Recent Results on Penguin Decays From BaBar

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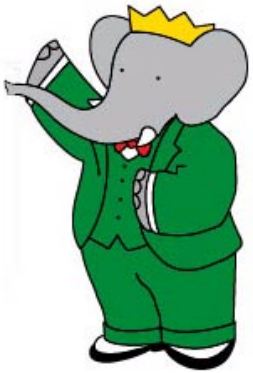
(on behalf of the BaBar collaboration)



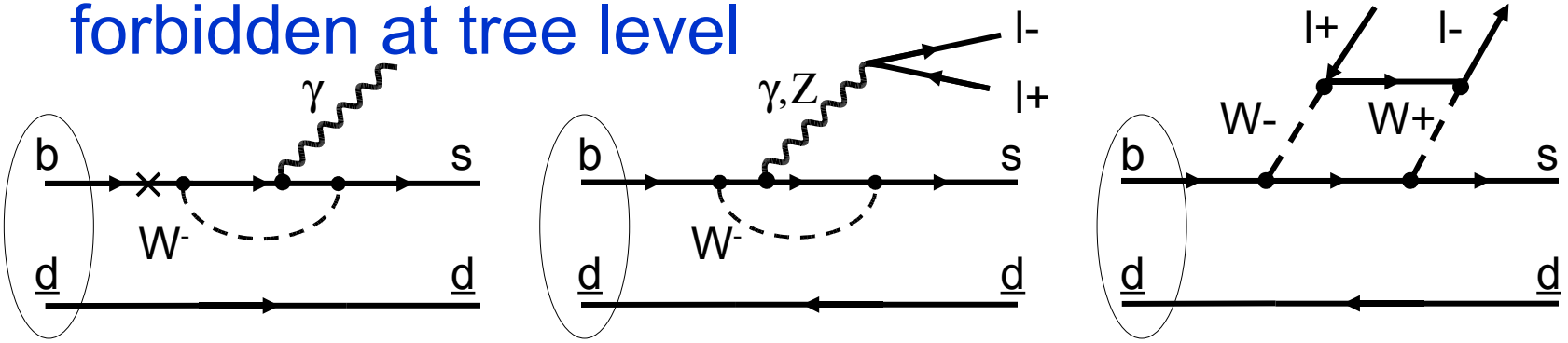
Rencontres de Moriond EW 2008

Outline

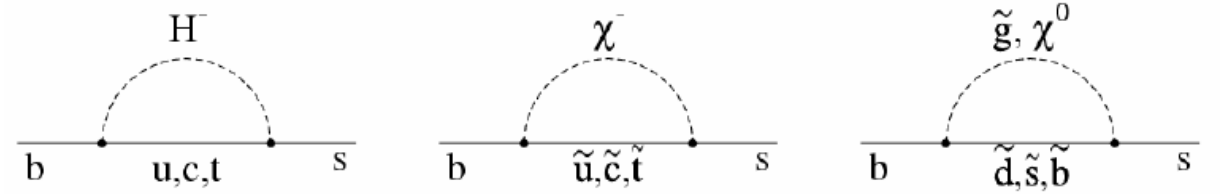
- EW Penguins
  - $B \to K^* l^+ l^-$
    - A_{FB}, F_L
  - $B \to K^* \gamma$
    - γ polarization
  - $B \to X_{s,d} \gamma$
    - BF, E_γ, A_{CP}, Δ_{0-}
- QCD Penguins
  - $B \to a_1 K$
    - penguin 'pollution' in α_{eff}

What can we learn from b→s,d transitions?

- Probe FCNC in the SM: b→s,d transitions are forbidden at tree level

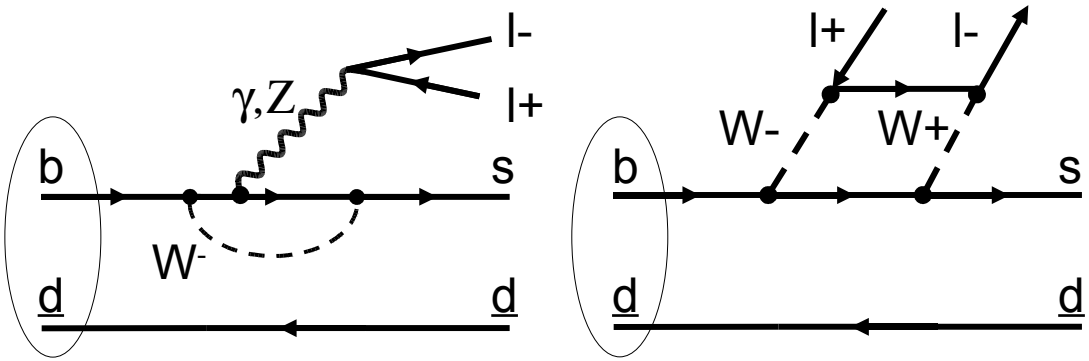


- New physics effects: new particles in the loops can give leading order effects



- QCD Dinamics: m_b, μ_π
- Measure $|V_{td}/V_{ts}|^2$: from $B(B\to\rho\gamma)/B(B\to K^*\gamma)$

Angular asymmetries in B→K*ll

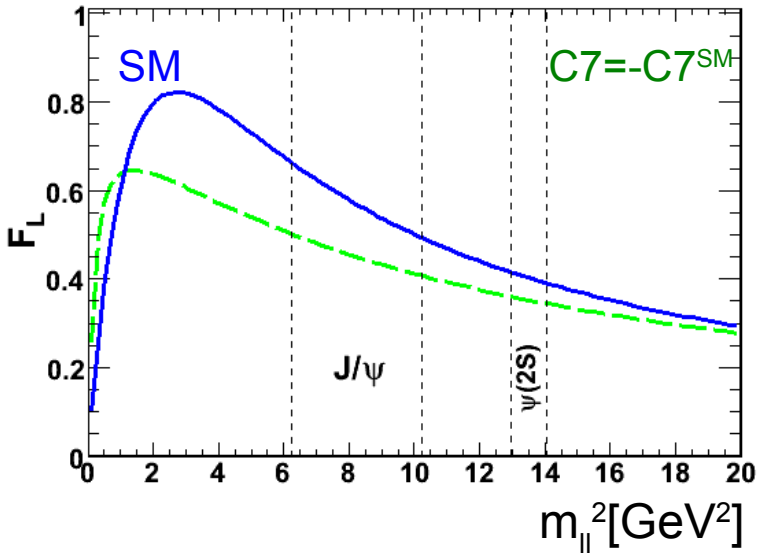


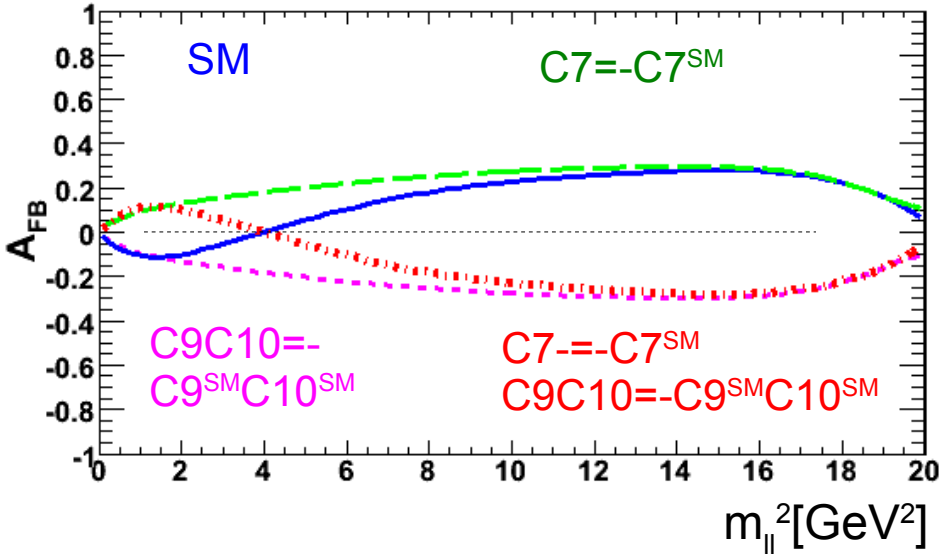
EM penguin encoded in C7, EW penguin & W-box encoded in C9 & C10

