New measurements of jet v_2 properties with ALICE

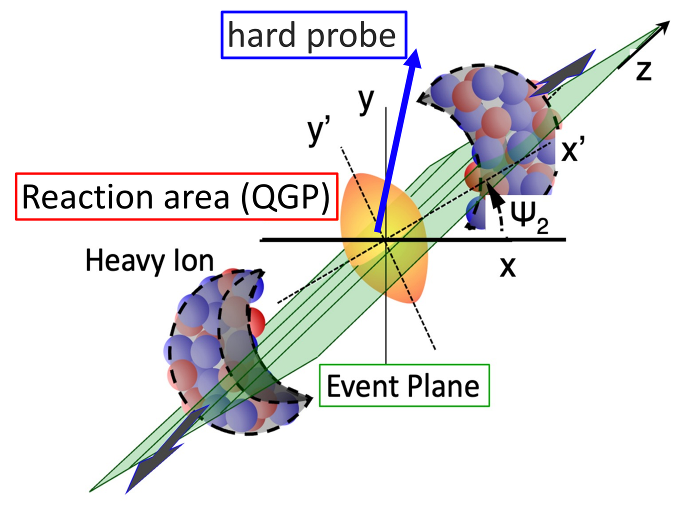
Takuya Kumaoka for the ALICE collaboration
RIKEN, University of Tsukuba, University Grenoble Alpes

1. Introduciton

Physcs Motivation : Investigate **quark-gluon plasma (QGP) properties** and **in-medium parton energy loss**

→ Use hard probes (heavy-flavor quarks, **jets**)
- The production cross section is **calculable by pQCD**
- High-energy partons are **produced in the initial collision stages**

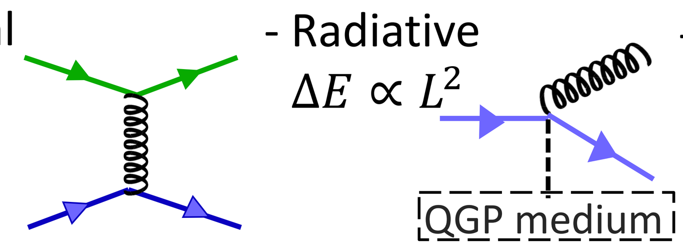
→ As a parton traverses the QGP, it **interacts with medium constituents and loses energy**.



No direct access to partonic energy loss and medium properties.
→ Still not clarified the parton quenching mechanism and related parameters.
- $\hat{q}$: transport coefficient
- n: power for path length

Energy loss
$\Delta E \propto \hat{q} L^n$
$\hat{q}$: transport coefficient
L: path length in QGP

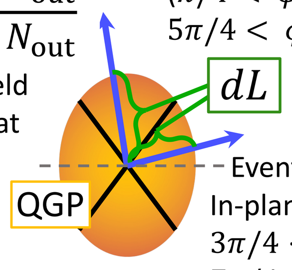
Jet suppression mechanism
- Collisional $\Delta E \propto L$
- Radiative $\Delta E \propto L^2$
- AdS/CFT $\Delta E \propto L^3$



→ Use azimuthal anisotropy of jet yield for event shape
Elliptic flow coefficient (v_2)

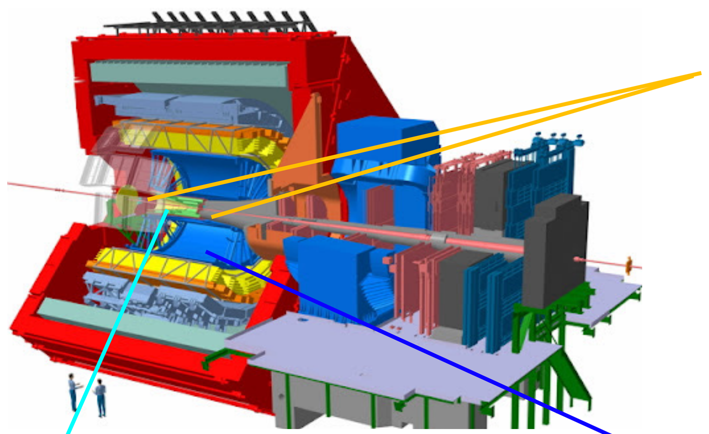
$$v_2^{\text{jet}} \propto \frac{N_{\text{in}} - N_{\text{out}}}{N_{\text{in}} + N_{\text{out}}}$$

