Performance Studies with $B^0 \to \pi^+ \pi^-$

(Using FastSim)

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Overview

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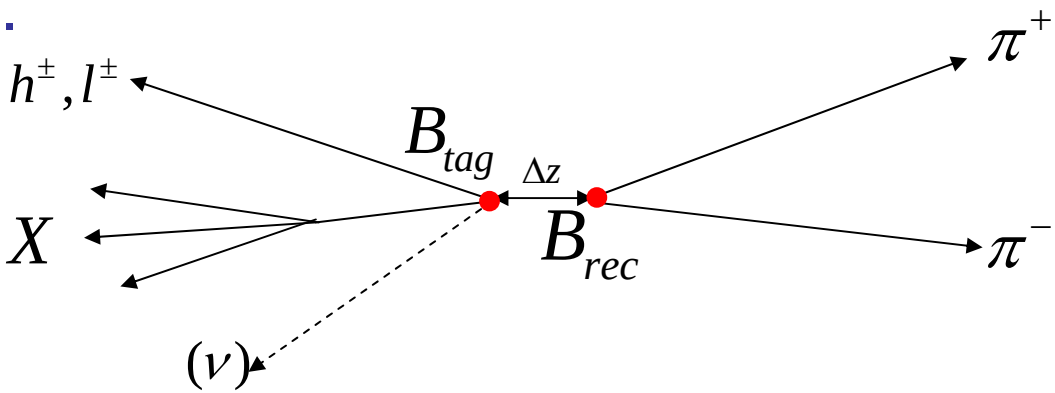
Aims

- Low level and high level distribution comparisons between BaBar and the current SuperB configuration.
- Sliding scale → so need to have a stable selection.
- Care about:
  - Impact parameter, hit resolution, efficiency, PID, Δt, etc.
  - Want to check (analysis level)
    - Δt resolution function
    - Tagging performance (background suppression/time-dependent)
    - sensitivity on S and C for time-dependent results (i.e. new physics searches, and SM reference points)
  - Longer term want to go beyond SM reference points…
- Personally interested in SVT optimization.

Motivation

- Use $B^0 \to \pi^+\pi^-$ as a reference point to enable extrapolation of BaBar time-dependent results to SuperB.



$\Delta z = \beta\gamma\Delta t$,
$\beta\gamma = 0.28$ [0.55]
for SuperB [BaBar]

B_{rec}:
- vertex 2 tracks in detector to look at low level parameters.
- Study vertex resolution for rec side.

B_{tag}:
- Study vertex resolution for tag side.
- Detail tagging performance using MC truth $\to$ Q / $\varepsilon_{slow\ \pi}$ etc.

Event:
- efficiency, Δz and Δt resolutions $\sigma(S)$ & $\sigma(C)$.

Selection

- Use FastSim V0.0.1
  - http://mailman.fe.infn.it/superbwiki/index.php/SuperB_fast_simulation_User_Guide
- BetaTupleMaker in R24.3.4
- Same selection as for BaBar analysis:
  - $M_{ES} > 5.26\ GeV/c^2$
  - $|\Delta E| < 0.1\ GeV$
  - $|\Delta t| < 20.0\ ps$
  - $\sigma(\Delta t) < 2.5\ ps$
  - $\cos(\theta_{sphericity}) < 0.8$
  - $R_2 < 0.7$
  - $Prob(\chi^2) > 0.001$

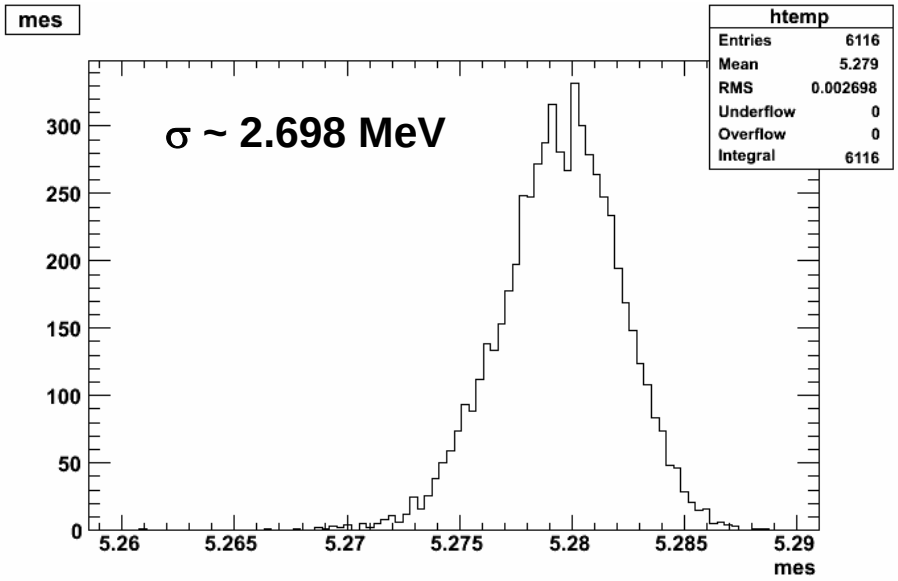
Event Selection Criteria (no PID)

