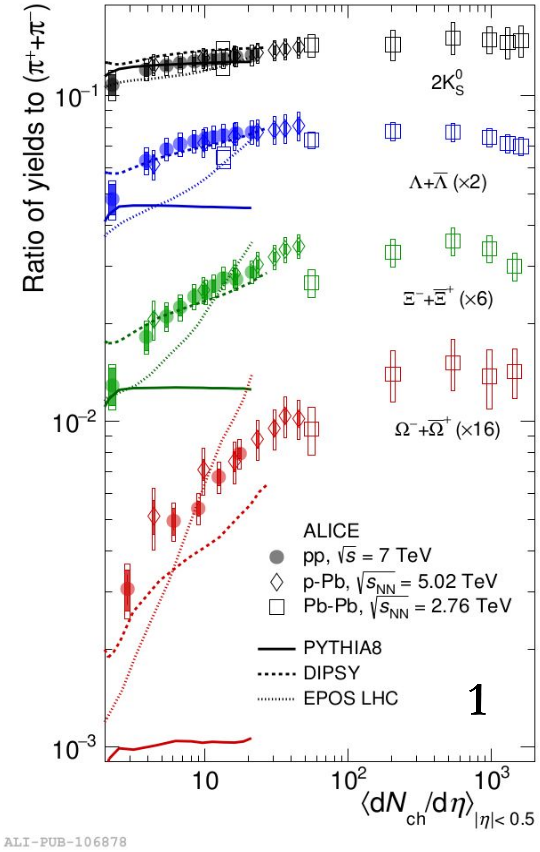
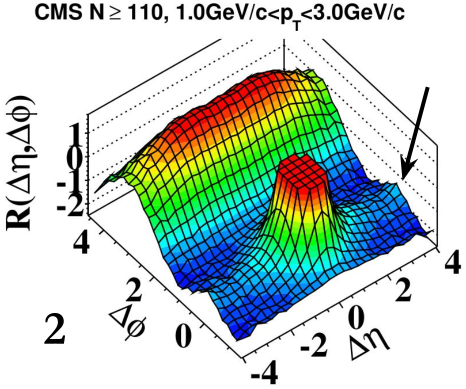
Searching for jet quenching effect using high multiplicity inclusive and semi-inclusive jets in pp collisions with ALICE

Kotliarov Artem
for the ALICE Collaboration
Nuclear Physics Institute of the Czech Academy of Sciences

Signatures of QGP-like formation in small-collision systems

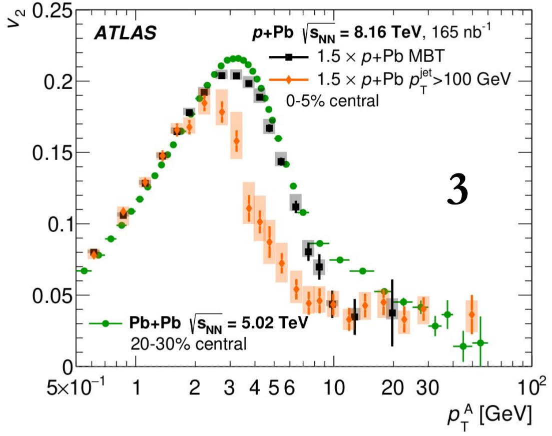
ALICE, Nature Physics 13 (2017) 535–539





CMS, JHEP 09 (2010) 091

ATLAS, Eur. Phys. J. C 80 (2020) 73



How do QGP signatures evolve with the system size?

1. Enhancement of strange hadron production in high-multiplicity pp collisions
2. Pronounced ridge structures in high-multiplicity pp collisions
3. Non-zero v_2 coefficient for low and high-p_T particles in p-Pb collisions

Do we observe signs of jet quenching in small systems?

Measurement of nuclear modification factor in p-Pb collisions

Yield suppression of high-p_T inclusive jets/hadrons relative to minimum bias pp

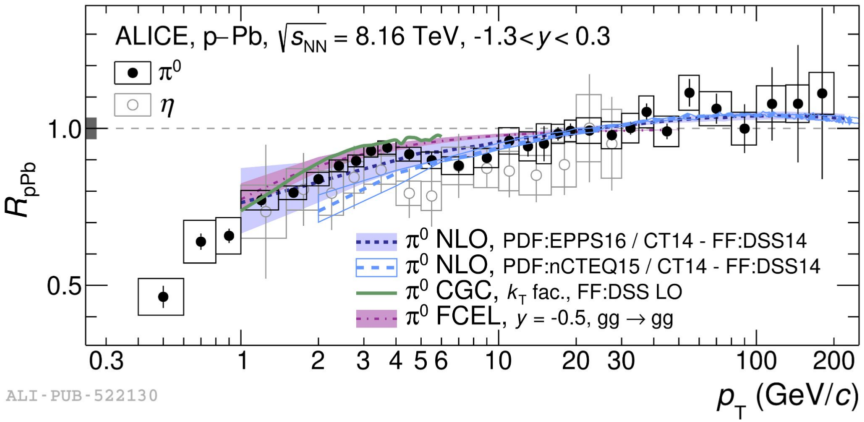
$$R_{AA} = \frac{d^2 N_{AA}/dy dp_T}{\langle T_{AA} \rangle \, d^2 \sigma_{pp}^{INEL}/dy dp_T}$$

