Colloquium, University of South Alabama, October 28, 2010

Strange Beauty and Other Beasts: At and Above the $\Upsilon(5S)$ with Belle

- Belle/KEKB: B-factory
  - $\Upsilon(4S)$ Resonance, B meson
- $\Upsilon(5S)$ Resonance and B_s
  - motivation
  - data, selected results
  - prospects

Kay Kinoshita
University of Cincinnati
Belle Collaboration

The people

Belle collaboration

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Chiba U.
Chonnam Nat'l U.
U. of Cincinnati
Ewha Womans U.
Frankfurt U.
Gyeongsang Nat'l U.
U. of Hawaii
Hiroshima Tech.
IHEP, Beijing
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Kanagawa U.
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Krakow Inst. of Nucl. Phys.
Kyoto U.
Kyungpook Nat'l U.
EPF Lausanne
Jozef Stefan Inst. / U. Ljubljana / U. of Maribor
U. of Melbourne

Nagoya U.
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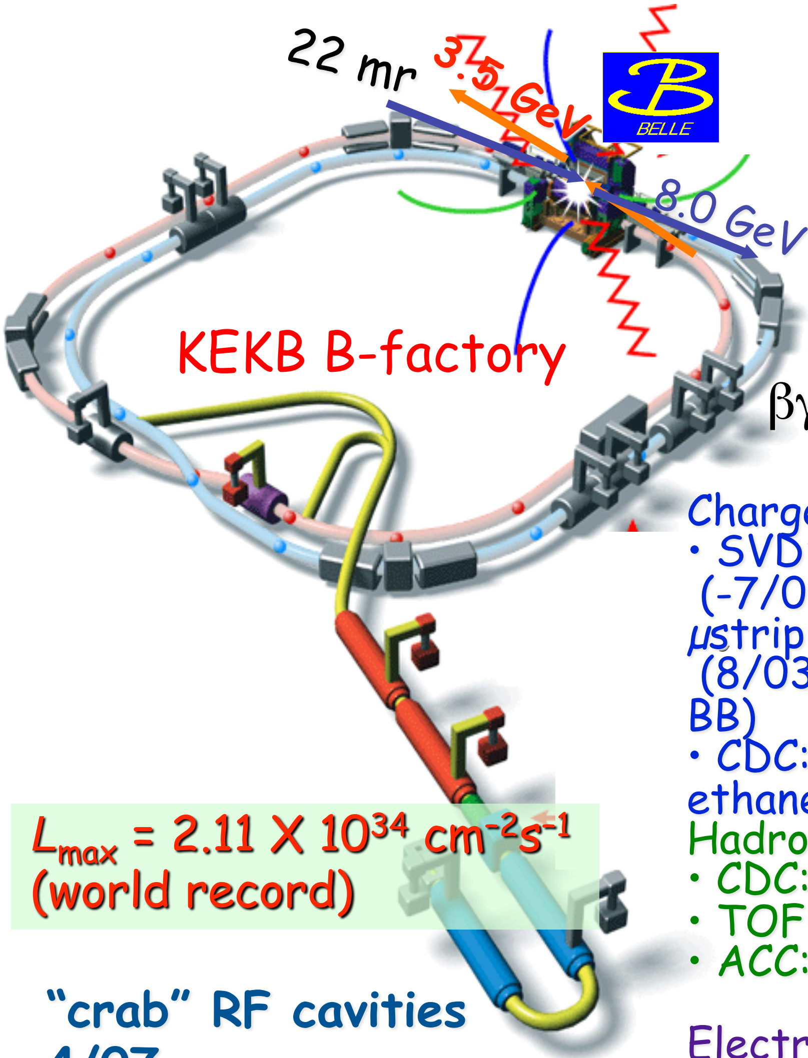
National Central U.
National Taiwan U.
National United U.
Nihon Dental College
Niigata U.
Osaka U.
Osaka City U.
Panjab U.
Peking U.
U. of Pittsburgh
Princeton U.
Riken
Saga U.
USTC

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.
Toyama Nat'l College
U. of Tsukuba
VPI
Yonsei U.

~14 nations, 55 institutes, ~400 collaborators

(authors vary, each paper)

... the hardware



$\beta\gamma$ = 0.425

L_{max} = 2.11 X 10^{34} $cm^{-2}s^{-1}$
(world record)

"crab" RF cavities
4/07-

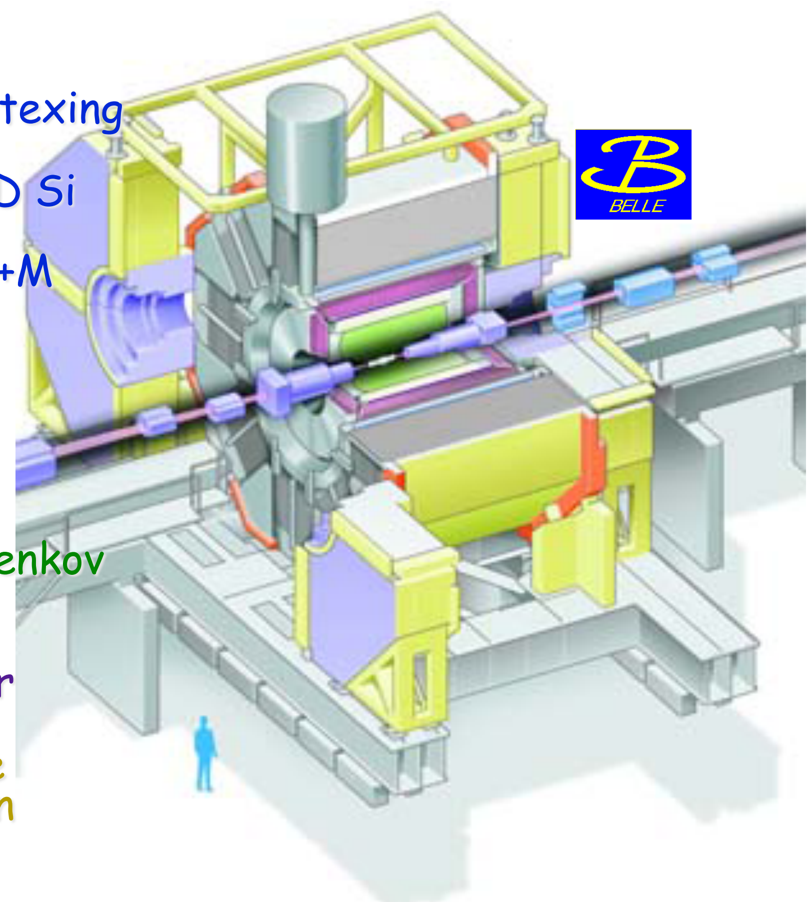
4/07- COPPER pipelined
DAQ system

Charged tracking/vertexing
- SVD:
 (-7/03) 3-layer DSSD Si μstrip (152M B pairs)
 (8/03-) 4-layer (550+M BB)
- CDC: 50 layers (He-ethane)

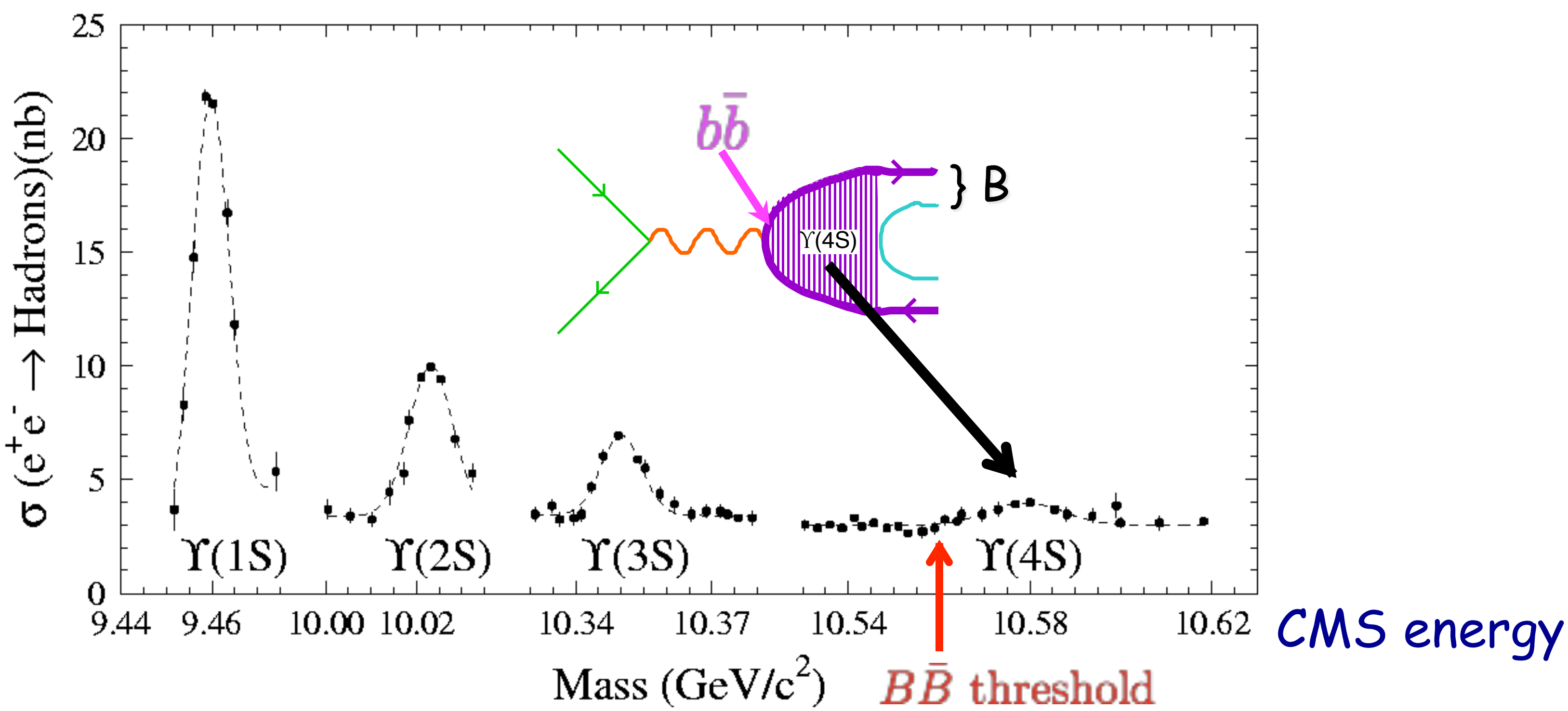
Hadron identification
- CDC: dE/dx
- TOF: time-of-flight
- ACC: Threshold Cerenkov (aerogel)

Electron/photon
- ECL: CsI calorimeter

Muon/K_L
- KLM: Resistive plate counter/iron



... the Physics $e^+e^- \to \Upsilon(4S) \to B\bar{B}$ (mostly)



"B-factory"

Primary goal: discover CP violation in weak decays of B meson

DONE! (2001)

... why is this significant?

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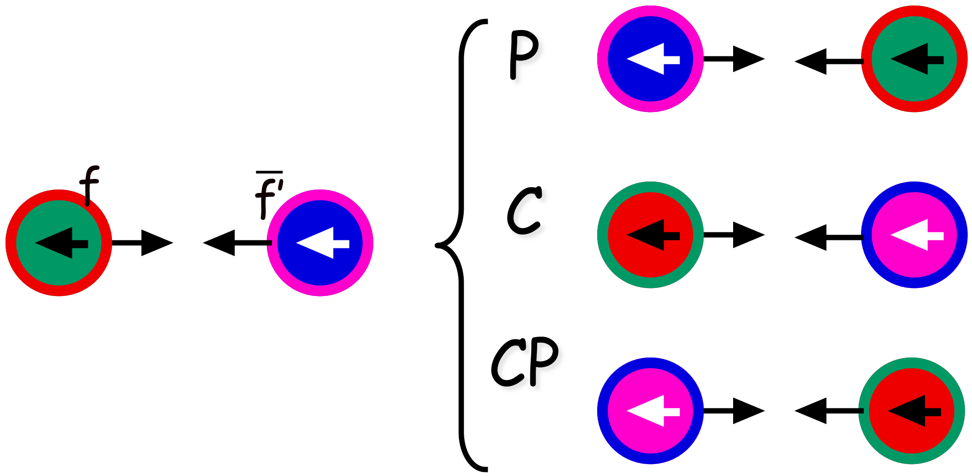
CP Violation & weak force

Weak force: under symmetry operations



violated maximally

" "

conserved (mostly)

How can an interaction violate CP?

Complex coupling constant

$$CP\{\, f \quad g \quad f' \,\} = \bar{f}' \quad g \quad \bar{f} \;\neq\; \bar{f}' \quad g^{*} \quad \bar{f}$$ (hermitian conjugate)

Why is CP violation of interest?