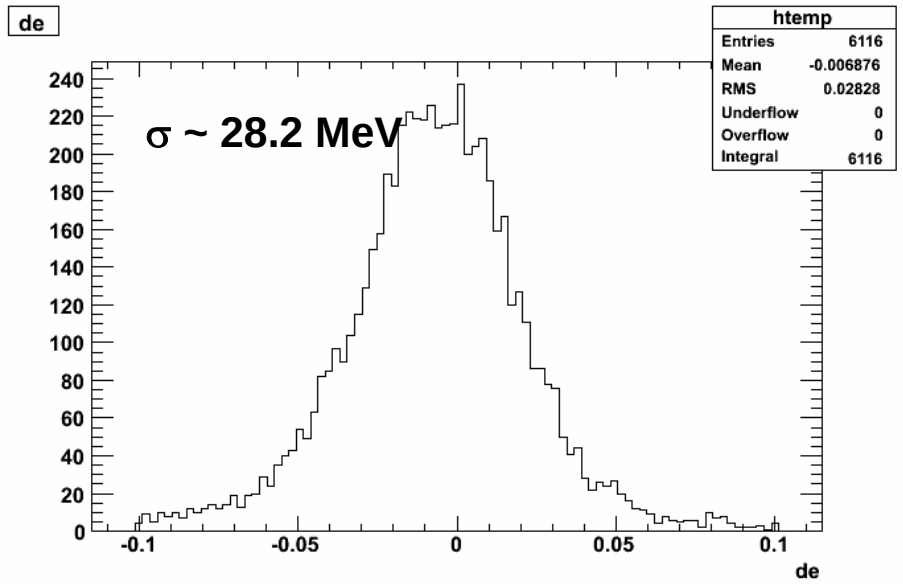
The *BABAR* efficiency for these cuts is $(53.62 \pm 0.31)\%$.

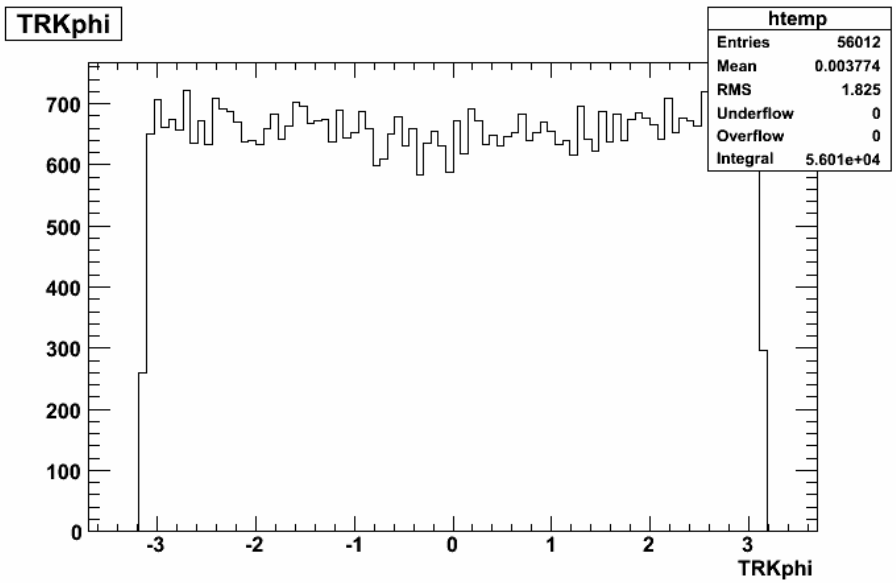
- Efficiency ~61%.
- Need to add PID vetoes: $\varepsilon_{PID}^{BABAR} = (77.3 \pm 0.8)\%$, $\varepsilon_{\pi\pi}^{BABAR} = 39.3\%$

PID not implemented
(hope to rectify this asap)

