Photon-hadron Correlations in Au+Au Collisions

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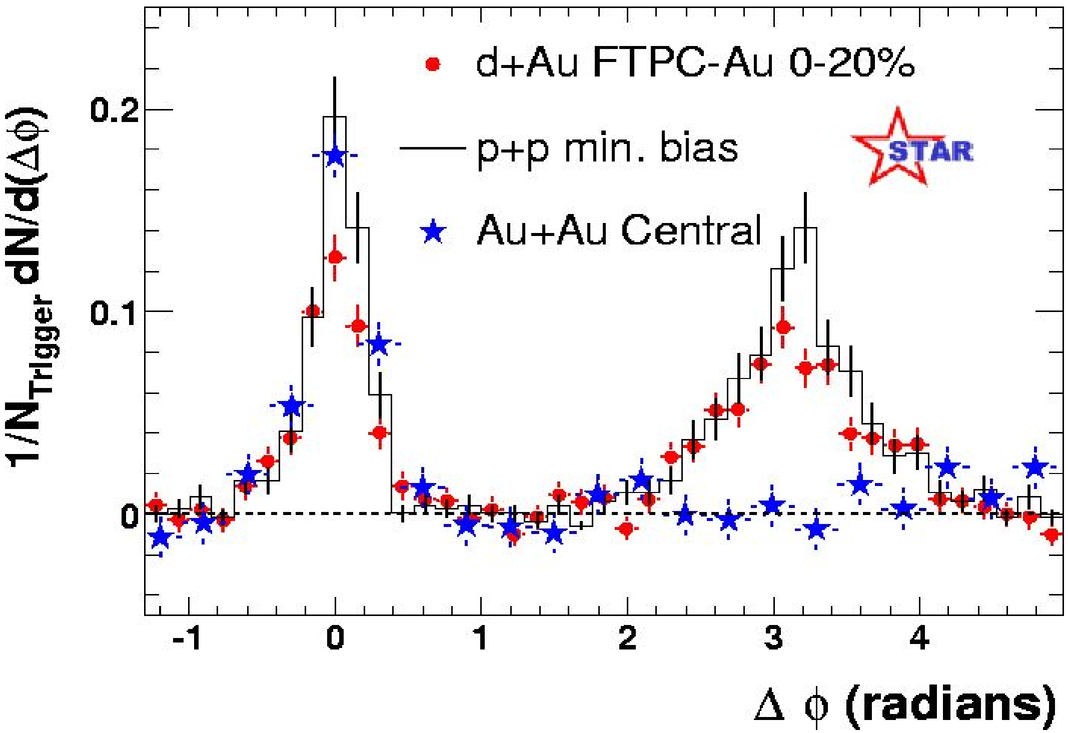
for the

STAR-Collaboration

- Introduction
- Experimental Setup
- Analysis Method
- Data and Interpretation
  - Near-side yield & prompt photon identification
  - Away-side yield
  - Hadron identification
- Summary

Motivation

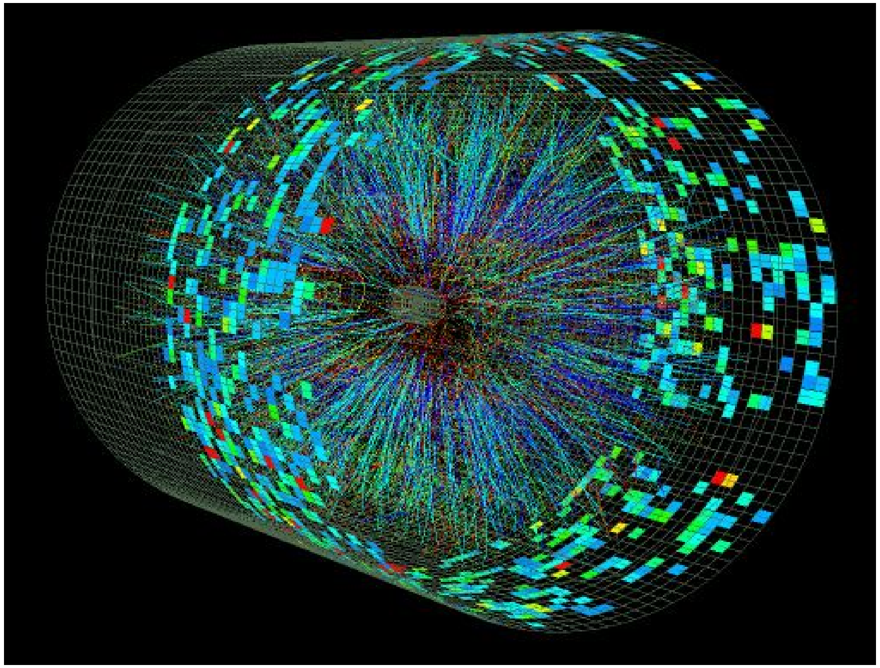
- Two-particle high-p_T correlations are an established tool
- Extension: Probing the medium with truly hard probes (**E_T> 10 GeV**)



- **Photon-hadron and hadron-hadron correlations using EM calorimetry**

see also: poster by S. Chattopadhyay: $\pi^0 \rightarrow \gamma\gamma$ in d-Au (EMC+TPC)
talk by D. Magestro: charged-charged correlations (TPC)

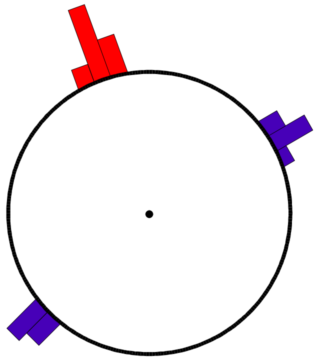
STAR Experiment and Dataset

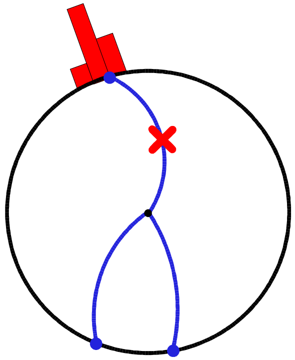


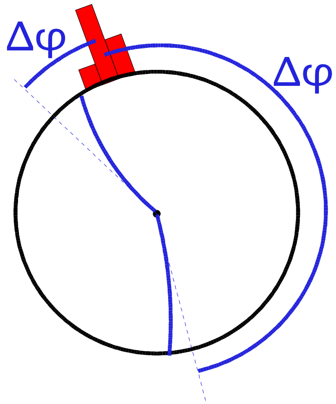
- TPC
  - main tracking detector
- EM calorimeter (EMC)
  - $0<\eta<1$ (AuAu 2004)
  - tower size 0.05x0.05
  - shower max detector (SMD)

- Au+Au @ 200GeV, 2004 run
- High-tower trigger
  - Very high threshold (9 GeV)
  - Prioritized reconstruction: "Express Stream"
  - Very small data volume: 20k events
- Available statistics:
  - this analysis: ~25 μb^{-1} equivalent of 180M minbias events
  - total on tape: ~40 μb^{-1} equivalent of 280M minbias events

Analysis method







- Use cluster (4 towers) with highest E_T as "trigger particle"
- Apply charged track veto
  - $p_T > 1 GeV$
  - $\Delta\eta < 0.03$ $\Delta\varphi < 0.03$
- Correlate with charged tracks above threshold
  - correct for tracking efficiency, track veto cut

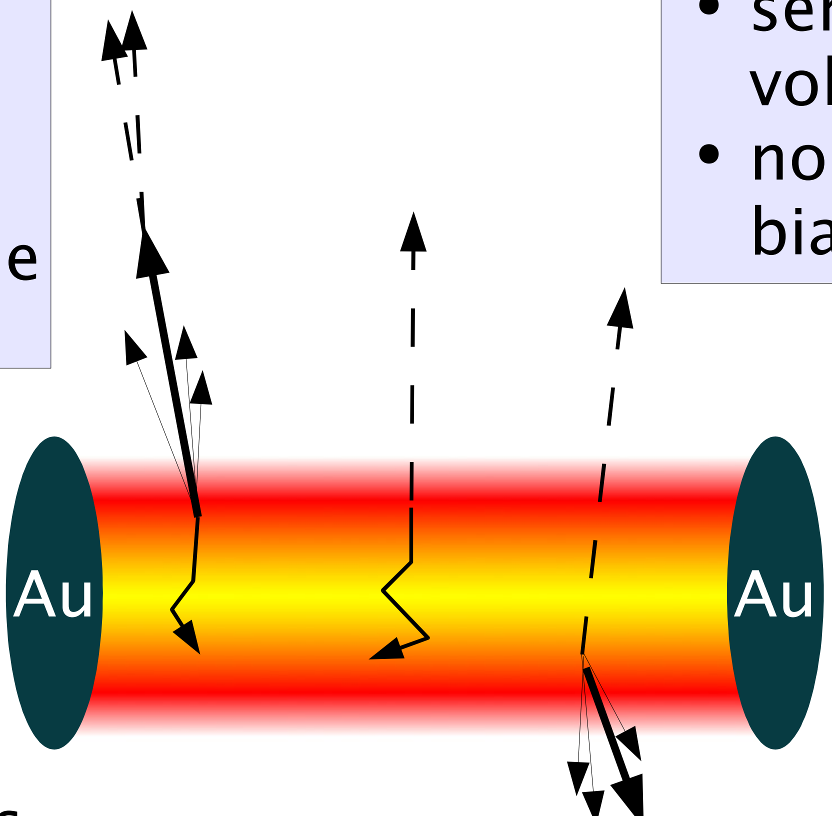
Trigger particles

Hadrons: $\pi^0 \rightarrow 2\gamma$
dijets

- interaction with medium
- surface emission
- fragmentation $E_\pi < E_{jet}$
- small opening angle → 1 EMC cluster

