ALICE

Activities Report

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1. (FCFM-BUAP) 2.(ICN-UNAM)

ACO meeting

25 August 2017

Outlook

- some news:

1. Almost ready for Initial Stages 2017, Flight to Krakow (IS2017) is bought by red-ALICEMX, lodging is arrange (a reembolso)
2. I receive an e-mail from Holly Young (IoP-JPG) for an interview at IS2017.
3. Also inscribe to Collider Physics in Mexico (5-8 sept Ibero)

- Work during vacations:

4. Modification on analysis note.
5. Additional plots for approval to present this monday.
6. Draft slides for IS2017.
7. Thesis draft

1. Additional plots for approval to present this monday.

Performance plots on: transverse sphericity for unidentified charge particles production in pp collisions $\sqrt{s}$ = 13 TeV

Héctor Bello Martínez

IS preview LF monday
28/08/2017

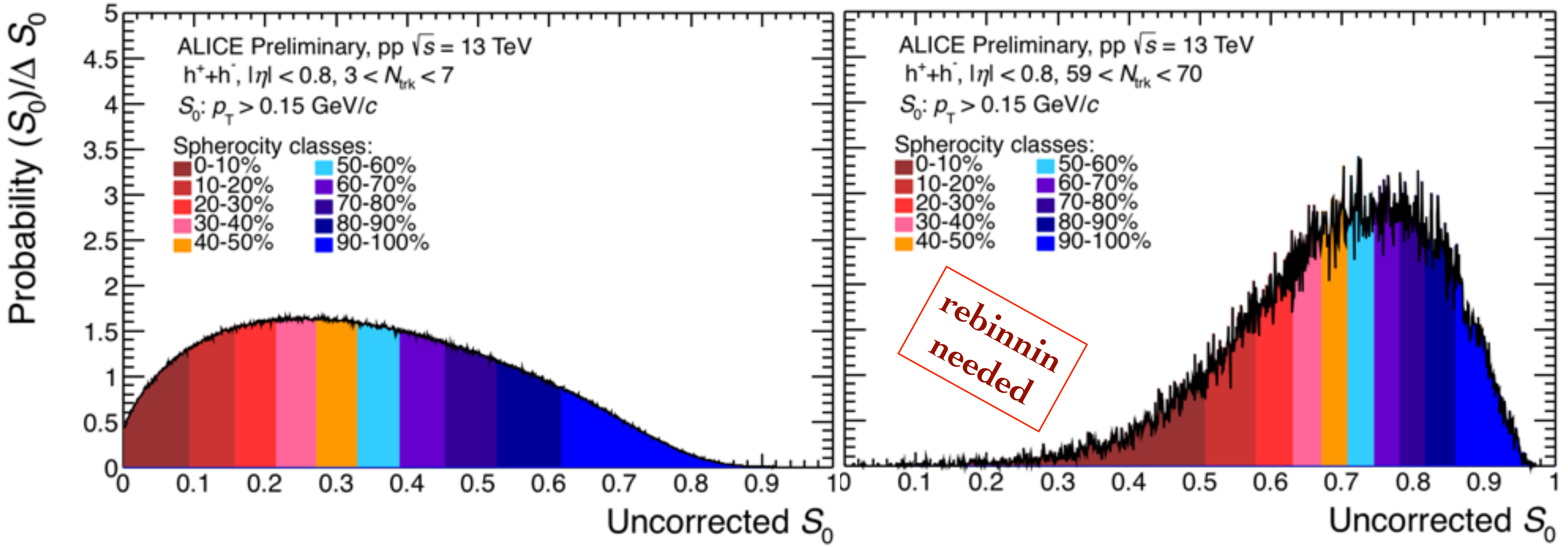
Outlook

- Rebinned So probability
- Perfomance plot for multiplicity correction
- Performance plot for sphericity selection

Spherocity percentile selection (uploaded alice-info)

Analysis details:

- Data: pp $\sqrt{s}$ = 13 TeV
- Multiplicity selection: primary charge tracks with $p_T > 0$, in $|\eta| < 0.8$.
- Spheroctiy selection: more than 3 tracks for $p_T > 0.15$ GeV/c in $|\eta| < 0.8$.



