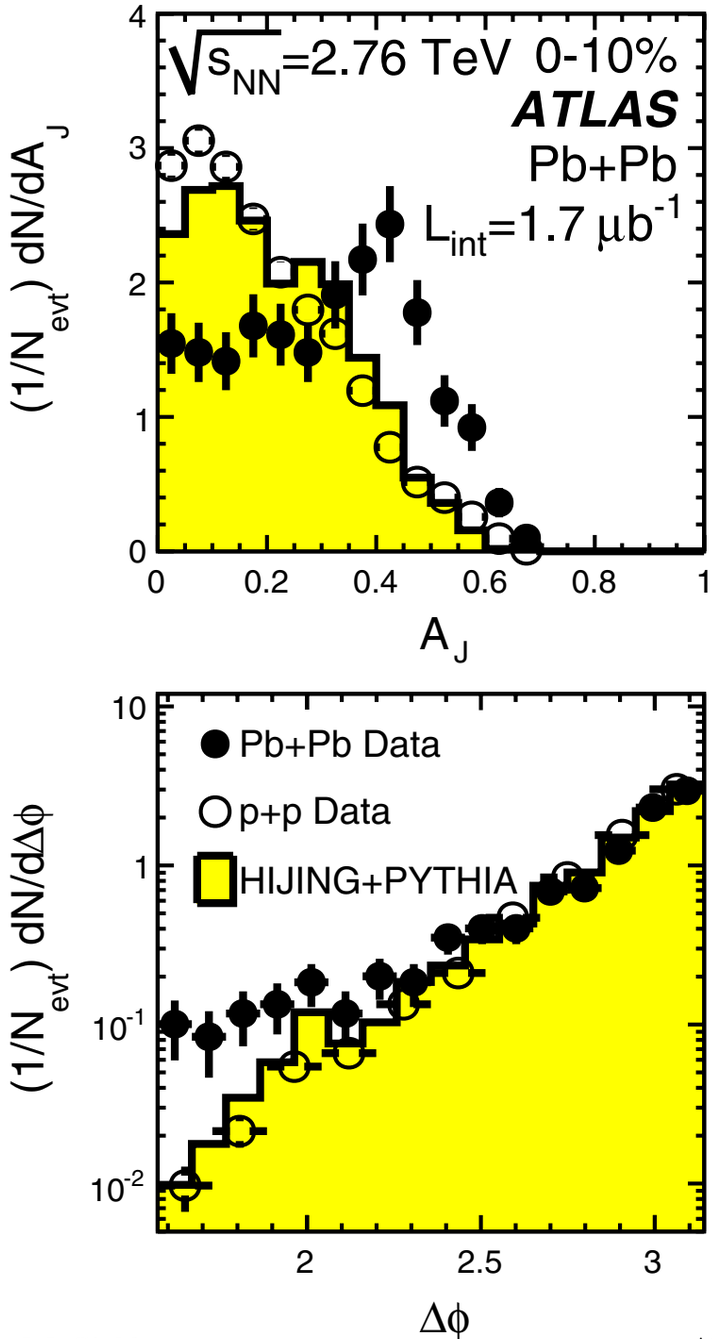
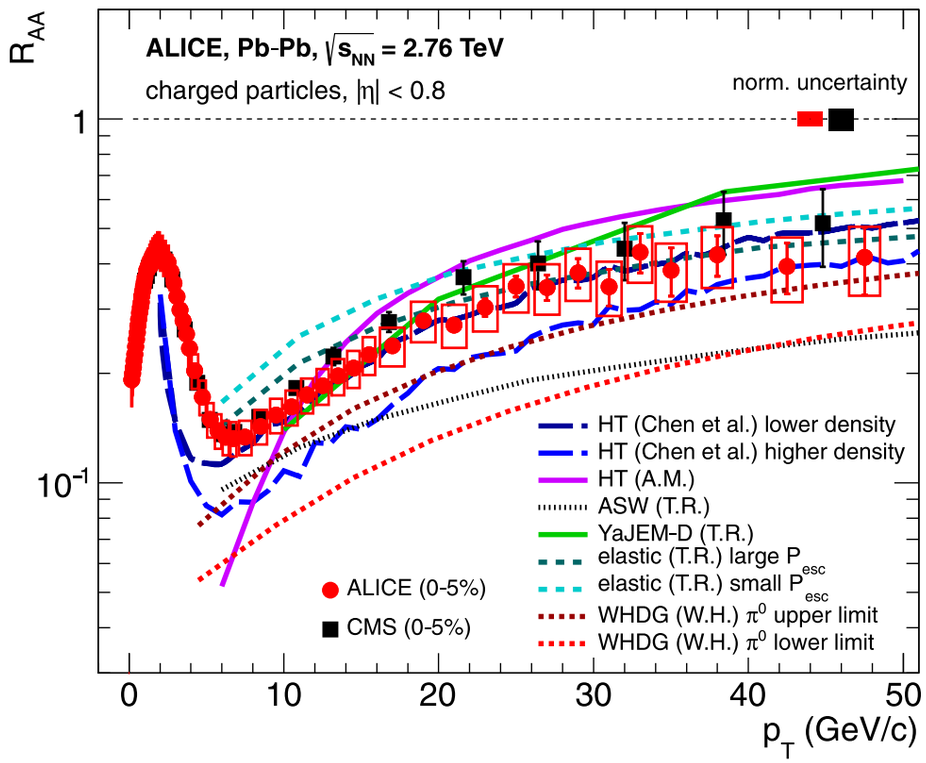
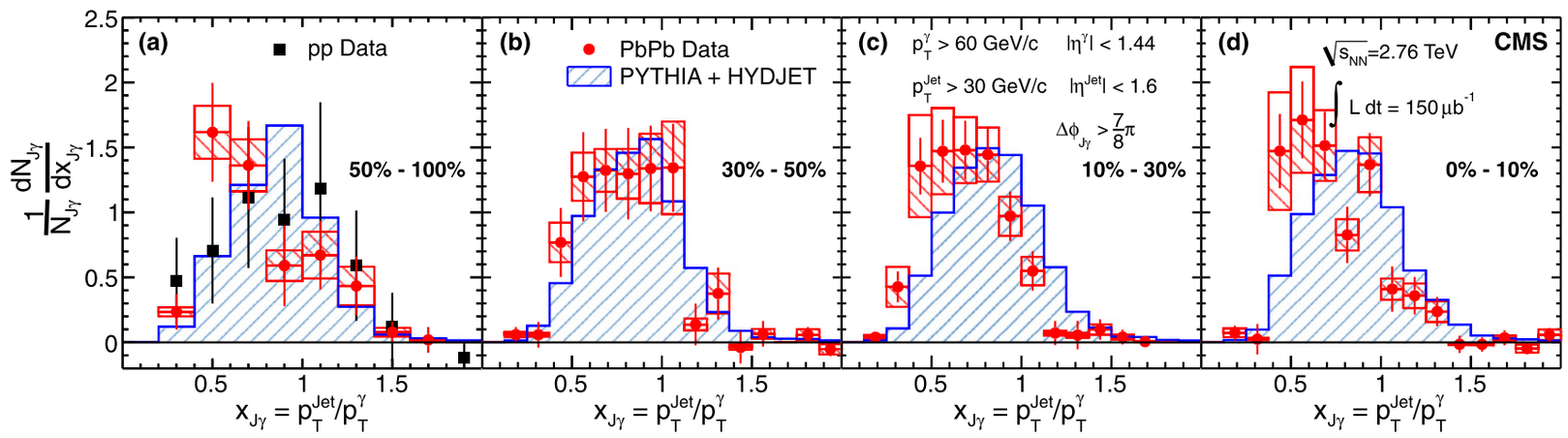
Jets Quenching at RHIC: Present and Future

Anne Sickles
Brookhaven National Lab

- LHC has brought the field fantastic new jet measurements
  - high jet rates, huge detectors, new system, large kinematic reach

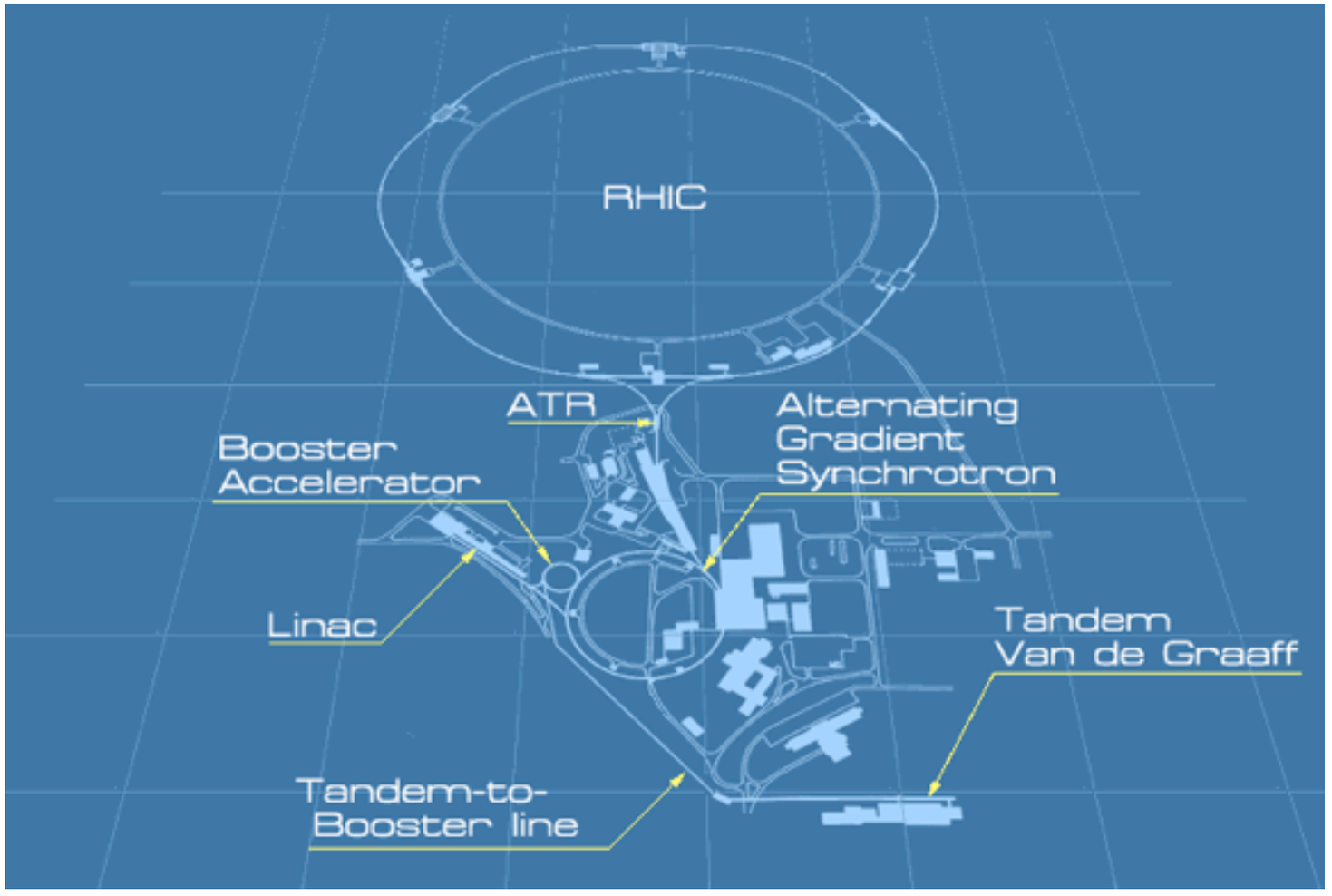






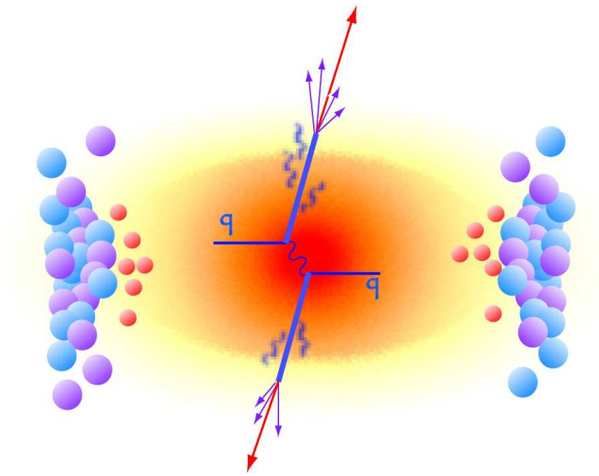
ATLAS PRL 105 252303, ALICE PLB 720 52, CMS PLB 718 773

what do we want from jets @ RHIC?

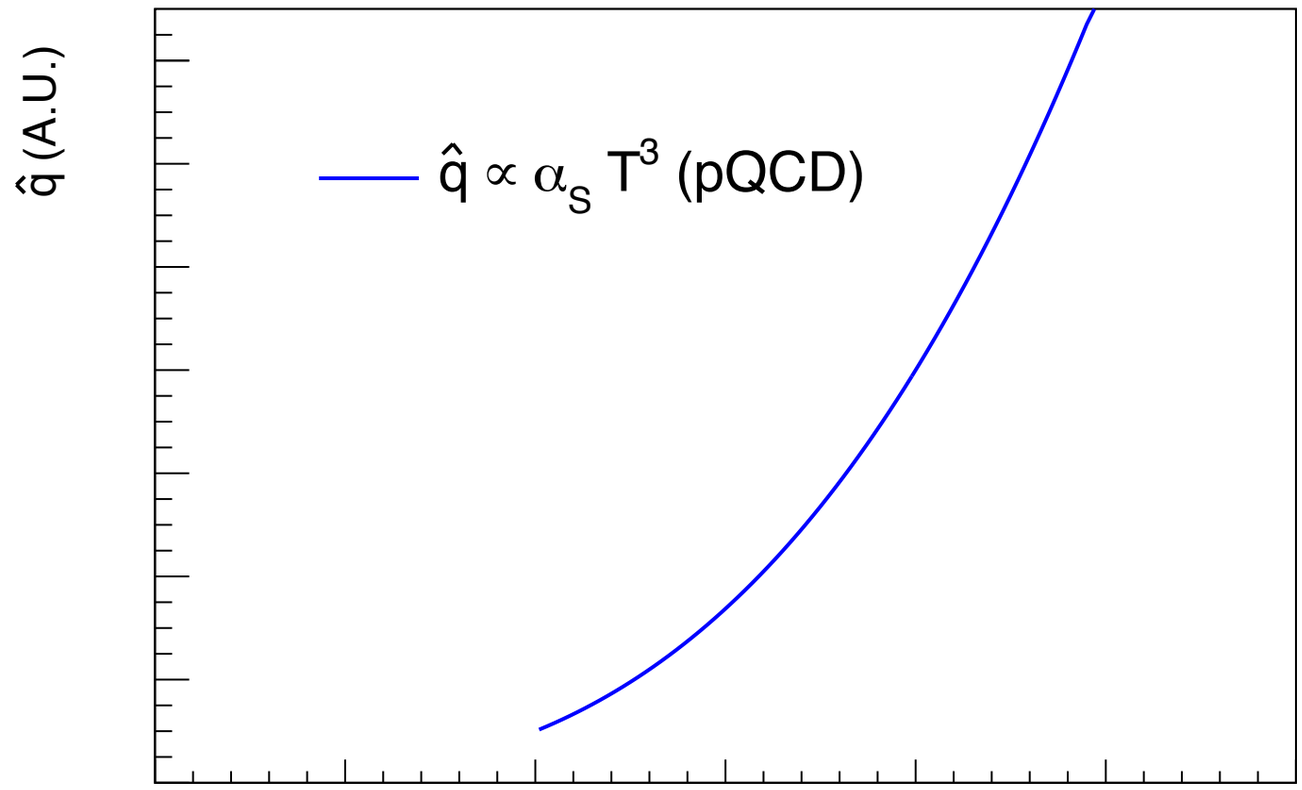


- probe the properties of jets near Tc
- exploit the large collision energy difference between RHIC and LHC to understand the physics of quenching
- exploit RHIC's flexibility to study different systems, small and large:
  - geometry, initial state effects...

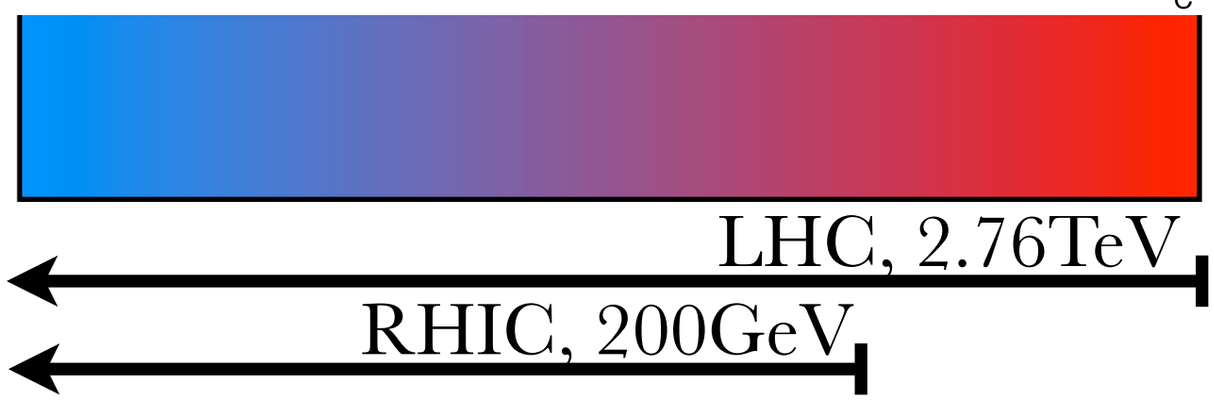
quenching vs temperatue



strongest quenching at the highest temperature in the collision

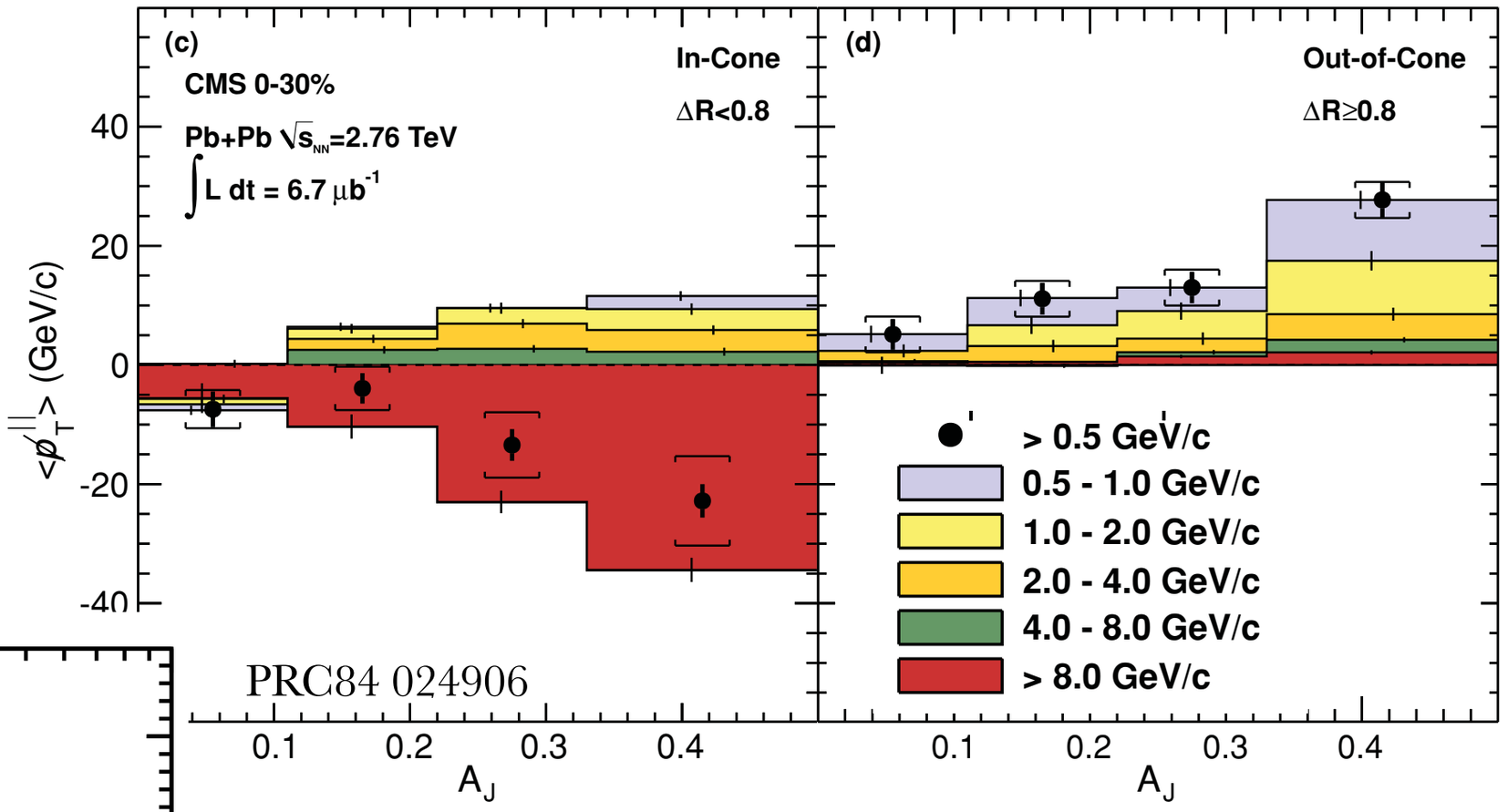


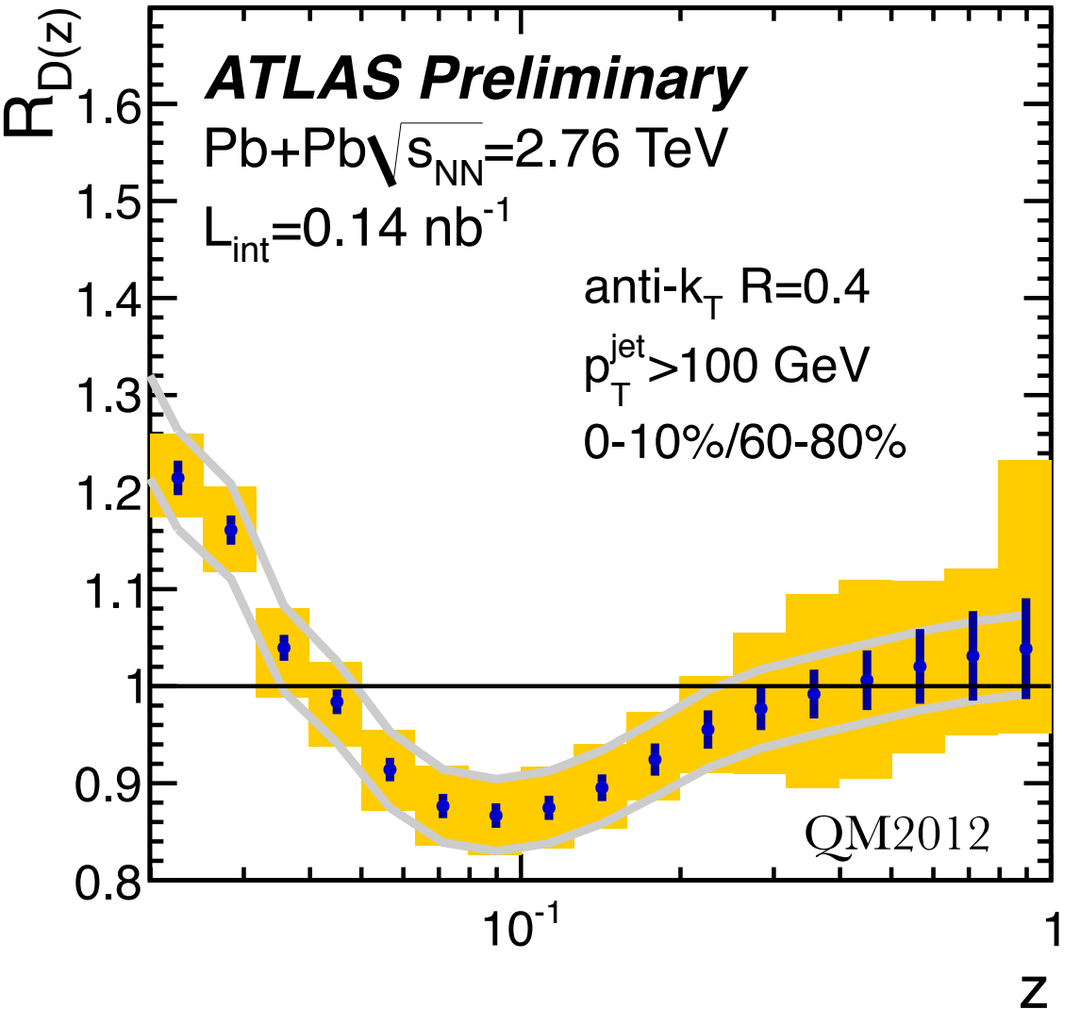
q(T) change the initial collision temperature by changing the collision energy



