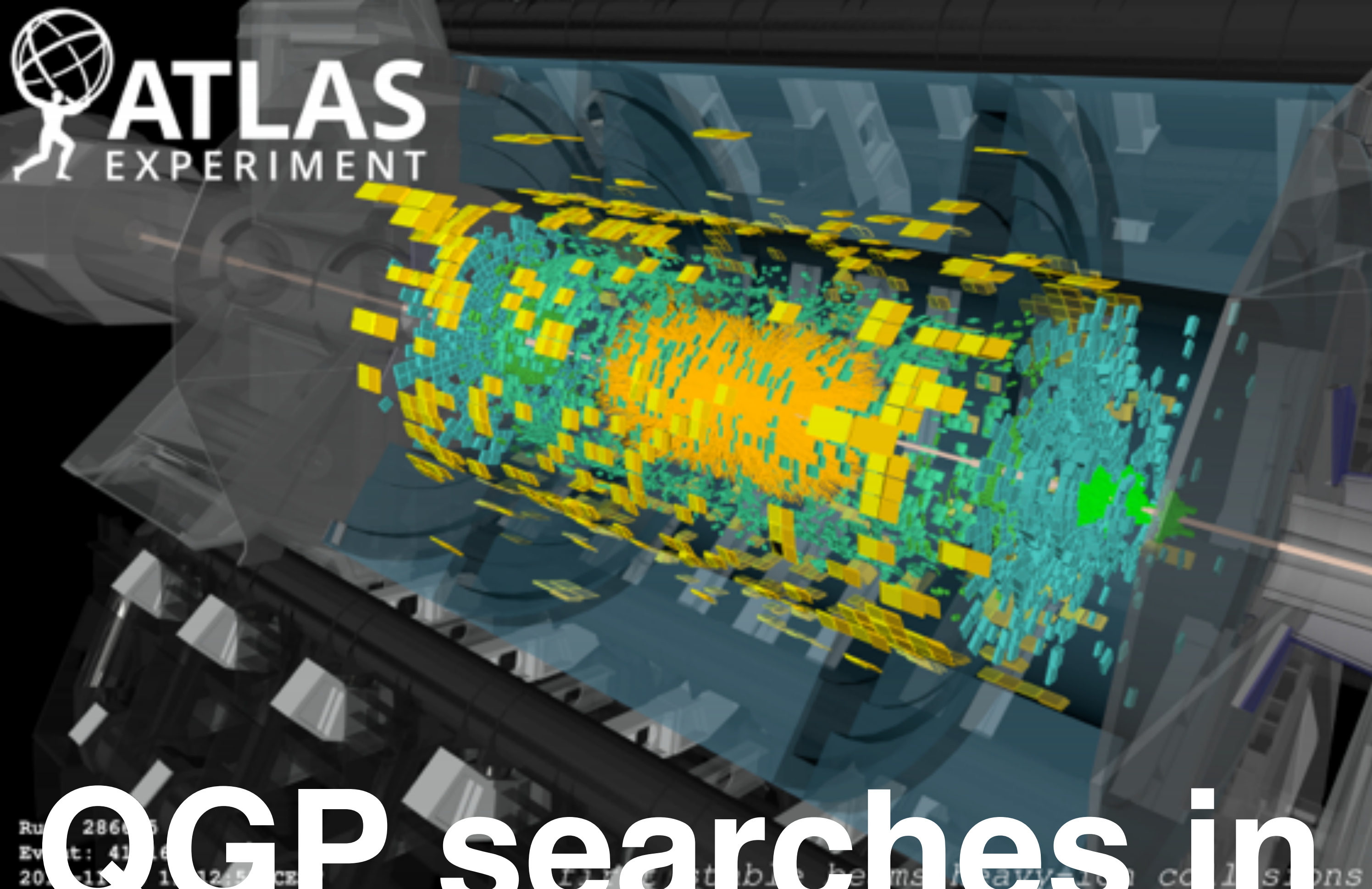
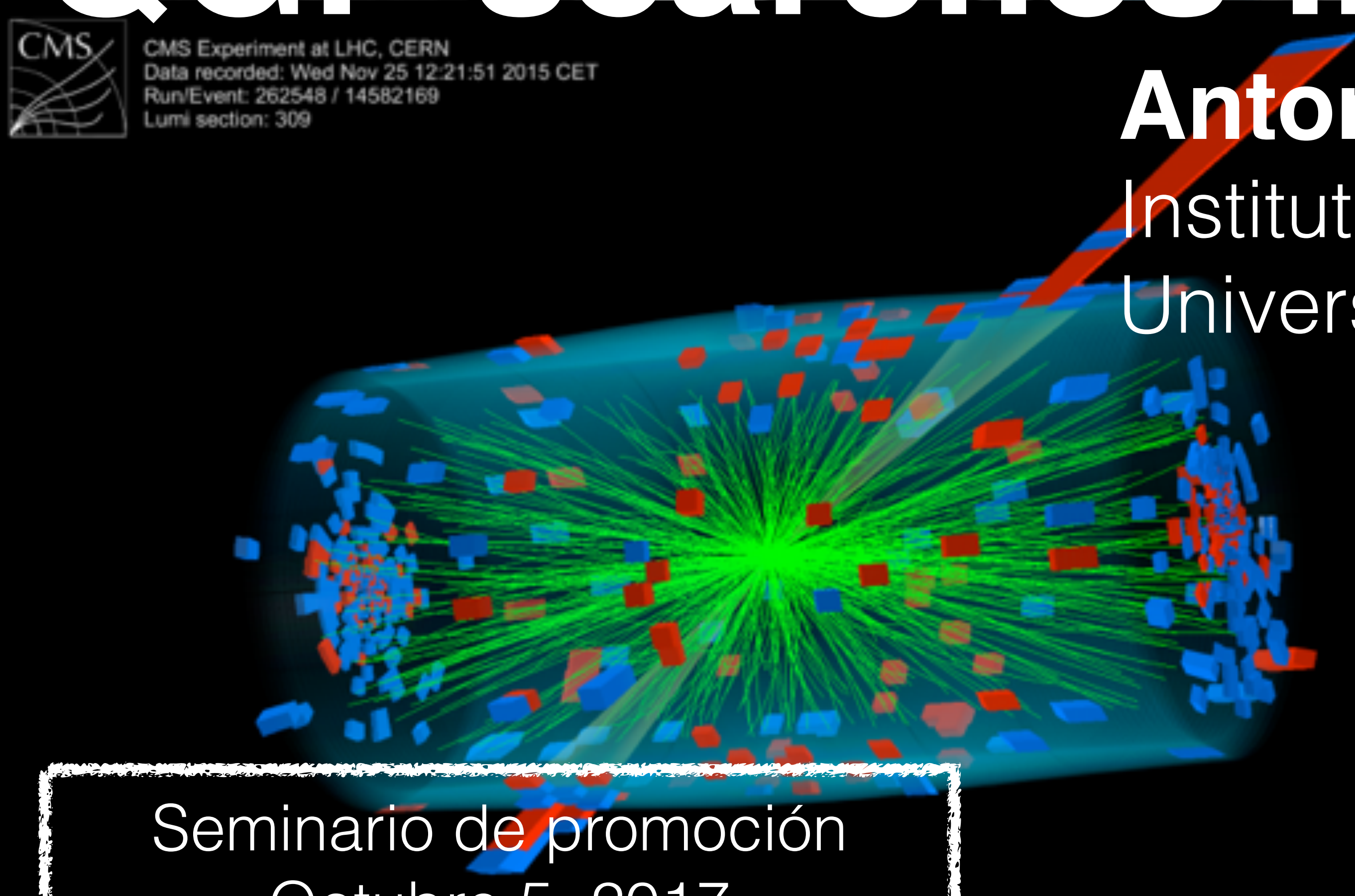
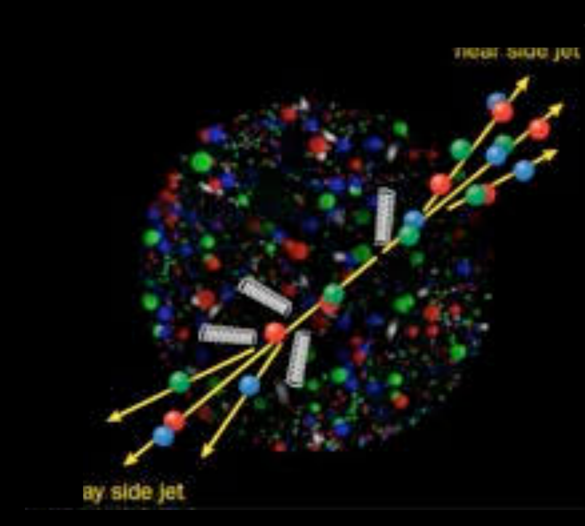


QGP searches in small systems

Antonio Ortiz
Instituto de Ciencias Nucleares
Universidad Nacional Autónoma de México





Seminario de promoción
Octubre 5, 2017

nature International weekly journal of science

Published online 19 April 2005 | Nature | doi:10.1038/news050418-5

News

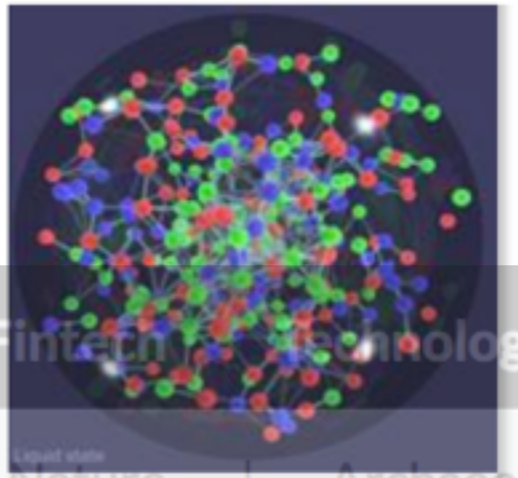
Early Universe was a liquid

Quark-gluon blob surprises particle physicists.

Mark Peplow

The Universe consisted of a perfect liquid in its first moments, according to results from an atom-smashing experiment.

Scientists at the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory on Long Island, New York, have spent five years searching for the quark-gluon plasma that is thought to have filled our Universe in the first microseconds of its existence. Most of them are now convinced they have found it. But, strangely, it seems to be a liquid rather than the expected hot gas.



Quarks and gluons have formed a unexpected liquid. Click here to see animation. © RHIC/BN

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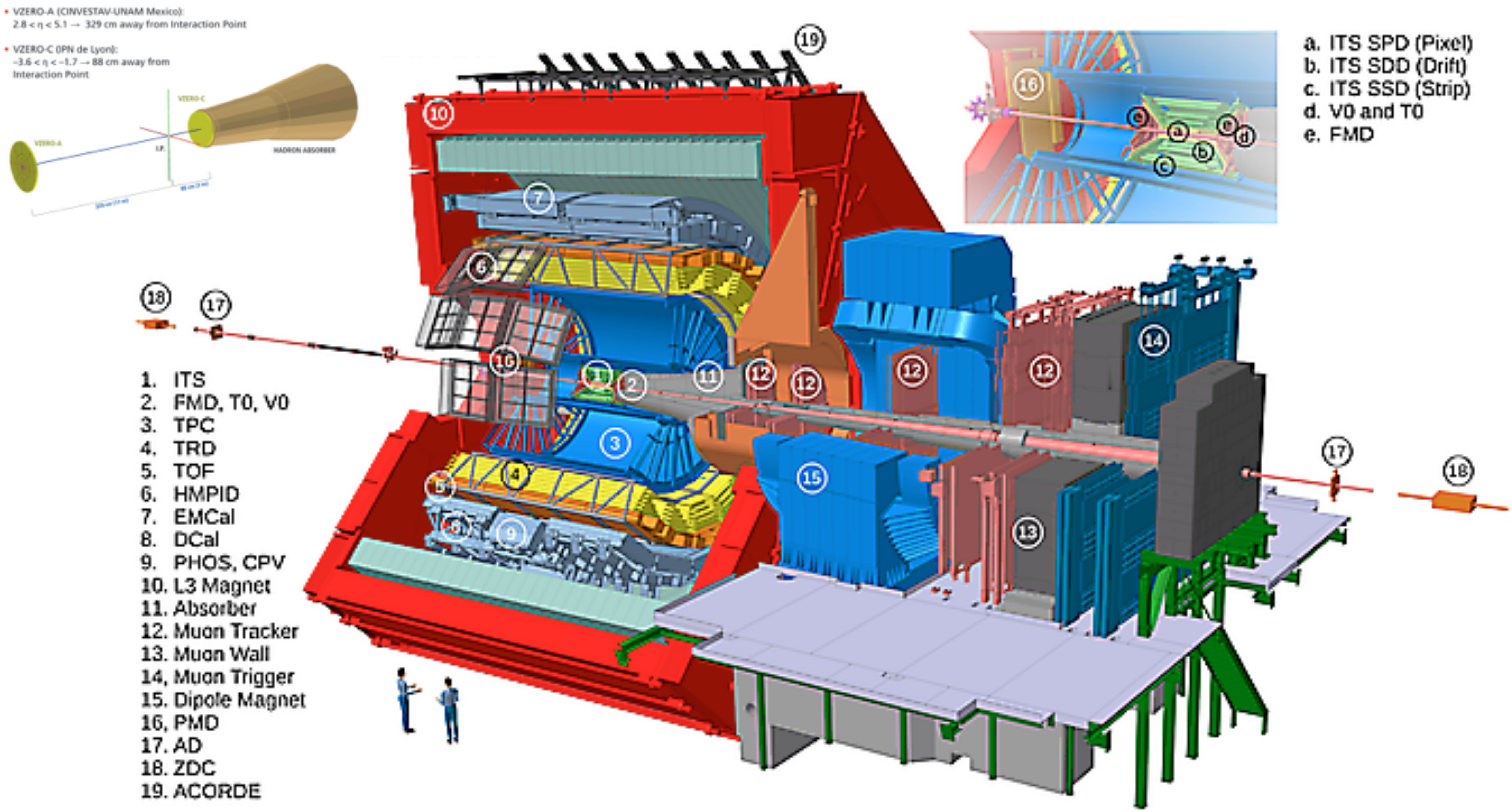
Big Bang primordial soup created by Cern's LHC shows early universe behaved like a liquid

The ALICE detector



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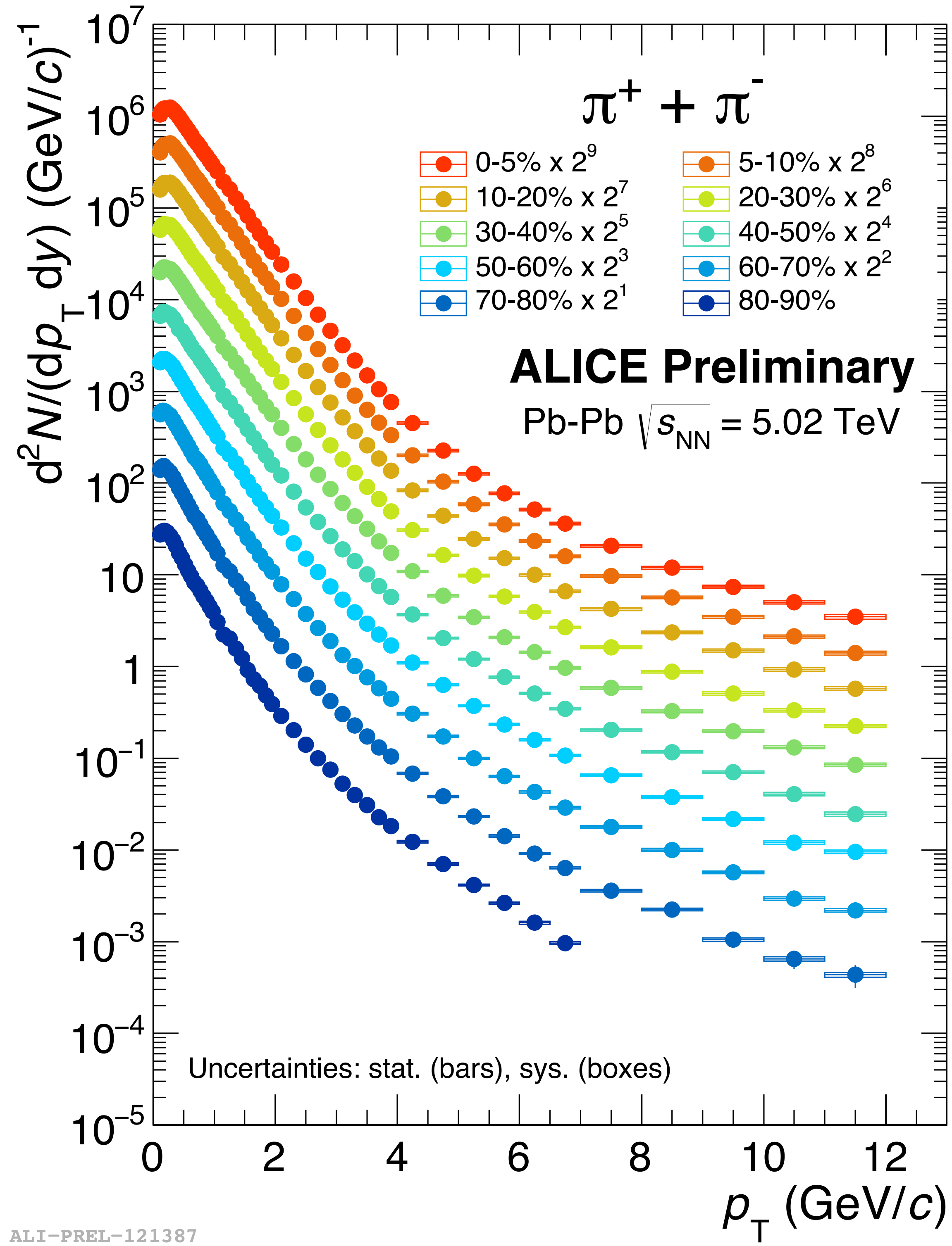
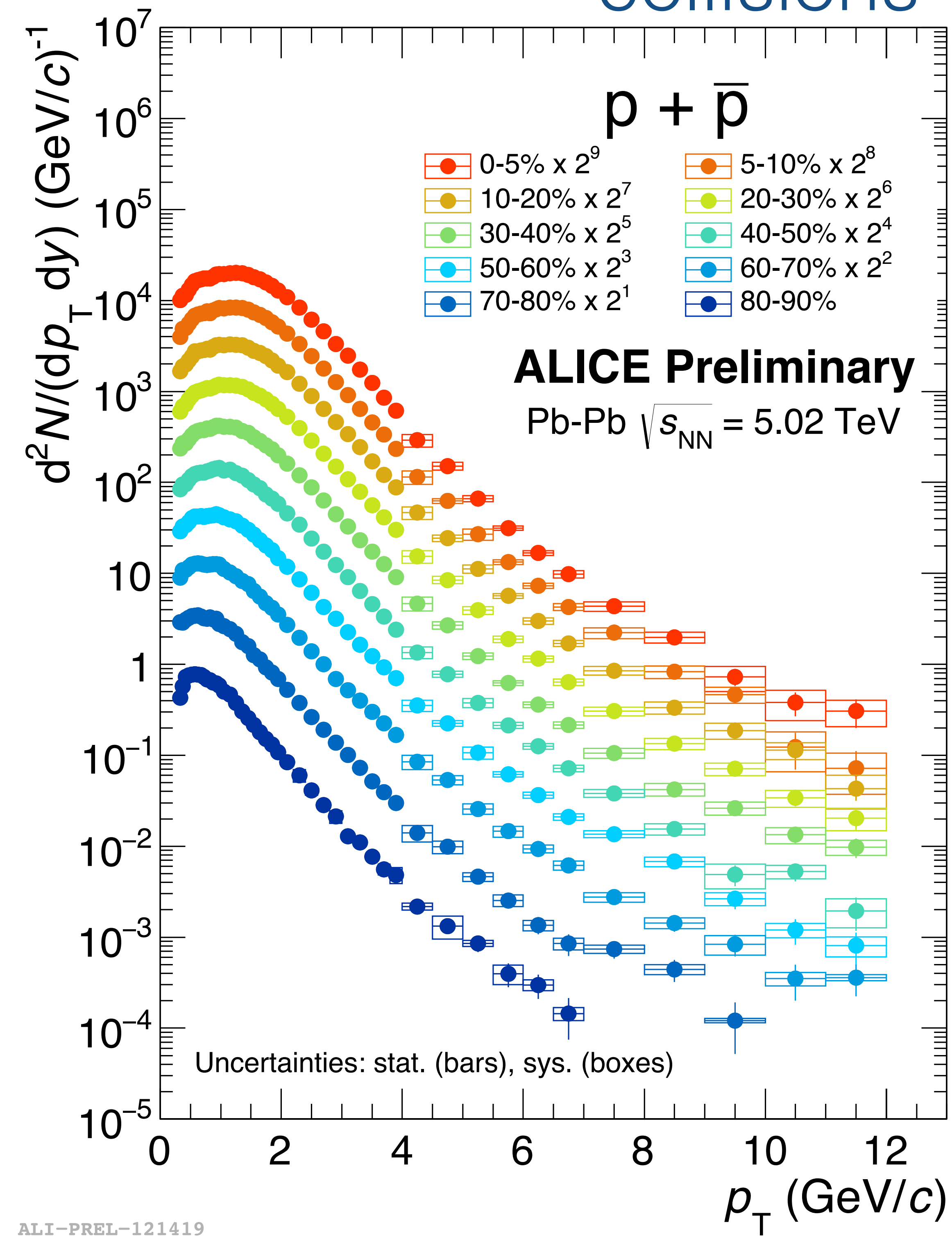
Similarities among pp, p-Pb and Pb-Pb collisions

Hereafter, pp and p-Pb collisions are referred as **small** collisions **systems**

p_T spectra in Pb-Pb collisions





Low p_T parts of the spectra are well described by models which incorporates the **hydrodynamical** evolution of the system

p_T spectra in Pb-Pb collisions

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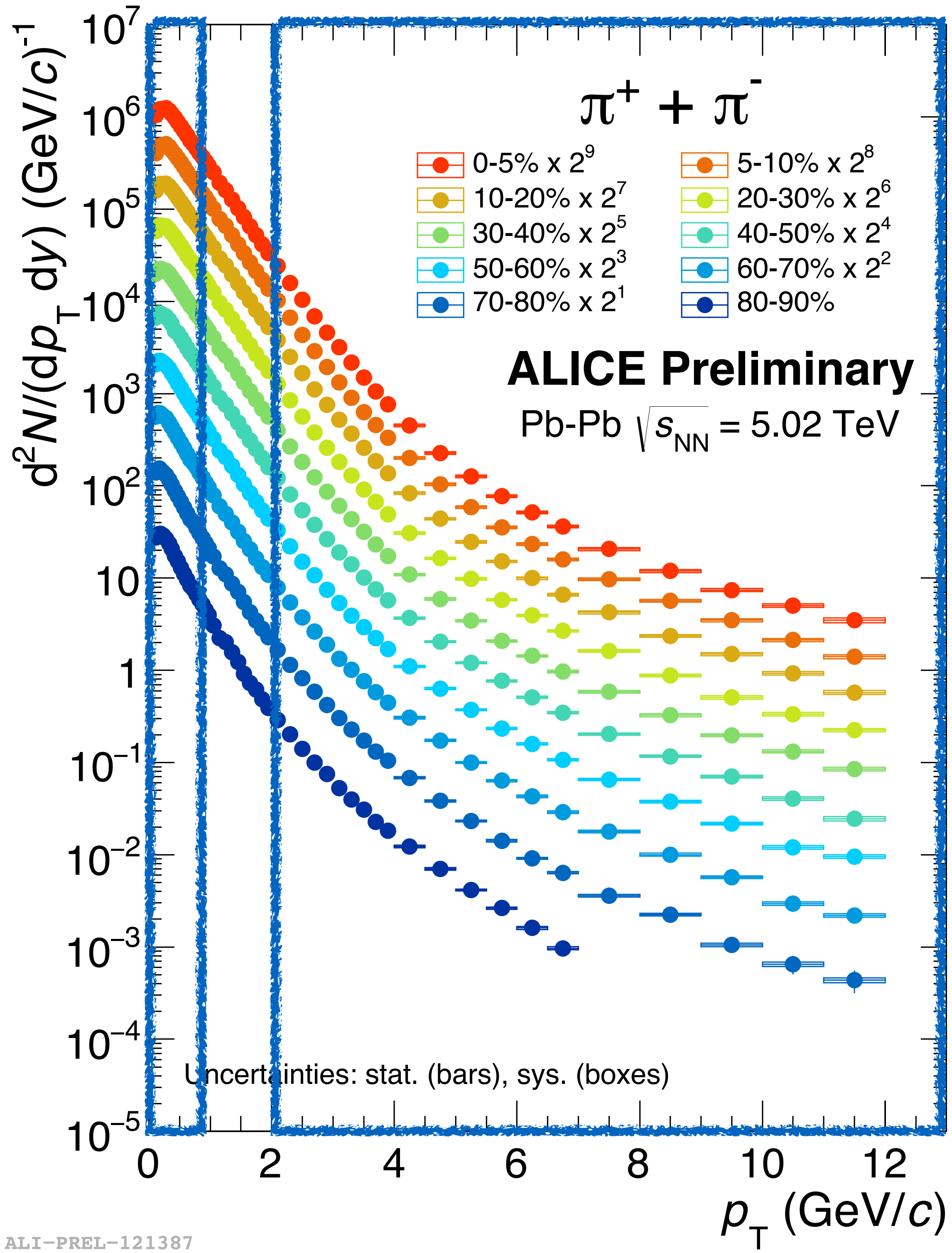
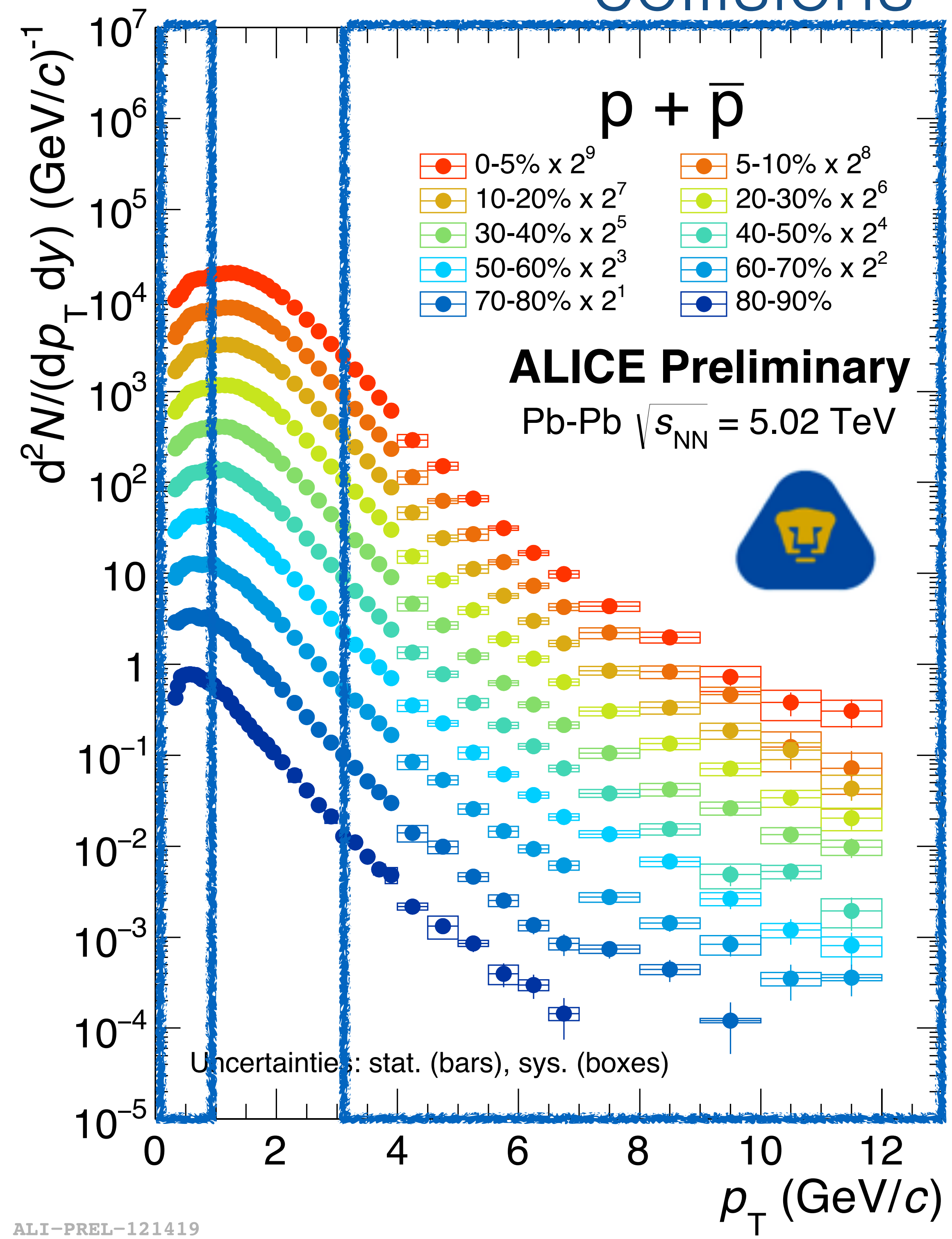


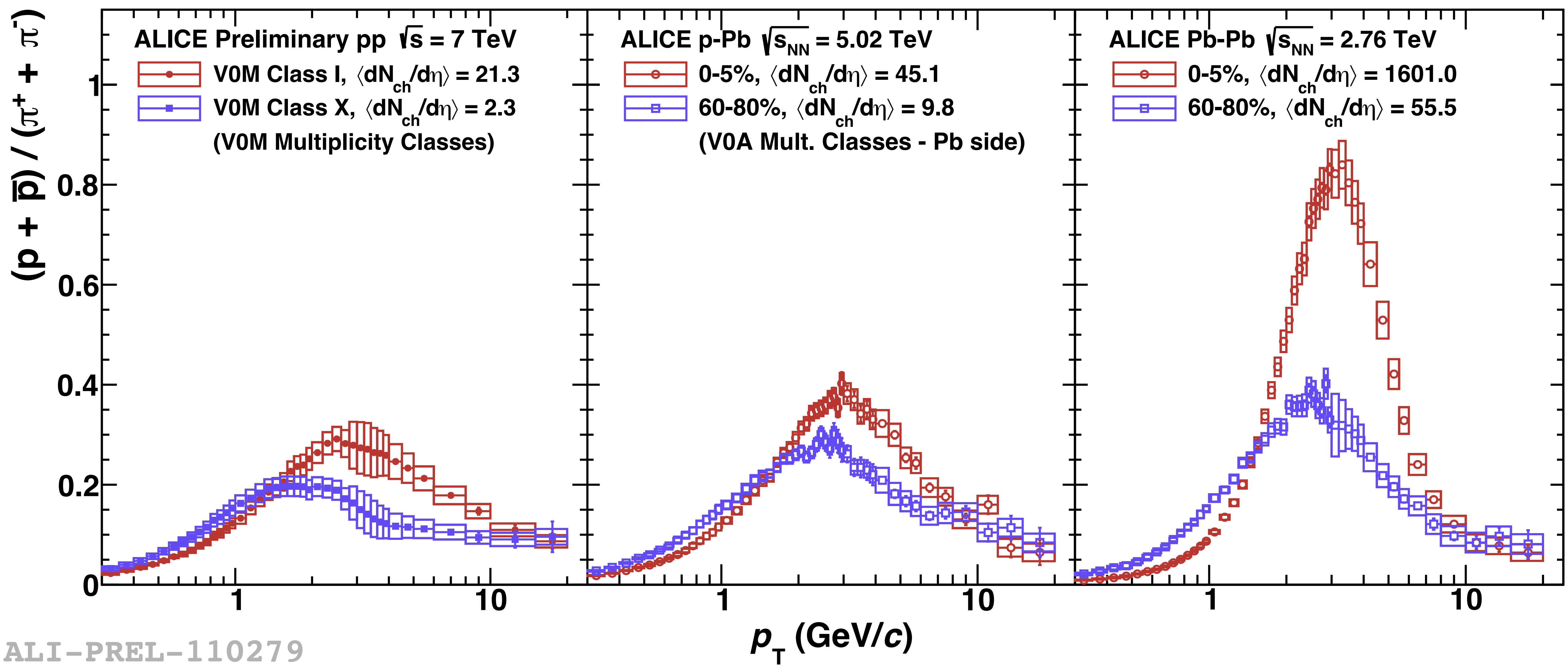


Low p_T parts of the spectra are well described by models which incorporates the **hydrodynamical** evolution of the system

O. Vázquez, A. Ortiz et al., ALICE-ANA-3345
Paper in preparation

Particle production

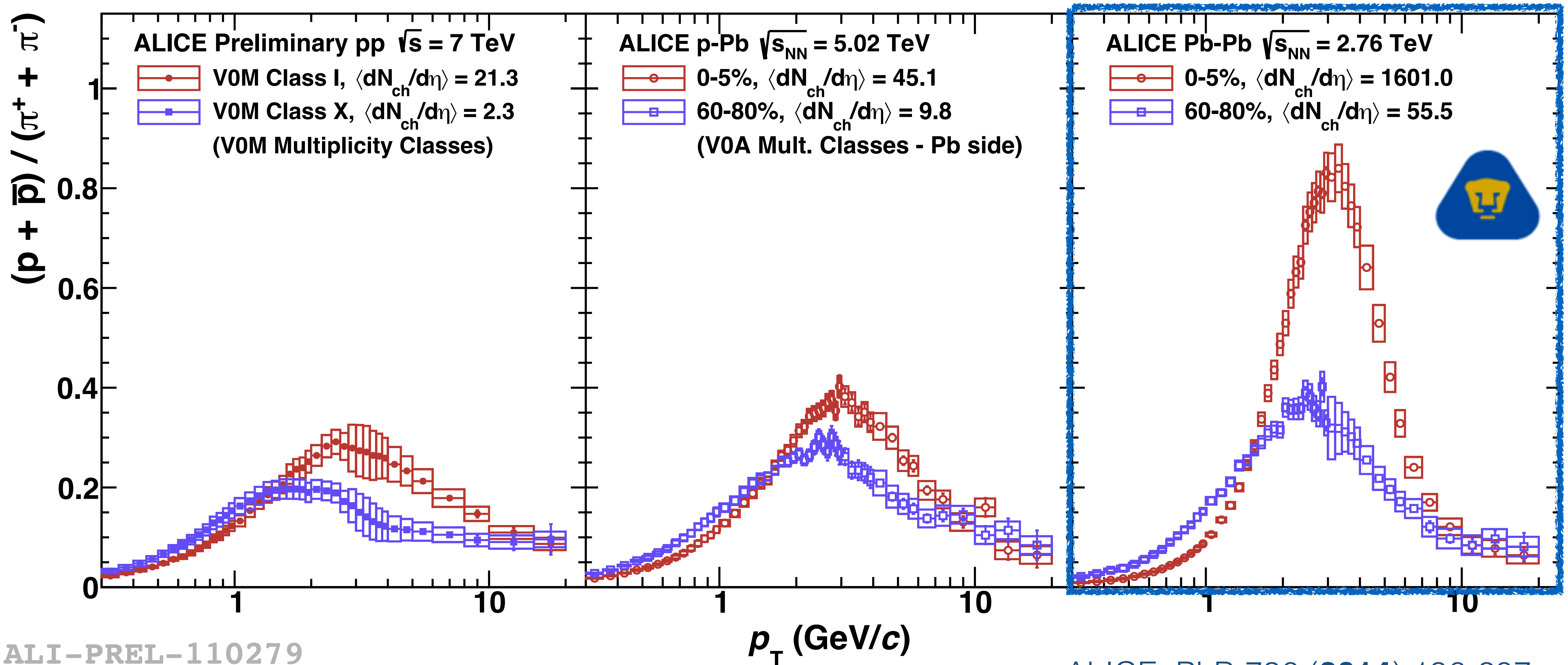
Identified particle production vs multiplicity in pp, p-Pb and Pb-Pb collisions exhibits remarkable similarities



Mass dependent modification of the p_T spectral shapes going from low to high multiplicities

Particle production

Identified particle production vs multiplicity in pp, p-Pb and Pb-Pb collisions exhibits remarkable similarities



ALICE, PLB 736 (**2014**) 196-207
ALICE, PRC 93 (**2016**) no.3, 034913
A. Ortiz et al., ALICE-ANA-644
A. Ortiz et al., ALICE-ANA-232

Particle production

Instituto de Ciencias Nucleares UNAM

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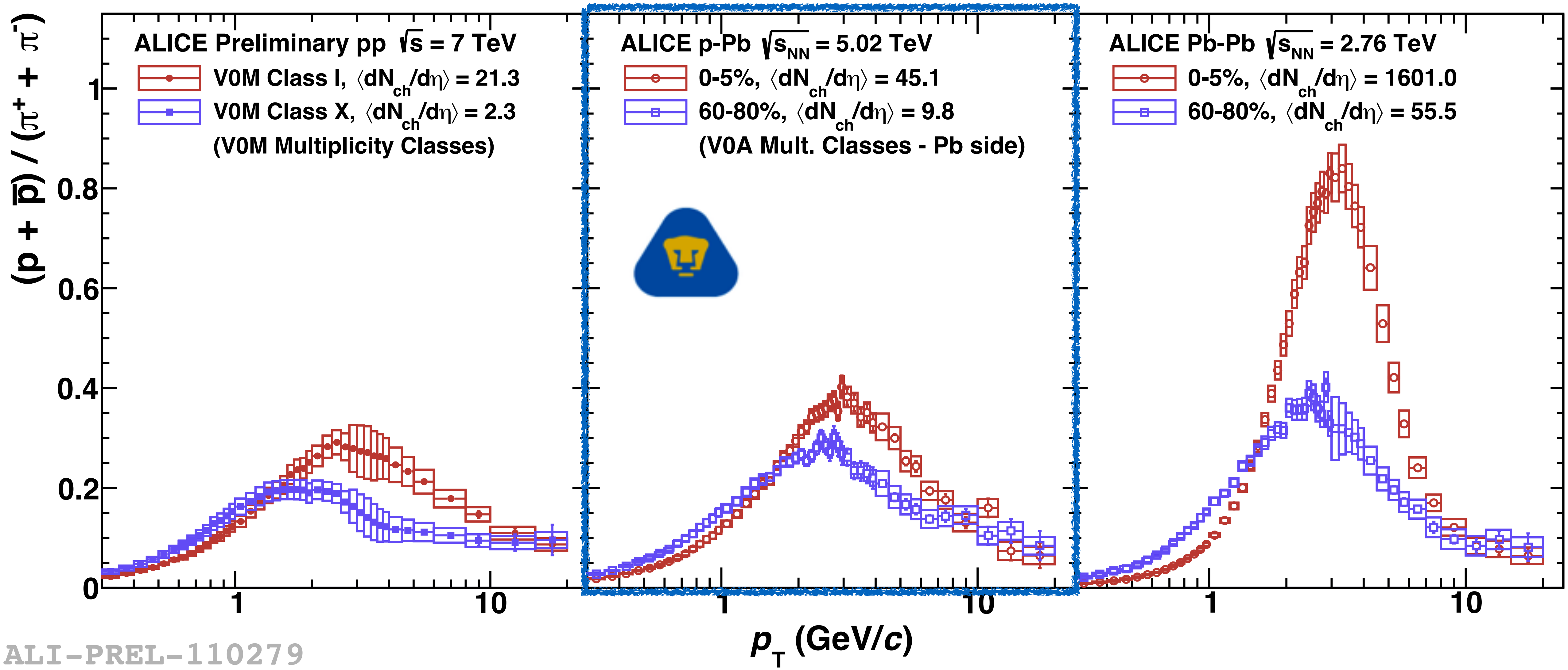
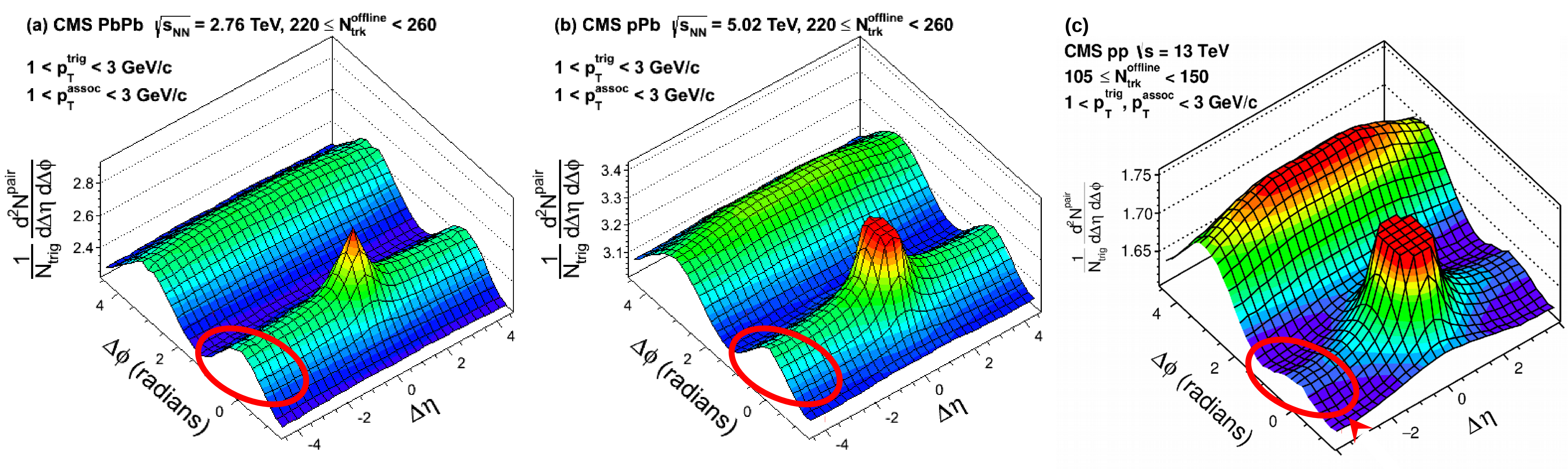


ALICE, PLB 760 (**2016**) 720-735

G. Bencedi, A. Ortiz and P. Christiansen, ALICE-ANA-2692
A. Ortiz et al., ALICE-ANA-1091

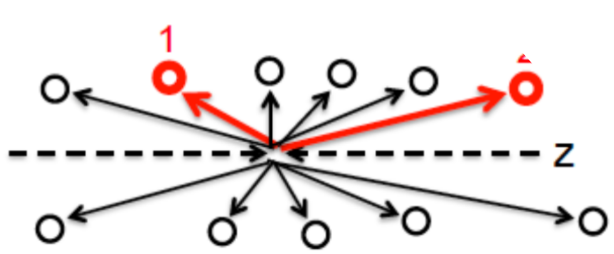
Long-range correlations

Two-particle correlations with inclusive charged particles



CMS, PLB 724 (2013) 213

CMS, PLB 765 (2017) 193

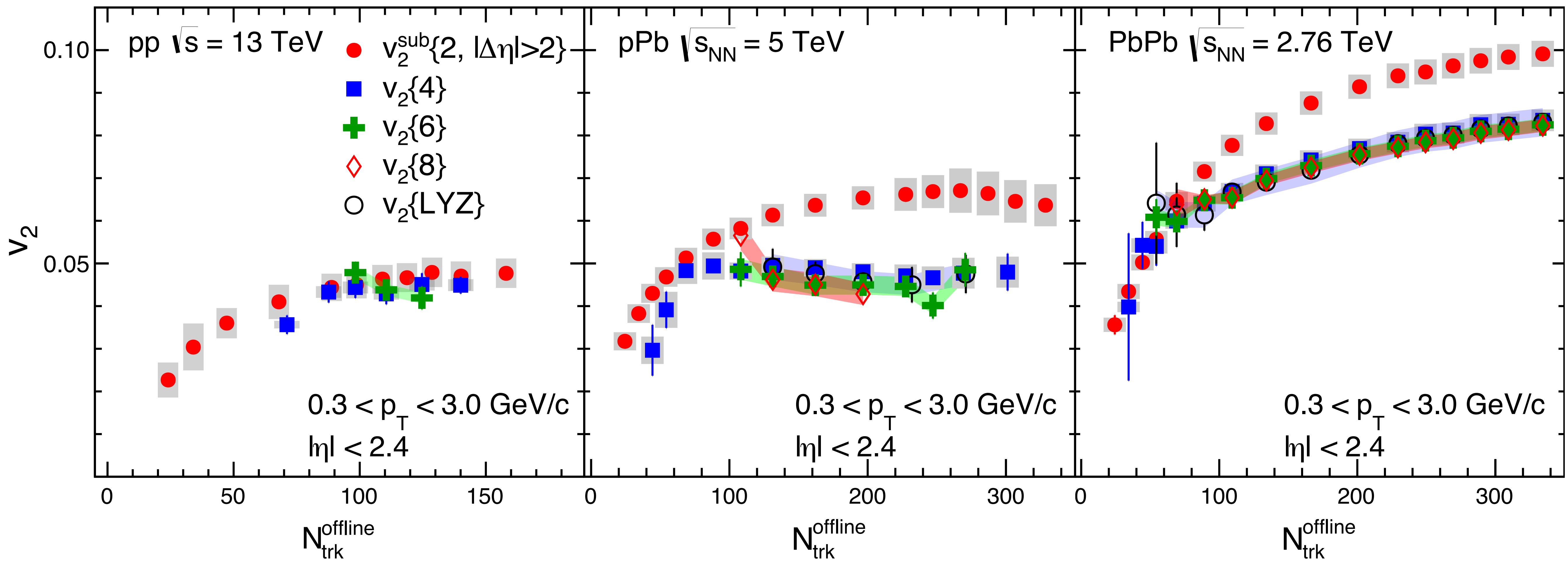


What is the nature of long-range correlations observed in small systems?

