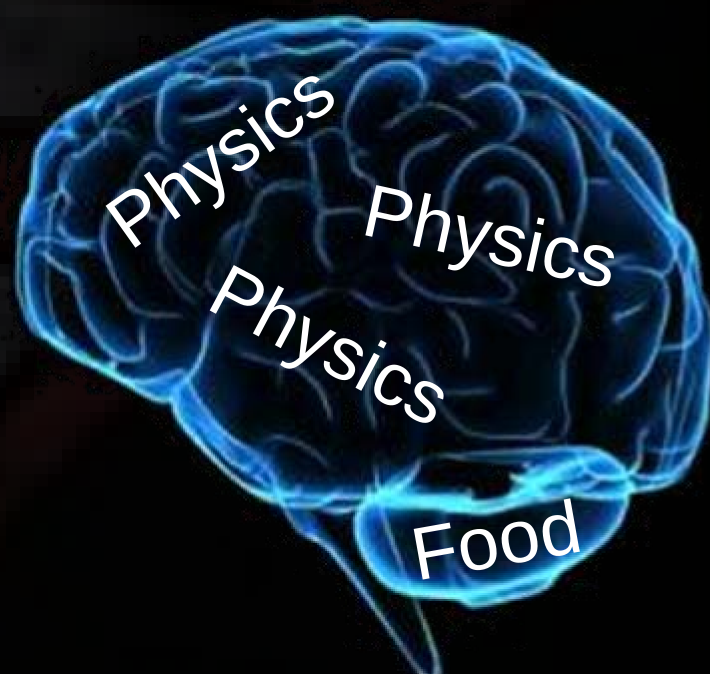
Next Decade Plans:
Super sPHENIX

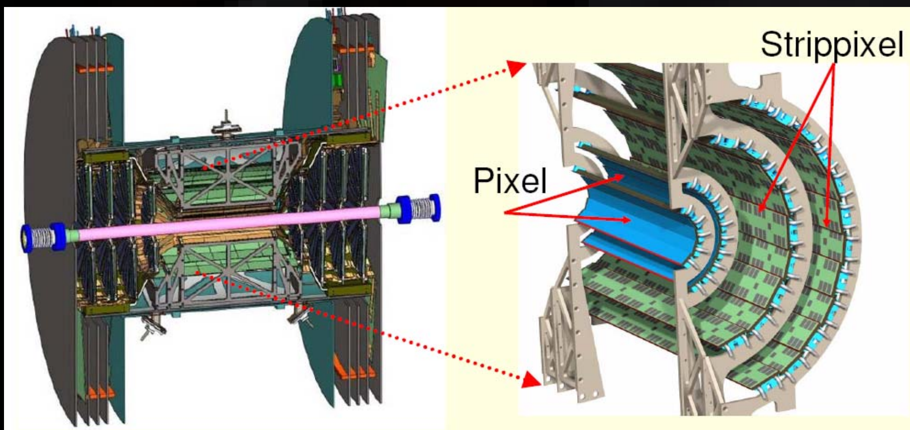
Jamie Nagle
Deputy Spokesperson, Trigger Coordinator
University of Colorado at Boulder

Some Insight on
Our Thoughts



Near Term Plan: 2010-2015

The physics priorities are set by our upgrades
(which were set by our physics priorities).



Muon RPC Chambers

Run-11:
Silicon VTX on schedule.
Precision Heavy Flavor Era!

Muon Trigger Upgrade on schedule!
Forward $W \rightarrow \mu$

DAQ2010 Upgrade on schedule.

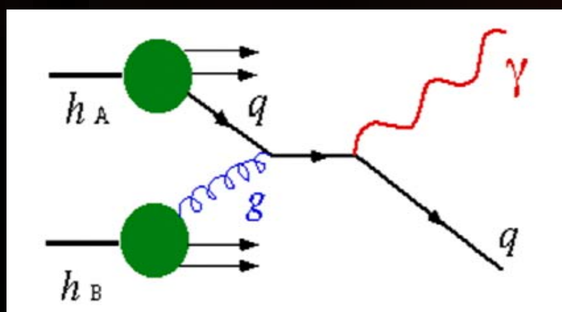
Run-12:
Forward Silicon VTX available.

Run-14:
* Forward Calorimetry (potential proposal)
Gluon Saturation Physics

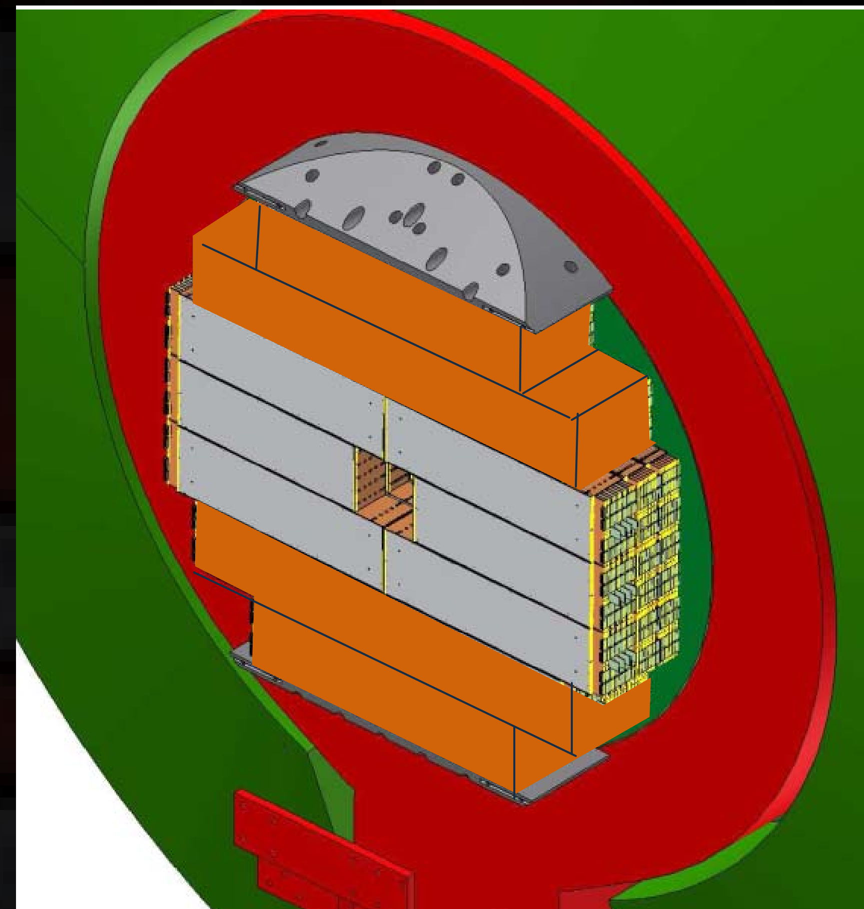
*SuperDAQ Upgrade (double AuAu rate)

Forward Calorimetry (FOCAL)

- Physics Goal:
  Gluon PDF at low-x via direct photons



- Si-W calorimeter
  - 44cm from the interaction point
  - Tracking Calorimeter



This is a new type of detector. Excellent test beam results.
Time scale → 2014, Cost scale → $1.8M

Currently under PHENIX internal review

Is there more after 2015?

Not easy to predict the future, but we expect that the following will be in hand:

Heavy Ions:

1. Full characterization of bulk medium dynamics (e.g. η/s, ζ, T, ε)
2. Completion of Low Energy scan for critical point
3. Experimental measure of charm/beauty dynamics $p_T \sim 6$ GeV
4. Parton energy loss (jets) start on program

Spin:

1. W→lepton measurements to constrain Δu, Δubar, Δd, Δdbar
2. Completion of gluon Δg via π^0, η, $h^{+/-}$ A_{LL} @ 200 and 500 GeV
3. A_N measurements for hadrons

Unanswered and Emerging Questions (HI)

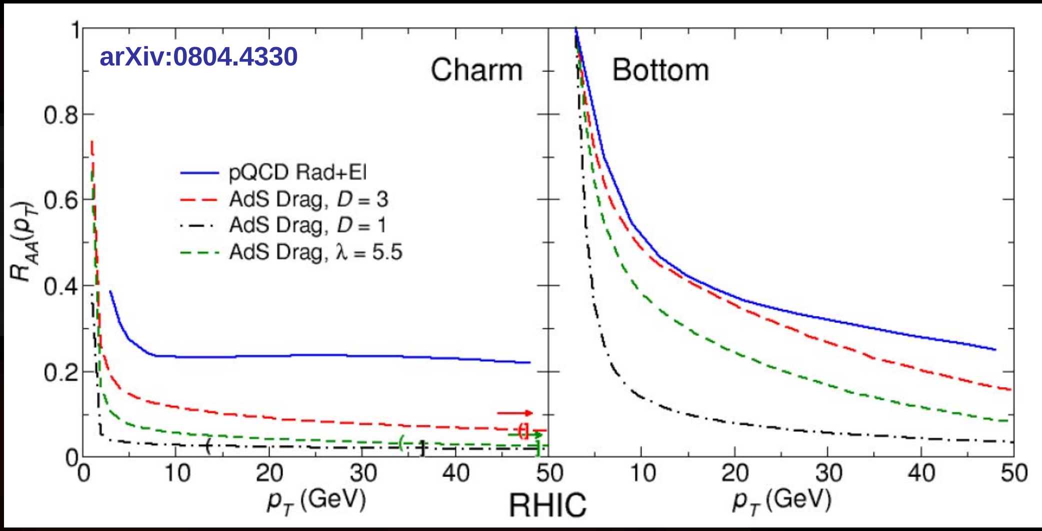
Are quarks strongly coupled to the QGP at all distance scales?

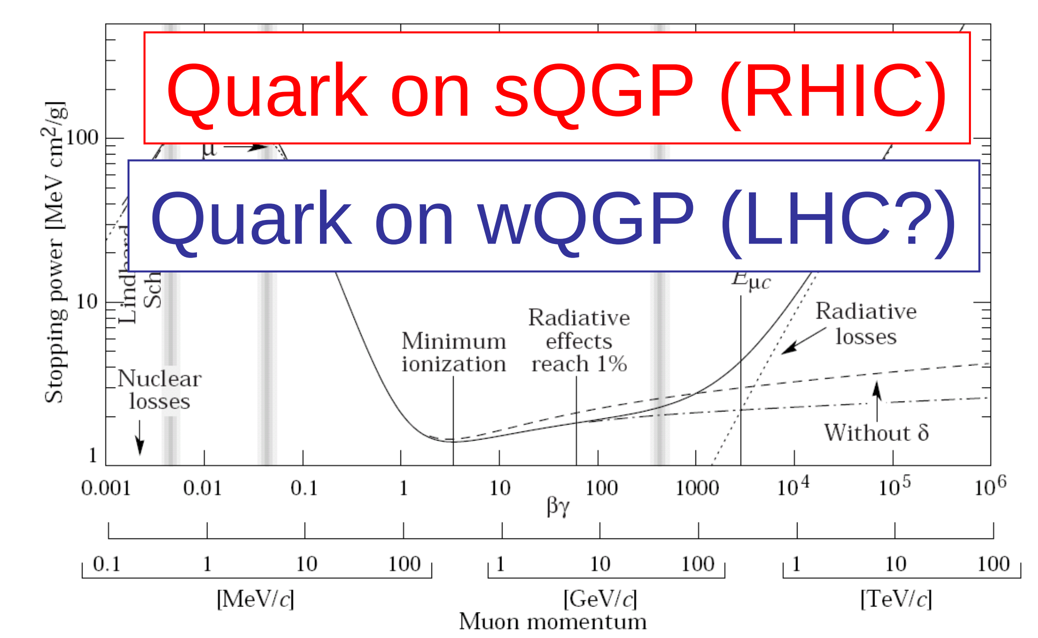
What are the detailed mechanisms for parton-QGP interactions and responses?

Are there quasiparticles at any scale?

Is there a relevant screening length in the QGP?

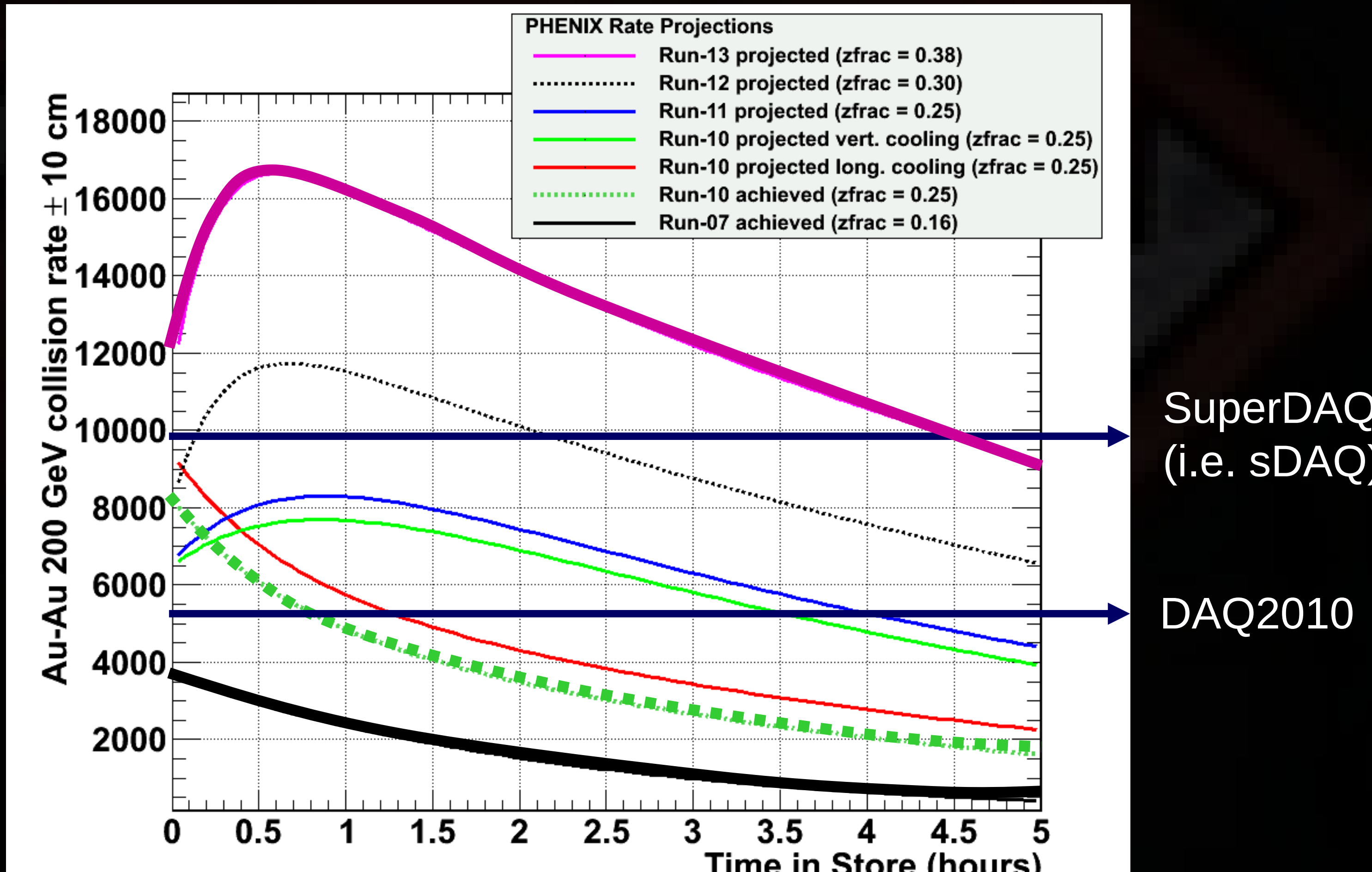
How is rapid equilibration achieved?





What is needed to answer these questions?

