A PYTHIA Simulation Study of Direct-Photon and π^0-Triggered Hadron Correlations in p+p Collisions at $\sqrt{s_{NN}} = 200$ GeV

By Chris Marble (REU Student, Tarleton State University)

Advisor: Dr. Saskia Mioduszewski (Texas A&M University)

A&M Cyclotron REU Presentation

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Outline

- Background and Motivation
- PYTHIA Simulation Conditions and Analysis
- Comparison of Simulation vs. STAR Data
- Study of pT trigger/pT parton distribution
- Future Work

Background

- Relativistic Heavy Ion Collider (RHIC) collides Au+Au at 0.99995 c.
- The collision is believed to temporarily create a new state of matter called Quark Gluon Plasma.
- Early collisions of quarks and gluons (within protons and neutrons) in the Au nuclei can result in hard scattering. However in Au+Au collisions hard scattered partons must pass through QGP.

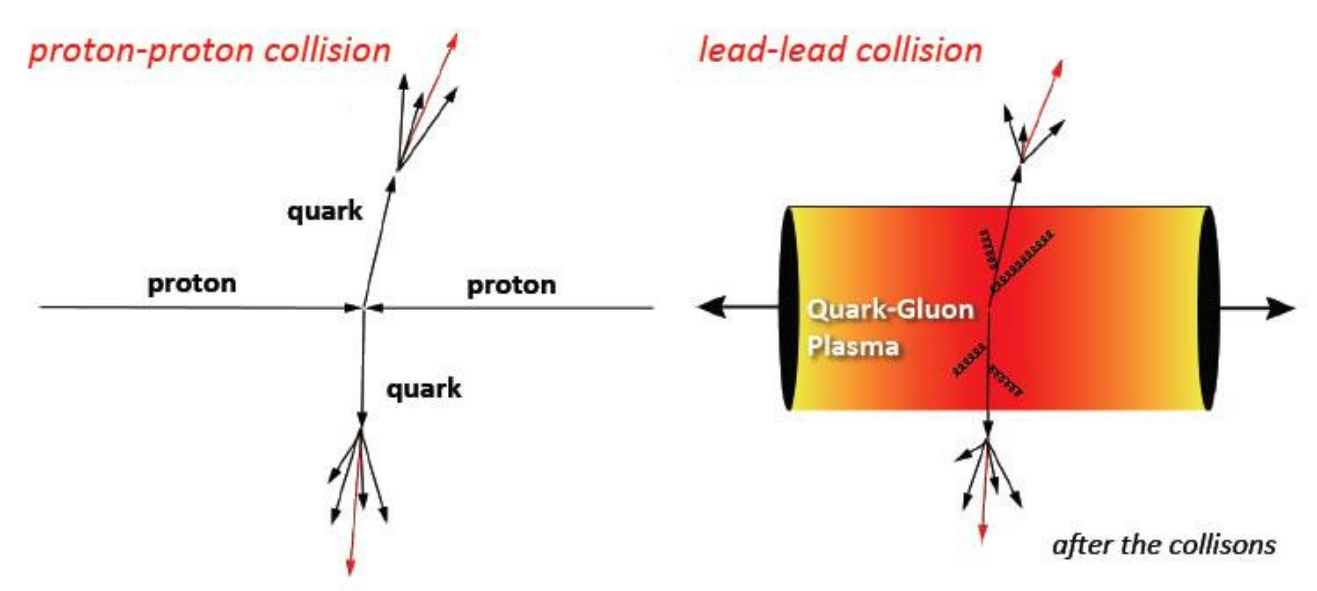

Image from: http://www.staff.science.uu.nl/~misch101/research.htm

Motivation

- Simulation of photon + jet versus jet + jet production
  - How well are per-trigger yields measured in p+p reproduced by simulation?
  - What can simulation tell us about how much of the jet energy is carried by the trigger particle?

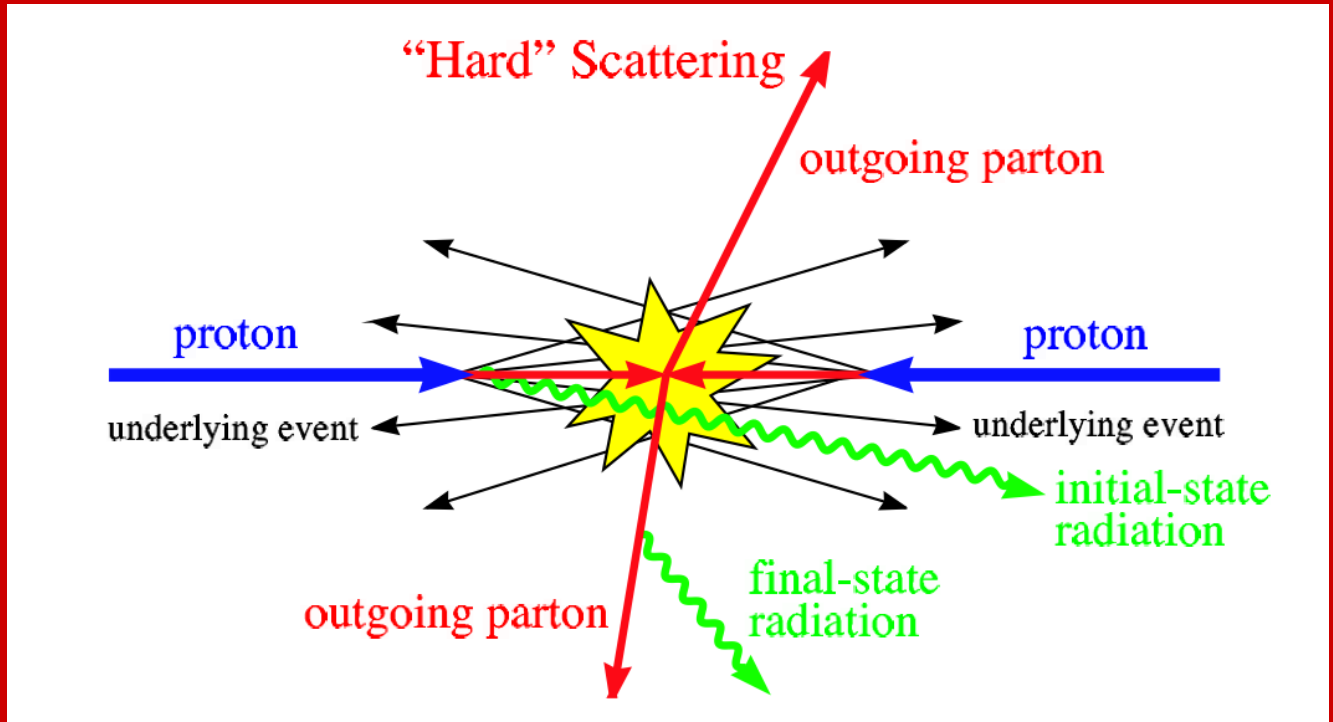

Image 1 from: http://inspirehep.net/record/853601/plots

Image 2 from: http://www-cdf.fnal.gov/physics/new/qcd/run2/ue/chgjet/

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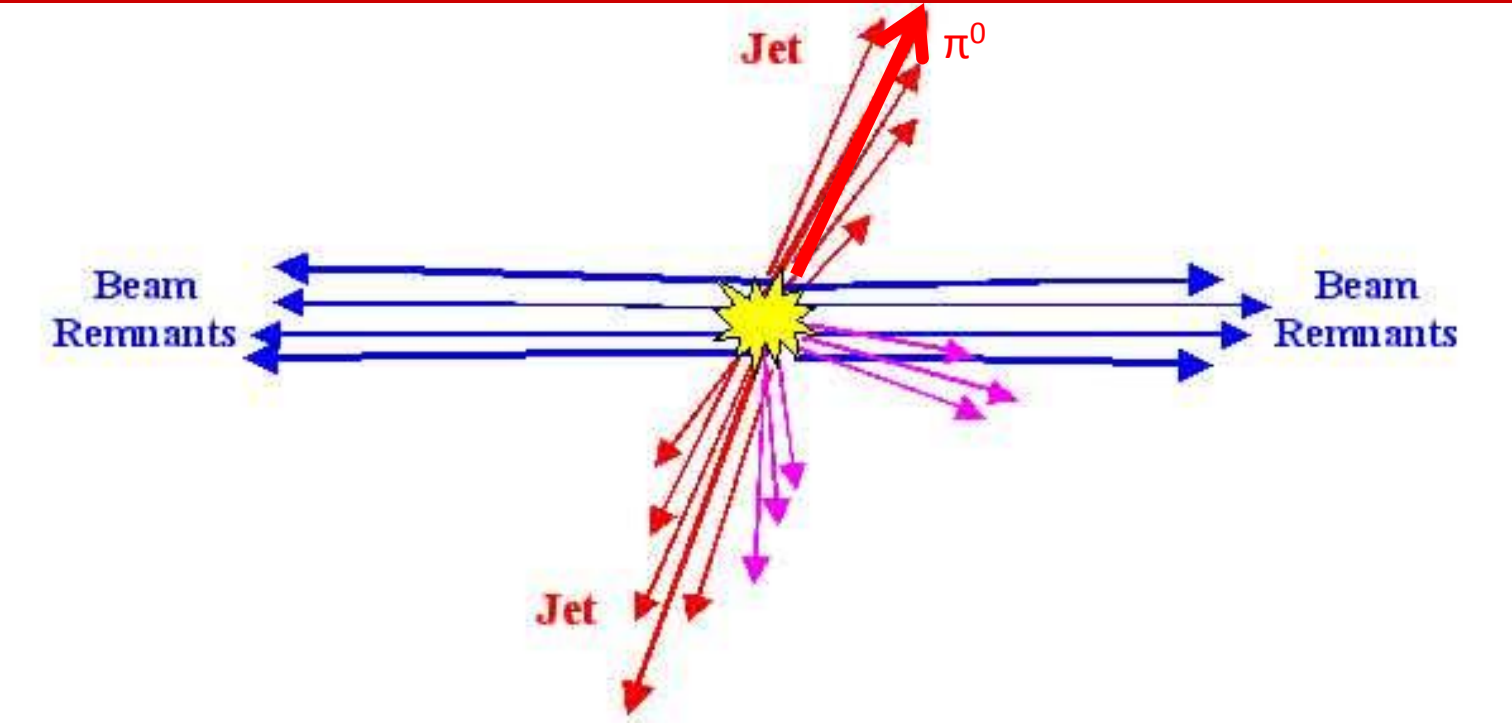

