# Results and prospects of Y(5S) running at Belle.

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***LPHE seminar***

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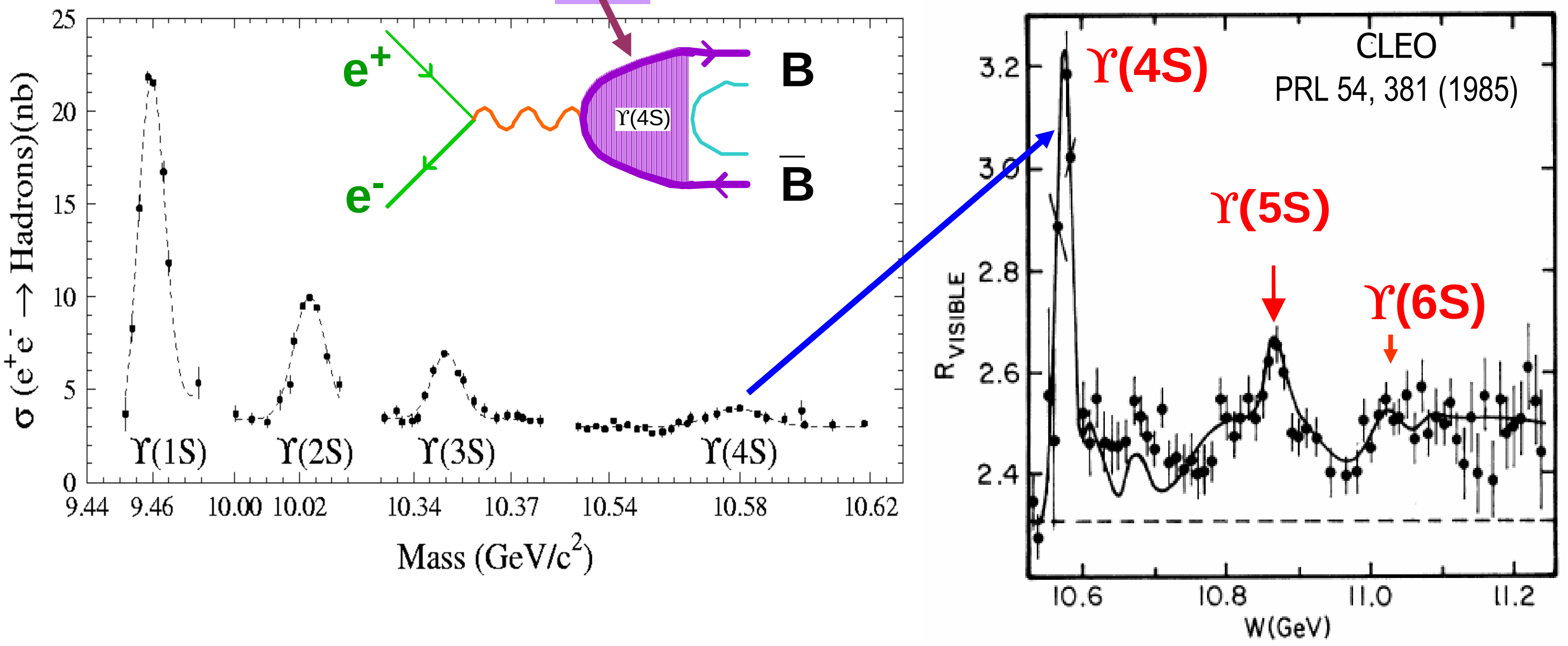
# Outline

- Introduction.
- Recent Belle measurements at Υ(5S).
- Prospects of $B_s$ meson (and other) studies at Υ(5S).
- My thoughts (speculations) about Υ(5S) -> Υ(6S) ->…   .
- Conclusion.

# $e^+ e^-$ hadronic cross section

$b\bar{b}$ + $(c\bar{c}, s\bar{s}, u\bar{u}, d\bar{d})$



Resonance to continuum hadron production ratios are **Y(4S)/Cont ~ 1./3.5** and **Y(5S)/Cont ~ 1./10.**

# Running at Y(4S) and Y(5S)

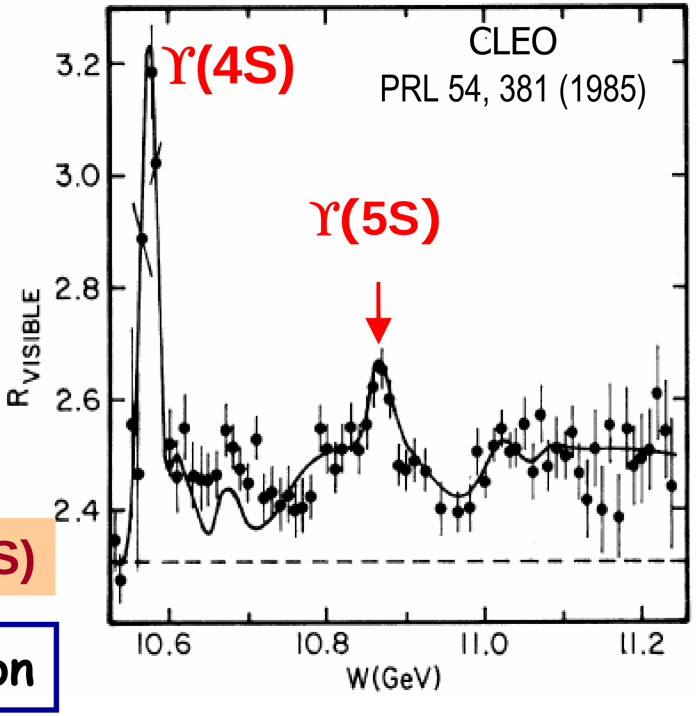
Asymmetric energy $e^+e^-$ colliders (*B* Factories) running at Y(4S) :
**Belle** and **BaBar**

1985: CESR (CLEO,CUSB) ~ 0.1 $pb^{-1}$ at Y(5S)

2003: CESR (CLEO III) ~ 0.42 $fb^{-1}$ at Y(5S)

2005: Belle, KEKB ~ 1.86 $fb^{-1}$ at Y(5S)

2006, June 9-31: Belle, KEKB ~21.7 $fb^{-1}$ at Y(5S)



CLEO
PRL 54, 381 (1985)

$e^+$ $e^-$ ->Y(4S) -> $B\bar{B}$, where B is $B^+$ or $B^0$ meson

$e^+$ $e^-$ -> Y(5S) -> $B\bar{B}$, $B^*\bar{B}$, $B^*\bar{B}^*$, $B\bar{B}\pi$, $B\bar{B}\pi\pi$, $B_s\bar{B}_s$, $B_s^*\bar{B}_s$, $B_s^*\bar{B}_s^*$

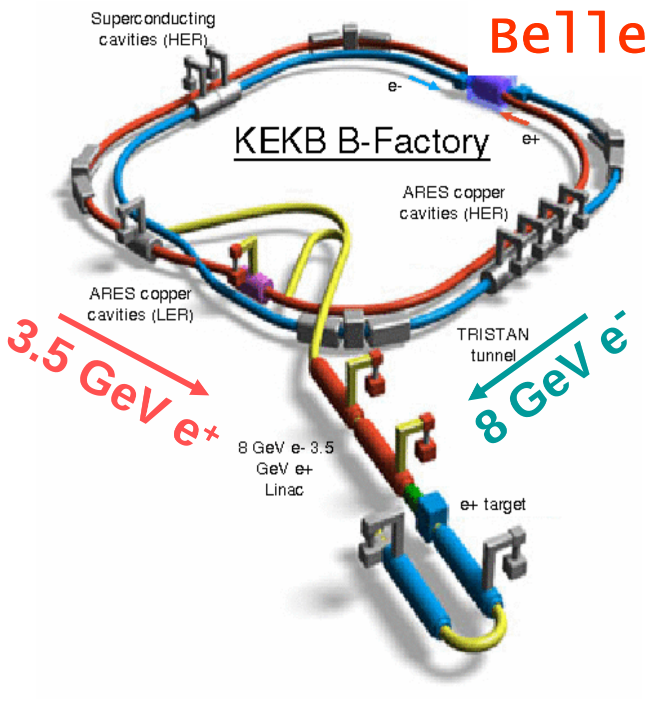
where $B^*$ -> B $\gamma$ and $B_s^*$ -> $B_s$ $\gamma$

M(Y(5S)) = 10865 ± 8 MeV/$c^2$ (PDG)

Γ(Y(5S)) = 110 ± 13 MeV/$c^2$ (PDG)

$B_s$ rate is ~10-20% => high lumi $e^+e^-$ collider at Y(5S) -> $B_s$ factory.

# First Y(5S) runs at the KEKB $e^+e^-$ collider



**Electron and positron beam energies were increased by 2.7% (same Lorentz boost $\beta\gamma = 0.425$) to move from Y(4S) to Y(5S).**

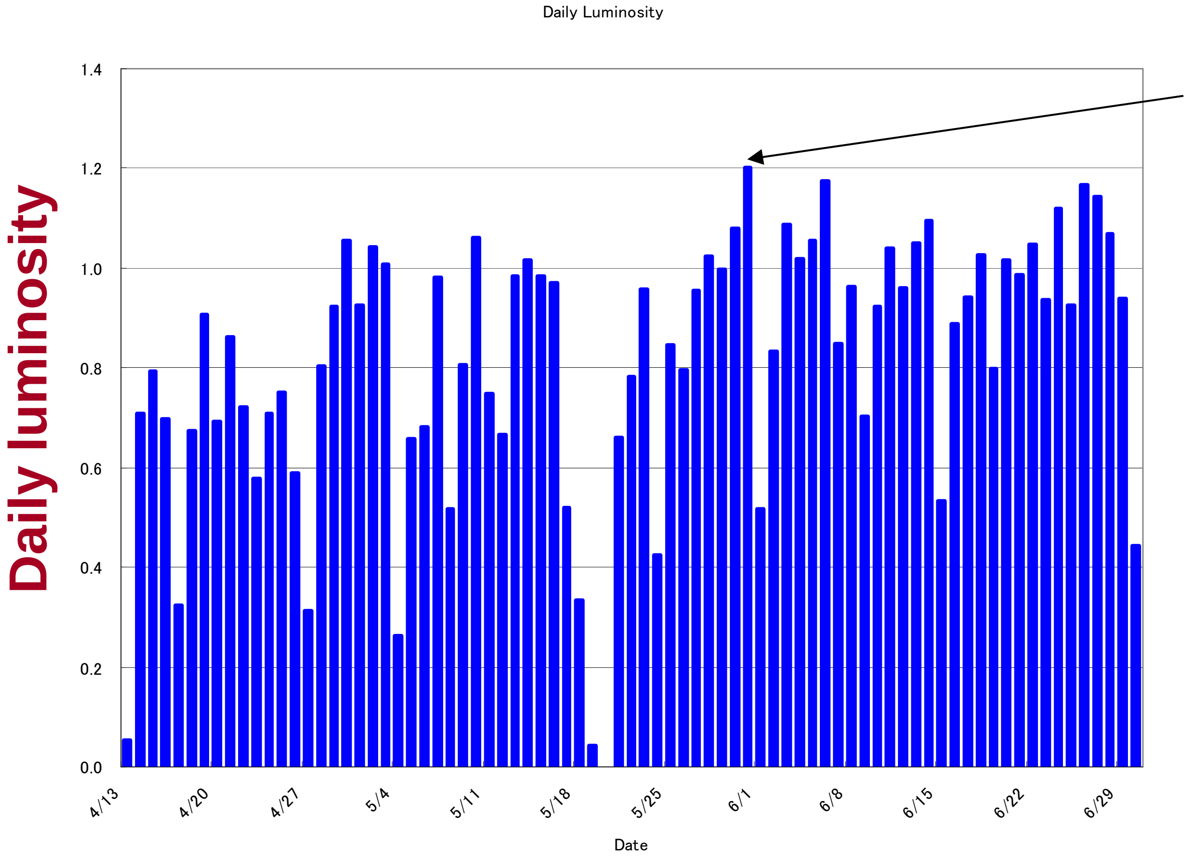
**No modifications are required for Belle detector, trigger system or software to move from Y(4S) to Y(5S).**

