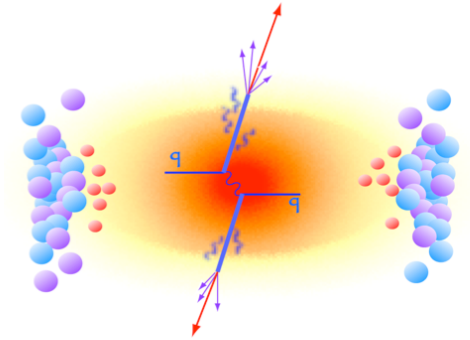

Inclusive jet measurements in pp and PbPb collisions with ALICE

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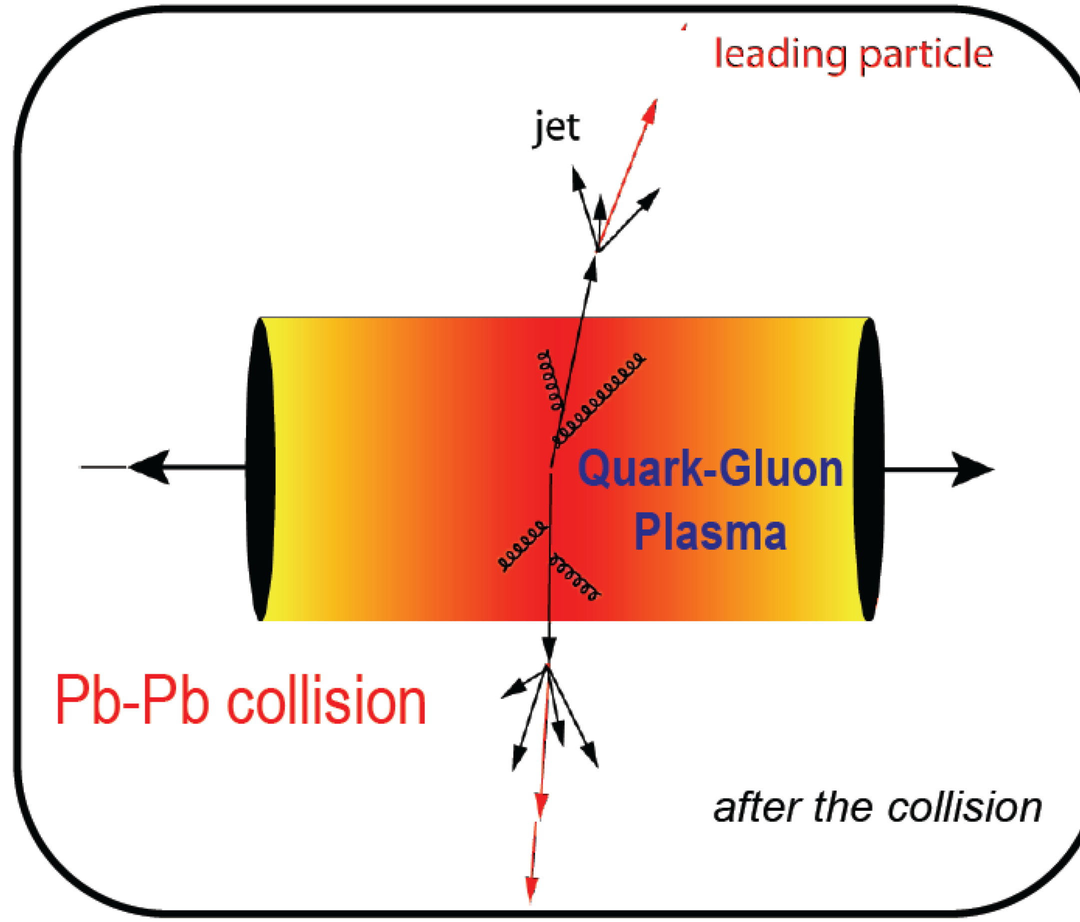
for ALICE Collaboration

Central China Normal University

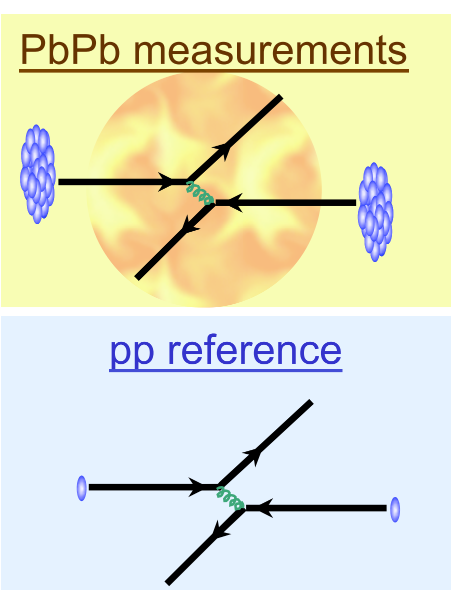
Probing hot QCD matter with hard probes

- Hard probes (jets) serve as calibrated probe (pQCD)
- Hard probes traverse through the medium and interact strongly with the hot QCD matter
- Suppression pattern provides density measurements
- General picture: parton energy loss through medium-induced gluon radiation and collisions with medium constituents

$$\text{Jet}(E) \rightarrow \text{Jet}\ (E' = E - \Delta E) + \text{soft particles}(\Delta E)$$



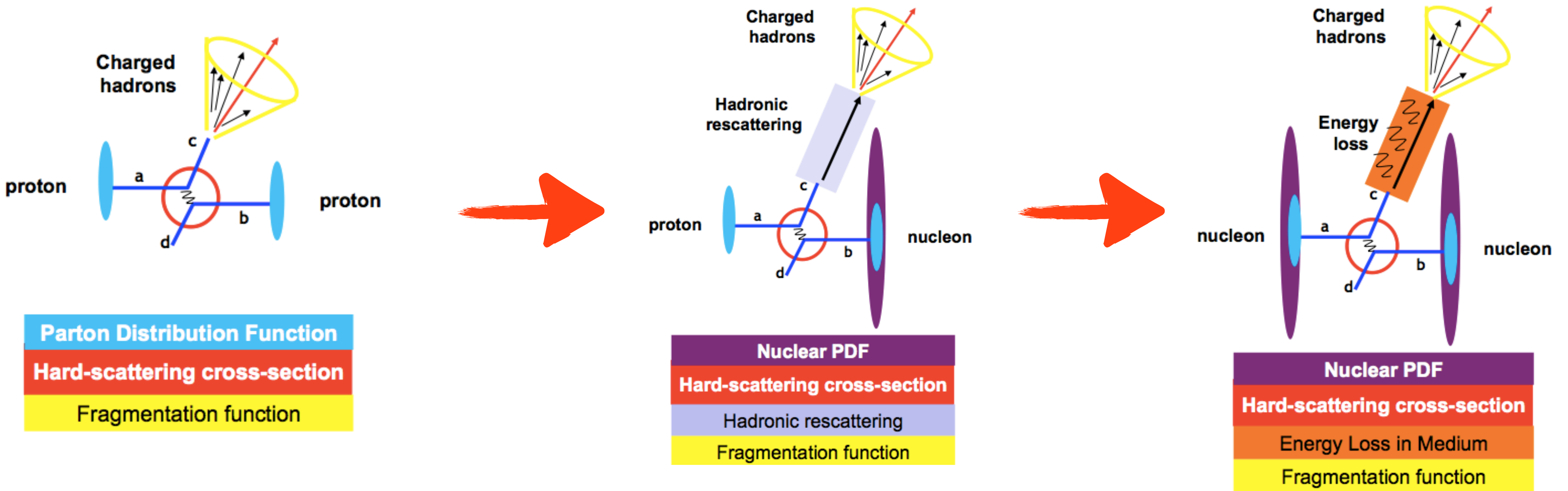
- Quantify the medium effects with nuclear modification factor



$$= \quad R_{AA} = \frac{\sigma_{pp}^{inel}}{\langle N_{coll} \rangle} \frac{d^2N_{AA}/dp_T d\eta}{d^2\sigma_{pp}/dp_T d\eta}$$

- $R_{AA} > 1$ (enhancement)
- $R_{AA} = 1$ (no medium effect)
- $R_{AA} < 1$ (suppression)

Nuclear effects probed by jet production

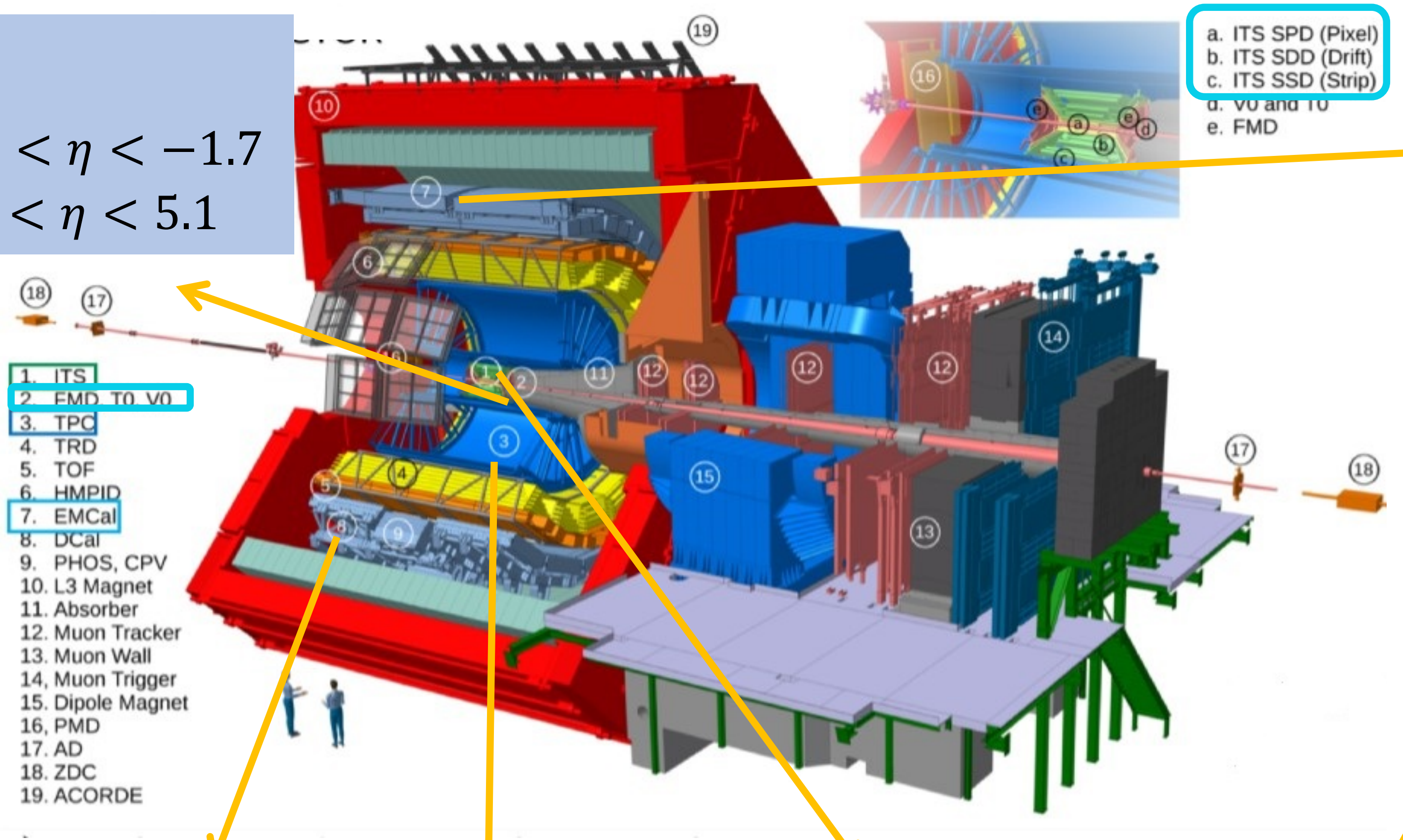


- Disentangle initial and final state effects
- Characterize nuclear PDFs
- Significant increase in integrated luminosity allows more precise investigation of statistic hungry probes

systems	years	$\sqrt{s_{NN}}$ (TeV)	L_{int}
Pb-Pb	2010-2011	2.76	~75 μb^{-1}
	2015	5.02	~250 μb^{-1}
	2018	5.02	~0.908 nb^{-1}
Xe-Xe	2017	5.44	~0.3 μb^{-1}
p-Pb	2013, 2016	5.02	~18 nb^{-1}
	2016	8.16	~25 nb^{-1}
p-p	2009-2013	0.9, 2.76, 7, 8	~200 μb^{-1}, ~100 nb^{-1} ~1.5 pb^{-1}, ~2.5 pb^{-1}
	2015, 2017	5.02	~1.3 pb^{-1}
	2015-2018	13	~59 pb^{-1}

Jet measurements in ALICE

- Event selection and multiplicity categorization: SPD, V0
- Track and jet reconstruction: ITS, TPC, EMCal and DCal



V0
$-3.7 < \eta < -1.7$
$2.8 < \eta < 5.1$

EM calorimeter
$|\eta| < 0.7,\ 80° < \varphi < 188°$

D calorimeter
$0.22 < |\eta| < 0.7, 260° < \varphi < 320°$
$|\eta| < 0.7,\ 320° < \varphi < 327°$

