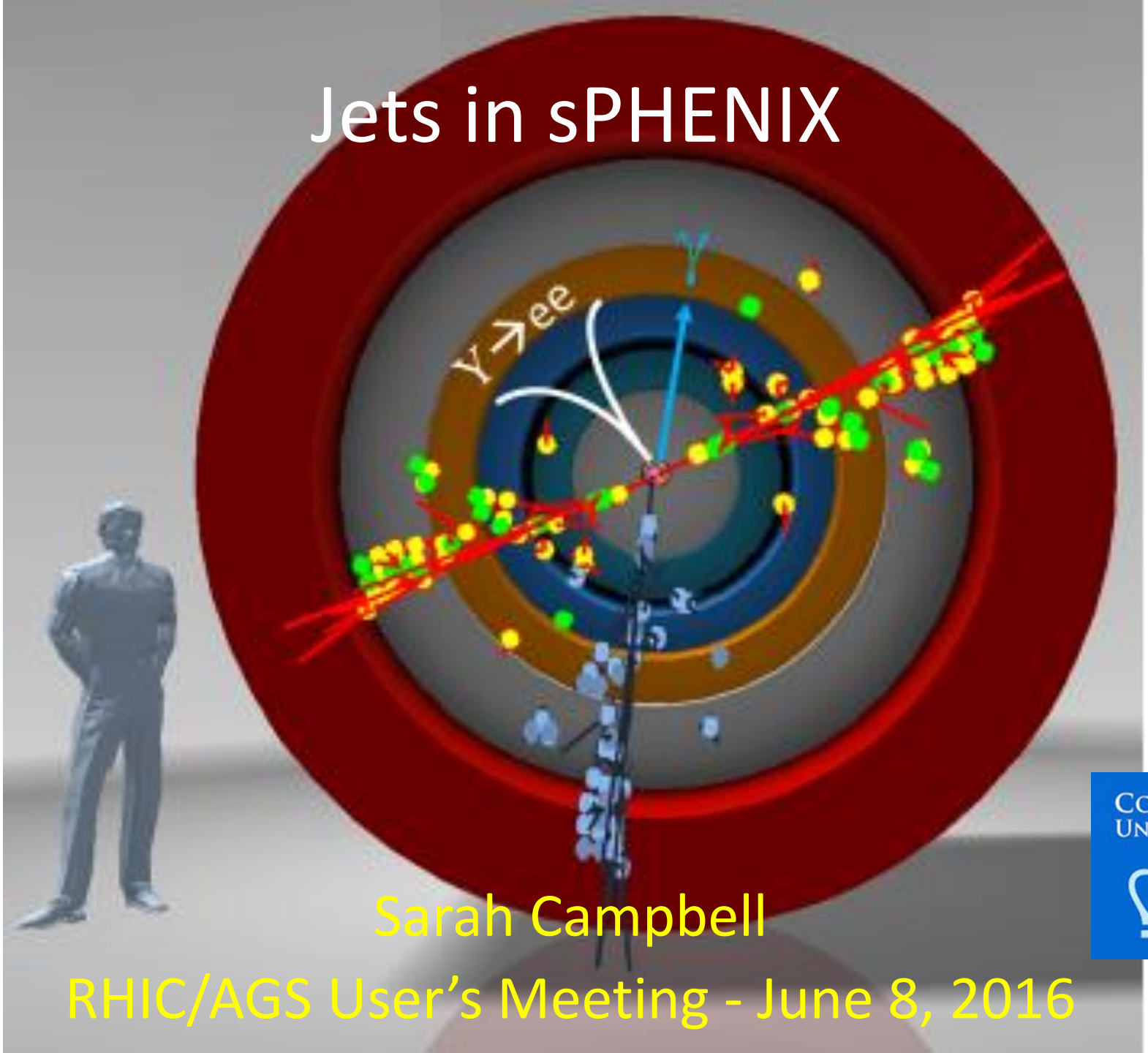
Jets in sPHENIX

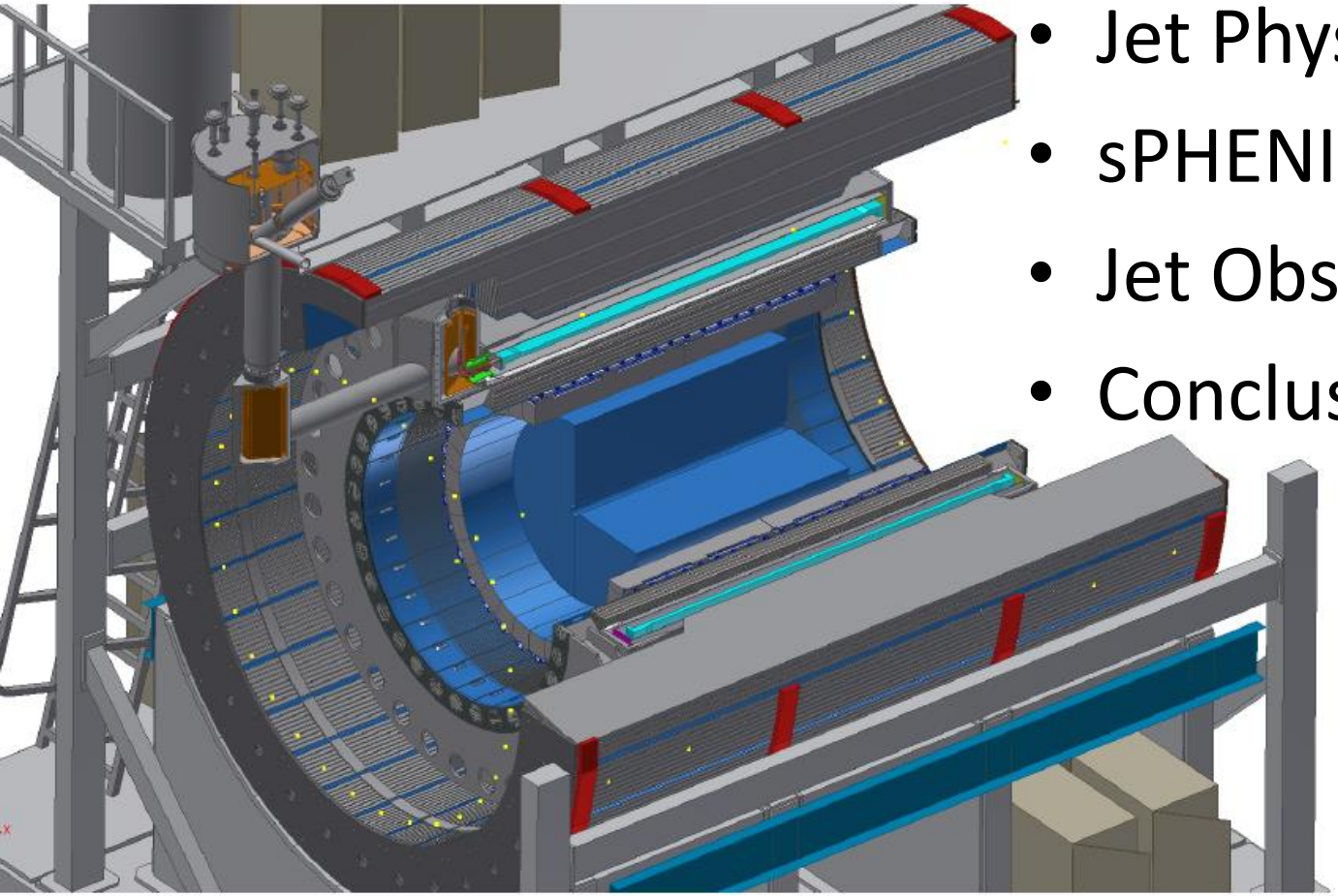


Sarah Campbell

RHIC/AGS User's Meeting - June 8, 2016

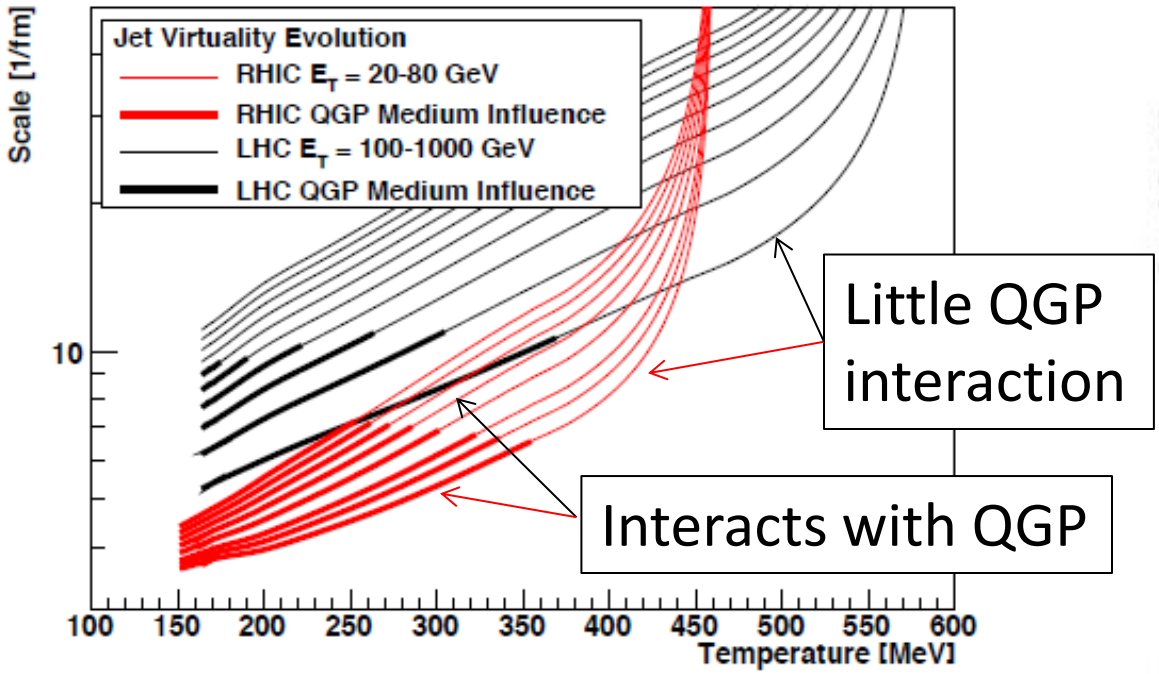
COLUMBIA UNIVERSITY

Outline



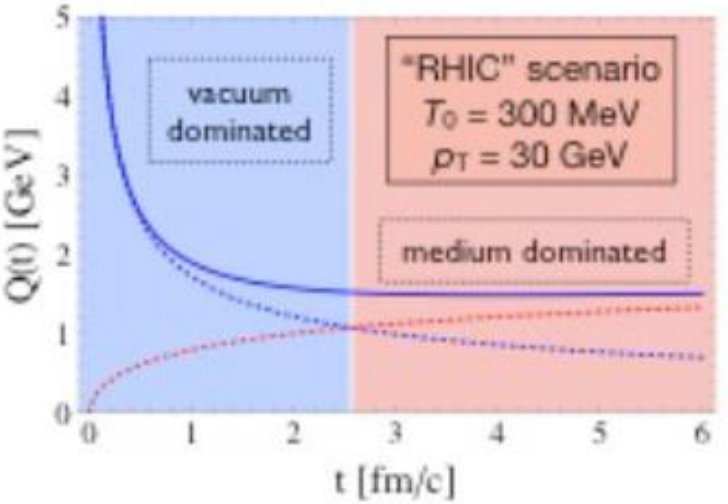
- Jet Physics in sPHENIX
- sPHENIX Design
- Jet Observables
- Conclusions

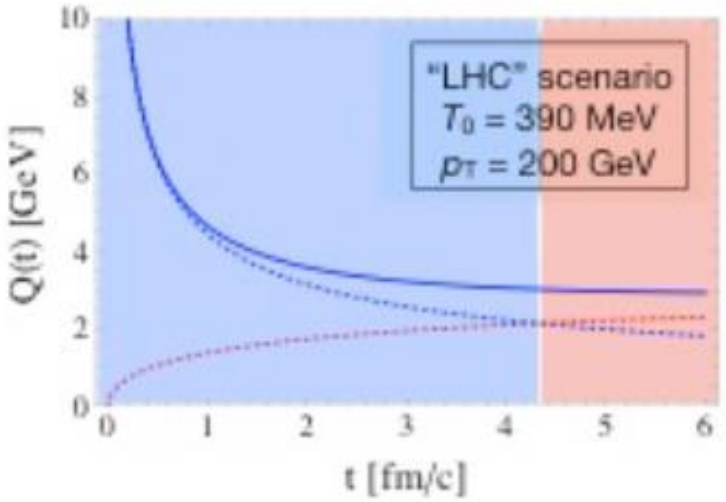
Jet Evolution and Virtuality



Little QGP interaction

Interacts with QGP





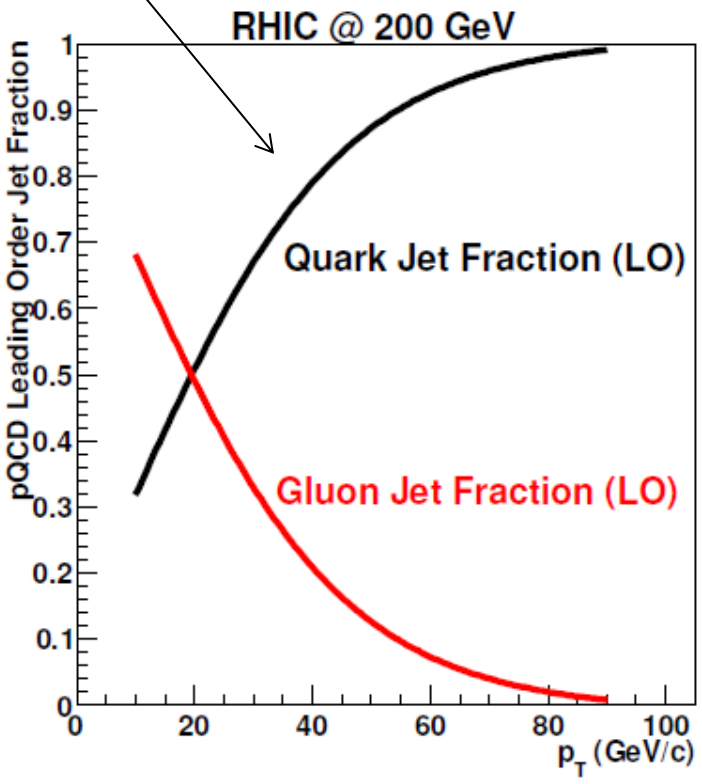
Lower energy jets, jets at RHIC have increased sensitivity to QGP interactions

