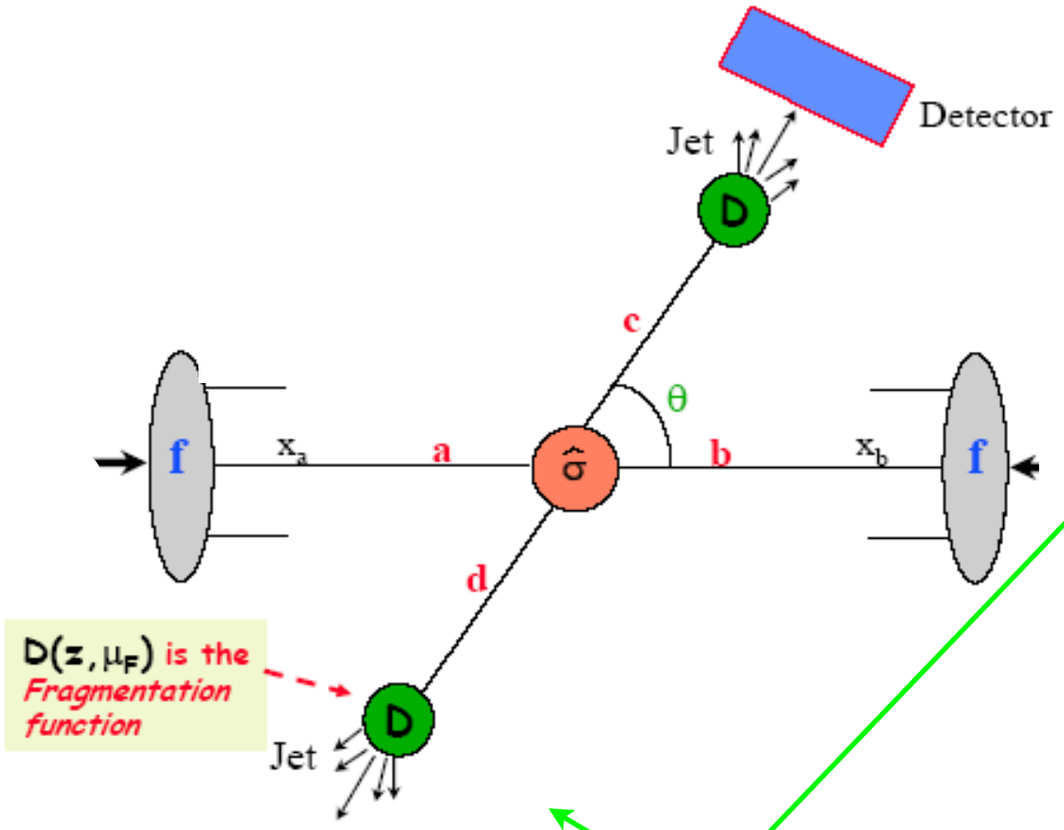
Open heavy flavor production via semi-leptonic decayed muons in Pb+Pb collisions with the ATLAS detector

Yujiao Chen on behalf of the ATLAS Collaboration

COLUMBIA UNIVERSITY

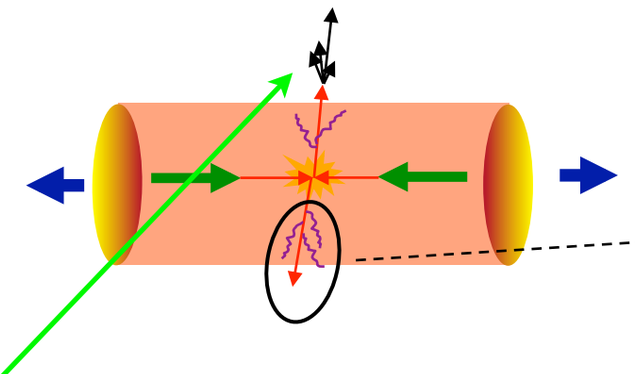
Motivation

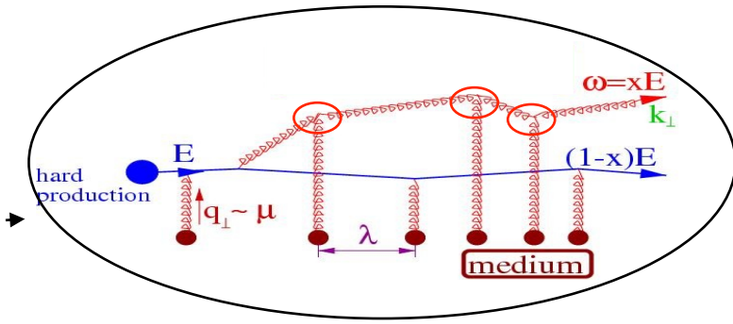
- Study the properties of QGP
- Jet quenching, pQCD framework

