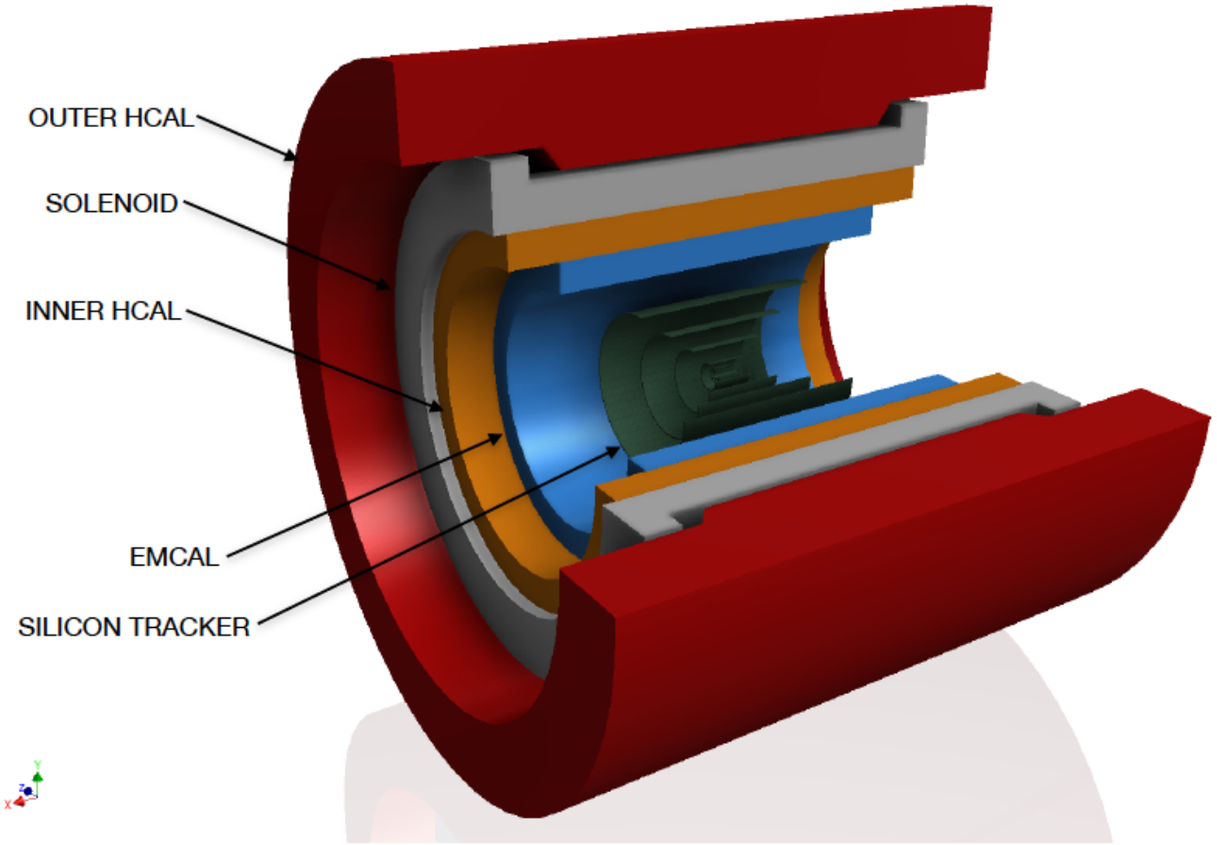
sPHENIX and Beyond



Ali Hanks

for the (s)PHENIX collaboration

ICPAQGP 2015

February 6th, 2015

sPHENIX

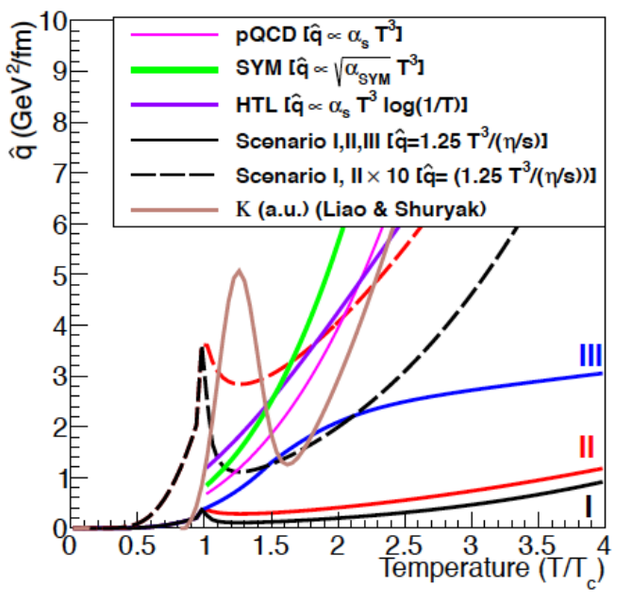
Stony Brook University | The State University of New York

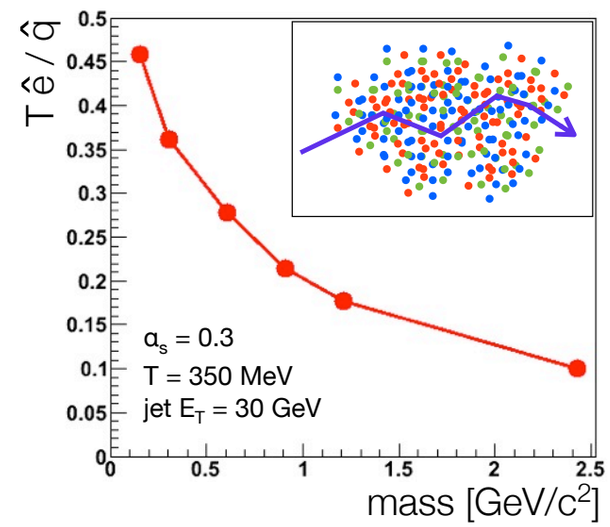
Why sPHENIX?

- Formation of QGP as nearly perfect fluid near the phase transition is well established while temperature dependence of basic medium properties remain poorly constrained
- Lack a fundamental connection of QCD to this emergent phenomena, leaving open questions such as "HOW" and "WHY" medium is produced
- sPHENIX will use jets, jet correlations and upsilons together to determine temperature dependence of transport properties and color screening length of the QGP
- Design leaves room for additional upgrades to expand p+p, p+A and ultimately e+A capabilities

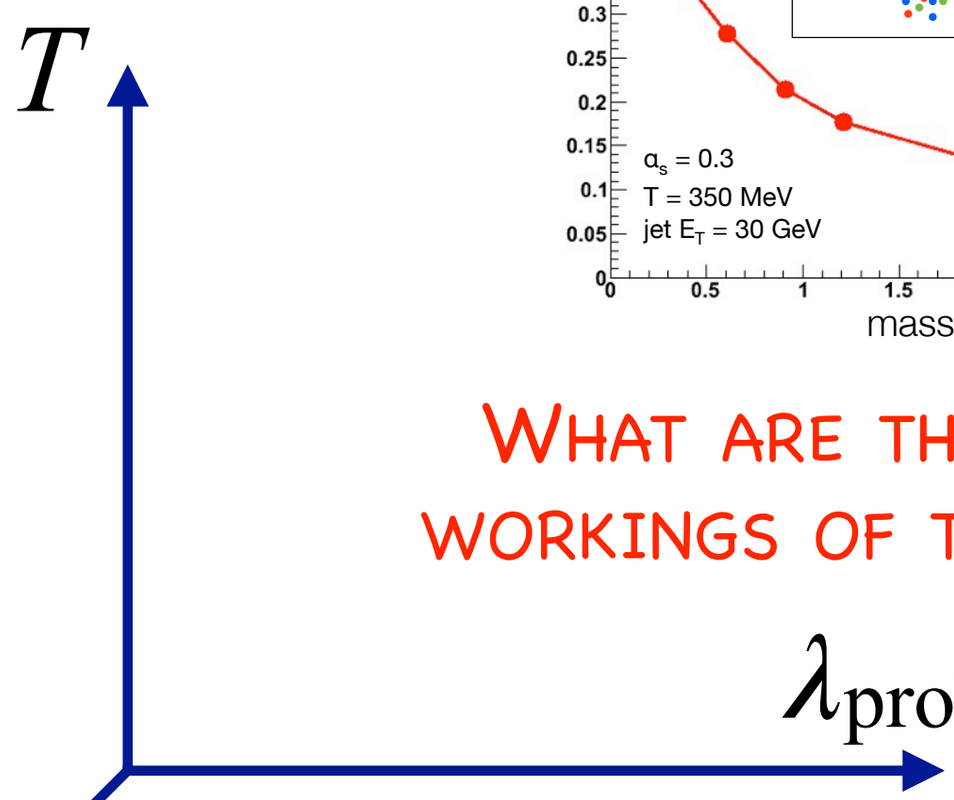
Pushing and probing the medium

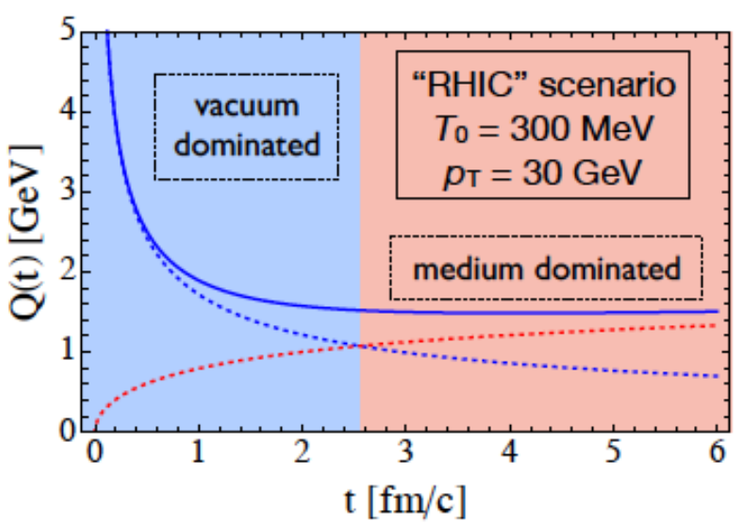
What is the temperature dependence of the QGP?





What are the inner workings of the QGP?

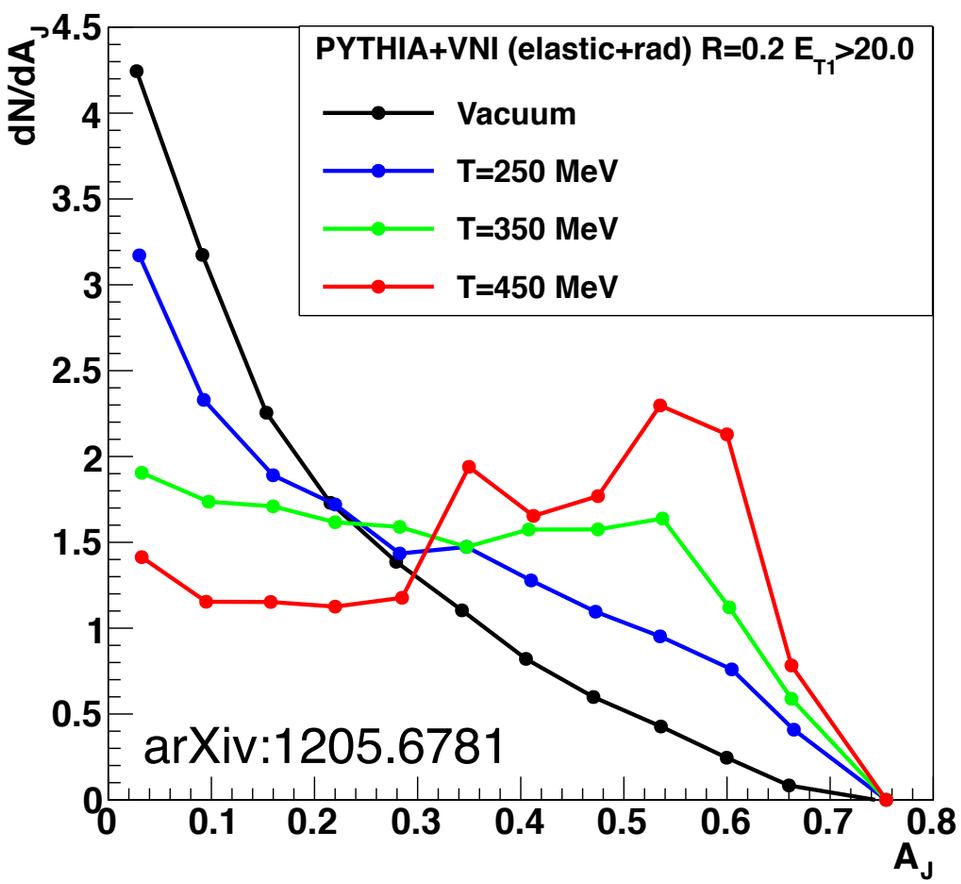




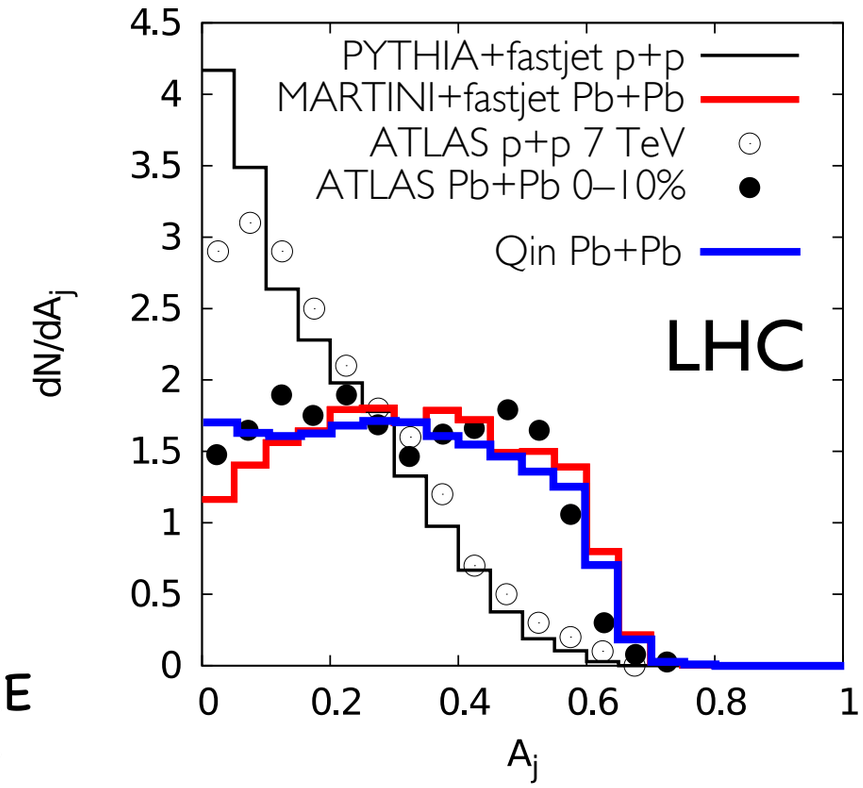
How does the QGP evolve along with the parton shower?

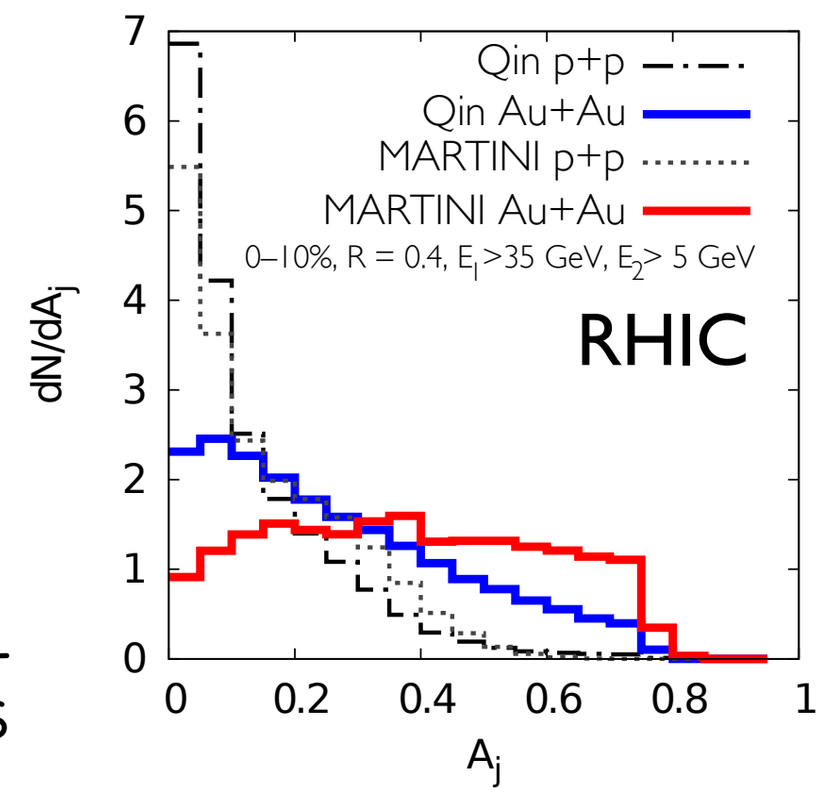
The effect of temperature

What is the temperature dependence of the QGP?



Strong temperature dependence on key observables

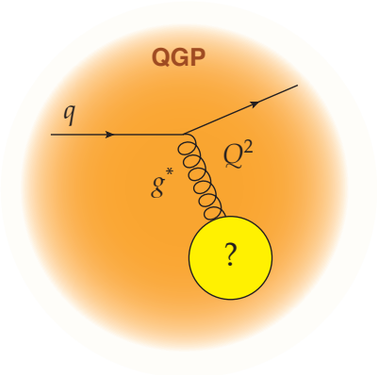




Comparisons of LHC and RHIC will help to distinguish between models

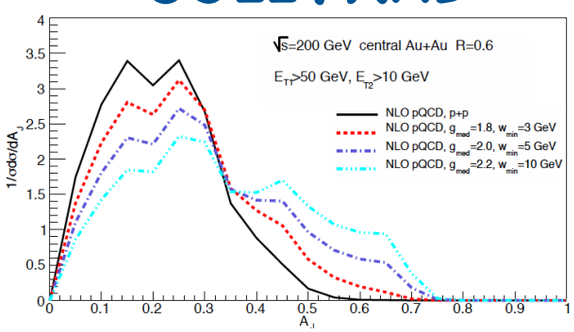
Probing the length scale

What are the inner workings of the QGP?

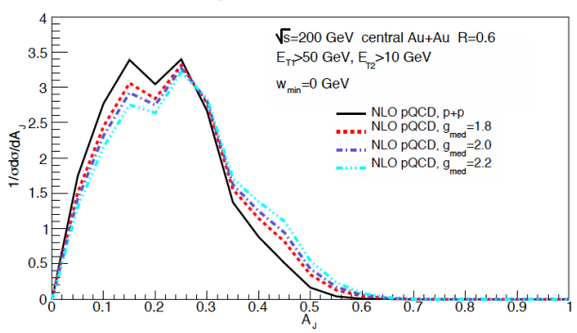


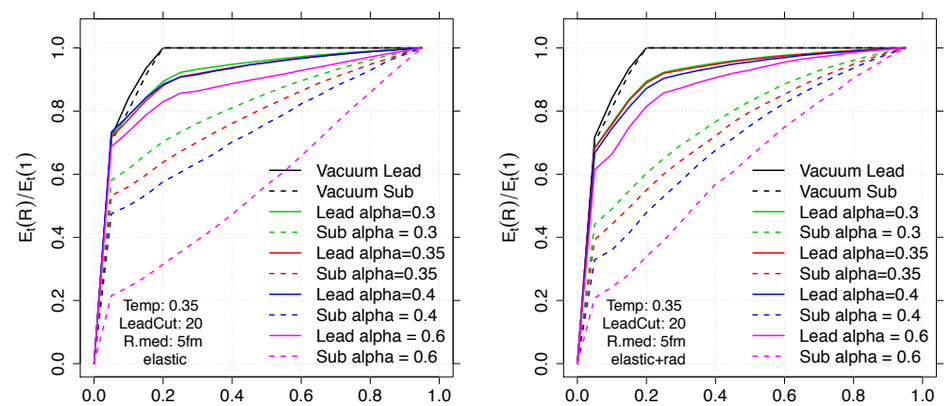
Radiative vs Collisional energy loss

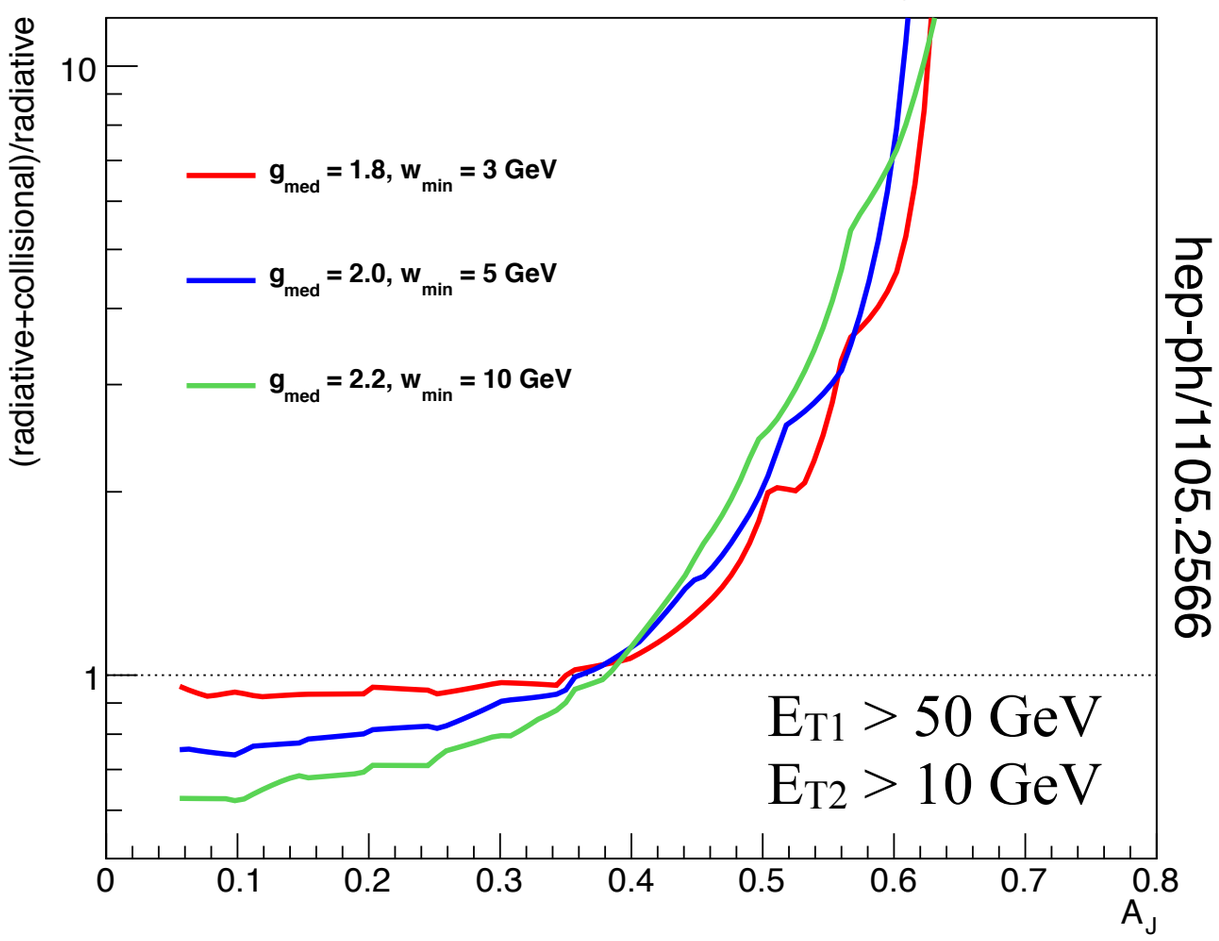
Coll+Rad

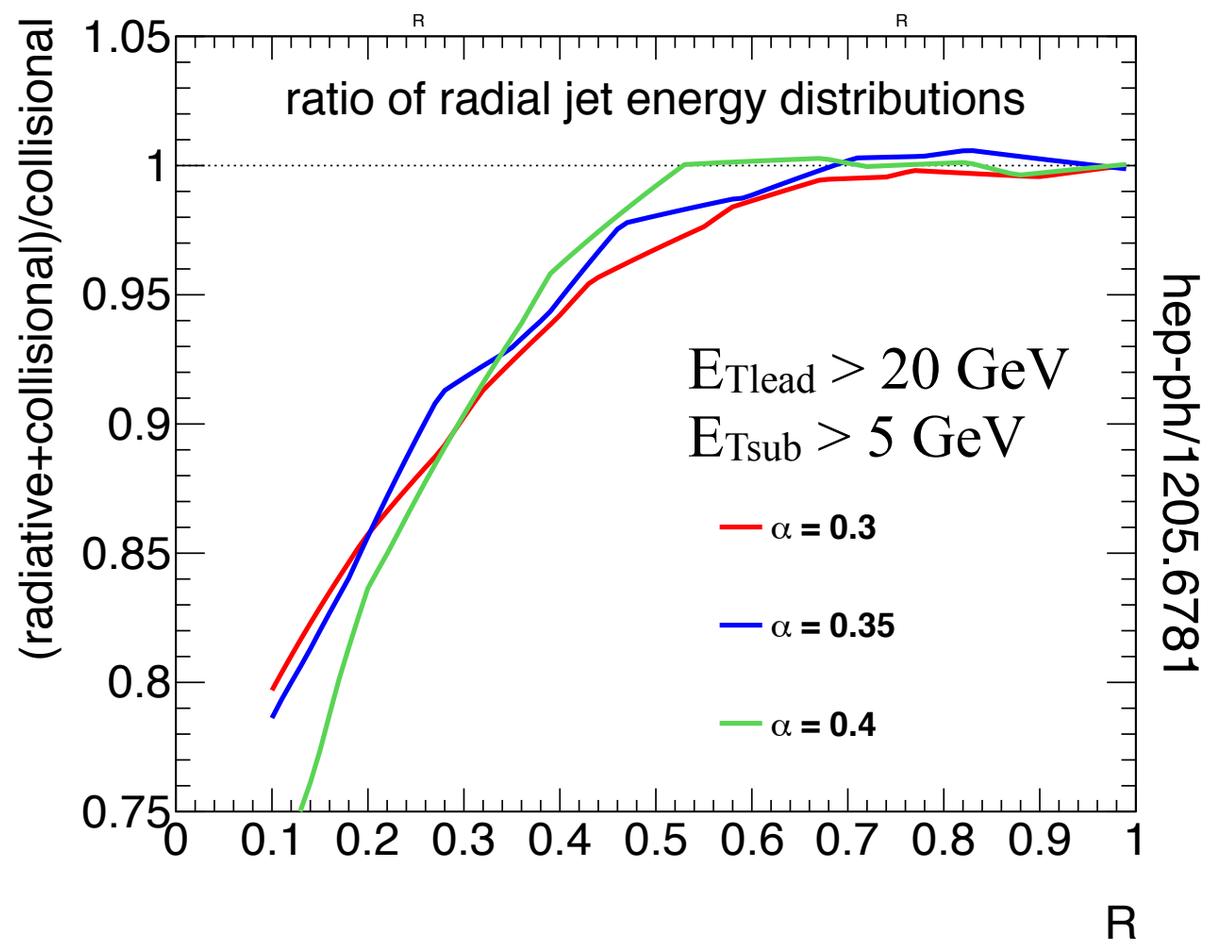


Coll





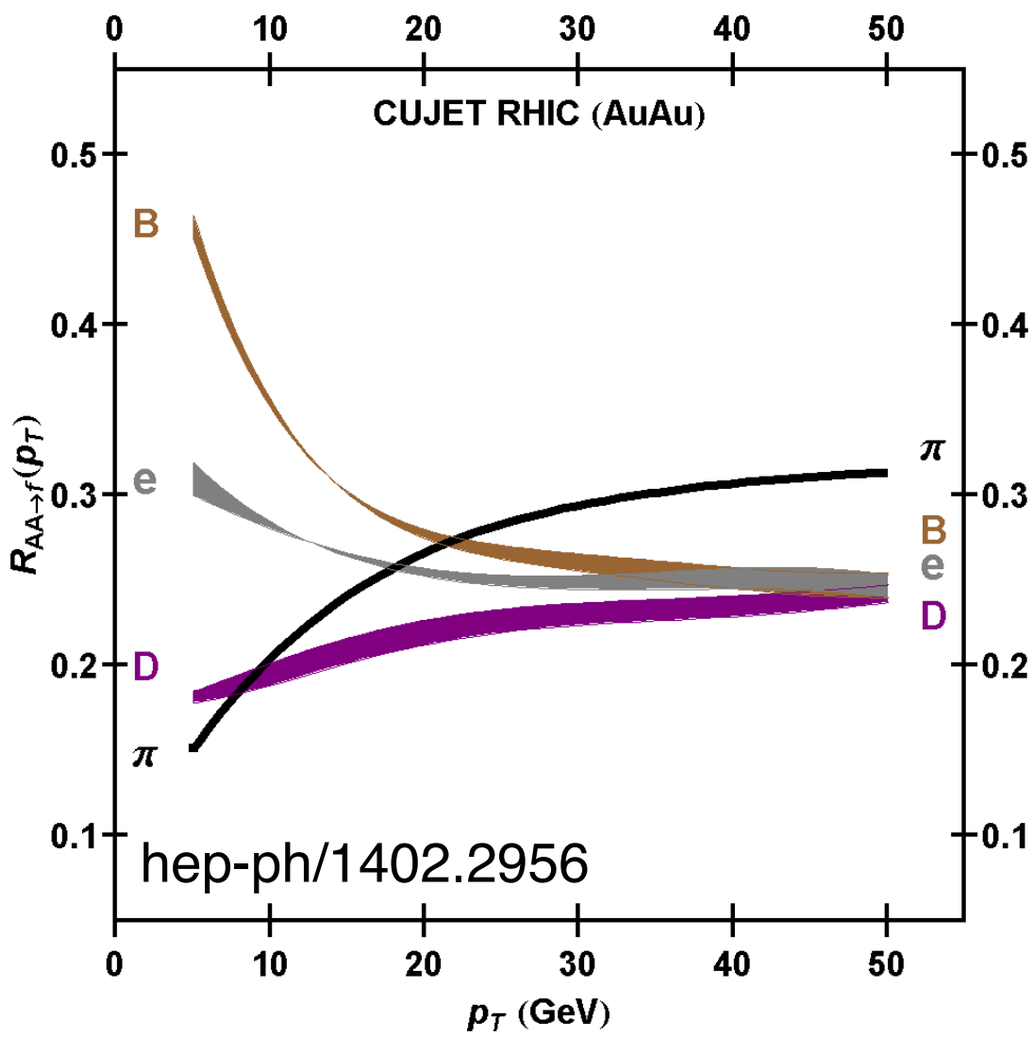


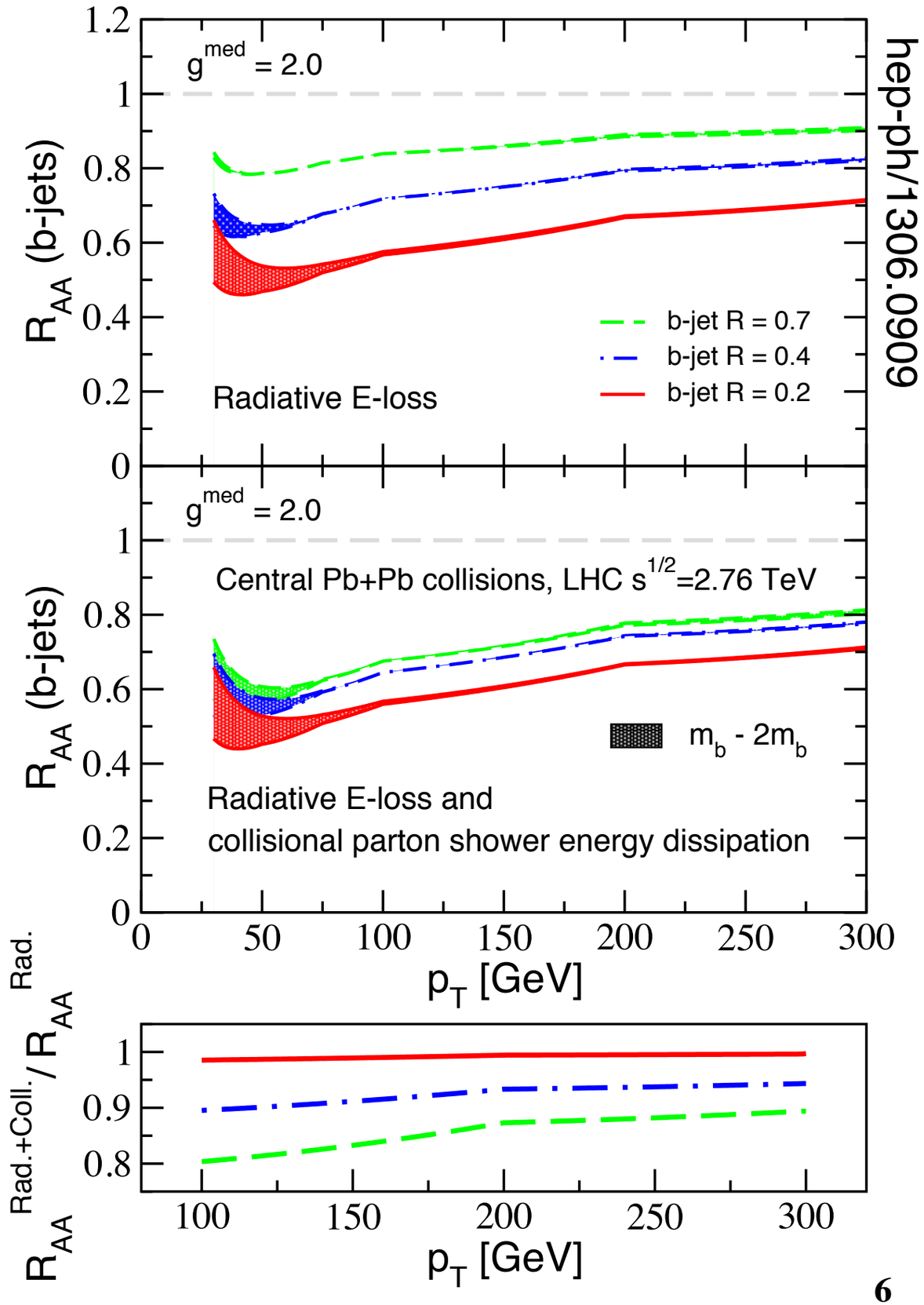


Probing the length scale

What are the inner workings of the QGP?

