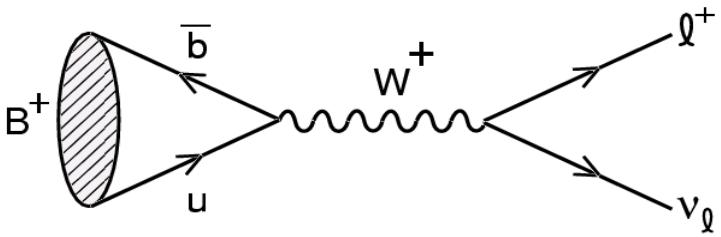
B tag studies for $B \to \tau\nu$ and $B \to K^{*}\nu\nu$

Mario Merola, Elisa Manoni, Guglielmo De Nardo

Belle II italian meeting, 21/12/15

Outline:

- $B \to \tau\nu$ decay
- Full Event Interpretation
- Selection and comparison plots
- Summary



B leptonic decays

- Helicity suppressed: $BR_{SM}\left(B \to \ell\, \nu\right) = \frac{G_F^2 m_B \tau_B}{8\pi} f_B^2 |V_{ub}|^2 m_\ell^2 \left[1 - \frac{m_\ell^2}{m_B^2}\right]^2$

τ:μ:e
1: 5×10^{-3}:10^{-7}

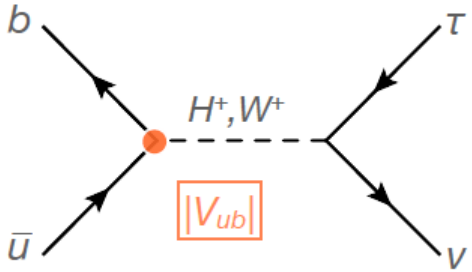
- The SM predicts a branching ratio of

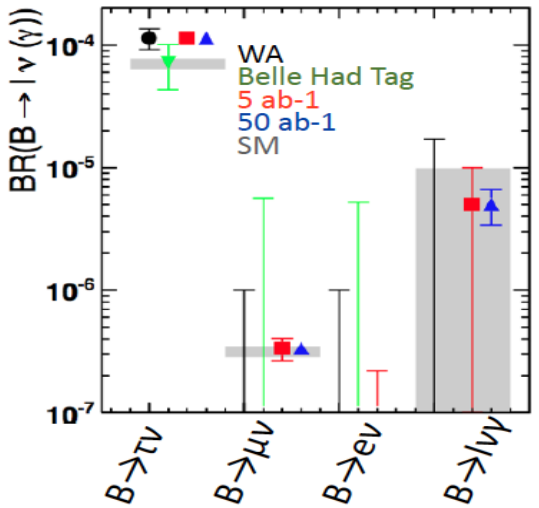
$$\mathcal{B}(B^+ \to \tau^+ \nu_\tau) = (0.75^{+0.10}_{-0.05}) \times 10^{-4}$$

- Higgs doublet models predict interference with SM decay with a modification of the branching ratio

$$B = B_{SM} \times \left(1 - m_B^2 \frac{\tan^2\beta}{m_{H^\pm}^2}\right)$$

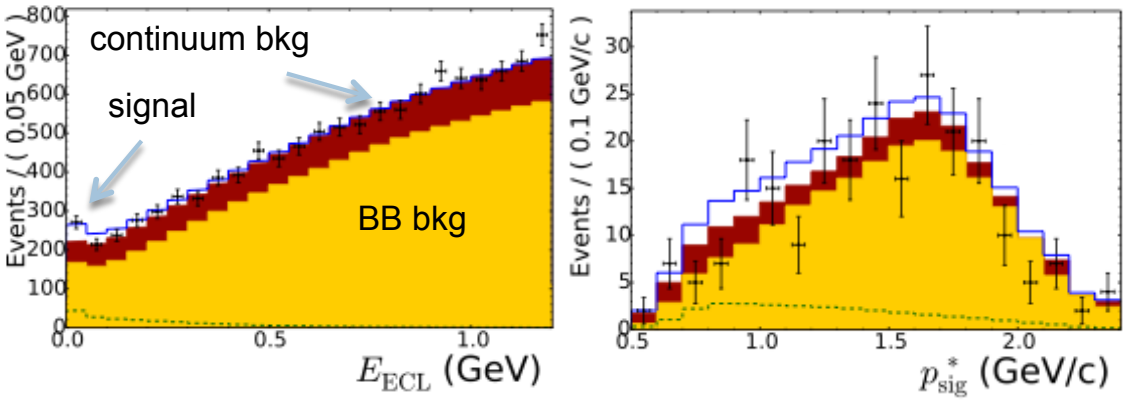
ratio of the two Higgs vacuum expectation values





Recent results on $B \to \tau\nu$

- First evidence at Belle (2006) and Babar (2012)
- Most recent measurement (Belle - 2015):
  - use of multivariate techniques (neural network) to reconstruct the tag side
  - the signal side is reconstructed in four modes: $\tau \to \mu\nu\nu, e\nu\nu, \pi\nu, \rho\nu$
  - the signal is extracted through a two-dimensional maximum likelihood fit to the E_{ECL} and p^*_{sig} distributions



- E_{ECL} is the sum of the energies of clusters in the ECL not associated to reconstructed B mesons
- p^*_{sig} is the momentum of the signal side particle in the CM