- Limited precision of $\langle T_{AA} \rangle$ for centrality biased events
- Undefined Glauber scaling for high-multiplicity pp collisions

No conclusive results on jet quenching in small systems

→ more sensitive approaches are needed

ALICE, PLB 827 (2022) 136943

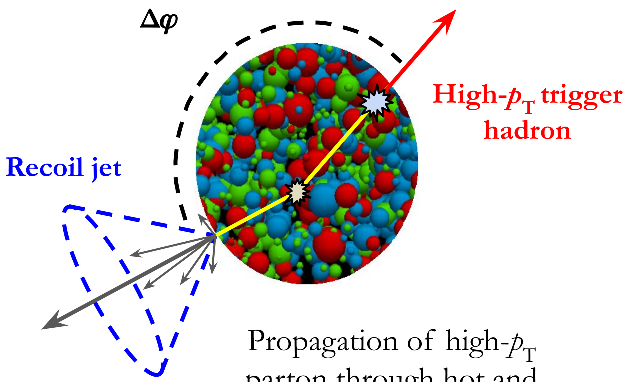


Semi-inclusive measurements of hadron-jet acoplanarity

$$\left.\frac{1}{N_{\mathrm{trig}}^{\mathrm{AA}}}\frac{\mathrm{d}^2 N_{\mathrm{jet}}^{\mathrm{AA}}}{\mathrm{d}p_{\mathrm{T,\,jet}}^{\mathrm{ch}}\mathrm{d}|\Delta\varphi|}\right|_{p_{\mathrm{T,\,trig}}\in\,\mathrm{TT}} = \left.\left(\frac{1}{\sigma^{\mathrm{pp}\to\mathrm{h}\,+\,\mathrm{X}}}\frac{\mathrm{d}^2\sigma^{\mathrm{pp}\to\mathrm{h}\,+\,\mathrm{jet}\,+\,\mathrm{X}}}{\mathrm{d}p_{\mathrm{T,\,jet}}^{\mathrm{ch}}\mathrm{d}|\Delta\varphi|}\right)\right|_{p_{\mathrm{T,\,trig}}\in\,\mathrm{TT}} \times \cancel{\frac{\langle T_{\mathrm{AA}}\rangle}{\langle T_{\mathrm{AA}}\rangle}}$$

Cross section for trigger hadron production

Differential cross section for coincidence production of trigger hadron and recoil jet



Propagation of high-p_{T} parton through hot and dense medium

- Applicable in pp collisions
- Equality in case of no nuclear effects
- **Self-normalized observable, reference spectrum has no dependence on $\langle T_{\mathrm{AA}}\rangle$**

Hadron-jet acoplanarity measurements in Pb-Pb collisions → talk by Yongzhen Hou on 8 July at 3:05 pm, “Heavy Ions” session

Event activity selection in pp collisions at $\sqrt{s}$ = 13 TeV

Online data triggers based on V0 detectors:

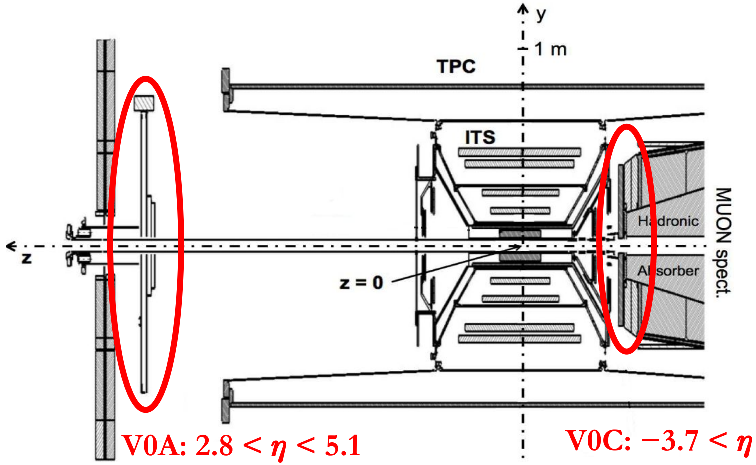
- Minimum-bias (MB) trigger $\rightarrow L_{\mathrm{Int}} \approx 32\ \mathrm{nb}^{-1}$
- High-multiplicity (HM) trigger $\rightarrow L_{\mathrm{Int}} \approx 10^{4}\ \mathrm{nb}^{-1}$

Offline event activity (EA) selection:

V0M = V0A + V0C → sum of signals

Characterization of EA in terms of V0M/⟨V0M⟩

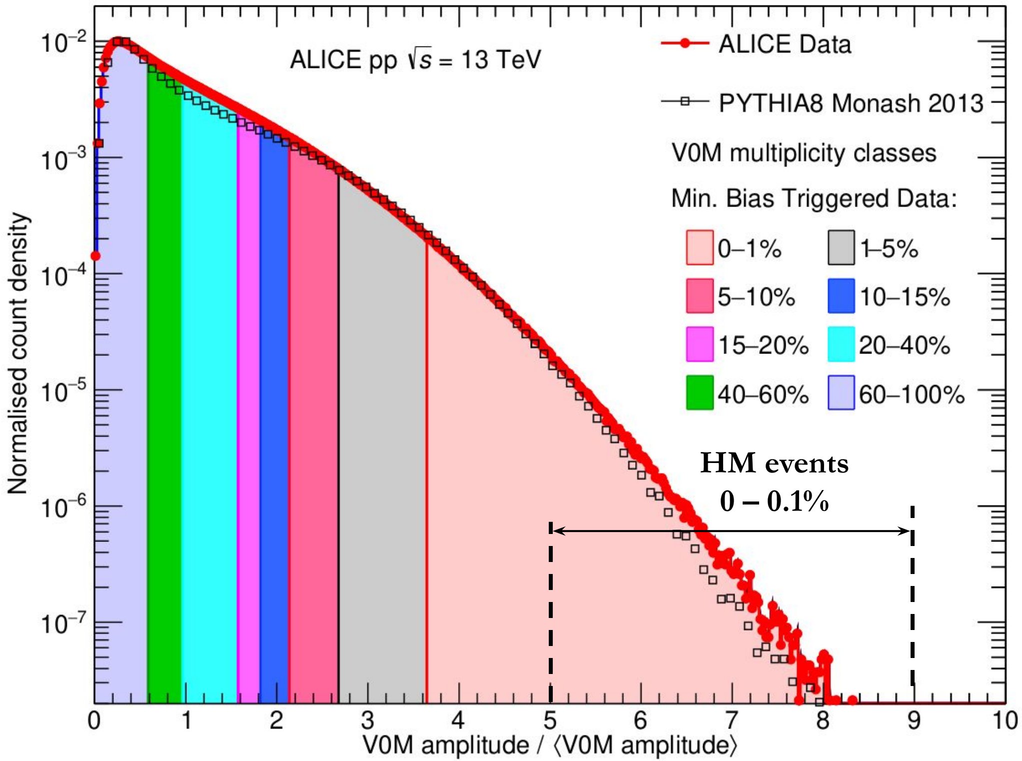
⟨V0M⟩ - mean of MB distribution



V0A: $2.8 < \eta < 5.1$

V0C: $-3.7 < \eta < -1.7$

ALICE, Eur.Phys.J.C 82 (2022) 6, 514



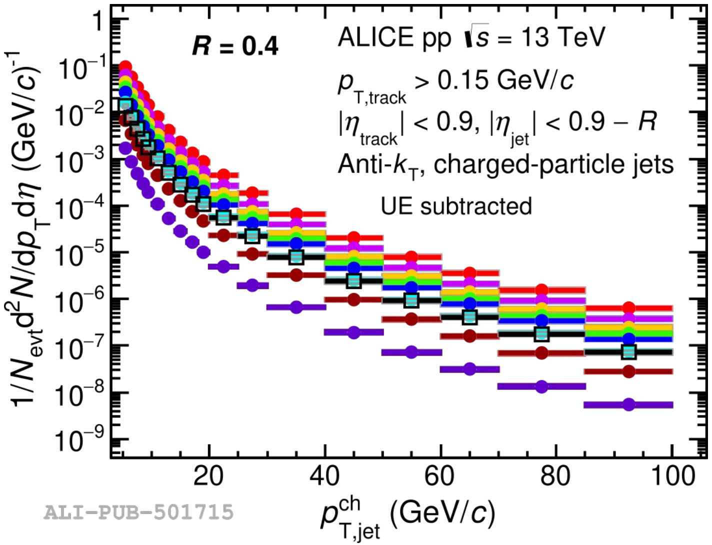
Inclusive jet yield in different multiplicity classes

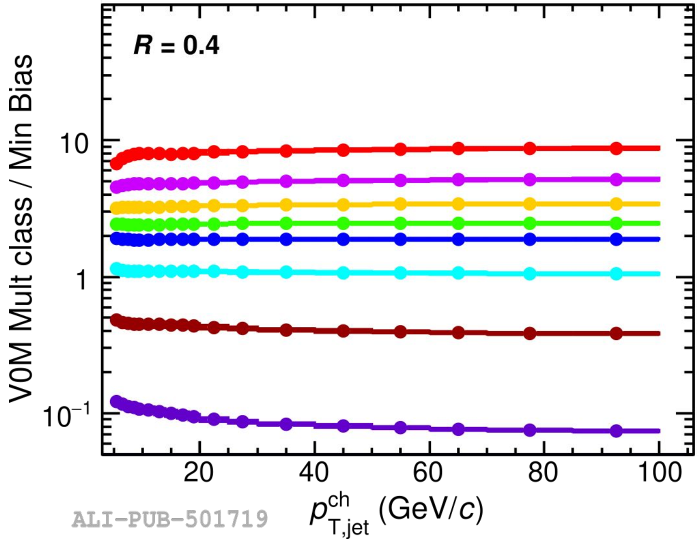
ALICE

NEW

V0M multiplicity classes

0–100% | 0–1% | 1–5% | 5–10% | 10–15% | 15–20% | 20–40% | 40–60% | 60–100% | Syst. uncert.





