

Charged Particle Angular and Momentum Distributions around jets in 5.02 TeV PbPb Collisions measured by ATLAS

Akshat Puri for the ATLAS Collaboration
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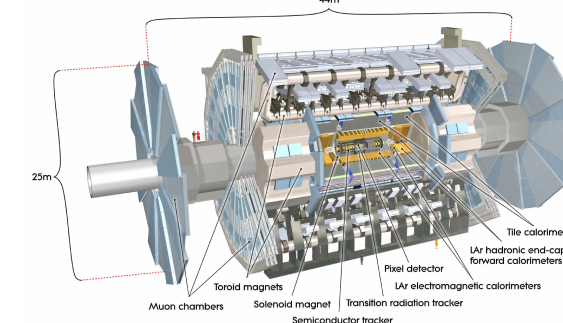
Measurement of angular and momentum distributions of charged particles within and around jets in Pb+Pb and pp collisions at 5.02 TeV with ATLAS at the LHC



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The ATLAS Detector

- This detector is well-suited for jet measurements.
- This measurement uses the calorimeter and tracking system.
- The Pb+Pb data was recorded in 2015 and had an integrated luminosity of 0.49 nb⁻¹.
- The pp data was also recorded in 2015 and had an integrated luminosity of 25 pb⁻¹.



Motivation

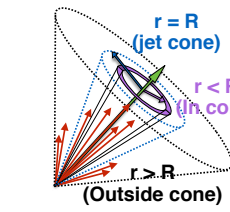
- The Quark Gluon Plasma (QGP) created in Pb+Pb collisions can be probed with jets.
- Inclusive jet production rates are modified in central Pb+Pb collisions compared to pp collisions [2-4].
- Di-jet and photon-jet pairs have unbalanced transverse momentum [5-8].
 - Energy of the parton showering process migrates out of the jet cone.
- This measurement determines the radial distribution of transverse momentum inside and around the jet cone.

Observables

- The charged particle transverse momentum distribution in and around a jet at a distance r , normalized by the number jets and area of the annulus under investigation is measured as [9]:

$$D(p_T, r) = \frac{1}{N_{\text{jet}}} \frac{1}{2\pi r} \frac{d^2 n_{\text{ch}}(r)}{dr dp_T}$$

$$D(p_T) = \frac{1}{N_{\text{jet}}} \frac{dn_{\text{ch}}}{dp_T}$$

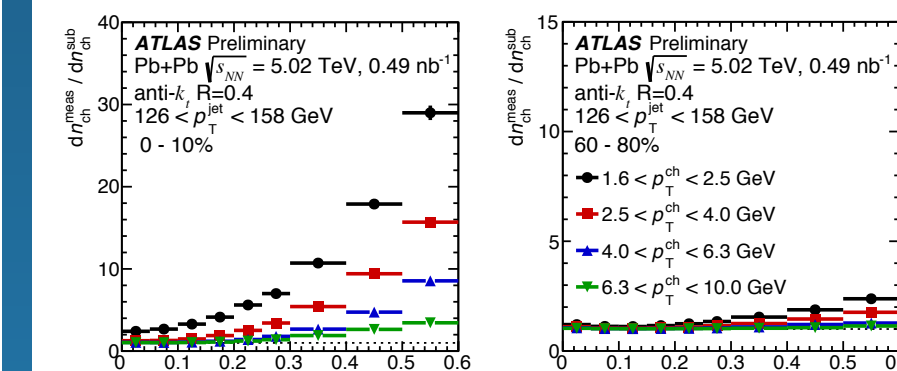


- This quantity can be integrated over the jet cone to give $D(p_T)$, as defined in [10].
- Comparison between Pb+Pb and pp collisions is given as:

$$R_{D(p_T, r)} = \frac{D(p_T, r)_{\text{Pb+Pb}}}{D(p_T, r)_{pp}}$$

Analysis cuts and corrections

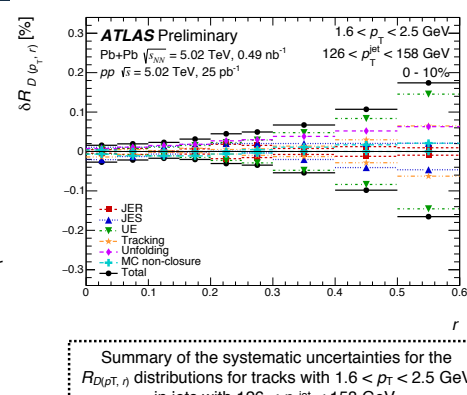
- Analysis cuts:
 - jets: $R = 0.4$, $|y| < 1.3$, $100 < p_T^{\text{jet}} < 400$ GeV
 - charged particles: $|\eta| < 2.5$, $1.6 < p_T < 63$ GeV, within $r < 0.6$ of jet axis
- Corrections:
 - efficiency corrections (η , p_T)
 - underlying event subtraction
 - two dimensional Bayesian Unfolding (in jet and track p_T)
 - jet position resolution correction - Bin by bin unfolding



Comparing the charged particle distributions before and after UE subtraction as a function of r for $126 < p_T^{\text{jet}} < 158$ GeV, in central (left) and peripheral (right) collisions [9].

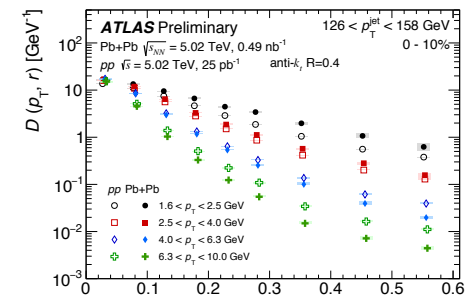
Systematic Uncertainties

- Systematic uncertainties:
 - jet energy scale (2-4%)
 - jet energy resolution (3-5%)
 - underlying event (0-15%)
 - tracking (2-4%)
 - unfolding (5-7%)
 - MC non-closure (1-2%)
 - UE uncertainty dominates at large r and low p_T .