Spherocity has been measured in a wide range of multiplicity, 10% of the sample has been chosen for the different binning in the sphericity probability distribution, the results show the multiplicity dependence (low N_{ch} -> low S_O, high N_{ch} -> high S_O)

Spherocity percentile selection (rebinned)

Analysis details:

- Data: pp $\sqrt{s}$ = 13 TeV
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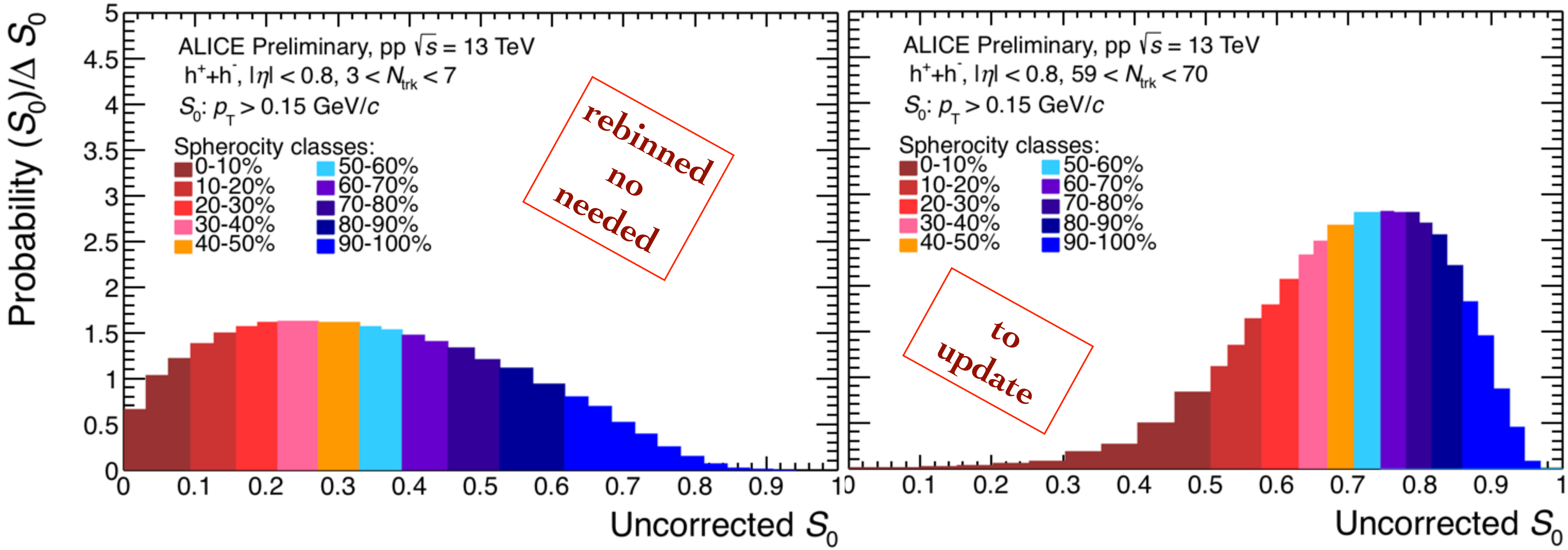