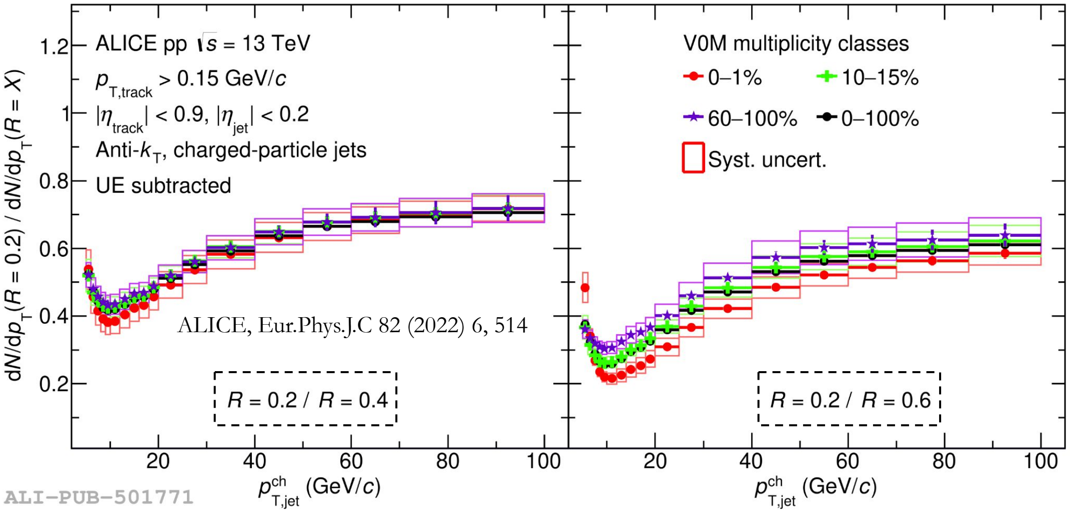
ALICE, Eur.Phys.J.C 82 (2022) 6, 514

- Jet p_{T} corrected for underlying events and instrumental effects
- **Event activity bias has a mild effect on the shape** for $p_{\mathrm{T,\,jet}} > 20$ GeV/c
- Jet yield increases with event activity bias

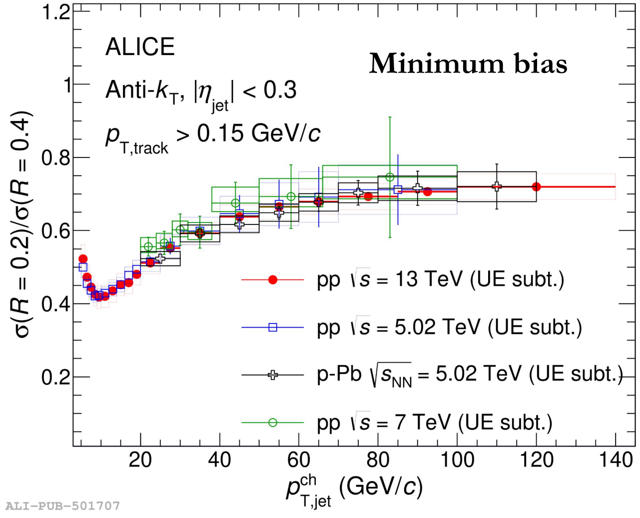
Jet production ratio using different jet R

