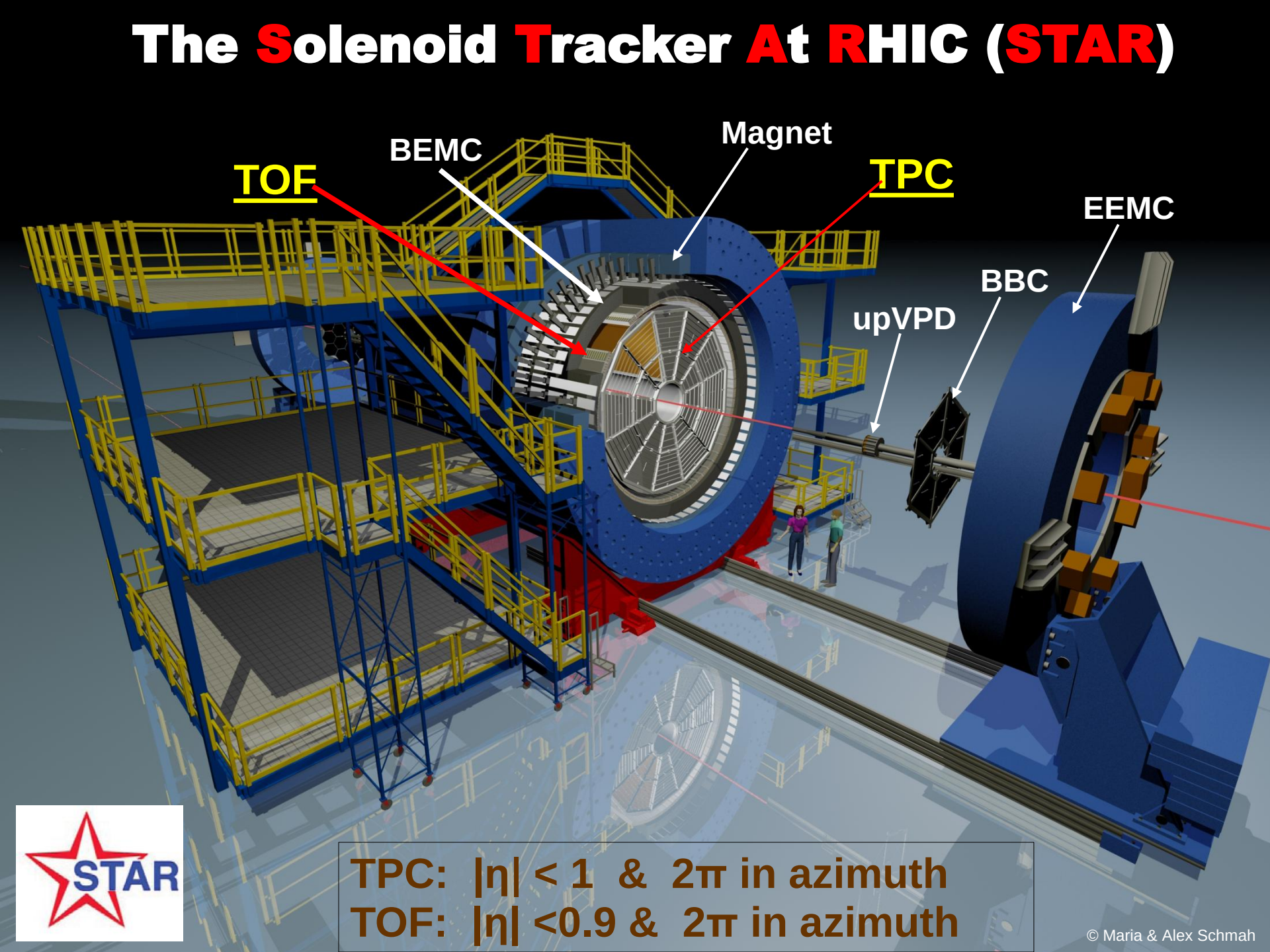
Comparison of AMPT and HIJING generated p_T spectra at mid-rapidity to those measured in the Beam Energy Scan from STAR

Stephen Horvat
for the STAR collaboration

Contents:

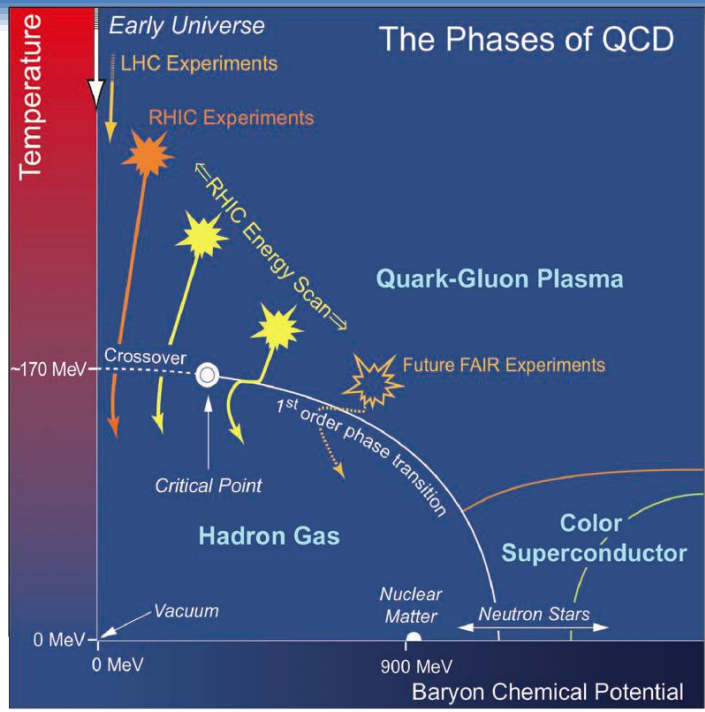
- STAR Detector
- Beam Energy Scan
- Nuclear Modification Factors (R_{CP})
- Physics
  - Suppression at high p_T
  - Cronin enhancement
- Charged hadron R_{CP} results from STAR
- Model comparisons

The Solenoid Tracker At RHIC (STAR)



Beam Energy Scan

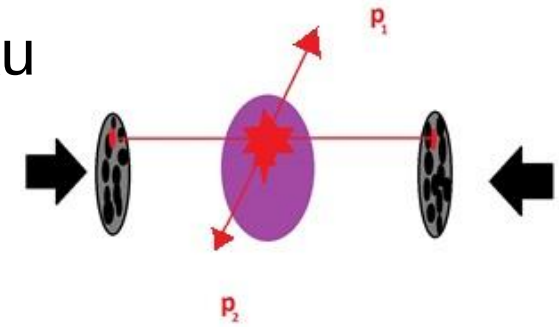
- Is there a critical point?
  - If so, where?
- Is there evidence for a first order phase transition?
- At what energy do key QGP signatures turn off?
  - Suppression of high p_T particles
    - measured by nuclear modification factor



Nuclear Modification Factor (R_{AA})

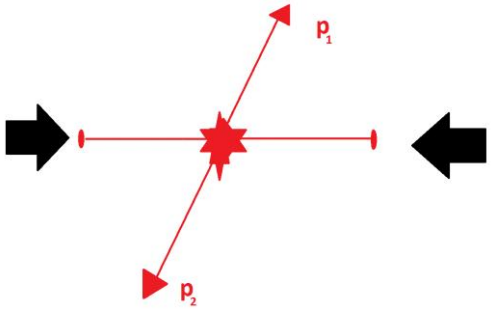
hard scatterings produce early high p_T probes

Au + Au



$$R_{AA} = \frac{1}{(N_{bin})_{AA}} \times \frac{(Spectra)_{AA}}{(Spectra)_{pp}}$$

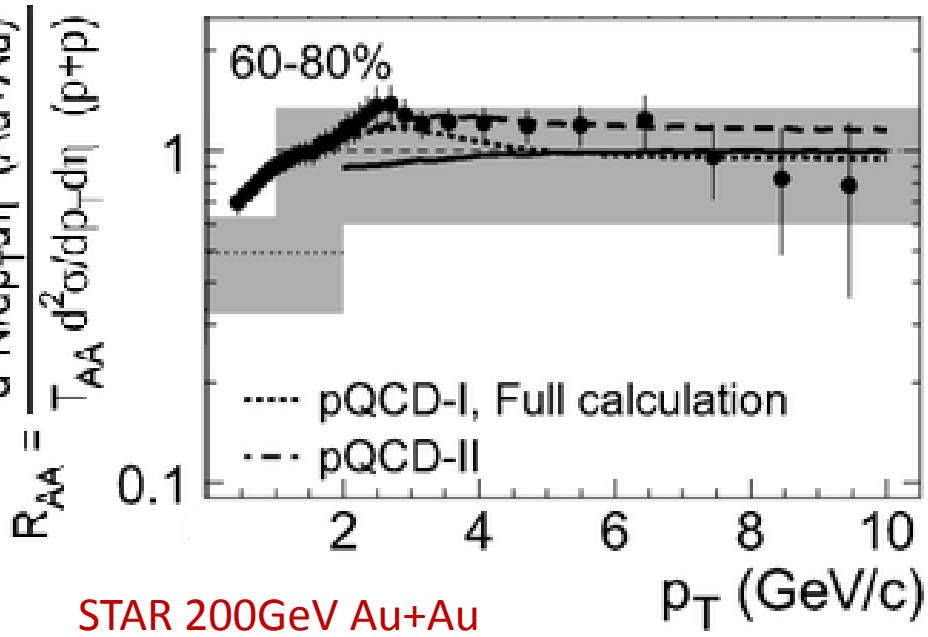
p + p



N_{bin} ≡ number of binary collisions (from a Glauber MC model)

Ann. Rev. of Nucl. and Part. Sci. 57, 205 (2007)

High p_T suppression



STAR 200GeV Au+Au

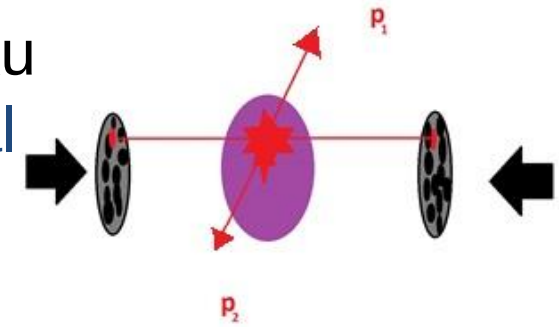
peripheral Au+Au is similar to p+p at $\sqrt{s_{NN}}$ = 200GeV

Phys. Rev. Lett. 91, 172302 (2003)

Nuclear Modification Factor (R_{CP})

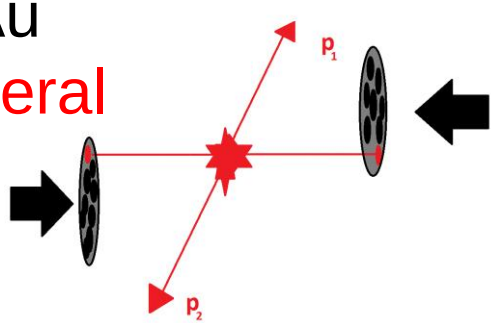
hard scatterings produce early high p_T probes

Au + Au
Central



$$R_{CP} = \frac{(N_{bin})_P}{(N_{bin})_C} \times \frac{(Spectra)_C}{(Spectra)_P}$$

