Studying energy loss in QGP through hard probes

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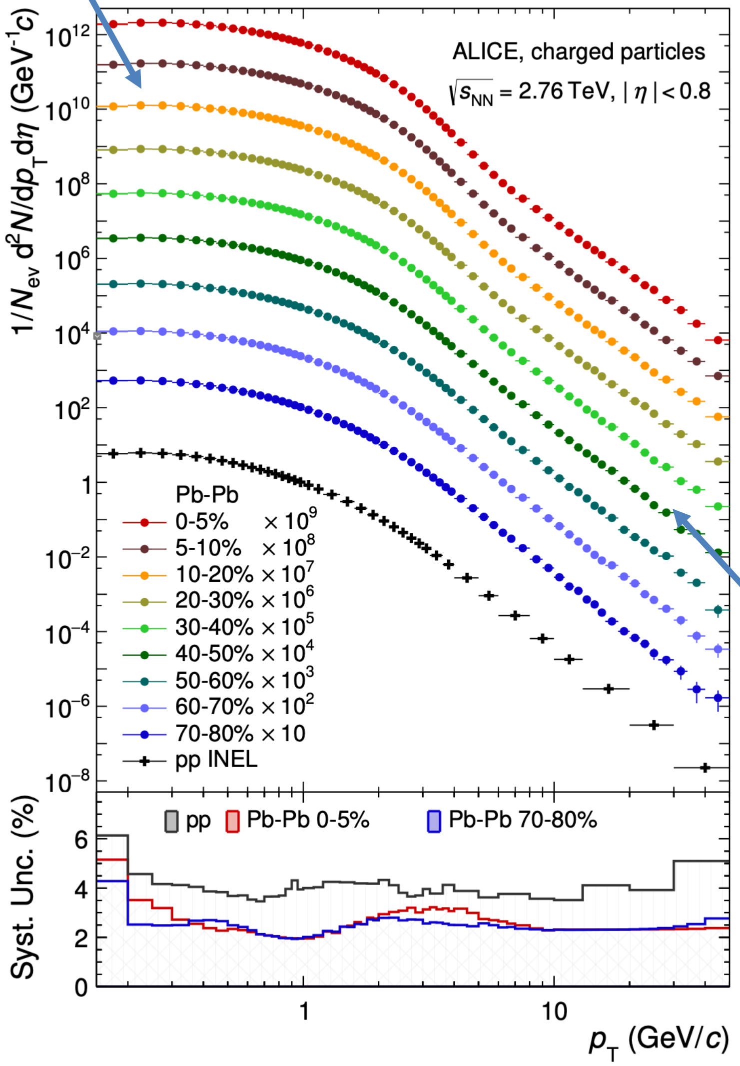
How to probe the QGP properties?

SOFT PROBES



HARD PROBES

ALICE, 2019, arXiv:1802.09145

- **SOFT PROBES:**

Low-$p_T \Rightarrow$ long time: full hadronisation

Thermodynamical properties of QGP

(T_{fo} , T_{Ph} , EOS, η/s)

- **HARD PROBES:**

High-$p_T \Rightarrow$ short time ($1/Q^2 \approx \tau_{form}$): high Q^2

Hard parton interactions with QGP

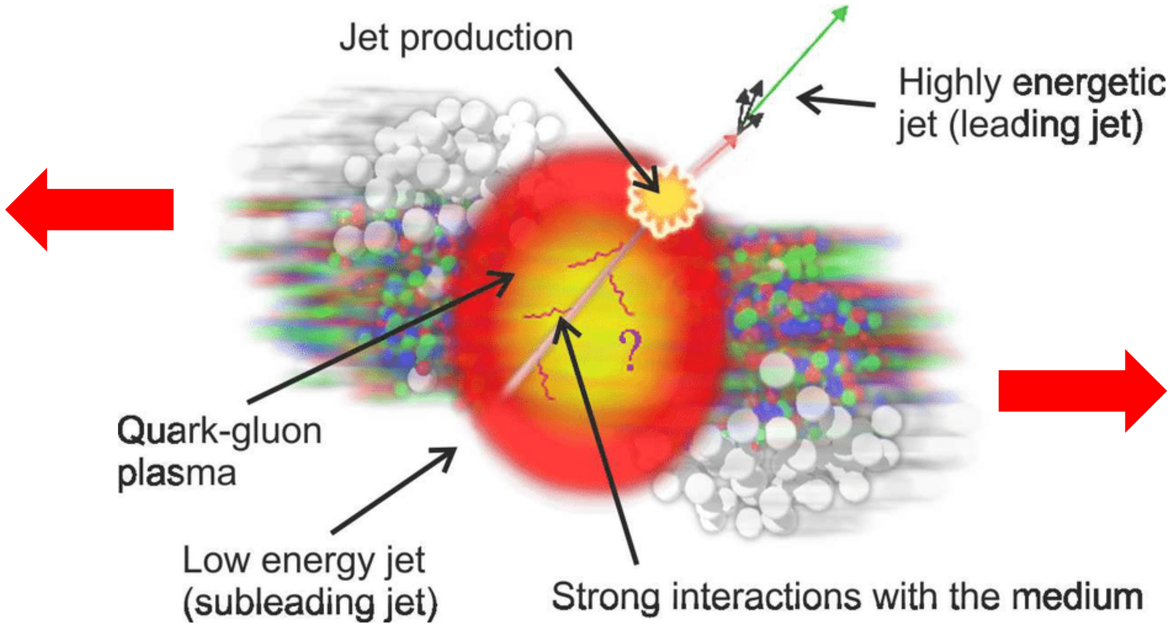
Sensitive to how opaque is the QGP

Hard probes

○ **HARD PROBES:**

Small cross section: rare

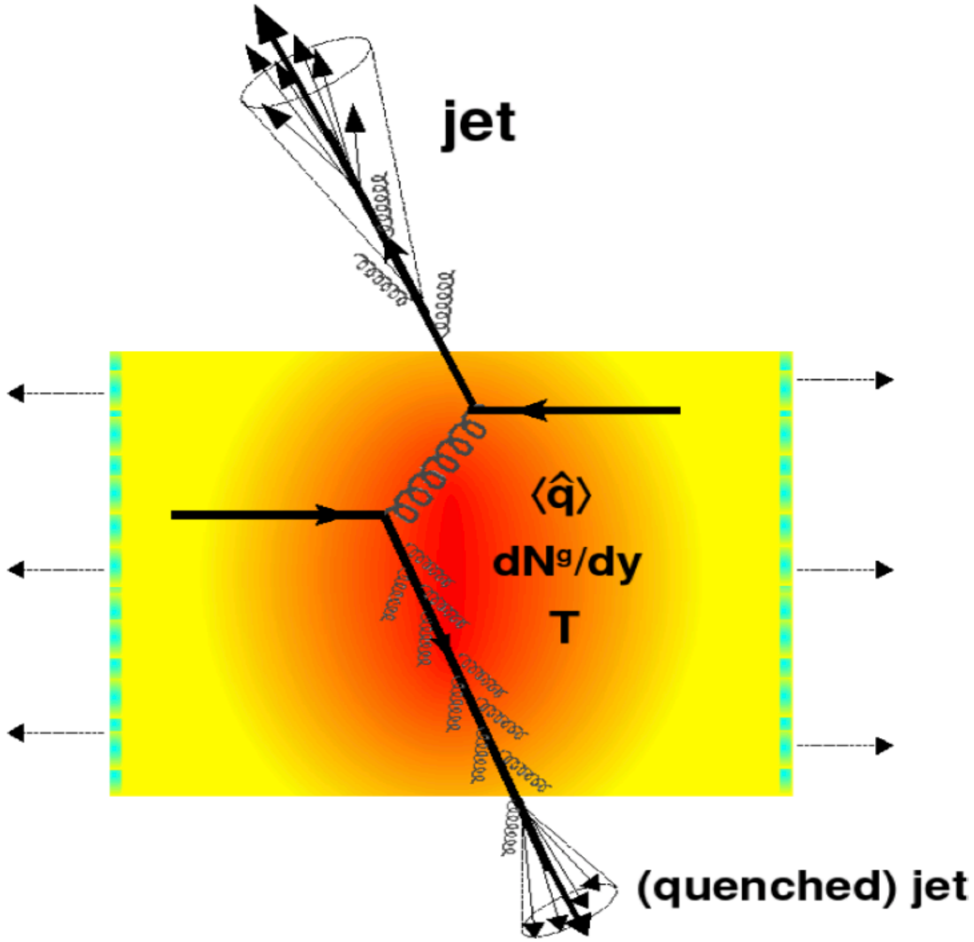
High transferred momentum $Q^2 \Rightarrow$ low $\alpha_S \Rightarrow$ perturbative QCD



Examples of Hard Probes:

- **Jets**: jet spectra, sub-structure and high p_T particle production (**open heavy flavour** and **Quarkonia**)
- **EM bosons** (γ, Z)

Parton energy loss



In Pb-Pb high energy partons lose energy.
QCD inspired models try to describe ΔE: e.g BDMPS
Two mechanisms:

- Collisional
- Radiational

$$\Delta E_{loss\,rad} \propto \alpha_s \hat{q} C_F L^2$$

$\hat{q}$ = QGP property

Theoretical calculation — Experimental measurement

Link experiment & theory

Gauge bosons energy loss: $\Delta E_{\gamma} = 0$ $\Delta E_q < \Delta E_g$

Nuclear Modification Factor

Hypothesis:

hard particle production should scale with $N_{coll} \Rightarrow$ *binary scaling*

The ***nuclear modification factor*** is:

$$R_{AA}(p_T) = \frac{1}{< N_{coll} >} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T}$$

Binary scaling $\Rightarrow$

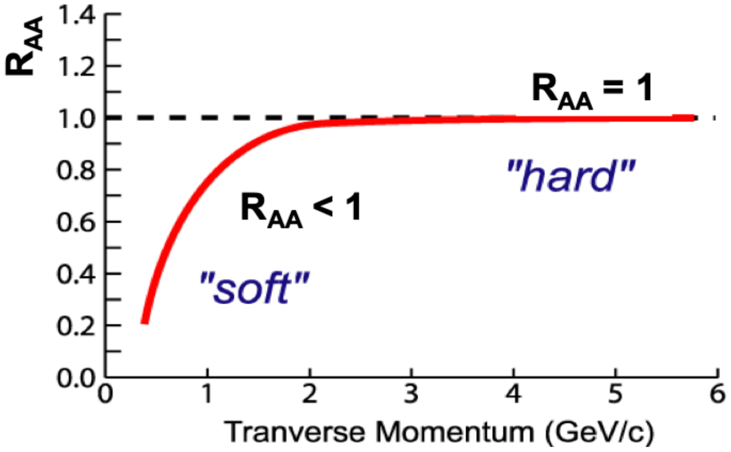
Pb-Pb = superposition of elementary collisions $\Rightarrow$

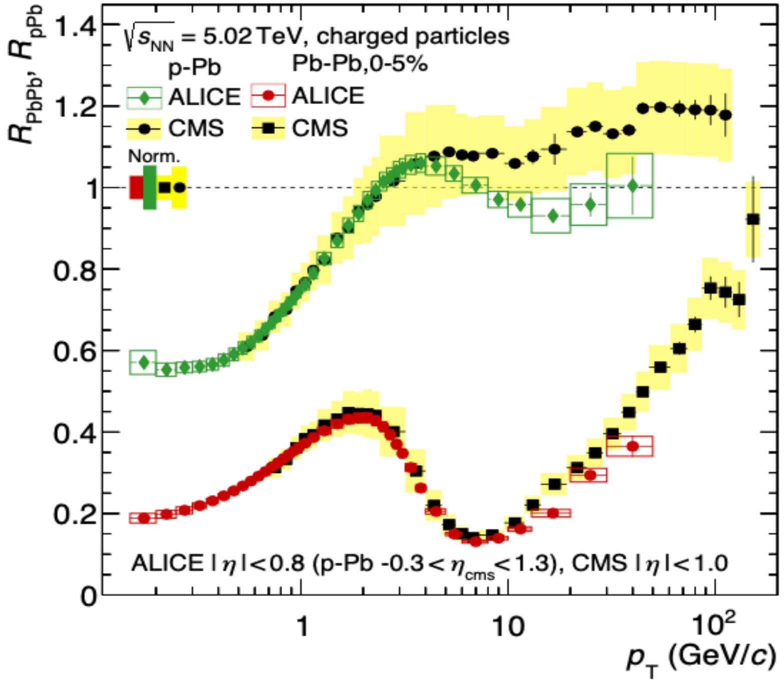
$$R_{AA}(p_T) = 1$$

Experimentally:

$$R_{AA}(p_T) < 1$$

Medium presence $\Rightarrow$ energy loss $\Rightarrow$ break of the *binary scaling*





ALICE, 2018, arXiv:1802.09145

Outline of energy loss means

Observables

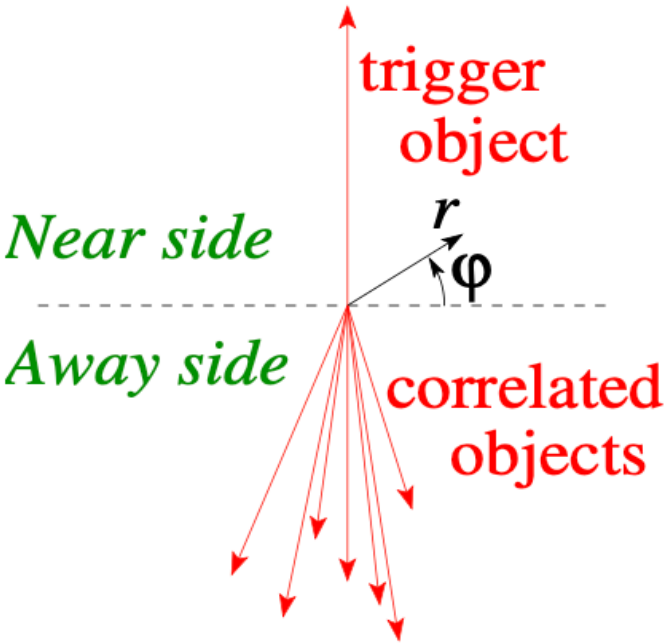
Jets, hadrons
"dirty" measurement
high-statistics

γ, Z
"clean" measurement
low-statistics

Means for energy loss measurements

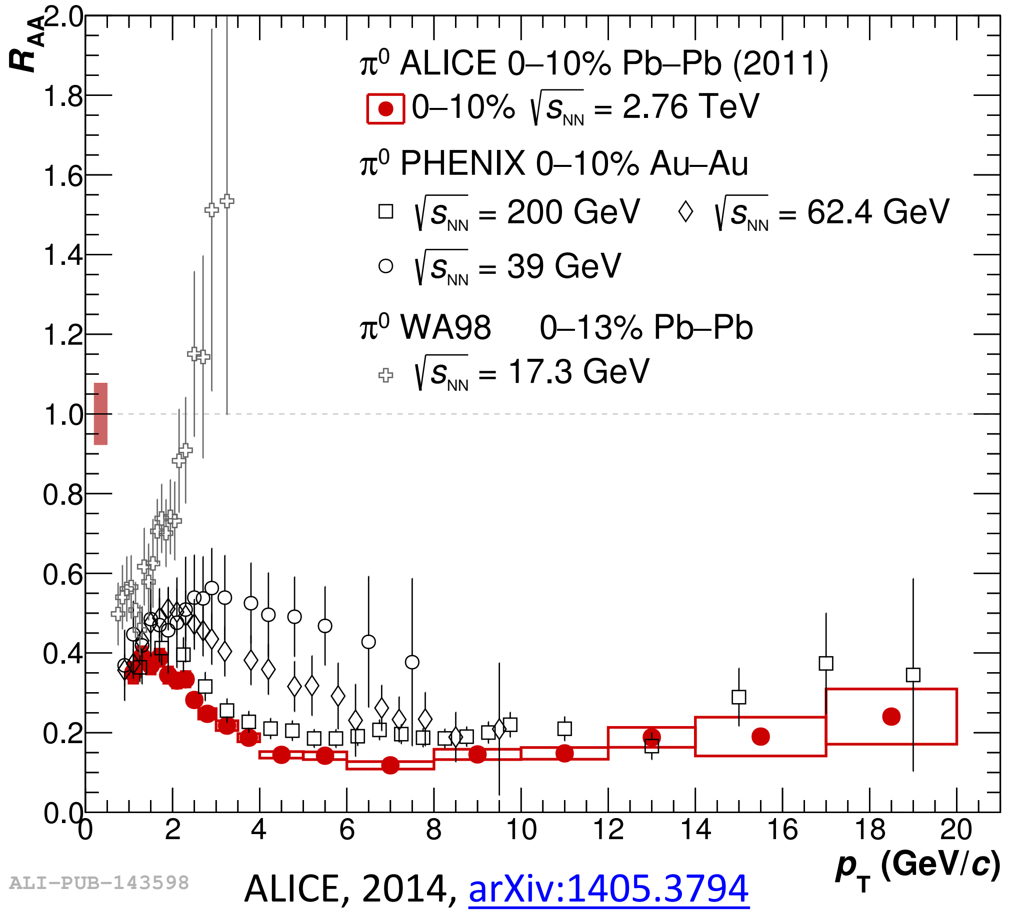
Not triggered: stand-alone measurements
R_{AA}, heavy flavour, Jet shapes, Fragmentation function

Triggered: combining 2 observables
Asymmetries, Di-jet imbalance, Correlation, Jet deflection, I_{AA}



R_{AA}

- Not triggered
- To quantify modification particle production in A+A collisions wrt *pp*



ALICE, 2014, arXiv:1405.3794

At LHC the R_{AA} is lower than at RHIC.

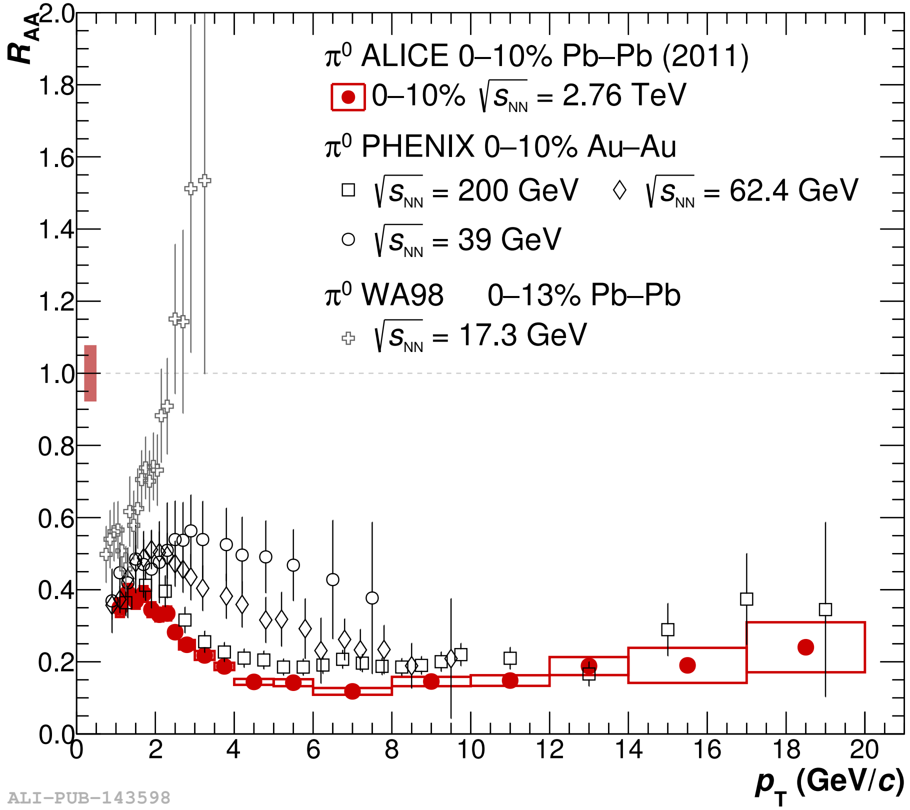
$$\text{RHIC } \sqrt{s_{NN}} \neq \text{LHC } \sqrt{s_{NN}}$$

Different QGP temperature, energy density, volume

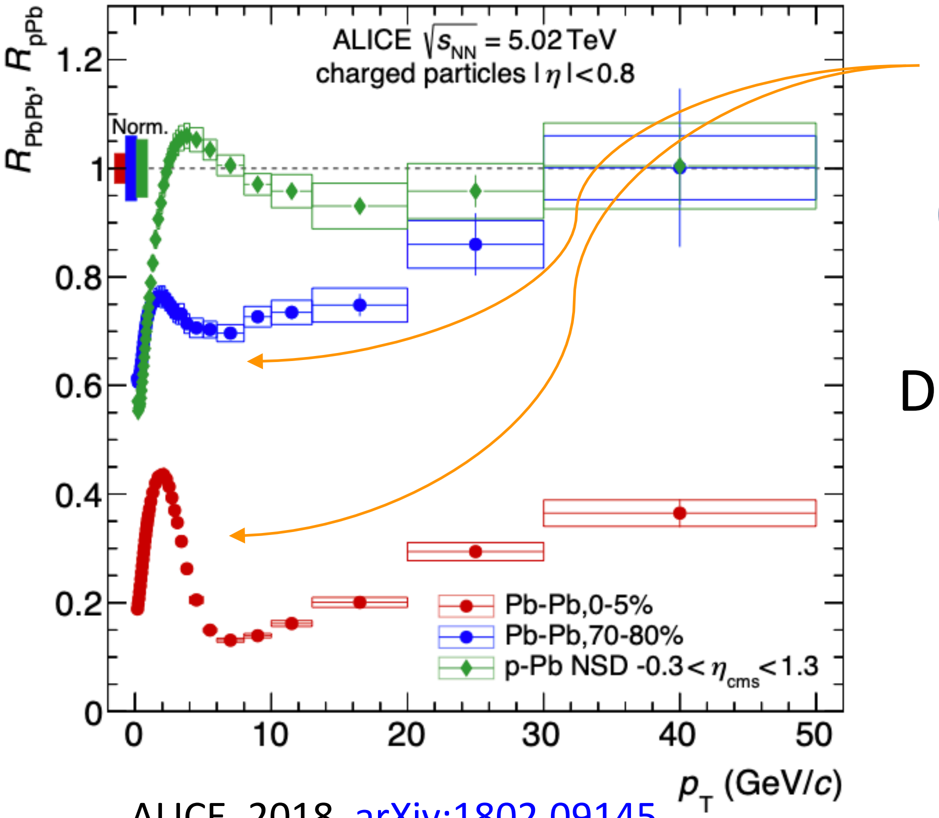
Enhanced energy loss at LHC = denser medium.

