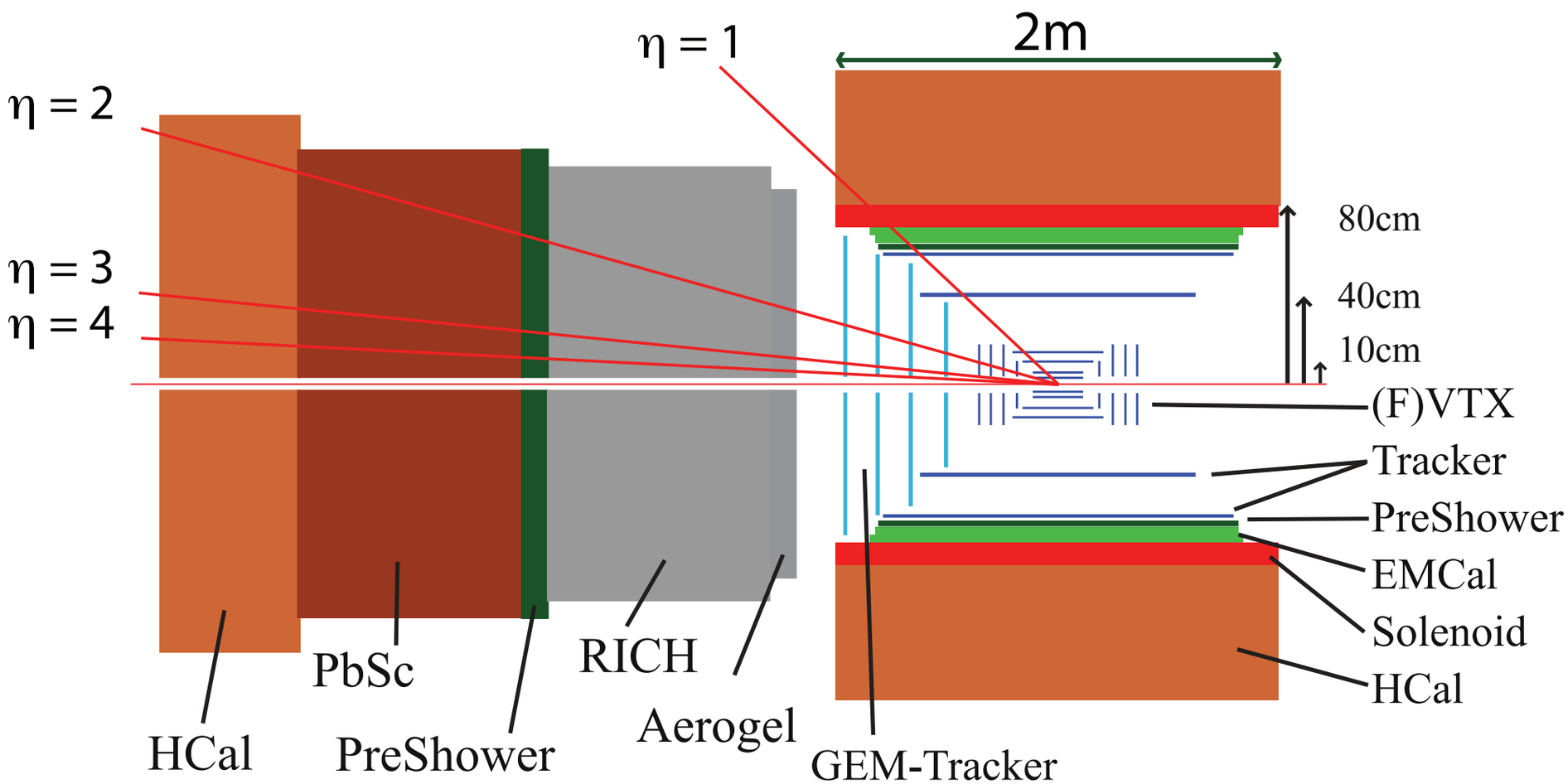
Upgrading PHENIX for deeper investigations of partonic interactions



David Morrison (BNL)

for the PHENIX Collaboration

Are quarks strongly coupled to the QGP at all distance scales?

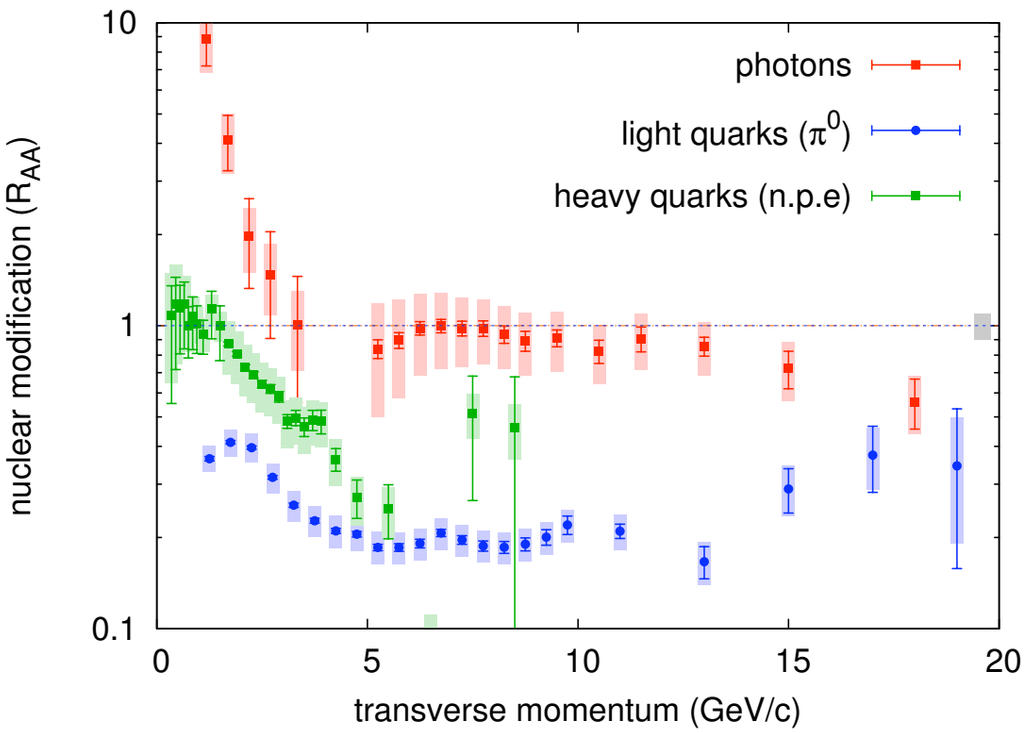
What are the detailed mechanisms for parton-QGP interactions and responses?

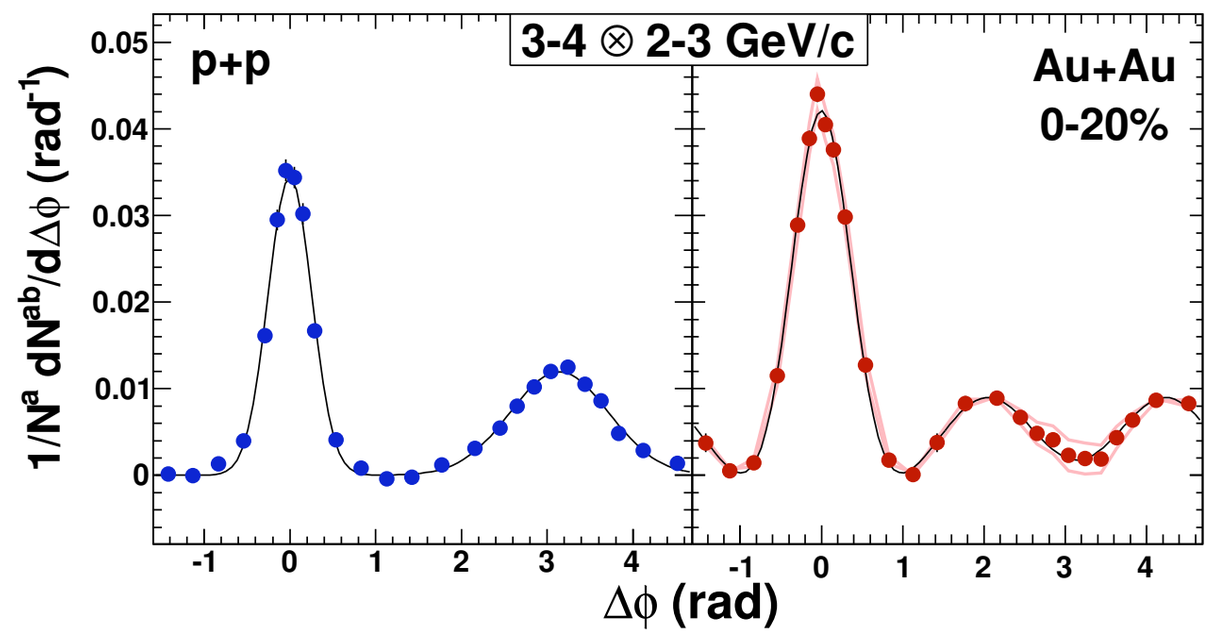
Are there quasiparticles at any scale?

