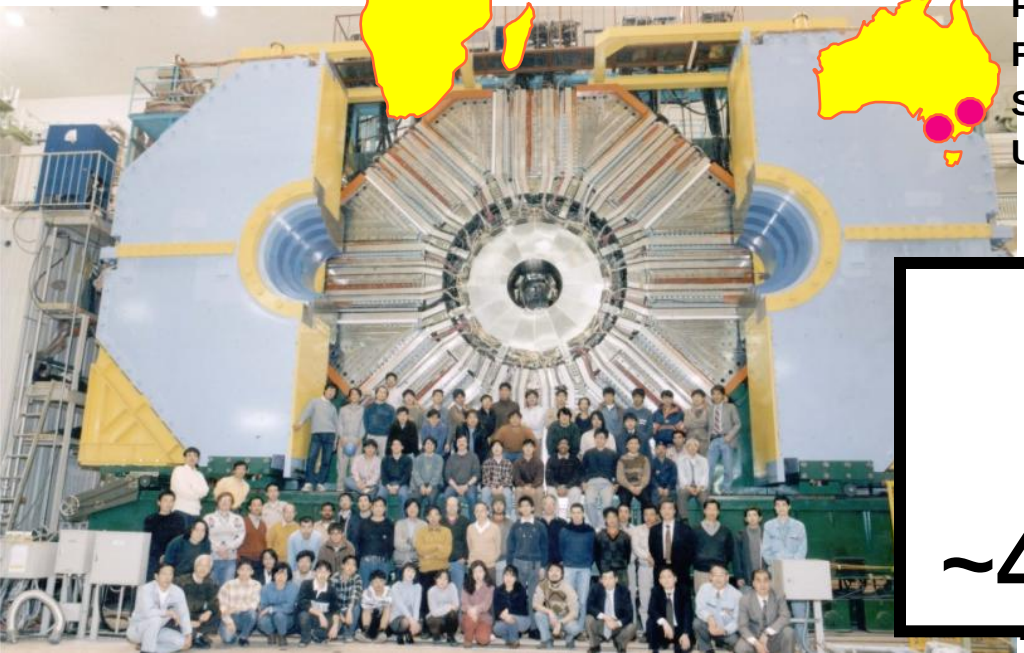


Belle detector



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
U. of Melbourne
Nagoya U.
Nara Women's U.
National Central U.
National Taiwan U.
National United U.
Nihon Dental College
Niigata U.
Nova Gorica
Osaka U.
Osaka City U.
Panjab U.
Peking U.
Princeton U.
Riken
Saga U.
USTC
Seoul National U.
Shinshu U.
Sungkyunkwan U.
U. of Sydney
Tata Institute
Toho U.
Tohoku U.
Tohuku Gakuin U.
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.



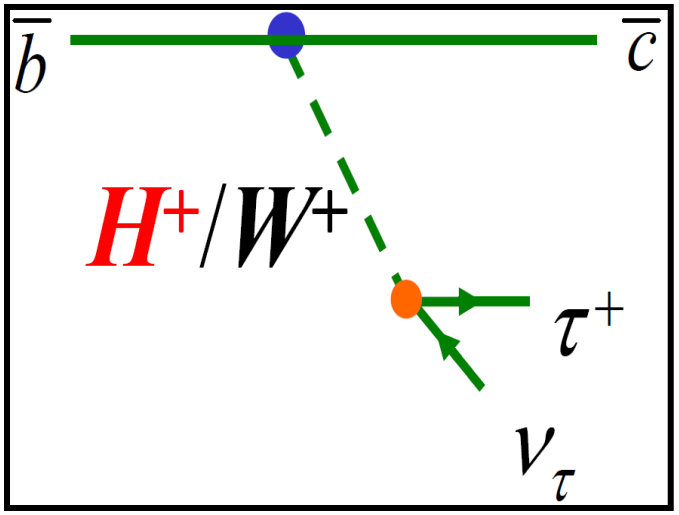
15 countries
62 institutes
~400 collaborators

Outline

- Introduction
  - KEKB / Belle
- **Constraints on NP**
  - **$B^+ \to D^{(*)0} \tau \nu$, $b \to s\gamma$, $b \to sll$,**
  - **$X(214)^0$, $D^0 \to l^+ l^-$**
- Polarization puzzle in $B \to VV$
- Exploring B_s sector
  - $B_s \to D_s^* \pi/\rho$, $\Delta\Gamma_s/\Gamma_s$
- Summary

$B^+ \to \bar{D}^{(*)0} \tau\nu$ (657MBB)

- **$B \to D^{(*)}\tau\nu$ is sensitive to H^+**
  - $Br = G_F^2 \tau_B |V_{cb}|^2 f(F_v, F_s, g_s)$
    - Fv : vector form factor
    - Fs : scalar form factor
    - 2HDM : $g_s = (m_B/m_H)^2 \tan^2\beta$
  - $R = Br(B \to D\tau\nu) / Br(B \to Dl\nu)$
    - $|V_{cb}|$ cancels out
    - Form factor uncertainties can be reduced



- **Br in SM (e.g. JHEP 0610,053)**
  - $Br(B \to D\tau\nu)$ ~0.7%
  - $Br(B \to D^*\tau\nu)$ ~1.4%
- **N(ν)≥2 makes measurements challenging**

$B^+ \to \bar{D}^{(*)0} \tau \nu$ (657MBB)

Preliminary

Inclusive reconstruction of B_{tag}

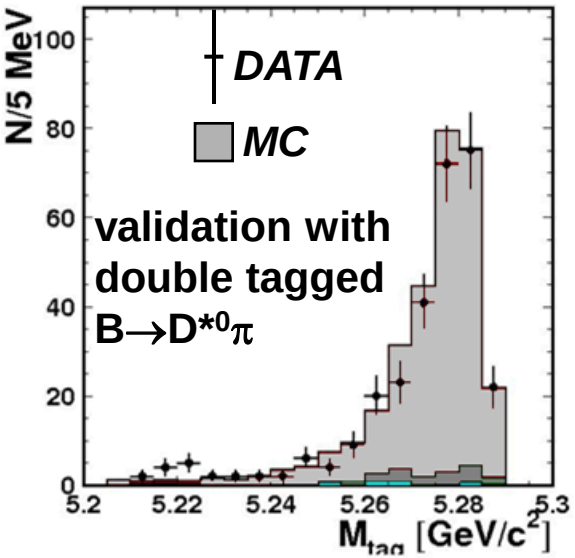
(1)Reconstruct signal candidate:

- $D^0 \to K\pi$, $K\pi\pi$,
- $D^{*0} \to D^0\pi$, $D^0\gamma$
- $\tau \to e\nu\nu$, $\mu\nu\nu$, $\pi\nu$

(2)Reconstruct B_{tag} from remaining tracks

$$M_{tag} = \sqrt{E_{beam}^2 - (\sum \vec{p}_i)^2}$$

tag-side B-mass

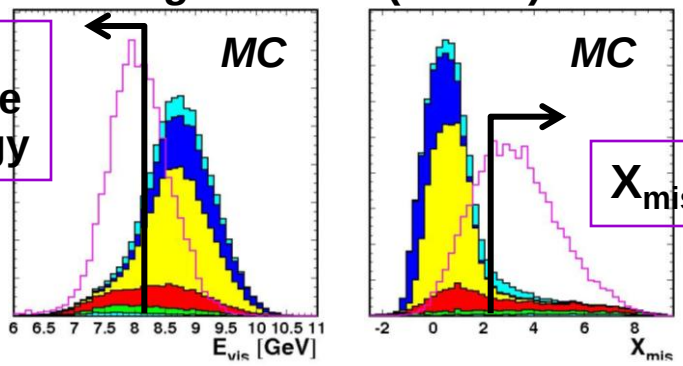


(3)Suppress background

- signal
- $B \to D^{**} l\nu$
- $B \to D\, l\nu$
- $B \to D^*\, l\nu$
- other B dec.
- continuum

e.g. $B^+ \to D^0\tau^+(\to e^+\nu\nu)\nu$

E_{vis} visible energy

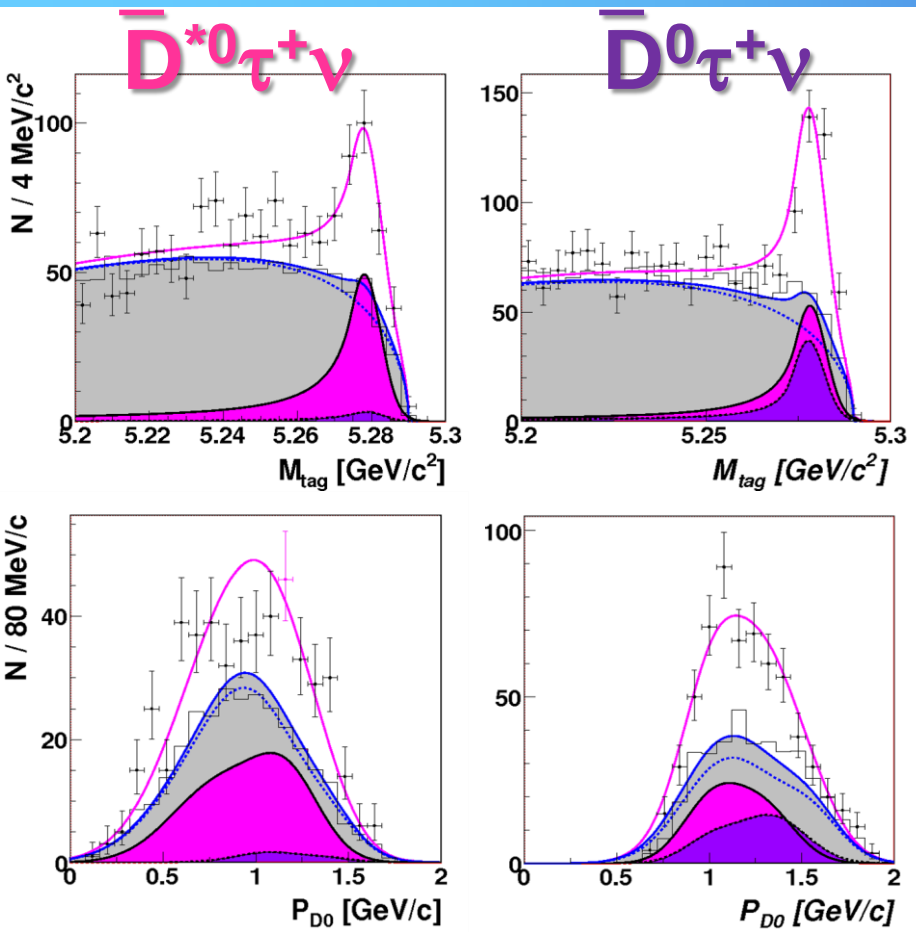


$X_{mis} = [(E_{beam}\text{-}E_{sig}) - |p_{sig}|] / |p_B|$

(4) Signal extraction by fit on M_{tag} and $p^*(D^0)$ from signal side

$B^+ \to \bar{D}^{(*)0}\tau\nu$ (657MBB)

Preliminary



$$N(\bar{D}^{*0}\tau^+\nu_\tau) = 446^{+58}_{-56} \quad 8.1\sigma$$

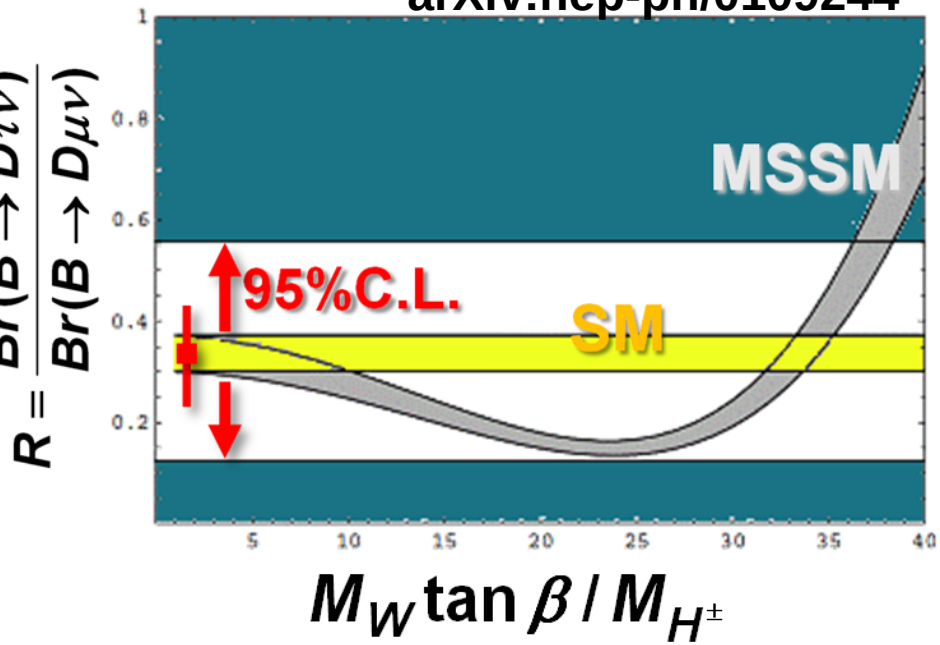
$$Br(\bar{D}^{*0}\tau^+\nu) = (2.12^{+0.28}_{-0.27} \pm 0.29)\%$$

$$N(\bar{D}^{0}\tau^+\nu) = 146^{+42}_{-41} \quad 3.5\sigma$$

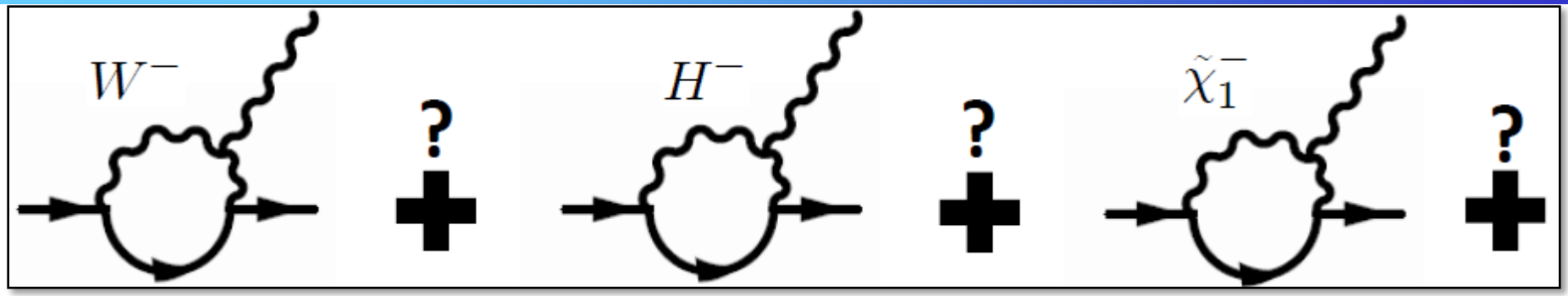
$$Br(\bar{D}^{0}\tau^+\nu) = (0.77 \pm 0.22 \pm 0.12)\%$$

First evidence

arXiv:hep-ph/0109244

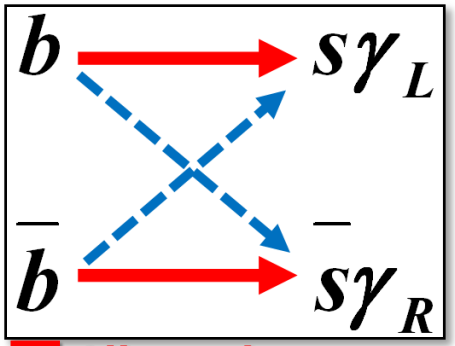


$b \to s\gamma$



- $b \to s\gamma$ proceed via FCNC process
  - New particle may change Br dramatically
  - Most powerful tool to constrain new physics

- Search for right-handed currents



Allowed

Suppressed by m_s / m_b

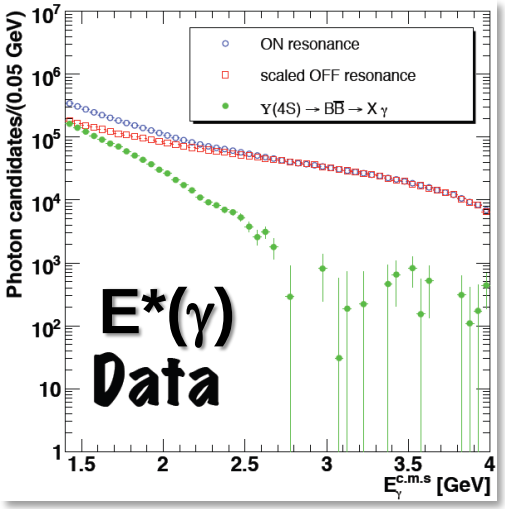
- In SM, photon is (almost) left-handed.
  - mixing-induced CPV is very small.
- Large CPV would be an evidence of NP.

Inclusive $B \rightarrow X_s\gamma$ (657MBB)

PRL 103, 241801(2009)

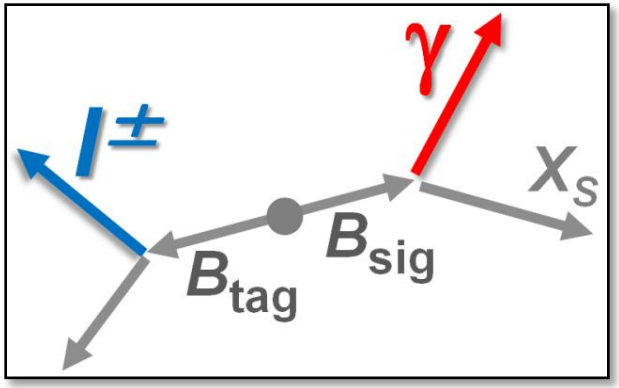
Untagged method

(On reso.) − α(off reso.) = B→Xγ

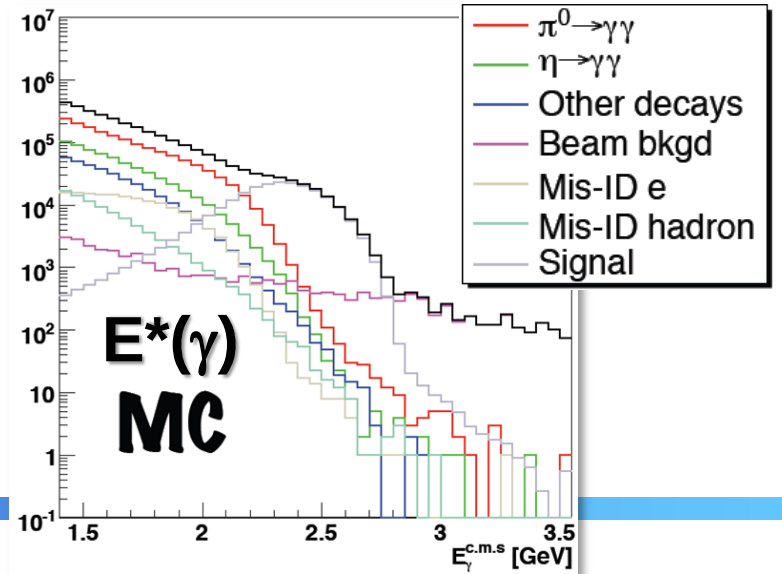


Lepton tag method

- Tag semi-leptonic B decay
- p*($l^{\pm}$) = 1.26 - 2.20GeV/c
- qq bkg is well-suppressed.