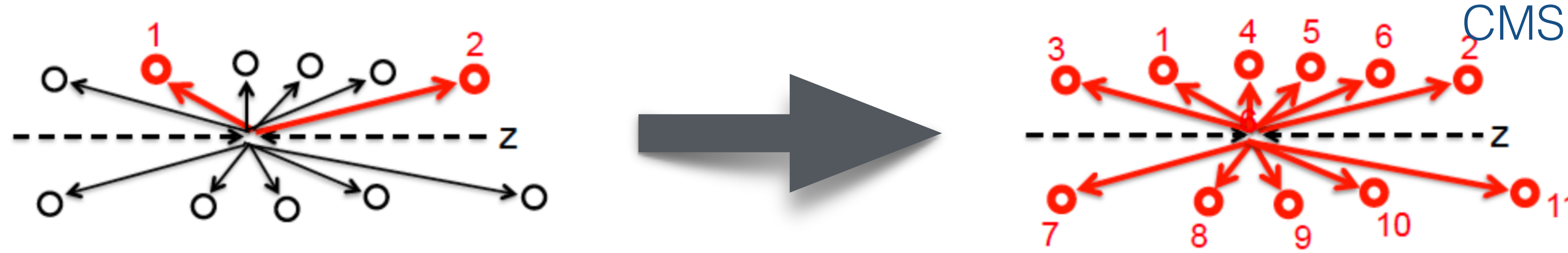
Collectivity in small systems?

v_2 from four- and six-particle correlations in pp at $\sqrt{s}$ = 13 TeV:

- comparable magnitude to those form two-particle correlations
- similar to those seen in p-Pb and Pb-Pb collisions



CMS, PLB 765 (2017) 193



Less sensitive to non-flow effects

Collectivity in small systems?

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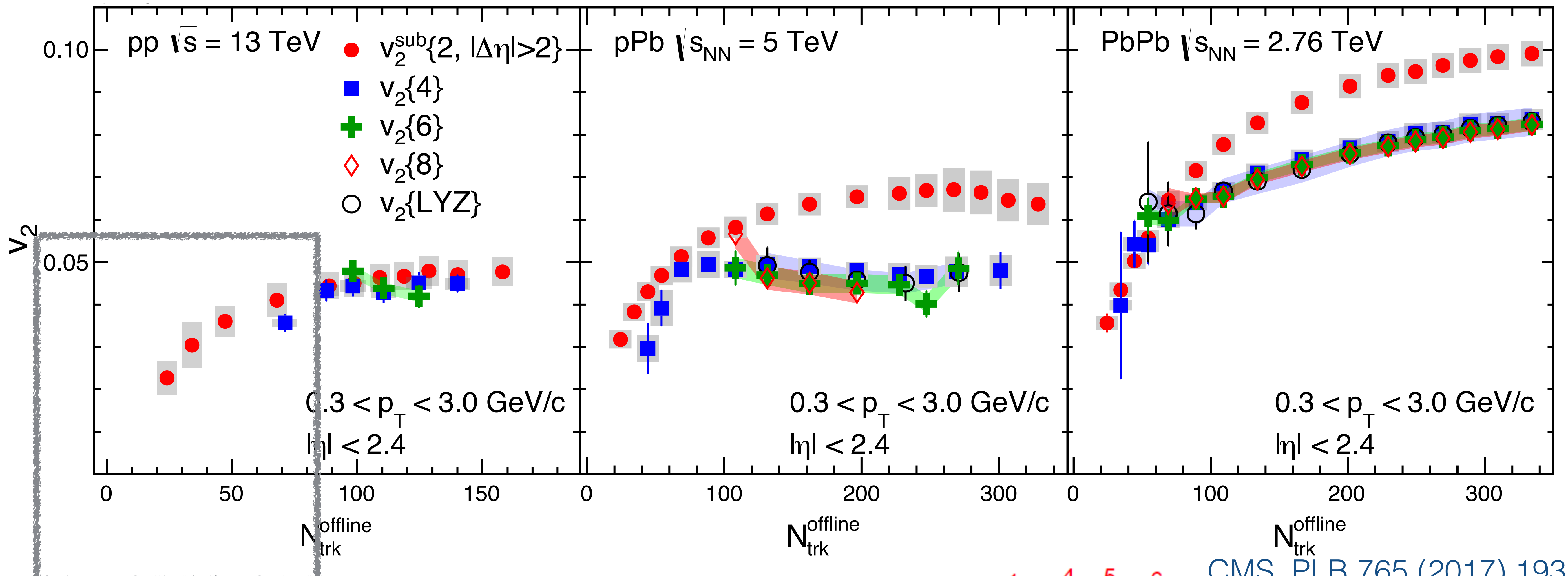
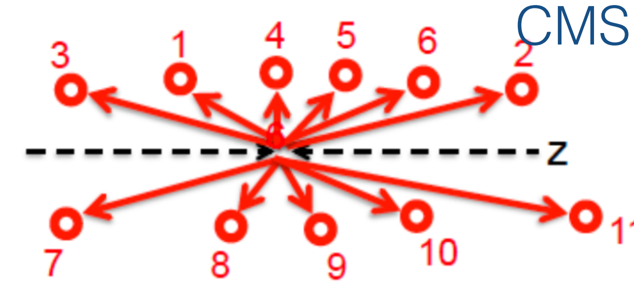


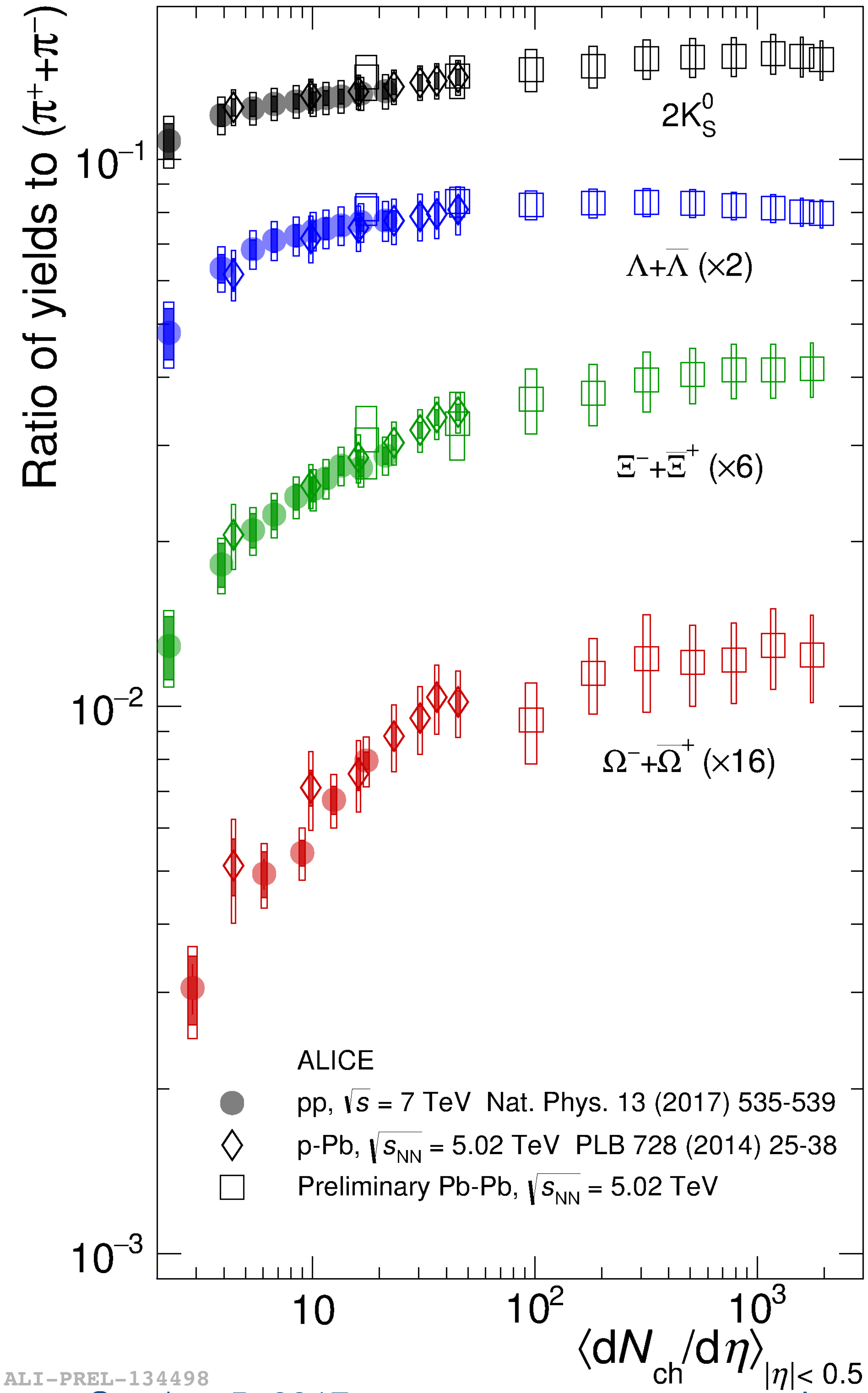
CMS, PLB 765 (2017) 193

Discrepancy with ATLAS results, new methods needed for low multiplicity events



Medium effects in low multiplicity events?

Less sensitive to non-flow effects

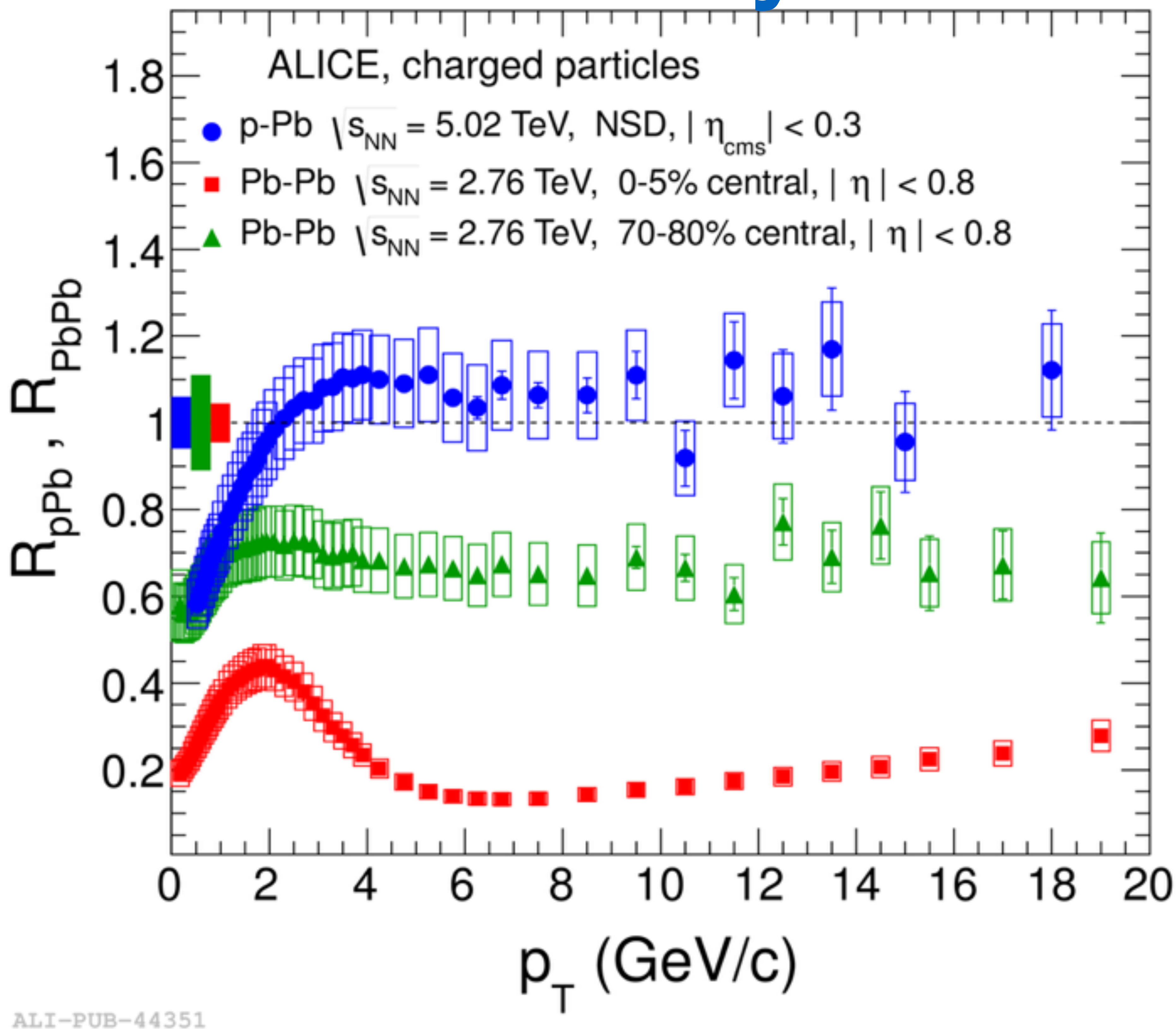


Strangeness

First observation of a multiplicity dependent strangeness enhancement in high-multiplicity pp collisions

- Enhancement is due to strangeness content and not due to mass
- Multiplicity dependence of the enhancement is strikingly similar in pp and p-Pb, and approaches values similar to those measured in central Pb-Pb
- QCD inspired MC generators fail to describe these observations

No jet quenching signatures in small systems



No jet quenching signatures in small systems

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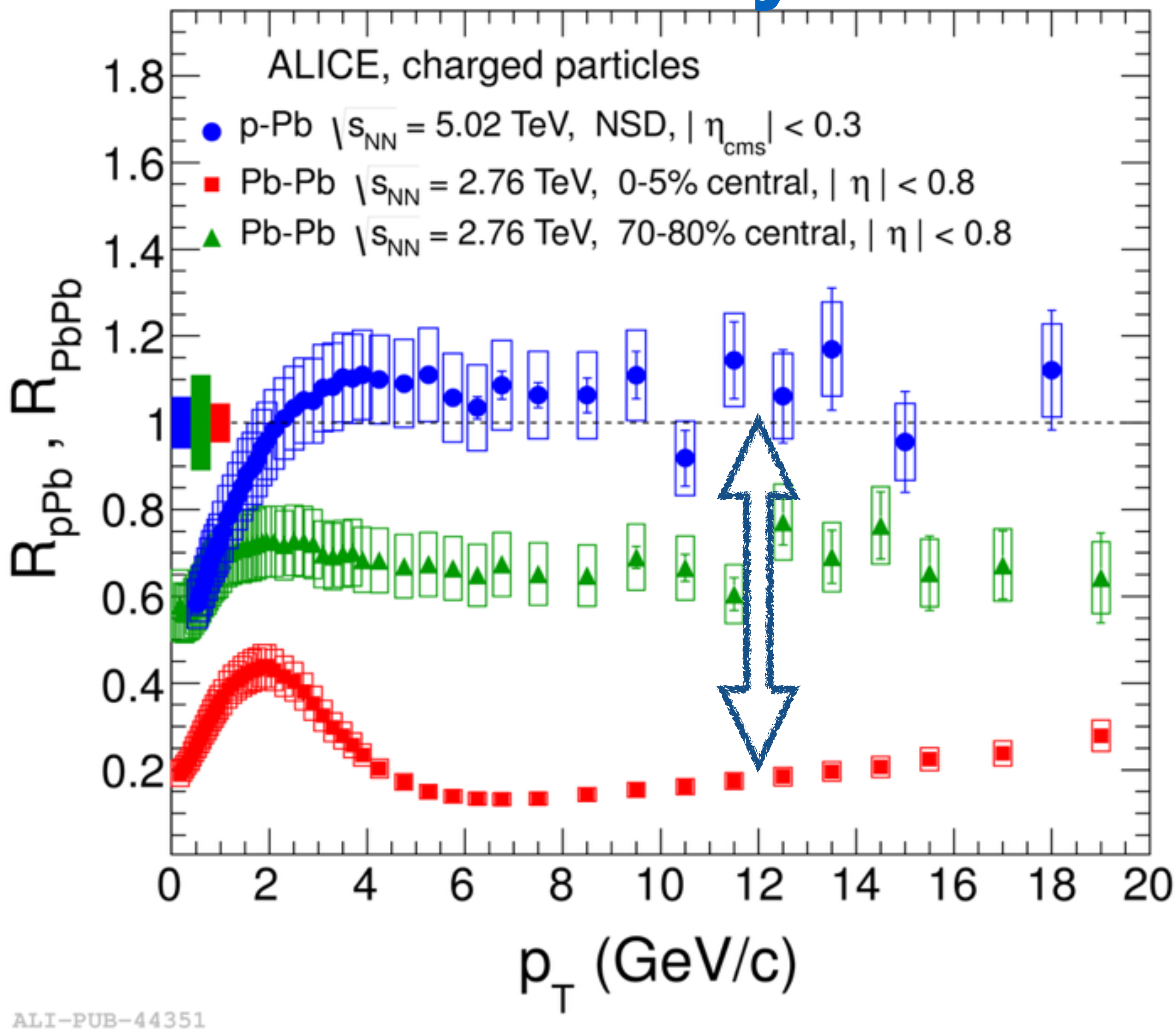

$$R_{\mathrm{AA,pA}} = \frac{\mathrm{d}^2 N_{\mathrm{ch}}^{\mathrm{AA,pA}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}}{\langle N_{\mathrm{coll}}\rangle \mathrm{d}^2 N_{\mathrm{ch}}^{\mathrm{pp}}/\mathrm{d}y\mathrm{d}p_{\mathrm{T}}}$$

Small systems

Open questions

Thoughts and opportunities
in the soft-QCD sector from high-energy nuclear collisions

Federico Antinori, Francesco Becattini, Peter Braun-Munzinger, Tatsuya Chujo, Hideki Hamagaki, John Harris, Ulrich Heinz, Boris Hippolyte, Tetsufumi Hirano, Barbara Jacak, Dmitri Kharzeev, Constantin Loizides, Silvia Masciocchi, Alexander Milov, Andreas Morsch, Berndt Müller, Jamie Nagle, Jean-Yves Ollitrault, **Guy Paić**, Krishna Rajagopal, Gunther Roland, Jürgen Schukraft, Yves Schutz, Raimond Snellings, Johanna Stachel, Derek Teaney, Julia Velkovska, Sergei Voloshin, Urs Achim Wiedemann, Zhangbu Xu, William Zajc

arXiv:1604.03310

Flow-like phenomena in small systems

- Is there a minimum size for the onset of collective behavior?
- Do the systematic variations across beam energies, collision centralities, system size and transverse and longitudinal momentum support a fluid dynamical interpretation?

√s dependence of
π/K/p in pp collisions

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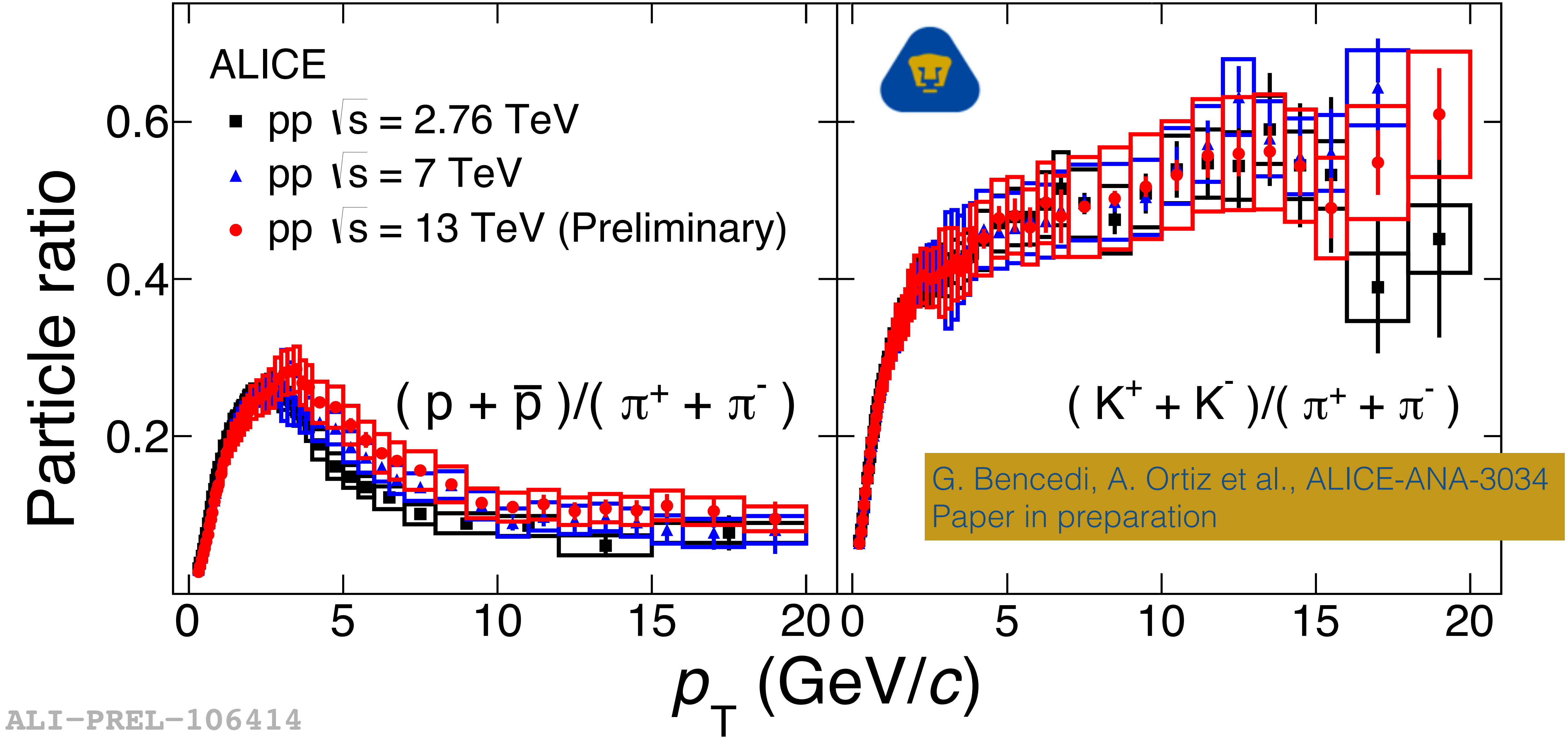
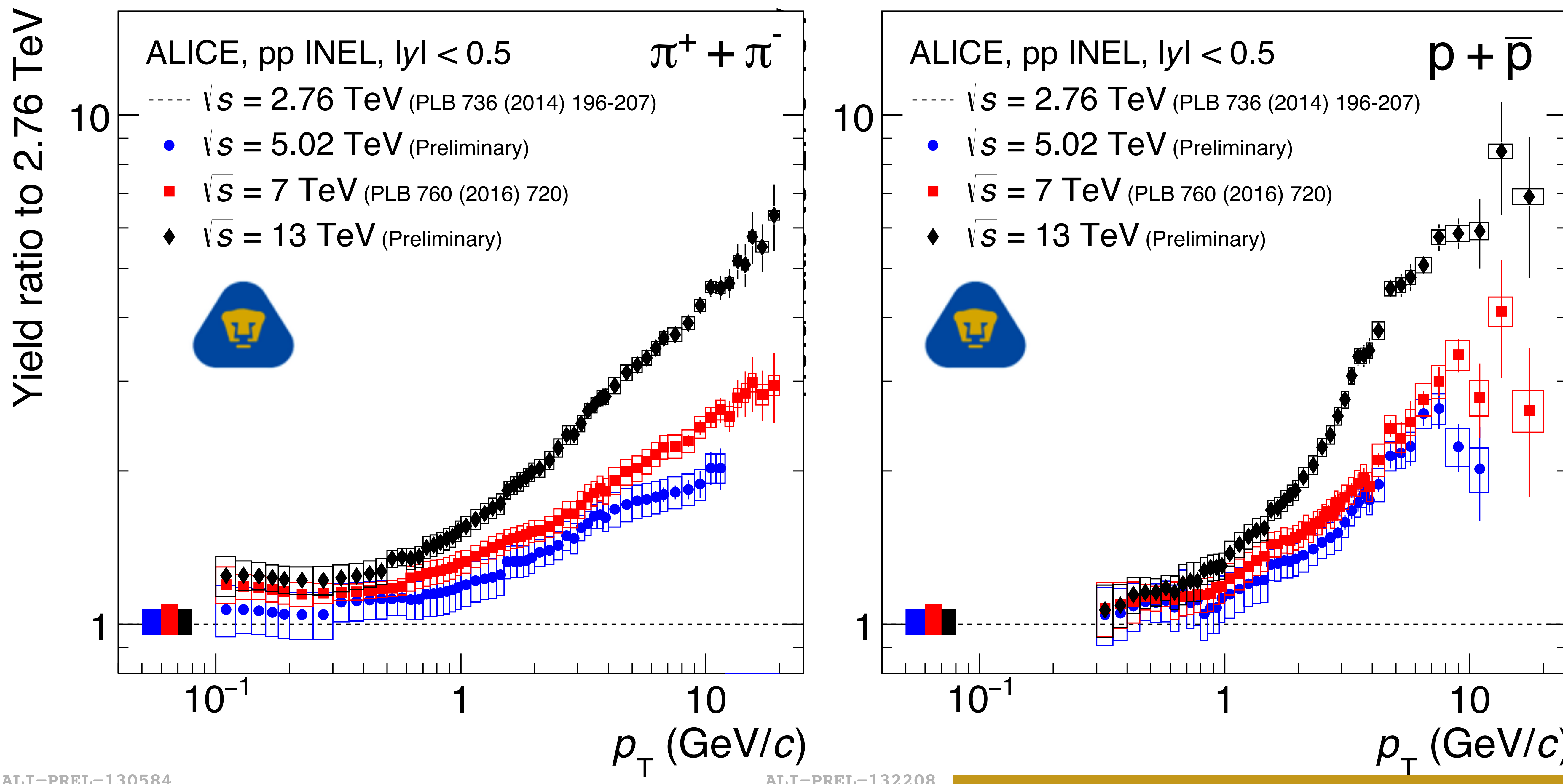


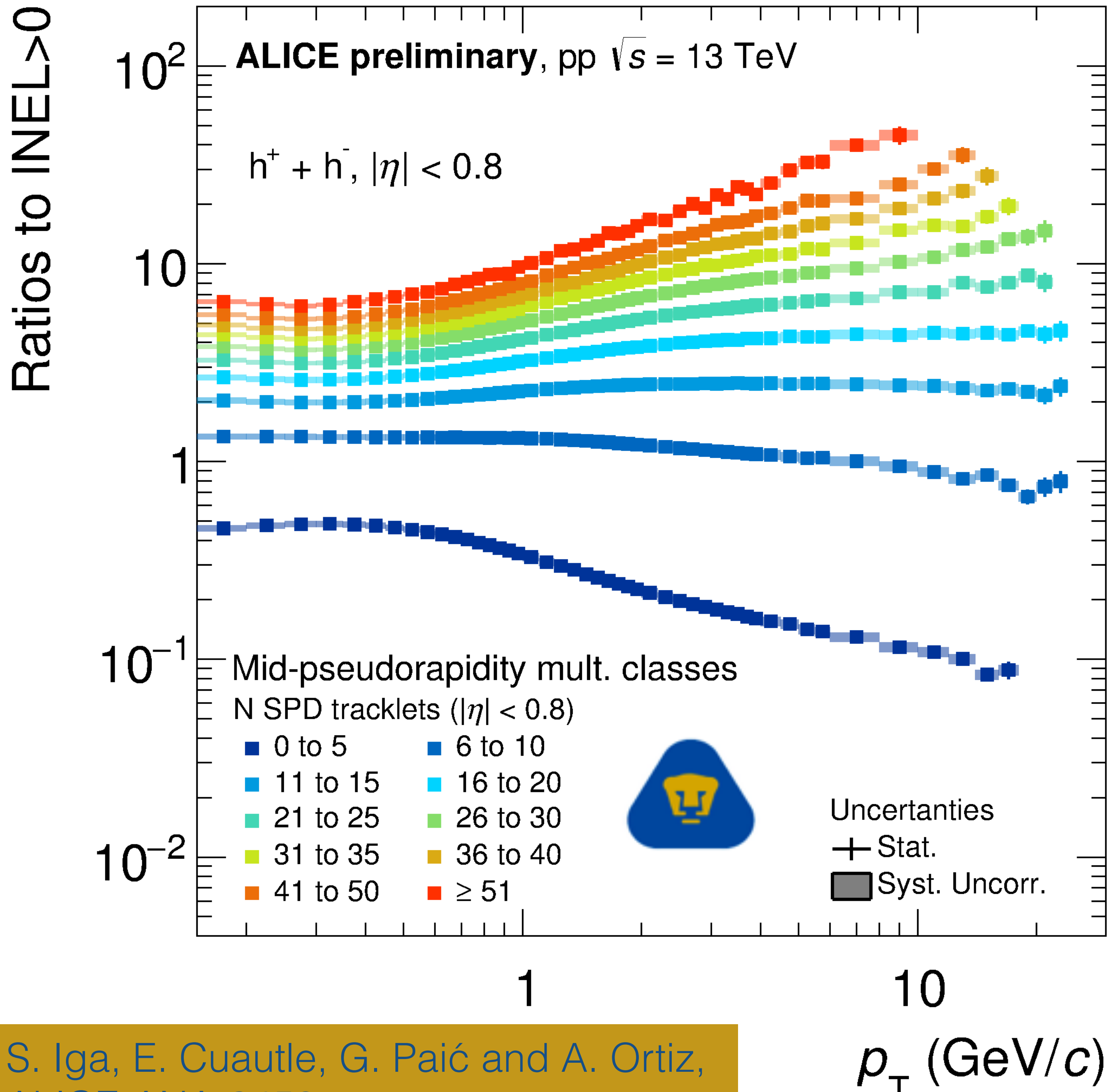
The evolution of the "particle ratios" with $\sqrt{s}$ is consistent with the expected behaviour driven by the change in $\langle N_{\mathrm{ch}} \rangle$

Hardening of the p_T spectra with increasing $\sqrt{s}$



G. Bencedi, A. Ortiz et al., ALICE-ANA-3034
Paper in preparation

Inclusive charged p_T vs N_{ch}



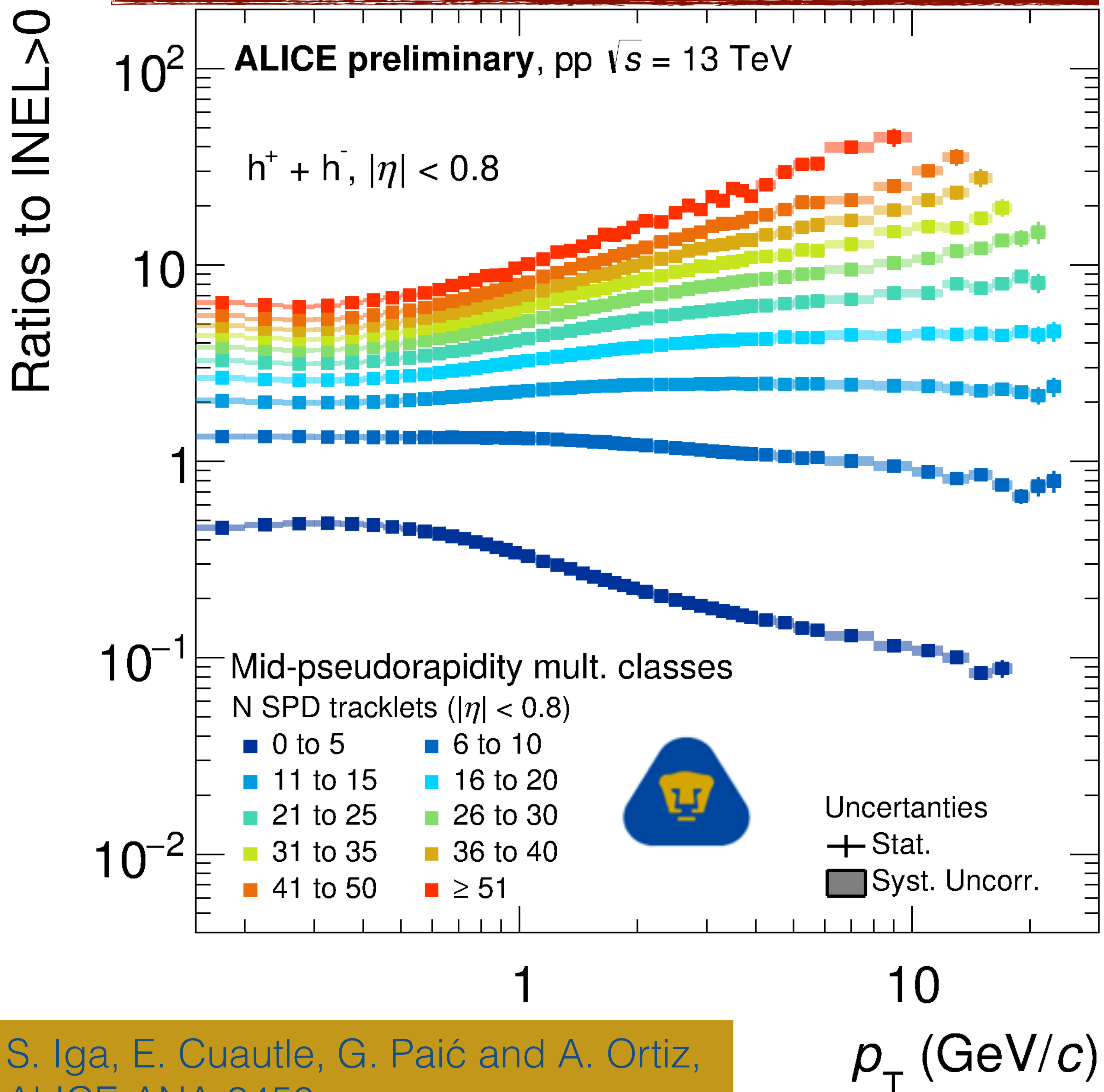
S. Iga, E. Cuautle, G. Paić and A. Ortiz, ALICE-ANA-3450

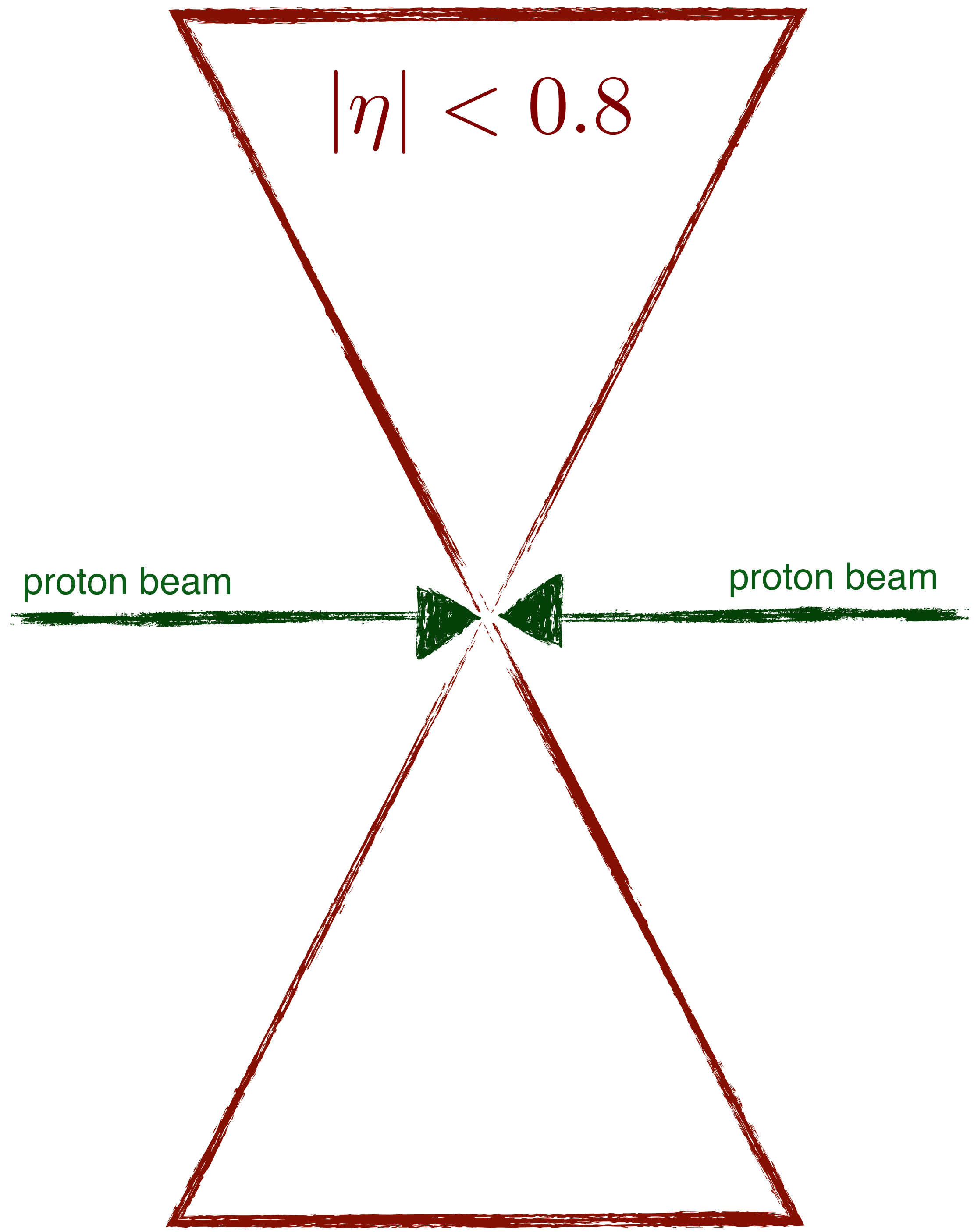
Ratios to MB exhibit two common features

- Little or no p_T dependence is observed for $p_T < 1$ GeV/c
- Strong p_T dependence for larger transverse momenta
- The trends are well described by PYTHIA 8.212 tune Monash 2013

Inclusive charged p_T vs N_{ch}

Potential biases for high multiplicity events selected with mid-rapidity estimators