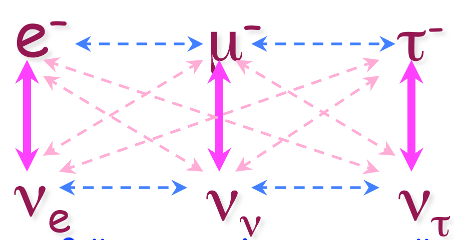
- matter-antimatter asymmetry of universe requires CP-violating interactions (Sakharov 1967)

Flavor & the weak force

Standard Model: 12 fermion flavors (+antifermion)

- 3 generations(distinguished only by mass)x2 typesx2 ea(strong & EM couplings) (stable, but for weak interaction)
- leptons: ~universal coupling, no generation x-ing

W± "charged current"



Z0 "neutral current"

seen

not seen

- quarks: neutral current – ~universal, no generation x-ing
- quarks: charged current – all different, approx. generation-conserving

suppressed

i.e., Matrix of Charged Current couplings shows no universality…

$$g_F \times \begin{array}{cc} & \begin{array}{ccc} d & s & b \end{array} \\ \begin{array}{c} u \\ c \\ t \end{array} & \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \end{array}$$

9 complex couplings
-> 18 free parameters

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Unless viewed via **GIM** (Glashow-Iliopoulos-Maiani) picture:

"weak eigenstates" ≠ mass eigenstates d, s, b

-> need linear transformation between 2 sets:

$$\begin{pmatrix} d' \\ s' \\ b' \end{pmatrix} = \mathcal{M} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Cabibbo-Kobayashi-Maskawa (CKM) matrix

complex
preserves metric
" orthogonality

≡ unitary

So matrix is then

$$g_F \times \begin{array}{c c} & \begin{array}{ccc} d' & s' & b' \end{array} \\ \begin{array}{c} u \\ c \\ t \end{array} & \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \end{array}$$

universal, generation-conserving

Explains

- suppression of flavor-changing neutral currents
- multiplicity of charged current couplings
- AND ....

Irreducible complexity follows from unitarity for >2 generations
--> proposed as explanation of CP violation in K_L

e.g. for 3 generations,
4 free parameters, including
1 irreducible **imaginary** part

(Kobayashi-Maskawa 1973)

explicit parametrization(Wolfenstein):

$$\begin{pmatrix} 1-\lambda^2/2 & \lambda & \lambda^3 A(\rho - i\eta) \\ -\lambda & 1-\lambda^2/2 & \lambda^2 A \\ \lambda^3 A(1-\rho-i\eta) & -\lambda^2 A & 1 \end{pmatrix}$$

irreducibly complex

> CP Violation

First 3rd- generation particle (τ) seen in 1975
CP-violation measured in B-decays 2002

Belle experiment

~325 papers published/in press (since 3/2001)

http://belle.kek.jp/bdocs/b_journal.html

Highlights

- Constraints on CKM; precision sin $2\varphi_1$, $|V_{cb}|$, $|V_{ub}|$
- overconstraints on CKM; limits/hints on New Physics
- evidence for D^0 mixing
- new charmonium-like states Z(4430), Y(4660), Y(4008), X(4160), Y(3940), X(3872)
- bottomonium-like?
- Kobayashi & Maskawa 2008 Nobel

Data

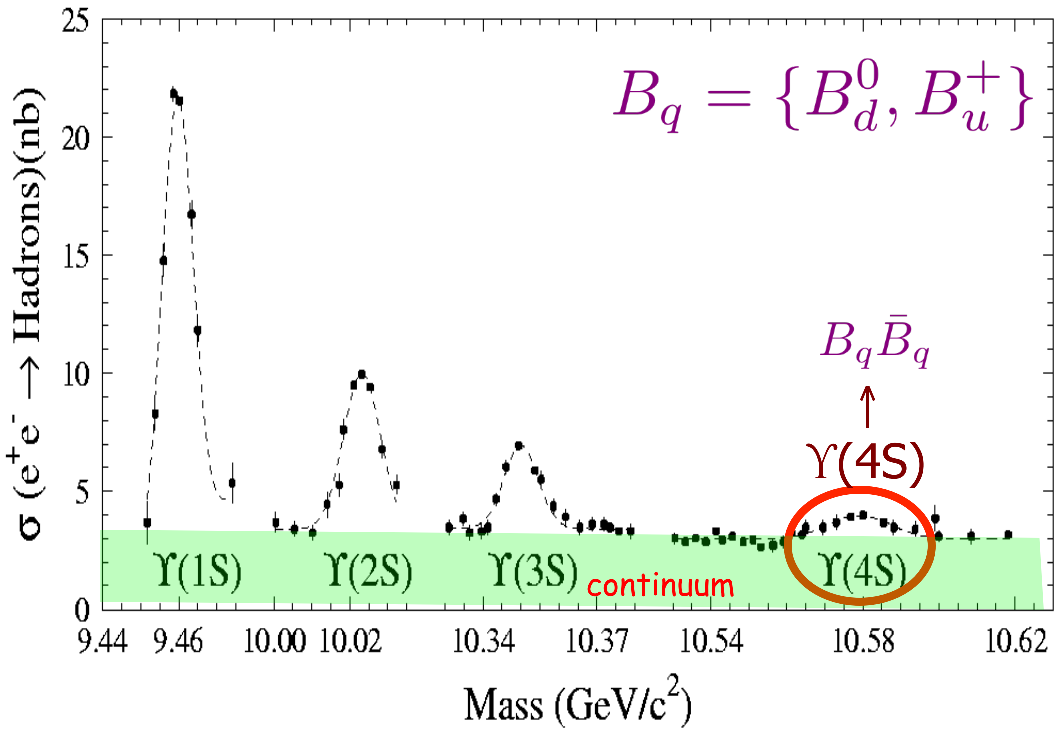
1041 fb^{-1} = 1 ab^{-1} recorded by Belle as of 7/10

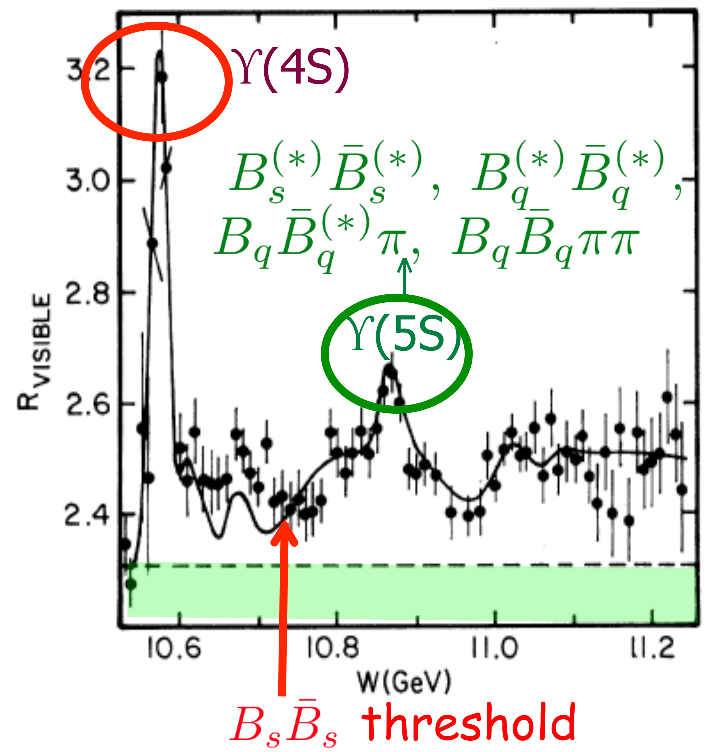
***∫Ldt* since 6/1999**

- $\Upsilon(4S)$
  710 fb^{-1}
- sub–$\Upsilon(4S)$ continuum
  ~100 fb^{-1}
- $\Upsilon(5S)$
  ~120 fb^{-1}
- $\Upsilon(3S)$, $\Upsilon(2S)$, $\Upsilon(1S)$
  ~34fb^{-1}
- $\Upsilon(5S)$+ scan
  ~31 fb^{-1}

- B pairs (7.7 x 10^8 events)
- charm (1.1 x 10^9 events)
- tau (~8 x 10^8 events)
- 2-photon events
- B_s (~7 x 10^6 events)

Υ(10860), or Υ(5S)

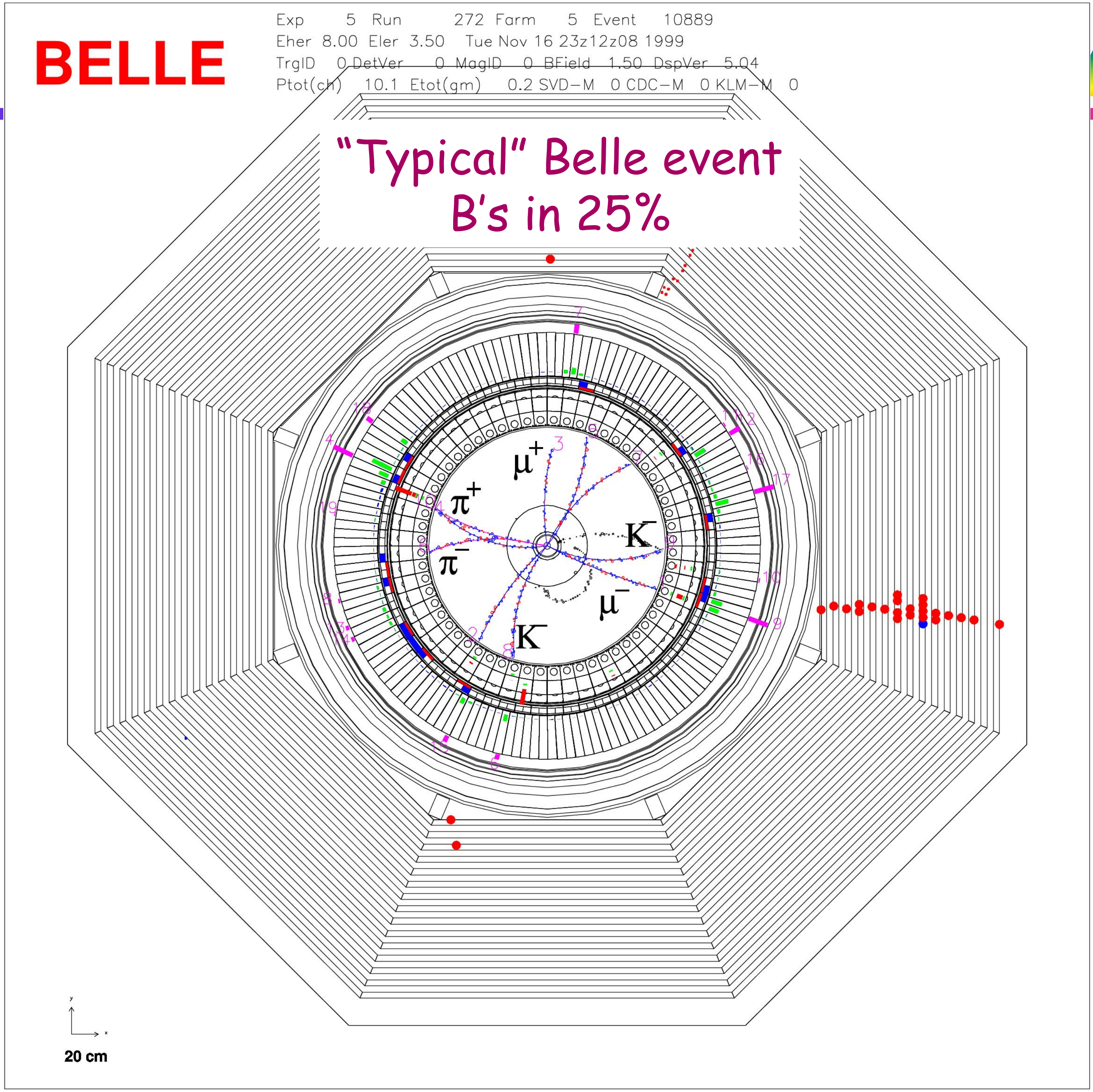


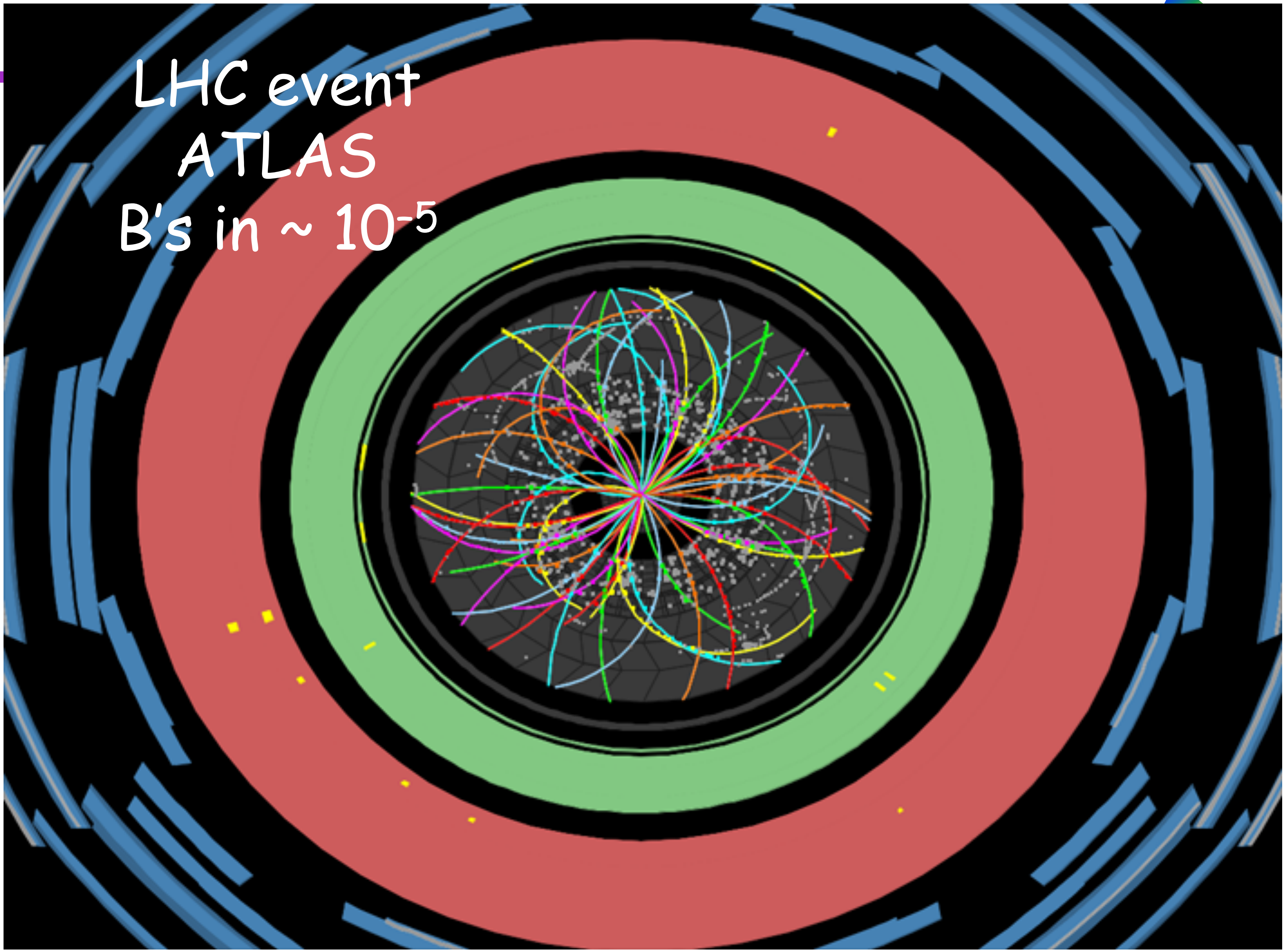


B_s are produced copiously in pp(bar) collisions (FNAL, LHC) – why study B_s at the Υ(5S)?