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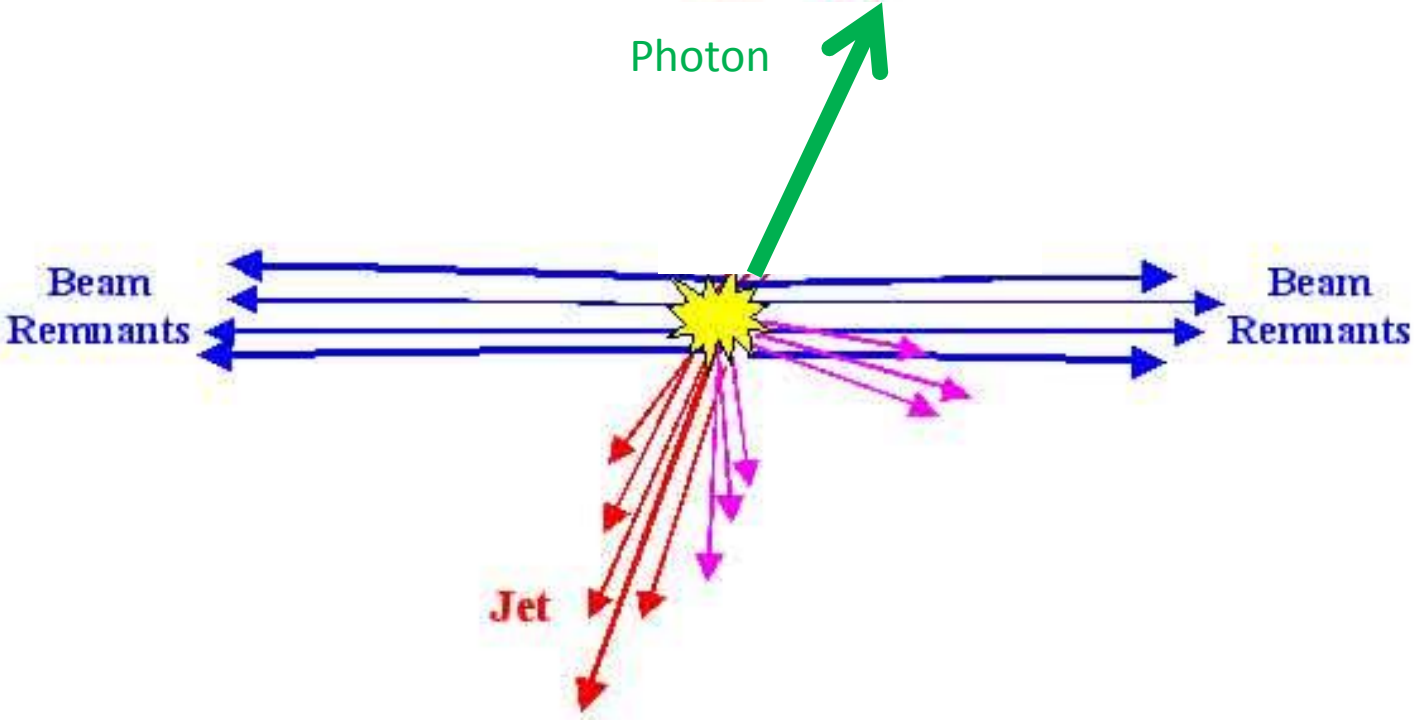

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Simulation Parameters

- Using the PYTHIA 8.185 event generator
- Kept events with a photon or π^0 with a high transverse momentum (pT) > 5 GeV/c and pseudorapidity ($|\eta|$) < 1.
- Kept associated hadrons that were charged with a pT > 1 GeV/c and $|\eta|$ < 1.

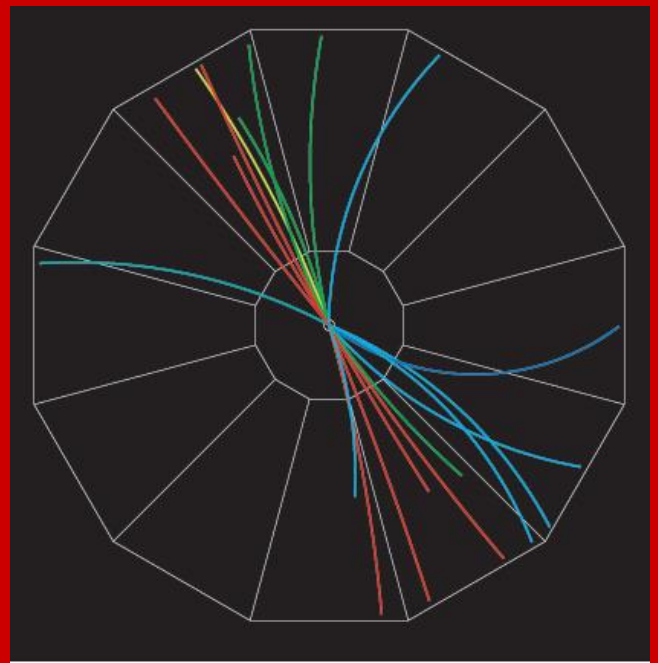


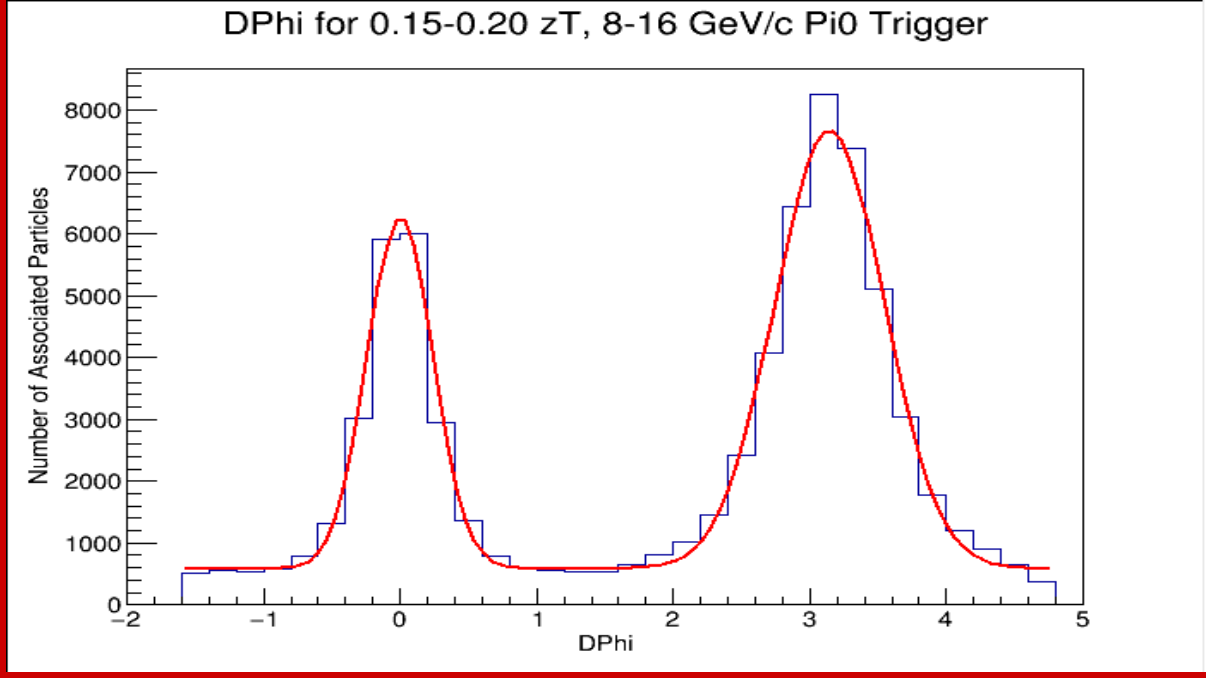
Image from:
http://www.quantumdiaries.org/tag/heavy-ion-physics/

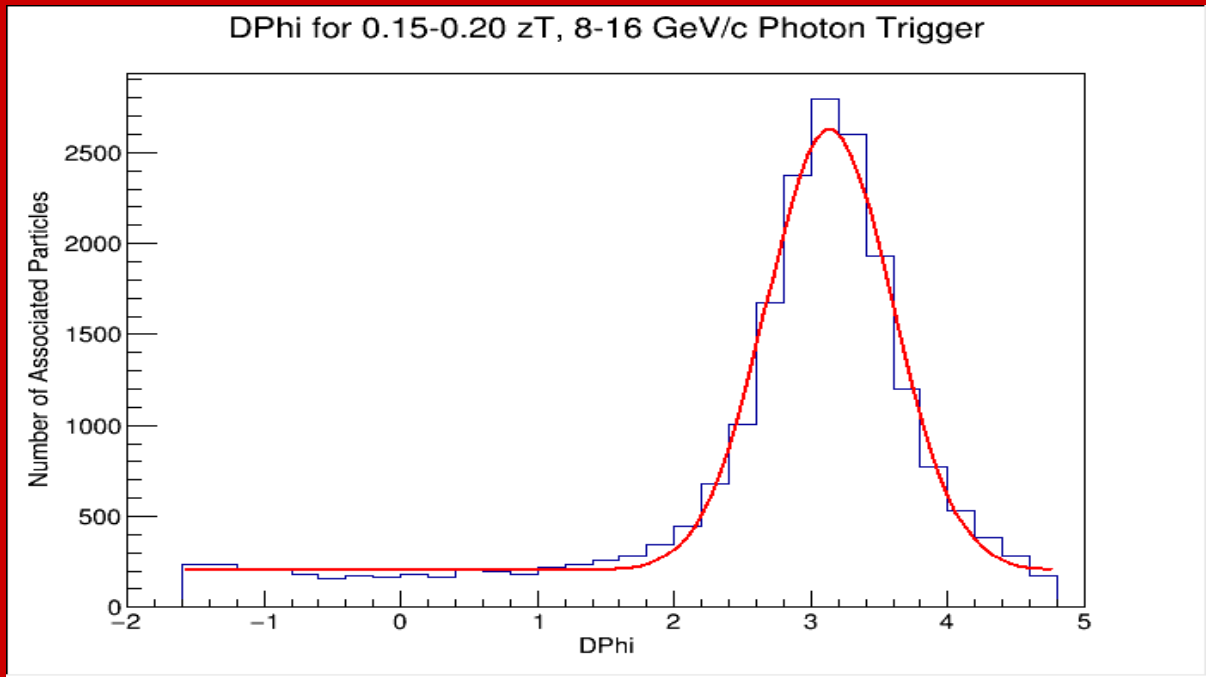
Analysis

- Analyzed events with transverse trigger momentum $8 < \mathrm{pT} < 16$ GeV/c (previous publication) or $12 < \mathrm{pT} < 20$ GeV/c (current paper draft)
- Studied pT of associated particles in away jet and near jet (π^0 case).
- Made separate histograms for different zT cuts
- $zT \equiv pT^{\mathrm{assc}} / pT^{\mathrm{trig}}$

