Exploring light flavor particle production as a function of event shape classifiers in small systems with ALICE at the LHC

Rutuparna Rath (for the ALICE collaboration)

INFN Sezione di Bologna, Italy

1. Physics motivation:

- Multiplicity-dependent study in small systems allows us to bridge the gap between minimum bias pp and peripheral heavy-ion collisions
- In order to pin down the origins of the effects observed in small collision systems, one has to study particle production as a function of event topology/underlying event (UE) activity
- In small systems, event shape observables such as transverse spherocity are sensitive to hard and soft QCD processes and therefore useful to disentangle such processes while studying them as a function of charged-particle multiplicity
- On the other hand, the relative transverse event activity classifier (R_T) allows one to probe the UE activity in an MPI-suppressed (-enhanced) environment

2. A Large Ion Collider Experiment (ALICE)

- At the LHC, ALICE has collected data in pp collisions at $\sqrt{s}$ = 0.9, 2.76, 5.02, 7.0, 8.0 and 13.0 TeV
- Global tracking is performed using ITS and TPC
- The kinematic cuts for track acceptance: $|\eta| < 0.8$ with $p_T > 0.15$ GeV/c

Detectors used :

- Inner Tracking System (ITS)

Tracking and Vertexing

- Time Projection Chamber (TPC)

Particle Tracking

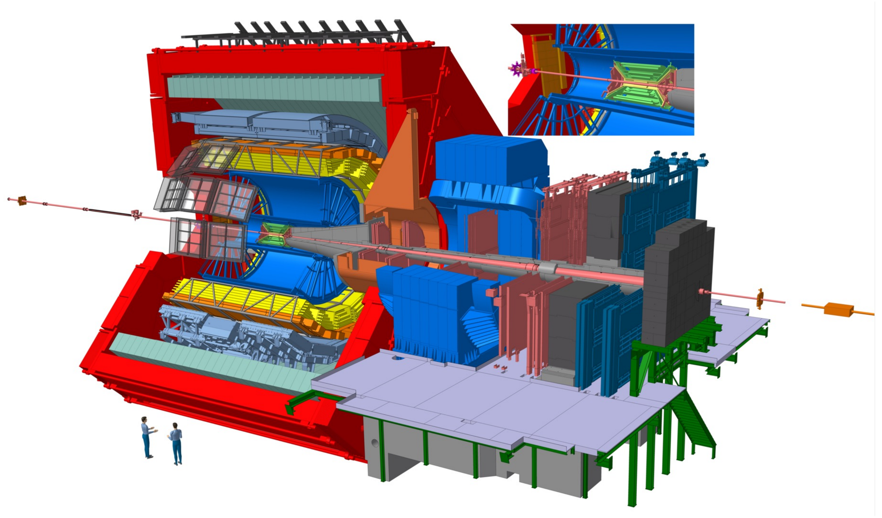
Particle Identification (PID) via dE/dx measurement

- Time of Flight (TOF)

PID via time-of-flight measurement

- V0 (V0A and V0C)