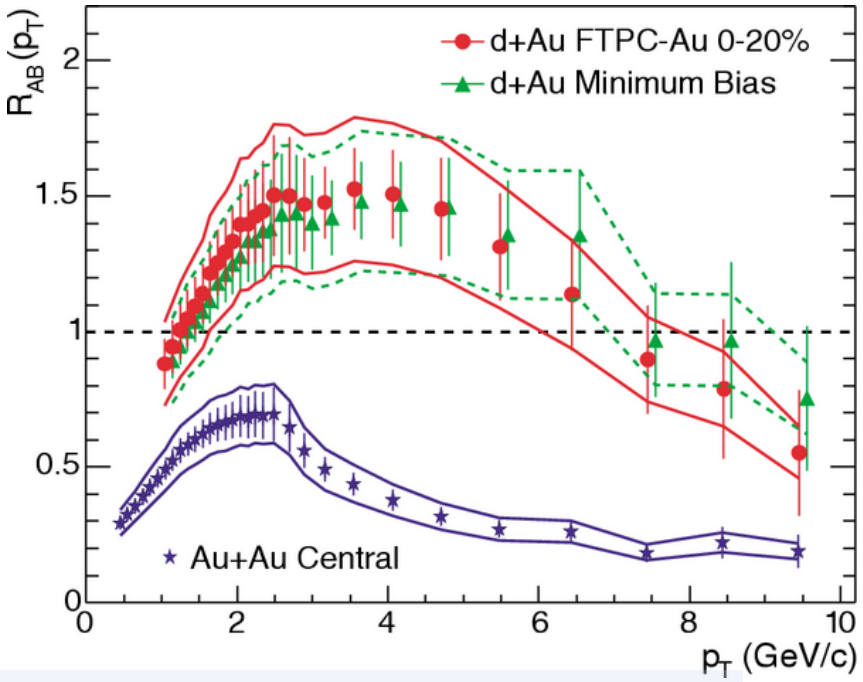
Au + Au
Peripheral



N_{bin} ≡ number of binary collisions (from a Glauber MC model)

Ann. Rev. of Nucl. and Part. Sci. 57, 205 (2007)

Suppression in Au+Au, enhancement of d+Au from Cold Nuclear Matter (CNM)



deuteron + Au at 200GeV

'Suppression' ≡ $R_{CP} < 1$

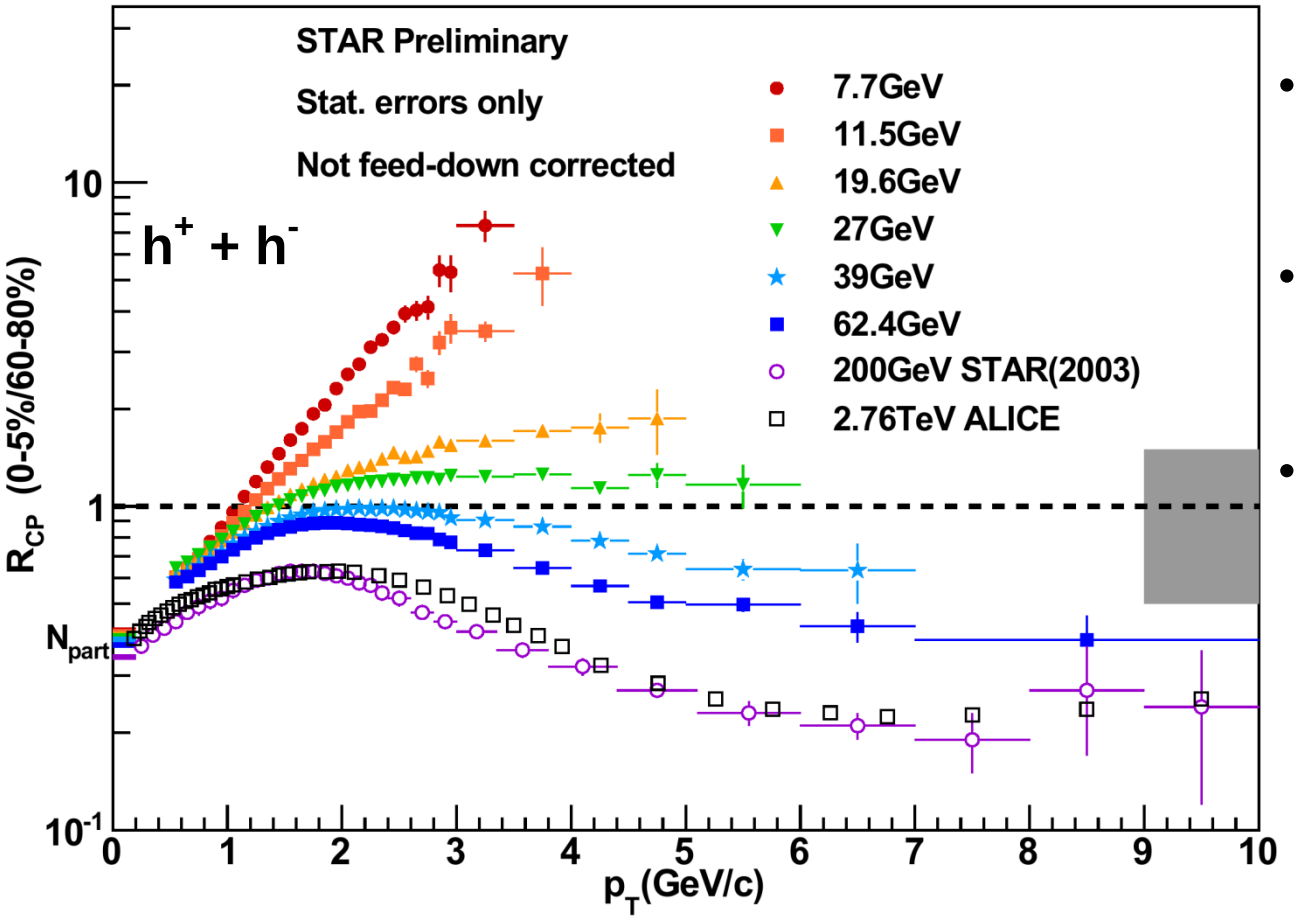
'Quenching' ≡ loss of energy for high momentum particles

- CNM effects depend on the presence of a heavy nuclei
- A significant QGP is unlikely to be formed in d + Au collisions
- Suppression observed in Au+Au at 200GeV is not a CNM effect

The 'Cronin Effect' was first observed as the enhancement of spectra in asymmetric collisions relative to a p+p reference

Phys. Rev. Lett. **91** (2003) 072304

Results - R_{CP}



- Lower energies strongly enhanced
- Large $\sqrt{s_{NN}}$ suppressed
- Enhancement at low $\sqrt{s_{NN}}$ competes with jet quenching, hiding where jet quenching "turns off"

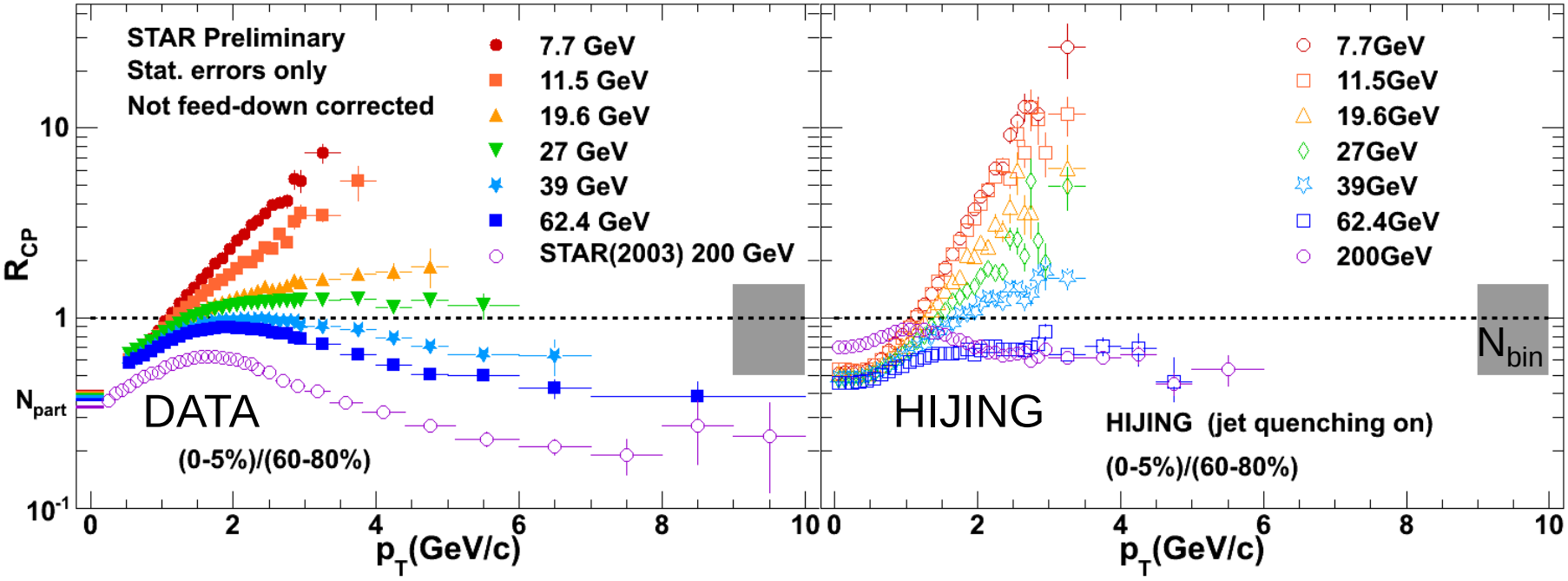
Phys. Rev. Lett. **91** (2003) 172302
Nucl. Part. Phys. **38** (2011) 124080

Models

- We plan to use event generators to disentangle the relative contributions of quenching and enhancement
- This requires verifying that the event generators can reproduce the data
- HIJING 1.383
  - QCD based Monte Carlo
- AMPT
  - Similar to HIJING but adds transport mechanisms
  - string melting (SM) off uses Lund string fragmentation for hadronization (v1.21)
  - SM on uses quark coalescence for hadronization (v2.21)

Gyulassy M. and Wang X. 1994 *Comput. Phys. Commun.* **83** 307
Zhang B. et al. 2000 *Phys. Rev.* C **61** 067901

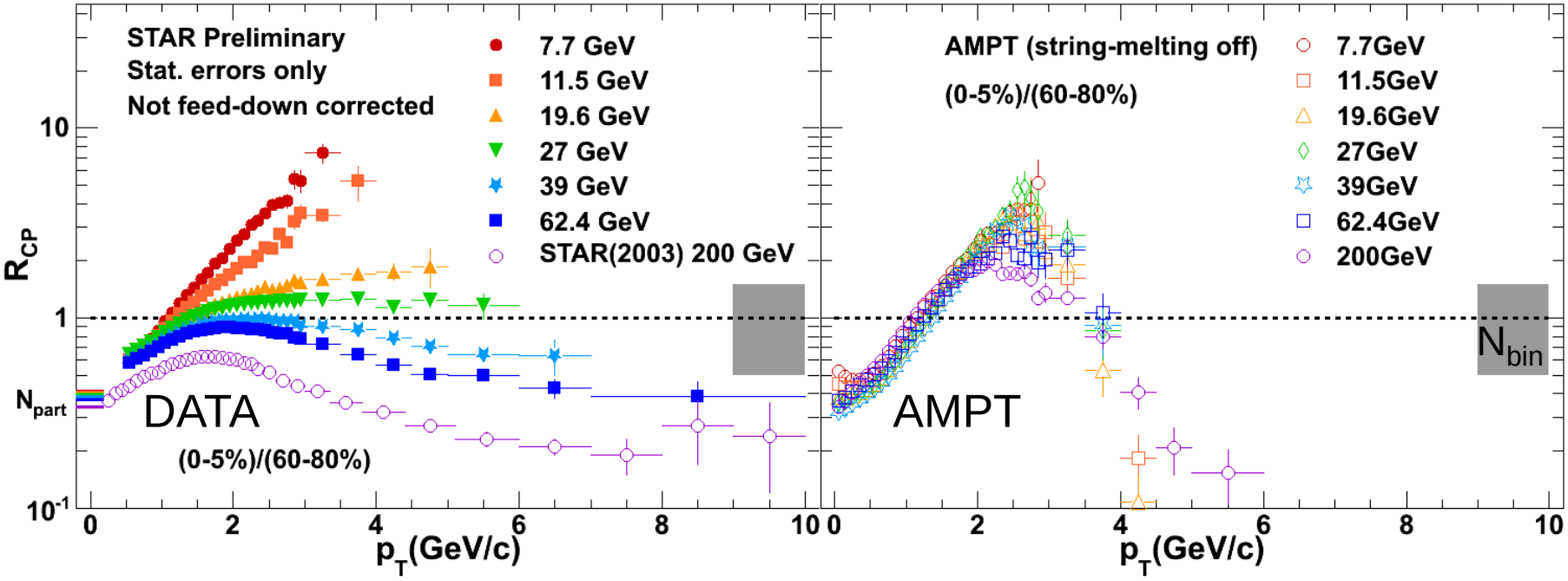
HIJING



HIJING:

