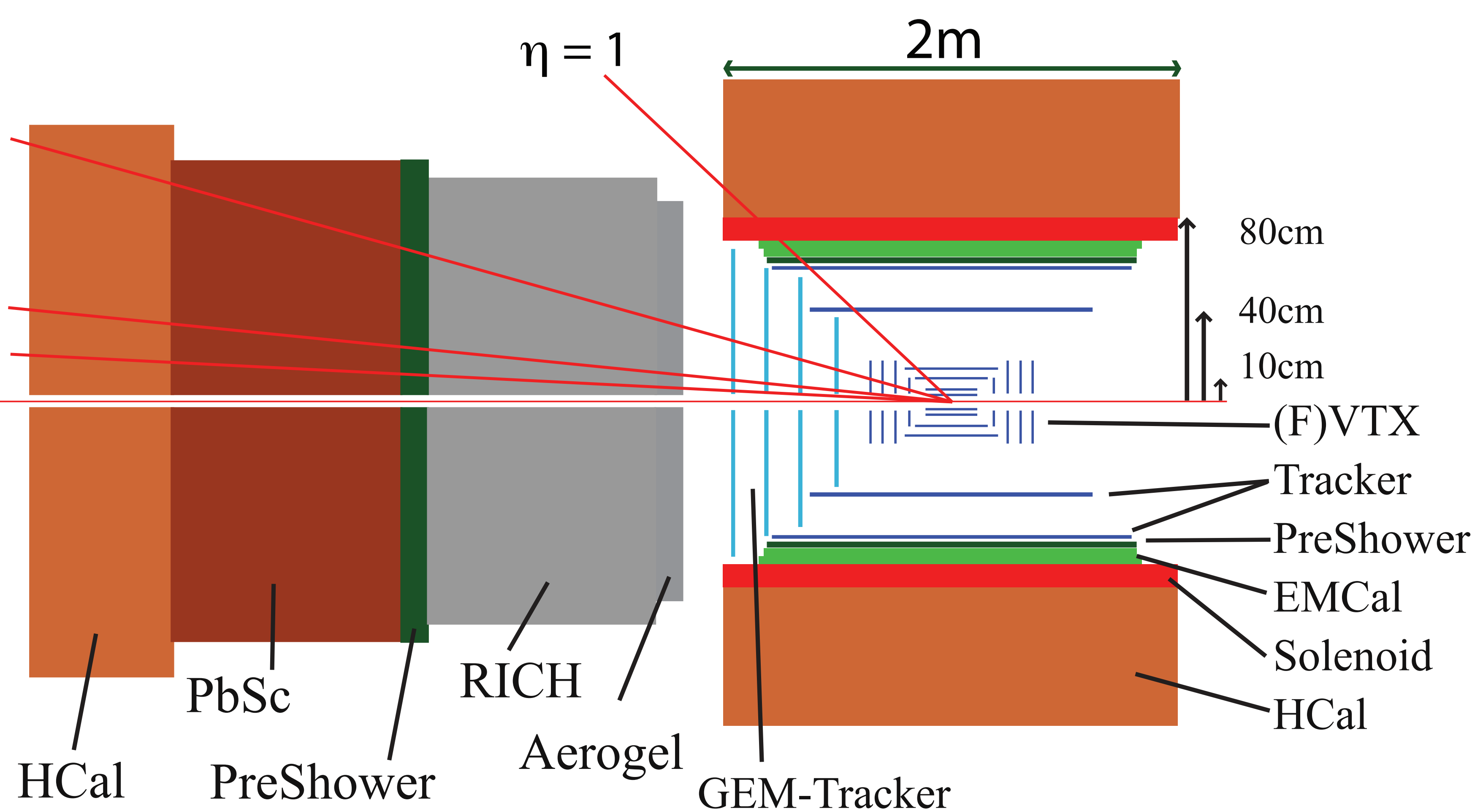
The sPHENIX Detector

Dave Morrison (BNL) for the PHENIX Collaboration

RHIC & AGS Annual Users' Meeting
June 13, 2012

sPHENIX at the last Users' Meeting

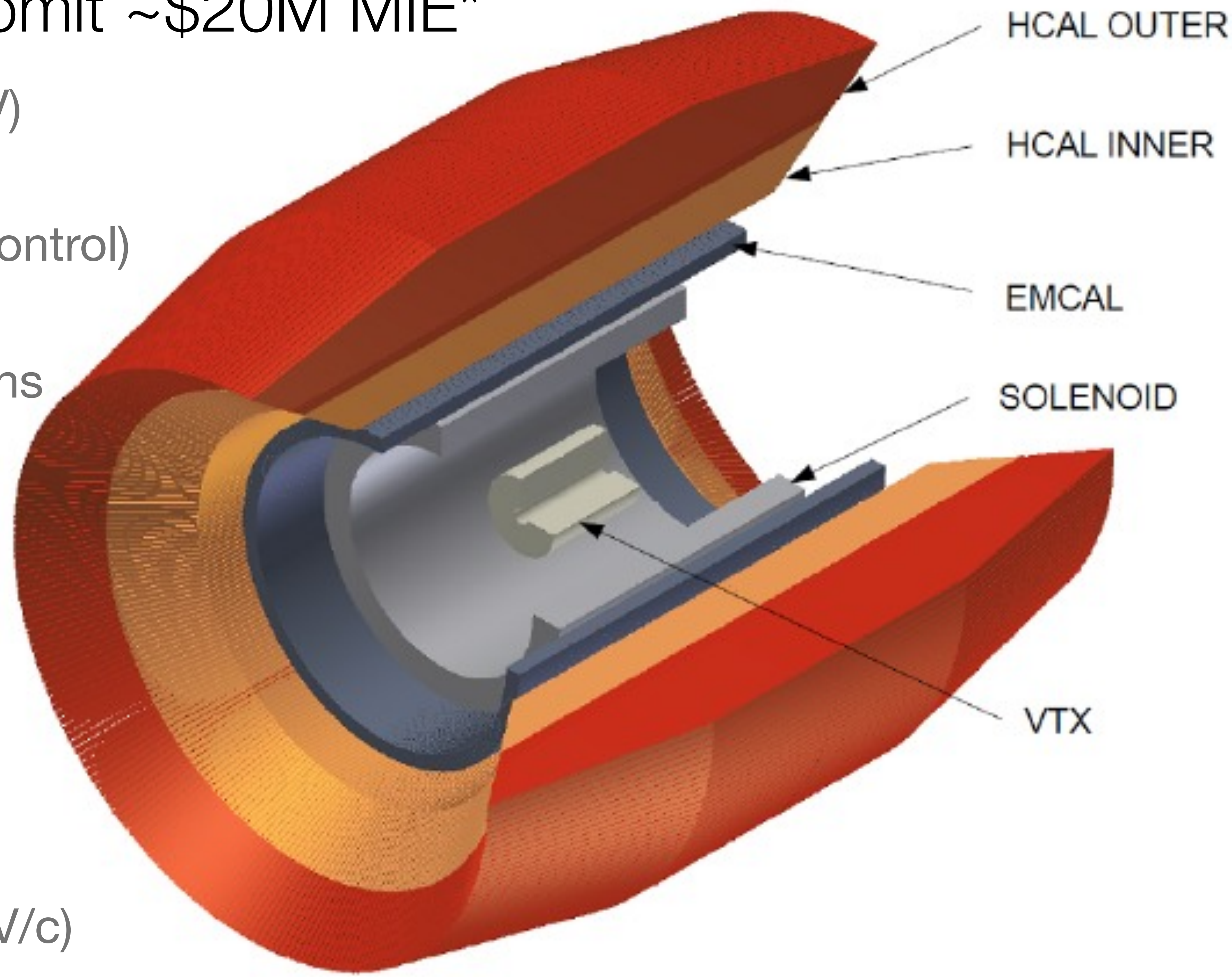


- high statistics upsilons
- large dijet and γ+jet rates
- charm/beauty jet tagging
- γ/π^0 to 40 GeV/c
- fragmentation functions
- forward p+A low-*x* jets
- quarkonia
- transverse spin probes
- evolution to ePHENIX

A first stage – recover full plan with later increments

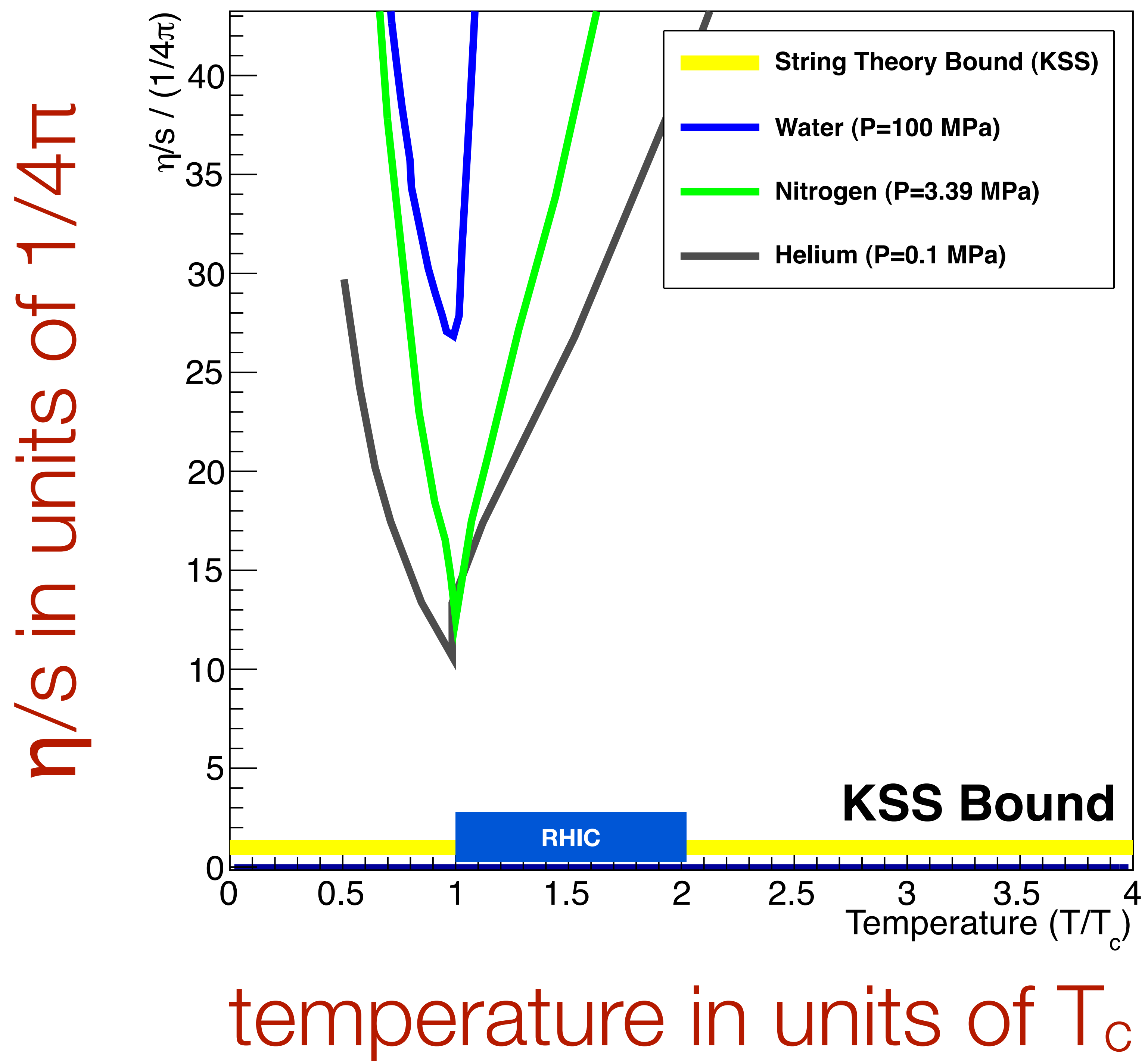
DOE guidance: submit ~$20M MIE*

- inclusive jets (20–60 GeV)
  - R_{AA} (with geometric control)
- dijet and γ+jet correlations
  - A_J, E_{jet}/E_{γ}
- direct γ (p_T > 10 GeV/c)
- tracking with VTX
  - jet-hadron (p_T < 4 GeV/c)

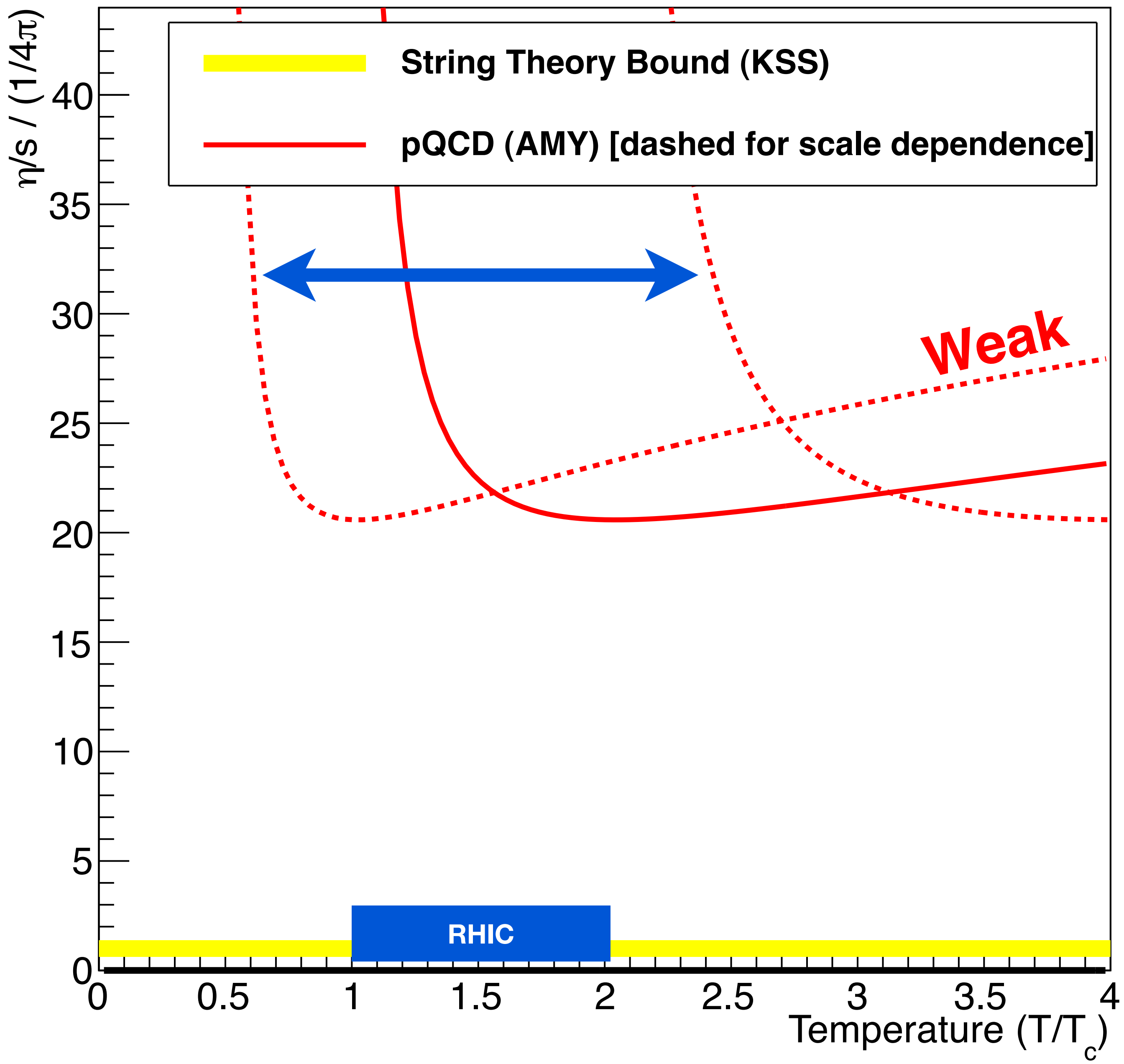


*DOE glossary: MIE = Major Item of Equipment

η/s for QED and QCD fluids

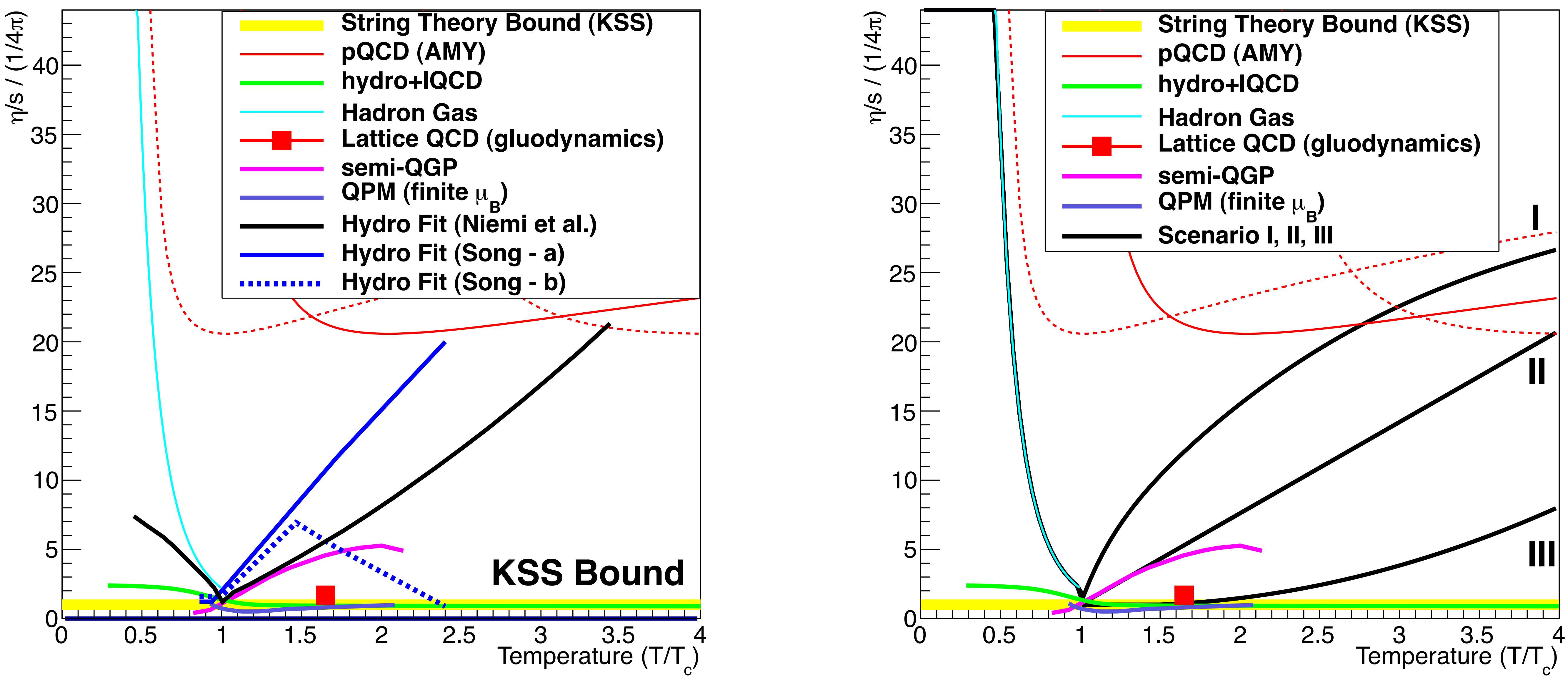


Calculation of η/s for case of weak coupling



scale dependence becomes apparent

How does the effective coupling evolve with T?