ITS (Inner Tracking System)
$|\eta| < 0.9,\ 0 < \varphi < 2\pi$

TPC (Time Projection Chamber)
$|\eta| < 0.9,\ 0 < \varphi < 2\pi$

Remove charged particle contributions

Neutral constituents

$E_{cluster} > 0.3$ GeV

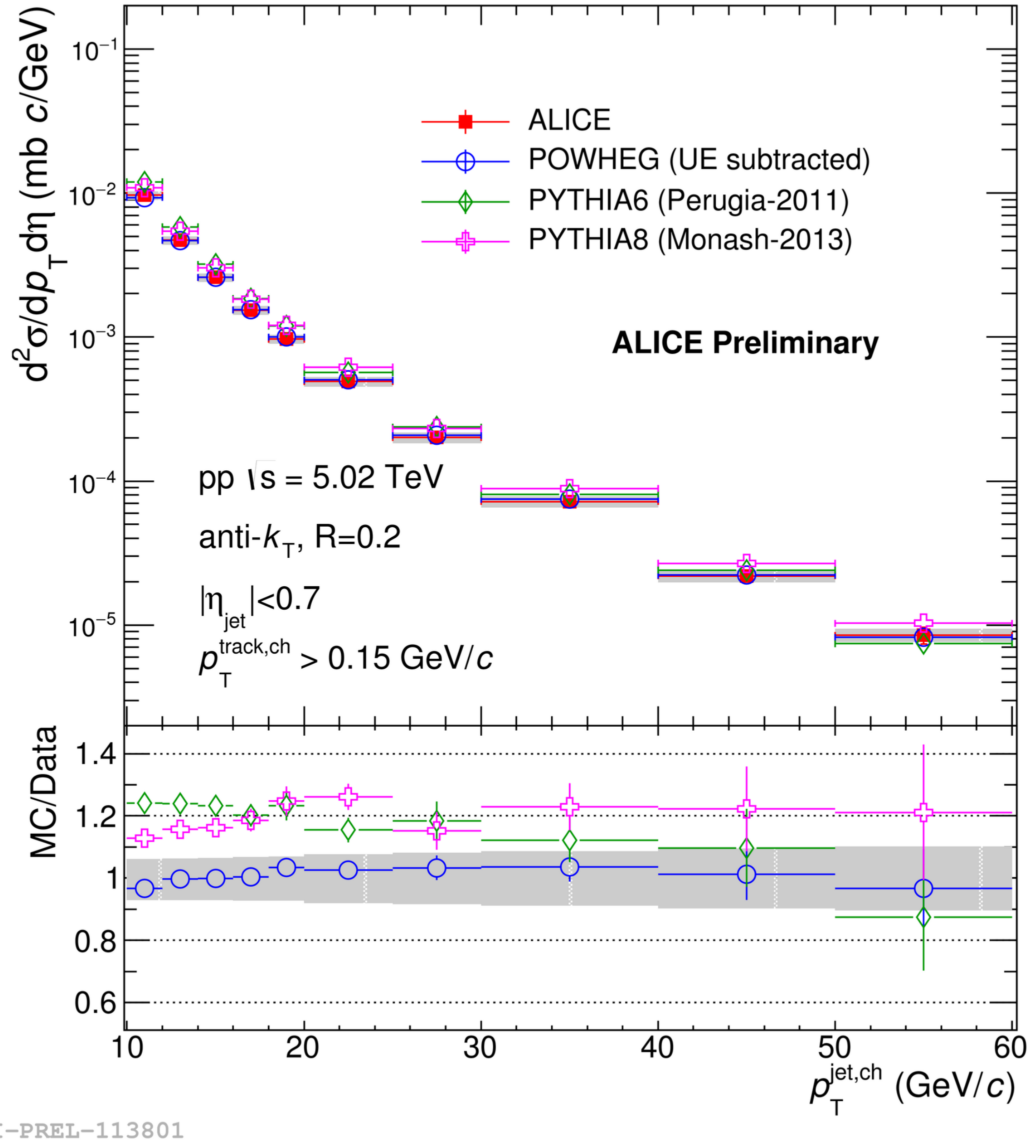
full jet

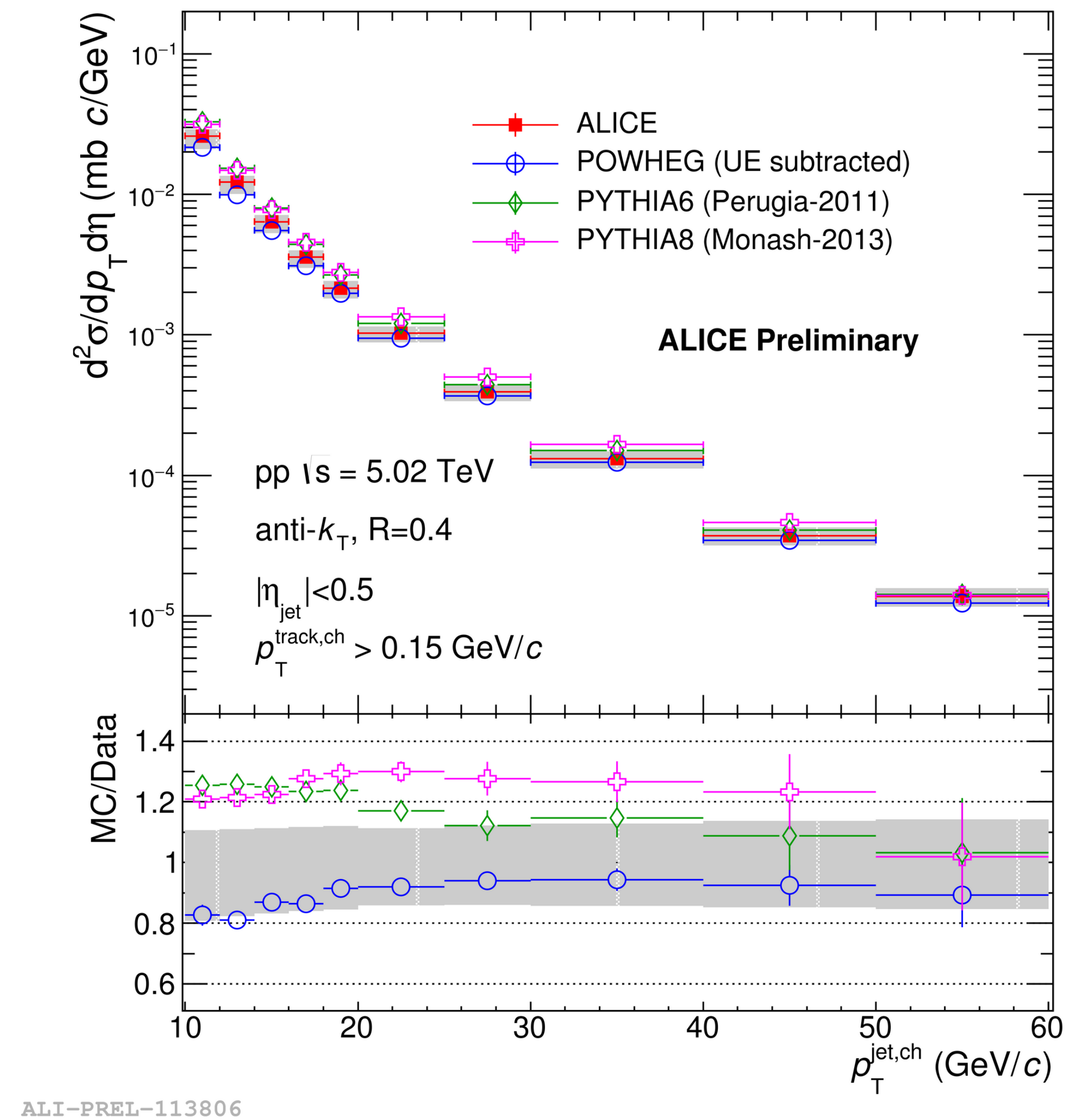
Charged constituents

$p_{T}^{track} > 0.15\ \mathrm{GeV}/c$

Charged jet

Charged jet cross section in pp collisions

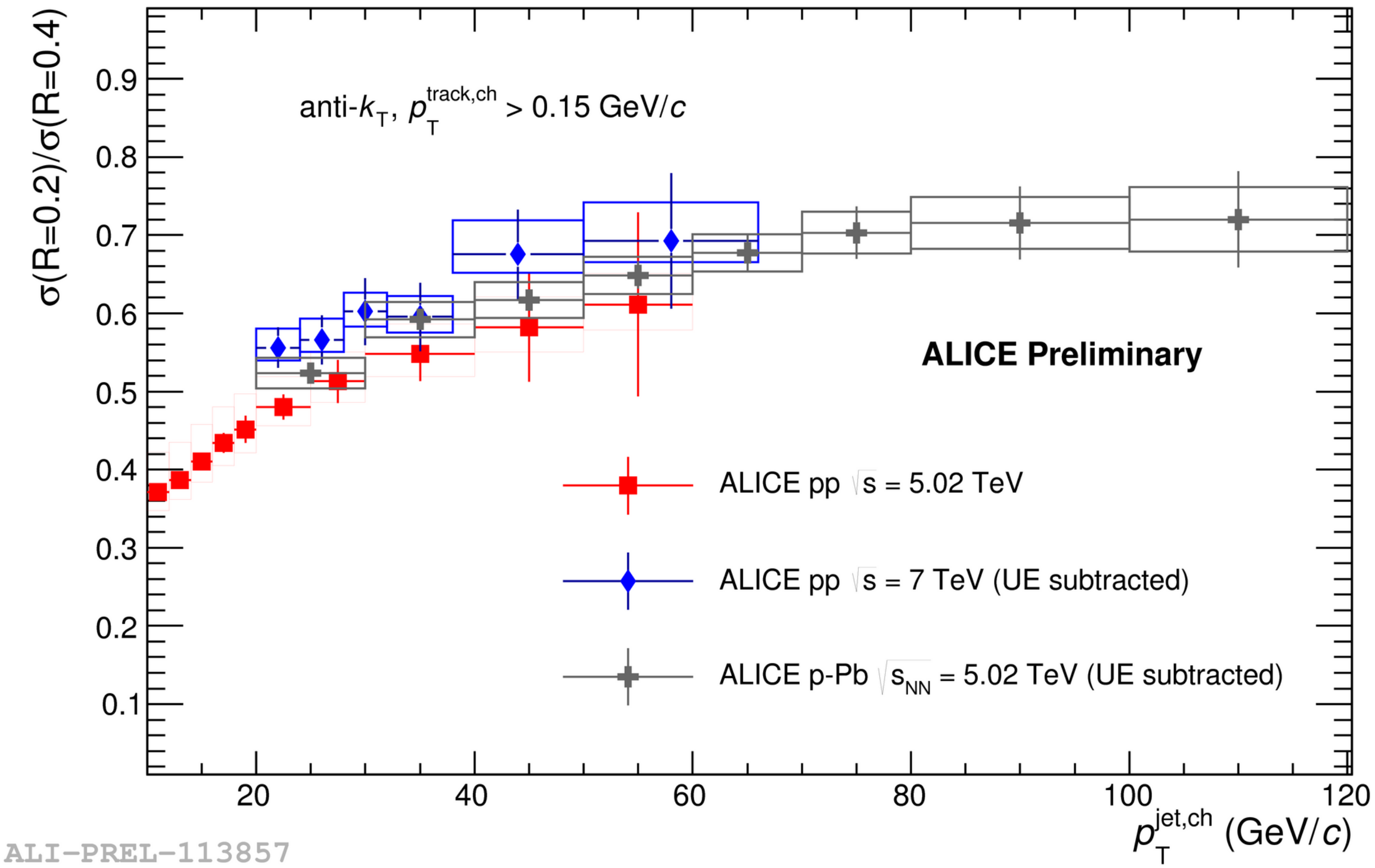


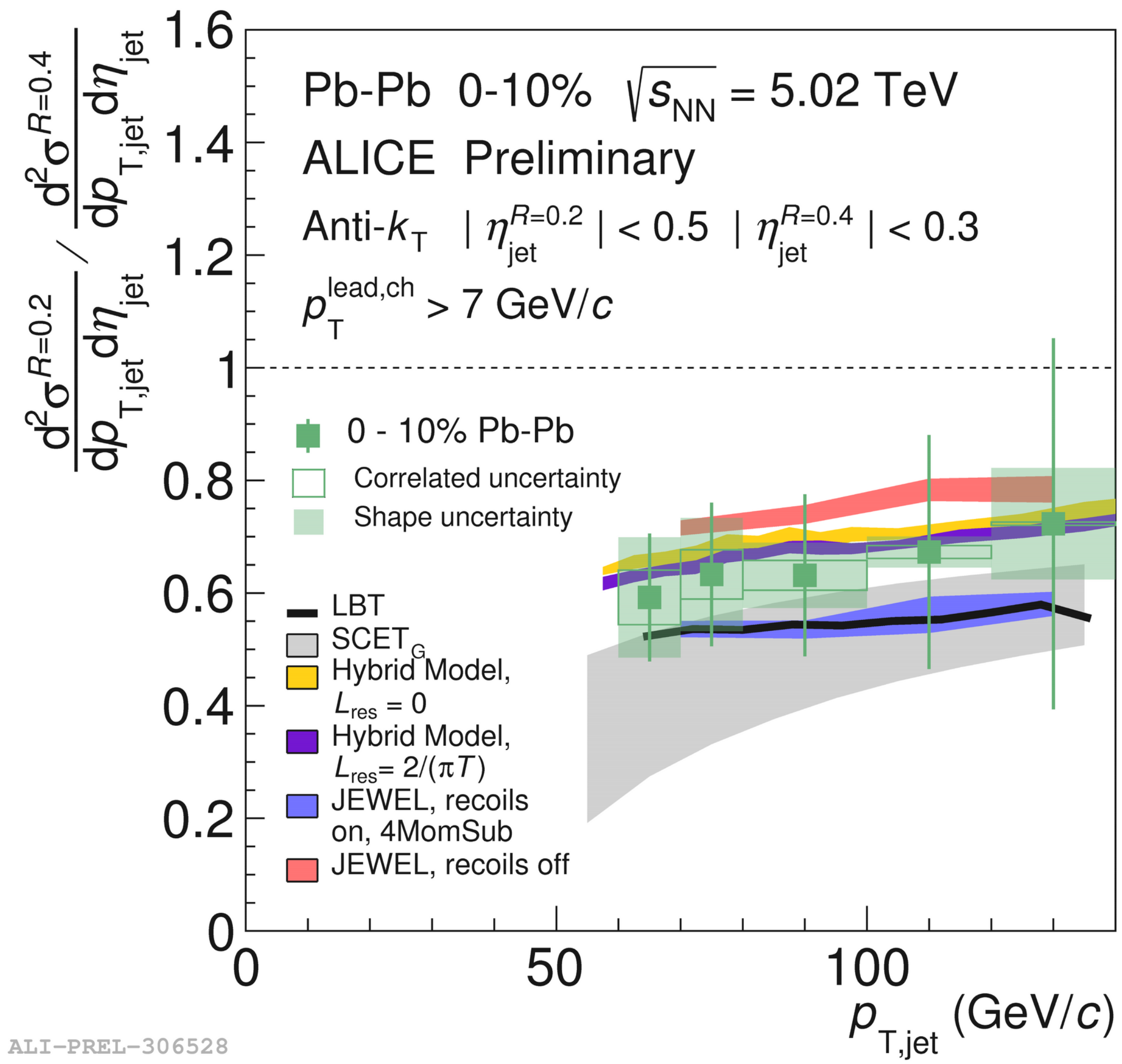


- Charged jets are reconstructed using different resolution parameters and down to very low p_T (p_{Tjet} >5 GeV/c)
- Jet cross section is well described by POWHEG+PYTHIA8 predictions (NLO pQCD+parton shower+hadronization) within systematic uncertainties