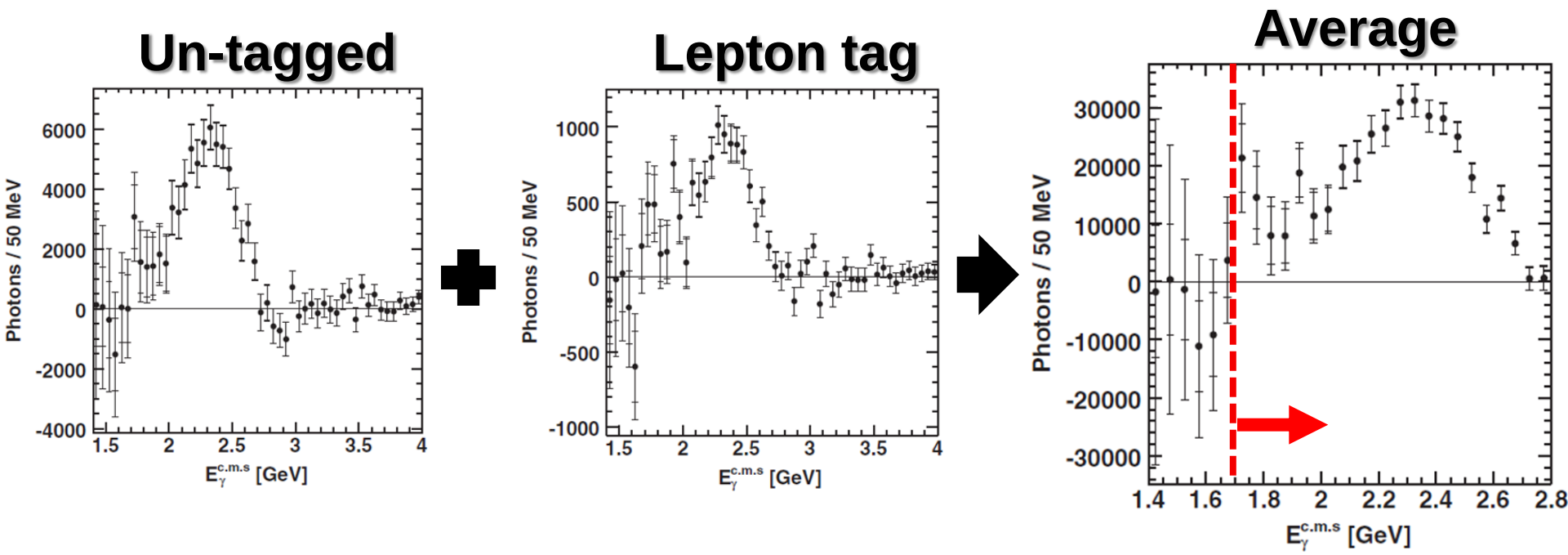


Background from B decay is subtracted by MC calibrated by control samples.



Inclusive $B \to X_s\gamma$ (657MBB)

PRL 103, 241801(2009)



$$1.7\ \text{GeV} < E\gamma < 2.8\ \text{GeV}$$

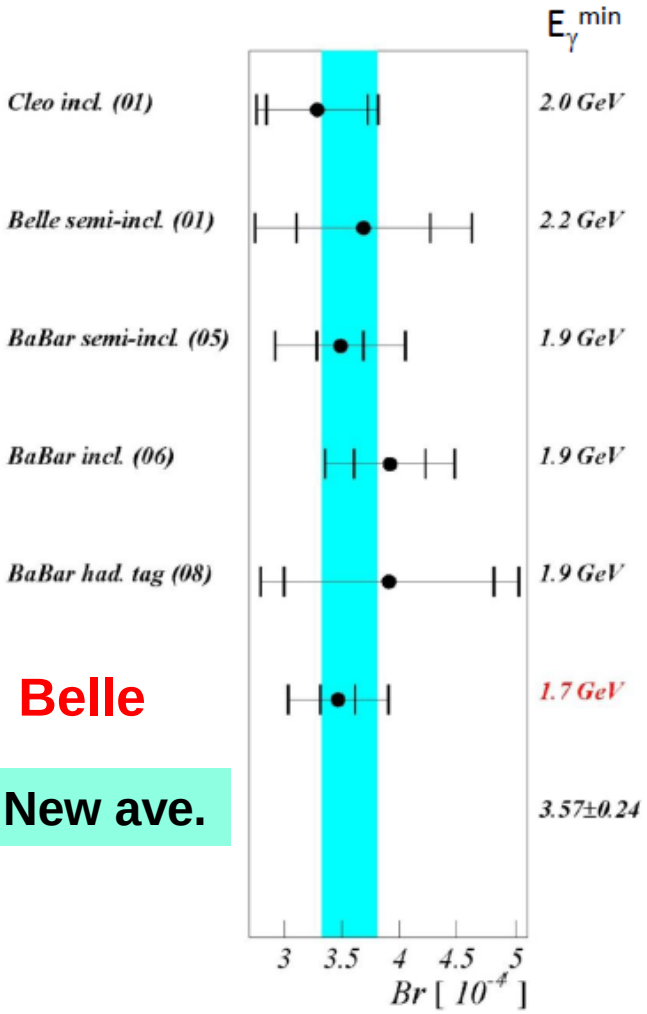
$$\text{Br}(B \to X_s\gamma) = (3.45 \pm 0.15 \pm 0.40) \times 10^{-4}$$

Consistent with NNLO SM calculation

$E\gamma > 1.6$GeV [PRL98, 022022(2007)]

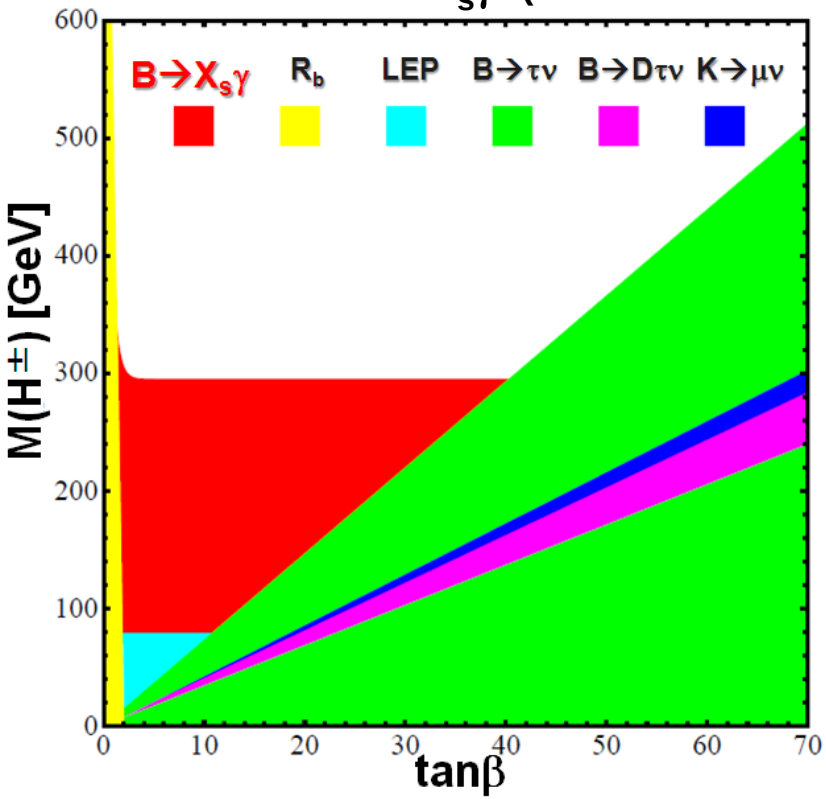
$\text{Br}(B \to X_s\gamma) = (3.15 \pm 0.23) \times 10^{-4}$

Inclusive $B \to X_s\gamma$ (constraints on NP)



New ave. = (3.57±0.24)x10^{-4}

Constraints on type-II 2HDM using new ave. of $B \to X_s\gamma$ (arXiv:0805.2141v2)

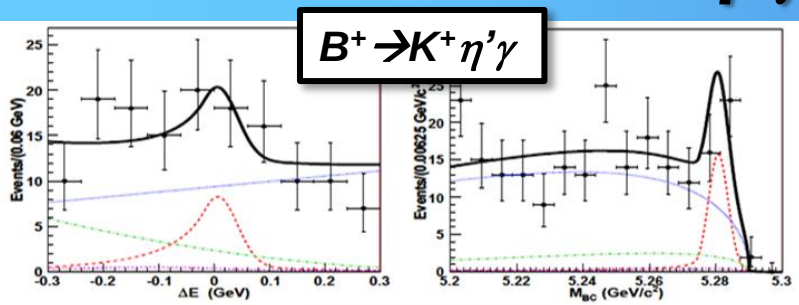


$M(H^\pm)$>295GeV @95%C.L.

Competitive with direct search at hadron collider

Exlusive $B \to K\eta'\gamma$, $B \to K\phi\gamma$

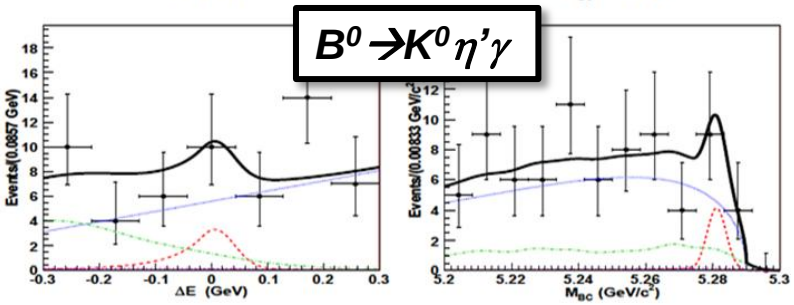
arXiv:0810.0804(submitted to PRD)
arXiv:0911.1779(Preliminary)



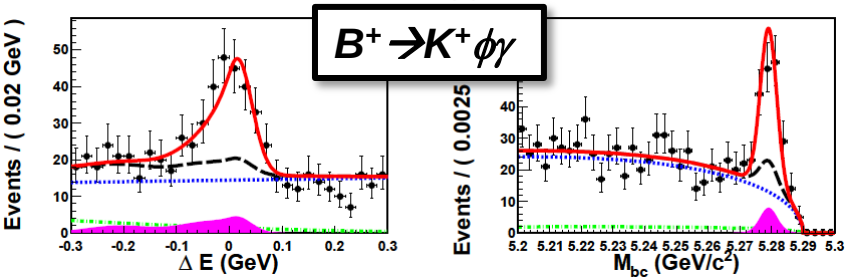
$B \to K\eta'\gamma$ (657MBB)

$Br(B^+ \to K^+\eta'\gamma) = (3.6 \pm 1.2 \pm 0.4) \times 10^{-6}$

First evidence w/ 3.3σ



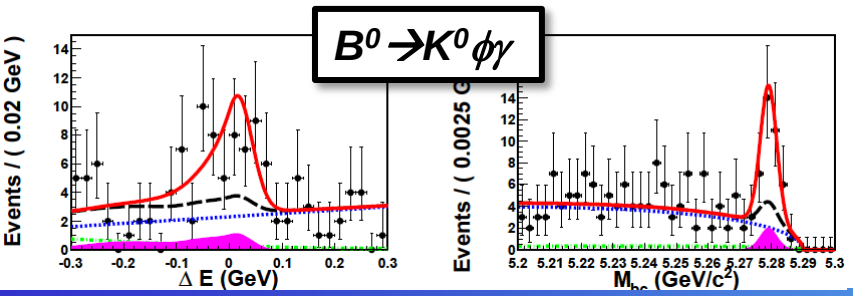
$Br(B^0 \to K^0\eta'\gamma) < 6.4 \times 10^{-6}$ @ 90% C.L.



$B \to K\phi\gamma$ (772MBB)

$Br(B^+ \to K^+\phi\gamma) = (2.34 \pm 0.29 \pm 0.23) \times 10^{-6}$

9.6σ



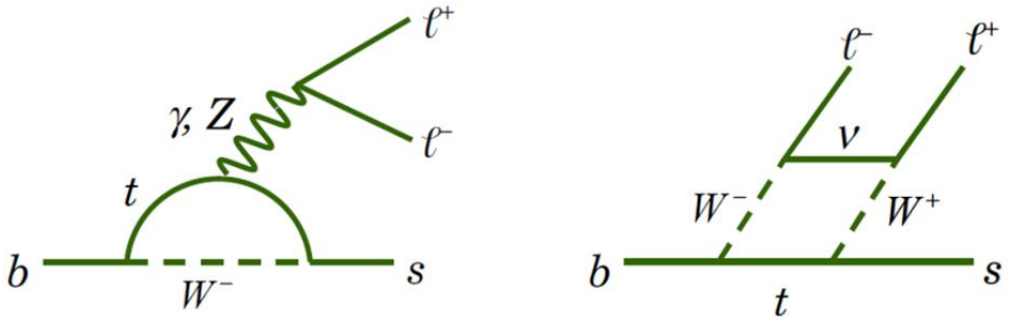
$Br(B^0 \to K^0\phi\gamma) = (2.66 \pm 0.60 \pm 0.32) \times 10^{-6}$

First observation w/ 5.4σ

Mixing indeuced CPV analysis is ongoing to search for right handed current…

$b \to s l^+ l^-$

- ***b→s* FCNC process(γ/Z penguin and box diagrams)**



- **The amplitude is a function of $s=q^2/m^2_b$, $q=m(l^+l^-)$**

$$\frac{d\Gamma(b \to s\ell^+\ell^-)}{d\hat{s}} \propto \left[(1+2\hat{s})\left(|C_9^{\text{eff}}|^2 + |C_{10}^{\text{eff}}|^2\right) + 4\left(1+\frac{\hat{s}}{2}\right)|C_7^{\text{eff}}|^2 + 12\text{Re}\left(C_7^{\text{eff}} C_9^{\text{eff}}\right)\right] + \text{corr.}$$

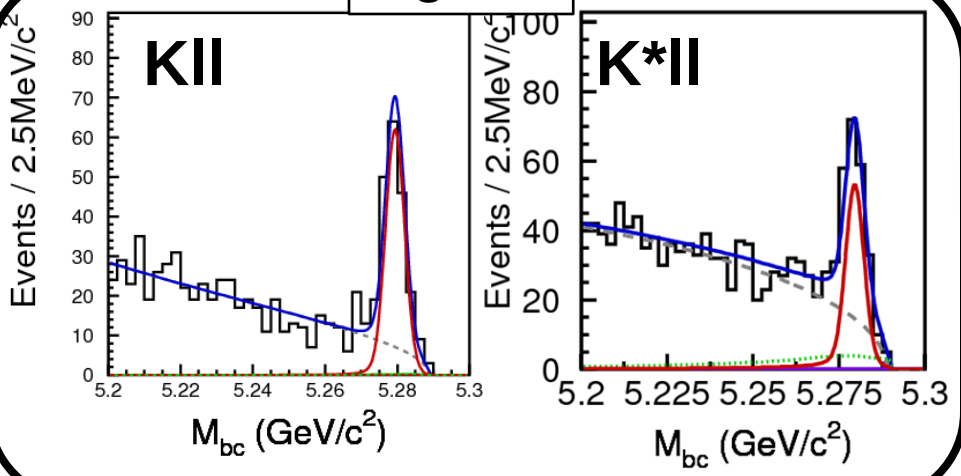
- **Sensitive to Wilson coefficients; sign(C_7), C_9, and, C_{10}**
  - **New physics may change Wilson coefficients, $C_i = C_i^{SM} + C_i^{NP}$**
- **Many observables: Br, A_{CP}, F_L, A_{FB}…**
  - **NP hints & models can be examined from various perspectives**

- **Exclusive *B→K(*)ll* : experimentally clean, but large theoretical error**
- **Inclusive *B→X$_s$ll* : bkg is large, but smaller theoretical error**

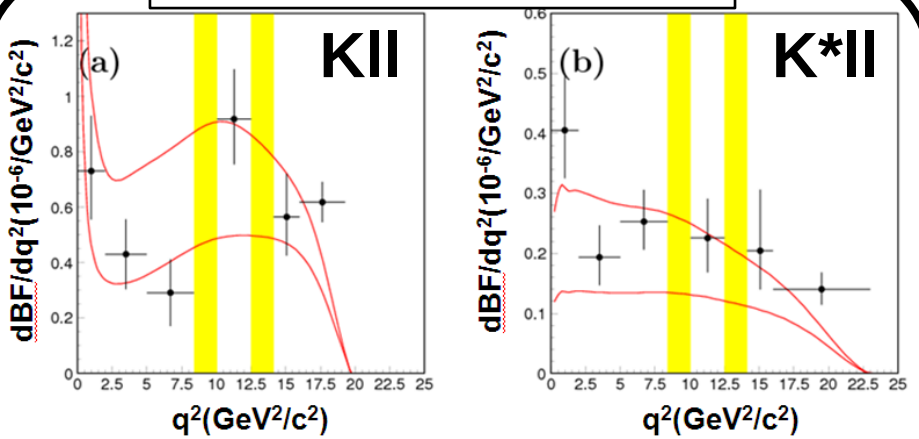
$B \to K^{(*)} l^+ l^-$ (Br, A_{CP}) (657MBB)

PRL 103, 171801(2009)

signals



Partial branching fractions



min., max. allowed form factors in SM

J/Ψ(Ψ')K(*) veto

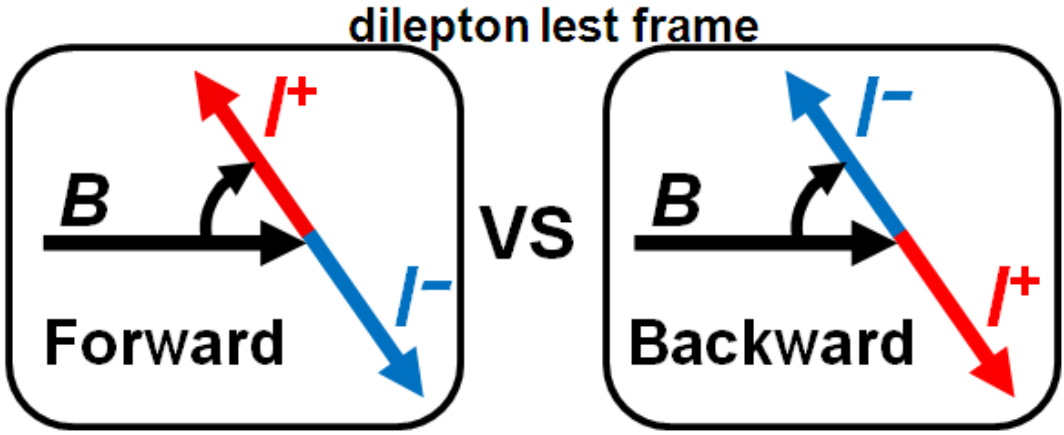
Mode	Branching fraction (x10^{-7})	A_{CP} $(N_{\bar{B}} - N_B)/(N_{\bar{B}} + N_B)$
$B \to Kll$	$4.8^{+0.5}_{-0.4} \pm 0.3$	$+0.04 \pm 0.10 \pm 0.02$
$B \to K^*ll$	$10.7^{+1.1}_{-1.0} \pm 0.9$	$-0.10 \pm 0.10 \pm 0.01$

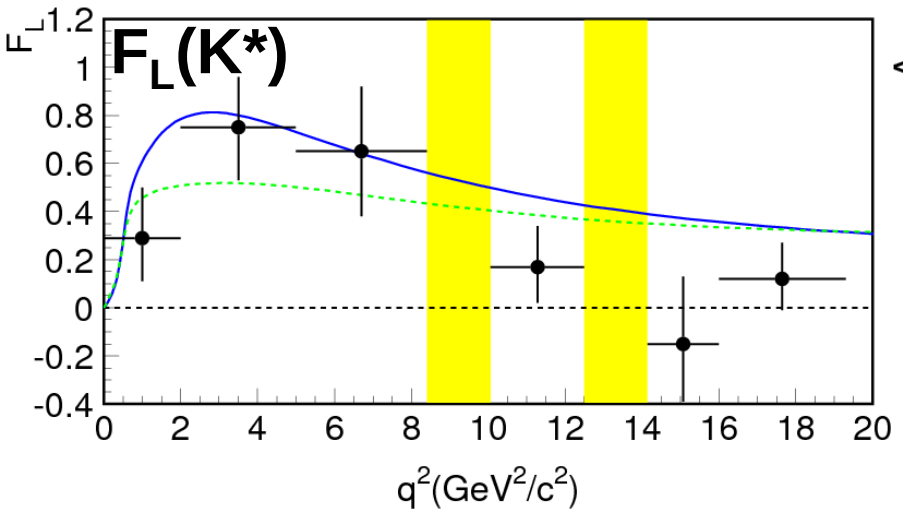
$B \to K^* l^+ l^-$ (lepton FB asymmetry)