- Effective Wilson coeff. (C_i) encode short distance physics, calculated to NNLO in SM to ~5% accuracy
- Coefficients can be affected by NP entering at the same order as the SM
- Interference term generates asymmetries in angular observables over m_{ll}^2:A_{FB}, F_L

K*ll: angular observables

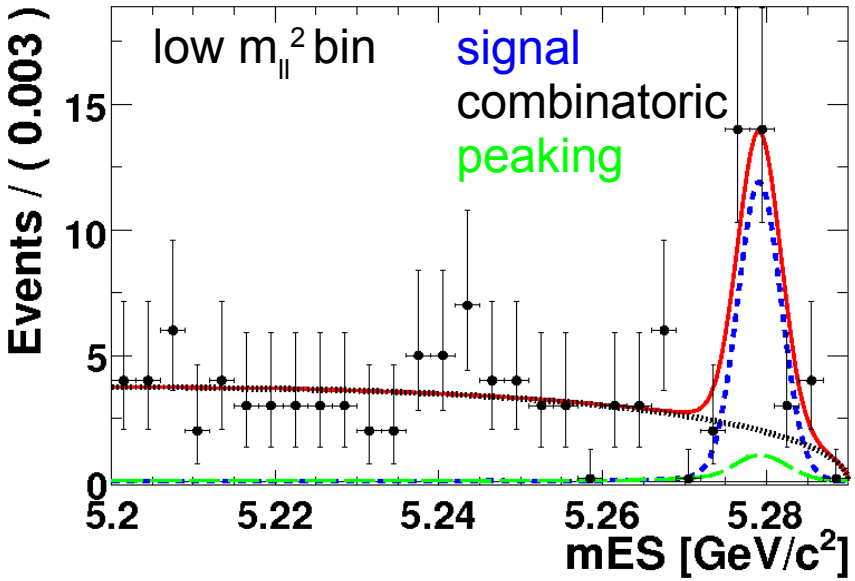
- A_{FB} and F_L have distinctive m_{ll}^2 dependence

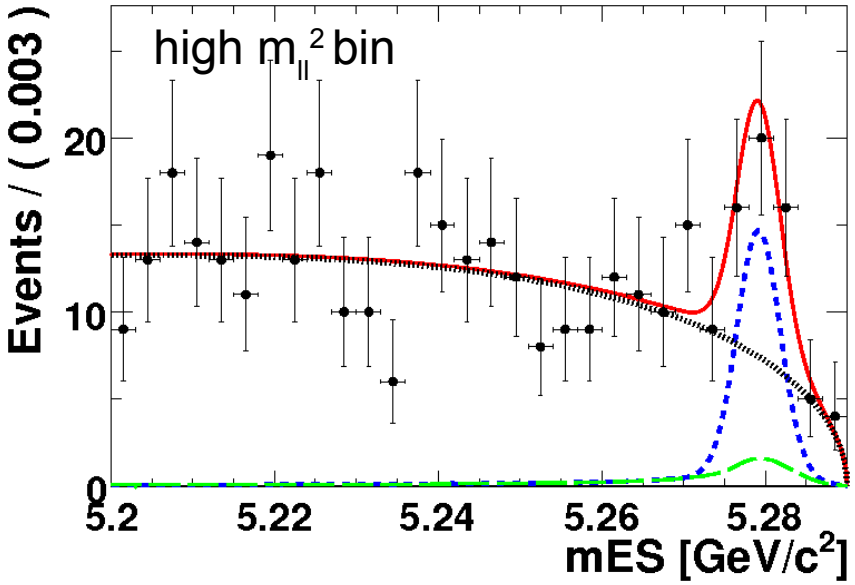




K*ll: signal extraction

- Reconstruct $B^{+(0)} \to K\pi l^+ l^-$, l=e,μ
- Tight particle ID on e,μ,K to reduce fakes
- NN suppression of combinatoric background (qq̄ and BB̄)
- Veto most peaking background (J/ψ,ψ(2S),D(K*π)π)
- Divide sample in two bins of m_{ll}^2, extract yield from a fit to M_{ES}

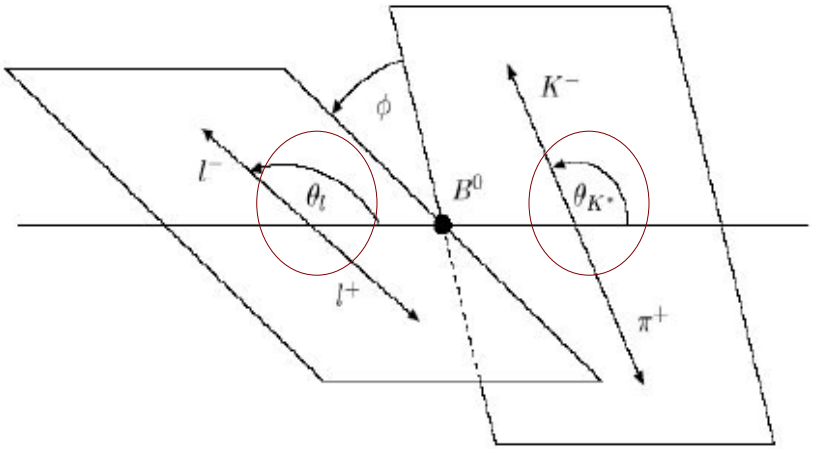




$$M_{ES} = \sqrt{(s/2 + \mathbf{p_0}\mathbf{p_B})^2/E_0^2 - p_B^2}$$

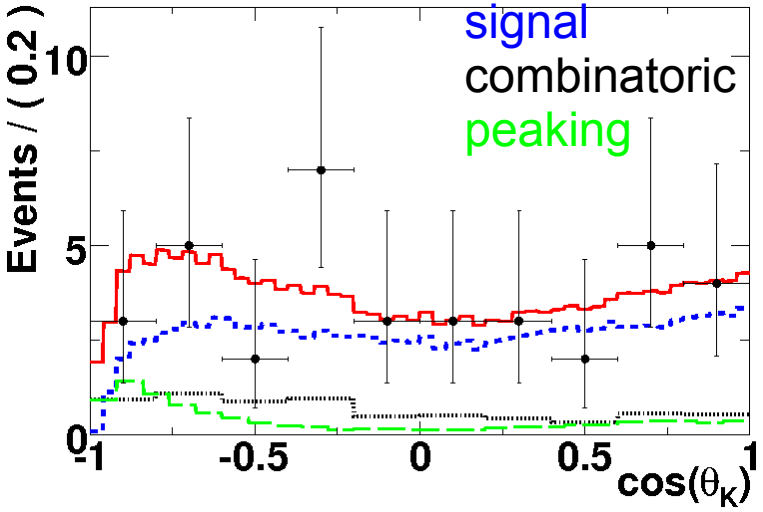
K*ll: A_{FB} and F_L extraction

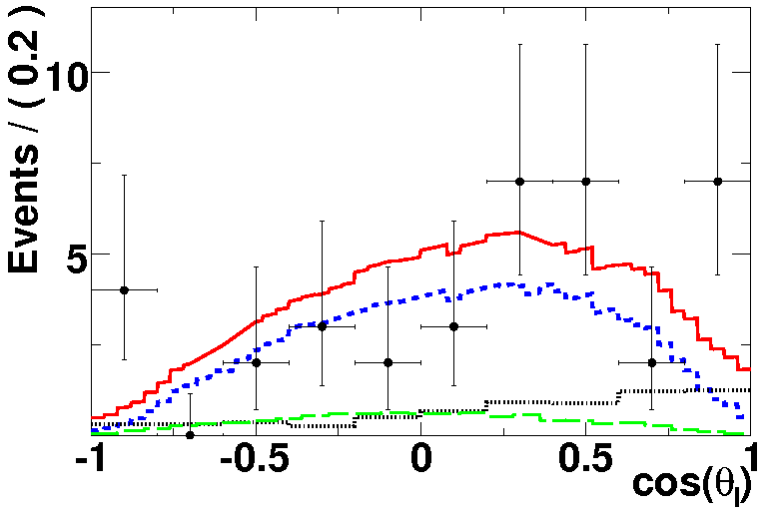
- θ_k – angle between kaon and B in K* rest frame
- θ_l – angle between lepton and B in di-lepton rest frame