Validation: BaBar Configuration

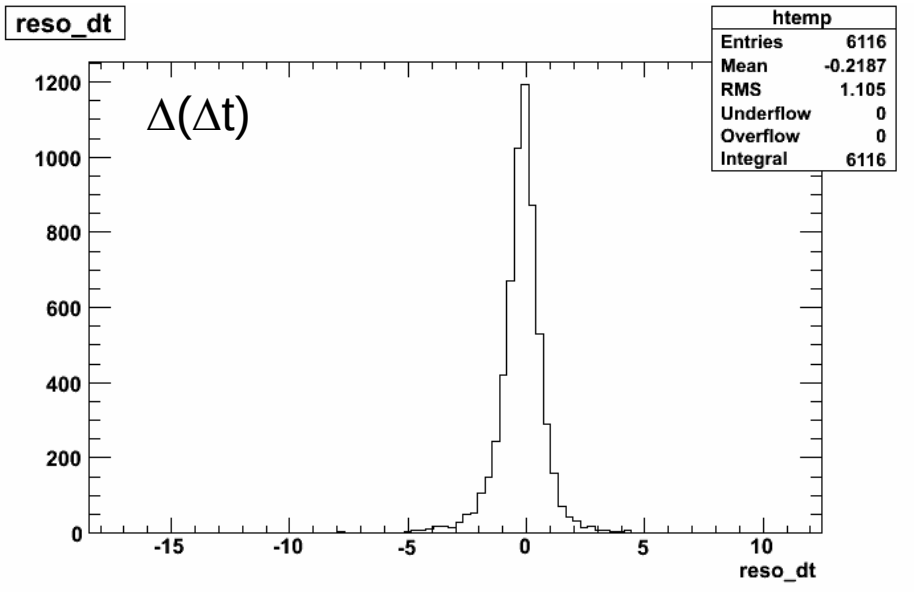


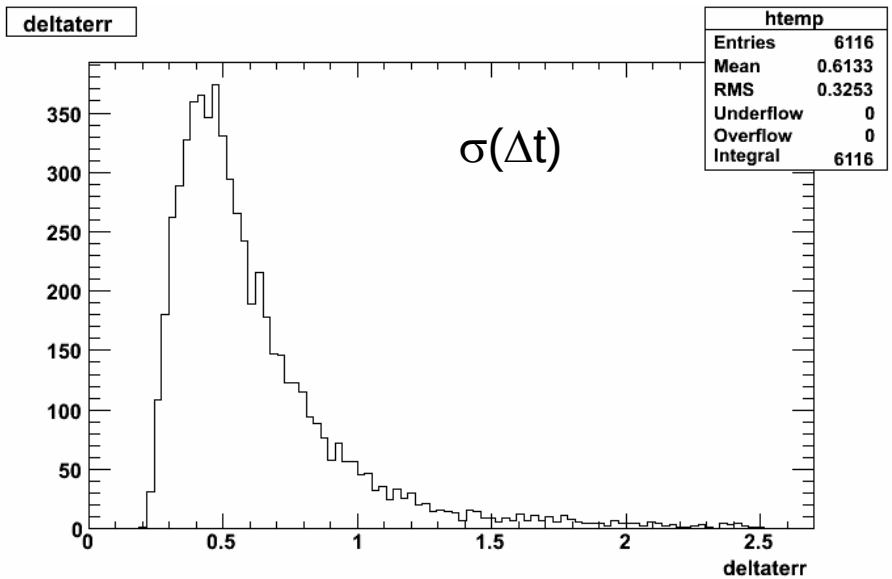




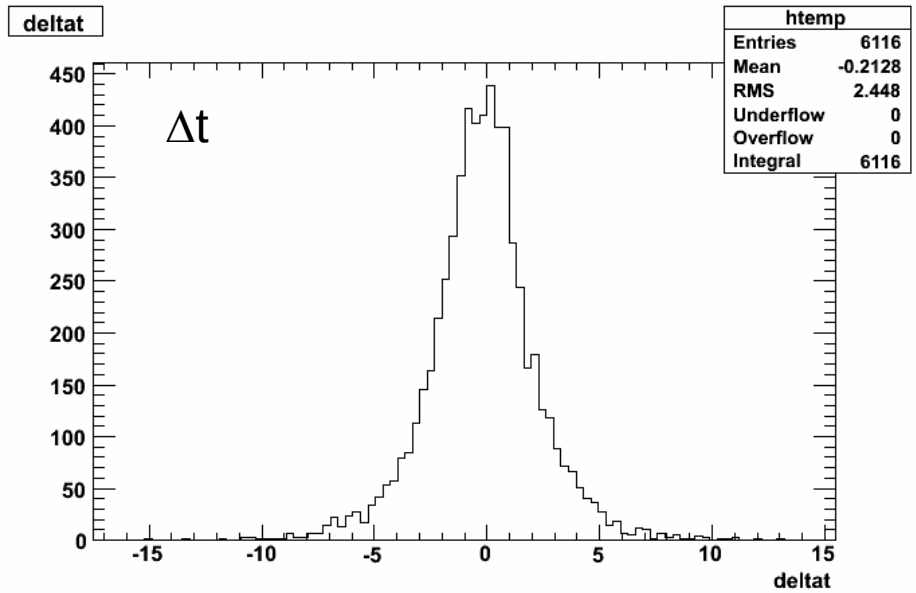
- 2-body kinematics reasonable
- M_{ES} and ΔE are as expected
- Track occupancy independent of θ

