Underlying-event Activity in Proton+Proton Collisions at RHIC by STAR

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On behalf of the STAR Collaboration
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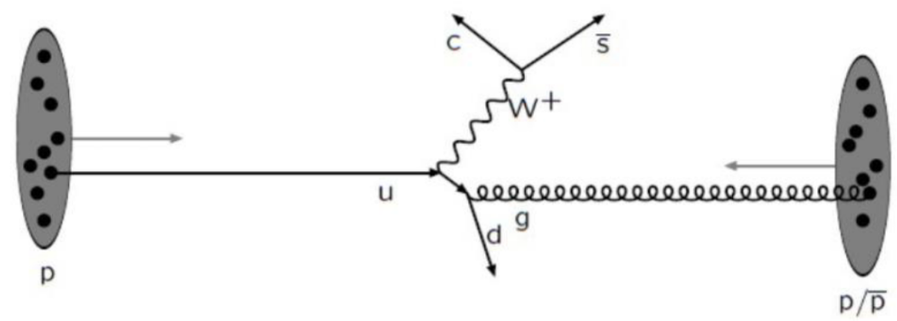
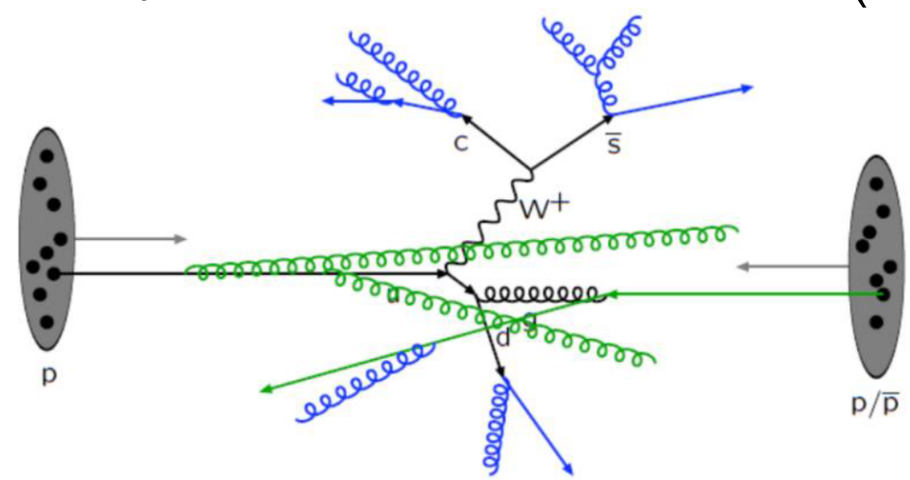
Motivation

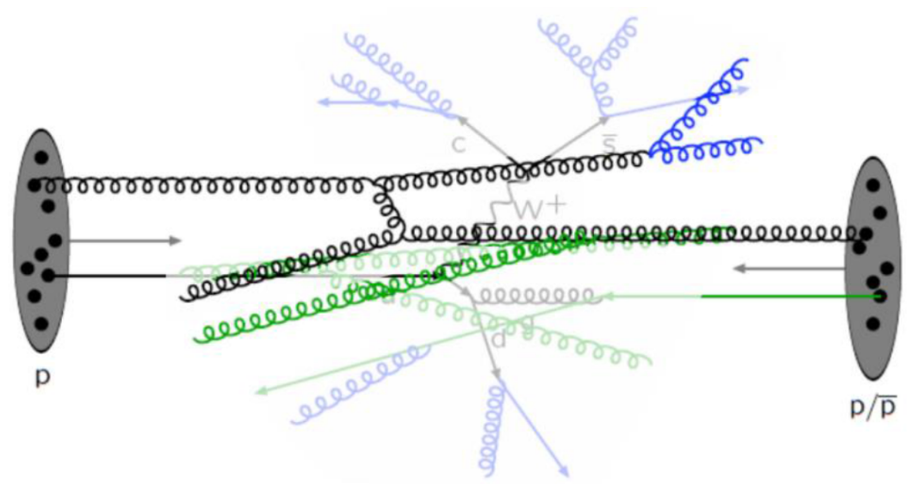
Hard Scattering



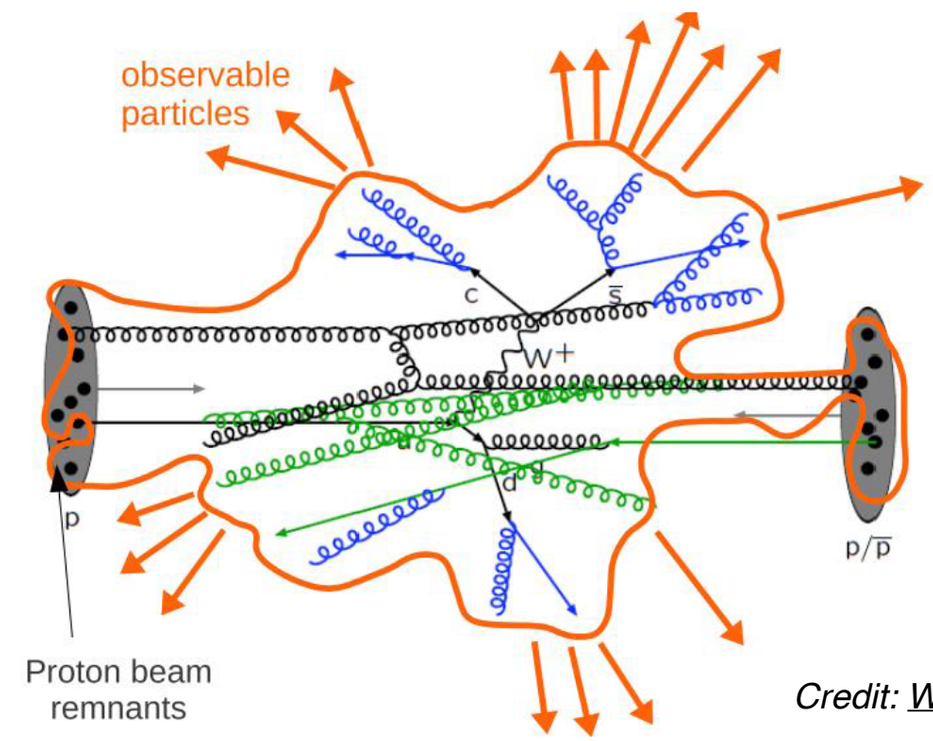
Initial / Final State Radiation (ISR/FSR)



Multiple Parton Interaction (MPI)



Color reconnection with beam remnants

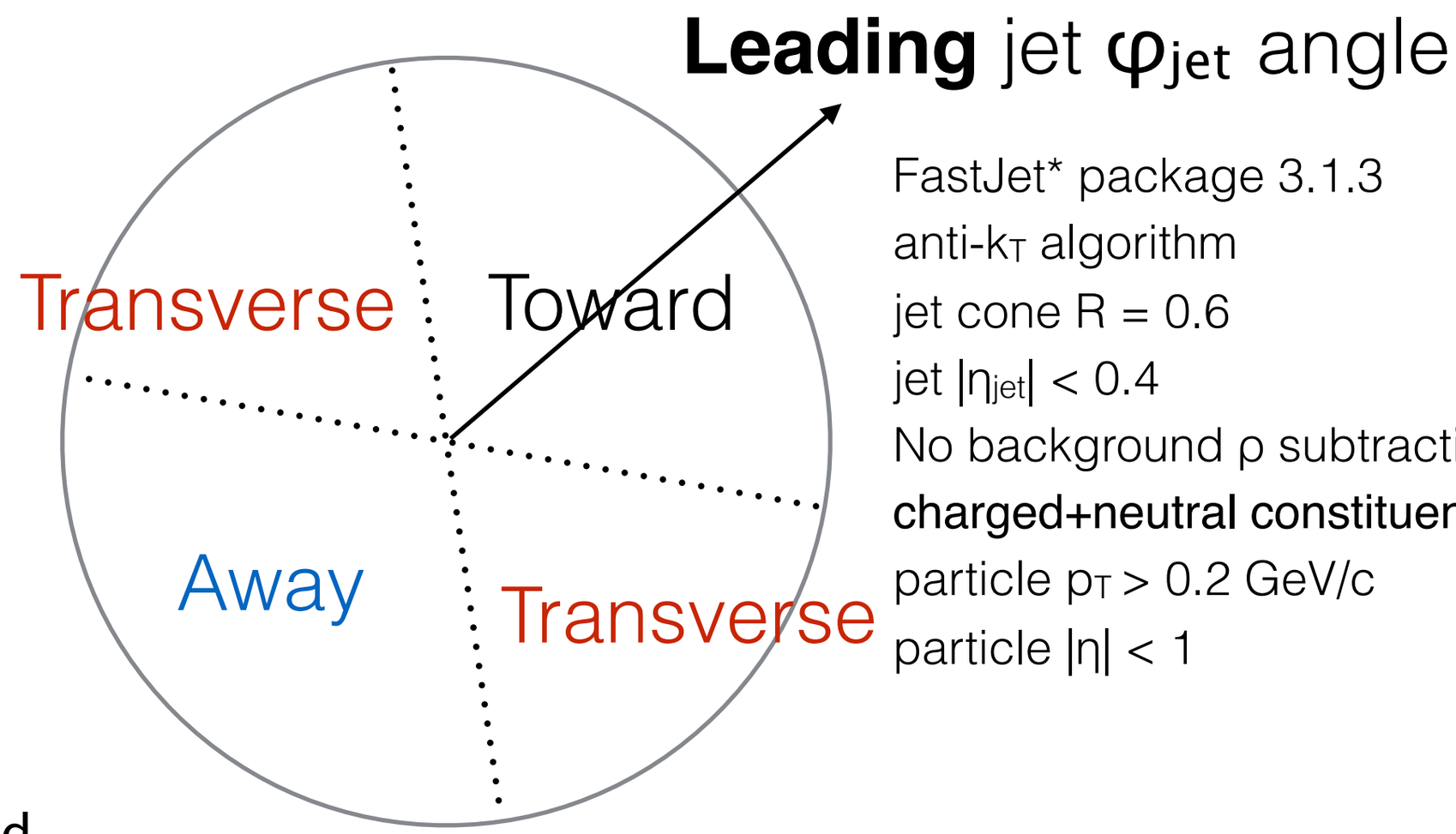


Credit: Wei Yang Wang

Underlying-event activity:

- particle productions not directly from the final fragmentation of hard-scattered partons (gluons/quarks): ISR/FSR, MPI, Color reconnection with beam remnants…
- Tool to study non-factorizable and non-perturbative phenomena

