Direct Photon Analysis via External Conversions in Run14 Au+Au

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Dataset and cuts

Event selection

- BBC narrow trigger
- $|z_{vtx}| < 10cm$
- **ZDC coincidence:** ZDCEn>0 && ZDCEs and ZDCZ>-9000
- A conversion candidate found

Single track selection (eID)

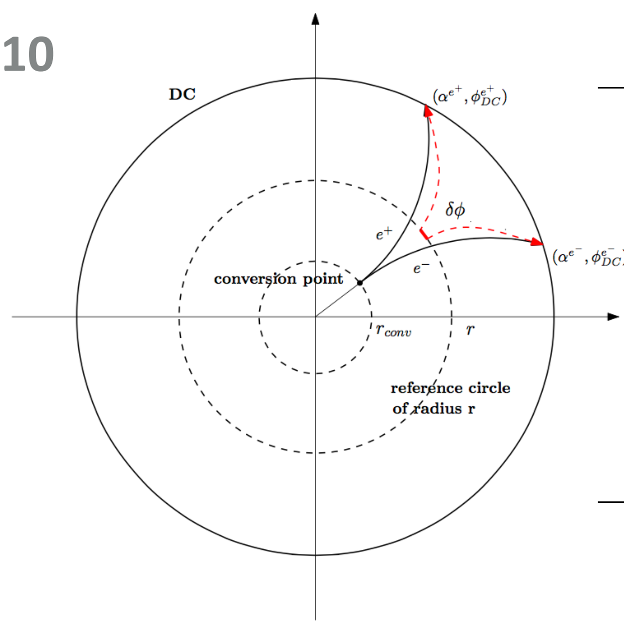
- quality 31 || 53 || 63, $|z_{DC}| < 75cm$
- $p_T > 200MeV$
- n0 > 1, disp < 5cm, χ^2/npe0 < 10
- -2 < dep <5
- prob > 0.01

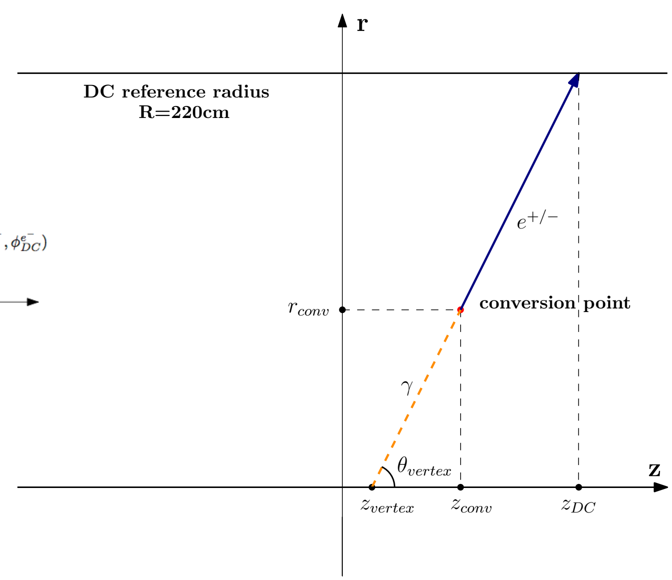
EMCal cluster selection

- $E_{min} > 500MeV$
- $\chi^2 < 3.0$
- EMCal dead map

Conversion pair selection

1. loose cut: same arm, require a solution for r_{conv}
2. dzed cut: loose && $|dz_{DC}| < 4cm$
3. default cut:
   - two tracks from the same arm
   - $|\pi - \phi_V| < 0.1rad$
   - $|dz_{DC}| < 4cm$
   - $9cm < r_{conv} < 23cm$
   - $d\theta_{conv} < 0.01rad$





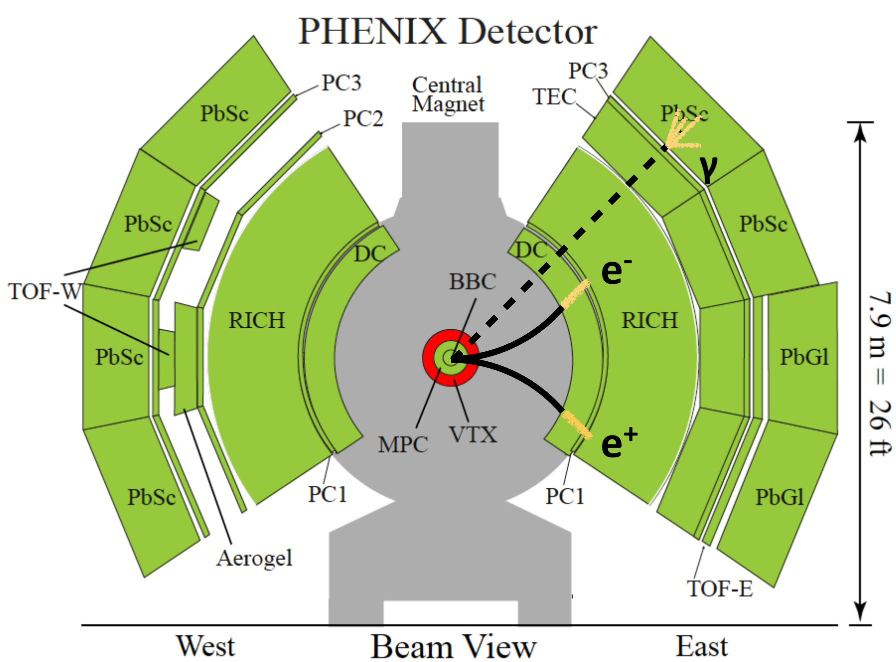
Constructing R_γ

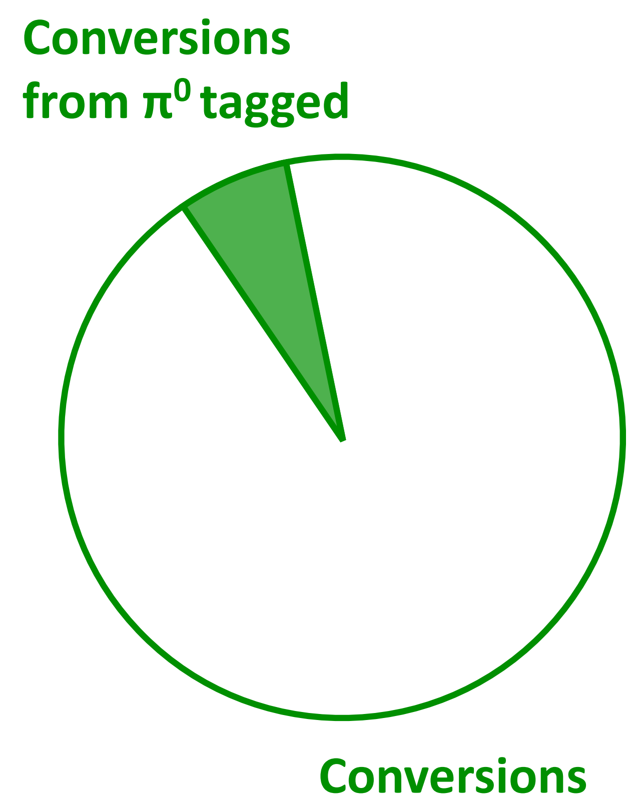
- Double ratio tagging method (R_γ>1 indicating direct photon signal)

$$R_\gamma = \frac{\gamma^{incl}}{\gamma^{hadron}} = \frac{\frac{\gamma^{incl}}{\gamma^{\pi^0}}}{\frac{\gamma^{hadron}}{\gamma^{\pi^0}}} = \frac{\langle \epsilon f \rangle \boxed{\left(\frac{N_\gamma^{incl}}{N_\gamma^{\pi^0}}\right)_{Data}}}{\left(\frac{\gamma^{hadron}}{\gamma^{\pi^0}}\right)_{Sim}}$$

Raw counts

❖ **N^{incl}/N^{tag} from real data:** # of conversion photons/# of conversion photons tagged as coming from π^0





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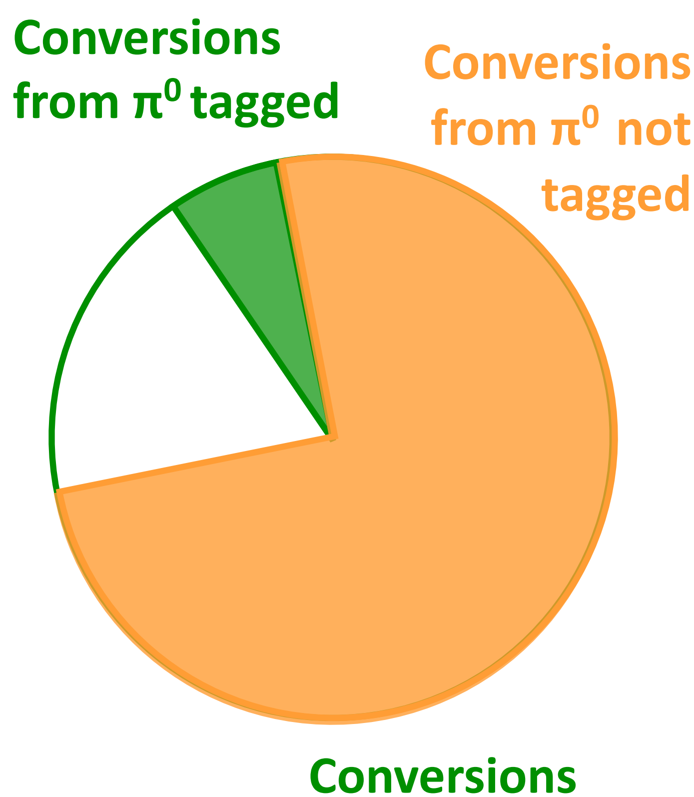
Correct for detector effects

❖ **Conditional acceptance and efficiency:** the acceptance for the second photon in the EMCal from π^0 decay given that we already reconstructed the first photon from a conversion pair



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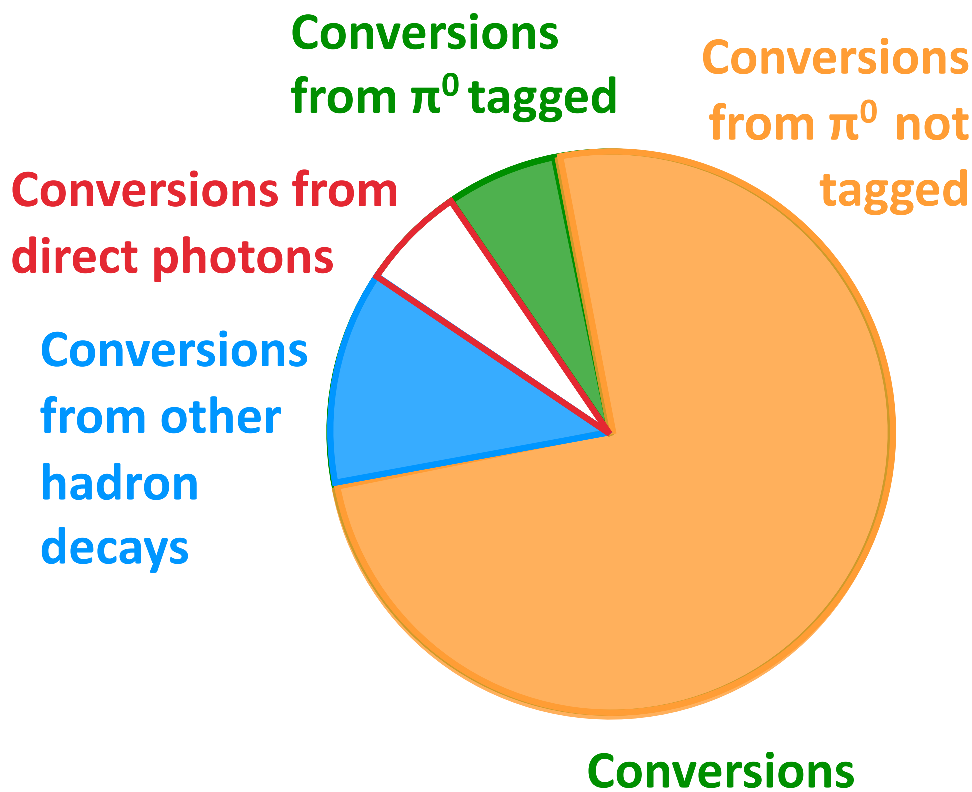
Correct for detector effects