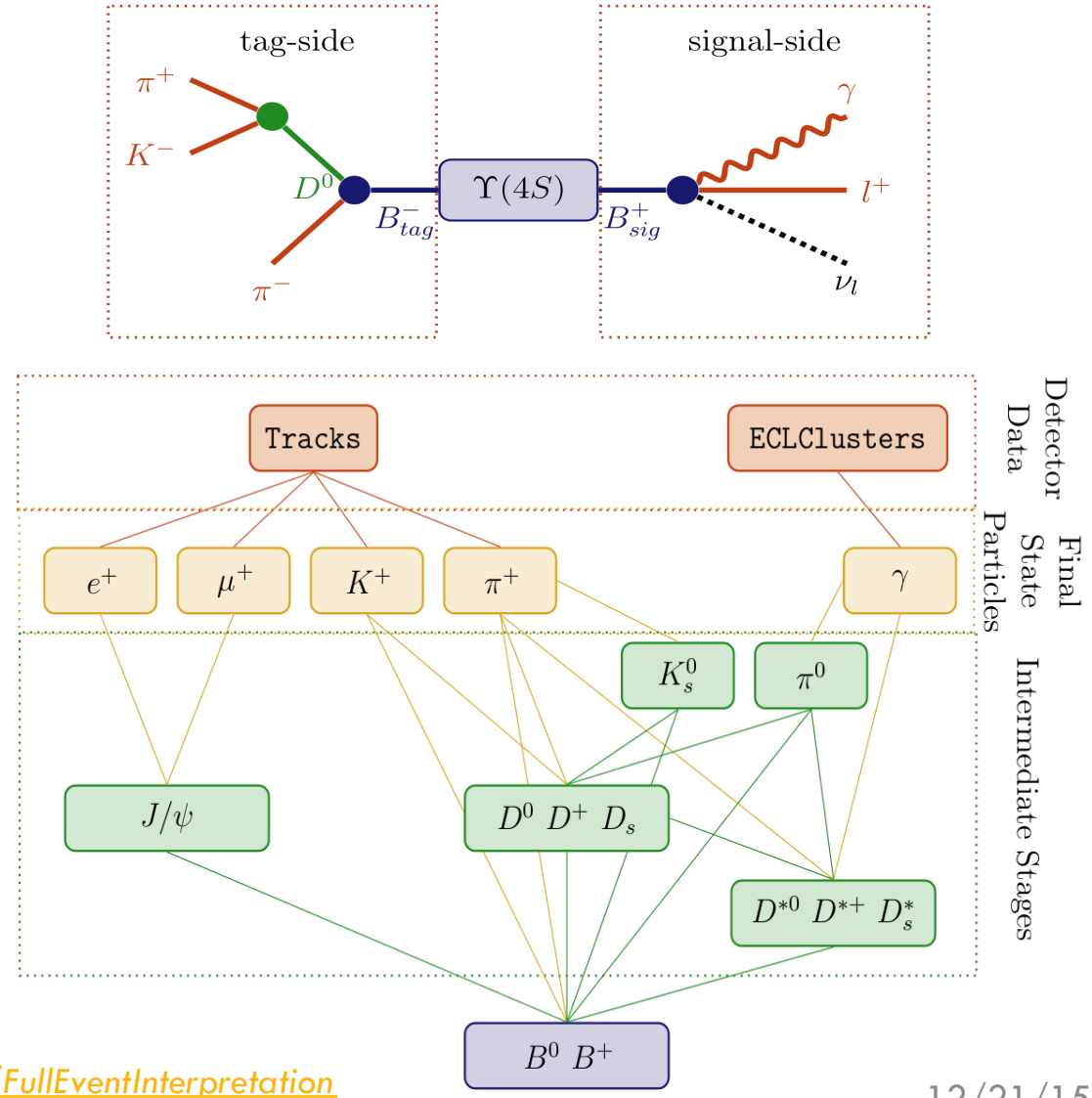
$$\mathcal{B} = [0.91 \pm 0.19(\text{stat.}) \pm 0.11(\text{syst.})] \times 10^{-4}$$ (evidence at ~4.6 σ level)

http://arxiv.org/abs/1503.05613v2

Full Event Interpretation (FEI)

- Developed by Thomas Keck*, it's an extension of the Full Reconstruction used in Belle, and uses a multivariate technique to reconstruct the B-tag side through lots of decay modes in an Y(4S) decay.

- Hierarchical approach: first train multivariate classifiers (MVC) on FSP, then reconstruct intermediate particles and build new dedicated MVC. For each candidate a "signal probability" is defined, which represents the "goodness" of its reconstruction.



*https://belle2.cc.kek.jp/~twiki/bin/view/Physics/FullEventInterpretation

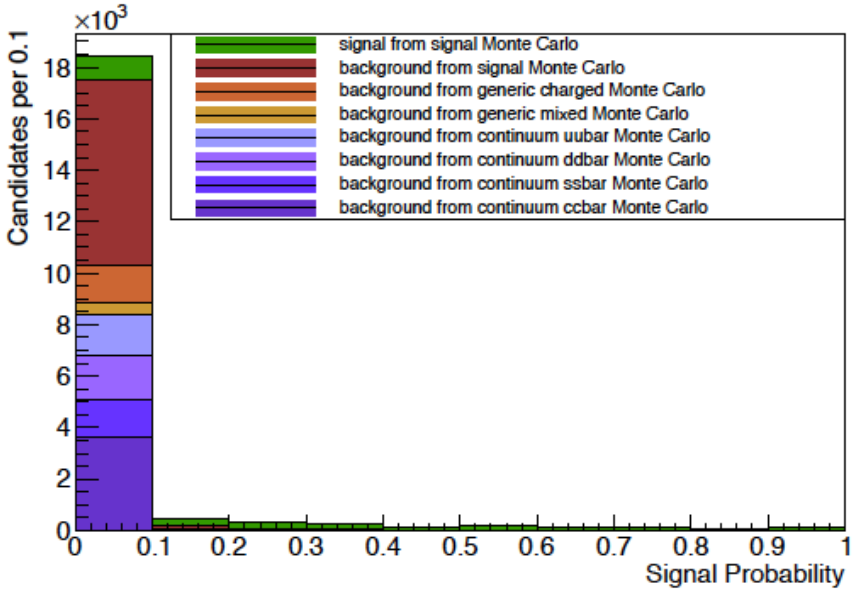
Full Event Interpretation (FEI)

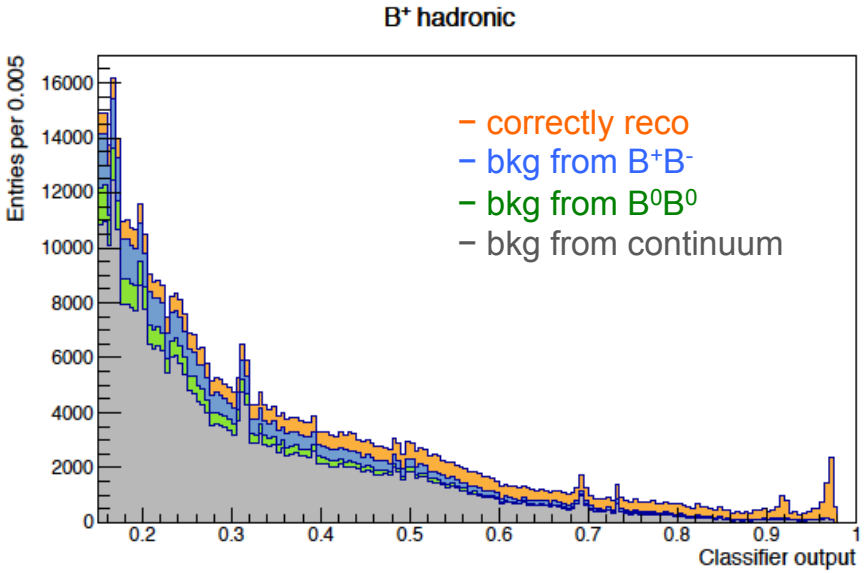
- Input variables used to train the multivariate classifiers:
  - PID, tracks momenta, impact parameters (charged FS particles);
  - cluster info, energy and direction (photons);
  - invariant mass, angle between photons, energy and direction (π^0);
  - released energy, invariant mass, daughter momenta and vertex quality ($D^{(*)}_{(s)}$, J/ψ);
  - the same as previous step plus vertex position, ΔE (B);
  - additionally, for each particle the classifier output of the daughters are also used as discriminating variables.

- Generic training performed on $87*10^6$ B^+B^-/B^0B^0 without beam bkg ~ 80/fb

- The result – analysis independent – is centralized so that all the analyzers can use the same training.