$N_{\text{in}}, N_{\text{out}}$:Jet yield at in-plane and at out-of-plane



New points of this study for Energy loss
- Use **new central collision energy data set** for charged jet v_2
- It has both **unique and overlapping p_T** region for other experiments.

2. ALICE Detector and Data in Run 2



ALICE detector overview

V0
[V0A ($2.8 < \eta < 5.1$) and V0C ($-3.7 < \eta < -1.7$)]
- Trigger
- Centrality determination
- Event plane estimation

ITS ($|\eta| < 0.9$)
- Charged-particle tracking
- Primary/secondary vertexing

TPC ($|\eta| < 0.9$)
- Particle identification (PID) via dE/dx
- Charged-particle tracking

- Pb—Pb collisions: $\sqrt{s_{\text{NN}}}$ = 5.02 TeV (30-50%: $\mathcal{L}_{\text{int}} \sim$ 56 ub^{-1})

3. Event Plane Angle Estimation

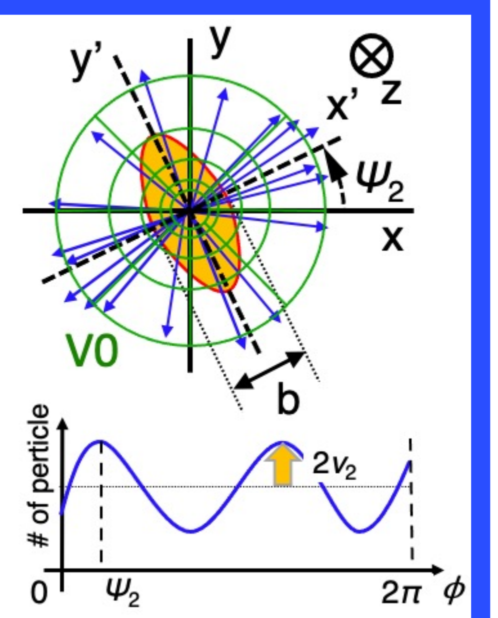
Event Plane Angle ($\Psi_{\text{EP},n}$)
- Classify jets for in-plane and out-of-plane.
- Estimate background p_T depending azimuthal angle.
- Used for event plane angle resolution($Res\{\Psi_{\text{EP},2}^{\text{meas}}\}$).

$$\Psi_{\text{EP},n} = \frac{1}{n}\arctan\frac{Q_{n,y}}{Q_{n,x}}$$

Flow vector from detector measurement

$$Q_{n,x} = \sum_i \omega_i \cos n\phi_i$$
$$Q_{n,y} = \sum_i \omega_i \sin n\phi_i$$

(ϕ_i : Track angle, ω_i :multiplicity weight, n: Fourier order)