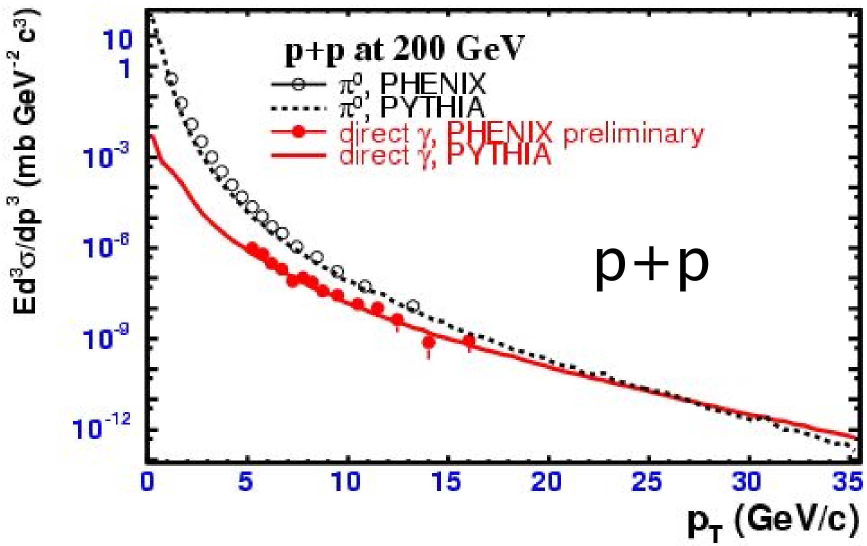
Prompt photons
γ+jet

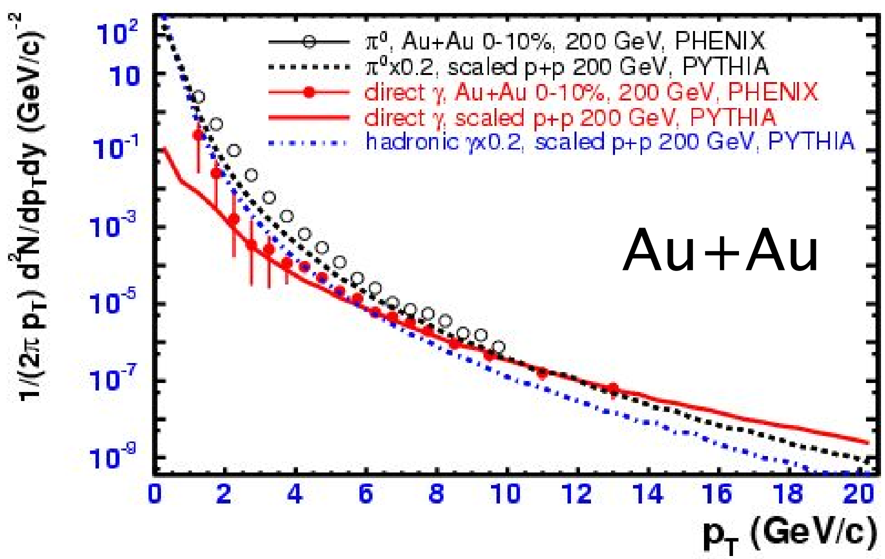
- **no** interaction with medium
- sensitive to full volume
- no fragmentation bias: $E_\gamma \approx E_{jet}$



Other sources: hadron decays, fragmentation photons

Trigger particles in AA



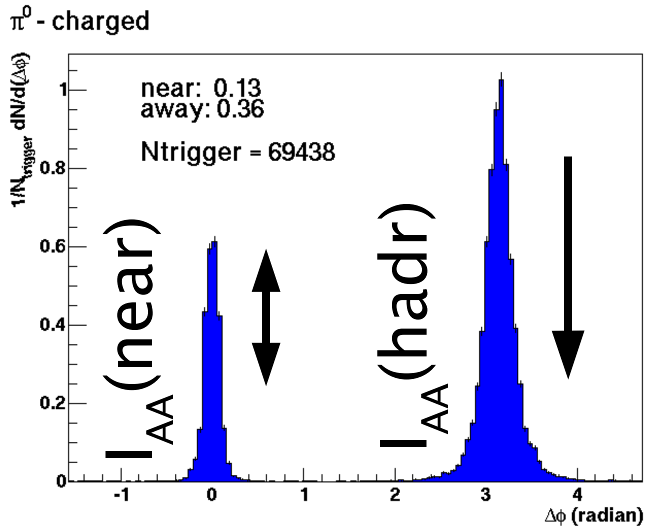


- π^0 – as hadrons – are suppressed in central AuAu
- Direct photon production is unmodified
- Prompt photon and π^0 yields similar at 10 GeV in central AuAu
- Next step: correlations
  - dijets and γ+jet: the best tools to probe the medium

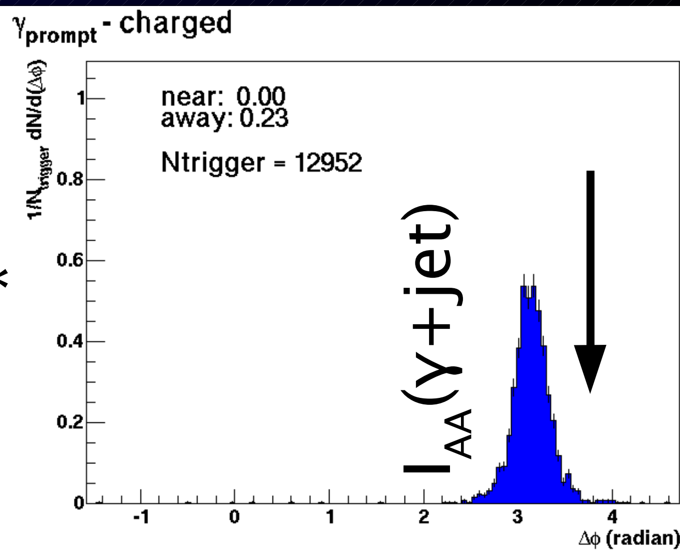
Plots from K. Filimonov, nucl-ex/0505008

Mixing dijets and γ+jet

$$\frac{\pi^0}{\pi^0+\gamma} *$$



$$+ \frac{\gamma}{\pi^0+\gamma} *$$



Near–side

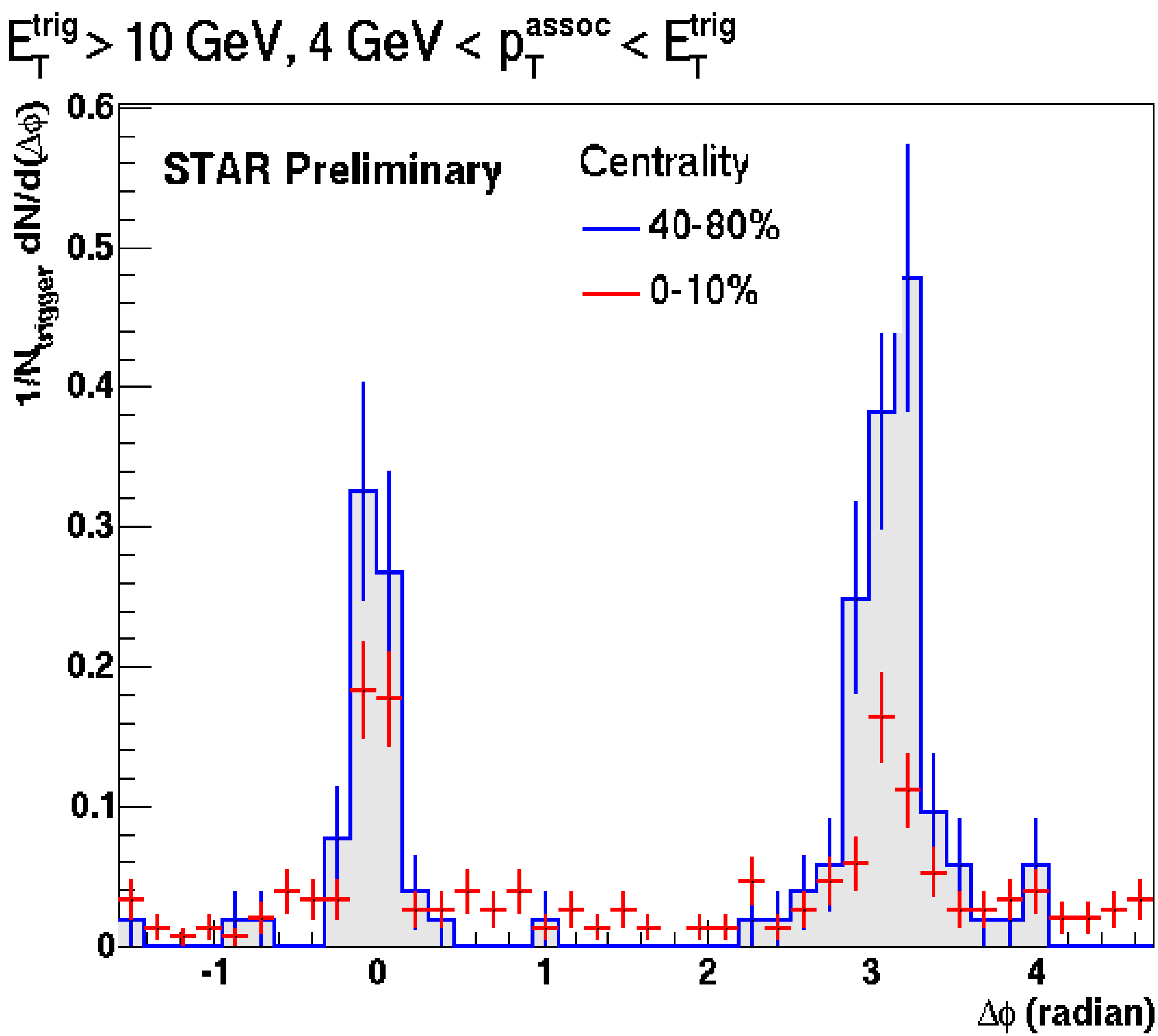
- small modification of near–side correlation with π^0: $I_{AA}(\text{near}) \approx 1$
- no associated particles in γ+jet

⇒ decrease due to higher yield of prompt photons in AA

Away–side

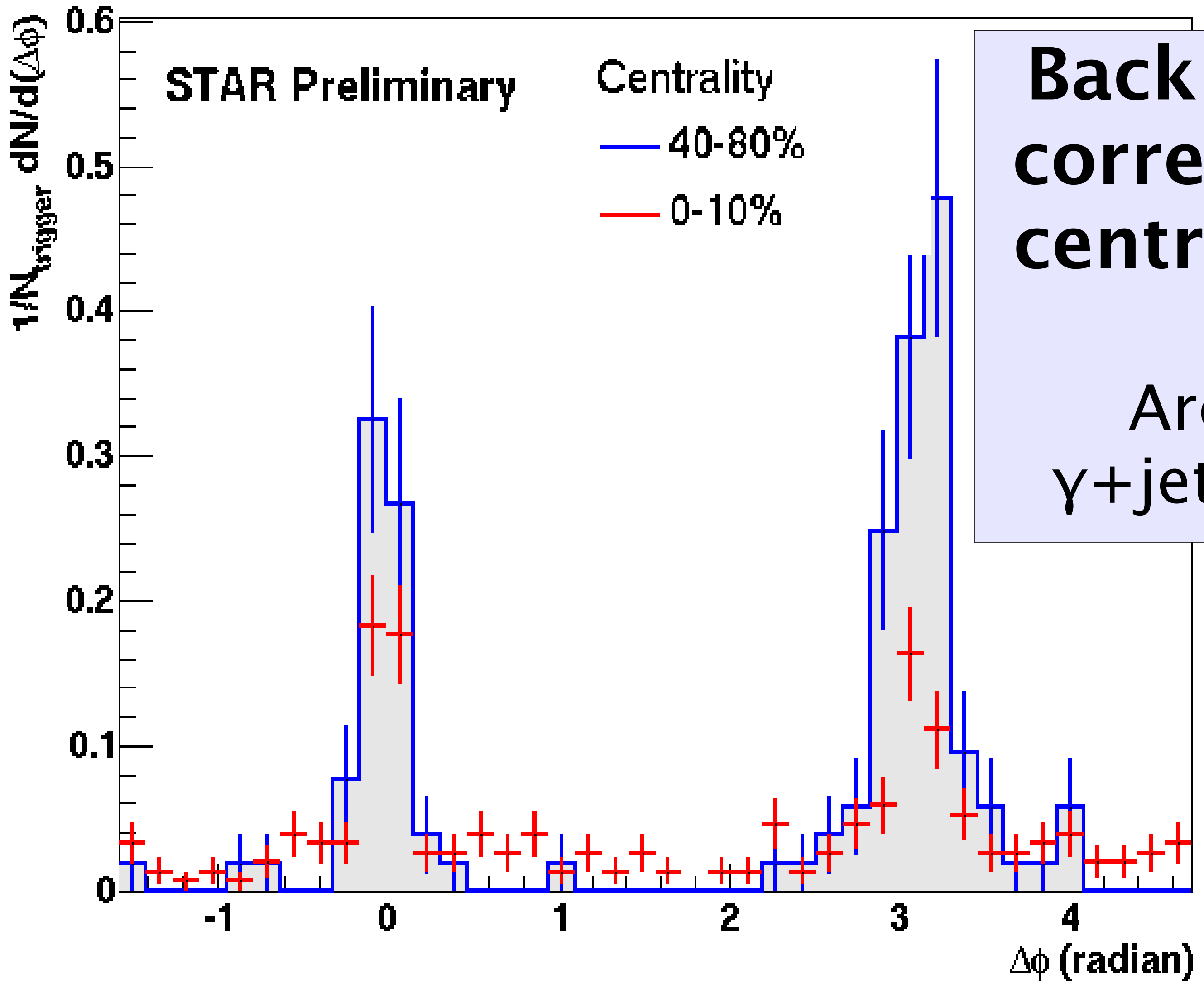
- Suppression depends on trigger particle:
  - $I_{AA}(\text{hadr})$
  - $I_{AA}(\gamma+\text{jet})$
- both unknown → **measure**