S. Iga, E. Cuautle, G. Paić and A. Ortiz, ALICE-ANA-3450

Inclusive charged p_{T} vs N_{ch}

Instituto de Ciencias Nucleares UNAM

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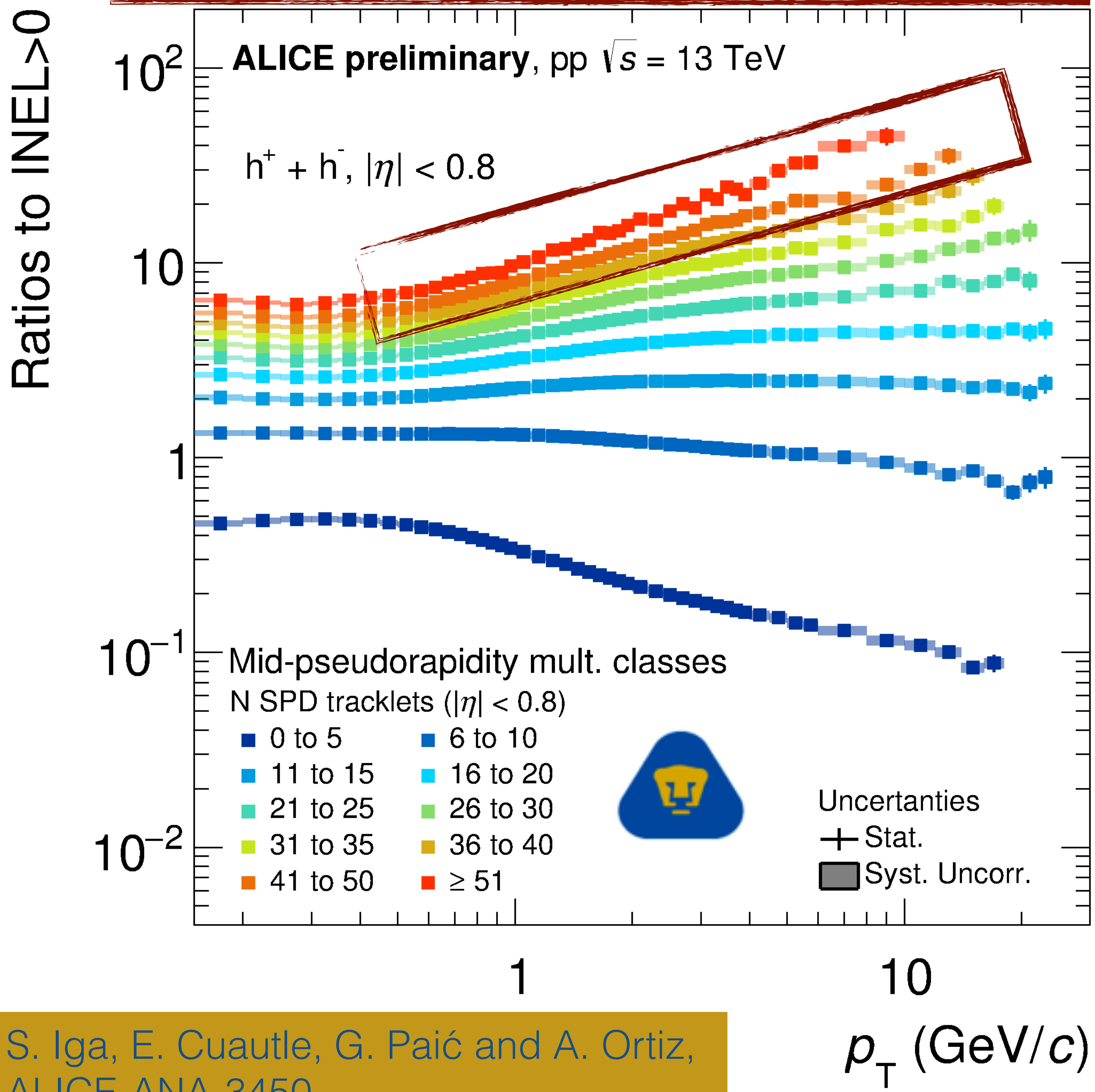
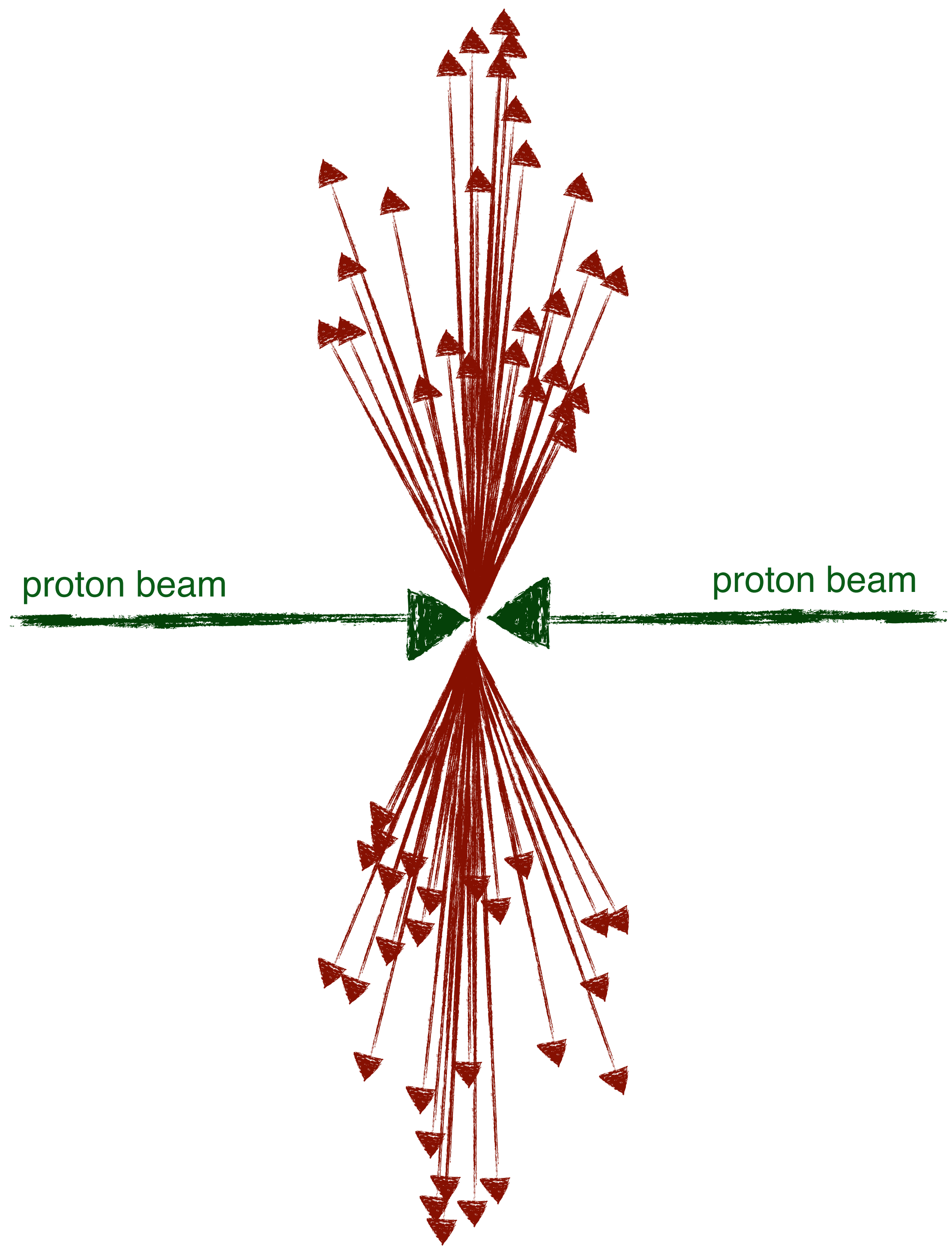


High probability for picking up jets



S. Iga, E. Cuautle, G. Paić and A. Ortiz, ALICE-ANA-3450

Inclusive charged p_T vs N_{ch}

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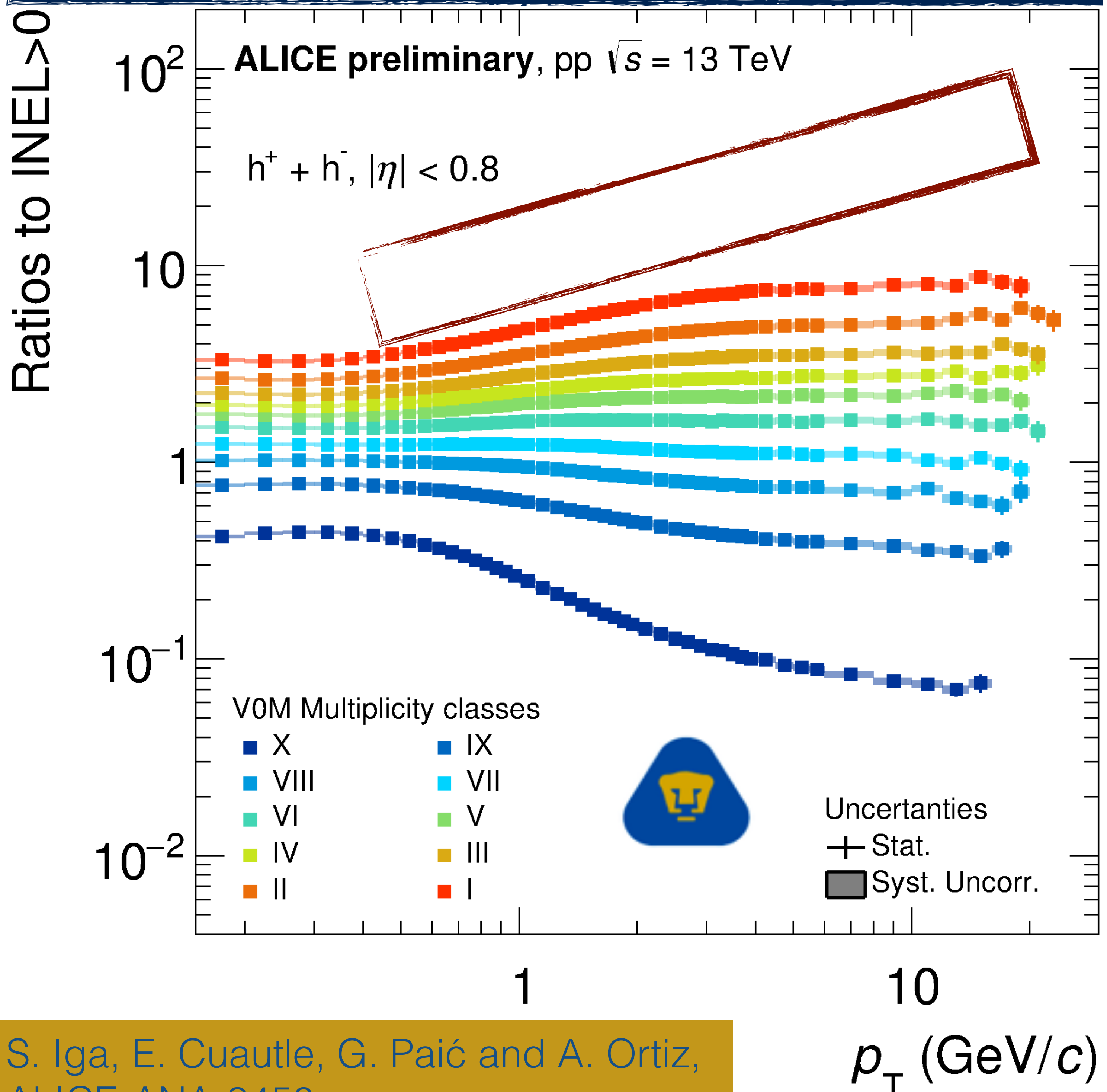
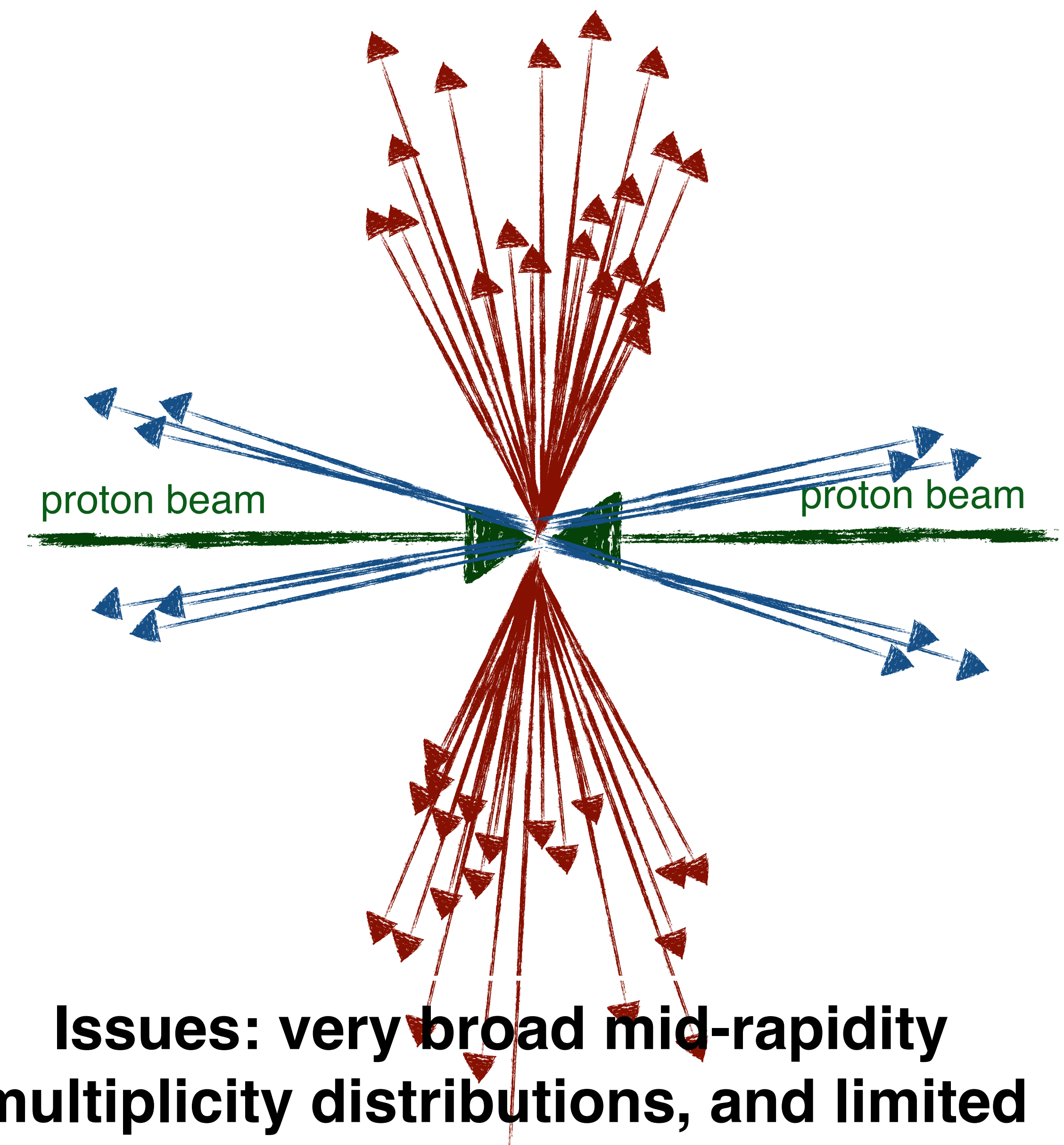
To study the effect we also performed an analysis using a multiplicity selector based on VZERO

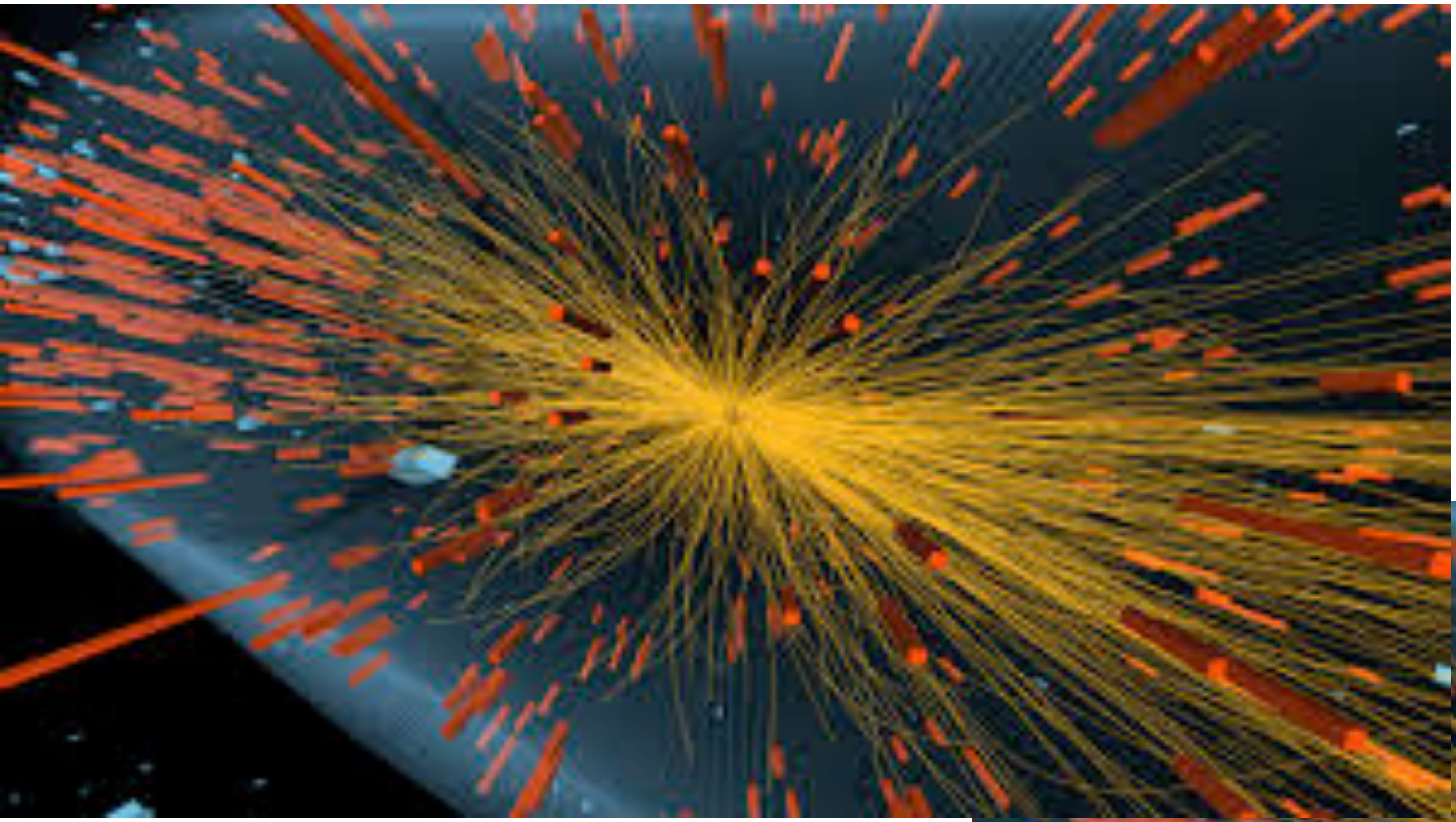


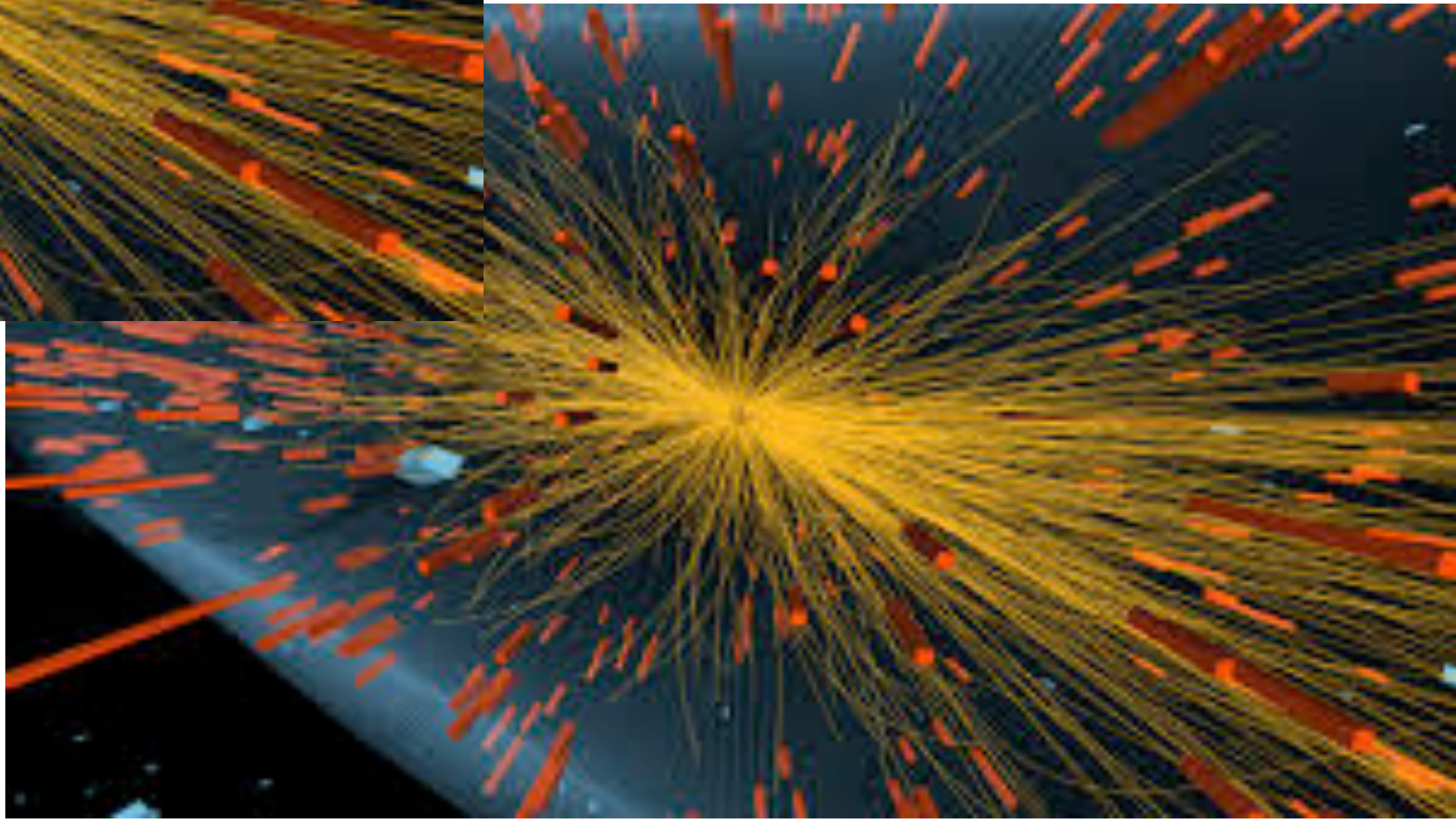


Issues: very broad mid-rapidity multiplicity distributions, and limited average mid-rapidity multiplicity

S. Iga, E. Cuautle, G. Paić and A. Ortiz, ALICE-ANA-3450

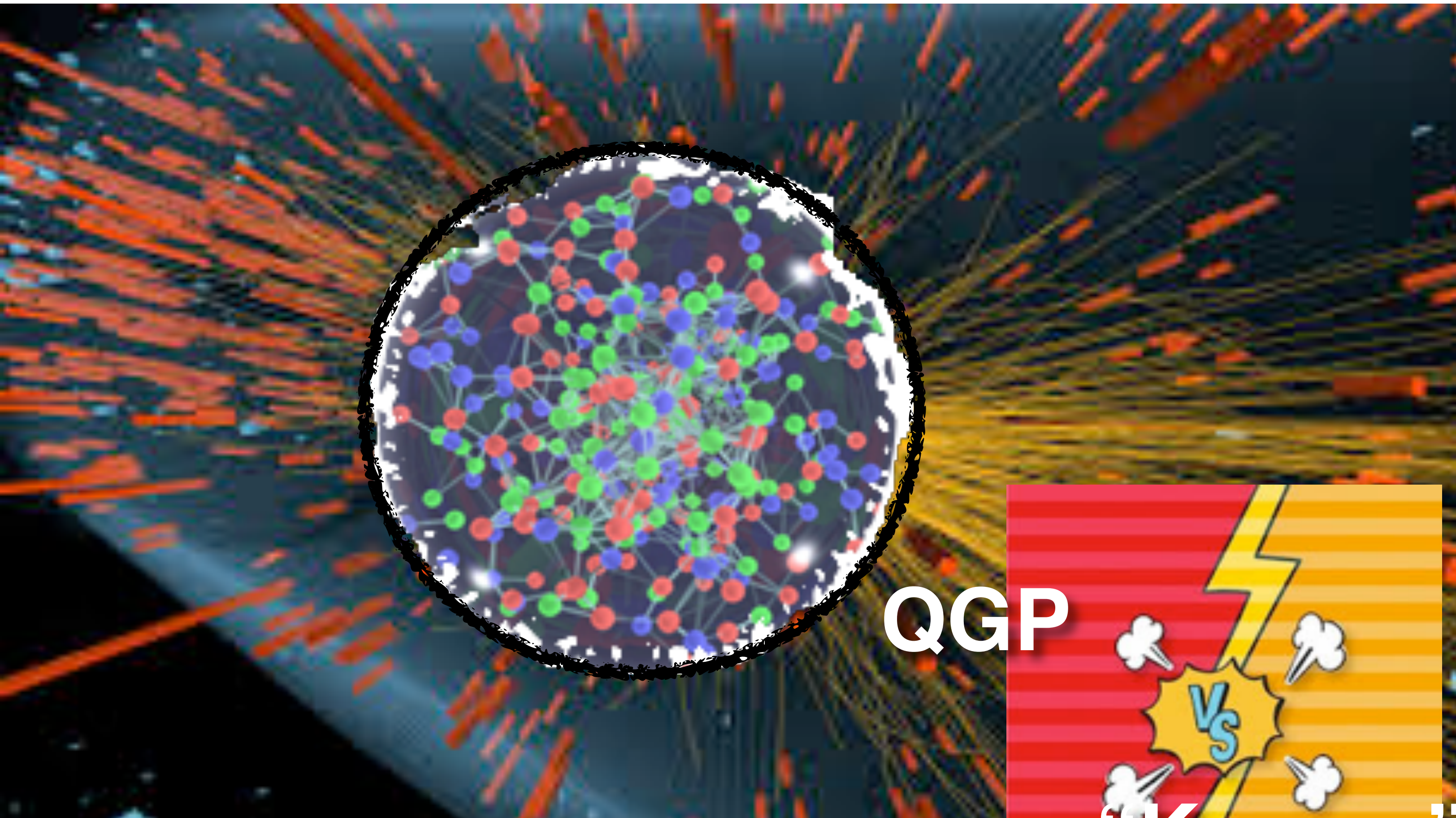
How can we isolate the new physics?

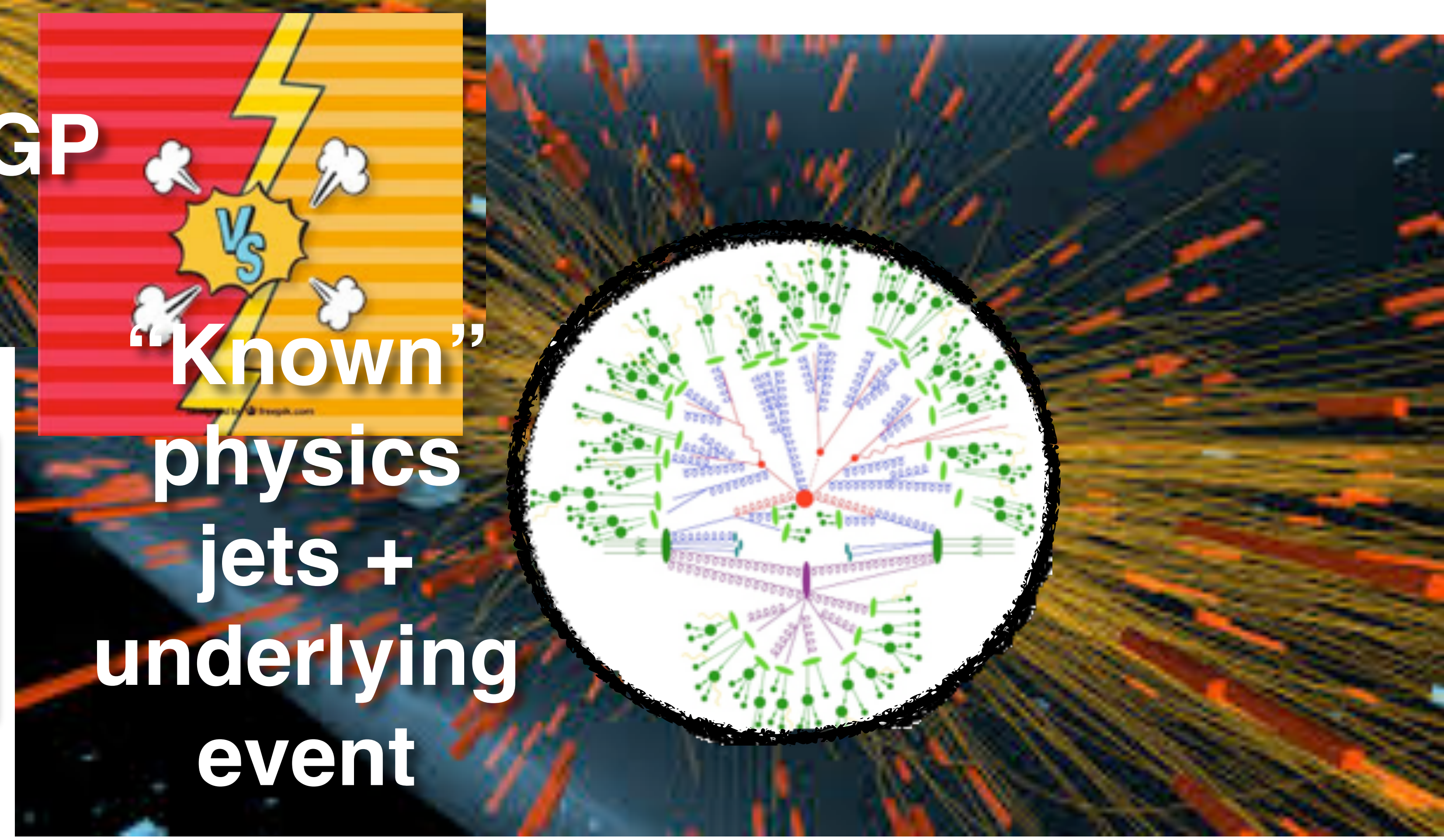




High multiplicity pp collisions

How can we isolate the new physics?





Goal: study the extreme high multiplicity events ➡ multiplicity selection should be done at mid-rapidity

A. N_{ch} and Jet

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Idea: implement a double-differential analysis, i.e., make a selection based on the multiplicity and leading jet transverse momentum ($p_T^{leading}$) both determined at mid-rapidity

A. Ortiz, G. Bencedi and H. Bello, JPG 44 (2017) no.6, 065001

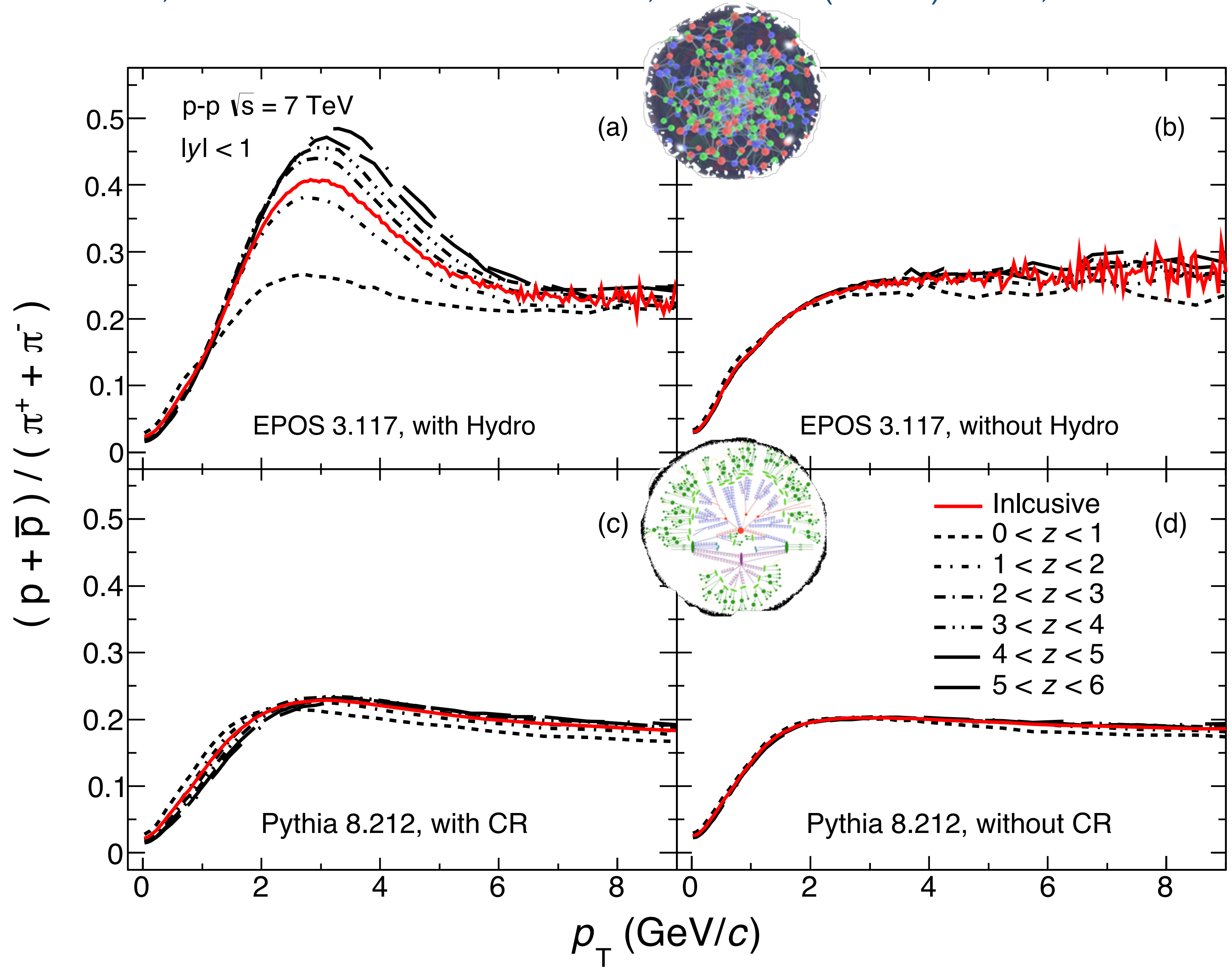
EPOS 3.117

corona: string segments with high p_T escape

core: lower p_T string segments used for initial conditions for hydro

PYTHIA 8.212

jets + **underlying event** (UE = MPI color reconnected with beam remnants, ISR, FSR)

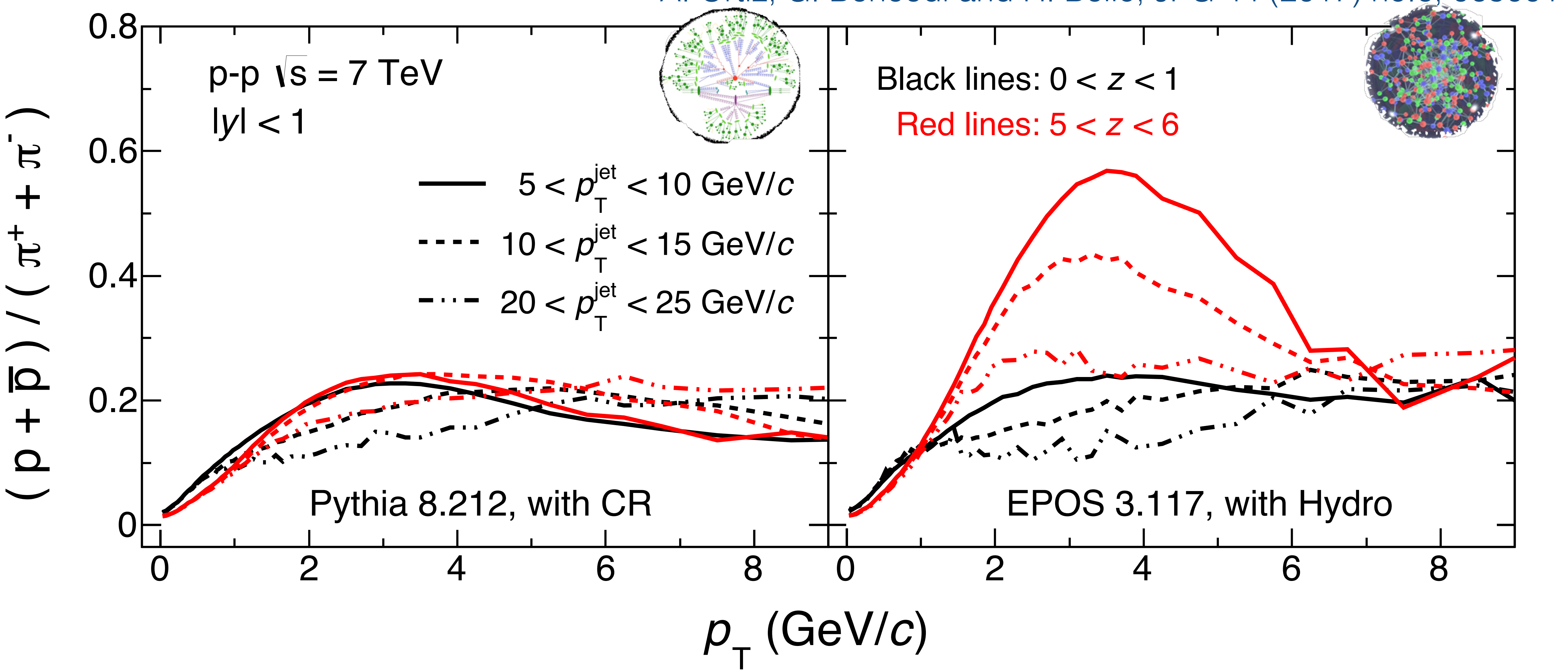


Testing the idea (p/π)

Low N_{ch} behave very similar in EPOS and PYTHIA

High N_{ch}: PYTHIA gives little or no dependence on $p_T^{leading}$. Whereas EPOS 3 gives a remarkable increase of the ratio with decreasing $p_T^{leading}$

A. Ortiz, G. Bencedi and H. Bello, JPG 44 (2017) no.6, 065001



B. N_{ch} and spherocity

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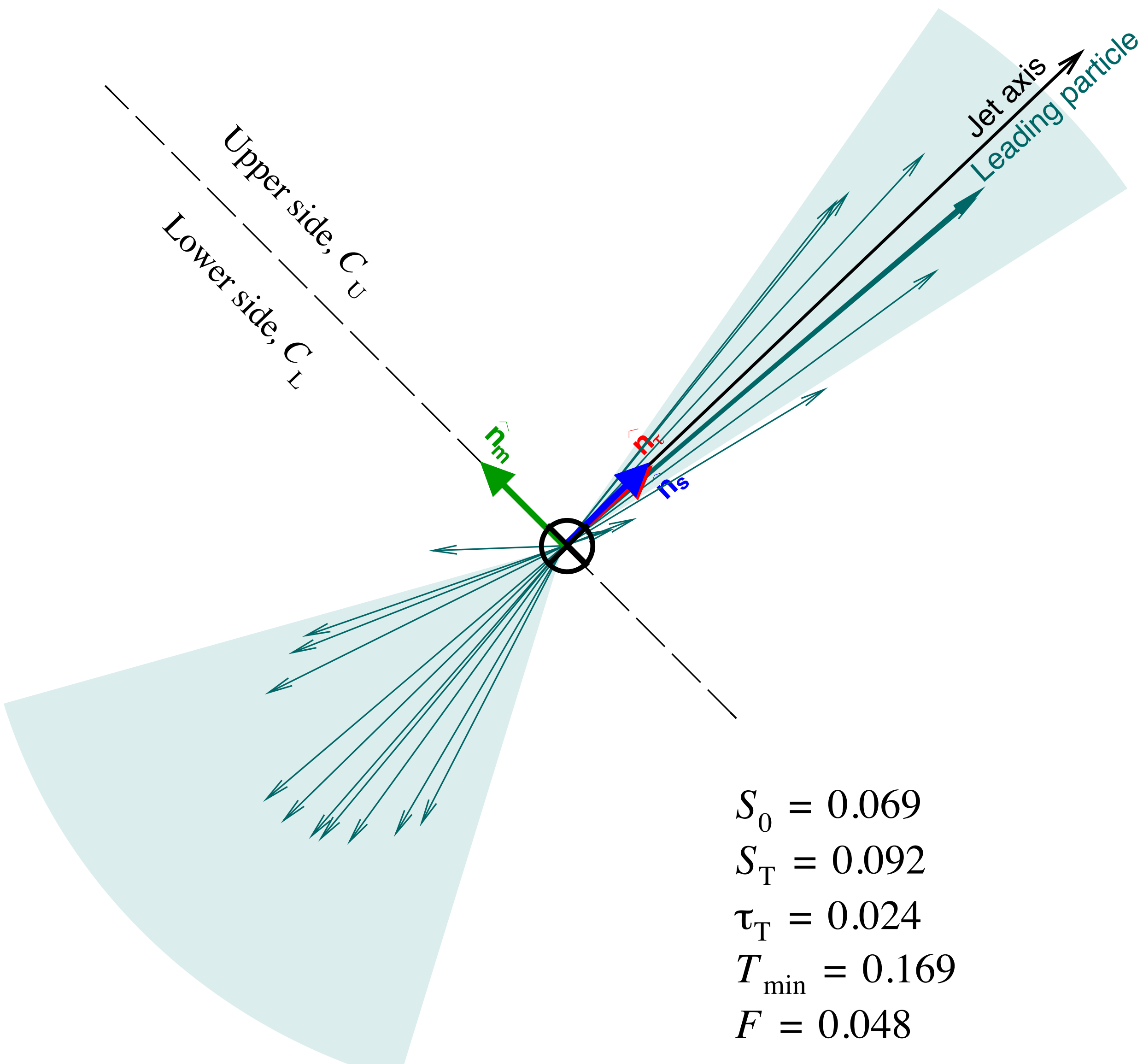
Event shapes measure the geometrical properties of the energy flow in QCD events and, notably, its deviation from that expected based on pure lowest order partonic predictions



A. Banfi et al., JHEP 1006 (2010) 038

At hadron colliders, the event shape axis lies in the plane perpendicular to the beam axis (⨯)

A. Ortiz, arXiv:1705.02056 (chapter of a book on multiple-partonic interactions. *In preparation*)

B. N_{ch} and spherocity

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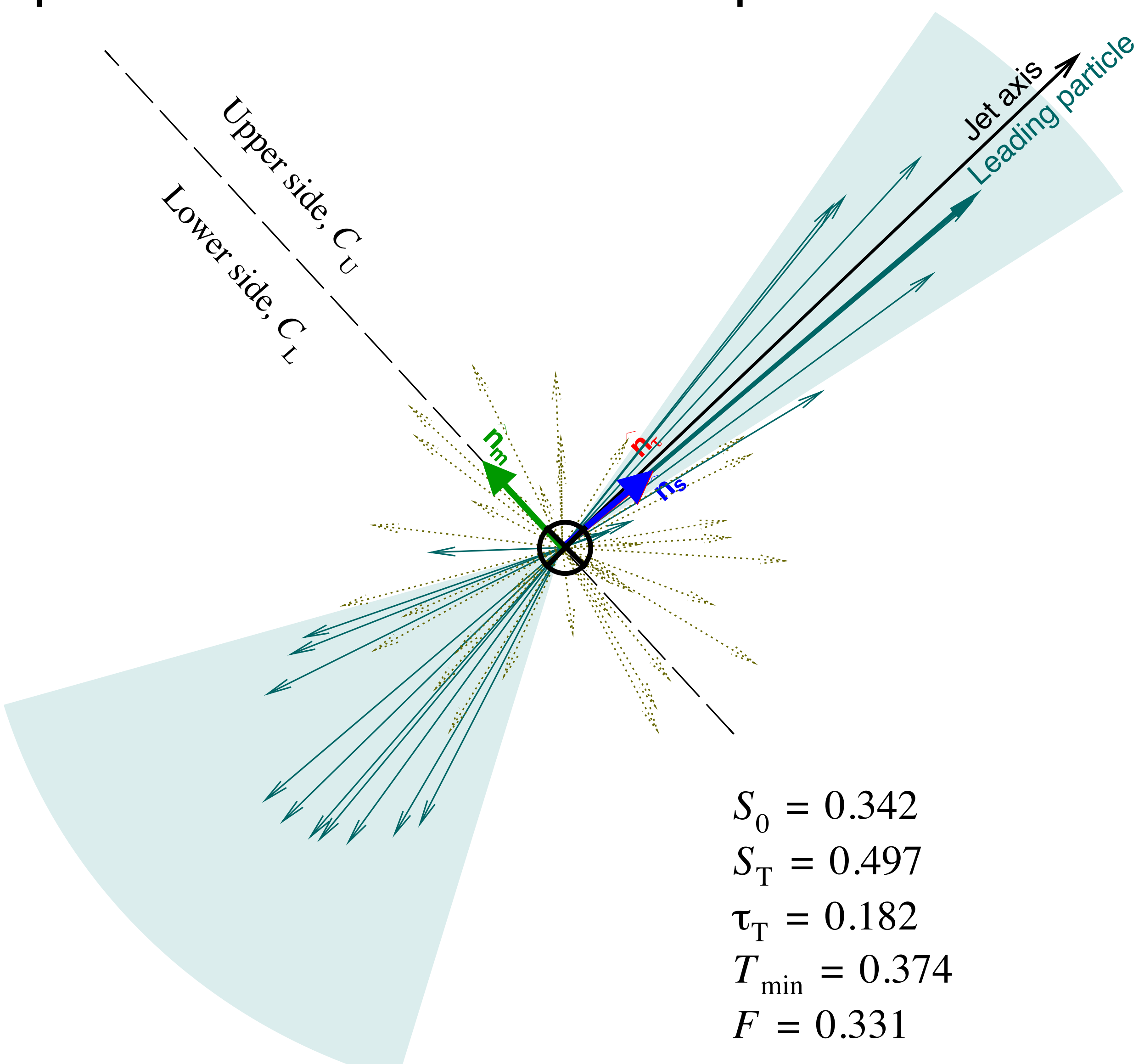

A. Banfi et al., JHEP 1006 (2010) 038

At hadron colliders, the event shape axis lies in the plane perpendicular to the beam axis (⨉)

➠The radiation perpendicular to the plane defined by the event shape axis and the beam one should be sensitive to soft physics