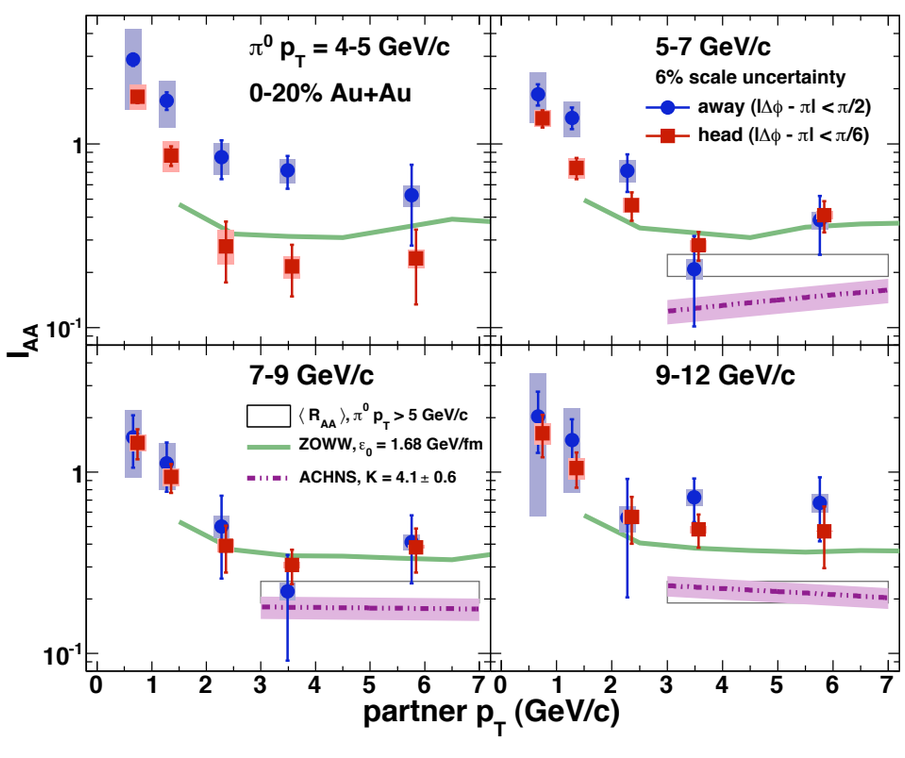
Is there a relevant screening length in the QGP?

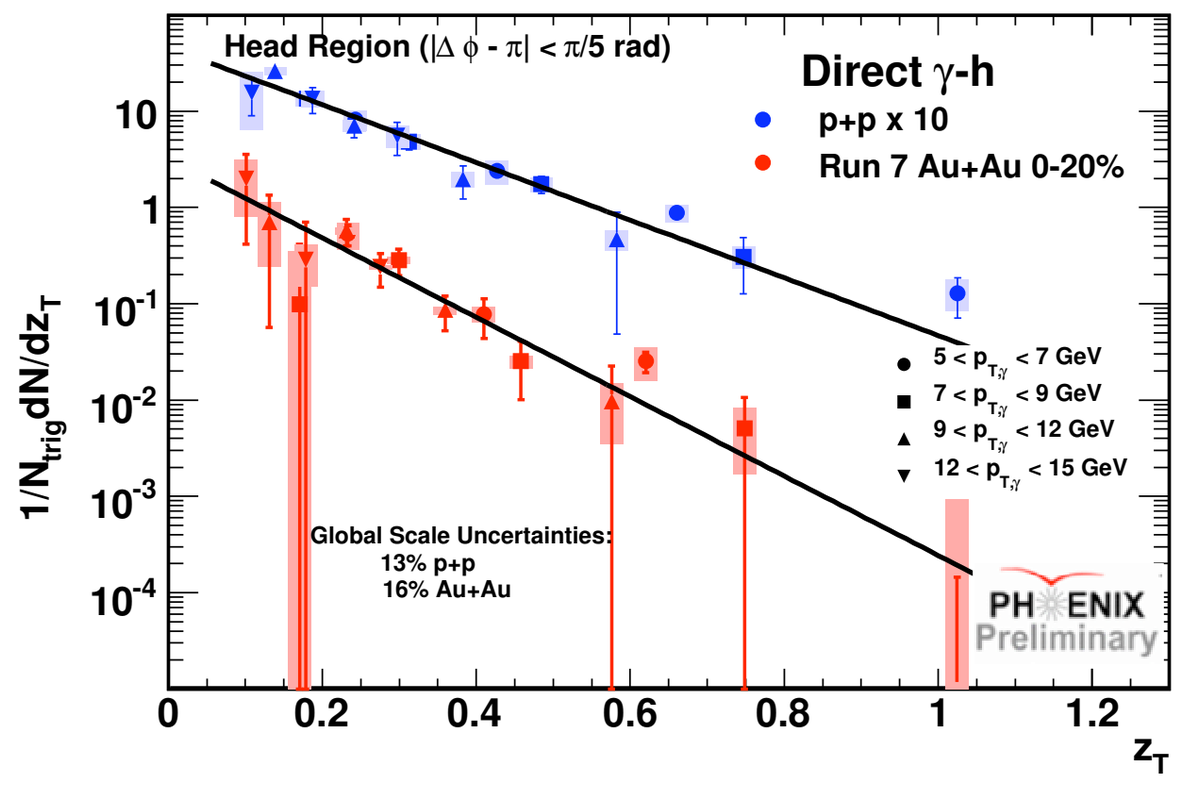
How is rapid equilibration achieved?

We have learned many things from leading hadrons ...