❖ **Conditional acceptance and efficiency:** the acceptance for the second photon in the EMCal from π^0 decay given that we already reconstructed the first photon from a conversion pair

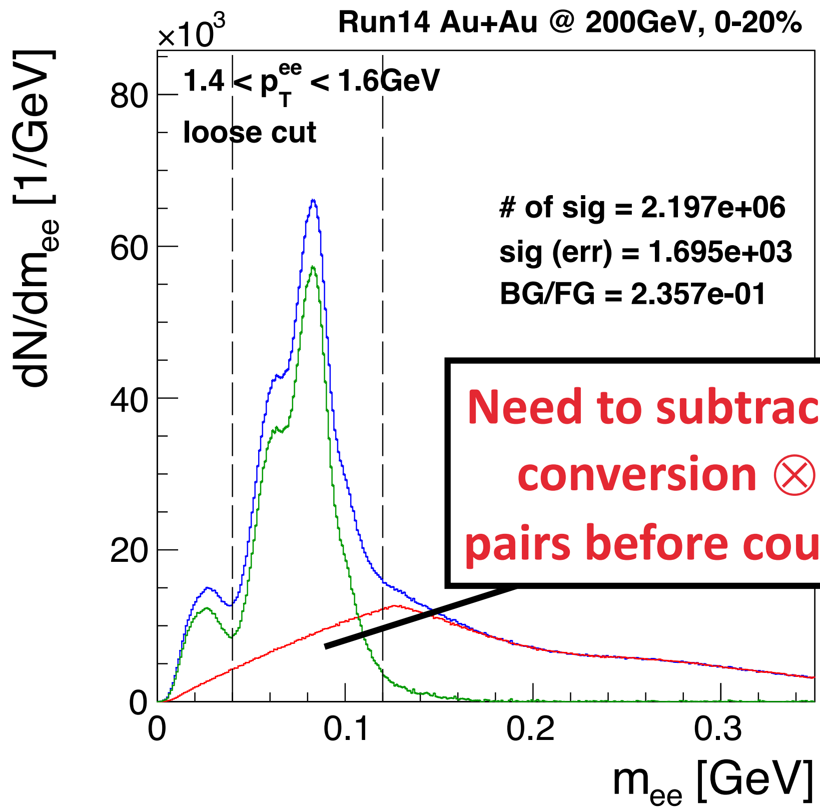
Correct for other background sources

❖ **Cocktail ratio (other sources of decay photons)**

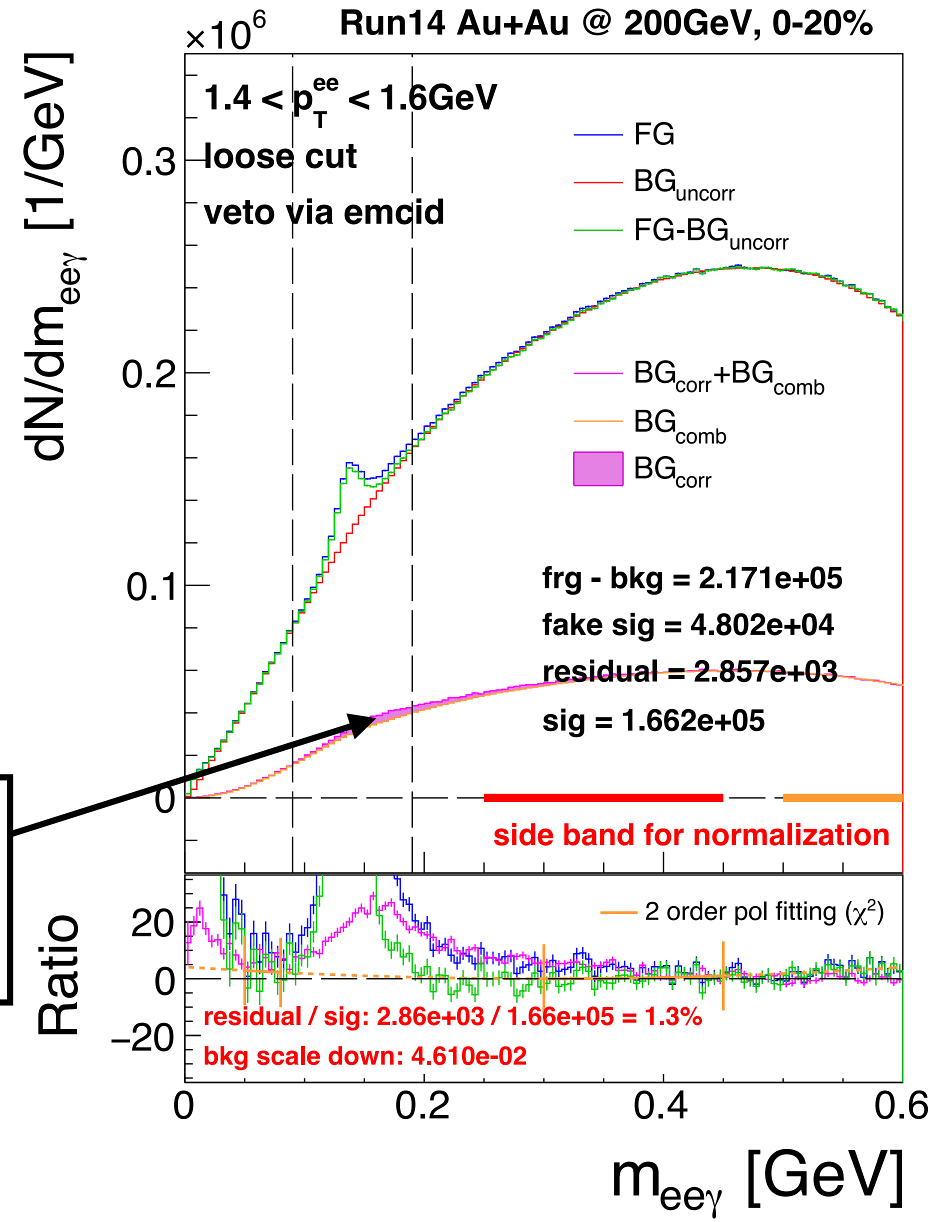


Fake conversion and fake π^0

- After conversion photon selection, there are still fake conversions in the inclusive photon sample
  - For conversions (e^+e^-): the fake conversions are estimated via event mixing and statistically subtracted
  - For tagged photons ($e^+e^-\gamma$): the fake conversion $\otimes$ cluster pairs has a peak shape under π^0 peak



Need to subtract the fake conversion $\otimes$ cluster pairs before counting N_{tag}



Closure test with high multiplicity simulation

- Simulate high multiplicity π^0 events
  - 280 π^0 per event, flat along η and φ
  - p_T distribution: 0-10% Hagedorn

centrality	c $[(\mathrm{GeV/c})^{-2}]$	a $[(\mathrm{GeV/c})^{-1}]$	b $[(\mathrm{GeV/c})^{-2}]$	p_0 $[\mathrm{GeV/c}]$	n	$\mathrm{dN}_{\pi^0}/\mathrm{dy}$
min. bias	504.5	0.5169	0.1626	0.7366	8.274	95.7
0 - 10 %	1331.0	0.5654	0.1945	0.7429	8.361	280.9
10 - 20 %	1001.0	0.5260	0.1628	0.7511	8.348	200.6

- N^{incl}/N^{tag}
  - Treat this high multiplicity simulation as pseudo-data
  - Check the background sources in e^+e^- and $e^+e^-\gamma$ sample
  - Test the background subtraction with event mixing technique

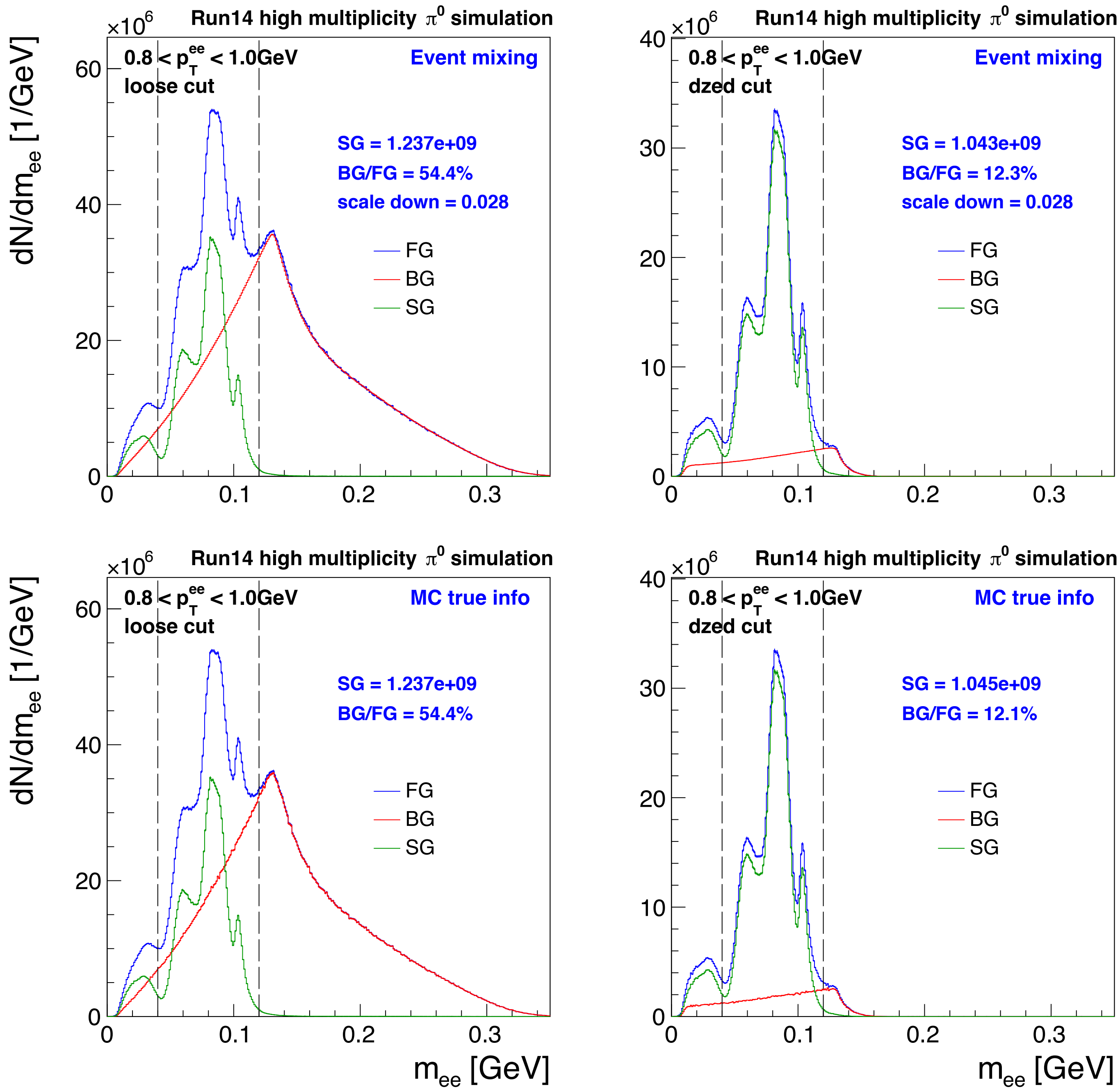
- $<\varepsilon f>$
  - N^{tag}/N^{incl} using the embedded single π^0 simulation

