Tracking efficiency study

Pisa, 12 October 2018

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Outline

- Brief reminder about measurement strategy
- Selected Sample
- Preliminary Results
- Summary

Reminder: measurement overview

Strategy: exploit charge conservation and kinematic constrains on simple (= with a well recognizable topology) τ-pairs events to deduce the existence of a track.

Reference: "*Track finding efficiency in BaBar*" https://arxiv.org/abs/1207.2849

BaBar strategy was based on *Tau31 events selection:*

- Tracking efficiency, including the detector acceptance, is computed as:
  - $\varepsilon x A = N4/(N3+N4)$
    - N4 = Tau31 events where the 4th track has been found
    - N3 = Tau31 as reconstructed in the 1+2 selection (further details in the next slide) where the 4th is not found.
- MC-data difference in tracking efficiency is then given by:
  - $\Delta = 1 - \varepsilon_{MC}/\varepsilon_{data}$
    - With ε the tracking efficiency evaluated respectively on MC/data, including the detector acceptance A.

Tau31 events & BaBar strategy

→ Tau decay length @10.58 GeV ~ 200 um (measurable but not impacting the tracking efficiency)

→ One tau is required to decay leptonically (17.36%), the other semi-leptonically to a 3-prong final state (14.56%) → ***5% of total events*** exploited for the study, so-called *Tau31 events*

$$\tau^{\pm} \rightarrow \mu^{\pm}\nu_{\mu}\nu_{\tau},$$
$$\tau^{\pm} \rightarrow h^{\mp}h^{\mp}h^{\pm}\nu_{\tau}$$

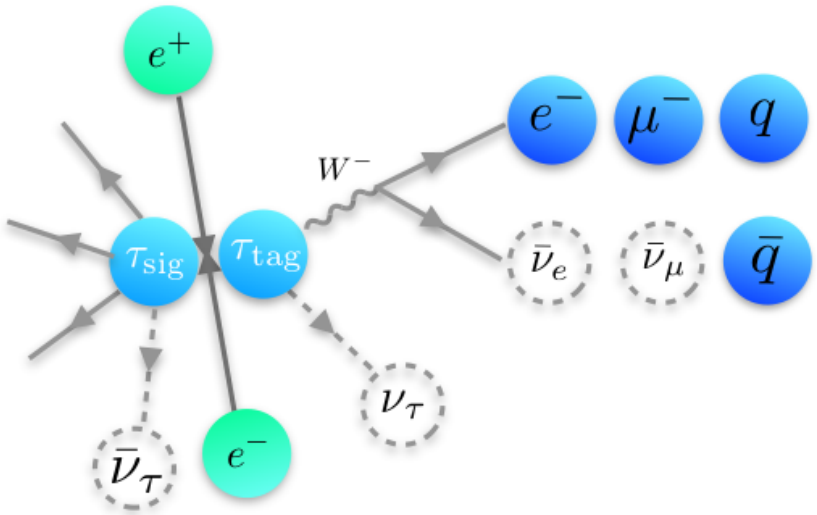
- *Reconstruction requirements:*
  - *one isolated muon track (suppress non-tau backgrounds)*
  - *2 charged hadronic tracks (2 categories: "same/opposite sign")*
    - *Track quality selection (max 5 charged tracks, of which at least 3 "good" tracks)*
    - *pt >100 MeV*
    - *K_S veto, PID, angular (θ,φ) isolation requirements are applied.*

- *Background rejection:*
  - reject events with energy deposit from neutral particles $>$ 0.5 GeV within 90° from muon track
  - $0.2*E^{CM}/2 <$ Muon pt $< 0.8*E^{CM}/2$: suppress di-muon, BhaBha radiative decays.

Charge conservation implies the fourth track.