POWHEG: JHEP 1006 (2010) 043; JHEP 1104 (2011) 081
PYTHIA8: Comput. Phys. Commun. 191 (2015) 159

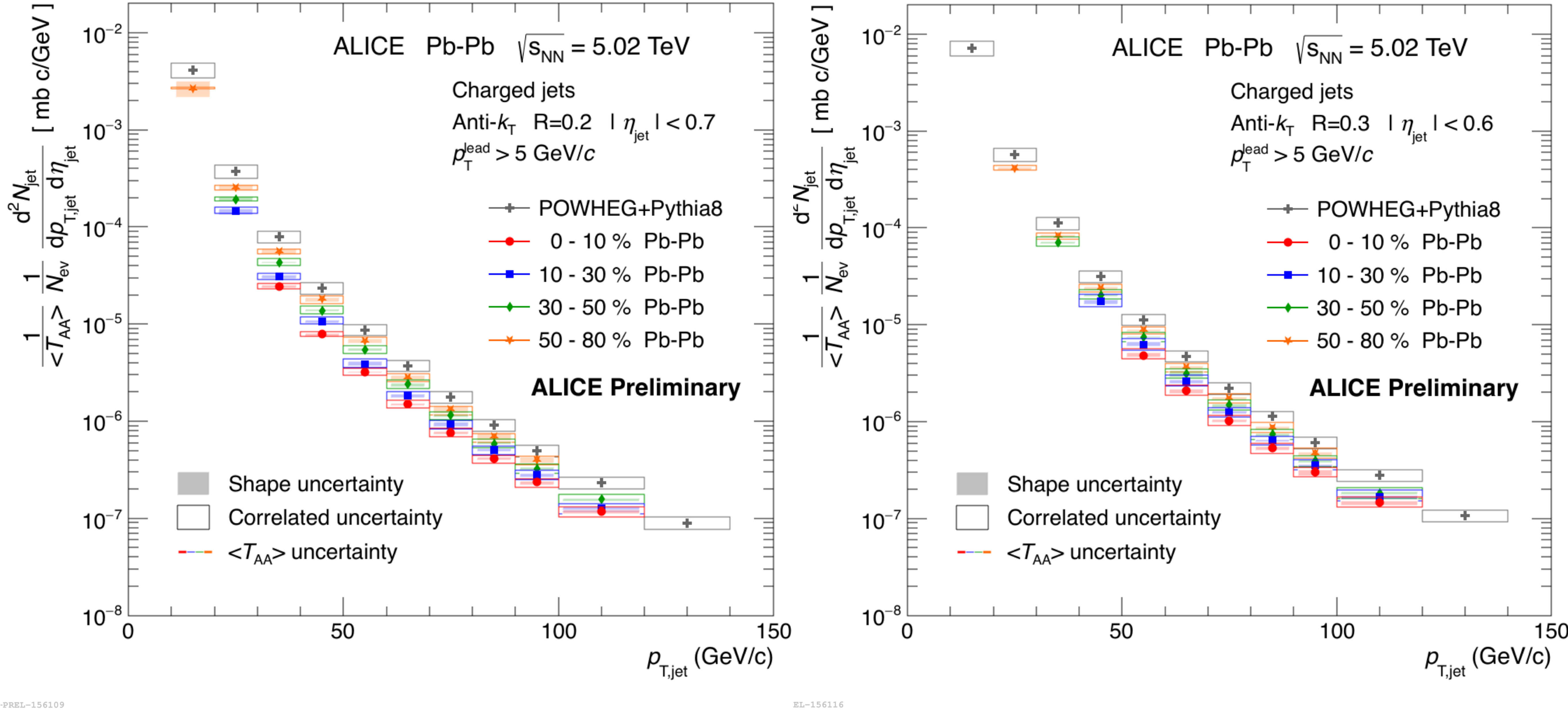
Jet cross section ratio





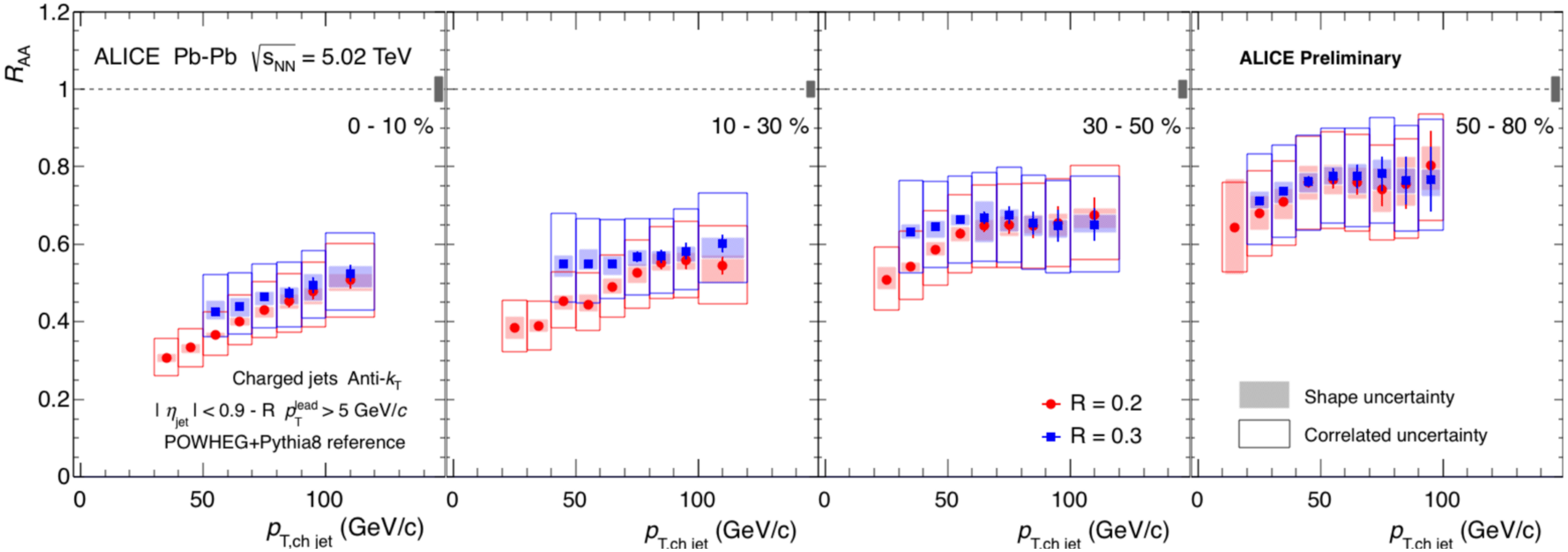
- Jet cross section ratio measurements are the reflection of jet collimation
- Different jet cross section ratio is slightly increasing with jet p_T, consistent with Monte Carlo simulation
- Jet cross section ratio is consistent with different $\sqrt{s}$

Charged jets in Pb-Pb collisions

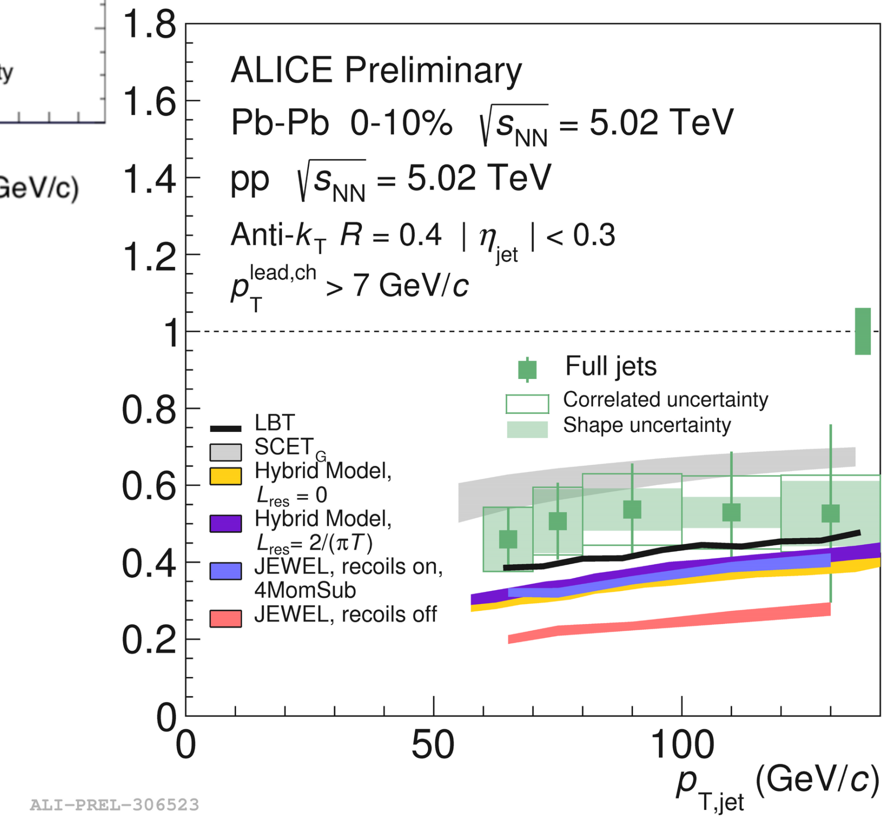


- Charged jet spectra in different centrality intervals are measured in Pb-Pb collisions with different cone radii
- Centrality ordered jet production yield are observed after T_{AA} scaling