***Integrated luminosity of ~1.86 $\text{fb}^{-1}$ at 2005 and ~21.6 $\text{fb}^{-1}$ at 2006 was taken by Belle detector at Y(5S). The same luminosity per day was taken at Y(5S) as it is at Y(4S).***

→ Very smooth running

# New 2006 runs at Y(5S) at Belle

Belle collected data at Y(5S): June 9-June 31, 2006 => 21.7 fb$^{-1}$



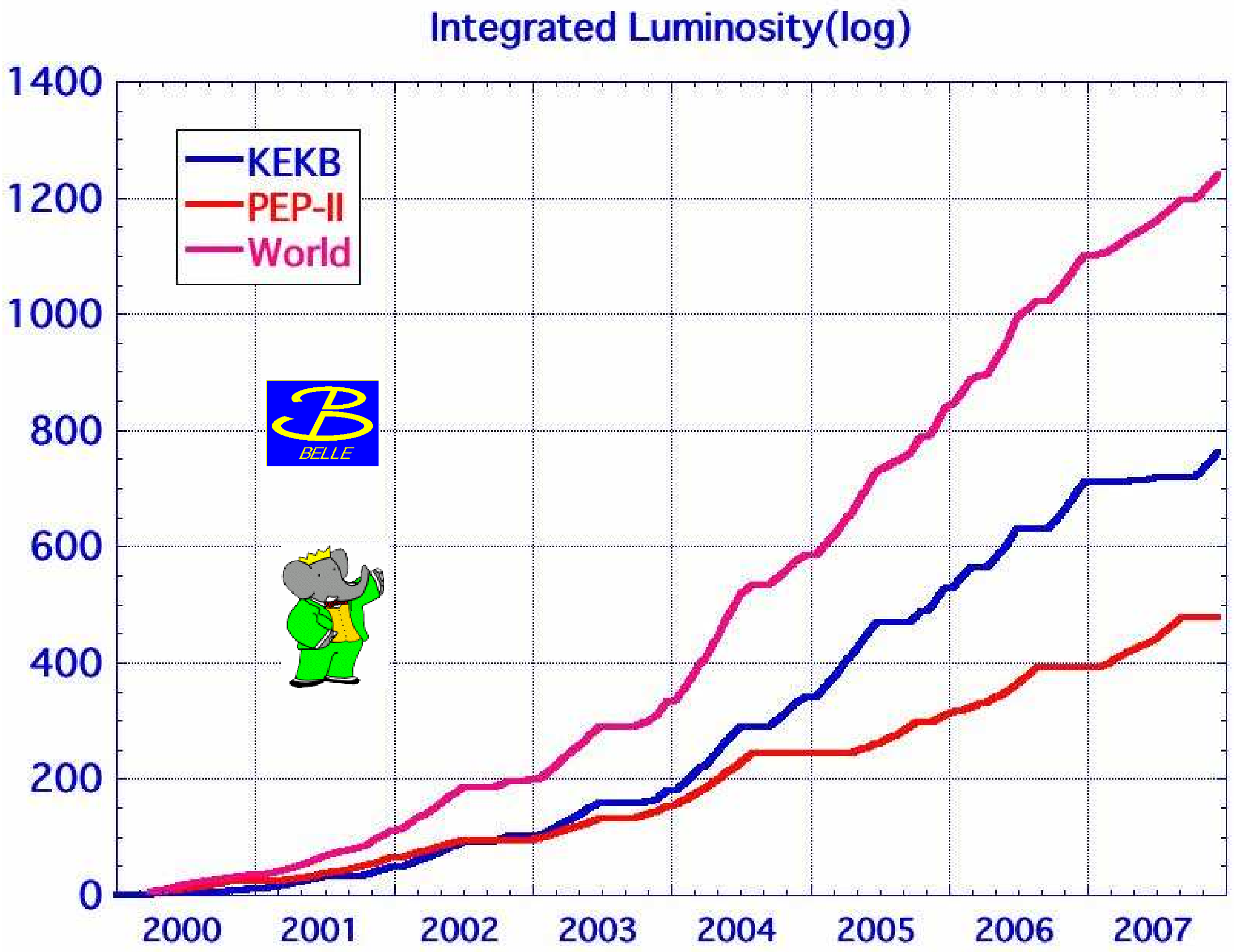
**Exceeded 1.2fb$^{-1}$/day for the first time at Y(4S).**

Correction factor(1.056) is necessary for 5S run due to smaller Bhabha Cross section.

**Off-resonance run**

**5S run ~22 fb$^{-1}$**

# Integrated luminosity



**Belle (10 Mar 08)**

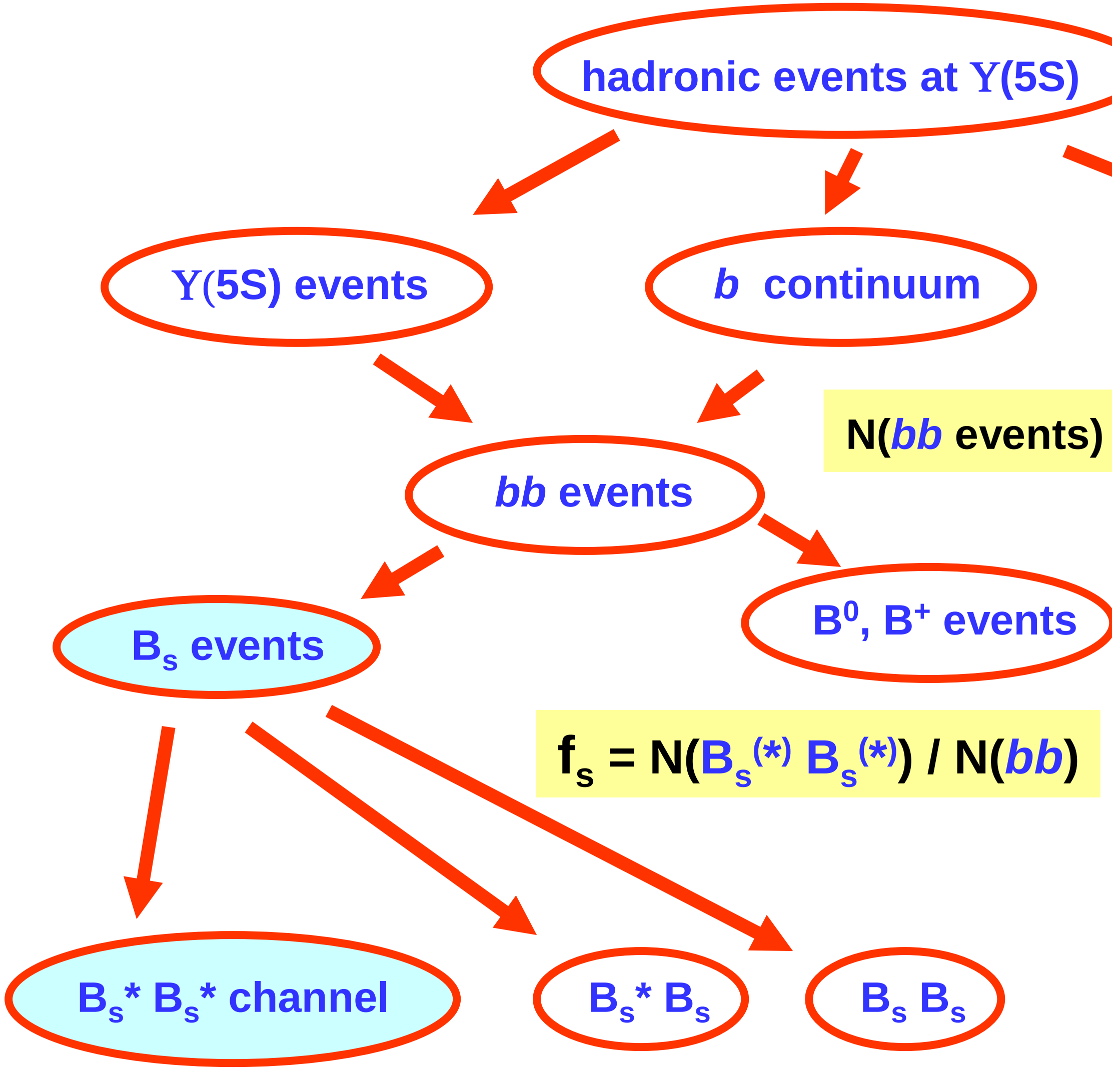
**All: ~778 fb$^{-1}$ ,**

**Cont: ~68 fb$^{-1}$ ,**

**Y(5S): ~24 fb$^{-1}$**

Belle + BaBar > 1 ab$^{-1}$

# Hadronic event classification



hadronic events at $\Upsilon(5S)$

$\Upsilon(5S)$ events

*b* continuum

*u,d,s,c* continuum

*bb* events

$B^0$, $B^+$ events

$B_s$ events

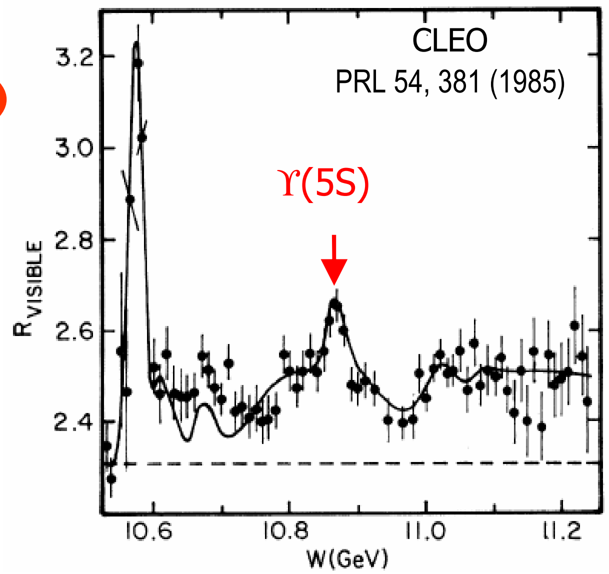
$B_s^* B_s^*$ channel

$B_s^* B_s$

$B_s B_s$

**N(*bb* events) = N(hadr, 5S) - N(*udsc*, 5S)**

$$f_s = N(B_s^{(*)} B_s^{(*)}) / N(bb)$$



CLEO
PRL 54, 381 (1985)

