Measurement of t.d. CP Asimmetry in $B\to K^0_S\pi^0$ $B\to K^{*0}\gamma$

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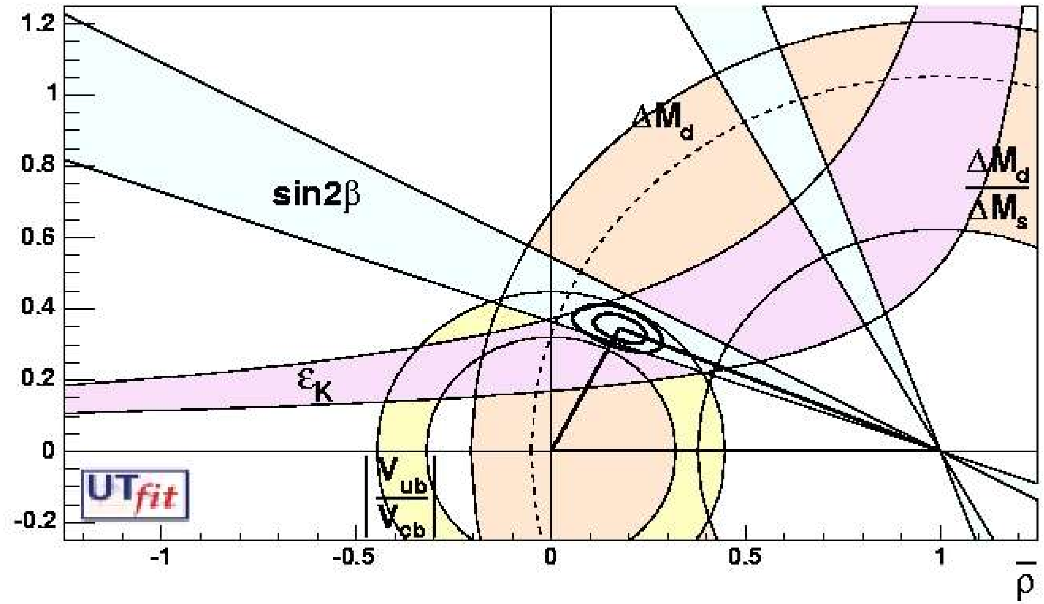
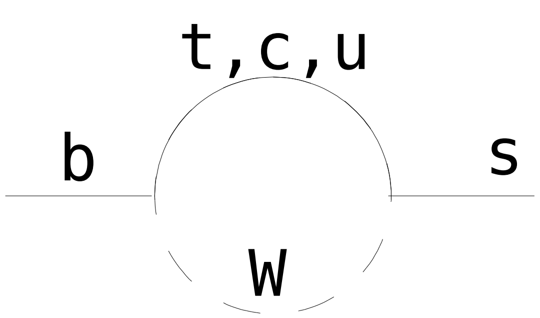
~~CP~~, UT*fit* and New Physics

- UT*fit* proved consistency of CKM mechanism explaining flavour mixing and CP violation in the Standard Model
- but b→s and b→d processes are not strongly constrained
- new physics effects can be present in penguin loops

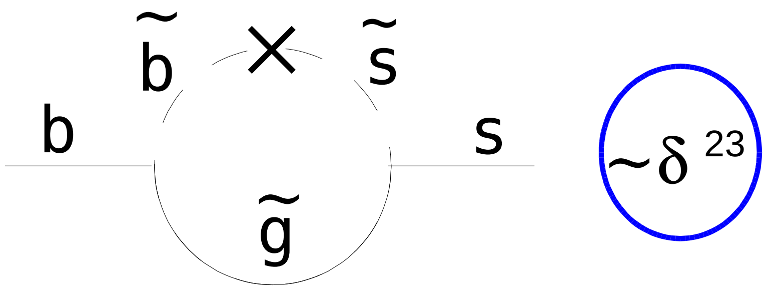
Bona et al.
http://www.utfit.org



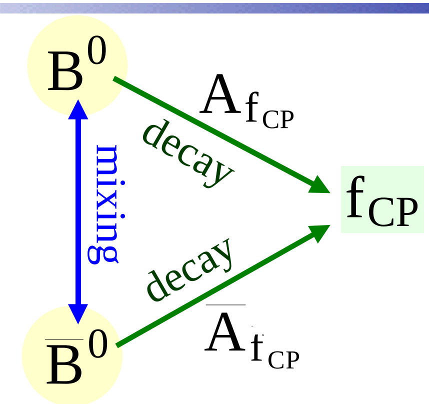


Standard Model Contribution
Weak interaction

SUSY contribution
Strong interaction



~~CP~~ in the interference between decay and mixing



$$\lambda_{f_{CP}} = \frac{q}{p} \cdot \frac{\bar{A}_{f_{CP}}}{A_{f_{CP}}} = |\lambda_{f_{CP}}| \cdot e^{-2i\phi_{CP}}$$

mixing ($\frac{q}{p}$) — *decay* ($\frac{\bar{A}_{f_{CP}}}{A_{f_{CP}}}$)

$$S_{f_{CP}} = -\frac{2\Im\lambda_{f_{CP}}}{1+|\lambda_{f_{CP}}|^2}$$

$$C_{f_{CP}} = \frac{1-|\lambda_{f_{CP}}|^2}{1+|\lambda_{f_{CP}}|^2}$$

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

|q/p|=1→ C=-A

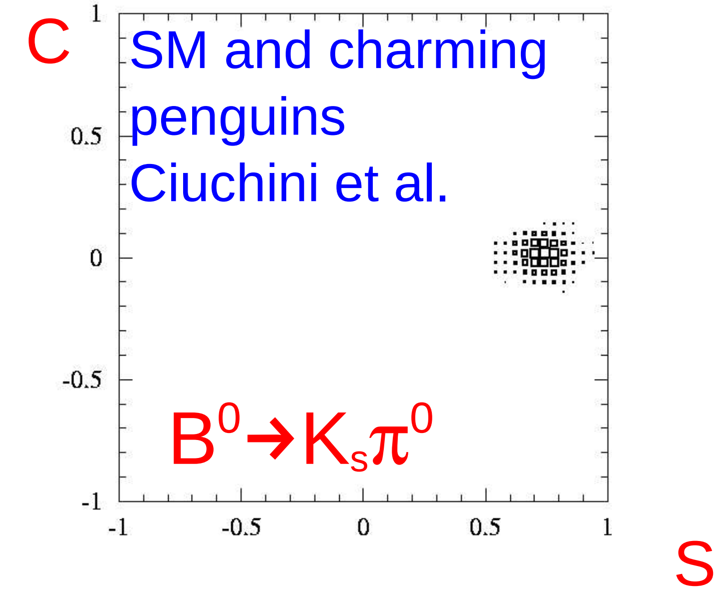
When only one CKM term enters the decay amplitude

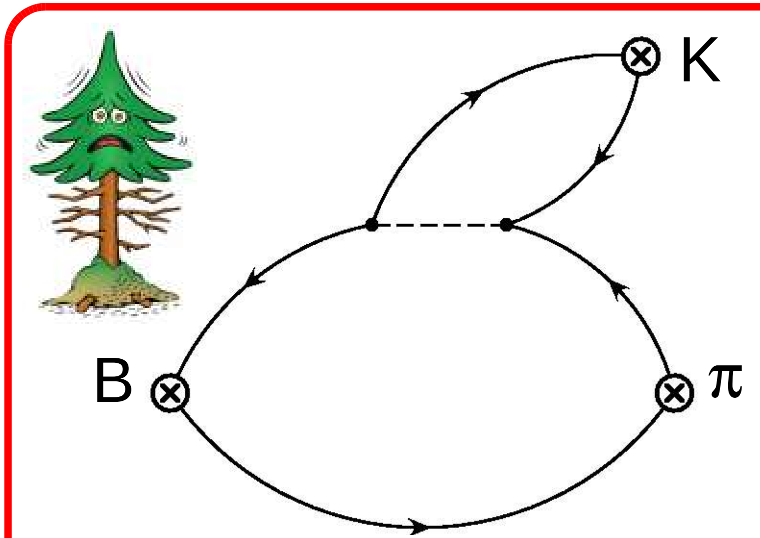
$$S_{f_{CP}} = \eta_{CP} \cdot \sin(2\beta) \quad ; \quad C_{f_{CP}} = 0$$

NP and $B^0 \rightarrow K_s \pi^0$?

