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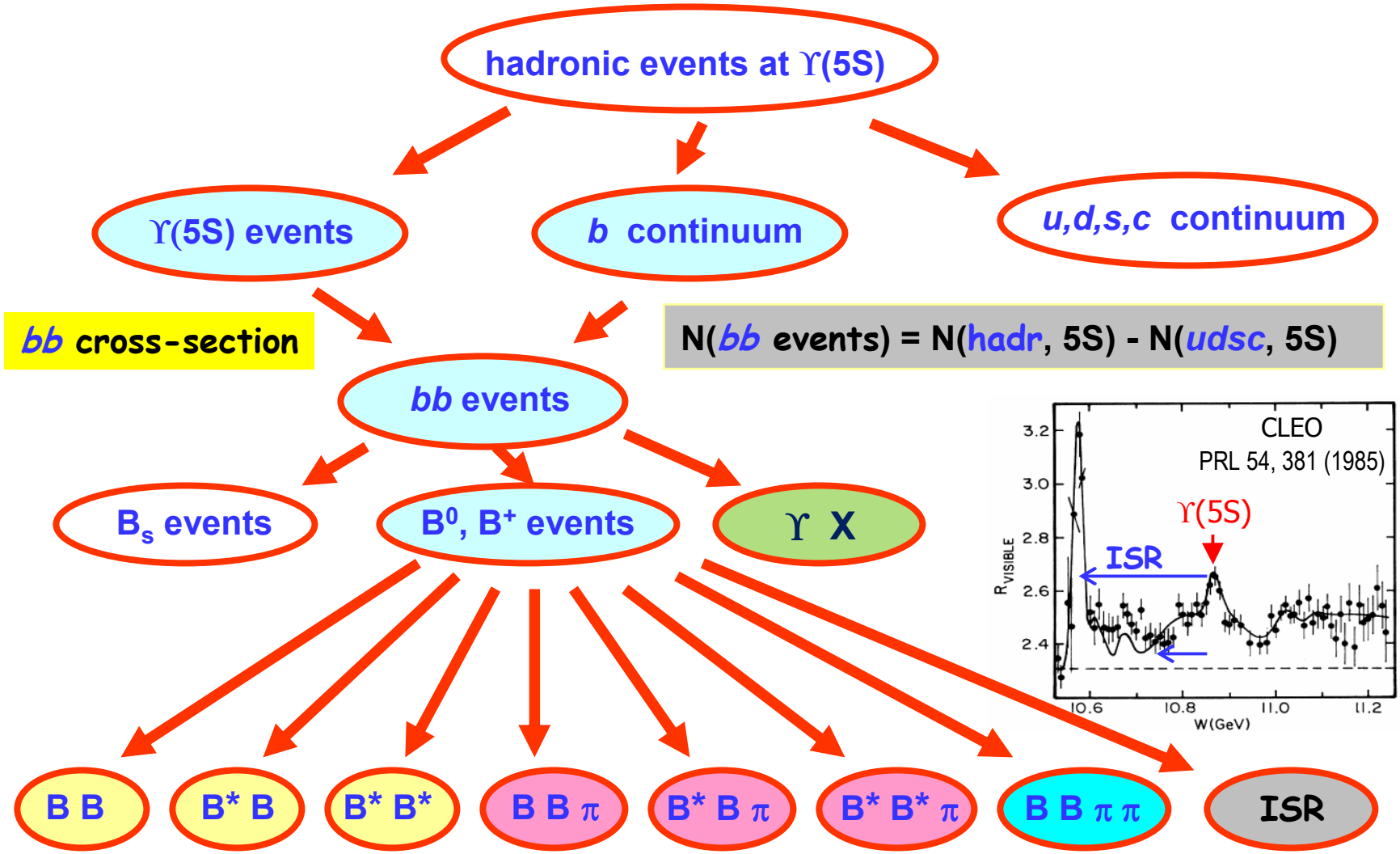
sin 2β from 5S tagged events (Belle publ.)