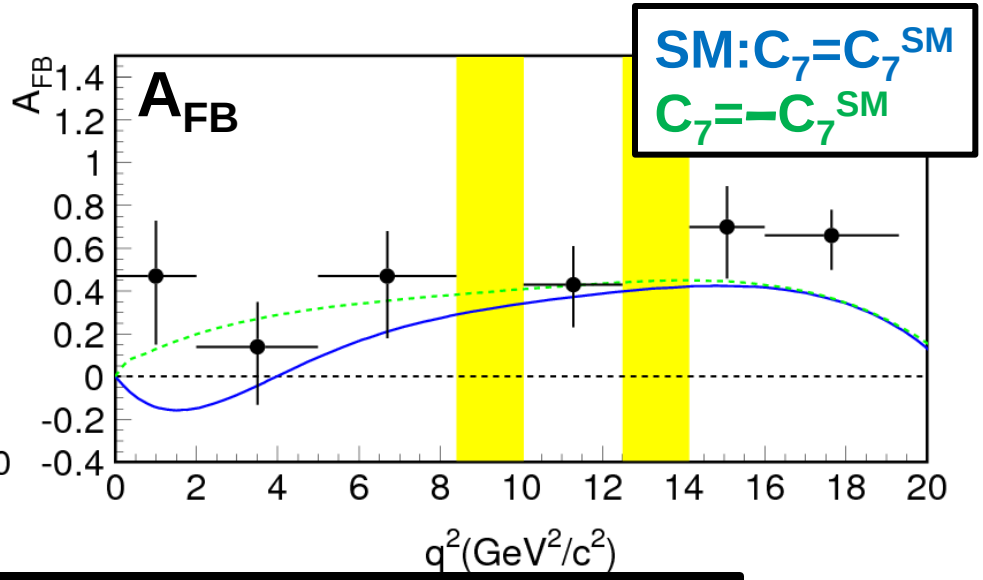
PRL 103, 171801(2009)

A_{FB} due to an interference between γ & Z contribution

$$A_{FB} = \frac{\Gamma(Forward) - \Gamma(backward)}{\Gamma(Forward) + \Gamma(backward)}$$



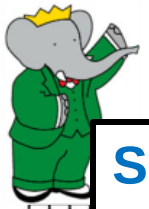


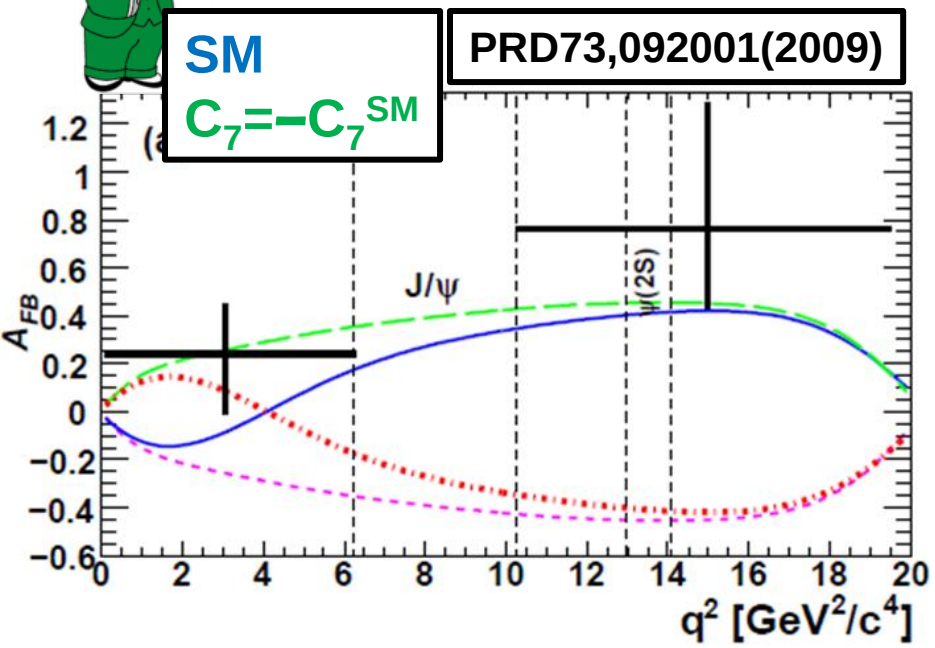


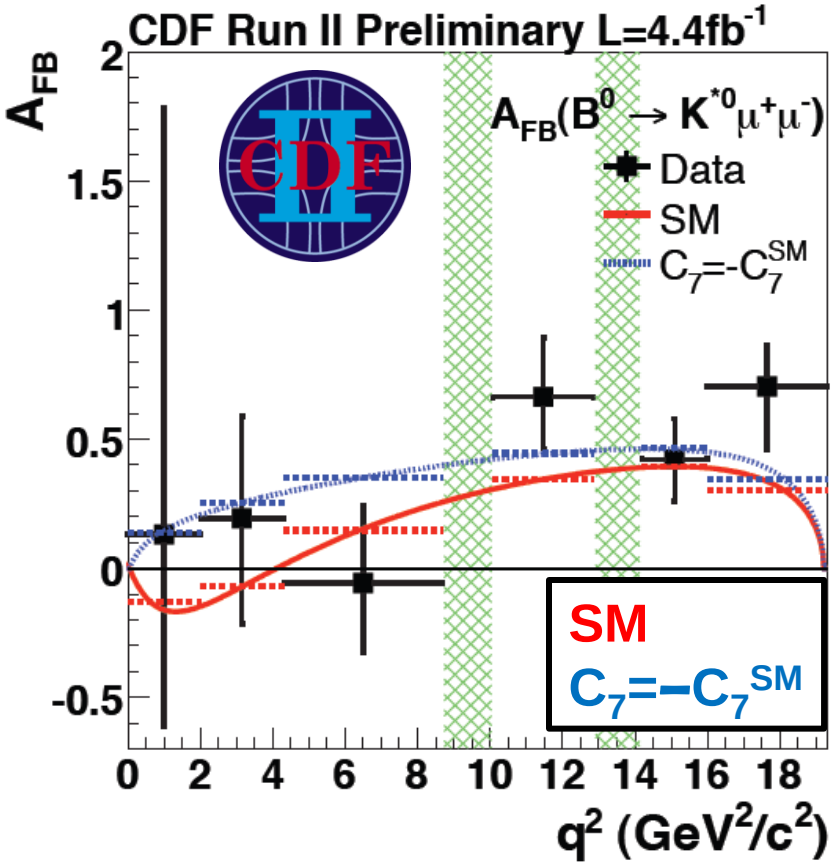
In A_{FB}, flipped sign C_7 is preferred(?!)

Hint of new physics(?!)

$B \to K^{(*)} l^+ l^-$ (lepton FB asymmetry)







Babar and CDF results also prefer flipped sign C_7

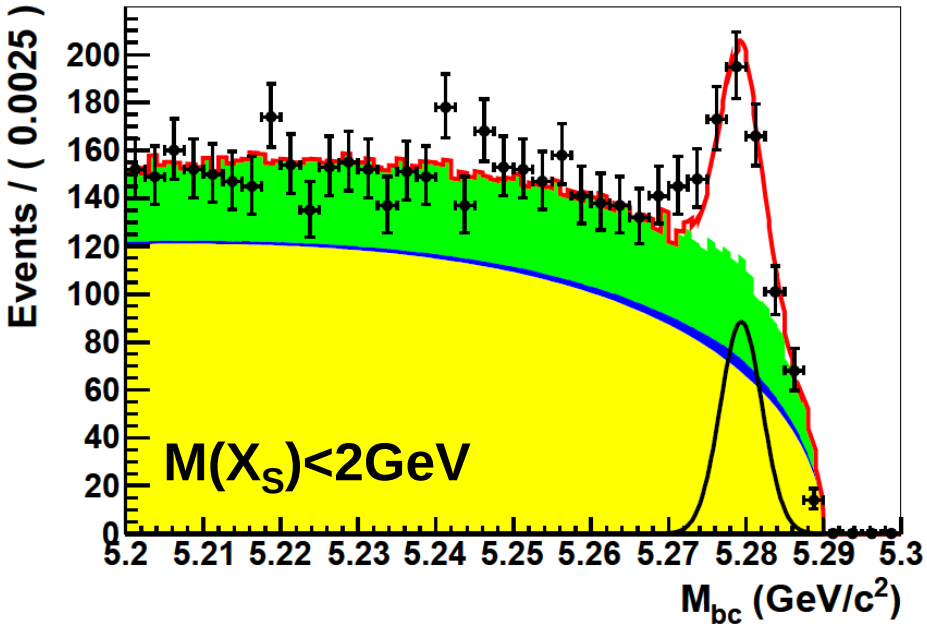
Inclusive $B \to X_s l^+ l^-$ (657MBB)

Preliminary

- Sum of exclusive method
  - $X_s = K^+/K_S + n\pi$, n=0-4
  - Sum of Kll, K*ll, and high-mass $X_s$ll
- 4.5 times lager data than previous result

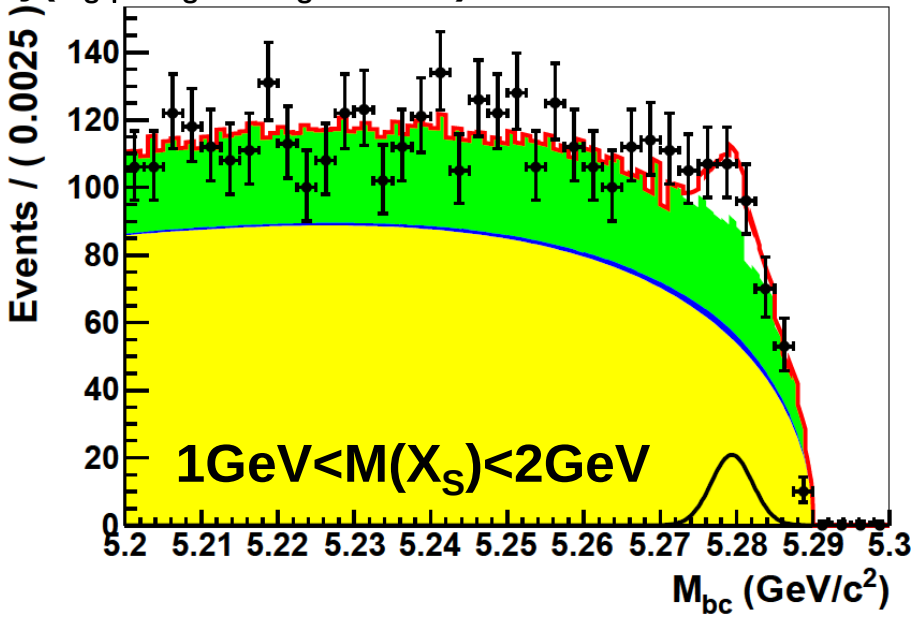
qq + non-peaking bkg from B decay

Peaking bkg from B decay($X_s\psi$, $X_s\pi\pi$, $X_s\pi l\nu$, etc)



$N_{sig} = 238.3 \pm 26.4 \pm 2.3$

10σ significance

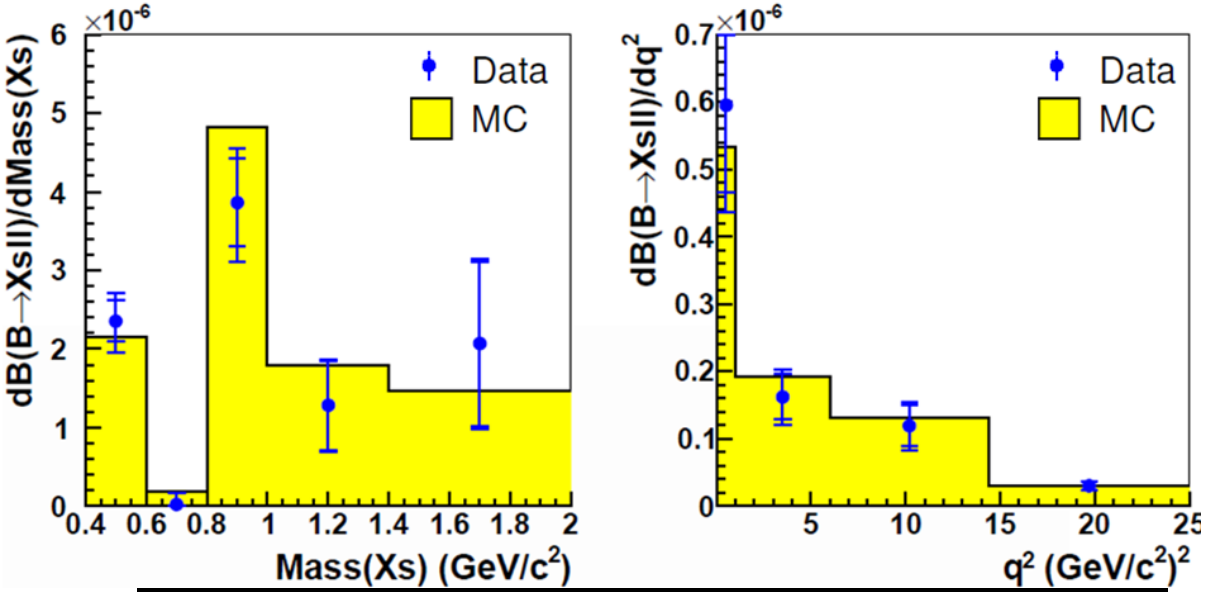


$N_{sig} = 53.8 \pm 19.1 \pm 0.7$

3σ significance

Inclusive $B \to X_s l^+ l^-$ (657MBB)

Preliminary

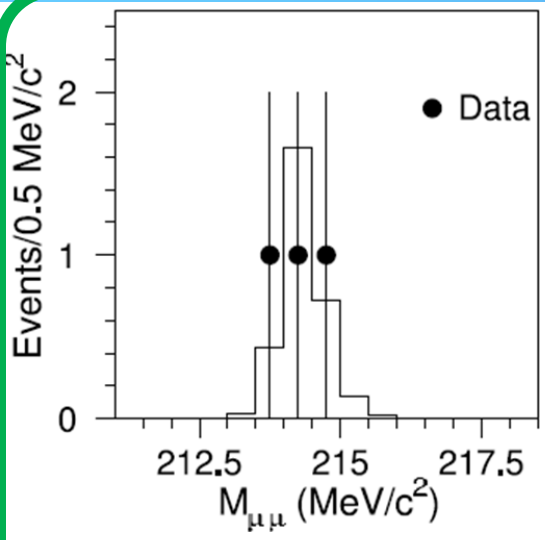


$$Br = (3.33 \pm 0.80^{+0.19}_{-0.24}) \times 10^{-6}$$

- Theoretical expectation [PRL94,061803(2005)]
  - **Br($C_7 = C_7^{SM}$) = (4.4±0.7)x10^{-6}**
  - **Br($C_7 = -C_7^{SM}$) = (8.8±1.0)x10^{-6}**
- **$X_s ll$ result prefers SM-like C_7**
  - **$A_{FB}(B \to K^* ll)$ prefers flipped sign C_7**
- **$A_{FB}(X_s ll)$ will be shown soon**

Puzzle?!...

Search for $X(214)^0$



HyperCP experiment : PRL 94, 021801

- Observation of 3 events in $\Sigma^+ \rightarrow p\mu^+\mu^-$
- Mass($X^0 \rightarrow \mu^+\mu^-$) = (214.3±0.5) MeV/$c^2$

Possible theoretical interpretations

- **Pseudo-scalar sgoldstino in SUSY(PRD73,035002)**
- **Light pseudo-scalar Higgs in NMSSM (PRL98,081802)**
- **Vector U-boson(JHEP 0907,51, PLB 663, 100, etc)**

No evidence of X(214) in other experiments yet…

- **D0** [PRL 103, 061801(2009)]
- **Babar** [PRL103,081803(2009)]
- **CLEO** [PRL101,151802(2008)]
- **E391@KEK** [PRL102,051802(2009)]
- **E949@BNL** [PRD79,092004(2009)]

Belle has searched for X^0 in B decays.

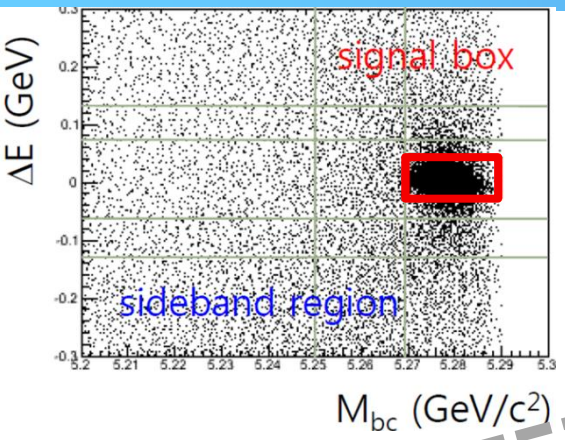
Prediction with sgoldstino interpretation:

(JETP Letters, v84, 9, p479-484)

- $Br(B^0 \rightarrow K^{*0}X^0(\rightarrow \mu^+\mu^-)) = 10^{-9}\text{-}10^{-6}$
- $Br(B^0 \rightarrow \rho^0 X^0(\rightarrow \mu^+\mu^-)) = 10^{-9}\text{-}10^{-7}$

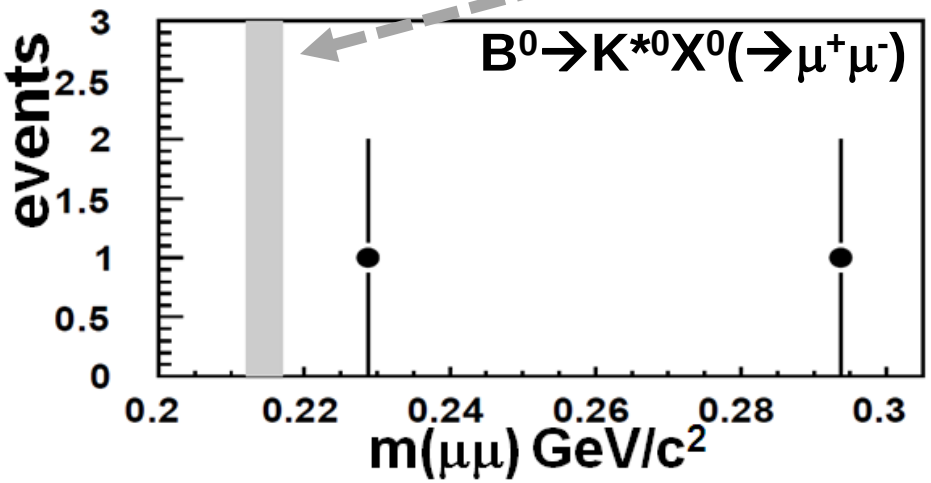
Search for $X(214)^0$ (657MBB)

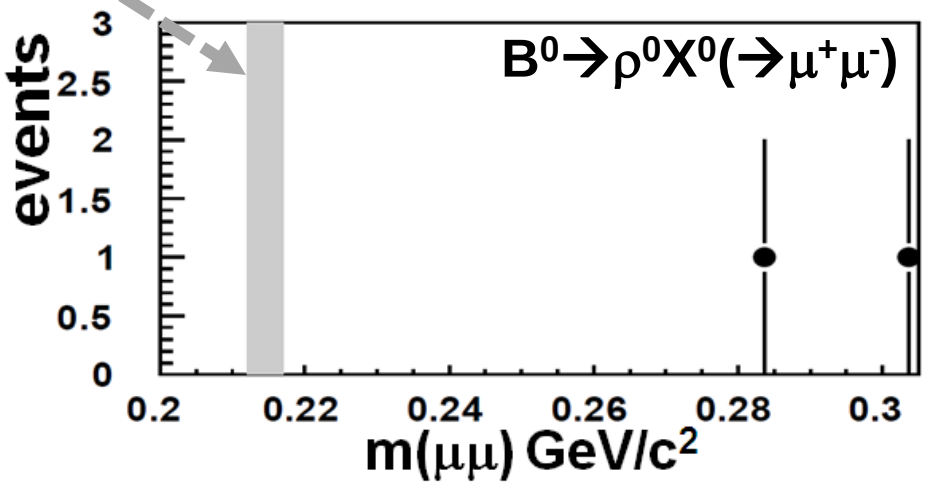
Preliminary



- Reconstruct $B^0 \to K^{*0}\mu^+\mu^-$ and $B^0 \to \rho^0\mu^+\mu^-$ with ΔE and m_{bc}
- See $\mu^+\mu^-$ mass in ΔE and m_{bc} signal region