A. Ortiz, arXiv:1705.02056 (chapter of a book on multiple-partonic interactions. *In preparation*)

Definition

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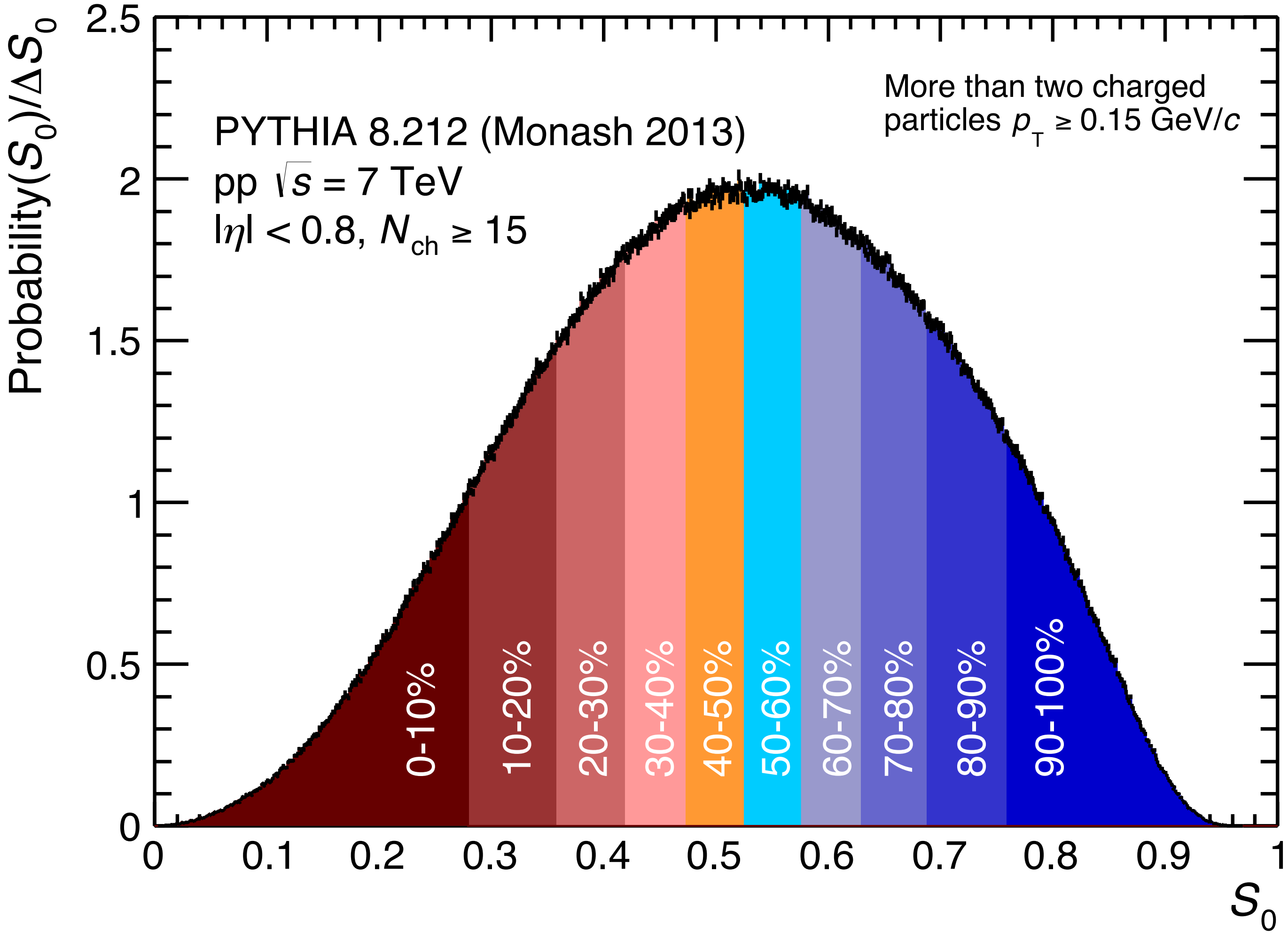
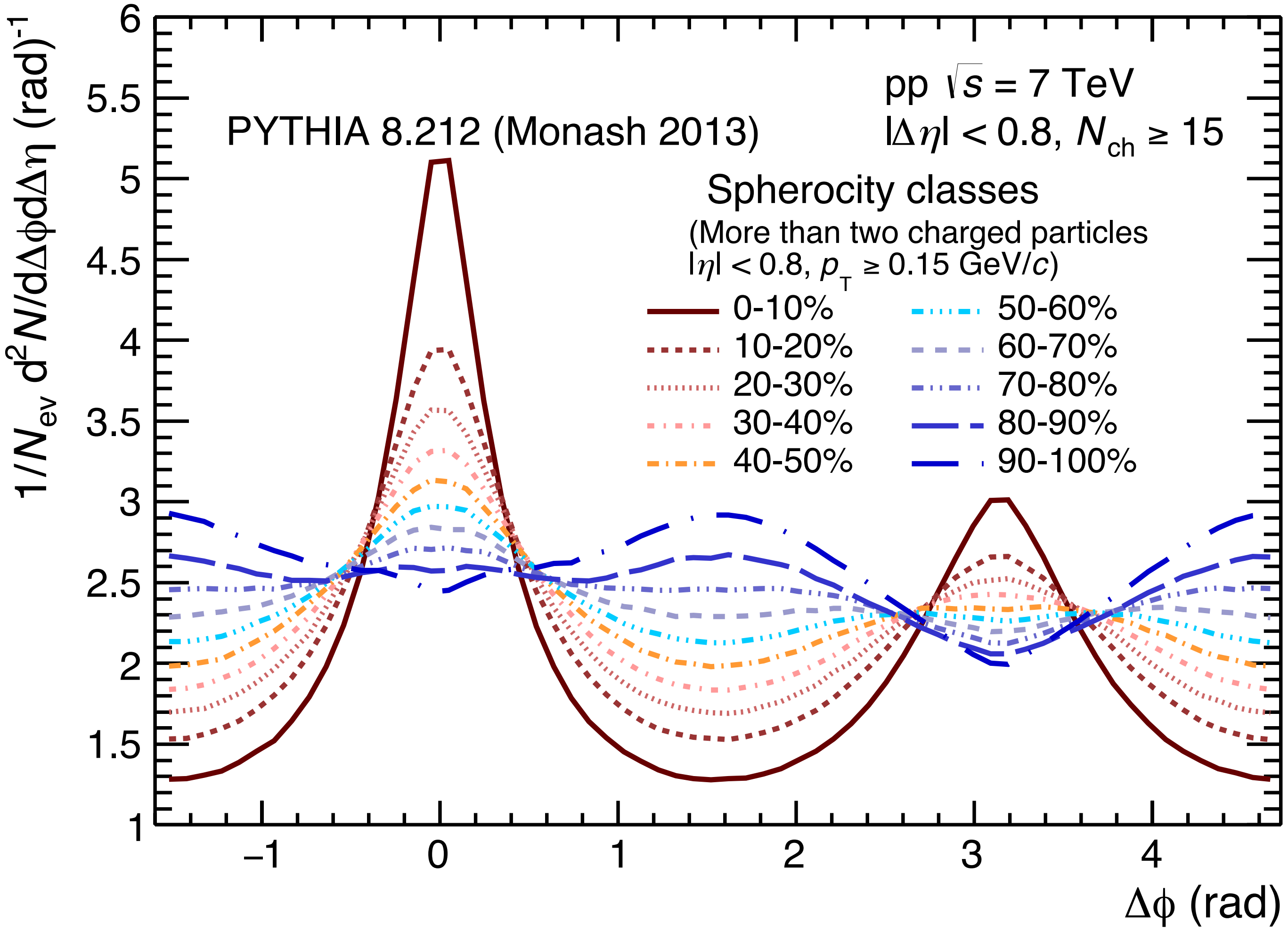
Transverse spherocity is an event shape which measures the radiation perpendicular to the plane formed by the beam axis and that of the main partonic scattering (~spherocity axis, $\mathbf{n}_\mathbf{S}$)

$$S_0 \equiv \frac{\pi^2}{4}\left(\frac{\sum_i^{N_{\rm ch}} |\vec{p}_{{\rm T},i} \times \hat{\mathbf{n}}_{\rm S}|}{\sum_i^{N_{\rm ch}} p_{{\rm T},i}}\right)^2$$

- Spherocity axis ($\mathbf{n}_\mathbf{S}$) is that which minimises the ratio above
- For the calculation of spherocity we consider primary charged particles, $p_{\rm T}$>0.15 GeV/c, $|\eta|$<0.8
- We proposed for the first time the use of event shapes for soft physics studies





PYTHIA

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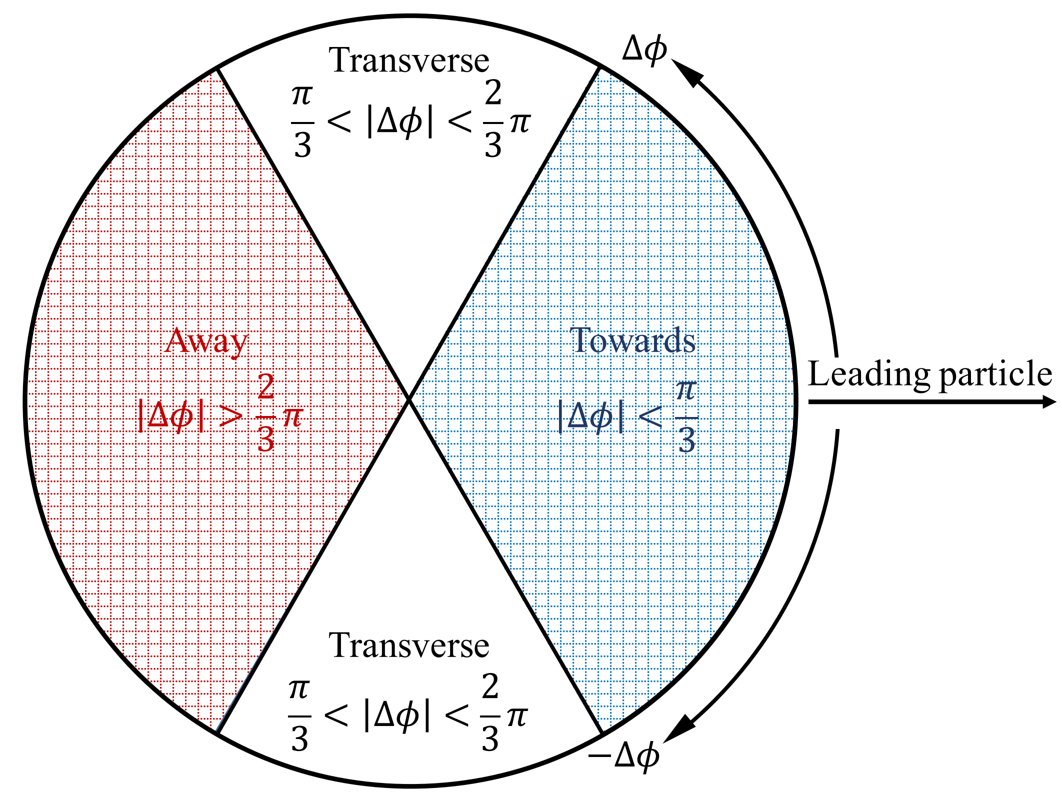
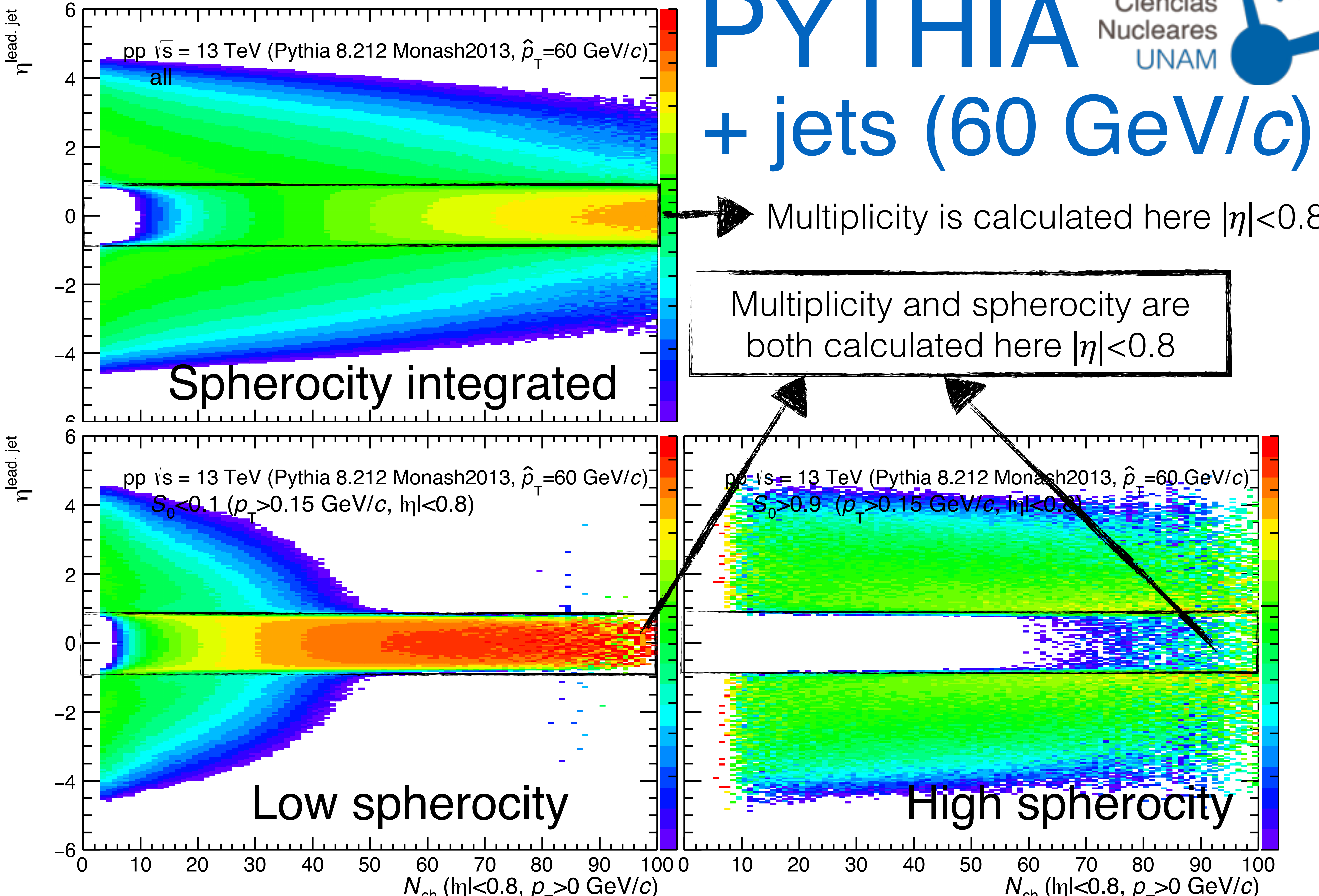
Event classification based on spherocity percentiles ➡now adopted by ALICE

Characteristics of the events selected using spherocity



PYTHIA + jets (60 GeV/c)



PYTHIA + jets (60 GeV/c)

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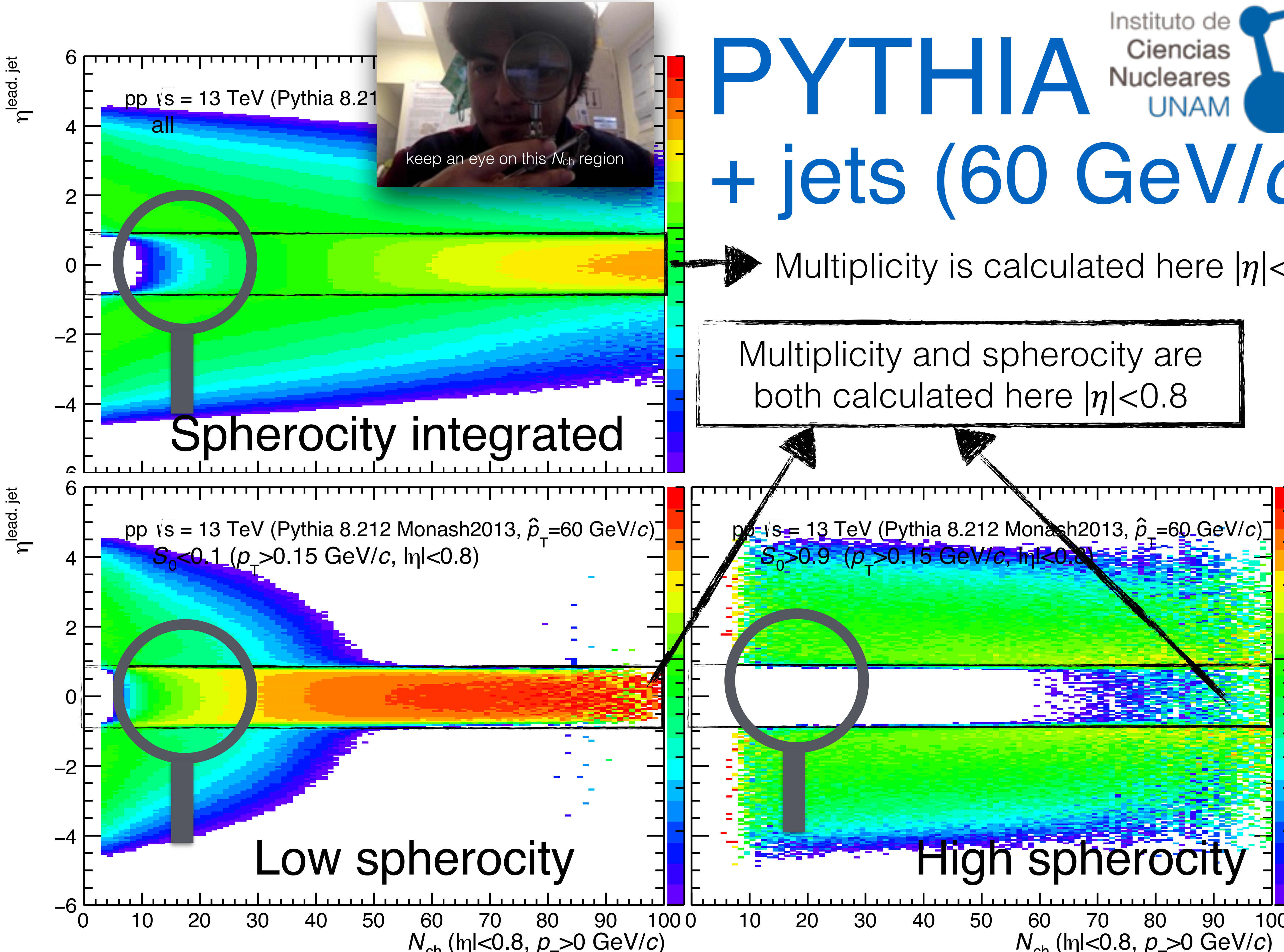

Multiplicity is calculated here $|\eta|<0.8$

Multiplicity and spherocity are both calculated here $|\eta|<0.8$

Core-corona separation

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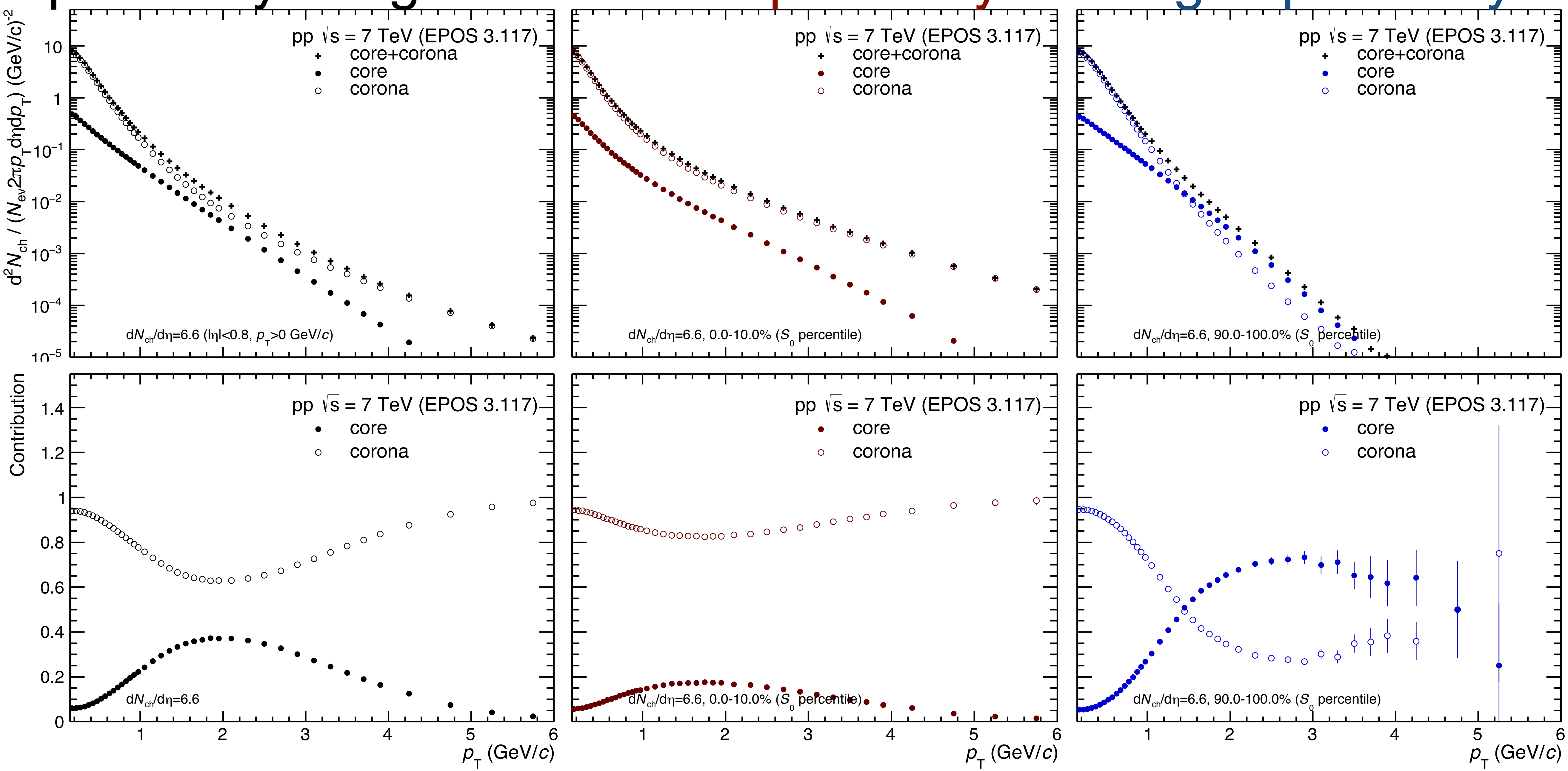
The study was conducted using pp collisions at $\sqrt{s}$ = 7 TeV simulated with EPOS 3.117

Spherocity integrated | Low spherocity | High spherocity



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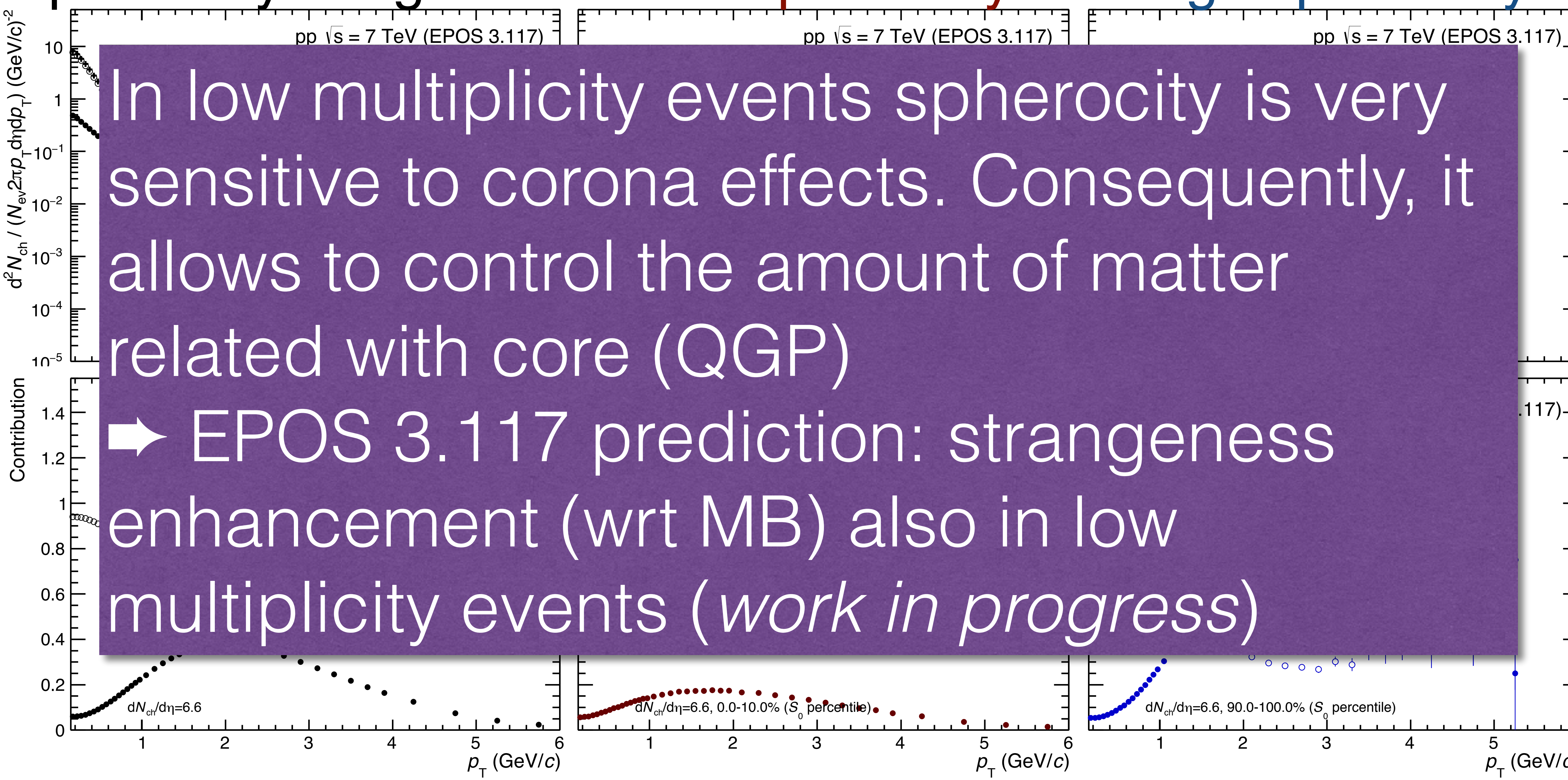
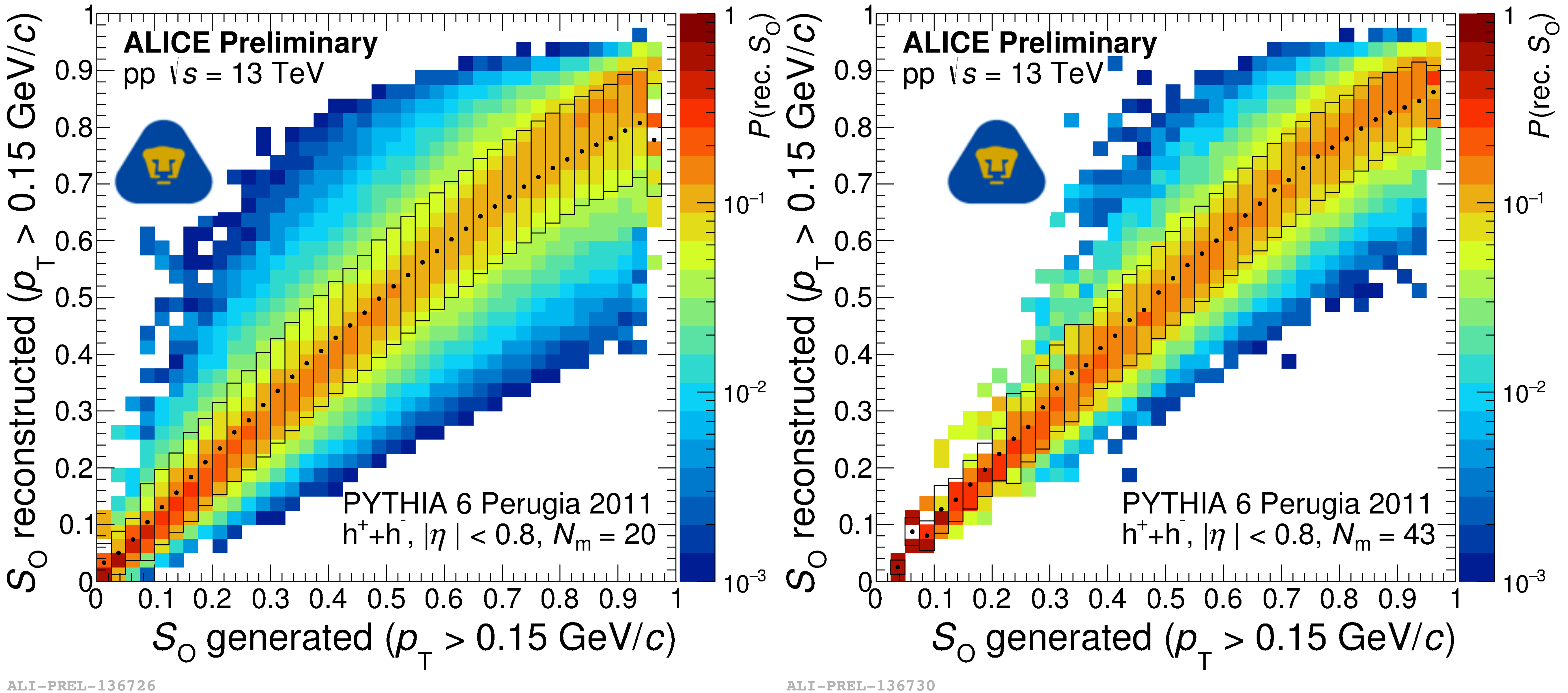


In low multiplicity events spherocity is very sensitive to corona effects. Consequently, it allows to control the amount of matter related with core (QGP)

➡ EPOS 3.117 prediction: strangeness enhancement (wrt MB) also in low multiplicity events (*work in progress*)

Data analysis



A. Ortiz, ALICE-ANA-3321

H. Bello, A. Fernández, A. Ortiz and G. Paić ALICE-ANA-3959

Implementation, PhD thesis of Héctor Bello

$\langle p_T \rangle$ vs N_{ch}

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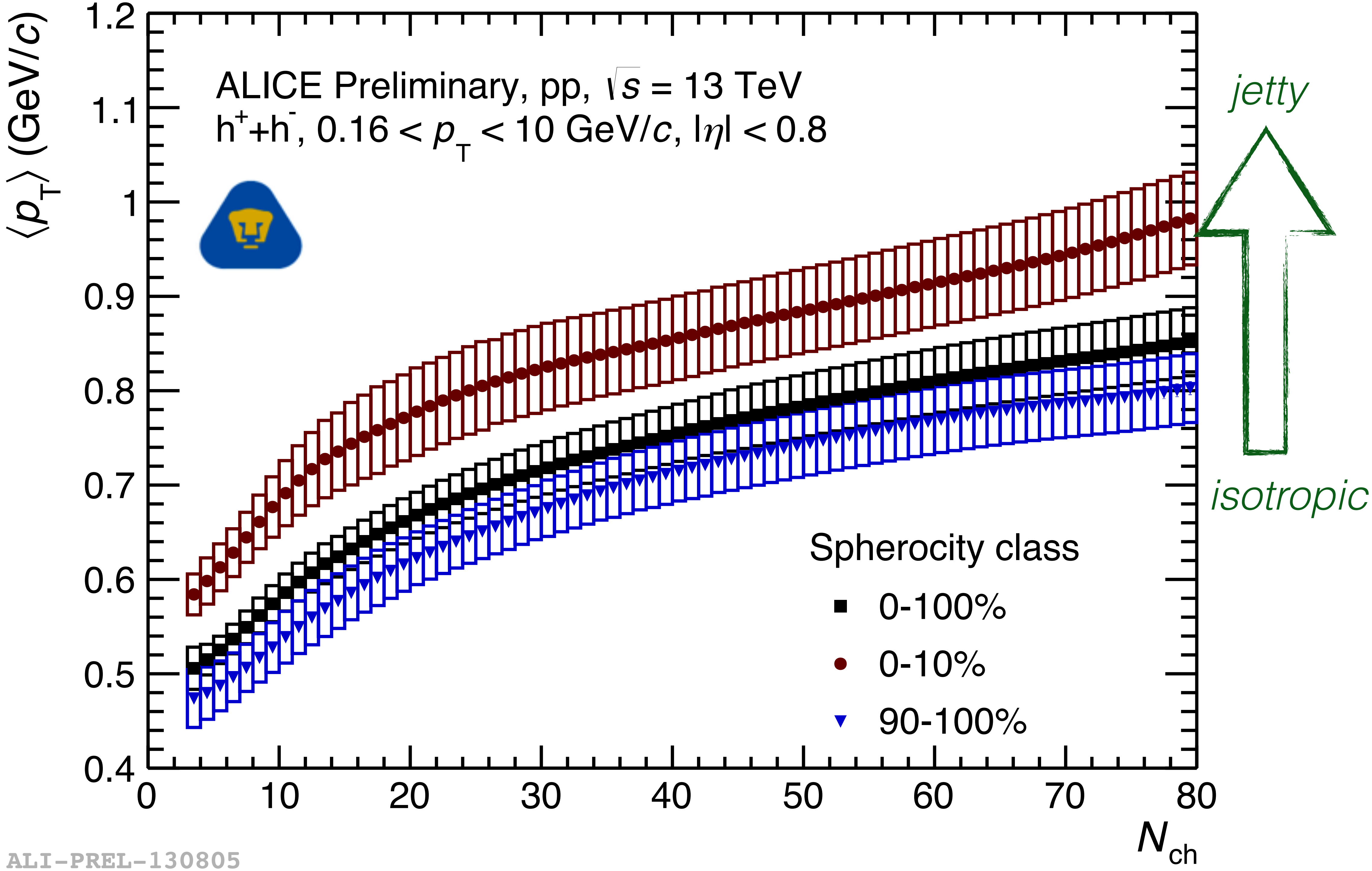

Implementation, PhD thesis of Héctor Bello

H. Bello, A. Fernández, A. Ortiz and G. Paić ALICE-ANA-3959

⟨p_T⟩ vs N_{ch}

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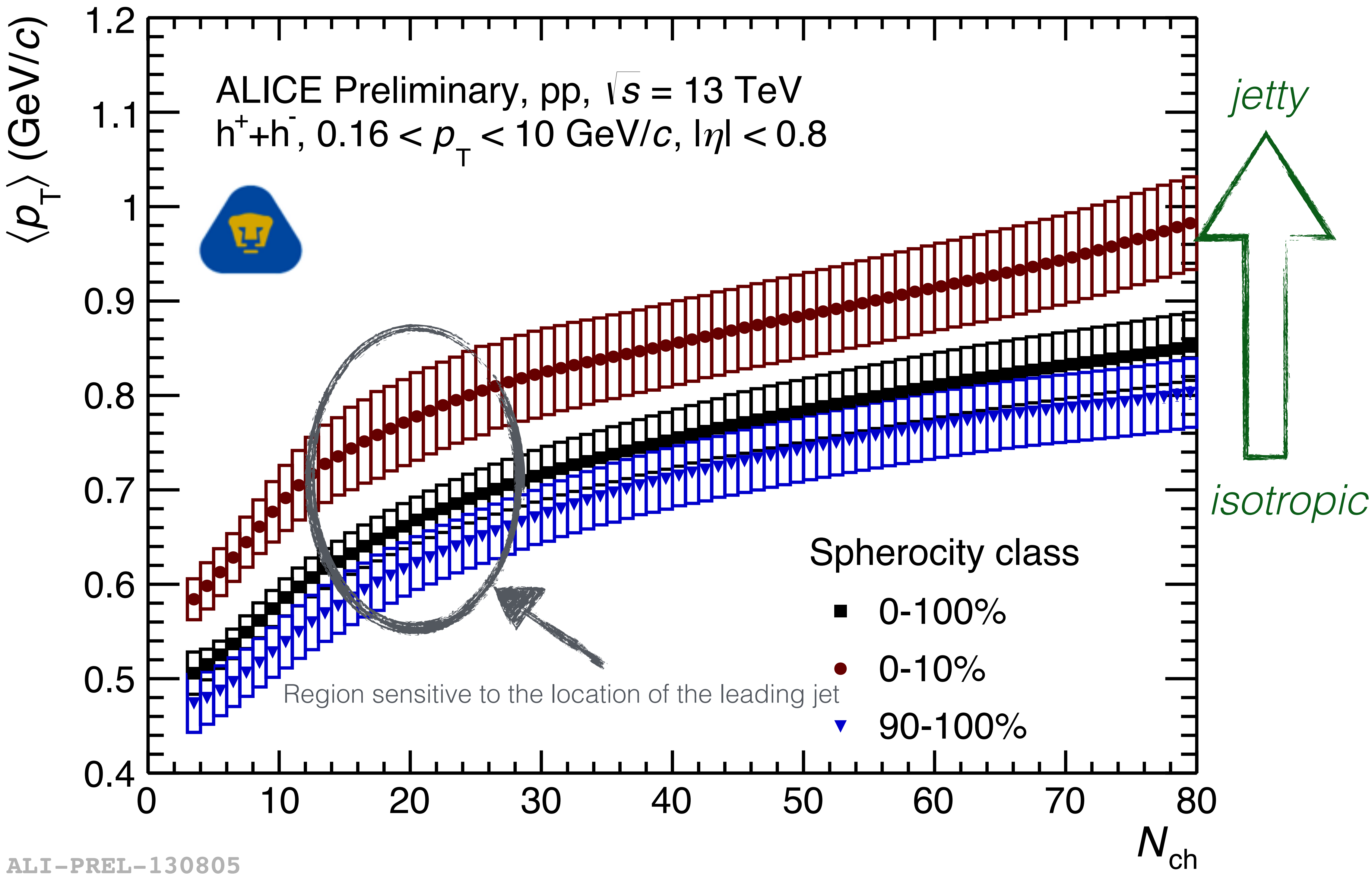

Implementation, PhD thesis of Héctor Bello

H. Bello, A. Fernández, A. Ortiz and G. Paić ALICE-ANA-3959

$(\langle p_T \rangle$ vs $N_{ch})$ vs S_0

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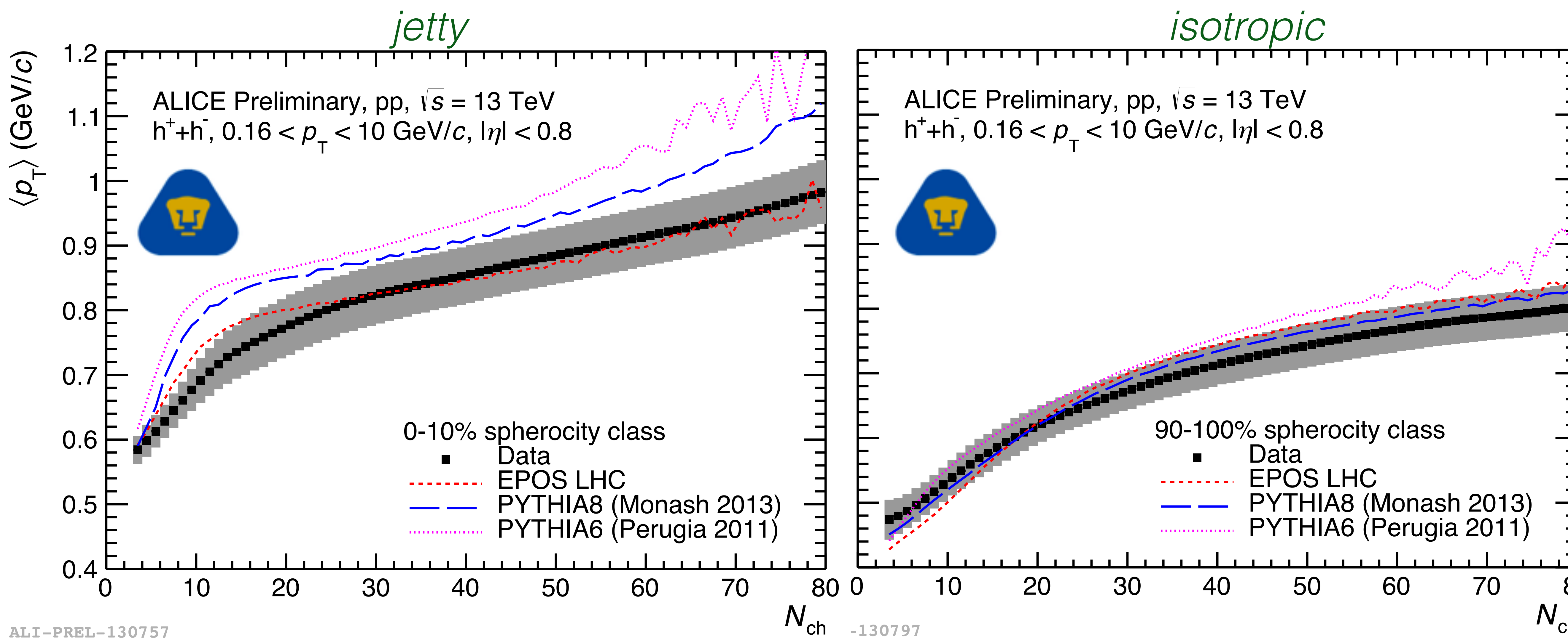
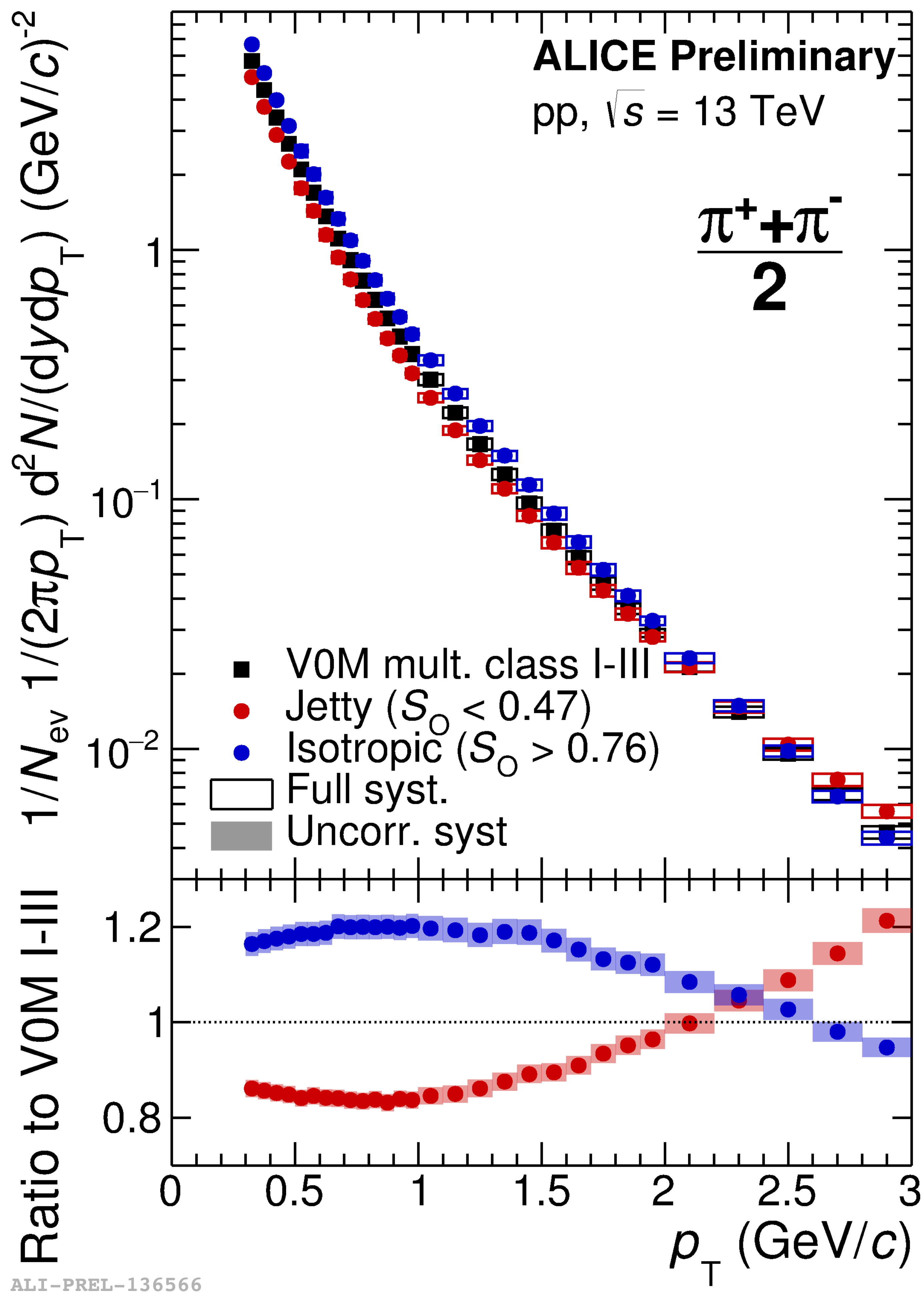
The average p_T is calculated considering low p_T particles, in that regime, most of MC generators describe well the data. However, for jetty events we observe some discrepancies