CAD Projections

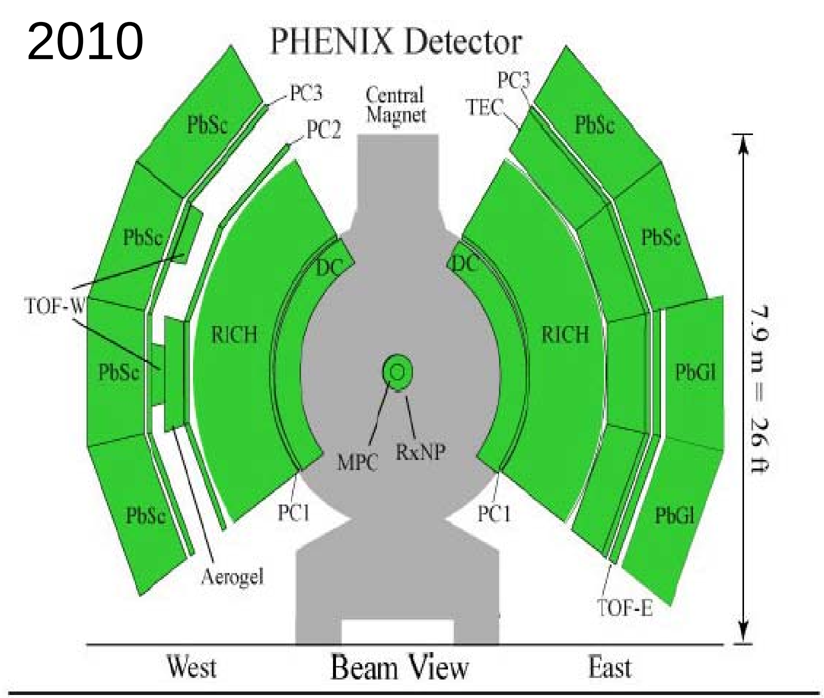


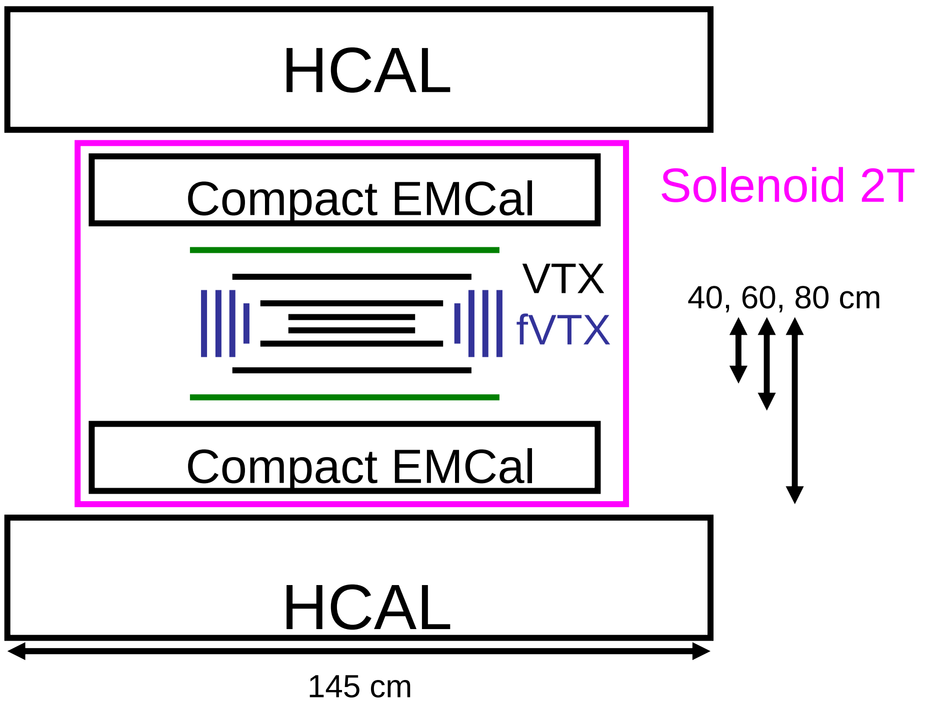
RHIC II luminosity and new proposed DAQ upgrades can sample 50 billion AuAu events, including recording ~25 billion minimum bias events (i.e. no trigger bias).

Thanks to Wolfram Fischer and CAD for input.

PHENIX Upgrade Conceptual Design (Compact Detector)

- Current inner silicon vertex tracker, remove outer detectors
- New solenoid (B = 2 Tesla and inner radius = 70 cm)
- New silicon tracking layers at 40 and 60 cm
- Compact EmCal (Silicon/Tungsten) $|\eta|<1.0$
  8 cm total depth and pre-shower layer
- Hadronic Calorimeter Outside Magnet
- Maintain PHENIX high DAQ bandwidth and triggers

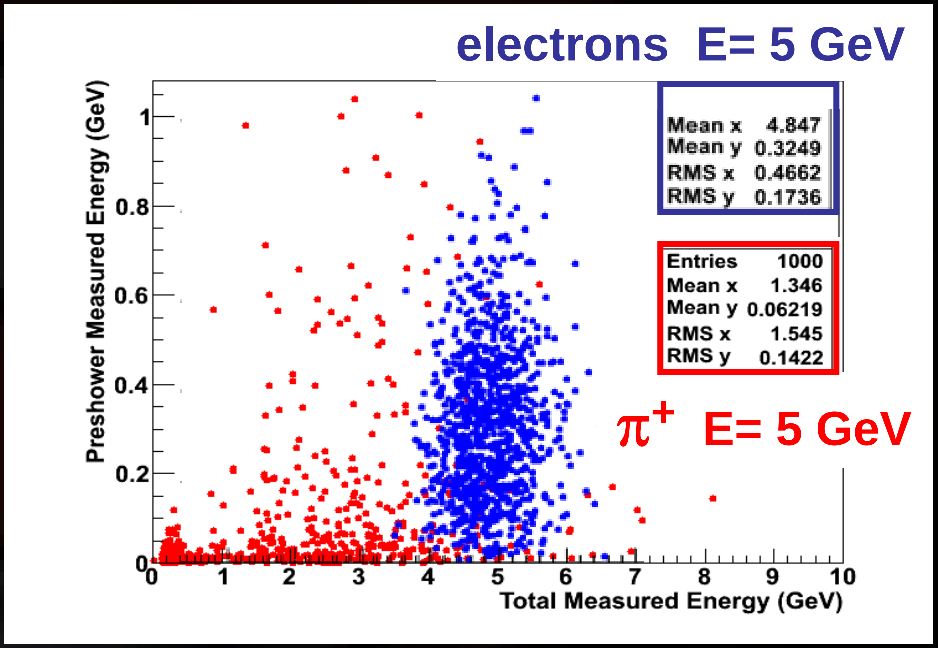




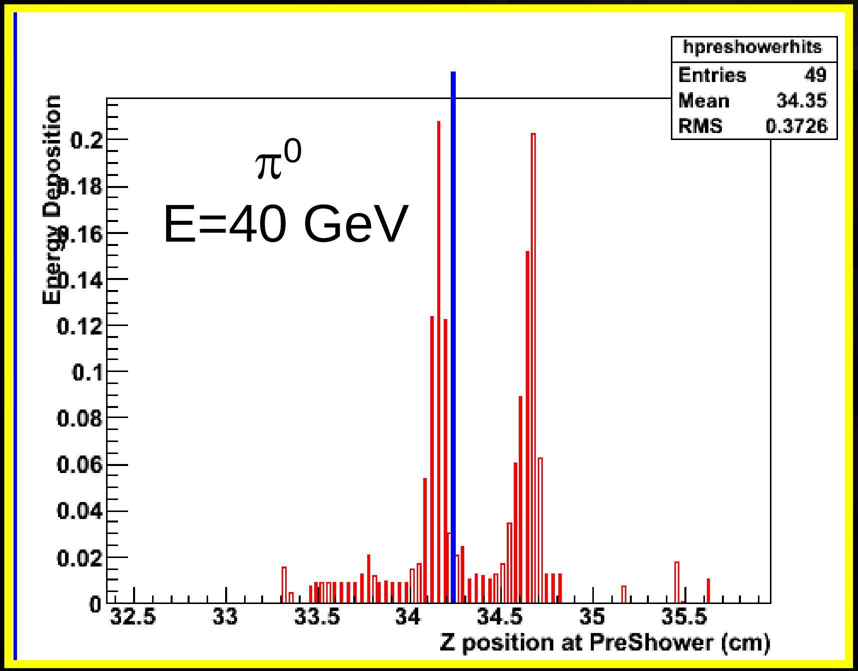
GEANT-4 Performance Evaluation Underway

Excellent electron-ID for p_T > 2 GeV

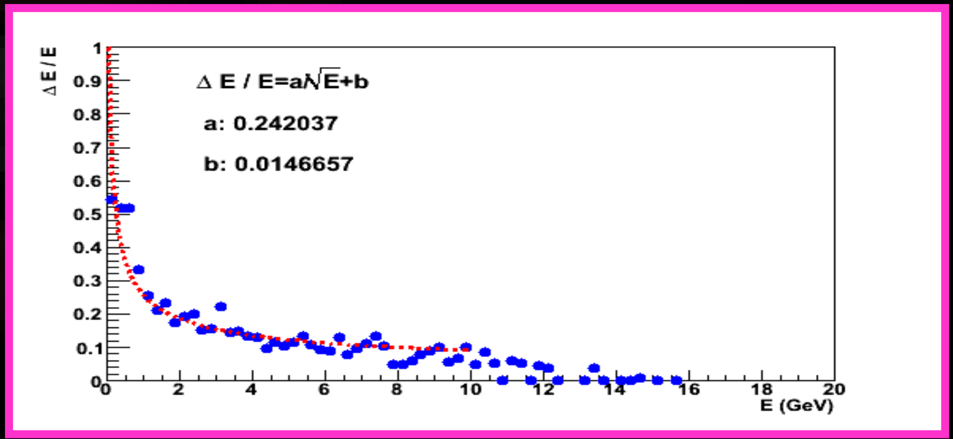
Need detailed study at lower p_T as well.



γ/π^0 separation over full kinematics > 50 GeV



Energy Resolution

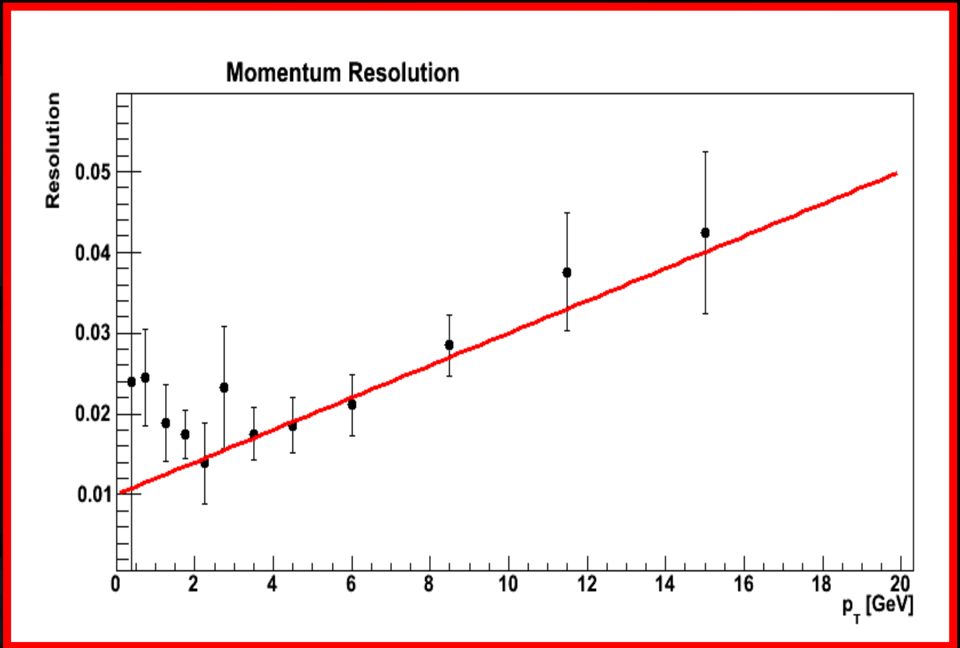


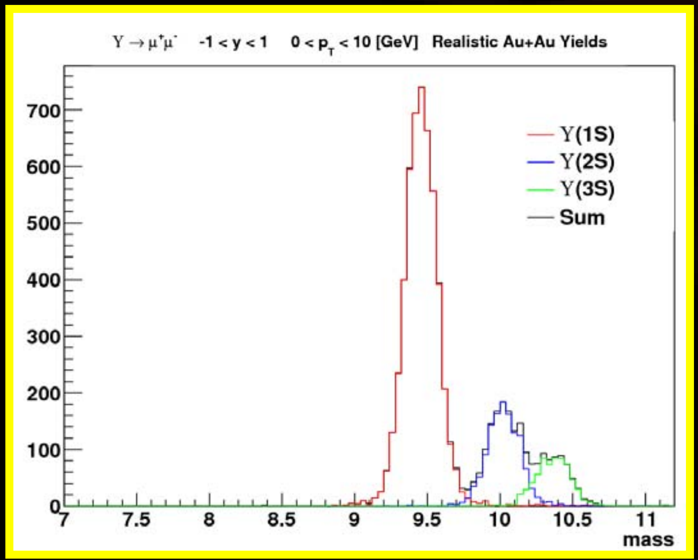
Alex Linden-Levy (LLNL)

GEANT-4 Performance Evaluation Underway

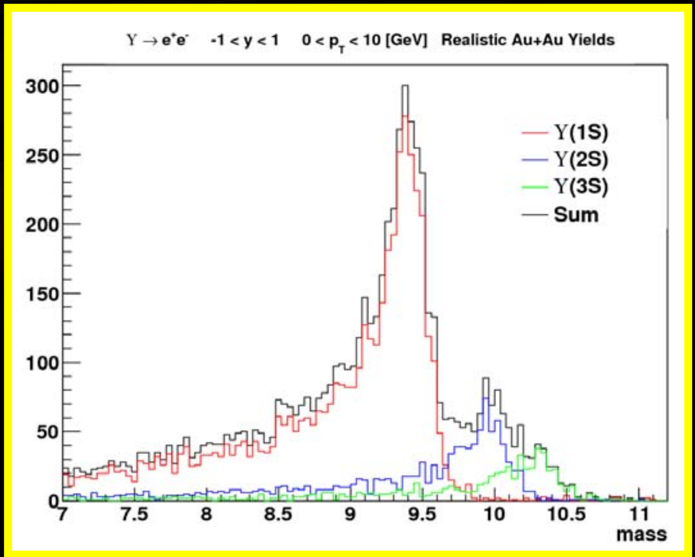
Very good momentum resolution.

Evaluation of fake high p_T track rate underway.



