Search for jet quenching effects in high-multiplicity proton-proton collisions at $\sqrt{s}$ = 13 TeV

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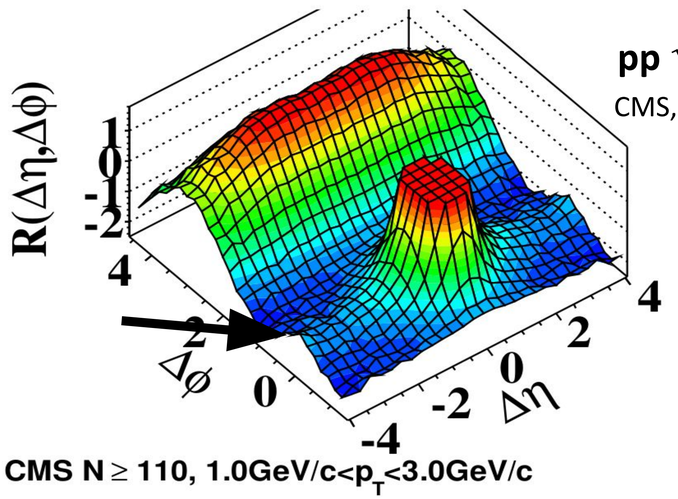
Motivation: quark-gluon plasma in small collision systems?

