Apparent modification of the jet-like yield in high-multiplicity proton-proton collisions

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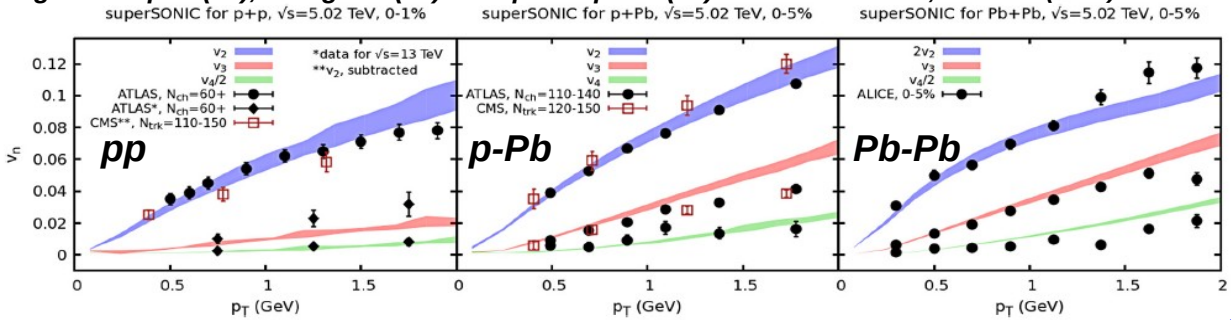
Motivation

-> High-multiplicity proton-proton collisions show collective behavior

$$\frac{\mathrm{d}n}{\mathrm{d}\phi} \propto 1 + \sum_n 2v_n(p_T)\cos[n(\phi - \Psi_n)]$$

-> Good agreement with relativistic viscous hydrodynamic calculations

Figure: Elliptic (v2), triangular (v3) and quadrupolar (v4) flow coefficients, PLB 774 (2017) 351-356



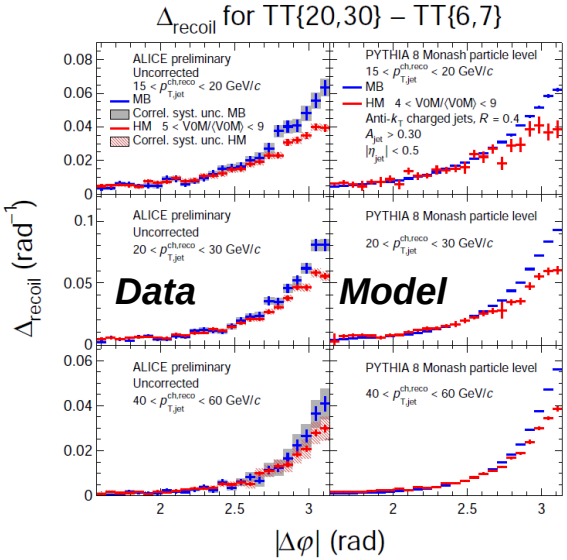


Figure: Uncorrected acoplanarity distributions for ALICE data (left) and PYTHIA 8 Monash (right), Nucl.Phys.A 1005 (2021) 121924

No jet quenching found so far -> searches warranted: ***first measurement from ALICE collaboration***: Search for jet quenching effects in high multiplicity pp collisions at 13 TeV (preliminary)

- Event activity classes based on average multiplicities
- broadening of recoil jet acoplanarity -> characteristic of jet quenching
- similar effect observed in the PYTHIA model (which lacks the mechanism of jet-quenching)

Goal:

Study high-multiplicity pp events in PYTHIA to understand the potential

Methods - Observable and Event activity classifier R_T

Standard two-particle azimuthal correlation analysis to study jet-quenching effects

I_{AA}: *ratio of jet-like yield from AA to the one from pp collisions*

-> interplay between the parton production spectrum and energy loss in the medium

-> Towards (away) region: enhancement (suppression)