Event plane estimation

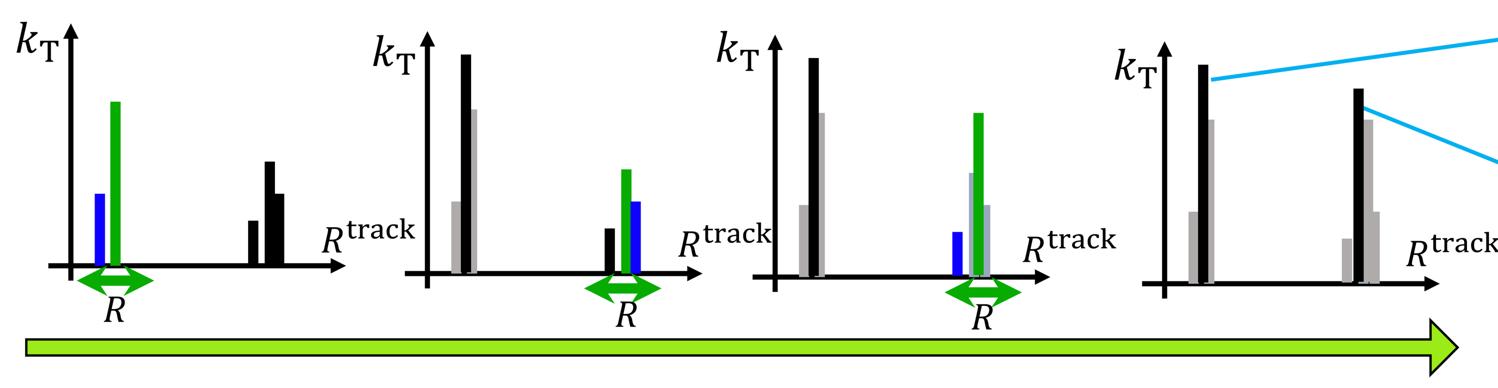
Calibration *Qn* vector
- Gain calibration :Calibrate detector cell gain for azimuthal angle.
- Cetrality calibration :Calibrate *Qn* vector for centrality.

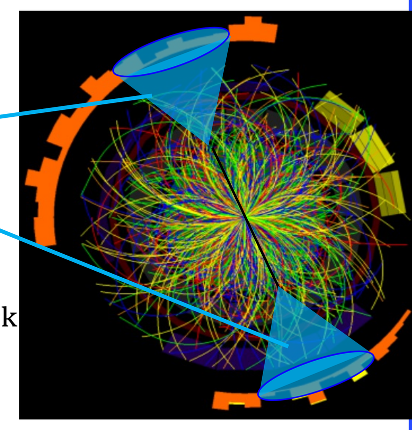
Event Plane Angle resolution

$$Res\{\Psi_{\text{EP},2}^{\text{meas}}\} = \langle\cos(2[\Psi_{\text{EP},2}^{\text{V0M}} - \Psi_{\text{EP},2}])\rangle$$
$$= \sqrt{\frac{\langle\cos(2[\Psi_{\text{EP},2}^{\text{V0M}} - \Psi_{\text{EP},2}^{\text{TPC},\eta<0}])\rangle\langle\cos(2[\Psi_{\text{EP},2}^{\text{V0M}} - \Psi_{\text{EP},2}^{\text{TPC},\eta>0}])\rangle}{\langle\cos(2[\Psi_{\text{EP},2}^{\text{TPC},\eta<0} - \Psi_{\text{EP},2}^{\text{TPC},\eta>0}])\rangle}}$$

4. Jet Reconstruction

Jet Reconstruction algorithm : anti-k_T of Fast jet package[1]
- Clustering track p_T to minimize $d_{ij} = \min(k_{ti}^{-2}, k_{tj}^{-2})\Delta R_{ij}^2/R^2$