modified fragmentation patterns

CMS: balancing energy at low p_T and large angles

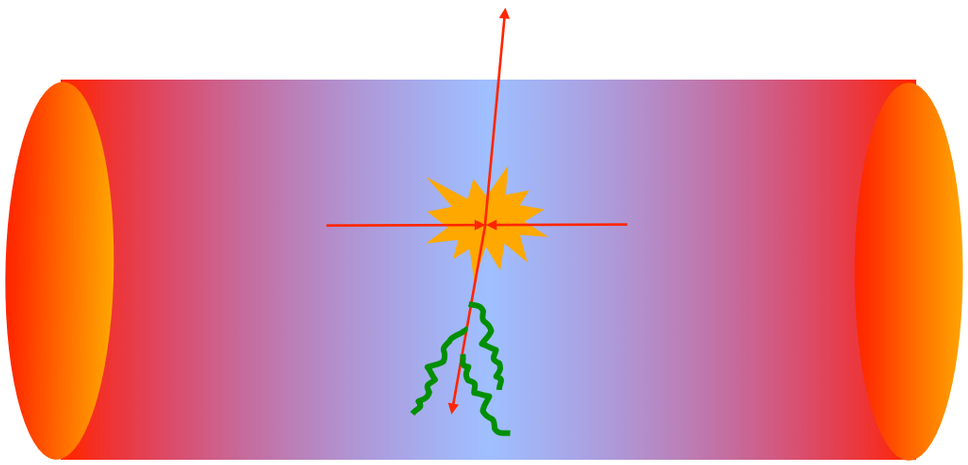




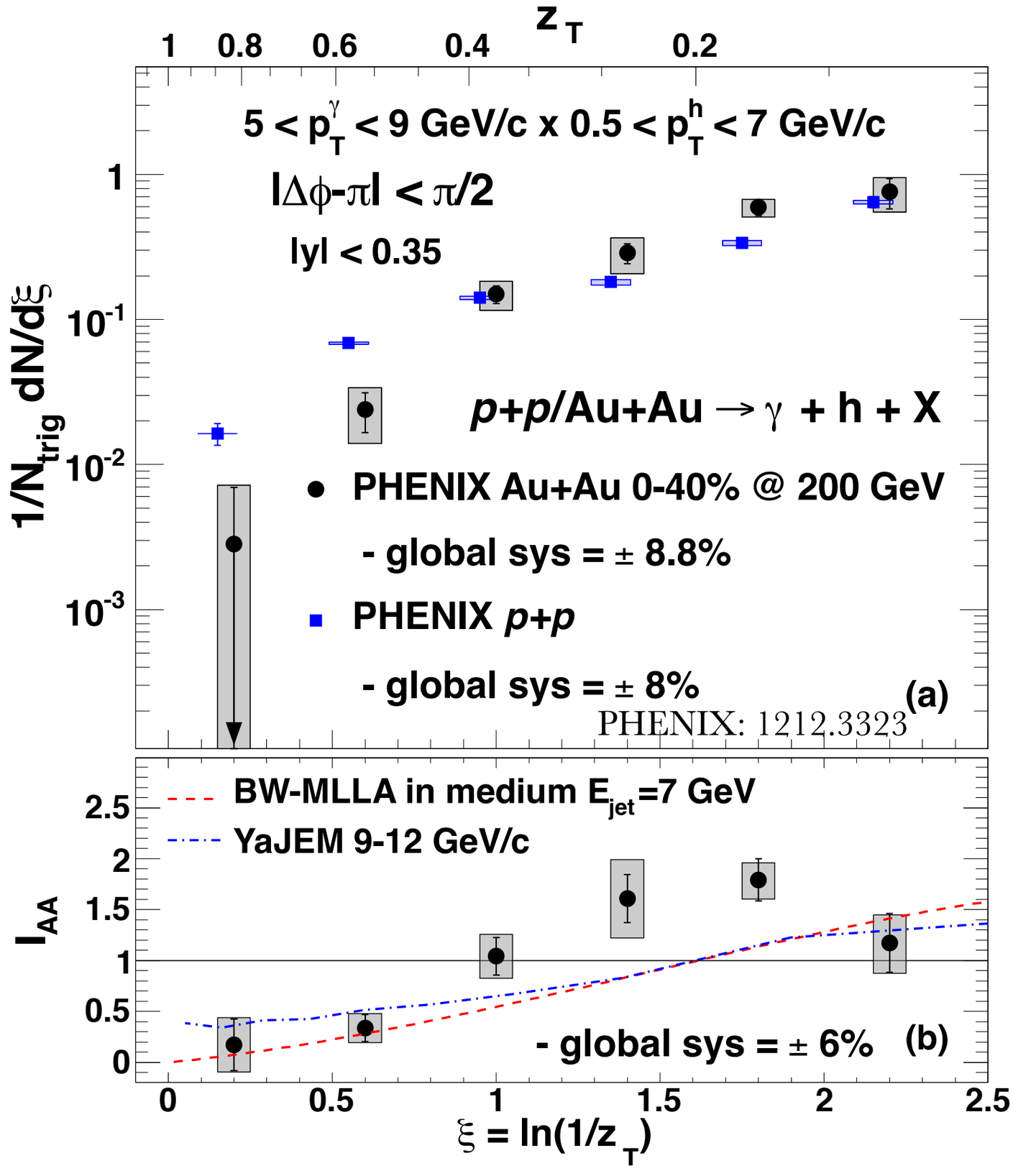
ATLAS: softening of jet fragmentation functions

modifying fragmentation patterns

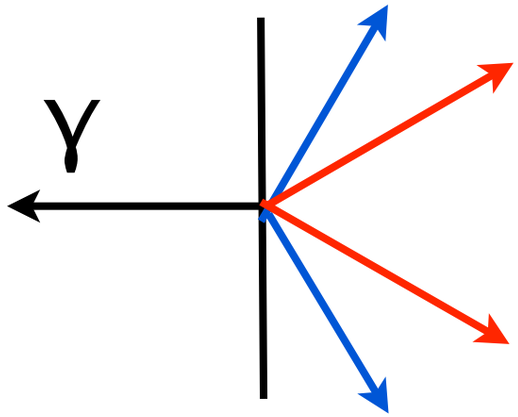
γ-hadron correlations

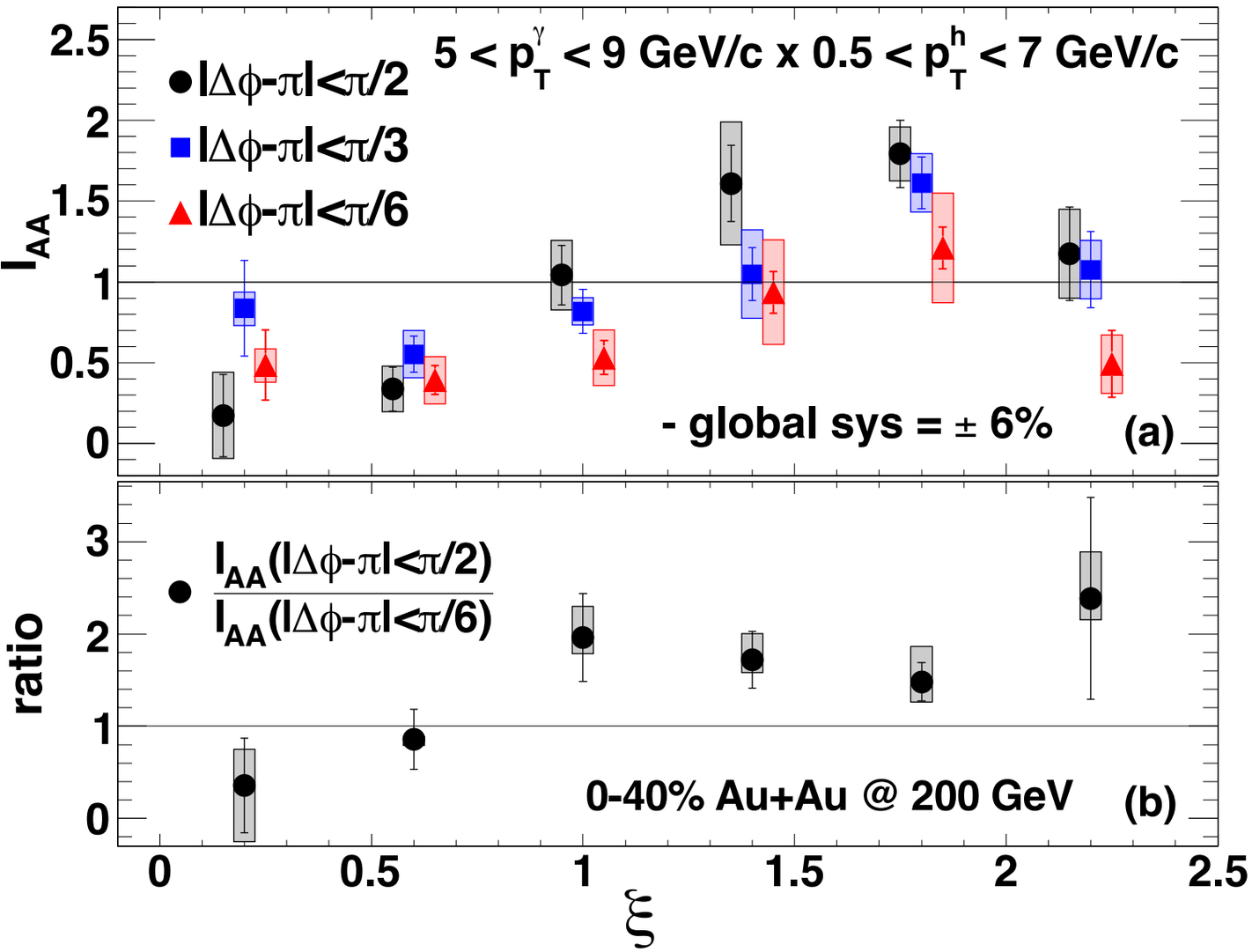


PHENIX: extra low p_T (<2GeV) hadrons in AuAu



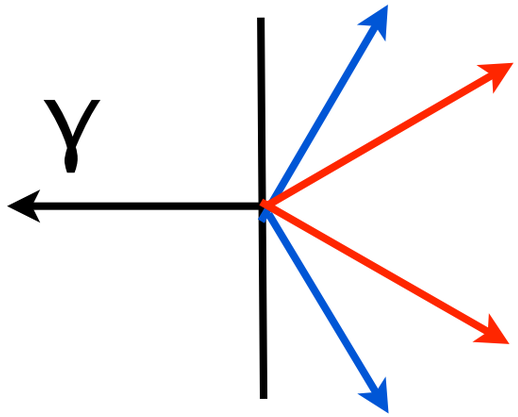
broadening of angular distribution

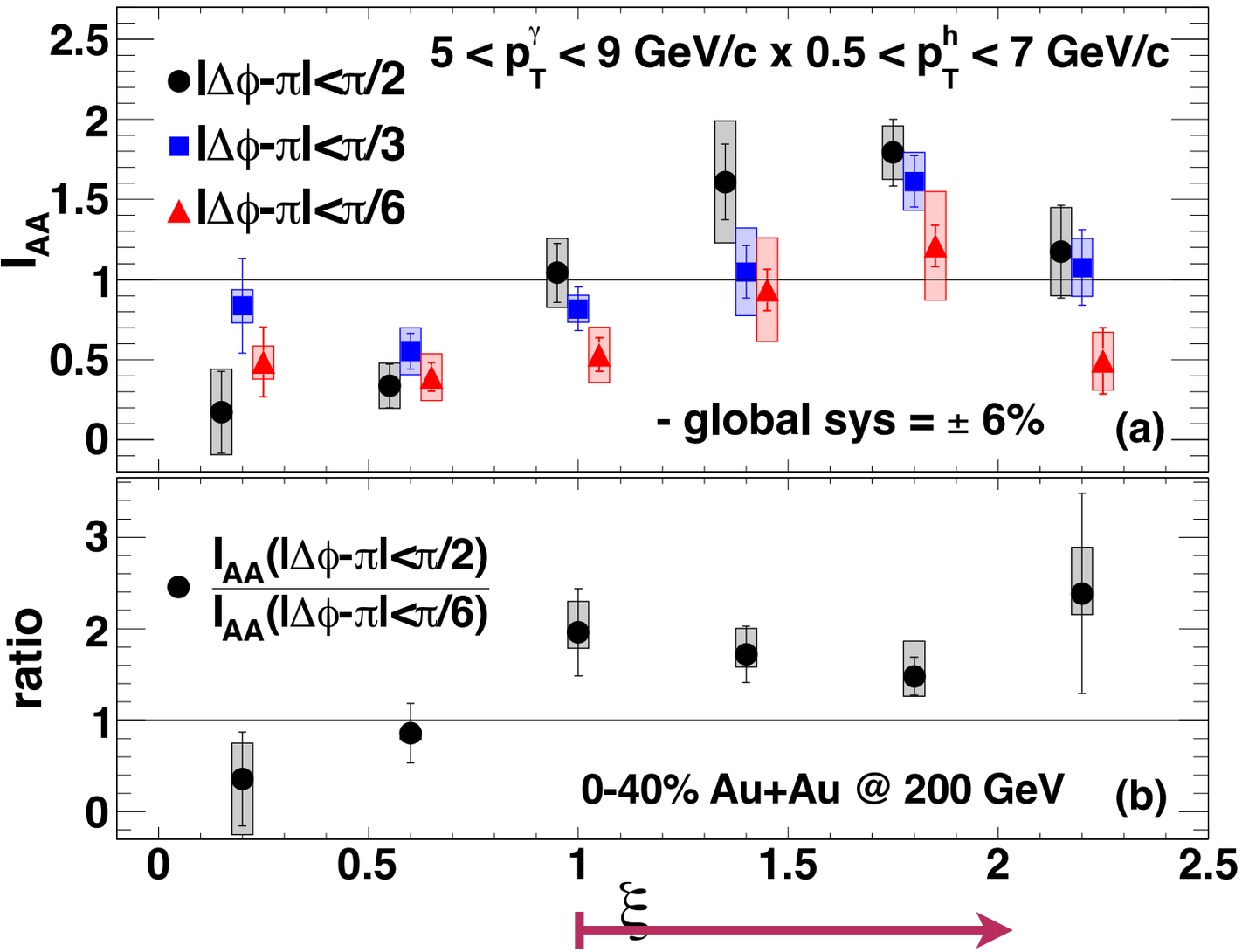




PHENIX: 1212.3323

broadening of angular distribution

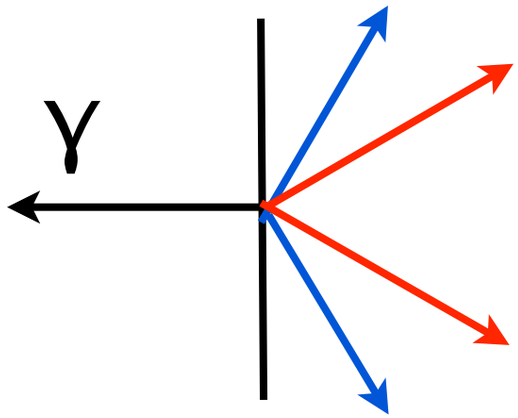


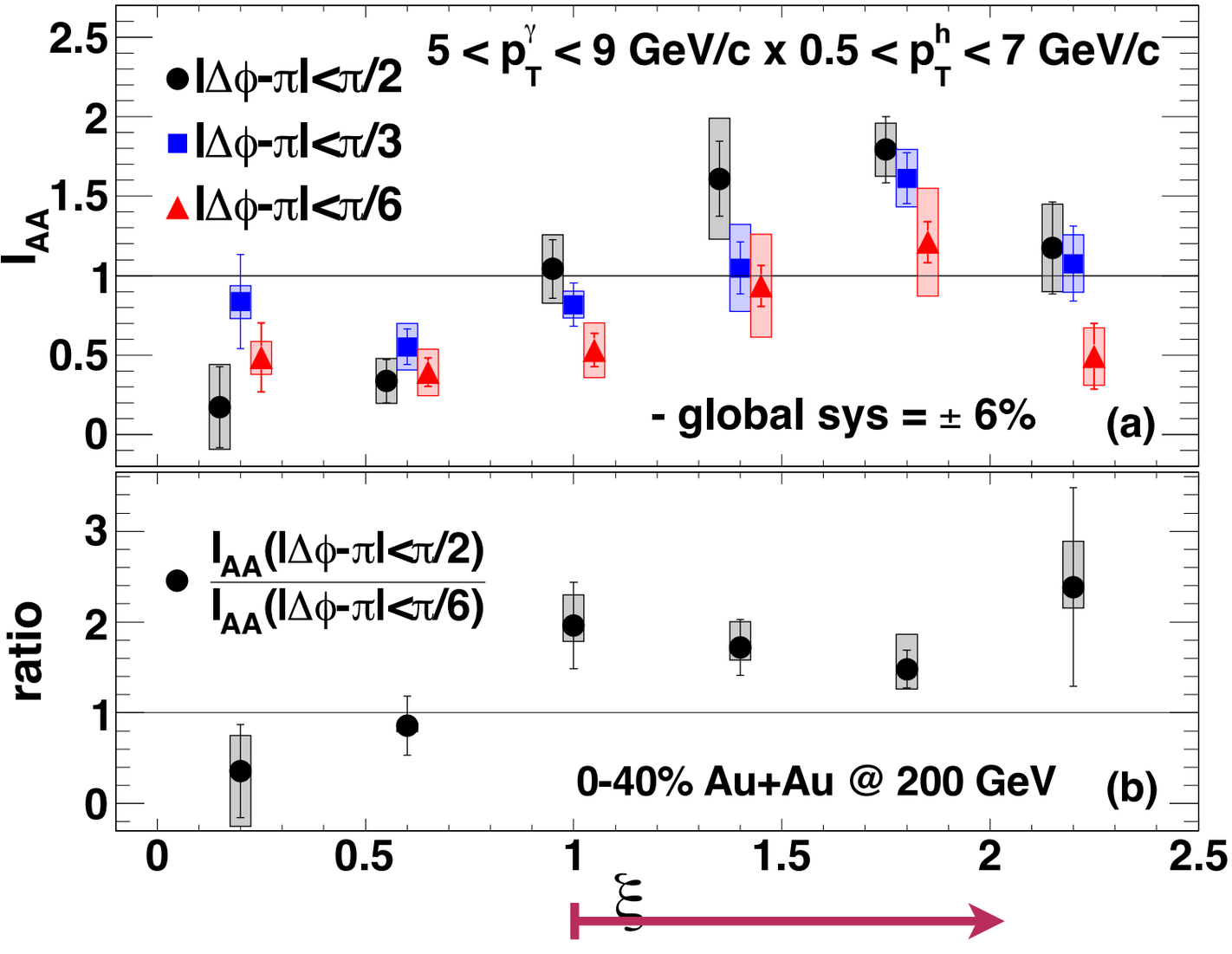


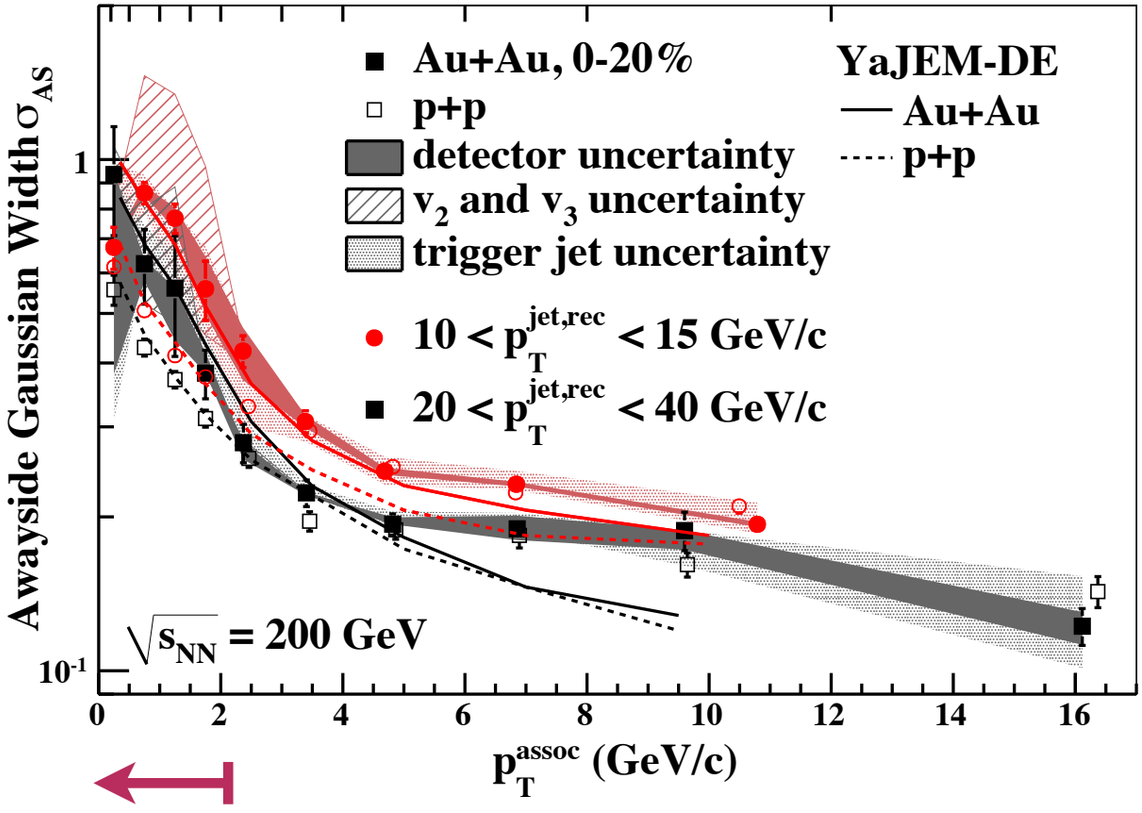
broadening of hadron distribution for pT < 2GeV/c