8-16 GeV/c Histograms Analyzed:

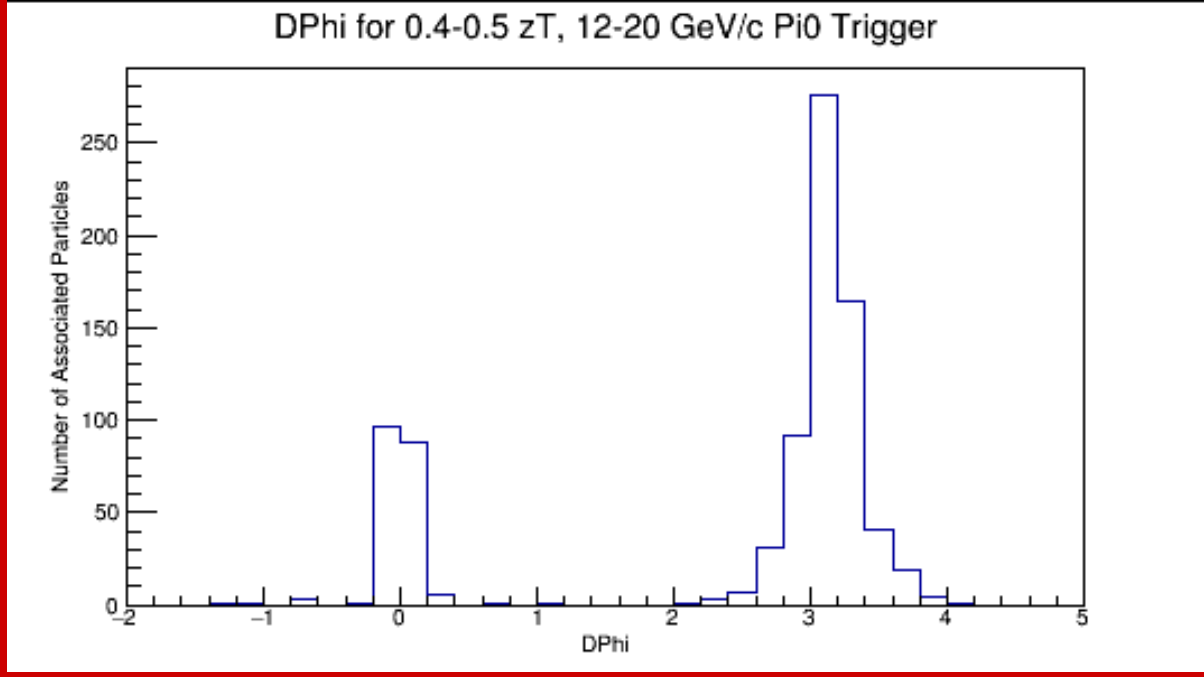
1. Fit two Gaussians and a uniform background.
2. Took background value and uncertainty from the fit
3. Integrated histogram peaks (-0.63, 0.63) and (π – 0.63, π + 0.63)
4. Subtracted the background
5. Normalized by dividing by the number of trigger particles.

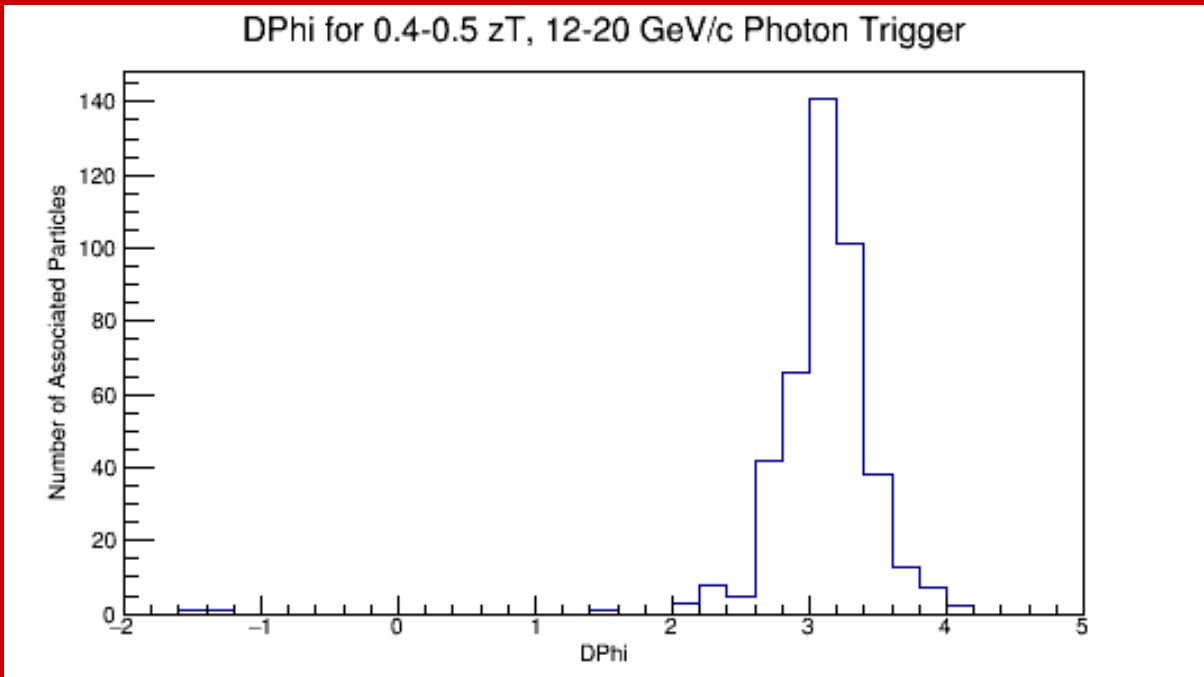


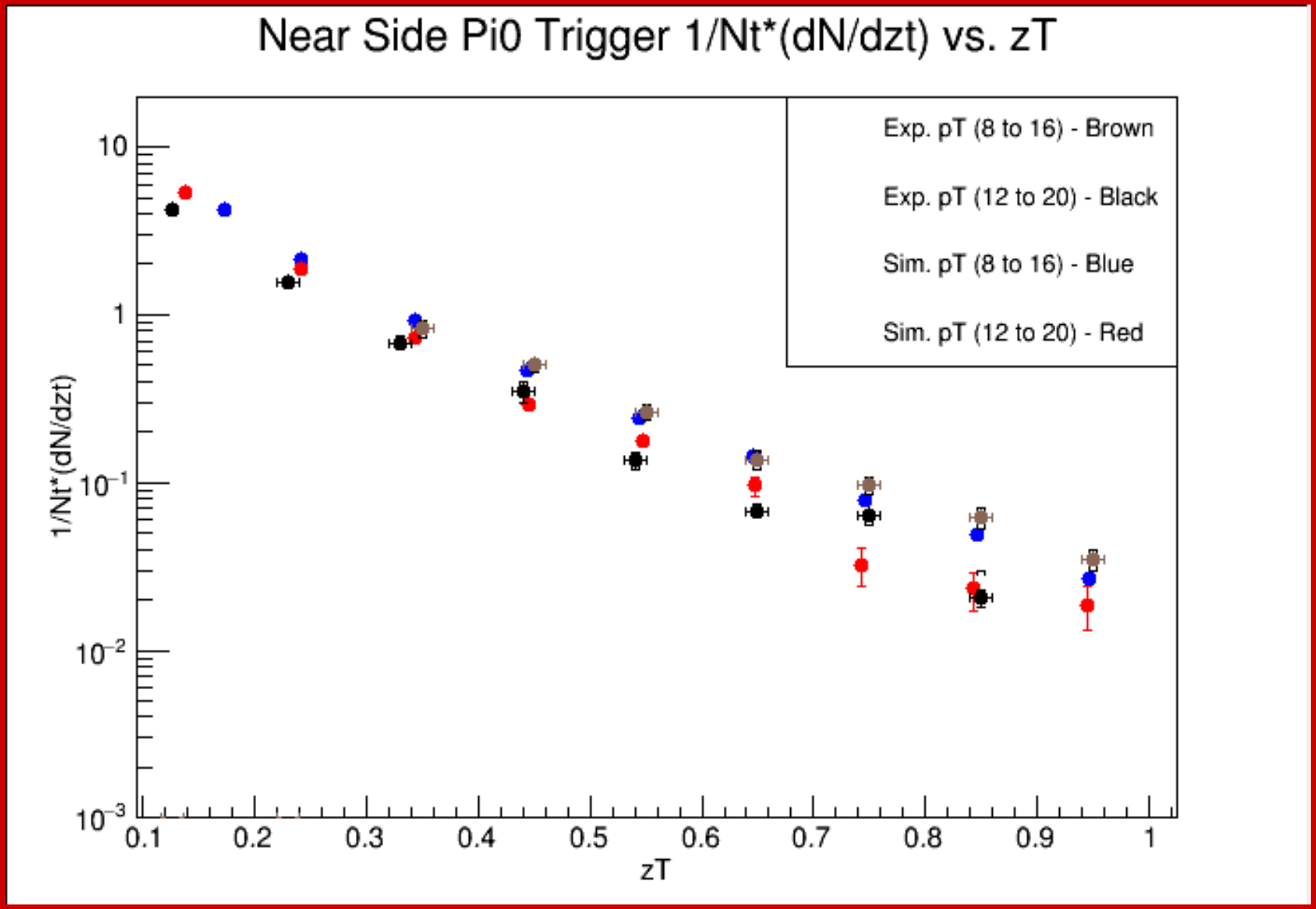


12-20 GeV/c Histograms Analyzed:

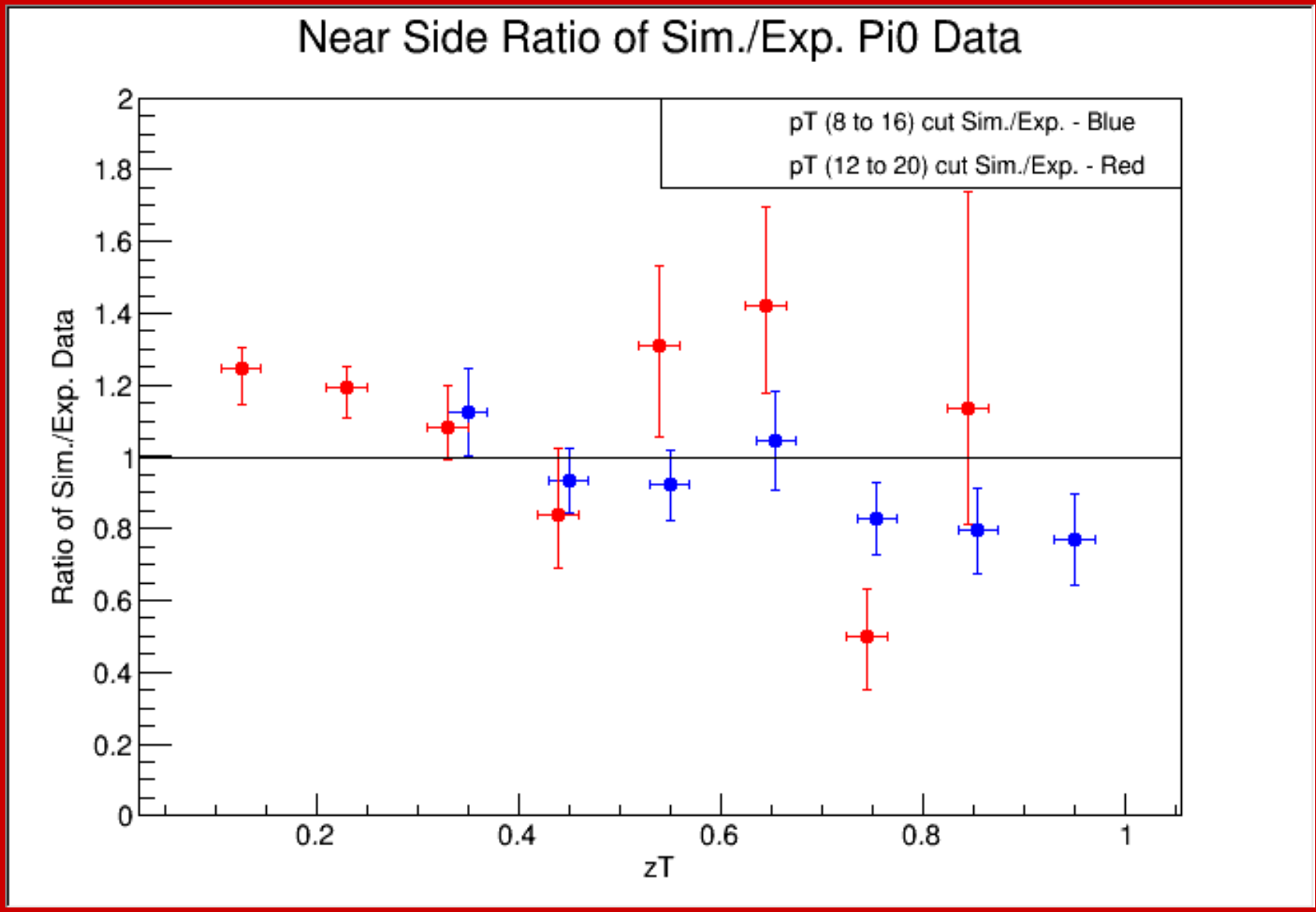
1. Integrated peaks (-1.4, 1.4) and (π - 1.4, π + 1.4)
2. Subtracted the background calculated as the average value over (-1.4 , -0.8) and (0.8 ,1.4)
3. Normalized by dividing by the number of trigger particles.



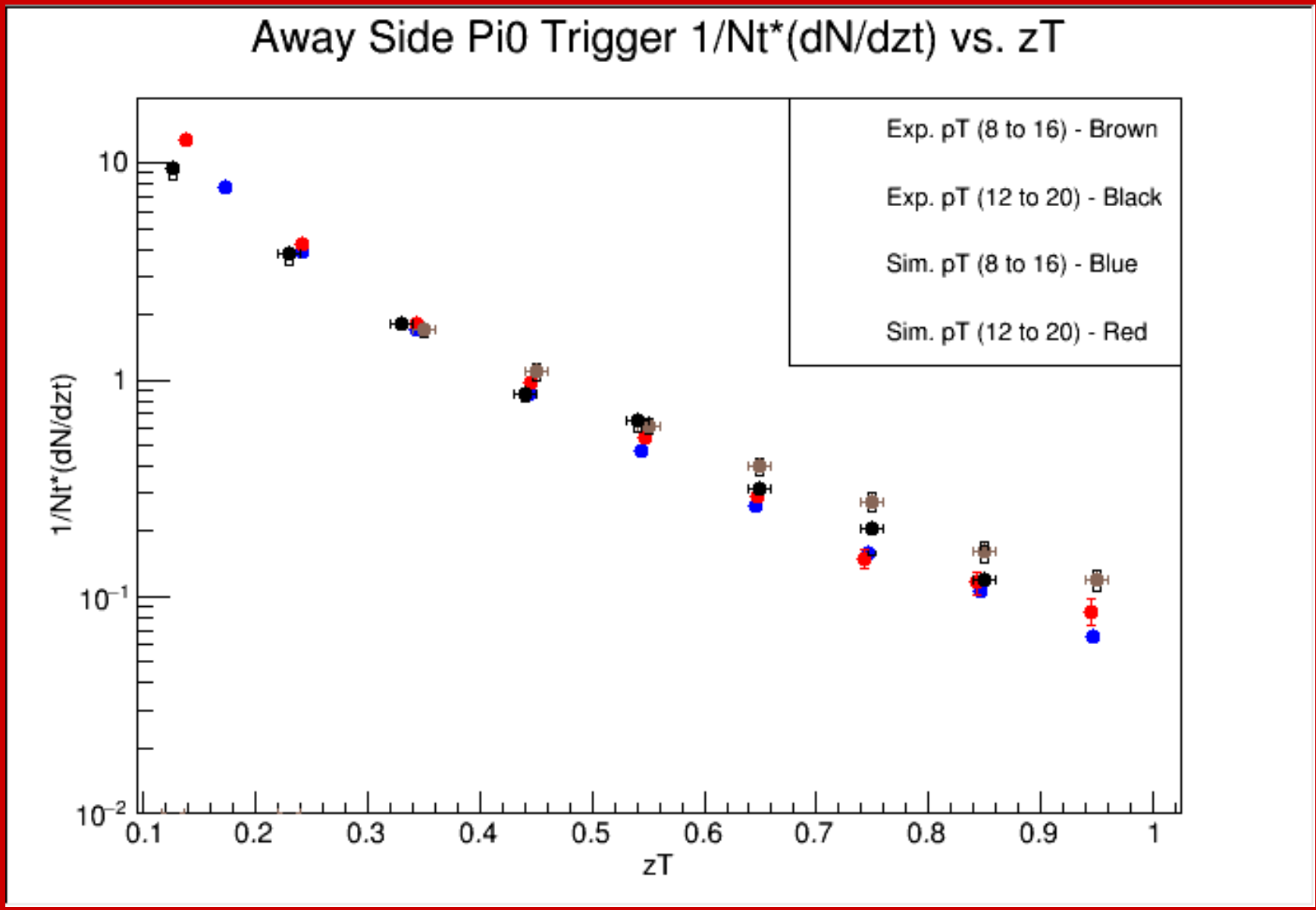




Compare Sim. to Exp.
blue to brown (8-16 GeV/c), red to black (12-20 GeV/c)