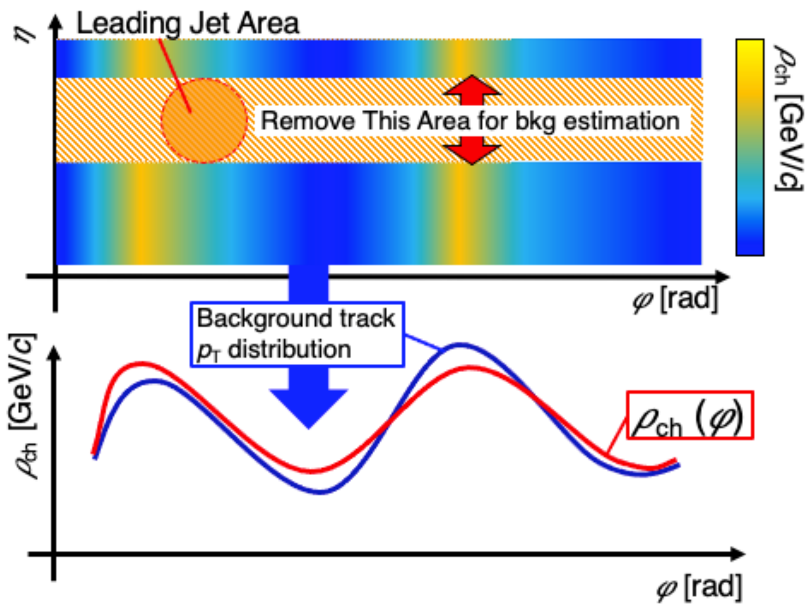


Jet reconstruction setting
- Charged jet
- Jet resolution parameter (R) :0.2
- Leading track p_T cut :5 GeV/c

Background Estimation
- In Heavy-ion collisions, a huge number of particles are produced.

→ Signal jets are reconstructed with the background particles.
→ Use fitting function ($\rho_{\text{ch}}(\phi)$) assuming background p_T distribution for azimuthal angle except for leading jet η area.

$$\rho_{\text{ch}}(\varphi) = \rho_0 \times \left(1 + 2\left\{v_2^{\text{obs}}\cos(2[\varphi - \Psi_{\text{EP},2}]) + v_3^{\text{obs}}\cos(3[\varphi - \Psi_{\text{EP},3}])\right\}\right)$$

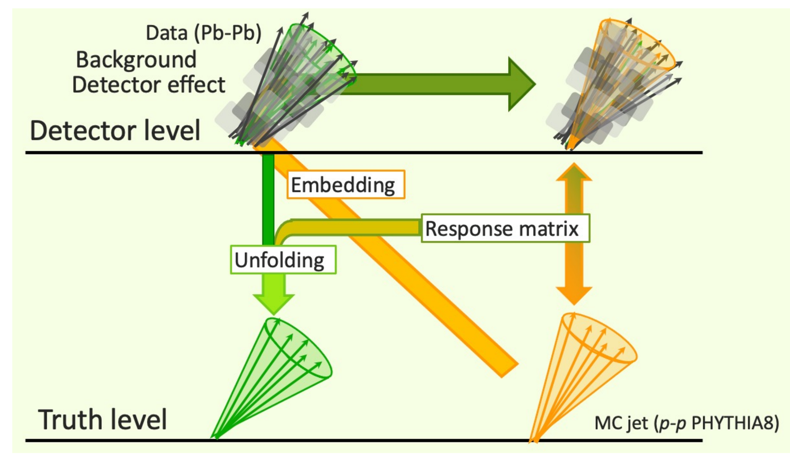


Background estiamtion process

Unfolding
- The measured jet p_T distribution is affected by *the background fluctuations* and *the finite resolution / efficiency of the detector*