The Sample: 2vs1

- DISCLAIMER: results presented here are studied on the sample 2vs1 + (at maximum) 1 ROETrack, where the *Thrust Axis* is built from all the tracks in the event → *need to release this reconstruction by applying only angular isolation on the tag side track (mimic the BaBar measurement)*
- $e^+e^- \to \tau\bar{\tau}$ events in collision data (prod5): ***Exp3, prod5, release-02-00-01/GT425*** and in signal MC (1M tau pair events)+ pseudo BG included (real machine BG). Physics BG still to be included.
- RECONSTRUCTION ("good tracks"):
  - Pt $>$ 0.1 GeV
  - -0.8660 $<$ cosTheta $<$ 0.9535
  - abs(dz) $<$ 5.0 cm
  - abs(dr) $<$ 1.0 cm
  - At maximum 1 ROETrack

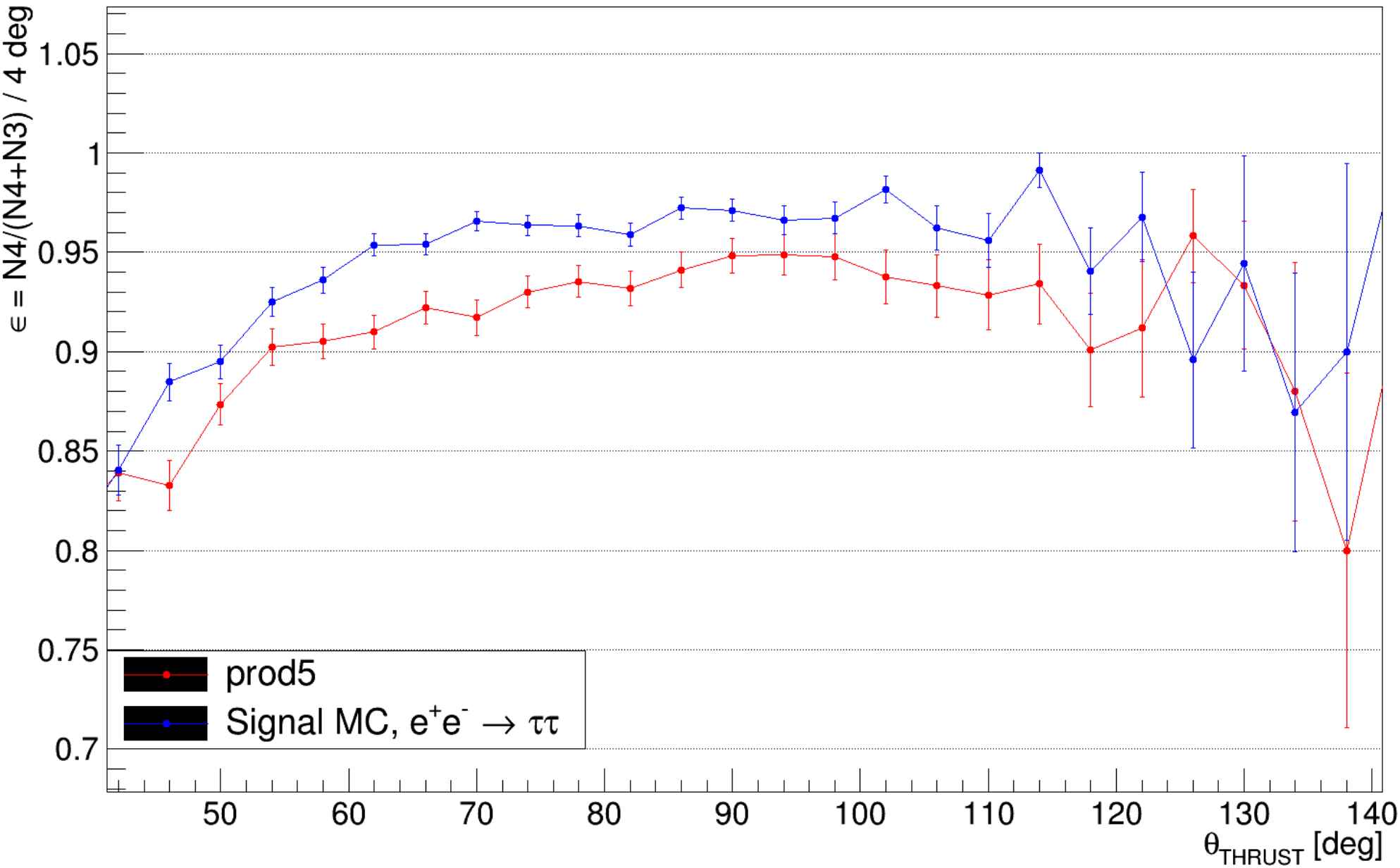


→ *reconstruct Thrust axis, which divides the event into two hemispheres (according to CosToEventThrust sign) :* ***Signal side (total null charge, two opposite pions) and Tag side (one muon)***