Full Event Interpretation (FEI) performances





from Christian Pulvermacher PhD thesis

Total reconstruction efficiency compared with Belle I

Belle II

B^+ (hadronic)	0.78 %	B^+ (semileptonic)	1.05 %
B^0 (hadronic)	0.59 %	B^0 (semileptonic)	1.17 %

Belle I

B^+ (hadronic)	0.39 %	B^+ (semileptonic)	0.80 %
B^0 (hadronic)	0.28 %	B^0 (semileptonic)	0.86 %

Event pre-selection

B tag side

$$B^+ \to D^{(*)0}, D_s^{(*)0}, D^+, J/\psi\ X$$

Hadronic tag using FEI with tens of decay modes*

- $M_{bc} > 5.22$ GeV
- $|\Delta E| < 200$ MeV
- signal Prob > 0.05
- Highest prob. B candidate

B signal side

$$B^+ \to K^{*+} \nu\nu \qquad B^+ \to \tau^+ \nu$$

K^{*+} → $K^+\pi^0$, $K_s\pi^+$ (with $K_s \to \pi^+\pi^-$)

τ^+ → $\mu^+\nu\nu$

- $E(\gamma) > 50$ MeV
- $110 < M(\pi^0) < 150$ MeV
- $400 < M(K_s) < 600$ MeV

* https://belle2.cc.kek.jp/~twiki/bin/viewauth/Physics/GenericFEIResults

MC signal and background samples

MC5 production

- *~11*10⁶ events of generic B^+/B^- with beam background*
- ~50*10⁶ events of signal MC ($B \to \tau\nu \to \mu\nu\nu\nu$)
- ~43*10⁶ events of generic B^+/B^- without beam background
- *~10⁶ events of signal MC ($B \to K^*\nu\nu$)*

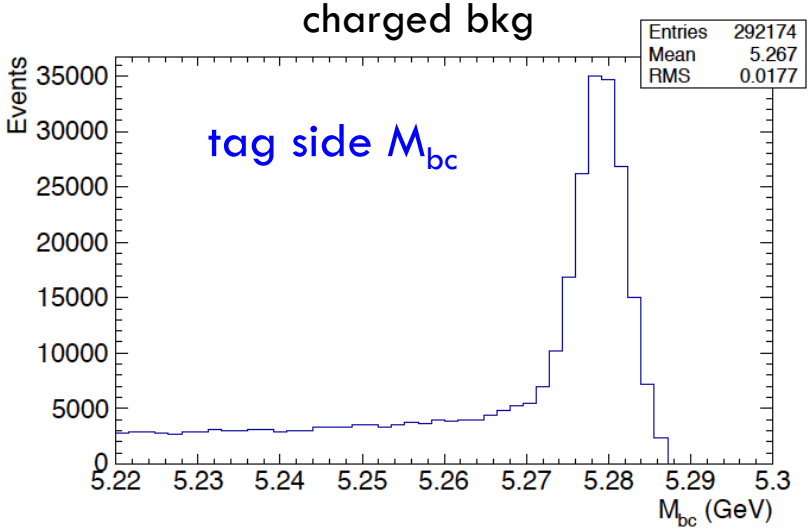
} Elisa

https://belle2.cc.kek.jp/~twiki/bin/viewauth/Computing/MC5Release4PhysicsGenericContinuum

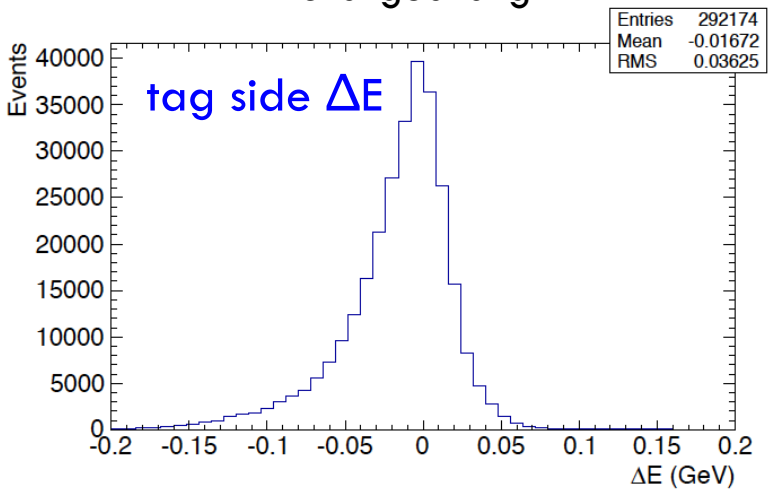
https://belle2.cc.kek.jp/~twiki/bin/view/Computing/MC5Release4PhysicsSignal