- $R_\gamma = N^{incl}/N^{tag} \times <\varepsilon f>$
  - Should be 1 and independent of photon p_T bin

N^{incl}: event mixing and normalization for BG_{ee}

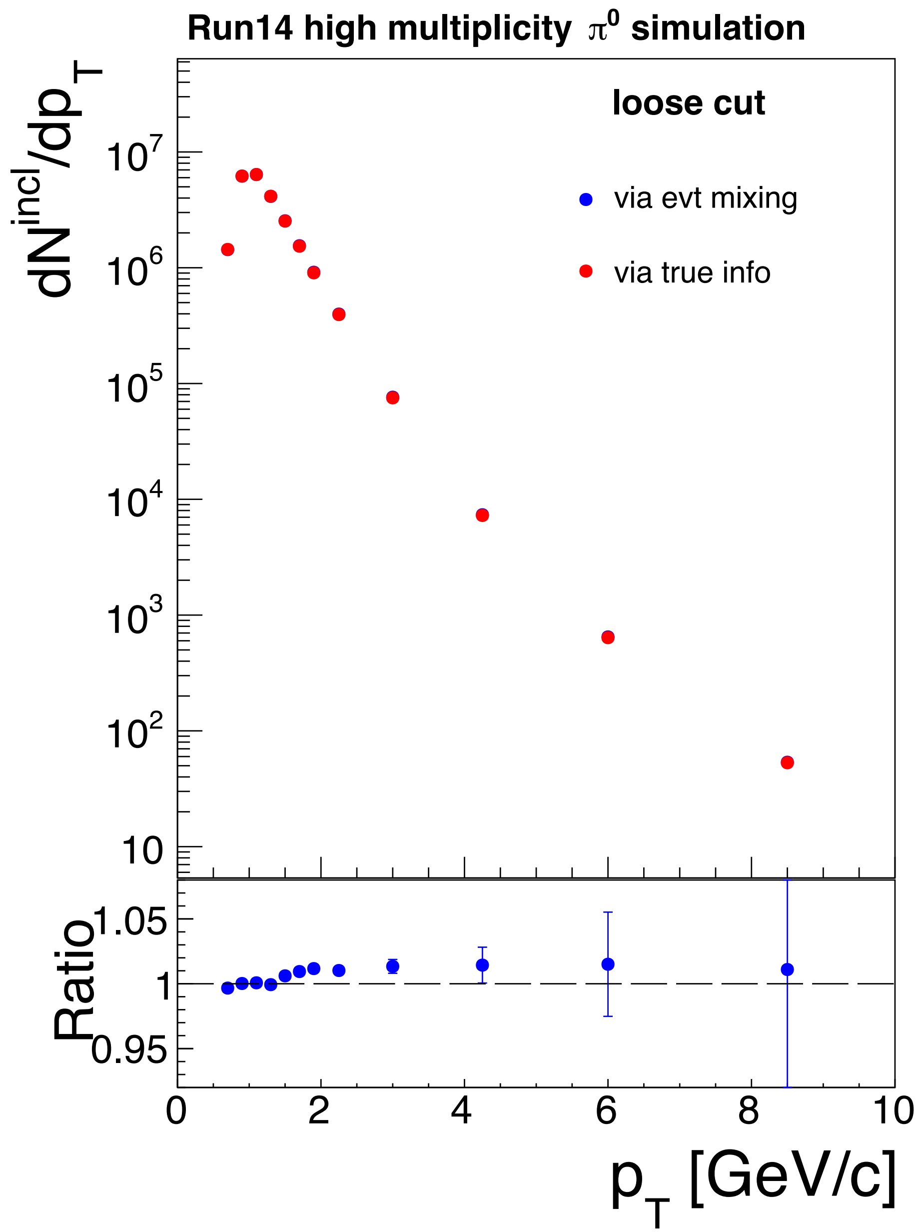
Use event mixing

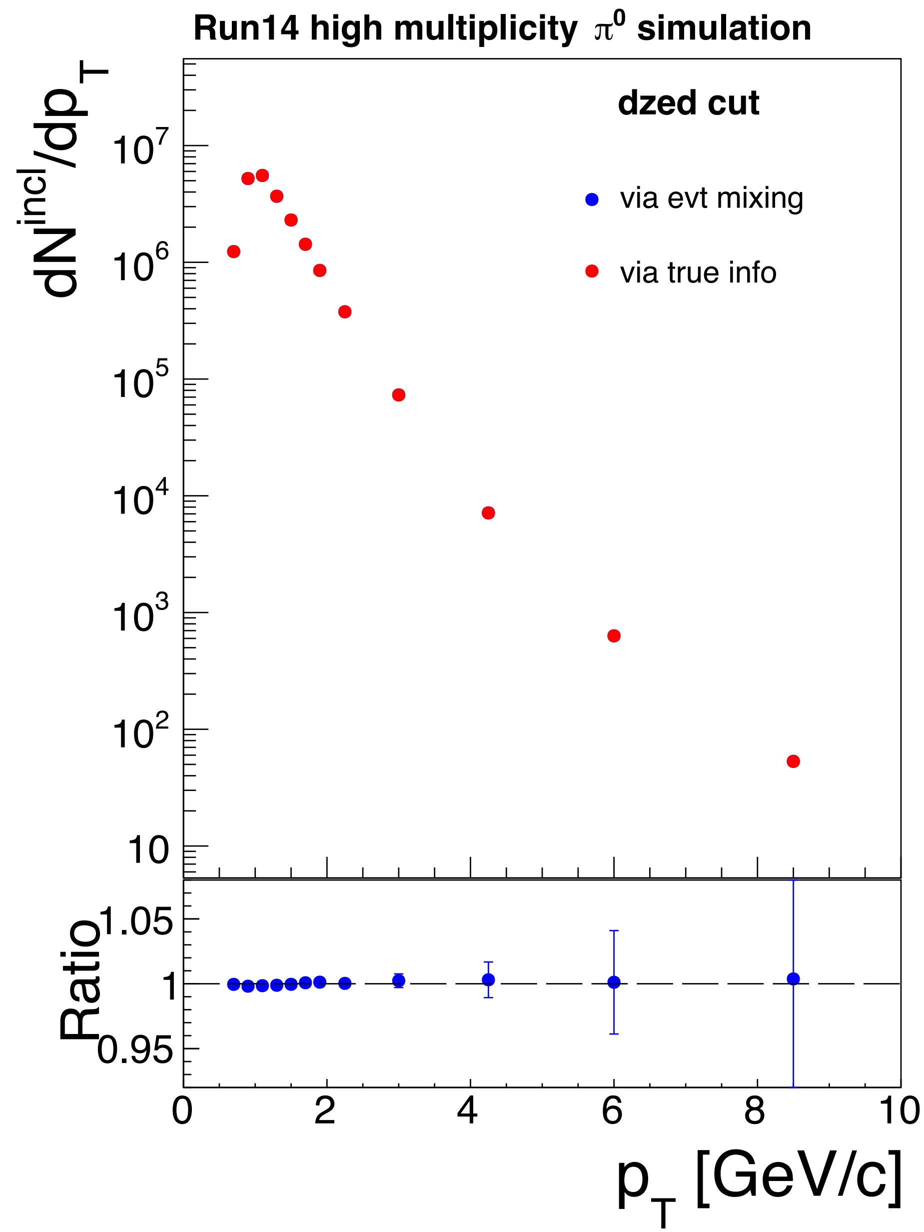
Use MC true info



N^{incl}: event mixing and normalization for BG_{ee}

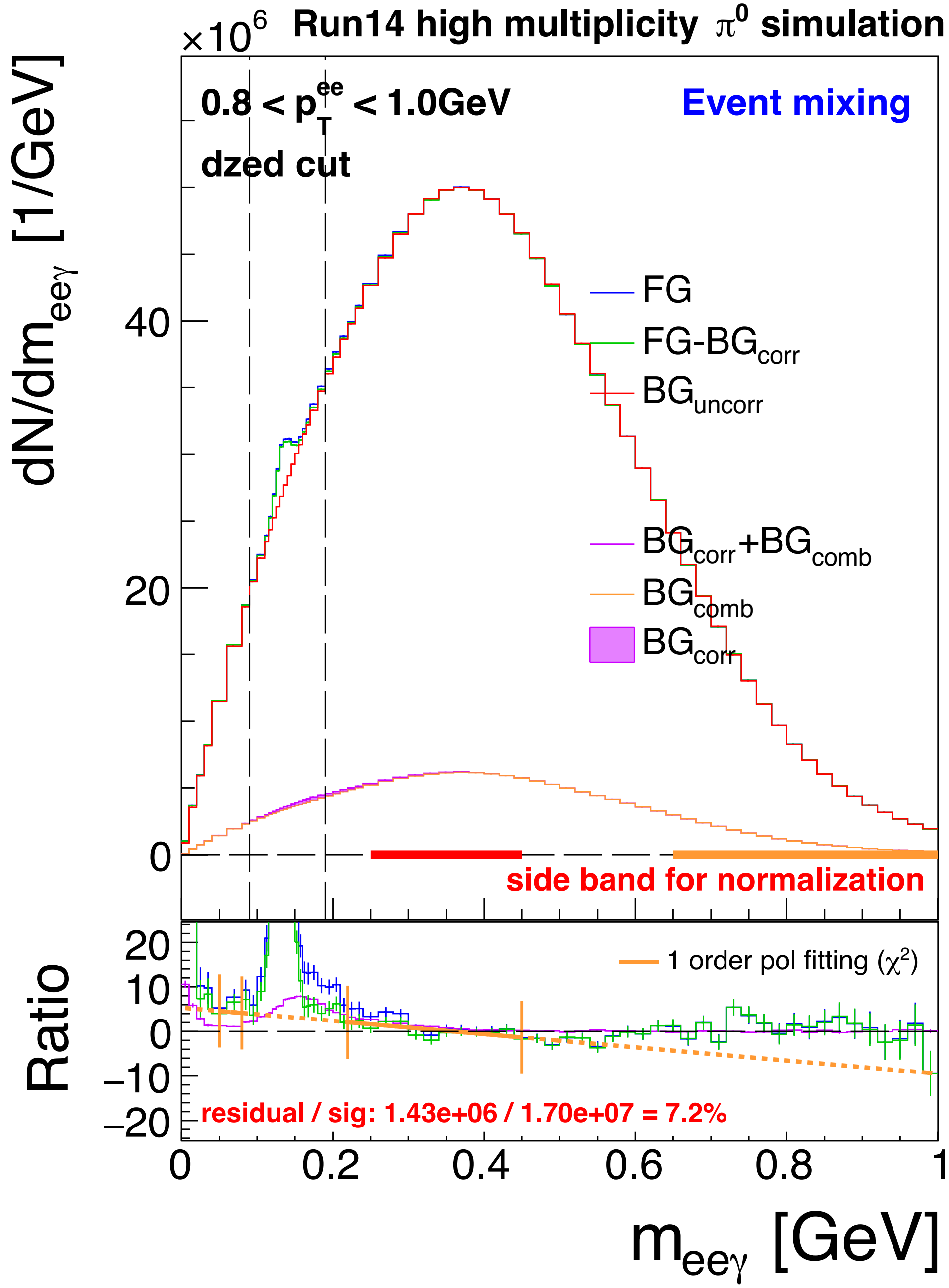
- Event mixing & normalization works better in tighter conversion selection cases