BaBar Configuration: Δt



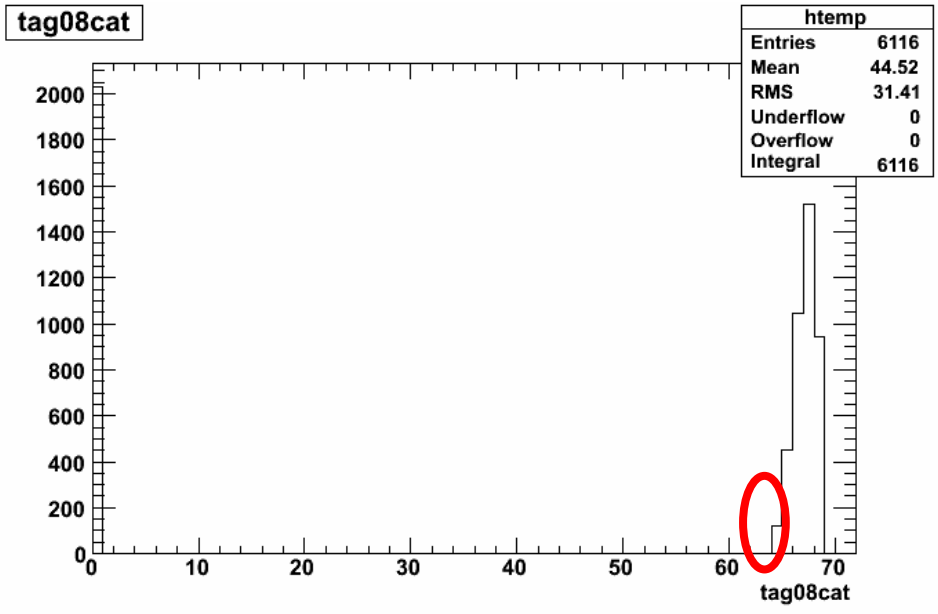


- Resolution RMS ~ 1.1ps (same as BaBar)
- σ(Δt) peaks at 0.61ps (slightly better than BaBar's $\rho^+\rho^-$)

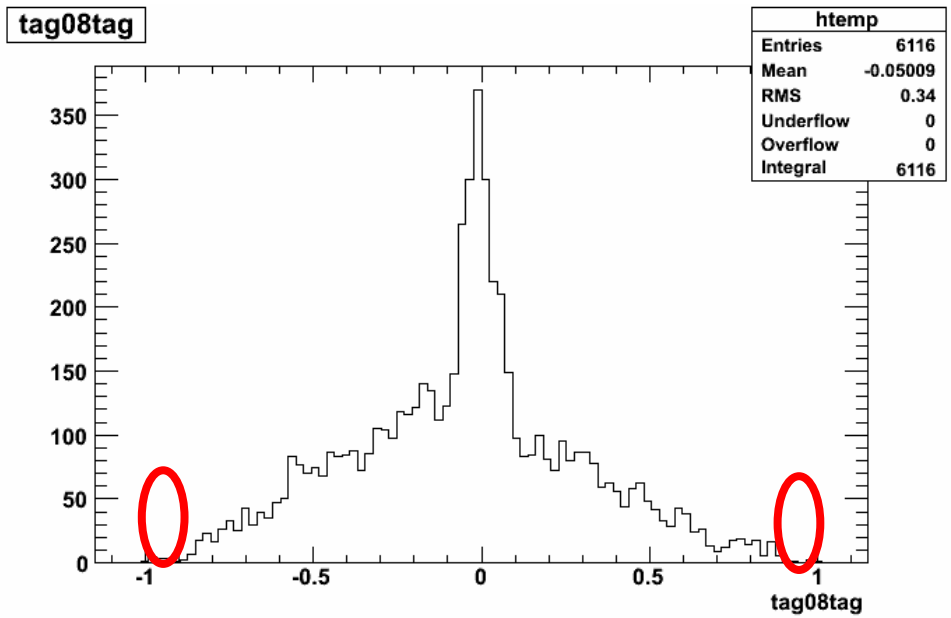


- Δt looks OK.