R_{AA}

- Not triggered
- To quantify modification particle production in AA collisions wrt *pp*

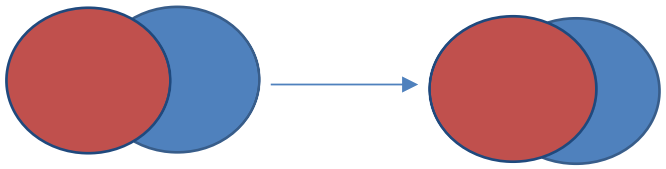


ALICE, 2014, arXiv:1405.3794



ALICE, 2018, arXiv:1802.09145

- ROLE OF CENTRALITY

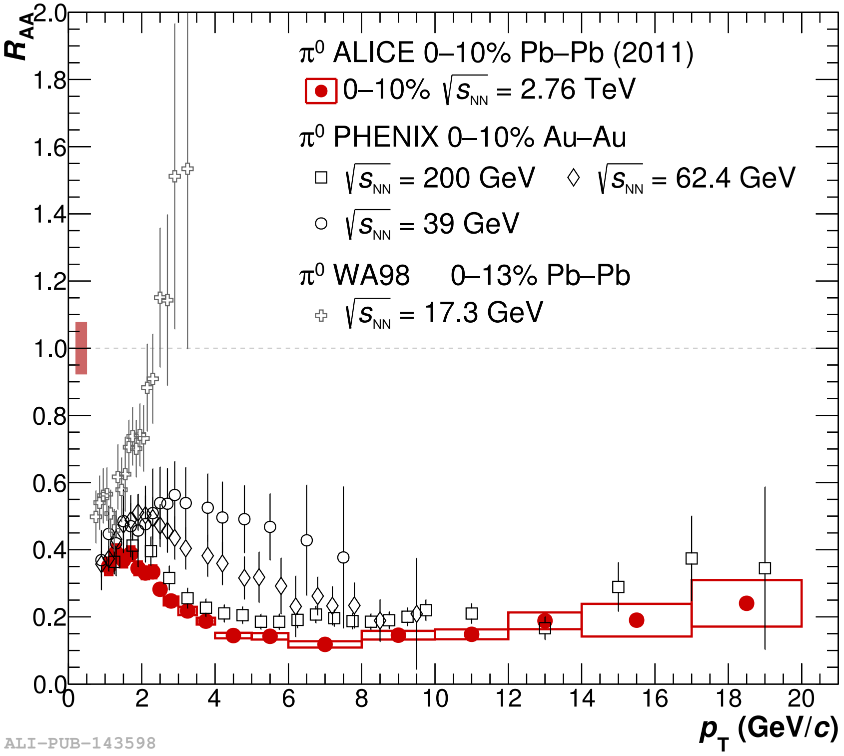


Different superposition ⇒ different energy, volume and geometry

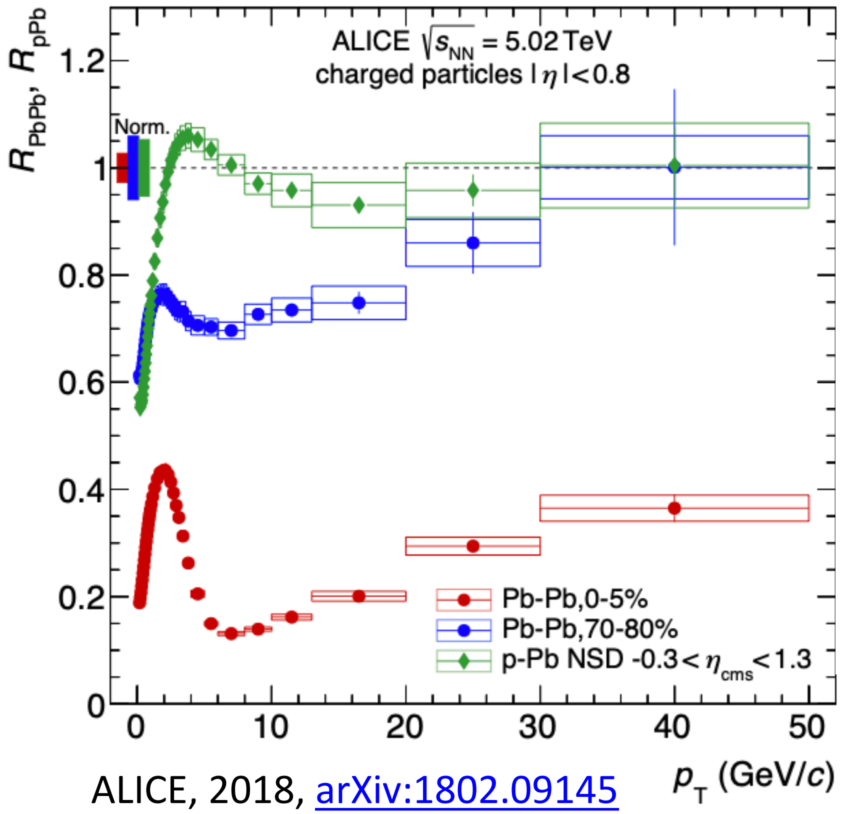
R_{AA}

- Combining with models ⇒ estimation of $\hat{q}$
- R_{AA} poor variable ⇒ not sensible to QGP properties, but…

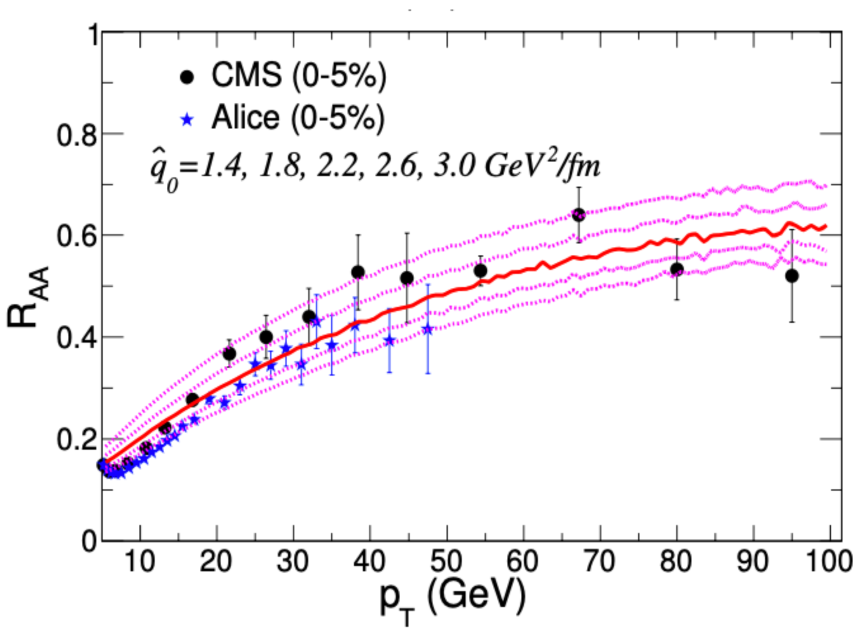
★ See jet quenching



ALICE, 2014, arXiv:1405.3794



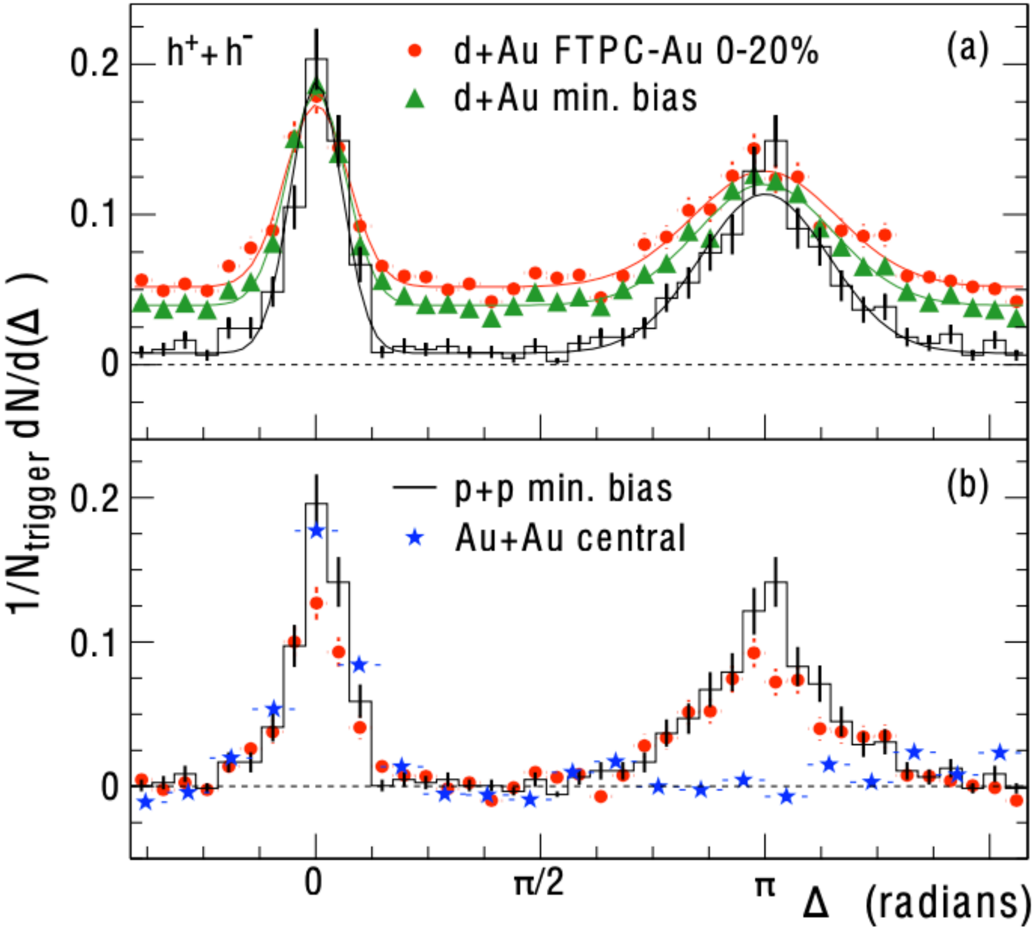
ALICE, 2018, arXiv:1802.09145



ALICE, 2014, arXiv:1312.5003

Azimuthal distribution

$\sqrt{s}$=200 GeV



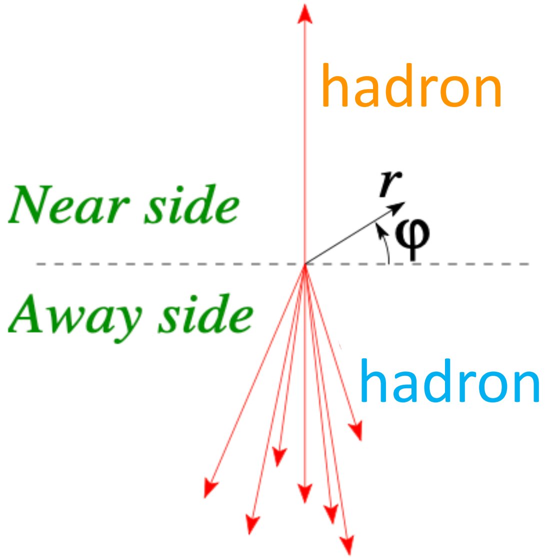
STAR, 2003, arXiv:nucl-ex/0306024

Main tool: hadron + hadron

Two-particle azimuthal distribution D(Δϕ) :

$$D(\Delta\phi) \equiv \frac{1}{N_{trigger}} \frac{1}{\epsilon} \frac{dN}{d(\Delta\phi)},$$

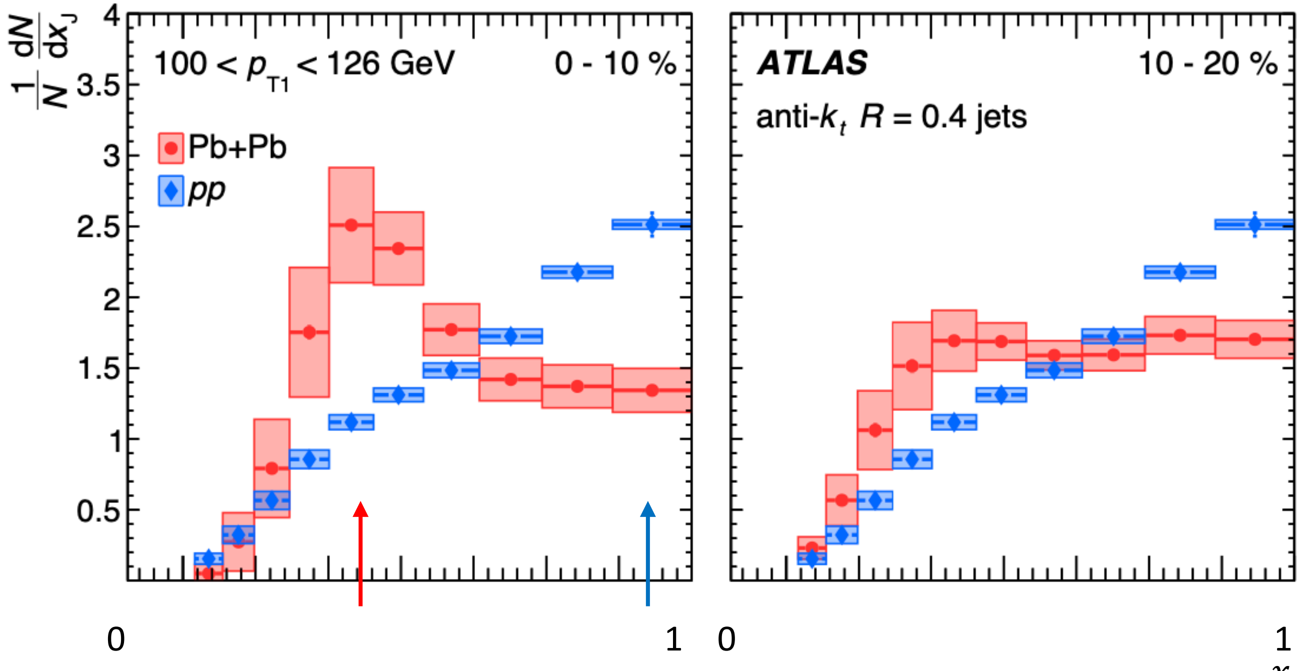
QGP effect: in Au-Au no peak in π



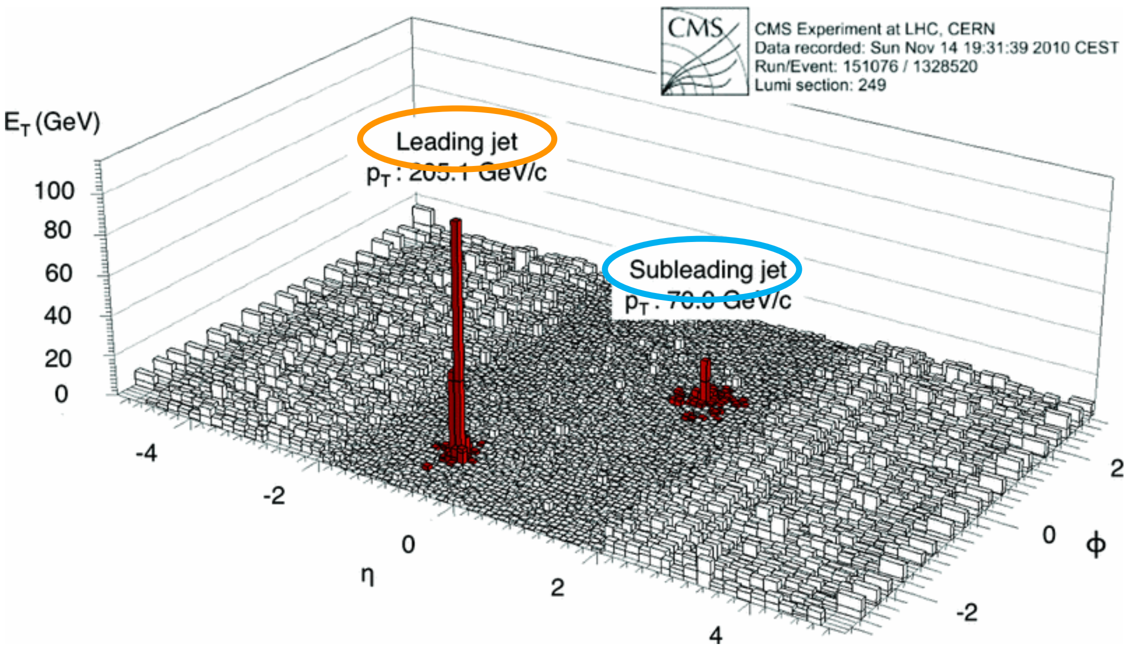
Di-jet imbalance

Main tool: leading jet + jet

- $x_j = \frac{p_T^{sublead}}{p_T^{lead}}$
- Access to ***energy loss distribution***
- If no effect QGP the peak as to be at $x_j \approx 1$



ATLAS, 2017, *J. Phys.: Conf. Ser.* **832** 012007

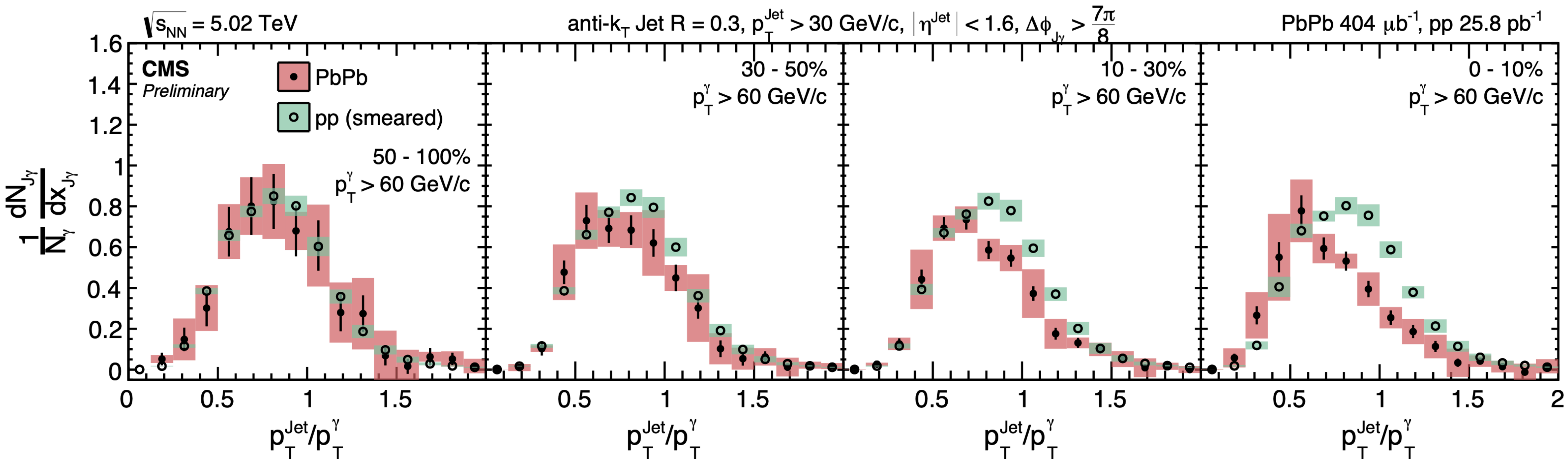


- Role of centrality

Di-jet imbalance

- $p_T^{Jet} / p_T^{\gamma - Z}$
- Access to ***energy loss distribution***
- If no effect QGP the peak as to be at $p_T^{Jet} / p_T^{\gamma - Z} \approx 1$

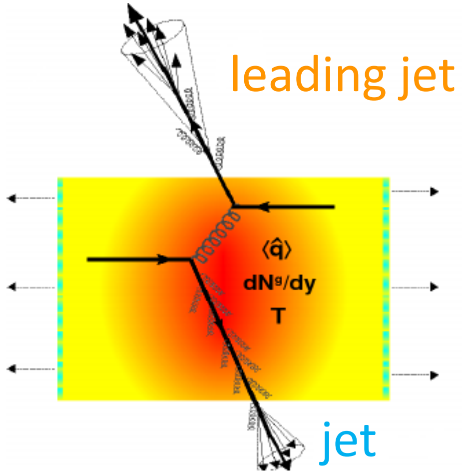
Main tool: γ, Z + jet



CMS, 2016, CMS-PAS-HIN-16-002

★ Jet energy loss: where does the energy go?