- captures the collision-energy dependence
- 200GeV has odd low p_T behavior
- Generally overestimates R_{CP}

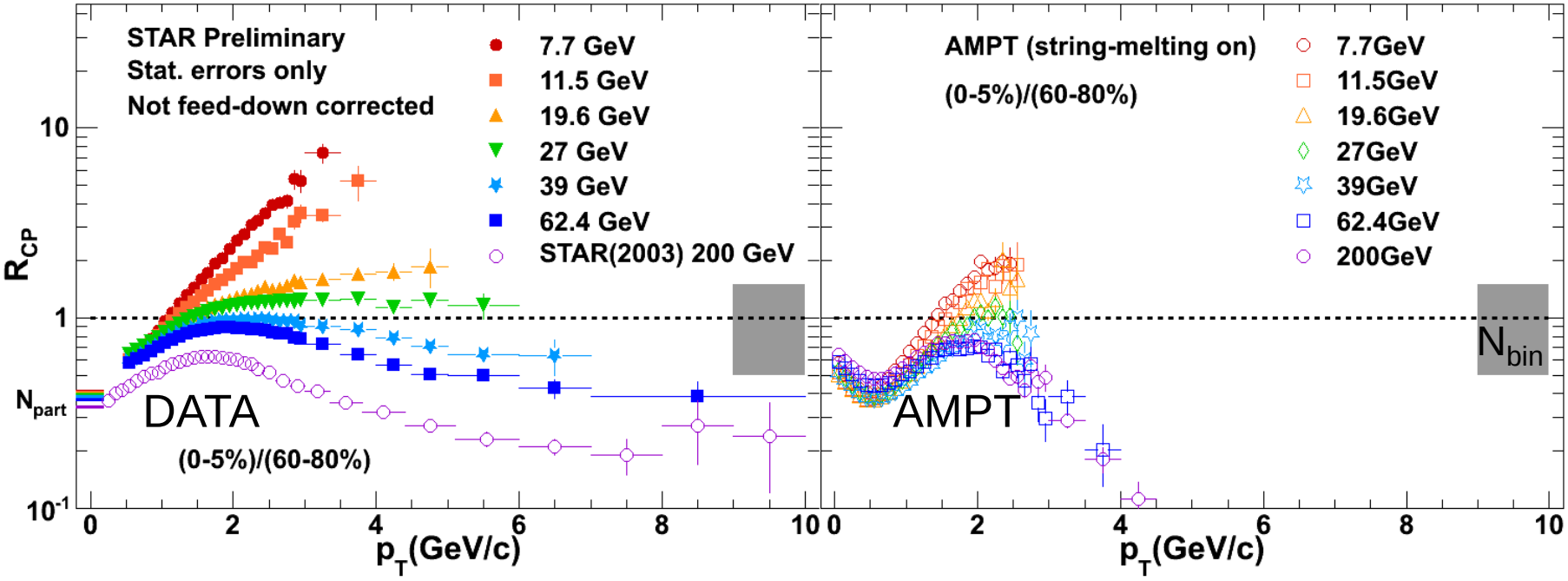
AMPT SM off



AMPT SM off:

- Minimal beam energy dependence
- Fails to match data
- Sharp turn over near 2.5GeV/c
  - Possibly due to AMPT's hadronic transport model dominating at low pt

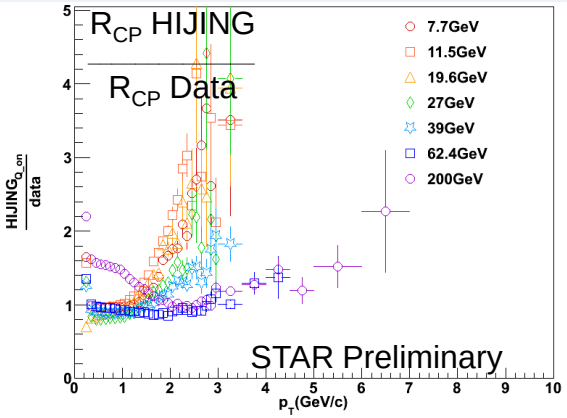
AMPT SM on



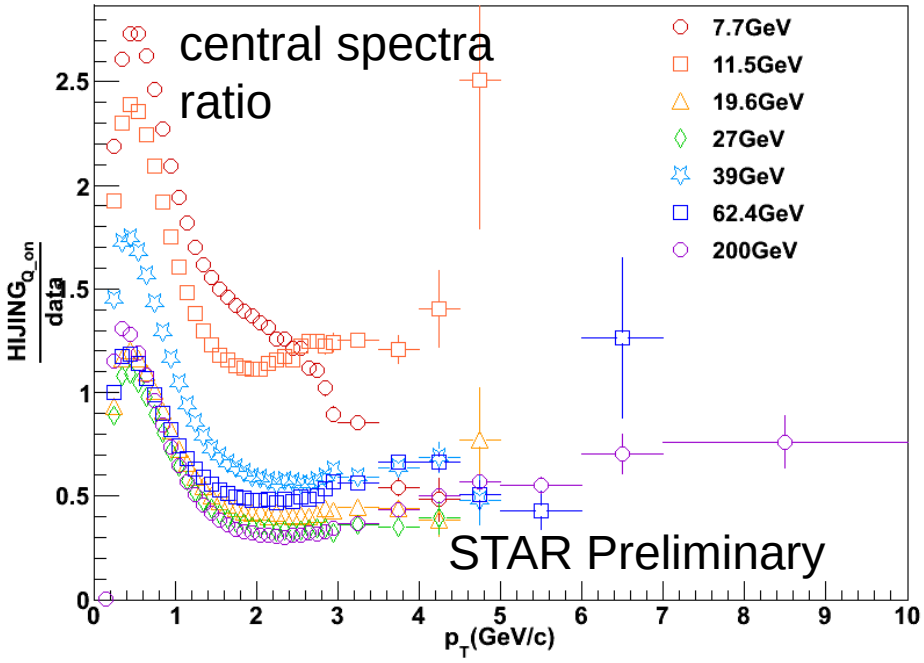
AMPT SM on:

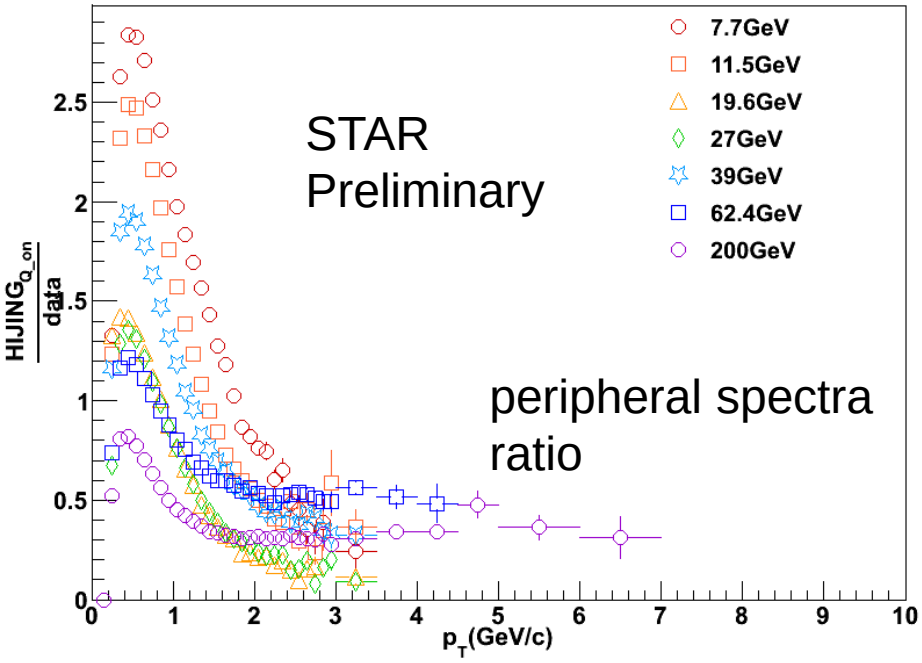
- Recovers beam energy dependence
- Limited p_T reach (same number of simulated events for SM on/off)