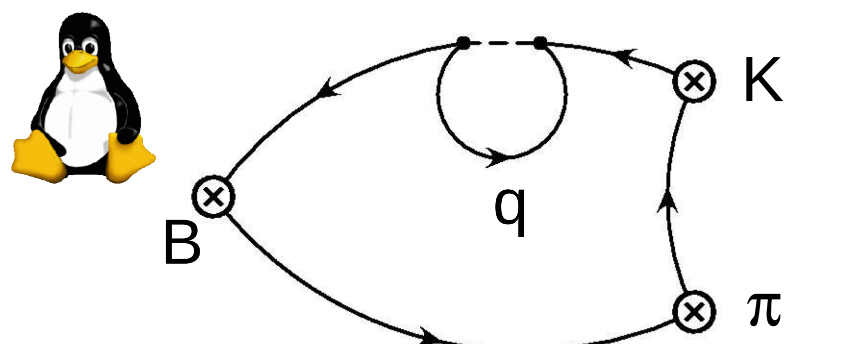
$$\sqrt{2}\cdot\mathcal{A}(B^0\rightarrow K^0\pi^0) = -V_{ts}\, V_{tb}^*\, \mathbf{P_1}(c) - V_{us}\, V_{ub}^*\{T_c + \mathbf{P_1}^{GIM}(u-c)\}$$

- From BR measurements we know that $K\pi$ channels are dominated by $\mathbf{P_1}(c)$...
- ...in particular in $K^0\pi^0$, where tree diagram is Cabibbo and color suppressed
- In SM $S \sim \sin(2\beta)$ & $C \sim 0$





$T_C \sim 1/N_C \sim O(1)$



$\mathbf{P_1}(q) \sim \Lambda_{QCD}/m_b \sim O(1)$

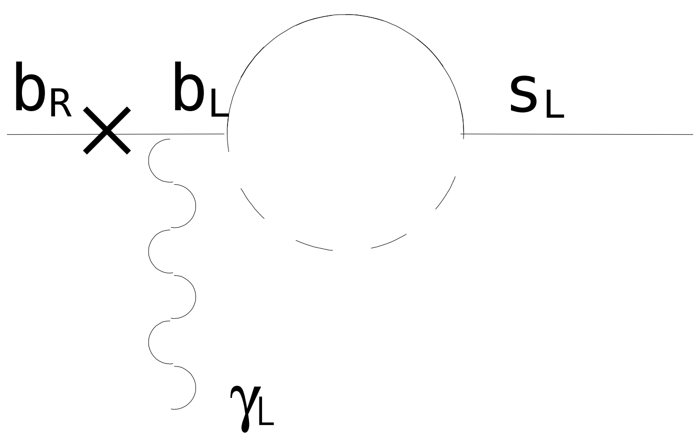
NP and $B^0 \rightarrow K^{0*}$?

- In SM the photon is almost fully polarized: $A_R \sim m_s/m_b\ A_L$
- New Physics effects can enhance A_R

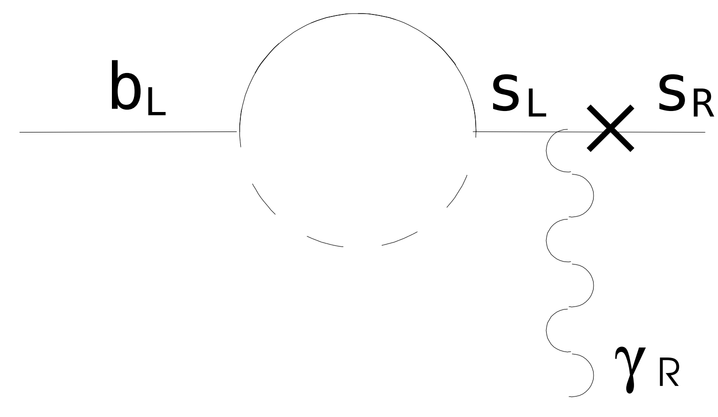
$$\lambda_{||} = \frac{q}{p}\frac{\bar{A}_{||}(0)}{A_{||}(0)} \quad \lambda_{\perp} = \frac{q}{p}\frac{\bar{A}_{\perp}(0)}{A_{\perp}(0)}$$

- CP Asimmetry from a final state with mixed CP content. In SM $C \sim 0$, $S \sim 2m_s/m_b \cdot \sin(2\beta)$