BaBar Configuration: Tagging

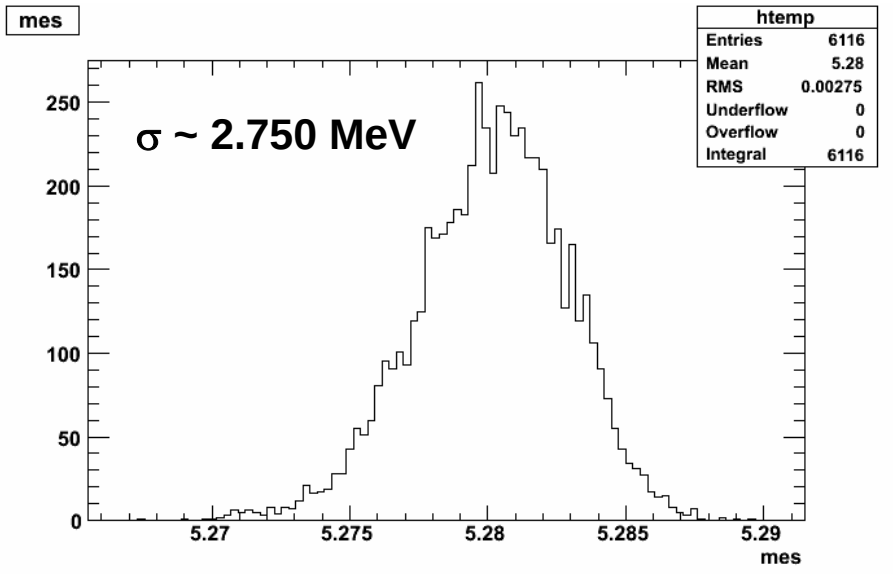


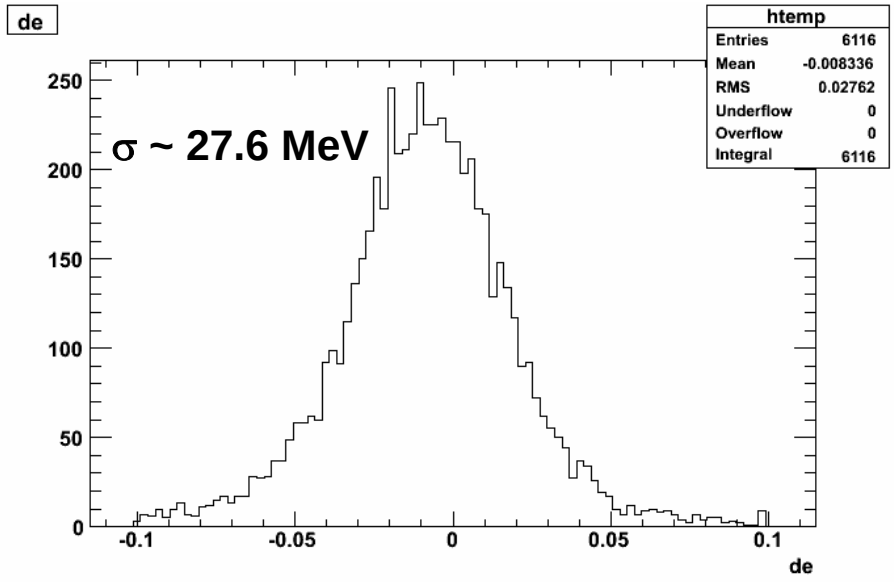
- No lepton tagged events.
  - Haven't had time to look into this in more detail.
  - Consistent with the flavour tag distribution (peaks missing at +/–1 that would correspond to Lepton events.