3rd SuperB Collaboration meeting

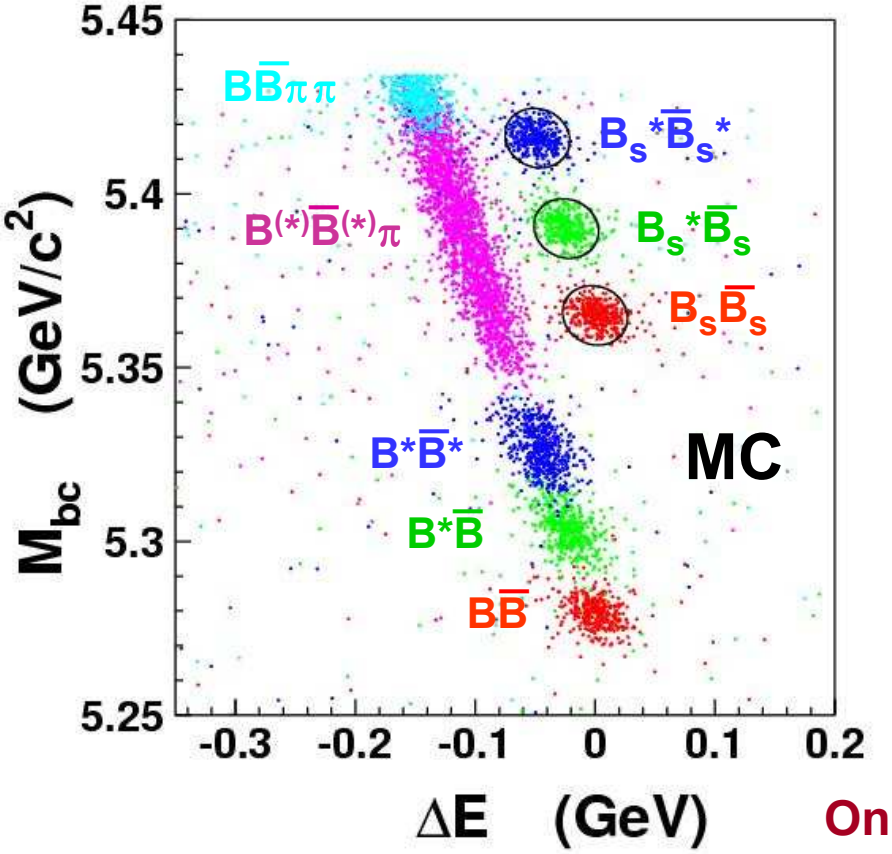
March 19-23, 2012, LNF, Frascati, Italy

Hadronic event classification at $\Upsilon(5S)$

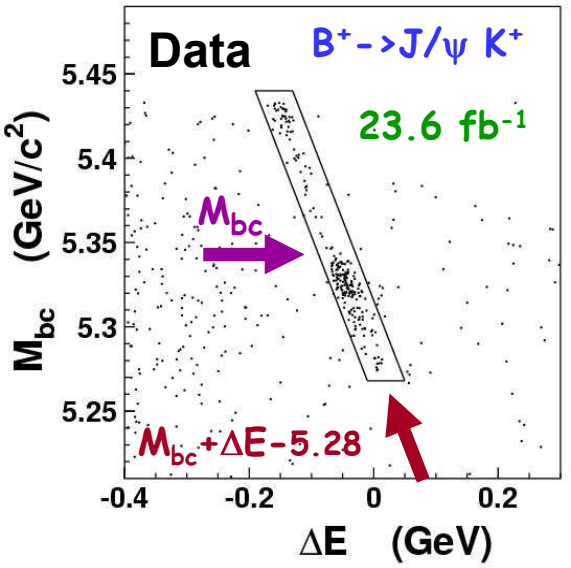


$\Upsilon(5S)$ decays to B^0 and B^+ mesons

A.Drutskoy et al (Belle coll.) PRD 81, 112003 (2010)



$e^+ e^-$ -> $\Upsilon(5S)$ -> $B^{(*)}B^{(*)}(\pi)(\pi)$,
where B^* -> $B\gamma$



