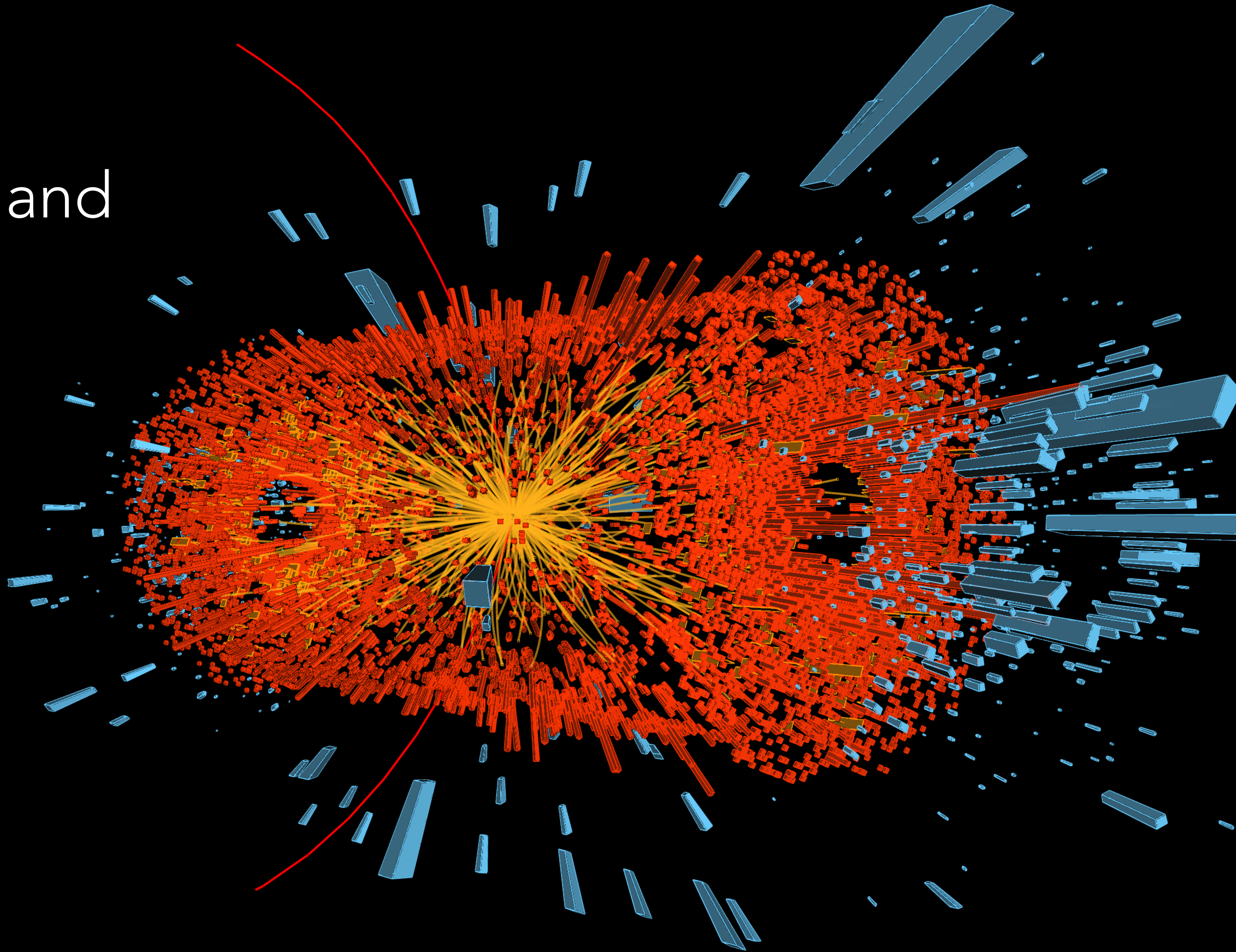
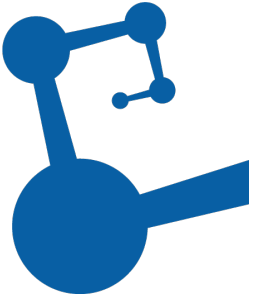


Untangling Soft and Hard Physics in Proton-Proton Collisions

Jesús Eduardo Muñoz Méndez

23 Sept 2026





Hard and soft processes as probes of the quark-gluon plasma

Underlying event
characterization in
pp collisions at
 $\sqrt{s} = 13.6$ TeV

Dijet
acoplanarity
with flattenicity
in pp collisions

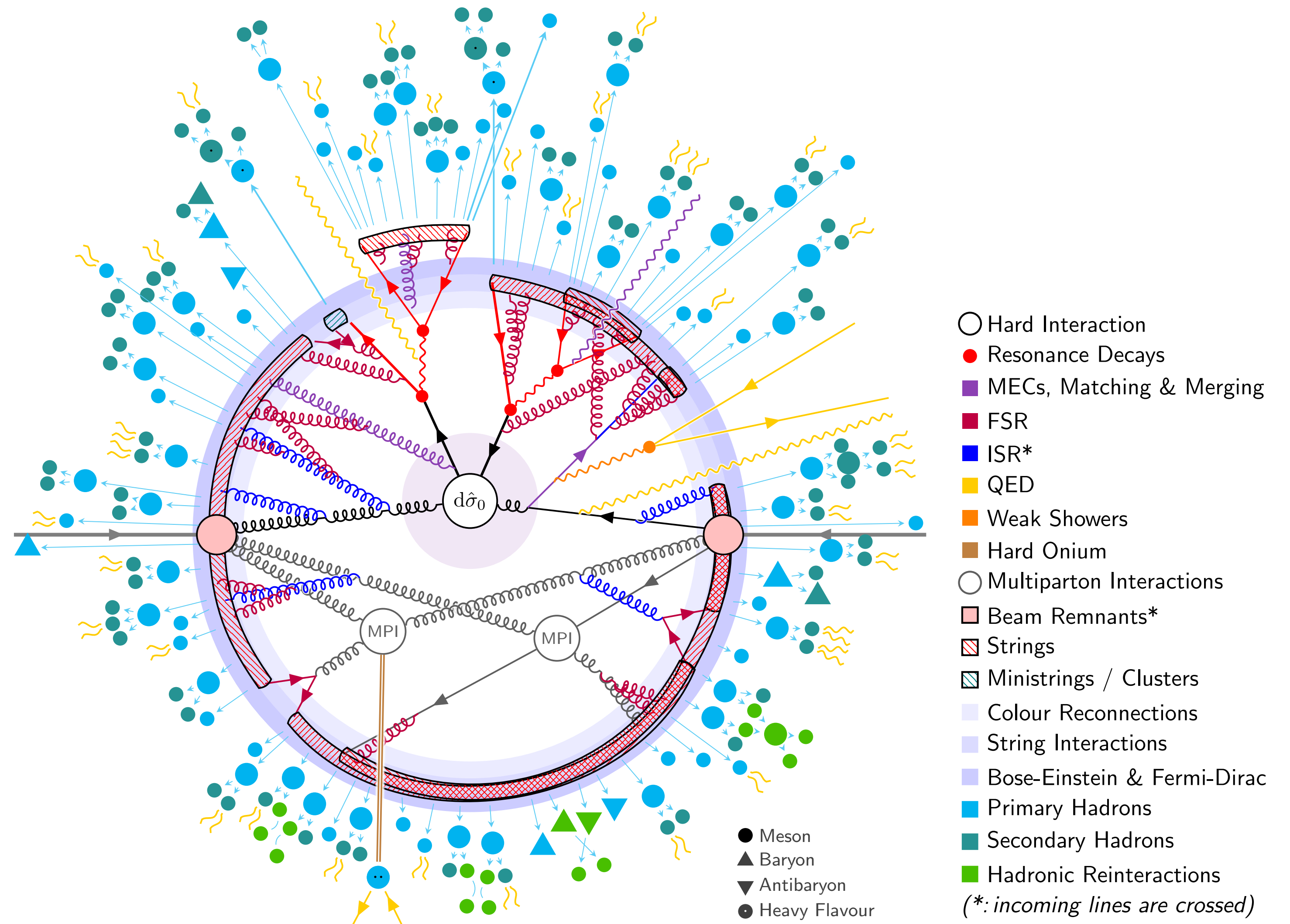


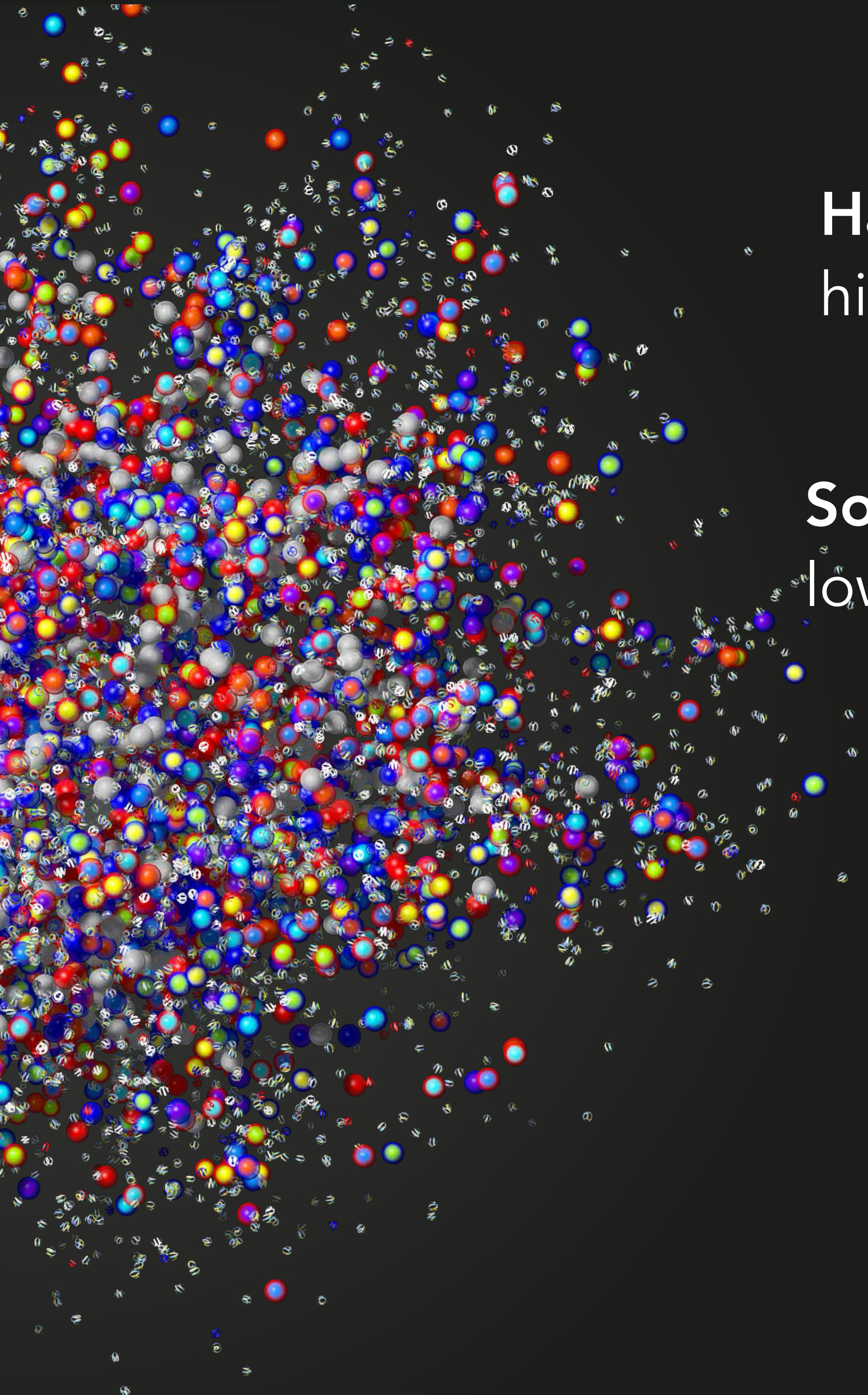
Momentum transfer

Introduction

A relativistic hadronic collision involves **many** different processes...

However, these can be broadly grouped in two categories

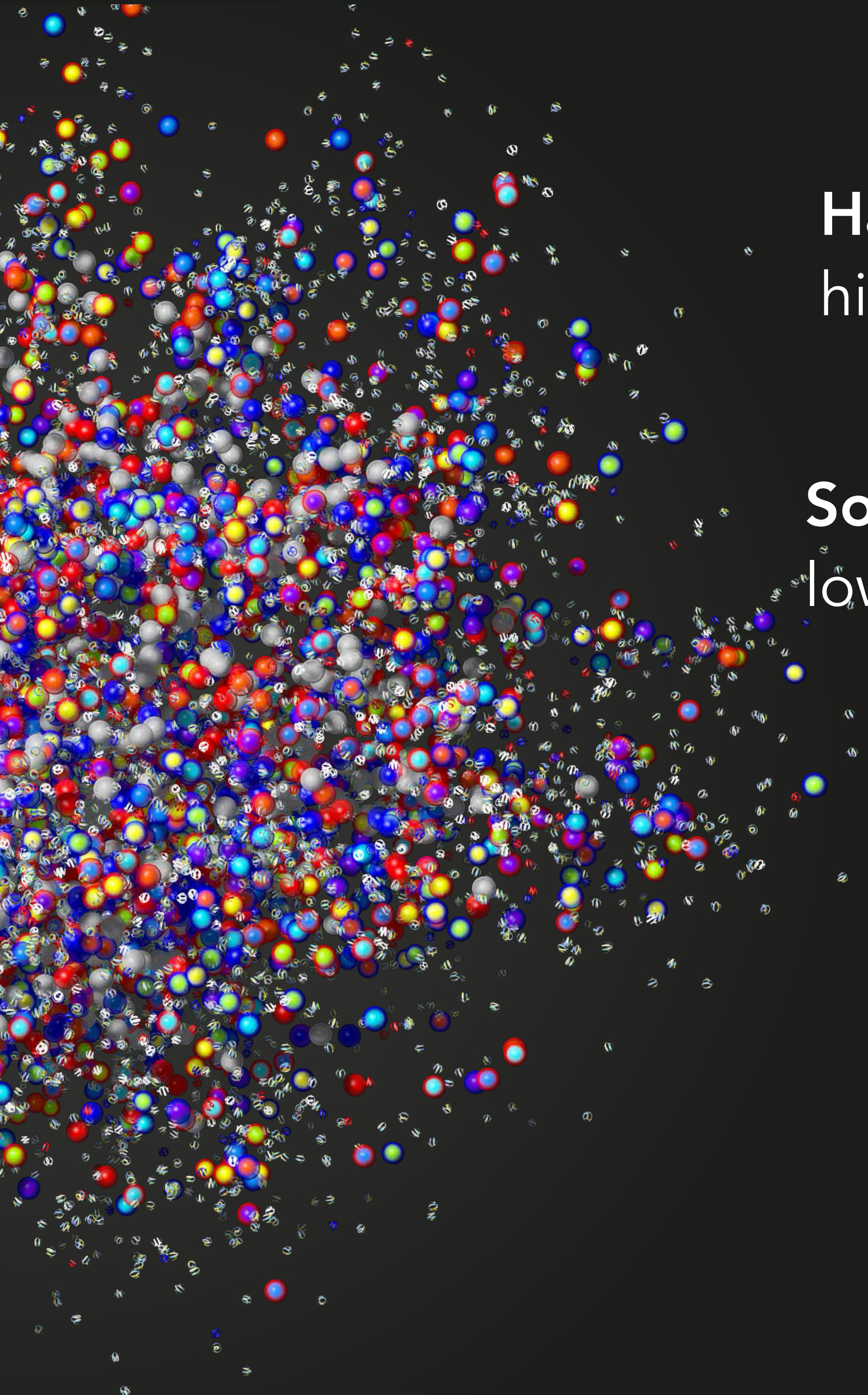




Hard process: perturbative,
high- p_T (many GeV/c) physics

Soft process: non-perturbative,
low- p_T (a few GeV/c) physics

Hard scattering(s) are
superimposed on a soft
background

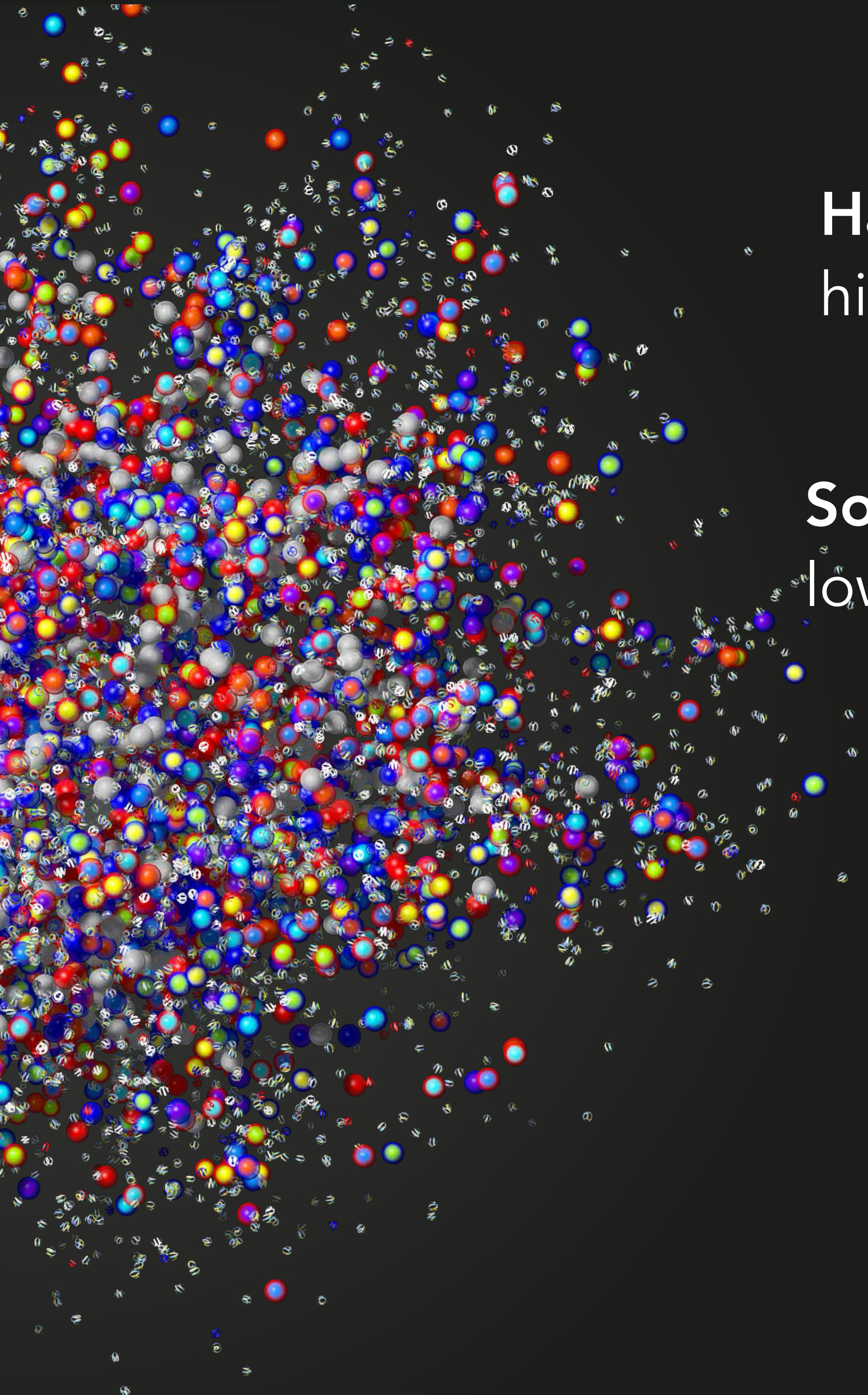


Hard process: perturbative,
high- p_T (many GeV/c) physics

Soft process: non-perturbative,
low- p_T (a few GeV/c) physics

Hard scattering(s) are
superimposed on a soft
background

- Disentangling the two is non-trivial

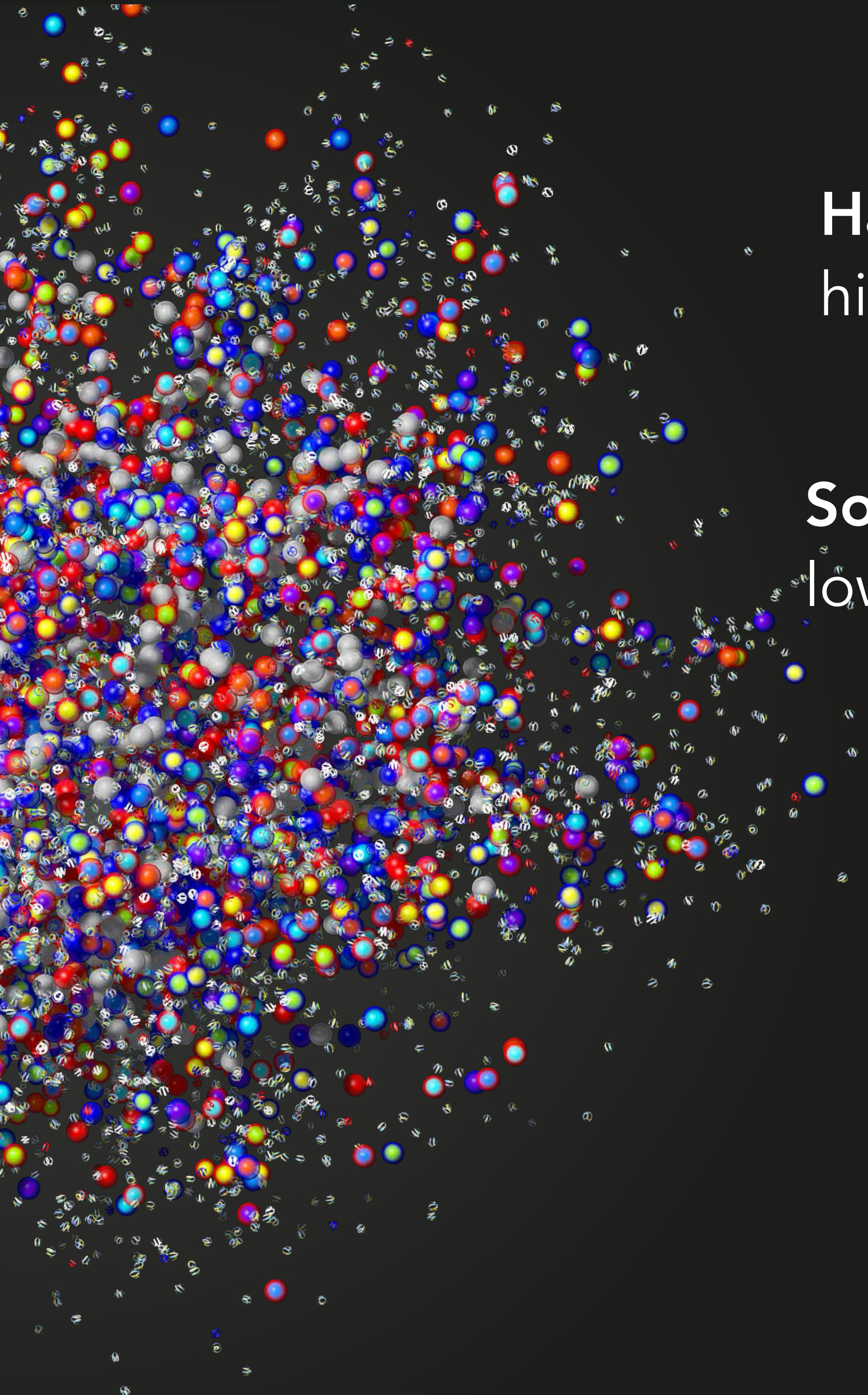


Hard process: perturbative,
high- p_T (many GeV/c) physics

Soft process: non-perturbative,
low- p_T (a few GeV/c) physics

Hard scattering(s) are
superimposed on a soft
background

- Disentangling the two is non-trivial
- Each leaves a distinct, traceable mark in the final-state particles of a collision



Hard process: perturbative,
high- p_T (many GeV/c) physics

Soft process: non-perturbative,
low- p_T (a few GeV/c) physics

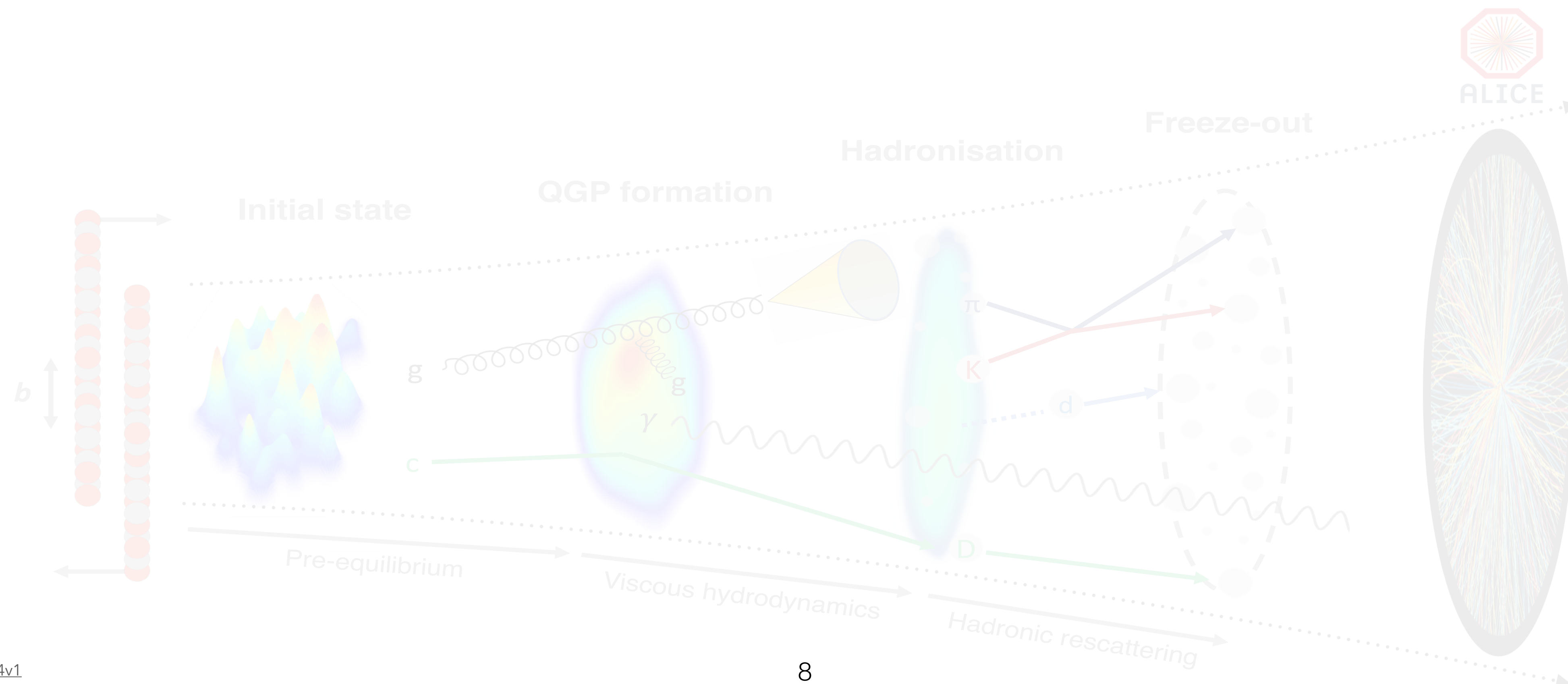
Hard scattering(s) are
superimposed on a soft
background

- Disentangling the two is non-trivial
- Each leaves a distinct, traceable mark in the final-state particles of a collision
- These marks reveal properties of the quark-gluon plasma (QGP)

The evolution of a heavy-ion collision

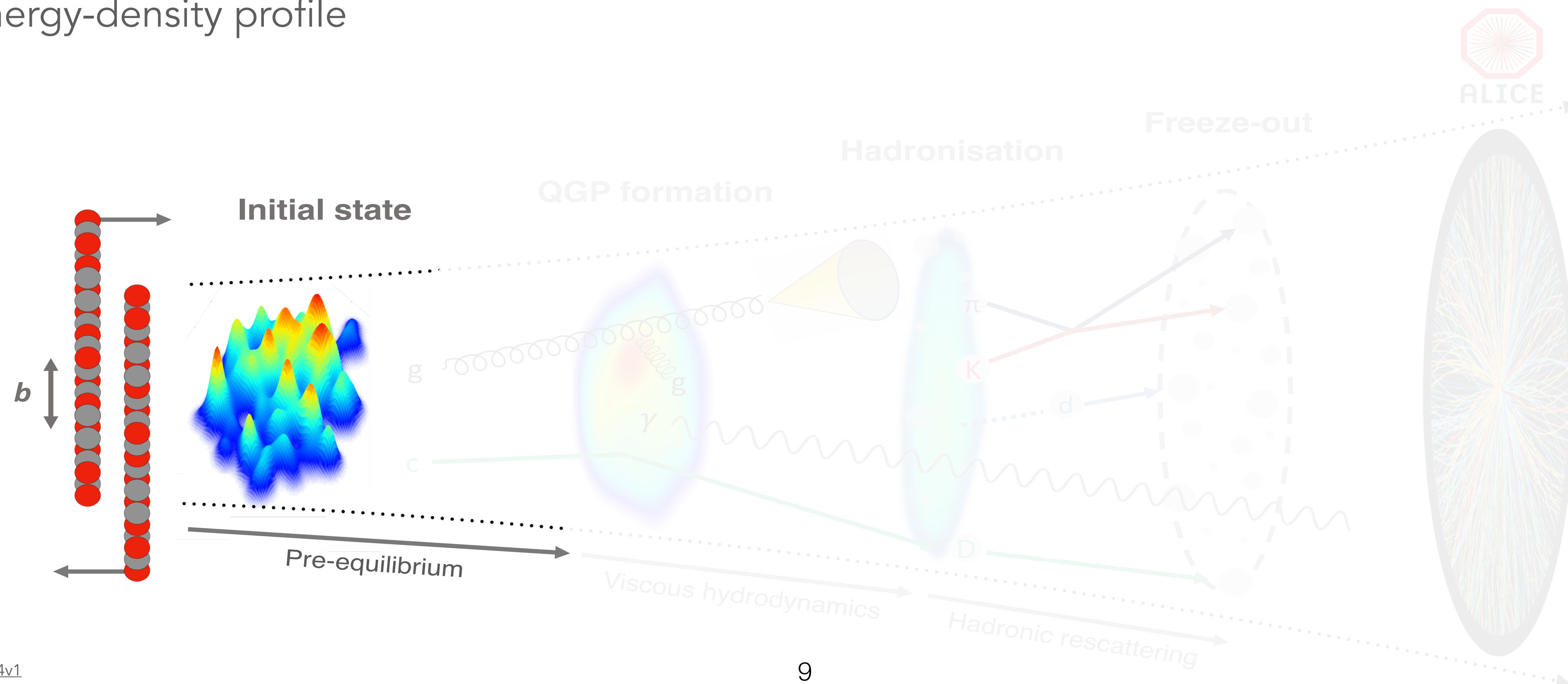


Each stage of a collision involves different physics:



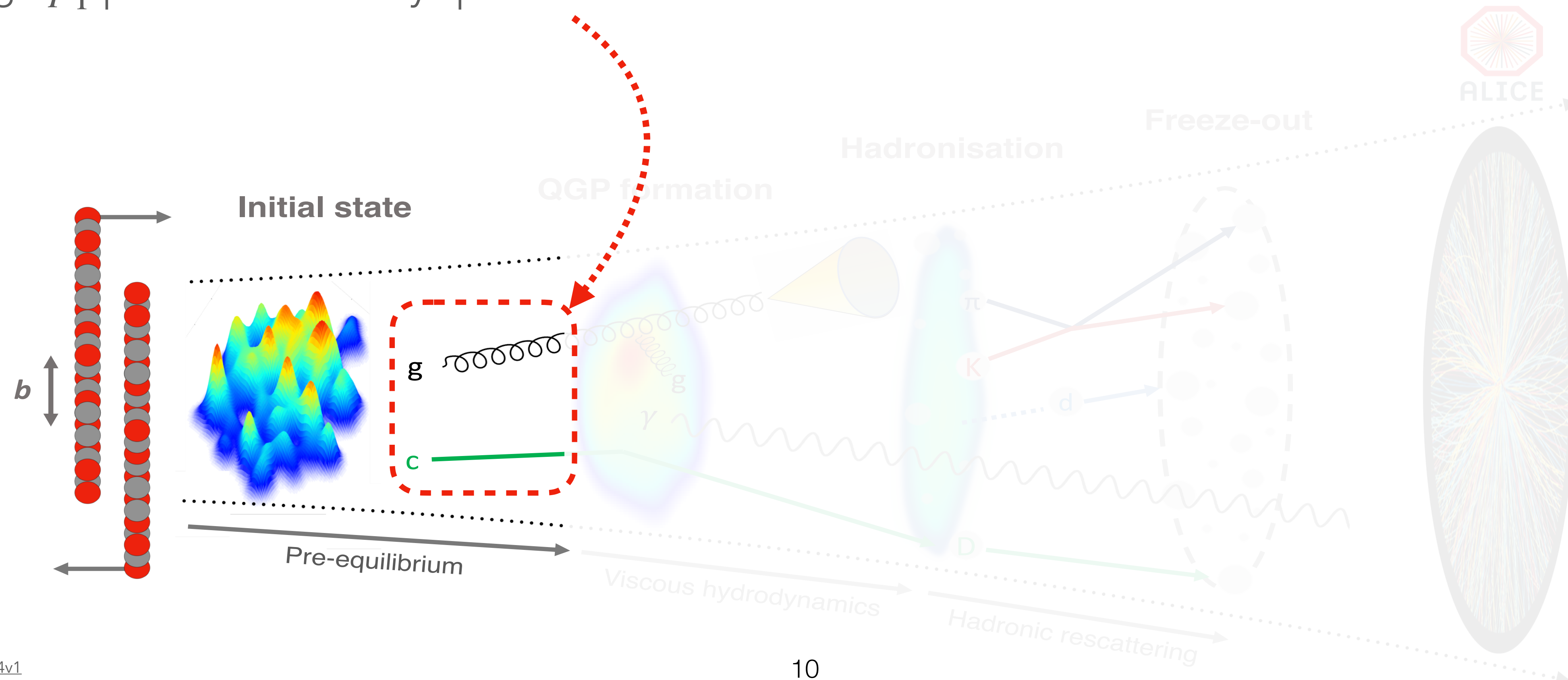
The evolution of a heavy-ion collision

Initial state: Lorentz-contracted nuclei collide, and event-by-event fluctuations produce an irregular energy-density profile



The evolution of a heavy-ion collision

Hard scatterings: Early production of high- p_T partons and heavy quarks

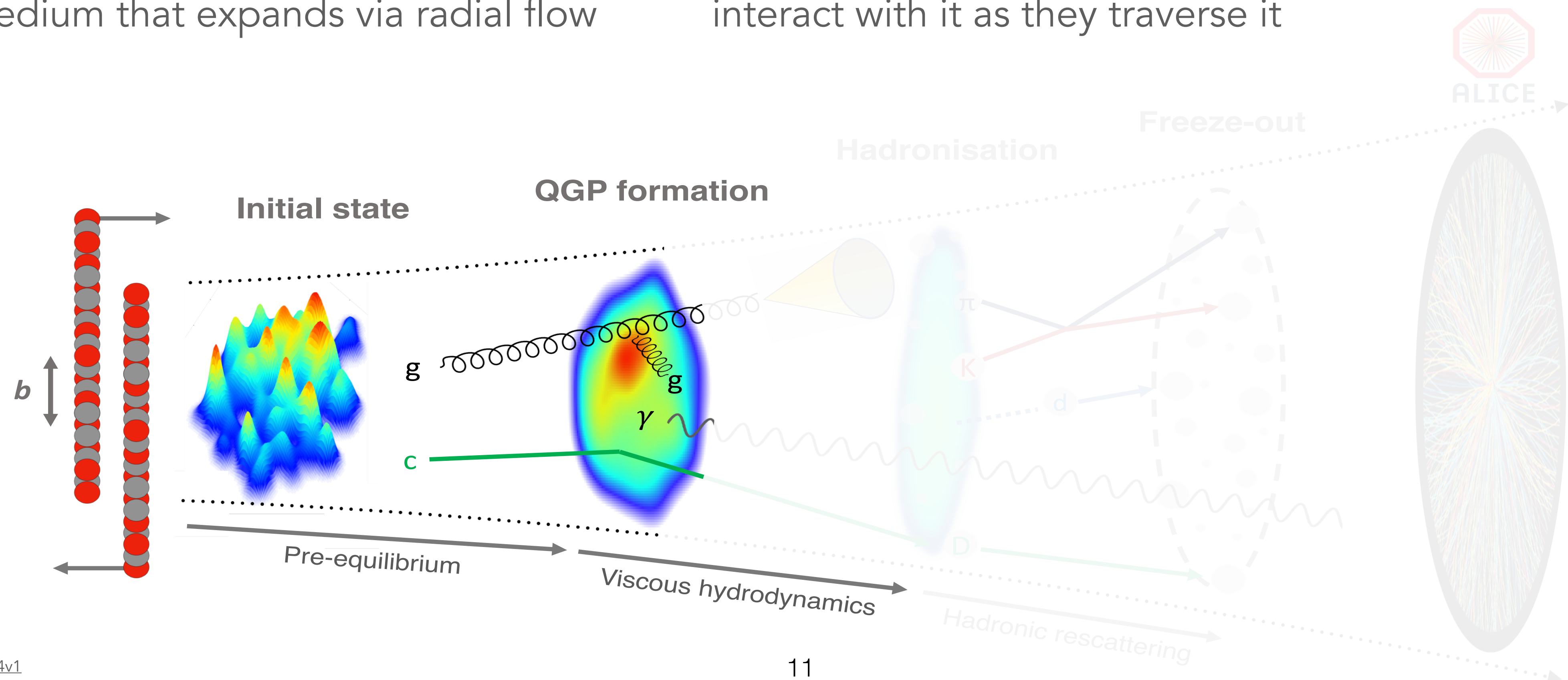


The evolution of a heavy-ion collision

QGP formation and expansion:

Soft interactions form a deconfined medium that expands via radial flow

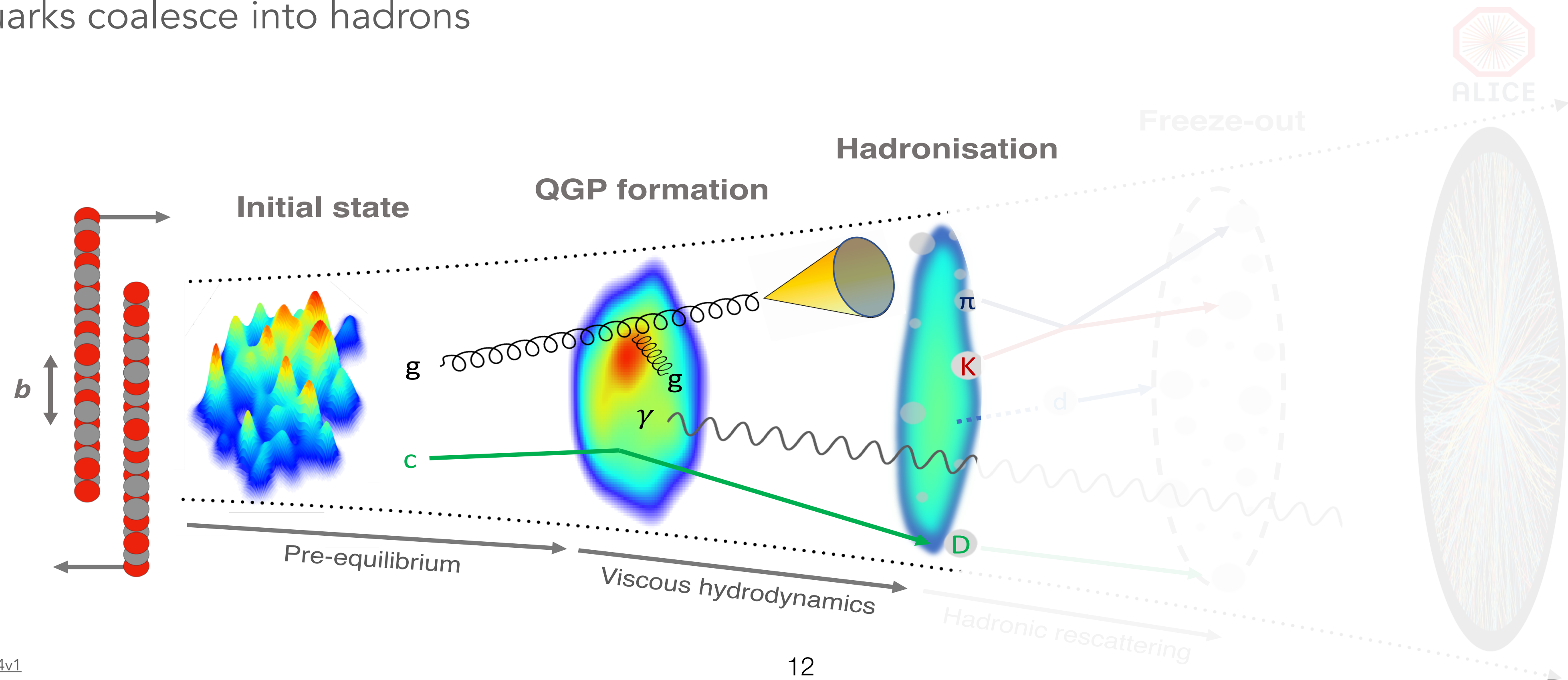
Leptons serve as a thermometer for this medium, while hard probes interact with it as they traverse it



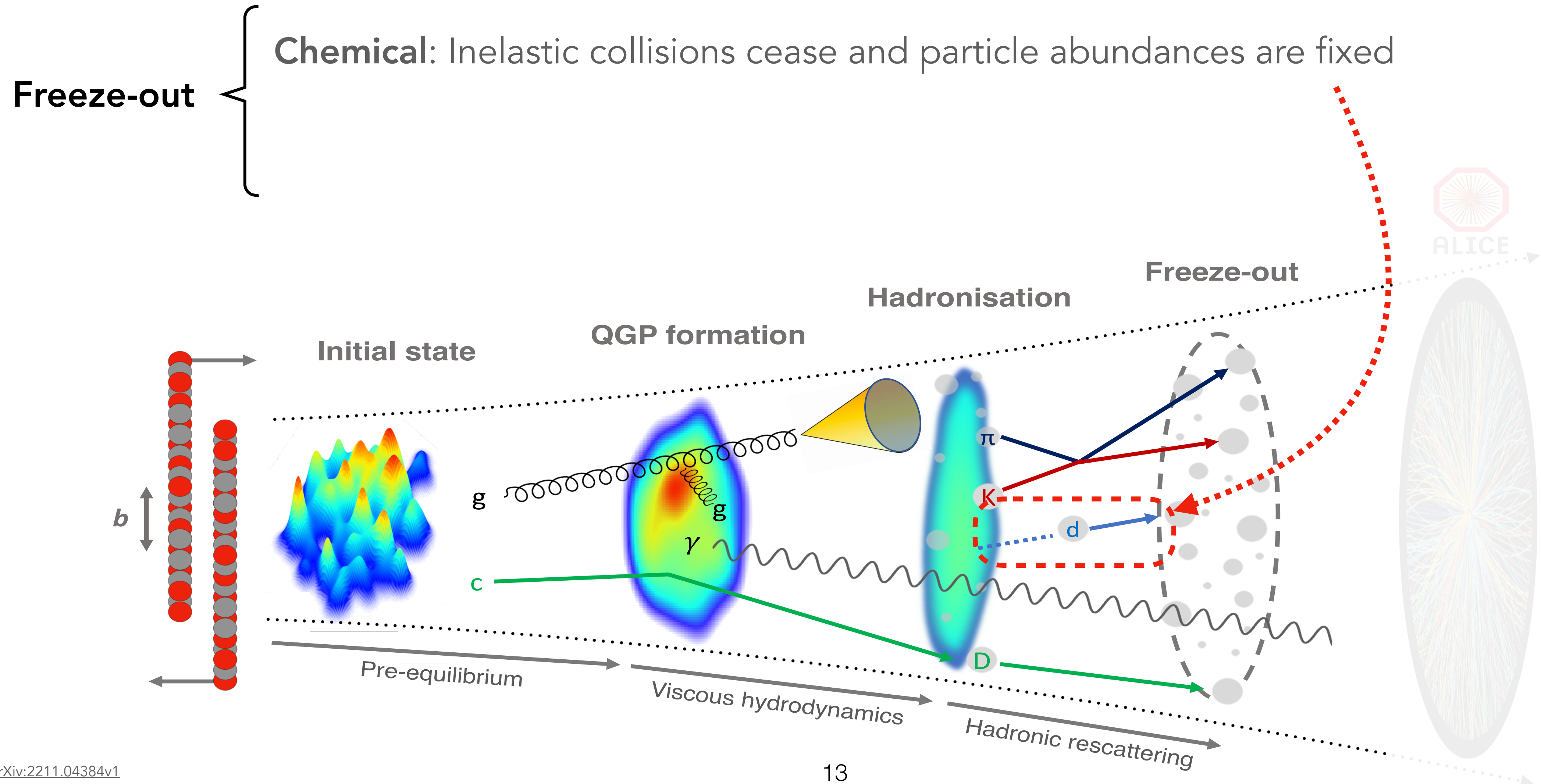
The evolution of a heavy-ion collision

Hadronization: A smooth crossover.

High- p_T partons fragment, while low- p_T quarks coalesce into hadrons



The evolution of a heavy-ion collision

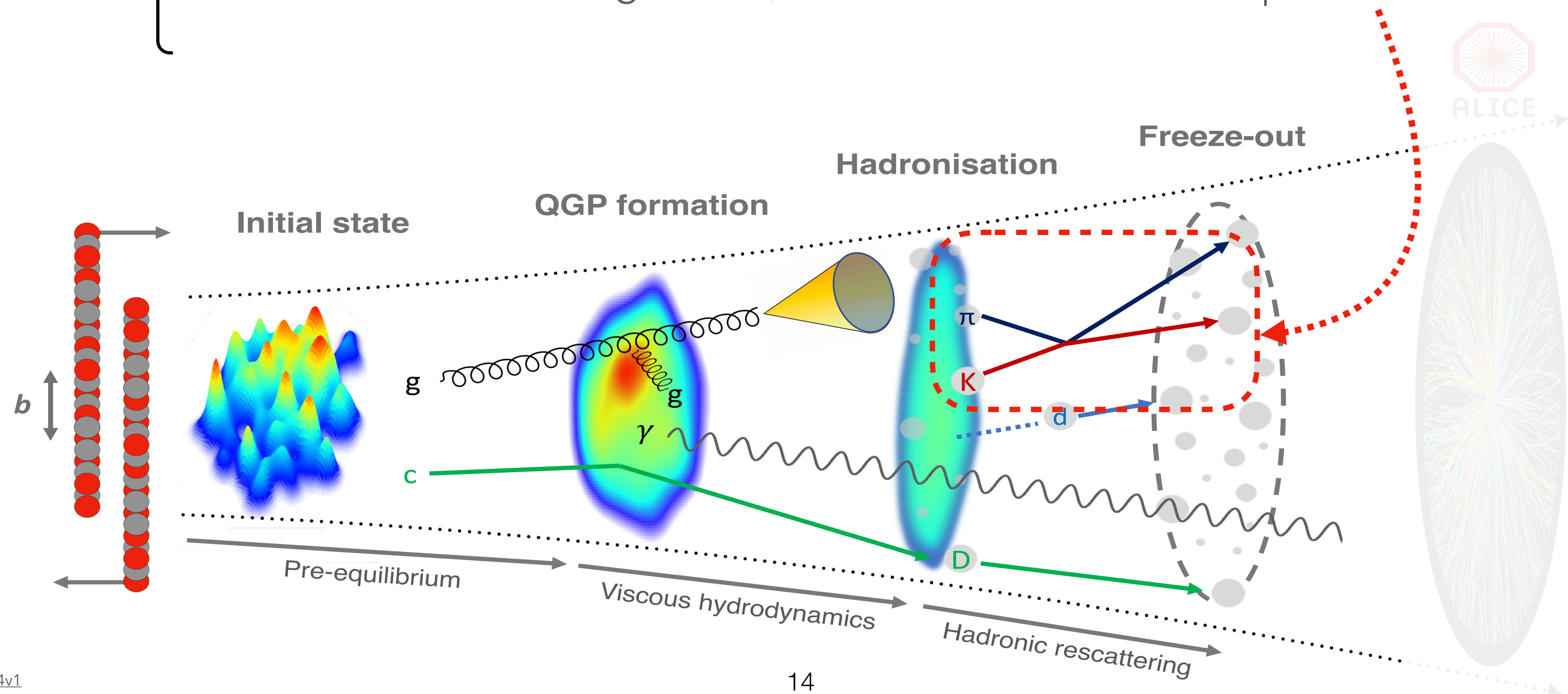


The evolution of a heavy-ion collision

Freeze-out

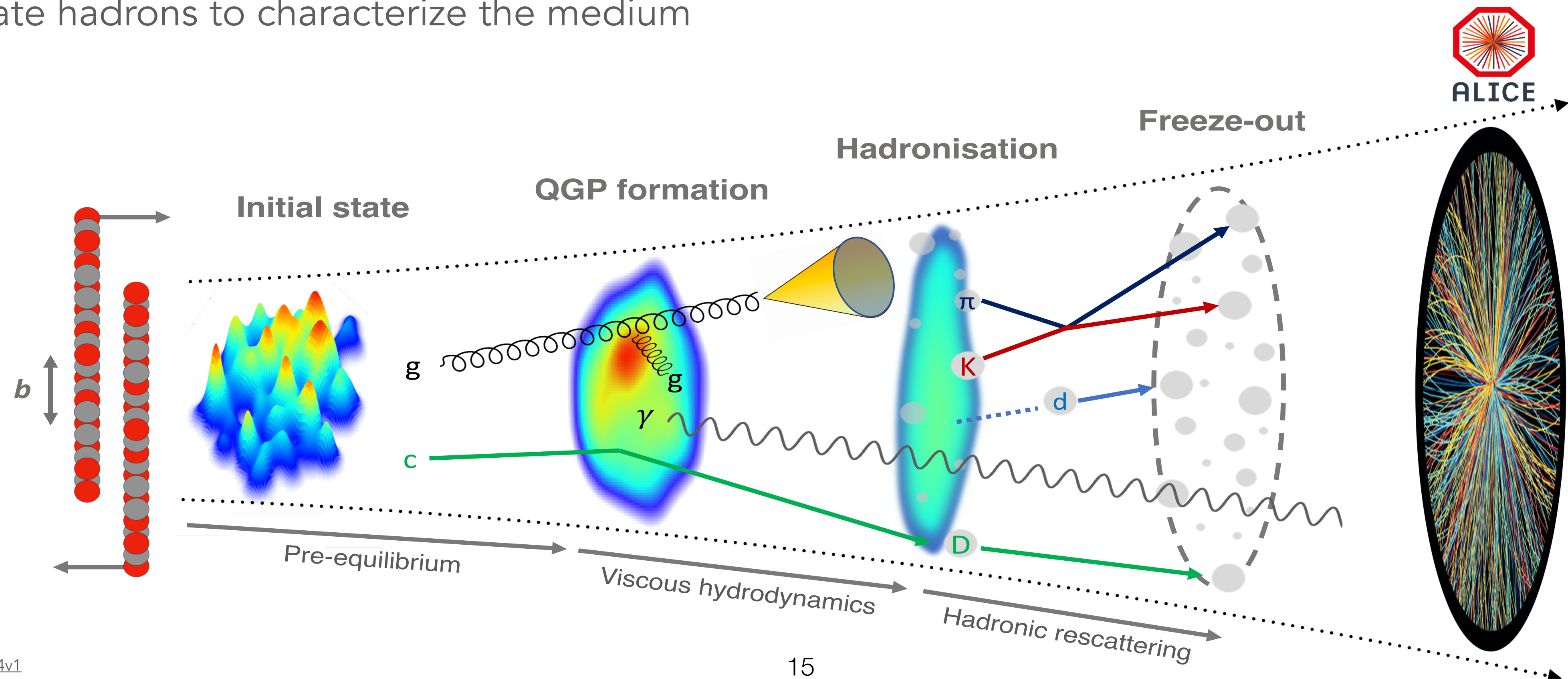
Chemical: Inelastic collisions cease and particle abundances are fixed

Kinetic: Elastic scatterings cease, so momenta are fixed and particles free-stream

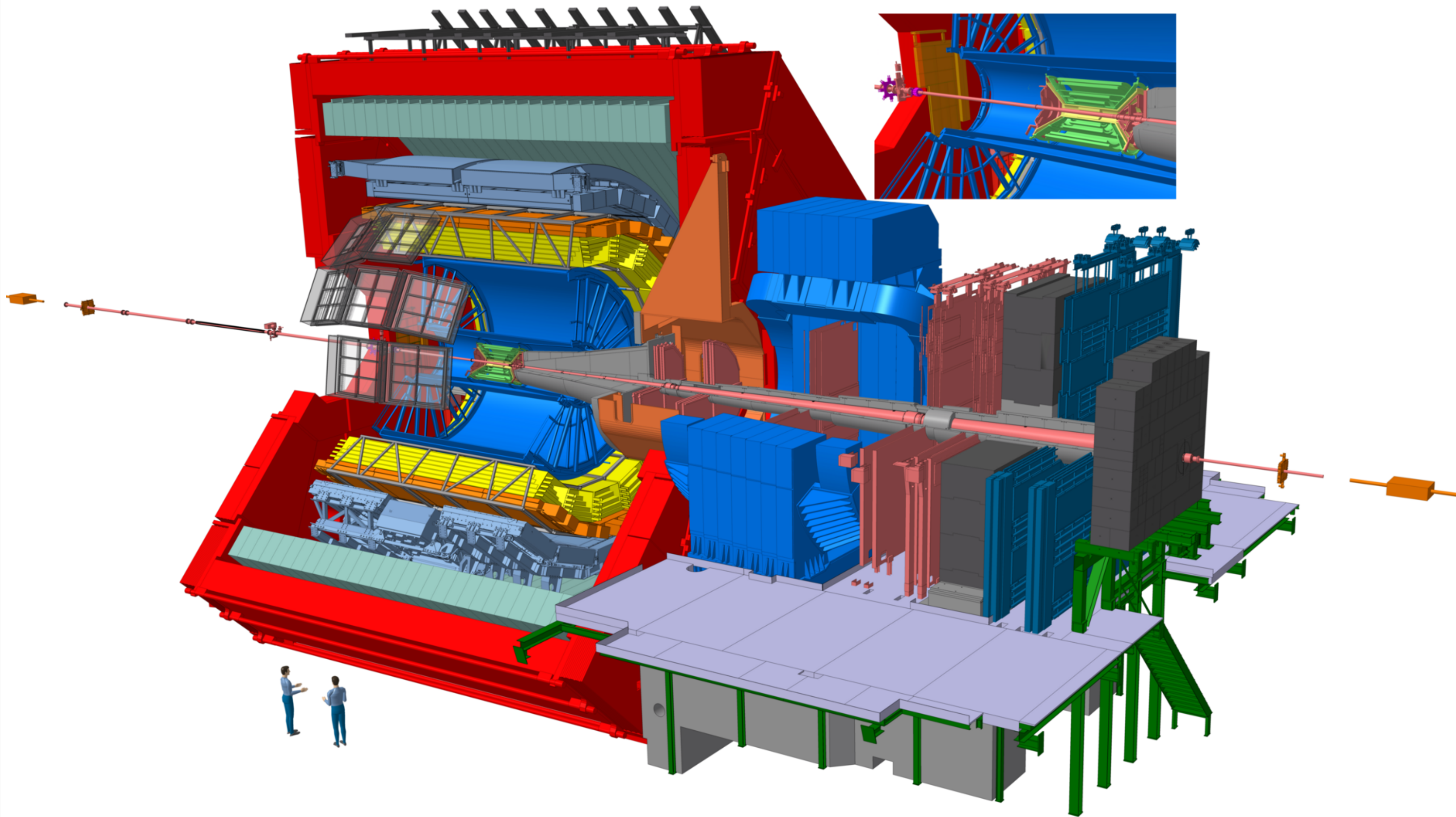
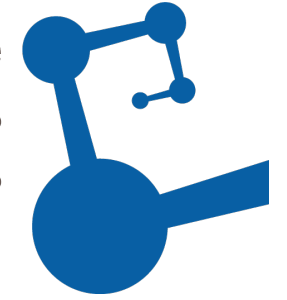


The evolution of a heavy-ion collision

Detection: Experiments like ALICE measures spectra and correlations of final-state hadrons to characterize the medium

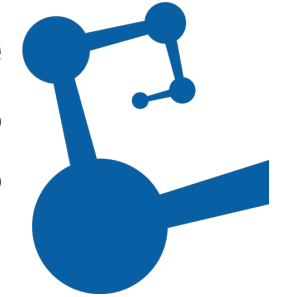


ALICE experiment (Run 2)



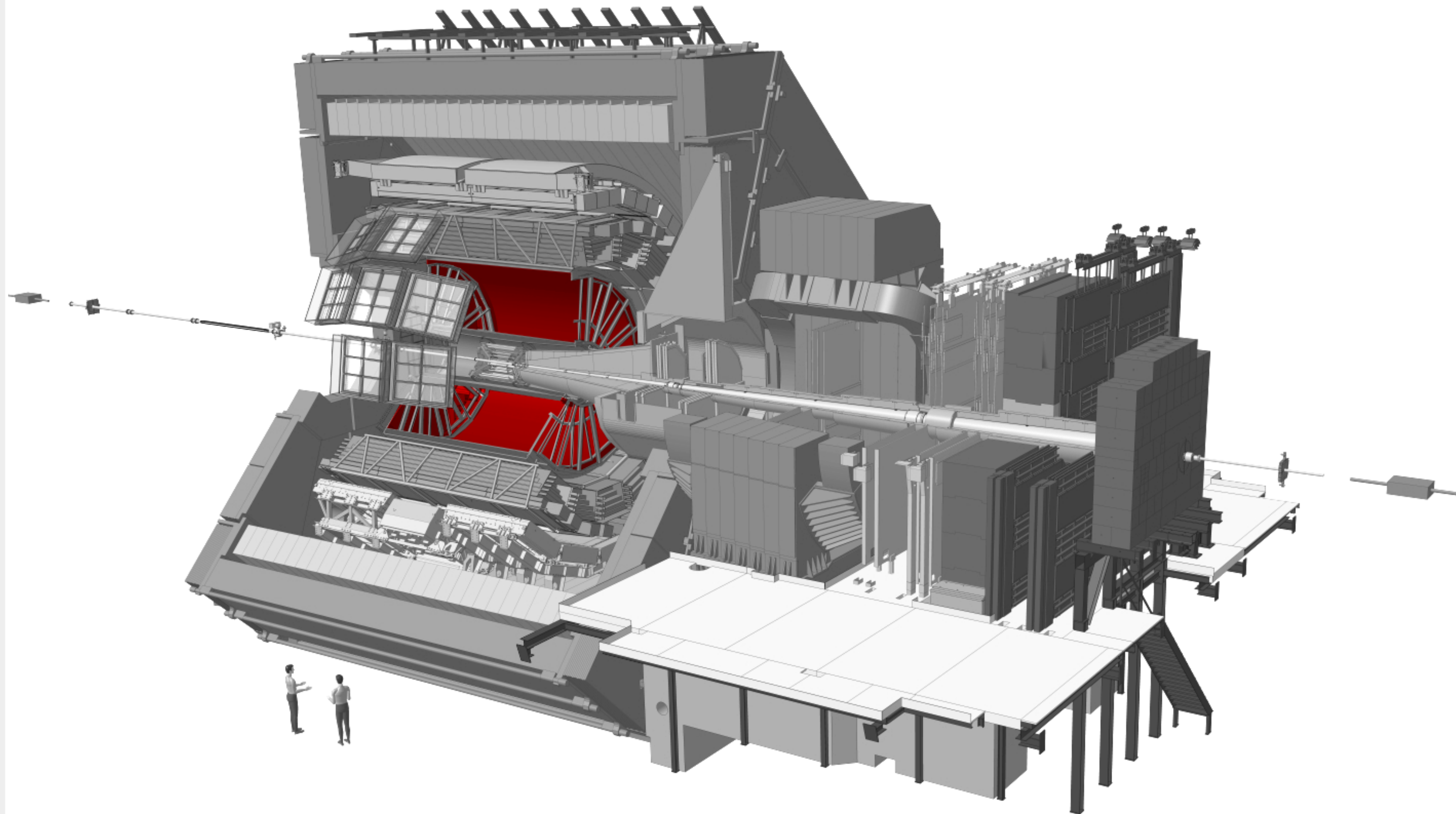
ALICE aims to determine the
properties of the **QGP**
through a series of detectors:

ALICE experiment (Run 2)

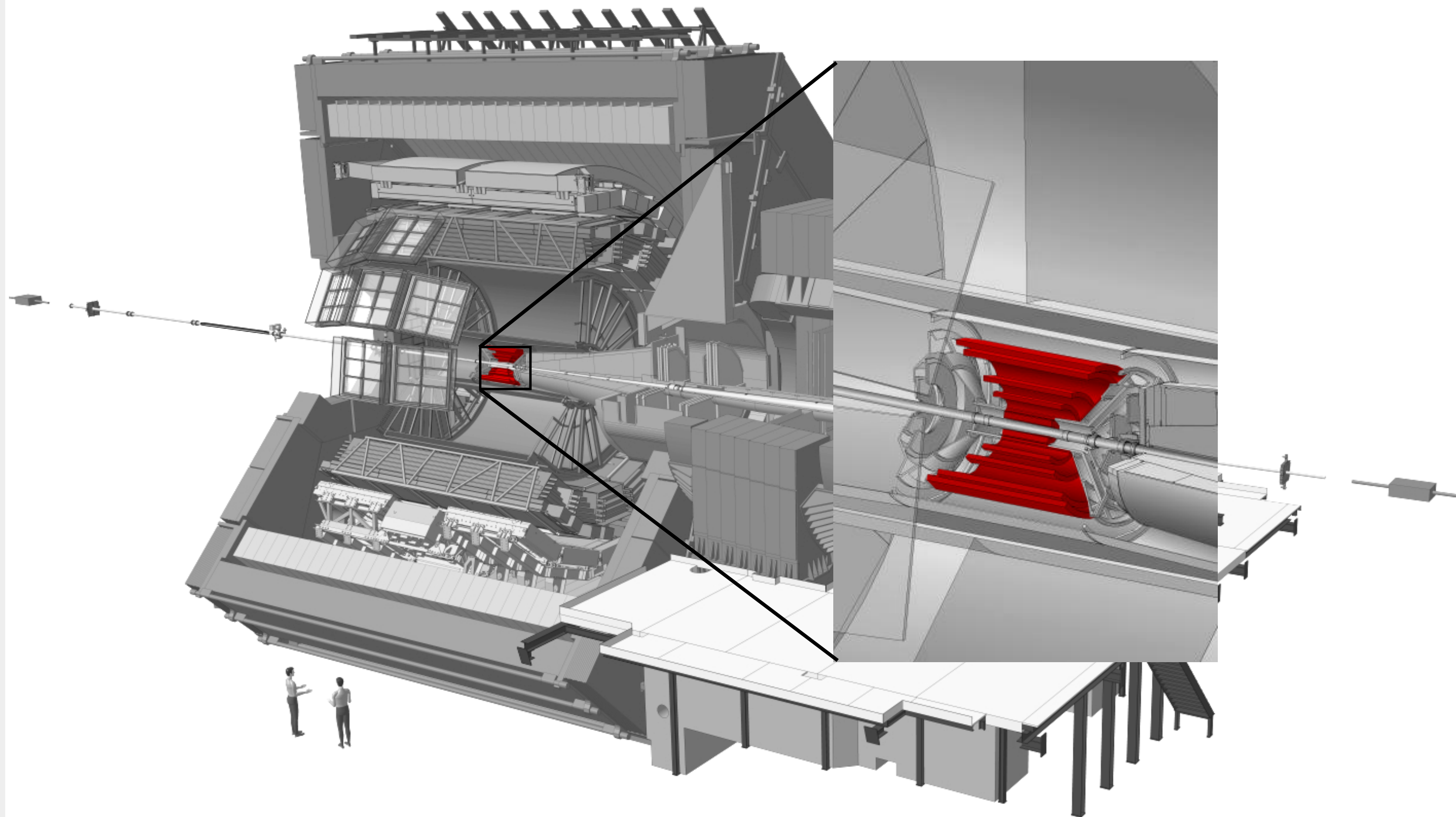
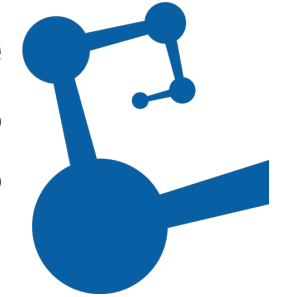


ALICE aims to determine the
properties of the QGP
through a series of detectors:

- **TPC:** Tracking and particle identification using the energy deposited in the gas



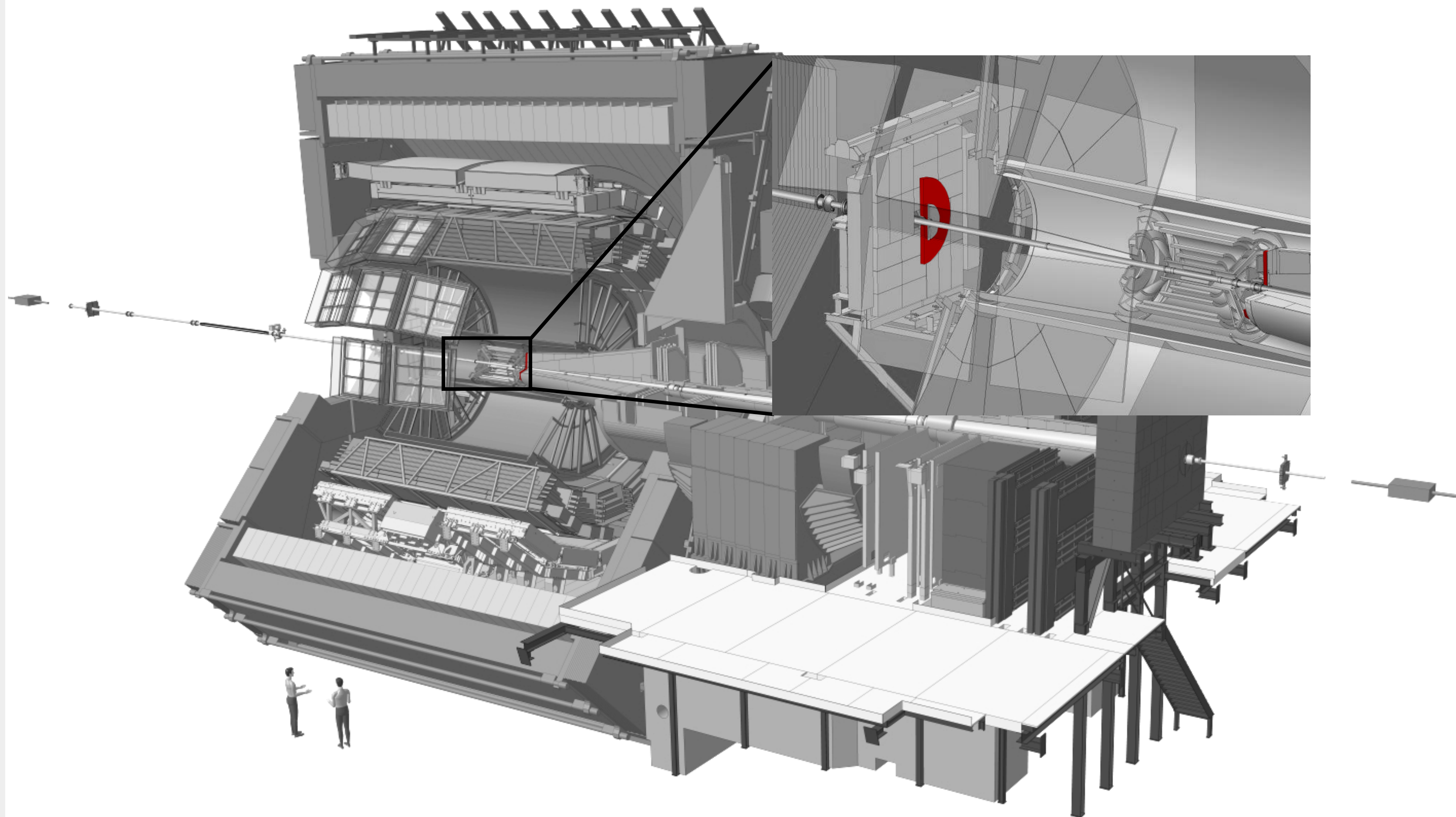
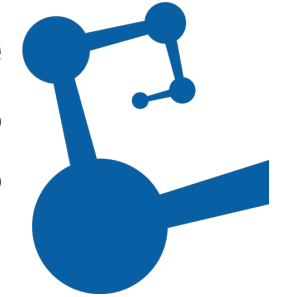
ALICE experiment (Run 2)



ALICE aims to determine the
properties of the QGP
through a series of detectors:

- **TPC:** Tracking and particle identification using the energy deposited in the gas
- **ITS:** Interaction vertex and decays

ALICE experiment (Run 2)



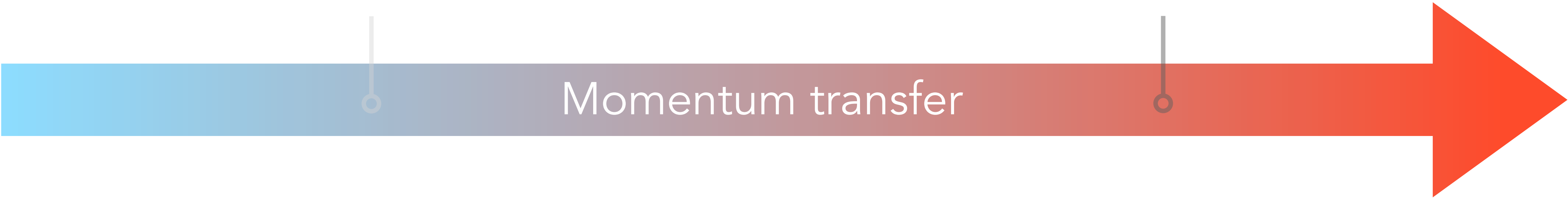
ALICE aims to determine the **properties of the QGP** through a series of detectors:

- **TPC:** Tracking and particle identification using the energy deposited in the gas
- **ITS:** Interaction vertex and decays
- **V0:** Trigger, background suppression, and multiplicity estimation

Hard and soft processes as probes of the quark-gluon plasma

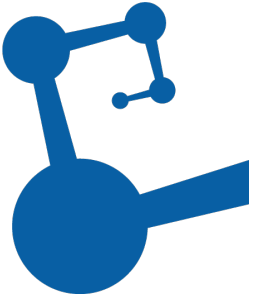
Underlying event
characterization in
pp collisions at
 $\sqrt{s} = 13.6$ TeV

**Dijet
acoplanarity
with flattenicity
in pp collisions**

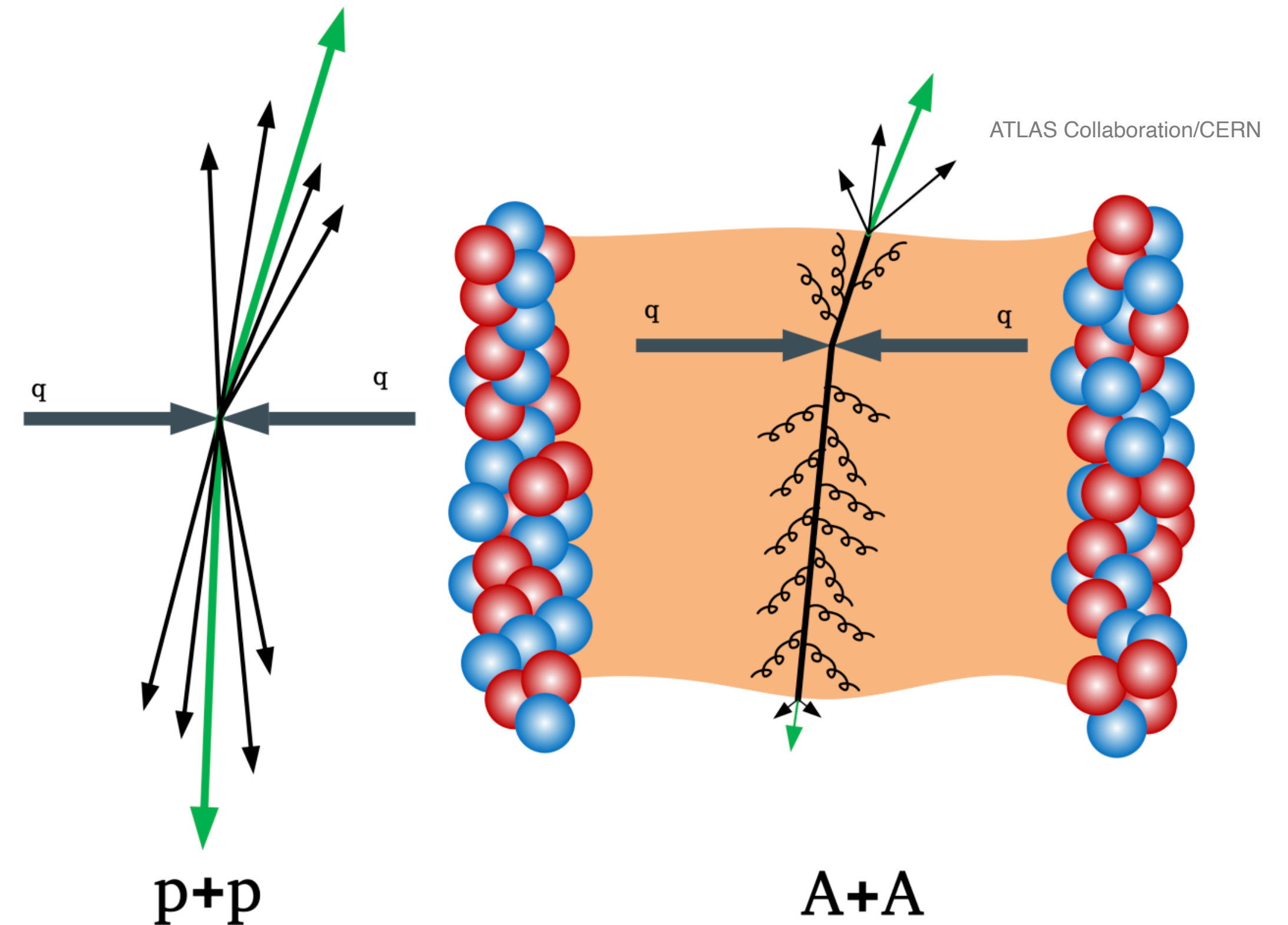


Momentum transfer

Jet quenching



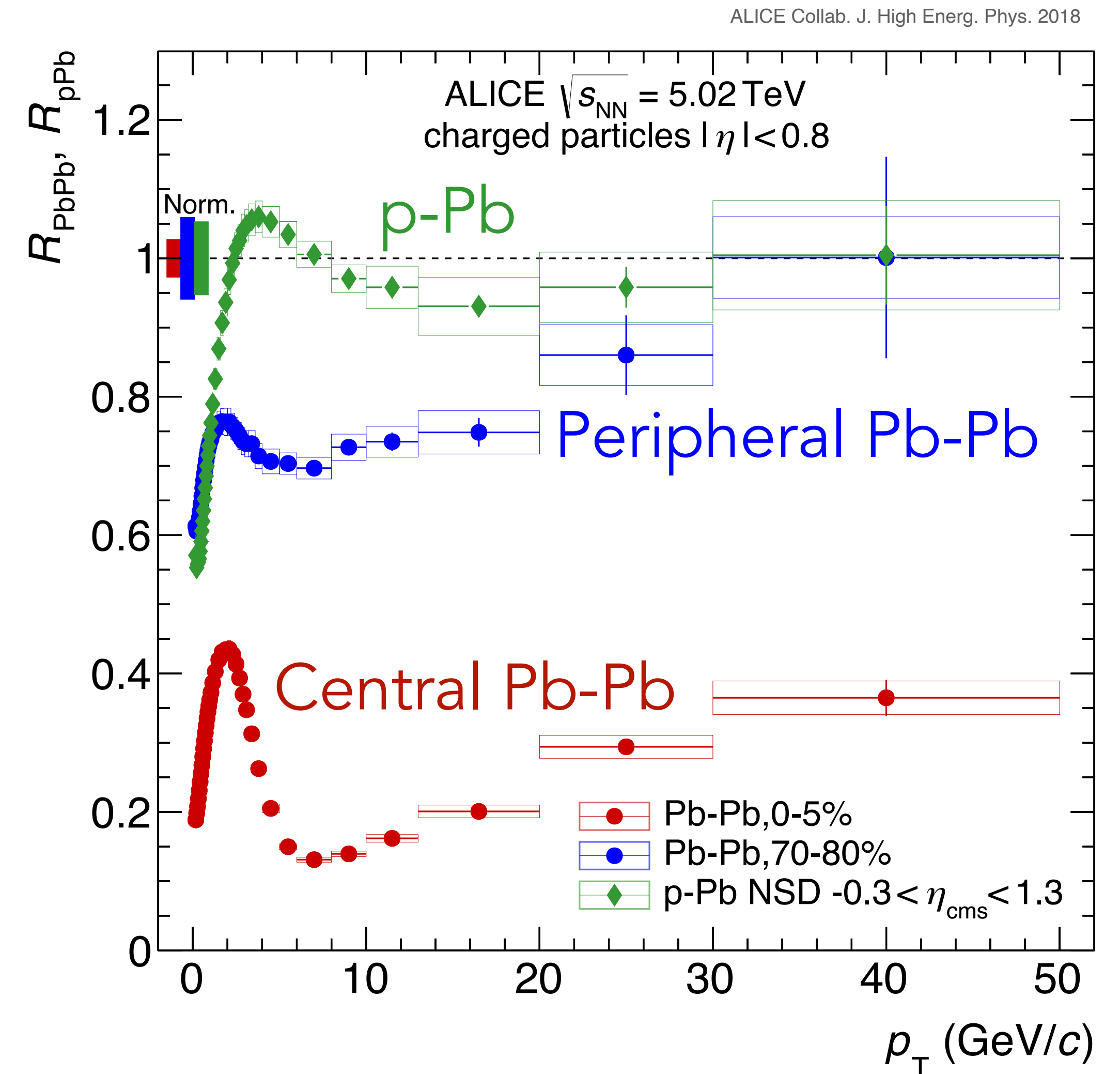
- **Jet quenching:** the energy loss suffered by high- p_T partons while traversing the QGP