Underlying-event Observables



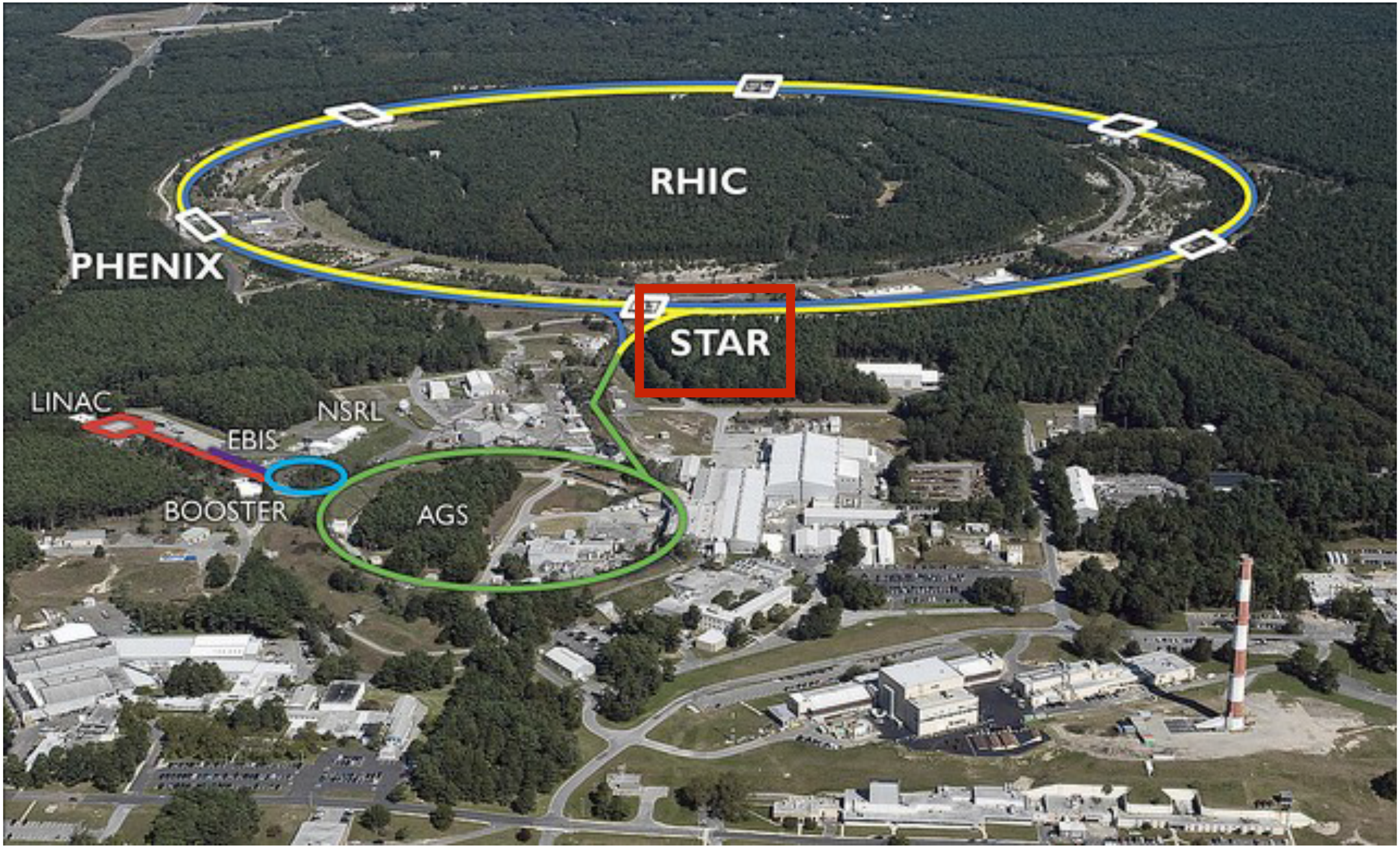
FastJet* package 3.1.3
anti-k_T algorithm
jet cone R = 0.6
jet $|\eta_{jet}| < 0.4$
No background ρ subtraction
charged+neutral constituents
particle $p_T > 0.2$ GeV/c
particle $|\eta| < 1$

$|\varphi-\varphi_{jet}|<60°$ --> Toward
$|\varphi-\varphi_{jet}|>120°$ --> Away
60 degree$<|\varphi-\varphi_{jet}|<120°$ --> Transverse