MULTIPLICITY

Low → High

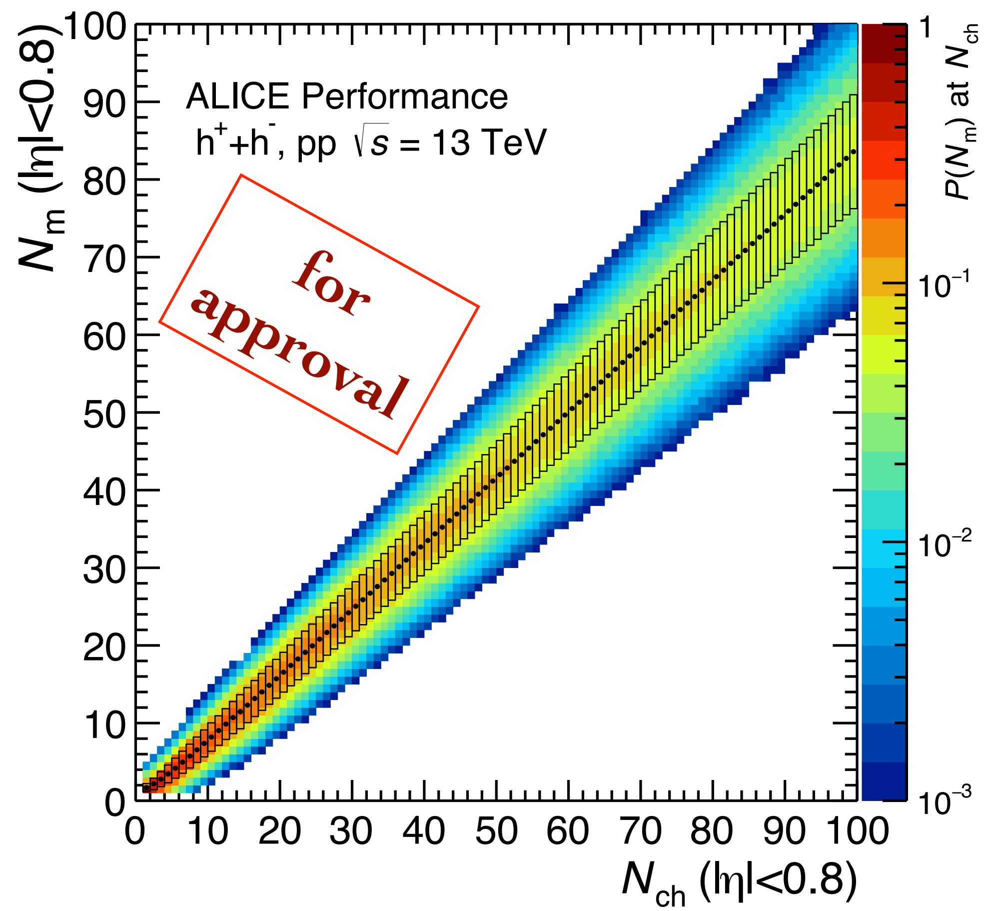
Spherocity has been measured in a wide range of multiplicity, 10% of the sample has been chosen for the different binning in the sphericity probability distribution, the results show the multiplicity dependence (low N_{ch} -> low S_O, high N_{ch} -> high S_O)

Corrections by multiplicity

- In order to explain the correction procedure.
- Due to reconstruction efficiency in multiplicity and spherocity some corrections were done.
- For correction of multiplicity we based on:

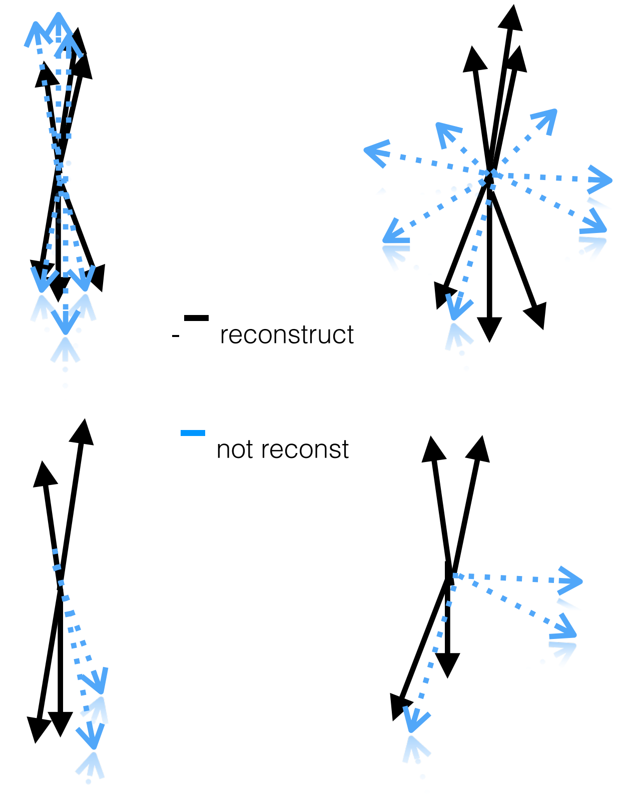
$$\langle p_{\mathrm{T}}\rangle(N_{\mathrm{ch}}) = \sum_{\mathrm{m}} \langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}) R(N_{\mathrm{ch}}, N_{\mathrm{m}})$$