helicity suppression



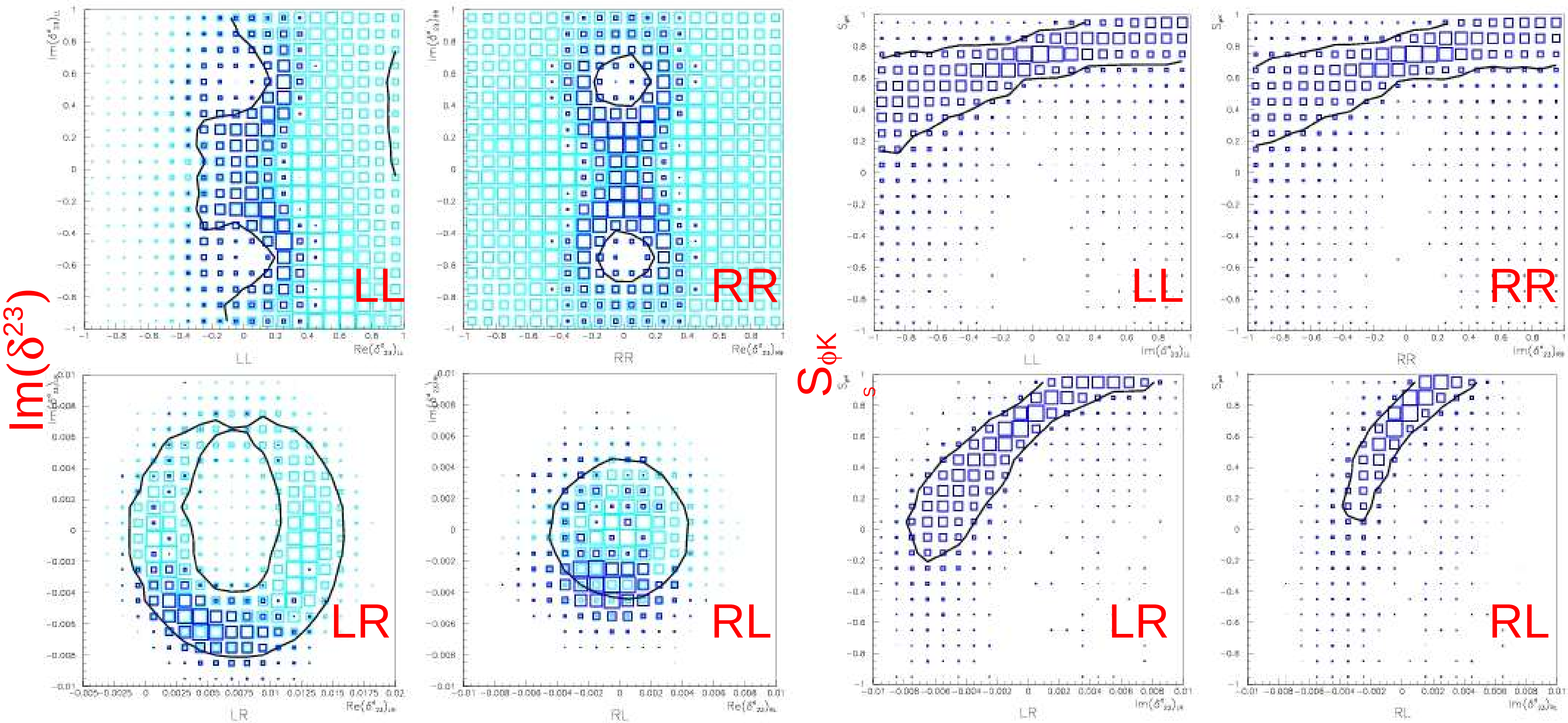
$\sim m_b$



$\sim m_s$

New Physics: state of art

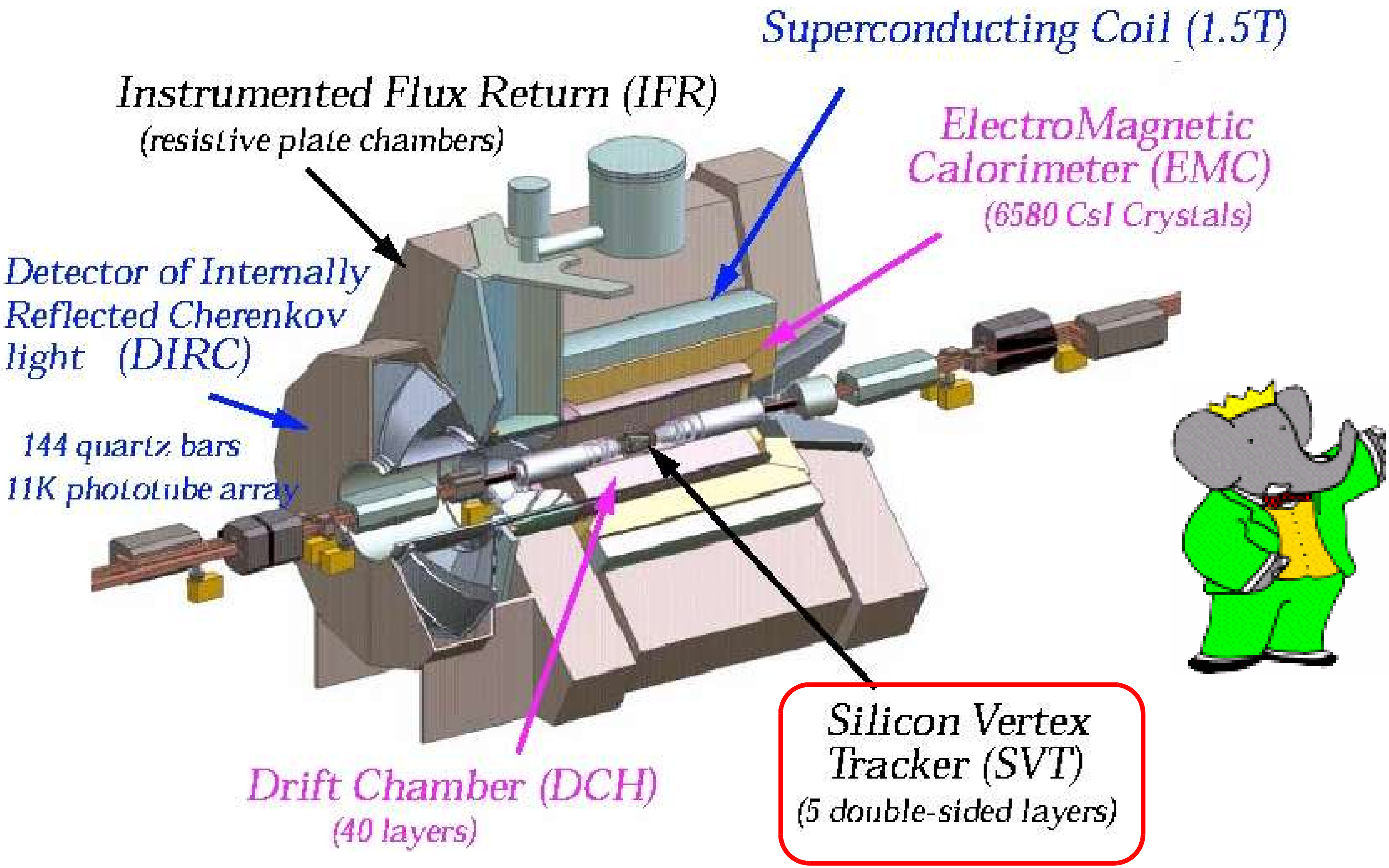
Ciuchini et al. hep-ph/0307191



$Re(\delta^{23})$ — Allowed parameters space

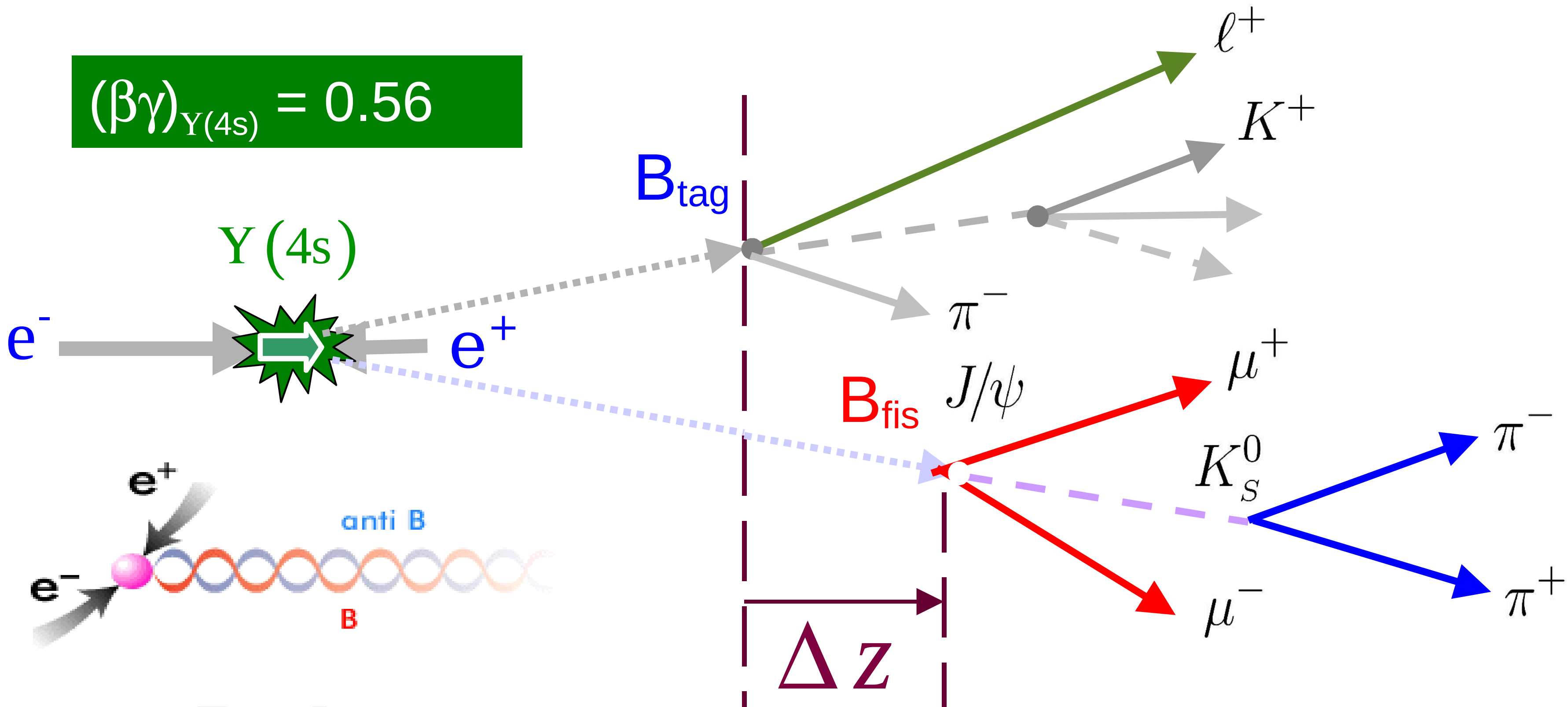
$Im(\delta^{23})$ — Implications on $S_{\phi Ks}$

BaBar



Superconducting Coil (1.5T)
Instrumented Flux Return (IFR)
(resistive plate chambers)
ElectroMagnetic Calorimeter (EMC)
(6580 CsI Crystals)
Detector of Internally Reflected Cherenkov light (DIRC)