Raw Correlations in AuAu @ 200GeV



Raw Correlations in AuAu @ 200GeV

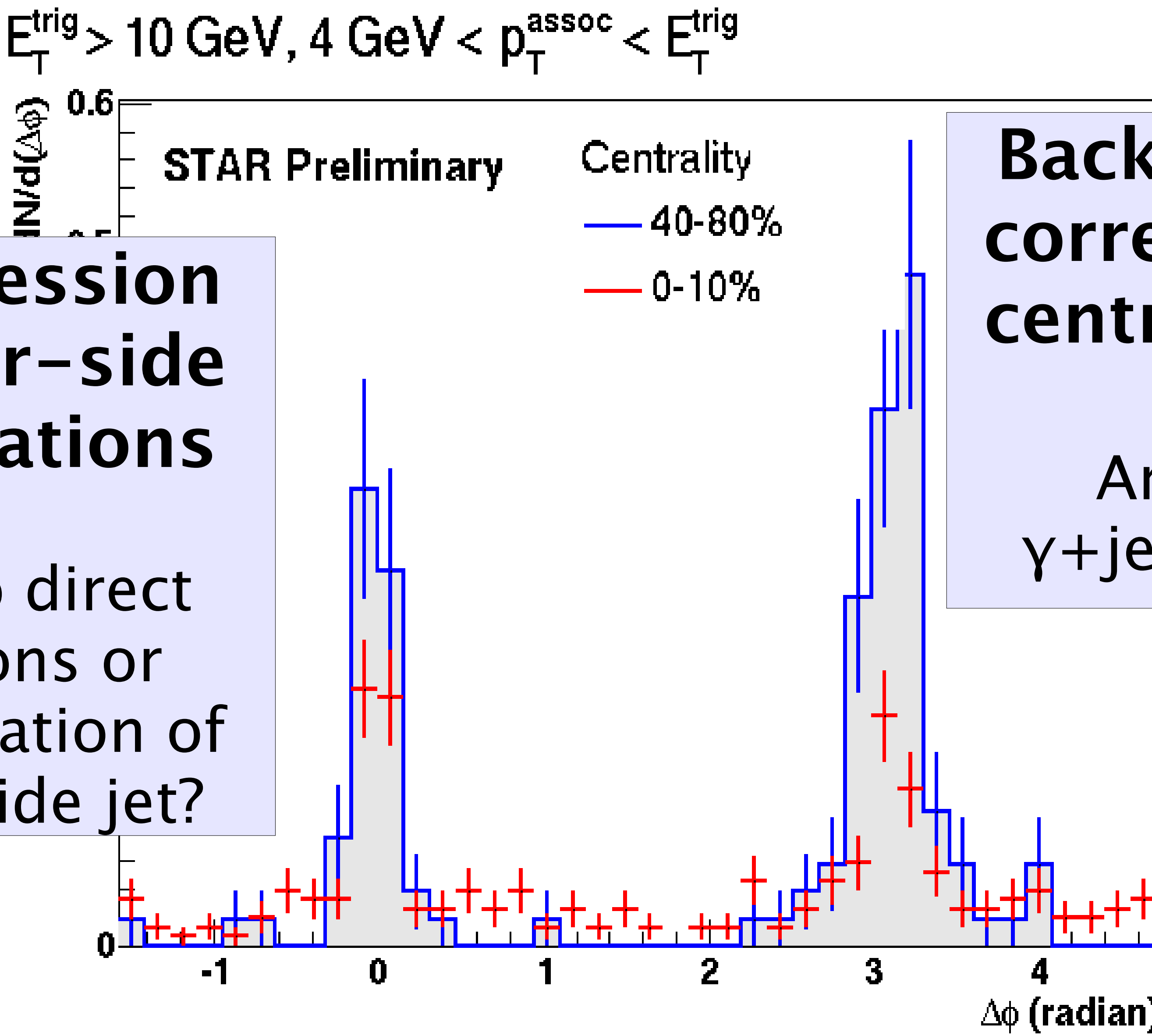
$E_T^{trig} > 10$ GeV, 4 GeV $< p_T^{assoc} < E_T^{trig}$



Back-to-back correlations in central Au+Au

Are these γ+jet or dijets?

Raw Correlations in AuAu @ 200GeV



Suppression of near-side correlations

Due to direct photons or modification of near-side jet?

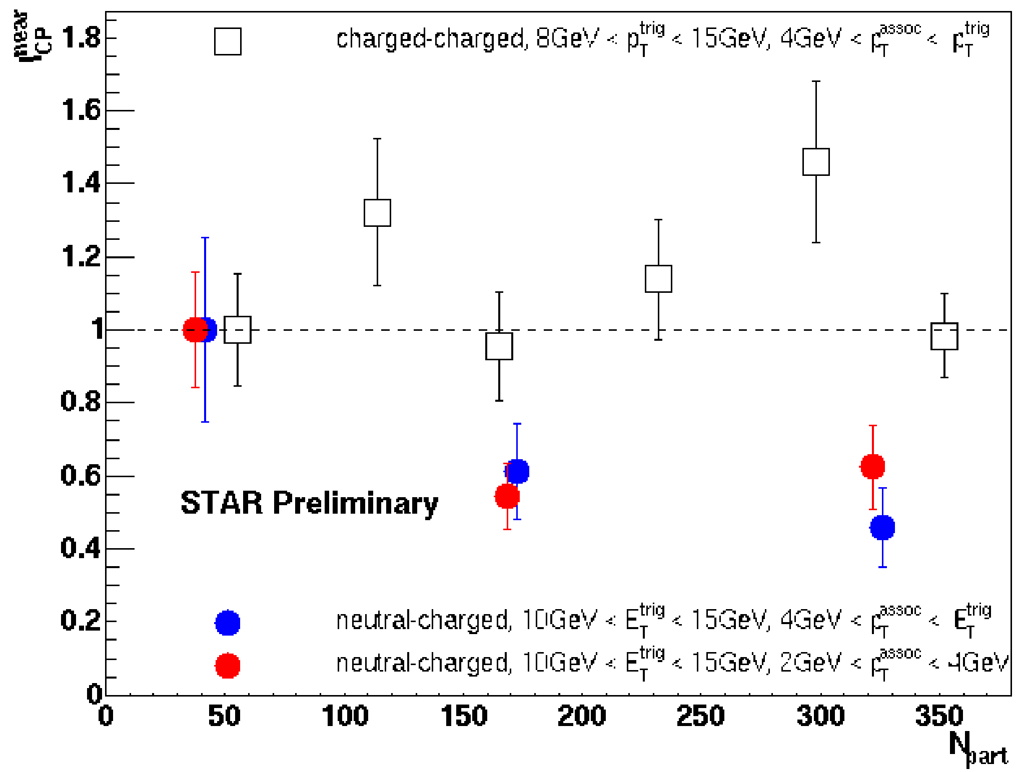
Back-to-back correlations in central Au+Au

Are these γ+jet or dijets?

Decrease of near-side yield

- $I_{CP} = (N_{near}/N_{trig})_{Central} : (N_{near}/N_{trig})_{Peripheral}$
- Clear difference
  - **charged triggers:** compatible with $I_{AA}=1$
  - **neutral triggers:** decreasing near-side yield
- Measures fraction of π^0 and γ+jet triggers

Near-side I_{CP}



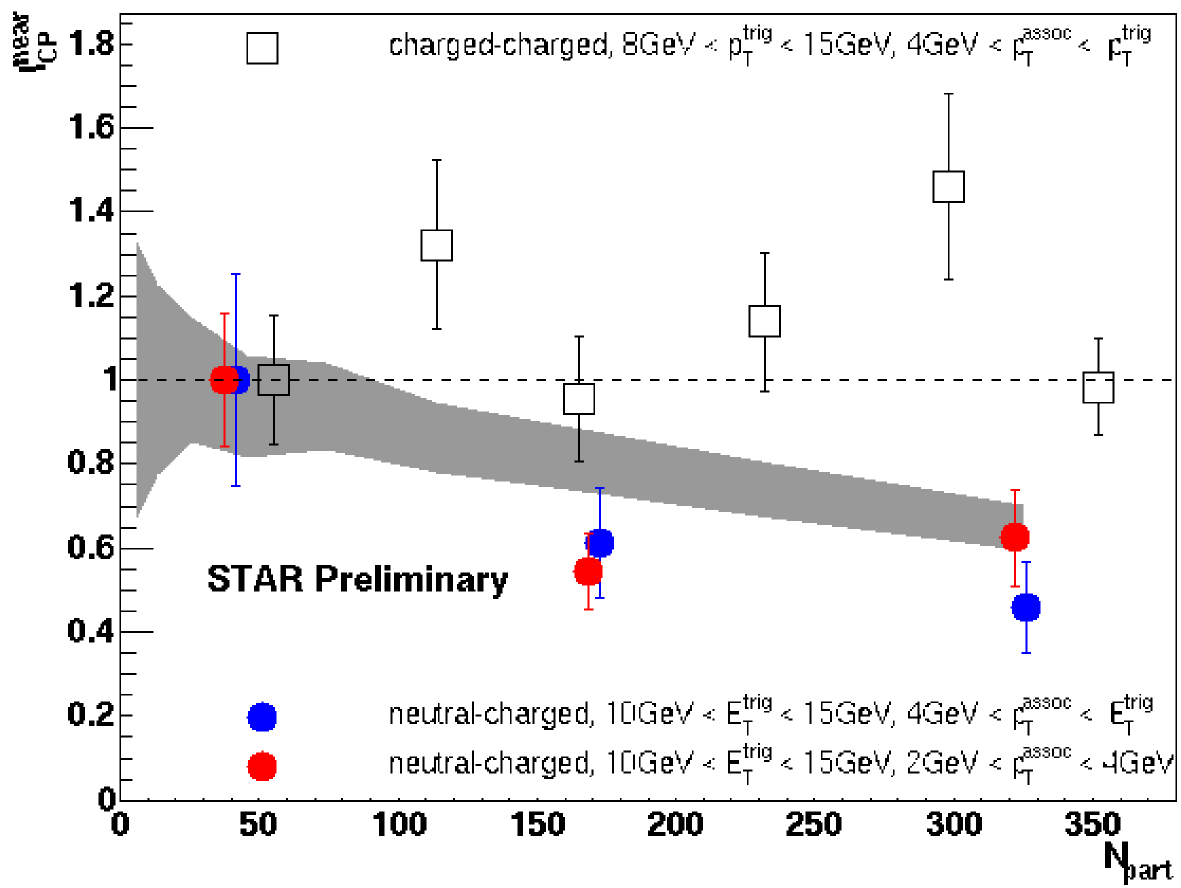
π^0:$\gamma \approx 1$

[11]