where the response matrix is:



Corrections by spherocity

- In order to explain the correction procedure.
- For spherocity correction was made in 2 steps:



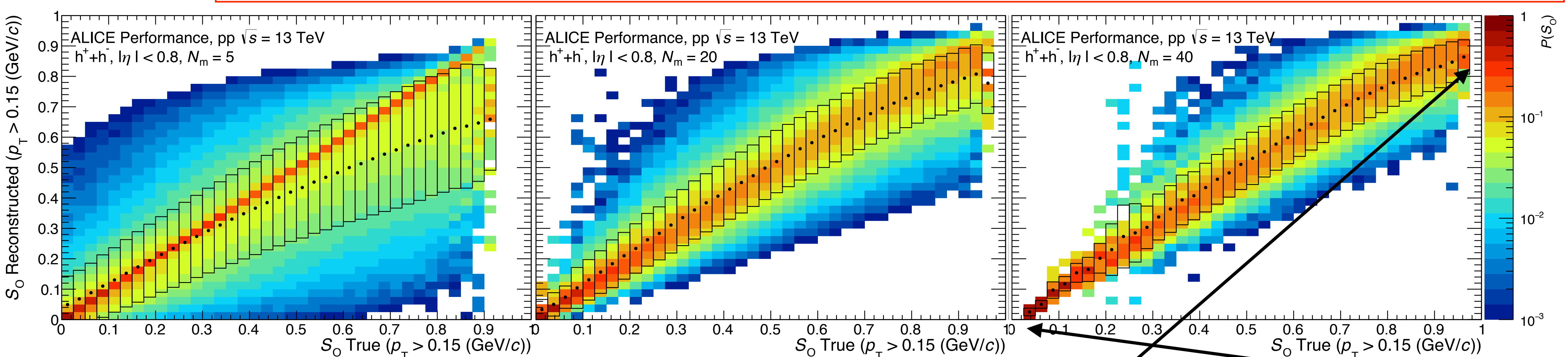
To correct the $<p_T>$ in the S_O bin

$$\langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}, S_{0,\mathrm{t}}) = \sum_{\mathrm{m}} \langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}, S_{0,\mathrm{m}}) R(S_{0,\mathrm{t}}, S_{0,\mathrm{m}})$$

Then
$$\langle p_{\mathrm{T}}\rangle(N_{\mathrm{ch}}) = \sum_{\mathrm{m}} \langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}) R(N_{\mathrm{ch}}, N_{\mathrm{m}})$$

the response for sphericity is:

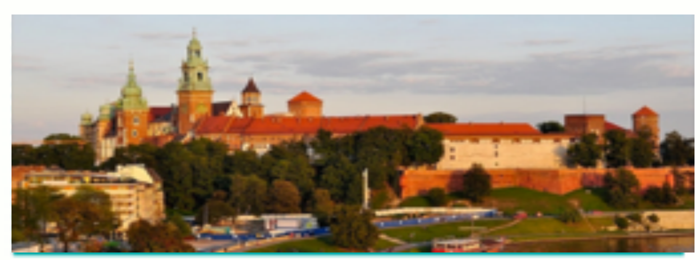
Sphericity response for three Nch bins (low,mid,high) for approval



2. Draft slides for IS2017.

A double differential study of the particle production in pp collisions $\sqrt{s}$ = 13 TeV using transverse spherocity and multiplicity with ALICE

Héctor Bello Martínez
on behalf of the ALICE Collaboration



Initial Stages 2017

Polish Academy of Arts and Sciences
September 18-22 2017, Cracow, Poland

IS2017 rehearsal
sept, 2017

Outlook

- Introduction
- Motivation
- ALICE at LHC
- Results
- Conclusions

Introduction

- **ALICE** is optimized for heavy ion (HI) physics.