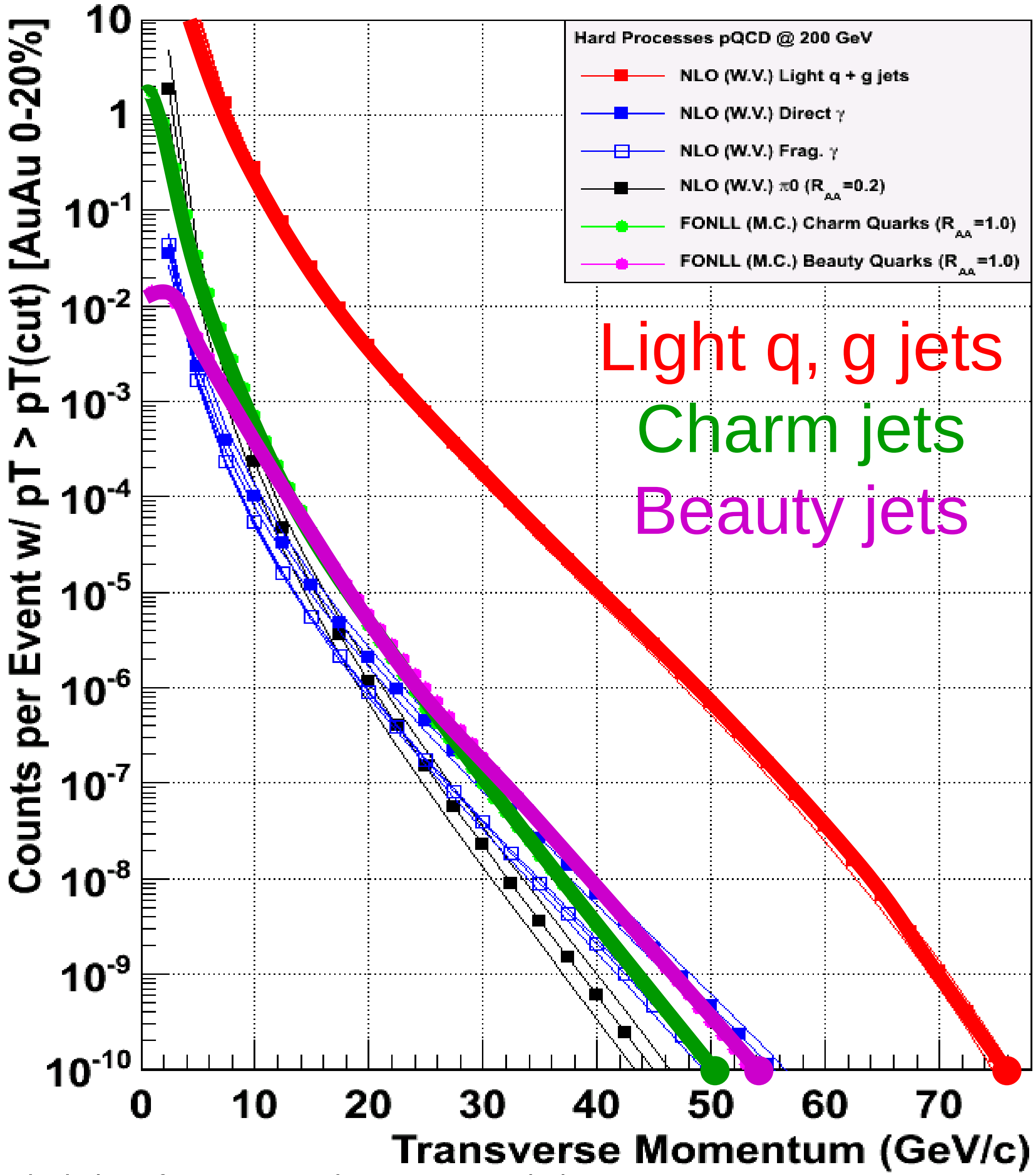


Upsilon Separation of States (with very different binding energies)



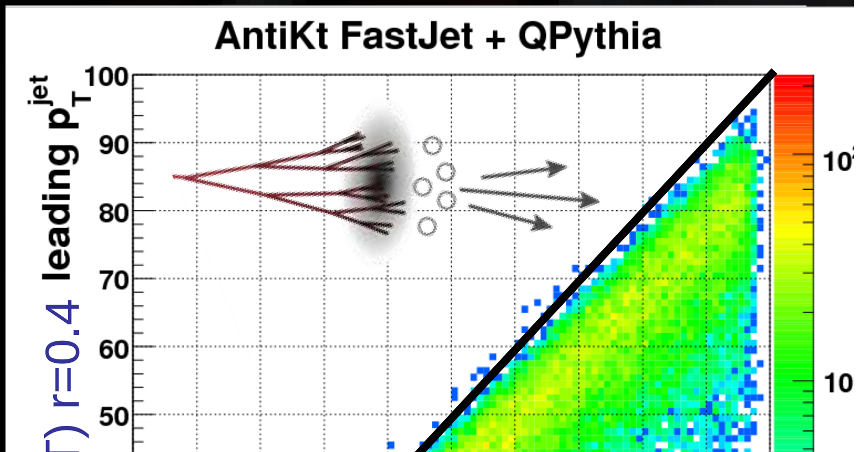
Darren McGlinchey (FSU)

AuAu Jet Rates



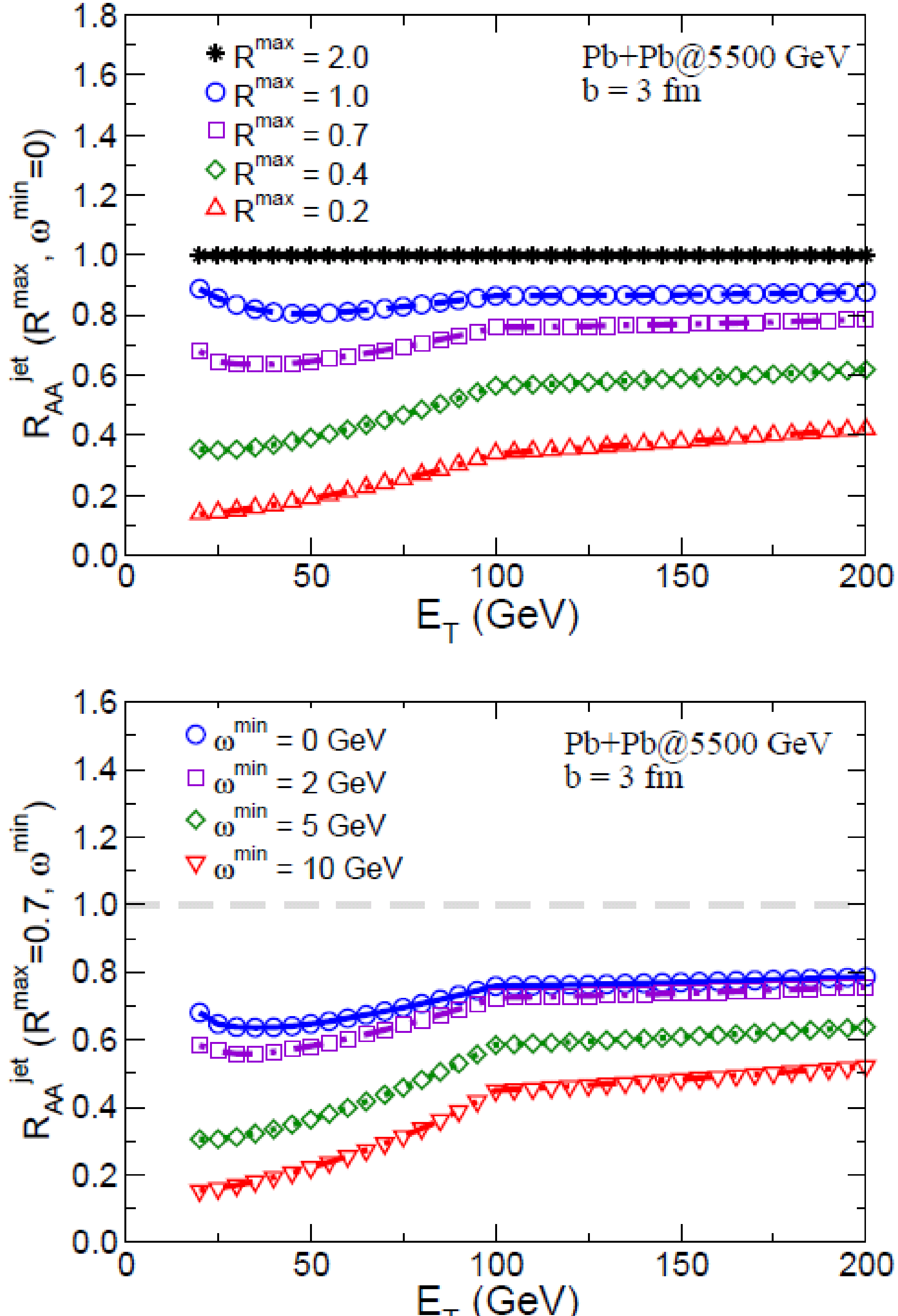
Calculations from W. Vogelsang, M. Cacciari

Exciting opportunity fo
level interactions. Key
interactions of partor



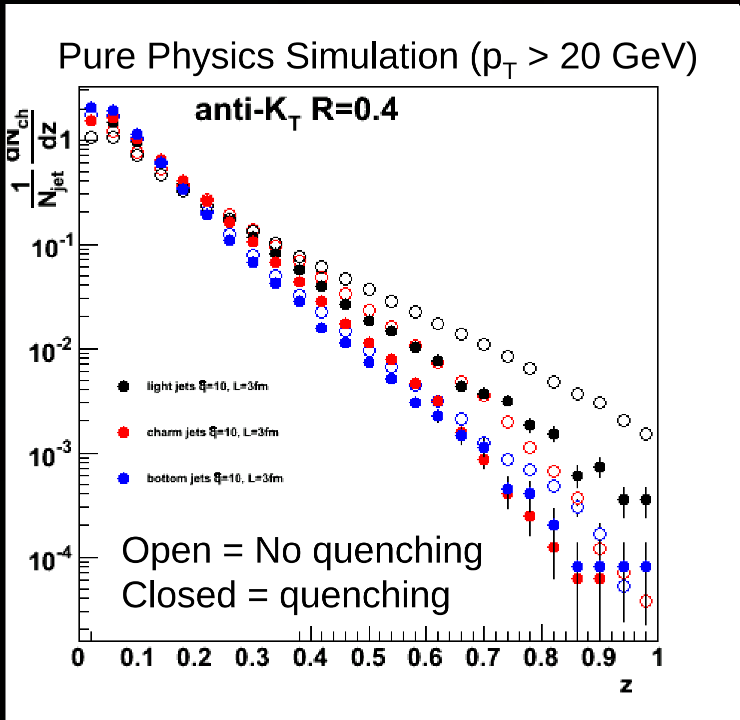
LHC Jet Measurements Optimal E_T > 80 GeV

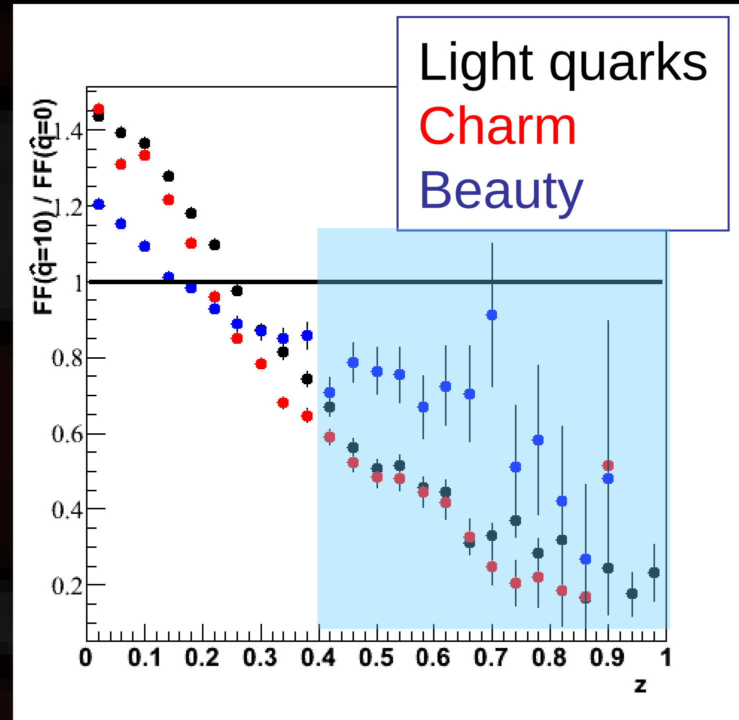
RHIC E_T < 80 GeV with lower background and no trigger issues



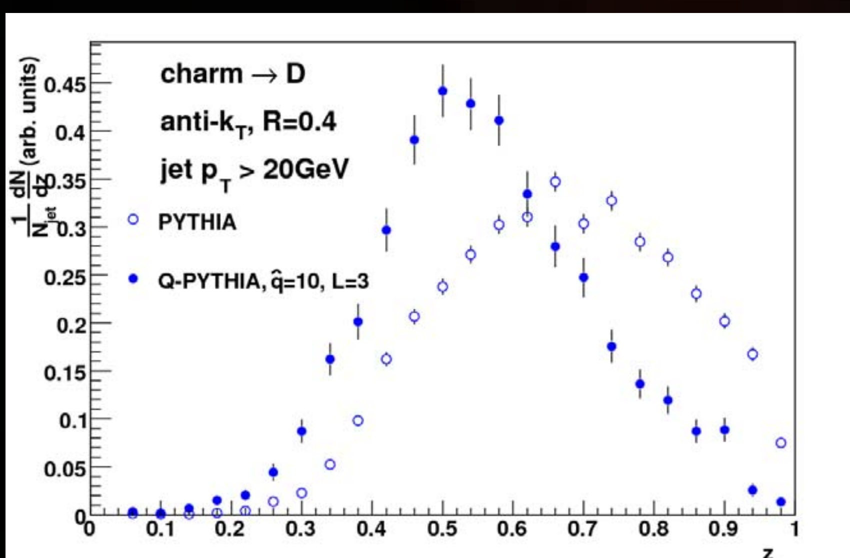
Vitev et al., arXiv:0810.2807v1

Modified Fragmentation Functions





Excellent fake track and fake jet rejection needed for this kinematics.

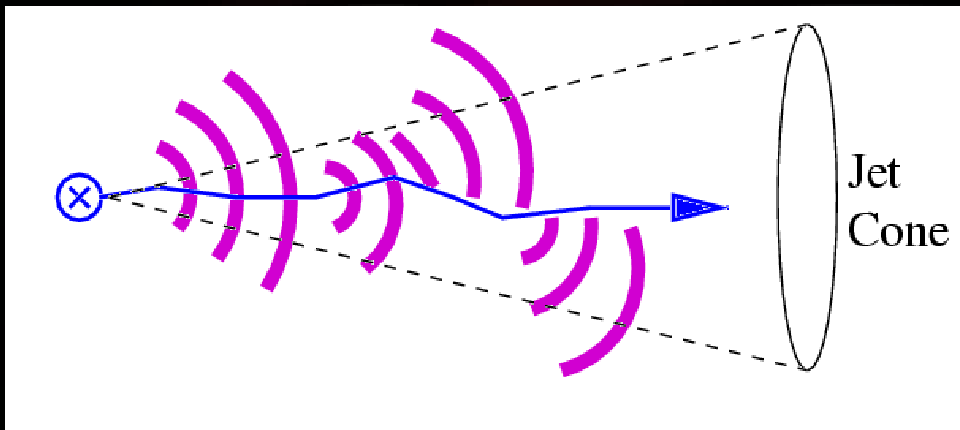


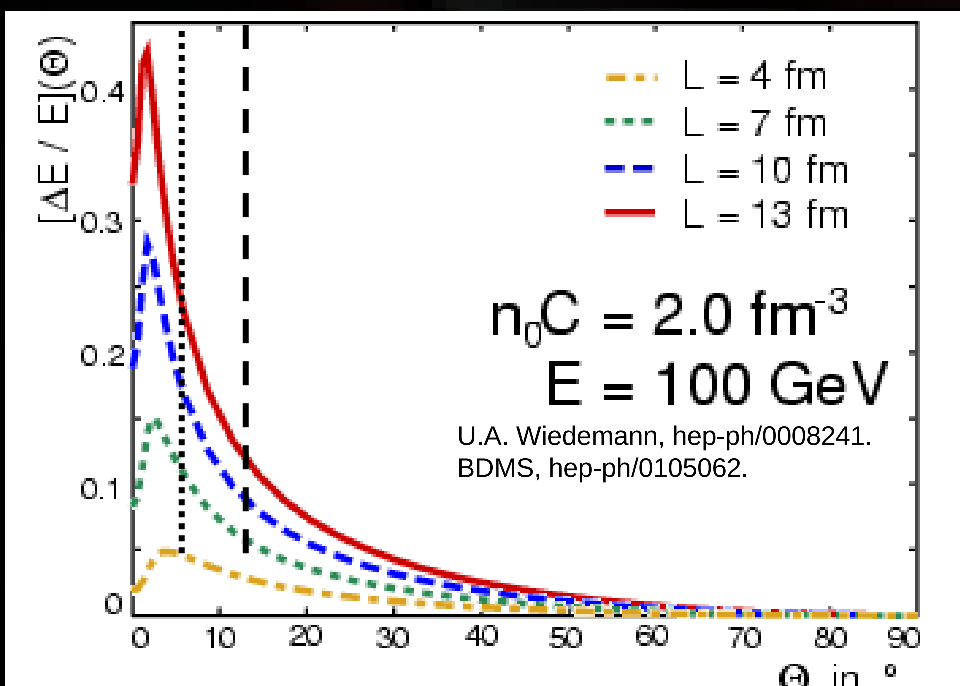
Modified FF for D mesons specifically tags the shift in the leading parton.

