Testing QCD and probing the QGP with jets in the ALICE experiment

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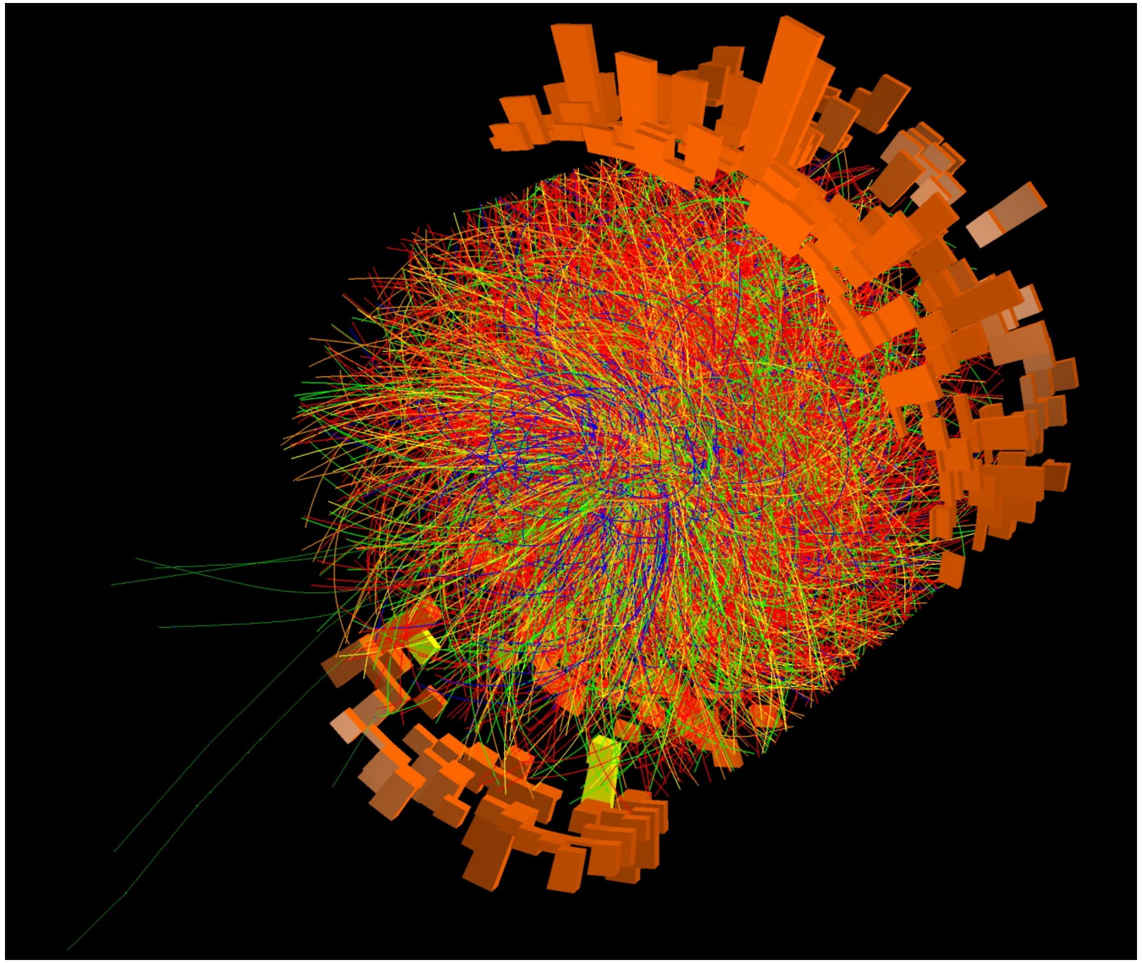
The ALICE physics motivations

- Main mission: probing the quark-gluon plasma (QGP), with focus on heavy-ion (Pb-Pb) collisions at total energies of hundreds of TeV inside the LHC

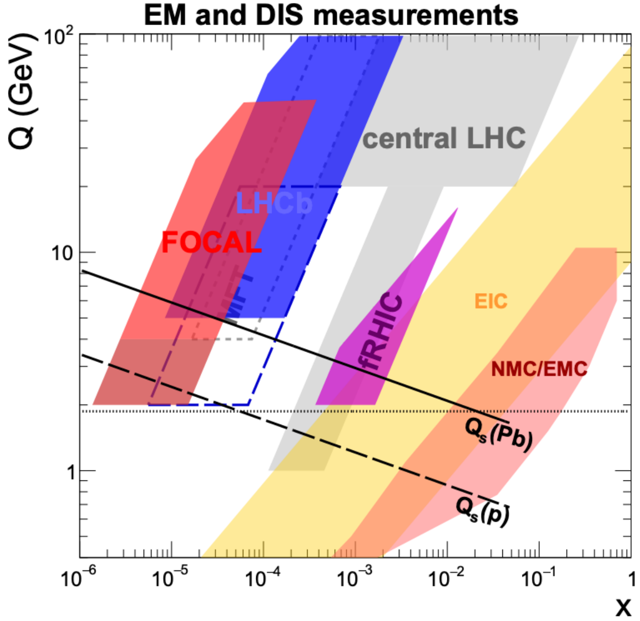
- Various probes: heavy-flavour production, low-mass dileptons, strangeness enhancement, jets, …