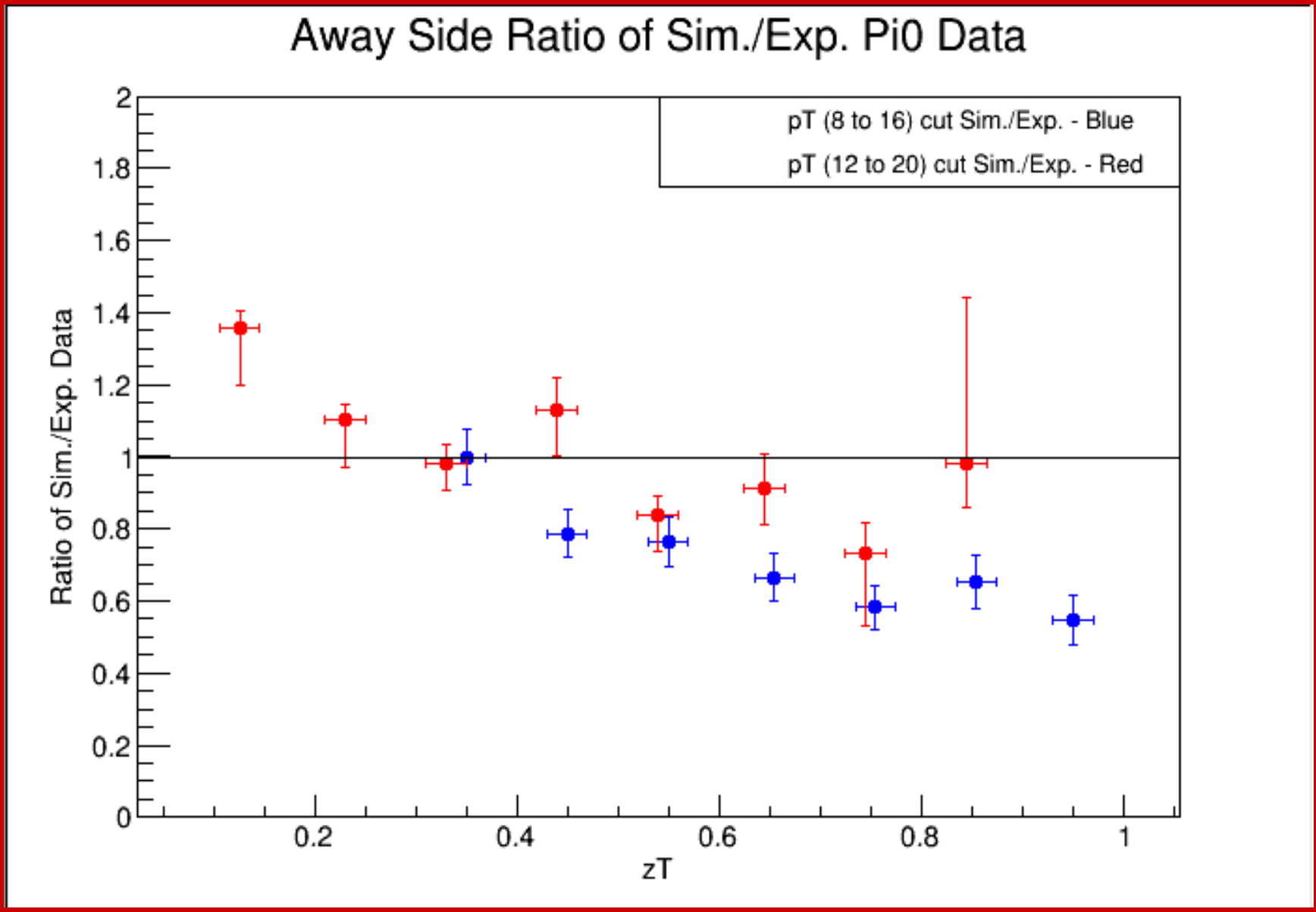


Reasonable agreement for both pT ranges

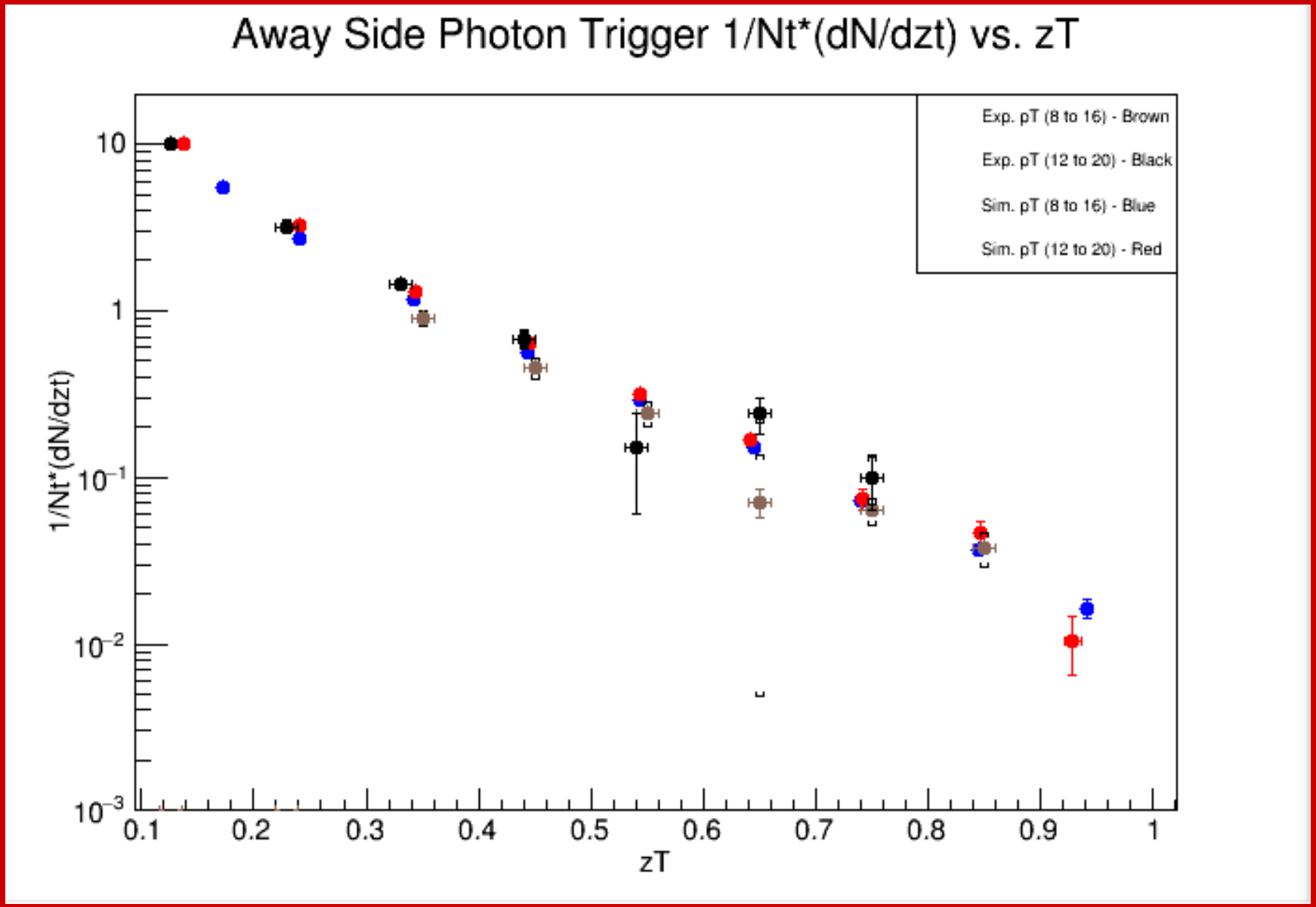


Compare Sim. to Exp. for the away side jet with π^0 triggers

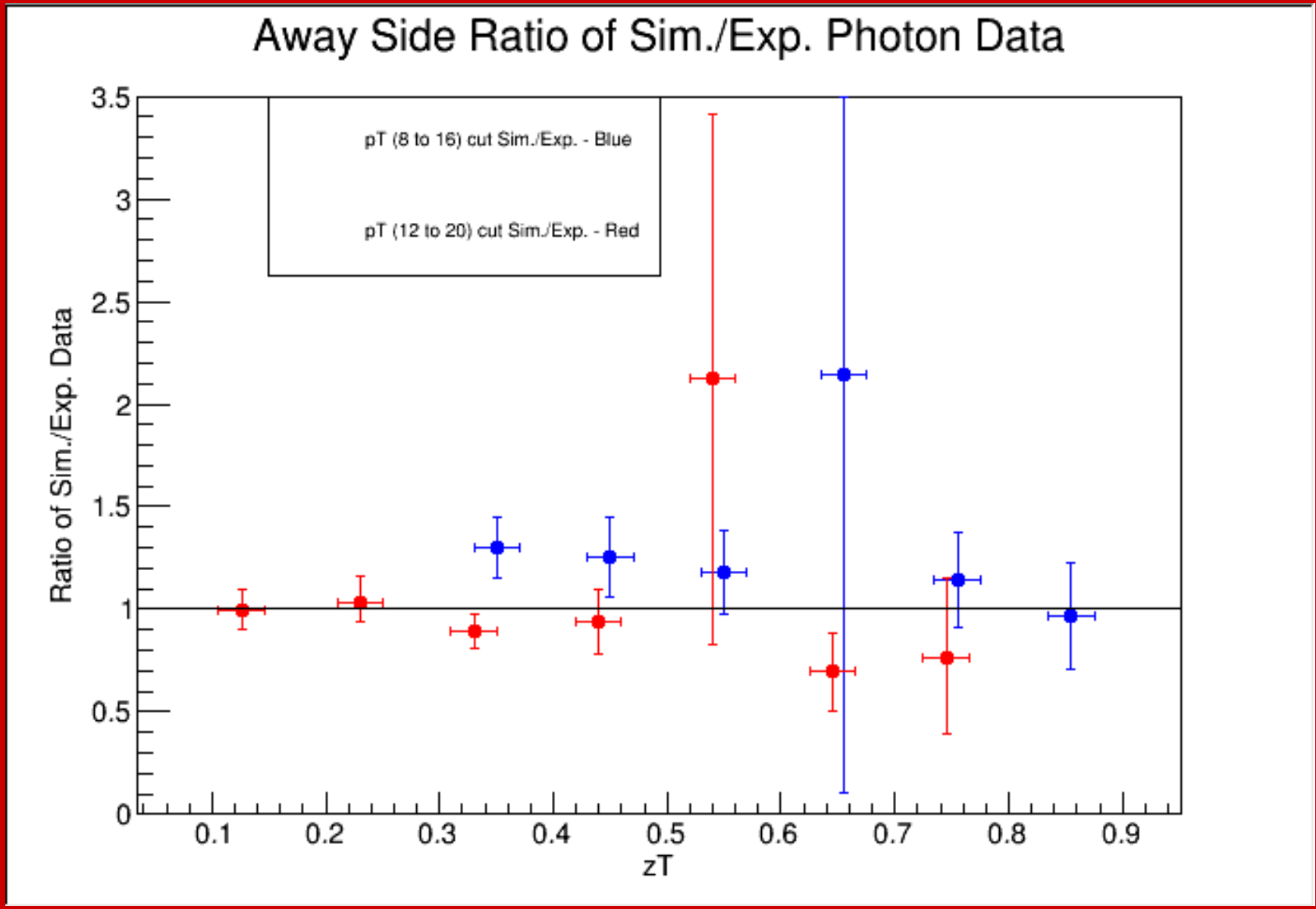
Note: blue to brown (8-16 GeV/c) is not in agreement at high zT



Simulation underestimates yield for 8-16 GeV/c pT range
Reasonable agreement for 12-20 GeV/c pT range



Compare Sim. to Exp for the away side jet for photon triggers
Reasonable agreement for simulation and experiment