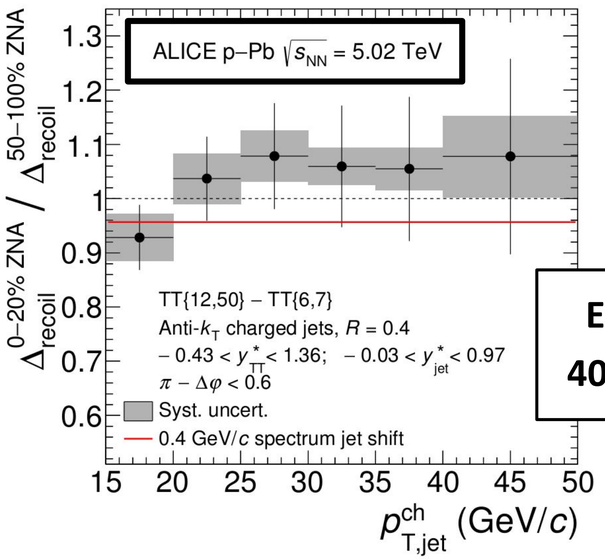
Evidence of collective effects



pp $\sqrt{s}$ = 7 TeV

CMS, JHEP 09 (2010) 091

No significant evidence of jet quenching

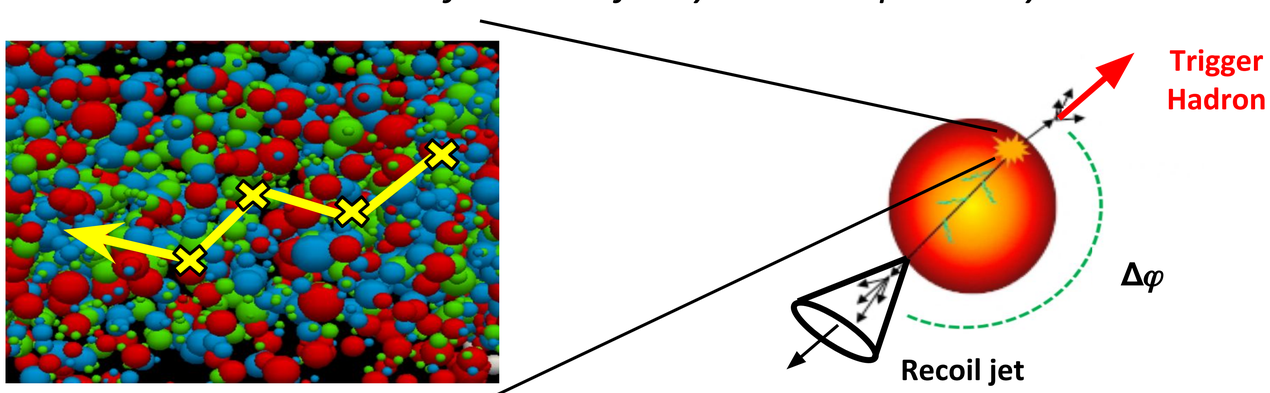


ALICE, PLB 783 (2019) 95

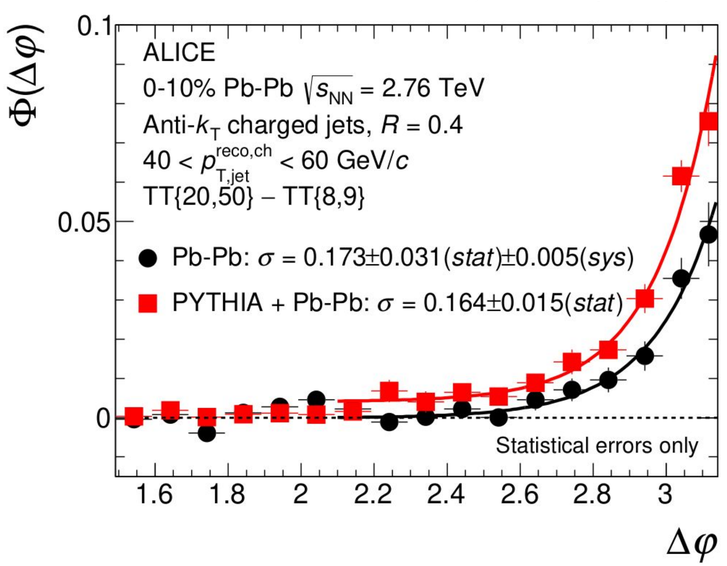
Energy loss-limit
400 MeV@ 90% CL

Jet quenching in high particle multiplicity pp collisions

- **Inclusive measurements** → undefined Glauber scaling
- **Semi-inclusive measurements** → *increase of hadron-jet system acoplanarity*