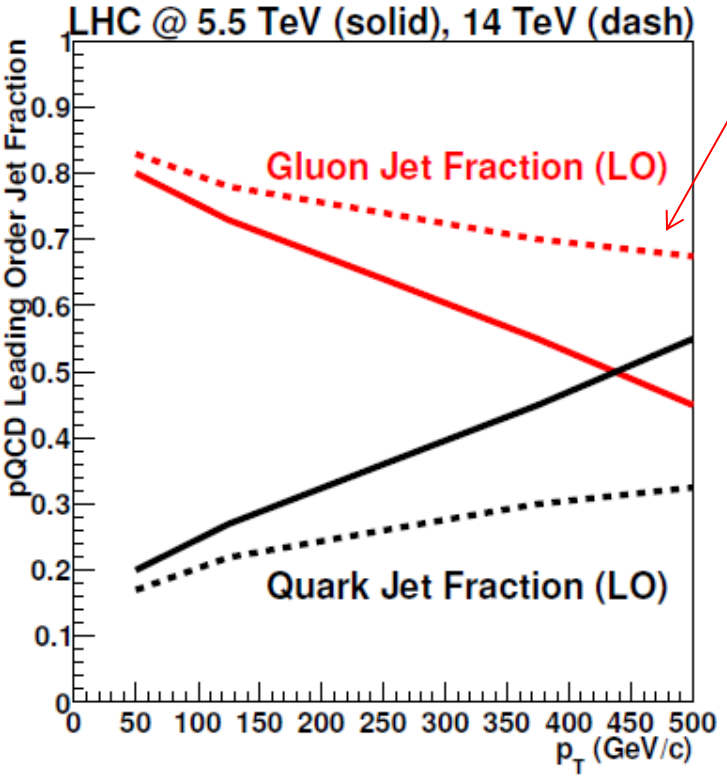
Complementary measurements at RHIC & LHC

Jet Partonic Composition

Higher quark-jet fraction at RHIC

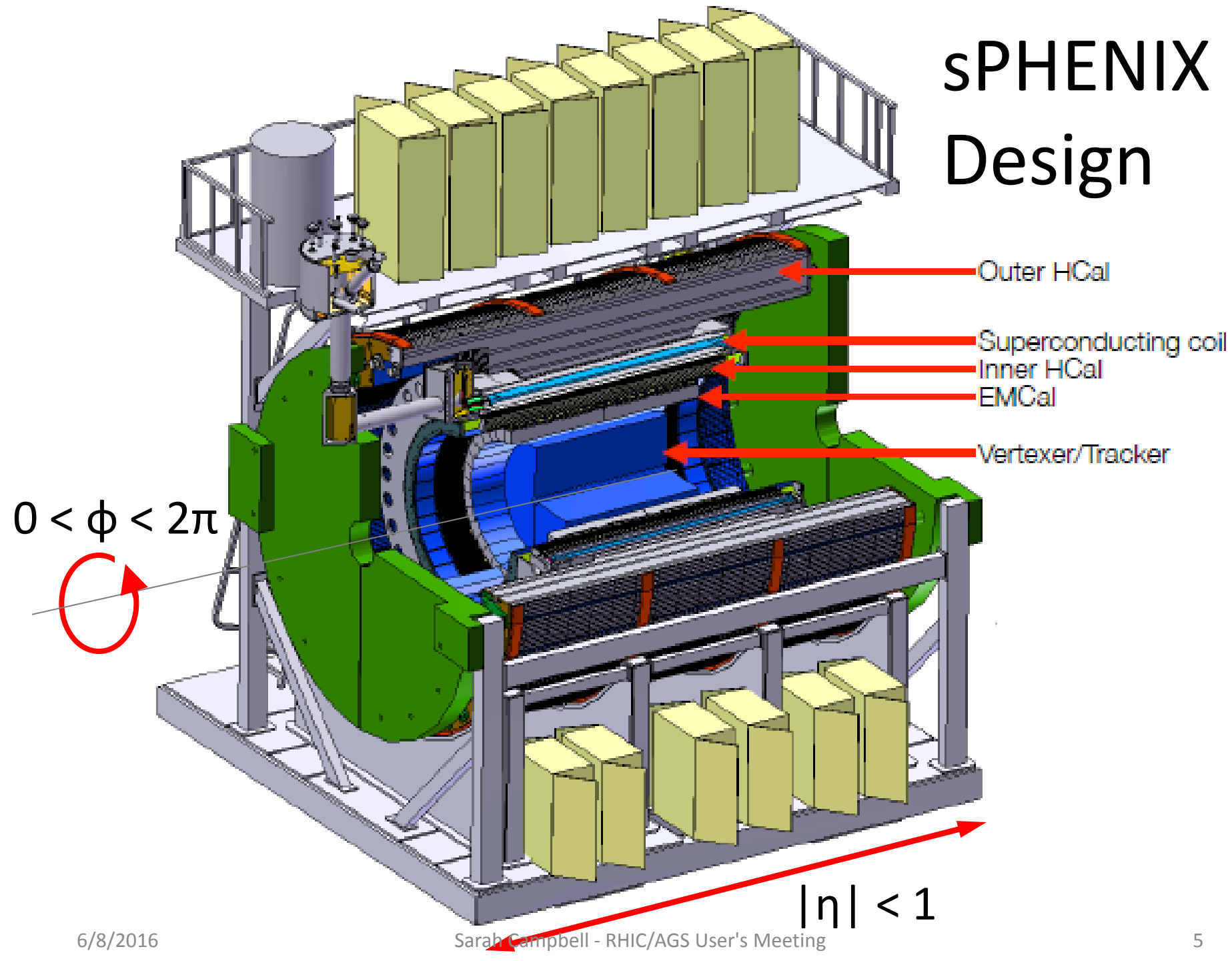
LHC gluon-jet dominated until significantly higher jet energies





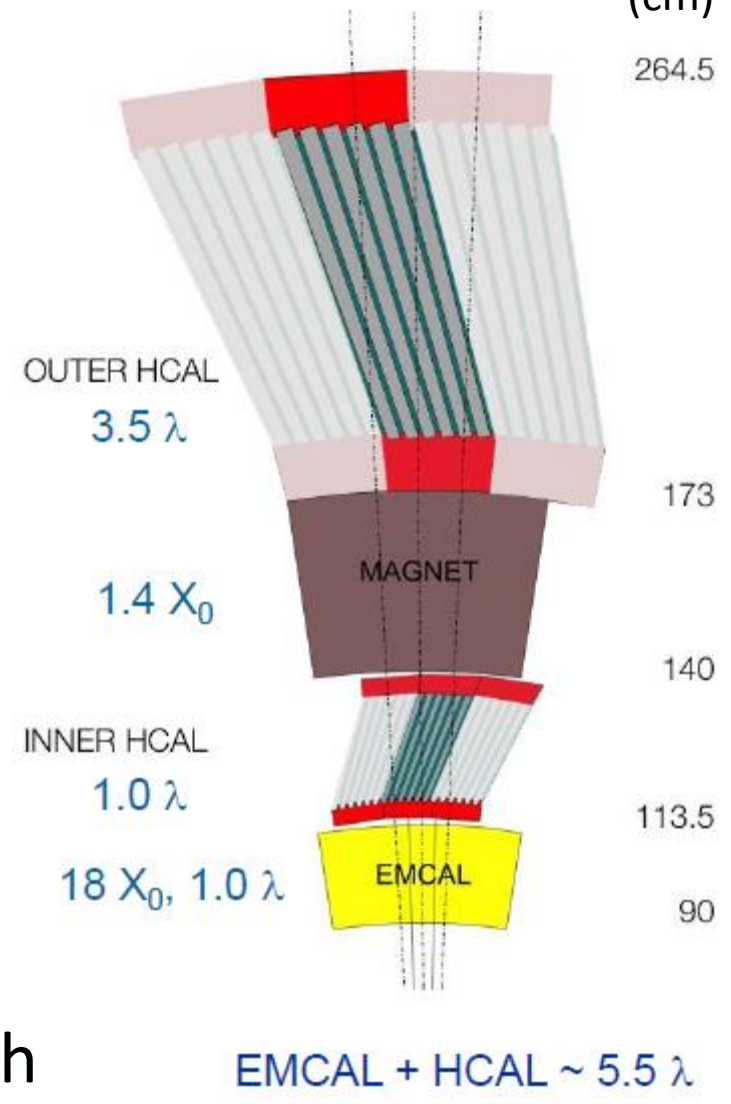
Complementary measurements at RHIC & LHC

sPHENIX Design



Subsystems

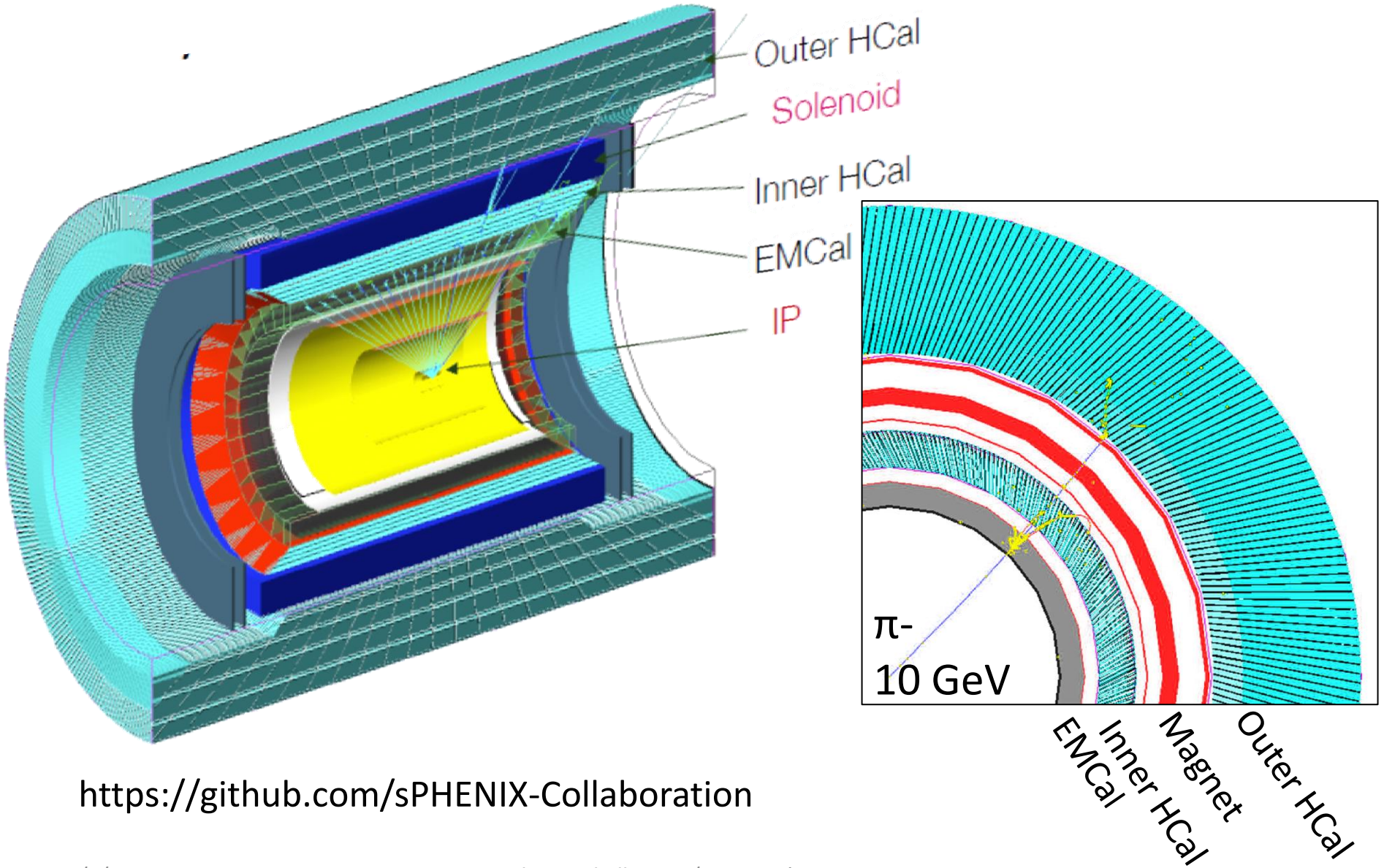
- HCal: Tilted Steel-Si plates
  - Inner and Outer HCal
  - $\Delta\phi$ x $\Delta\eta$ = 0.1 x 0.1
- 1.5T Superconducting magnet
  - From BaBar, cold tested at BNL
- EMCal: W-Si fiber
  - $\Delta\phi$ x $\Delta\eta$ = 0.025 x 0.025
- Tracker: vertex + outer tracker
  - Options still being considered, including MAPS inner tracker with gateless TPC



