Experimental Summary

Helen Caines - Yale University

Wealth of data shown at this conference

Collision energy and beam species

	2.4	8	9	12	15	20	23	27	39	56	62	130	193	200	410	500	510	2760	5020	7000	13000
pp							x				x			x	x	x	x	x	x	x	x
p+Al														x							
p+Au														x							
p+Pb																			x		
d+Au						x			x		x			x							
He^3+A														x							
Cu+Cu							x				x			x							
Cu+Au														x							
Au+Au	x	x	x	x	x	x		x	x	x	x			x							
U+U													x								
Pb+Pb																		x	x		

+ SMOG + SPS

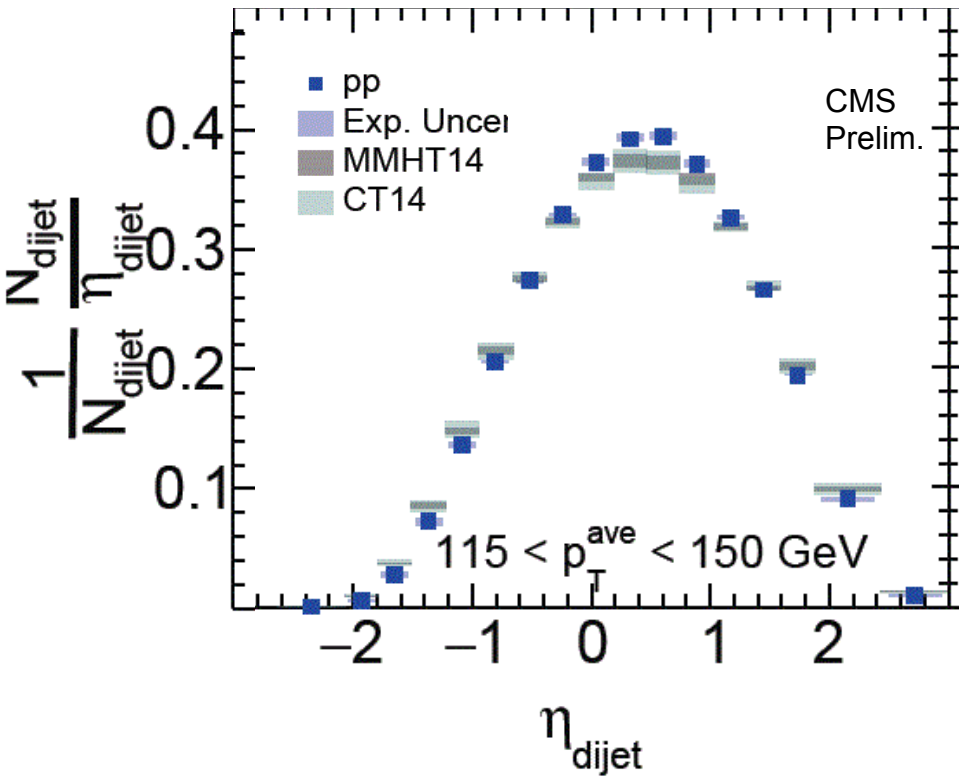
Coming soon isobars at 200 GeV, 8 TeV pPb, low √s beams

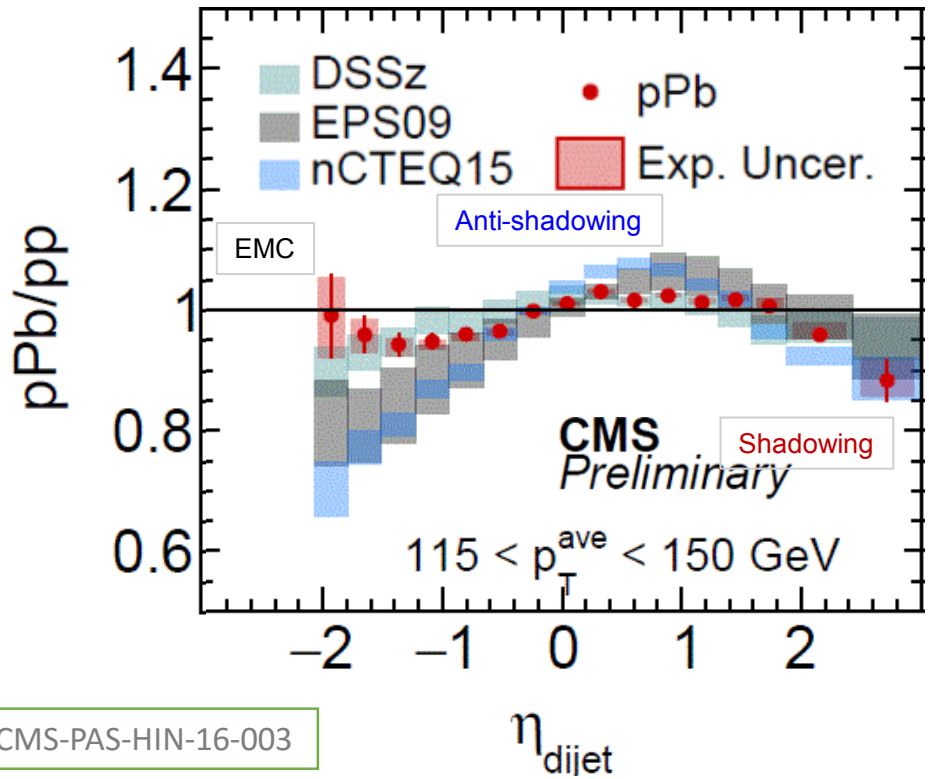
Constraining gluon (n)PDFs

Precision measurements of $\eta_{dijet} = (\eta_1+\eta_2)/2 \propto 0.5 \log(x_p/x_{pB}) + \eta_{CM}$

η_{dijet} Theoretically: can be calculated in pQCD

Experimentally: "avoid" fragmentation and hadronization effects





CMS-PAS-HIN-16-003

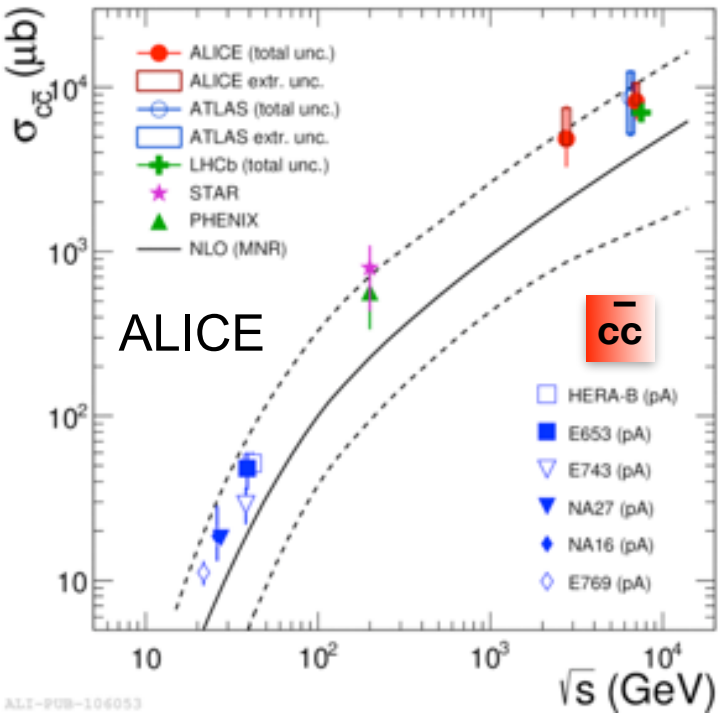
η_{dijet} as function p_T has given access to Q^2 dependencies

Neither PDFs nor nPDFs gives good fit across whole range

Constraining HF pp cross-sections

C. Da Silva (PHENIX),
G. Luparello (ALICE),
Y. Yang (STAR)

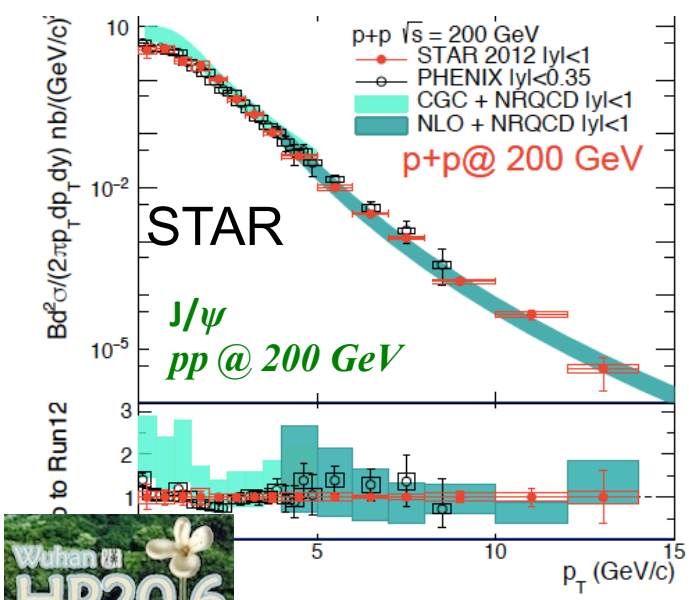
arXiv:1605.07569



D^0 measurement down to 0 p_T
Access to total charm cross-section

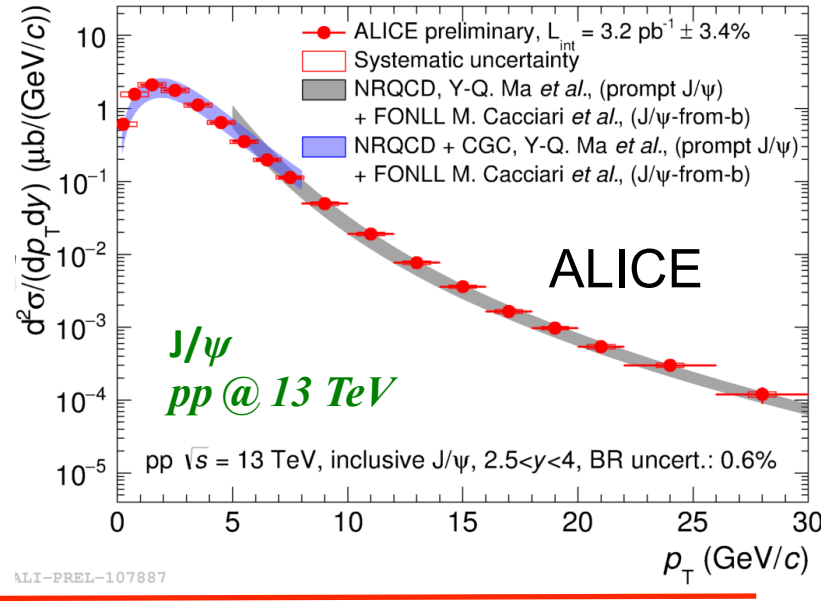
Key for detailed regeneration considerations

Charm quark production well understood in pp



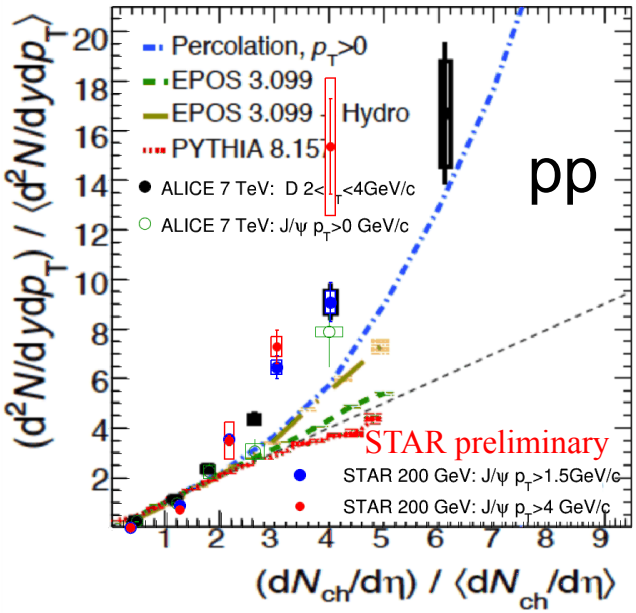
Good description of charmonium production from 0.2 to 13 TeV

Integrated B→J/Ψ fraction independent of $\sqrt{s}$



HF production versus event activity

G. Luparello (ALICE)



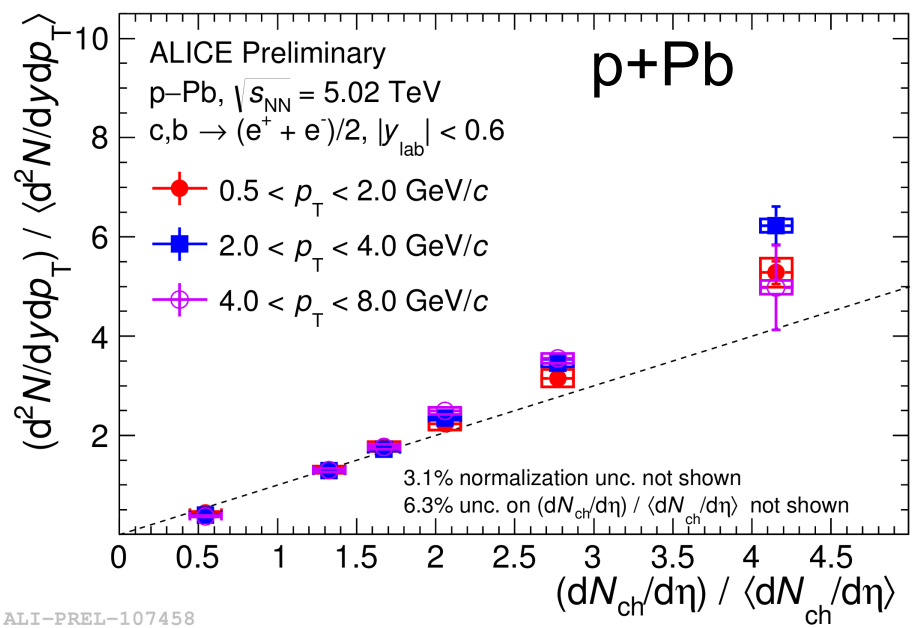
Self normalized yields grows faster than event activity at both LHC and RHIC

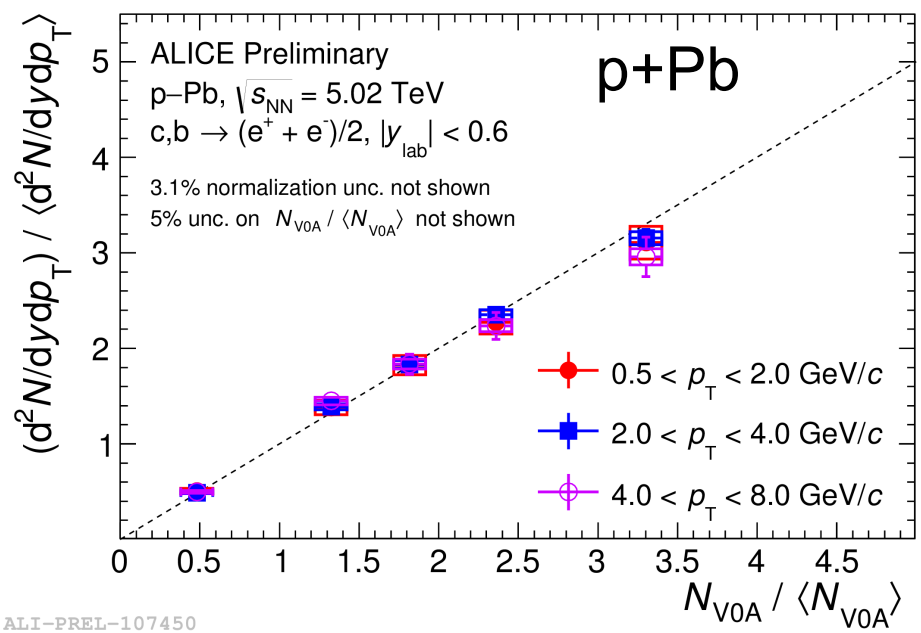
- Soft vs hard processes competing?
- MPI at work?

Also seen in p+Pb

NPE show no difference above/below 4 GeV/c

- b behaves like c

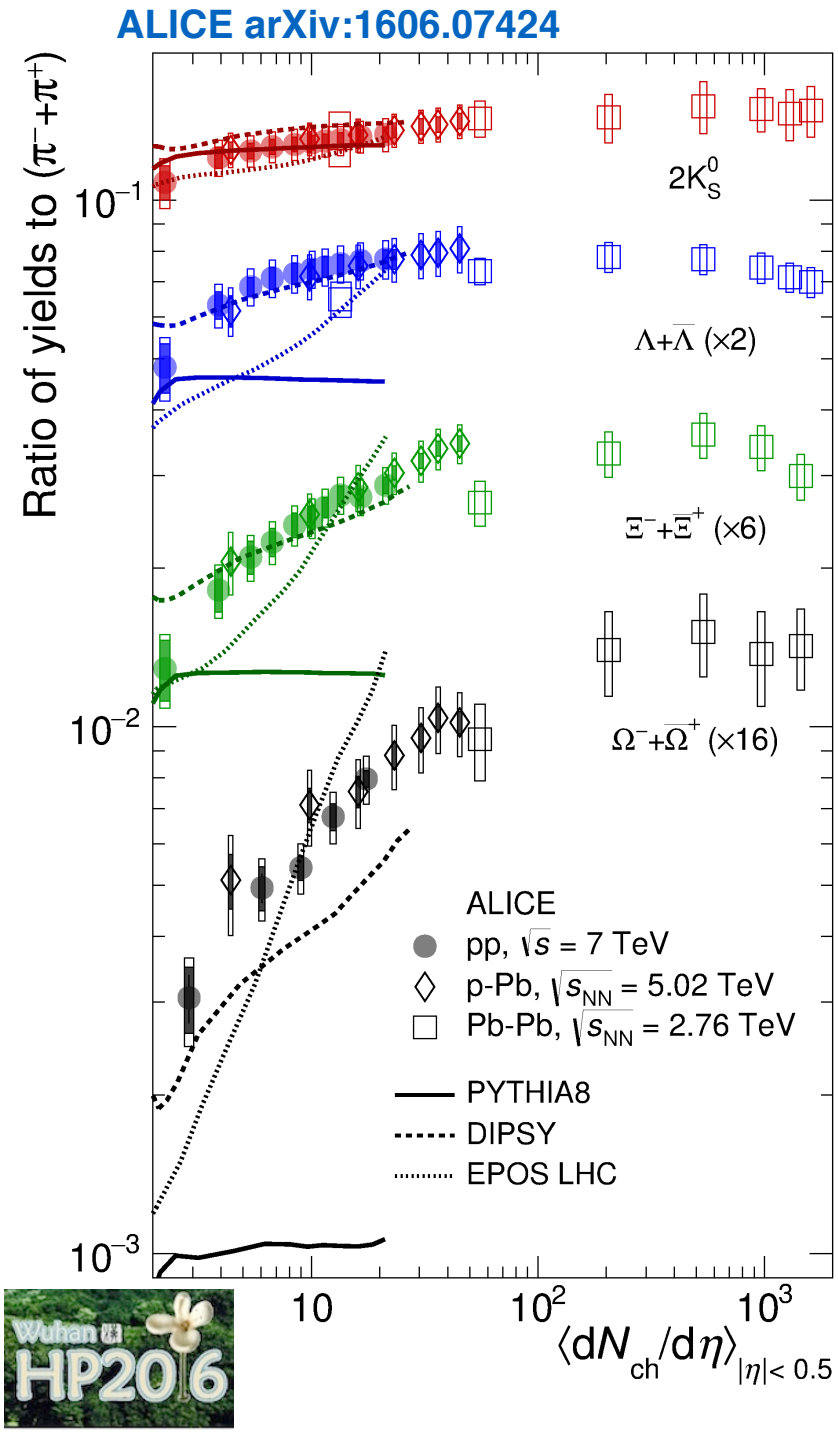




Results depend on where event activity measured

Physics or ill defined reference?