Asymmetries



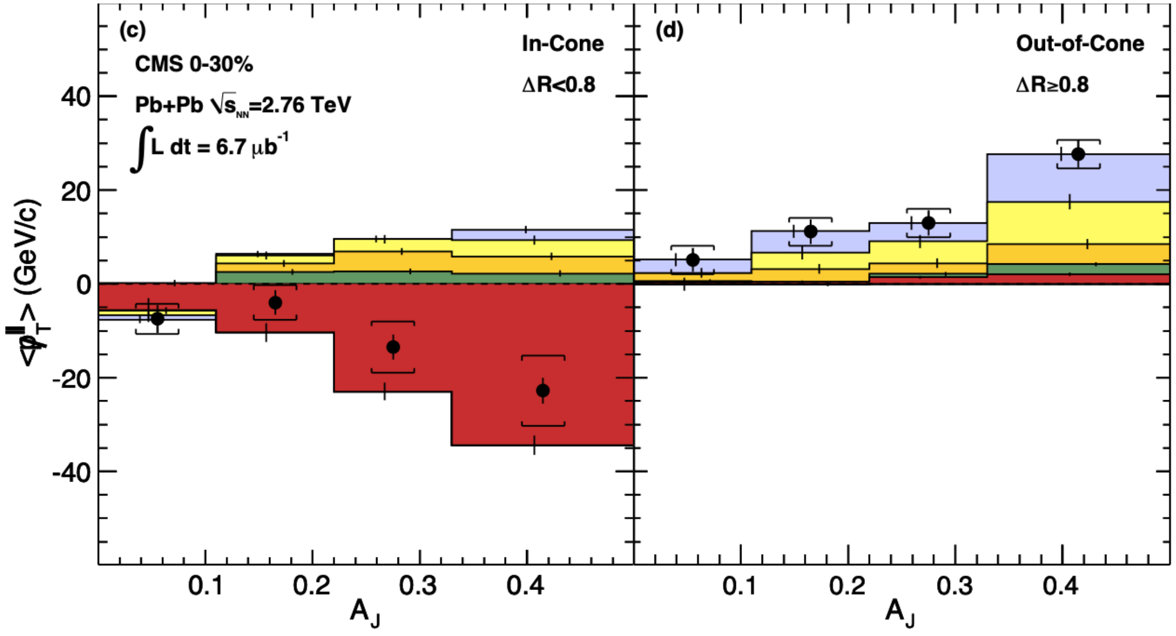
- $A_J = (p_{T1} - p_{T2})/(p_{T1} + p_{T2})$

Main tool: leading jet + jet

- $p_{T1} > 120$ GeV
- $p_{T2} > 50$ GeV
- Average missing transverse momentum $\not{p}_T^{\parallel} = \sum_i -p_T^i \cos(\phi_i - \phi_{\text{Leading Jet}})$,

$\sqrt{s}$=2.76 TeV

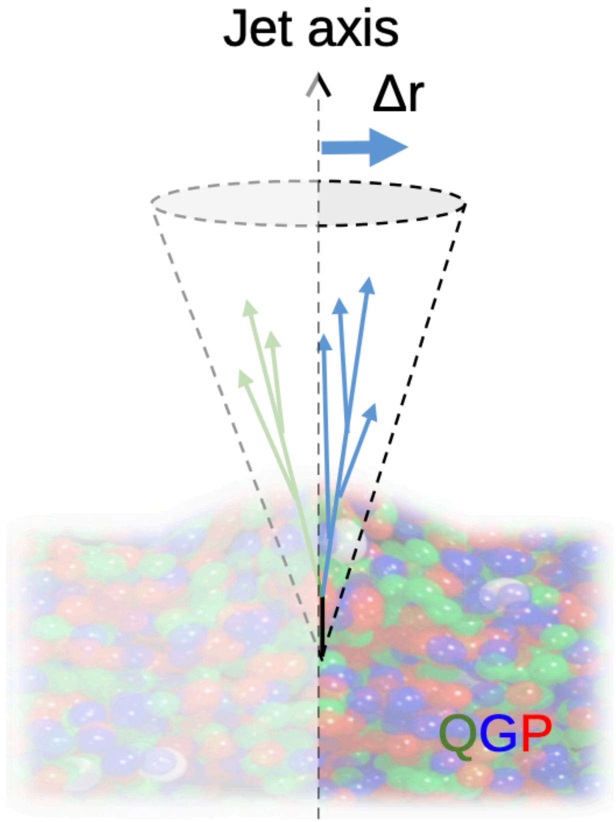
CMS, 2011, arXiv:1011.6182



★ Energy loss goes to particles emitted with high angle value !

Jet shapes

- Radial momentum distribution of jet $\mathrm{P}(\Delta \mathrm{r}) = \frac{1}{\delta \mathrm{r}} \frac{1}{N_{\mathrm{jets}}} \Sigma_{\mathrm{jets}} \Sigma_{\mathrm{tracks} \in (\Delta \mathrm{r_a}, \Delta \mathrm{r_b})} p_{\mathrm{T}}^{\mathrm{trk}}, \, \Delta \mathrm{r} < 1,$



$\Delta r = \sqrt{(\Delta\eta)^2 + (\Delta\varphi)^2}$: relative angular distance from the jet axis

Δr_{a}, Δr_{b}: annular edges of Δr

$$\delta r = \Delta r_{\mathrm{a}} - \Delta r_{\mathrm{b}}$$

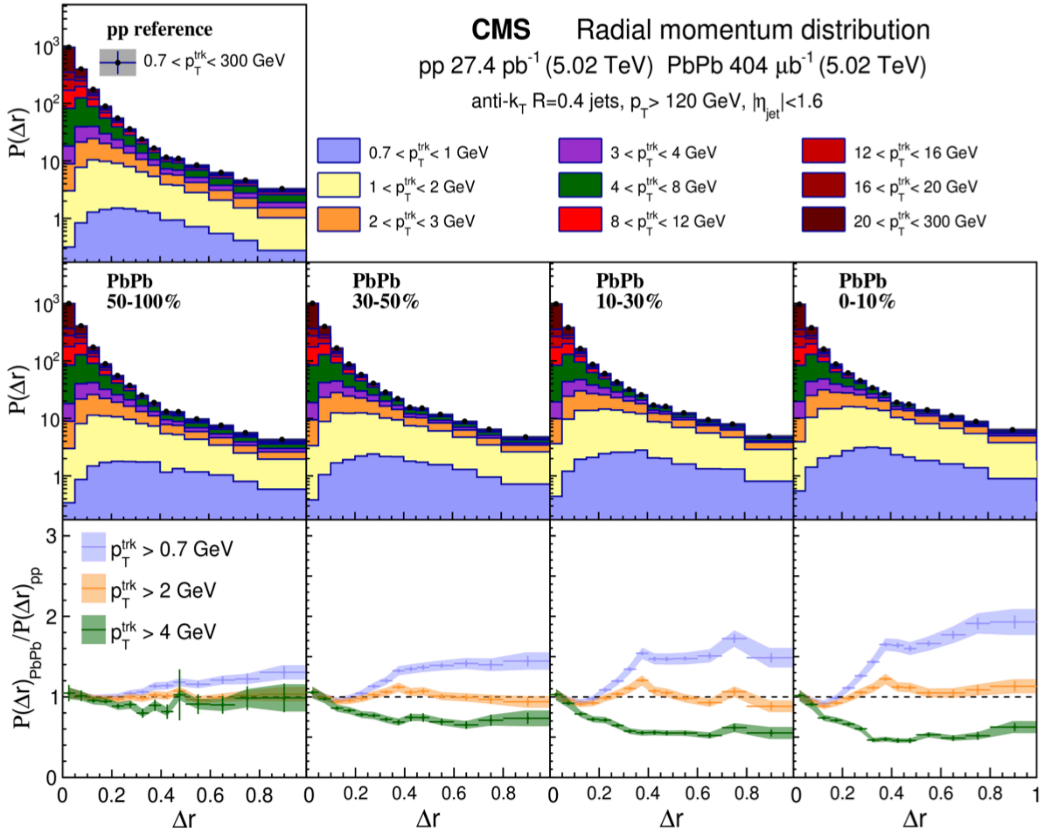
Jet shapes

- $P(\Delta r)$ for inclusive jets $p_T > 120$ GeV
- Study $P(\Delta r)_{PbPb}/P(\Delta r)_{pp}$

pp

PbPb

ratio



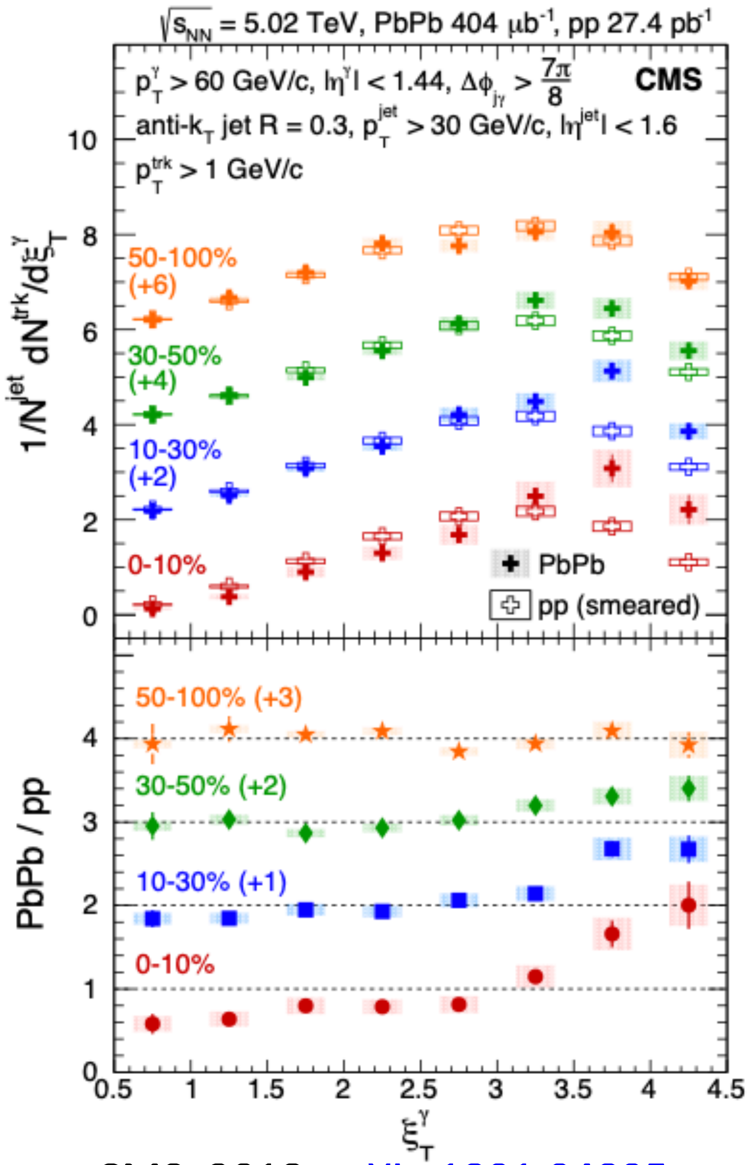
- ROLE OF CENTRALITY

Suppression of high-p_T hadrons at a very low Δr
Enhancement of low-p_T at a higher Δr

★ Energy goes in low-p_T $\Rightarrow$ Δr increases

CMS, 2018, arXiv:1509.09029

Fragmentation function



CMS, 2018, arXiv:1801.04895

Main tool: γ+ jet

FF in Pb-Pb are expected to be different wrt vacuum (pp)

x axis: $\xi^\gamma = \ln(-1/z_T)$

y axis: $R_D(\xi^\gamma) = FF^{PbPb}/FF^{pp}$

- $R_D(\xi^\gamma)$ for different centralities
- High ξ^γ values ⇒ low-p_T values
- Enhancement at low-p_T ⇒ jet fragments passing through medium

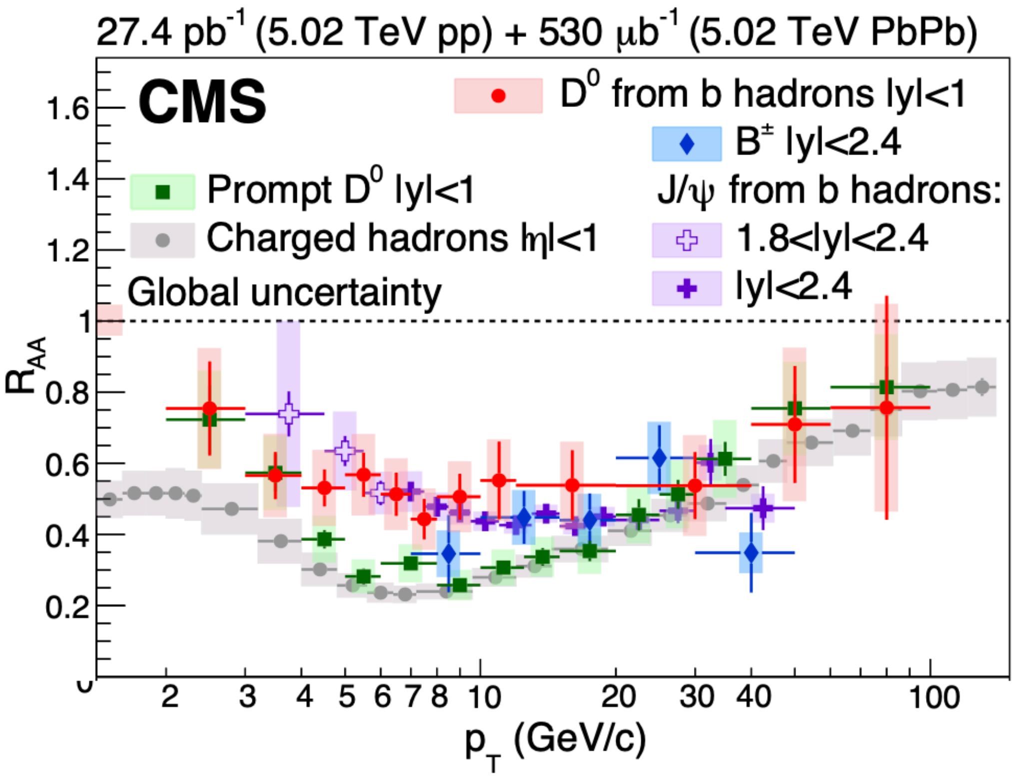
γ tagged jet ⇒ effect more evident

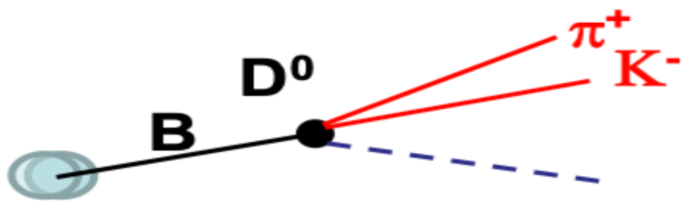
★ How energy is shared!

Heavy flavours

- Heavy flavours (D, B) = with high mass quarks → produced in partons scattering with high Q^2
- ΔE loss depends on quark masses.
- Dead cone effect: gluonstralhung suppressed at $\theta < \frac{M_q}{E_q}$

$$\Delta E_{u,d,s} > \Delta E_c > \Delta E_b \Longrightarrow R_{AA}(\boldsymbol{\pi}) < R_{AA}(\boldsymbol{D}) < R_{AA}(B)$$





Non-prompt

lower energy loss

=

higher R_{AA}

Hint of flavour dependence of in-medium energy loss

Some results

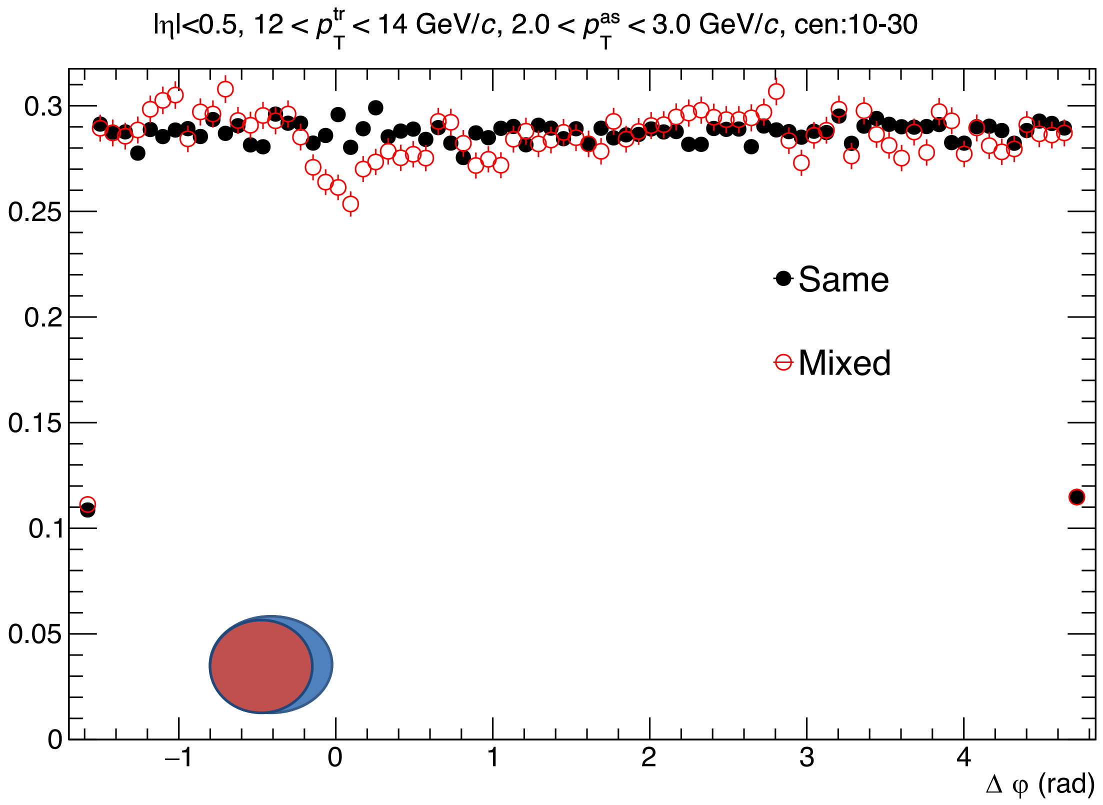
Analysis data

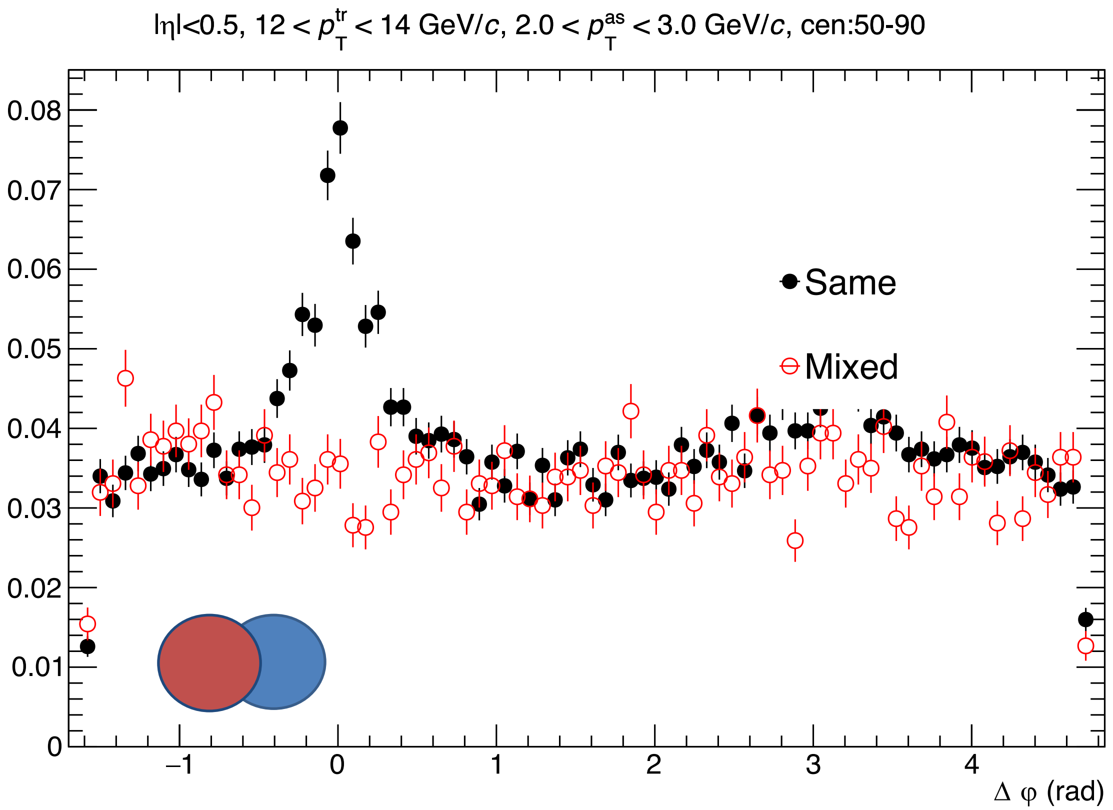
- Data selection: LHC18qr AOD252 , LHC15o AOD252
  - 30% of LHC18qr jobs failed
- Centralities: 0-10 %, 10-30 %, 30-50 %, 50-90 %
- Trigger: MB+EMCAL

