$B^0 \to \eta' K^0$ Time Dependent Analysis @ SuperB FastSim Preliminary Study

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Overview

- Talk Overview
  - One slide of Physics.
  - m_{ES}, ΔE and ΔT resolution.
  - Efficiency of $\eta' K^0_S$ ($\eta' \rightarrow \eta\pi\pi$, $\eta \rightarrow \gamma\gamma$) decay mode.
  - Systematics balance and reduction.
- DISCLAIMER:
  - Modes $\eta' \rightarrow \rho\gamma$, $\eta' \rightarrow \eta\pi\pi$ ($\eta \rightarrow \pi^+\pi^-\pi^0$) not analyzed yet.
  - A priori, there are no different issues with respect to $\eta' \rightarrow \eta\pi\pi$ ($\eta \rightarrow \gamma\gamma$).
  - Analysis performed using V.0.2.3 + tagging packages (see Simone's talk) for signal, and Feb. Production (V.0.2.1) background.

η'K⁰ Physics

$B^0 \to \eta' K^0$ decay discovered with an unpredicted high BF by CLEO, CP Violation first observed in 2006 by BaBar.

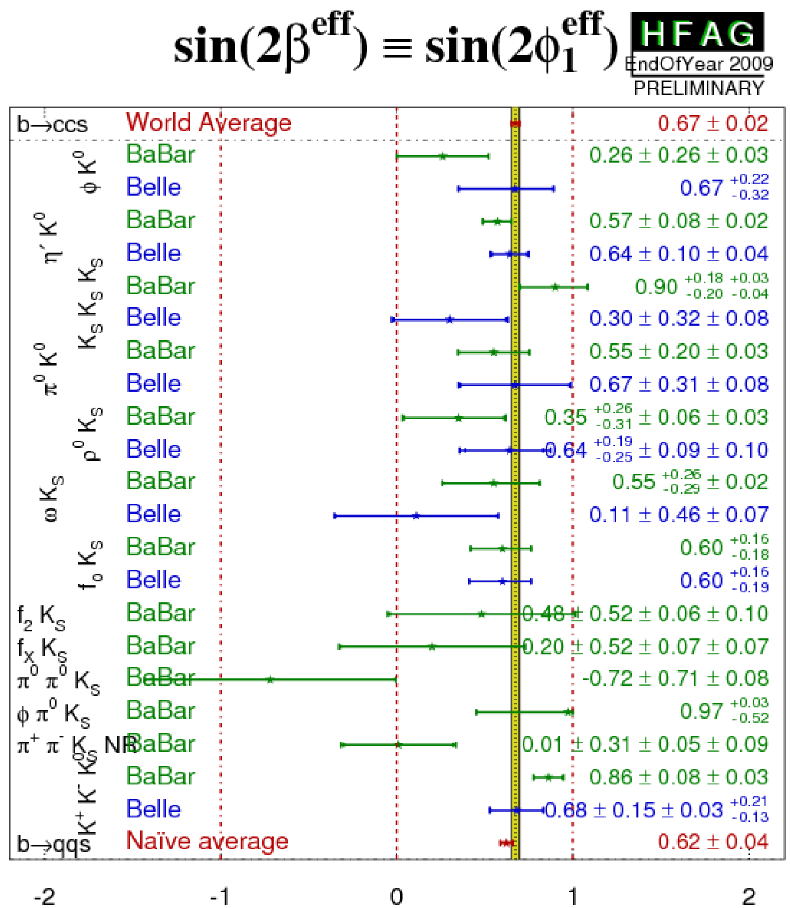
$B^0 \to \eta' K^0$ is a $b \to s$ penguin-mediated process: NP effects may appear due to heavy particles in the loop.

CPV is investigated trough Time-Dependent Analysis.

$$A_{CP} = \frac{\Gamma(\overline{B^0} \to \eta' K) - \Gamma(B^0 \to \eta' K)}{\Gamma(\overline{B^0} \to \eta' K) + \Gamma(B^0 \to \eta' K)} = S \sin(\Delta m t) + C \cos(\Delta m t)$$

Neglecting Cabibbo-suppressed contributions, S is expected to be equal to the value measured in $B^0 \to (c\bar{c})K^0 = \sin 2\beta$.

Deviations from this value may arise from SM effects and are computed in various approaches.



$\eta' K^0$ Analysis

Why $B^0 \to \eta' K^0$?

- Has large BF with two of the dominant modes with low background.
- Theory predicts difference with $(c\bar{c})K^0$ to be up to ~0.01-0.04.

$B^0 \to \eta' K^0$ at BaBar:

$$S_{\eta' K} = 0.586 \pm 0.078 \pm 0.015 \quad S_{c\bar{c}} = 0.687 \pm 0.028 \pm 0.012$$