HIJING/data

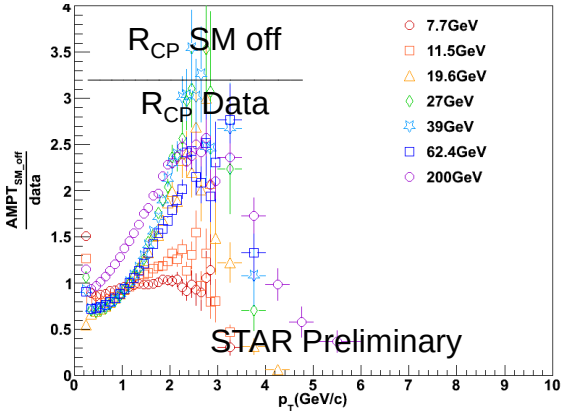


Spectra for central and peripheral from data disagree with HIJING

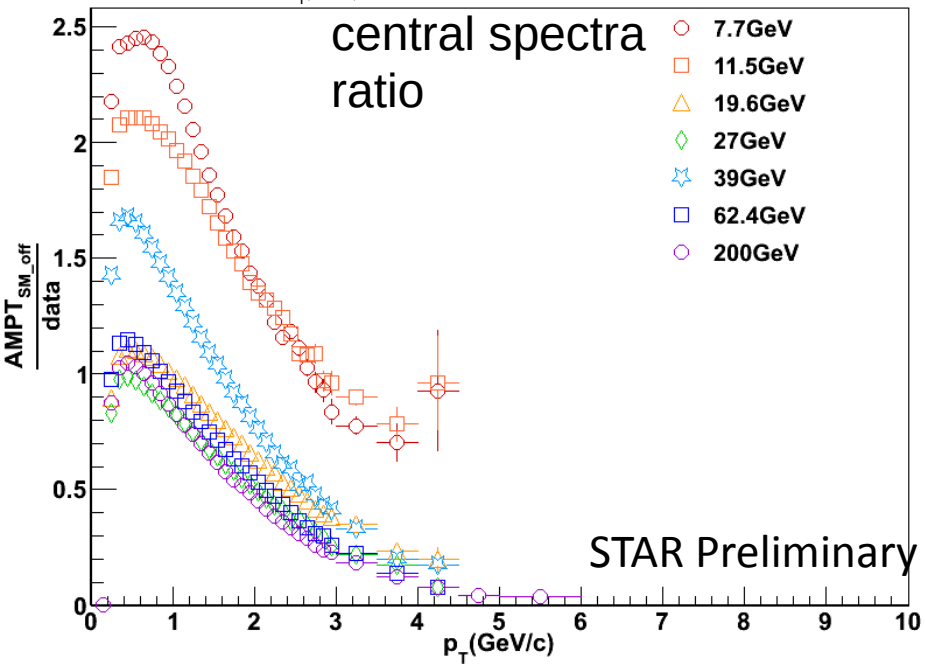


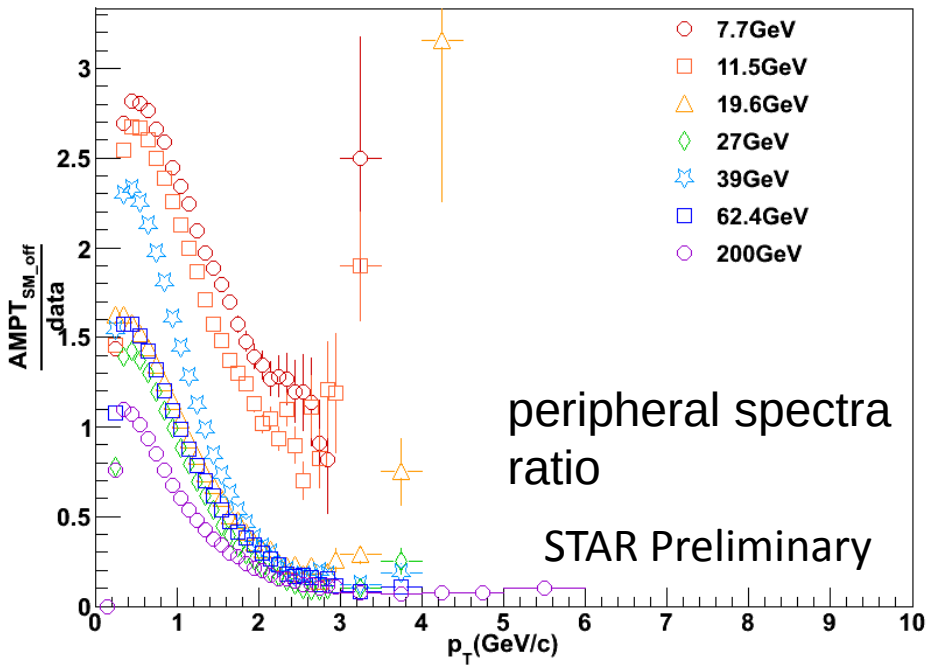


AMPT SM off/data

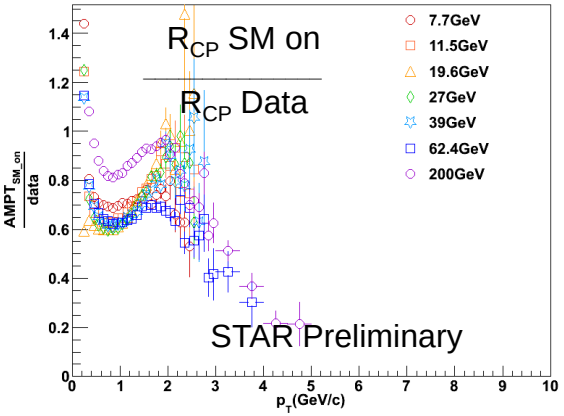


- Spectra for central and peripheral from data disagree with AMPT w/ SM off
- Recall no $\sqrt{s_{NN}}$-dependence to R_{CP}

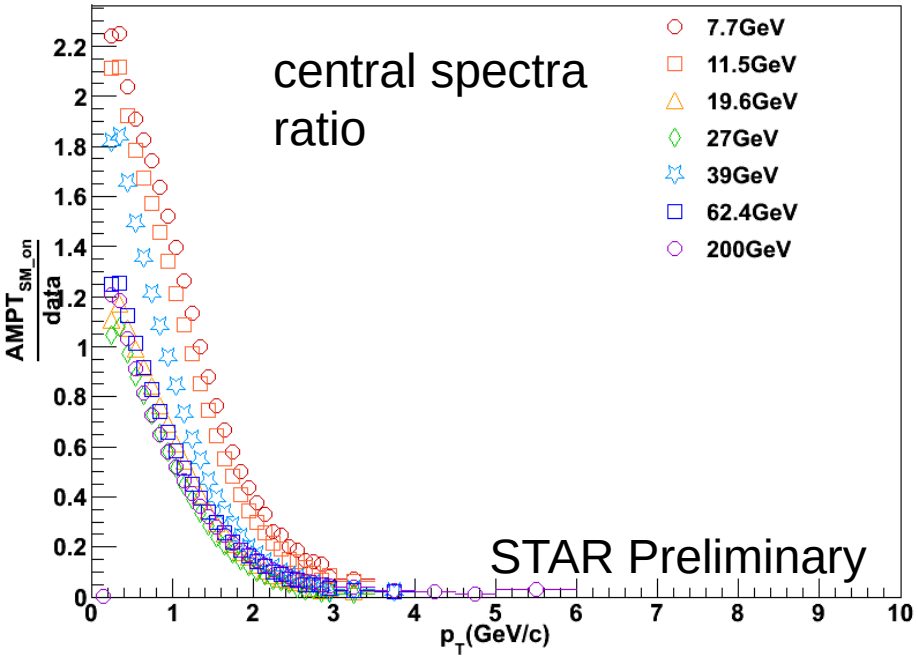


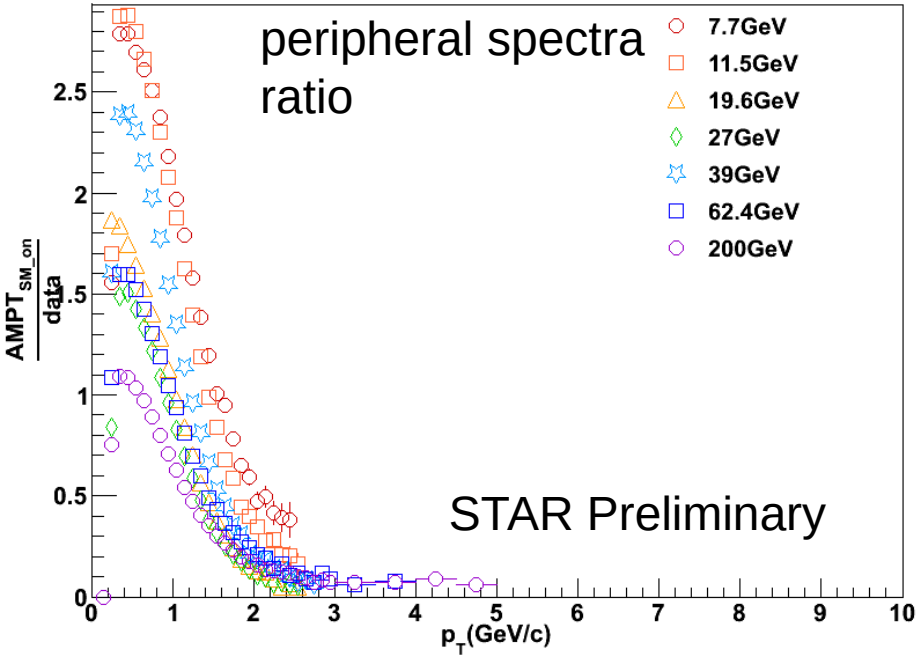


AMPT SM on/data



- Spectra for central and peripheral from data disagree with AMPT w/ SM on, though shape of R_{CP} are close





Conclusions

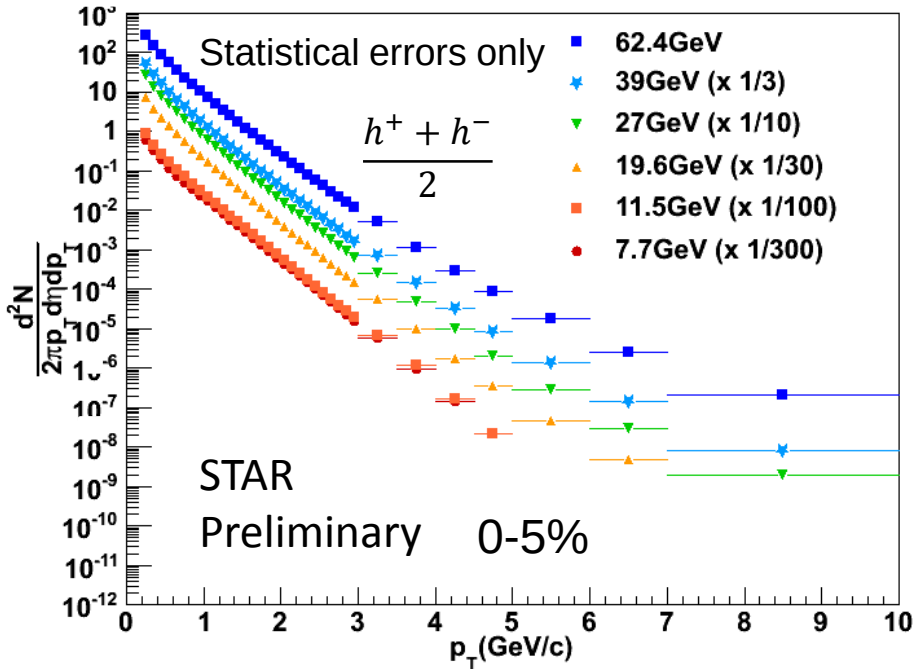
- Clear energy ordering is observed in the data
- Charged R_{CP} is suppressed for high $\sqrt{s_{NN}}$ data-sets
- At the lower beam energies charged R_{CP} is strongly enhanced
- Neither AMPT nor HIJING matches the measured central or peripheral spectra
- AMPT generated spectra depends strongly on string melting
- HIJING has a strong $\sqrt{s_{NN}}$-dependence, similar to the data

Outlook

- Additional models and tunes may allow us to disentangle the relative contributions of quenching and enhancement
- Look into PID comparisons to models