PHENIX: 1212.3323

broadening of angular distribution





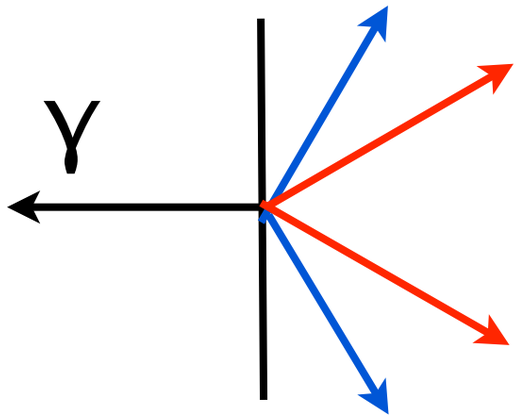


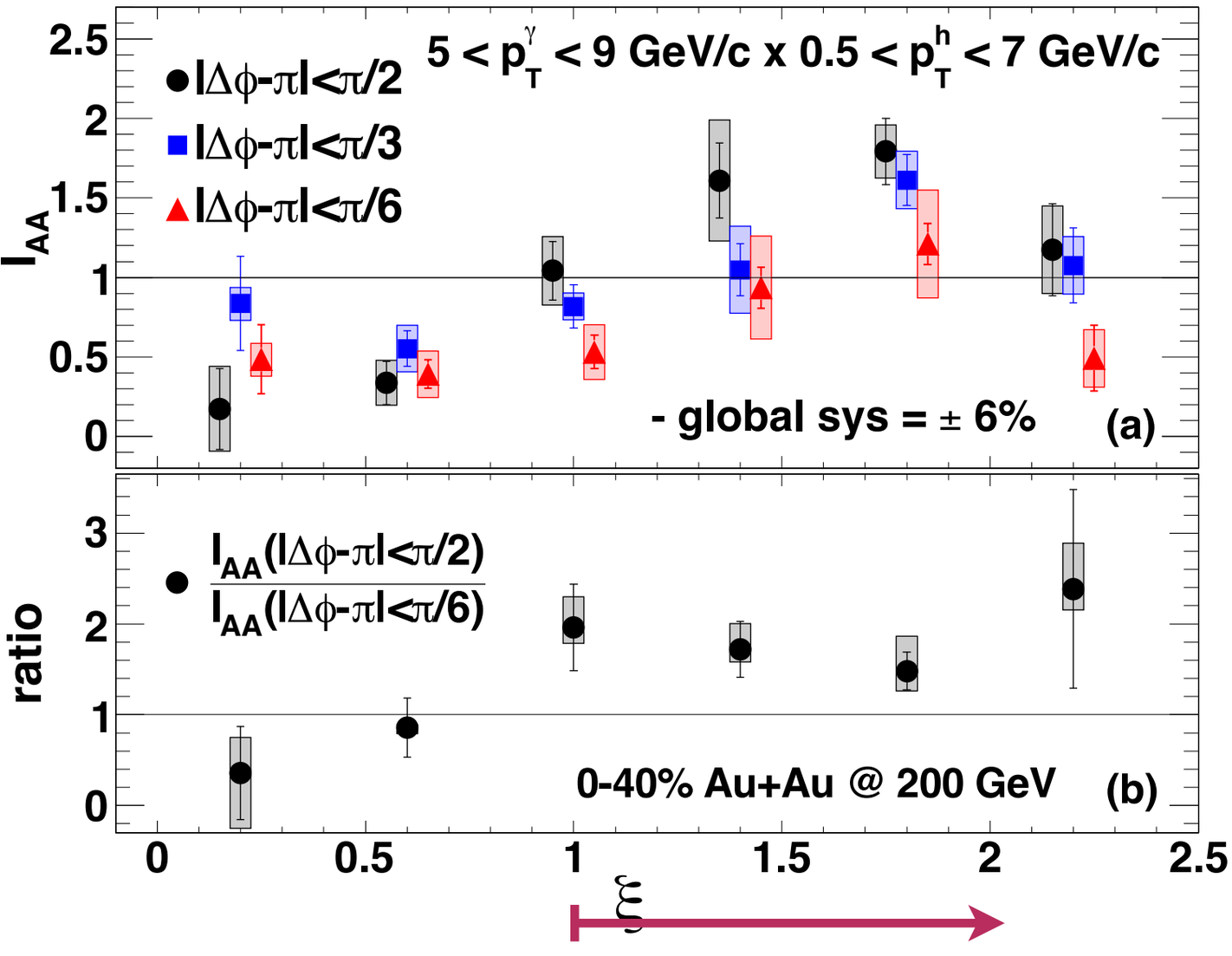
STAR: 1302.6184

broadening of hadron distribution for pT < 2GeV/c

PHENIX: 1212.3323

broadening of angular distribution





broadening of hadron distribution for pT < 2GeV/c

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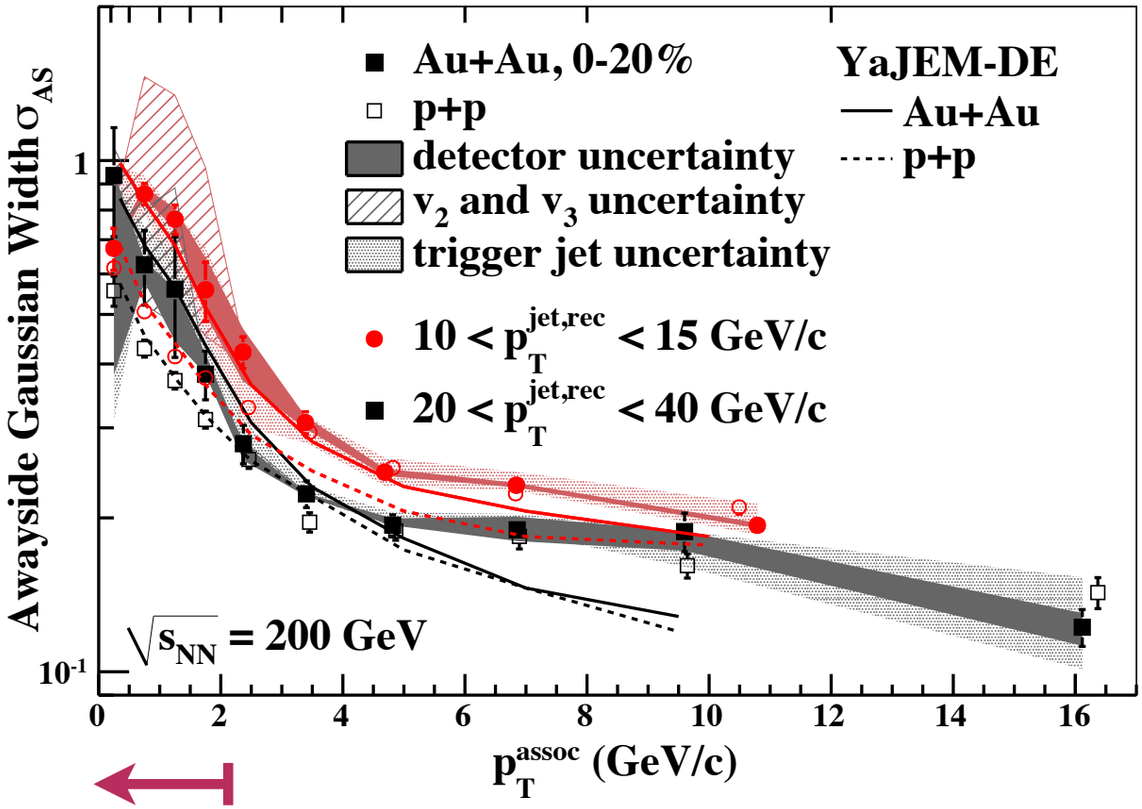
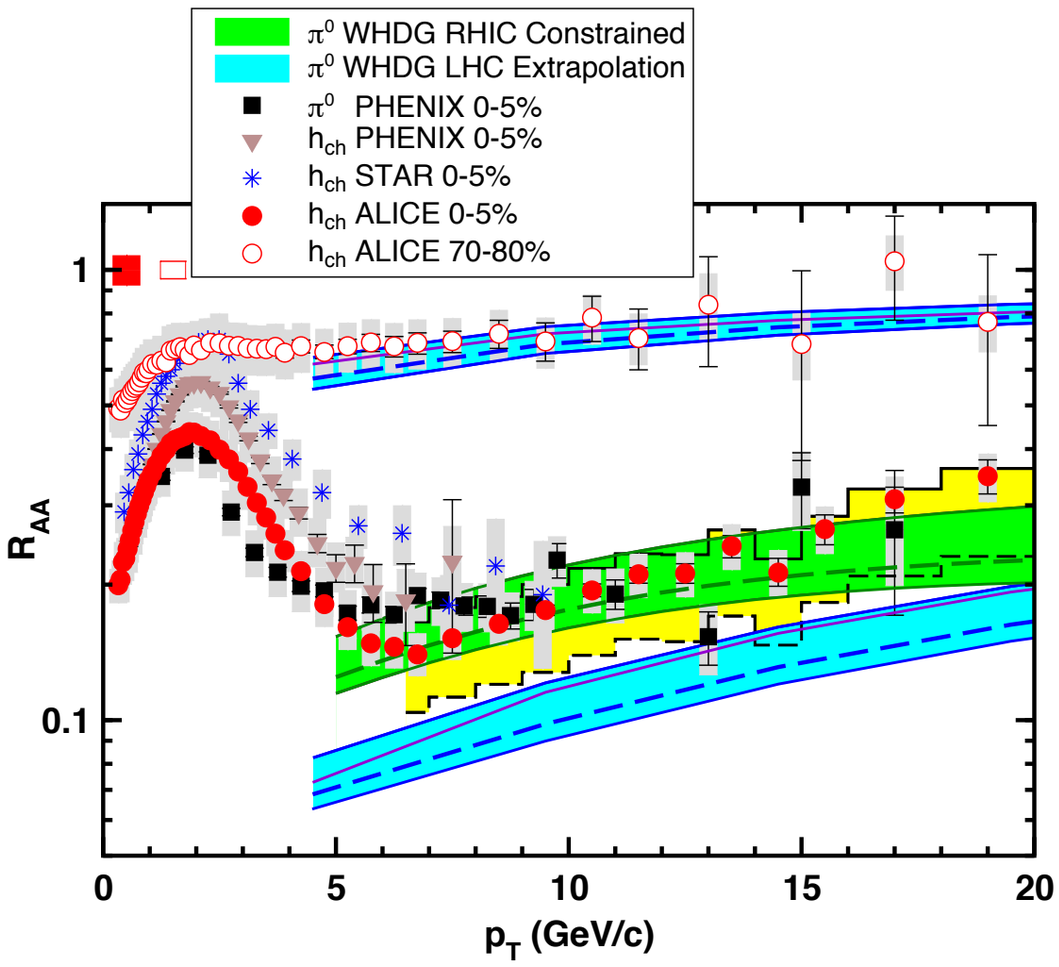
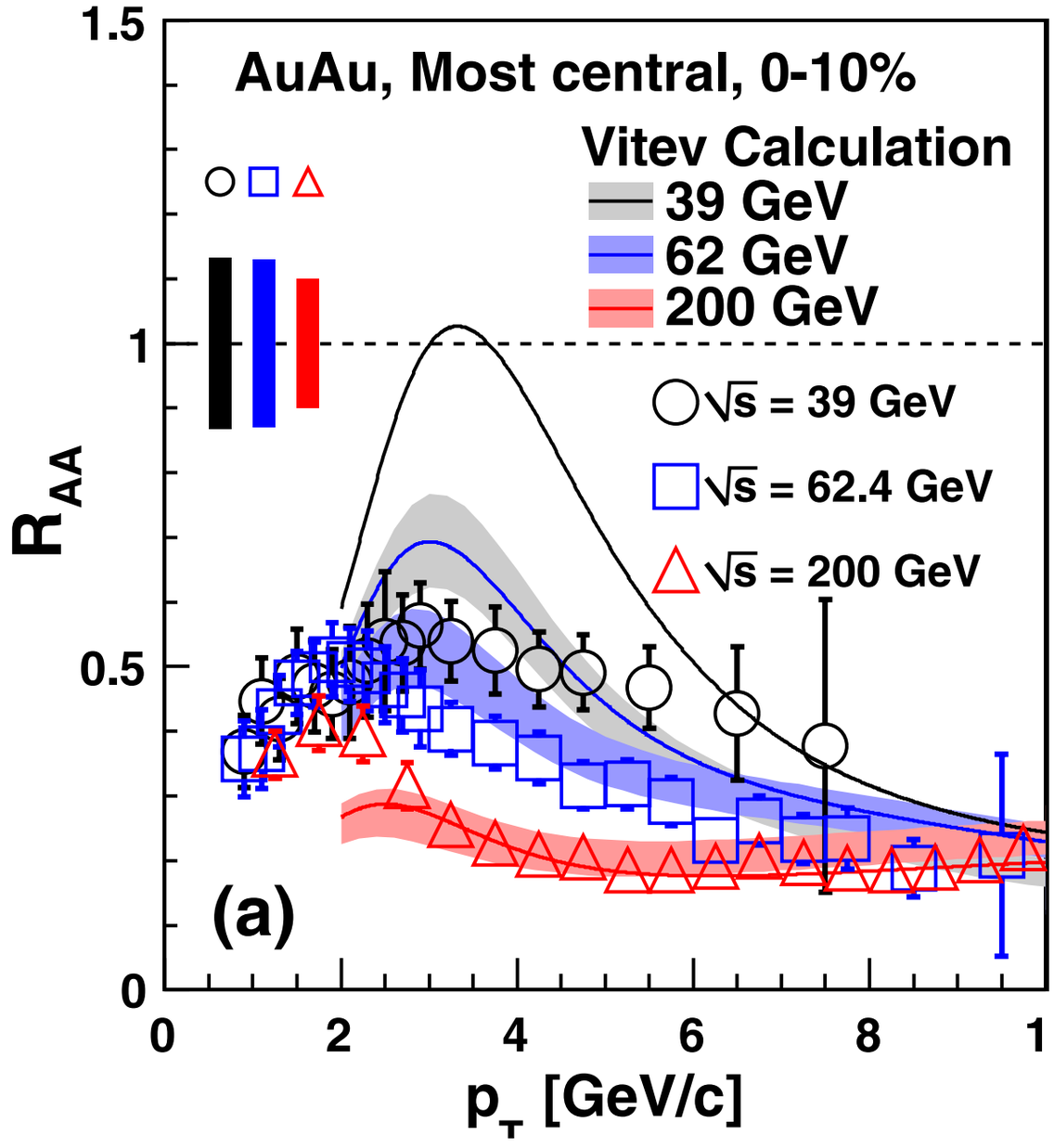


STAR: 1302.6184

evidence for low p_T broadening of hadrons opposite jets/photons

quenching vs $\sqrt{s_{NN}}$



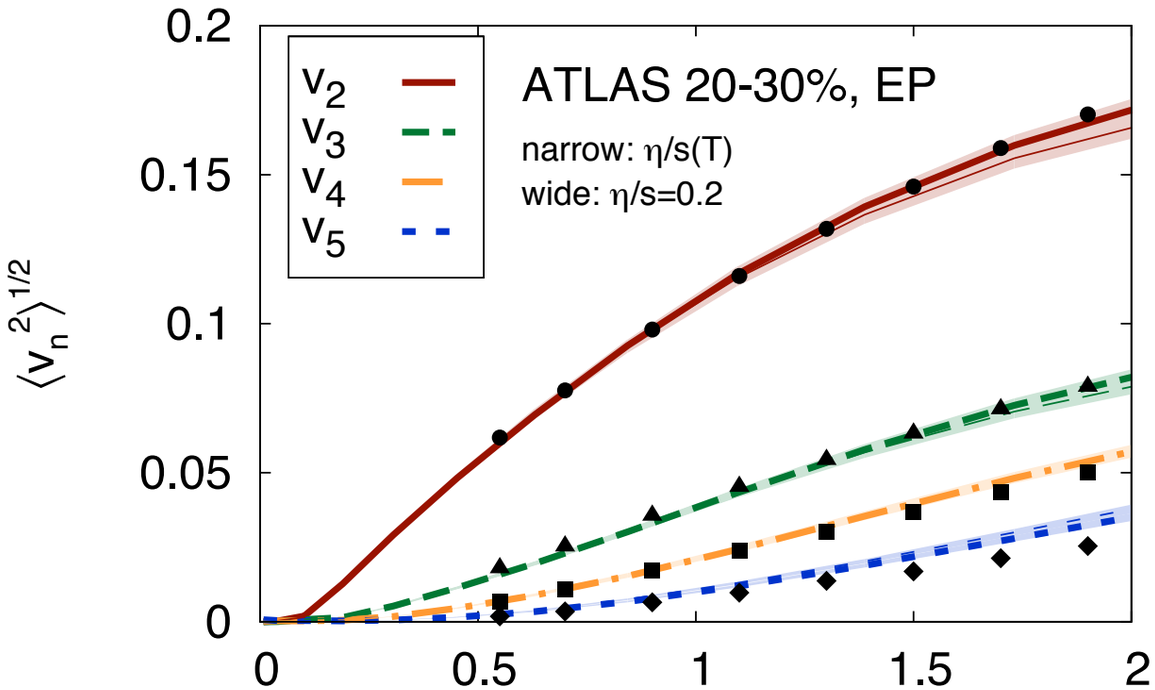


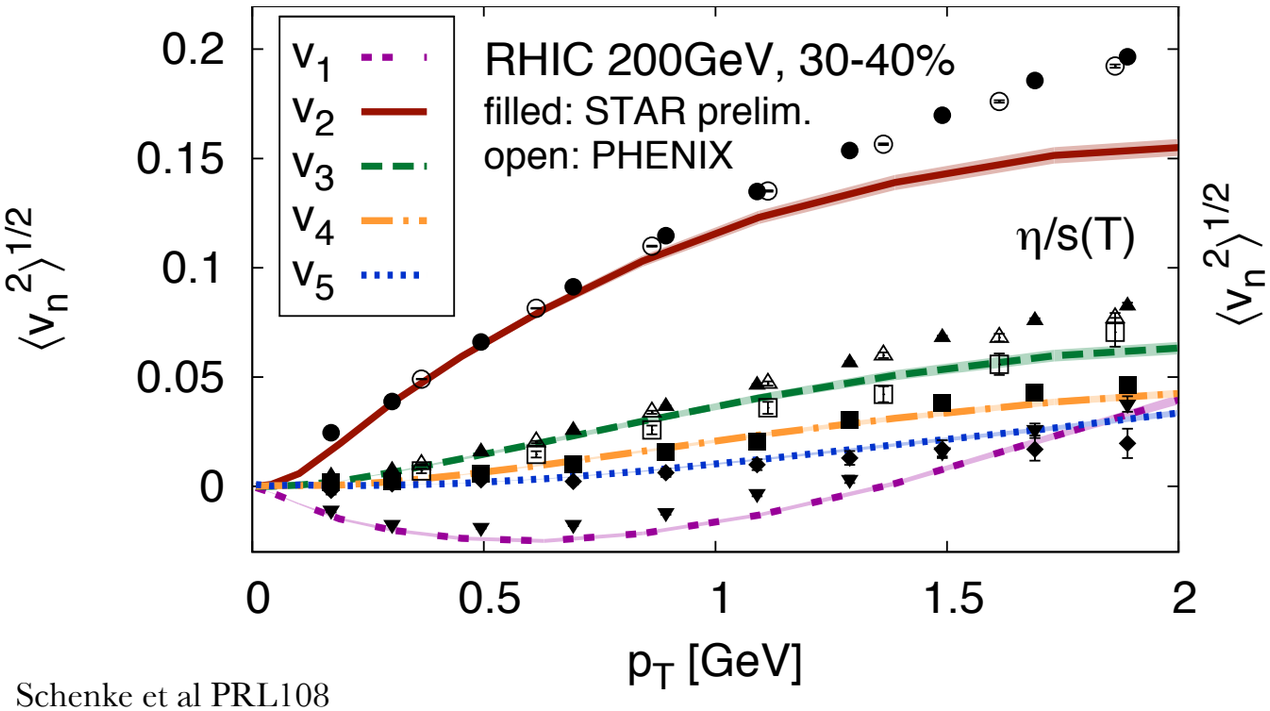
- $R_{AA} \sim 0.5$ at 39GeV
- p_T reach ~10GeV at 62.4GeV, R_{AA} consistent with 200GeV
- *pA measurements needed to understand initial state effect

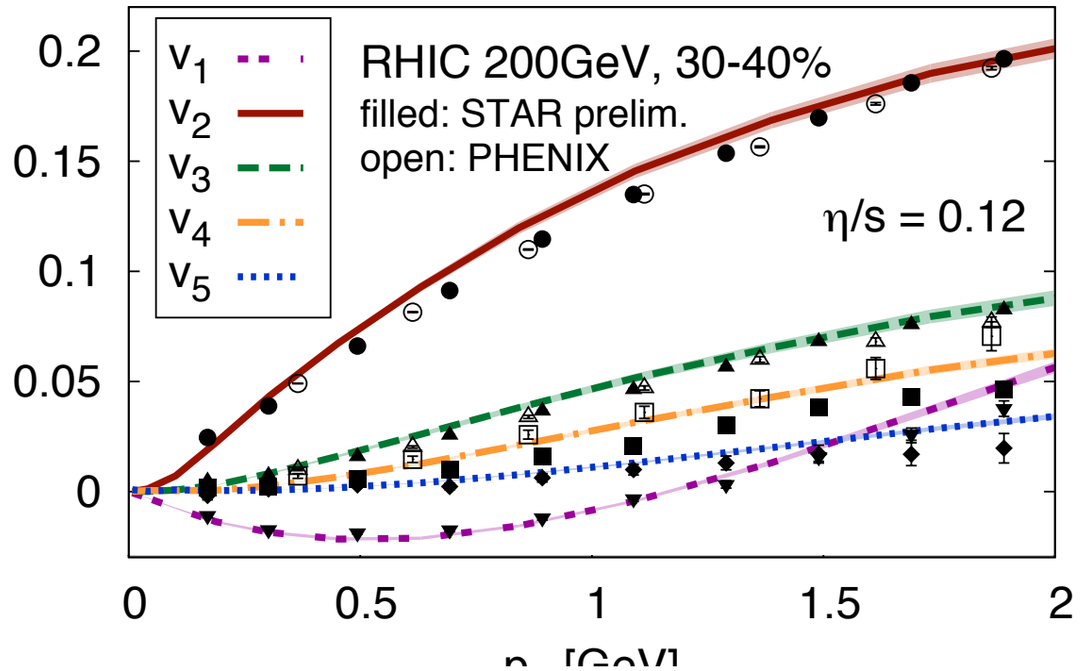
Horowitz & Gyulassy NPA872 265, PHENIX PRL 109 152301

a peak into the future of hard probes...

using RHIC and LHC to constrain temperature dependence of η/s within hydro



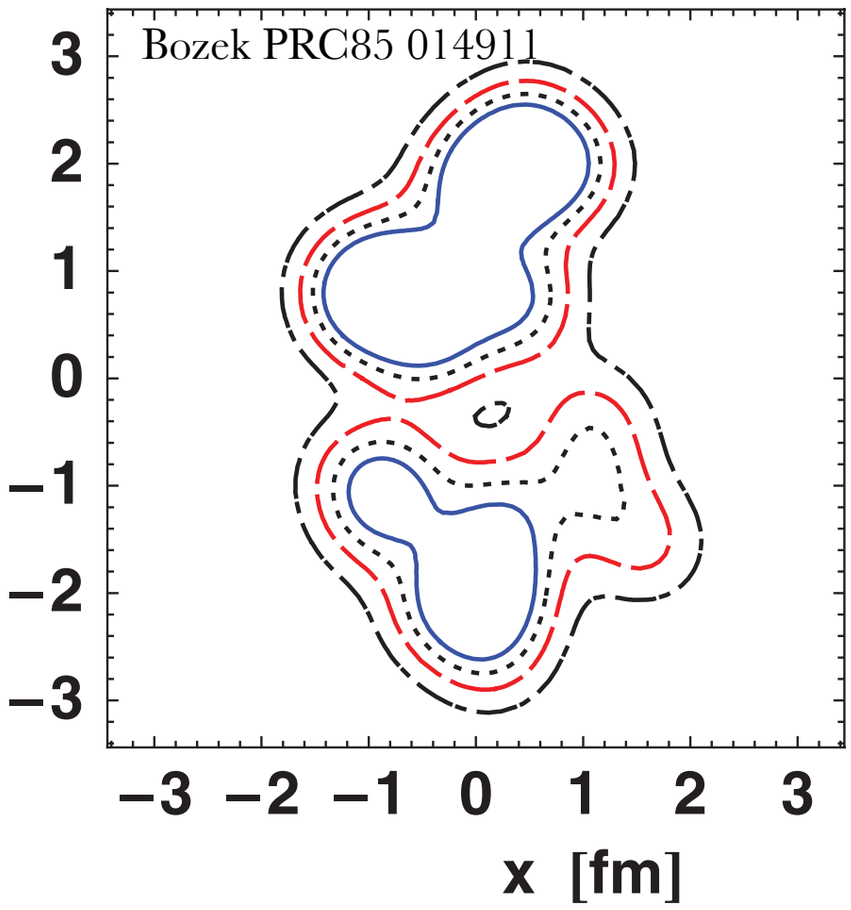




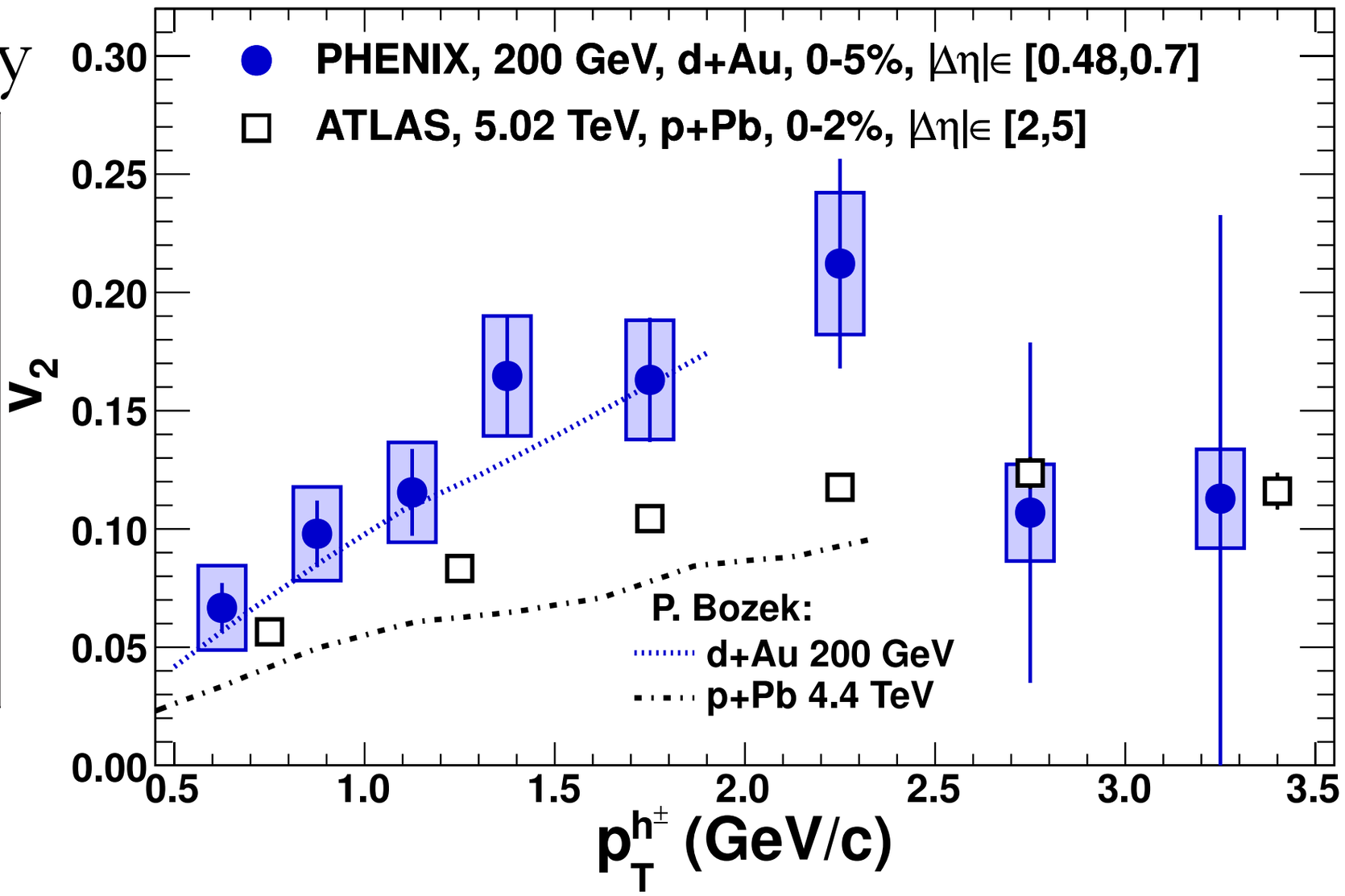
Schenke et al PRL108 252301
Gale et al 1209.6330