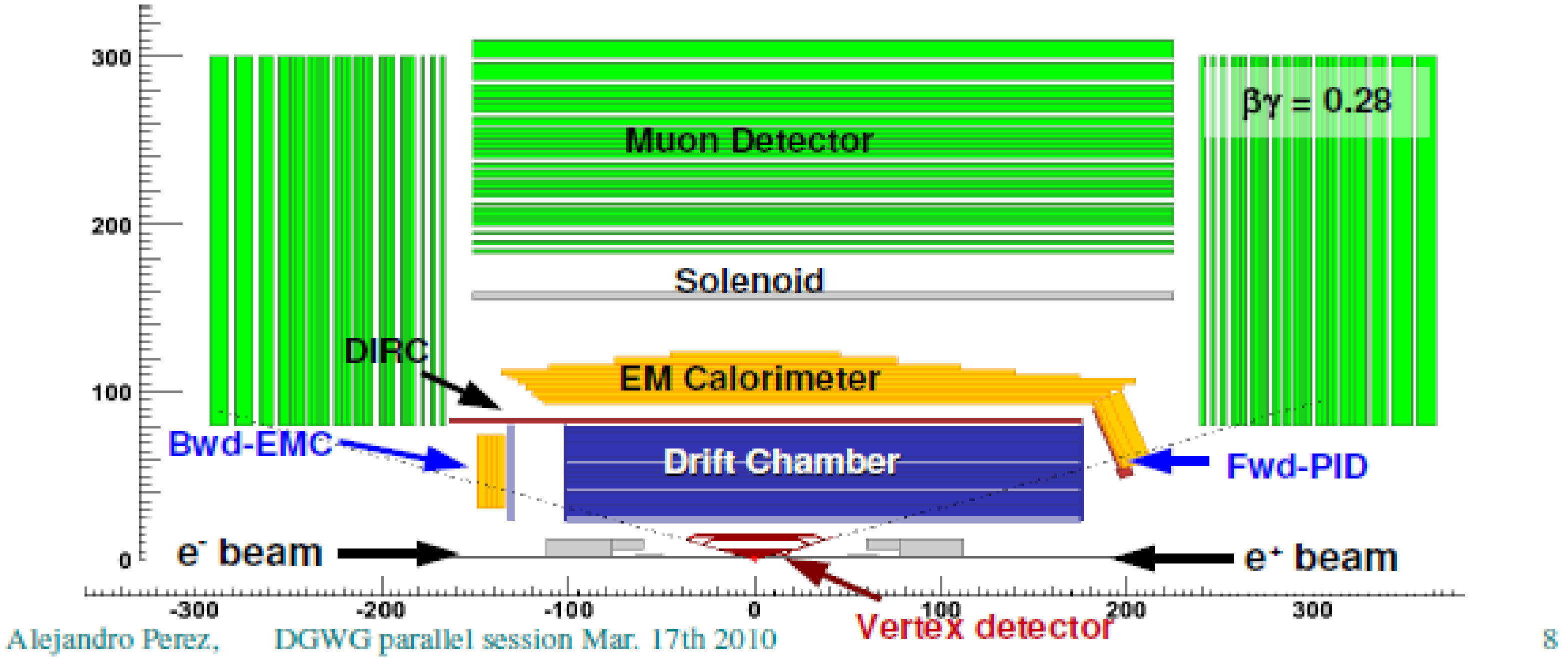
- Simultaneous fit to K^0_S and K^0_L samples.
- 3 $K^0_S \to \pi^+\pi^-$ modes + 2 $K^0_S \to \pi^0\pi^0$ + 2 K^0_L modes = 7 decay modes.
- Main systematics are statistical in origin.

$B^0 \to \eta' K^0$ at SuperB:

- At this stage: reperform BaBar analysis with no changes.
- With 75 ab^{-1} modes with $K^0_S \to \pi^0\pi^0$ (high backgrounds) are not needed.
- K^0_L modes may provide an independent measurement (may add another subdecay).