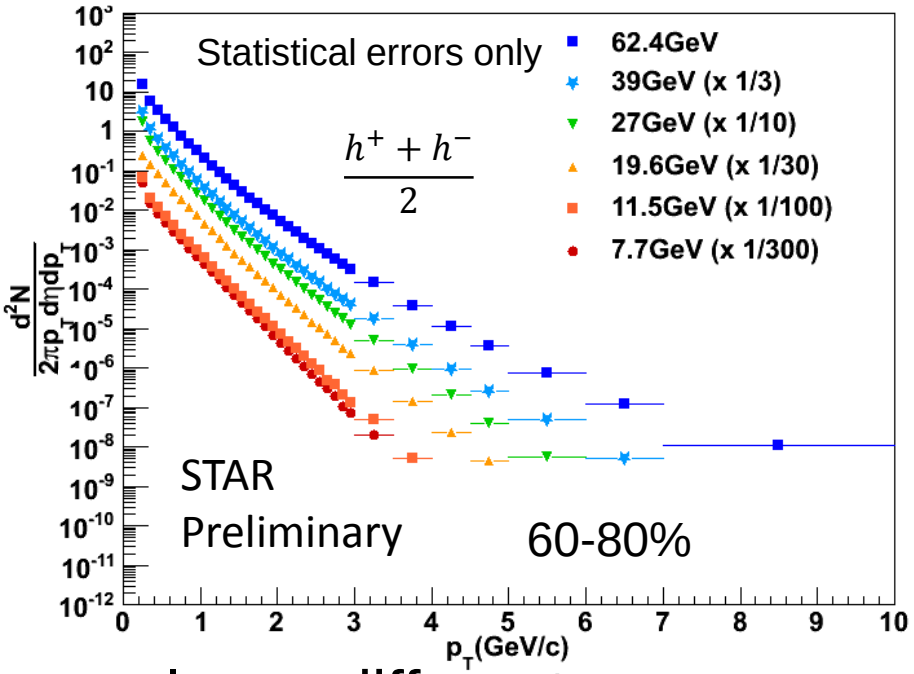
Results - Spectra

Central



slopes ~ equal

Peripheral



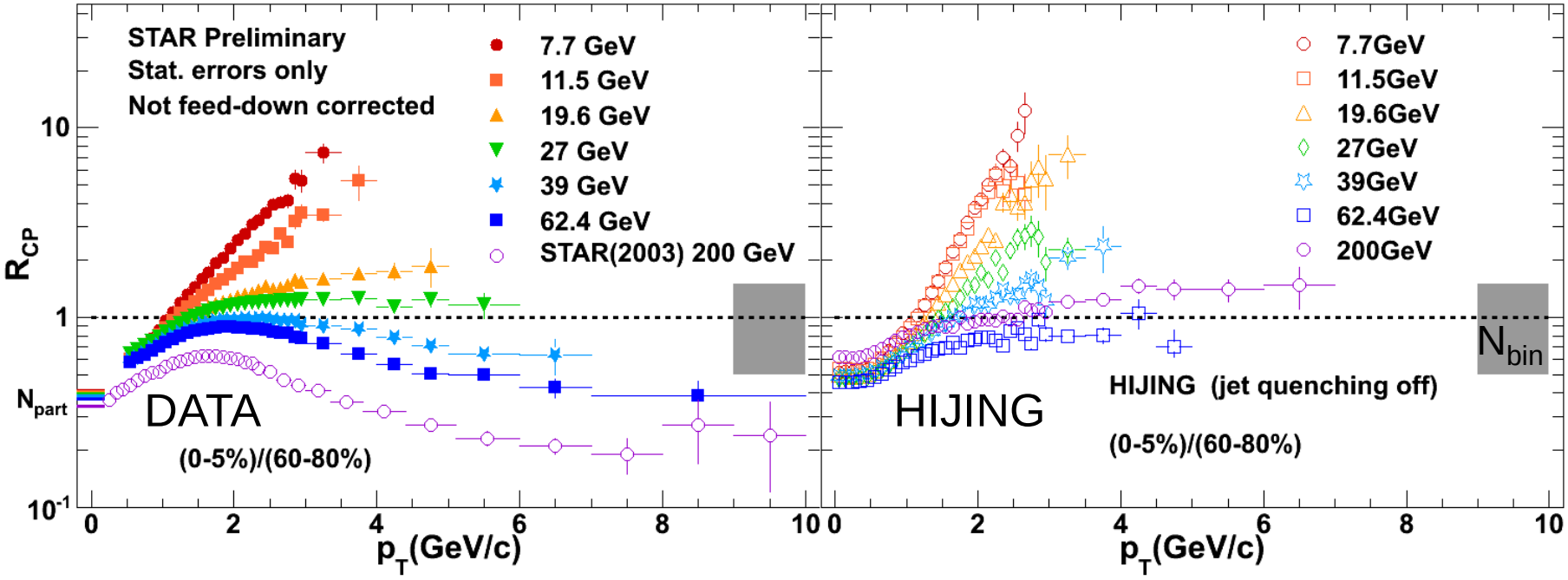
slopes different

Peripheral spectra shows stronger dependence on beam energy

Model statistics

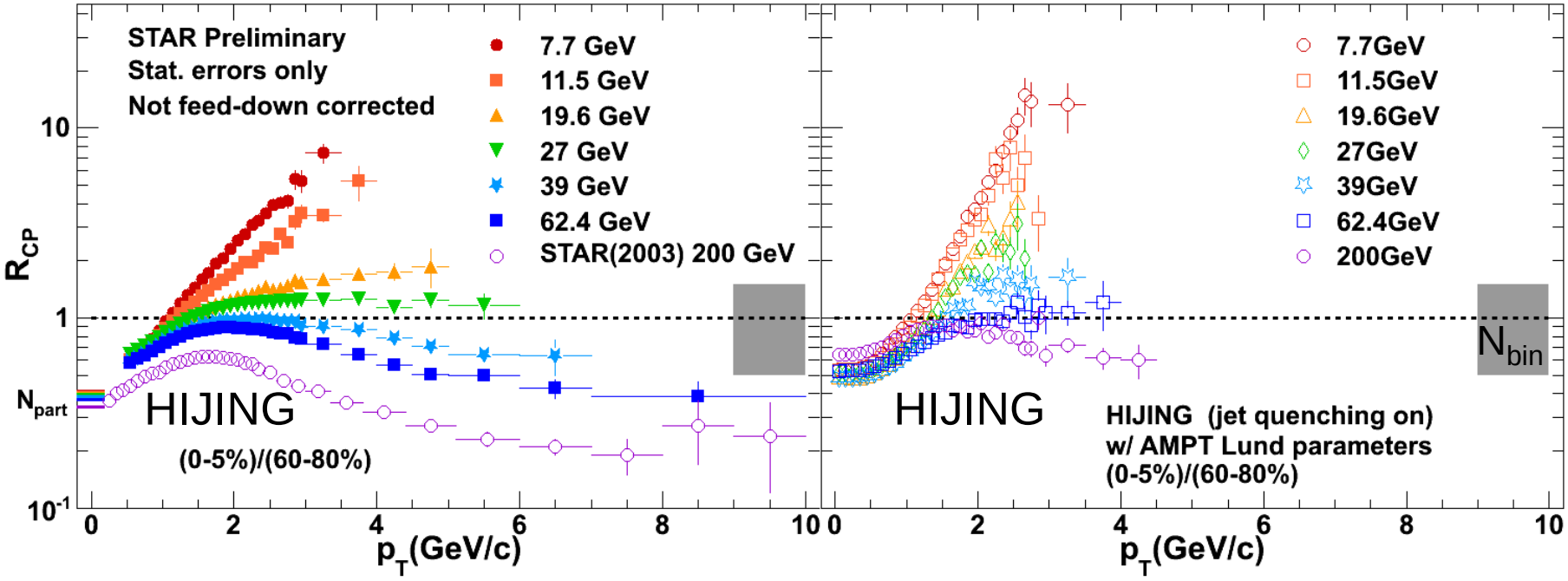
$\sqrt{s_{NN}}$(GeV)	Year	N_{event} MB	AMPT	AMPT SM	HIJING	HIJING Qoff	HIJING alternate Lund
7.7	2010	4M	1.2M	1.2M	5.2M	2.2M	4.3M
11.5	2010	12M	1.2M	1.2M	2.5M	500k	9.3M
19.6	2011	36M	1.2M	1.2M	970k	1.7M	1M
27	2011	70M	1.2M	1.2M	1M	1.4M	950k
39	2010	130M	1.2M	1.0M	1M	1M	800k
62.4	2010	67M	1.2M	1.0M	1M	1M	1M
200	2001	4M	1.3M	1.0M	1M	1M	1M

HIJING quenching off



7.7GeV barely changed from quenching on

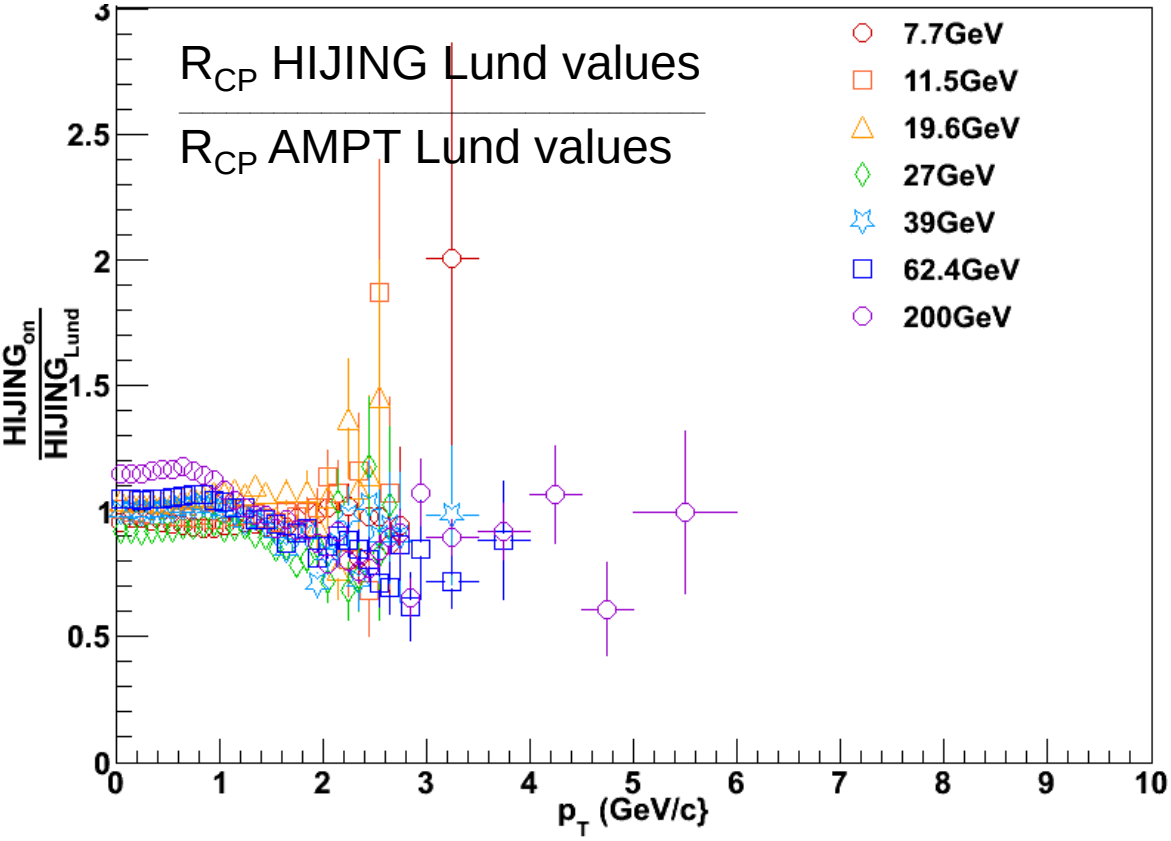
HIJING quenching on, alt

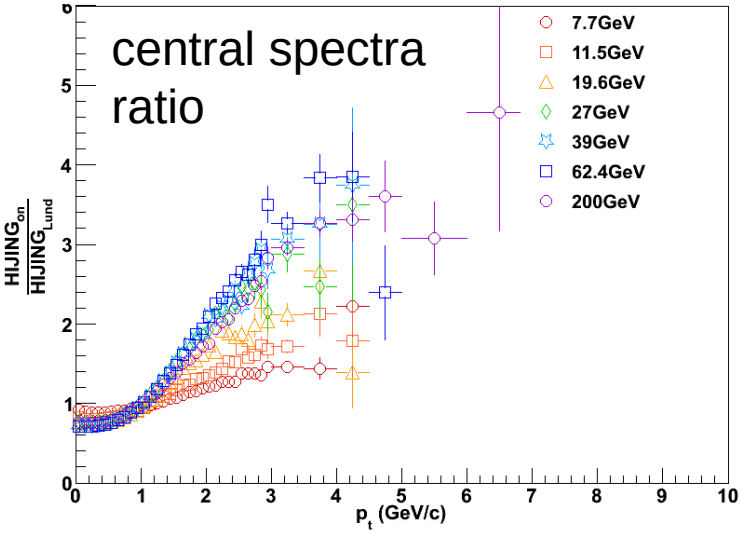


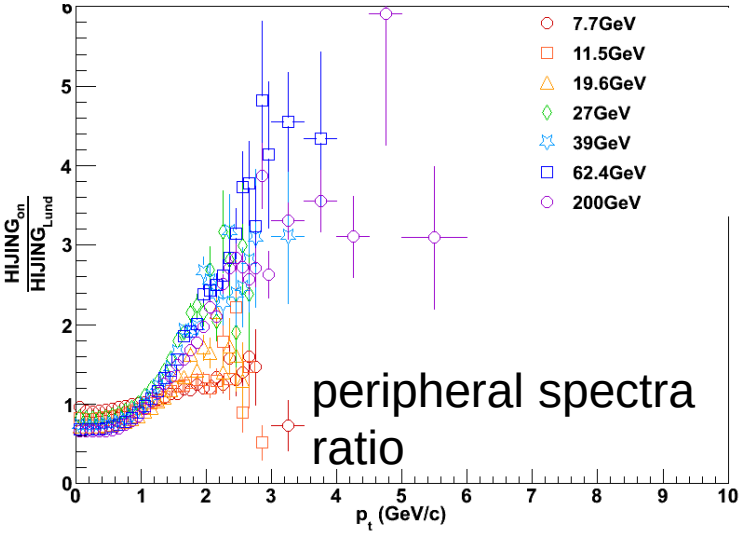
HIJING with AMPT's Lund splitting parameters