Signal region of X^0 mass is 214.3 ± 3 x resolution(HyperCP + Belle)





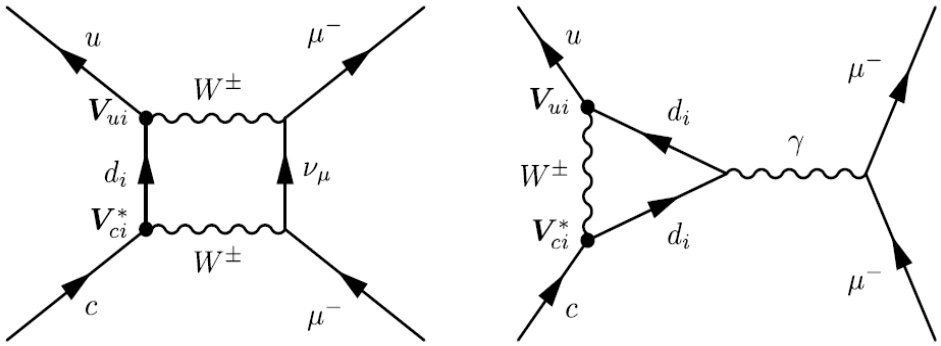
U.L. @ 90% C.L. with $\tau(X^0)=10^{-15}$

- $Br(B^0 \to K^{*0}X^0) \times Br(X^0 \to \mu^+\mu^-) < 2.23 \times 10^{-8}$
- $Br(B^0 \to \rho^0X^0) \times Br(X^0 \to \mu^+\mu^-) < 1.71 \times 10^{-8}$

Ruled out most of $Br(10^{-9}\text{-}10^{-6})$ by sgoldstino interpretation

Search for $D^0 \to l^+ l^-$

- **$D^0 \to \mu^+\mu^-$, $D^0 \to e^+e^-$**
  - FCNC decays, $D^0 \to \mu^+\mu^-$, e^+e^-, are highly suppressed in SM



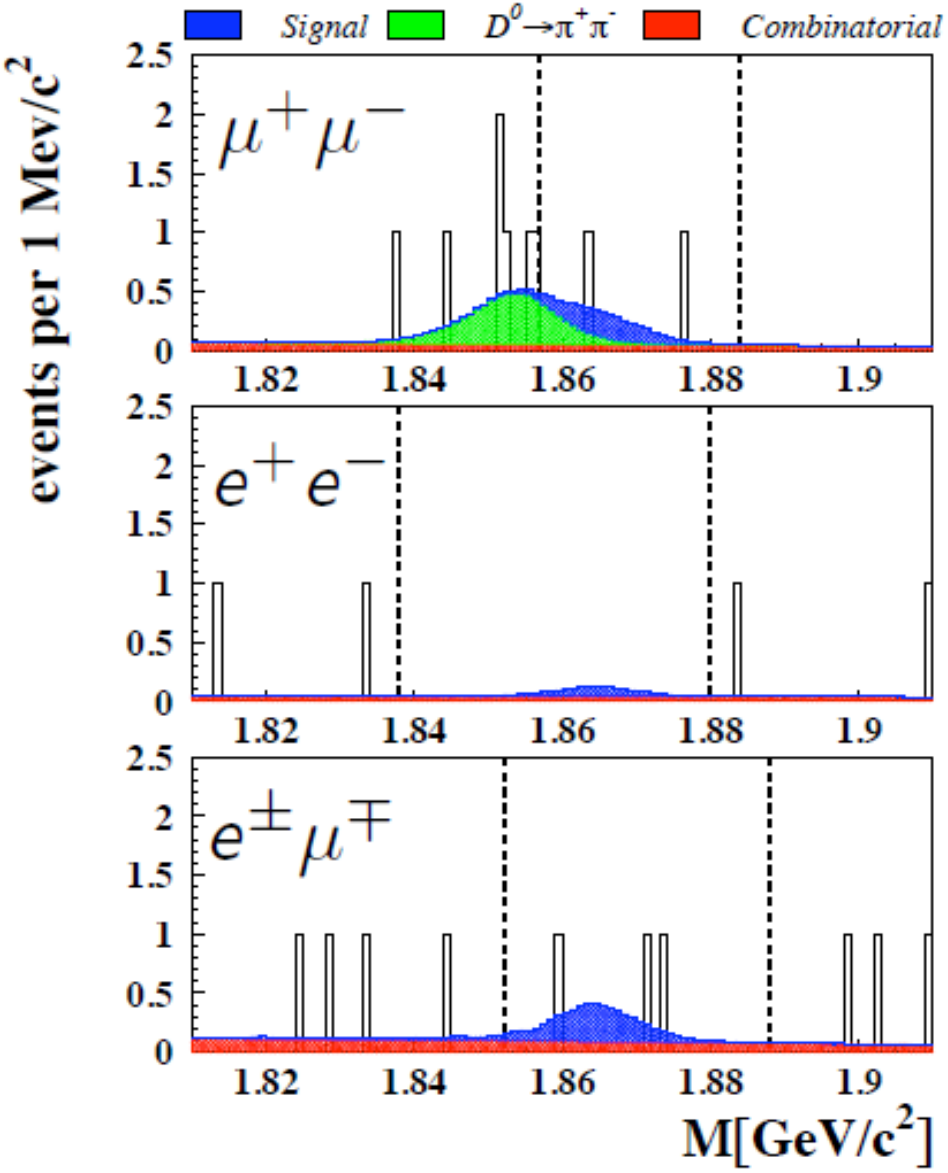
	$\mu^+\mu^-$	e^+e^-
PDG	**< 1.3x10^{-6}**	**< 1.2x10^{-6}**
SM	**~O(10^{-13})**	**~O(10^{-23})**
NP(RPV -SUSY)	**~O(10^{-8})**	**~O(10^{-12})**

- **$D^0 \to e\mu$**
  - Lepton-flavor violating decay is forbidden in the SM

- **Analysis w/ 660 fb^{-1}**
  - Reduce combinatorial bkg by D* tag ($D^{*+} \to D^0\pi^+$, $D^0 \to l^+l^-$)
  - Suppress bkg from B decay ($p(D^{*+})$>2.5GeV/c)
  - Reduce systematics (Normalized by $D^0 \to \pi^+\pi^-$)

Search for $D^0 \to l^+ l^-$ (660 fb^{-1})

Submitted to PRD
arXiv:1003.2345



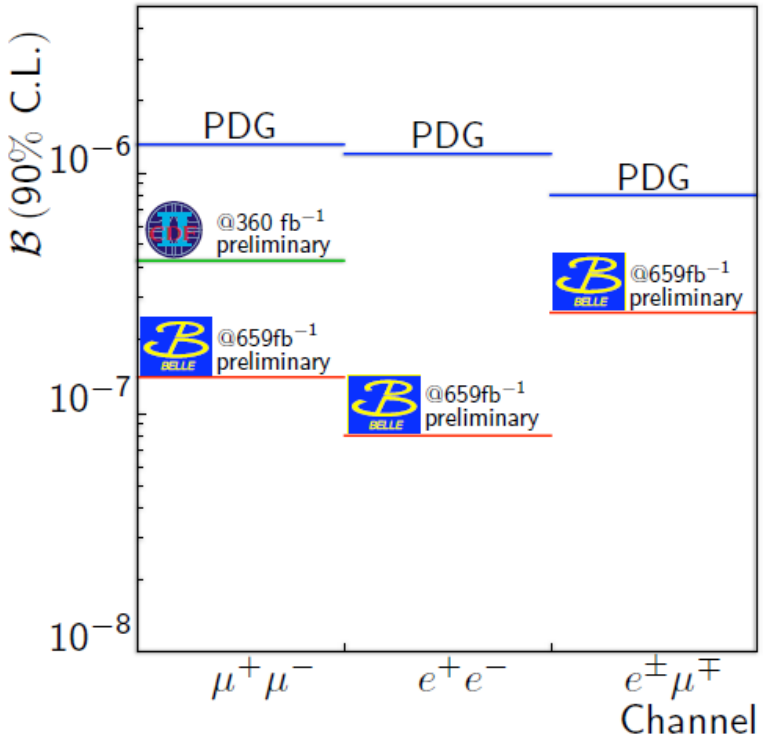
World best limits

90% C.L. upper limits (preliminary)

$$\mathcal{B}(D^0 \to \mu^+\mu^-) < 1.4 \times 10^{-7}$$

$$\mathcal{B}(D^0 \to e^+e^-) < 7.9 \times 10^{-8}$$

$$\mathcal{B}(D^0 \to e^\pm\mu^\mp) < 2.6 \times 10^{-7}$$

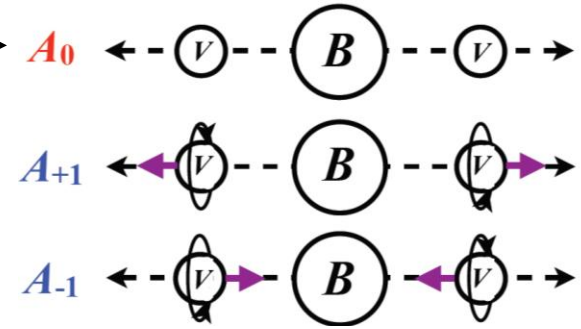


Outline

- Introduction
  - KEKB / Belle
- Constraints on NP
  - $B^+ \to D^{(*)0} \tau \nu$, $b \to s\gamma$, $b \to sll$,
  - $X(214)^0$, $D^0 \to l^+ l^-$
- **Polarization puzzle in $B \to VV$**
- Exploring B_s sector
  - $B_s \to D_s^* \pi/\rho$, $\Delta\Gamma_s/\Gamma_s$
- Summary

Charmless B→VV

- In B→VV, three polarization states contribute:
  - Longitudinal → A_0
  - Transverse → A_{+1}, A_{-1}

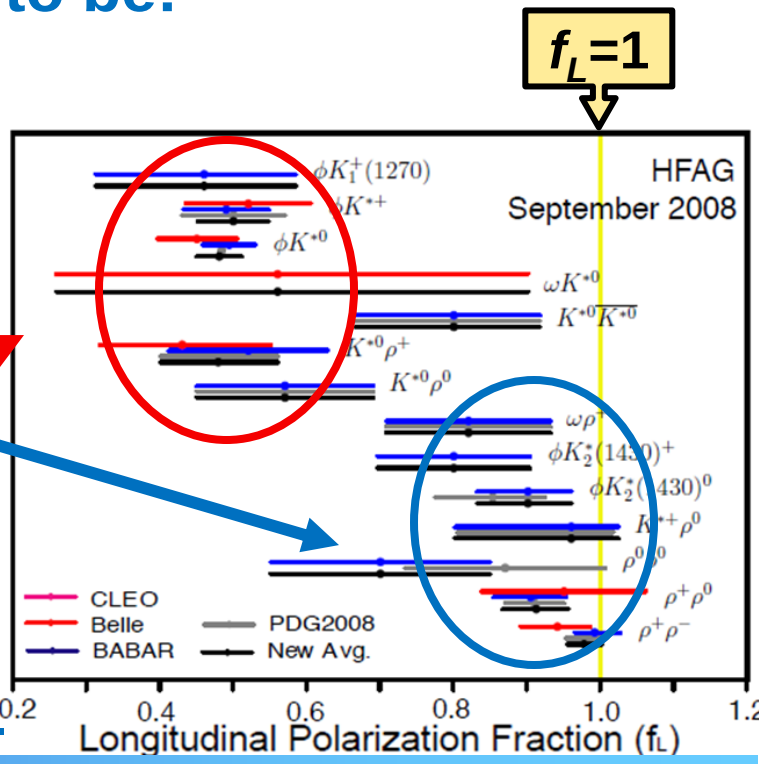


- The amplitudes in SM are expected to be:

$$A_0 : A_+ : A_- = 1 : \frac{m_V}{m_B} : \frac{m_V^2}{m_B^2}$$

$$f_L = \frac{\Gamma_L}{\Gamma} = \frac{|A_0|^2}{|A_0|^2 + |A_+|^2 + |A_-|^2} \sim 1 - \frac{m_V^2}{m_B^2} \sim 1$$

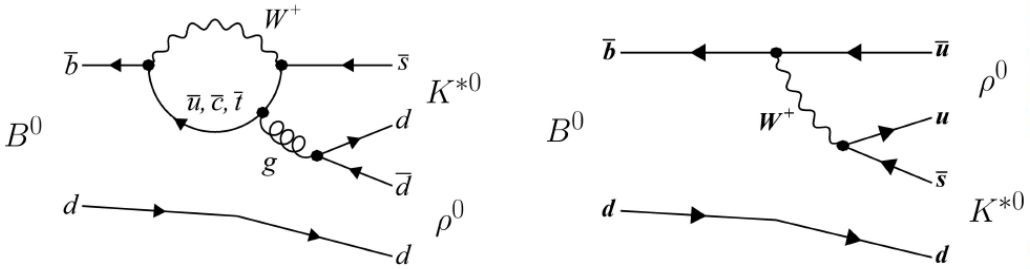
- f_L~1.0 for tree dominant
- f_L~0.5 for penguin dominant
  - Many theoretical attempts to explain within SM(P annihilation or rescattering) and beyond SM
- Br, f_L of ϕK^* SU(3) related modes are important for improved understanding.



$B^0 \to \rho^0 K^{*0}$ (657MBB)

PRD80,051103(2009)

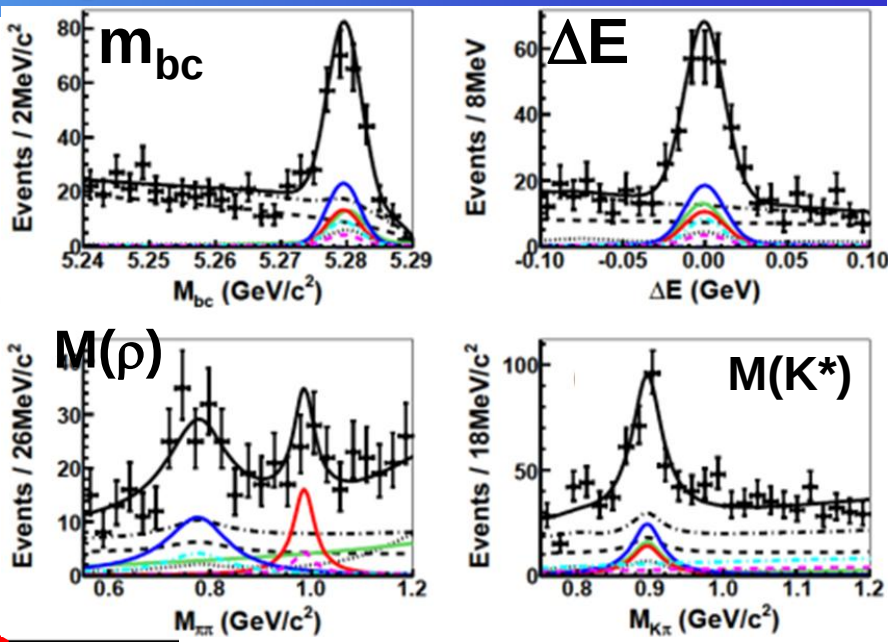
- $\rho^0 K^{*0}$ is through P and C



- First observation by BABAR

(232MBB : PRL 97,201801(2006))

- Br($\rho^0 K^{*0}$) = (5.6±0.9±1.3)x10^{-6}(5.3σ)
- $f_L(\rho^0 K^{*0})$ = 0.57±0.09±0.08



Mode	Y (events)	$\mathcal{S}$ (σ)	$\mathcal{B}$ (10^{-6})	$\mathcal{B}_{UL}$ (10^{-6})
$\rho^0 K^{*0}$	$77.6^{+28.6}_{-27.9}$	2.7	$2.1^{+0.8+0.9}_{-0.7-0.5}$	< 3.4
$f_0(980)K^{*0}$	$51.2^{+20.4}_{-19.3}$	2.5	$1.4^{+0.6+0.6}_{-0.5-0.4}$	< 2.2
$\rho^0 K^+\pi^-$	$207.8^{+39.8}_{-39.2}$	5.0	$2.8 \pm 0.5 \pm 0.5$	-
$f_0(980)K^+\pi^-$	$106.9^{+31.6}_{-29.9}$	3.5	$1.4 \pm 0.4^{+0.3}_{-0.4}$	-
$\pi^+\pi^- K^{*0}$	$200.7^{+46.7}_{-44.9}$	4.5	$4.5^{+1.1+0.9}_{-1.0-1.6}$	-
$\pi^+\pi^- K^+\pi^-$	$-5.4^{+54.9}_{-44.9}$	0.0	$-0.1^{+1.2+1.4}_{-1.1-0.8}$	< 2.1

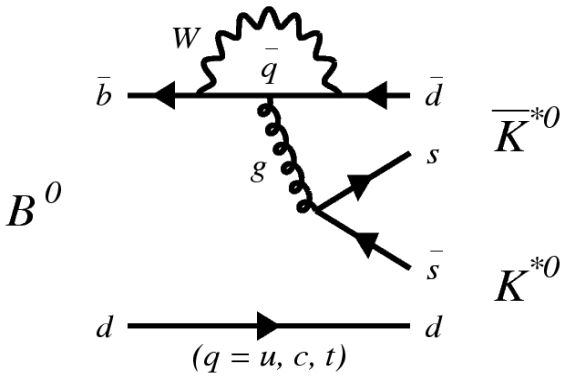
Excess but no evidence…
Difference between Belle and BABAR is less than 2σ, so this would be statistical fluctuation

First observations for three body decays

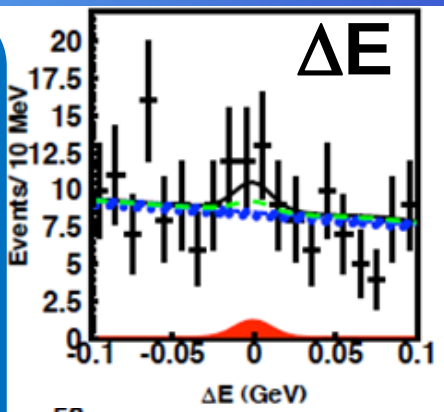
$B^0 \to K^{*0}\bar{K}^{*0}$, $K^{*0}K^{*0}$ (657MBB)

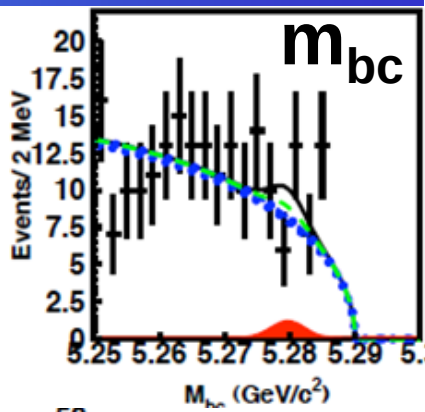
Accepted by PRD

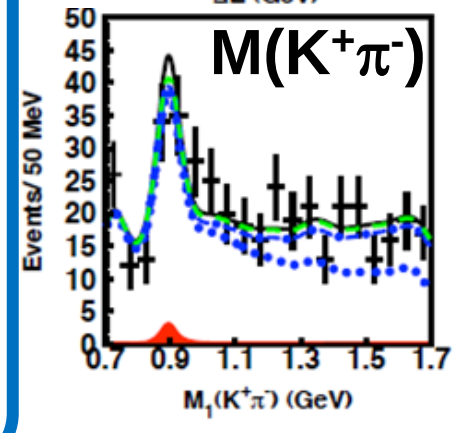
- $B^0 \to K^{*0}\bar{K}^{*0}$ is pure $b \to d$ penguin