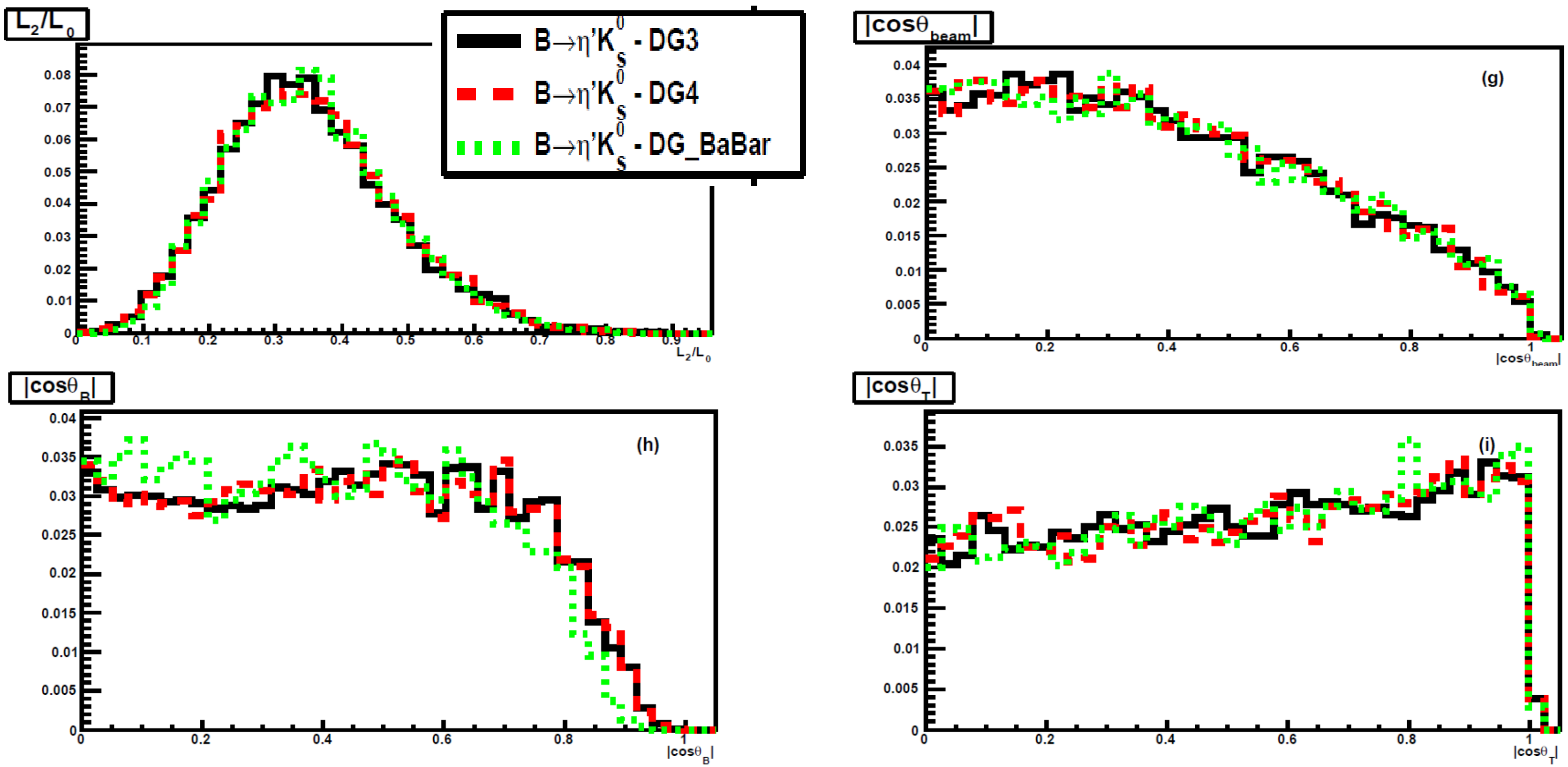
Detector

- Baseline configuration: BaBar with reduced boost ($\beta\gamma = 0.28$)
- Generated geometries:
  - Baseline + Bwd-EMC + Extended Dch (**DG_3**)
  - Baseline + Bwd-EMC + Fwd-PID (**DG_4**)

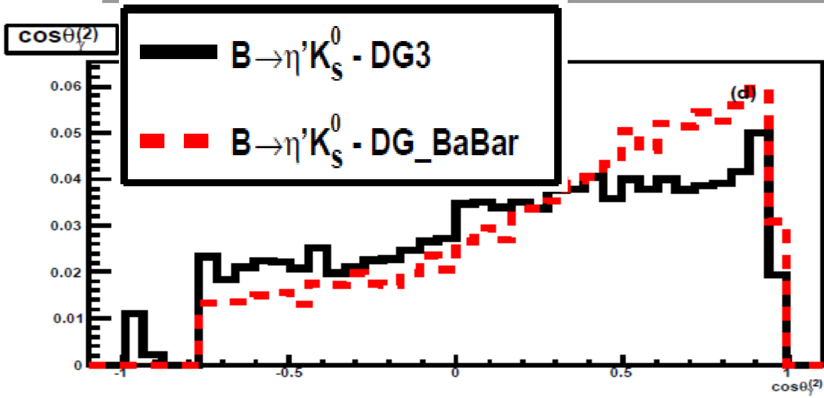


$\eta'(\eta_{\gamma\gamma}\pi\pi)K^0$ Variables

First we checked that all the variables used in BaBar analysis don't show strange behavior for signal @ SuperB.

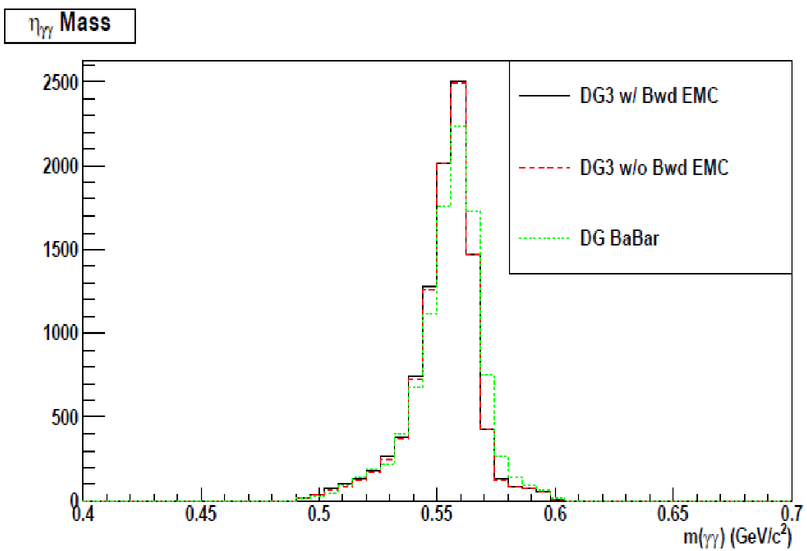


BWD EMC Impact



Angular distribution of reconstructed photons is quite different wrt BaBar baseline.

1% of the events have photons reconstructed in Bwd EMC.



Changes in $\eta_{\gamma\gamma}$ mass resolution is small when moving from DGBaBar to DG3.

Including Bwd EMC events doesn't worsen the resolution.

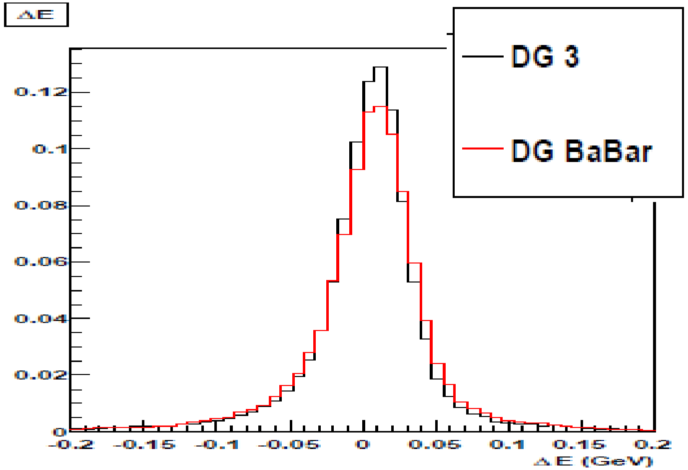
No advantage in including Bwd EMC, 1% signal efficiency gain.