K*ll: AFB and FL determination

- Extract F_L from a fit to $\cos(\theta_k)$, extract A_{FB} from $\cos(\theta_l)$



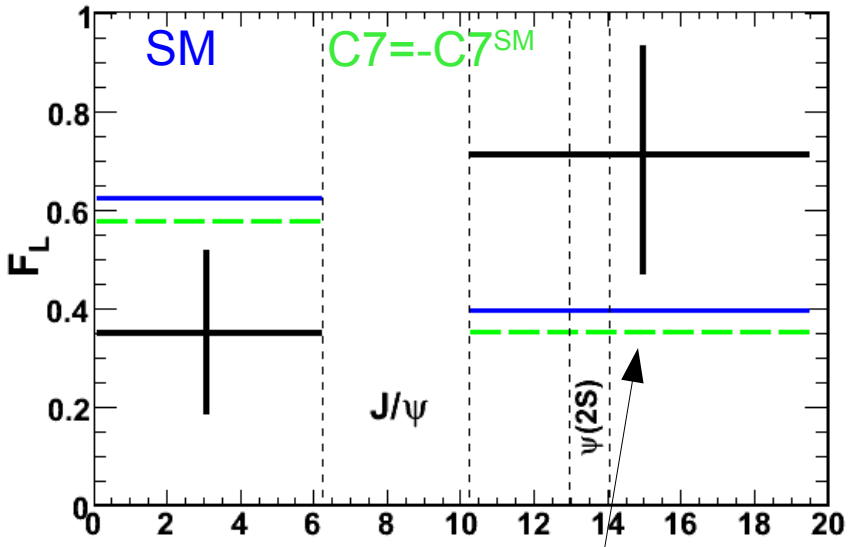


$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos(\theta_K)} = \frac{3}{2}F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$

$$\frac{1}{\Gamma}\frac{d\Gamma}{d\cos(\theta_l)} = \frac{3}{4}F_L(1-\cos^2\theta_l) + \frac{3}{8}(1-F_L)(1+\cos^2\theta_l) + A_{FB}\cos\theta_l$$

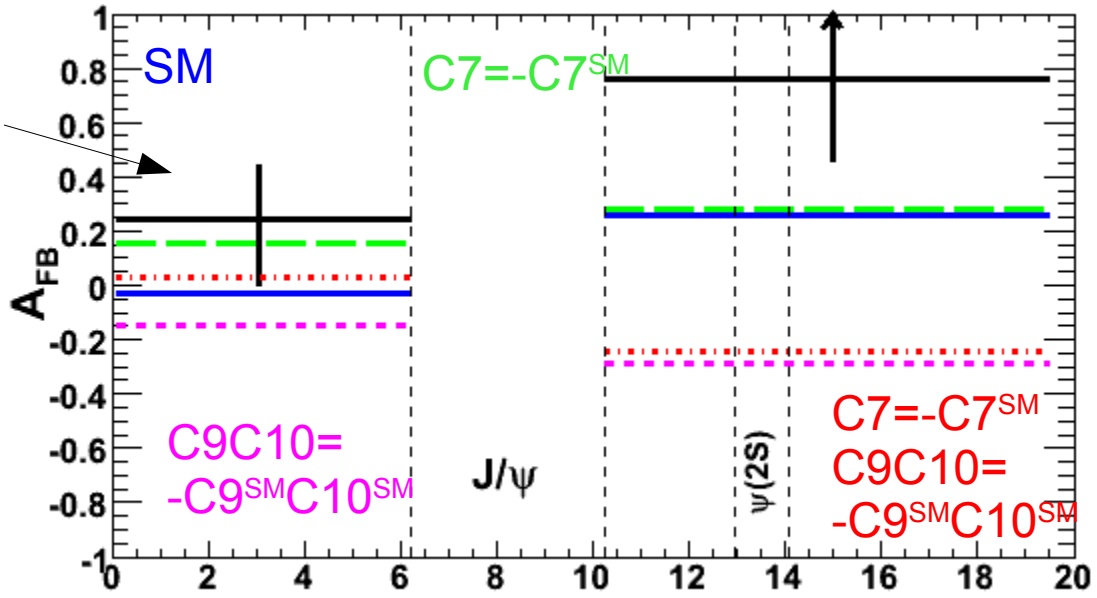
- Control sample:
  - $B\rightarrow K\pi J/\psi$, $\psi(2S)$: signal pdf, check yield, A_{FB} and F_L fit
  - $B\rightarrow Kll$: check fit in all m_{ll}^2 region

K*ll: results



Decay	q^2	N_S	F_L	$\mathcal{A}_{FB}$
$K\ell^+\ell^-$	low	26.0 ± 5.7		$+0.04^{+0.16}_{-0.24}$
	high	26.5 ± 6.7		$+0.20^{+0.14}_{-0.22}$
$K^*\ell^+\ell^-$	low	27.2 ± 6.3	0.35 ± 0.16	$+0.24^{+0.18}_{-0.23}$
	high	36.6 ± 9.6	$0.71^{+0.20}_{-0.22}$	$+0.76^{+0.52}_{-0.32}$

- integrated asymm.
- wrong sign C_9C_{10} excluded with more than 3σ significance



B→ K*($K_S\pi^0$) γ: photon polarization

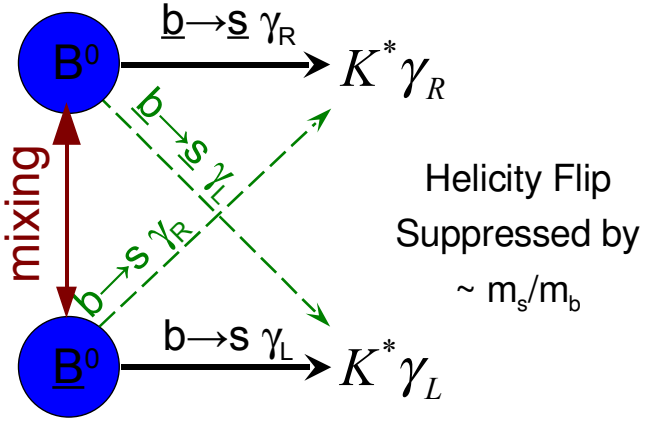
- Idea: measure the photon polarization using mixing induced TDCP asymmetry

$$\mathcal{P}_{\pm}(\Delta t) = \frac{e^{-|\Delta t|/\tau_B}}{4\tau_B} \times [1 \pm S\sin(\Delta m_d \Delta t) \mp C\cos(\Delta m_d \Delta t)]$$

- γ is polarized in the SM → final state is almost flavor specific
- The interference can happen only with helicity flip
- SM 'naive' estimate
  - S ~ $-2m_s/m_b*\sin(2\beta)$ ~ -0.04
- QCD sum rules:
  - S ~ 2% [Phys. Lett. B642: 478-486, 2006]
- If we see large CPV asymmetry it would clearly point to NP