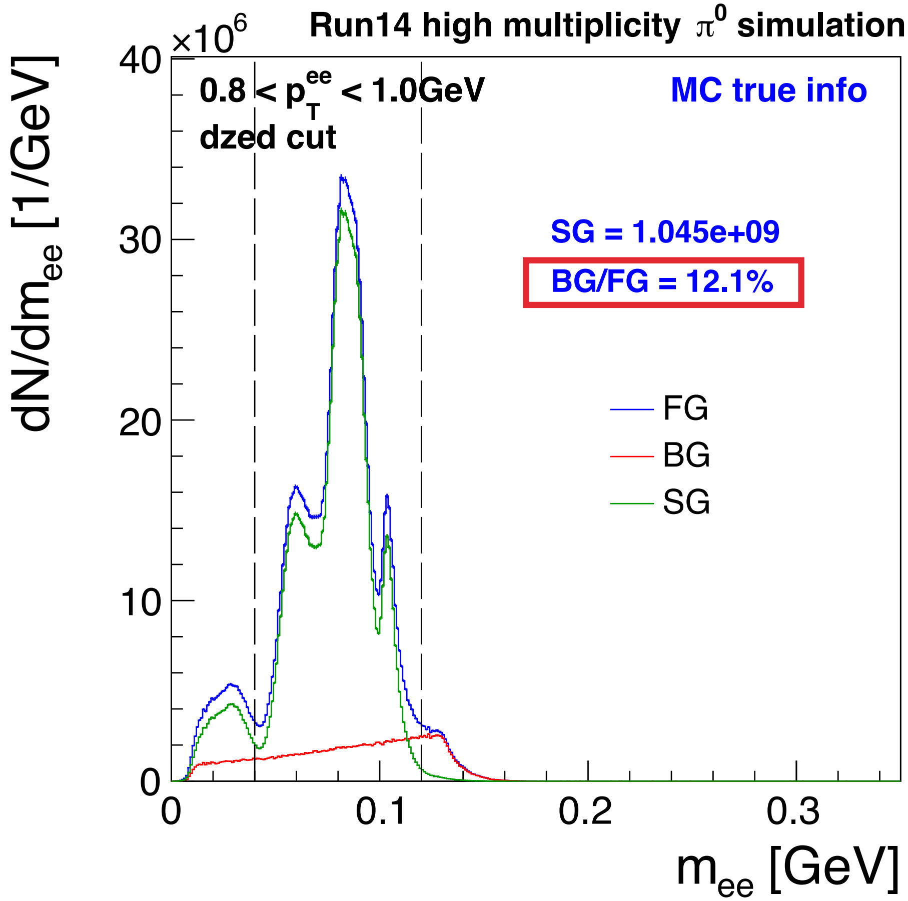
N^{tag}: event mixing and normalization for BG_{uncorr} & BG_{corr}

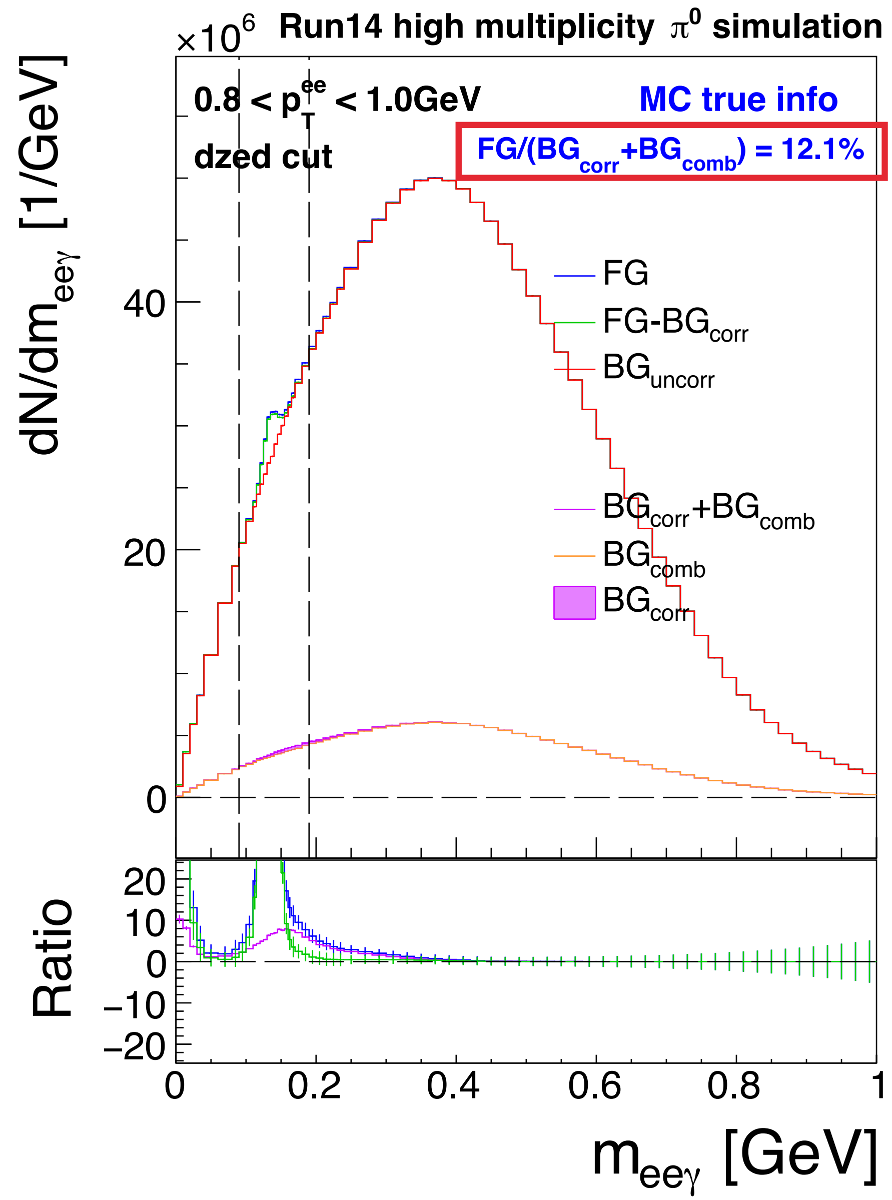
- Un-correlated bkg: BG_{uncorr}
  - pick two tracks from event 1 and pair with clusters from event 2
  - Normalize BG_{uncorr} using integral in [0.25,0.45] GeV
- Correlated bkg: BG_{corr}
  - BG_{corr} + BG_{comb}: pick one track from event 1, one track from event2 and pair with clusters from event 1 & 2
  - BG_{comb}: pick one track from event 1, one track from event2 and pair with clusters from event 3
  - Normalize BG_{corr} + BG_{comb} (see next slide)
  - Normalize BG_{comb} using integral in [0.65,1.00] GeV
- FG - BG_{uncorr} - BG_{corr} and then residual bkg subtraction



N^{tag}: event mixing and normalization for BG_{uncorr} & BG_{corr}

$$\frac{\text{\# of fake conversions}}{\text{\# of conversions}} = \frac{\text{\# of fake conversions in \{fake conversion} \otimes \text{cluster pairs\}}}{\text{\# of conversions in \{conversion} \otimes \text{cluster pairs\}}}$$