FWD PID Impact

- Kaon, proton and electron PID selectors used as veto on η' pion daughters.
- Only Kaon selector considered in this study.
- Impact of FWD PID in our analysis is small:
  - Changes in signal efficiency is <1%.
  - Background rejection increase by ~2-3%.
- [ASIDE] 25-35% of non π tracks hitting FWD PID are electrons.
  - Global effect on our decay mode is marginal.
  - However this can be interesting for other modes.
- Some benefit can come from improved Tag performance thanks to larger PID coverage (to be tested).

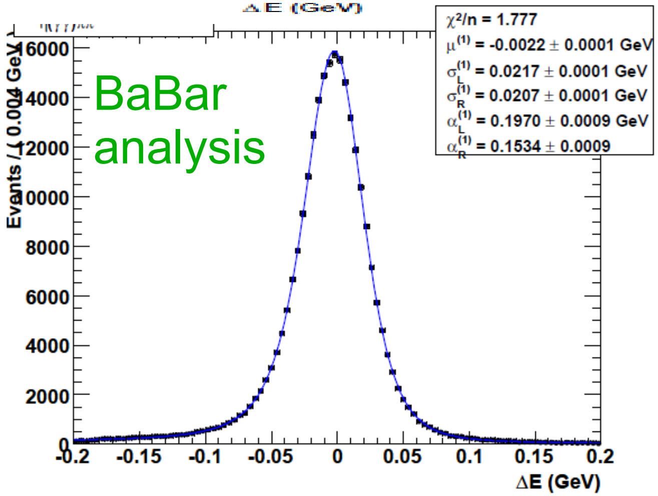
Test Performed with Feb. Production! (V0.2.1)
NOT UPDATED!

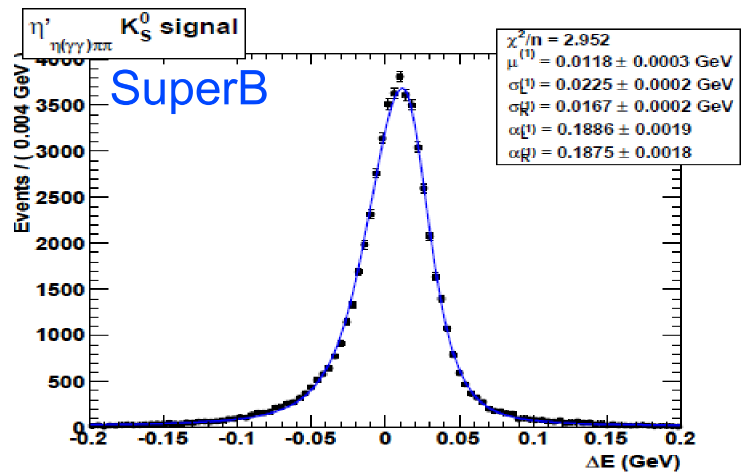
ΔE Distribution



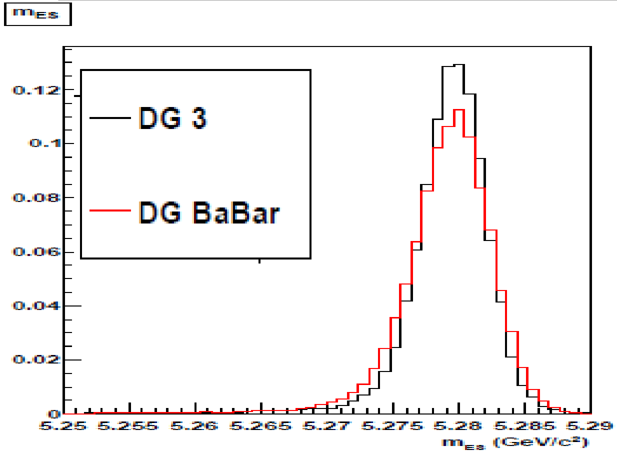
@SuperB Machine:
DG3 has better resolution wrt DGBaBar.

- DG3 @ SuperB Vs BaBar @ PEPII:
  - BaBar resolution 20-21 MeV.
  - DG3 resolution 17-23 MeV.



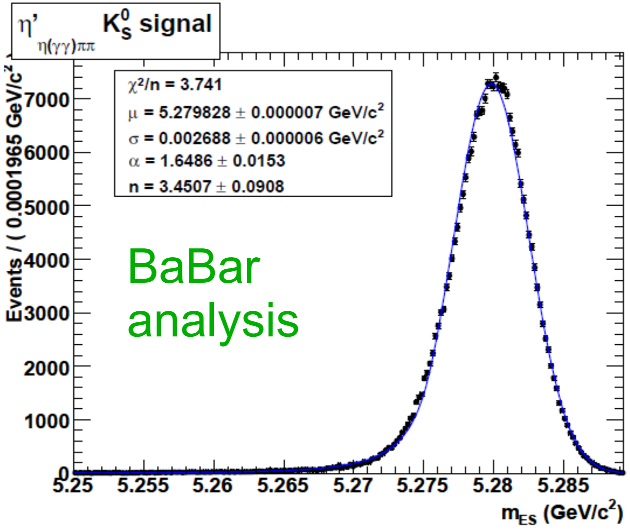


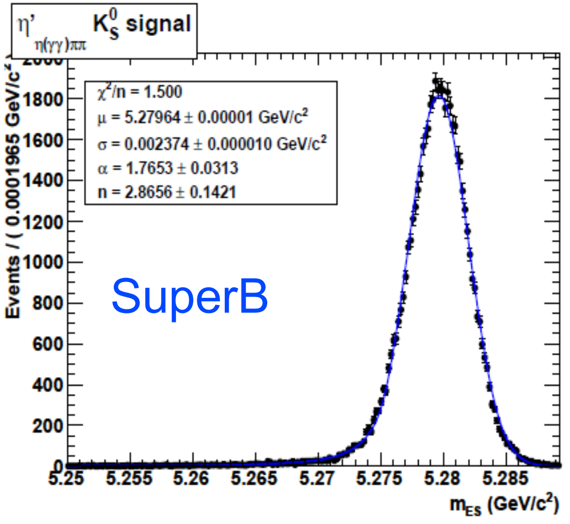
m_{ES} Distribution



@SuperB Machine:
DG3 has better resolution wrt DGBaBar.