Heavy-ion collision
in ALICE – $\sqrt{s_{NN}} = 5.02$ TeV

The ALICE physics motivations – looking forward

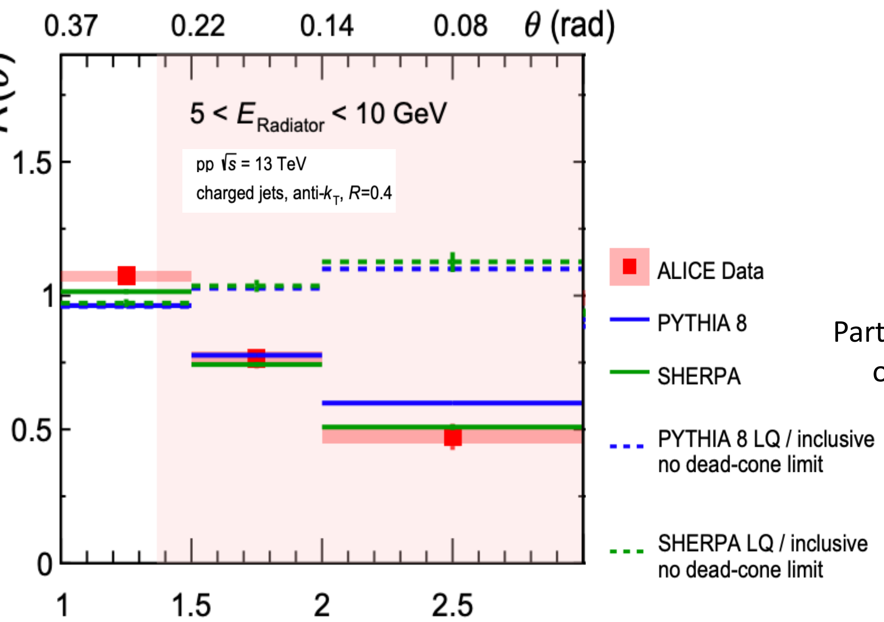
- QGP droplets in small systems
- QCD: jet substructure (dead cone, …)
- Accessing the color-glass-condensate and saturation scale with FoCal



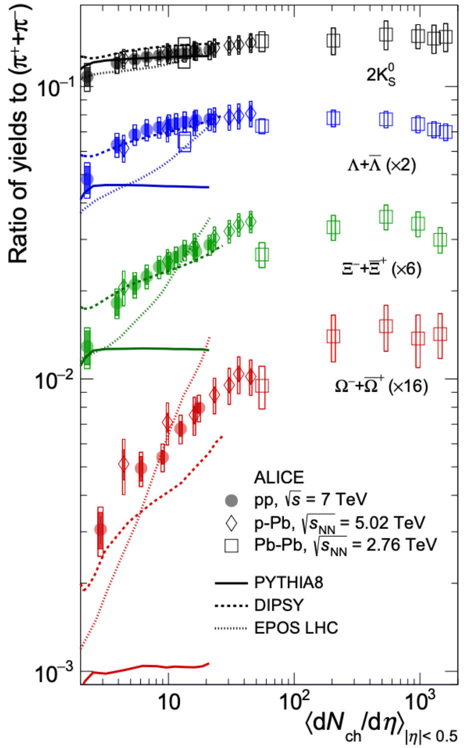
Letter of Intent: A Forward Calorimeter (FoCal) in the ALICE experiment

Approximate (x,Q) coverage of FOCAL and various experiments for regions probed by electromagnetic and deep inelastic scattering measurements – saturation scales Qs shown

arXiv:2106.05713



Ratio of splitting angle probability distributions of D^0 and inclusive jets, for pp collisions in ALICE at $\sqrt{s} = 13\text{TeV}$ - Pink shaded area : zone where emission is supressed, i.e. dead cone