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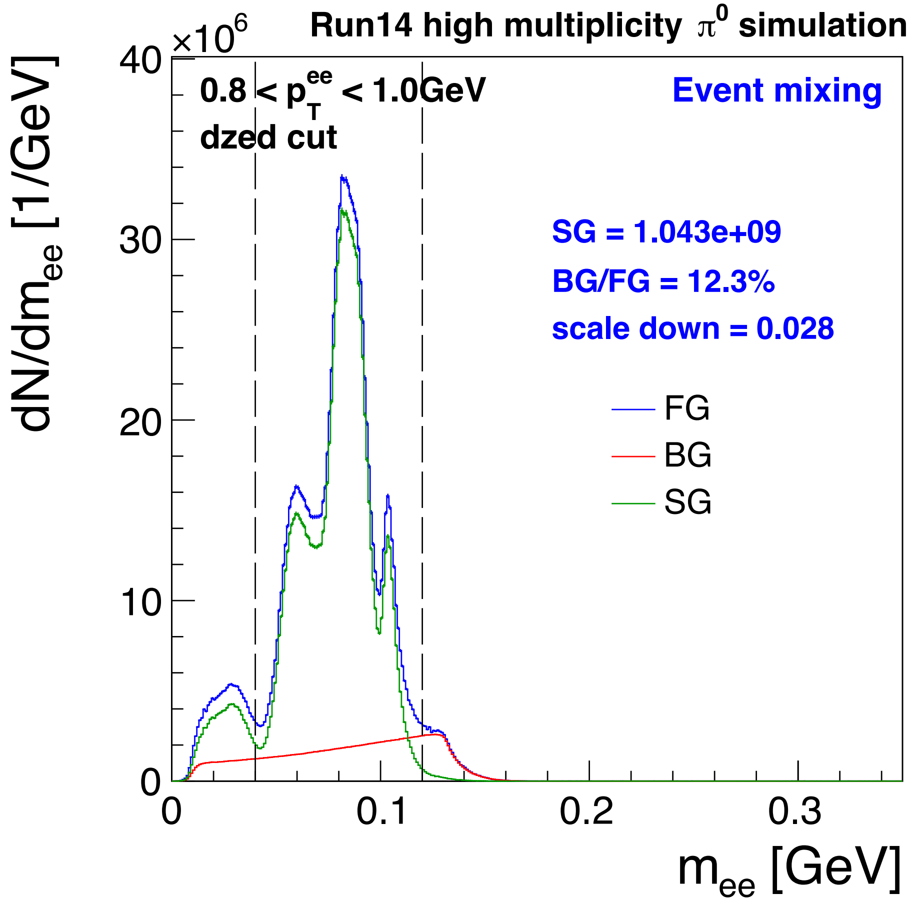
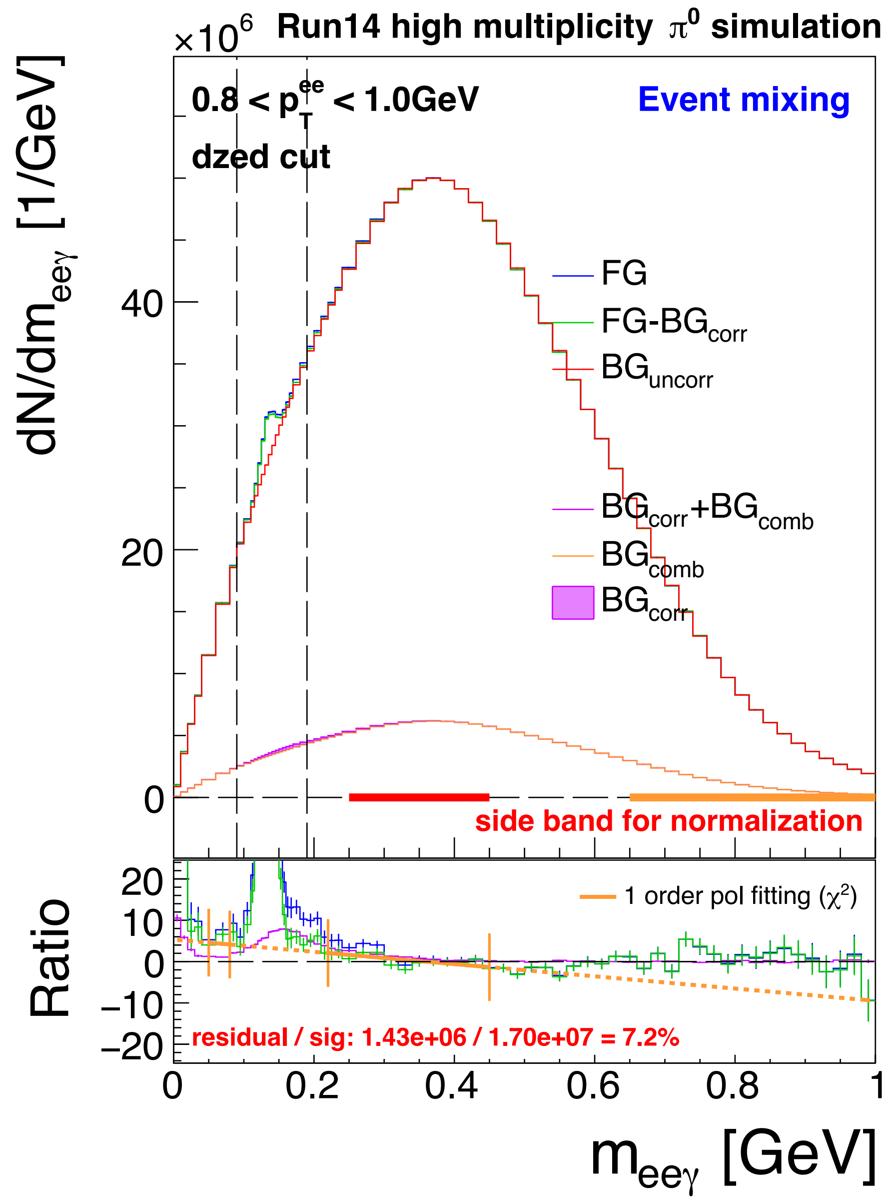
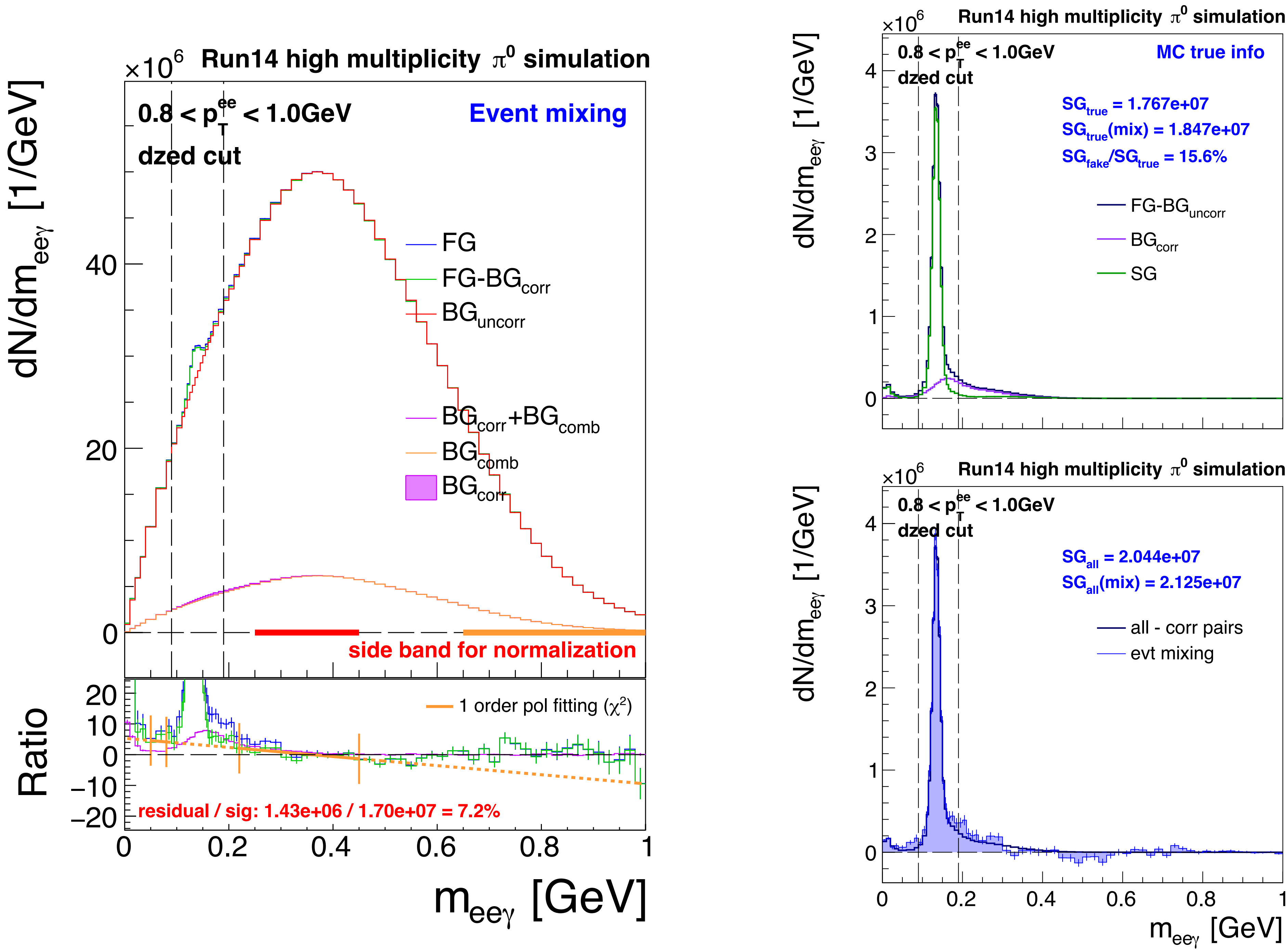
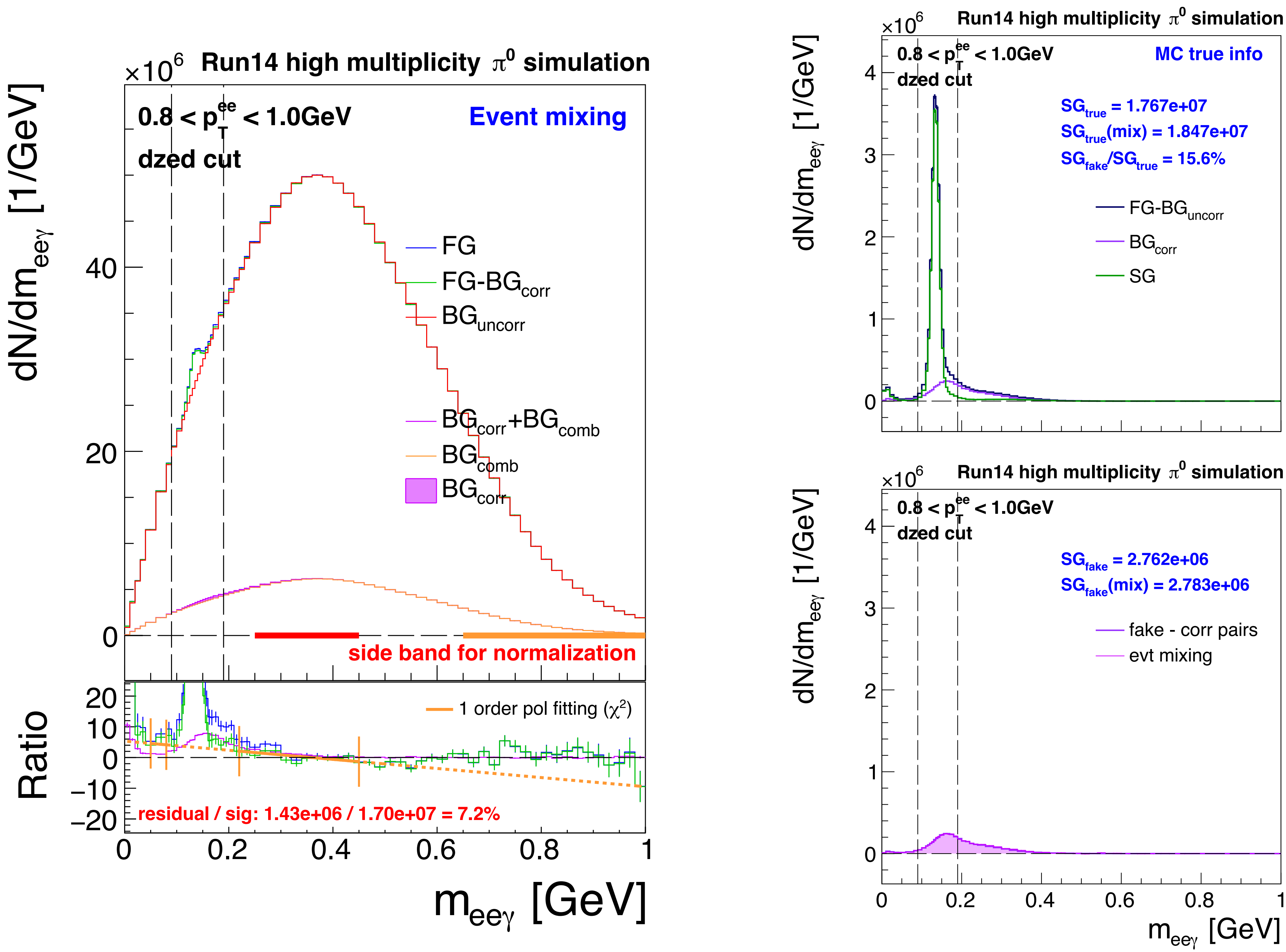