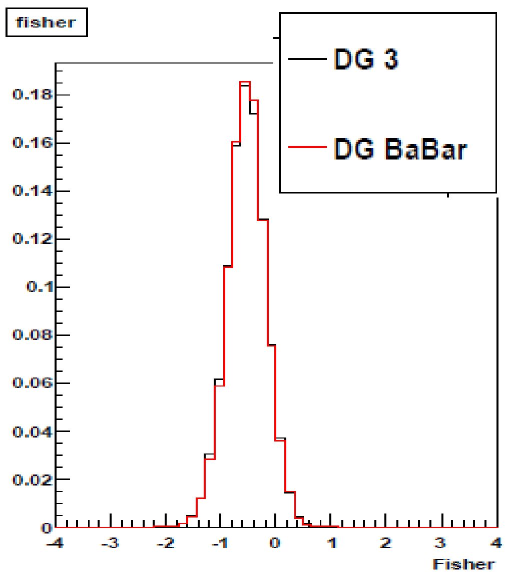
- DG3 @ SuperB Vs BaBar @ PEPII:
  - BaBar resolution 2.7 MeV/c^2.
  - DG3 resolution 2.4 MeV/c^2.

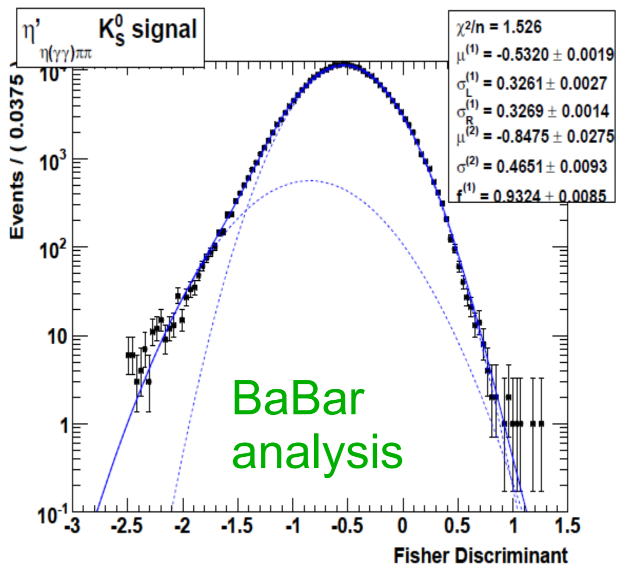


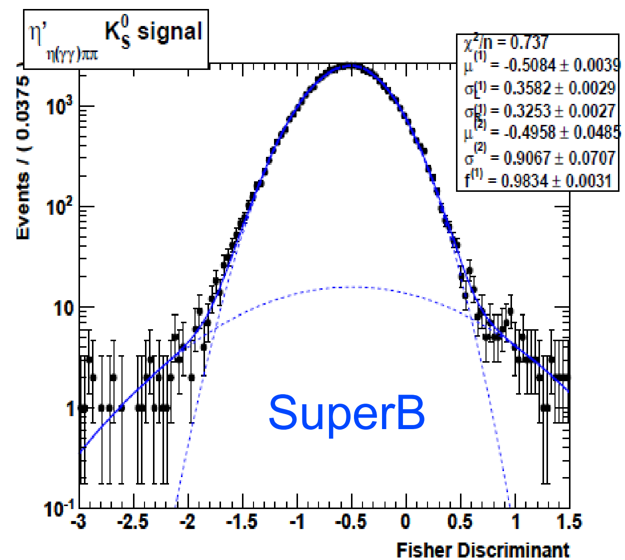


Fisher Distribution

- Fisher combines 4 event shape variables + output of tagging algorithm.
- Coefficients optimized for η'K TD analysis @ BaBar.
- Check the Fisher in order to be able to perform toys:
  - Similar fit configuration as BaBar.
  - Don't trust the coefficient optimization, just use it.
  - Impact of tagging algorithm is small ~2-3% in Fisher shape.