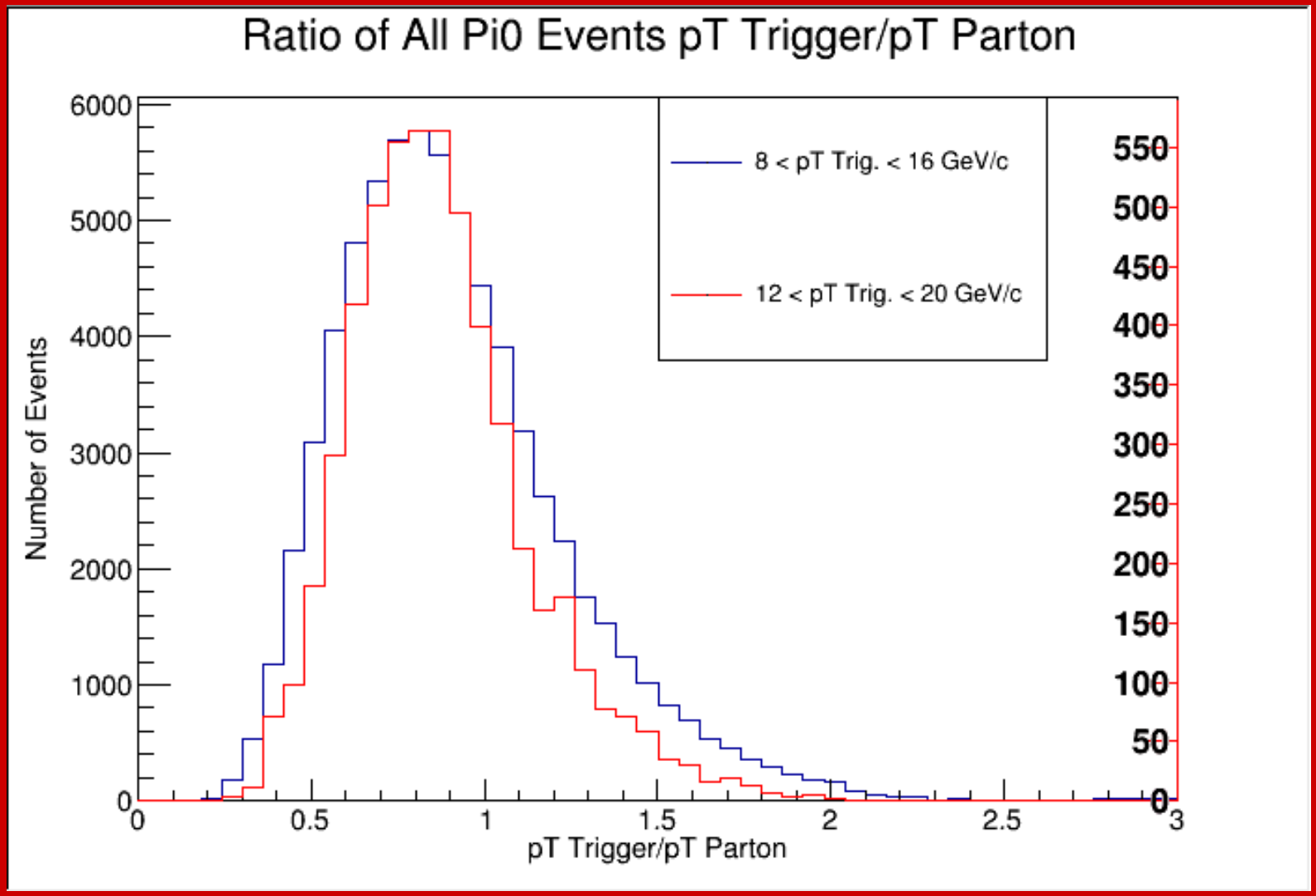


Note: Large uncertainties caused by large uncertainties in the experimental data points

Simulation Verification

- 12-20 GeV/c simulation appears to be in agreement with the STAR Data
- 8-16 GeV/c simulation is also in agreement with STAR Data except for high-zT π^0 away jet values
- Reason is undetermined.

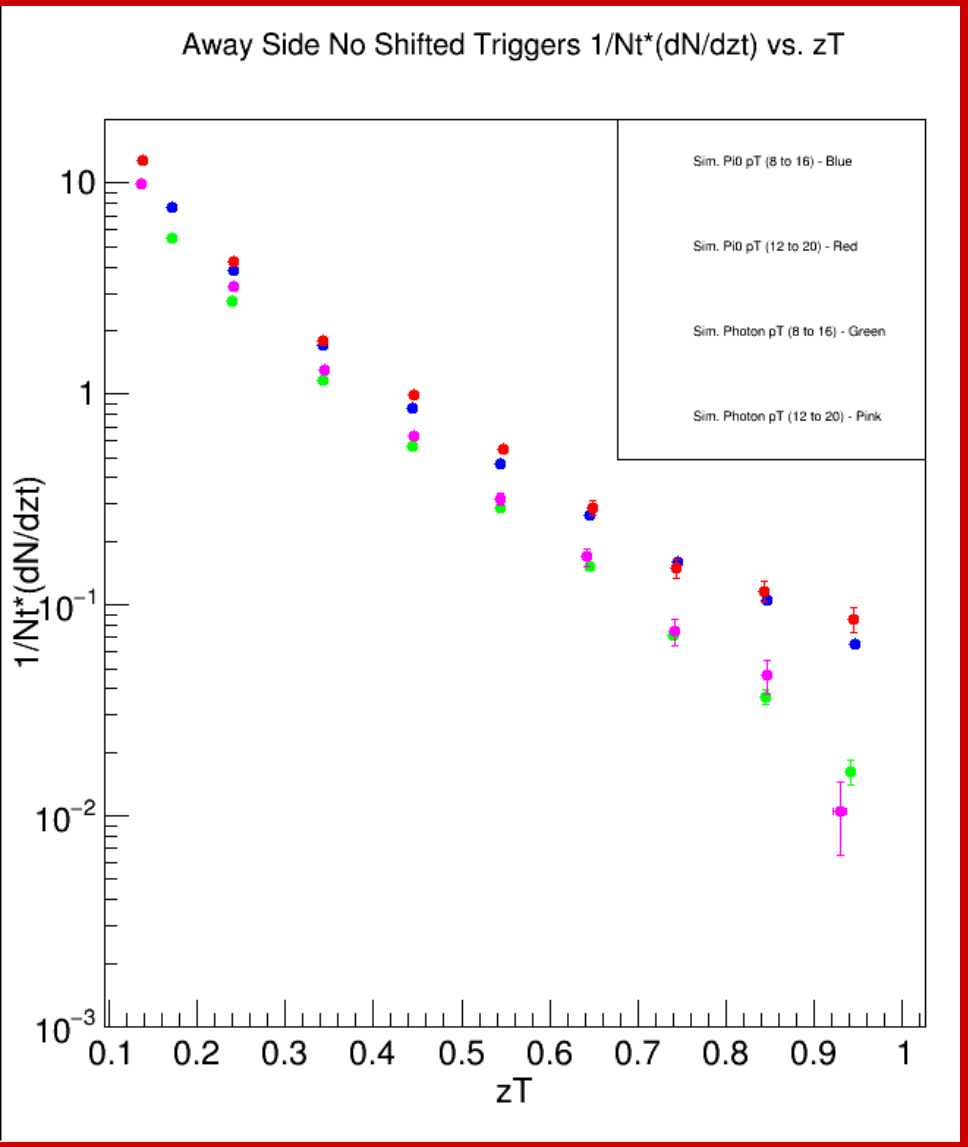
Now lets compare the away side jet zT yields for photon triggers versus π^0 triggers.

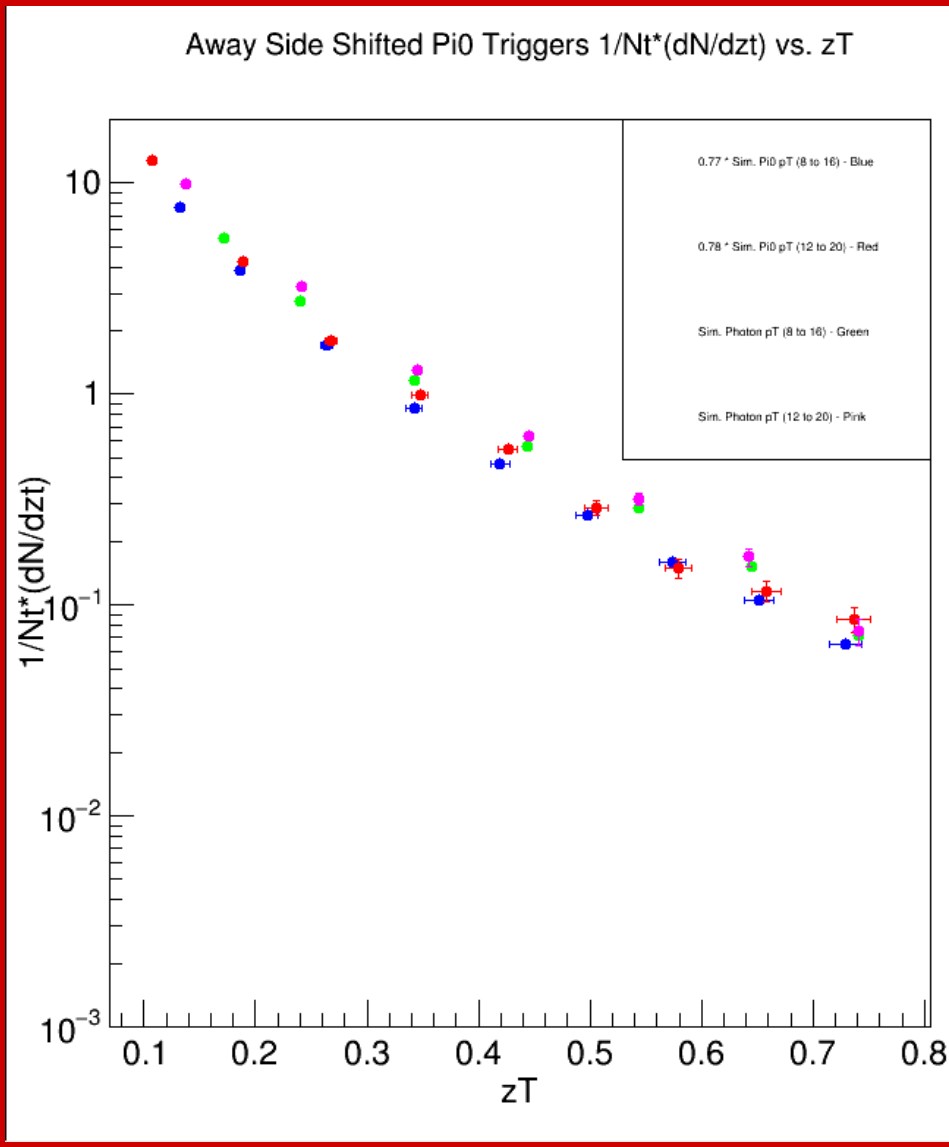


8-16 GeV/c Pi0 Peak: 0.77 ± 0.02

12-20 GeV/c Pi0 Peak: 0.78 ± 0.02

*where pT Parton is the pT of the away-side jet parton





π^0 simulation data
unshifted

π^0 pT 8-16 GeV/c shifted 0.77*zT
π^0 pT 12-20 GeV/c shifted 0.78*zT

Photon vs. π^0 summary

- π^0 triggers have on average approximately 80% of the pT of the scattered parton
- Correcting for this results in yields for π^0 and photon triggering that are close to agreement

Future Work

- Understand pT π^0 Trigger/pT Parton > 1
- Look at the effect of removing kT (intrinsic parton pT) from the π^0 simulation
- Look at the effects of removing Initial and Final State Radiation from the π^0 simulation.

