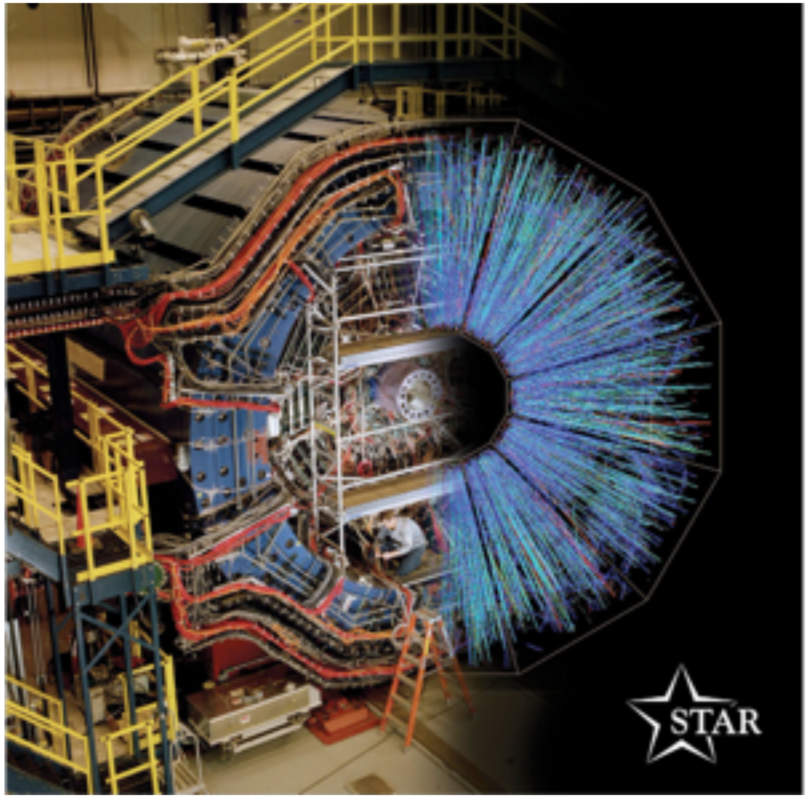
Probing the Initial Stages with STAR



All truth passes through three stages.
First, it is ridiculed.
Second, it is violently opposed.
Third, it is accepted as being self-evident.

- Arthur Schopenhauer (1788-1860)

Helen Caines - Yale University

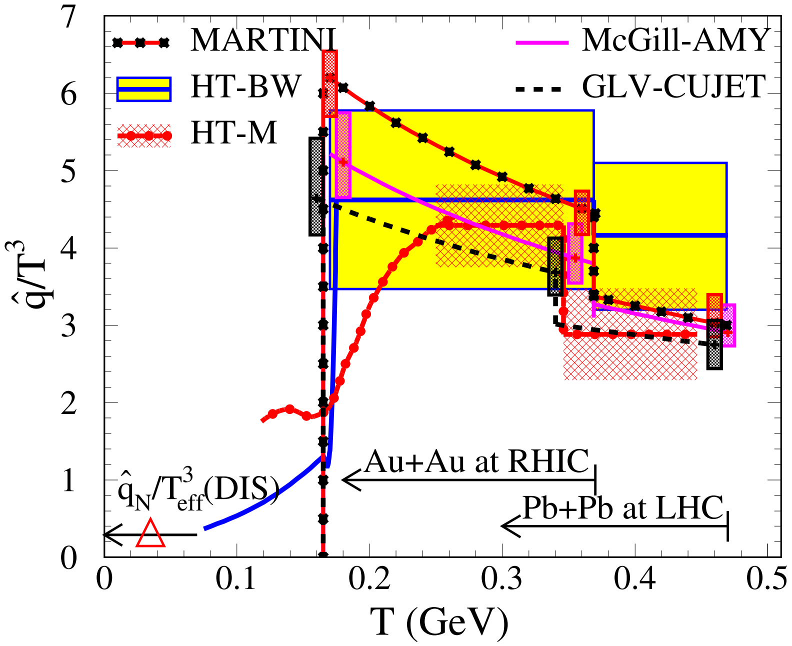
The 2nd International Conference on
the Initial Stages in High-Energy
Nuclear Collisions
Nappa Valley, Dec 3rd-7th 2014

RHIC/LHC complimentarity

Why should I care about RHIC now there's LHC?

Different initial conditions and evolutionary paths:

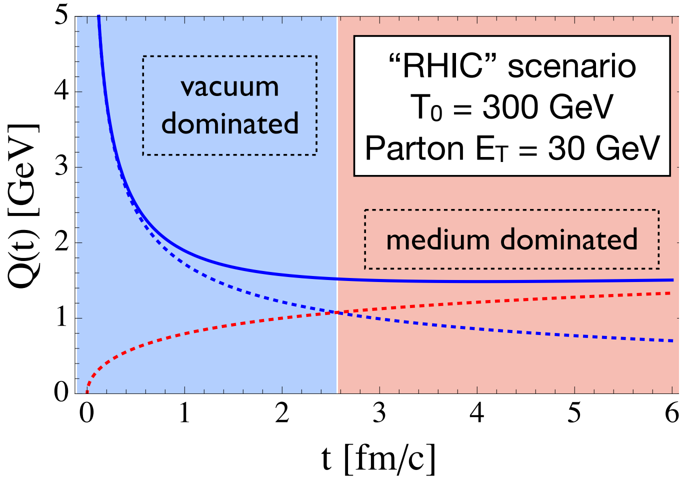
$$\hat{q} \sim \begin{matrix}1.2 \pm 0.3\\ 1.9 \pm 0.7\end{matrix}\ \mathrm{GeV^2/fm}\quad \begin{matrix}T=370\ \mathrm{MeV}\\ T=470\ \mathrm{MeV}\end{matrix}$$

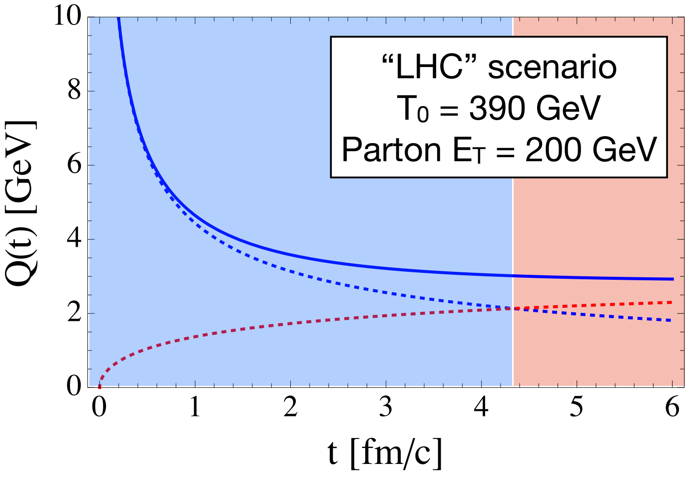


RHIC probes may behave differently to LHC probes and be in "different" medium

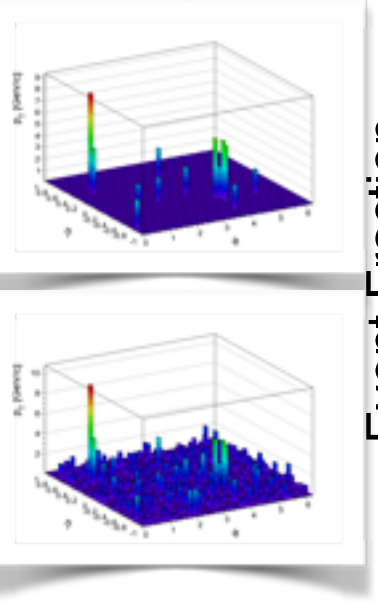
Different virtuality evolutions:

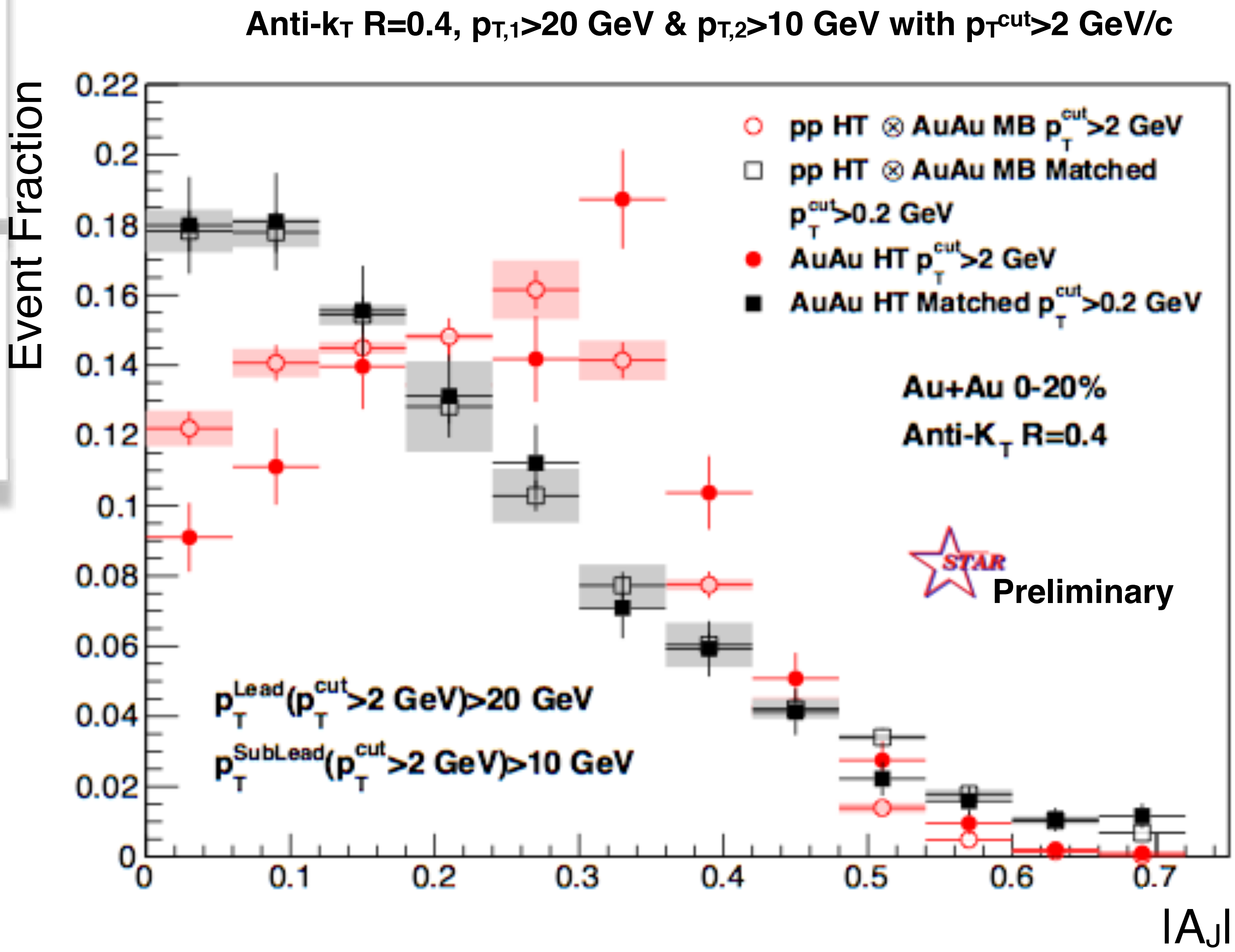
How/when does parton become "aware" of medium