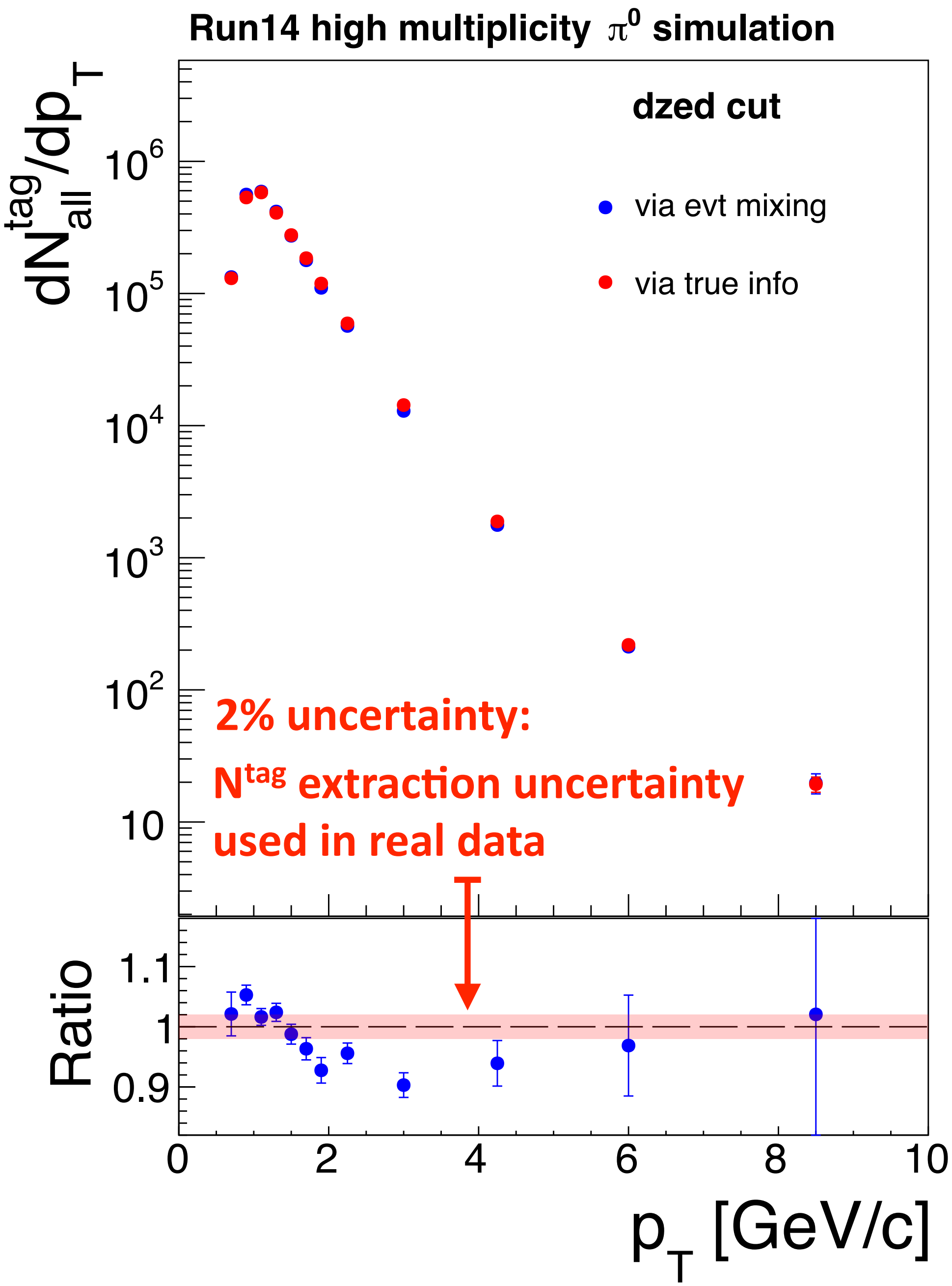
BG subtraction for N^{tag}: BG_{uncorr}

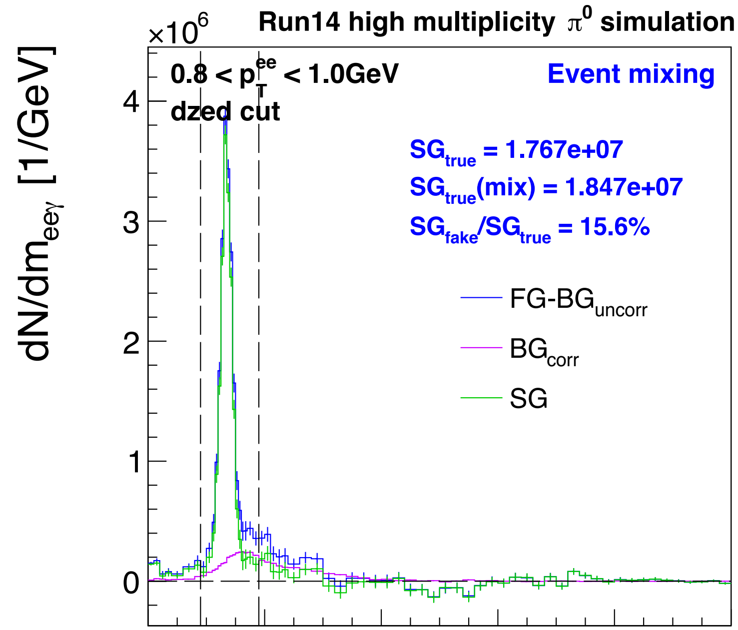


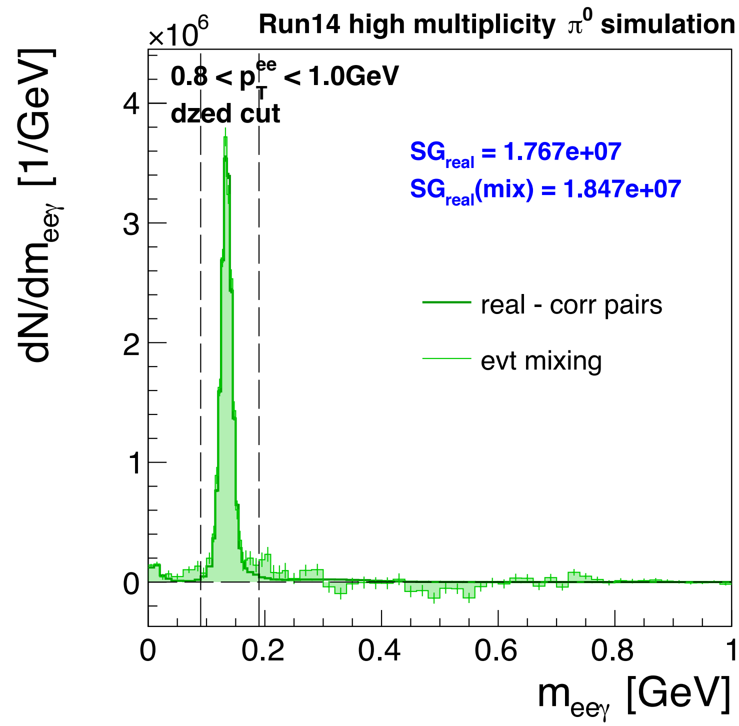
BG subtraction for N^{tag}: BG_{corr}



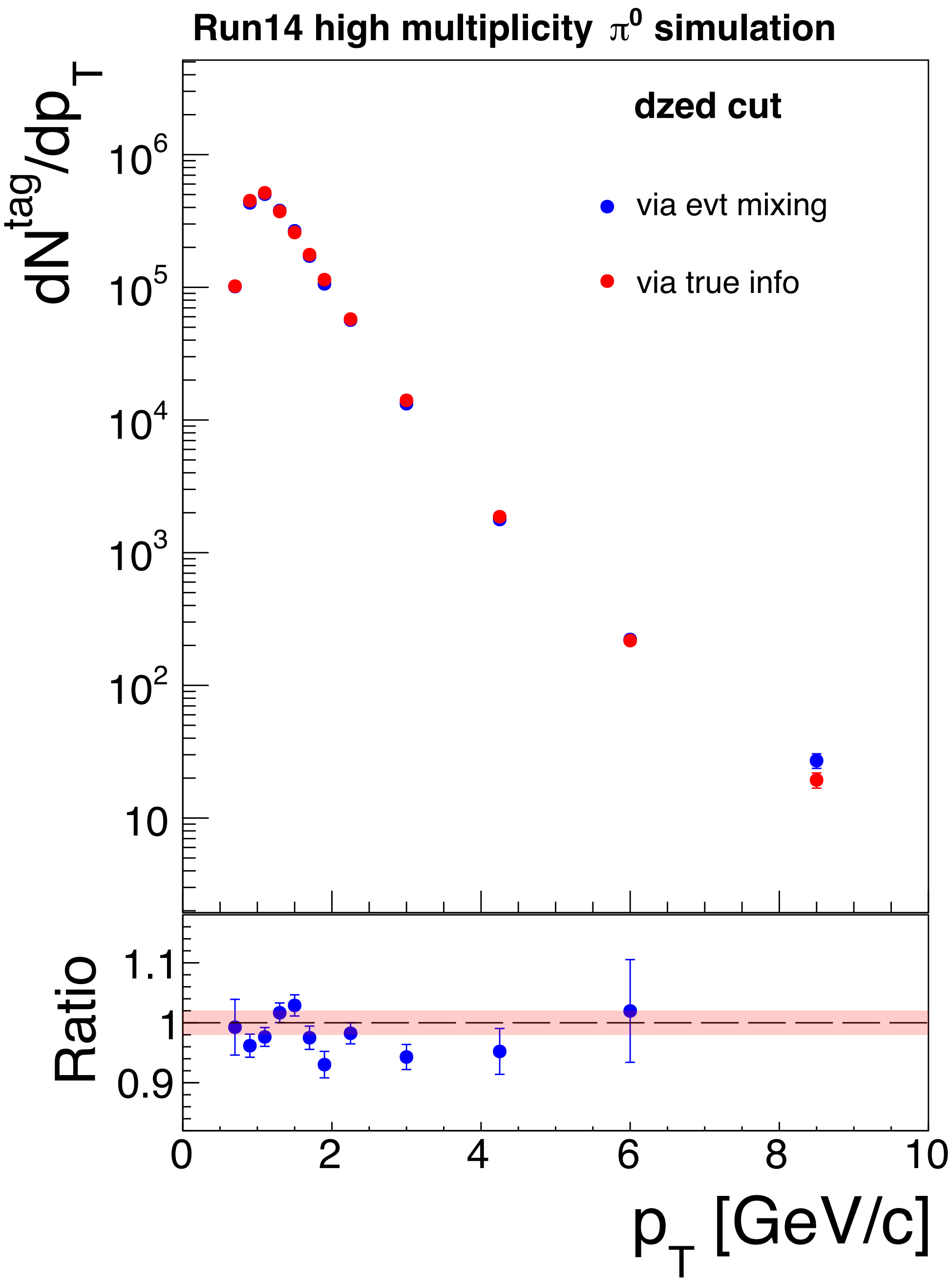
BG subtraction for N^{tag}: SG w/o residual bkg subtraction