Acknowledgements

- My advisor: Dr. Saskia Mioduszewski
- Dr. Nihar Sahoo - for providing guidance as well as the pT 12-20 GeV/c experimental data
- Derek Anderson - for helping me learn Root and PYTHIA as well as providing the initial simulation code

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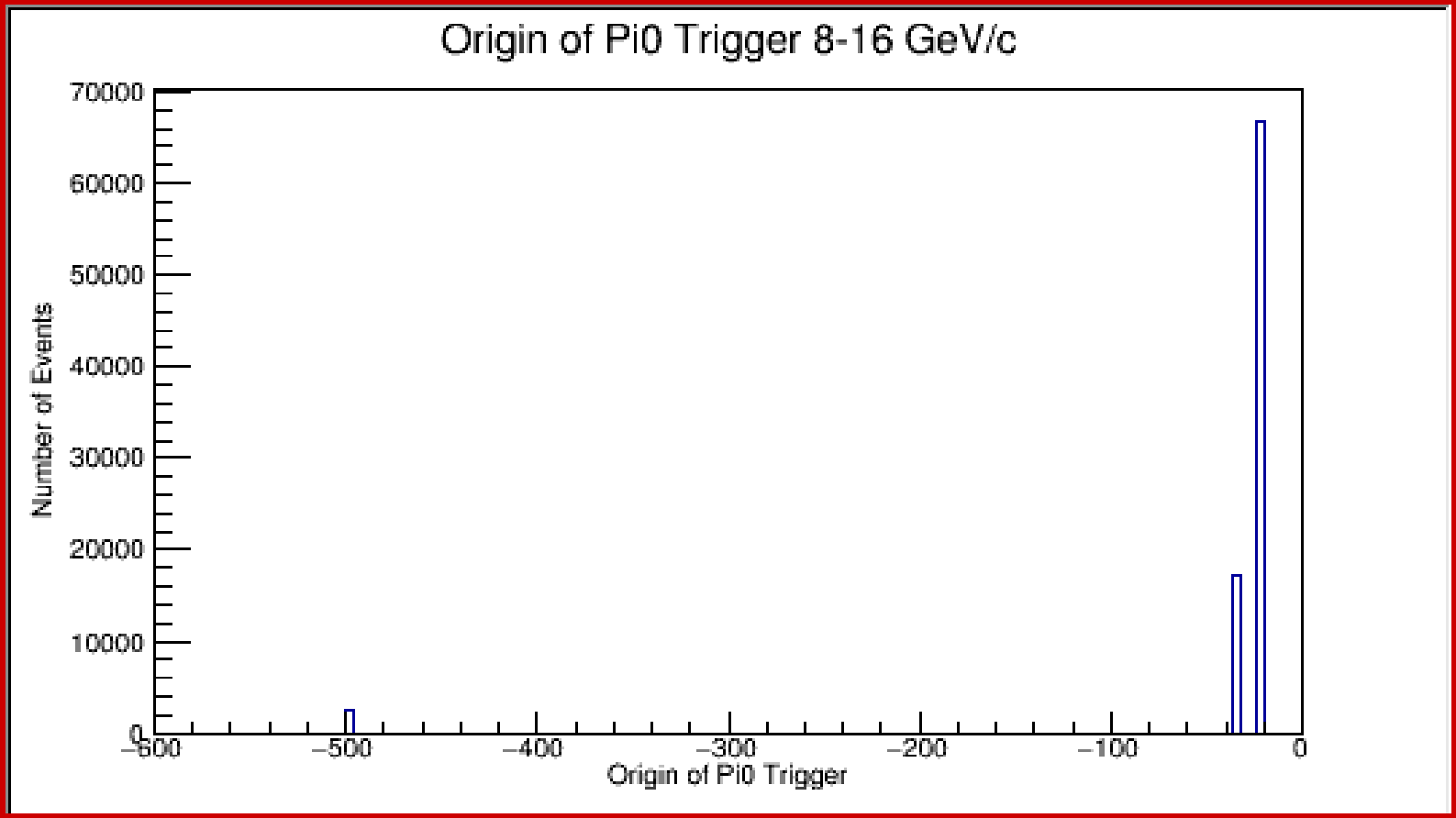
8-16 GeV/c data from: Abelev *et al.* (STAR Collaboration), Phys. Rev. C **82** (2010)

12-20 GeV/c data from: STAR Preliminary data, STAR manuscript to be submitted for publication

Extra Slides

Additional Information

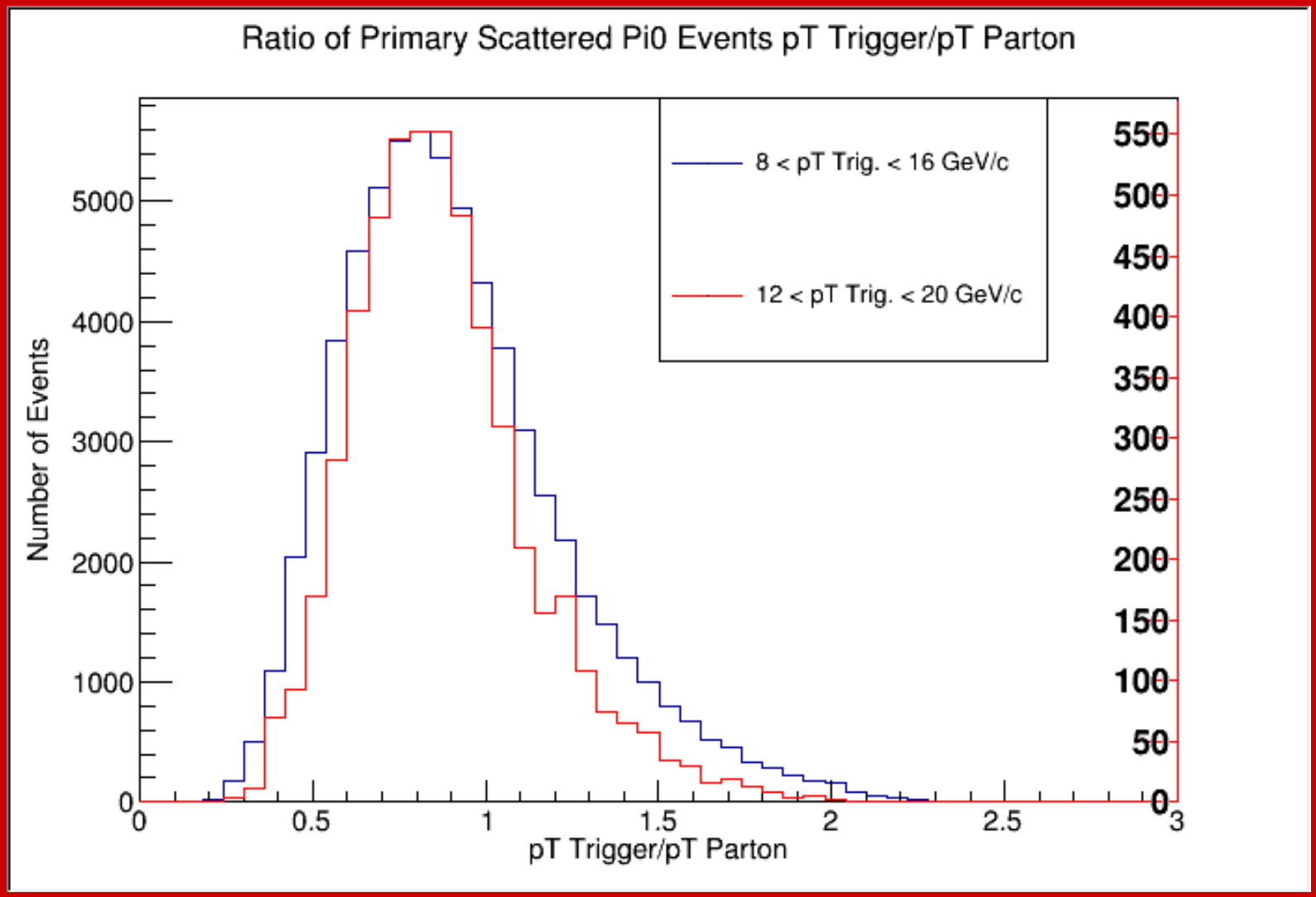
- Initial and Final State Radiation Enabled
- pTHatMin = 4 GeV/c (minimum invariant pT considered)
- 500M HQCD events simulated:
  - 86502 8-16 GeV/c Pi0 Triggers
    - 307358 Associated Particles
  - 6447 12-20 GeV/c Pi0 Triggers
    - 30764 Associated Particles
- 1M Prompt Photon events simulated:
  - 45512 8-16 GeV/c Photon Triggers
    - 93292 Associated Particles
  - 6677 12-20 GeV/c Photon Triggers
    - 18432 Associated Particles



From Primary Hard Scatter: -23

From Secondary Hard Scatter: -33

From Other (Decay, Baryogenesis of quarks not involved in the hard scatter, etc.): -500