Di-jet imbalance A_J Au+Au 0-20% R=0.4





Anti-k_T R=0.4, $p_{T,1}$>20 GeV & $p_{T,2}$>10 GeV with p_T^{cut}>2 GeV/c

p-value<10^{-5}
(stat. error only)

p-value~0.8
(stat. error only)

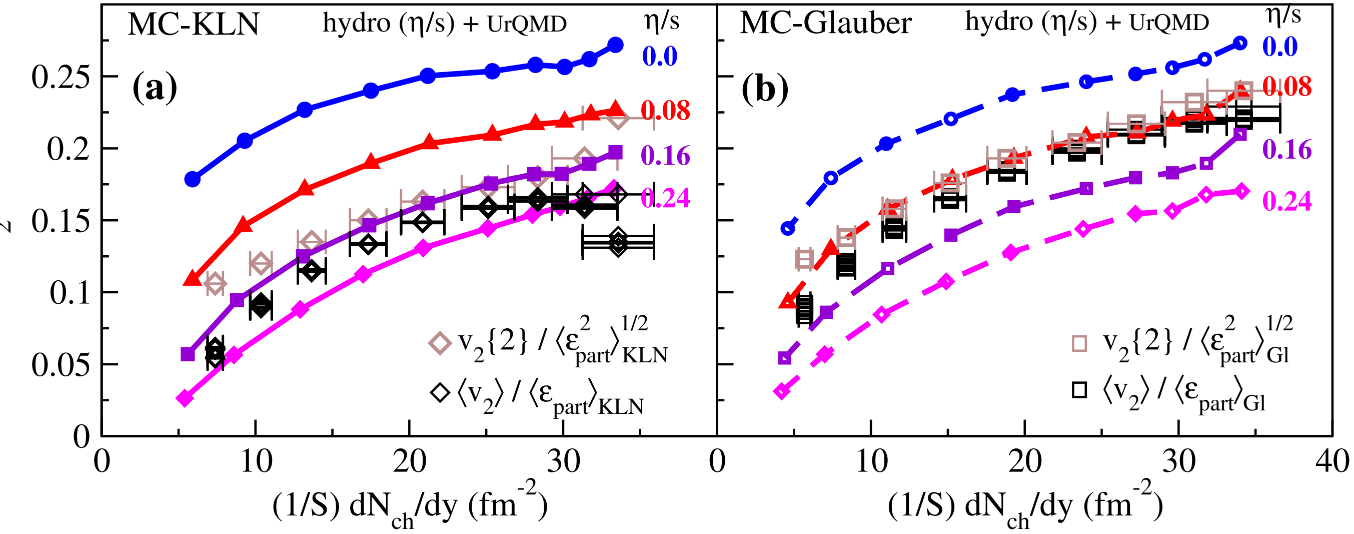
Sys. Uncertainties:
- tracking eff. 6%
- tower energy scale 2%

Au+Au di-jets more imbalanced than p+p for p_T^{cut}>2 GeV/c

Au+Au A_J ~ p+p A_J for matched di-jets R=0.4 (Not true when R = 0.2)

Different behavior to LHC?
but different jet p_T and biases

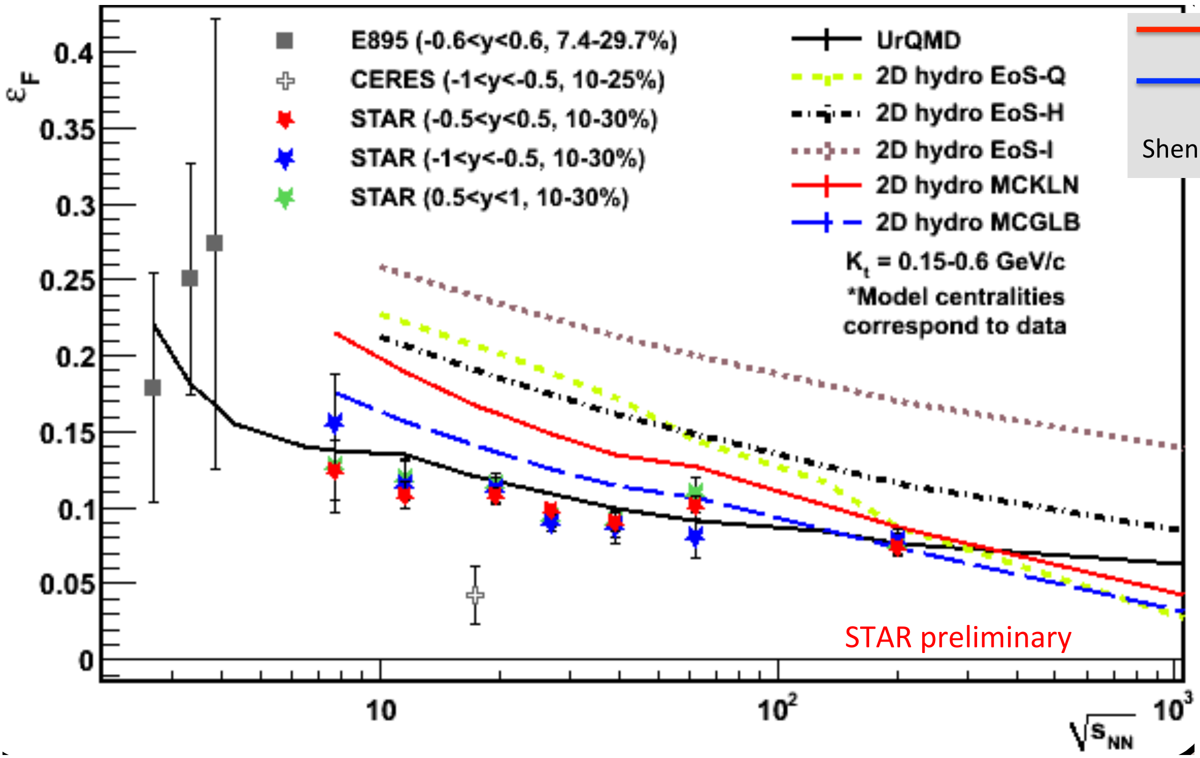
Initial conditions via v_n and HBT



Song et al. PRL 106 192301 (2011)

$$\frac{\eta}{s} = 0.08 \rightarrow 0.2$$

Details of initial configuration large source of uncertainty



MC-KLN η/s = 0.2

MC-Glauber η/s = 0.08

Shen and Heinz (PRC85 054902 (2012))

Reveals spatial anisotropy *after* expansion

Azimuthal coordinate space measurement breaks degeneracy from azimuthal momentum space

Ultra-central geometry fluctuations

Fri: H. Wang

Probe correlation of multiplicity and v_n in very central ZDC selected data

v_3:

Au+Au and U+U:

Slope zero or slightly positive

Fluctuations dominate

v_2:

Au+Au:

Slope zero or slightly positive

Fluctuations dominate

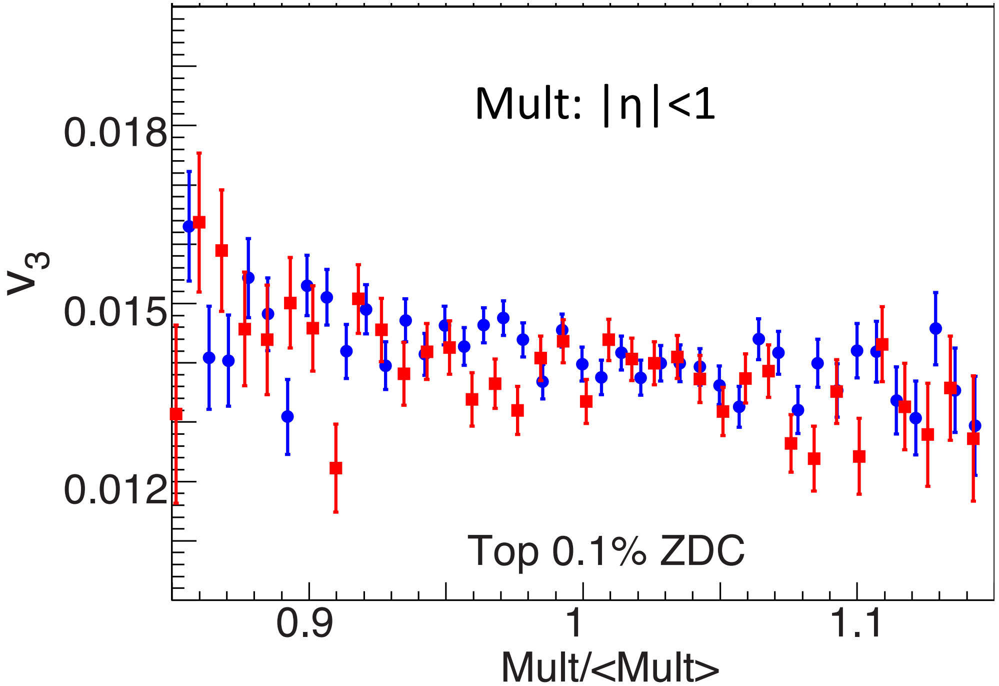
U+U:

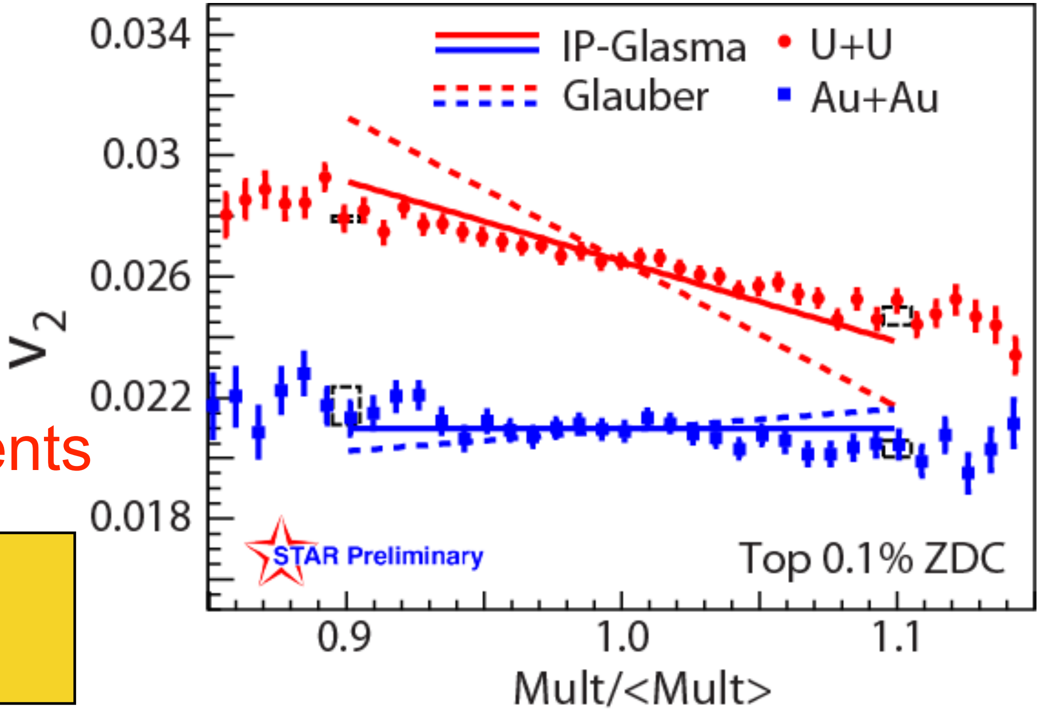
Slope negative

Geometry also matters

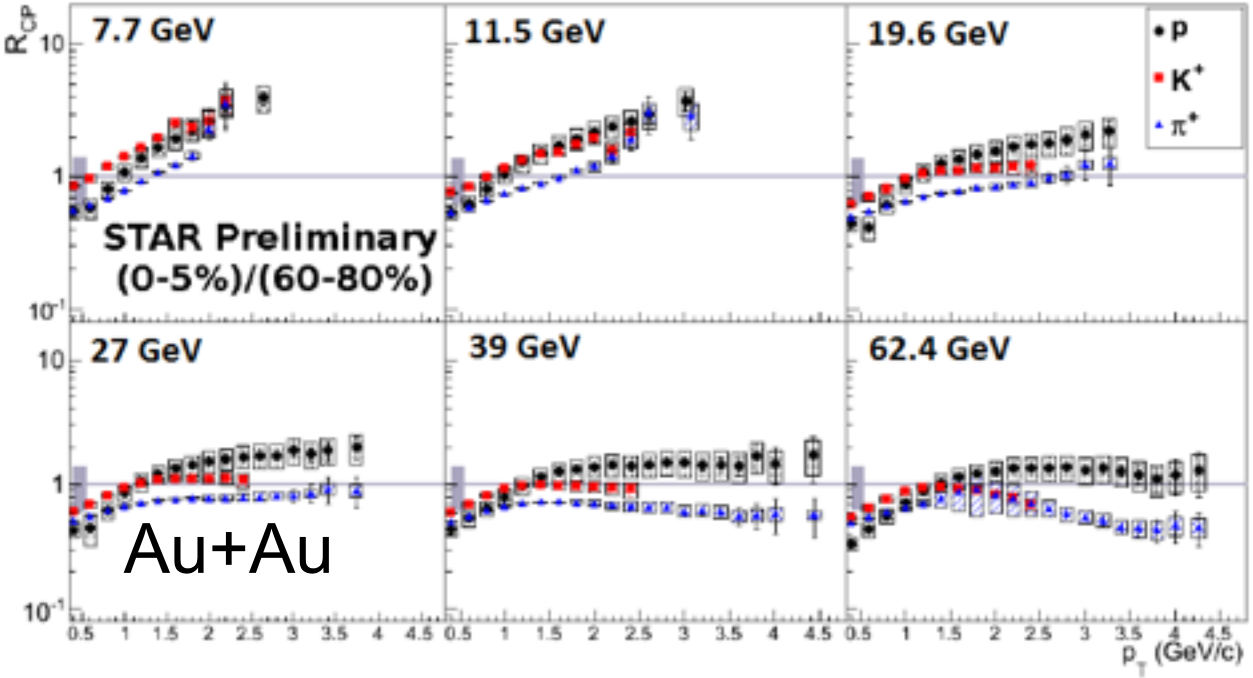
Select tip-tip in high mult. events

U+U very sensitive to Initial State
IP-Glasma better match to the data





Cronin at lower energies/smaller systems



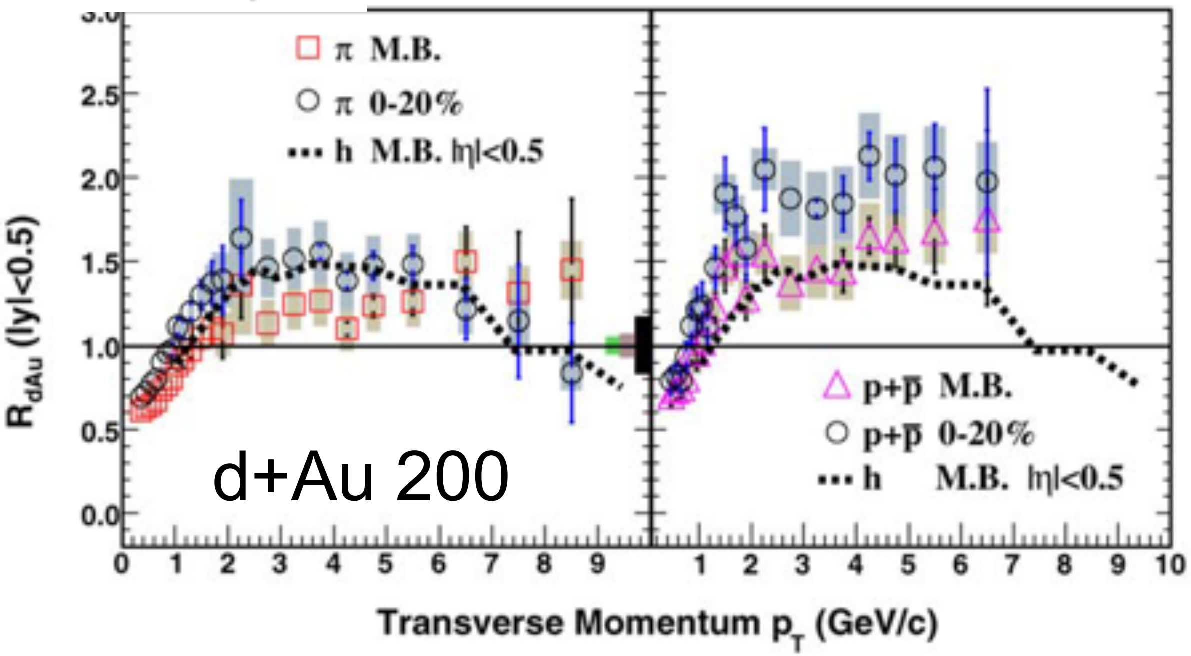
Species dependent effect seen as in original Cronin data