- **ALICE** aims to study the formation of the strongly interacting QCD matter, the Quark-Gluon Plasma (QGP) created in high energy heavy-ion collisions

- Small systems

See You Zhou's talk
ALICE results on small systems on Thursday

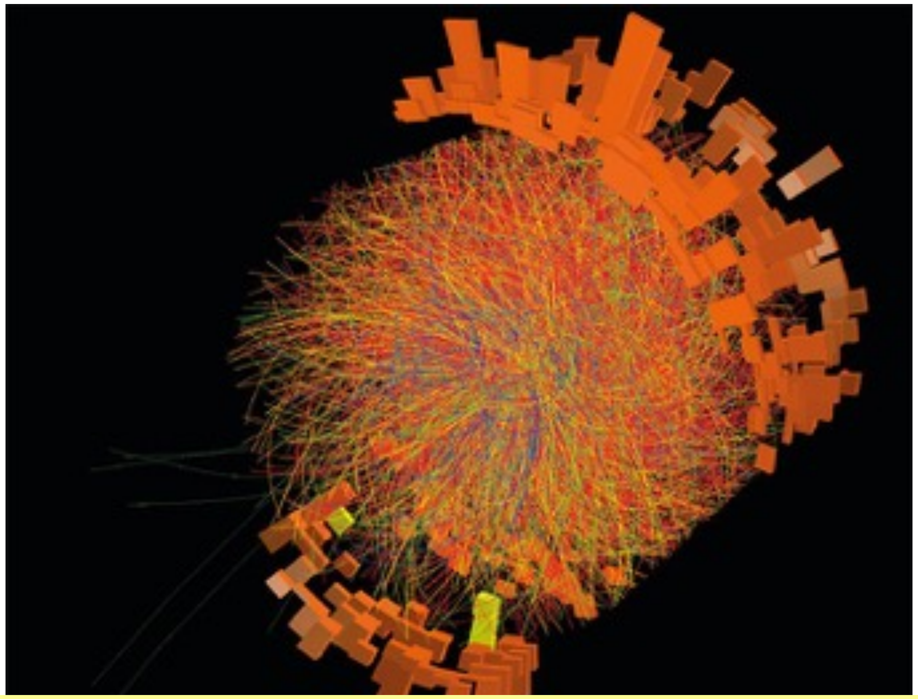
as pp or p-Pb are used as a reference frame to compare Pb-Pb systems, for example in the measurement of R_{AA} to see the suppression in Pb-Pb.

$$R_{AA}(p_T) = \frac{d^2N_{ch}^{AA}/d\eta dp_T}{\langle T_{AA}\rangle d^2\sigma_{ch}^{pp}/d\eta dp_T}$$