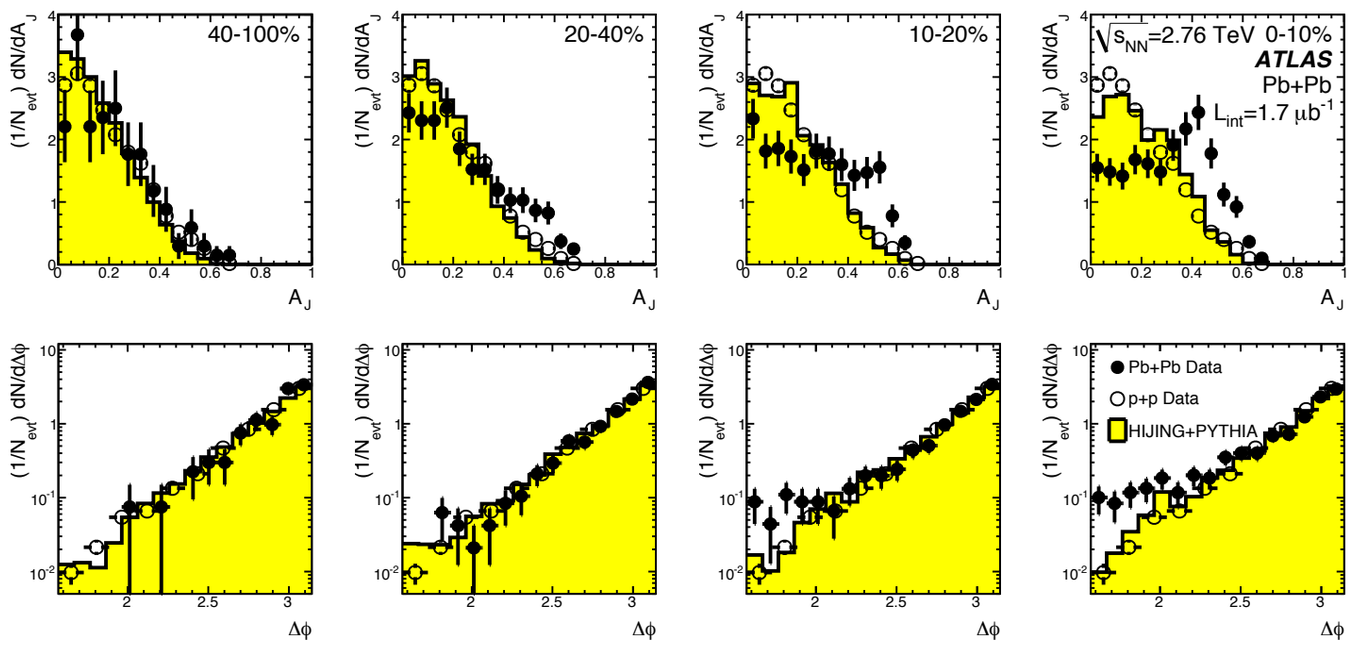


Calculable final state medium effects

Radioactive energy loss in medium

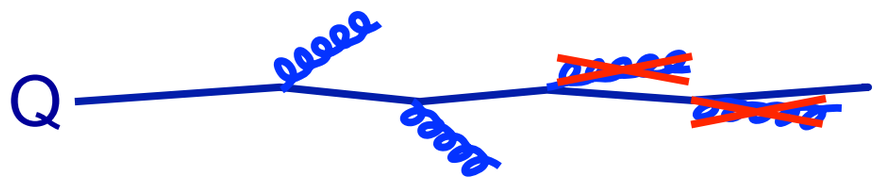






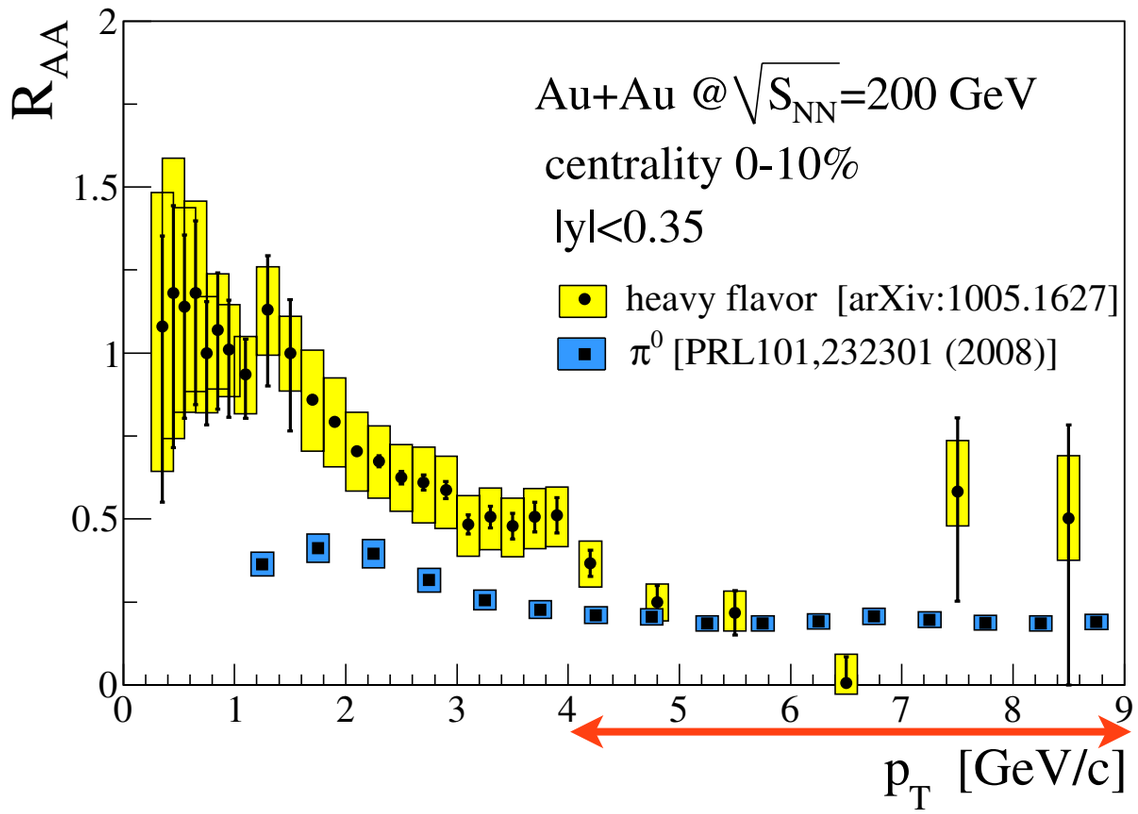
Motivation

- C/B quarks much heavier, pQCD framework
- "Dead cone" effect: gluon radiation suppressed at small angles



Dokshitzer, Khoze, Troyan, JPG 17 (1991) 1602.
Dokshitzer and Kharzeev, PLB 519 (2001) 199.

- Leptons from heavy flavor decays
  - PHENIX,STAR@RHIC with electrons

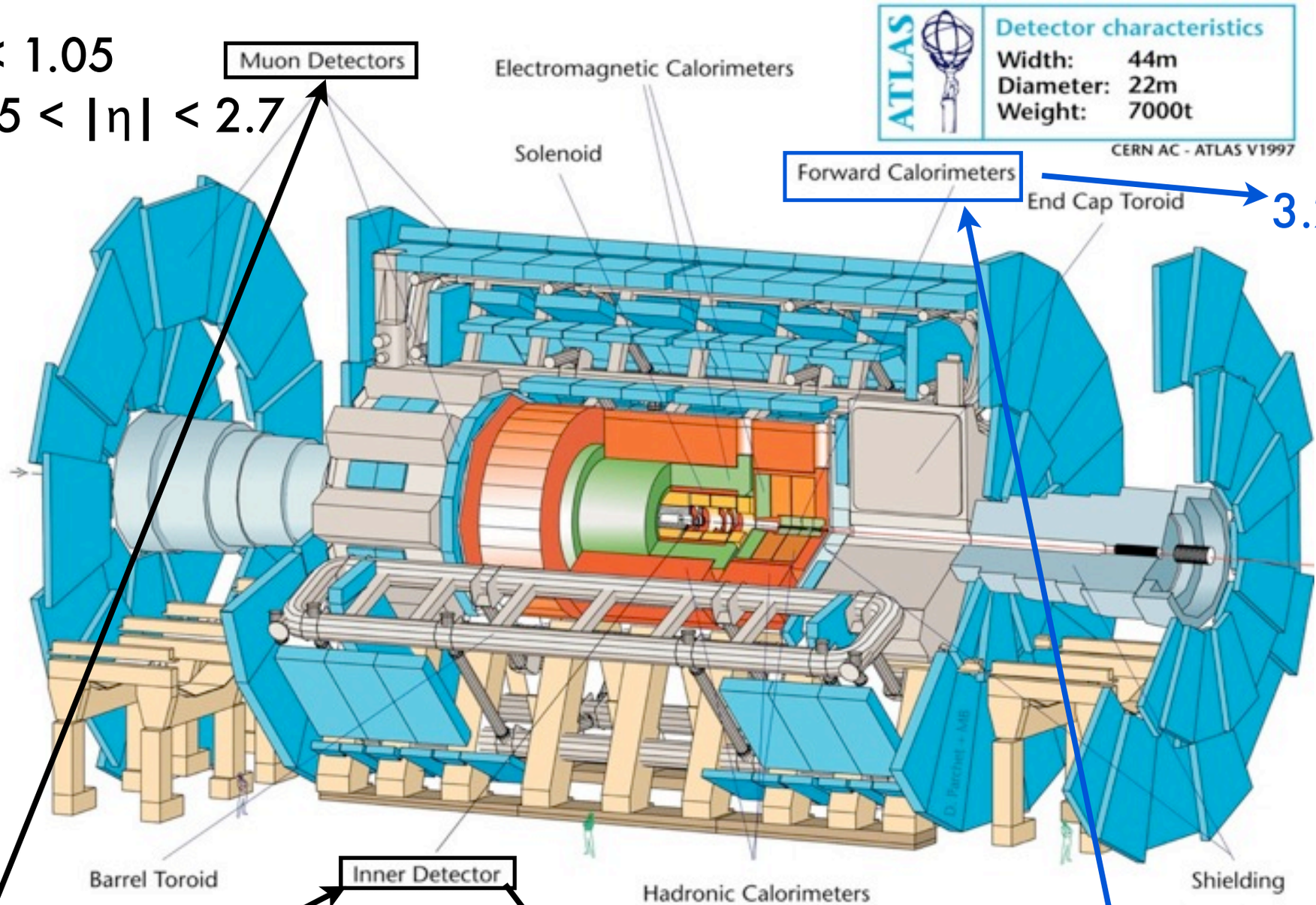


- Heavy flavor suppression at RHIC shows similar behavior as single hadron measurement. How about at LHC?