leveraging RHIC/LHC differences

initial entropy densitiy



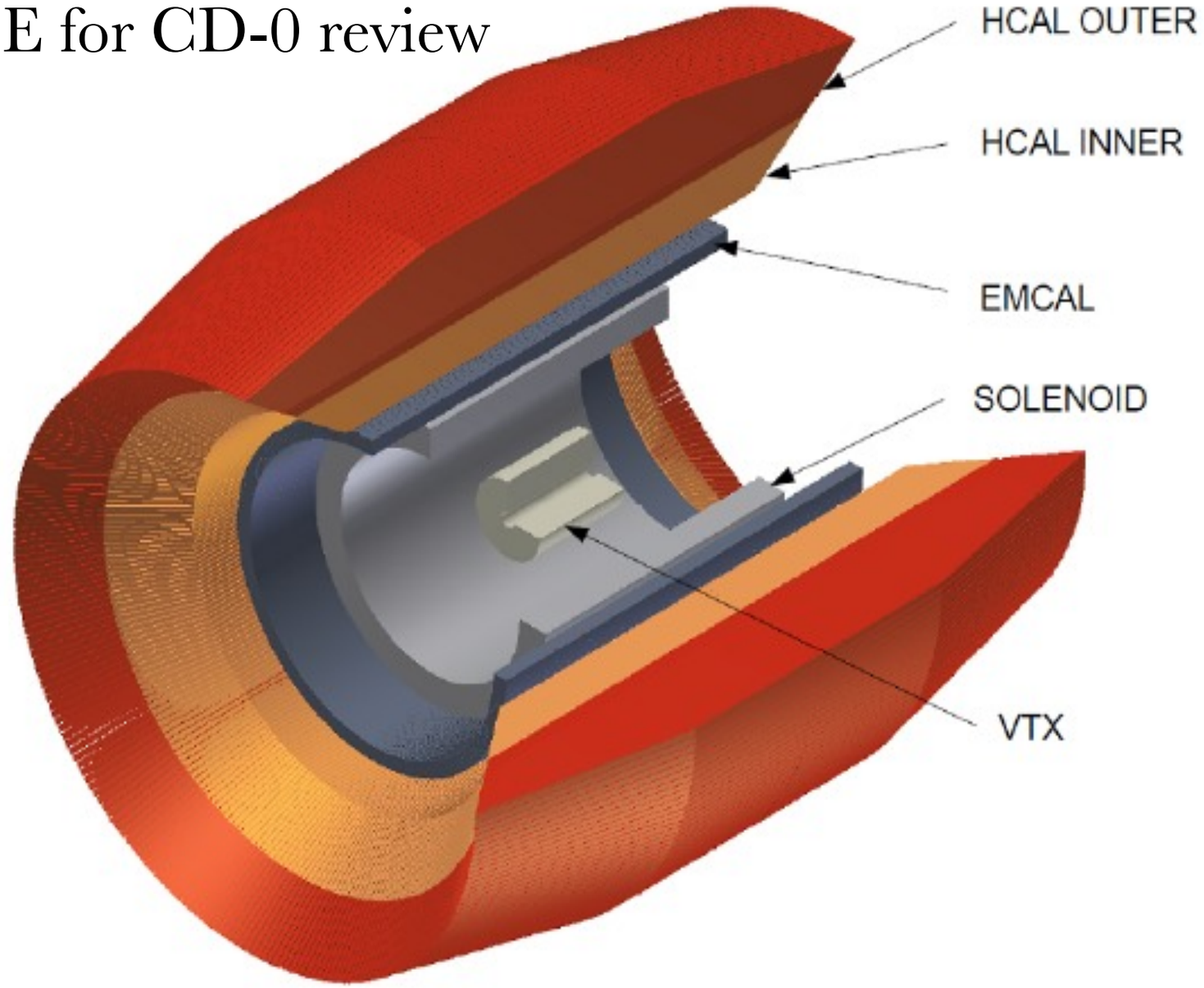
1303.1794



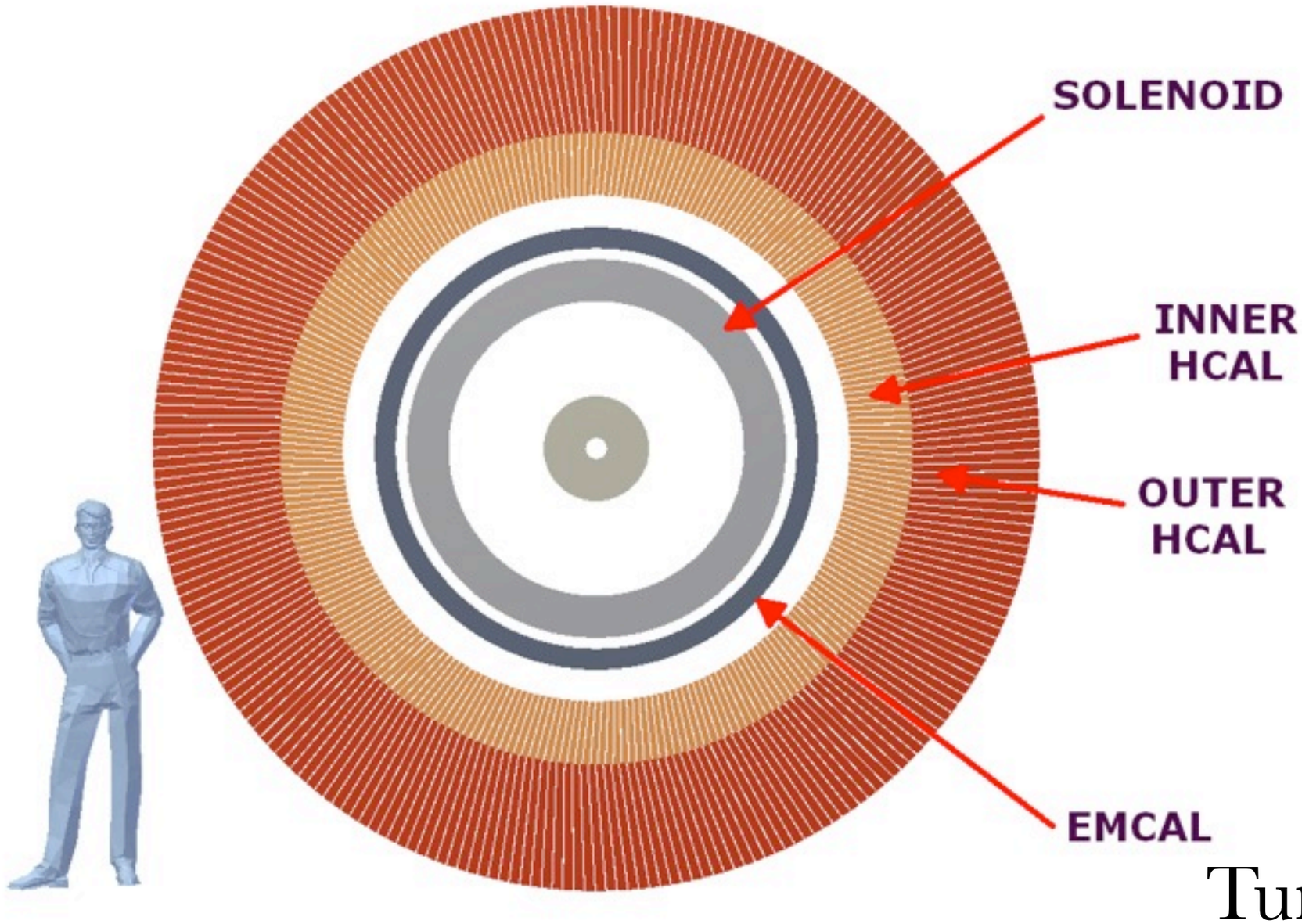
- changing both the collision energy and the shape of the initial system as compared to the ridge seen in pPb

sPHENIX

- upgrade optimized around jet/di-jet/photon measurements
- high rate, large uniform acceptance over $|\eta|<1$, hadronic calorimetry
- submitted last month to DOE for CD-0 review



inside sPHENIX



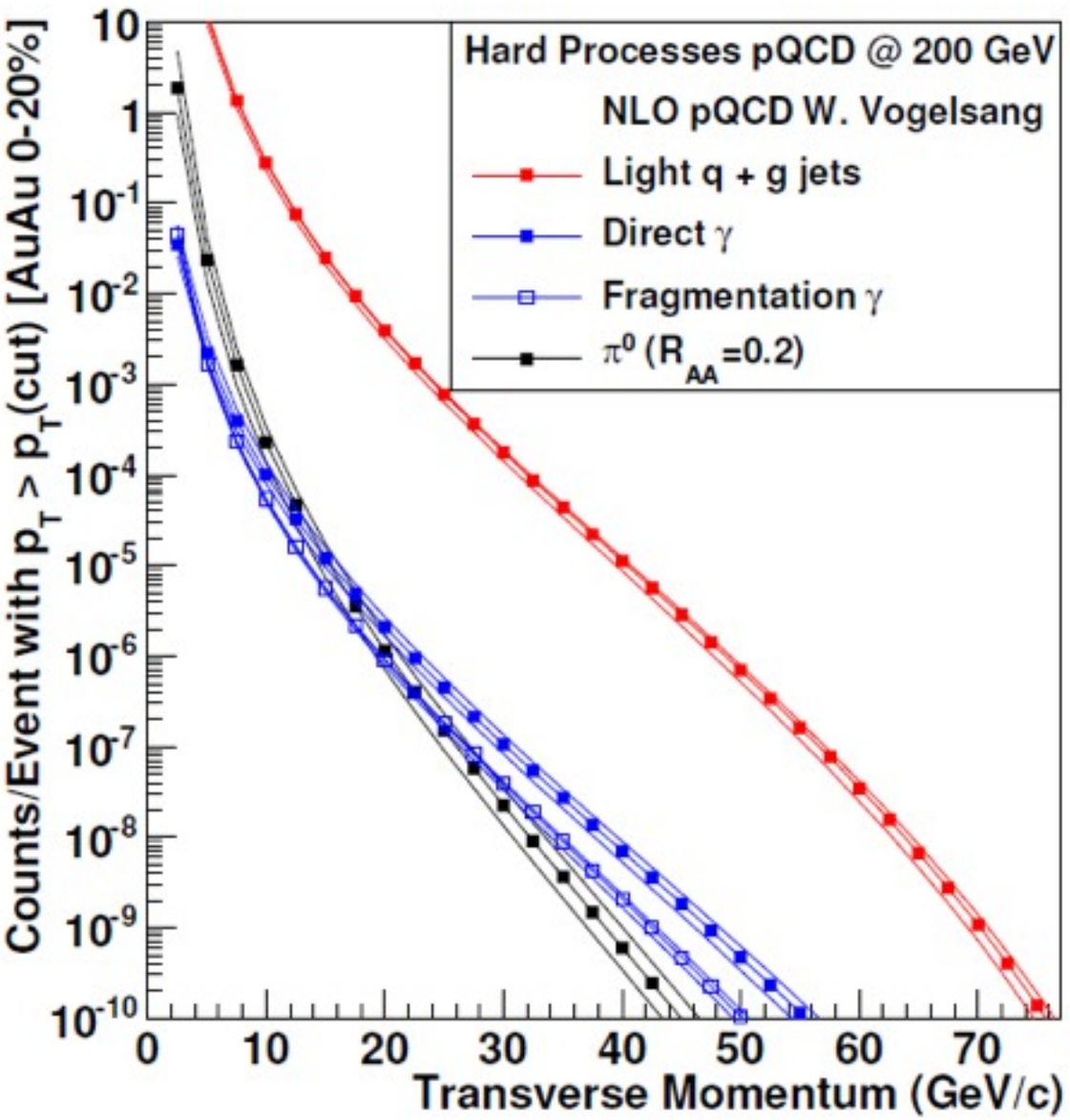
Rin = 70cm
2T, 1X_0

Fe-Scintillator HCal

Tungsten-scintillator
10cm thick

How Realistic Is this at RHIC?

RHIC Jet Rates



rates based on full stochastic cooling, but no additional accelerator upgrades

	Au+Au (central 20%)	p+p	d+Au
>20GeV	10^7 jets 10^4 photons	10^6 jets 10^3 photons	10^7 jets 10^4 photons
>30GeV	10^6 jets 10^3 photons	10^5 jets 10^2 photons	10^6 jets 10^3 photons
>40GeV	10^5 jets	10^4 jets	10^5 jets
>50GeV	10^4 jets	10^3 jets	10^4 jets

Huge rates allow differential measurements with geometry (v_2, v_3, A+B, U+U, …) & precise control measurements (dAu & pp) over 80% as dijets!

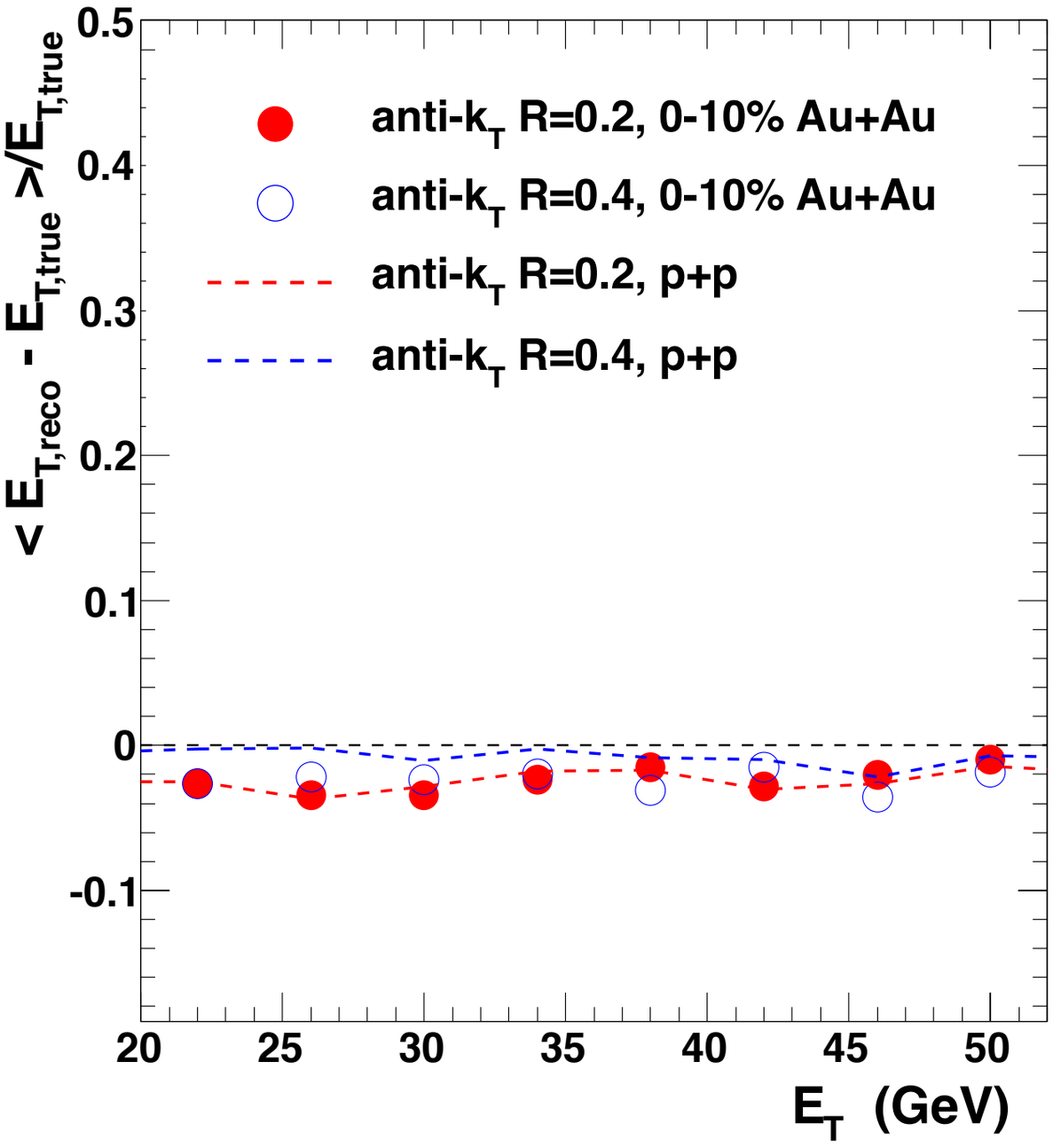
jet reconstruction performance

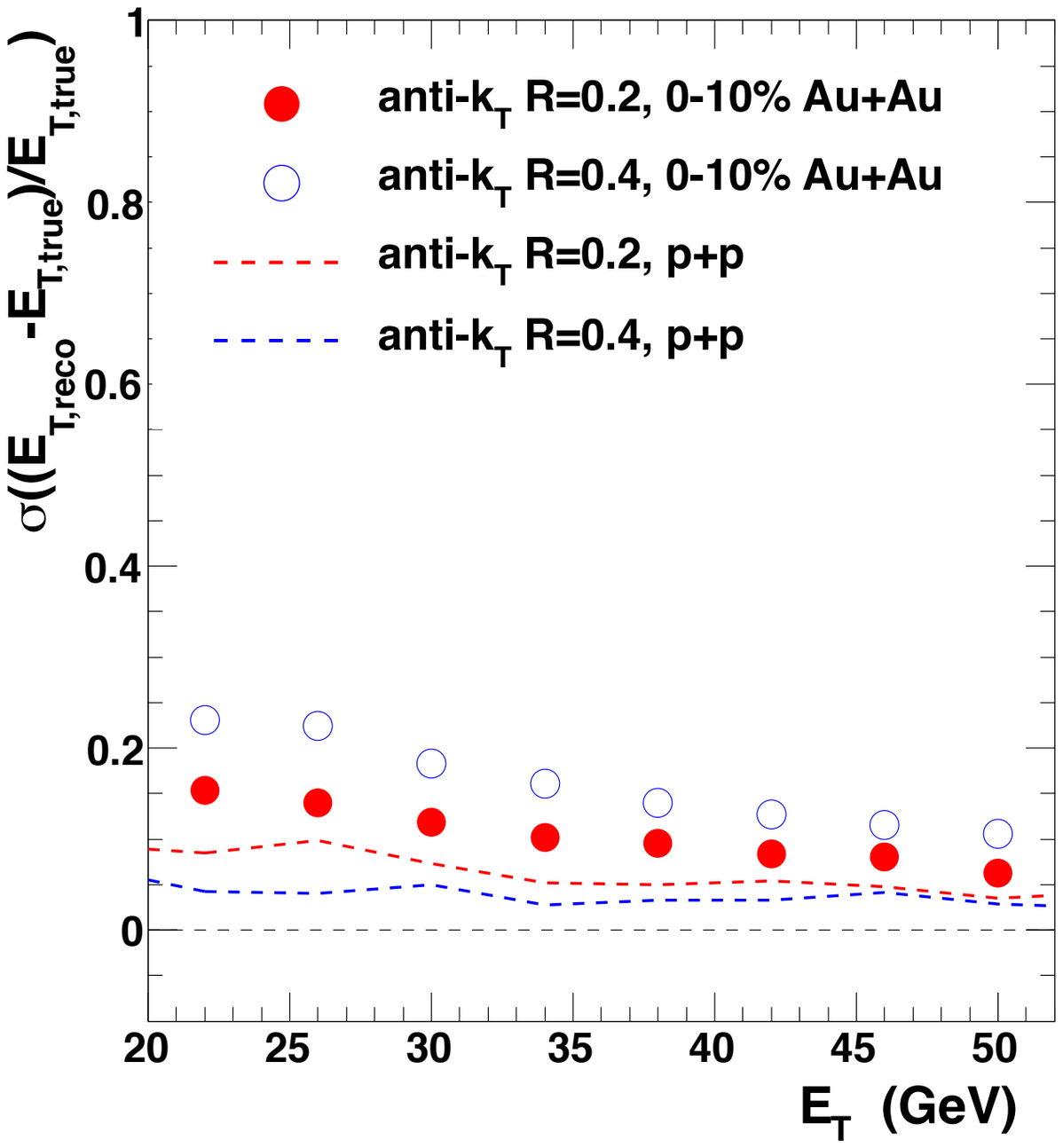
- how well can we measure real jets?
  - jet energy scale, jet energy resolution
- how are the jet measurements impacted by background fluctuations masquerading as jets--fakes

- large HIJING study
  - embedding PYTHIA jets into HIJING events to evaluate jet reconstruction performance
  - 750M minimum bias HIJING events to study relative rates of fake and real jets in HI background
- iterative background subtraction as in ATLAS

detailed study in: Hanks, Sickles et al: PRC86 024908

reconstruction performance





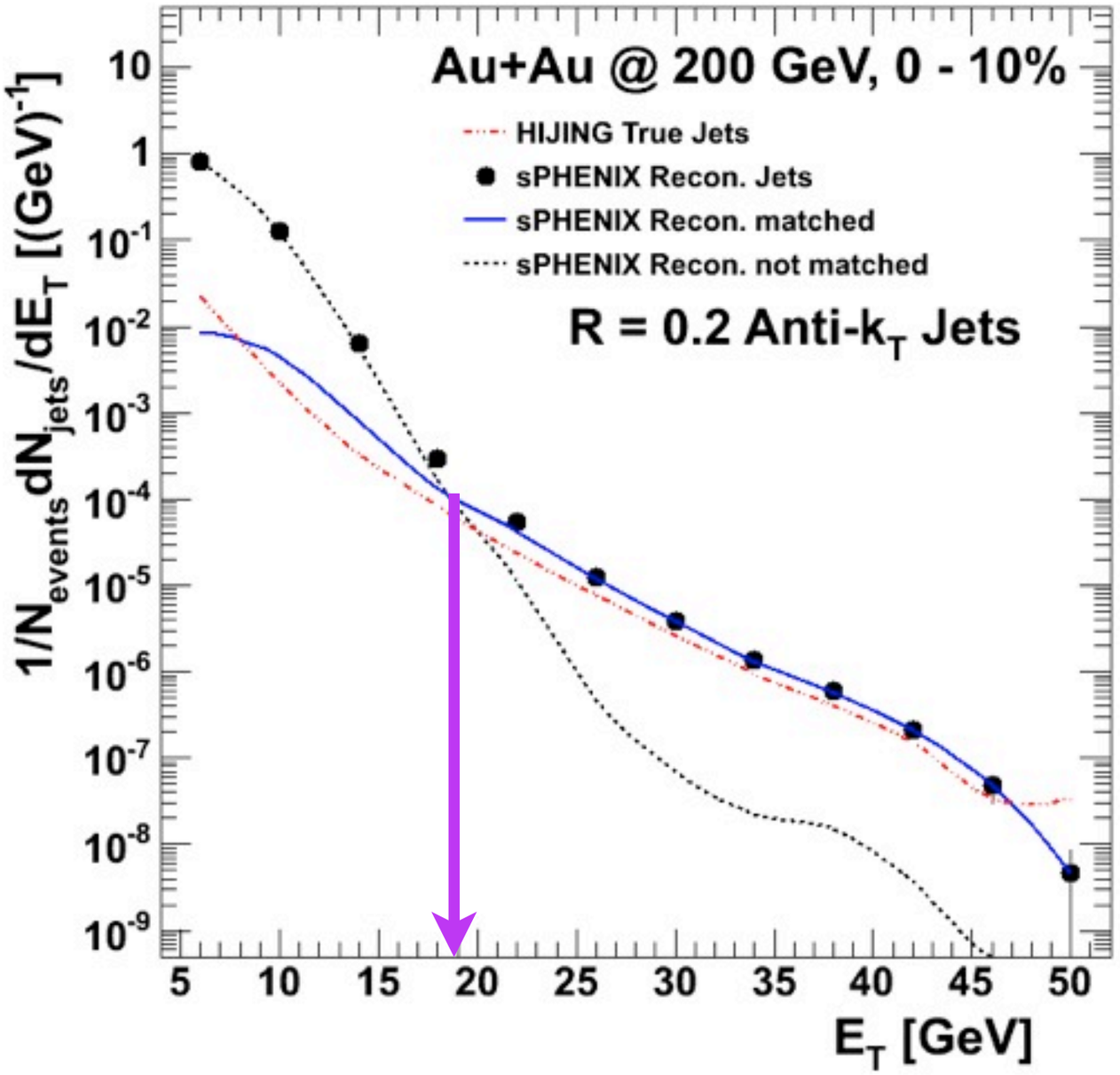
- good performance in heavy ion background
- resolution only from the underlying event, no detector resolution included

reconstructed jets

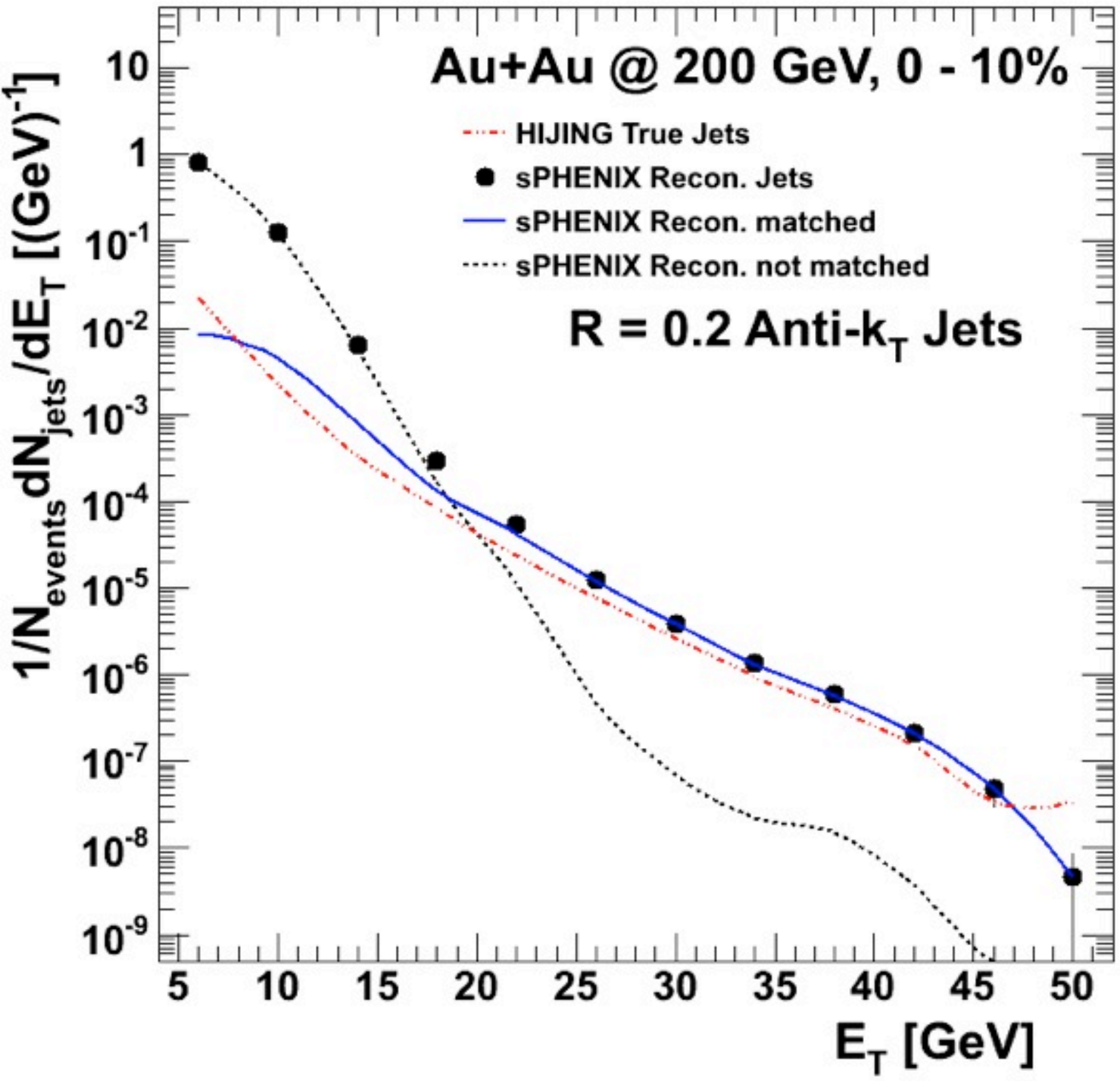
reconstructed jets

matched jets:
within $\Delta R < 0.25$ of a HIJING truth jet (>5GeV)

not matched jets:
no nearby HIJING jets
"fakes"