Specifications for Jet Measurements

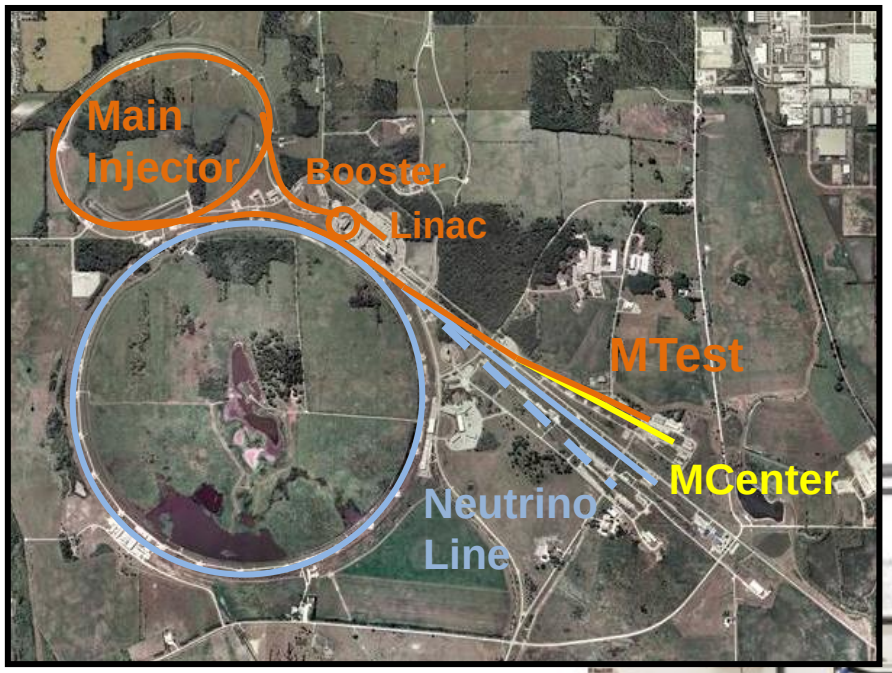
- Jets
  - Energy resolution
    - Single particle: $\sigma/E < 100\%/\sqrt{E}$
    - Jet: $\sigma/E < 120,150\%/\sqrt{E}$ in p+p, A+A
  - Measure R = 0.2 jets
    → $\Delta\phi \times \Delta\eta = 0.1 \times 0.1$
  - Energy scale uncertainty < 3%
  - Reject (>95%) high p_T charged track backgrounds → HCal
- Dijets
  - > 70% containment for R=0.2 dijets → $0 < \phi < 2\pi$, $|\eta| < 1$
- Fragmentation Functions
  - $\Delta p/p < 0.2\%$ p tracking resolution out to 40GeV/c → 1.5T magnet
  - Independently measure E and p for z = p/E → Tracker
- Gamma-Jet
  - EMCal resolution $\sigma/E < 15\%/\sqrt{E}$
  - EMCal trigger in p+p and p+A, rejection > 100 for E > 10 GeV
- Heavy Flavor-Jet
  - Electron ID at $p_T > 4$ GeV/c
  - DCA < 100 μm for $p_T > 4$ GeV/c electrons
- High statistics
  → 15 kHz DAQ rate
  - Jets without trigger bias