$R_{cp}^{p} > R_{cp}^{K} > R_{cp}^{\pi}$

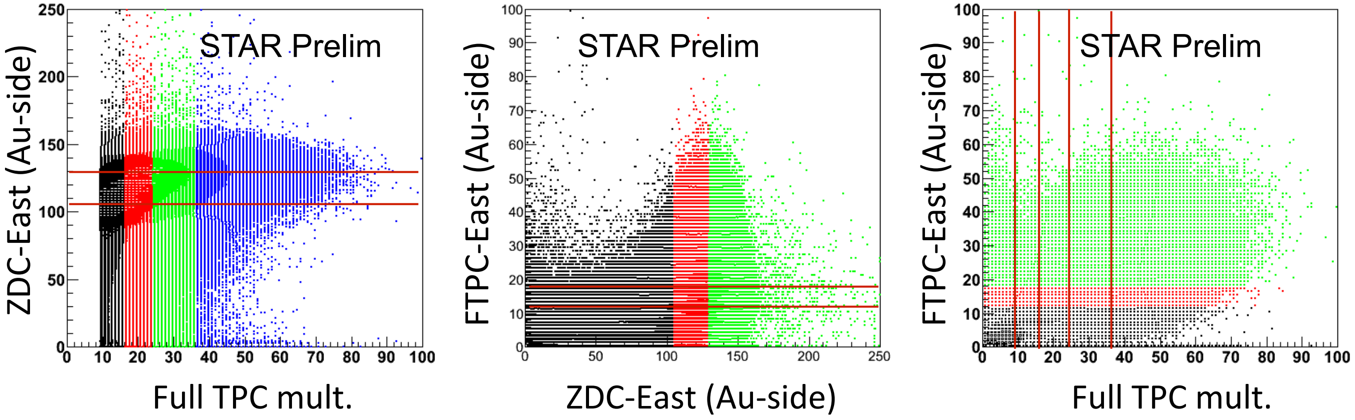
Compare:

d+Au √s=200		Au+Au √s=27
R_{dAu}	~	R_{cp}
$\langle p_T \rangle$	~	$\langle p_T \rangle$
μ_B	<	μ_B
dN/dy	<	dN/dy
$dN/dy/N_{part}$	>	dN/dy_{part}

Flow in both systems?



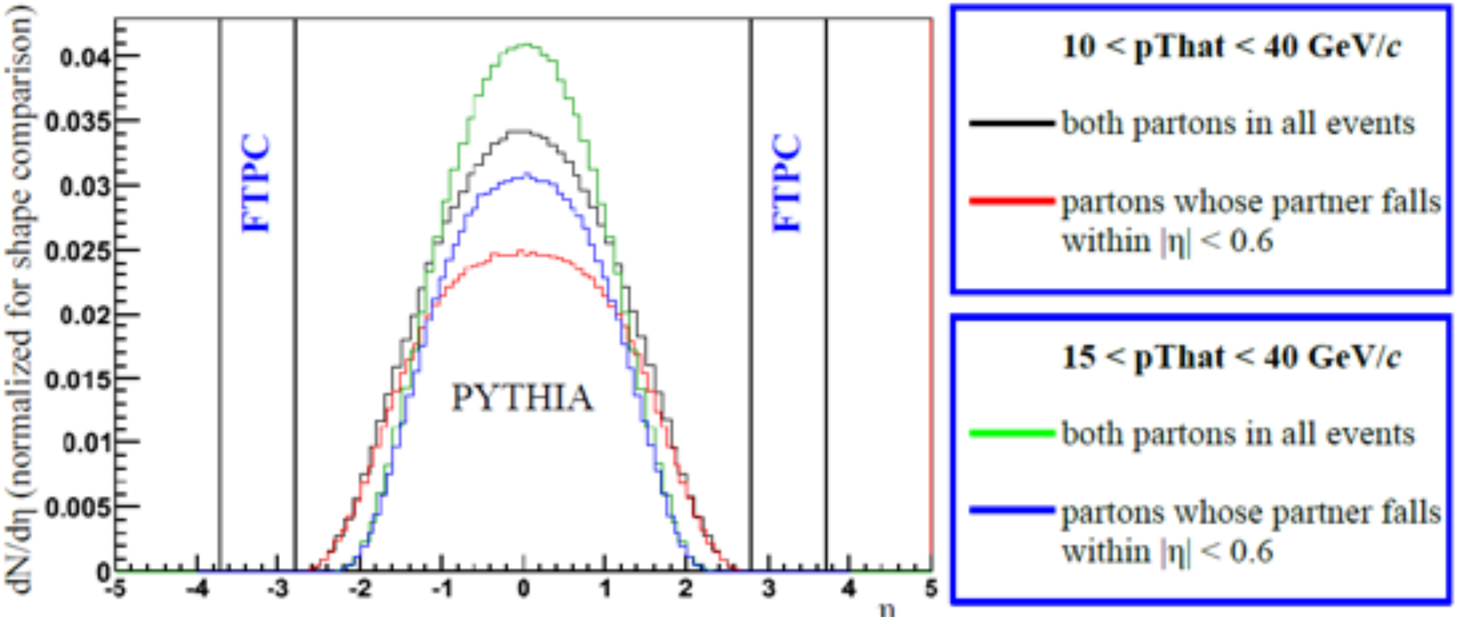
Centrality in d+Au



Different rapidity ranges to define centrality → different event samples

STAR TPC -1<η<1, FTPC 2.8<η<3.7, ZDC η>6

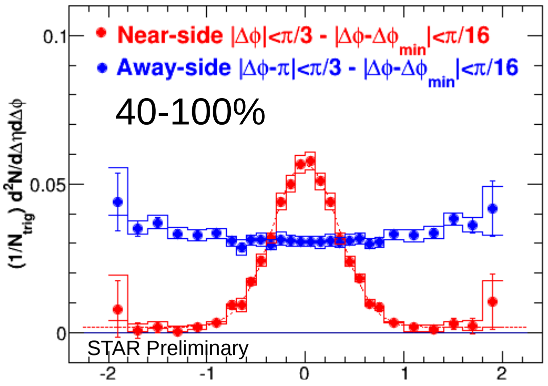
Different fluctuations/ jet contamination

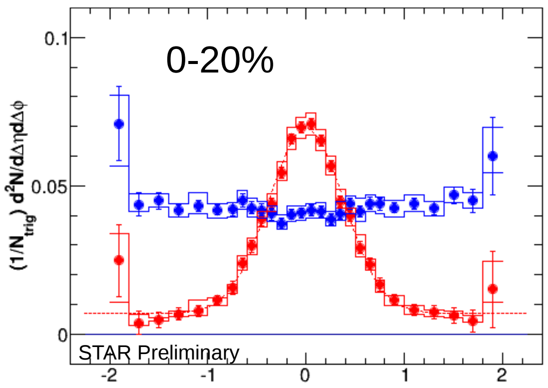


If η>3 for centrality trigger di-jet partner not at mid-rapidity Fluctuations different

High vs Low multiplicity d+Au

Fri: L. Yi

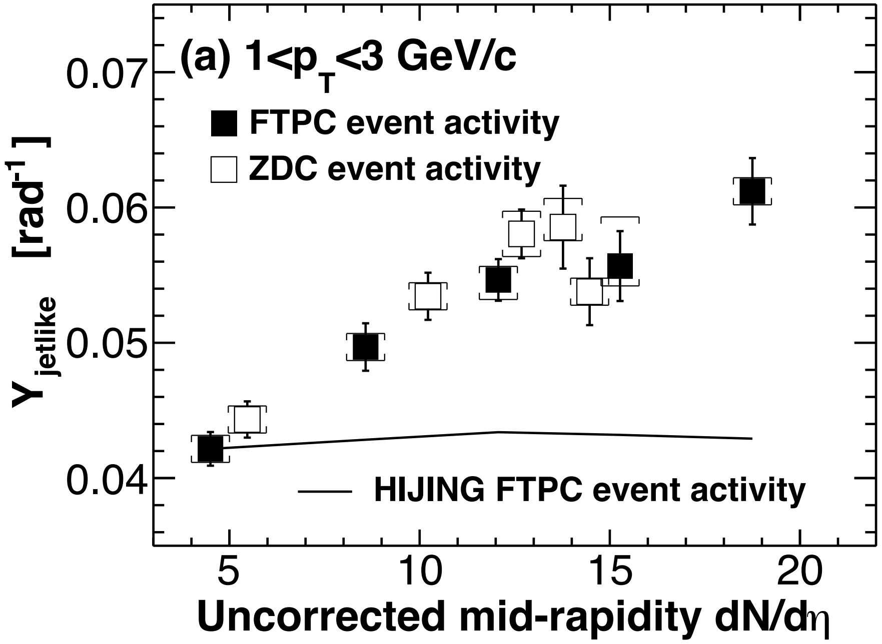


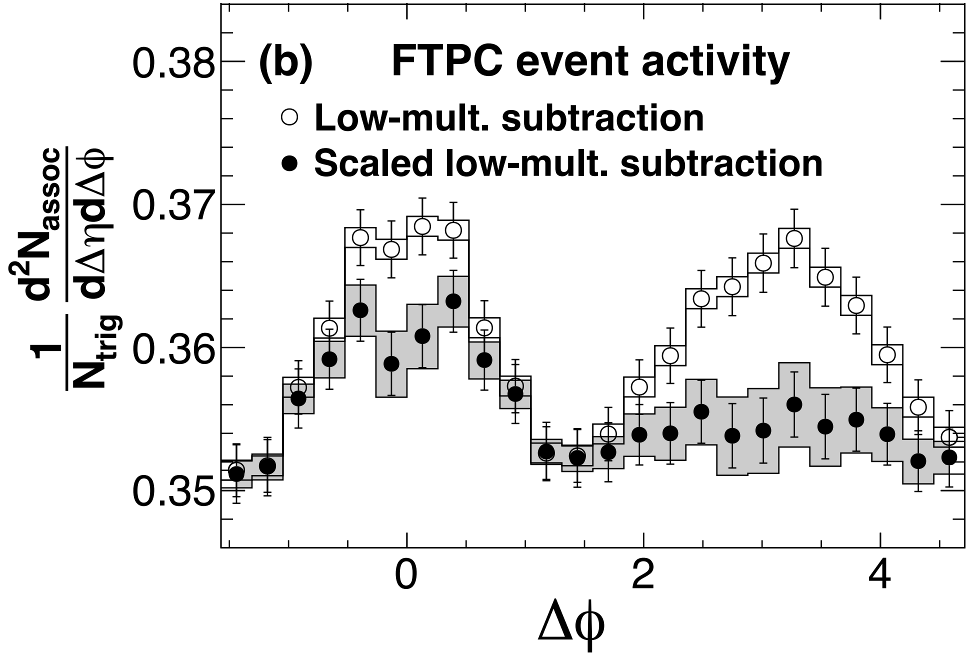


Near-side jet not the same in High and Low mult.