Strangeness saturation in pp?



Steep rise in strangeness yields per π as function of event activity

Strong function of strangeness content

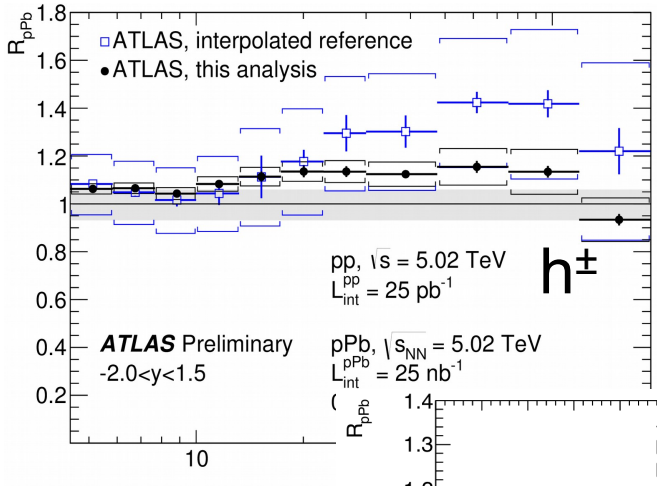
Trend in pp same as that in p+Pb with smooth transition to Pb+Pb

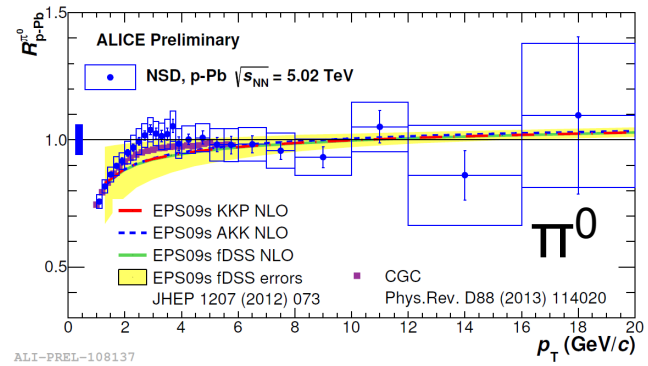
Not reproduced by models

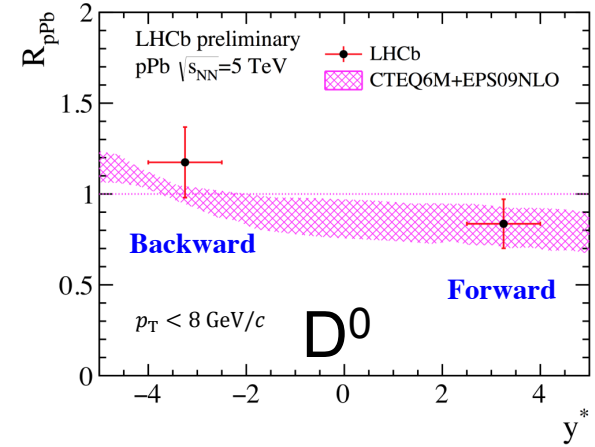
Is this increase dependent on p_T and/or event activity definition as for HF?

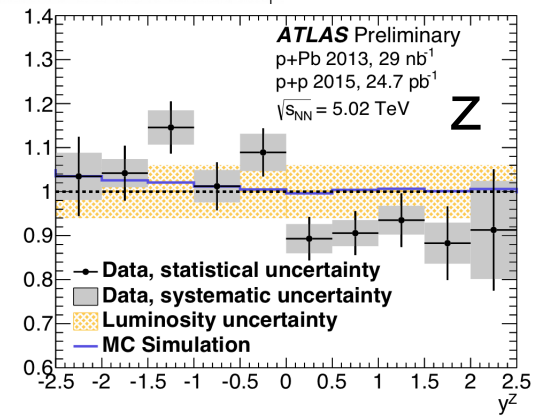
Minbias R_{pPb}

P. Balek (ATLAS), A. Dubla (ALICE), M. Dumancic (ATLAS),
T. Okubo (ALICE), B. Schmidt (LHCb), X. Zhu (LHCb)

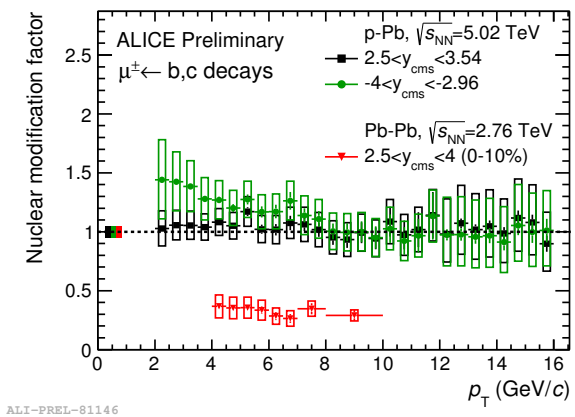




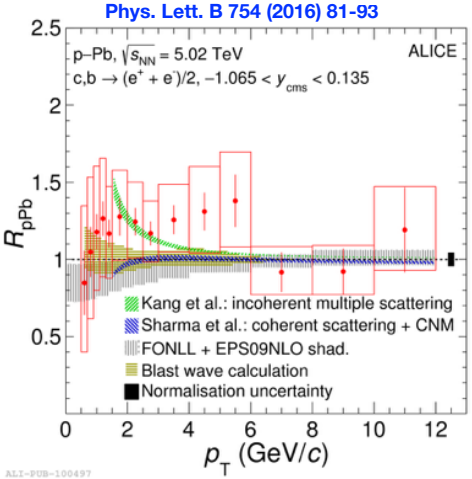




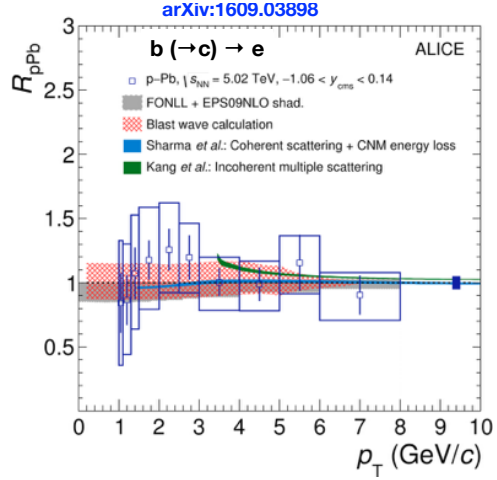
Consistent with nPDF expectations

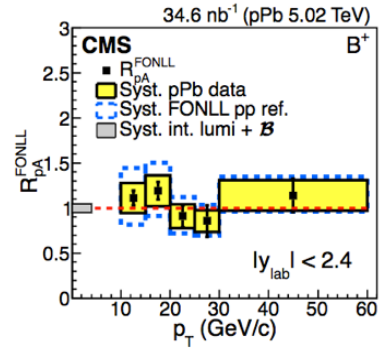


Phys. Lett. B 754 (2016) 81-93

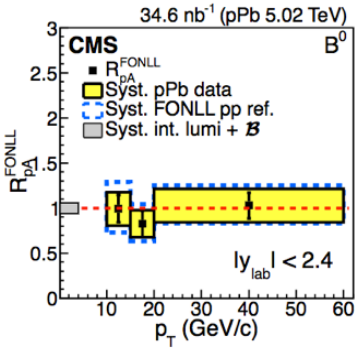


arXiv:1609.03898

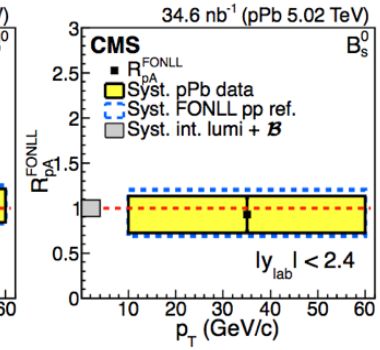




R^{FONLL}_{pA} vs p_T of B^+



R^{FONLL}_{pA} vs p_T of B^0

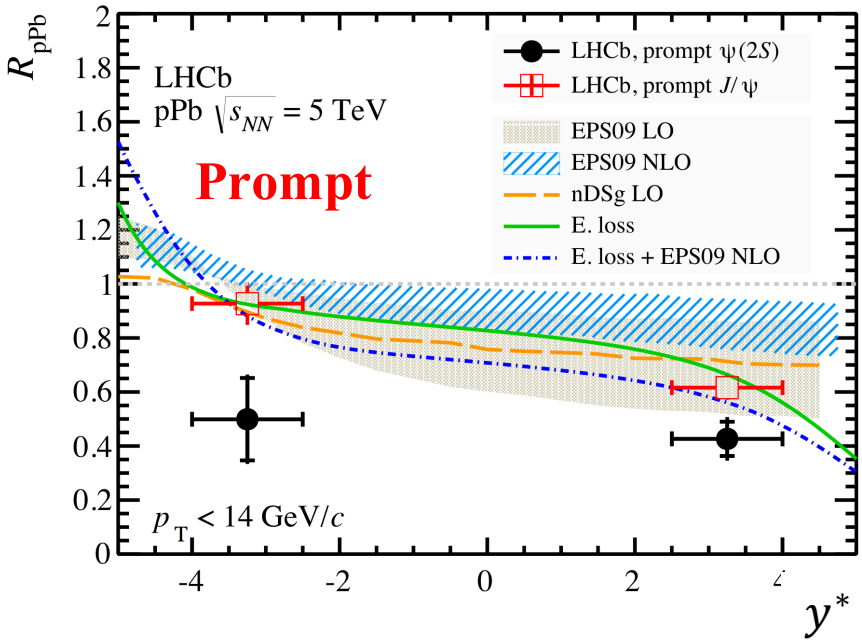


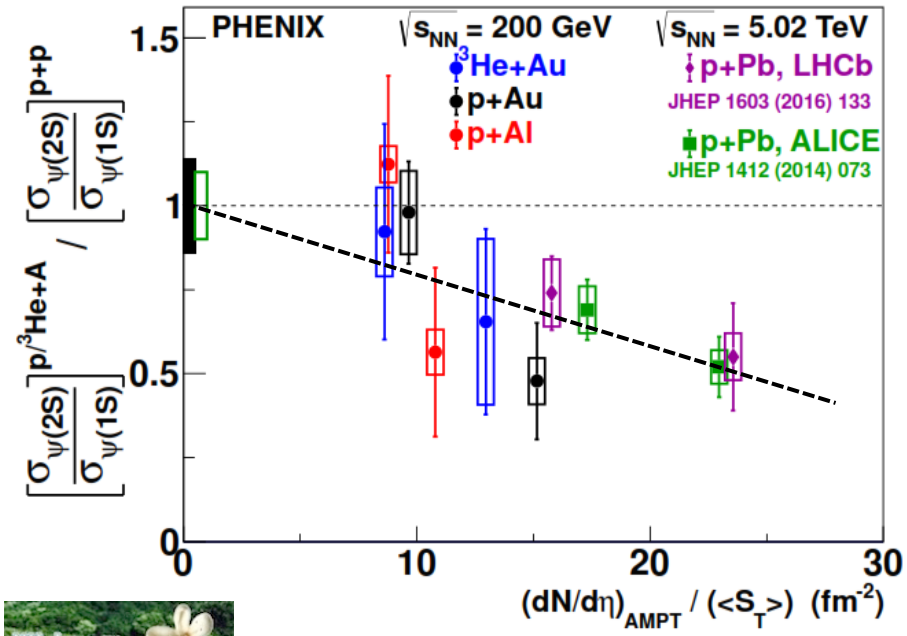
R^{FONLL}_{pA} vs p_T of B^0_s

Nothing enormously unexpected is occurring!

Charmonia in p+A

A. Drees (PHENIX), B. Schmidt (LHCb)





p+Pb:

Prompt J/ψ :

- Forward - strong suppression
- Backward - no suppression

Consistent with shadowing expectations (Errors allow for some energy loss)

Prompt Ψ(2S):

- More suppressed than J/ψ
- Unpredicted suppression for backward rapidities

p+Al, p+Au, He^3+Au:

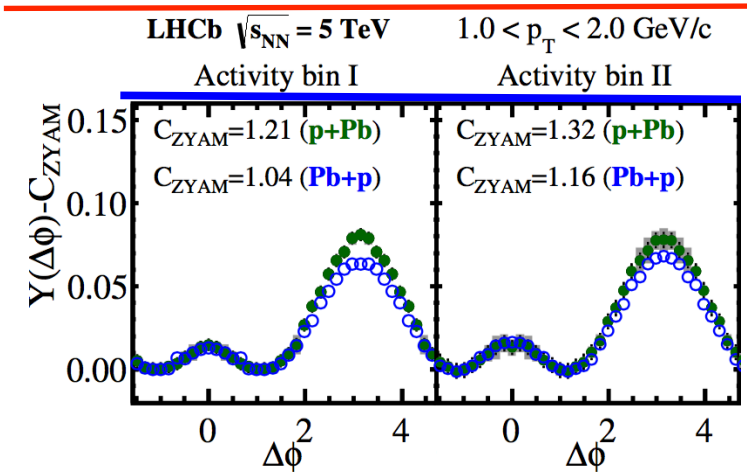
Ψ(2S) more suppressed backwards

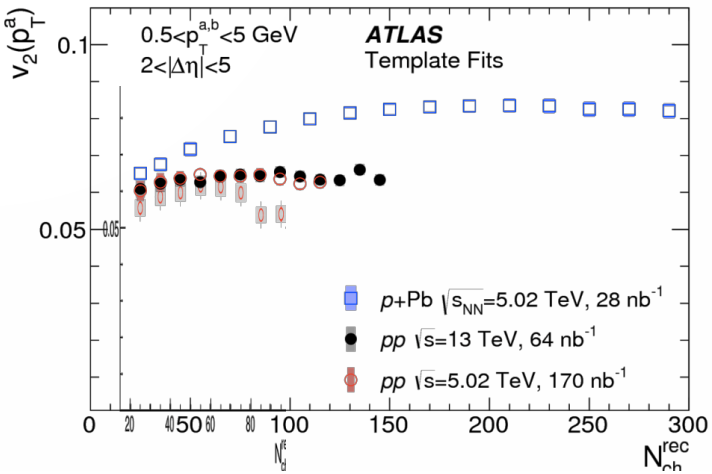
Need another mechanism:

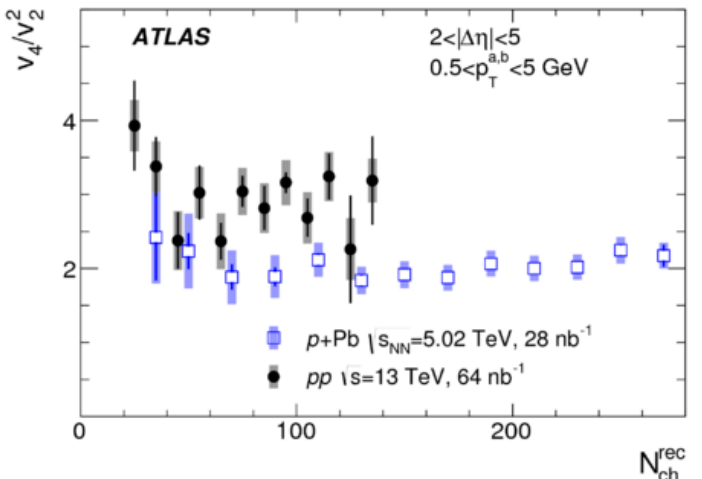
Small systems data from LHC and RHIC consistent with co-mover interpretation

The p+Pb ridge and event activity

S. Milov (ATLAS),
Y. Zhang (LHCb)







The ridge seen at large η

the same magnitude forward and backward if same absolute local UE activity selected

pp

v_n : no dependence on event activity

v_n : same for 5.02 and 13 TeV

v_4/v^2_2 : no dependence on event activity

p+Pb

v_n : rise with event activity

v_4/v^2_2 : no dependence on event activity

Suggestive of common origin

Hydrodynamic flow or not in p+Pb?

S. Milov (ATLAS)

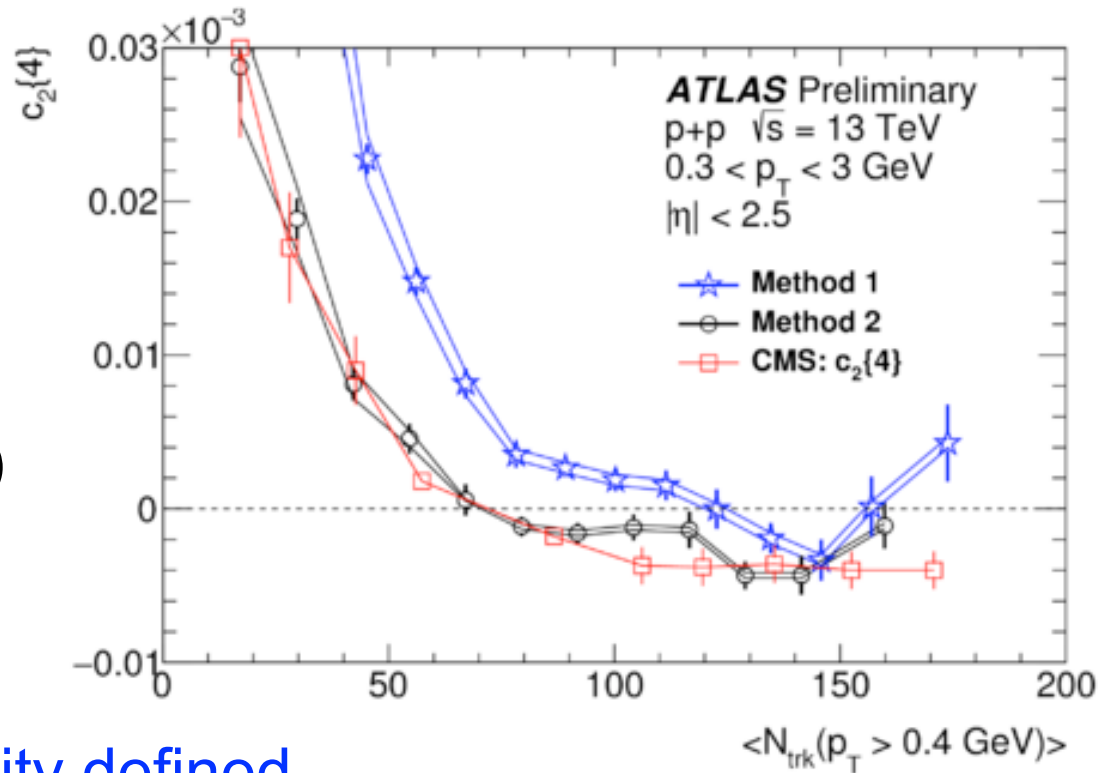
Study Q-Cumulants as function of event activity

If v_2 has origin in elliptic flow $c_2\{4\}$ must be negative ($v_2\{4\} = \sqrt[4]{-c_2\{4\}}$)

Use different methods to determine event activity

Method 1: strict single track class (no multiplicity fluctuations in events)