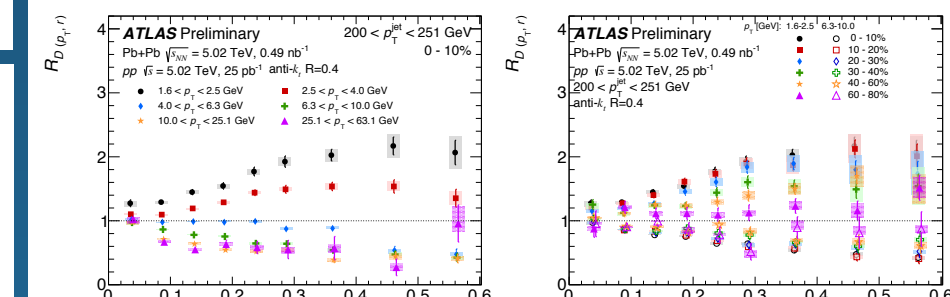


Results

- Centrality dependent modifications to the $D(p_T, r)$ distributions for Pb+Pb collisions are observed.
- Particles with $p_T < 4$ GeV ($p_T > 4$ GeV) in Pb+Pb collisions exhibit broadened (narrowed) $D(p_T, r)$ distributions compared to pp collisions.
- The $D(p_T, r)$ distributions for peripheral Pb+Pb collisions are similar in shape to the pp collisions.
- The $R_{D(p_T, r)}$ distributions increase (decrease) for low (high) p_T particles up to $r < 0.3$, and are constant for $0.3 < r < 0.6$.
- The modifications decrease for more peripheral collisions and $R_{D(p_T, r)}$ goes towards unity for decreasing centrality across the $r < 0.6$ range.
- In the $0.1 < r < 0.3$ range, $R_{D(p_T, r)}$ increases with increasing p_T^{jet} for low p_T particles, with no significant p_T^{jet} dependence seen for high p_T particles.
- These results are consistent with fragmentation function measurements from Ref. [10].
- The $R_{D(p_T, r)}$ distributions (for particles within the jet cone) for tracks with $p_T > 4$ GeV are shown at the bottom right

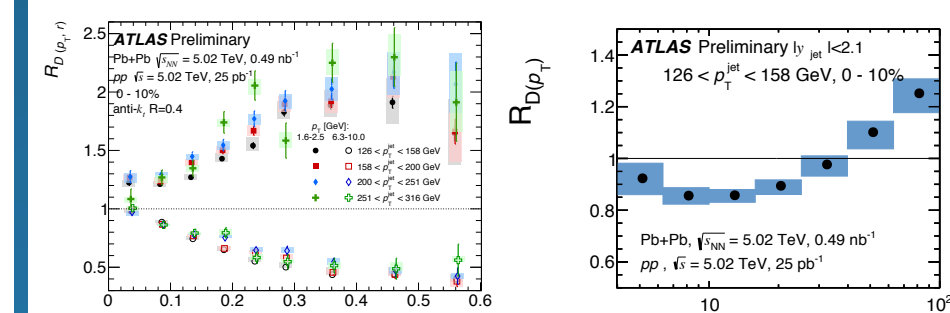


$D(p_T, r)$ for central Pb+Pb (closed points) and pp (open points) as a function of r for different track p_T ranges, for $126 < p_T^{\text{jet}} < 158$ GeV as measured in Ref. [9].



$R_{D(p_T, r)}$ distributions as a function of r for 0-10% central collisions, for $200 < p_T^{\text{jet}} < 251$ GeV as measured in Ref. [9].

$R_{D(p_T, r)}$ distributions as a function of r for low and high p_T tracks, for different centrality selections, for $200 < p_T^{\text{jet}} < 251$ GeV, as measured in Ref. [9].



Left: $R_{D(p_T, r)}$ for low p_T (closed points) and high p_T (open points) particles, for different p_T^{jet} selections as measured in Ref. [9].

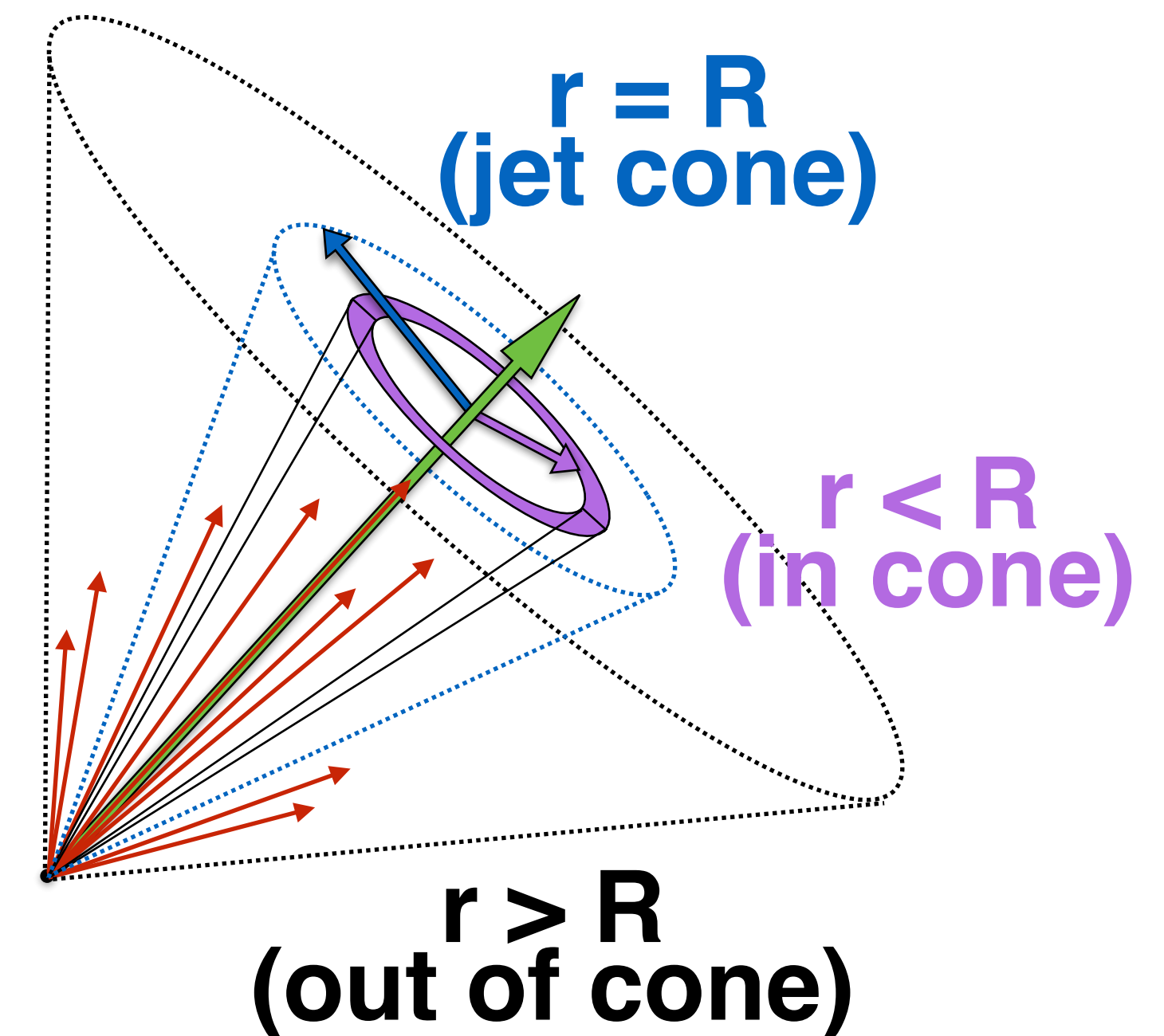
The $R_{D(p_T, r)}$ distribution as a function of p_T , as measured in Ref. [10] for jets in the $126 - 158$ GeV p_T^{jet} range.