Underlying event is accessed through the Transverse region

* FastJet package: Cacciari, Salam and Soyez, arXiv:1111.6097

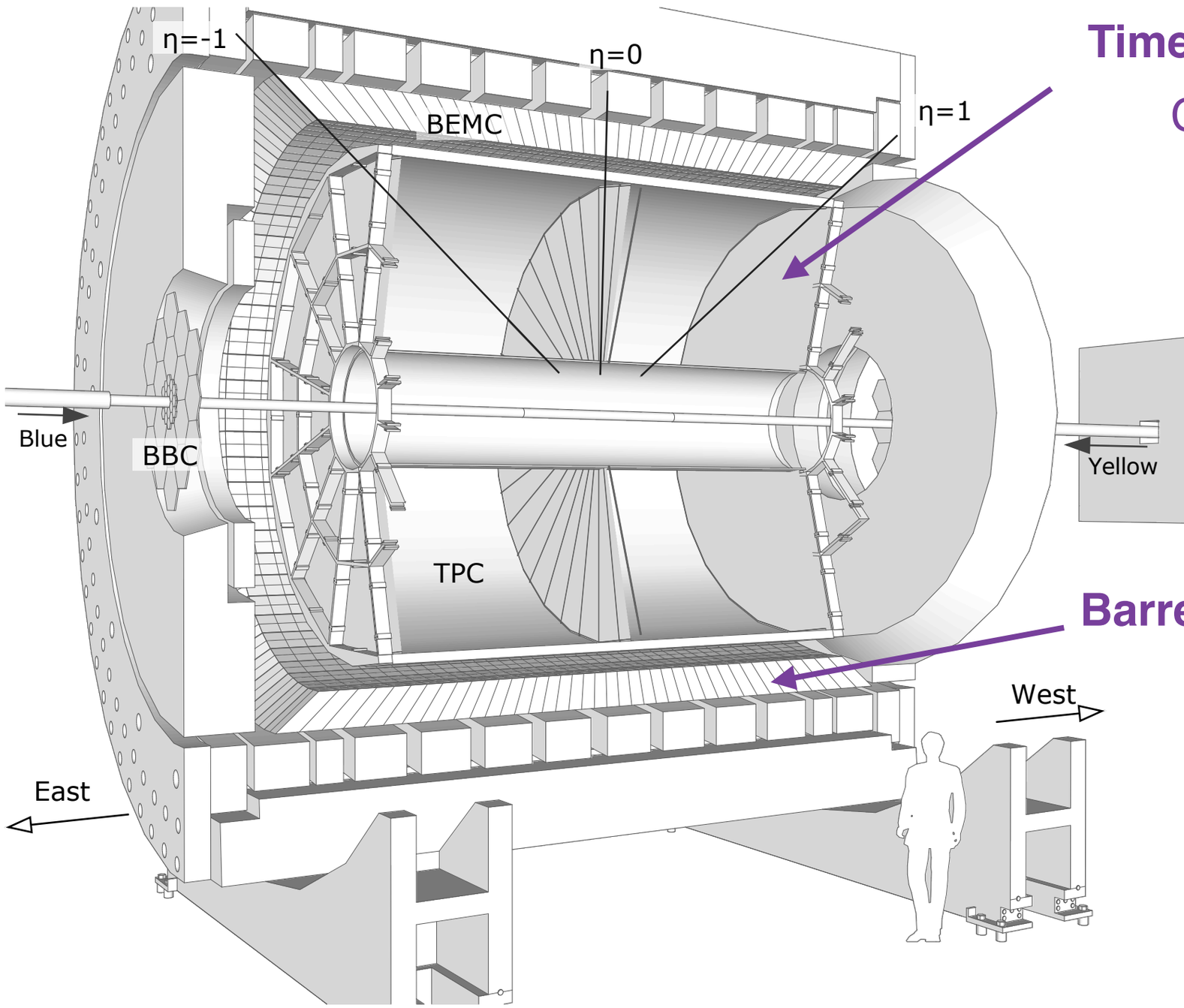
The Relativistic Heavy Ion Collider



Proton+Proton collisions at $\sqrt{s_{NN}}$ = 200 GeV and 500 GeV

STAR Detector

Proton+Proton collisions at $\sqrt{s_{NN}}$ = 200 GeV and 500 GeV



Time Projection Chamber

Charged particles

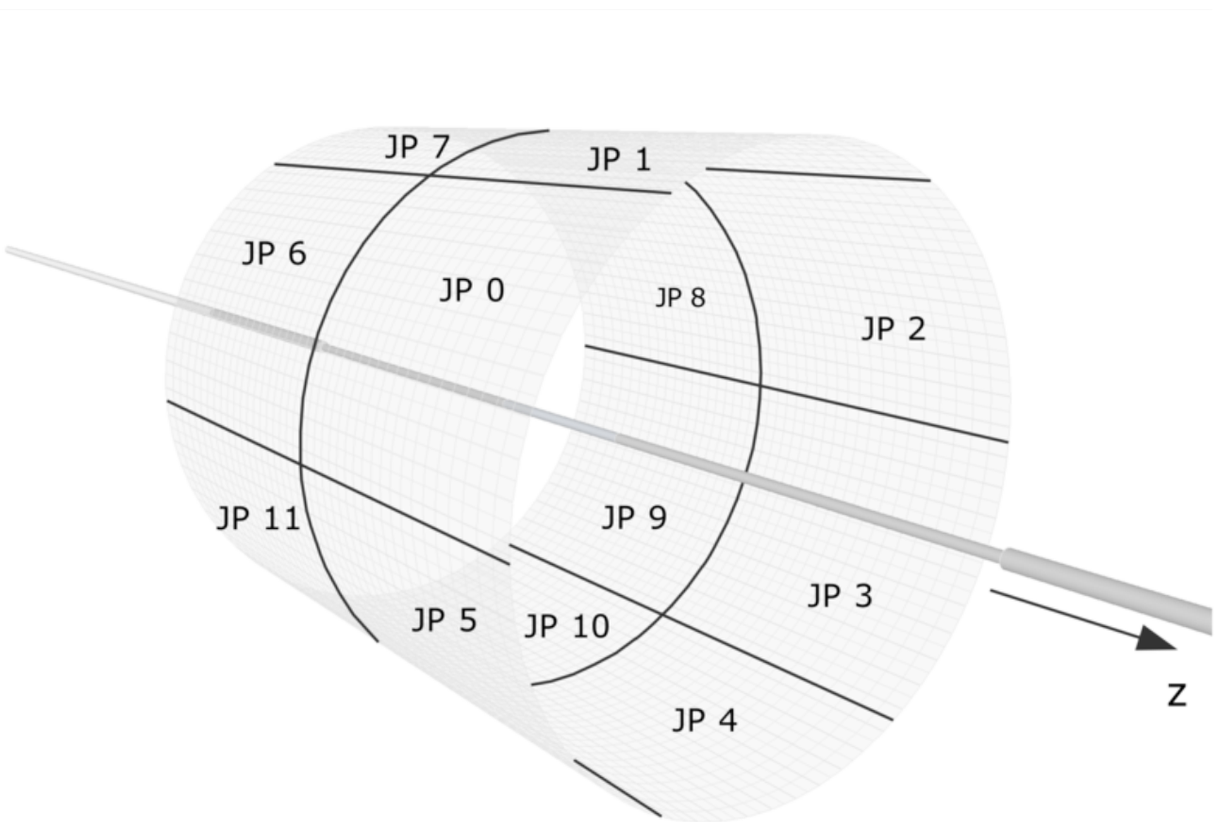
Barrel Electromagnetic Calorimeter

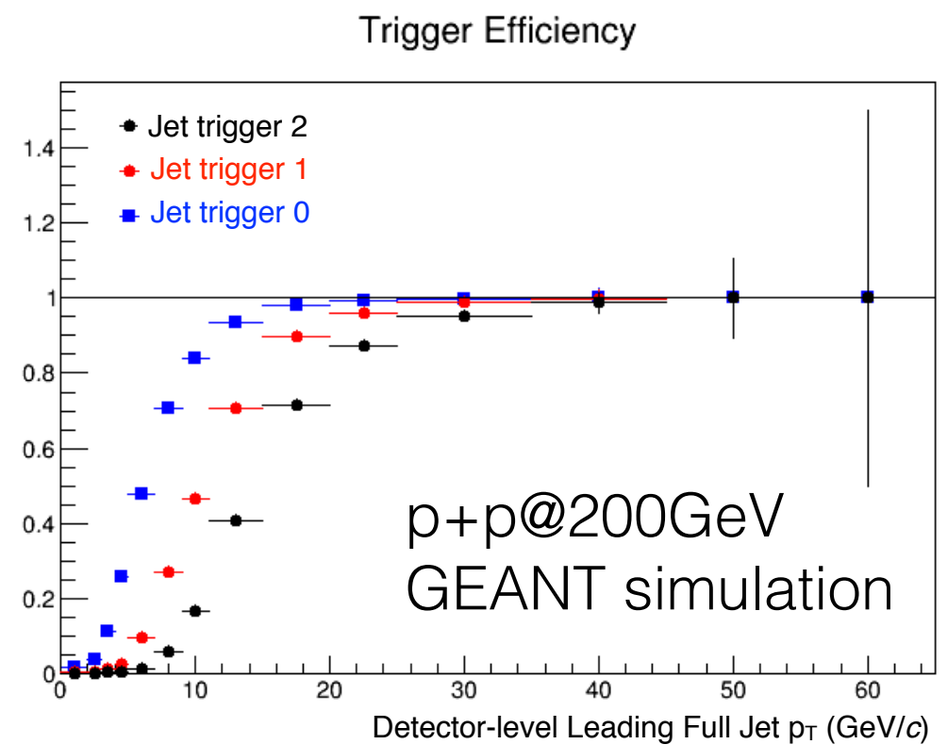
Neutral energy

Trigger detector for jets

Jet Triggers Setup

Barrel Electromagnetic Calorimeter as trigger detector





Jet Patch size 1x1 in η x φ

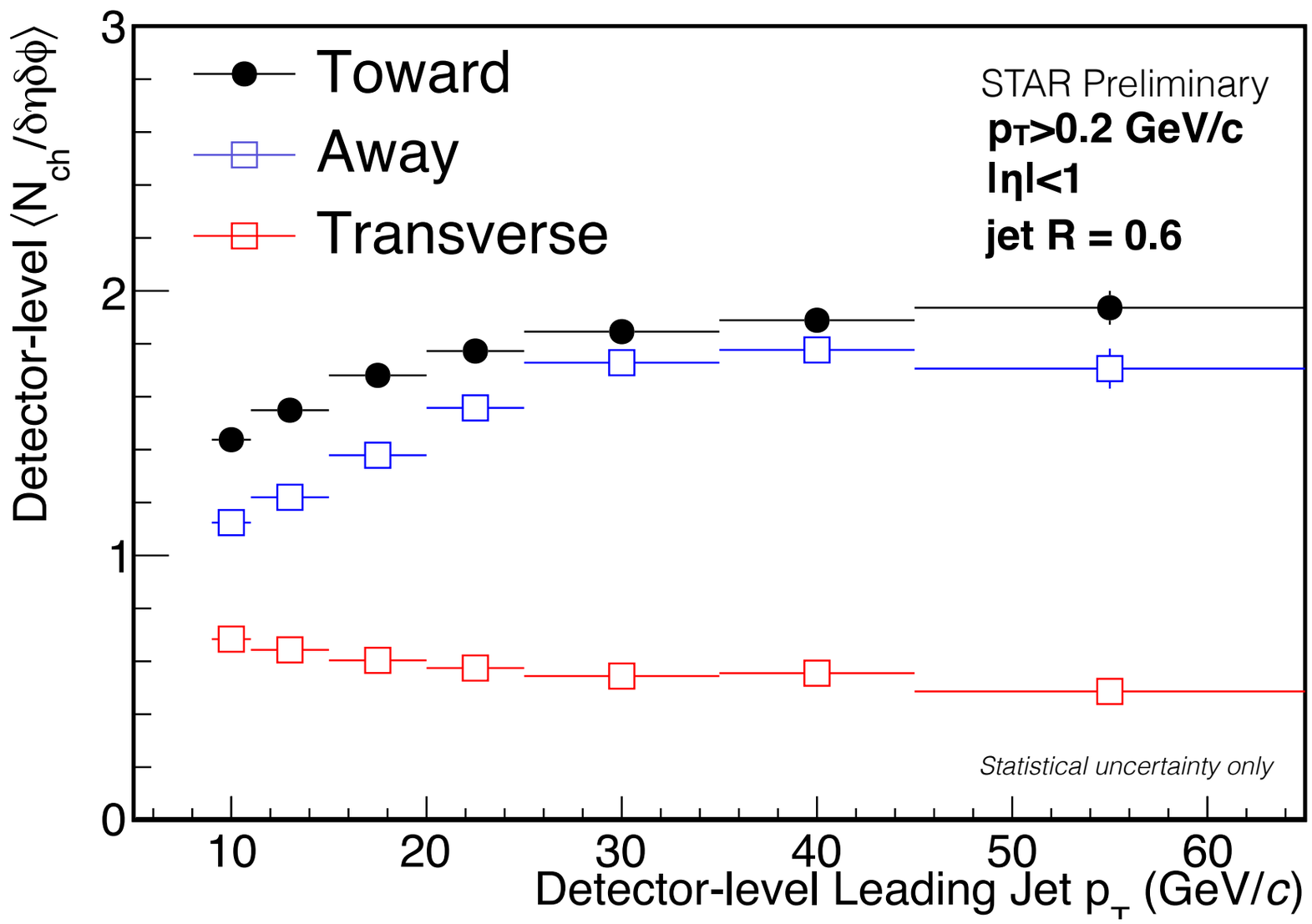
Trigger Thresholds at 200GeV (neutral energy):

Jet trigger 0	3.5 GeV
Jet trigger 1	5.4 GeV
Jet trigger 2	7.3 GeV

Charged Particle Density

jet triggered events

p+p@200GeV Year 2012

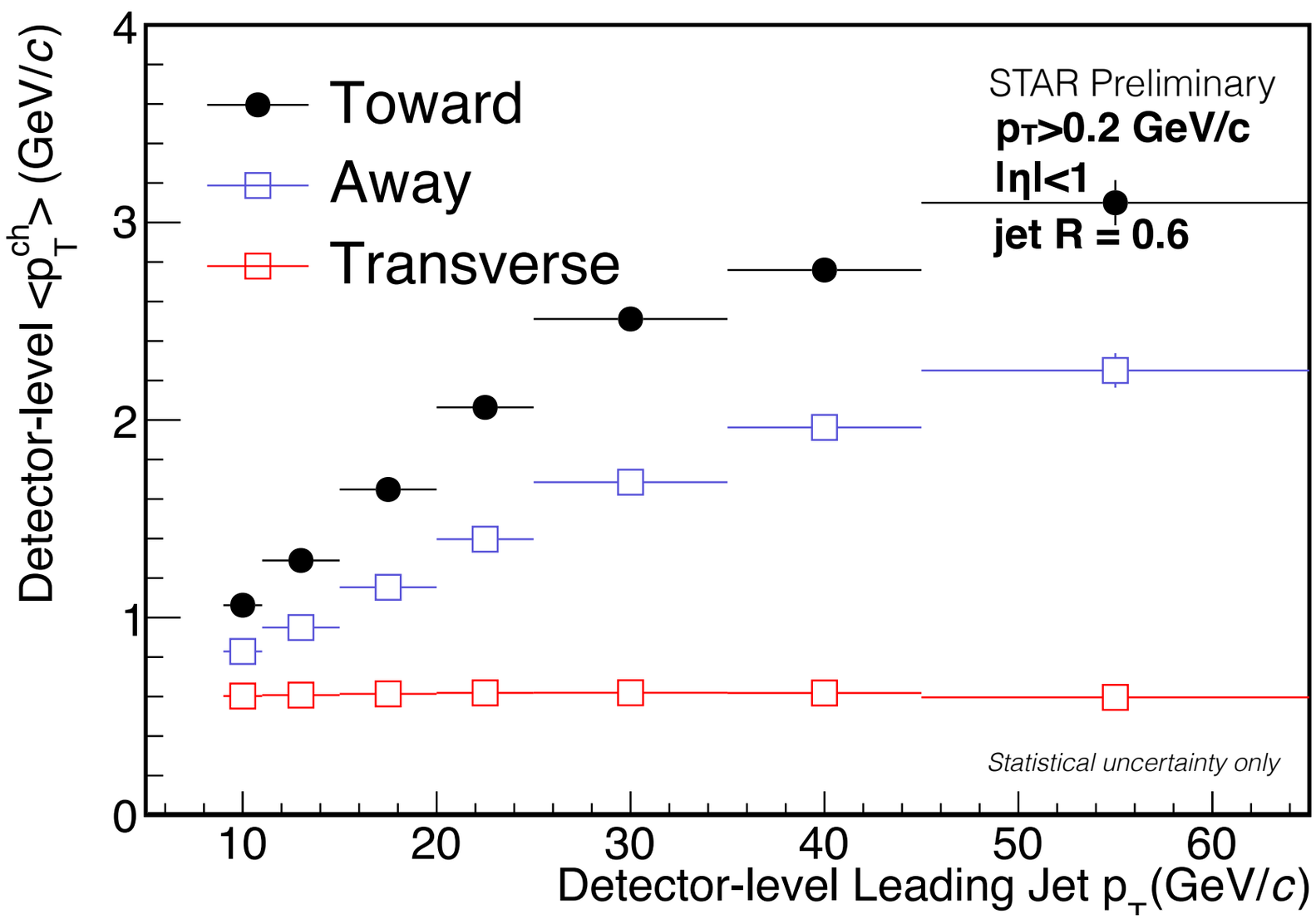


Transverse charged particle density slightly decreases with leading jet p_T for jet p_T >10 GeV/*c*