Method 2: has multiplicity fluctuations



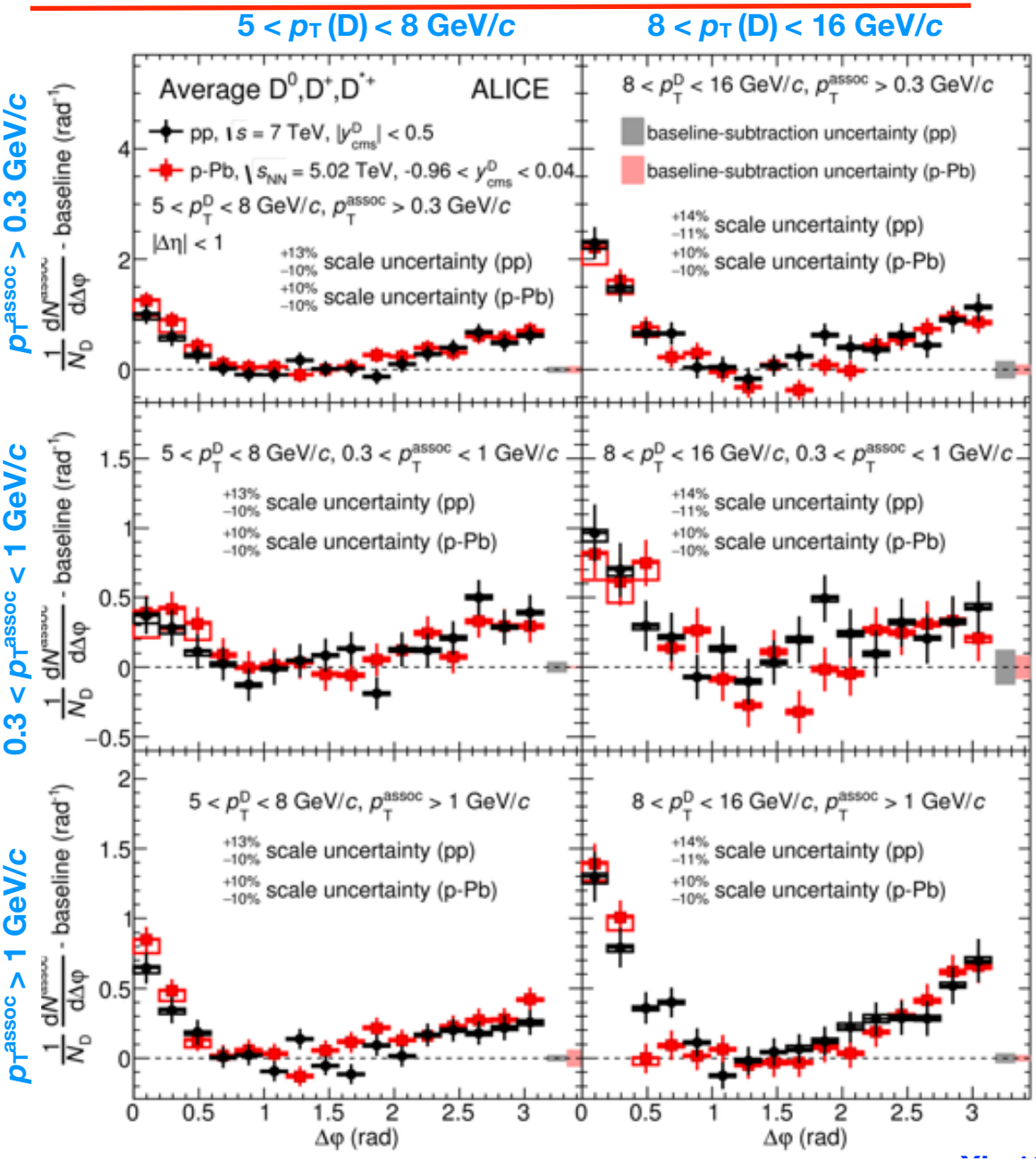
Results depend on how event activity defined

$c_2\{4\}$ only negative when method involving multiplicity fluctuations used

Tension between CMS and ATLAS on cumulant results

D-hadron correlations in p+Pb

G. Luparello (ALICE)



Correlations are the same in pp and p+Pb after background subtraction

No evidence of any change in jet properties

No need to include flow term in background

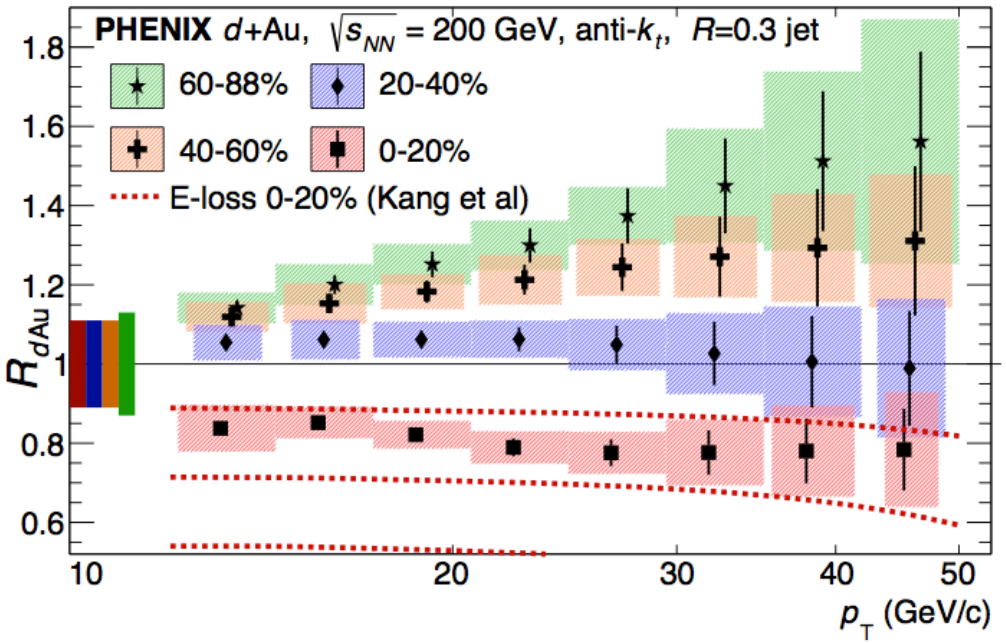
Are D's also "flowing" in p+A?

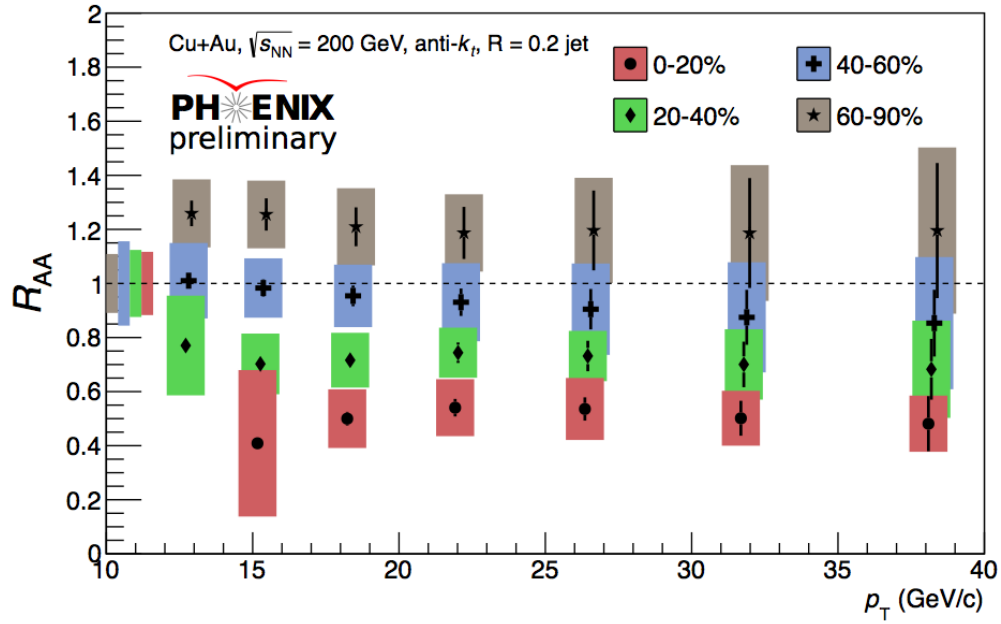
More data needed to perform study in event activity classes

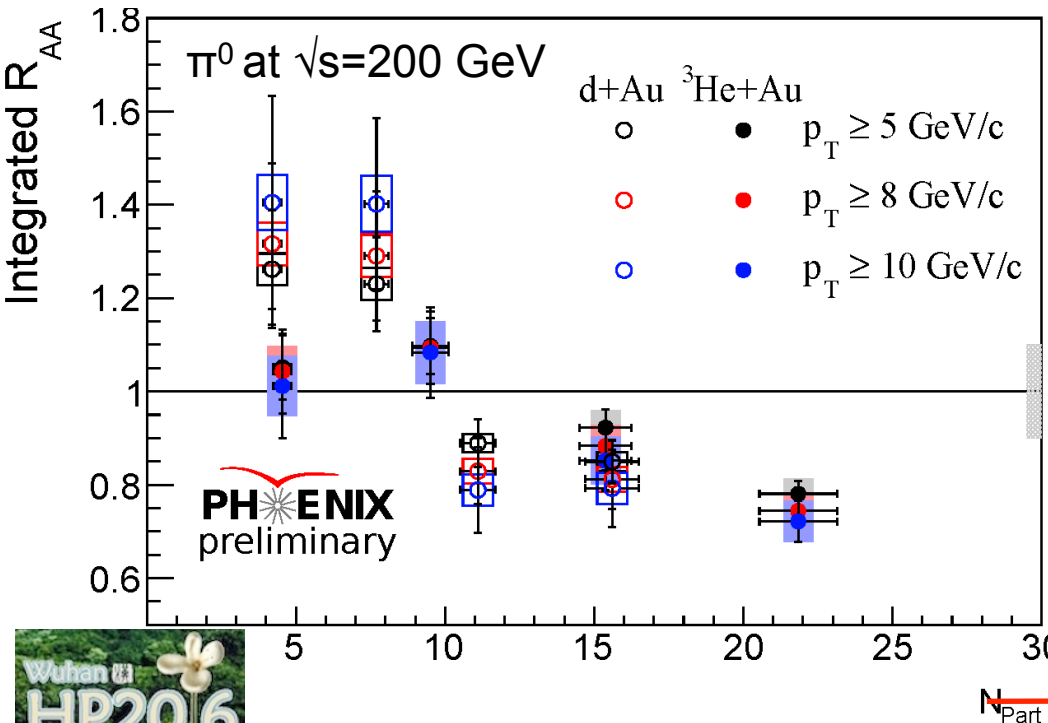
arXiv:1605:06963

$R_{dA,AA}$ in asymmetric systems at RHIC

T. Sakaguchi (PHENIX), S, Zharko (PHENIX)







Centrality dependence of jet and π^0 suppression in d+Au, He+Au, Cu+Au

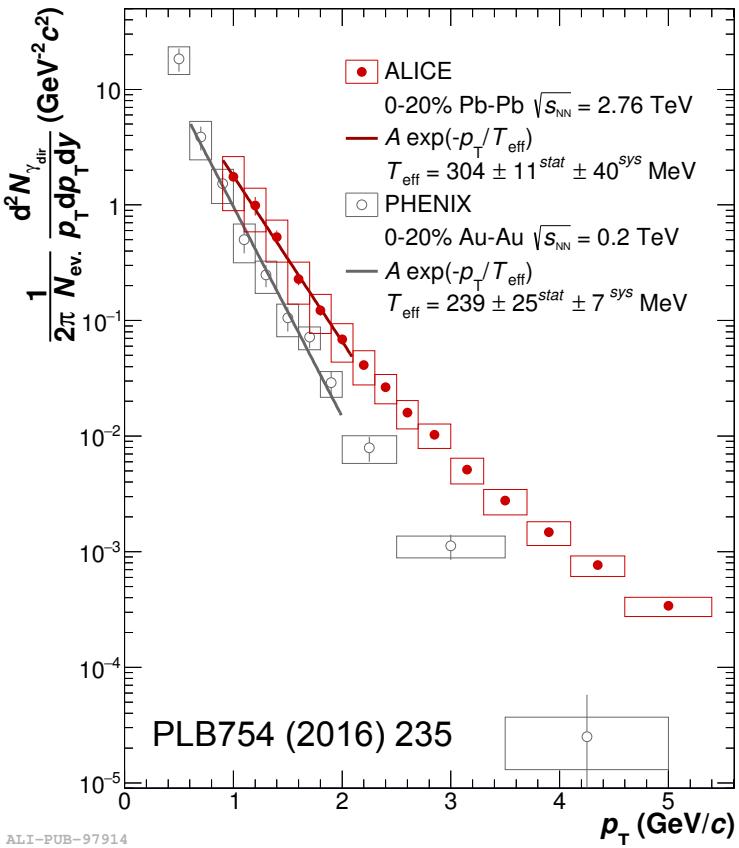
- suppressed in central
- enhanced in peripheral

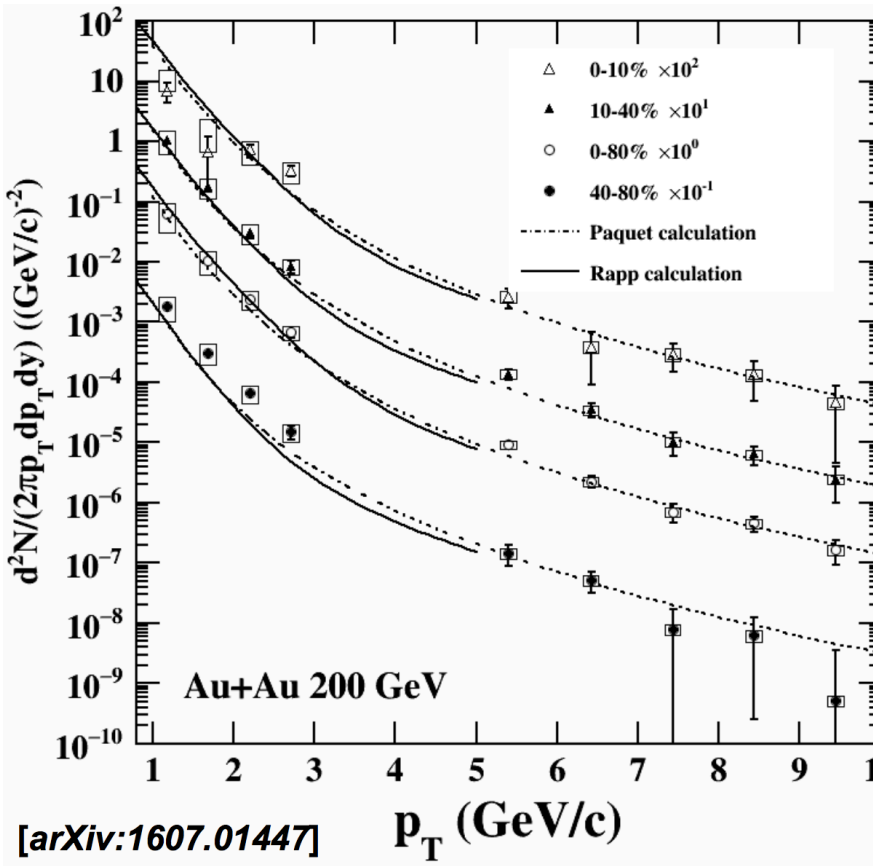
Similar suppression for $N_{part}>12$

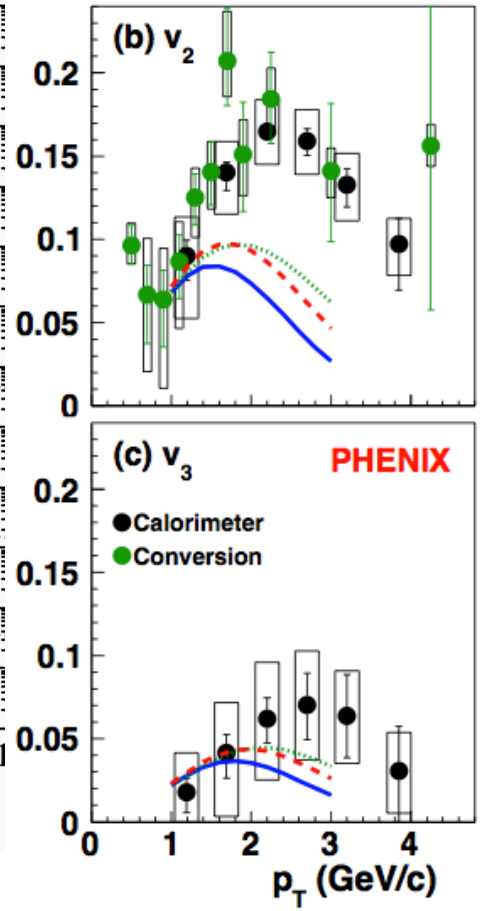
How to explain N_{part} behavior?

Direct thermal photons

W. Fan (PHENIX), D. Lodato (ALICE), C. Yang (STAR)







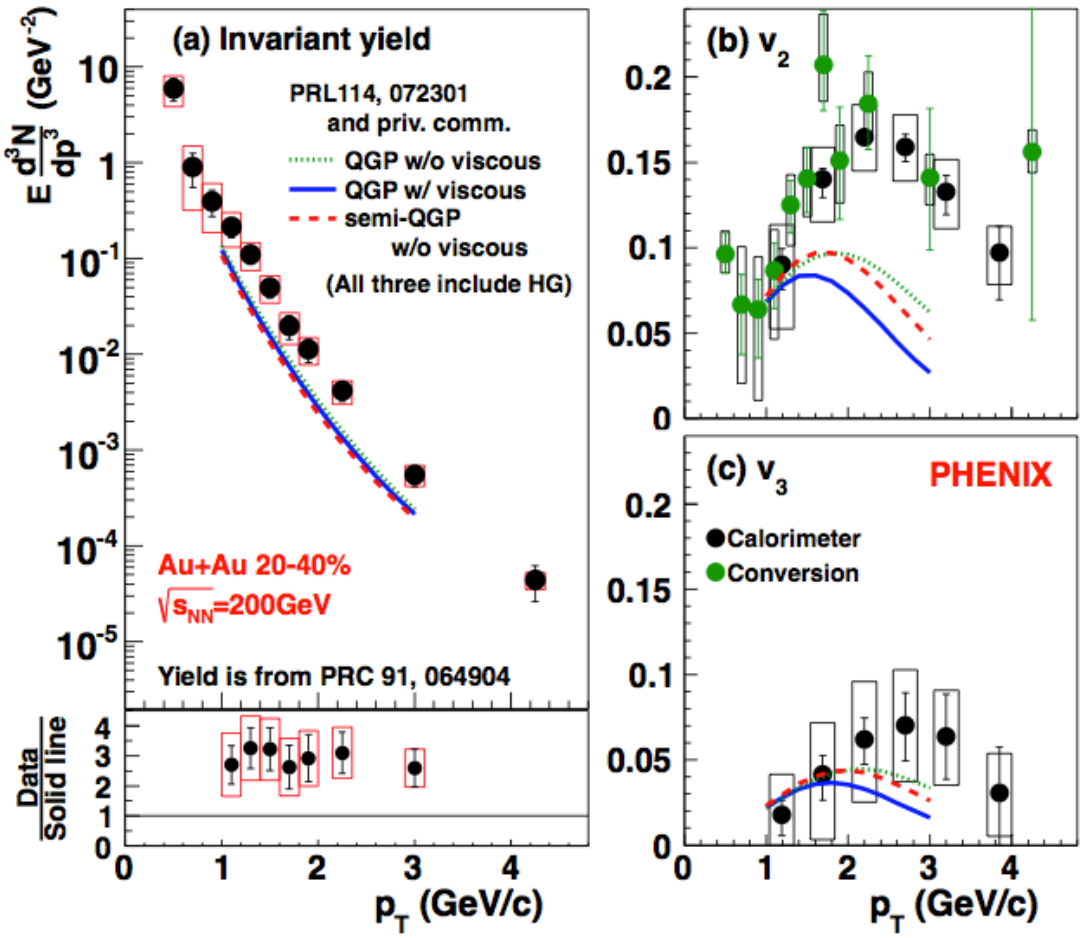
At RHIC and LHC there is an excess at low p_T
: thermal contribution