Heavy flavor more sensitive to collisional effects





Probing the length scale

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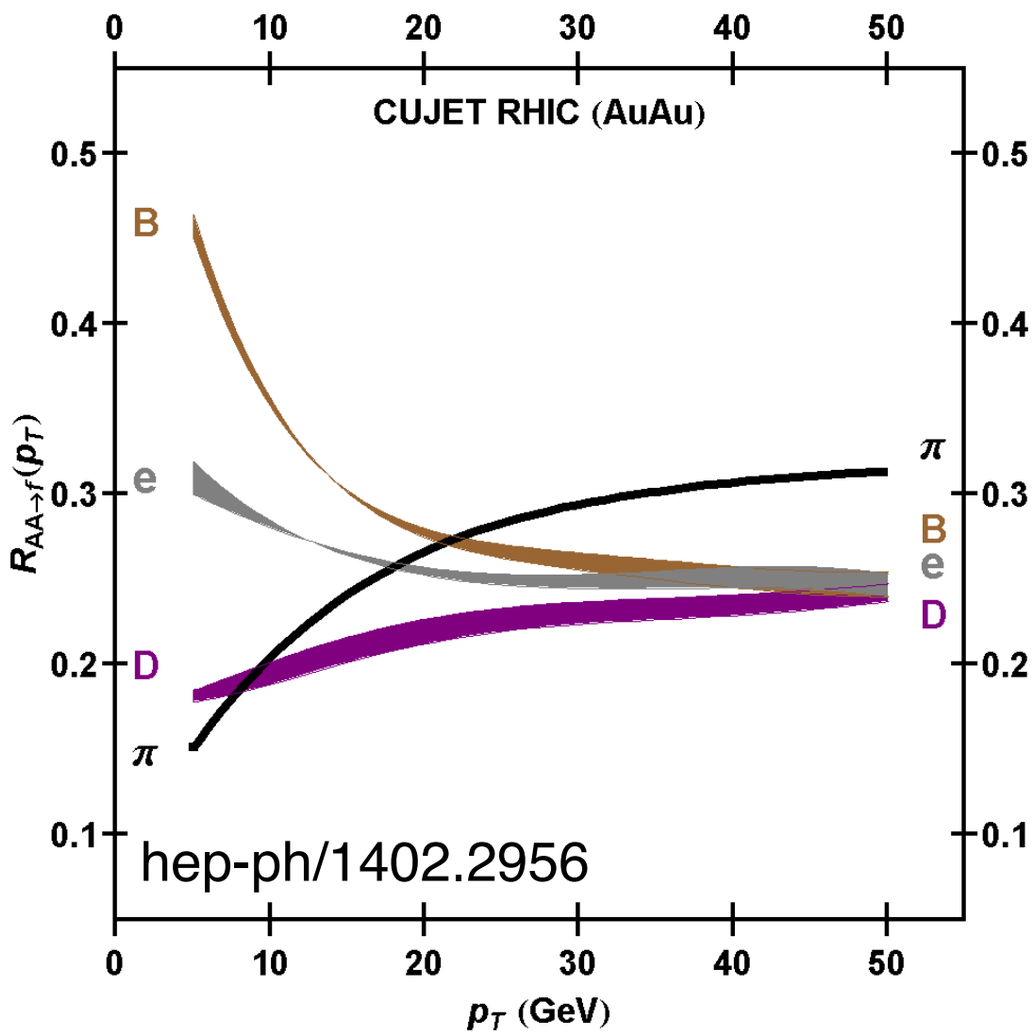
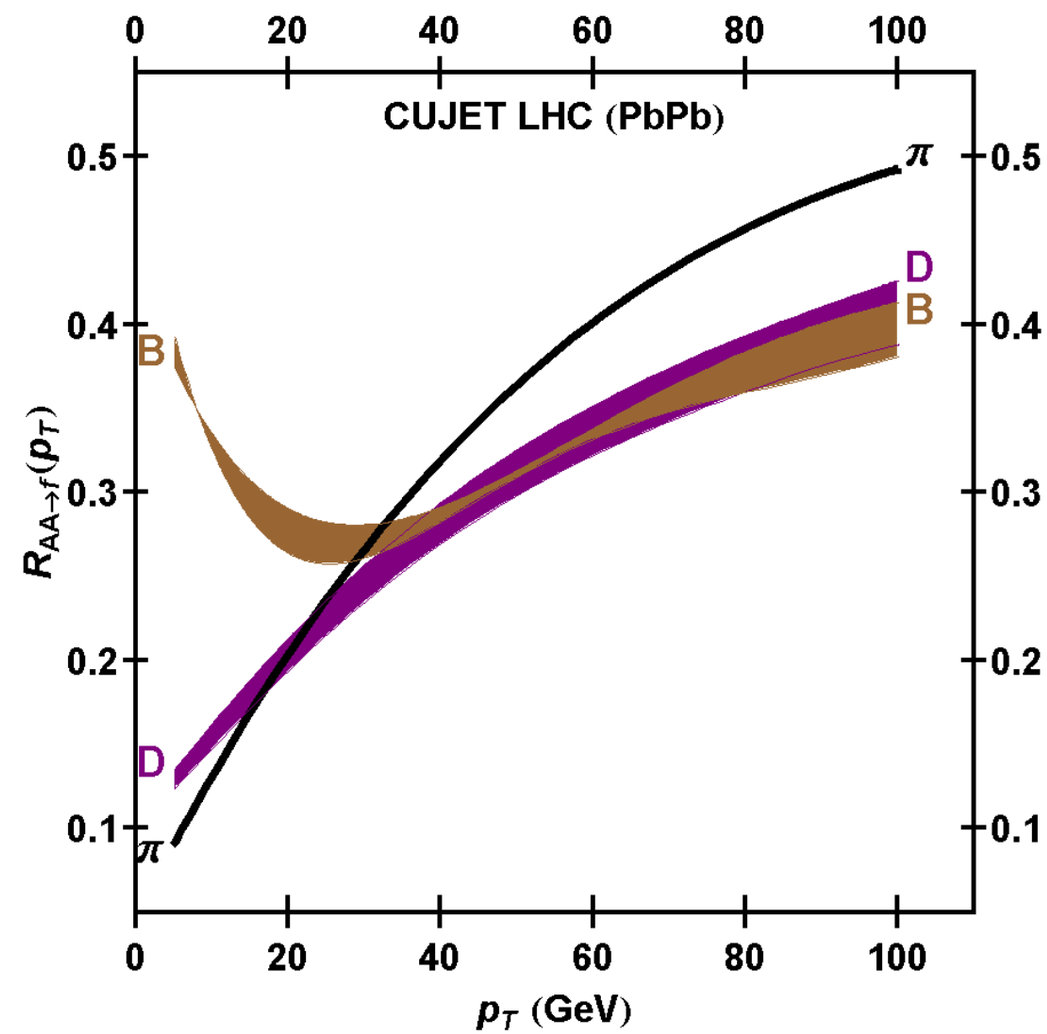
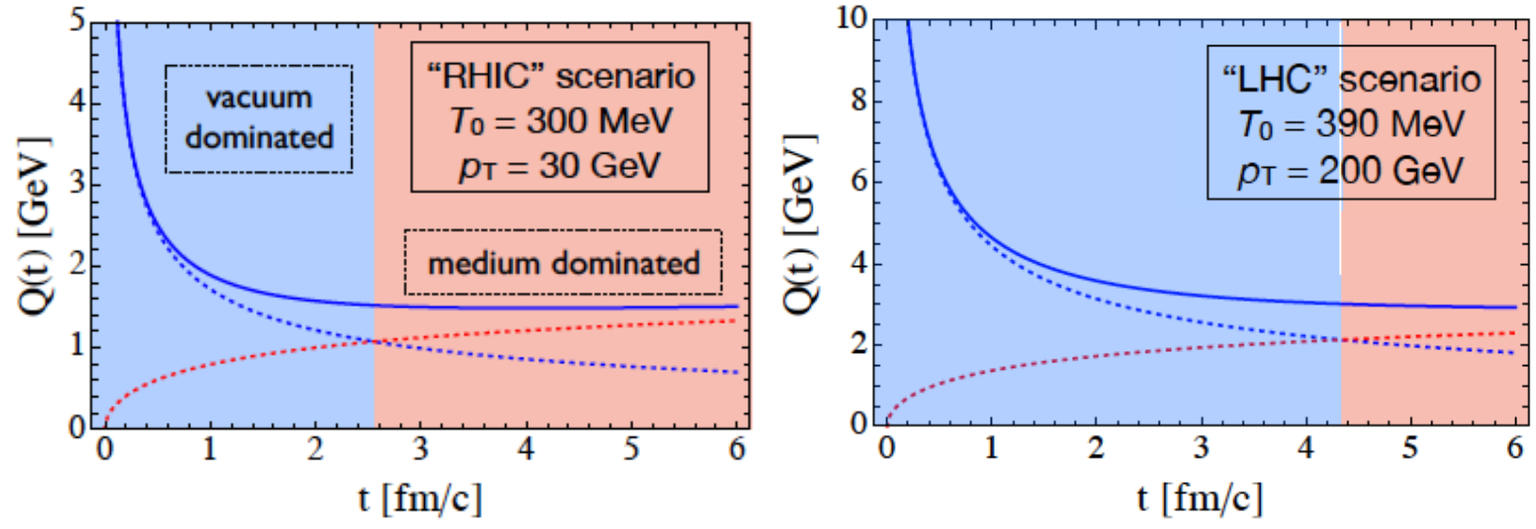


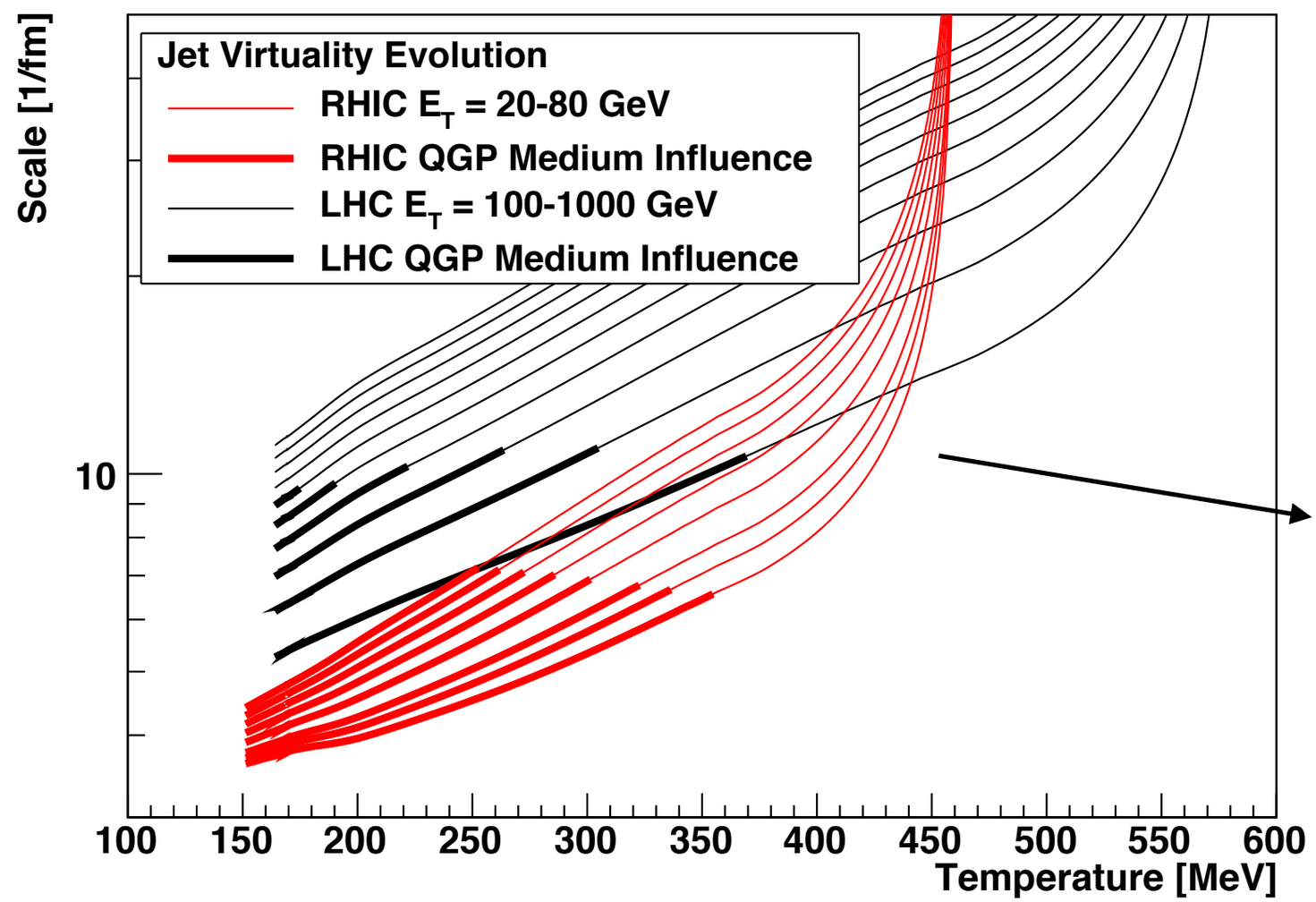


Evolution of Jet Virtuality

How does the QGP evolve along with the parton shower?

B. Muller talk given at RHIC/AGS Users Meeting '11





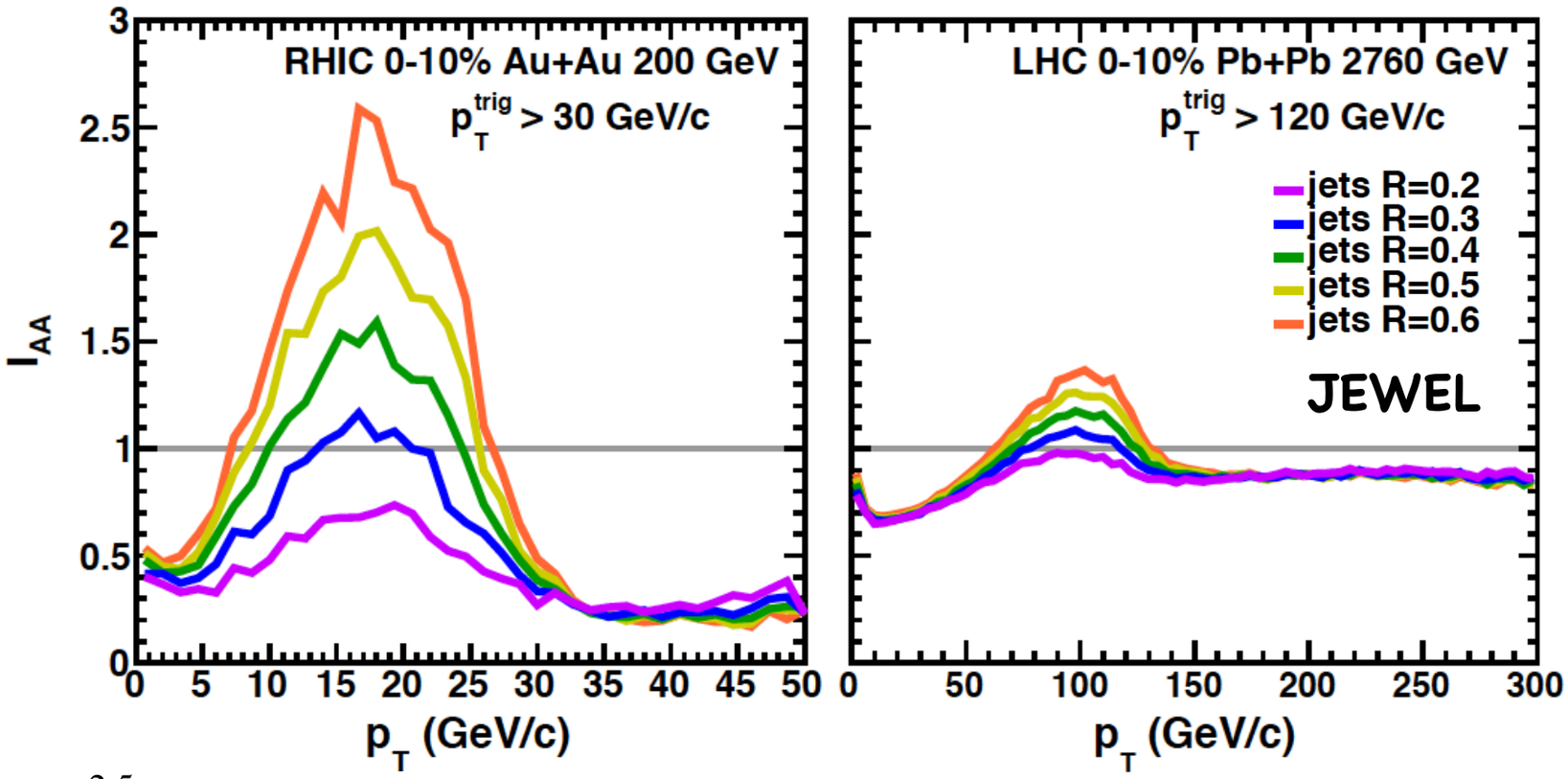
Parton splitting modified while **medium influence** dominates

RHIC and LHC have different sensitivity to medium

Overlapping jet energies will provide important constraints

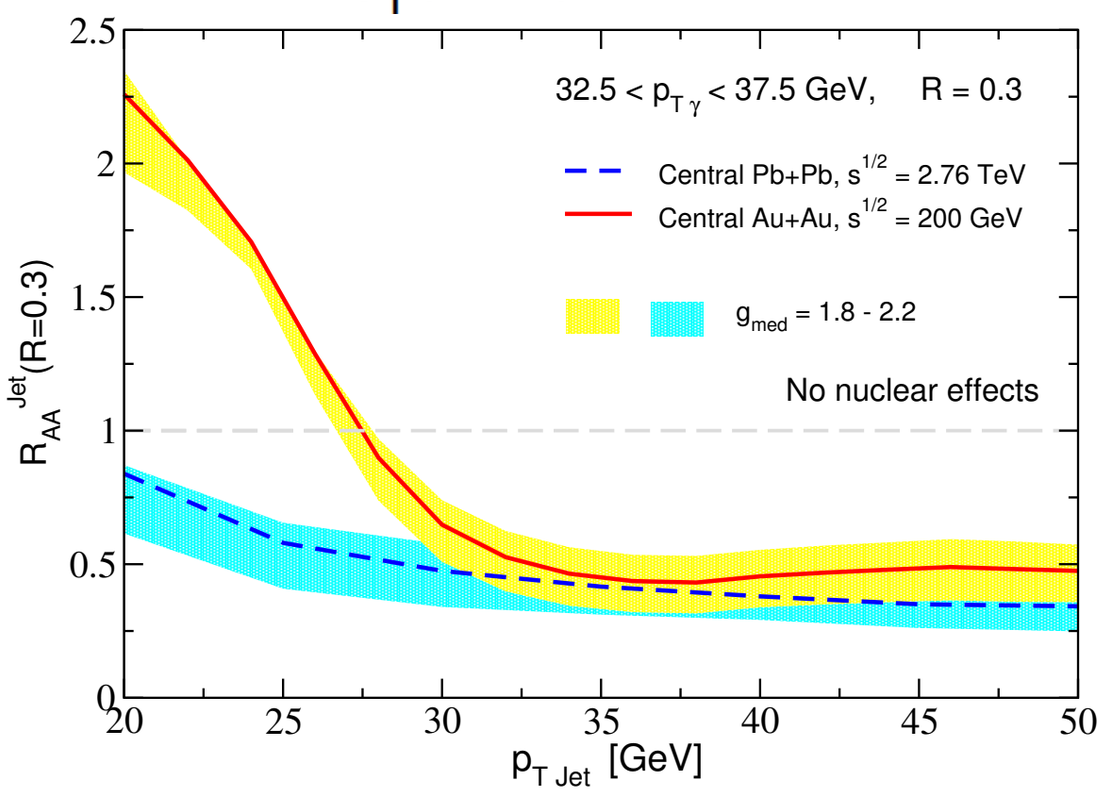
Predicted RHIC vs LHC

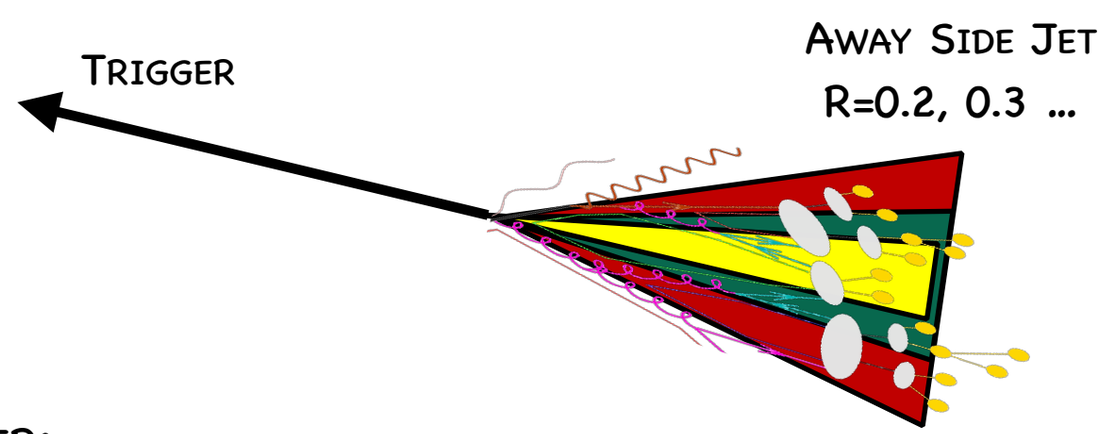
Many observables where greater sensitivity expected at RHIC



Trigger:

High p_T track

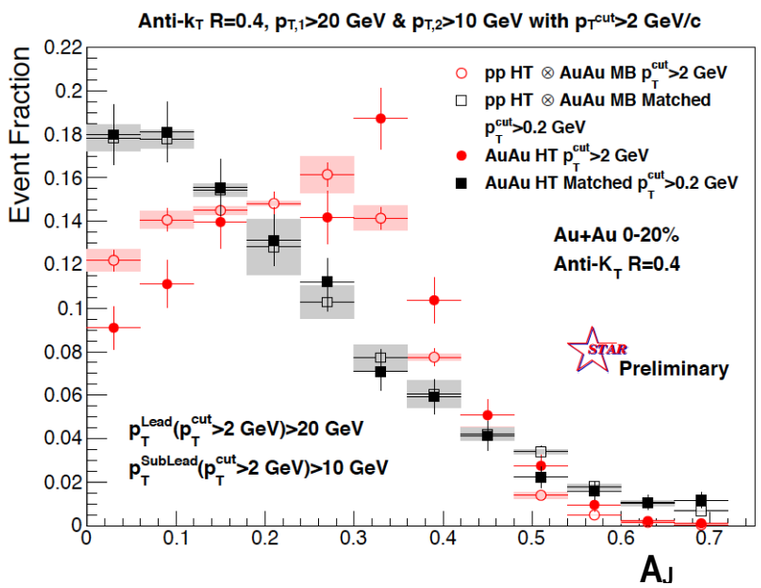




Trigger:

High p_T photon

RHIC vs LHC now



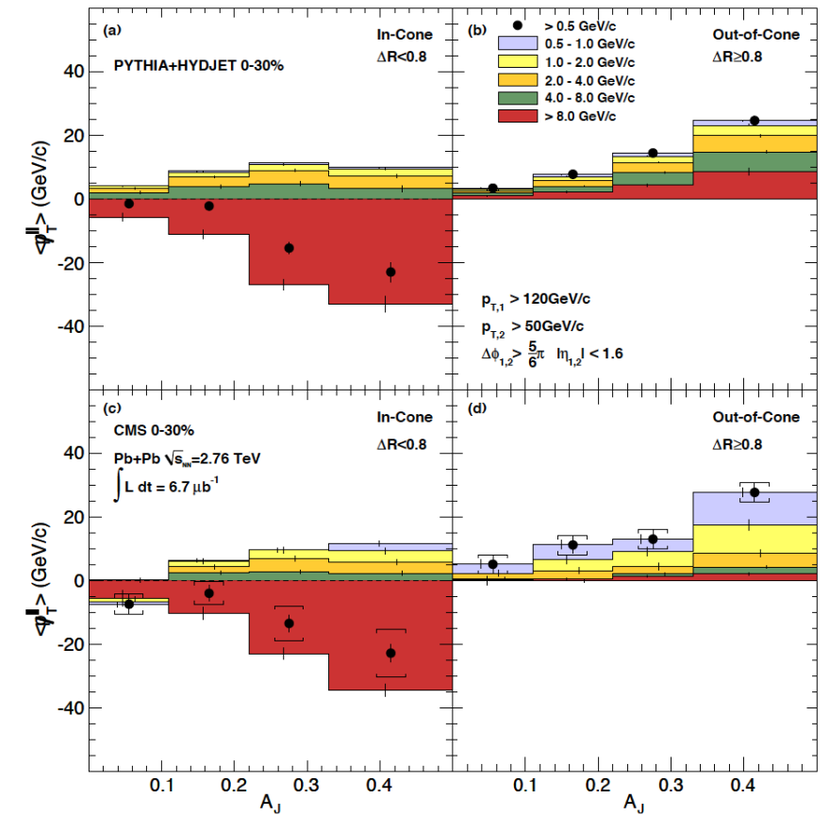
Energy recovered:

INSIDE the jet cone

at **RHIC**

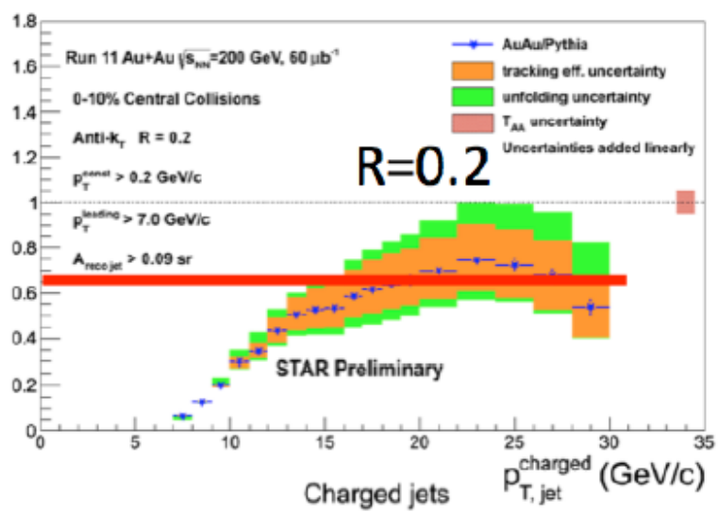
OUTSIDE the jet cone

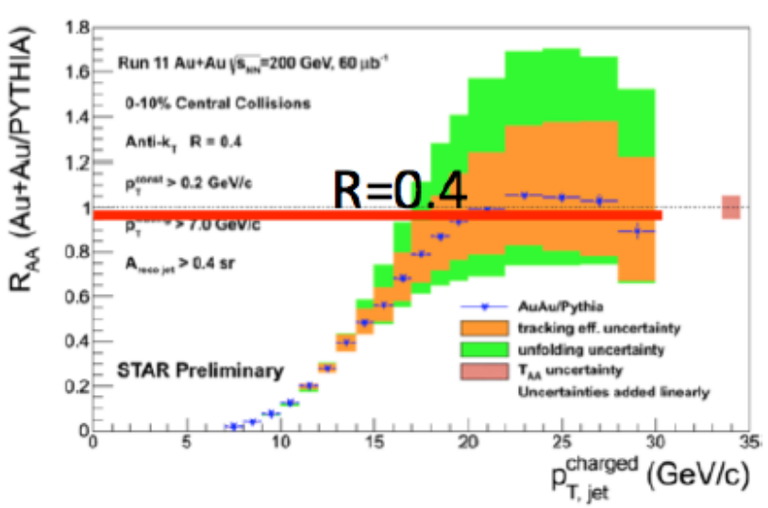
at **LHC**



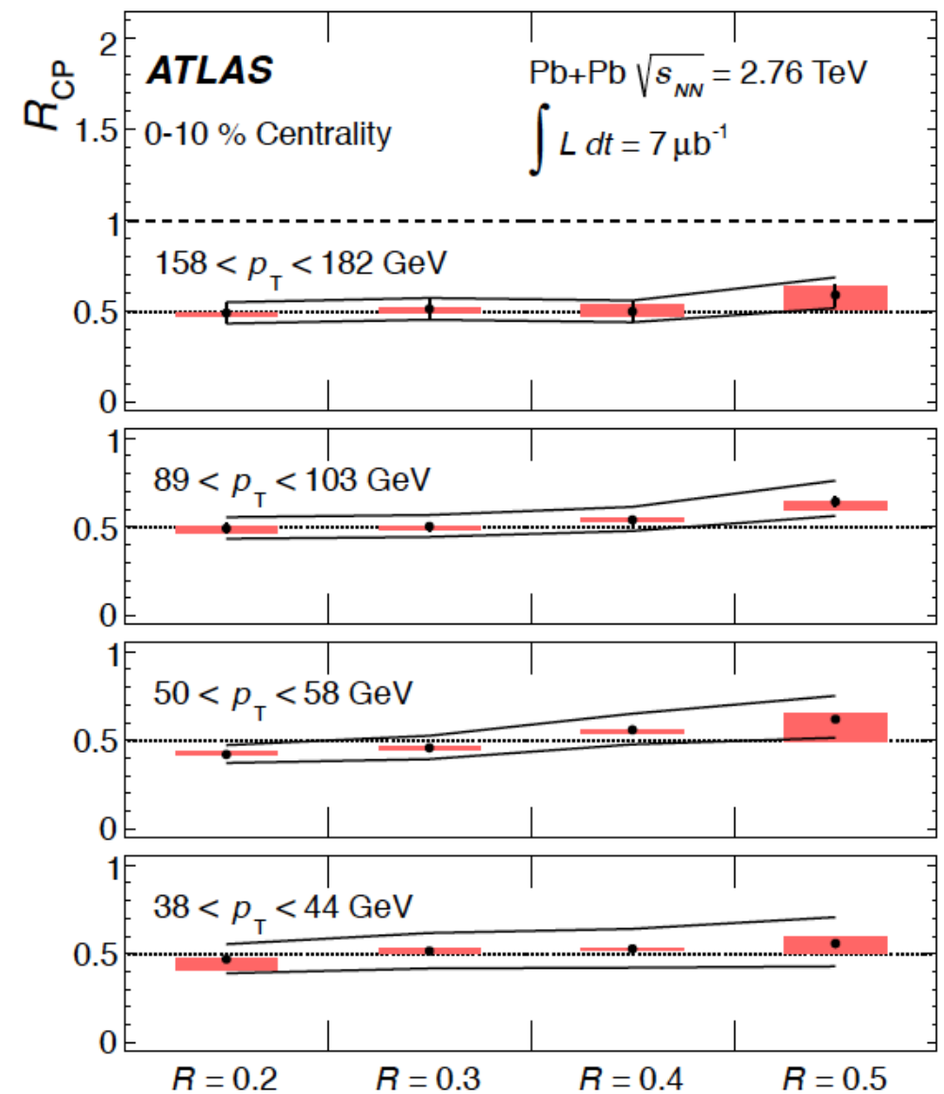
nucl-ex/1102.1957

RHIC vs LHC now





Stronger R dependence at RHIC



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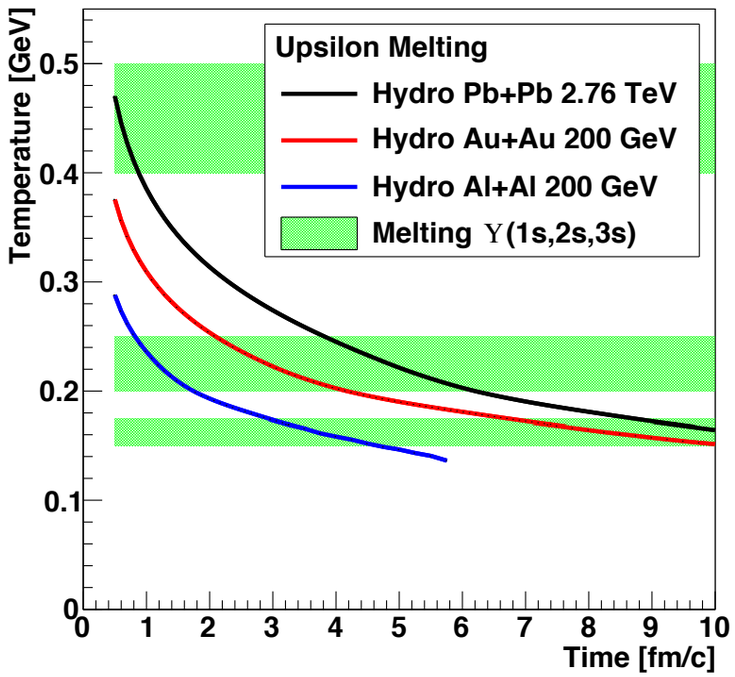
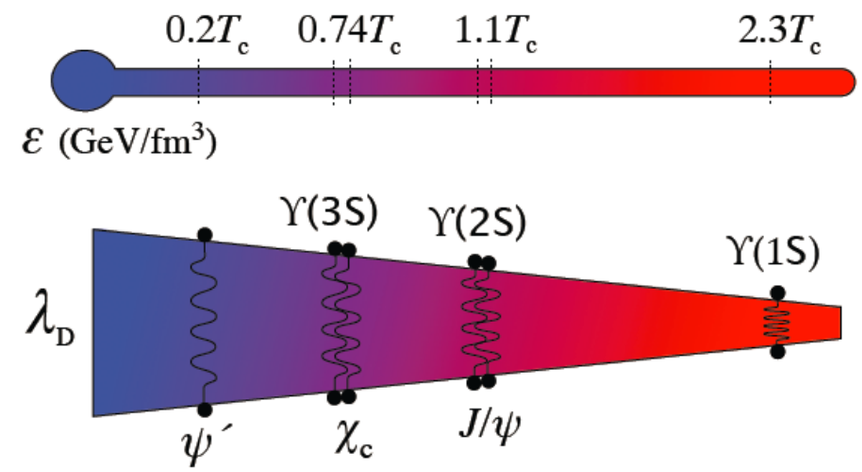
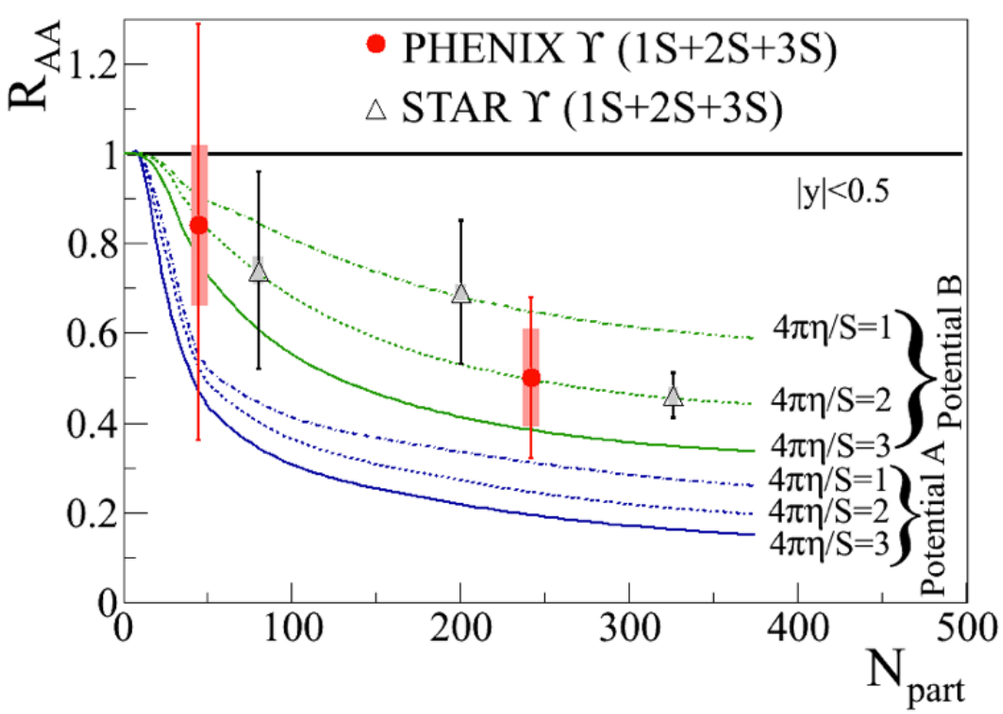
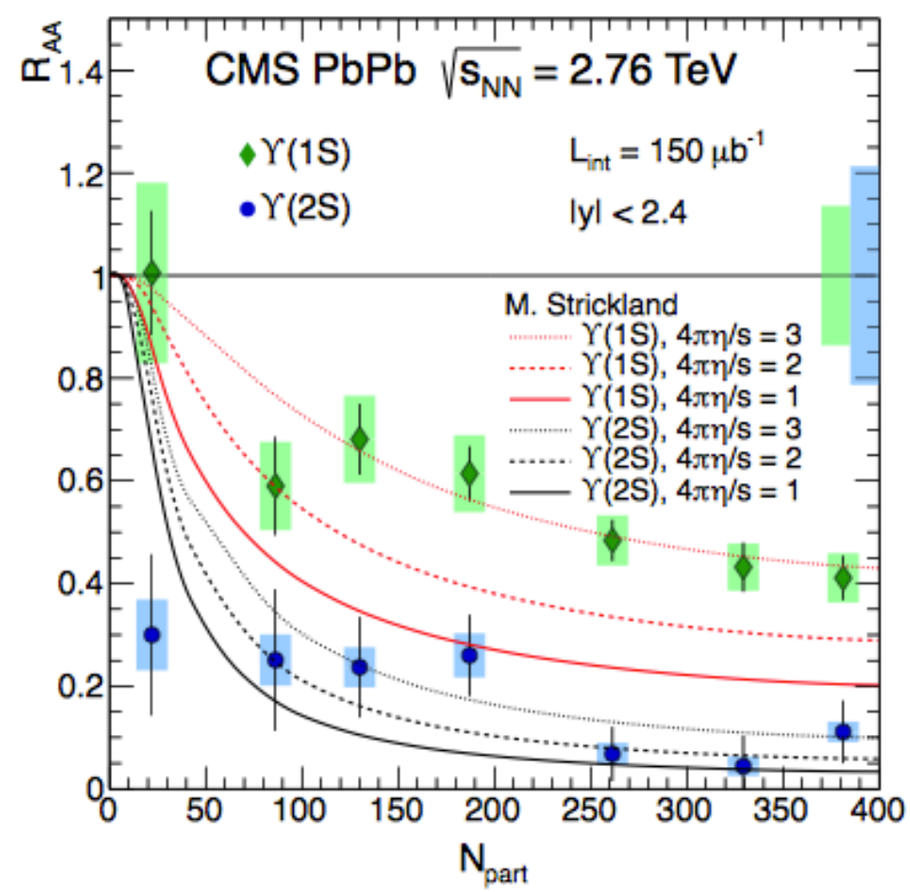
Color screening



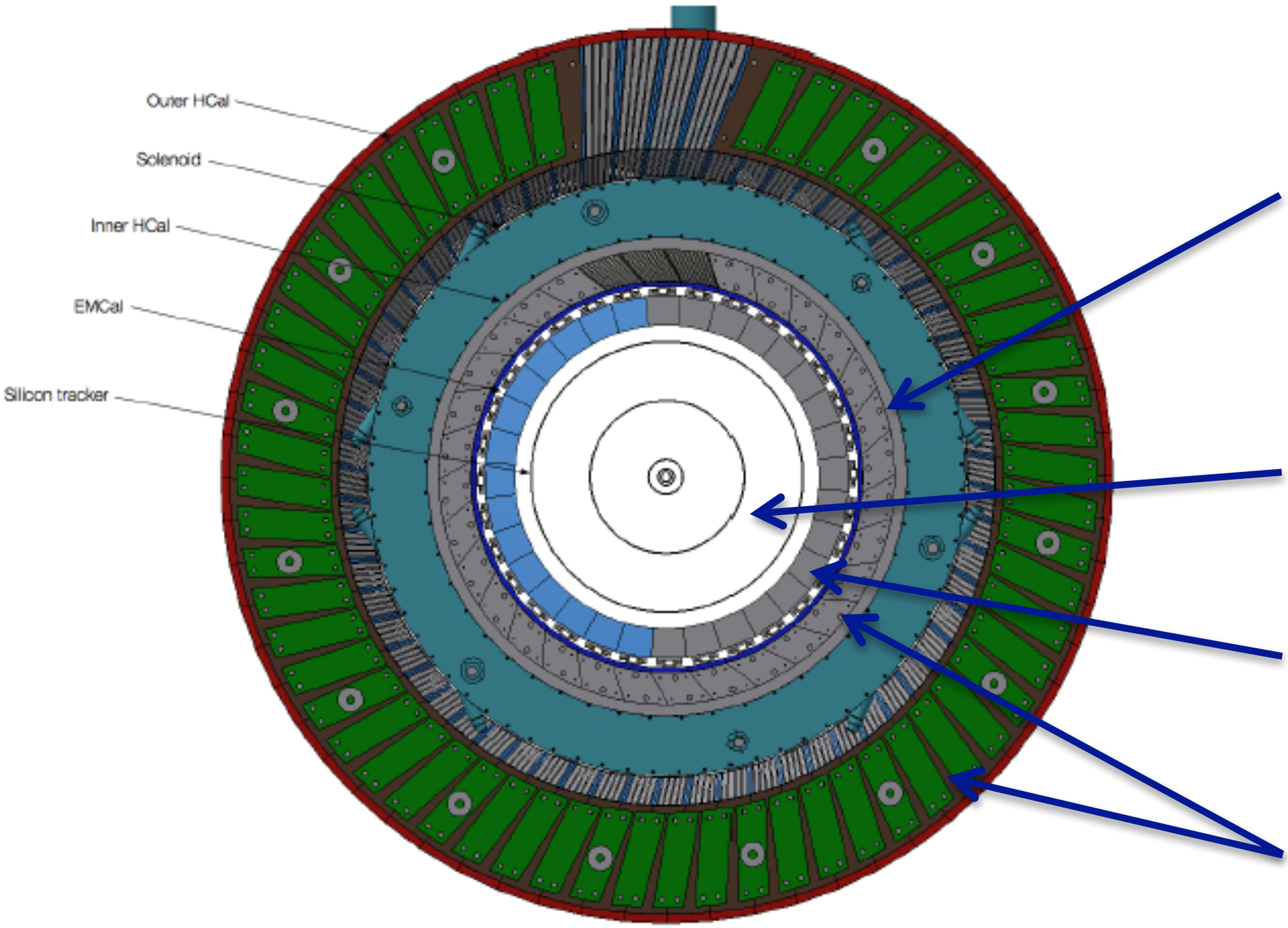
Differences in temperature and rate -> differences in screening environment and coalescence effects







Detector Design



BaBar Magnet 1.5 T

Coverage $|\eta| < 1.1$

All silicon tracking
Heavy flavor
tagging

Electromagnetic
Calorimeter

Two longitudinal
Segment Hadronic
Calorimeter

High data acquisition rate capability ~ 15 kHz

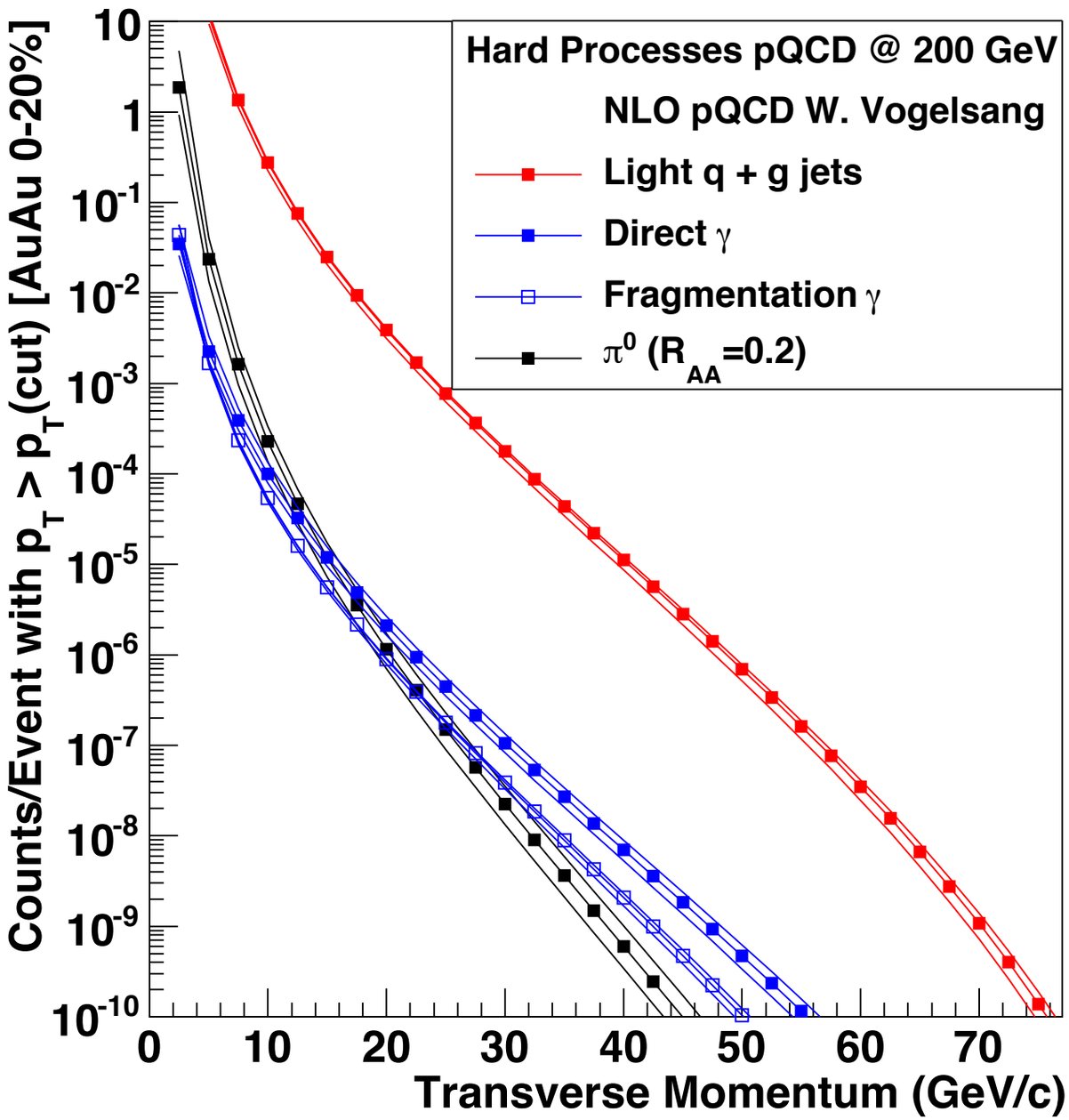
The BaBar magnet has arrived!

left SLAC Jan. 16th

arrived at BNL Feb. 6th

www.symmetrymagazine.org/article/january-2015/20-ton-magnet-heads-to-new-york

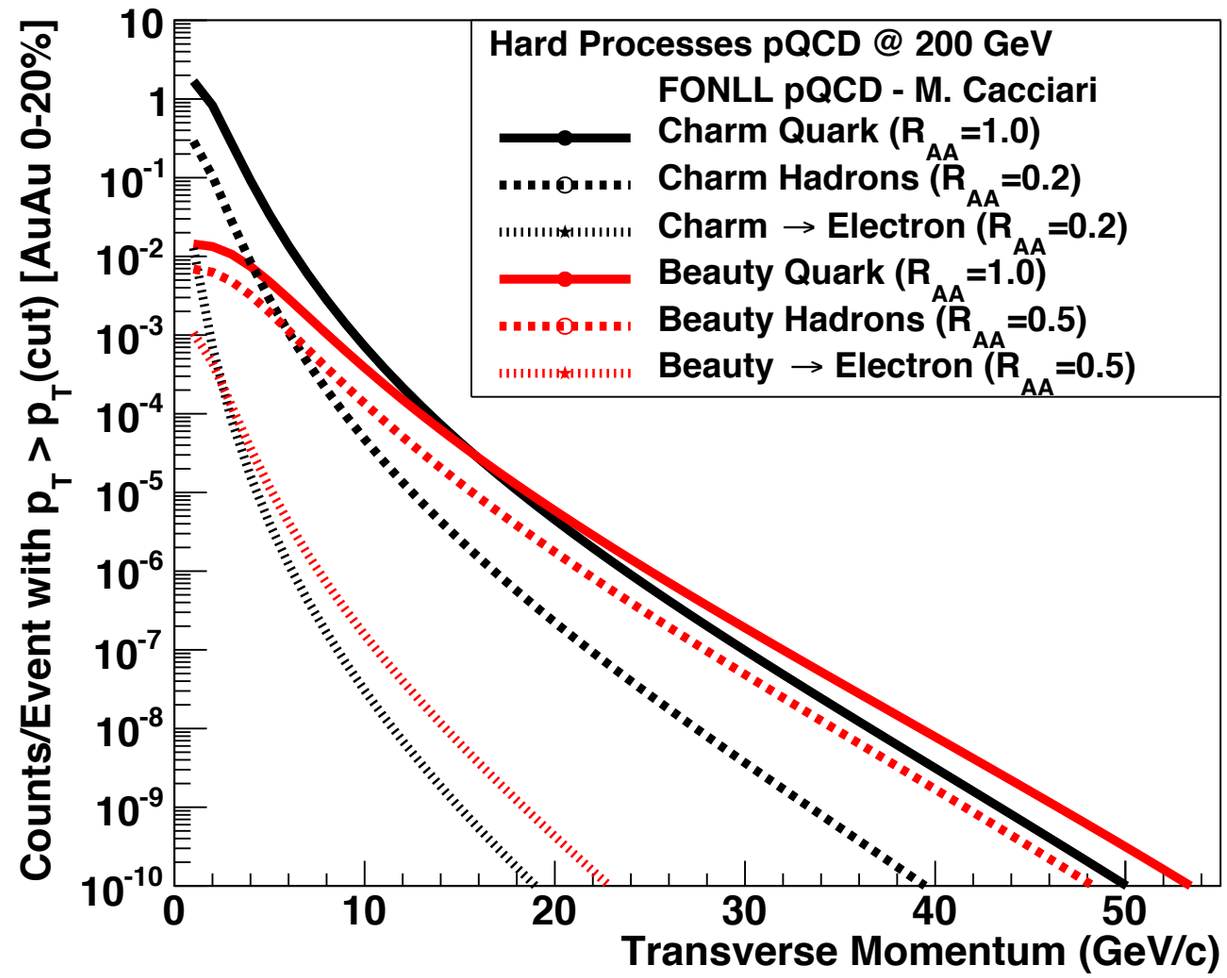
Expected Rates



RHIC II + sPHENIX can record

50 billion events

within |z|<10cm in 20-weeks

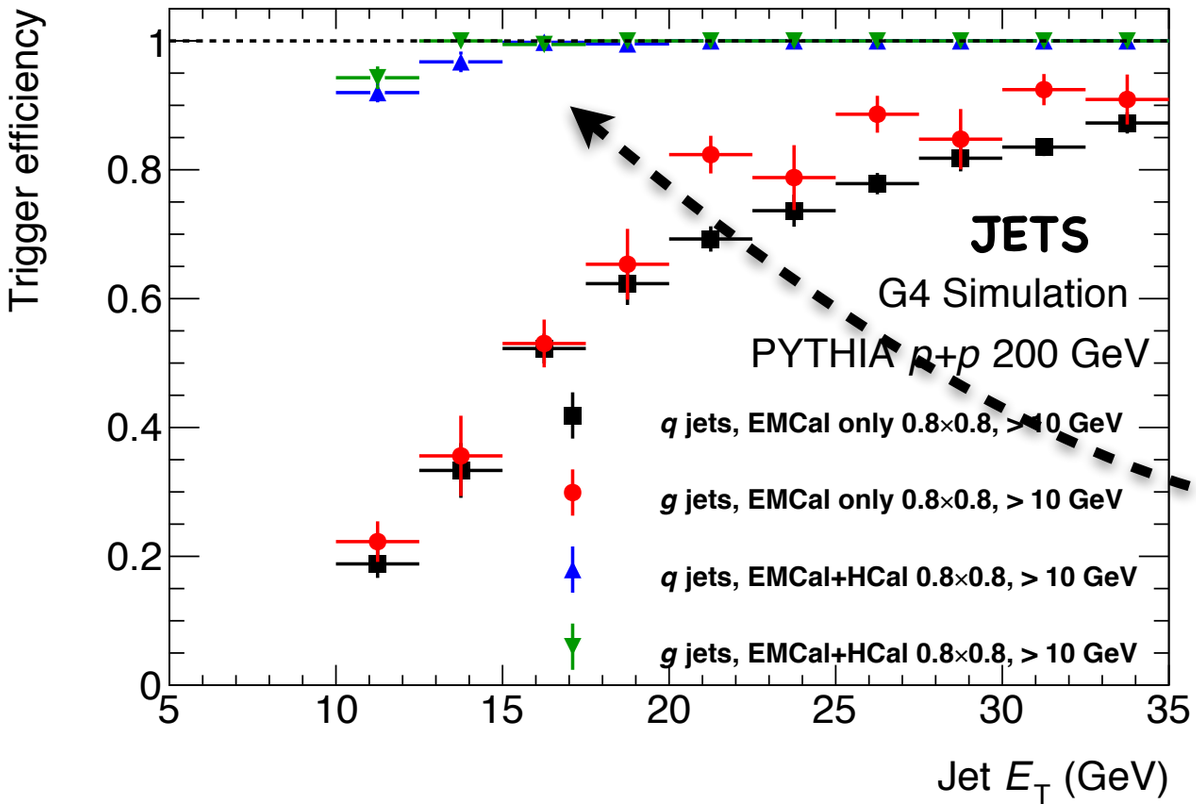


Min. Bias ~ **9,000 jets > 50 GeV** in central events

10^5 photons/b-jets > 20 GeV

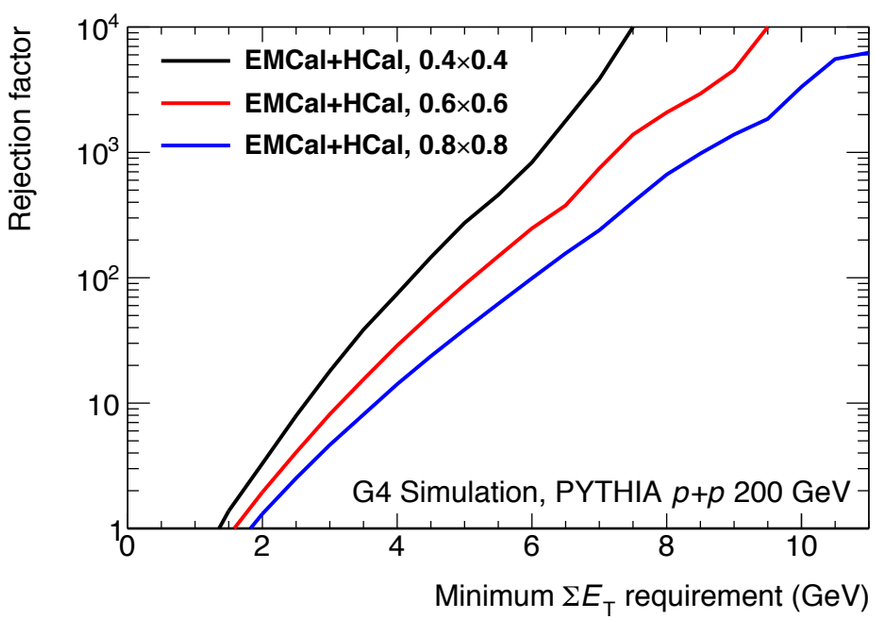
Critical similar statistics in p+p and p+A

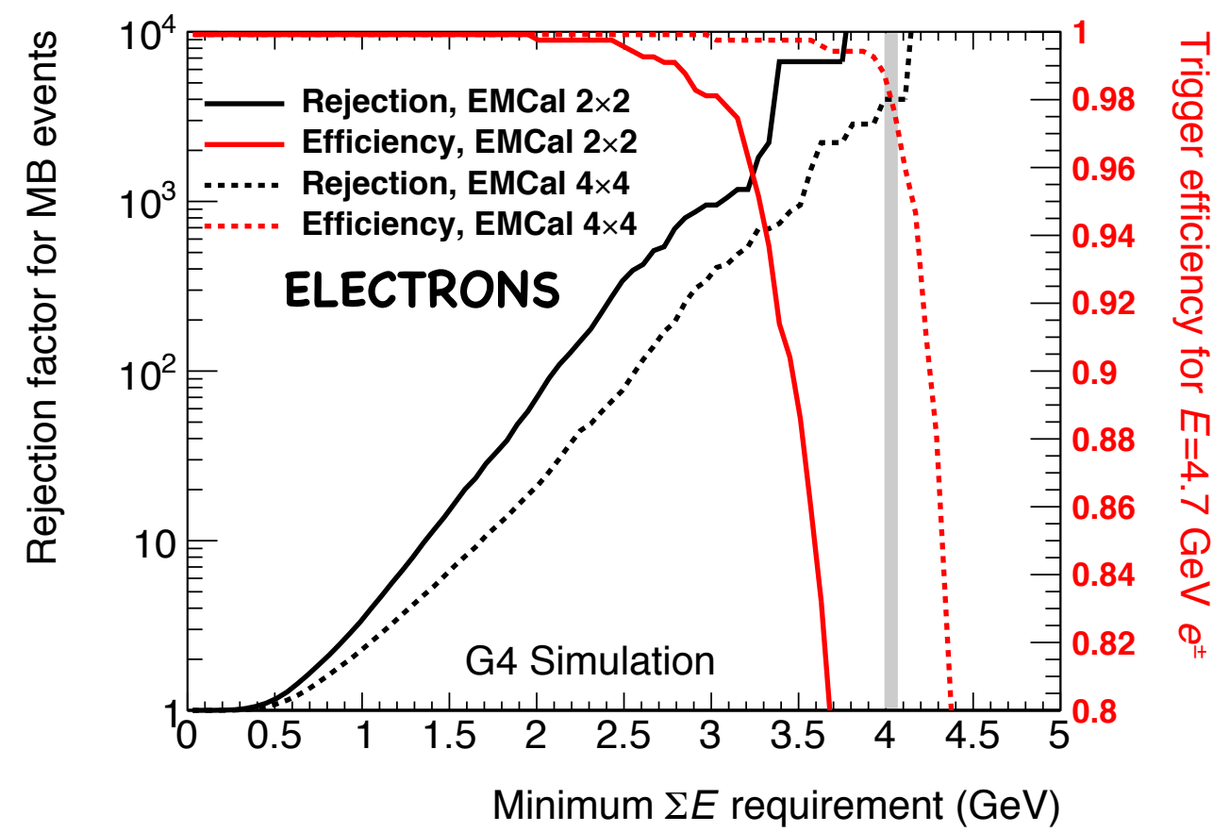
Triggering



New C-AD projection will allow Au+Au sampling of <u>0.5 trillion events</u>

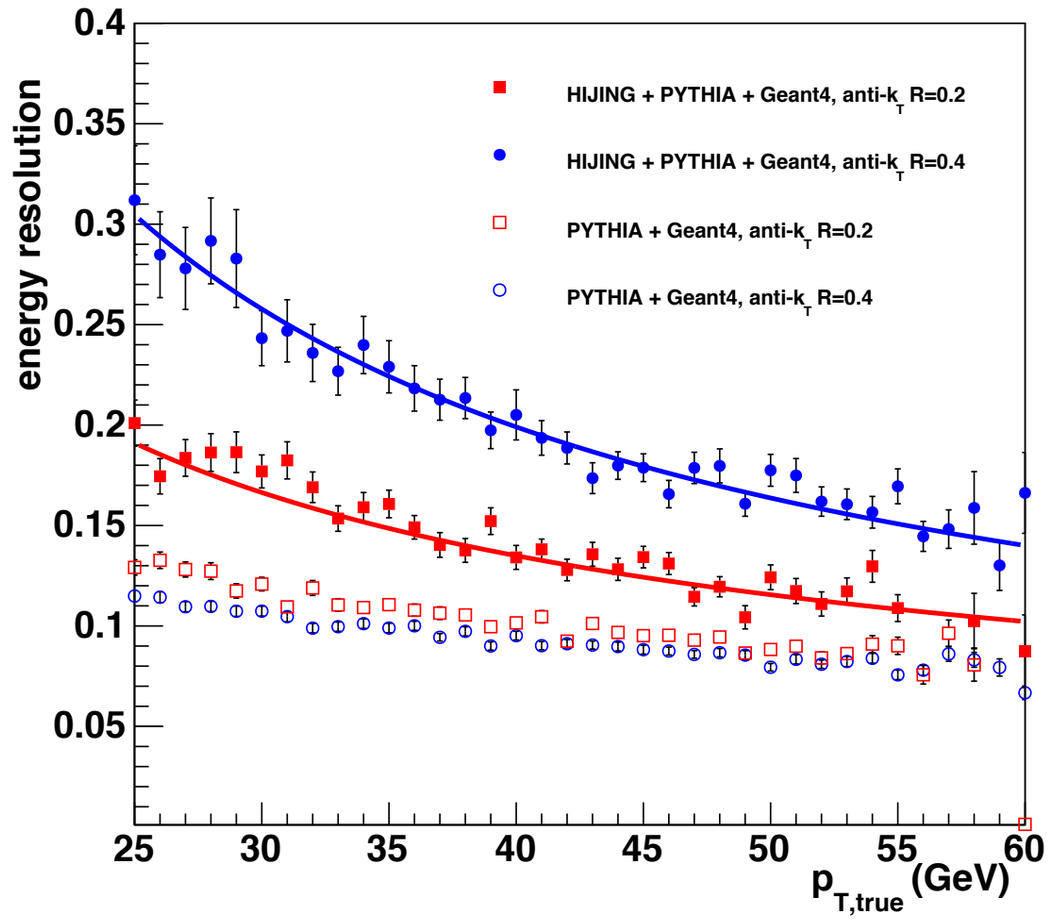
Full Calorimeter Trigger improves efficiency and removes potential flavor biases