Charged Particle Average p_T

jet triggered events

p+p@200GeV

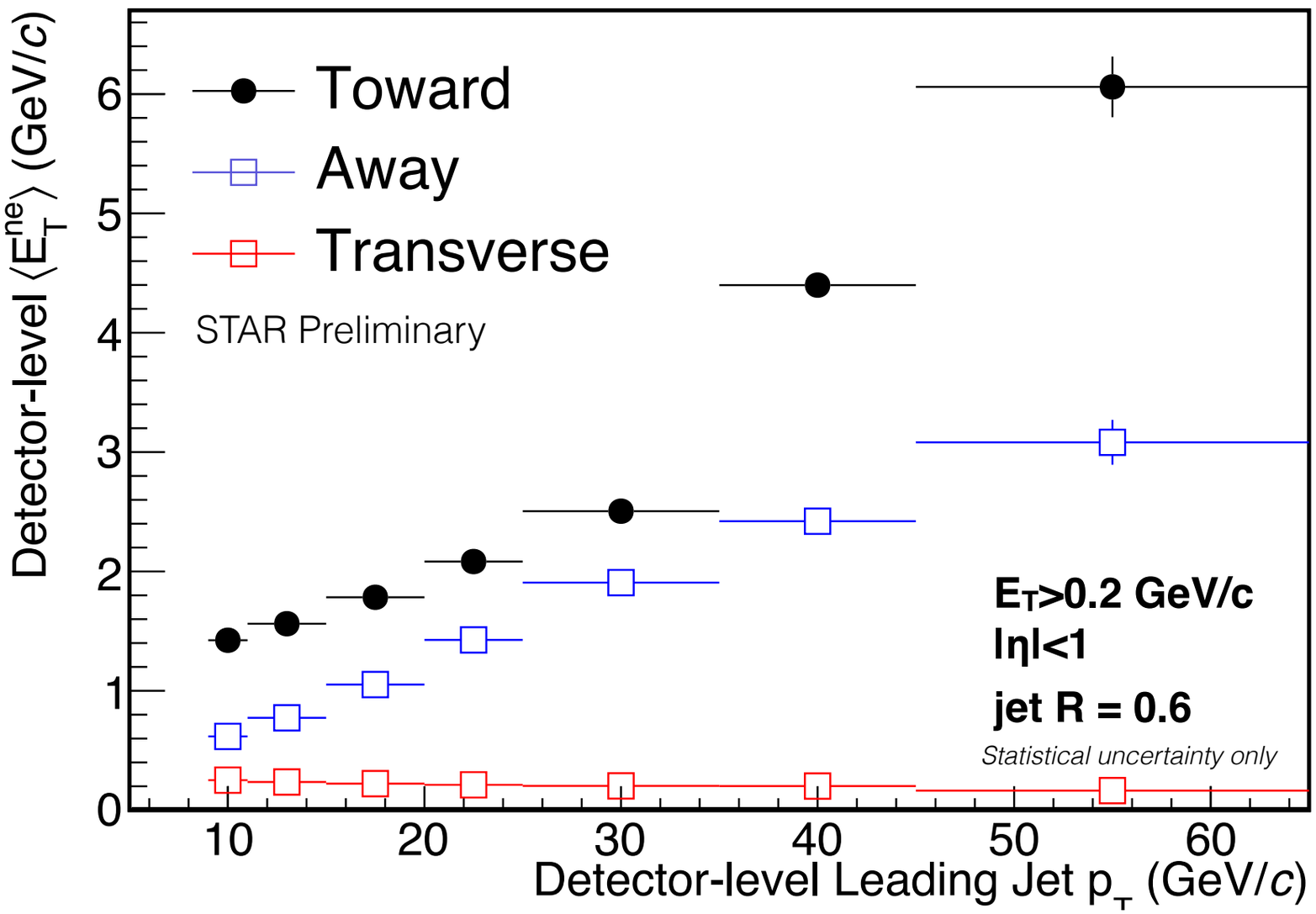


Transverse charged < p_T > weakly depends on leading jet p_T for p_T >10 GeV/*c*

Neutral Energy Density

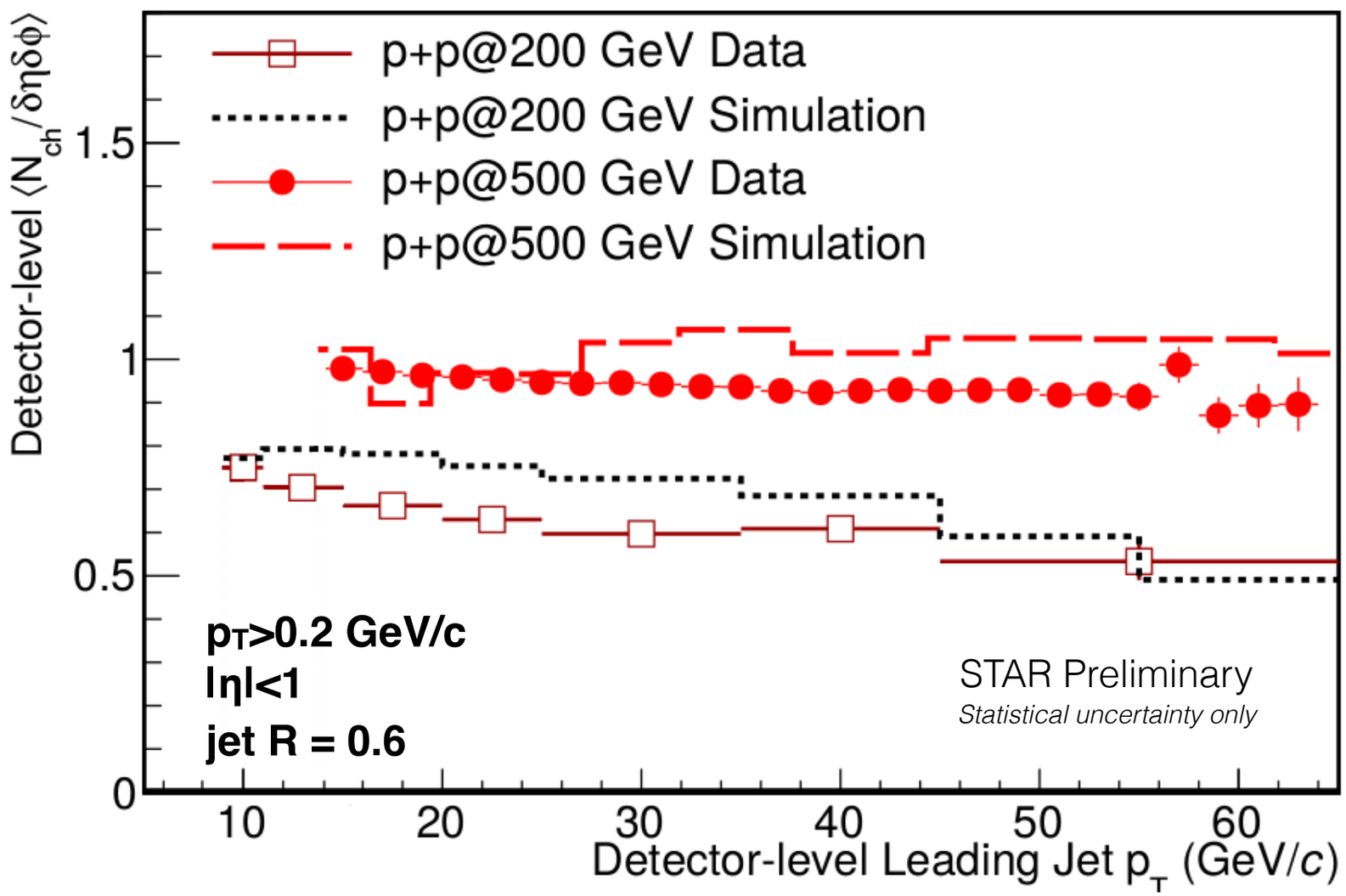
jet triggered events

p+p@200GeV



Transverse neutral energy density slightly decreases with leading jet p_T for jet p_T >10 GeV/*c*

Transverse Charged Particle Density Collision Energy Dependence



PYTHIA tunes into GEANT:

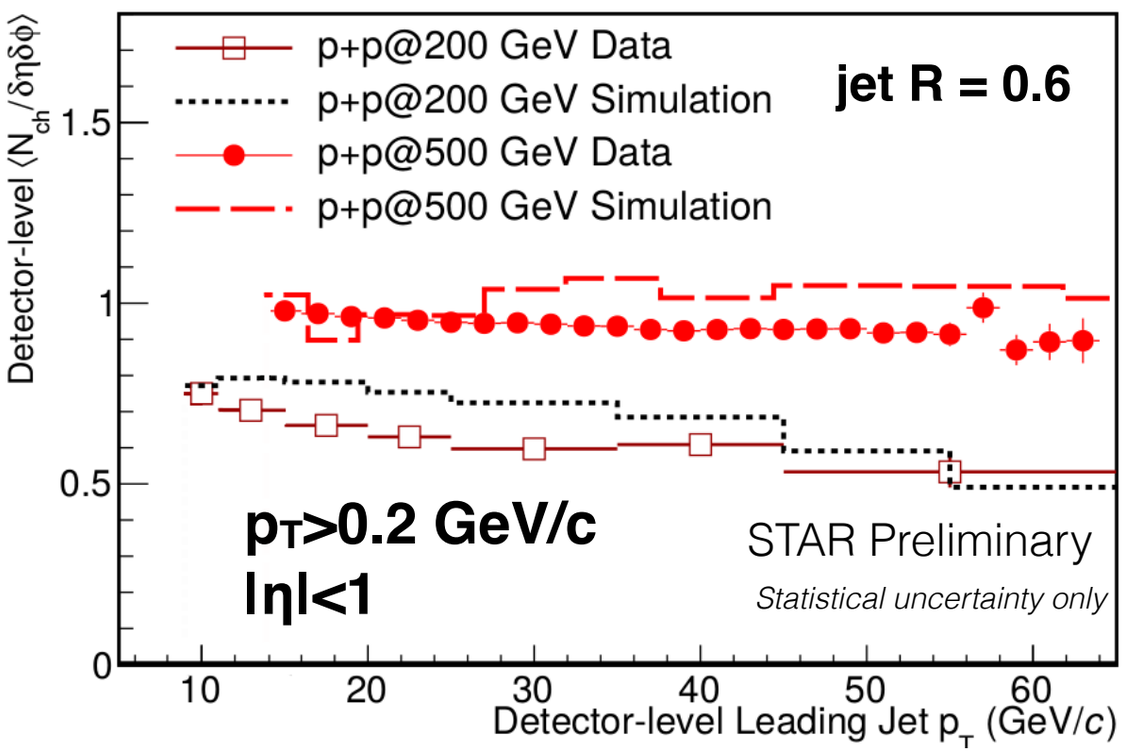
200GeV	perugia 2012 CTEQ6L1 PDF PARP(90)=0.213
500GeV	perugia 0