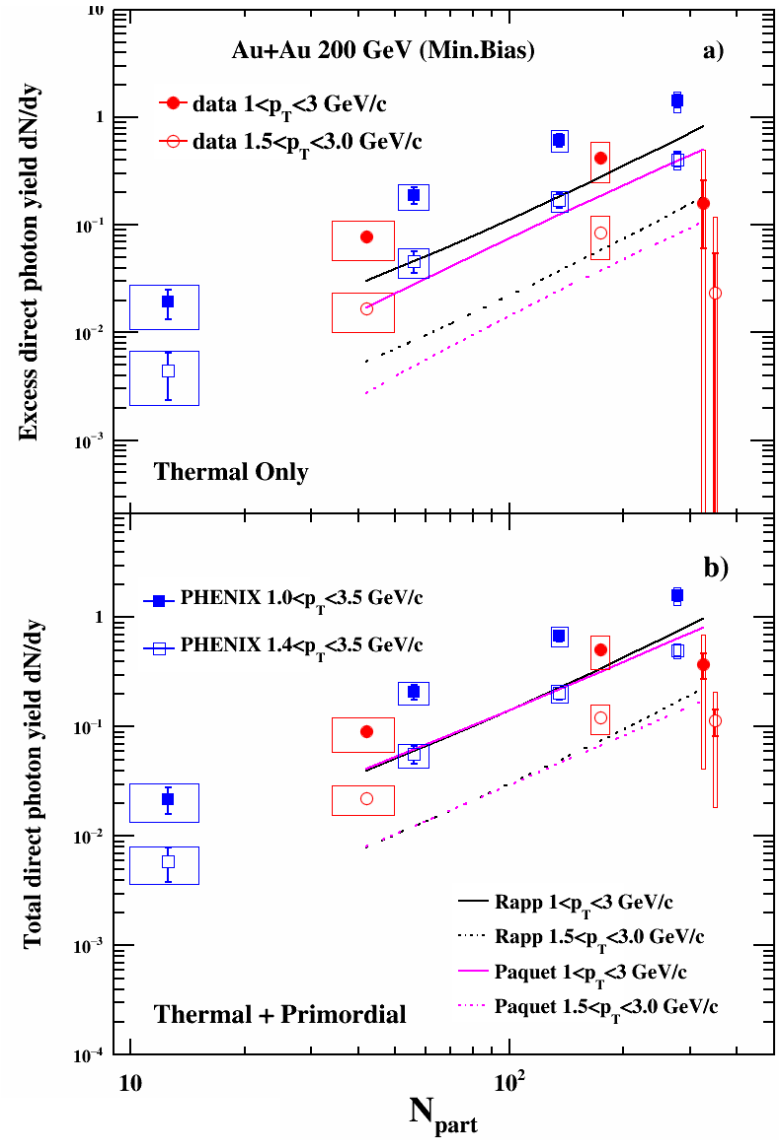
Slope at LHC 30% higher than at RHIC as expected from hotter source

What is v_n at other $\sqrt{s}$ and in small systems?

Direct photons at RHIC

W. Fan (PHENIX), C. Yang (STAR)





Failure to simultaneously reproduce PHENIX spectra and v_n

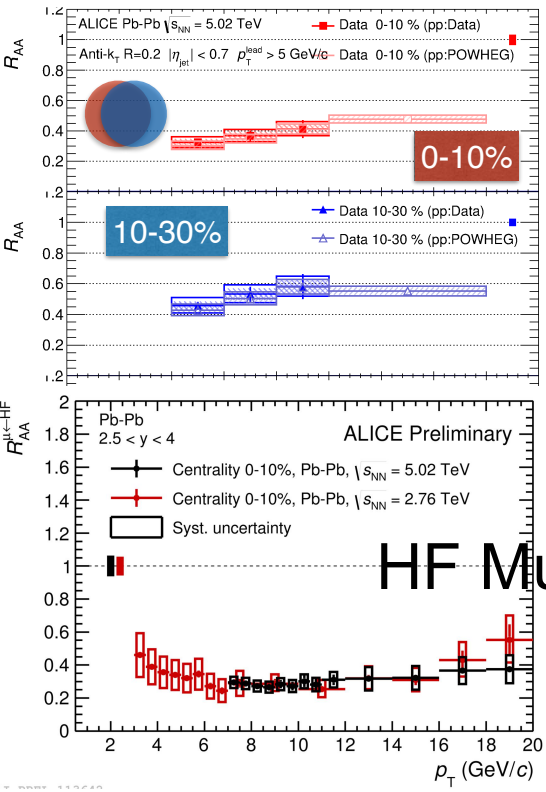
Early emission for yield
Late emission for flow

Tension between PHENIX and STAR

R_{AA} at 5 TeV

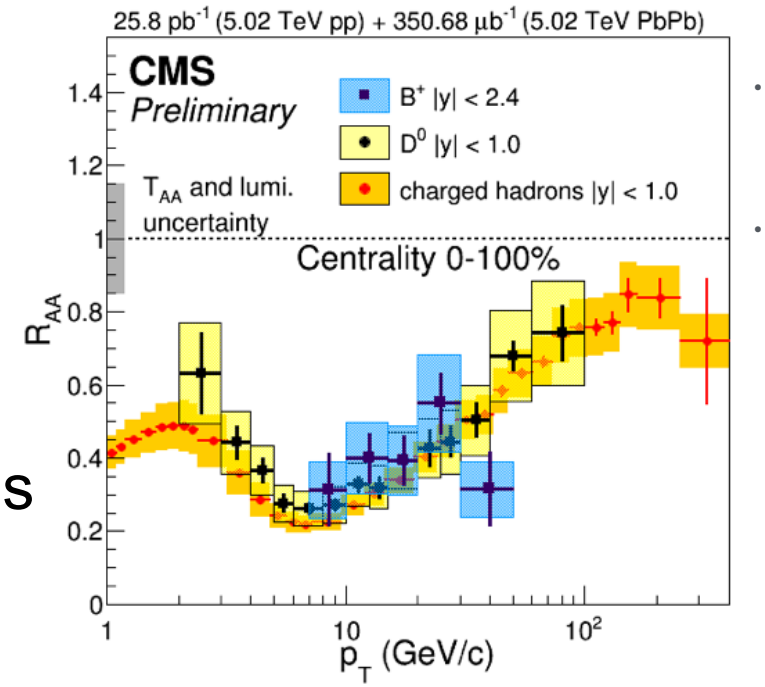
A. Batty (CMS), M. Knichel (ALICE), J. Sun (CMS), S. Tapia Araya (ATLAS), T-W. Wang (CMS), H. Yokohama (ALICE), Z. Zhang (ALICE)

Charged Jets

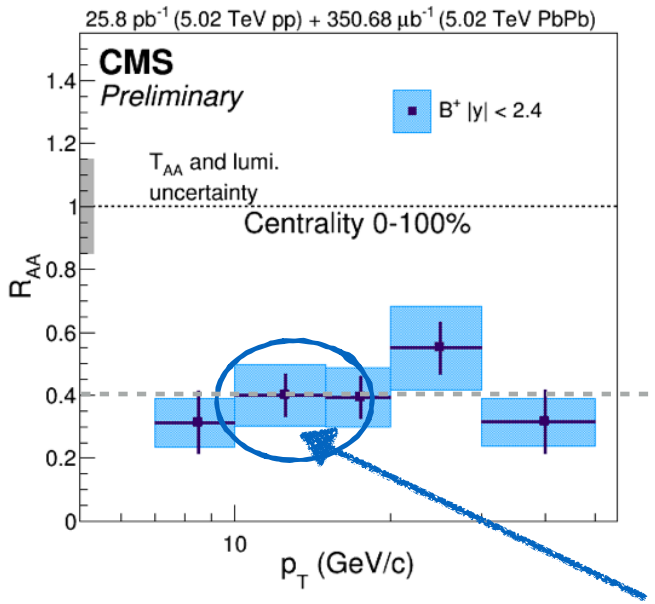


HF Muons

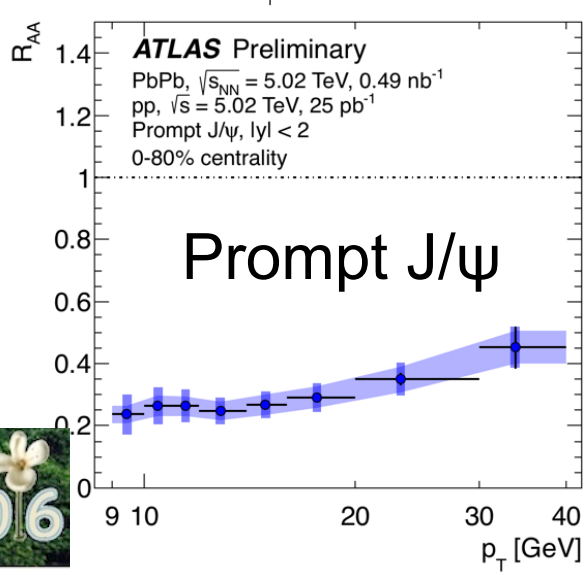
D^0 and charged hadrons and B mesons!

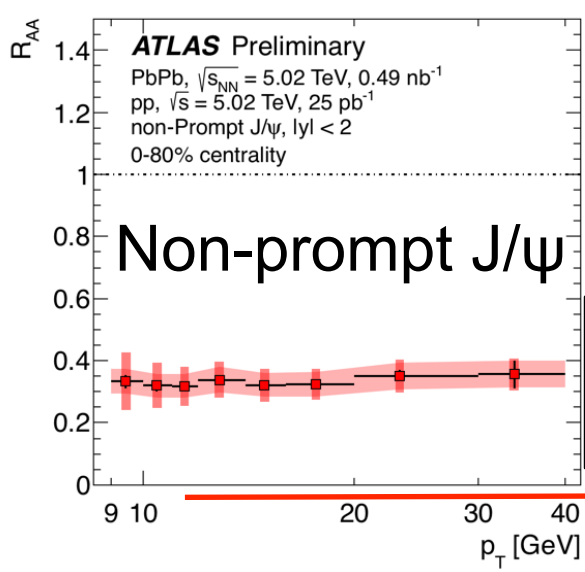


B —> J/ψ



Strong suppression in central events





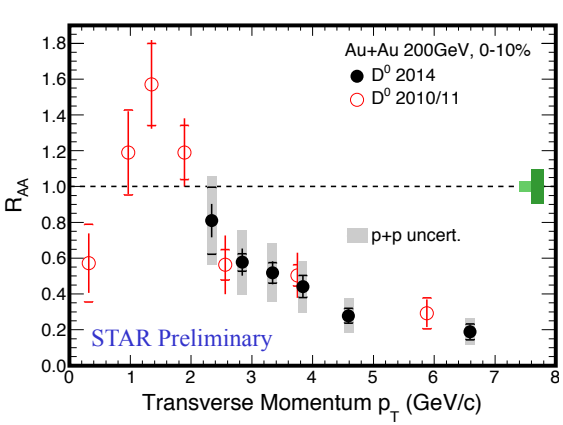
At very high p_T (>200 GeV/c) approaches 1

Not significantly different to values at 2.76 TeV

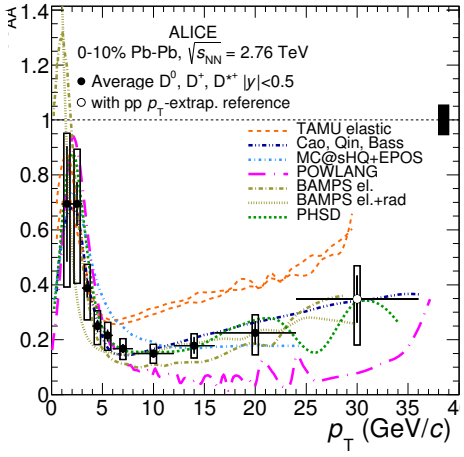
Charm-medium interactions

A. Dubla (ALICE), Q. Hu (ATLAS), L. Ma (STAR), J. Sun (CMS), J. Wang (CMS), Y. Wang (STAR), G. Xie (STAR), L. Zhou (STAR)

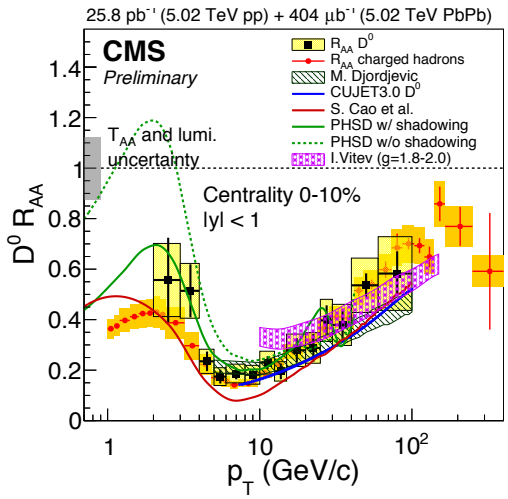
STAR 0.2 TeV



ALICE 2.76 TeV



CMS 5.02 TeV



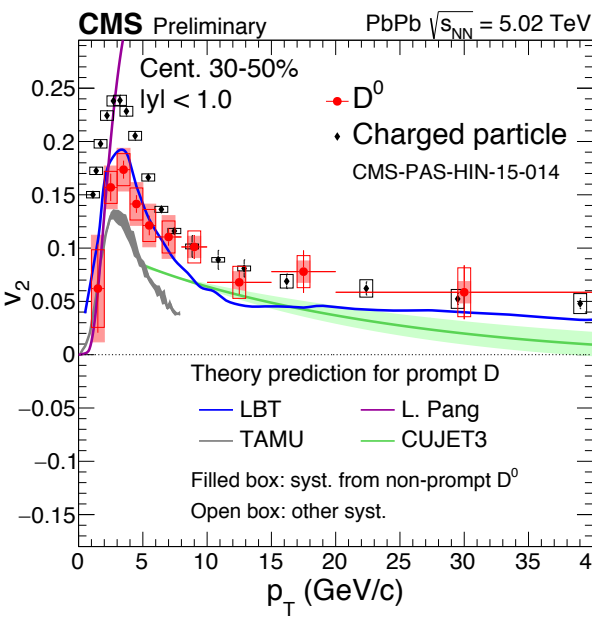
At low p_T:

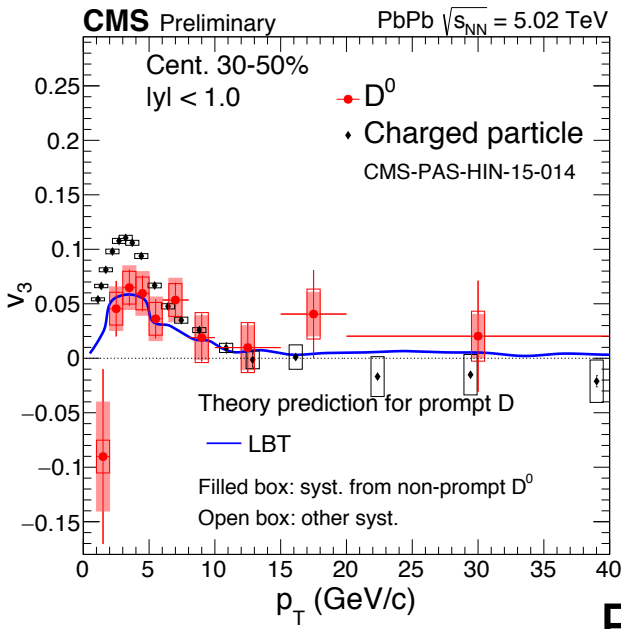
R_{AA} ~ 1.5 at RHIC (similar result for HF electrons)

R_{AA} ~ 0.6 at LHC

JHEP 03 (2016) 081

Are we seeing effects of flow + shadowing?





Charm v_2 and **v_3** at LHC (HF leptons also reveal v_2)

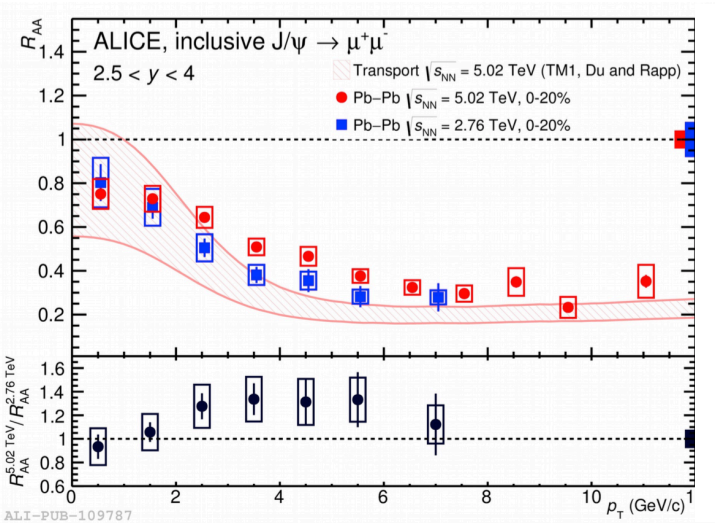
High p_T suppression + flow

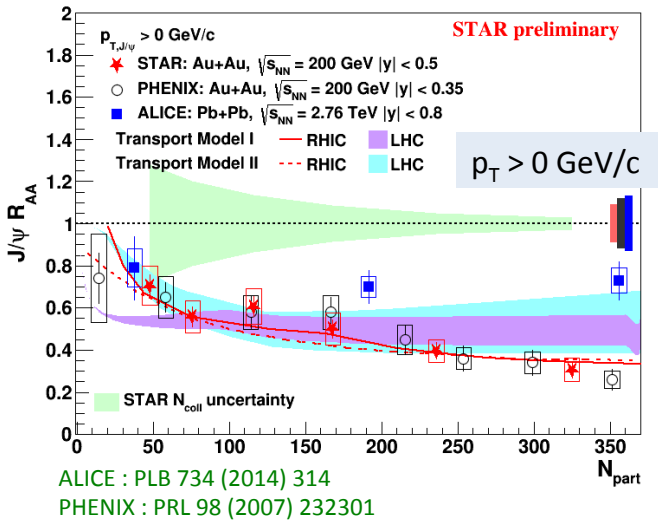
Strong charm-medium interactions at LHC and RHIC

Enhanced D_s production at RHIC

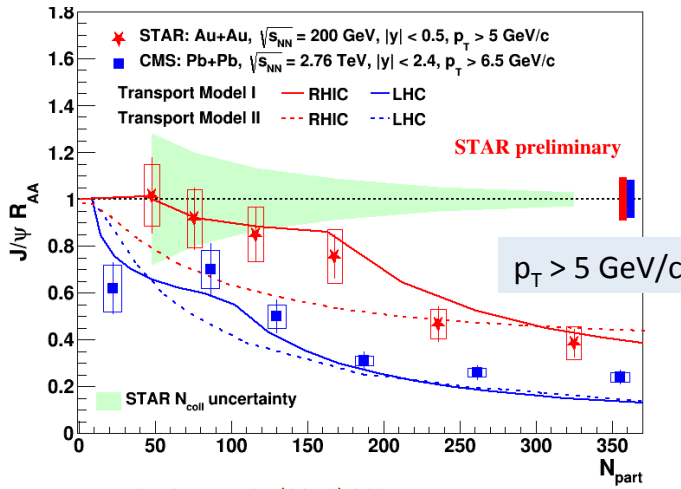
J/ψ suppression

E. Chapon (CMS), V. Feuillard (ALICE), Y. Yang (STAR)





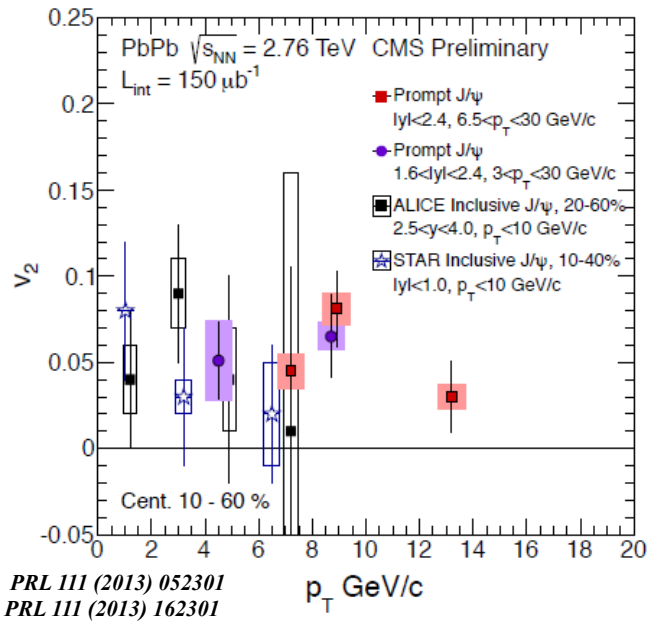
ALICE : PLB 734 (2014) 314
PHENIX : PRL 98 (2007) 232301