144 quartz bars
11K phototube array
Drift Chamber (DCH)
(40 layers)
Silicon Vertex Tracker (SVT)
(5 double-sided layers)

Experimental technique



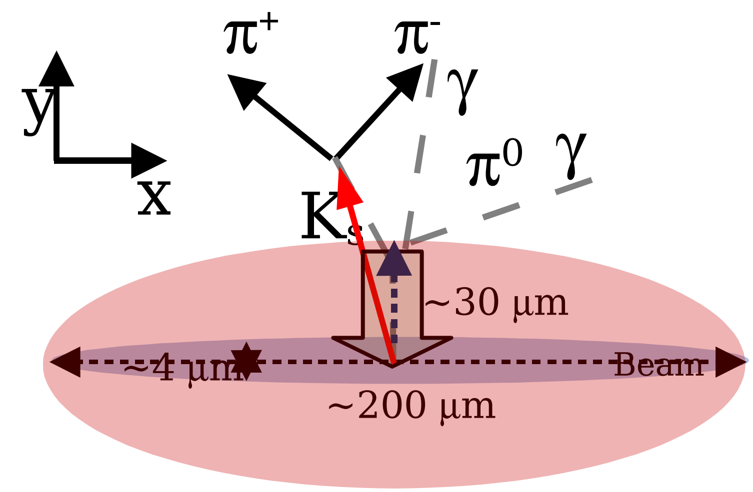
Two B mesons
in a coherent quantistic state

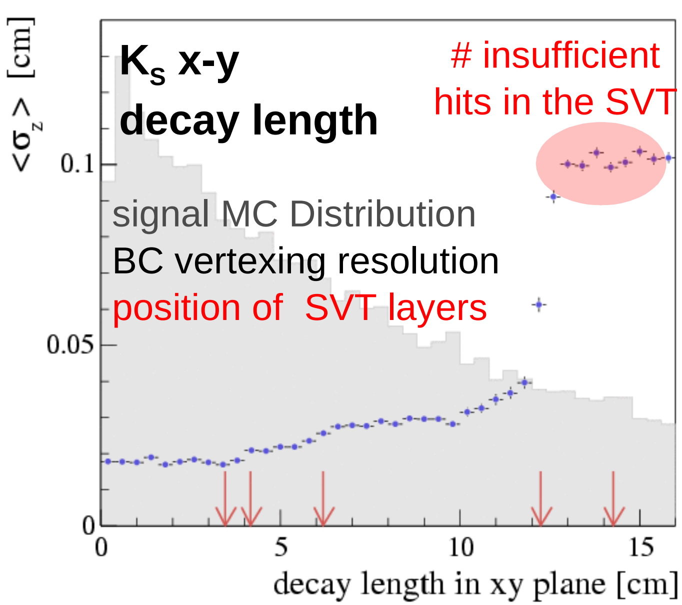
$$<|\Delta z|> \sim 250\,\mu m$$

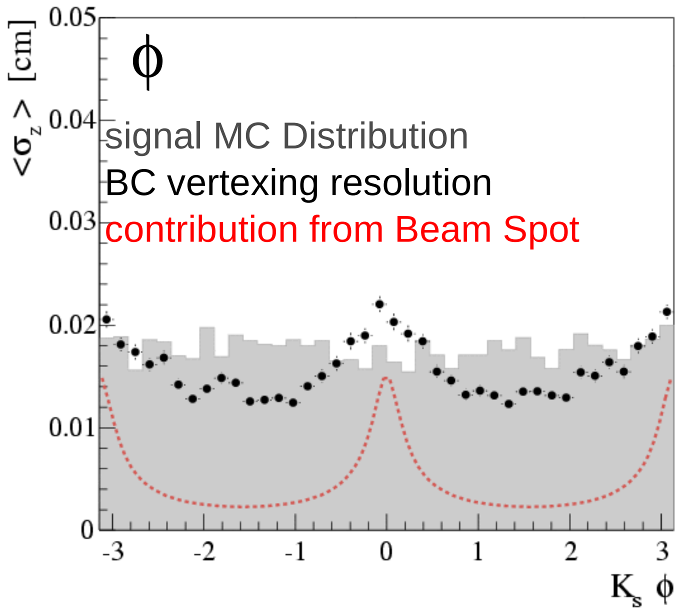
$$\Delta t \approx \frac{\Delta z}{<\beta\gamma>c}$$

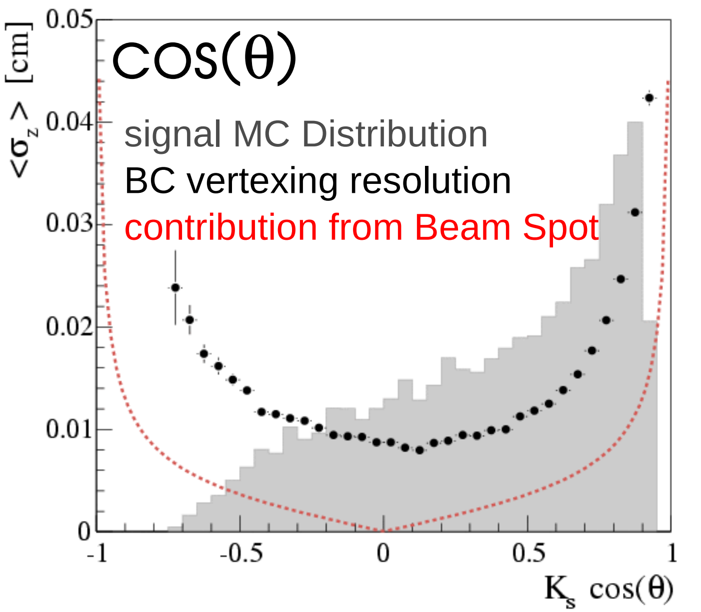
Δt determination: BC vertexing (I)