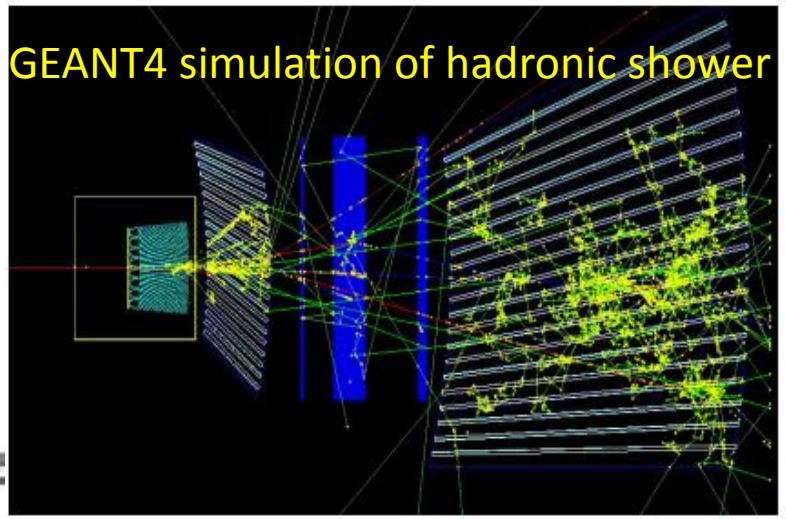
GEANT4 Simulations

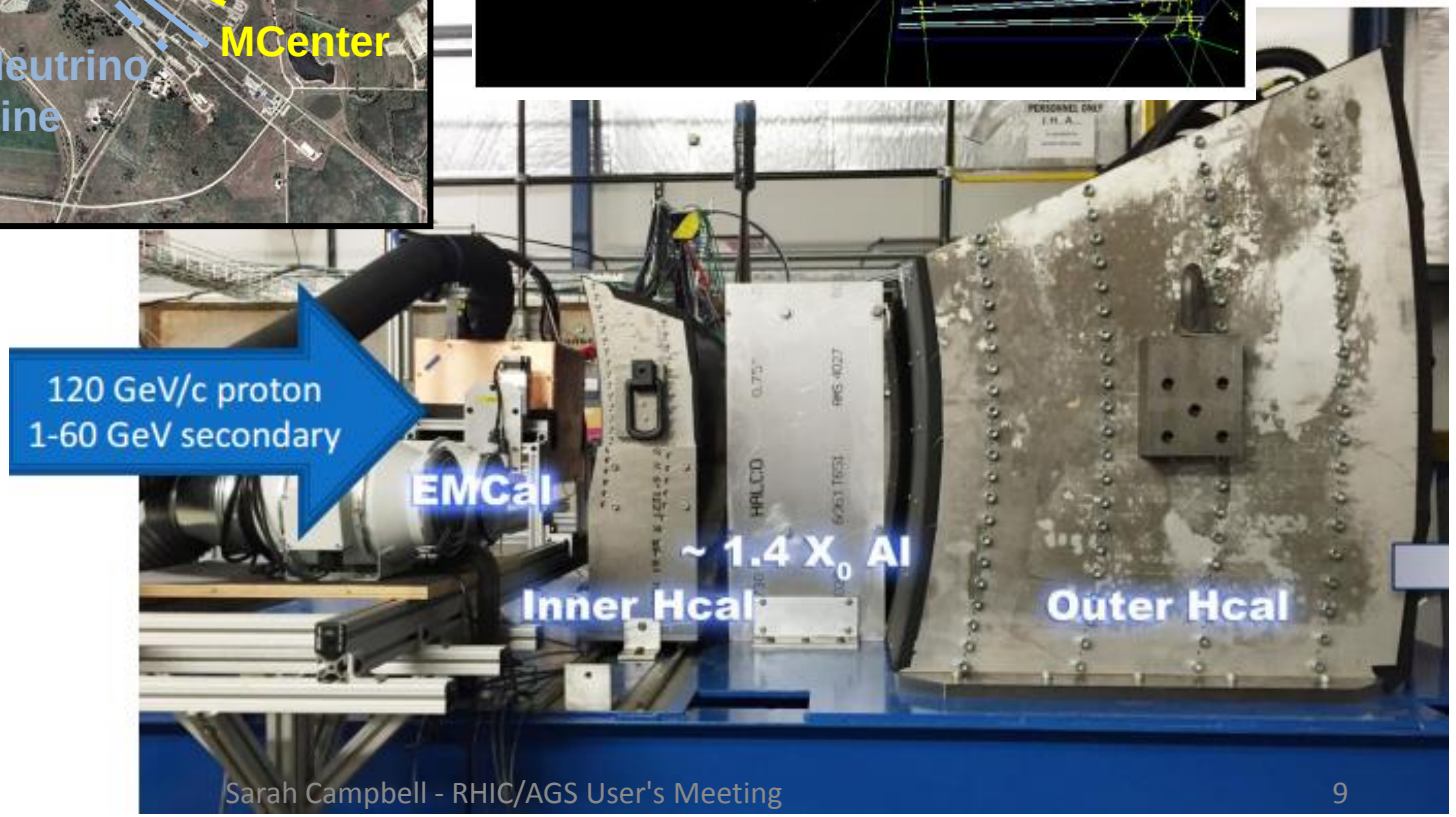


https://github.com/sPHENIX-Collaboration

Test Beam at FermiLab

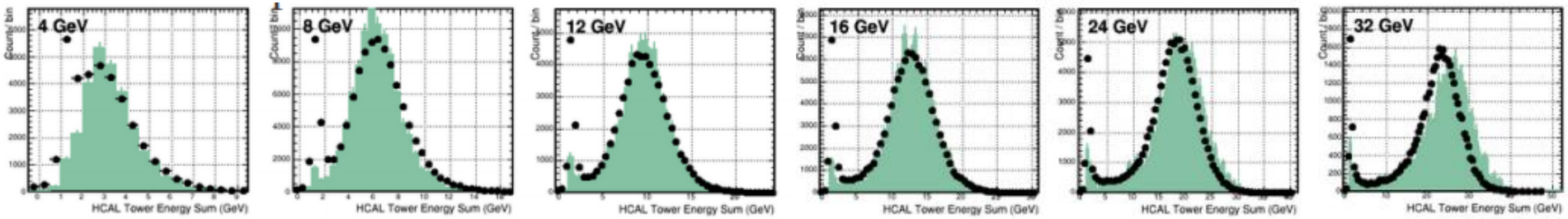


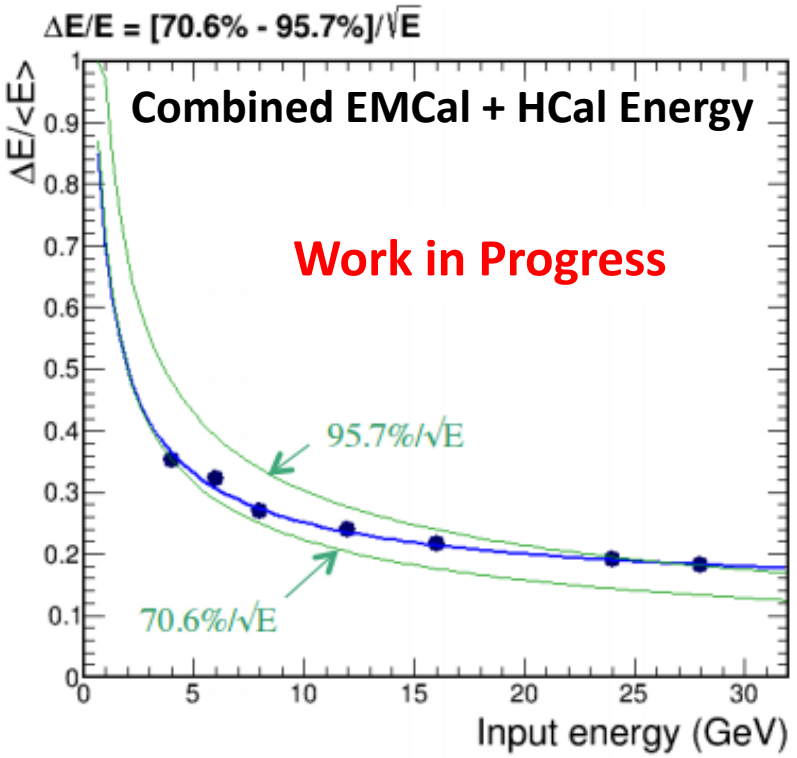


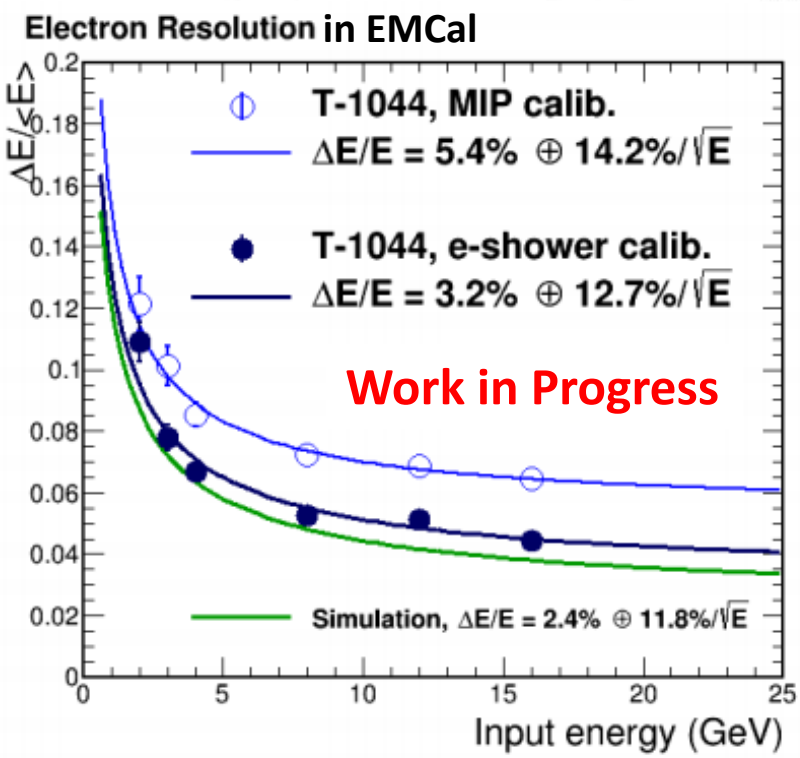


Early Test Beam Results

HCal energy distributions well described by simulation



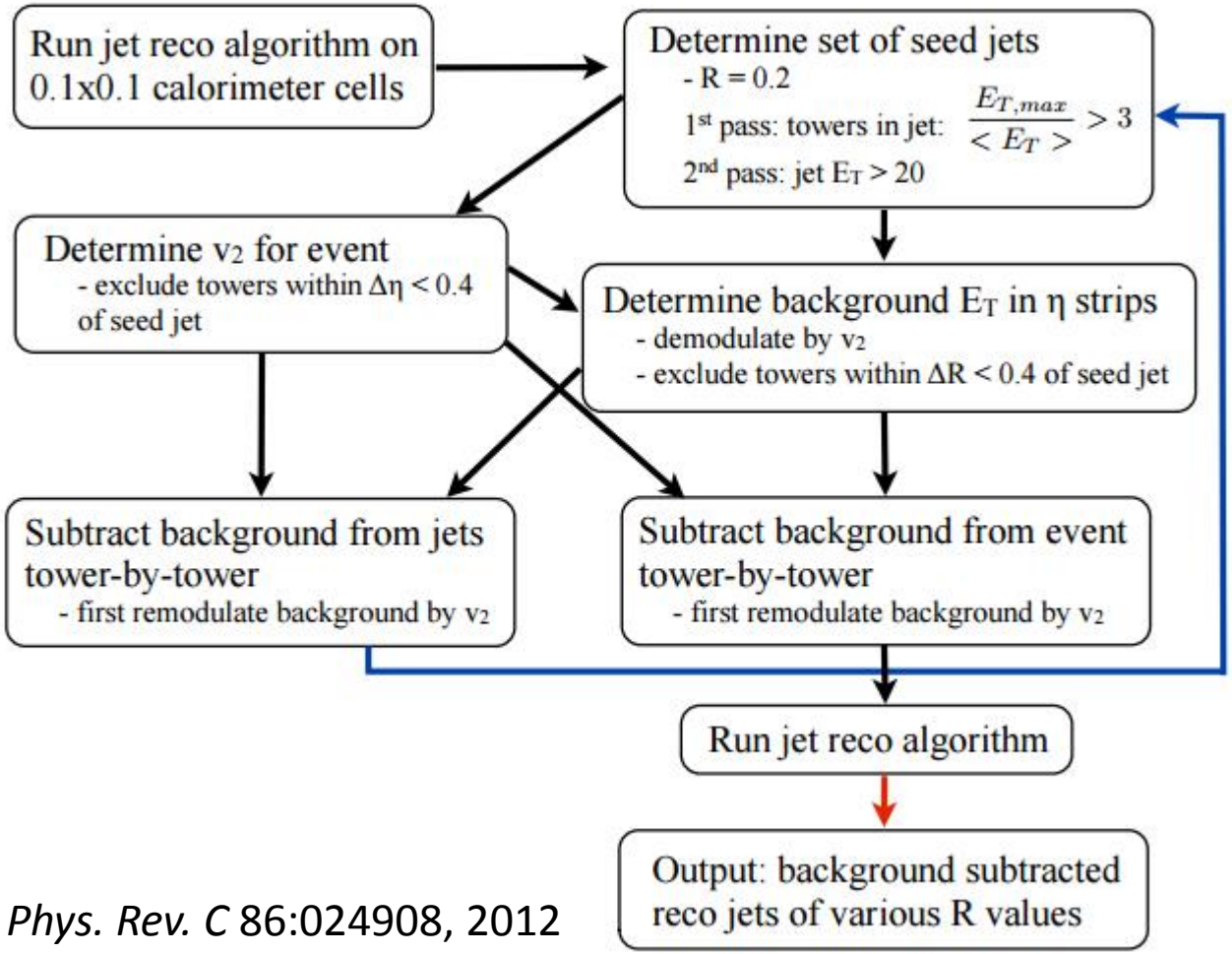




Meets design goals of <100%/√E and <15%/√E for EMCal

Jet Reconstruction

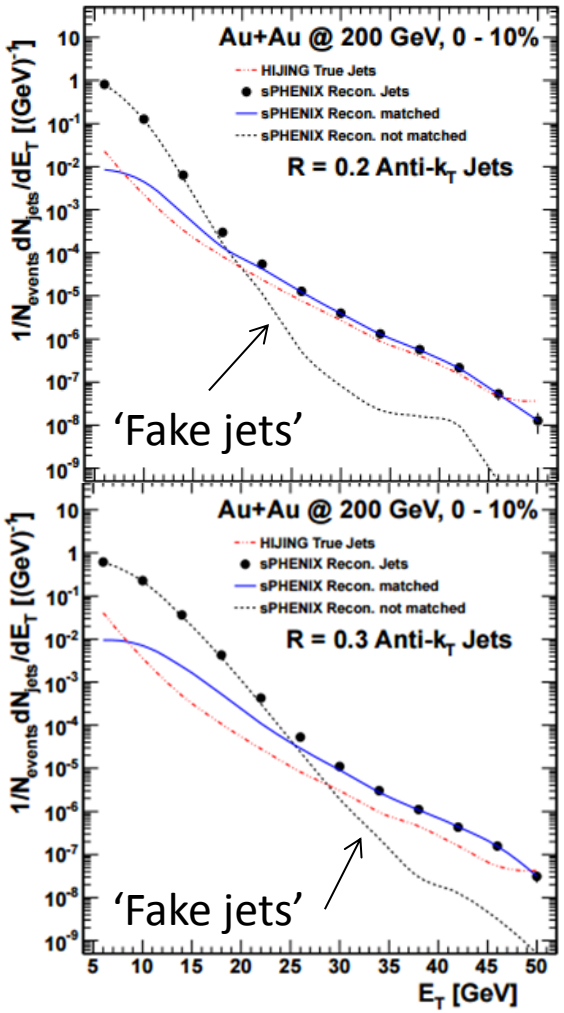
Inspired by ATLAS' heavy ion jet reconstruction:

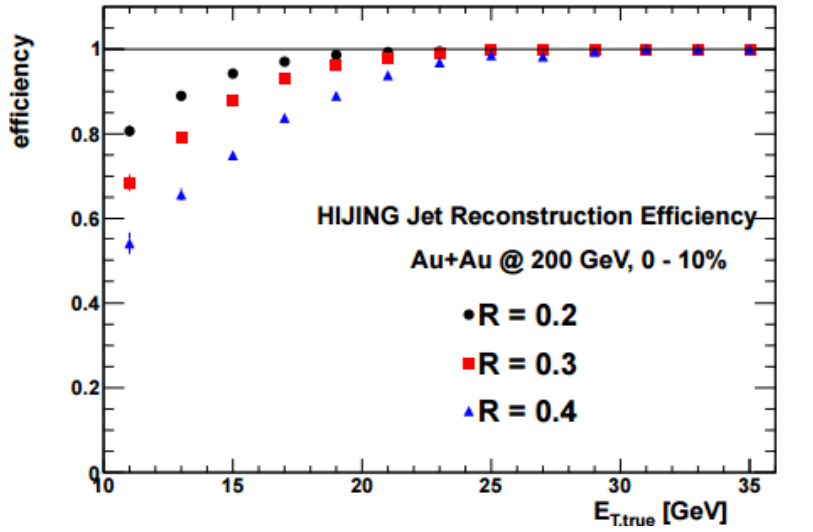


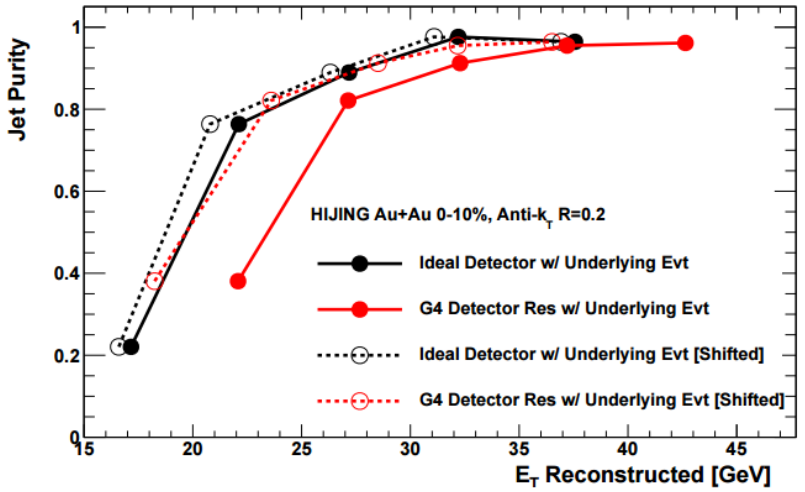
Hanks et al. *Phys. Rev. C* 86:024908, 2012

Jet Reconstruction

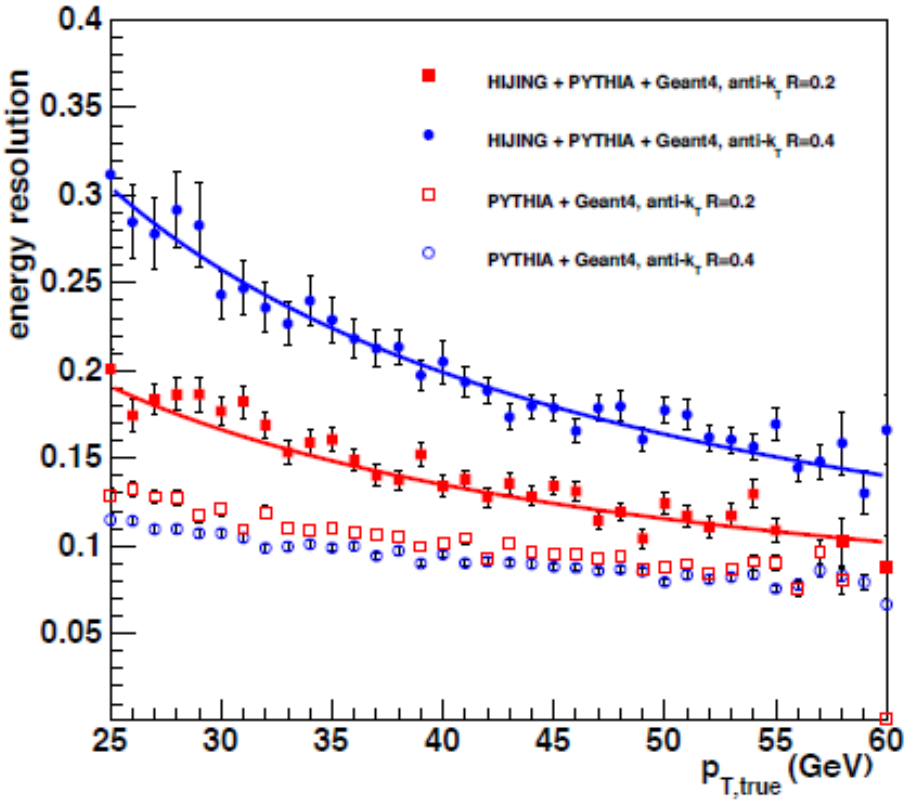
Fluctuations in the underlying event create ‘fake jets’