CMS: JHEP 05 (2012) 063

Low p_T: LHC_5 > $LHC_{2.76}$ > RHIC - decreasing regeneration; less c quarks

High p_T: $LHC_{2.76}$ < RHIC - decreasing dissociation; cooler medium



PRL 111 (2013) 052301
PRL 111 (2013) 162301

Hints of v_2

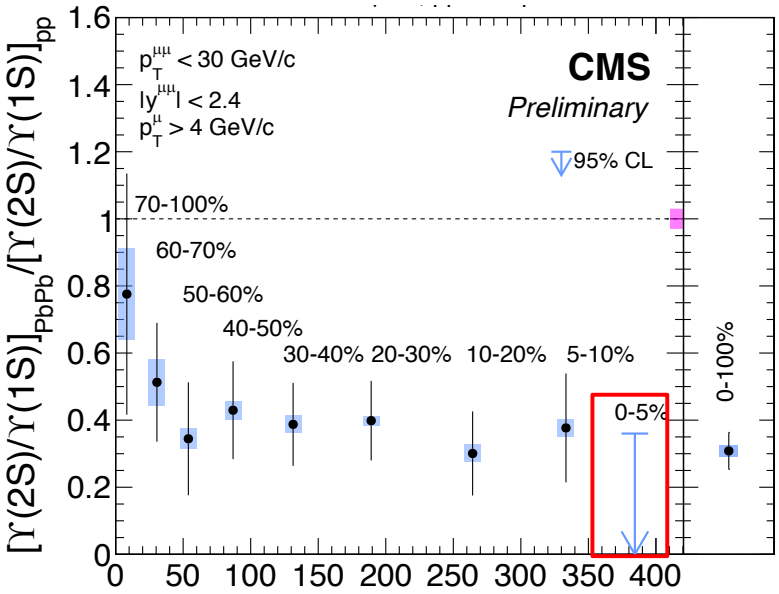
low p_T expectation:

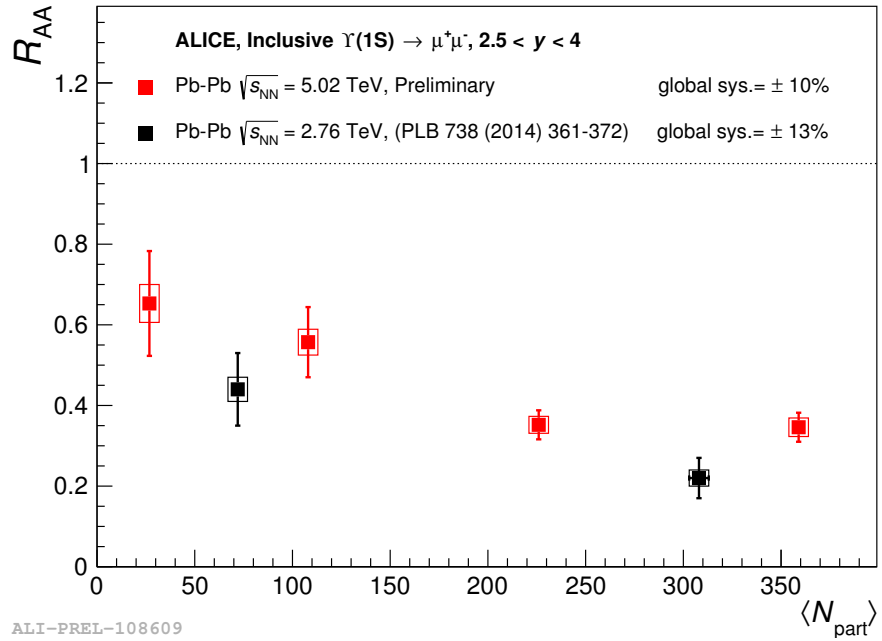
only regenerated show flow from thermal c quarks

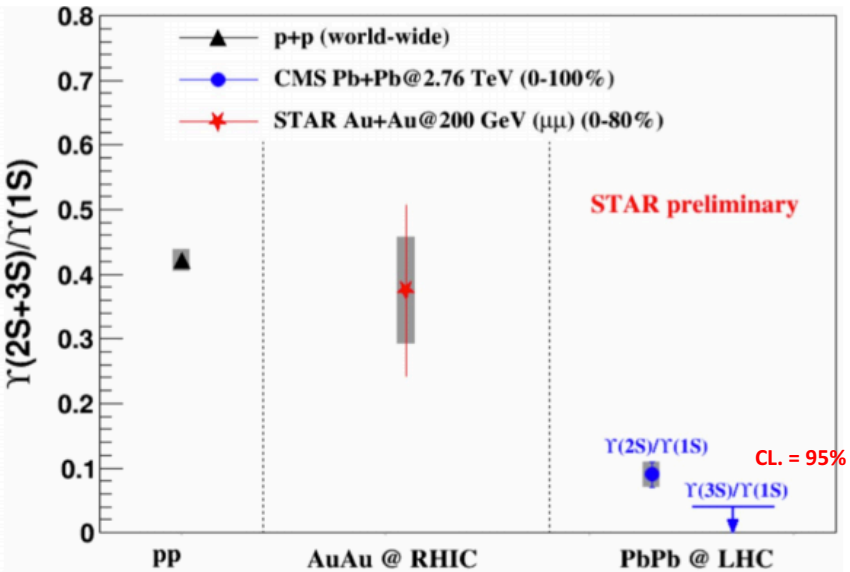
Precise v_n measurements needed to confirm flowing charm

Υ suppression

G. Fronze (ALICE), Y. Kim (CMS), Z. Ye (STAR)







5 TeV

Υ(3s): No evidence in data

Υ(2s): Consistent with 0 in central events

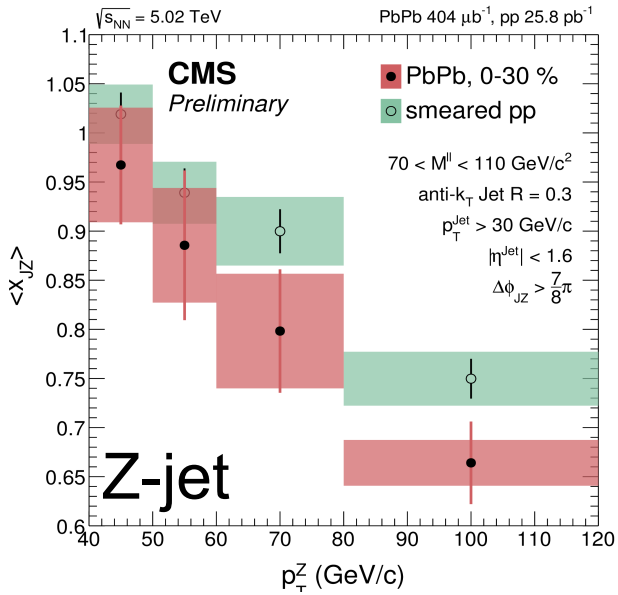
Υ(1s): Hint that $R_{AA,2.76} < R_{AA,5}$

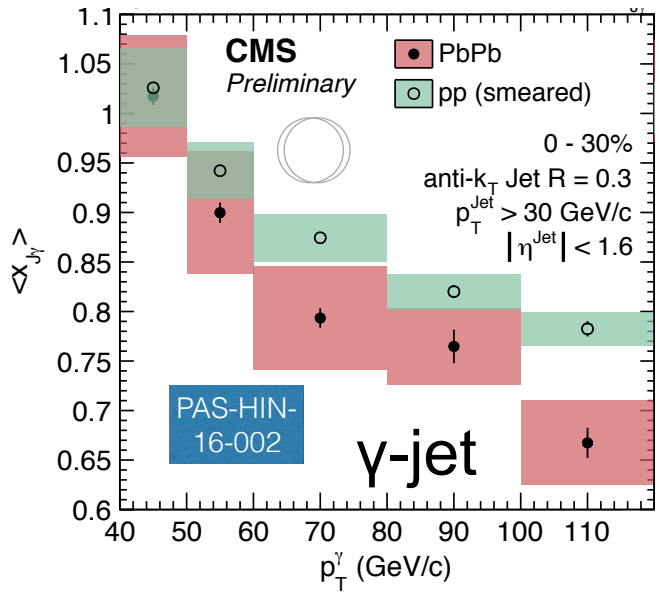
Regeneration of bottom?

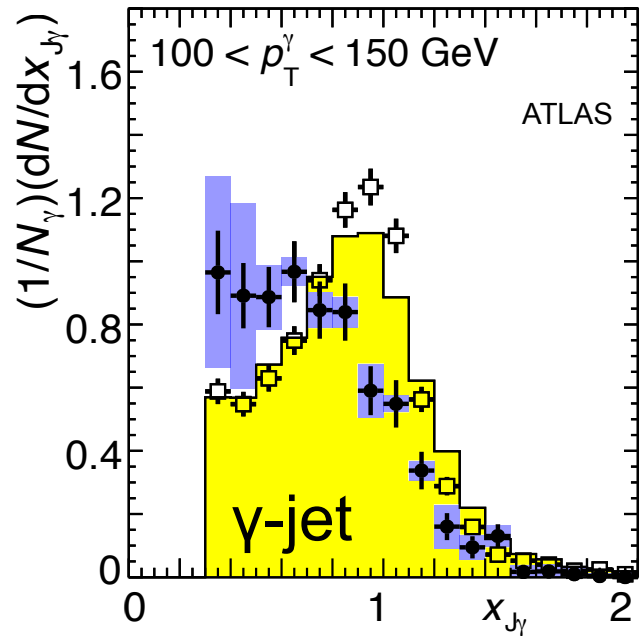
Less suppression of Υ(2s+3s)/Υ(1s) at RHIC

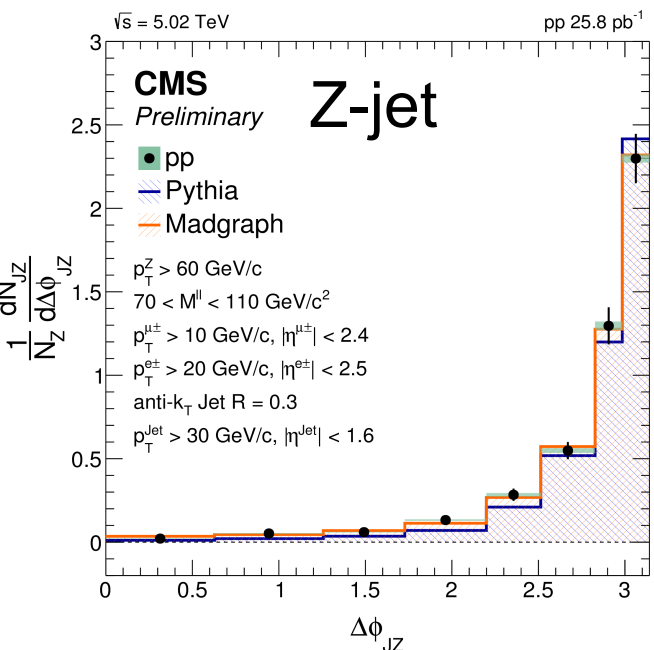
Colorless high p_T triggers

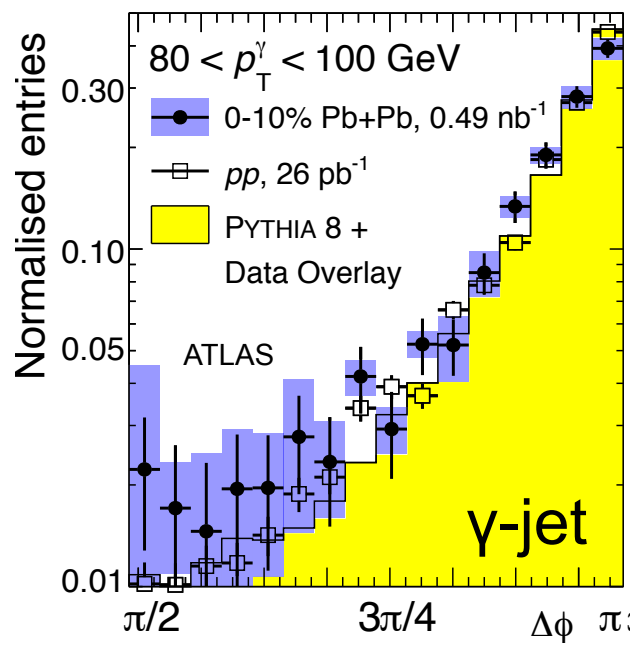
B. Cole (ATLAS), C.Mc Ginn (CMS), K.Tatar (CMS)











Now have results for both γ and Z triggers!

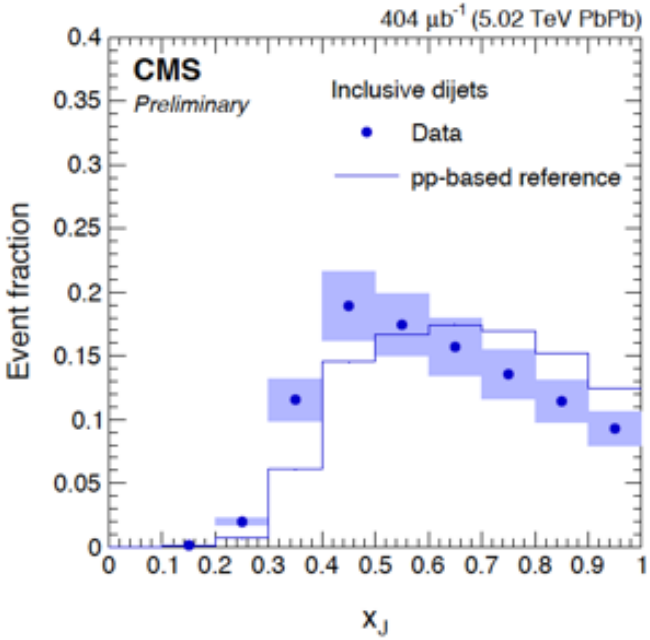
Significant change in x_J distribution

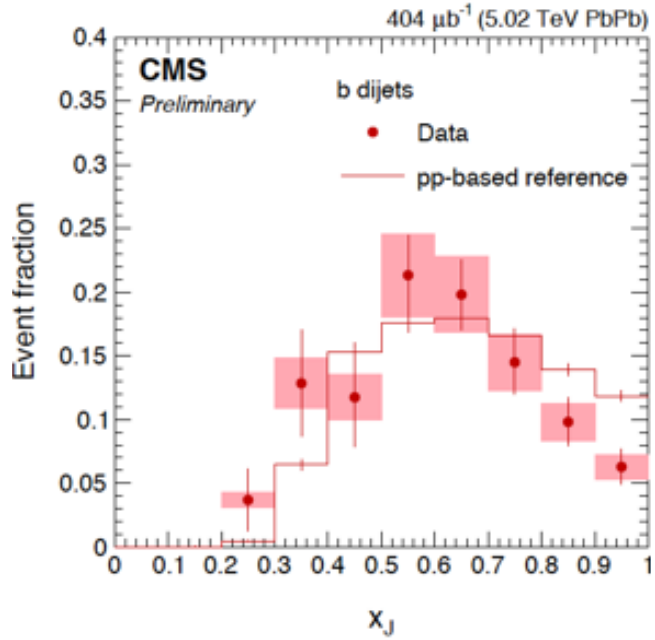
No angular deflection

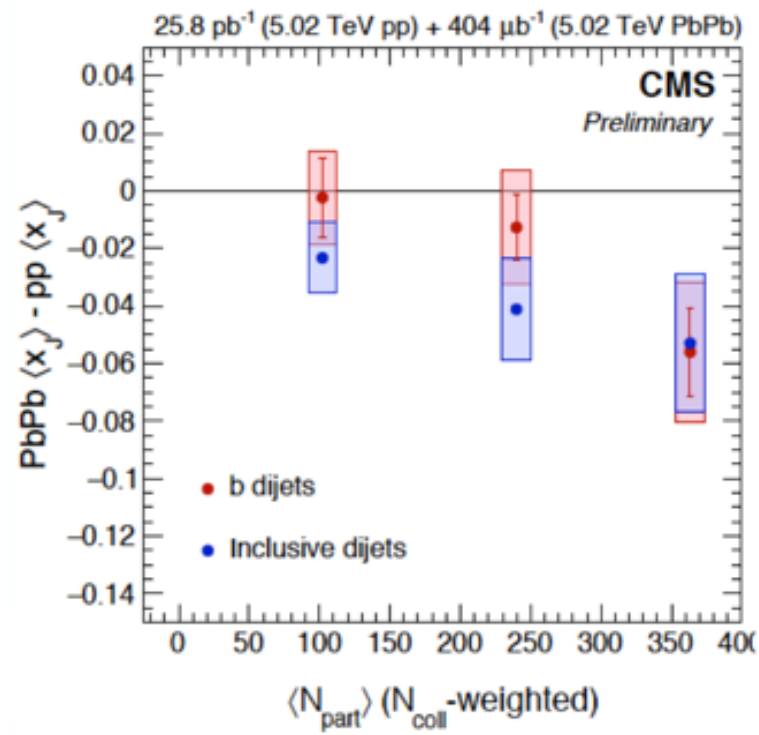
Results do not change (within errors) if either Z or γ used

Di-(b-)jet momentum imbalance

C.C.Peng (CMS), R. Slovak (ATLAS)