NEW

Ratio of jet p_T spectra



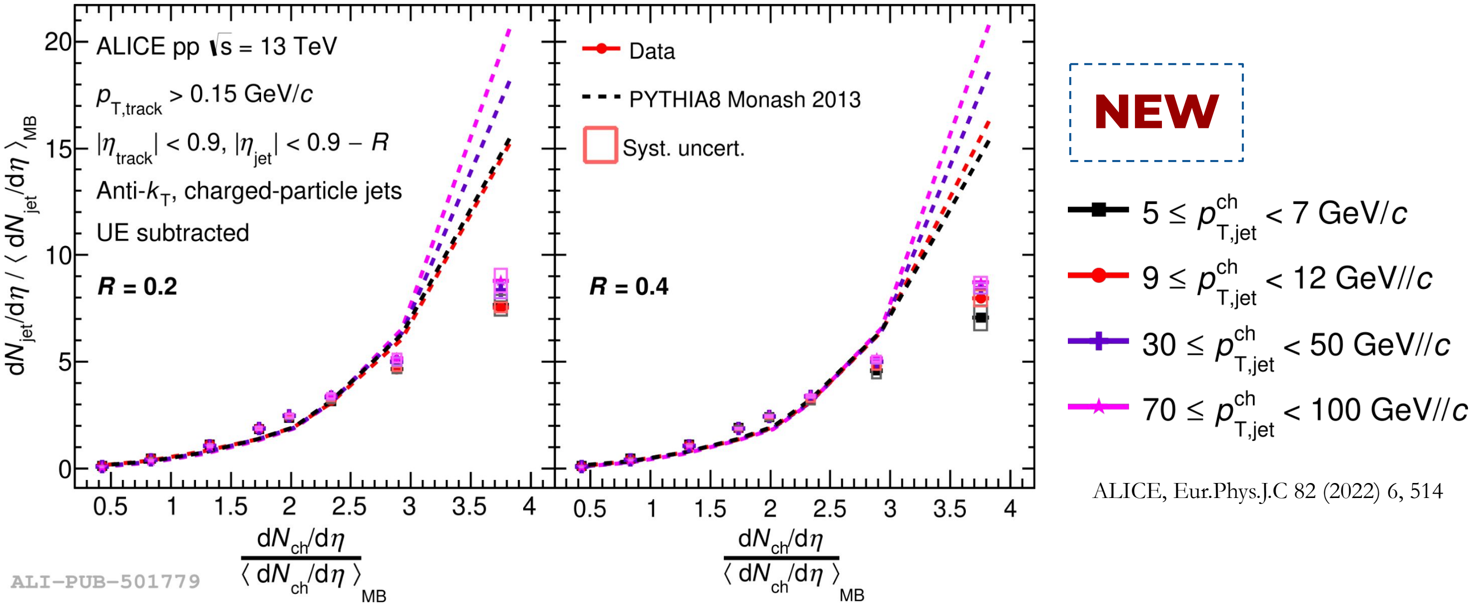
Ratio of p_T differential cross sections



- **Small R** → weak dependence on event activity bias
- **Large R** → hint of jet production ordering

- **No dependence** on $\sqrt{s}$ observed
- p-Pb ratio compatible with pp one

Self-normalized jet production vs self-normalized multiplicity

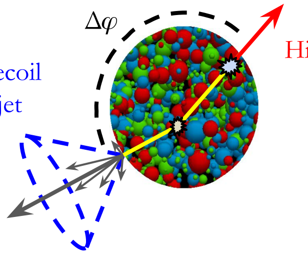


ALICE, Eur.Phys.J.C 82 (2022) 6, 514

- **Non-linear rising with multiplicity** observed for jet production in midrapidity, similar trend as for J/ψ [1]
- Electrons from W decay **follow linear trend**, talk by Mingrui Zhao on 7 July at 5.30 pm, “Heavy Ions” session
- PYTHIA 8 **overestimates** data at high particle multiplicities

[1] ALICE, Phys. Lett. B 810 (2020)

Semi-inclusive p_T distribution of recoil jets



- Jet p_T corrected for underlying event density

$$p_{\mathrm{T,jet}}^{\mathrm{ch}} = p_{\mathrm{T,jet}}^{\mathrm{raw,ch}} - \rho A_{\mathrm{jet}}$$

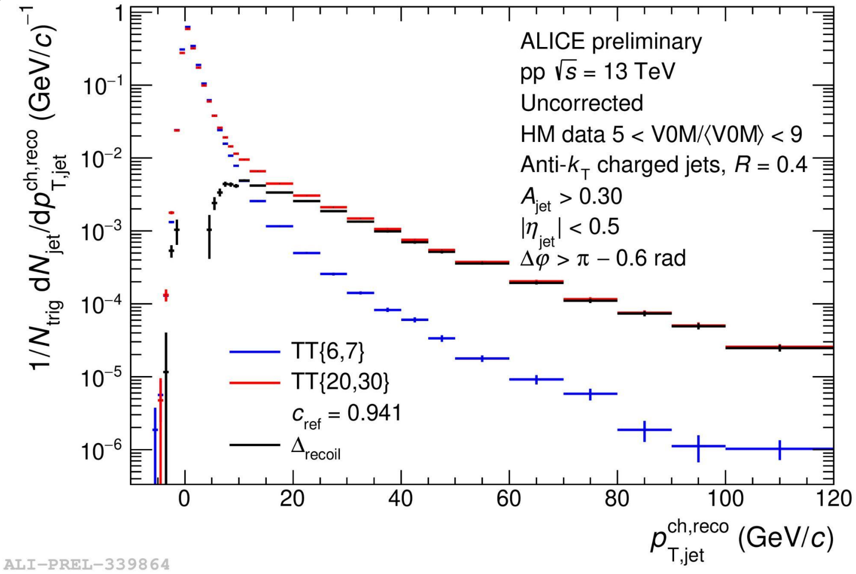
- Negative and low p_T region

  → **contribution of combinatorial background jets**

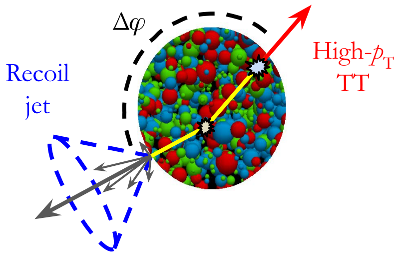
- Yield of combinatorial jets **has no dependence on p_T of TT**
- Data-driven approach for removal of uncorrelated jet yield