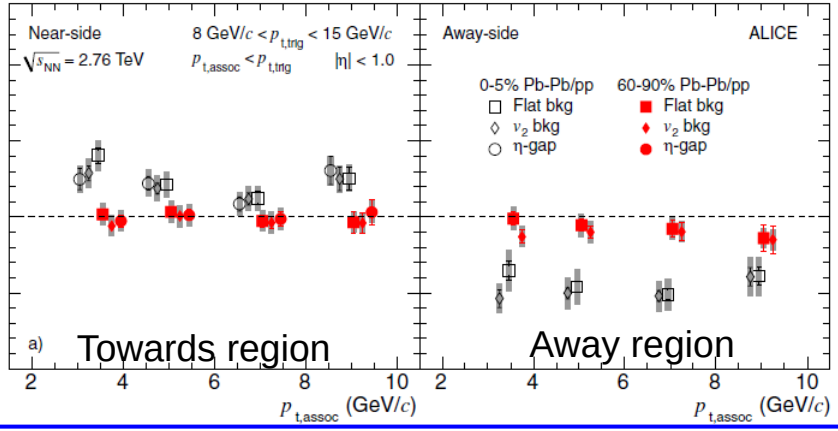


Figure:

I_{AA} for central (black) and peripheral (red) collisions, PRL 108, 092301 (2012)

-> ***PYTHIA 8 model:*** 2->2 process + parton shower (Initial- and Final state radiation), Color Reconnection, MPI

-> primary charged particles in $|\eta|<0.8$, $\sqrt{s}$ = 5.02 TeV

-> trigger particle: 8 GeV/c < p_T < 15 GeV/c

-> Study Underlying Event activity (semi-hard and multi-parton interactions)

-> Use ***relative transverse activitv classifier R_T***

$$R_{\mathrm{T}} = \frac{N_{\mathrm{ch}}^{\mathrm{trans.}}}{\langle N_{\mathrm{ch}}^{\mathrm{trans.}} \rangle}$$

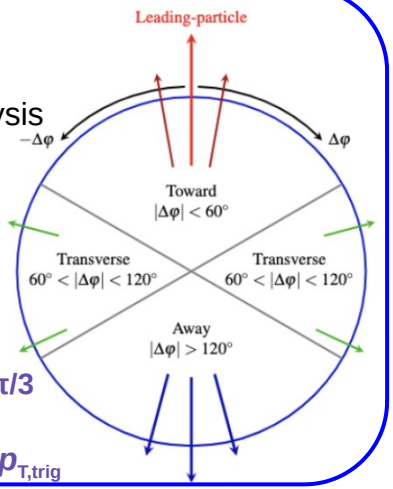
=> ***Goal: study how event selection based on R_T biases towards and away regions***

R_T :defined in the 'transverse region', adopted in the Underlying Event analysis

-> Towards region: $|\Delta\varphi| < \pi/3$

-> Away region: $|\Delta\varphi| > 2\pi/3$
Sensitive to string fragmentation

-> **Transverse region: $\pi/3 < |\Delta\varphi| < 2\pi/3$**
- Sensitive to Underlying Event
- Used to build R_T; insensitive to $p_{T,trig}$



Methods - jet-like signal $C(\Delta\eta\Delta\phi)$ extraction

-> **correlations at partonic level** (due to gluon radiation or colour reconnection) are turned **on and off:** Initial- and Final state radiation, CR

-> **Monash tune:** above given R_T value $\langle N_{MPI} \rangle$ saturates -> towards region "picks up" particles from jet fragments -> **activity biased**