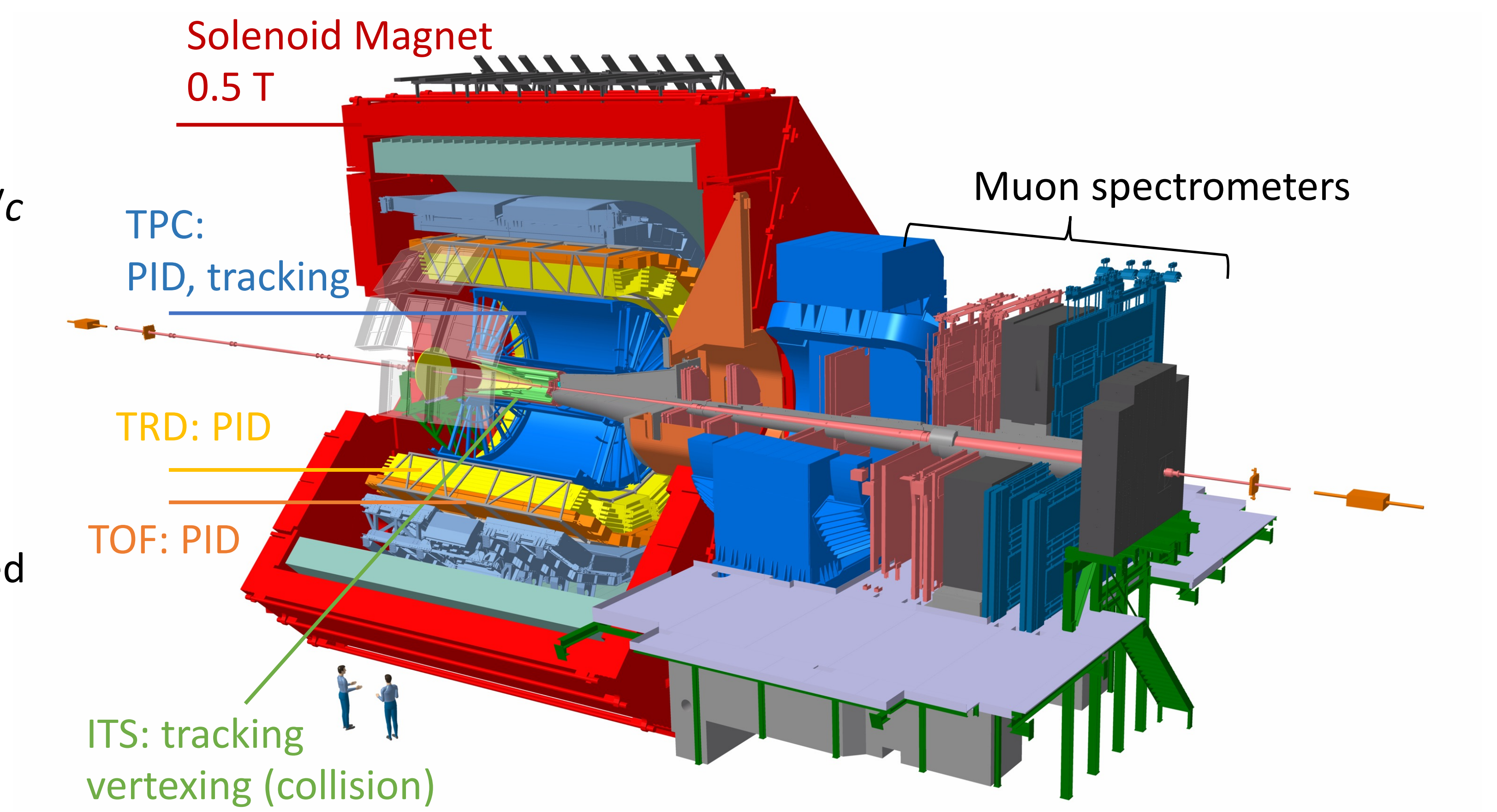


Particle yield ratios to pions as a function of charged multiplicity for different collision systems and energies