Jet quenching

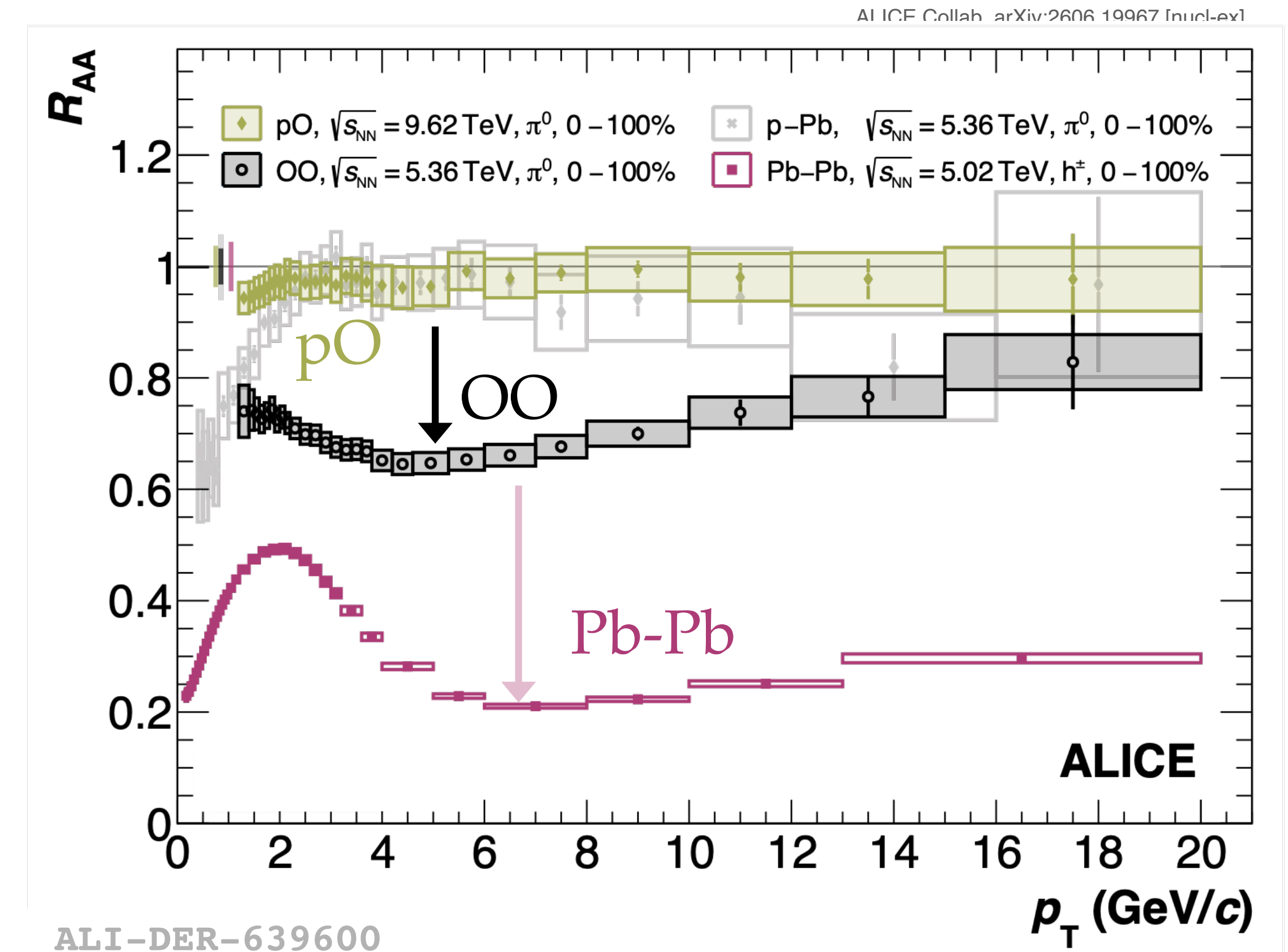
- **Jet quenching:** the energy loss suffered by high- p_T partons while traversing the QGP
- **Established in Pb-Pb but missing in p-Pb,** as reported in the measurements of the nuclear modification factor

$$R_{AA}(p_T) = \frac{1}{\langle N_{col} \rangle} \frac{dN^{AA}/dp_T}{dN^{pp}/dp_T} \rightarrow \frac{\text{QGP}}{\text{reference vacuum}}$$

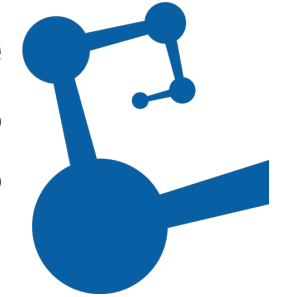


Jet quenching

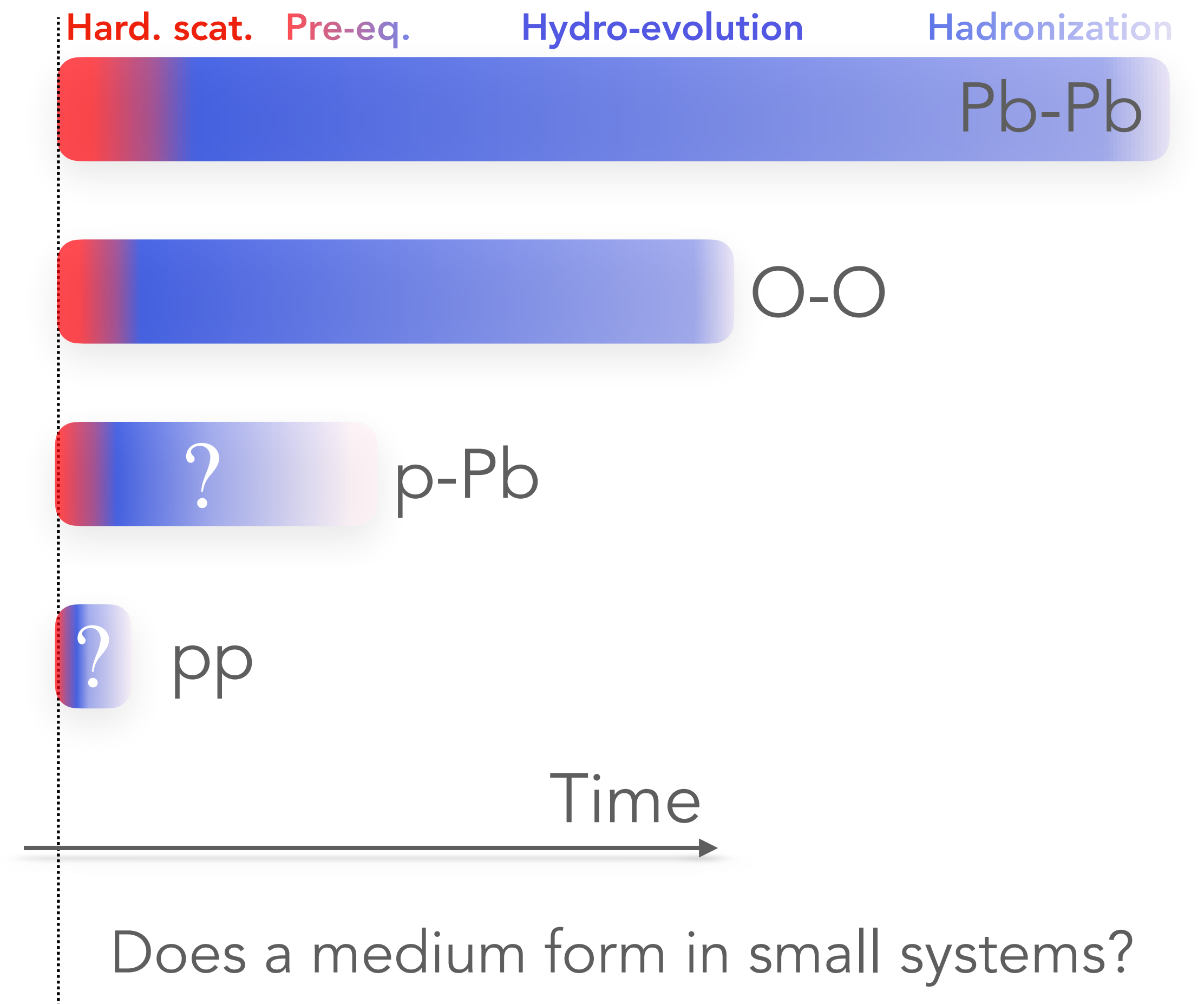
- **Jet quenching:** the energy loss suffered by high- p_T partons while traversing the QGP
- **Established in Pb-Pb but missing in p-Pb,** as reported in the measurements of the nuclear modification factor
- **OO results:** ALICE measurements show indications of jet quenching in OO collisions



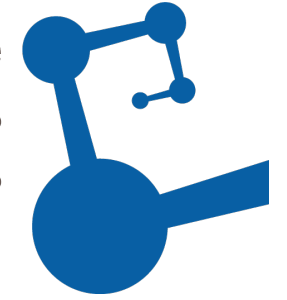
Jet quenching



- **Jet quenching:** the energy loss suffered by high- p_T partons while traversing the QGP
- **Established in Pb-Pb but missing in p-Pb,** as reported in the measurements of the nuclear modification factor
- **OO results:** ALICE measurements show indications of jet quenching in OO collisions
- **What about pp collisions?** Observing jet quenching here is key to establishing the minimum system size for QGP formation

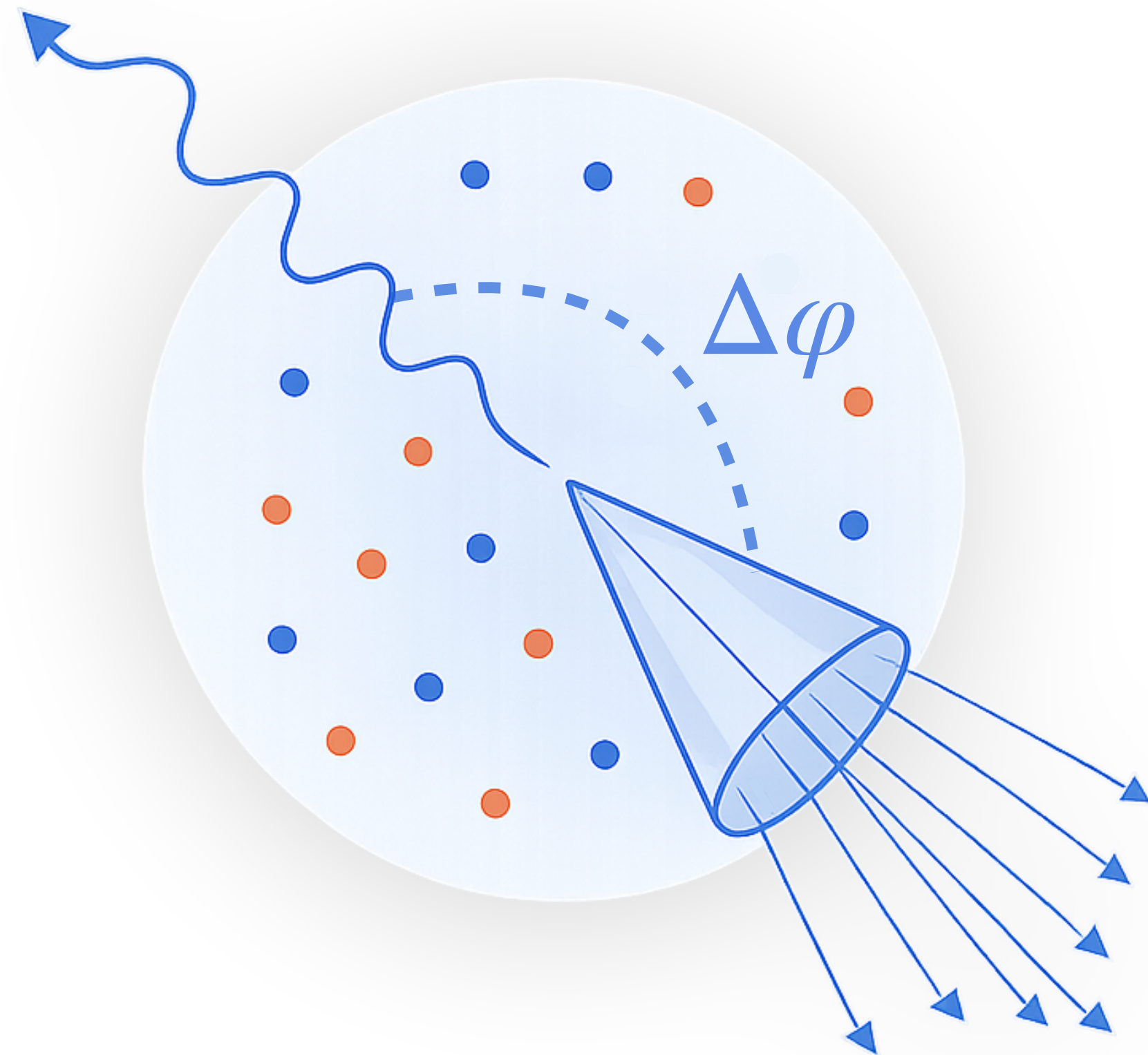


Acoplanarity distribution



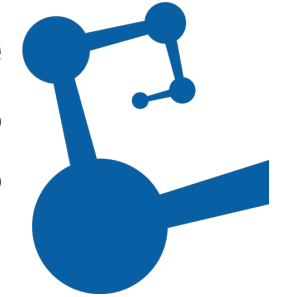
In pp collisions, jet quenching is study via the **azimuthal distribution** of charged-particle jets recoiling from a high- p_T trigger hadron.

Trigger Track



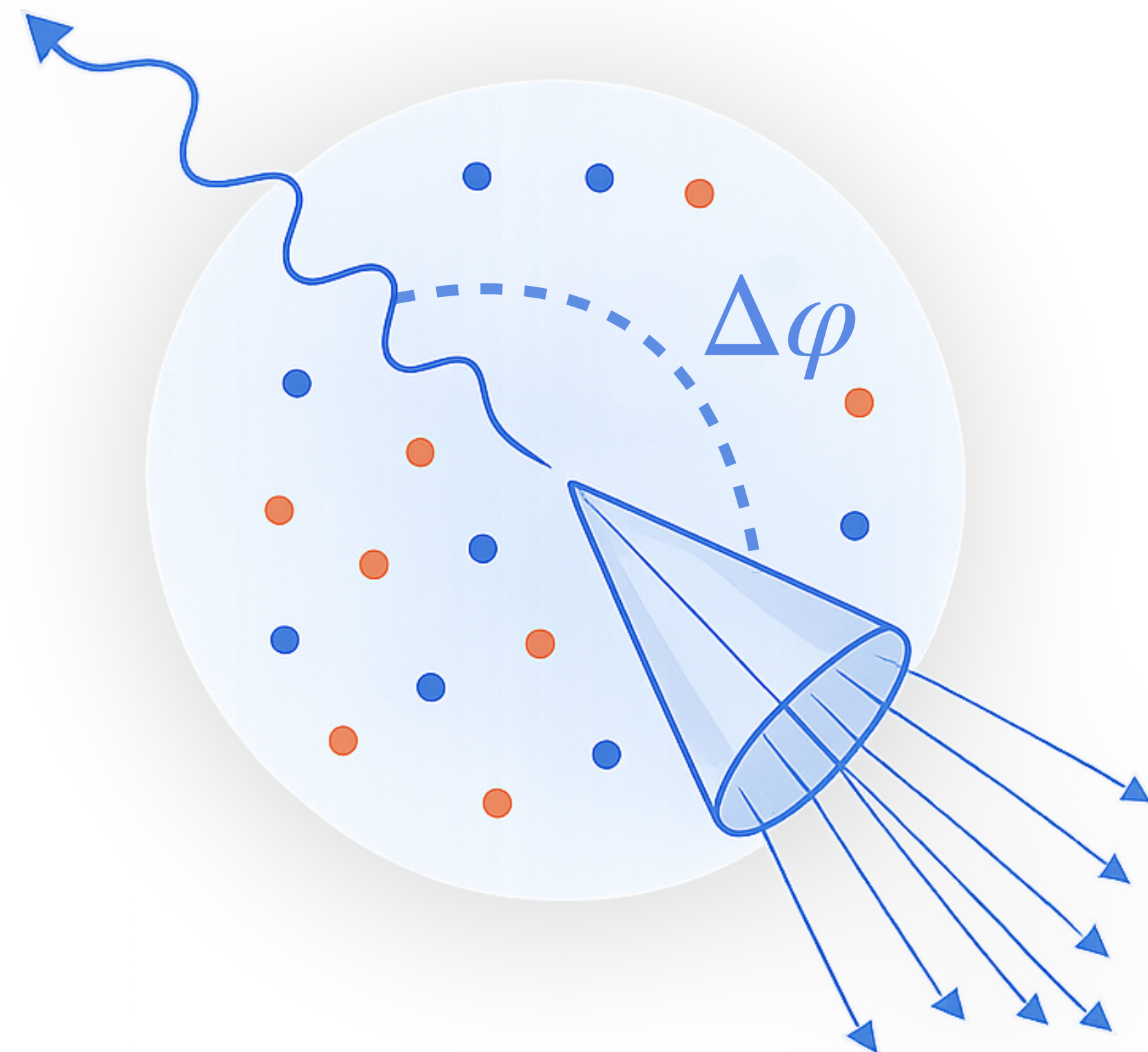
Recoiling jet

Acoplanarity distribution



In pp collisions, jet quenching is study via the **azimuthal distribution** of charged-particle jets recoiling from a high- p_T trigger hadron.

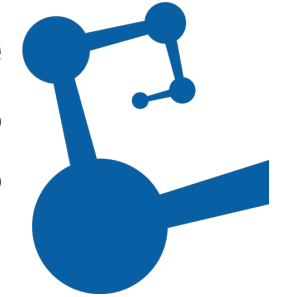
Trigger Track



Recoiling jet

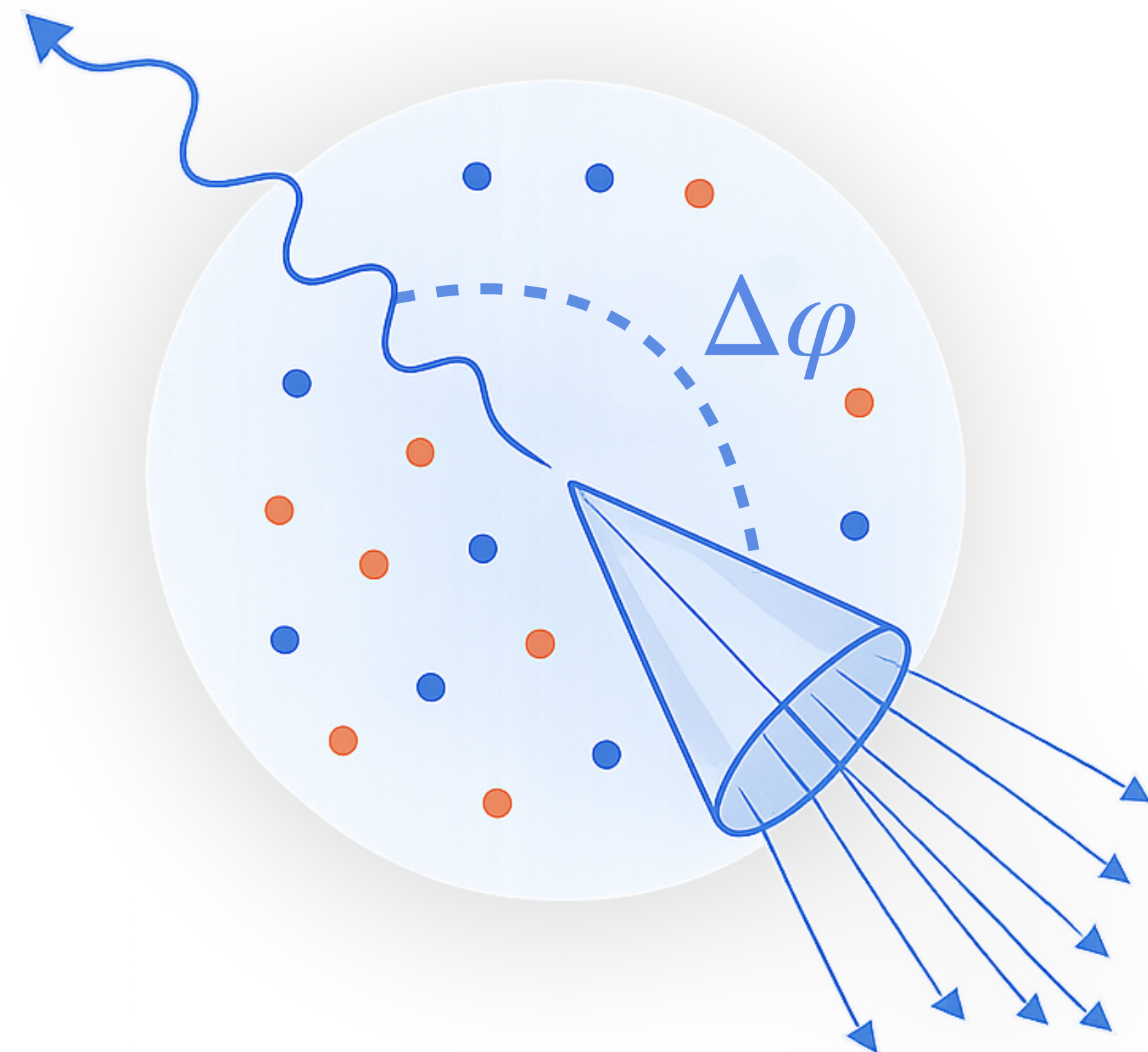
A back-to-back configuration is expected in vacuum
Any deviation could hint a possible jet quenching effect

Acoplanarity distribution



In pp collisions, jet quenching is study via the **azimuthal distribution** of charged-particle jets recoiling from a high- p_T trigger hadron.

Trigger Track



Recoiling jet

A back-to-back configuration is expected in vacuum
Any deviation could hint a possible jet quenching effect

Measured with:

$$\Delta_{\text{recoil}} = \underbrace{(\text{Recoil signal distribution})}_{\text{Signal + Background}} - c_{\text{Ref}} \times \underbrace{(\text{Recoil reference distribution})}_{\text{Background}}$$

Published results

The ALICE Collaboration reported the following findings

- The azimuthal distribution is **broadened in HM** events, which is also seen in PYTHIA 8

Data:

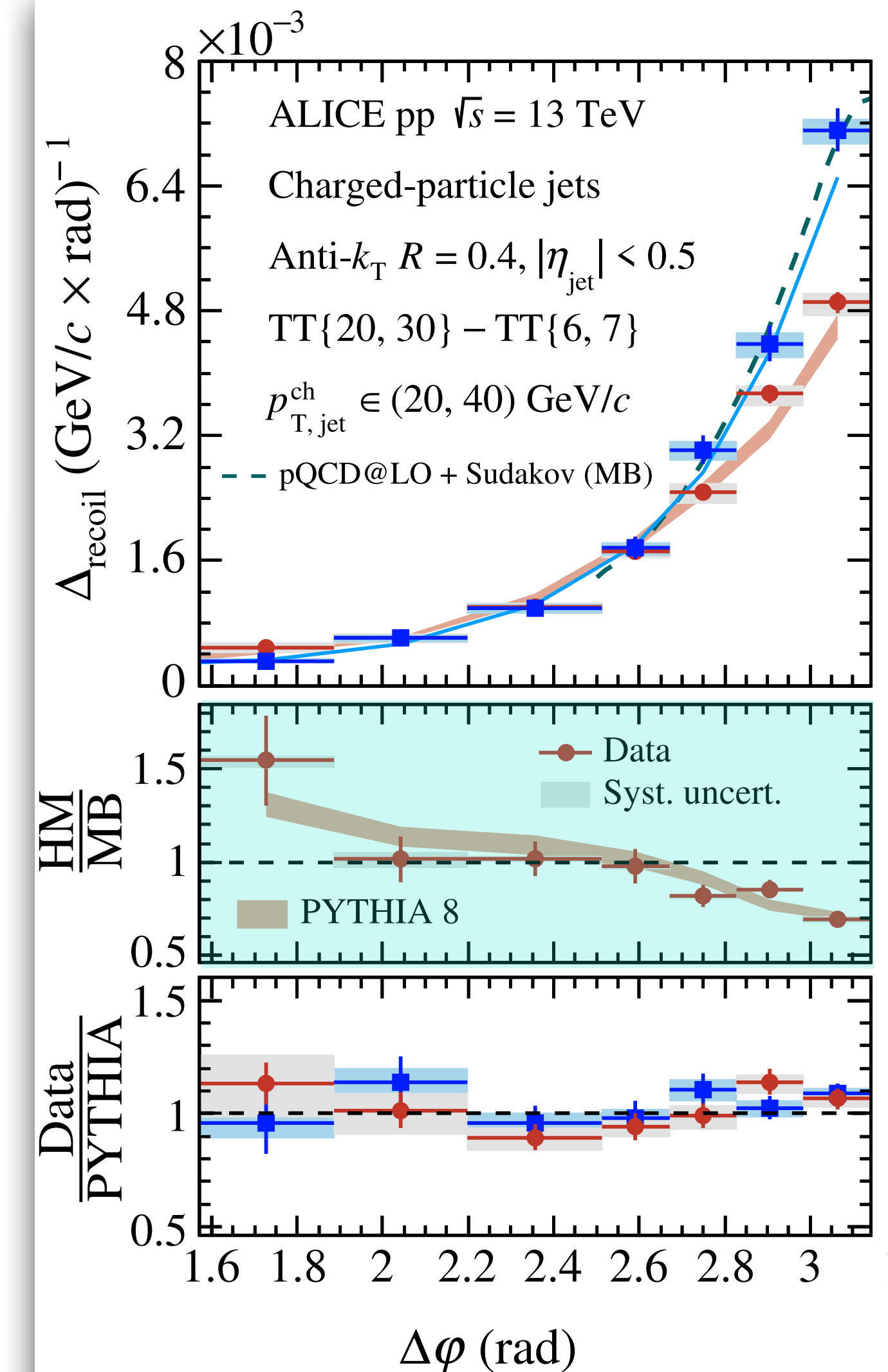
■ MB

● HM

PYTHIA 8:

— MB

■ HM



Published results

The ALICE Collaboration reported the following findings

- The azimuthal distribution is broadened in HM events, which is also seen in PYTHIA 8
- Since **PYTHIA 8 lacks any medium**, the observed broadening is unlikely to be predominantly driven by jet quenching

Data:

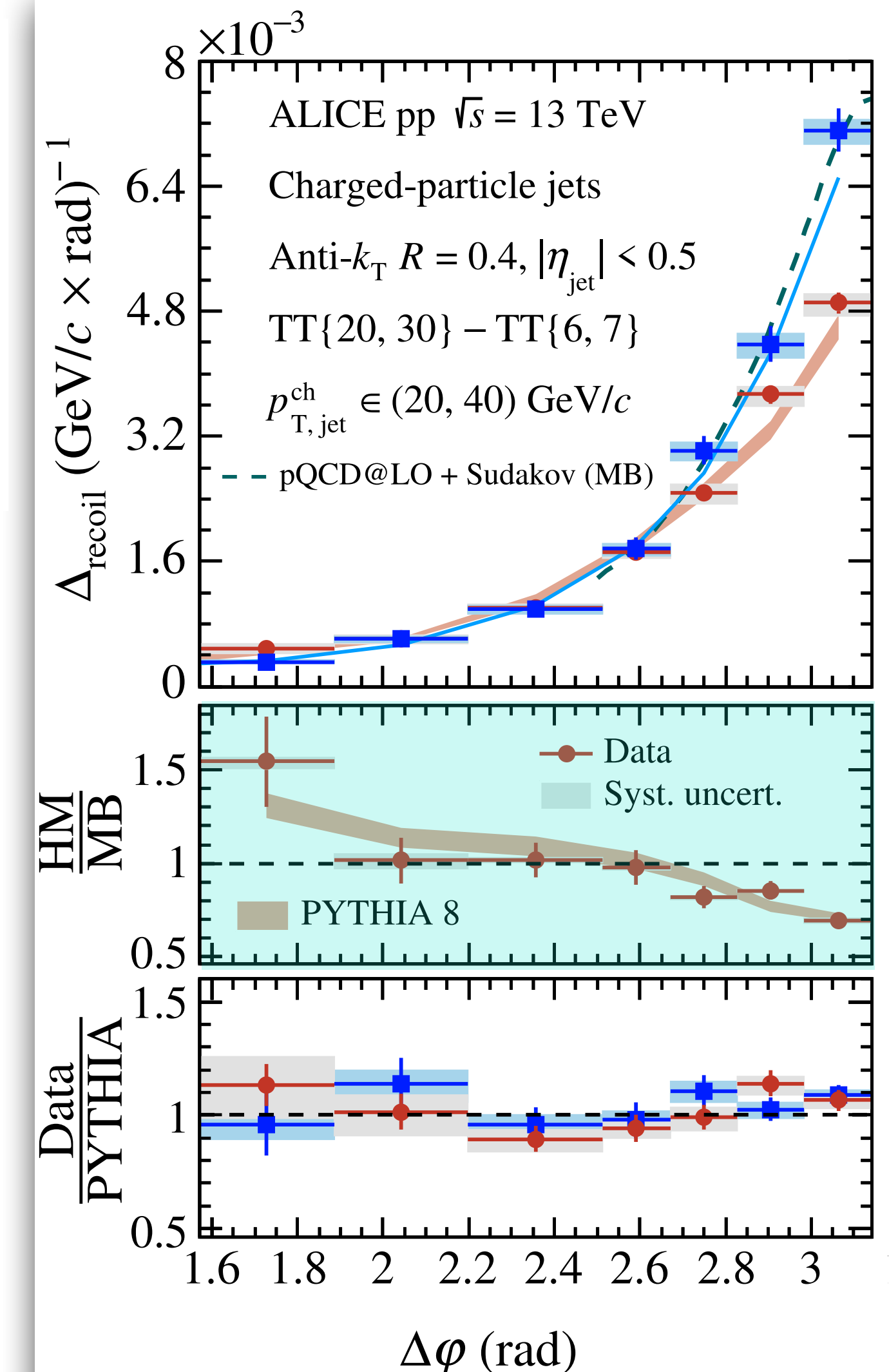
■ MB

● HM

PYTHIA 8:

— MB

■ HM



Published results

The ALICE Collaboration reported the following findings

- The azimuthal distribution is broadened in HM events, which is also seen in PYTHIA 8
- Since PYTHIA 8 lacks any medium, the observed broadening is unlikely to be predominantly driven by jet quenching
- Nonetheless, this broadening is caused by a **event selection bias** rather than a physical jet quenching effect

Data:

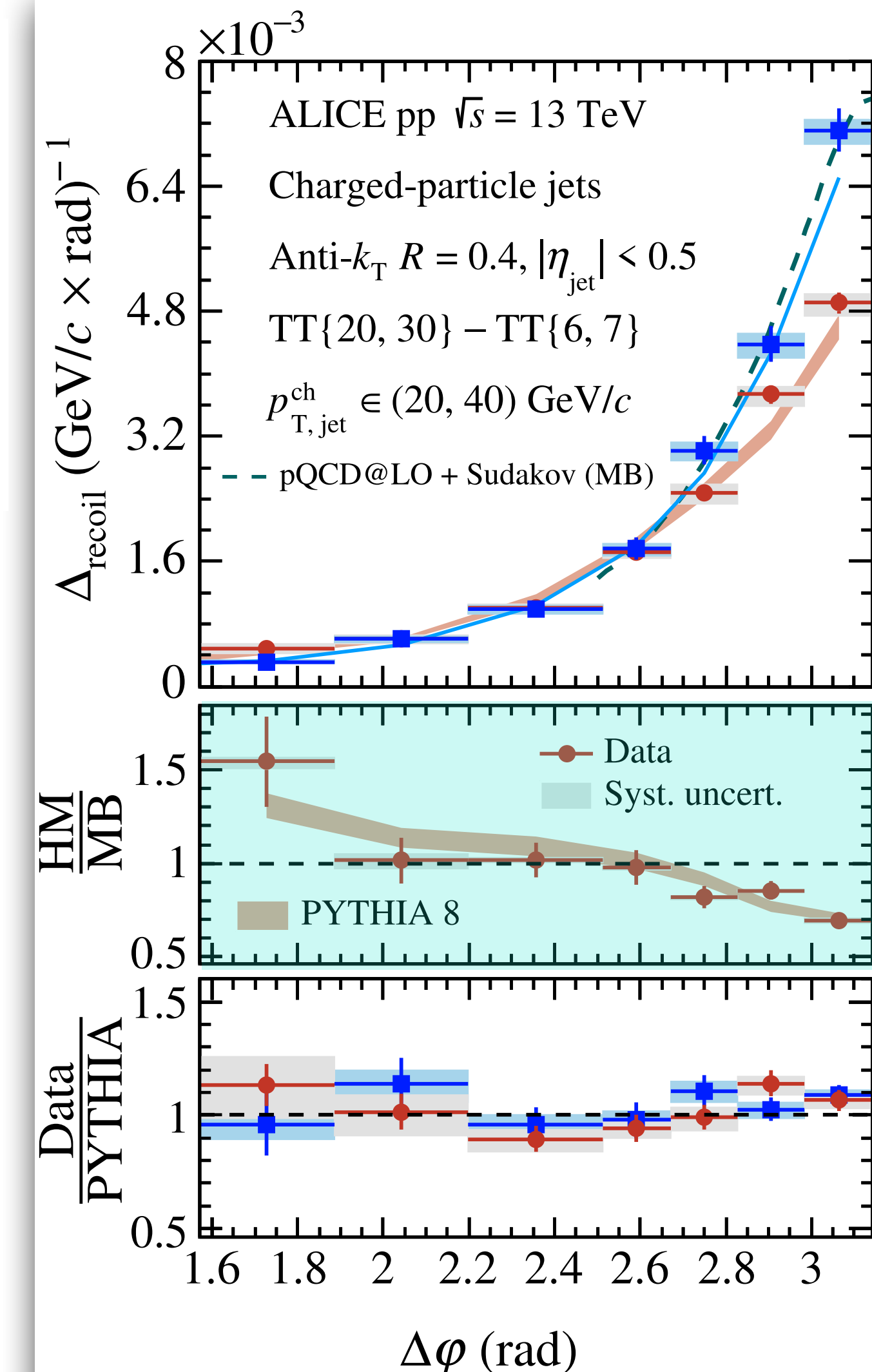
■ MB

● HM

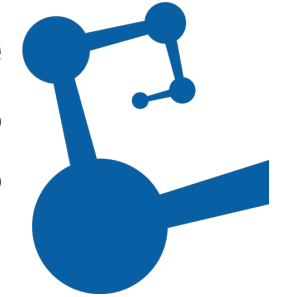
PYTHIA 8:

— MB

■ HM

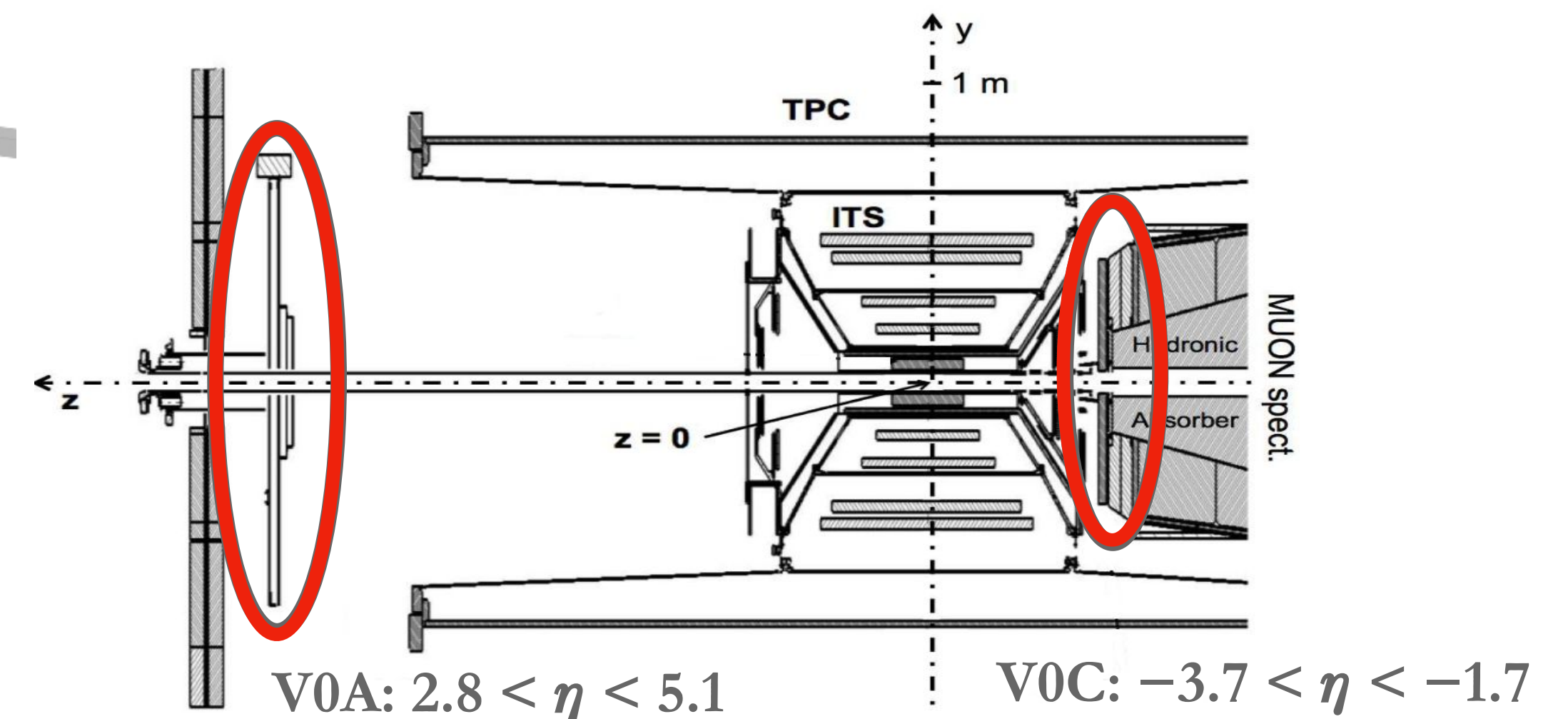
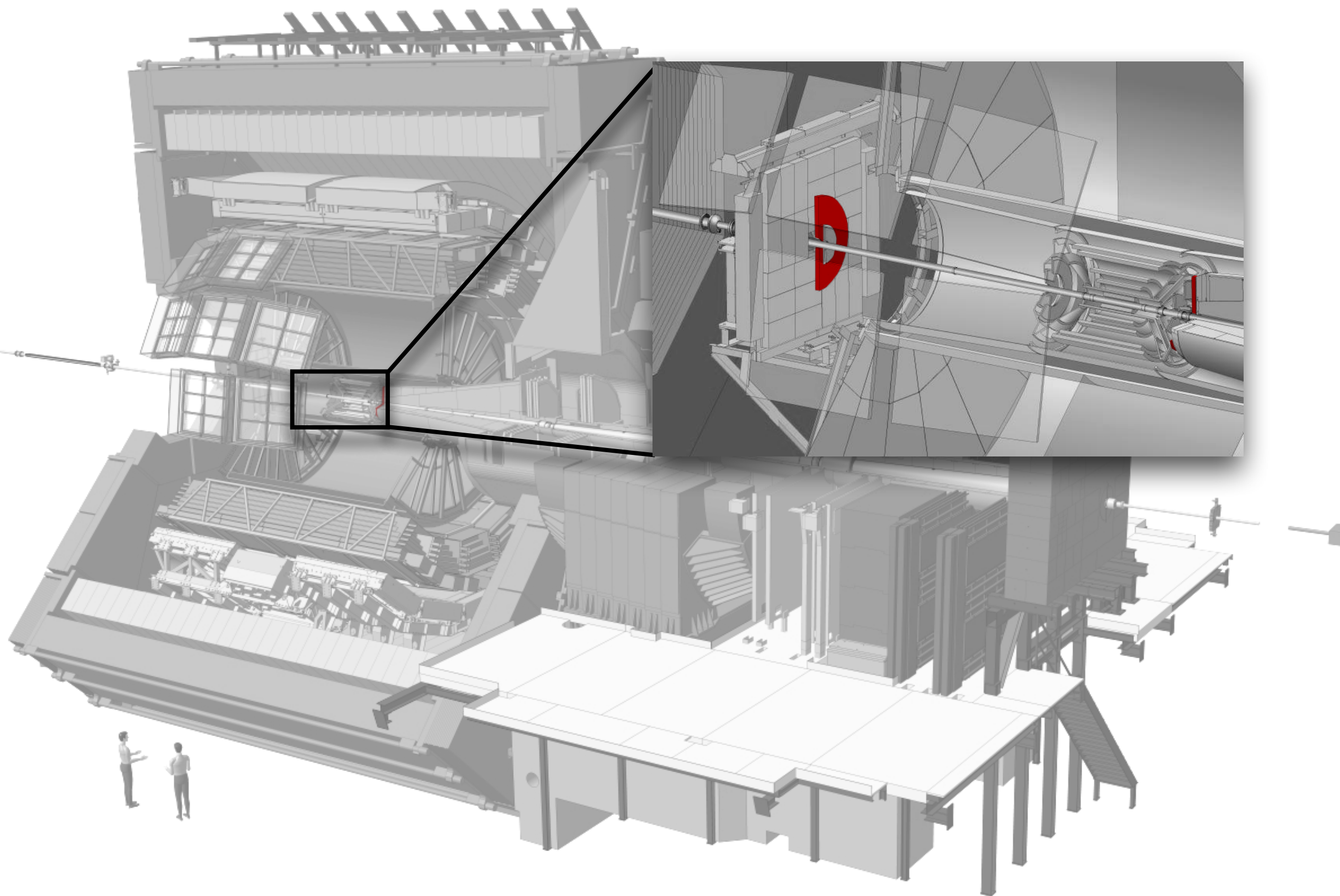


V0M estimator



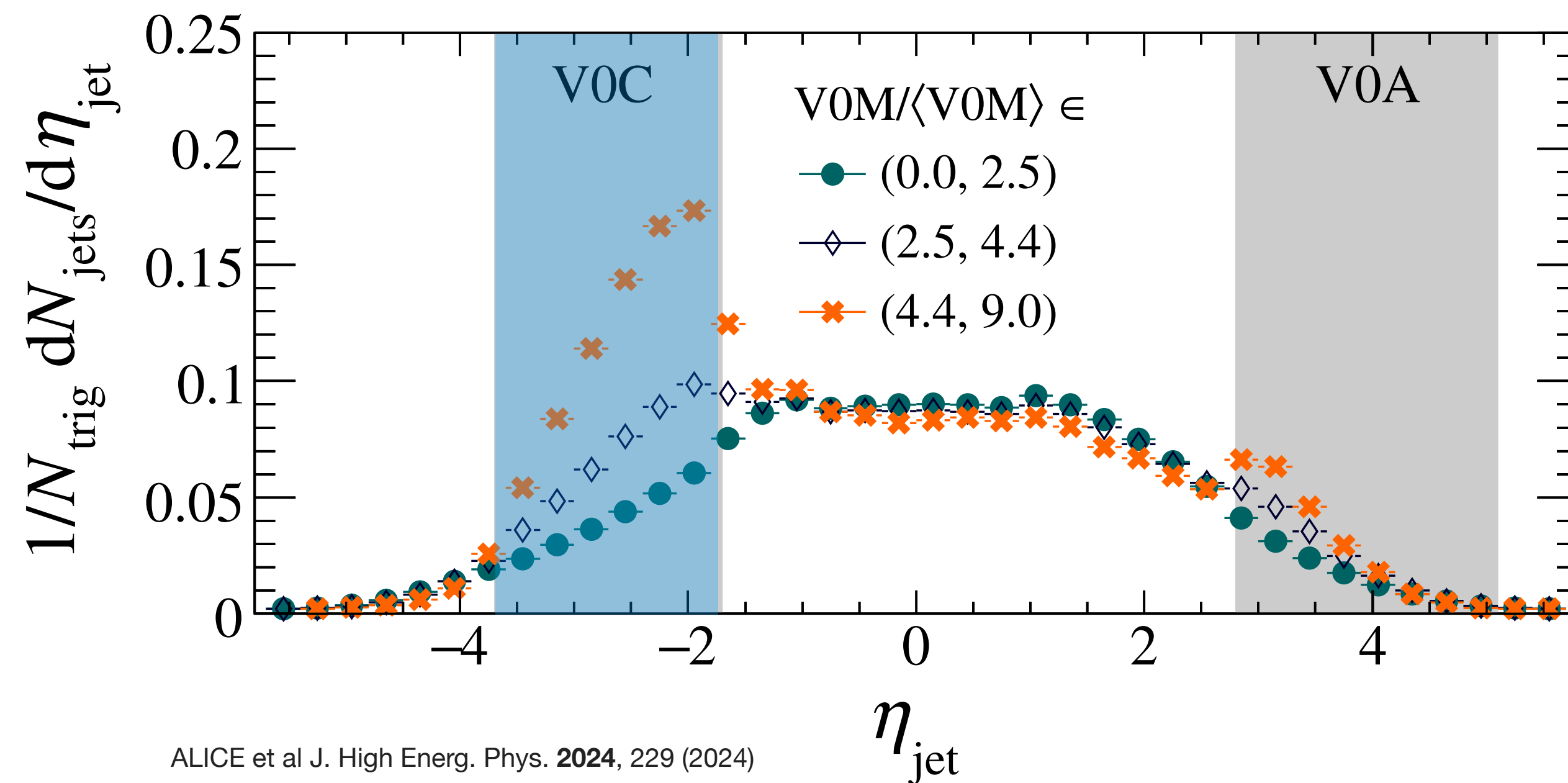
The selection of high-multiplicity events is based on the signal detected at VZERO

- Minimum Bias (**MB**): at least one temporal coincidence of signals at V0A and V0C
- High Multiplicity (**HM**): $HM \geq 5\langle V0M \rangle$



Bias toward local fluctuations

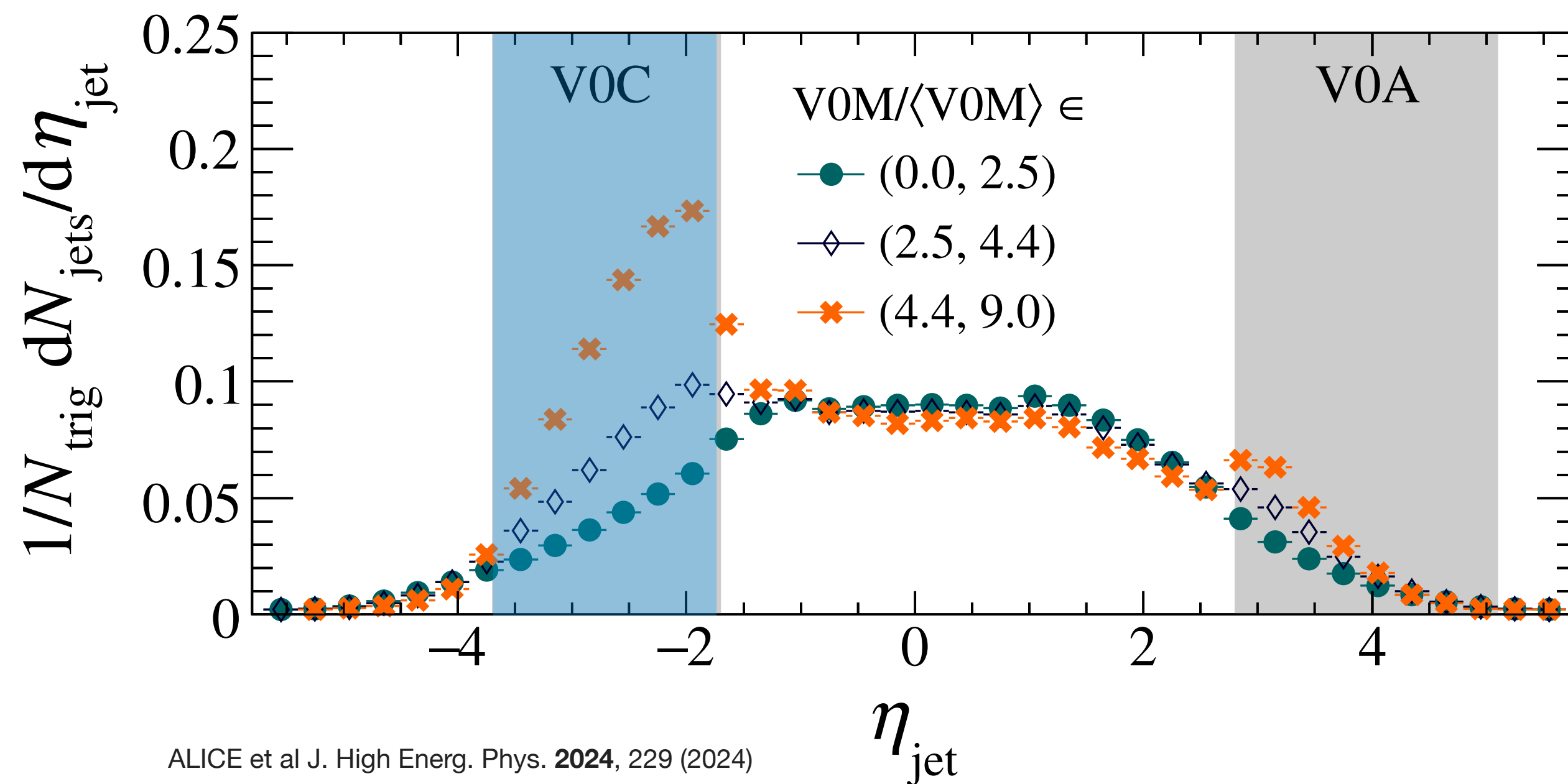
Recoil jet eta distributions for different activity based on the V0M



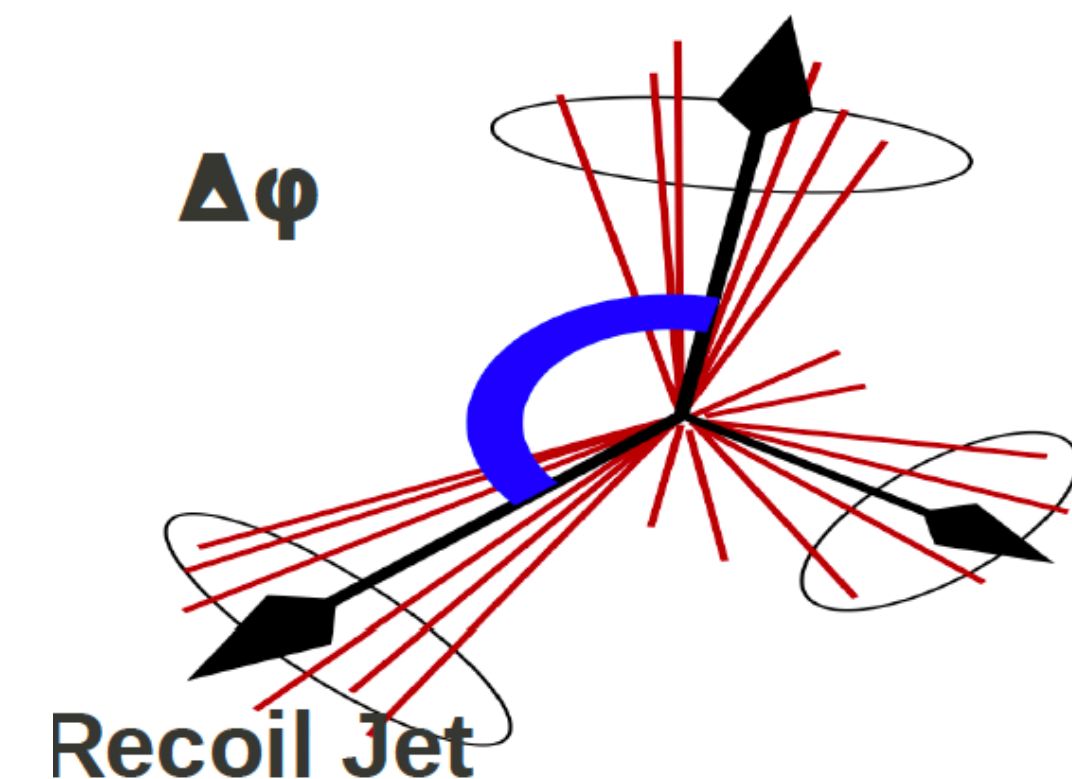
- The **HM requirement** preferably selects events with a recoil jet in the **V0C acceptance**

Bias toward local fluctuations

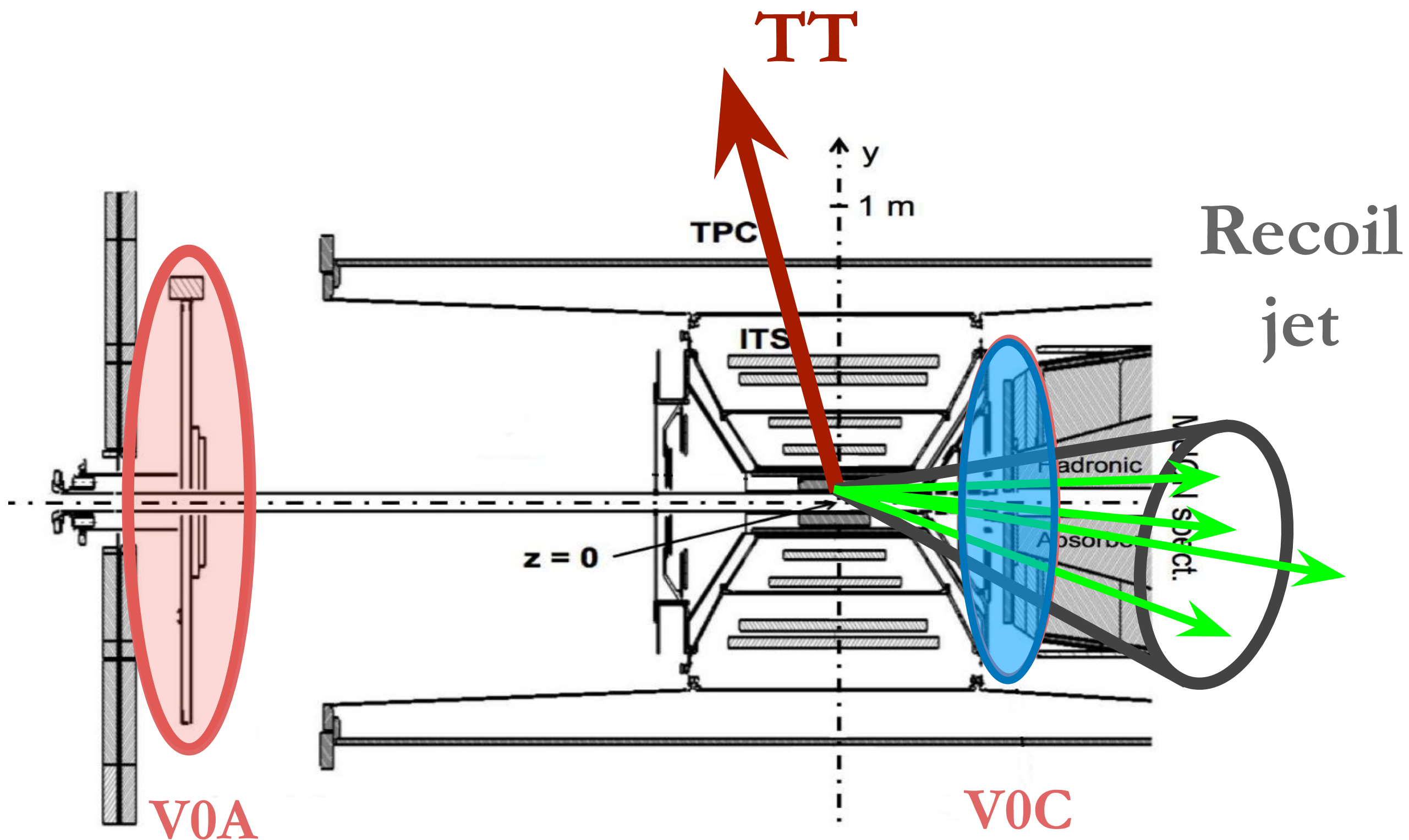
Recoil jet eta distributions for different activity based on the V0M



- The HM requirement preferably selects events with a recoil jet in the V0C acceptance
- These jets come from higher-order processes and **have broader distribution in $\Delta\varphi$ LO jets**



Bias toward local fluctuations

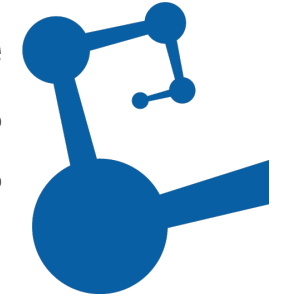


- The HM requirement preferably selects events with a recoil jet in the V0C acceptance
- These jets come from higher-order processes and have broader distribution in $\Delta\varphi$ LO jets
- Lower enhancement in **V0A** is caused by the asymmetric coverage of V0 array

Event classifiers study

- This result raises the question of whether alternative event classifiers can mitigate this bias
- Motivated by this, a comparison between the most used event classifiers at the LHC was performed

Event classifiers study



- This result raises the question of whether alternative event classifiers can mitigate this bias
- Motivated by this, a comparison between the most used event classifiers at the LHC was performed

Which estimator selects high-activity events without simultaneously biasing the sample?

- N_{ch}
- VOM
- Spherocity
- Sphericity
- R_T
- Flattenicity

OPEN ACCESS

IOP Publishing

Journal of Physics G: Nuclear and Particle Physics

J. Phys. G: Nucl. Part. Phys. **52** (2025) 095001 (15pp)

<https://doi.org/10.1088/1361-6471/ae02ac>

Investigating the most active *pp* collisions (top 0.1%) using the tools developed by experiments at the LHC

Jesús Eduardo Muñoz Méndez^{*}  and Antonio Ortiz

Instituto de Ciencias Nucleares, UNAM, Apartado Postal 70-543, Coyoacán, 04510, Mexico City, Mexico

Event classifiers

Event classifiers highlight a desired characteristic of a collision

Event classifier	Symbol	η coverage	φ coverage (rad)	is η used ?	is φ used ?
Mid-pseudorapidity mult.	N_{ch}	$-0.8 < \eta < 0.8$	2π	yes	no
Sphericity	S_{T}	$-0.8 < \eta < 0.8$	2π	yes	no
Spherocity	S_0	$-0.8 < \eta < 0.8$	2π	yes	no
Rel. trans. activity classifier	R_{T}	$-0.8 < \eta < 0.8$	$\pi/3 < \Delta\varphi < 2\pi/3$	yes	yes
Forward multiplicity	V0M	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	no
Flattenicity	$1-\rho_{\text{nch}}$	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	yes

The most basic classifiers are based on **collision activity**, though more recent tools further distinguish **event topology**

Event classifiers

Event classifiers highlight a desired characteristic of a collision

Event classifier	Symbol	η coverage	φ coverage (rad)	is η used ?	is φ used ?
Mid-pseudorapidity mult.	N_{ch}	$-0.8 < \eta < 0.8$	2π	yes	no
Sphericity	S_{T}	$-0.8 < \eta < 0.8$	2π	yes	no
Spherocity	S_0	$-0.8 < \eta < 0.8$	2π	yes	no
Rel. trans. activity classifier	R_{T}	$-0.8 < \eta < 0.8$	$\pi/3 < \Delta\varphi < 2\pi/3$	yes	yes
Forward multiplicity	V0M	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	no
Flattenicity	$1-\rho_{\text{nch}}$	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	yes

- V0M and flattenicity are calculated in the forward pseudorapidity

Event classifiers

Event classifiers highlight a desired characteristic of a collision

Event classifier	Symbol	η coverage	φ coverage (rad)	is η used ?	is φ used ?
Mid-pseudorapidity mult.	N_{ch}	$-0.8 < \eta < 0.8$	2π	yes	no
Sphericity	S_{T}	$-0.8 < \eta < 0.8$	2π	yes	no
Spherocity	S_0	$-0.8 < \eta < 0.8$	2π	yes	no
Rel. trans. activity classifier	R_{T}	$-0.8 < \eta < 0.8$	$\pi/3 < \Delta\varphi < 2\pi/3$	yes	yes
Forward multiplicity	V0M	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	no
Flattenicity	$1-\rho_{\text{nch}}$	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	yes

- V0M and flattenicity are calculated in the **forward pseudorapidity**
- Flattenicity uses information both from **pseudorapidity and azimuthal angle**

Event classifiers

Event classifiers highlight a desired characteristic of a collision

Event classifier	Symbol	η coverage	φ coverage (rad)	is η used ?	is φ used ?
Mid-pseudorapidity mult.	N_{ch}	$-0.8 < \eta < 0.8$	2π	yes	no
Sphericity	S_T	$-0.8 < \eta < 0.8$	2π	yes	no
Spherocity	S_0	$-0.8 < \eta < 0.8$	2π	yes	no
Rel. trans. activity classifier	R_T	$-0.8 < \eta < 0.8$	$\pi/3 < \Delta\varphi < 2\pi/3$	yes	yes
Forward multiplicity	V0M	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	no
Flattenicity	$1-\rho_{\text{nch}}$	$-3.7 < \eta < -1.7$ and $2.8 < \eta < 5.1$	2π	yes	yes

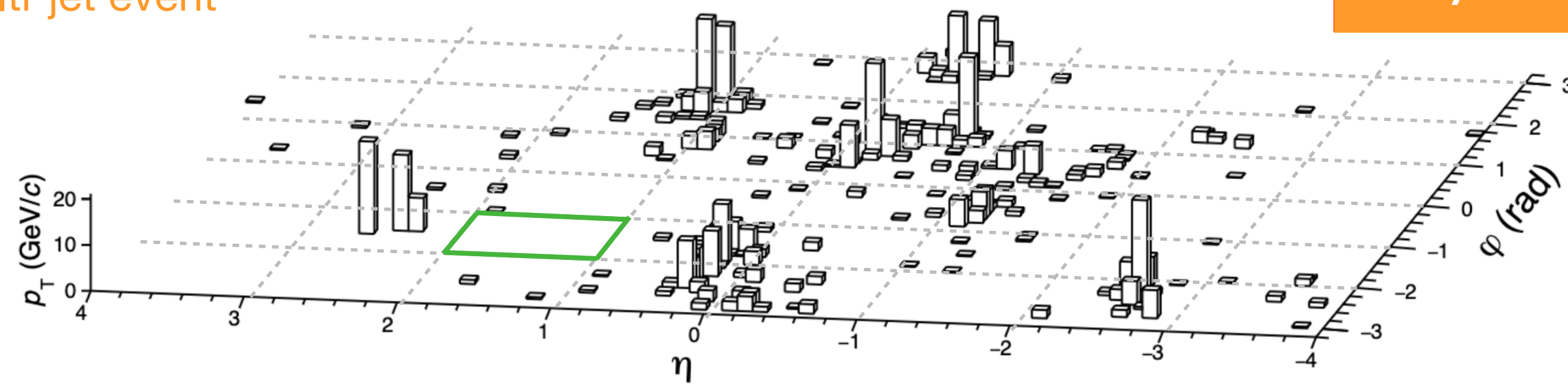
- V0M and flattenicity are calculated in the **forward pseudorapidity**
- Flattenicity uses information both from **pseudorapidity and azimuthal angle**
- In contrast, the other estimators (N_{ch} , R_T , S_T and S_0) are calculated at **mid-pseudorapidity**

Flattenicity

Multi-jet event

PYTHIA 8.303 (Monash 2013), pp $\sqrt{s} = 13$ TeV, $N_{\text{mpi}}=1, N_{\text{ch}}=235$

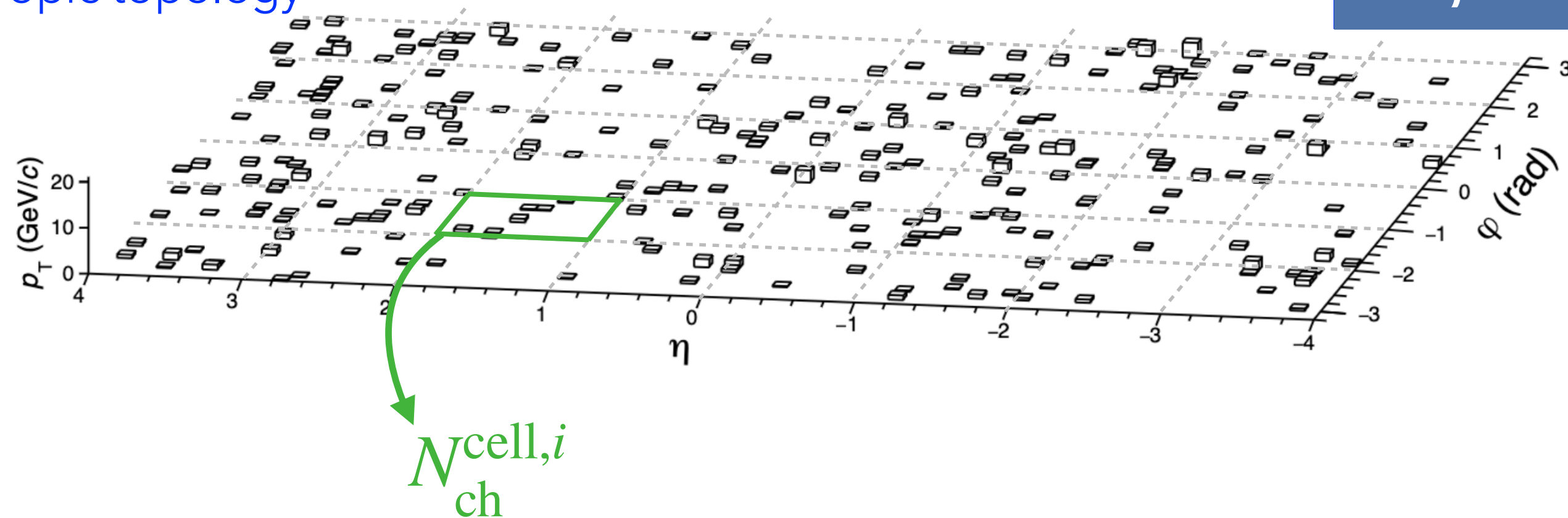
$1 - \rho \rightarrow 0$



Isotropic topology

PYTHIA 8.303 (Monash 2013), pp $\sqrt{s} = 13$ TeV, $N_{\text{mpi}}=22, N_{\text{ch}}=305$

$1 - \rho \rightarrow 1$



Event-by-event, the relative standard deviation defines flattenicity as follows

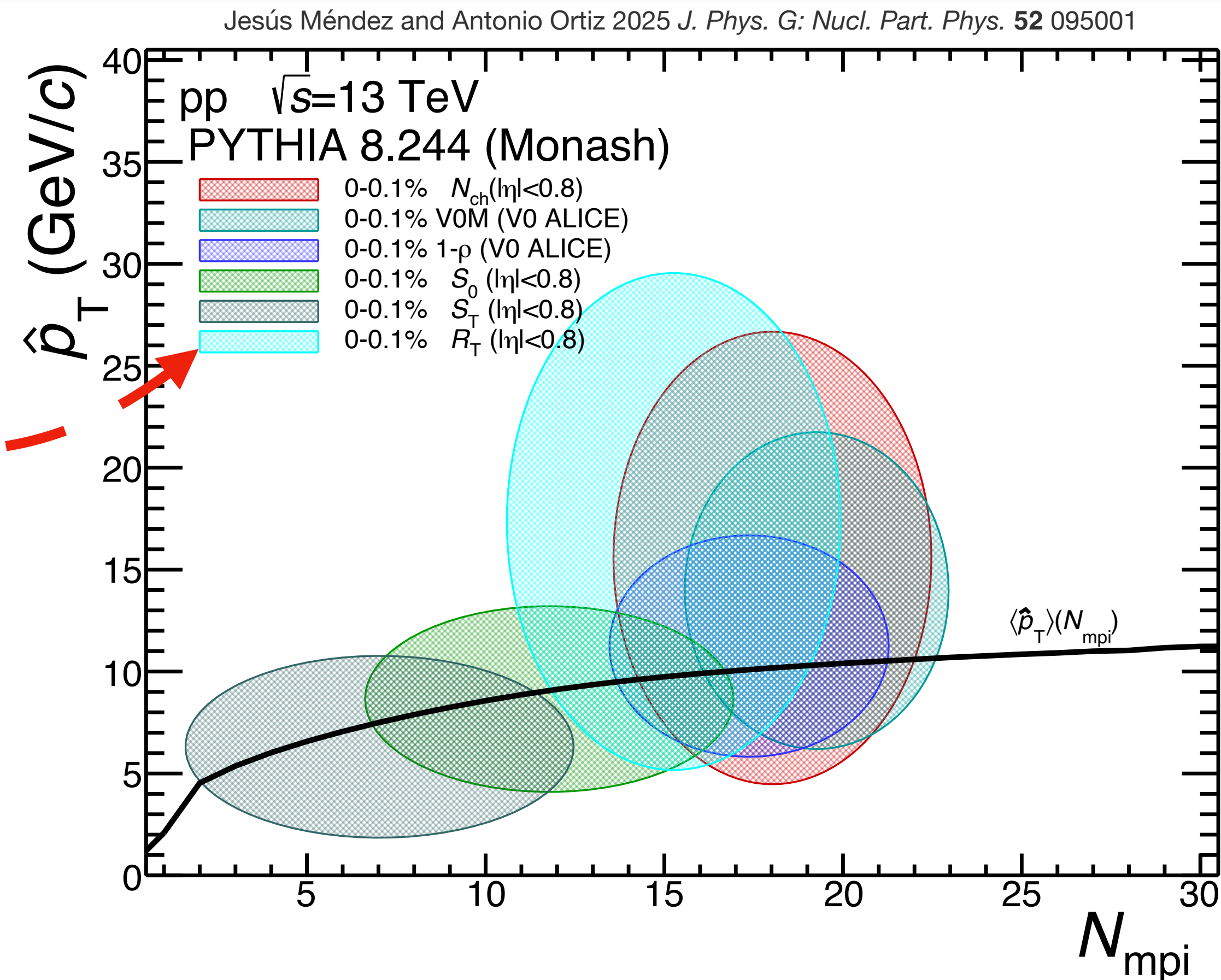
$$\rho = \frac{\sqrt{\sum_i^{N_{\text{cell}}} (N_{\text{ch}}^{\text{cell},i} - \langle N_{\text{ch}}^{\text{cell}} \rangle)^2 / N_{\text{cell}}^2}}{\langle N_{\text{ch}}^{\text{cell}} \rangle}$$

$1 - \rho \rightarrow 0$: low-multiplicity events

$1 - \rho \rightarrow 1$: high- multiplicity events

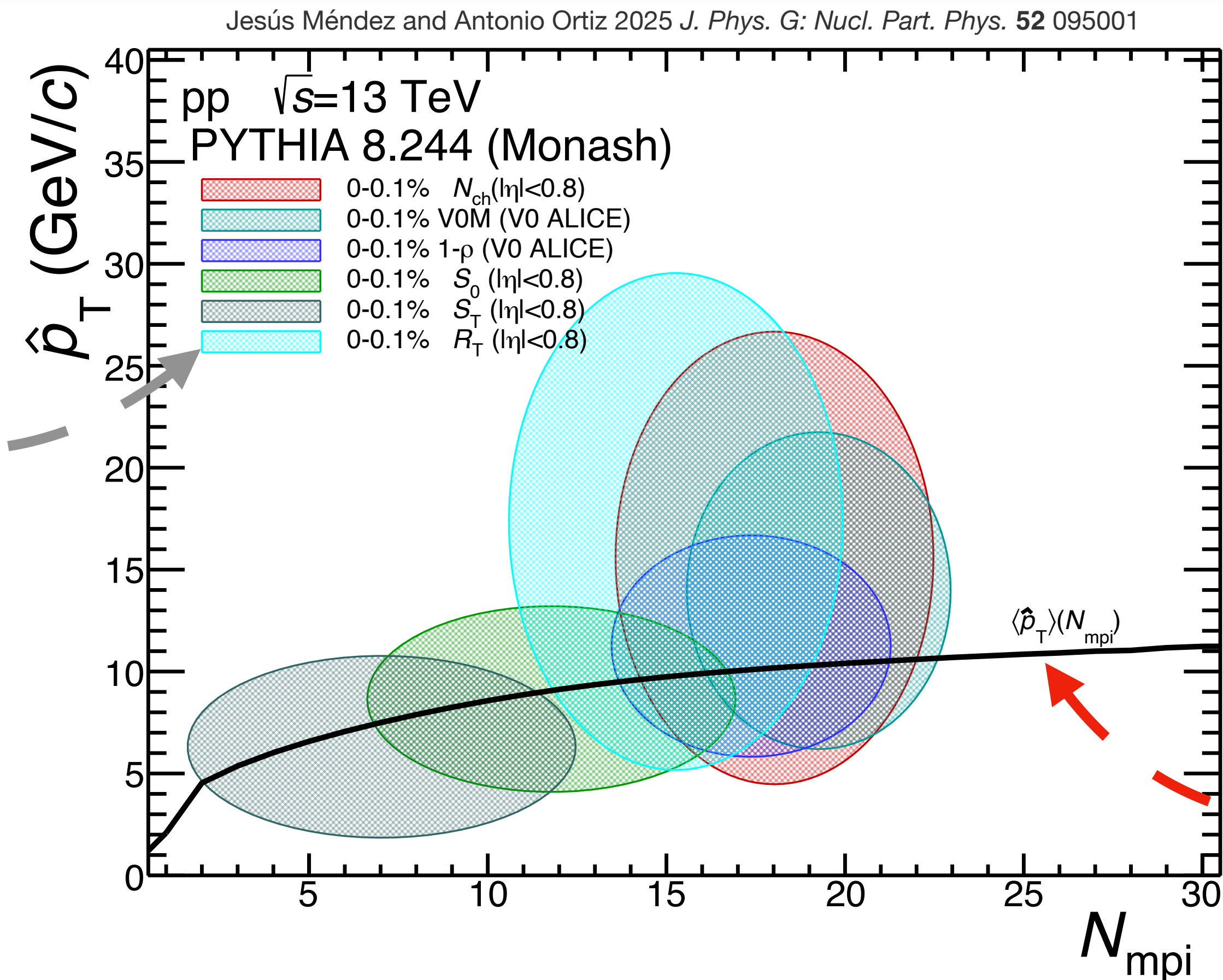
Phase-space

One-sigma area
covered by the
classifier



Phase-space

One-sigma area
covered by the
classifier

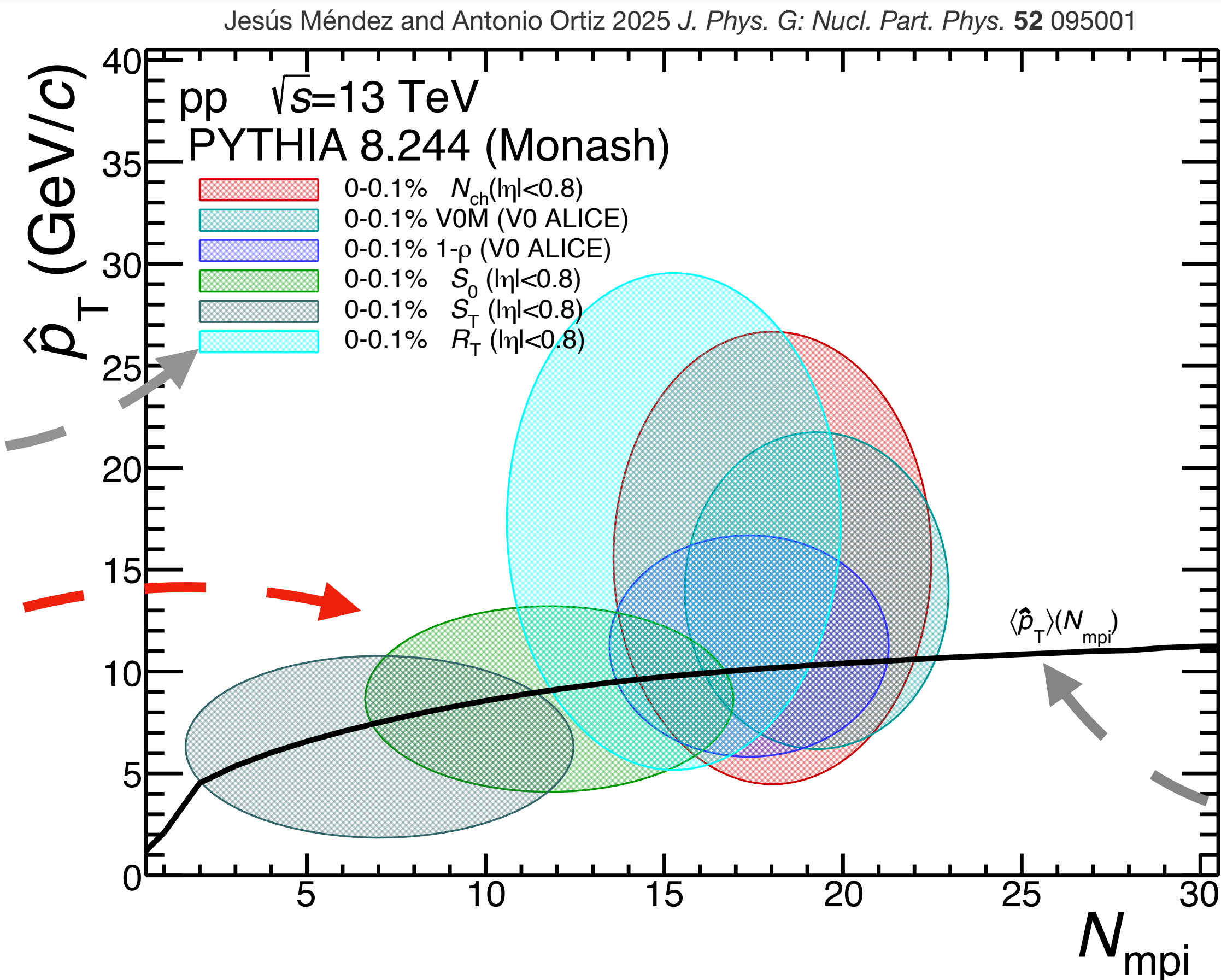


Average
behavior

Phase-space

One-sigma area
covered by the
classifier

Narrower coverage
from event-shape
classifiers



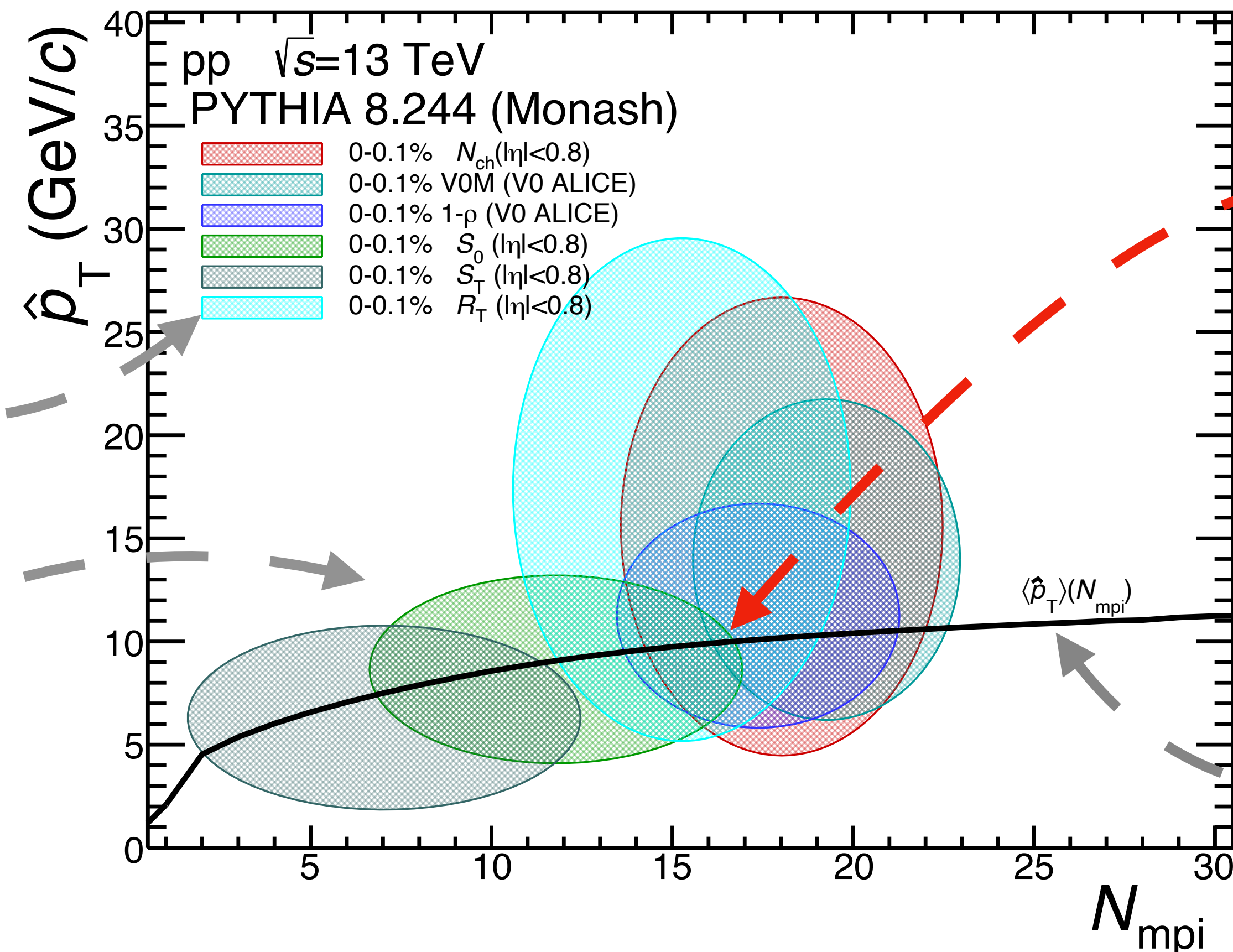
Average
behavior

Phase-space

Jesús Méndez and Antonio Ortiz 2025 *J. Phys. G: Nucl. Part. Phys.* **52** 095001