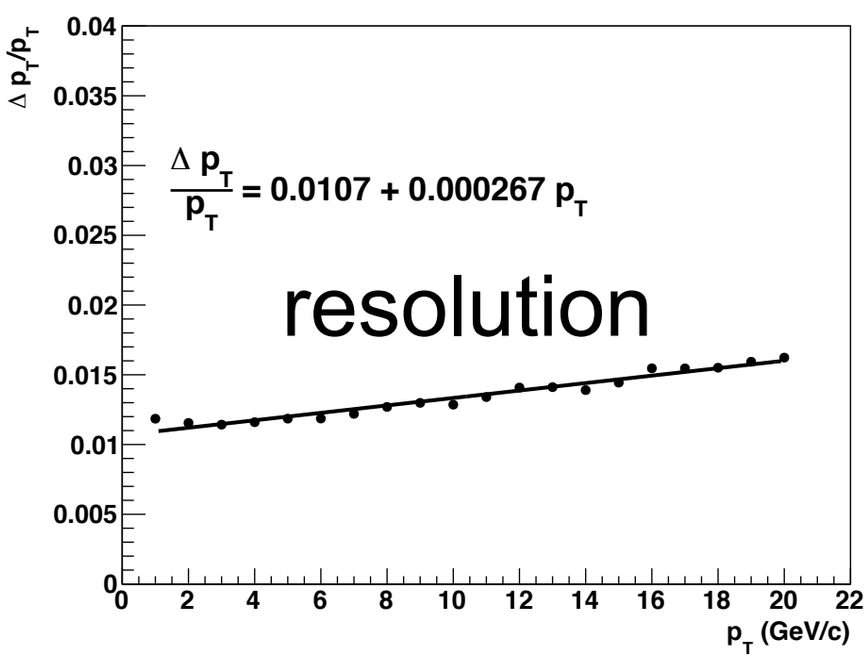
sPHENIX full calorimeter Trigger ~ 50,000 jets > 50 GeV in central events

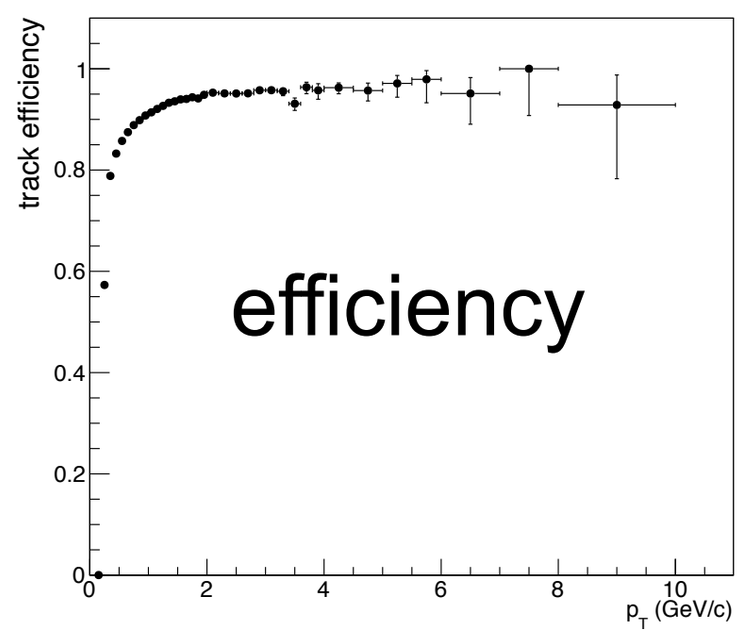
Detector capabilites

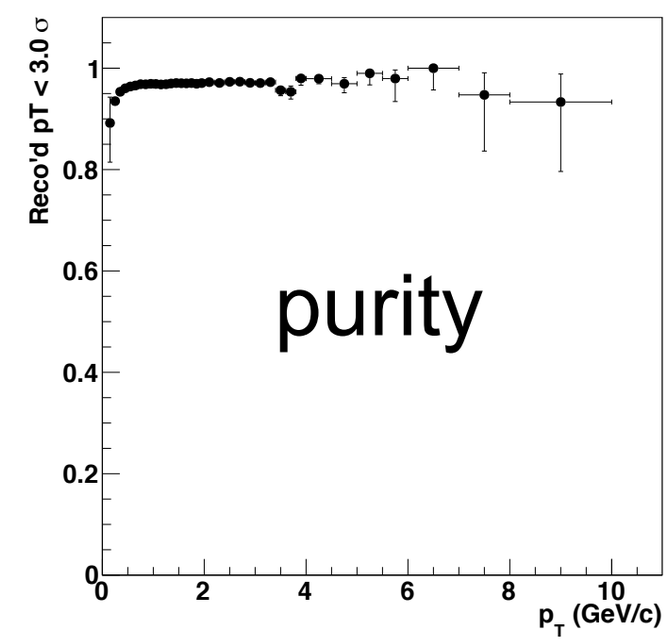


Jet resolutions substantially better than required

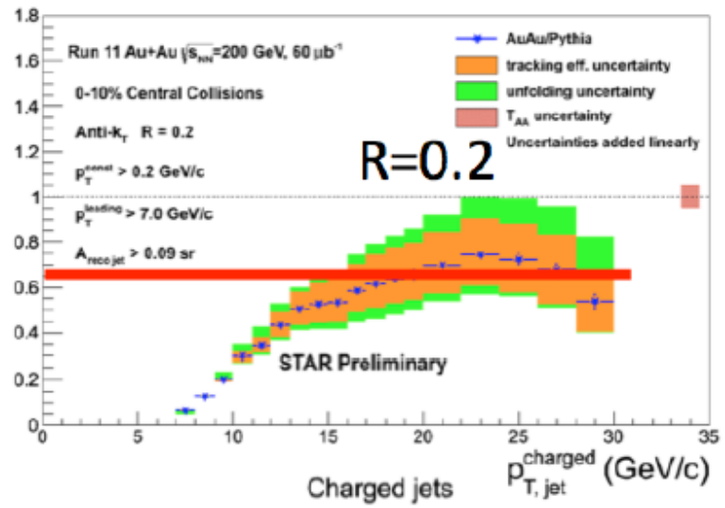
Precision tracking capabilities driven by desired Υ mass resolution (<100 MeV/c^2)

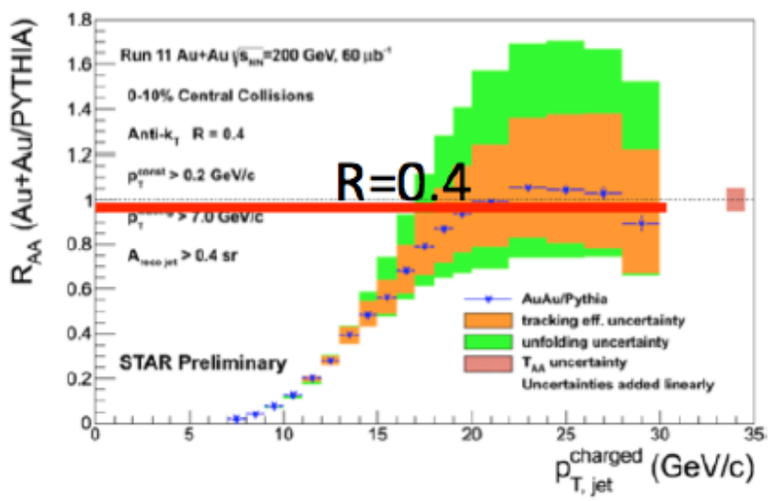


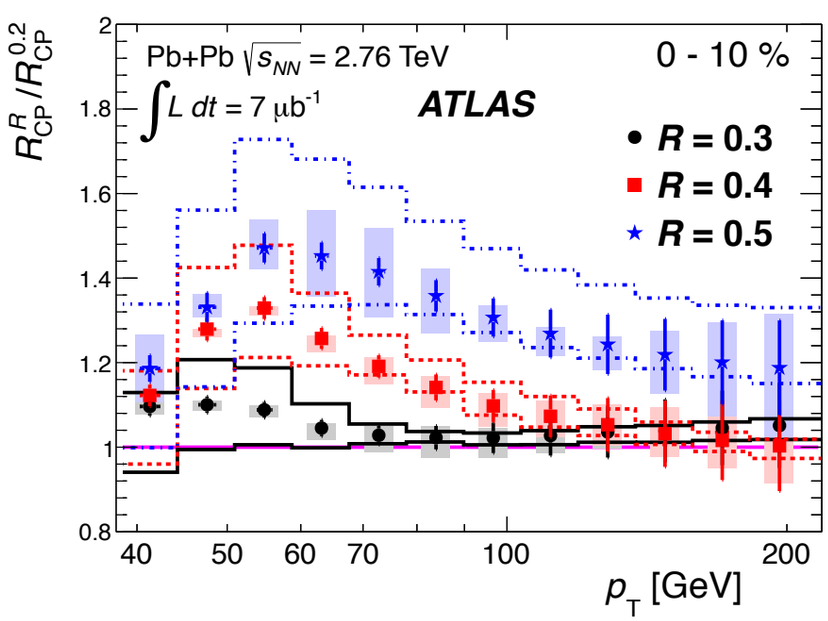


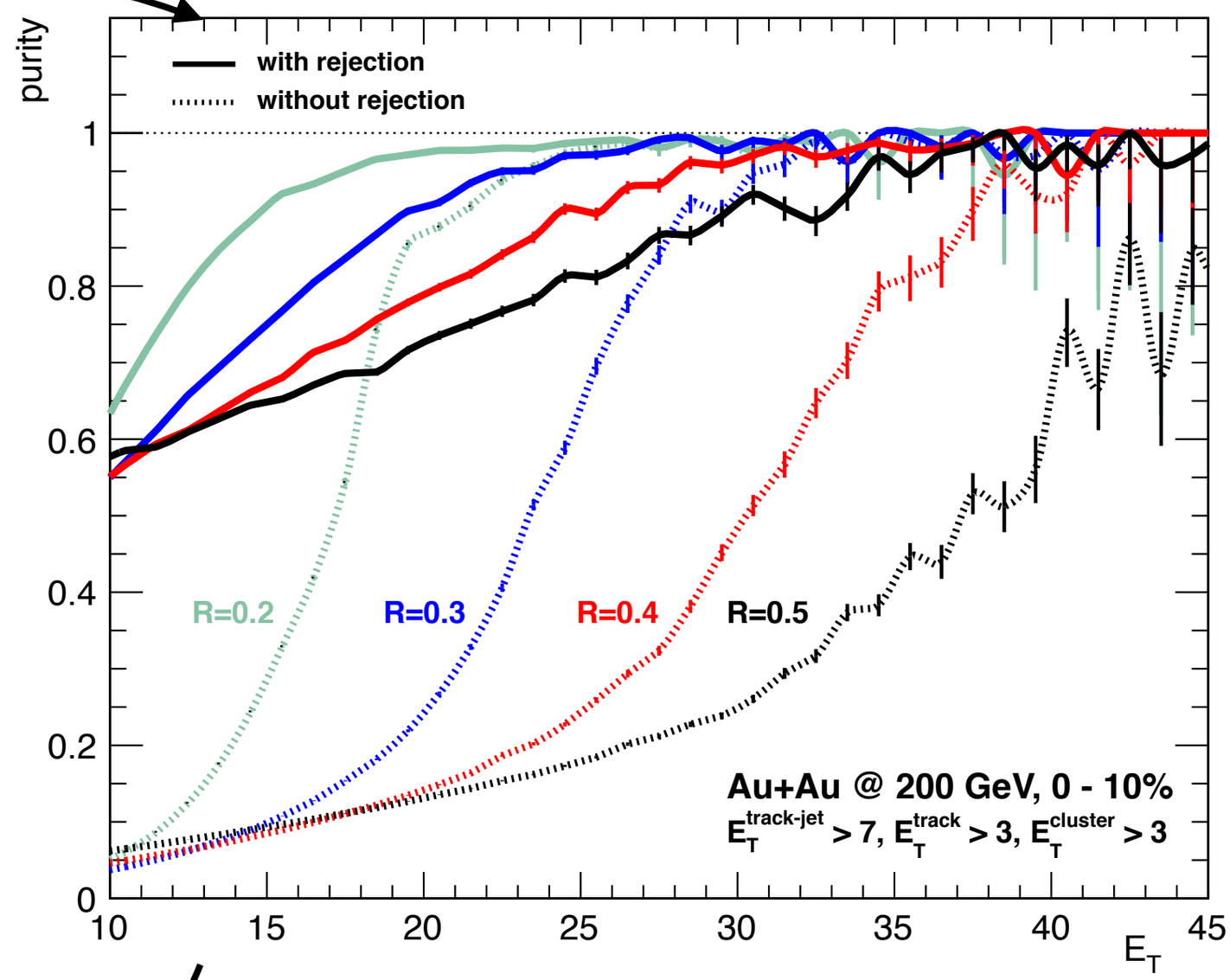


EXTENDING KINEMATIC REACH



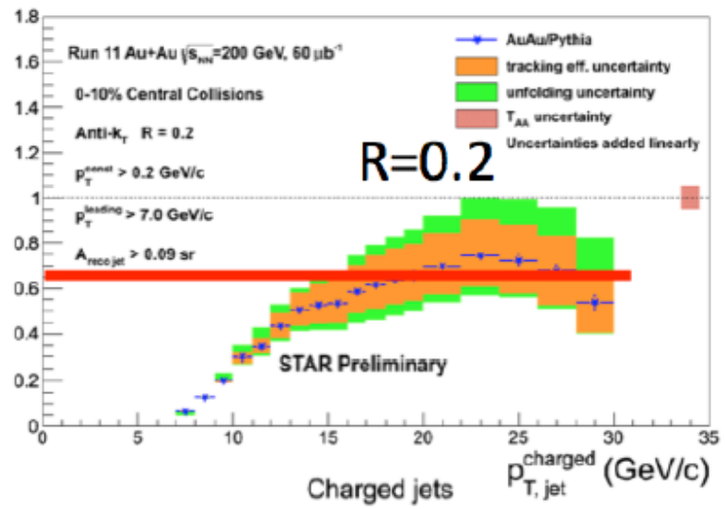


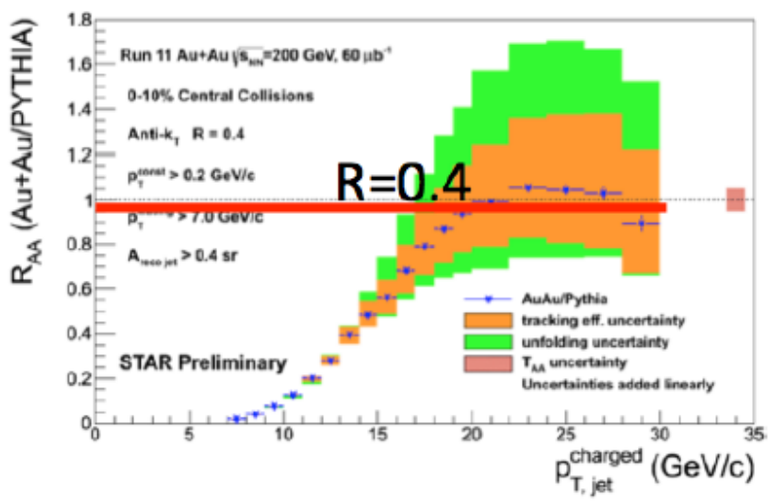


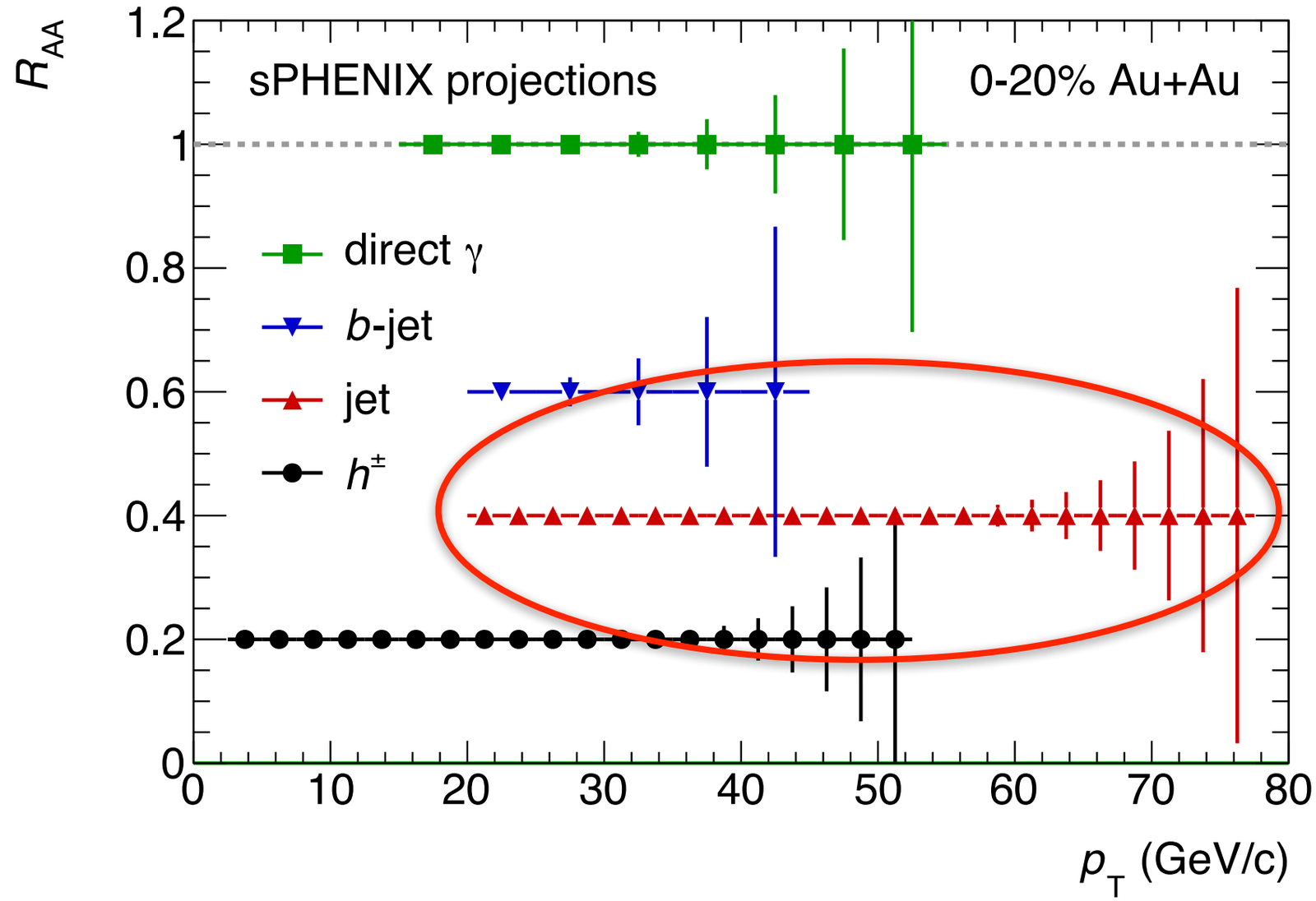


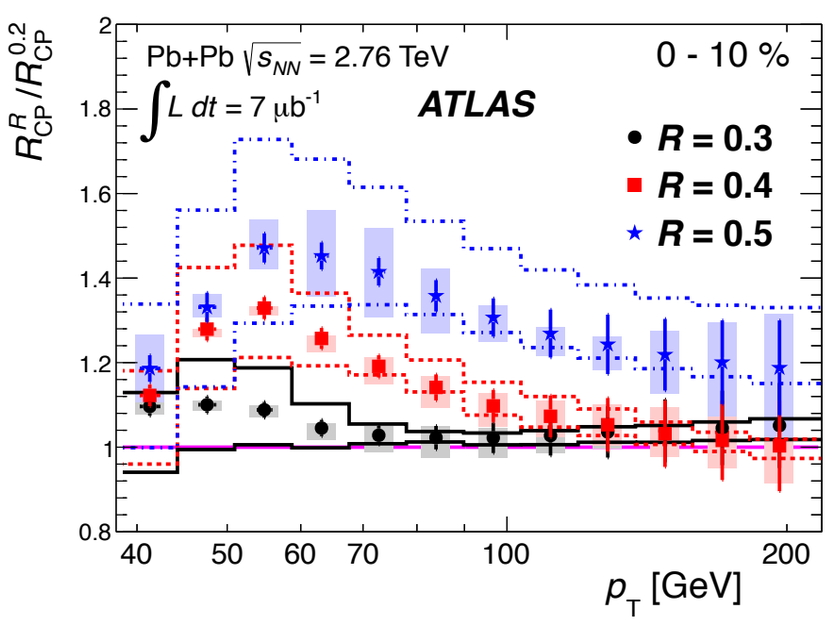
PURITY OF JETS RELATIVE TO BACKGROUND FLUCTUATIONS IMPROVED USING ATLAS-LIKE REJECTION (HIGH-p_T TRACK-JET OR CLUSTER)