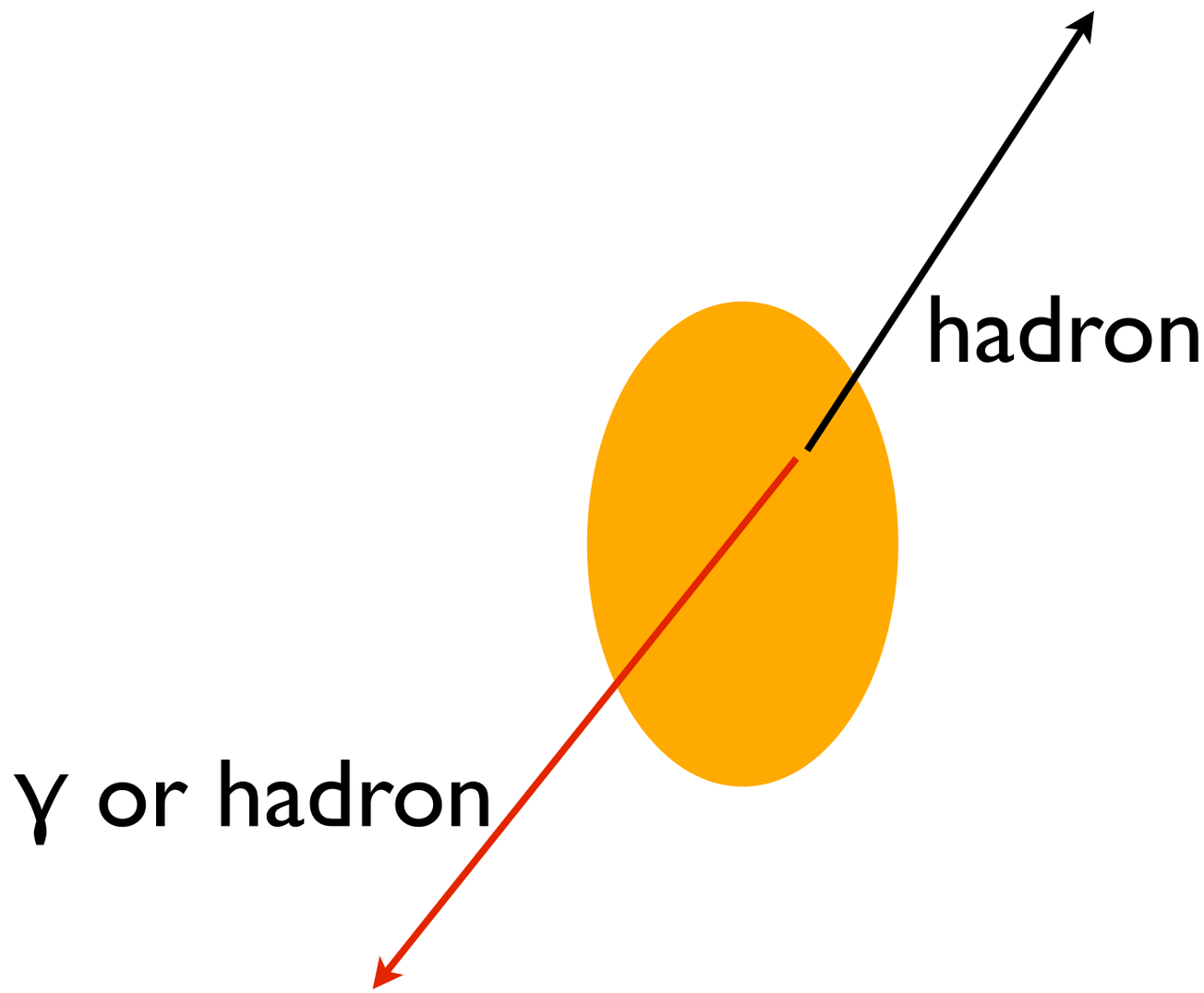








... but leading hadron studies do have their limits



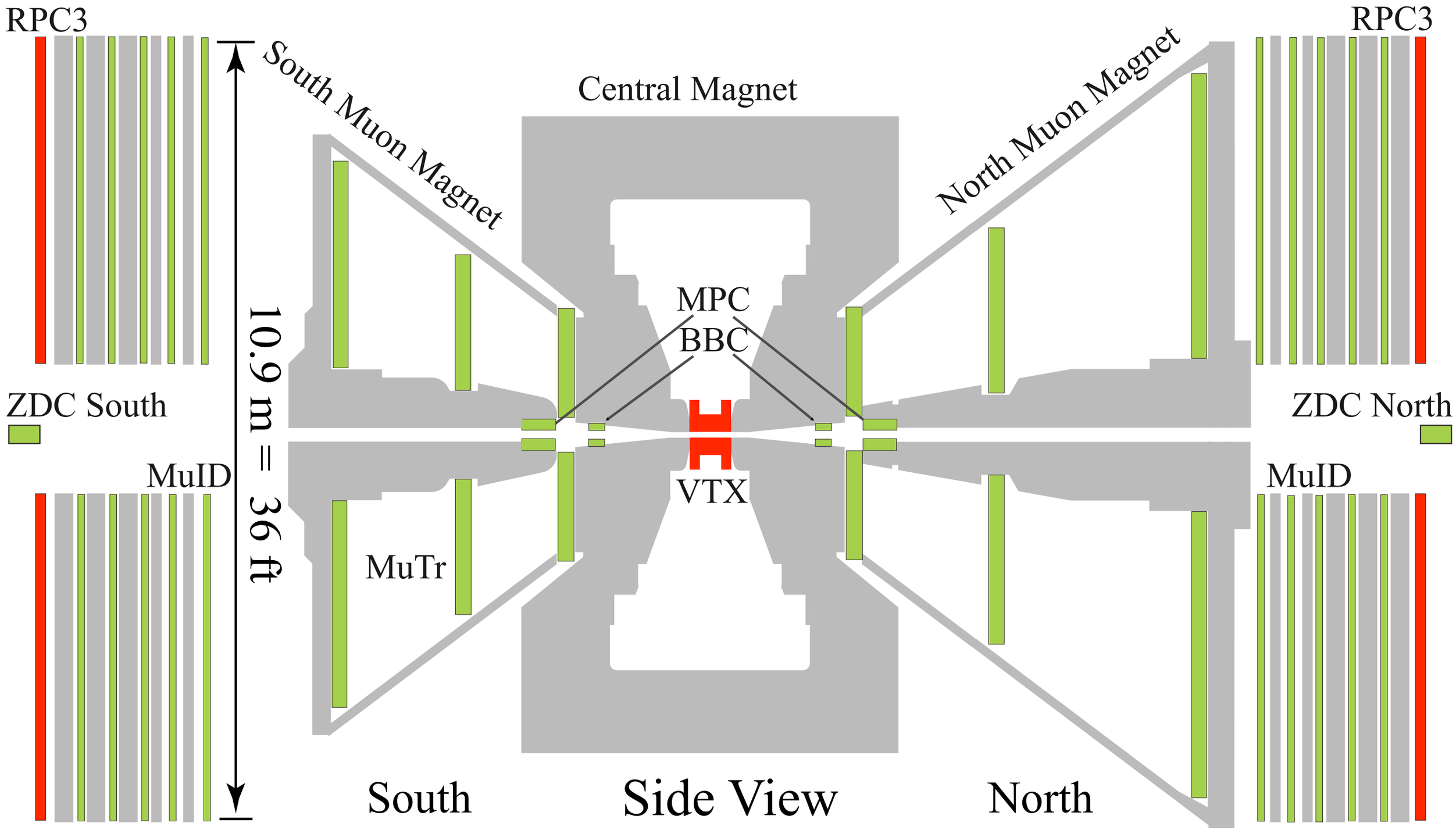
surface bias, fluctuations from (modified?) fragmentation, bias toward high z fragmentation, increasing backgrounds for high p_T tracks, etc

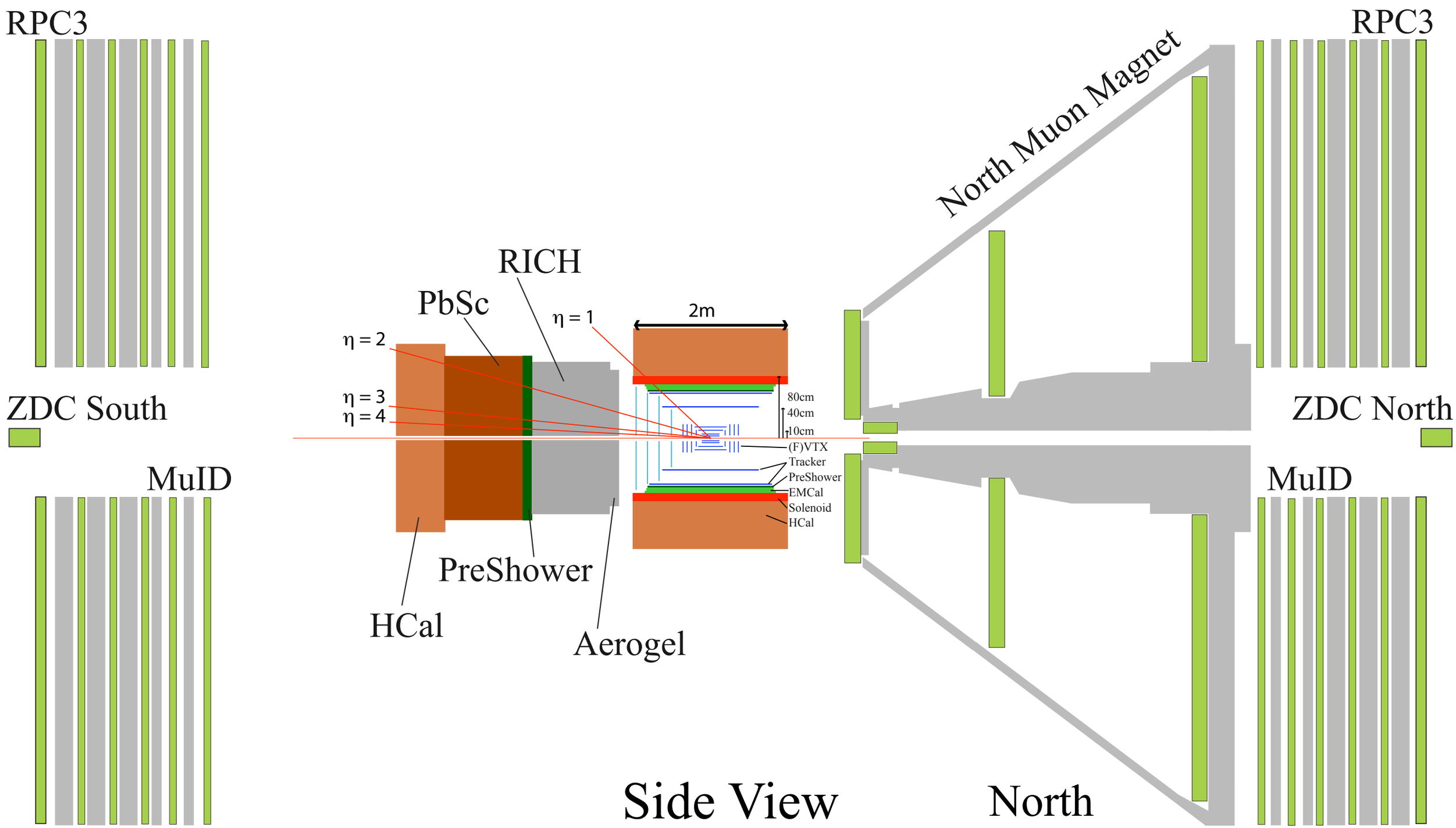
What's needed?

- Establish length dependence of energy loss.
- Establish energy dependence of energy loss.
- Measure medium modification of angular and momentum distribution of radiated energy.
- Measure quark mass dependence of energy loss.

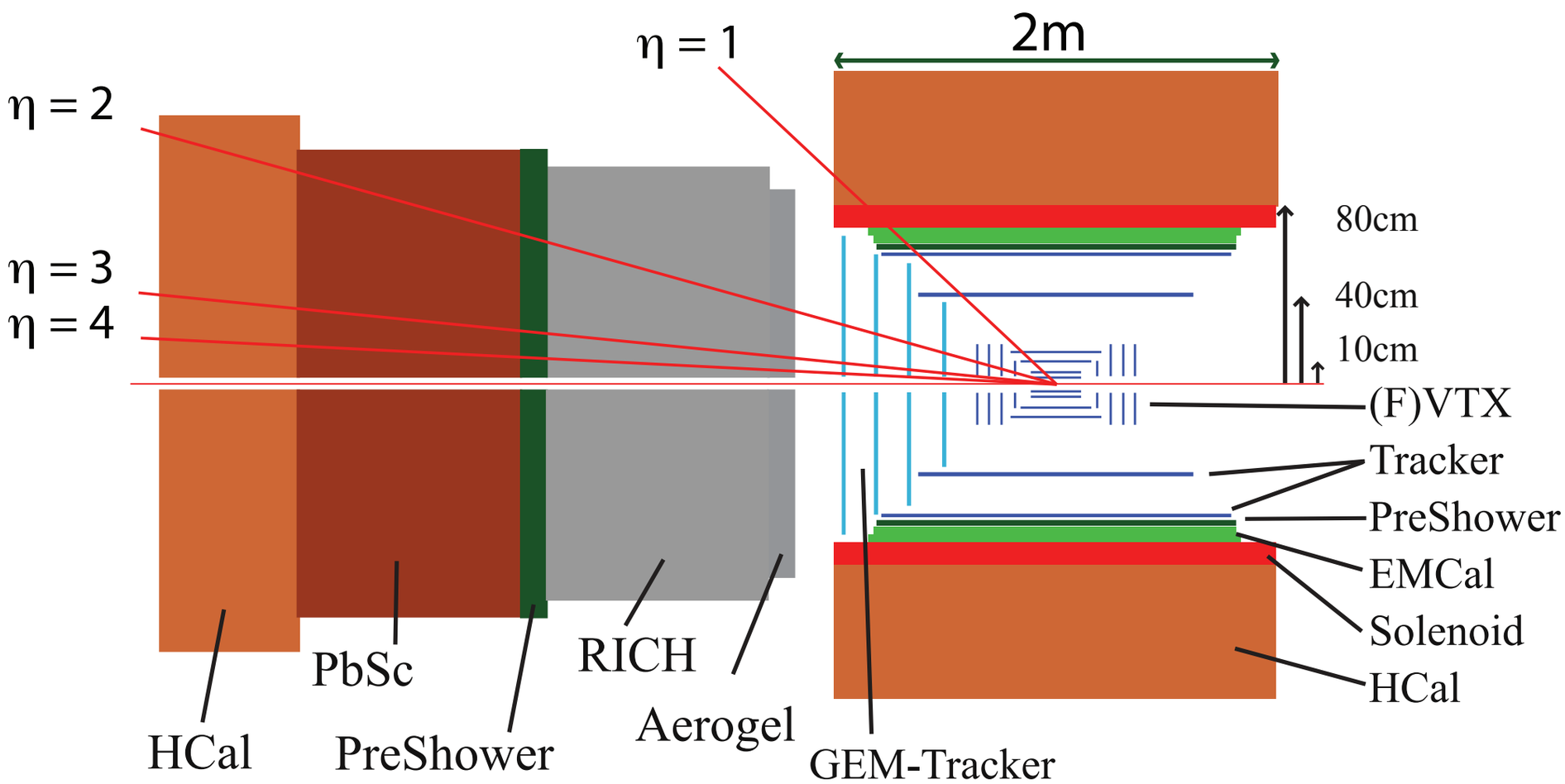
- Many opportunities at RHIC and LHC:
  - Tagged jets (energy, flavor)
  - Angle dependence
  - System size dependence
  - Fully reconstructed jets
- A world-class jet detector at RHIC is needed