Signal vs B^+/B^- background

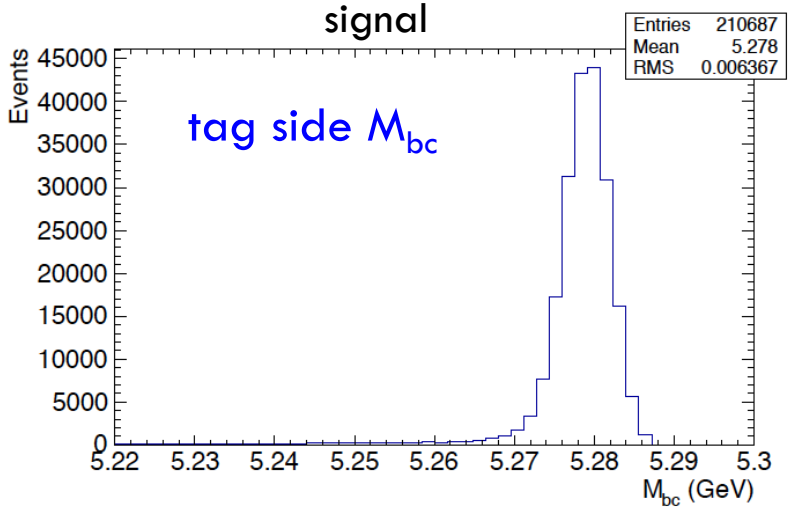
charged bkg



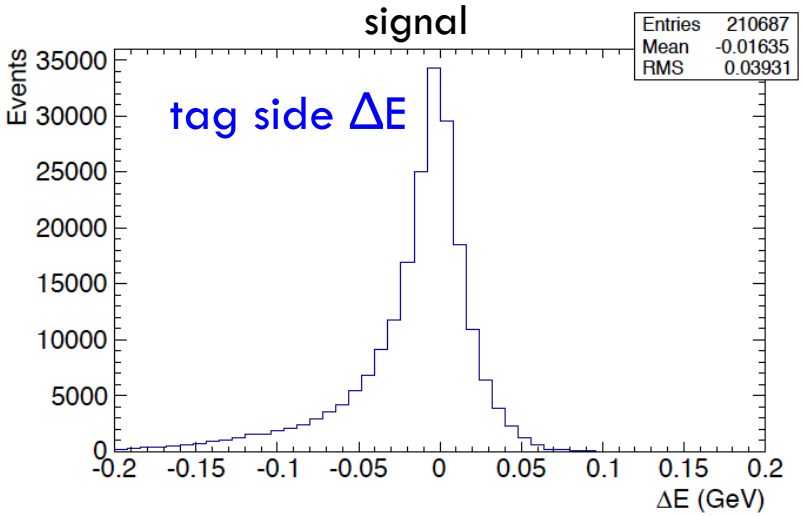
charged bkg



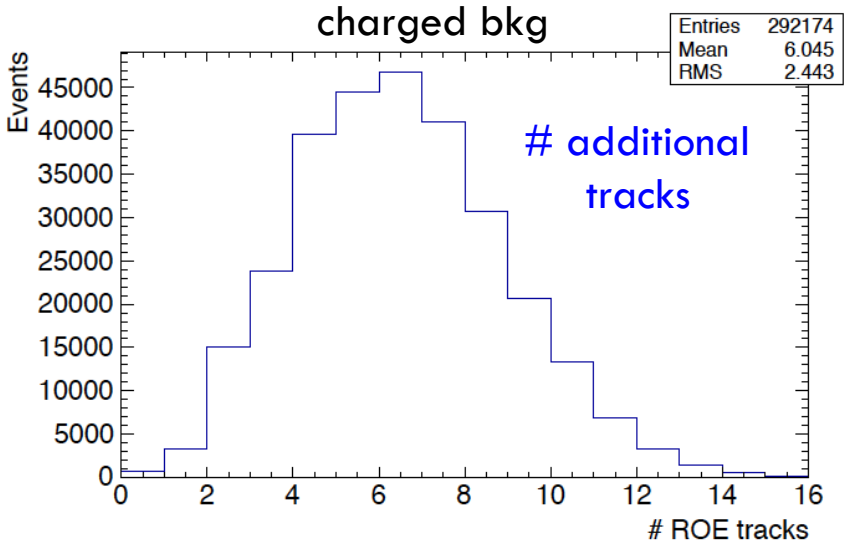
signal

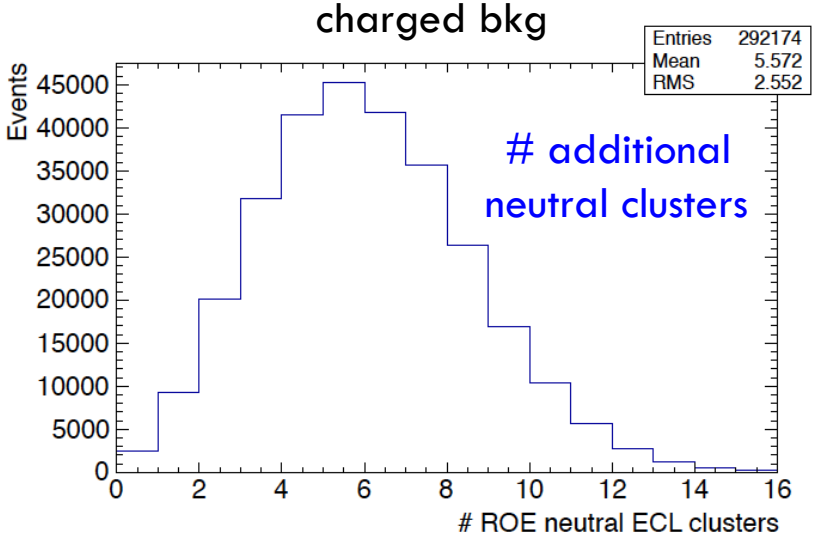


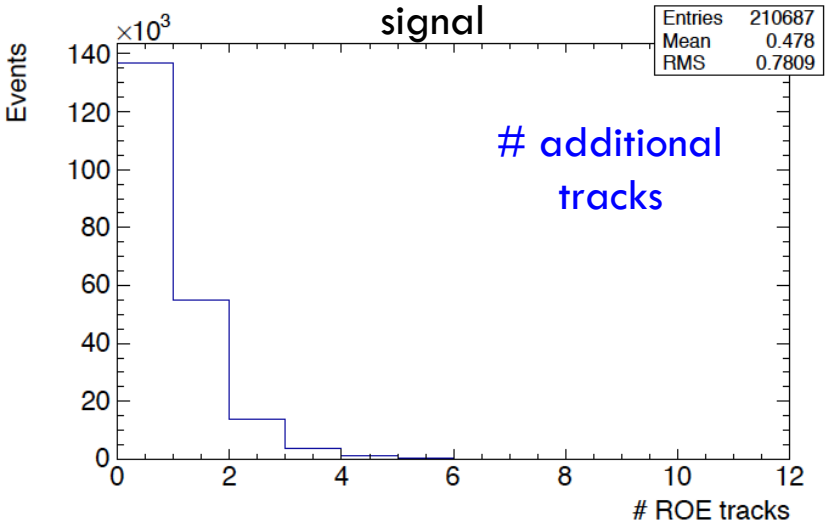
signal