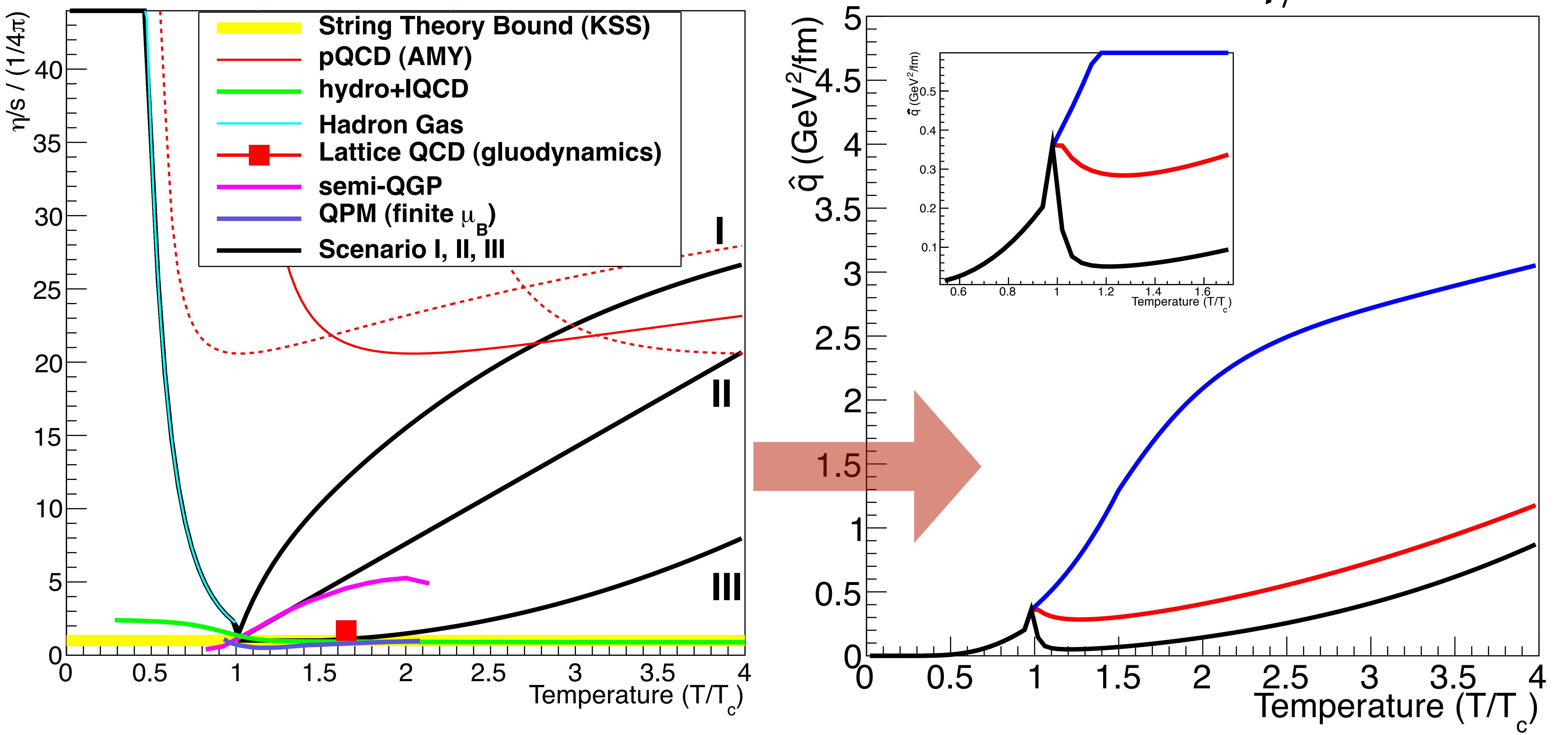


Is the change from strong coupling to weak coupling associated with changes in quasi-particles, excitations, strong classical fields?

η/s is related to transport coefficient q̂

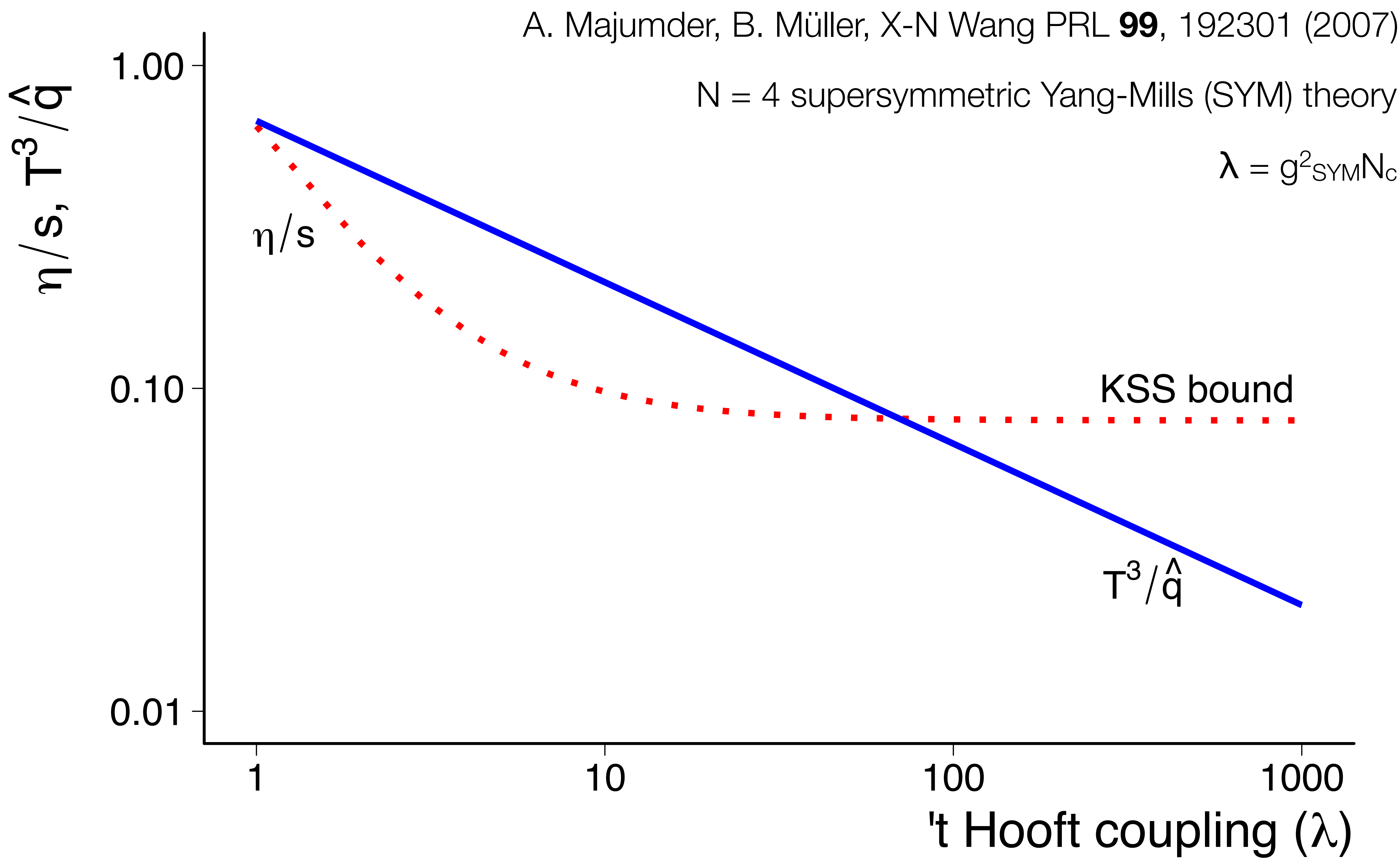
"Small shear viscosity implies strong jet quenching"
A. Majumder, B. Müller, X.N. Wang, PRL (2007)

$$\hat{q} = \frac{1.25T^3}{\eta/s}$$



measure ***both*** to explore transition from weak to strong coupling!

$\hat{q}$ retains sensitivity to coupling strength

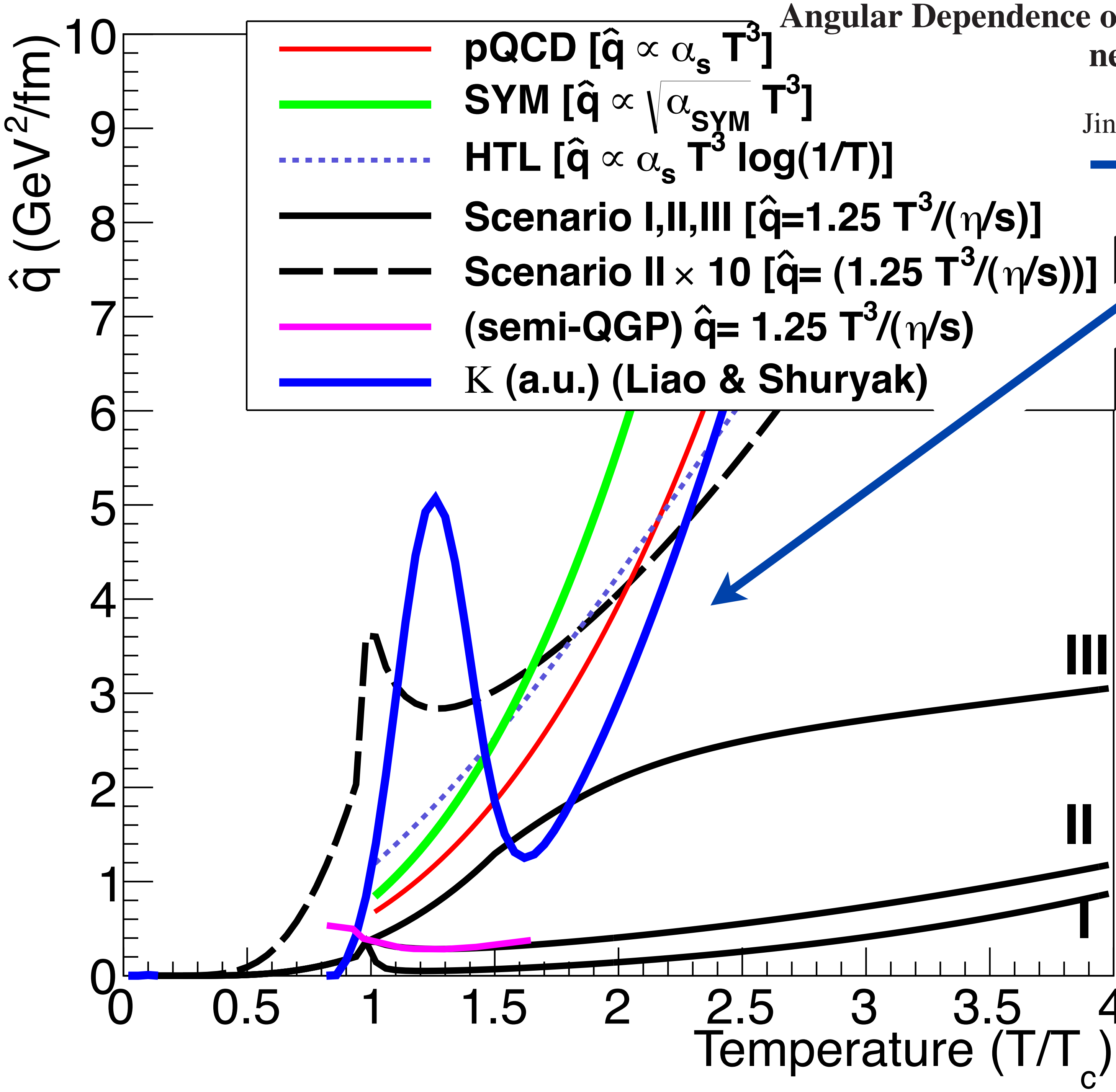


Many possibilities for $\hat{q}$ near T_C

PRL **102,** 202302 (2009) PHYSICAL REVIEW LETTERS week ending 22 MAY 2009

Angular Dependence of Jet Quenching Indicates Its Strong Enhancement near the QCD Phase Transition

Jinfeng Liao[1,2,*] and Edward Shuryak[1,†]

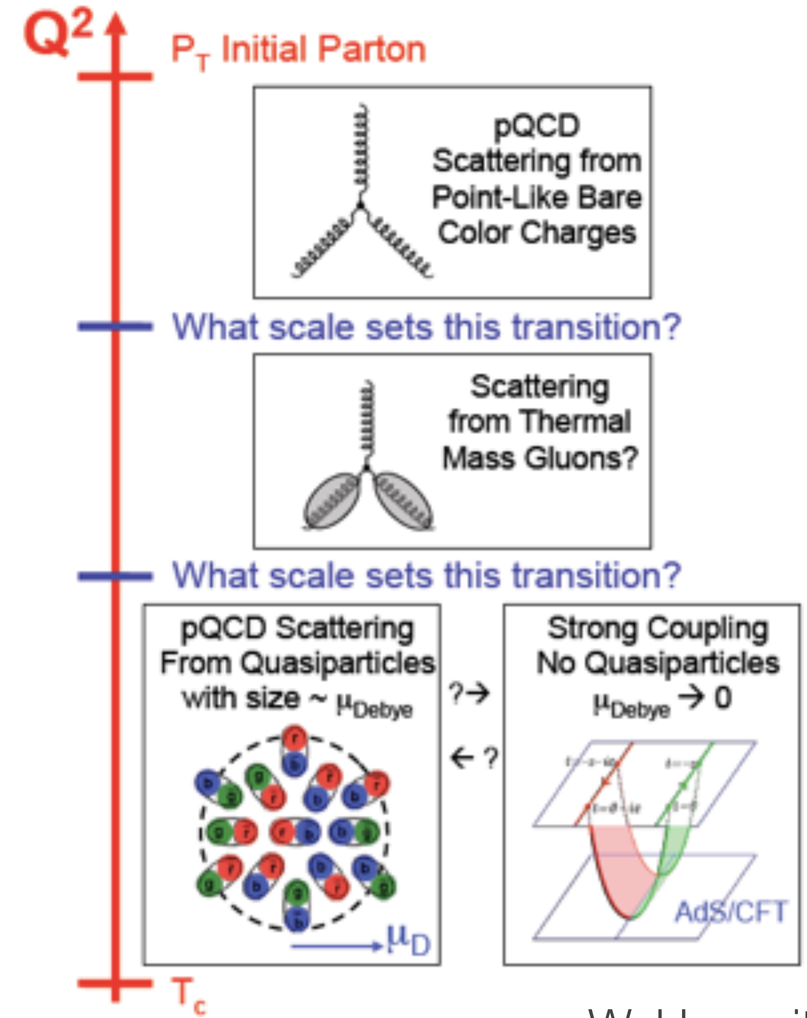


"[We find] the jet quenching is a few times stronger near T_C relative to the QGP at $T > T_C$."

temperature

effective coupling

investigate the QGP along multiple axes



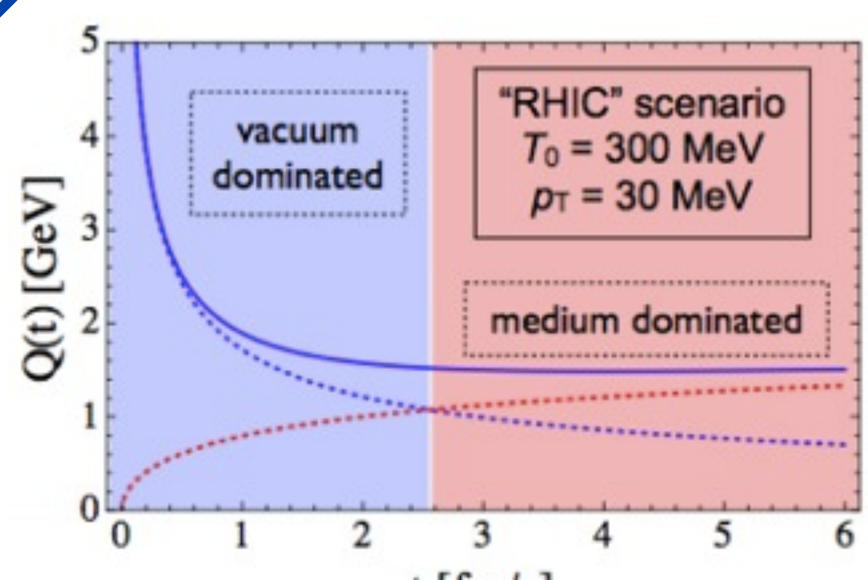
W. Horowitz

λ

relevant length scale

Q^2

virtuality evolution



B. Muller

Nucl.Phys., A855:74–82, 2011

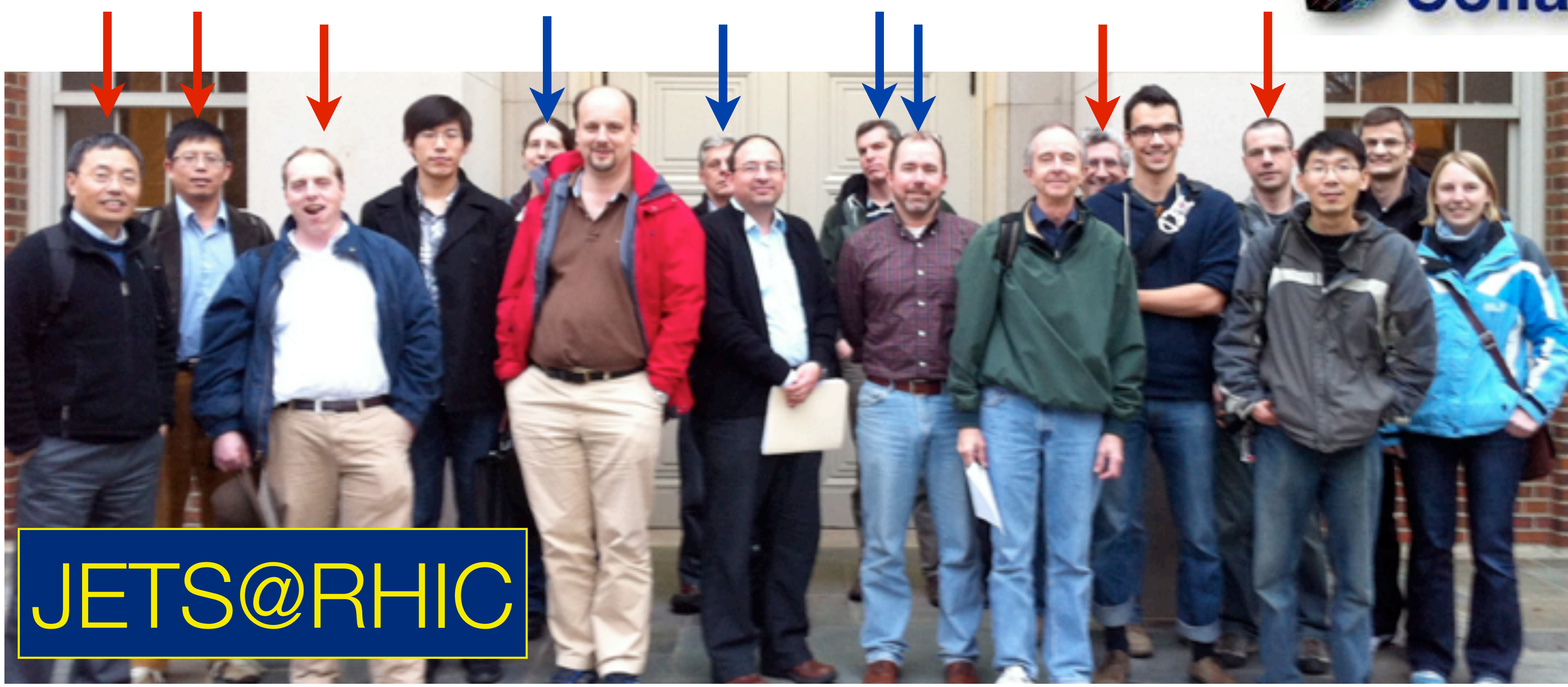
RHIC/AGS Users Meeting 2011

What *is* the nature of the strongly coupled QGP?

- How does the strongly coupled quark-gluon plasma emerge from an asymptotically free theory of quarks and gluons?
- How rapidly does the quark gluon-plasma transition from the most strongly coupled system near T_c to a weakly coupled system of partons?
- What are the dynamical and other underlying changes to the medium as one varies the temperature? quasi-particles? excitations? strong fields?