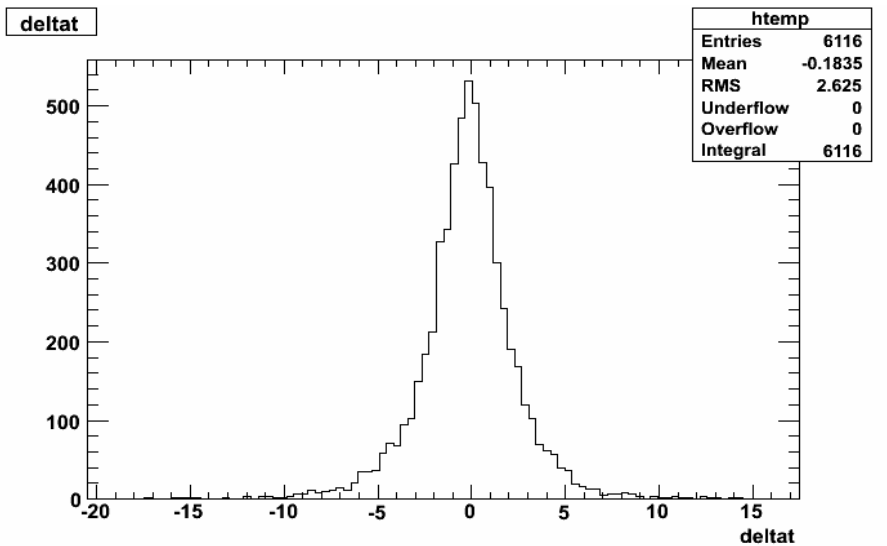


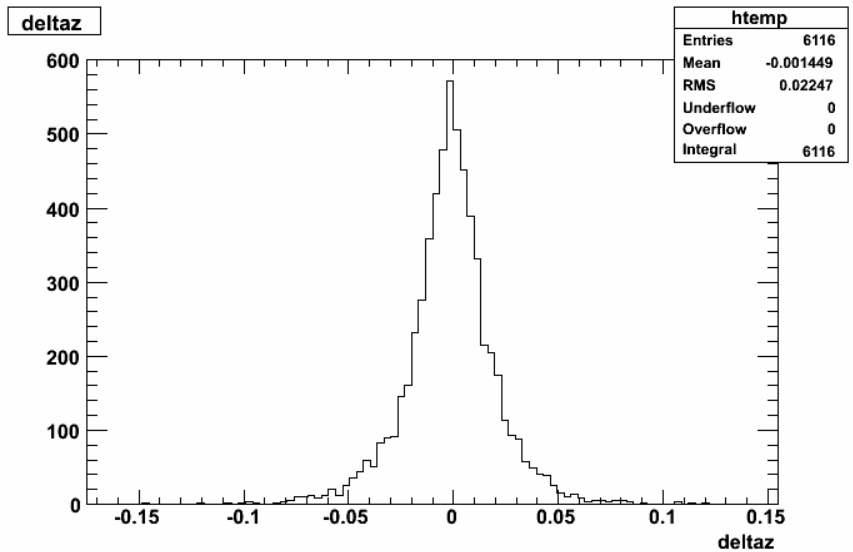
- PID selectors are not implemented in the FastSim, so the tagging algorithm does something illdefined.

Validation: SuperB Configuration

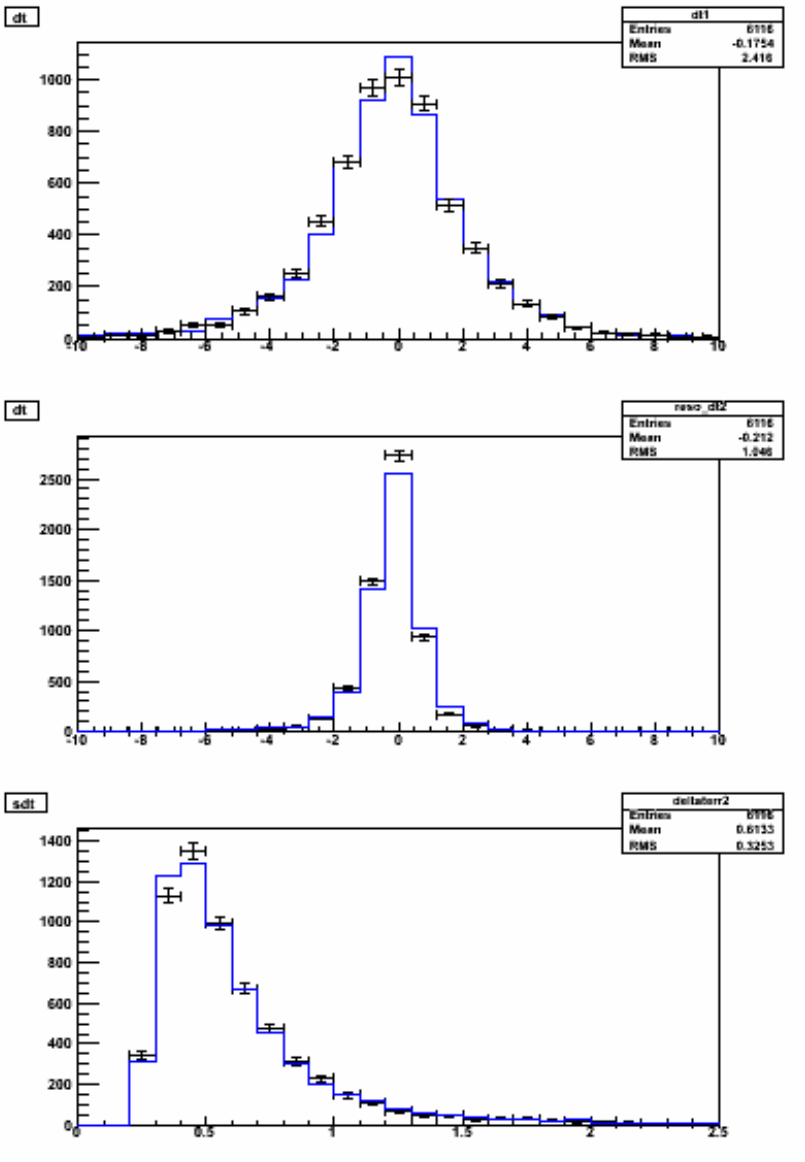








Δt Resolution Function



- Comparison of
  - Δt (top)
  - Δt resolution (middle)
  - σ(Δt) (bottom)