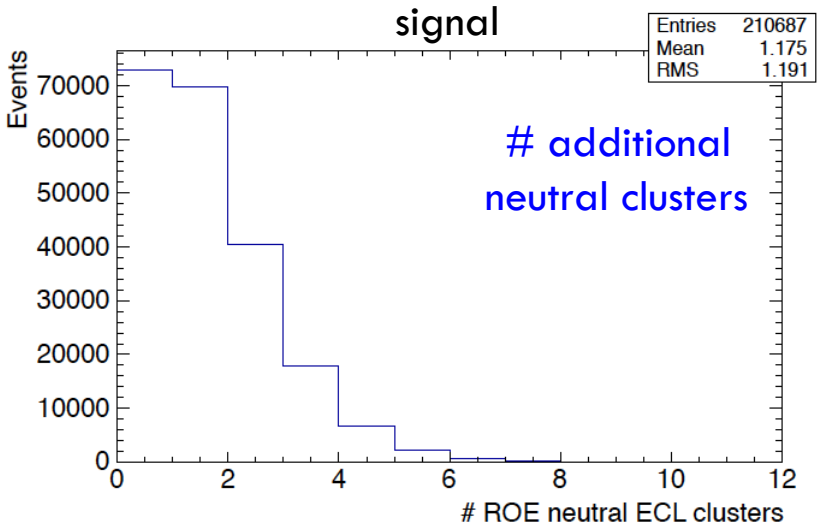


Signal vs B^+/B^- background

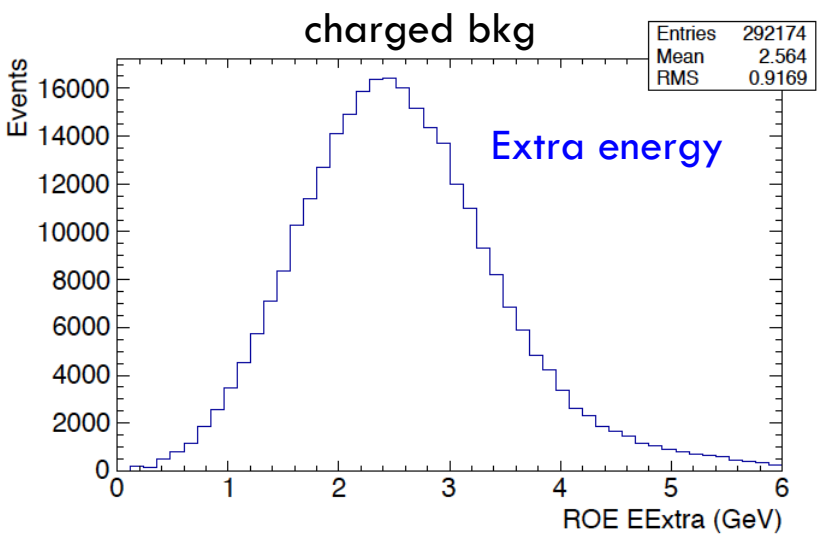


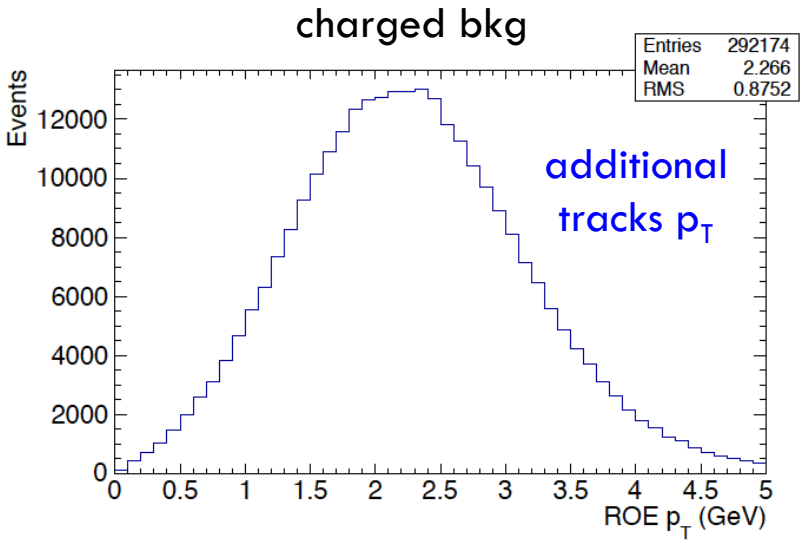


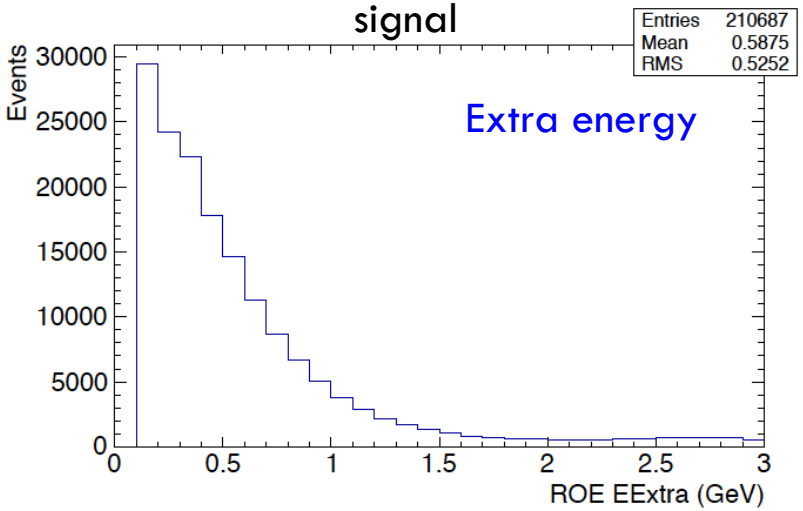


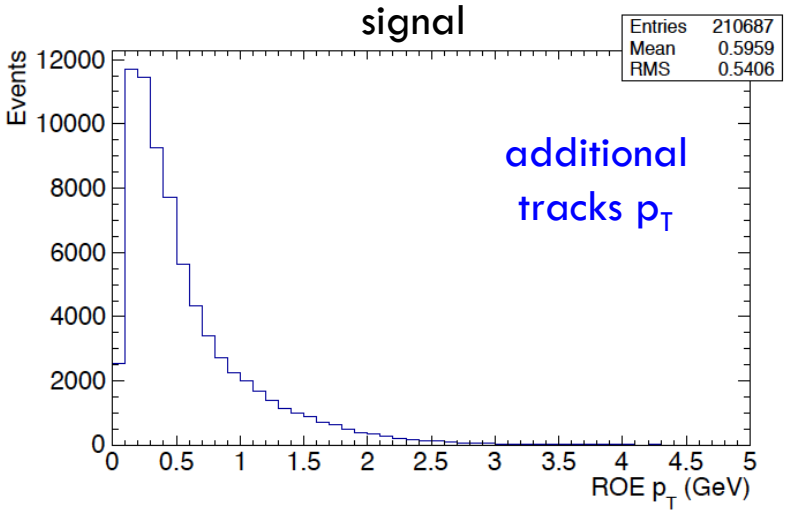


Signal vs B^+/B^- background