Only one B meson is reconstructed

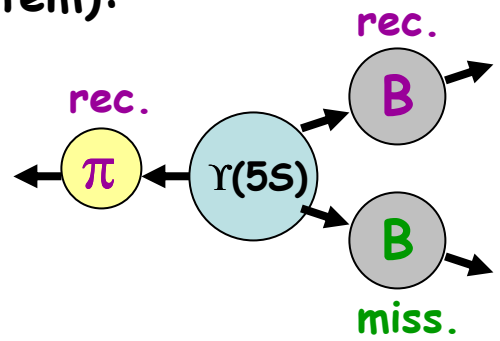
Two variables calculated: $M_{bc} = \sqrt{E^*_{beam}{}^2 - P^*_B{}^2}$, $\Delta E = E^*_B - E^*_{beam}$

B energy (E^*_B) and momentum (P^*_B) are reconstructed; no rec. γ from B^*

Decomposition of 3-body channels

We can separate 2-body final states using M_{bc}.
How to separate 3-body final states?

We reconstruct directly produced pion in $B^{(*)}\bar{B}^{(*)}\pi^+$ channels.
Then we calculate parameters (all in CM system):



Reconstructed B meson:

M_{bc}, ΔE ; $\Delta X(rec) = M_{bc} + \Delta E - 5.28$

Missing B meson:

use momentum $P(B\pi)$ and energy $E(B\pi)$ of reconstructed B and π:

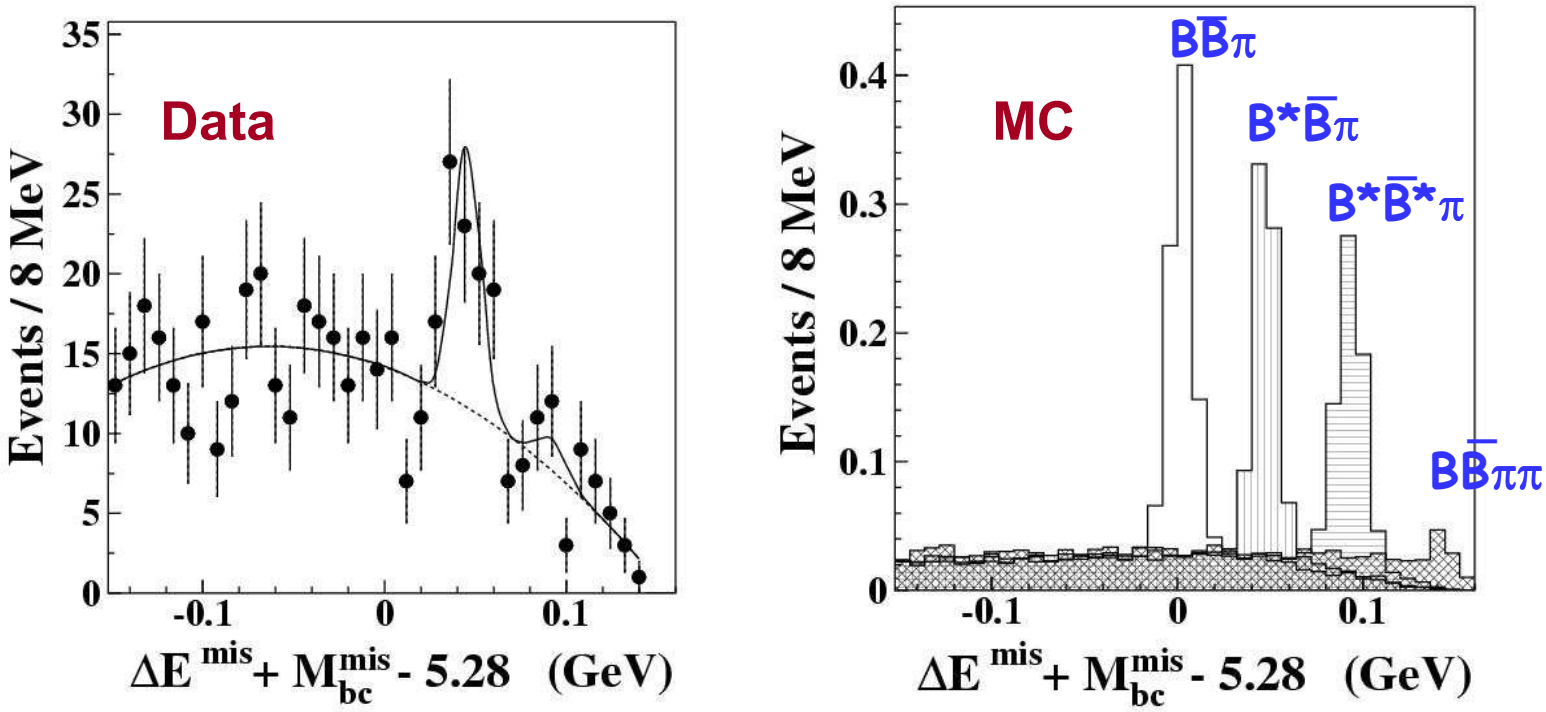
$\Delta X(miss) = M_{bc}^{miss} + \Delta E^{miss} - 5.28$ (Belle 2010 paper)