Observables

- Density of charged particles in an annulus at a distance r from the jet axis, per unit area per jet
- Reported as a function of track p_T , centrality, and r

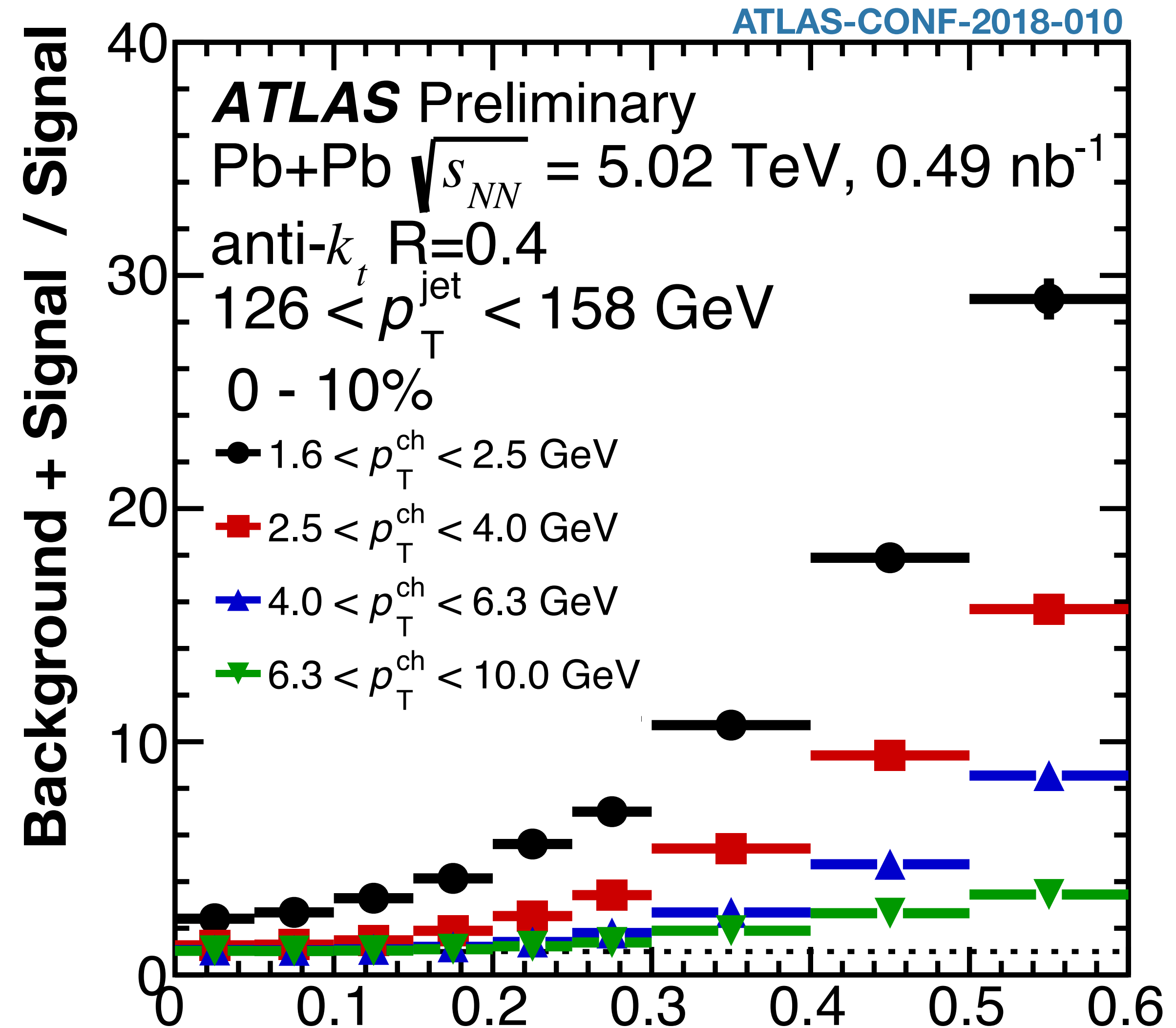
$$D(p_T, r) = \frac{1}{N_{\text{jet}}} \frac{1}{2\pi r} \frac{d^2 n_{\text{ch}}(r)}{dr dp_T}$$