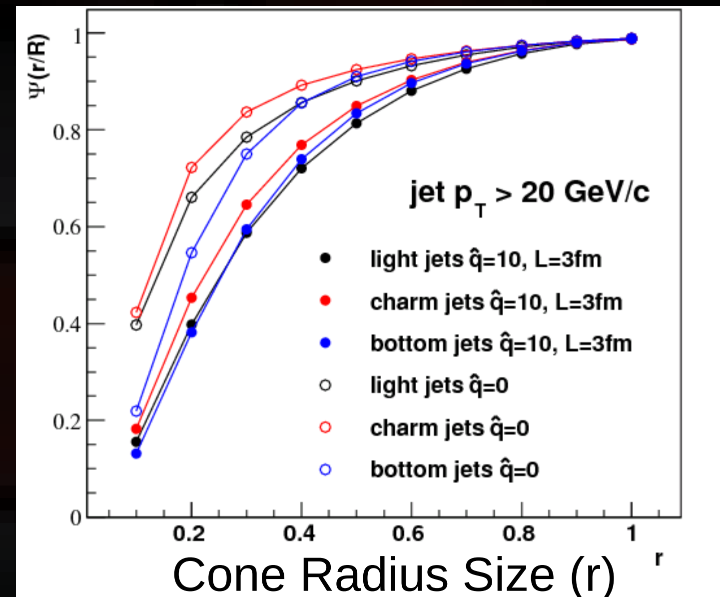
We are working out the tagging efficiency.

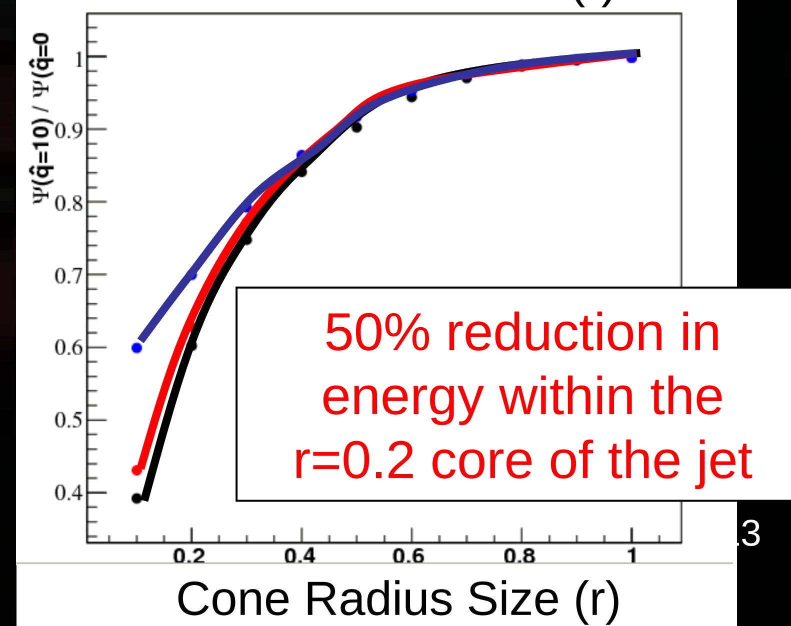
* pQCD – radiative vs collisional (dependent on QGP content)