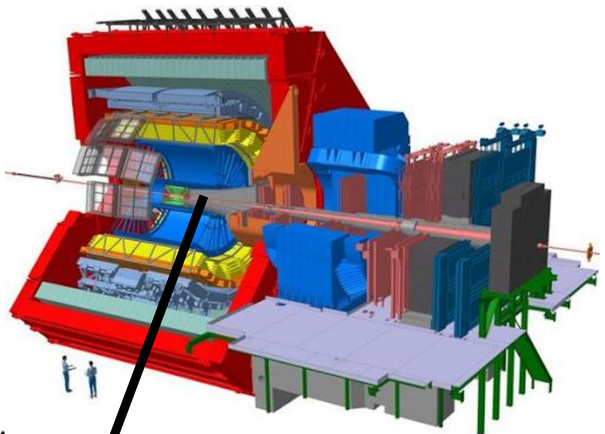


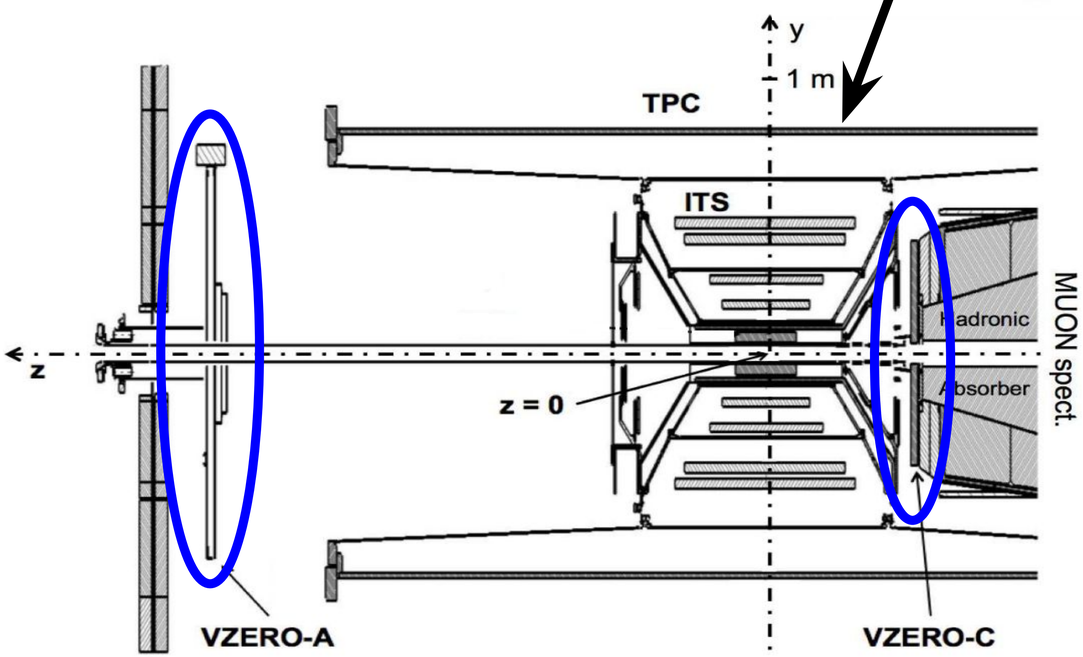
ALICE, JHEP 09 (2015) 170



pp collisions at $\sqrt{s}$ = 13 TeV

- Data from 2016 - 2018
- Online triggers:
  - **Minimum bias** (MB): 0.098 pb^{-1}
  - **High-multiplicity** (HM): 13 pb^{-1}





V0A: 2.8 < η < 5.1

V0C: -3.7 < η < -1.7

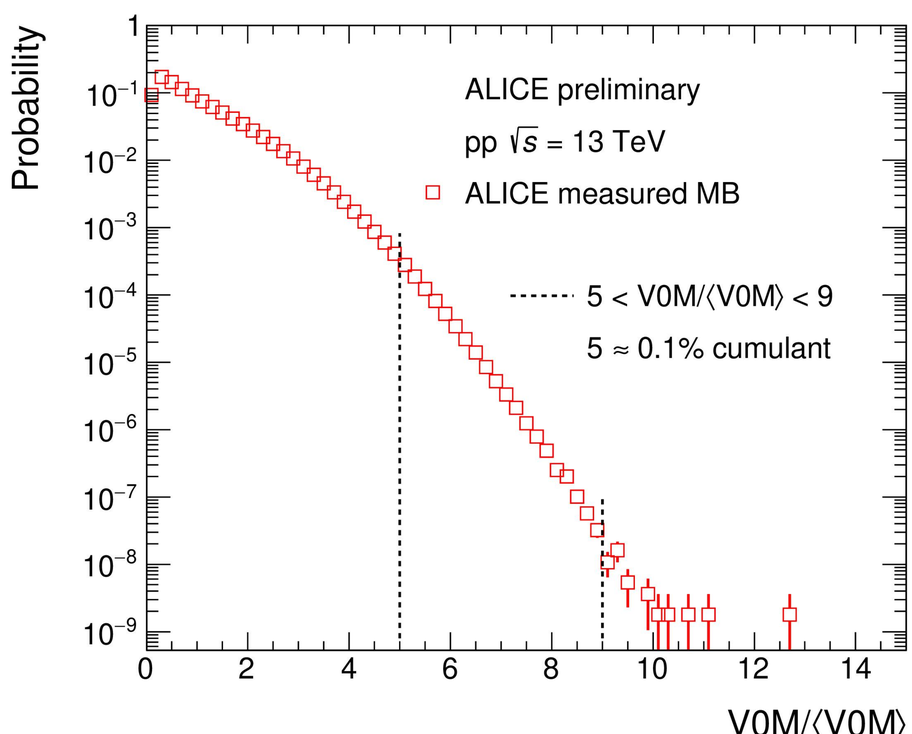
- **Offline event activity (EA) selection**:

  V0M = V0A + V0C
- **Scaled multiplicity:** V0M/⟨V0M⟩

⟨V0M⟩ - **mean of MB distribution** → Enables comparison of runs with differing V0 gain, and with theory

- **HM trigger are limited from above to exclude pile-up events**

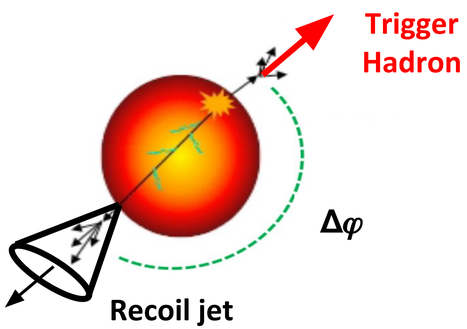
  5 < V0M/⟨V0M⟩ < 9 ≈ 0.1 % of MB cross section