$M^2_{miss} = [\, P_{total} - (P_B + P_\pi) \,]^2$ (P- 4-momenta) (Belle 2012 paper)

These two parameters are close to each other within 1 MeV.
Missing mass is bit more natural variable.

Decomposition of 3-body channels

Belle 2010 paper, sum of 5 modes



3 – body channels can be well separated using direct pion

B_s^0 and $B^{0/+}$ production rates at $\Upsilon(5S)$ (at E_{cm}=10867 MeV)

B_s^0 $(19.5 \pm {}^{3.0}_{2.3})$ %

$f(B_s^* \bar{B}_s^*) = (90.1 \pm {}^{3.8}_{4.0} \pm 0.2)\%$

$f(B_s^* \bar{B}_s) = (7.3 \pm {}^{3.3}_{3.0} \pm 0.1)\%$

$f(B_s \bar{B}_s) = (2.6 \pm {}^{2.6}_{2.5})\%$

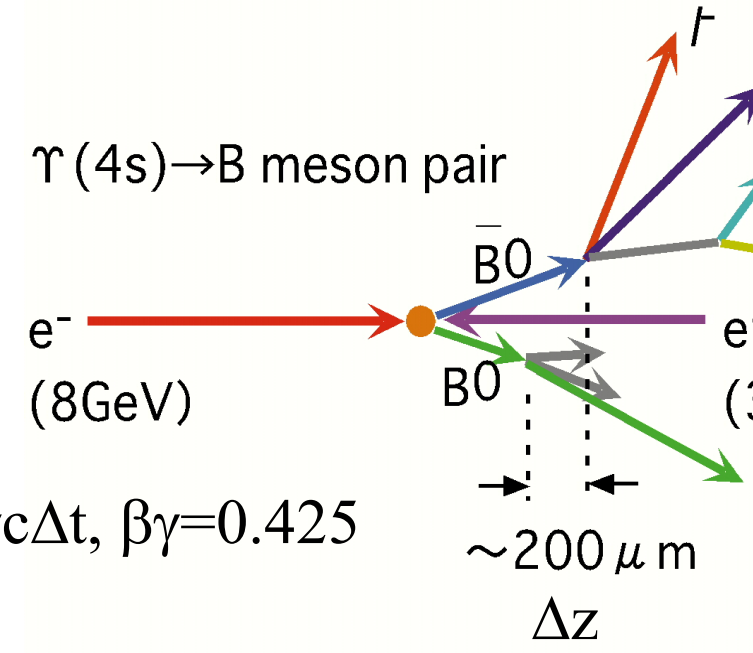
B (73.7 ± 3.2 ± 5.1) %

B^0 $(77.0 \pm {}^{5.8}_{5.6} \pm 6.1)$ %

B^+ $(72.1 \pm {}^{3.9}_{3.8} \pm 5.0)$ %

2 - body	$B\bar{B}$:	$(5.5 \pm {}^{1.0}_{0.9} \pm 0.4)$ %
	$B^*\bar{B}$:	(13.7 ± 1.3 ± 1.1) %
	$B^*\bar{B}^*$:	$(37.5 \pm {}^{2.1}_{1.9} \pm 3.0)$ %
3 - body	$B\bar{B}\,\pi$	(0.0 ± 1.2 ± 0.3) %
	$B^*\bar{B}\,\pi$	$(7.3 \pm {}^{2.3}_{2.1} \pm 0.8)$ %
	$B^*\bar{B}^*\,\pi$	$(1.0 \pm {}^{1.4}_{1.3} \pm 0.4)$ %
Residual (ISR)		$(9.2 \pm {}^{3.0}_{2.8} \pm 1.0)$ %

Time dependent CPV



Decays into f_{CP} (CP side)

Identify B or $\bar{B}$ by leptons, kaons… (Tag side)

$\Delta z = \beta\gamma c \Delta t$, $\beta\gamma = 0.425$