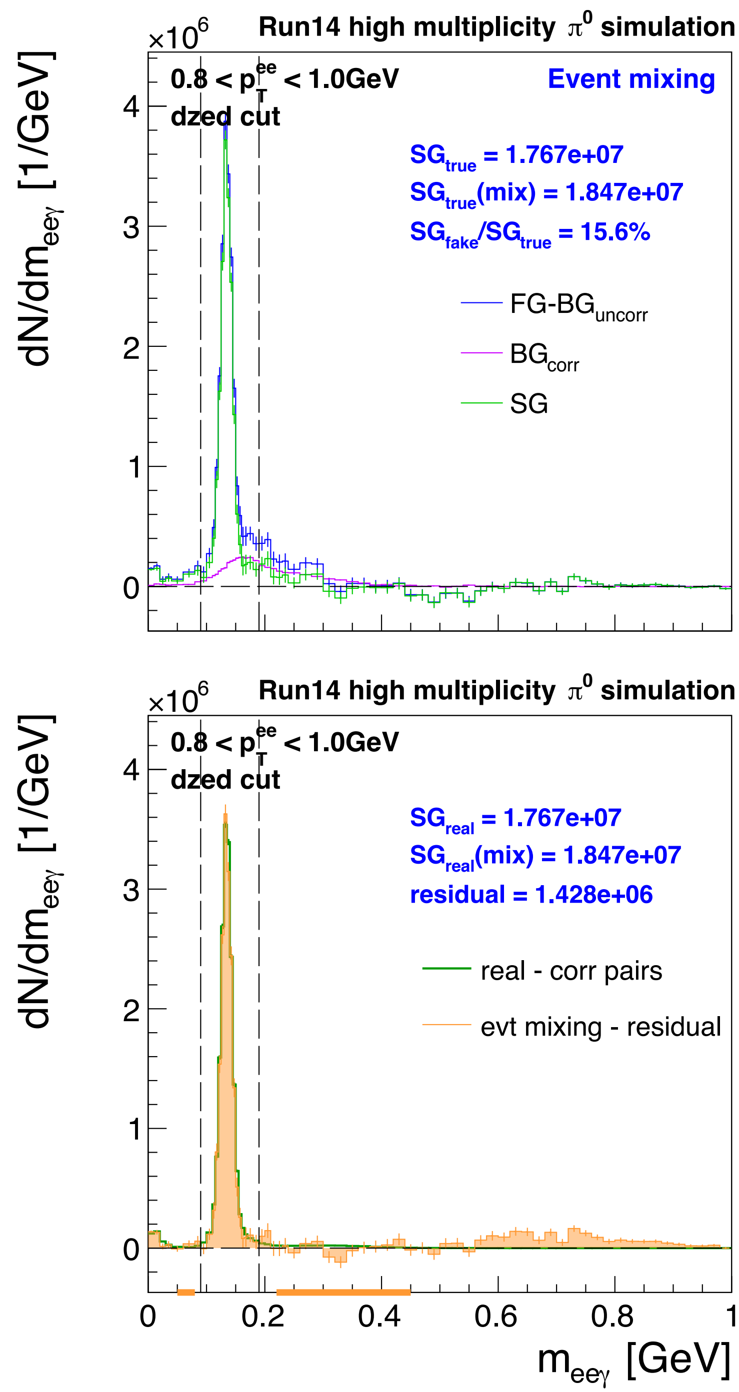






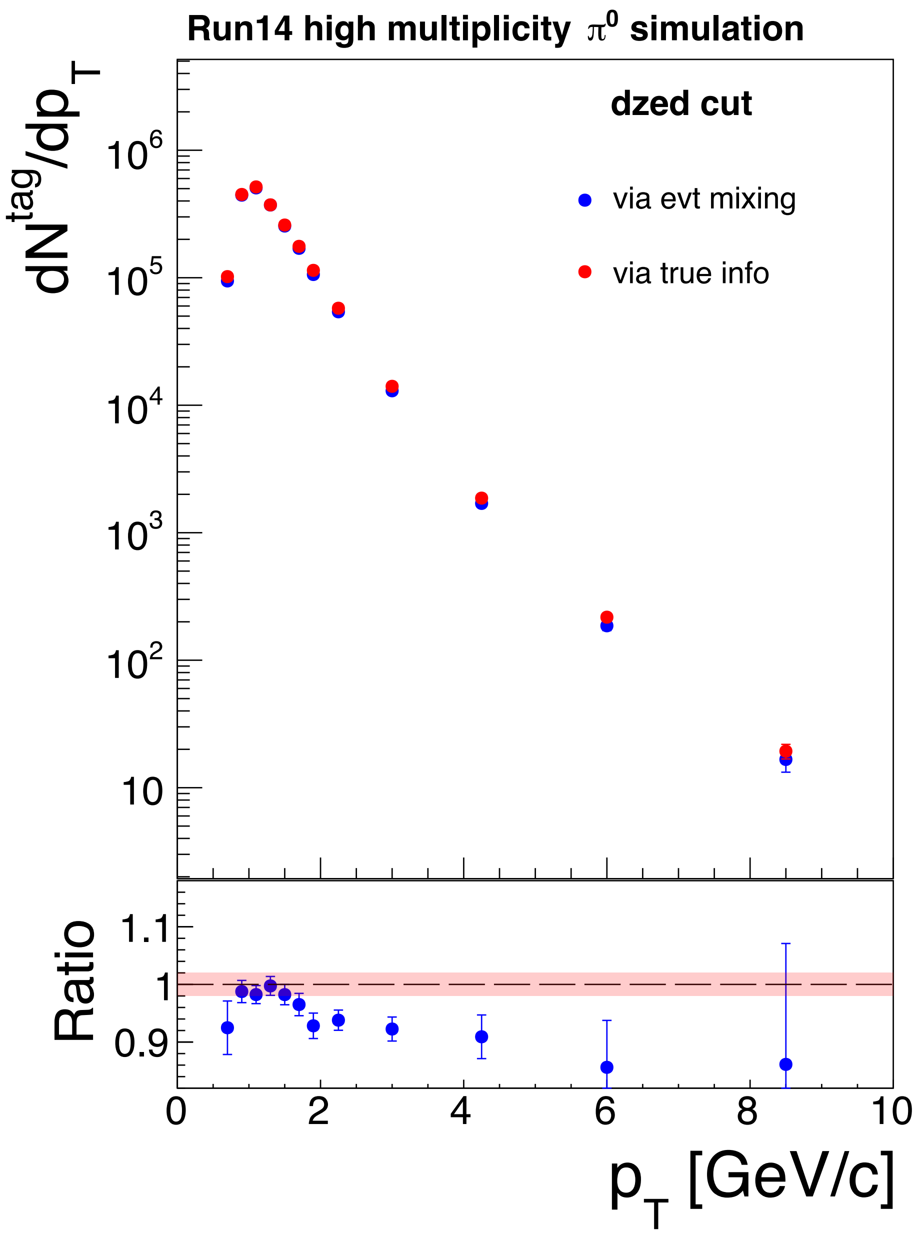
BG subtraction for N^{tag}: SG w/ residual bkg subtraction