Implementation, PhD thesis of Héctor Bello

H. Bello, A. Fernández, A. Ortiz and G. Paić ALICE-ANA-3959

PID
First attempt using TPC and TOF



High multiplicity events selected using the VZERO detector

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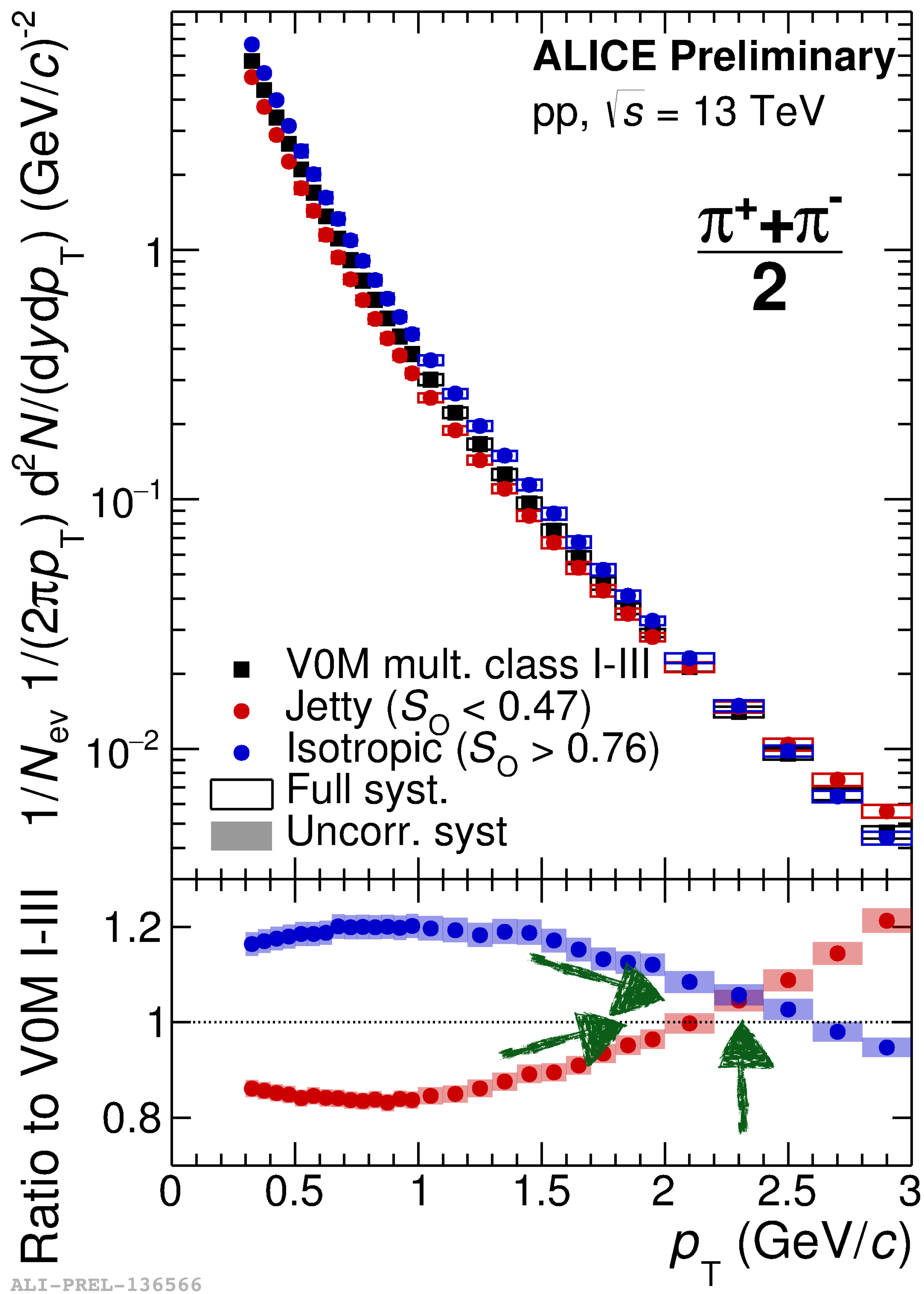
PID first attempt using TPC and TOF



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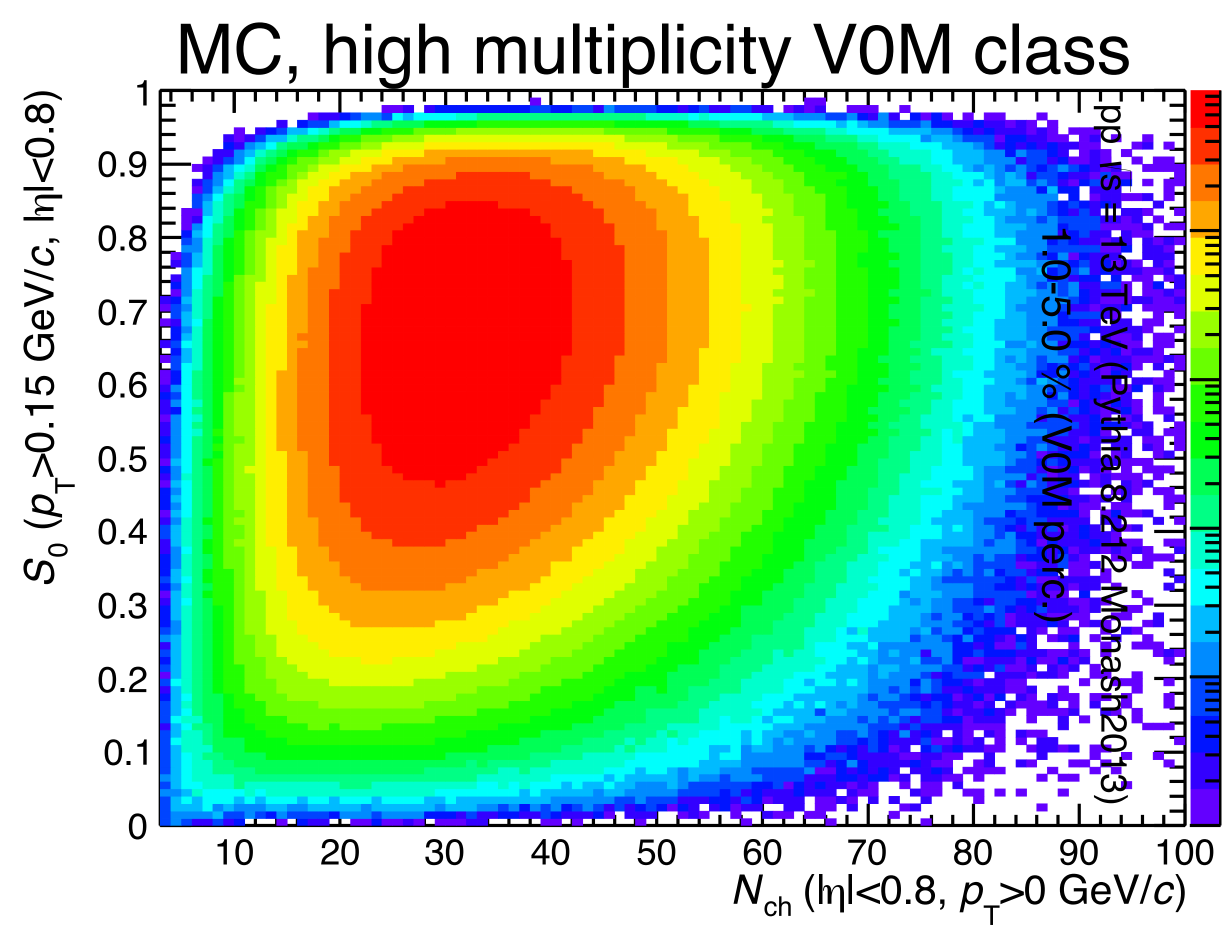
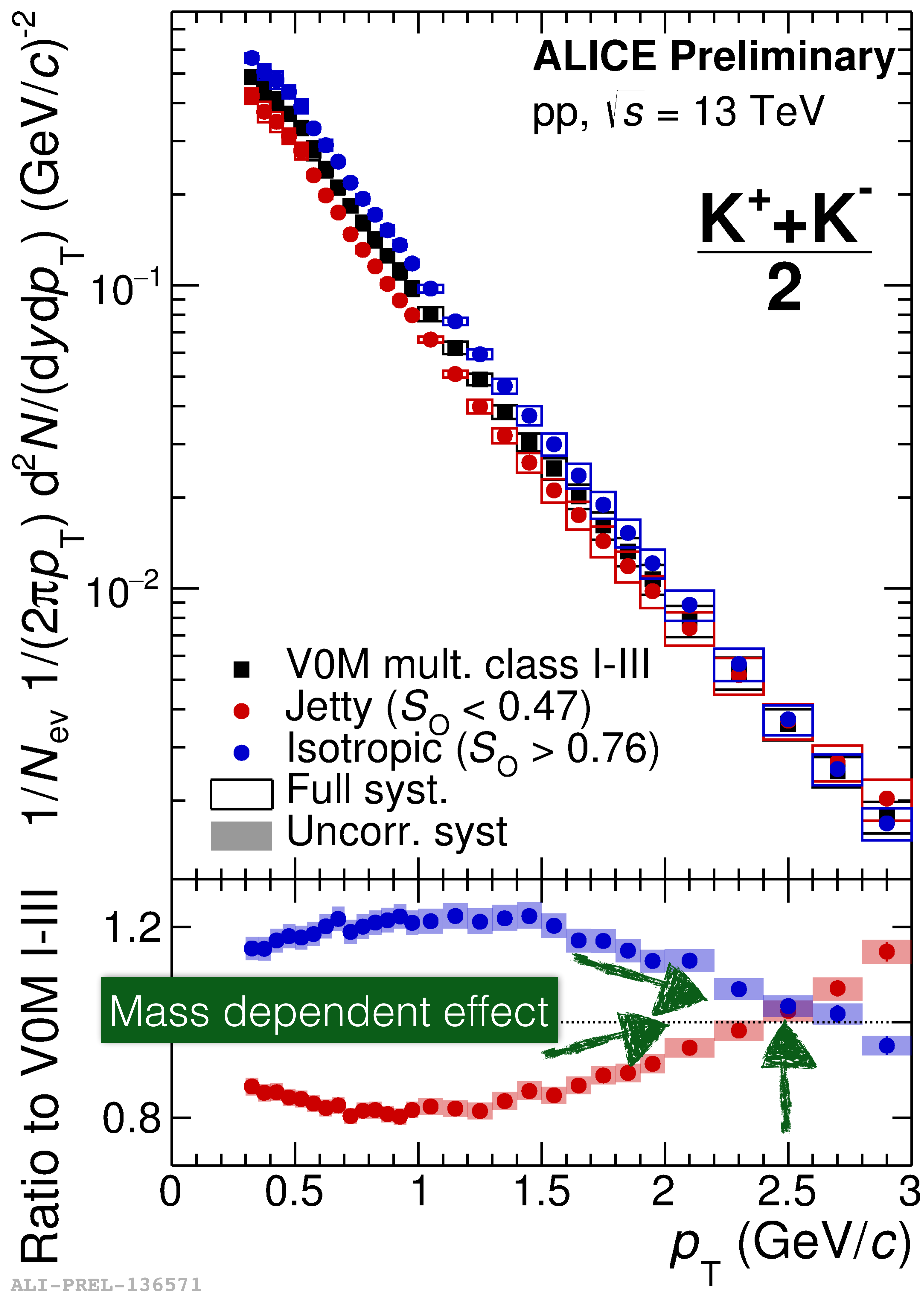
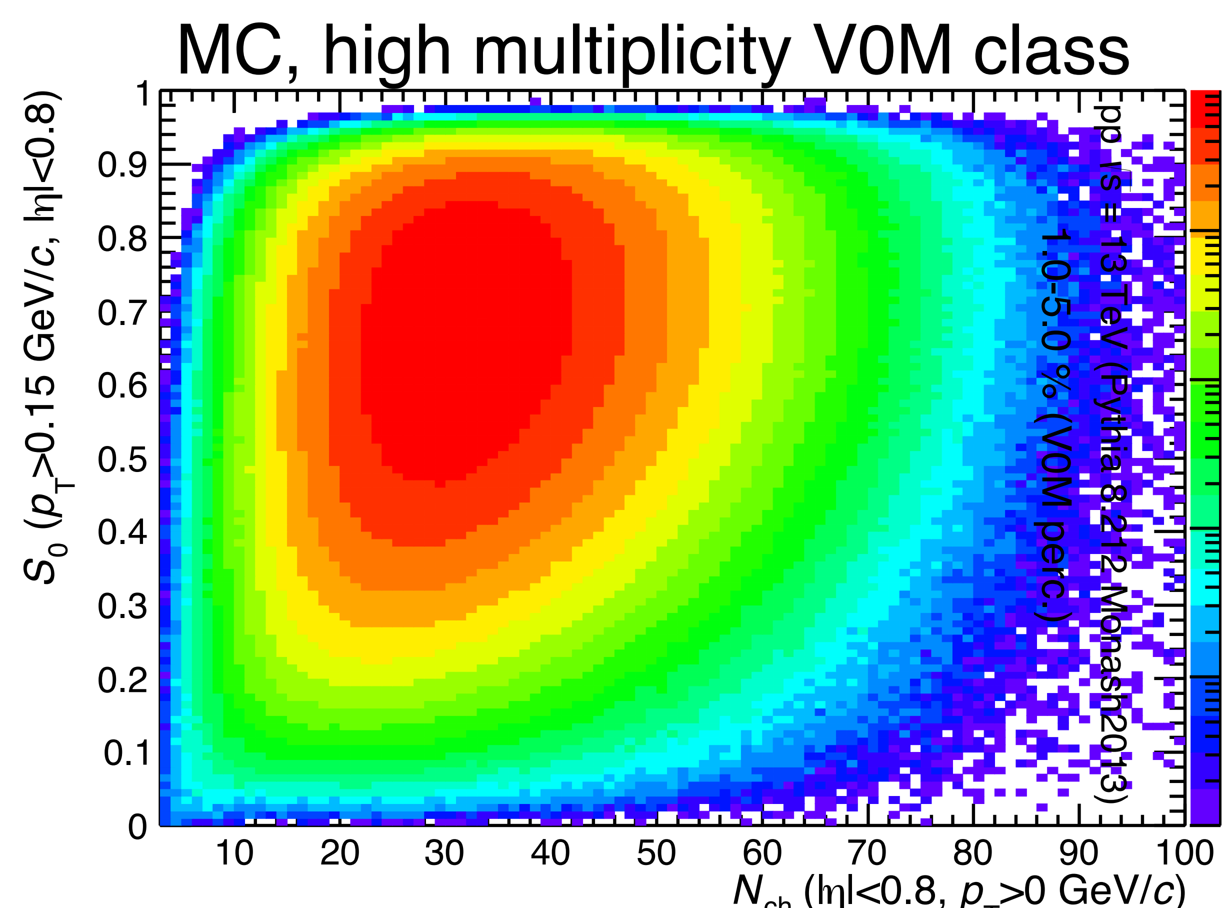


PID
first attempt using TPC and TOF



High multiplicity events selected using the VZERO detector



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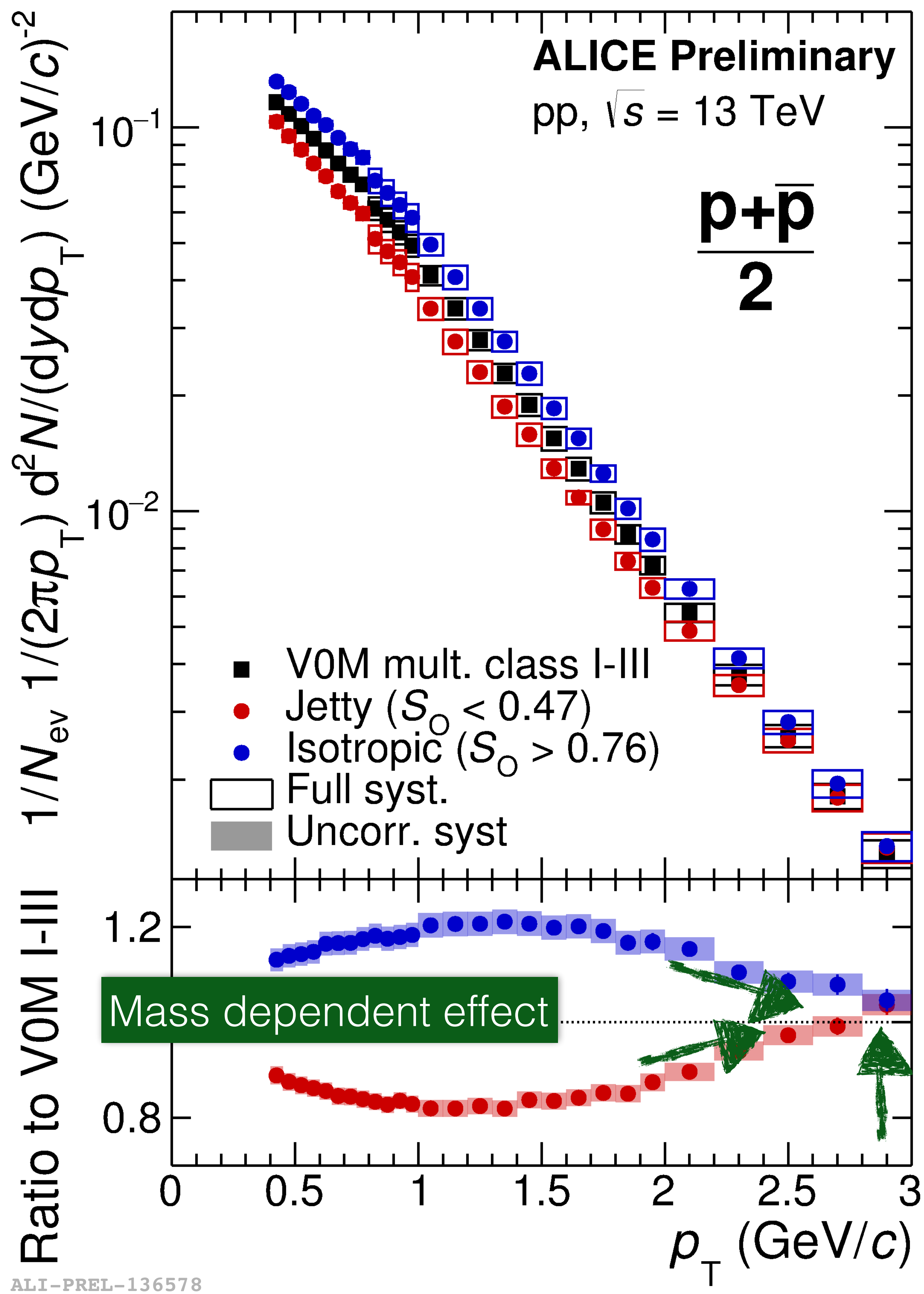
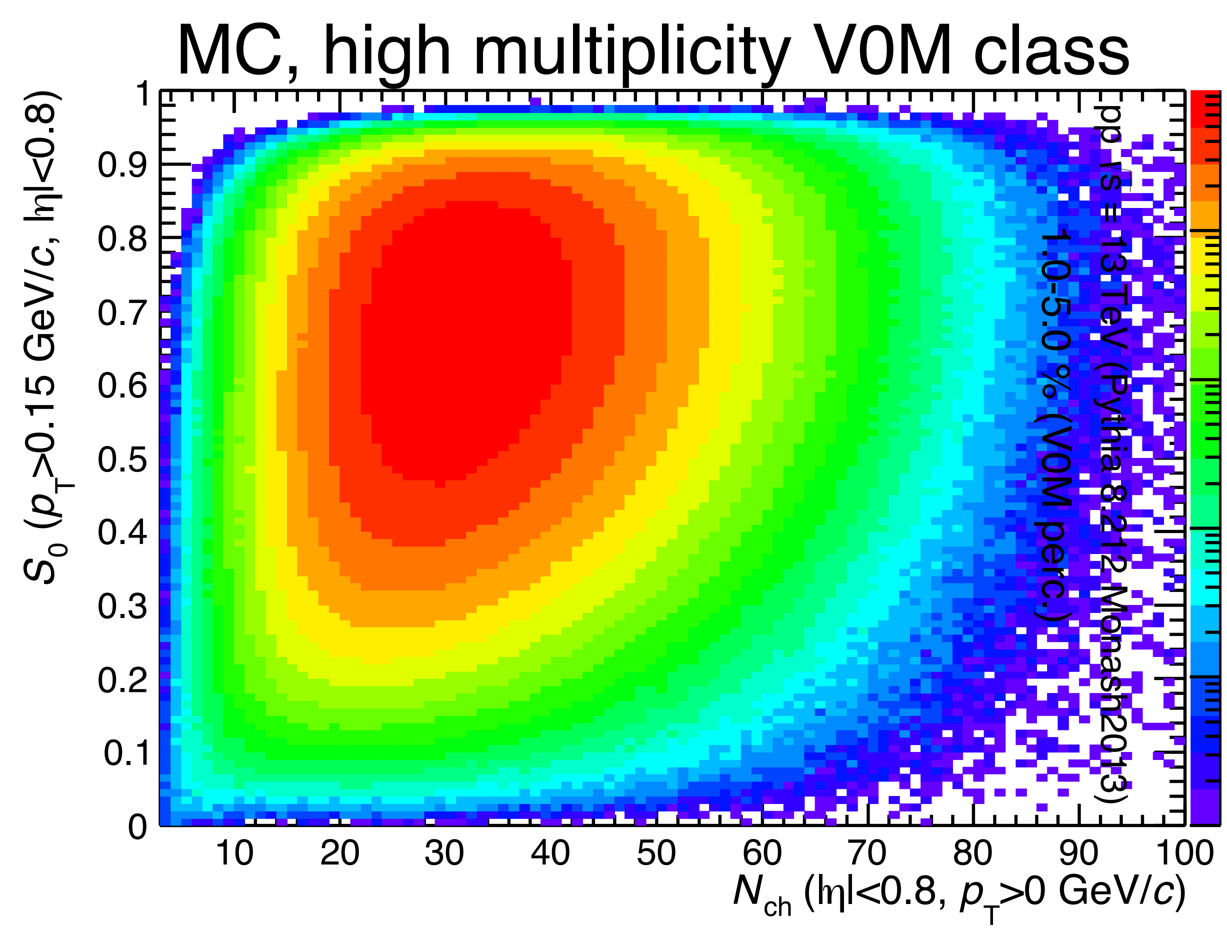
PID first attempt using TPC and TOF



High multiplicity events selected using the VZERO detector



More about small systems

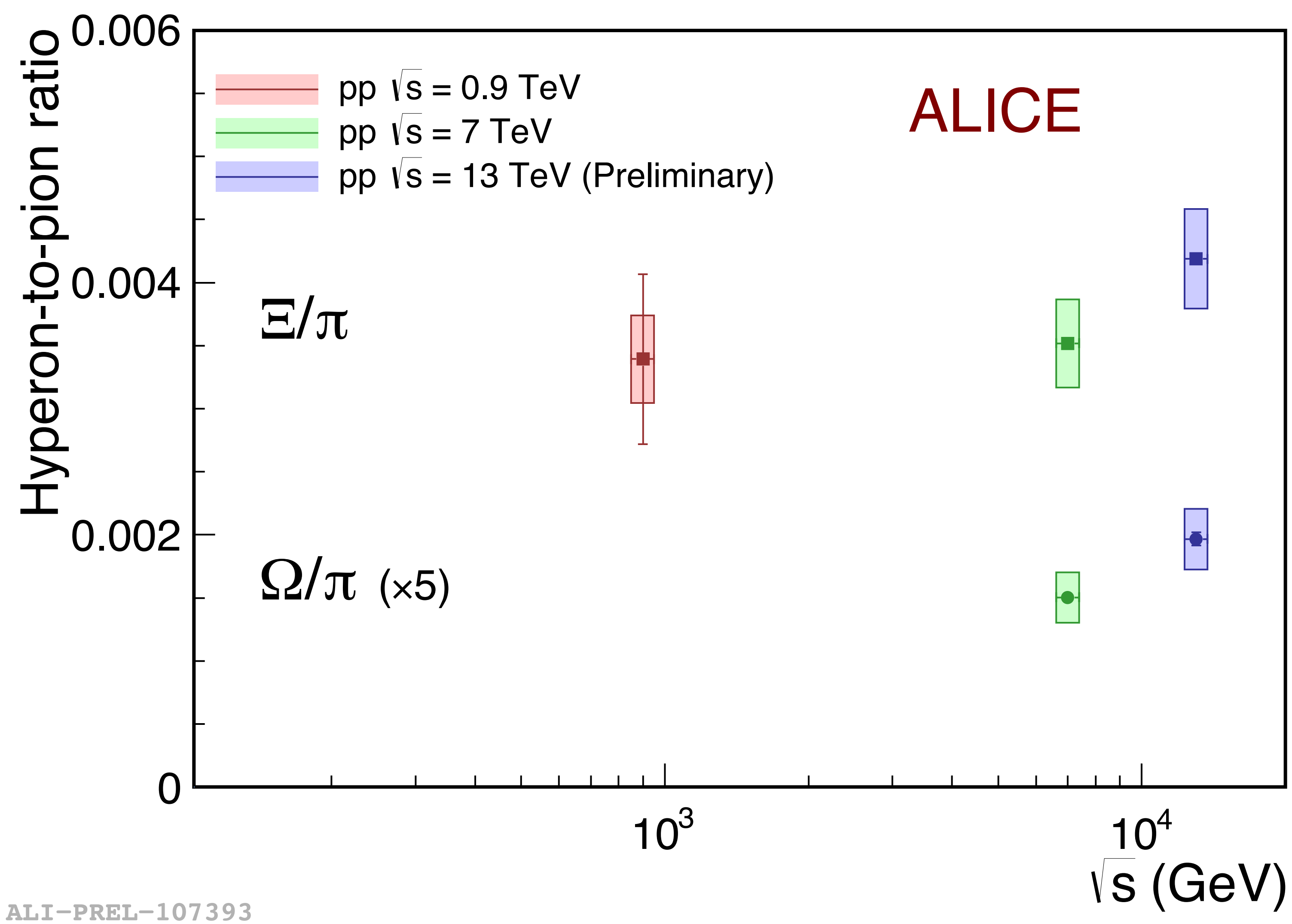
Some comments

- The results using the new tool, S_0, show interesting features. For the story to be completed, further studies are needed (check the S_0 dependence at fix $\langle N_{ch} \rangle$, use the full statistics)

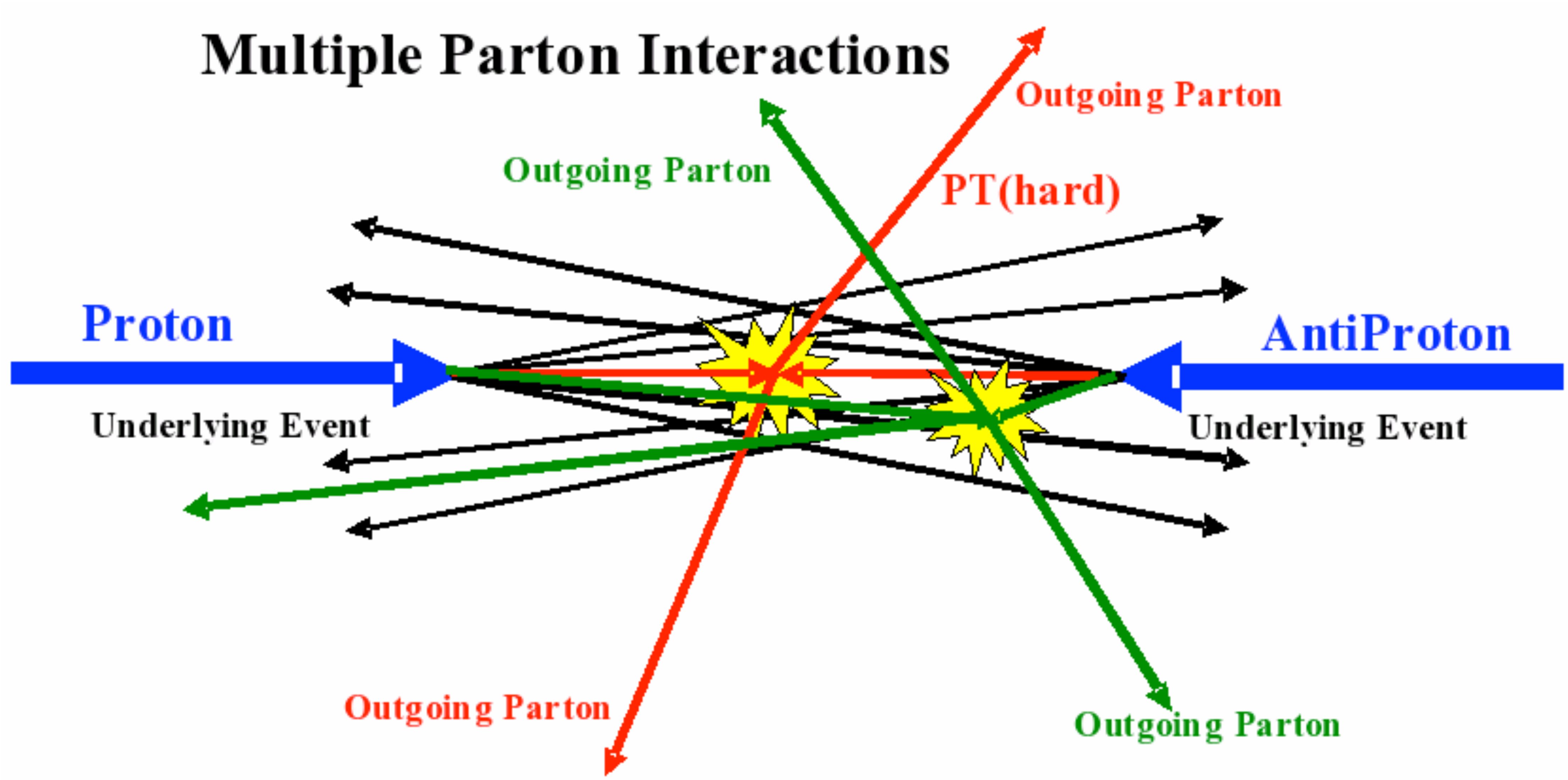
Some comments

- The results using the new tool, S_0, show interesting features. For the story to be completed, further studies are needed (check the S_0 dependence at fix $\langle N_{ch} \rangle$, use the full statistics)

- One needs to check the consistency with results for different $\sqrt{s}$. We know that the increase of $\sqrt{s}$ is accompanied by an increase of $\langle N_{ch} \rangle$. One consequence is, for example, the increase of the strangeness with $\sqrt{s}$



√s dependence of UE



In the context of event simulation the Underlying Event (UE) refers to everything that does not originate from the hard scatter outgoing partons

$\sqrt{s}$ dependence of UE

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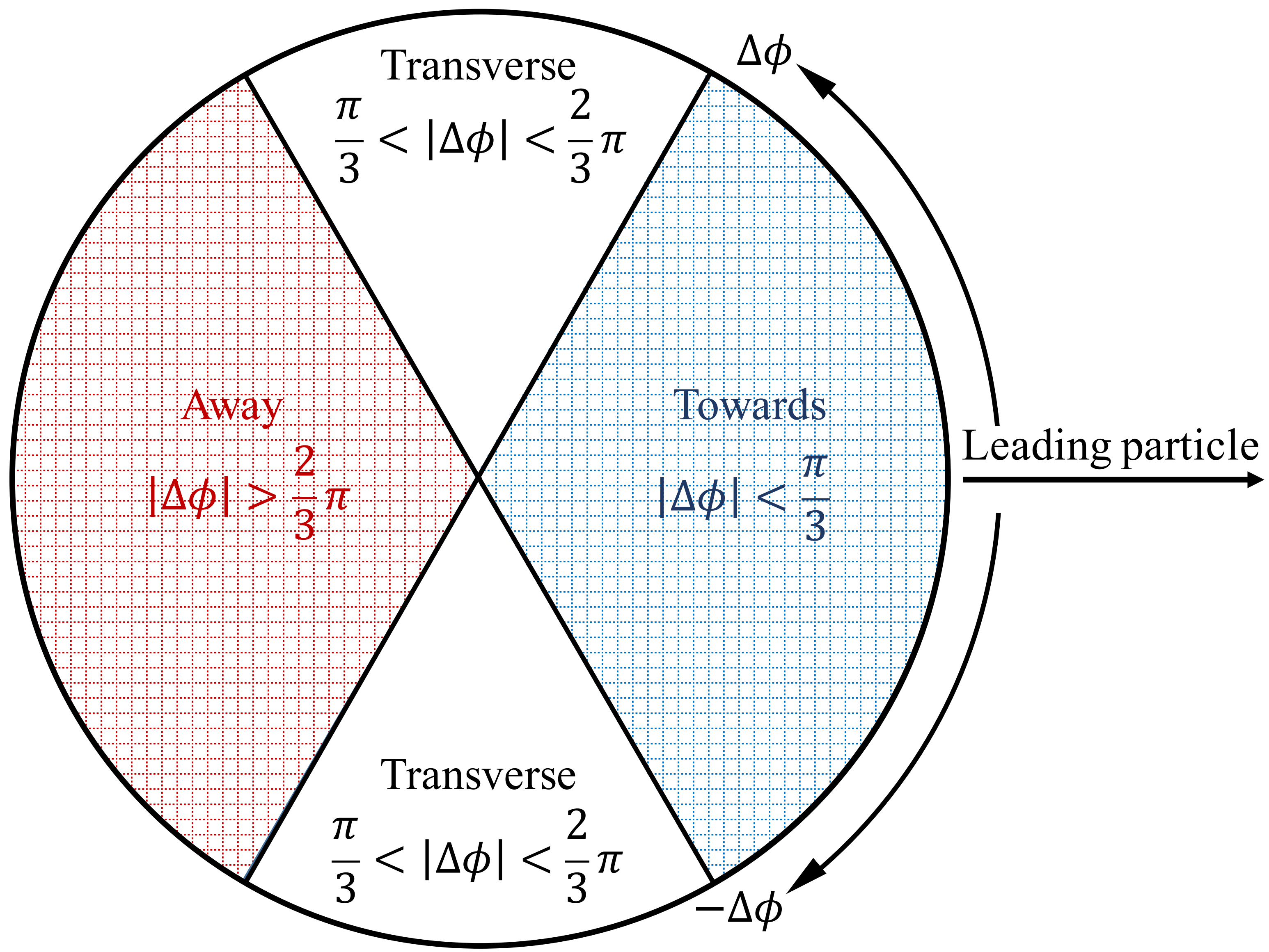

Experimentally we measure quantities which are sensitive to UE, however, it is difficult to isolate this component (e.g. interaction among coloured objects before the hadonization)

ATLAS results

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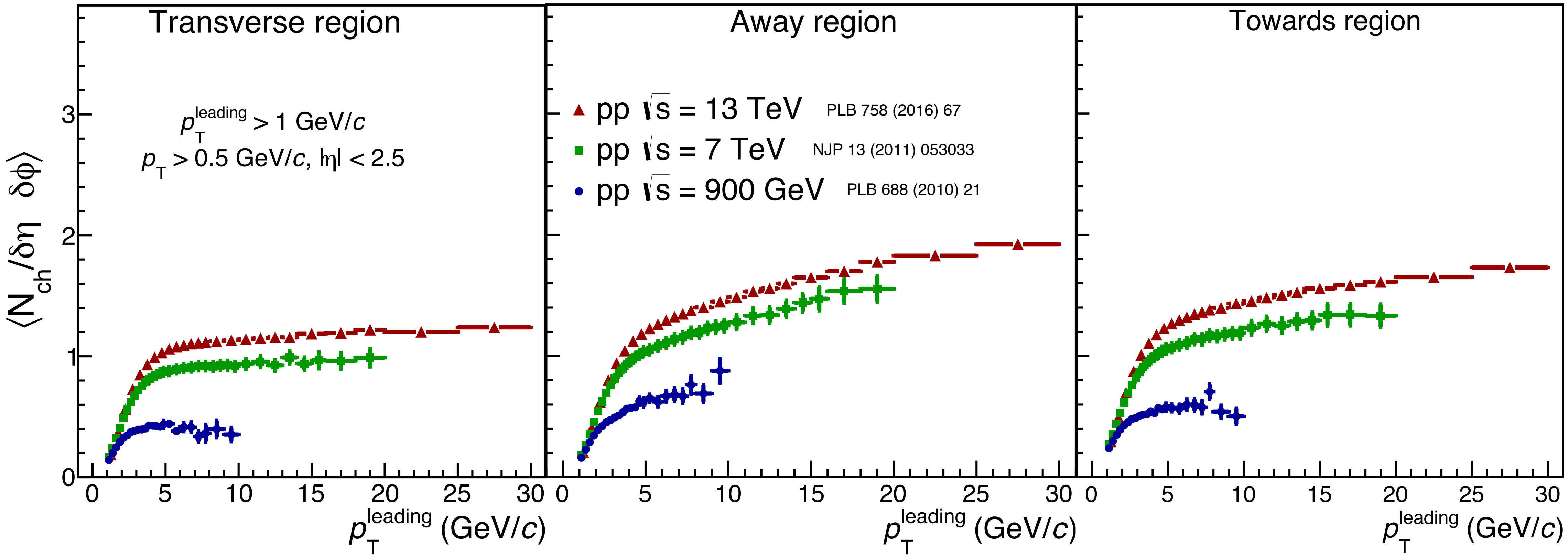
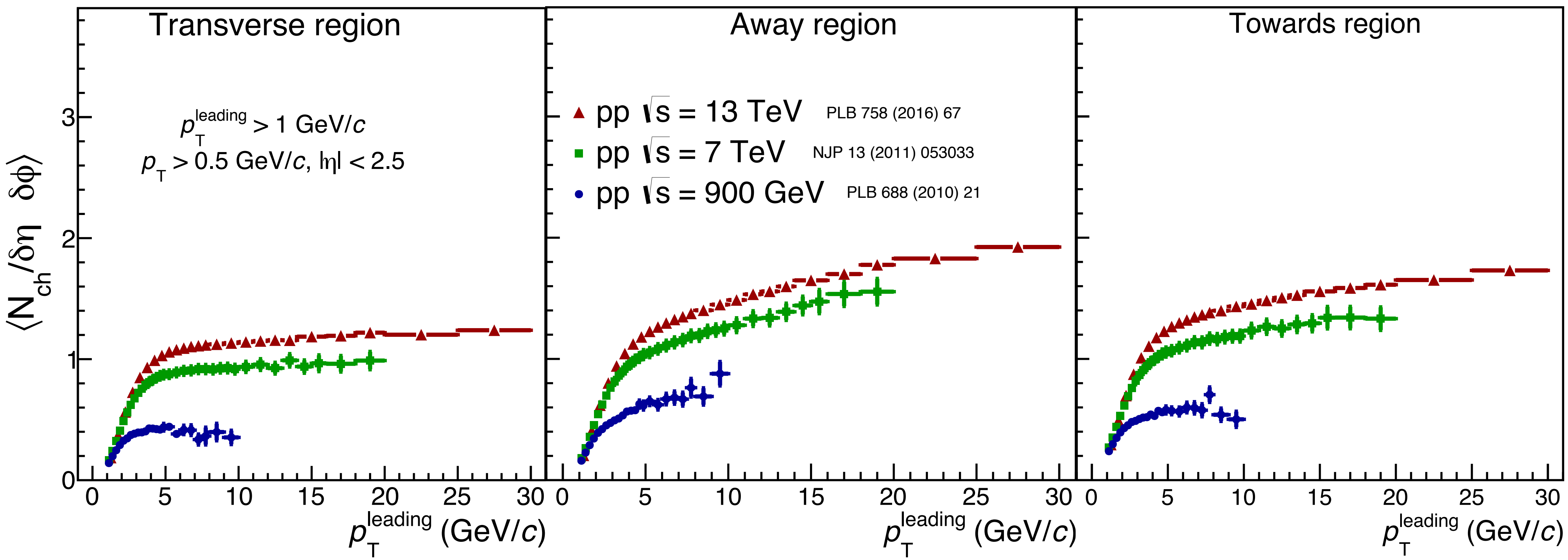
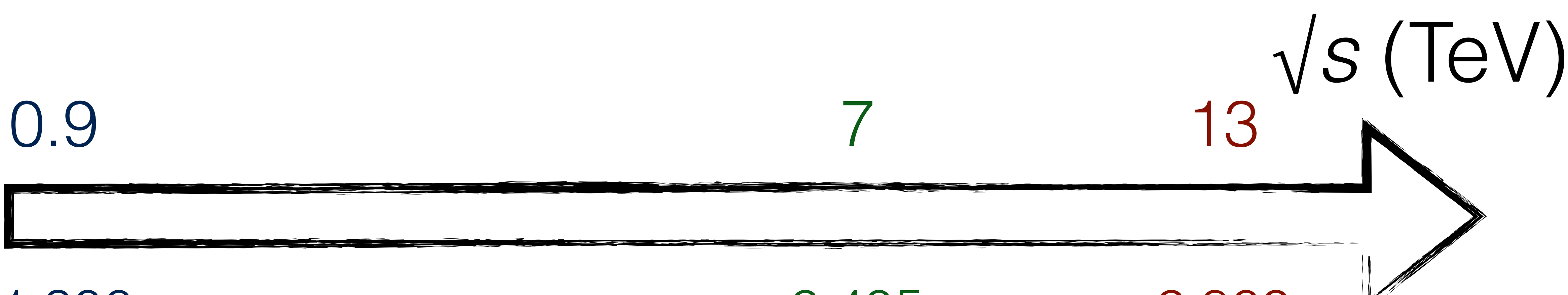


Multiplicity density of primary charged-particles (number density) as a function of the largest transverse momentum (leading charged particle) of the event

ATLAS results





	0.9	7	13
$\langle dN_{ch}/d\eta \rangle$	1.306	2.405	2.862

p_T > 0.5 GeV/c
$|\eta|<2.5$

In collaboration with Lizardo Valencia (UNACH, UNISON)

ATLAS results (scaled)