Yield Ratio = 1.29

Widths Ratio = 1.13





"Jet"-like yield increases with multiplicity

Increase not observed in Hijing

At RHIC high-low may not work to remove jet signals

After simple scaling:

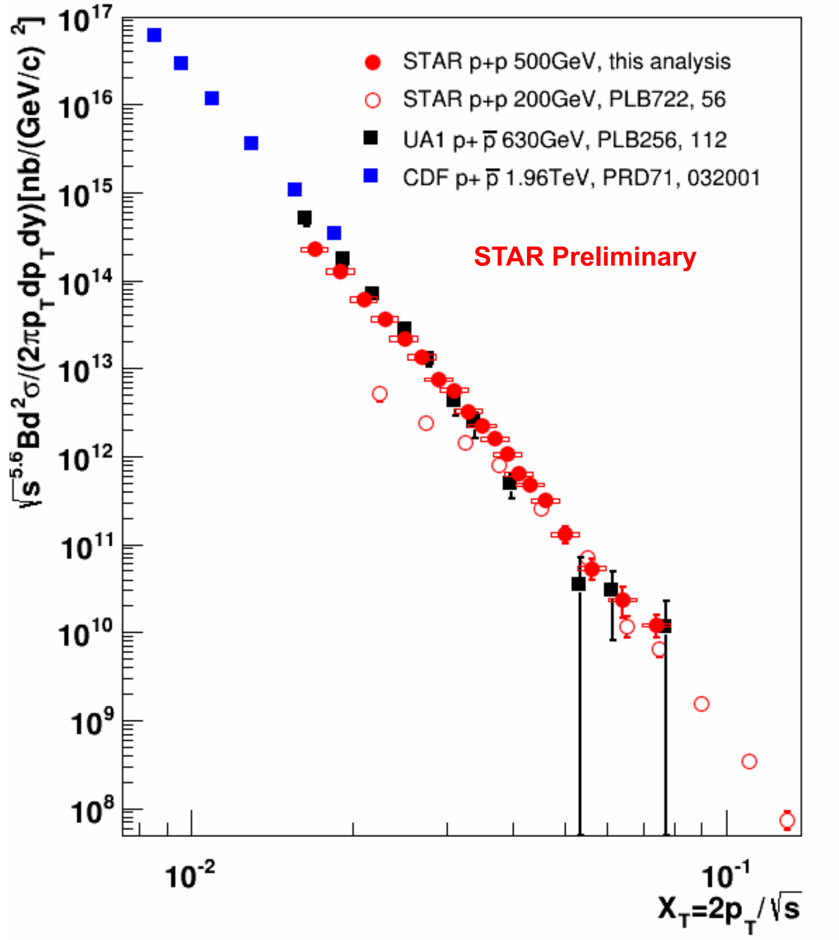
Away-side	Near-side
High = Low	High != Low

J/Ψ in p+p and d+Au

J/Ψ in p+p exhibits x_T scaling

for p_T>4 GeV/c, n=5.6

Including new 500 GeV data

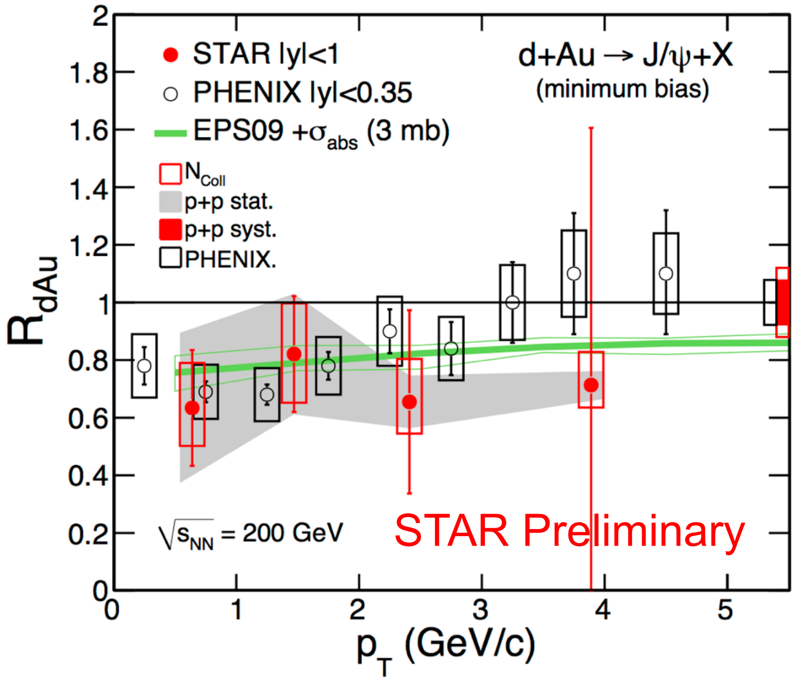


At 200 GeV:

prompt NLO CS+CO describes data

prompt CEM describes data at high p_T

direct NNLO CS under-predicts high p_T



R_{dAu} consistent with model calculations

shadowing from EPS09 nPDF

nuclear absorption $\sigma_{abs}^{J/\Psi}$ ~ 3mb

Eskola et al. Nucl. Phys A 830, 599 (2009)

Υ in p+p and d+Au

p+p

Consistent with NLO pQCD CEM across all rapidity

d+Au

Consistent with models including

Gluon nPDF (anti-shadowing)

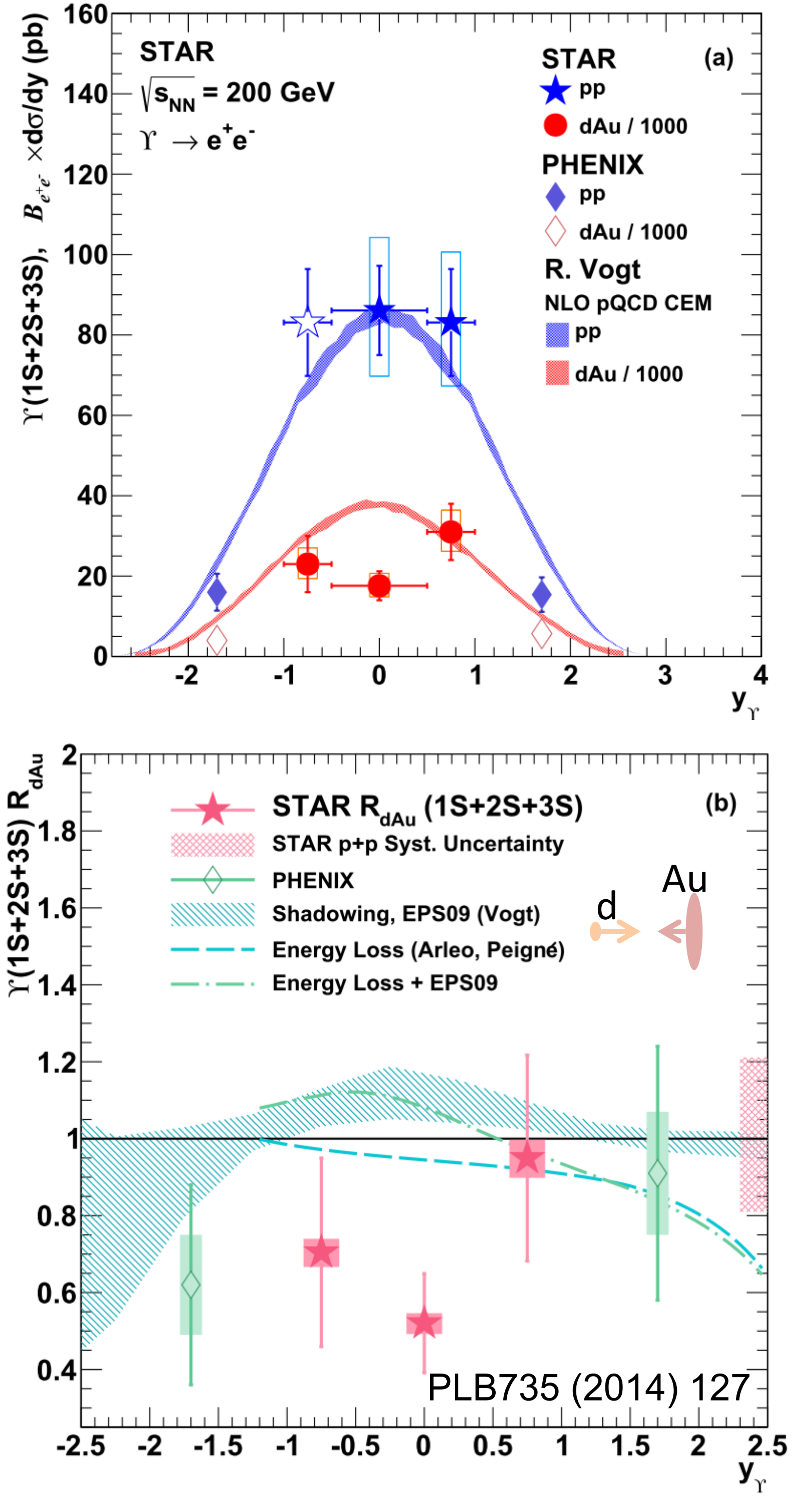
Initial parton energy loss

Indication of suppression at mid-rapidity beyond that of current models

$R_{dAu} = 0.48 \pm 0.14$ (stat) ± 0.07 (sys) ± 0.02 (pp stat) ± 0.06 (pp sys)