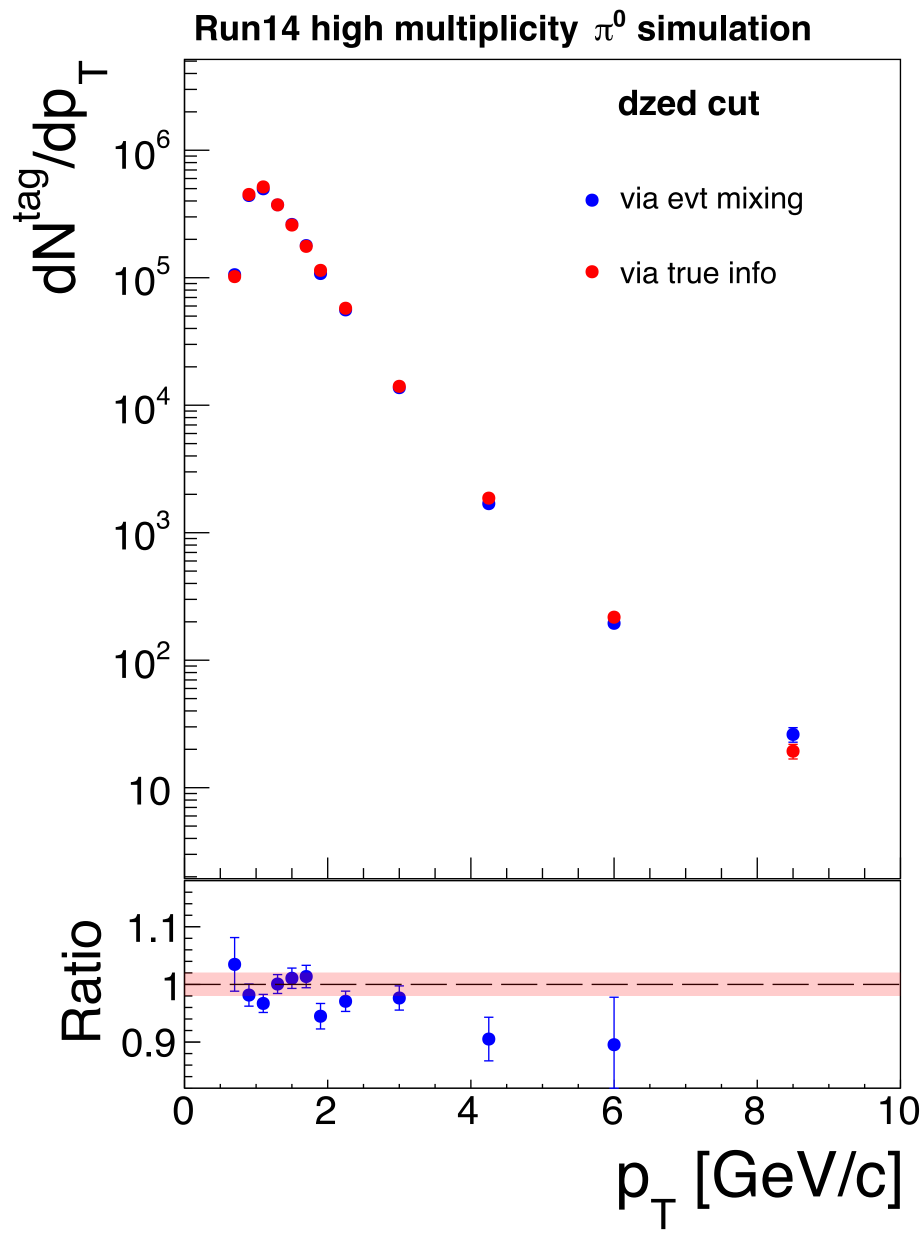




Another way of event mixing for BG_{uncorr}

- Mix with clusters from the events with at least one conversion candidate



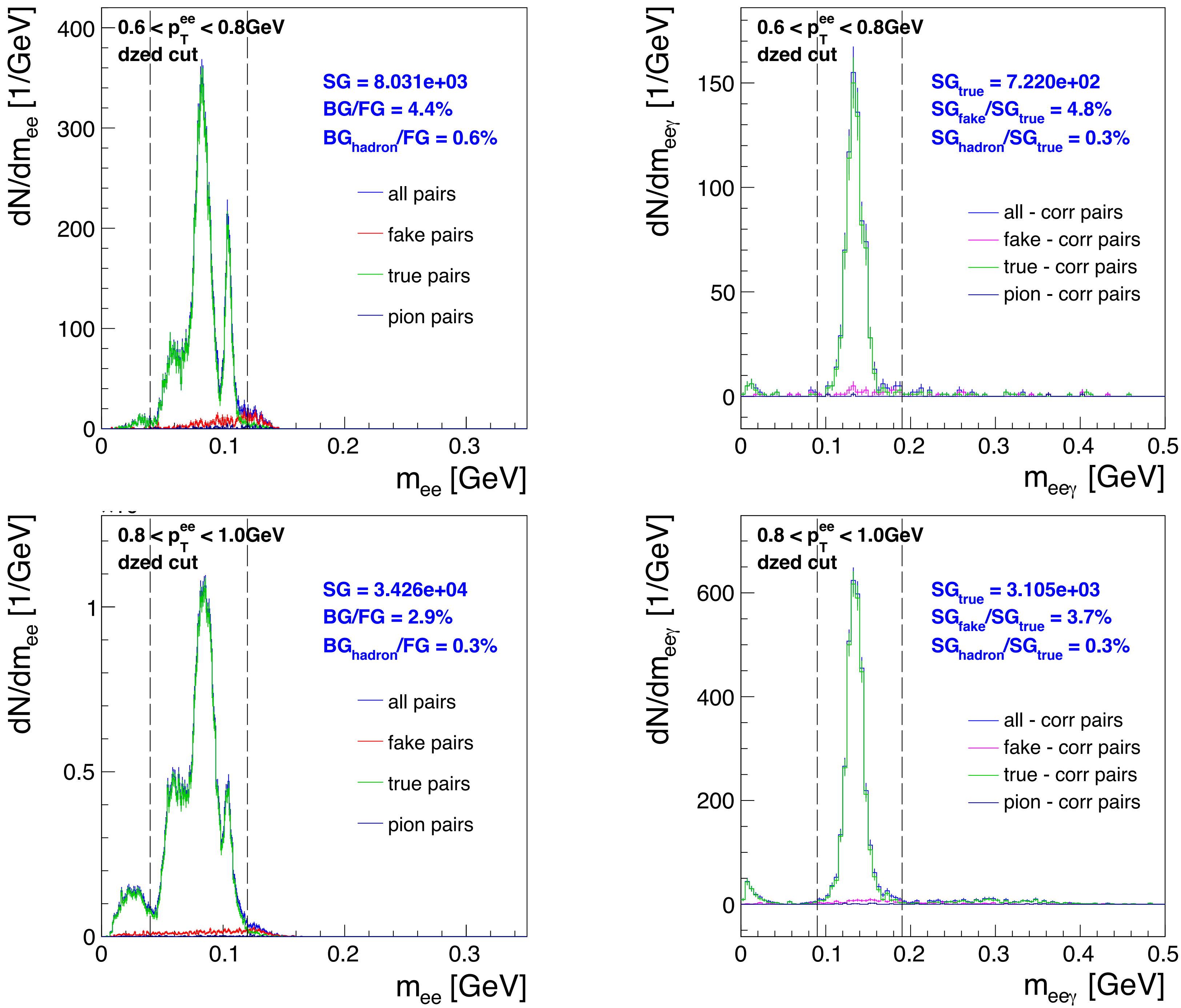


Summary

- Set up high multiplicity π^0 simulation
  - Random ee pairs form the fake conversions
  - Fake conversion $\otimes$ cluster pairs shows peak structure under π^0
- Use the high multiplicity simulation as pseudo data to test the background subtraction method
  - N^{incl}: signal extracted using event mixing is very consistent with using true info
  - N^{tag}: signal extracted using event mixing fluctuate around the true info result mostly within 2% uncertainty
- Next step: obtain $R_\gamma = N^{incl}/N^{tag} \times \langle \varepsilon f \rangle$ within the simulation framework
  - $\langle \varepsilon f \rangle = N^{tag}/N^{incl}$ using the embedded single π^0 simulation
  - Check if R_γ is flat at 1 (no direct photon signal in the pseudo-data)

BACKUP

Background from charged hadron contamination



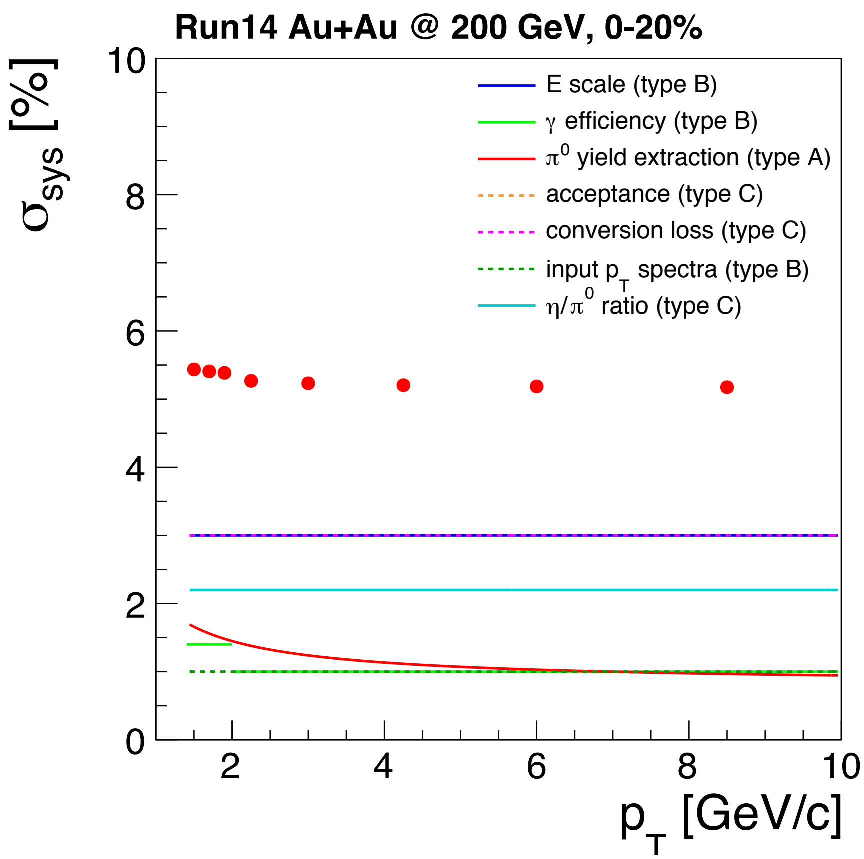
Systematic uncertainties on R_γ

- **N^{incl}/N^{tag} from real data:**
  - N^{tag} (π^0) extraction (~2%)
  - Conversion sample purity (<1%)

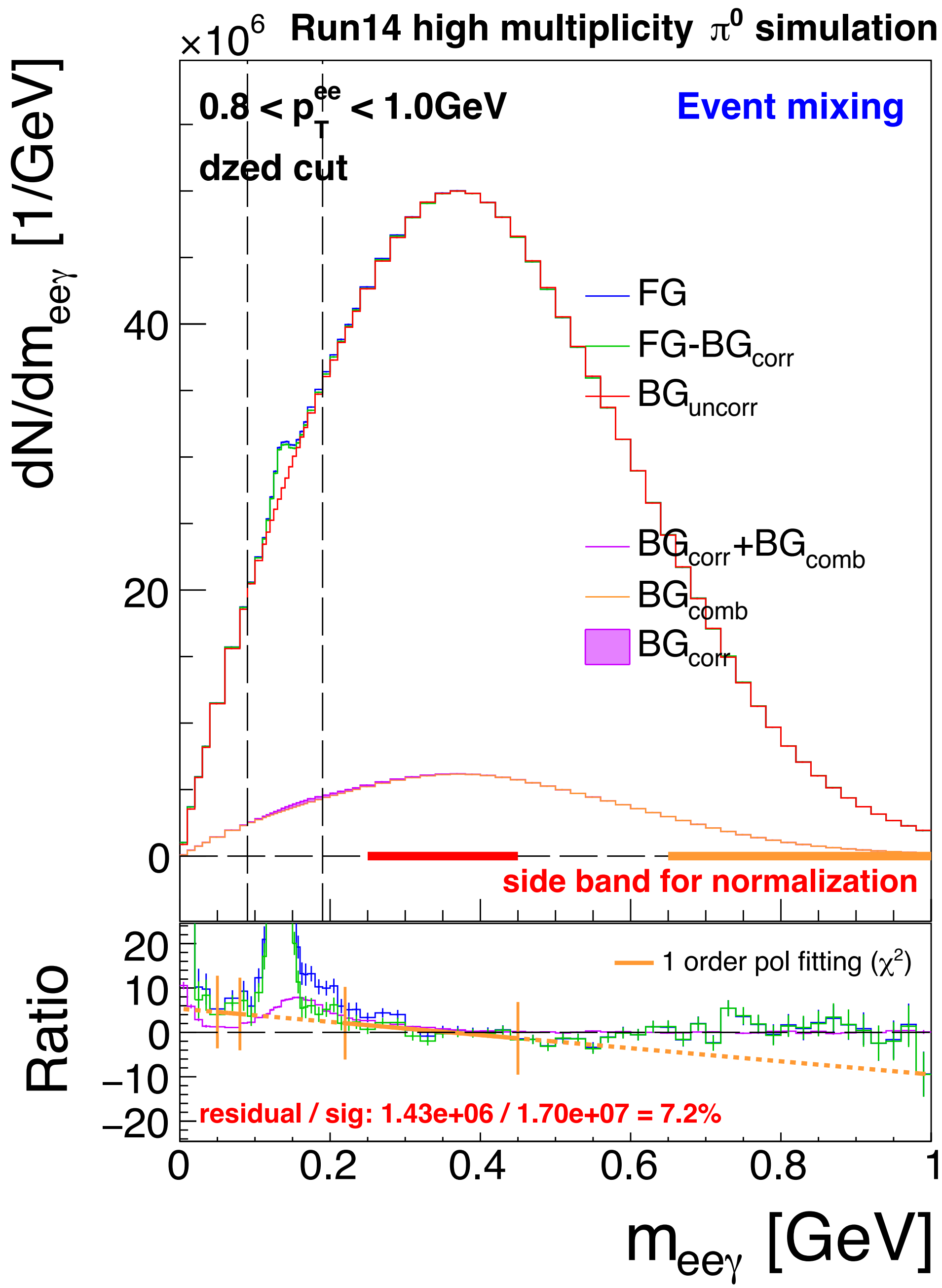
- **Conditional acceptance and efficiency:**
  - Energy scale and resolution (3%)
  - Conversion photon loss due to second conversions = material budget (3%)
  - γ efficiency (~1%)
  - Active area (1%)
  - Input p_T spectra (1%)

- **Cocktail ratio:**
  - η/π^0 ratio (2%)

$$\frac{\boxed{\langle \epsilon f \rangle}\boxed{\left(\frac{N_\gamma^{incl}}{N_\gamma^{\pi^0}}\right)_{Data}}}{\boxed{\left(\frac{\gamma^{hadron}}{\gamma^{\pi^0}}\right)_{Sim}}}$$



Fake π^0 subtraction — event mixing method



FG = conversion ⊗ cluster pairs (pick two tracks from event1, and then pair with clusters from event1)

BG_{uncorr} = conversion ⊗ uncorrelated cluster pairs (pick two tracks from event1, and then pair with clusters from event2)

BG_{corr} + BG_{comb} = fake conversion ⊗ cluster pairs (pick one track from event1, one track from event2, and then pair with clusters from both events)

BG_{comb} = fake conversion ⊗ uncorrelated cluster pairs (pick one tracks from event1, one track from event2 and then pair with clusters from event3)

Residual background subtraction

Embedding in high multiplicity simulation vs real data

- Embed single π^0 ($ee\gamma$) in 280 π^0 event
  - generate $ee\gamma$ + 280 π^0 oscar file (no vertex match)
  - feed oscar input to PISA (use $ee\gamma$ event vertex)
  - run pisaToDST (vertex smearing 0.5cm)
  - run analysis module (smearing & scaling constants applied)

associate true info

save charged tracks out	McSingle $\longrightarrow$	particle+parent id, generation, vertex, momentum, primary id, primary vertex, primary momentum)
save clusters out	emcGeaTrack	

- $N_{incl/tag}$: e^+e^- and $e^+e^-\gamma$ pairs from $ee\gamma$ event (originate from the same primary particle)