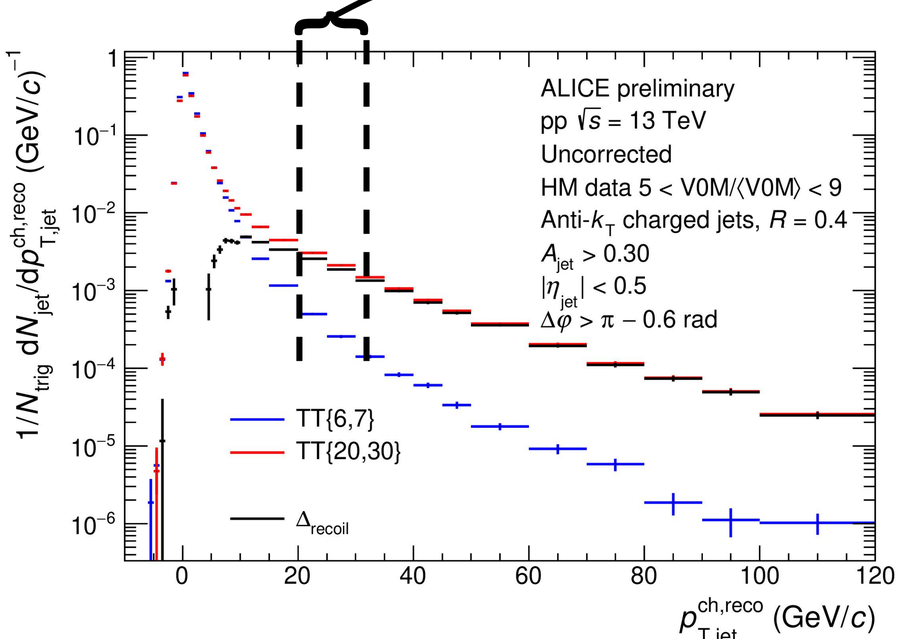
Semi-inclusive recoil jet analysis

- Anti-k_T charged-track jets recoiling from a high-p_T trigger hadron
- Jet p_T is corrected according to **area-based *ρ*A approach**
- TT - uncorrelated jet yield **removed on statistical basis with data driven approach** (see details [1]):

$$\Delta_{\mathrm{recoil}} = \frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}N_{\mathrm{jet}}}{\mathrm{d}p^{\mathrm{ch}}_{\mathrm{T\,jet}}}\bigg|_{\mathrm{TT}\{20,30\}} - \frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}N_{\mathrm{jet}}}{\mathrm{d}p^{\mathrm{ch}}_{\mathrm{T\,jet}}}\bigg|_{\mathrm{TT}\{6,7\}}$$



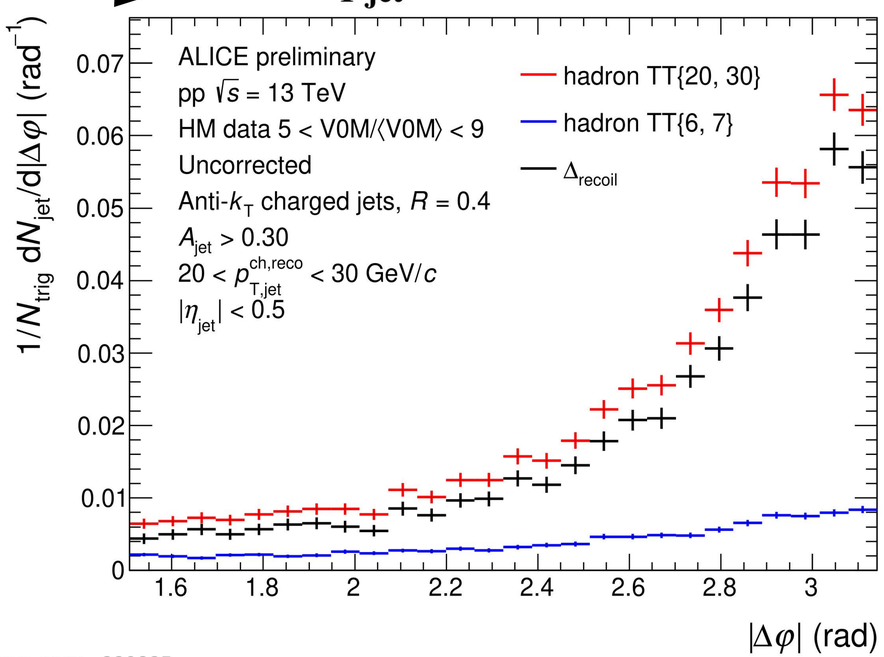
- TT{x,y} ⟶ trigger hadron with $p_T \in$ (x,y) GeV/c