EXTENDING KINEMATIC REACH





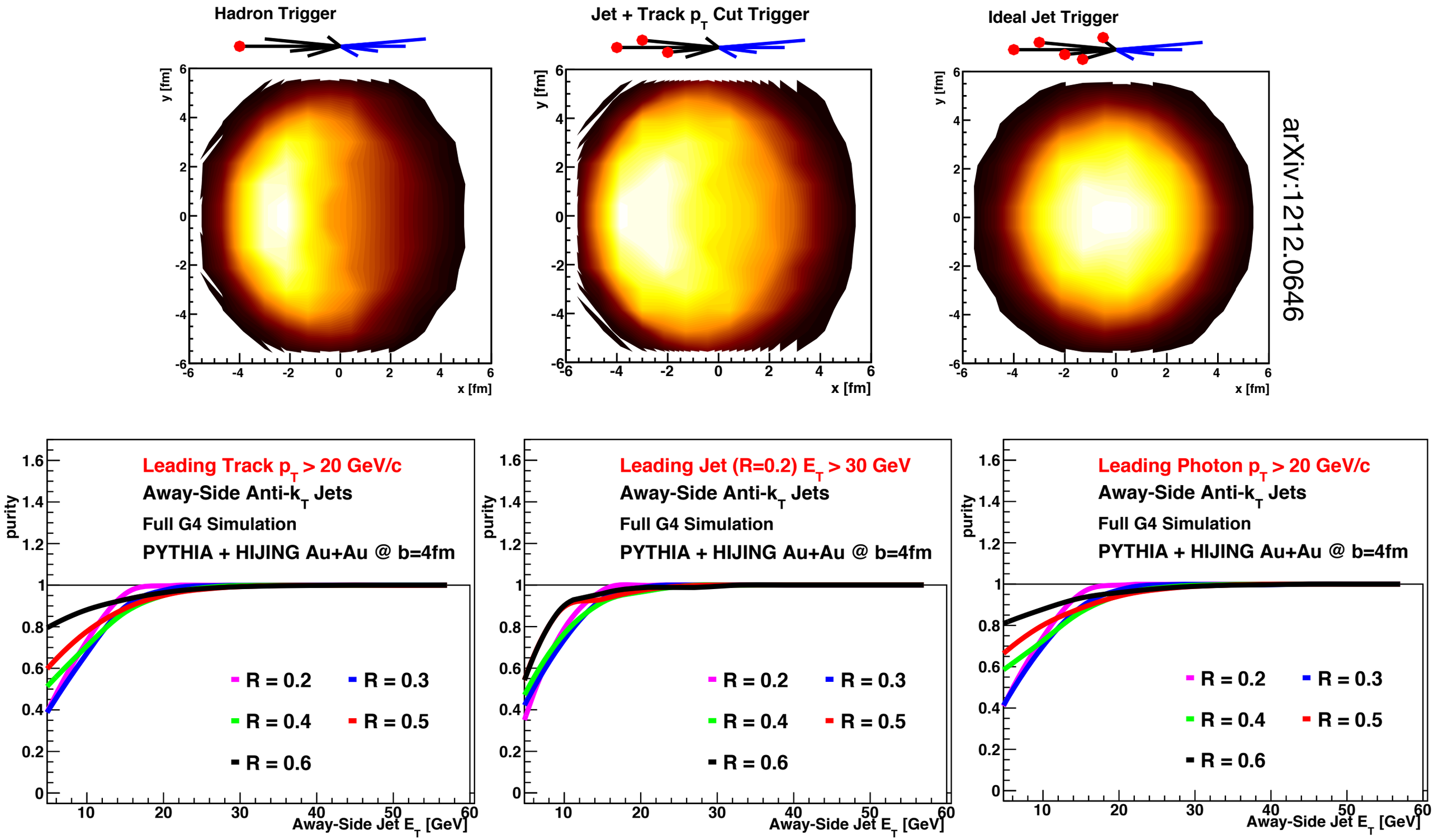




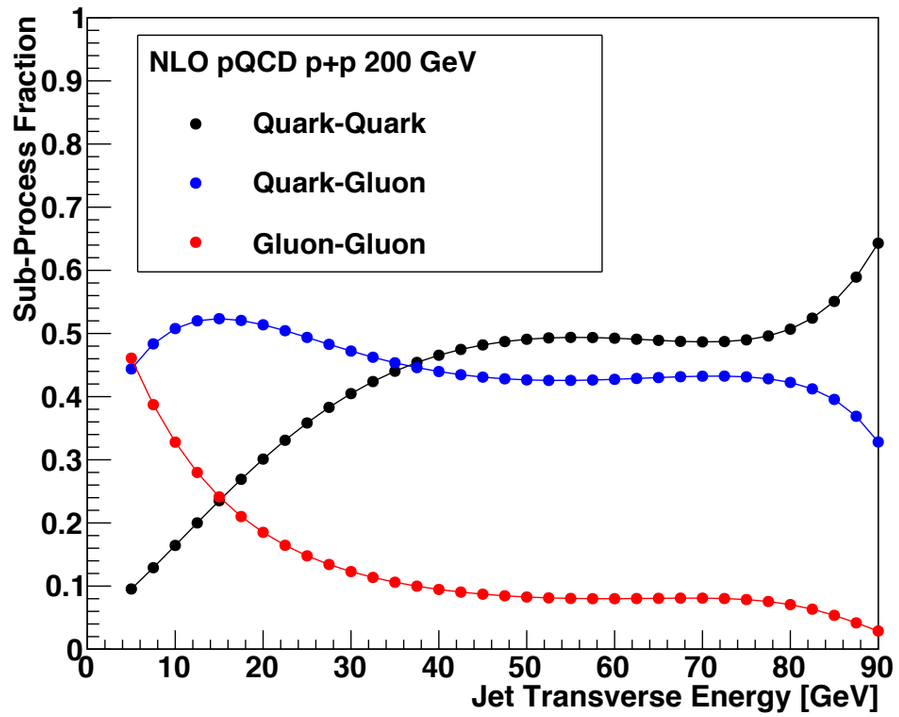
GOOD STATISTICS OUT TO 60 GEV

Learning from Surface Bias

Jet Surface Emission Engineering

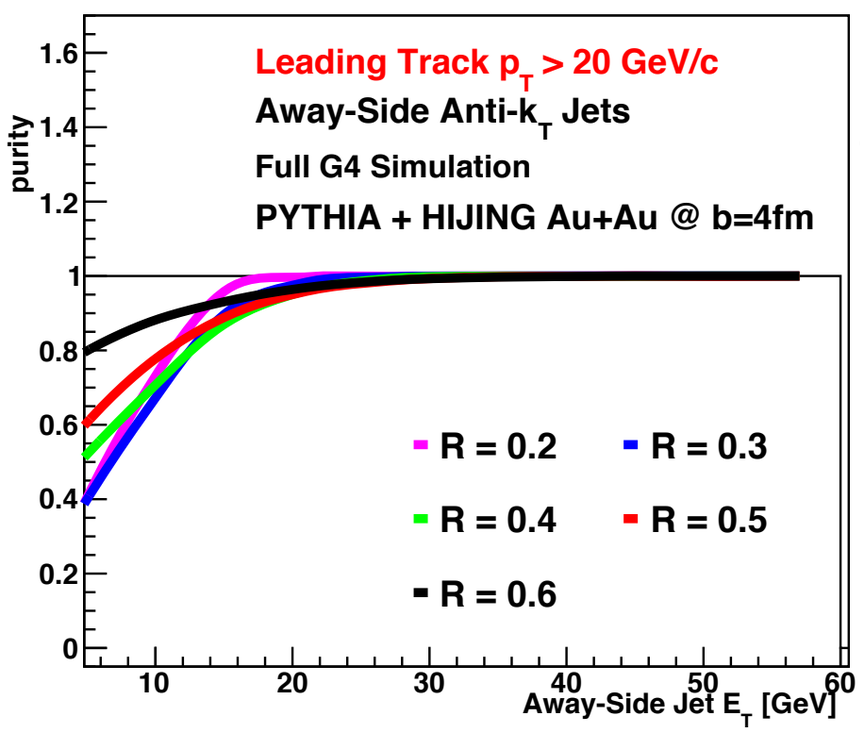


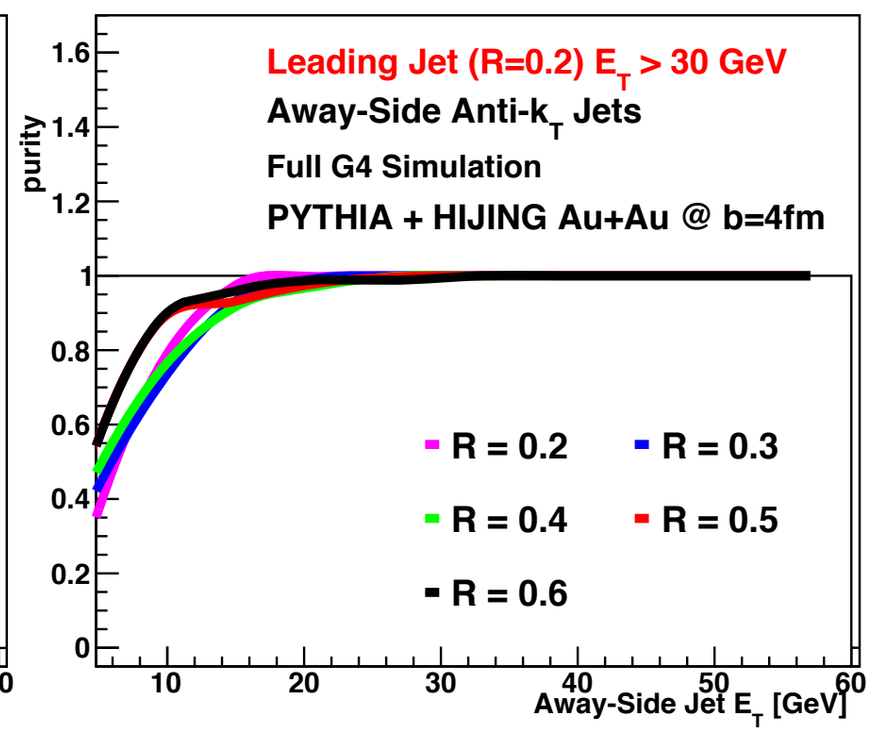
Flavor dependence

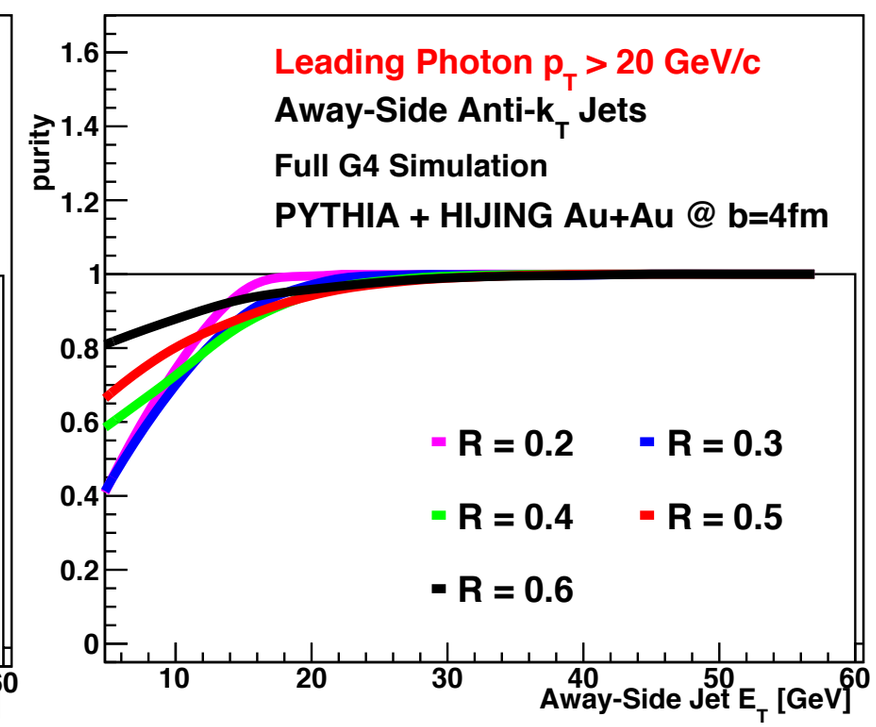


Gluon enhanced jets

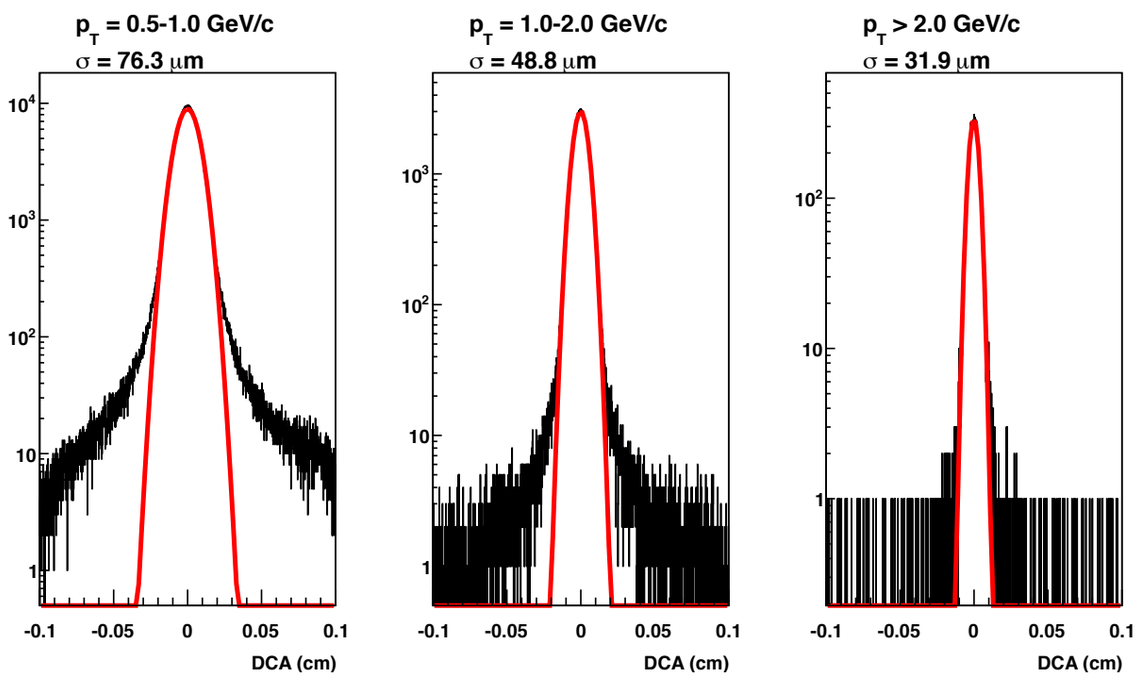
Quark enhanced jets

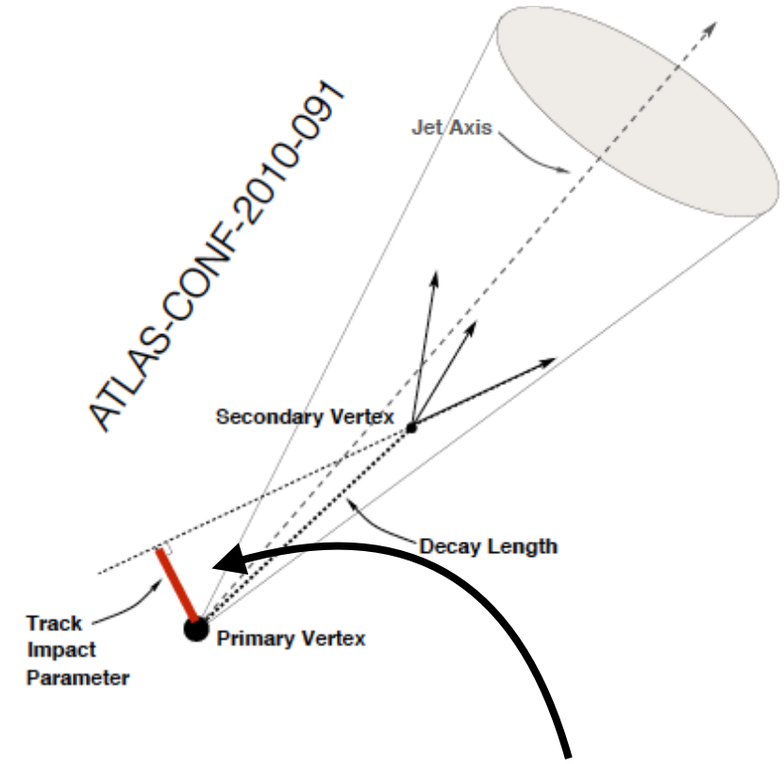


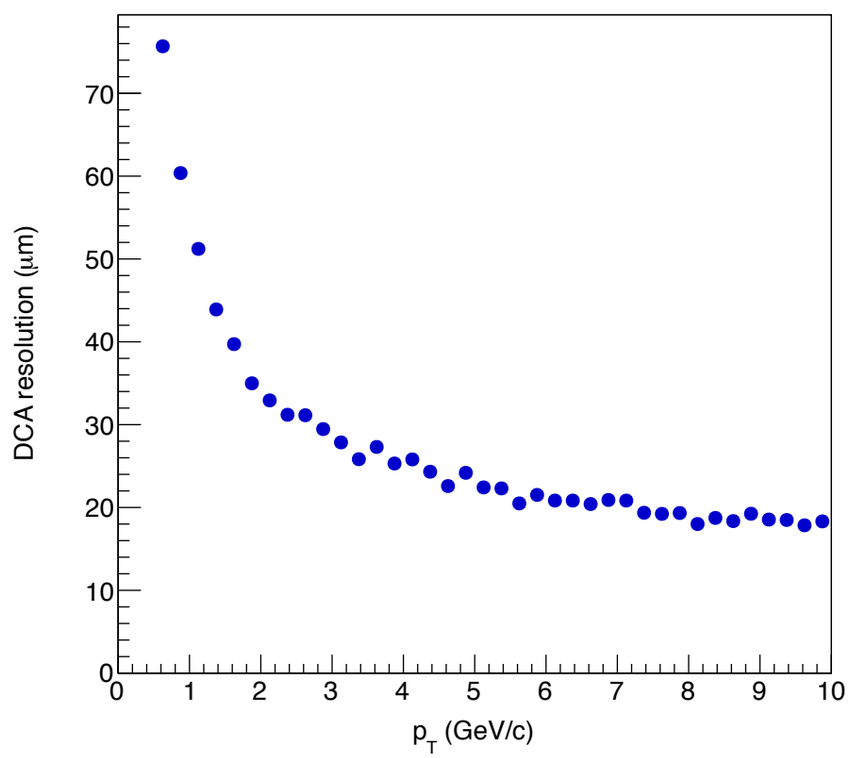




HEAVY FLAVOR TAGGED JETS







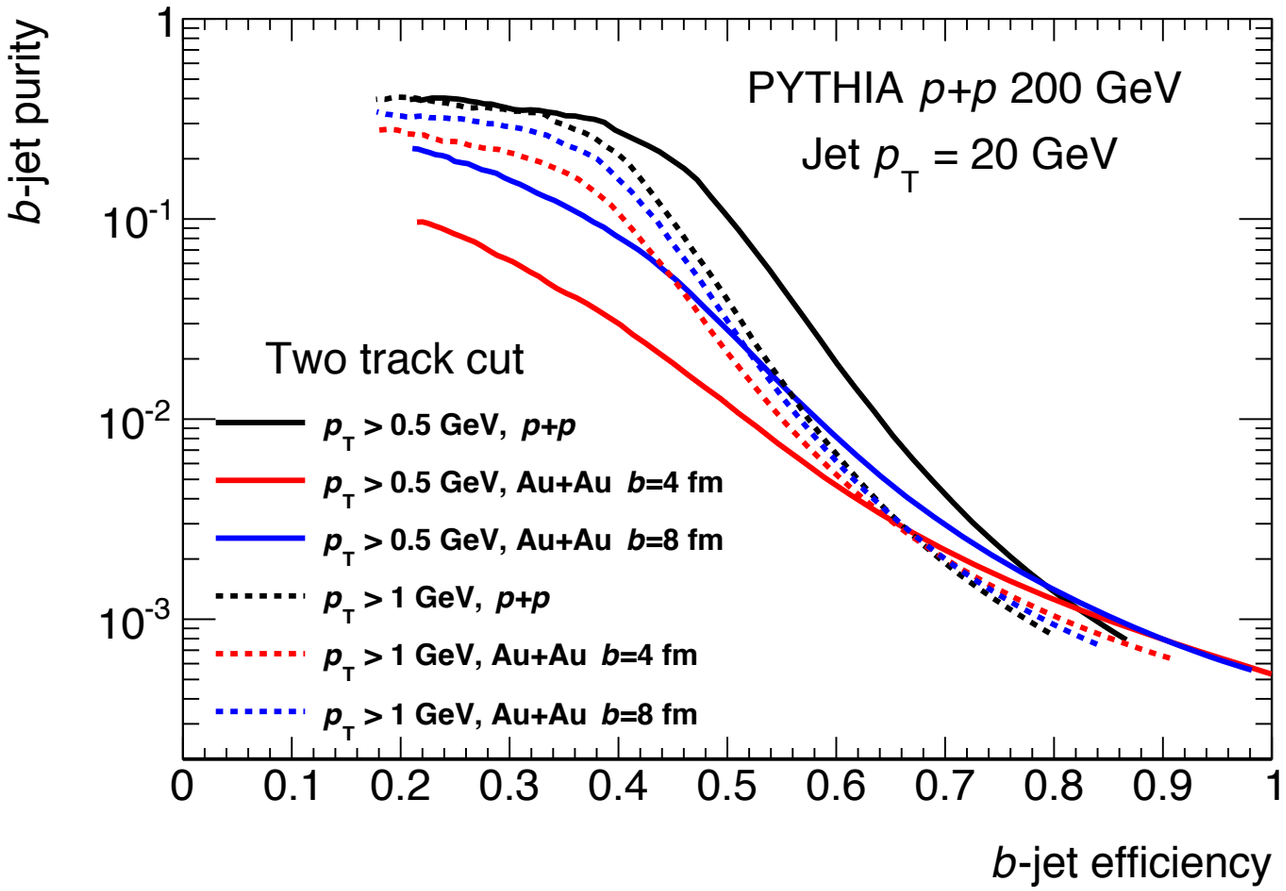
REQUIRE ONE OR MORE TRACKS WITH NON-ZERO IMPACT PARAMETER

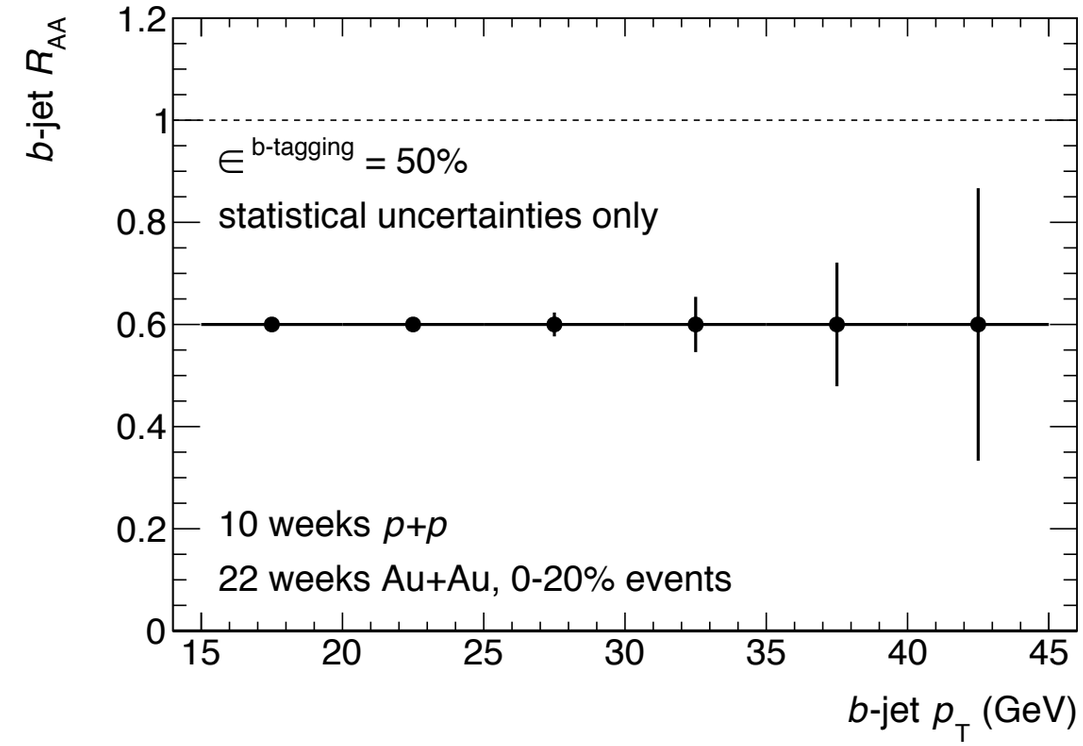
DETERMINED USING 2D DISTANCE OF CLOSEST APPROACH:

$$S_{DCA} = DCA / \sigma_{DCA}$$

REQUIRES GOOD DCA RESOLUTION + TRACKING EFFICIENCY

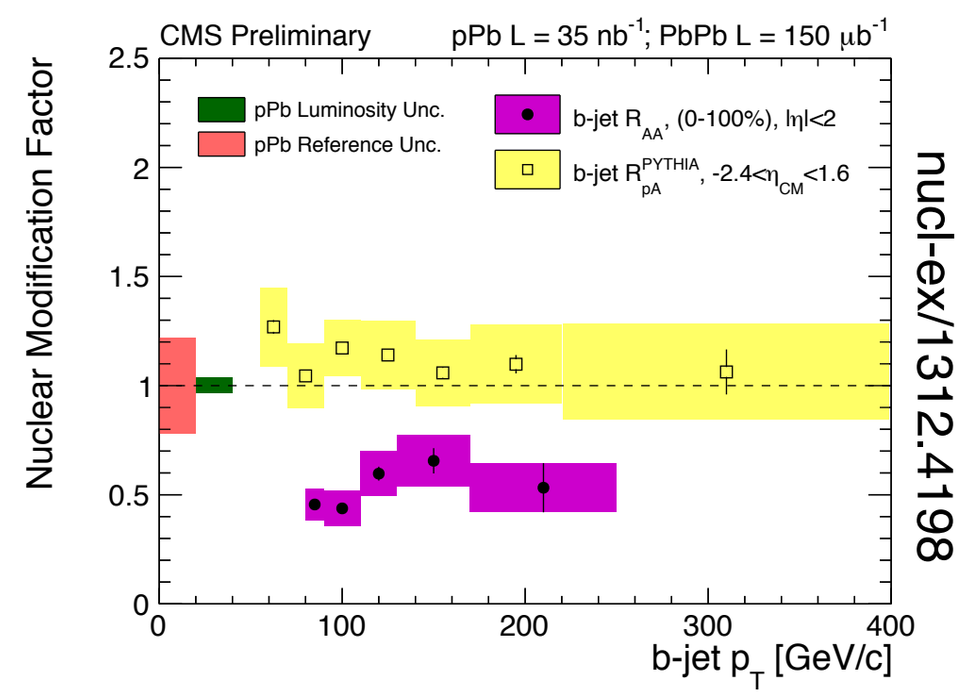
HEAVY FLAVOR TAGGED JETS





PROJECTED UNCERTAINTIES AT 50% TAGGING EFFICIENCY

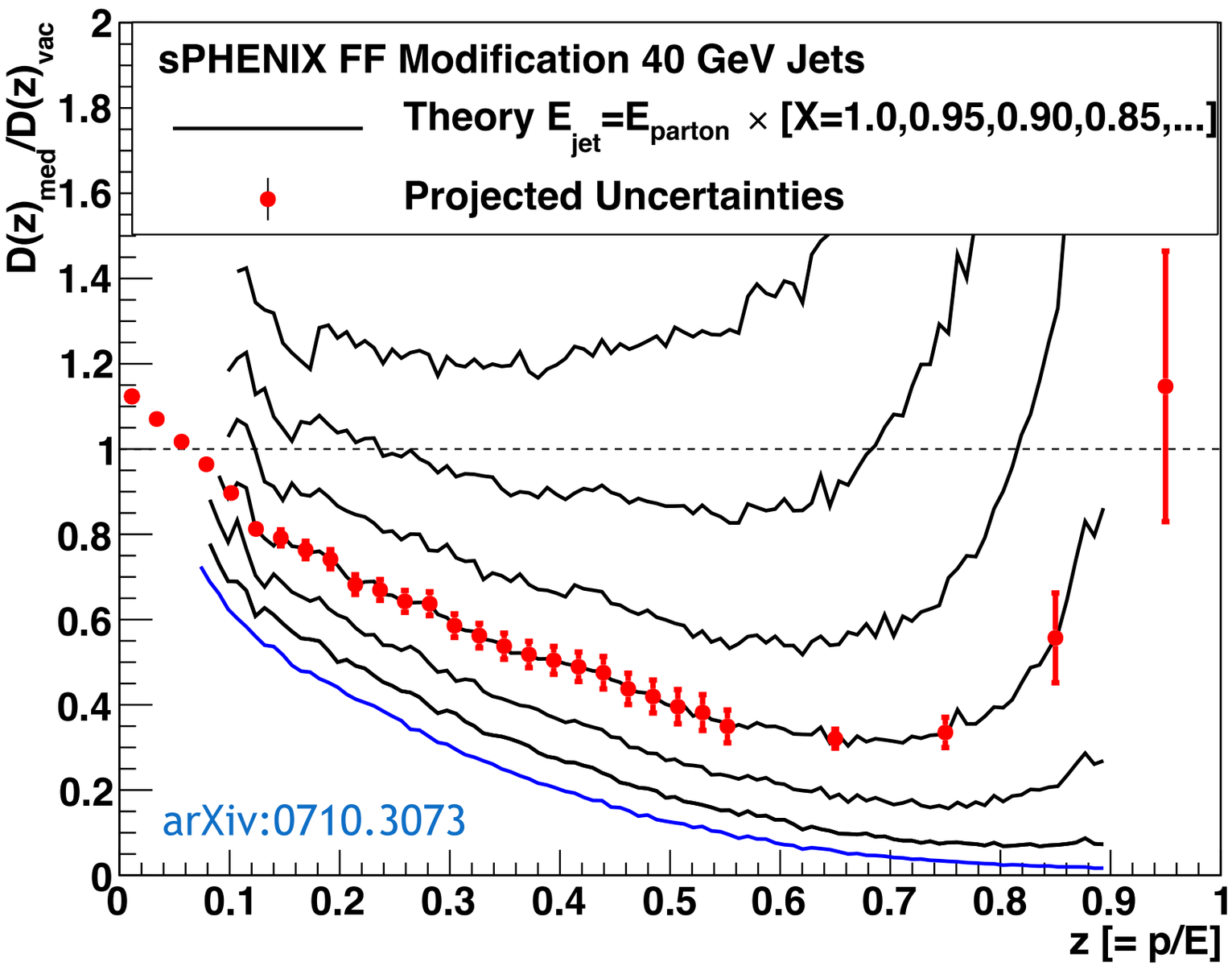
PURITY VS EFFICIENCY → SYSTEMATIC VS STATISTICAL UNCERTAINTIES



nucl-ex/1312.4198

Jet fragmentation

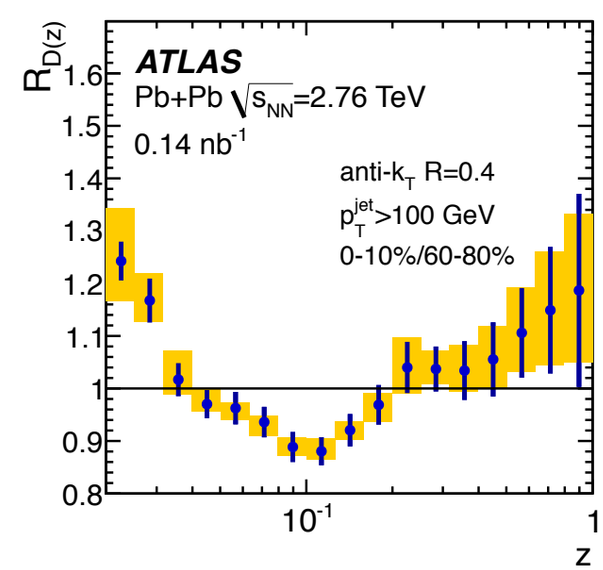
Predictions that FF $D(z) = p / E_{JET}$ will have dramatic high-z suppression



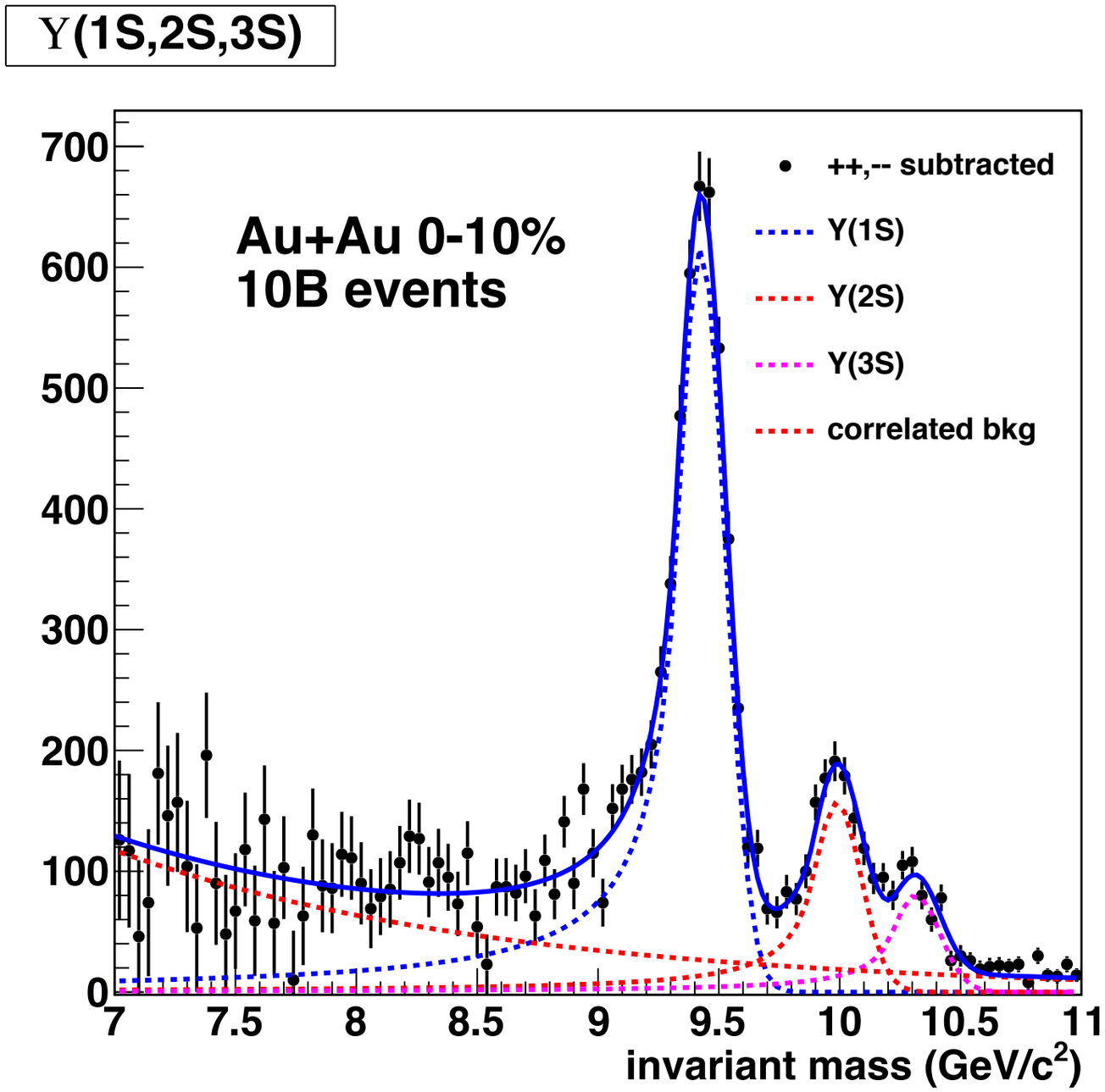
Modification sensitive to energy contained in jet cone

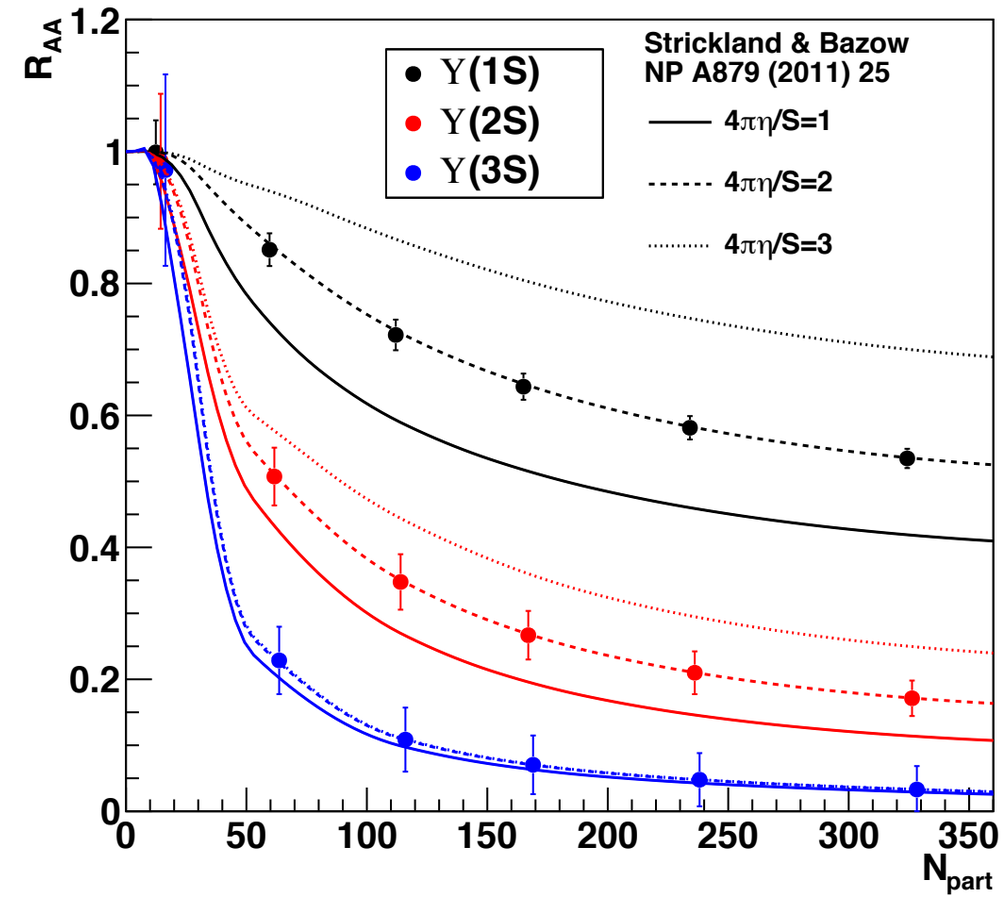
Requires measurement of **full jet energy** (calorimetric jets)