The ALICE detector

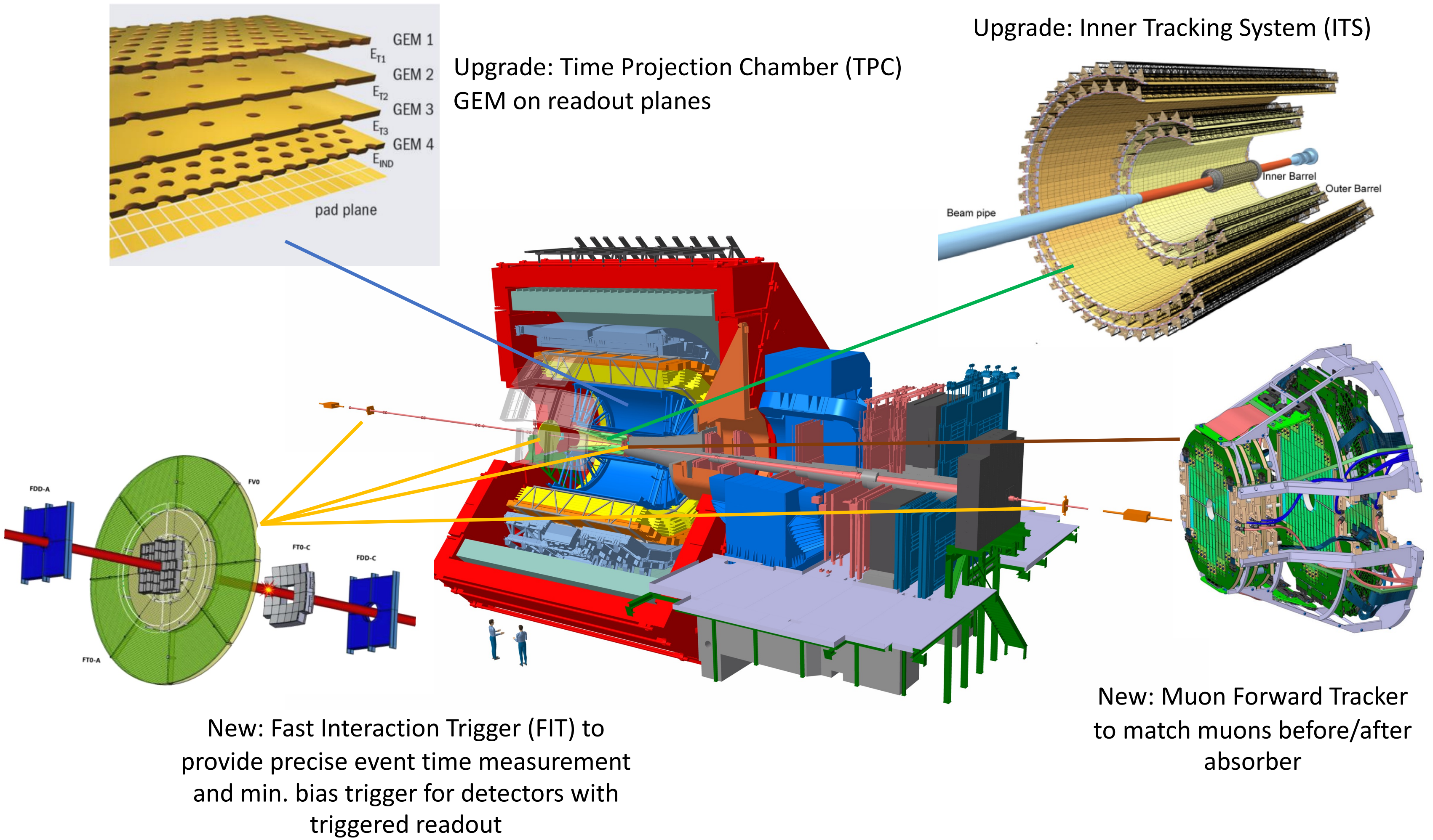
- Combination of different detector technologies
- Tracking and identification of particles (PID) within 0.01-100 GeV/c p_{T} range

- Run 2: Pb-Pb at 1 kHz trigger rate, $\sim 1\ \mathrm{nb}^{-1}$ collected luminosity
- Run 3: Pb-Pb at 50 kHz interaction rate, $\sim 7.5\ \mathrm{nb}^{-1}$ luminosity projected

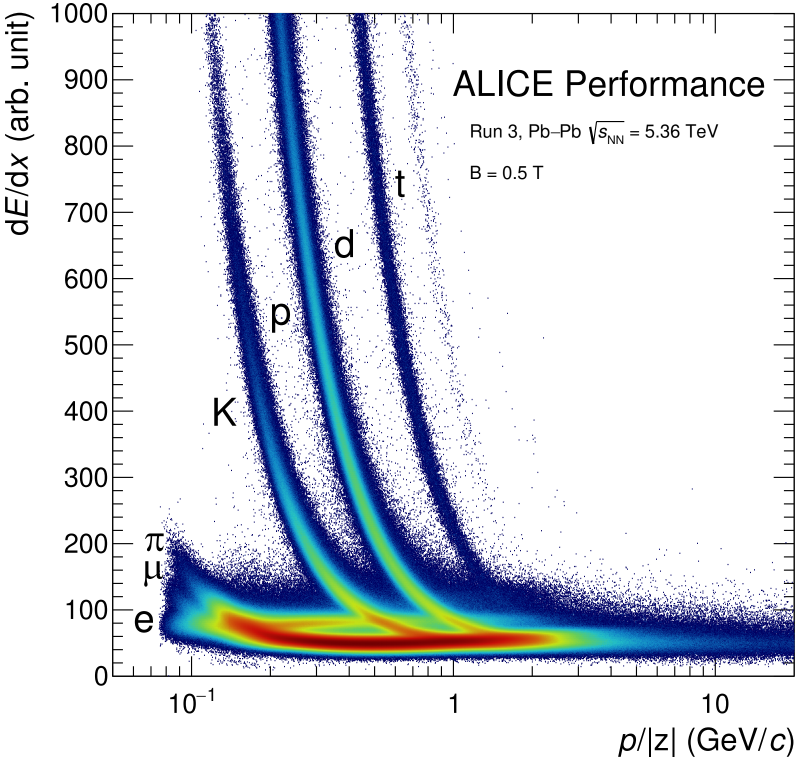


Upgrade of the ALICE detector

- Continuous readout to fully exploit the increased Pb-Pb interaction rate of 50 kHz
- Improve tracking efficiency and low-p_T resolution
- Preserve PID capabilities
- Online analysis to significantly reduce the data volume (expected raw data flow rate up to 3.5 TB/s)
- Offline trigger for pp ran yearly to save a fraction of the full pp data