# Number of *bb* events, number of $B_s$ events

Continuum event yield ($u\bar{u}, d\bar{d}, s\bar{s}, c\bar{c}$) is estimated using data taken below the Υ(4S):

$$N_{cont}(5S) = N_{cont}(E=10.519) * \mathcal{L}(5S) / \mathcal{L}(cont) * (E_{cont}/E_{5S})^2 \ (\varepsilon_{5S}/\varepsilon_{cont})$$

Υ(5S) : Lumi = $1.857 \pm 0.001$ (*stat*) $fb^{-1}$

Cont (below 4S) : $3.670 \pm 0.001$ (*stat*) $fb^{-1}$

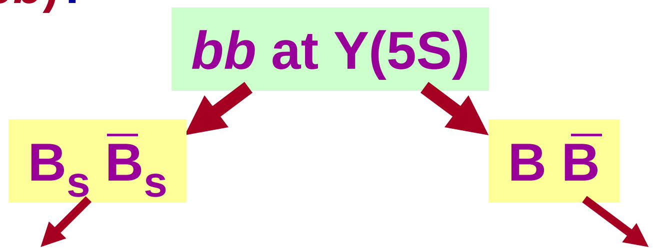
$N_{bb}(5S) =$ 561,000 ± 3,000 ± 29,000 events

=> 5% uncertainty from luminosity ratio

$N_{bb}(5S) / fb^{-1} = 302{,}000 \pm 15{,}000$

CLEO: $N_{bb}(5S)/ fb^{-1} = 310{,}000 \pm 52{,}000$

How to determine $f_s = N(B_s^{(*)} B_s^{(*)}) / N(bb)$?



*bb* at Υ(5S)

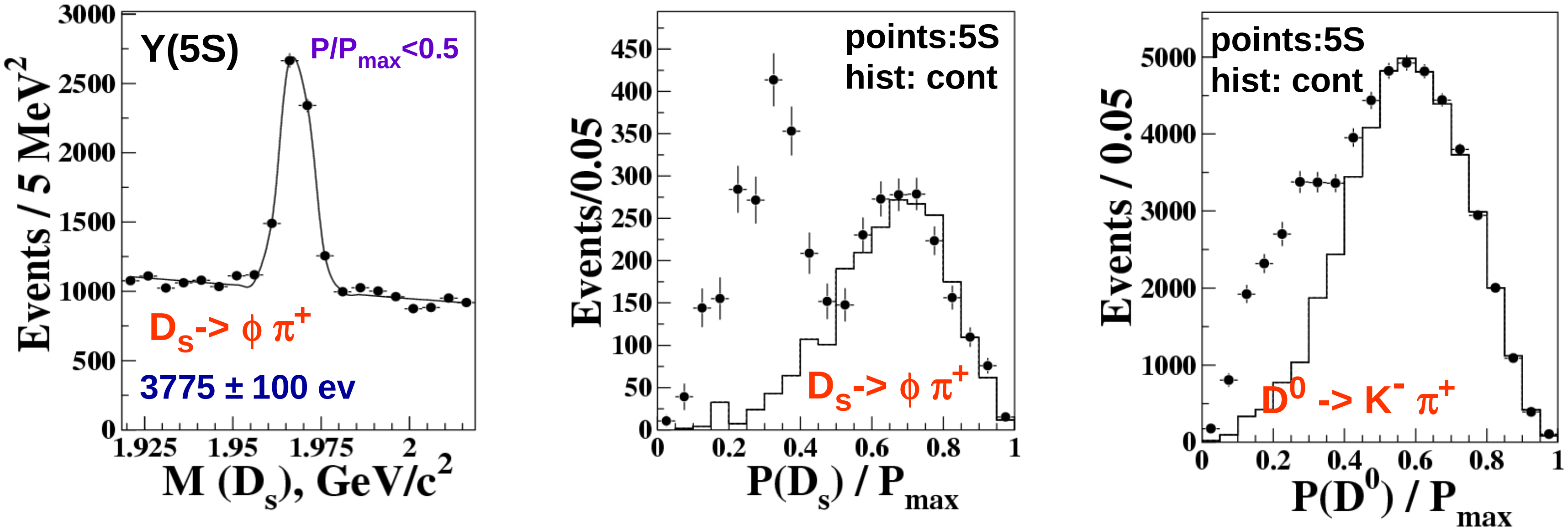
$B_s \bar{B}_s$

$B \bar{B}$

$$Bf\,(\Upsilon(5S) \to D_s X) / 2 = f_s \times Bf\,(B_s \to D_s X) + (1 - f_s) \times Bf\,(B \to D_s X)$$

1. *Bf* ($B_s \to D_s X$) can be predicted theoretically, tree diagrams, large.
2. *Bf* ($B \to D_s X$) is well measured at the Υ(4S).

# Inclusive analyses: Y(5S)->$D_s$ X, Y(5S)->$D^0$X



After continuum subtraction and efficiency correction:

**Bf (Y(5S) -> $D_S$ X) / 2 = (23.6 ± 1.2 ± 3.6) %**

**Bf (Y(5S) -> $D^0$ X) / 2 = (53.8 ± 2.0 ± 3.4) %**

**L = 1.86 $fb^{-1}$**

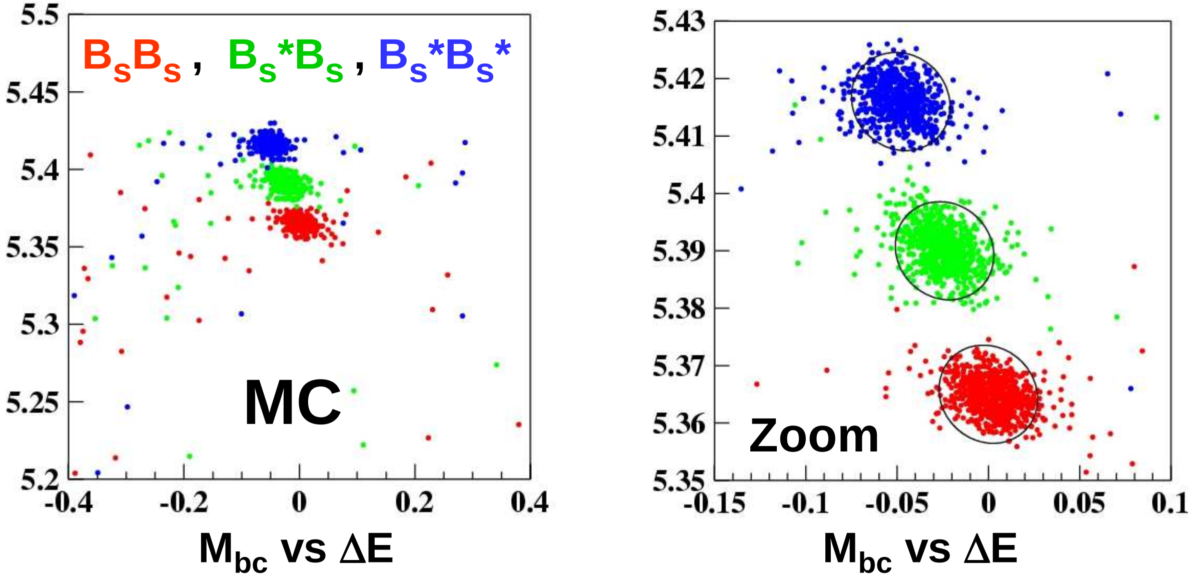
**$N_{bb}$(5S) =**

**561,000 ± 3,000 ± 29,000 events**

**=> $f_s$ = N($B_s^{(*)}$ $B_s^{(*)}$) / N(*bb*) = (18.0 ± 1.3 ± 3.2 )%**

**σ(Y(5S)->*bb*) = (0.302 ± 0.015)nb at E=10869MeV**

# Signature of fully reconstructed exclusive $B_s$ decays



**$e^+ e^-$ -> Y(5S) -> $B_sB_s$, $B_s{}^*B_s$, $B_s{}^*B_s{}^*$, where $B_s{}^*$ -> $B_s\ \gamma$**

**Reconstruction: $B_s$ energy and momentum, photon from $B_s{}^*$ is not reconstructed.**

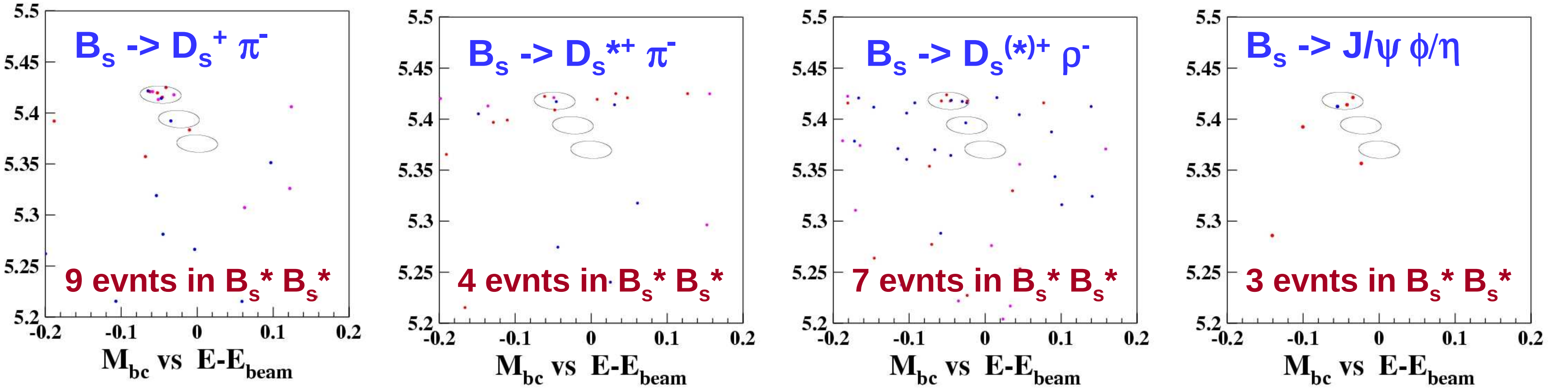
**Two variables calculated: $M_{bc} = \sqrt{E^{*2}_{beam} - P^{*2}_{B}}$, $\Delta E = E^*_B - E^*_{beam}$**