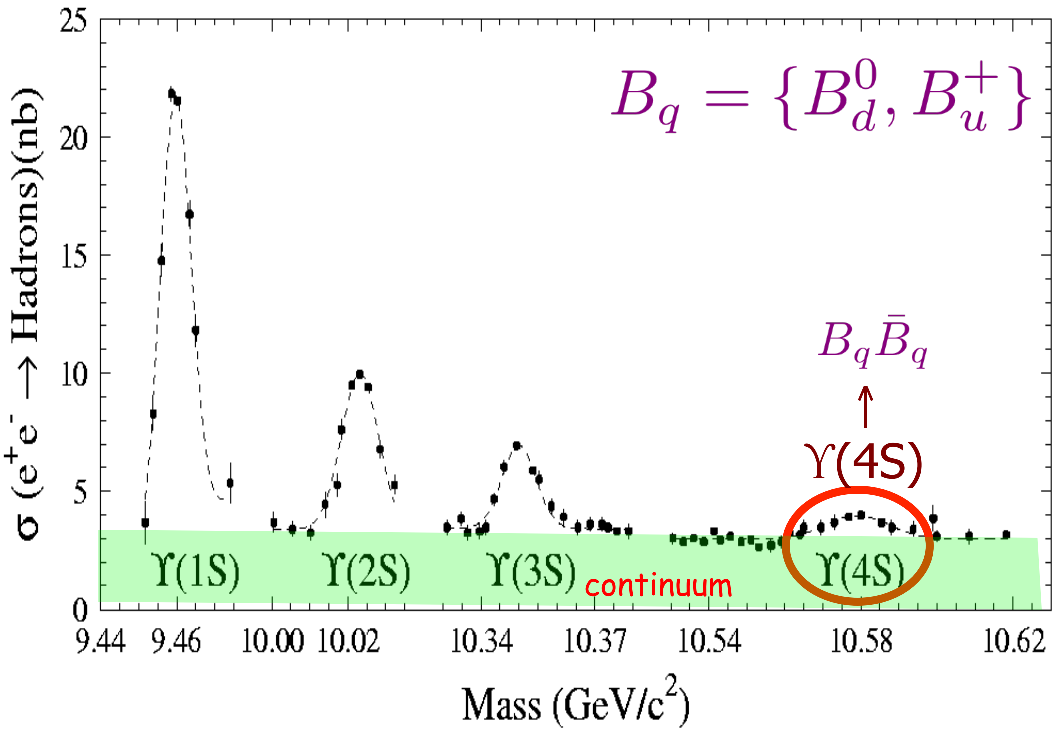
pro's

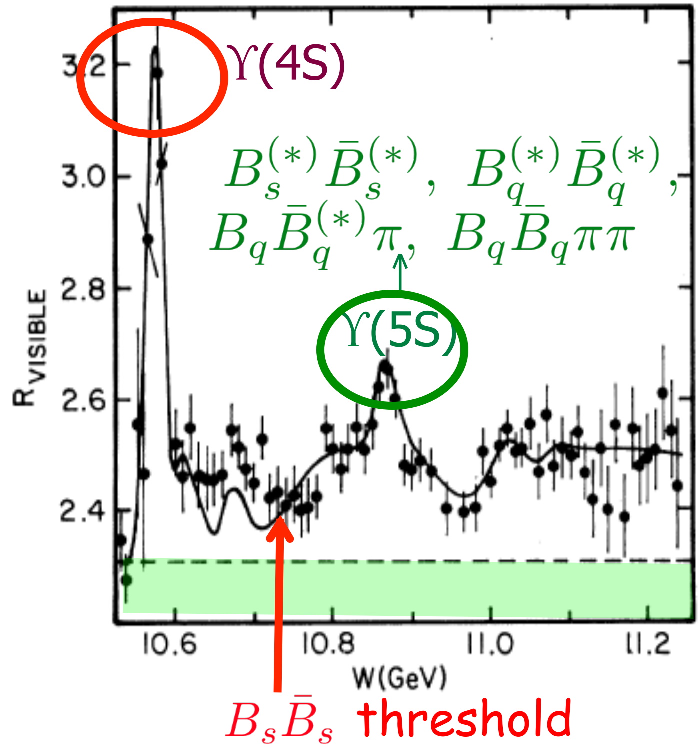
- CLEAN events, energy definition, γ's; ~100% trigger efficiency


BELLE
Exp 5 Run 272 Farm 5 Event 10889
Eher 8.00 Eler 3.50 Tue Nov 16 23z12z08 1999
TrgID 0 DetVer 0 MagID 0 BField 1.50 DspVer 5.04
Ptot(ch) 10.1 Etot(gm) 0.2 SVD-M 0 CDC-M 0 KLM-M 0
"Typical" Belle event
B's in 25%
μ^+
π^+
π^-
K^-
μ^-
K^-
20 cm


LHC event
ATLAS
B's in ~ 10-5

Υ(10860), or Υ(5S)





B_s are produced copiously in pp(bar) collisions (FNAL, LHC) –
why study B_s at the Υ(5S)?

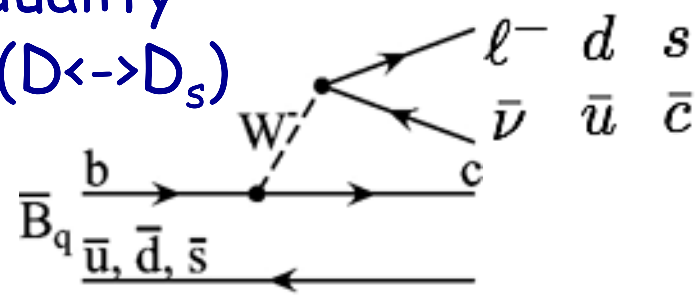
pro's

- CLEAN events, energy definition, γ's; ~100% trigger efficiency
- high luminosity, established detector, Υ(4S) data for comparison
- resonance - absolute event count

Υ(5S) physics

B_s decay in Standard Model

- similar to non-strange B
  - spectator decay -> quark-hadron duality
  - correspondence btw final particle ($D \leftrightarrow D_s$)
- dissimilarities
  - $\Delta\Gamma/\Gamma_{CP}/\Gamma = O(10\%)$
  - CP-asymmetry ~ 0



spectroscopy

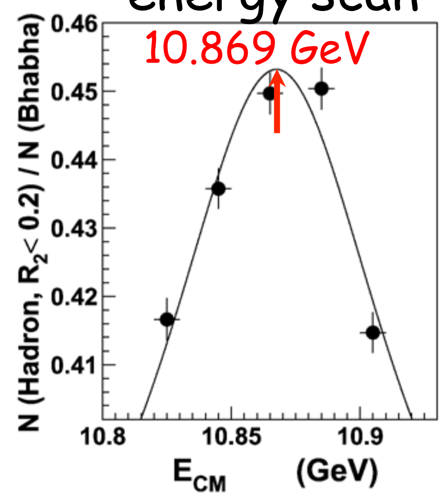
- $B_s^{(*)}$ mass
- $B_{(s)}^{(*)}(\pi)$ event fractions
- bottomonium, bottomonium-like states

Data at $\Upsilon(5S)$

June 2005: 3-day "engineering" run
- basic $\Upsilon(5S)$, $B_s^{(*)}$ properties,
- test KEKB at $\Upsilon(5S)$ - L_{max}~$1.39\times10^{34}cm^{-2}s^{-1}$
- 1.86 fb^{-1} at peak (10869 MeV)
  = 4 x largest previous sample (CLEO)

A. Drutskoy et al., PRL 98, 052001 (2007)
A. Drutskoy et al., PRD 76, 012002 (2007)

energy scan



June 2006: 20-day run
- + 21.7 fb^{-1} on resonance

K.F. Chen et al., PRL 100, 112001 (2008)
J. Wicht et al., PRL 100, 121801 (2008)
R. Louvot et al., PRL 102, 021801 (2009)
A. Drutskoy et al., PRD 81, 112003(R)(2010)
R. Louvot et al., PRL 104, 231801 (2010)
J. Li et al., arXiv:0912.1434[hep-ex]
C.-C. Peng et al., arXiv:1006.5115v1(PRD in press)
S. Esen et al., arXiv:1005.5177(PRL in press)

December 2007: scan 6 pts
- + 7.9 fb^{-1} above resonance

K.F. Chen et al., arXiv:0808.2445 (PRD in press)

Oct 2008-Dec 2009: extended run
- ~100 fb^{-1} on resonance

April-June 2010:
- ~23 fb^{-1} scan

B_s at $\Upsilon(5S)$: $B_s\bar{B}_s + B_s^*\bar{B}_s + \bar{B}_s^* B_s + B_s^*\bar{B}_s^*$

Full reconstruction of B_s candidates: Energy, momentum
example: $B_s \to D_s^- \pi^+$