B. Mueller, Hard Probes 2010

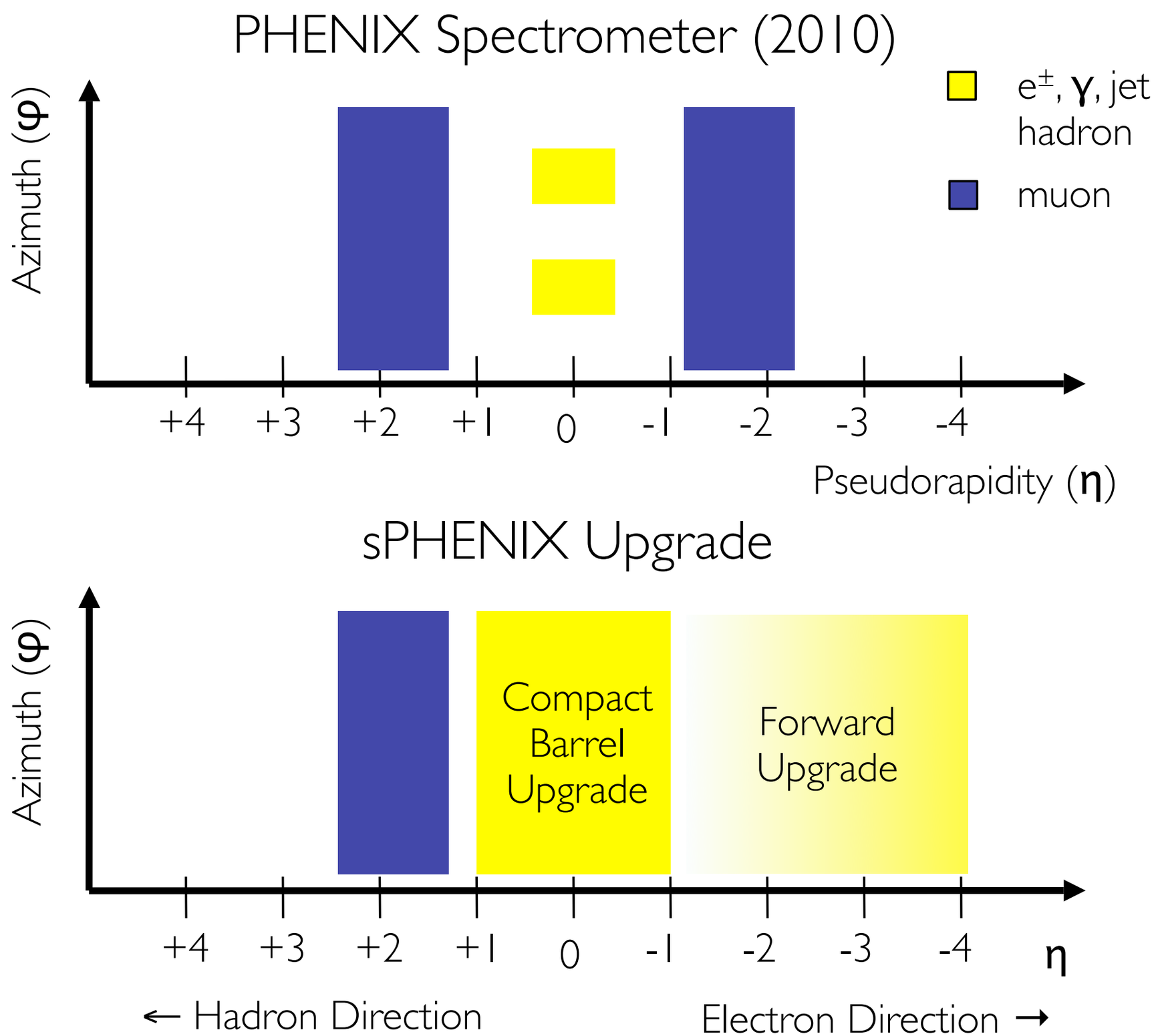

RPC3
South Muon Magnet
Central Magnet
North Muon Magnet
RPC3
MPC
BBC
10.9 m = 36 ft
ZDC South
ZDC North
MuID
MuID
VTX
MuTr
South
Side View
North


RPC3
RPC3
North Muon Magnet
RICH
PbSc
η = 1
2m
η = 2
η = 3
η = 4
80cm
40cm
10cm
(F)VTX
Tracker
PreShower
EMCal
Solenoid
HCal
ZDC South
ZDC North
MuID
MuID
PreShower
HCal
Aerogel
Side View
North

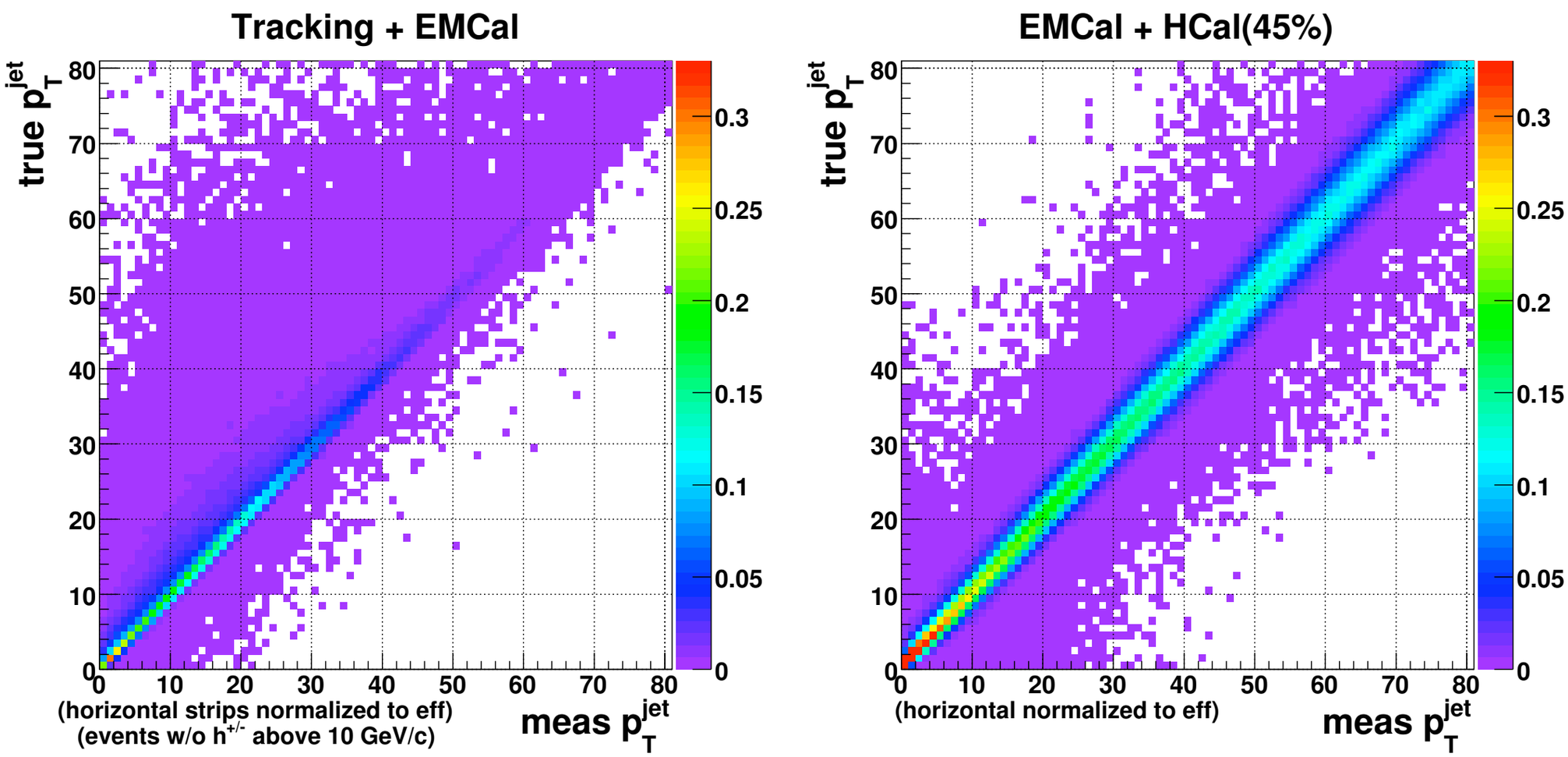
sPHENIX strawman



dimensions, technology, additional capabilities still under investigation


PHENIX Spectrometer (2010)
Azimuth (φ)
e±, γ, jet
hadron
muon
+4
+3
+2
+1
0
-1
-2
-3
-4
Pseudorapidity (η)
sPHENIX Upgrade
Azimuth (φ)
Compact
Barrel
Upgrade
Forward
Upgrade
+4
+3
+2
+1
0
-1
-2
-3
-4
η
← Hadron Direction
Electron Direction →