One-sigma area
covered by the
classifier

Narrower coverage
from event-shape
classifiers

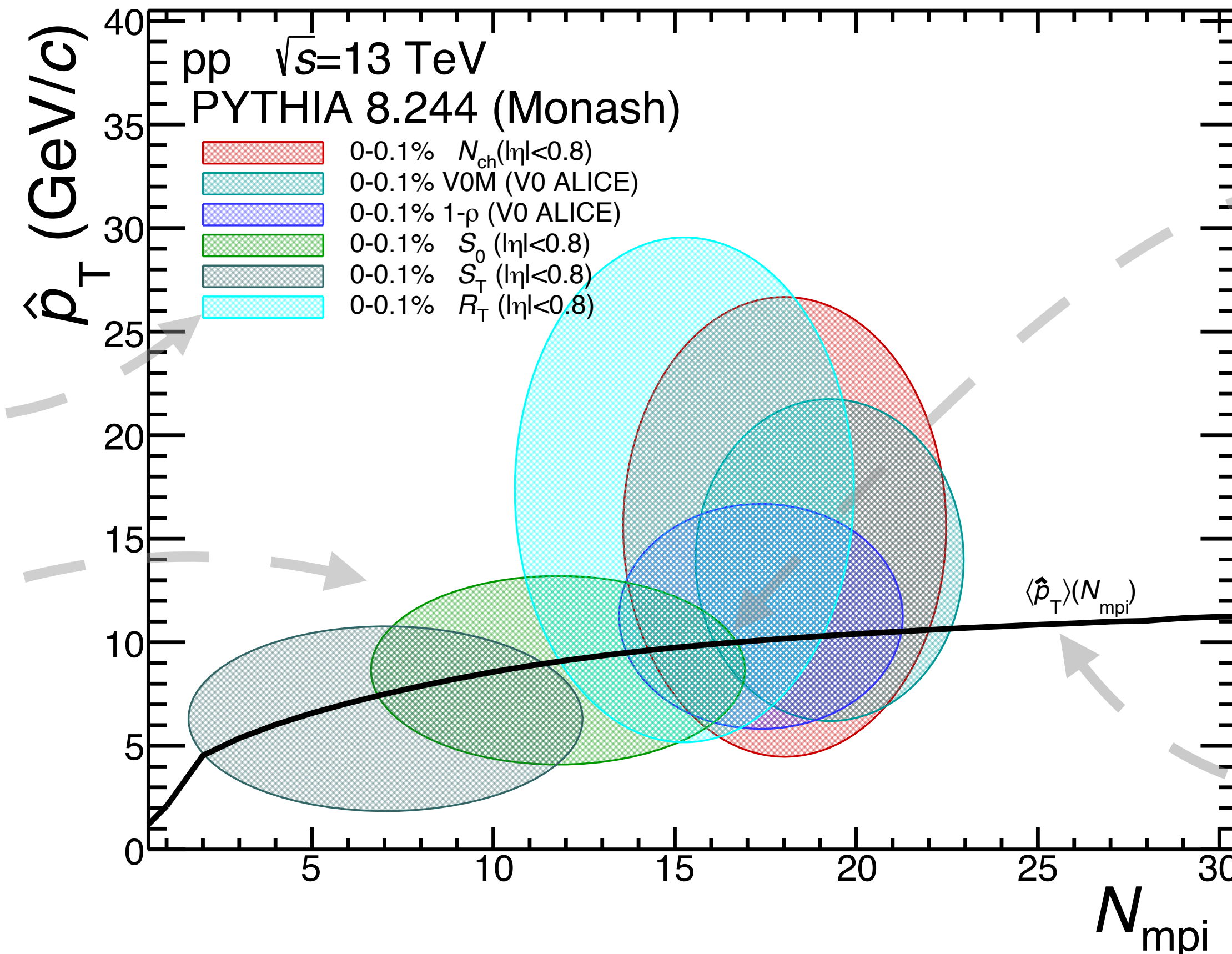


Small overlap
among classifiers

Average
behavior

Phase-space

Jesús Méndez and Antonio Ortiz 2025 *J. Phys. G: Nucl. Part. Phys.* **52** 095001



One-sigma area
covered by the
classifier

Small overlap
among classifiers

Narrower coverage
from event-shape
classifiers

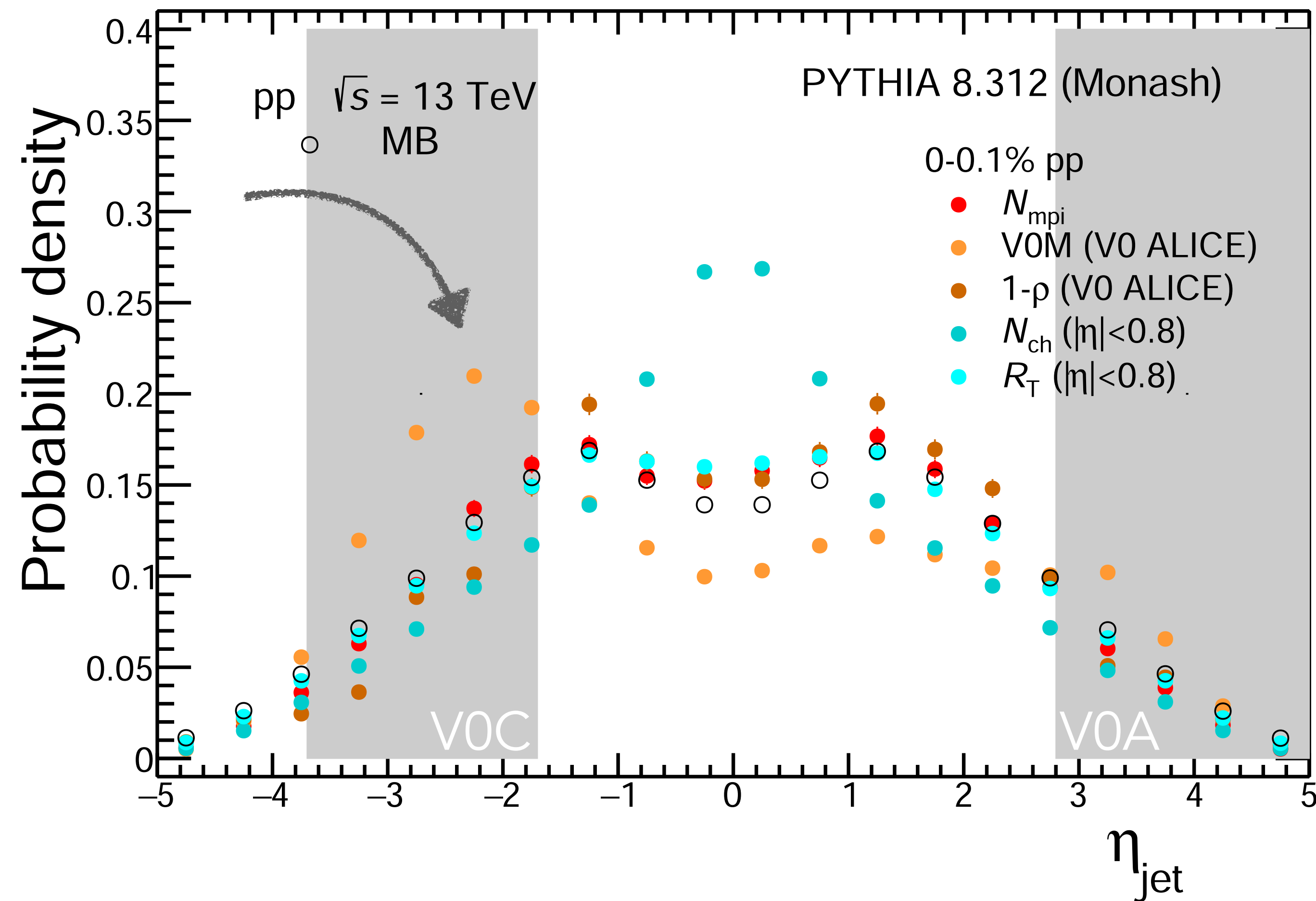
Average
behavior

Each classifier probes a different slice of the collision landscape

Therefore, a direct comparison of the result obtained with different classifiers is not advisable

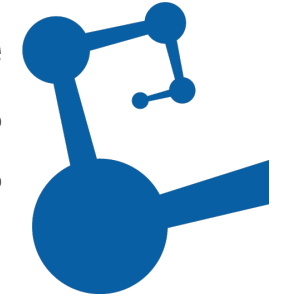
Bias toward local fluctuations

Jesús Méndez and Antonio Ortiz 2025 *J. Phys. G: Nucl. Part. Phys.* **52** 095001

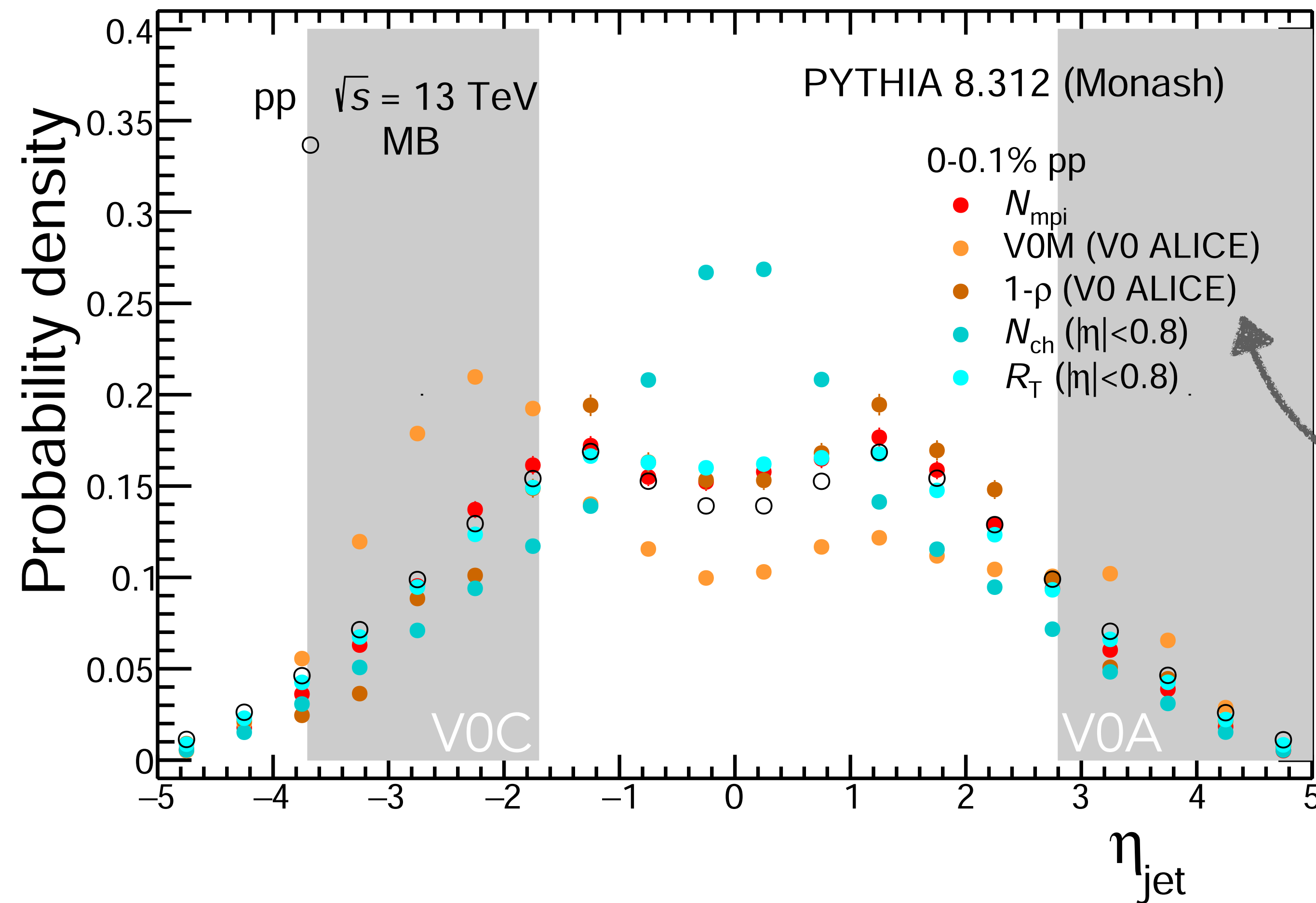


- The **V0M** preferably selects events with a recoil jet in the **V0C acceptance**

Bias toward local fluctuations



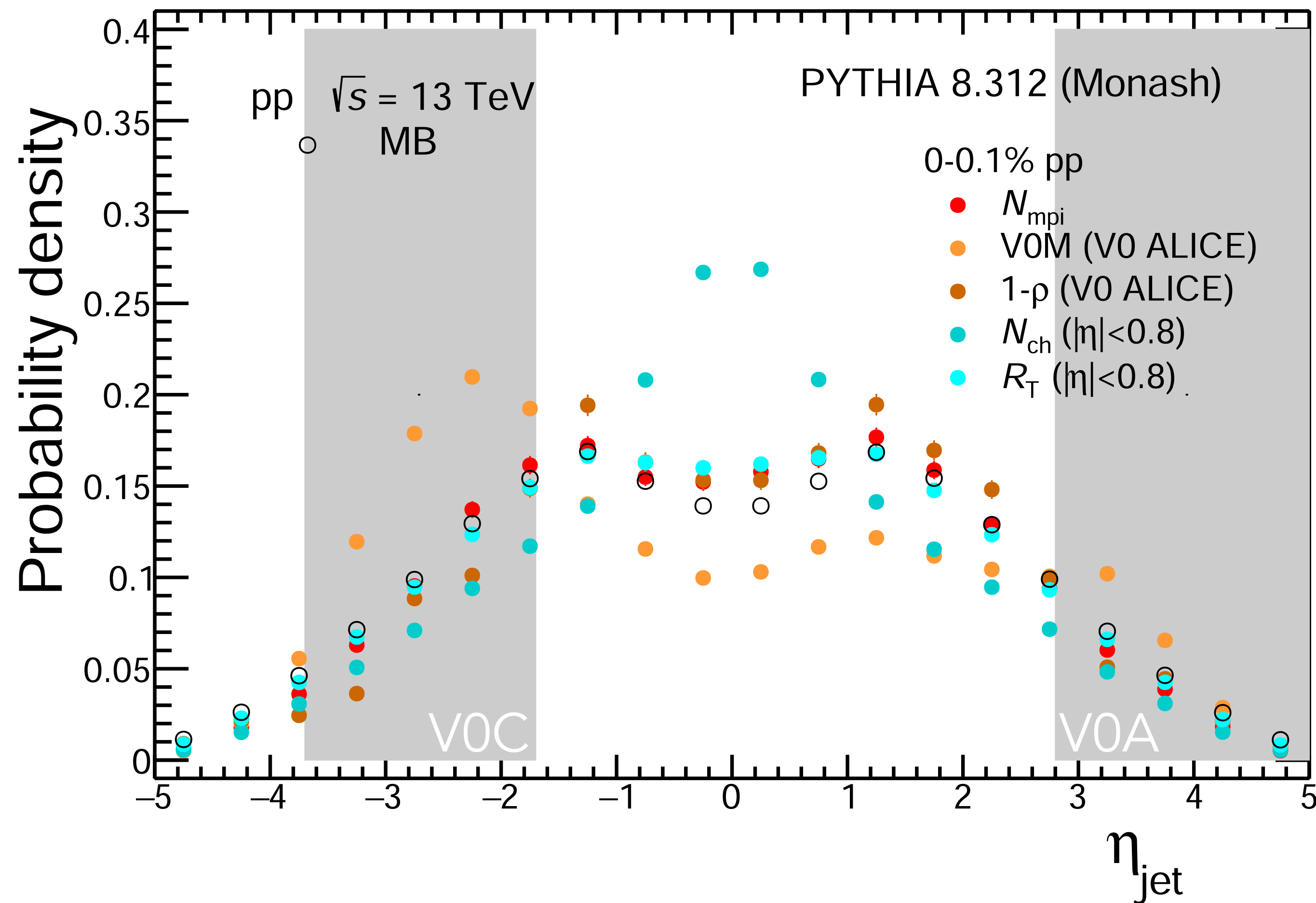
Jesús Méndez and Antonio Ortiz 2025 *J. Phys. G: Nucl. Part. Phys.* **52** 095001



- The **V0M** preferably selects events with a recoil jet in the **V0C acceptance**
- This bias is absent in events triggered with **flattenicity** ($1 - \rho$)

Bias toward local fluctuations

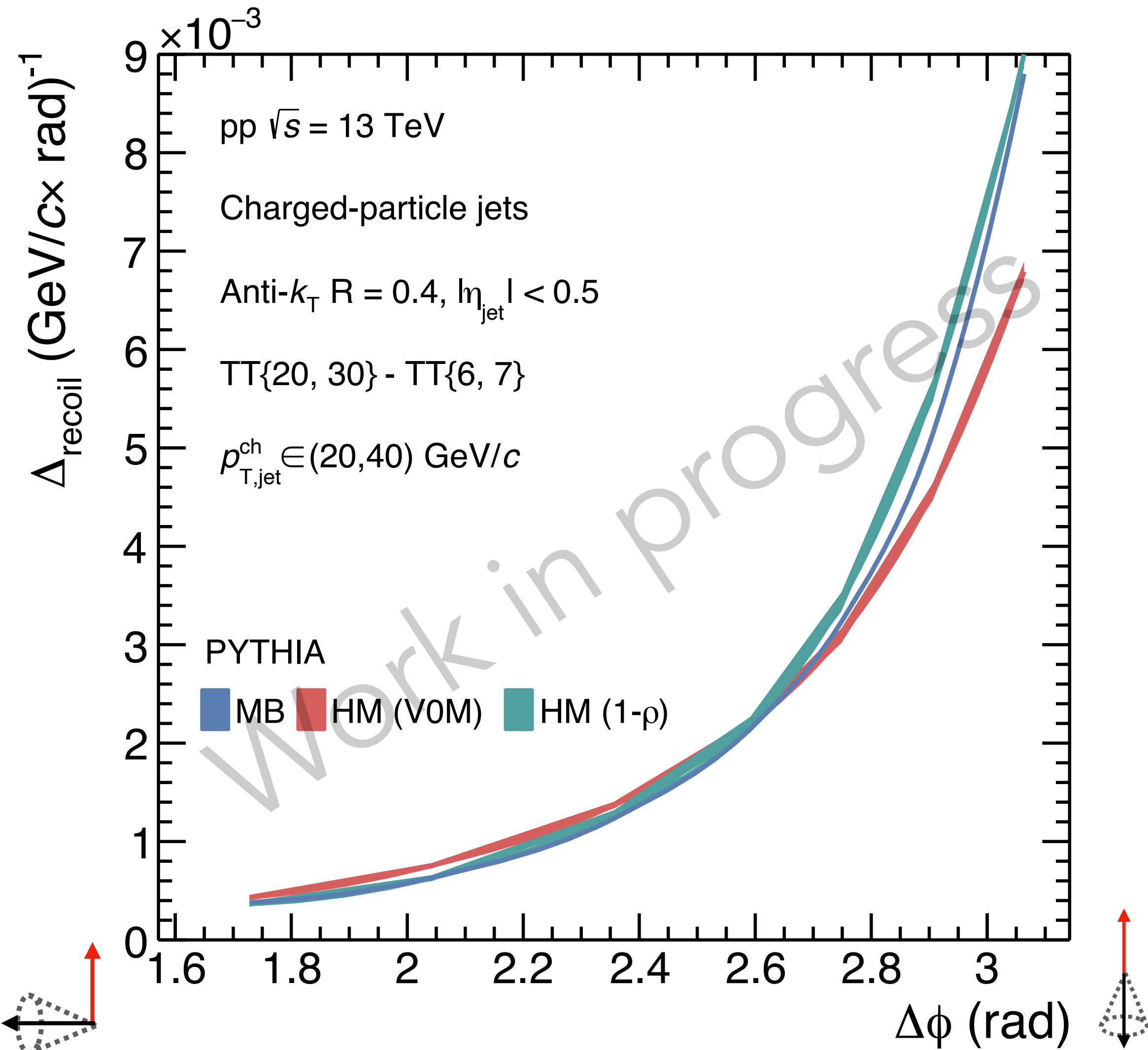
Jesús Méndez and Antonio Ortiz 2025 *J. Phys. G: Nucl. Part. Phys.* **52** 095001



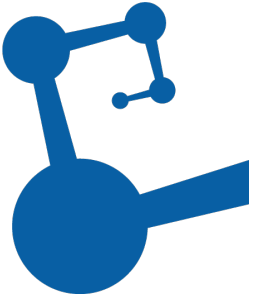
- The **V0M** preferably selects events with a recoil jet in the **V0C acceptance**
- This bias is absent in events triggered with **flattenicity** ($1 - \rho$)
- This result encourages the use of flattenicity in jet quenching studies

Does the reported broadening persists once this bias is removed?

Dijet acoplanarity with flattenicity



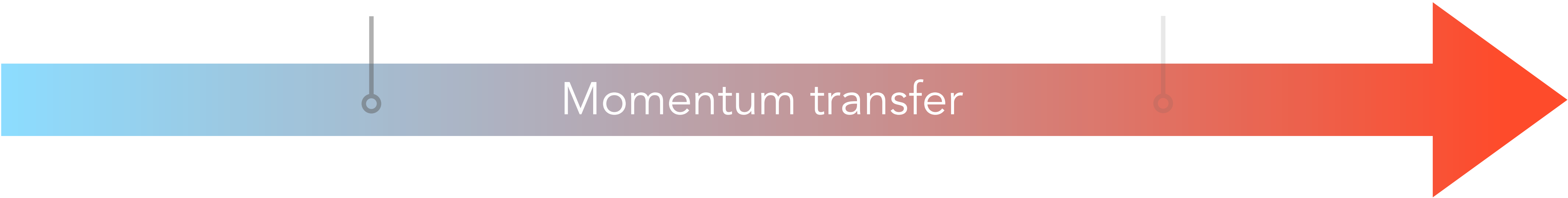
- **Restoring Consistency with MB:**
Results triggered with flattenicity are fully consistent with MB
- **A Robust Proxy for QGP Searches:**
Since flattenicity minimizes jet fragmentation biases, any future broadening observed will be a stronger candidate for true medium-induced jet quenching



Hard and soft processes as probes of the quark-gluon plasma

Underlying event
characterization
in pp collisions at
 $\sqrt{s} = 13.6 \text{ TeV}$

Dijet
acoplanarity
with flattenicity
in pp collisions



Momentum transfer

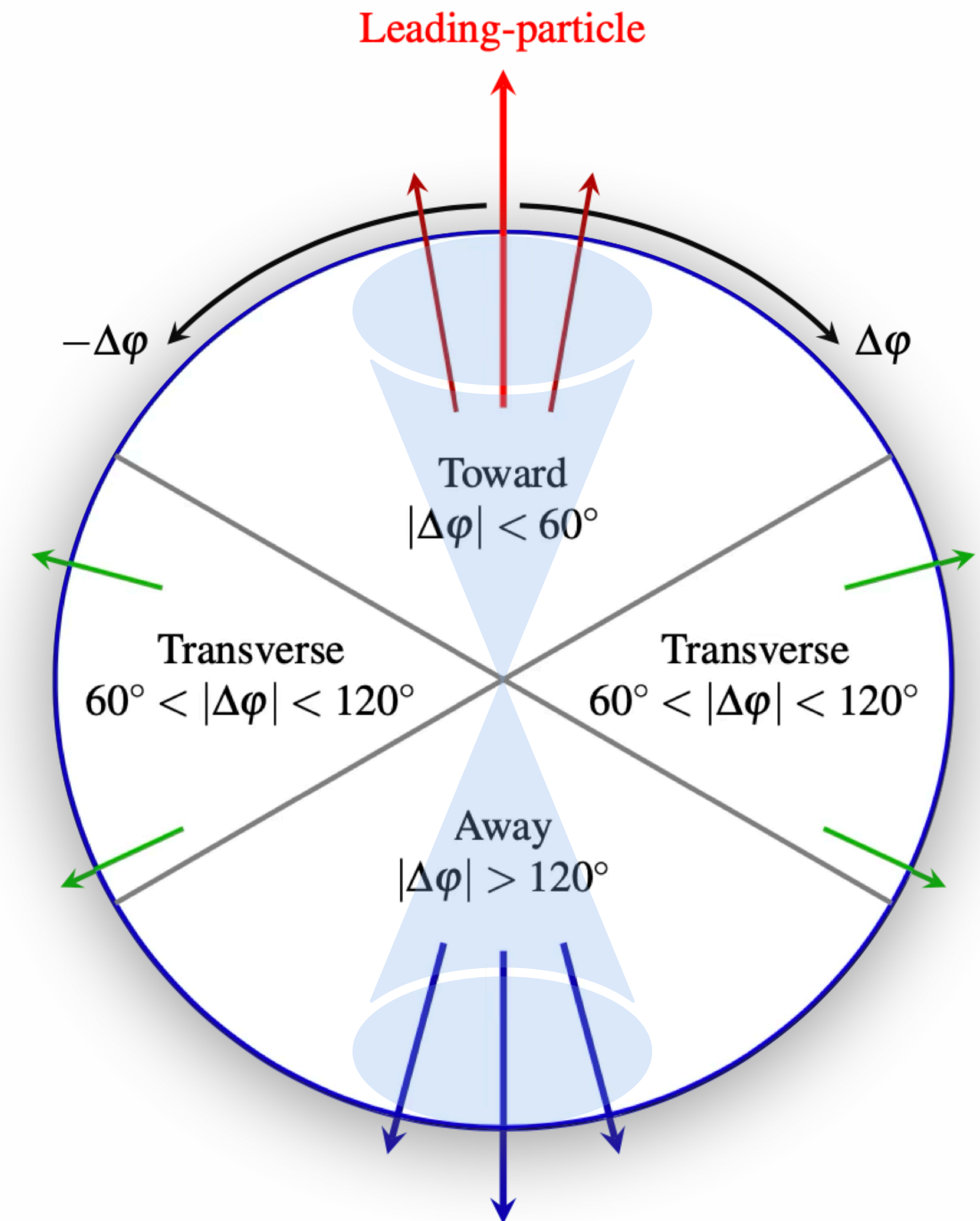
Underlying event (UE)

The particles that are not produced by the main hard scattering constitute the UE, dominated by the multiple-parton interactions (MPI)

The analysis of the UE focuses on the study of charged particles production in three topological regions



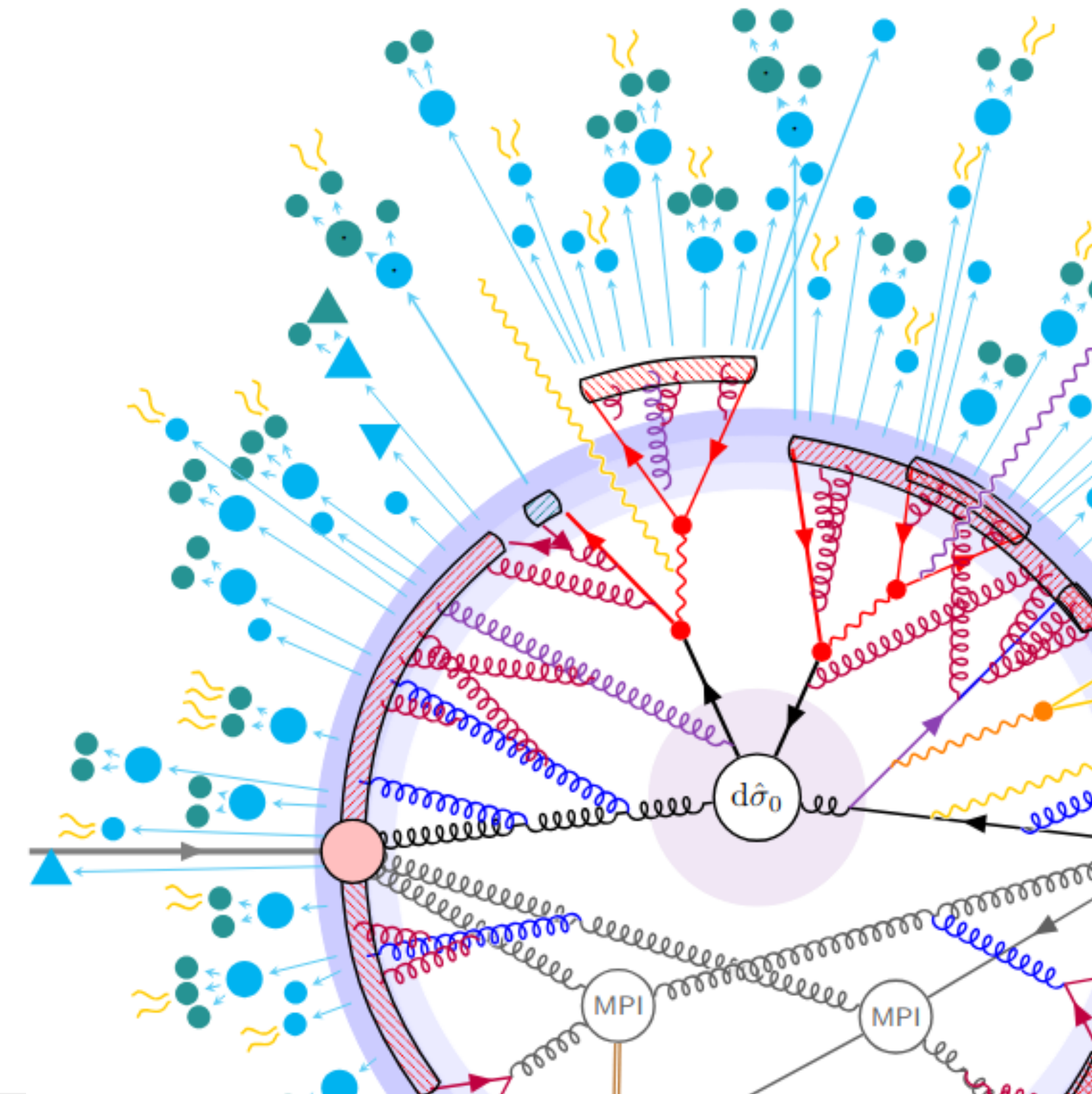
- **Toward** and **away**: dominated by the hard scattering
- **Transverse**: sensitive to the **UE**



Motivation

UE studies are essential to:

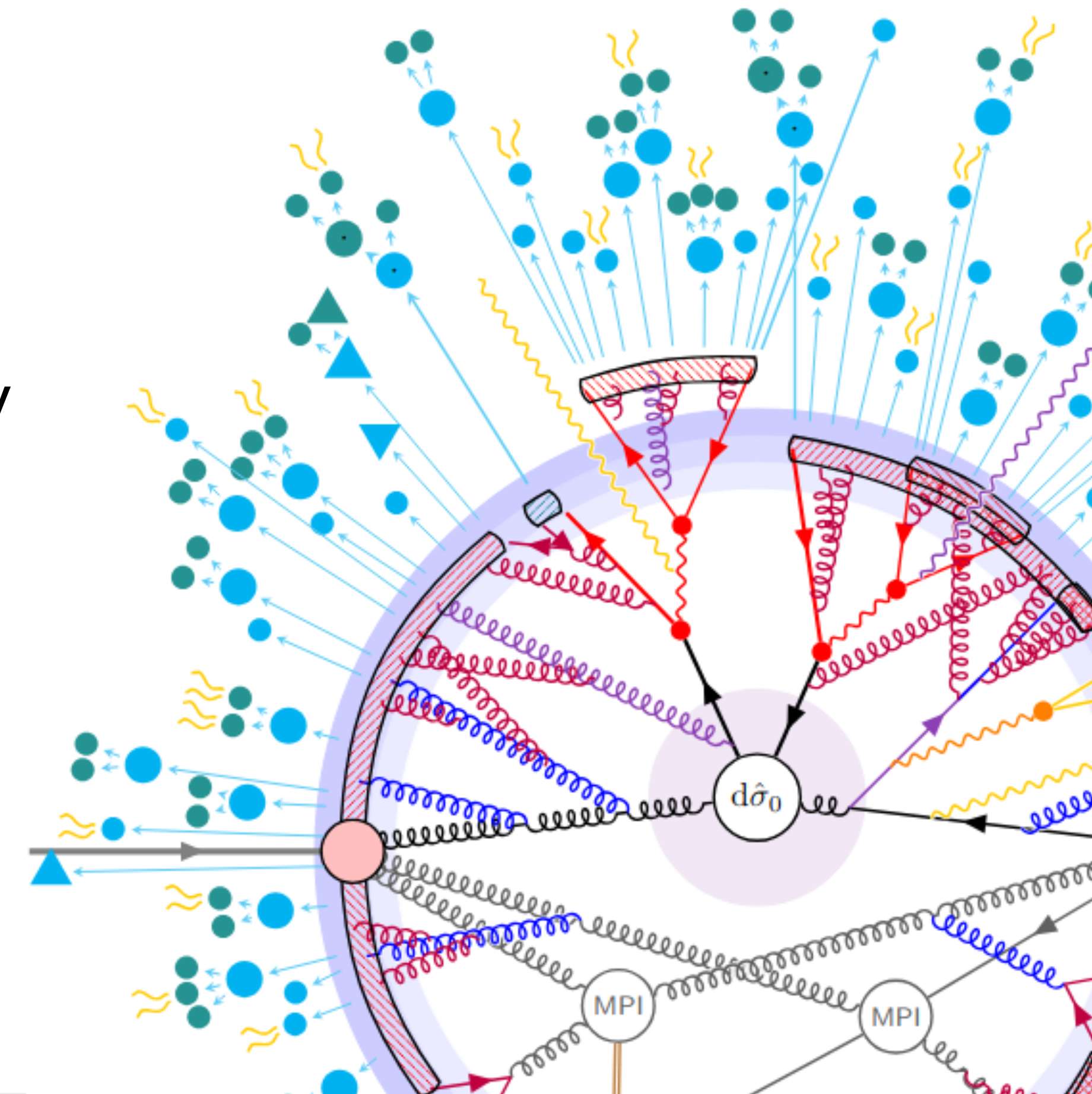
- **tune** Monte Carlo event generators



Motivation

UE studies are essential to:

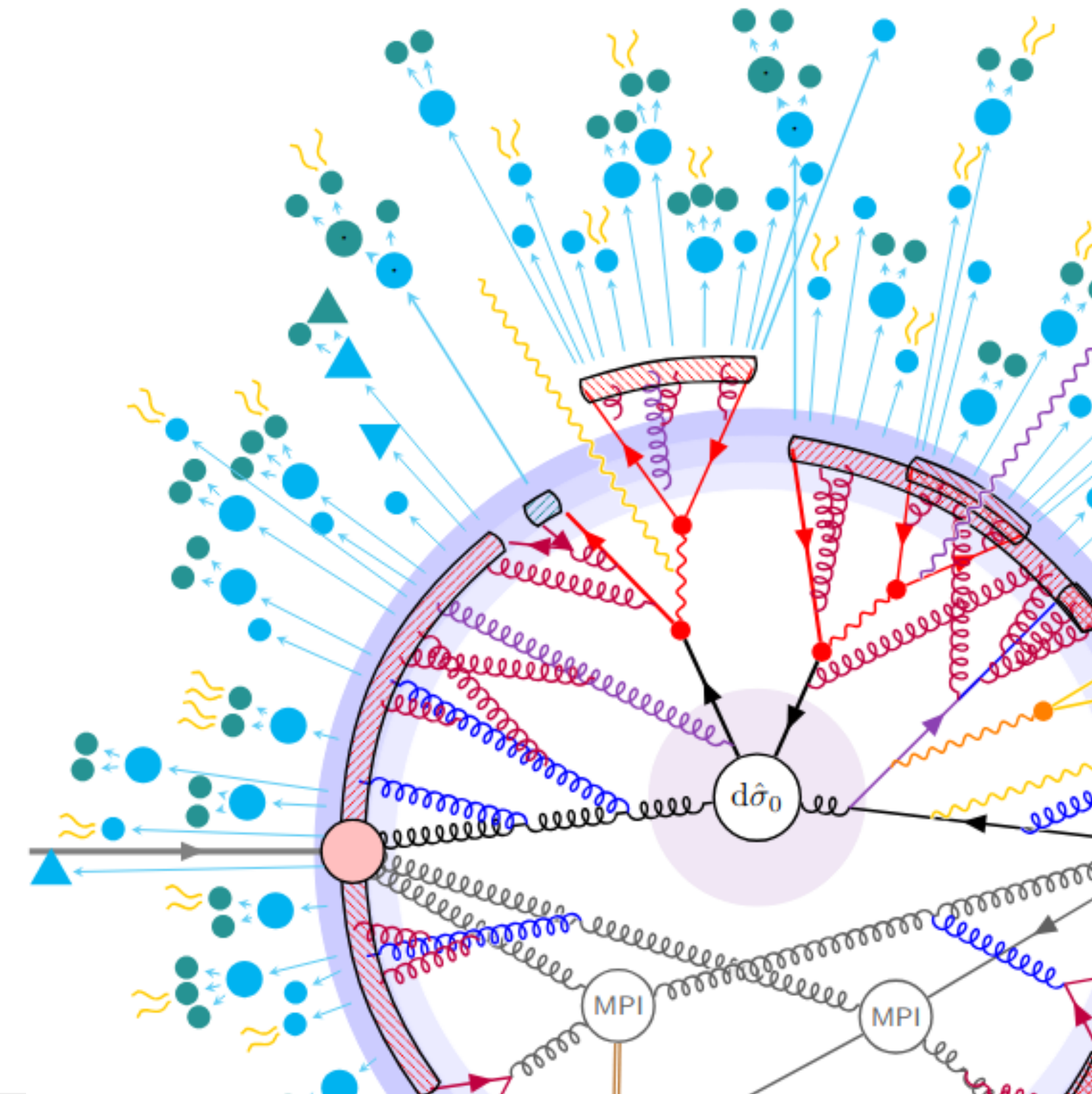
- tune Monte Carlo event generators
- **separate** jet/hard-process signals from soft activity



Motivation

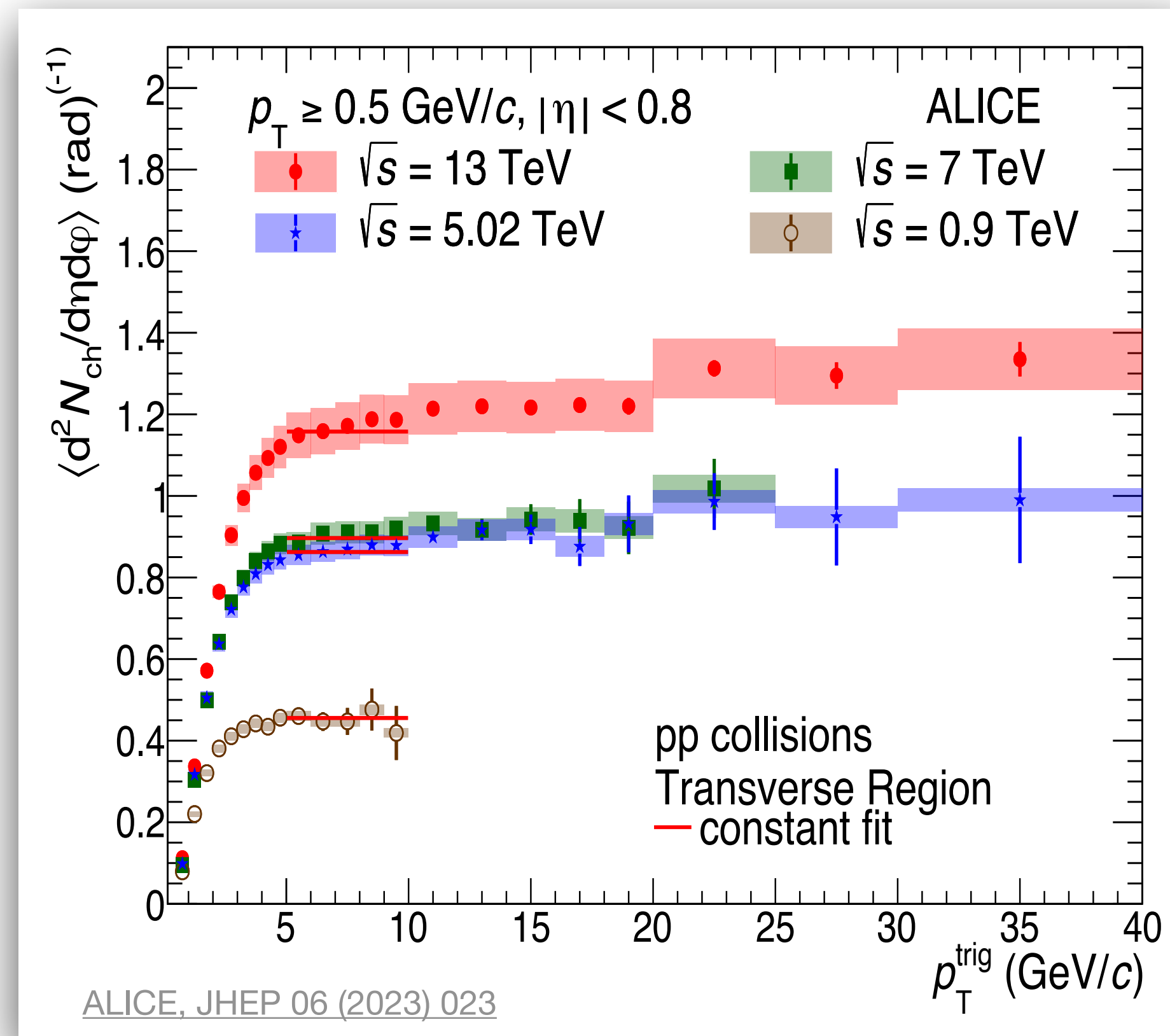
UE studies are essential to:

- tune Monte Carlo event generators
- separate jet/hard-process signals from soft activity
- **understand** whether QGP-like (collective) signatures in small systems originate from a dense, MPI-driven medium or from other effects



Current status and prediction

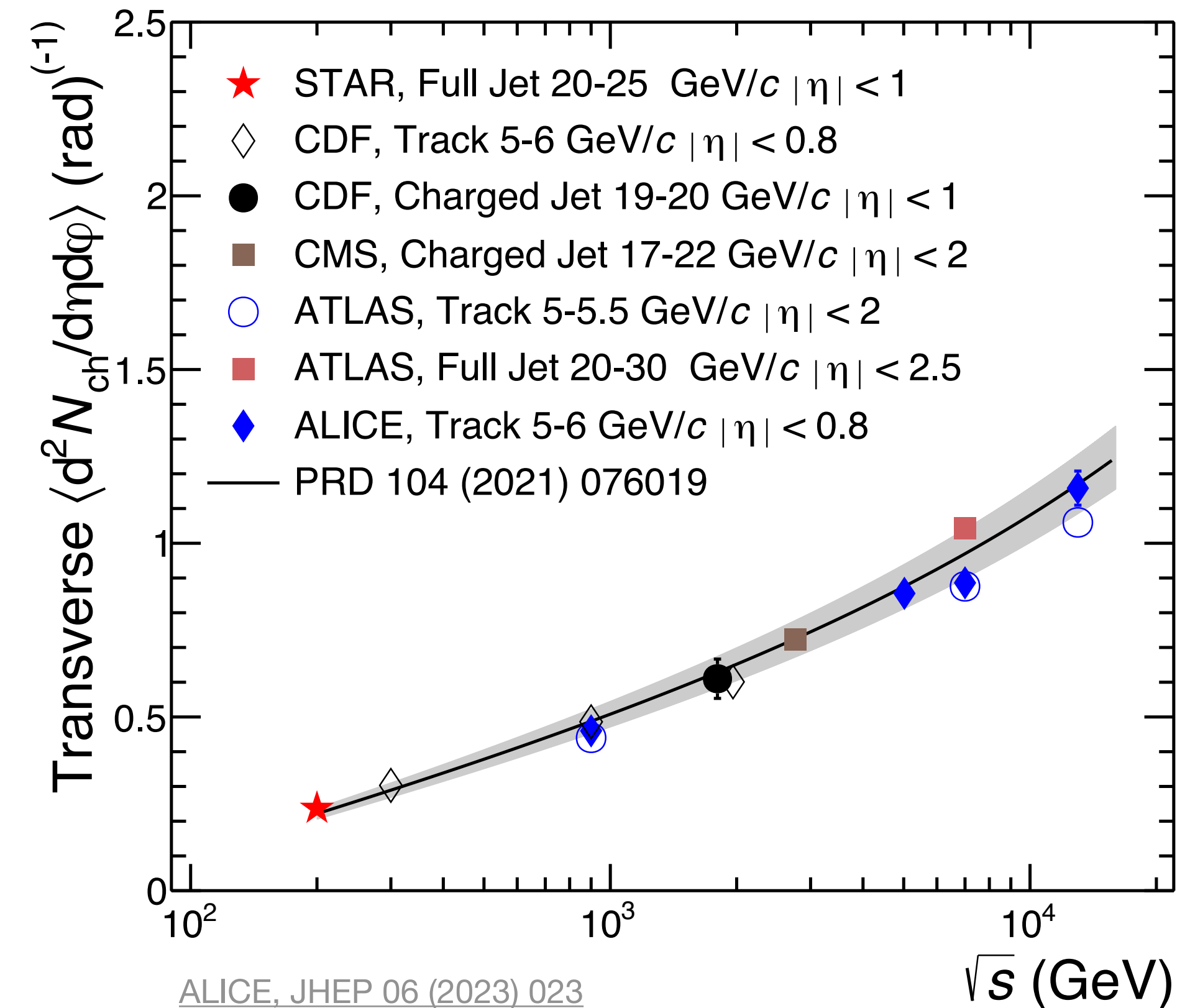
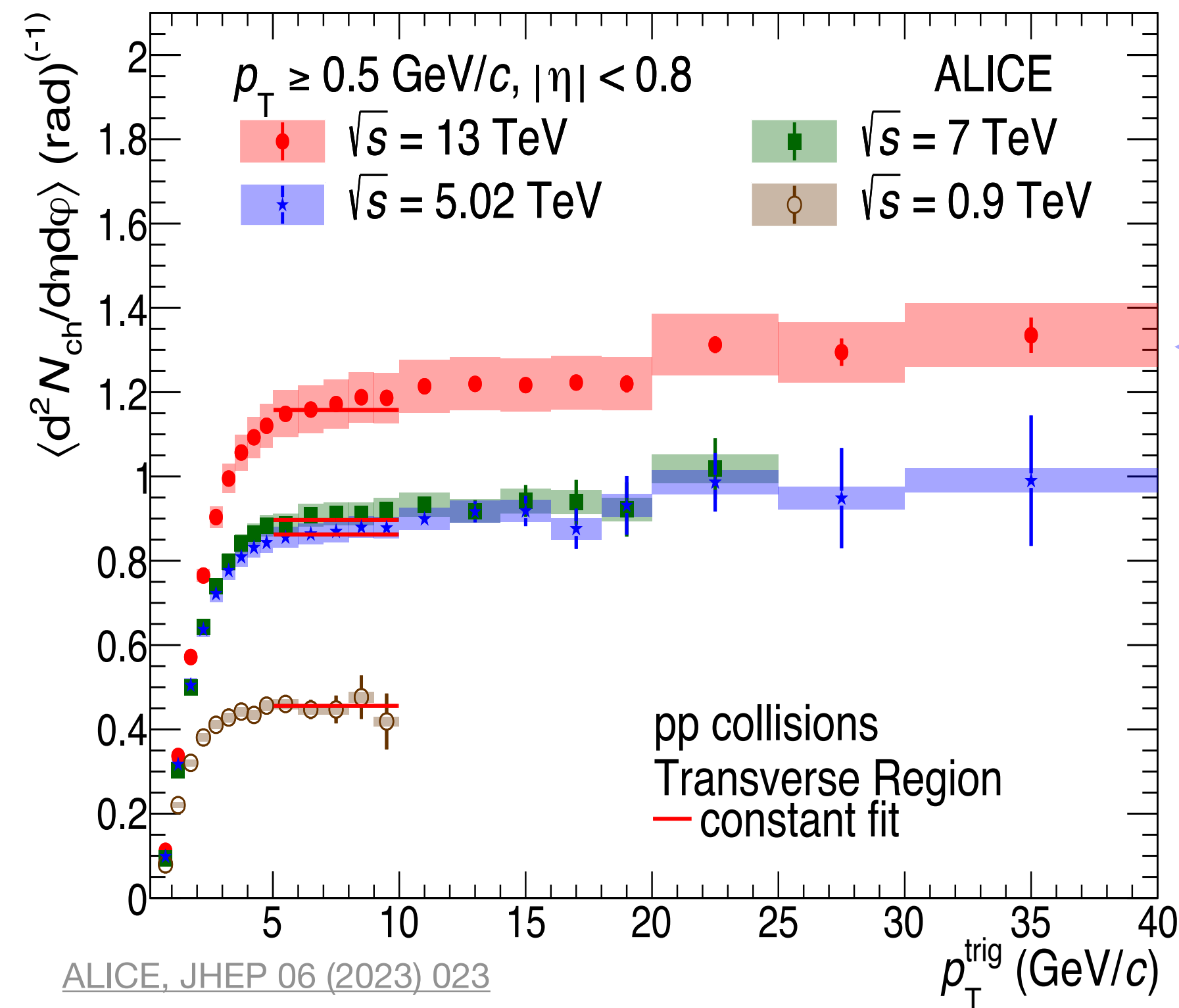
UE activity presents an
energy dependence



Current status and prediction

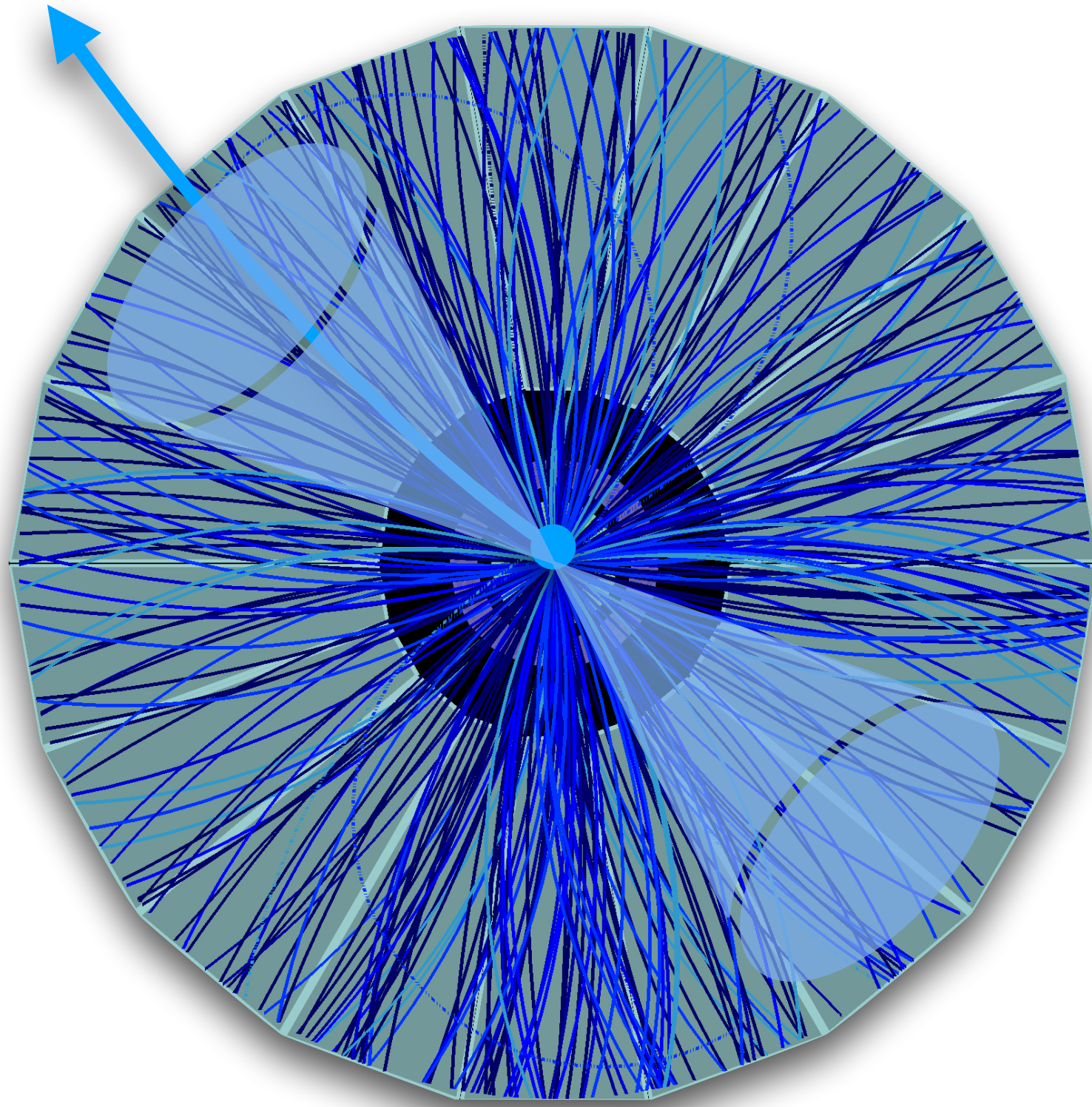
UE activity presents an
energy dependence

Plateau value for pp at $\sqrt{s} = 13.6$ TeV
is expected to be slightly above

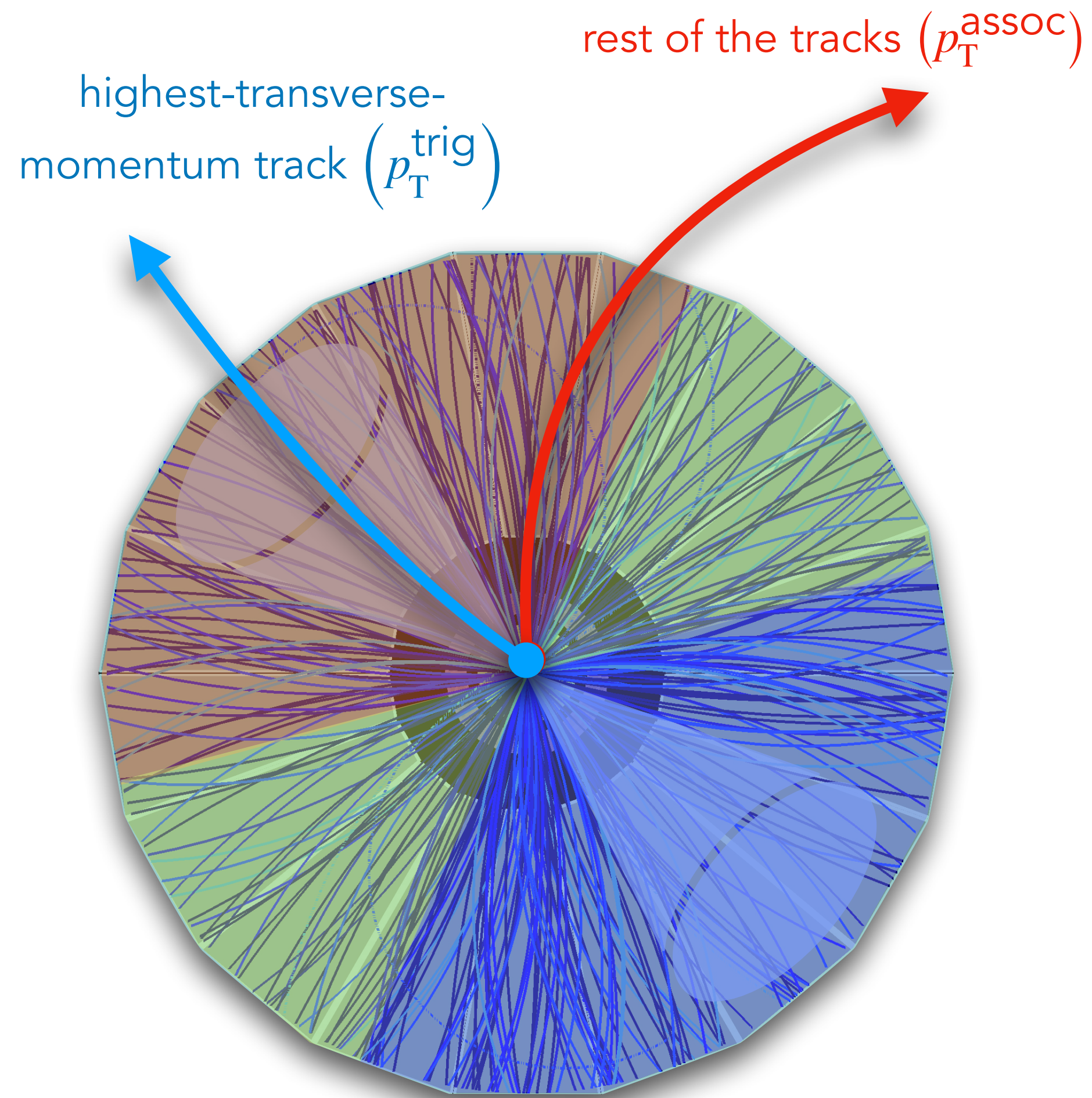


Analysis strategy

highest-transverse-
momentum track (p_T^{trig})

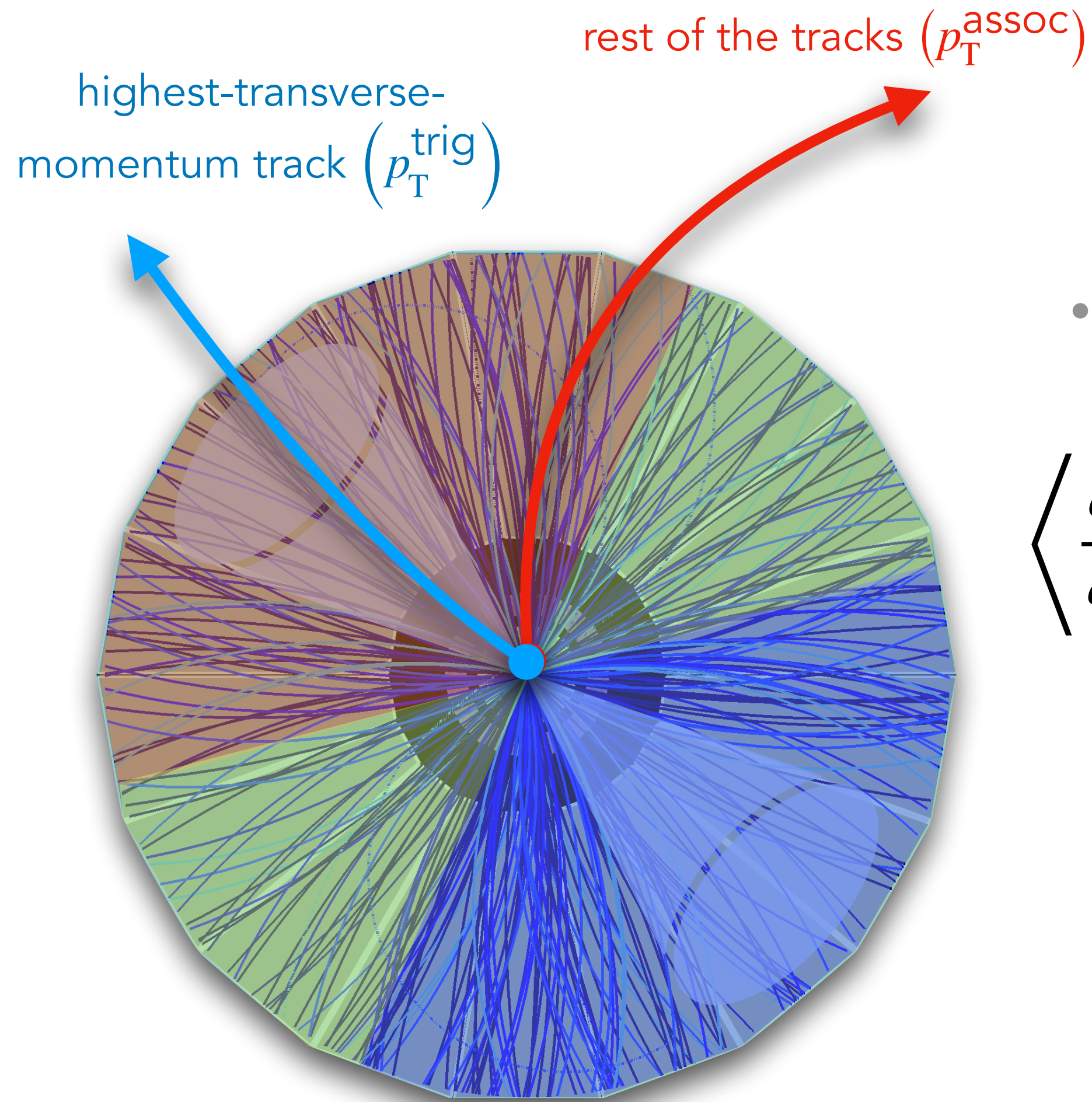


Analysis strategy



The topological regions are defined

Analysis strategy



- The **average particle density** must be corrected to account for any detector effects:

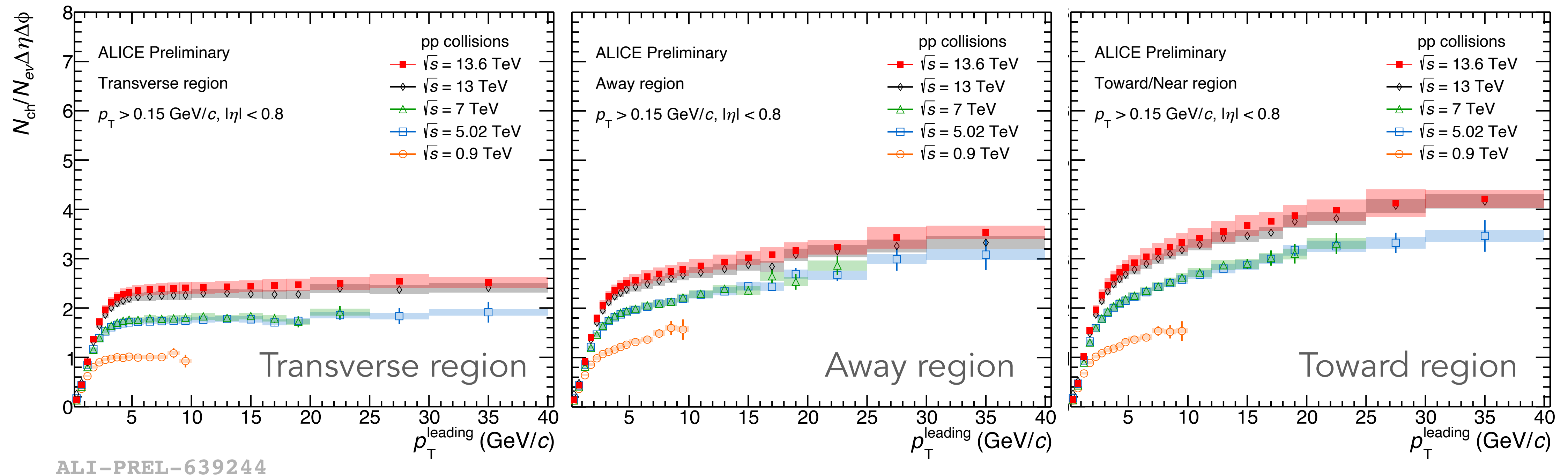
$$\left\langle \frac{d^2 N_{\text{ch}}}{d\eta d\varphi}(p_T^{\text{trig}}) \right\rangle = \frac{1}{N_{\text{ev}}(p_T^{\text{trig}})} \frac{1}{\Delta\eta \Delta\varphi} N_{\text{ch}}(p_T^{\text{trig}})$$

$$= \frac{1}{N_{\text{ev}}^{\text{rec}}(p_T^{\text{trig}})} \frac{1}{\Delta\eta \Delta\varphi} \left(N_{\text{trk}}(p_T^{\text{trig}}) \times \frac{1-c}{\epsilon_{\text{trk}} \times a} \times \epsilon_{\text{trigger}} \times \epsilon_{\text{MisID}} \right)$$

The topological regions are defined

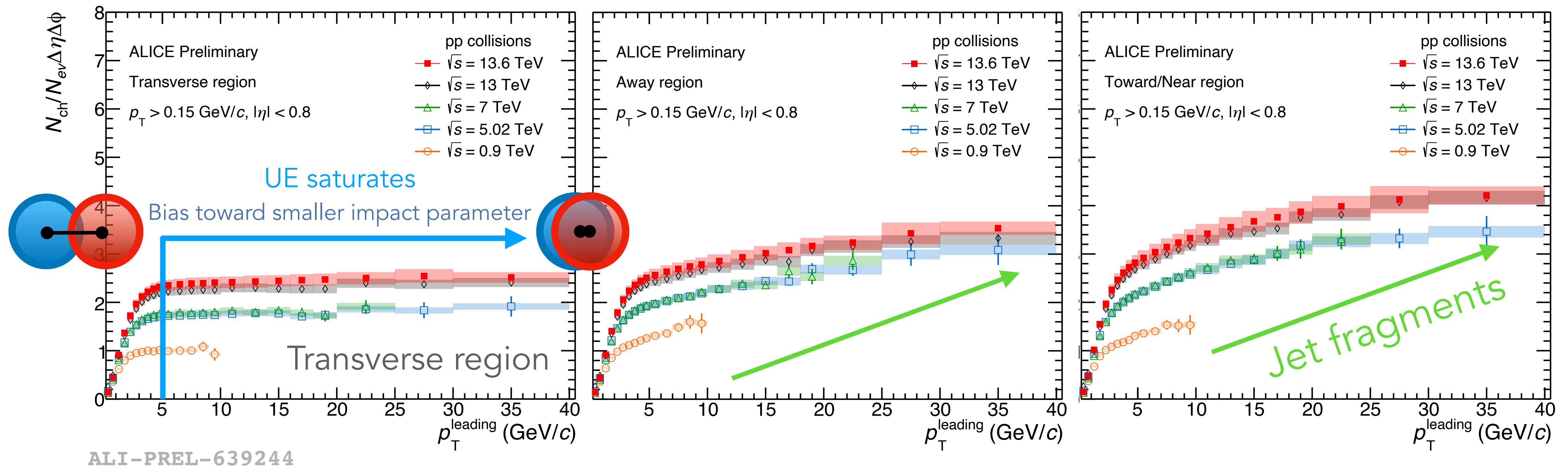
Data comparison

UE activity dependent on the energy of the collision



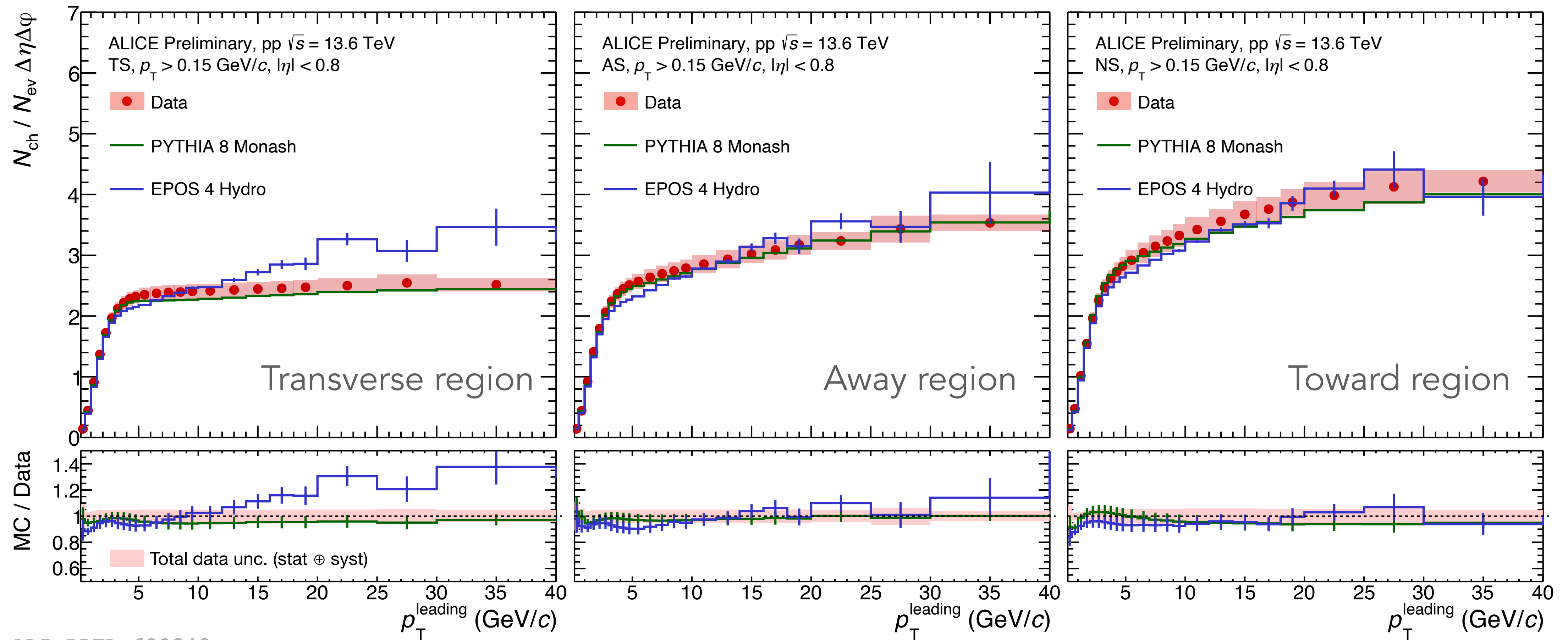
Data comparison

UE activity dependent on the energy of the collision



Topological regions present different behaviors

Comparison with MC

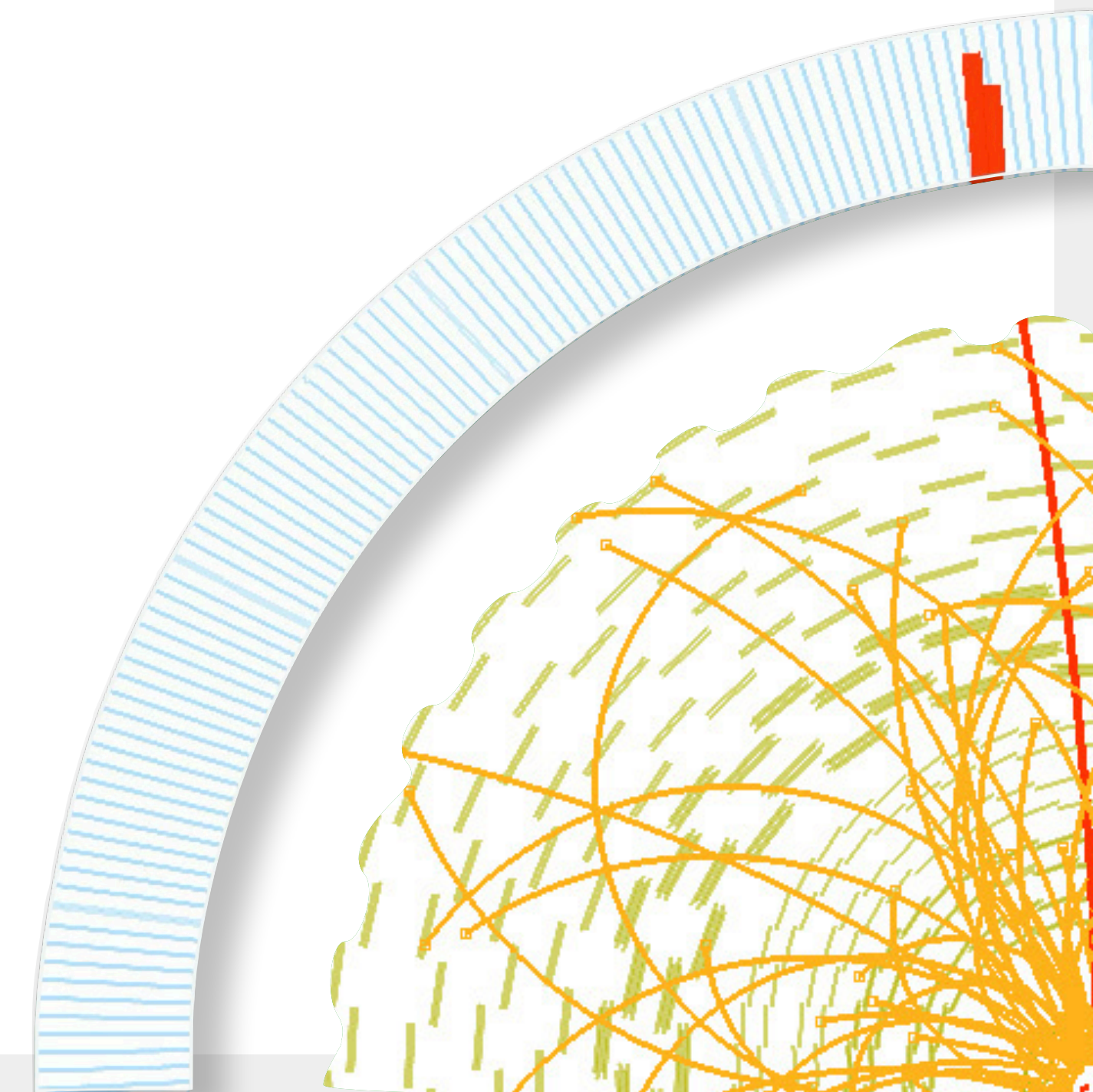


ALI-PREL-639249

Good compatibility with MPI-based model (PYTHIA 8)