$B_s\bar{B}_s$

$$E_{B_s} = E_{beam}$$

$$p_{B_s} = \sqrt{E_{B_s}^2 - M_{B_s}^2}$$

$B_s^* \to B_s\gamma$

$$\Delta M \equiv M_{B_s^*} - M_{B_s} \approx 50\ \mathrm{MeV}/c^2$$

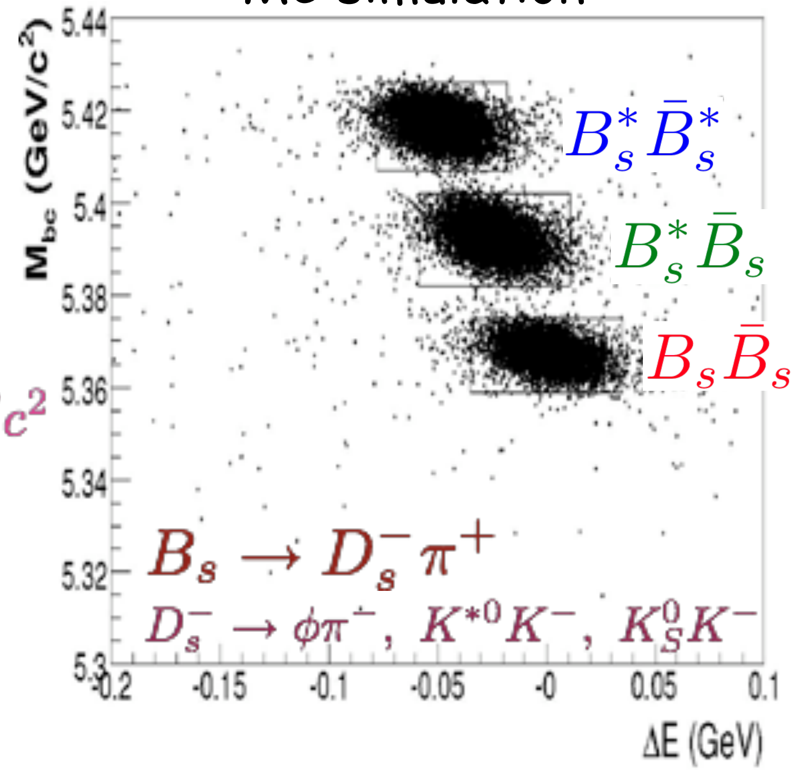
$B_s^*\bar{B}_s$

$$E_{B_s} \approx E_{beam} - \Delta M/2$$

$B_s^*\bar{B}_s^*$

$$E_{B_s} \approx E_{beam} - \Delta M$$

MC simulation



$$M_{bc} \equiv \sqrt{E_{beam}^2 - p_{cand}^2}$$

$$\Delta E \equiv E_{cand} - E_{beam}$$

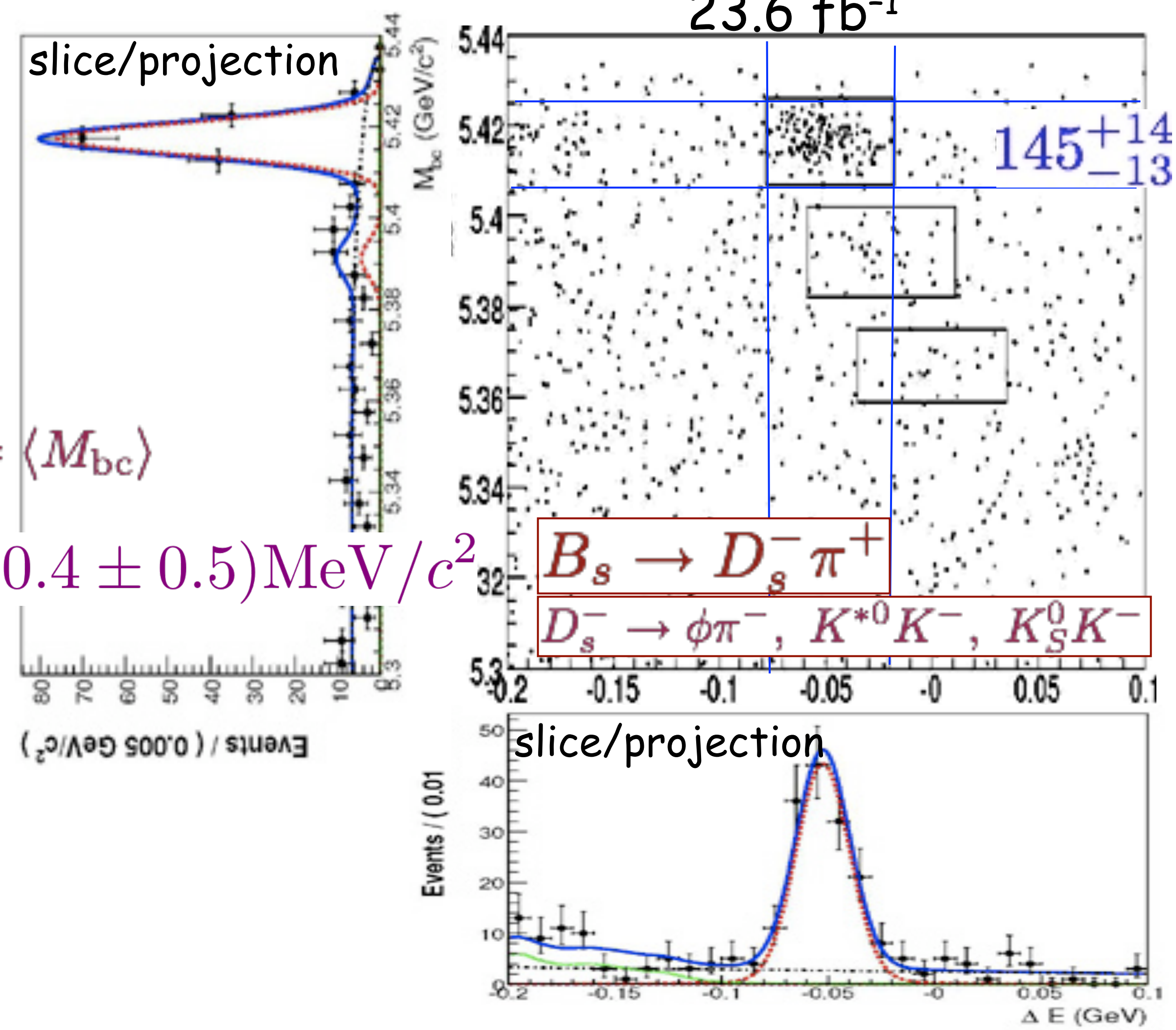
B_s at $\Upsilon(5S)$: $B_s\bar{B}_s + B_s^*\bar{B}_s + \bar{B}_s^* B_s + B_s^*\bar{B}_s^*$

Full reconstruction of B_s candidates

$B_s^*\bar{B}_s^*$

[PRL 102, 021801 (2009)]

23.6 fb^{-1}



masses:

$\langle p_{Bs}\rangle = p_{B^*}$

$$\Rightarrow M_{B_s^*} = \langle M_{\rm bc}\rangle$$

$$= (5416.4 \pm 0.4 \pm 0.5)\,\mathrm{MeV}/c^2$$

$$M_{\rm bc} \equiv \sqrt{E_{beam}^2 - p_{cand}^2}$$

B_s at Υ(5S): $B_s\bar{B}_s + B_s^*\bar{B}_s + \bar{B}_s^* B_s + B_s^*\bar{B}_s^*$

Full reconstruction of B_s candidates

$B_s^*\bar{B}_s^*$

[PRL 102, 021801 (2009)]

23.6 fb^{-1}

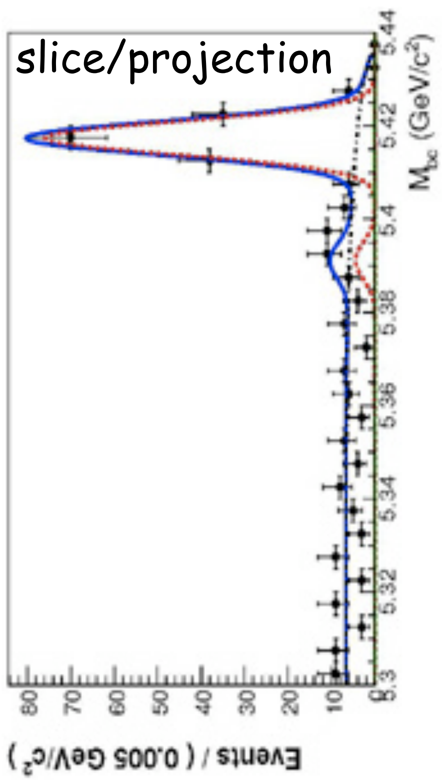
masses:

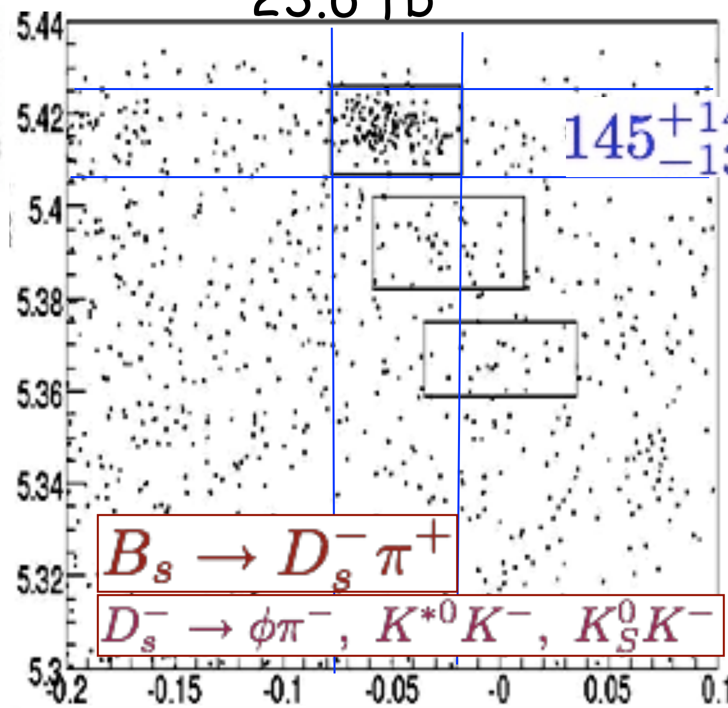
$\langle E_{Bs} \rangle$
$= E_{beam} - \langle \Delta E \rangle$

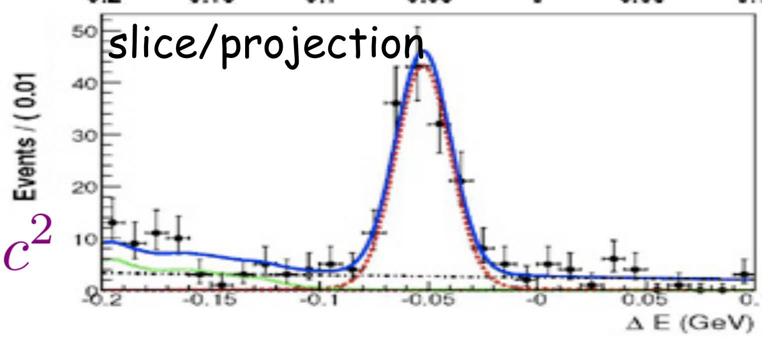
$\Rightarrow M_{B_s}$

$$= \left\langle \sqrt{(E_{beam} - \langle \Delta E \rangle)^2 - p_{cand}^2} \right\rangle$$

$$= (5364.4 \pm 1.3 \pm 0.7)\mathrm{MeV}/c^2$$







$$M_{bc} \equiv \sqrt{E_{beam}^2 - p_{cand}^2}$$

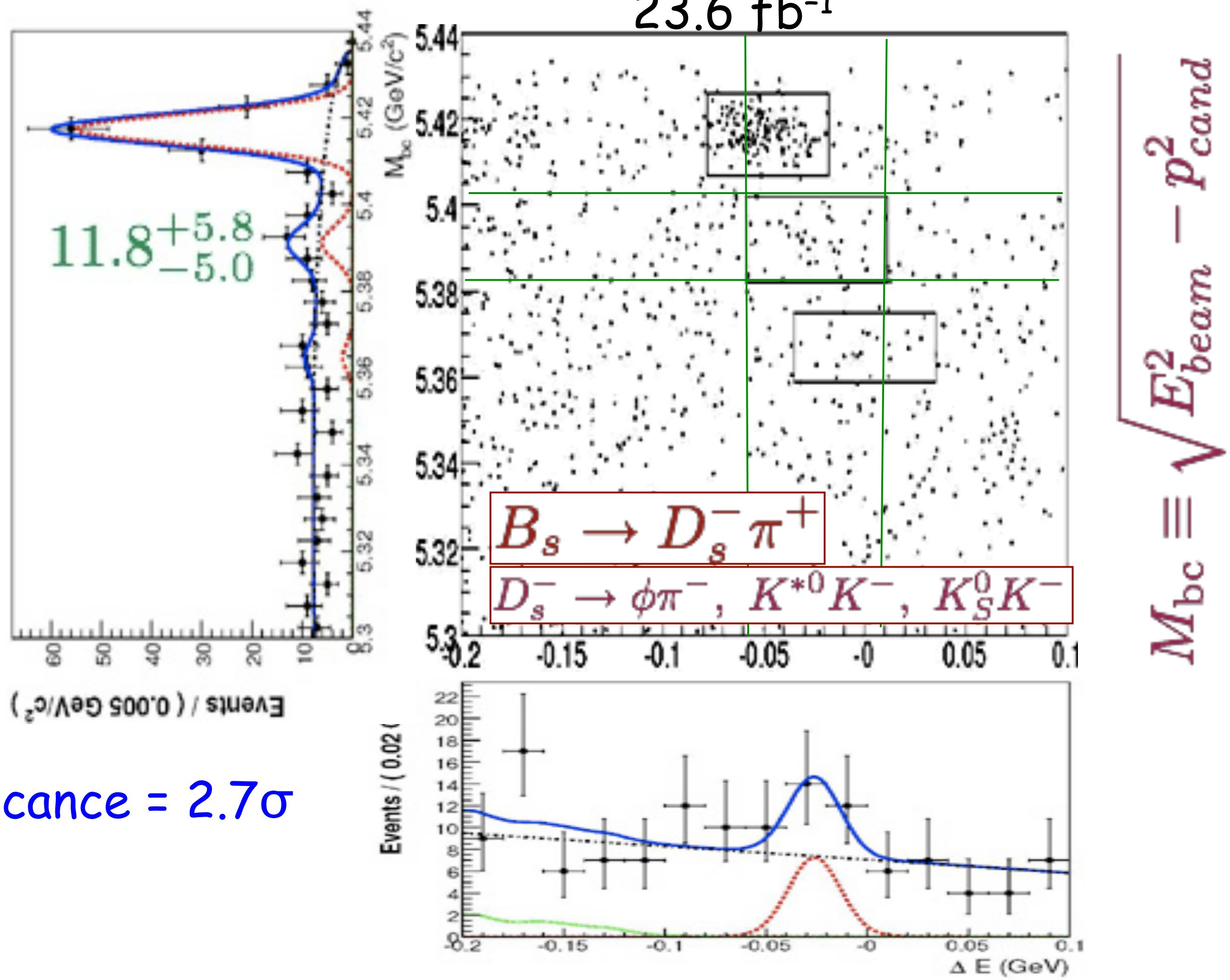
B_s at Υ(5S): $B_s\bar{B}_s + B_s^*\bar{B}_s + \bar{B}_s^* B_s + B_s^*\bar{B}_s^*$

Full reconstruction of B_s candidates

$B_s^* B_s$

[PRL 102, 021801 (2009)]

23.6 fb^{-1}



significance = 2.7σ

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B_s at $\Upsilon(5S)$: $B_s\bar{B}_s + B_s^*\bar{B}_s + \bar{B}_s^*B_s + B_s^*\bar{B}_s^*$