Cross-check using measured R_{AA}

- π^0 and γ cross sections are known
- Compare to reduced fraction of π^0s
  - Reference (grey band) uses
    - $I_{AA}(near)=1$
    - R_{AA} of π^0s

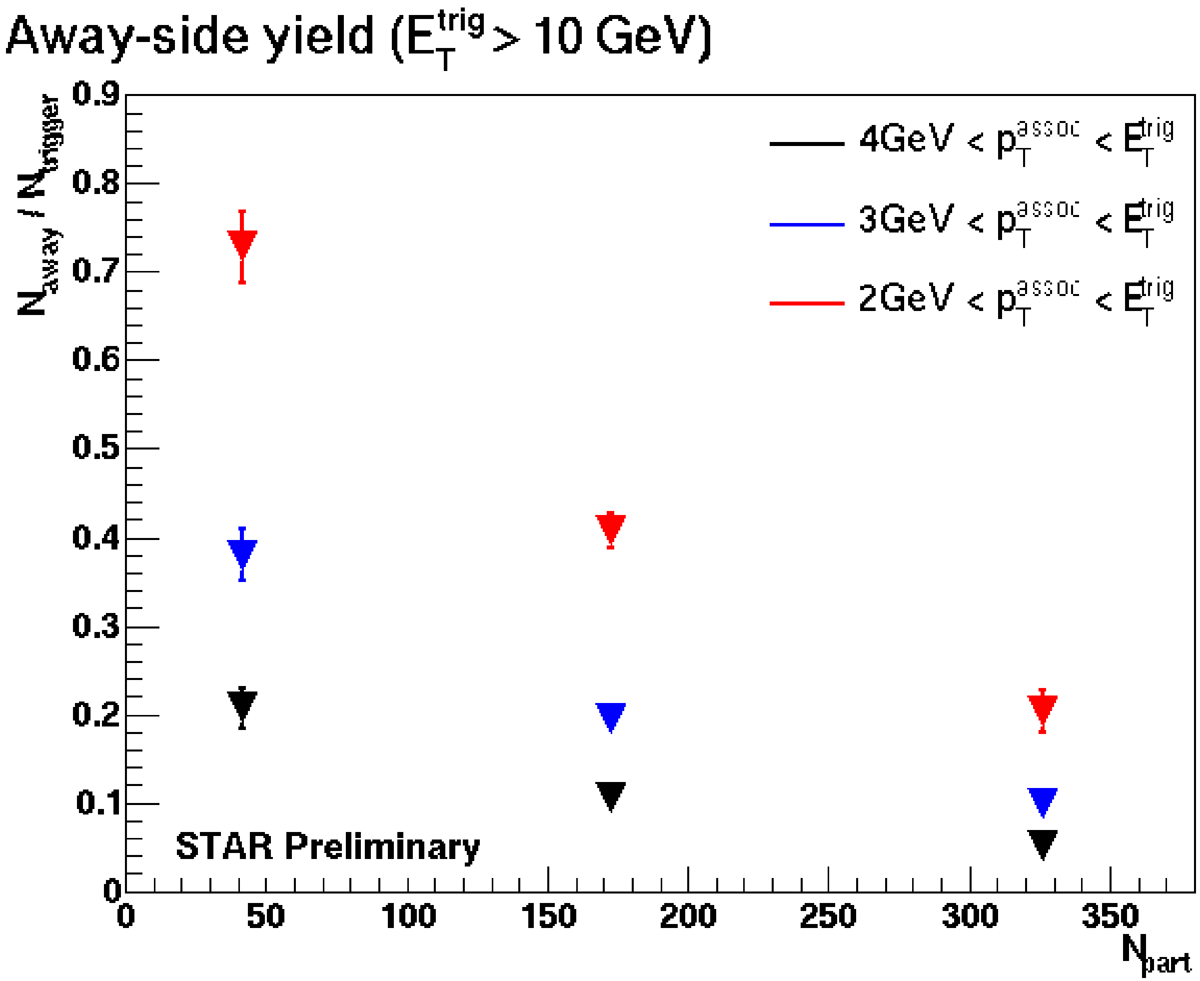
Near-side I_{CP}



Consistent with spectra measurements

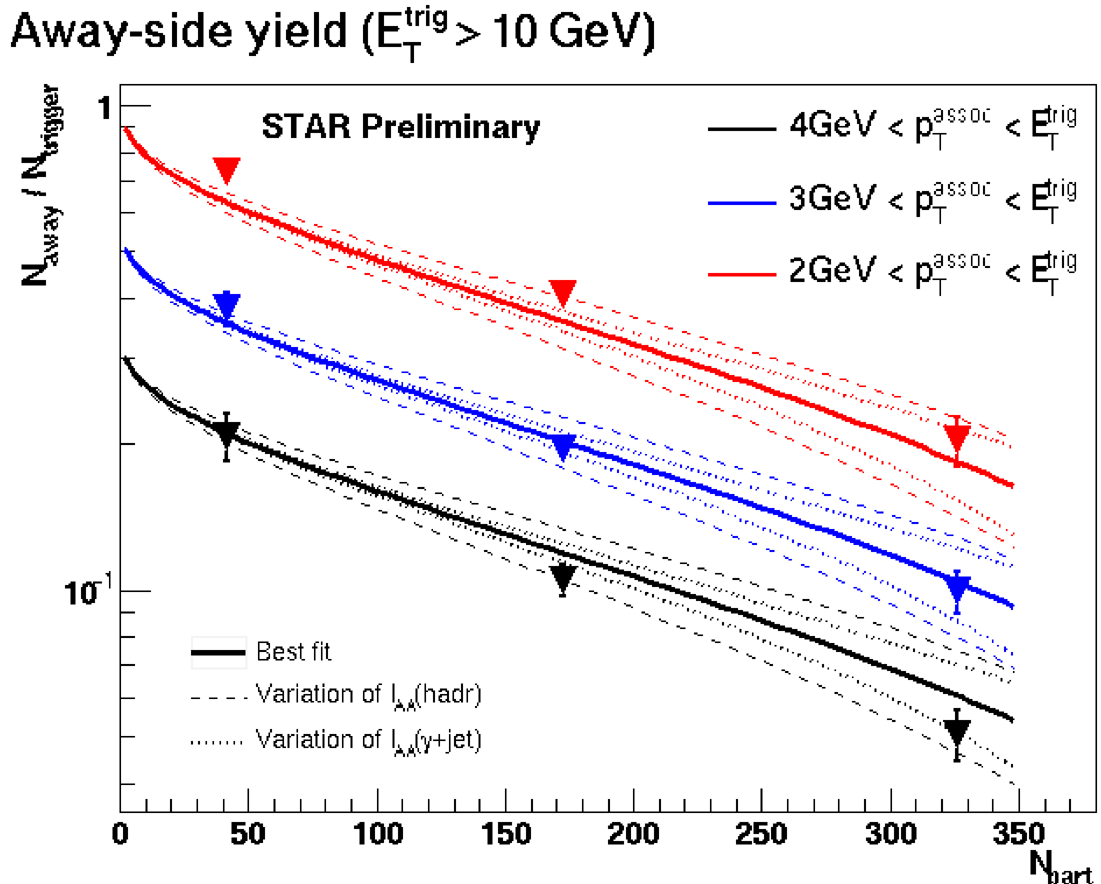
Away-side yield

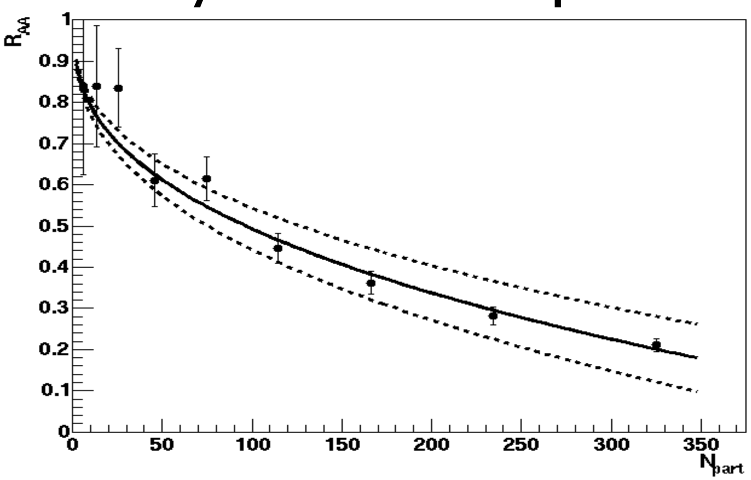
- Suppression in central Au+Au
- No complete disappearance of away-side
- Need to disentangle I_{AA}(hadr) and I_{AA}(γ+jet)



Constraining the away-side yield

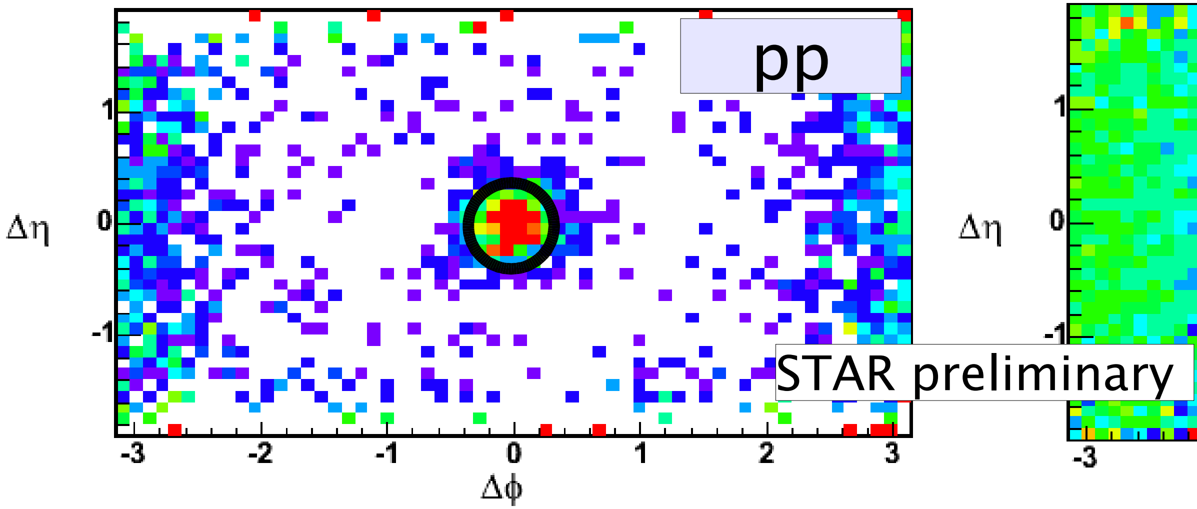
- For comparison put: I_{AA}(hadr) = I_{AA}(γ+jet) = R_{AA}
- Vary I_{AA}(hadr) and I_{AA}(γ+jet) separately within indicated curves
- Caveat: R_{AA} and I_{AA} are very different quantities