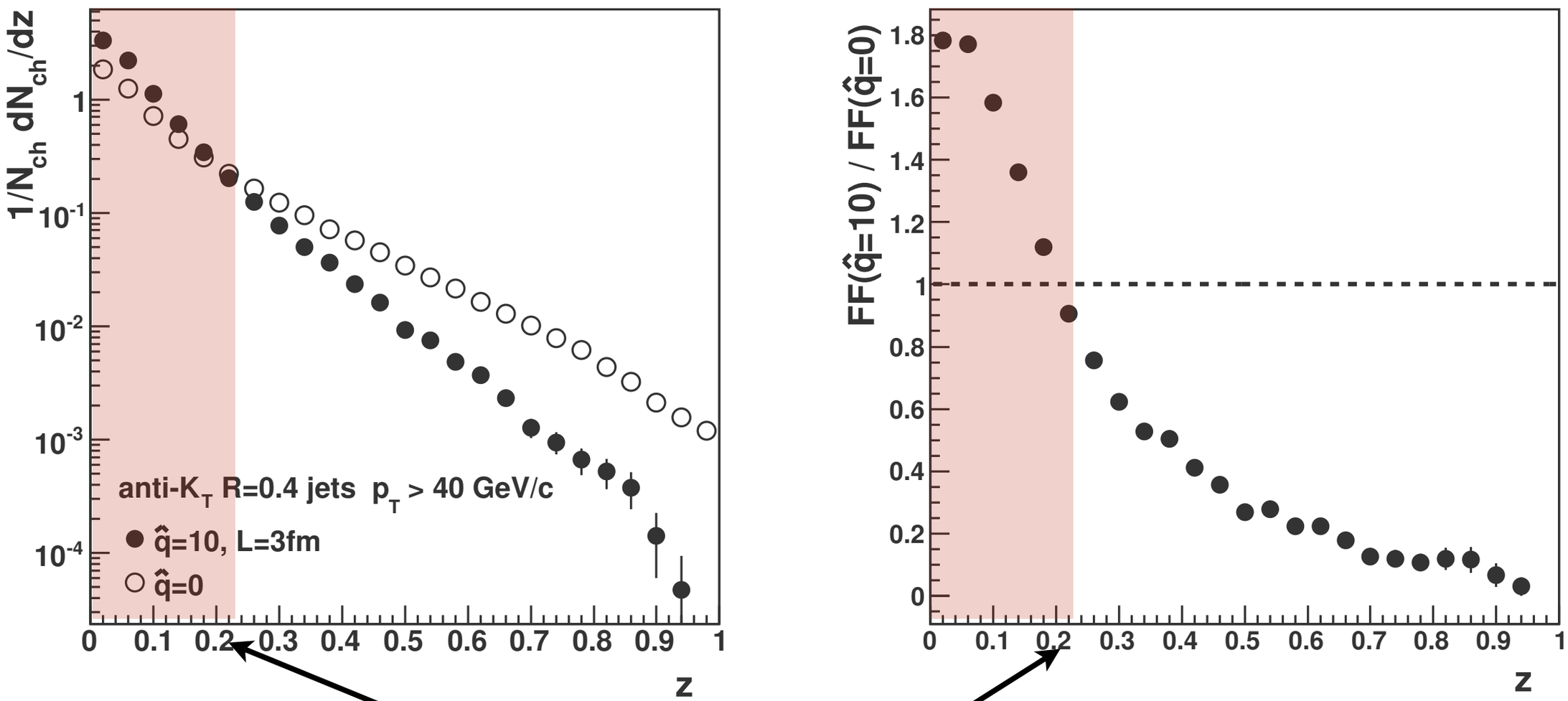
hadronic calorimetry tightens correlation between measured and true jet energy



– reduced high p_T background

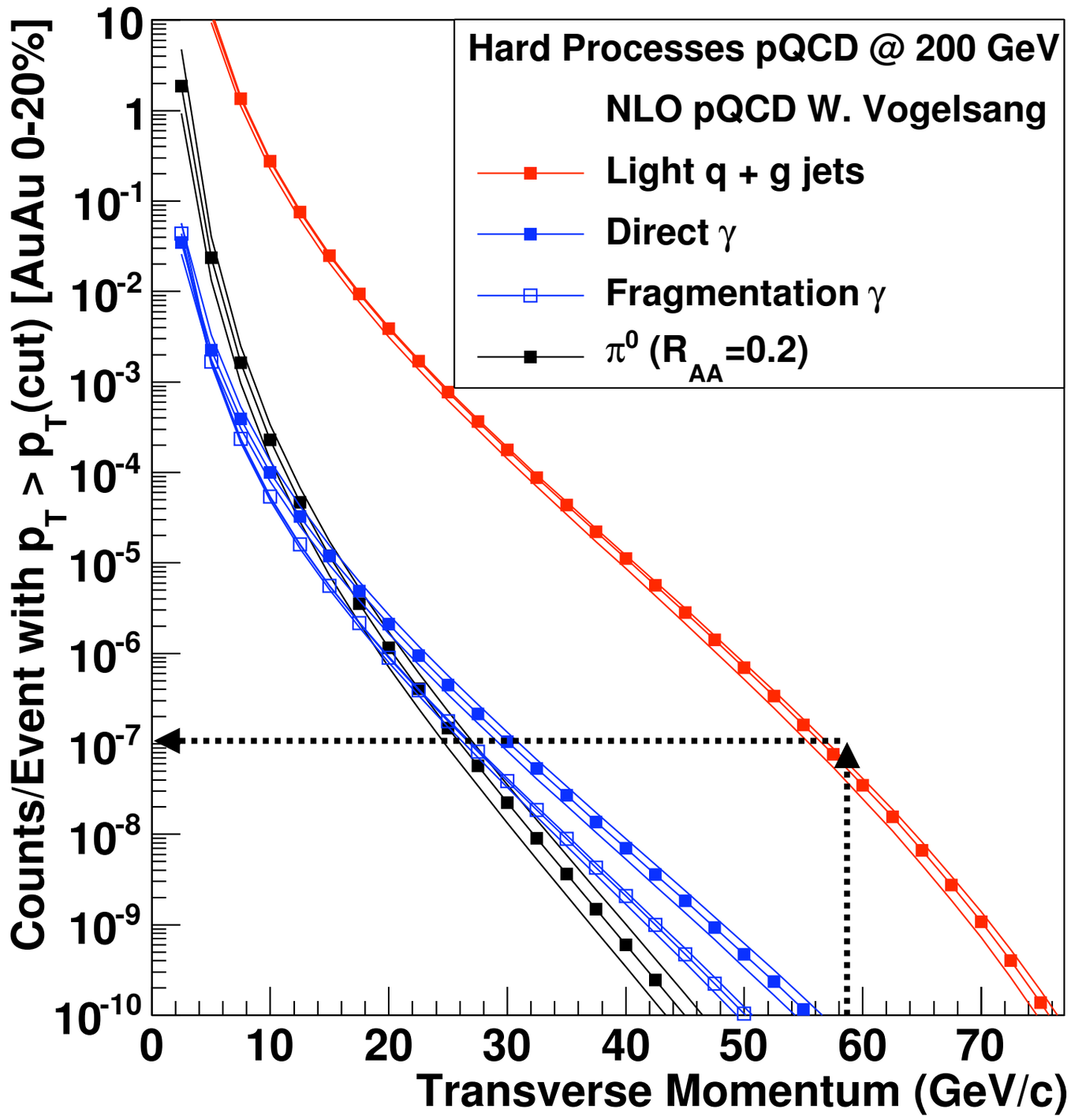
– catch neutral energy

hadronic calorimetry ⇒ ability to study modifications of fragmentation functions to high *z*