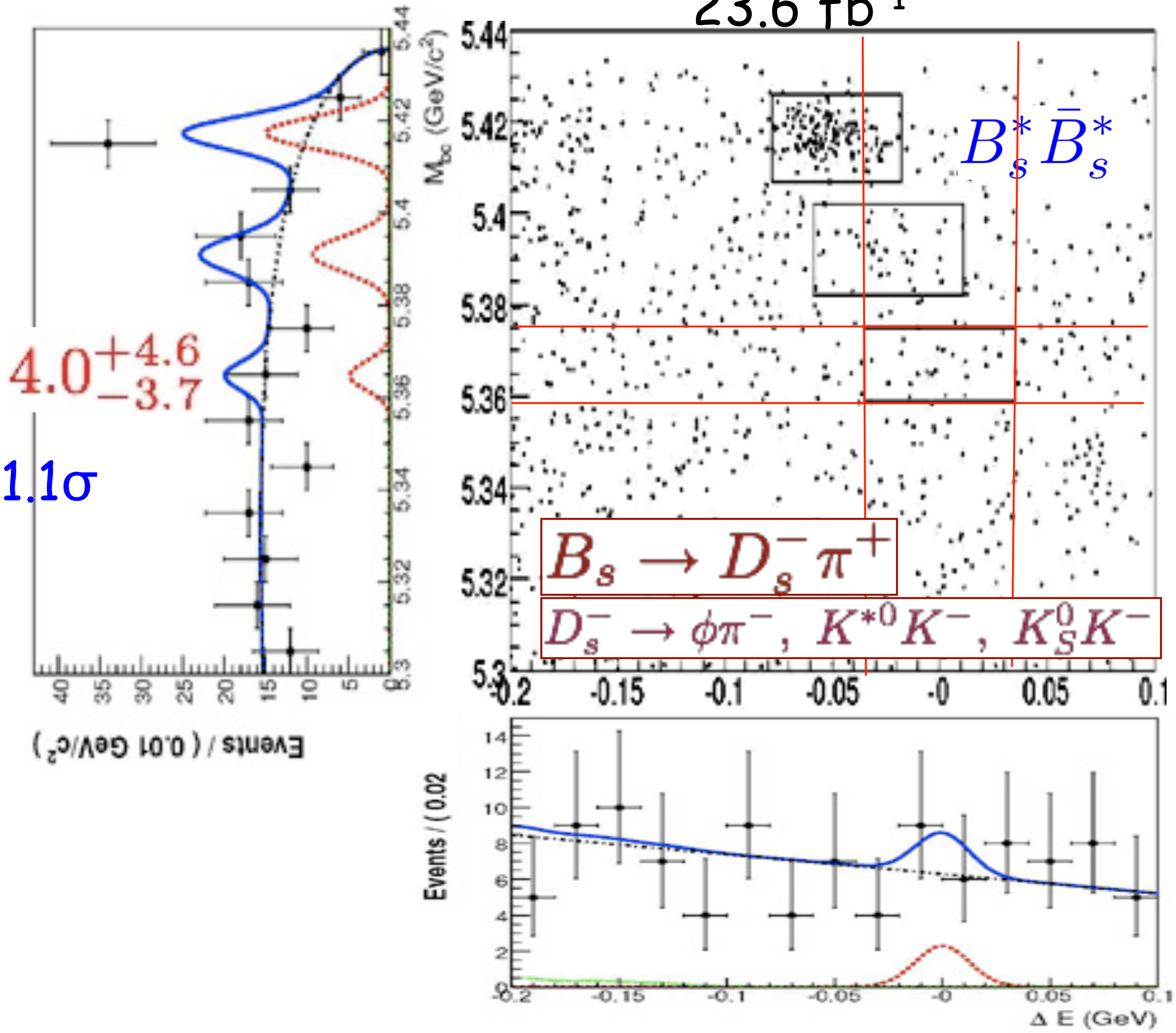
Full reconstruction of B_s candidates

B_sB_s

[PRL 102, 021801 (2009)]

23.6 fb^{-1}

significance 1.1σ



$$M_{bc} \equiv \sqrt{E_{beam}^2 - p_{cand}^2}$$

B_s at $\Upsilon(5S)$: $B_s\bar{B}_s + B_s^*\bar{B}_s + \bar{B}_s^* B_s + B_s^*\bar{B}_s^*$

Full reconstruction of B_s candidates

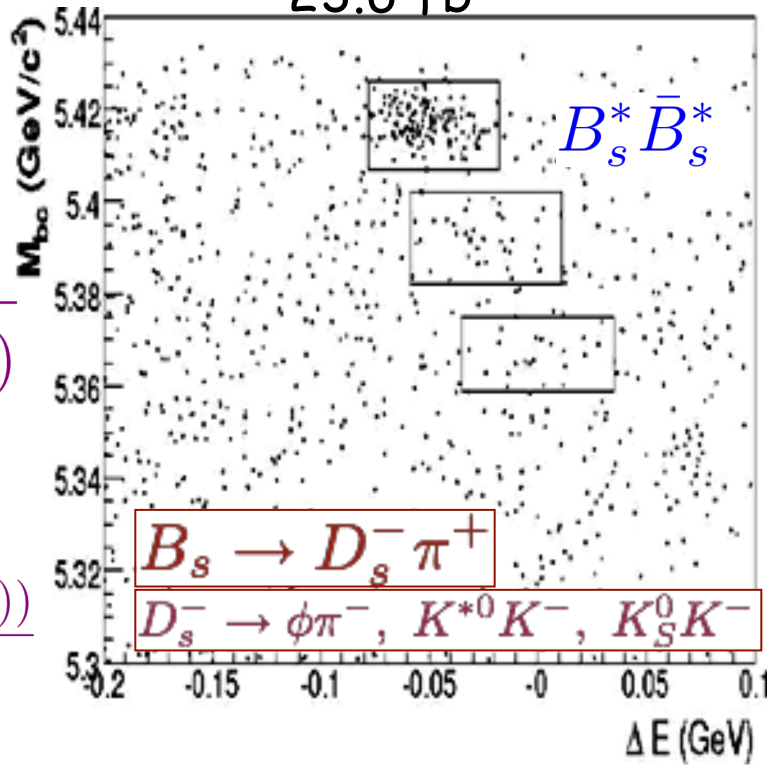
[PRL 102, 021801 (2009)]

23.6 fb^{-1}

Comparing rates:

$$f_{B_s^* B_s^*} \equiv \frac{\sigma(e^+e^- \to B_s^*\bar{B}_s^*)}{\sigma(e^+e^- \to B_s^{(*)}\bar{B}_s^{(*)})} = (90.1^{+3.8}_{-4.0} \pm 0.2)\%$$

$$f_{B_s^* B_s} \equiv \frac{\sigma(e^+e^- \to B_s^*\bar{B}_s + B_s\bar{B}_s^*))}{\sigma(e^+e^- \to B_s^{(*)}\bar{B}_s^{(*)})} = (7.3 \pm 0.3 \pm 0.1)\%$$



$$M_{bc} \equiv \sqrt{E_{beam}^2 - p_{cand}^2}$$

$$\Delta E \equiv E_{cand} - E_{beam}$$

$$\mathcal{B}(B_s \to D_s\pi) = (3.67^{+0.35+0.43}_{-0.33-0.42}) \times 10^{-3}$$

CP Eigenstates

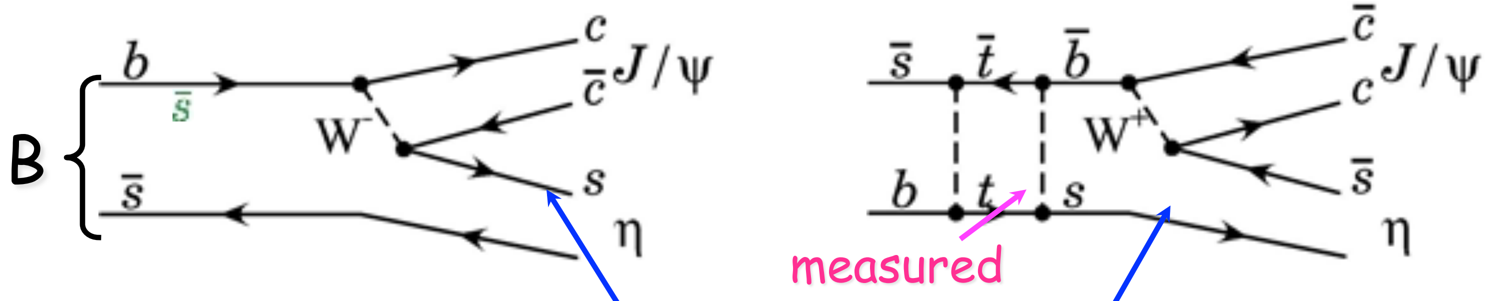
What about CP violation? **... look at weak couplings in SM…**

CP asymmetry in B_s -> $J/\psi\ \eta$

Analogous to B -> J/ψ K_s(Sanda/Bigi/Carter)

tree (real V_{ij}) $\propto V_{cb}^{*} V_{cs}$

mixing+tree ($\propto V_{td}^{*2}$)
$\propto V_{tb}^{*2} V_{ts}^{2} V_{cb} V_{cs}^{*}$



identical hadronic processes

Bottom line: CP-dependent oscillation in *t* from cross-term(s)
- no theoretical uncertainty:

$$\frac{dN}{dt}(B \rightarrow f_{CP}) = \frac{1}{2}\Gamma e^{-\Gamma t}(1 + \eta_b \eta_{CP} \sin\phi \sin(\Delta m \Delta t))$$

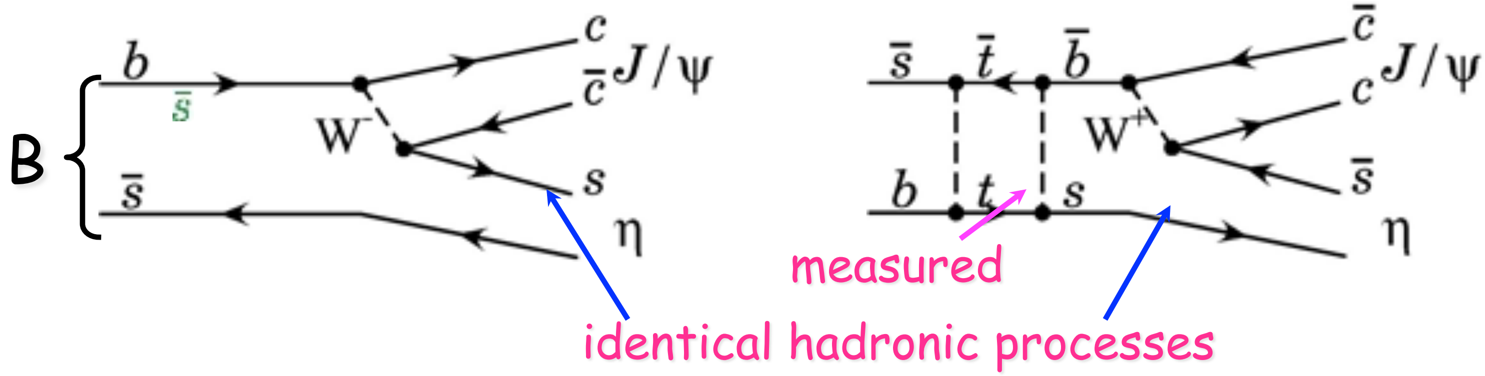
Where $\eta_{CP} = \begin{pmatrix} +1 \text{ if } CP \text{ even} \\ -1 \text{ if } CP \text{ odd} \end{pmatrix}$ $\quad \eta_b = \begin{pmatrix} +1 \text{ if } B_{t=0} = B^0 \\ -1 \text{ if } B_{t=0} = \bar{B}^0 \end{pmatrix}$

CP asymmetry in B_s -> $J/\psi\ \eta$

Analogous to B -> J/ψ K_s(Sanda/Bigi/Carter)

tree (real V_{ij}) $\propto V_{cb}^{*}V_{cs}$

mixing+tree ($\propto V_{td}^{*2}$) $\propto V_{tb}^{*2}V_{ts}^{2}V_{cb}V_{cs}^{*}$



Bottom line: CP-dependent oscillation in *t* from cross-term(s)

- no theoretical uncertainty:

$$\frac{dN}{dt}(B \to f_{CP}) = \frac{1}{2}\Gamma e^{-\Gamma t}(1 + \eta_b \eta_{CP} \sin\phi \sin(\Delta m \Delta t))$$

and $\varphi = \arg(V_{tb}^{*2}V_{ts}^{2}) = 0$

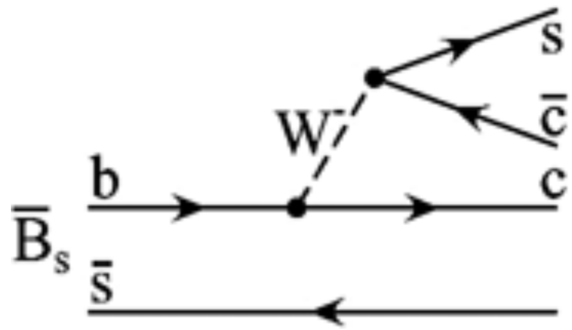
-> any CP asymmetry is evidence for New Physics!

Why is non-CKM CP violation of interest?

- CP asymmetry in CKM is insufficient for matter-antimatter asymmetry of the universe!