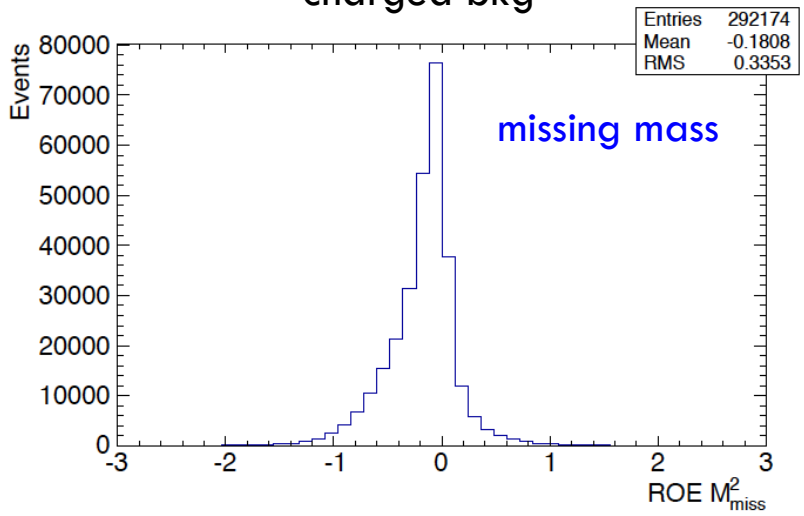




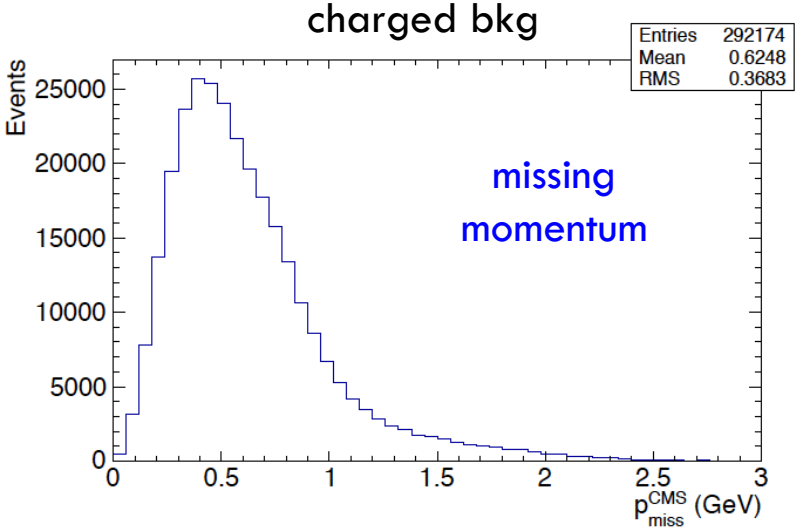


Signal vs B^+/B^- background

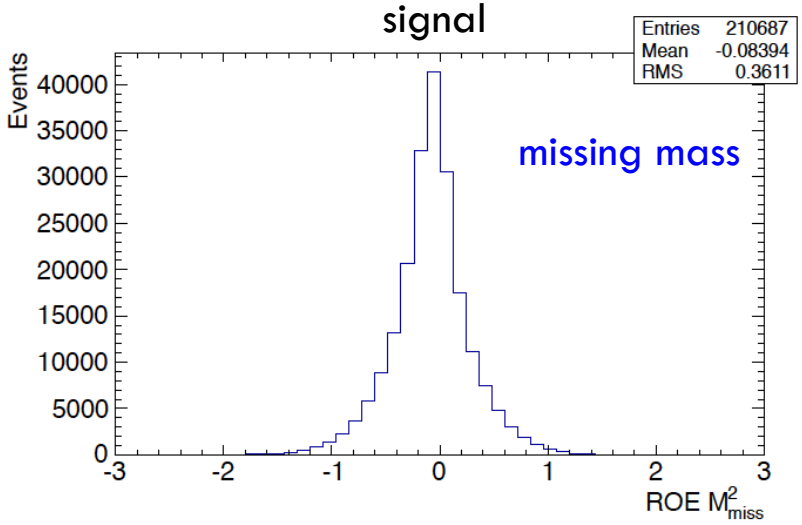
charged bkg



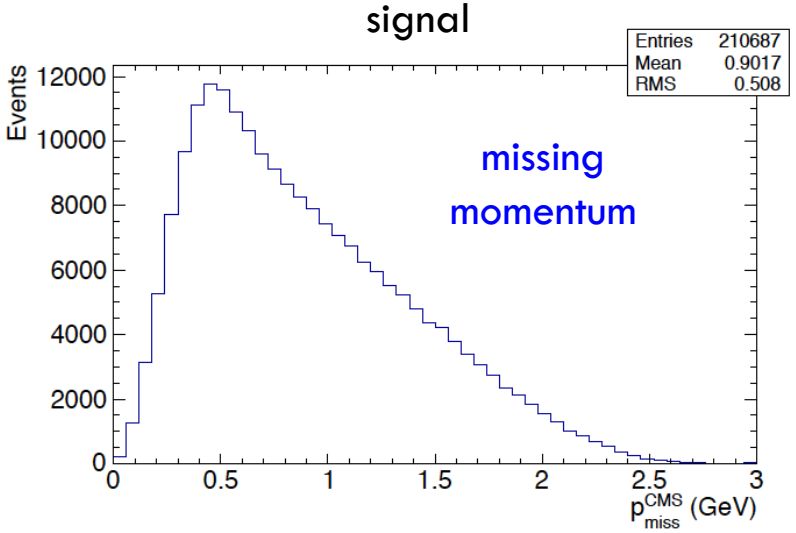
charged bkg



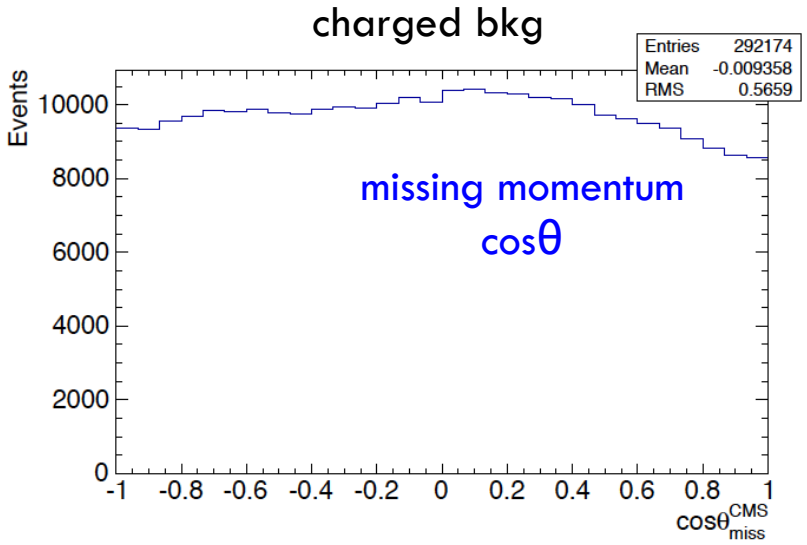
signal

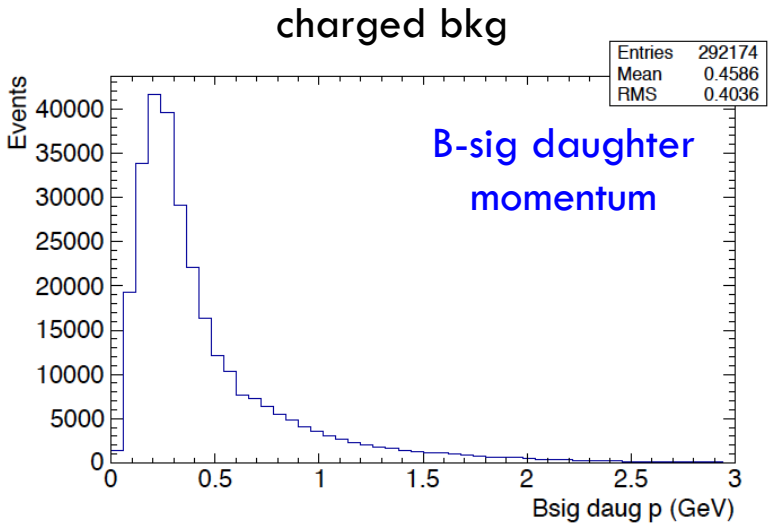