**Figures (MC simulation) are shown for the decay mode $B_s \to D_s^- \pi^+$ with $D_s^- \to \phi\ \pi^-$ .**

**The signals for $B_sB_s$, $B_s{}^*B_s$ and $B_s{}^*\ B_s{}^*$ can be separated well.**

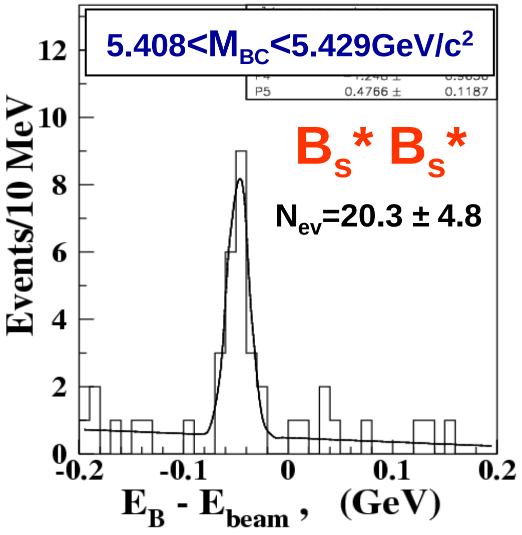
# Exclusive $B_s \to D_s^{(*)+}\ \pi^-/\rho^-$ and $B_s \to J/\psi\ \phi/\eta$ decays

## Data at Y(5S), 1.86 $fb^{-1}$



$$N(B_s^*B_s^*)\ /\ N(B_s^{(*)}B_s^{(*)}) = (93\pm{}^{7}_{9}\pm 1)\%$$

**Potential models predict $B_s^*\ B_s^*$ dominance over $B_s^*B_s$ and $B_sB_s$ channels, but not so strong.**



**Conclusions:**

1. Belle can take ~30 $fb^{-1}$ per month.
2. Number of produced $B_s$ at Y(5S) is ~$10^5/fb^{-1}$.
3. $B_s^*B_s^*$ channel dominates over all $B_s^{(*)}B_s^{(*)}$.
4. Backgrnds in exclusive modes are not large.

# Number of $B_s$ in dataset

hadronic events at $\Upsilon(5S)$

Lumi = 1.857 $fb^{-1}$

***bb*** **continuum included**

*bb* events

N ev = 561,000 ± 3,000 ± 29,000

$f_s = (18.0 \pm 1.3 \pm 3.2)\%$

$B_s$ events

N ev = 101,000 ± 7,000 ± 19,000

$f(B_s^*B_s^*) = (93 \pm {}^{7}_{9} \pm 1)\%$

$B_s^*\,B_s^*$ channel

N ev = 94,000 ± 7,000 ± 20,000

~$10^5$ $B_s$ mesons per 1 $fb^{-1}$ at $\Upsilon(5S)$

Biggest uncertainty comes from $f_s$ systematics. How to improve it (3 times)?

# Improved measurement of $f_s$

How to measure $f_s$ with 5% uncertainty ?

***I spent a lot of time thinking about that. It could be:***

1. CLEO method, from Bf(Υ(5S)-> $D_s$ X), with better statistics.
2. Using same-sign lepton-lepton sample, maybe with z-distance measurement between profile-lepton vertices
3. J/ψ vertex xy-distance from profile.
4. Bf(B-> $D^+\pi^-$), Bf(B-> $D^0\pi^-$), Bf(B-> $D^{*0}\pi^-$) measurements.
5. Number of slow photons from $B_s^*$ decays.

No one of these methods is perfect

# New Belle results with 23.6 $fb^{-1}$

- First observation of $B_s \to \phi\gamma$ and new upper limit for $B_s \to \gamma\gamma$.

$Bf(B_s \to \phi\gamma) = (5.7\,^{+1.8+1.2}_{-1.5-1.1})\,10^{-5}$

$Bf(B_s \to \gamma\gamma) < 8.7\times10^{-6}$ (90% CL)

Jean Wicht

- First measurement of $\Upsilon(5S) \to \Upsilon(nS)\,\pi^+\pi^-$ decays (21.7 $fb^{-1}$).

# Is the Υ(10860) purely Υ(5S)?

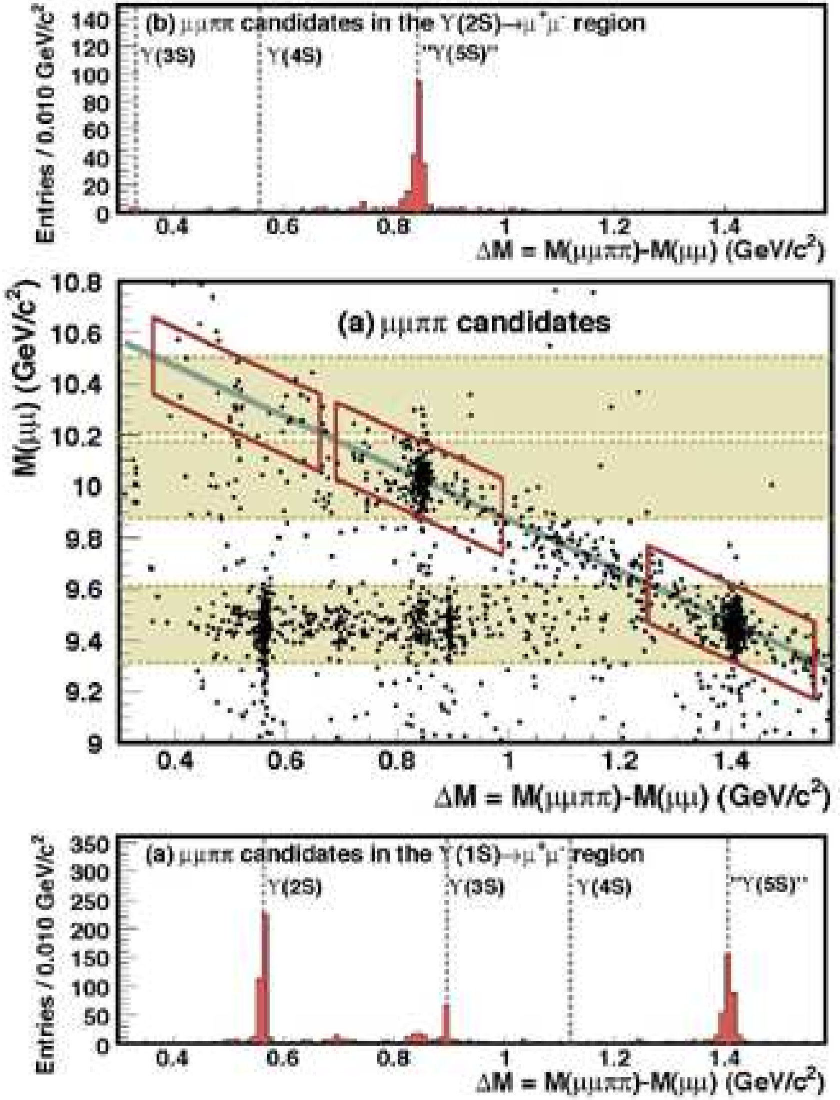
-> look for: $\mu^+\mu^- h^+h^-$

$e^+e^- \to \Upsilon(1S)\,\pi^+\pi^- X$

$e^+e^- \to \Upsilon(2S)\,\pi^+\pi^- X$

arXiv:0710.2577[hep-ex]
(accepted PRL)

Study motivated by observation of Y(4230) -> J/Ψ π+π- signal (analogous?).



Υ(2S)

Υ(3S)

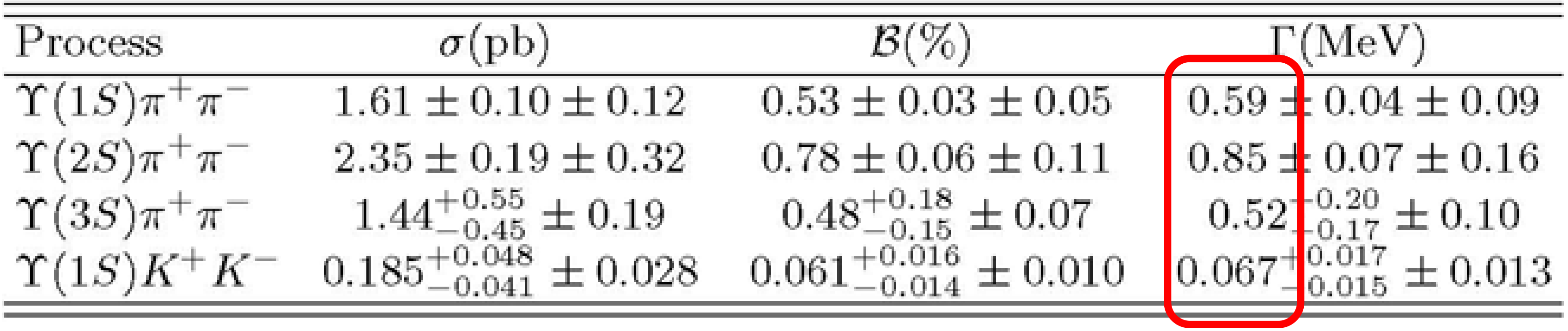
Υ(2S)

Υ(1S)

Υ(1S)

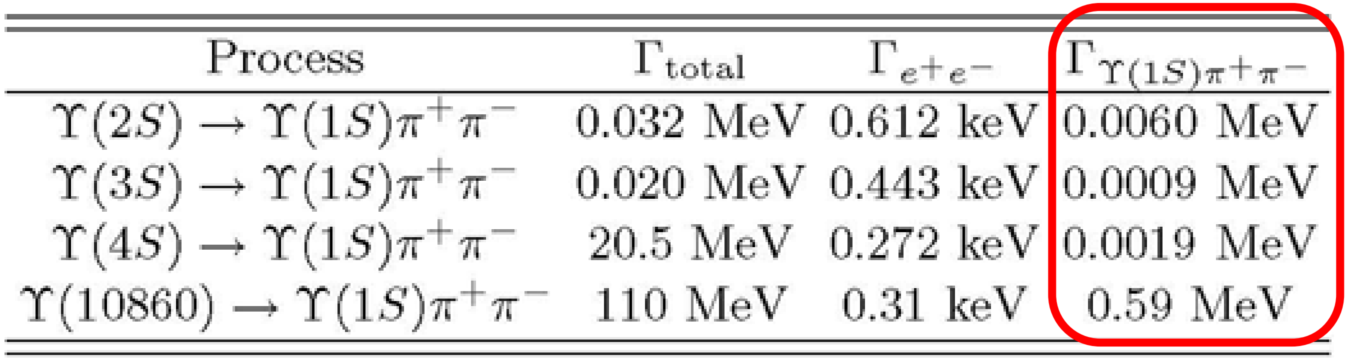
# Is the Υ(10860) purely Υ(5S)?