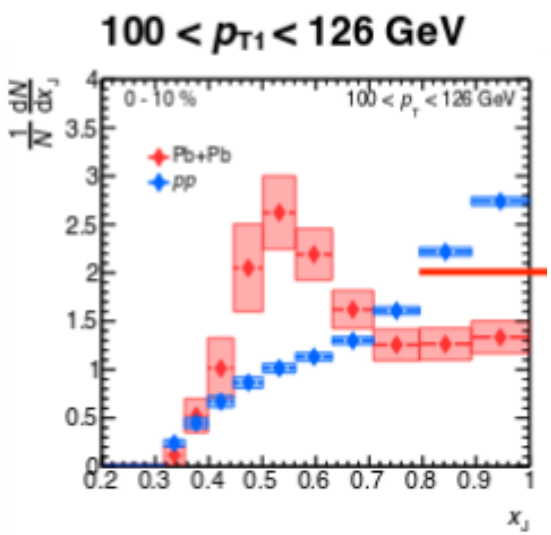


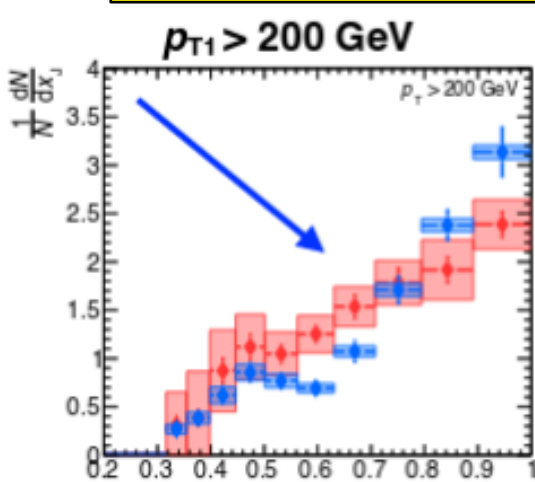




di-b-jets suppresses gluon splitting contribution

Di-jet imbalance not significantly different for di-b-jets and inclusive di-jets

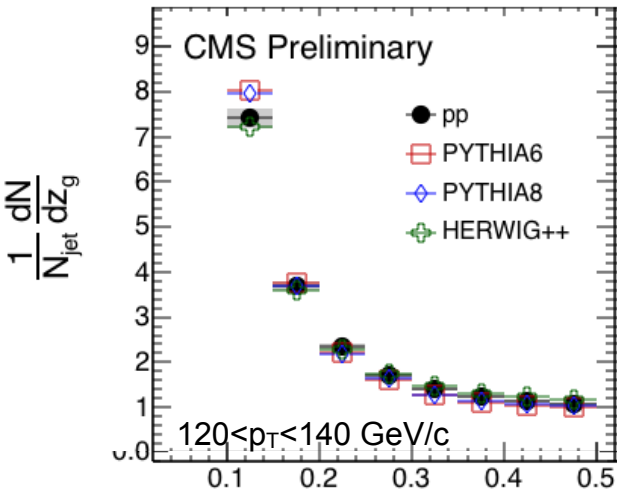


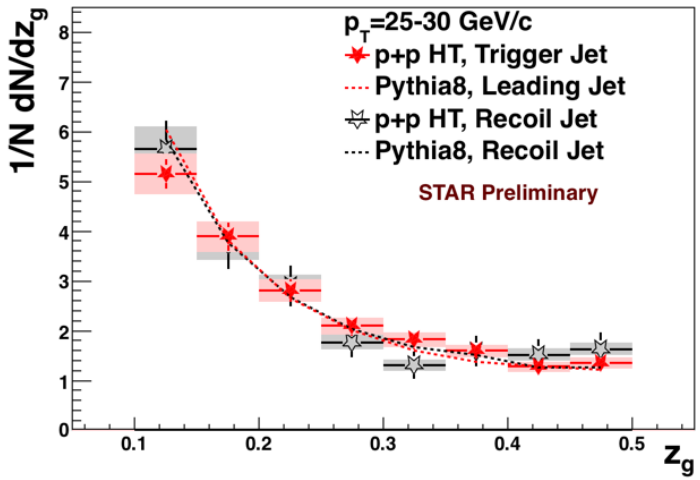


Di-jet asymmetries become similar for pp and Pb+Pb at very high lead jet p_T

Subjet shared momentum fractions

K. Kauder (STAR), M. Verweij (CMS)

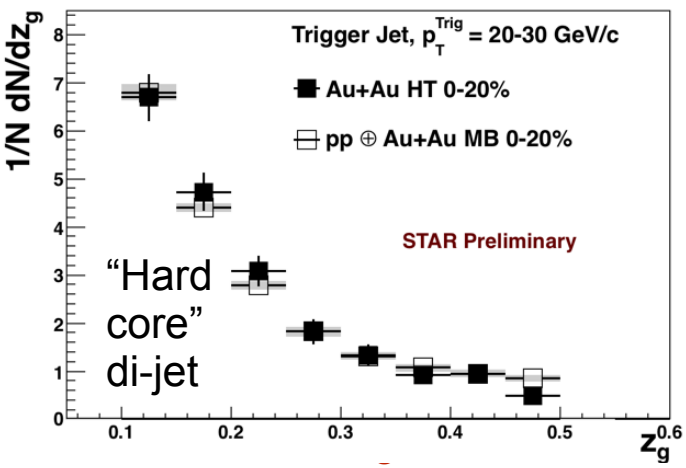




"Groom" jet into two subjets

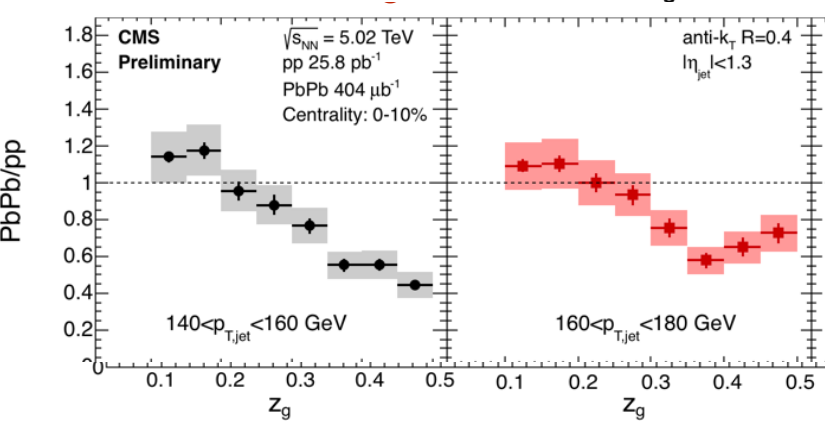
$$z_g = \frac{\min(p_{T,1}, p_{T,2})}{p_{T,1} + p_{T,2}}$$

Good agreement between pp data and models



No change at RHIC for either of the "hard core" di-jets

Significant change at LHC for inclusive jets $140<p_T<200$ GeV/c



Results not necessarily contradictory **many** differences

Future: explore angular dependence to probe subjets color (de)coherence

Access to virtuality?

C. Bianchin (ALICE), D.Gulhan (CMS)

Higher jet mass → higher virtuality

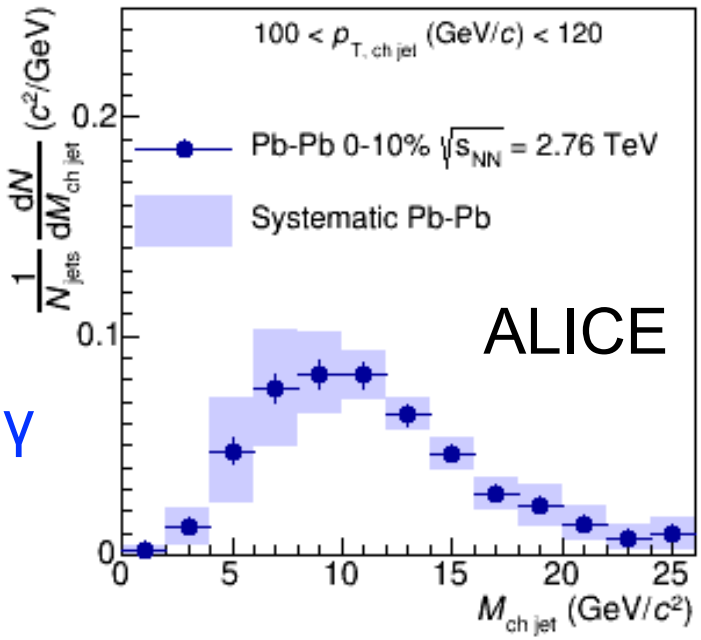
Z triggers → higher virtuality

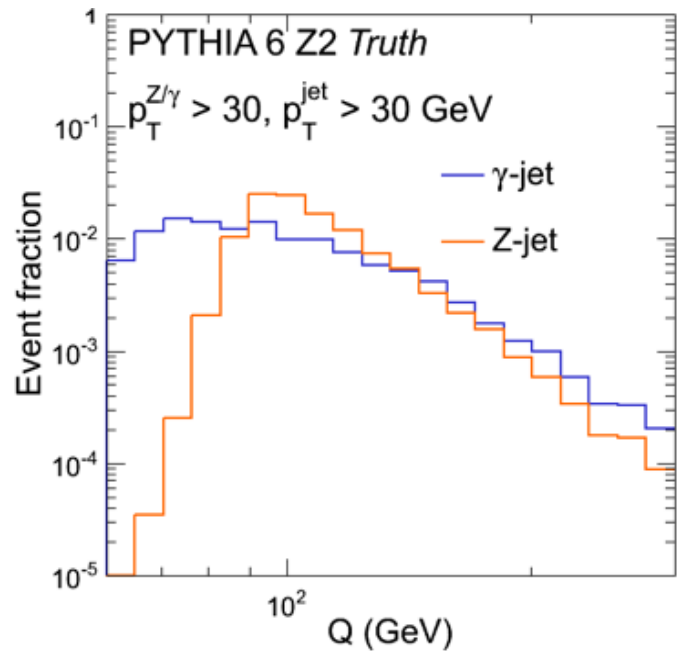
Studies are just beginning at LHC
- no large differences observed for Z vs γ triggers

Theoretical expectation[1] that higher virtuality probes different length scale of the medium

Experimentally do higher jet mass/ Z trigger events show different amount of quenching compared to low mass/other triggers with same jet p_T?

Promising avenue of exploration

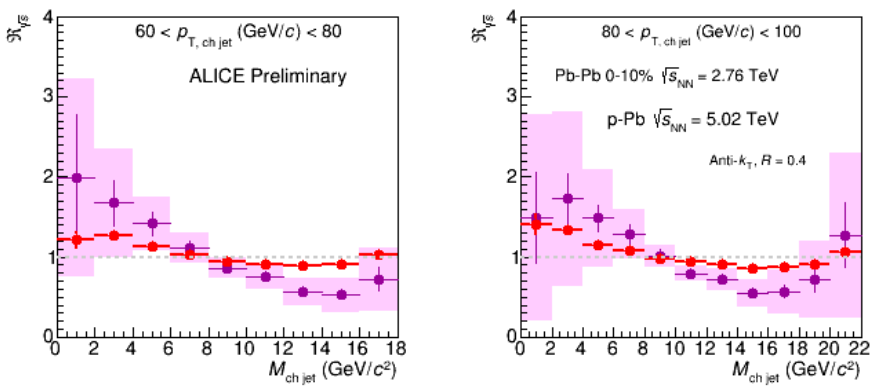




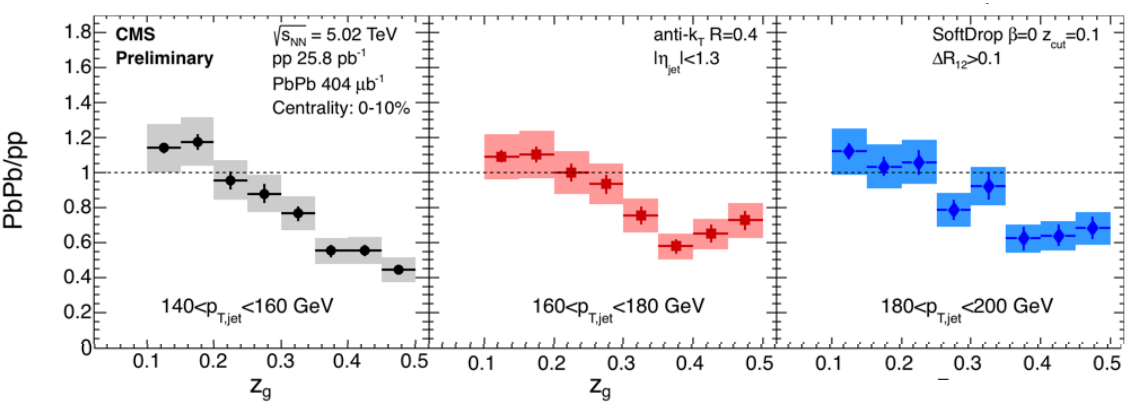
[1] Majumder, Putschke PRC 2016

Hints that quenched jets are collimated

C. Bianchin (ALICE), M. Rybar (ATLAS),
M. Verweij (CMS), X. Zhang (ALICE)

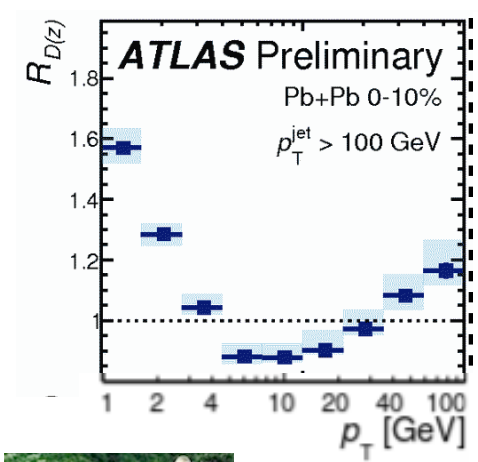


Jet mass shifts to lower values

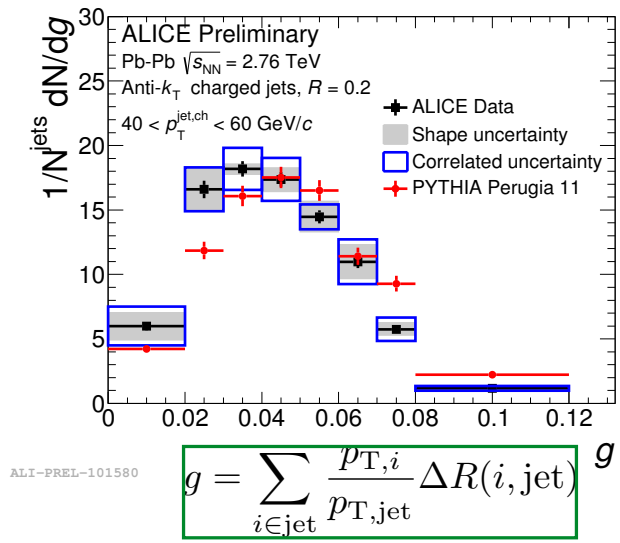


Subjet z_g more imbalanced

Suggest Pb+Pb inclusive jets have "harder cores" than pp jets of same energy



Enhanced yield at high z

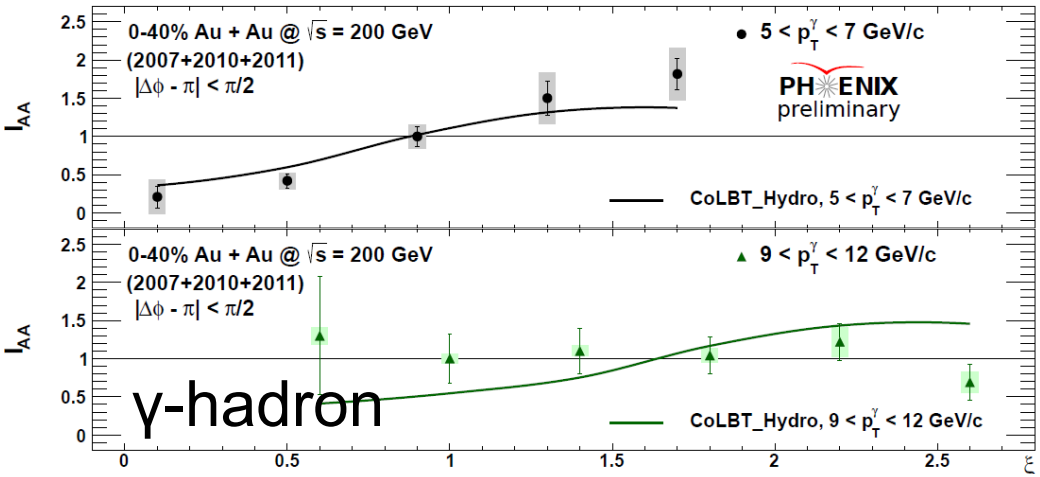


$$g = \sum_{i \in \text{jet}} \frac{p_{\text{T},i}}{p_{\text{T,jet}}} \Delta R(i, \text{jet})$$

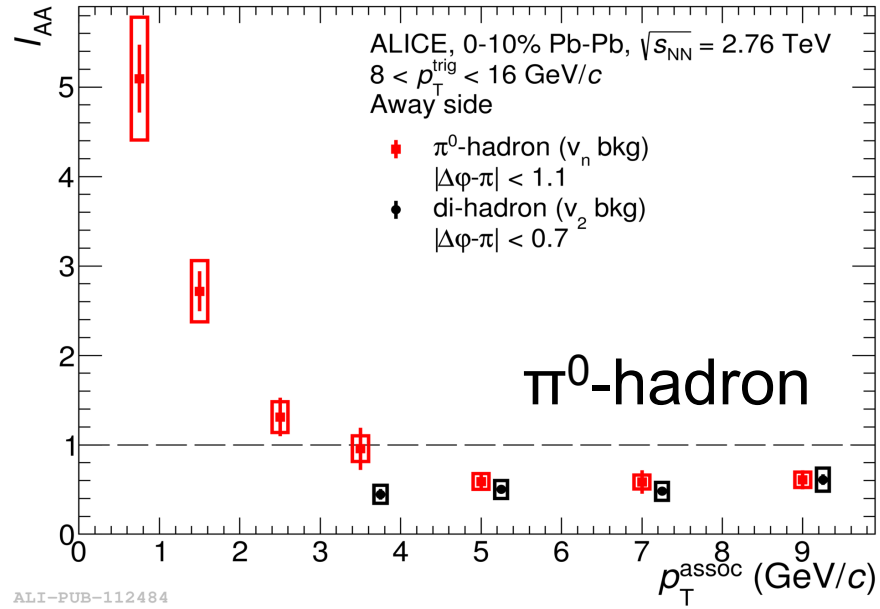
Radial momentum shifts to lower values

How the lost energy re-emerges

H. Ge (PHENIX), X. Peng (ALICE),
D.Velicanu (CMS), X. Zhang (ALICE)



Energy "restored" at low p_T not low z_T!