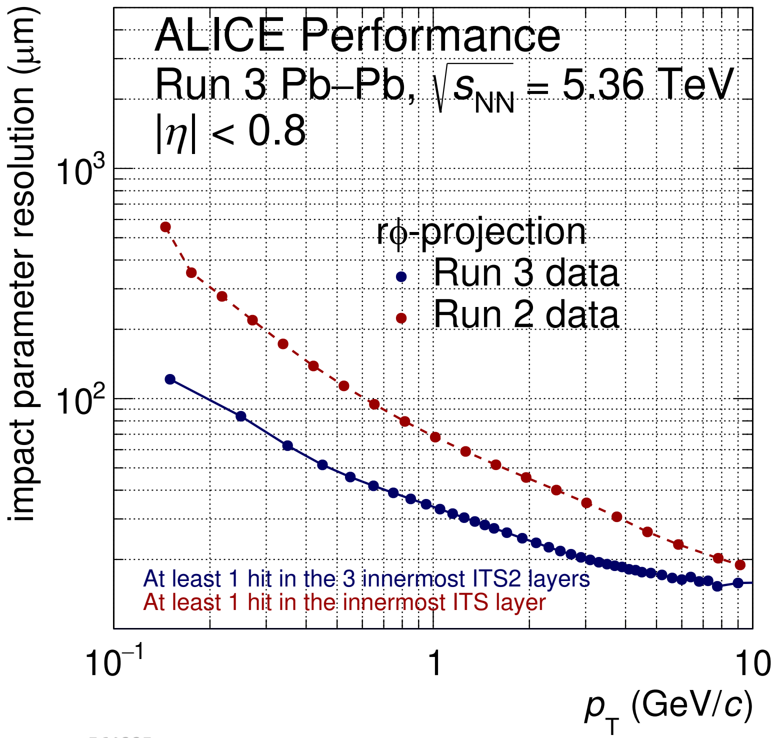
Performance of the ALICE detector



ALI-PERF-529714

Ionisation energy loss of a particle in the ALICE TPC as a function of its momentum, for Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.36$ TeV

- PID capabilities: hadrochemistry, jet content (strangeness)



ALI-PERF-564335

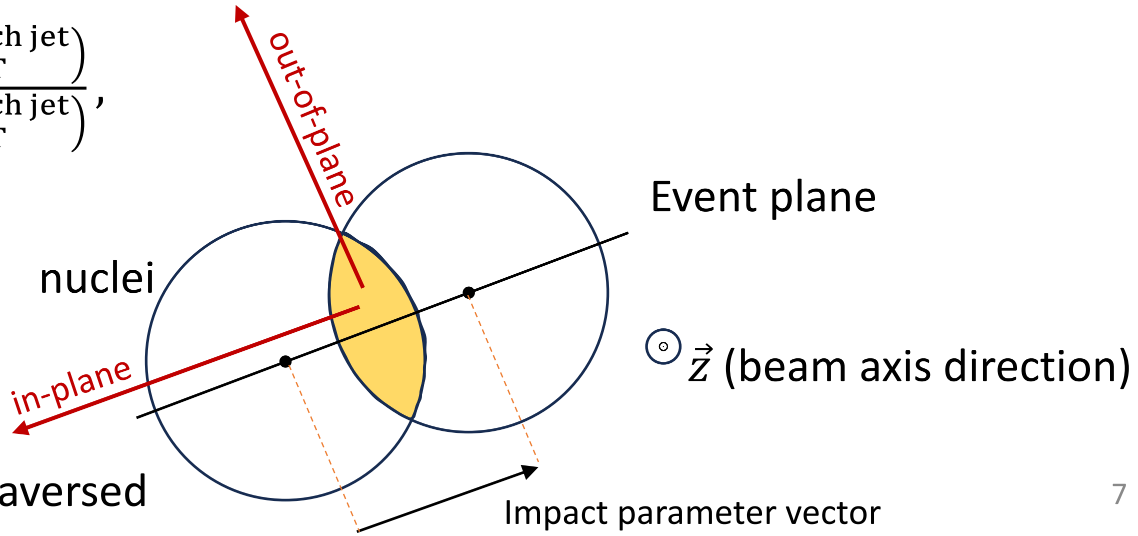
Impact parameter resolution in rφ as a function of p_{T} in Pb-Pb collisions – Run 2 vs Run 3 data