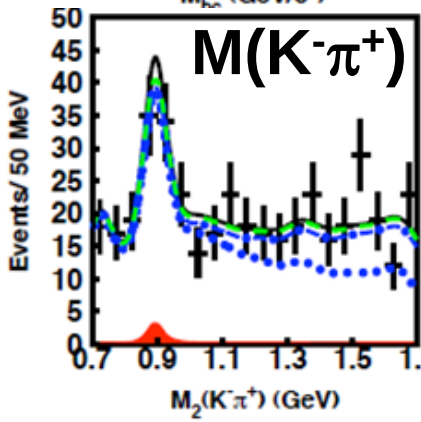


  - In SM, Br ~ $(0.17\text{-}0.92)\times10^{-6}$
  - Babar w/ 383MBB
    - Br = $(1.28^{+0.35}_{-0.30}\pm0.11)\times10^{-6}$ (6σ)
    - $f_L = 0.8\pm0.1\pm0.1$
- $B^0 \to K^{*0}K^{*0}$ is forbidden in SM









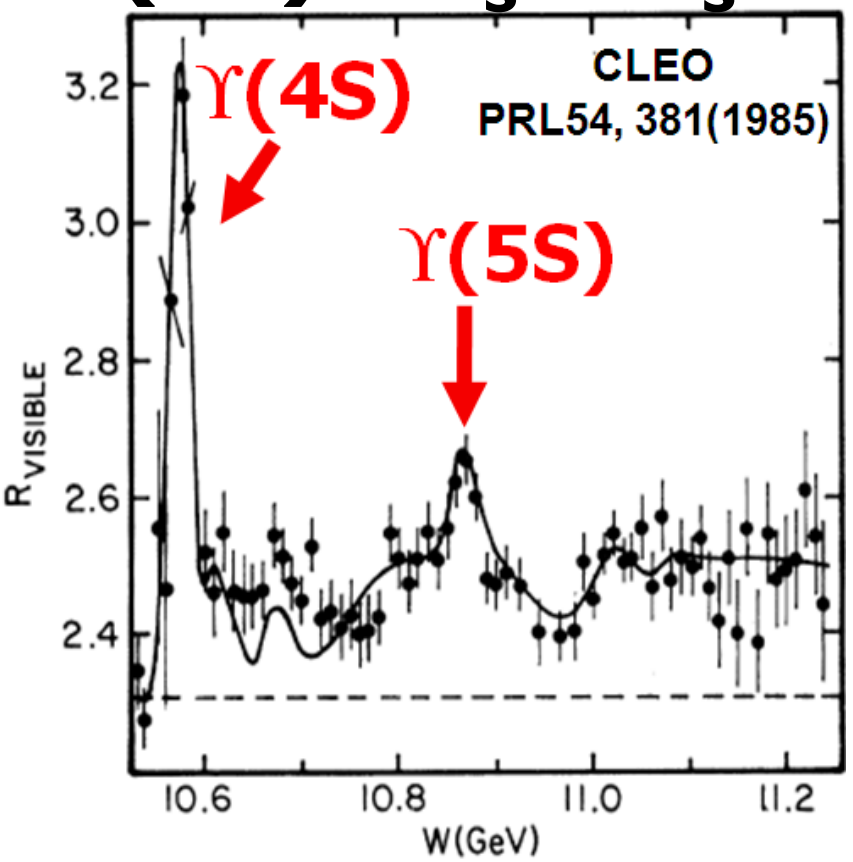
Mode	Yield	$S(\sigma)$	$Br(10^{-6})$	$U.L.(10^{-6})$
$B^0 \to K^{*0}\bar{K}^{*0}$	$7.7^{+9.7+2.8}_{-8.5-2.2}$	0.9	$0.26^{+0.33+0.10}_{-0.29-0.08}$	< 0.8
$B^0 \to K^{*0}K^{*0}$	$-3.7\pm3.3^{+2.5}_{-2.7}$	–	–	< 0.2

Outline

- Introduction
  - KEKB / Belle
- Constraints on NP
  - $B^+ \to D^{(*)0} \tau \nu$, $b \to s\gamma$, $b \to sll$,
  - $X(214)^0$, $D^0 \to l^+ l^-$
- Polarization puzzle in $B \to VV$
- **Exploring B_s sector**
  - **$B_s \to D_s^* \pi/\rho$, $\Delta\Gamma_s/\Gamma_s$**
- Summary

$\Upsilon(5S)$, B_s physics

$\Upsilon(5S) \rightarrow B_s^{(*)} B_s^{(*)}$



Since 2005, we accumulated ~121 fb^{-1} @ $\Upsilon(5S)$
Today's results are based on 23.6 fb^{-1}

Events at $\Upsilon(5S)$

Hadronic events at $\Upsilon(5S)$

$\sigma_{b\bar{b}}^{\Upsilon(5S)} = (0.302 \pm 0.015)\,nb$

Υ(nS) +hadron

uu,dd,ss,cc continuum

bb event

$f_s = (19.5^{+3.0}_{-2.3})\%$

B_s event

$B_s^*B_s^*$ $B_s^*B_s$ B_sB_s

B^0 or B^+ event

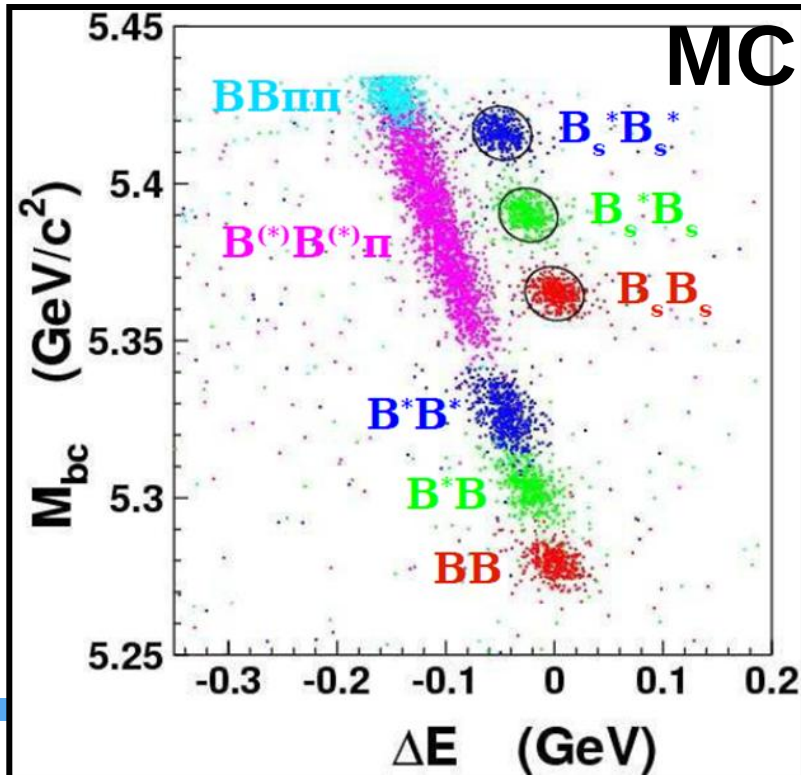
B^*B^* B^*B BB

$B^*B^*\pi$ $B^*B\pi$ $BB\pi$

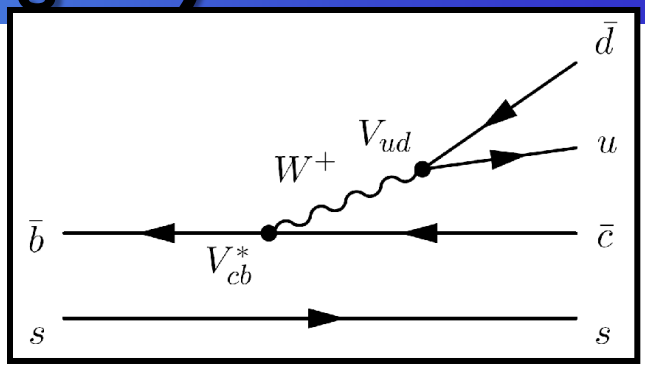
$BB\pi\pi$

$B_s^* \rightarrow B_s\gamma$

$B^* \rightarrow B\gamma$



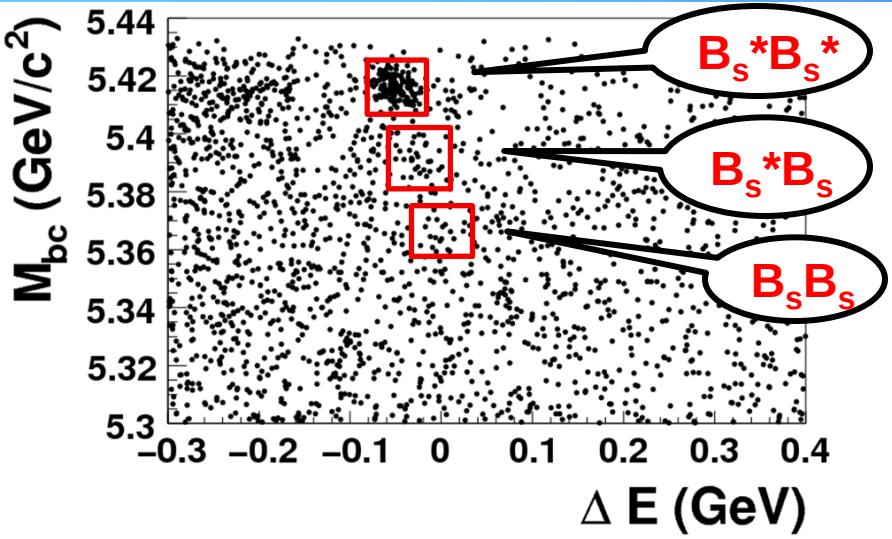
$B_s \rightarrow D_s^{(*)-}\pi^+$ and $B_s \rightarrow D_s^{(*)-}\rho^+$

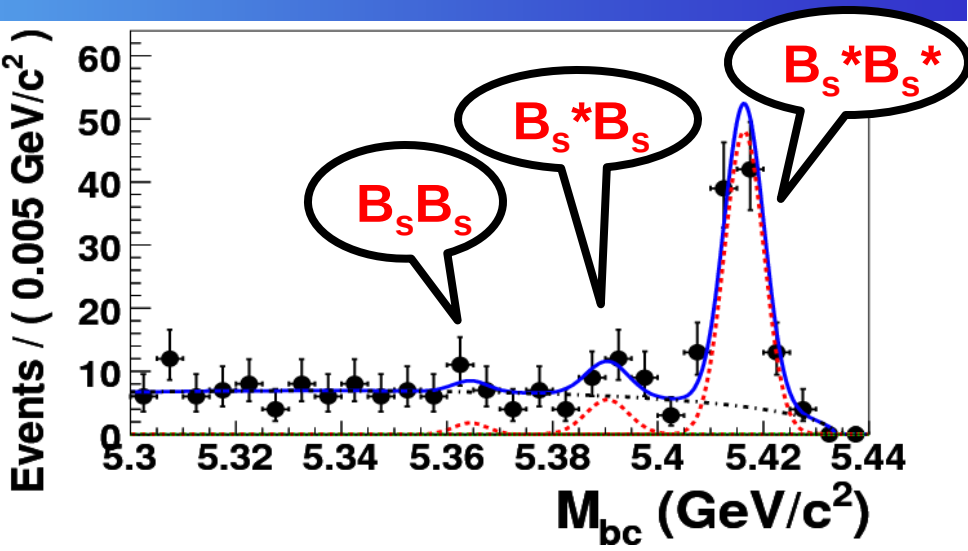


- **Cabibbo-favored modes**
  - gives us very rich sample
- **Fundamental parameters**
  - B_s and B_s* mass
  - Fraction of $B_s^{(*)}B_s^{(*)}$ production
- **Measure absolute Br**
  - D_s^{*-}, ρ^+ are difficult at hadron collider
  - helps precise normalization in hadron collier
- **Polarization measurement in $B_s \rightarrow D_s^{*-}\rho^+$**
  - SM(f_L~0.88)
  - $f_L(B^0 \rightarrow D_s^{*-}\rho^+)=0.885\pm0.016\pm0.012$

$B_s \to D_s^- \pi^+$

PRL100,021801(2009)





$$Br(B_S \to D_S^- \pi^+) = [3.67^{+0.35+0.43}_{-0.33-0.42} \pm 0.49(f_S)] \times 10^{-3}$$

(CDF : Br = $(3.8 \pm 0.3 \pm 1.3) \times 10^{-3}$)

Fraction of $B_s^{(*)} B_s^{(*)}$ production

$$f(B_S^* B_S^*) = \frac{\sigma(e^+e^- \to B_S^* B_S^*)}{\sigma(e^+e^- \to B_S^{(*)} B_S^{(*)})} = (90.1^{+3.8}_{-4.0} \pm 0.2)\%$$

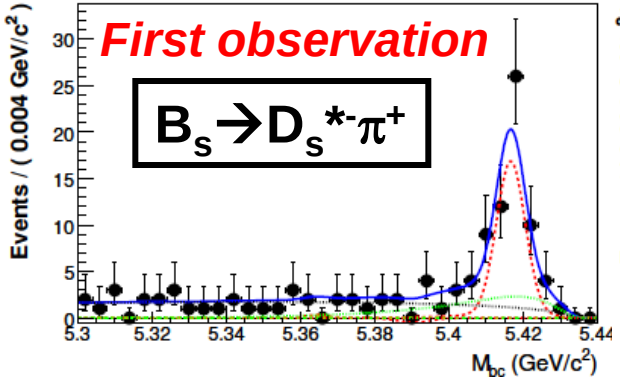
$$f(B_S^* B_S) = \frac{\sigma(e^+e^- \to B_S^* B_S)}{\sigma(e^+e^- \to B_S^{(*)} B_S^{(*)})} = (7.3^{+3.3}_{-3.0} \pm 0.1)\%$$

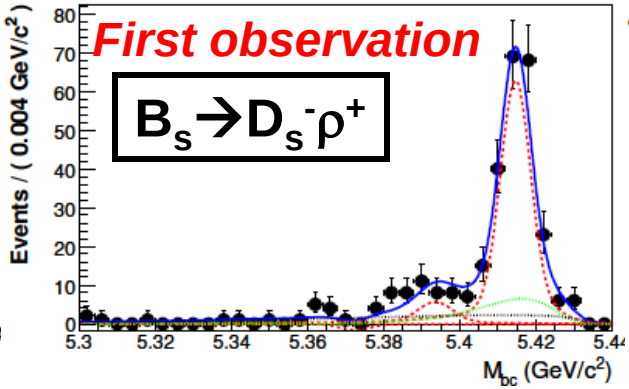
Mass measurement(MeV/c^2)

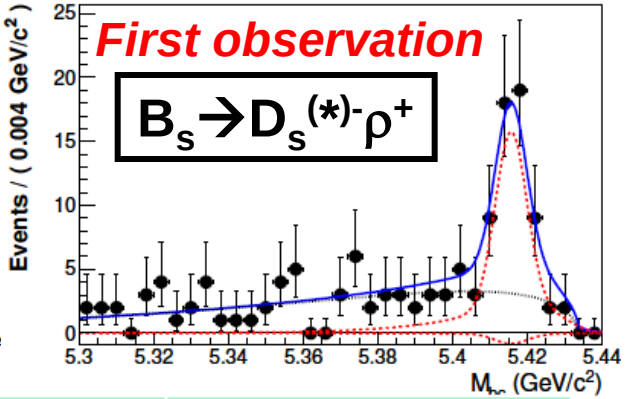
- $m(B_s^*) = 5416.4 \pm 0.4 \pm 0.5$
  - (CLEO = $5411.7 \pm 1.6 \pm 0.6$)
- $M(B_s) = 5364.4 \pm 1.3 \pm 0.7$
  - (CDF = $5366.01 \pm 0.73 \pm 0.33$)

$B_s \to D_s^{*-}\pi^+$, $B_s \to D_s^{(*)-}\rho^+$

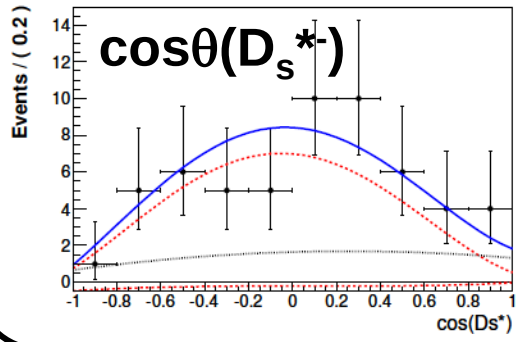
Preliminary

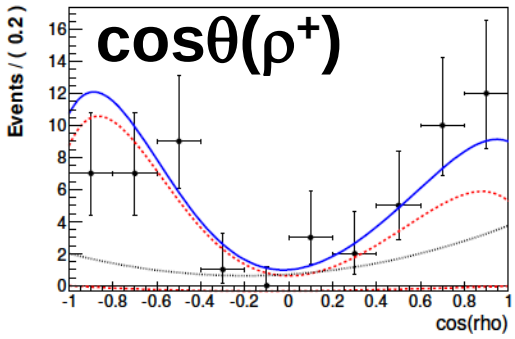






Mode	σ	Br(x10^{-3})	SM(HQET)
$B_s \to D_s^{*-}\pi^+$	7.1	$2.4^{+0.5}_{-0.4} \pm 0.3 \pm 0.4$	2.8
$B_s \to D_s^{-}\rho^+$	8.2	$8.5^{+1.3}_{-1.2} \pm 1.1 \pm 1.3$	7.5
$B_s \to D_s^{*-}\rho^+$	7.4	$11.8^{+2.2}_{-2.0} \pm 1.7 \pm 1.8$	8.9





Polarization measurement

$$f_L(B_s \to D_s^{*-}\rho^+) = 1.05^{+0.08+0.03}_{-0.10-0.04}$$

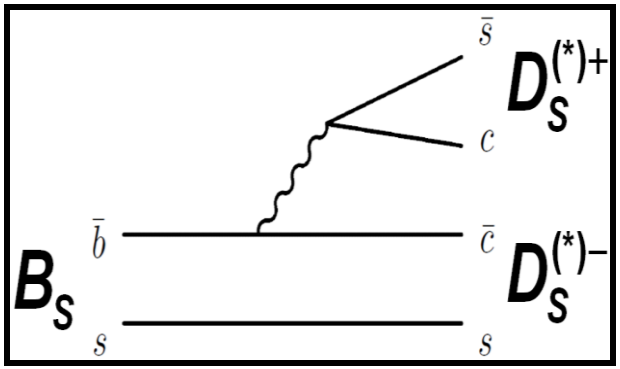
consistent with

- o SM(f_L~0.88)
- o $f_L(B^0 \to D_s^{*-}\rho^+) = 0.885 \pm 0.016 \pm 0.012$

$\Delta\Gamma_s/\Gamma_s$ from $B_s \to D_s^{(*)+} D_s^{(*)-}$

Preliminary

- CP eigen state is used to measure CPV parameters, β_s, $\Delta\Gamma_s$…
- B_s oscillation is too fast for Belle



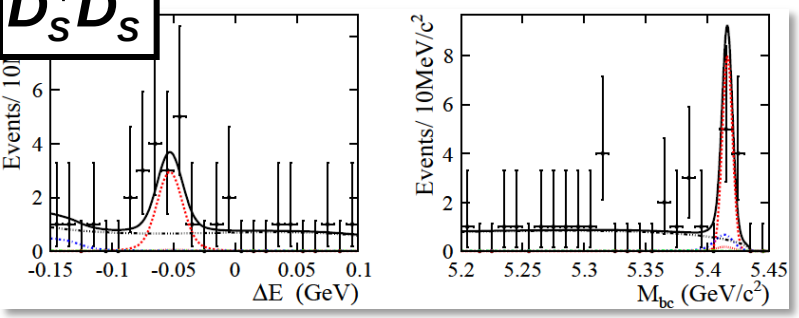
- $\Delta\Gamma_s/\Gamma_s$ can be obtained from Br($B_s \to D_s^{(*)+} D_s^{(*)-}$)
  - CKM favored $B_s \to D_s^{(*)+} D_s^{(*)-}$ is
    - CP-even is dominant($D_s D_s$ is pure CP-even)
    - CP-odd part can be ignored (under heavy quark limit for m_c)

$$\frac{\Delta\Gamma_s}{\Gamma_s} \cong \frac{2Br(B_s \to D_s^{(*)+} D_s^{(*)-})}{1 - Br(B_s \to D_s^{(*)+} D_s^{(*)-})}$$