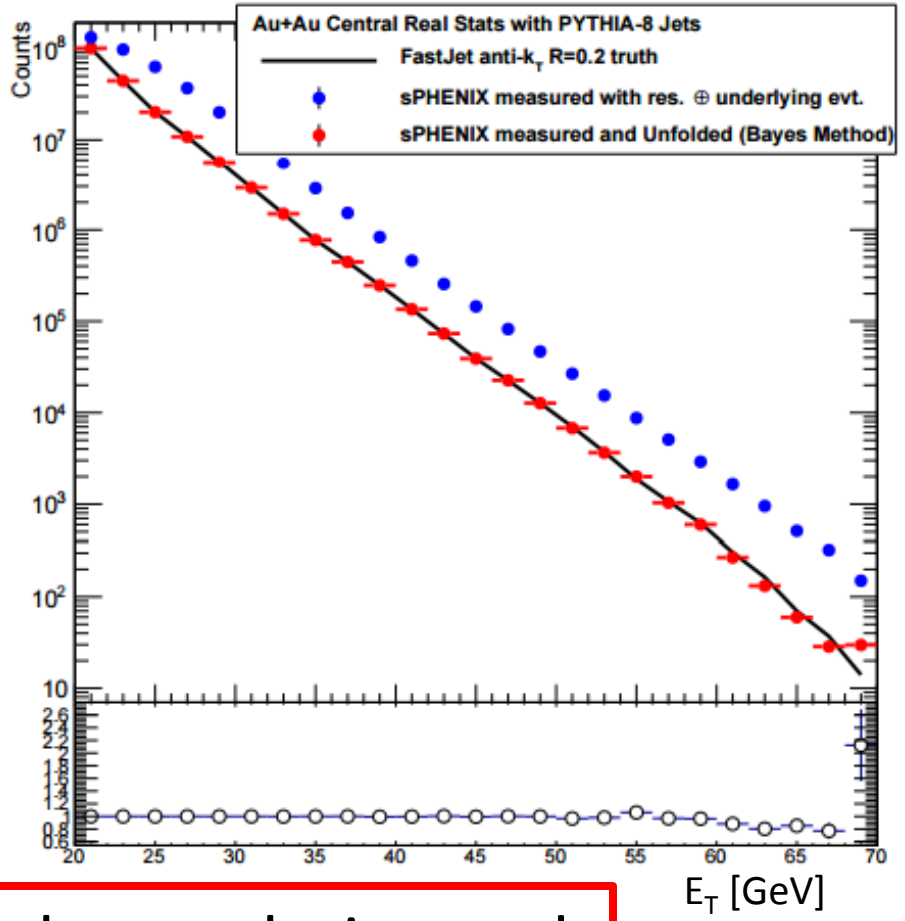






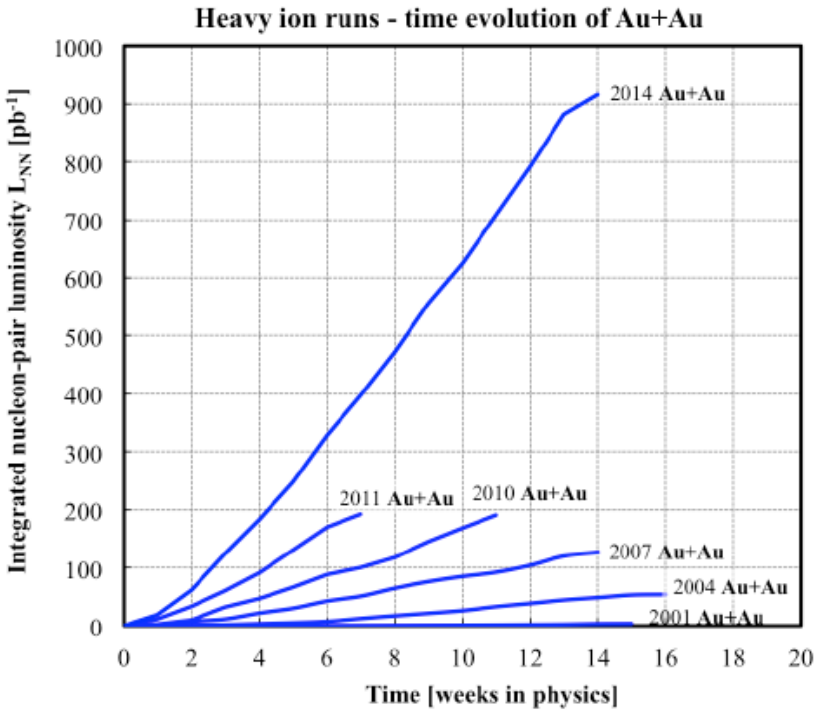
Jet Energy Resolution and Unfolding





Unfolding corrects for the resolution and underlying event fluctuation effects

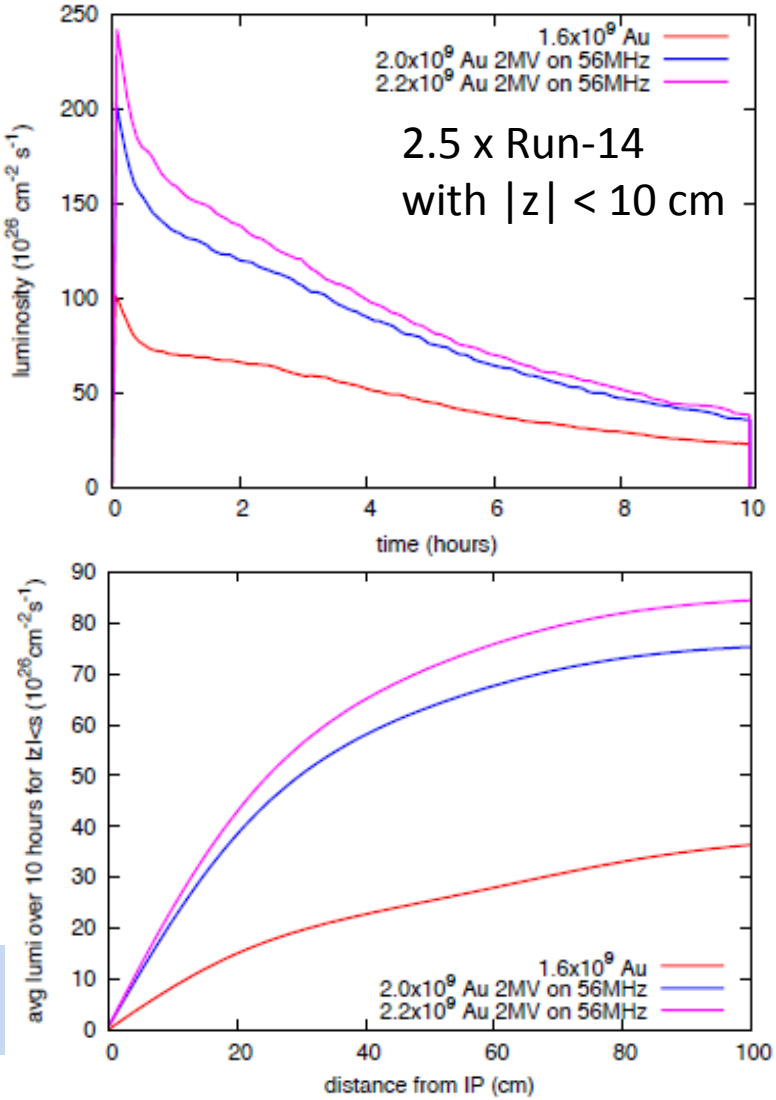
Increased Luminosity at RHIC



22-weeks 200 GeV Au+Au
→ 100B Min Bias events

High statistics requirement met

Luminosity projections from C-AD

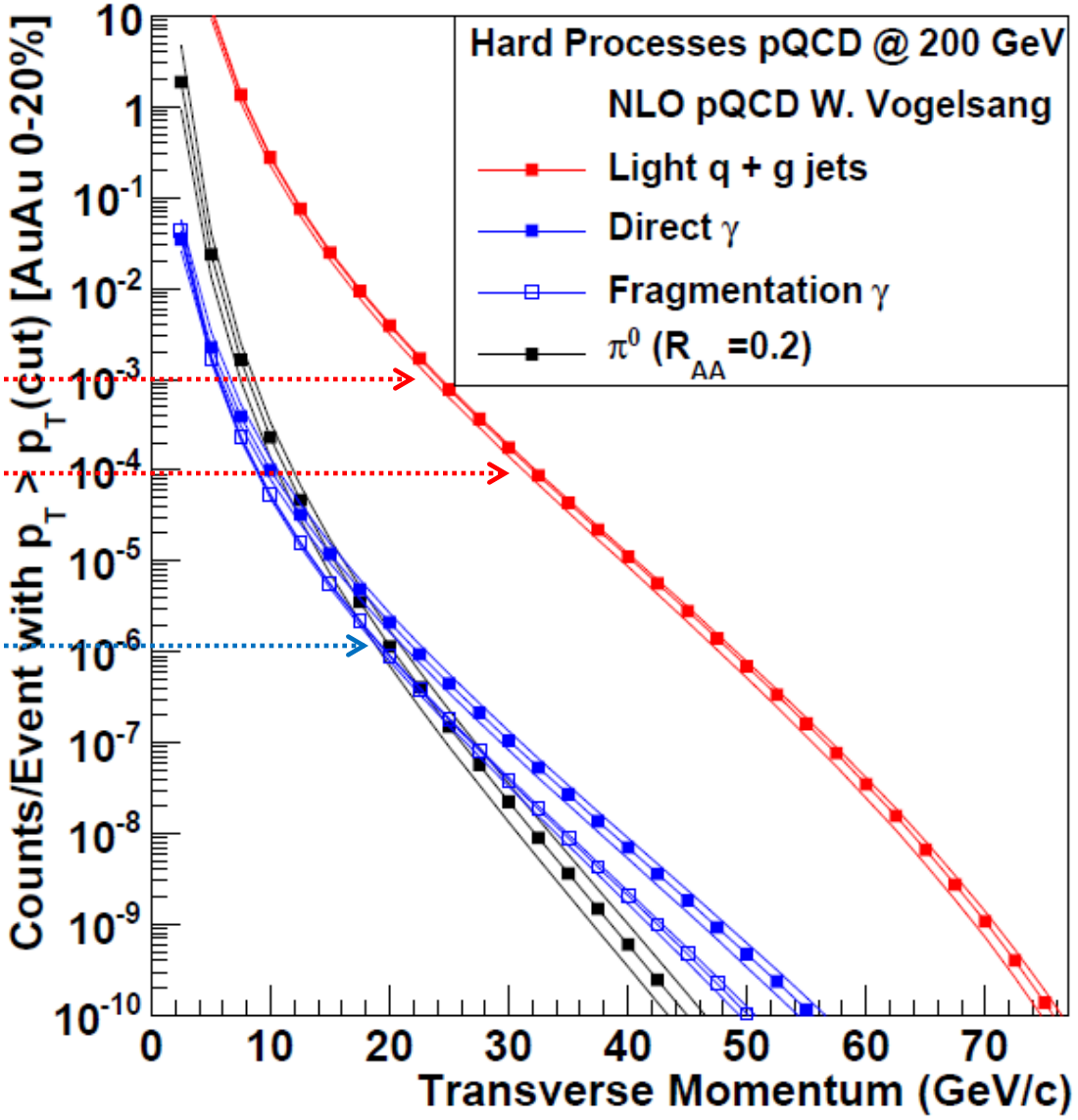


pQCD Jet Rates

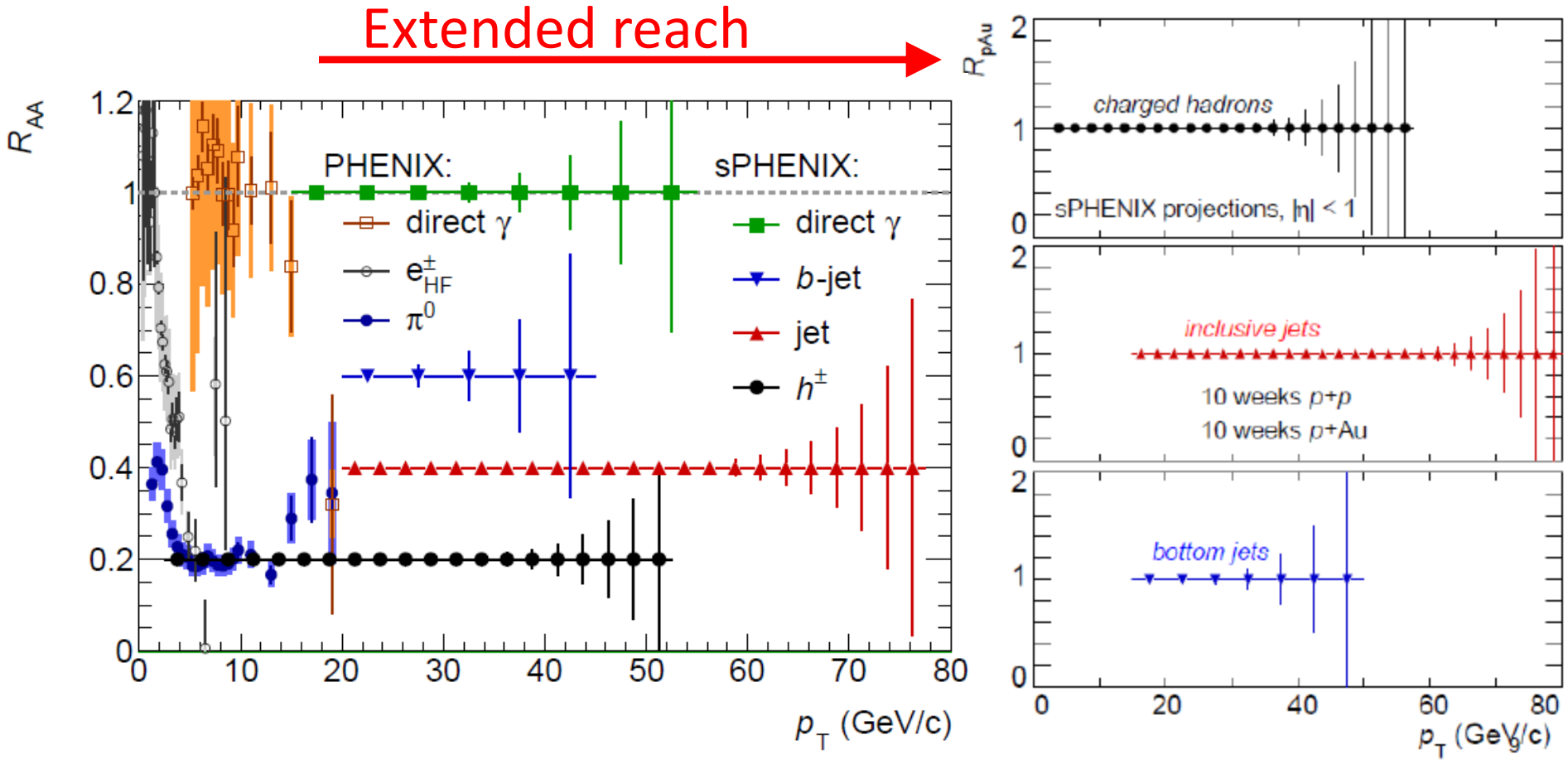
22 weeks Au+Au
→ 20B 0-20% events

10^7 jets $p_T > 20$ GeV/c
10^6 jets $p_T > 30$ GeV/c

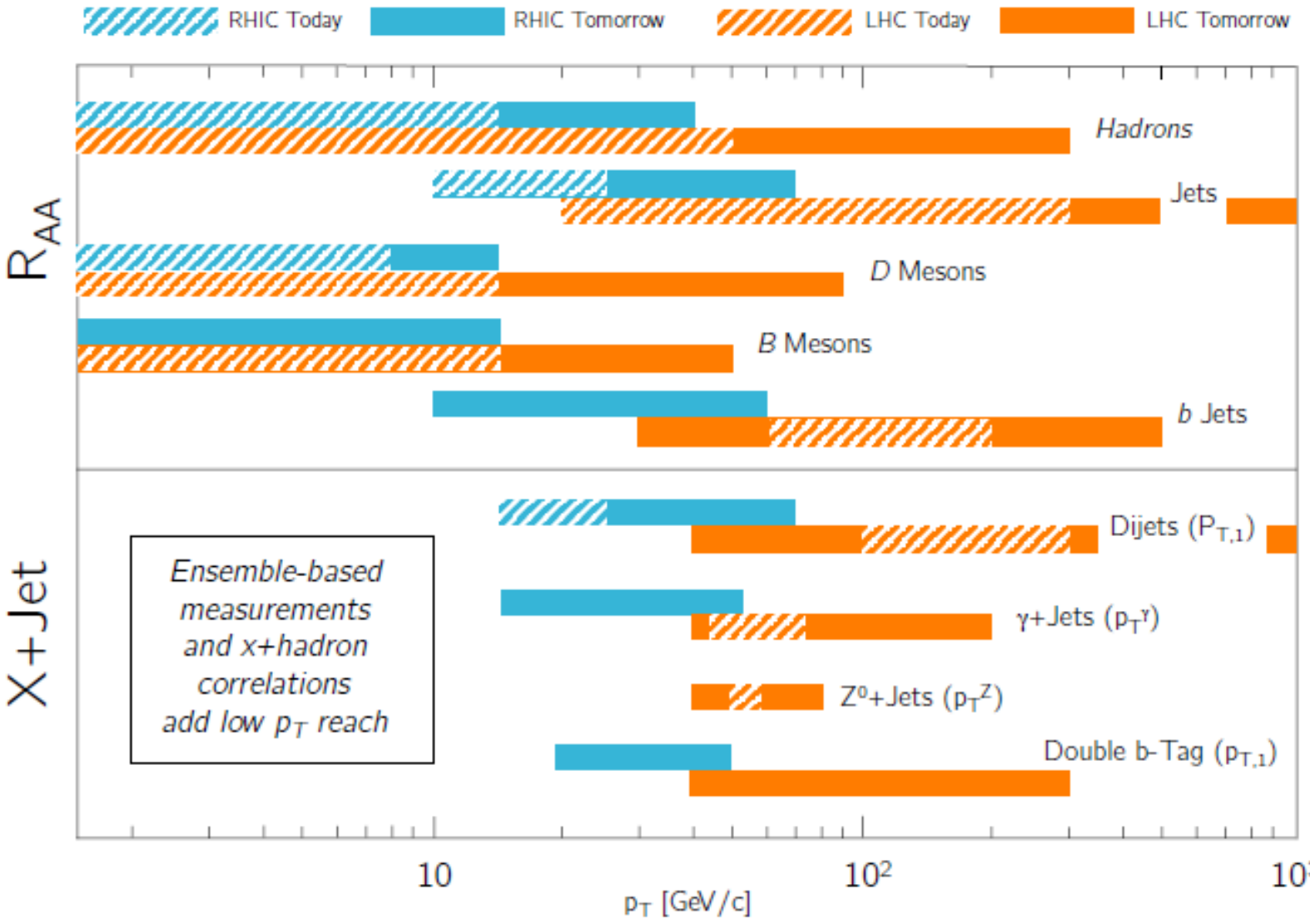