4 modes seen : **Y(5S) -> Y(nS) $h^+h^-$**



| Process | $\sigma$(pb) | $\mathcal{B}$(%) | $\Gamma$(MeV) |
|---|---|---|---|
| $\Upsilon(1S)\pi^+\pi^-$ | $1.61 \pm 0.10 \pm 0.12$ | $0.53 \pm 0.03 \pm 0.05$ | $0.59 \pm 0.04 \pm 0.09$ |
| $\Upsilon(2S)\pi^+\pi^-$ | $2.35 \pm 0.19 \pm 0.32$ | $0.78 \pm 0.06 \pm 0.11$ | $0.85 \pm 0.07 \pm 0.16$ |
| $\Upsilon(3S)\pi^+\pi^-$ | $1.44^{+0.55}_{-0.45} \pm 0.19$ | $0.48^{+0.18}_{-0.15} \pm 0.07$ | $0.52^{+0.20}_{-0.17} \pm 0.10$ |
| $\Upsilon(1S)K^+K^-$ | $0.185^{+0.048}_{-0.041} \pm 0.028$ | $0.061^{+0.016}_{-0.014} \pm 0.010$ | $0.067^{+0.017}_{-0.015} \pm 0.013$ |

Expectation: Υ (5S) width comparable to Υ (2S/3S/4S)



| Process | $\Gamma_{\text{total}}$ | $\Gamma_{e^+e^-}$ | $\Gamma_{\Upsilon(1S)\pi^+\pi^-}$ |
|---|---|---|---|
| $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$ | 0.032 MeV | 0.612 keV | 0.0060 MeV |
| $\Upsilon(3S) \to \Upsilon(1S)\pi^+\pi^-$ | 0.020 MeV | 0.443 keV | 0.0009 MeV |
| $\Upsilon(4S) \to \Upsilon(1S)\pi^+\pi^-$ | 20.5 MeV | 0.272 keV | 0.0019 MeV |
| $\Upsilon(10860) \to \Upsilon(1S)\pi^+\pi^-$ | 110 MeV | 0.31 keV | 0.59 MeV |

larger by > $10^2$

Conclusion: not pure Υ (5S)? Energy scan: 12/07 .

# New Belle results with 23.6 $\text{fb}^{-1}$

- First observation of **$B_s \to \phi\gamma$** and new upper limit for **$B_s \to \gamma\gamma$**.

$Bf(B_s \to \phi\gamma) = (5.7\,^{+1.8+1.2}_{-1.5-1.1})\,10^{-5}$

$Bf(B_s \to \gamma\gamma) < 8.7\times10^{-6}$ (90% CL)

Jean Wicht

- First measurement of **$\Upsilon(5S) \to \Upsilon(nS)\,\pi^+\pi^-$** decays (21.7 $\text{fb}^{-1}$).

- First measurement of **$B_s \to X\,\ell^+\ell^-\,\nu$** decay.

# Motivation, feasibility of $B_s$ lifetime measurement.

**PDG 2007:** Bf( $B^0 \to X^+ l^- \nu$ ) = ( 10.33 ± 0.28 )%

Semileptonic decays have no hadronic corrections.

Theory predicts about 12%. It is not yet understood by theory. Some recent models predict better (dis)agreement. Calculation problems? Exotics? Maybe semilep. $B_s$ decays can shed some light.

$\tau(B^0) > \tau(B_s)$ - $2.9\sigma$ difference (in contrast with theory).

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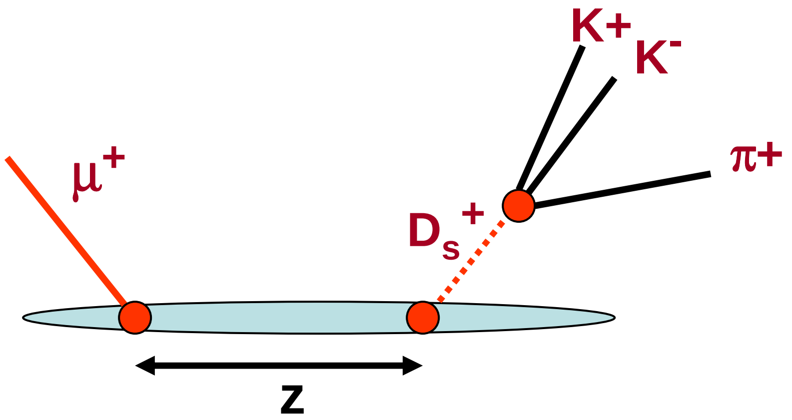
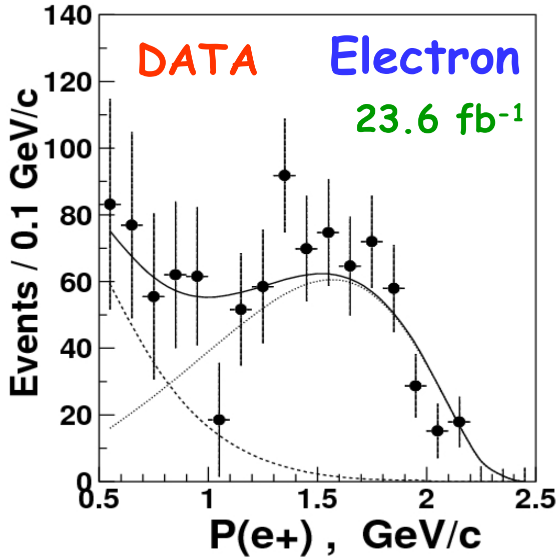
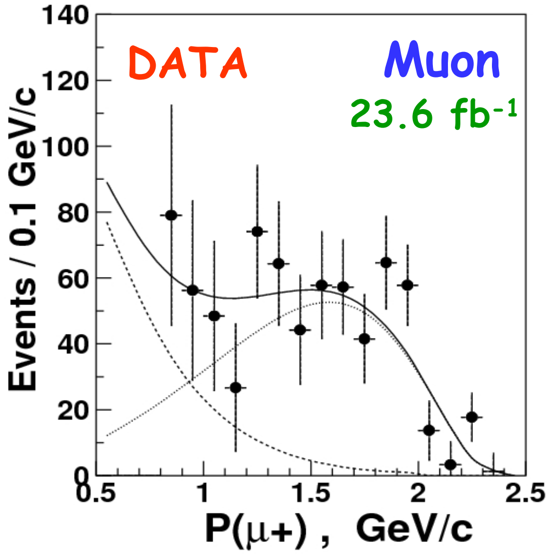
**$B_s$ and $D_s$ lifetimes can be measured using $D_s$ vertex, lepton track and beam profile.**

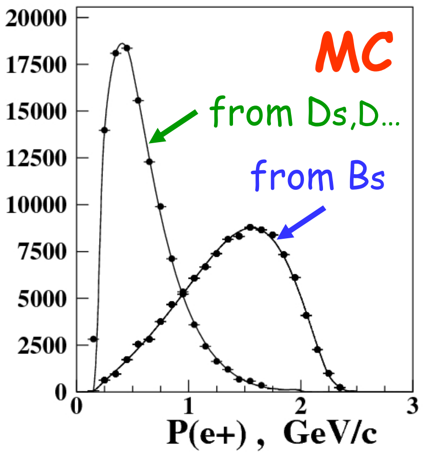


**This analysis requires much more work … .**

# First measurement of $B_s\text{-}{>}\ X^+\ell^-\nu$ decay







*preliminary*

Electron : $Bf(\ B_s\text{-}{>}X^+e^-\nu\ ) = (\ 10.9 \pm 1.0 \pm 0.9\ )\%$

Muon : $Bf(\ B_s\text{-}{>}X^+\mu^-\nu\ ) = (\ 9.2 \pm 1.0 \pm 0.8\ )\%$

**Combined fit (electron+muon) :**

$Bf(\ B_s\text{-}{>}X^+l^-\nu\ ) = (\ 10.2 \pm 0.8 \pm 0.9\ )\%$

*preliminary*

Assuming similar decay widths and $\tau(B_s)/\tau(B^0)=1.00\pm0.01$ (theory; exp.diff.~$2.3\sigma$)
it can be compared to PDG 2007: $Bf(\ B^0\text{-}{>}X^+l^-\nu\ ) = (\ 10.33 \pm 0.28\ )\%$

# New Belle results with 23.6 $fb^{-1}$

- First observation of **$B_s$-> $\phi\,\gamma$** and new upper limit for **$B_s$-> $\gamma\gamma$.**

*Bf* $(B_s\to\phi\gamma)=(5.7\ ^{+1.8+1.2}_{-1.5-1.1})\ 10^{-5}$

*Bf* $(B_s\to\gamma\gamma) < 8.7\times10^{-6}$ **(90% CL)**

Jean Wicht

- First measurement of **Y(5S) -> Y(nS)** $\pi^+\pi^-$ decays (21.7 $fb^{-1}$).

- First measurement of **$B_s$-> $X^+\ell^-\nu$** decay.

- Measurement of **$B_s$-> $D_s^+\pi^-$** **and $B_s$- >$D_s^+K^-$** decays.

*Bf* $(B_s\to D_s^+\pi^-)=(3.31\ ^{+0.31+0.67}_{-0.30-0.64})\ 10^{-3}$

*Bf* $(B_s\to D_s^+\pi^-)=(2.2\ ^{+1.1+0.5}_{-0.9-0.4})\ 10^{-4}$

R. Louvot,
T. Aushev, J.Wicht

**R=0.066 ±0.015**

# Why it is interesting?

1. $Bf(B_s \to D_s^+\pi^-)=(3.31\ ^{+0.31+0.67}_{-0.30-0.64})\ 10^{-3}$

   PDG: $Bf(B \to D^+\pi^-)=(2.68 \pm 0.13)\ 10^{-3}$

   W-exchange diagram? Difference is not yet significant.