Theoretical guidance on observables/sensitivity

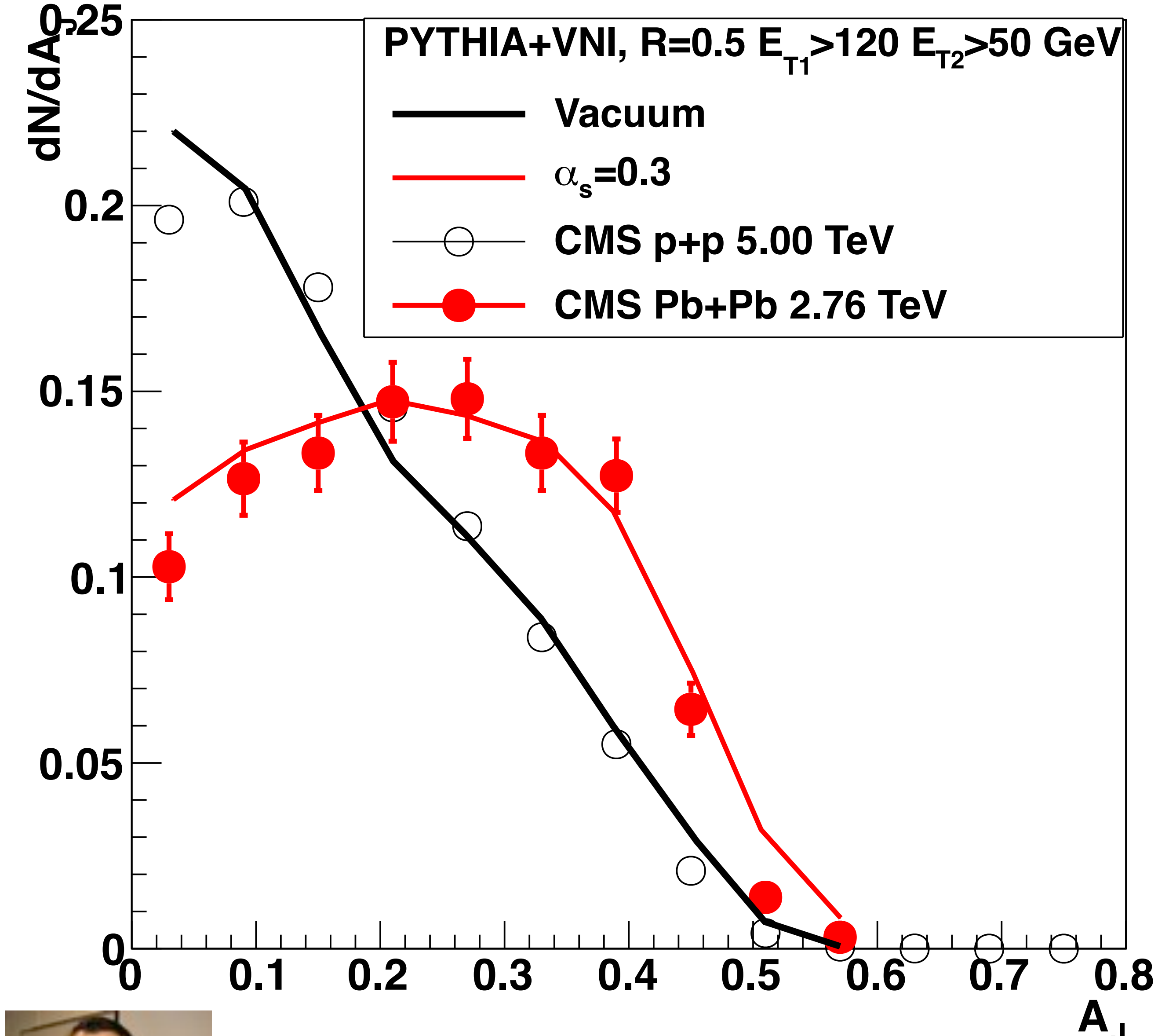
Connection of measurement to the interesting and unknown medium properties of deconfined color charges is under active construction by many theorists



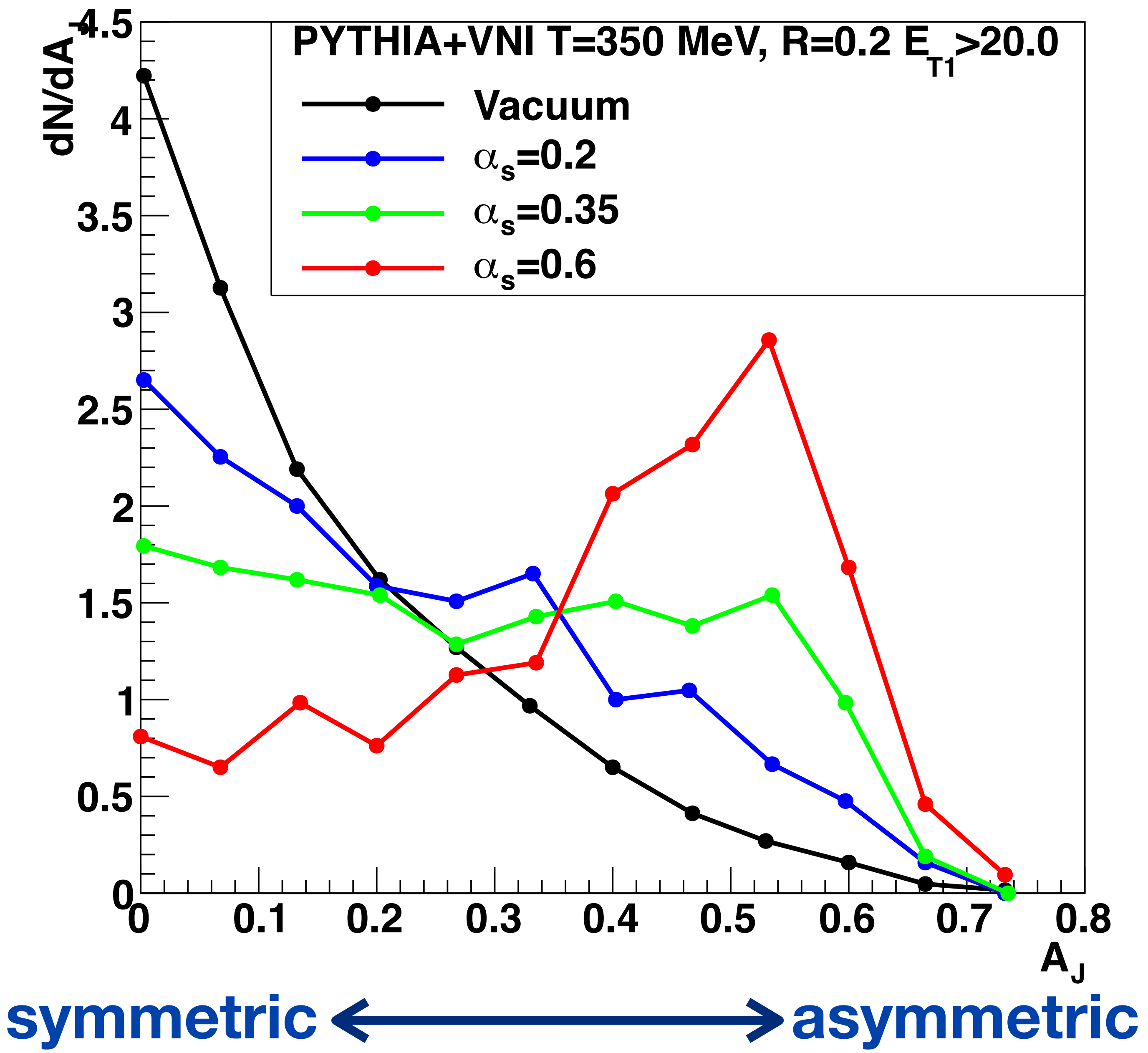
Just one example: March 3-4, 2012 Jet Collaboration meeting at Duke University (and followup meetings)
Lots of interest from theory community

Sensitivity to effective coupling

Comparison to LHC data



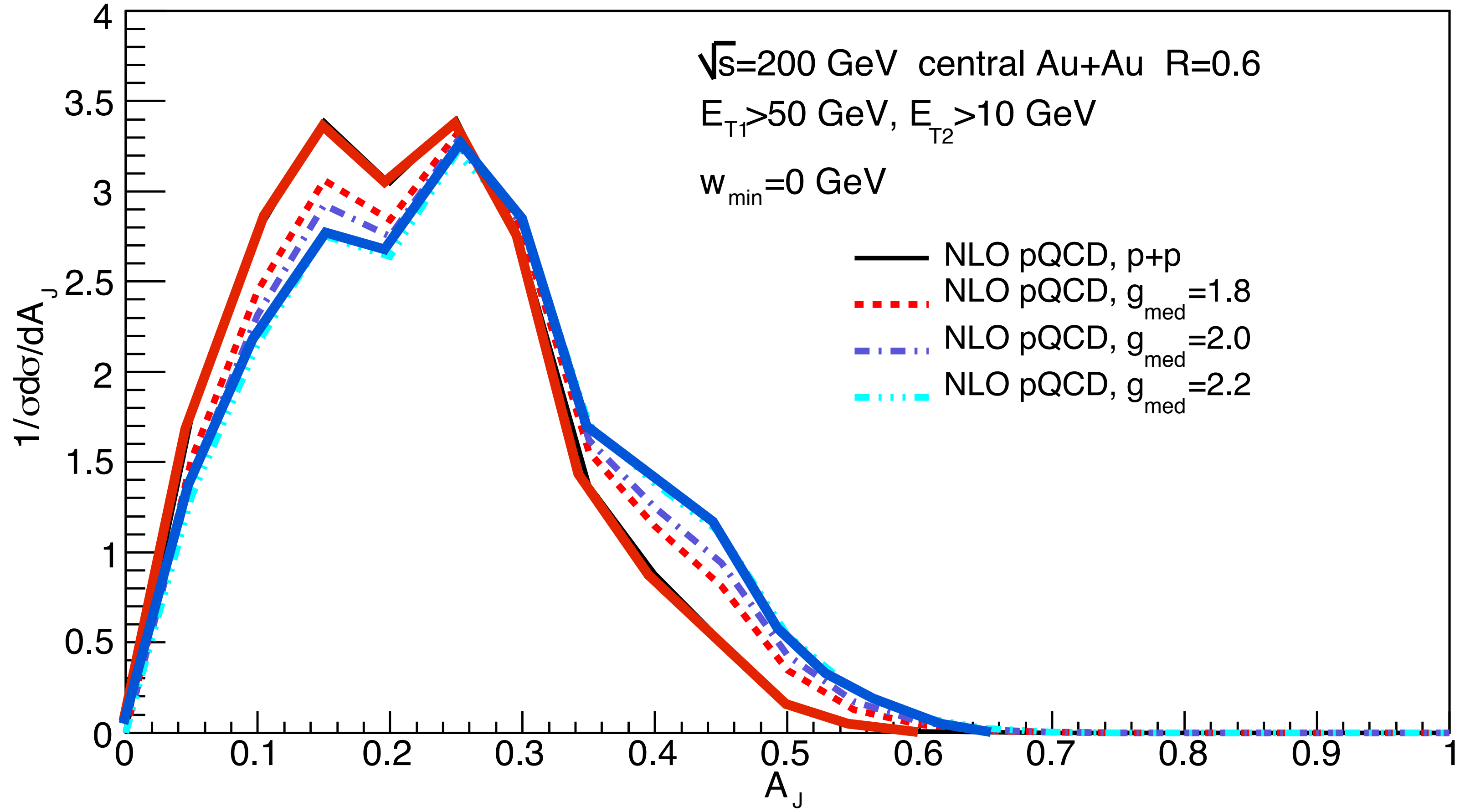
Sensitivity at RHIC energies



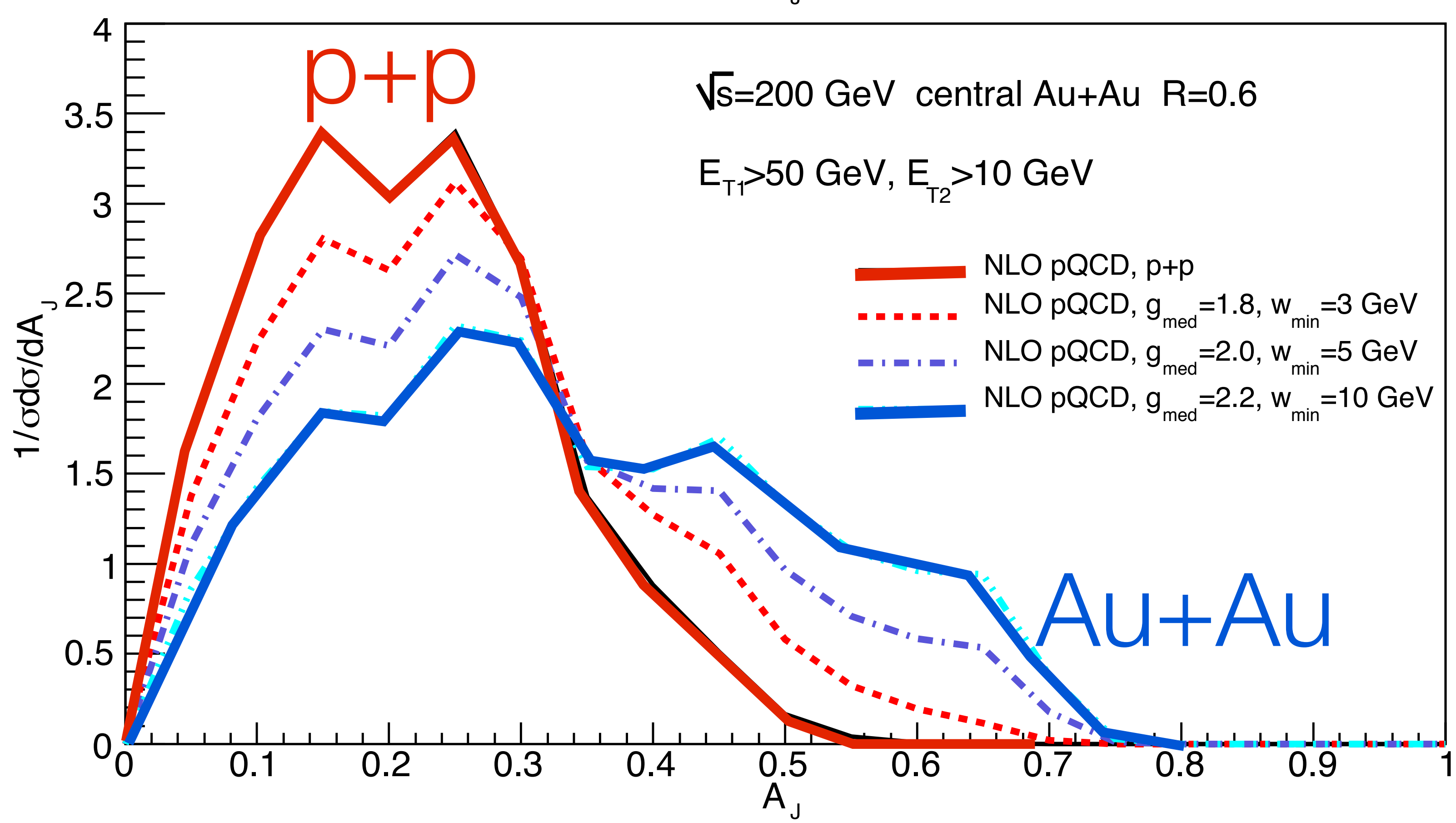
Chris Coleman-Smith (Duke)

What are the effective constituents of the QGP?