$$R_D(p_T, r) = \frac{D(p_T, r)_{\text{Pb+Pb}}}{D(p_T, r)_{pp}}$$

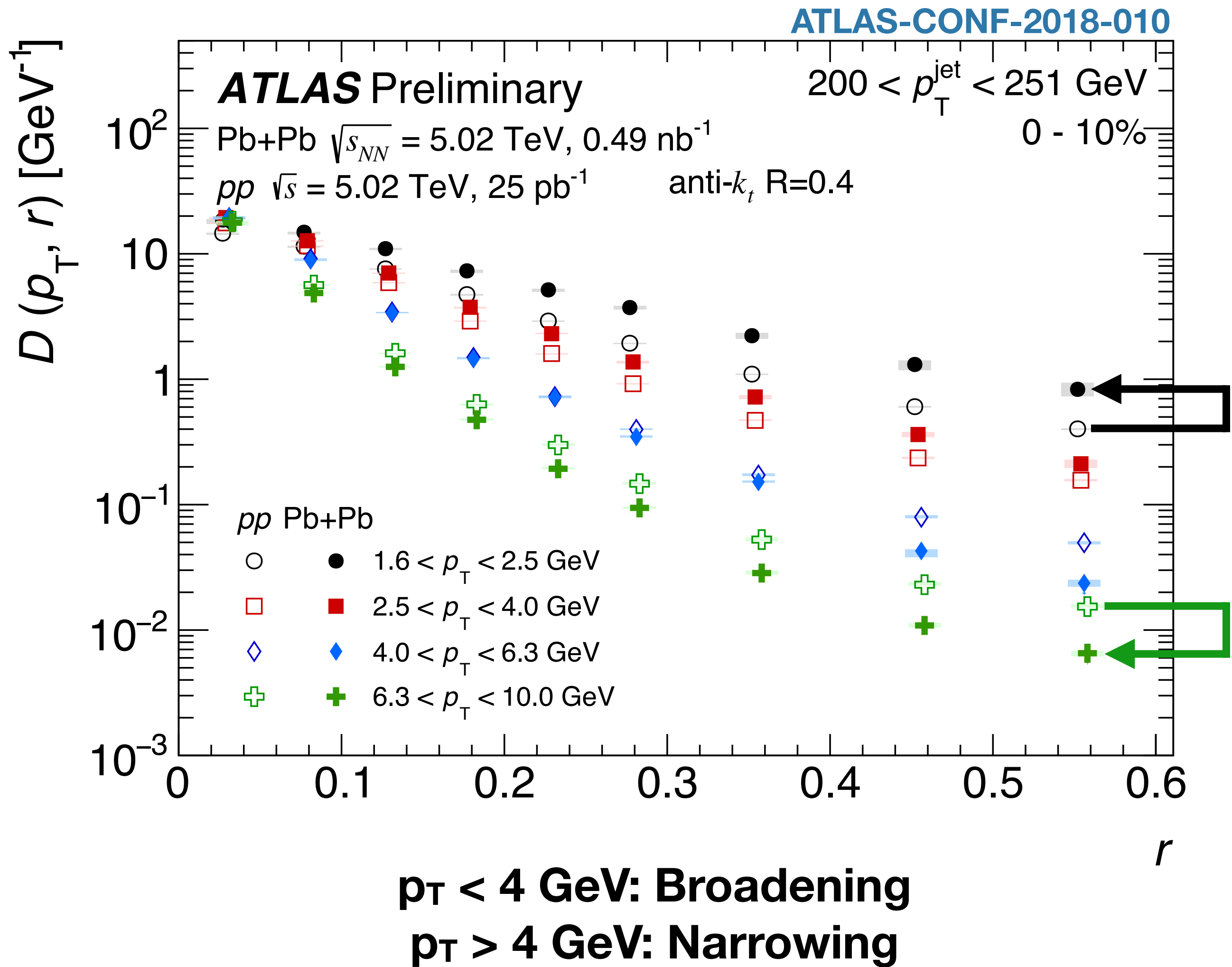


Underlying Event

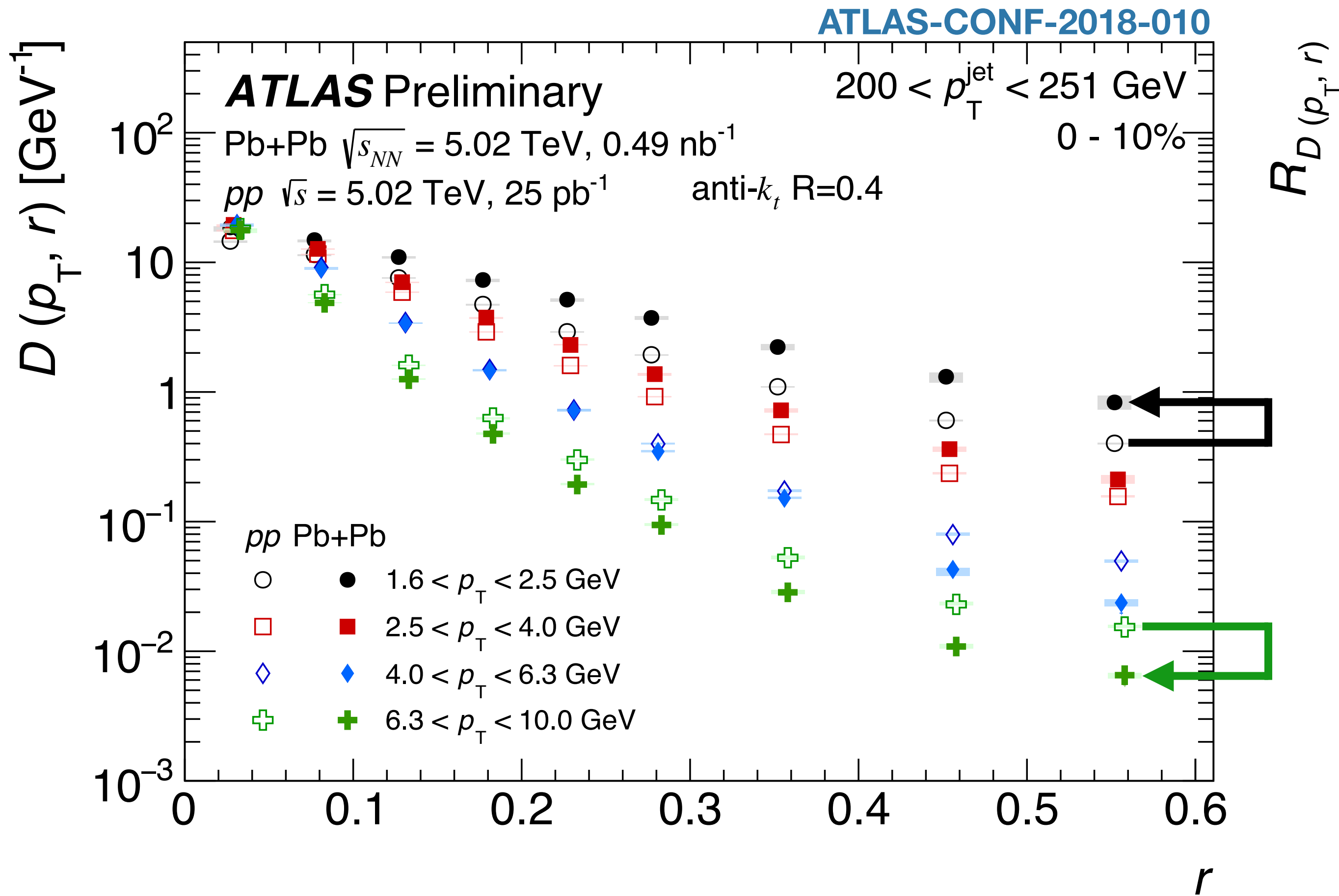
- Biggest experimental challenge
- Estimated using data driven techniques
- Strongly dependent on p_T and centrality