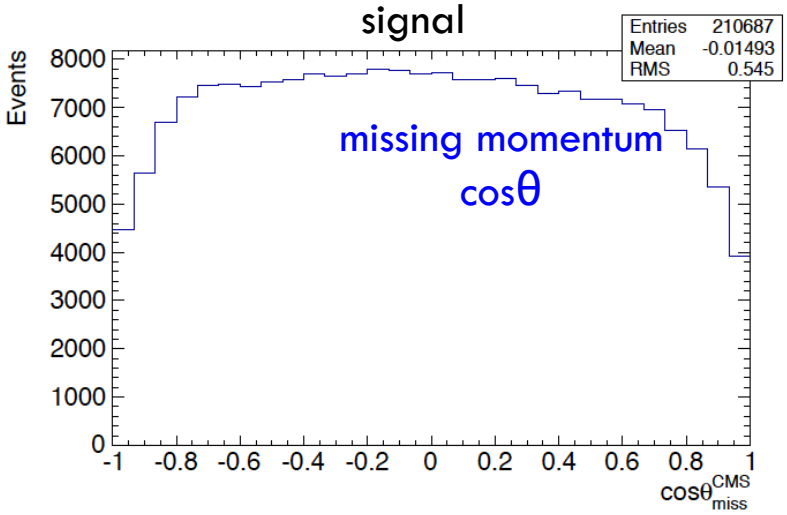
signal

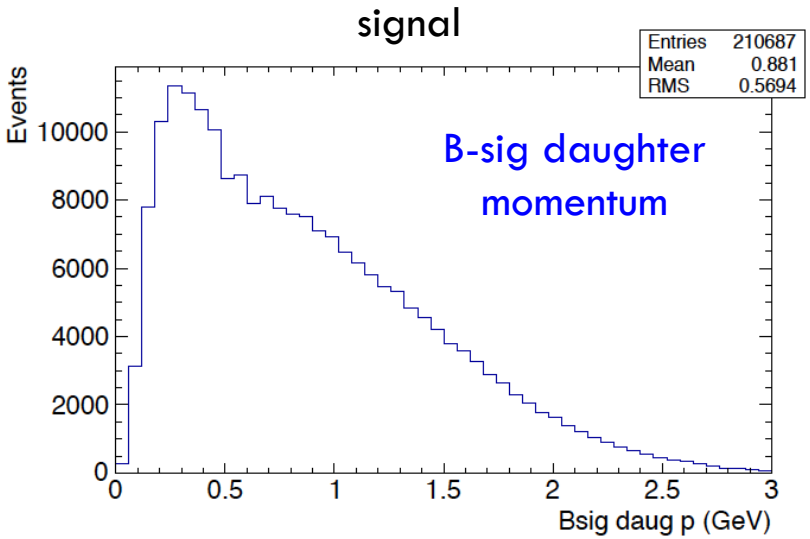


Signal vs B^+/B^- background





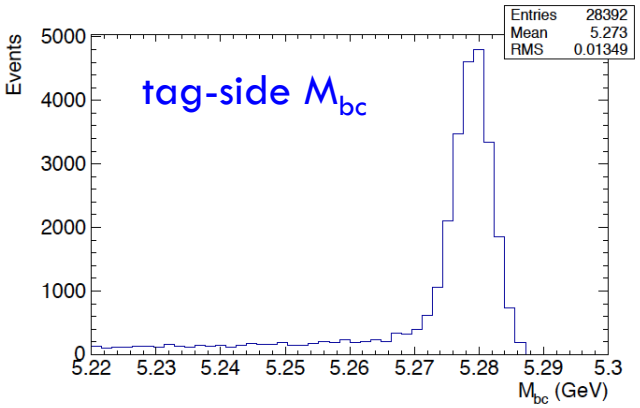




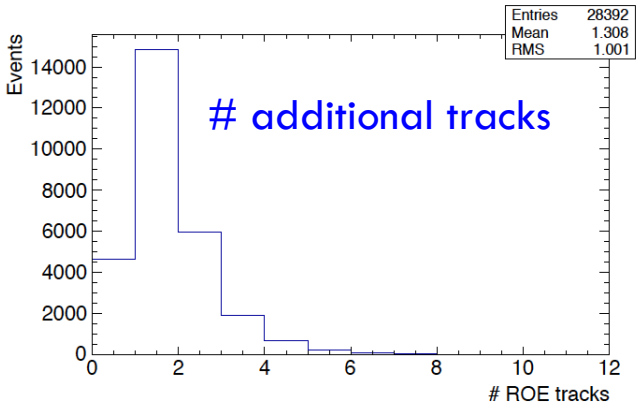
Mis-reconstructed vs correctly reconstructed signal side