Radiative energy loss only



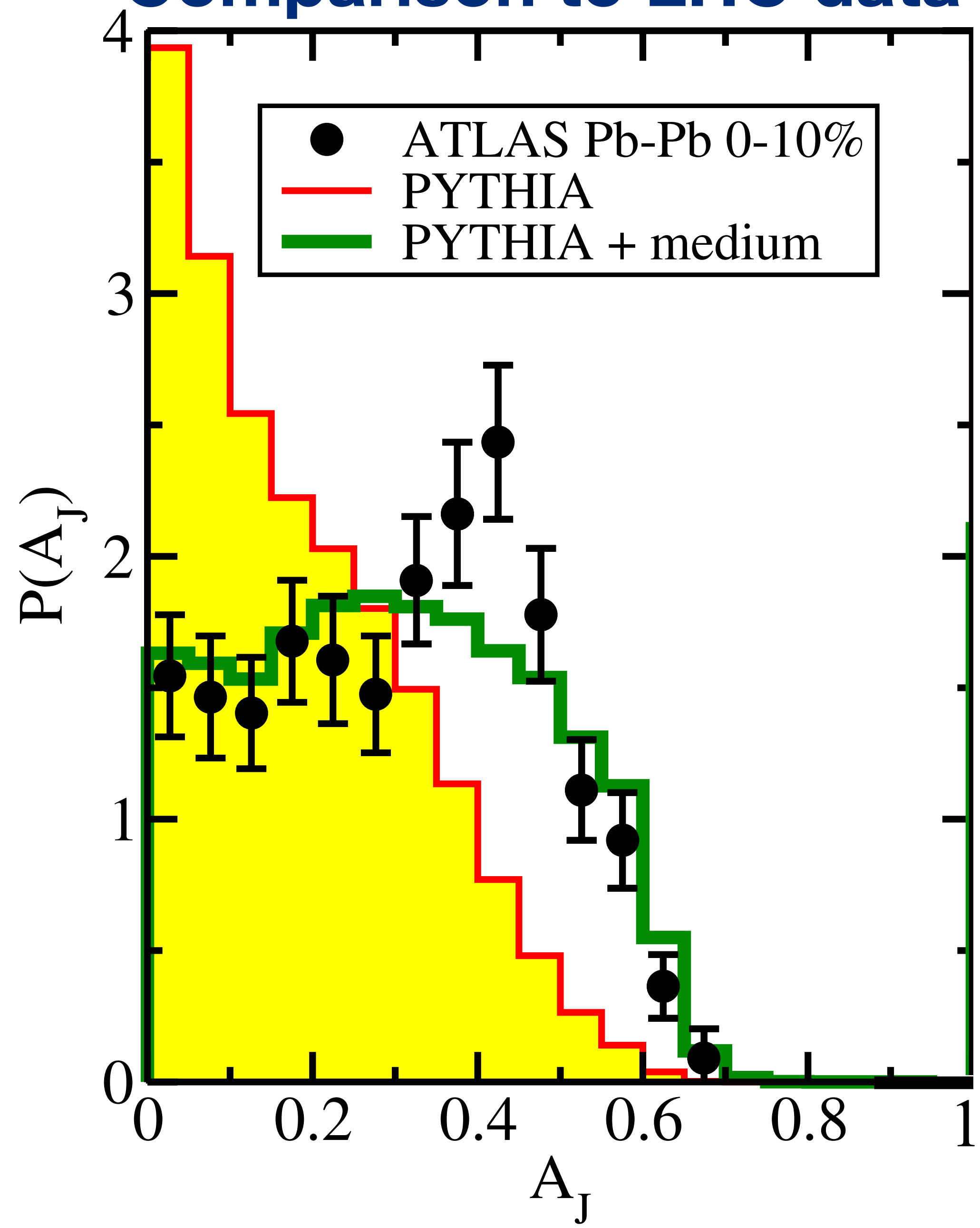
Radiative + Collisional energy loss



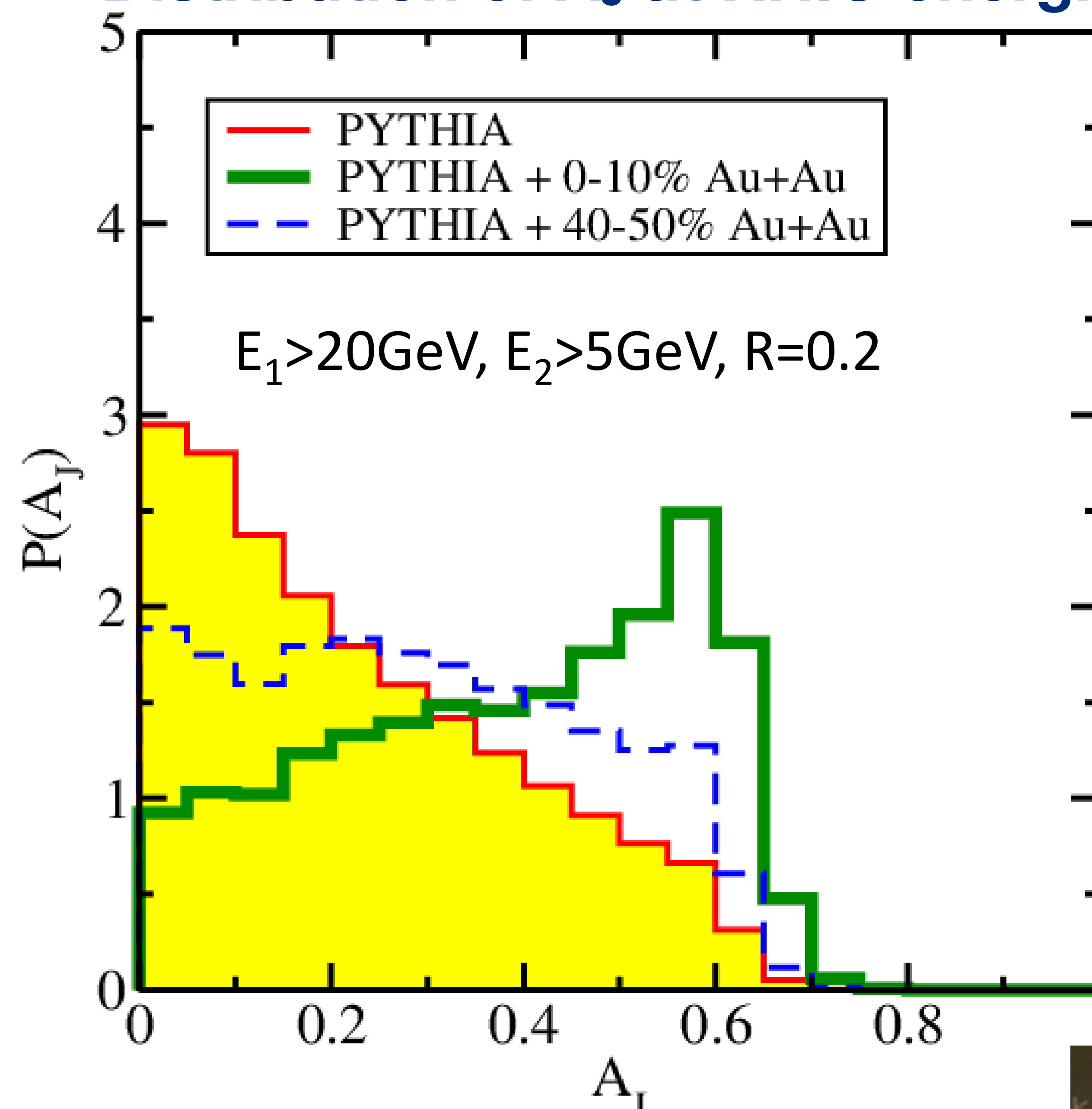
Ivan Vitev, et al

Interaction of jet with medium

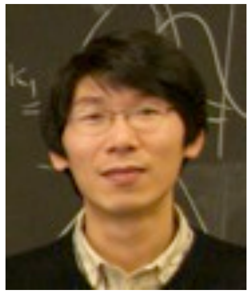
Comparison to LHC data



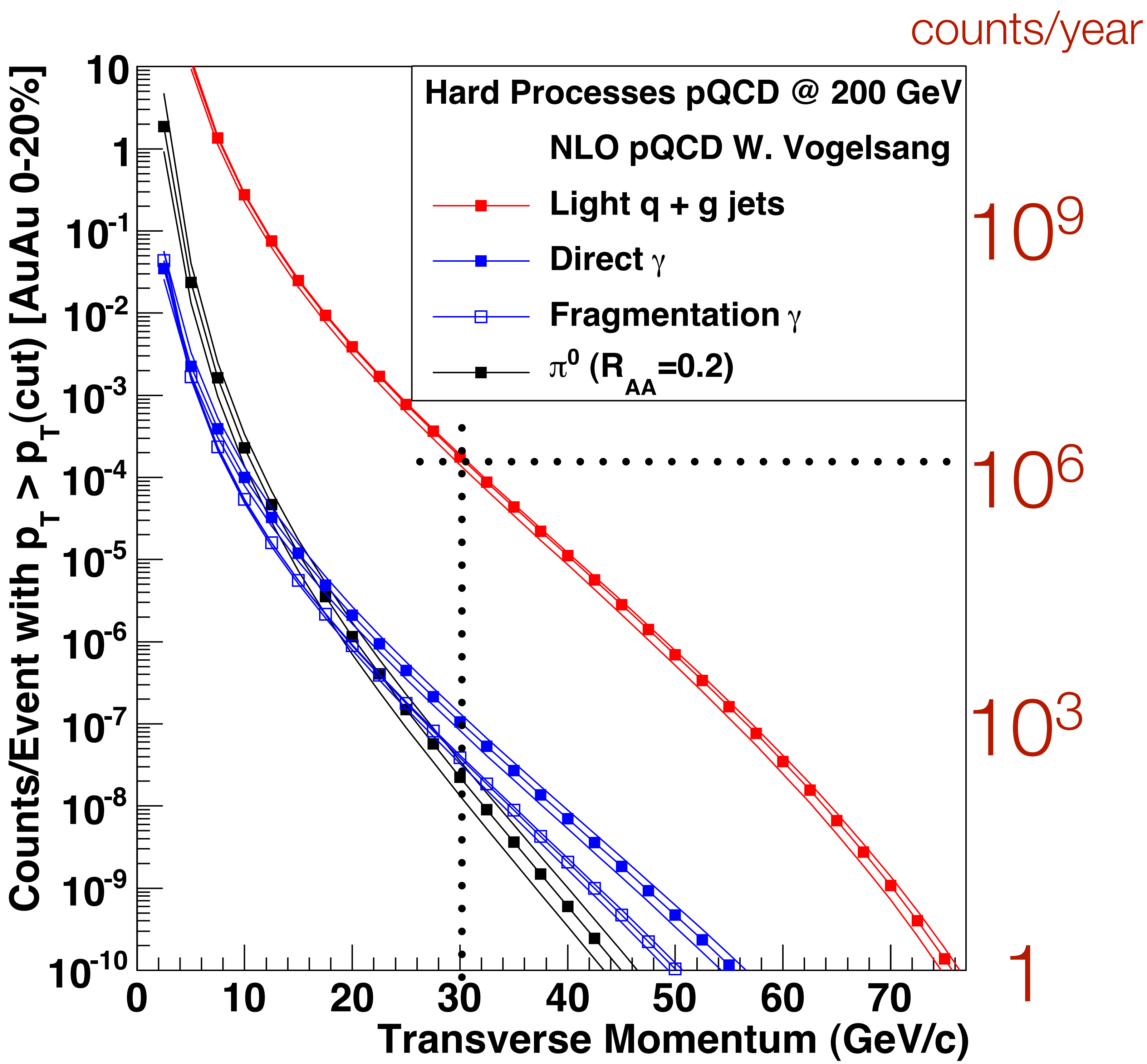
Distribution of A_J at RHIC energies



Guang-You Qin, Berndt Muller
PRL 106, 162302 (2011)



Jet rates in Au+Au at RHIC



There are *lots* of jets!

Only stochastic cooling of Au beams assumed

Greater rate and p_T reach than singles

1 RHIC year = 50 billion min. bias Au+Au events = 10 billion central

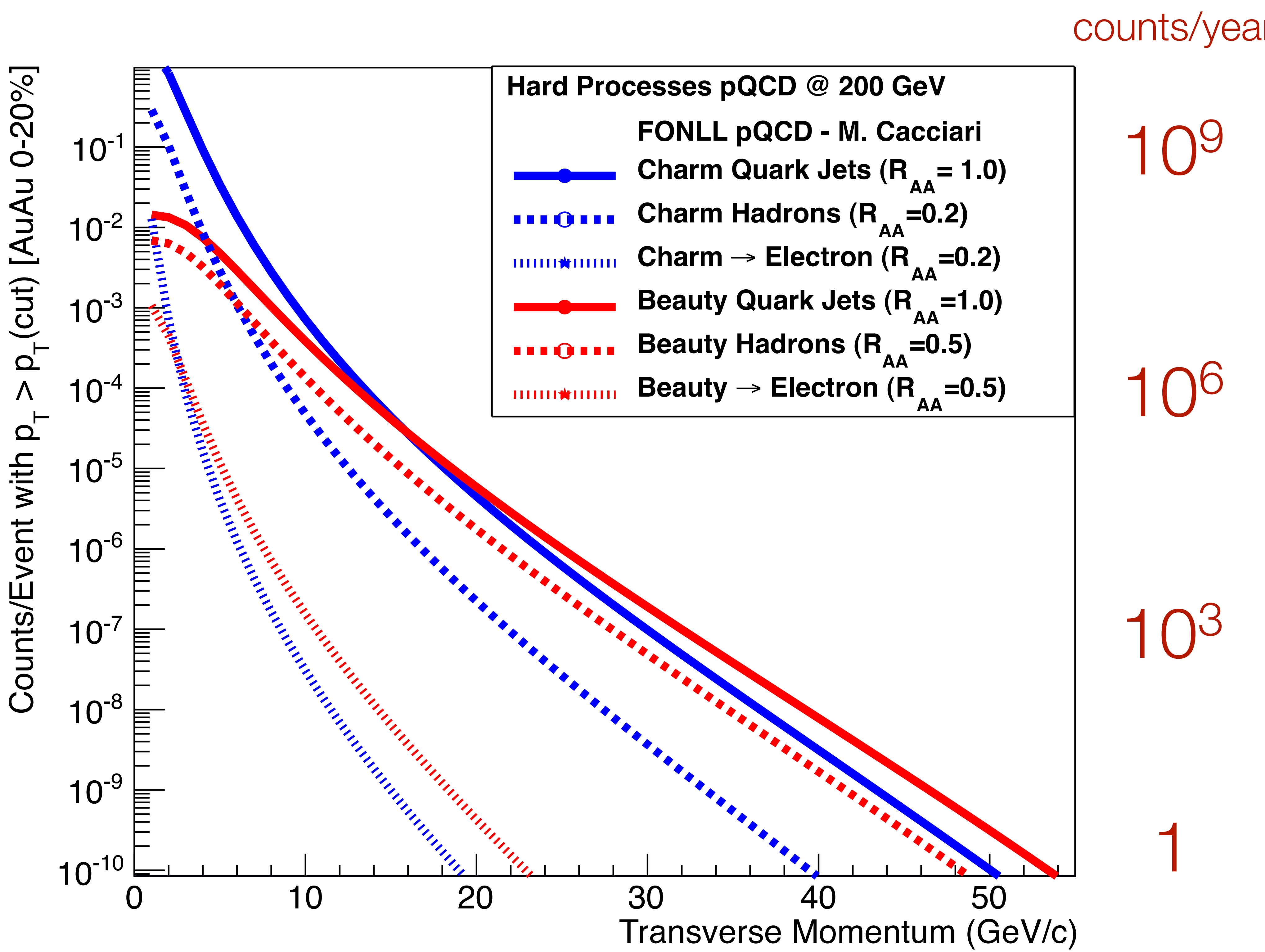
Expected counts in a 20 week run

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

Huge rates allow differential measurements <u>with</u> geometry
(v_2, v_3, A+B, U+U, …)
precise control measurements (d+Au & p+p).
Over 80% as dijets into $|\eta|<1$

Cu+Au ~ Au+Au/5
U+U (tip-tip) ~ Au+Au/500

Heavy flavor rates at RHIC

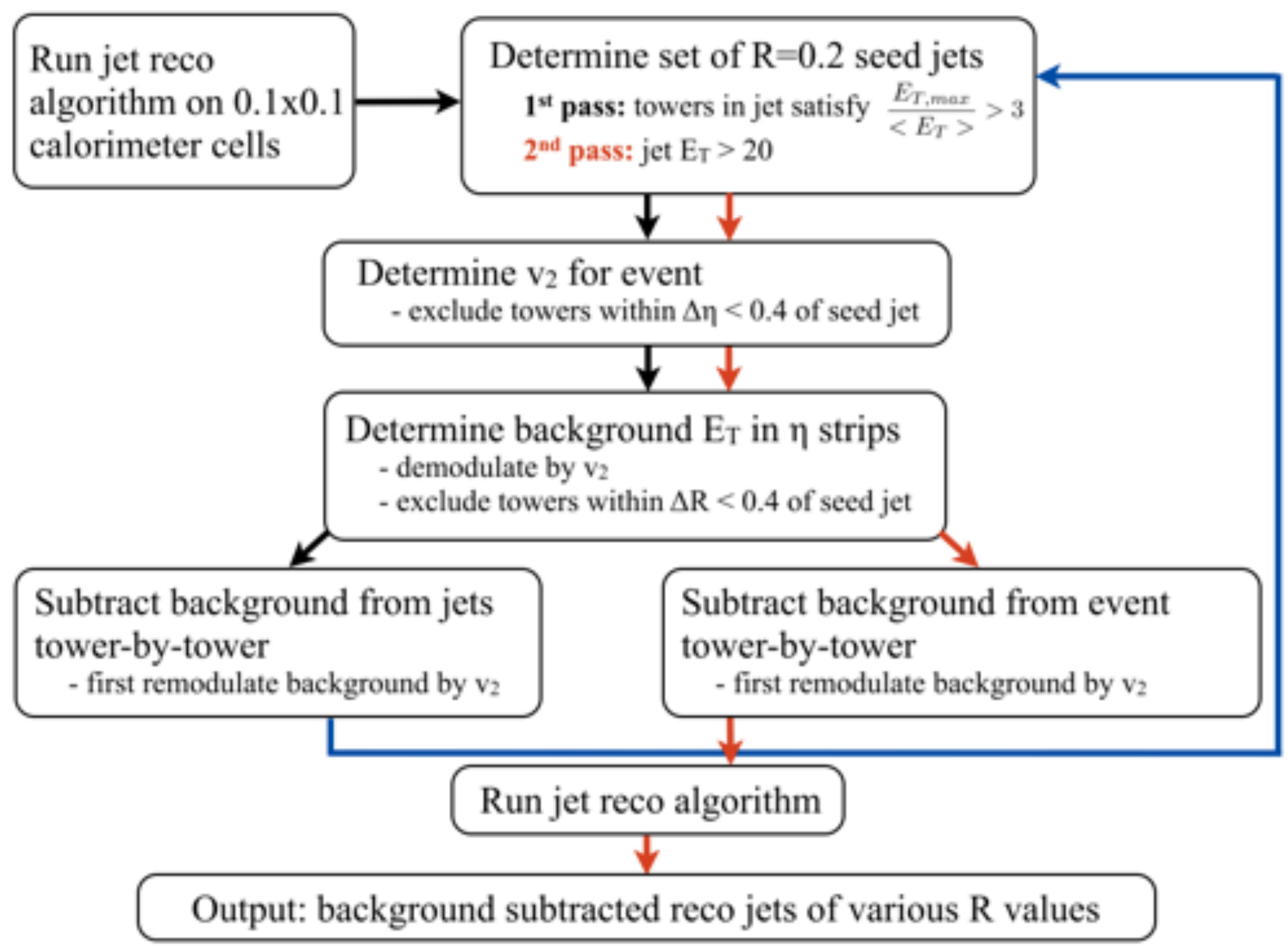


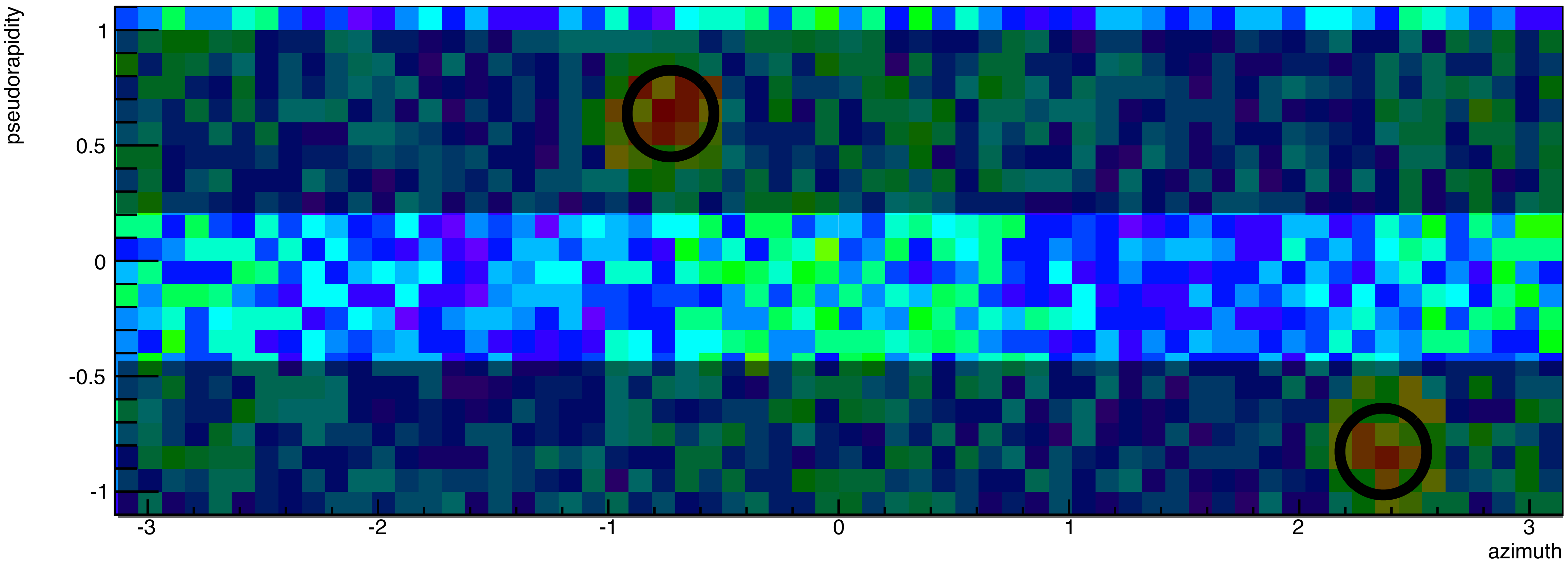
Are jets in HI at RHIC dominated by *fakes*?

Jet - Underlying Event Separation Method for Heavy Ion Collisions at the Relativistic Heavy Ion Collider arXiv:1203.1353

J. A. Hanks[1], A. M. Sickles[2], B. A. Cole[3], A. Franz[2], M. P. McCumber[4], D. P. Morrison[2], J. L. Nagle[4], C. H. Pinkenburg[2], B. Sahlmueller[1], P. Steinberg[2], M. von Steinkirch[1], M. Stone[4]
[1] *Department of Physics and Astronomy, Stony Brook University, SUNY, Stony Brook, New York 11794-3400, USA*
[2] *Physics Department, Brookhaven National Laboratory, Upton, New York, 11973-5000*
[3] *Columbia University, New York, New York 10027 and Nevis Laboratories, Irvington, New York 10533, USA and*
[4] *University of Colorado, Boulder, Colorado 80309, USA*
(Dated: March 8, 2012)

Over *1 billion* HIJING events run, tagging of fragmentation jets, with full "ATLAS style" background subtraction method employed