Selection:

- Shower shape:
  - γ 0.10-0.30
  - background 0.40-2.00
- $p_t^{iso} < 4\ \mathrm{GeV}/c$
- Radius Cone: 0.05 < R < 0.2

Δφ distributions



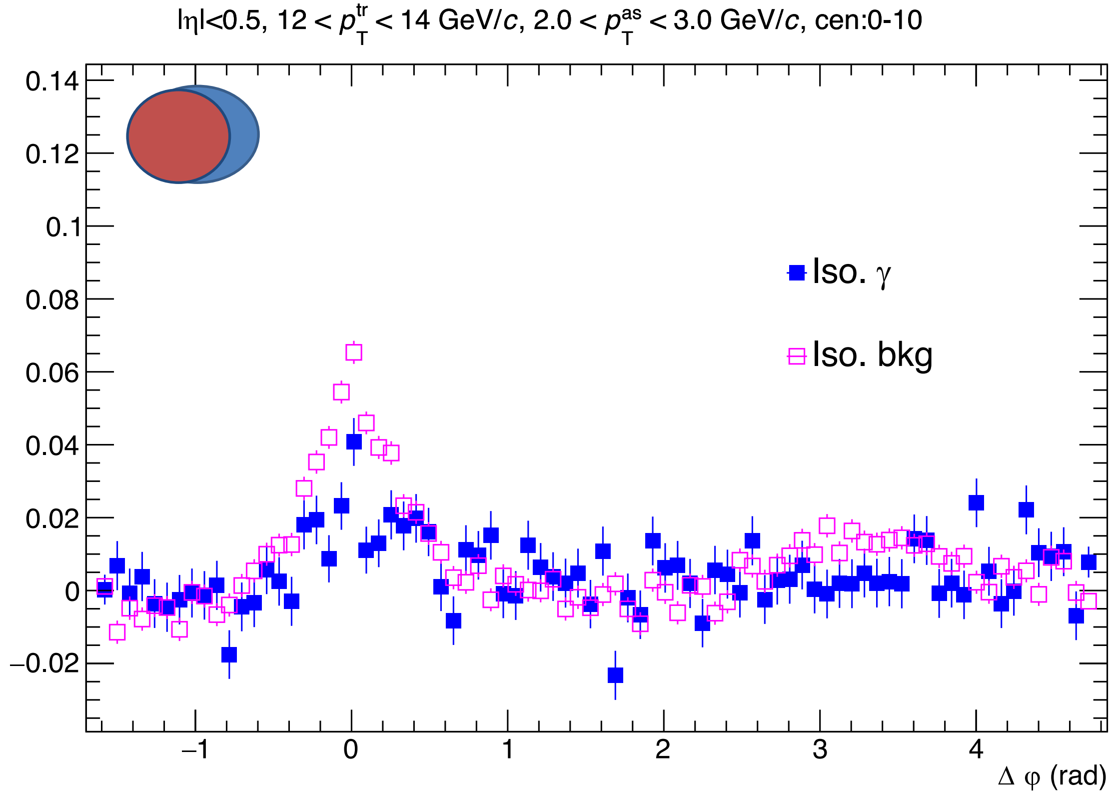


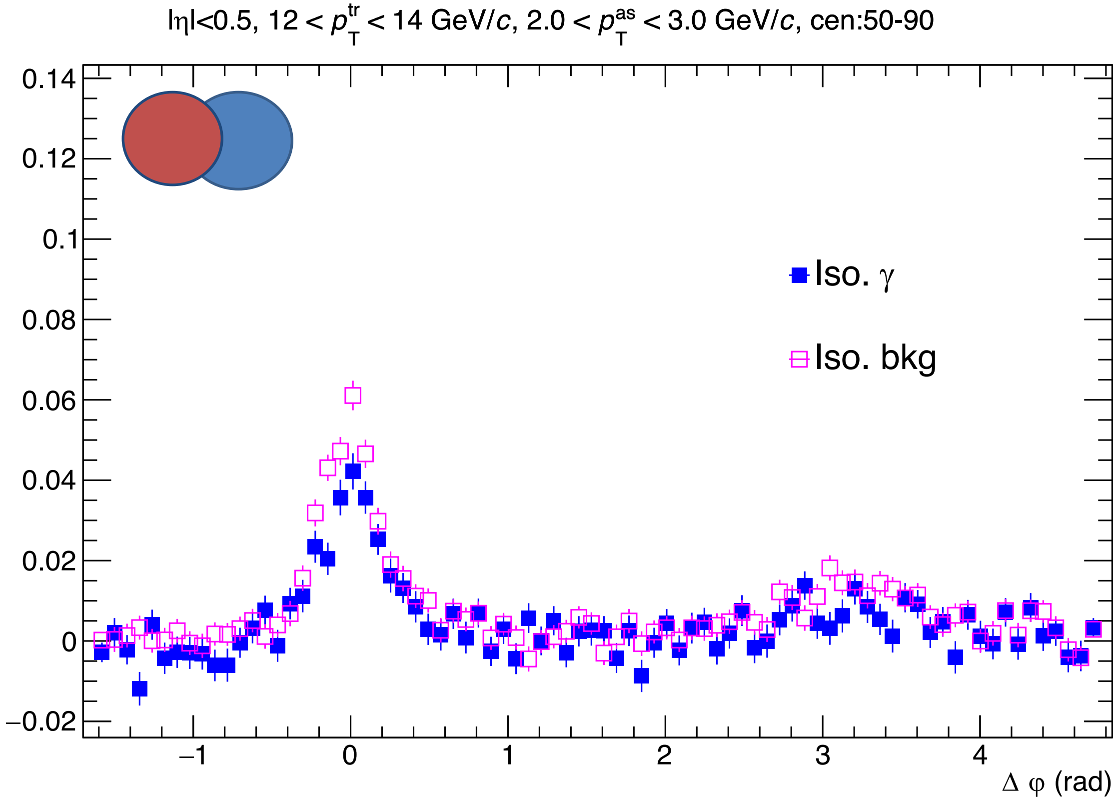
$12 < p_T^{trig} < 14\ \mathrm{GeV}/c \qquad 2 < p_T^{ass} < 3\ \mathrm{GeV}/c$

Same ⇒ Signal Mixed ⇒ UE

Isolation ON

Shower shape: 0.10 - 0.30 (γ)



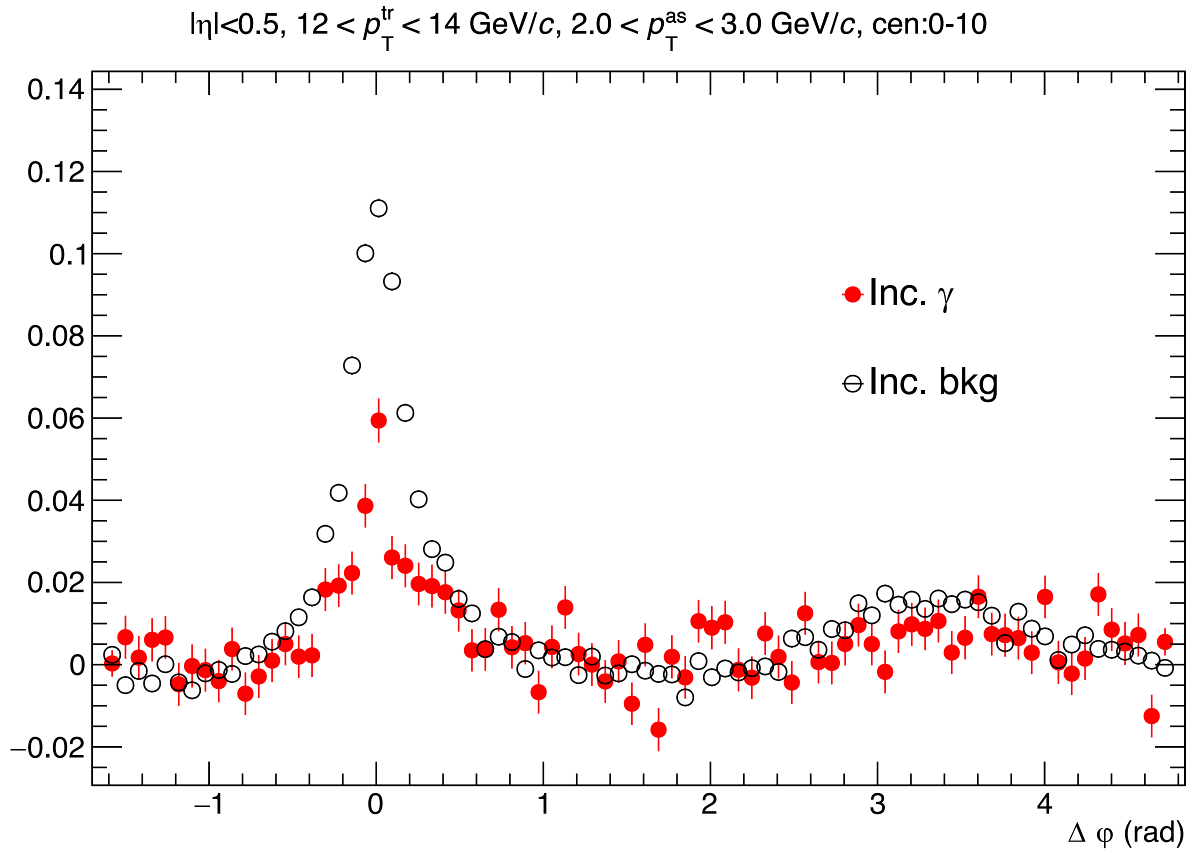


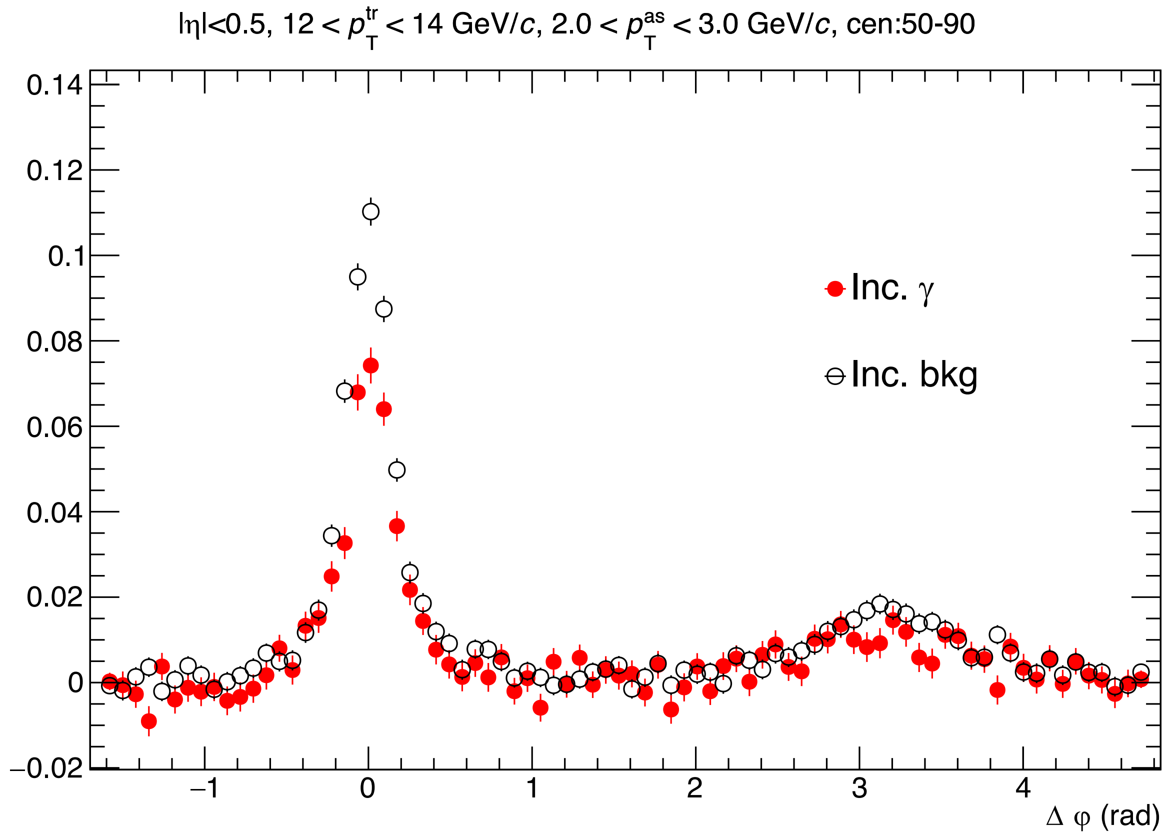
$12 < p_T^{trig} < 14\ \mathrm{GeV}/c \qquad 2 < p_T^{ass} < 3\ \mathrm{GeV}/c$

Subtraction of UE

Isolation ON

Shower shape: 0.10 - 0.30 (γ and its bkg)





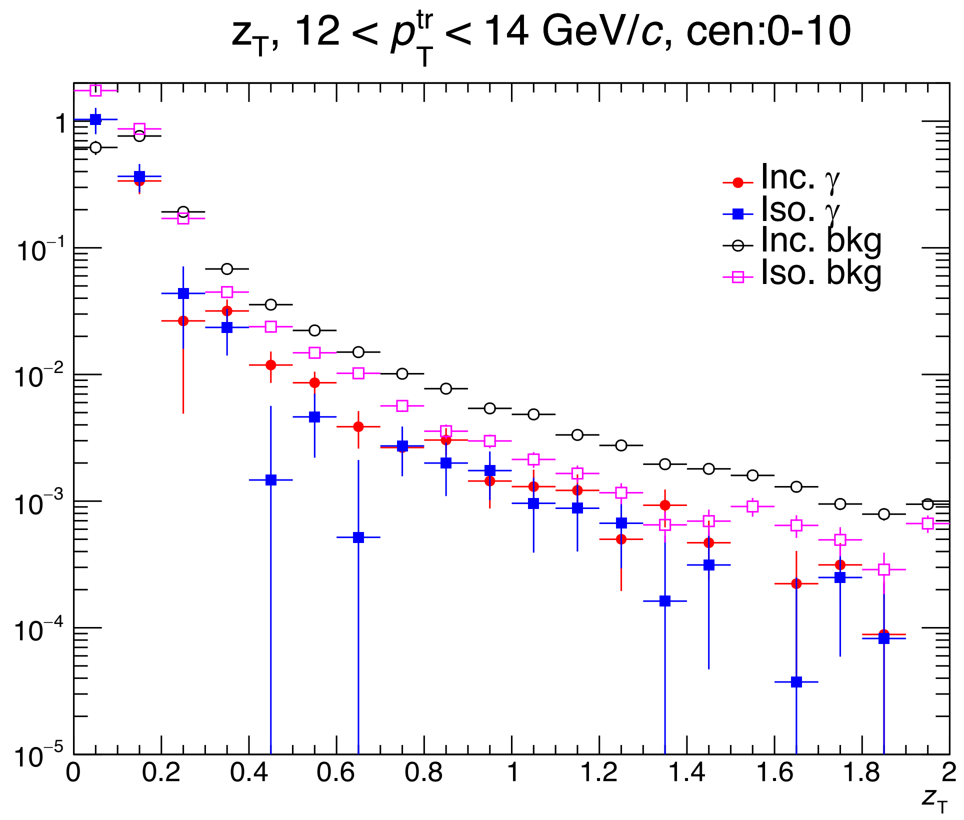
$12 < p_T^{trig} < 14$ GeV/c $\quad 2 < p_T^{ass} < 3$ GeV/c

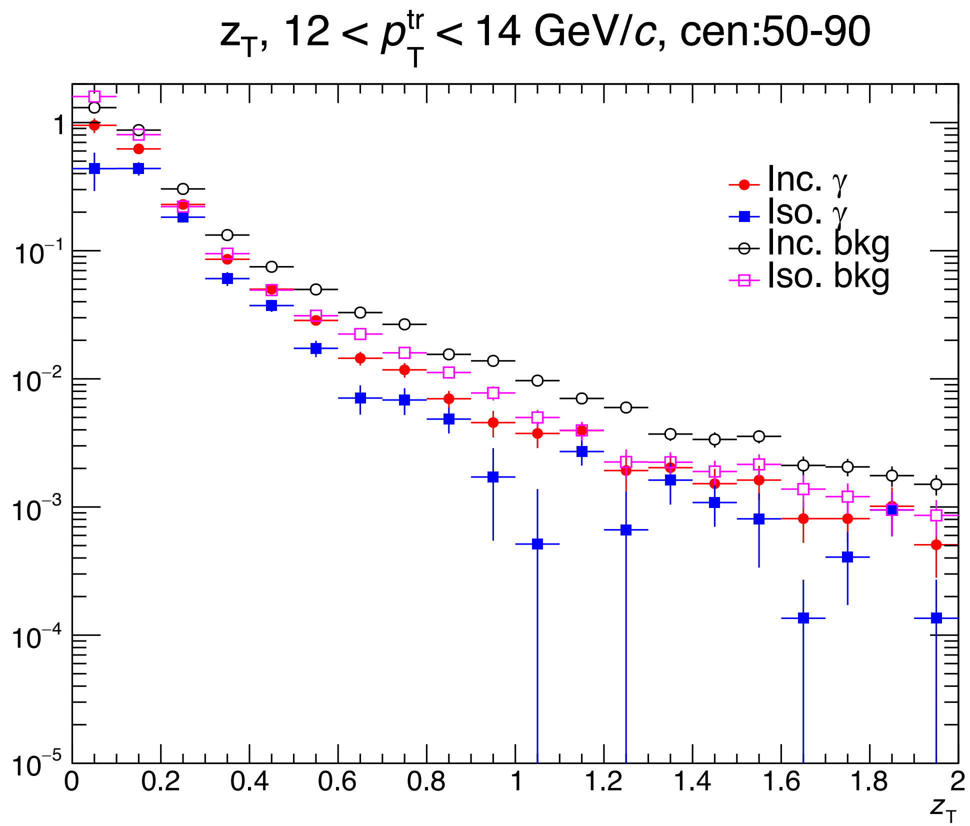
Subtraction of UE

Isolation OFF

Shower shape: 0.10 - 0.30 (γ and its bkg)

z_T distributions





Central collision results dominated by fluctuations ⇒ difficult measurements

Feasible measurements in peripheral collisions

Still preliminary tests $\Rightarrow$ finding the best configuration and improve statistics

Run trains with different conditions:

- $p_t^{iso} < 2$ GeV/c
- Cone radius: R < 0.2 (without the smaller radius)
- Changing bin

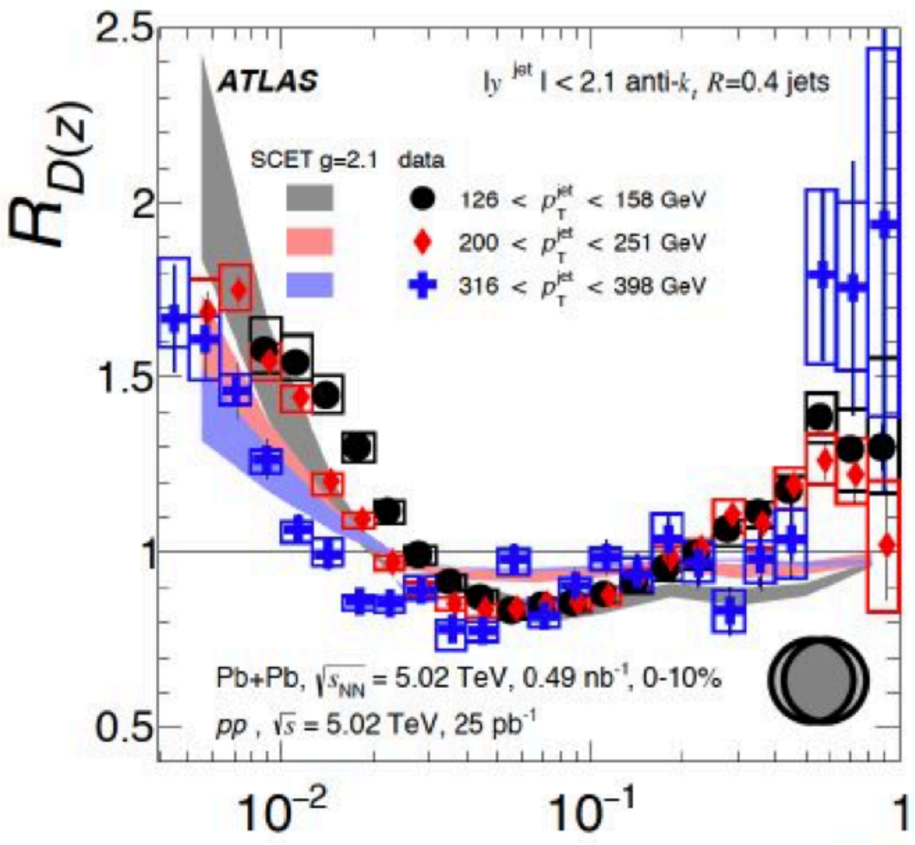
TO DO LIST

- Check the new data train
- Remove the background from the isolated gamma
- Apply the purity correction

Thank you for the attention!