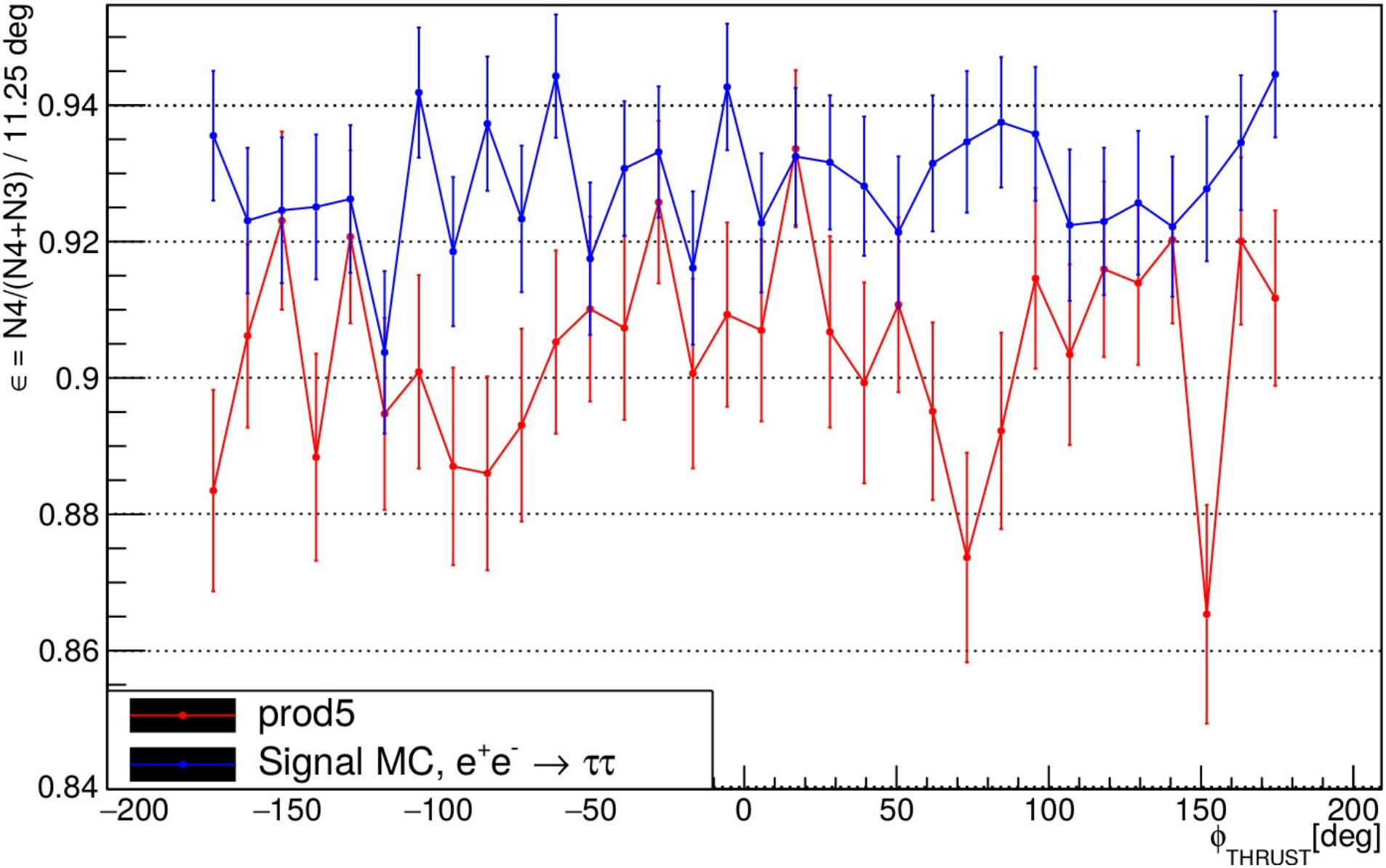
The Sample: applied selection

- Further Selection requirements (taken from the Belle II note for the tau mass rediscovery, still to be optimized for this study):
  - ThrustValue > 0.87
  - VisibleEnergyCMS $<$9.7 GeV
  - tau_{sig} energy$<$5.29 GeV
  - tau_{tag} energy$<$5.22 GeV
- Muon selection (tag side):
  - vpho_tau_mu_clusterE $>$0. (matched cluster) && vpho_tau_mu_clusterE$<$ 0.4
  - vpho_tau_mu_EoverP $<$ 0.25 (mainly to reject electrons)
- Signal side prong selection:
  - vpho_tau_pi0_EoverP $<$ 0.8 && vpho_tau_pi0_EoverP$>$0.2
  - vpho_tau_pi1_EoverP $<$ 0.8 && vpho_tau_pi1_EoverP$>$0.2