limit of *z*-reach if rejecting tracks over 10 GeV/c

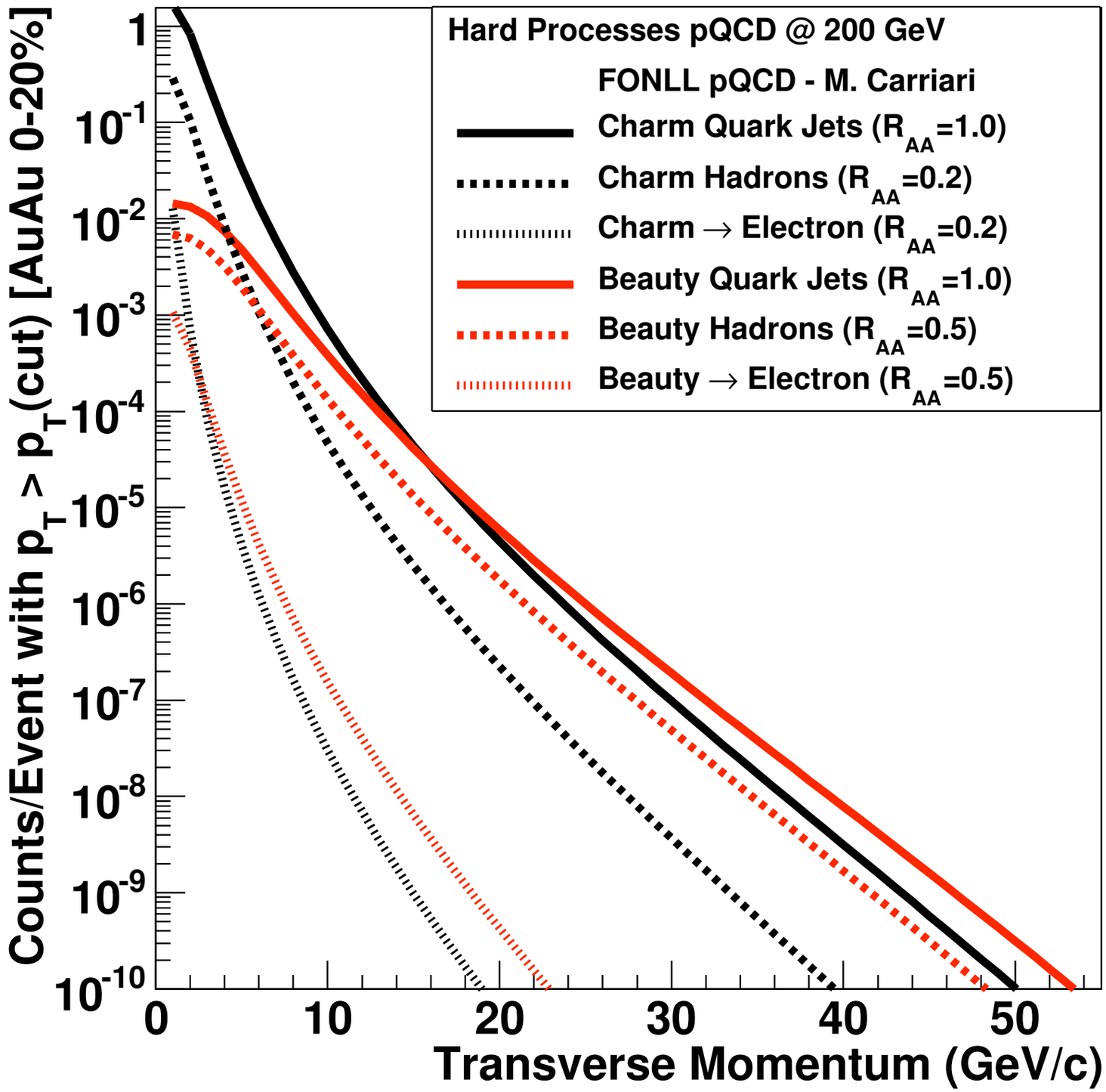
jet, photon, and π^0 rates in $|\eta| < 1$



(50x10^9 events $\Rightarrow$ 10^{10} central events)

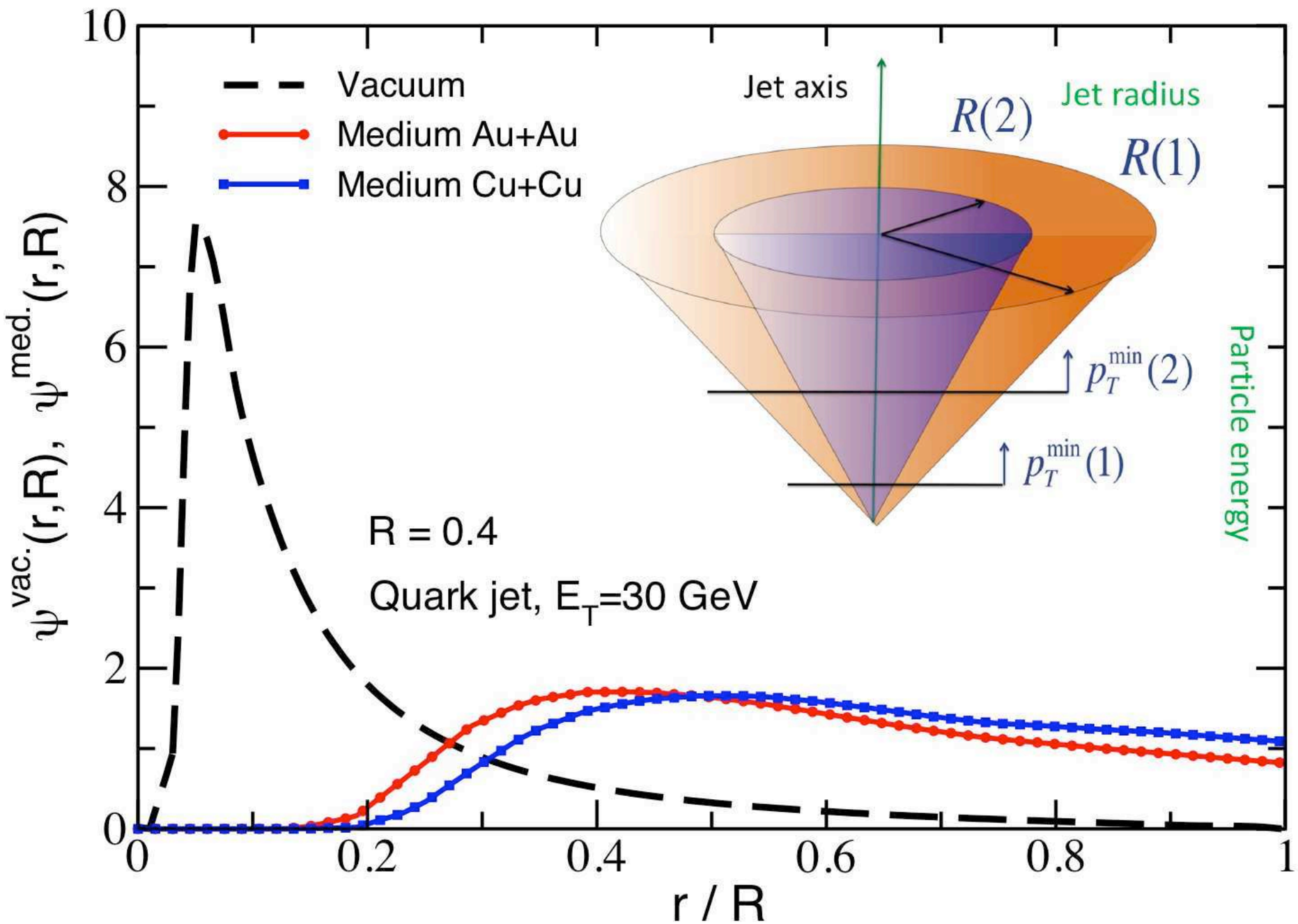
W. Vogelsang, private comm.

significant rates for heavy flavor tagged jets



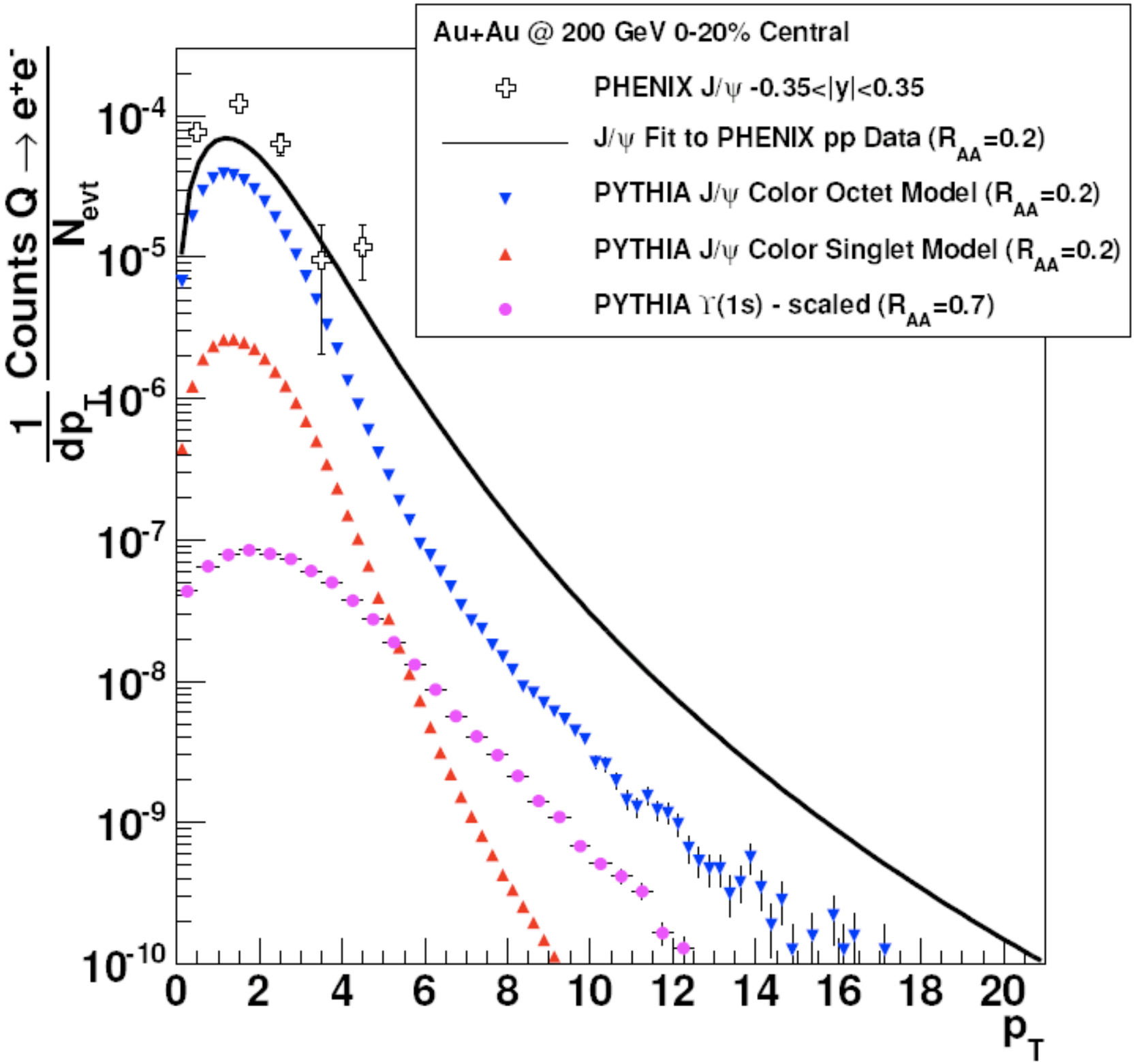
M. Cacciari, private comm.