- Beam Spot Constrained Vertexing:
  - B meson forced to come from beamspot *in transverse plane*
  - Intersection of flight direction of the corrected K_S with z direction gives B vertex position
  - Error inflated by (σ_{Bxy}) (4 μm→30 μm)
  - Resolution dominated by tag side





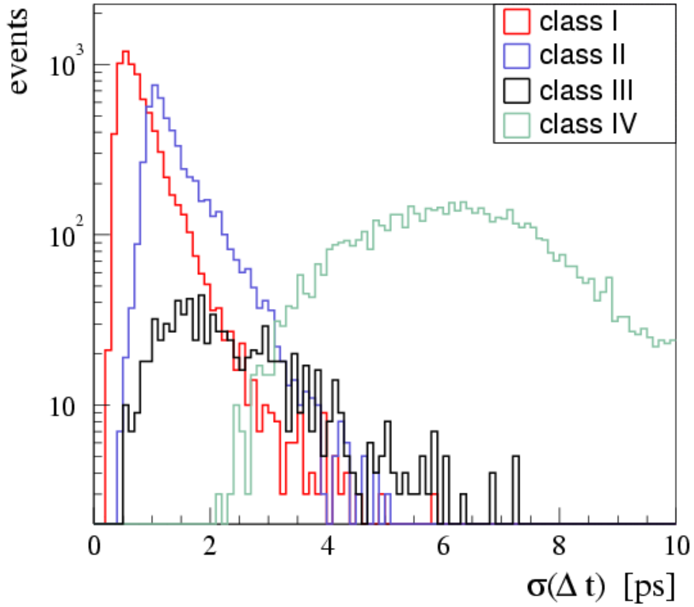




Δt determination: BC vertexing (II)

- Events classification:
  - Class I: 2 tracks with1 z hit & 1 ϕ hit in the first 3 layers
  - Class II: events not Class I, with with 1 z hit & 1ϕ hit ϕ in the 1-5 layers on both tracks
  - Class III: only one SVT hit on both tracks
  - Class IV: no hits on SVT
- We use Class I and Class II events

Δt resolution

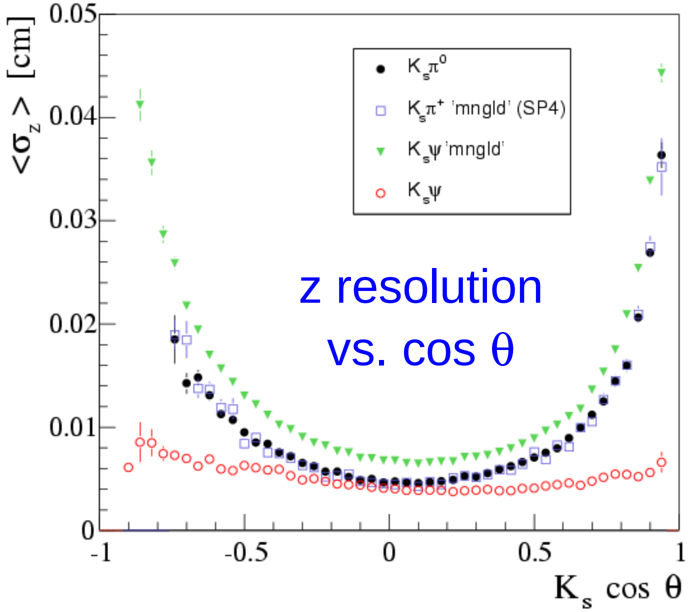


category events fractions

class	$B^0 \to K^{*0}\gamma, (K^{*0} \to K^0_S \pi^0)$	$B^0 \to K^0_S \pi^0$	$B^0 \to J/\psi K^0_S$
I	0.469 ± 0.003	0.373 ± 0.003	0.479 ± 0.003
II	0.280 ± 0.003	0.273 ± 0.003	0.261 ± 0.002
III	0.049 ± 0.001	0.045 ± 0.002	0.061 ± 0.002
IV	0.201 ± 0.002	0.308 ± 0.003	0.198 ± 0.002

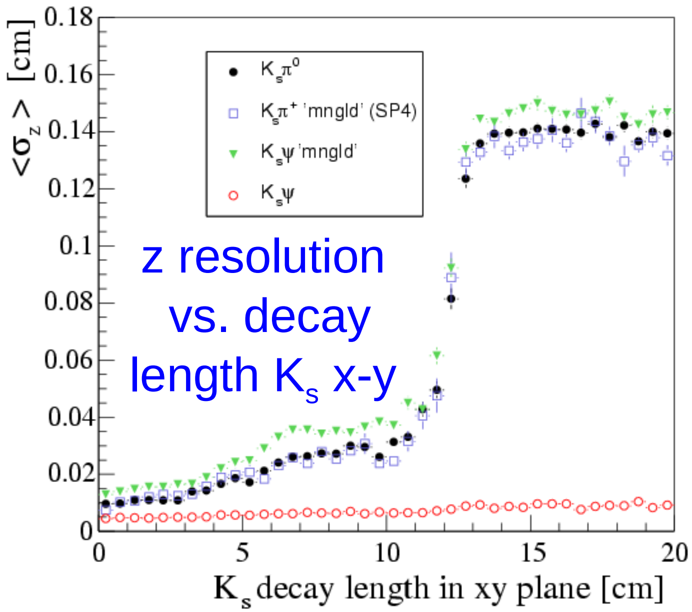
Δt determination: BC vertexing (III)

- J/ψ K_S without J/ψ in the vertexing
  high statistics control sample
  - Data/MC Comparison
  - BC vtx /nominal vtx Comparison
- $K_S \pi^+$ without π^+ in the vertexing:
  - Check resolution and efficiencies for Class I and Class II
- Validation using Toy MC: unbiased pulls