2. $M(B_s^*)=5417.4 \pm 0.4 \pm 1.0$ MeV/c$^2$

   PDG: $M(B_s)=5366.1 \pm 0.6$ MeV/c$^2$

   $\Delta(B_s^0)= 51.3 \pm 1.2$ MeV/c$^2$ $\Delta(B^0)= 45.78 \pm 0.35$ MeV/c$^2$

   Very unexpected difference

3. $N(B_s^*B_s^*)\ /\ N(B_s^{(*)}B_s^{(*)}) = (90\pm\ ^{3.7}_{3.9} \pm 0.2)\%$ very unexpected

4. Flat B direction angular distribution -> has to be explained.

# Belle results expected soon with 23.6 $fb^{-1}$

1. K. Sayeed, A. Schwartz: $B_s$-> $J/\psi$ $\phi$ and $B_s$-> $J/\psi$ $K_s$ decays.

   Important for future CP studies.

2. J.-H. Chen : Search for $B_s$-> $K^+$ $K^-$ decay.

   CP eigenstate, can be used in future for $\Delta\Gamma_s/\Gamma_s$ measurement.

## Analysis started:

1. S. Esen : Measurement $B_s$-> $D_s^{+(*)}$ $D_s^{-(*)}$

   Mostly CP eigenstates, important for indirect $\Delta\Gamma_s/\Gamma_s$ measurement.

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

$M_{Bs} = (M_H + M_L)/2$ $\Gamma_s = (\Gamma_H + \Gamma_L)/2$

$\Delta m_s = M_H - M_L$ $\Delta\Gamma = \Gamma_L - \Gamma_H$ >0 in SM

$$i \frac{d}{dt} \begin{pmatrix} B_s \\ \overline{B}_s \end{pmatrix} = (M - i/2\,\Gamma) \begin{pmatrix} B_s \\ \overline{B}_s \end{pmatrix}$$ - Schrödinger equation

Matrices **M** and **G** are t-dependent, Hermitian 2x2 matrices

*Assuming CPT*: $M_{11} = M_{22}$ $\Gamma_{11} = \Gamma_{22}$

$$|B_{H,L}(t)\rangle = \exp(-(i M_{H,L} + \Gamma_{H,L}/2)t)\ |B_{H,L}\rangle$$

**SM:** $\beta_s = \arg(-V_{ts} V_{tb}^* / V_{cs} / V_{cb}^*) = O(\lambda^2)$ - no CP-violation in mixing

**BSM :** $\phi_s = \arg(-M_{12}/\Gamma_{12})$ $2\theta_s = \phi_s$ $\Delta\Gamma_s = 2\,|\Gamma_{12}|\cos 2\theta_s$

# $\Delta\Gamma_s/\Gamma_s$ measurement from *Bf* ($B_s$ -> $D_s^{+(*)}$ $D_s^{-(*)}$)

(first proposed by Y. Grossman)

$\Delta\Gamma_s = 2\,|\,\Gamma_{12}|\cos\phi_s$ $\Delta\Gamma_s^{SM} = \Delta\Gamma_{CP}^{s} = 2\,|\,\Gamma_{12}|$

Since $\Delta\Gamma_{CP}^{s}$ is unaffected by NP, NP effects will decrease $\Delta\Gamma_s$.

$$\Delta\Gamma_{CP}^{s} = \Sigma\,\Gamma(CP=+) - \Sigma\,\Gamma(CP=-)$$

$B_s$->$D_s^{(*)+}D_s^{(*)-}$ decays have *CP*-even final states with largest *BF's* of ~ (1-3)% each, saturating $\Delta\Gamma_s/\Gamma_s$ .

$$\frac{\Delta\Gamma_{CP}^{s}}{\Gamma_s} \approx \frac{Bf(B_s\text{->}D_s^{(*)+}D_s^{(*)-})}{1-Bf(B_s\text{->}D_s^{(*)+}D_s^{(*)-})/2}$$

To prove this formula experimentally : a) Contribution of $B_s$ -> $D_s^{+(*)}$ $D_s^{-(*)}$ $n\pi$ is small b) Most of $B_s$ -> $D_s^{+}$ $D_s^{-}$* and $B_s$ -> $D_s^{+*}$ $D_s^{-}$* states are *CP*- even.

Assuming corrections are small (~5-7%), *Bf* measurement will provide information about $\Delta\Gamma_{CP}^{s}$ or $|\Gamma_{12}|$.

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

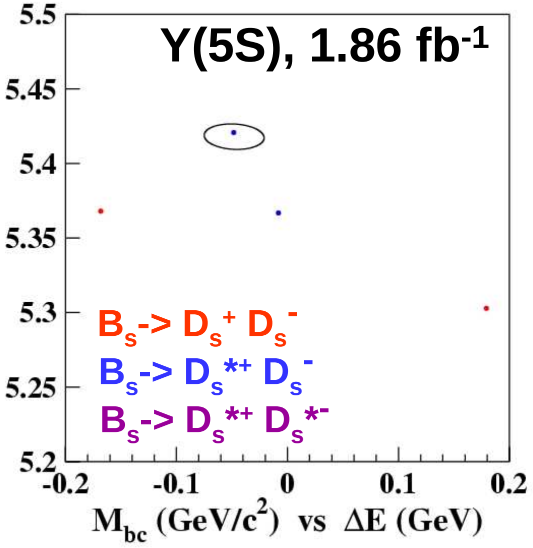
***Expected with 25 fb$^{-1}$ at Y(5S):***

**$\mathrm{Eff}(B_s \to D_s^+ D_s^-) \sim 2\times10^{-4}$** $N \sim 10^7 \times 2\times10^{-4} \times 10^{-2} \sim 5$ ev

**$\mathrm{Eff}(B_s \to D_s^{*+} D_s^-) \sim 1\times10^{-4}$** $N \sim 10^7 \times 10^{-4} \times 2\times10^{-2} \sim 5+5$ ev

**$\mathrm{Eff}(B_s \to D_s^{*+} D_s^{*-}) \sim 5\times10^{-5}$** $N \sim 10^7 \times 5\times10^{-5} \times 3\times10^{-2} \sim 4$ ev

=>Accuracy of *Bf* ($B_s \to D_s^{(*)+} D_s^{(*)-}$) has to be ~25%.



$D_s^+ \to \phi\pi^+$, $K^{*0} K^+$, $K_s K^+$

$$\frac{\Delta\Gamma_{CP}^{s}}{\Gamma_s} \approx \frac{Bf(B_s \to D_s^{(*)+} D_s^{(*)-})}{1 - Bf(B_s \to D_s^{(*)+} D_s^{(*)-})/2}$$

<= should be compared with direct $\Delta\Gamma_s/\Gamma_s$ measurement to test SM.

$\Delta\Gamma_s/\Gamma_s$ lifetime difference can be measured directly with high accuracy at Y(5S) and also at Tevatron and LHC experiments.

# Further physics program with 23 $\mathrm{fb}^{-1}$

1. $B_s$ -> $D_s^+ \rho^-$ , $B_s$ -> $D_s^+ a_1^-$ ,

   $B_s$ -> $D_s^{*+} \pi^-$ , $B_s$ -> $D_s^{*+} \rho^-$ , $B_s$ -> $D_s^{*+} a_1^-$ .

   BF's should be compared with $B^0$ partners to test SU(3).

2. $B_s$ -> $J/\psi\, \eta$ , $J/\psi\, \eta'$ , $J/\psi\, \omega$, $J/\psi\, f_0(980)$ , … ,$B_s$-> $J/\psi\, K^+ K^-$.

   What is fraction of $s\bar{s}$ component in different mesons?

   Quark model : $\psi(\eta)=(u\bar{u}+d\bar{d}-s\bar{s})/\sqrt{3}$ $\psi(\eta')=(u\bar{u}+d\bar{d}+2s\bar{s})/\sqrt{6}$

   $B(B_s^0\text{->}J/\psi\ \eta) = 1/3\ B(B_s^0\text{->}J/\psi\ \phi)$

   $B(B_s^0\text{->}J/\psi\ \eta') = 2/3\ B(B_s^0\text{->}J/\psi\ \phi)$

   Mixed channels? Enhanced branching fractions?

# Further physics program with 23 $fb^{-1}$

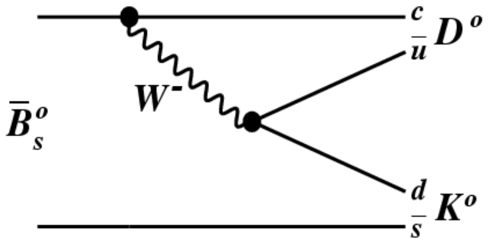
**3.** $B_s \to D_{sJ}^+ \pi^-$ (4 states).

Interesting physics issues, critical test of $D_{sJ}$ nature.
Inclusive $D_{sJ}$ production study?

**4.** $B_s \to D^0 K^{0(*)}$.

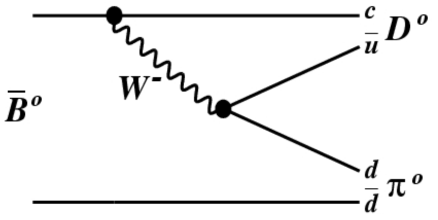
Statistically significant signals are expected with BF's predicted at [C-K.Chua,W-S.Hou, hep-ph/0712.1882].

Color-suppressed

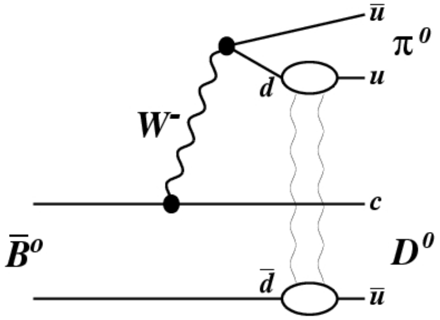


$Bf(B_s \to D^0K^0) \sim 8\times10^{-4}$ => ~20 signal events should be seen with 23.6 $fb^{-1}$ at Υ(5S).

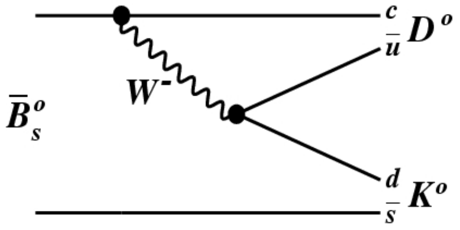
# Color-suppressed $B_s$-> $D^0$ $K^0$ decay



Color-suppressed



FSI



Color-suppressed

$$\frac{Bf\,(B^0\text{->}D^0\pi^0)}{Bf\,(B^0\text{->}D^+\pi^-)} = \frac{(2.91 \pm 0.28)\ \text{x}10^{-4}}{(3.4 \pm 0.9)\ \text{x}10^{-3}} \approx 0.1$$

Which diagram, color-suppressed or FSI, is dominant in $B^0$->$D^0\pi^0$ decay ? Decay mode $B_s$->$D^0K^{(*)0}$ has no FSI diagram. If the ratio $Bf(B_s$->$D^0K^0)/Bf(B_s$->$D_s^+\pi^-)$ ~0.1, then color-suppressed diagram dominates. If the ratio is significantly smaller, then FSI diagram dominates.