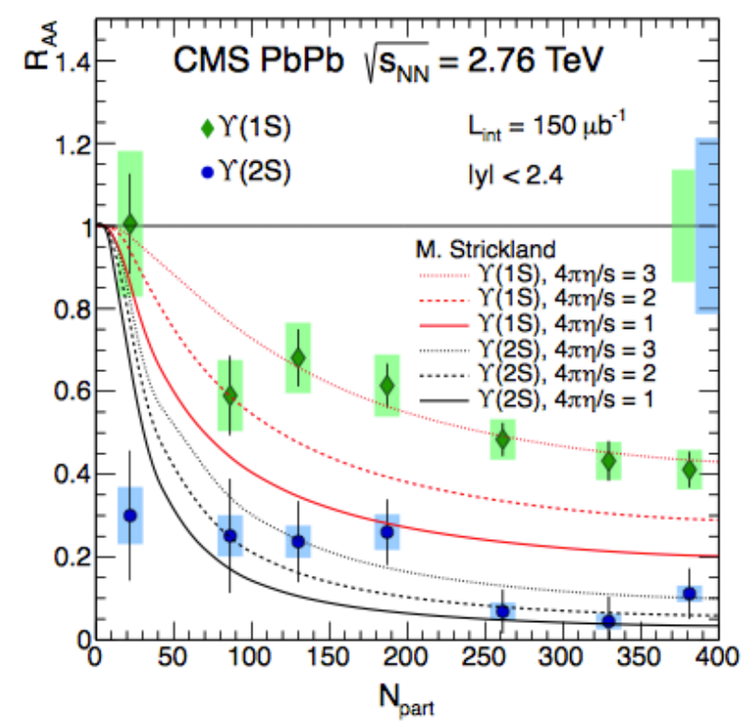
Requires precision tracking



Resolvable Upsilon states



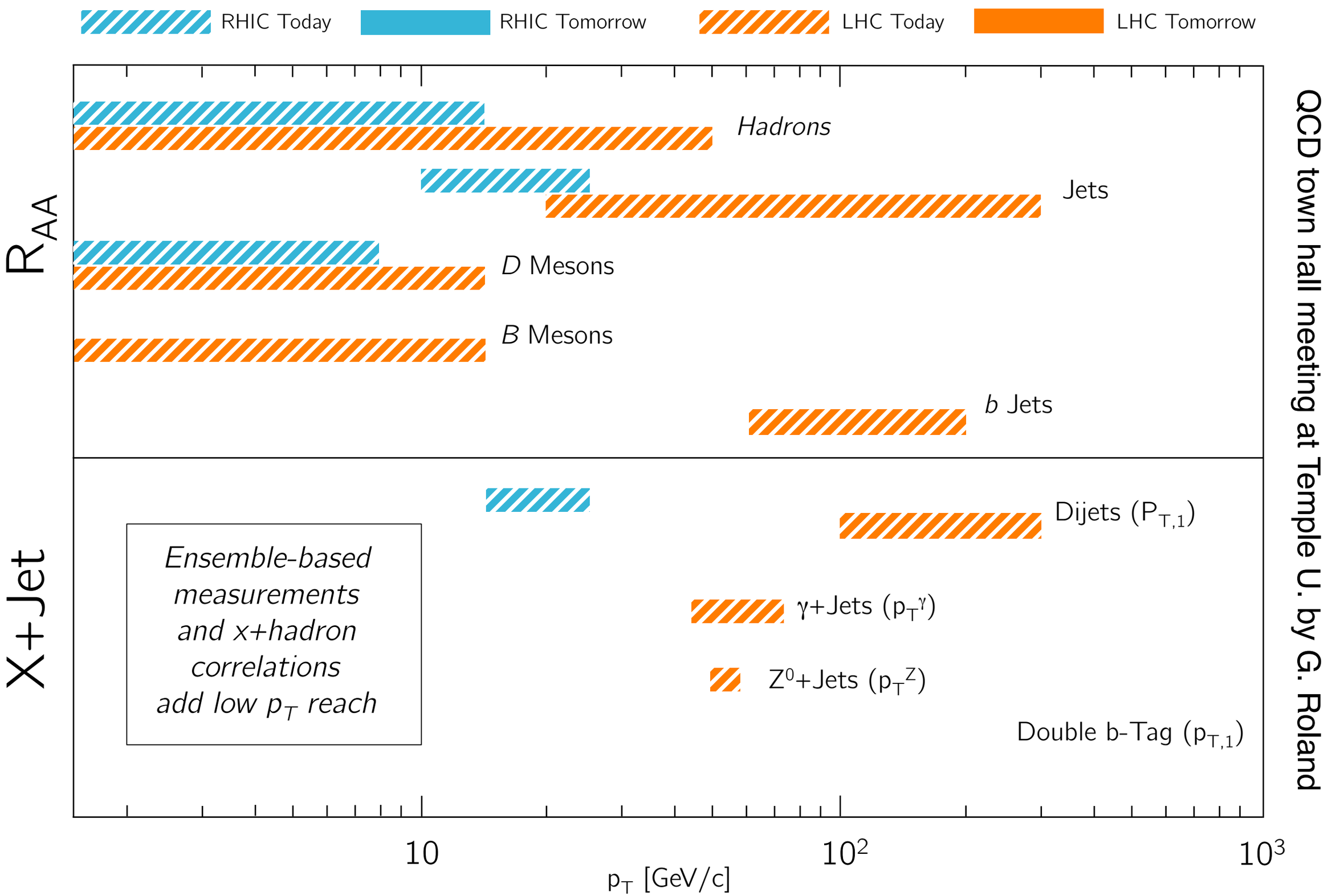




Tracking gives mass resolution of <100 MeV/c^2

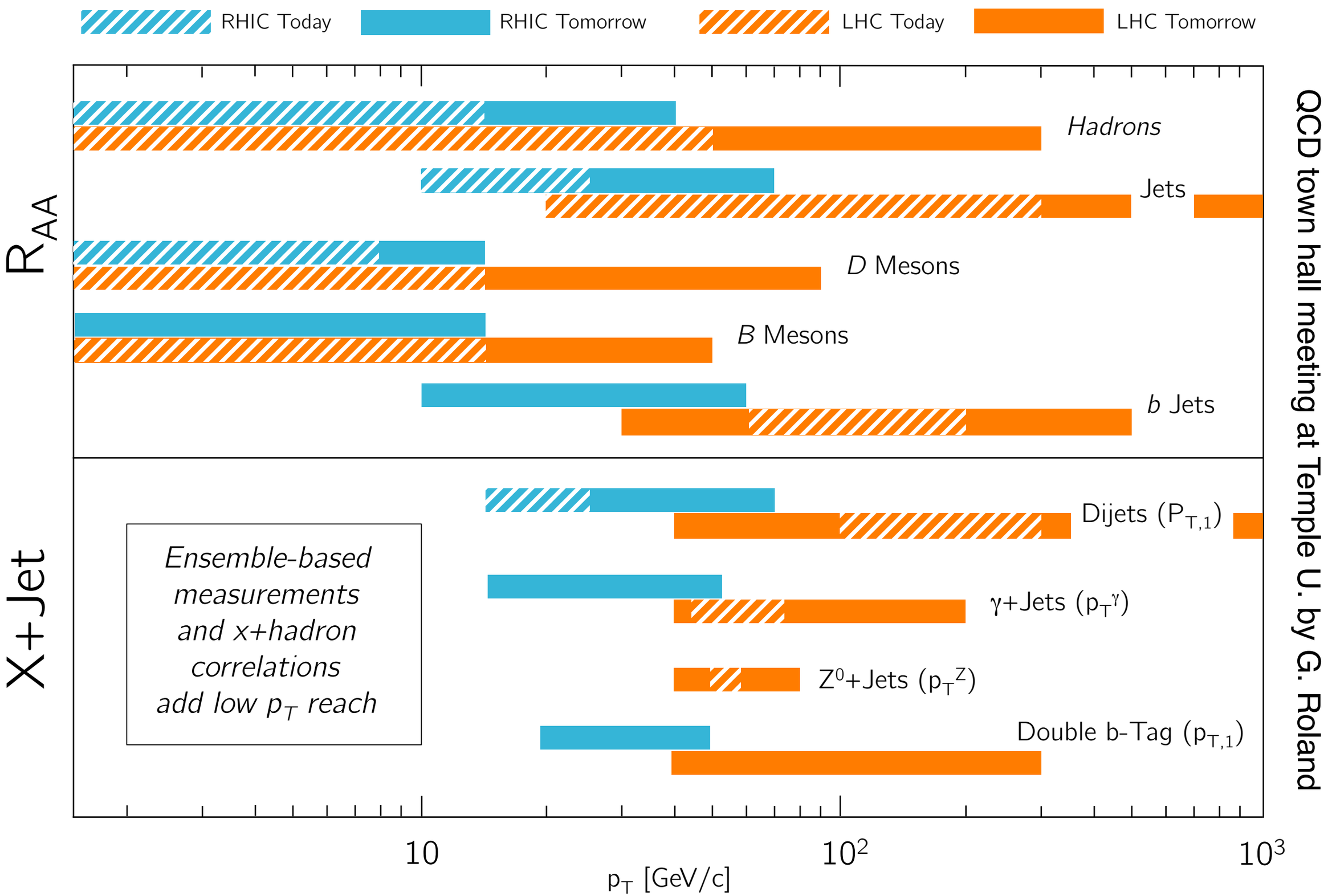
Separation of all three states with "LHC" precision

EXPANDED COMPLEMENTARITY



QCD town hall meeting at Temple U. by G. Roland

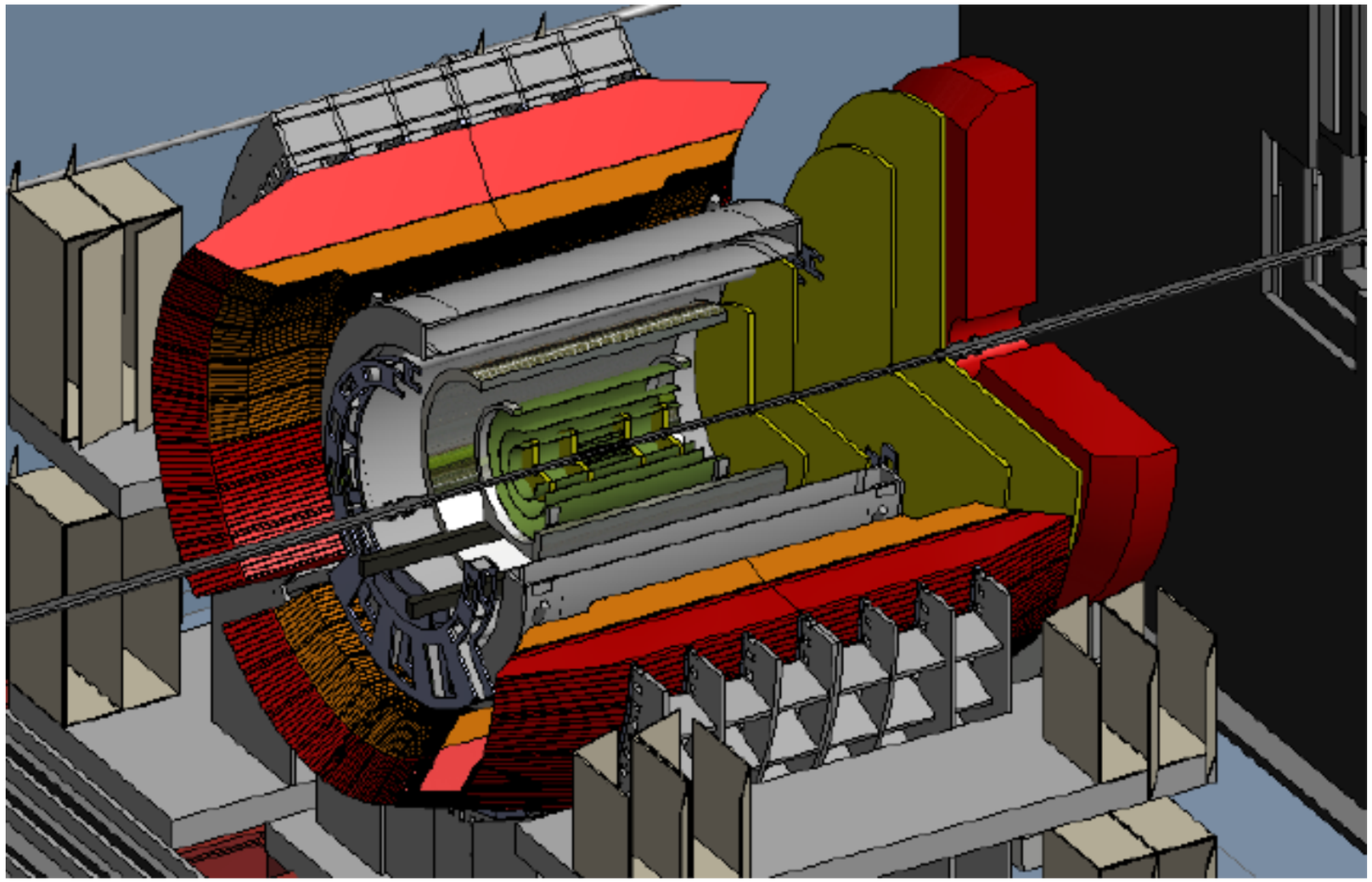
EXPANDED COMPLEMENTARITY



QCD town hall meeting at Temple U. by G. Roland

Forward sPHENIX

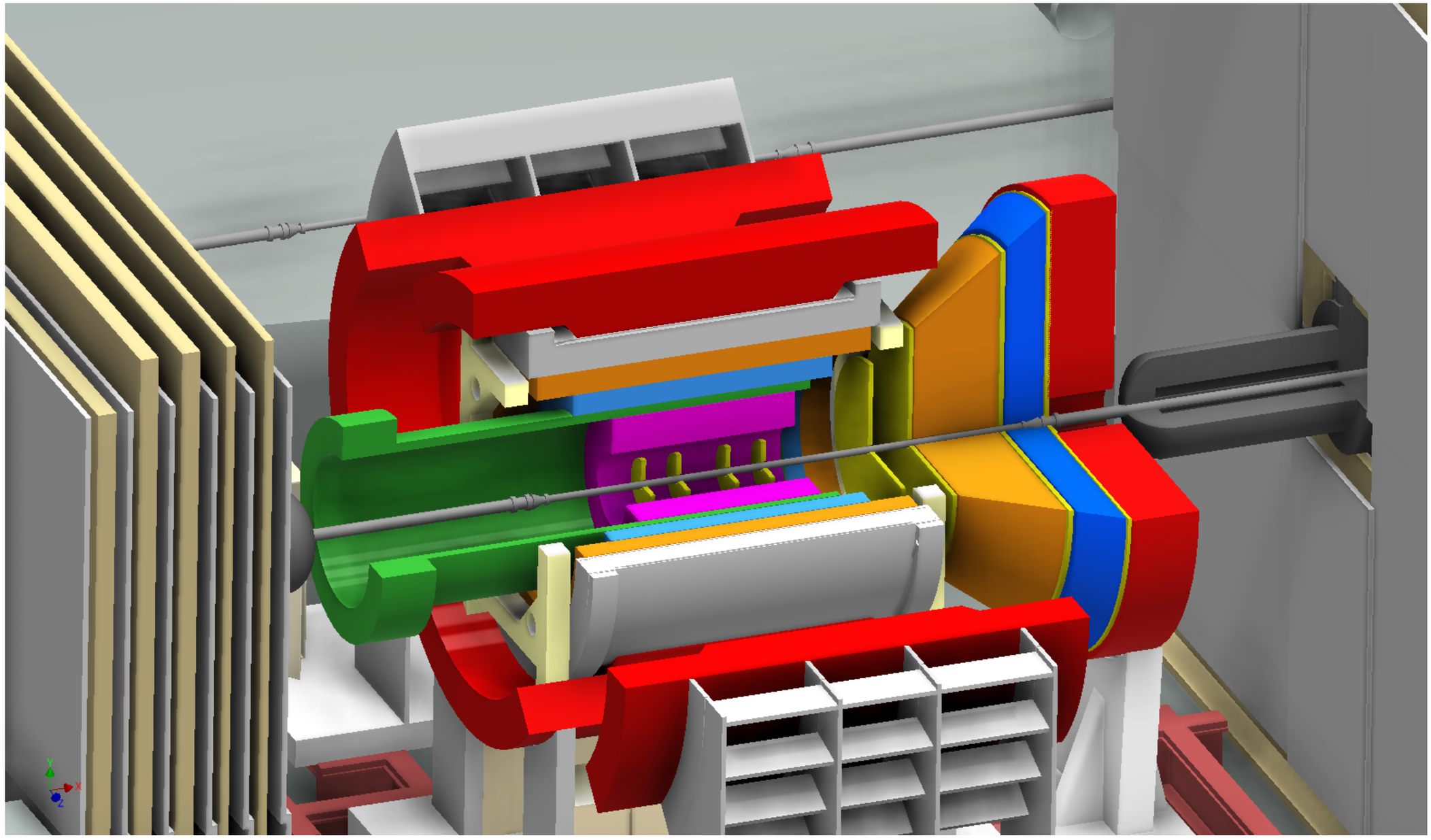
Expanded spin-polarized p+p and p+A measurements
with addition of forward calorimetry
- improved jet acceptance for HI



http://www.phenix.bnl.gov/phenix/WWW/publish/dave/sPHENIX/pp_pA_whitepaper.pdf

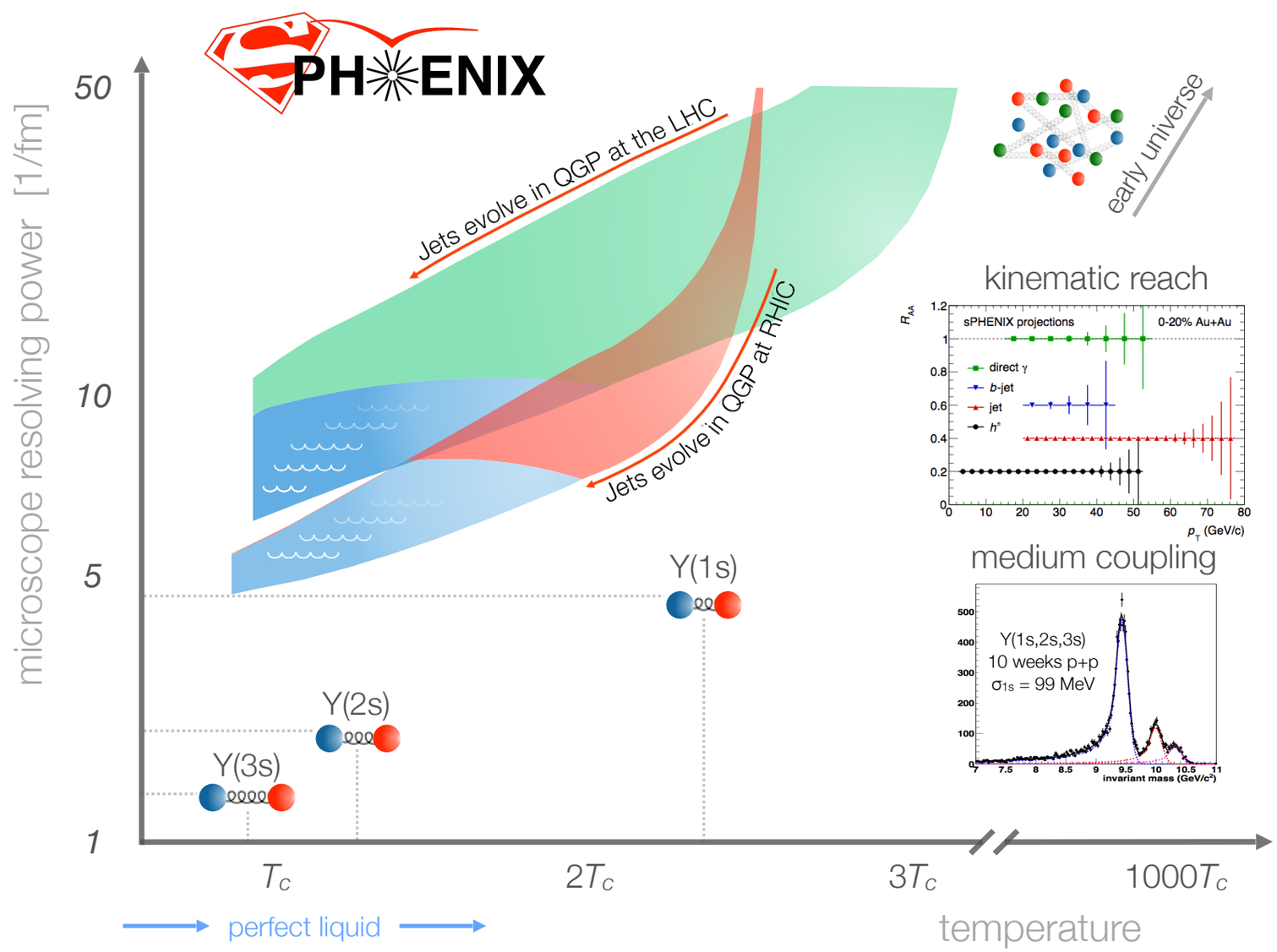
An EIC detector

Make use of BaBar magnet and sPHENIX calorimetry
as first part of full EIC capable detector
w/added tracking/PID capabilities



Summary

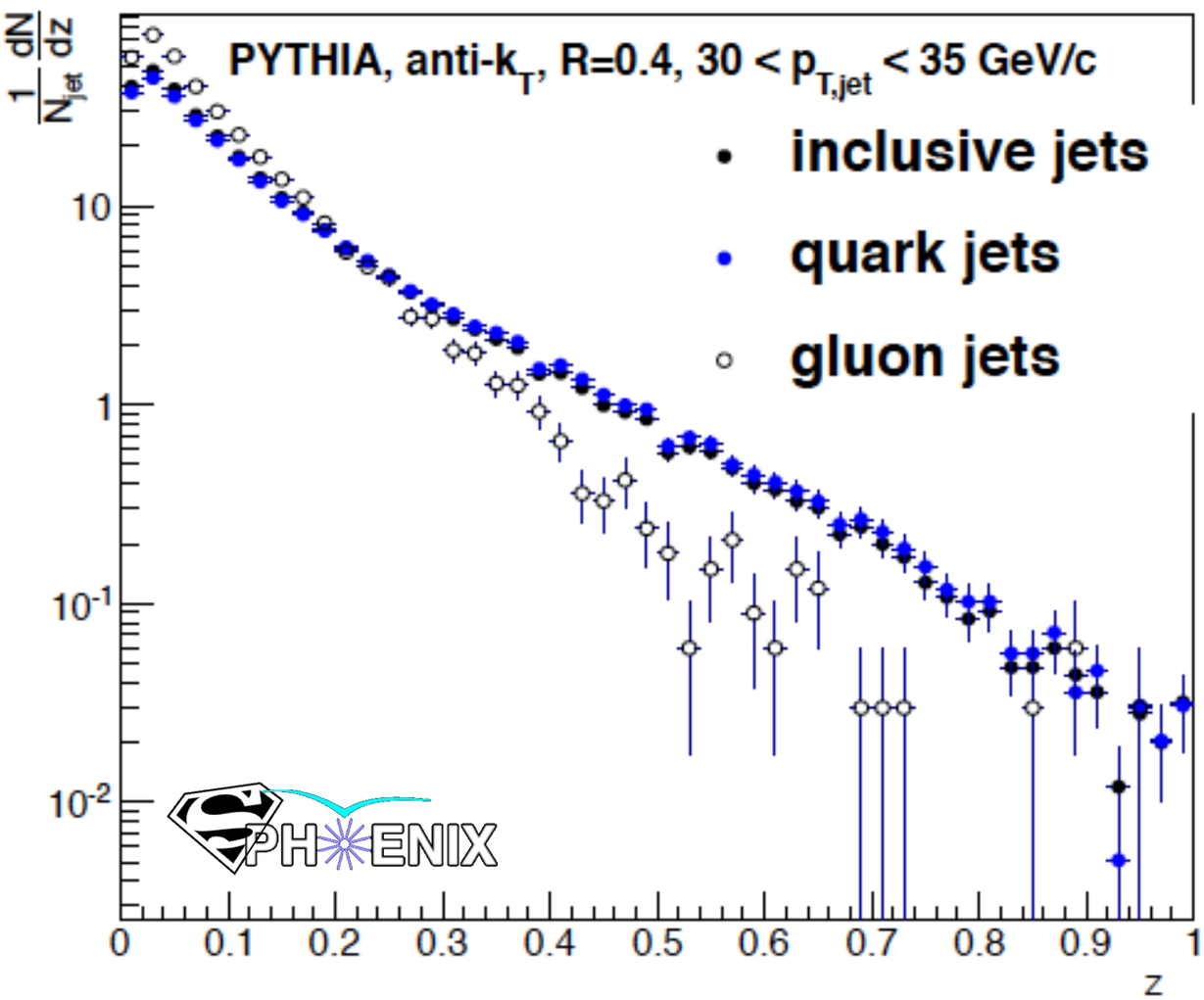
- Major goals of sPHENIX: to use jets, jet correlations and upsilons together to determine temperature dependence of transport properties and color screening length of the QGP
- Clear path to forward capabilities for p+p and p+A and ultimately an EIC detector

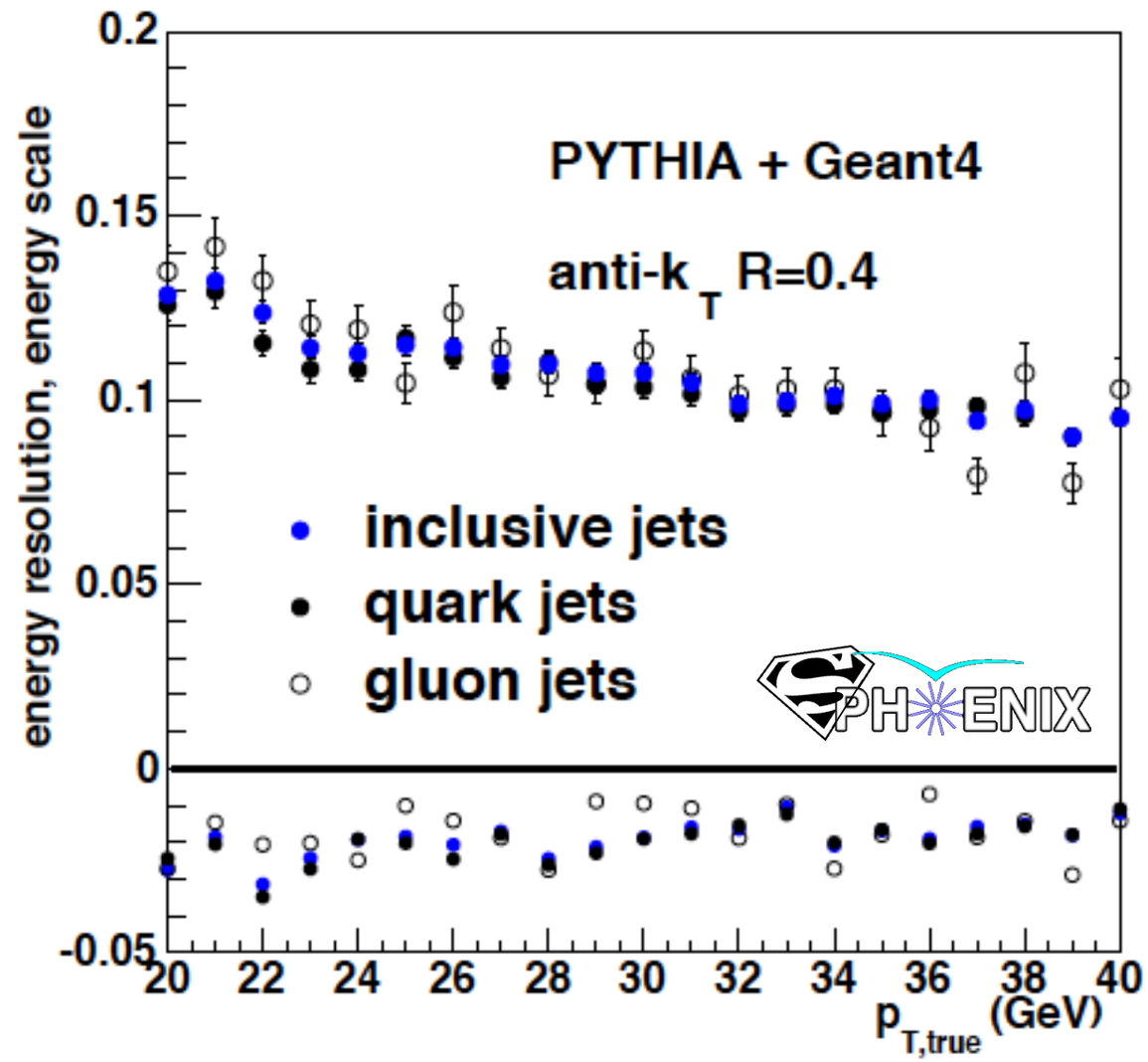


Full text:
http://arxiv.org/abs/1501.06197

Backup Slides

Quark vs Gluon

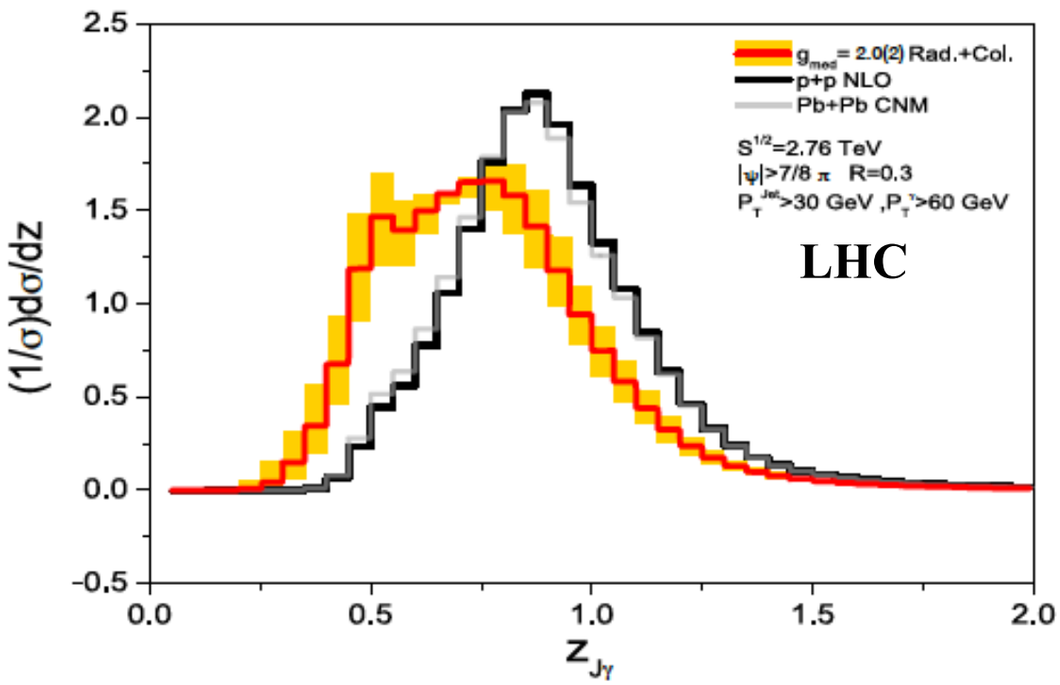


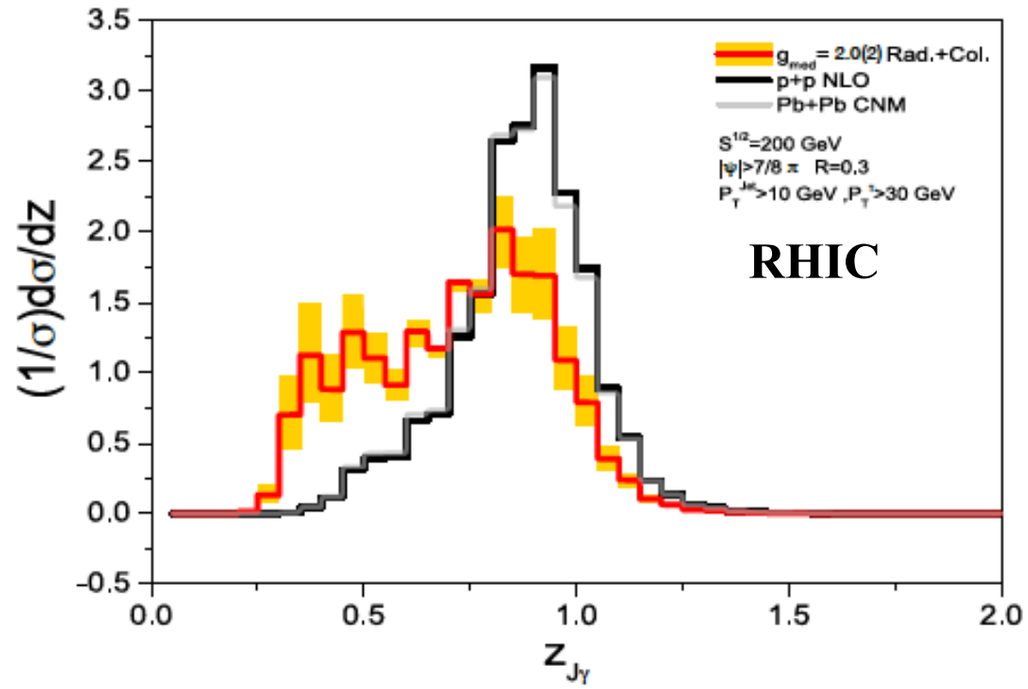


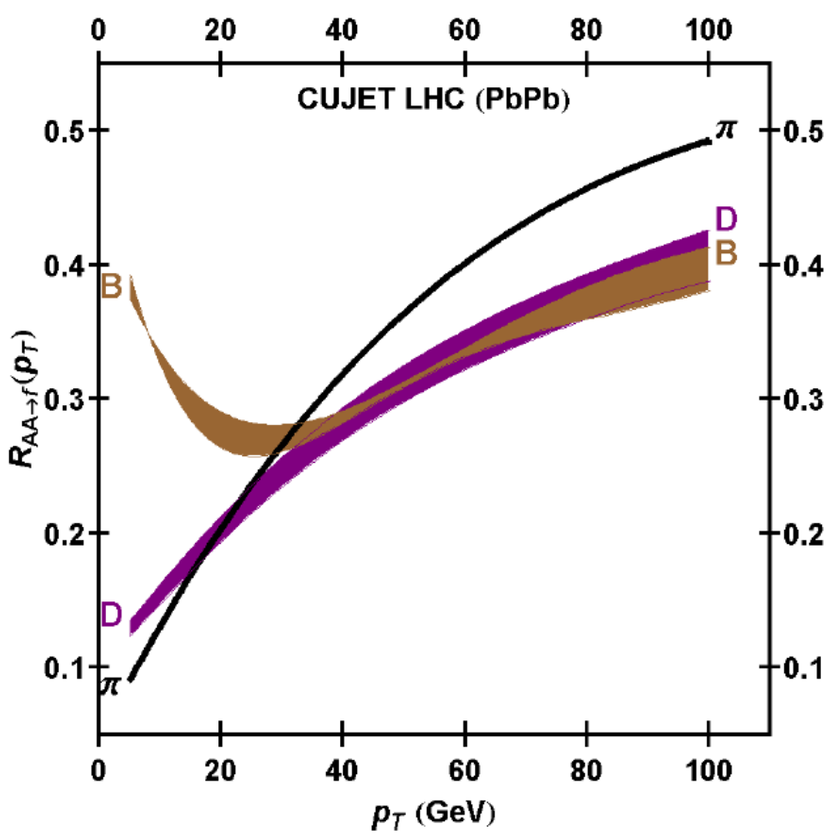
jet resolution similar for quark & gluon jets
gluon jets have softer FF (like a quenched jet)