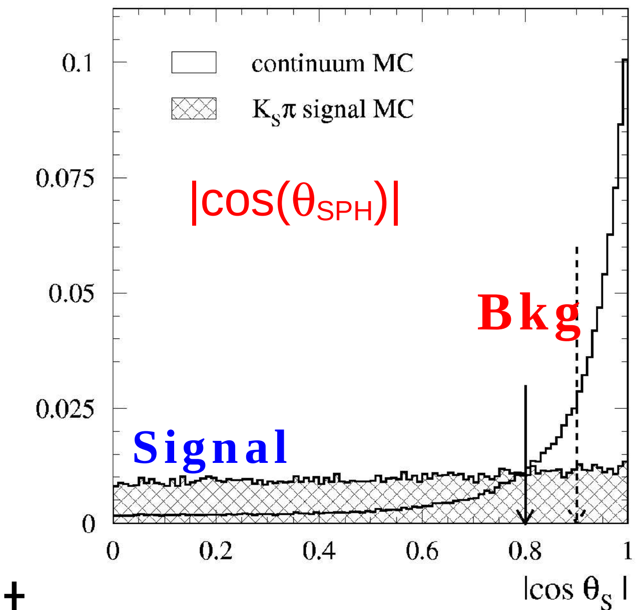
J/ψ K_S

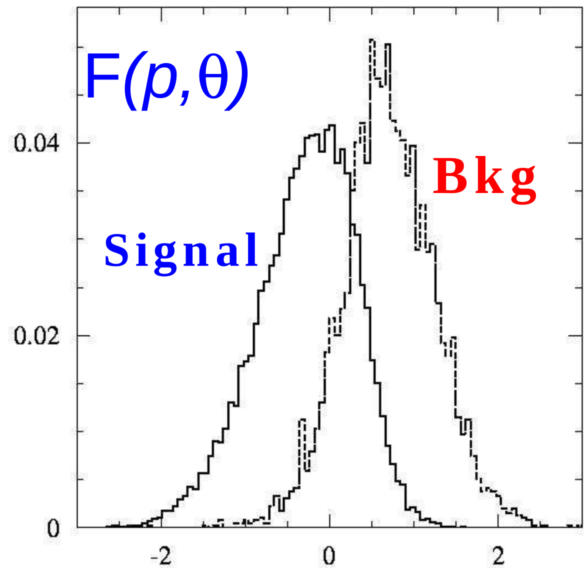
- BC Vtx (blinded):
  - C=0.238±0.077 & S= 0.484±0.113
- Nominal Vtx (blinded):
  - C=0.272±0.073 & S=0.457±0.095

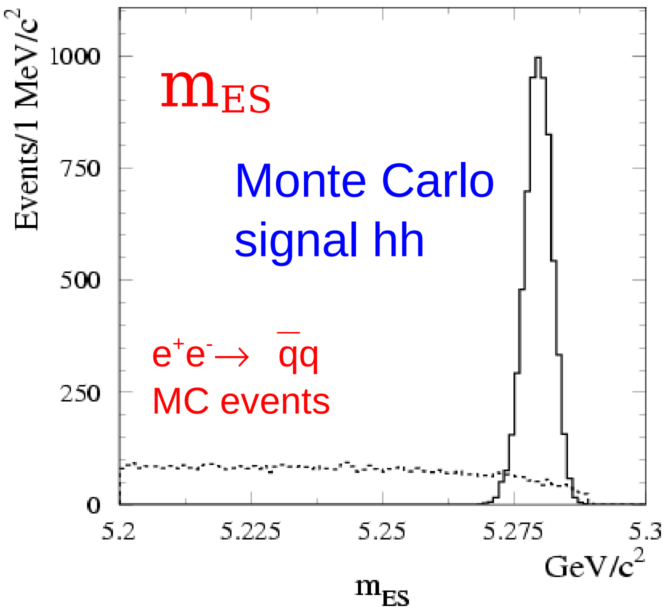


Analysis strategy

- Initial Selection: bkg suppression to get S/B~10^{-2}
- Kinematic Variables
  - $m_{ES}=\sqrt{(\sqrt{s}/2)^2-p_B^{*2}}$
  - $\Delta E=E_B^{*}-\sqrt{s}/2$
- Maximum Likelihood fit
  - m_{ES}, ΔE, Legendre Fisher (K* mass) and Δt

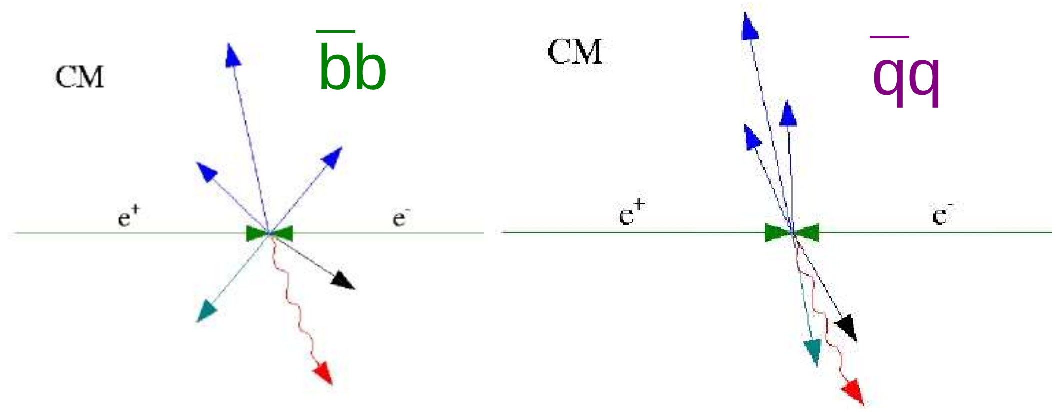


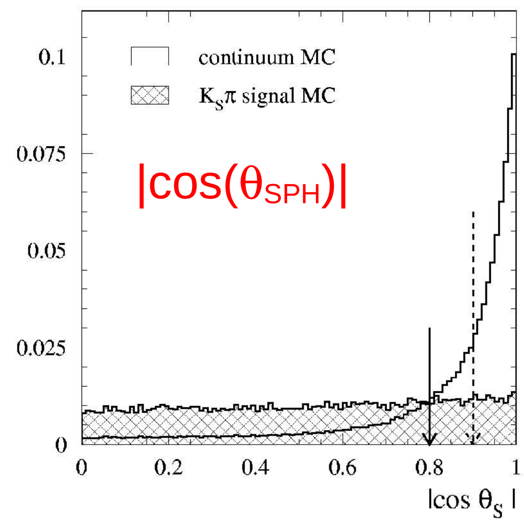


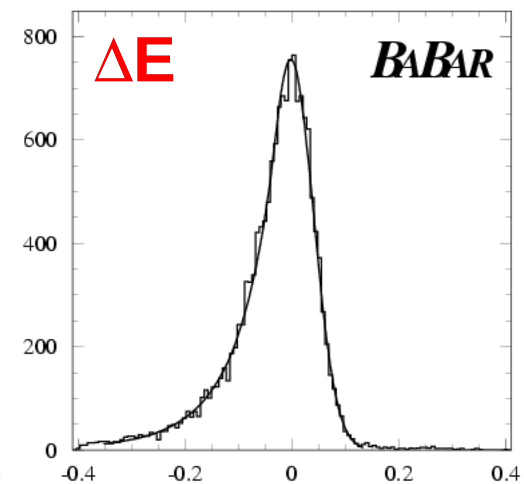


$B^0 \rightarrow K_S \pi^0$ Selection

- Starting selection:
  - $|\cos(\theta_{SPH})| < 0.8$
- K_S definition cuts
  - $|m(\pi\pi) - m(K_S)| < 11.2$ MeV
  - $\tau(K_S)/\sigma_\tau(K_S) > 5$
- π^0 definition cuts
  - 110 MeV $< m(\gamma\gamma) <$ 160 MeV
  - $0.01 <$ LAT < 0.6
    (shape of the EMC cluster)
  - $|\cos(\theta^*_\gamma)| < 0.95$