$$\Delta_{\mathrm{recoil}} = \frac{1}{N_{\mathrm{trig}}} \frac{\mathrm{d}^2 N_{\mathrm{jets}}}{\mathrm{d}p_{\mathrm{T,\,jet}}^{\mathrm{ch}} \mathrm{d}|\Delta\varphi|}\Bigg|_{\mathrm{TT}\{20,30\}} - \frac{1}{N_{\mathrm{trig}}} \frac{\mathrm{d}^2 N_{\mathrm{jets}}}{\mathrm{d}p_{\mathrm{T,\,jet}}^{\mathrm{ch}} \mathrm{d}|\Delta\varphi|}\Bigg|_{\mathrm{TT}\{6,7\}}$$

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



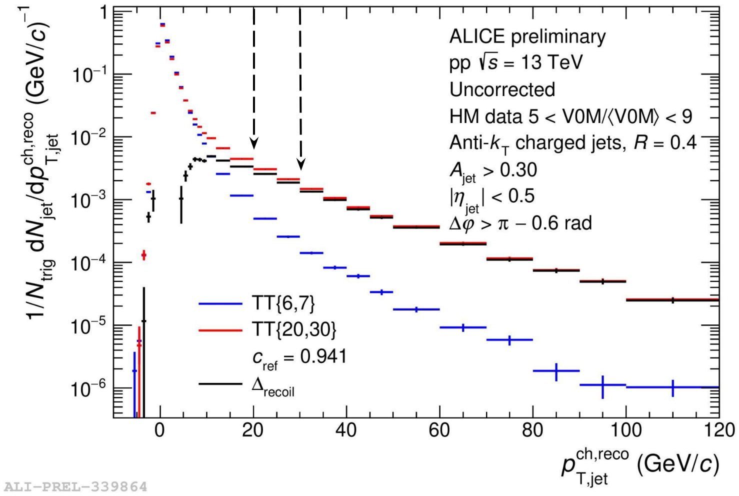
Semi-inclusive azimuthal distribution of recoil jets



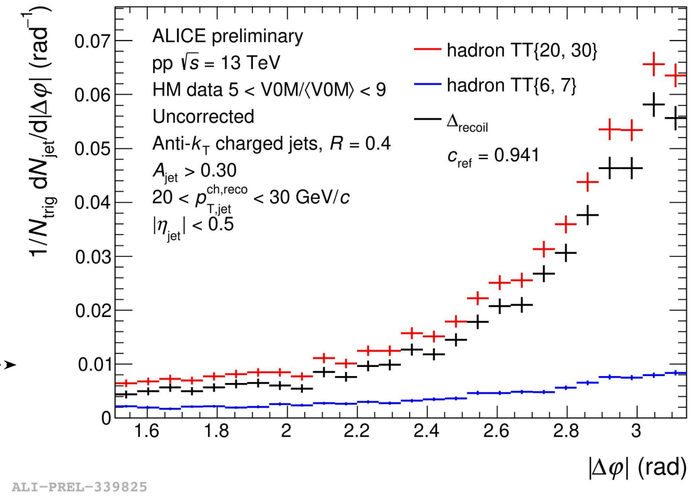
Construction of Δ_{recoil} observable as a function of TT-jet opening angle for a given $p_{T,\,jet}$

$$\Delta_{recoil} = \frac{1}{N_{trig}} \frac{d^2 N_{jets}}{dp^{ch}_{T,\,jet}\, d|\Delta\varphi|}\Bigg|_{TT\{20,30\}} - \frac{1}{N_{trig}} \frac{d^2 N_{jets}}{dp^{ch}_{T,\,jet}\, d|\Delta\varphi|}\Bigg|_{TT\{6,7\}}$$

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



Projection for specified jet p_T region



Measurements of hadron-jet acoplanarity with Δ_{recoil} ($\Delta\varphi$)