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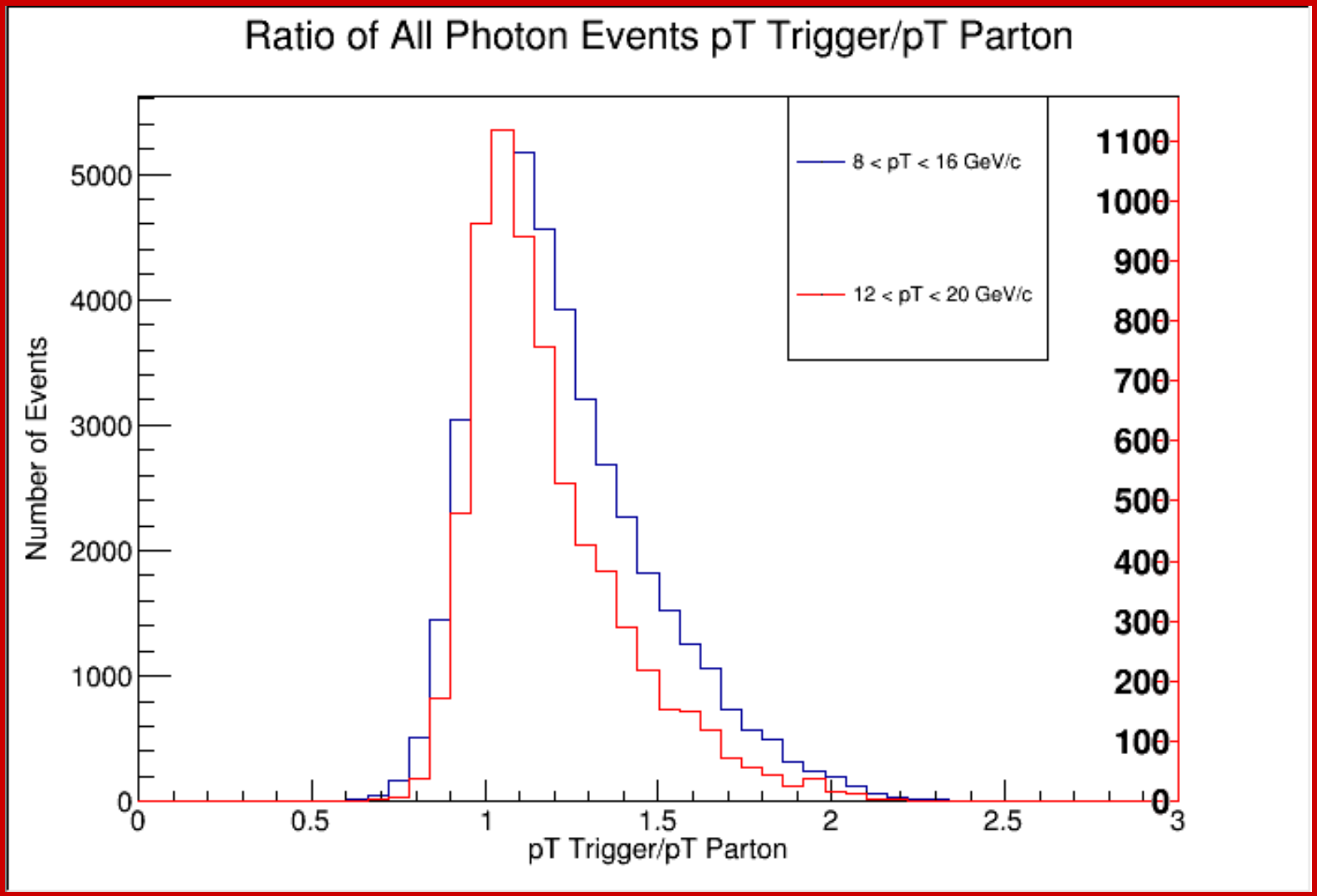
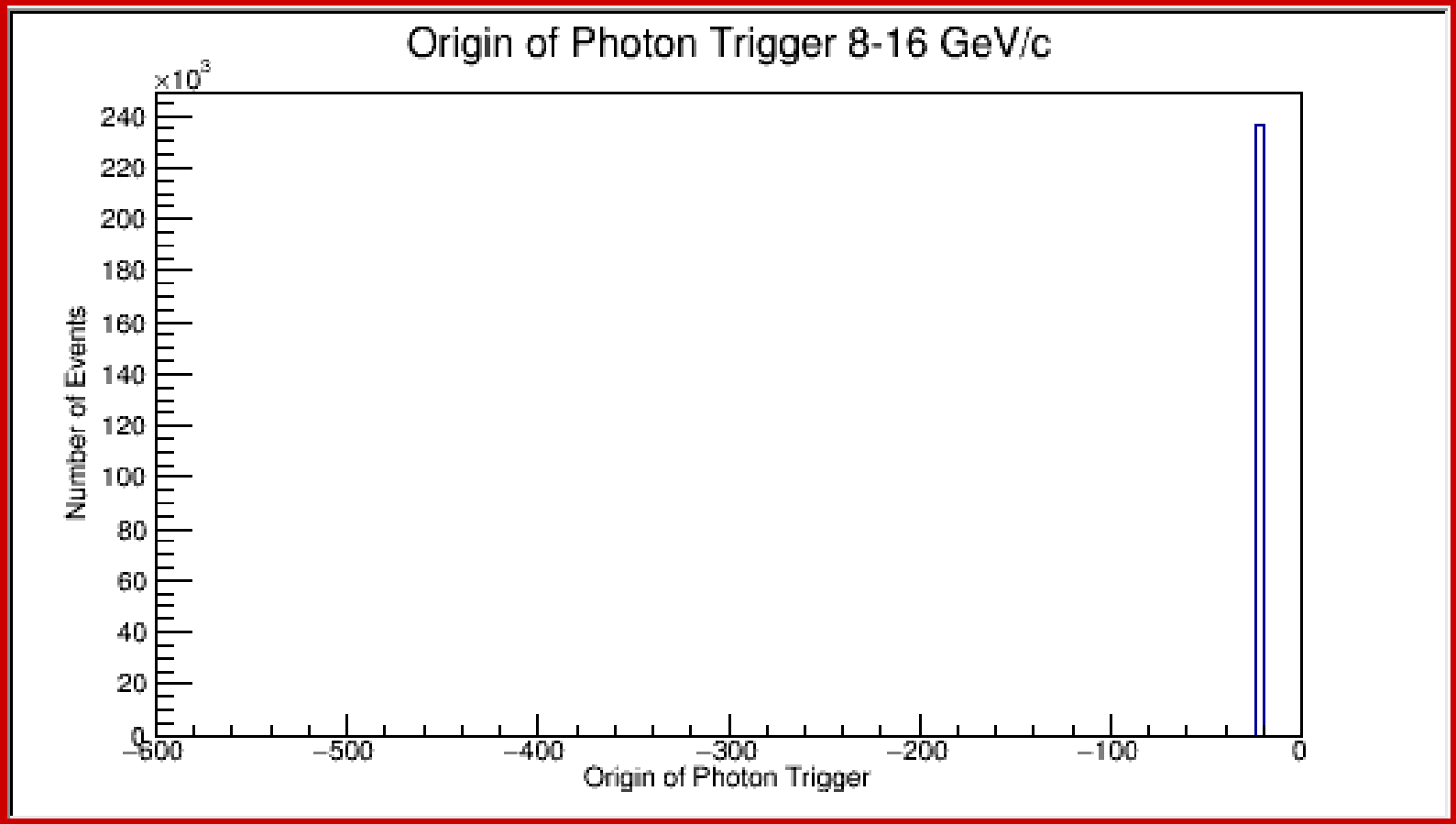


8-16 GeV/c Photon Peak: 1.07 ± 0.02

12-20 GeV/c Photon Peak: 1.04 ± 0.02

*where pT Parton is the pT of the away-side jet parton



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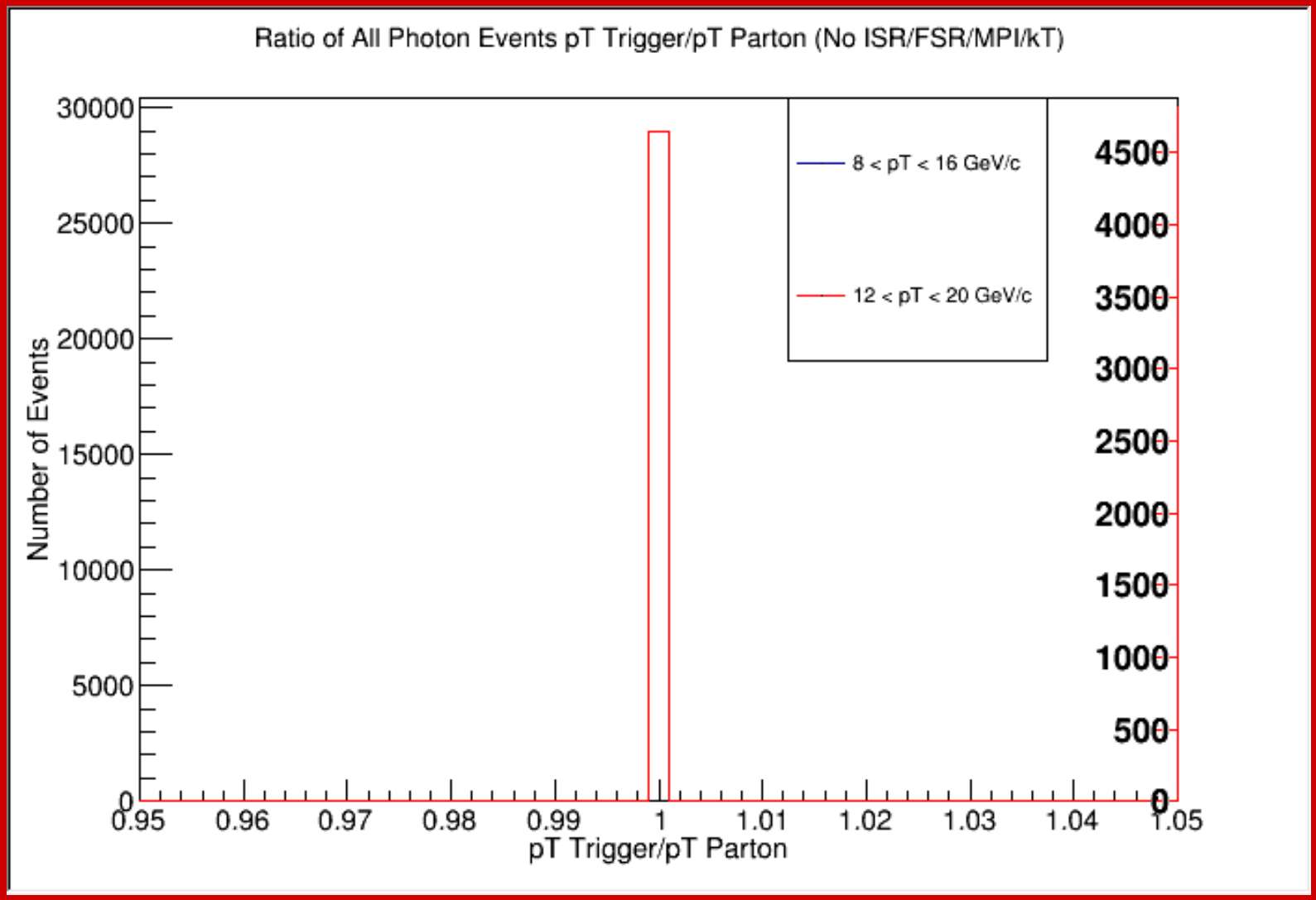

Photon Simulation without Initial and Final State Radiation (ISR and FSR), Multi-Parton Interactions (MPI) and Initial Parton pT (kT)

Note: The red line completely overlaps the blue line