Selection

- $K^{*0}\gamma$ uses previously published BR analysis by *BaBar*
  - $R_2 < 0.9$
  - EMC acceptance: $-0.74 < \cos\theta < 0.93$
  - $0.115 < m_{\gamma\gamma} < 0.155$ GeV
  - $0.487 < m_{\pi\pi} < 0.508$ GeV && Vtx OK && Flight length > 3 mm
  - $0.8 < m(K_S\pi^0) < 1.0$ GeV
  - π^0 (η) veto: combining γ with other γ's in the event E > 50 MeV (250 MeV) we reject the event if $0.115 < m_{\gamma\gamma} < 0.155$ GeV ($0.507 < m_{\gamma\gamma} < 0.588$ GeV)
  - Bump isolated from neutral and charged clusters (> 25 cm)
  - Second moment > 0.002

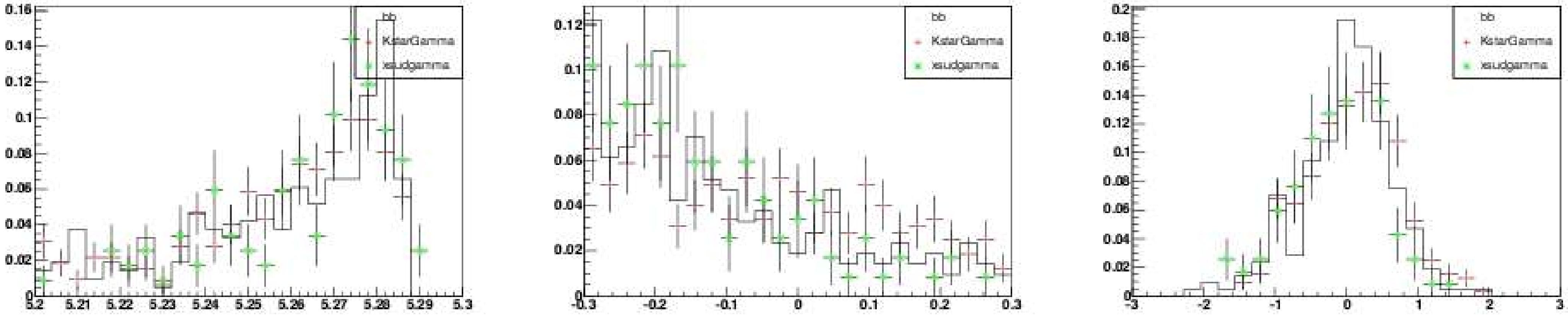
Photon Selection

  - $|\cos(\theta_H)| > 0.6$ && $|\cos\theta_S| < 0.9$ + $m(K_S\pi^0)$ in the Fit
  - Best candidate selecte with K_S e π^0 mass pulls

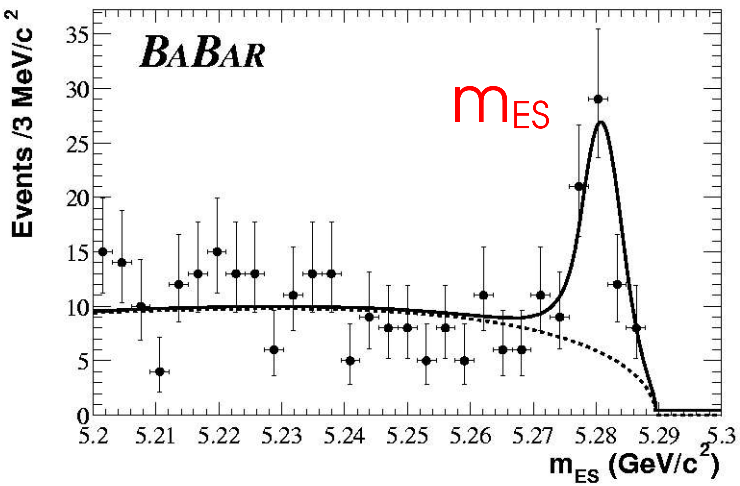
$\bar{B}B$ background

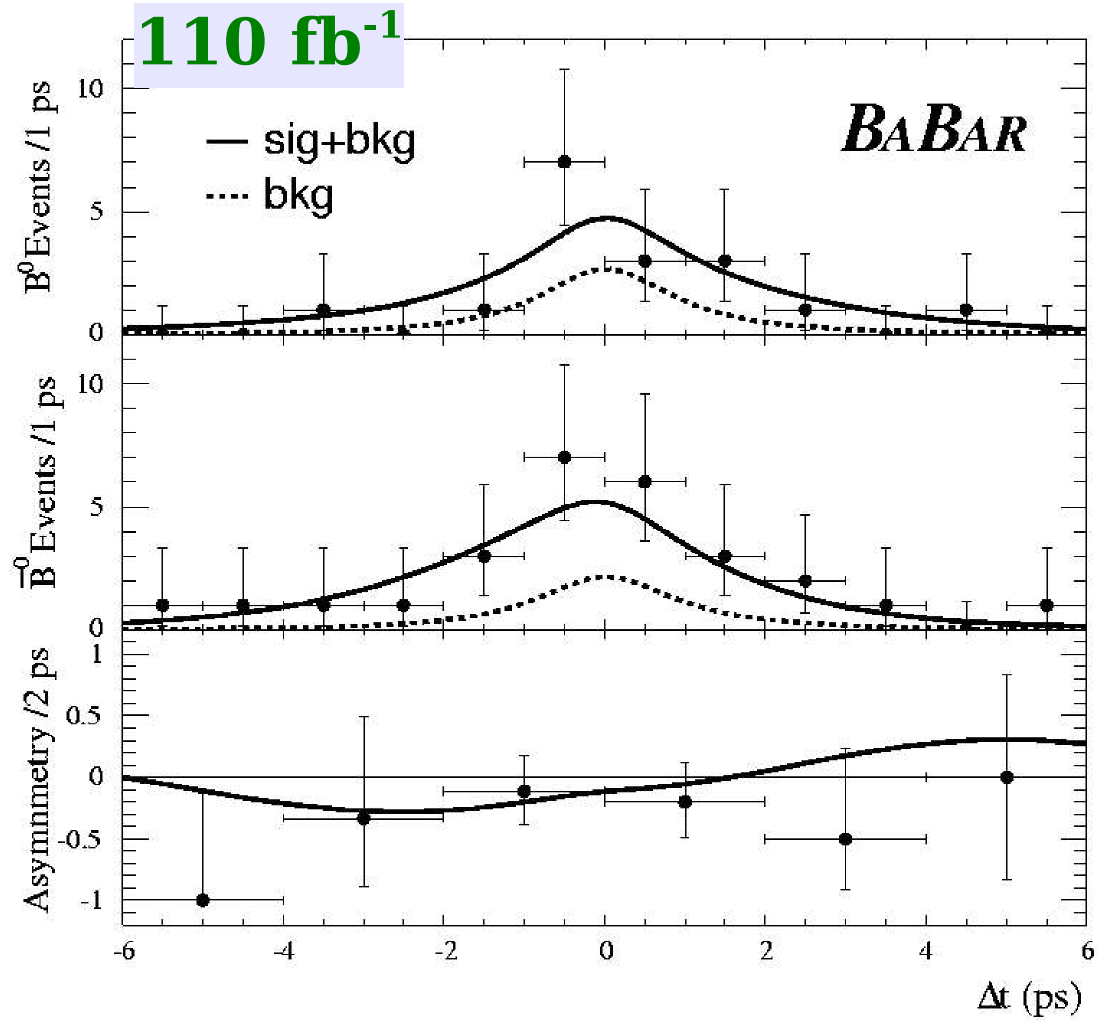
- Negligible for $K_S\pi^0$
- Important in $K^{*0}\gamma$
  - strongly reduced by $\cos\theta_H$ cut
  - component in the likelihood with fixed yield
  - yield, S_{BB} e C_{BB} floated in [-0.5,0.
    for systematics
  - p.d.f. parameterized with seve
    MC samples ($K^*\gamma$, $\bar{B}B$, $X_S\gamma$)