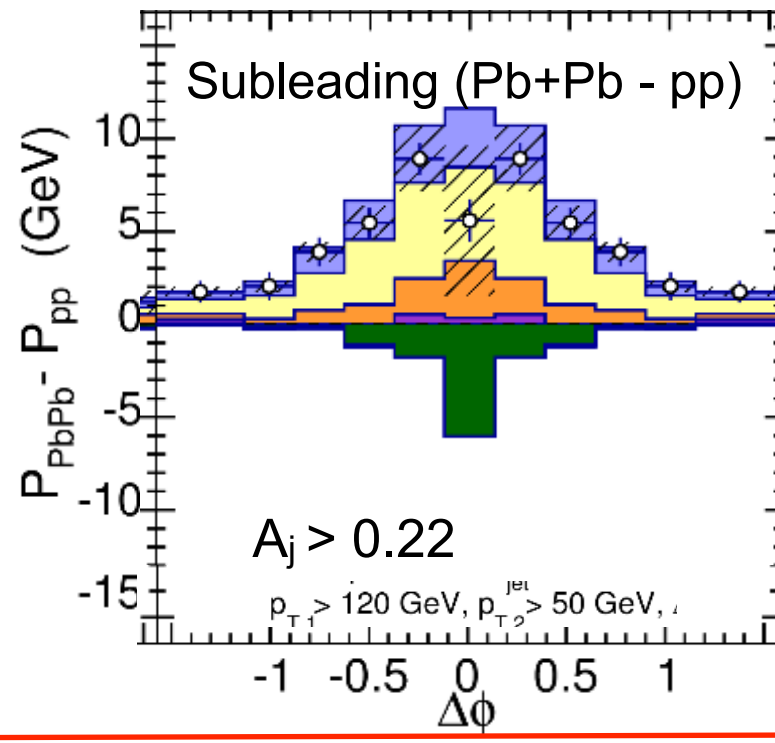
New results confirm enhancement starts below:

- ~2 GeV/c at RHIC
- ~3 GeV/c at LHC

(similar conclusion for strangeness in jet)

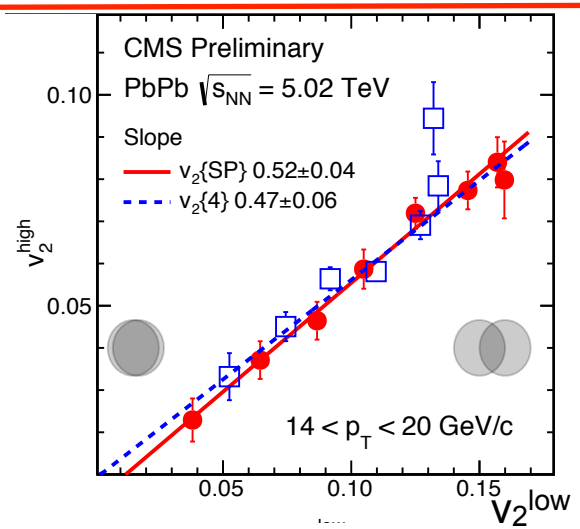
Jet-Track:

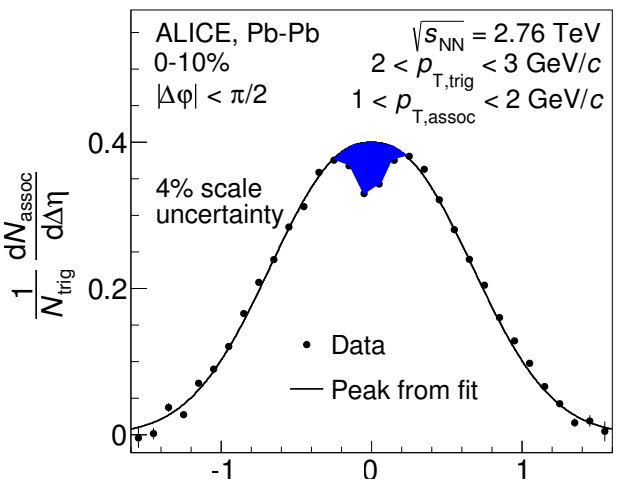
Particles emerge at large angles (larger than typical jet cones at LHC)

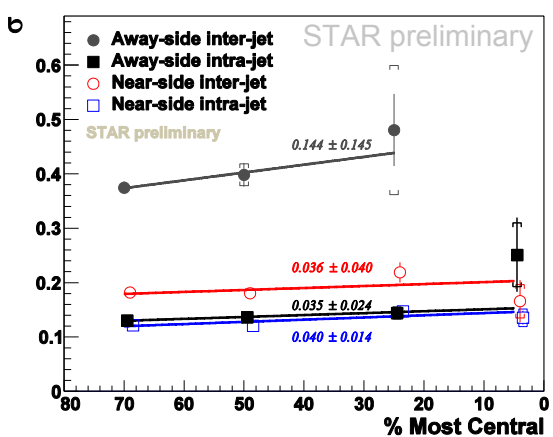


Interplay of medium with jets

K. Burka (ATLAS), K. Jiang (STAR),
M. Kofarago (ALICE), Q. Wang (CMS)







v_n now observed up to n=7 and up to 25 GeV
- No significant difference from 2.76 to 5 TeV

v_2(low p_T) highly correlated to v_2(highly p_T)
- Increasing p_T flattens slope of correlation
- Initial state effect?

Nearside low p_T di-hadron correlations
- Broadening in $\Delta\eta$
- Depletion of yield near $\Delta\eta = 0$

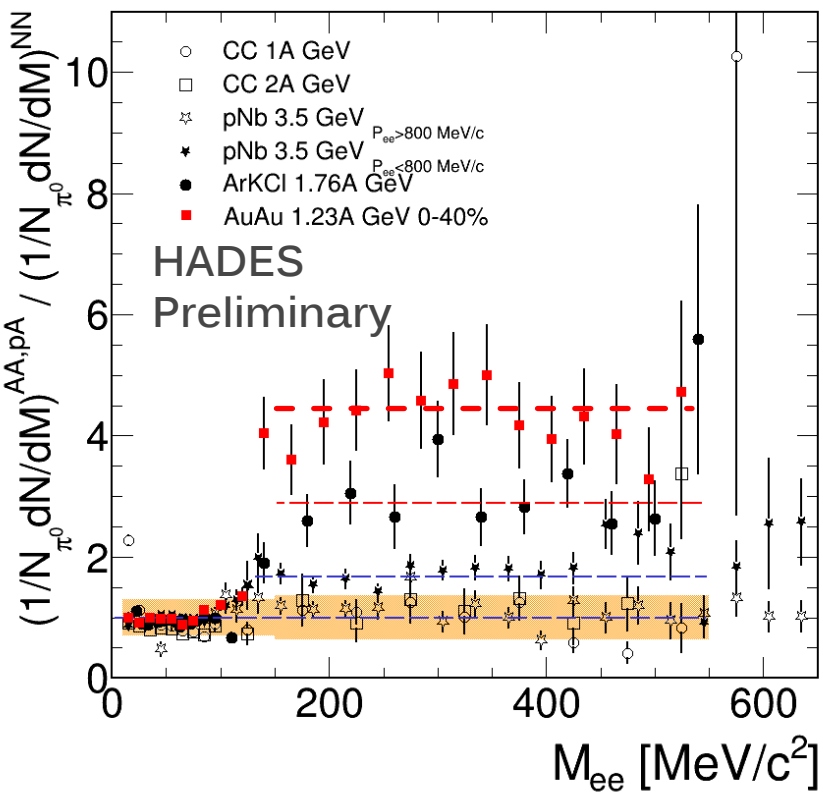
Interpreted as due to strong longitudinal and radial expansion

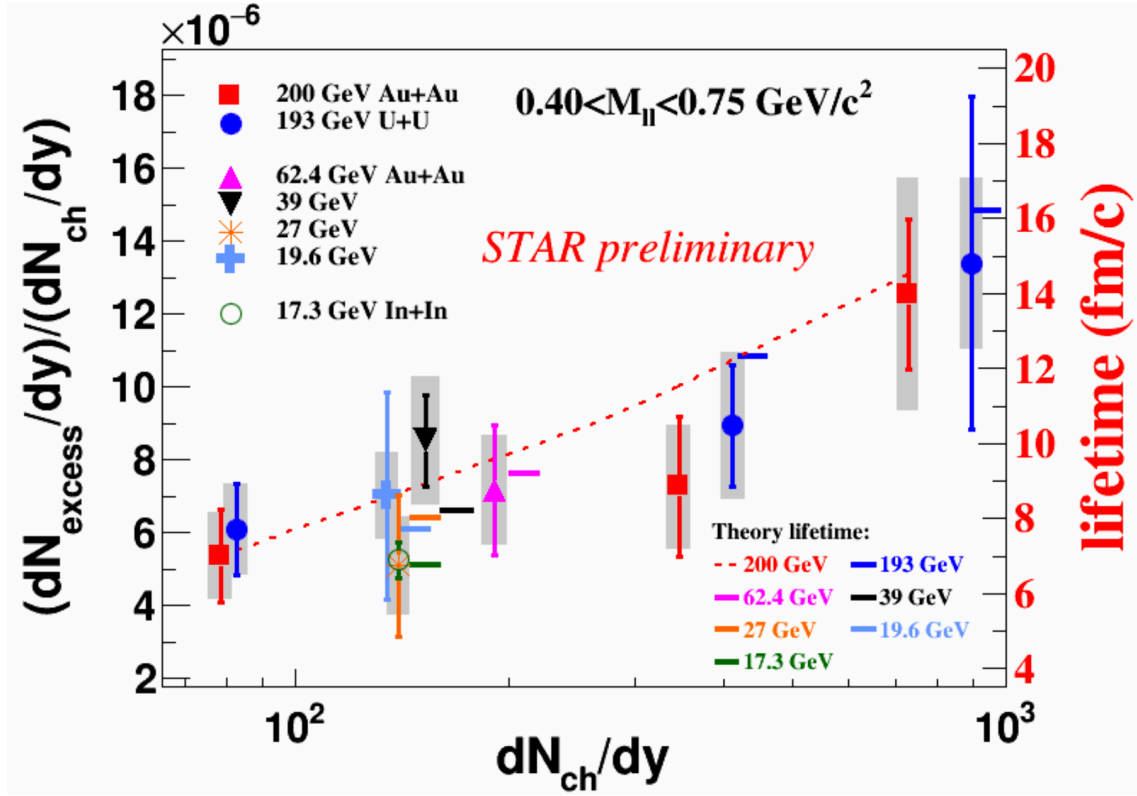
Inter-jet correlation >> intra-jet correlation
- Significant k_T and/or flow deflection

Studies of medium's response to jets starting

Low mass di-lepton excess

J. Butterworth (STAR), T. Gunji (ALICE),
P. Sellheim (HADES)





In Au+Au excess scales as $A^{1.3}_{part}$

Low mass excess ∝ fireball lifetime

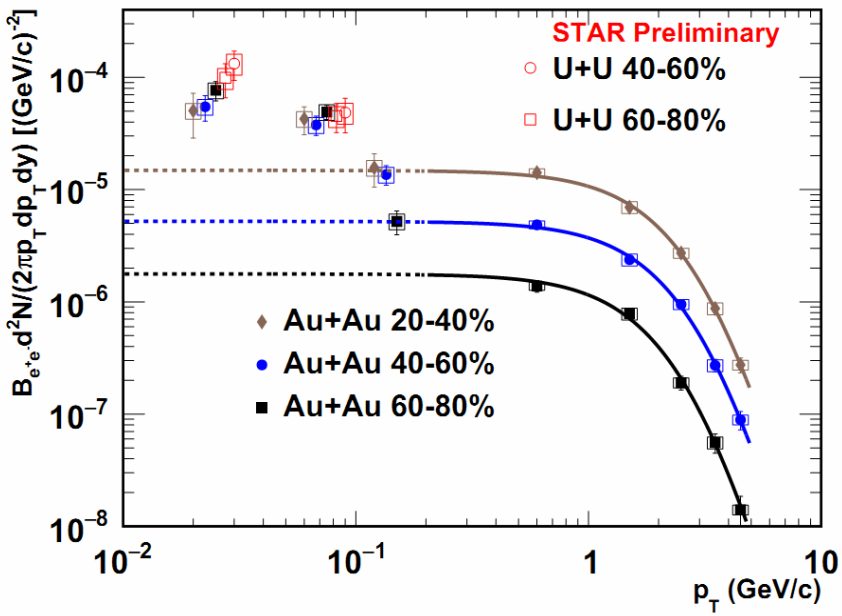
for large range of beam energies and centralities

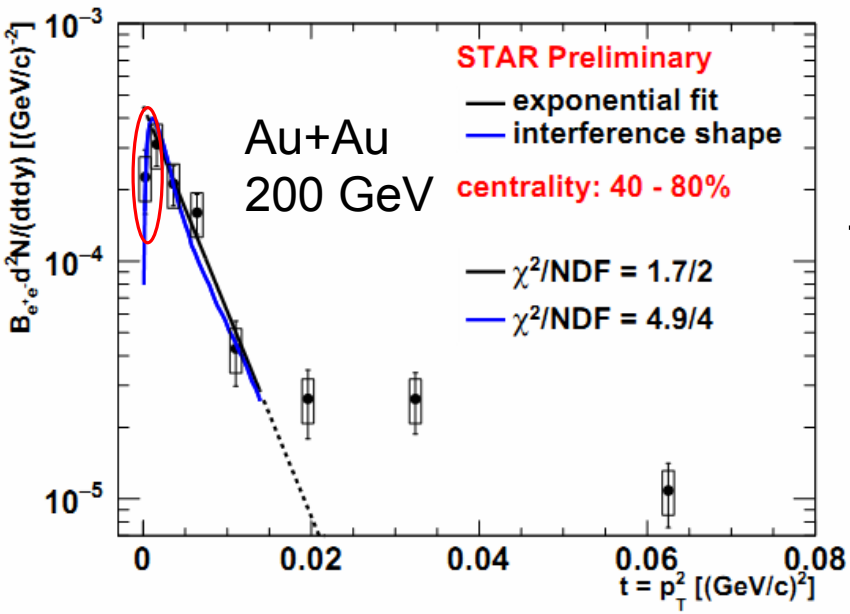
Results suggest excess due to total baryon driven medium effects

Looking forward to adding HADES, BES-II and LHC data into trend plots

Very low p_T J/Ψ

W. Zha (STAR)





Slope ~190 (GeV/c)$^{-2}$

Large excess seen for peripheral events

R_{AA} ~ 20

Excess decreases with centrality

Opposite of hadronic production expectations (N_{part} scaling)

(Similar effect seen by ALICE)

Slope of $t \sim p_T^2$ consistent with expectations from coherent photon-nucleon interaction

reflects size and shape of Au nucleus

Coherent photon-nucleus production even when nucleus disintegrates?

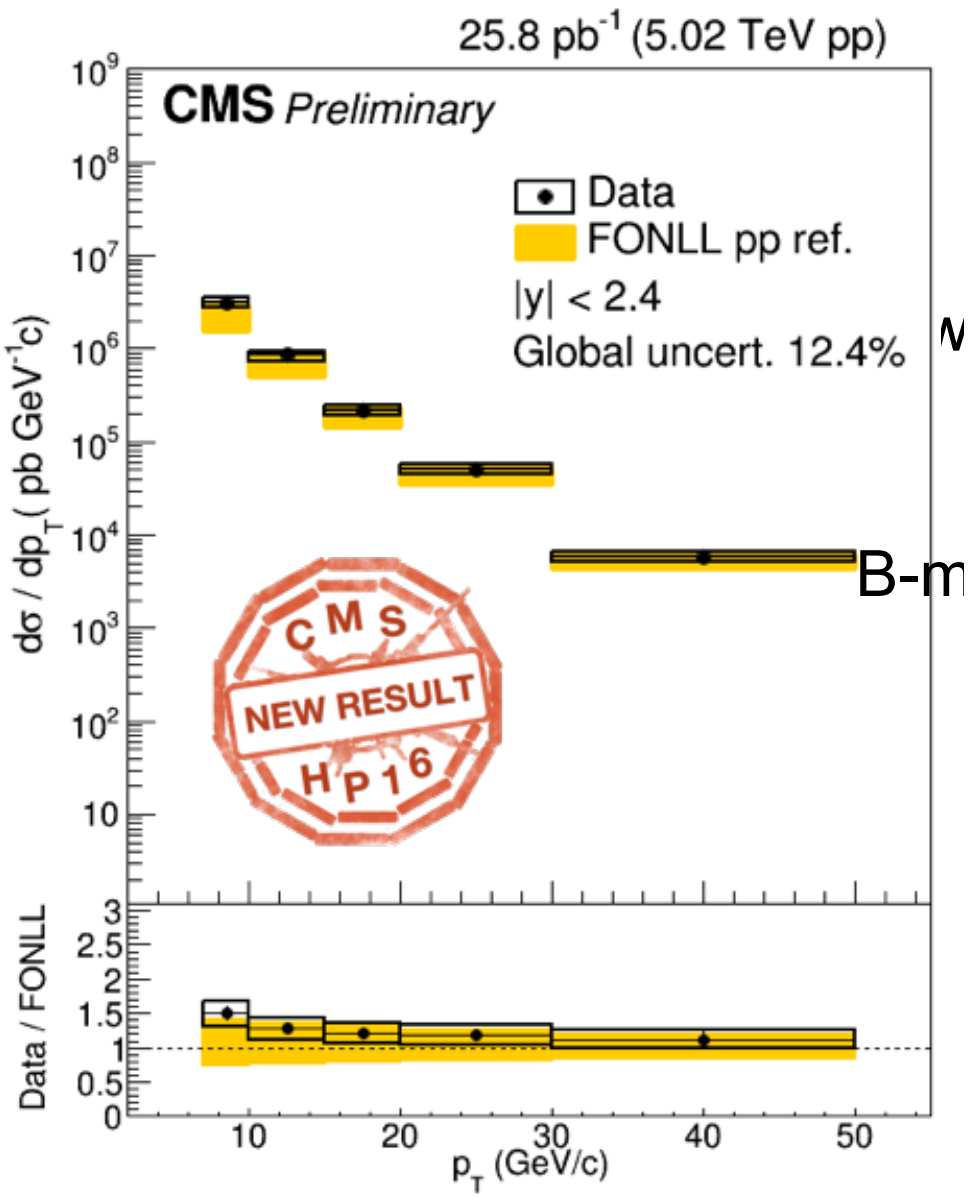
Summary

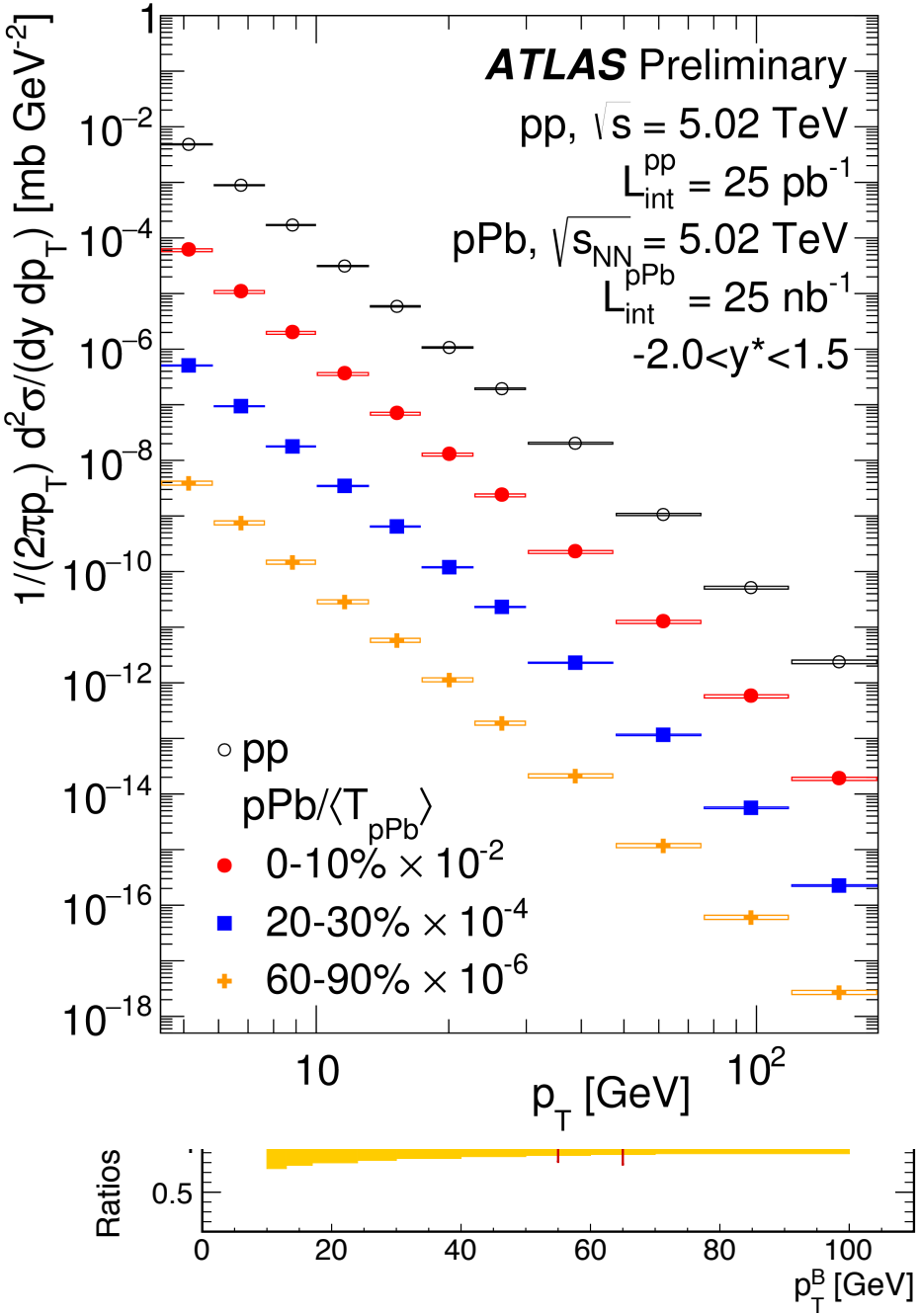
Need to go home and digest further all the data shown