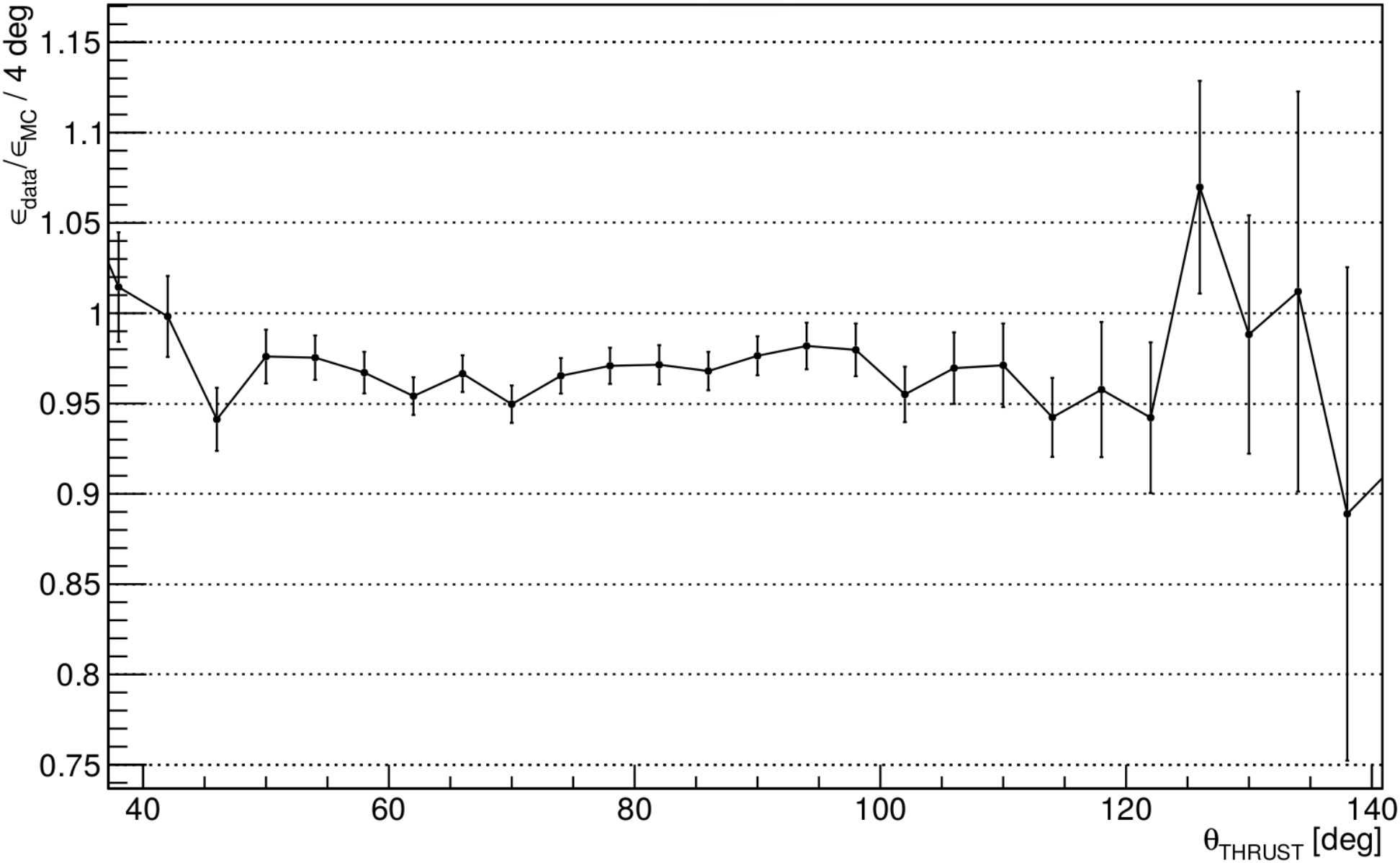
Efficiency Vs. θ_{THRUST}



Efficiency Vs. φ_{THRUST}



Efficiency Ratio (Data/MC) Vs. θ_{THRUST}



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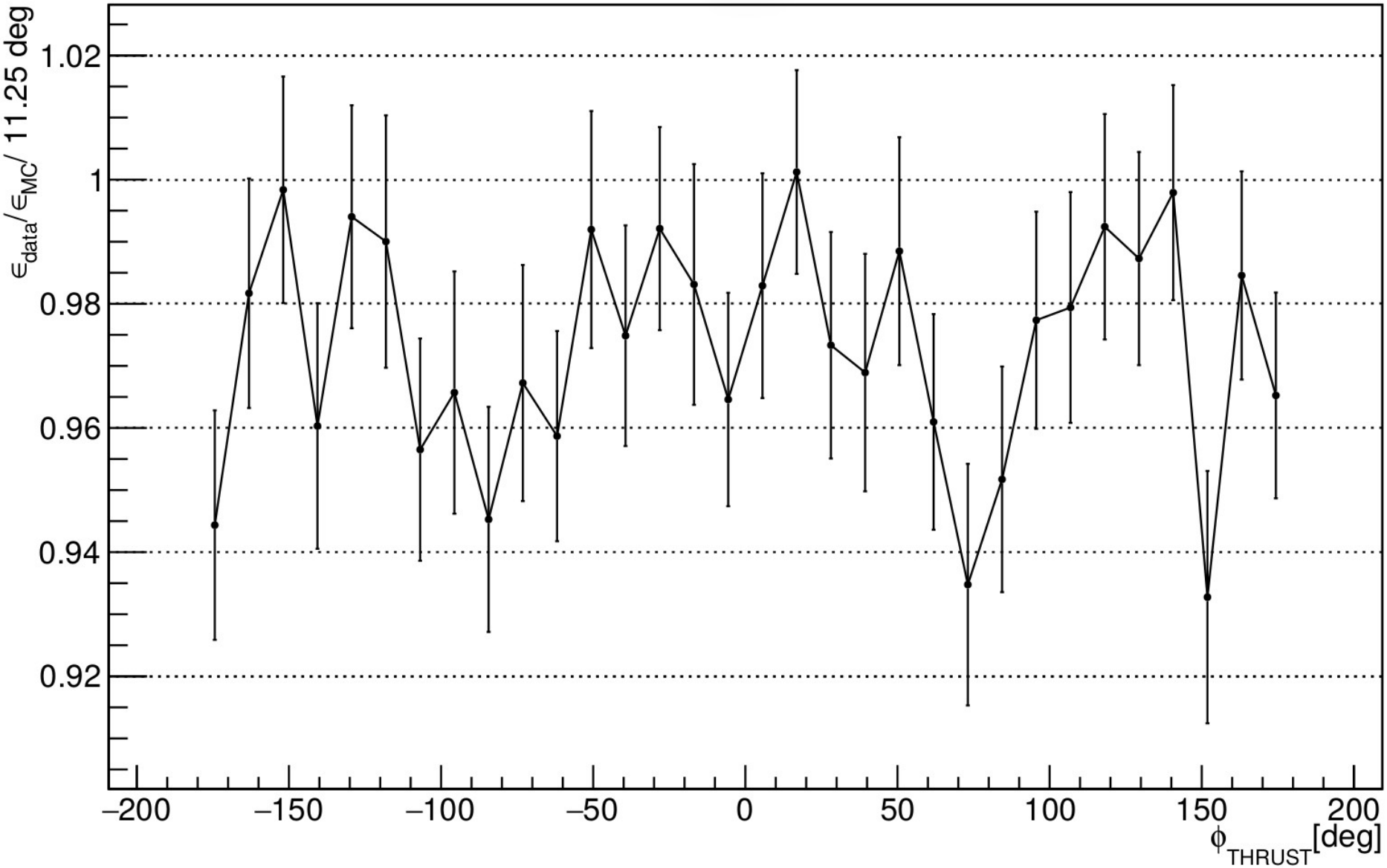

Summary

→ A very preliminary estimate of the Data-MC tracking efficiency discrepancy integrated in phi is around 3%

To do:

→ Run on background MC samples (add *continuum*)

→ Mimic *verbatim* BaBar measurement: do not rely on Thrust Axis for event selection

Backup

Systematics uncertainties @BaBar

- Compute:
  - $\varepsilon \times A = N4/(N3+N4)$
  - $\Delta = 1 - \varepsilon_{MC}/\varepsilon_{data}$
  - $a_{\pm} = (\varepsilon_{+}-\varepsilon_{-})/(\varepsilon_{+}+\varepsilon_{-})$, charge asymmetry in tracking efficiency
- BIASING backgrounds:
  - *2 primary tracks events + photon conversion*
  - $q\bar{q}$ *and tau pairs events with 6 tracks*
  - $K_S \to \pi\pi$ *events with displaced vertex (limited by the applied veto)*

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Mis-modeling of background contamination (fake rate)+ unaccounted background sources in the simulation may systematically affect the calculated efficiency

... εxA' evaluated on control samples enriched in photon conversion events

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The difference εxA – εxA' is assumed as systematic uncertainty and propagated on Δ