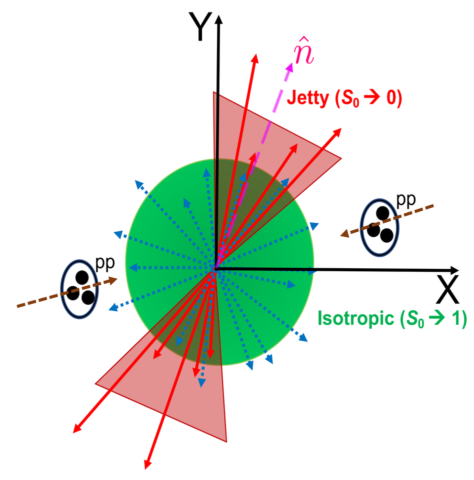
Trigger and multiplicity estimator



3. Transverse spherocity

Transverse spherocity is defined as

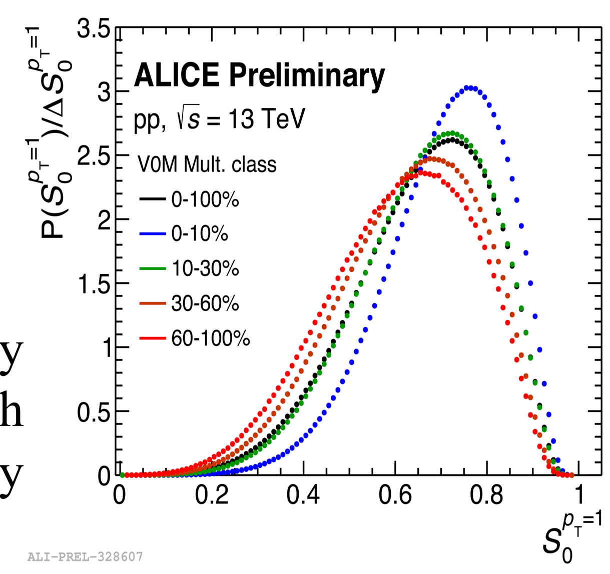
$$S_0^{p_T=1} = \frac{\pi^2}{4} \min_{\hat{n}} \left(\frac{\Sigma_i |\hat{p}_{T_i} \times \hat{n}|}{N_{trk}} \right)^2$$



- The limit $S_0(p_T=1) \to 0$ defines a jetty event, which is dominated by hard QCD processes
- The limit $S_0(p_T=1) \to 1$ defines an isotropic event, which is dominated by soft QCD processes

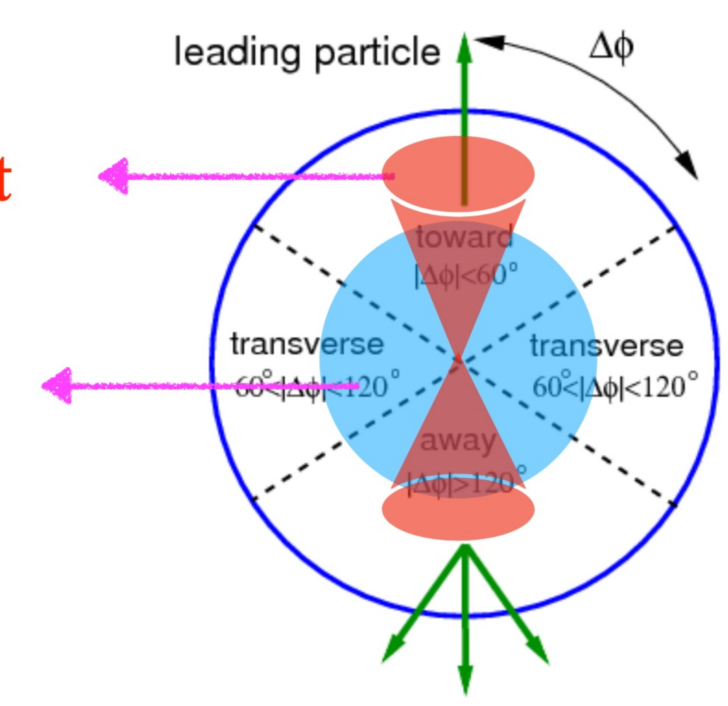
Multiplicity dependence:

- High multiplicity pp collisions are primarily dominated by isotropic events, whereas events with low multiplicity are more likely to be dominated by the jets in comparison to high-multiplicity events.