- Δ_{recoil} can be constructed as a **function of TT-jet opening angle**

$$\Delta_{\mathrm{recoil}}(\Delta\varphi) = \frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}N_{\mathrm{jet}}}{\mathrm{d}\Delta\varphi}\bigg|_{\mathrm{TT}\{20,30\}\&p_{\mathrm{T\,jet}}} - \frac{1}{N_{\mathrm{trig}}}\frac{\mathrm{d}N_{\mathrm{jet}}}{\mathrm{d}\Delta\varphi}\bigg|_{\mathrm{TT}\{6,7\}\&p_{\mathrm{T\,jet}}}$$

Jet $p^{\mathrm{ch}}_{\mathrm{T\,jet}} \in$ (20, 30) GeV/c



[1]: Nucl.Phys. A910-911 (2013) 314–318

Acoplanarity versus event activity: raw data and PYTHIA 8

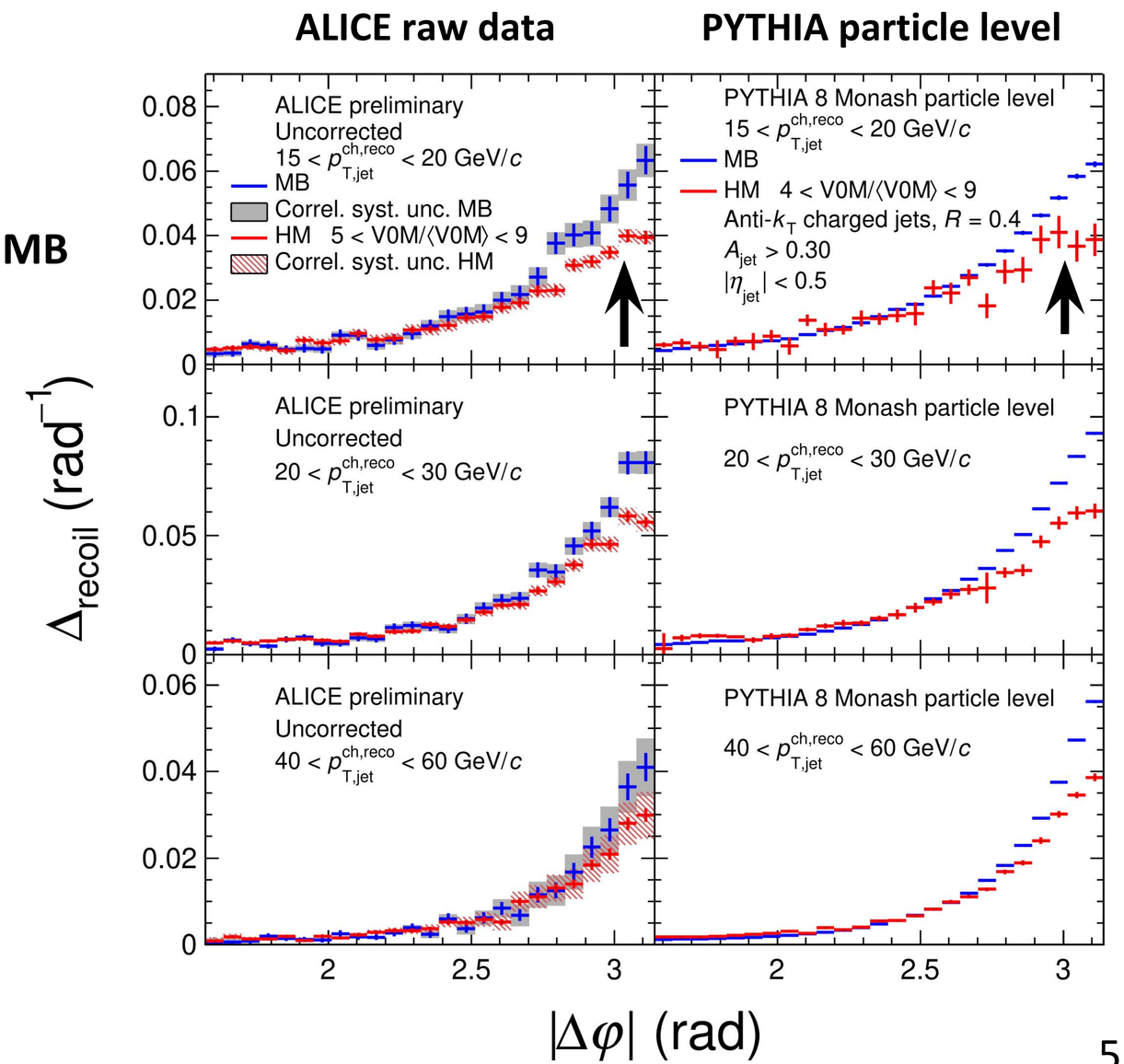
Raw data

- Estimated uncertainty from tracking efficiency
- **Significant suppression and broadening of HM data w.r.t. MB**

PYTHIA 8 data

- PYTHIA 8 Monash **exhibit qualitatively similar suppression** effect as raw data
- The effect **may be not caused by jet quenching**