signal MC

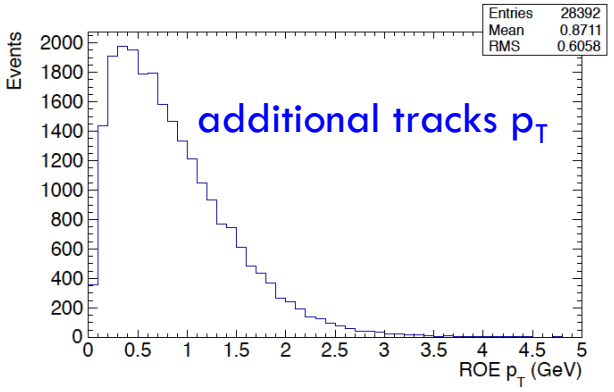
mis-reconstructed



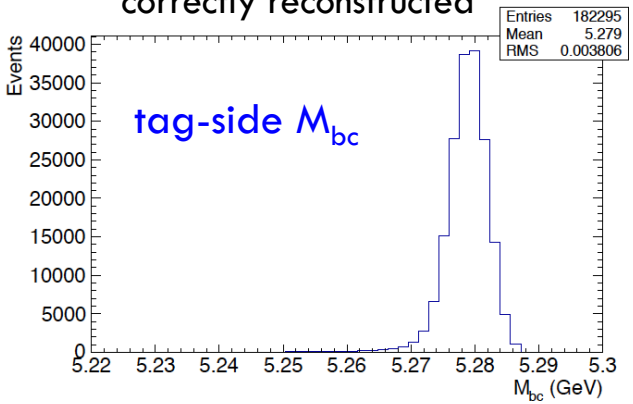
mis-reconstructed



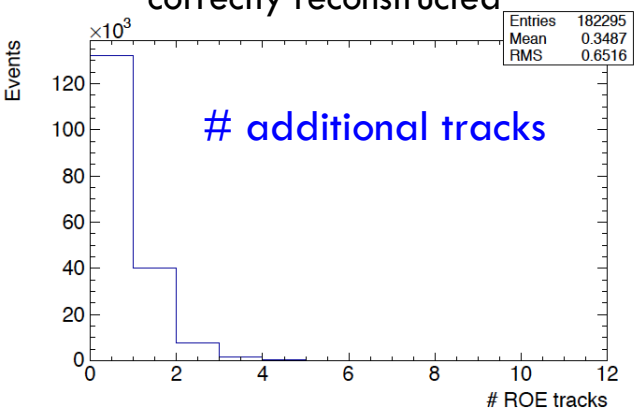
mis-reconstructed



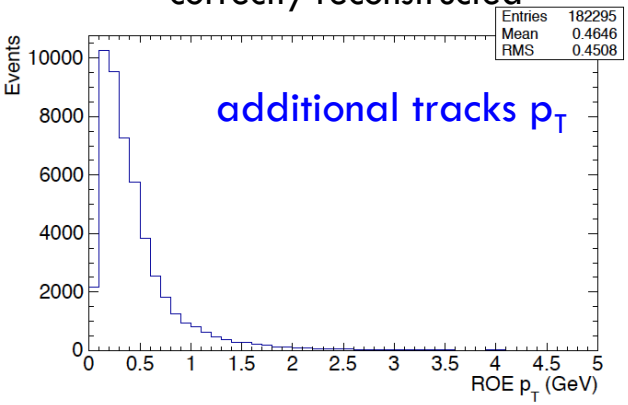
correctly reconstructed



correctly reconstructed



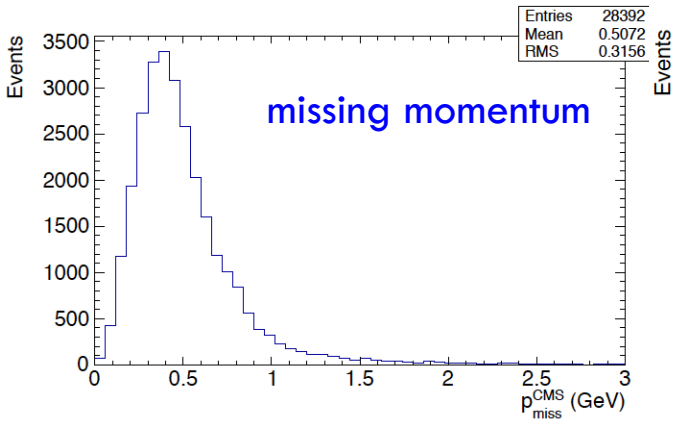
correctly reconstructed



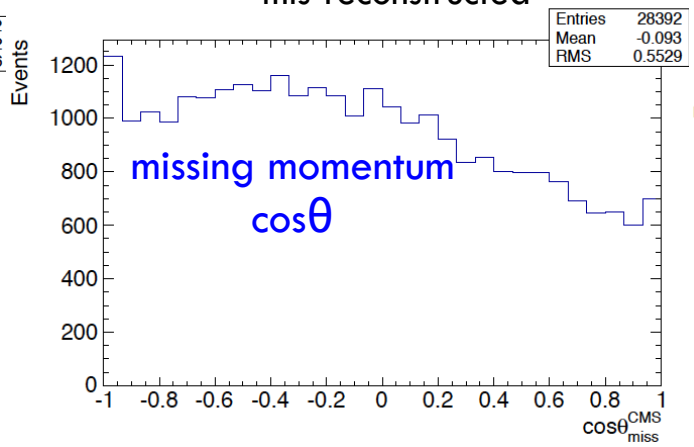
Mis-reconstructed vs correctly reconstructed signal side

signal MC

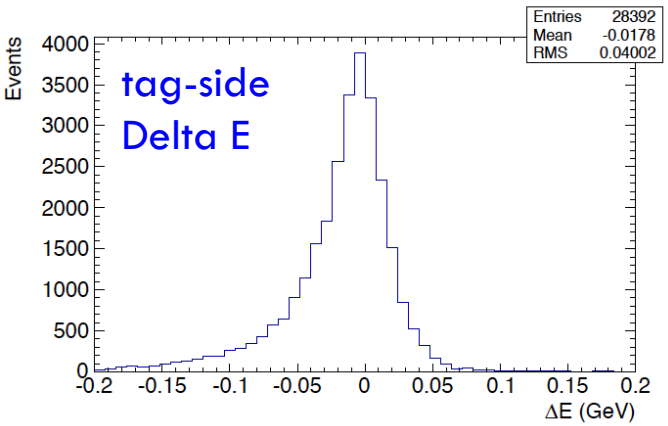
mis-reconstructed



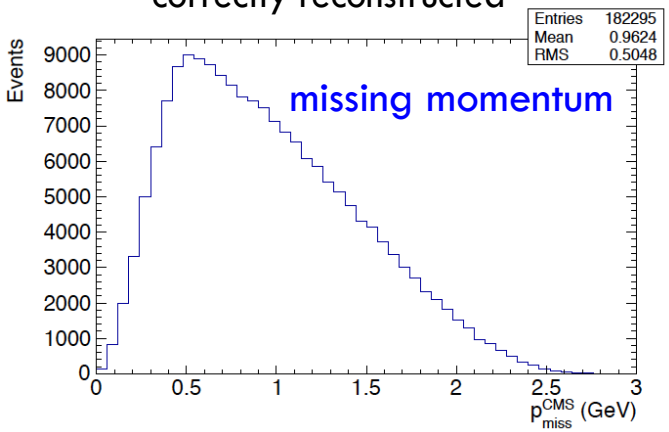
mis-reconstructed



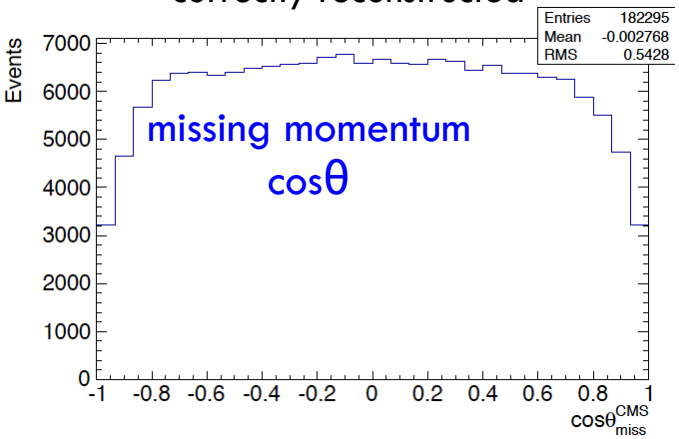
mis-reconstructed



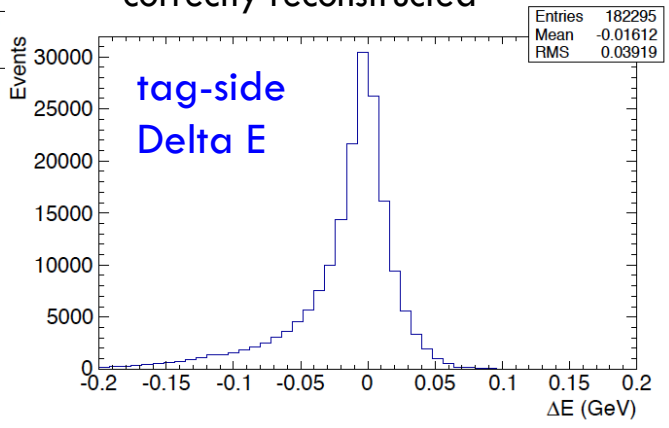
correctly reconstructed



correctly reconstructed



correctly reconstructed



Summary

- Full Event Interpretation provides higher reconstruction efficiency w.r.t. standard methods

- First look at $B \to \tau\nu$ signal side using the FEI reconstruction of tag side

- Next steps:
  - run on B^0B^0 and continuum backgrounds
  - add other τ decay modes (e,ρ,π) and optimize event selection
  - set up an analysis strategy for $B \to \tau\nu / K^*\nu\nu$ (based on multivariate techniques ?)
  - FEI: optimization of input variables, training with beam background, "specific training"

Backup