4. Transverse event activity classifier

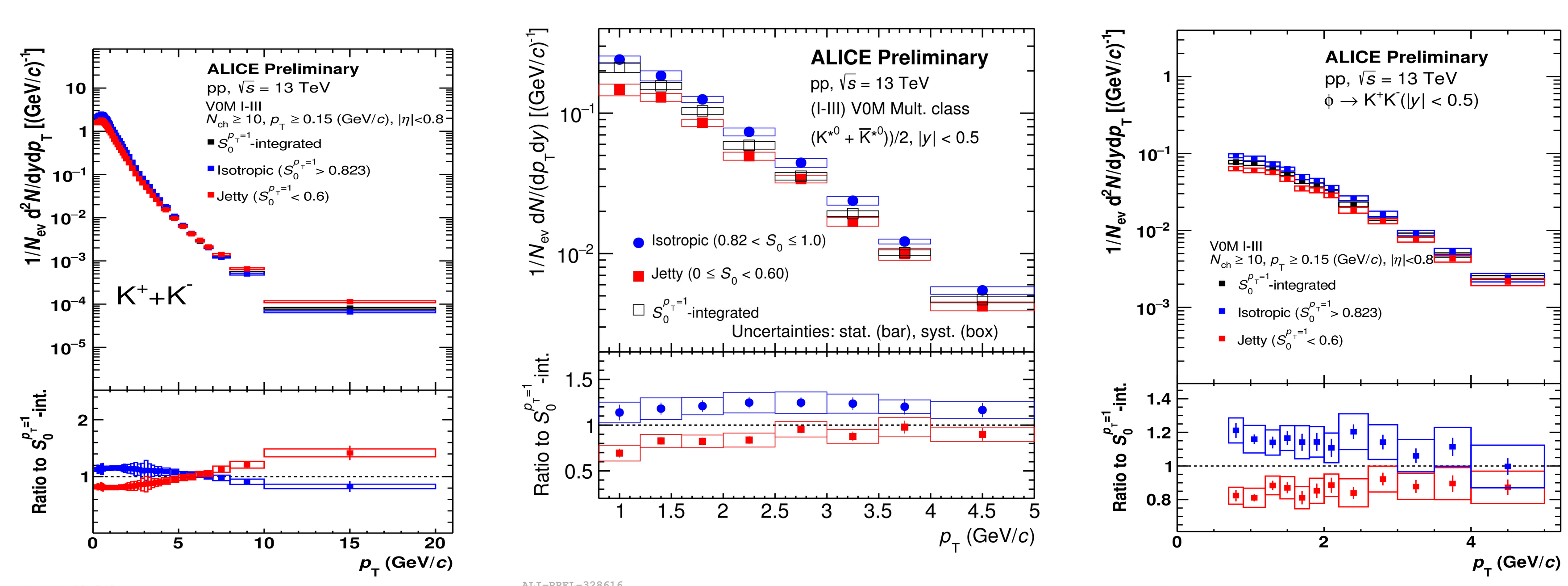
- An observable that allows for the study of particle production as a function of the event activity
- $R_T = N_T / \langle N_T \rangle$, where N_T is the charged-particle multiplicity in the transverse region
- $R_T = 1$ cleanly divides events with 'higher-than-average' UE ($R_T > 1$) from 'lower-than-average' ones
- The $R_T \to 0$ limit allows the opportunity to measure event properties in an 'MPI suppressed', environment where particle ratios may be closer to those of e^+e^- collisions



The UE properties are derived based on the leading charged-particle direction in the event

5. Transverse momentum (p_T) spectra as a function of $S_0(p_T=1)$

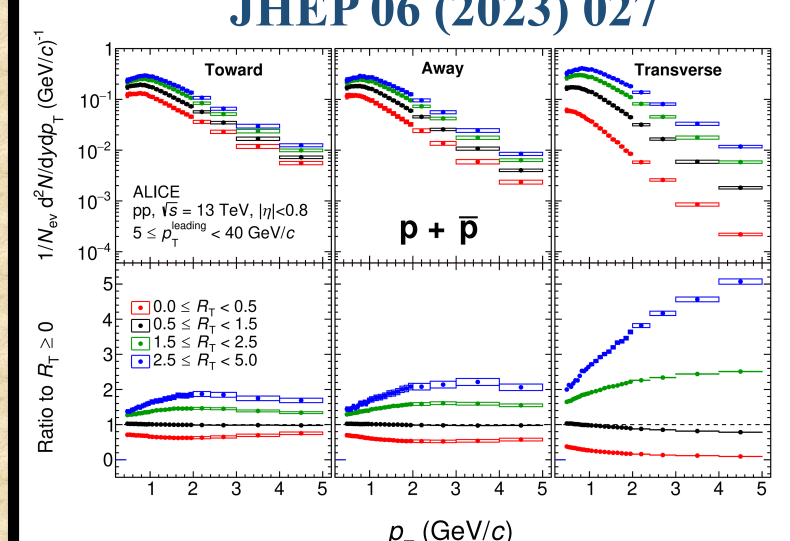
- As a function of S_0 event classes, low-p_T region is dominated by isotropic like events, whereas, the high-p_T region is dominated by the jetty like events