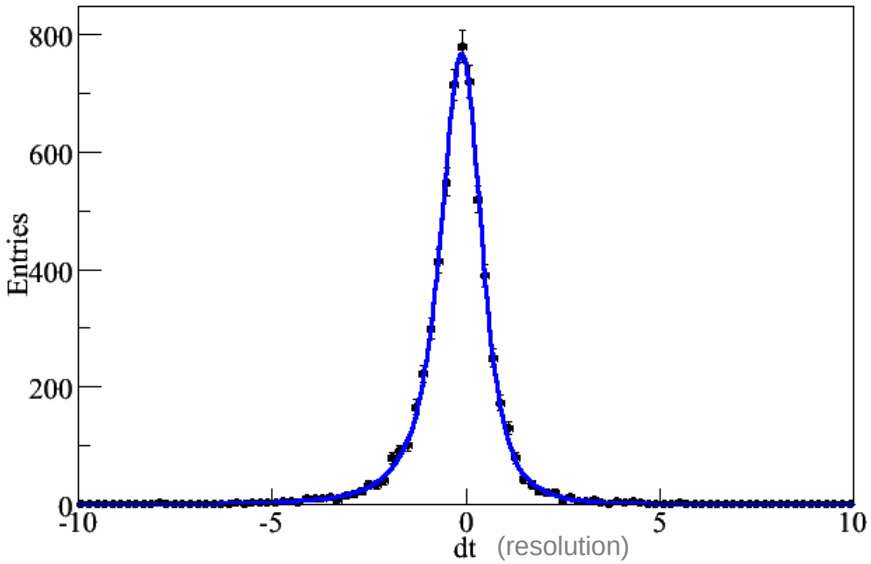
  for BaBar (points) and SuperB (histogram).
- Resolution slightly better for BaBar configuration.
- Similar efficiencies for both configurations.
  - ~61% without PID.
  - c.f. 54% for BaBar.

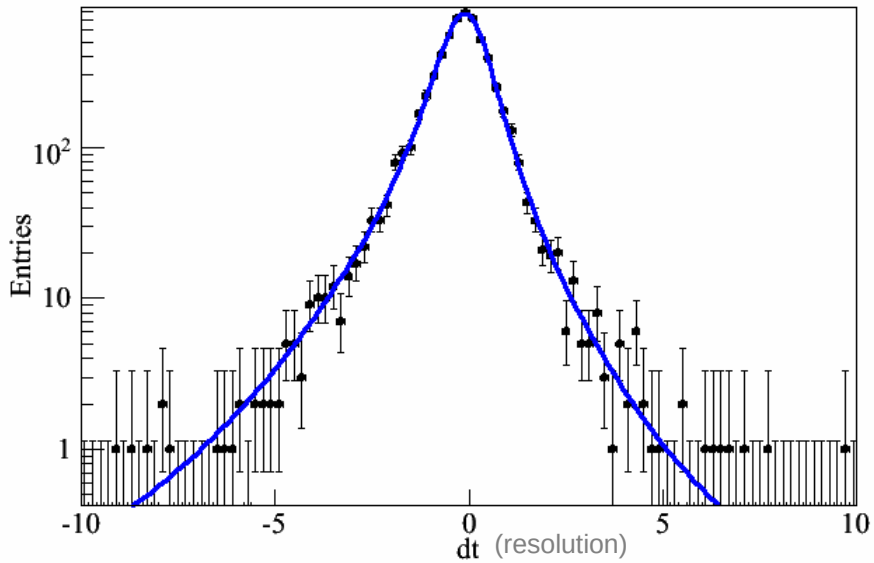
Δt Resolution Function: BaBar

- Do a simple comparison:

$$\mathcal{R}(\Delta t, \sigma_{\Delta t}) = f_{CORE} G_{CORE}(\Delta t, \sigma_{\Delta t}) + f_{TAIL} G_{TAIL}(\Delta t, \sigma_{\Delta t}) + (1 - f_{CORE} - f_{TAIL}) G_{OUTLIER}(\Delta t)$$

i.e. same as BaBar's TDCPV $\mathcal{R}$.





$$\mu_{CORE} = -0.27 \pm 0.02 \qquad \mu_{TAIL} = -1.00 \pm 0.15 \qquad \mu_{OUT} = 0.0 \text{ (fixed)}$$

$$\sigma_{CORE} = 1.14 \pm 0.03 \qquad \sigma_{TAIL} = 2.9 \pm 0.2 \qquad \sigma_{OUT} = 8.0 \text{ (fixed)}$$