Data consistent with E772 p+A collision at $\sqrt{s} = 42$ GeV

CNM effects need more study →p+A run

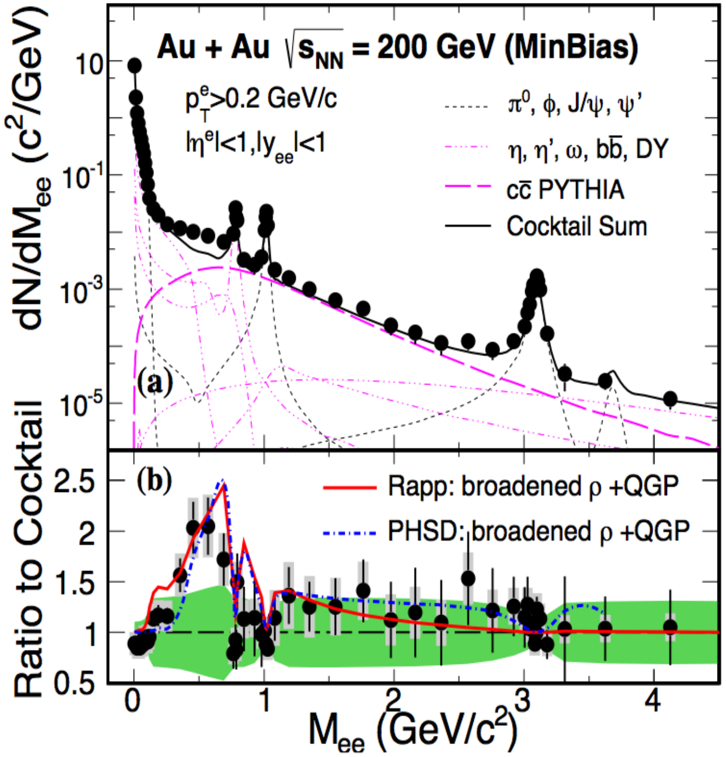


PLB735 (2014) 127

Di-electrons & Direct Virtual Photons

Fri: C. Yang

Phys. Rev. Lett. 113 (2014) 22301



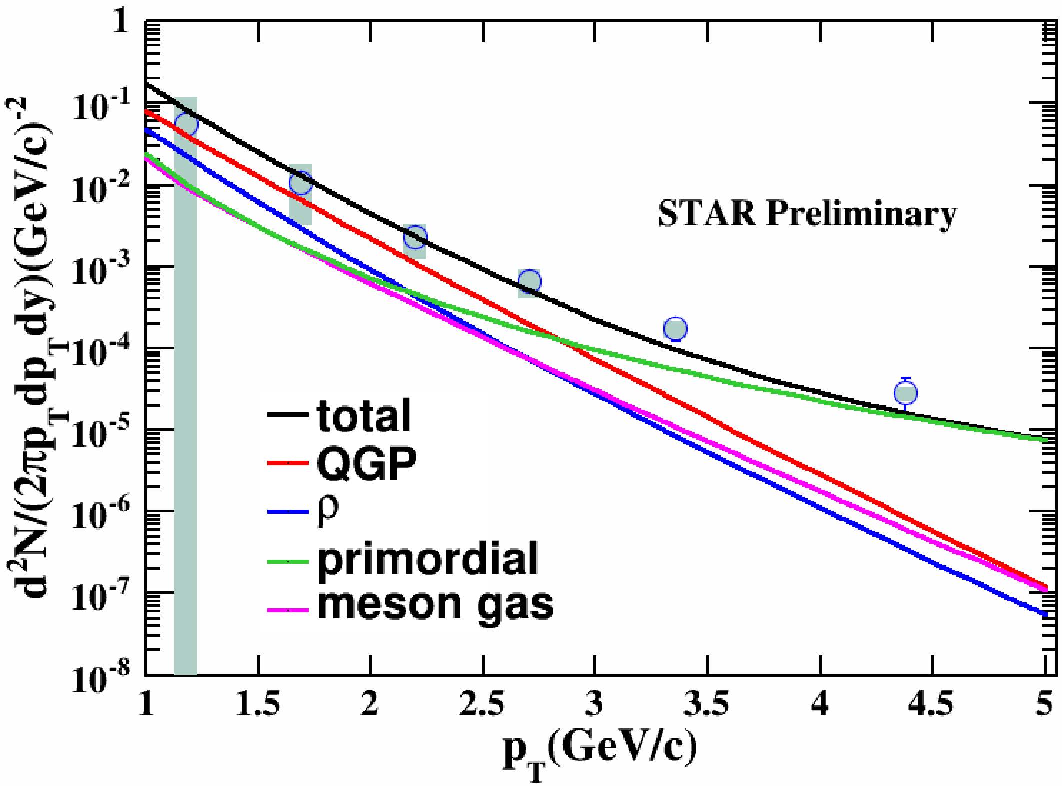
Enhancement in ρ-like region

1.77 ± 0.11 (stat) ± 0.24 (sys) ± 0.33 (cocktail)

Broadened ρ models can explain data

Rapp[1]: Effective many-body model

PHSD[2]: Parton-Hadron string dynamics



Rapp model prediction[3] including QGP, ρ, primordial and meson gas in good agreement with data

T = 320 MeV at 0.36 fm/c fireball lifetime ~10 fm/c

1:R.Rapp PoS CPOD2013, 008 (2013)
2: O.Linnyk et al. Phys. Rev. C 85, 024910 (2012)
3: Van Hees,Gale and Rapp, Phys. Rev. C 84, 054906