Jet modification in Pb-Pb collisions: R_{AA}

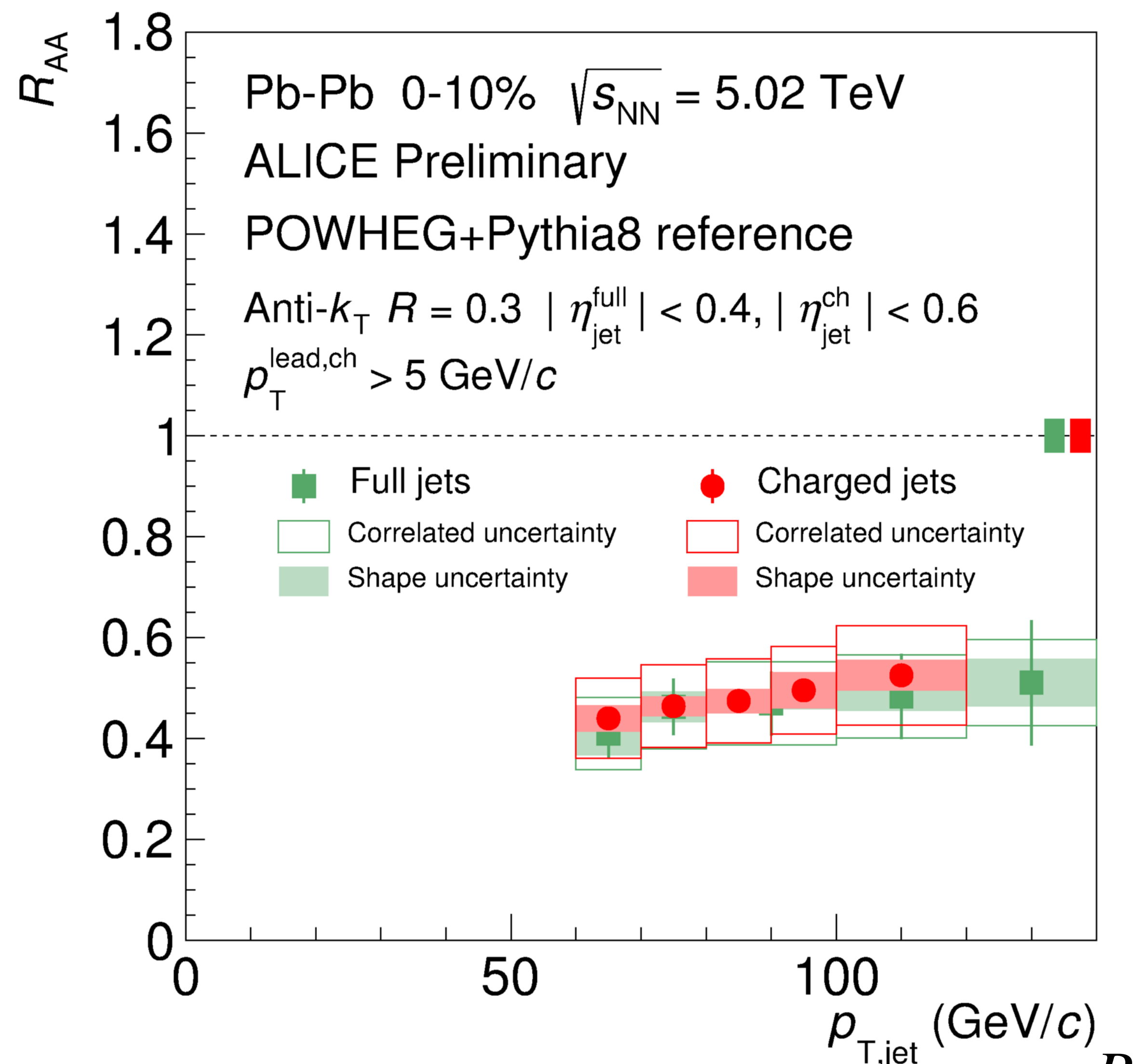


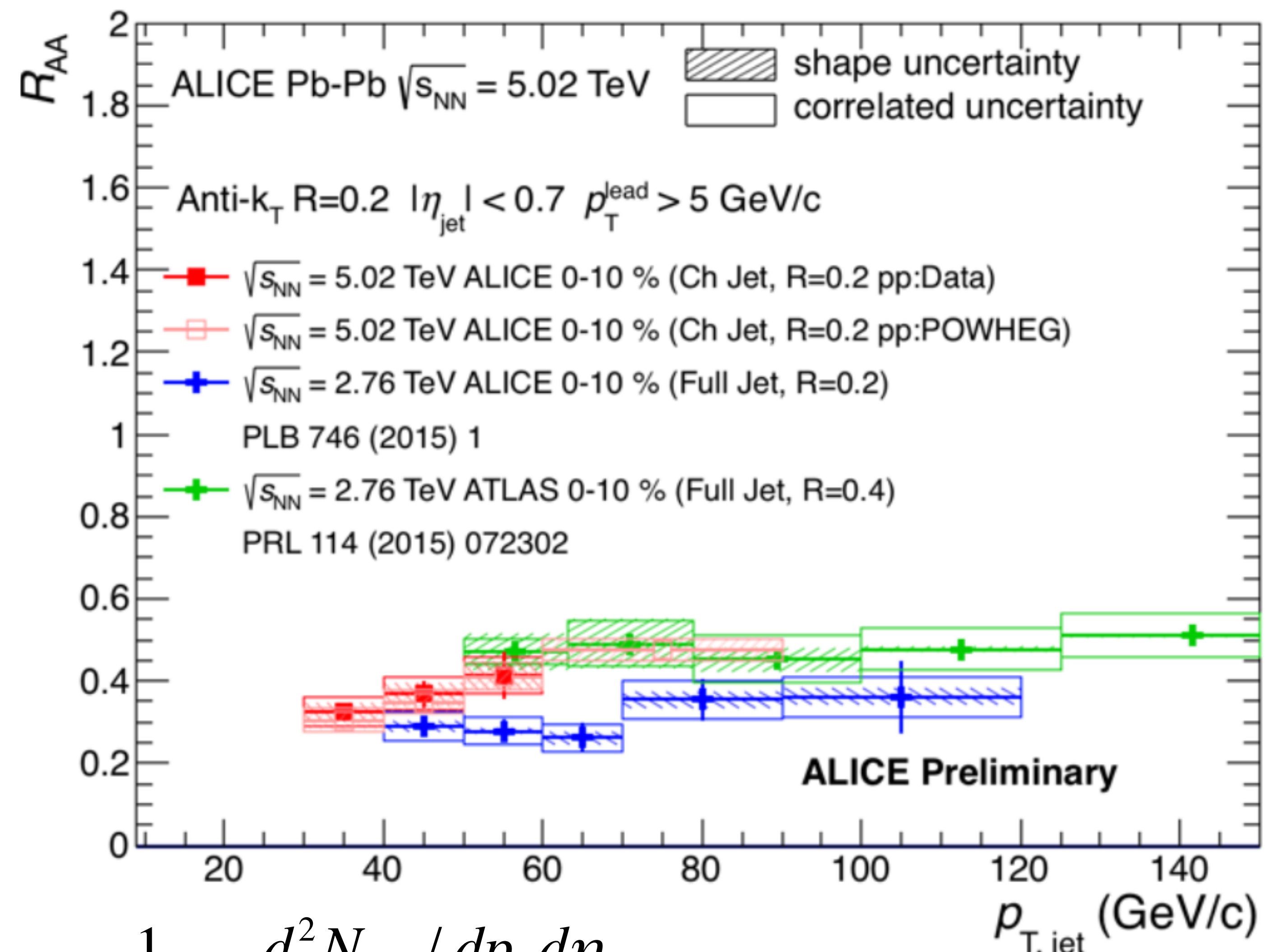
$$R_{AA} = \frac{1}{< N_{coll} >} \frac{d^2N_{AA} / dp_T d\eta}{d^2N_{pp} / dp_T d\eta}$$



- Strong suppression of jet yield in most central collisions
- Less suppression for peripheral events
- R_{AA} of different radius jets are consistent with systematic errors
- Theoretical models can describe the shape of R_{AA} but not absolute amplitude (LBT agrees data best)

Jet R_{AA} comparisons



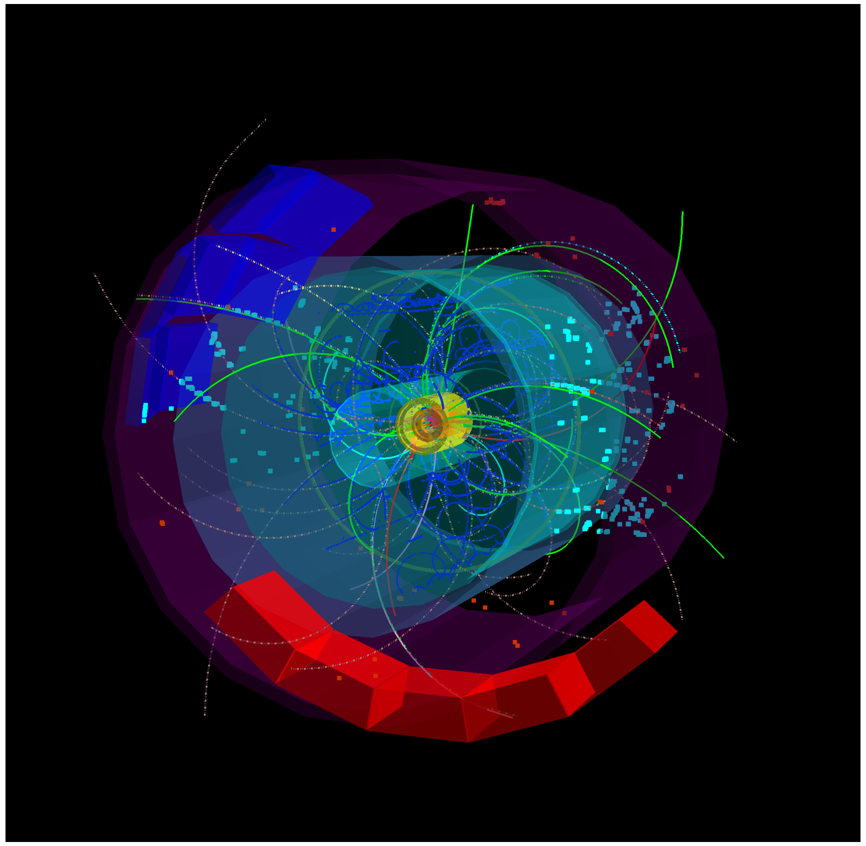


$$R_{AA} = \frac{1}{\langle N_{coll} \rangle} \frac{d^2N_{AA}/dp_T d\eta}{d^2N_{pp}/dp_T d\eta}$$

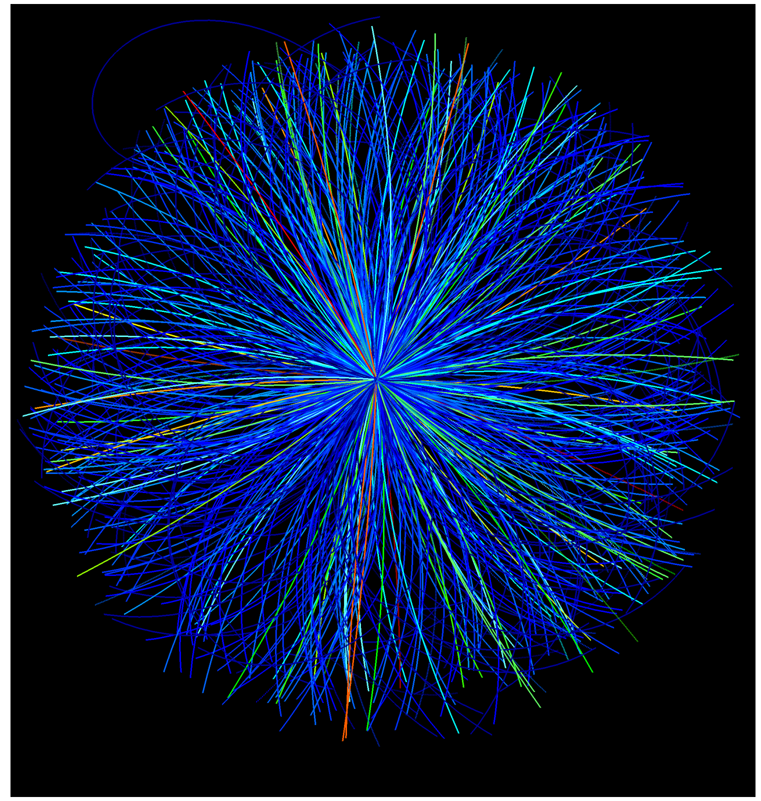
- Full jets and charged jets are suppressed similarly
- R_{AA} at 5.02 TeV similar to 2.76 TeV
  - ➡ "compensation" between increasing suppression and change of the shape of the spectra

Different or similar between HM pp and HI?