- rφ resolution: secondary vertices of heavy flavour decays

Jets as probes

- Jets – hard probes:
  - Acess to kinematics of scattered partons in inelastic collisions (very well described with pQCD)
  - Jet quenching: probes QGP through collisional and radiative energy loss, and changes to jet subtructure:
    - $R_{\mathrm{CP}} = \frac{\langle N_{\mathrm{coll}}^{P}\rangle}{\langle N_{\mathrm{coll}}^{C}\rangle}\frac{\mathrm{d}^2N^C/\mathrm{d}p_T\mathrm{d}\eta}{\mathrm{d}^2N^P/\mathrm{d}p_T\mathrm{d}\eta}$, P: peripheral collision, C: central collision
    - $R_{\mathrm{AA}} = \frac{1}{\langle T_{\mathrm{AA}}\rangle}\frac{\mathrm{d}^2N/\mathrm{d}p_T\mathrm{d}\eta}{\mathrm{d}^2\sigma_{\mathrm{pp}}/\mathrm{d}p_T\mathrm{d}\eta}$, where T_{AA} is the nuclear overlap of the studied centrality class
    - $v_2^{\mathrm{ch\,jet}}\left(p_{\mathrm{T}}^{\mathrm{ch\,jet}}\right) = \frac{\pi}{4}\frac{1}{R_2}\frac{N_{\mathrm{in}}\left(p_{\mathrm{T}}^{\mathrm{ch\,jet}}\right)-N_{\mathrm{out}}\left(p_{\mathrm{T}}^{\mathrm{ch\,jet}}\right)}{N_{\mathrm{in}}\left(p_{\mathrm{T}}^{\mathrm{ch\,jet}}\right)+N_{\mathrm{out}}\left(p_{\mathrm{T}}^{\mathrm{ch\,jet}}\right)}$,

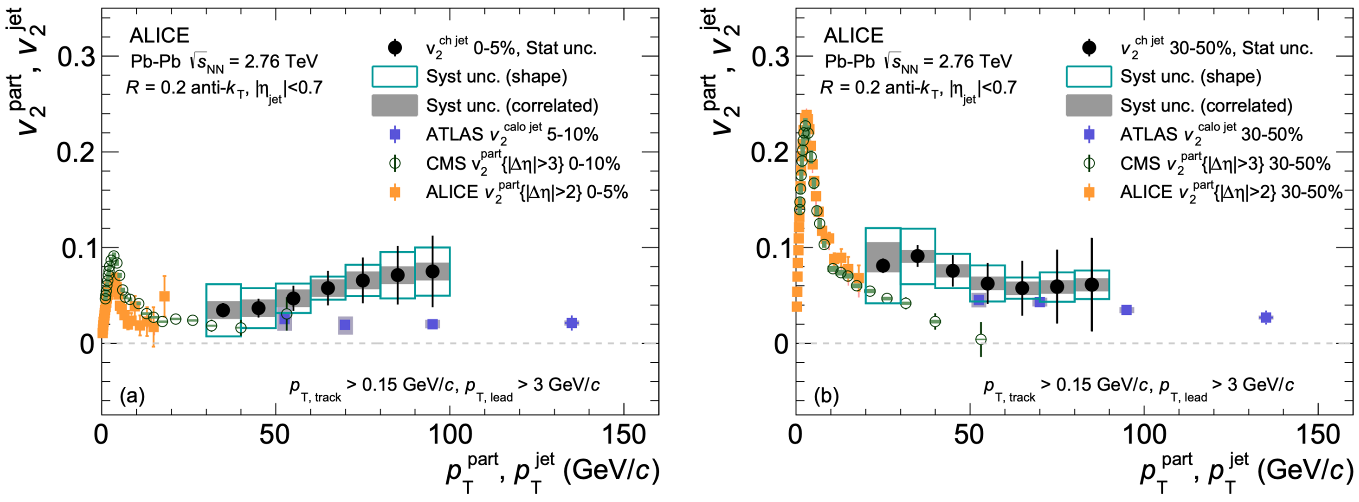
    where R_2 is the event plane resolution