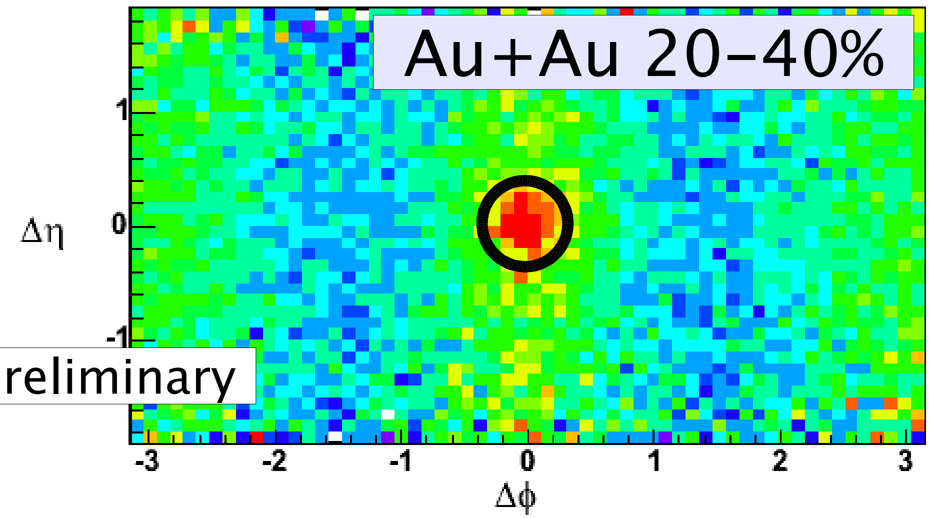




- R_{AA} is numerical approximation for I_{AA}(hadr) and I_{AA}(γ+jet)
- Sensitive to I_{AA}(hadr) and I_{AA}(γ+jet)

π^0 identification: Hadron tagging

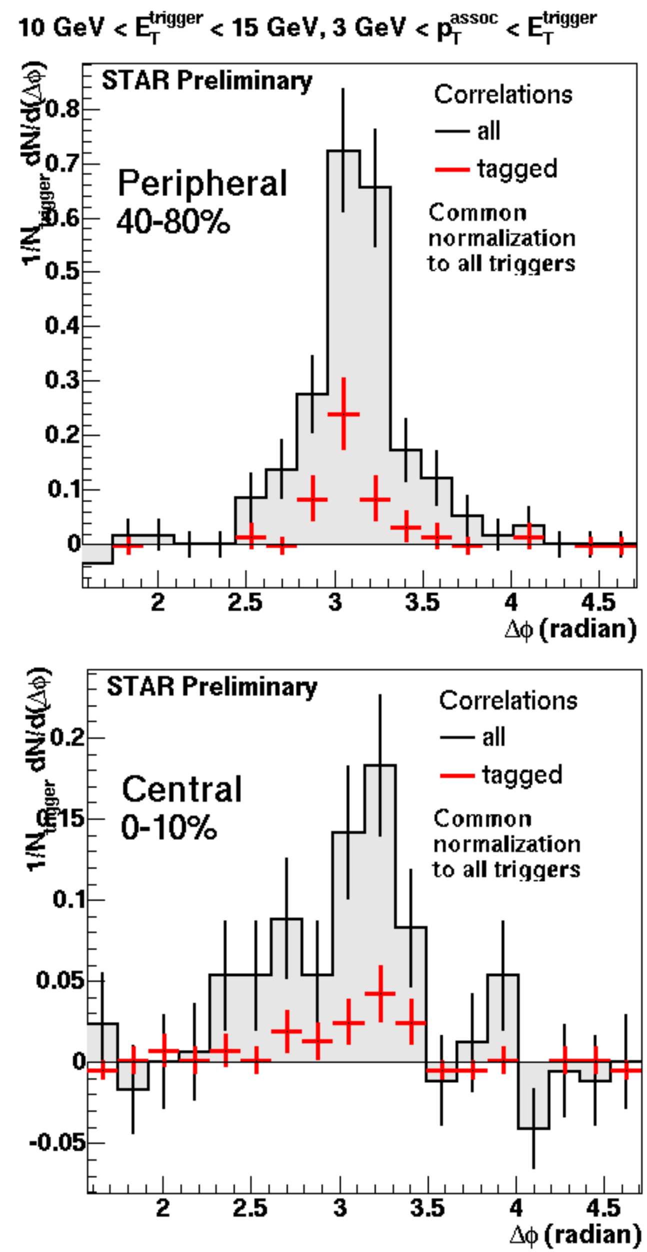




- Tagging with high-pt track in near-side cone → hadron selection
- Tradeoff between efficiency and purity
  - used cuts: pT>2.5GeV, cone radius 0.15
  - false tagging on background: 1.4%
  - tagging efficiency ~ 20% (potentially high uncertainty due to sensitivity to jet shape)

Hadron-tagged correlations

- Tag triggers using associated track:
  - $p_T > 2.5$ GeV, distance < 0.15
  - background: 1.4%
- Large dijet component of back-to-back correlations
- Next: Determination of γ+jet contribution
  - use shower shape from SMD
  - work in progress

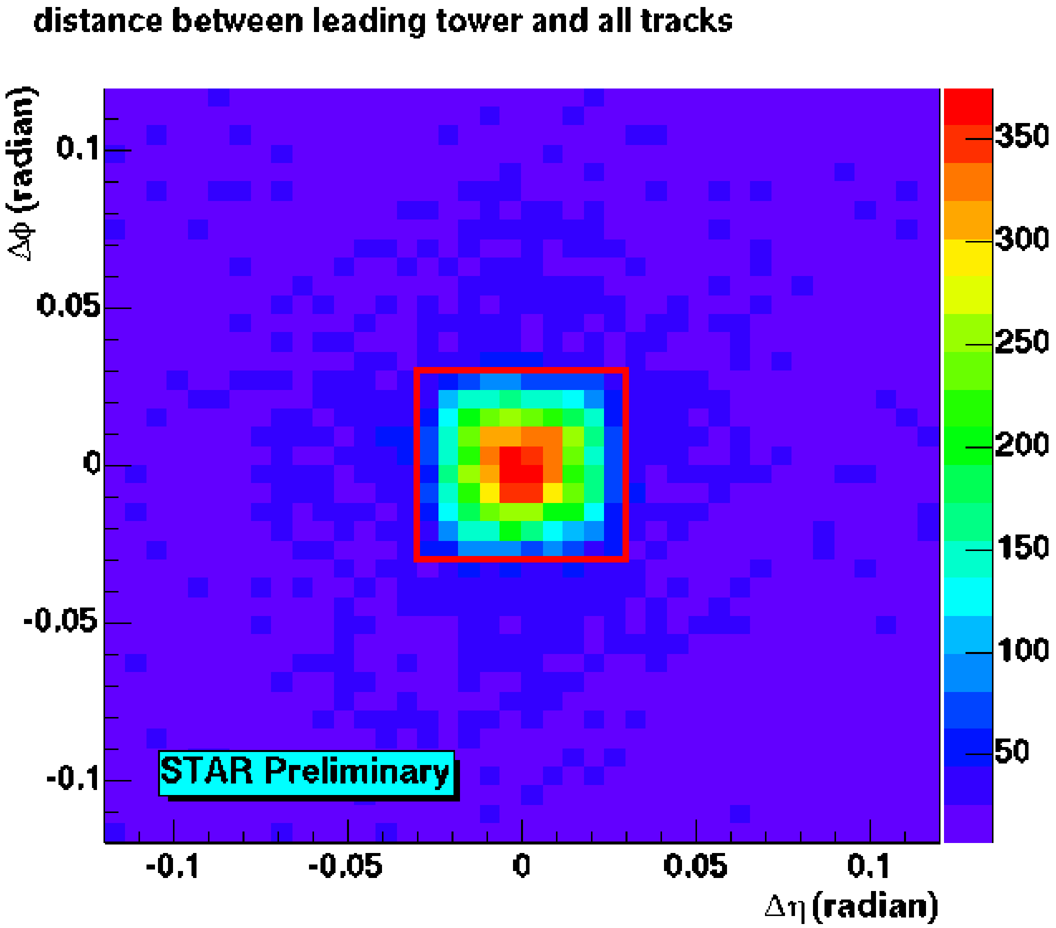


Summary

- Clear correlation signals at very high pT:
  - back-to-back correlation in central AA
  - near-side yield reduced due to prompt photons
- Large fraction of prompt photon triggers: $\gamma/\pi^0 \approx 1$
  - Important step towards γ+jet correlations
- Away-side correlation is mixture of dijets and γ+jet
  - "Reappearance" of dijet back-to-back correlations
    - see also Dan Magestro's talk
  - Shower Maximum Detector will provide γ ID
  - Sensitivity to $I_{AA}(\gamma+\text{jet})$ and $I_{AA}(\text{hadr})$
    - $I_{AA}(\text{hadr})$ will constrain $I_{AA}(\gamma+\text{jet})$