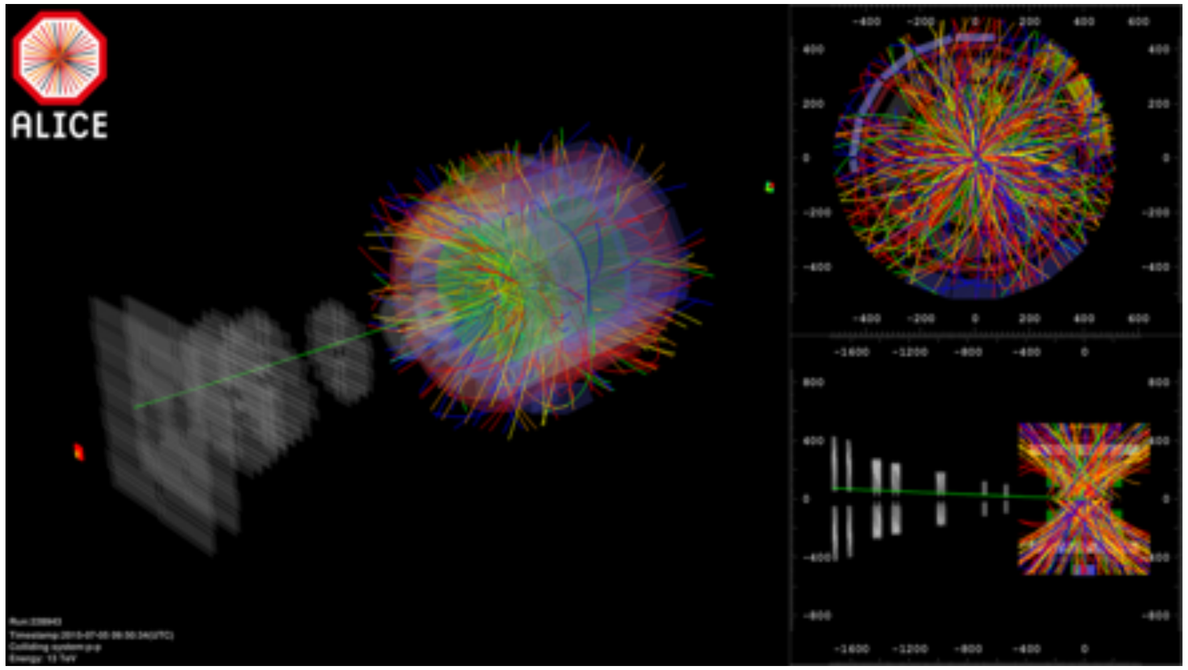
- However high multiplicity (HM) pp collisions has became interesting to understand many phenomena as for example collectivity in HI.