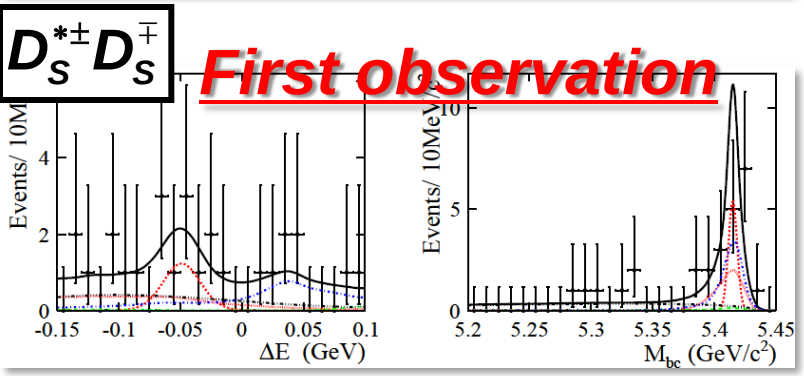
Z.phys., C54, 653(1992)
PRD63, 114015(2001)

$\Delta\Gamma_s/\Gamma_s$ from $B_s \to D_s^{(*)+} D_s^{(*)-}$ Preliminary

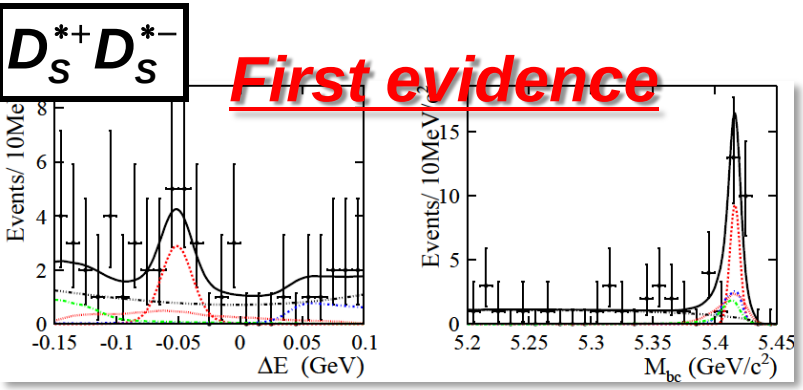
$D_s^+ D_s^-$



$D_s^{*\pm} D_s^{\mp}$ **First observation**



$D_s^{*+} D_s^{*-}$ **First evidence**



Mode	Yield	Br(%)	S(σ)
$D_s^+ D_s^-$	$8.5^{+3.2}_{-2.6}$	$1.0^{+0.4+0.3}_{-0.3-0.2}$	6.2
$D_s^{*\pm} D_s^{\mp}$	$9.2^{+2.8}_{-2.4}$	$2.8^{+0.8}_{-0.7} \pm 0.7$	6.6
$D_s^{*+} D_s^{*-}$	$4.9^{+1.9}_{-1.7}$	$3.1^{+1.2}_{-1.0} \pm 0.8$	3.2
Sum	$22.6^{+4.7}_{-3.9}$	$6.9^{+1.5}_{-1.3} \pm 1.9$	

Theoretical error (PLB 316, 567)

$$\frac{\Delta\Gamma_s}{\Gamma_s} = \frac{2Br}{1-Br} = (0.147^{+0.036+0.044}_{-0.030-0.042} \pm 0.004)$$

Consistent with PDG and SM, and Comparable with PDG

$$PDG : \Delta\Gamma_s/\Gamma_s = 0.092^{+0.051}_{-0.054}$$

$$SM : \Delta\Gamma_s/\Gamma_s = 0.127 \pm 0.024$$

(hep-ph/0612167)

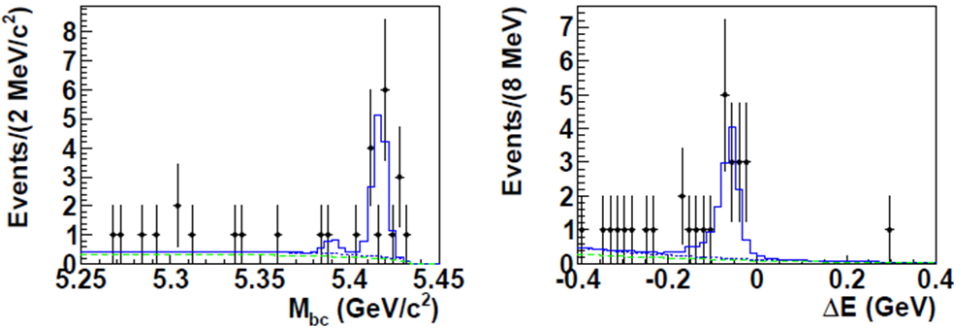
$B_s \rightarrow J/\psi\eta$, $B_s \rightarrow J/\psi\eta'$

Preliminary
arXiv:0912.1434

- Pure CP even states.
- Aiming direct $\Delta\Gamma_s$ measurement(Δt).
- With large signal, we can also measure $\Delta\Gamma_s$

$B_s \rightarrow J/\psi\eta$

$\eta \rightarrow \gamma\gamma$, $\eta \rightarrow \pi\pi\pi^0$ combined



First observation

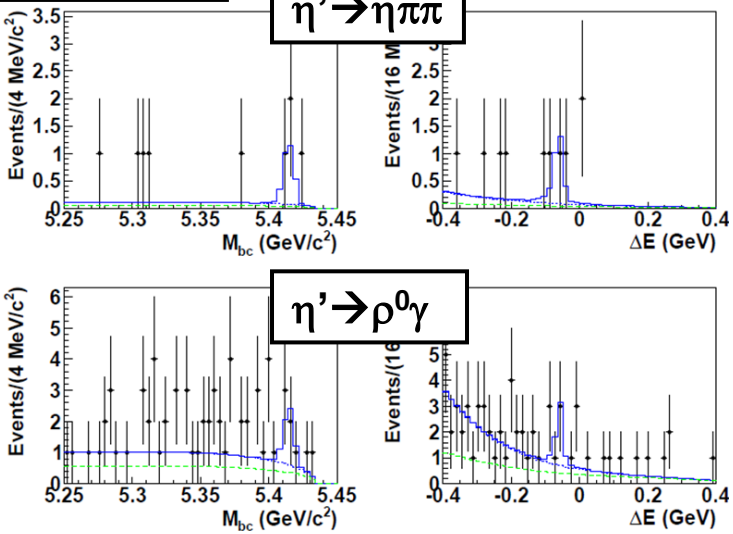
$N_{sig} = 15 \pm 4$ (7.3σ)

$Br = (3.3 \pm 0.9 \pm 0.3 \pm 0.4(f_s)) \times 10^{-4}$

$B_s \rightarrow J/\psi\eta'$

$\eta' \rightarrow \eta\pi\pi$

$\eta' \rightarrow \rho^0\gamma$



First evidence

Nsig = 11 ± 5 (3.8σ)

$Br = (3.1 \pm 1.2^{+0.5}_{-0.6} \pm 0.38) \times 10^{-4}$

Summary

- KEKB / Belle has accumulated int. $\mathcal{L} = 1\ ab^{-1}$
- Using a part of data set, we have
  - set strong constraint on some NP models
  - found some hints of NP

- Many programs are running to search for NP effects now.
  - B, Bs, Y(nS; n=1,2,3), charm, tau, two-photon
  - Results with full data will come in this summer

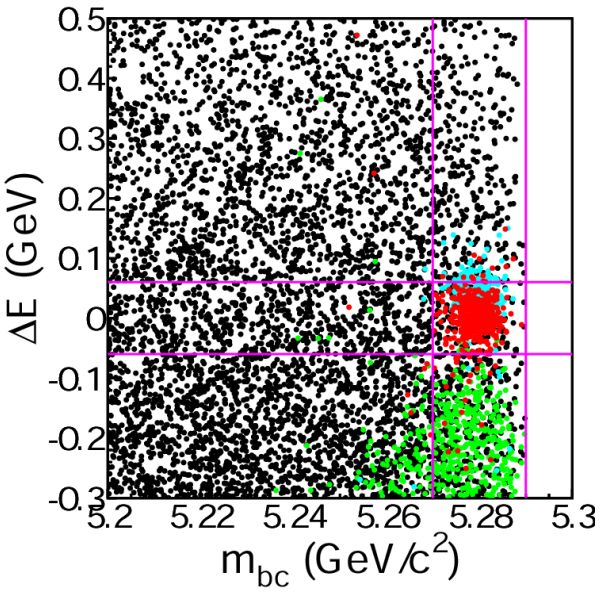
- However, many analyses need much more data…
  - Super-B factories will solve the statistical issue

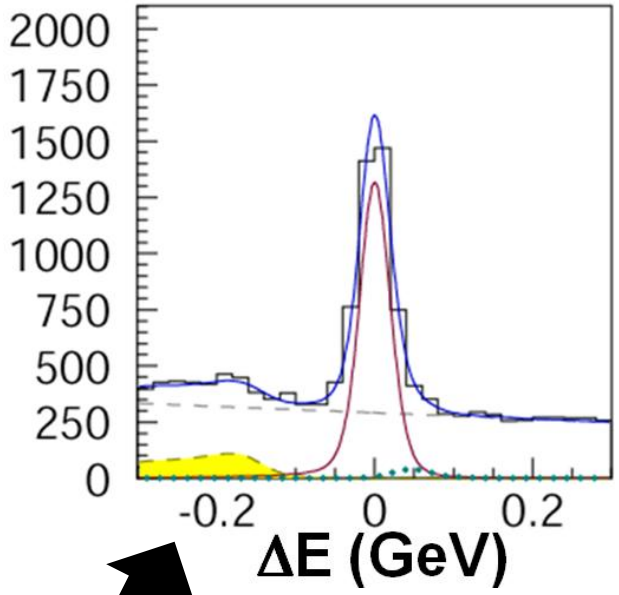
Belle 物理解析の発表

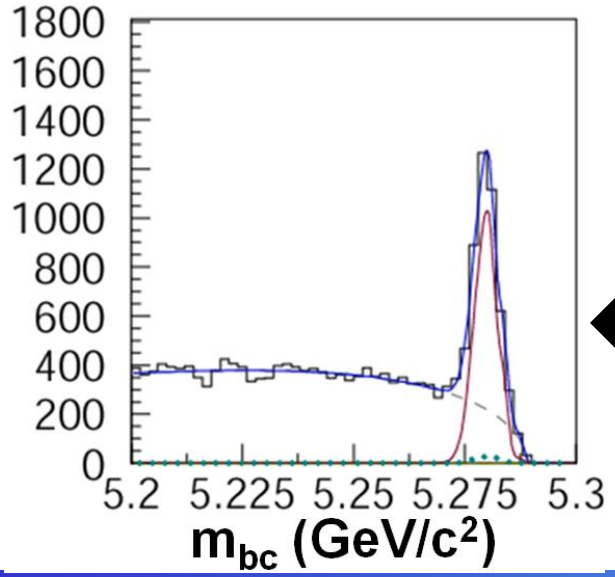
- [21aBA-4:若手奨励賞] 中浜優 (LAL-Orsay)
  - Measurement of CP-violating asymmetries in the flavor-changing neutral current decays of the B-boson
- [23pBA-9] 根岸健太郎 (東北大)
  - B → DK*崩壊分岐比の研究
- [23pBA-11] 樋口岳雄 (KEK)
  - $B^0 \to J/\psi K^0$、$D^{(*)}h$、および$D^*l\nu$崩壊を用いたCPT非対称パラメータの測定
- [23pBA-13] 上原貞治 (KEK)
  - 二光子過程におけるη中間子対生成反応の測定

Back up

B reconstruction







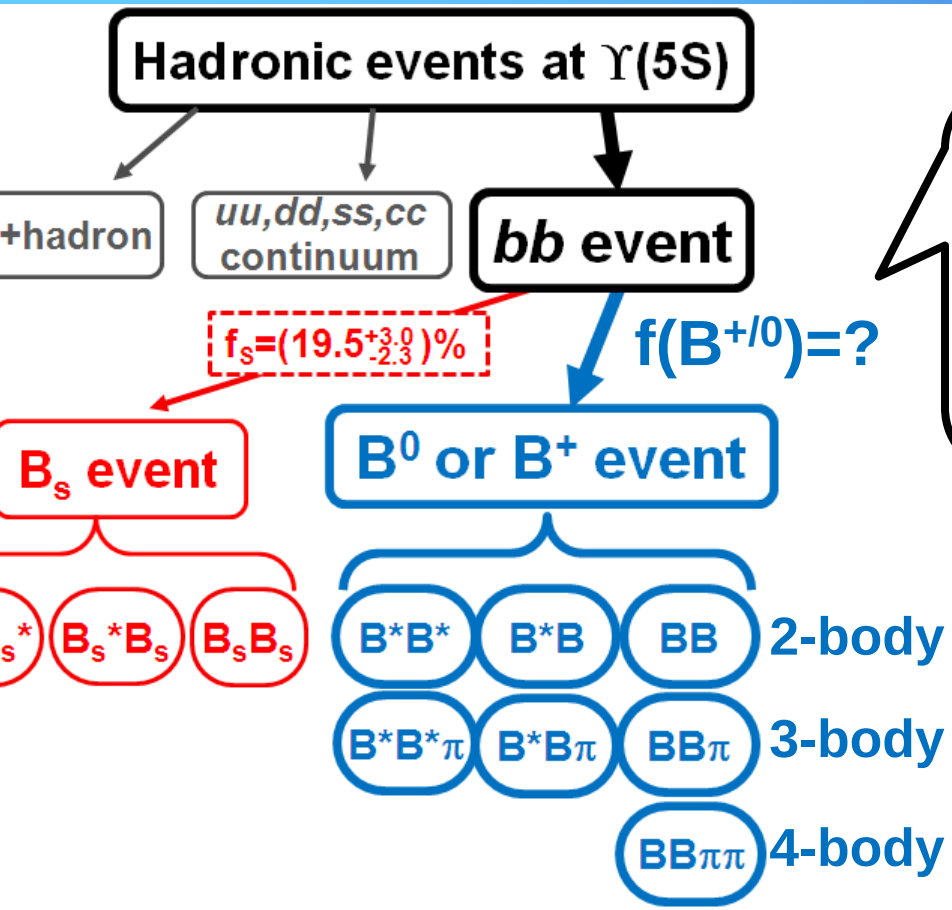
- **Energy difference(ΔE)**

$$\Delta E = E_B^* - E_{beam}^*$$

- **Beam energy constraint mass(m_{bc})**

$$m_{bc} = \sqrt{(E_{beam}^*)^2 - |p_B^*|^2}$$

$\Upsilon(5S) \rightarrow B^{(*)}B^{(*)}, B^{(*)}B^{(*)}\pi$



PRD75,012002(2007)
CLEO based on 0.42 fb^{-1}
- $f(B^{+/0})=(58.9\pm10.0\pm9.2)\%$
- Found only 2-body decays

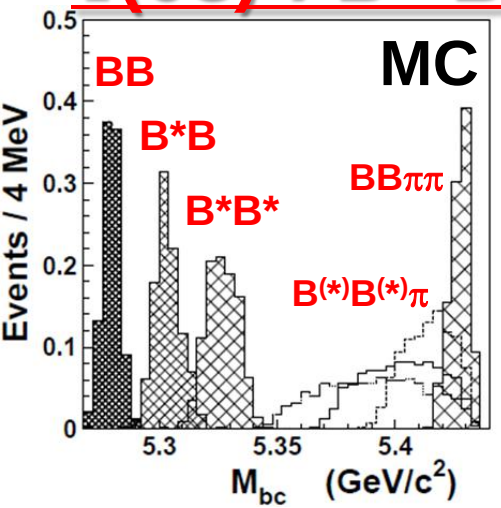
In theoretical prediction
3,4-body fraction~(0.03-0.3)%
- NPB 405, 55(1993)
- hep-ph/0805.4518(2008)

Reconstruct clean and well kwon $B^{+/0}$ decays
- $B^+ \rightarrow J/\psi K$, $D^0(K\pi)\pi$, $D^0(K3\pi)\pi$
- $B^0 \rightarrow J/\psi K^{*0}$, $D^-(K\pi\pi)\pi$

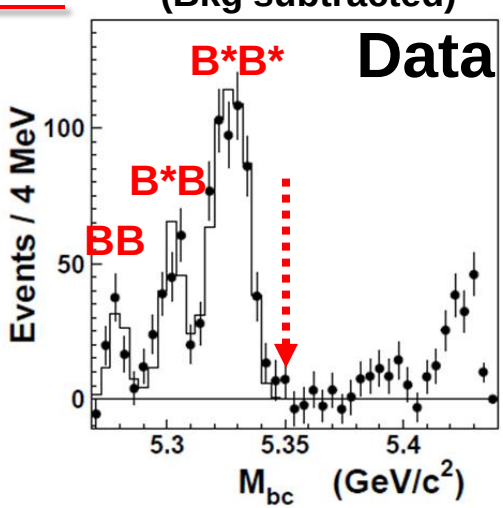
$\Upsilon(5S) \to B^{(*)}B^{(*)}, B^{(*)}B^{(*)}\pi$

Preliminary

$\Upsilon(5S) \to B^{(*)}B^{(*)}$



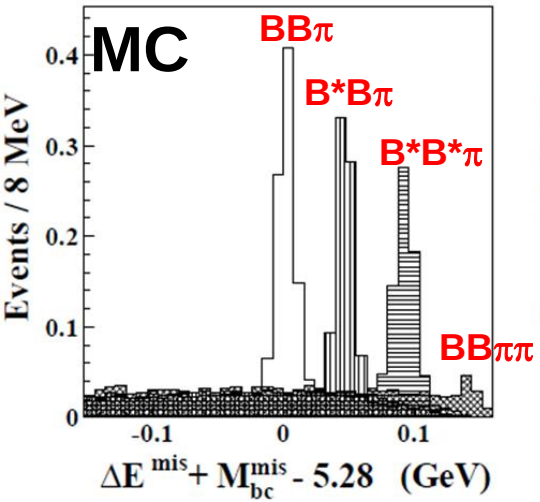
(Bkg subtracted)

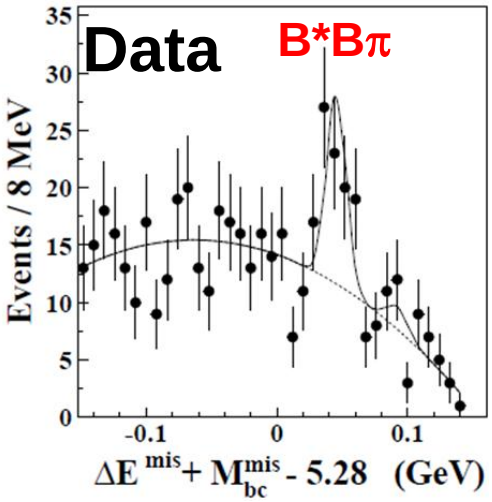


Fit M_{bc}<5.35 GeV/c²

Channel	Fraction for *bb* (%)
$B\bar{B}$	$5.5\,^{+1.0}_{-0.9} \pm 0.4$
$B\bar{B}^* + B^*\bar{B}$	$13.7 \pm 1.3 \pm 1.1$
$B^*\bar{B}^*$	$37.5\,^{+2.1}_{-1.9} \pm 3.0$
Large $M_{\rm bc}$	$17.5\,^{+1.8}_{-1.6} \pm 1.3$