The ATLAS detector

Barrel: $|\eta| < 1.05$

End cap: $1.05 < |\eta| < 2.7$



$3.2 < |\eta| < 4.9$

Pixel,SCT,TRT

$|\eta| < 2.5$

Centrality determination

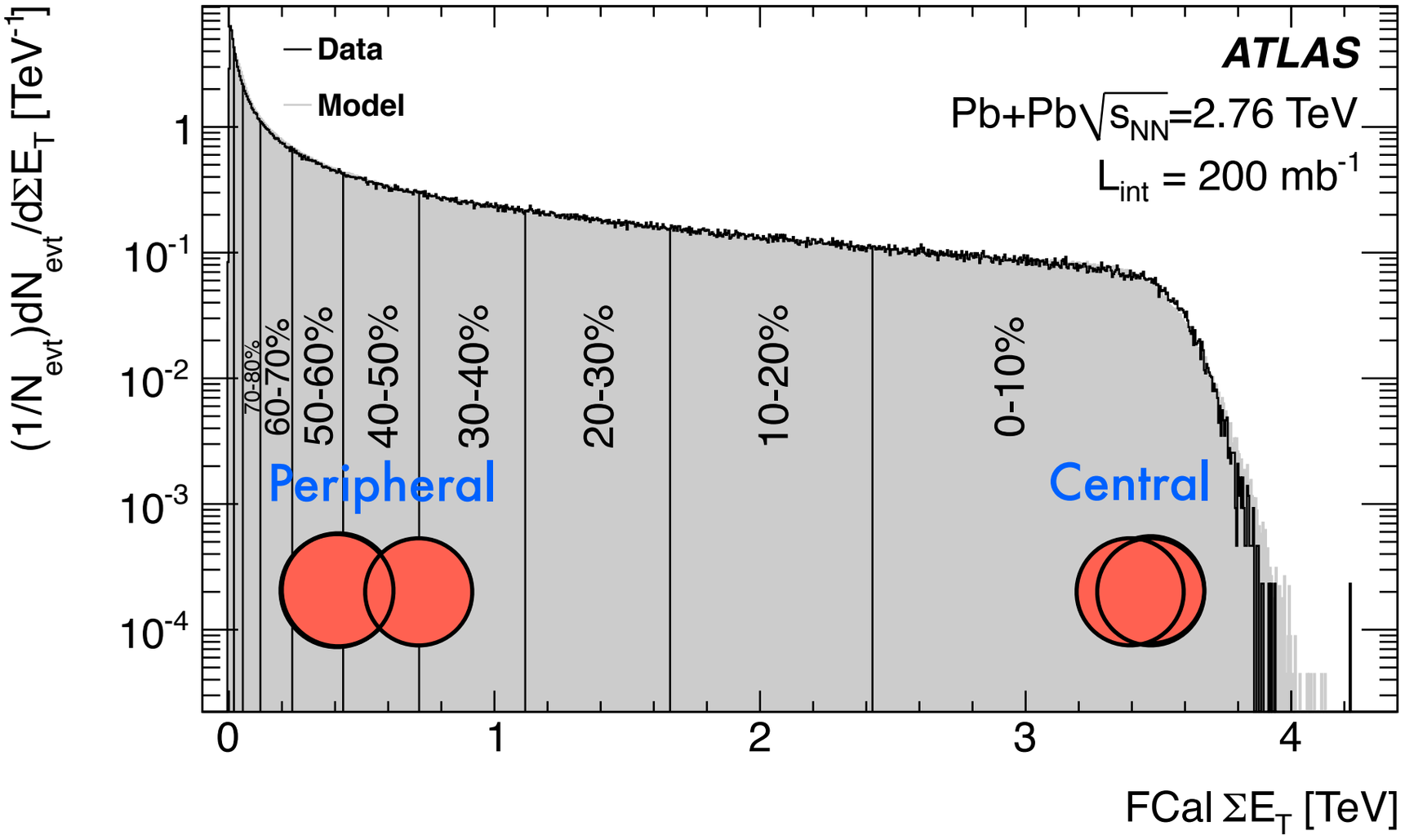
Muon measurement

Data and MC samples

- Data, 2010 Pb+Pb collisions at 2.76 TeV, 7 μb^{-1}
- MC, Di-jet J1,J2,J3,J4,J5 overlayed with HIJING
- Event selection:
  - Good lumi block, ZDC_AND or ZDC_A_C trigger
  - Δt_{MBTS}<3 ns, a primary vertex
- 53236871 events are selected.
- MinBias sample, no trigger on muons
- Select good quality muons, $|\eta|<1.05$ and $4 < p_T < 14$ GeV.
- Characterize centrality with forward calorimeter transverse energy

Centrality determination

Use forward calorimeter transverse energy



Sampling fraction: 98±2%

Discriminant to separate muon source

- Discriminant I: momentum balance

$$\frac{\Delta p_{loss}}{p_{ID}} = \frac{p_{ID} - p_{MS} - p_{param}(p_{MC}, \eta, \phi)}{p_{ID}}$$

- Discriminant II: scattering angle significance

$$s_i = q\frac{\Delta\phi_i}{\phi_i^{msc}} \qquad S(k) = \frac{1}{\sqrt{n}}(\sum_{i=1}^{k} s_i - \sum_{j=k+1}^{n} s_j)$$

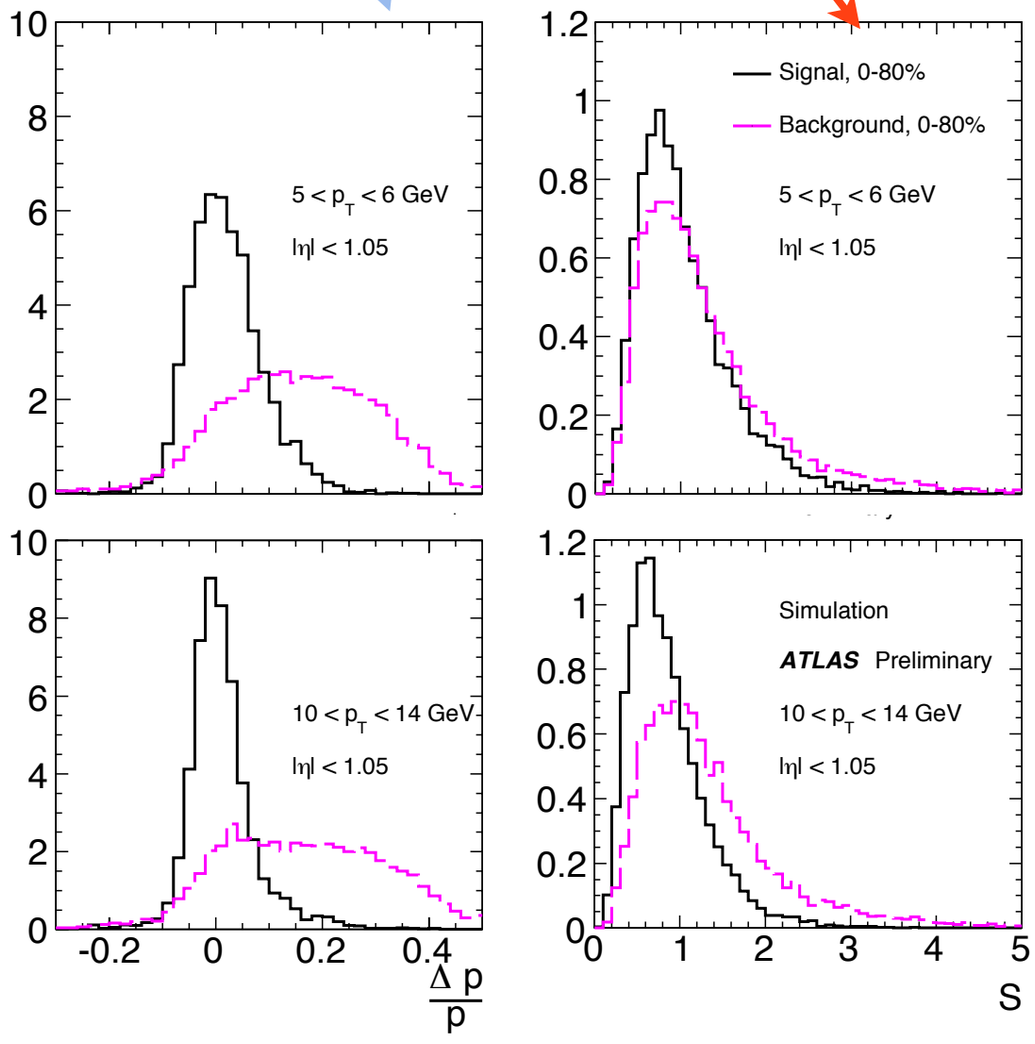
- Composite discriminant

$$c(r) = |\frac{\Delta p_{loss}}{p_{ID}}| + r|S|$$

$$r = 0.07$$

pT

- Momentum balance has more discrimination power, more weight in constructing composite discriminate.
- Discrimination power increases with p_T for both discriminant.