Fake Jets at RHIC (R=0.2)



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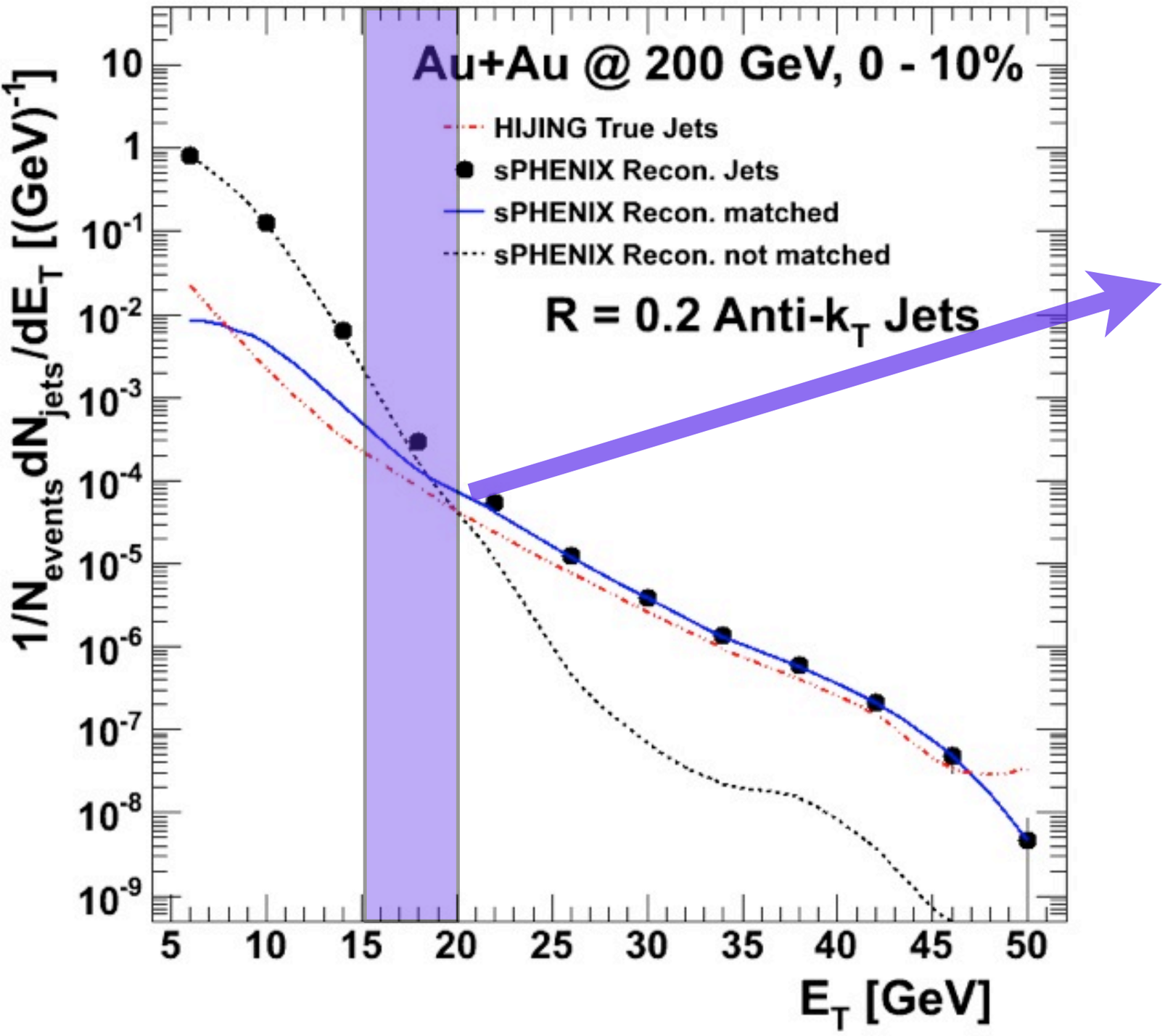

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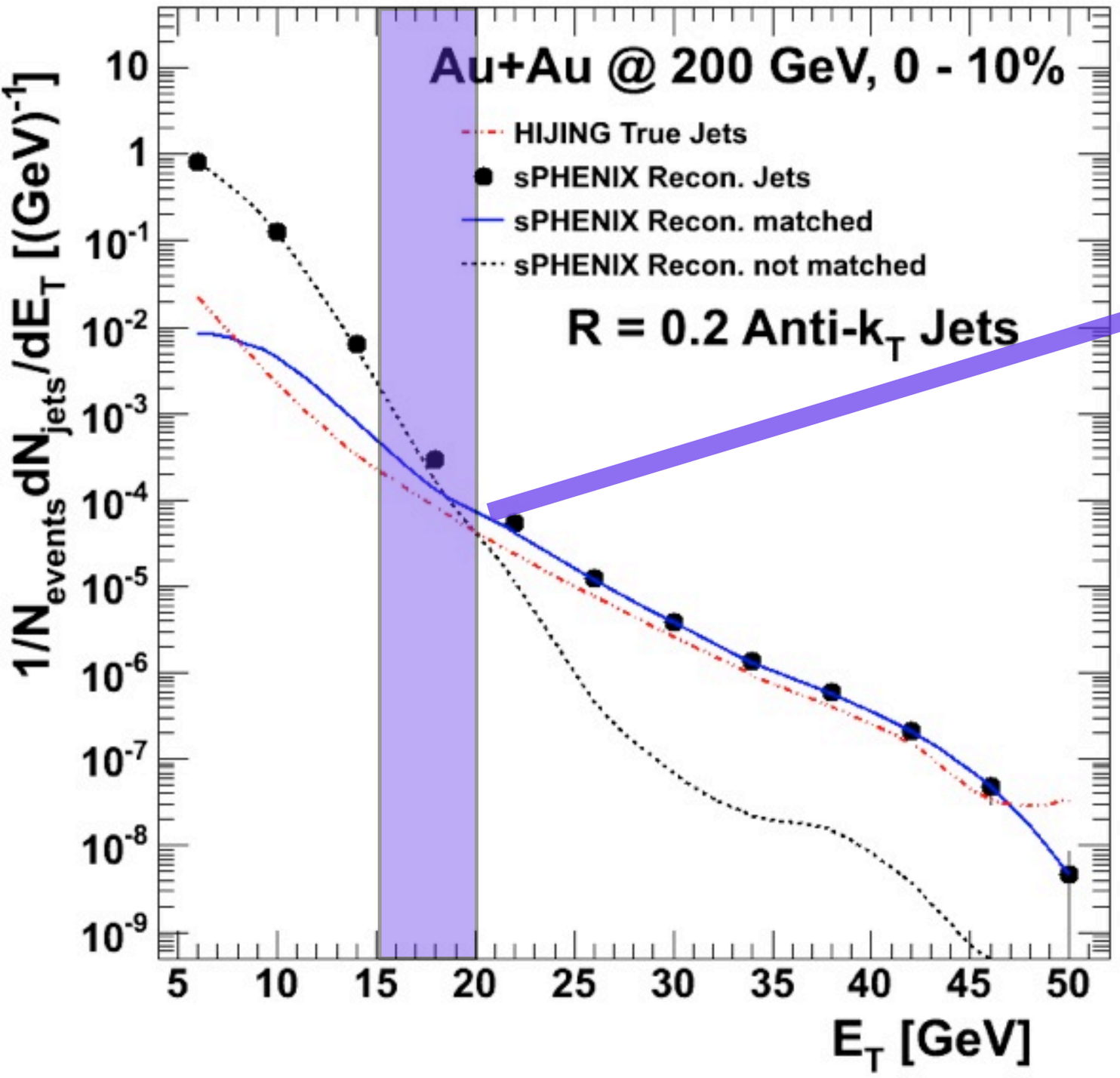

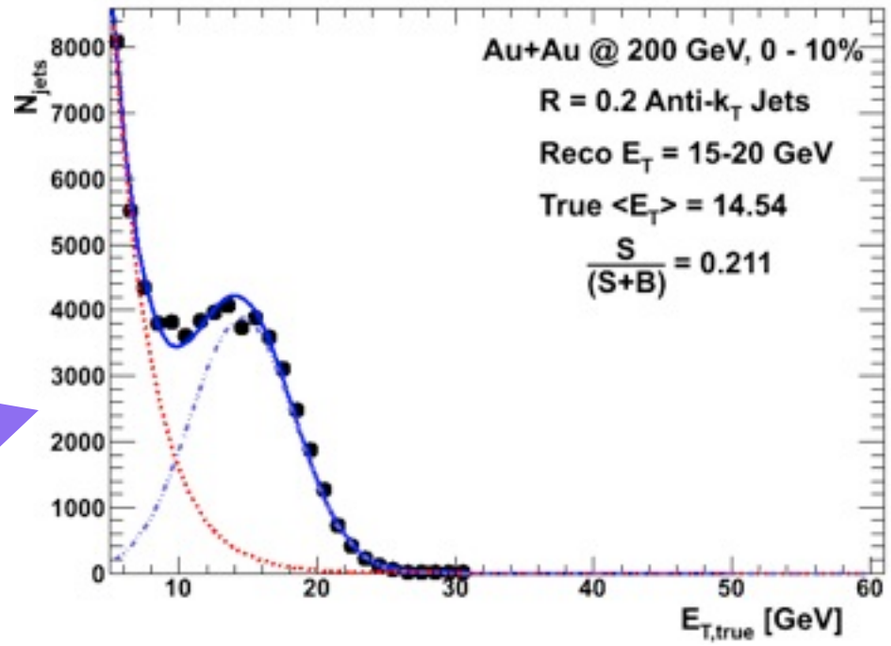

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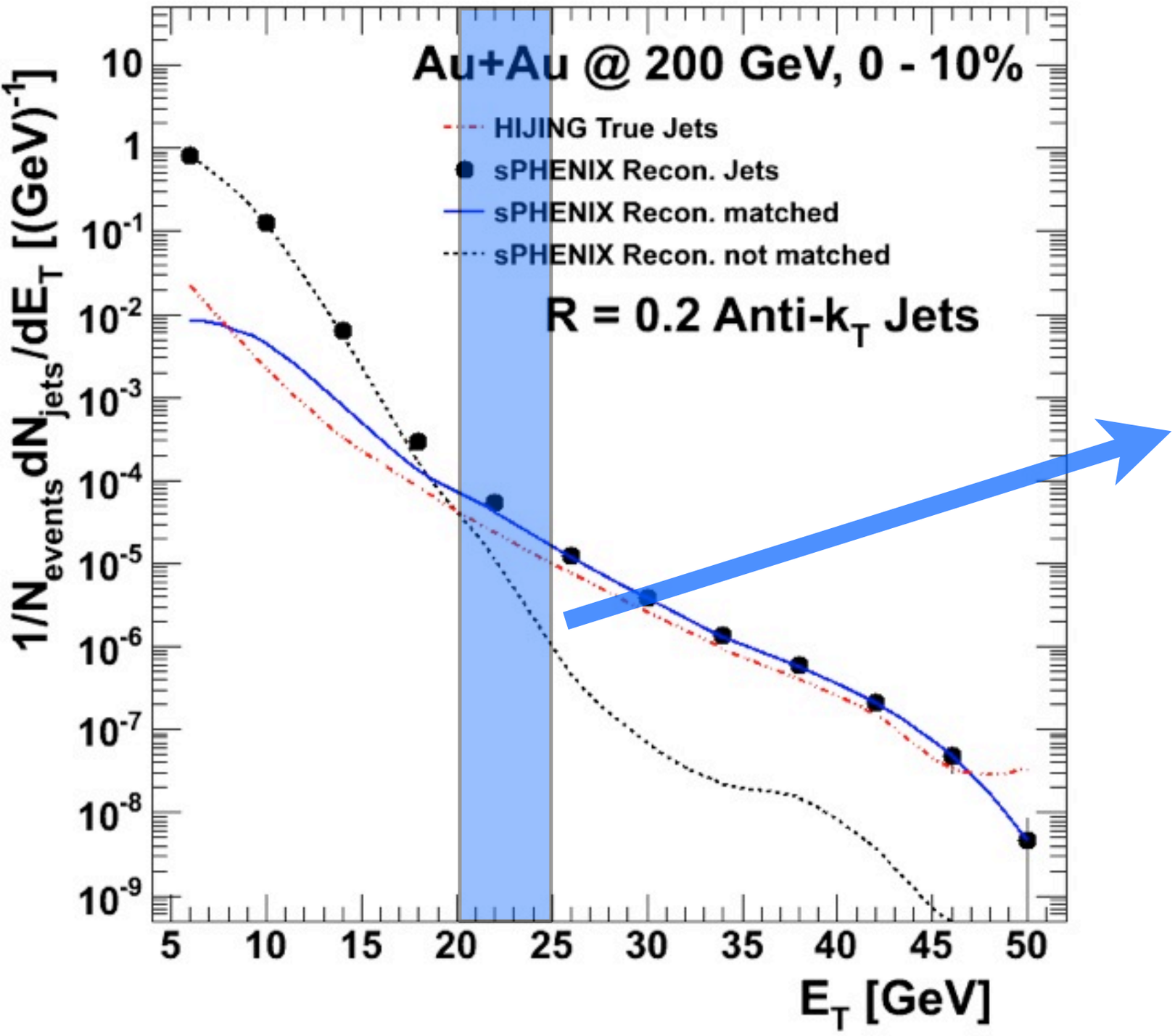

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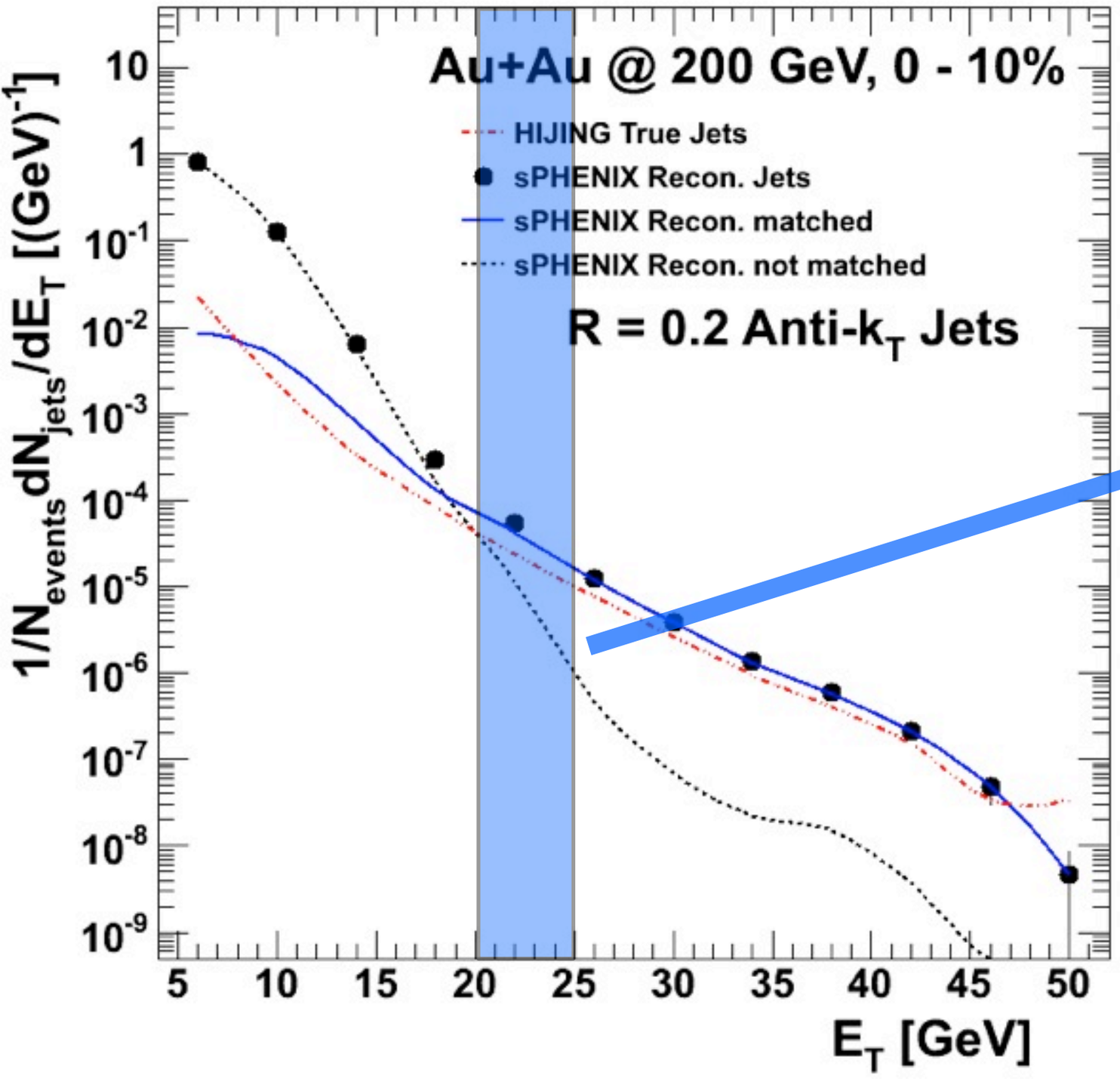

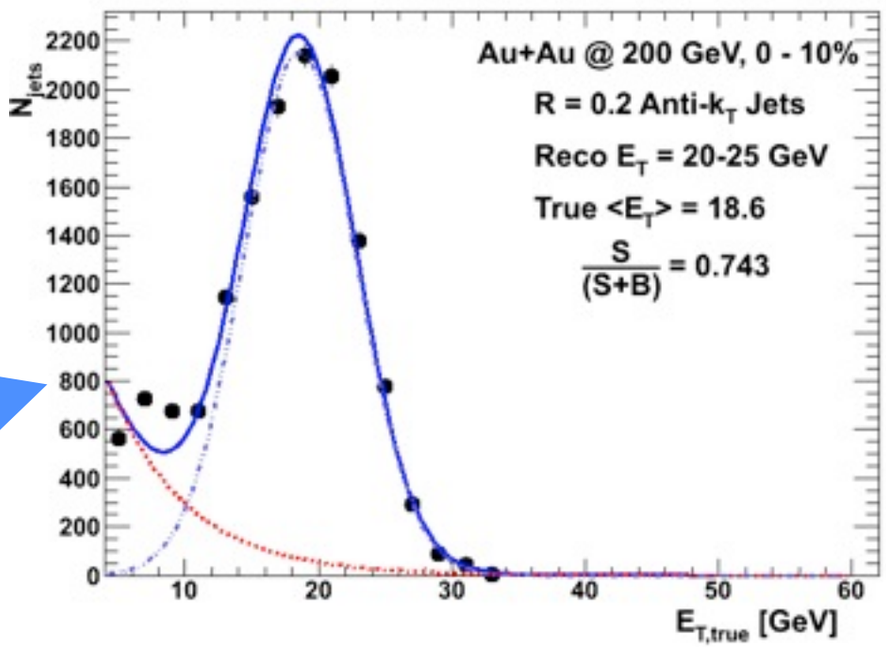

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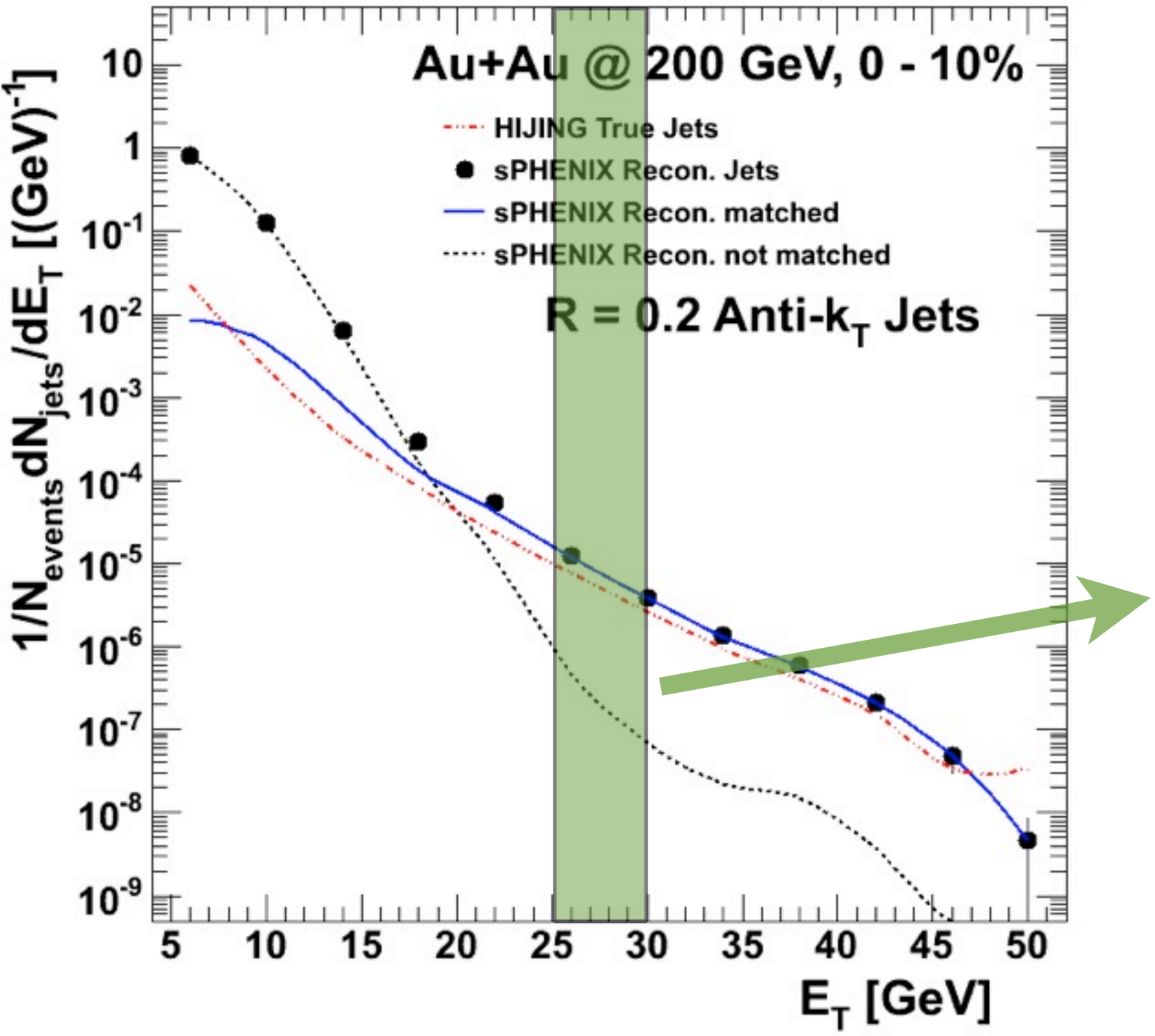

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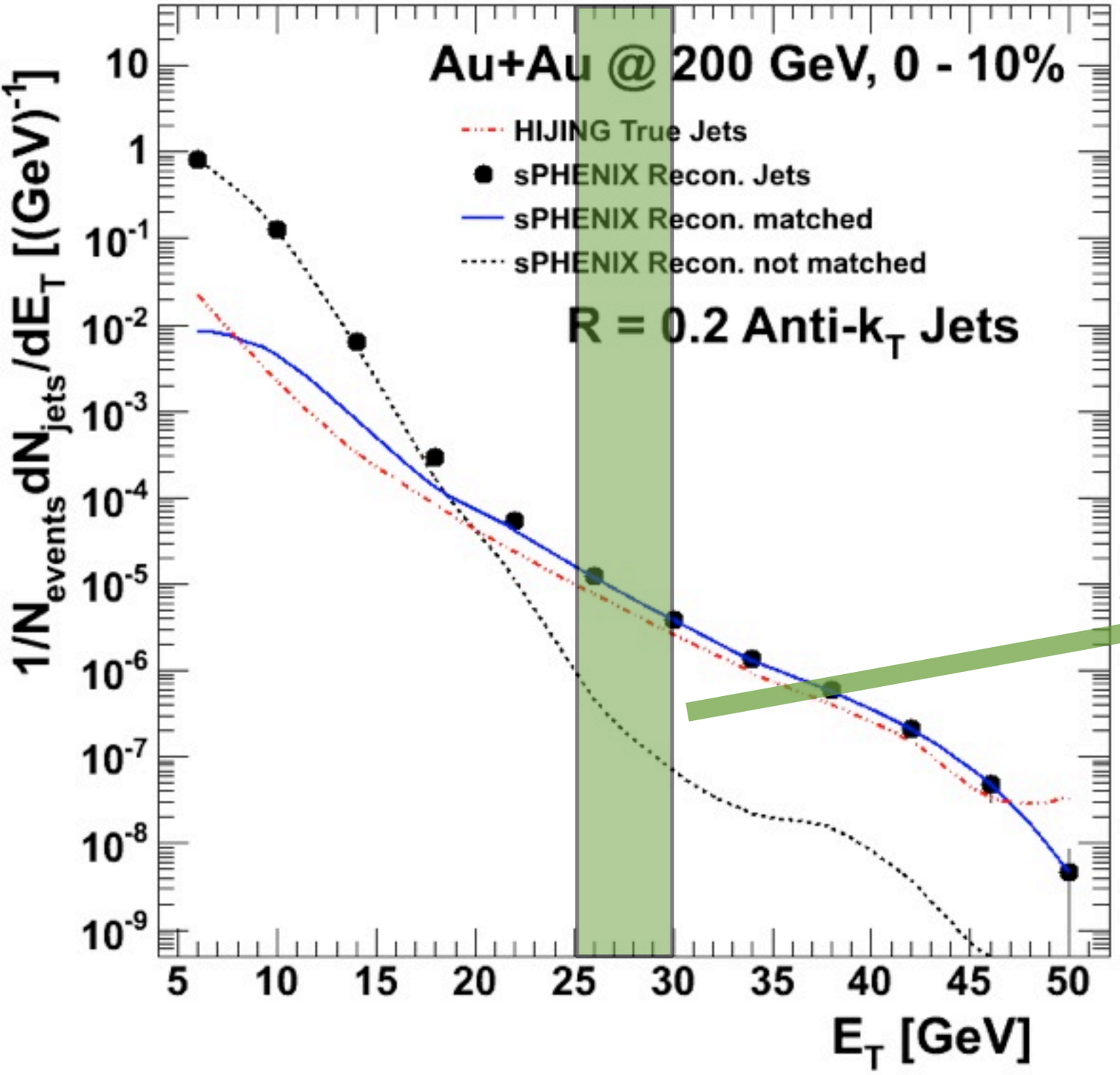