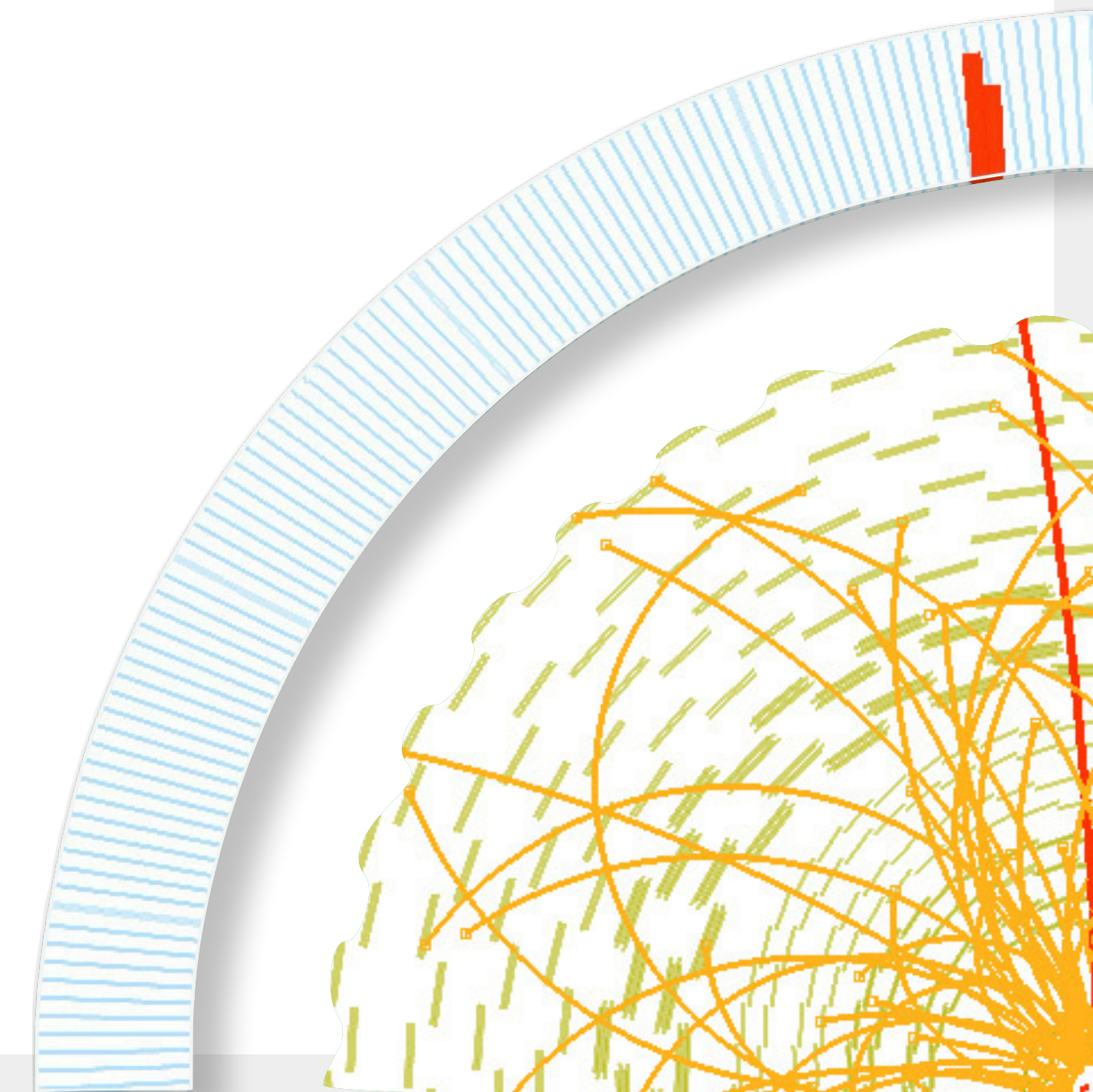
Summary

- **Bias** in jet quenching searches can be **mitigated with flattenicity**, making this amore reliable tool for future jet searches



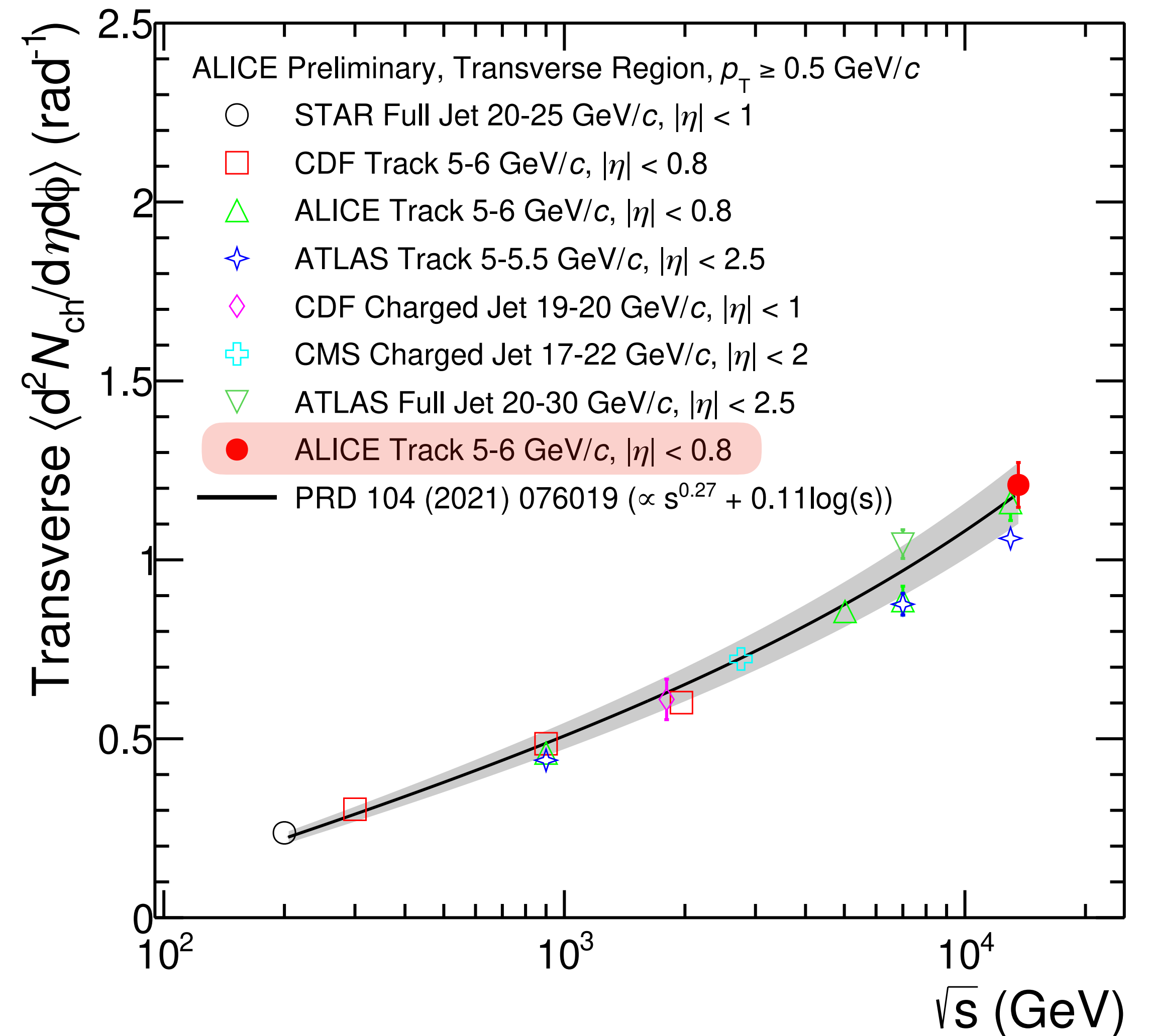
Summary

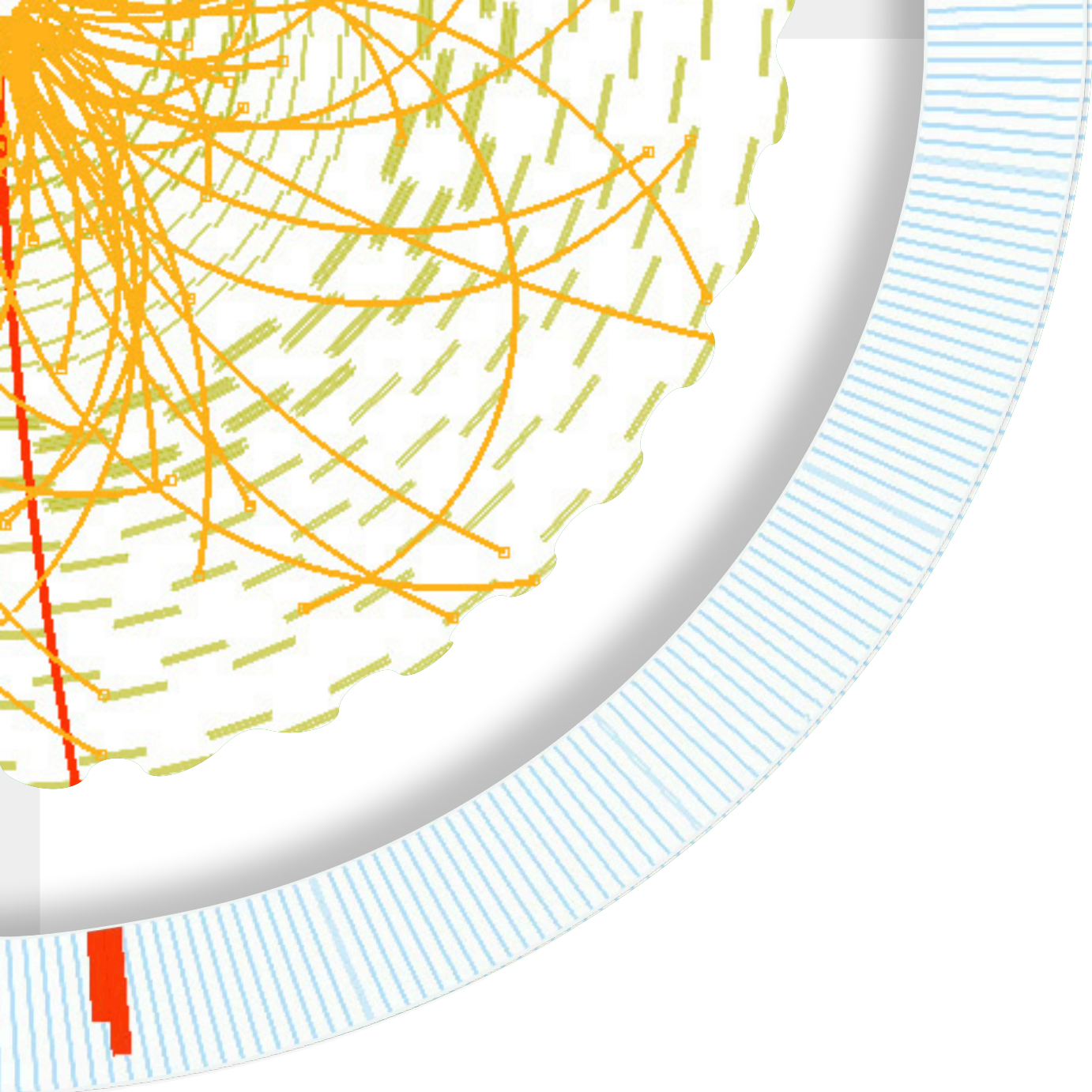
- **Bias** in jet quenching searches can be **mitigated with flattenicity**, making this amore reliable tool for future jet searches
- **Underlying Event** activity studied in pp collisions at $\sqrt{s} = 13.6$ TeV, considering latest ALICE data



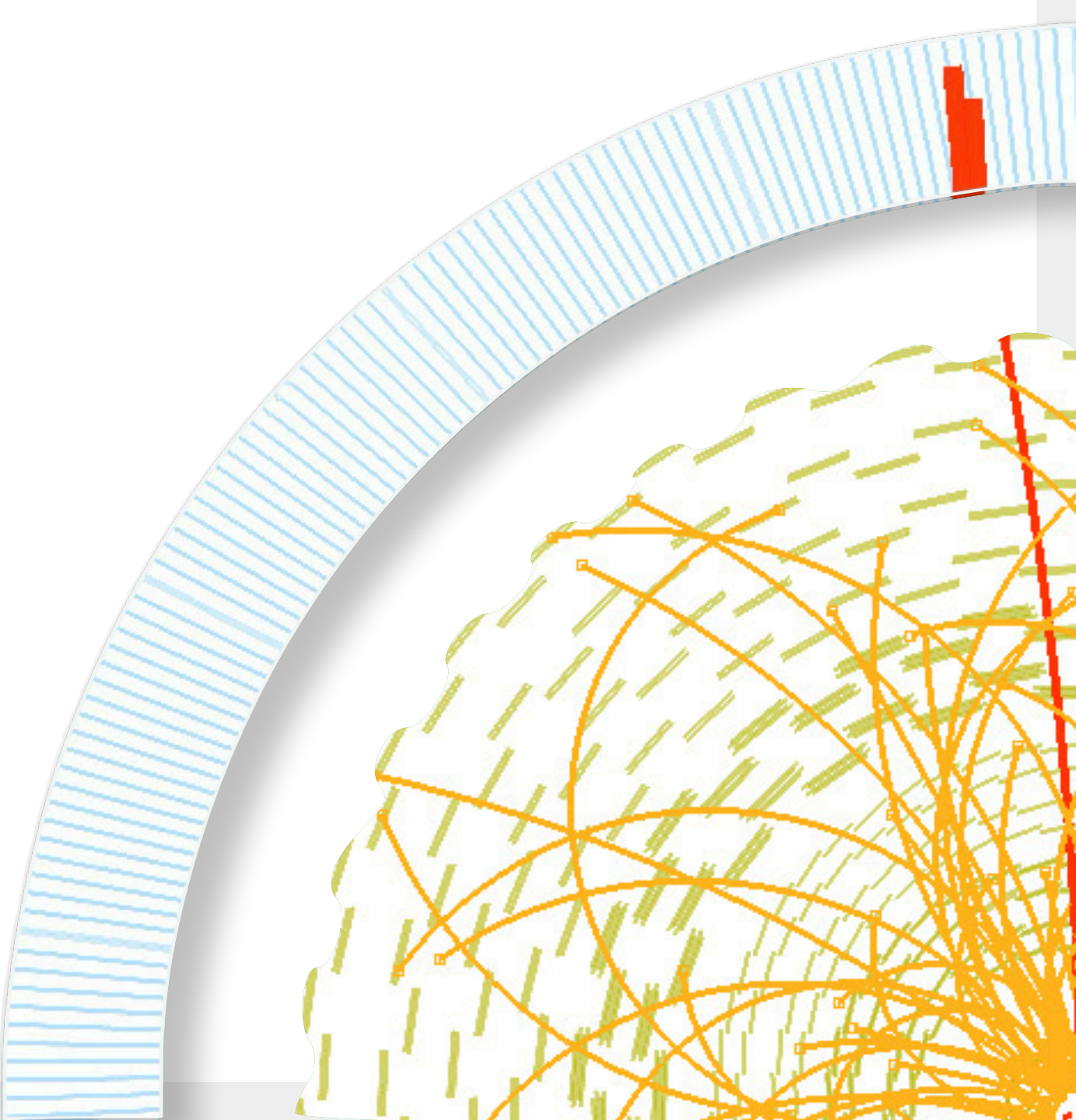
Summary

- **Bias** in jet quenching searches can be **mitigated with flattenicity**, making this amore reliable tool for future jet searches
- **Underlying Event** activity studied in pp collisions at $\sqrt{s} = 13.6$ TeV, considering latest ALICE data
- **Results show good agreement** with expectations: Run 3 activity is slightly higher than Run 2, consistent with energy trend

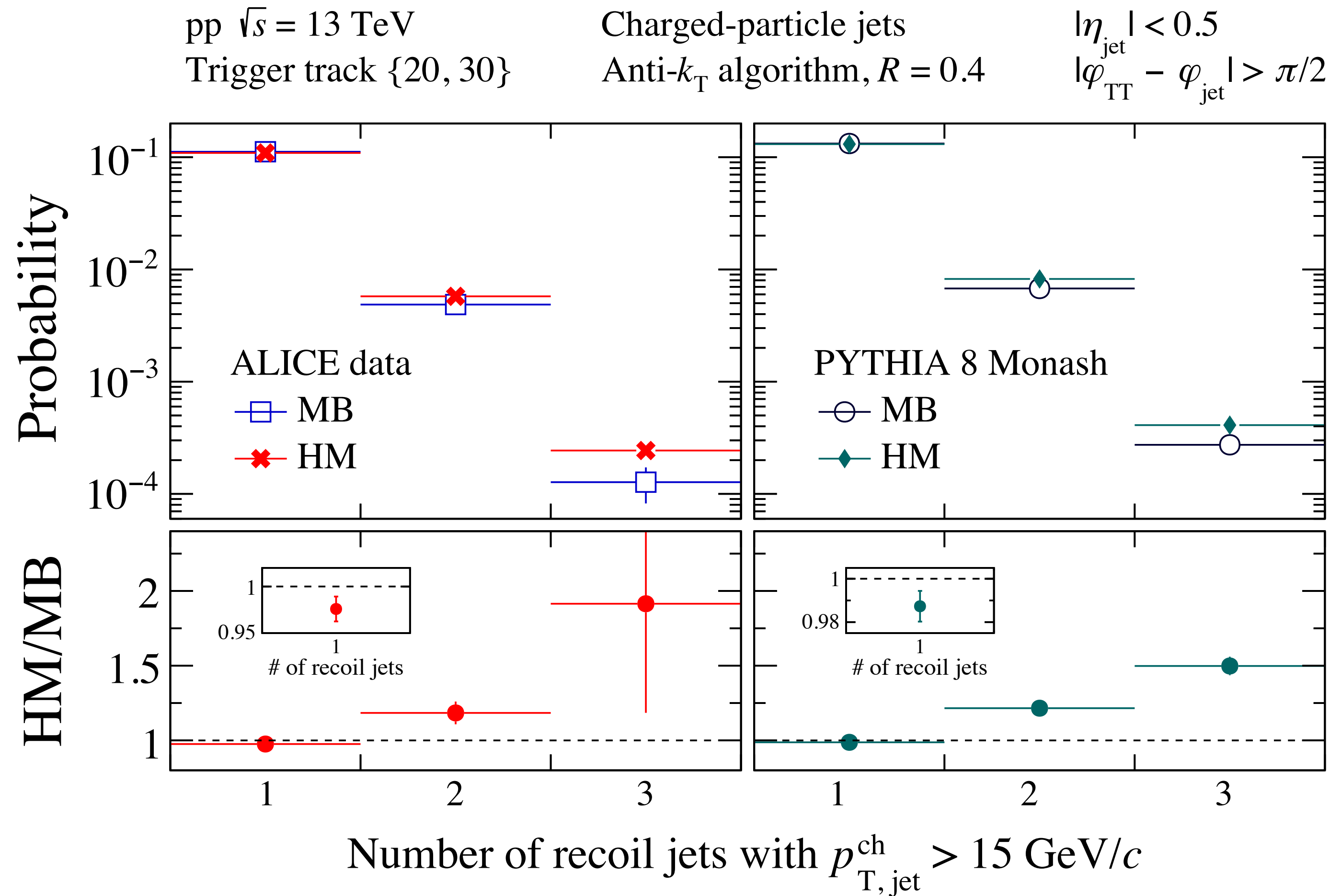




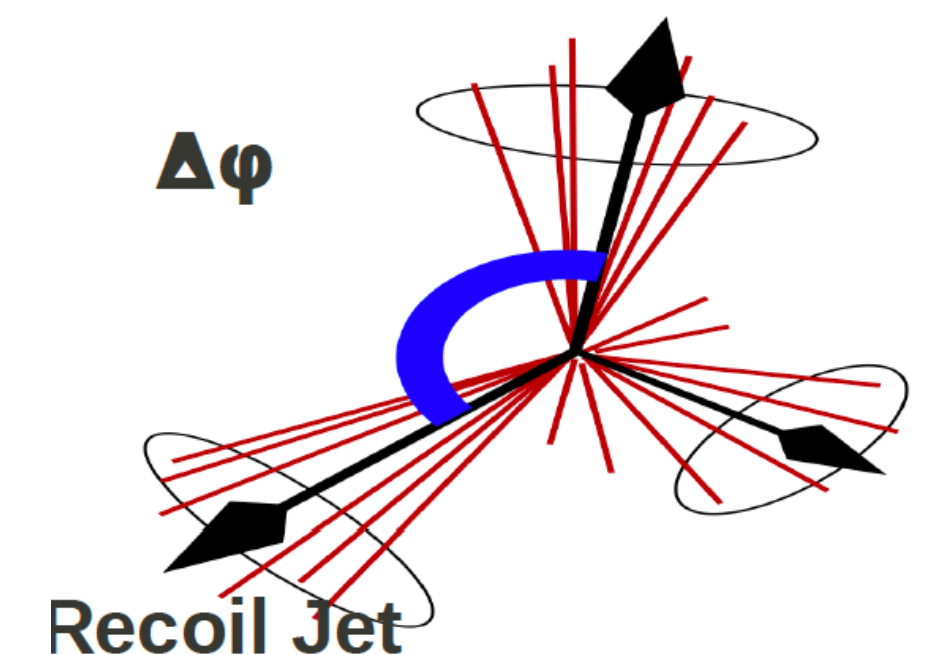
Thank you



Bias toward local fluctuations

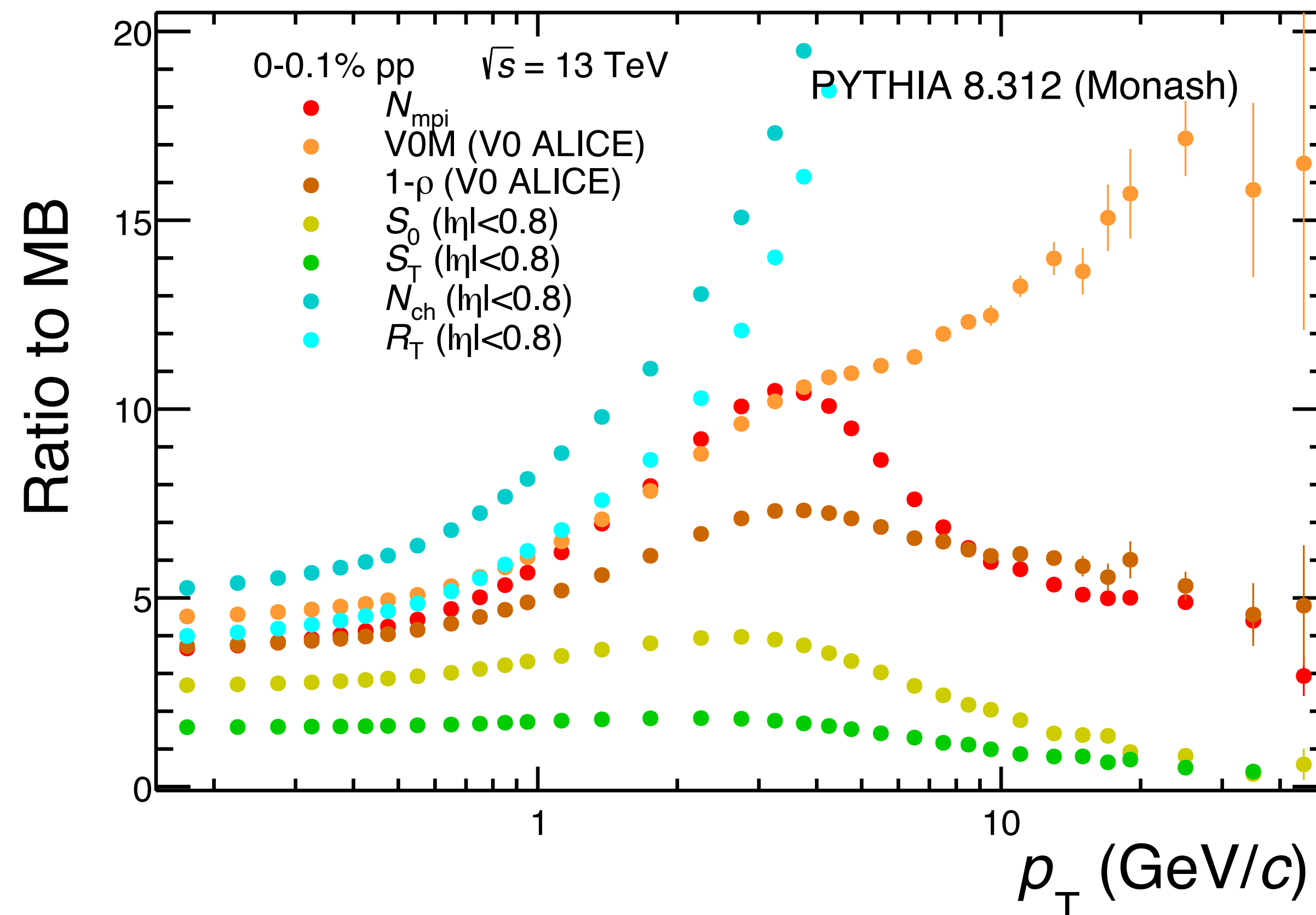


- For the leading-order (LO) di-jet channel: TT and recoil jet are azimuthally back-to-back
- The jets reconstructed in HM events are not the true LO recoil jets
- We are selecting higher-order production processes, with multiple recoil jets in the final state.
- These jets from higher-order processes have broader distribution in $\Delta\varphi$ than jets from LO production.



Bias toward harder-than-average events

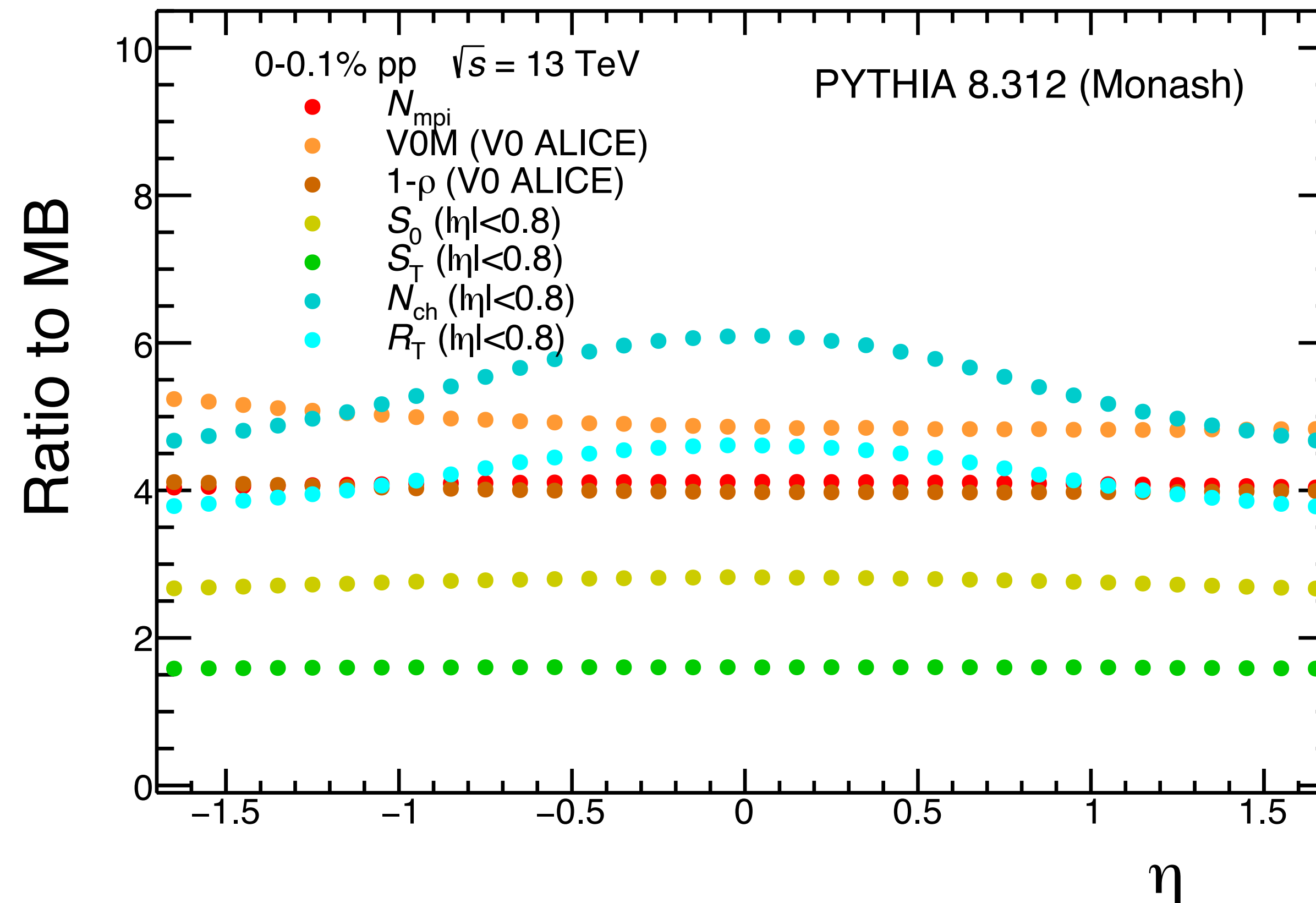
Jesús Méndez and Antonio Ortiz 2025 *J. Phys. G: Nucl. Part. Phys.* **52** 095001



Transverse momentum spectra for the 0-0.1% event class normalized to the minimum bias p_T spectrum. The error bars represent the statistical uncertainty

Bias toward local fluctuations

Jesús Méndez and Antonio Ortiz 2025 *J. Phys. G: Nucl. Part. Phys.* **52** 095001

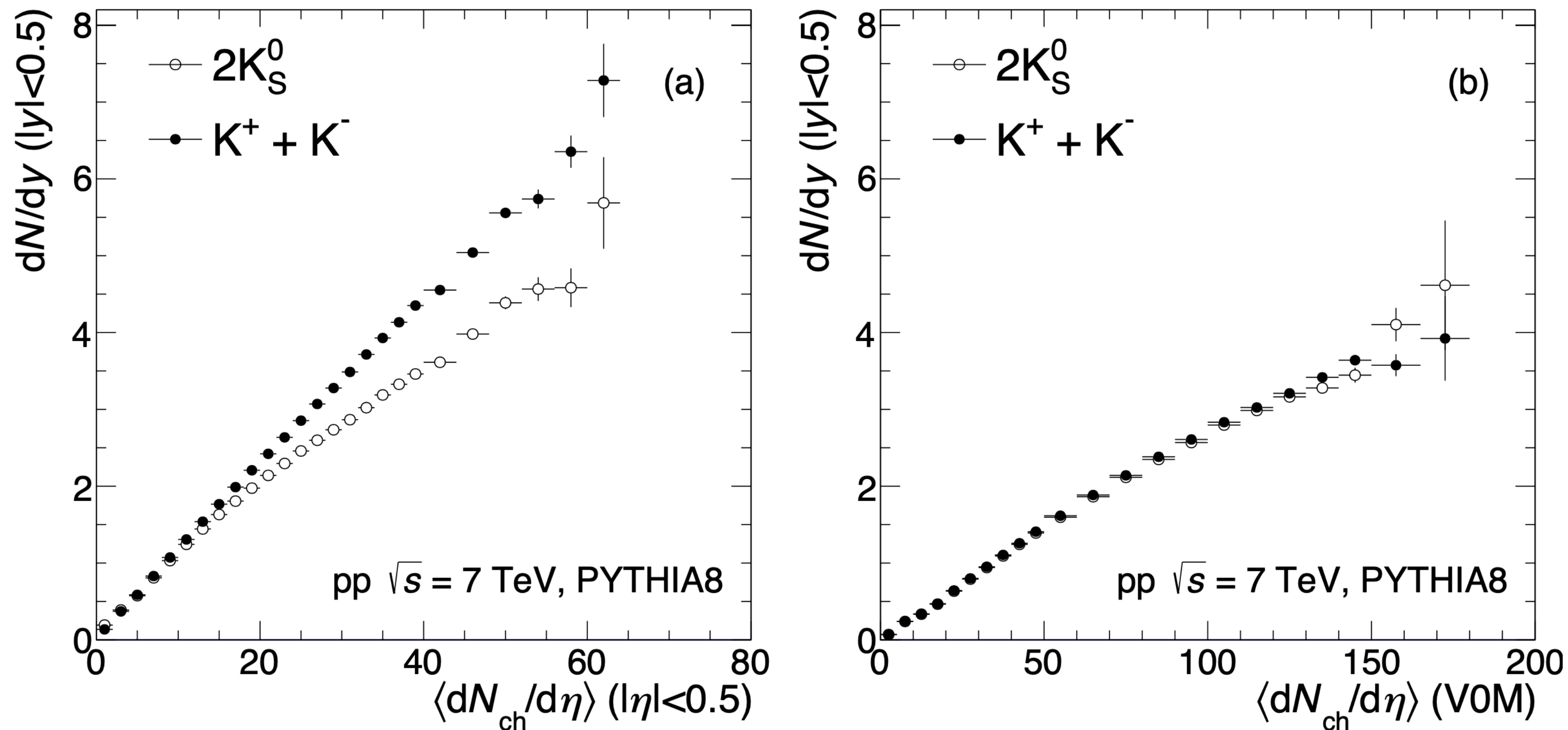


The **pseudorapidity** distributions for the 0-0.1% event class normalized to the minimum bias distribution. The error bars represent the statistical uncertainty

Bias toward charged particles

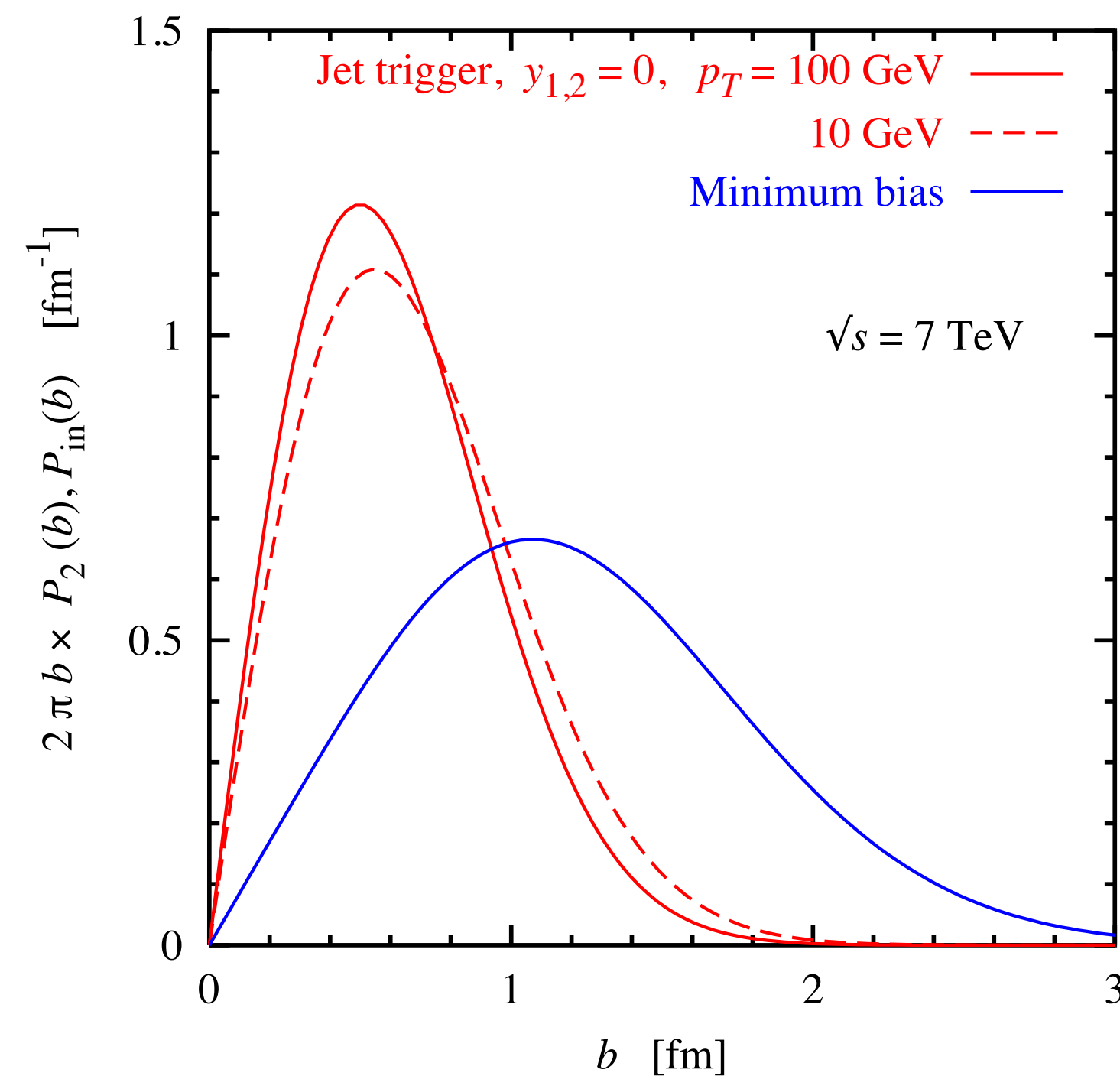


La medición de multiplicidad en rapidez central implica un sesgo hacia partículas cargadas, el cual puede ser **eliminado con el V0**

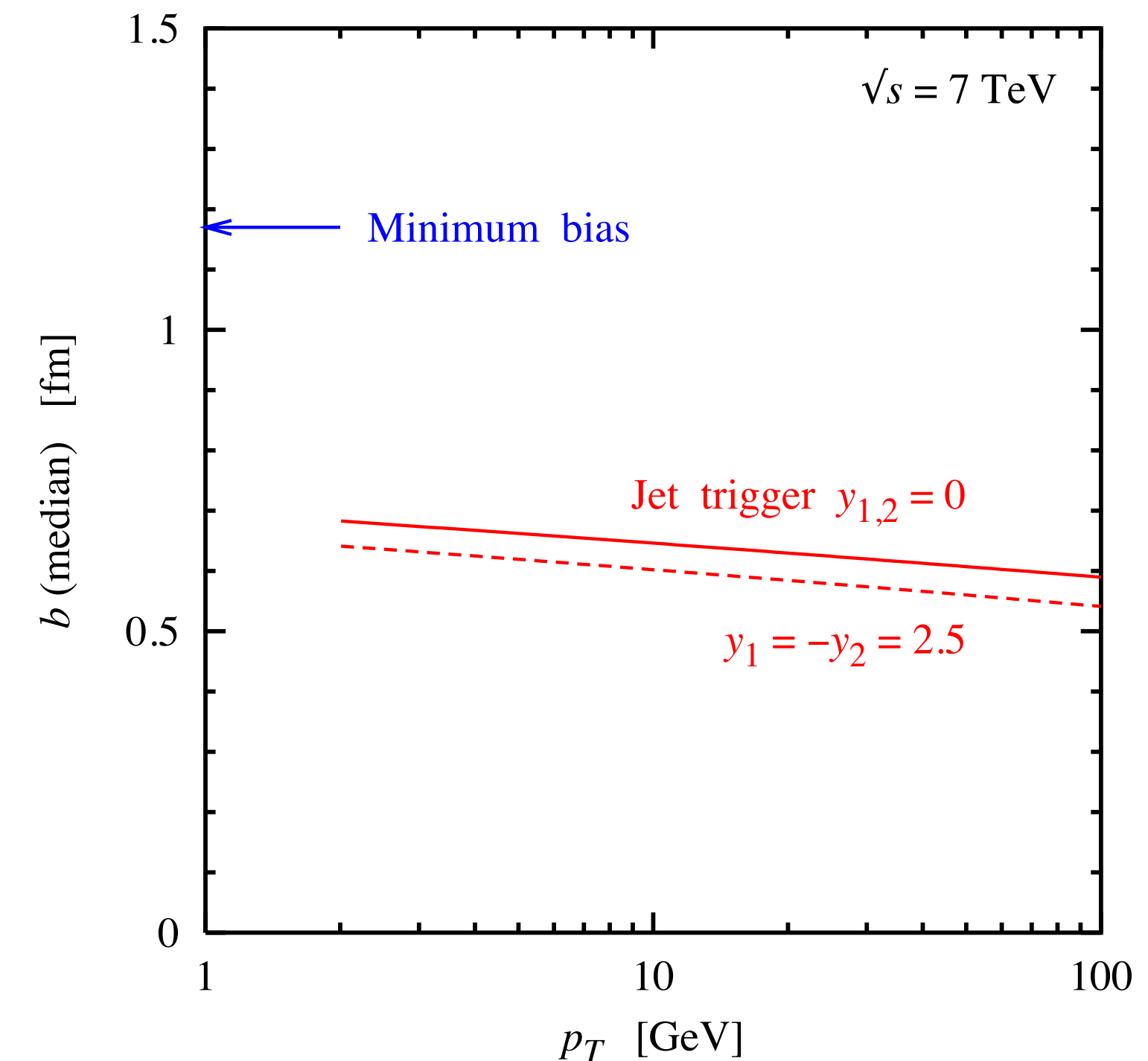


Bias towards smaller b

When we require a very energetic particle in the event, collisions are biased towards smaller impact parameter b . This concept is implemented in PYTHIA [Sjöstrand, T. Phys.Lett.B 188 (1987) 149-154]



Impact parameter distributions of inelastic pp collisions at $\sqrt{s} = 7$ TeV with a dijet trigger at zero rapidity



Dependence of median b on p_T for different rapidities of the dijets

Corrections

- The **average particle density** is calculated as follows

$$\left\langle \frac{d^2 N_{\text{ch}}}{d\eta d\varphi}(p_{\text{T}}^{\text{trig}}) \right\rangle = \frac{1}{N_{\text{ev}}(p_{\text{T}}^{\text{trig}})} \frac{1}{\Delta\eta \Delta\varphi} N_{\text{ch}}(p_{\text{T}}^{\text{trig}})$$

$$= \frac{1}{N_{\text{ev}}^{\text{rec}}(p_{\text{T}}^{\text{trig}})} \frac{1}{\Delta\eta \Delta\varphi} \left(N_{\text{trk}}(p_{\text{T}}^{\text{trig}}) \times \frac{1-c}{\epsilon_{\text{trk}} \times a} \times \epsilon_{\text{trigger}} \times \epsilon_{\text{MisID}} \right)$$

- N_{trk} : Number of reconstructed tracks passing the event and track selection criteria within $|\eta| < 0.8$.
- $N_{\text{ev}}^{\text{rec}}$: Number of reconstructed events that pass the event selection criteria.