Fragmentation function

Main tool: leading jet + jet



ATLAS, 2018, arXiv:1805.05424

FF in Pb-Pb are expected to be different wrt vacuum (pp)

Jet in the away side, the FF ratio is:

$$R_{D(z)} = D(z)^{Pb-Pb}/D(z)^{pp}$$

$$z \equiv p_T \cos \Delta R \,/\, p_T^{jet}.$$

- Enhancement of low-p_T $\Rightarrow$ jet fragments passing through medium
- Depletion of high-p_T: sensitive to parton shower modification
- Not a completely understanding for $z \approx 1$

★ How energy is shared

Jet shapes

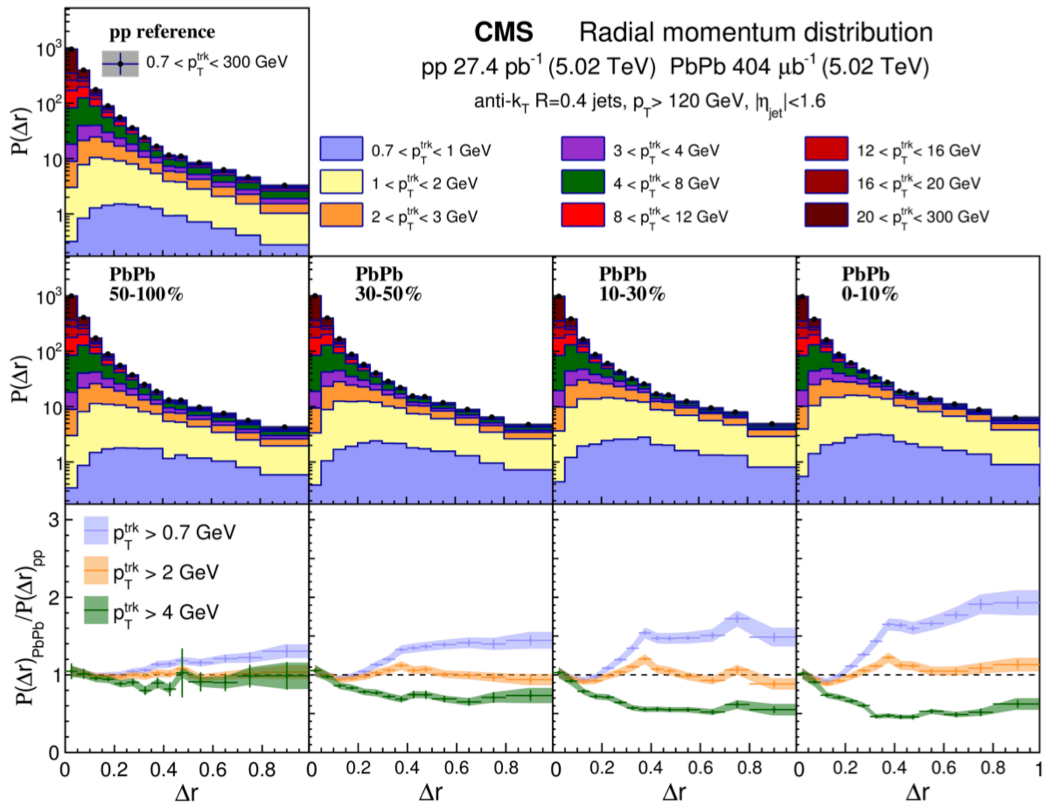
- CMS: $P(\Delta r)$ for inclusive jets $p_T > 120$ GeV
- Study $P(\Delta r)_{PbPb}/P(\Delta r)_{pp}$

arXiv:1509.09029

pp

PbPb

ratio



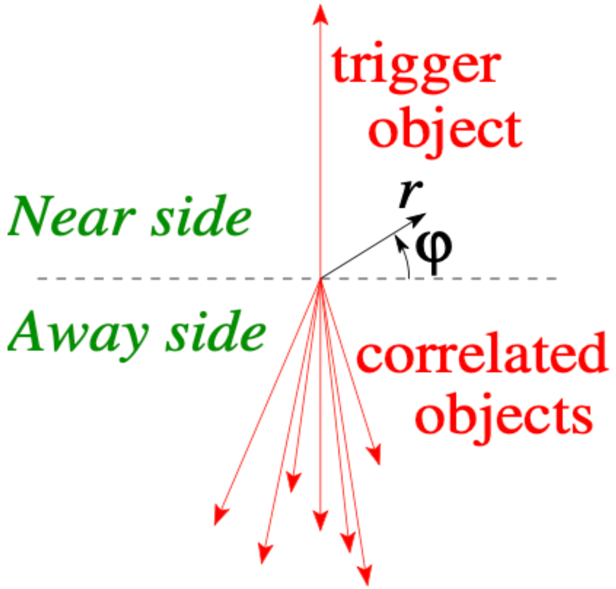
- ROLE OF CENTRALITY

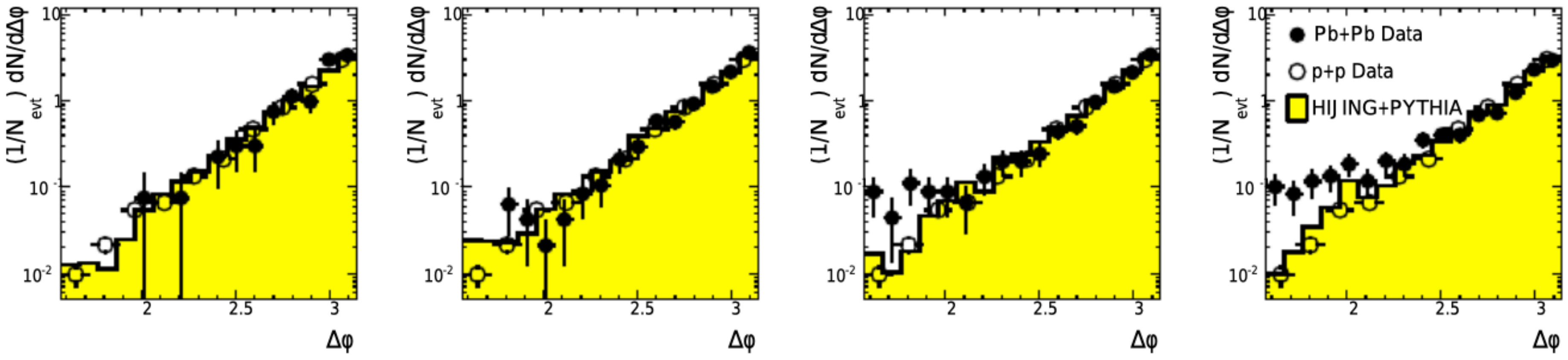
Suppression of high p_T hadrons at a very low Δr

Jet deflection

- Azimuthal distribution of the recoil jet
- Evolution with centrality
- Change of Pb-Pb distribution

Main tool: leading jet + jet





40-100% 40-20% 20-10% 10-0%

ATLAS, 2010, arXiv:1011.6182

Photons as probes of the QGP

Electromagnetic particles → insensitive to strong interaction.

TYPES OF PHOTONS:

- Prompt→ from quark-gluon Compton scattering and quark-antiquark annihilation
- Decay→ from π^0 and η (main source of BKG)
- Fragmentation

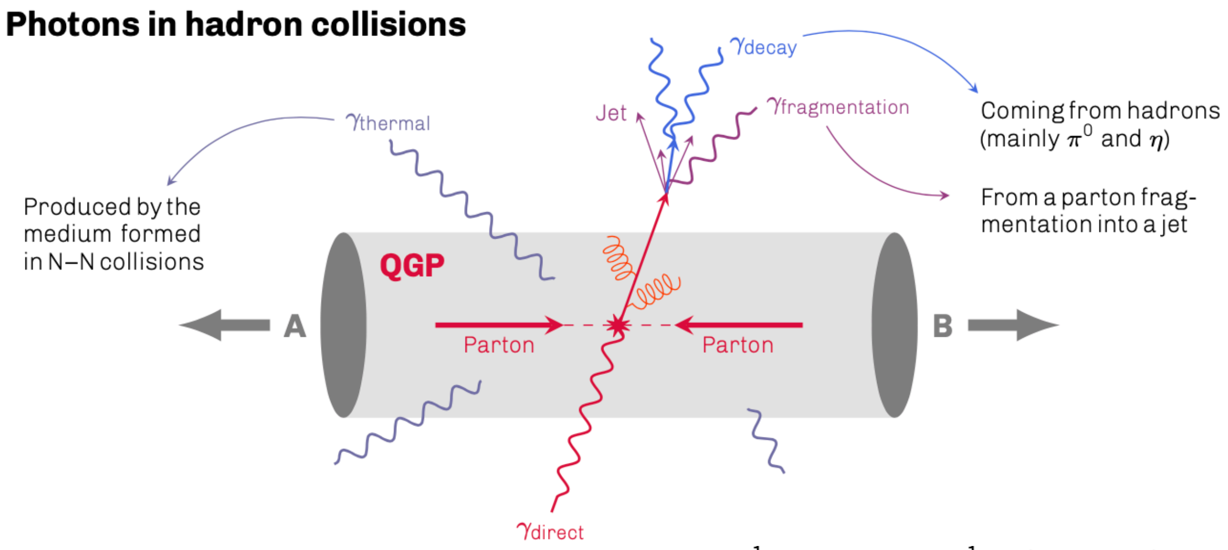
Fragmentation + Decay γ:

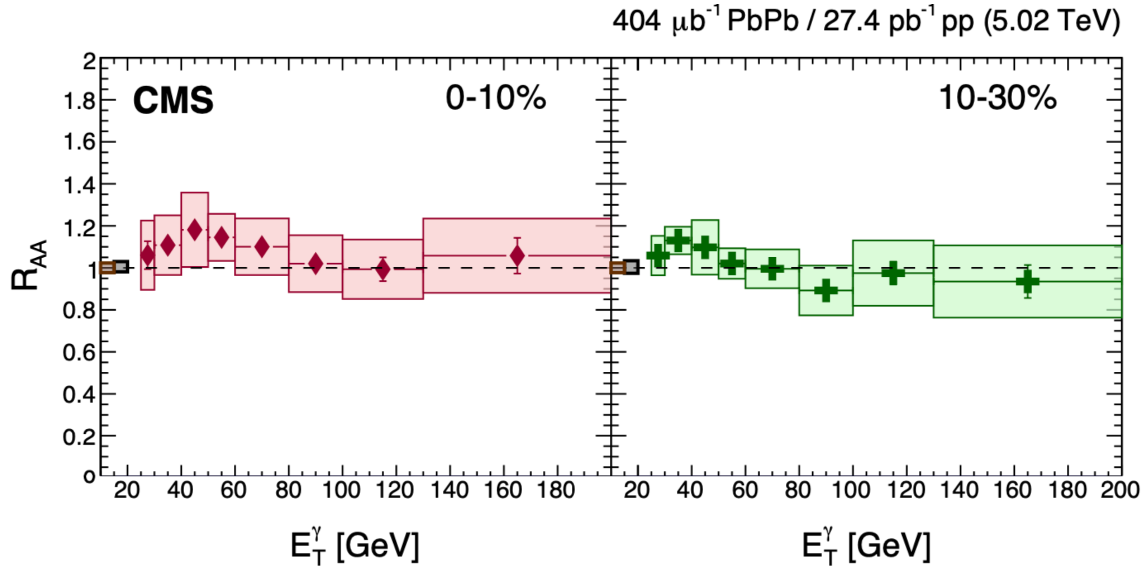
$$R_{AA}(p_T) < 1$$

BUT

Prompt γ: $R_{AA}(p_T) = 1$

NO NUCLEAR MODIFICATION → NO PT SPECTRA MODIFICATION





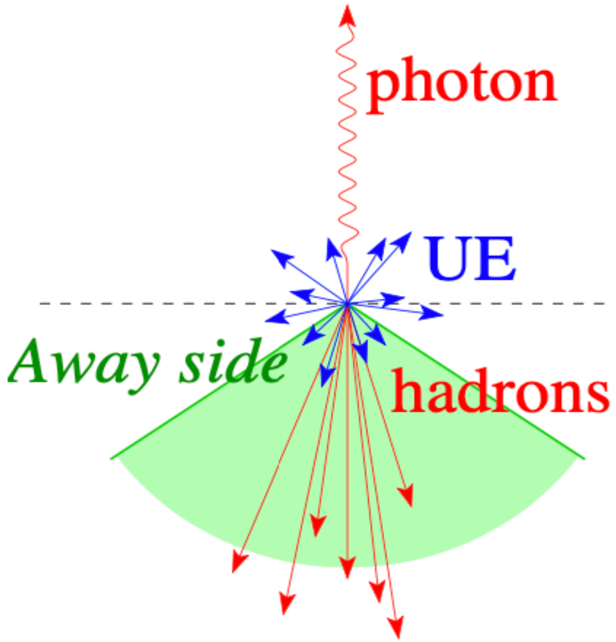
arXiv:2003.12797v2

WHICH MEASUREMENTS? CORRELATIONS

Photon blinded to color → direct access parton initial energy

Events with prompt photons associated to a jet from a quark or a gluon back-to-back.

γ prompt-hadron correlations: **reference for parton energy loss studies**

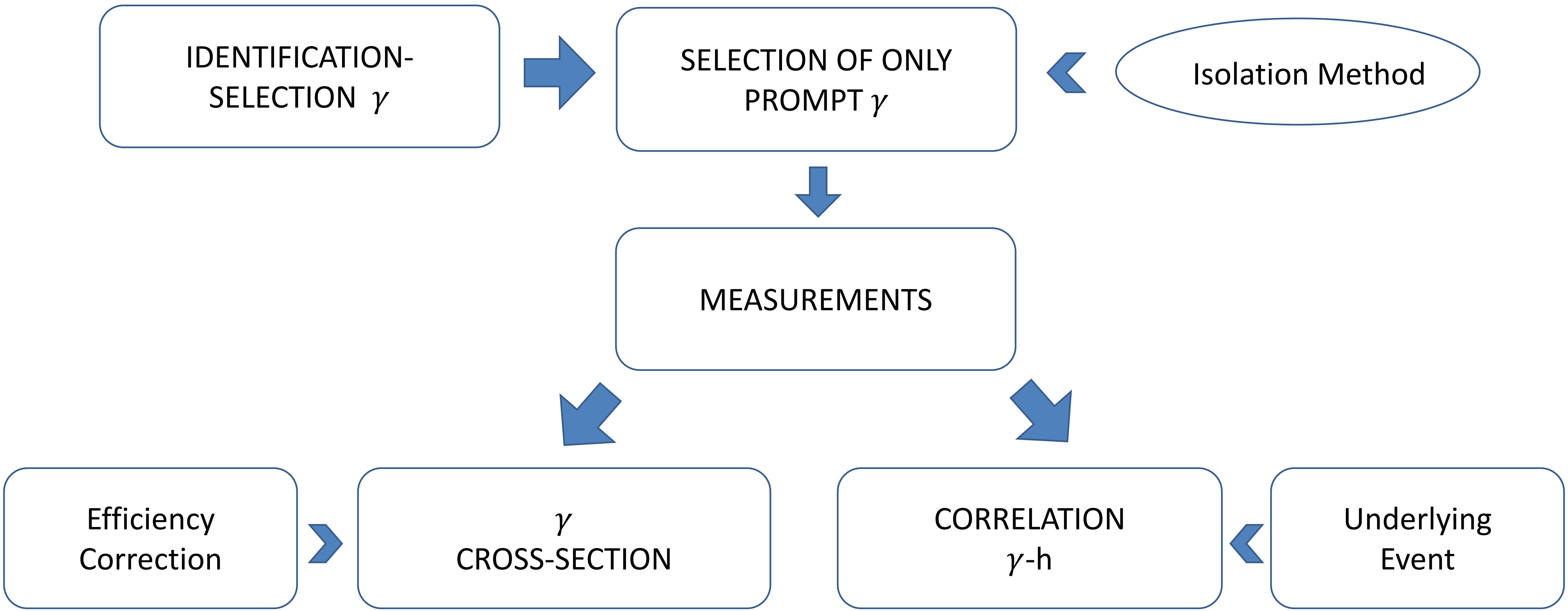


Studying correlations allows to evaluate how the initial parton energy is distributed among hadrons.

What is a correlation analysis?

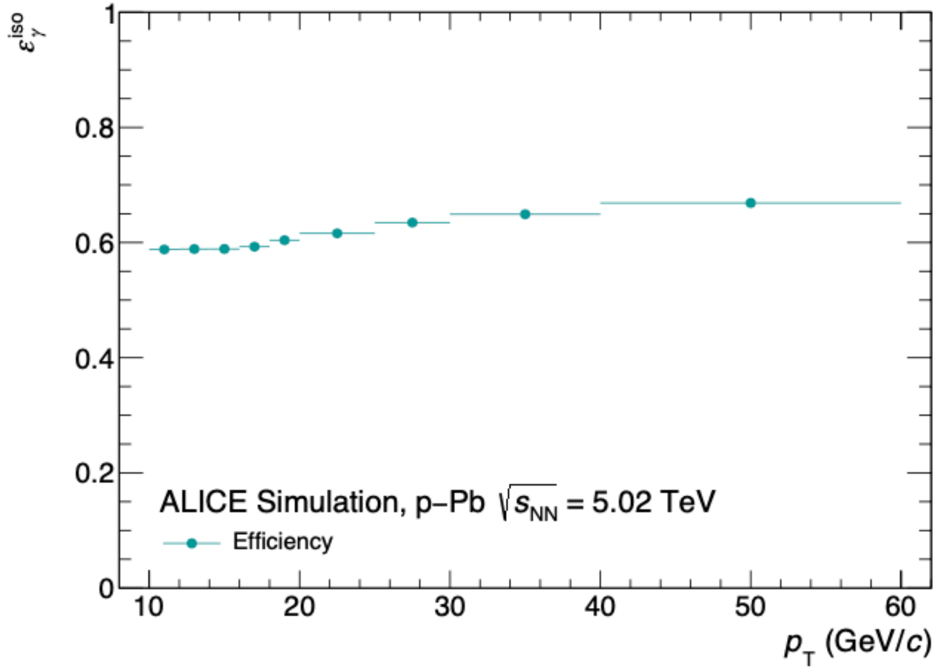
- Given a trigger photon, selecting hadrons in the near or away φ angle regions with respect to the trigger
- $\Delta\varphi = (\varphi^{trig} - \varphi^{ass})$

Analysis steps

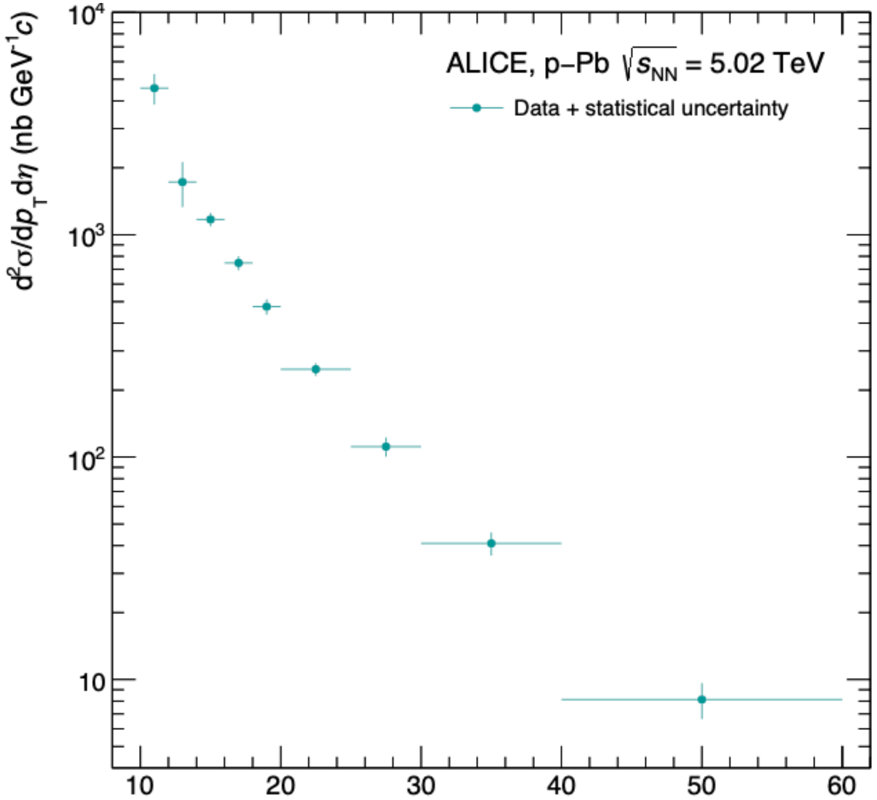


Isolated γ cross-section

Measurements # photons $\rightarrow$ isolated γ cross section
Efficiency = capacity of detectors + analysis to reconstruct γ
Used in cross section calculation to correct γ signal extraction