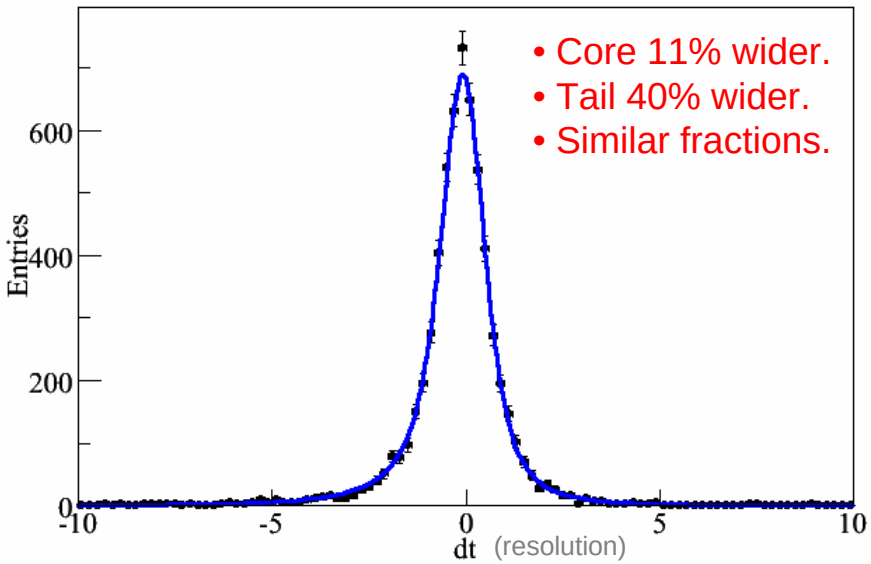
$$f_{CORE} = 0.86 \pm 0.02 \qquad f_{TAIL} = 0.14 \pm 0.02 \qquad f_{OUT} = 0.003$$

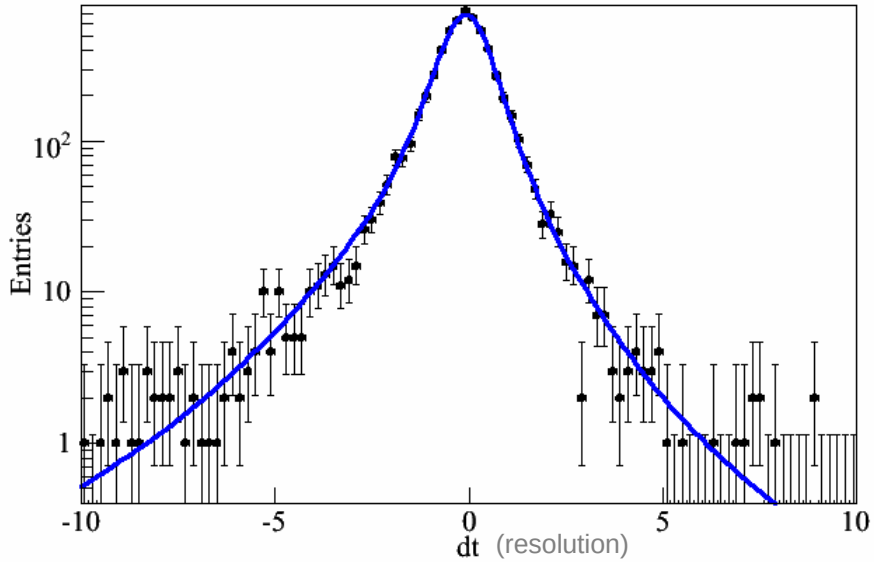
Δt Resolution Function: SuperB

- Do a simple comparison:

$$\mathcal{R}(\Delta t,\sigma_{\Delta t}) = f_{CORE}G_{CORE}(\Delta t,\sigma_{\Delta t}) + f_{TAIL}G_{TAIL}(\Delta t,\sigma_{\Delta t}) + (1 - f_{CORE} - f_{TAIL})G_{OUTLIER}(\Delta t)$$

i.e. same as BaBar's TDCPV $\mathcal{R}$.





$\mu_{CORE} = -0.20 \pm 0.02$ $\quad \mu_{TAIL} = -1.4 \pm 0.3$ $\quad \mu_{OUT} = 0.0$ (fixed)

$\sigma_{CORE} = 1.27 \pm 0.05$ $\quad \sigma_{TAIL} = 4.0 \pm 0.5$ $\quad \sigma_{OUT} = 8.0$ (fixed)

$f_{CORE} = 0.87 \pm 0.03$ $\quad f_{TAIL} = 0.13 \pm 0.03$ $\quad f_{OUT} = 0.002$

Summary

- Signal efficiencies are similar for both configurations.
- M_{ES} and ΔE distributions are reconstructed as expected.
  - SuperB's performance is essentially the same as BaBar's.
- Δt resolution is slightly wider for the baseline detector configuration.
- $\mathcal{R}(\Delta t, \sigma_{\Delta t})$ still does a reasonable job of modelling the resolution.
- PID selectors are not implemented [next step]
  - Flavour tagging not possible without PID selectors
  - Similarly can't check CP observables:
  - $A(\Delta t)$, Q_i and ω_i errors and S and C etc.

Future Goals

- Intend to fit for CP parameters when possible
  - Compare detector resolution on Δt and errors on S and C for different configurations.
- Expand the channels studied
  - $\pi^+\pi^-$ has all tracks coming from primary vertex
  - $J/\psi K_s$ is another new physics reference point
    - But also needed to validate $K^0_s\pi^0(\gamma)$ vertexing technique
  - $\tau^+ \rightarrow \mu^+\gamma$ as a LFV reference point (Hermiticity).
- Perform low-level and high level distribution comparisons between BaBar and the current SuperB configurations as design evolves.