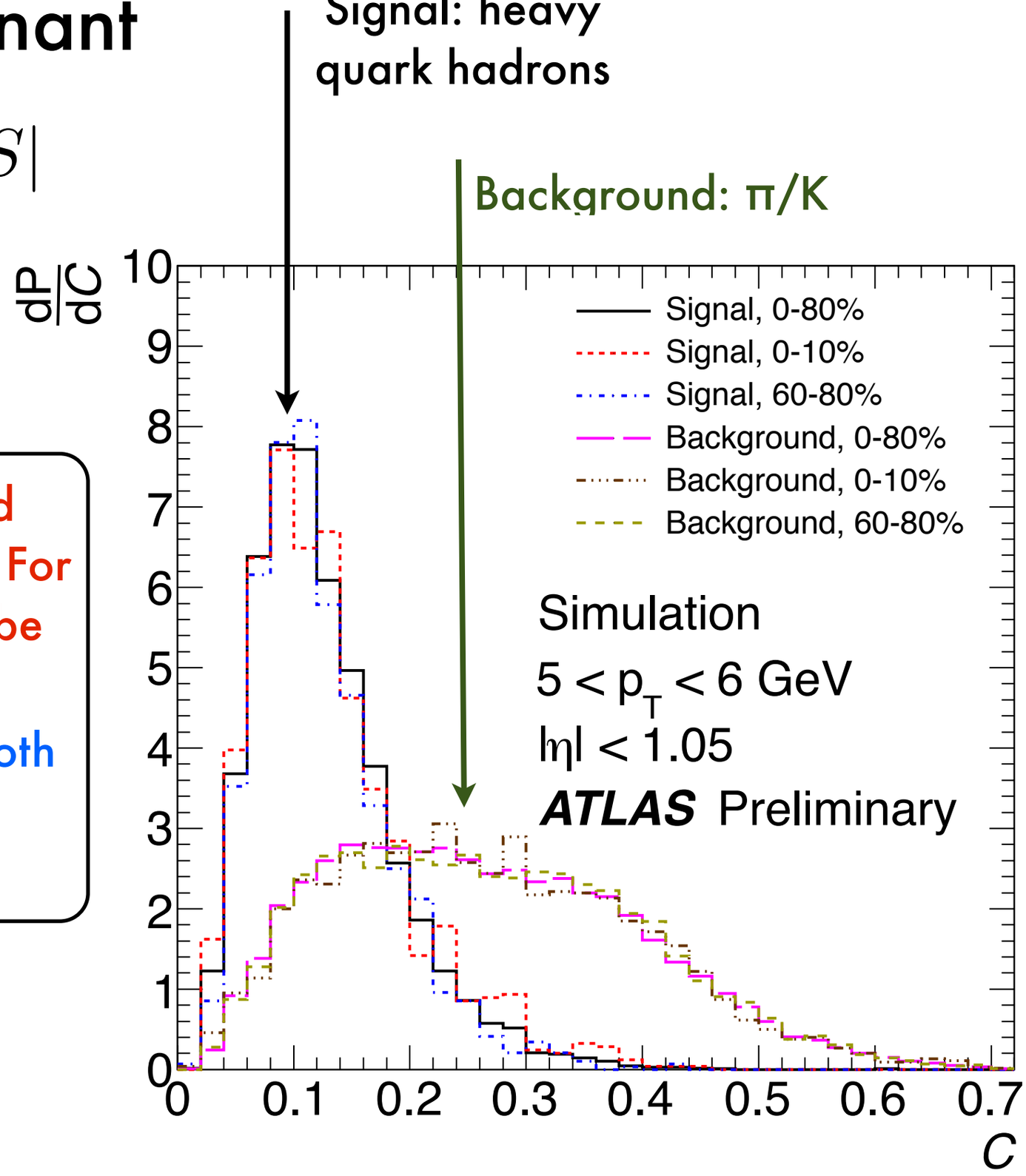


Composite distribution

- **Composite discriminant**

$$c(r) = |\frac{\Delta p_{loss}}{p_{ID}}| + r|S|$$

$$r = 0.07$$



- Very well distinguishable signal and background composite distributions. For data, template fitting technique can be used to separate them statistically.
- No dependence on centrality for both signal and background composite distributions.

Template Fitting

MC templates are built from JX samples by RooFit package which uses kernel estimation method.

Data are modeled by two component templates: signal and background.

$$\frac{dP}{dC} = f_{\mathrm{S}} \left.\frac{dP}{dC}\right|_{\mathrm{S}} + (1 - f_{\mathrm{S}}) \left.\frac{dP}{dC}\right|_{\mathrm{B}}$$

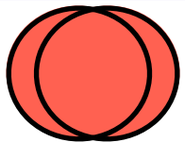
To account for the possible momentum scale shift and momentum resolution worsening in date, we added shift, stretch and smear parameters:

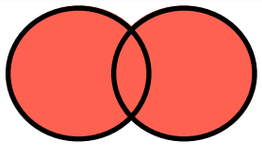
$$C' = a + \langle C \rangle + b\,(C - \langle C \rangle)$$

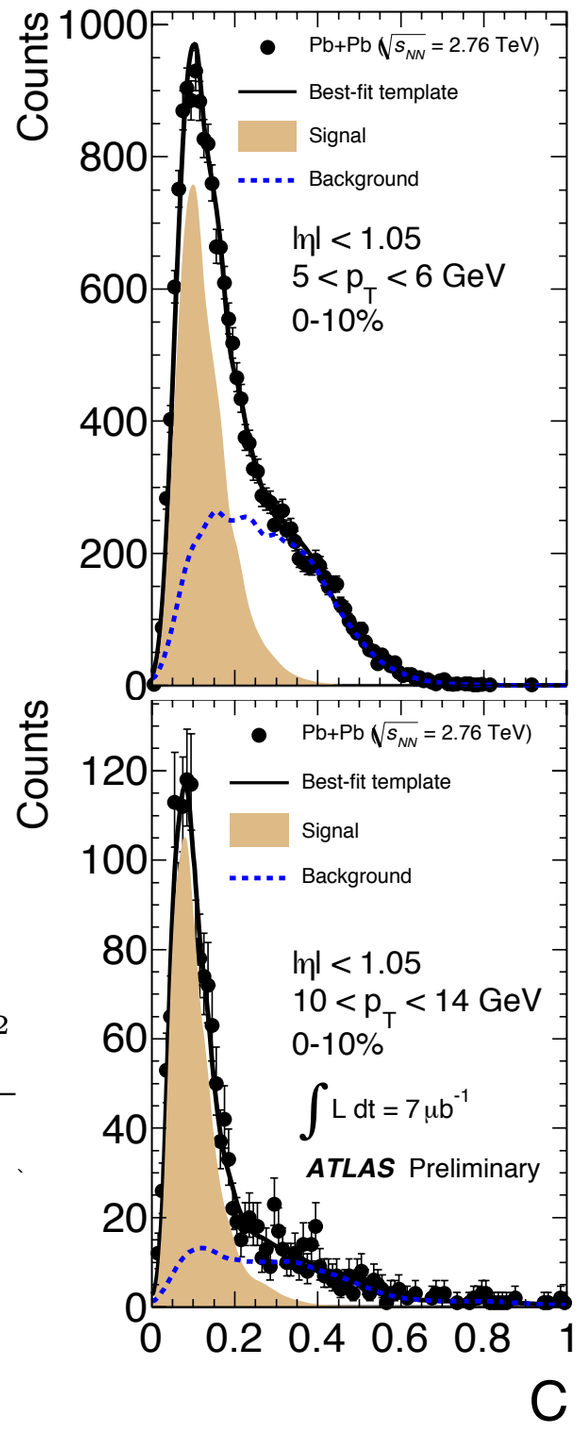
$$\frac{dP'}{dC'} \equiv \left(f_{\mathrm{S}} \left.\frac{dP}{dC'}\right|_{\mathrm{S}} + (1 - f_{\mathrm{S}}) \left.\frac{dP}{dC'}\right|_{\mathrm{B}} \right) \otimes \frac{e^{-C'^2/2\sigma^2}}{\sqrt{2\pi}\sigma}$$