The induced gluon radiation is measurable via the angular energy distribution

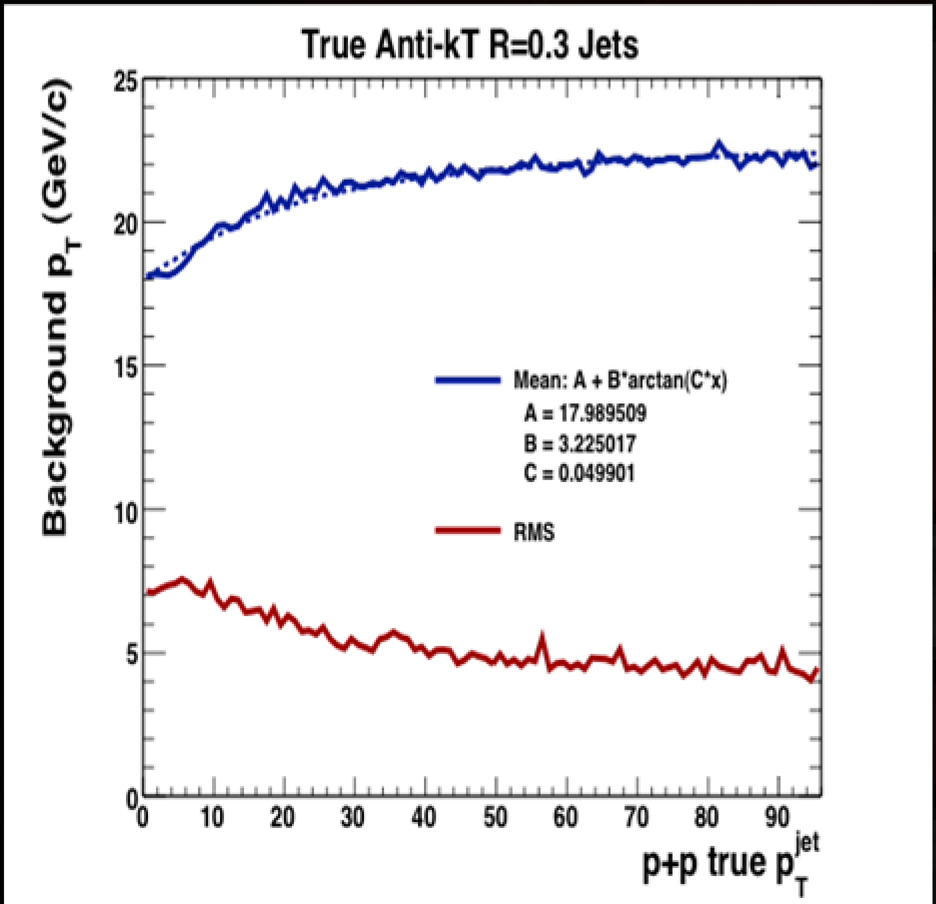


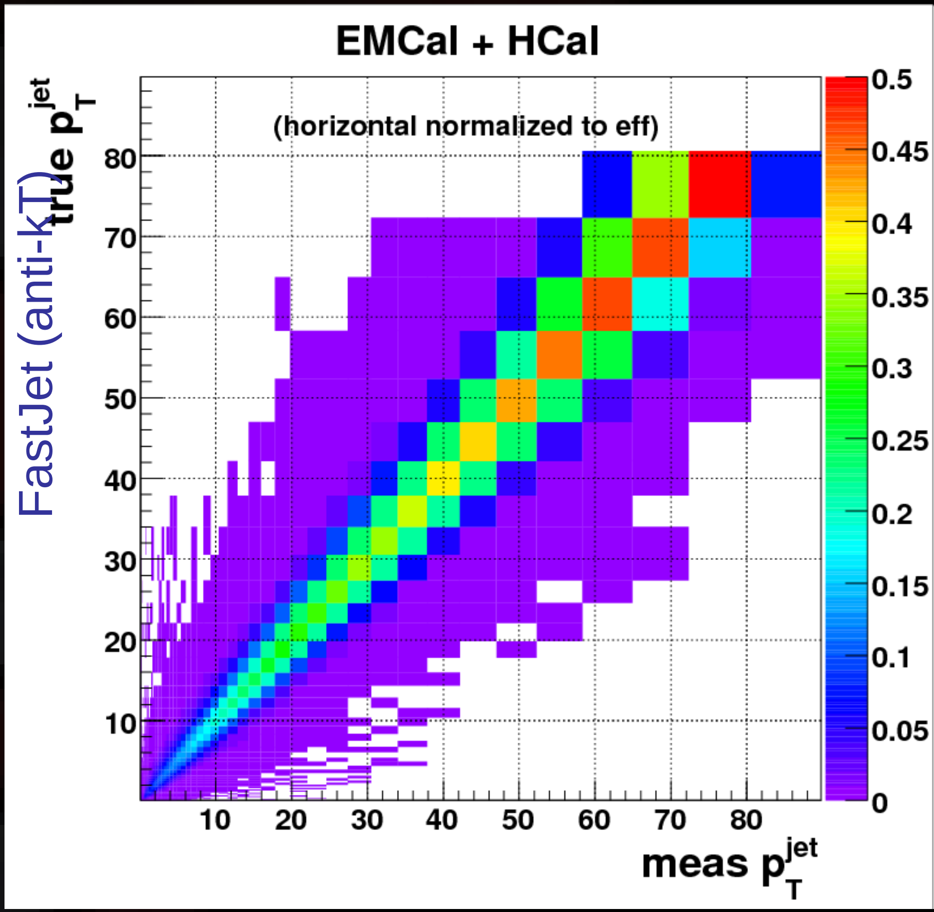






Jet Studies





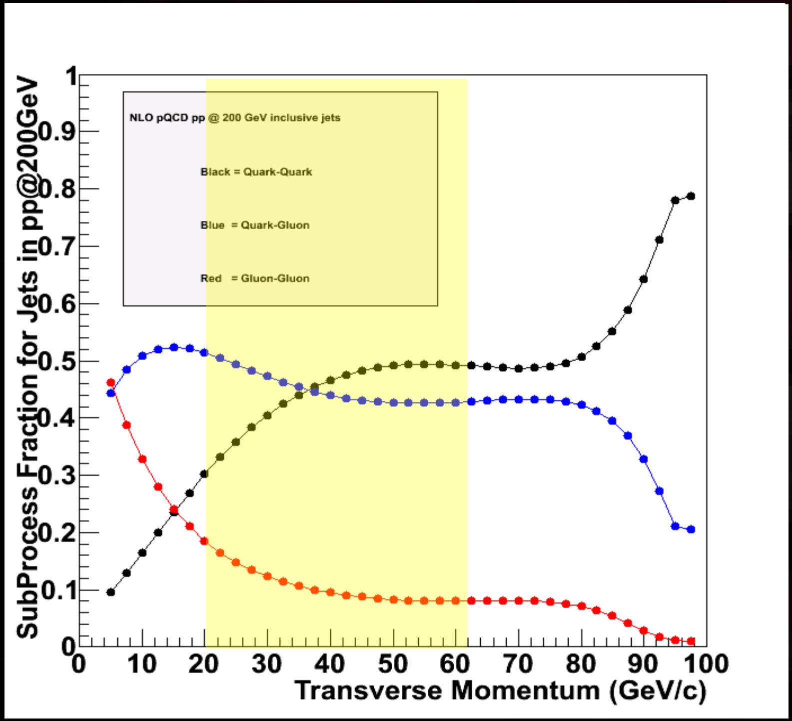
Jets embedded into HIJING AuAu central

Linearity of Jet energy response with EmCal + HCAL

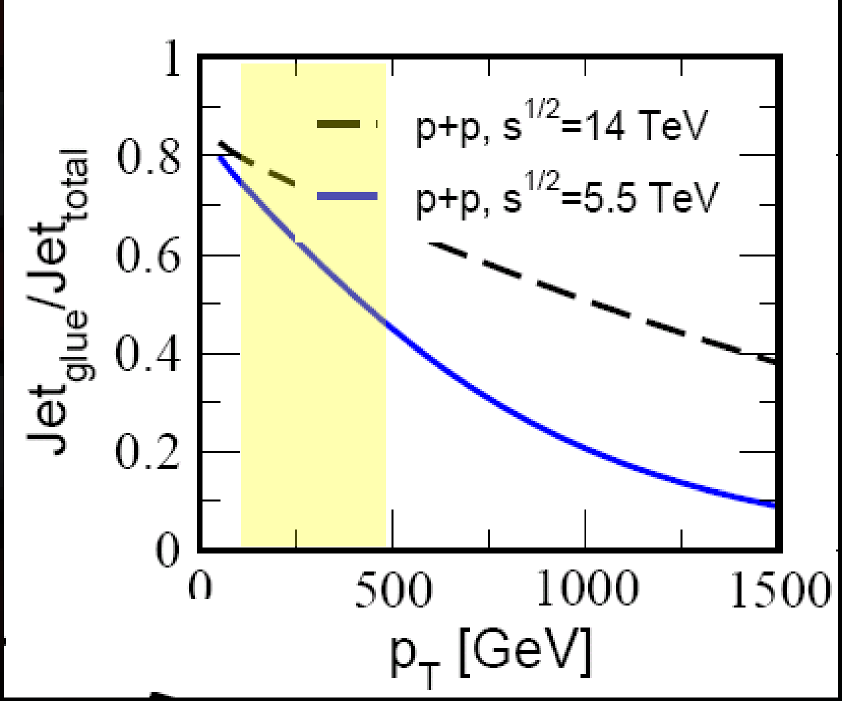
RHIC versus LHC

1. Probe difference
2. Medium difference
3. Key machine flexibility pA, light AA, ultra-heavy AA

RHIC ~ 75% quark jets

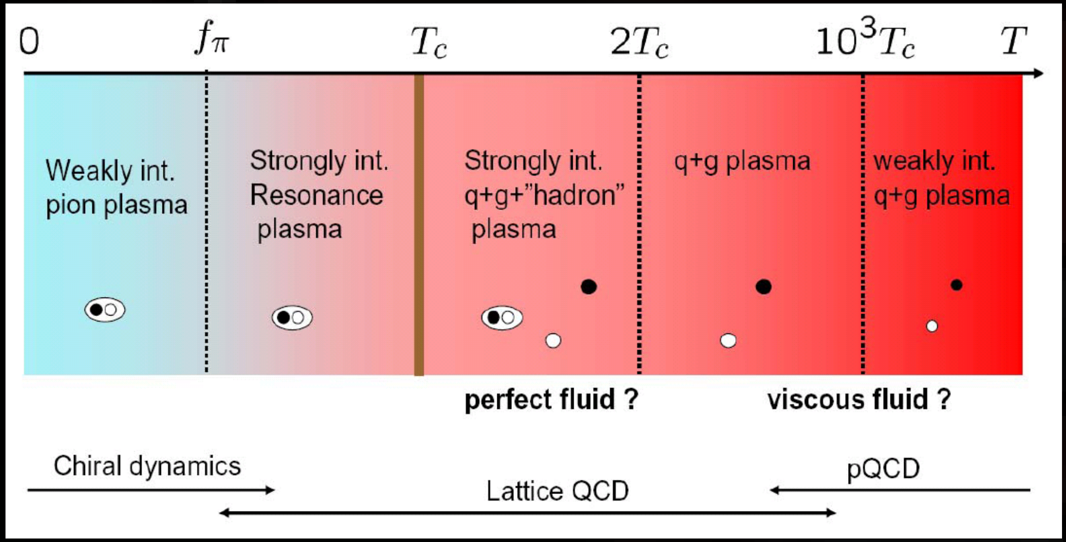


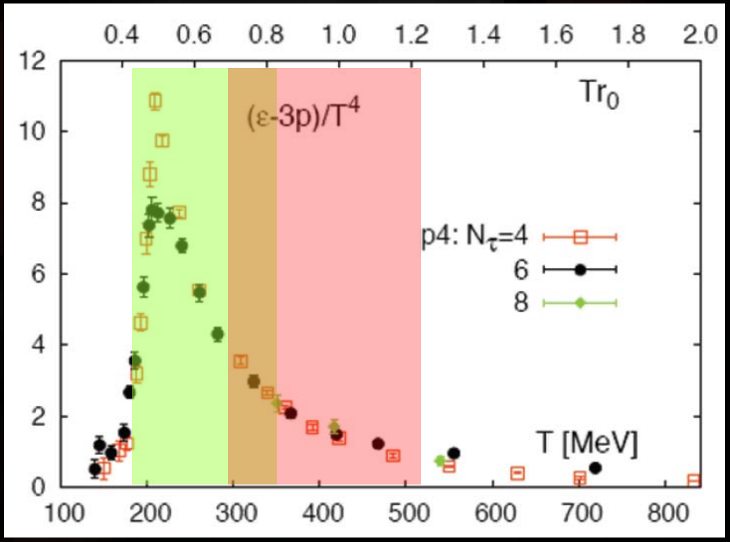
LHC ~ 50-75% gluon jets



RHIC versus LHC

1. Probe difference
2. Medium difference
3. Key machine flexibility pA, light AA, ultra-heavy AA





RHIC QGP dominated by 1-2 T_c

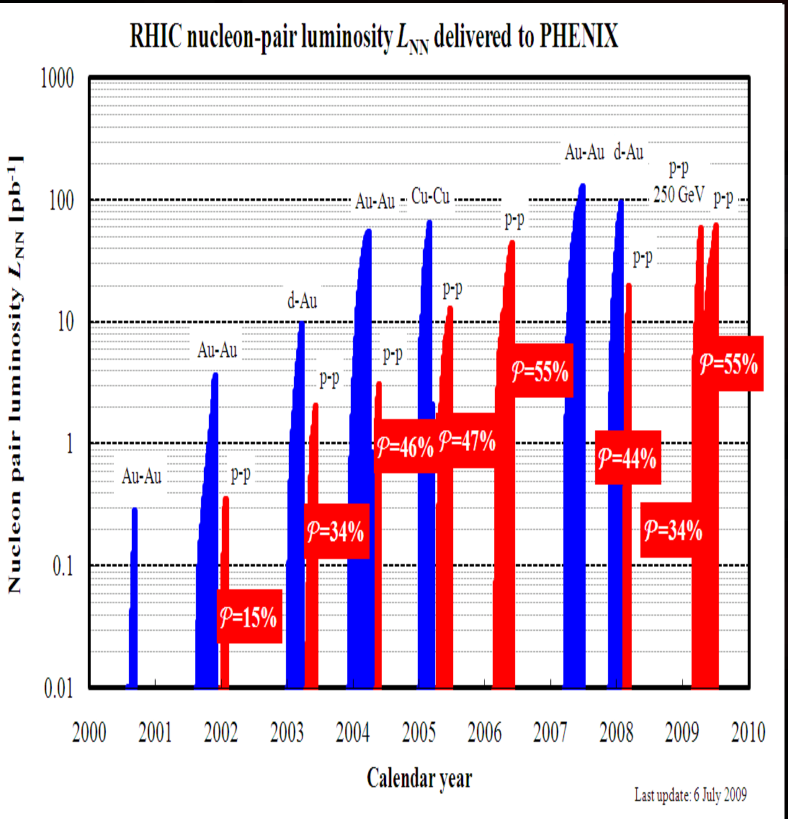
LHC QGP dominated by 2-4 T_c (?)

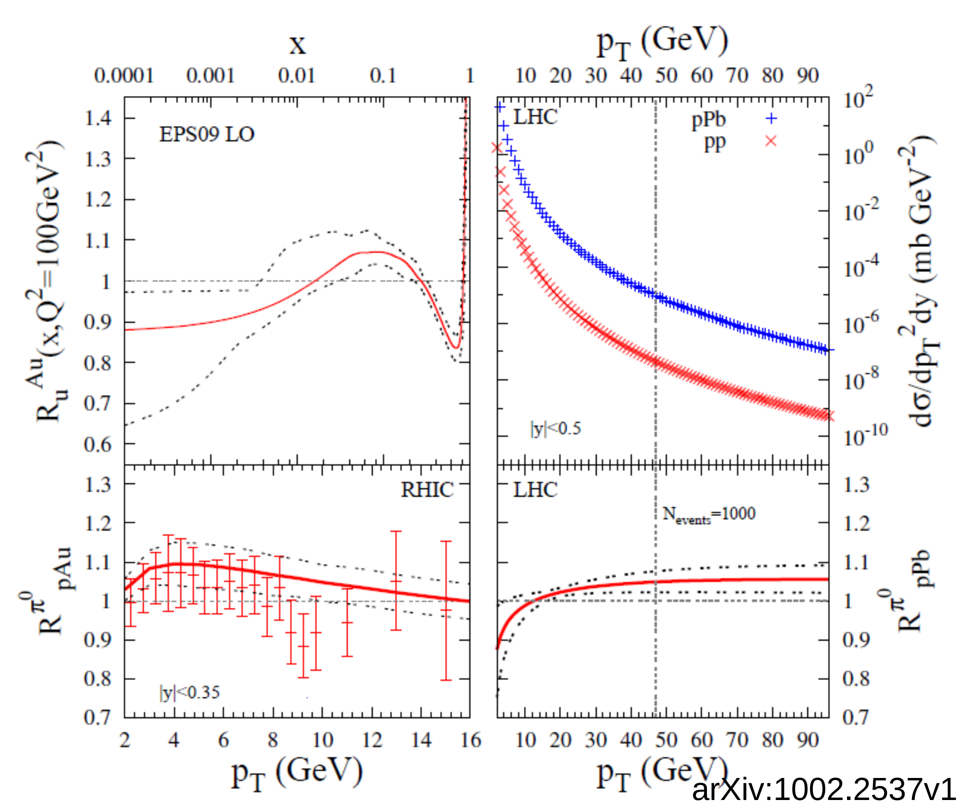
RHIC optimal for strong coupling studies.

RHIC versus LHC

1. Probe difference
2. Medium difference
3. Key machine flexibility pA, light AA, AA, high rates

* This cannot be over-stated





arXiv:1002.2537v1

Jet Flow Chart

Jet R_{AA}

Jet Fragment
$dN/dz\ dk_T^2$

Jet Fragment
dN/dR, $\Psi(R)$

Centrality,
ϕ dependence

Di-jet,
γ-jet

Light vs c vs b

+ energy loss calculations & MC

pQCD-like parton showers or not?

Radiative vs collisional

Transport parameter(s)

L dependence

Mass dependence

+ theory

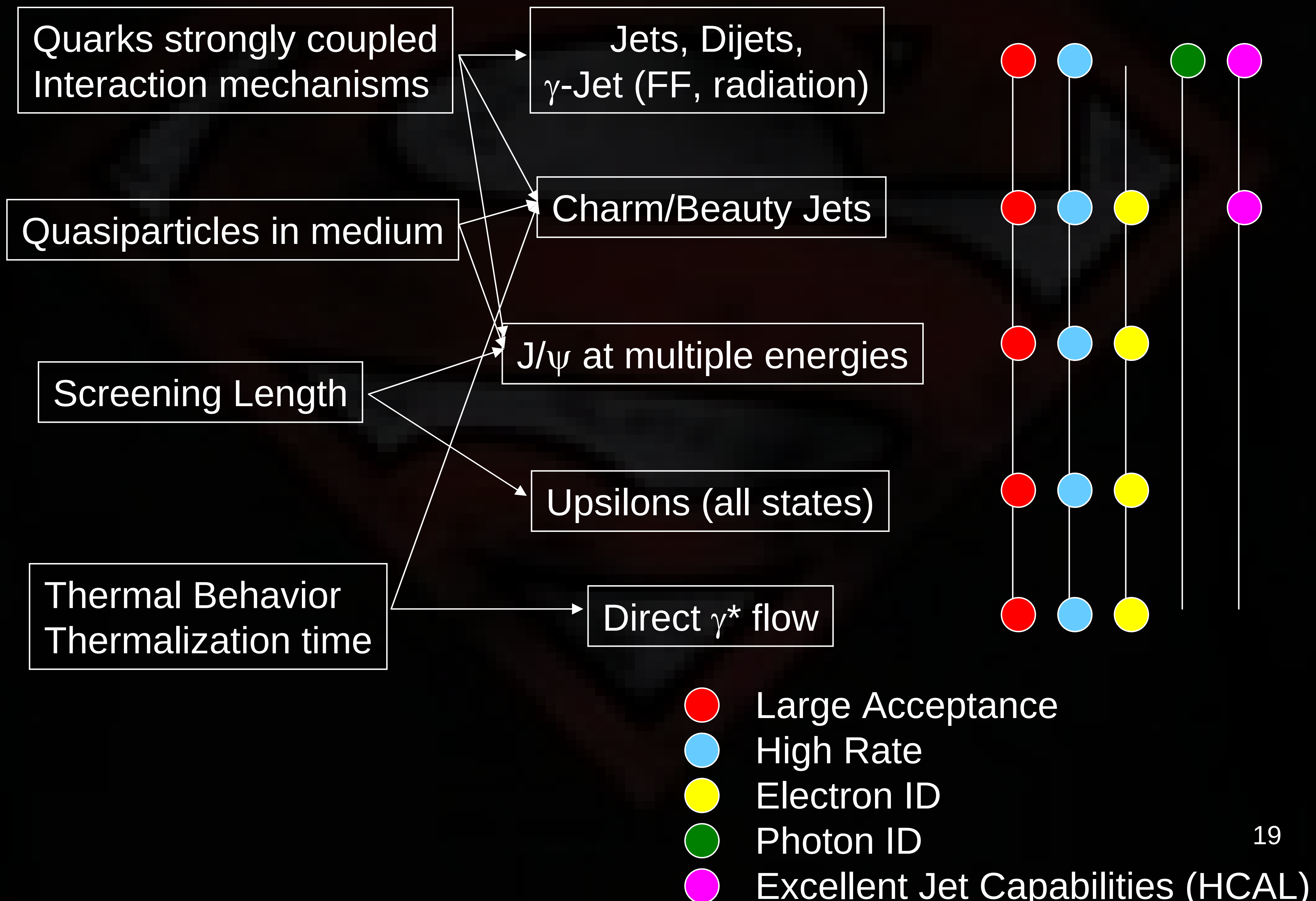
Weak vs strong coupling (jets to medium)

2→2, 2→3 dominant? (weak + quasi-particles?)

Medium properties: thermal masses, screening scales, …

Less speculative/ambitious → More speculative/ambitious

Questions Observables Needs



Nuclear Parton Distribution Functions

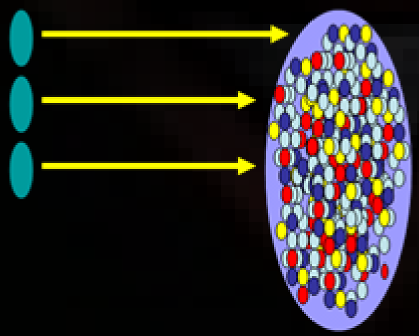
High-x nuclear PDF constraints from very high p_T direct photons

(reach is ~ 30-50 GeV → x~ 0.3-0.5).

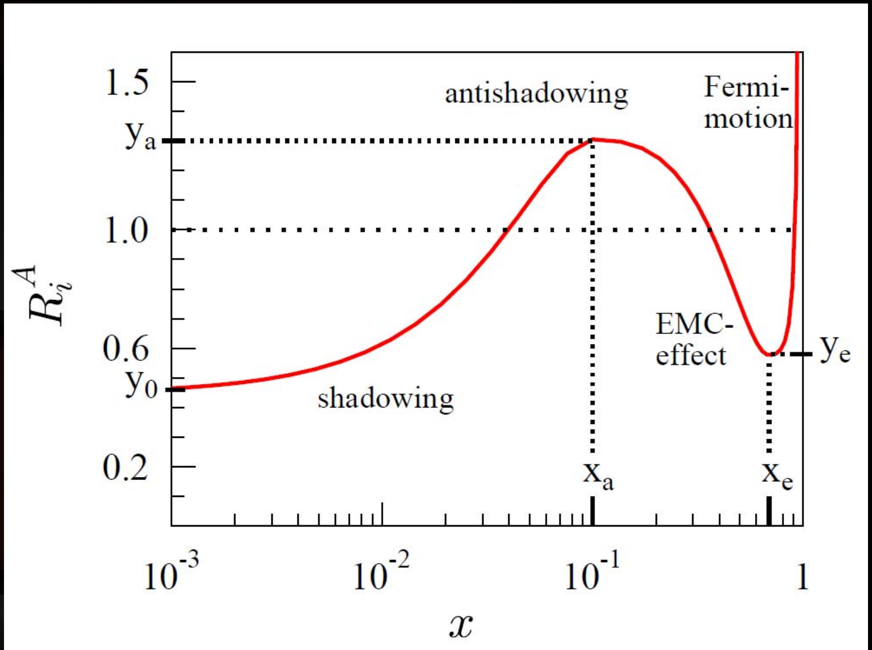
Also, W boson measurement in p(d)+Au and Au+Au @ 200 GeV now possible.

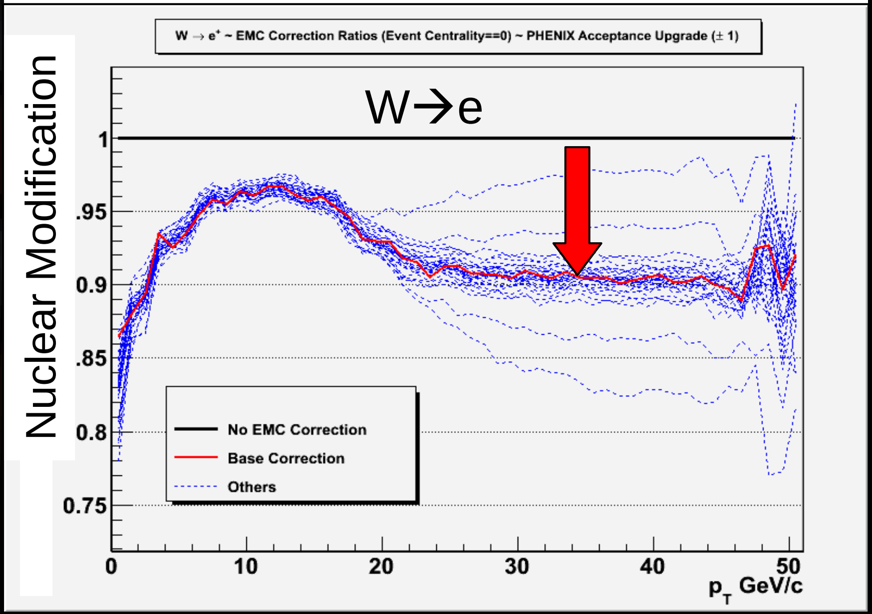
(W→e p_T > 20 GeV : x~0.3-0.5)

Example EPS09 EMC effect, and <u>geometry dependence</u>.