p+p@500GeV: Year 2009 data

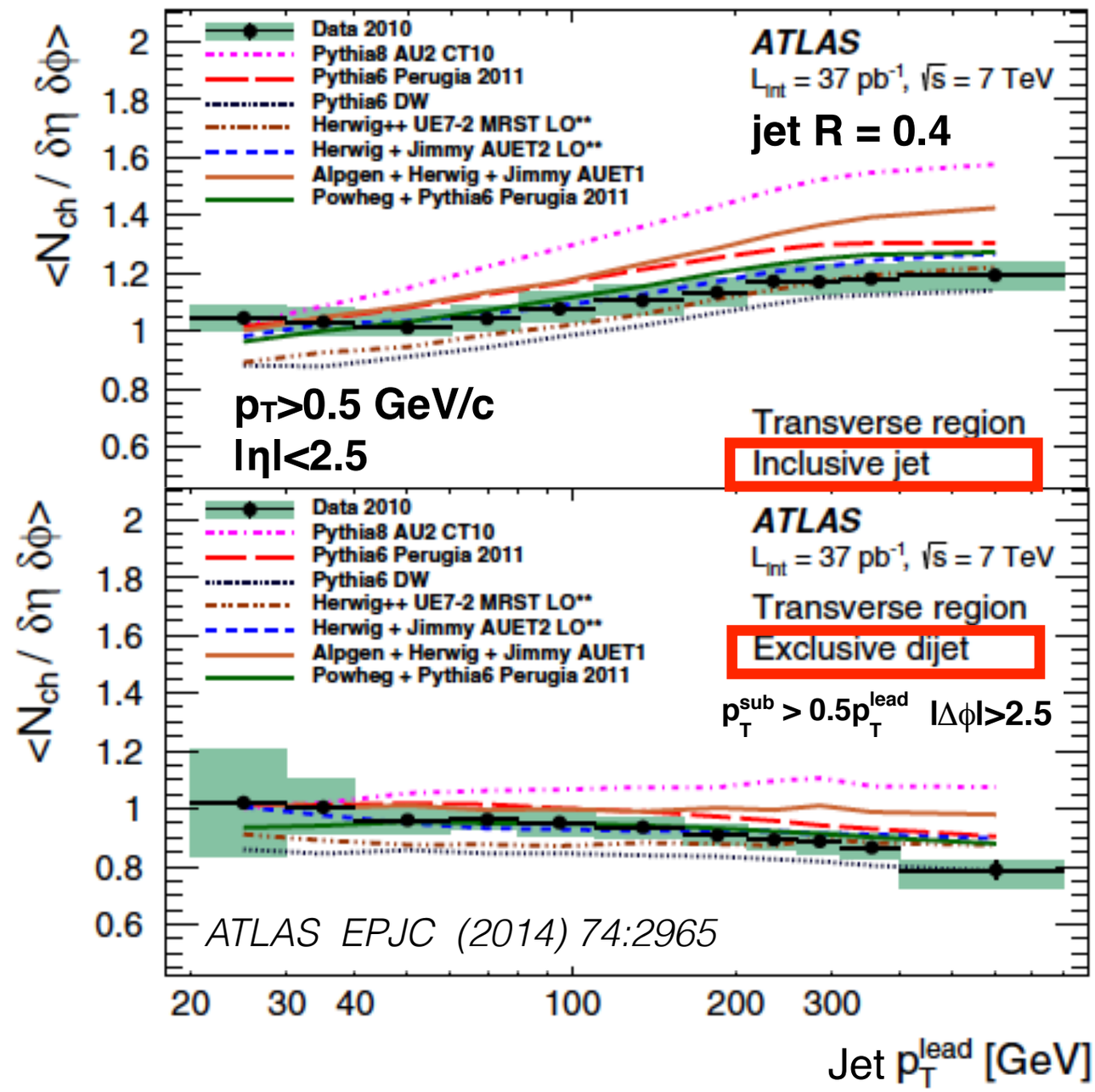
- Transverse charged particle density slightly decreases with leading jet p_T for jet p_T >10 GeV/*c* in both 200 and 500GeV collisions
- PYTHIA tunes over-predict data

Collision Energy Dependence

p+p@200GeV, 500GeV

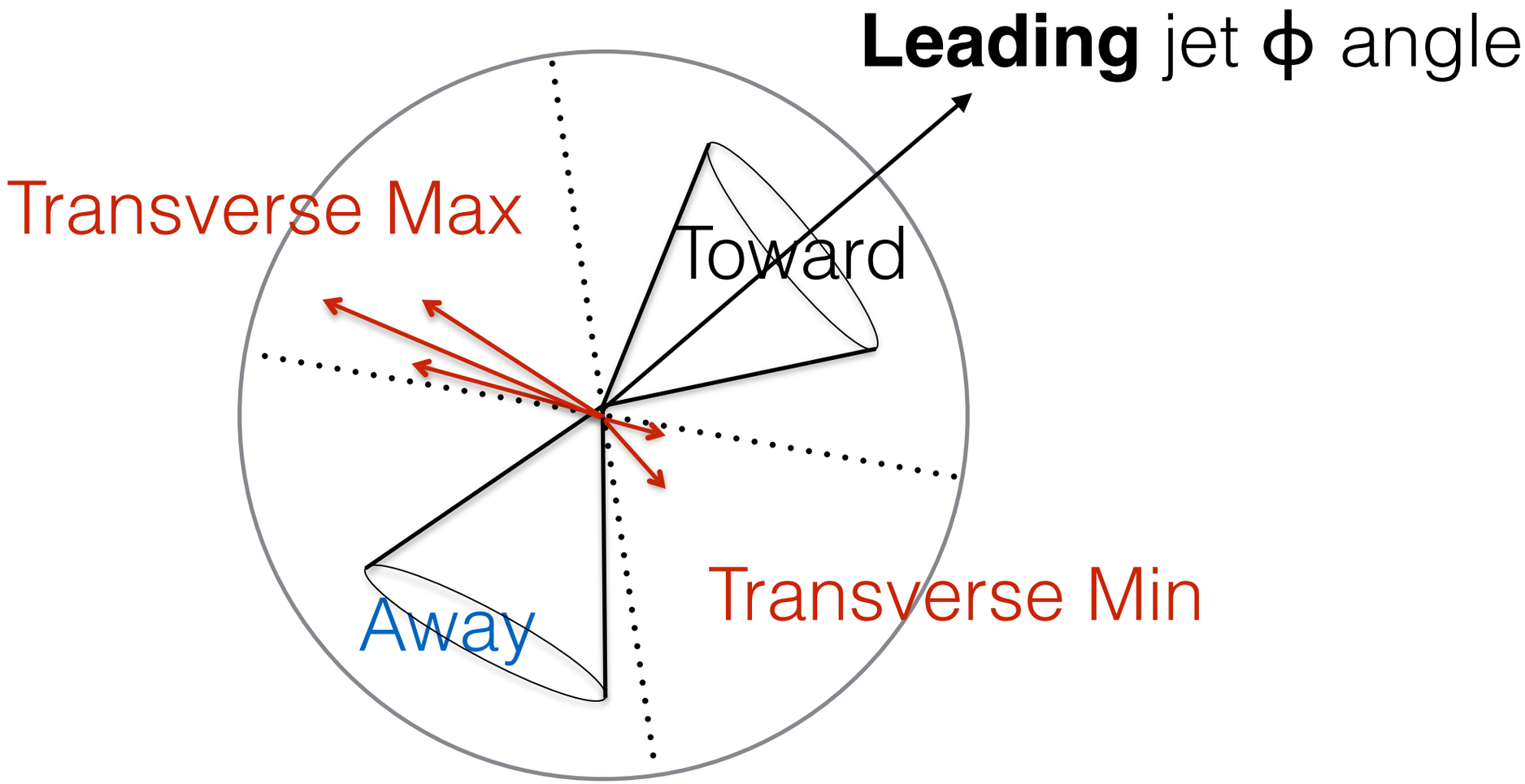


p+p@7TeV



Increase at higher LHC energy could be due to 3-jet and/or MPI process

Transverse Max & Transverse Min

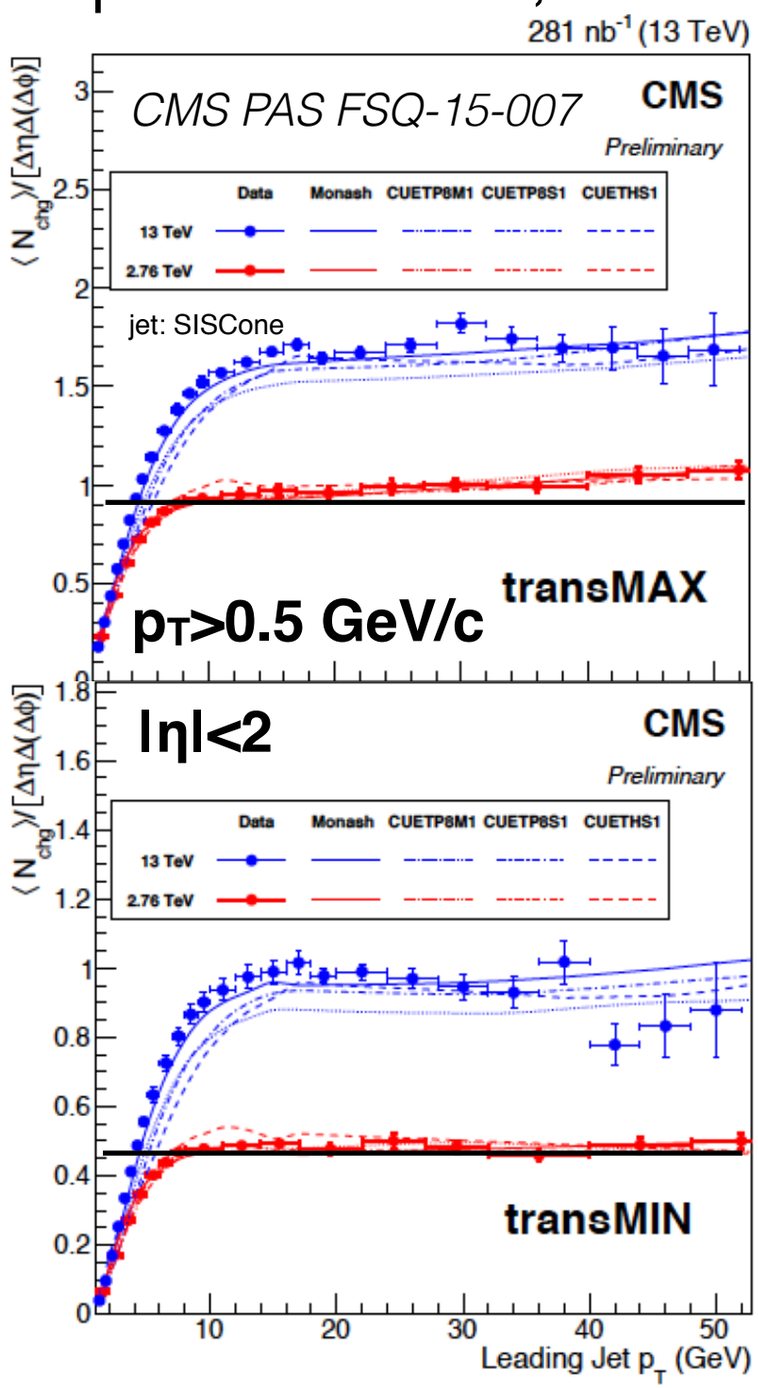


Smaller Multiplicity/Sum of energy --> Transverse Min
Larger Multiplicity/Sum of energy --> Transverse Max