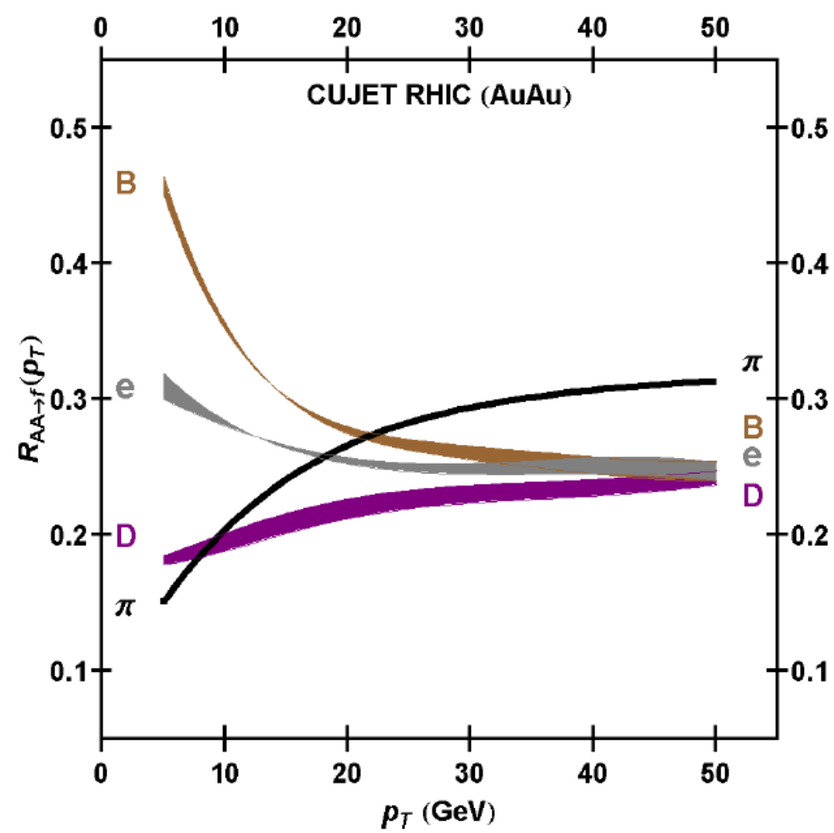
Predicted RHIC vs LHC

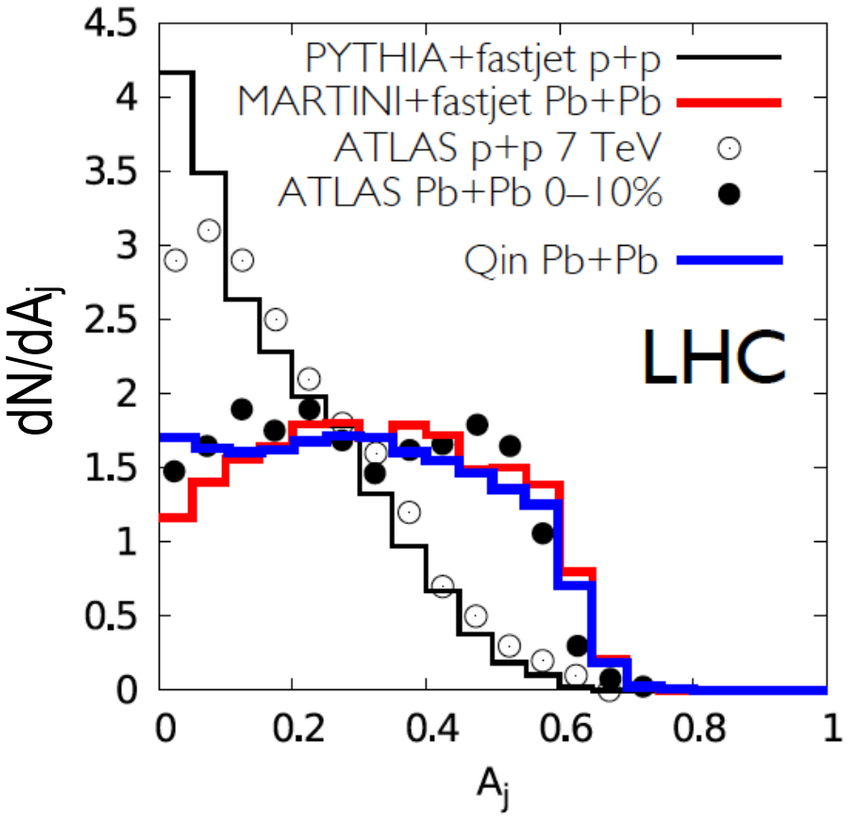
Many observables where greater sensitivity expected at RHIC



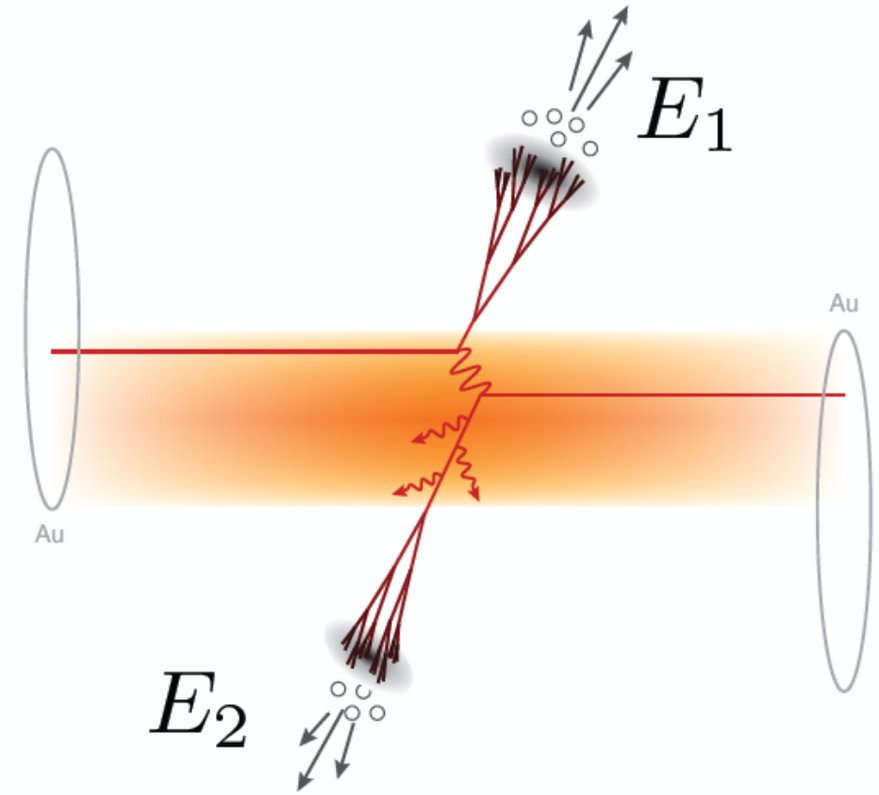


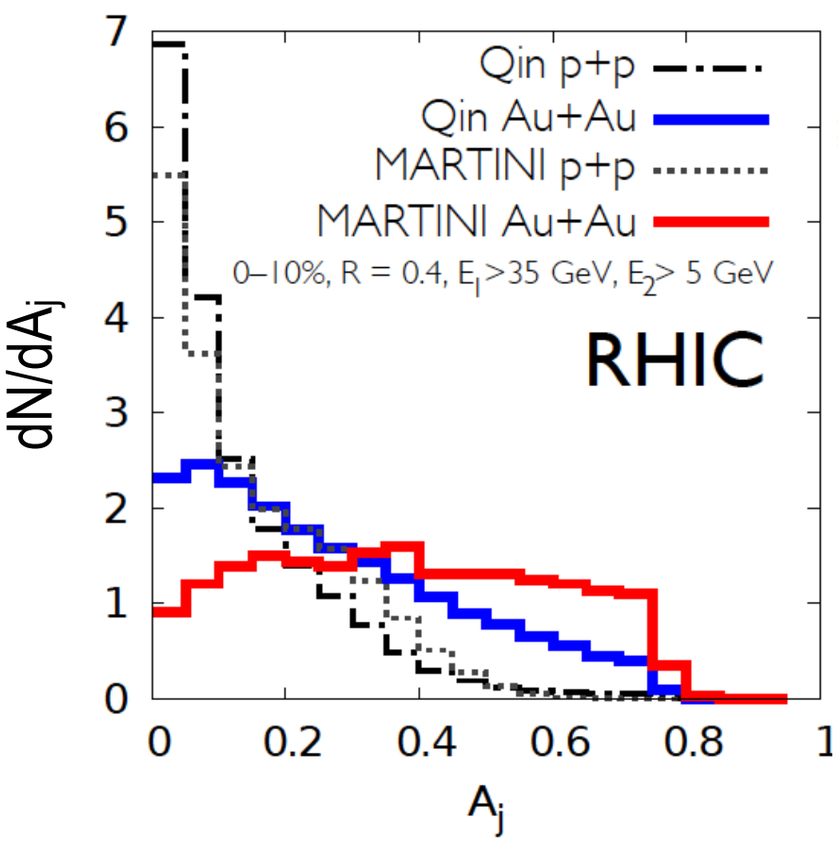




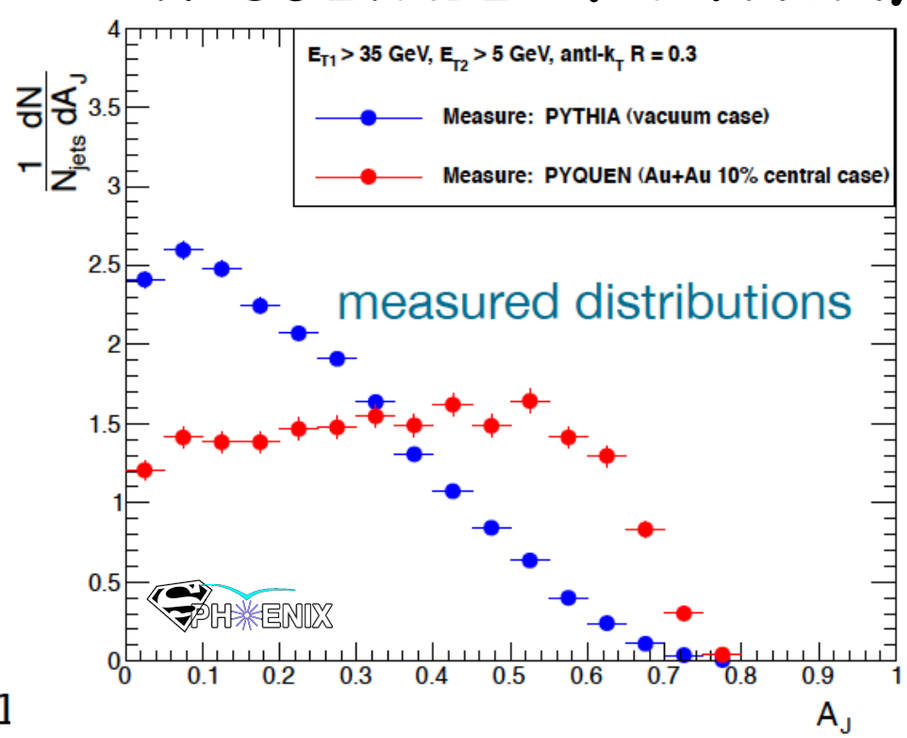


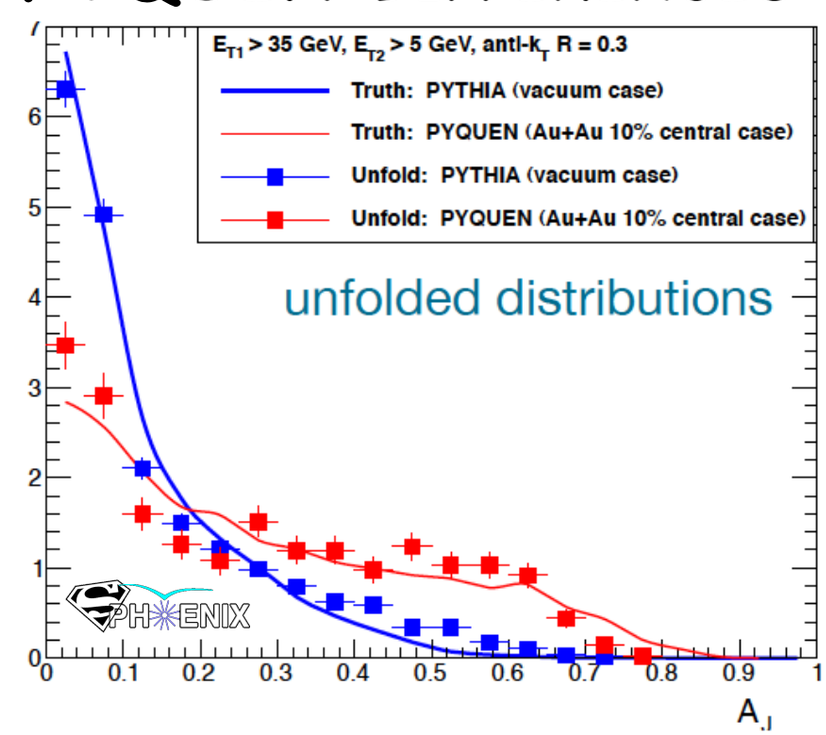
$$A_J = \frac{E_{T,1} - E_{T,2}}{E_{T,1} + E_{T,2}}$$



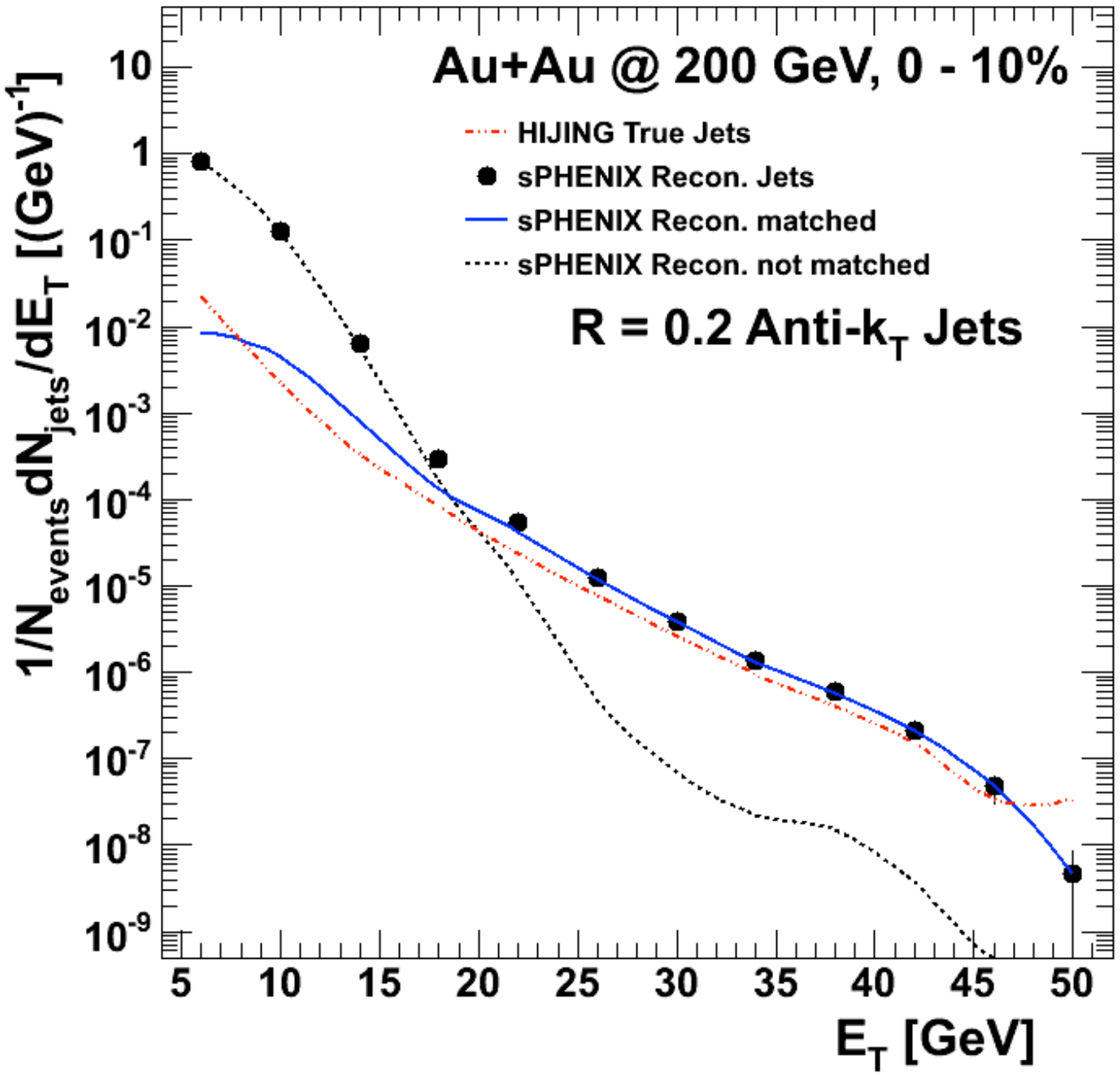


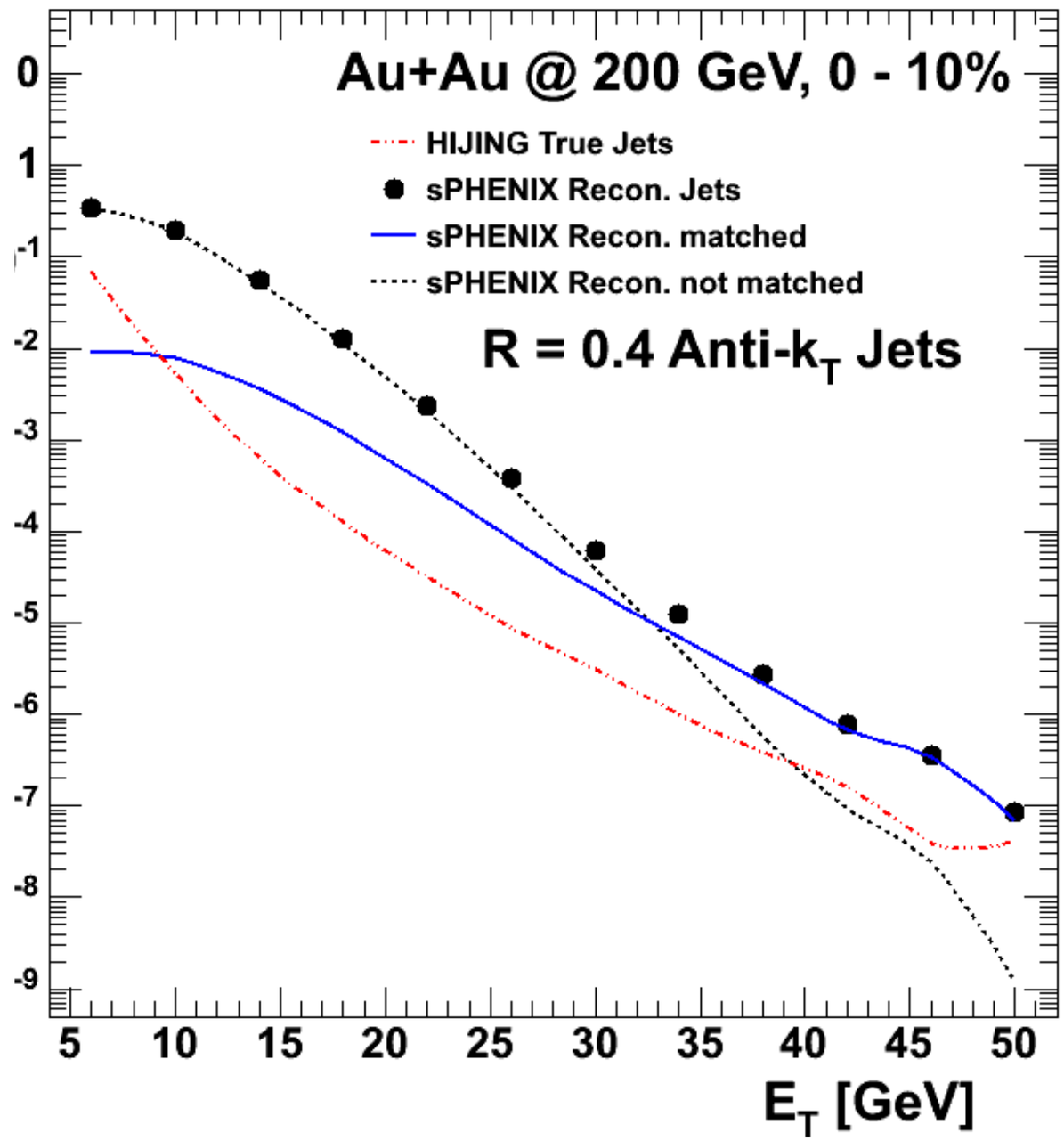
RESOLVABLE PYTHIA/PYQUEN DIFFERENCES





Measuring jets in HI events





Subtract <UE>

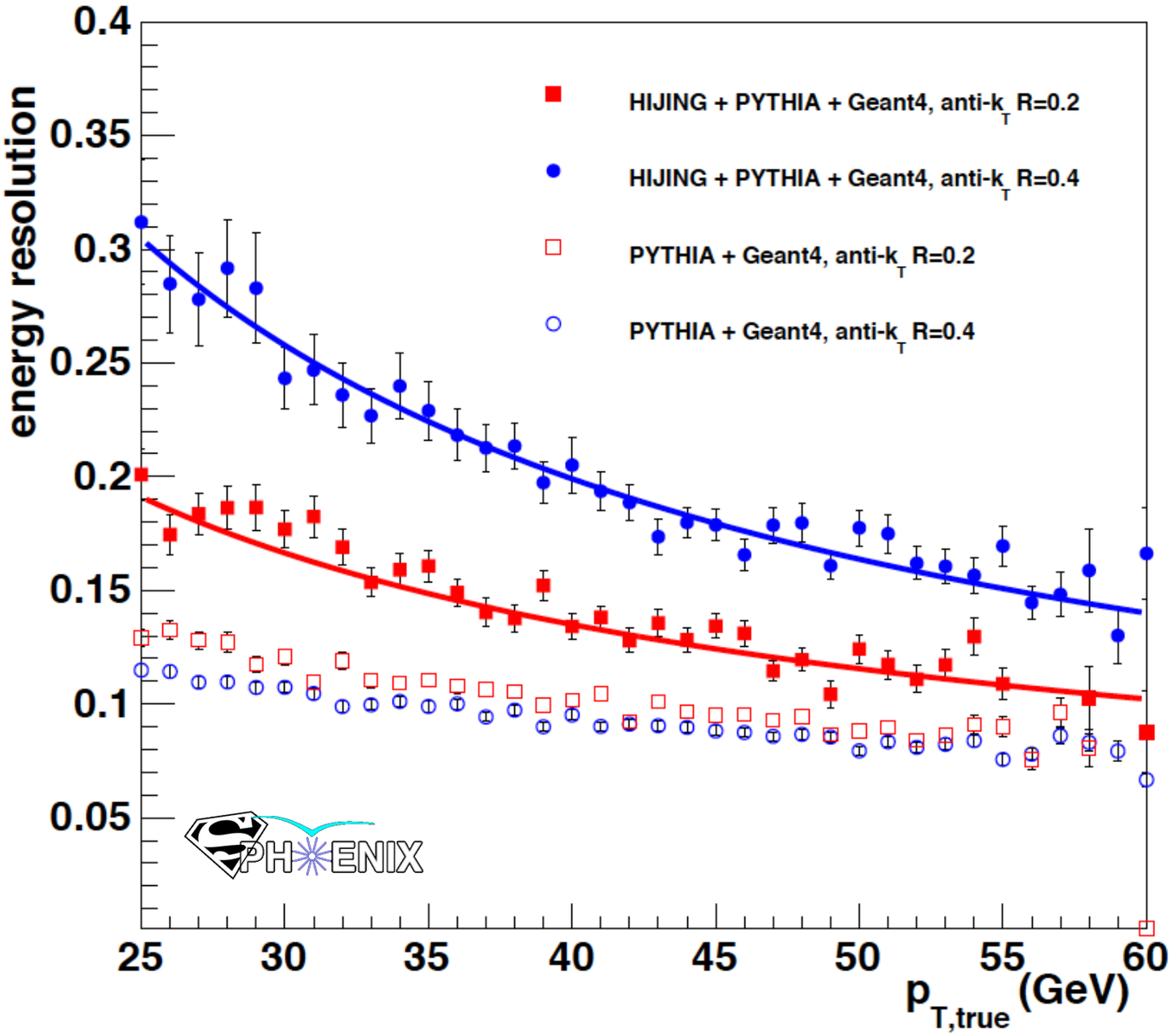
RMS smears jet – require unfolding

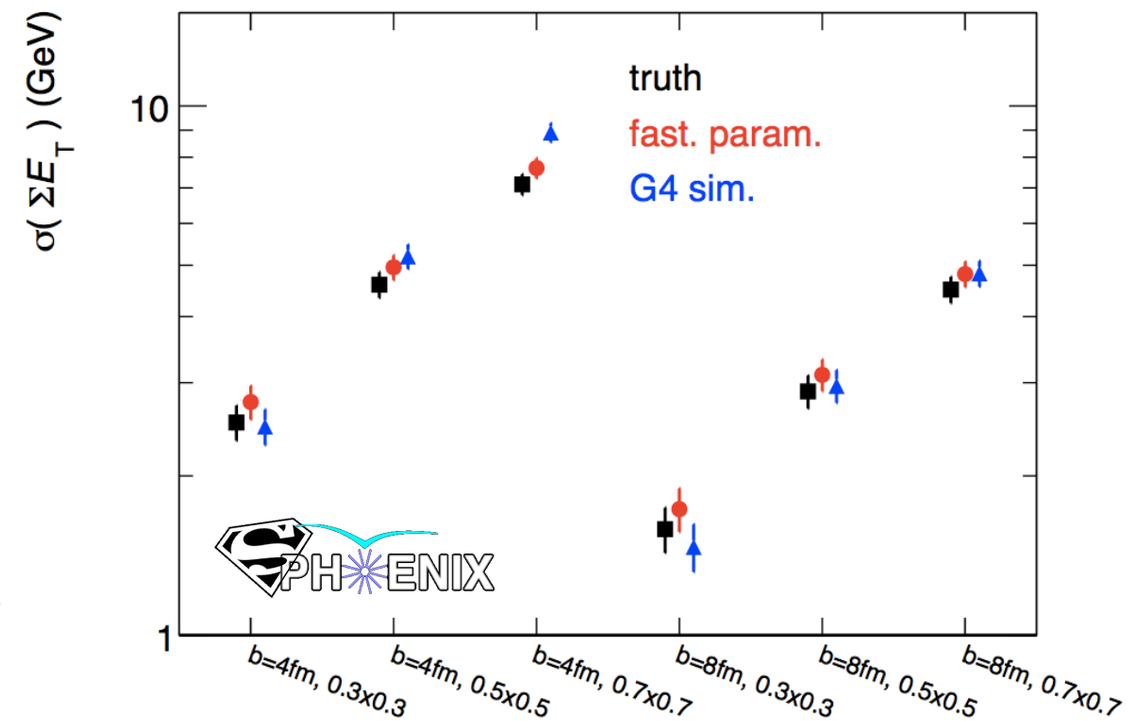
Fluctuations can look like jets – fakes

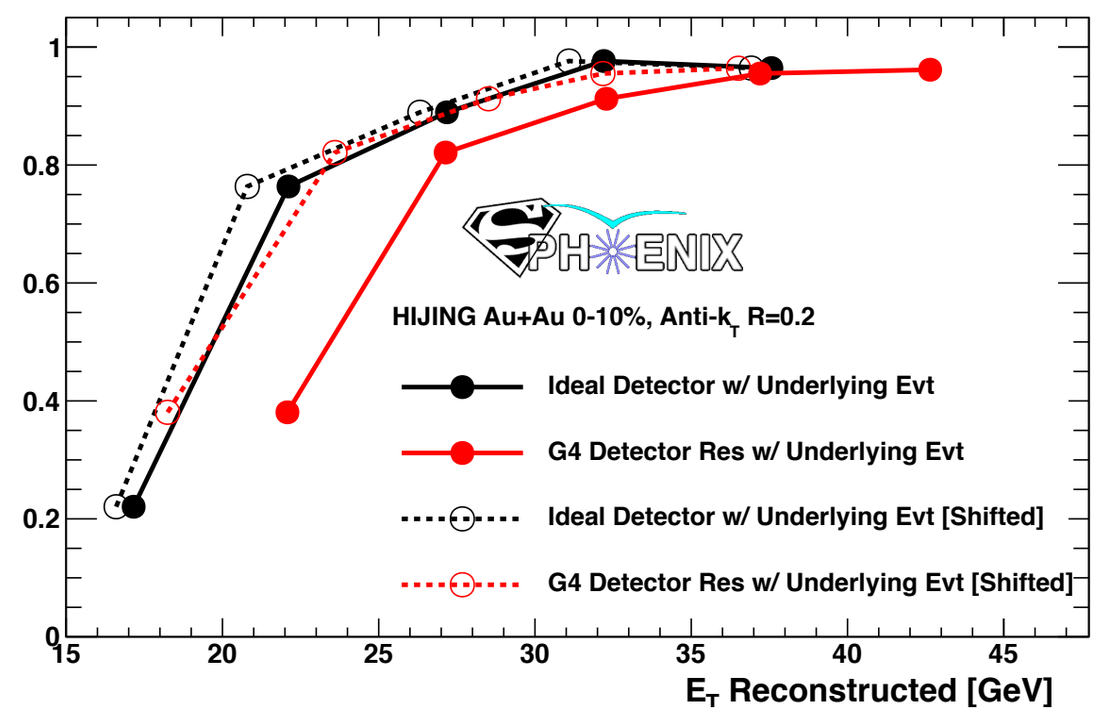
Real jets start to dominate above

~20 GeV (R=0.2) and ~35 GeV (R=0.4)