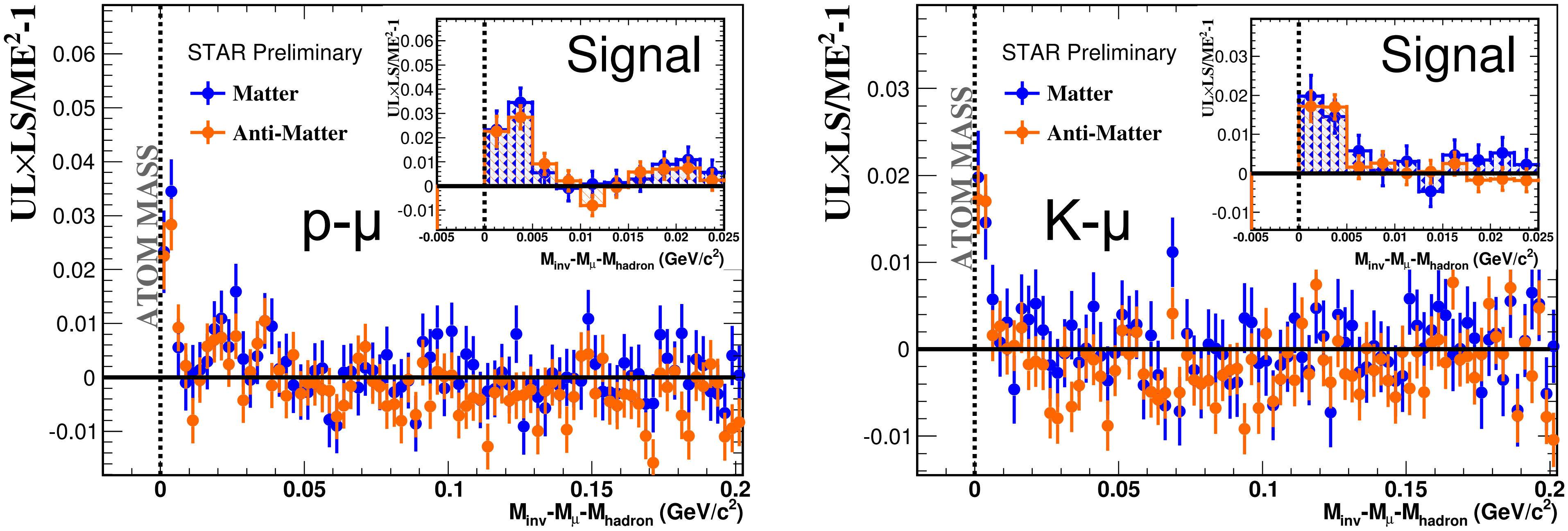
Muonic atoms

hadron-μ Coulomb bound state

- Formed in early dense part of collision from low p_T thermal μ

First observation of anti-matter and strange μ atoms

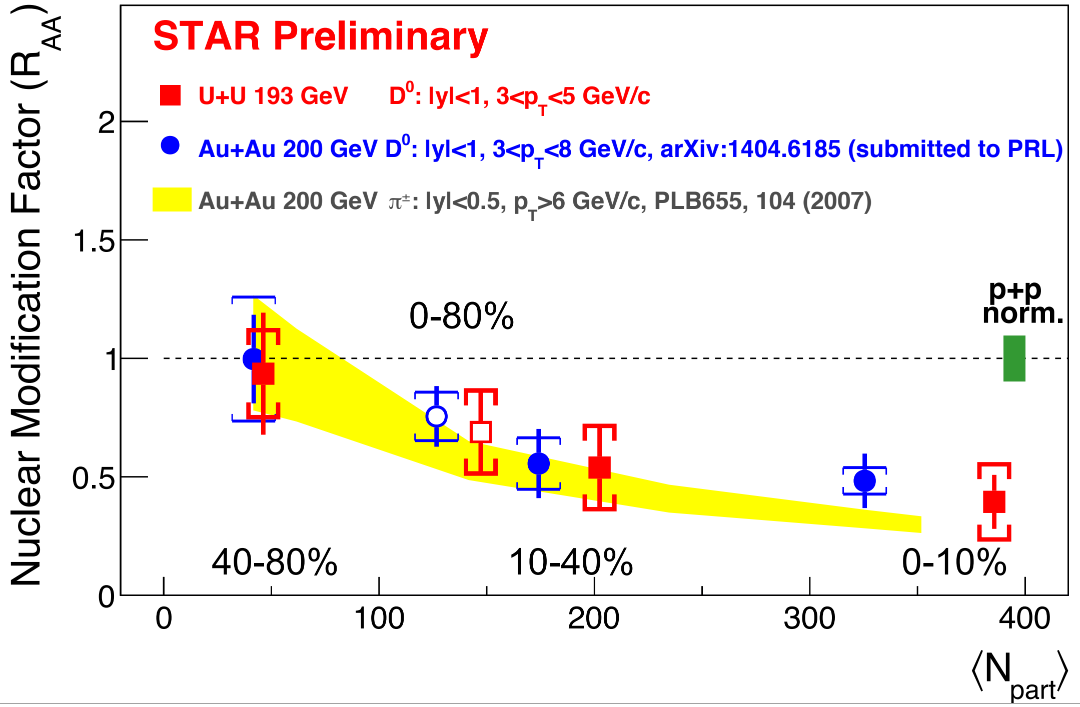
Au-Au 200 GeV

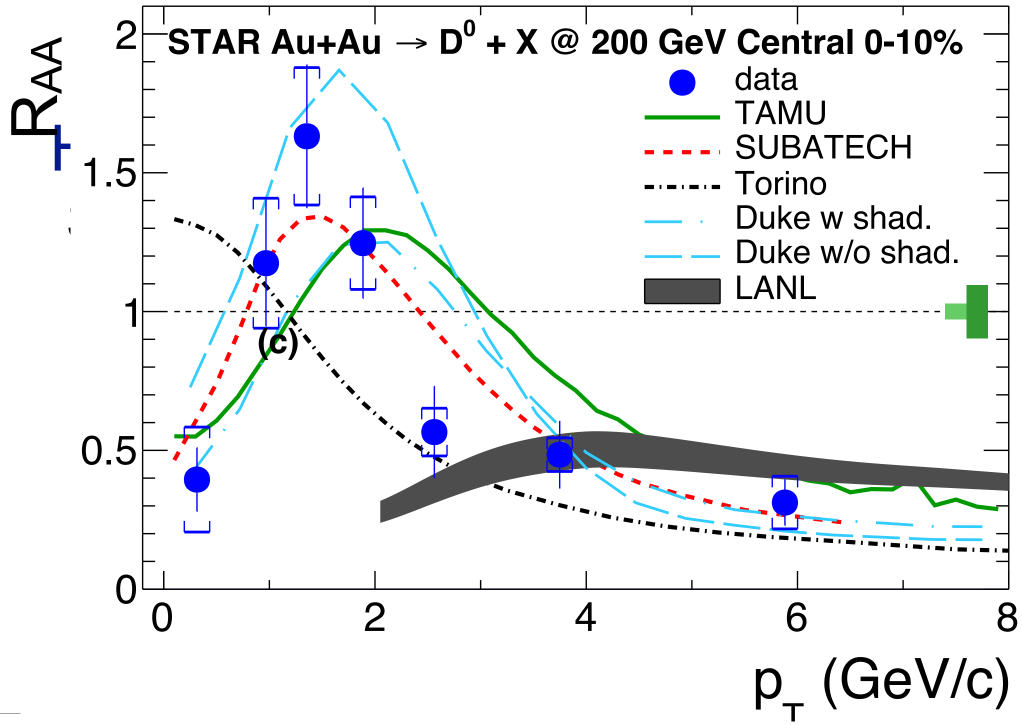


μ “Perfect” early time probe

- colorless no interaction with QGP
- little background from later stages

Direct charm suppression





Low p_T enhancement

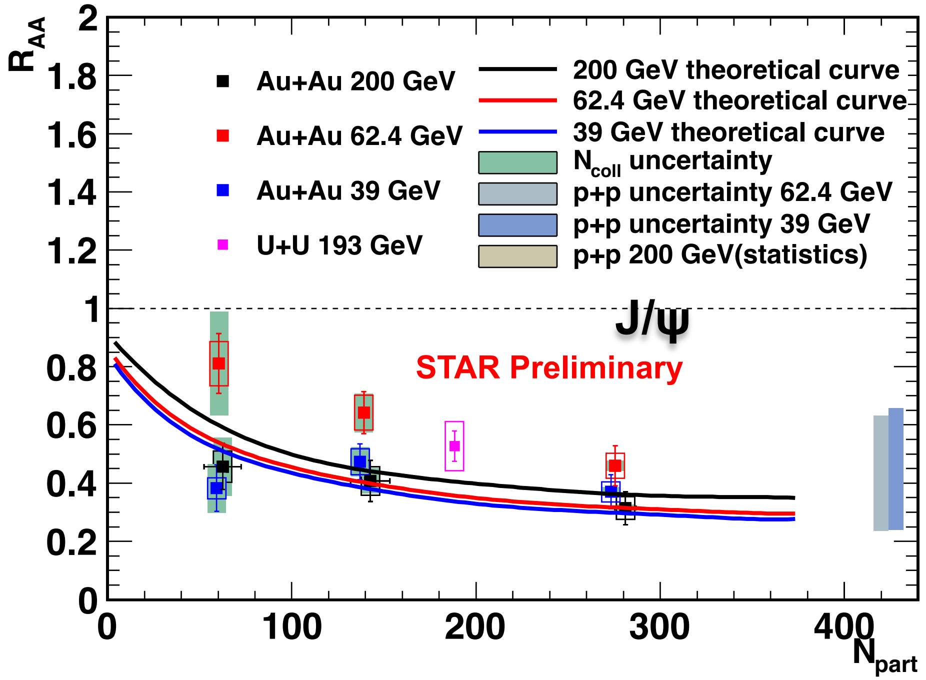
Described by models including coalescence of charm quarks

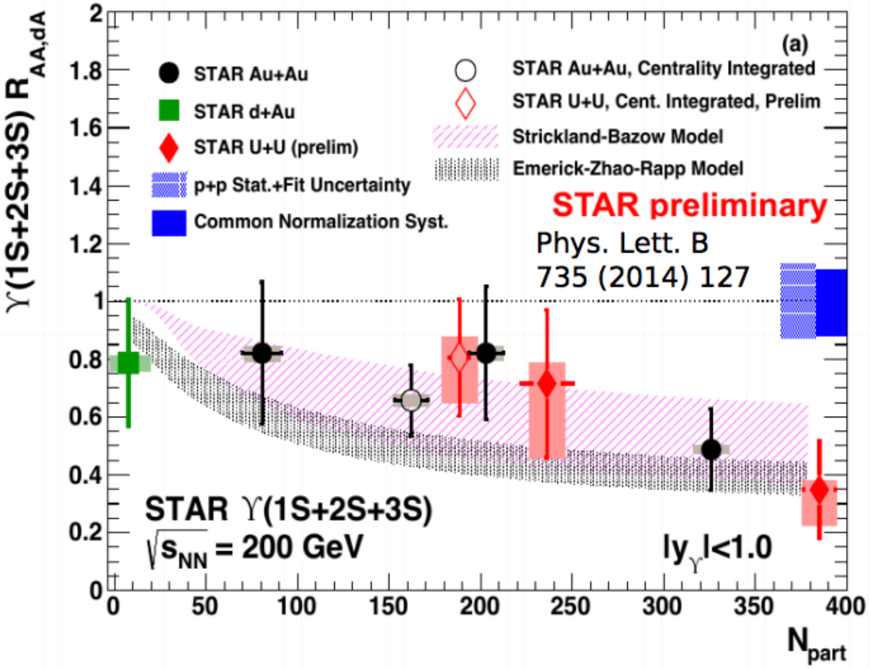
flow and/or shadowing?

CNM effects could be important

	TAMU	SUBATECH	Torino	Duke	LANL
HQ prod.	LO	FNOLL	NLO	LO	LO
QGP-Hydro	ideal	ideal	viscous	viscous	ideal
HQ eLoss	coll.	coll. +rad.	coll. +rad.	coll. +rad.	diss. +rad.
Coalescence	Yes	Yes	No	Yes	No
Cronin effect	Yes	Yes	No	No	Yes
Shadowing	No	No	Yes	Yes/No	Yes