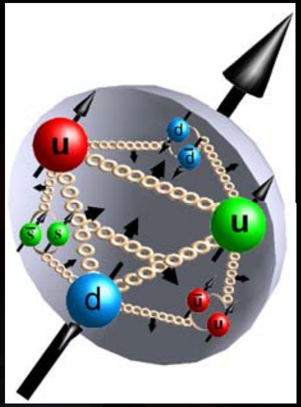


Also isospin parton dependencies…





Transverse Spin at RHIC



1. Transversity quark distributions and Collins or Interference fragmentation

   Correlation between proton and quark spin and spin dependent fragmentation

$$\propto \delta q(x) \cdot H_1^{(\perp,<)}(z_2, k_\perp^2)$$

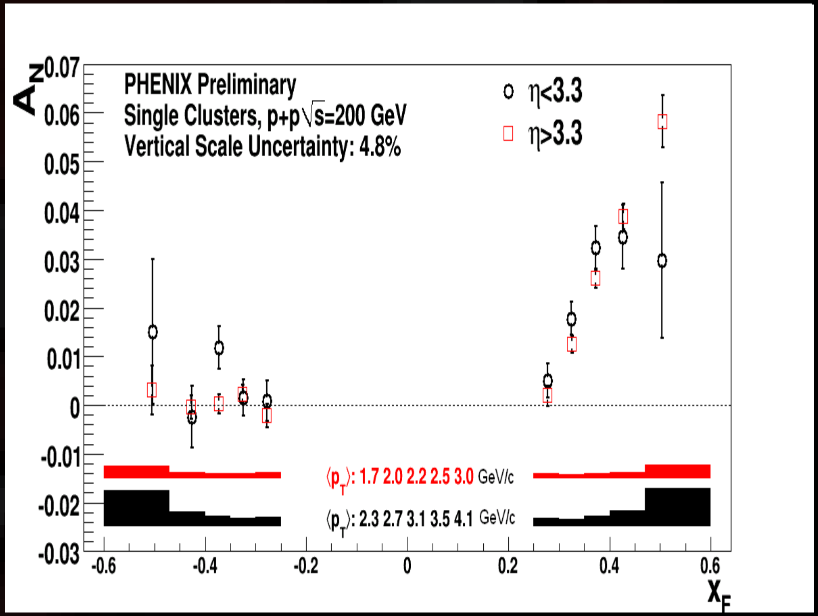
2. Sivers quark distribution

   Correlation between proton-spin and transverse quark momentum

$$\propto \ f_{1T}^{\perp q}(x, k_\perp^2) \cdot D_q^h(z)$$

3. Higher Twist Contributions

   Equivalent to Sivers at small k_T



Transverse Spin Structure Functions

Transversity

correlation between transverse proton spin and quark spin

$S_p - S_q$ coupling

$$\delta q(x) = q_{\Uparrow}^{\uparrow}(x) - q_{\Uparrow}^{\downarrow}(x)$$

Sivers

correlation between transverse proton spin and quark/gluon transverse momentum

$S_p - k_T$ coupling $(L_q?)$

$$f_{1T}^{\perp q}(x, k_\perp^2)$$

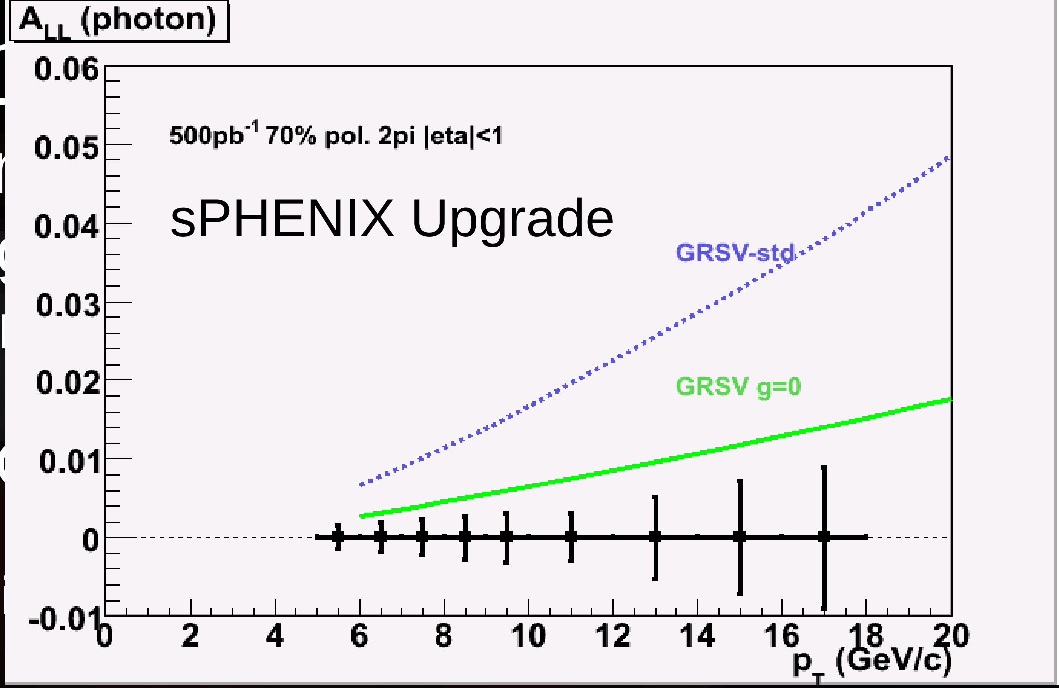
Boer/Mulders
quark momentum

correlation between transverse spin and quark transverse

$S_q - k_T$ coupling $(L_q?)$

$$h_1^{\perp q}(x, k_\perp^2)$$

Unanswered and En

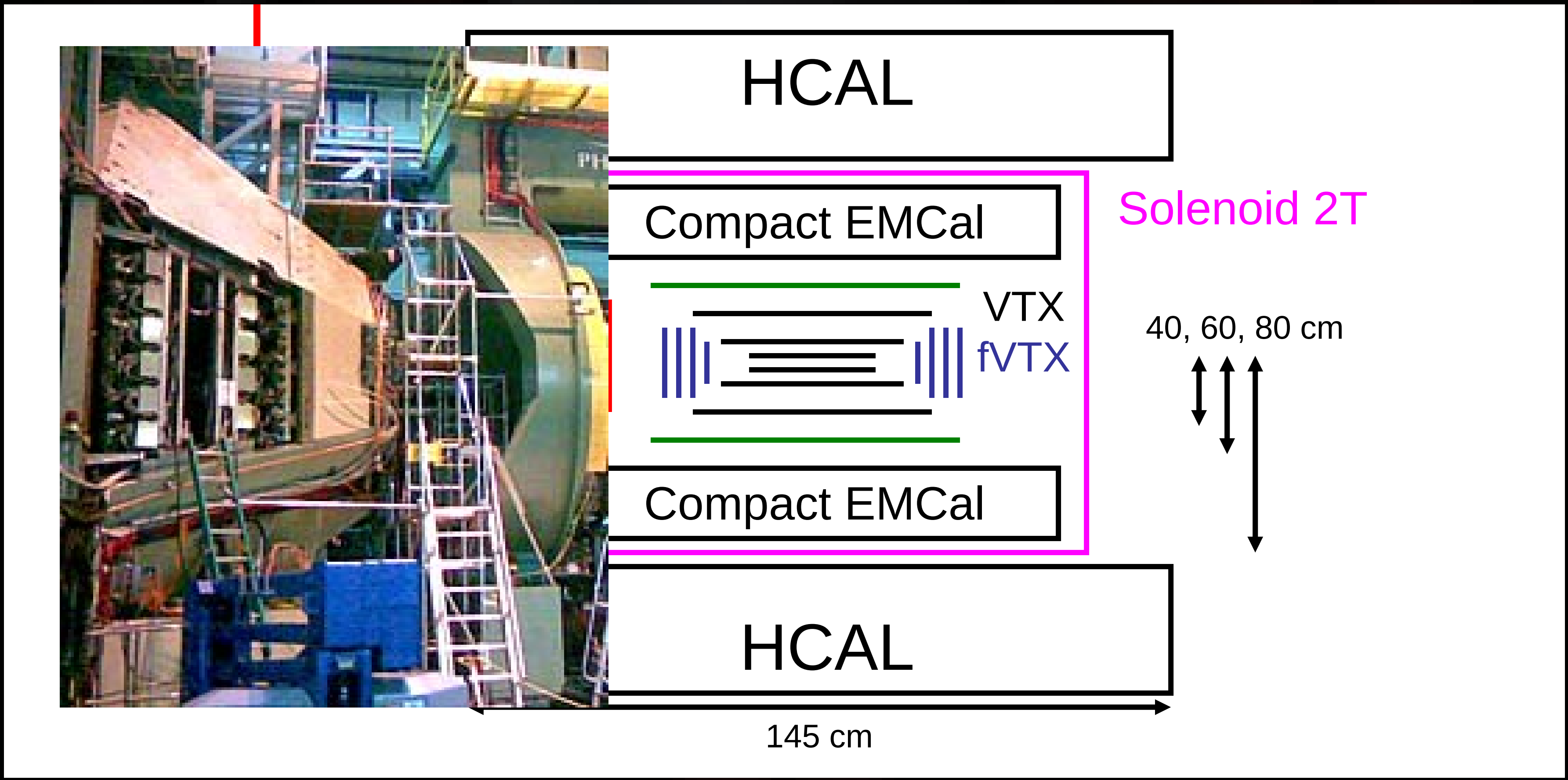


- Transverse spin phen
  - Kinematics high x_f, hig
  - Drell-Yan test QCD pr and DY
  - Separate Sivers and C for the PDFs
    - π^0-jet, γ – jet, IFF for i
    - jet A_N, direct photon
- Longitudinal spin phenomena
  - high rapidity $|\eta| > 2 \rightarrow$ extend x coverage for ΔG and Δq
  - Key cross check test on ΔG with direct photons
- EIC physics
  - Measure polarized and unpolarized inclusive structure functions in ep / eA (F_2, F_L, F_3, g_1, $g_{2,}$ g_5)
  - "Diffractive physics" (DVCS, etc.)

* Pushes towards increased forward coverage (η>2) and electron capabilities.

Proposal: in 2015 remove the south muon spectrometer $|\eta|$=1.2-2.2
and replace with electron/photon endcap spectrometer $|\eta|$=1.2-4.0

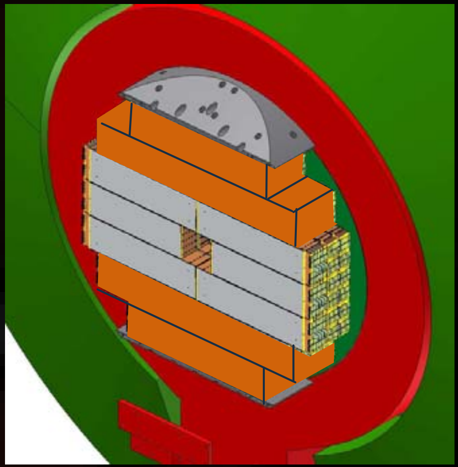
Current Lead-Scintillator and Lead-Glass PHENIX central arm EMCal



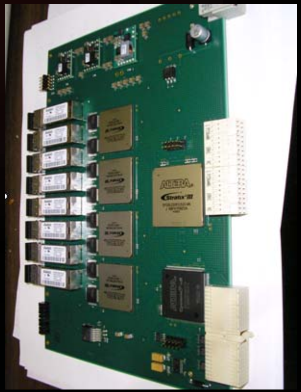
Transverse Drell-Yan measurement
Collins/Sivers measurements
ePHENIX capabilities

Reality Check

- Detector maintenance
  key for aging detectors (20+ yrs)

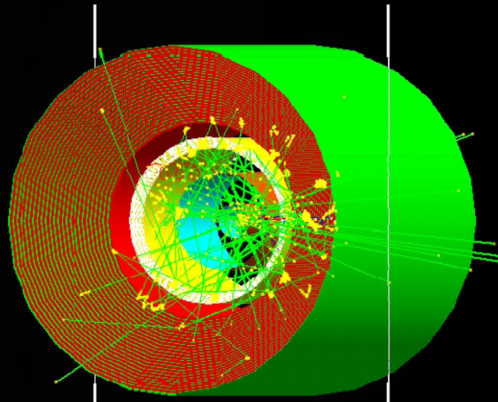


- FOCAL – internal PHENIX review now



- SuperDAQ upgrade (5 kHz → 9 kHz)
  Switch to all DCM II (cost $970k)
  Time scale 2012-2013

- R&D needed for Compact Detector
  (synergy with EIC)



- Working up full detector cost estimates

We are excited to answer these fundamental physics questions!

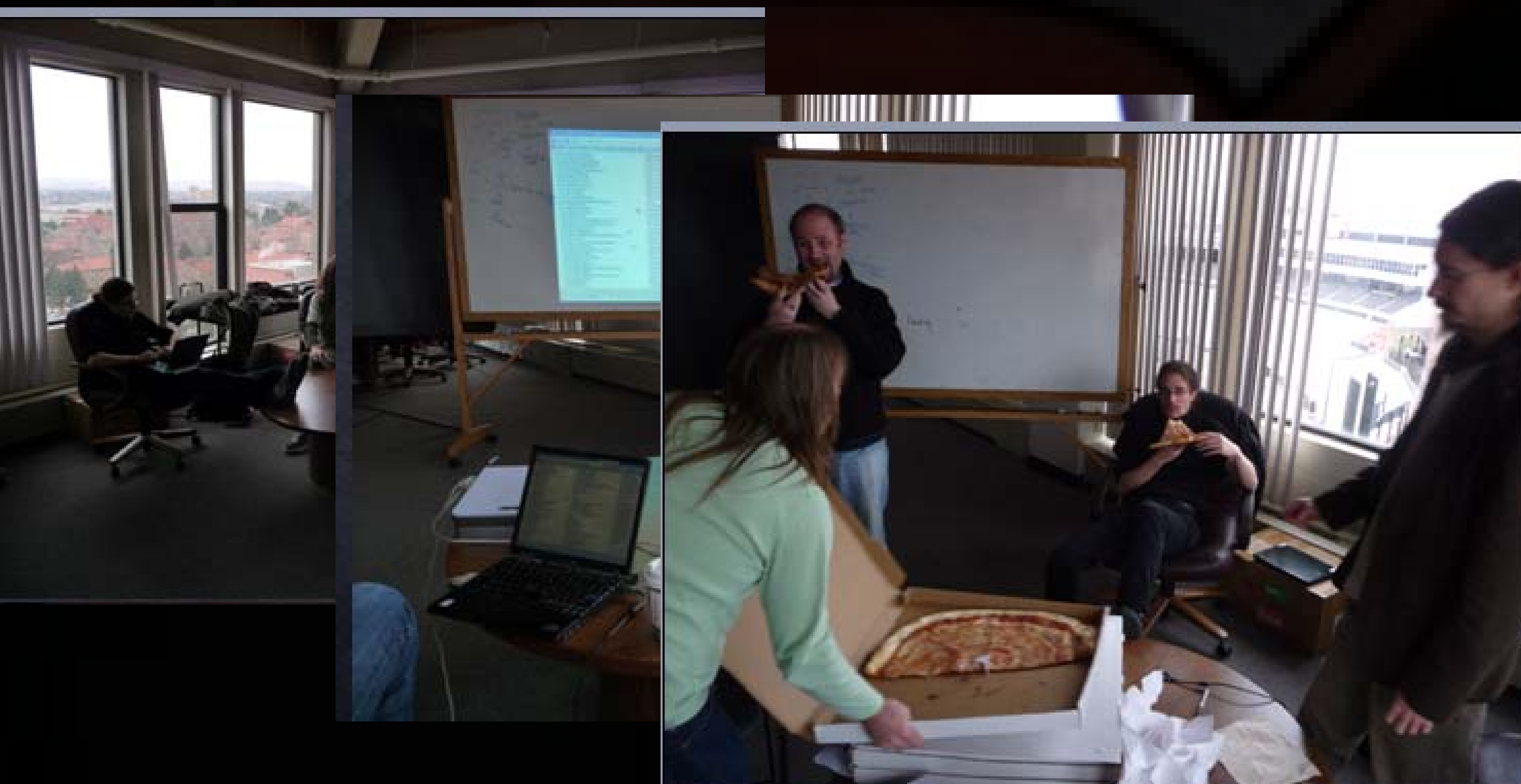
What are your thoughts?

EXTRAS

Many different input/work mechanisms for next decade planning within PHENIX.

Three work-fests for putting physics ideas together with detector options.

Writing Committee formed to coordinate effort.