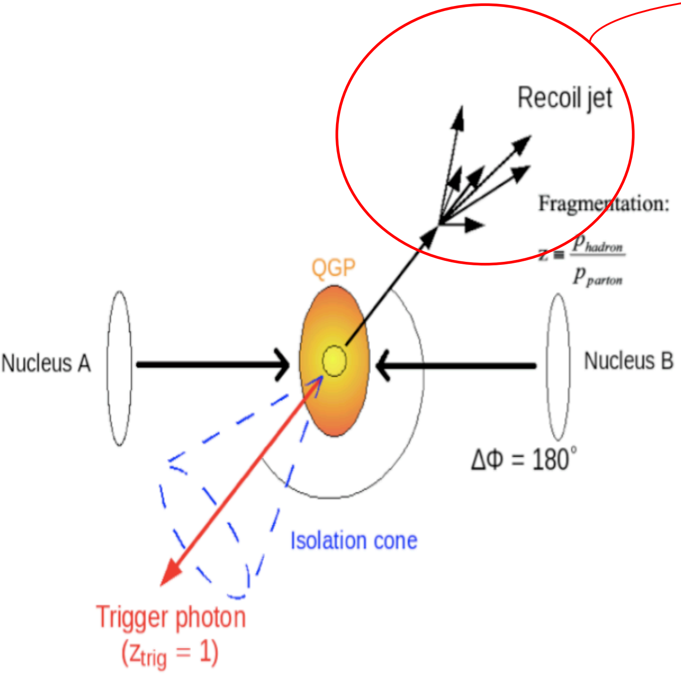


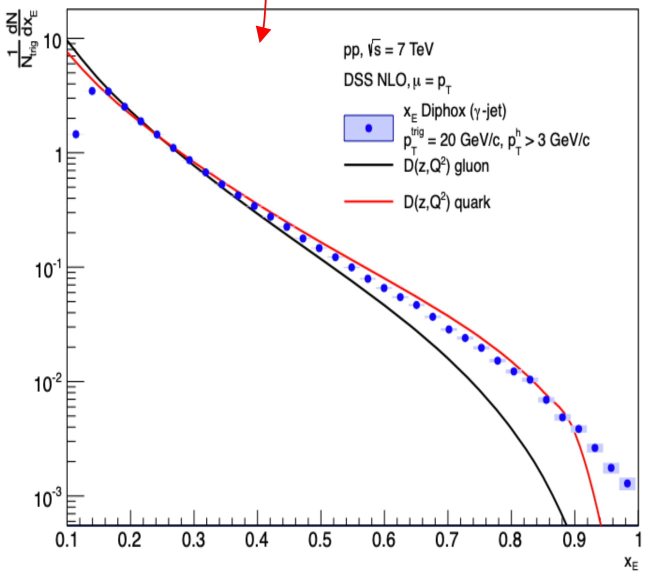
$$\varepsilon_\gamma^{\rm iso} = \frac{{\rm d}N^{\rm rec}_{\gamma_{\rm iso}}}{{\rm d}p_{\rm T}^{\rm rec}} \Big/ \frac{{\rm d}N^{\rm gen}_{\gamma_{\rm iso}}}{{\rm d}p_{\rm T}^{\rm gen}},$$



$$\frac{{\rm d}^2\sigma}{{\rm d}p_{\rm T}\,{\rm d}\eta} = \frac{N_{\rm ev}\times P}{\mathcal{L}_{\rm int}\times\varepsilon_\gamma^{\rm iso}} \times \frac{{\rm d}^2N}{N_{\rm ev}\,{\rm d}p_{\rm T}\,{\rm d}\eta}$$

Isolated γ-h correlations





https://tel.archives-ouvertes.fr/tel-01743801

$$z_T = \frac{p_T^{hadr}}{p_T^{jet}}$$

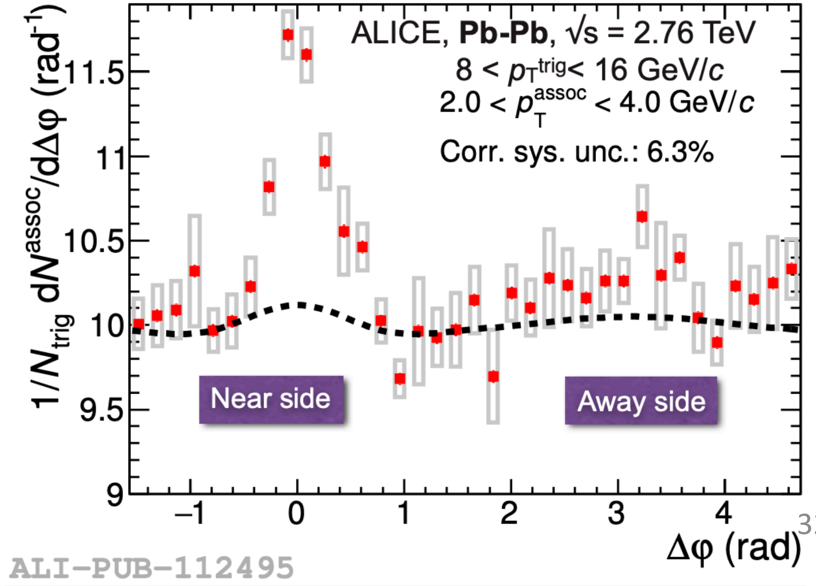
access to the partons ***fragmentation function (FF)***

Related variable: $x_E = \frac{p_T^{hadr}}{p_T^{jet}}\cos(\Delta\varphi) \approx z_T$

Evaluating γ-h correlations ($\Delta\varphi$) = evaluate FF + information on how the energy is distributed.

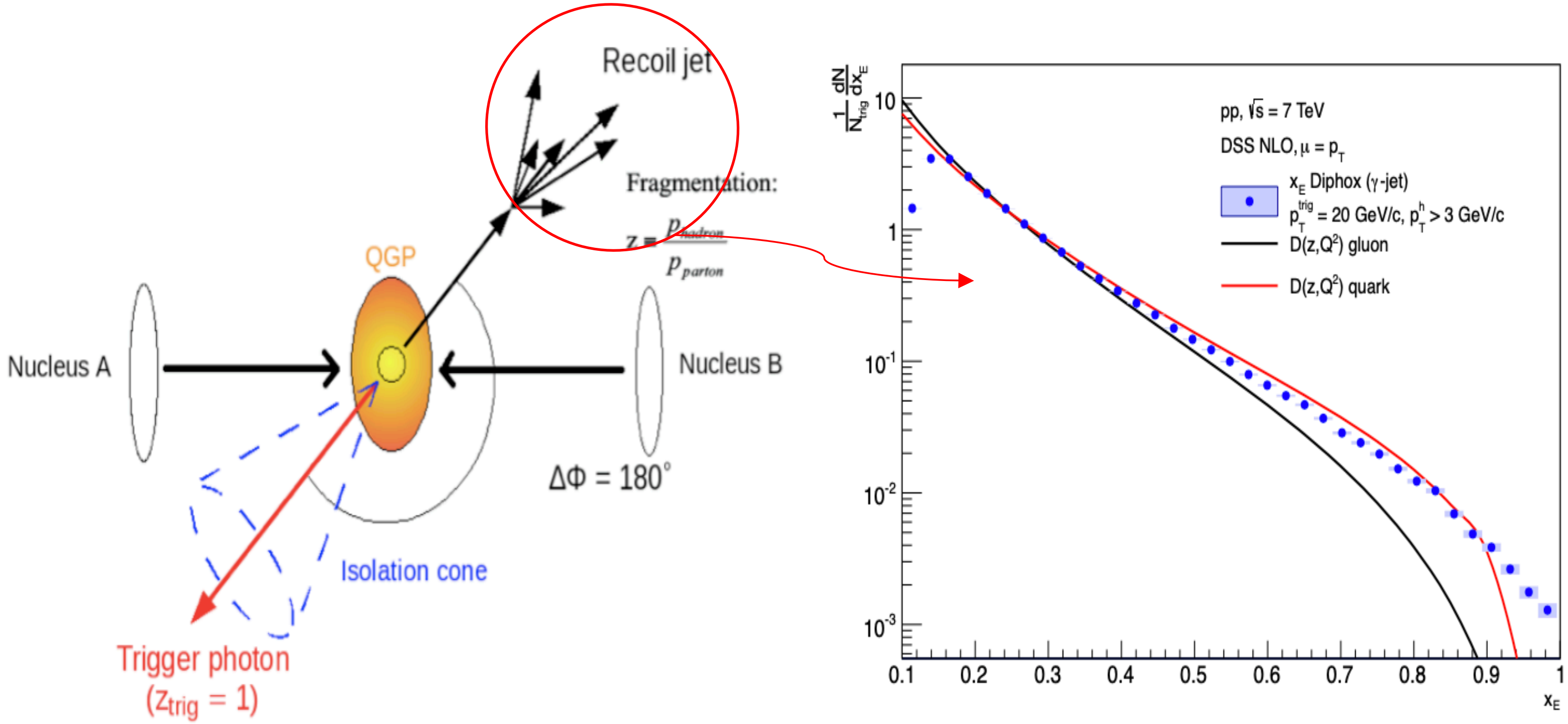
$f(x_E)$ distribution describes the emission of jet (Away side)

Fitting the slope of the $f(x_E)$ distribution for isolated γ → comparison with the quark FF slope.



arXiv:1608.07201v2

Isolated γ-h correlations



https://tel.archives-ouvertes.fr/tel-01743801

$f(x_E)$ distribution describes the emission of jet (Away side)
It is necessary to evaluate the UE (underlying event) inside the cone of the recoil jet.
We want only the jet associated to γ
not all the particles in the away side

Factorisation theorem

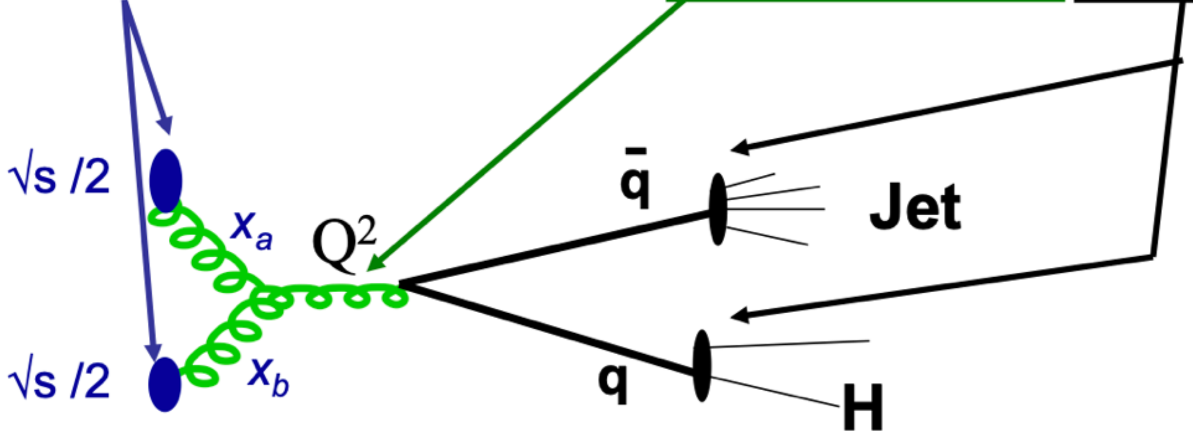
$$\sigma_{hh\to Hx} = PDF(x_a, Q^2)PDF(x_b, Q^2) \otimes \sigma_{ab\to q\bar{q}} \otimes D_{q\to H}(z_q, Q^2)$$

Cross-section in hadronic collisions

Parton Distribution Functions

Partonic cross-section

Quark Fragmentation function



Partonic cross-section can be calculated through pQCD

Fragmentation function cannot be calculated through pQCD

Fragmentation function is the probability that a quark q creates an hadron H

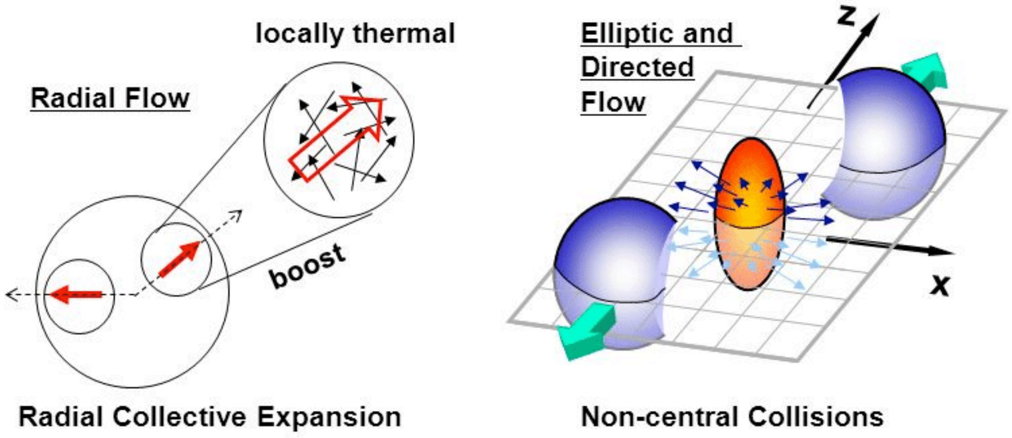
Introduction

- **SOFT PROBES:**

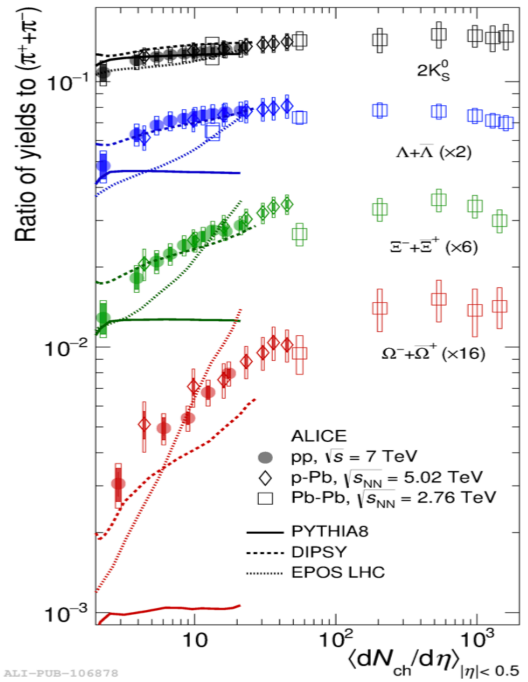
Flow = Collective movement

$$v_n = \langle \cos[n(\phi - \Psi_{RP})] \rangle$$

- radial: low p_T boost + mass dependent
- elliptical: anisotropic expansion (initial geometry & viscosity)



Strangeness enhancement = hadrons production containing s quark increased (help to constrain theoretical models)



Introduction

WHAT?

<u>Phase transition</u> from **<u>hadronic matter</u>** to the Quark-Gluon Plasma (**<u>QGP</u>**).

<u>QGP</u>: Matter under extreme temperatures and densities = deconfined medium, where quarks and gluons strongly interact

HOW?

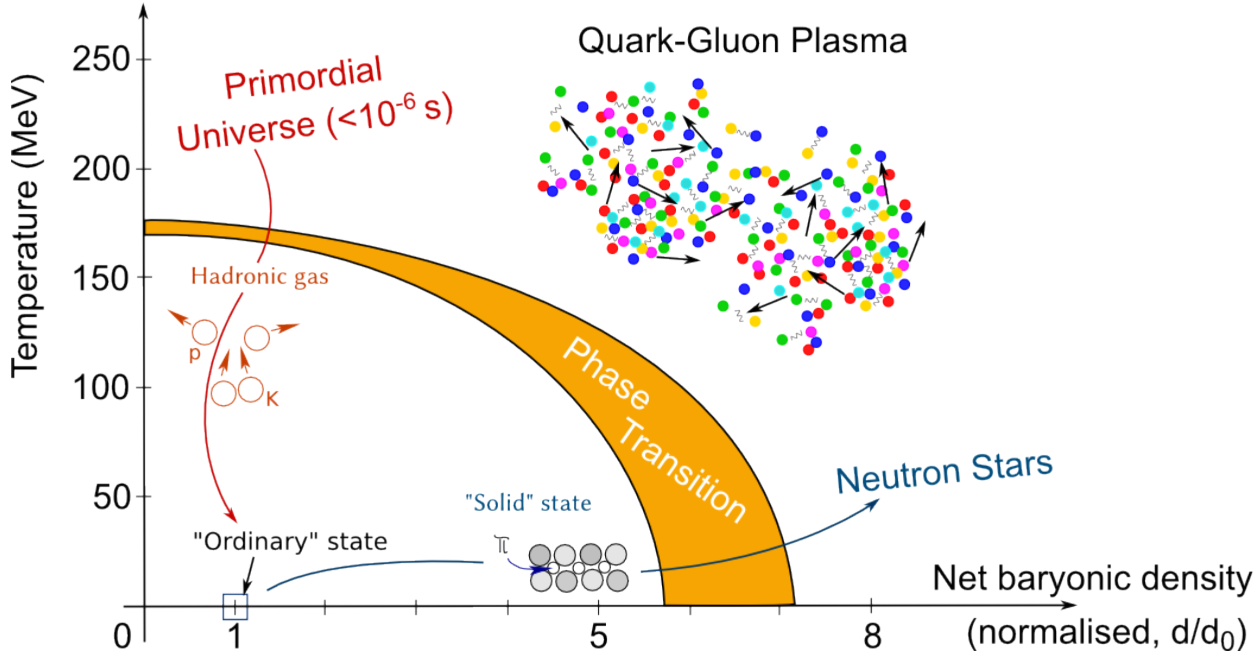
Via ultra-relativistic heavy-ion collisions:

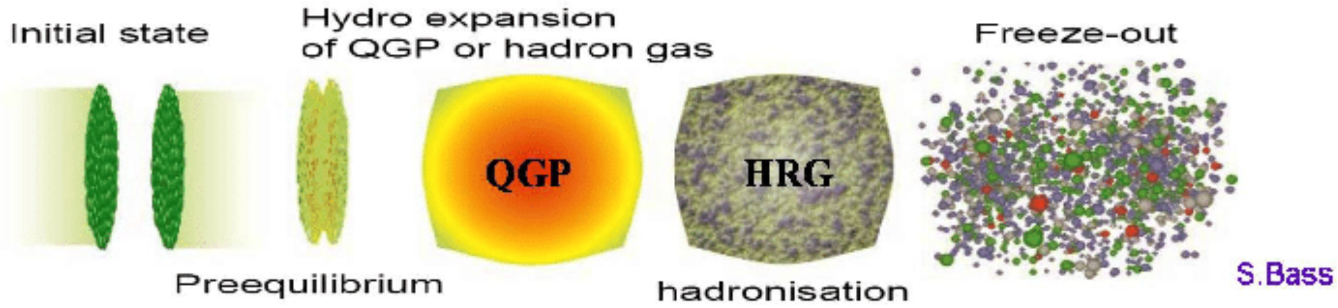
Mini Big-bang experiments!

GOAL:

Medium properties (temperature, density, viscosity, opacity…)

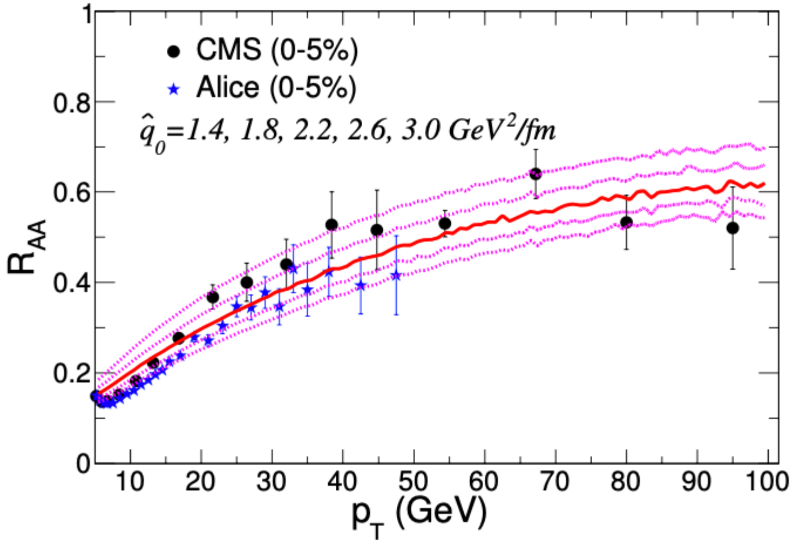
Phase transition: T_C , ε_C VS Lattice QCD calculations

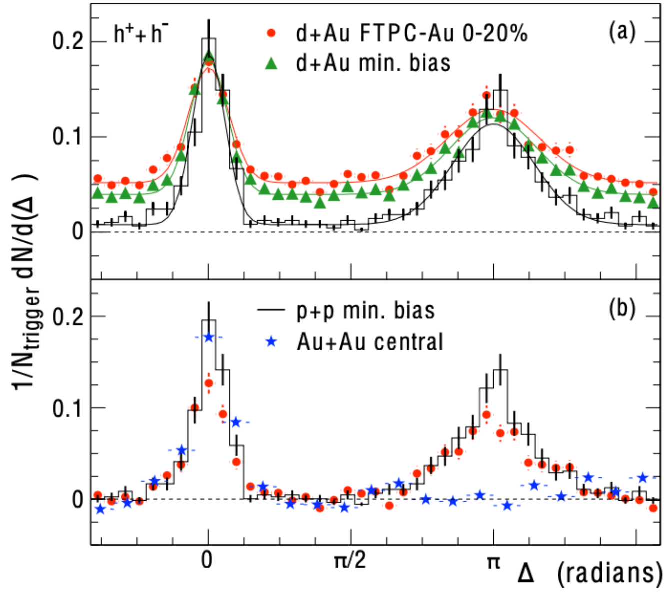




Means for energy loss

- Using R_{AA}:
  - Stand-alone measurement not very sensitive to QGP properties
  - combining its measurement with models → estimation of $\hat{q}$
- Using jet:
  - measurement of the jet fragments p_T
  - Difficult to measure well the jet p_T
- Using angular distribution (jets & others)
  - high-p_T trigger hadron and associated hadrons emitted back-to-back





Outline

- Introduction
  - Nuclear modification factor
  - Energy Loss model
  - Photons as probes of QGP
- ALICE detector
- Data Reconstruction
  - Clusterization
- Data Analysis
  - Track Matching
  - Shower Shaper
  - Isolation method and UE subtraction
  - Purity
- Conclusions

Data reconstruction steps

1) *Raw data fitting*:

   APDs provide pulse shapes.