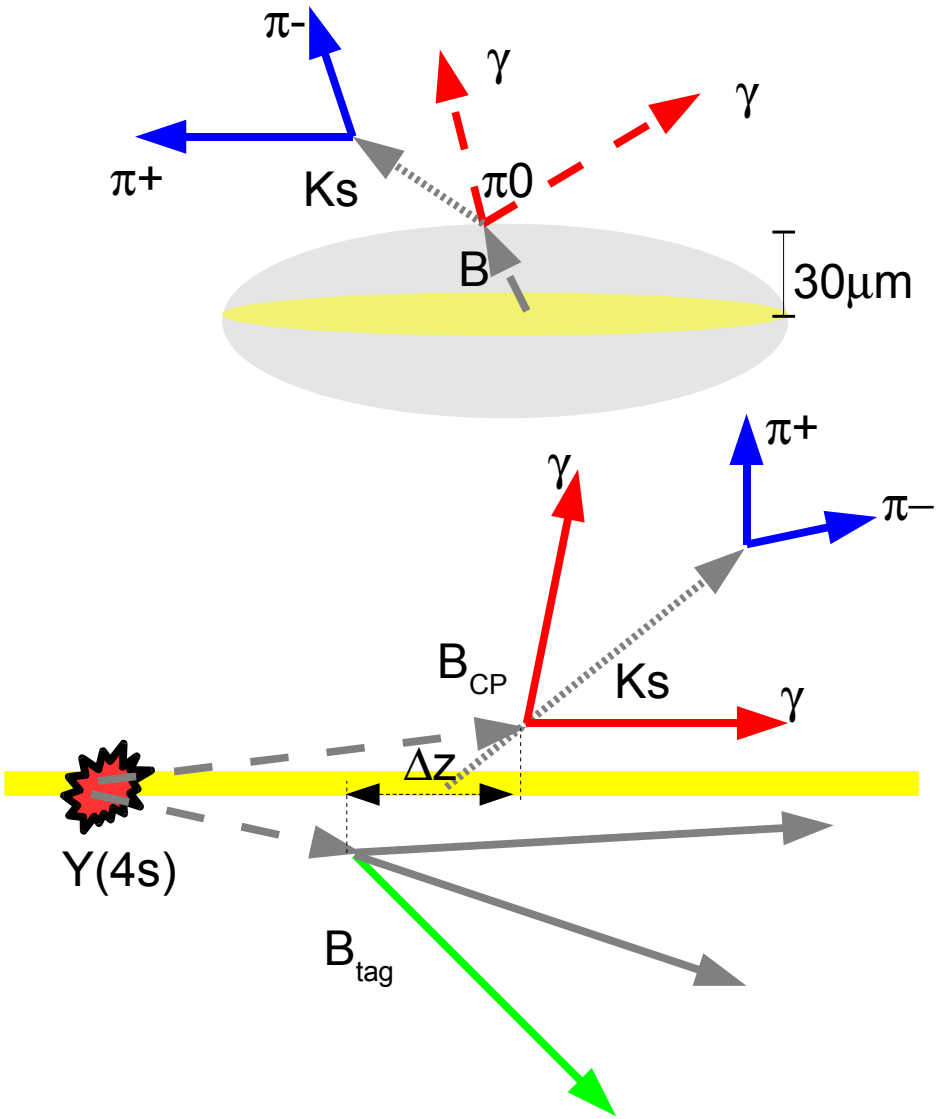
b→s γ_R

b→s γ_L

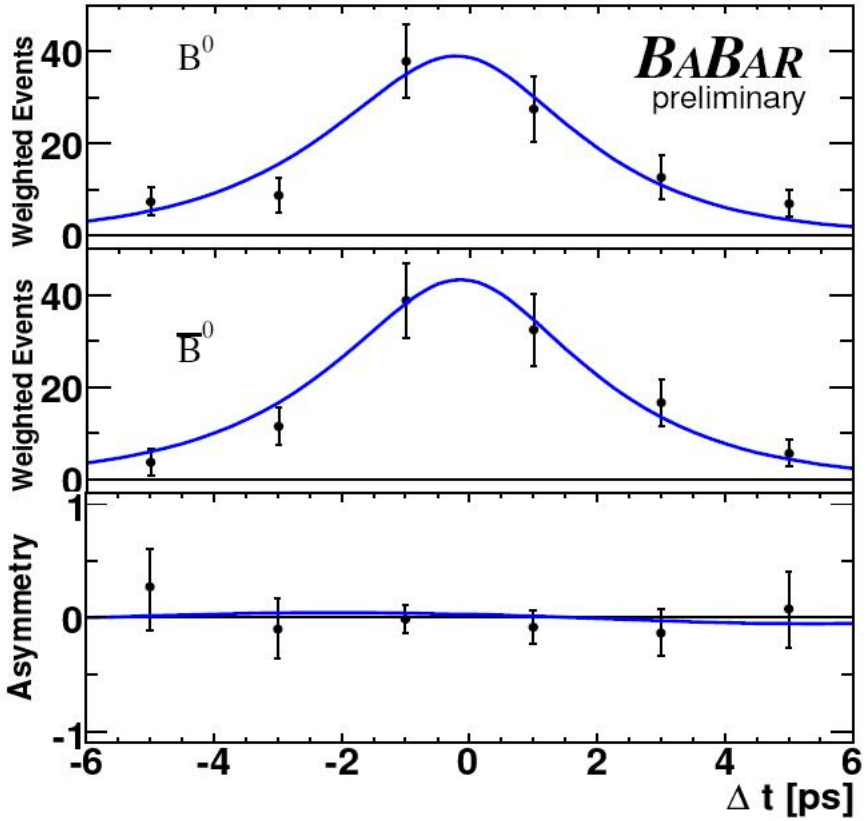


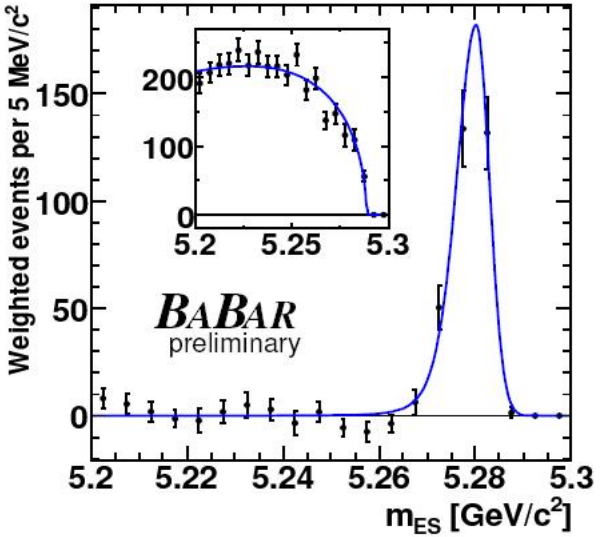
$B \to K_S \pi^0 \gamma$: Δt Reconstruction

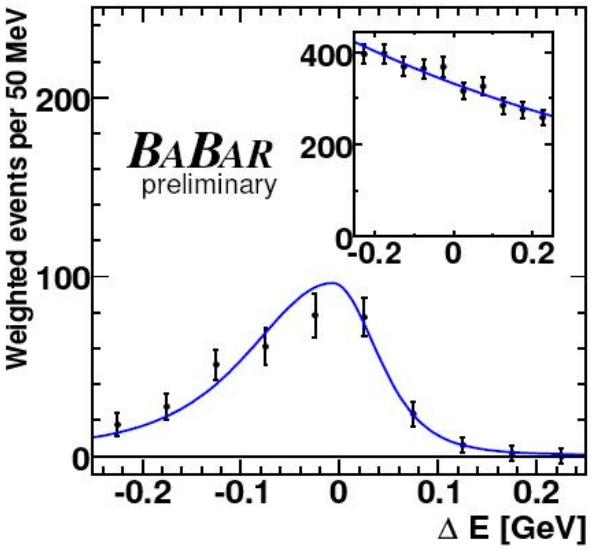
- Reconstruct Btag vertex from charged tracks
- Extrapolate the KS flight direction to the beam spot
- Fit the Y(4S)->BB using a geometrical constraint that takes the IP into account
- Validate technique with $B \to J/\psi\ K_S$ control sample
- Same method used for $B \to Ks\pi^0$



$B \to K_s \pi^0 \gamma$: results

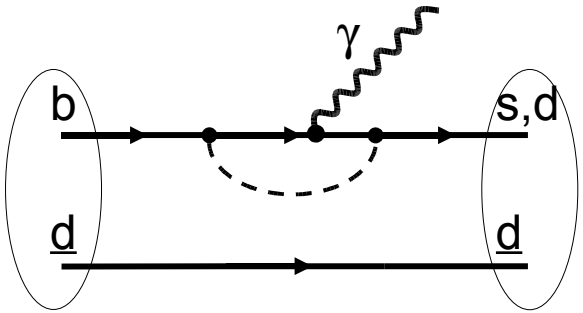






- $N_{sig} = 316 \pm 22$
- $S = -0.08 \pm 0.31 \pm 0.05$
- $C = -0.15 \pm 0.17 \pm 0.03$