$$A_{CP}(t) = \frac{\Gamma(\bar{B}^0(\Delta t) \to f_{CP}) - \Gamma(B^0(\Delta t) \to f_{CP})}{\Gamma(\bar{B}^0(\Delta t) \to f_{CP}) + \Gamma(B^0(\Delta t) \to f_{CP})} = S_{f_{CP}} \sin(\Delta m \Delta t) + A_{f_{CP}} \cos(\Delta m \Delta t)$$

S_{fCP} and A_{fCP} are obtained by unbinned maximum likelihood fit to Δt distribution(CP fit).

Measurement sin 2β with tagging method at Υ(5S)

Y. Sato, H. Yamamoto et al (Belle coll.) arXiv:1201.3502, to appear in PRL

Method was proposed by H. Yamamoto (not published), details are presented at L.Lellouch, L. Randal, E. Sather, NP B405, 55 (1993).

Select $B^{(*)}B^{(*)}\pi^+$ and $B^{(*)}B^{(*)}\pi^-$ tagged events at Y(5S) with reconstructed CP-fixed B^0 states ($B^0 \to J/\psi\, K^0_S$).

$$A_{BB\pi} = \frac{N_{BB\pi^-} - N_{BB\pi^+}}{N_{BB\pi^-} + N_{BB\pi^+}} = \frac{Sx + A}{1 + x^2}$$

where S and A – mixing induced and direct CP- violating parameters, (A=0 with very small theoretical uncertainties)

No time measurement is required to obtain sin 2β

Cross checks at $\Upsilon(5S)$

Using the same method a few channels were checked ($L=121\ fb^{-1}$):

$B^0 \to J/\psi\ K^{*0}$ and $D^{*-}\pi^+$

$\chi_d = N_{mixed} / (N_{mixed} + N_{unmixed}) = 0.19 \pm 0.09$ (stat)

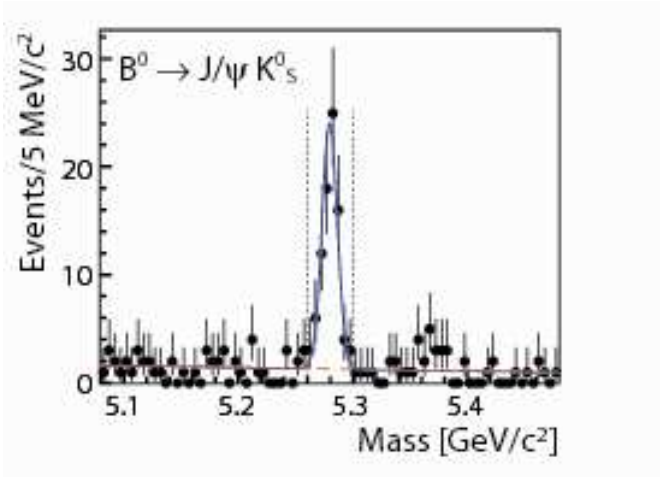
World average 0.1864 ± 0.0022

$B^0 \to J/\psi\ K^+$

$A_{BB\pi} = 0.02 \pm 0.17$ as expected, $N_{ev} = 64.8 \pm 11.9$

These two measurements validate method.