out-of-plane : more medium traversed

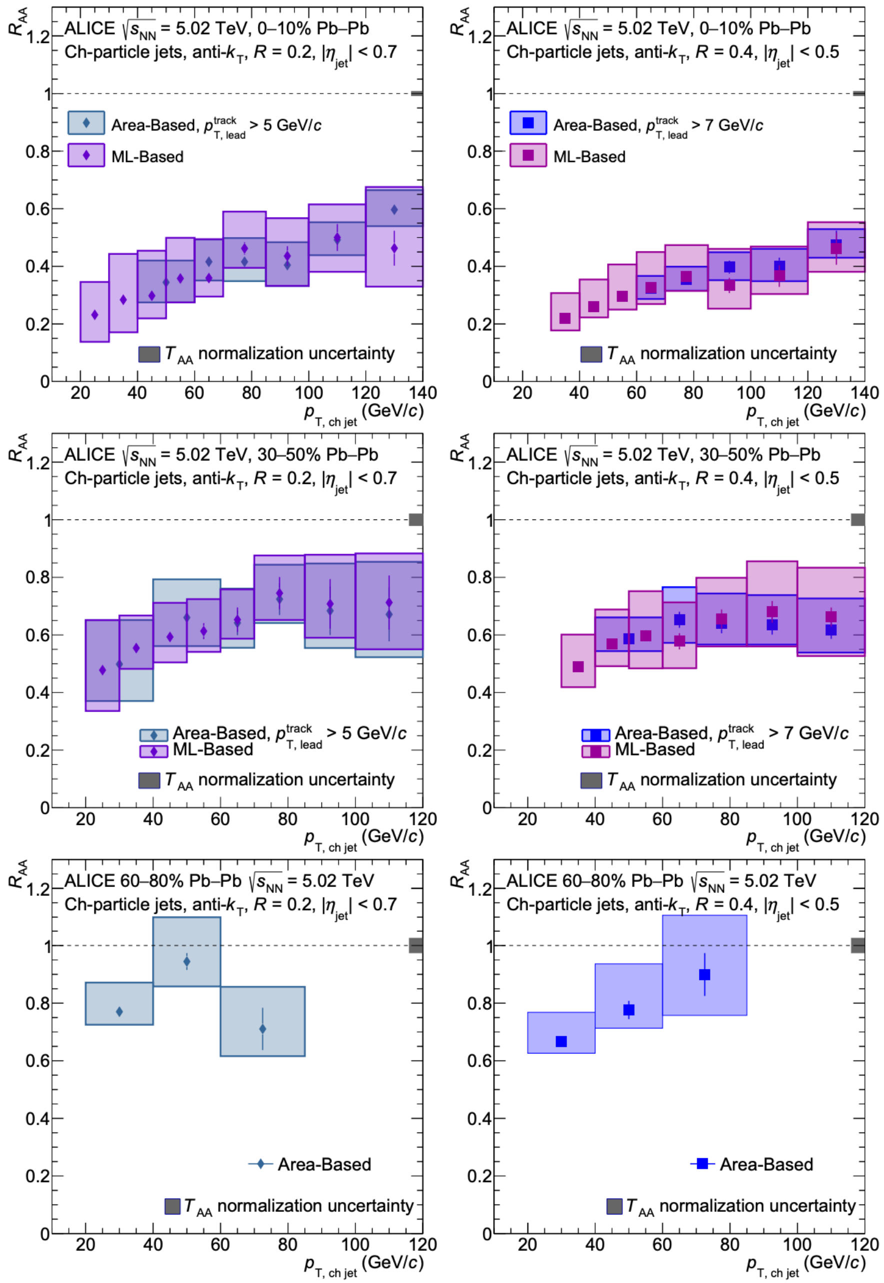
Jets as probes

arXiv:1509.07334



Eliptic flow coefficient v_2 of charged jets (full black circles) compared to that of particles and full jets as a function of p_{T} in central (left) and semi-central (right) Pb-Pb collisions in ALICE at $\sqrt{s} = 2.76\mathrm{TeV}$

- Limited statistics improved with Run 3
- Systematics that need to be improved with Run 3
- ML allows to look at lower p_{T}



arXiv:2303.00592

Nuclear modification factor R_{AA} of charged jets as a function of p_{T} for R=0.2 and R=0.4 in central, semi-central and peripheral Pb-Pb collisions in ALICE at $\sqrt{s} = 5.02$ TeV

Jets as probes – first step in Run 3: R_{CP}

Raw spectrum

Background subtraction

Corrected spectrum

Detector effects

Background fluctuation effects

Unfolded spectrum

$$R_{\mathrm{CP}} = \frac{\langle N_{\mathrm{coll}}^{P} \rangle}{\langle N_{\mathrm{coll}}^{C} \rangle} \frac{\mathrm{d}^2 N^C / \mathrm{d}p_T \mathrm{d}\eta}{\mathrm{d}^2 N^P / \mathrm{d}p_T \mathrm{d}\eta}$$