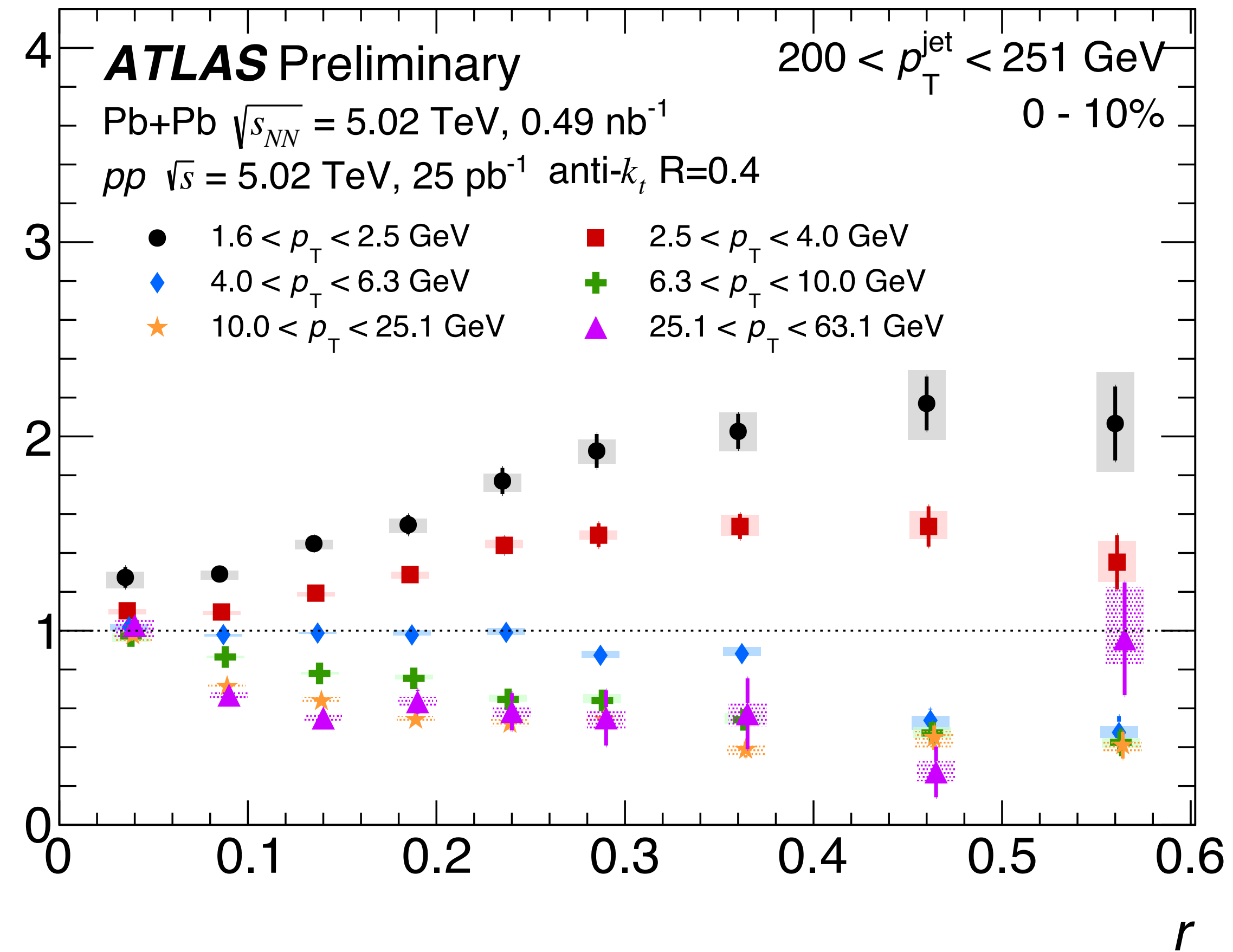
Results: $D(p_T, r)$ and $R_D(p_T, r)$



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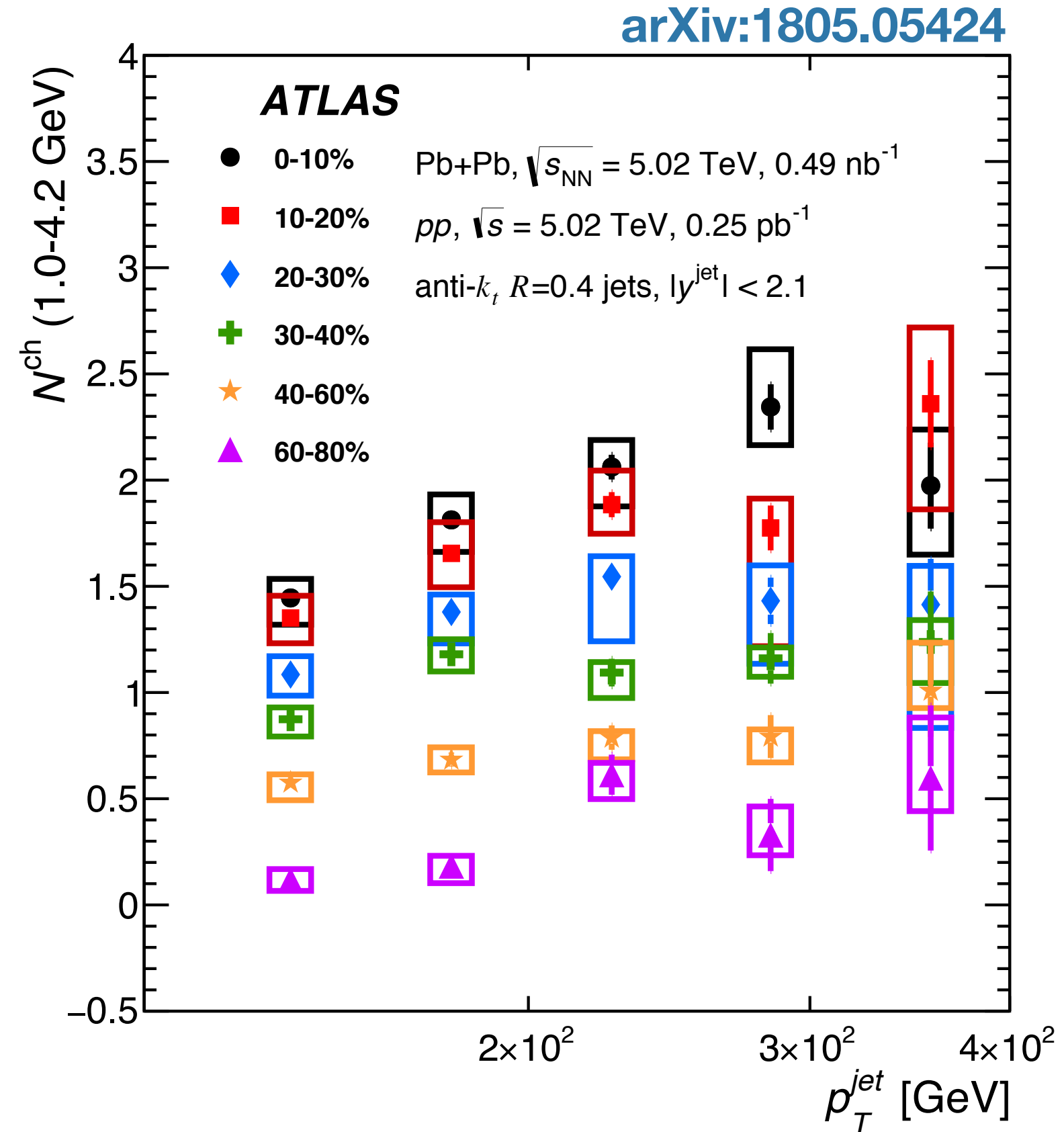