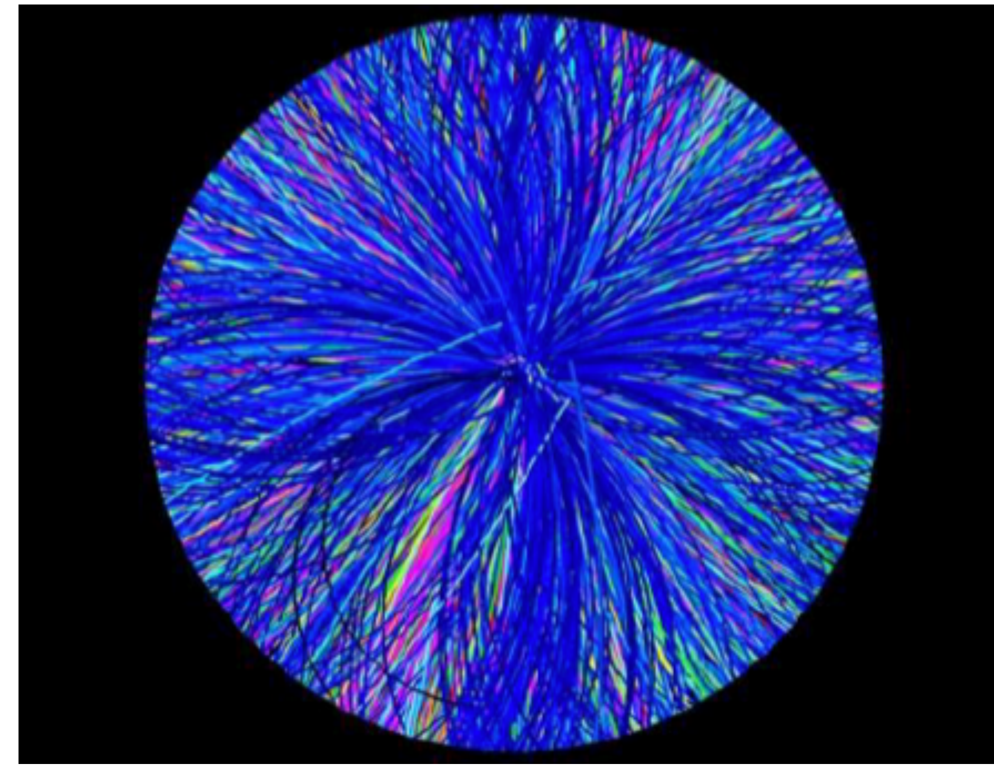
pp: MB

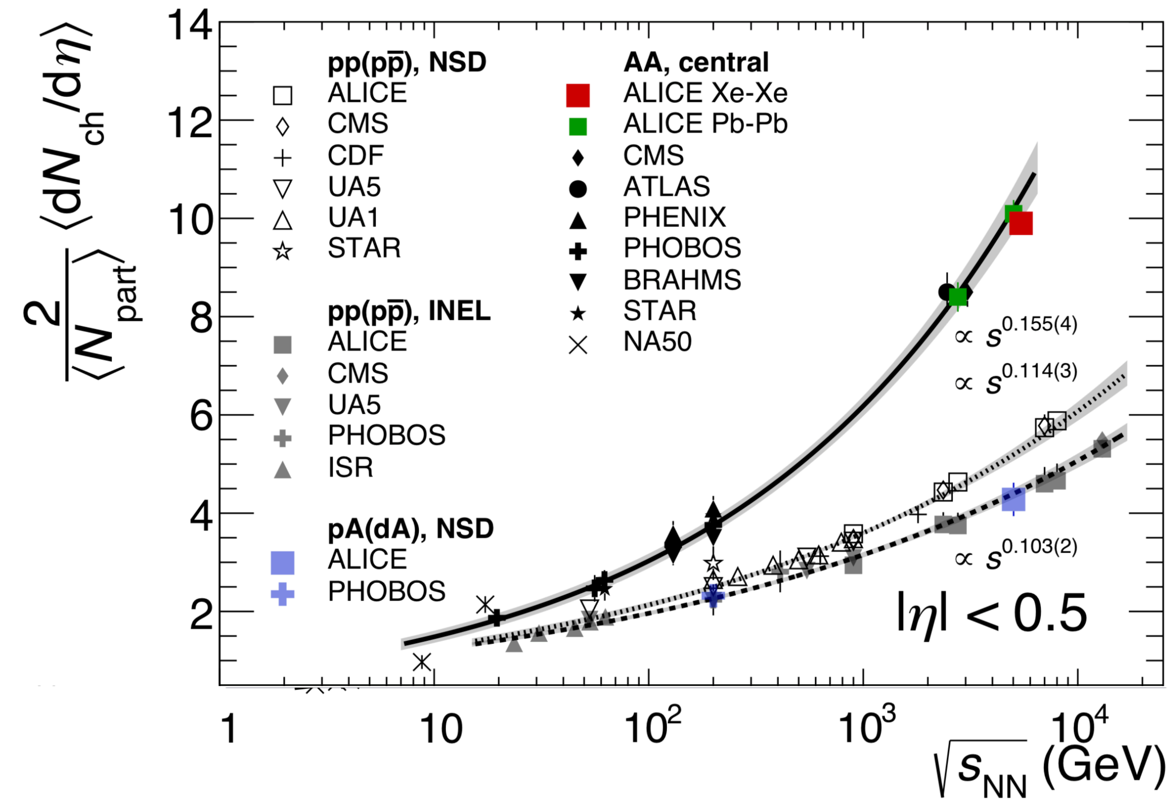


pp: high multiplicity



Pb-Pb

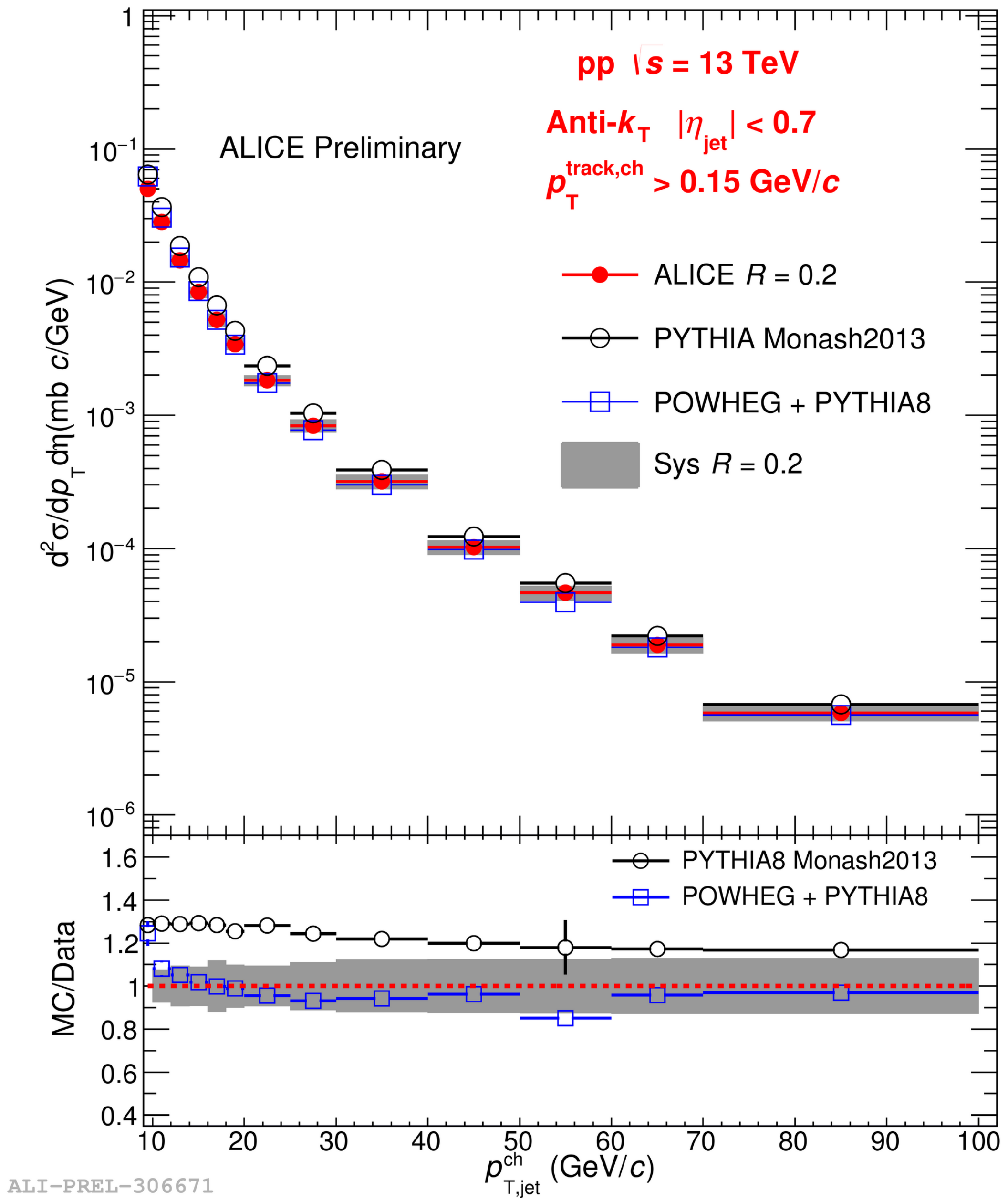


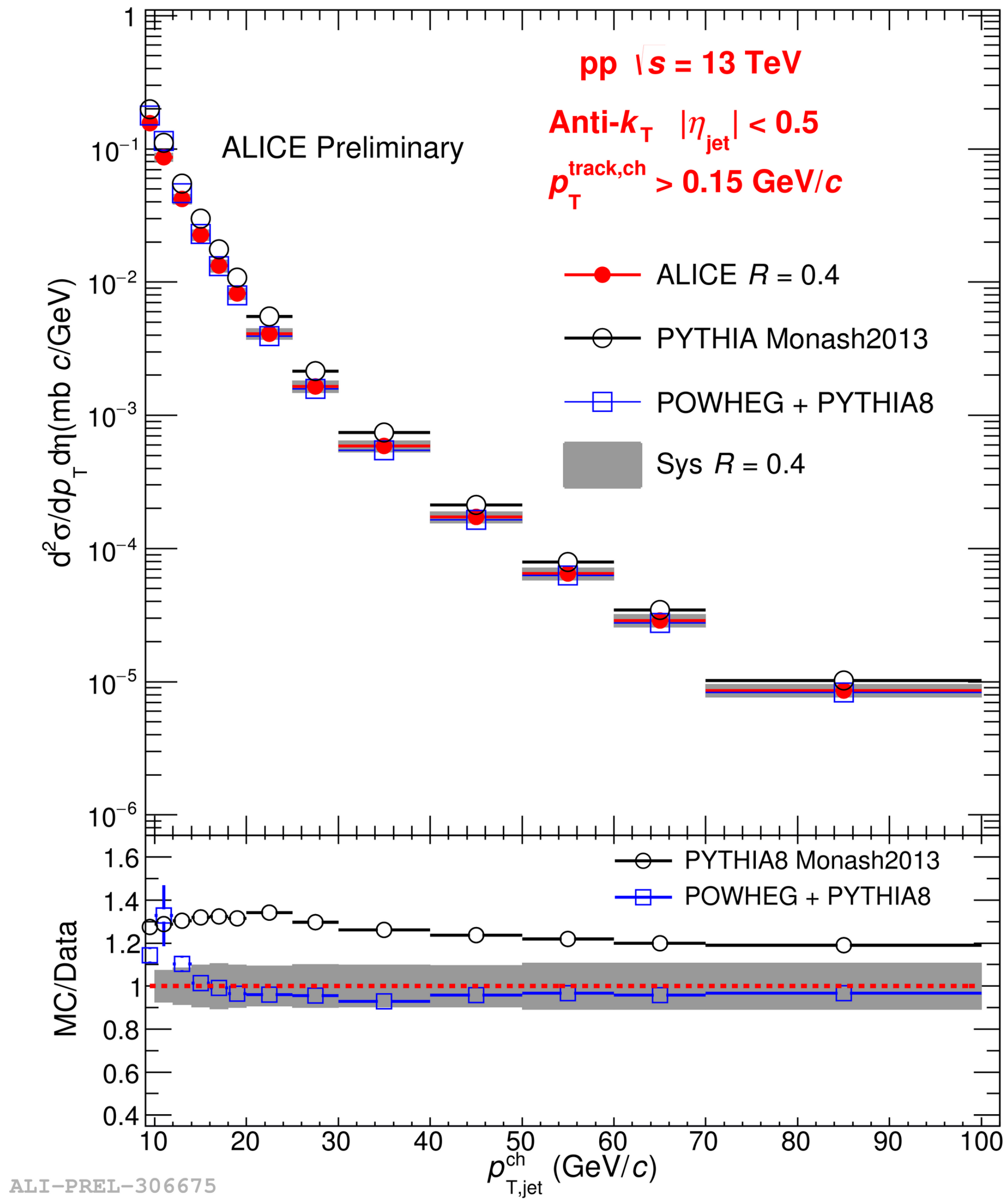


- Charge particle density increases with $\sqrt{s}$ for all collision systems
- High multiplicity pp events can have similar multiplicity as in pA/AA collisions

➡ what happens for jets in high multiplicity events?