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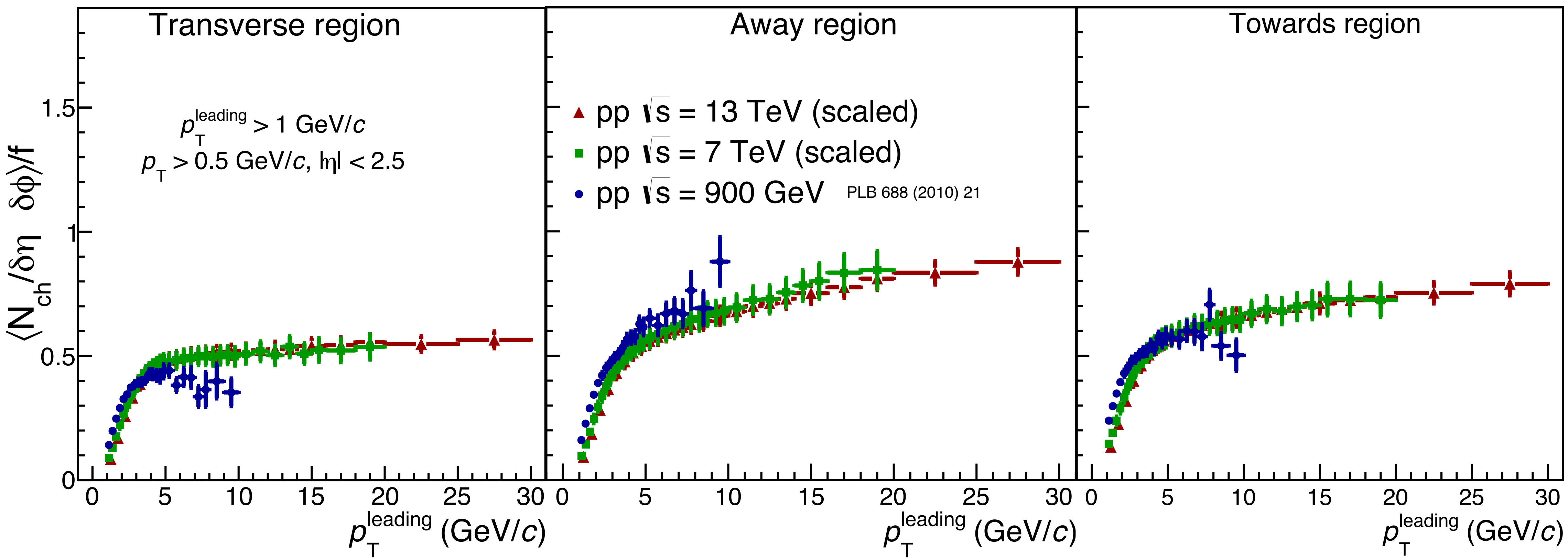
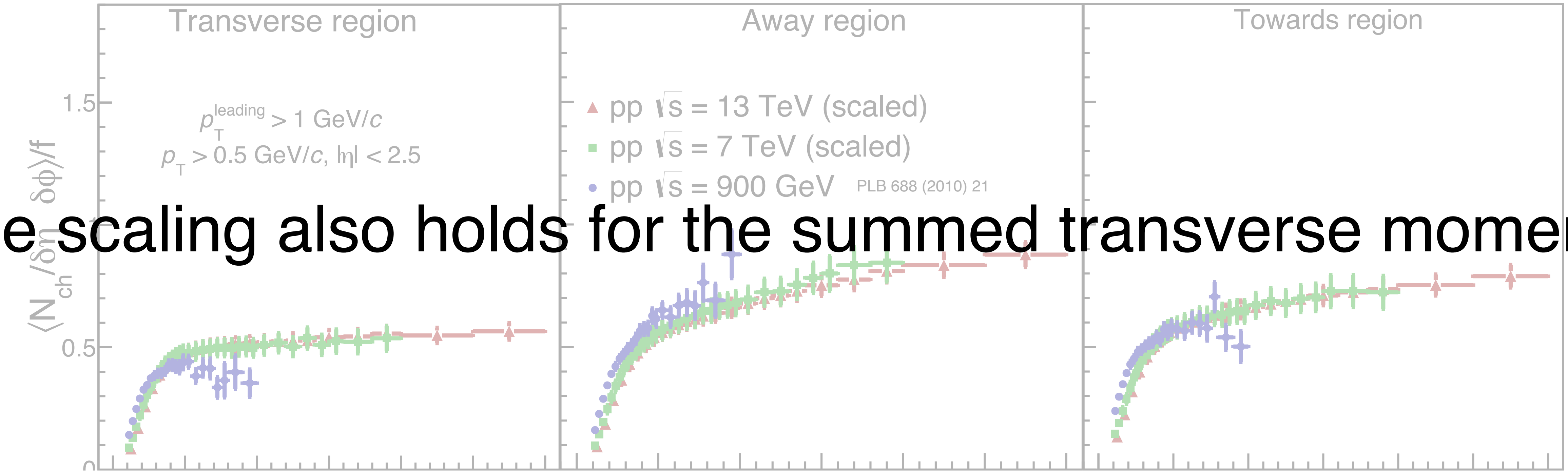


- Interesting scaling of the number density as a function of the leading p_T. The effect is unveiled once the number density is scaled according with the change variation of multiplicity wrt pp at $\sqrt{s} = 0.9$ TeV
- Same factor for regions sensitive to different physics

In collaboration with Lizardo Valencia (UNACH, UNISON)

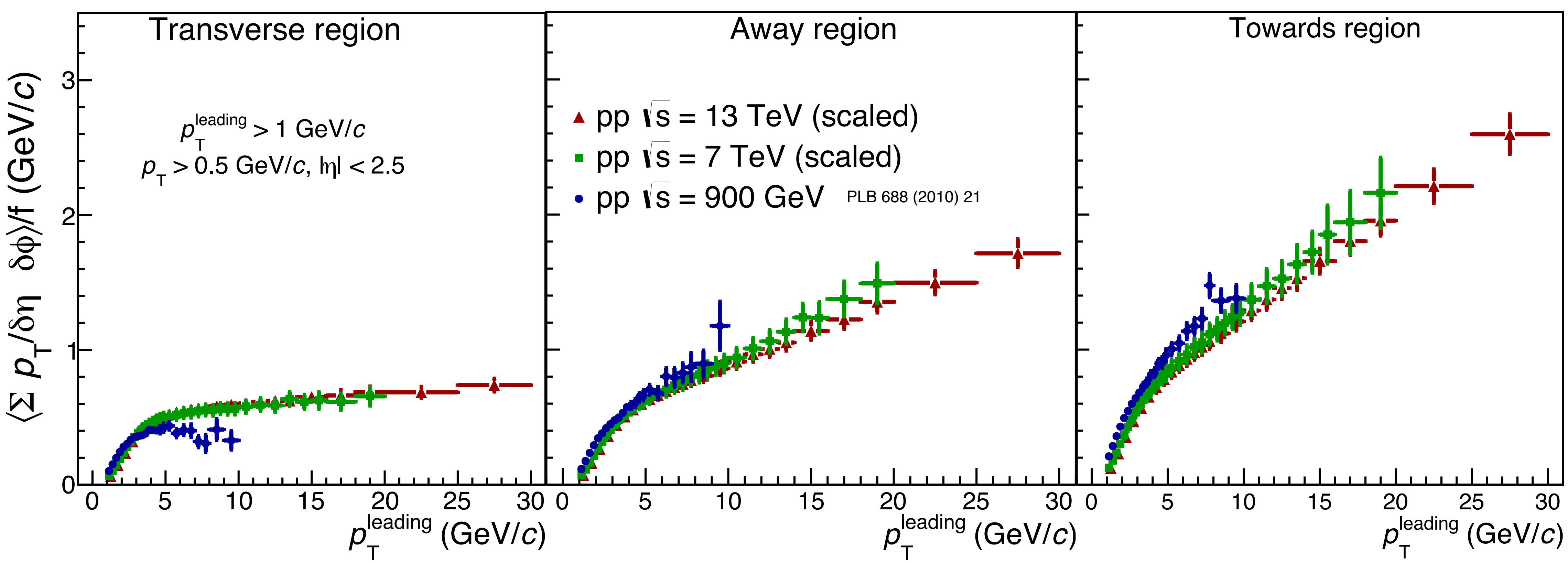
ATLAS results (scaled)

Instituto de Ciencias Nucleares UNAM

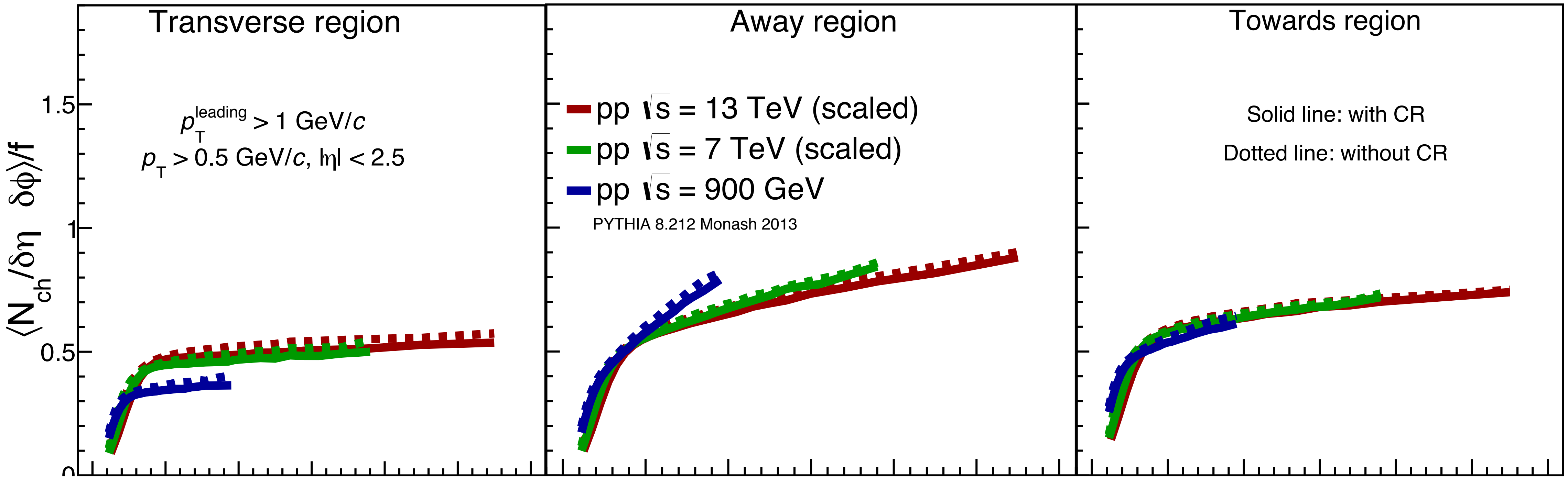


The scaling also holds for the summed transverse momentum

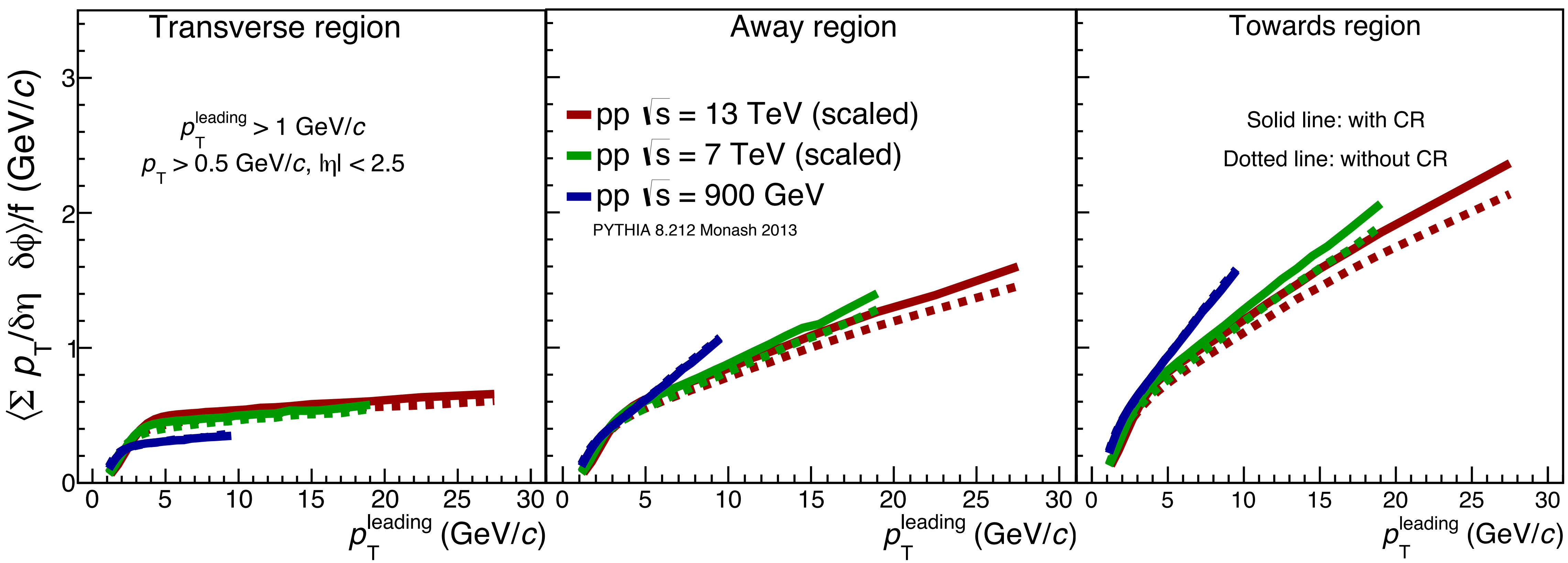
In collaboration with Lizardo Valencia (UNACH, UNISON)



PYTHIA 8.212 (scaled)



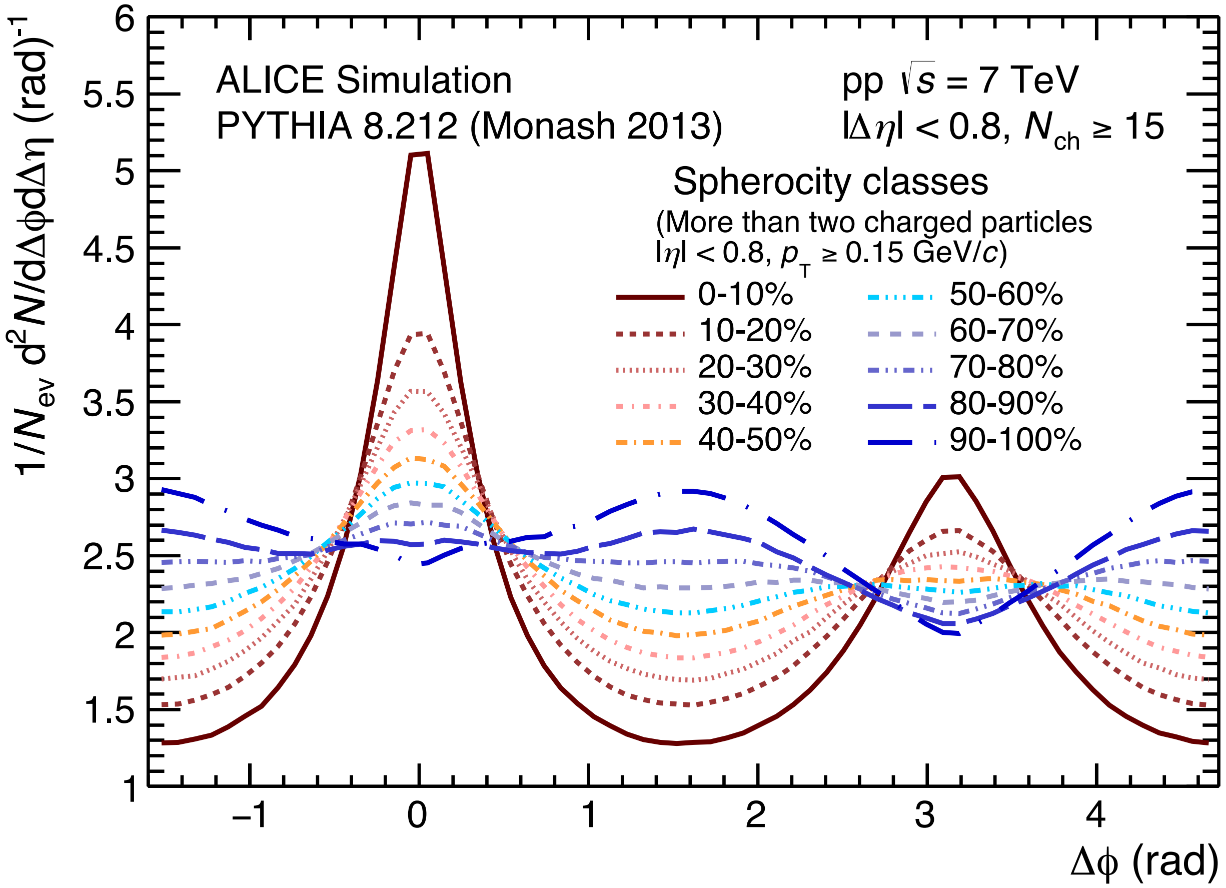
In collaboration with Lizardo Valencia (UNACH, UNISON)



Some comments

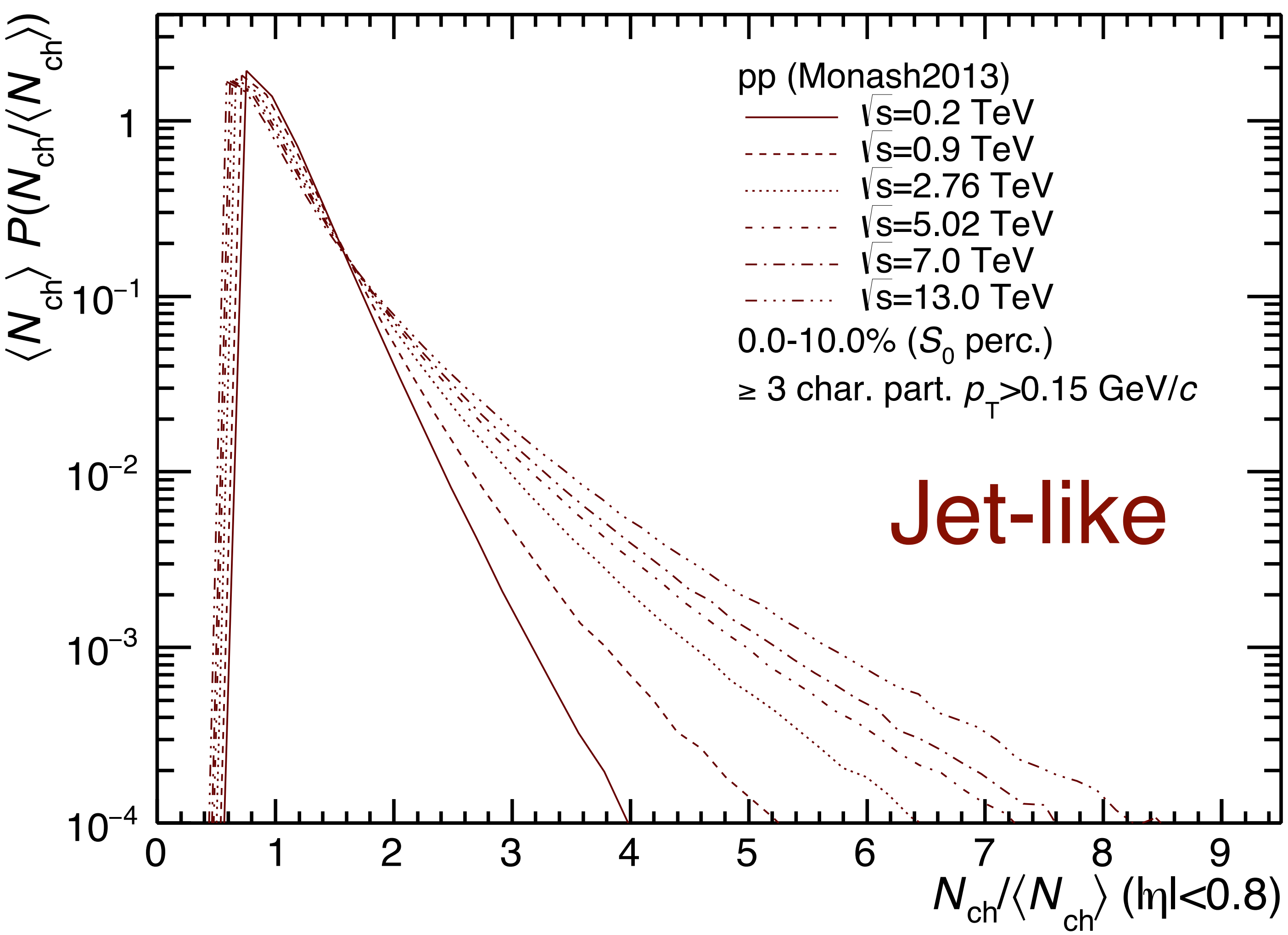
- The observed scaling is achieved by considering the change in the inclusive average multiplicity. Since we consider low p_{T} charged particles ($p_{T} > 0.5$ GeV/c) to calculate the scaling factor, we are dominated by soft physics
- Within 15%, the scaling is well reproduced by PYTHIA

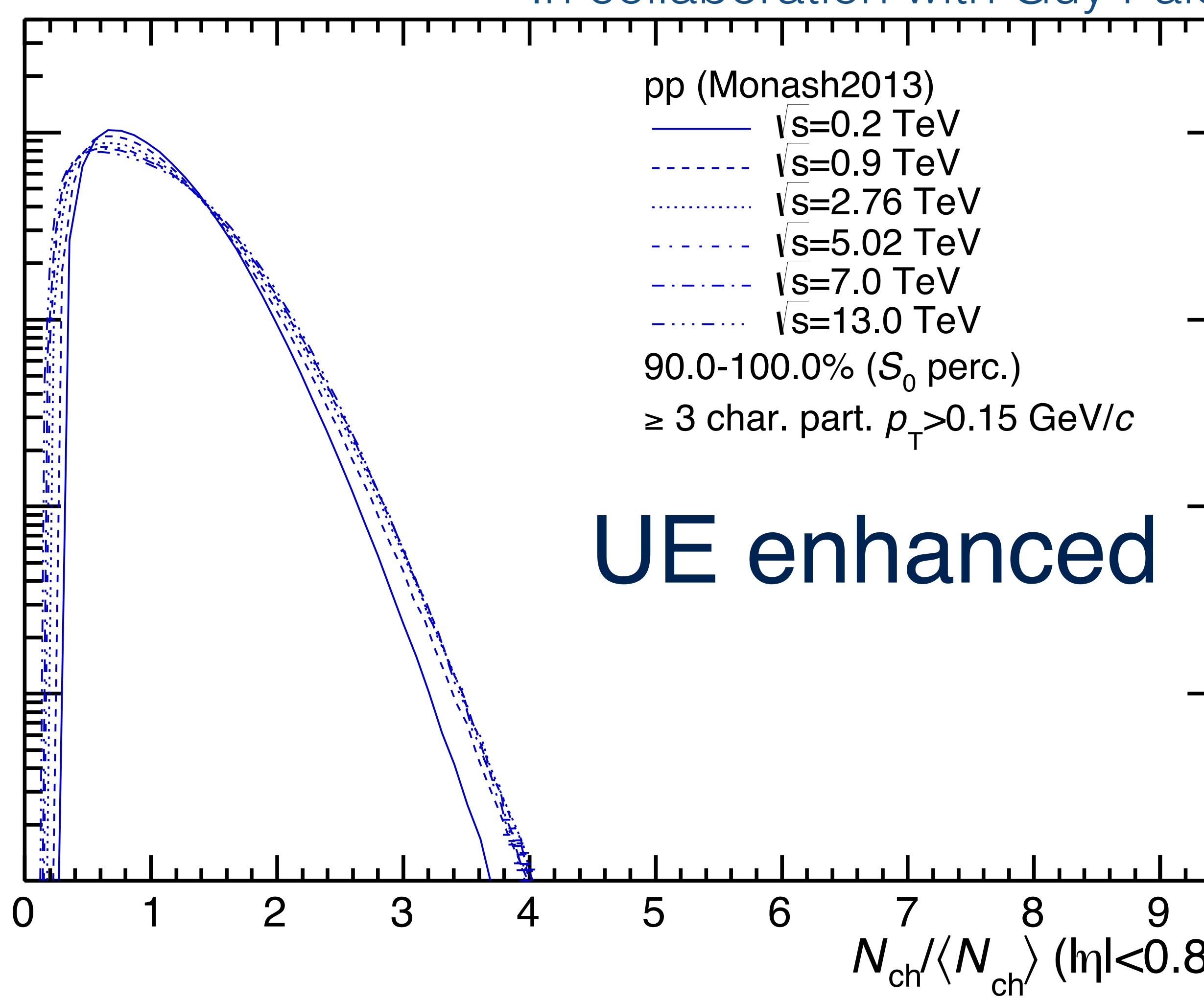
➡We can test the scaling properties of UE by running an event shape analysis



Going from pp at $\sqrt{s}$ = 0.2 to 13 TeV the UE-enhanced samples give essentially the same $N_{ch}/\langle N_{ch}\rangle$ distributions

In collaboration with Guy Paić

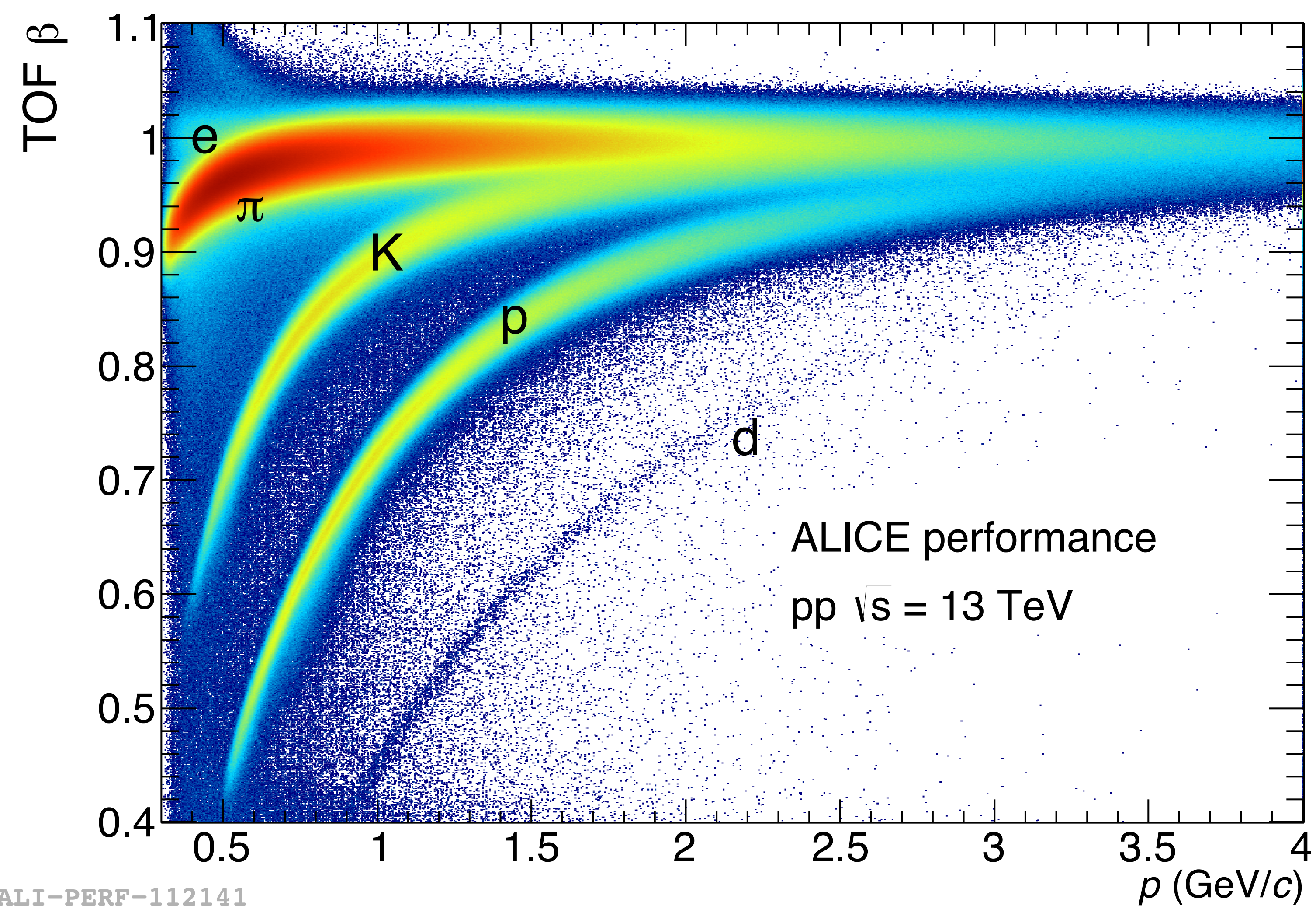




About the importance of PID

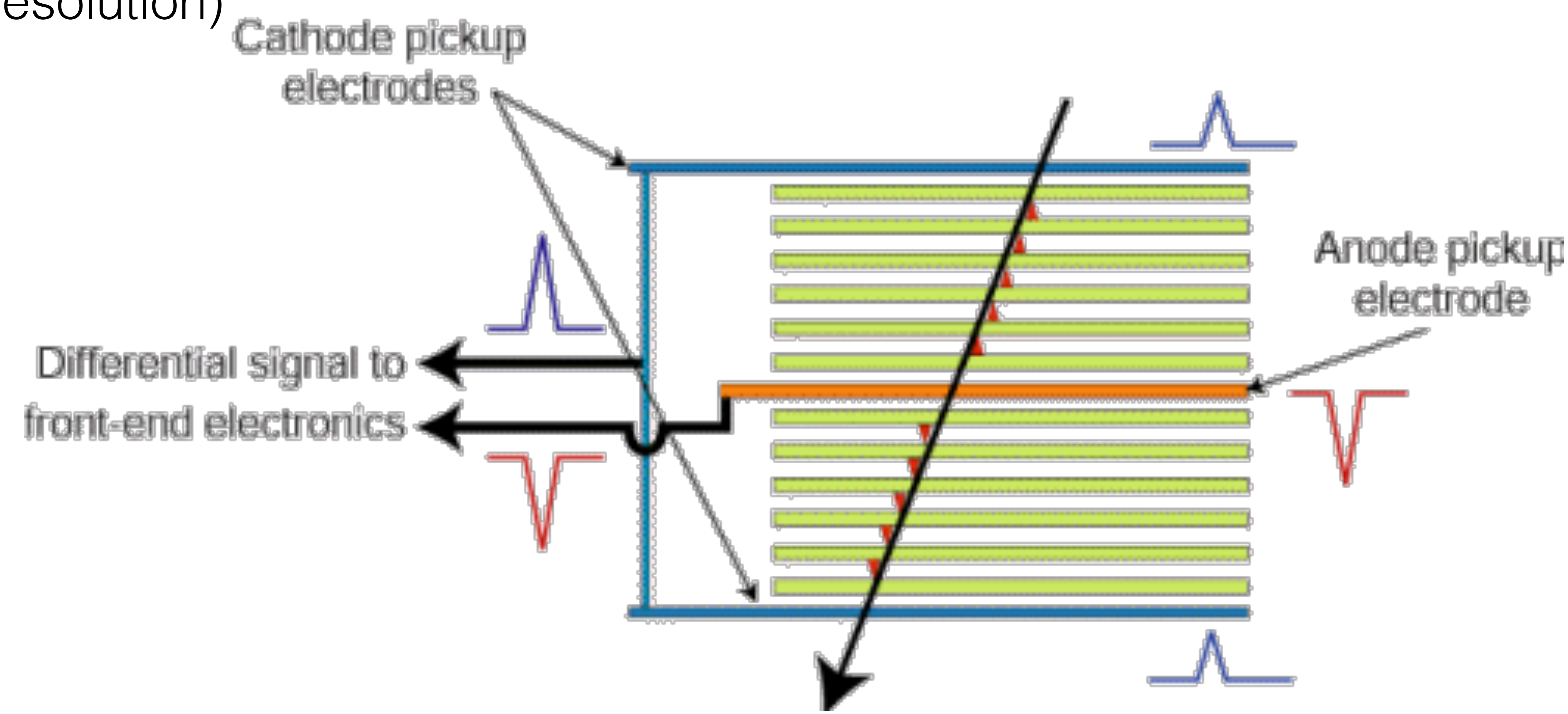
Charged particles in the intermediate momentum range are identified in ALICE by the Time Of Flight (TOF) detector. The time measurement with the TOF, in conjunction with the momentum and track length measured by the tracking detectors is used to calculate the particle mass

- Each TOF module contains a total of 1638 detector elements (MRPC strips), covering an area of 160 m2 with 157248 readout channels (pads)

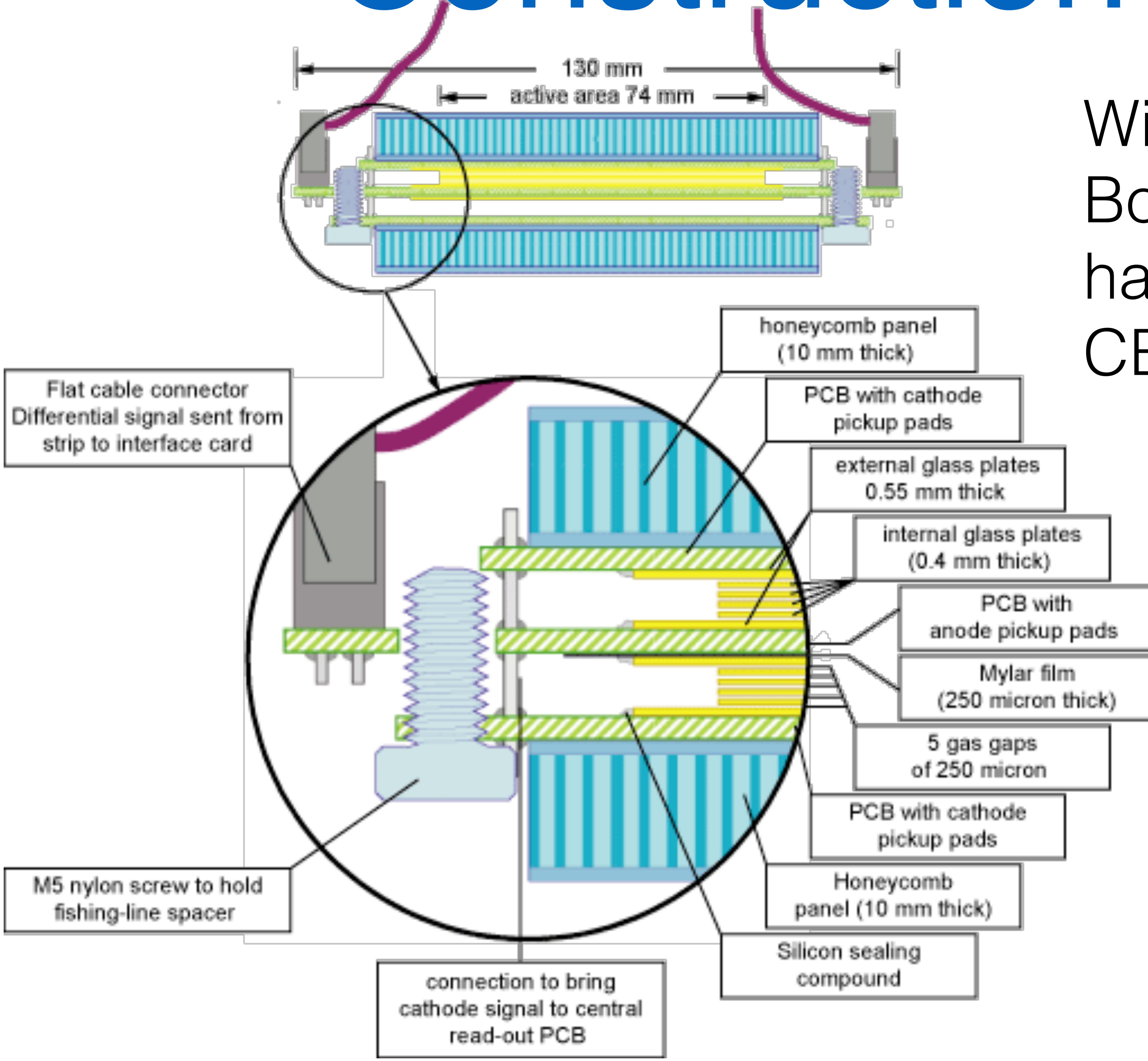


MRPC

The MRPC is a stack of resistive glass plates. A high voltage is applied to the external surfaces of the stack. Further out there are pickup electrodes. A charged particle ionises the gas and the high electric field amplifies this ionization by an electron avalanche. The resistive plates stop the avalanche development in each gap; they are however transparent to the fast signal induced on the pickup electrodes by the movement of the electrons. So the total signal is the sum of the signals from all gaps (the reason for many gaps is to achieve high efficiency), whereas the time jitter of the signal depends on the individual gap width (the reason for narrow gaps is to achieve good time resolution)



Construction



With the help of Bologna's group we have built a chamber at CERN

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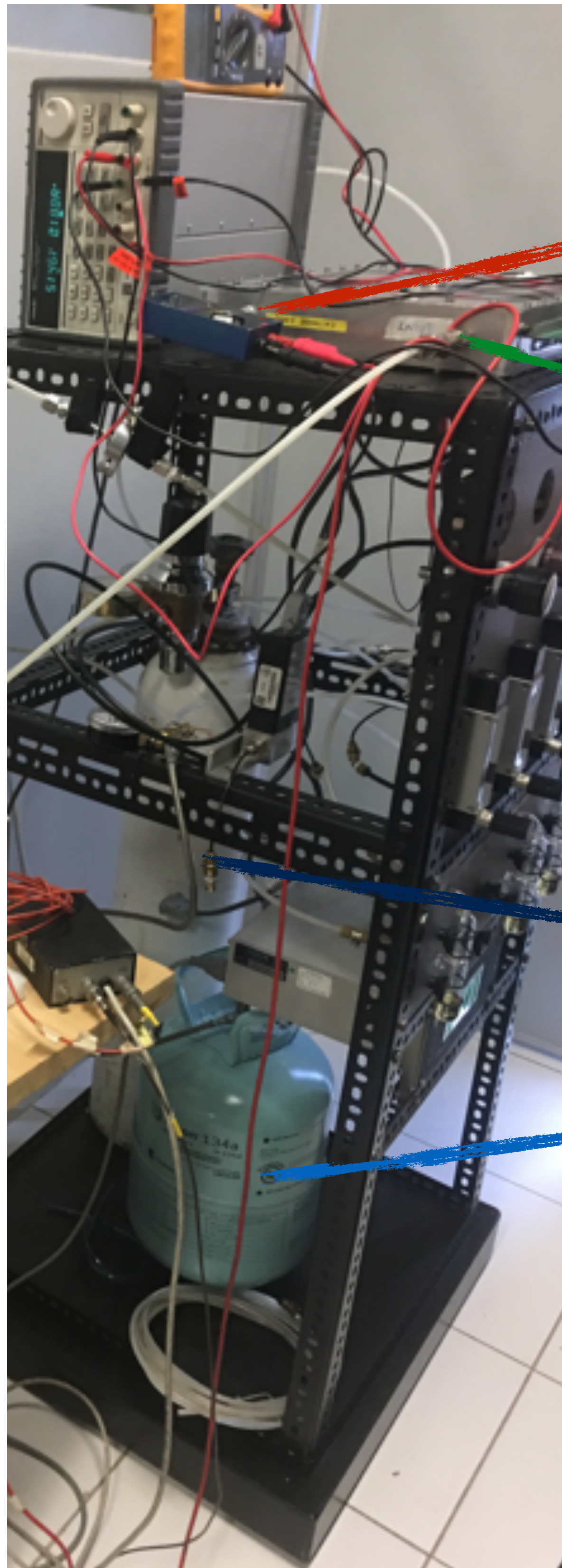
Installation

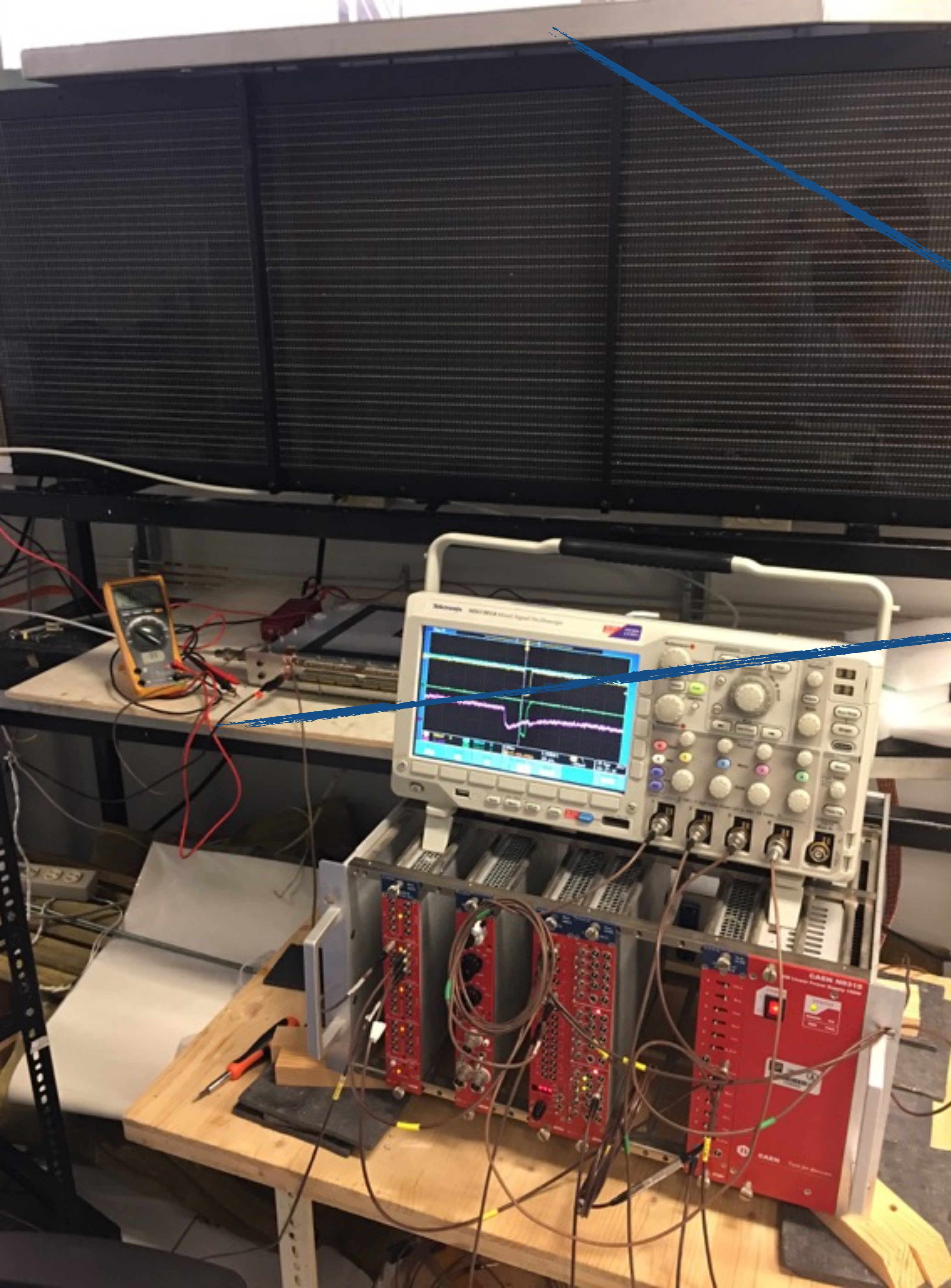


DC-to-DC converter

MRPC

SF6 (~2%)

Freon (~98%)