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

S. Esen
arXiv:1005.5177



- CKM-favored AND flavor-neutral
  CP=+1 in heavy quark limit, $m_c \to \infty$
  ~ saturated by 2-body $D_s^{(*)+} D_s^{(*)-}$
  -> difference in widths of CP=±1

$$\frac{\Delta\Gamma_{CP}}{\Gamma} \approx \frac{2\mathcal{B}(B_s \to D_s^{(*)+} D_s^{(*)-})}{1 - \mathcal{B}(B_s \to D_s^{(*)+} D_s^{(*)-})}$$

Aleksan et al., Phys. Lett. B316, 567 (1993)

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

Reconstruction

$$D_s^{*+} \to D_s^+ \gamma$$

$$D_s^+ \to \phi\pi^+$$

$$D_s^+ \to K_S^0 K^+$$

$$D_s^+ \to \bar{K}^{*0} K^+$$

$$D_s^+ \to \phi\rho^+$$

$$D_s^+ \to K^{*+} K_S^0$$

$$D_s^+ \to K^{*+} \bar{K}^{*0}$$

$$\phi \to K^+ K^-$$

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

$$\bar{K}^{*0} \to K^-\pi^+$$

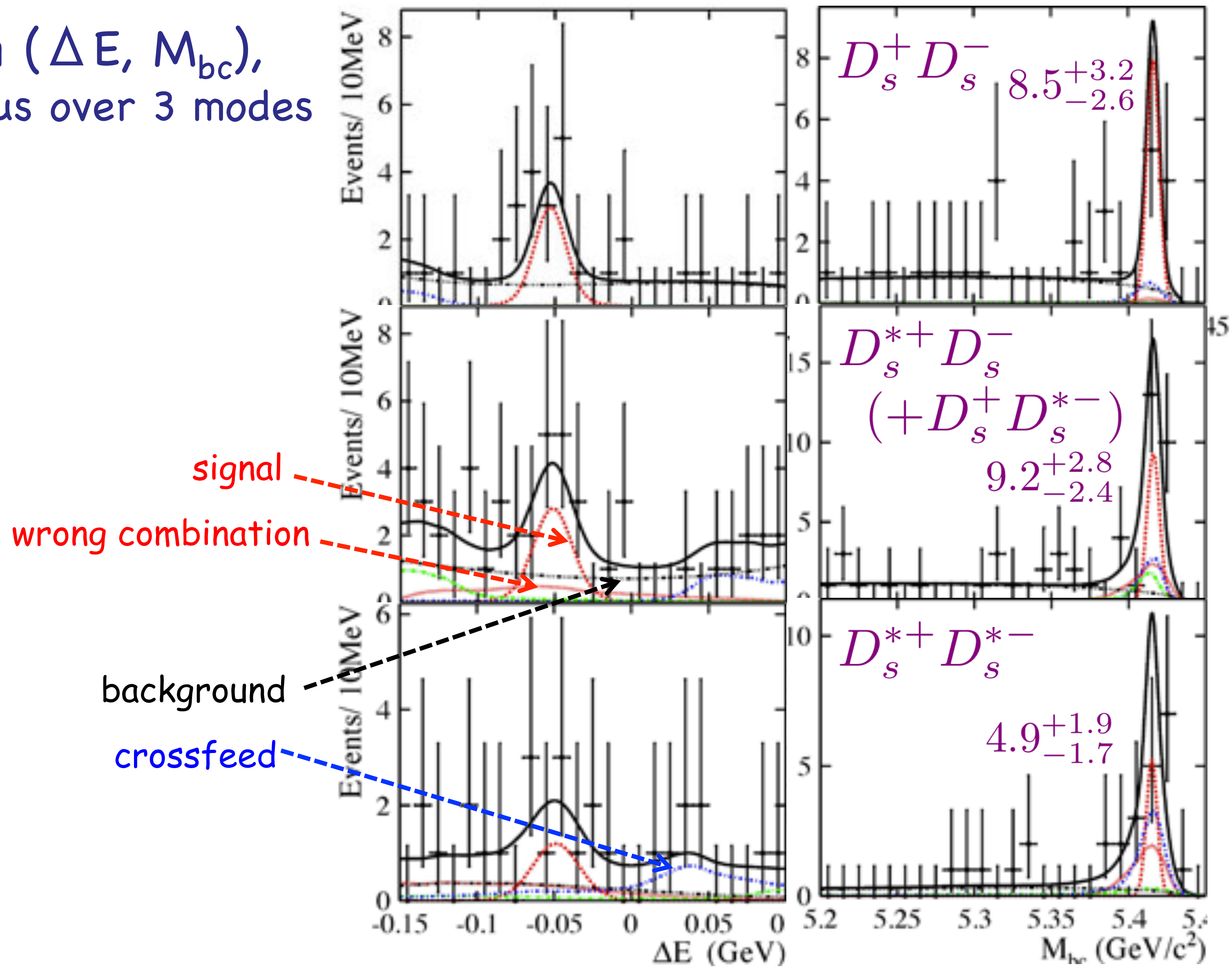
$$\rho^+ \to \pi^+\pi^0$$

$$K^{*+} \to K_S^0 \pi^+$$

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

23.6 fb^{-1}

2-d fit in (ΔE, M_{bc}),
simultaneous over 3 modes



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

Branching fraction

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

FIRST OBSERVATION

FIRST EVIDENCE

$$\frac{\Delta\Gamma_{CP}}{\Gamma} = \frac{2\mathcal{B}}{1-\mathcal{B}} \boxed{= 0.147^{+0.036+0.044}_{-0.030-0.042} \pm 0.004}$$

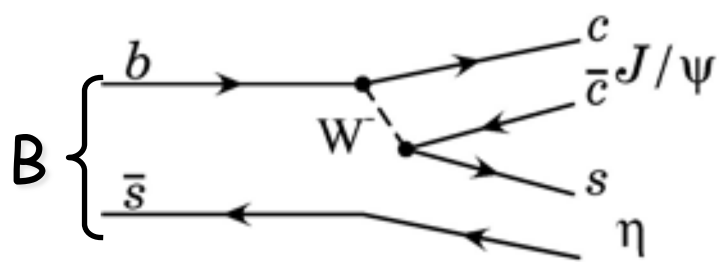
$$[PDG : 0.092^{+0.051}_{-0.054}]$$

[theory; Aleksan et al., PLB 316, 567 (1993)

Need updated theory input!

$B_s \to J/\psi\eta^{(\prime)}$

arXiv:0912.1434
J. Li



CP eigenstate; expectation

$\mathcal{B}(B_s \to J/\psi\eta) \approx 3.5 \times 10^{-4}$ $\mathcal{B}(B_s \to J/\psi\eta') \approx 4.9 \times 10^{-4}$

Based on flavor SU(3) symmetry + PDG: $\mathcal{B}(B_d^0 \to J/\psi K^0) = 8.71 \times 10^{-4}$

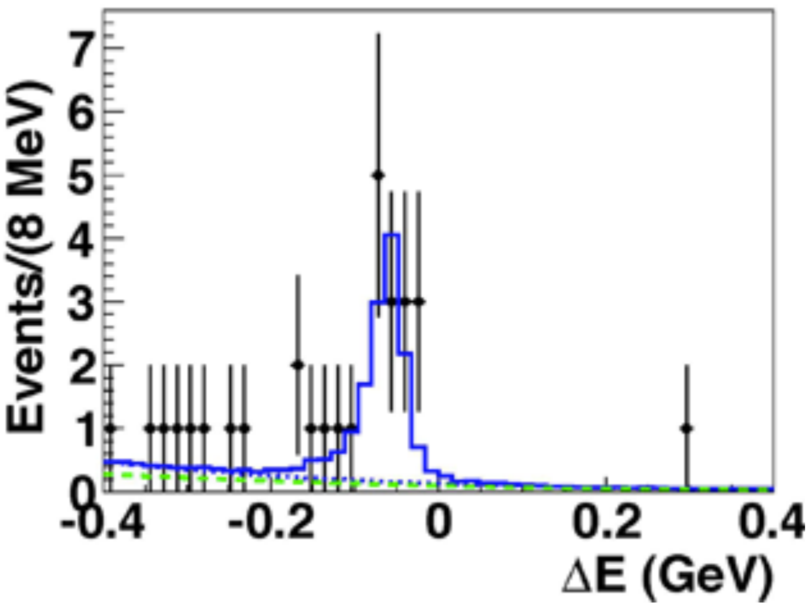
Reconstruction

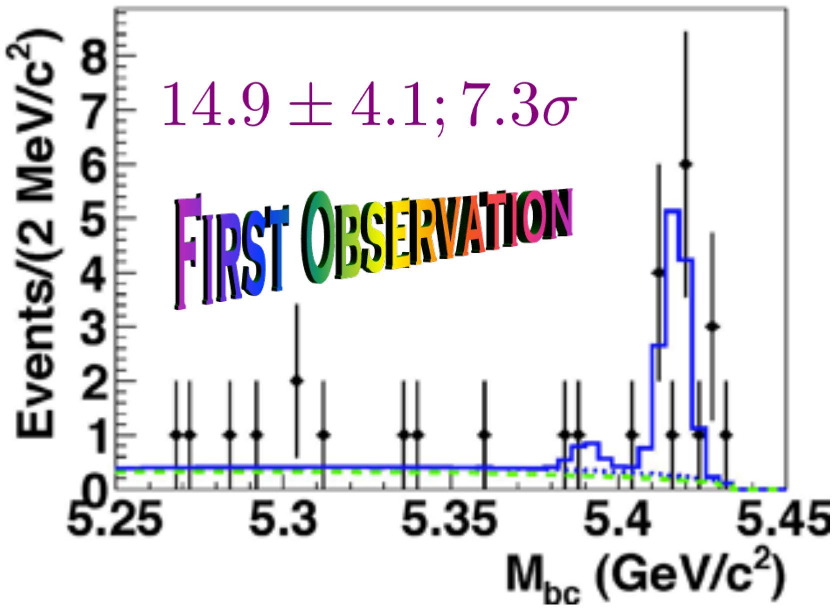
$$J/\psi \to e^+e^-,\ \mu^+\mu^-$$
$$\eta \to \gamma\gamma,\ \pi^+\pi^-\pi^0$$
$$\eta' \to \eta\pi^+\pi^-,\ \rho^0\gamma$$

$B_s \to J/\psi\eta$

2-d fit in (ΔE, M_{bc}), simultaneous over sub-modes

23.6 fb^{-1}



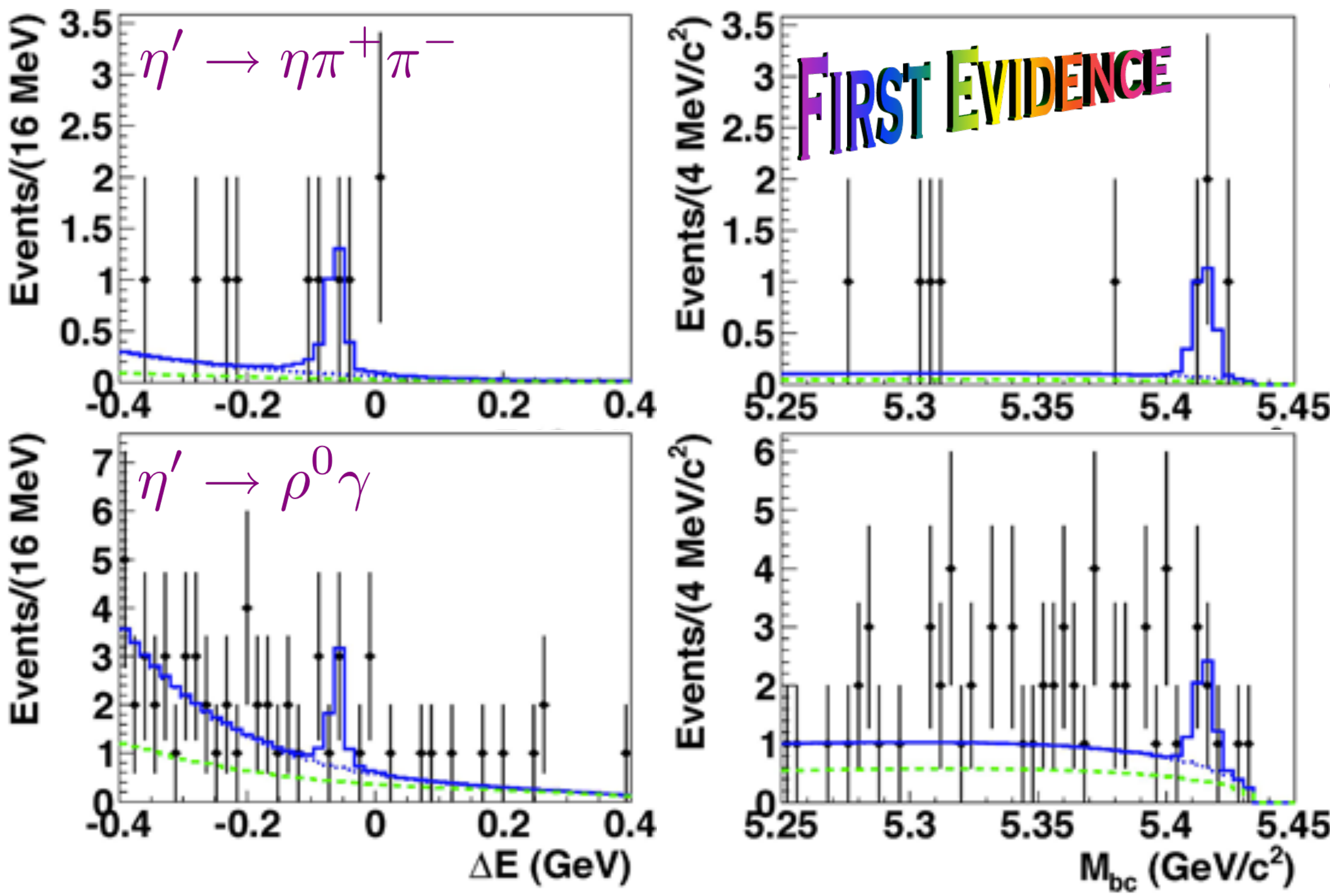


$$\boxed{\mathcal{B}(B_s \to J/\psi\eta) = (3.32 \pm 0.87(stat)^{+0.32}_{-0.28}(sys) \pm 0.42(f_s)) \times 10^{-4}}$$