$p_T < 4$ GeV: Broadening
 $p_T > 4$ GeV: Narrowing



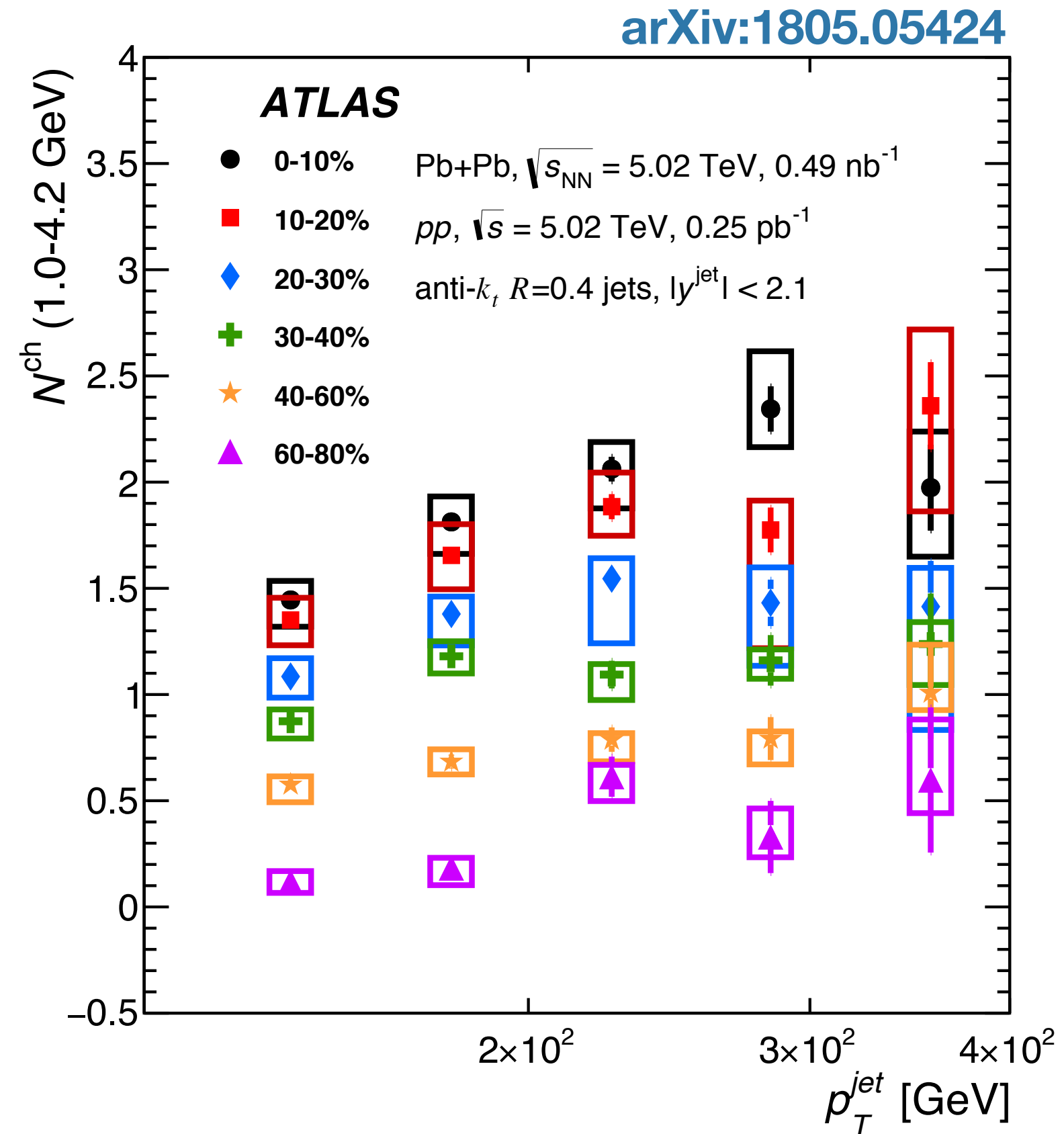
Increasing up to $r = 0.3$, constant for $r > 0.3$
Decreasing up to $r = 0.3$, constant for $r > 0.3$