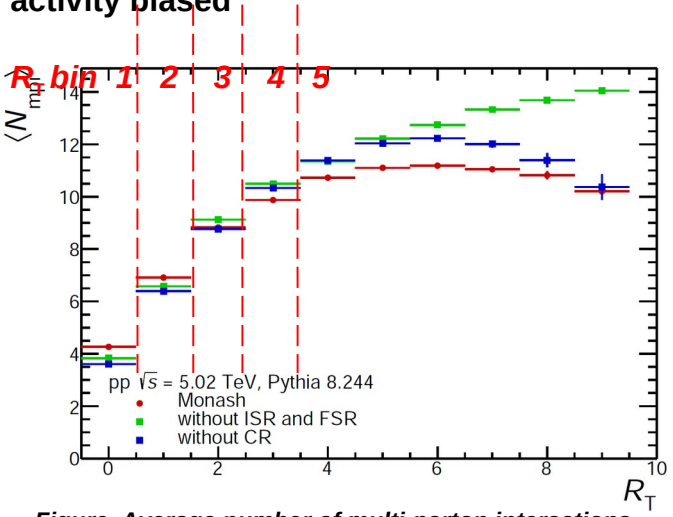


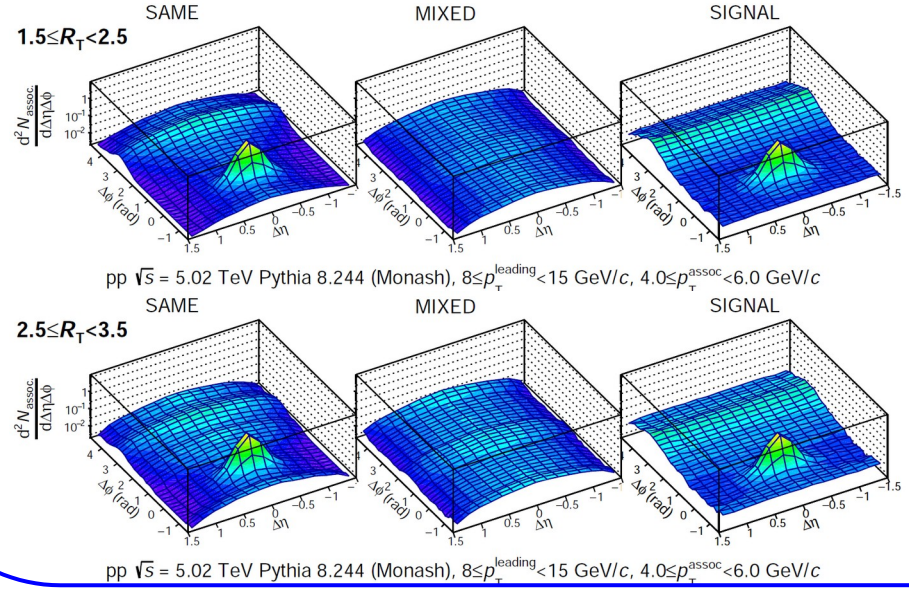
Figure. Average number of multi-parton interactions as a function of R_T

-> selection on R_T, ***a third structure in the transverse region*** ($\pi/3 < |\Delta\varphi| < 2\pi/3$): associated yield increases with R_T

-> **contribution** to the towards and the away regions has to be ***removed: using mixed event technique***

-> Underlying event subtracted using Zero Yield at Minimum method

-> **evolution of jet signal with R_T is studied** $C(\Delta\eta, \Delta\phi) = B(0,0)\frac{S(\Delta\eta, \Delta\phi)}{B(\Delta\eta, \Delta\phi)}$