- Small effect to R_{CP} from different parameters

HIJING quenching on, alt





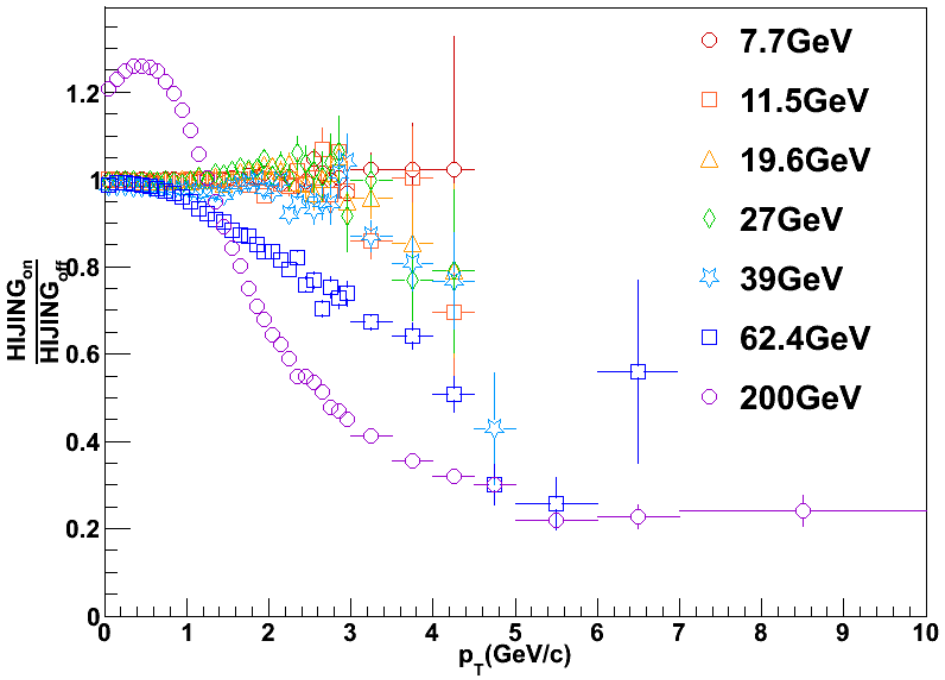


Spectra for central and peripheral are altered by similar amounts when fragmentation parameters are changed

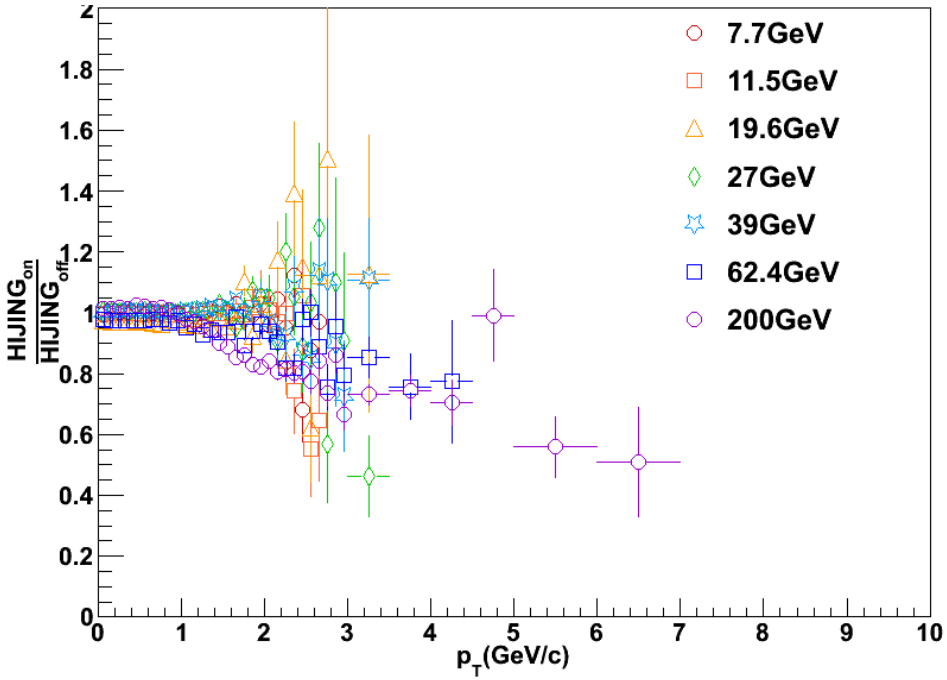
HIJING quenching on/off

Spectra Ratios

Central 0-5% ratio



Peripheral 60-80% ratio

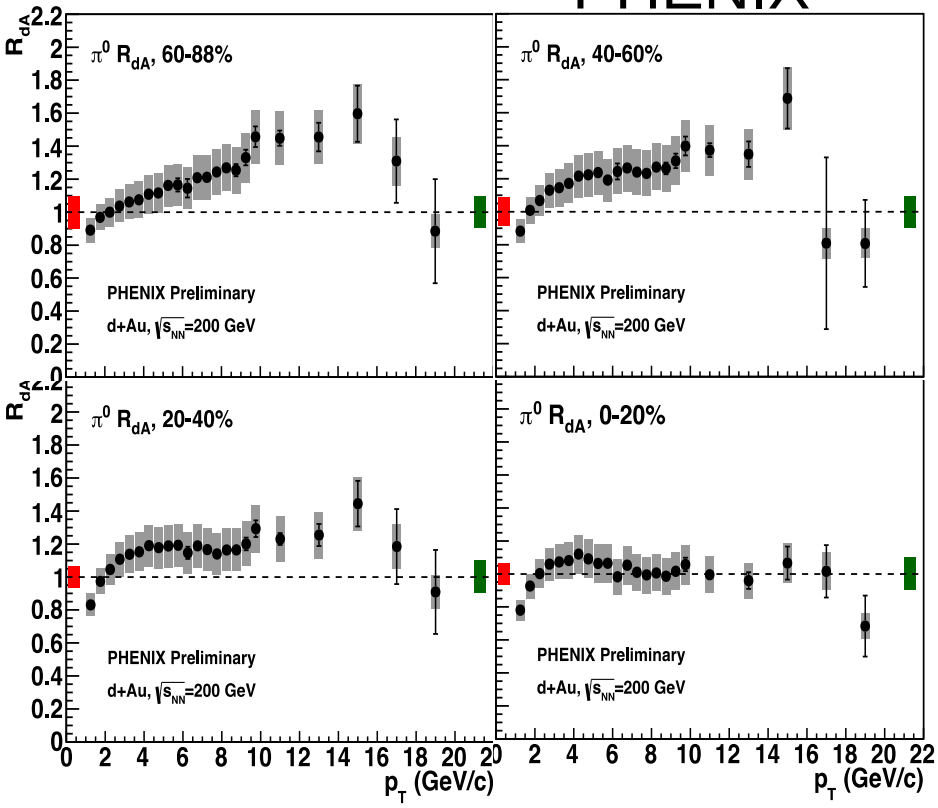


As might be expected, quenching mostly effects central spectra

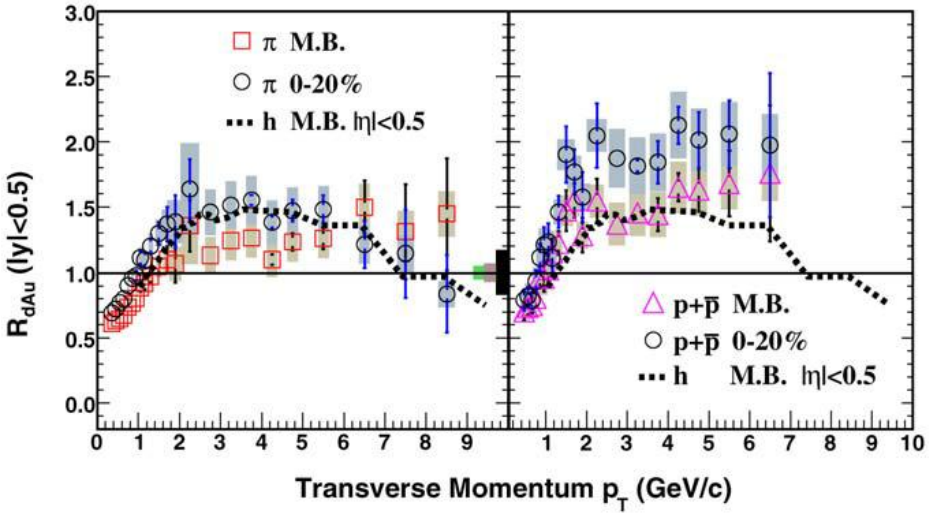
PHENIX QM2012

- PHENIX and STAR results are not completely consistent
- STAR sees greater enhancement of central pion spectra for p_T<5GeV/c