Thanks for inviting me to Wuhan!
(I hope to see outside of the hotel next visit)

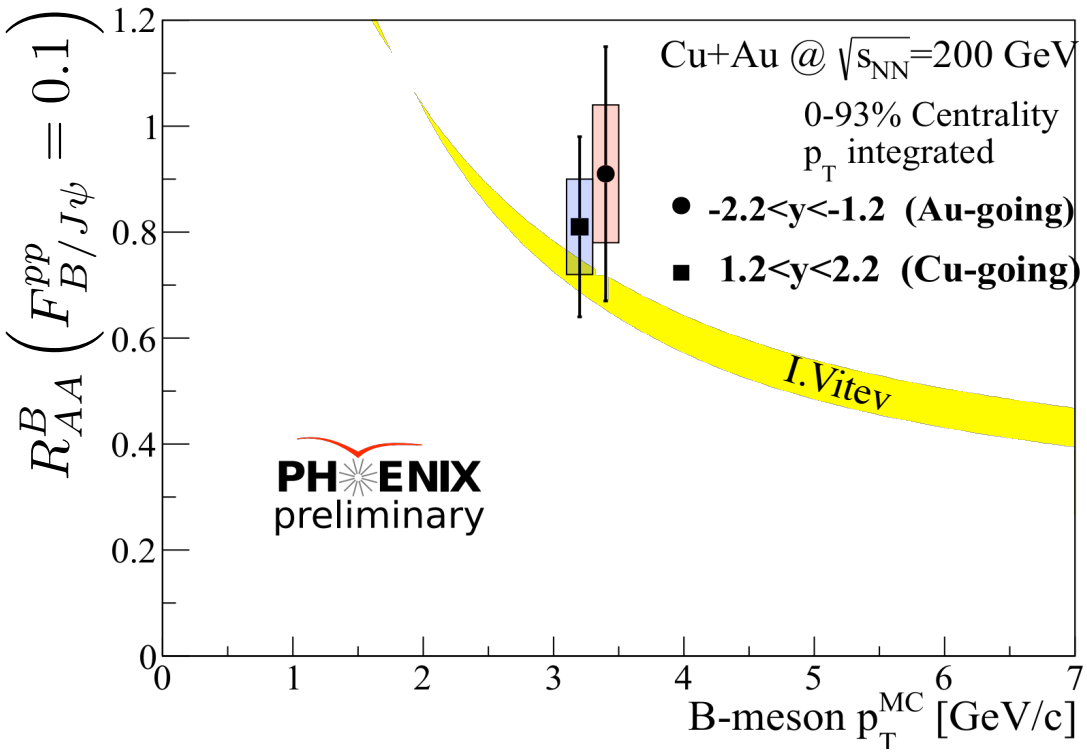
THE END

pp Spectra


25.8 pb^{-1} (5.02 TeV pp)
CMS Preliminary
Data
FONLL pp ref.
|y| < 2.4
Global uncert. 12.4%
CMS
NEW RESULT
HP16
dσ / dp$_T$(pb GeV^{-1}c)
Data / FONLL
p$_T$ (GeV/c)


ATLAS Preliminary
pp, √s = 5.02 TeV
L$_{int}^{pp}$ = 25 pb^{-1}
pPb, √s$_{NN}$ = 5.02 TeV
L$_{int}^{pPb}$ = 25 nb^{-1}
-2.0<y*<1.5
1/(2πp$_T$) d^{2}σ/(dy dp$_T$) [mb GeV^{-2}]
pp
pPb/⟨T$_{pPb}$⟩
0-10% × 10^{-2}
20-30% × 10^{-4}
60-90% × 10^{-6}
p$_T$ [GeV]
Ratios
p$_T^B$ [GeV]

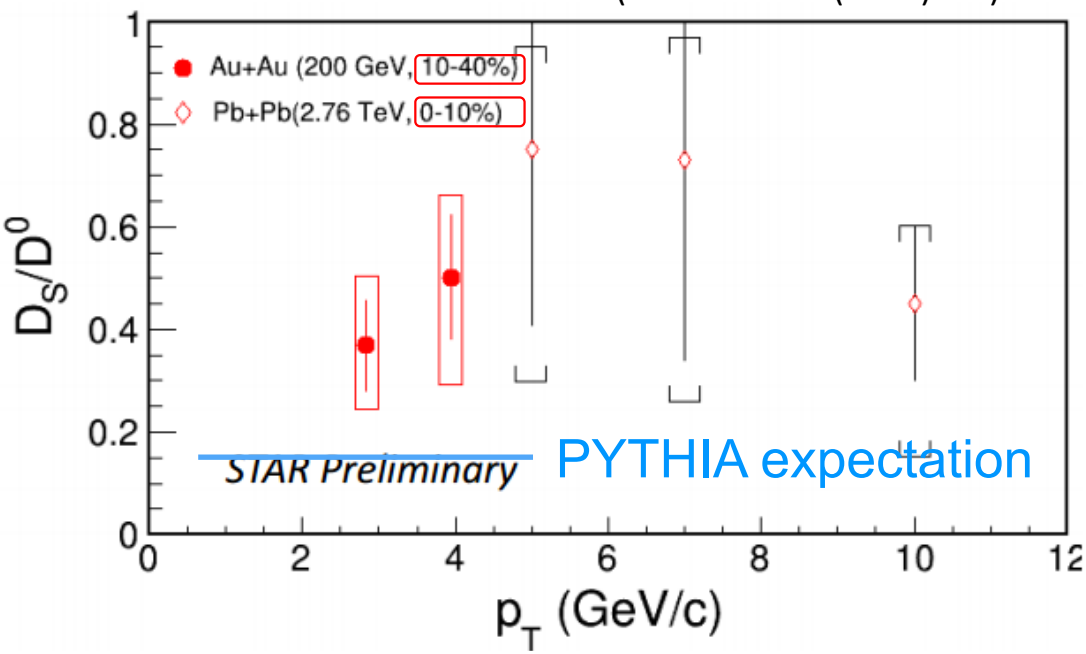
B suppression at RHIC



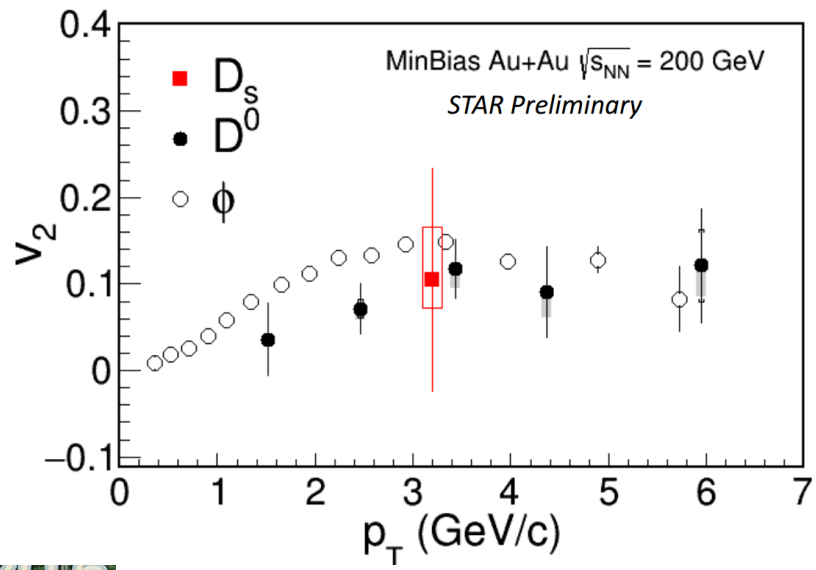
No suppression in Cu+Au for B-meson in foward or backward region at low p_T

D_s in A+A

Pb+Pb (ALICE:JHEP03(2016)082)

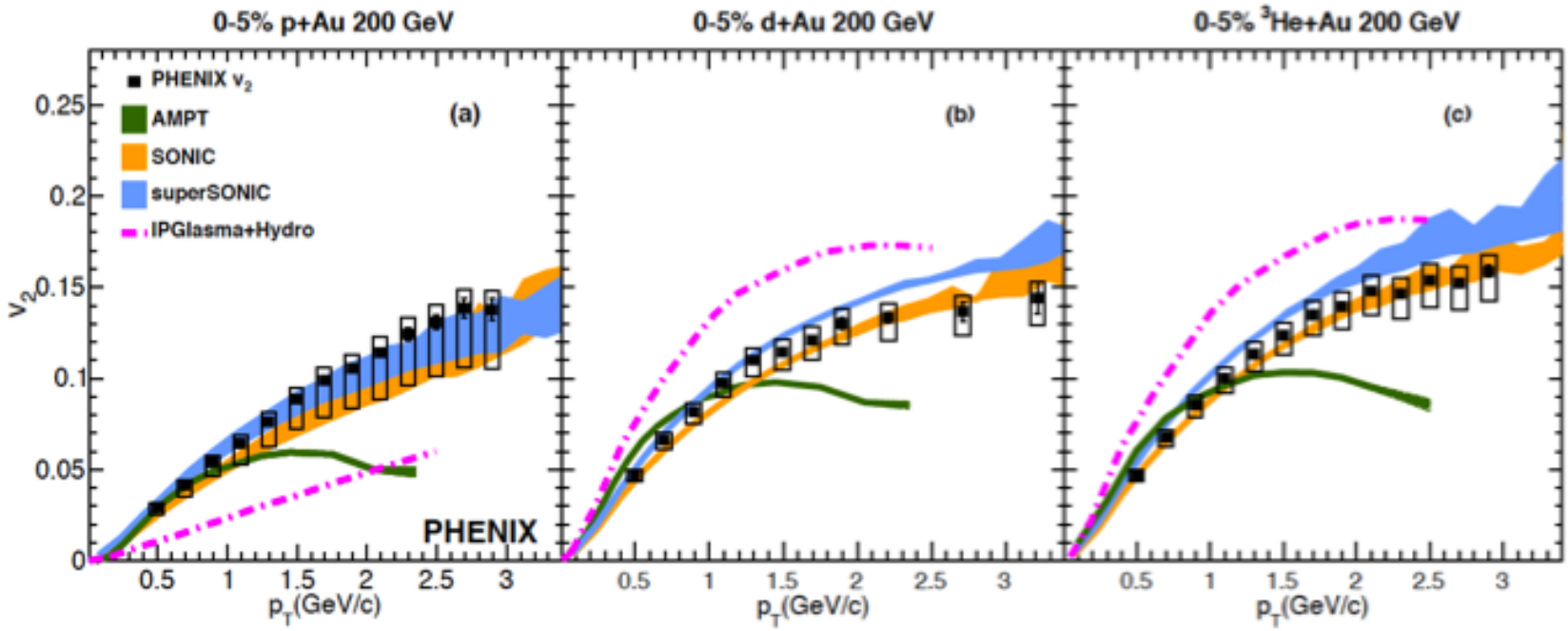


Ratio enhanced compared to pp at RHIC and the LHC

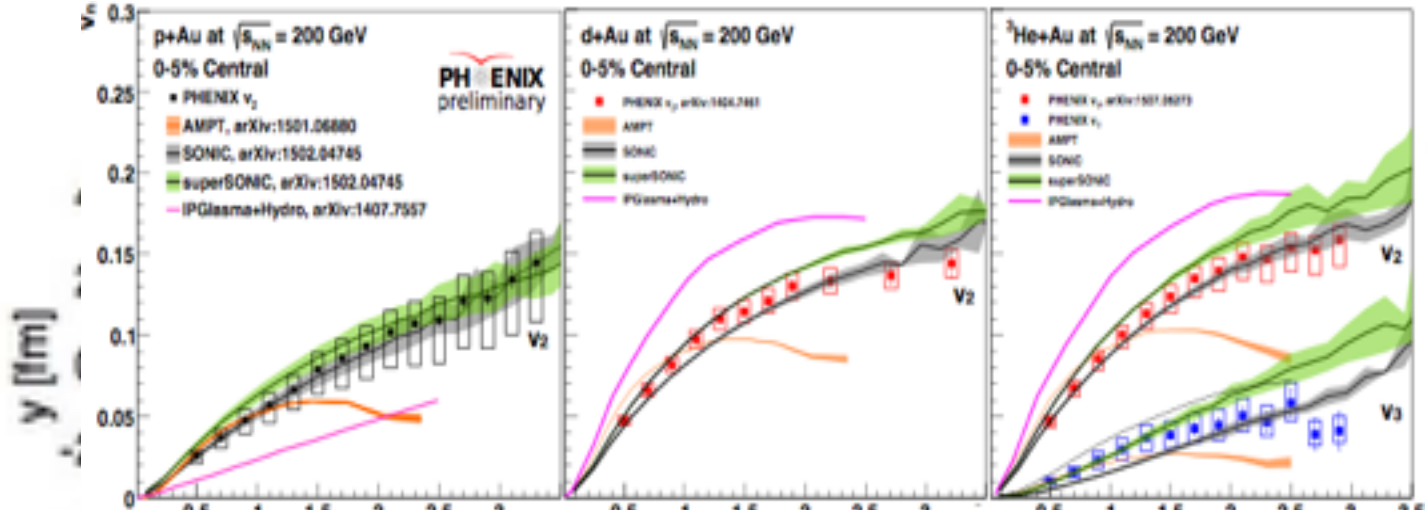


D_s v_2 at RHIC

v_n behavior in asymmetric systems

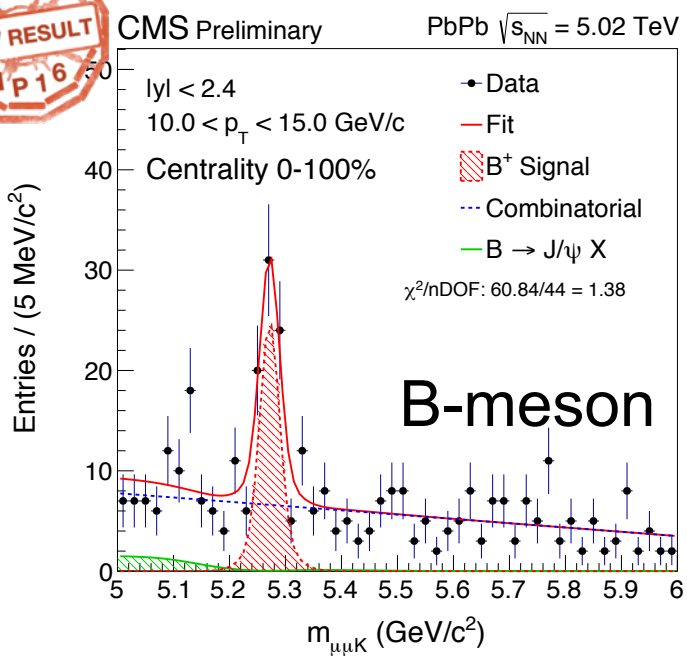


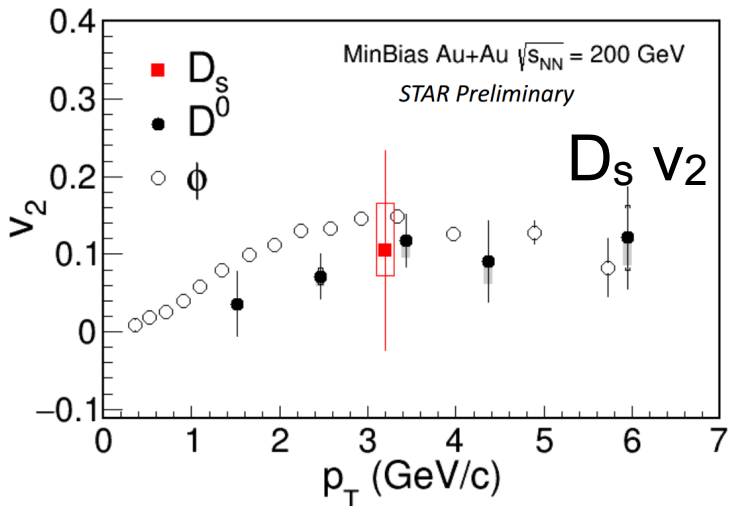
v_2 in high multiplicity p+Au

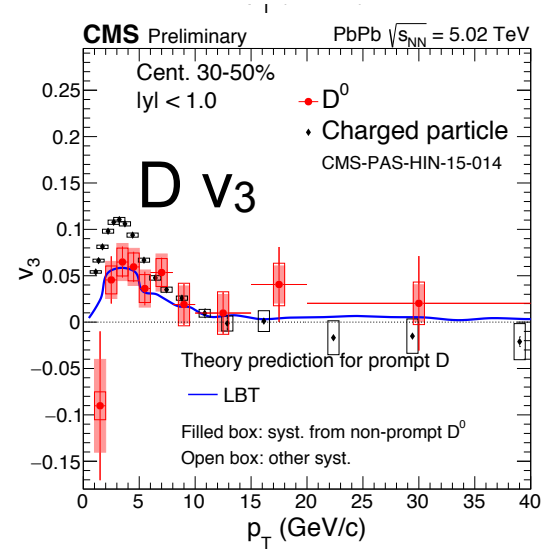


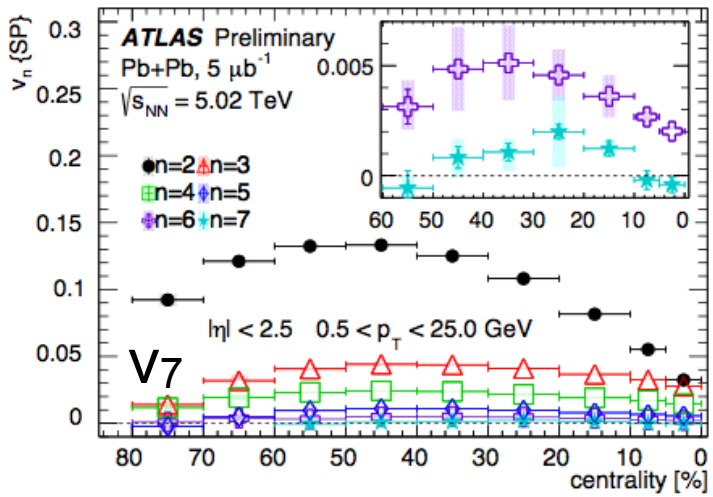
First time measured - HP scoops

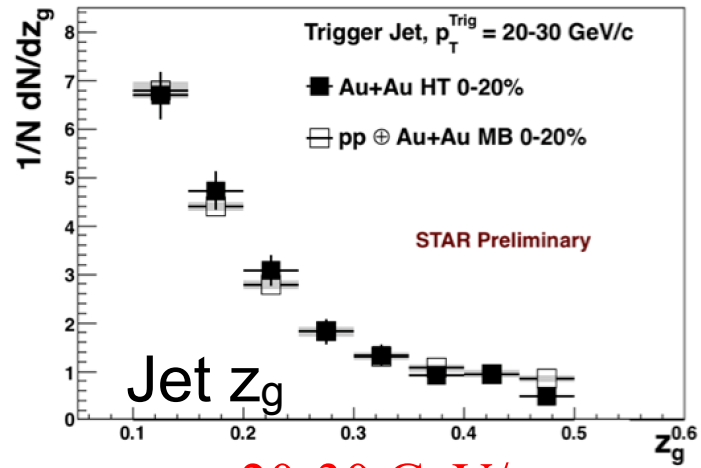
PbPb 5TeV











20-30 GeV/c