Coincidences with scintillation counters

The characterisation of the chamber is in progress

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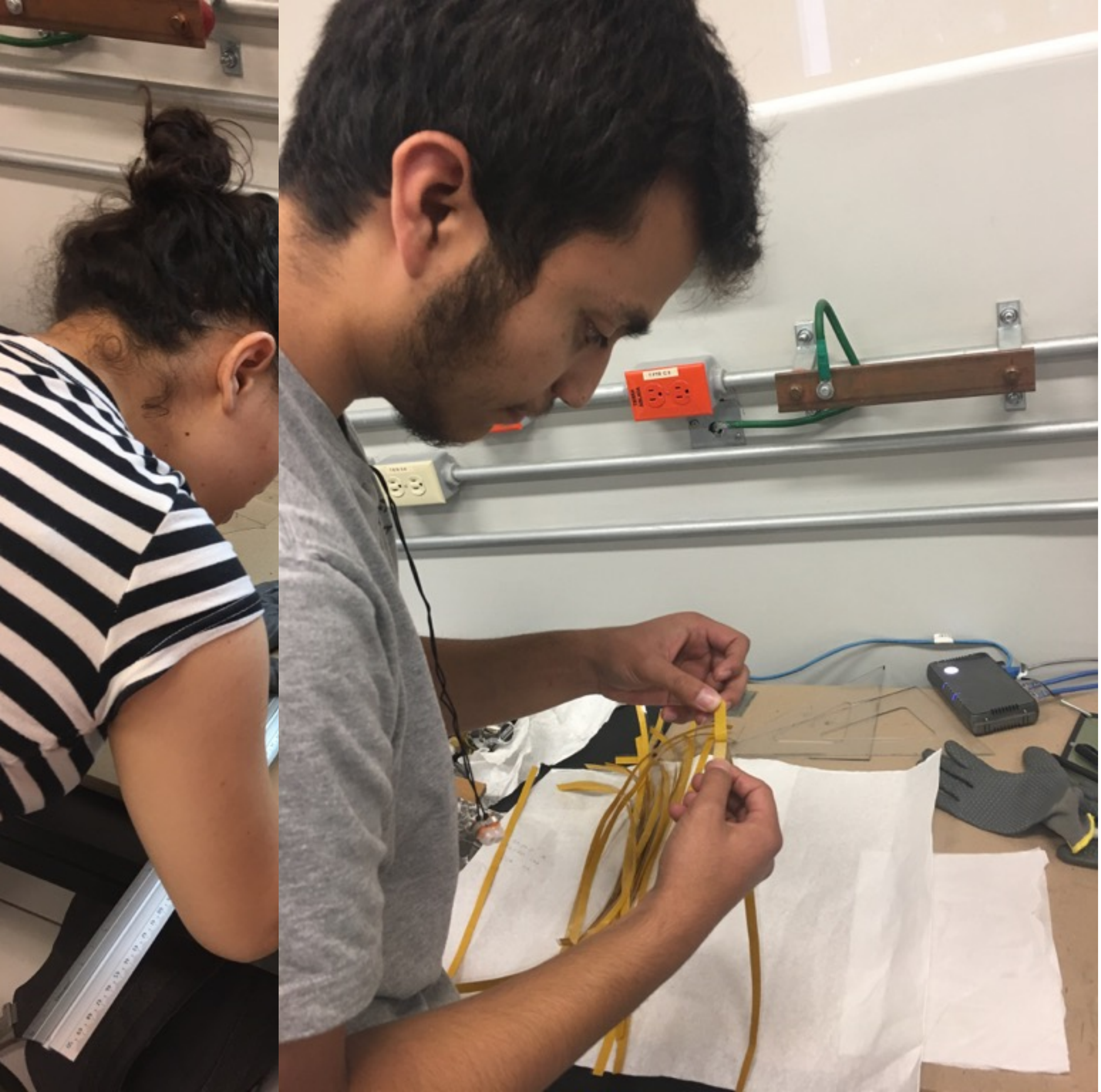
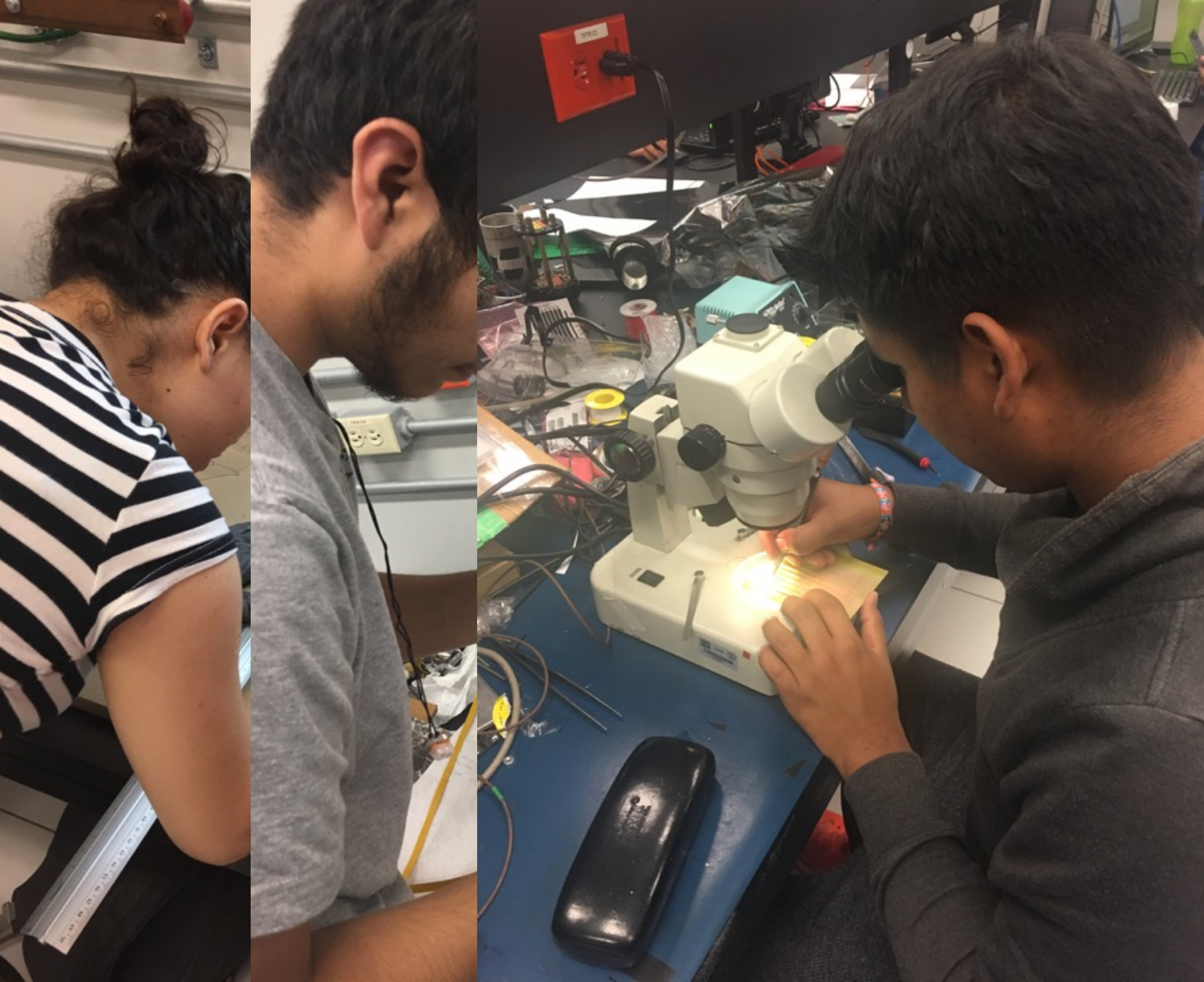
In parallel we are building our own chambers at ICN
Arlette Melo, Nelly Solano, Viridiana González, Luis Díaz, Alejandro Sánchez, Brandon Patiño, Diana Solano, Diego Garzón, José Reyes, Vladimir Ruiz, Josef
Guy, Eleazar, Enrique





Summary and outlook

- Results from small systems show similarity to those in Pb-Pb collisions
- Still under debate if the hot QGP matter has been produced in small systems
- Precise characterization of pp and p-Pb collisions is ongoing
- New tools have been proposed in order to understand the new phenomena
- New measurements are coming!

Backup

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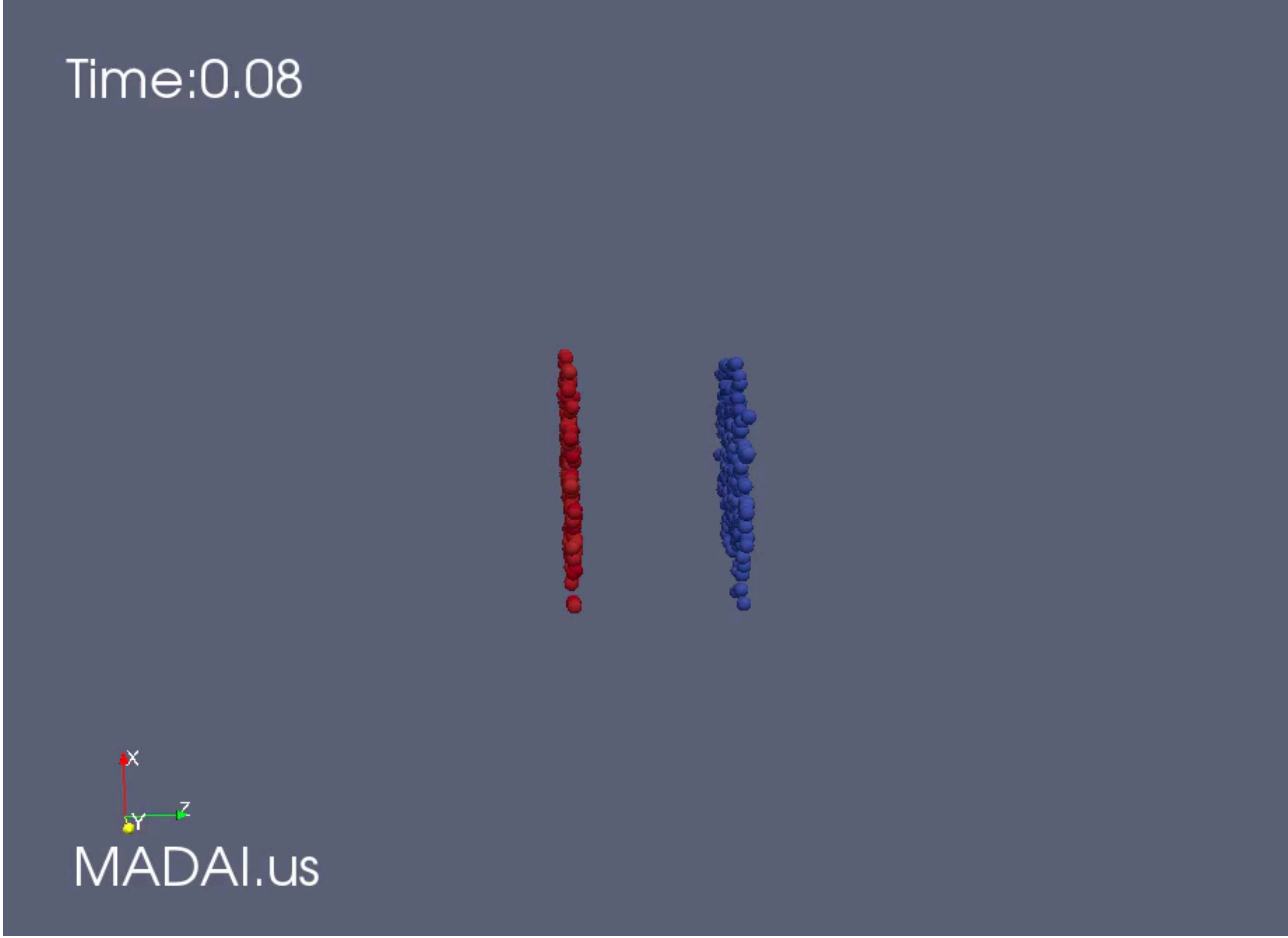
Multiplicity classes, pp √s = 7 TeV

Table 1: Event multiplicity classes used in the analysis, their corresponding fraction of the INEL>0 cross-section ($\sigma/\sigma_{\mathrm{INEL}>0}$) and their corresponding $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$ in $|\eta| < 0.5$. The value of $\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$ in the inclusive INEL>0 class is 5.96 ± 0.23. The uncertainties are the quadratic sum of statistical and systematic contributions.

Class name	I	II	III	IV	V
$\sigma/\sigma_{\mathrm{INEL}>0}$	0-0.95%	0.95-4.7%	4.7-9.5%	9.5-14%	14-19%
$\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$	21.3 ± 0.6	16.5 ± 0.5	13.5 ± 0.4	11.5 ± 0.3	10.1 ± 0.3
Class name	VI	VII	VIII	IX	X
$\sigma/\sigma_{\mathrm{INEL}>0}$	19-28%	28-38%	38-48%	48-68%	68-100%
$\langle \mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta \rangle$	8.45 ± 0.25	6.72 ± 0.21	5.40 ± 0.17	3.90 ± 0.14	2.26 ± 0.12


Time:0.08
X
Y
Z
MADAI.us

Radial and elliptic flow

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Change from pp to Pb-Pb:

- ☐ Increase in mean p_T
- ☐ Larger effect for larger mass

First indication of collective behaviour

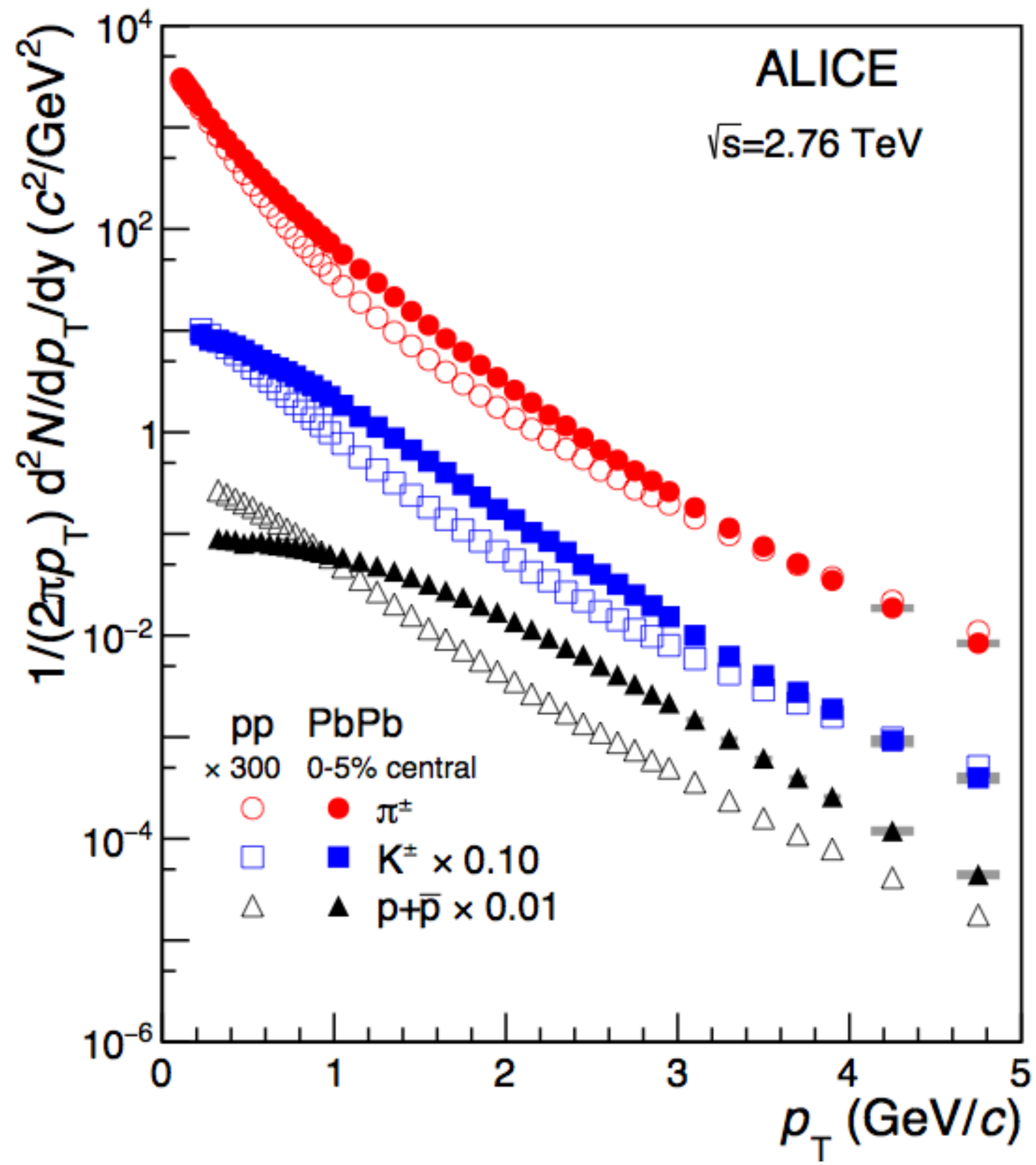
Pressure leads to radial flow

Same Lorentz boost (β) gives larger momentum for heavier particles

($m_p < m_K < m_\pi$)

Transverse momentum distribution

ALICE, PLB 736, 196



Azimuthal anisotropy

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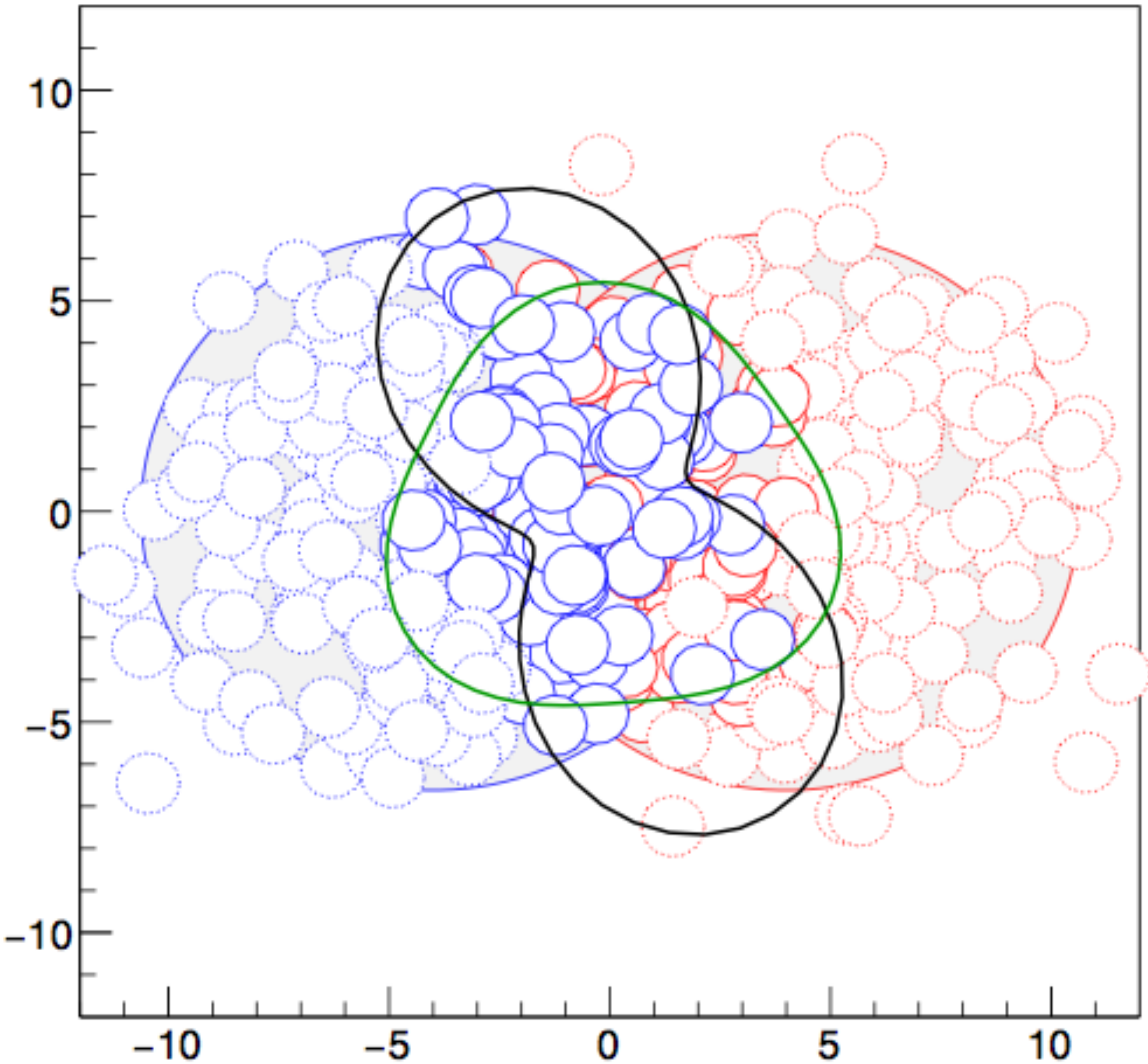
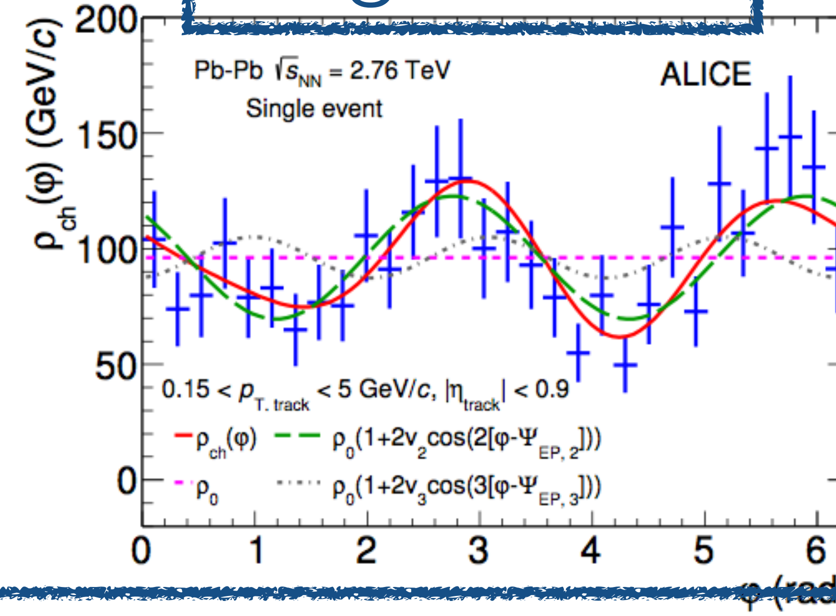
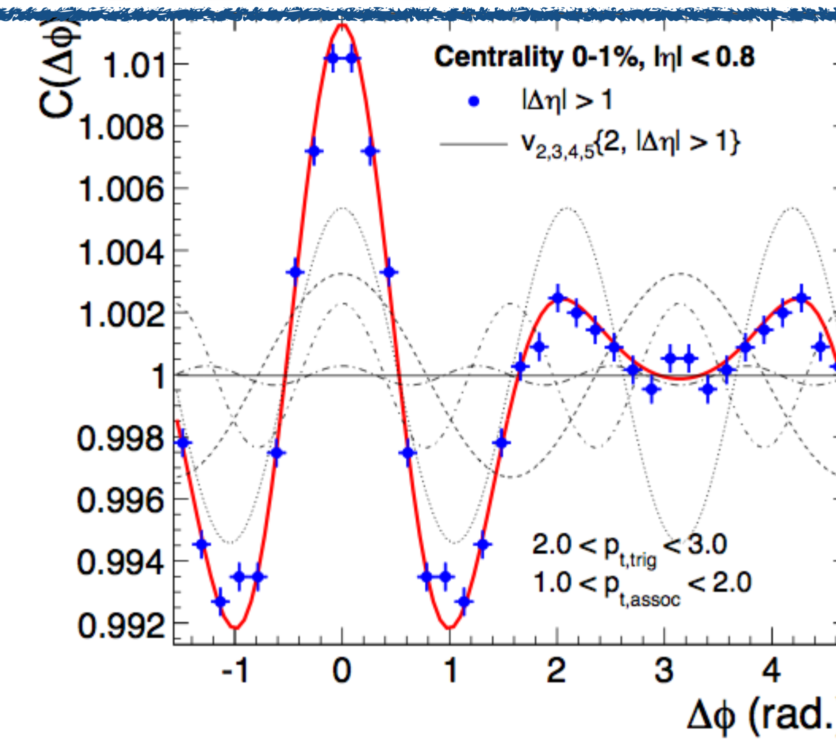


Single event



Sum over many events



Initial state spatial anisotropies ε_n are transferred into final state momentum anisotropies v_n by pressure gradients, flow of the QGP

The heavy-ion physics program

Heavy-ion collisions

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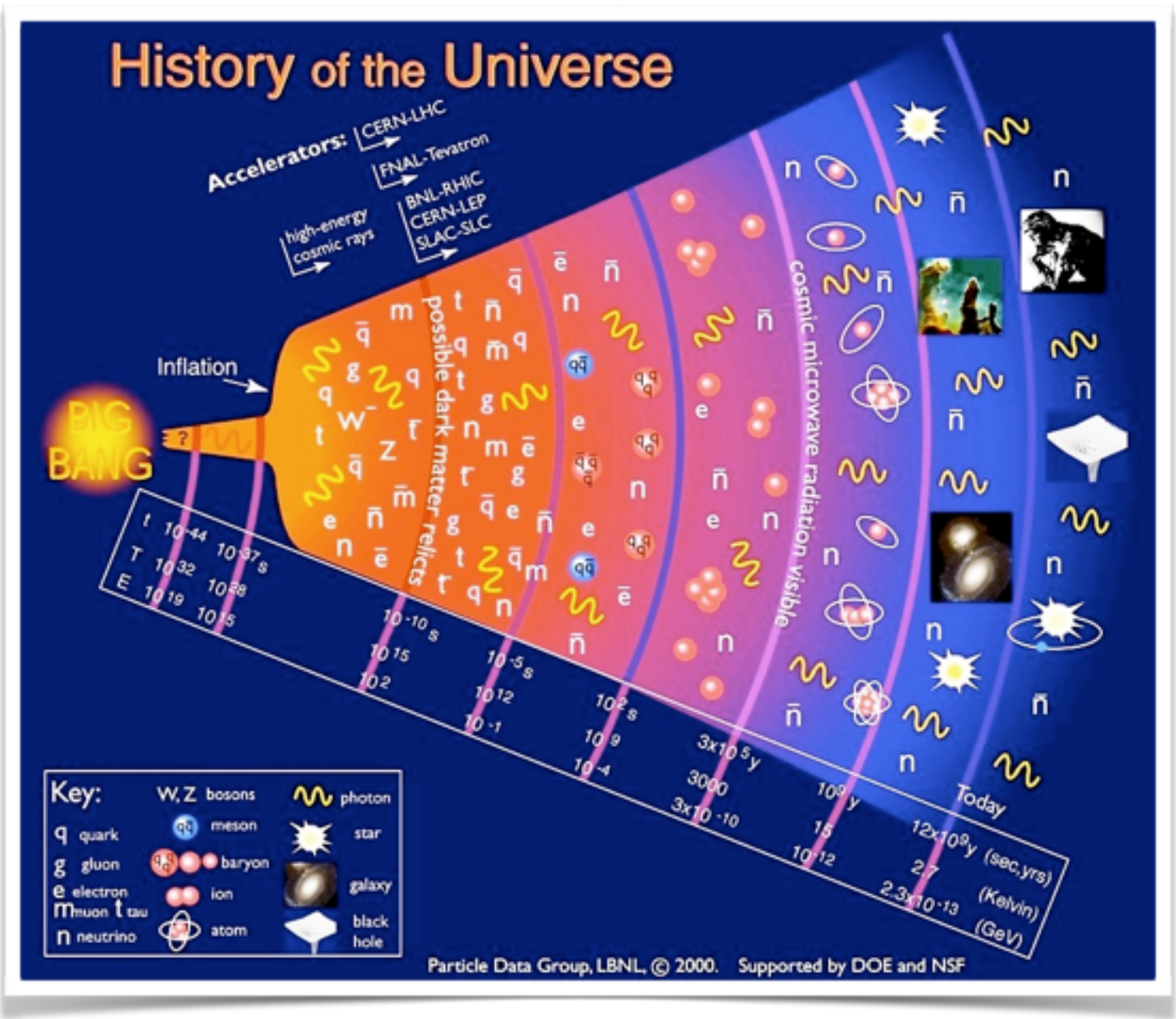

10^{-5} seconds: protons are formed
3 minutes: light nuclei
$3\ 10^{5}$ years: atoms

The main argument to convince Herwing Shopper (Director General of CERN, 1981-1988) to bring the heavy-ion program to CERN was the following:
"…find the theoretically predicted **Quark-Gluon Plasma (QGP)** which played an important role in the development of the Universe…"

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The LHC era

Soft physics

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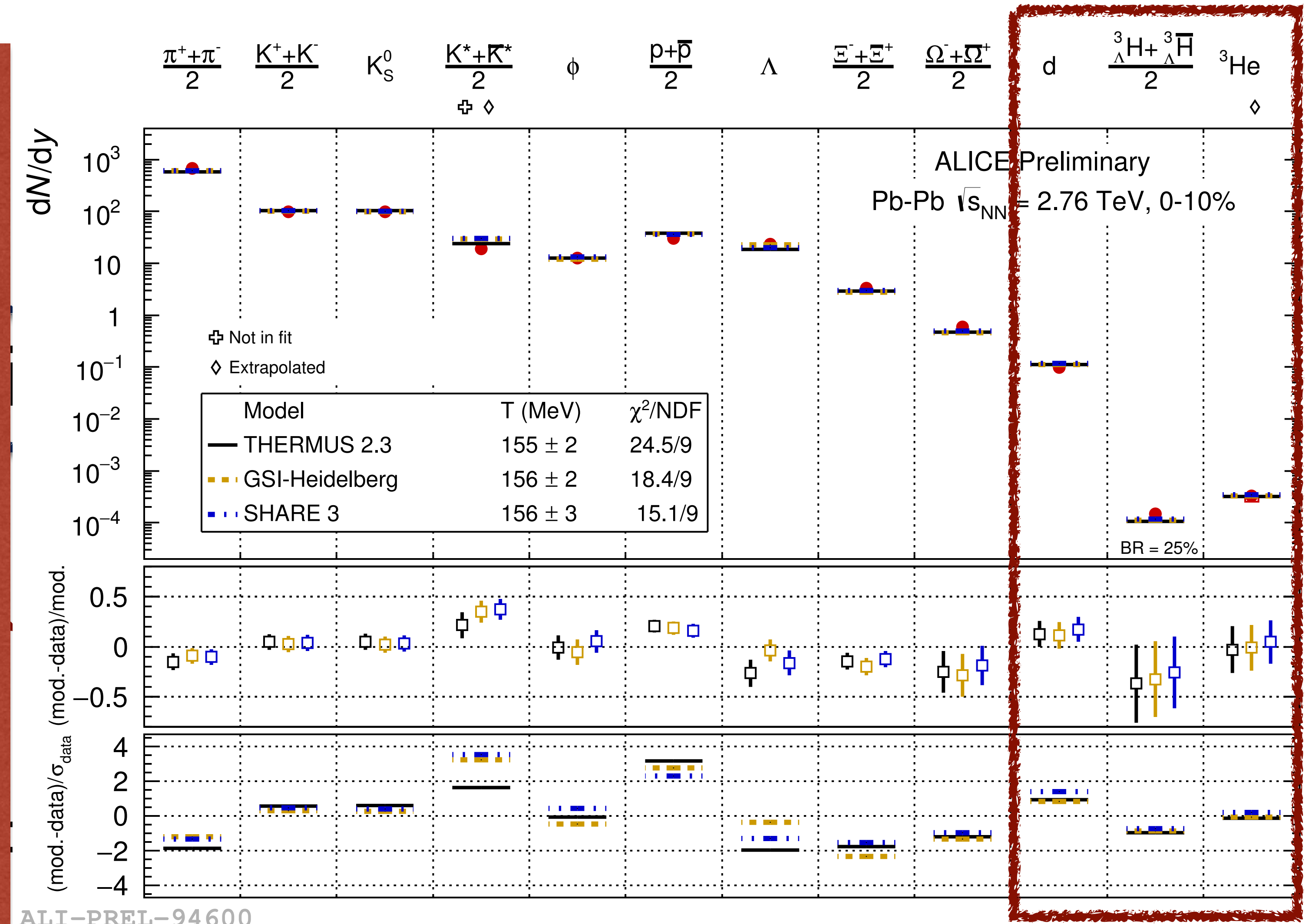
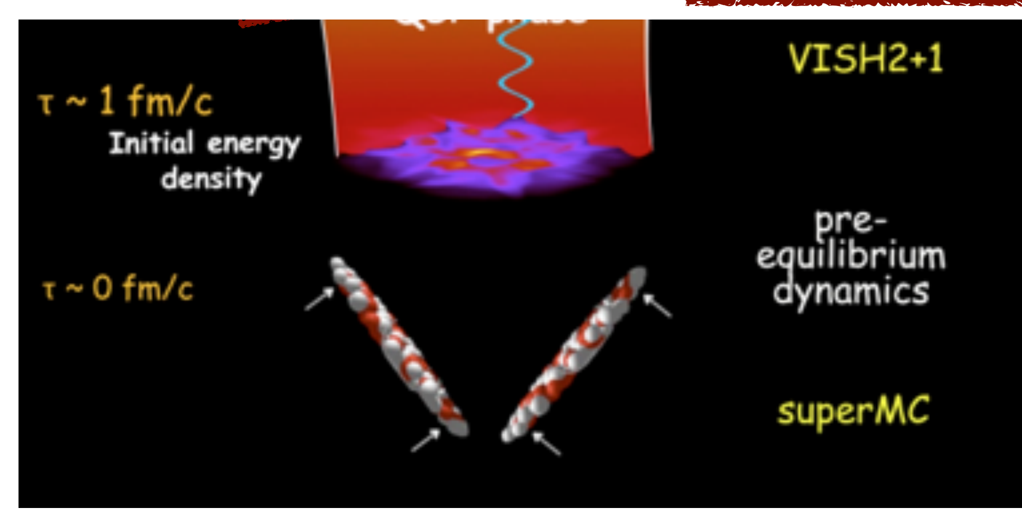
- The intriguing success of the Thermal model to describe dozens of particle yields (even nuclei) with very few parameters
  - Thermal production of nuclei (d, 3He)?
  - Little Bang Nucleosynthesis?
- Collective expansion of the system (radial and anisotropic flow)
  - How does the QCD perfect fluid emerges from the fundamental interactions of quarks and gluons?
- Medium modification due to energy deposition of jets?
- Strangeness enhancement



fixed

temperature is low enough that no more elastic interactions occur: **kinetic freeze-out**



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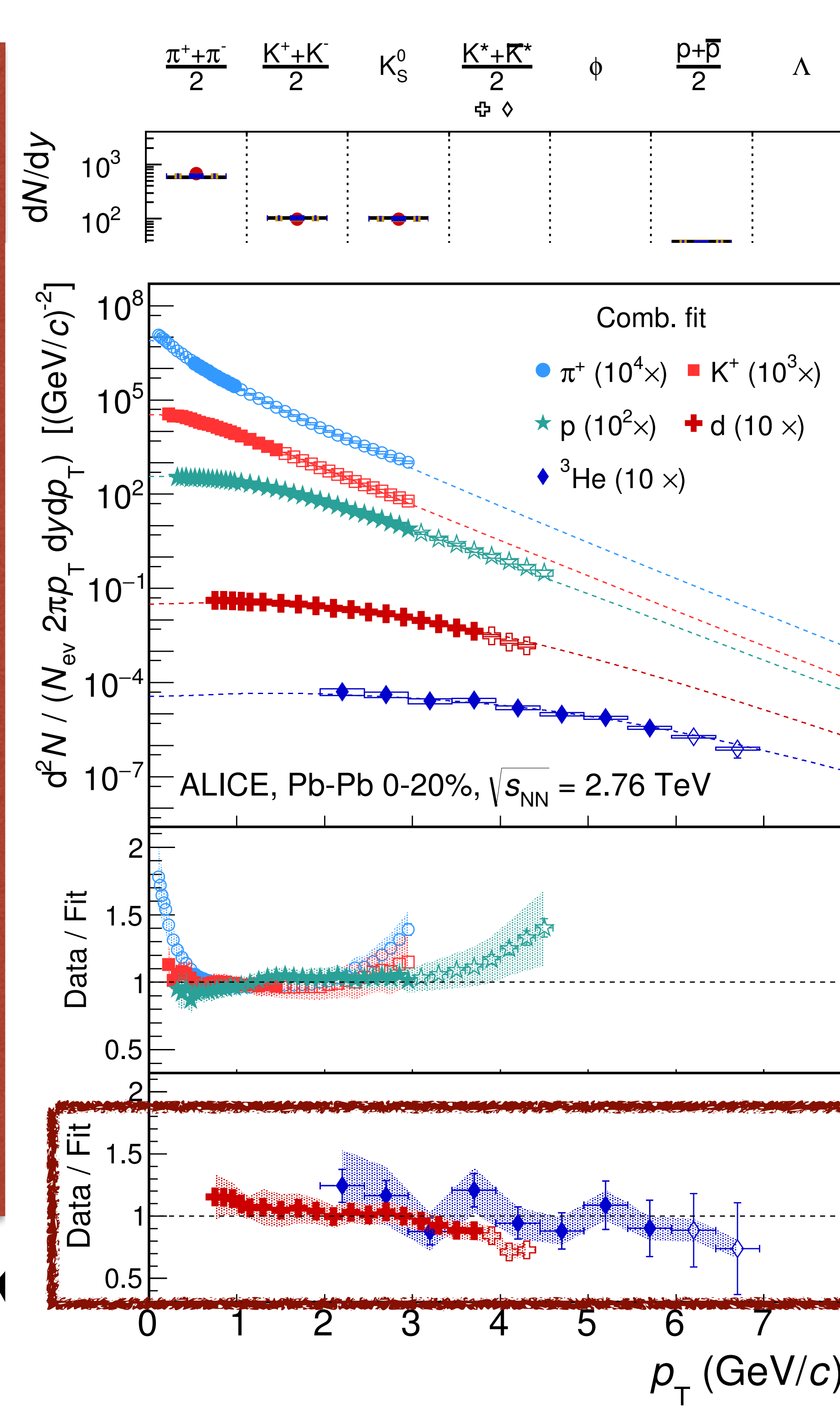
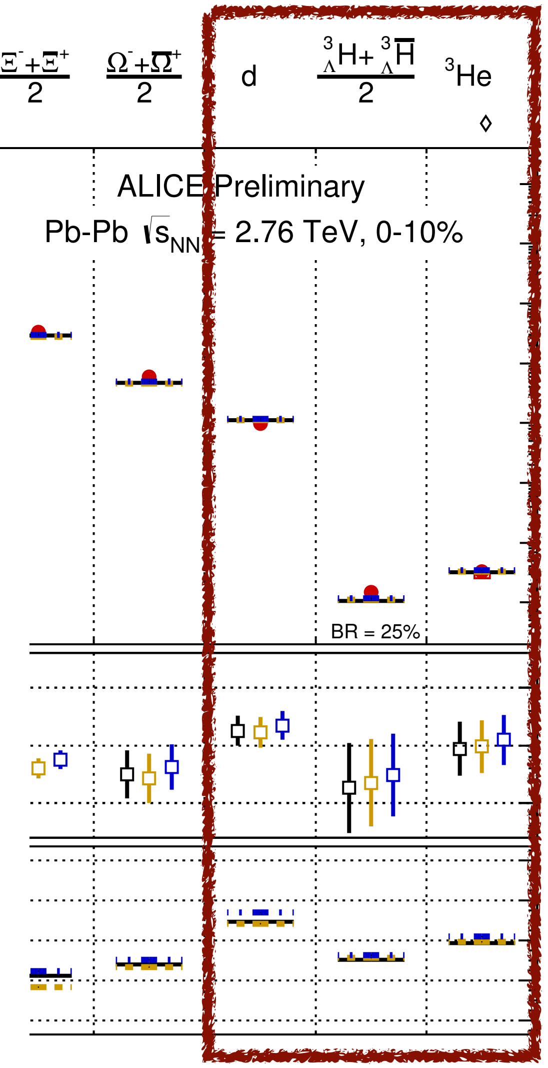
more elastic interactions occur: k

freeze-out





Soft physics

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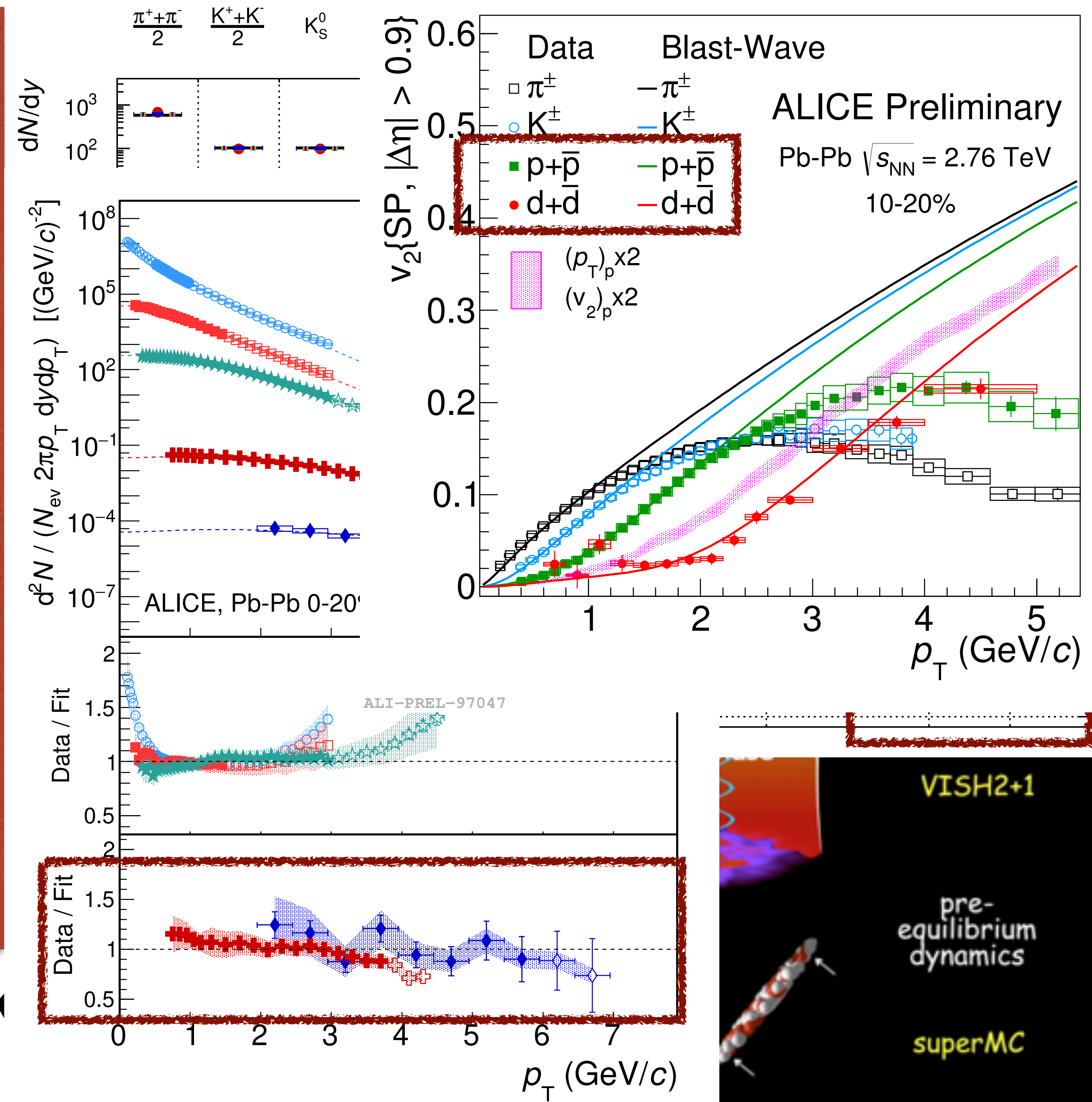
more elastic interactions occur: k