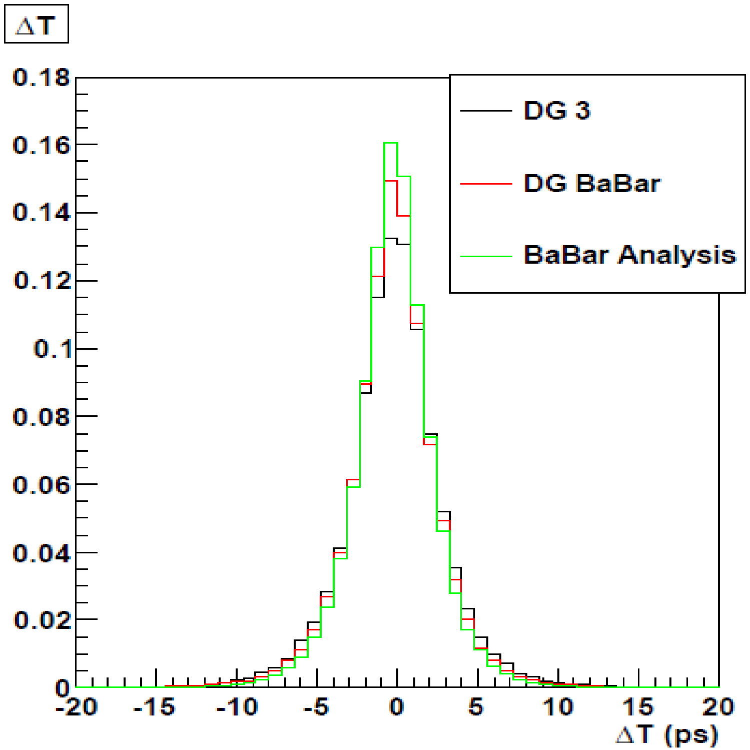


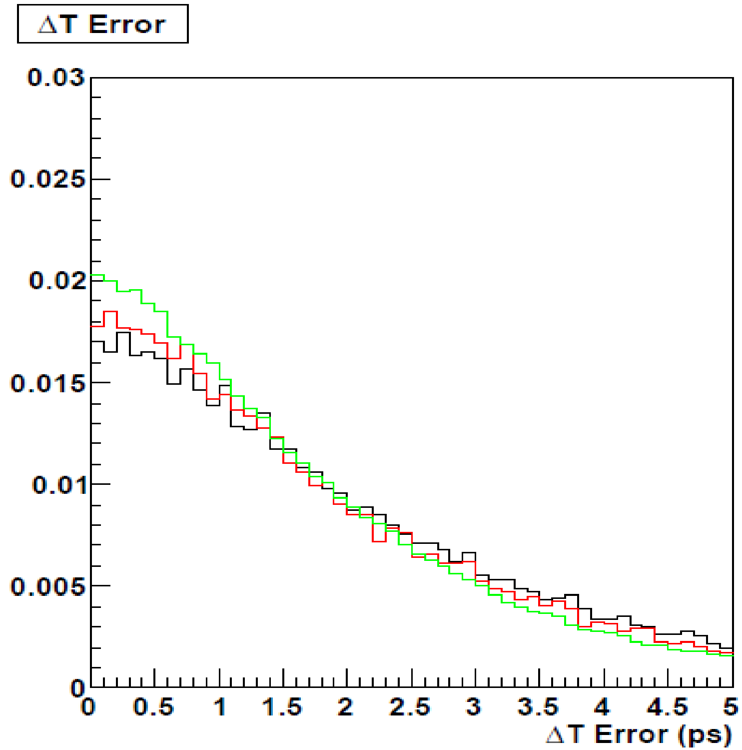




Δt Distribution

- We check the Δt distribution and fitted the resolution function for signal.





- DG BaBar seems to have better Δt resolution wrt DG3: is this expected?

Δt Distribution

- Fit to 50k MC events with CP model leaving Δt parameters floating.
- Tagging parameters (efficiencies, mistag, etc.) Fixed to BaBar Tag04.

	SuperB DG3	BaBar Analysis
δ(Δt) Non Lepton	-0.127 ± 0.015	-0.222 ± 0.014
Scale Non Lepton	1.204 ± 0.021	1.133 ± 0.023
δ(Δt) Lepton	0.026 ± 0.038	-0.051 ± 0.038
Scale Lepton	1.135 ± 0.048	1.208 ± 0.051
f(core)	0.824 ± 0.010	0.934 ± 0.011
δ(Δt) Tail	-0.569 ± 0.079	-1.290 ± 0.311
Scale Tail	3 (fixed)	3 (fixed)
f(outlier)	0.004 ± 0.001	0.005 ± 0.001
δ(Δt) Outlier	0 (fixed)	0 (fixed)
Scale Outlier	8 (fixed)	8 (fixed)

Core distribution
6% Wider

Tail distribution
11% higher

Global 10% Effect?

Tagging Variables

- In the present study we fix the tagging parameters to BaBar Tag04.
- However this is not the optimal choice.

From Simone's talk

Tag04 performances

		FastSim – BaBar			BaBar official Tag04		
		Eff (%)	W (%)	Q (%)	Eff (%)	W (%)	Q (%)
Lepton	63	7.3	2.8	6.5	9	2.7	8.1
Kaon I	64	5.2	5.4	4.1	10.5	5.0	8.5
Kaon II	65	10.4	14.0	5.4	16.9	14.1	8.7
Kaon & Pion	66	13.8	23.7	3.8	13.6	23.1	3.9
Pion	67	15.2	34.9	1.4	14.2	31.9	1.9
Others	68	8.6	43.0	0.2	9.6	41.5	0.3
	Total	60.5		21.4	73.8		31.3

Elba Tagger: Q=25.0

- Reduced efficiencies for leptons

- Need to check results after the tagger is improved.

Efficiency

- Event Selection Efficiency:

DG3	DGBaBar	BaBar Analysis
30.0%	27.1%	26.6%

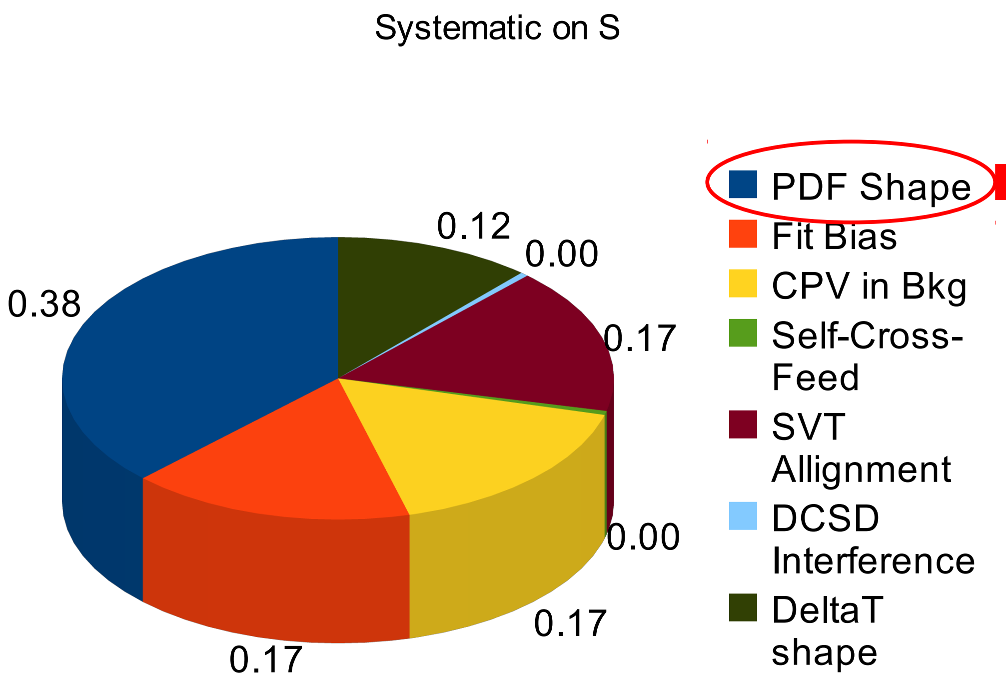
- DGBaBar and BaBar analysis have similar efficiencies.
- Why is DG3 higher?
  - 1.1% higher reconstruction efficiency (longer DCH?).
  - 1.4% PID – No Fwd (Is this realistic?).
  - 0.4% Mass Cuts – DG3 has a better mass resolution.
- Should check if these effects are expected (suggestions are welcome!).
- Possible effect of (machine) backgrounds?
  - BKGROOT /storage/gpfs_babar6/sb/prod/2010_february_bkg/
  - BKGMIX Bhabha RadBhabha

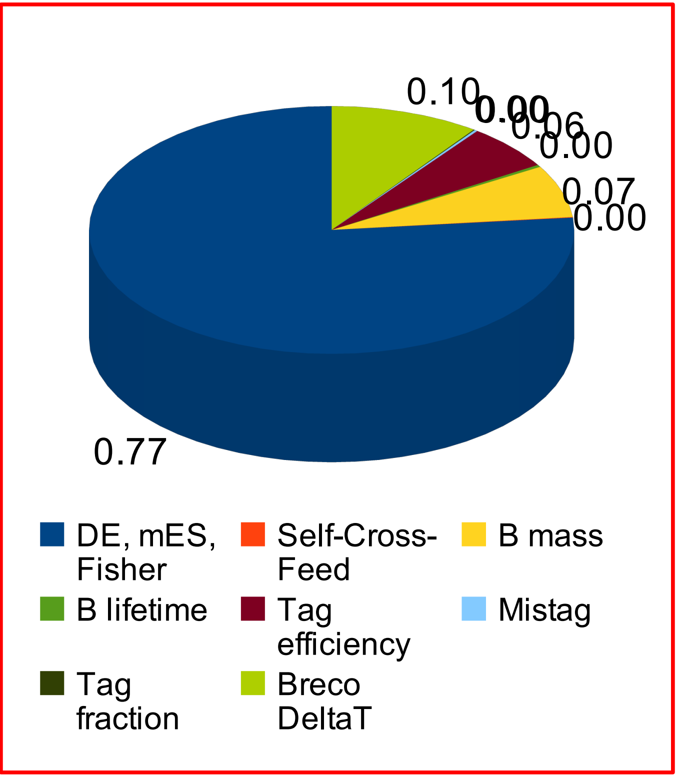
Signal Size and (no) toys

- Expected signal yield at 75 ab^{-1} : ~47k events.
- Unfortunately the available MC statistic for signal is too low to run some toy experiments:
  - Larger samples were available but tagging and ΔE looked weird in V0.2.1, fixes to tagging introduced few time ago.
  - We will run new 100x production (~10 days) after next code freeze.
- However m_{ES}, ΔE and Fisher looks good: no big surprises expected.
  - Need to find a reliable Δt parameterization (large MC Breco samples, BaBar-like?) and quantify the effect on S of the resolution worsening.
- What about $\eta'(\rho\gamma)$ and $\eta'(5\pi)$ modes?
  - $\eta'(5\pi)$ is similar to $\eta'(\eta_{\gamma\gamma}\pi\pi)$: no surprises expected.
  - $\eta'(\rho\gamma)$ has two additional issues:
    - $B\overline{B}$ backgrounds are known but show m_{ES}- ΔE correlation: need much MC to study this (probably too much for this stage).
    - SXF should be understood: need reliable MC Truth matching.

BaBar TD Analysis Systematic Breakdown

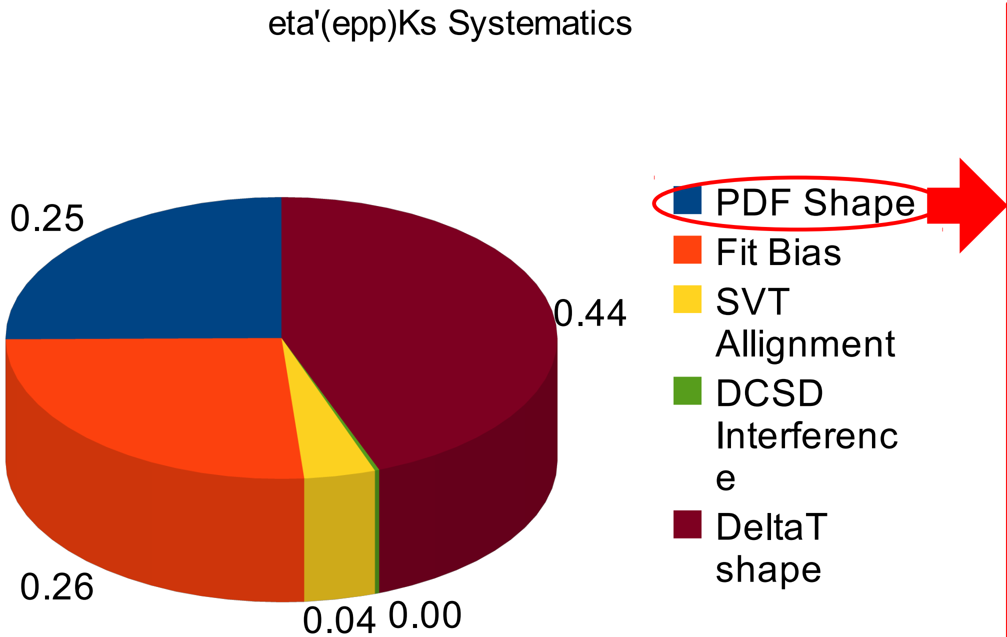
- Systematic Breakdown for BaBar K^0_S analysis including 5 submodes.