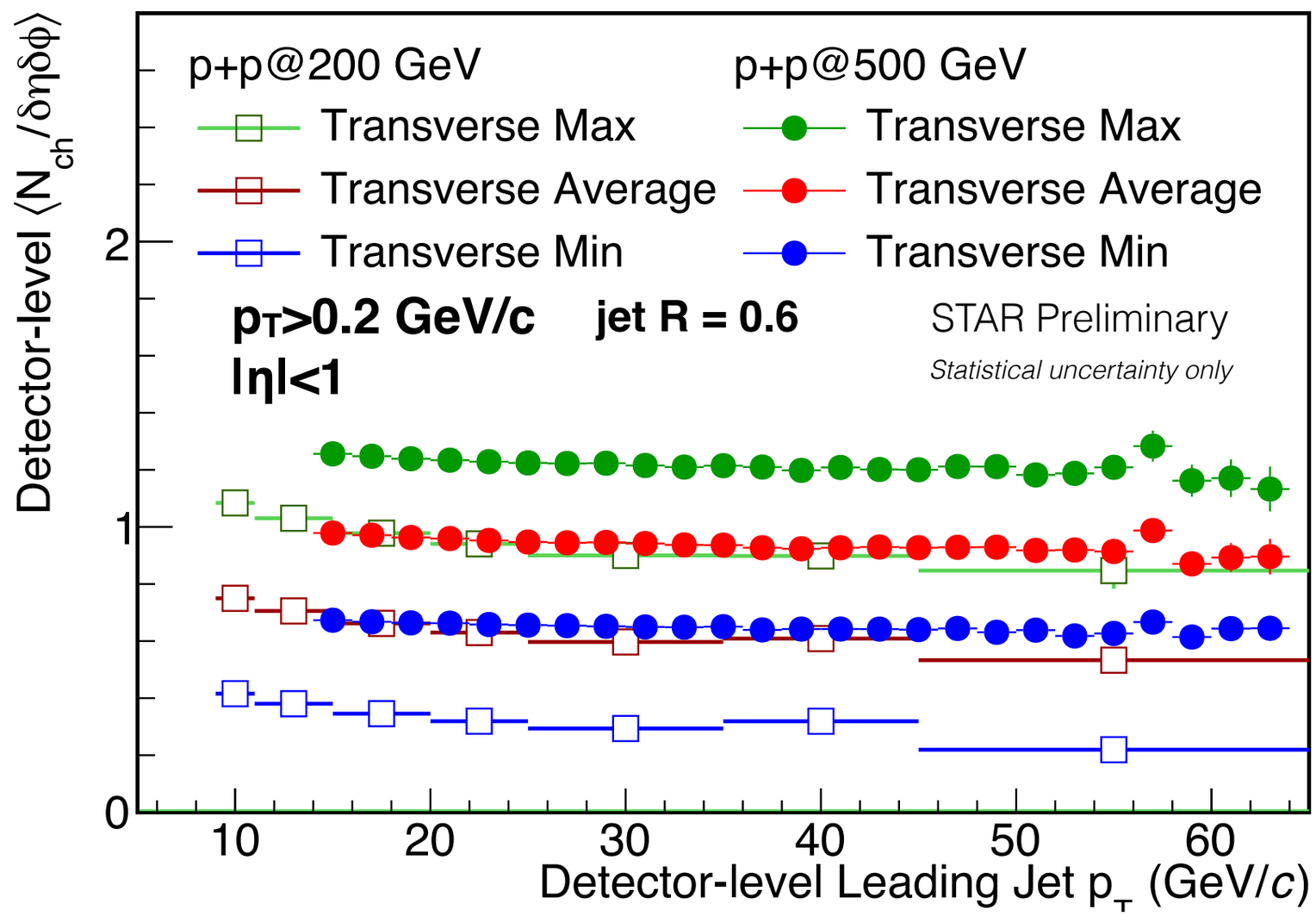
Transverse Min: more sensitive to MPI, Beam-Beam remnant
Transverse Max: more ISR/FSR contribution

Transverse Max Vs. Transverse Min

p+p@2.76TeV, 13TeV

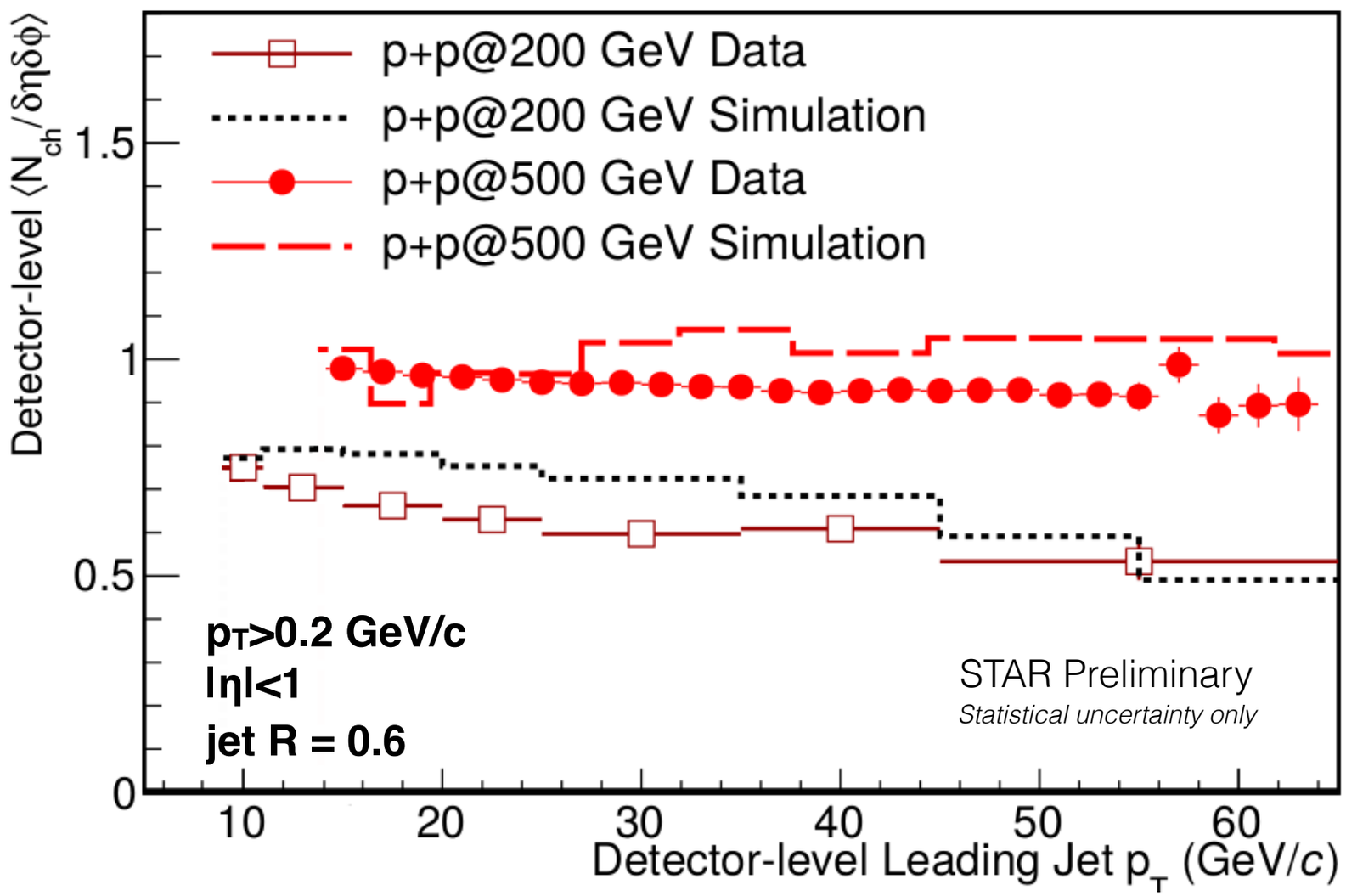


p+p@200GeV, 500GeV



Hints of less Initial/Final State Radiation at RHIC energies

Discussion on Pythia Tune



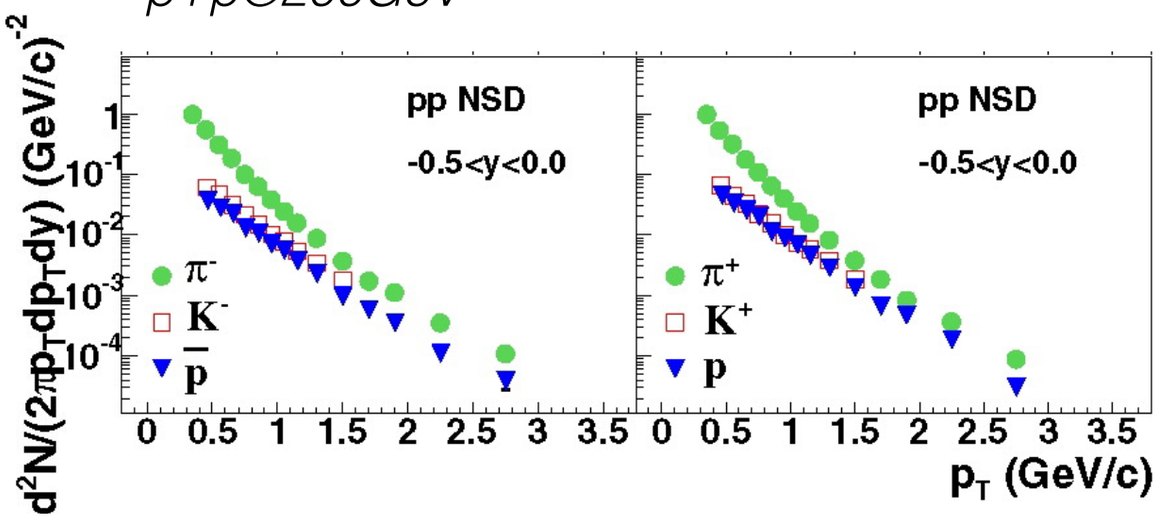
PYTHIA tunes into GEANT:

200GeV	perugia 2012 CTEQ6L1 PDF PARP(90)=0.213
500GeV	perugia 0

p+p@200GeV: Year 2012 data
p+p@500GeV: Year 2009 data

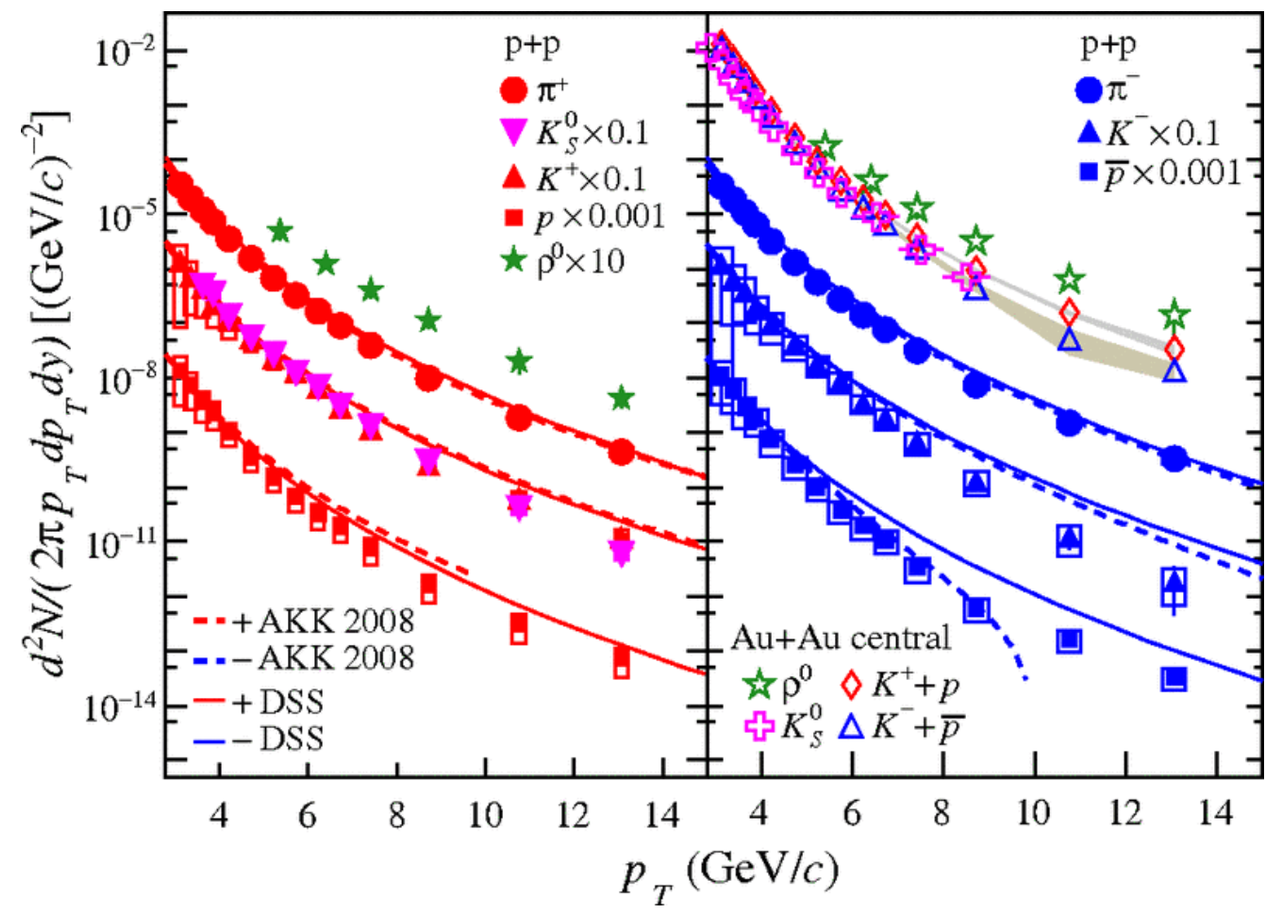
Discussion on Pythia Tune

p+p@200GeV



STAR, PLB **616**, 8-16

p+p@200GeV



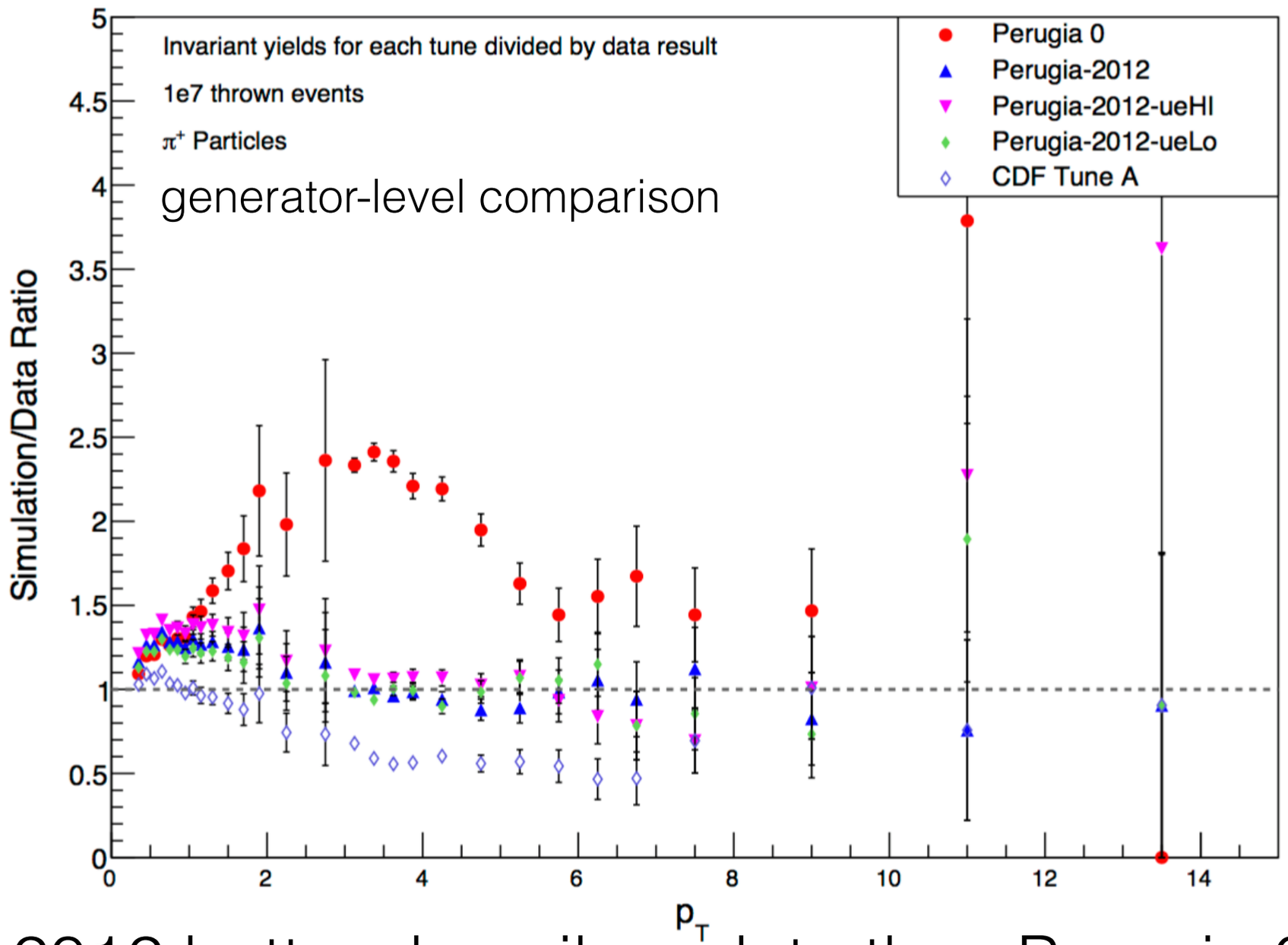
STAR, PRL **108**, 072302

Compare Pythia tunes with MinBias π spectra

Pythia Tunes: 200GeV π^+ Yield

STAR data: PRL **108**, 072302; PLB **616**, 8-16

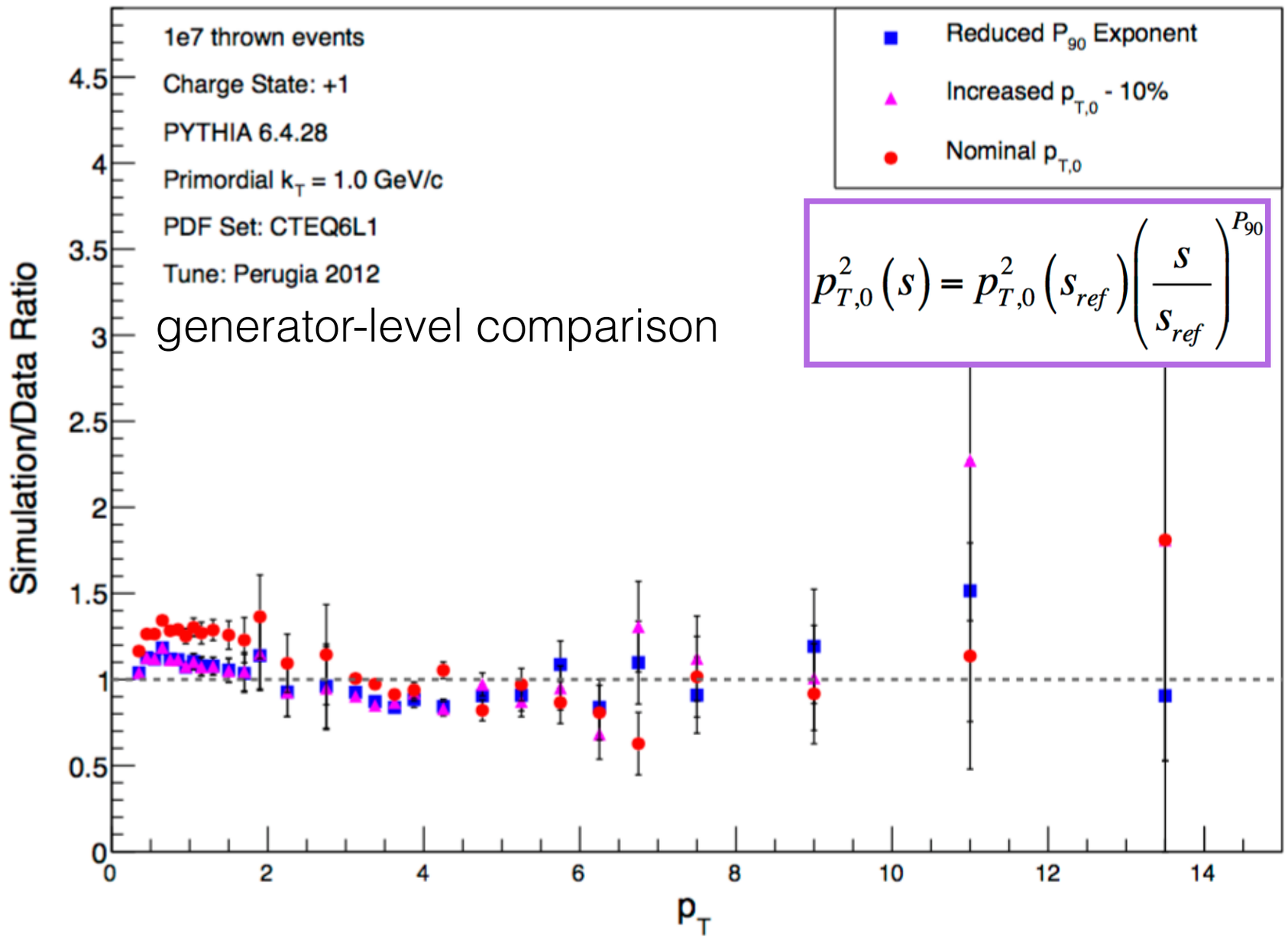
Thanks to Kevin Adkins for the simulations!



Perugia 2012 better describes data than Perugia 0 or Tune A at p_T>3GeV/*c*

Pythia Tunes: 200GeV π^+ Yield

STAR data: PRL **108**, 072302; PLB **616**, 8-16

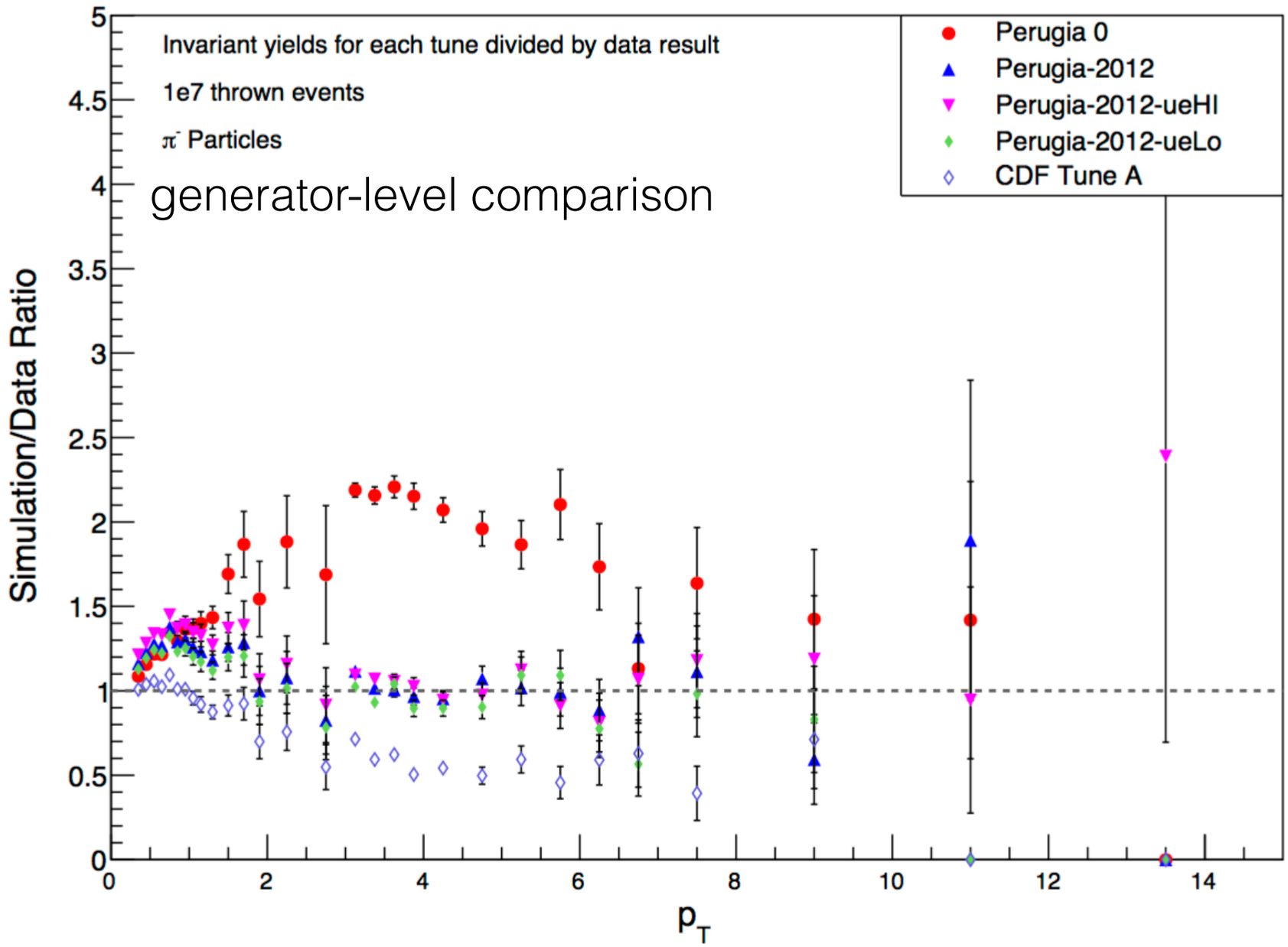


generator-level comparison

Reducing PARP(90) from 0.24 to 0.213 brings good agreement