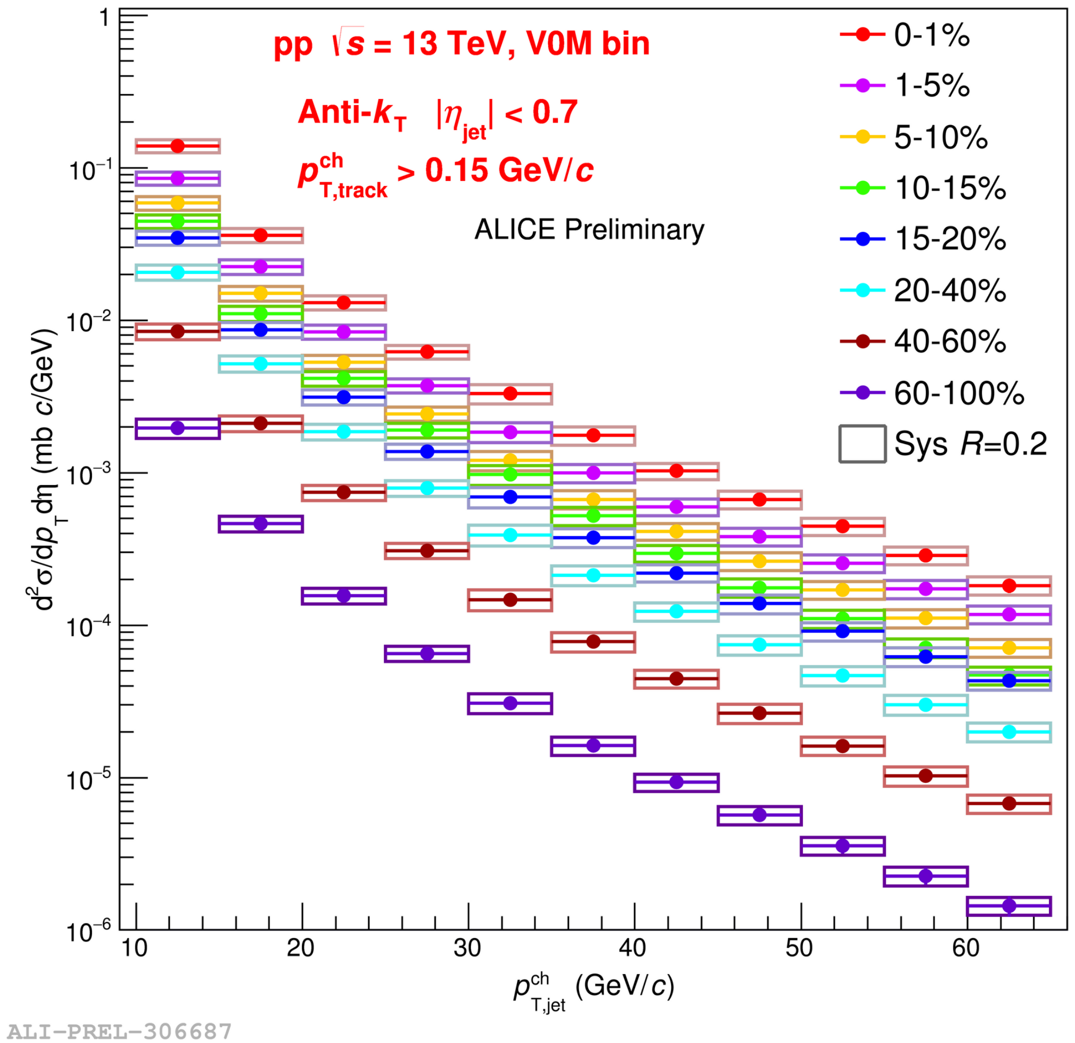
Charged jet cross section in pp 13 TeV

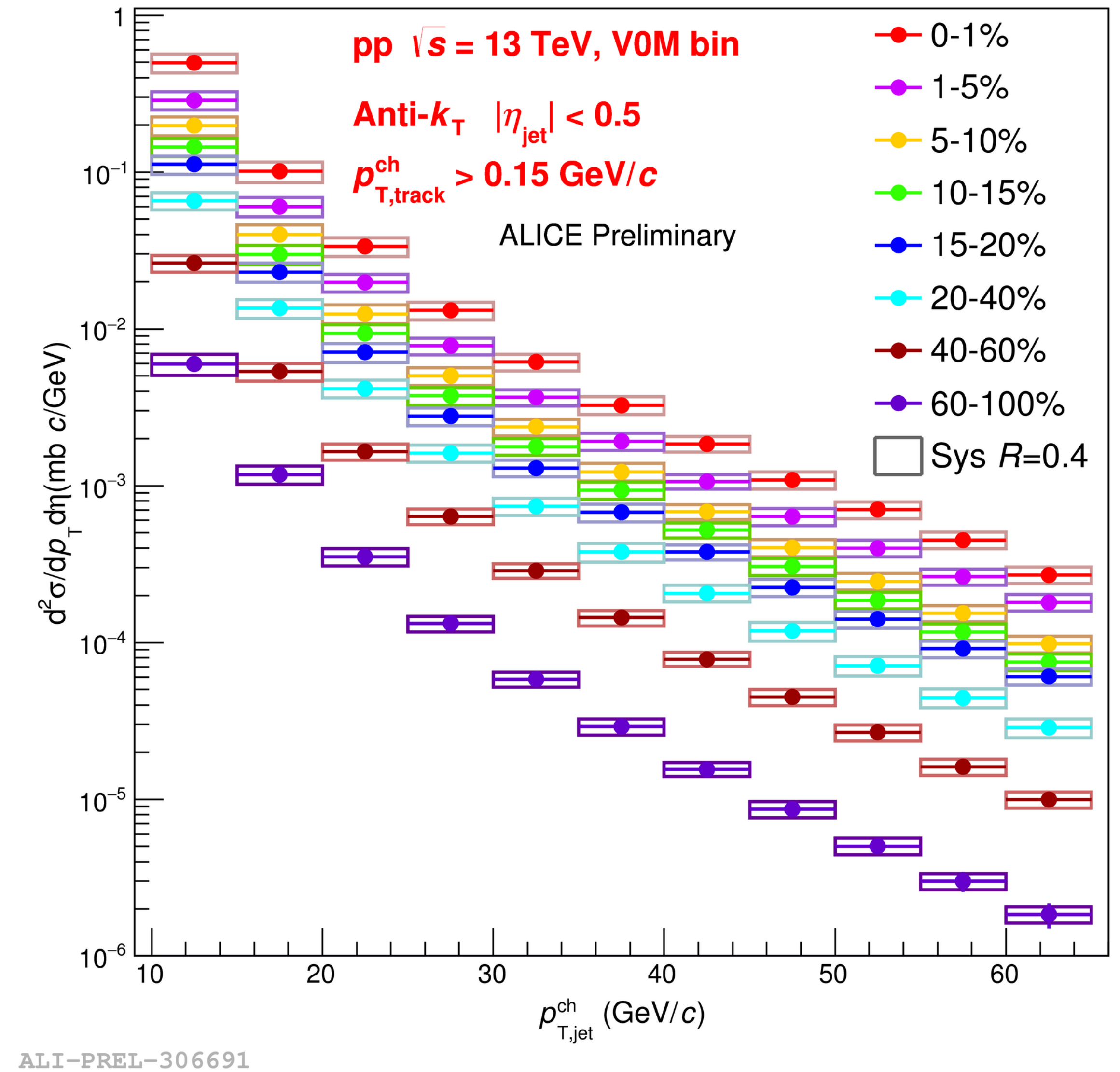




- Charged jets are reconstructed using different resolution parameters and down to low p_T (p_{Tjet} >10 GeV/c)
- Jet cross section is well described by POWHEG+PYTHIA8 predictions (NLO pQCD+parton shower+hadronization) within systematic uncertainties

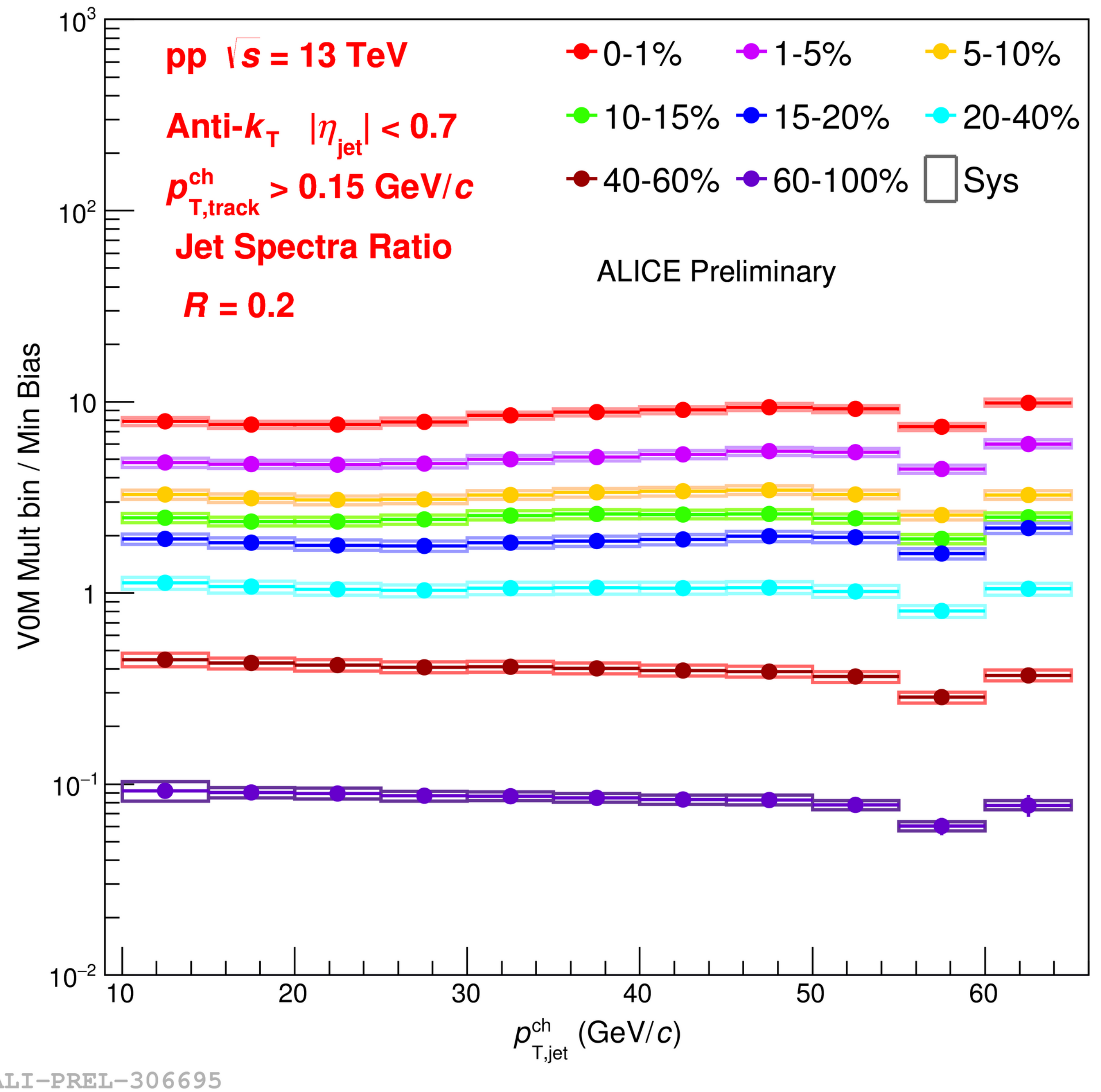
Multiplicity dependent charged jet productions

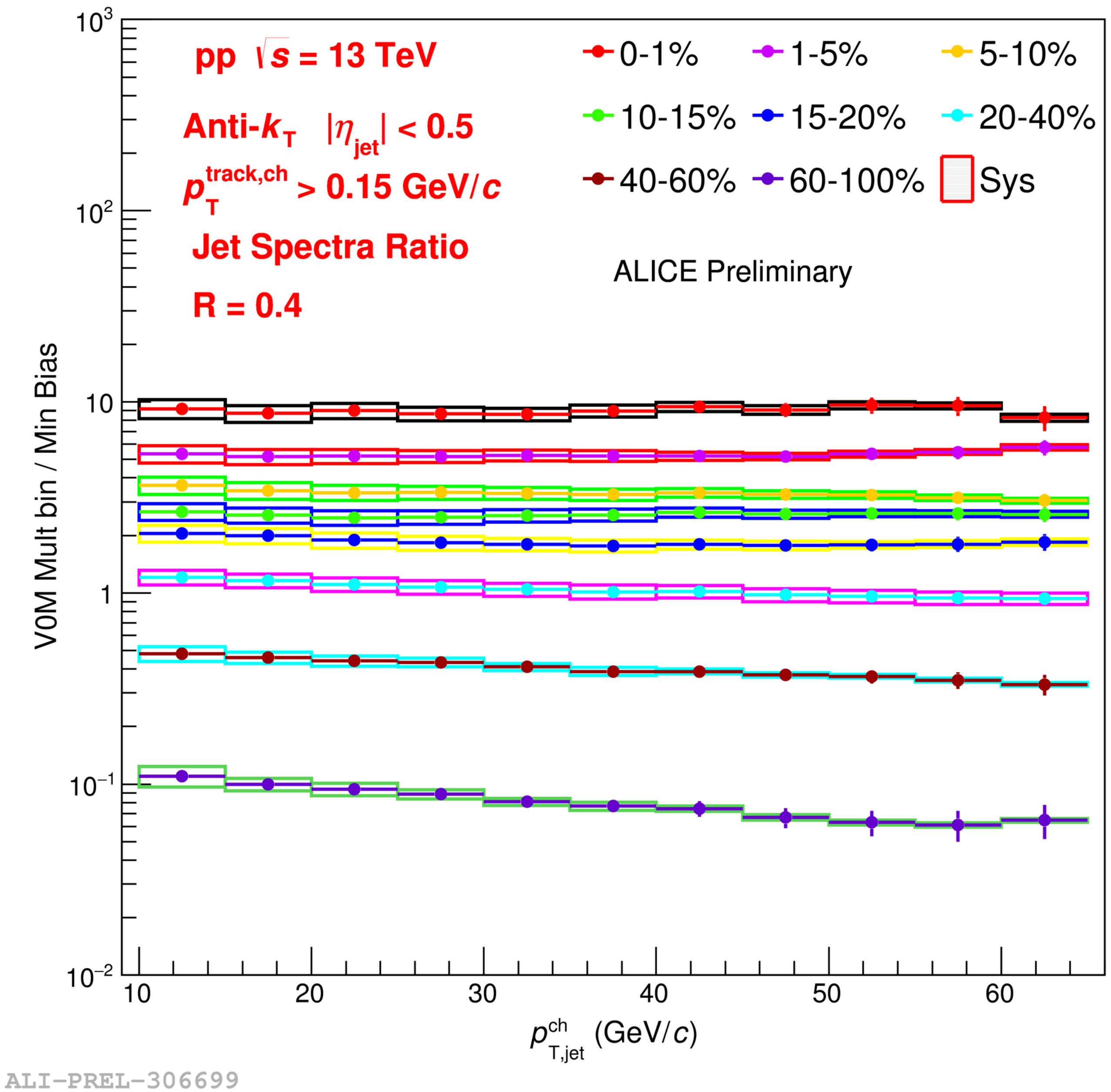




- Charged jets are reconstructed using different resolution parameters in different multiplicity percentile in pp collisions
- More jets are produced in high M bins compared to low M bins

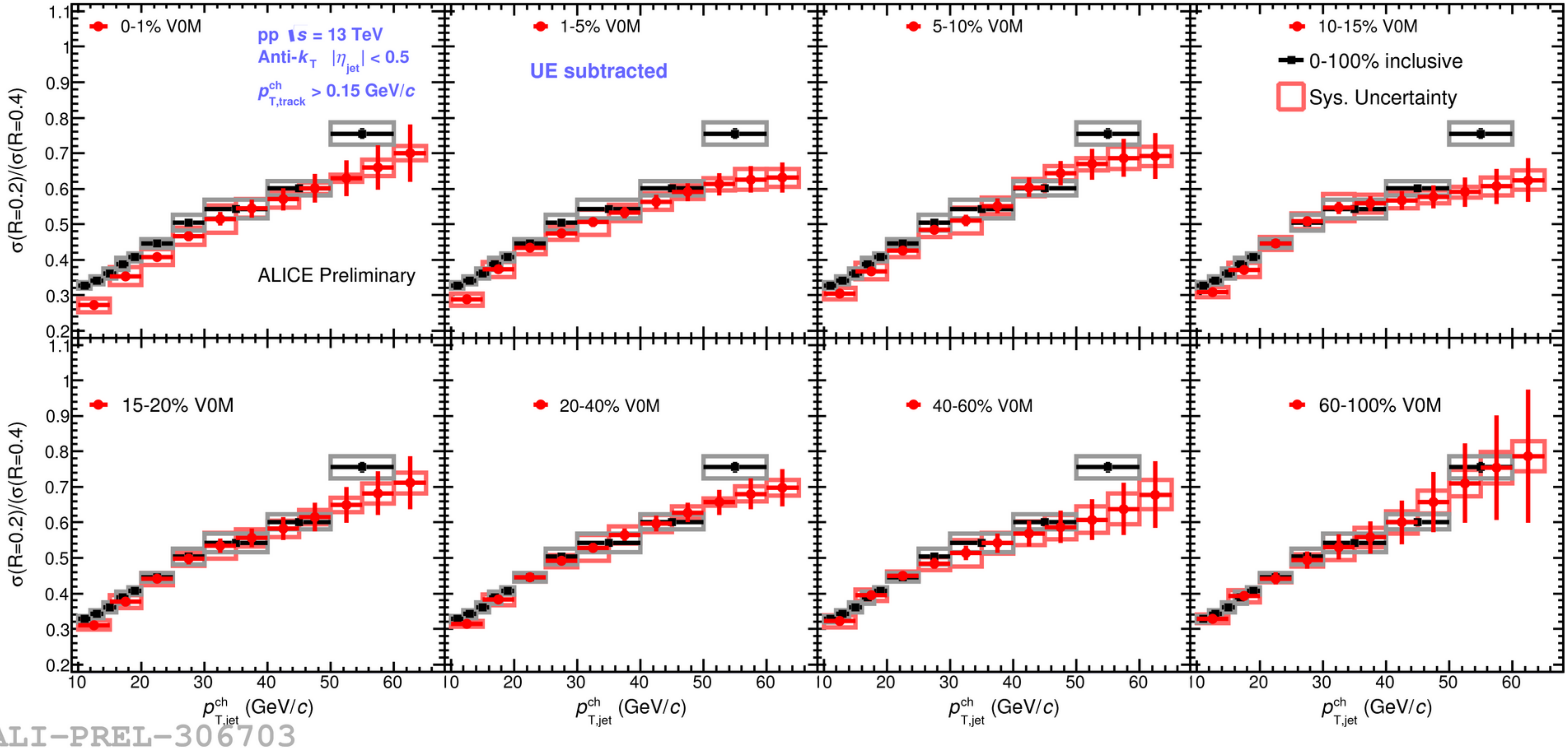
Multiplicity dependent charged jets vs. inclusive one