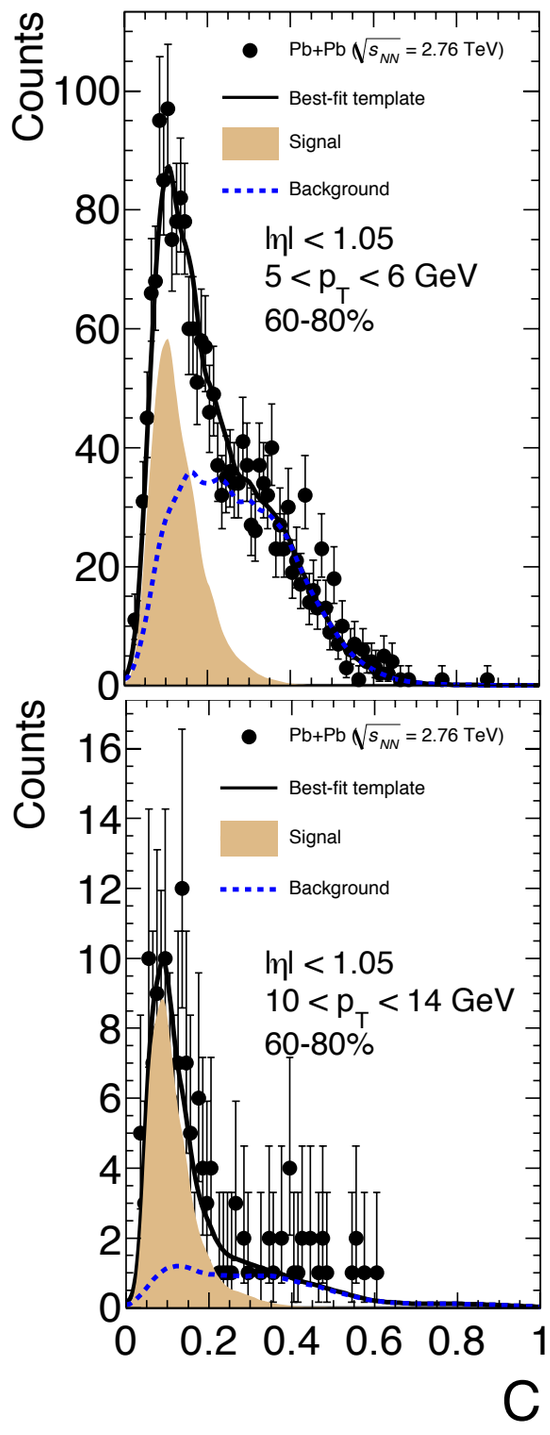
$a \sim 0.02 \quad b \sim 0.95 - 1.05$

$\sigma \sim 0.002$



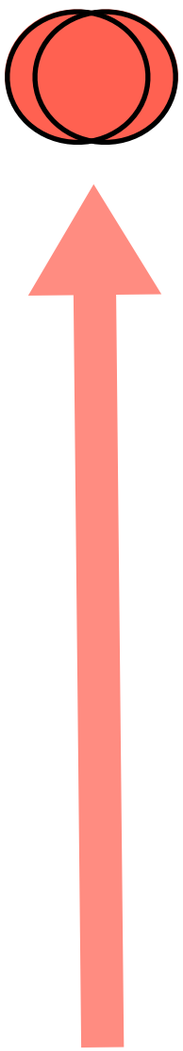


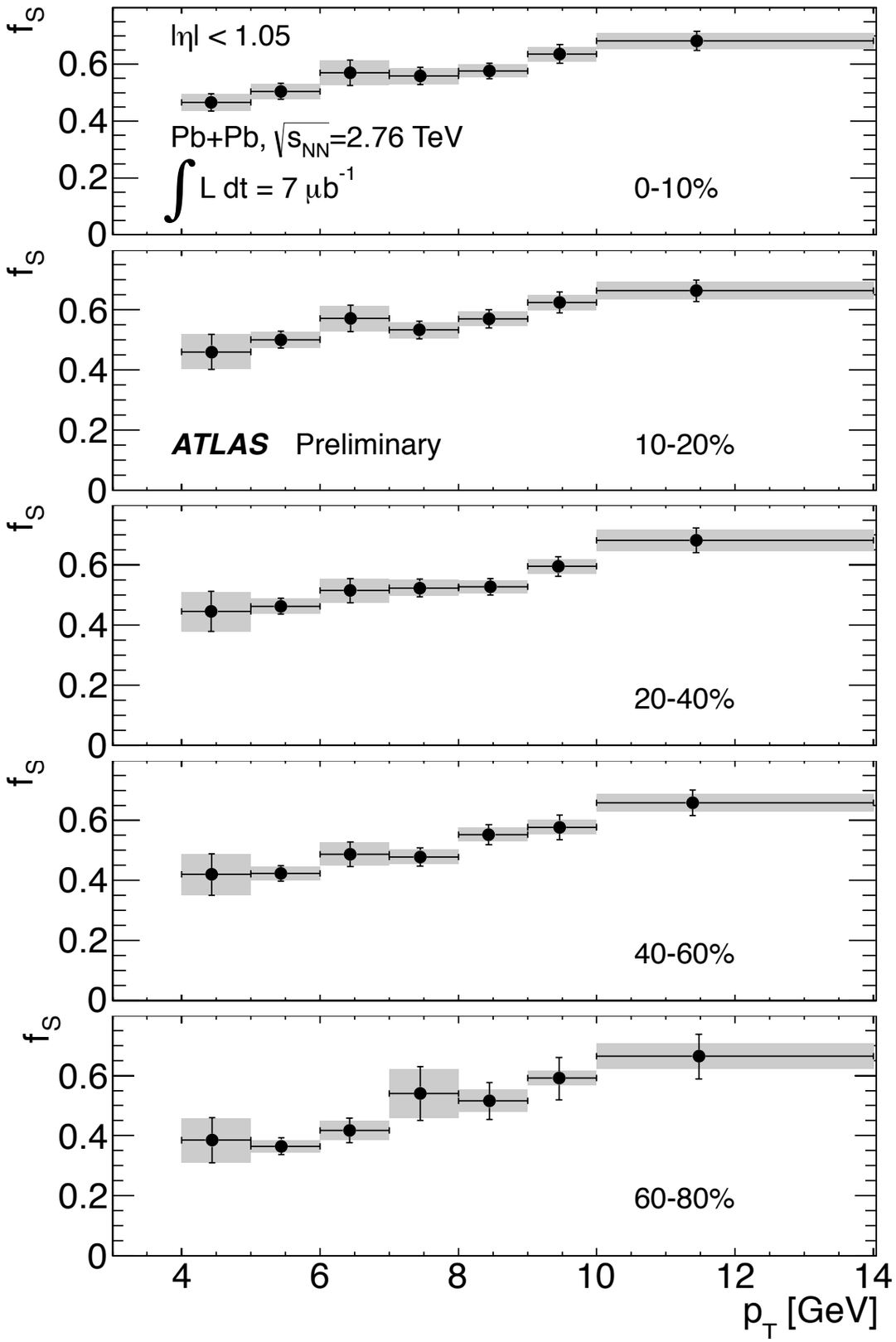


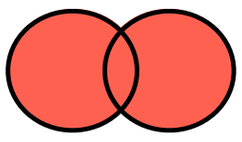


pT

Signal ratio: fraction of muons from HF







Systematic errors shown as shaded areas

Combined errors shown as bars

- f_S increase as a function of p_T.
- f_S increases from peripheral to central collisions, indication of heavy quarks less suppressed in central collisions.

Systematical uncertainties

- Efficiency
- Double π/K composition
- Fitting vs simple cut method
- Fitting with vs without shift, stretch, smear effect

	Uncertainty (%)				
p_T, centrality	dP/dC	Fit	K/π	ε	Total
4 – 5, 0-10%	4	0	5	3	7
7 – 8, 0-10%	5	0.5	0.5	2	5.5
10 – 14, 0-10%	4	1	1	2	5
4 – 5, 60-80%	18	1	5	3	19
7 – 8, 60-80%	14	5	0.5	2	15
10 – 14, 60-80%	4	4	2	2	6