10^4 γ_{dir} $p_T > 20$ GeV/c



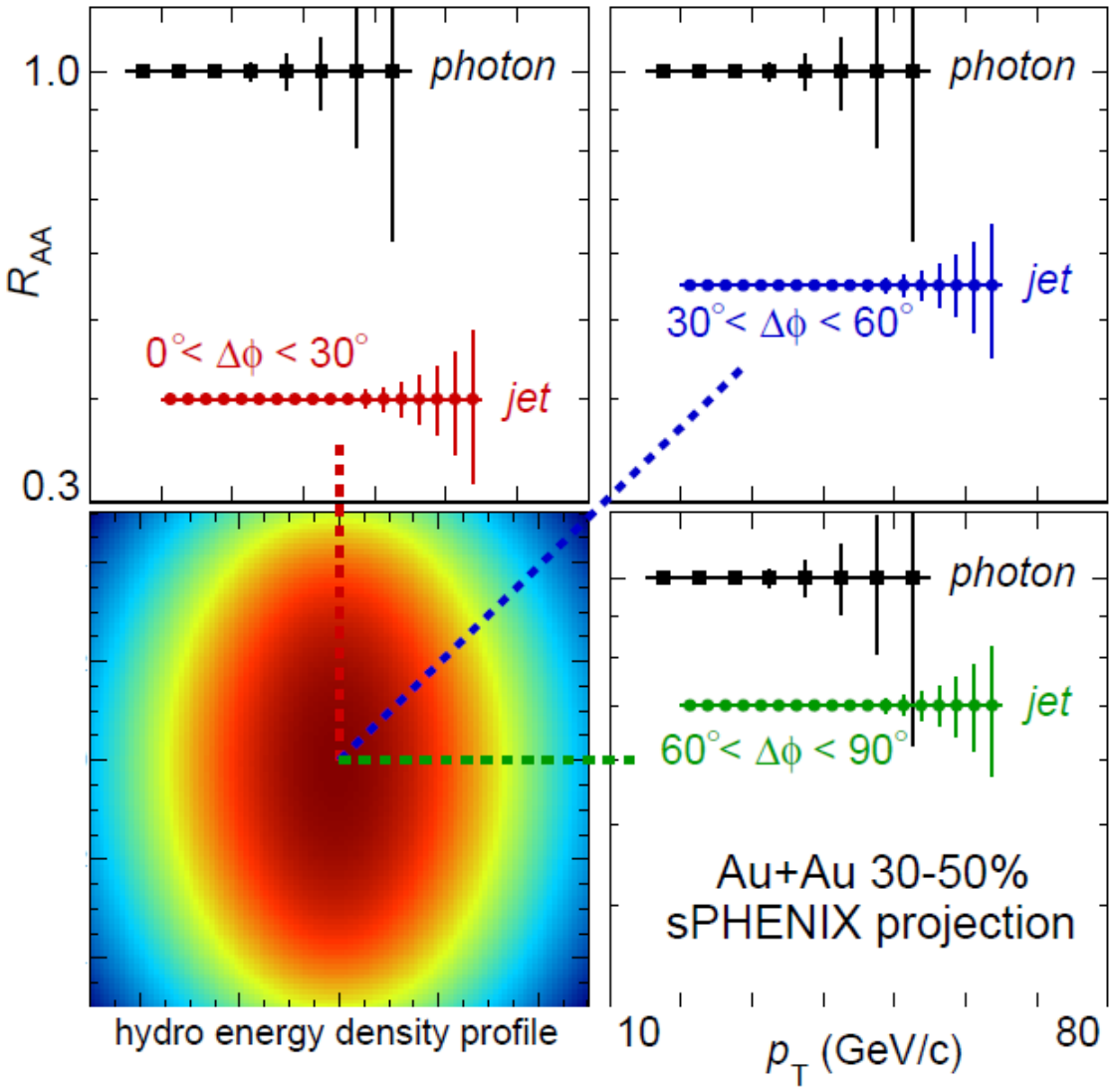
Increased Kinematic Range



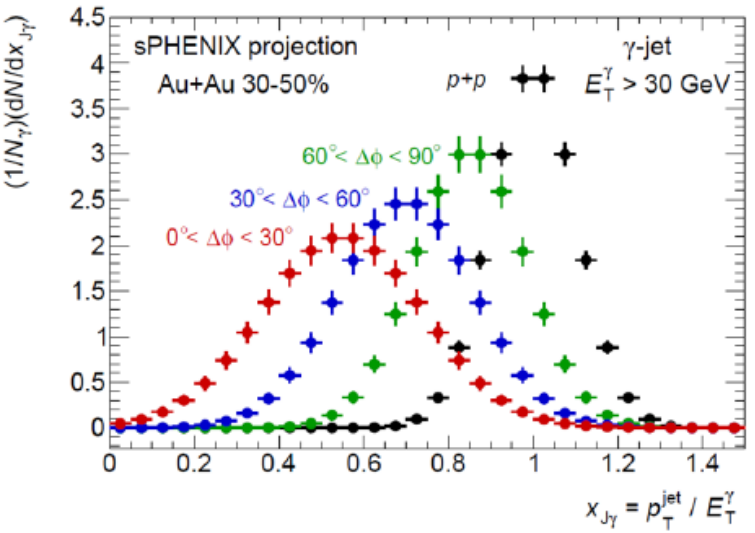
Overlap with LHC



Path Length Dependence

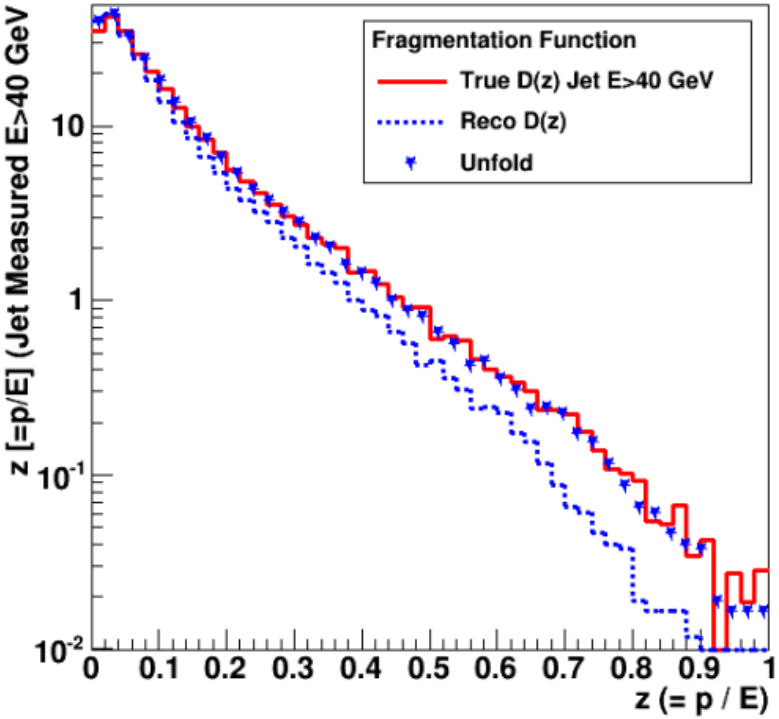


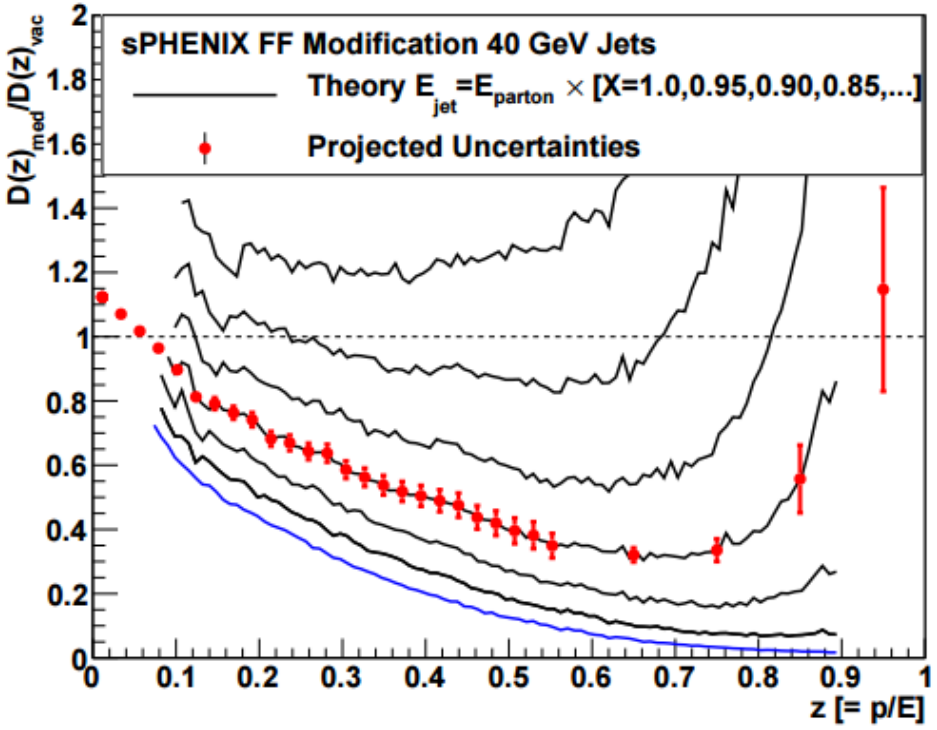
Important constraint to energy loss models



Fragmentation Functions, D(z)

Energy distribution within the jet → Dynamics of jet quenching

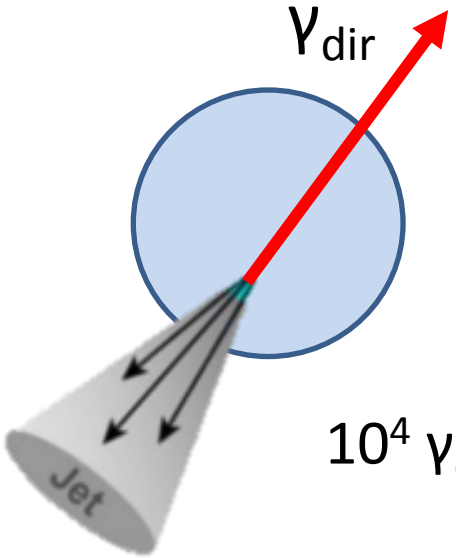




X=0.70
X=0.75
X=0.80
X=0.85
X=0.90
X=0.95
X=1.00

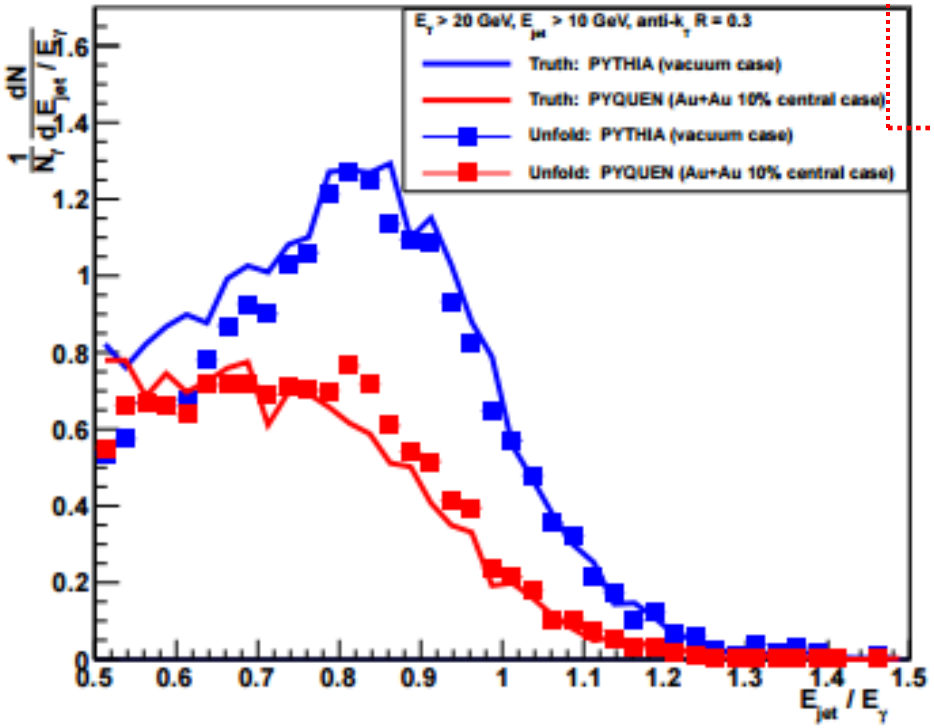
X ≡ fraction of parton energy retained in jet cone