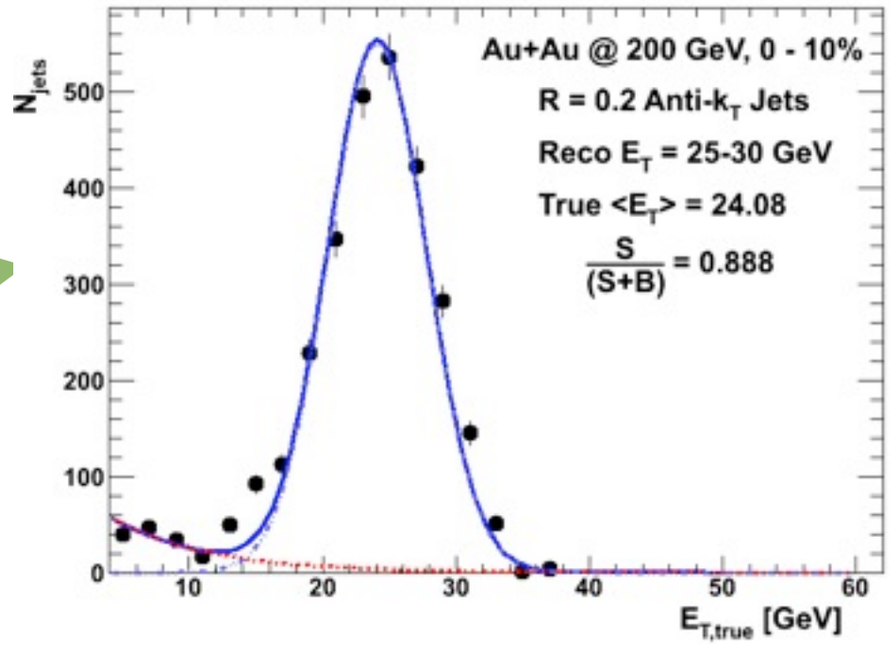

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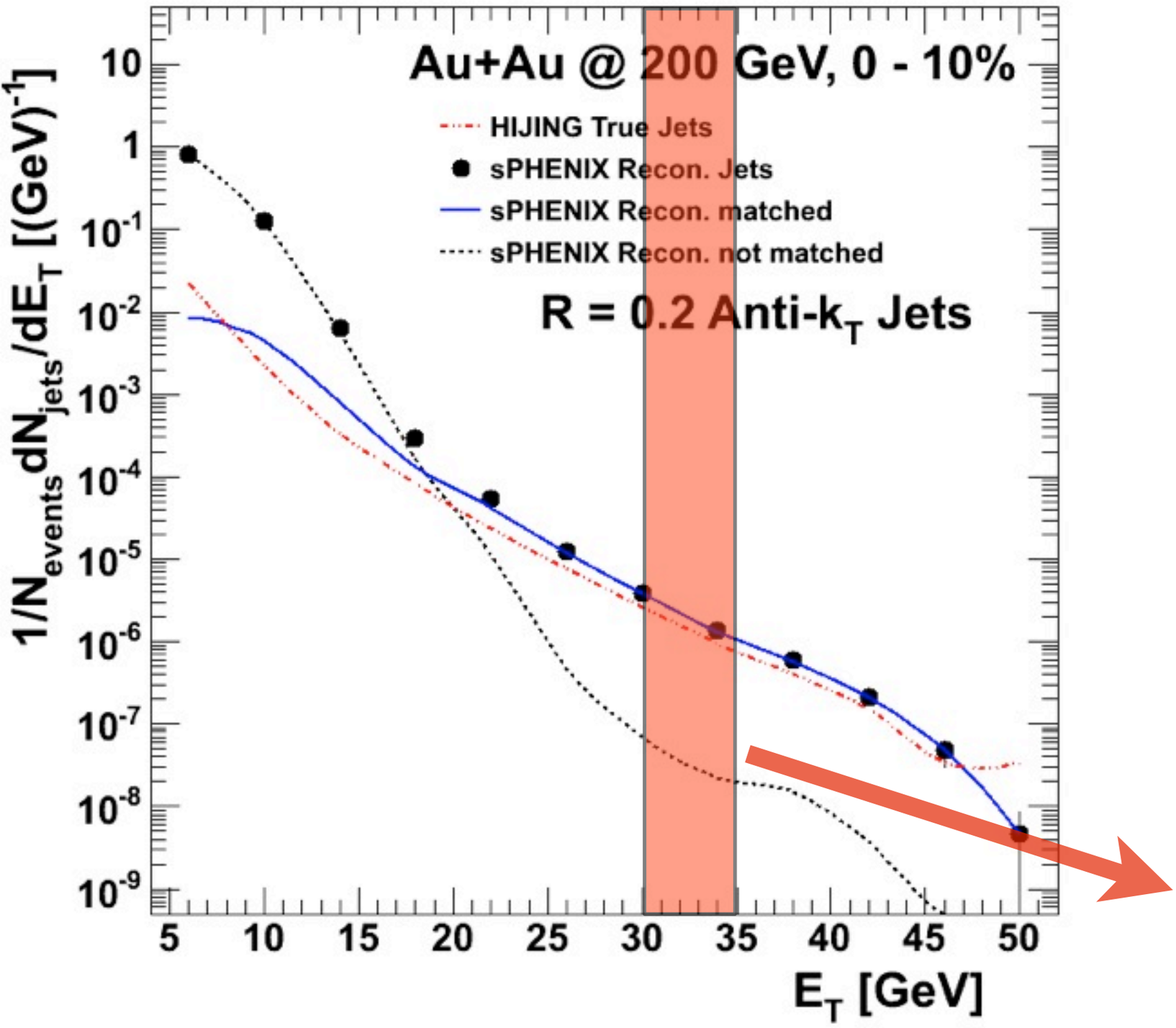

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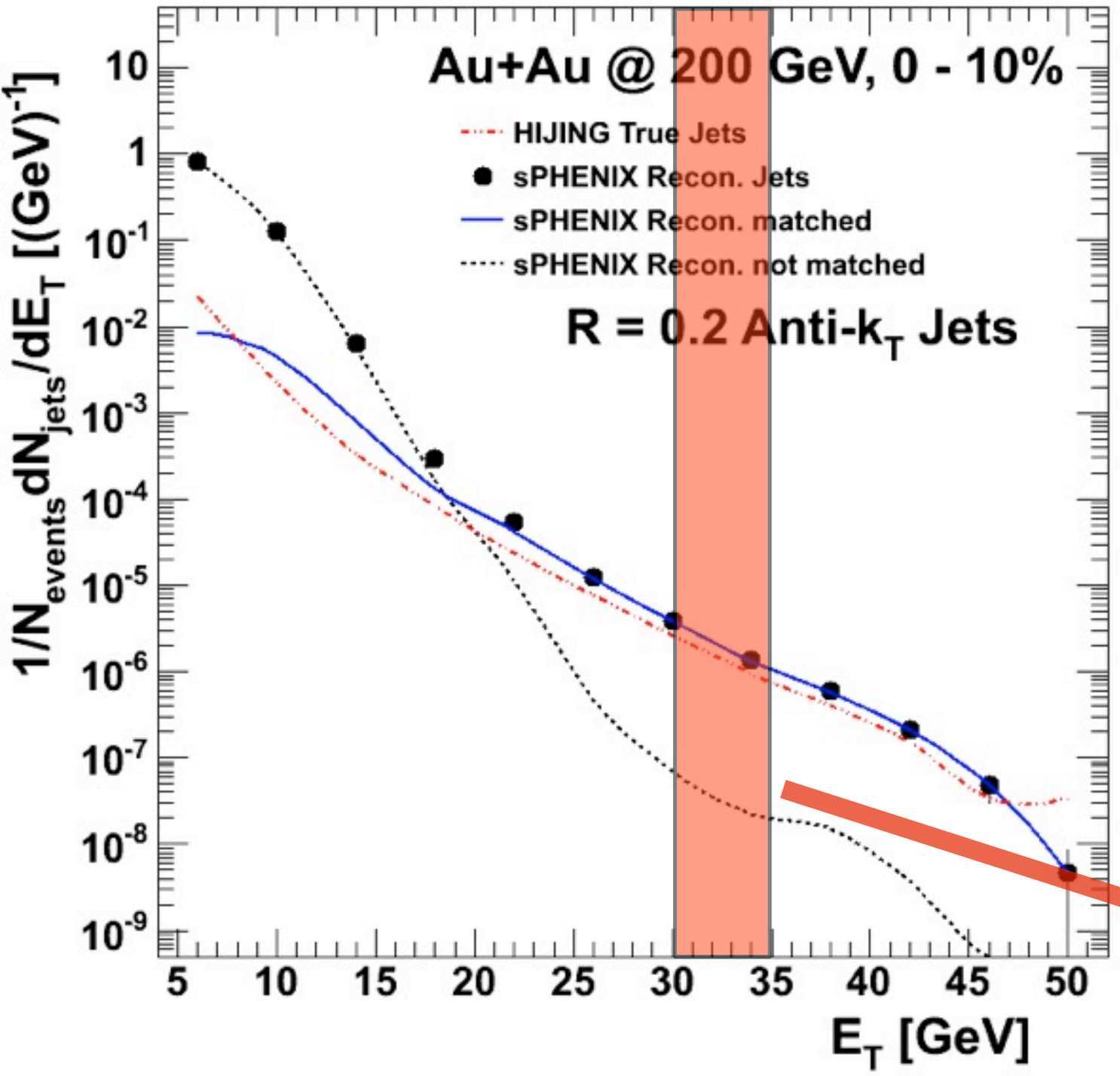

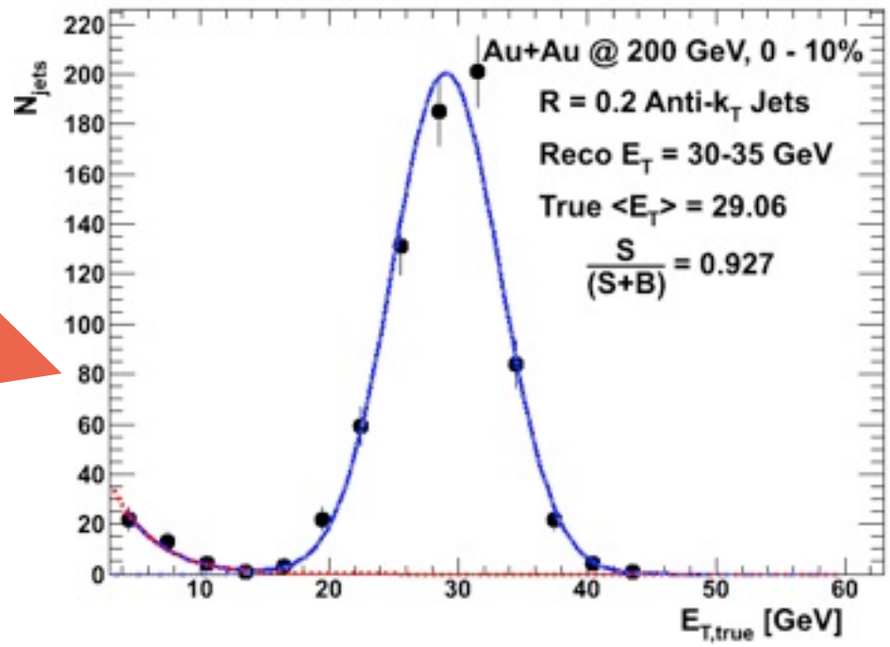

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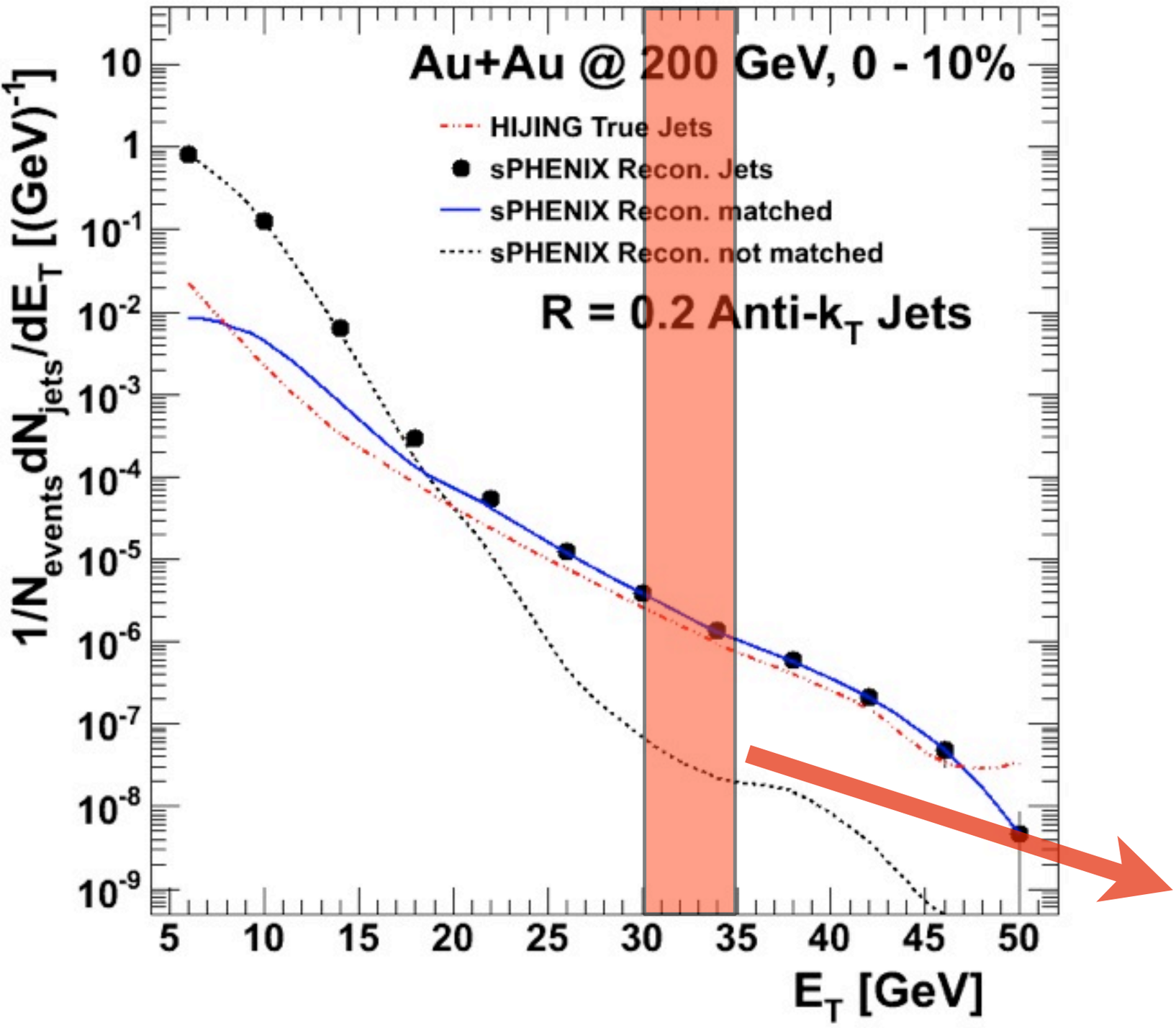
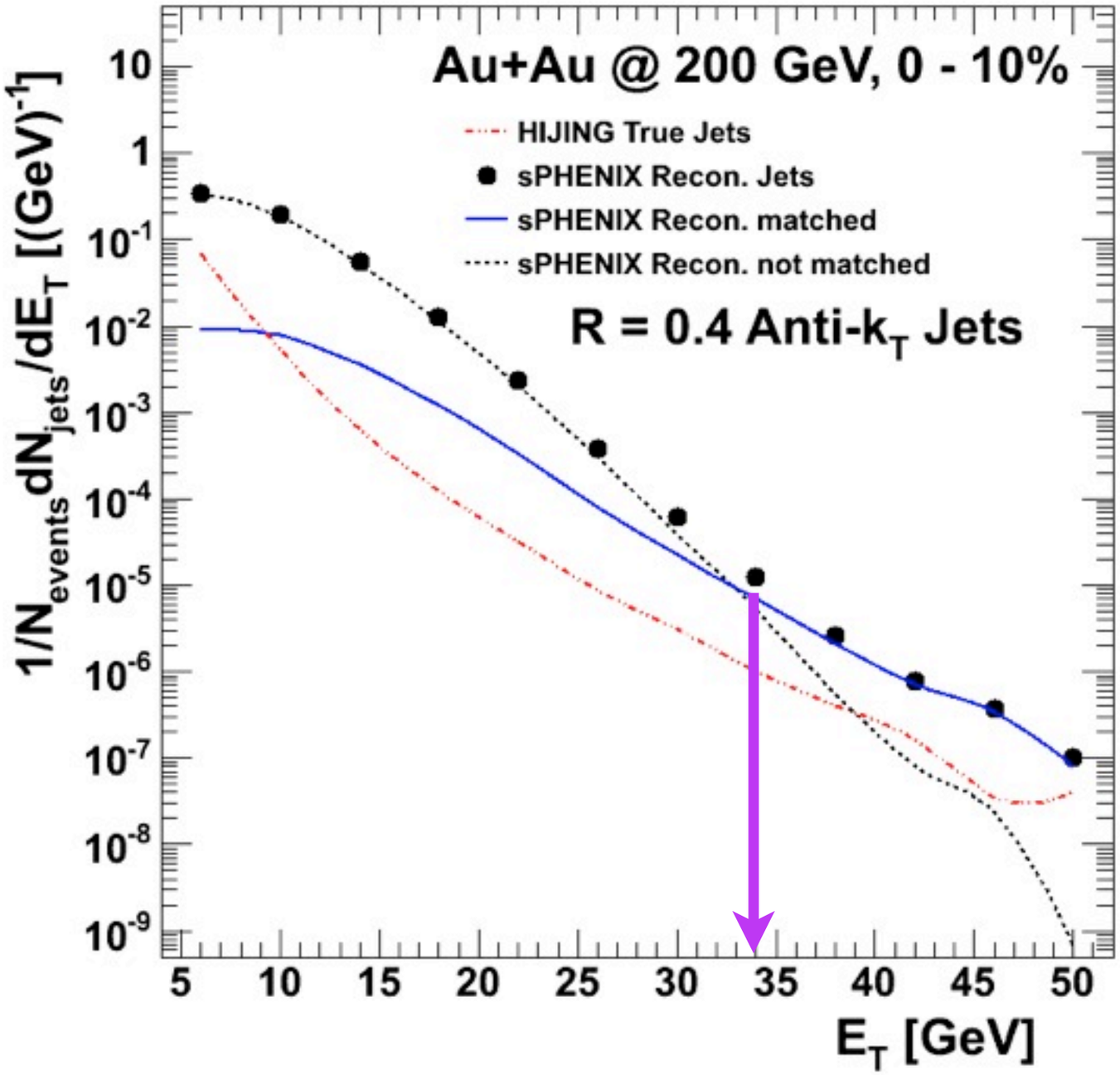


Fake Jets at RHIC (R=0.4)

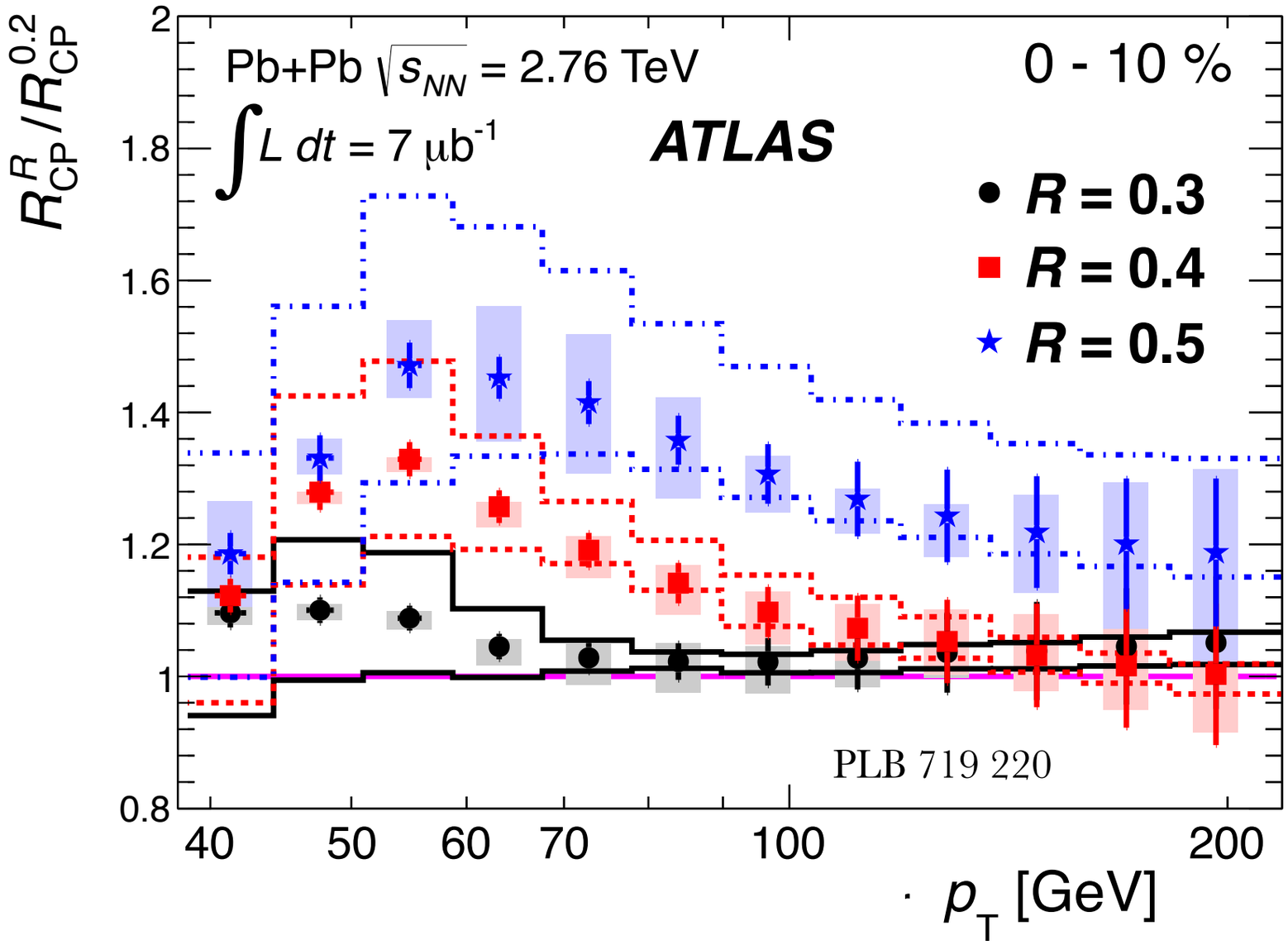


real jets outnumber fakes by ~35GeV

however, no fake jet rejection done yet

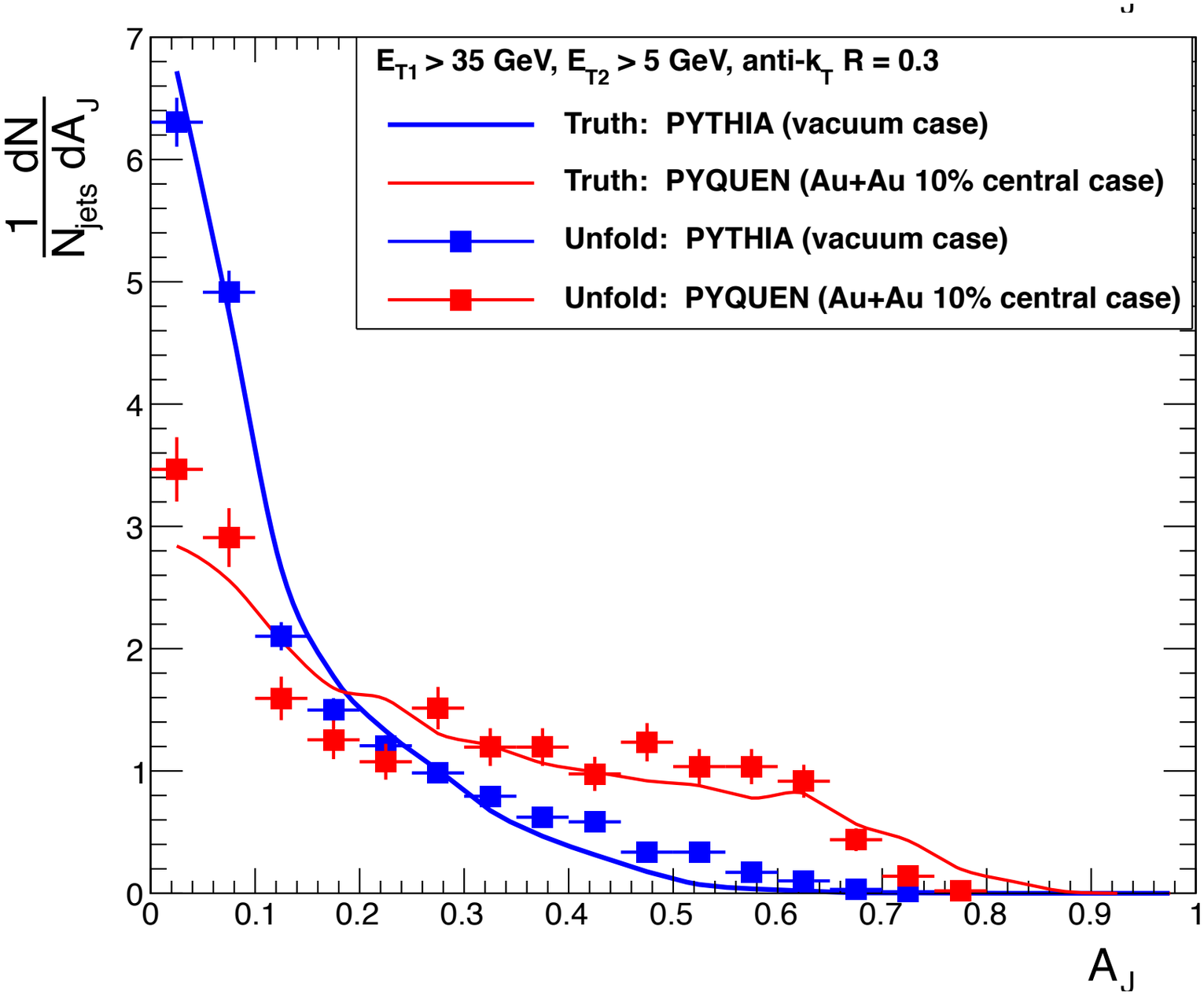
optimistic about lowering this crossover!

why are large jets so interesting?