Quarkonia suppression in A+A



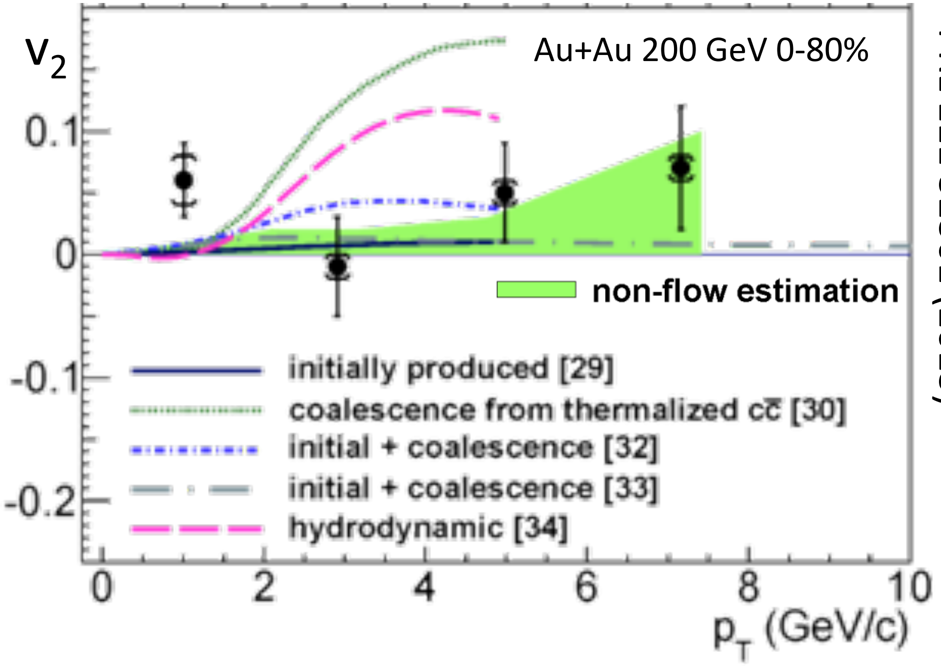


Similar suppression in U+U and Au+Au

Weak beam energy dependence
Some centrality dependence

v_2 consistent with no flow

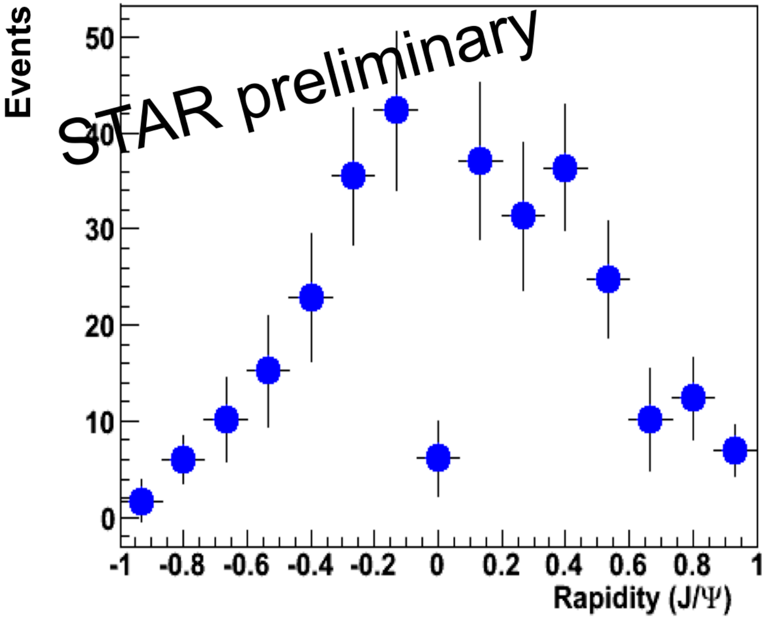
Disfavors production from thermalized charm



PRL 111 52301 (2013)

Vector meson photo-production (UPC)

J/Ψ cross-section as function of rapidity can provide insight into gluon distribution in the nucleus. $d\sigma/dy \sim [g(x,Q^2)]^2$



J/Ψ production observed over 2 rapidity units

$3<M_{ee}<3.2$ GeV/c^2

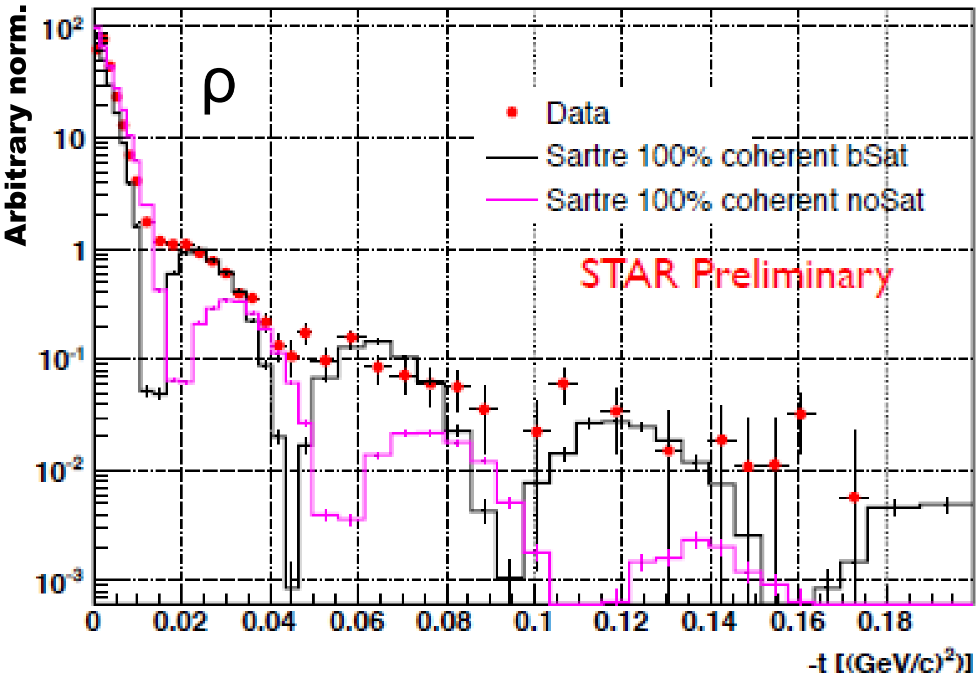
Only preliminary acceptance applied

- dip at zero due to cuts

$t = -p_T^2$ distribution

(only preliminary corrections applied)

Diffraction pattern visible to "3rd dip"

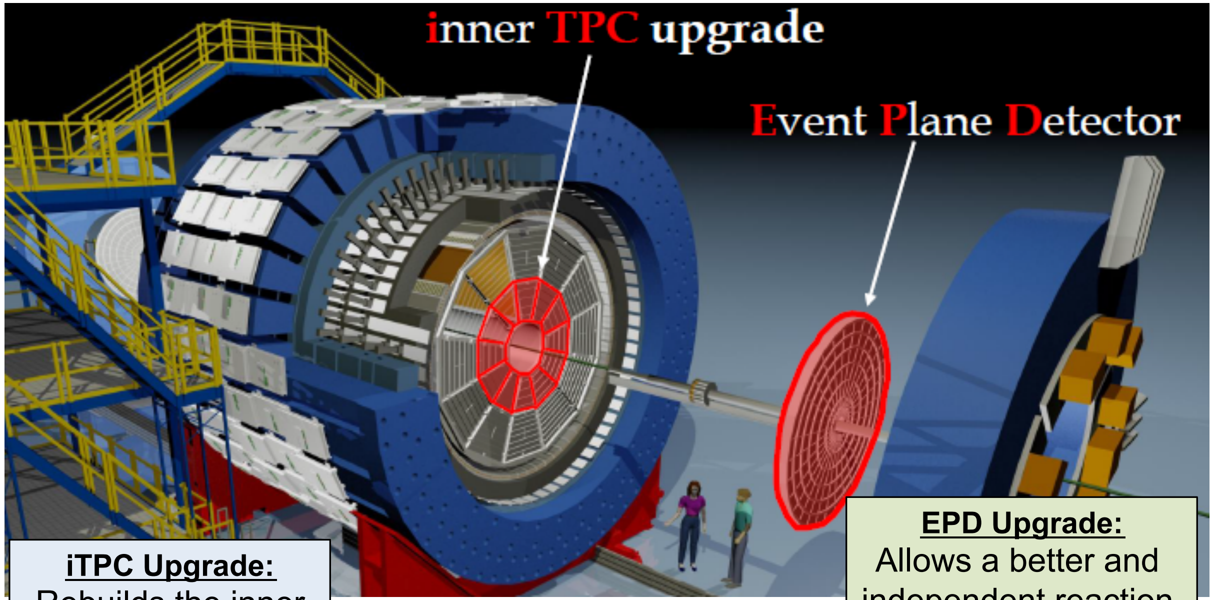


Data consistent with coherent interactions with a nuclear size ~6.38 fm

Model more consistent with data when saturation applied

Much to digest and more coming soon!

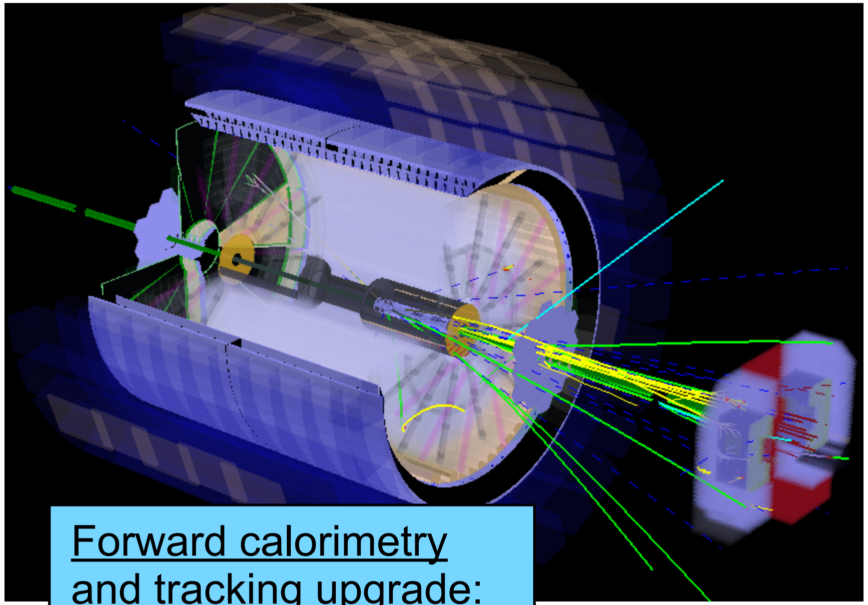
MTD and HFT - detailed heavy flavor measurements coming soon



iTPC Upgrade:
Rebuilds the inner sectors of the TPC

EndCap TOF Upgrade:
Rapidity coverage is critical for several proposed BES Phase II measurements

EPD Upgrade:
Allows a better and independent reaction plane measurement critical to BES physics



Forward calorimetry and tracking upgrade:
_New forward coverage

Ultimately onto eSTAR

BES-II

detailed exploration of systems close to CP and smaller systems

p+Au, d+Au, and ^{3}He+Au collisions

test when and how “more” becomes “different”

Polarized p+Au

unique RHIC capability single spin asymmetries probe saturation scale

Backup