# Further physics program with 23 $fb^{-1}$

5. $B_s \to D_s^+ l^- \nu$ , $B_s \to D_s^{*+} l^- \nu$ ($B_s \to K^+ l^- \nu$?).

   Important SU(3) test. CDF obtained large $D_{sJ}$ semileptonic BF (?).

6. $B_s$ decays with baryons (with $\Lambda^0$ baryons).

   Largest $B^0$ baryonic Bf's are $\sim 10^{-3}$. Is it similar in $B_s$ decays?

7. $B_s$ lifetime measurement.

   Different samples can be used: fully reconstructed events, CP-fixed modes, two lepton events, $D_s^+$ $lep^+$ events … .

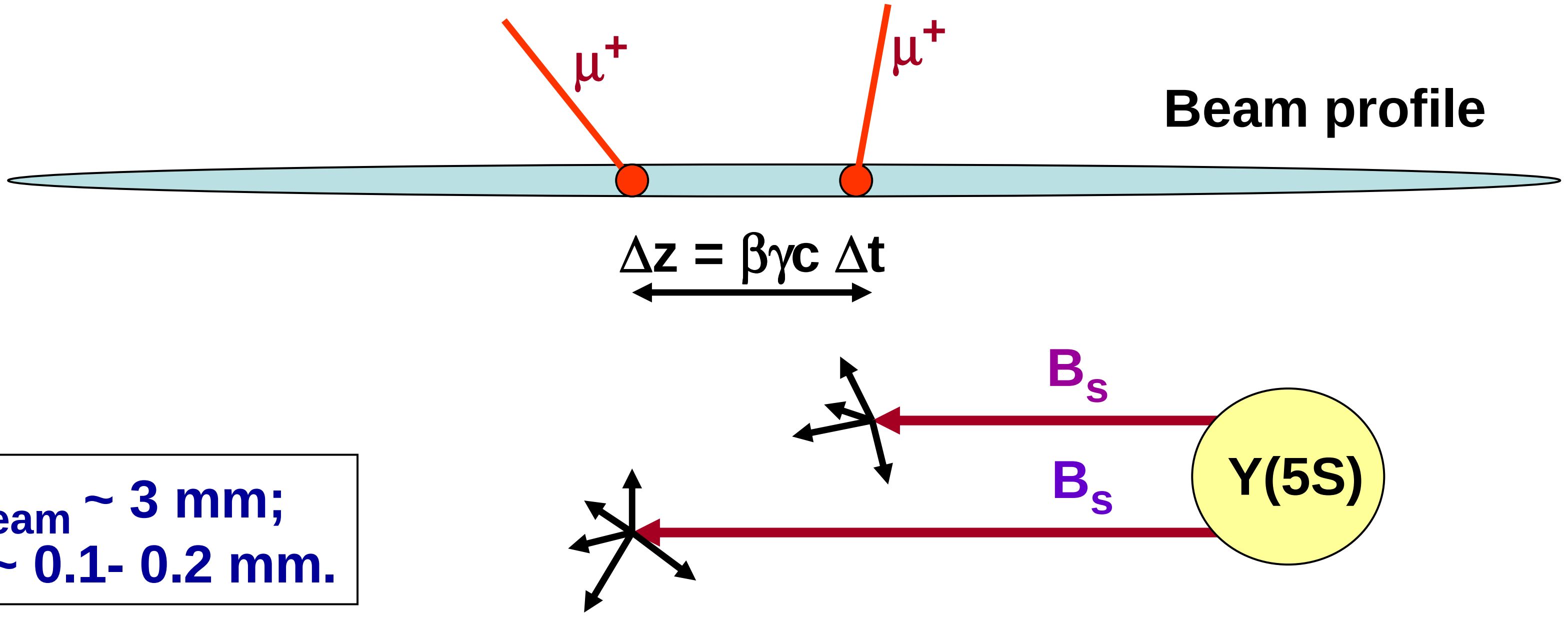
   Good accuracy is expected (5-10%). Important measurement.

# Feasibility of $B_s$ lifetime measurement with same-sign leptons

Lifetime can be measured using two fast same sign lepton tracks and beam profile. To remove secondary D meson semileptonic decays: $P(\ell)>1.4$ GeV.

$Y(5S) : B_s(\ell^+)\, B_s(\ell^+) \,/\, B_s(\ell^+)\, B_s(\ell^-) = 100\%$

$Y(4S) : B(\ell^+)\, B(\ell^+) \,/\, B(\ell^+)\, B(\ell^-) \sim 10\%$



$Z_{beam} \sim 3$ mm;
$\Delta z \sim 0.1$- $0.2$ mm.

# Comparison with Fermilab $B_s$ studies.

- There are several topics, where Υ(5) running has advantages comparing with CDF and D0:
  1) Model independent branching fraction measurements.
  2) Measurement of decay modes with $\gamma$, $\pi^0$ and $\eta$ in final state ($D_s^+\rho^-$).
  3) No trigger problems for multiparticle final states (like $D_s^+ D_s^-$).
  4) Inclusive branching fraction measurements (semileptonic $B_s$).
  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 (???).

# Future physics program at Υ(5S)

Realistic value of 200 $fb^{-1}$

Optimistic value of 2000 $fb^{-1}$

## Only big deals:

1. $\Delta\Gamma_s/\Gamma_s$ measurement

   Decay modes $D_s^{(*)}D_s^{(*)}$, $K^+K^-$, $\phi\phi$, $\phi\gamma$, $J/\psi\,\eta(\phi)$

   ~500 CP-fixed events with 200$fb^{-1}$ => 5-10% accuracy in $\Gamma_s$.

2. Measurement of **$B_s$-> $\gamma\gamma$** decay

   It also requires about 1000$fb^{-1}$ to measure.

3. $B_s$ mixing measurement

# $B_s$ mixing measurement

It is often postulated, that $B_s$ mixing cannot me measured at the Υ(5S). Have anybody checked it? Is it correct or not?

## Can we measure $B_s$ mixing? Let's check it.

Distance between max and min of oscillation function:
$\Delta z = \pi\, \Delta m_s\, \beta\gamma c = 22.5\mu m$ with $\beta\gamma=0.425$

Can we increase βγ at Υ(5S) runs by 50%? Probably yes.

Then we need to get single vertex resolution of ~20 μm.

Is is planned resolution for fast ($0^0$ dip angle) tracks (next slide).

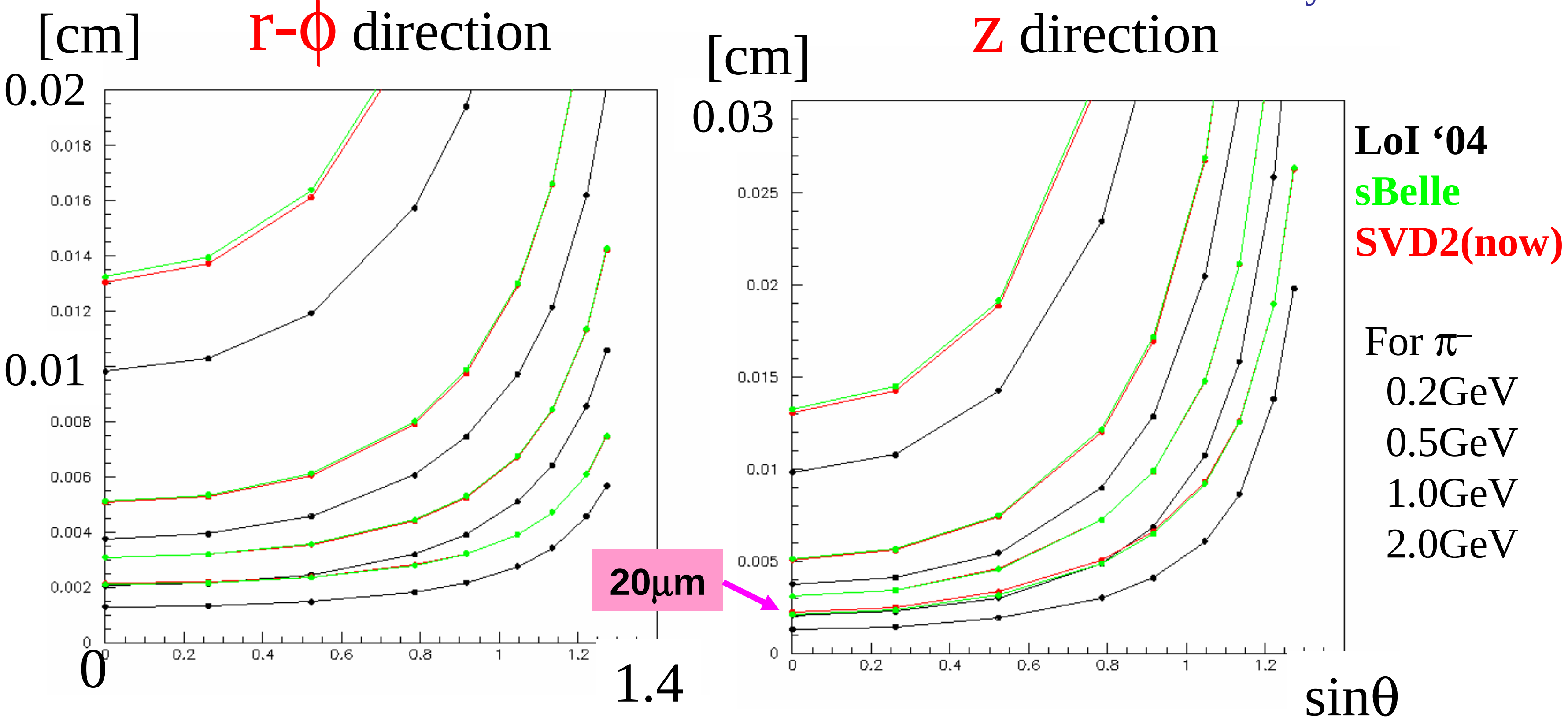
=> with high statistics we can select high vertex resolution events.