Measurement sin 2β with tagging method at Υ(5S)

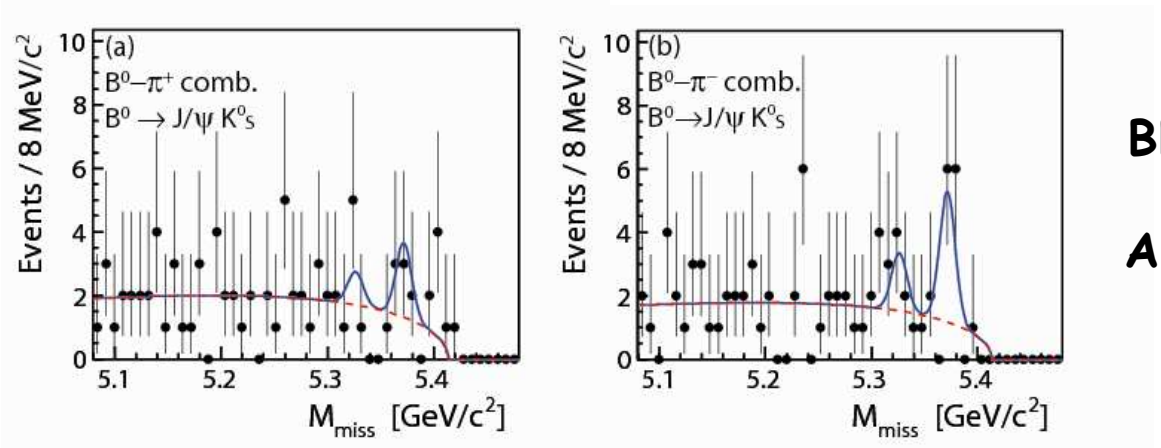


Belle preliminary, L=121 fb^{-1}

Channel B^0 -> J/ψ K^0_S

Full set of events (no BBπ selection)

N events = 75.9 ± 9.5

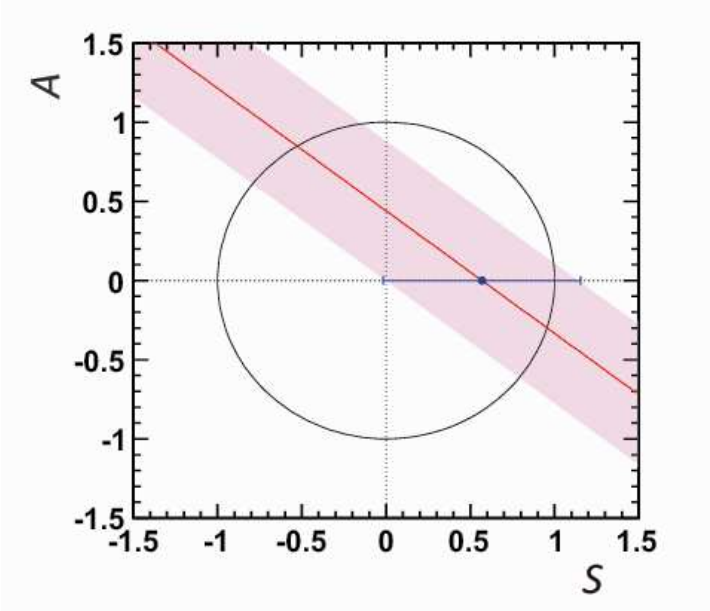


BBπ selections

$A_{BB\pi}$ = 0.28 ± 0.28 (stat)

sin 2β = 0.57 ± 0.58 (stat) ± 0.06 (syst) , assuming A=0

Conclusions



Two-dimensional confidence regions in S and A plane. Circle – physical boundary. Point with error – A=0. Here mixing parameter is taken from HFAG :

$x = 0.771 \pm 0.007$

Method of sin 2β measurement from 5S tagged events works well

Not enough data for precise measurement -> SuperB factory

With very large statistics -> CP measurement without vertex ($\pi^0\pi^0$)