one way to study the effect of the medium

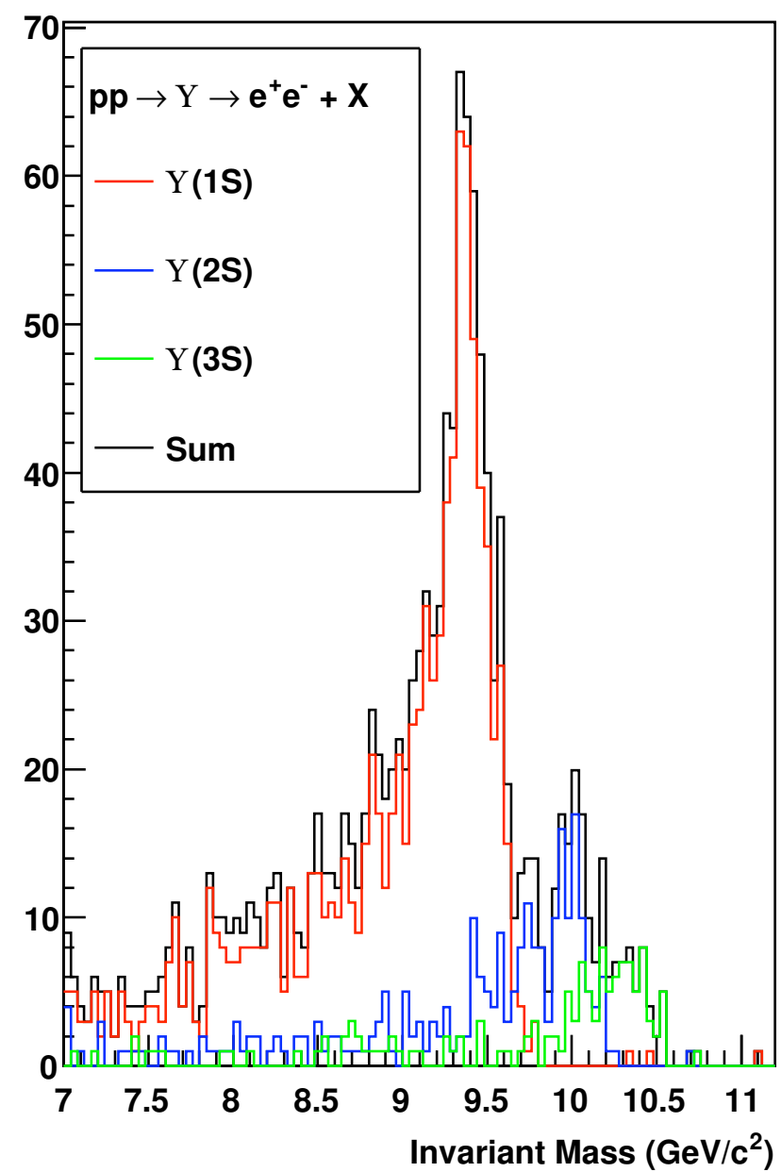


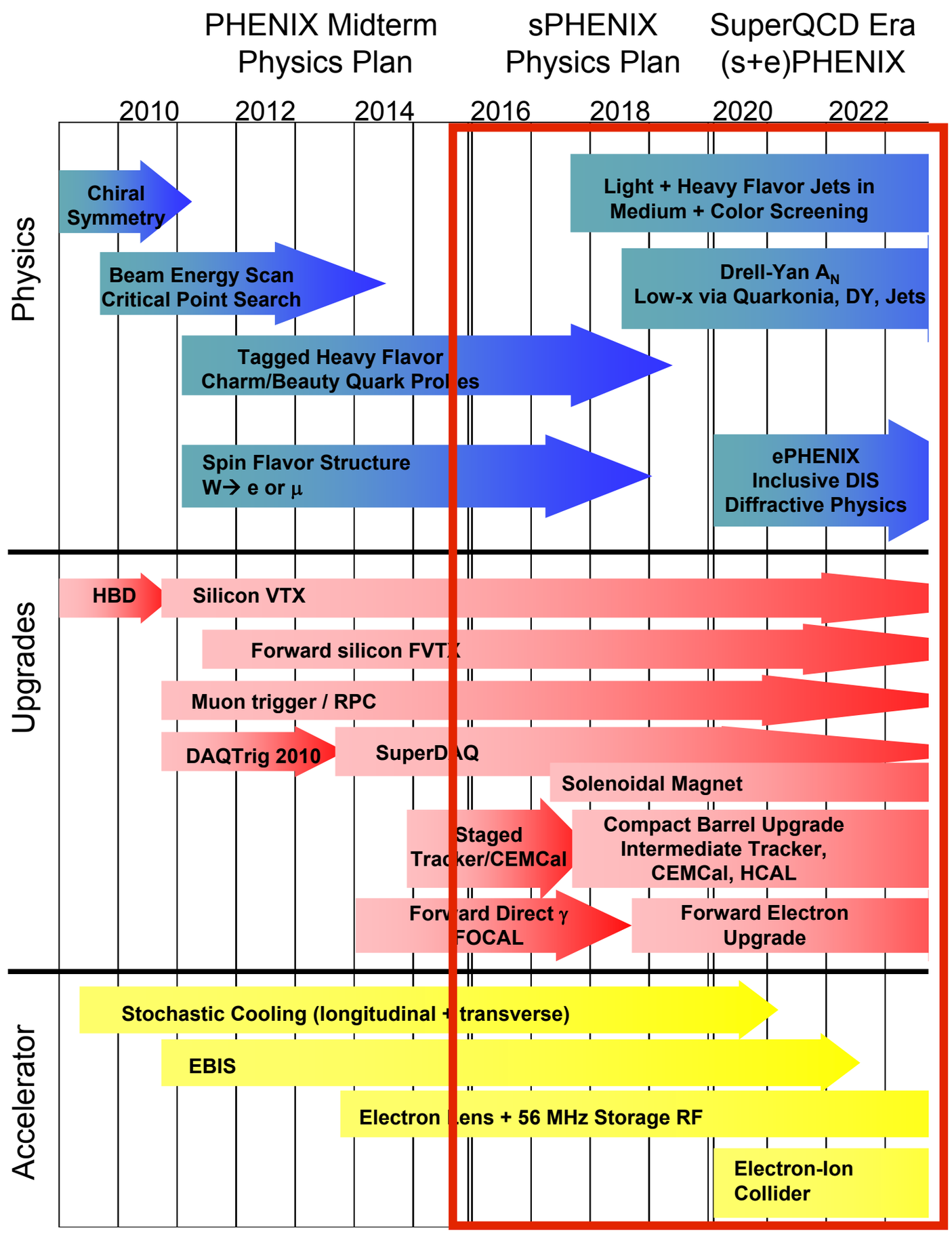
Vitev and Zhang, Phys. Rev. Lett., 104:132001, 2010