Adding detector effects

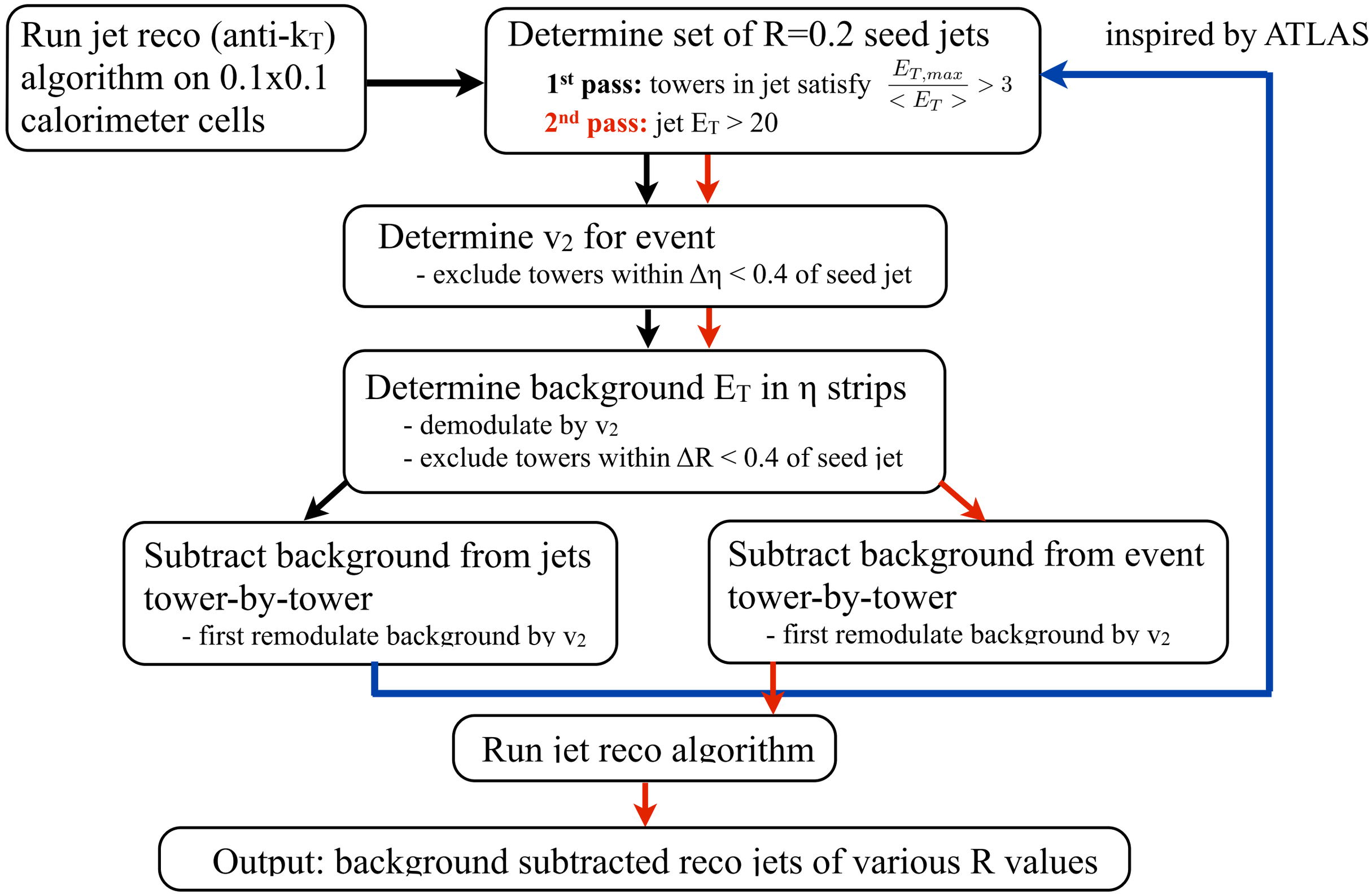






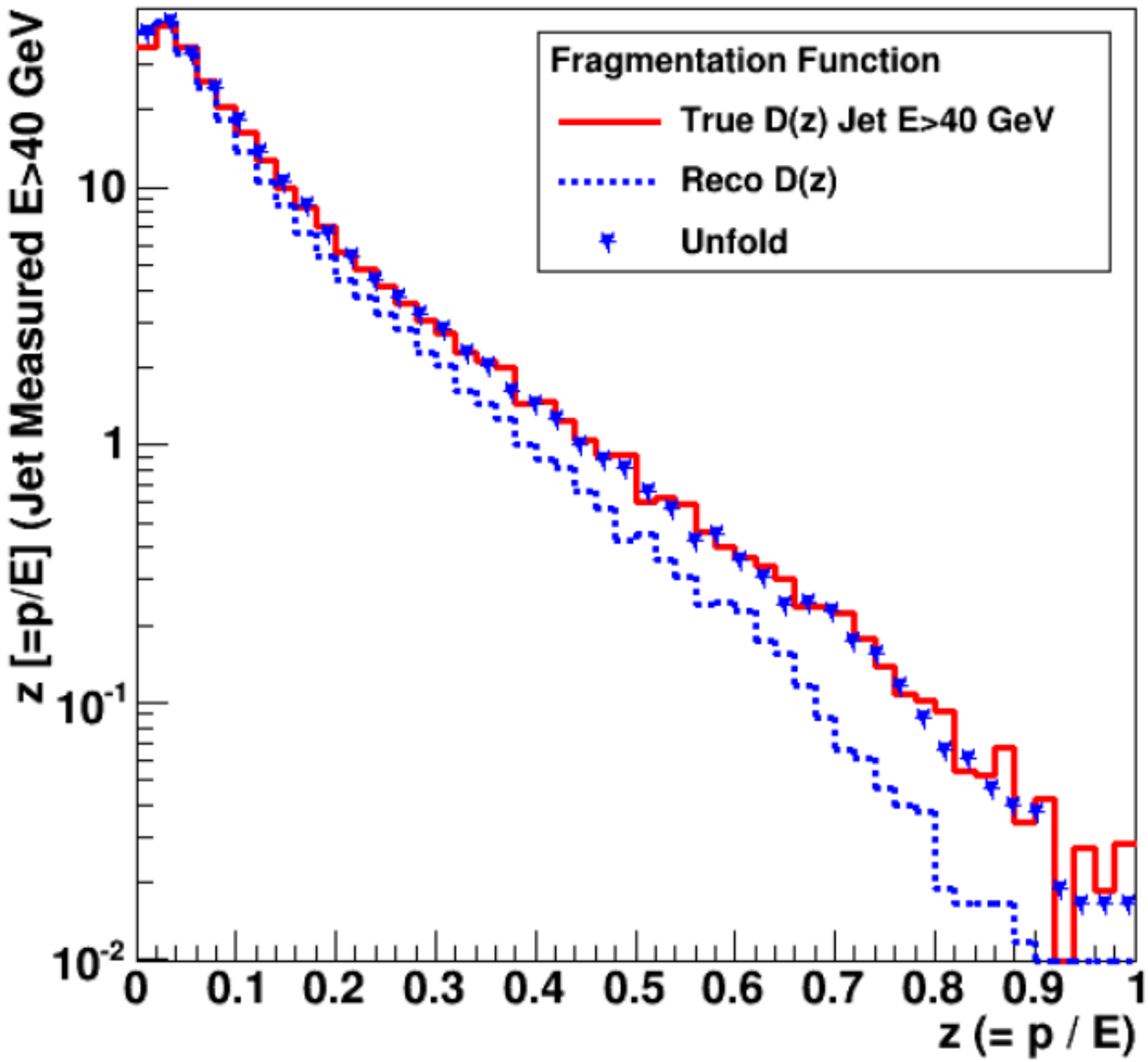
RESOLUTIONS SUBSTANTIALLY BETTER THAN REQUIRED

LARGELY RECOVER INITIAL PURITY AFTER UNFOLDING

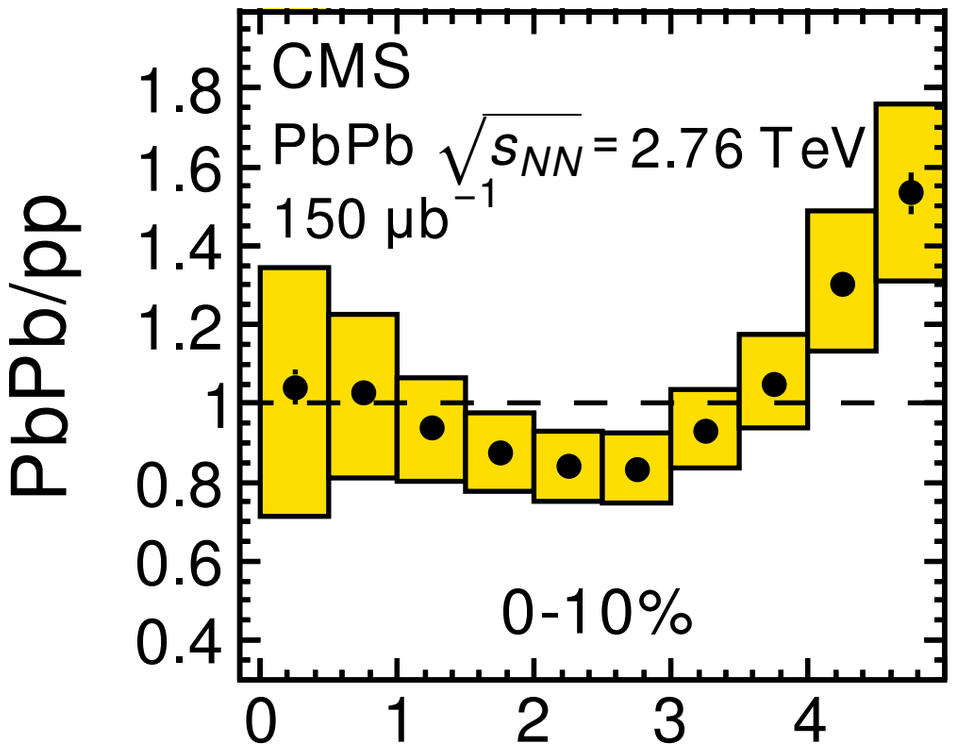


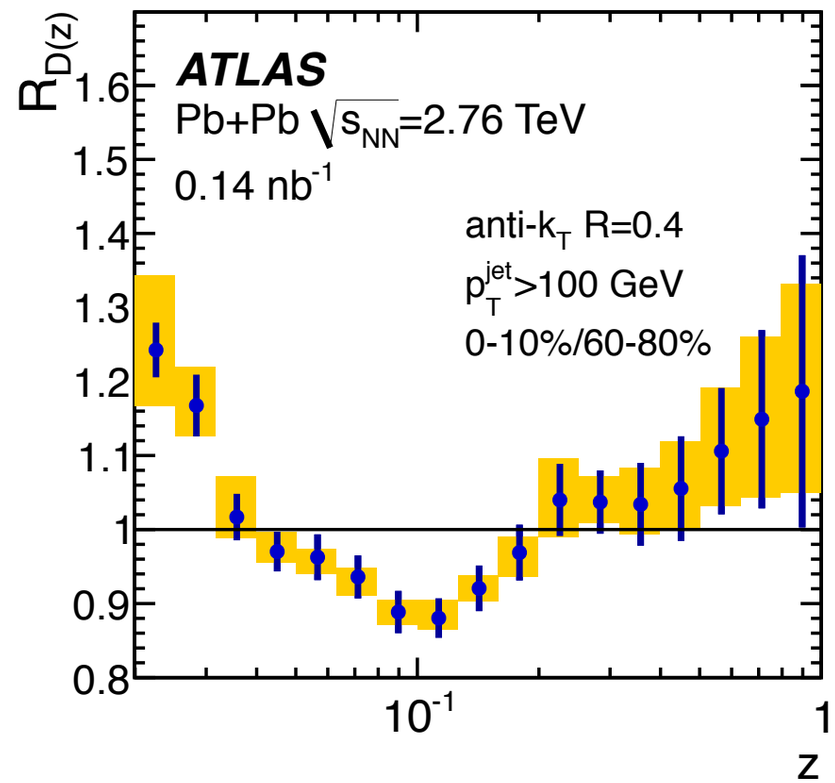
V_2 MODULATION ADDED TO **HIJING** EVENTS AND REMOVED BY ALGORITHM

Fragmentation Function Details



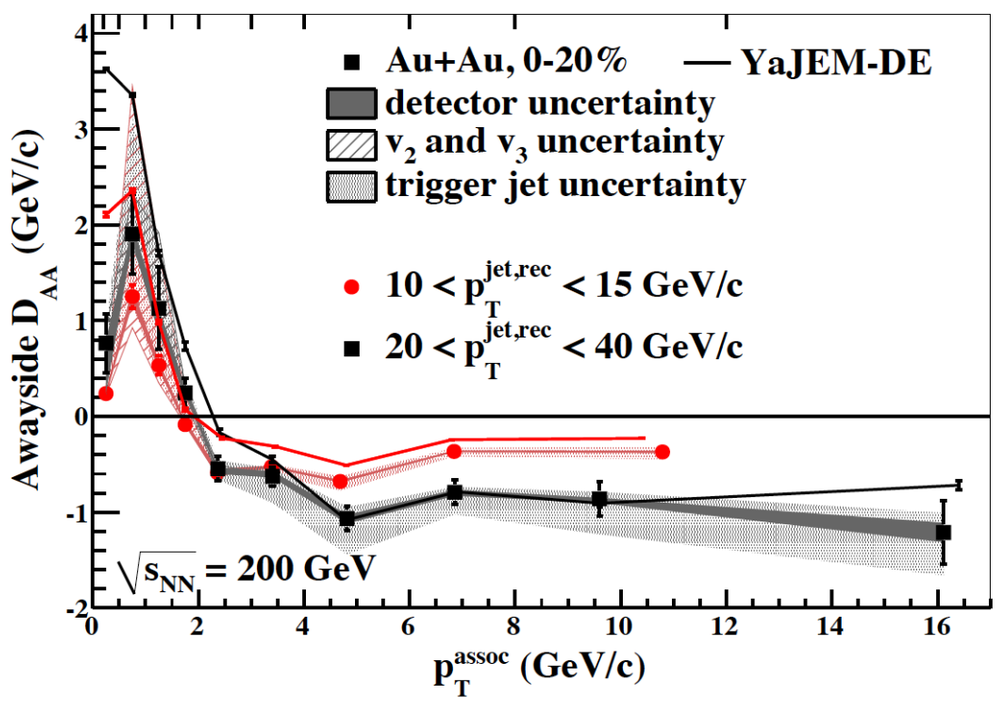
Jet fragmentation

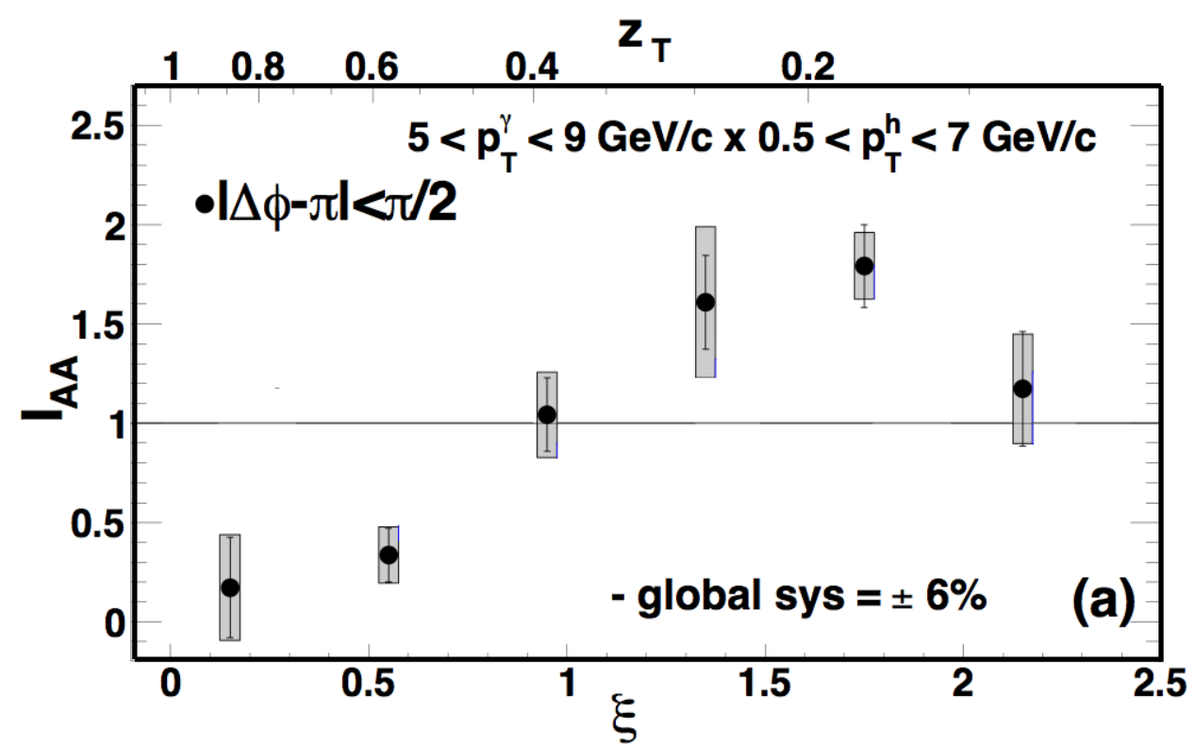




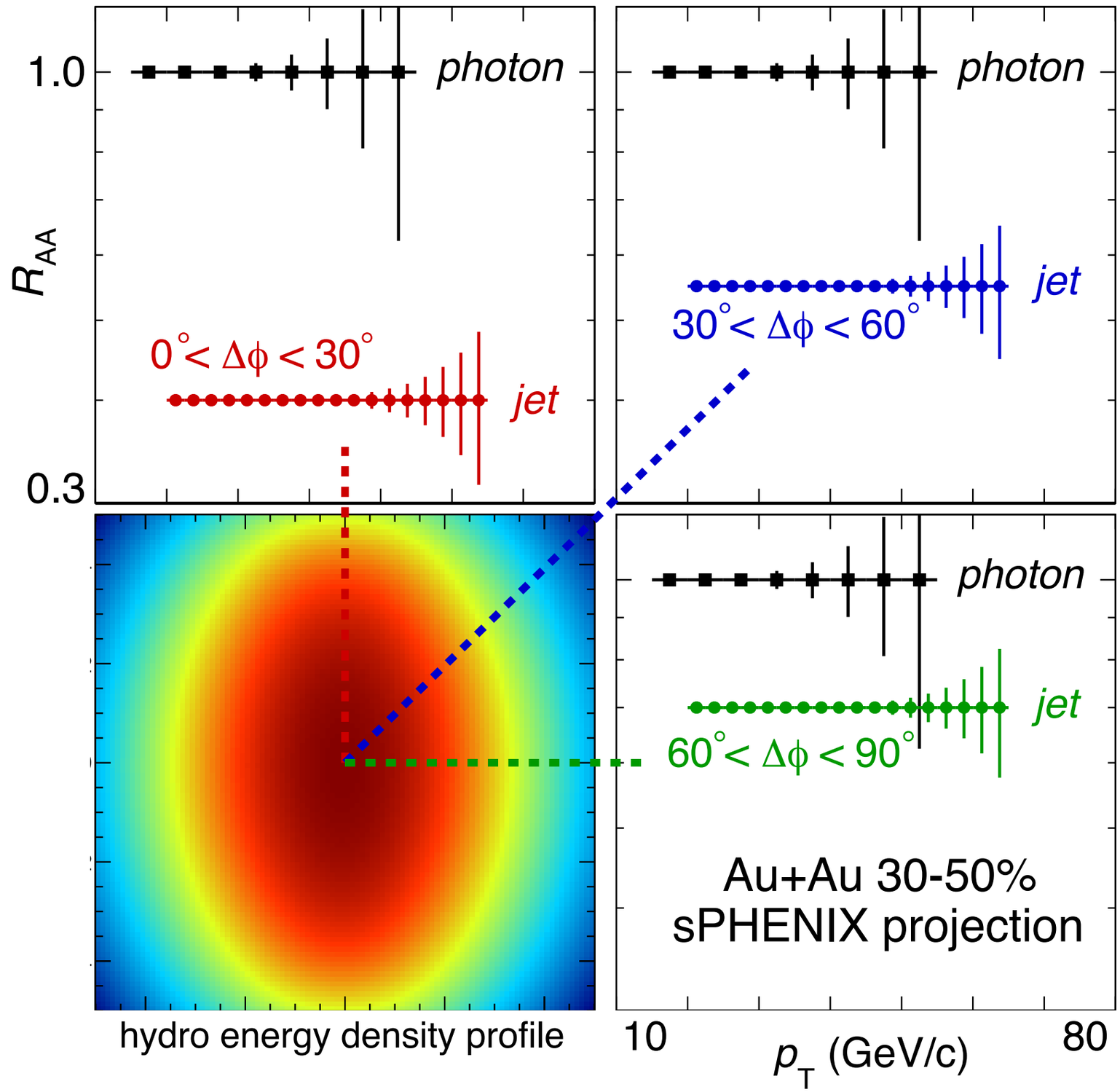
Qualitatively similar effects

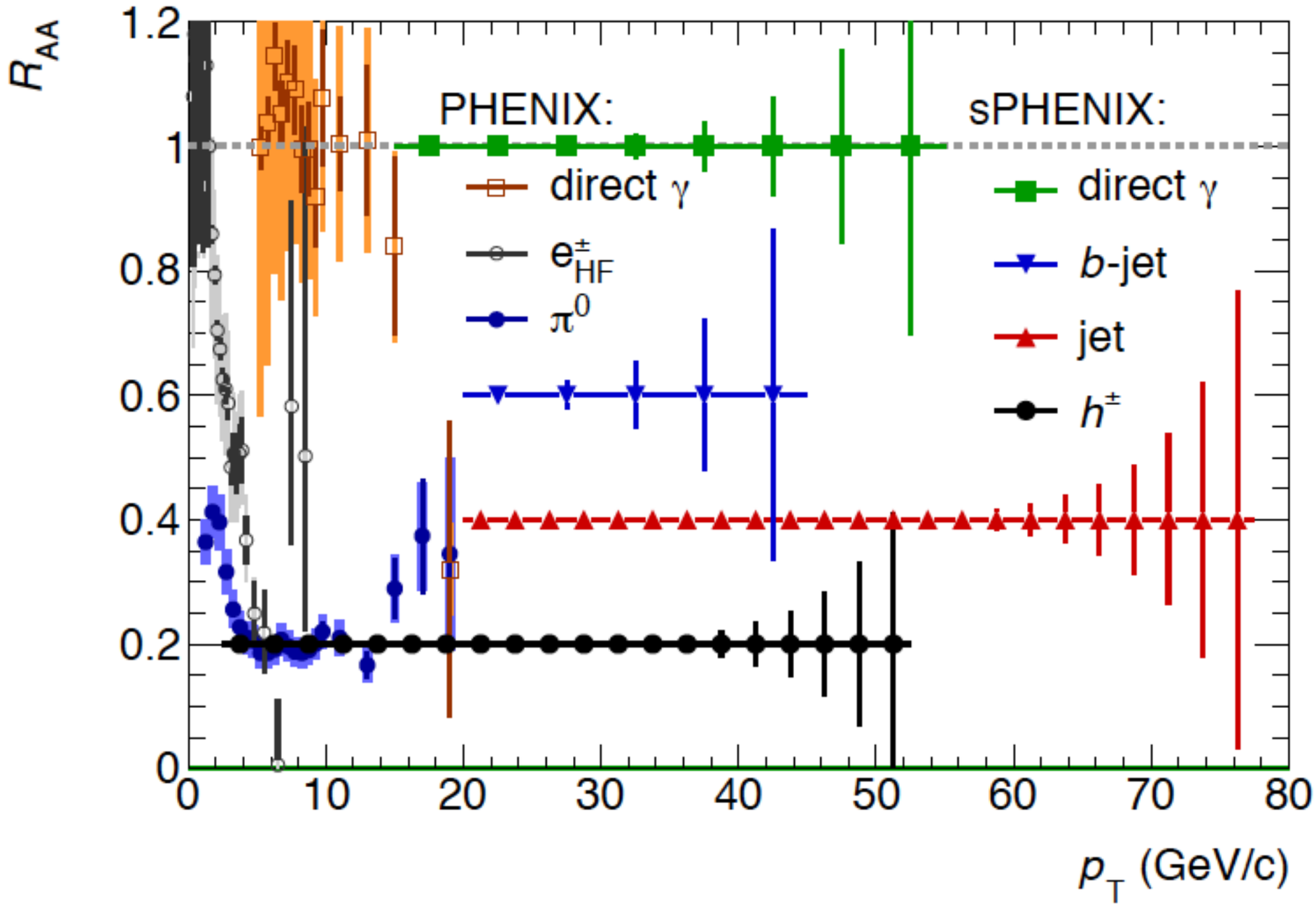
Not directly comparable measurements

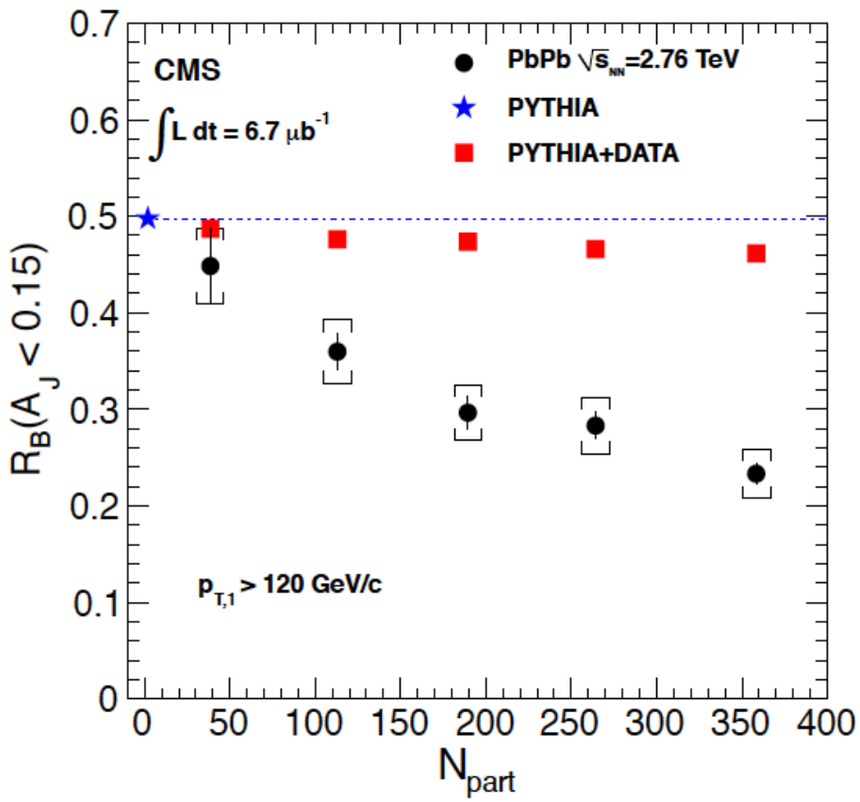


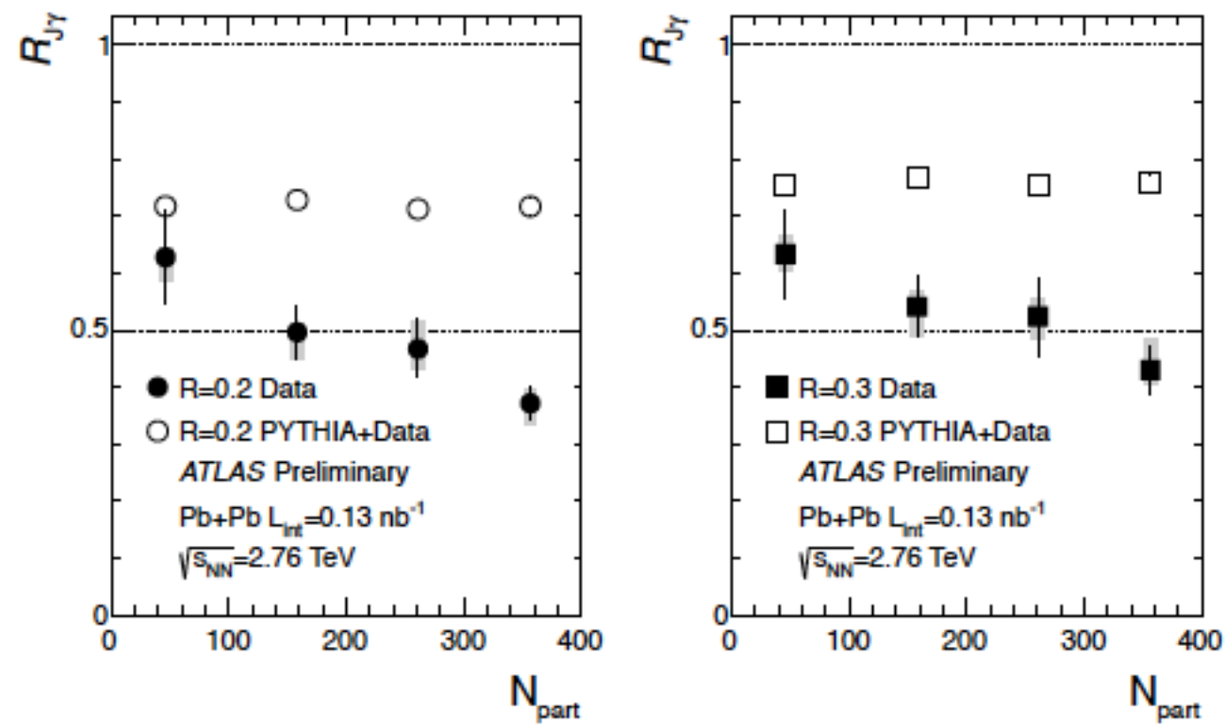


Path length dependence




R_{AA}
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
p_T (GeV/c)
PHENIX:
direct γ
$e^{\pm}_{HF}$
π^0
sPHENIX:
direct γ
b-jet
jet
$h^{\pm}$


CMS
PbPb √s_NN=2.76 TeV
PYTHIA
PYTHIA+DATA
∫L dt = 6.7 μb^-1
p_T,1 > 120 GeV/c
R_B(A_J < 0.15)
N_part


R_Jγ
R=0.2 Data
R=0.2 PYTHIA+Data
ATLAS Preliminary
Pb+Pb L_int=0.13 nb^-1
√s_NN=2.76 TeV
R=0.3 Data
R=0.3 PYTHIA+Data
N_part