From signal ratio to R_{cp}

$$R_{\mathrm{CP}}(p_{\mathrm{T}})|_{\mathrm{cent}} = \frac{1}{R_{\mathrm{coll}}^{\mathrm{cent}}} \left(\frac{\frac{1}{N_{\mathrm{evt}}^{\mathrm{cent}}} \frac{N_{\mathrm{S}}^{\mathrm{cent}}}{\varepsilon^{\mathrm{cent}}}}{\frac{1}{N_{\mathrm{evt}}^{60-80}} \frac{N_{\mathrm{S}}^{60-80}}{\varepsilon^{60-80}}} \right)$$

$$R_{coll} = \frac{< N_{coll} >}{< N_{coll} >_{60-80\%}}$$

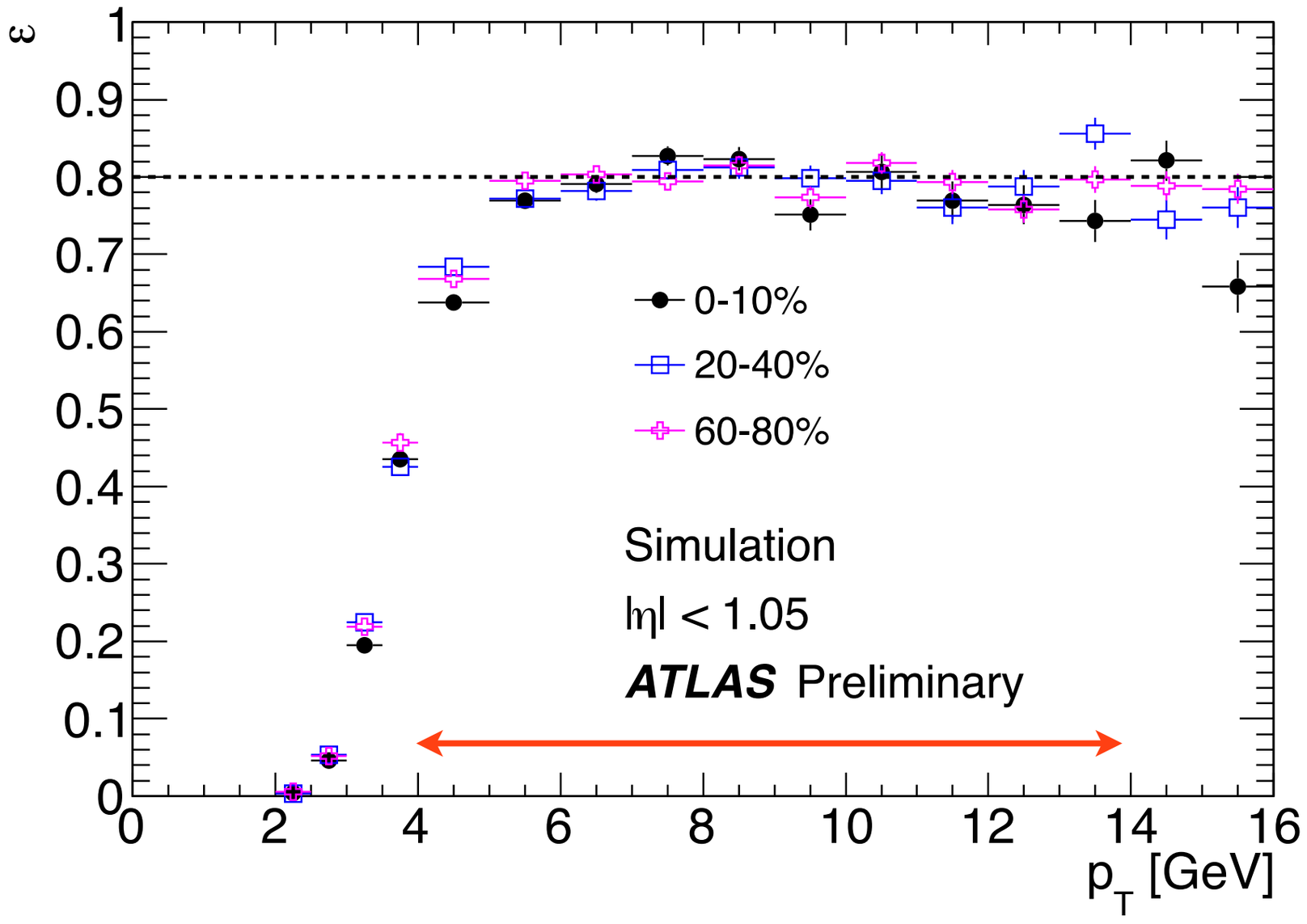
Centrality	R_{coll}	$\langle N_{part} \rangle$
0-10%	56.7 ± 6.2	356.2 ± 2.5
10-20%	34.9 ± 3.5	260.7 ± 3.6
20-40%	16.7 ± 1.5	157.9 ± 3.9
40-60%	4.9 ± 0.2	69.3 ± 3.5
60-80%	1.0	22.6 ± 2.3

60-80% as the reference

Centrality	R_{coll}
0-10%	1.0
10-20%	0.615 ± 0.006
20-40%	0.294 ± 0.009
40-60%	0.086 ± 0.006
60-80%	0.018 ± 0.002