Extra slides

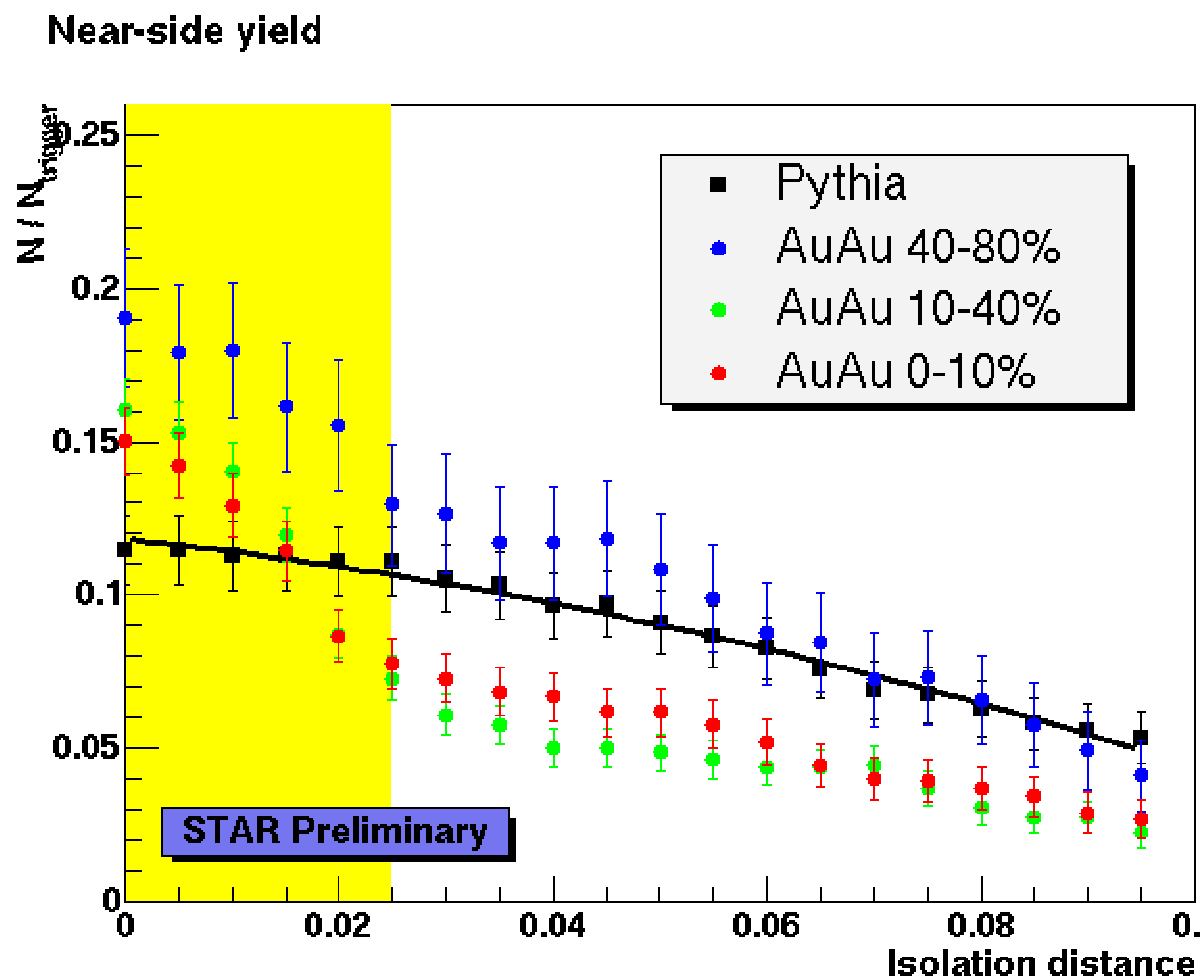
Isolation cut



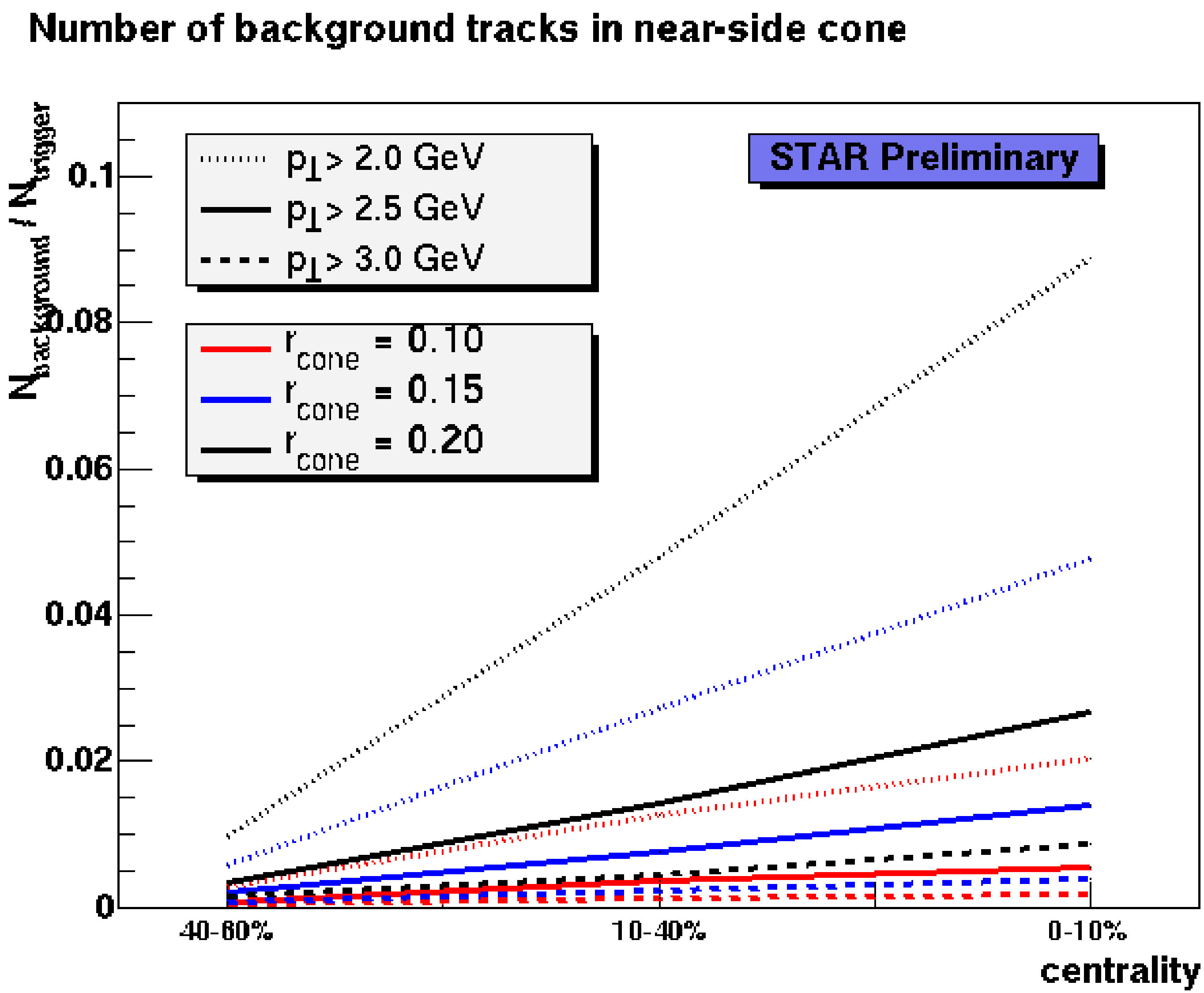
- Extrapolate charged tracks to EMC
- Find distance to highest tower
- Reject event, if:
  - $p_T > 1$GeV
  - $\Delta\varphi < 0.03$
  - $\Delta\eta < 0.03$

Efficiency of isolation cut

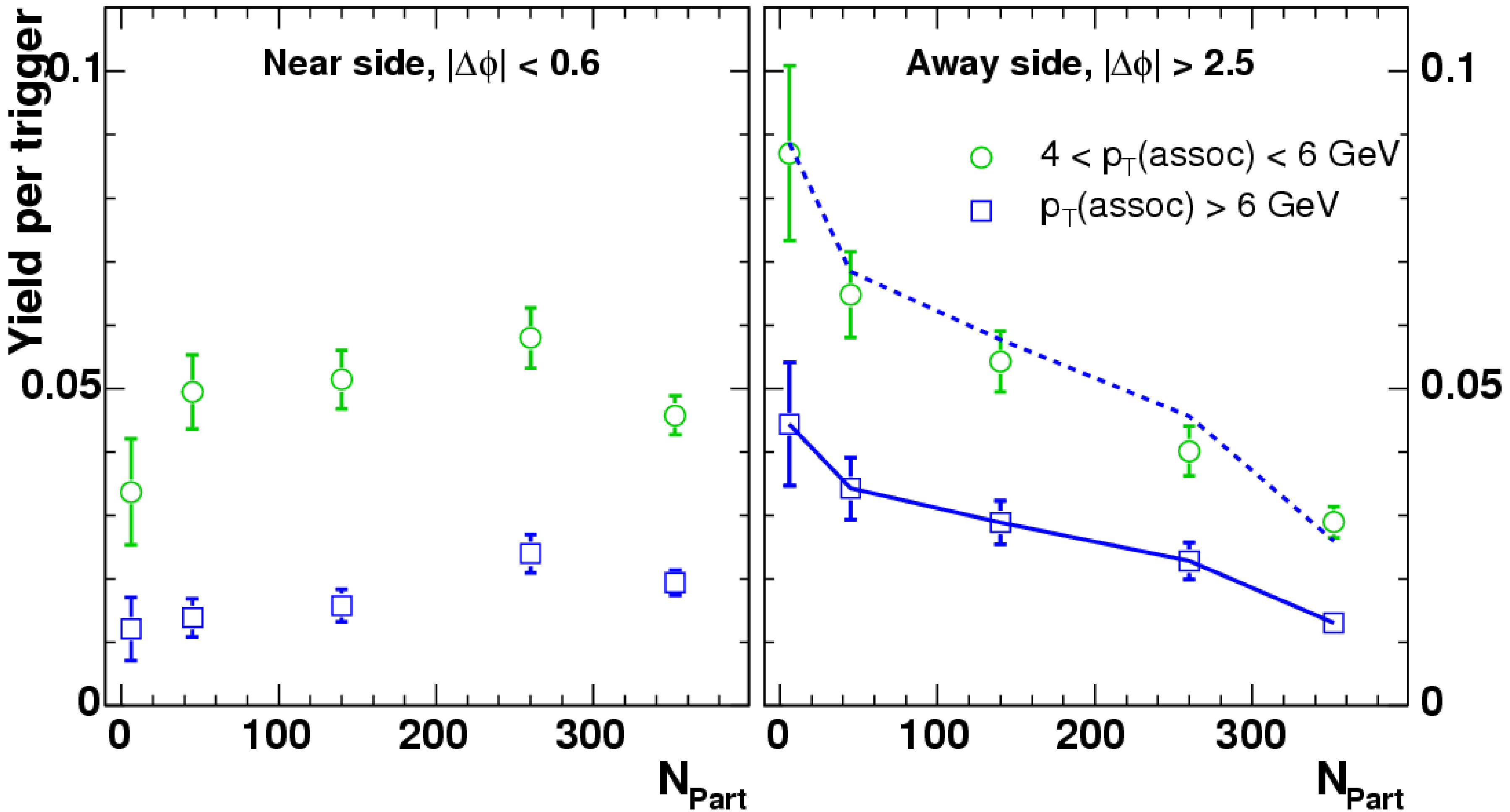
- Agreement of near-side yield between PYTHIA and peripheral AA
- Efficiency at chosen cut (0.03): 89%



Hadron tagging background



Charged-charged



See Dan's Talk

Old slides

Overview

I will present results on correlating very high energy deposition by neutral particles in the EMC with charged tracks and discuss the near- and away-side correlations

- Introduction
- STAR Experiment
- Analysis method
- Data and Interpretation
  - Hadron identification
  - Near–side yield &