**Yes, we can.**

**T.Kawasaki,**
**Atami BNM2008**
**Jan 2008**

# Impact Parameter resolution

Calculated by TRACKERR



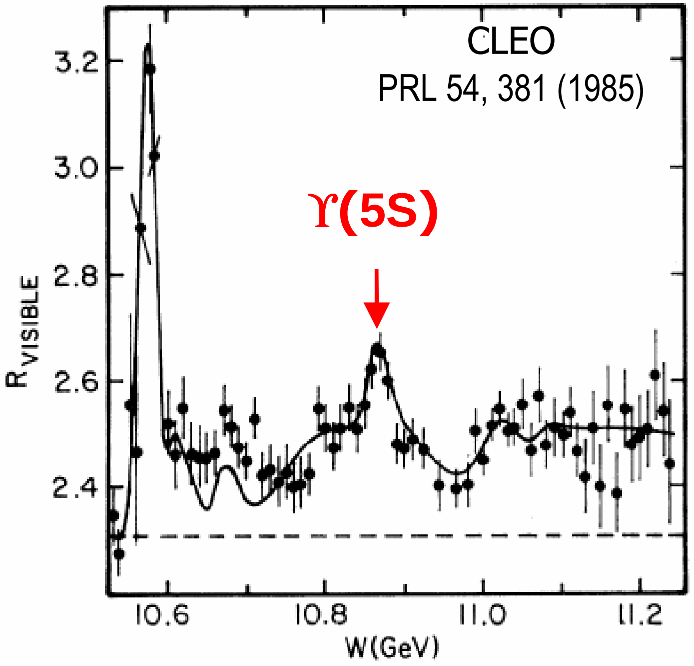
Beampipe radius is important
Competitive performance as the current SVD

**Occupancy effects.**
**Degradation of intrinsic resolution is included.**
**Efficiency loss is NOT included**

# What else can be done at Super B Factory?

PDG (Z->bb, pp at $S^{1/2}$=1.8TeV)

| b hadron | fraction(%) |
|---|---|
| $B^+$ , $B^0$ | 39.8 ± 1.0 |
| $B_s$ | 10.4 ± 1.4 |
| b baryons | 9.9 ± 1.7 |



Rates at e+e- continuum should be similar, baryon production is large.

$M(\Lambda_b)$ = (5624 ± 9) MeV/$c^2$

$M(\Lambda_b)$x2 = (11248 ± 18) MeV/$c^2$ => 6.3 % up from Y(4S) CME.

Can Super B factory CM energy range be increased ?

$M(B_c)$ = (6286 ± 5) MeV/$c^2$

e+e- → Y(6S,7S) → $B_s\bar{B}_s$, $\Lambda_b\bar{\Lambda}_b$, $B_c\bar{B}_c$, $\Xi_b\bar{\Xi}_b$ ... ?

# Conclusions

- $B_s$ decays with branching fractions down to $10^{-6}$ can be measured with statistics of ~100 $fb^{-1}$ at e+e- colliders running at Υ(5S).

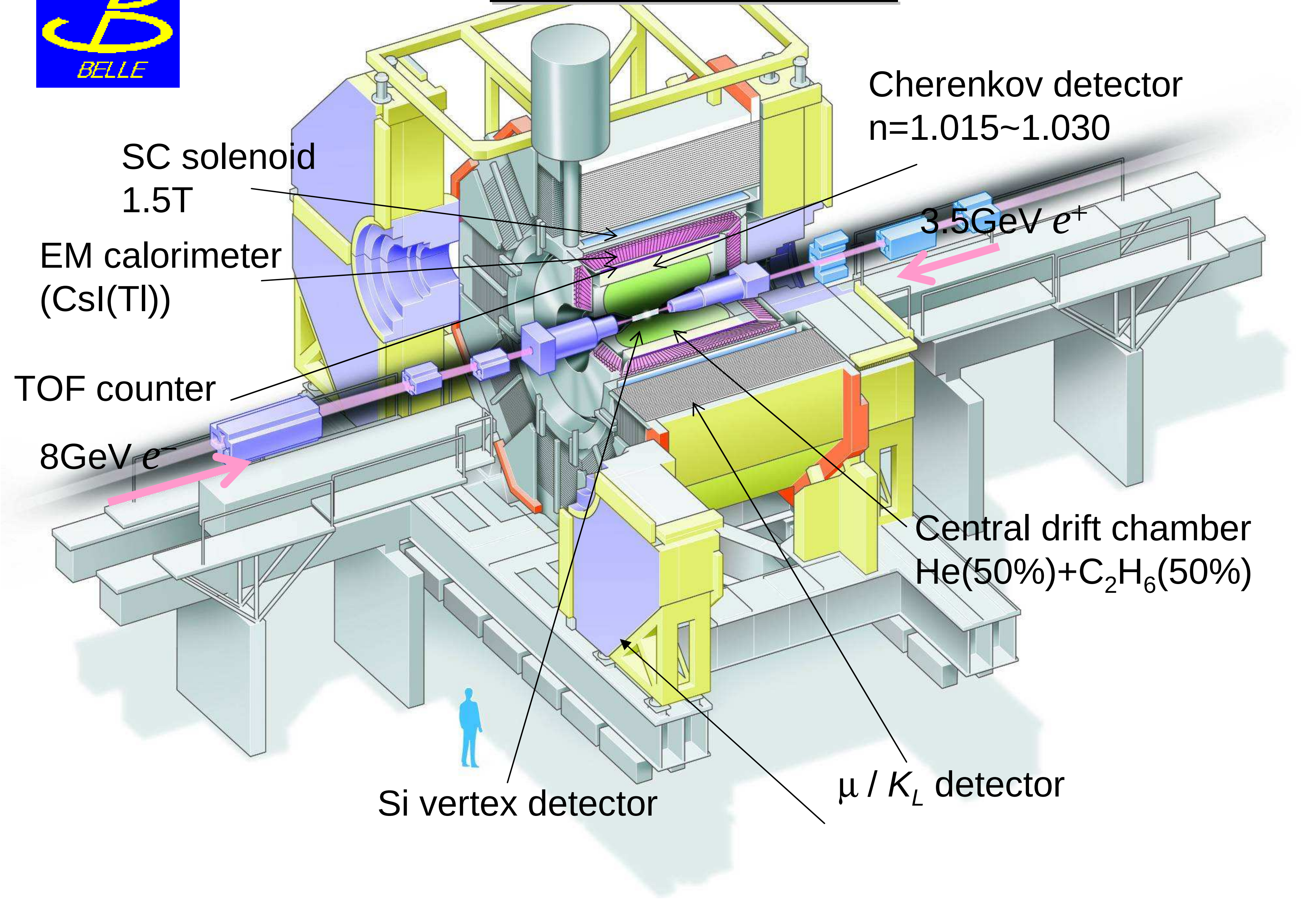
- Many important SM tests can be done with statistics of the order of 1000 $fb^{-1}$.

- $B_s$ studies at e+ e- colliders running at Υ(5S) have some advantages comparing with hadron-hadron colliders. These colliders are in some sense complementary.

- It is important to have more flexibility in beam energies.

# Background slides

# Belle Detector



Cherenkov detector
n=1.015~1.030

SC solenoid
1.5T

EM calorimeter
(CsI(Tl))

3.5GeV $e^+$

TOF counter

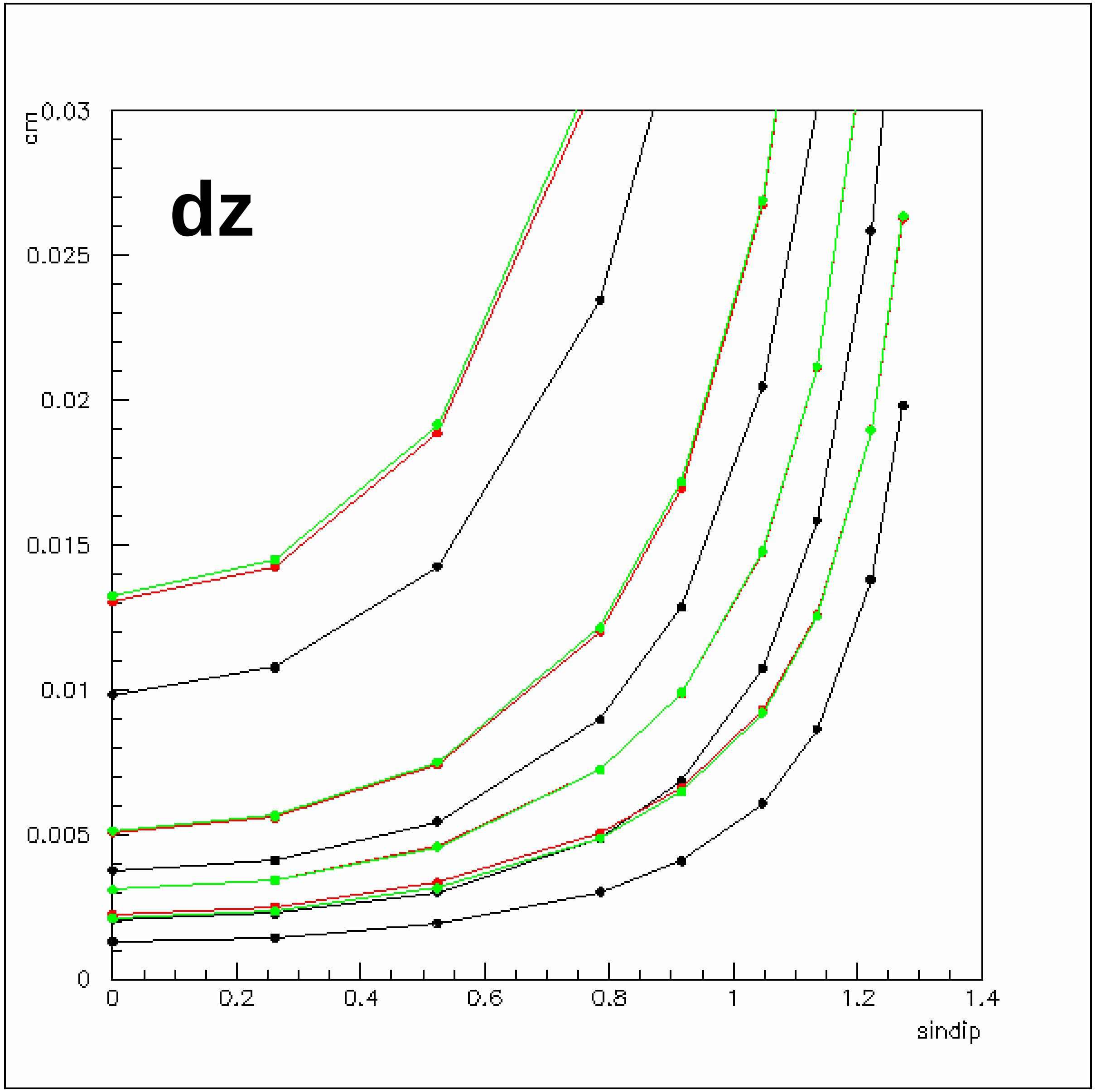
8GeV $e^-$

Central drift chamber
He(50%)+$C_2H_6$(50%)

Si vertex detector

$\mu$ / $K_L$ detector

# dz resolution



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**Jan 2008**

dz resolutoin

**SuperB**
**SVD3mod**
**SVD3**

For π
0.2GeV
0.5GeV
1.0GeV
2.0GeV