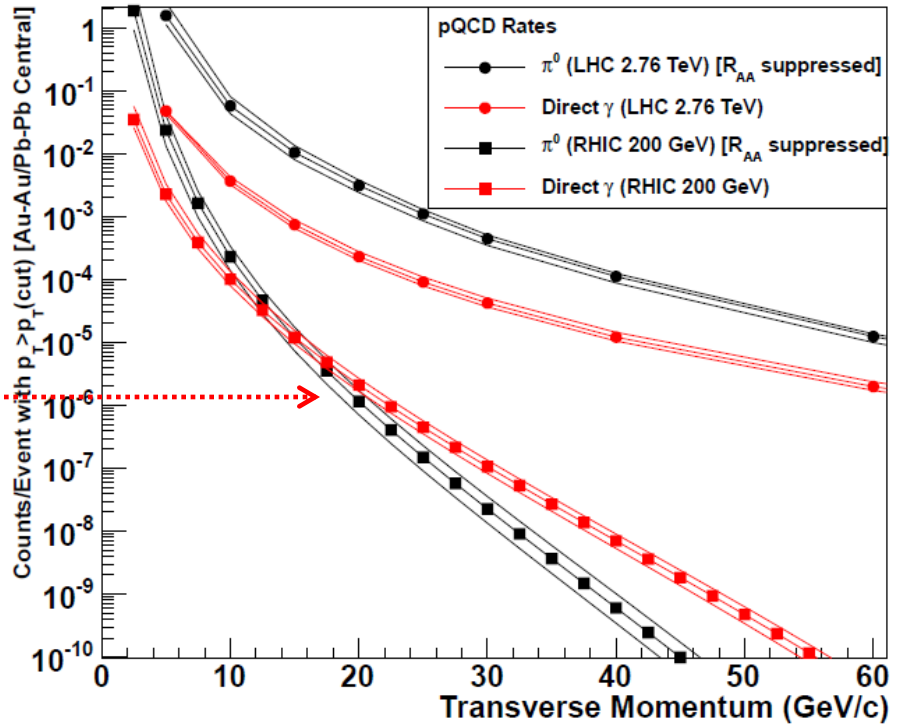
Gamma-Jet



Advantageous γ_{dir}-to-π^0 ratio at RHIC

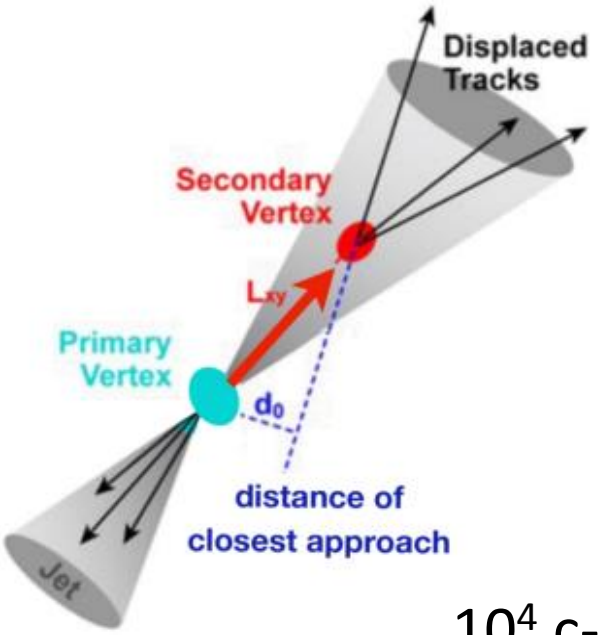
10^4 γ_{dir} p_T > 20 GeV/c





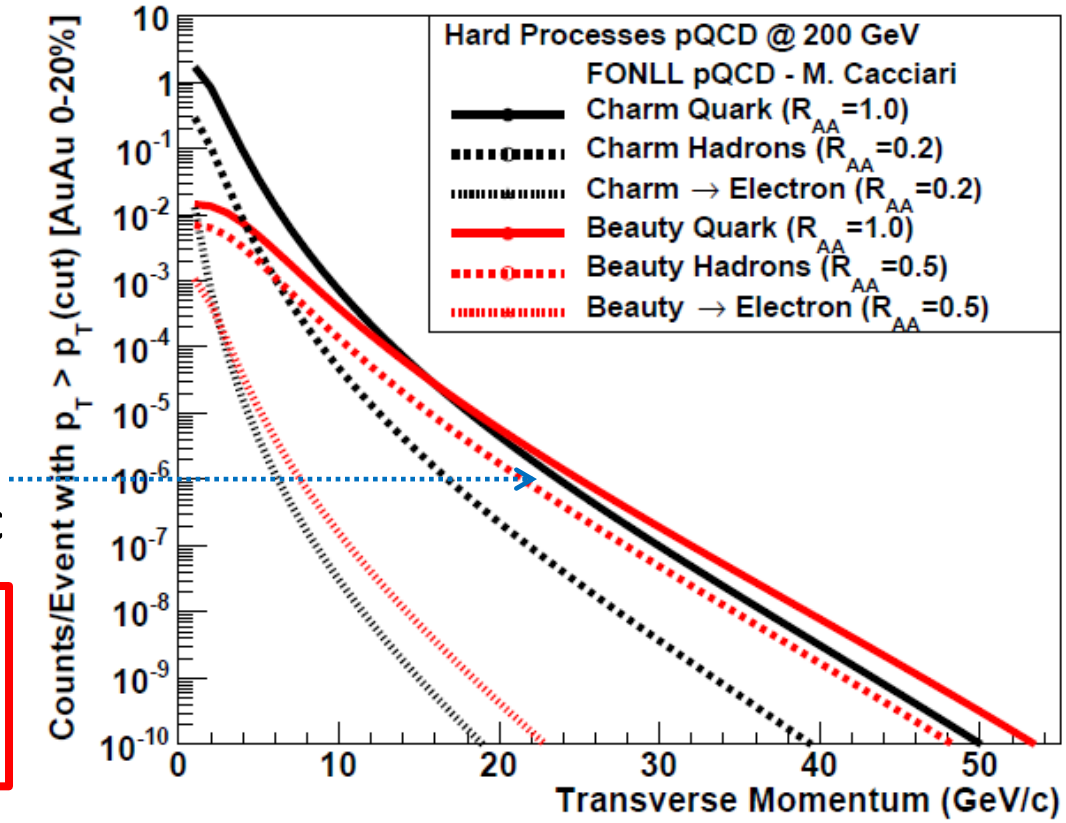
Range of direct photon ID

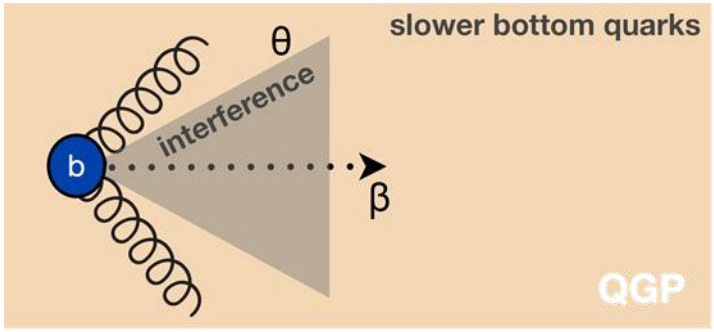
b-Jets

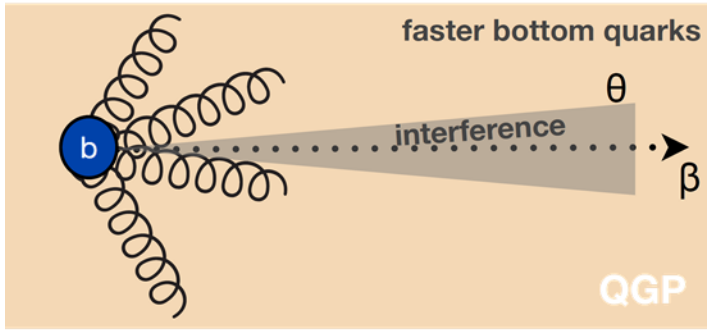


10^4 c-, b-jets
p_T >20 GeV/c

Sensitive to collisional vs radiative energy loss

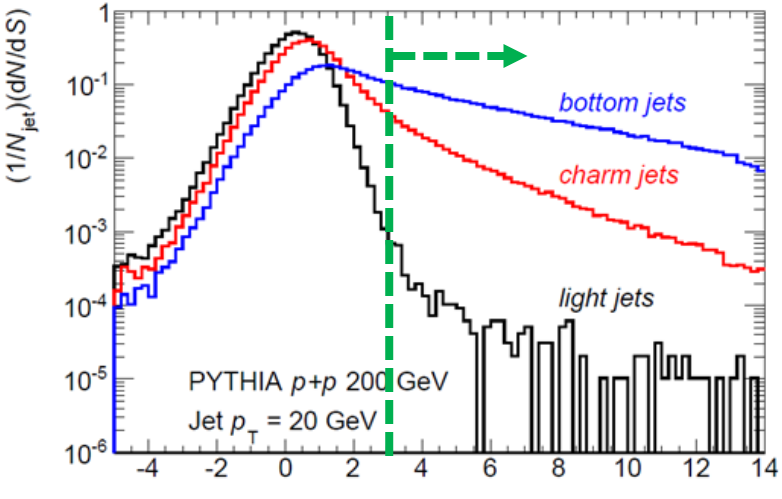


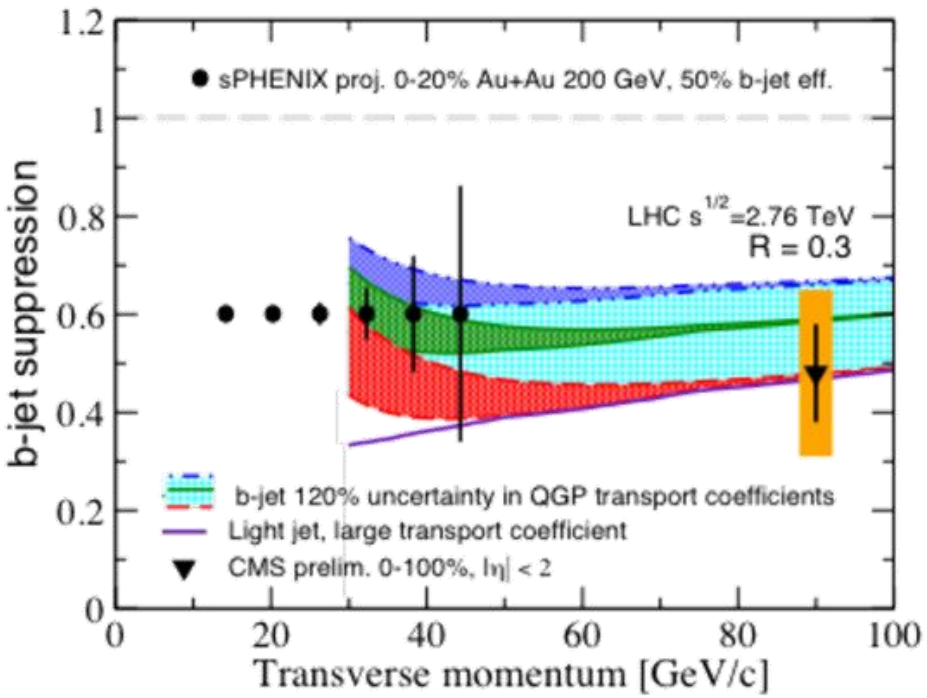


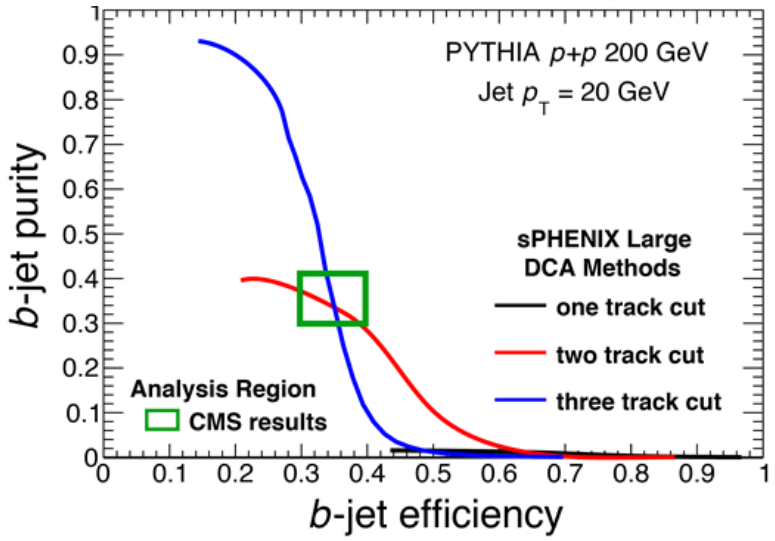


b-Jet Tagging

- Methods → Require a precision vertex detector
  - Multiple large DCA tracks
  - Secondary vertex mass
  - B-meson tagging by semi-leptonic decay or by $m_{Inv\ B}$