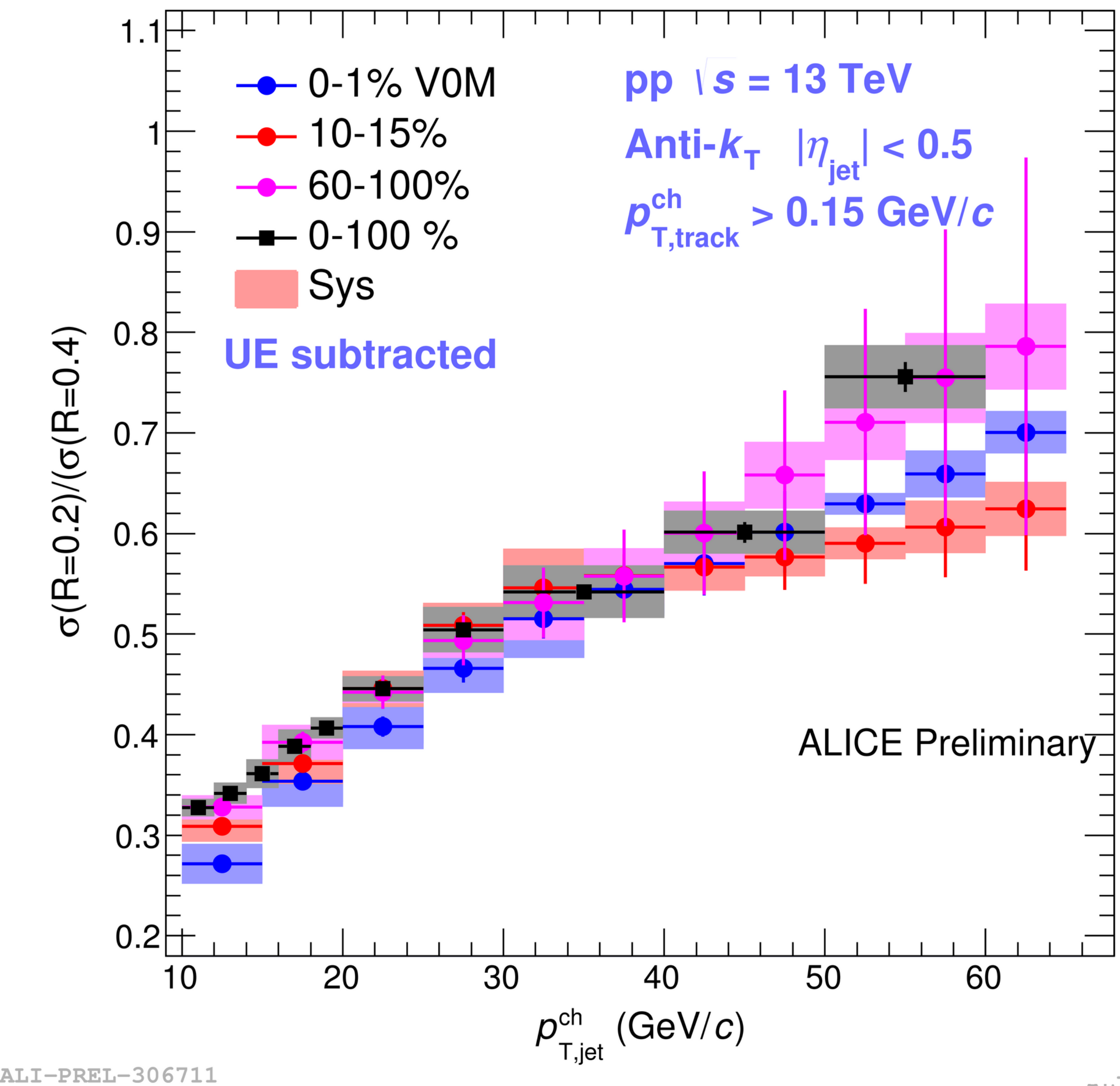
- Compare the charged jet productions in different multiplicity percentile to the inclusive jet production in pp collision
- Jet cross section ratios are weakly depend on jet p_T and resolution parameters

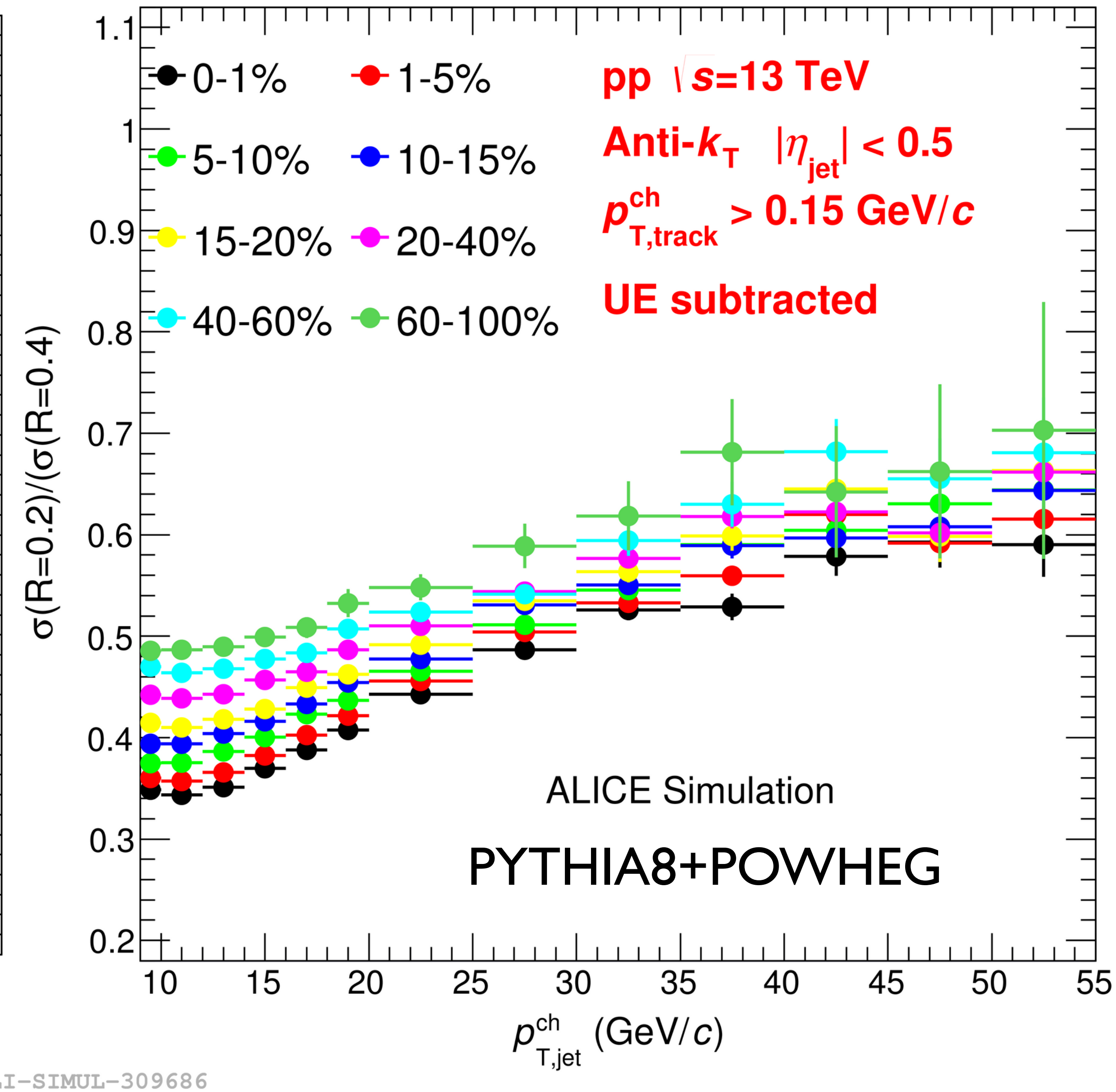
Multiplicity dependent charged jet cross section ratio



- Compare the charged jet cross section ratio in different multiplicity percentile to the inclusive ones
- No strong multiplicity dependence in the jet cross section ratio

Cross section ratio from data and MC

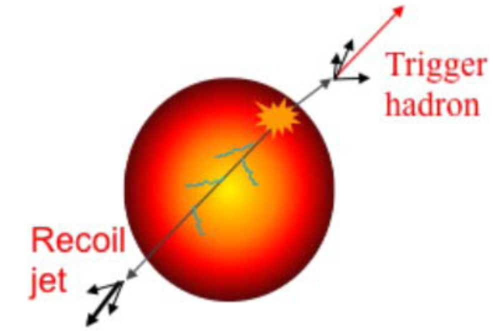




- Data measurements show centrality independent jet cross section ratio while MC shows centrality dependence
  - Inclusive jet cross section can be reproduced by POWHEG calculation but not the centrality dependent cross section in pp collisions

➡ Underlying event differences or other mechanism?

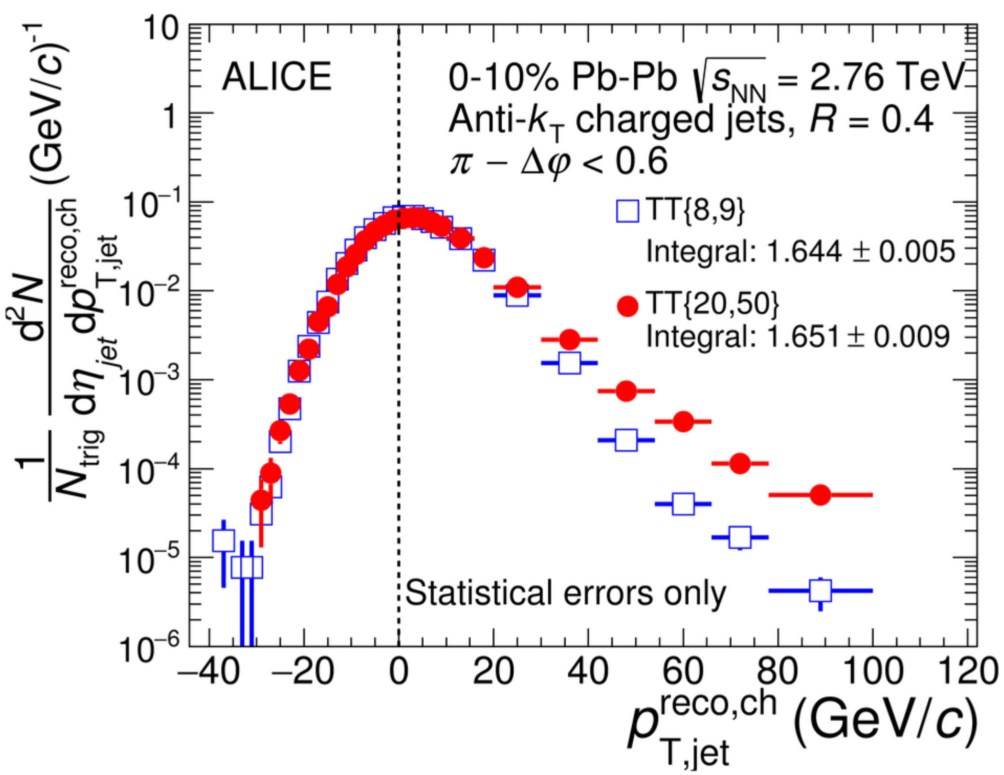
Semi-inclusive hadron-jet correlations



- New observables of recoil jet measurements:
  - pp: calculable via pQCD
  - AA: a good handle on the combinatorial background by varying $p_{T,trig}$ →systematically well-controlled at low p_{Tjet}, large R
  - Trigger hadron close to surface, but no bias on recoil jets
  - Per trigger quantity → no need for N_{coll}/N_{MPI} to compare event classes/centrality

$$\Delta_{recoil} = \frac{1}{N_{trig}} \frac{d^2 N_{jet}}{dp^{ch}_{T,jet} d\eta}\Big|_{p_{T,trig} \in \{20,50\}} - c_{Ref} \cdot \frac{1}{N_{trig}} \frac{d^2 N_{jet}}{dp^{ch}_{T,jet} d\eta}\Big|_{p_{T,trig} \in \{8,9\}}$$

c_{Ref}: accounts for invariance of jet density with TT-class ($c_{Ref} \approx 0.94$)