0-10% as the reference

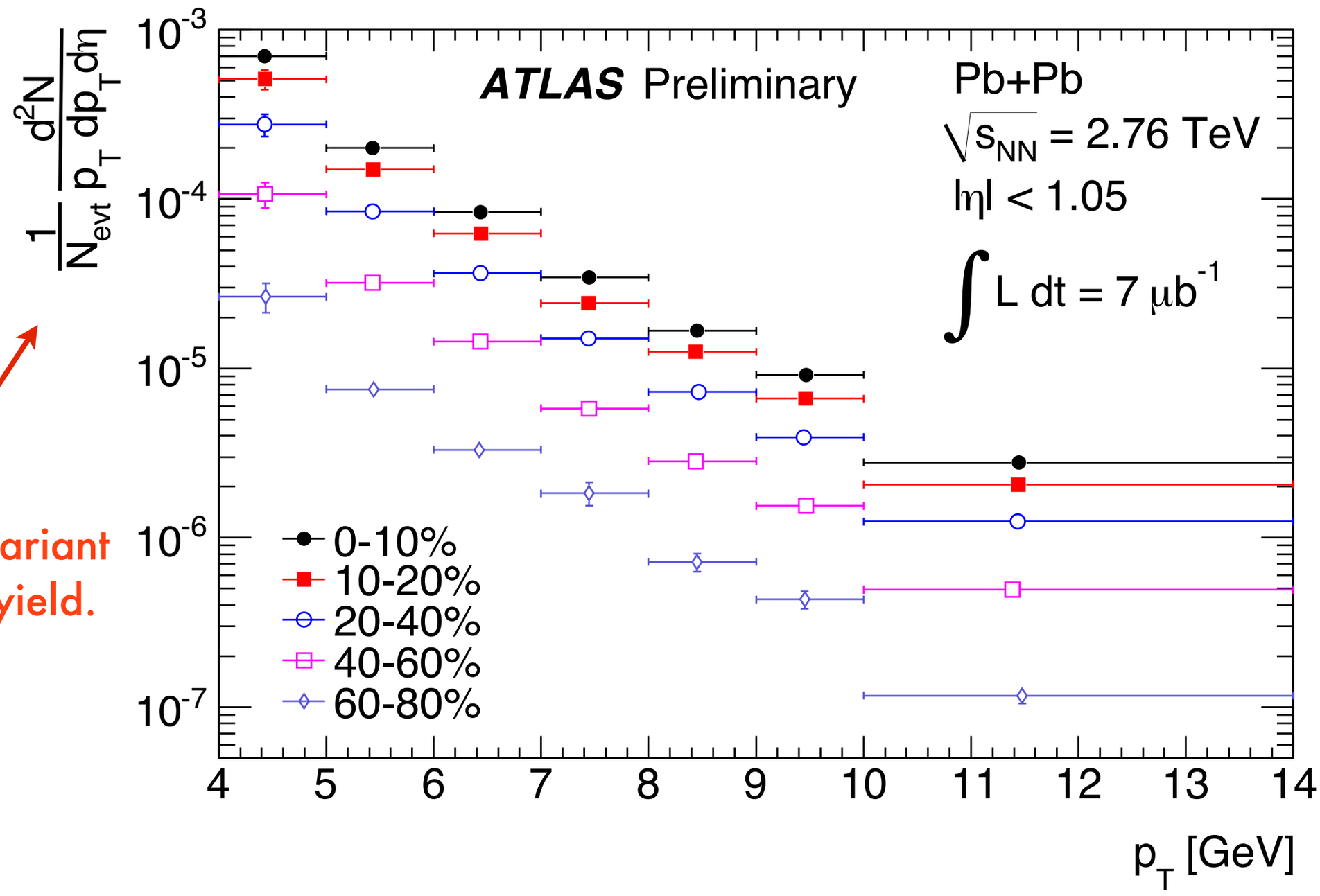
Efficiency



Reach plateau around 5 GeV @ 80%

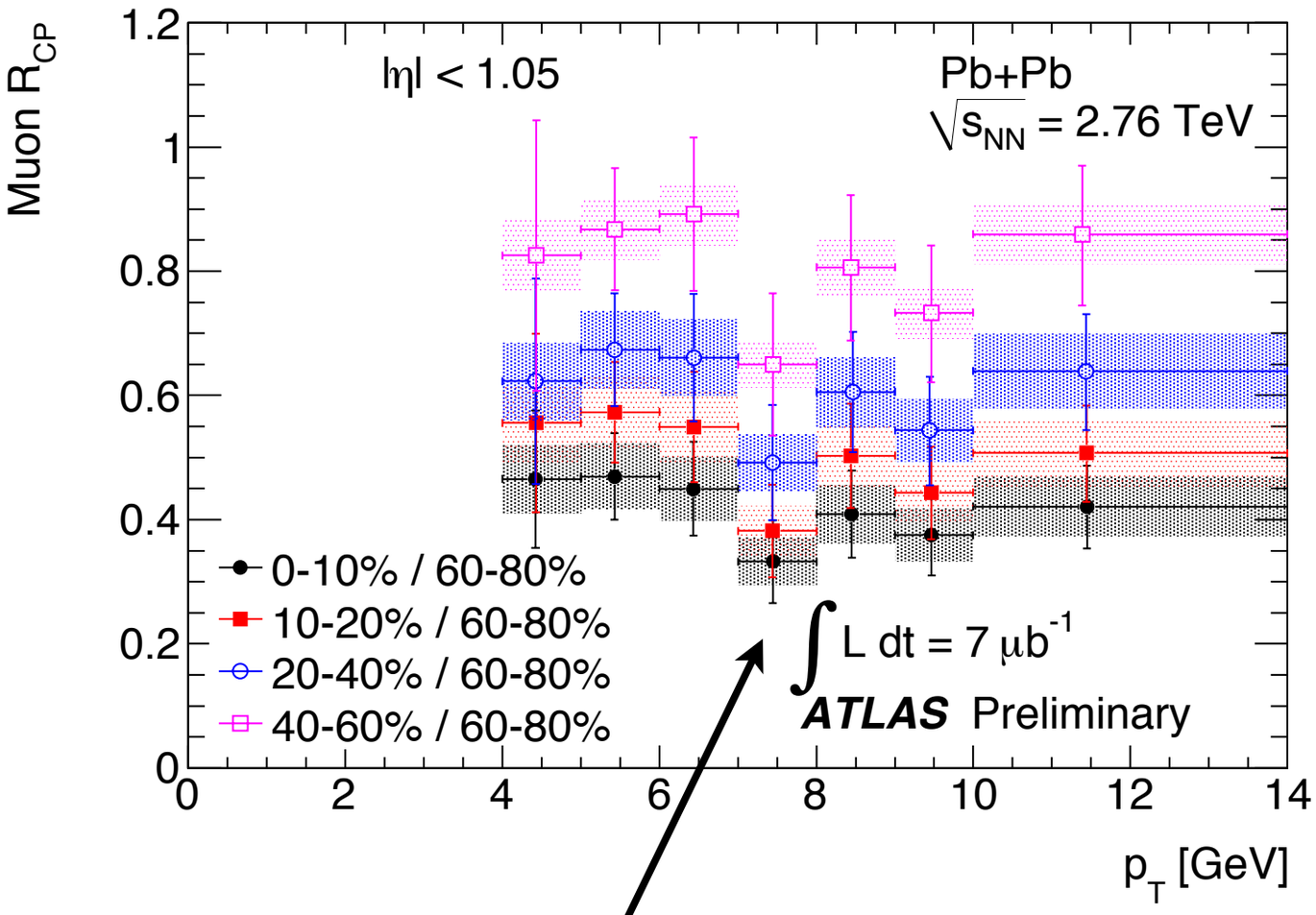
No dependence on centrality at plateau

Signal muon yield

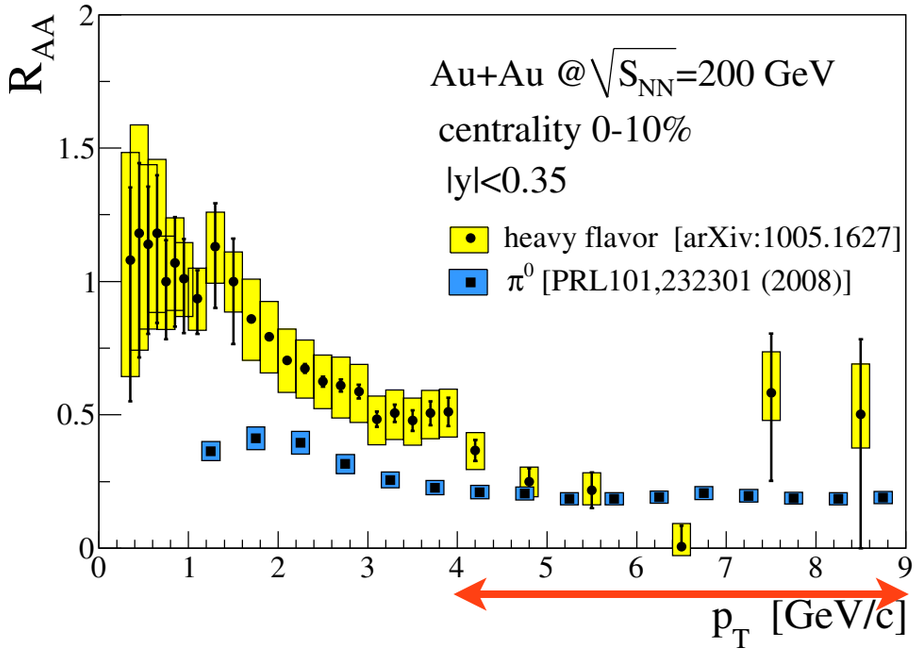


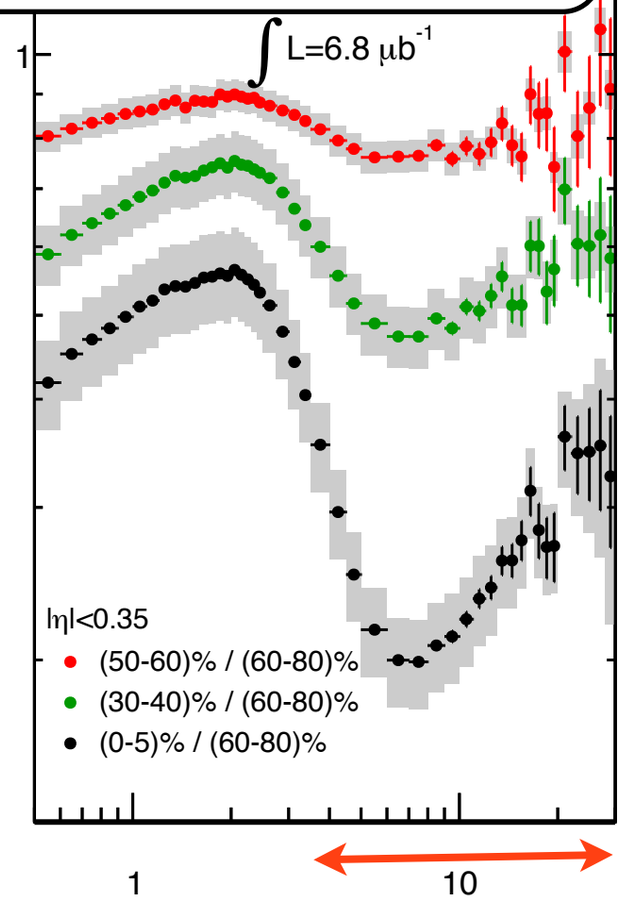
Lorentz invariant per-event yield.

R_{cp} vs p_T



- Rcp is around 0.45 for 0-10% with respect to 60-80%.
- No dependence of R_{cp} on muon p_T.
- Different from RHIC results where heavy flavor and light hadrons R_{AA} have similar suppression behavior.