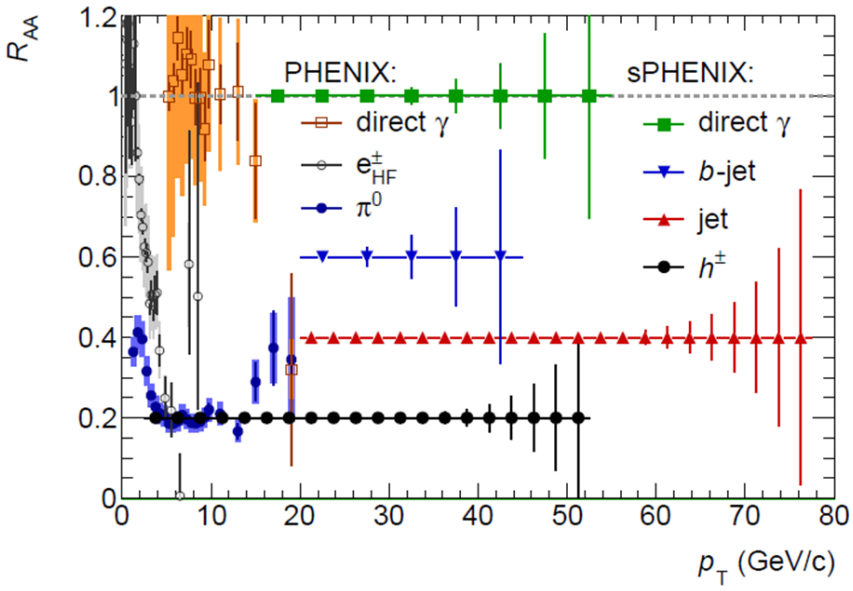


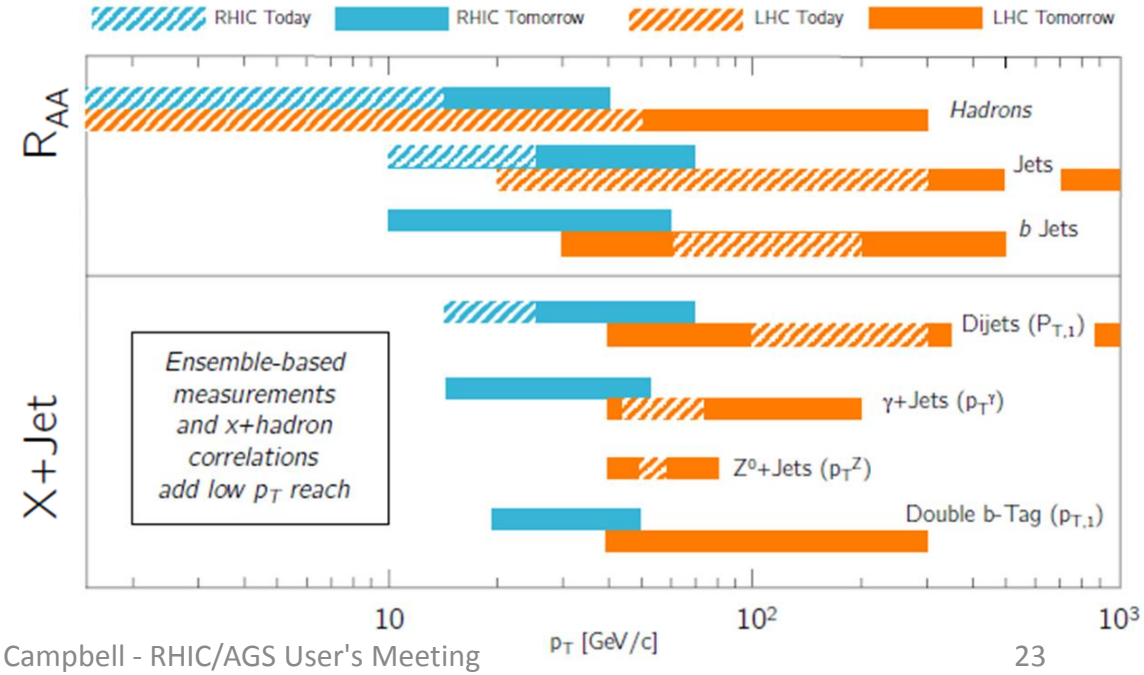


MIE-proposal projection
(100% tracking eff. assumed)

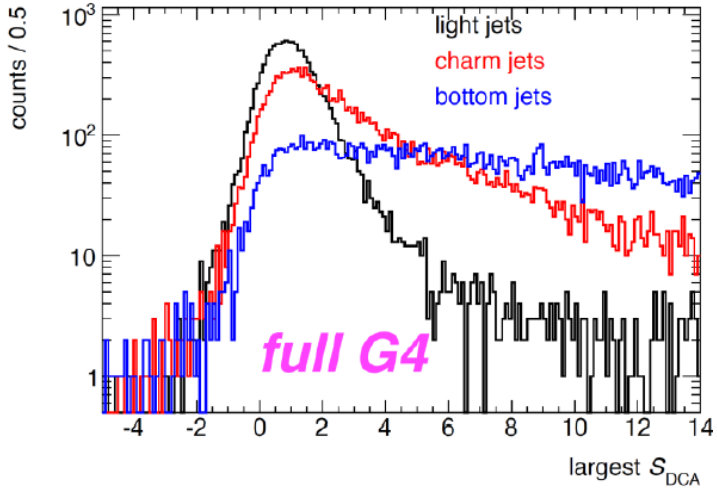
Conclusions

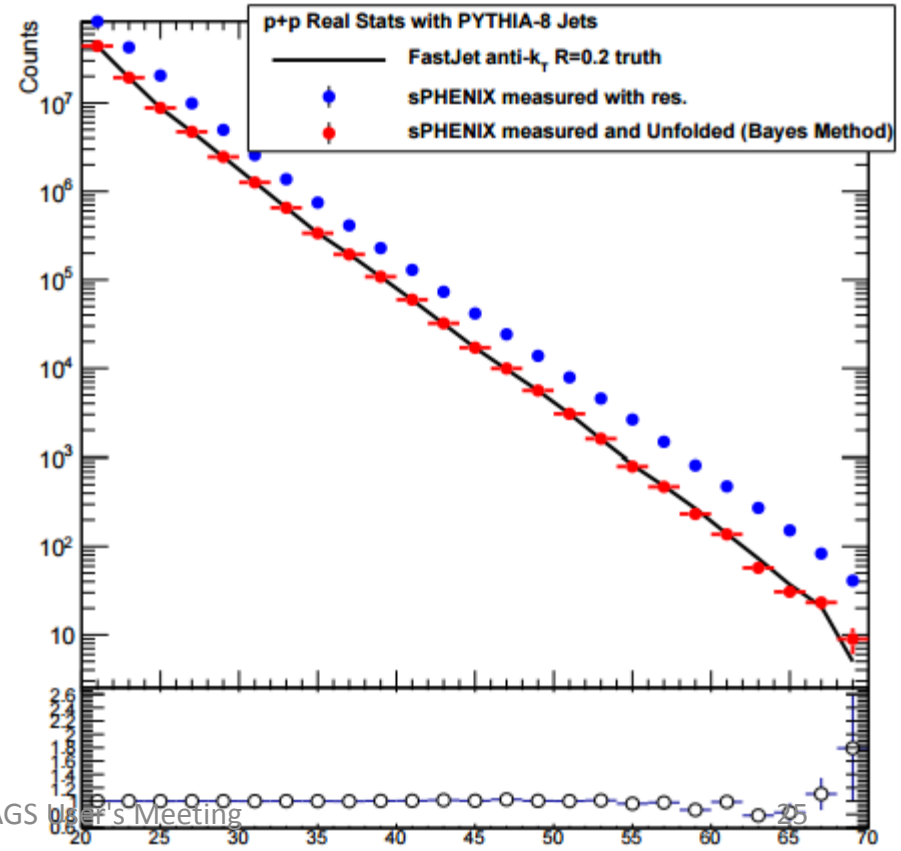
- sPHENIX design tailored to jet physics
- RHIC and LHC perform complimentary measurements
- Rich future in jet physics with sPHENIX
  - Dijet, Frag. Func., γ+jet, b+jet, etc.

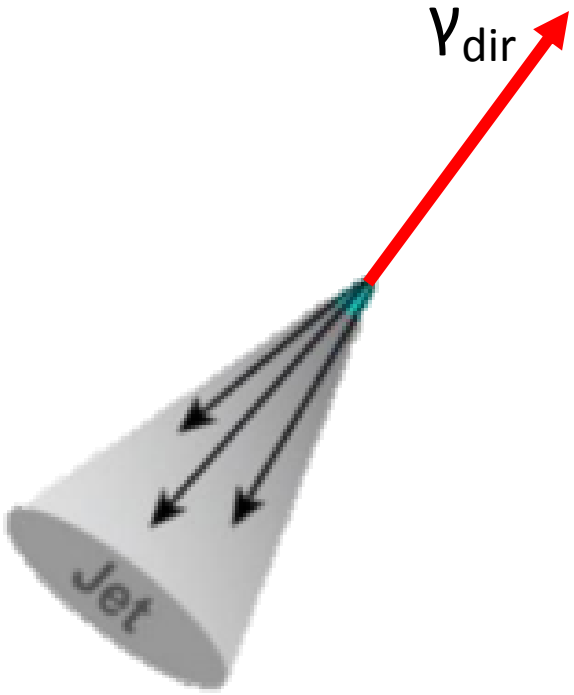




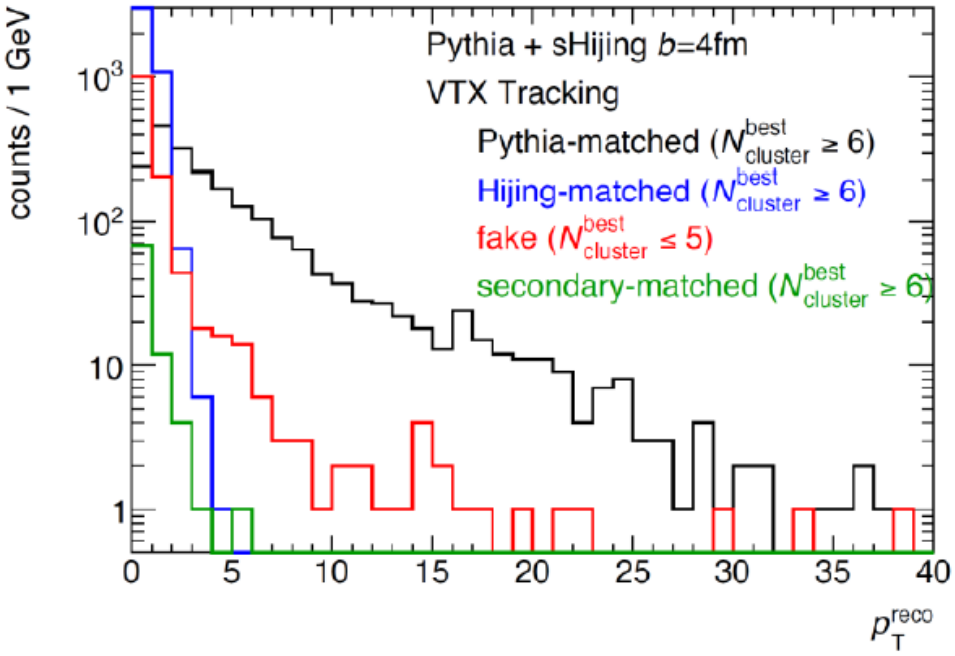
backup

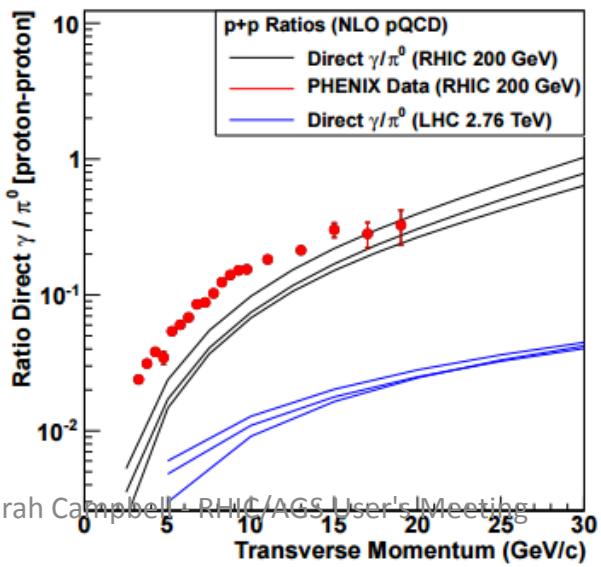

counts / 0.5
light jets
charm jets
bottom jets
full G4
largest S_{DCA}

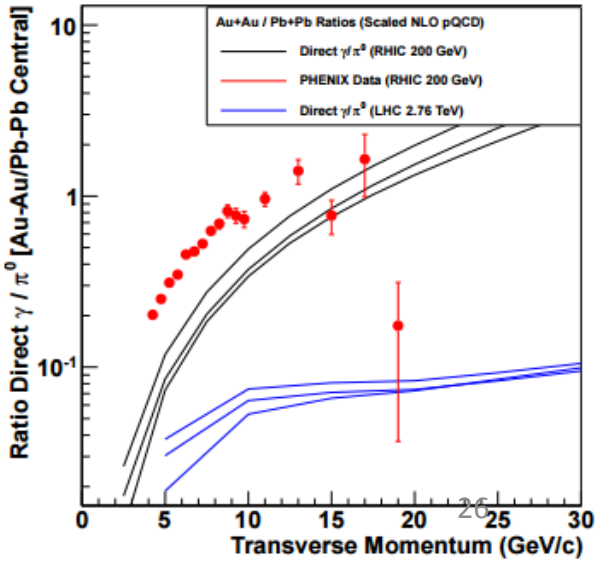

p+p Real Stats with PYTHIA-8 Jets
FastJet anti-k_T R=0.2 truth
sPHENIX measured with res.
sPHENIX measured and Unfolded (Bayes Method)
Counts


γ_{dir}
Jet

Gamma-Jet


Pythia + sHijing b=4fm
VTX Tracking
Pythia-matched ($N^{best}_{cluster} \geq 6$)
Hijing-matched ($N^{best}_{cluster} \geq 6$)
fake ($N^{best}_{cluster} \leq 5$)
secondary-matched ($N^{best}_{cluster} \geq 6$)
counts / 1 GeV
p_T^{reco}


p+p Ratios (NLO pQCD)
Direct γ/π^0 (RHIC 200 GeV)
PHENIX Data (RHIC 200 GeV)
Direct γ/π^0 (LHC 2.76 TeV)
Ratio Direct γ / π^0 [proton-proton]
Transverse Momentum (GeV/c)


Au+Au / Pb+Pb Ratios (Scaled NLO pQCD)
Direct γ/π^0 (RHIC 200 GeV)
PHENIX Data (RHIC 200 GeV)
Direct γ/π^0 (LHC 2.76 TeV)
Ratio Direct γ / π^0 [Au-Au/Pb-Pb Central]
Transverse Momentum (GeV/c)

sPHENIX timeline