freeze-out



Soft physics

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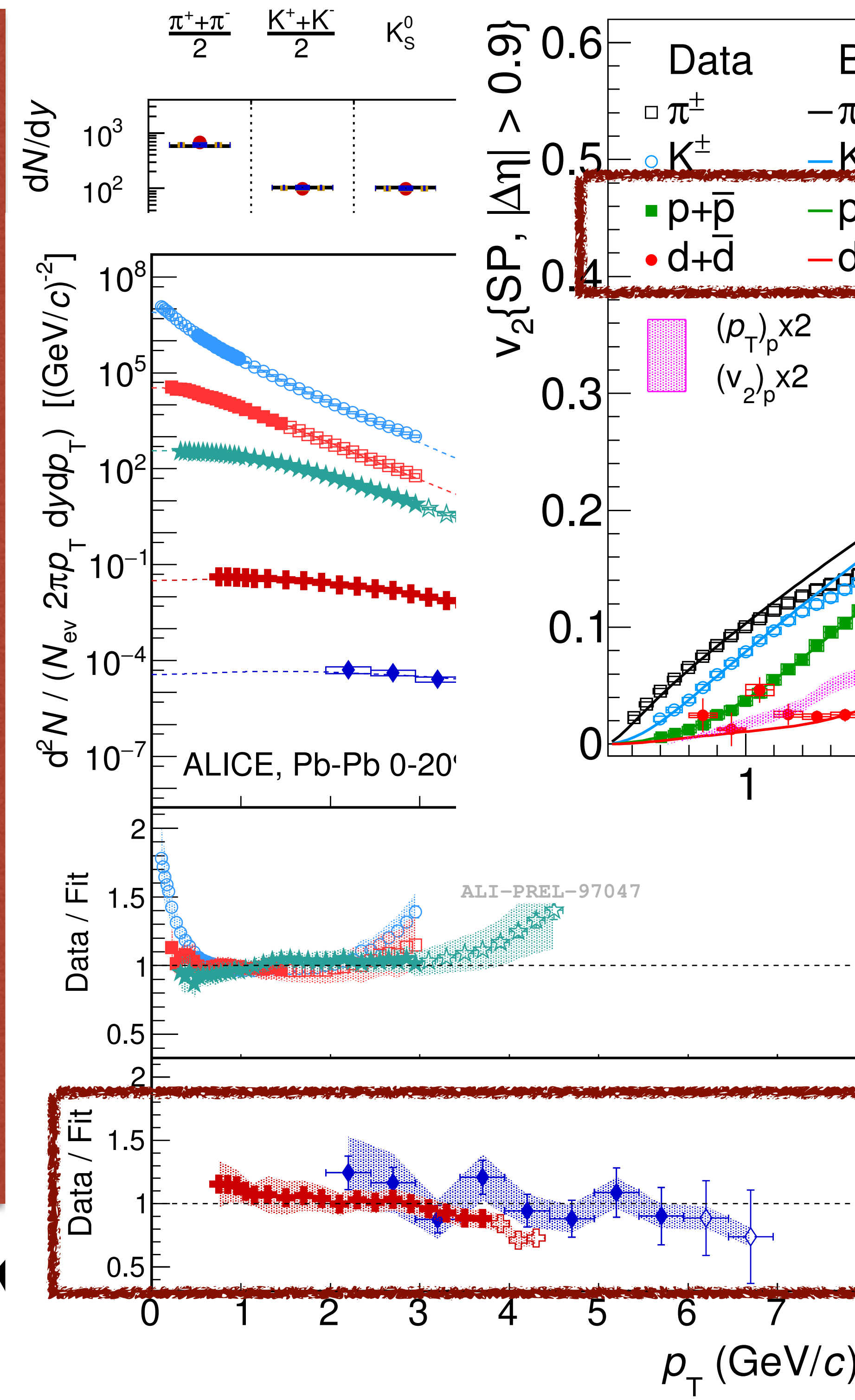
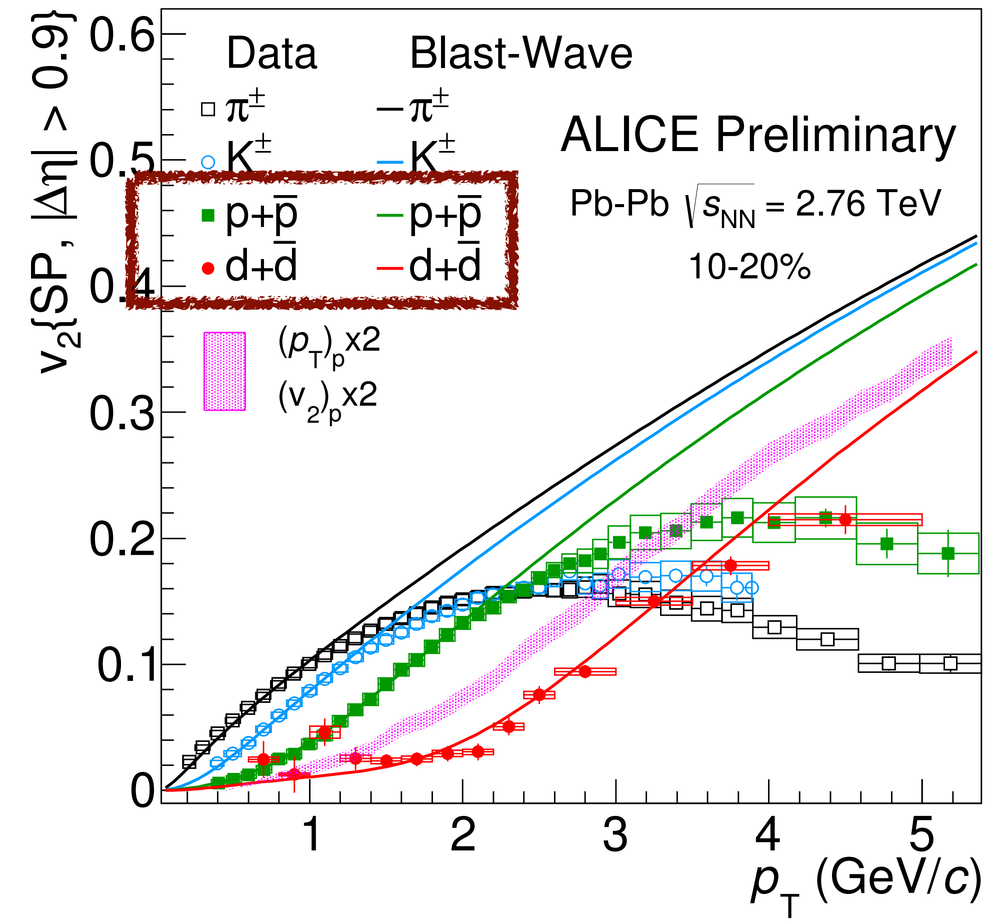
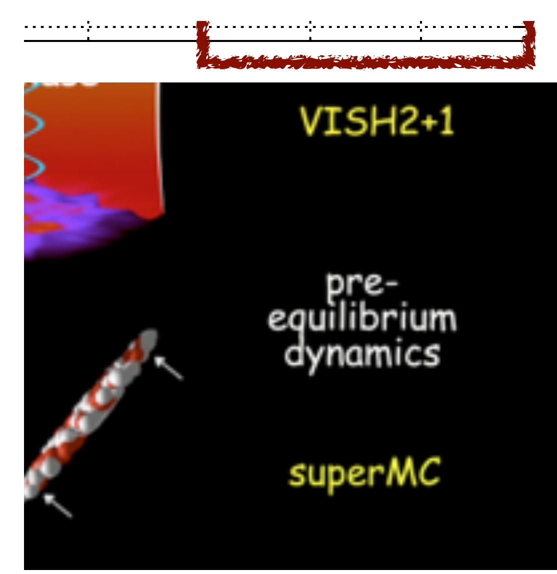
- Collective expansion of the system (radial and anisotropic flow)
  - How does the QCD perfect fluid emerges from the fundamental interactions of quarks and gluons?
- Medium modification due to energy deposition of jets?
- Strangeness enhancement

Temperature is low enough that more elastic interactions occur: k
freeze-out

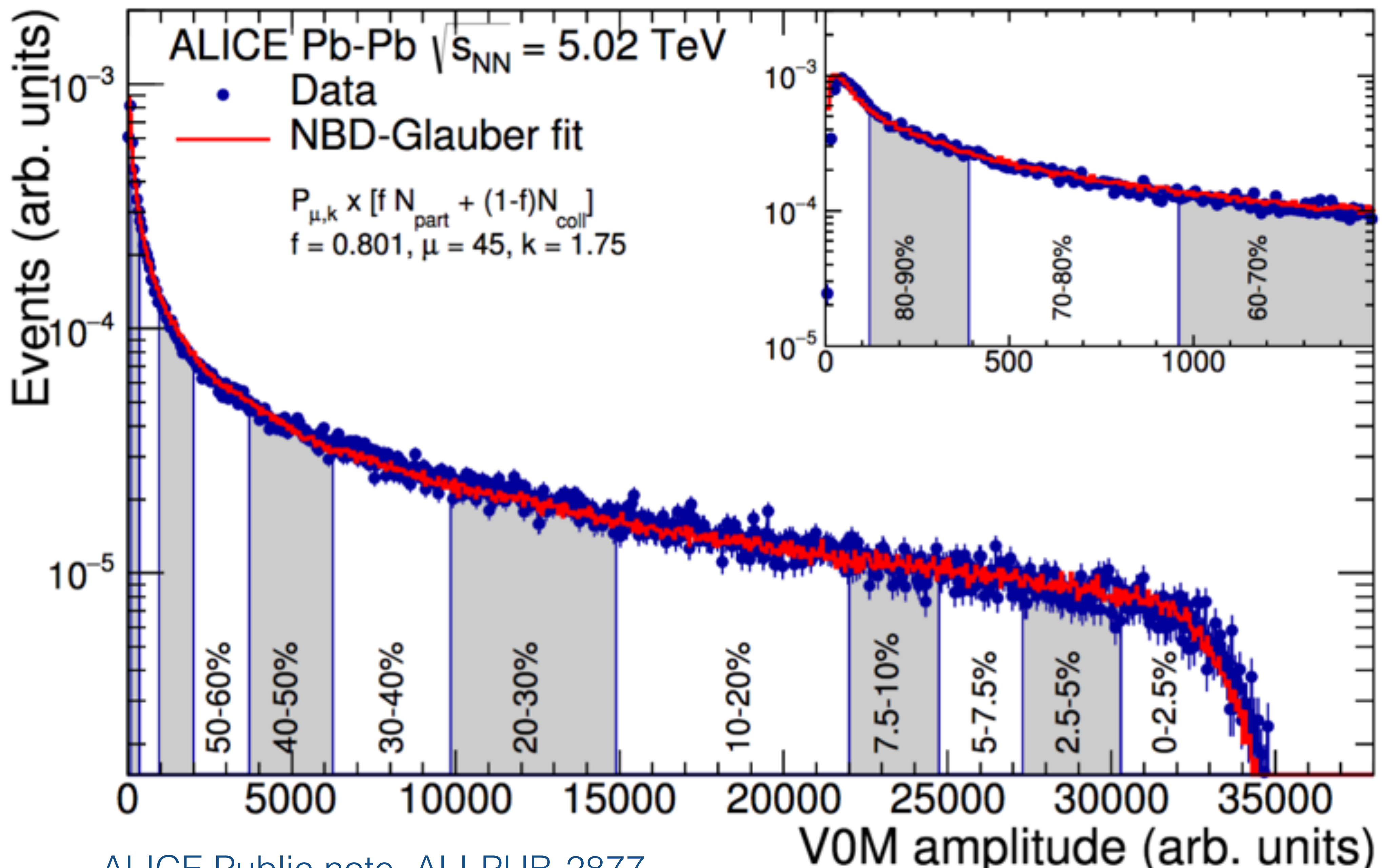






Event characterisation

Geometrical quantities are calculated using a Glauber Monte Carlo, the different event classes are classified according to their impact parameter



ALICE Public note, ALI-PUB-2877

Kinetic freeze-out

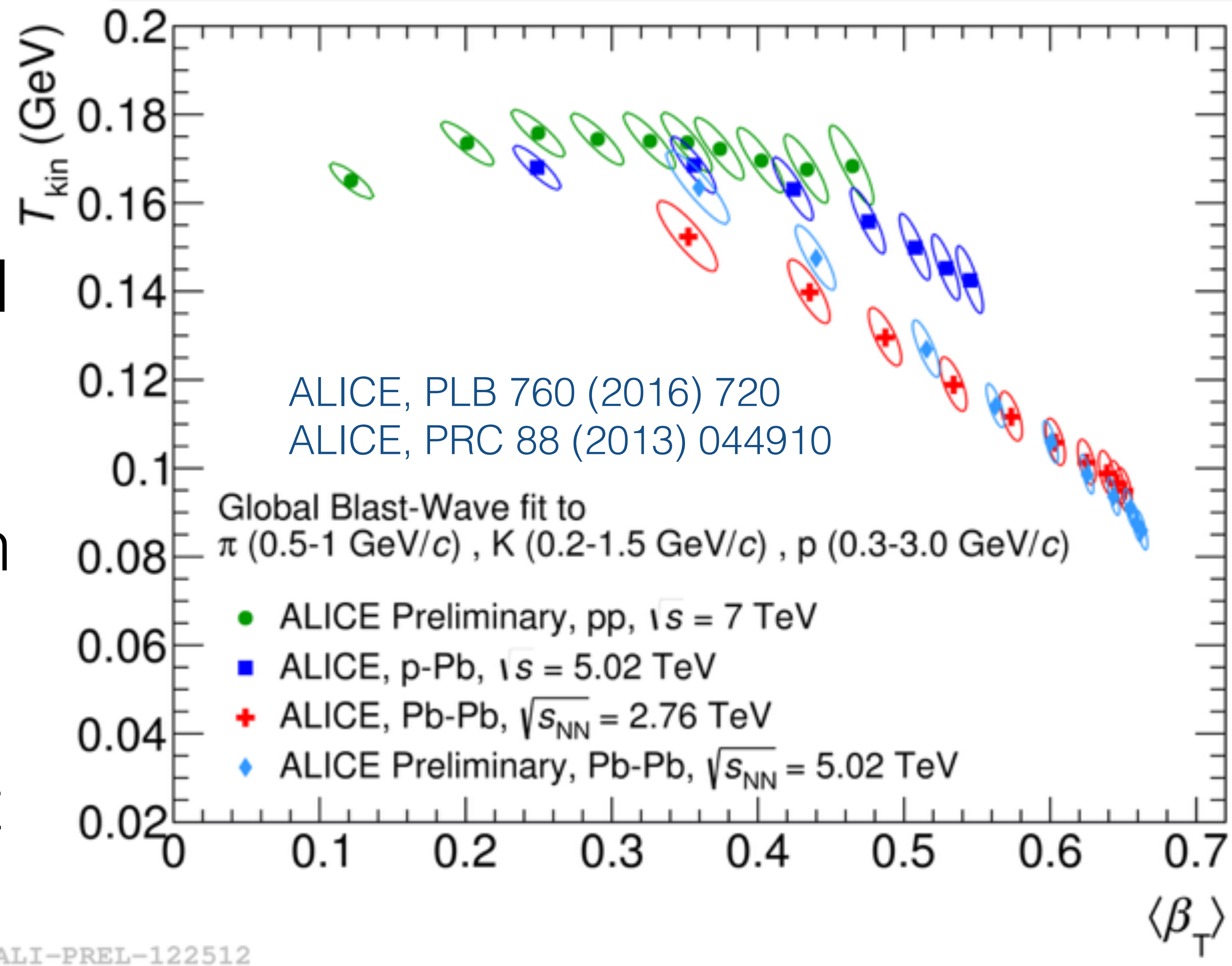
Simultaneous fit to π, K, p p_T spectra using the Boltzmann-Gibbs Blast-Wave model

E. Schnedermann et al., PRC 48 (1993) 2462

Simplified hydrodynamics model with only three parameters:

- β_T: radial expansion velocity
- T_{kin}: temperature at the kinetic freeze-out
- n: velocity profile

$T_{kin} < T_{ch}$: consistent with the existence of the hadronic phase. Results depend on the fit range. However, we always observe an increase of β_T with increasing multiplicity



Kinetic freeze-out

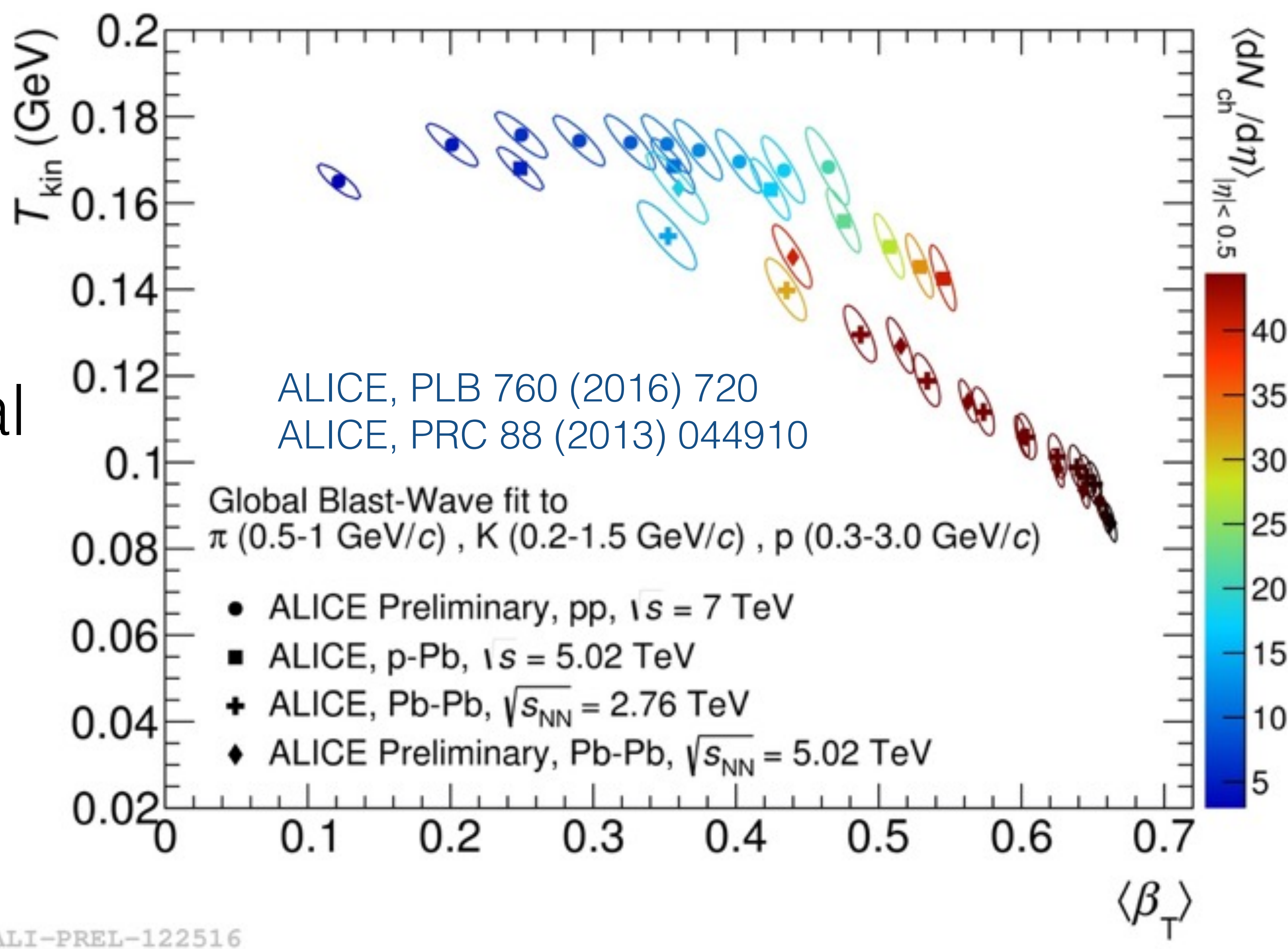
Simultaneous fit to π, K, p p_T spectra using the Boltzmann-Gibbs Blast-Wave model

E. Schnedermann et al., PRC 48 (1993) 2462

Same color indicates ~same multiplicities:

- Slightly higher radial flow in run II heavy-ion data
- Small systems also compatible with hydrodynamic model

Discussion about small collision systems (pp and p-Pb collisions) will be done at the end of the presentation



R_{AA} $\sqrt{s_{NN}}$ = 5.02 TeV

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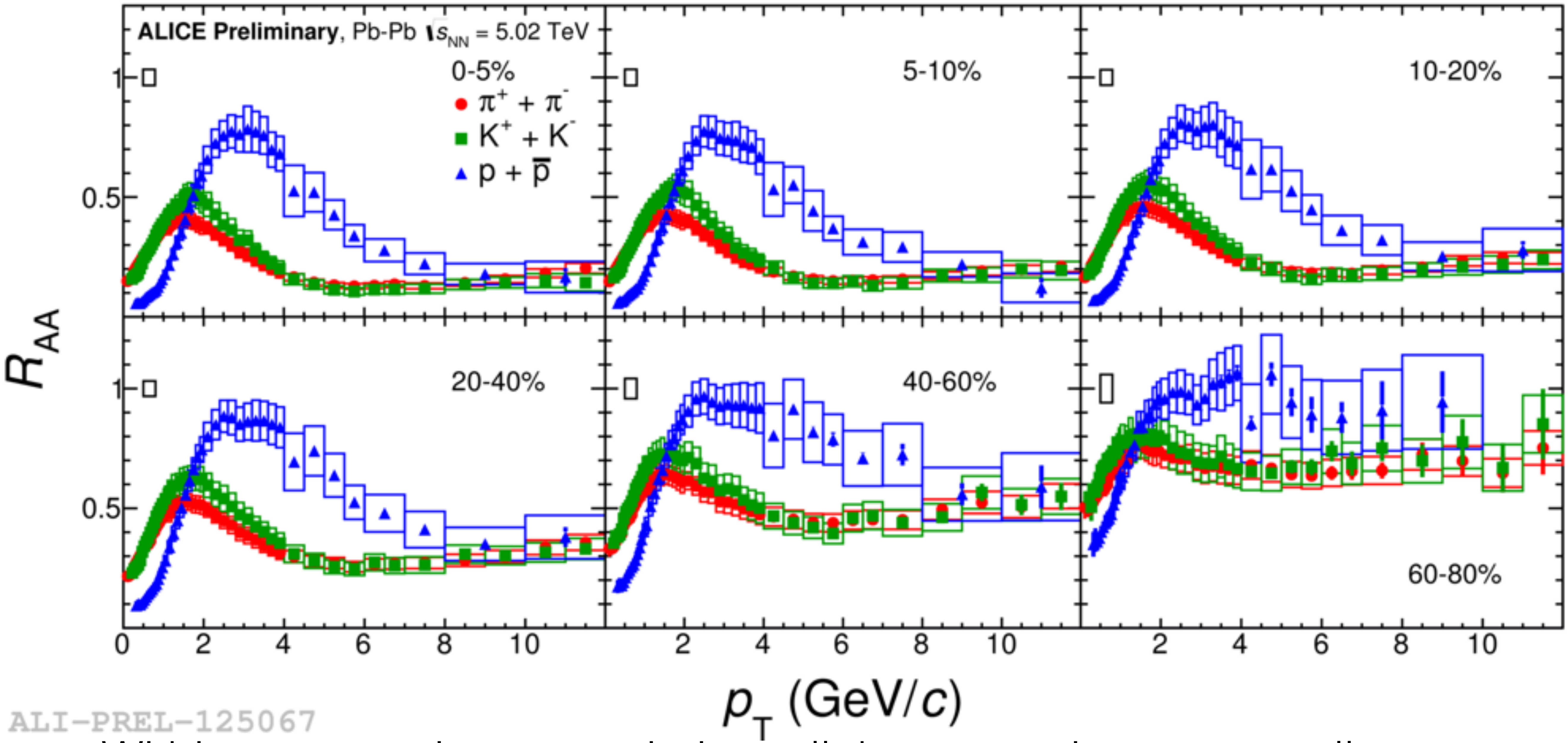

- Within systematic uncertainties, all three species are equally suppressed at high p_T (p_T>8 GeV/c)

R_{AA} $\sqrt{s_{NN}}$ = 5.02 TeV

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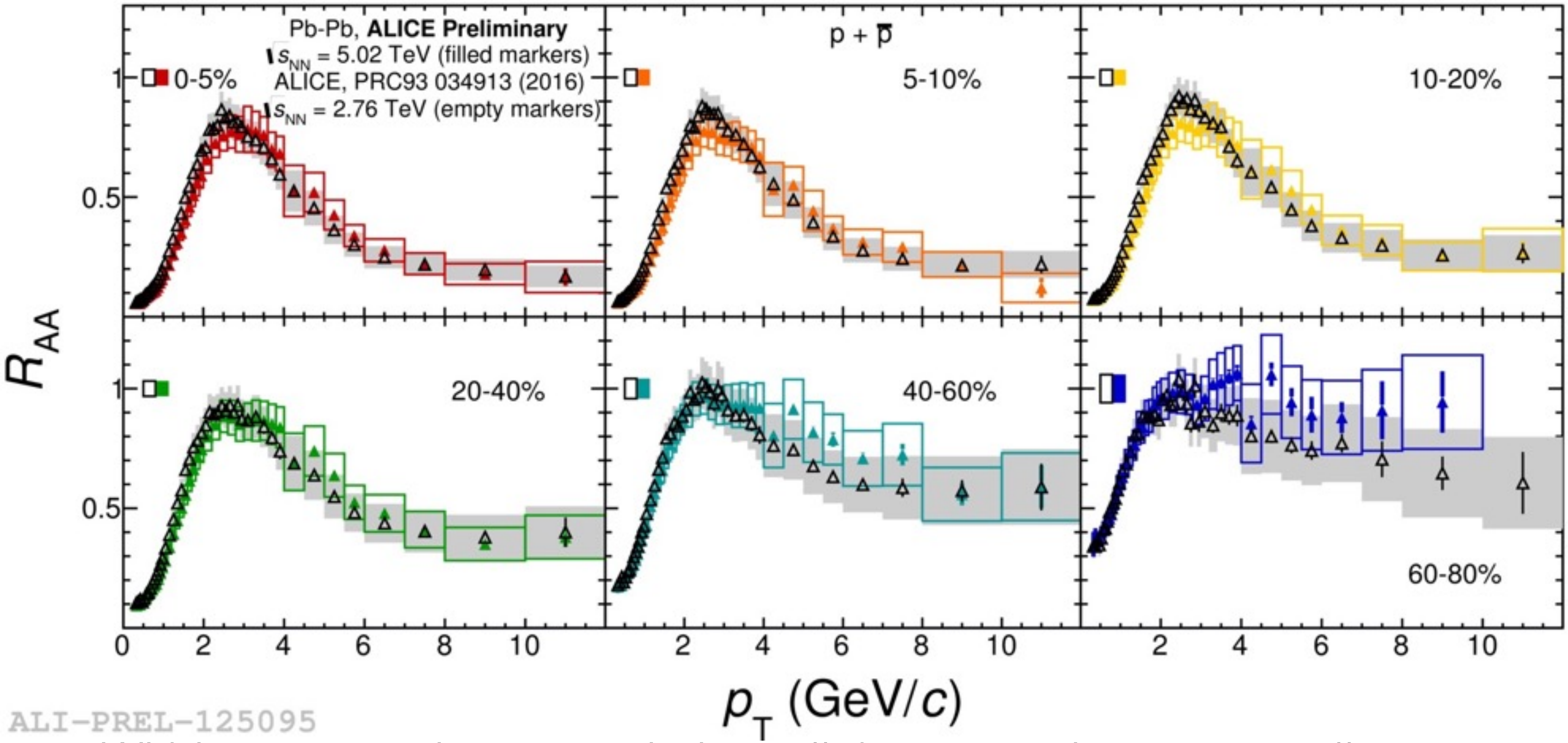
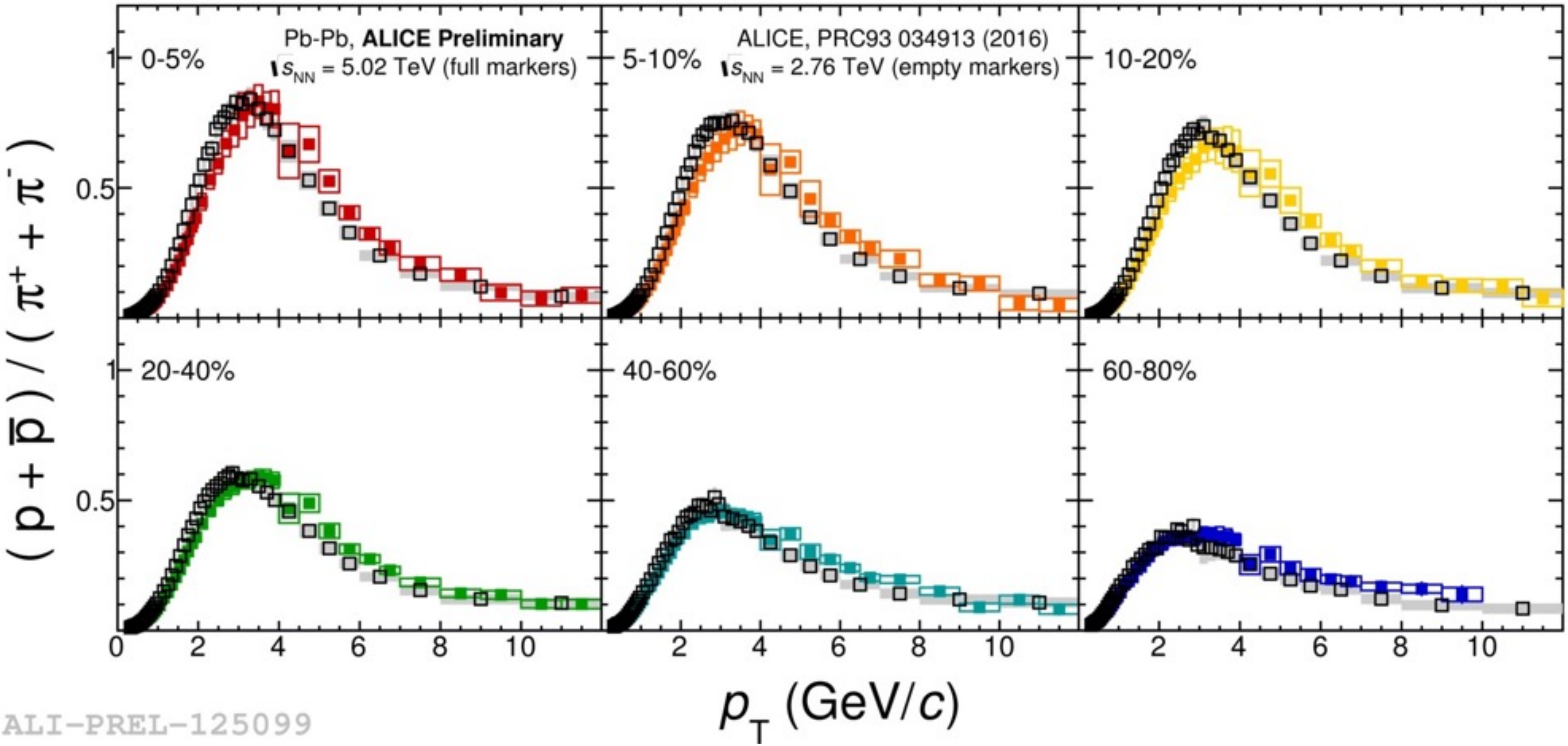


- Within systematic uncertainties, all three species are equally suppressed at high p_T (p_T>8 GeV/c)
- Similar results obtained in run I, albeit a small energy dependence is observed at low p_T (ALICE, PRC 93 (2016) 034913)

Particle ratios (I)



- Shift to the maximum of p/π to higher p_T with respect to lower energies (ALICE, PRC 93 (2016) 034913)

Particle ratios (II)

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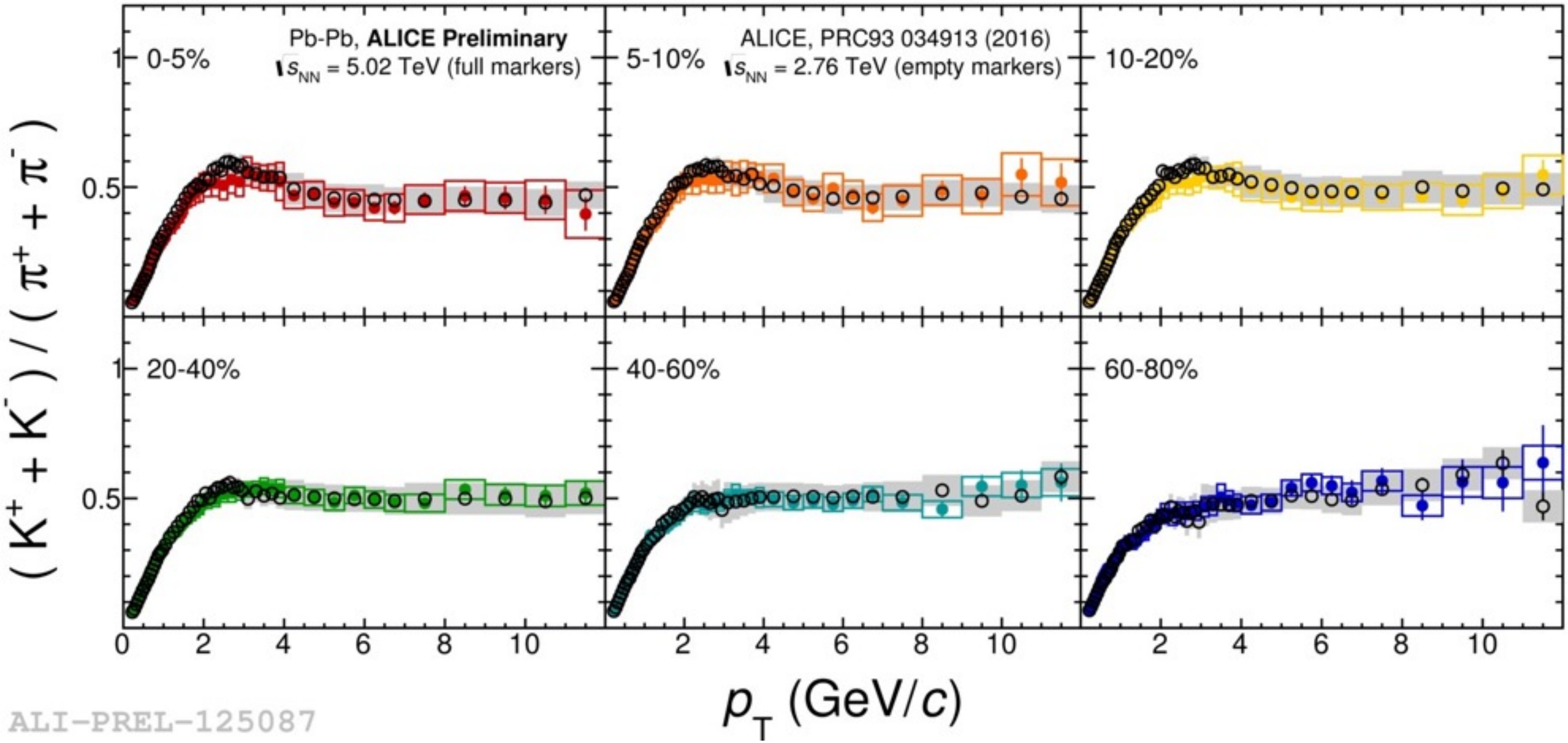
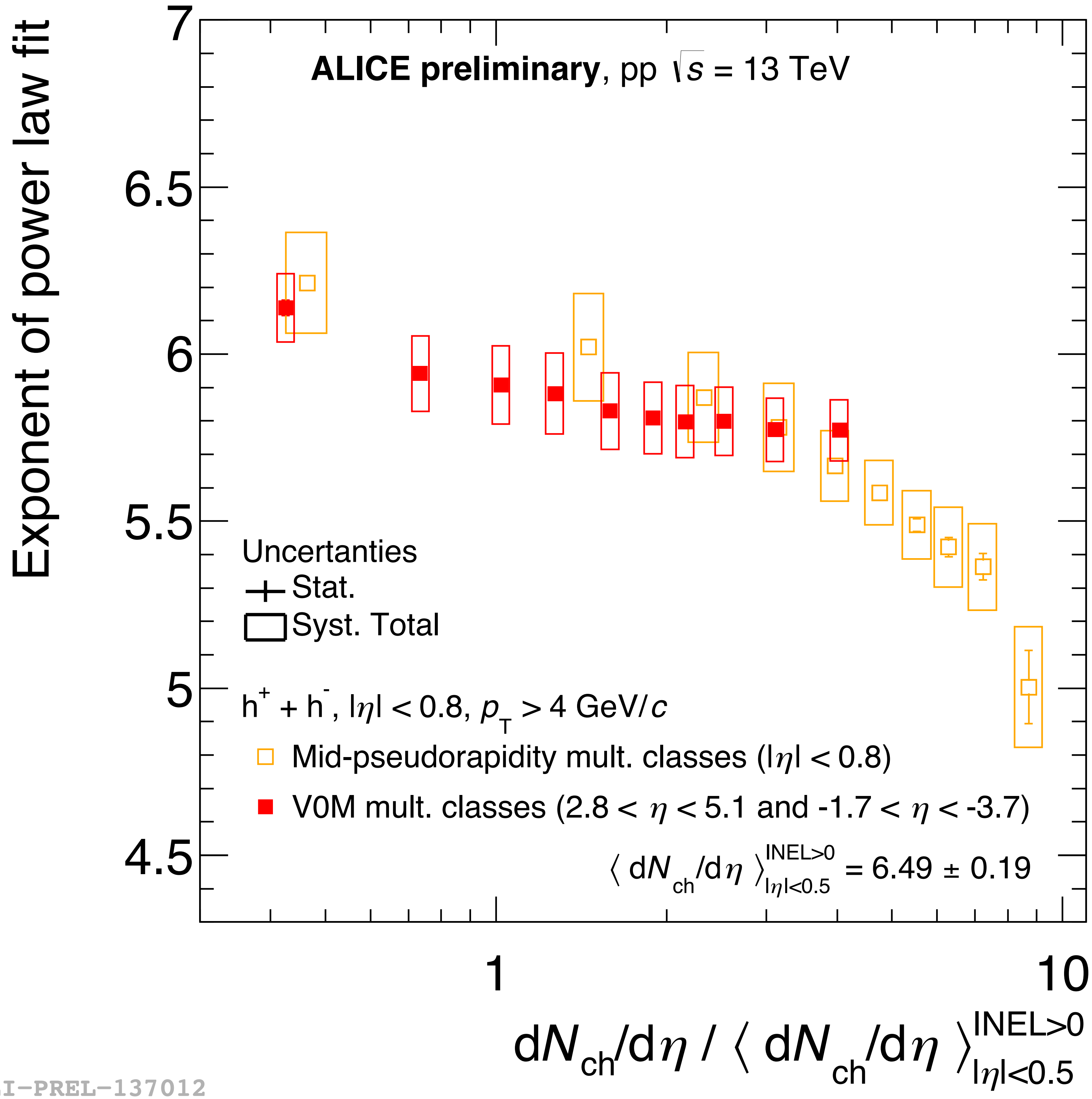


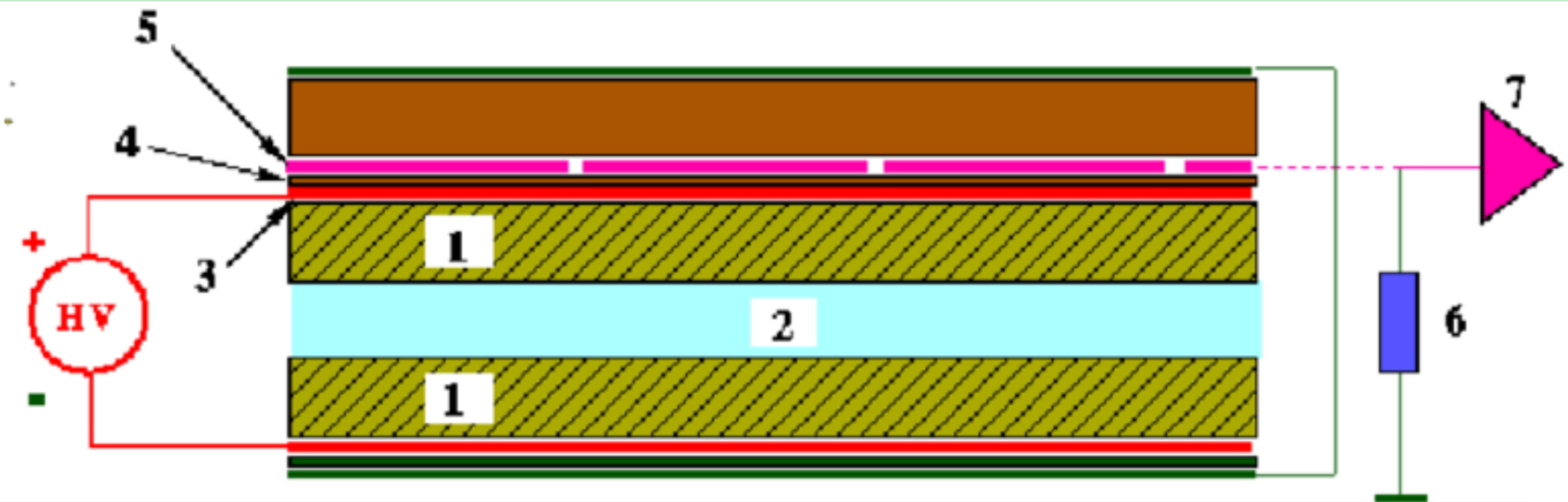
- No significant change between the two energies (ALICE, PRC 93 (2016) 034913)



ALICE preliminary, pp $\sqrt{s}$ = 13 TeV
Exponent of power law fit
7
6.5
6
5.5
5
4.5
1
10
$dN_{ch}/d\eta$ / $\langle dN_{ch}/d\eta \rangle^{INEL>0}_{|\eta|<0.5}$
Uncertanties
Stat.
Syst. Total
$h^+ + h^-$, $|\eta| < 0.8$, $p_T > 4$ GeV/c
Mid-pseudorapidity mult. classes ($|\eta| < 0.8$)
V0M mult. classes ($2.8 < \eta < 5.1$ and $-1.7 < \eta < -3.7$)
$\langle dN_{ch}/d\eta \rangle^{INEL>0}_{|\eta|<0.5} = 6.49 \pm 0.19$
ALI-PREL-137012

The RPC detector

Resistive Plate Counters → resistive parallel plate gaseous detector
Developed around 1980 in Italy by R. Santonico et al. NIM 187 (1981) 377-380



- **1. Electrodes: HPL made with melamine/phenol resins; Glass; Ceramic**
- Resistive electrodes: 10^{10}- 10^{12} Ωcm
- Internal electrode surface covered with a thin linseed oil layer (~μm)
- **2. Gap width: 2 mm**
- **3. High Voltage contacts: graphite paint (~100 μm)**
- **Operating pressure: atmospheric pressure**
- **Gas mixture: Ar, $C_2H_2F_4$, iC_4H_{10}, SF_6**
- **Gas flow: 0.2 vol/h**
- **Dimensions: Surface: ~ m², thickness: 1 cm**
- **Read-out strip: Al/Cu, ~cm**