PHENIX



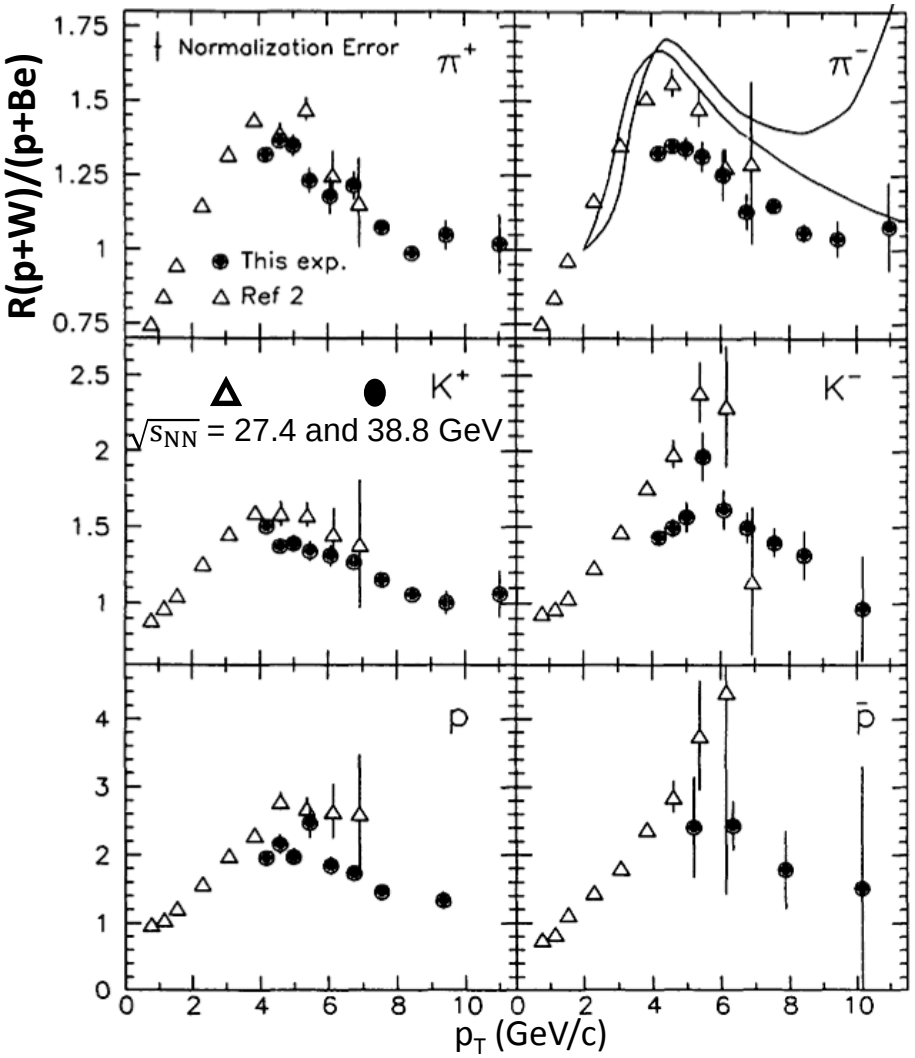
STAR



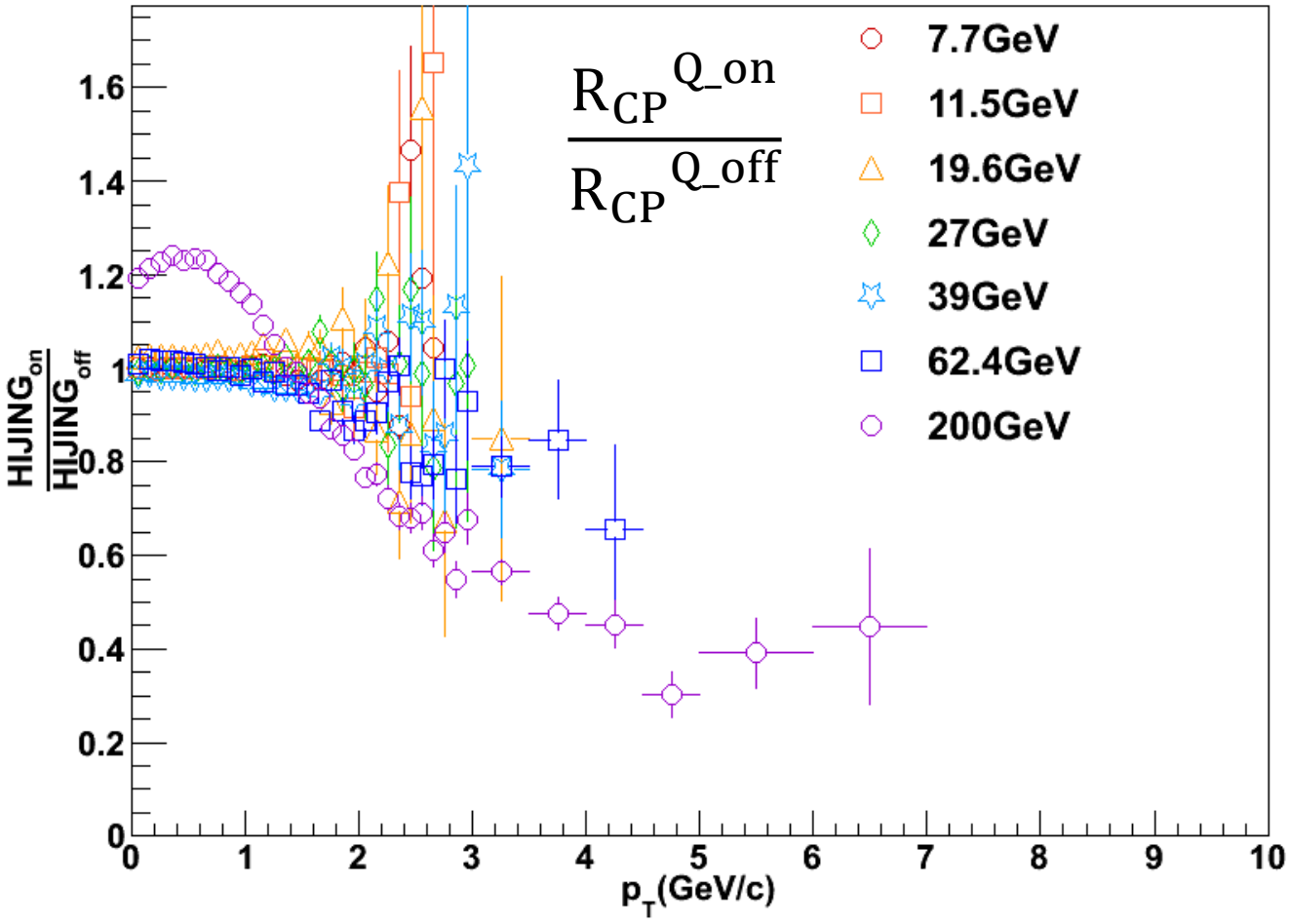
Cronin's result

Some beam energy dependence for the Cronin Effect was previously observed

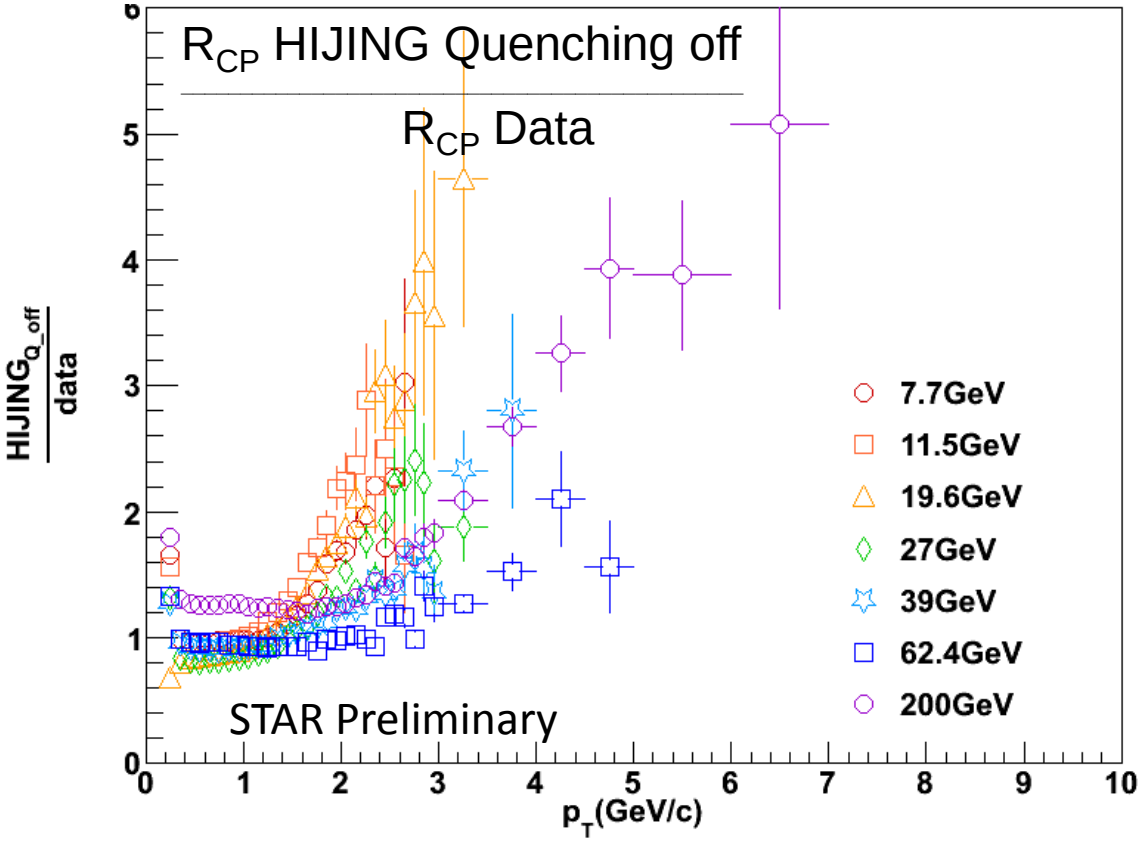
PRL 68, 452 (1992) Straub *et al.*

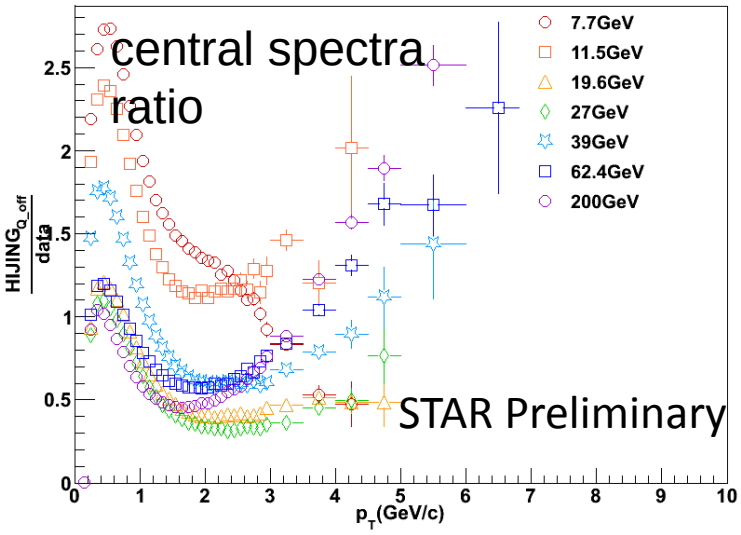


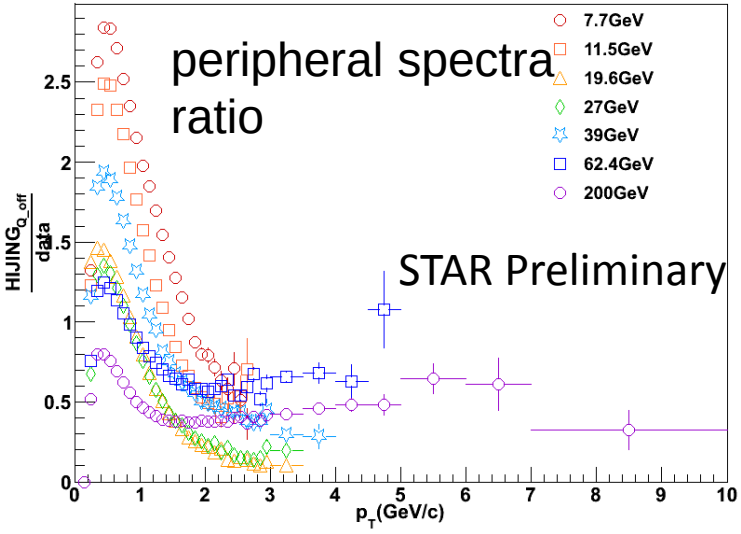
Effect of quenching in HIJING



HIJING quenching off/data

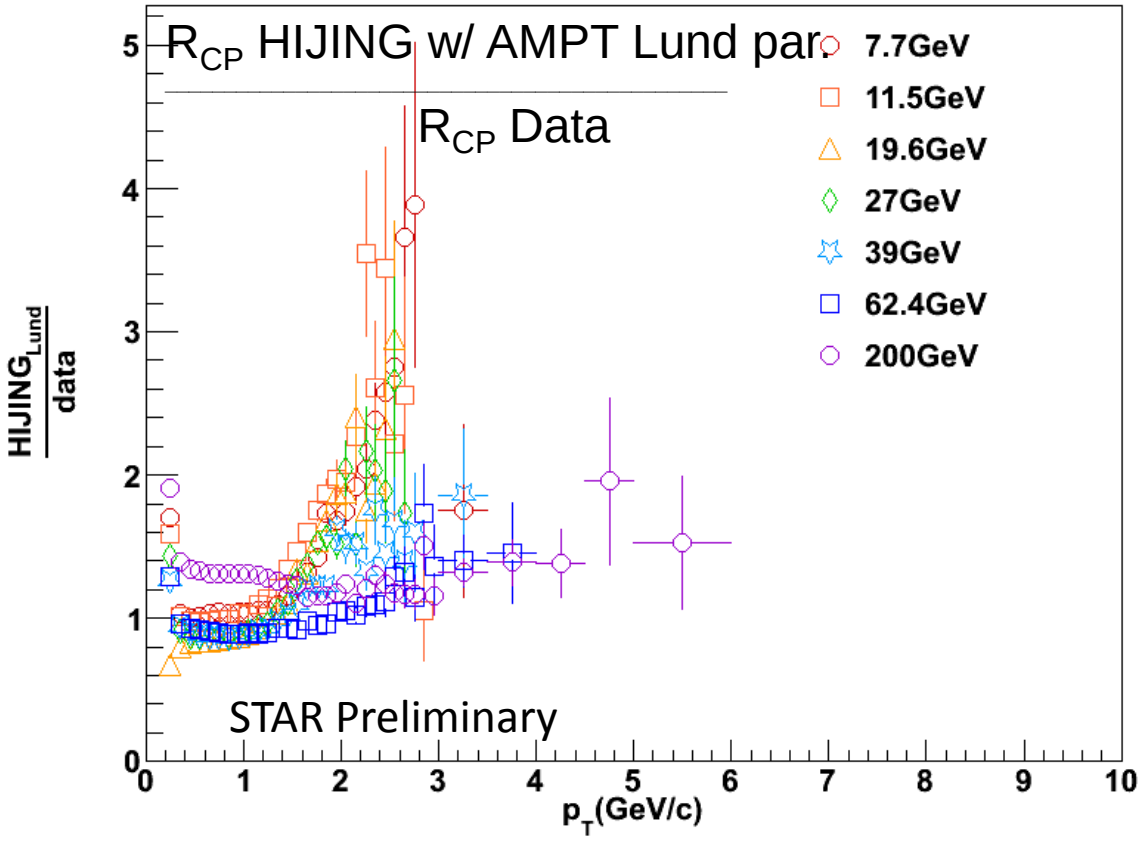


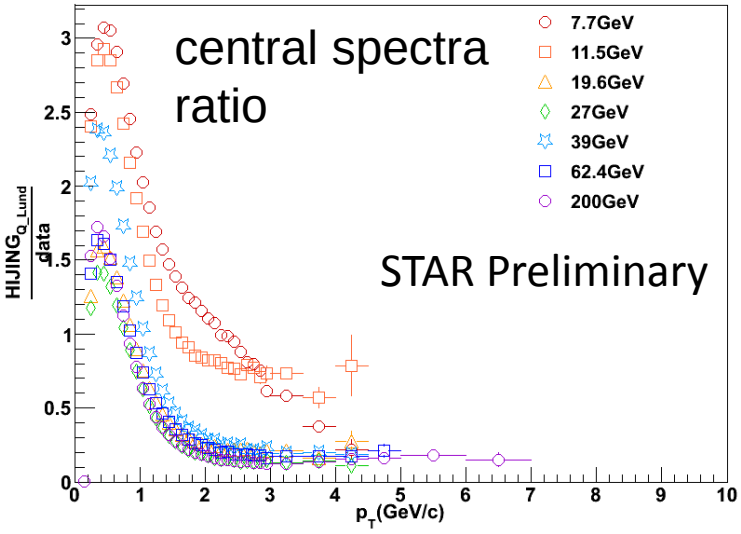


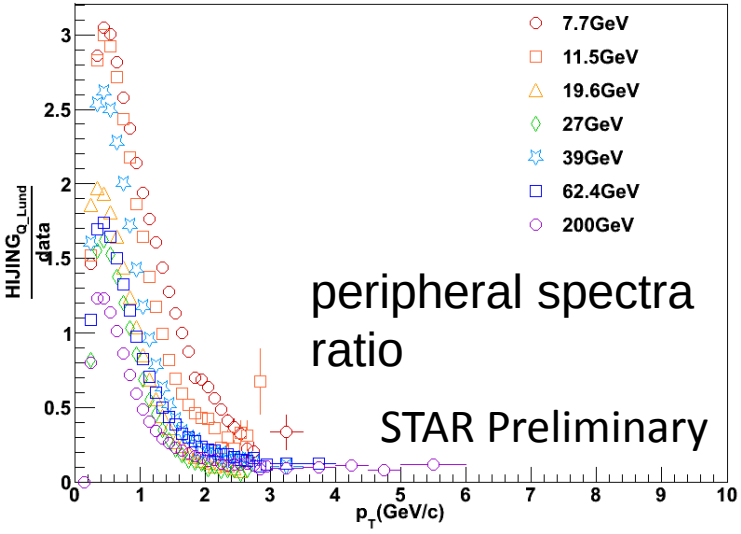


Spectra for central and peripheral from data disagree with model

HIJING quenching Lund/data