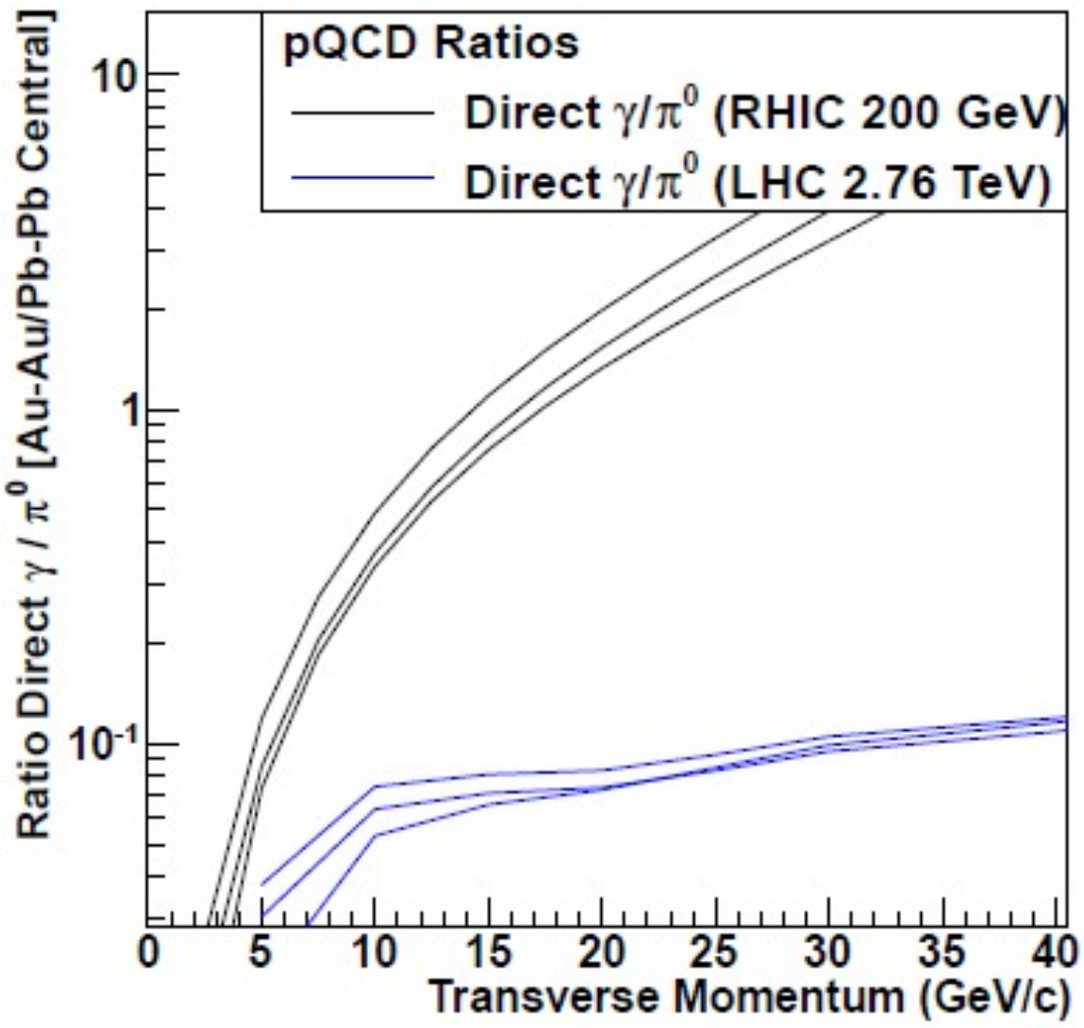
- evidence for large shape modifications in the region accessible at RHIC
- experimentally: require high statistics & good control of systematics

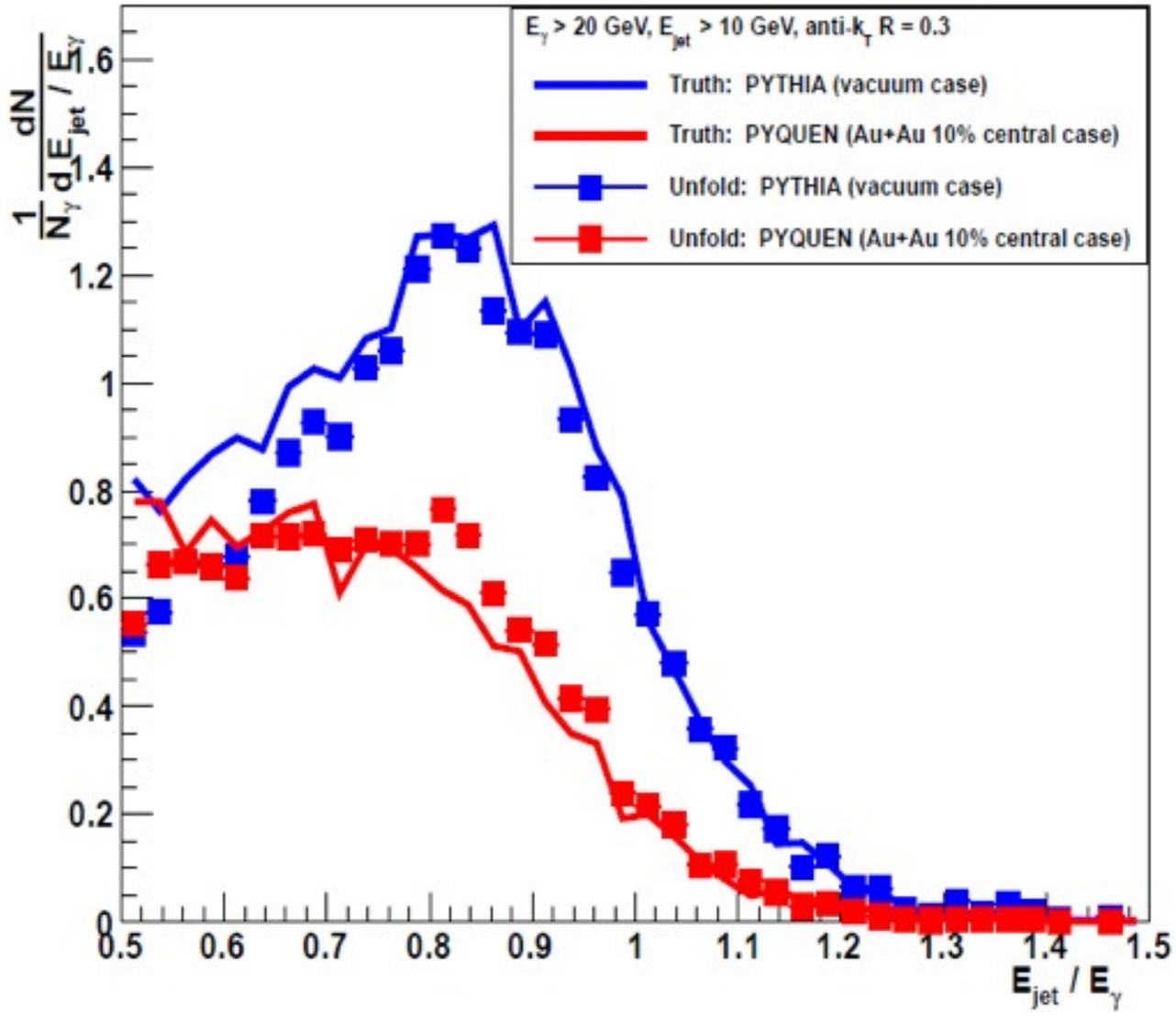
dijet measurements



- full Geant 4 detector simulation of dijets embedded in 0-10% central HIJING
- unfolding recovers the truth distribution very well

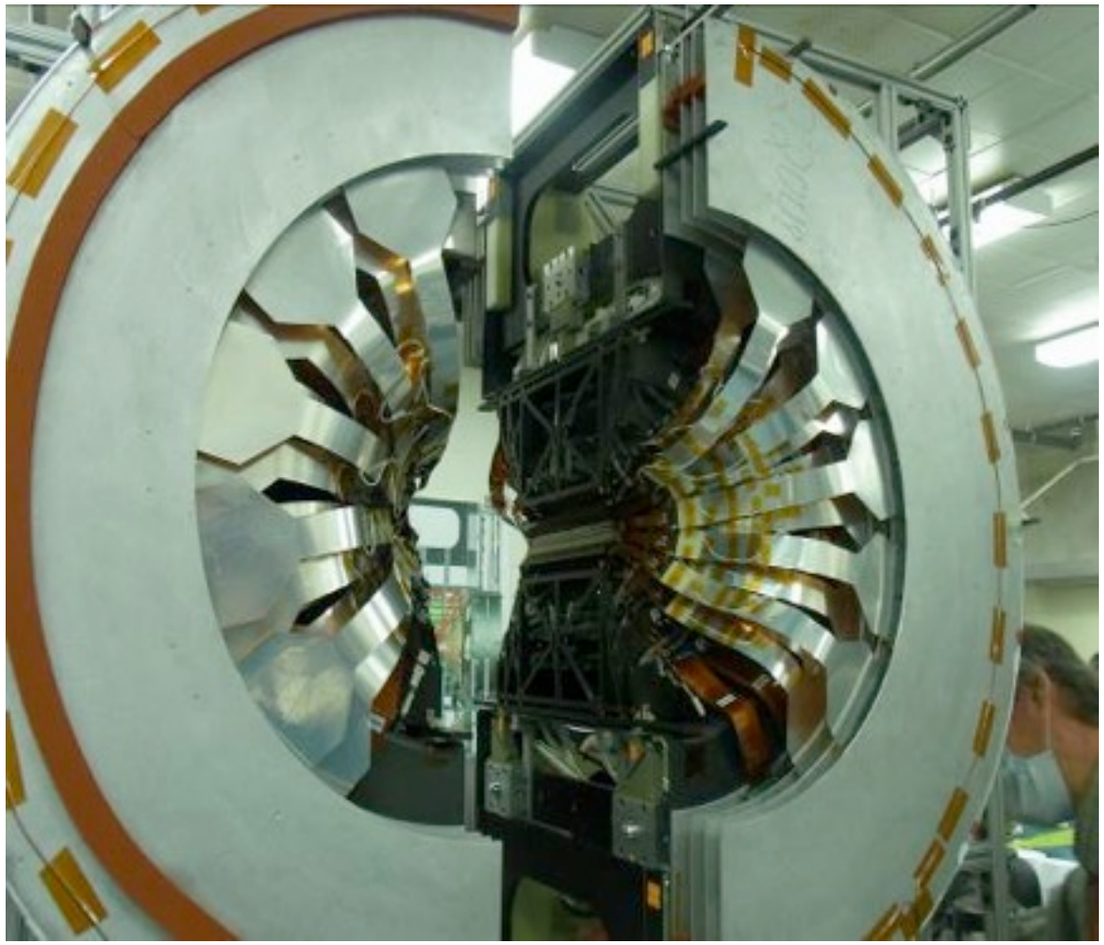
γ-jet measurements



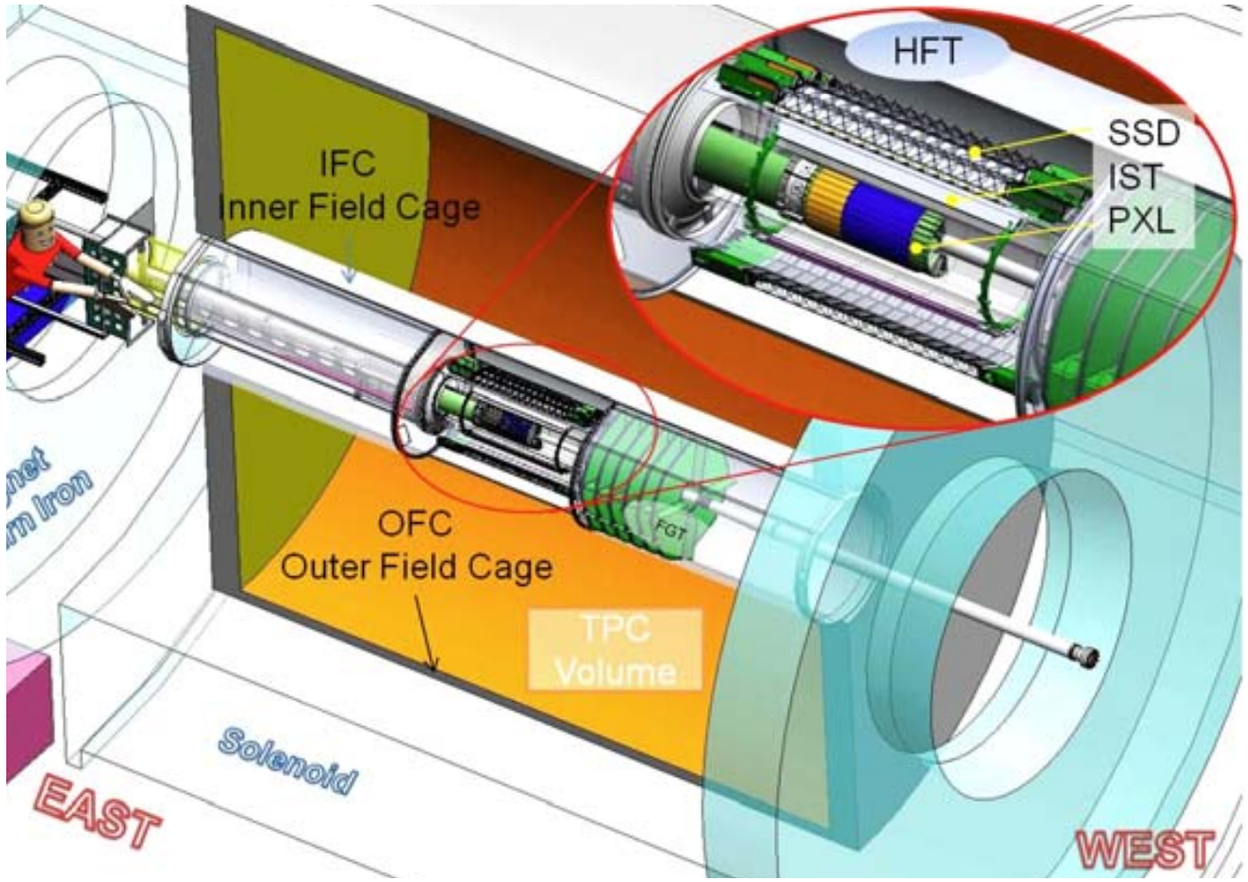


- γ/π0 very large at RHIC, large numbers out >30GeV
- unfolding the jet energy recovers the truth distributions from Geant4 simulation into central HIJING

heavy flavor at RHIC



PHENIX (F)VTX



STAR HFT

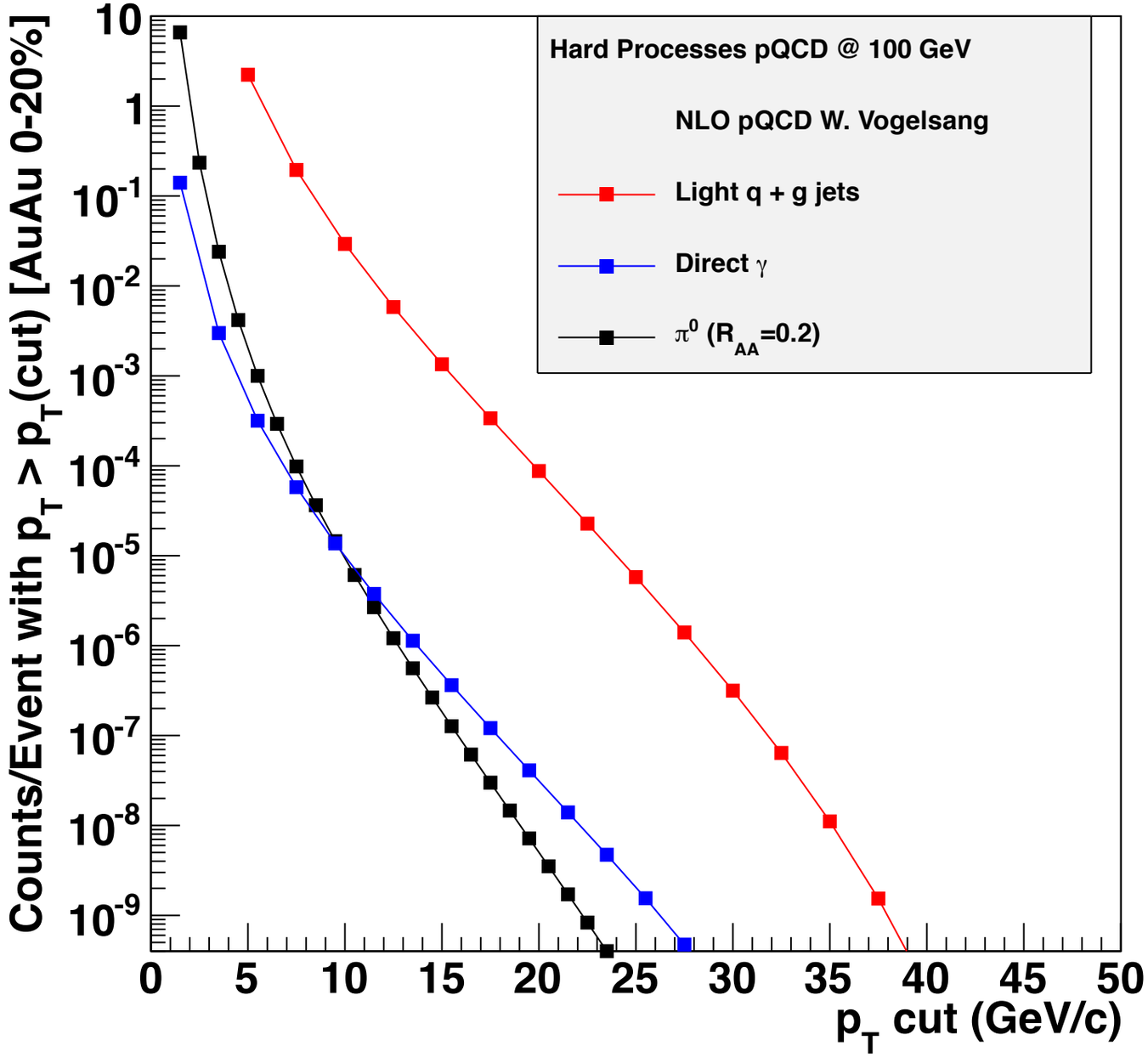
- upgrades coming online to address charm and bottom separation at RHIC
- essential piece of the jet quenching puzzle

jet quenching at RHIC

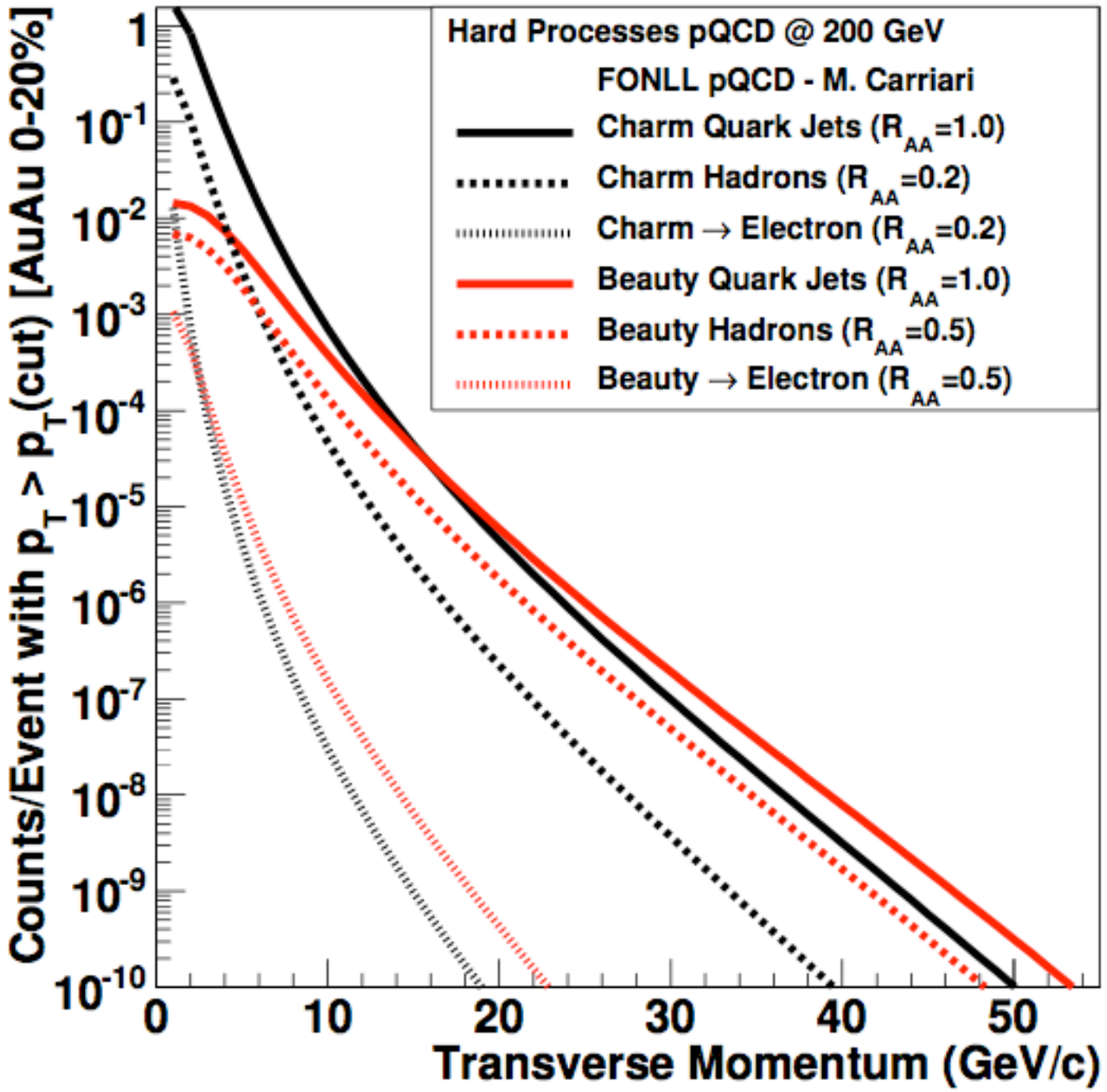
- **current measurements show evidence for softening of fragmentation and broadening of angular correlations**
- **ATLAS measurements show R dependence of jet suppression at jet energies accessible at RHIC**
- **together with LHC constrain T dependence of jet quenching**
- **extremely interesting physics accessible at RHIC**
- **sPHENIX: full calorimeter coverage at mid-rapidity**
  - take advantage of full RHIC luminosity: large acceptance, high rate
  - becomes central to ePHENIX
  - proposal submitted to DOE for CD-0 review last month!
- **silicon detectors at STAR and PHENIX will provide handle on heavy flavor**
- **detector upgrades critical to the success of hard probes at RHIC**

backups

further exploration of T dependence



heavy quarks



identifying truth jets

identifying truth jets

deep within the HIJING Event Generation...

identifying truth jets

deep within the HIJING Event Generation...

parton 1

identifying truth jets

deep within the HIJING Event Generation...

parton 1

↓

hadrons A

identifying truth jets

deep within the HIJING Event Generation...

parton 1

↓

hadrons A

↓

FastJet

anti-k_T

identifying truth jets

deep within the HIJING Event Generation...