$B \rightarrow X_{s,d}\gamma$

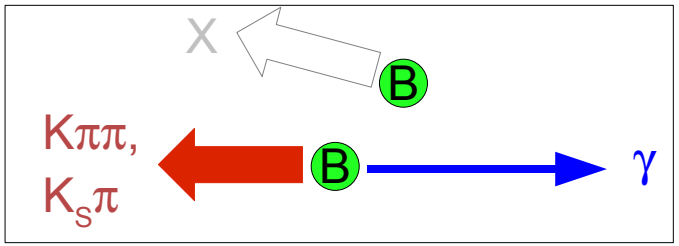


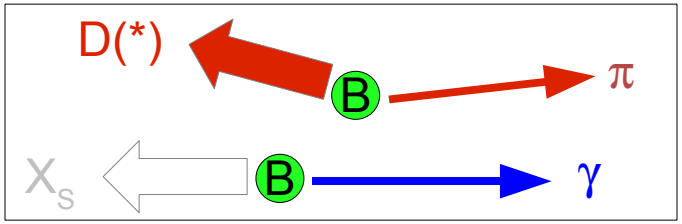
- Measure BF, E_γ, A_{CP}, Δ_{0-}
- Inclusive BF: can be accurately predicted at NNLO
  - Misiak et. al.: $(3.15 \pm 0.23)\ 10^{-4}$ [Phys. Rev. Lett. 98, 022002]
  - Becher et. al: $(2.98 \pm 0.26)\ 10^{-4}$ [Phys. Rev. Lett. 98, 022003]

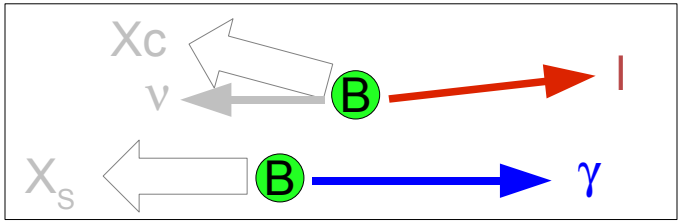
  } $E\gamma > 1.6$GeV
- E_γ distribution depends on the b mass (m_b) and the fermi motion (μ_π) of the b quark $\Rightarrow$ can be used to reduce the model dependence error on $|V_{ub}|$ and $|V_{cb}|$
- A_{CP}^{s} <1% in SM (CKM + GIM suppression), while it can be up to 15% in some new physics models Nucl. Phys. B704, 56
- $A_{CP}^{s,d}$ <<1% in SM: $\Delta\Gamma(b \rightarrow s\gamma) \approx -\Delta\Gamma(b \rightarrow d\gamma)$
- Isospin asymmetry Δ_{0-}: B^0 B^- partial rate asymmetry

$B \to X_{s,d}\gamma$: Methods

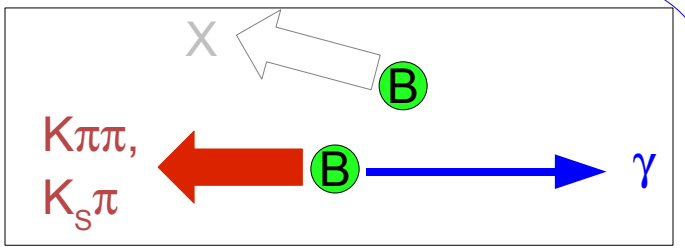
- Semi-inclusive
  - Reconstruct 38 exclusive final states
- B recoil NEW
  - Fully reconstruct one B
  - Measure photon from other B
- Inclusive
  - reconstruct only the photon
  - Reduce background with lepton tag







$B \to X_{s,d}\gamma$: Sum of exclusive modes



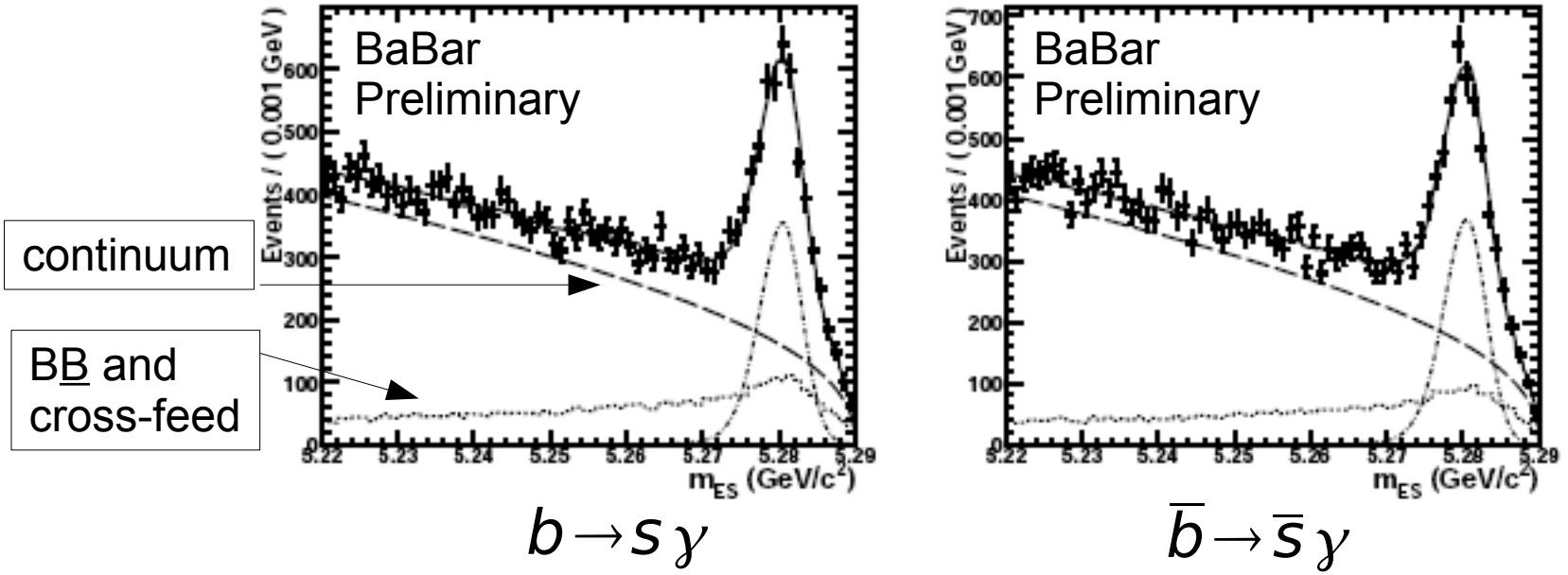
- Fully reconstruct $B \to X_s\gamma$ in 16 exclusive modes
  - X_s=1 or 3 K, up to 3π of which ≤ 2 π^0
- Main background: π^0 and η from continuum, ISR
  - veto photons which form good π^0 or η
- Extract yield from M_{ES} fit to signal region
  - background shapes from MC
- Sidebands and $B \to X_s\pi^0$ control sample used for:
  - detector bias (different interaction X-section for K^+ and K^-)
  - BB background shape uncertainty
  - continuum shape uncertainty

photon replaced with a high energy π^0

Sum of exclusive modes: A_{CP}^{s}

Journal article in preparation

383 MBB

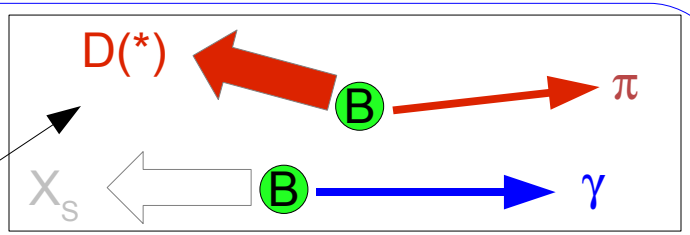


$b \to s\gamma$ $\quad\quad$ $\bar{b} \to \bar{s}\gamma$

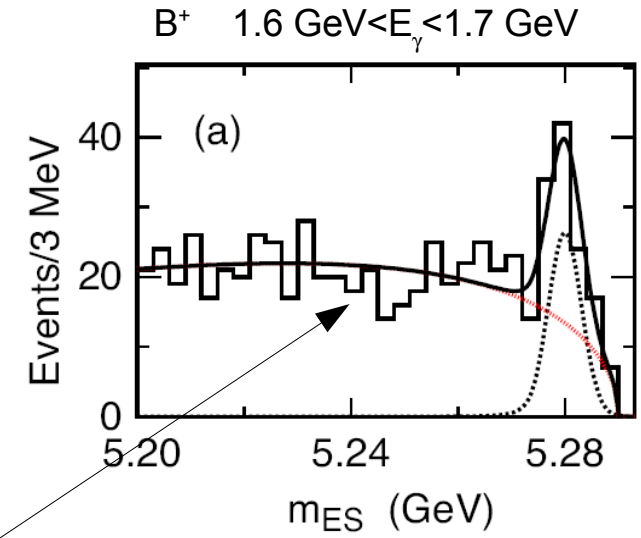
- A_{CP}^{s}= -0.012 ± 0.030 ± 0.019 [preliminary]
  [0.6GeV<M(X_s)<2.8GeV]
- Most accurate measurement of A_{CP} to date