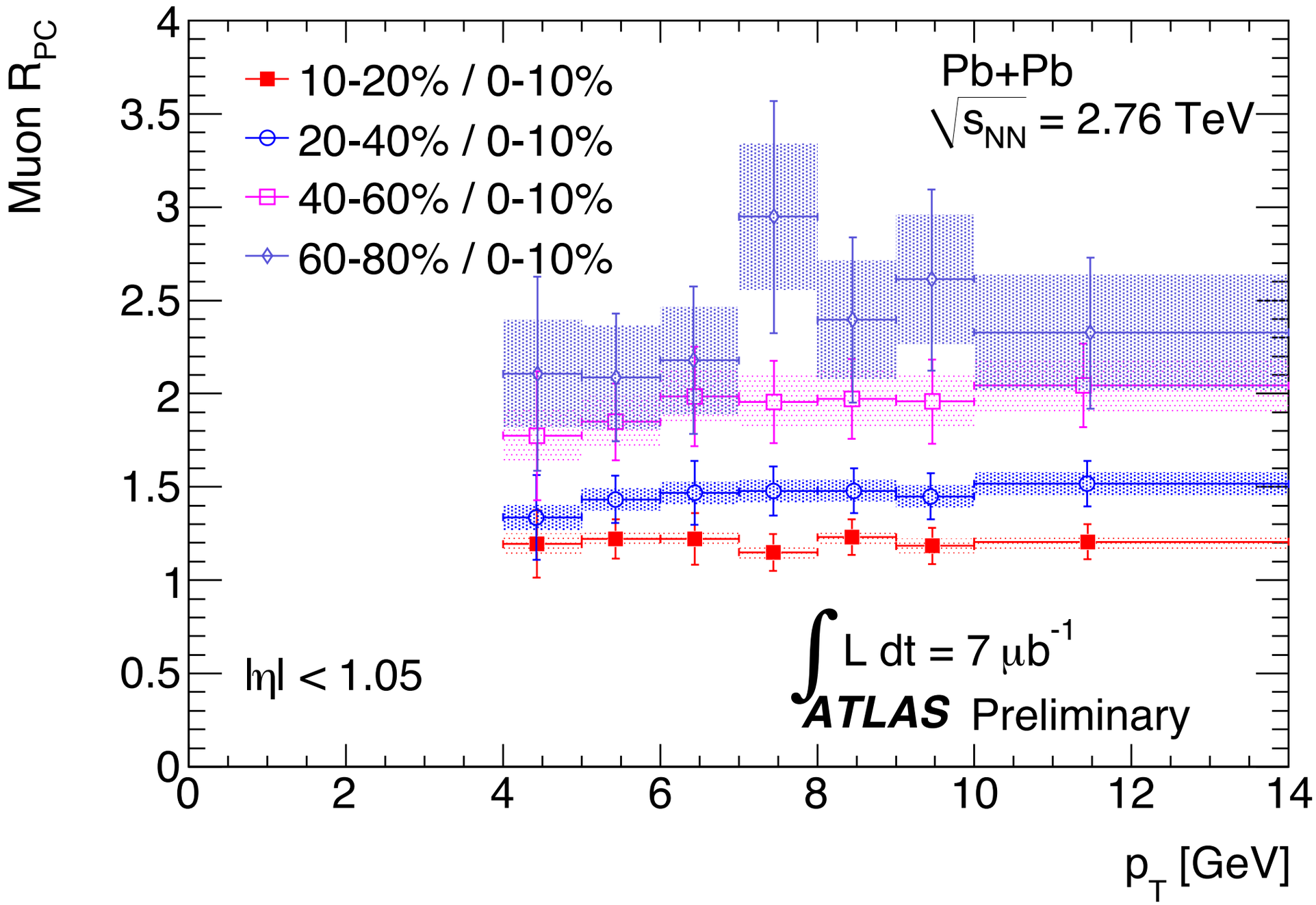




7-8 GeV bin caused by statistical fluctuation of 60-80% centrality.

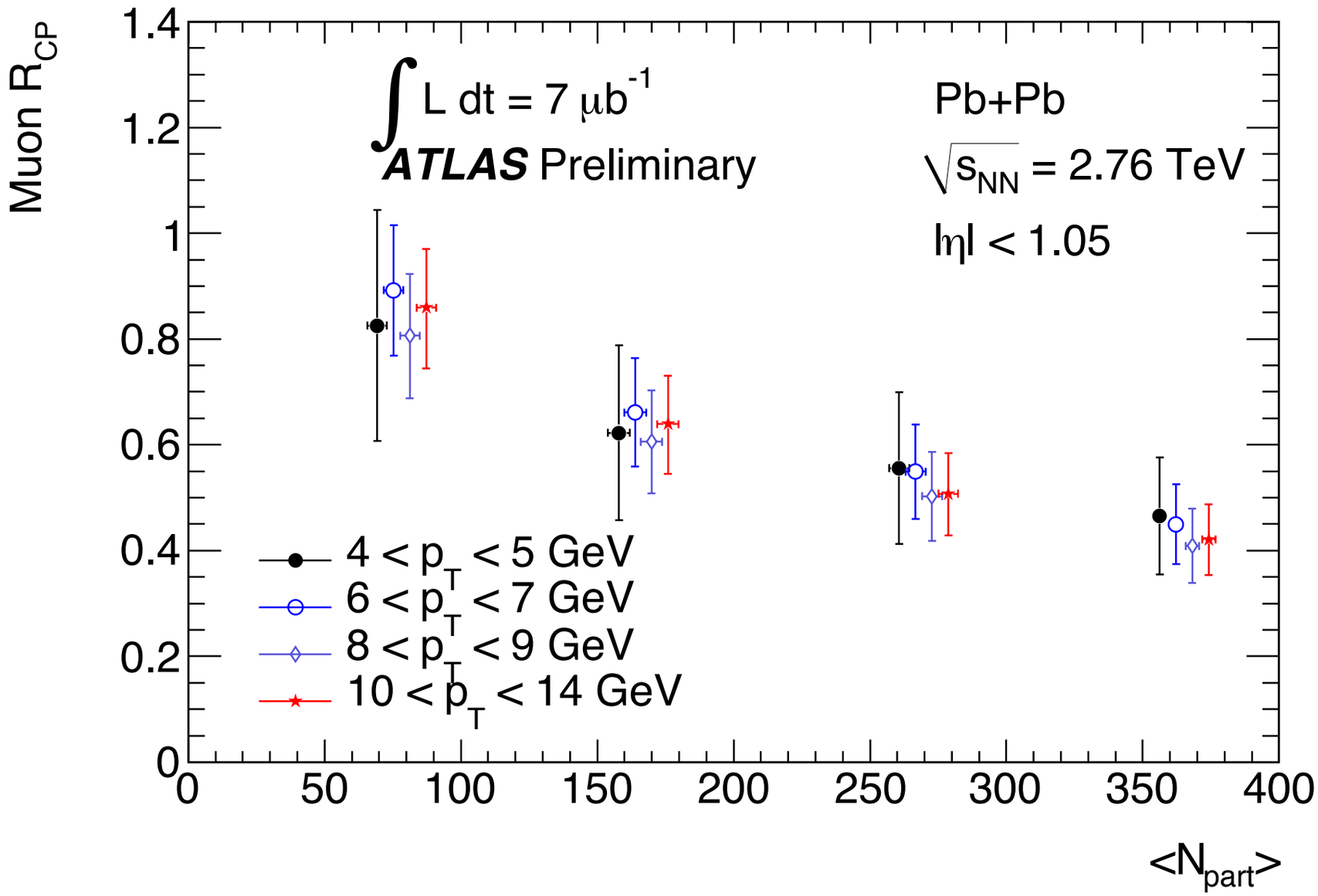
R_{pc} vs p_T

Correlated errors shown as shaded areas



R_{cp} vs $\langle N_{part} \rangle$

x-axis shifted by 6 for each higher p_T bin



- Rcp decreases smoothly from peripheral to central collisions.
- No dependence of R_{cp} on muon p_T in the range studied here.

Conclusions

- Measured muon yield and suppression from heavy quark decays for muons with $4 < p_T < 14$ GeV and $|\eta|<1.05$ in Pb+Pb collisions.
- R_{cp} indicates a factor of about 2 suppression in the yield of 0-10% collisions compared to 60-80% collisions.
- No significant variation of R_{cp} with muon p_T is observed.
- R_{cp} vs $\langle N_{part} \rangle$ shows a smooth suppression from peripheral to central collisions.
- R_{cp} vs p_T shows different behavior as compared with RHIC electron results.

Backup

- Backup

CMS non-prompt J/ψ