- Efficiency and geometrical acceptance

$$\epsilon_{\text{trk}} \times a = \left(\frac{N_{\text{trk, prim}}}{N_{\text{ch, prim}}} \right)_{\text{MC}}$$

- Sec. contamination

$$c = \left(\frac{N_{\text{trk, sec}}}{N_{\text{trk, prim}}} \right)_{\text{MC}}$$

- Trigger bias

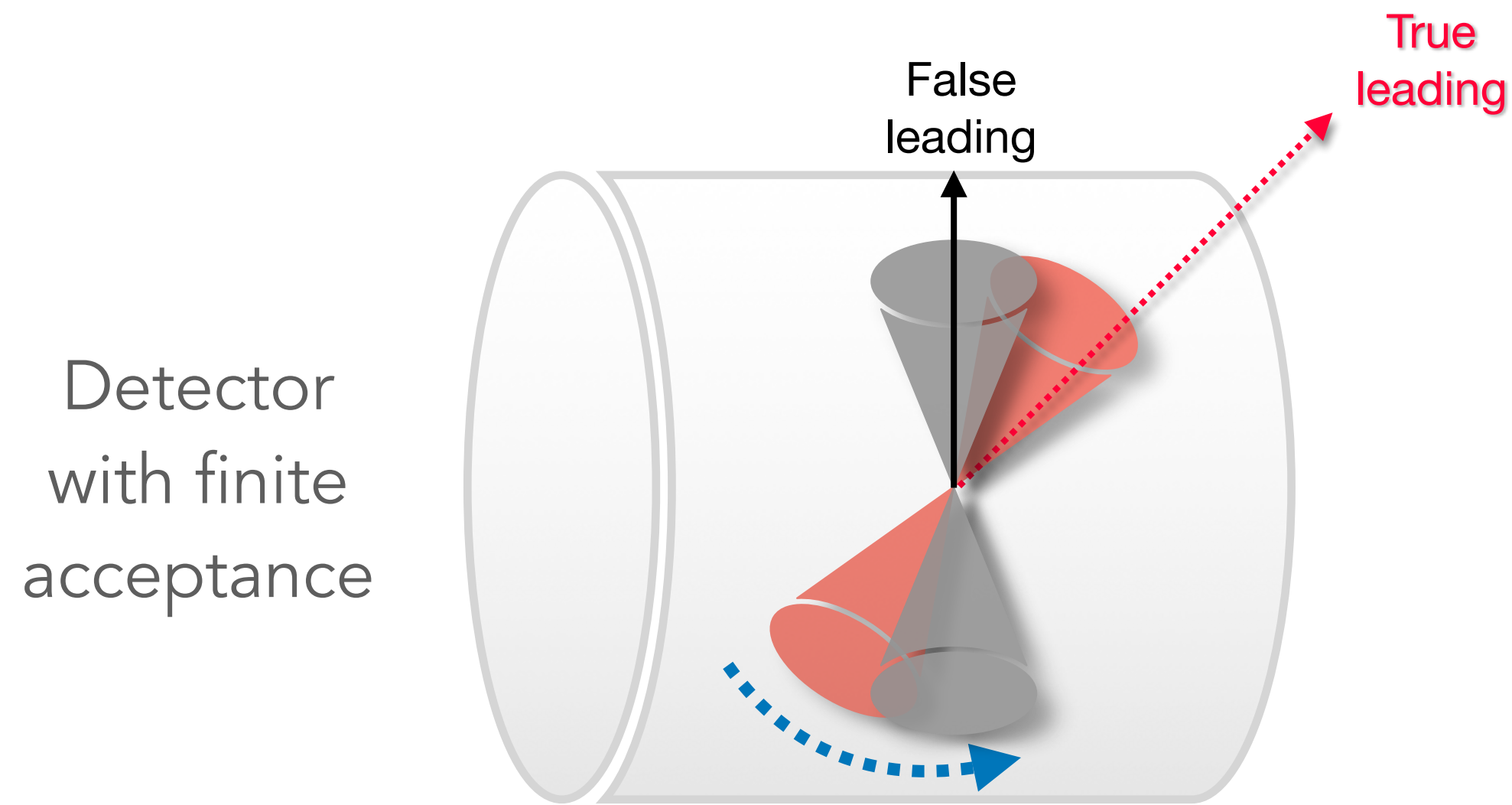
$$\epsilon_{\text{trigger}} = \left(\frac{\text{UE}^{\text{true}}}{\text{UE}^{\text{true, EvSel}}} \right)_{\text{MC}}$$

- MisID correction

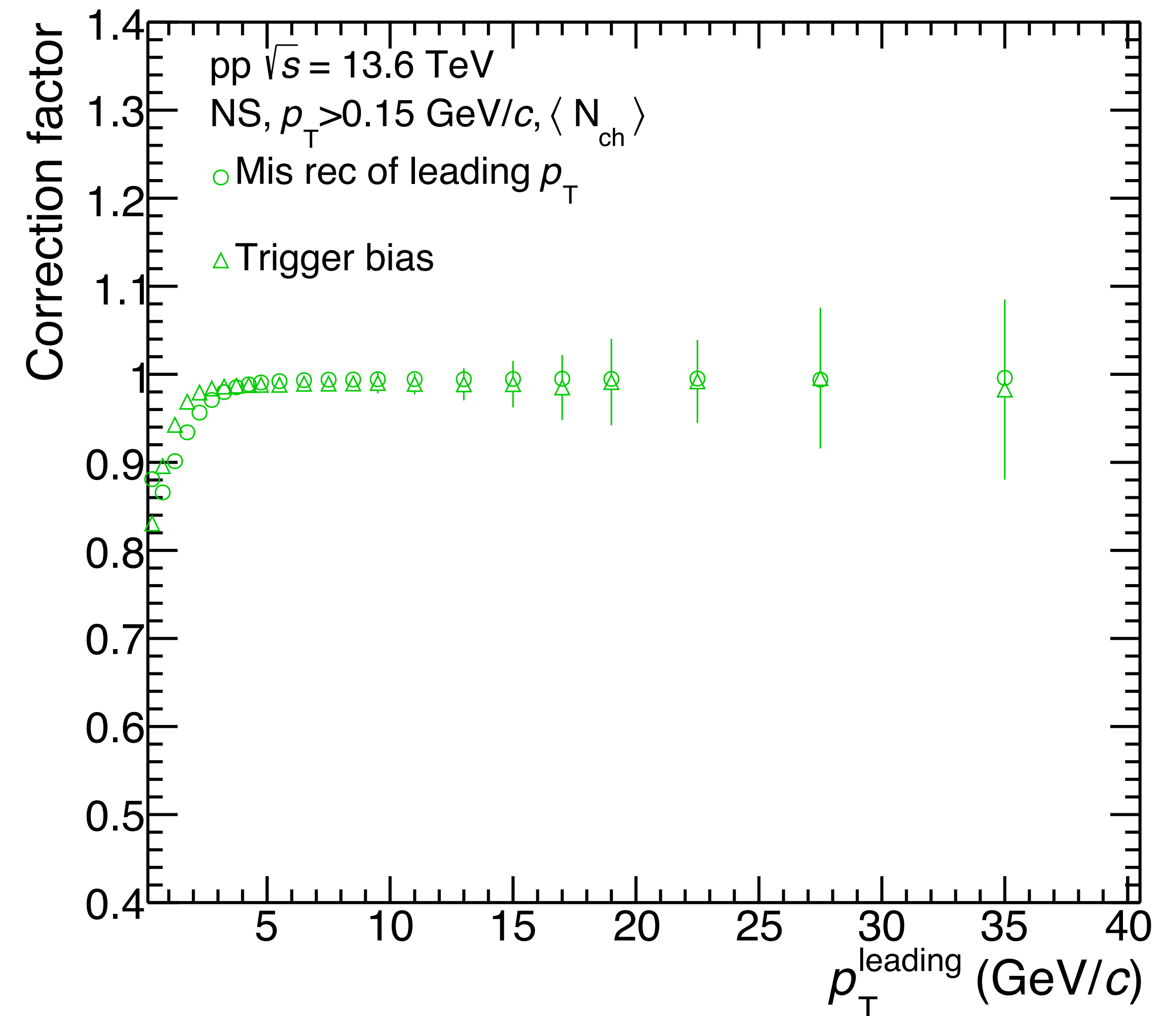
$$\epsilon_{\text{MisID}} = \left(\frac{\text{UE}^{\text{true leading}}}{\text{UE}^{\text{rec leading}}} \right)_{\text{MC}}$$

Misid of the leading particle

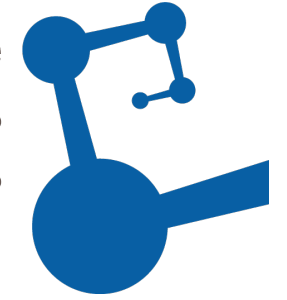
One of the implemented corrections accounts for the **misidentification of the leading particle**



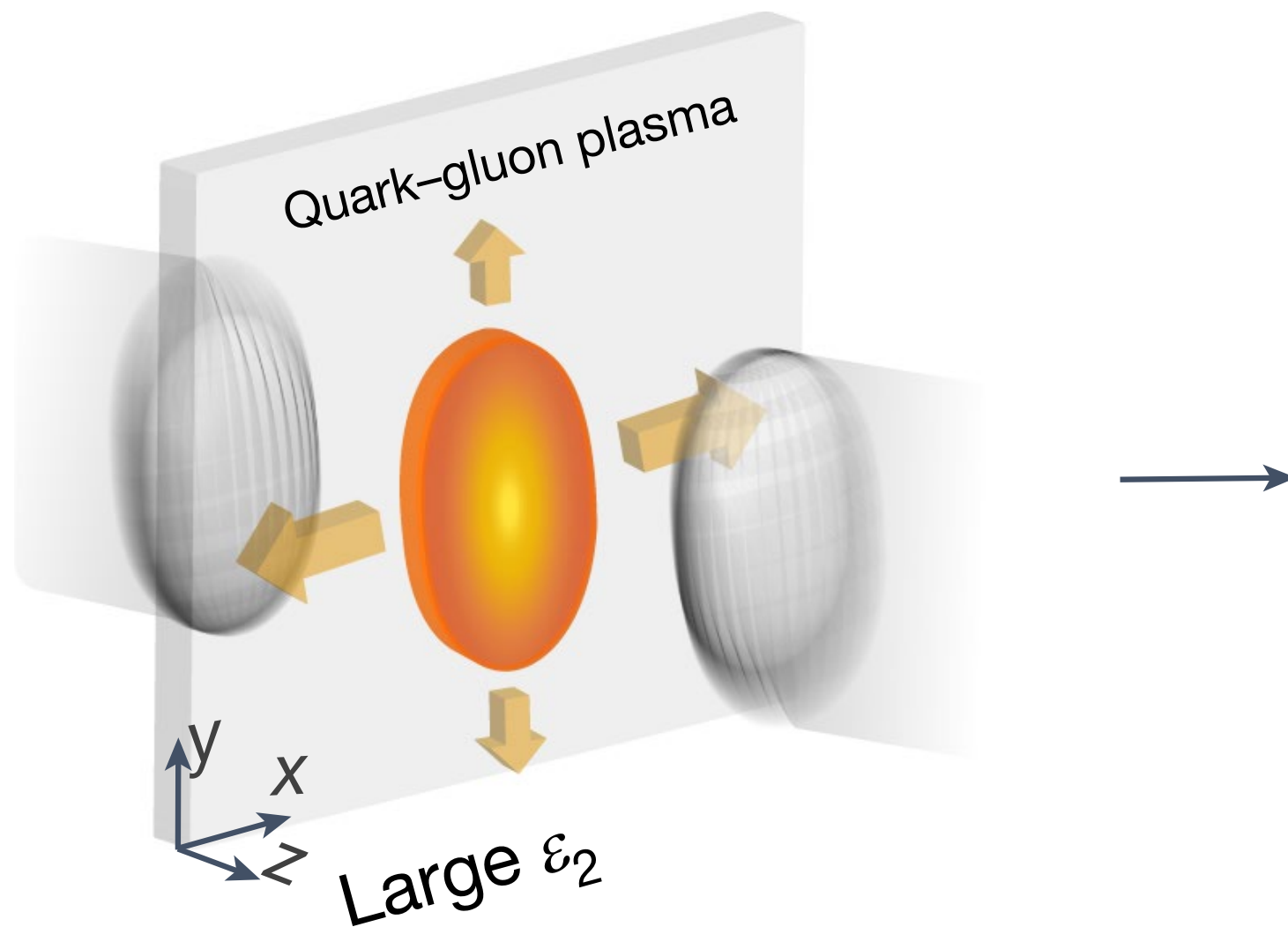
This could lead to a **rotation of the event topology** and cause a bias in the UE observables



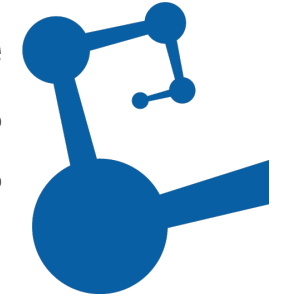
Elliptic flow



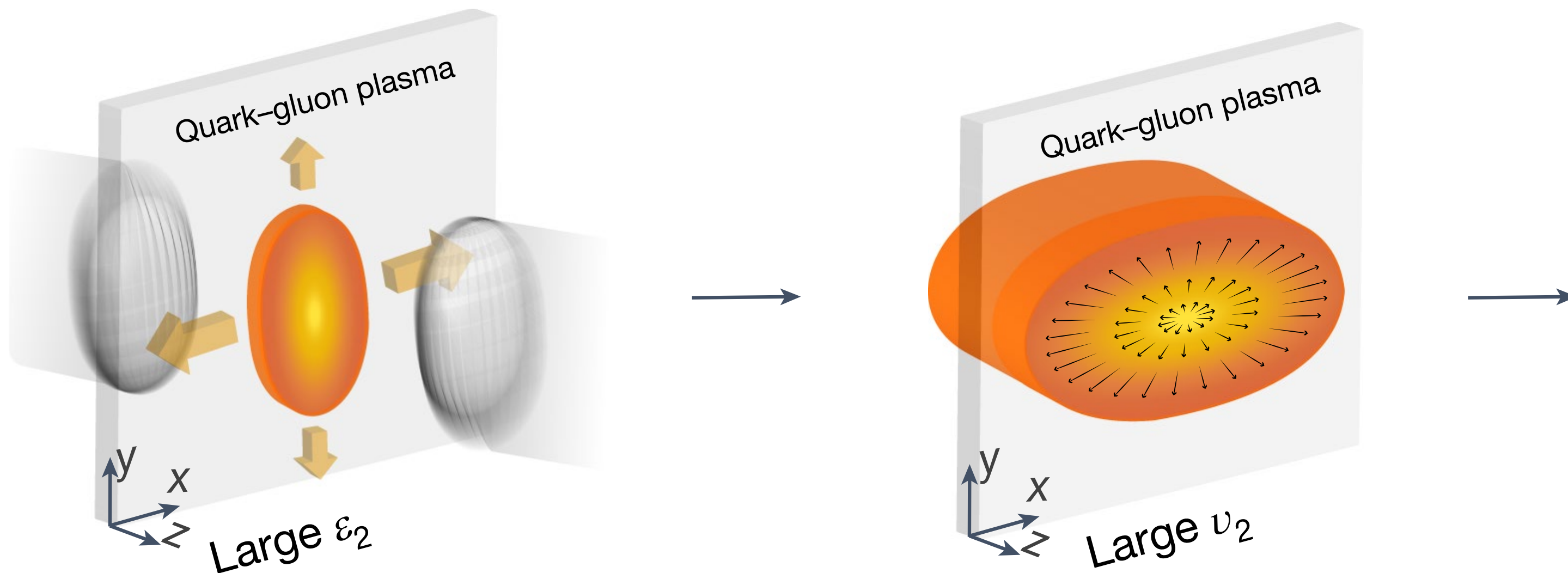
A non central heavy-ion
collision forms an
almond shaped medium



Elliptic flow

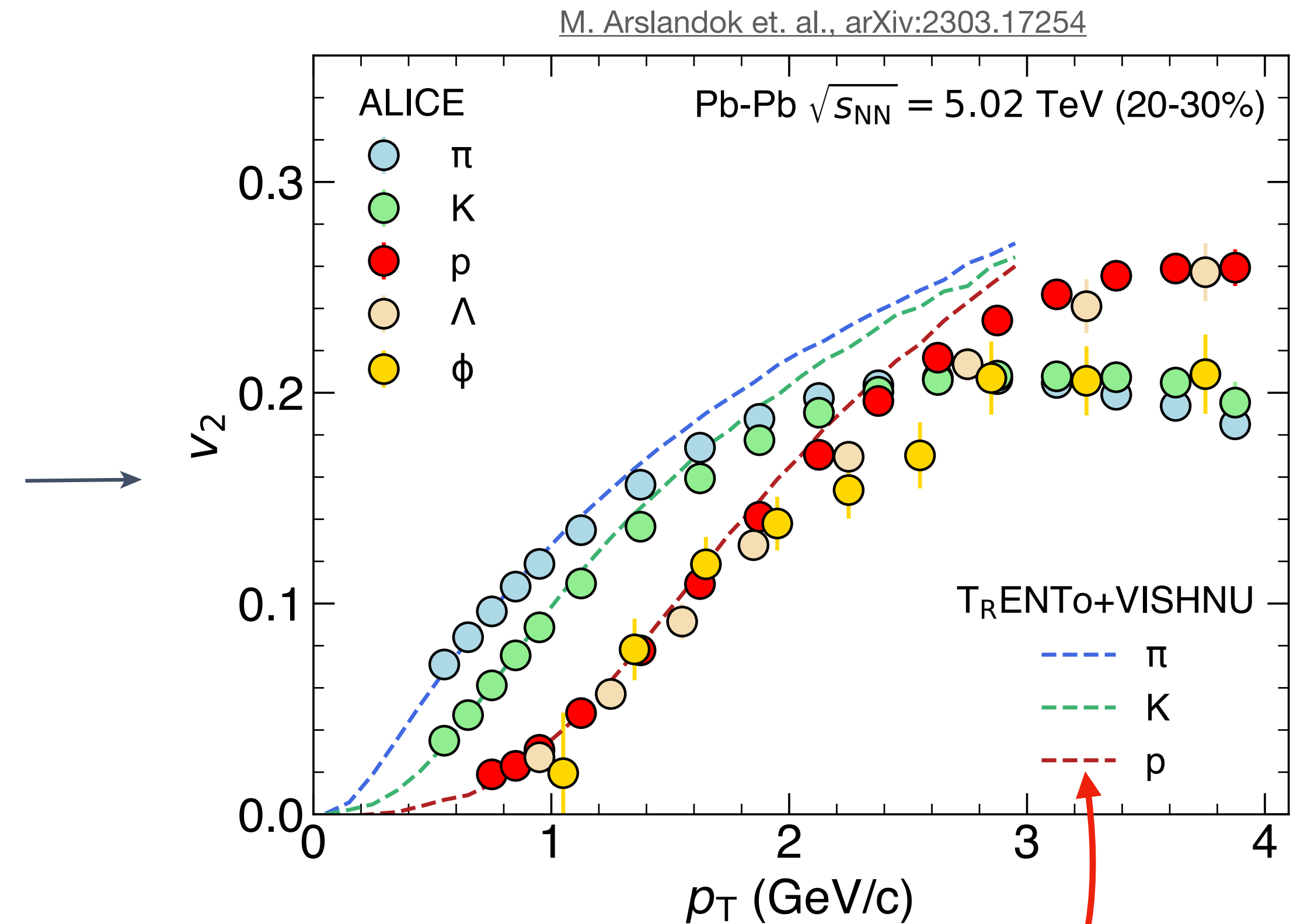
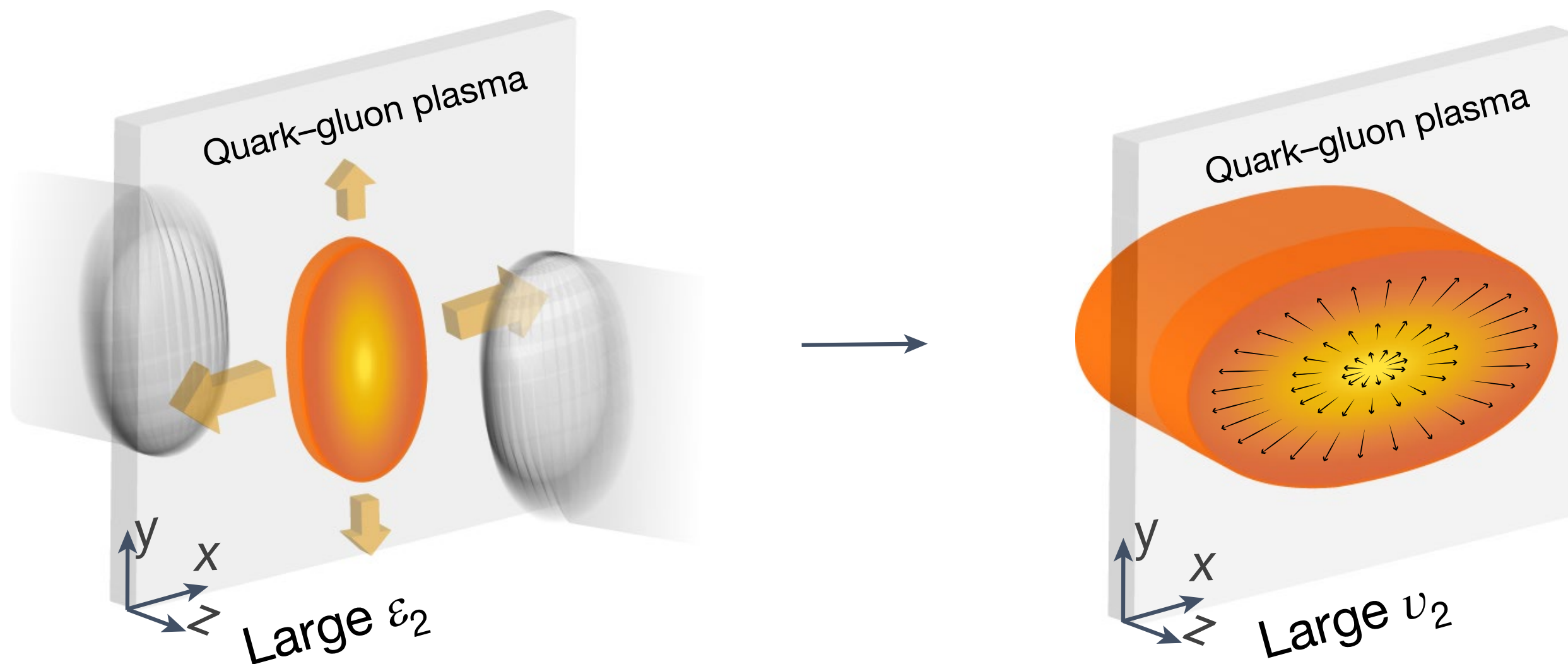


This spatial eccentricity is
transformed by pressure gradients
into momentum anisotropies



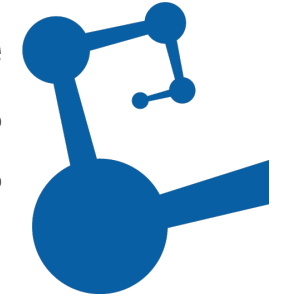
Quantified by performing a Fourier
transformation on the angular
distribution of the detected hadrons

Elliptic flow

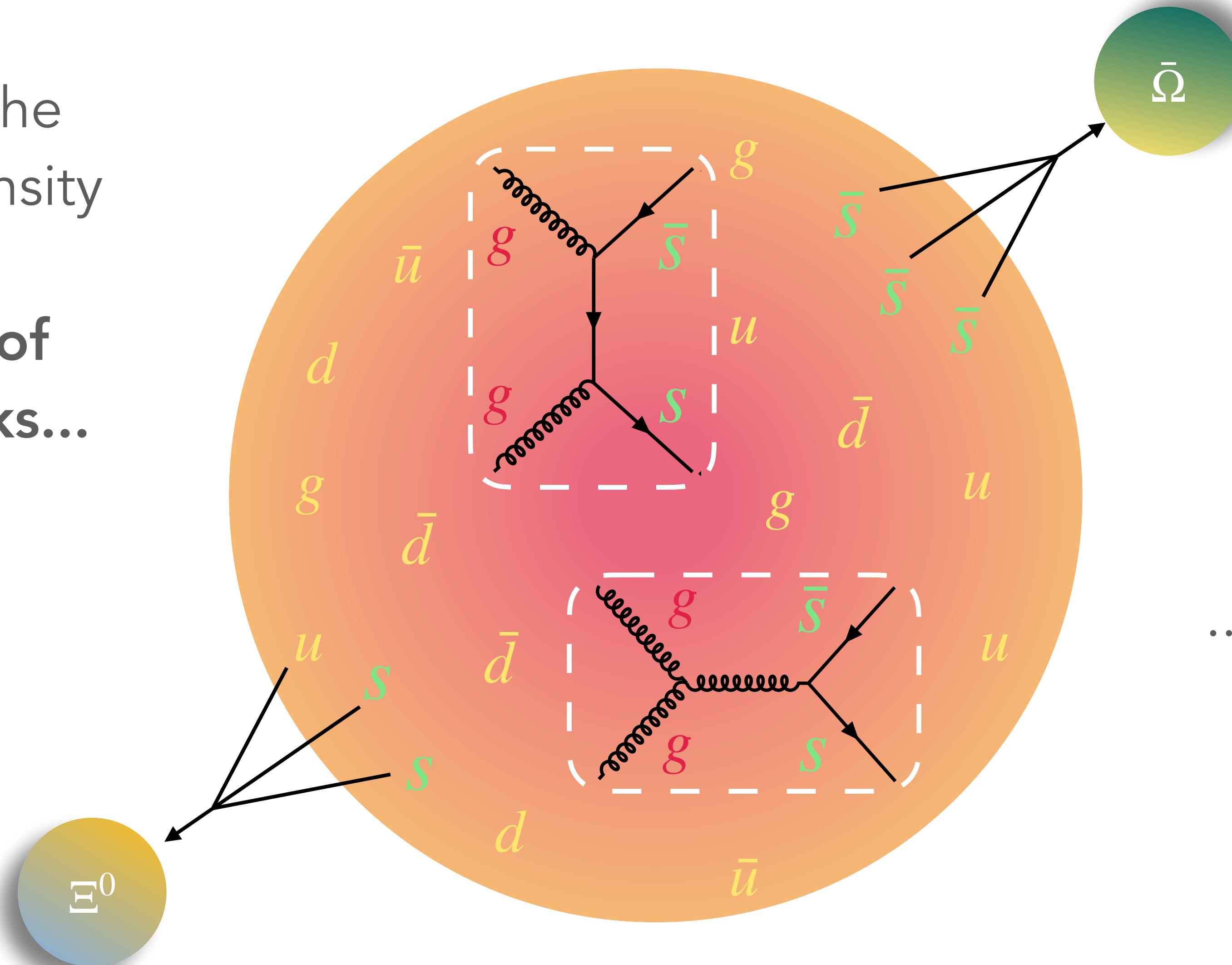


Hydrodynamic models of a perfect fluid provide a good description of the anisotropic distribution of the detected particles

Strangeness enhancement



In the QGP, the
high gluon density
**favors the
production of
strange quarks...**

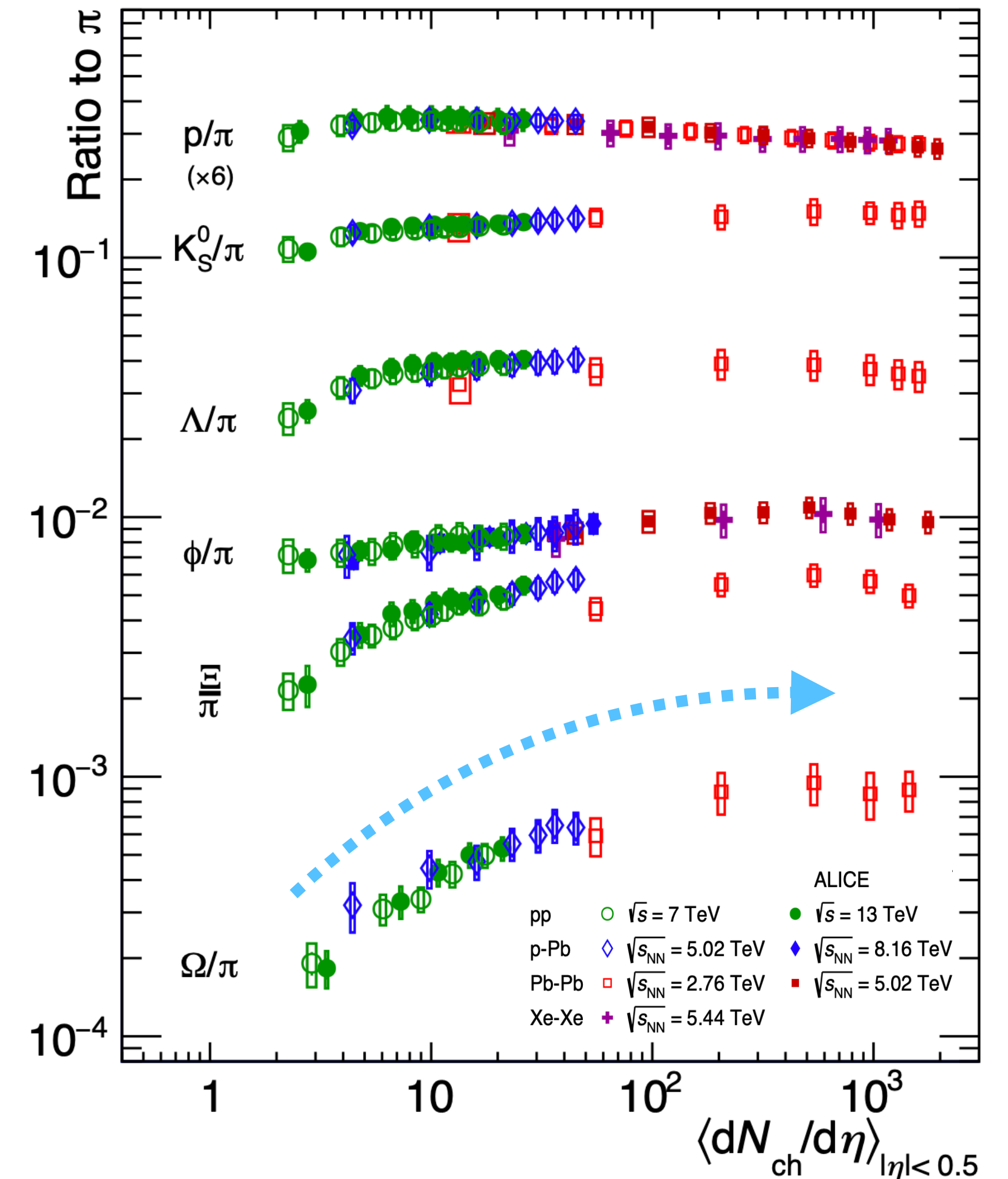


...this effect can be
observed in the
**detection of
(multi-)strange
hadrons**

Strangeness enhancement

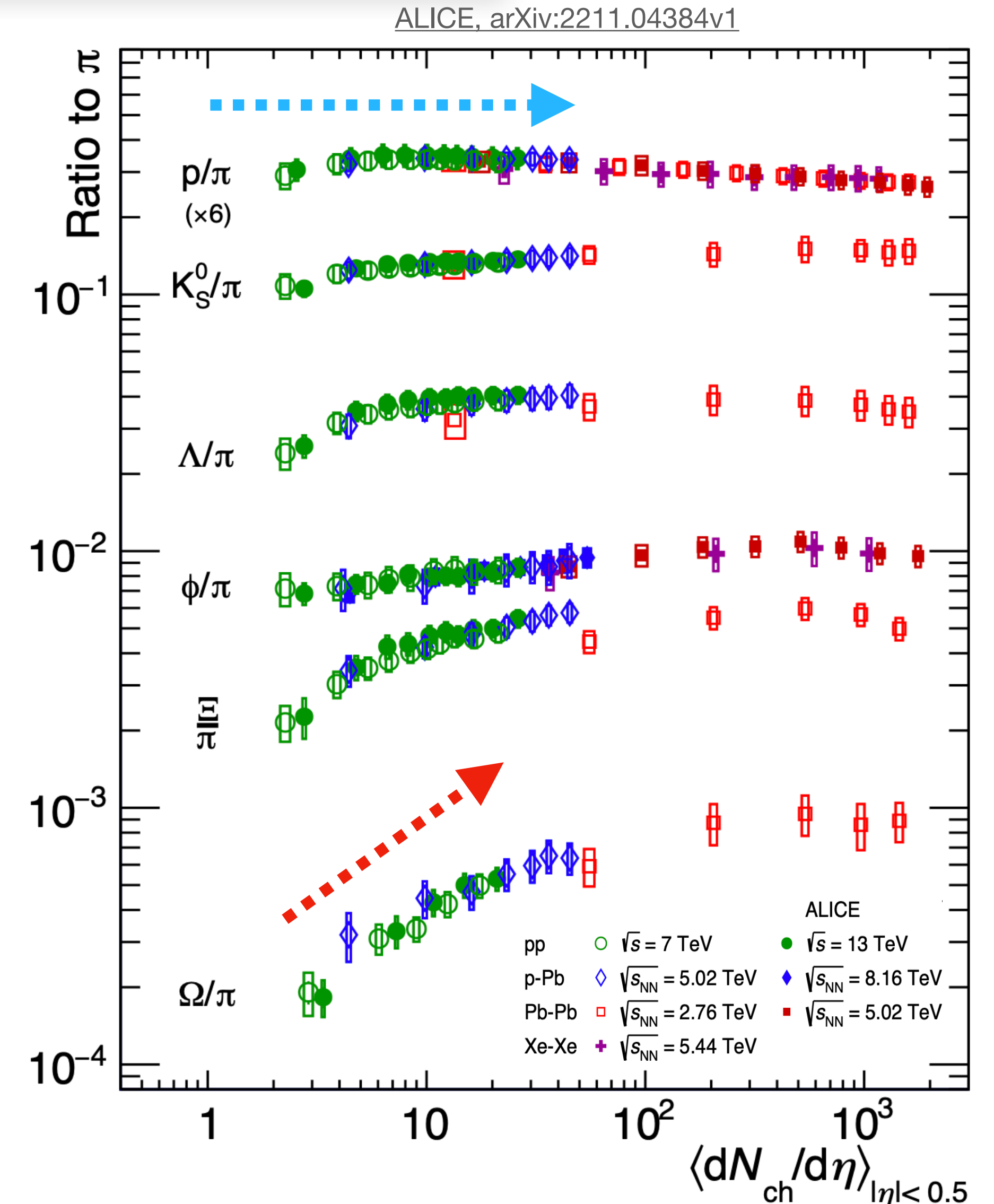
ALICE, arXiv:2211.04384v1

- This enhancement evolves smoothly across the different system sizes



Strangeness enhancement

- This enhancement evolves smoothly across the different system sizes
- Strange hadron yields grow faster with multiplicity than those of non-strange hadrons (e.g. protons)



Strangeness enhancement

- This enhancement evolves smoothly across the different system sizes
- Strange hadron yields grow faster with multiplicity than those of non-strange hadrons (e.g. protons)
- However, no MC model fully describes the data