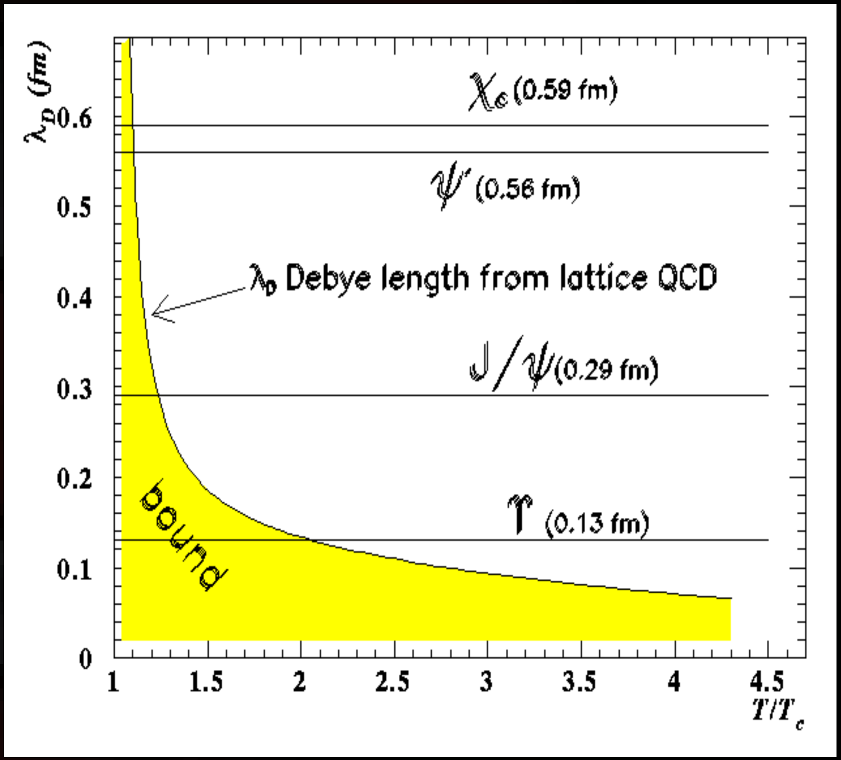


Screening Length

Quarkonia still hold the greatest promise for access to the right distance scales to learn the color screening length in the QGP.

Why Upsilon is very different:

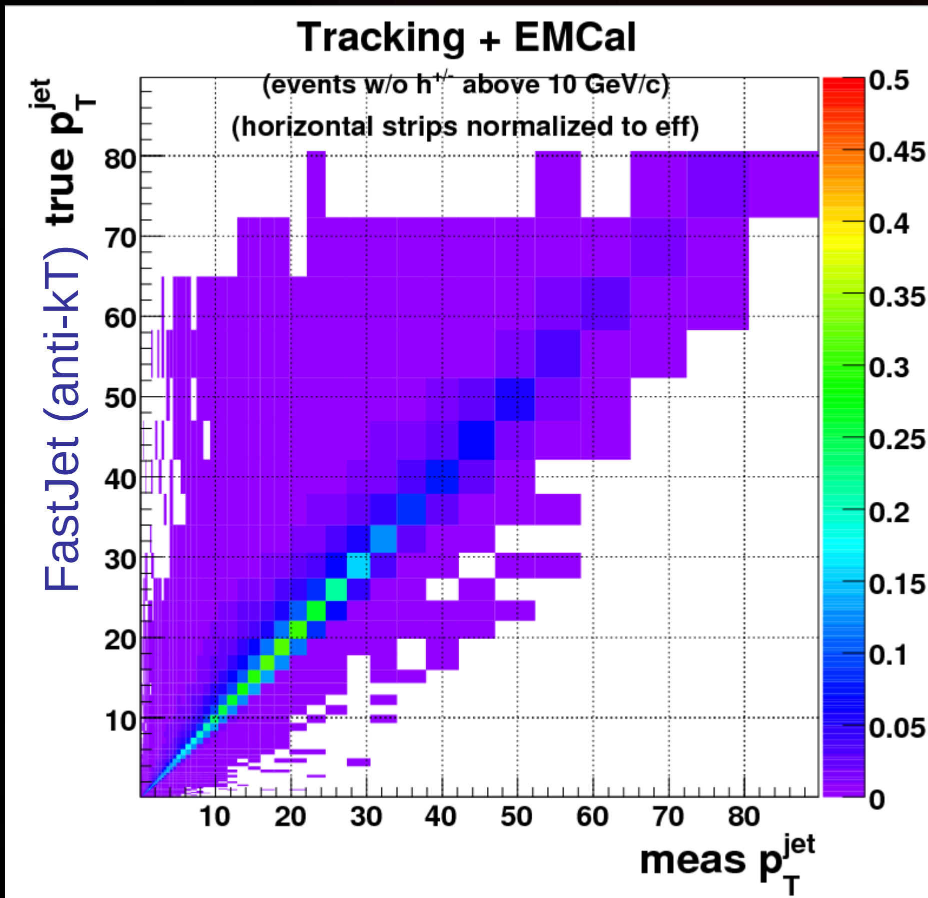
→ J/ψ recombination
→ J/ψ initial nPDF complication
→ Most important is 3 states!

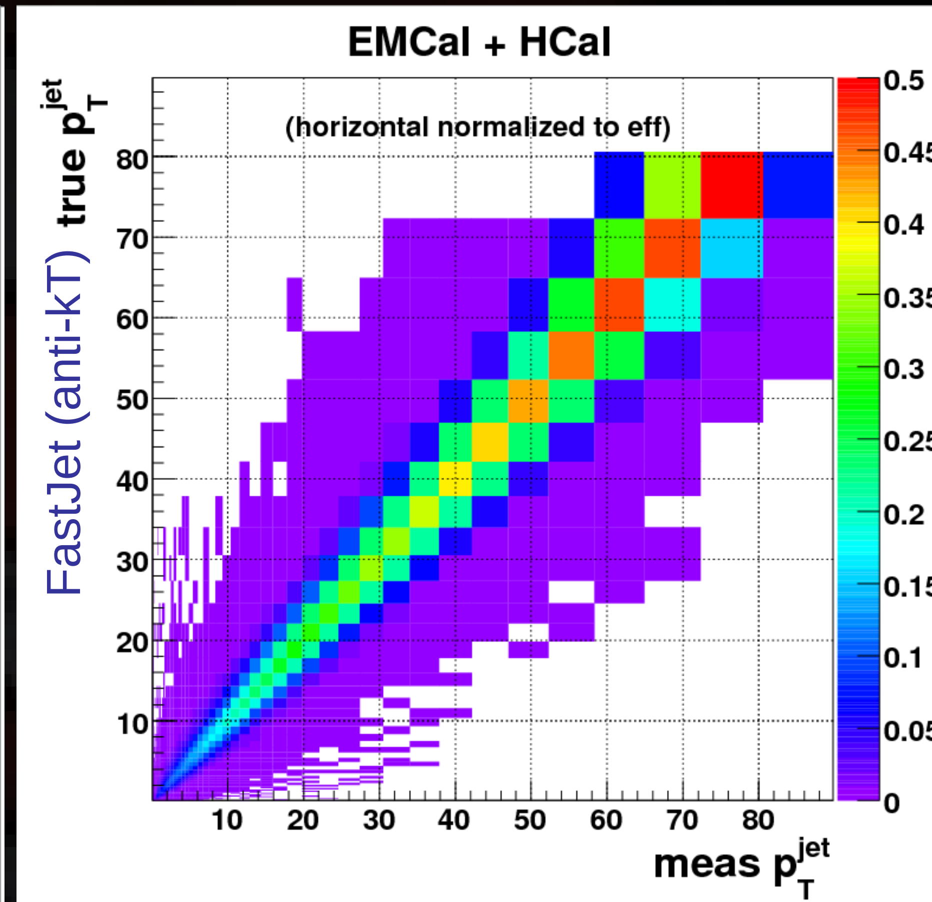


state	J/ψ	χc	ψ'	ϒ(1s)	χb	ϒ(2s)	χb'	ϒ(3s)
Mass [GeV}	3.096	3.415	3.686	9.46	9.859	10.023	10.232	10.355
B.E. [GeV]	0.64	0.2	0.05	1.1	0.67	0.54	0.31	0.2
T_d/T_c	---	0.74	0.15	---	---	0.93	0.83	0.74

hep-ph/0105234 - “indicate ψ’ and the χ_c dissociate below the deconfinement point.”

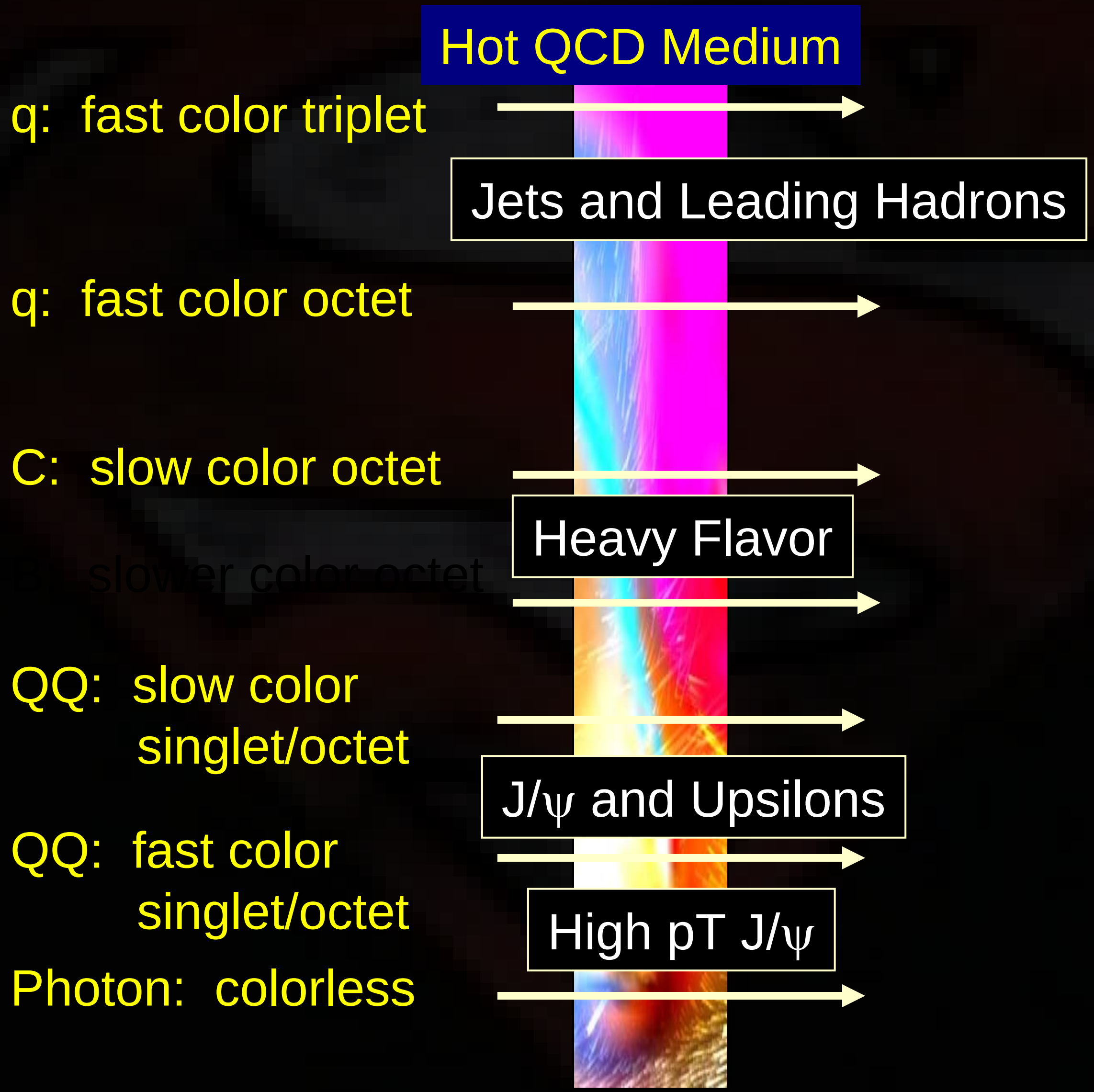
Fast Monte Carlo Jet Performance



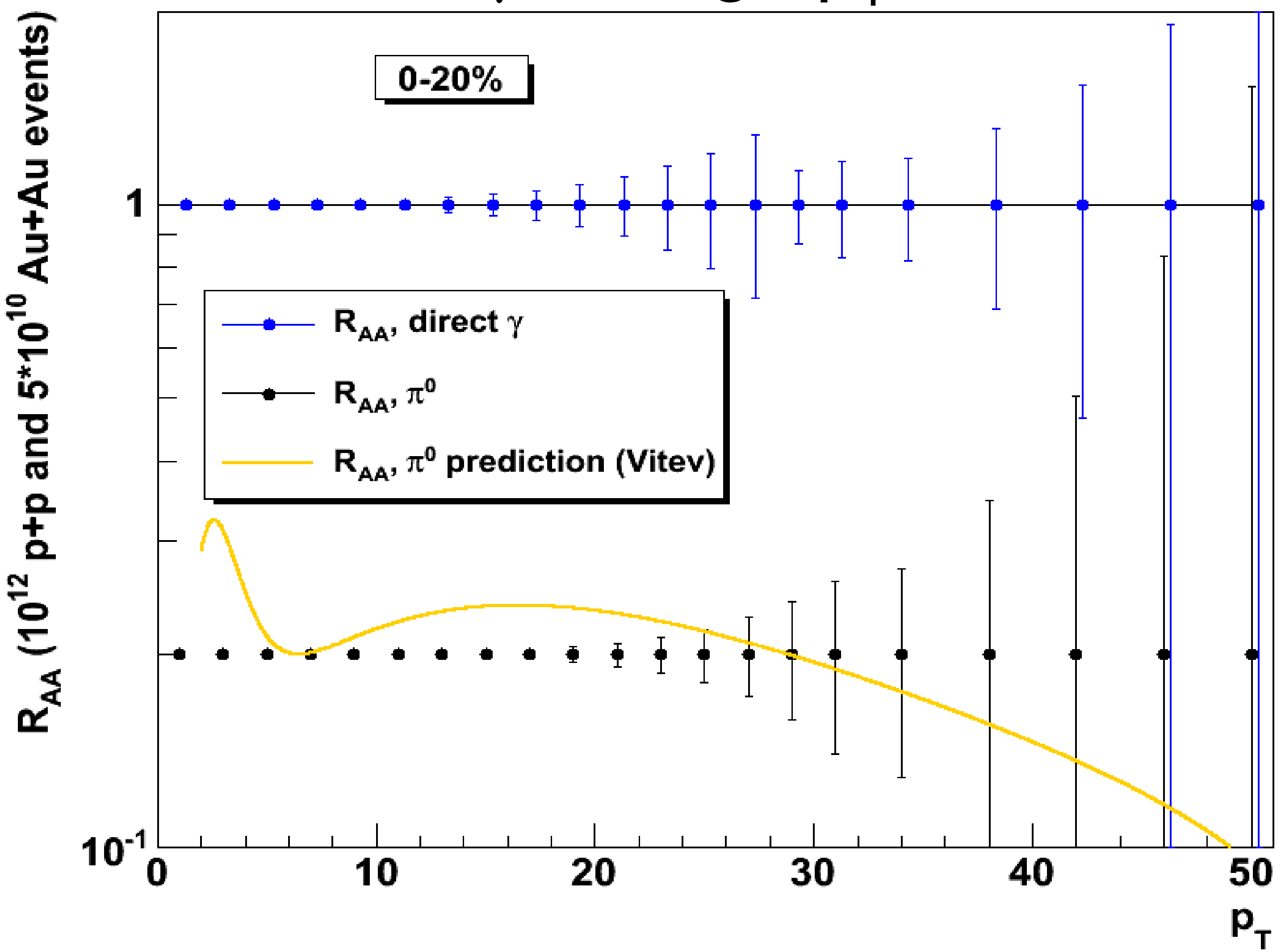


Mike McCumber (Colorado)