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

2-d fit in (ΔE, M_{bc}), simultaneous over sub-modes

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



3.8σ

23.6 fb^{-1}

Searches for radiative modes of B_s

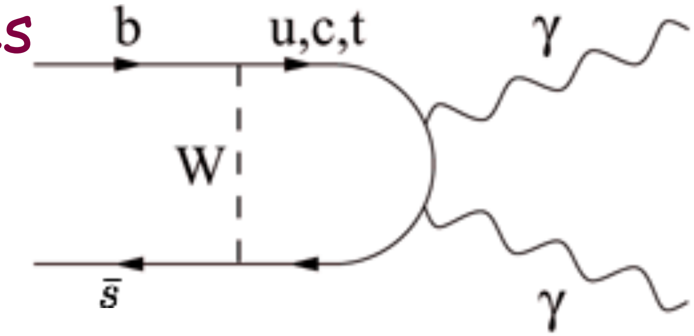
J. Wicht, et al.
PRL 100, 121801 (2008)

Searches for new modes of B_s

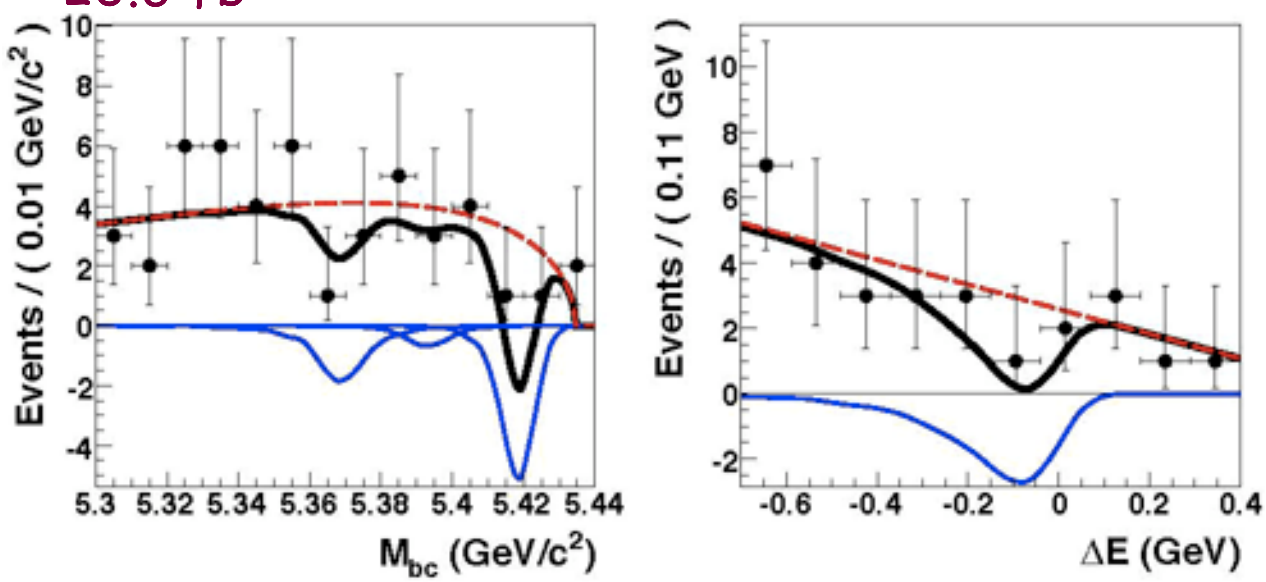
γγ: difficult for hadron machines

$$\mathcal{B}_{SM} \sim (0.4 - 1.0) \times 10^{-6}$$

beyond SM: up to 5×10^{-6}



23.6 fb^{-1}

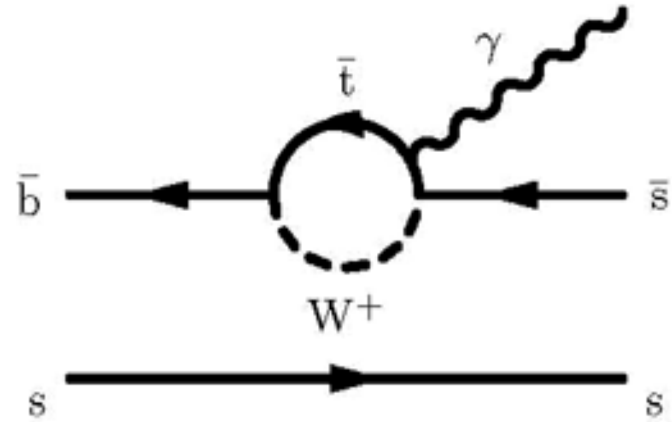


$$\mathcal{B} < 8.7 \times 10^{-6} \ (90\% \ CL)$$ (prev. Belle: $<5.3 \times 10^{-5}$)

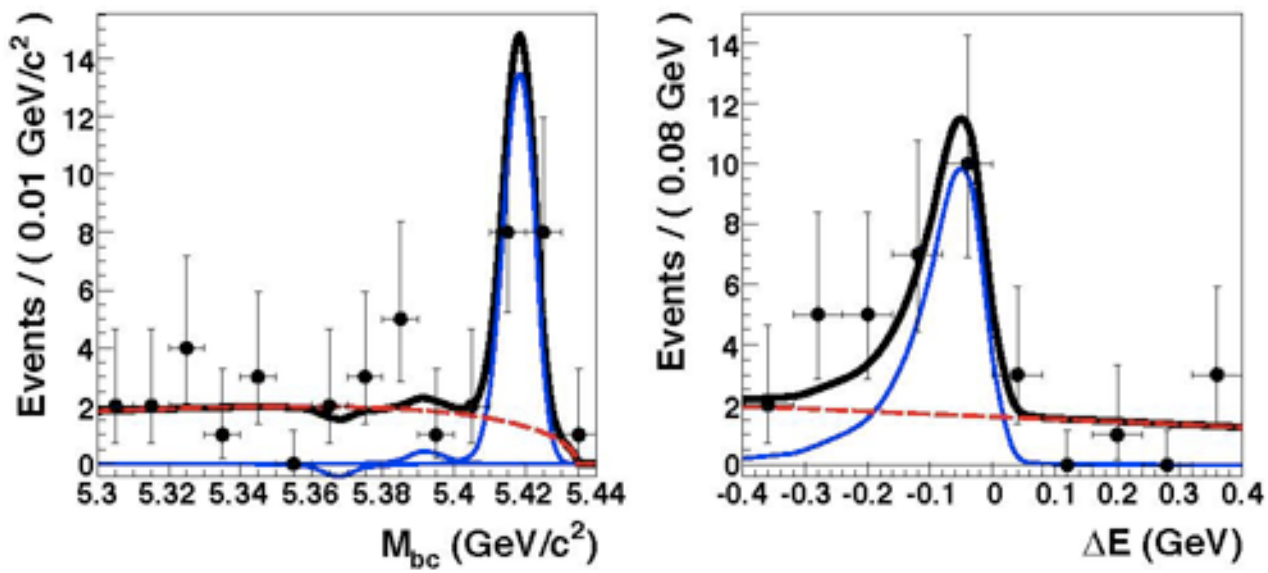
φγ

γ: difficult for hadron machines

Analogue: $B^0 \to K^{*0}\gamma$



23.6 fb^{-1}



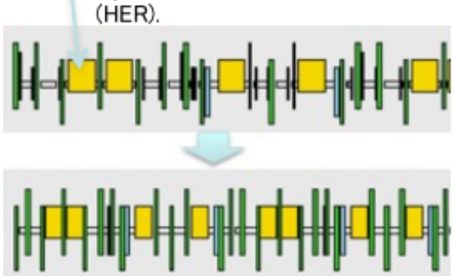
$$\mathcal{B} = (57^{+18}_{-15}(stat)^{+12}_{-11}(sys)) \times 10^{-6}$$

First observation

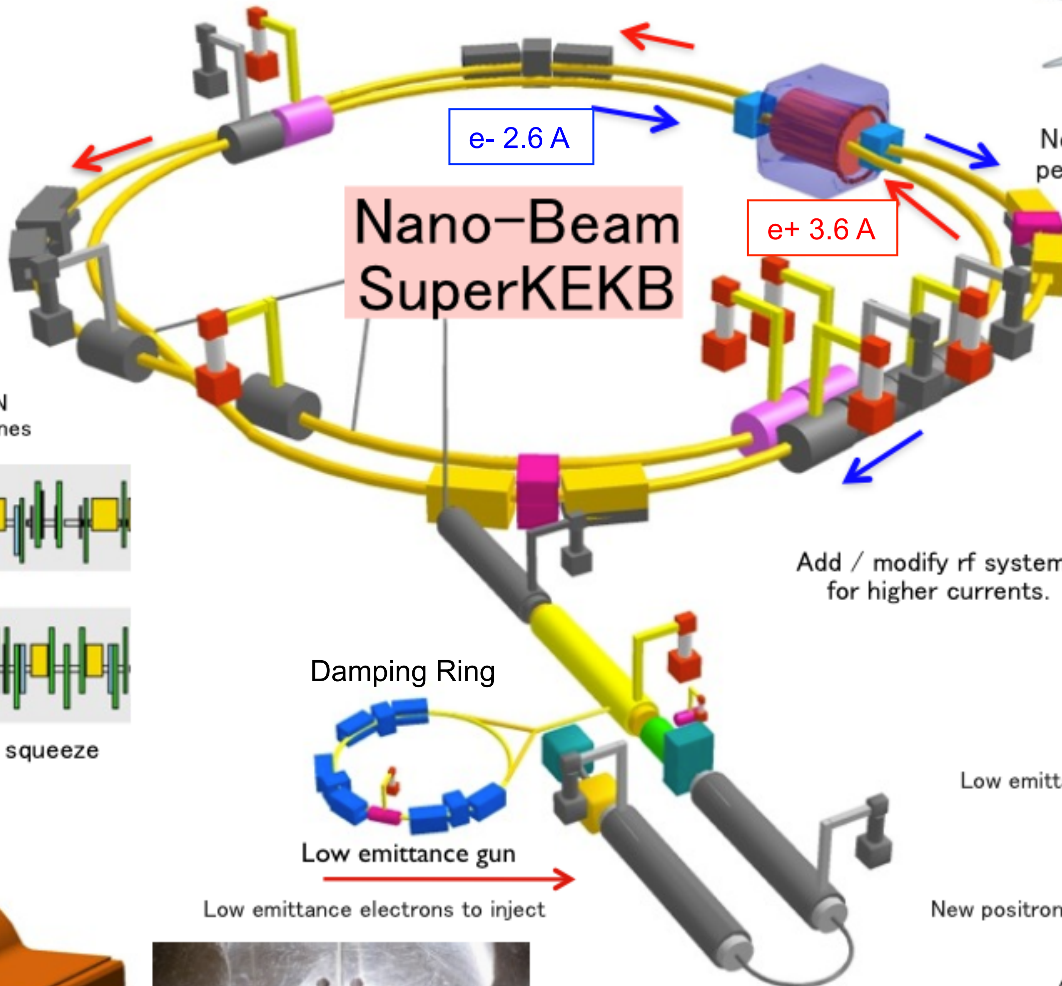
Flavor in the Future

"Super Flavor Factory"

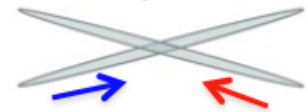
Replace long TRISTAN dipoles with shorter ones (HER).



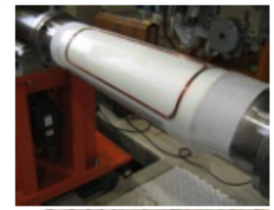
Redesign the HER arcs to squeeze the emitance.



Low emittance electrons to inject



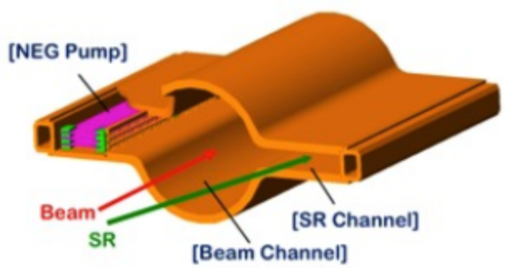
New Superconducting / permanent final focusing quads near the IP



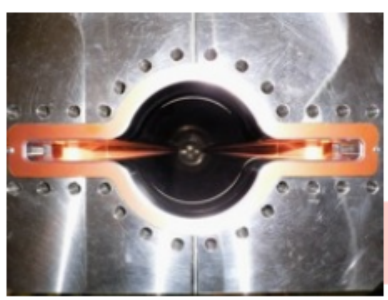
Add / modify rf systems for higher currents.