TT = Trigger Track

TT{X,Y} means $p_{T,trig} \in$ {X,Y} GeV/c

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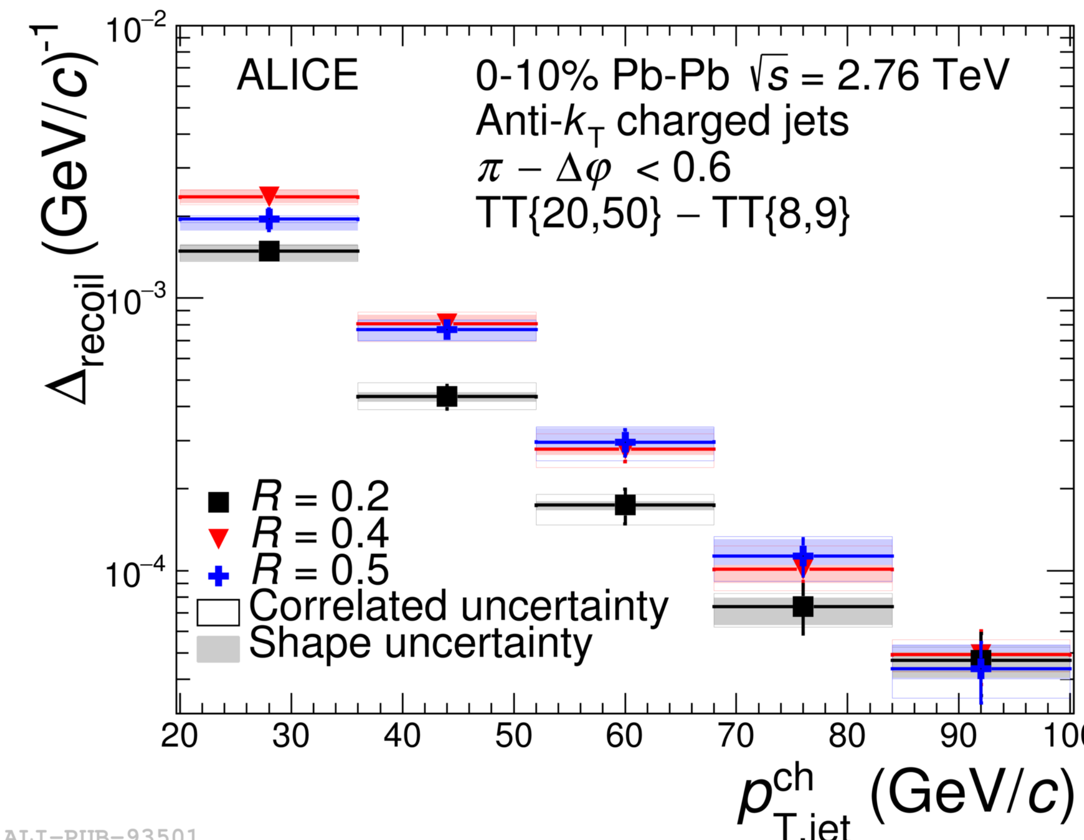
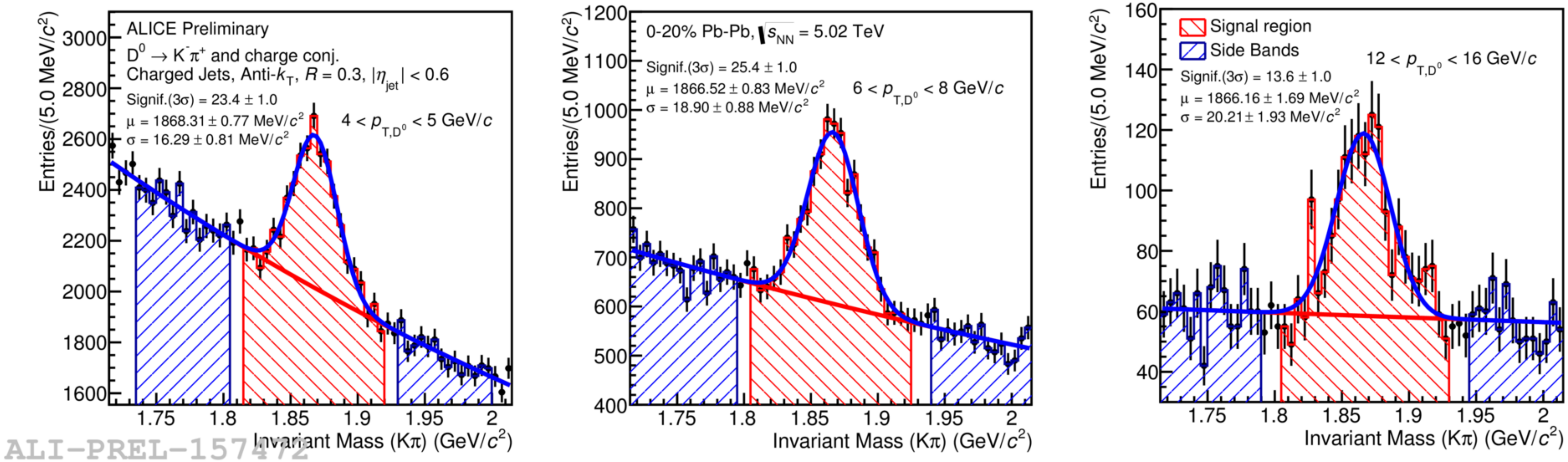
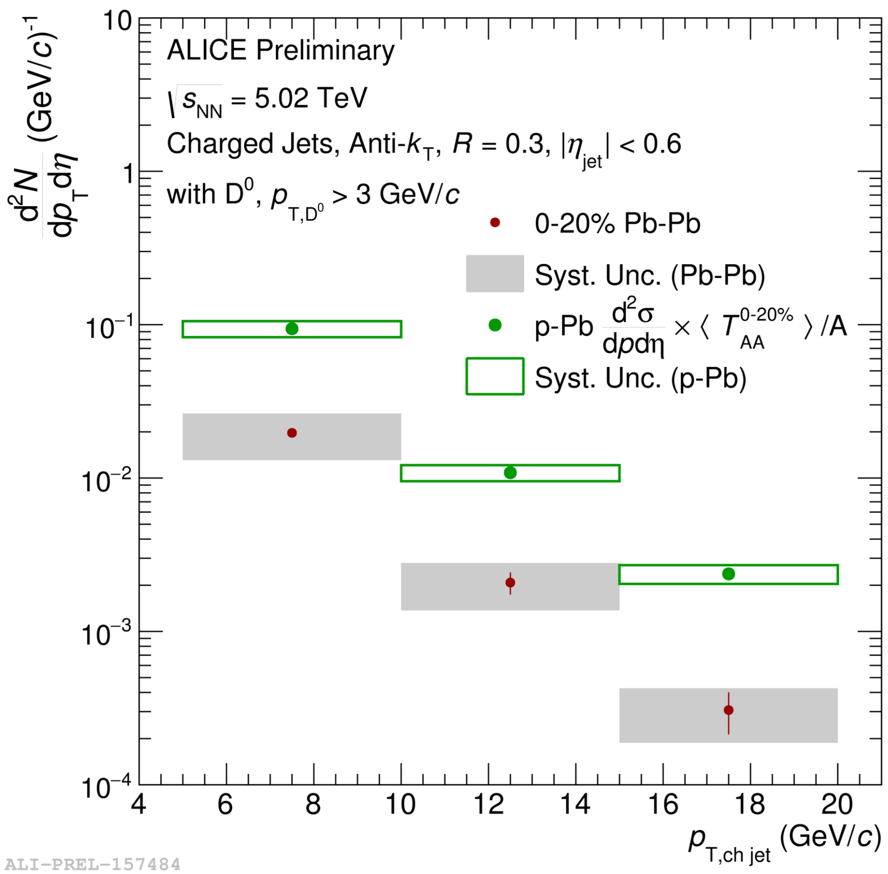


Heavy-Quark (c-)jet tagging

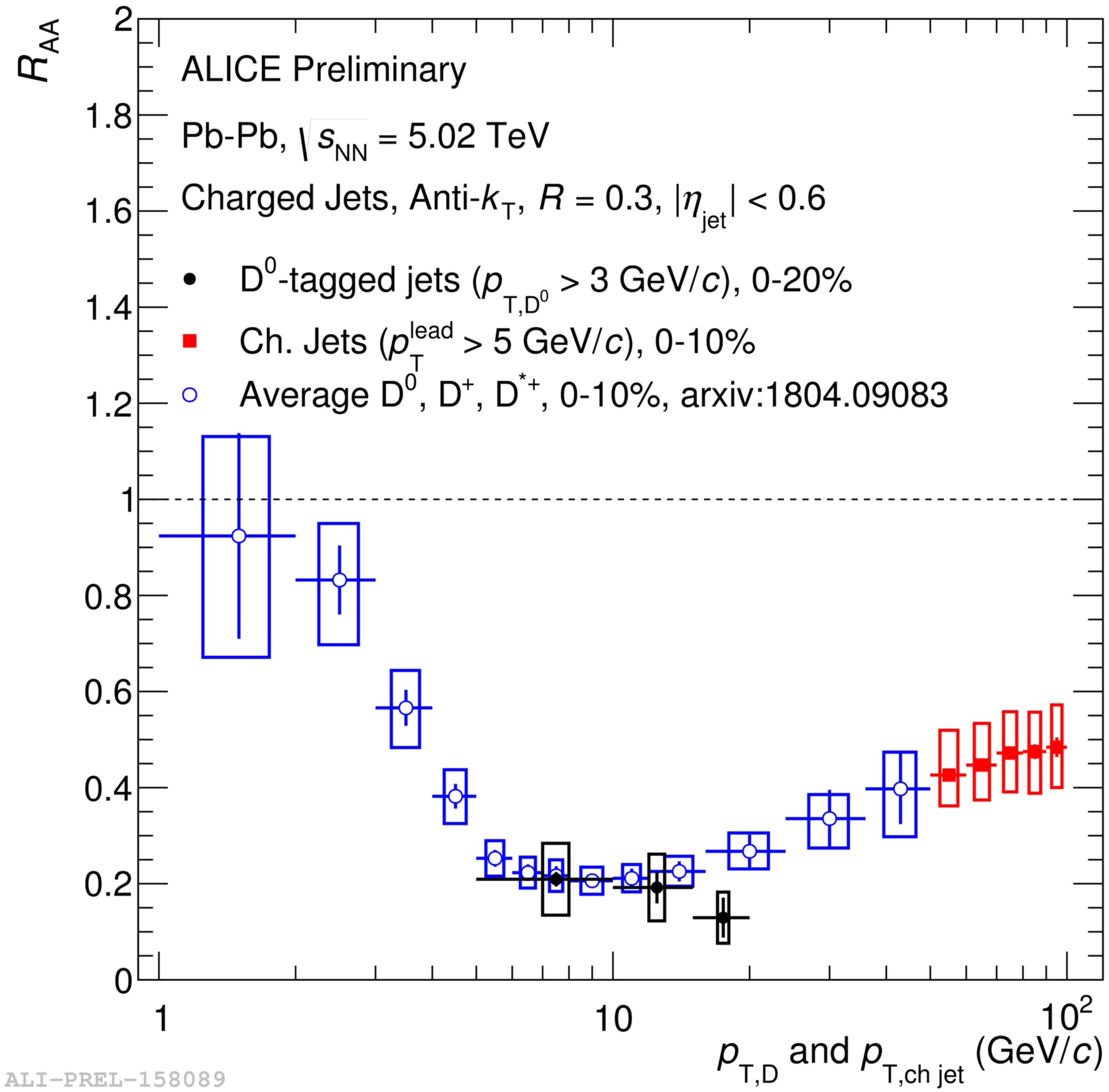
- Charged jet containing a D meson as one of the constituents





- Invariant mass analysis to extract D-jet raw spectrum
  - Background spectrum from side bands
- Corrected jet p_T spectra with unfolding for detector effects and background fluctuations
- D^0-tagged jets are measured down to 5 GeV/c
  - D^0 mesons must come from hard scattering
  - Jets from charm quarks are measured selectively

Jet R_{AA}: inclusive vs. tagged D^0-jet



$$R_{AA} = \frac{1}{<N_{coll}>} \frac{d^2N_{AA}/dp_T d\eta}{d^2N_{pp}/dp_T d\eta}$$

- Strong suppression of D^0-tagged jets in most central collisions
  - ➡ Hints of more suppression at low p_T D^0-tagged jets than inclusive jets at higher p_T
  - ➡ Similar to D meson R_{AA}
  - ➡ Importance of collisional energy loss for heavy flavor jets
- ➡ Current data is not precise enough to draw conclusion without same kinematical range

Summary and outlook

- Inclusive jet productions have been studied in pp and Pb-Pb collisions
  - Inclusive jet cross sections can be well described by POWHEG+PYTHIA8 model calculations
  - Jet cross section ratios using different resolution parameters calculated, no collision system or energy dependent
  - Nuclear modification factor R_{AA} has been measured
    - Strong suppression in most central Pb-Pb collisions
    - Consistent results between charged jets and full jets
- Multiplicity dependent jet productions have been studied
  - No strong jet p_T dependent jet production ratio compared to inclusive one
  - Jet cross section ratios using different parameters can't be reproduced by POWHEG MC

➡ More differential study using jet tagging with joint China-France effort ongoing! Stay tuned…

Thank you for your attention!