Pythia Tunes: 200GeV π^- Yield

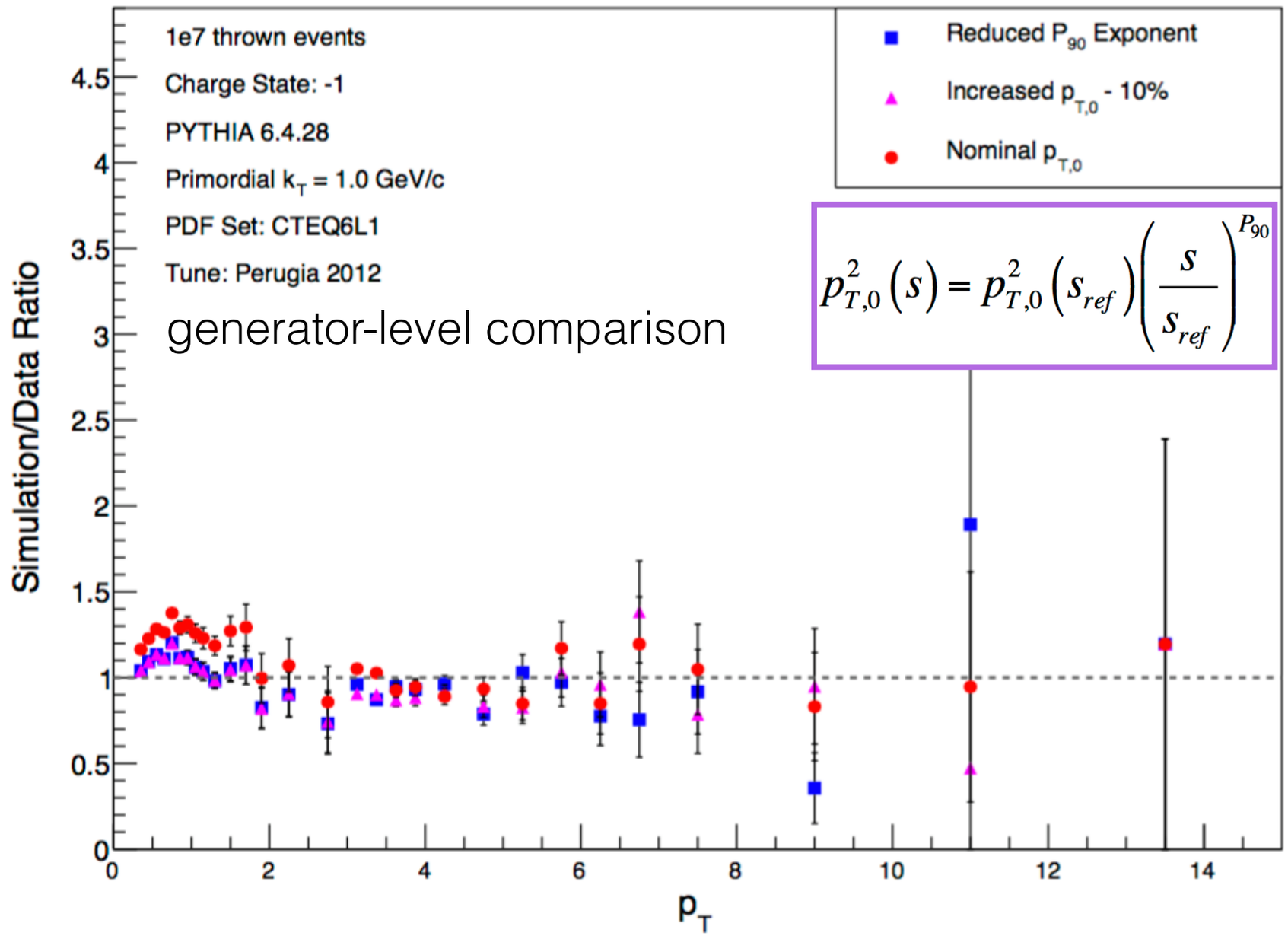
STAR data: PRL **108**, 072302; PLB **616**, 8-16



Tunes compared to π^- similar to π^+

Pythia Tunes: 200GeV π^- Yield

STAR data: PRL **108**, 072302; PLB **616**, 8-16



Perugia 2012 with PARP(90)=0.213 is optimized tune for 200GeV

Summary

- Underlying-event activity is measured by particle production in transverse region with respect to leading jet angle at p+p@200GeV by STAR
- Transverse charged particle multiplicity and total neutral energy slightly decreases at higher leading jet p_T
- PYTHIA perugia 2012 describes pion spectra but over-predicts transverse charged multiplicity at 200GeV
- Indication of less initial and final state radiation at RHIC energies than LHC energies