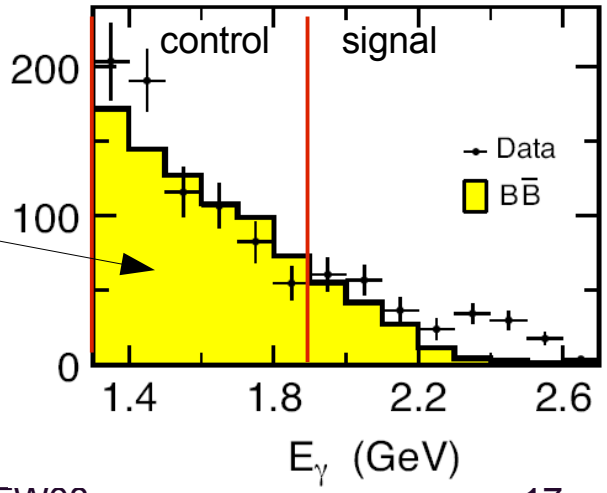
$$A_{CP}^{th}(B \to X_s\gamma) = (0.44^{0.15}_{-0.10} \pm 0.03^{+0.19}_{0.09})\,\%$$ Nucl. Phys. B704, 56

$B \to X_{s,d}\gamma$: B recoil



- Fully reconstruct one B in ~1k hadronic modes: efficiency ~ 0.3% but good S/B
  - can determine: $P_B \Rightarrow$ photon energy in B rest frame, B charge $\Rightarrow$ Isospin asymmetry, B flavor $\Rightarrow A_{CP}$
- Subtract $q\bar{q}$ and mis reconstructed B with a fit to M_{ES} in bins of E_γ
- Subtract γ from π^0, η with MC normalized in 1.3 GeV< E_γ<1.9 GeV
- Practically no background >2.3 GeV

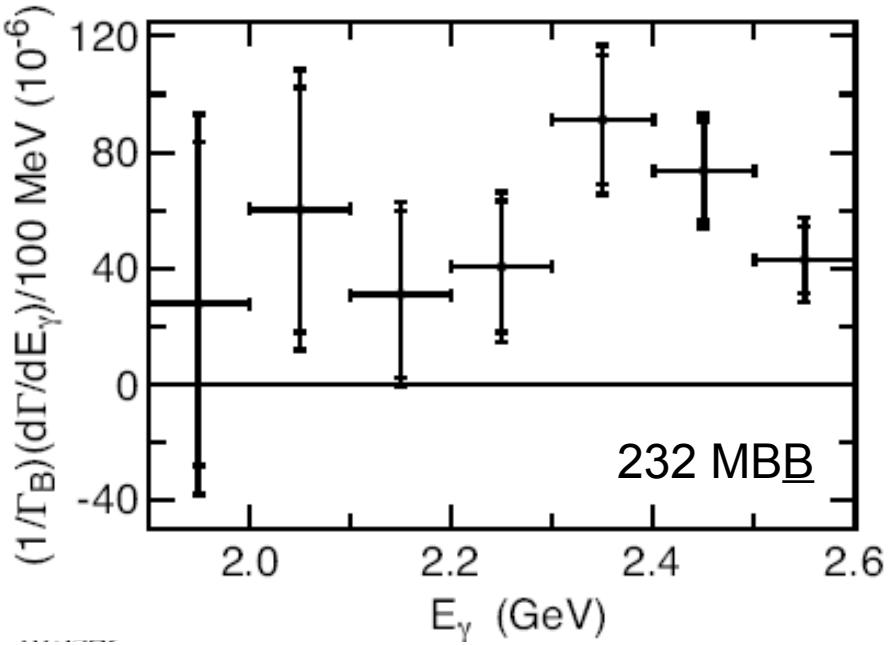




B recoil: Results

arXiv: 0711.4889 [hep-ex],
Accepted in Phys. Rev. D.

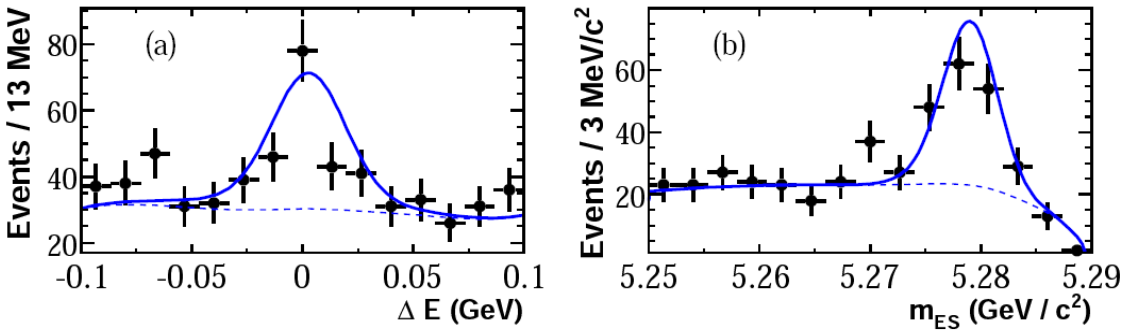
- Extract BF,A_{CP},Δ_{0-} from E_γ>1.9 GeV region
- $BF(B \to X_s \gamma) = (3.65 \pm 0.85 \pm 0.60) \times 10^{-4}$ } b->dγ subtracted
- $A_{CP} = 0.10 \pm 0.18 \pm 0.05$ } untagged asymmetries (b->s,d γ)
- $\Delta_{0-} = -0.06 \pm 0.15 \pm 0.07$



- $m_b = 4.46^{+0.21}_{-0.23}$
- $\mu_\pi^2 = 0.64^{+0.39}_{-0.38}$
- Method is statistics limited but can become competitive at a super B factory

$B \to a_1 K$: observation

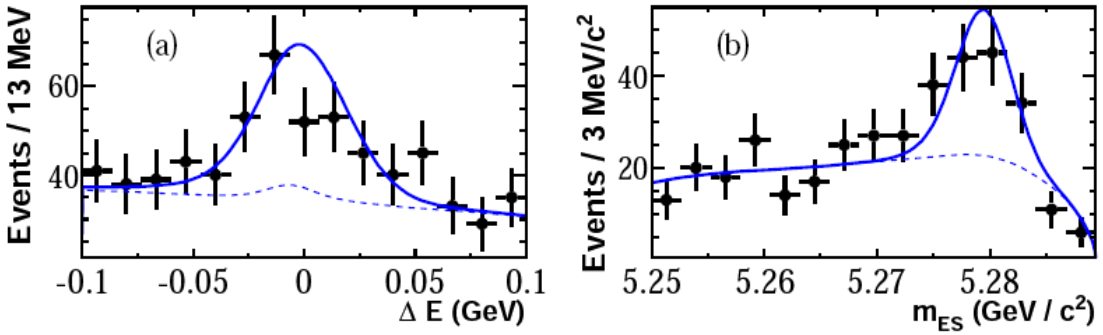
[Phys.Rev.Lett.,100, 51803]`



$BF(B^+ \to a_1^+ K^0_S) = (34.9 \pm 5.0 \pm 4.4)\ 10^{-6}$

First observation of this decay mode

significance 6.2σ



$BF(B^0 \to a_1^- K^+) = (16.3 \pm 2.9 \pm 2.3)\ 10^{-6}$

Observation of this decay mode

significance 5.1σ

$B \to a_1 K$: penguin 'pollution'