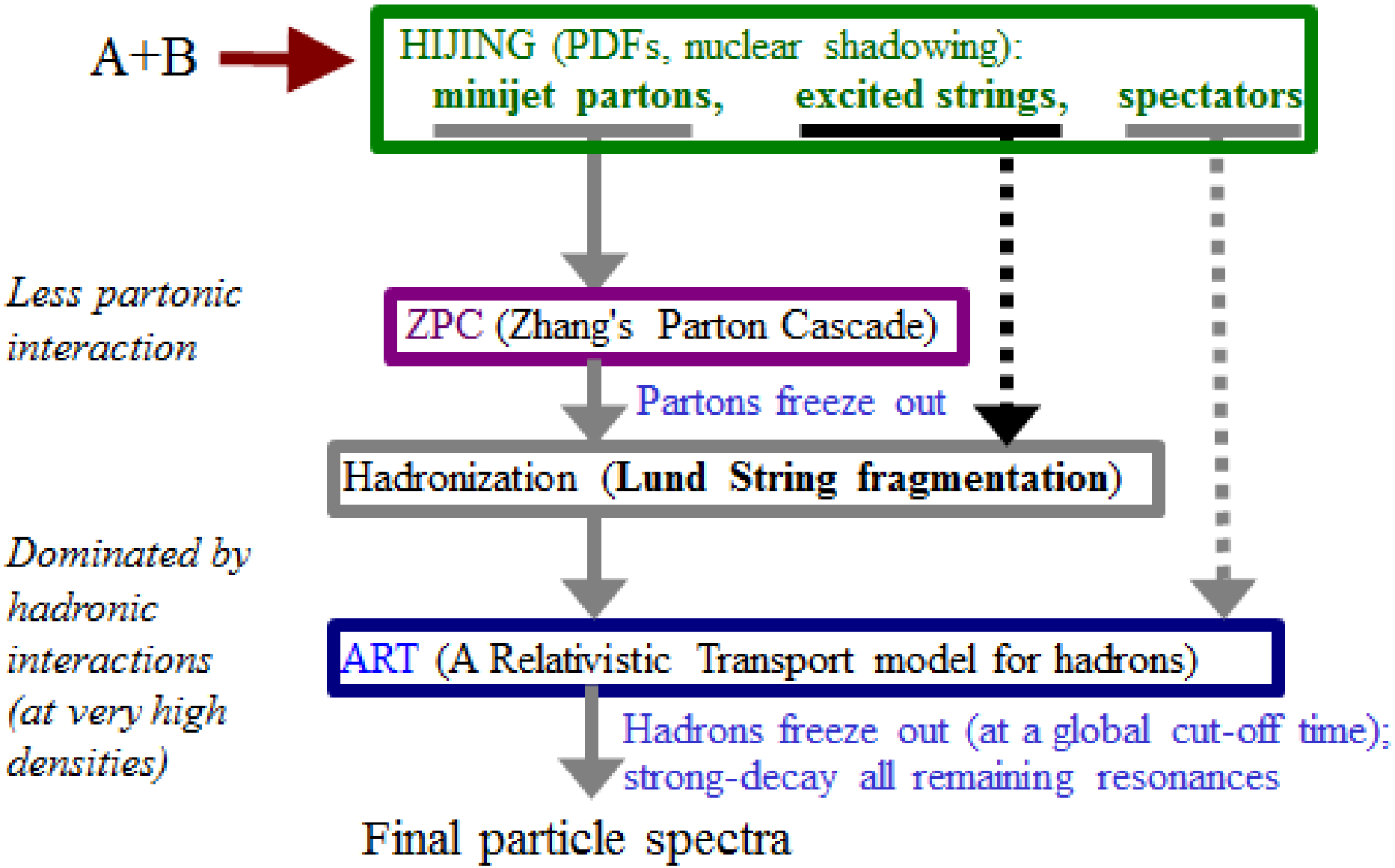




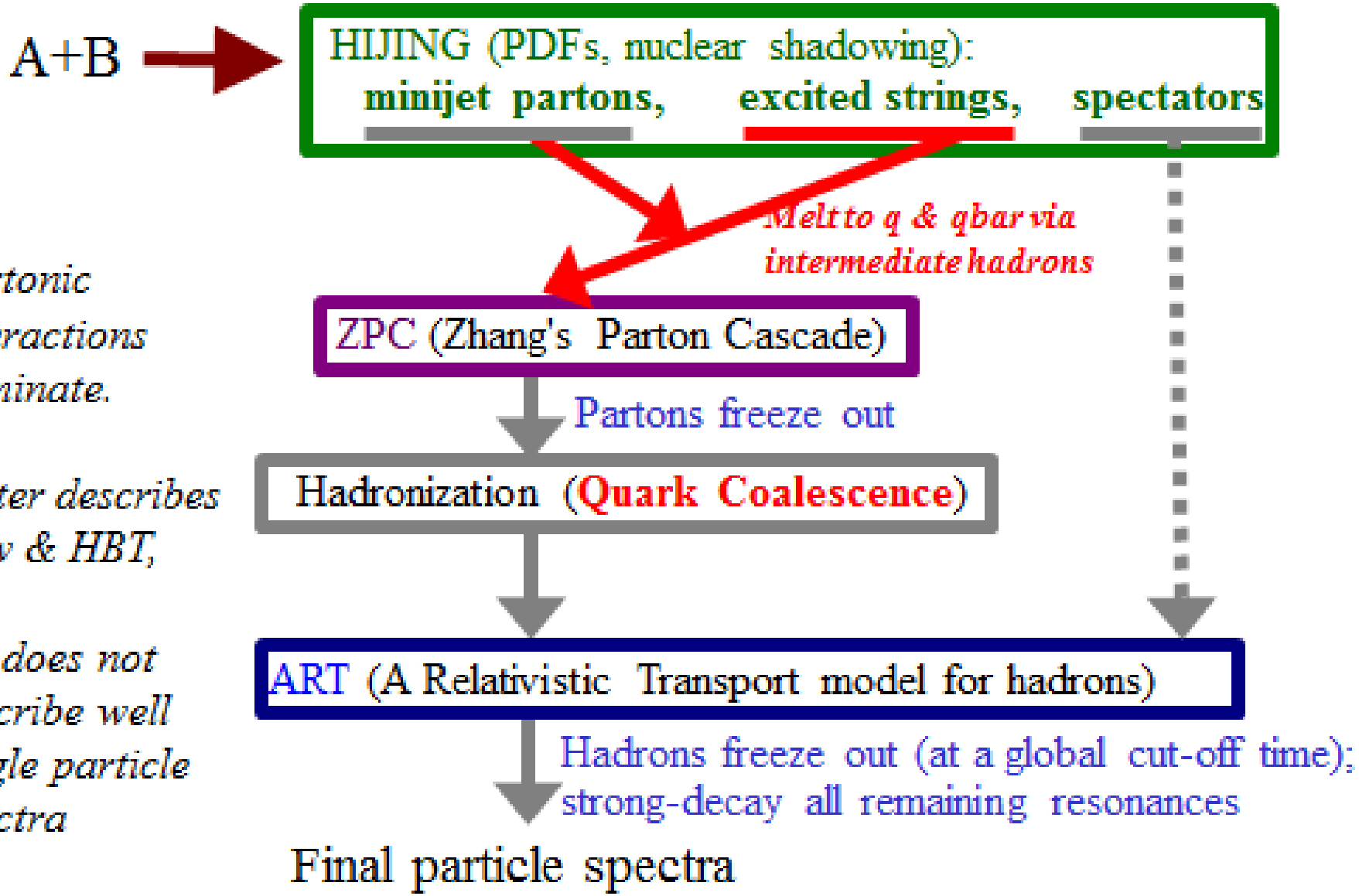


Spectra for central and peripheral from data disagree with model

Structure of AMPT v1.xx (default model)



Structure of AMPT v2.xx (String Melting model)



Models

- HIJING 1.383
  - default Lund splitting parameters a=0.5,b=0.9
- AMPT v1.21/v2.21
  - string melting (SM) off uses Lund string fragmentation for hadronization (v1.21)
  - SM on uses quark coalescence for hadronization (v2.21)
  - default Lund splitting parameters a=2.2, b=0.5

Lund fragmentation formula: $f(z) \mu \frac{(1-z)^a}{z} e^{-bm_\lambda^2/z}$