NEW

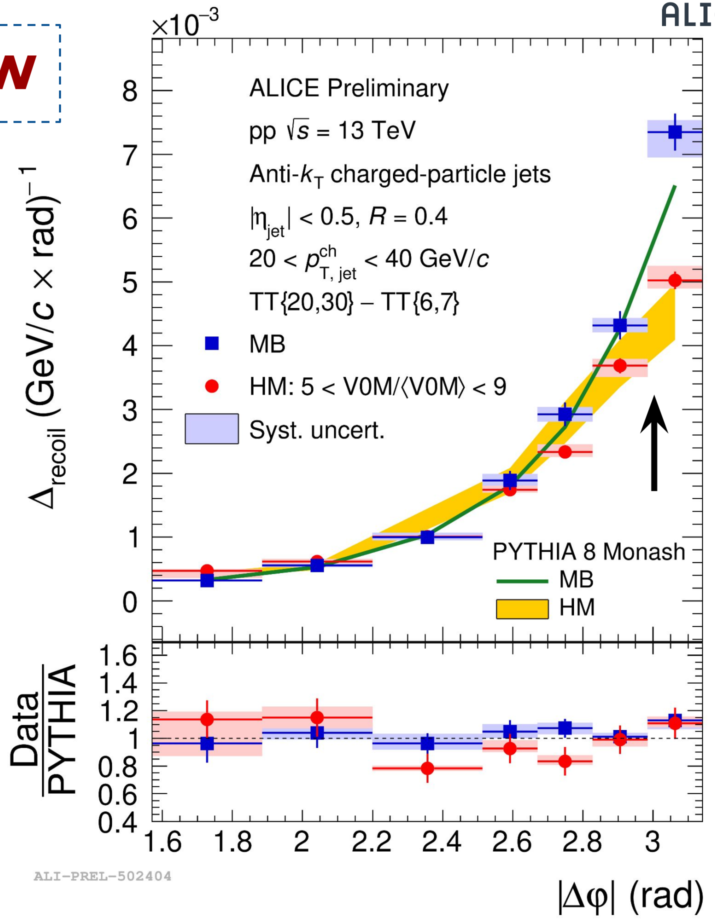
Fully corrected data:

- Substantial suppression of jets back-to-back w.r.t. TT in HM collisions
- Broadening of HM acoplanarity distribution with respect to MB
- Resembles jet quenching effects

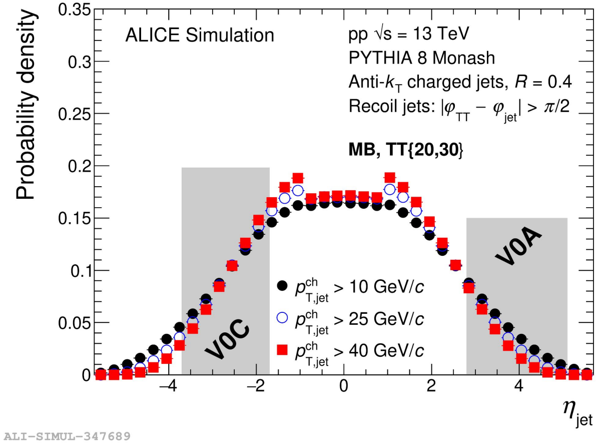
PYTHIA 8 Monash simulation:

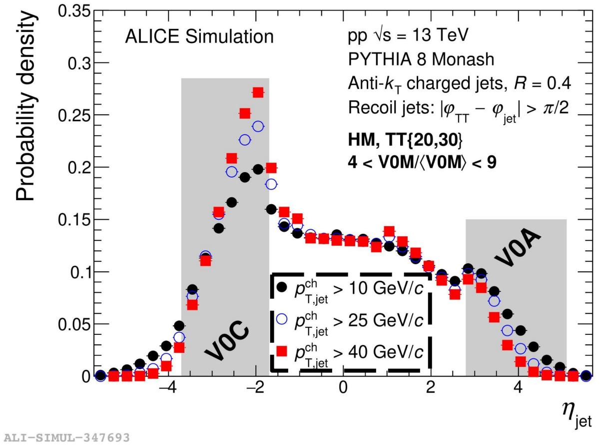
- V0M = # of charged, final state particles within V0A & V0C acceptances
- Does not account for jet quenching effects
- **Exhibits qualitatively similar features as experimental data**

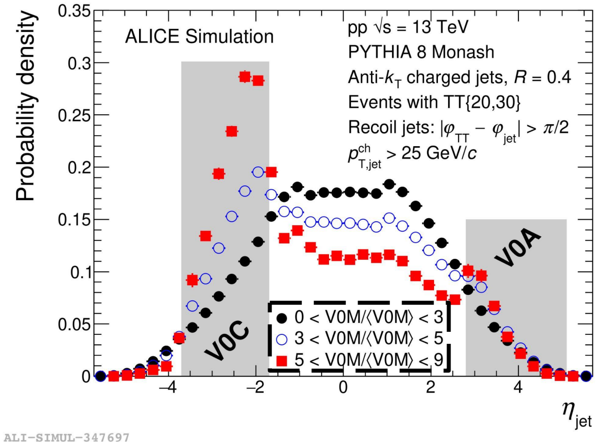
What can we learn from PYTHIA simulation about recoil jets in MB and HM events?