- $B^0 \to a_1^{\pm}\pi^{\pm}$ tree dominated ($b \to u\underline{u}d$)=> can be used to extract $\alpha = \arg(-V_{td}V_{tb}^*/V_{ud}V_{ub}^*)$
- Subleading penguin has different weak phase => measures $\alpha_{eff} = \alpha + \Delta\alpha$

$a_{eff} = 78.6 \pm 7.3$

Phys Rev. Lett. 98, 181803
384 MB$\underline{B}$

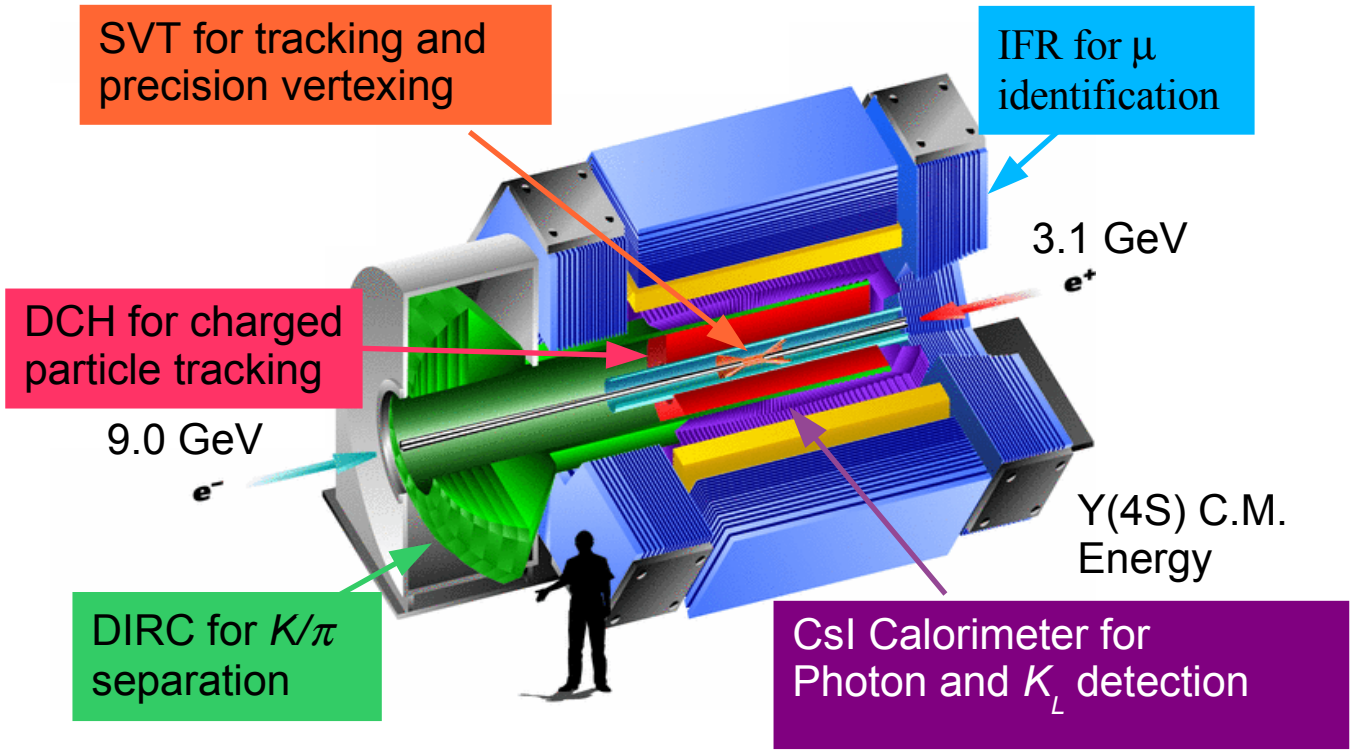
- Using the SU(3) related modes $B \to K_1\pi$, $B \to a_1 K$ is possible to bound $\Delta\alpha$ using the BF Phys. Rev., D73, 057502
- $B \to K_1\pi$ is being measured by BaBar, bound on α ~ 16-19 deg

Conclusions

- Measured A_{FB} and F_L in $B \to K^* l^+ l^-$ and excluded a wrong sign of $C_9 C_{10}$ at more than 3σ level
- Probed the 'wrong' γ polarization in $K^*\gamma$ and found it compatible with zero
- Precisely measured A_{CP} to 4% accuracy in $B \to X_s \gamma$
- Used the 'B recoil' technique to measure A_{CP}, BF, E_γ, A_{CP},Δ_{0-}
- Observed $B \to a_1 K$, useful in extracting α from $B \to a_1 \pi$

backup

BABAR Detector at PEPII



Integrated Luminosity 1999 – 2007

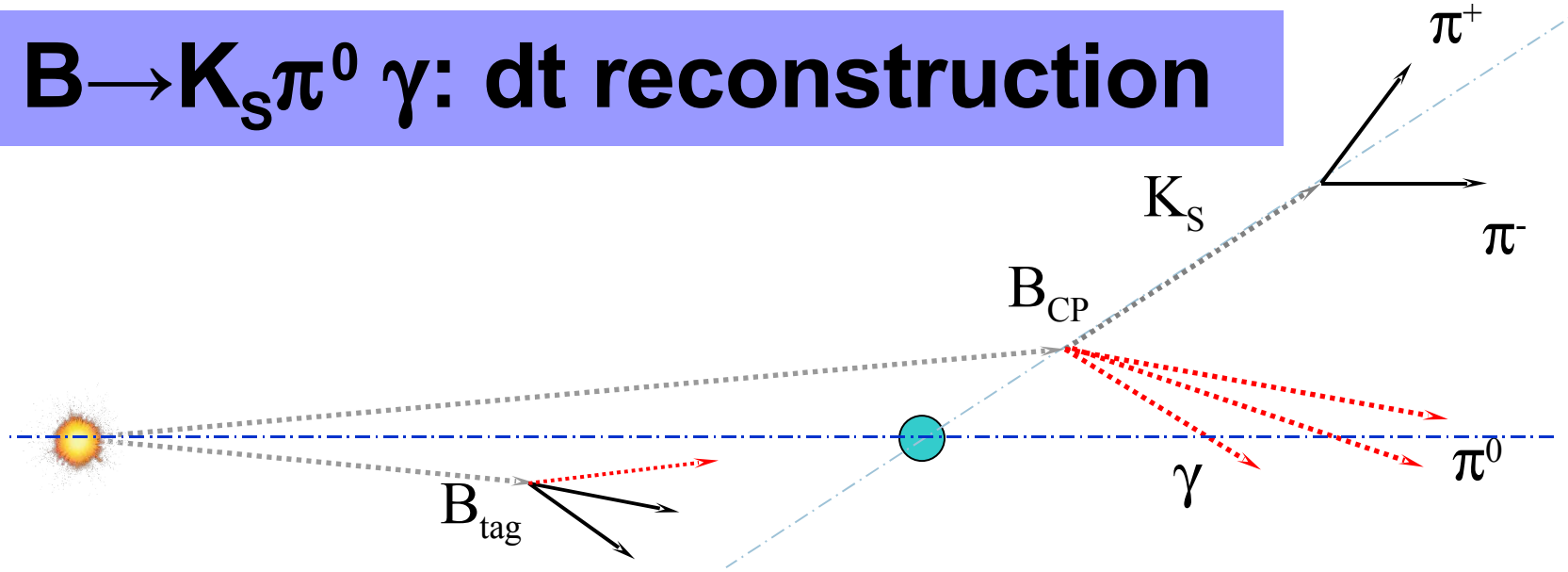
On-Peak 423 fb^{-1} ~466 MBB

Off-Peak 44 fb^{-1}

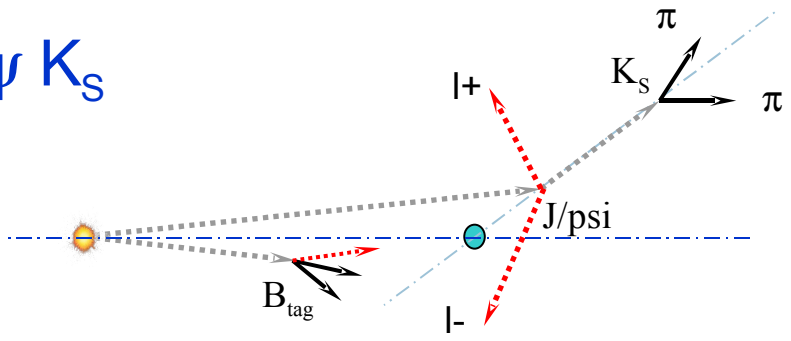
$$M_{ES} = \sqrt{(s/2 + \mathbf{p_0 p_B})^2 / E_0^2 - p_B^2}$$