pseudorapidity
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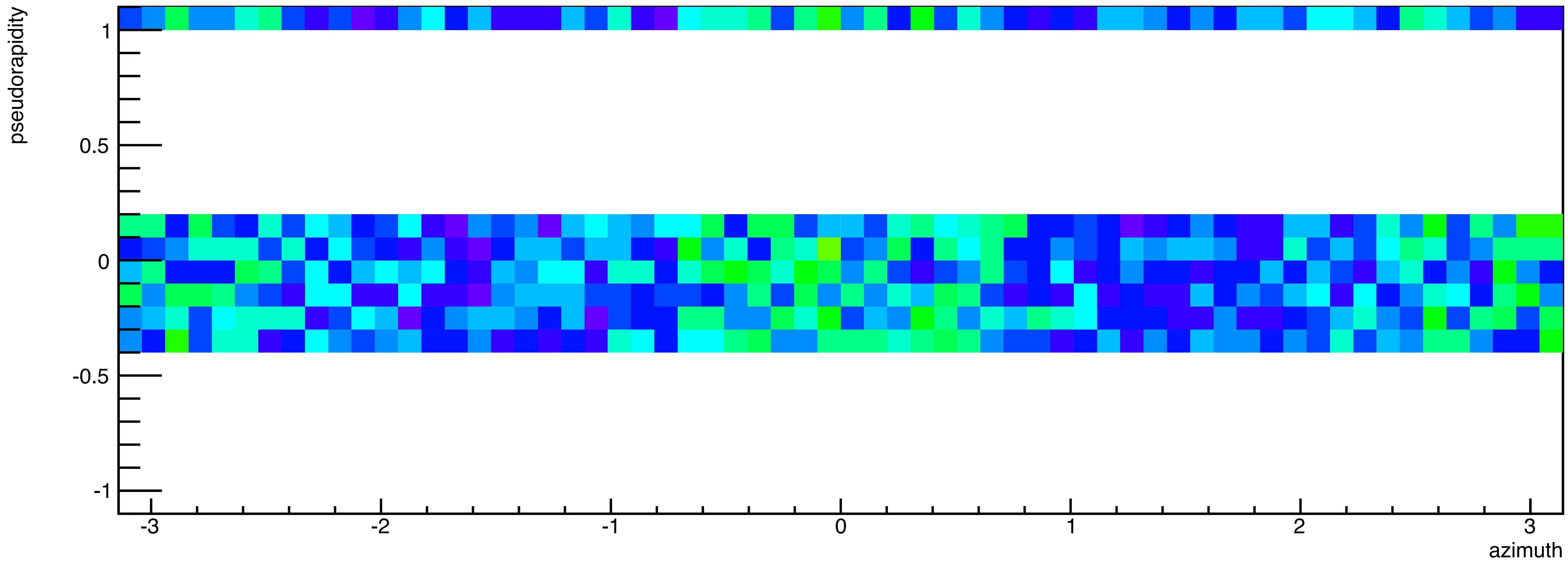
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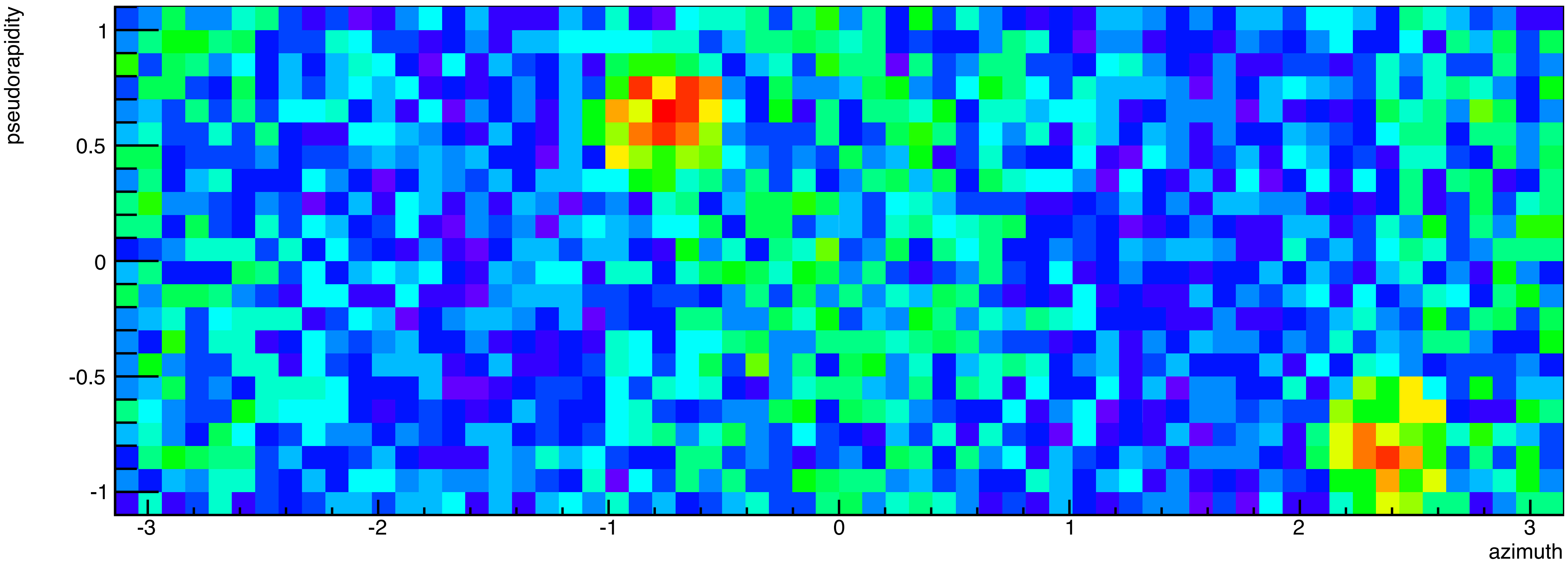
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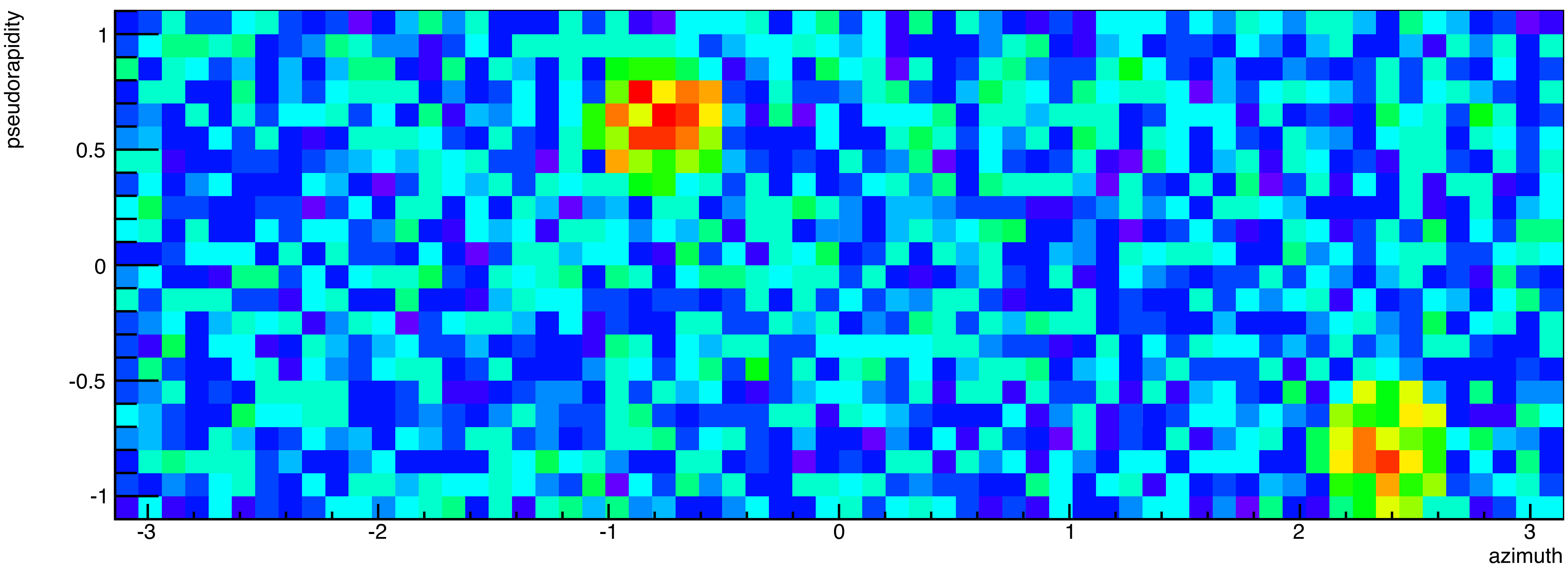
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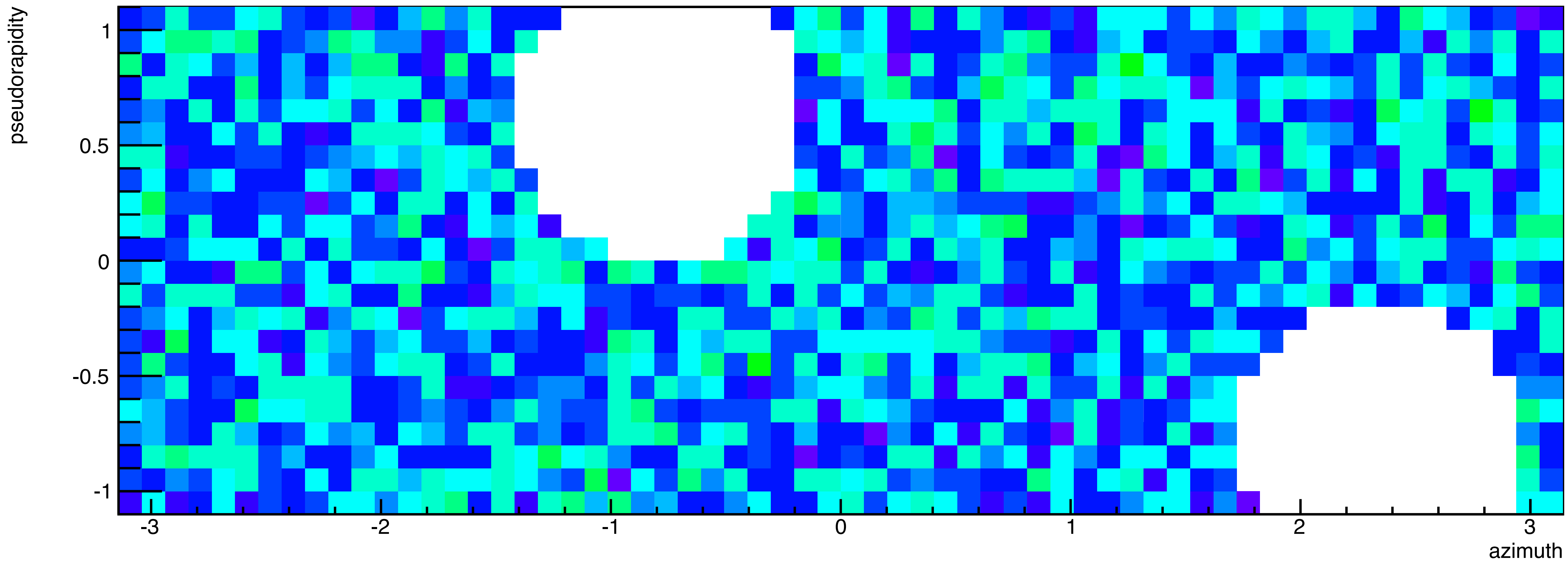

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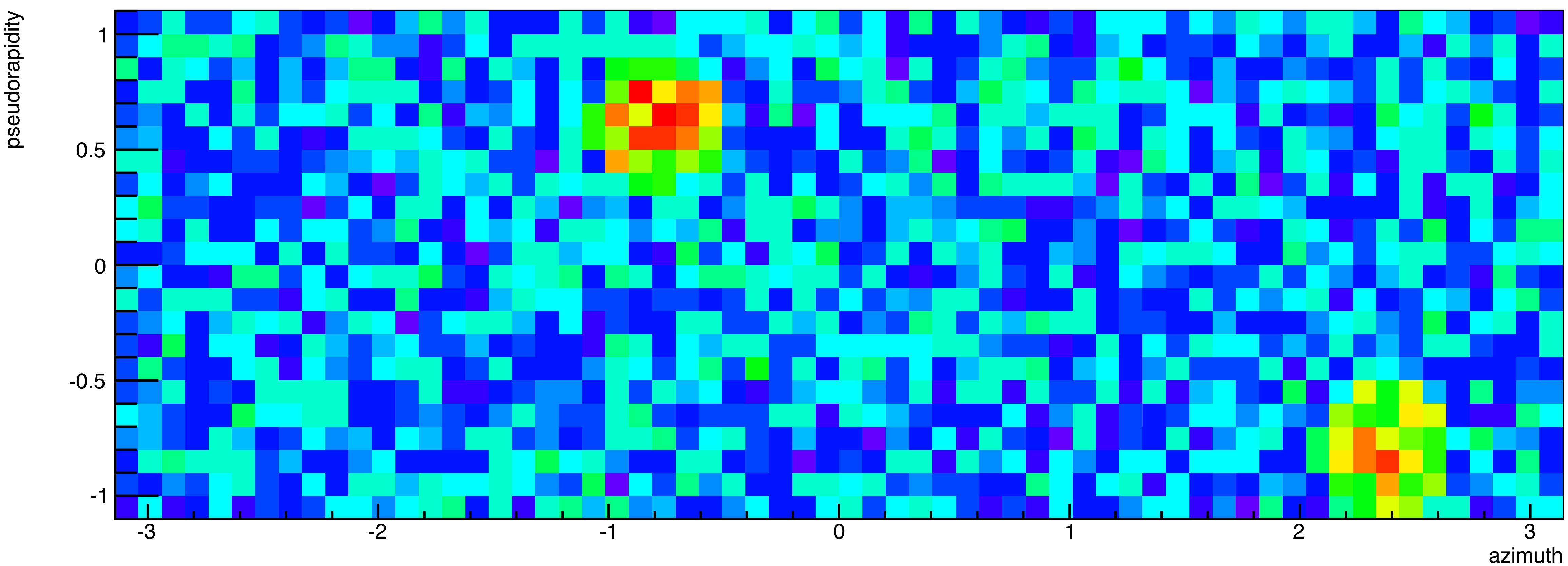
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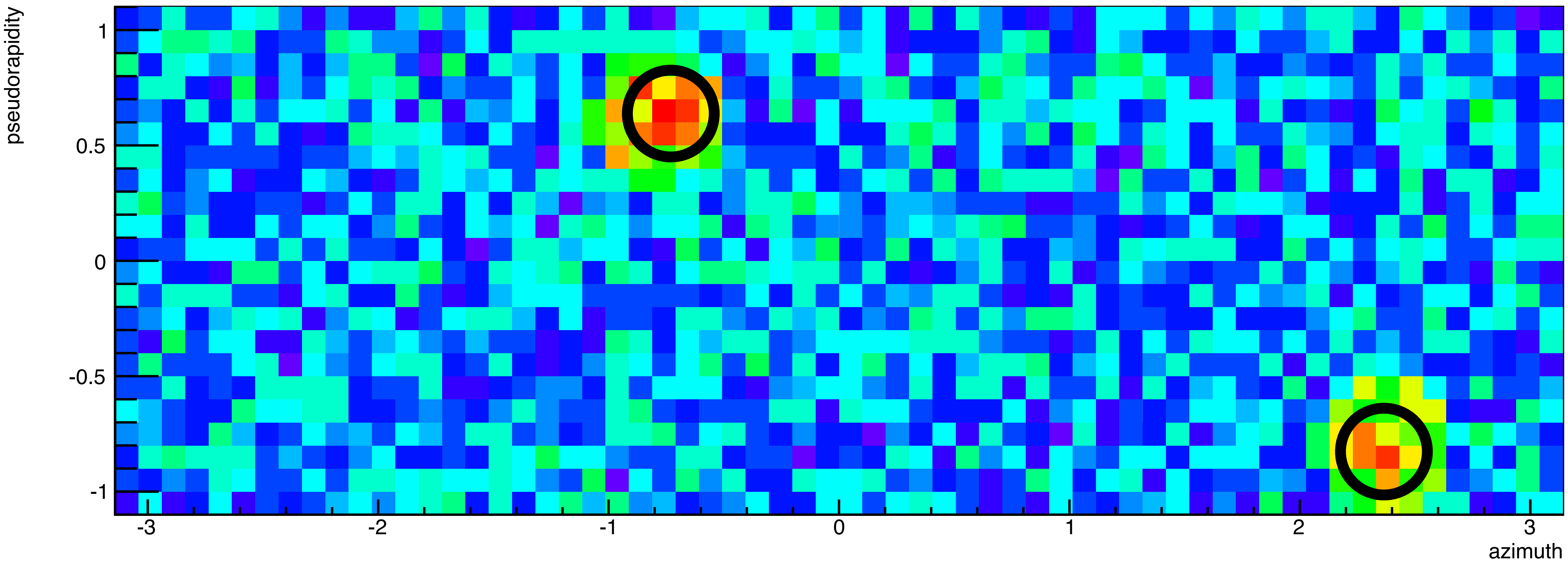
pseudorapidity
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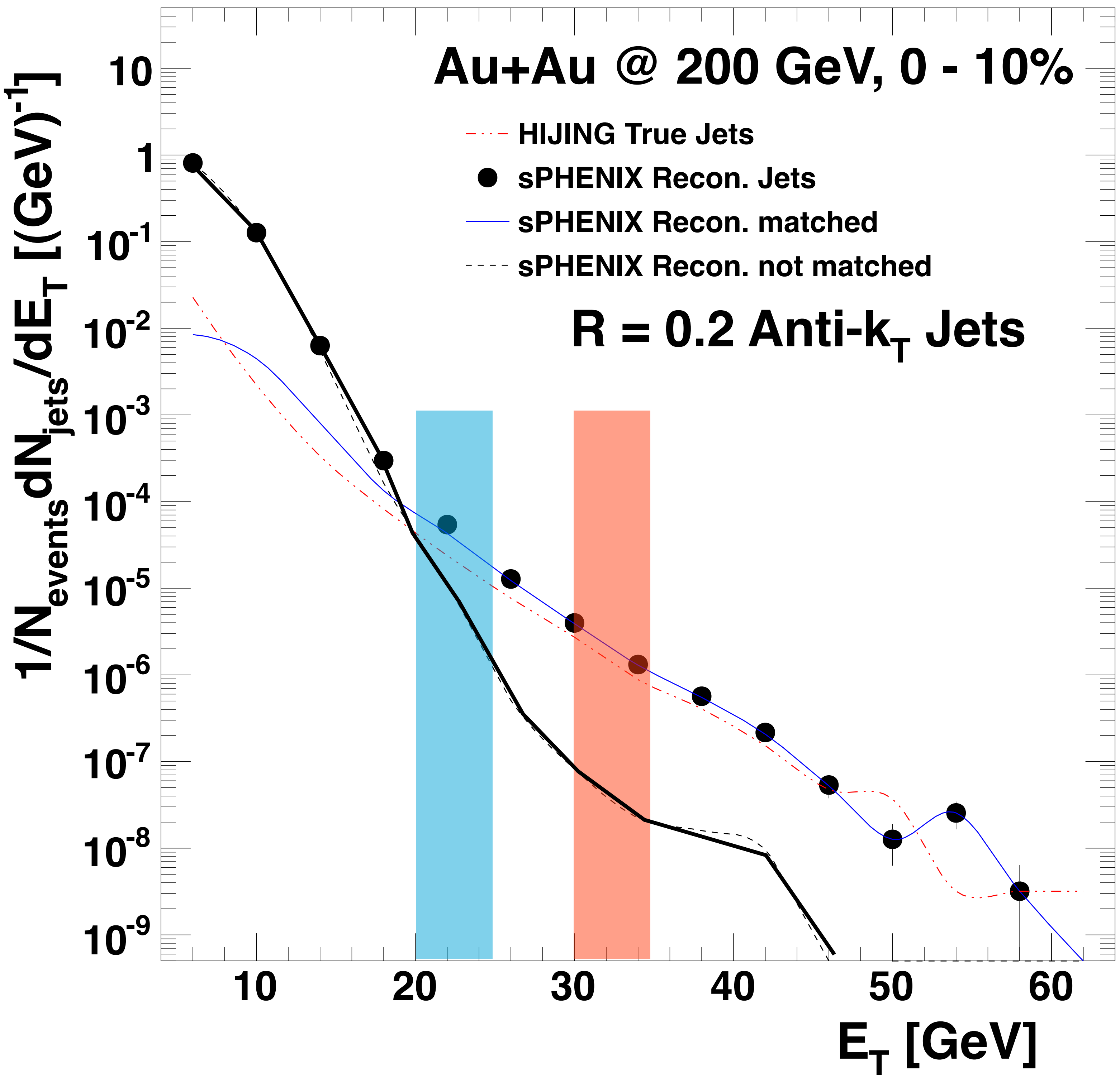
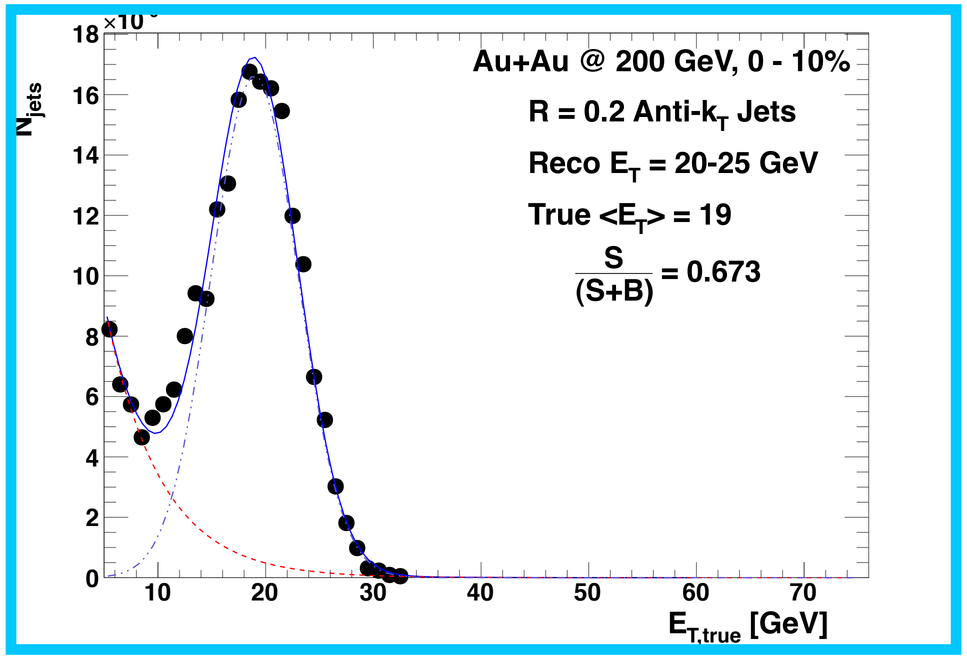
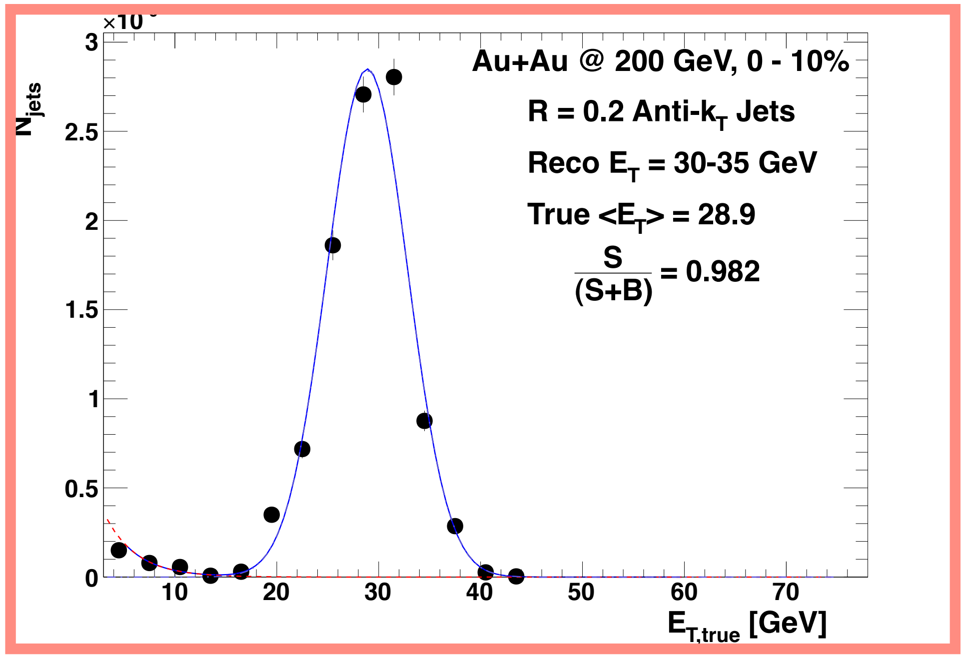
azimuth