   → fit → extraction of energy and arrival time per cell

2) *Clusterization*:

   a particle produces signals in different cells. Formation of "clusters" of EMCal cells.

   Definition of parameters used in analyses (Energy, Time, Global position, Cluster-to-track matching, Shower shape)

3) *Calibration*:

   the extracted cell energy and time are not calibrated, some cells do not work.

   A posteriori correction

4) *Data quality and selection*:

   parameters of the clusters used to control the quality of the data over periods of time

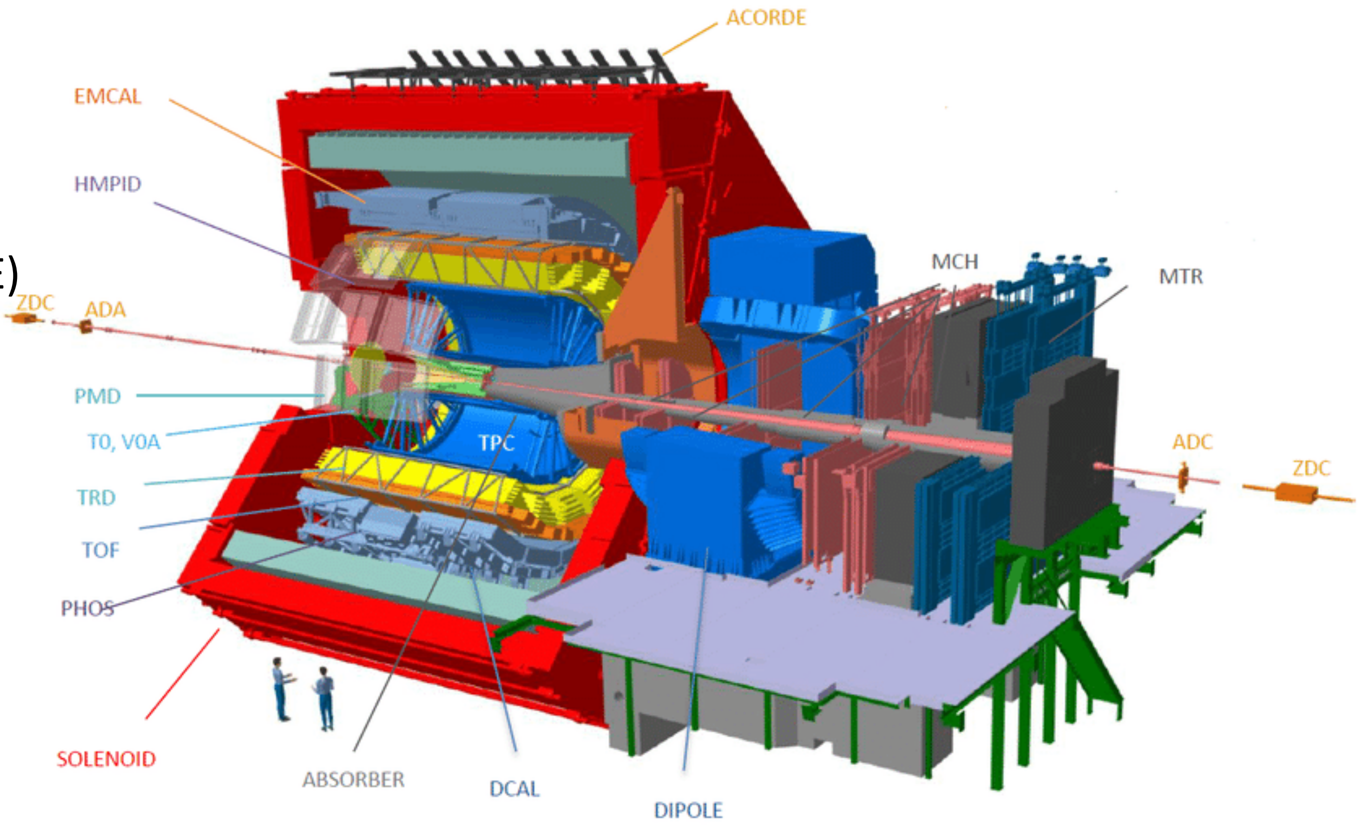
Overview of the ALICE Detector

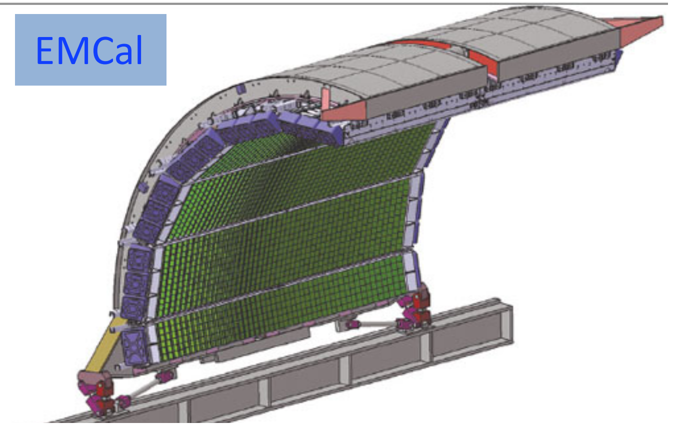
Central Barrel Detectors:
(ITS, TPC, TRD, TOF, EMCal, PHOS, …)
positioned inside a solenoid with B=0.5 T.

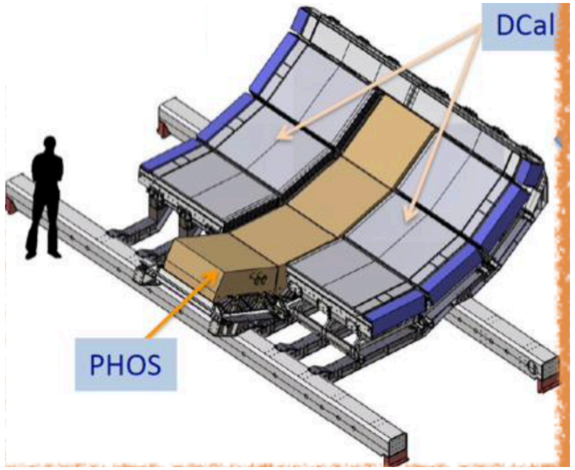
Trackers (ITS+TPC+TRD+…) → identify charged particle
In TPC/ITS : information from *particle tracks* = (p_x, p_y, p_z, E)

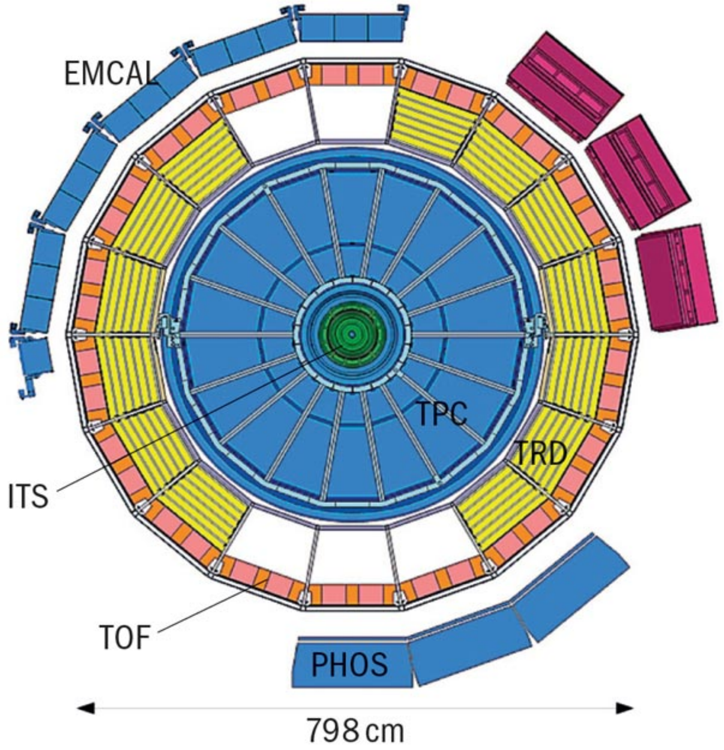
Neutral particles (γ, π^0 , η, …) can be detected in EMCal.
Calorimeters collects energy within the active volume in cells.
In EMCal: information from *clusters* = (η, φ, E_{int})

ITS, TPC and EMCal information combined for the analysis









EMCal+DCal

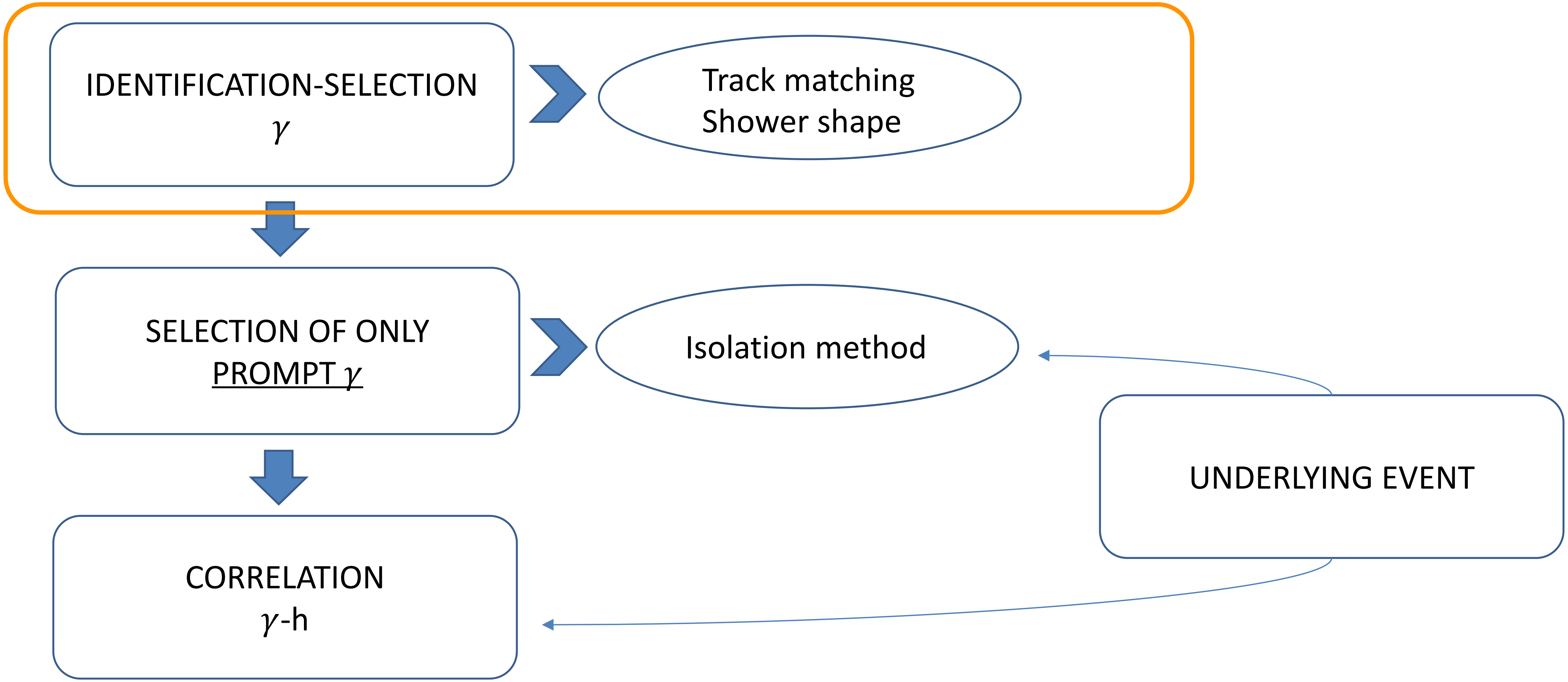
An EM calorimeter collects the EM shower, due to photon and electron interactions with matter:

- Photons deposit energy in different cells, looking at the energy distribution in the cells, photons can be identified

CHARACTERISTICS:

- layered lead-scintillator sampling calorimeter;
- $\sim$ 18000 towers, called "cells" with 6x6 cm^2 area
- scintillation light collected by Avalanche PhotoDiode (APD)
- ACCEPTANCE
  - EMCal: $|\eta| \leq 0.7, \Delta\varphi$ = 107°
  - DCal: $0.22 < \eta < 0.7,\ \ \Delta\varphi$ = 60° + $|\eta| \leq 0.7$, $\Delta\varphi$ = 7°
- Selection of events: trigger for high energy γ and jet

Analysis steps



★ If Pb-Pb or high pile-up, it is necessary evaluating before the UE contribution in the isolation cone, in order to not consider all the photon expected

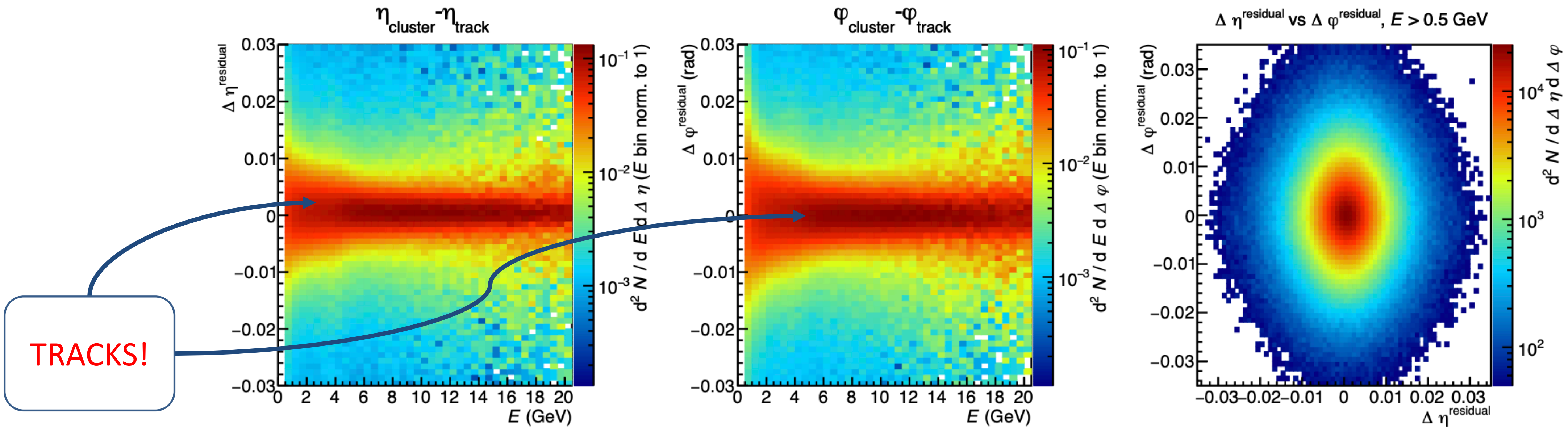
γ selection: track matching

Plan tagging photon: necessary to distinguish between clusters originated by charged particles and ones by γ

→ definition of a cut in the angular window $\Delta\eta$-$\Delta\varphi$

A cut in the residual angular position between the clusters and the projection of the TPC tracks to the EMCal is applied.

$\Delta\eta^{resid}=|\Delta\eta^{track}-\Delta\eta^{cluster}|\lesssim 0.010$ and $\Delta\varphi^{resid}=|\Delta\varphi^{track}-\Delta\varphi^{cluster}|\ \lesssim 0.020$



Clusters due to charged particles are located in 0

The effect of B is more pronounced along φ, so the distribution is wider

γ selection: shower shape

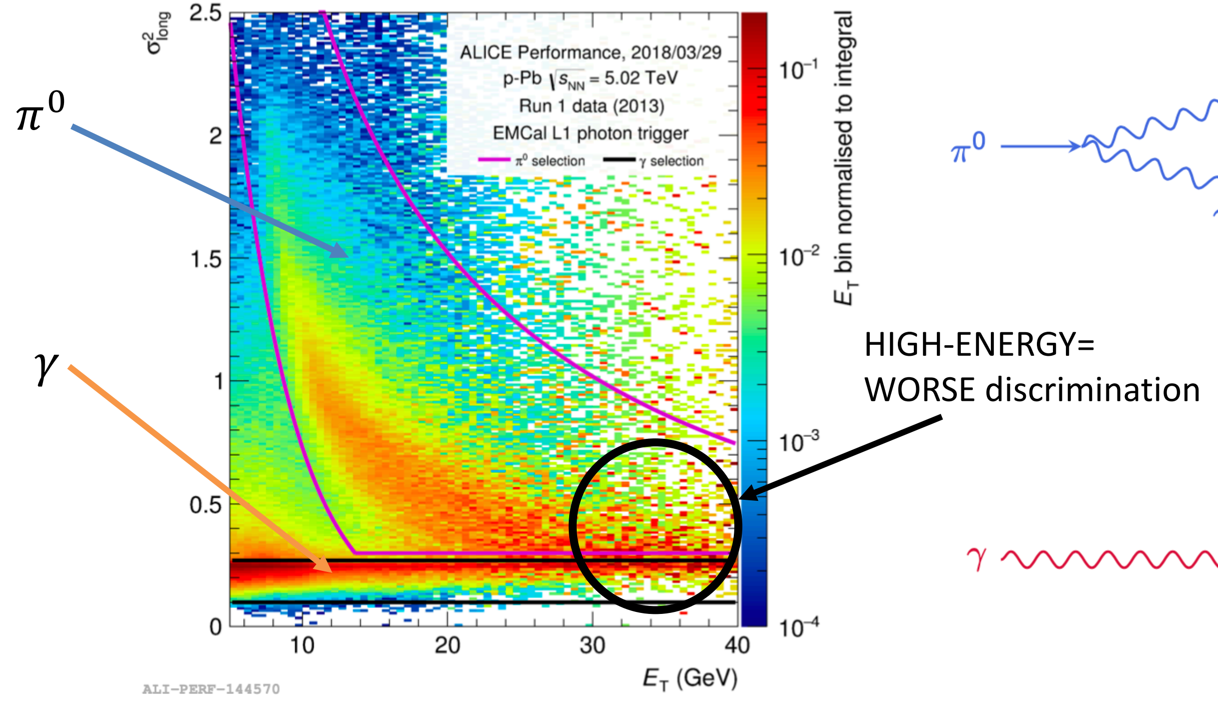
The neutral cluster samples are a mixture of neutral particles ($\gamma\ prompt, \eta, \pi^0, decay\ \gamma$).

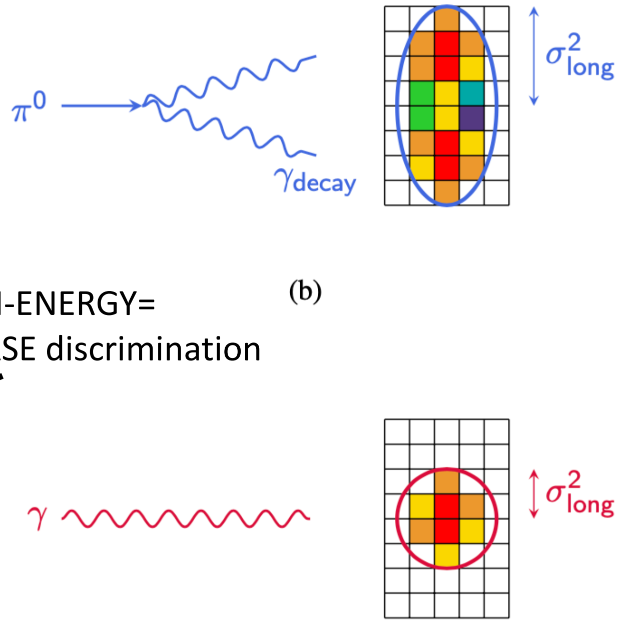
How to discriminate from decay and isolated photons?

- **Use shower shape for V1 cluster**

Through an elliptical parametrization → extrapolate the two axes + characterize the dispersion of the EM shower.

The semi-major axis σ^2_{long} allows to feature the *type* of photon.