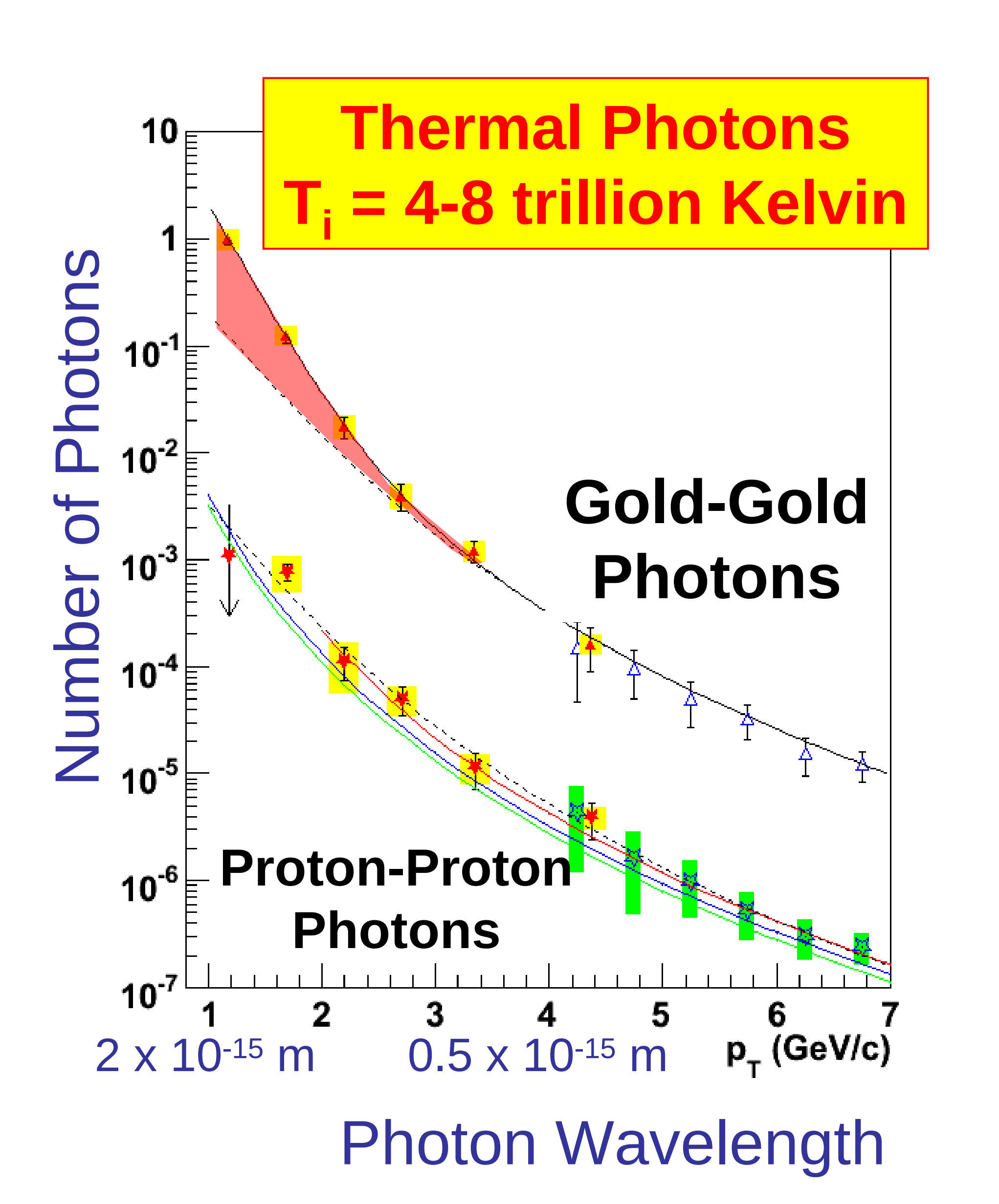
With tracking, dominated by "fakes" above some p_T (e.g. p_T > 10 GeV).
Thus, low overall efficiency for true high energy jets.
Bias in spectra reconstruction when FF is uncertain.
Issue largely solved with EMCal + HCal for jet energy!


Hot QCD Medium
q: fast color triplet
Jets and Leading Hadrons
q: fast color octet
C: slow color octet
Heavy Flavor
QQ: slow color singlet/octet
J/ψ and Upsilons
QQ: fast color singlet/octet
High pT J/ψ
Photon: colorless

γ, π^0 high p_T

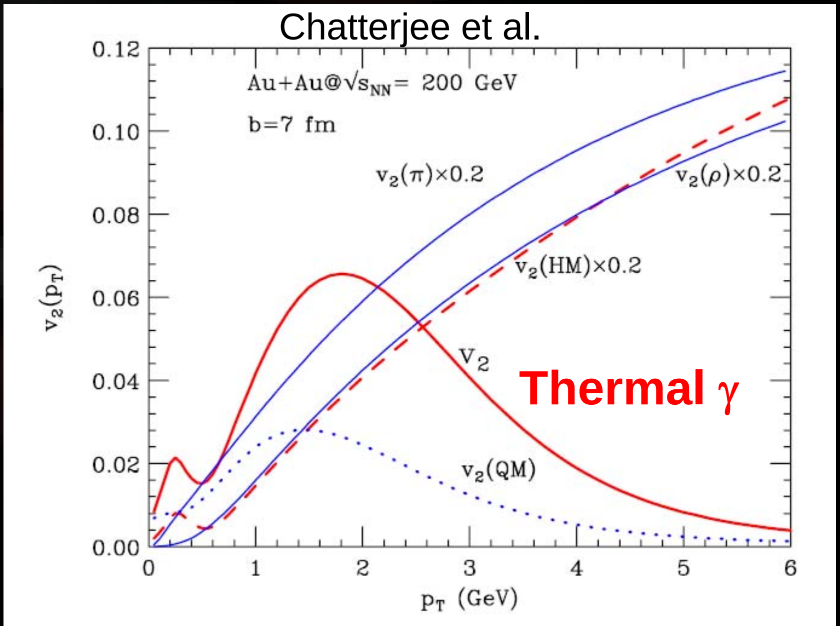

0-20%
R_AA, direct γ
R_AA, π^0
R_AA, π^0 prediction (Vitev)
R_AA (10^12 p+p and 5*10^10 Au+Au events)
1
10^-1
0
10
20
30
40
50
p_T

QGP Temperature

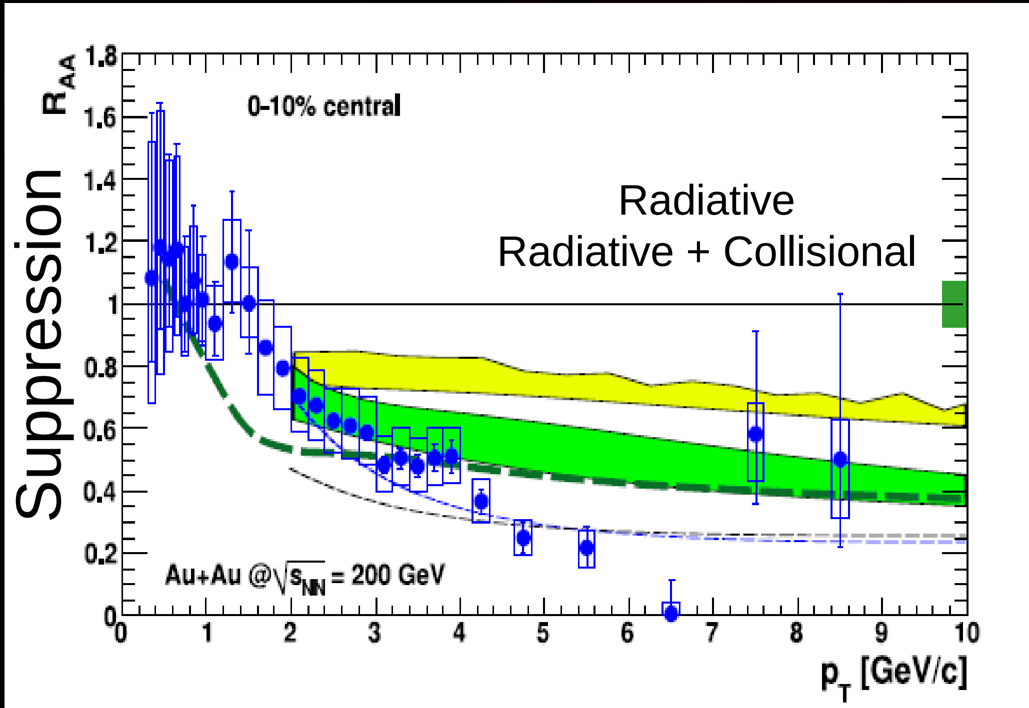


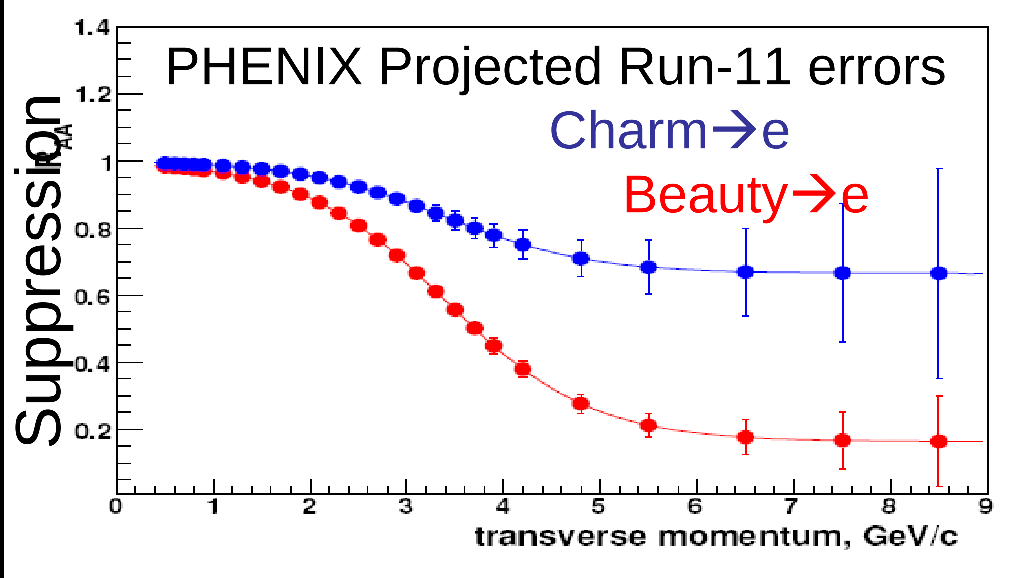
Again, with excellent science, always thinking of new tests.

How about v_2 of these photons?



One Example (2010-2015)

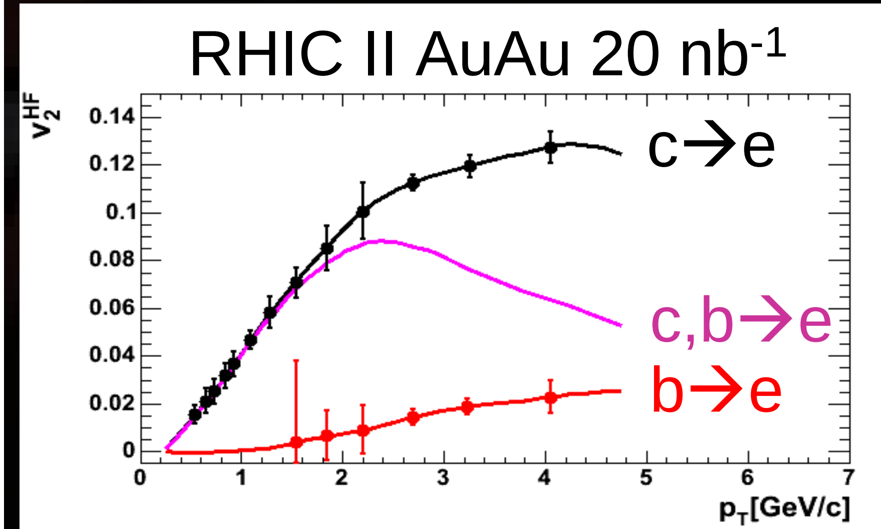


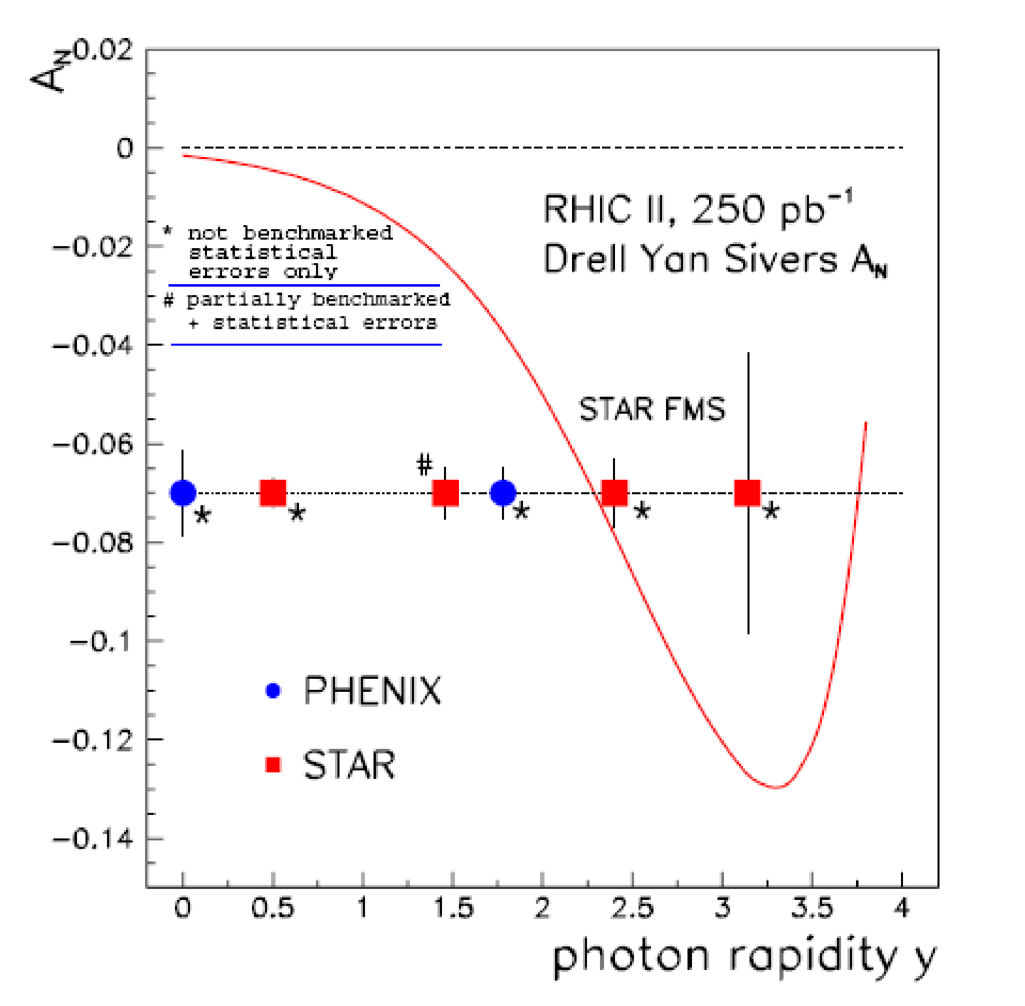


Multi-Year Program

Needs pp @ 200 GeV
dAu @ 200 GeV
AuAu @ 200 GeV

Eventually we will have flow, D^0 reconstruction, charm correlations, …





A_N
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
−0.12
−0.14
0
0.5
1
1.5
2
2.5
3
3.5
4
photon rapidity y
RHIC II, 250 pb^{-1}
Drell Yan Sivers A_N
* not benchmarked statistical errors only
# partially benchmarked + statistical errors
STAR FMS
PHENIX
STAR

Why a jet detector at RHIC?

- Complementarity to the LHC
  - Probes a different mixture of g-to-quark jets
  - Probes a different temperature and jet E_T scale vs. LHC, where $E_T < 50$ GeV is going to be very challenging
  - Lack of 5.5 TeV $p + p$, $p +$ A will dominate the LHC's systematics for some time
- Why now?
  - Compact EMCal becomes available (compare PHENIX FOCAL)
  - Need to extend the physics studied, vs. repeated runs with the same detector
  - R&D overlap with the EIC
- But ...
  - $\Delta\varphi = 2\pi$ EMCal + HCal means PHENIX loses PID capability

ALD Steve Vigdor has charged PHENIX and STAR to write decadal plans due August 1, 2010 (now set to October 1, 2010)

- Summarize detector upgrades underway and to be utilized in the next 5 years.

- Compelling science beyond 5++ years that require additional detector upgrades and machine capabilities.

- Prioritize the physics and the upgrades above.

- Discuss the option of an electron beam in the tunnel and thus an ePHENIX and eSTAR in the MeRHIC and EIC era.