$$\Delta E = E_B^* - 1/2\sqrt{s}$$

$B \to K_S \pi^0 \gamma$: dt reconstruction



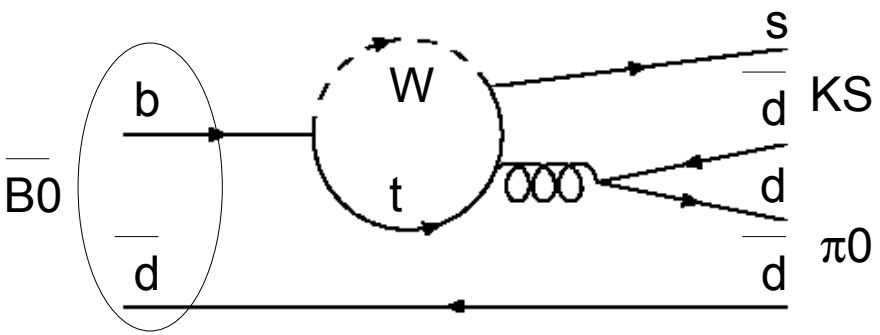
- Charged tracks only from K_S
- To reconstruct Δt exploit precise vertex detector and fit K_S track to the IP profile
- Validate the method using J/ψ K_S sample



B->$X_s\gamma$ B recoil: Eγ range

E_γ range (GeV)	$\mathcal{B}(B \to X_s\gamma)$ (10^{-4}) Value	$\sigma_{\rm stat}$	$\sigma_{\rm syst}$	Background modeling	$m_{\rm ES}$ fit parameterization	Detector response	$B \to X_s\gamma$ model
1.9-2.6	3.66	0.85	0.60	0.35	0.45	0.18	0.08
2.0-2.6	3.39	0.64	0.47	0.31	0.34	0.07	0.06
2.1-2.6	2.78	0.48	0.35	0.22	0.24	0.08	0.05
2.2-2.6	2.48	0.38	0.27	0.14	0.19	0.10	0.05
2.3-2.6	2.07	0.30	0.20	0.10	0.15	0.04	0.05

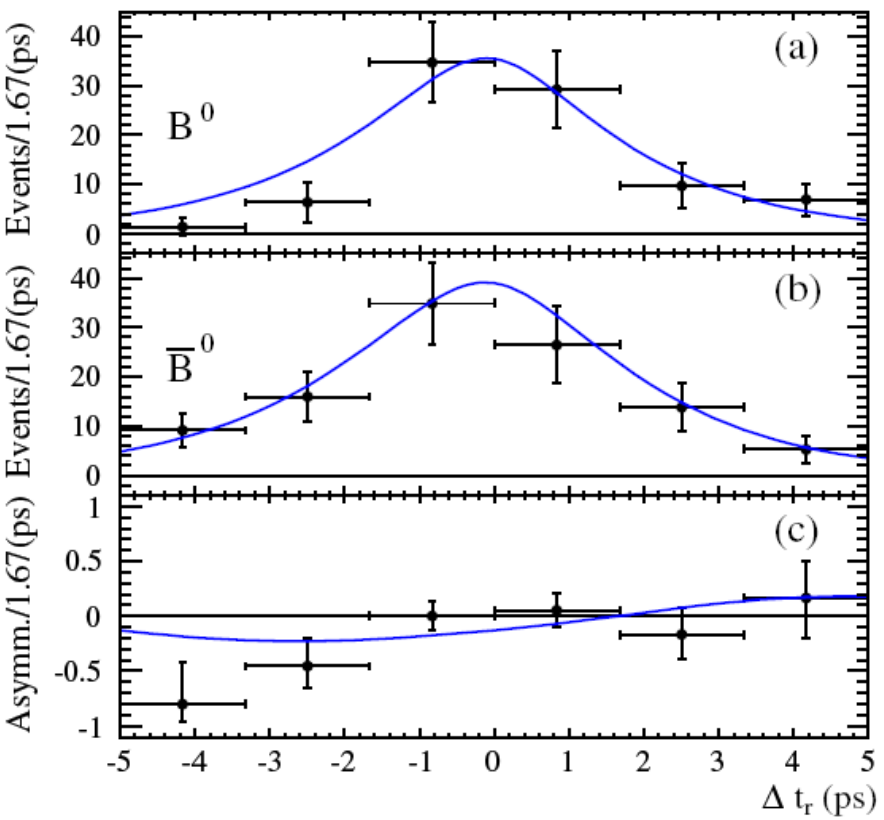
Gluonic Penguins

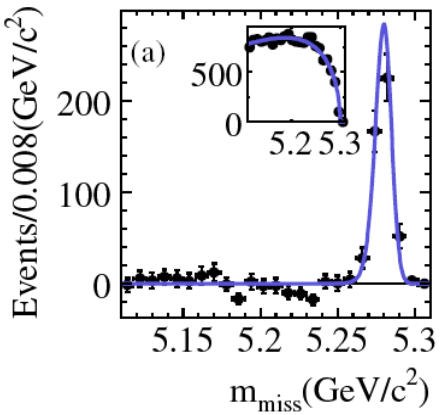


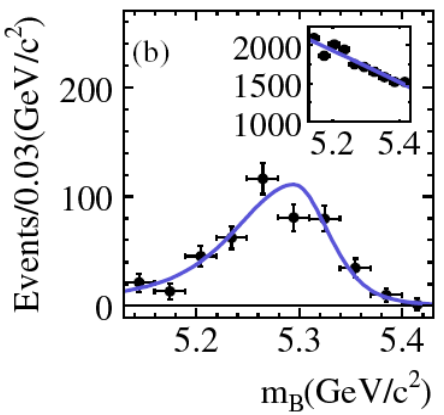
- Tree diagram is suppressed
- penguin diagram carries approximately the same weak phase as $b \to c\bar{c}s \Rightarrow -\eta_f S = \sin 2\beta$ from TDCP analysis
- Compare the value of sin2b extracted from penguin decays to the one from $b \to c\bar{c}s$ decays to search for new physics
- SM deviation from $\sin 2\beta$
  - SU(3) symmetry: < 0.2
  - QCD factorization: ~0.1

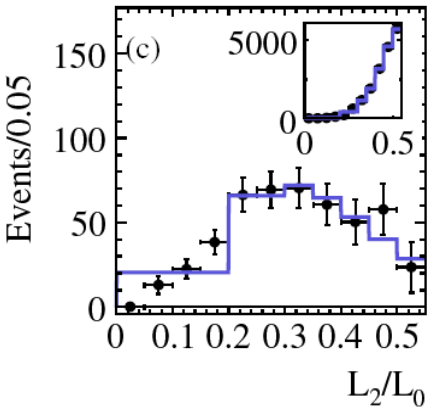
$K_s\pi^0$: results

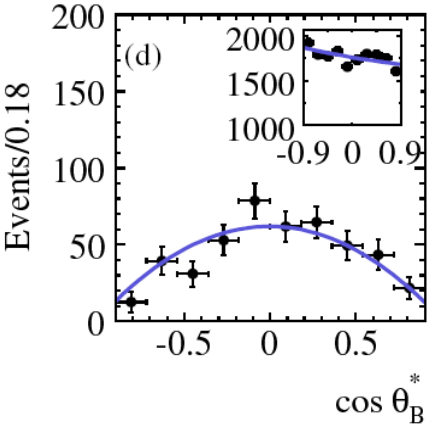
383 MBB
Phys. Rev. D77, 012003











- BR=10.3±0.7±0.6, S=0.40±0.23±0.03, C=0.24±0.15±0.03