- a cluster induced by a π0 decay is more likely to be elliptic (high σ^2_{long} value) due to the merging of its decay photons

- a cluster induced by a direct photon is expected to be rather circular (low σ^2_{long} value)

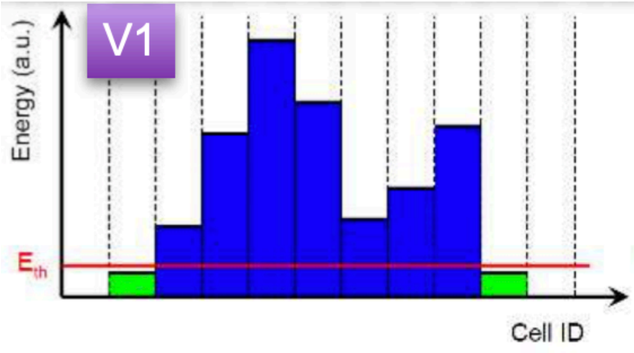
Clusterization methods

V1

Select a seed cell with energy $> E_{seed}$.
Add all the cells, that satisfy the threshold.

✓ cluster shape close to the real form

✗ not capable to separate deposits from more than one particle

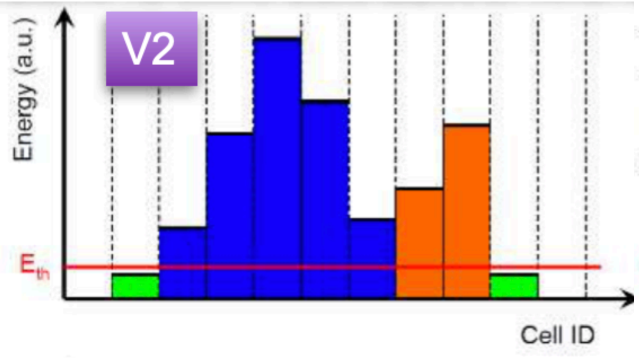


V2

similar to V1, but before associating a cell, its energy has to be < reference energy.

✓ Separation of the energy deposits from different particles

✗ Bias on the clusters shape

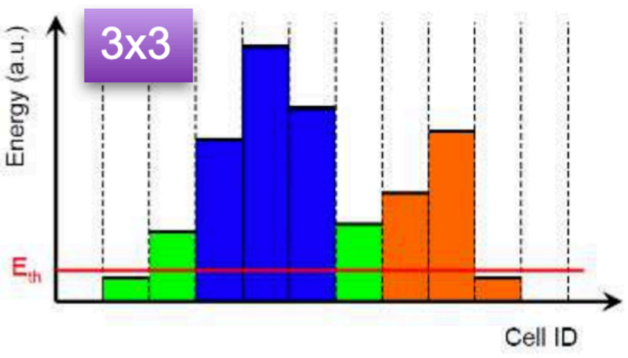


NxM

similar to V1, but with a predefined size of NxM cells.

✓ reducing probability of "mixing" different particles to same cluster

✗ Bias on the clusters shape

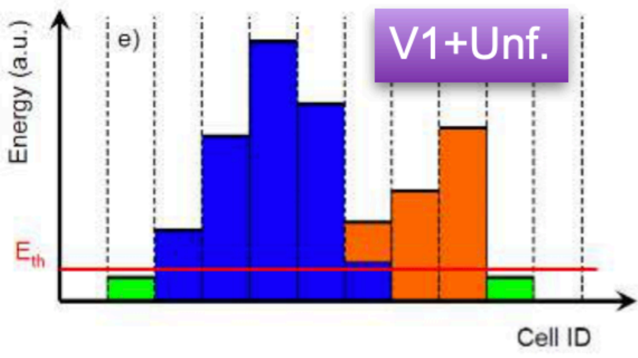


V1+unfold

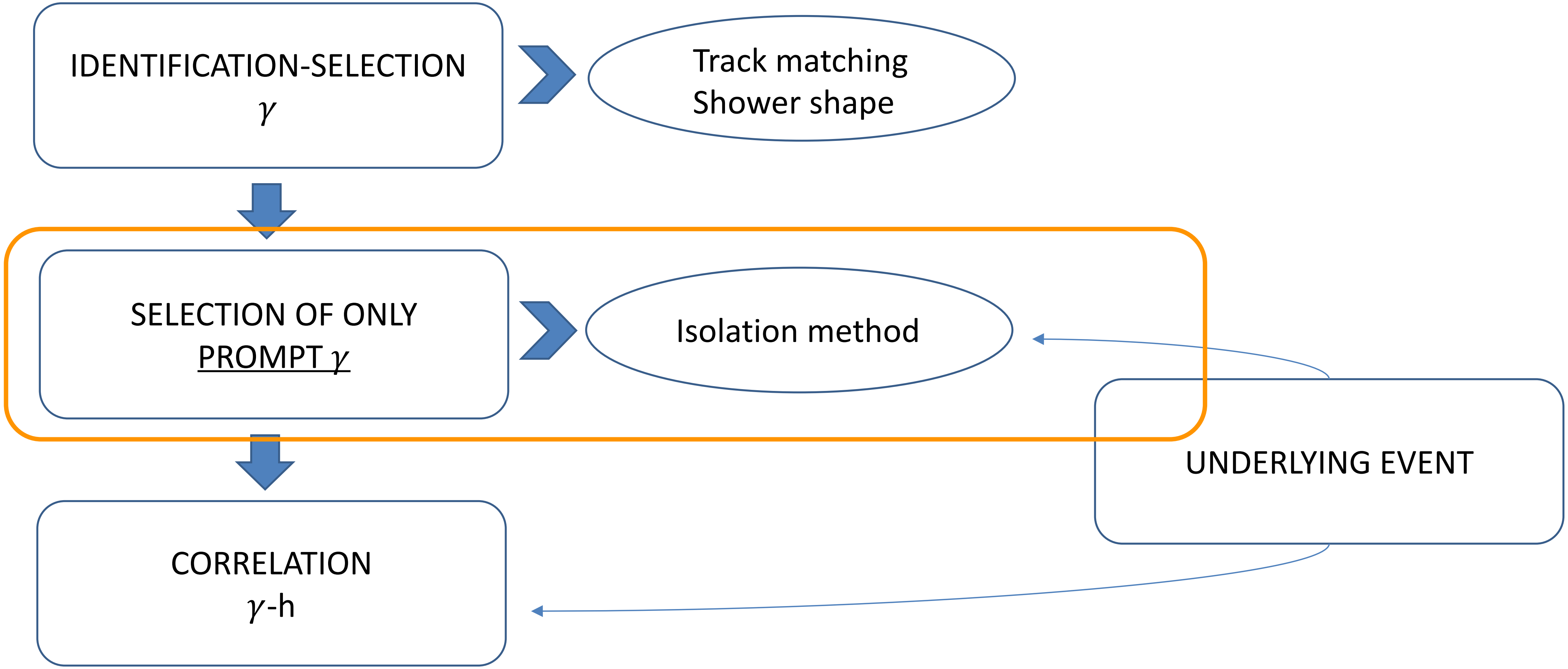
Separate finely the V1 clusters with local maxima and create sub-clusters more precise like in V2.

✓ Best separation

✗ The slowest one



Analysis steps



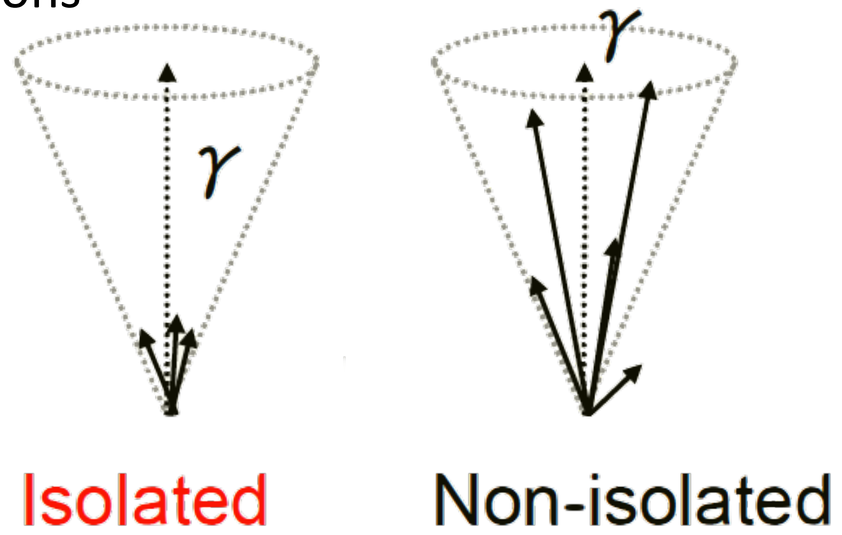
★ If Pb-Pb or high pile-up, it is necessary evaluating the UE contribution in the isolation cone, in order to not consider all the photon expected

Isolation method

Goal: isolate prompt photons and reject the largest part of non direct photons

The cone radius **around a candidate photon** at $(\eta_\gamma, \varphi_\gamma)$ is given by:

$$R_{\text{cone}} = \sqrt{(\eta - \eta_\gamma)^2 + (\varphi - \varphi_\gamma)^2}$$

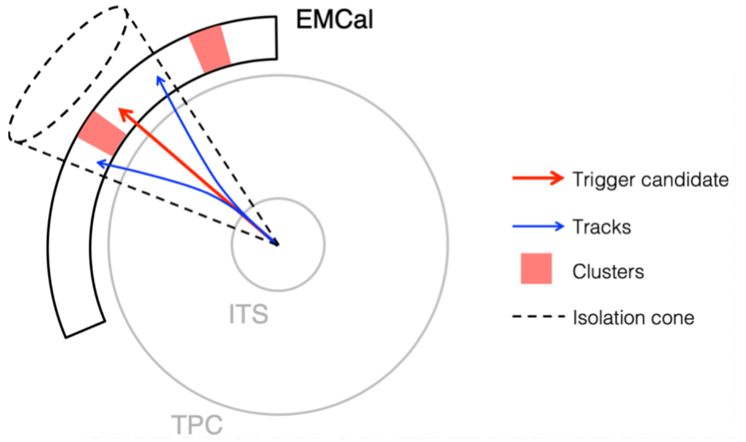


the condition on p_T that defines a isolated γ is :

$$\sum_{\text{cone}} p_{\text{T}} < p_{\text{T,max}}^{\text{iso}},$$

Before applying the isolation condition, it is necessary to evaluate the underlying event inside the cone

NECESSARY TO REMOVE UE IN ISOLATION CONE!



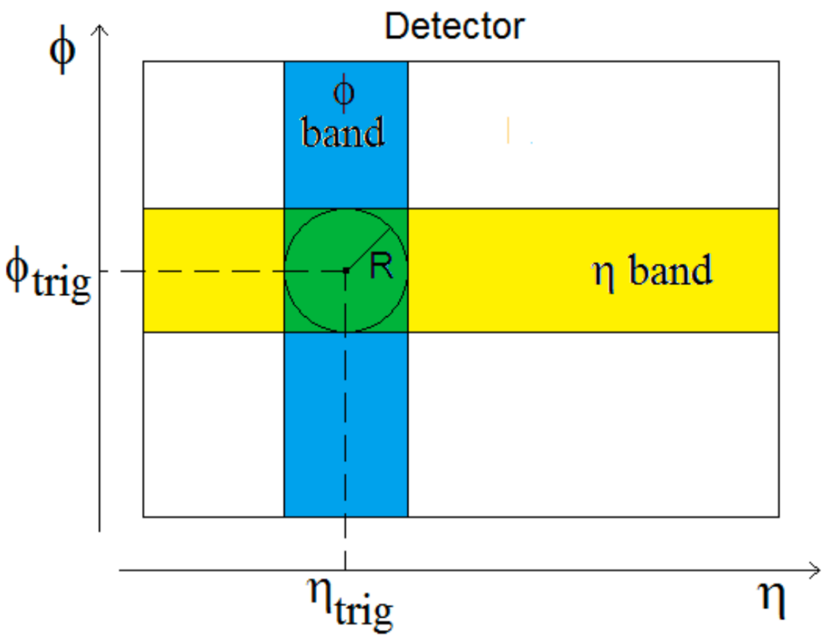
UE subtraction method

- In Pb-Pb collisions high multiplicity in final state.
- Subtracting the UE: background + all the other processes near the prompt γ
- The UE subtraction method measures energy in the environment around the cone of radius R.

HOW DOES IT WORK?

Select a high energy deposition in the calorimeter identified as photon
The photon candidate is characterized by a φ_{trig} and a η_{trig}.

It is possible two bands φ_{band} and η_{band} with the isolation cone of radius R.



The contribution of the UE in the cone is estimated as

$$(\sum p_T^{iso})_{UE} \cdot A_{cone}$$

It is removed from the total transverse momentum in the cone.

Isolation method

Once the UE in the cone region is subtracted, the condition on p_T becomes:

$$\sum_{\text{cone}} p_{\text{T}} < p_{\text{T,max}}^{\text{iso}}, \quad \longrightarrow \quad \sum_{\text{cone}} p_{\text{T}} - \left(\sum_{\text{UE}} p_{\text{T}} \right)_{\text{in cone}} < p_{\text{T,max}}^{\text{iso}}$$

Several combination of R_{cone} and $p_{T,max}^{iso}$ are evaluated to define the best criteria.

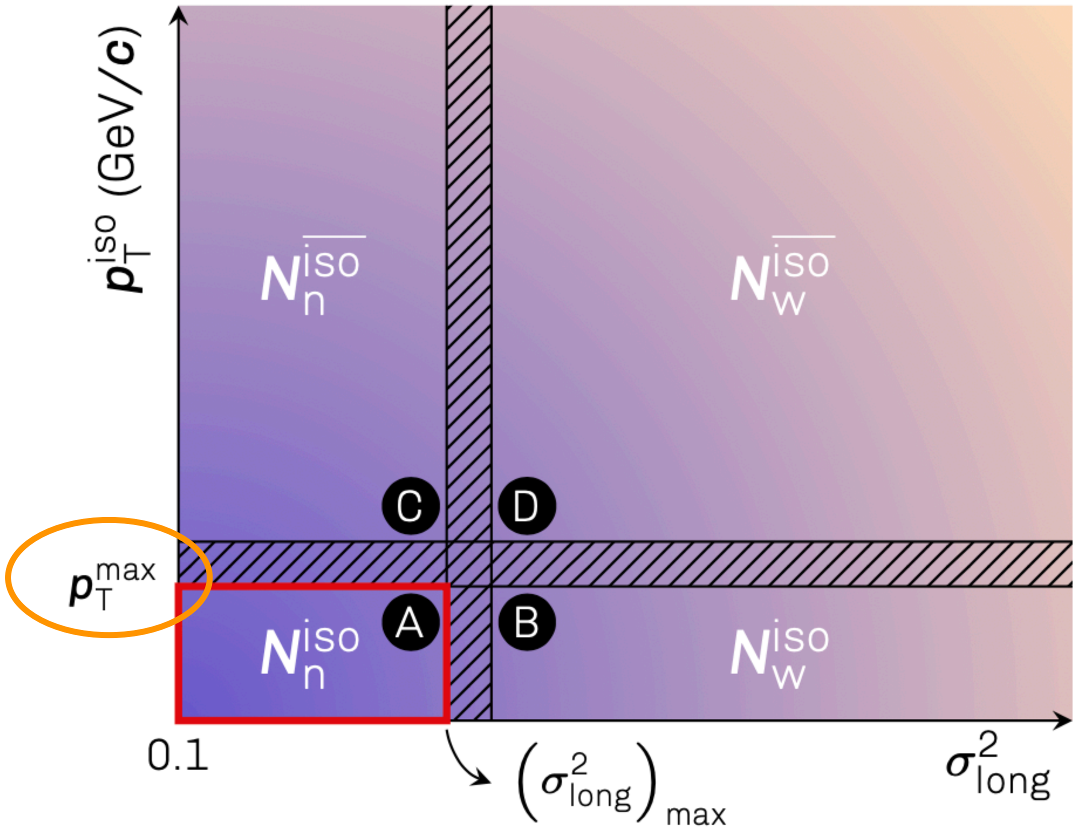
Then the chosen criteria are: $R_{cone} = 0.4$ and $p_{T,max}^{iso}$< 2 GeV/c

The criteria indicated are for pp and p-Pb

For Pb-Pb new evaluation are necessary

Purity estimation

- Notations:
  - S direct photons, B background (decay γ+ mesons)
  - Criteria:
  - Isolation condition on $p_{T,}^{max}$ GeV/c
  - condition on the circularity of cluster σ_{long}^{2}



Regions of the picture:

A) contains the interesting photon signal

B) is filled with isolated wide (i.e. elliptic) clusters

C) comprises non-isolated narrow clusters

D) contains non-isolated wide clusters

BACKGROUND REGIONS

Purity estimation

We want to estimate the purity of the candidate sample

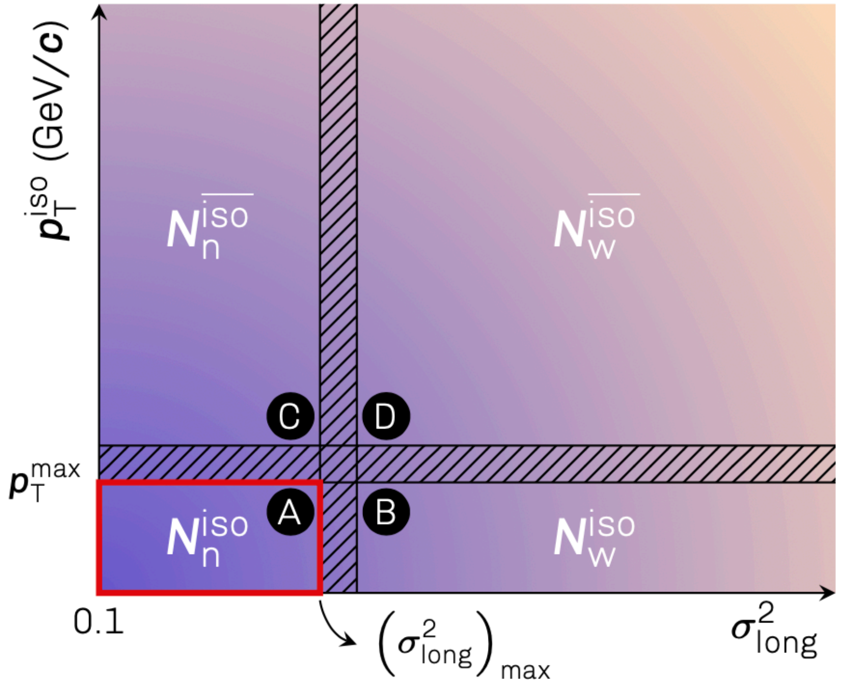
WHY? Isolated photon sample still has a contribution from bkg

<u>Assumptions</u>:

- B fraction is equal in narrow (A,C) and in wide (B,D) in σ^2_{long} regions:

$$B_n^{iso}/B_n^{\overline{iso}} = B_w^{iso}/B_w^{\overline{iso}};$$

- no S in BCD regions.



The purity definition in terms of amount of particles is given by:

$$\mathbb{P} = \frac{S_n^{iso}}{N_n^{iso}} = 1 - \frac{B_n^{iso}}{N_n^{iso}}$$

Simple definition, but… it does not work!

Purity estimation

Corrections due to:

- B isolation fraction depends on in which circularity we are.
- S is not contained only in A, but it spreads over B, C and D regions

Purity with correction:

$$\mathbb{P} = 1 - \left(\frac{N_n^{\overline{iso}}/N_n^{iso}}{N_w^{\overline{iso}}/N_w^{iso}}\right)_{data} x \left(\frac{B_n^{iso}/N_n^{\overline{iso}}}{N_w^{iso}/N_w^{\overline{iso}}}\right)_{MC}$$

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- B isolation fraction depends on in which circularity we are.
- S is not contained only in A, but it spreads over B, C and D regions

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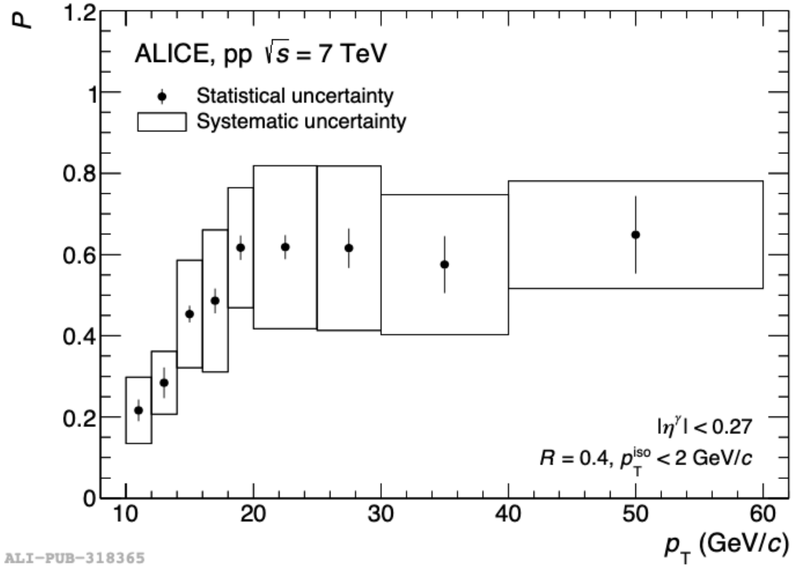

Low purity = Large contamination of bkg (80% at p_T = 10 GeV/c)
Improvement for p_T > 18 GeV/c