$\Upsilon(5S) \to B^{(*)}B^{(*)}\pi$





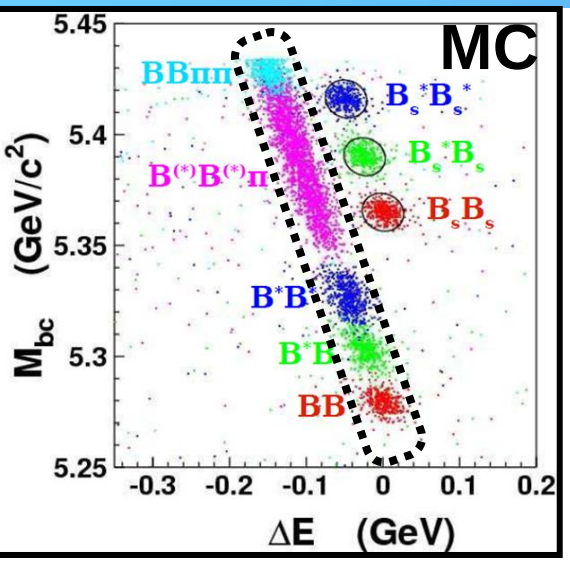
Channel	Fraction of 3,4-body, %	Fraction per $b\bar{b}$ event, %
$B\bar{B}\,\pi$	$0.2\,^{+6.8}_{-6.5}$	$0.0 \pm 1.2 \pm 0.3$
$B\bar{B}^*\pi + B^*\bar{B}\pi$	$41.6\,^{+12.1}_{-11.4}$	$7.3\,^{+2.3}_{-2.1} \pm 0.8$
$B^*\bar{B}^*\,\pi$	$5.9\,^{+7.8}_{-7.2}$	$1.0\,^{+1.4}_{-1.3} \pm 0.4$
Residual	$52.3\,^{+15.9}_{-15.0}$	$9.2\,^{+3.0}_{-2.8} \pm 1.0$
Large $M_{\rm bc}$	100.	$17.5\,^{+1.8}_{-1.6} \pm 1.3$

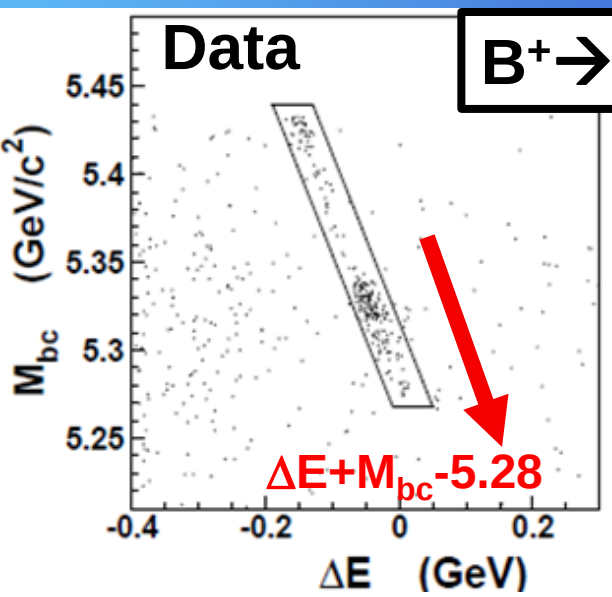
First evidence of 3-body decay with very large fraction. (Theory predicts <0.3%)

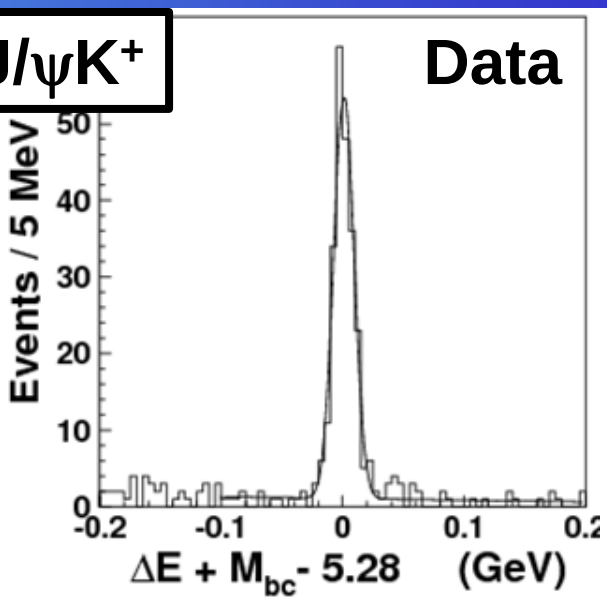
Puzzle?!

$\Upsilon(5S) \to B^{(*)}B^{(*)}, B^{(*)}B^{(*)}\pi$

Preliminary







Decay mode	$f(B^{+/0}), \%$
$B^+ \to J/\psi K^+$	$89.0^{+6.3}_{-6.1} \pm 8.0$
$B^0 \to J/\psi K^{*0}$	$85.3^{+9.2}_{-8.8} \pm 8.8$
$B^+ \to \bar{D}^0(K\pi)\pi^+$	$64.0 \pm 6.2 \pm 4.9$
$B^+ \to \bar{D}^0(K3\pi)\pi^+$	$68.3^{+8.0}_{-8.1} \pm 6.4$
$B^0 \to D^-\pi^+$	$72.9 \pm 7.4 \pm 6.4$

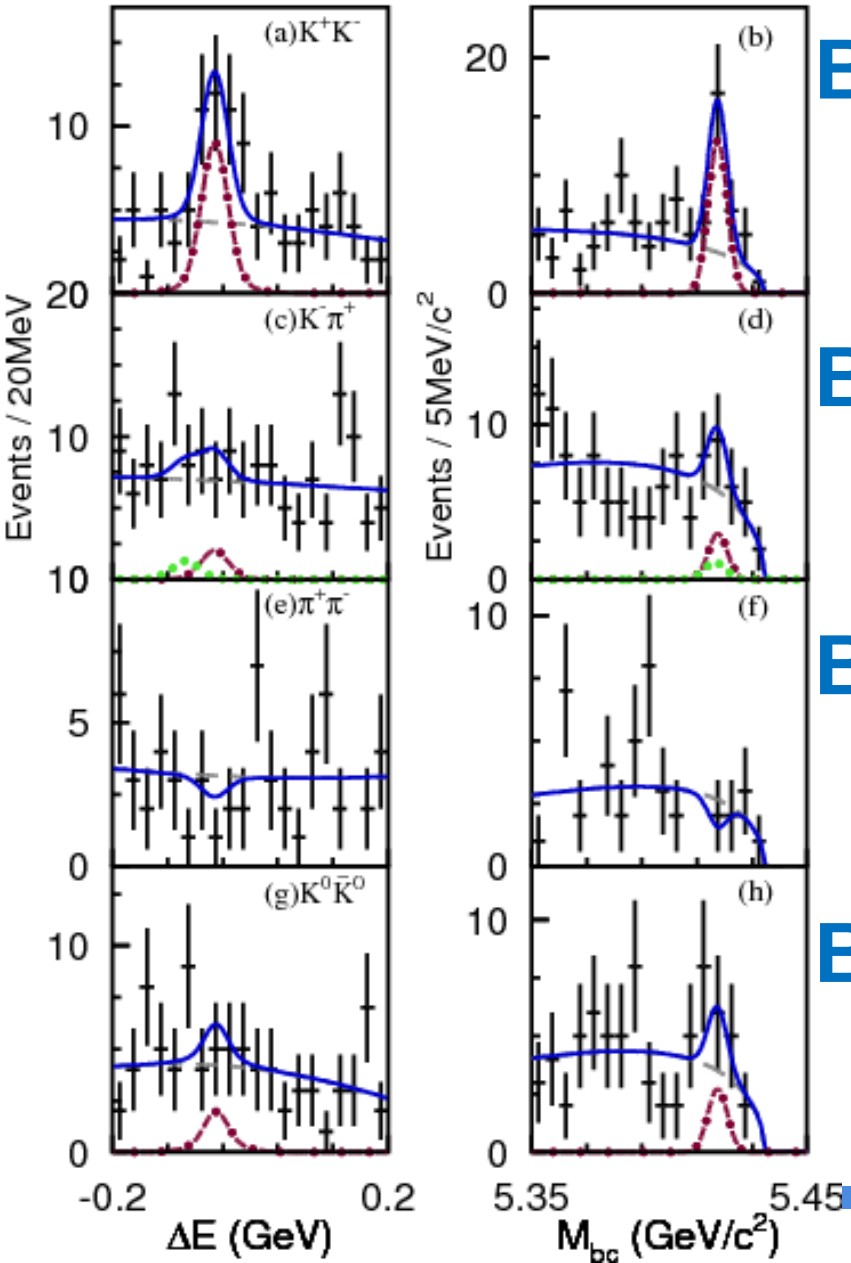
$$f(B) = \frac{N^{meas.}}{L_{int} \times \sigma_{b\bar{b}} \times \varepsilon \times Br}$$

$$= (73.7 \pm 3.2 \pm 5.1)\%$$

$$\left(f_s = (19.5^{+3.0}_{-2.3})\%\right)$$

$B_s \to h^+h^-$

Preliminary



$B_s \to K^+K^-$: observation

Br = $(3.8^{+1.0}_{-0.9} \pm 0.5 \pm 0.5(f_s)) \times 10^{-5}$

[CDF : Br = $(2.4 \pm 0.1 \pm 0.5) \times 10^{-5}$]

$B_s \to K^-\pi^+$: excess seen

Br < 3.3 x 10^{-5} (90% C.L.)

[CDF : Br = $(5.0 \pm 0.7 \pm 0.8) \times 10^{-6}$]

$B_s \to \pi^+\pi^-$

Br < 1.2 x10^{-5} (90% C.L.)

[CDF : Br < 1.2×10^{-6}]

$B_s \to K_sK_s$: first measurement

Br < 2.6 x10^{-5} (90% C.L.)

Observation of $D_s^+ \to K^+K^+\pi^-$

- **Doubly Cabibbo-suppressed(DCS) decay**
  - Not observed in D_s decay yet.
  - Help for further understanding on charm decay dynamics

- **Test SU(3) flavor symmetry: [NPB115,117 (2003)]**

$$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)} \Big/ \frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)} = \tan^8\theta_C$$

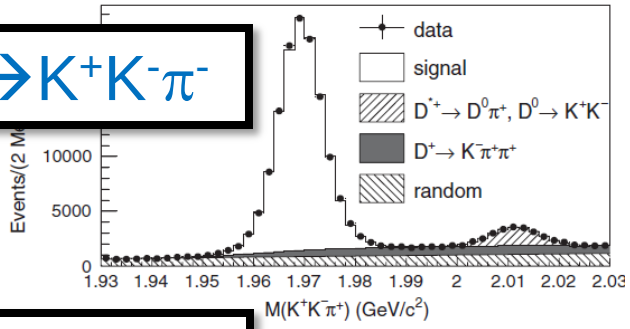
DCS / CF for D_s^+; DCS / CF for D^+

  - SU(3) breaking effect due to resonant intermediate states violates the equation above
- **Analysis data set is 605/fb**

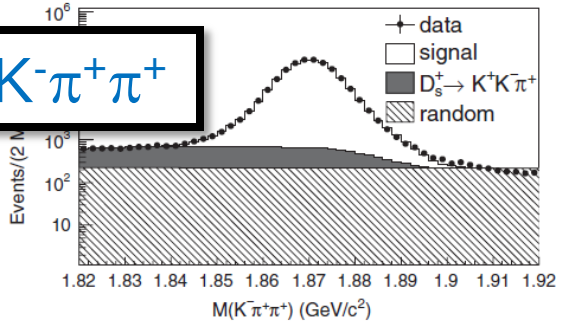
Observation of $D_s^+ \to K^+K^+\pi^-$

PRL102,221802(2009)

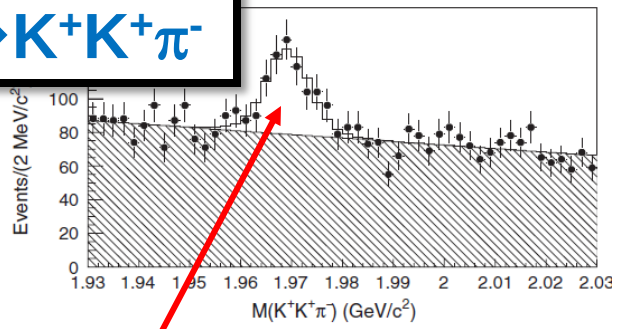
CF : $D_s^+ \to K^+K^-\pi^+$



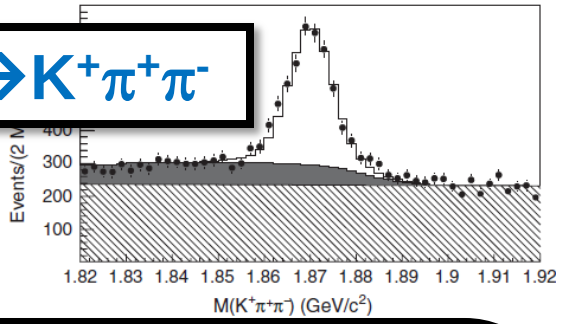
CF : $D^+ \to K^-\pi^+\pi^+$



DCS : $D_s^+ \to K^+K^+\pi^-$



DCS : $D^+ \to K^+\pi^+\pi^-$



- **First observation of $D_s^+ \to K^+K^+\pi^-$ (9.1σ)**

Branching fraction	Belle	World average [3]
$\mathcal{B}(D^+ \to K^+\pi^+\pi^-)$	$(5.2 \pm 0.2 \pm 0.1) \times 10^{-4}$	$(6.2 \pm 0.7) \times 10^{-4}$
$\mathcal{B}(D_s^+ \to K^+K^+\pi^-)$	$(1.3 \pm 0.2 \pm 0.1) \times 10^{-4}$	$(2.9 \pm 1.1) \times 10^{-4}$

- **Consistent with SU(3) flavor symmetry**

$$\frac{\mathcal{B}(D_s^+ \to K^+K^+\pi^-)}{\mathcal{B}(D_s^+ \to K^+K^-\pi^+)} \frac{\mathcal{B}(D^+ \to K^+\pi^+\pi^-)}{\mathcal{B}(D^+ \to K^-\pi^+\pi^+)} = (1.57 \pm 0.21)\cdot\tan^8\theta_C$$

Study of $D_{(s)}^{+} \rightarrow K_s h^{+}$

- **Measurement of ration $R(D_{(S)}^{+})$ = SCS/CF decays**
  - Help for better understanding on SU(3) symmetry

Mode	PDG	CLEO (arXiv:0906.3198v1)
$Br(D^{+} \rightarrow K_s K^{+}) / Br(D^{+} \rightarrow K_s \pi^{+})$	$0.189 \pm 0.016 \pm 0.007$	0.199 ± 0.007
$Br(D_s^{+} \rightarrow K_s \pi^{+}) / Br(D_s^{+} \rightarrow K_s K^{+})$	$0.082 \pm 0.009 \pm 0.002$	0.085 ± 0.007

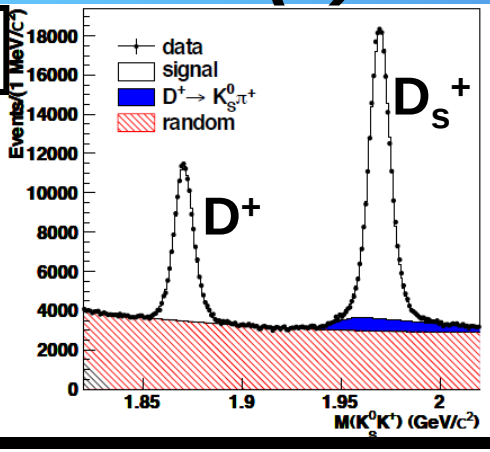
- **In SM, $A_{CP}(D_{(s)}^{+} \rightarrow K_s h^{+}) \sim O(0.1\%)$ or lower is expected**
  - O(1%) A_{CP} would indicate strong evidence of NP

	PDG	CLEO (arXiv:0906.3198v1)
$D^{+} \rightarrow K_s \pi^{+}$	-0.9 ± 0.9	$-1.3 \pm 0.7 \pm 0.3$
$D^{+} \rightarrow K_s K^{+}$	$+7 \pm 6$	$-0.2 \pm 1.5 \pm 0.9$
$D_s^{+} \rightarrow K_s \pi^{+}$	$+27 \pm 11$	$-16.3 \pm 7.3 \pm 0.3$
$D_s^{+} \rightarrow K_s K^{+}$	$+4.9 \pm 2.3$	$-4.7 \pm 1.8 \pm 0.9$

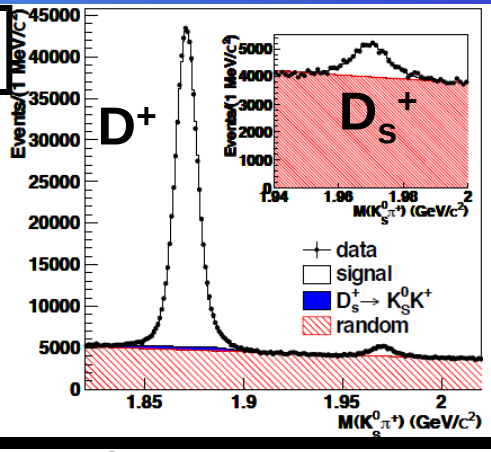
Study of $D_{(s)}^+ \to K_s h^+$

PRD 80,111101(2009)
arXiv:1001.3202

$D_{(S)}^+ \to K_S K^+$



$D_{(S)}^+ \to K_S \pi^+$



- **Most precise measurements (w/ 605 fb^{-1})**

Mode	Belle	CLEO
$Br(D^+ \to K_S K^+)$ / $Br(D^+ \to K_S \pi^+)$	0.1899±0.0011±0.0022	0.199±0.007
$Br(D_s^+ \to K_S \pi^+)$ / $Br(D_s^+ \to K_S K^+)$	0.0803±0.0024±0.0019	0.085±0.007

- **Null A_{CP} , but most stringent constraint (w/ 673 fb^{-1})**

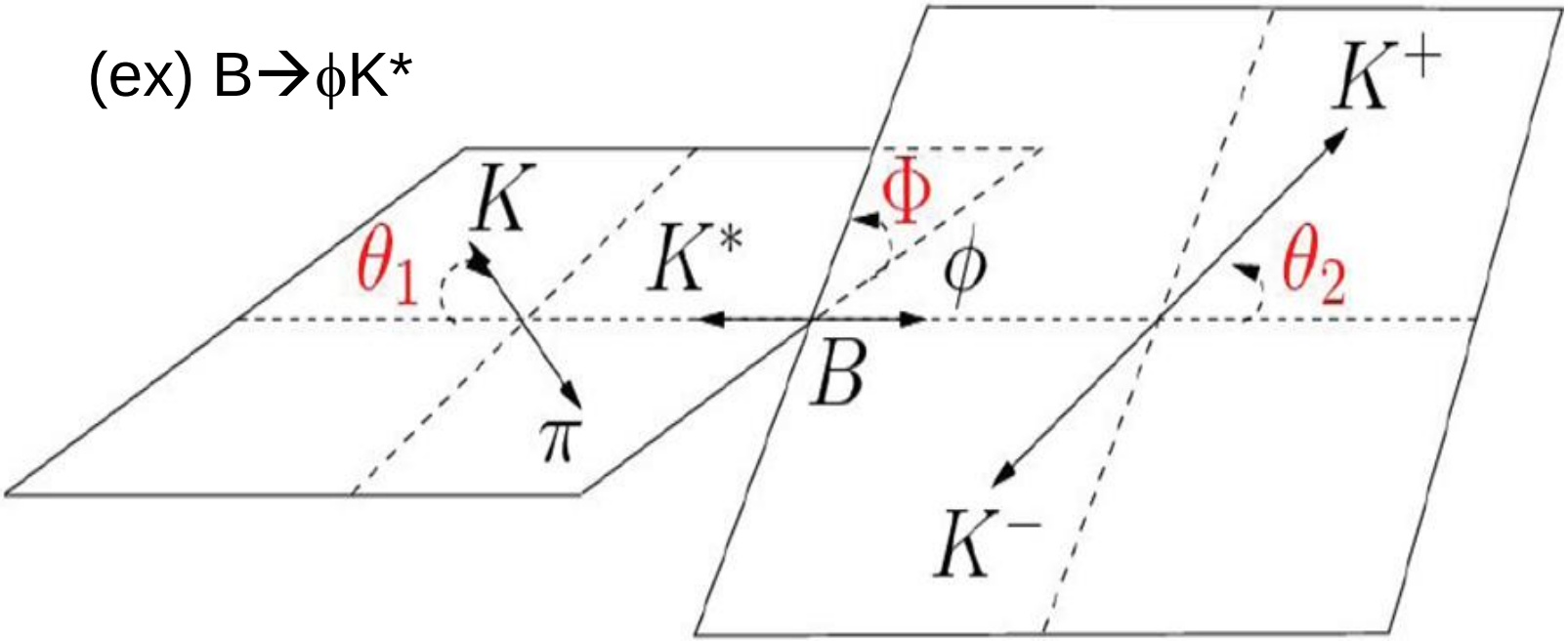
	Belle	CLEO
$D^+ \to K_S \pi^+$	-0.71±0.19±0.20	-1.3±0.7±0.3
$D^+ \to K_S K^+$	+5.45±2.50±0.33	-0.2±1.5±0.9
$D_s^+ \to K_S \pi^+$	-0.16±0.58±0.25	-16.3±7.3±0.3
$D_s^+ \to K_S K^+$	+0.12±0.36±0.22	-4.7±1.8±0.9