Use PYTHIA 8 generator to explore origin of the effect

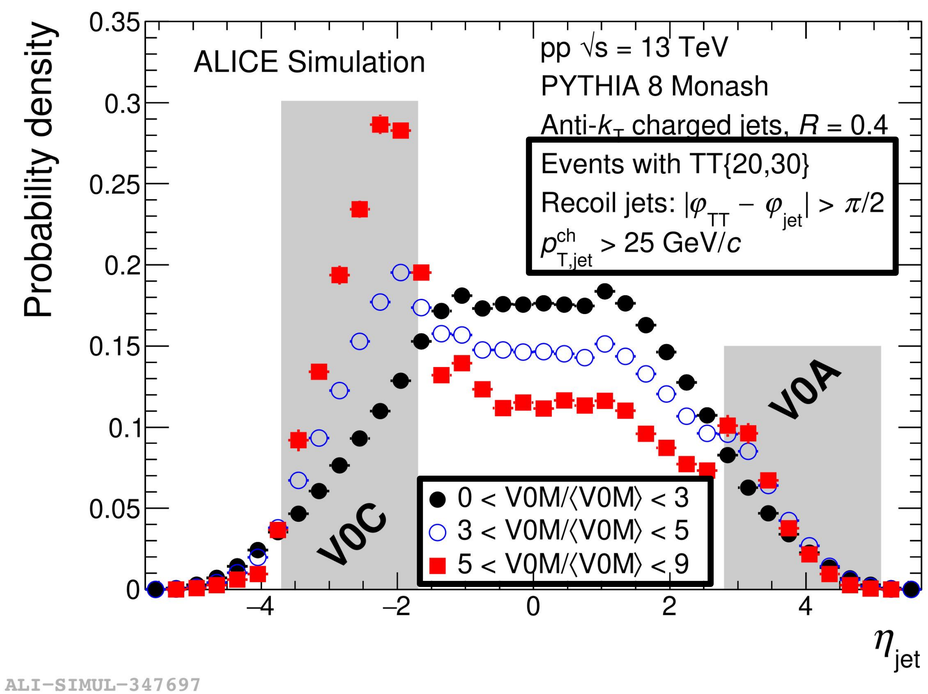


ALI-PREL-339740

PYTHIA 8 simulations: recoil jet η distribution vs. event activity

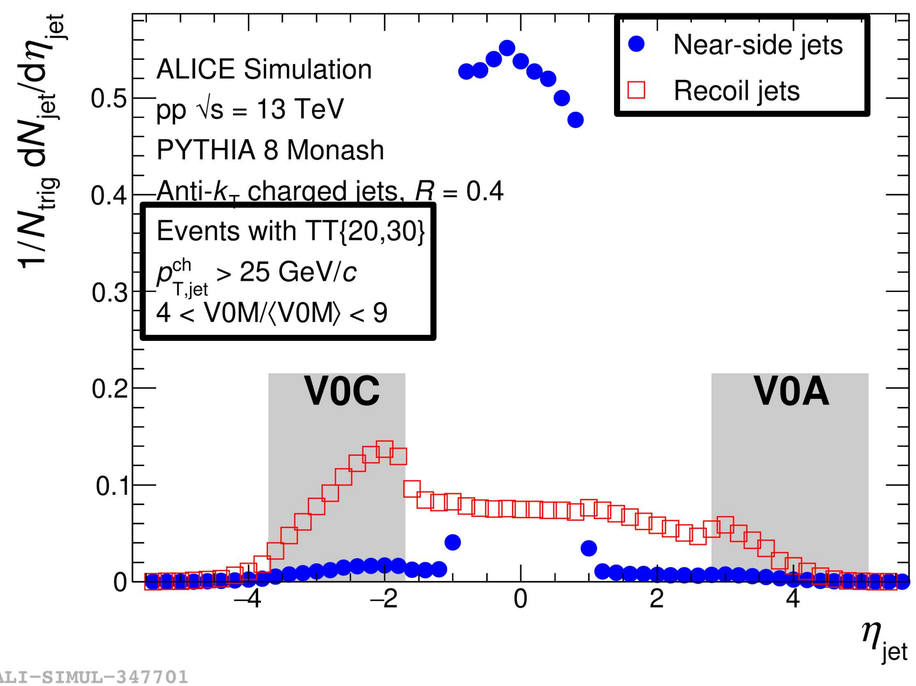
★ V0M is defined as **the number of charged, final state particles** within **V0A & V0C** acceptances

→ V0A: $2.8 < \eta < 5.1$ and V0C: $-3.7 < \eta < -1.7$



- **Increase of event activity bias enhances** the probability to find a **recoil jet in V0**
- Lower enhancement in V0A is caused by **asymmetric coverage of V0 arrays**