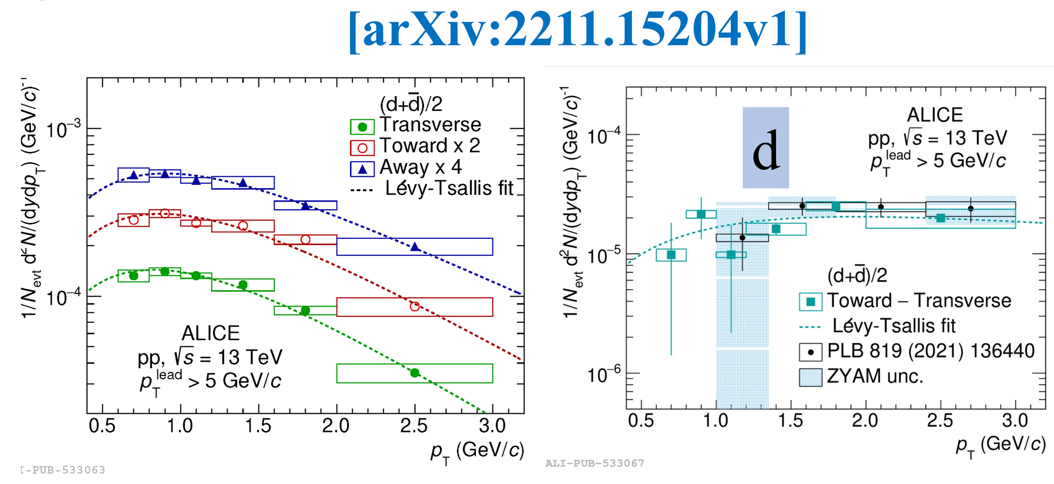
- Similar event shape classes dependence was observed across the particle species in V0M multiplicity

6. Transverse momentum (p_T) spectra as a function of R_T (in UE and in-jet region)

JHEP 06 (2023) 027



[arXiv:2211.15204v1]



Jet = Toward – Transverse (Jet+UE – UE)

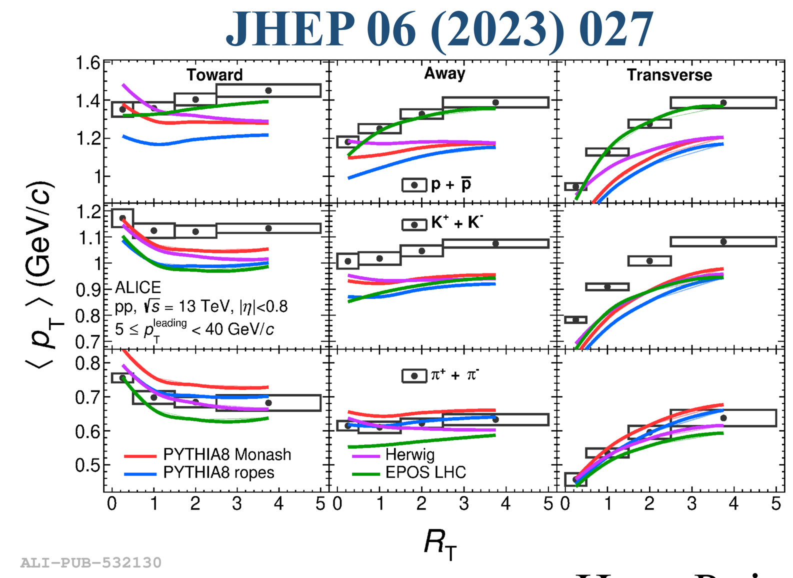
Toward and Away: Spectra softens with R_T as jet is diluted

Transverse: Spectra hardens with increasing R_T

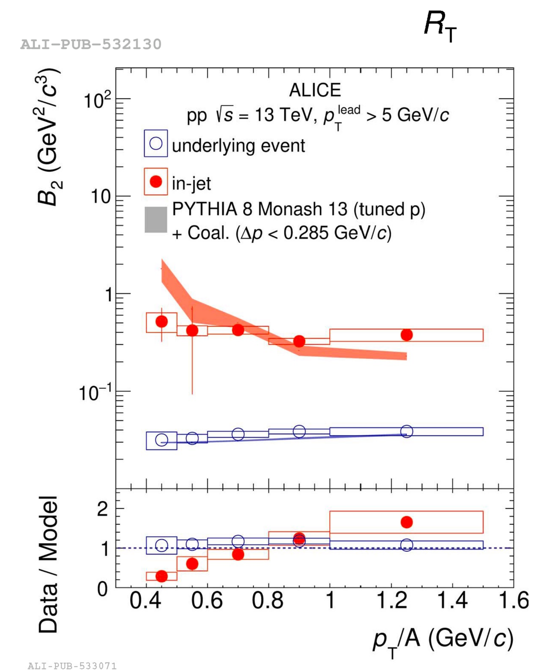
- The fraction of deuterons produced in the jet is ~ 10% wrt UE in pp
- The majority of the deuterons are produced in the underlying event