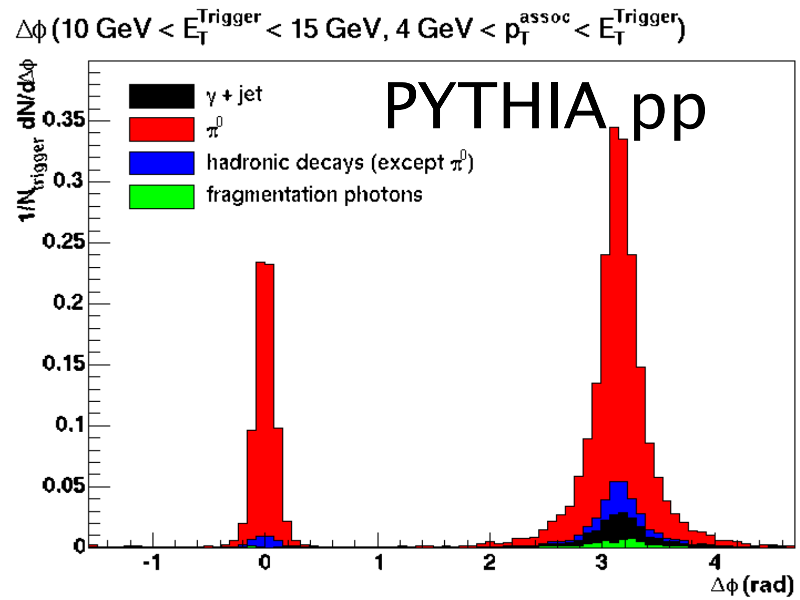
Dataset – merge with previous

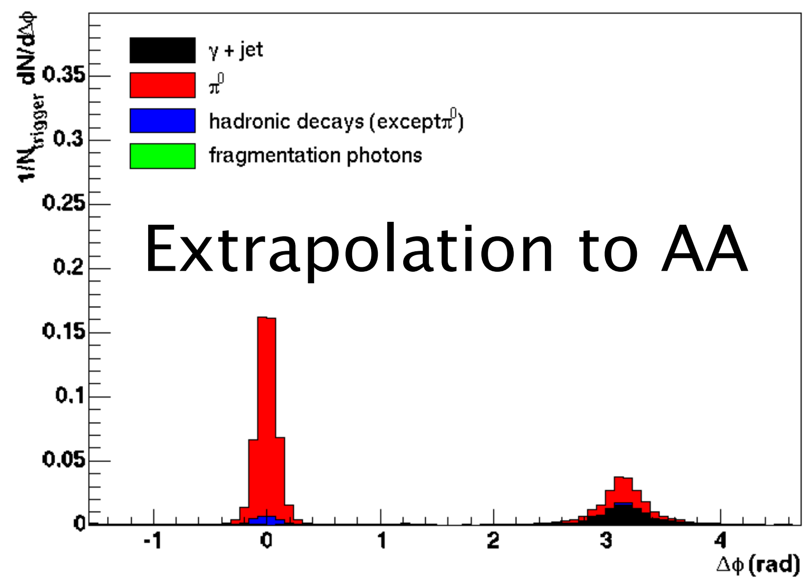
- Au+Au @ 200GeV, 2004 run
- High-tower trigger
  - very high threshold (9 GeV)
  - prioritized reconstruction and analysis "Express Stream"
  - Very small data volume: 20k events
- Available statistics:
  - this analysis: ~25 μb^{-1}
    equivalent of 180M minbias events
  - total on tape: ~40 μb^{-1}
    equivalent of 280M minbias events

Raus??? PYTHIA Extrapolation to AA

Assumptions for AA:

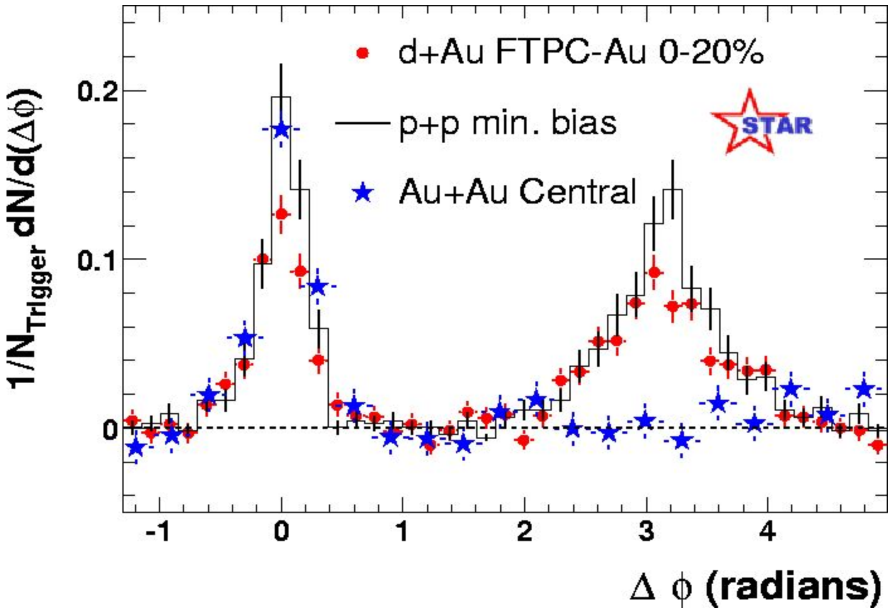
- Suppression of hadronic triggers particles
  - $R_{AA}=0.2$
- Unmodified hadronic near-side
  - $I_{AA}(\text{near}) = 1$
- Away-side suppression depends on trigger
  - $I_{AA}(\text{hadr}) = 0.1$
  - $I_{AA}(\text{prompt}) = 0.2$

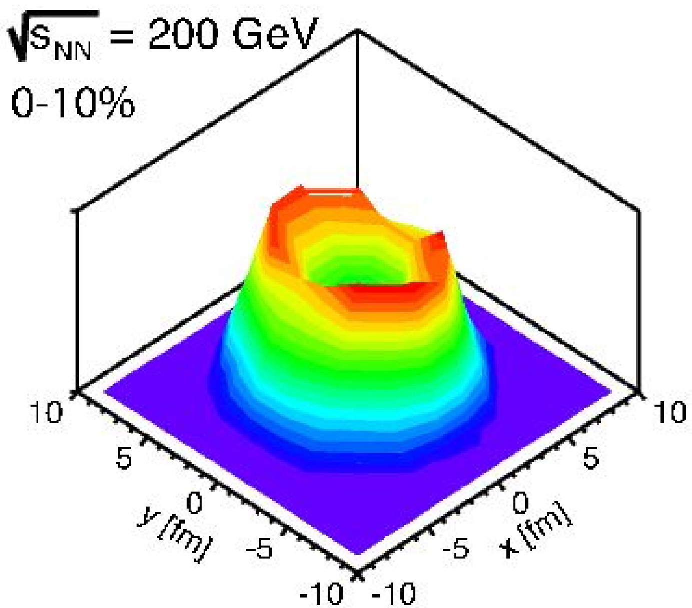




Hadron-hadron correlations

- Strong suppression of hard particles
- Single particles (R_{AA}) biased towards surface emission
- I_{AA}: interplay of bias on trigger and associated particles: tangential surface emission?

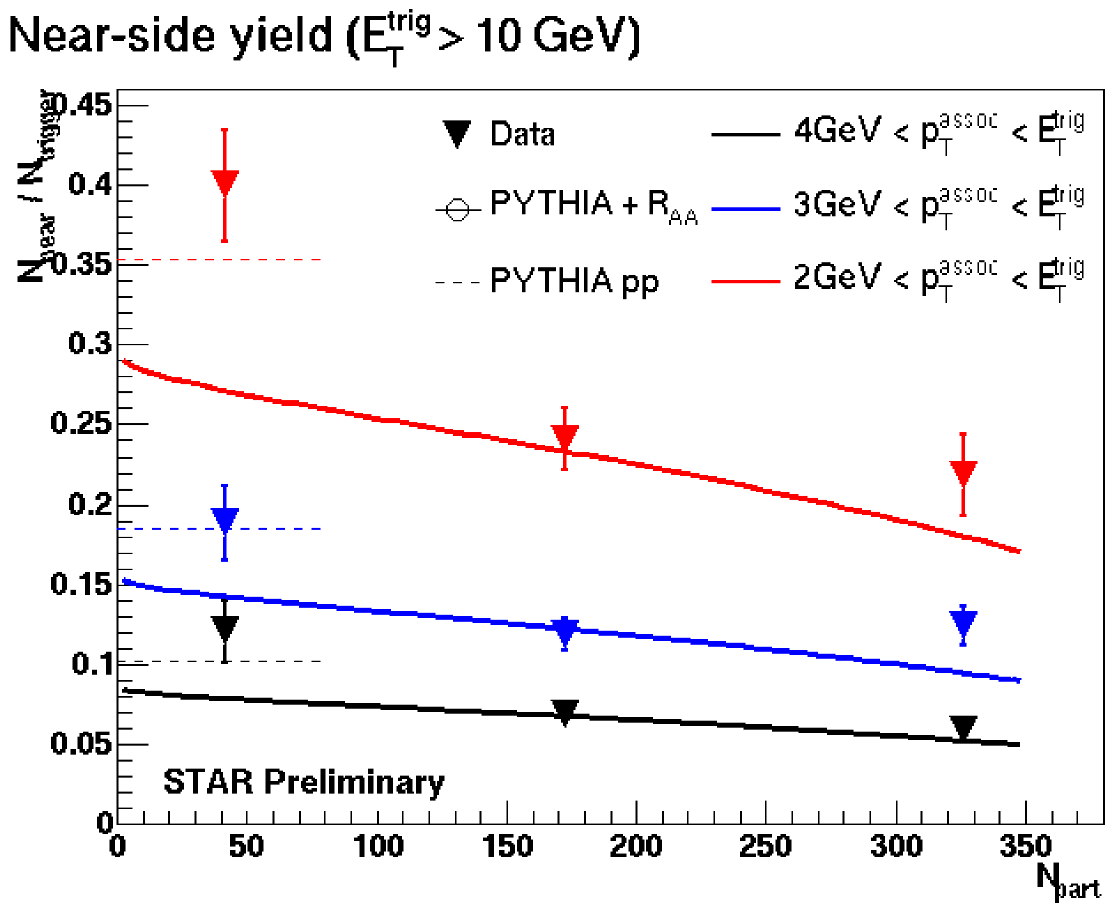




STAR, PRL 92(2003) 072304
Dainese et al., Eur.Phys.J. C38(2005) 461-474

Comparison with Extrapolation to AA

- Reference: Shift from π^0 to prompt photons
  - R_{AA} from PHENIX
  - $\gamma/(\pi^0+\gamma)$ = 16%in p+p (PYTHIA)
  - PYTHIA near-side correlation
  - Assume I_{AA}(near)=1