See Ivan's Ravasenga talk
collectivity in ALICE

- Run2 pp at 13 TeV gives a look into it and tells why its interesting …



30-year adventure with heavy ions

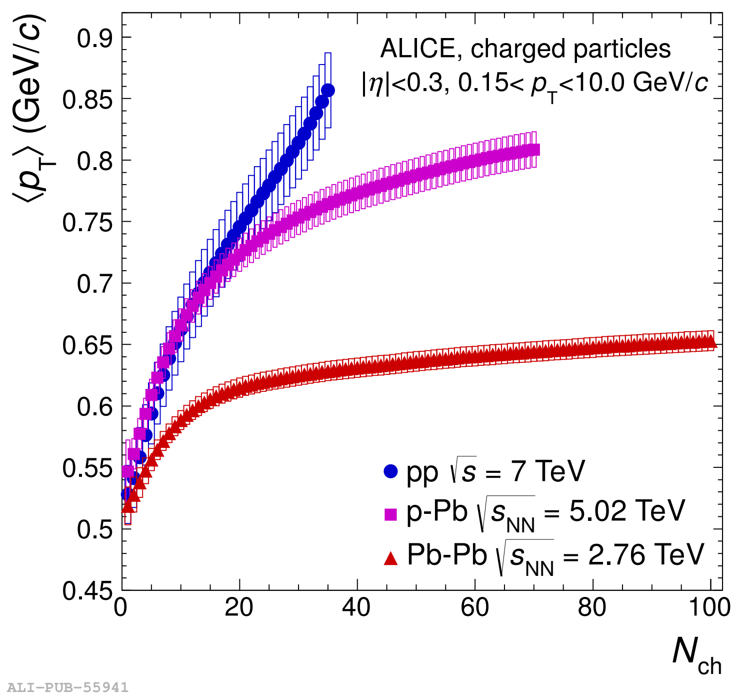


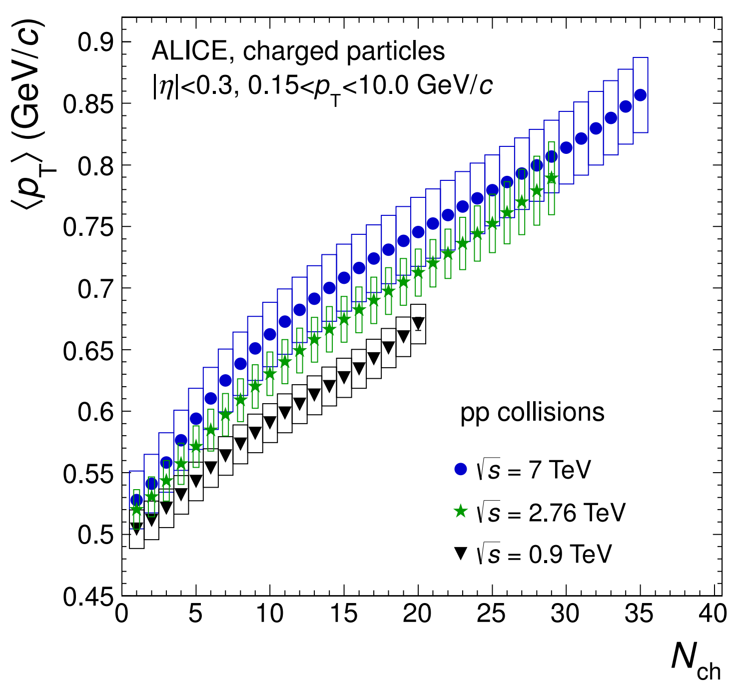
Run 2 pp collisions at 13 TeV

Experimental background at ALICE before RUN 2

Multiplicity dependence of the average transverse momentum in pp, p–Pb, and Pb–Pb collisions at the LHC

Phys. Lett. B 727 (2013) 371-380

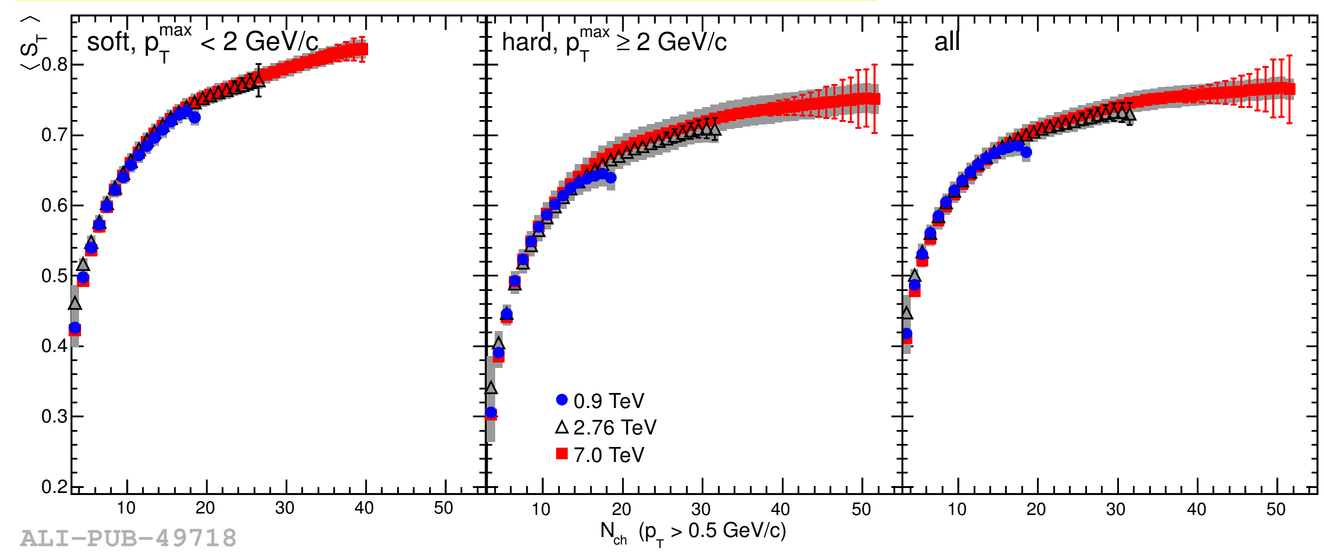




Difference in the mean transverse momentum for the three systems have seen, specially not saturation for pp systems, this behavior its independent of the collision energy.