parton 1

↓

hadrons A

↓

FastJet

anti-k_T

↓

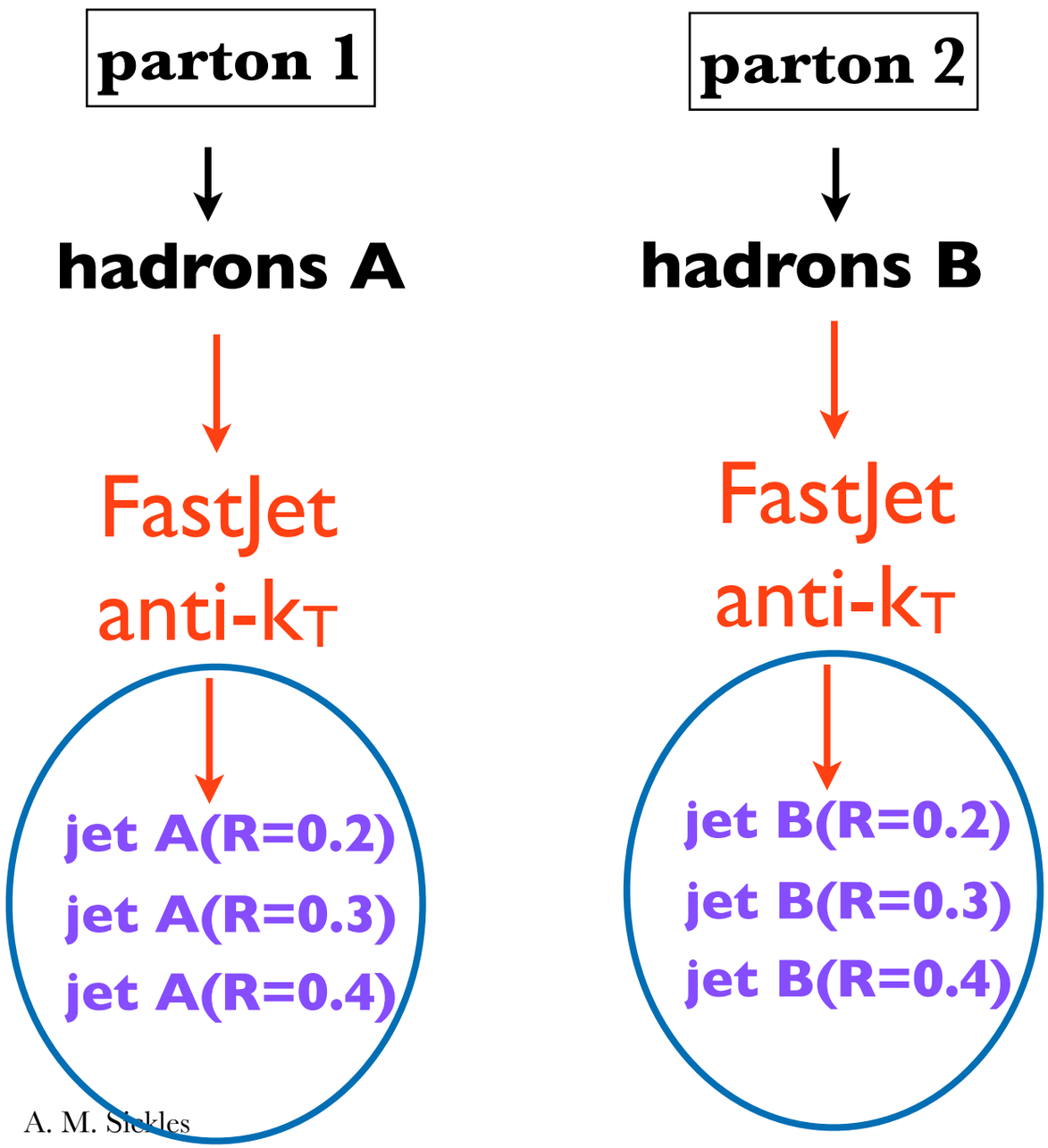
jet A(R=0.2)

jet A(R=0.3)

jet A(R=0.4)

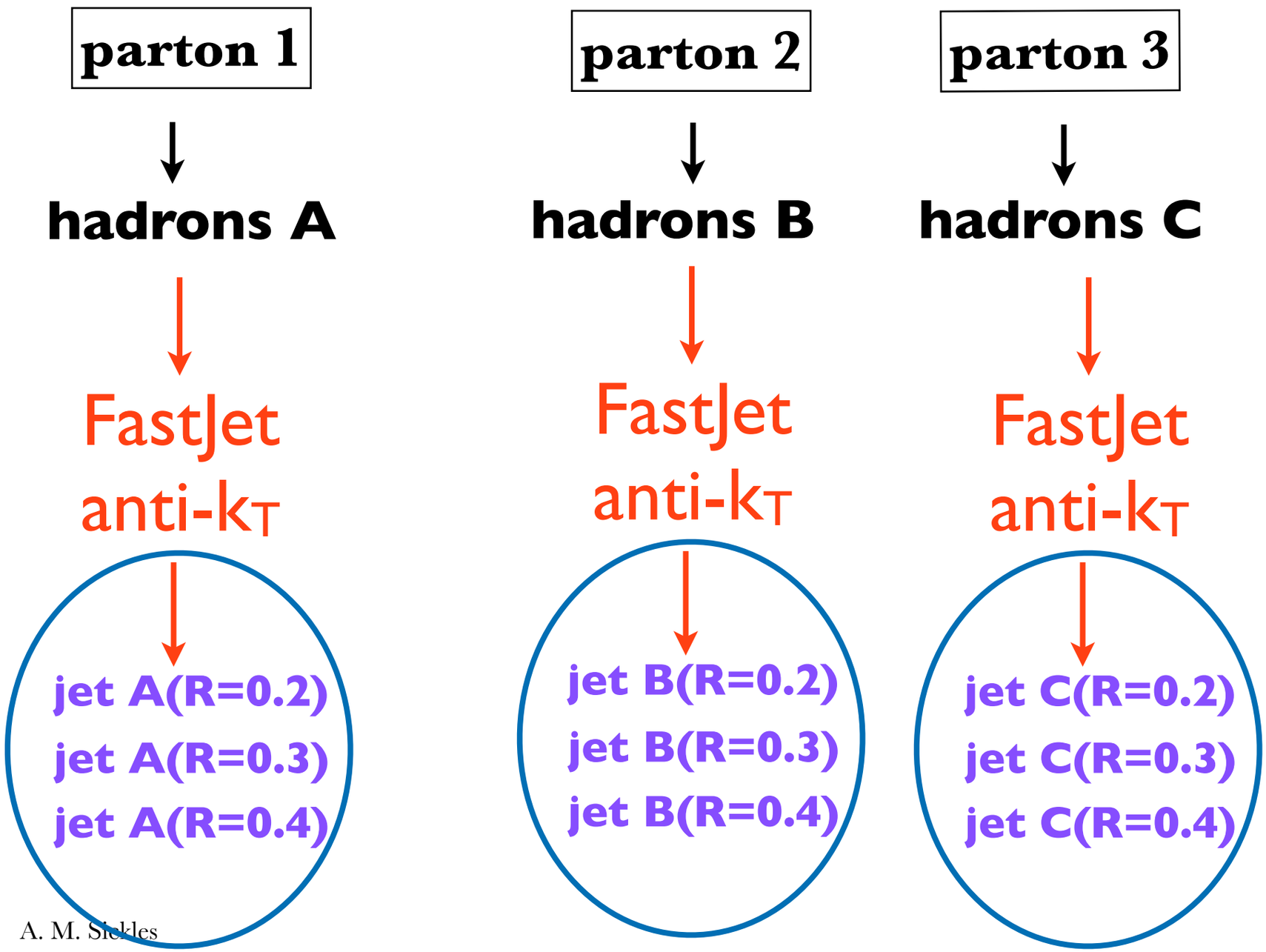
identifying truth jets

deep within the HIJING Event Generation...



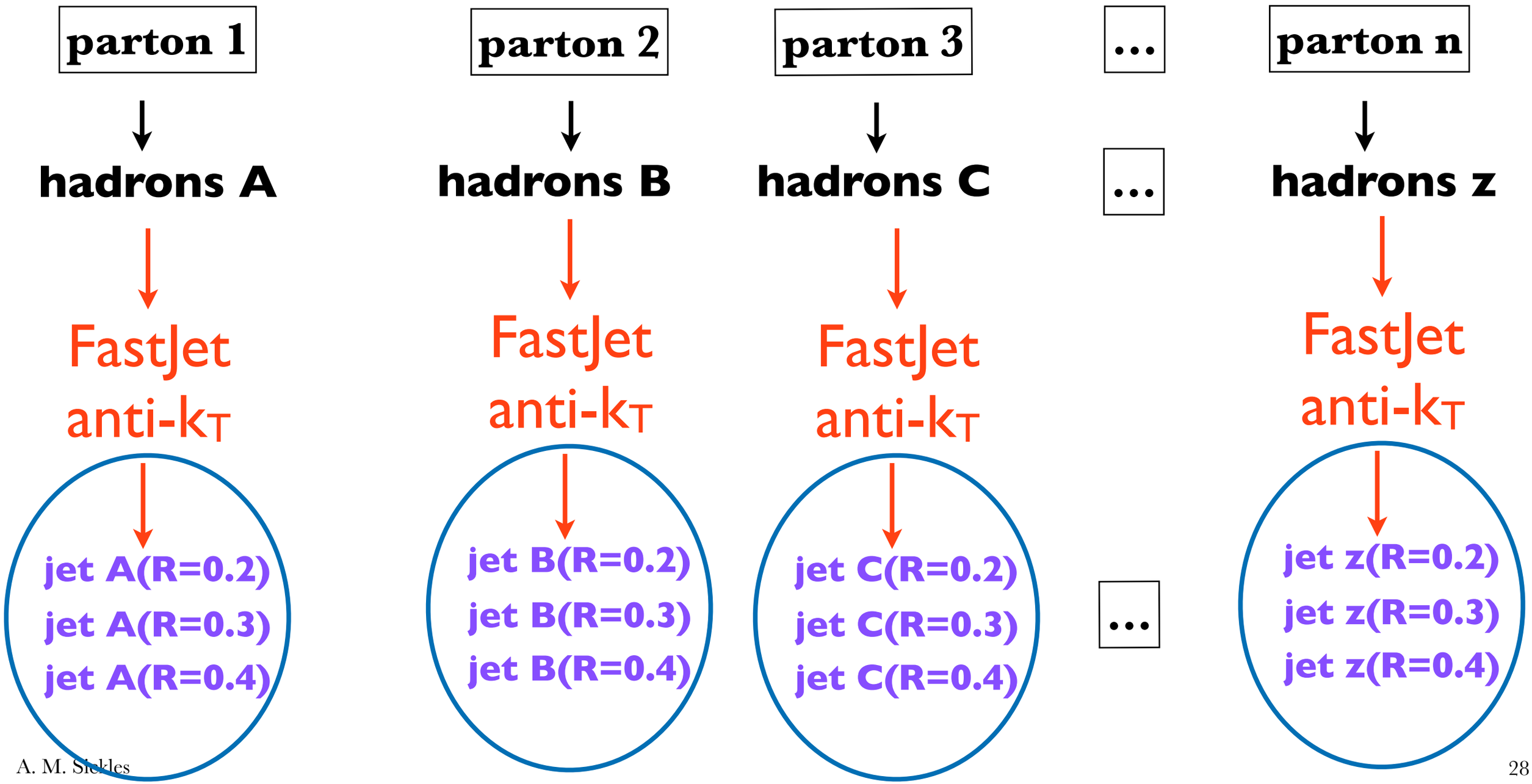
identifying truth jets

deep within the HIJING Event Generation...



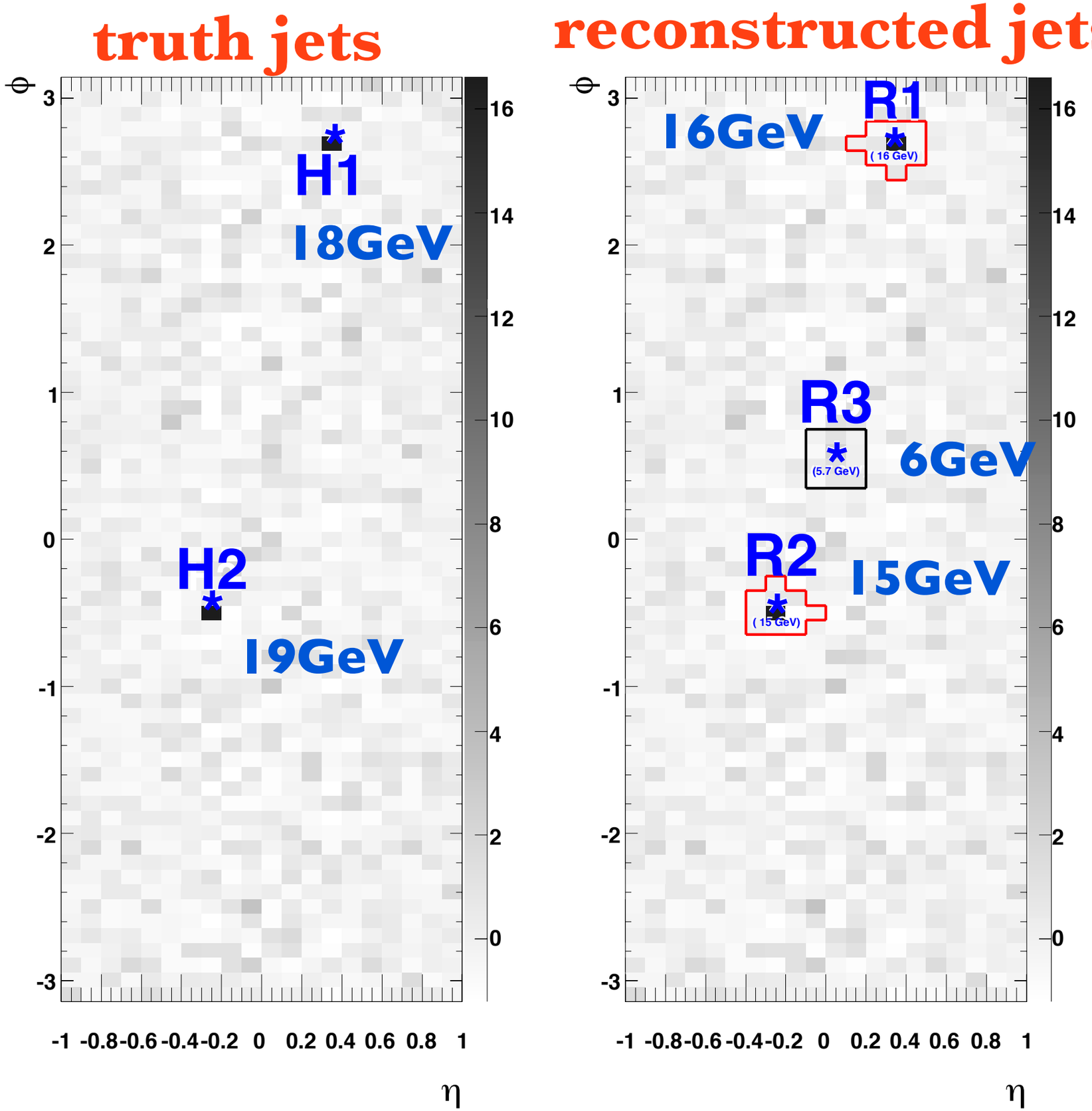
identifying truth jets

deep within the HIJING Event Generation...



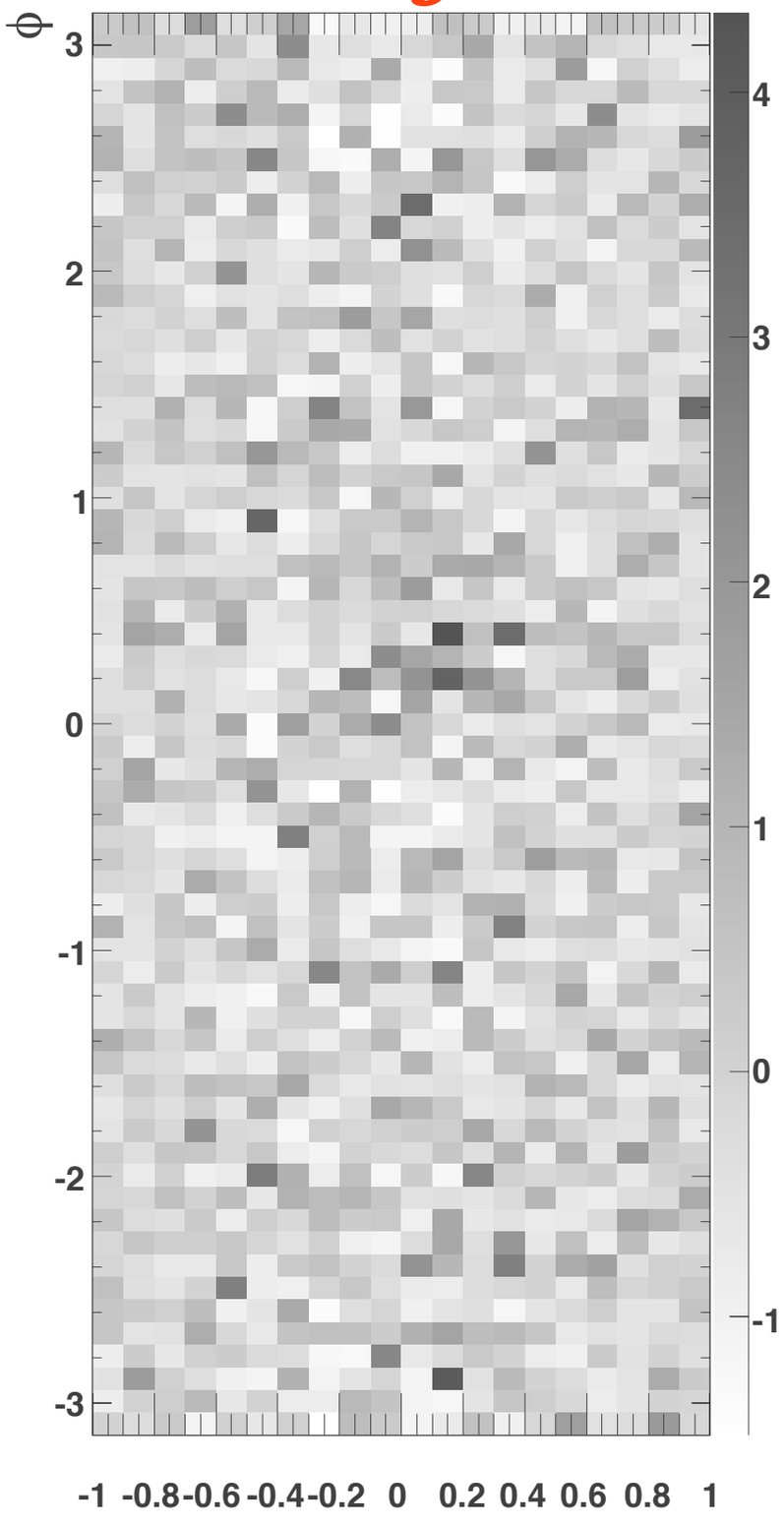
well reconstructed jets

- b = 1.8fm HIJING dijet event
- well reconstructed with anti-k_T R=0.2

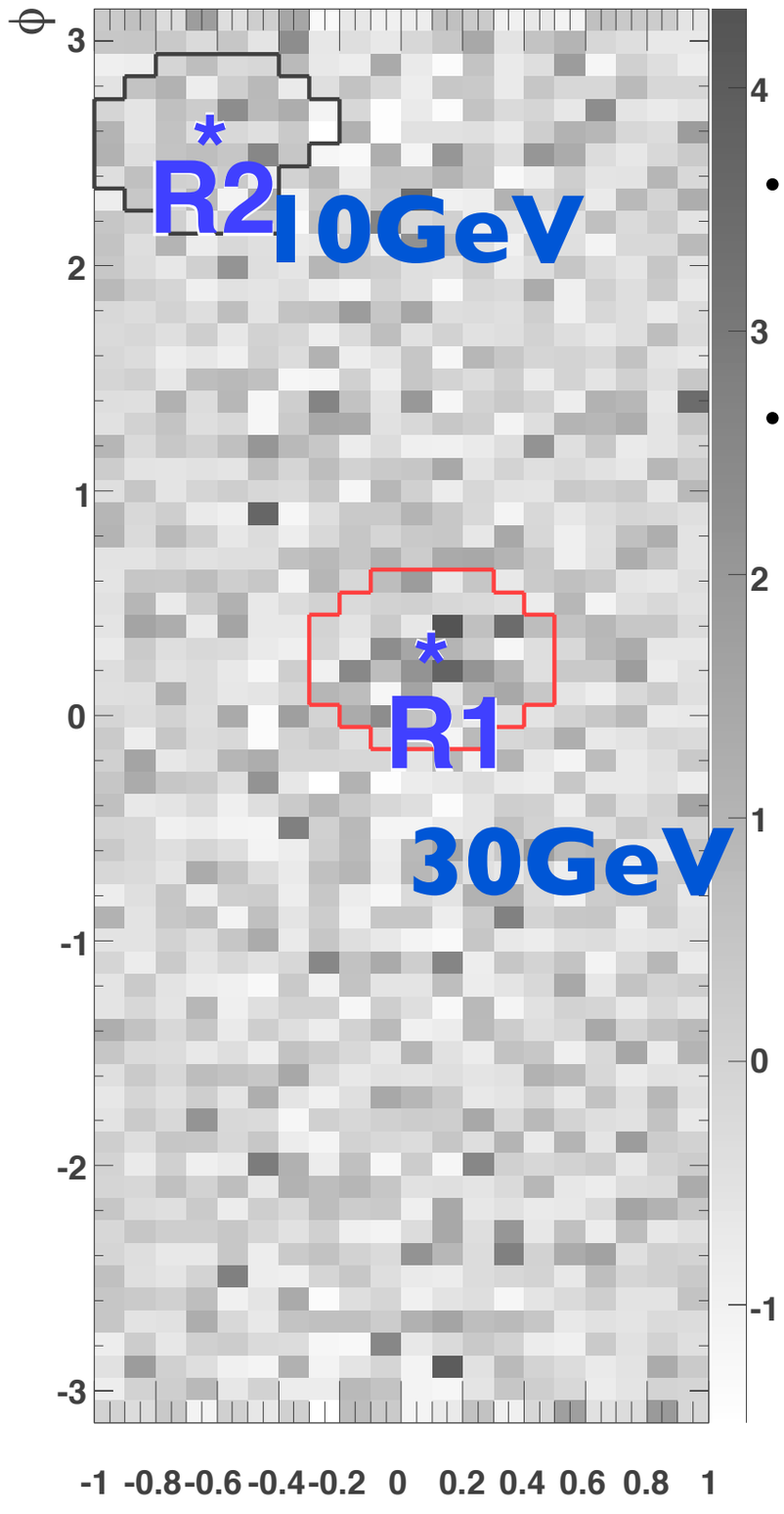


fake jets

truth jets



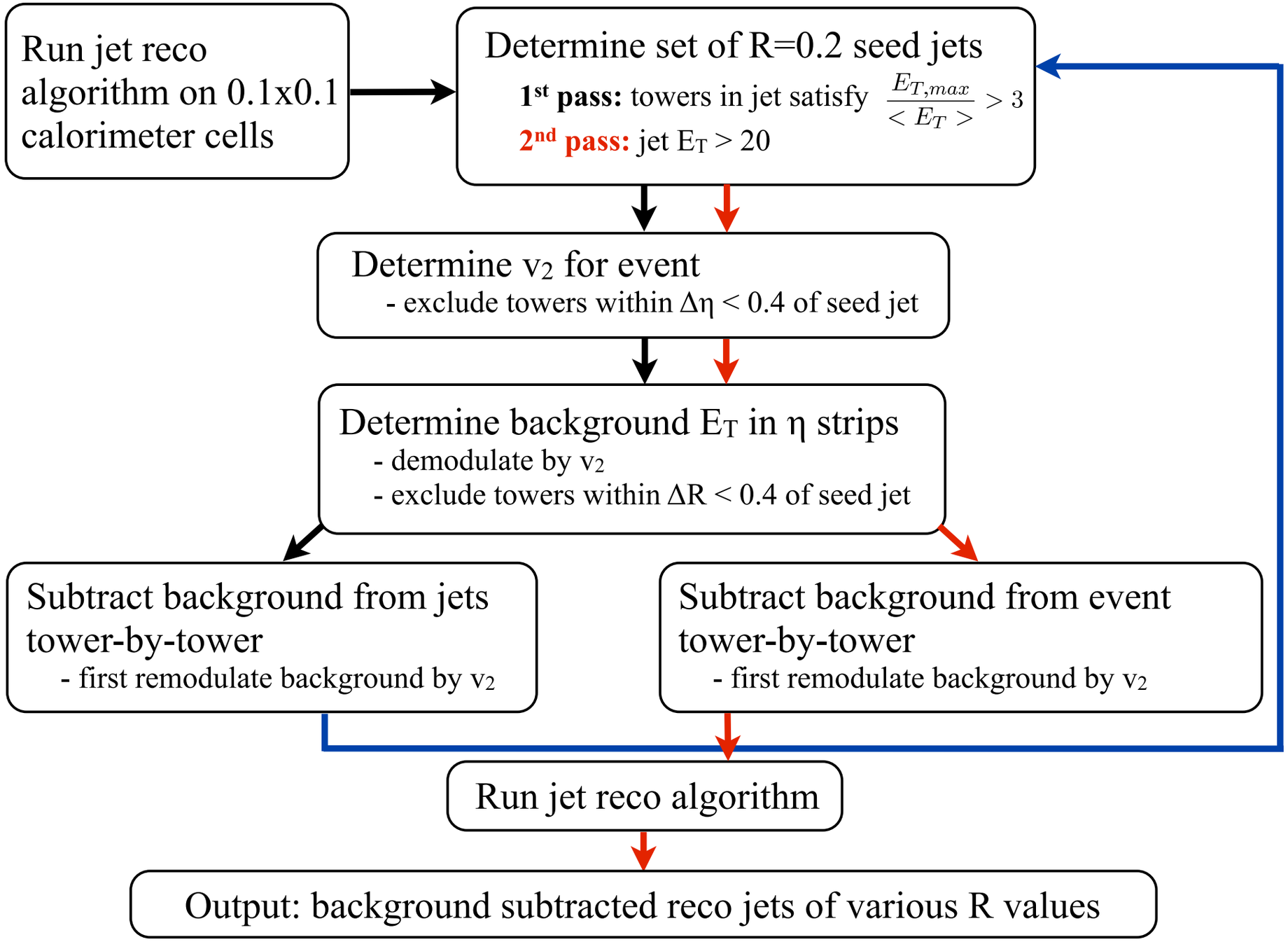
reconstructed jets



- b=2.4 HIJING event, no true jets
- 30 & 10GeV fake jets with anti-k_T R=0.4

however, we looked at 750M+ events! need quantitative rate assessment

iterative jet finding algorithm



- uses anti-k_T algorithm
- inspired by ATLAS algorithm