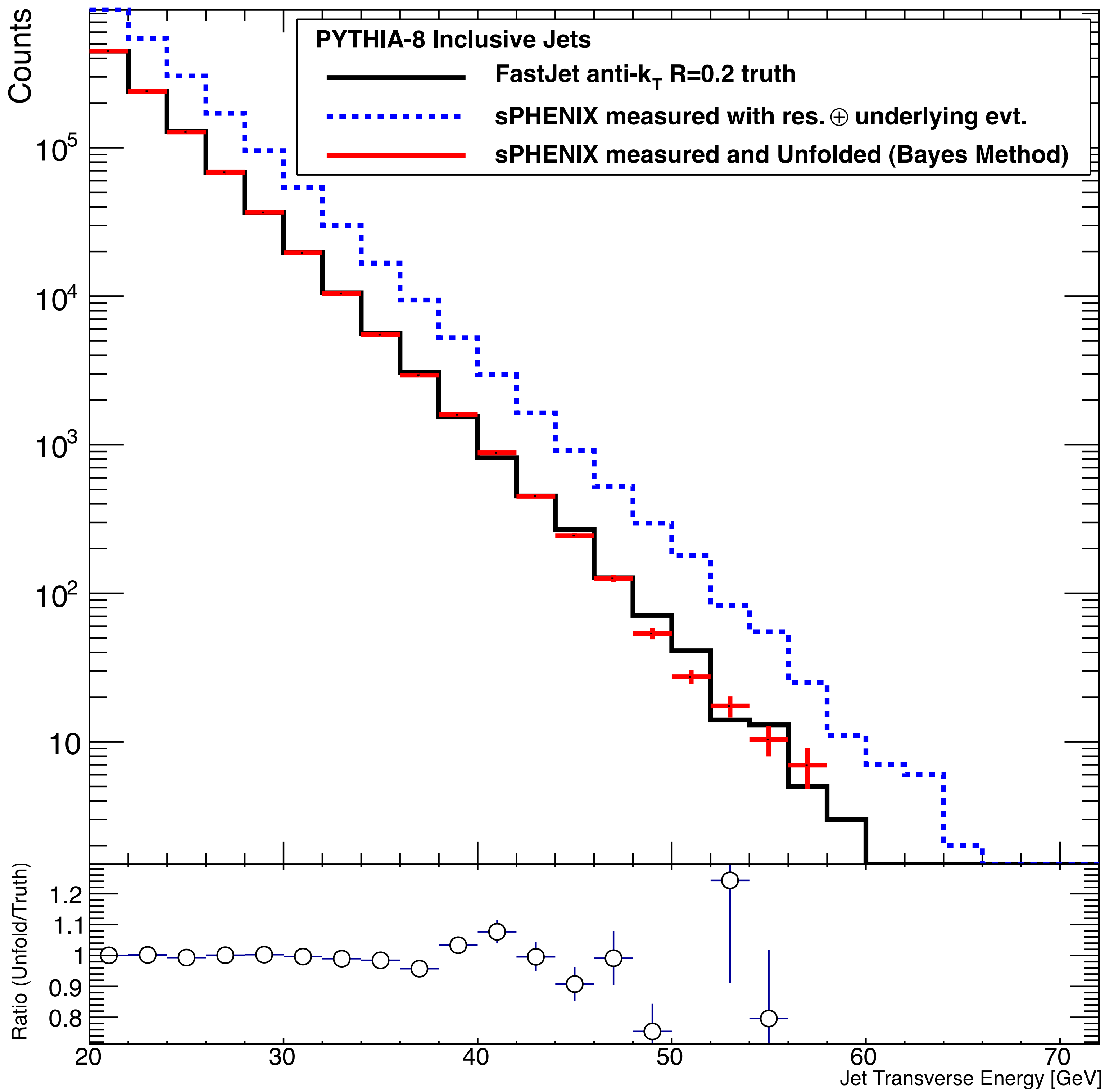
Clean jets above an R-dependent E_T lower bound







Unfolding the effects of detector smearing



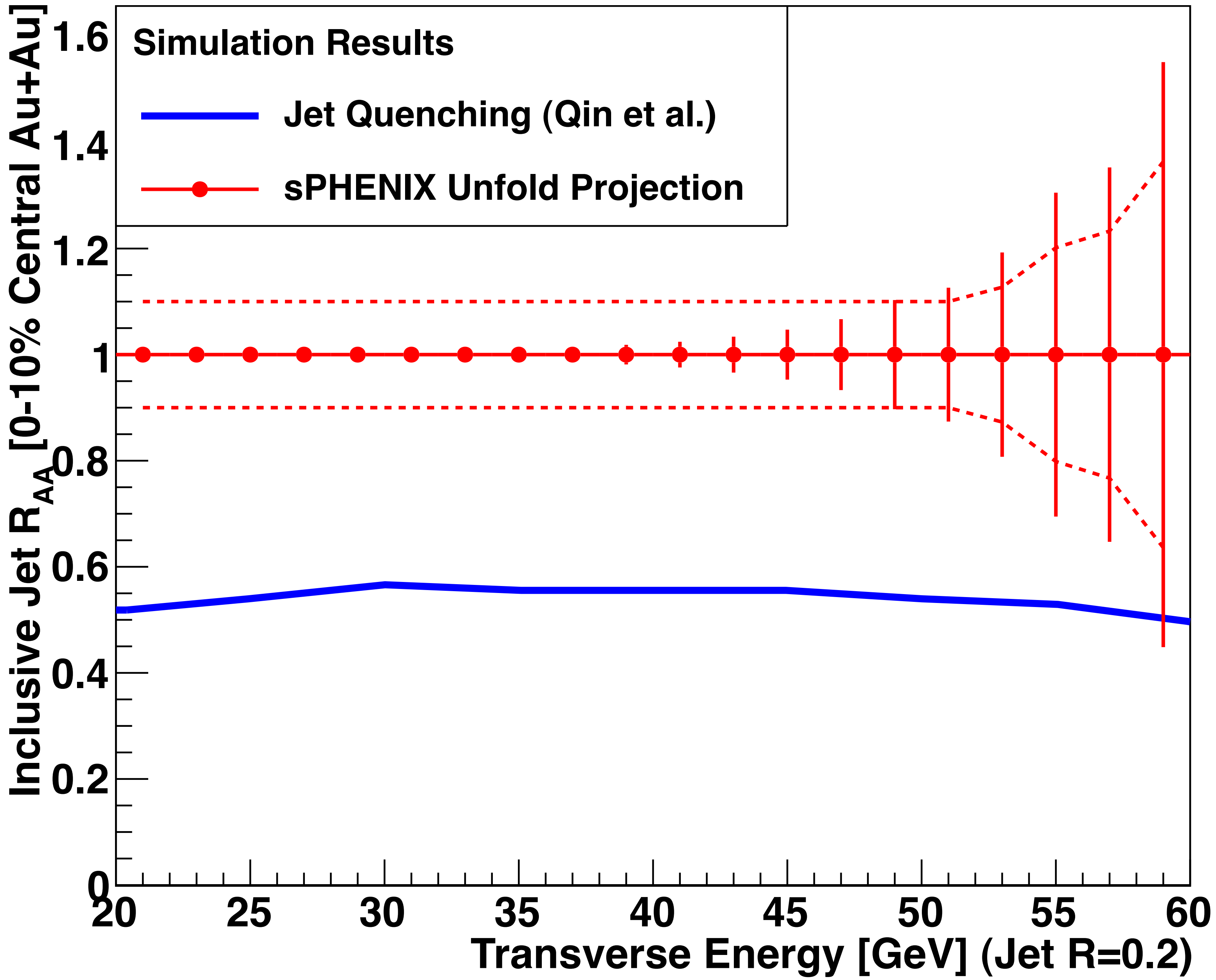
PYTHIA jets plus underlying central Au+Au event plus detector smearing

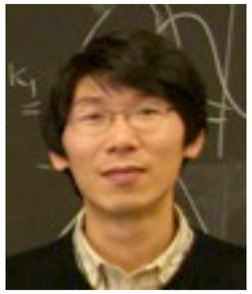
use ROOUNFOLD Iterative Bayes' method

recovers truth spectrum

jet R_{AA} to high p_T possible

Jet R_{AA} to high p_T

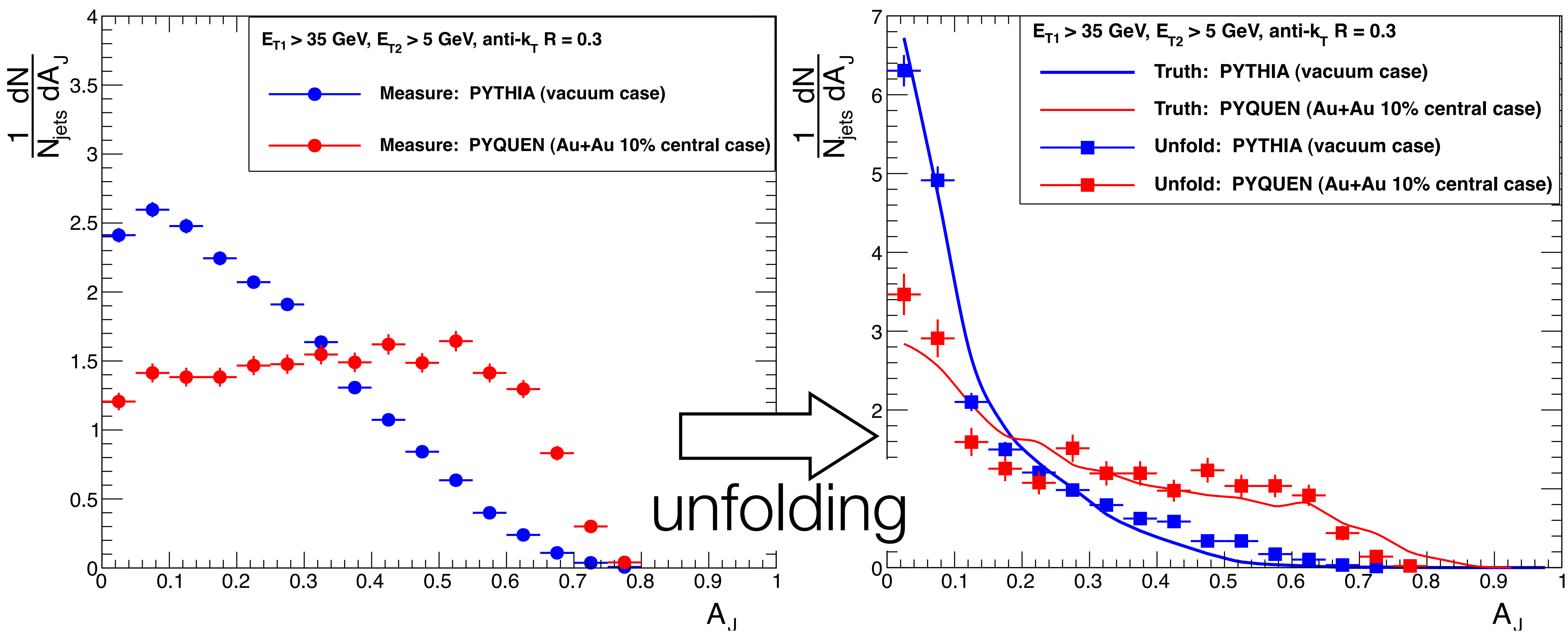




Guang-You Qin, private communication

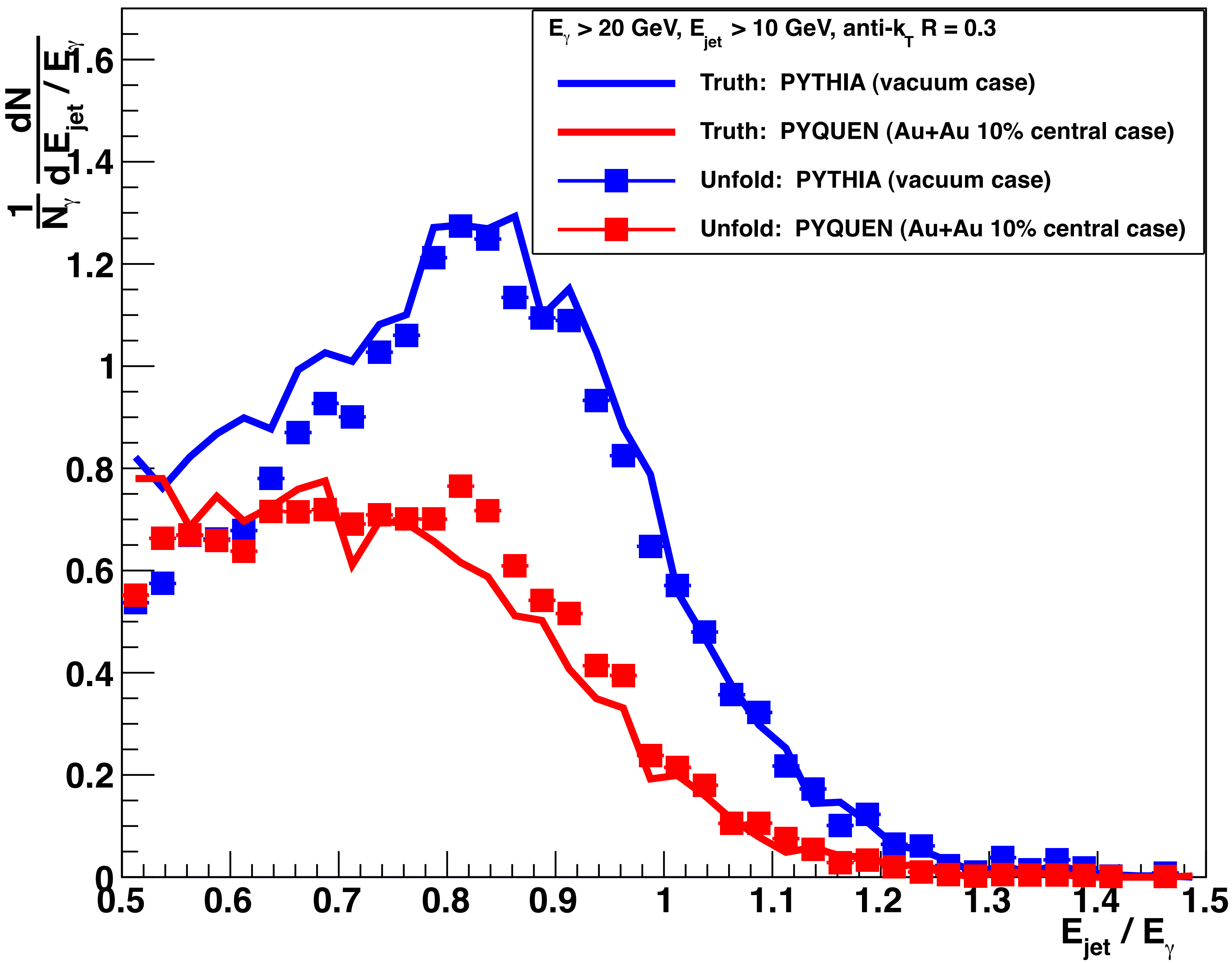
Dijet asymmetry in central Au+Au at RHIC

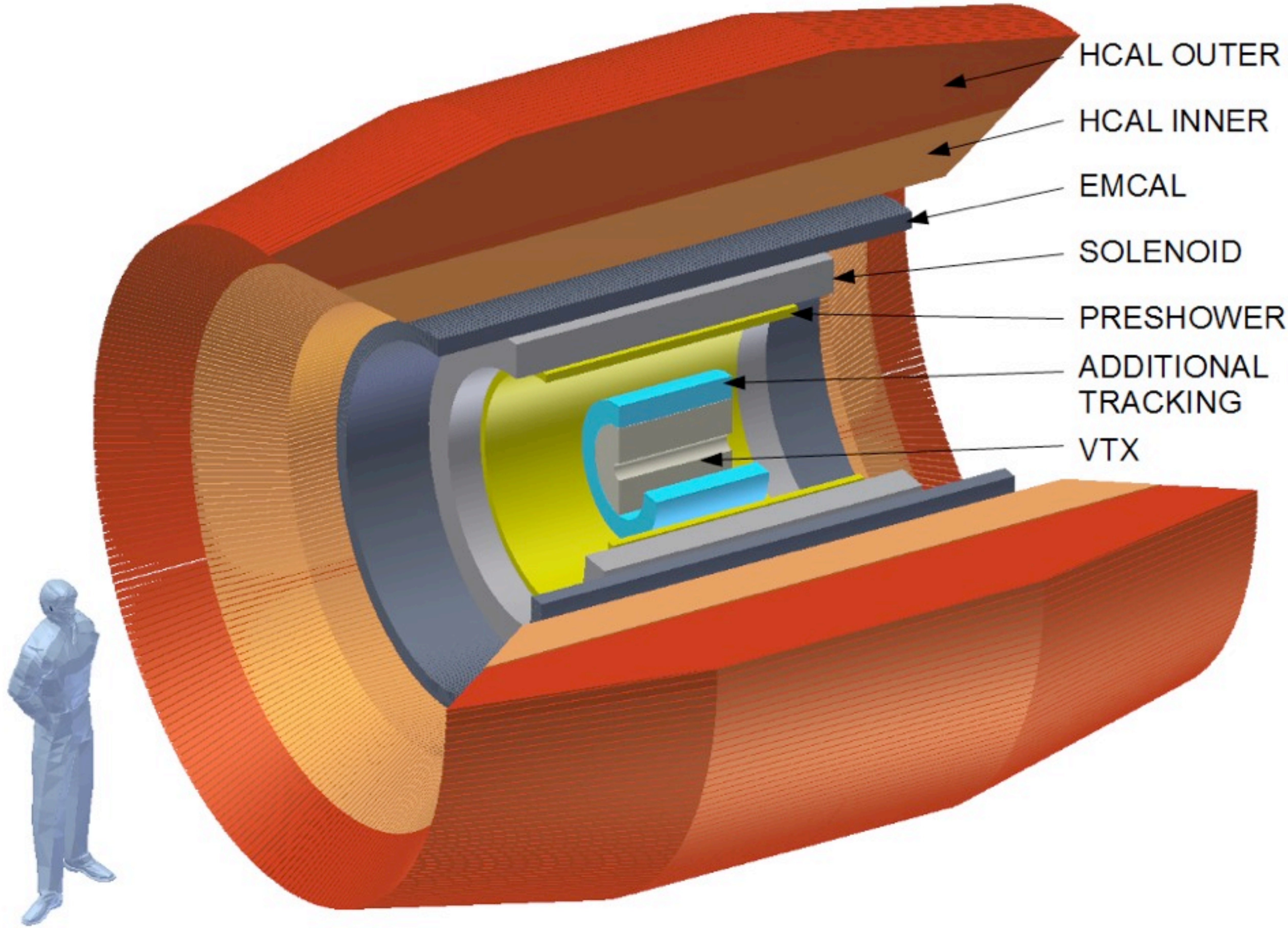
Clean trigger jet above 35 GeV ⇒ away side clean down to 5 GeV