→ <u>Correct p_T distribution distortions</u>

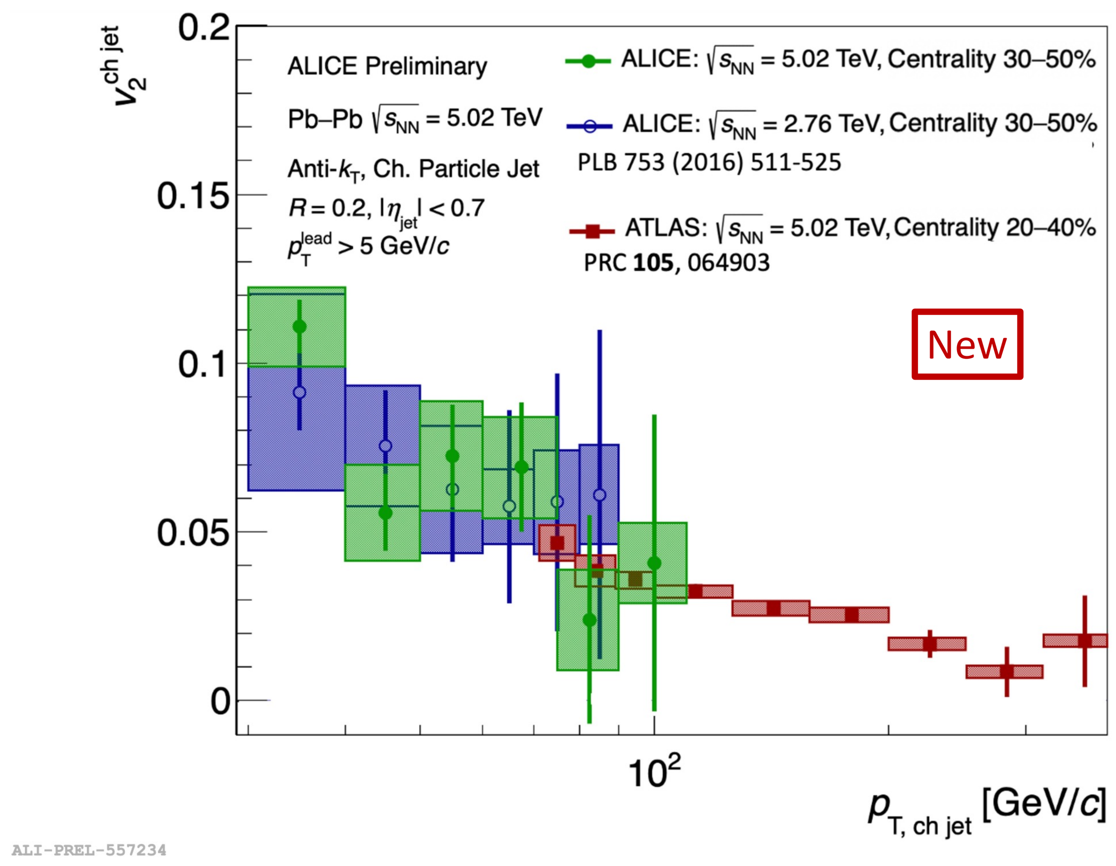
Setting
- Truth level jet: PYTHIA8
- Detector level jet: Embedding
- Number of iteration : 6
- Unfolding method : Bayes



Embedding and Unfolding

5. Inclusive Charged Jet v_2 in Pb–Pb Collisions (30-50%)

- At low p_T, the charged jet v_2 show **evidently positive value**. As it becomes high p_T, the charged jet v_2 gets **close to zero**.
- The charged jet v_2 of this measurement is **consistent with ATLAS result** within uncertainty around 70-110 GeV/c.



$$v_2^{\text{jet}} = \frac{1}{Res\{\Psi_{\text{EP},2}^{\text{meas}}\}}\frac{\pi}{4}\frac{N_{\text{in}} - N_{\text{out}}}{N_{\text{in}} + N_{\text{out}}}$$

$N_{\text{in}}, N_{\text{out}}$: jet yield at in-plane and at out-of-plane

6. Summary and Outlook

Summary
- To clarify jet quenching mechanism and estimate its parameters, charged jet v_2 measured using the data of Pb—Pb collision $\sqrt{s_{\text{NN}}}$ = 5.02 TeV.
- The charged jet v_2 in centrality 30-50% show positive value and it is consistent with other experiments.

Outlook
- Measure other centrality charged jet v_2.
- Compare with some model simulations in JETSCAPE.

→ Constrain models and determine quenching parameter.

Reference

[1] M. Cacciari, G. P. Salam, and G. Soyez, Eur. Phys. J. C 72 (2012) , arXiv:1111.6097 [hep-ph]
[2] *Physics Letters B*, Vol. 753, pp. 511–525, 2016.
[3] *Phys. Rev. C*, Vol. 105, p. 064903, Jun 2022.