Other sources of systematic uncertainties on Δ

- Track multiplicity and displaced vertexes

- Fake rate

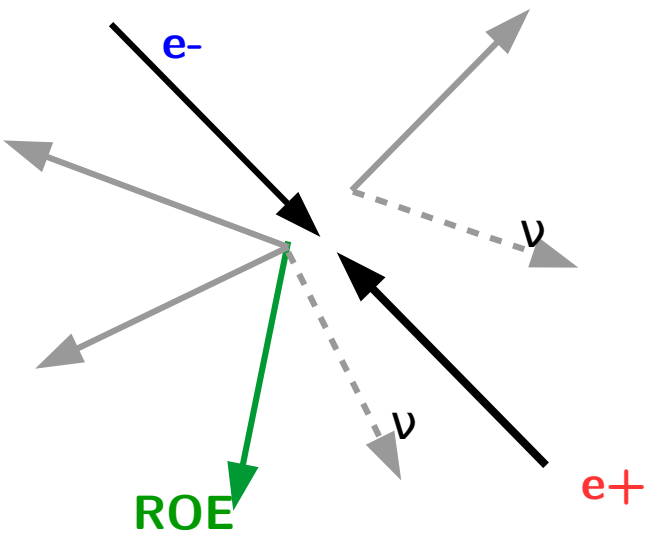
- Efficiency dependence on the track kinematics

- Evaluate εxA' without subtracting qq , K_S background
  → take the difference as uncertainty

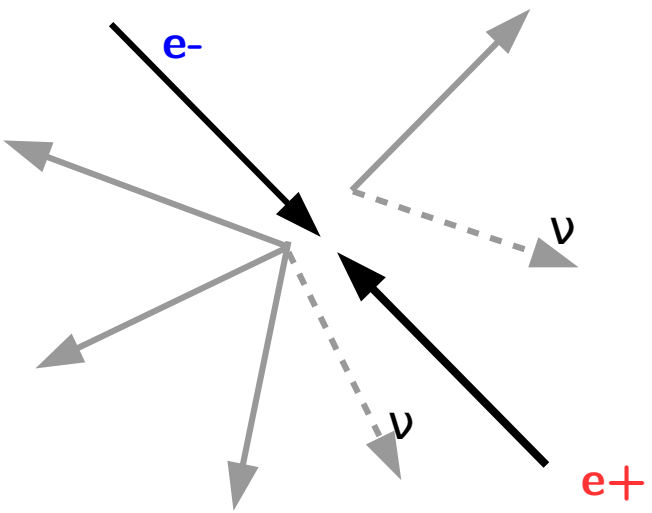
- Compute εxA' = N4/(N3+N4+N5), N5 = 4th and 5th track candidates found
  → take the difference as uncertainty

- Measure Δ, $a_{\pm}$ as a function of cosθ, pt of the 4th track → not possibile to directly determined them due to neutrinos in the event → use as estimators:
  - $\cos\theta^{Miss} = \cos(\theta_{\pi1\pi2})$
  - $Pt^{Miss} = \mathrm{sqrt}((E^{CM}/2 - E_{\pi1} - E_{\pi2})^2 - m_{\pi}^2) \times \cos\theta^{Miss}$

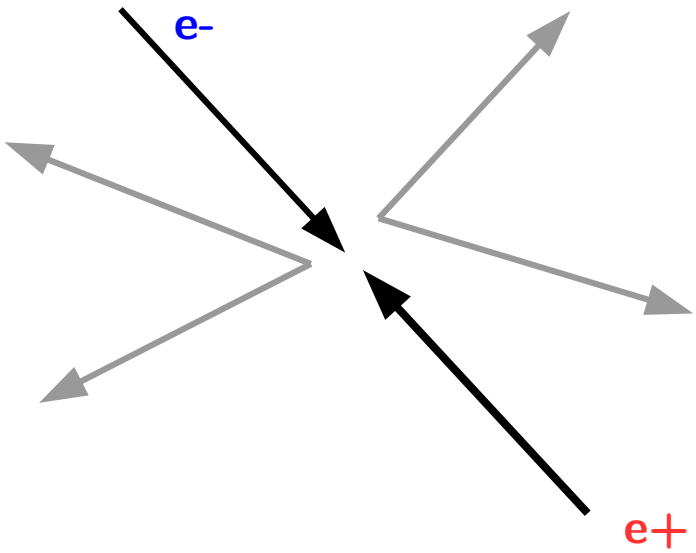
Reconstructed topologies



2vs1



3vs1



2vs2

Sanity check: overlay check between different topology