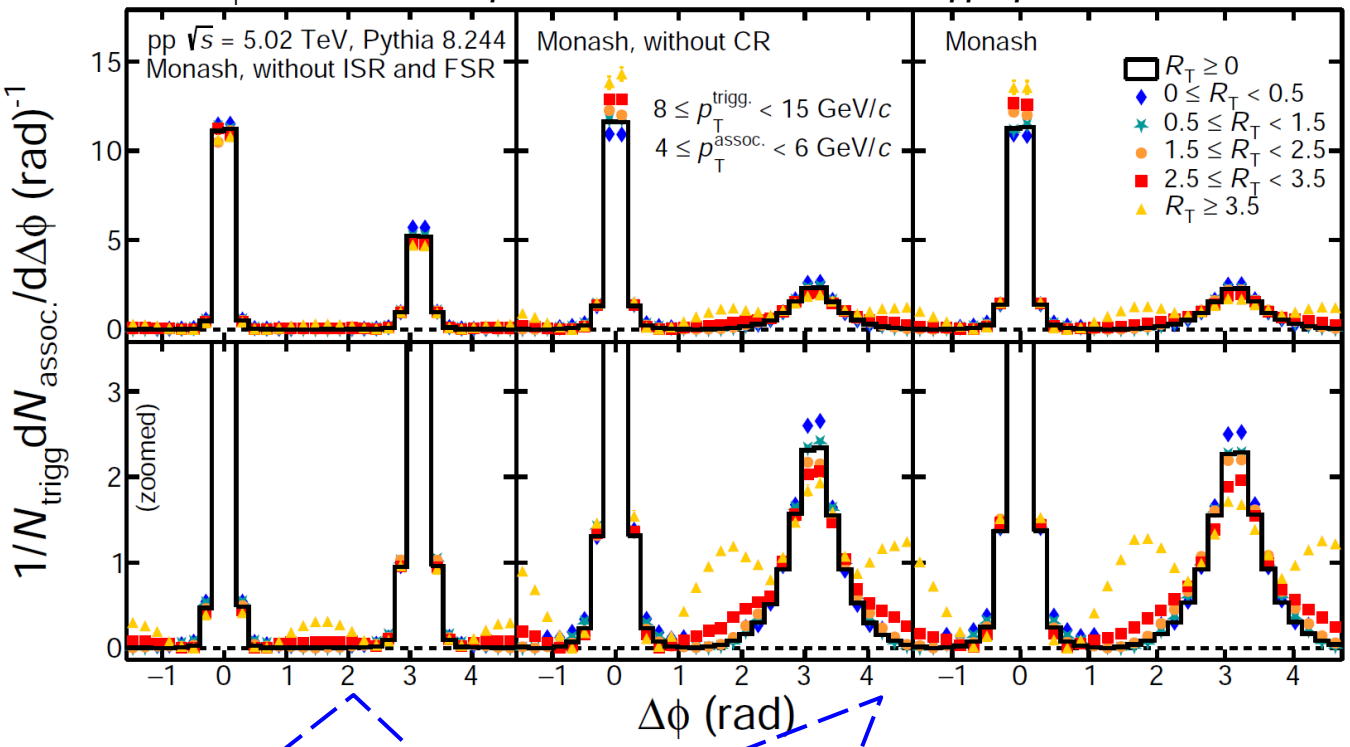
Results - I.

R_T > 2.5: distributions have peak at Δφ ~ 2 rad
-> region where NMPI saturates: presence of a third jet -> selection bias

-> experimentally also observed *ArXiv 1910.04457*: particle production strong increase with R_T

-> Quantify the effect: calculate the ratio of yields from different R_T classes to the R_T-integrated one -> I_{pp}

Figure. Charged particle yield as a function of Δφ. R_T-integrated distributions are compared to those from different R_T classes. The lower panels are zoomed versions of the upper panels.



-> different Δφ regions show no dependence on R_T for $0<R_T<2.5$
-> shape of the jet peaks are independent of R_T

-> away region exhibits a broadening with R_T
-> yield in the towards region increases with R_T