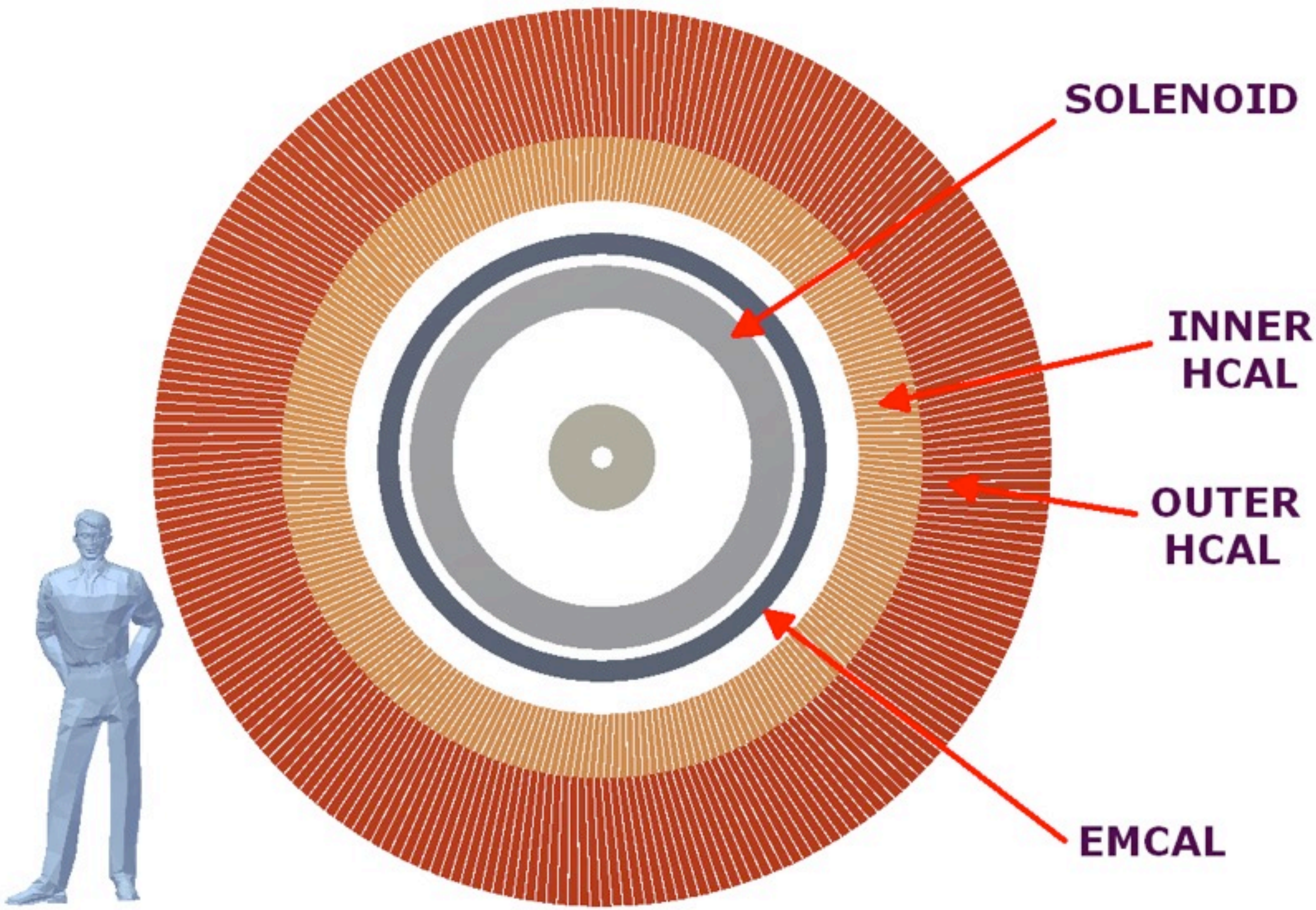


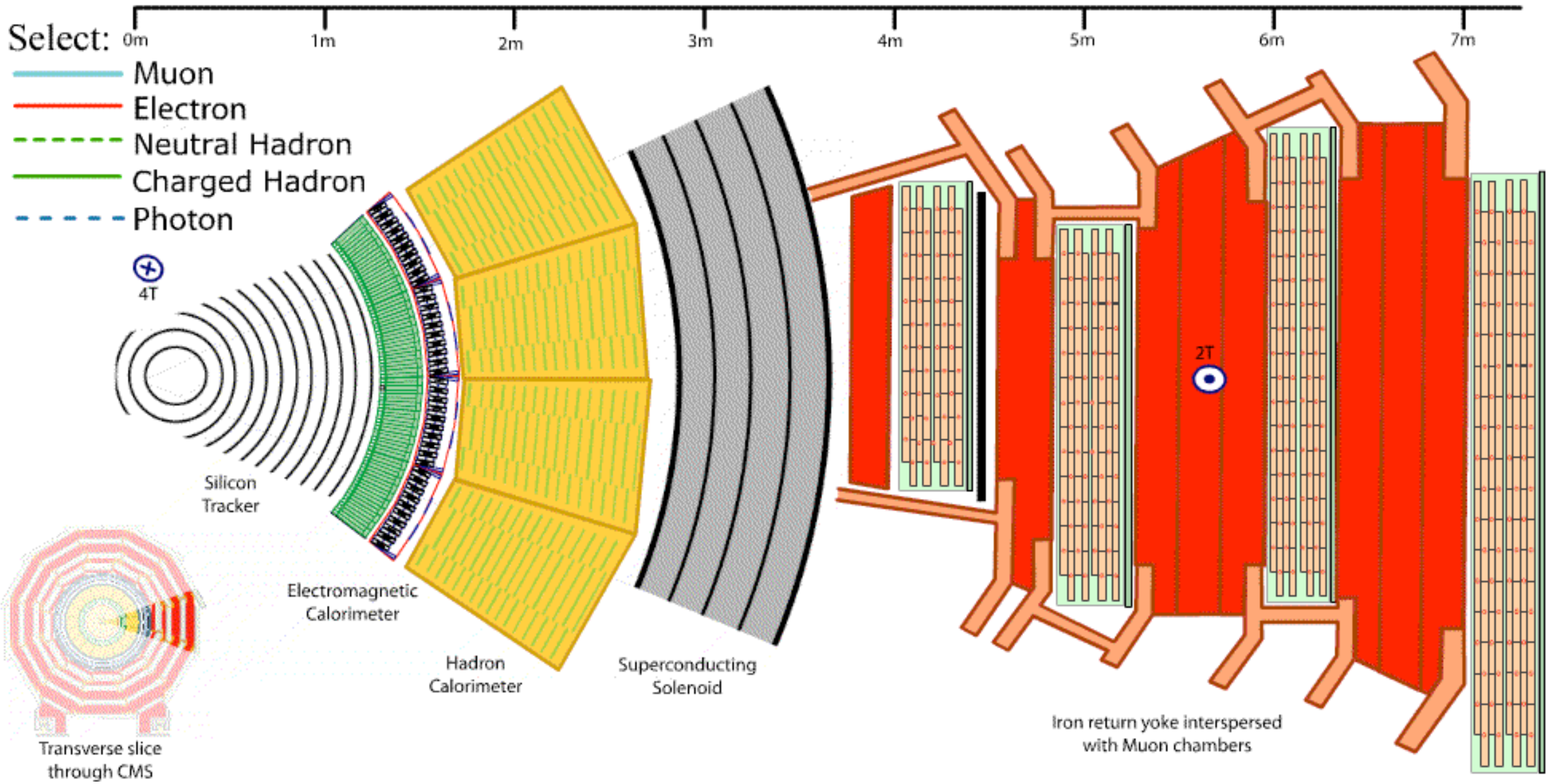
1D unfolding of *just* the trigger jet is very effective!

Unfolded γ+jet energy ratio in central Au+Au




HCAL OUTER
HCAL INNER
EMCAL
SOLENOID
PRESHOWER
ADDITIONAL
TRACKING
VTX


SOLENOID
INNER
HCAL
OUTER
HCAL
EMCAL


Select:
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Muon
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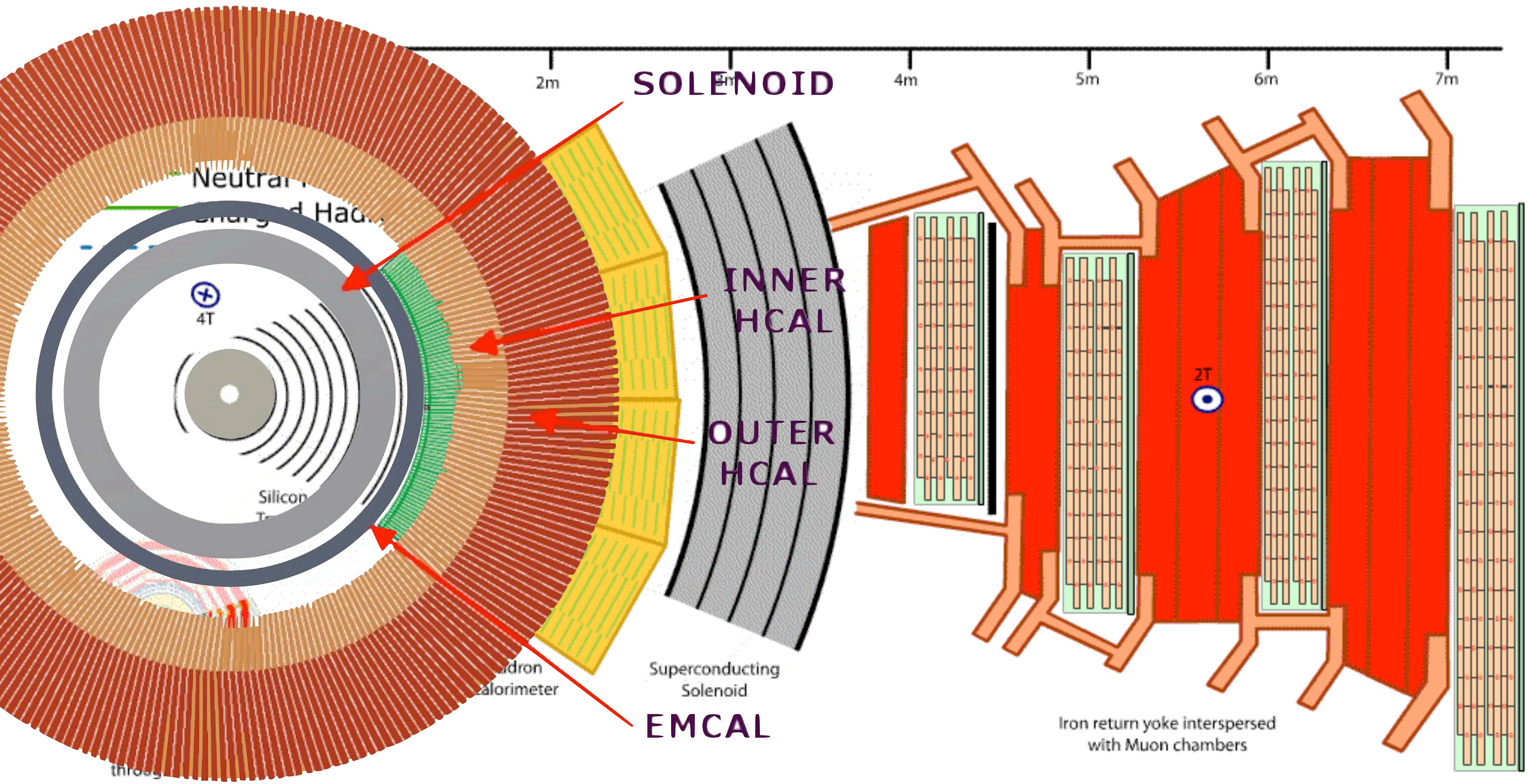
Neutral Hadron
Charged Hadron
Photon
4T
2T
Silicon Tracker
Electromagnetic Calorimeter
Hadron Calorimeter
Superconducting Solenoid
Iron return yoke interspersed with Muon chambers
Transverse slice through CMS

CMS Slice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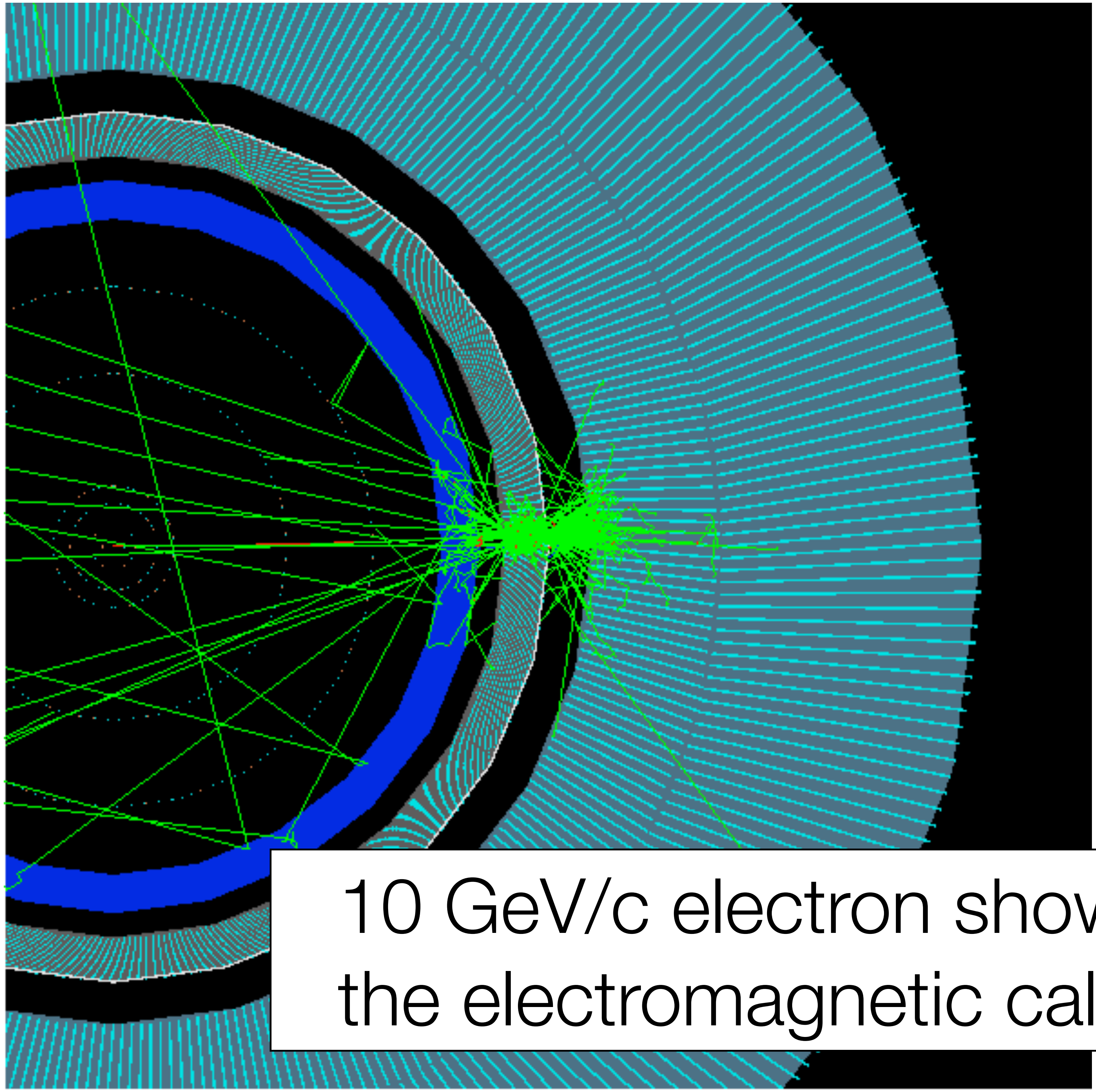
Superconducting
Solenoid
Iron return yoke interspersed
with Muon chambers

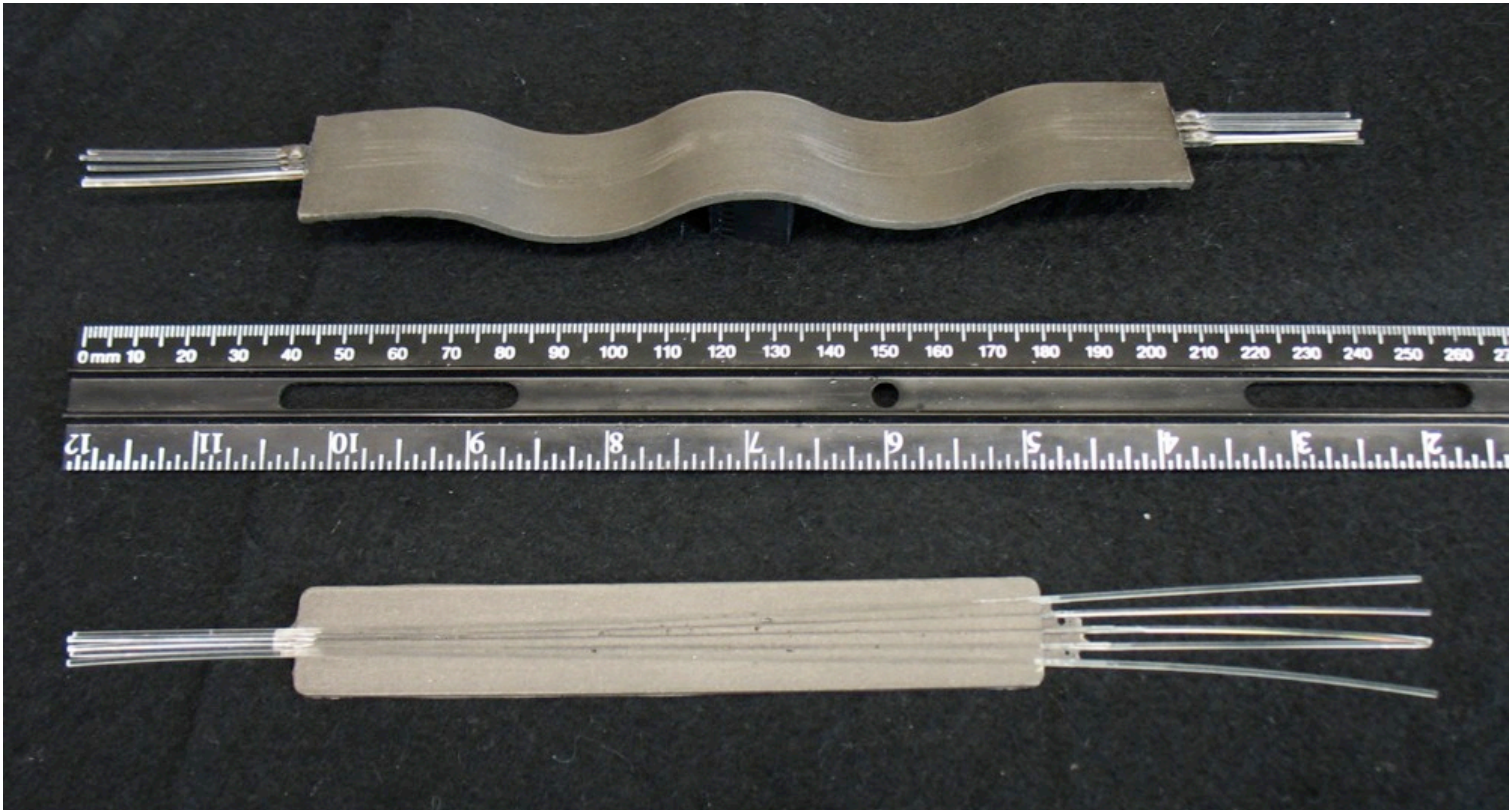
CMS Slice

Full GEANT4 simulation



10 GeV/c electron showering in the electromagnetic calorimeter

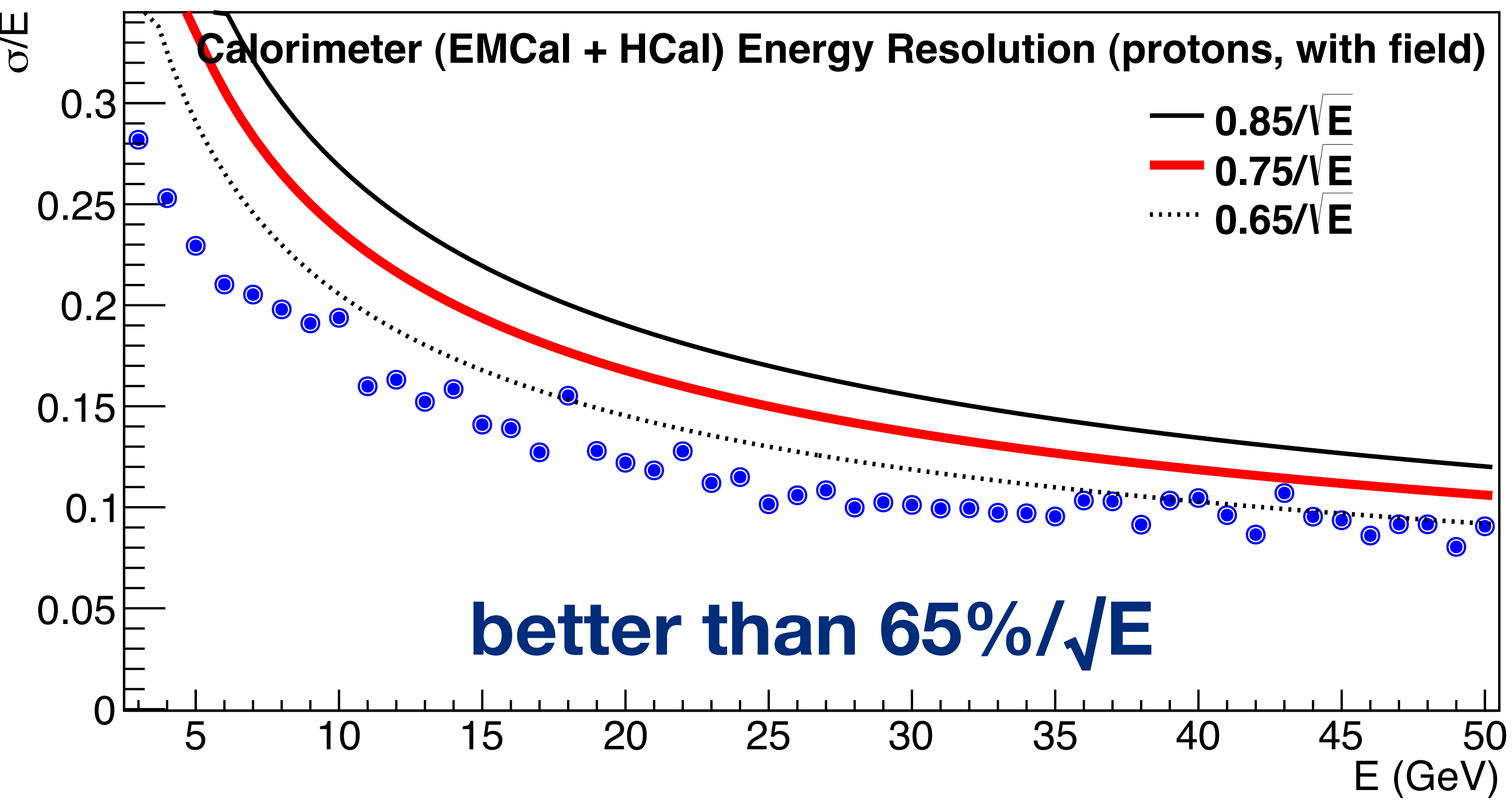
Major technological advances: tungsten + SiPMs



formed tungsten+epoxy with embedded fibers

How well would this new technology work?