Quarkonia



G4 studies of ϒ separation




PHENIX Midterm Physics Plan
sPHENIX Physics Plan
SuperQCD Era (s+e)PHENIX
2010
2012
2014
2016
2018
2020
2022
Physics
Chiral Symmetry
Beam Energy Scan Critical Point Search
Tagged Heavy Flavor Charm/Beauty Quark Probes
Spin Flavor Structure W→ e or μ
Light + Heavy Flavor Jets in Medium + Color Screening
Drell-Yan A_N Low-x via Quarkonia, DY, Jets
ePHENIX Inclusive DIS Diffractive Physics
Upgrades
HBD
Silicon VTX
Forward silicon FVTX
Muon trigger / RPC
DAQTrig 2010
SuperDAQ
Solenoidal Magnet
Staged Tracker/CEMCal
Compact Barrel Upgrade Intermediate Tracker, CEMCal, HCAL
Forward Direct γ FOCAL
Forward Electron Upgrade
Accelerator
Stochastic Cooling (longitudinal + transverse)
EBIS
Electron Lens + 56 MHz Storage RF
Electron-Ion Collider

bring it all together

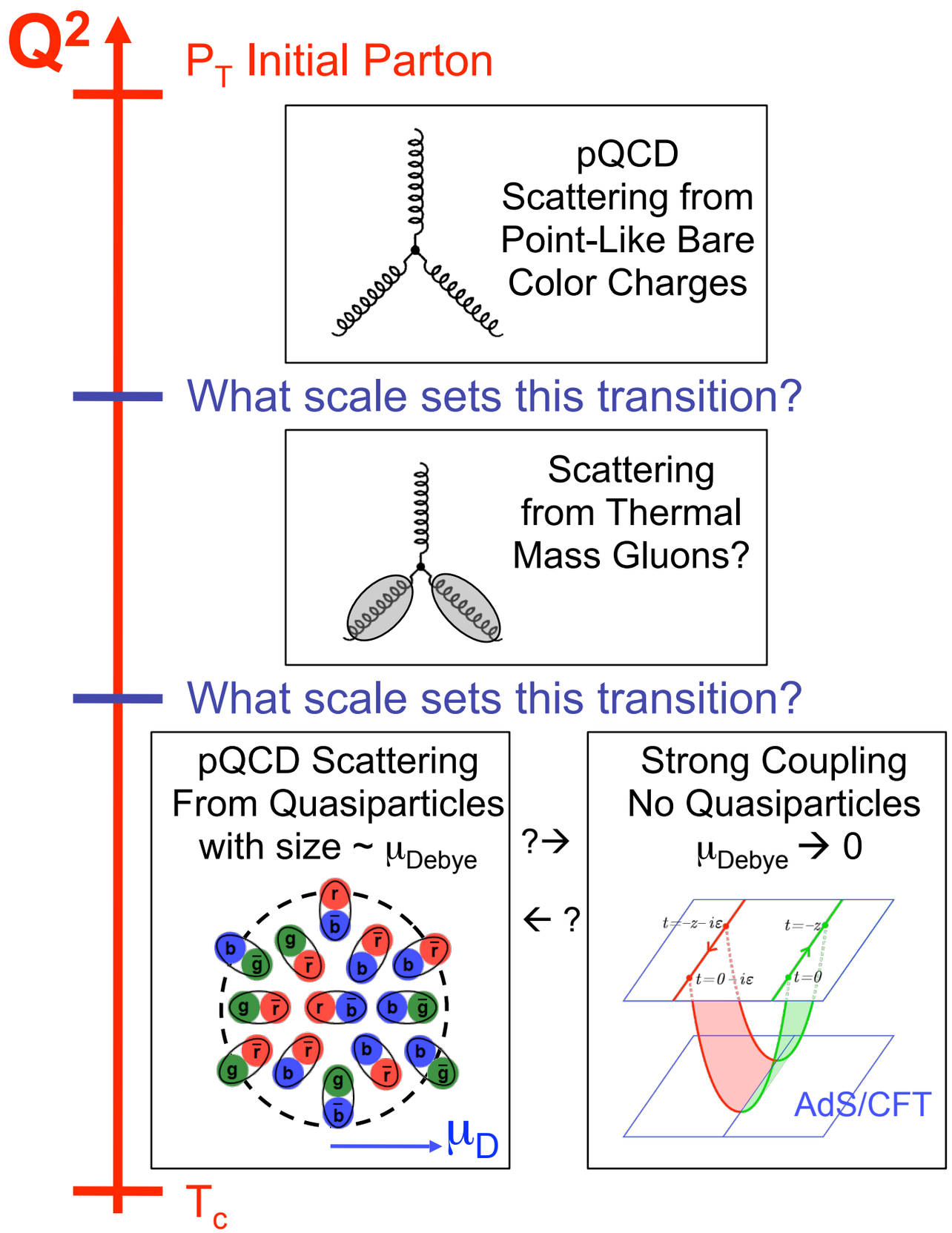
- Exciting near-term program driven by current upgrades: VTX, FVTX, MuTrig, DAQ2010
- Answering fundamental questions beyond that calls for qualitatively new capabilities
- "sPHENIX": compact, uniform detector
  - jets, quarkonia, γ-jet correlations, tagged jets
  - forward physics, spin, "0th order" EIC detector
  - DAQ to record 25 billion Au+Au events/20wks
  - utilize projected RHIC luminosity
- PHENIX decadal plan: www.bnl.gov/npp

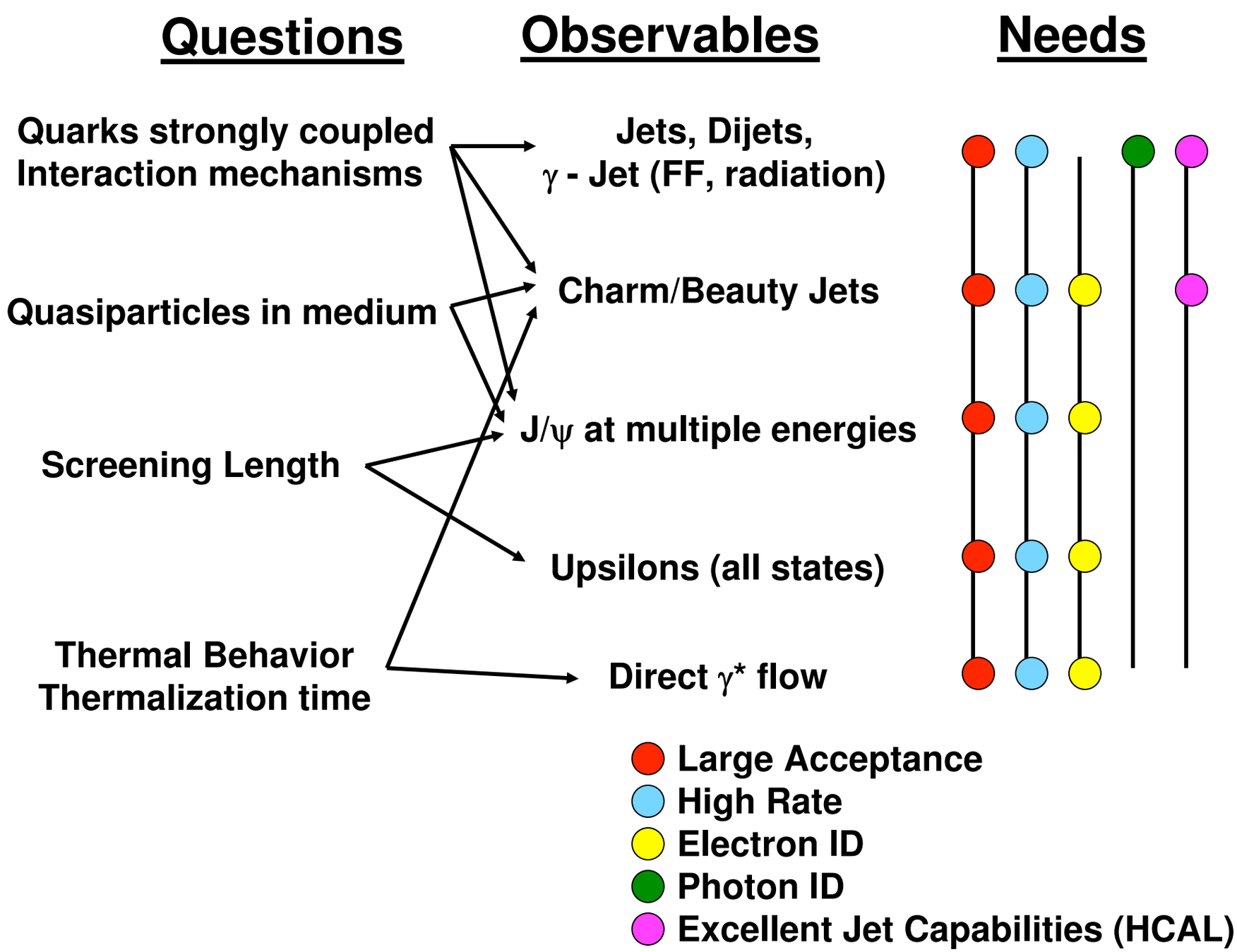
Complementarity of RHIC and LHC

A number of strengths of the RHIC physics program and the complementary role of the LHC are itemized here and then a detailed discussion of each follows.

- sQGP created at RHIC is optimal for *strongly coupled* studies. Whether the medium at the LHC is strongly or weakly coupled remains to be determined experimentally.
- RHIC is a powerful and flexible facility that will allow us to *dial* the medium properties via colliding different nuclear species, colliding at different energies, and comparison with critical baseline $p+p$ and proton(deuteron)-nucleus collisions at the same $\sqrt{s_{NN}}$.
- RHIC experiments will measure jets with energies $15 < E_T < 60$ GeV thus spanning a large range of scales in the medium as shown in Figure 3.3.
- RHIC collisions are dominated by quark jets over a wide E_T range. In a complementary way, LHC has a majority contribution from gluon jets.
- RHIC experiments have shown that cold nuclear matter initial state effects are modest at midrapidity for $p_T > 2$ GeV/c and can be separated from jet quenching effects.
- PHENIX and an upgraded PHENIX can sample a very large Au+Au luminosity with minimum bias triggers, which is crucial for lower energy jet studies and understanding calorimeter trigger biases for higher energy jet studies.

Probe Integrates Over a Range of Q^2




Questions
Observables
Needs
Quarks strongly coupled
Interaction mechanisms
Quasiparticles in medium
Screening Length
Thermal Behavior
Thermalization time
Jets, Dijets,
γ - Jet (FF, radiation)
Charm/Beauty Jets
J/ψ at multiple energies
Upsilons (all states)
Direct γ* flow
Large Acceptance
High Rate
Electron ID
Photon ID
Excellent Jet Capabilities (HCAL)