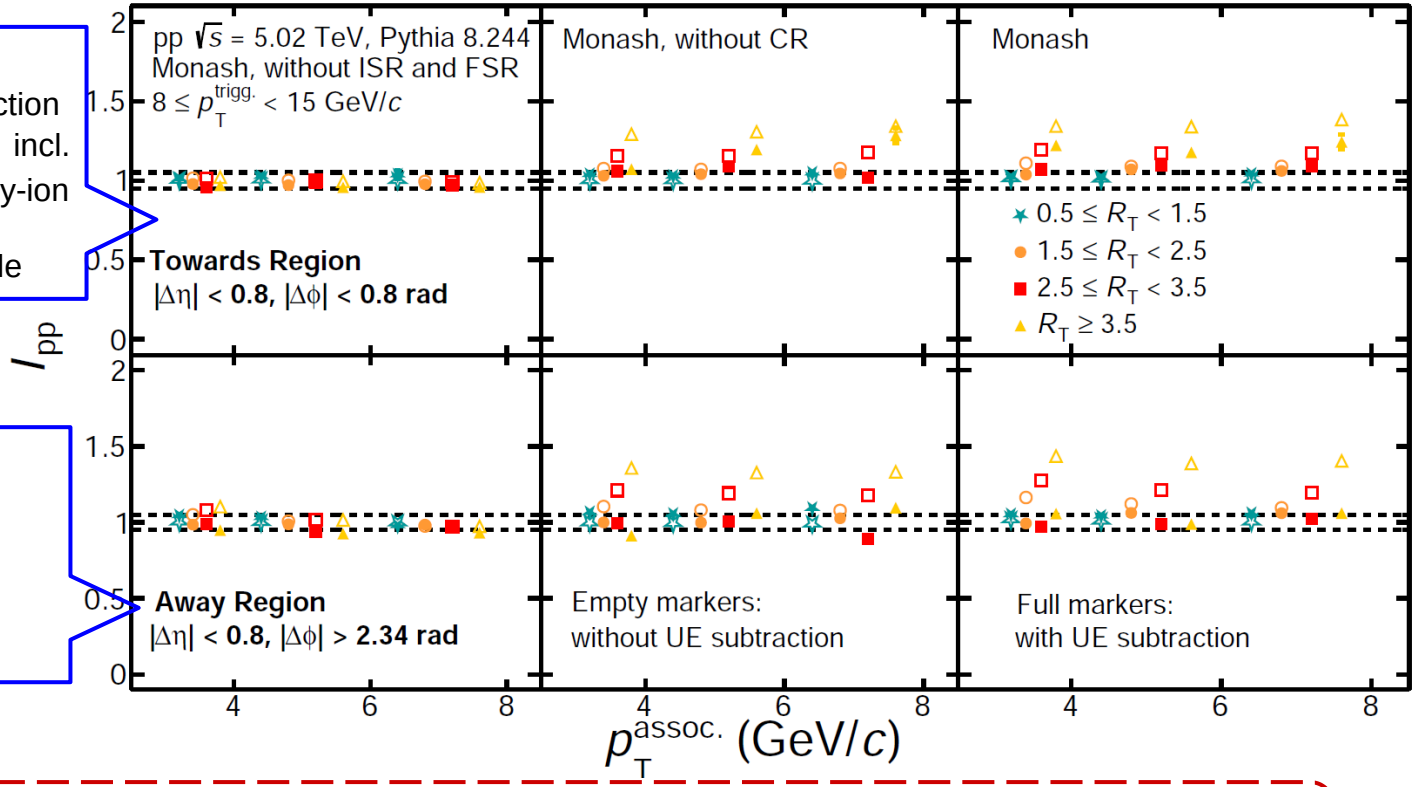
Results - II.

-> I_{pp}= 1: in the absence of selection bias

-> Selection bias reduced: integrate the Δφ distribution around the towards/away regions

-> I_{pp} = 1 w/o radiations
-> negl. difference w/ UE subtraction
-> I_{pp} increase with R_T incl. radiations: similar to heavy-ion results
=> Radiation plays significant role

-> I_{pp} = 1 w/o radiations
-> w/ UE subtraction: different behavior w.r.t. towards region
-> I_{pp} = 1 after UE subtraction: event selection bias negligible



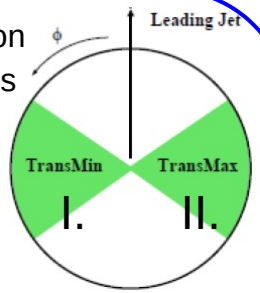
Takeaway message

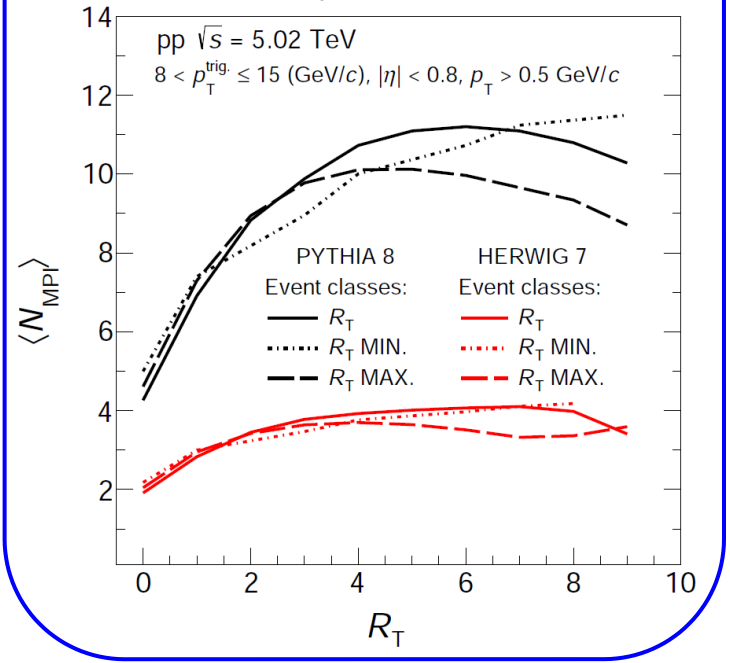
High-multiplcity pp events can be made bias-free using event classification based on R_T and study observables in the away region