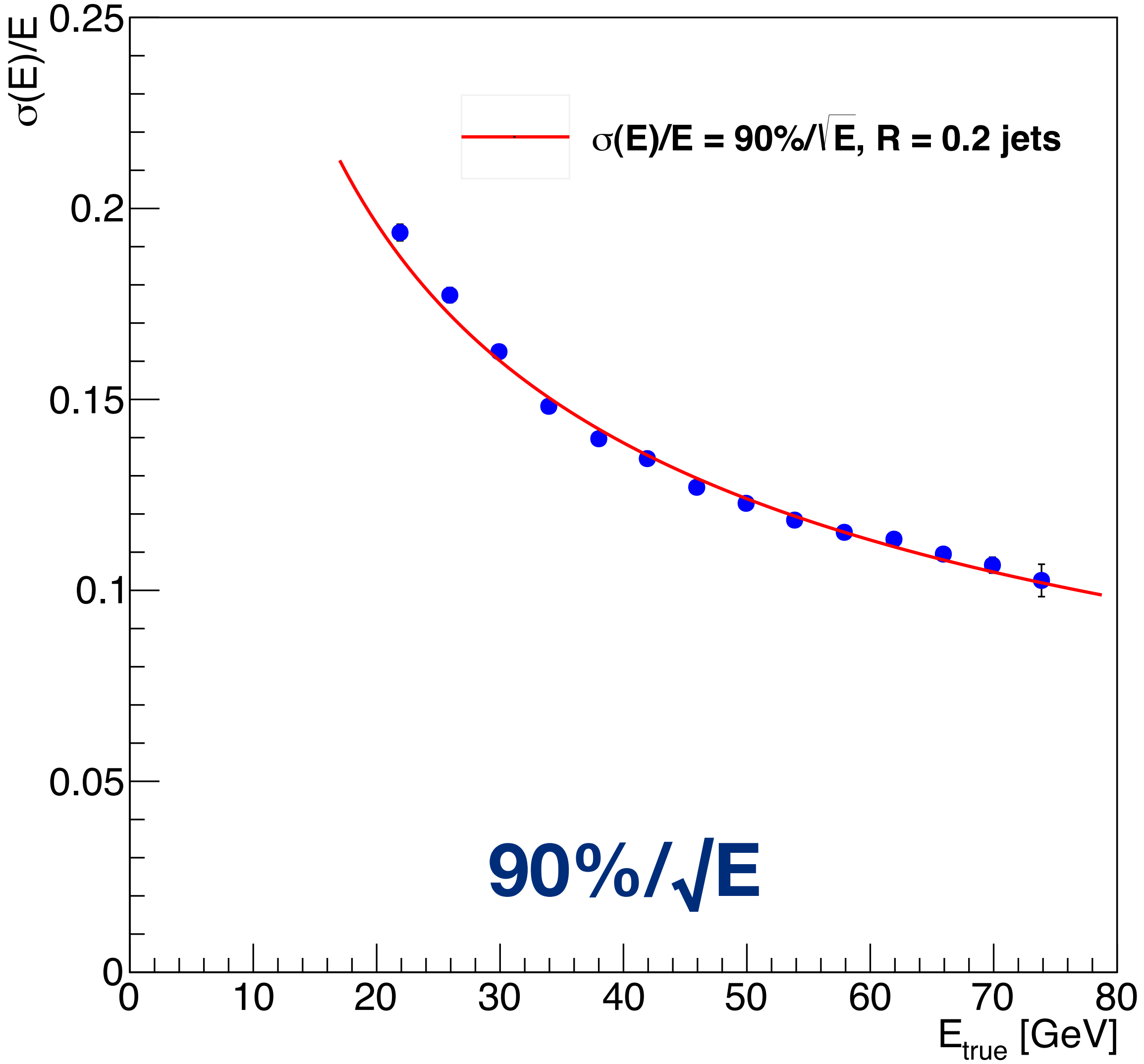
Single particle resolution in EMCal+HCal



Consistent with experience that jet resolution in p+p ~ 1.2–1.3x HCal resolution.

jet resolution in HI ~ 1.6x HCal

Jet energy resolution from full GEANT4 in *p+p*



sPHENIX

high rate calorimetric jet measurements at RHIC

- jets, dijets, γ-jets
- other very interesting possibilities: jet v_N, jet-hadron correlations
- heavy quark jets: needs additional tracking beyond VTX (expressions of interest from Japanese RIKEN)
- exploit RHIC's species flexibility to control initial state effects and geometry

***together* with LHC constrain physics of energy loss**

innovative detector concept exploits recent technological advances

we still aim to address the broader program in the decadal plan!

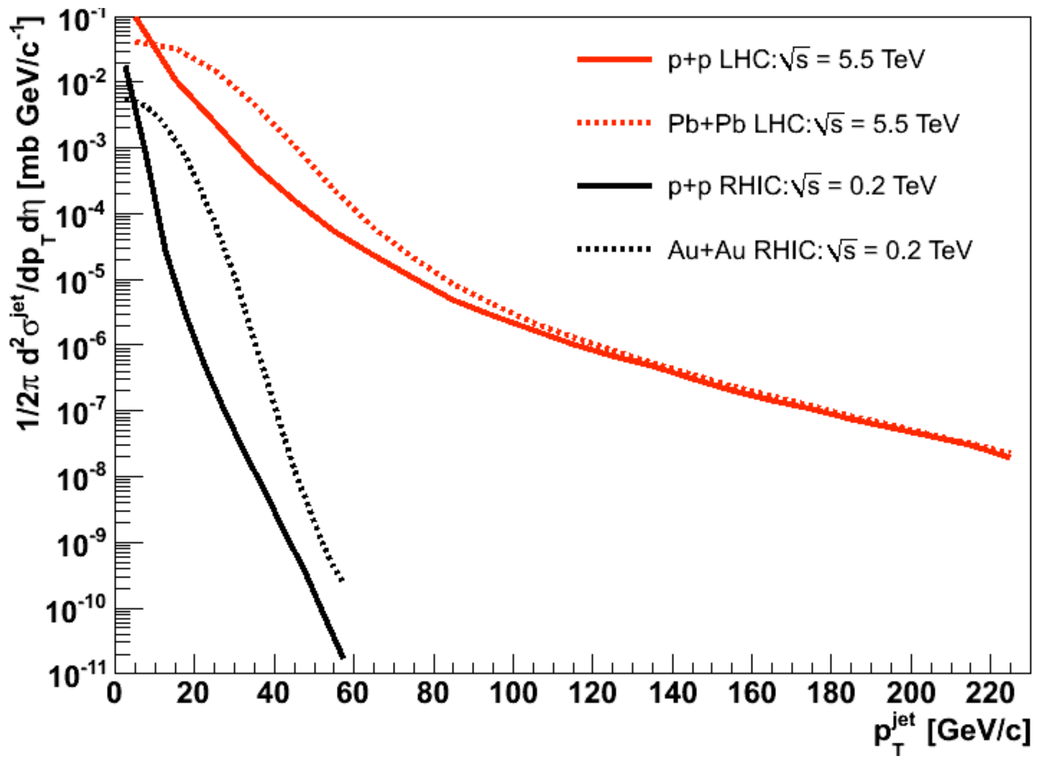
- staged approach includes quarkonia, forward spin and cold nuclear matter
- sPHENIX has path to evolve into EIC ePHENIX

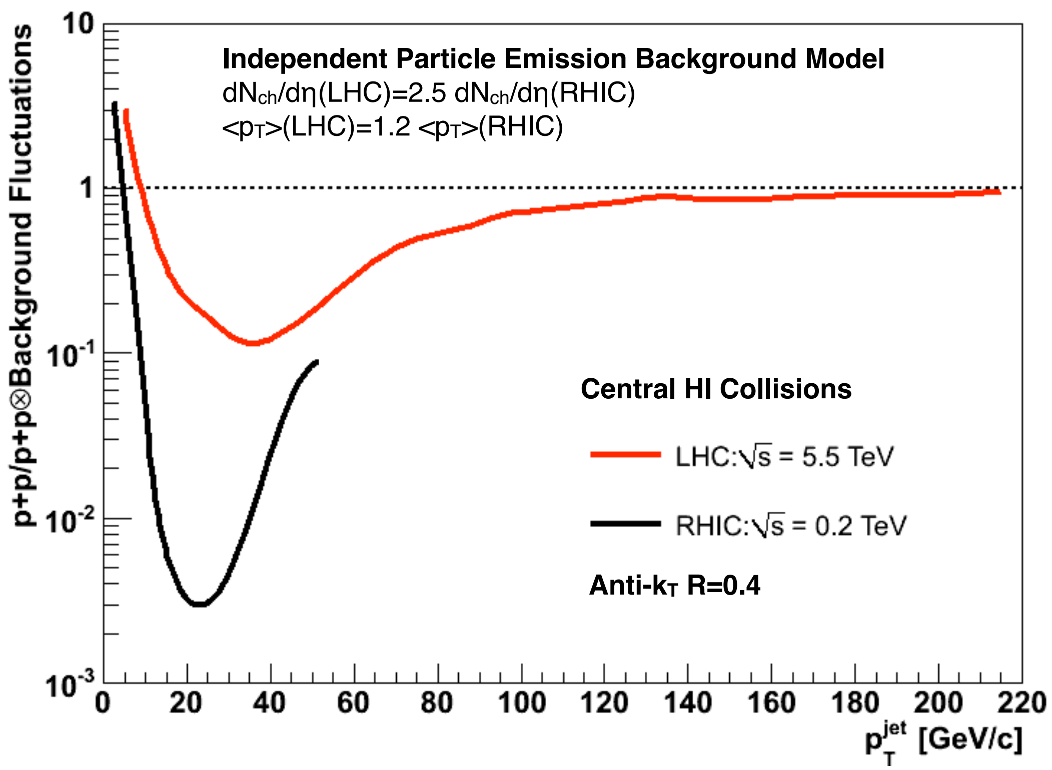
will submit MIE proposal to Steve Vigdor July 1.

look forward to review in September!

Extra slides

Jets at RHIC, really?

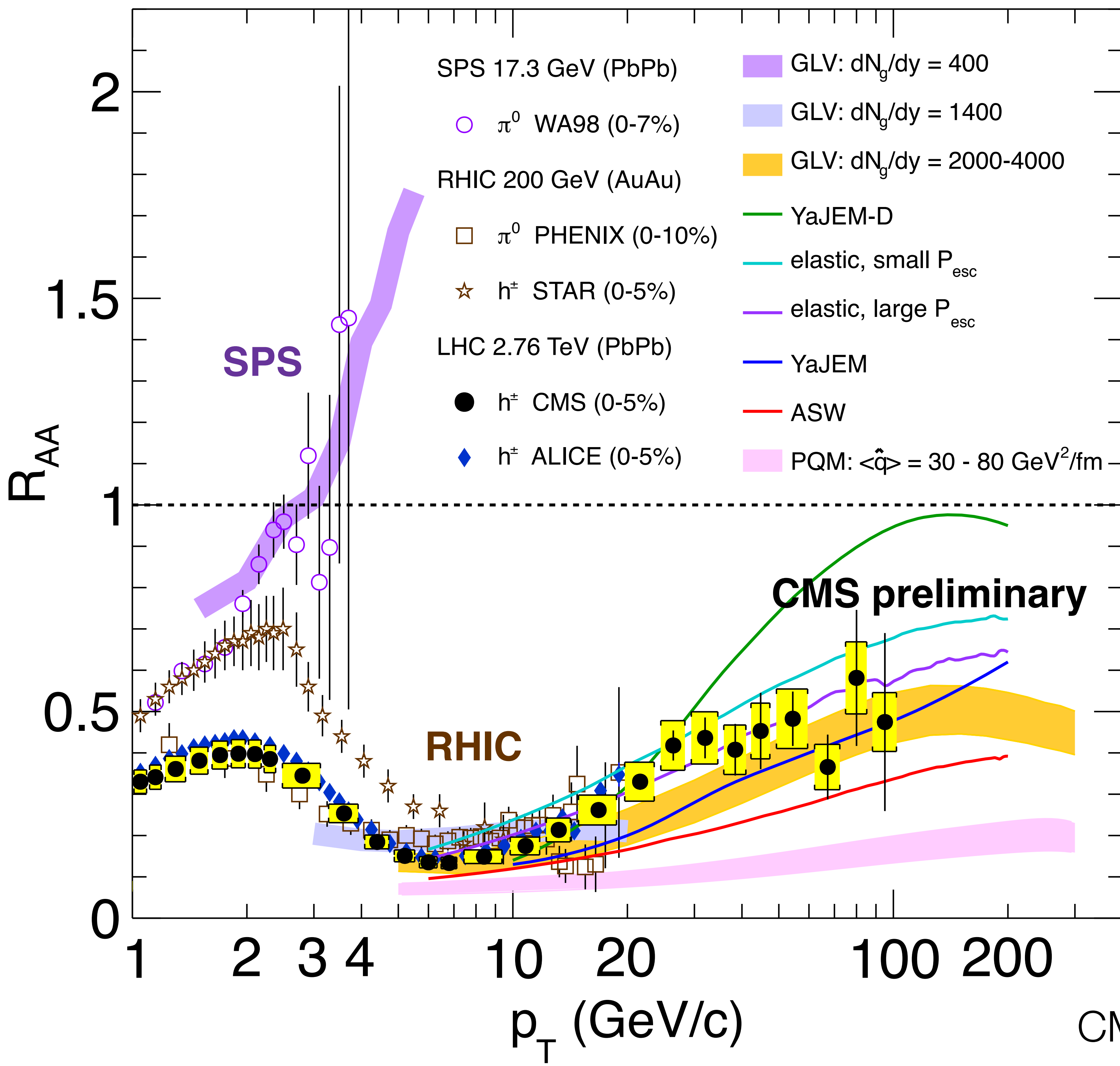




- smearing from very low p_T
- R can be smaller than 0.4 (say, 0.2)
  - agree that R = 0.4 at 20 GeV/c is B.G.
- energy in a cone doesn’t look like a jet
- jets from soft fluctuations ⇒modified FF’s
- CMS study: jets have a high p_T hadron
- ATLAS is pushing down to ~40 GeV/c with fake jet rejector

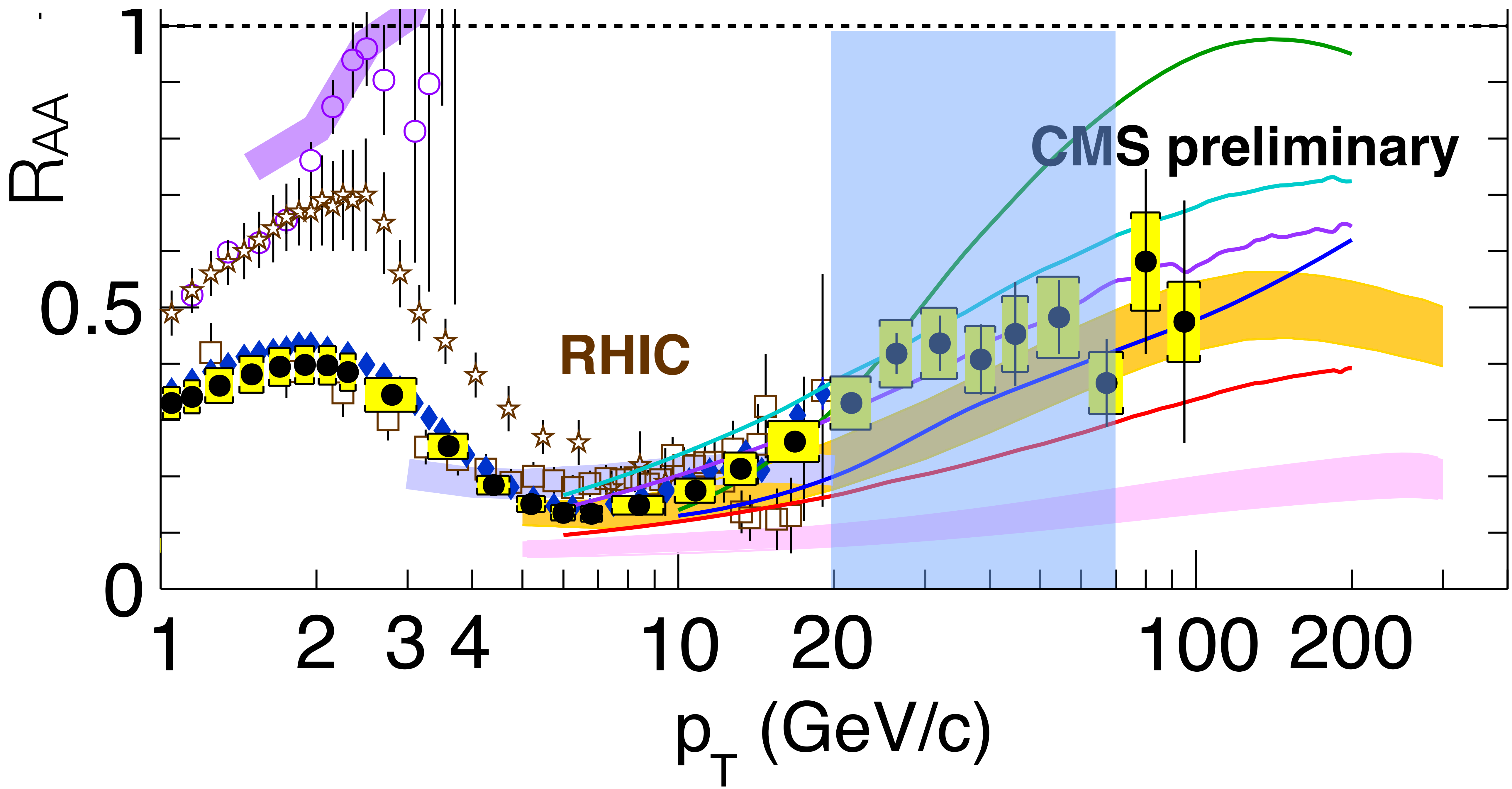
Jörn Putschke (HP’12, RHIC/AGS ’11); also Cacciari, Salaam, Soyez, Eur.Phys.J.C71:1692,2011

How would jet R_{AA} at RHIC extend our p_T reach?



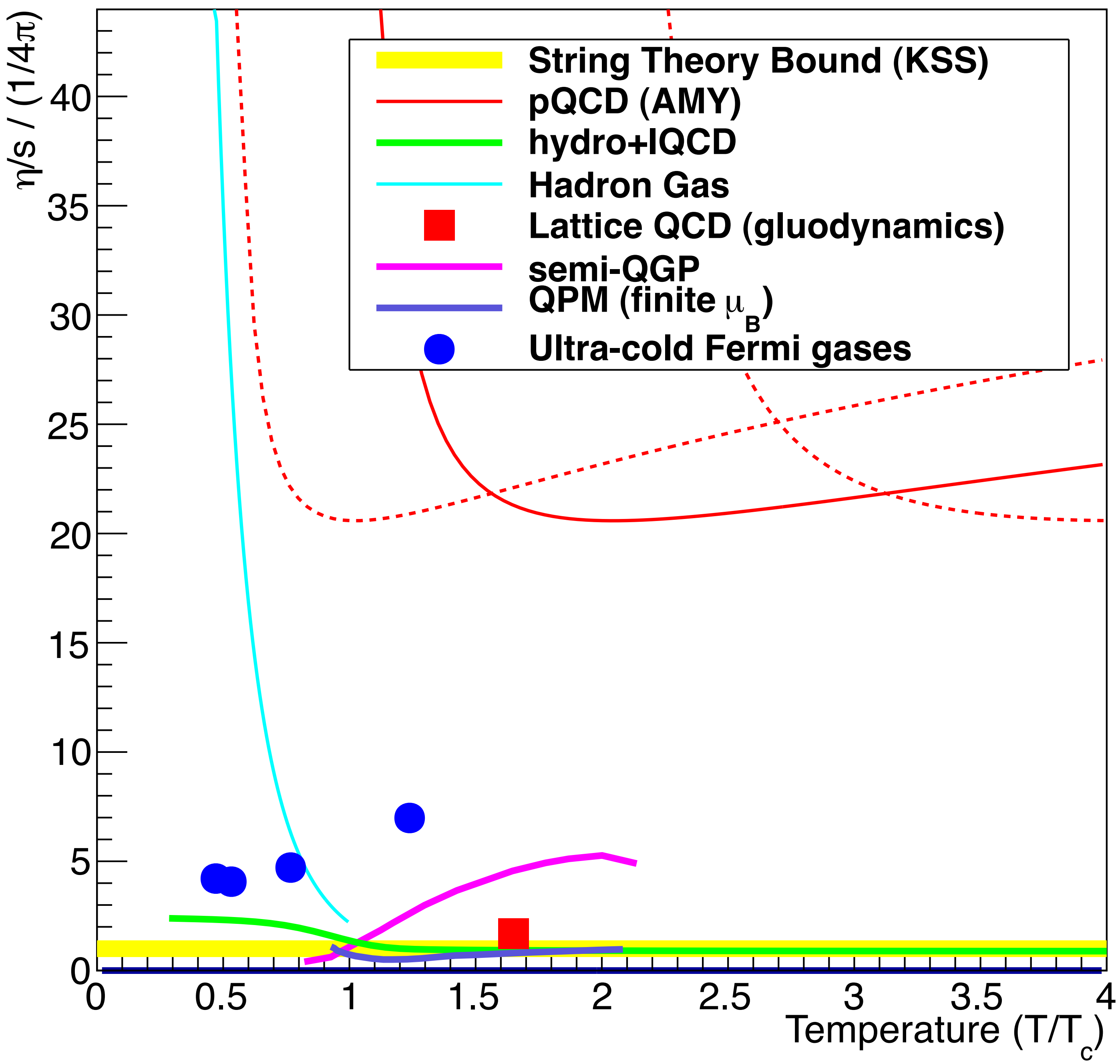
CMS-PAS-HIN-10-005

How would jet R_{AA} at RHIC extend our p_T reach?



CMS-PAS-HIN-10-005

strong coupling calculations (and a bit of data)



Hydro + lQCD calculation from Kovtun, Moore, and Romatschke
arXiv:1104.1586

Hadron gas calculation from Prakash (almost 20 years ago) $1/T^4$.
Phys. Rept. 227 (1993) 321-366

Lattice QCD result from Harvey Meyer (gluodynamics)
arXiv:0704.1801

QPM, finite μ_B calculation from Shrivistava and Singh
arXiv:1201.0445

Semi-QGP calculation from Rob Pisarski with κ = 8
arXiv:0912.0940

Ultra-cold Fermi gases from Adams, Carr, Schäfer, Steinberg, Thomas
arXiv:1205.5180v1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