$\Delta\Gamma_s/\Gamma_s$ from $B_s \to D^{(*)+}D^{(*)-}$

Source	$D_s^+ D_s^-$ $+\sigma$	$-\sigma$	$D_s^{*} D_s$ $+\sigma$	$-\sigma$	$D_s^{*+} D_s^{*-}$ $+\sigma$	$-\sigma$
DATA/MC calibration	0.3	0.3	0.0	0.1	0.2	0.1
CR PDF	0.7	0.7	0.2	0.3	0.5	0.4
Background PDF	1.1	1.3	1.9	2.0	3.0	3.0
WC+CF PDF	0.3	0.3	1.5	1.5	4.4	4.4
WC/CF fraction	0.2	0.2	5.0	5.0	8.7	8.7
Continuum suppression	1.8	1.8	1.8	1.8	1.8	1.8
Best candidate selection	6.9	0.0	2.2	0.0	2.2	0.0
$K^{\pm}$ identification	9.5	9.5	10.0	10.0	10.3	10.3
K_s	1.0	1.0	1.0	1.0	1.0	1.0
π^0	1.1	1.1	1.1	1.1	1.0	1.0
γ	-	-	3.8	3.8	7.6	7.6
Tracking	6.2	6.2	6.2	6.2	6.2	6.2
Polarization	0.2	0.0	0.8	0.5	0.7	0.3
Acceptance (ε)	1.1	1.1	0.9	0.8	1.0	1.0
$D_s^{(*)}$ BF's	12.4	12.4	12.4	12.4	12.5	12.5
Luminosity			± 1.3			
$\sigma_{\Upsilon(5S)}$			± 4.6			
$f_{B_s^{(*)}\overline{B}_s^{(*)}}$			± 15			
$N_{B_s^*\overline{B}_s^*}/N_{B_s^{(*)}\overline{B}_s^{(*)}}$			$^{+4.2}_{-4.4}$			
Total	24.6	23.7	24.8	24.8	27.2	27.2

$B \to VV$ (angular analysis)

(ex) $B \to \phi K^*$



Decay rate can be formulated:

$$\frac{1}{\Gamma}\frac{d^2\Gamma}{d\cos\theta_1 d\cos\theta_2} = \frac{9}{4}\left(f_L \cos^2\theta_1 \cos^2\theta_2 + \frac{1}{4}(1-f_L)\sin^2\theta_1 \sin^2\theta_2 \right)$$

Longitudinal Transverse

f_L can be obtained by fitting to $\cos\theta_1$ and $\cos\theta_2$

Study of $D_{(s)}^+ \to K_s h^+$

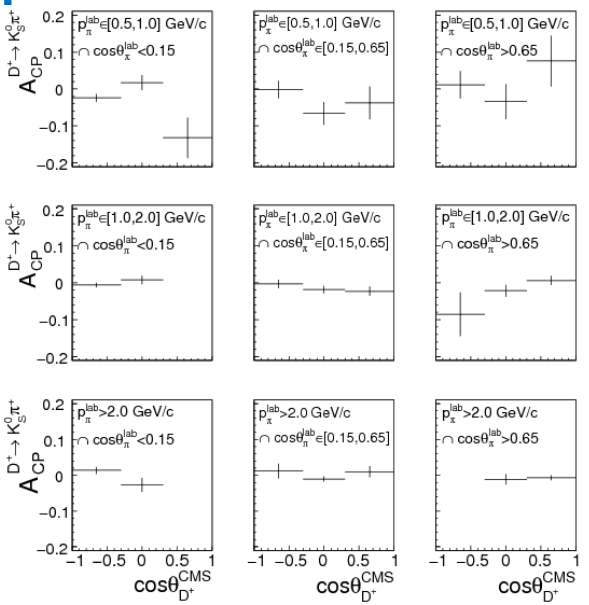
arXiv:1001.3202

$$A_{\rm rec}^{X^+\to K_S^0 h^+} = \frac{N_{\rm rec}^{X^+\to K_S^0 h^+} - N_{\rm rec}^{X^-\to K_S^0 h^-}}{N_{\rm rec}^{X^+\to K_S^0 h^+} + N_{\rm rec}^{X^-\to K_S^0 h^-}} = A_{CP}^{X^+\to K_S^0 h^+} + A_{FB}^{X^+} + A_\epsilon^{h^+}$$

- A_{FB} : Forward-backward asymmetry due to γ^*-Z^0 interference in $e^+e^- \to c\bar{c}$
- $A\varepsilon$: Asymmetry in charged track reconstruction

Control sample $D_s^+ \to \phi\pi^+$ for $D_{(s)}^+ \to K_s\pi^+$

- Assume A_{FB} is same for D and D_s
- Assume $A_{CP}(D_s^+ \to \phi\pi^+) = 0$
  - $A_{rec}(D_s^+ \to \phi\pi^+) = A_{FB}(D_s^+) + A\varepsilon(\pi^+)$
- 3D map for $p_{lab}(h^+)$, $\cos\theta(h^+)$, $\cos\theta(D_{(s)}^+)$



Study of $D_{(s)}^+ \to K_s h^+$

arXiv:1001.3202

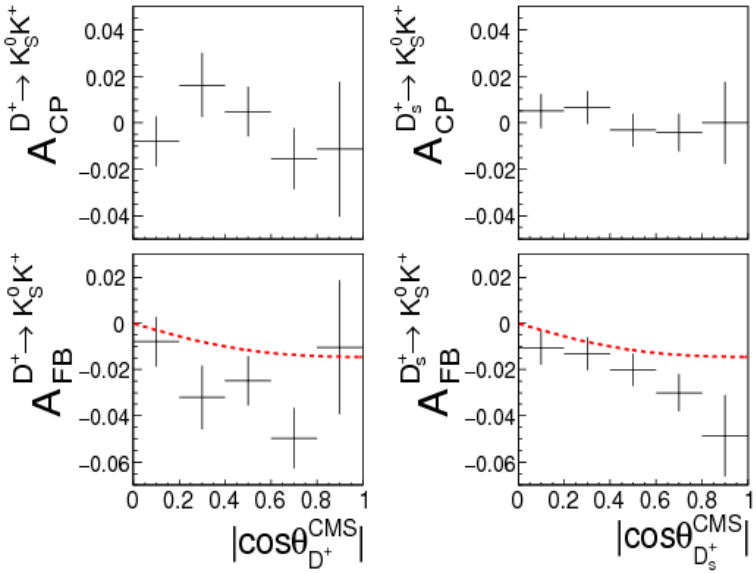
Control sample $D_s^+ \to \phi\pi^+$ and $D^0 \to K^-\pi^+$ for $D_{(s)}^+ \to K_s K^+$

- Assume A_{FB} is same for D and D_s
- Assume $A_{CP}(D_s^+ \to \phi\pi^+) = A_{CP}(D^0 \to K^-\pi^+) = 0$
- Then, we can obtaine only $A\varepsilon(K)$
  - $A_{rec}(D_s^+ \to \phi\pi^+) = A_{FB}(D_s) + A\varepsilon(\pi)$
  - $A_{rec}(D^0 \to K^-\pi^+) = A_{FB}(D^0) + A\varepsilon(\pi) + A\varepsilon(K)$
- 3D map for $p_{lab}(h^+)$, $\cos\theta(h^+)$, $\cos\theta(D_{(s)}^+)$

$$A_{\rm rec}^{D_{(s)}^+ \to K_S^0 K^+_{\rm corr}} = A_{\rm rec}^{D_{(s)}^+ \to K_S^0 K^+} - A_\epsilon^{K^+}$$

$$= A_{FB}^{D_{(s)}^+} + A_{CP}^{D_{(s)}^+ \to K_S^0 K^+}$$

$$A_{CP}^{D_{(s)}^+ \to K_S^0 K^+} = [A_{\rm rec}^{D_{(s)}^+ \to K_S^0 K^+_{\rm corr}}(\cos\theta^{\rm CMS}_{D_{(s)}^+}) + A_{\rm rec}^{D_{(s)}^+ \to K_S^0 K^+_{\rm corr}}(-\cos\theta^{\rm CMS}_{D_{(s)}^+})]/2$$

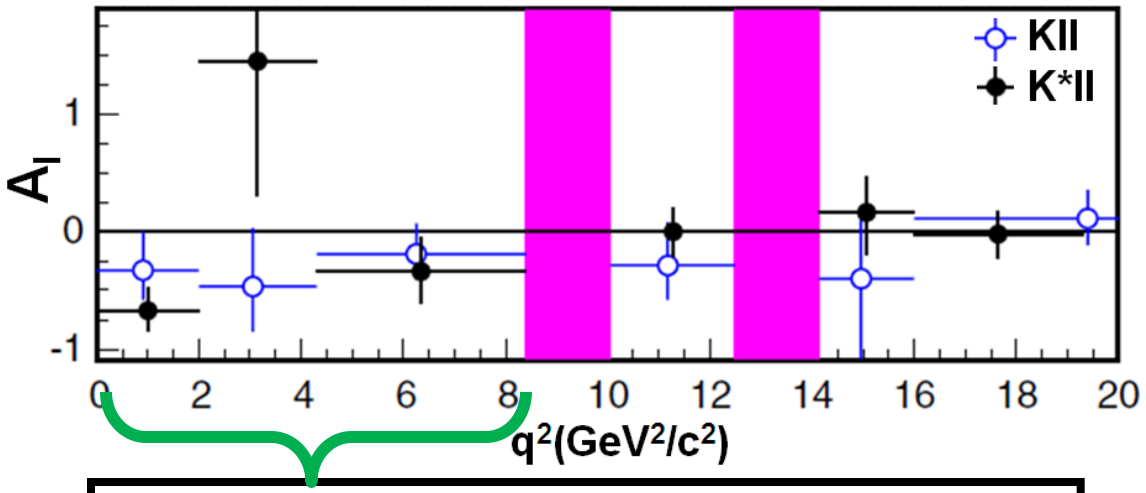


Source		$\sigma A_{CP}^{D^+\to K^0_S\pi^+}$ (%)	$\sigma A_{CP}^{D^+_s\to K^0_S\pi^+}$ (%)	$\sigma A_{CP}^{D^+\to K^0_S K^+}$ (%)	$\sigma A_{CP}^{D^+_s\to K^0_S K^+}$ (%)
$A_{\rm rec}^{D_s^+\to\phi\pi^+}$	$D_s^+\to\phi\pi^+$ statistics	0.18	0.18	-	-
	$A_{\rm rec}^{D_s^+\to\phi\pi^+}$ binning	0.03	0.03	-	-
	$M(K^+K^-)$ window	0.03	0.03	-	-
$A_\epsilon^{K^-}$	$D_s^+\to\phi\pi^+$ statistics	-	-	0.18	0.18
	$A_{\rm rec}^{D_s^+\to\phi\pi^+}$ binning	-	-	0.03	0.03
	$M(K^+K^-)$ window	-	-	0.03	0.03
	$D^0\to K^-\pi^+$ statistics	-	-	0.06	0.06
	$A_\epsilon^{K^-}$ binning	-	-	0.04	0.04
	Possible $A_{CP}^{D^0\to K^-\pi^+}$	-	-	0.01	0.01
$\cos\theta_{D^+_{(s)}}^{\rm CMS}$ binning		-	-	0.06	0.06
Fitting		0.04	0.27	0.12	0.05
$K^0/\bar{K}^0$-material effects		0.06	0.06	0.06	0.06
Total		0.20	0.33	0.25	0.22

$B \to K^{(*)} l^+ l^-$ (Isospin asymmetry)

PRL 103, 171801(2009)

$$A_I \equiv \frac{(\tau_{B^+}/\tau_{B^0}) \times B(B^0 \to K^{(*)0} ll) - B(B^\pm \to K^{(*)\pm} ll)}{(\tau_{B^+}/\tau_{B^0}) \times B(B^0 \to K^{(*)0} ll) + B(B^\pm \to K^{(*)\pm} ll)}$$



$$Kll = -0.31^{+0.17}_{-0.14} \pm 0.08 \quad \text{with} \sigma = 1.75$$

$$K^* ll = -0.29^{+0.16}_{-0.16} \pm 0.09 \quad \text{with} \sigma = 1.37$$

$$K^{(*)} ll = -0.30^{+0.12}_{-0.11} \pm 0.08 \quad \text{with} \sigma = 2.22$$

- InSM, A_I is expected to be zero
- Our results are slightly negative value…

$B \to K^{(*)} l^+ l^-$ ($R(K^{(*)})$ and A_{CP})

PRL 103, 171801(2009)

- **Lepton flavor ratio :** $R_{K^{(*)}} = B(K^{(*)}\mu^+\mu^-) / B(K^{(*)}e^+e^-)$
  - In SM, R(K*) ~0.75 , R(K)~1.0 are expected
  - $R_{K(*)}$ is sensitive to neutral SUSY Higgs if tanβ is large

Mode	$R_{K(*)}$	SM
Kll	1.03±0.19±0.06	~1.0
K*ll	0.83±0.17±0.08	~0.75

- **CP asymmetry :** $A_{CP} = (N_{\bar{B}} - N_B)/(N_{\bar{B}} + N_B)$
  - In SM, A_{CP} is expected to be very small

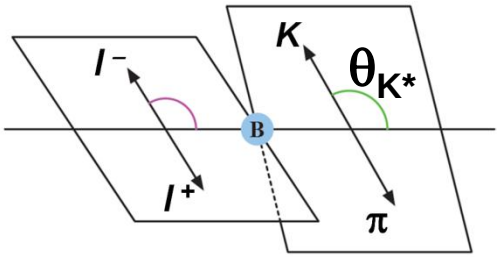
Mode	A_{CP}
Kll	+0.04±0.10±0.02
K*ll	-0.10±0.10±0.01

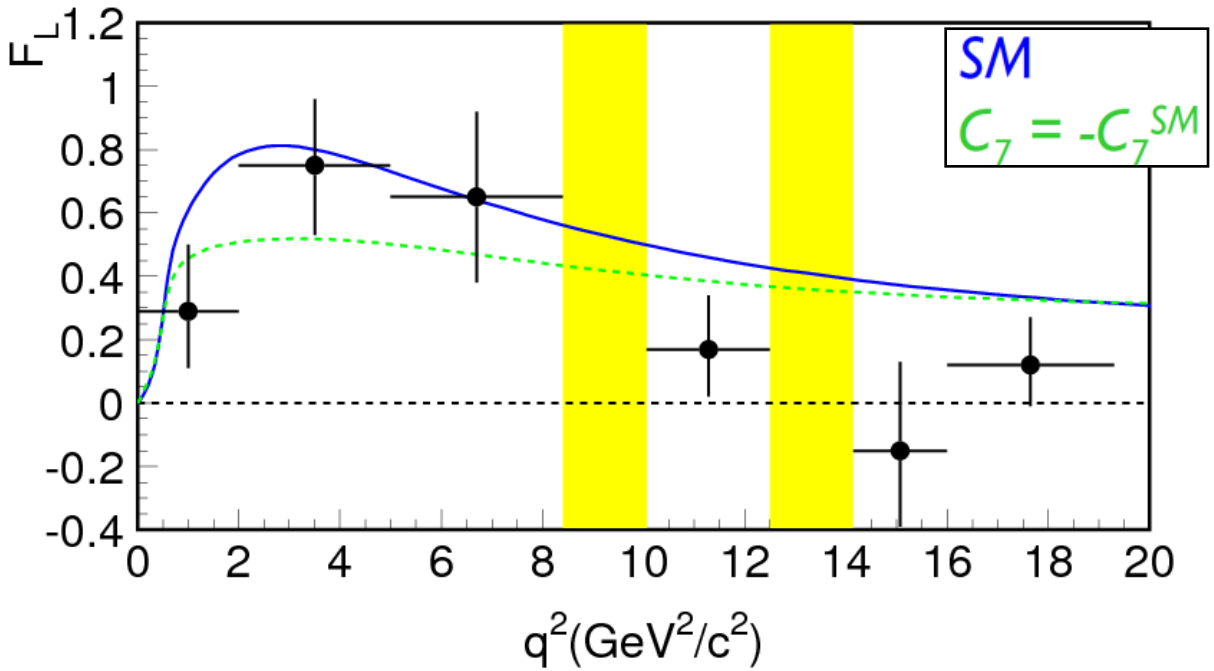
$B \to K^{(*)} l^+ l^-$ (K* polarization)

PRL 103, 171801(2009)

- Longitudinal K* polarization F_L by fitting to cos θ_{K^*}
- Important for model independent A_{FB}

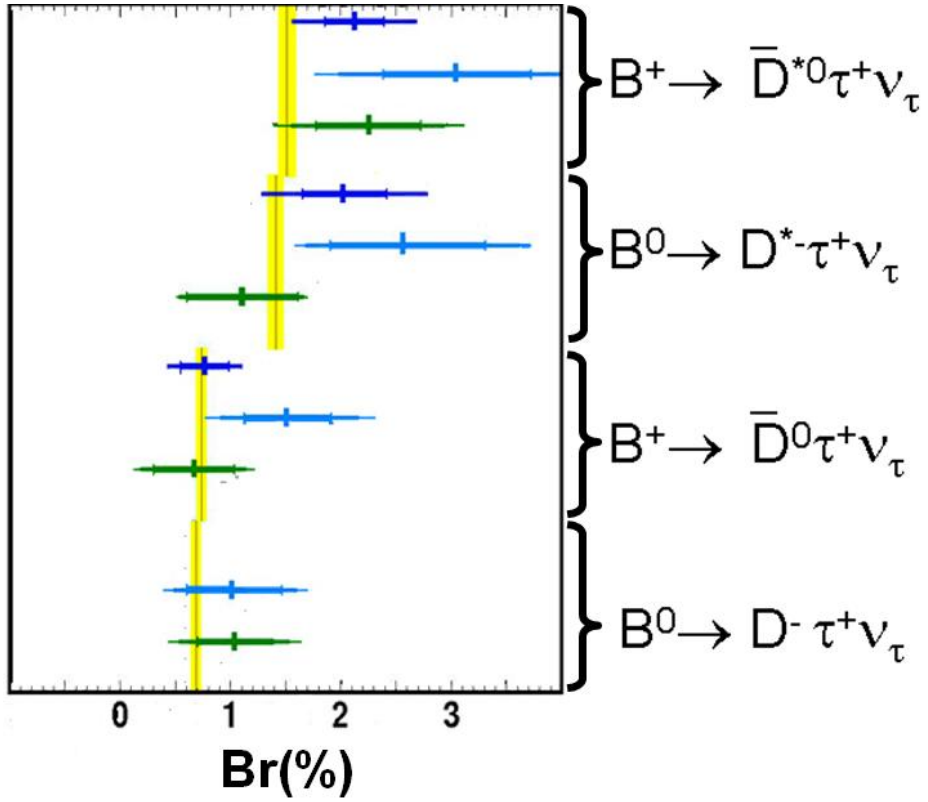
$$\frac{d\Gamma}{d\cos\theta_{K^*}} = \frac{3}{2}F_L\cos^2\theta_{K^*} + \frac{3}{4}(1-F_L)(1-\cos^2\theta_{K^*})$$





$B^+ \to \bar{D}^{(*)0}\tau\nu$ (657MBB)

Preliminary



"exclusive" B_{tag} reconstruction
"inclusive" B_{tag} reconstruction

this analysis and PRL 99, 191807(2007)

Belle preliminary, arXiv:0910.4301 [hep-ex]

BaBar PRL 100, 021801(2008)

SM

C.-H. Chen and C.-Q. Geng, JHEP 0610, 053 (2006)