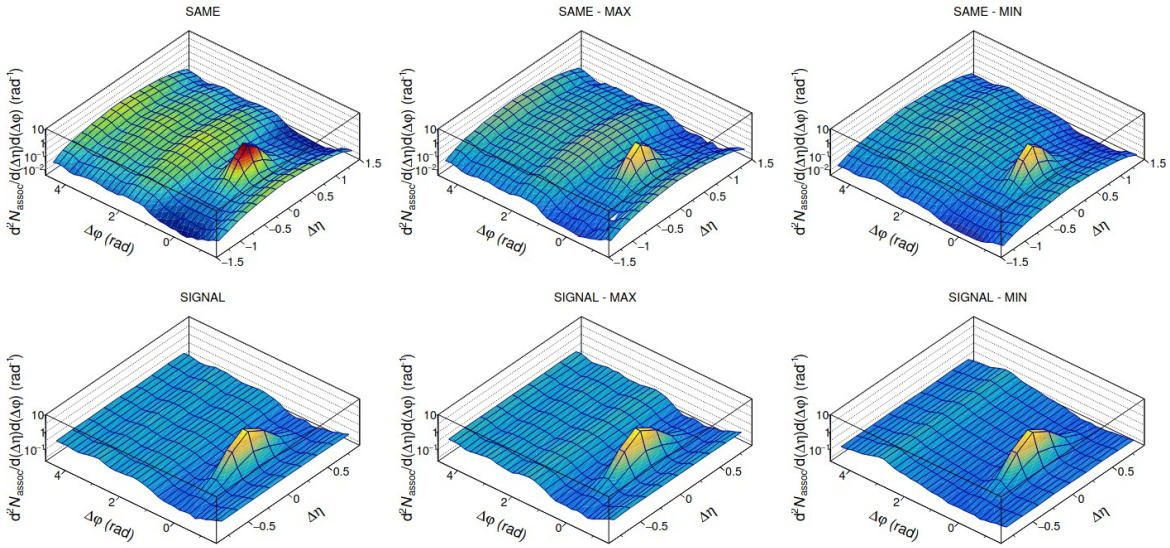
Outlook - Disentangling the hard gluon Bremsstrahlung effects

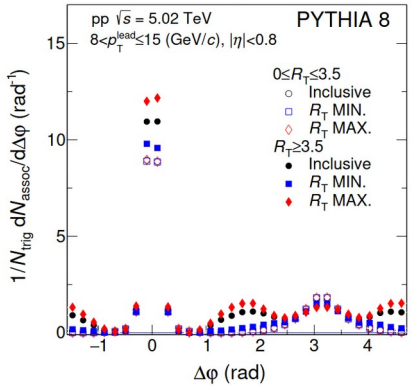
New selection of R_T based on charged-particle multiplicities $N_{ch}^{trans.max}$ and $N_{ch}^{trans.min}$

Trans-max (trans-min) = trans. region (I. or II.) with largest (smallest) N_{ch}









Di-hadron correlation as a function of UE activity

→ presence of more ISR and FSR in events with large $R_{T,max}$

→ $R_{T,min}$ better suited as event activity estimator (reduced bias)

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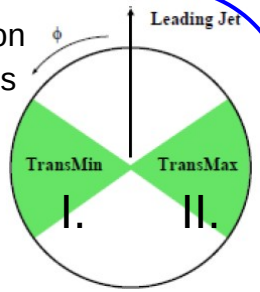