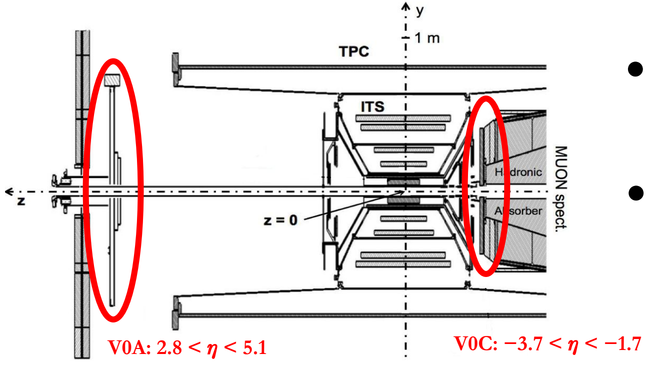


PYTHIA 8 simulation: recoil jet pseudorapidity distribution









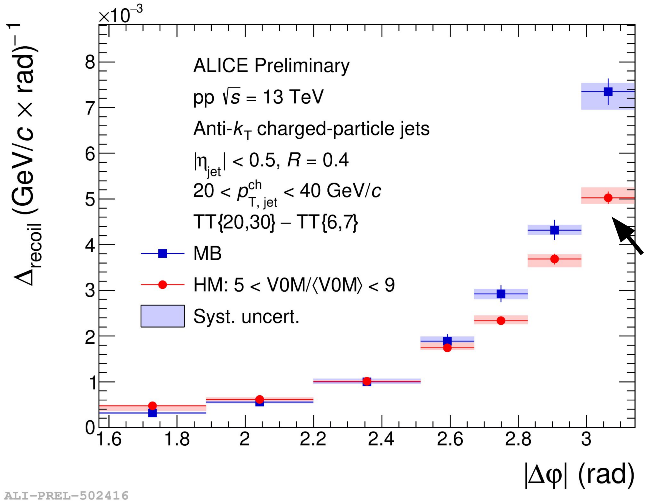
- Most likely HM trigger is induced by high-p_T recoil jets

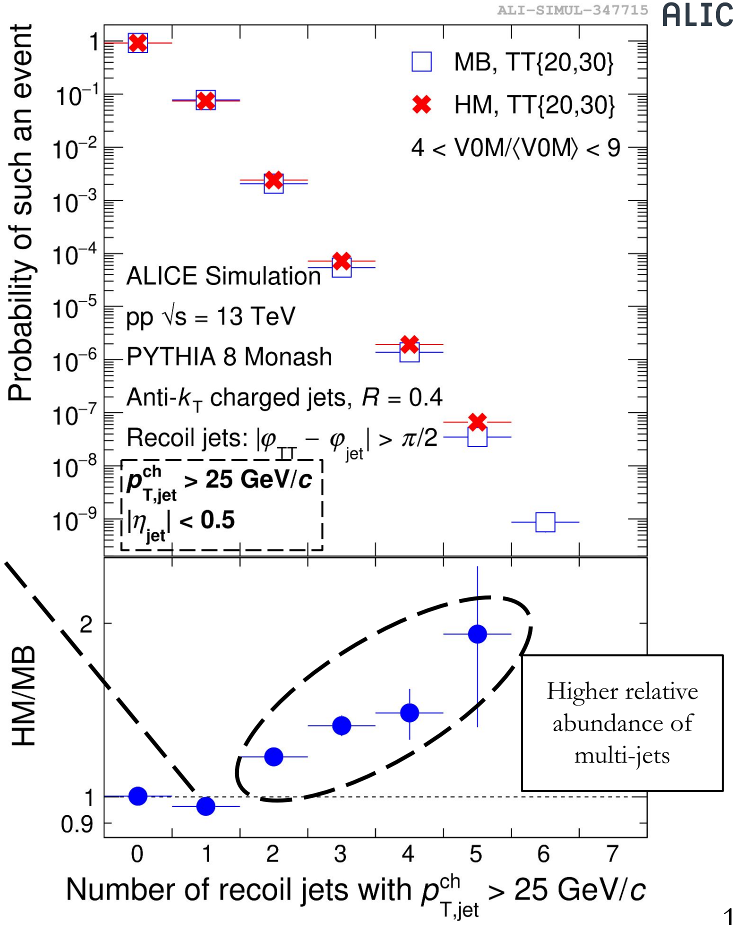
  ↔ **HM trigger imposes substantial bias on recoil jets**

- Lower enhancement in V0A is caused by asymmetric coverage of V0 detectors

  * Grey boxes represent acceptances of V0 detectors

PYTHIA 8 simulation: number of high-p_T recoil jets vs event activity





- Lower probability to observe 1 hard recoil jet in HM events
  → **results in suppression of acoplanarity**
- HM trigger → **bias toward multi-jet final state**

Summary

No jet quenching effects observed in high-multiplicity pp collisions. **Potentially, signal is too small**

Inclusive jet measurements

- Jet production **rises** with event activity
- Event activity bias has **weak impact on the spectrum slope for high-p_T jets**

Semi-inclusive jet measurements

- Broadening and suppression of back-to-back hadron-jet correlation in HM events relative to MB
- PYTHIA quantitatively reproduces the shape → **jet quenching signal is not genuine**
  - HM trigger enhances probability to measure high-p_T recoil jets in V0 acceptance
  - Bias towards multi-jet final state induced by HM trigger → **obscures possible jet quenching signal**
  - Multi-jet final state → **generic bias for HM measurements in small systems**

Thank you for your attention!