Low emittance positrons to inject

New positron target / capture section



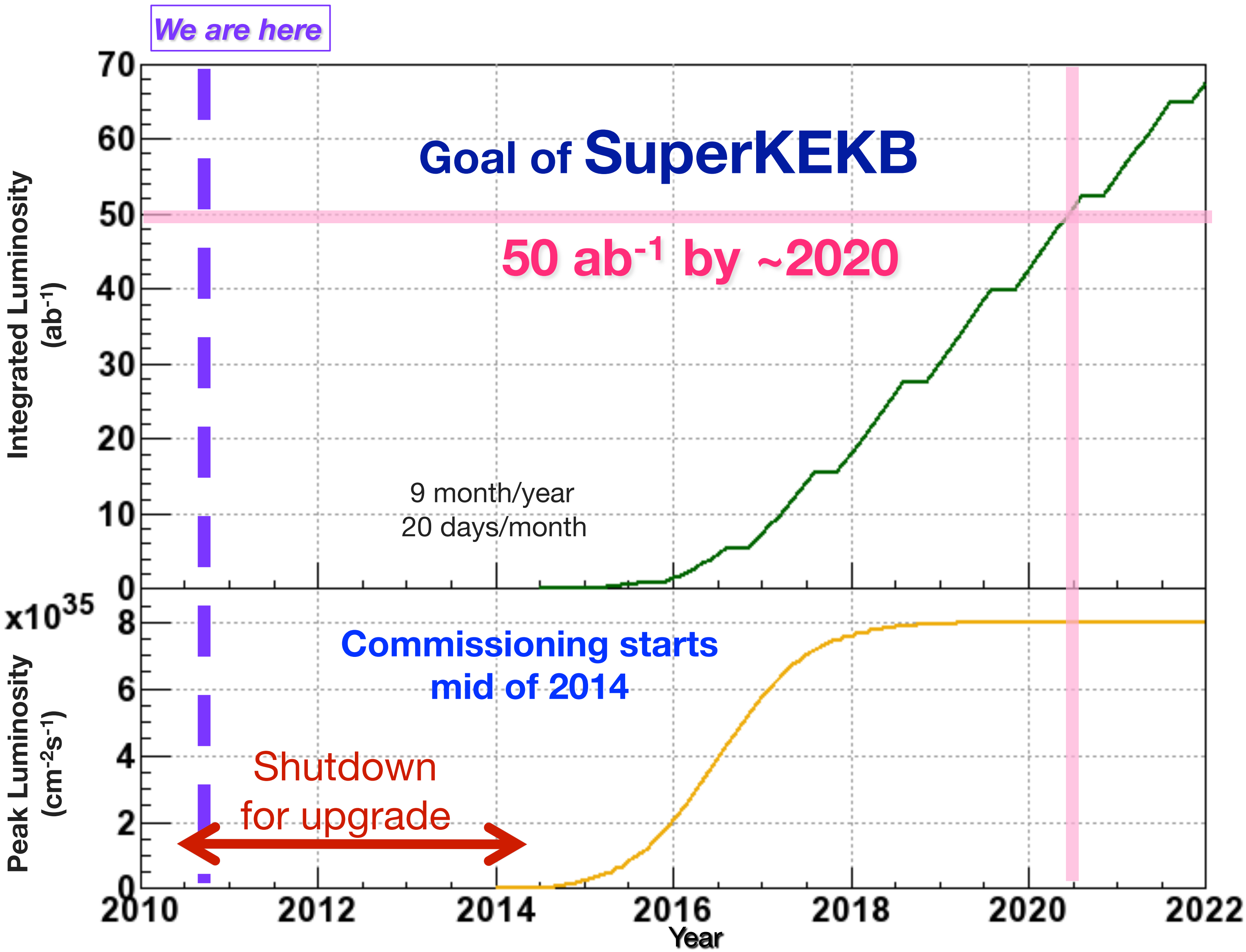
TiN coated beam pipe with antechambers



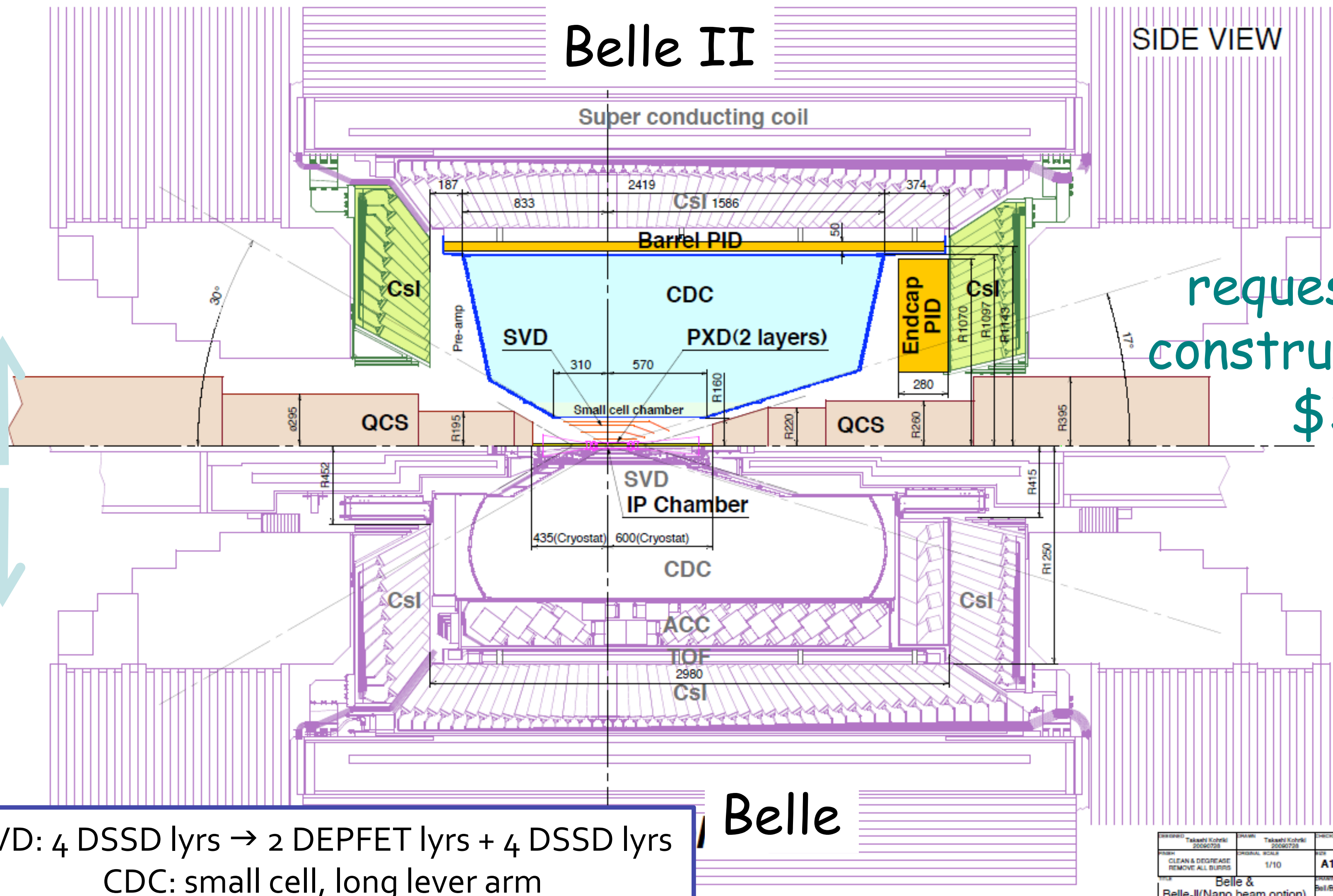
$$L = \frac{\gamma_\pm}{2er_e}\left(1+\frac{\sigma_y^*}{\sigma_x^*}\right)\left(\frac{I_\pm \xi_{\pm y}}{\beta_y^*}\right)\left(\frac{R_L}{R_y}\right)$$

x40 Gain in Luminosity

Luminosity projection



Belle II detector

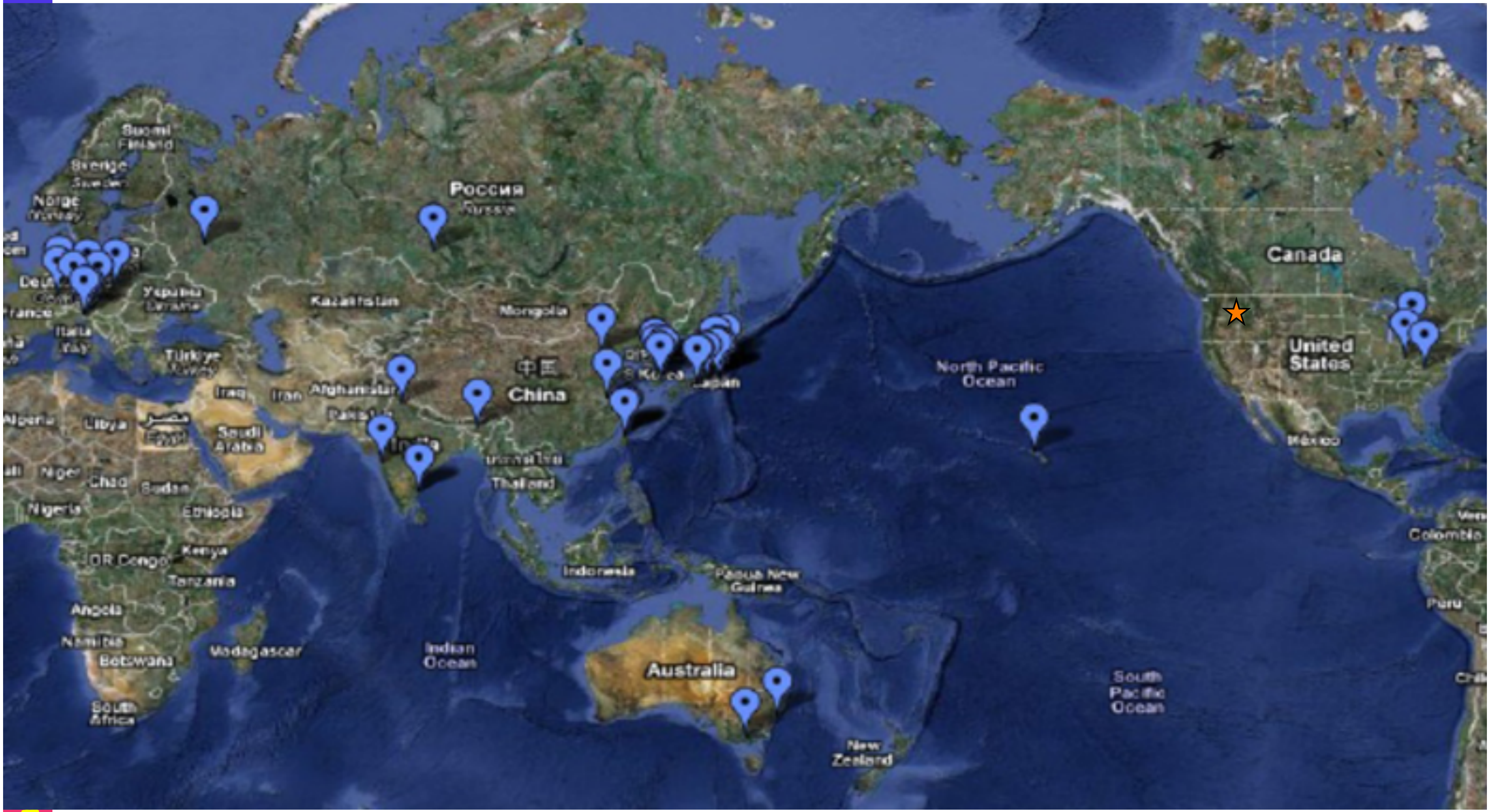


request for construction: $350M

SVD: 4 DSSD lyrs → 2 DEPFET lyrs + 4 DSSD lyrs
CDC: small cell, long lever arm
ACC+TOF → TOP+A-RICH
ECL: waveform sampling, pure CsI for end-caps
KLM: RPC → Scintillator +SiPM (end-caps)

Parameters are preliminary

Belle II Collaboration



Recent progress in funding

last update: 10/06/23

Press Release

KEKB upgrade plan has been approved

June 23, 2010
High Energy Accelerator Research Organization (KEK)

The MEXT, the Japanese Ministry that supervises KEK, has announced that it will appropriate a budget of 100 oku-yen (approx $110M) over the next three years starting this Japanese fiscal year (JFY2010) for the high performance upgrade program of KEKB. This is part of the measures taken under the new "Very Advanced Research Support Program" of the Japanese government.

"We are delighted to hear this news," says Masanori Yamauchi, former spokesperson for the Belle experiment and currently a deputy director of the Institute of Particle and Nuclear Studies of KEK. "This three- year upgrade plan allows the Belle experiment to study the physics from decays of heavy flavor particles with an unprecedented precision. It means that KEK in Japan is launching a renewed research program in search for new physics by using a technique which is complementary to what is employed at LHC at CERN."

Summary

K. Kinoshita U. of South Alabama 10/2010

KEKB and Belle at $\Upsilon(10860)$+

- Analyzed: 1.3M B_s events

- Strange beauty
  - spectator modes: $B_s \to D_s^{(*)}h$
  - $B_s^{(*)}B_s^{(*)}$ rates, masses of B_s^*, B_s
  - γ modes: $B_s \to \gamma\gamma$ (best limit), $B_s \to \varphi\gamma$ (first observation)
  - absolute measurement $B(B_s \to D_s^{(*)}D_s^{(*)})(\sim\Delta\Gamma_{CP}/2\Gamma)$
  - CP modes

- Starting to analyze: 5.2 M additional B_s events
  - (first results winter 2011)
- more to come ...
  - SuperKEKB/Belle II ~2014