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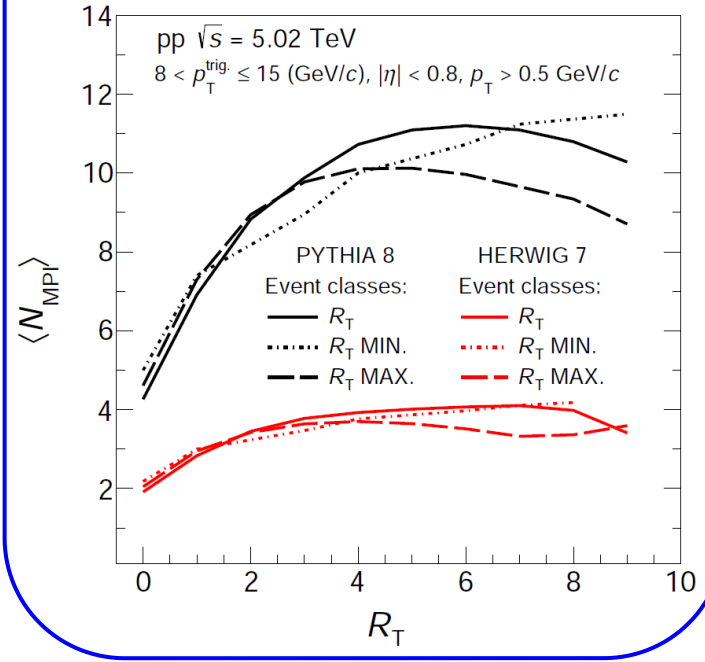

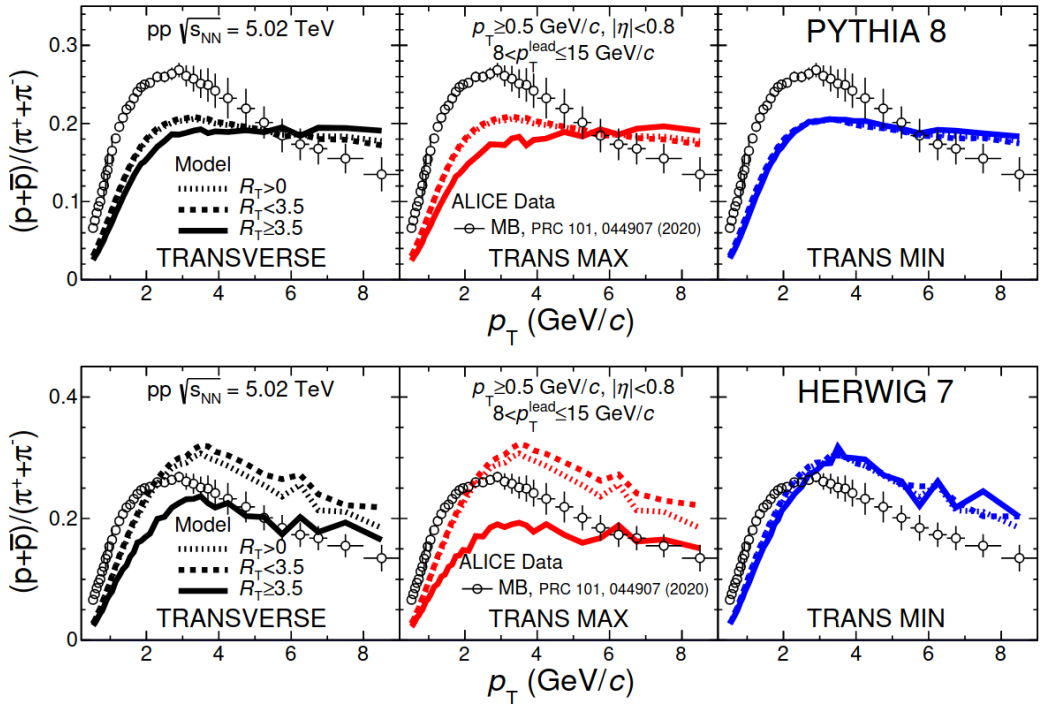

Barion-to-meson ratios as a function of UE activity

$R_{T,max}$: depletion consistent with the presence of jets in the trans. region

$R_{T,min}$: enhancement with increasing $R_{T,min}$ → expected in events with large avg. N_{MPI}