7. Physics results with model comparison

JHEP 06 (2023) 027



- At low R_T the presence of the jet increases the $\langle p_T \rangle$ (toward region). This is true in data for pions and kaons, but not for protons
- PYTHIA qualitatively describes the trend for pions and kaons but not for protons
- EPOS qualitatively describes all three species

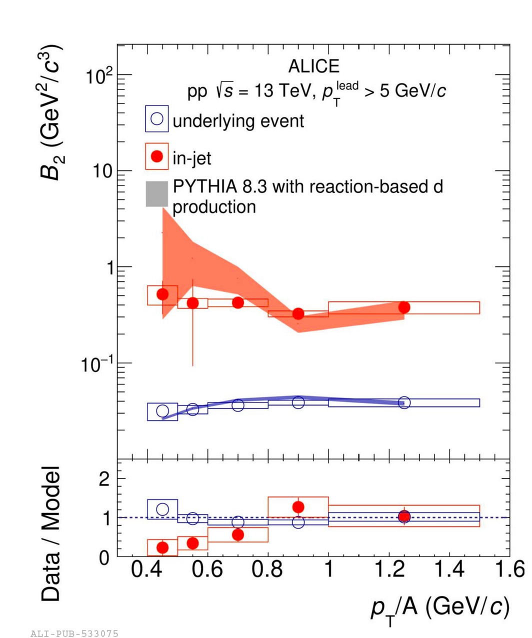


Here B_2 is the coalescence parameter for deuteron which is defined as

$$B_2 = \frac{E_d \frac{d^3 N_d}{dp_d^3}}{\left(E_p \frac{d^3 N_p}{dp_p^3}\right)^2}$$

- Both models qualitatively reproduce the data → large difference between B_2^{jet} and B_2^{UE}

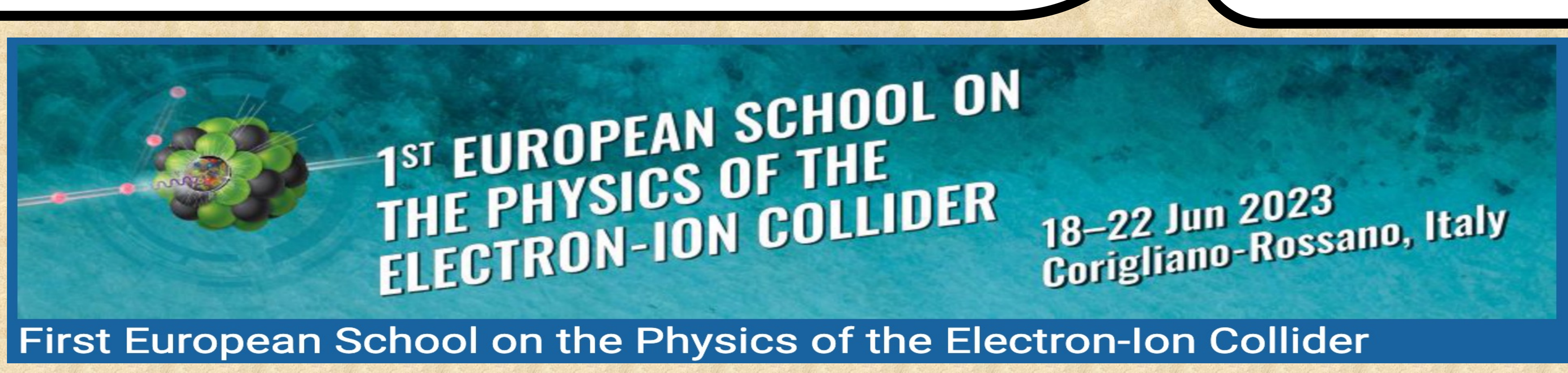
[arXiv:2211.15204v1]



- **B_2^{UE} in PYTHIA reproduces the trend of data**
- **B_2^{jet} in PYTHIA is consistent within uncertainties**

8. Outlook

- More data will be collected in Run 3 which will allow one to study light flavor hadrons and (anti)nuclei productions as a function of R_T and S_0 in a more differential manner
- This will certainly help to understand the (anti)nuclei production in jet (low- R_T) and UE dominated scenarios (high- R_T)



ALICE

INFN Istituto Nazionale di Fisica Nucleare