- $B^0\bar{B}^0$ (235M events $\approx 427 fb^{-1}$)
  - $B^0 \to X_{sd}\gamma \approx 133$ events
  - $B^0 \to D^{*+}l\bar{\nu}_l \approx 103$ events
  - $B^0 \to K_2^{*0}\gamma \approx 22$ events
  - $B^0 \to K_S\pi^0 \approx 20$ events
- B^+B^- (190M events $\approx 345 fb^{-1}$)
  - $B \to X_{su}\gamma \approx 167$ events
  - $B \to K^{*+}\gamma \approx 116$ events
  - $B \to K_2^{*}\gamma \approx 29$ events
  - $B \to D^{*0}l\bar{\nu}_l \approx 10$ events



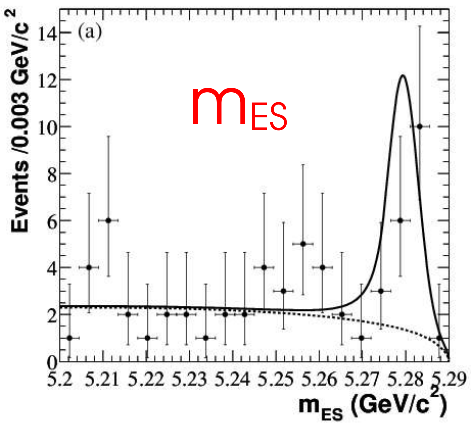
Results for $K_s\pi^0$

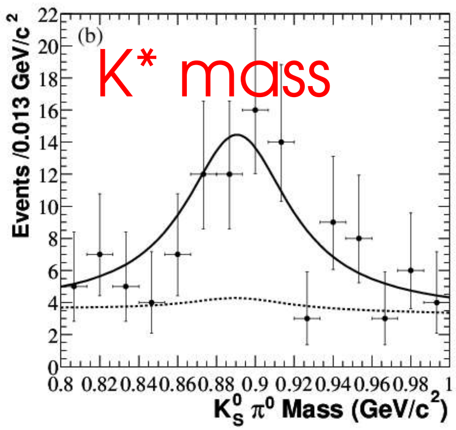




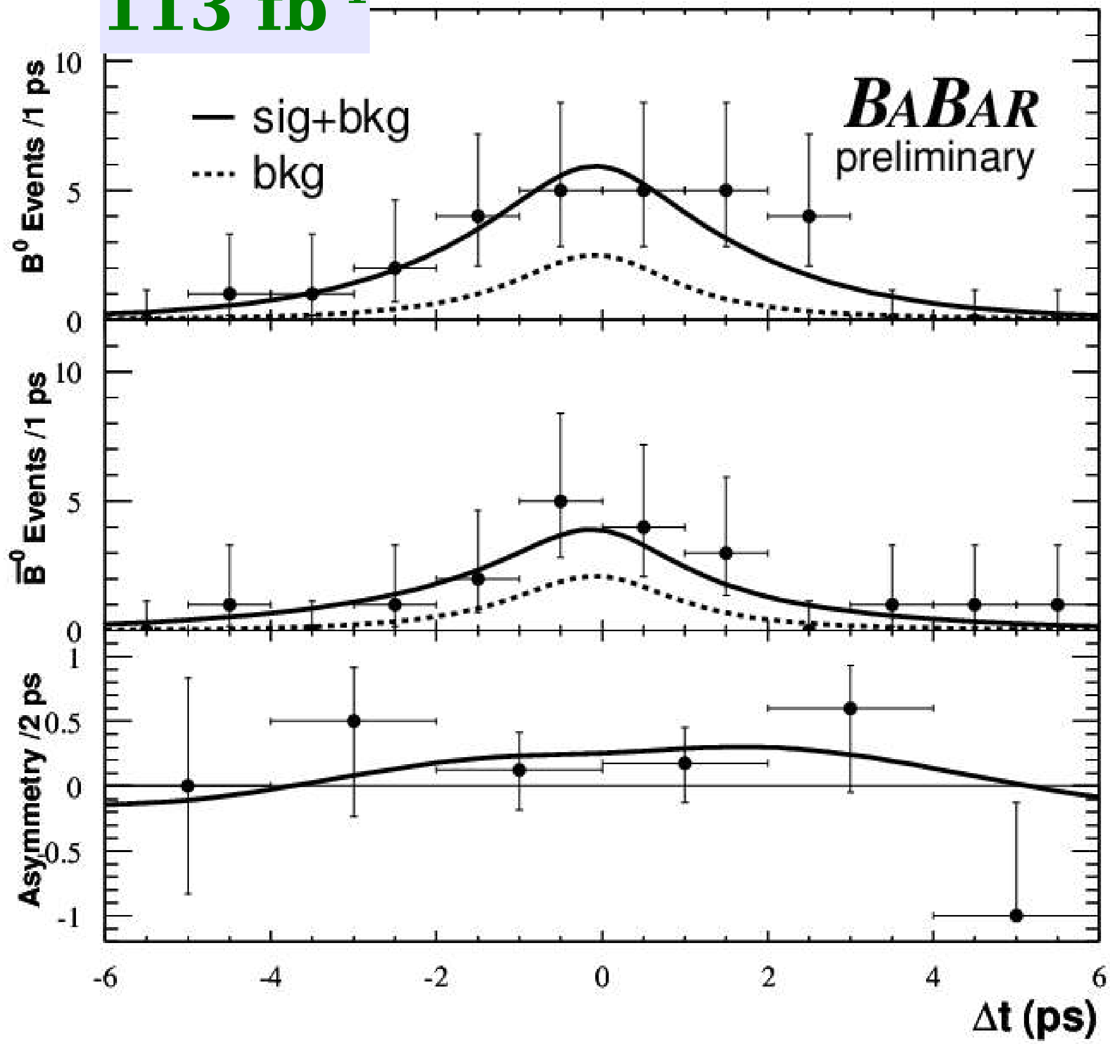
$$N = 123 \pm 16$$
$$C = 0.40 \pm 0.28 \pm 0.09$$
$$S = 0.48 \pm 0.43 \pm 0.06$$
$$S(C=0) = 0.41 \pm 0.45 \pm 0.06$$

Results for $K^{*0}\gamma$





113 fb^{-1}



$$N = 105 \pm 14$$
$$C = -0.57 \pm 0.32 \pm 0.09$$
$$S = 0.25 \pm 0.63 \pm 0.14$$
$$S(C=0) = 0.25 \pm 0.65 \pm 0.14$$

Conclusions

- Now that sin(2β) from b→c is well known , B Factories can start testing SM with b→s decays

- The Beam Spot Constrained Vertexing allows measurements previously considered impossible ($K_S\pi^0$ and $K^{*0}\gamma$ first)

- In principle we are statistics limited, but we can get σ(S)~0.2. Can theoretical errors be reduced below such value?

- Belle didn 't try these new tecnique yet. It should be important to have their results, to reduce the error from B Factories. For sure their SVT has some problem in terms of Class I & Class II efficiency. Too many neutrals for experiments @hadronic colliders?