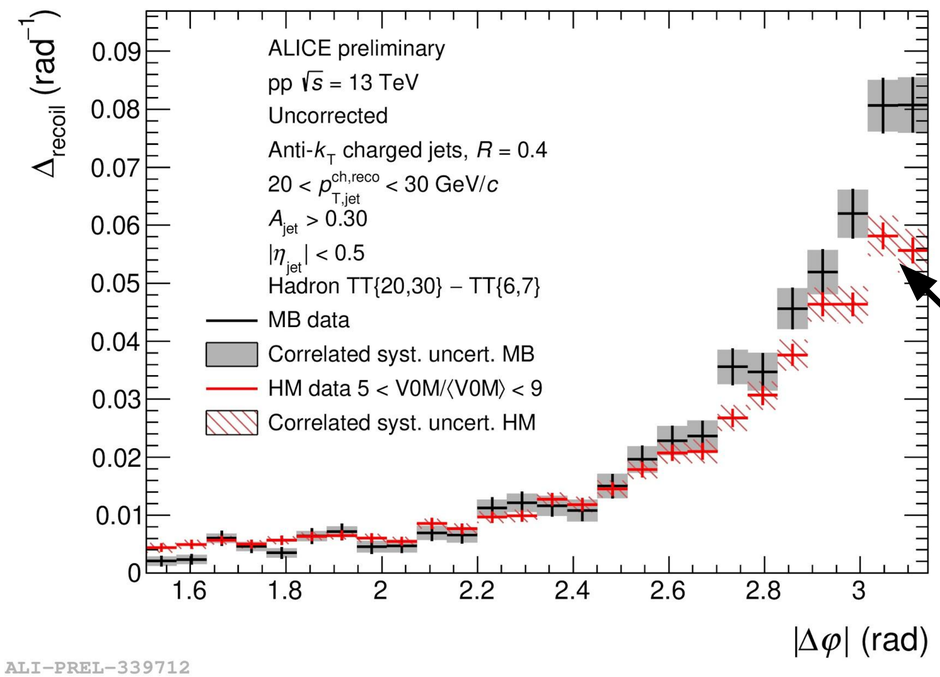
Recoil jets vs. near-side jets

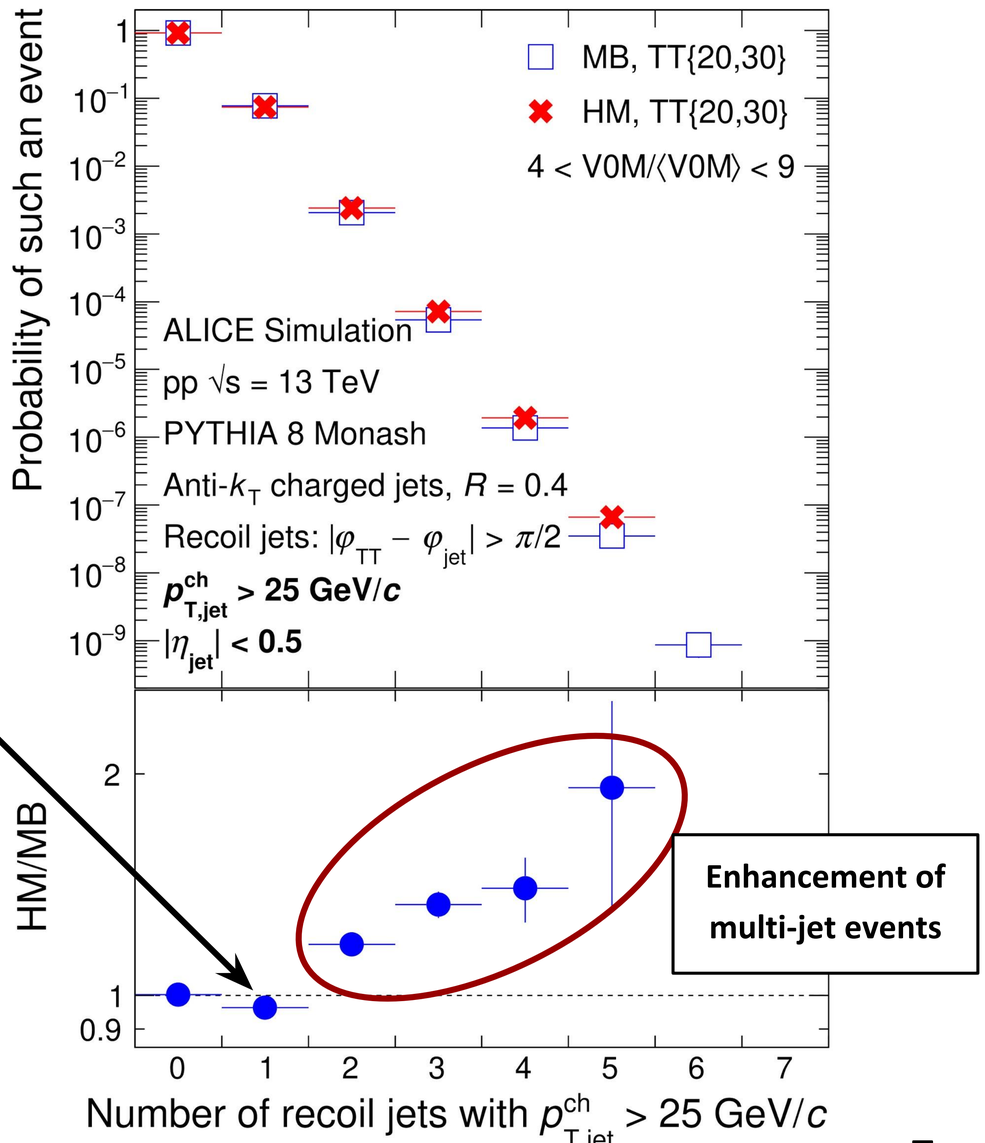


- Near-side jets are in the same hemisphere as trigger-track
- **Event activity selection biases recoil jets**

PYTHIA 8 simulations: Number of high-p_T recoil jets vs. event activity in ALICE central barrel

Raw data





- **HM events** have **suppressed probability** to have **1 hard recoil jet in ALICE central barrel w.r.t. MB**
- HM trigger **enhances multi-jet events**

Summary

Raw ALICE Data:

- Suppression and broadening of high-particle multiplicity acoplanarity distribution w.r.t. minimum bias
- **Qualitatively similar effect** is observed in **PYTHIA 8 events**

New PYTHIA 8 studies:

- High-multiplicity bias enhances probability to have a high-p_T recoil jet in V0 acceptance
- Forward high-multiplicity trigger induces **bias towards multi-jet final states** → increased acoplanarity at high-particle multiplicity is due to standard QCD effect; **Obscures possible jet quenching signal**
- **Multi-jet bias** must be taken into account when imposing high-particle multiplicity bias in small collision systems