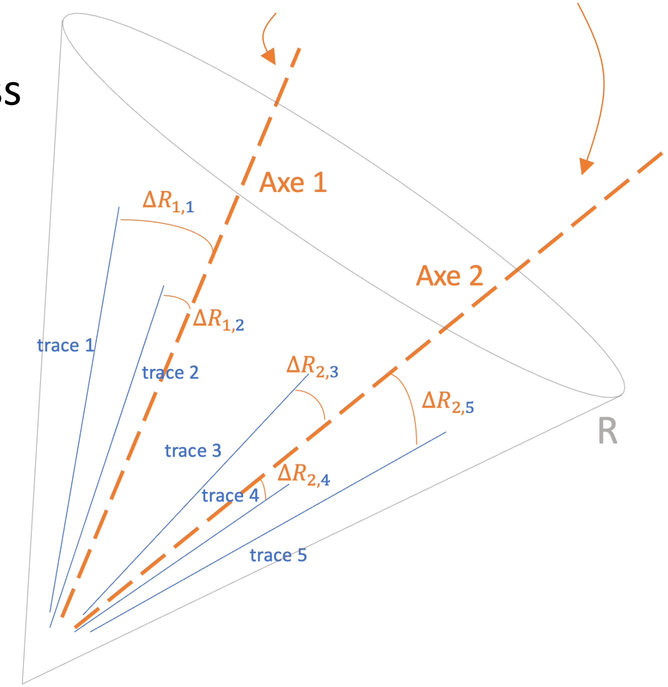
, P: peripheral collision, C: central collision

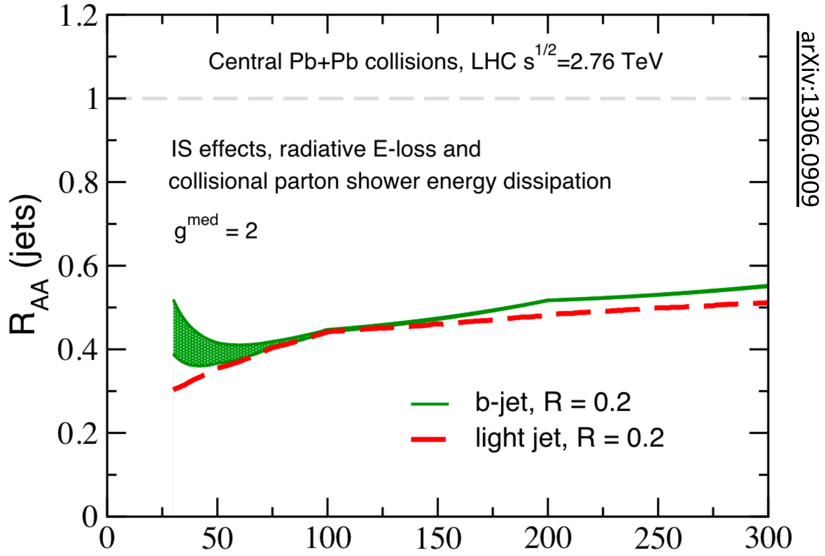
Jets as probes – future work

- Heavy flavour jets and subtructure:
  - Mass hierarchy, usd / c / b: fragmentation in vacuum (dead-cone for gluon emission), interaction with QGP ($\Delta E_{usd} > \Delta E_c > \Delta E_b$)
  - N-subjettiness: pp vs Pb-Pb to probe coherence effects in QGP, usd jets vs c jets for mass effects on fragmentation

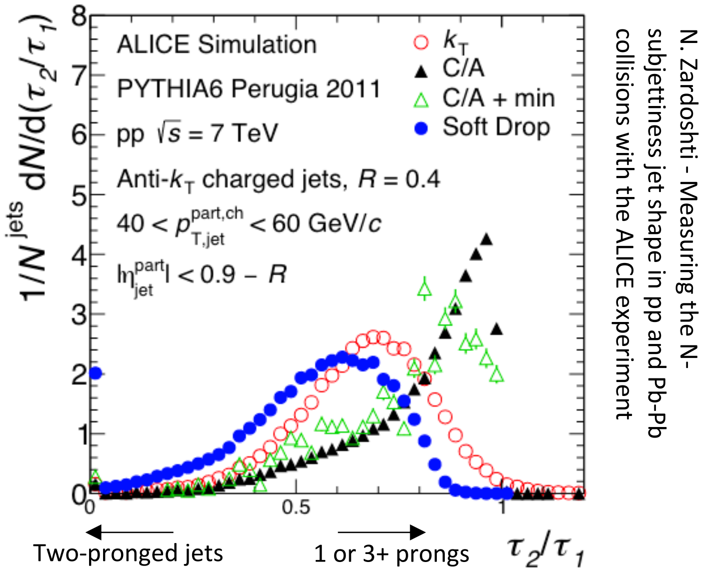
$$\tau_N = \frac{1}{p_{\mathrm{T,jet}} \times R} \sum_k p_{\mathrm{T},k} \, \mathrm{minimum}(\Delta R_{1,k}, \Delta R_{2,k}, \ldots, \Delta R_{\mathrm{N},k}),$$

Choice of axes: undo last step of C/A, anti-Kt or SD





Expected nuclear modification factor of b- and light- jets as a function of p_T for central Pb-Pb collisions in ALICE at $\sqrt{s} = 2.76\text{TeV}$



N-subjettiness ratio distribution for jets in pp collisions at $\sqrt{s} = 2.76\text{TeV}$ for different axis definitions

Thank you for your attention