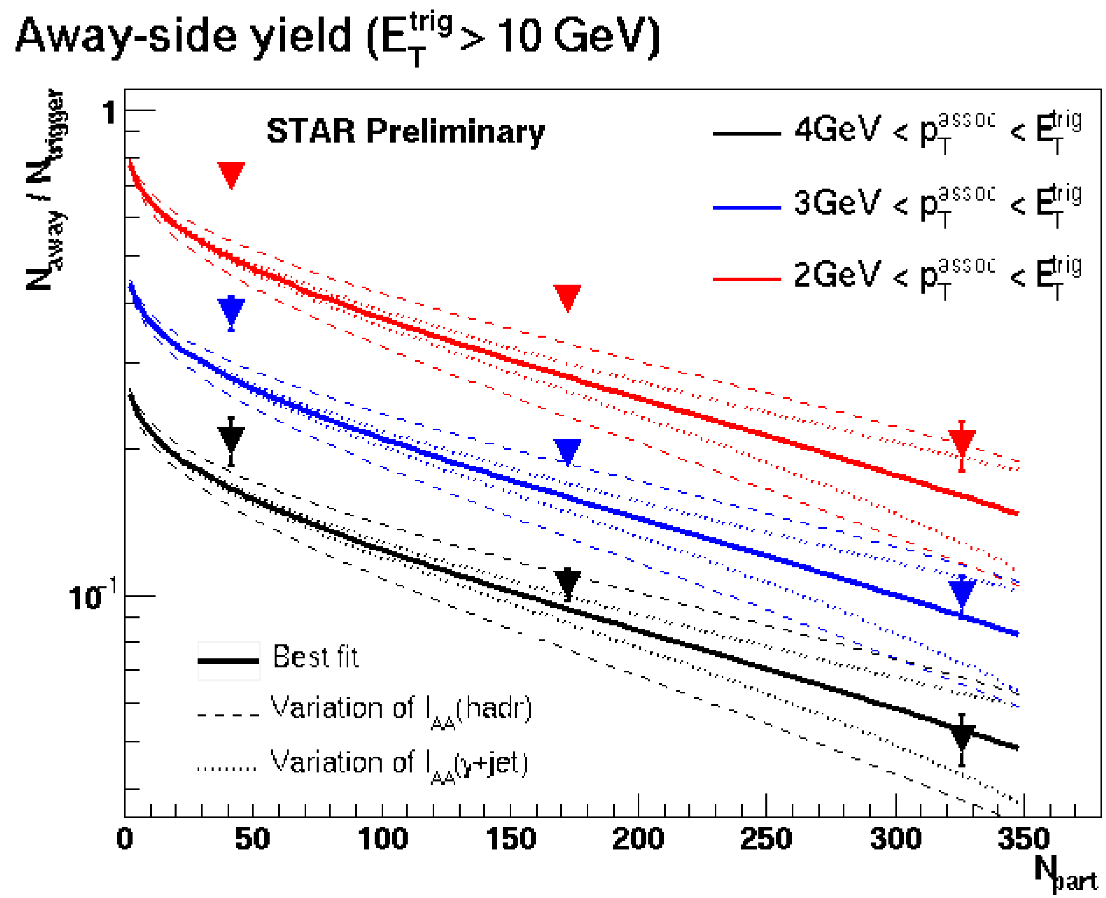
FIX

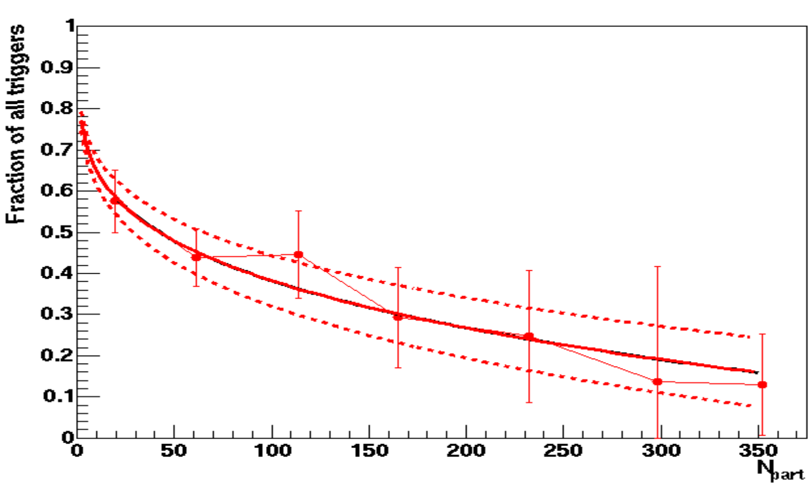
$\pi^0 \rightarrow$ prompt γ

Consistent with expected $\gamma:\pi^0 \approx 1:1$

Constraining the away-side yield

- Compare away-side suppression with I_{AA} from "back-to-back paper"
  - Caveat: energies off by factor 2
  - Redo the plot with Fuqiang's 2 data

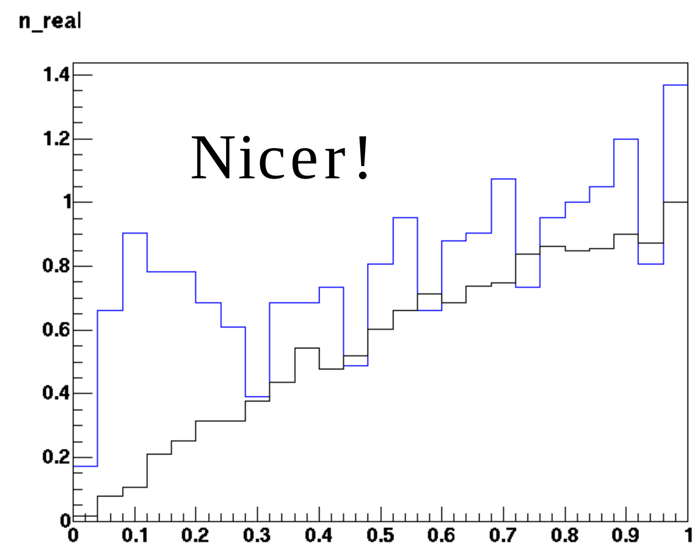


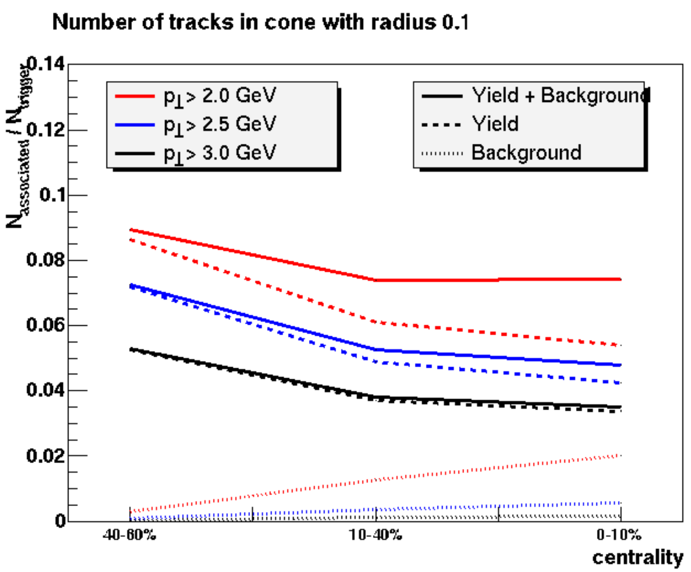


- **Remarkable agreement**
- **Add reference to two star iaa papers**

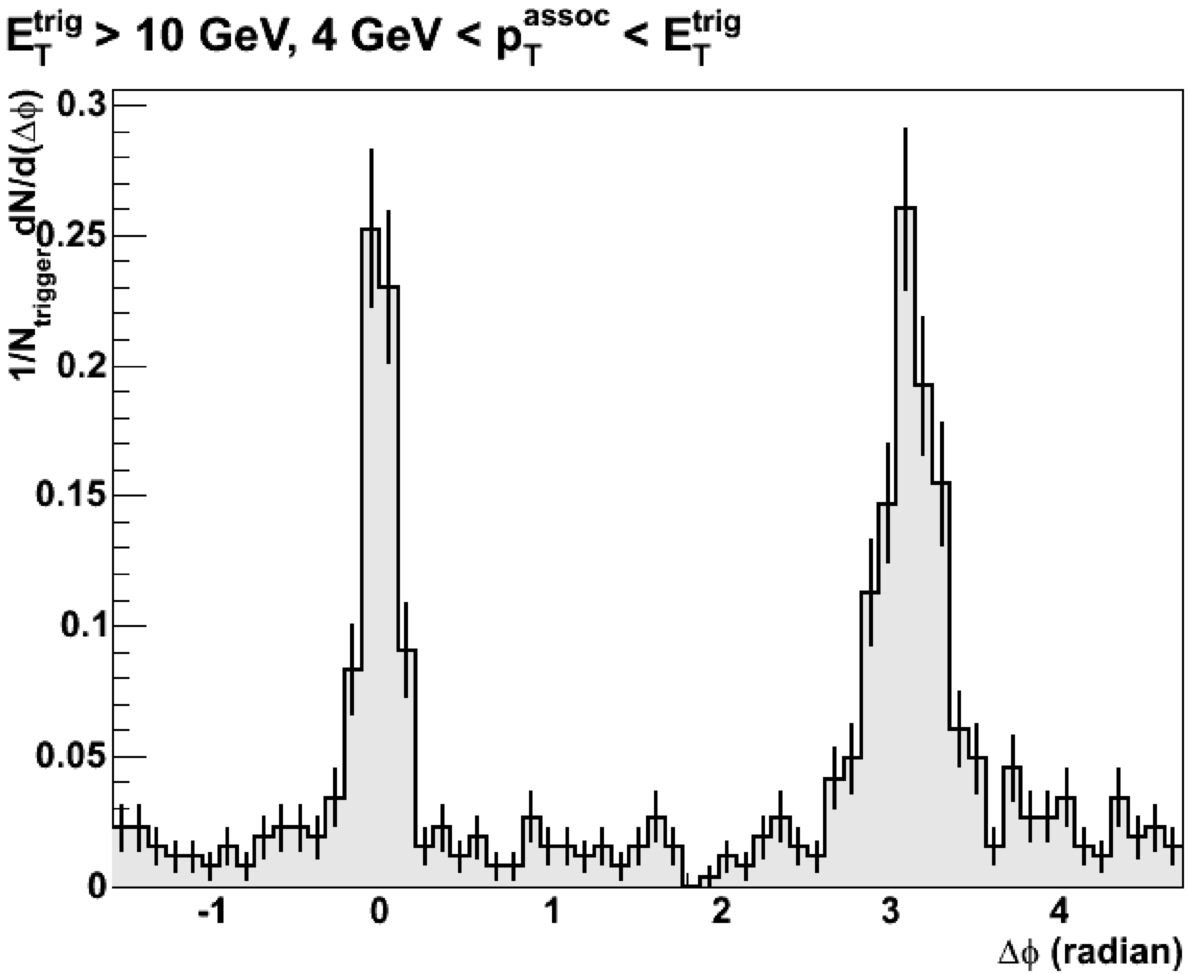
Hadron tagging

- Only hadrons have near-side associated tracks
- Tagging with close charged track selects hadron-hadron correlations
- Not all hadrons have associated track:
- Caveat: strong bias (increased jet energy)





Raw Δφ Correlations



- Very low background
- Near-, away-side peaks clearly defined
- Simple background subtraction

Hadron-tagged Correlations

- Hadron tag allows selection of dijet correlations
- Clear “reappearance” of back-to-back correlations
- Direct measurement of I_{AA} not possible due to biased jet energy

Trigger particles

- $\pi^0 \rightarrow 2\gamma$
  - small opening angle
  - clusters overlap/merge
  - separation of photons requires SMD
  - same physics as charged-charged
- Prompt photons
  - photon escapes medium
  - unbiased trigger particle
  - direct measure of jet energy
- Other sources: decays, fragmentation photons