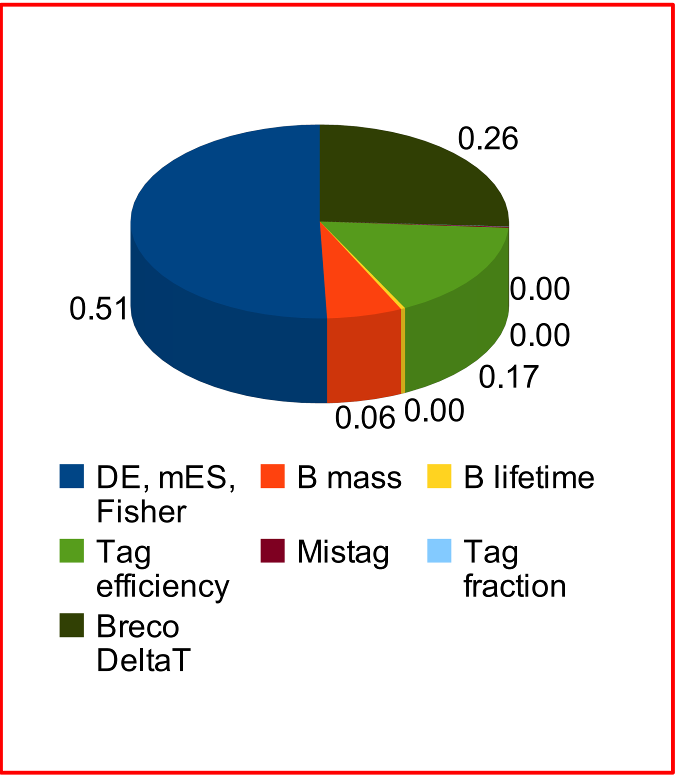




BaBar $\eta'(\eta\pi\pi)K^0_S$ TD Analysis Systematic Balance

- Systematic Breakdown for BaBar $\eta'(\eta_{\gamma\gamma}\pi\pi)K^0_S$ analysis.





- PDFs shapes, Δt resolution for signal side and bias are the main contributions.

Systematics Reduction @ SuperB (1)

- How can we reduce systematics?
  - Signal Δt resolution function:
    - May use data to fit the resolution: as done in $J/\psi K^0$ BaBar analysis.
    - Test on BaBar data: impossible to float all the parameters due to limited statistics.
    - Test floating Δt core parameters shows that error on S is stable. Fitted parameters consistent with Breco ones, inside very large errors.
    - This will also partially remove "Breco Δt" systematic in PDF Shapes.
  - Fit Bias:
    - Fit bias is observed only in MC embedded toy experiments, not in pures.
    - Maybe due to residual correlations in signal variables.
      - Correlation of higher order.
      - "Hidden correlations", i.e. some small subcomponent of signal (ex. SXF) has strong ΔE-m_{ES} correlation, this is not seen at first glance because the subcomponent is small.
    - May consider using 2D ΔE-m_{ES} PDFs as in BaBar $B^+ \rightarrow \rho^+\rho^0$.

Systematics Reduction @ SuperB (2)

- How can we reduce systematics?
  - PDF Shapes:
    - m_{ES}, ΔE main parameters may be left floating in the fit: error on S is stable and fitted parameters have values consistent with MC+corrections.
    - Breco Δt parameters: errors may be reduced by fitting resolution function on data.
    - Tagging parameters: will lower with increasing statistics, constant improvements in BaBar Tagging performance is good indication.
  - Conservative estimate: 50% reduction should be quite easy.
  - Systematic on S = 0.007. More work needed to push down to 0.001.
  - Some of these things are tested within BaBar analysis: why didn't you do this yet?
    - Due to small statistics 7 decay modes are used: 139 free parameters in the fit, not likely to leave more floating.
    - Some modes (es. $Ks \rightarrow \pi^0\pi^0$) are more problematic in term of fit stability: potential advantage from removing them.

Conclusions

- We performed a preliminary study of $\eta' K^0_S$ @ SuperB using FastSim.
- We only consider $\eta' \to \eta_{\gamma\gamma}\pi\pi$ decay mode.
  - No particular issues expected for the other two modes.
- No showstoppers identified in the analysis.
  - Understanding of increased efficiency would be a good point.
  - Need to asses the effect of Δt resolution worsening.
  - Need a quasi-reliable tagging algorithm.
- TD Toy experiments will be a useful tool.
  - The main issue is to have good Tagging and Δt description. May consider producing large Breco signal sample to train the Tagger?
- Systematics reduction:
  - Preliminary tests seems to point in the right direction.
  - Reducing systematic on S to 0.007 (-50%) should be quite straightforward.
  - Some more studies may be performed using toys.