Results: p_T^{jet} dependence

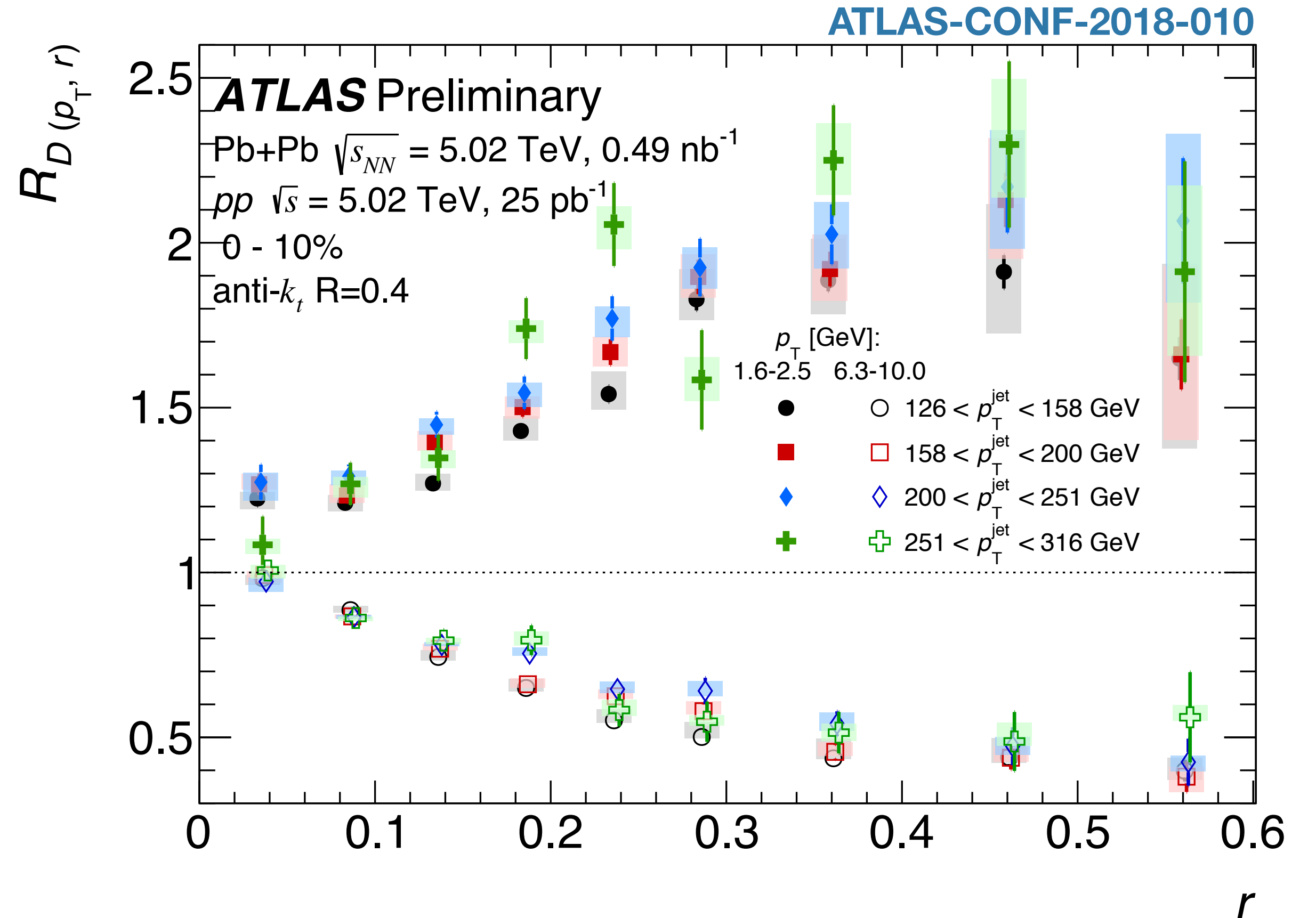


**Increase in number of particles
as a function of p_T^{jet} for charged
particles with $1 < p_T < 4$ GeV**

Results: p_T^{jet} dependence

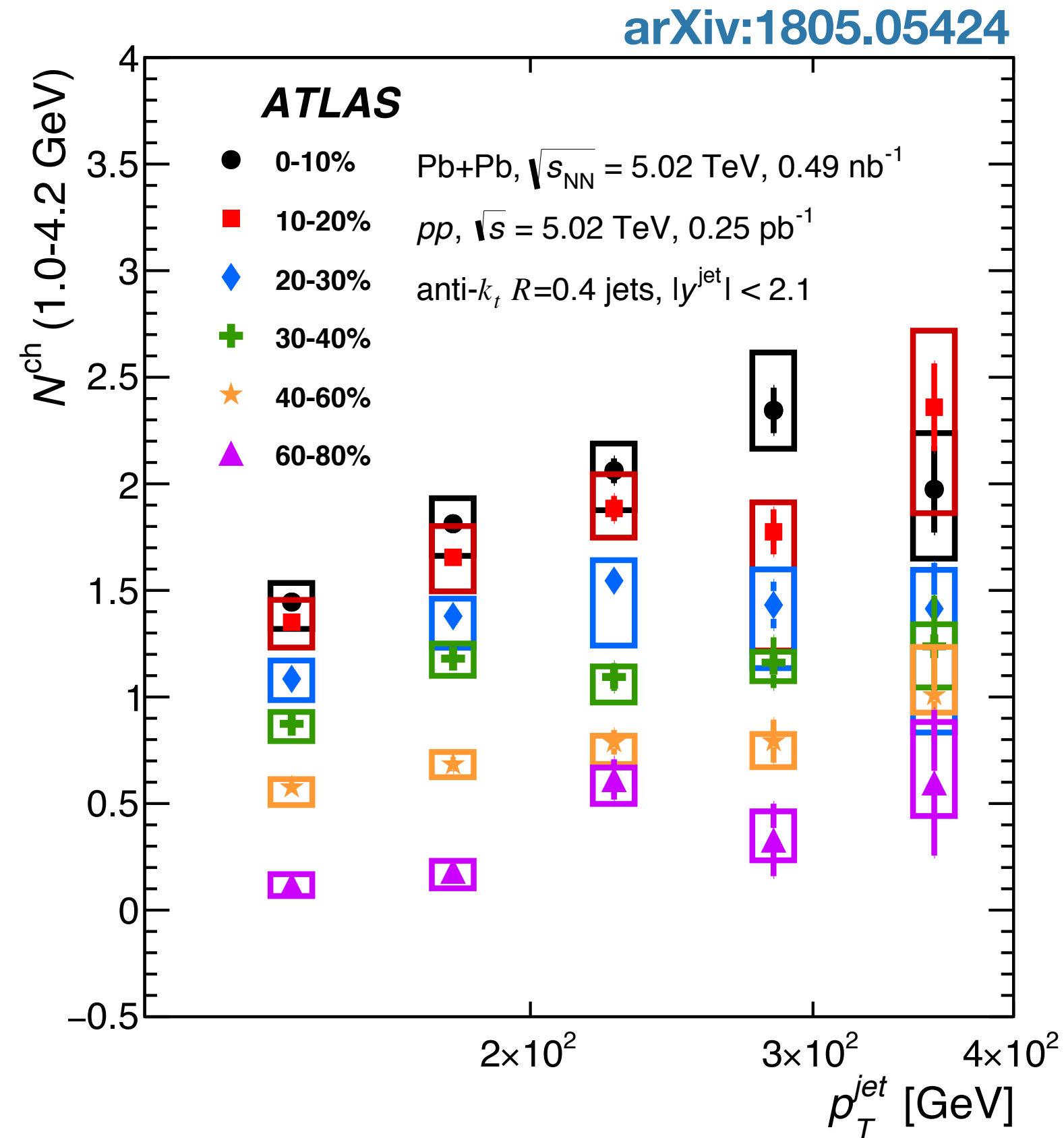


Increase in number of particles as a function of p_T^{jet} for charged particles with $1 < p_T < 4$ GeV

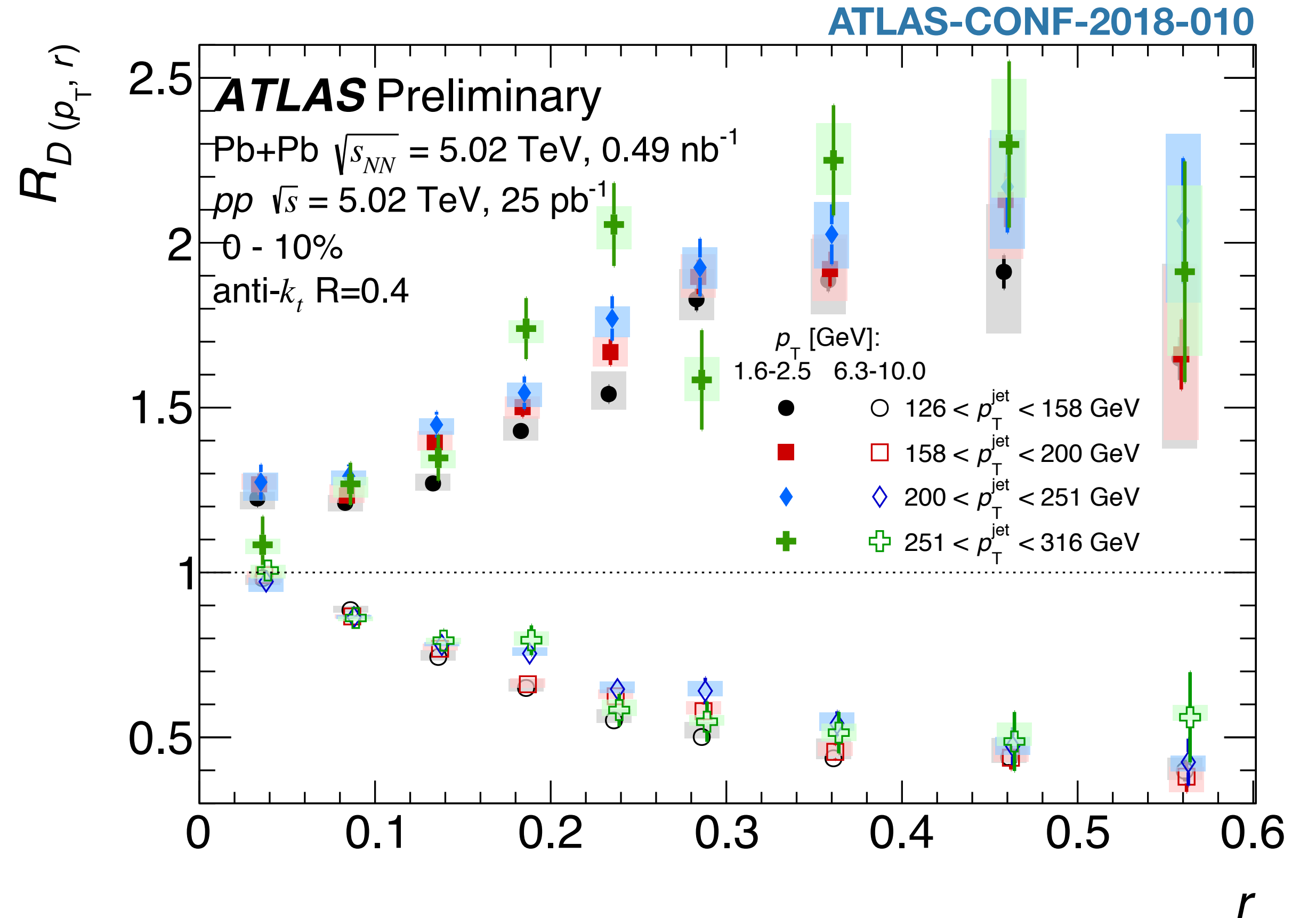


Low p_T (1.6 - 2.5 GeV): yield increases with p_T^{jet}
High p_T (6.3 - 10.0 GeV): No p_T^{jet} dependence

Results: p_T^{jet} dependence



Increase in number of particles as a function of p_T^{jet} for charged particles with $1 < p_T < 4 \text{ GeV}$



Low p_T (1.6 - 2.5 GeV): yield increases with p_T^{jet}
 High p_T (6.3 - 10.0 GeV): No p_T^{jet} dependence

More information on the differential distributions of charged particles in jets