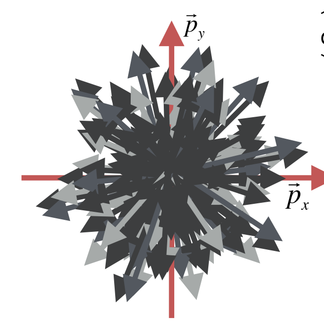
Transverse sphericity of primary charged particles in minimum bias proton-proton collisions at √s= 0.9, 2.76 and 7 TeV

Eur. Phys. J. C 72 (2012) 2124



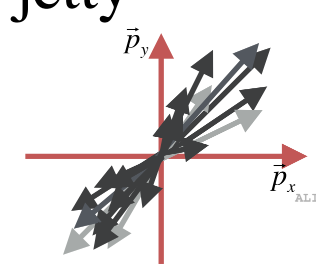
For the mean sphericity, it has been measured that increases at high multiplicity, this was not described in MC models.

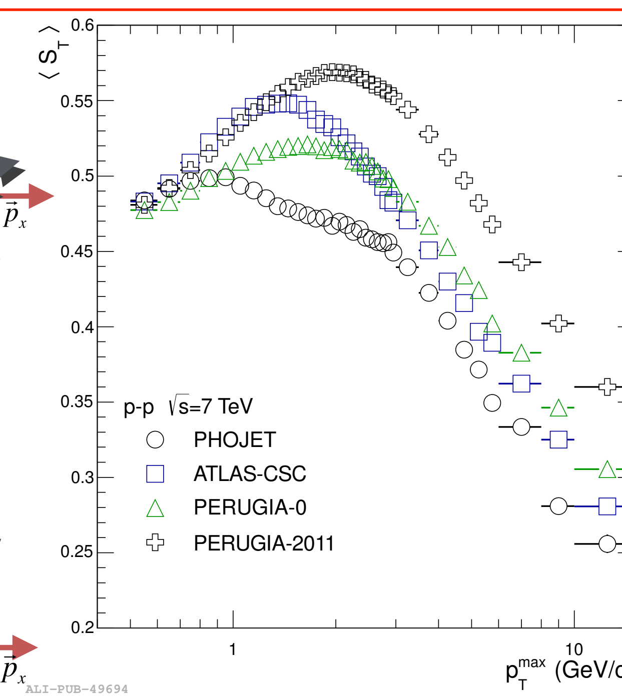
$$S_{xy}^{L} = \frac{1}{\sum_i p_{Ti}} \sum_i \frac{1}{p_{Ti}} \begin{pmatrix} p_{x_i}^2 & p_{x_i} p_{y_i} \\ p_{y_i} p_{x_i} & p_{y_i}^2 \end{pmatrix}$$



$$S_T = \frac{2\lambda_2}{\lambda_2+\lambda_1}$$ for $\lambda_1 >= \lambda_2$,

where sphericity limits are: $$S_T = \begin{cases} 1 \text{ isotropic} \\ 0 \text{ jetty} \end{cases}$$





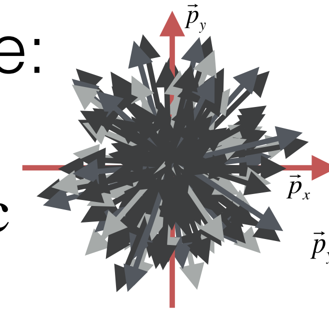
Hector Bello Martinez

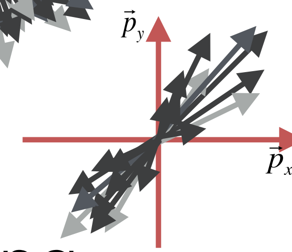
Spherocity

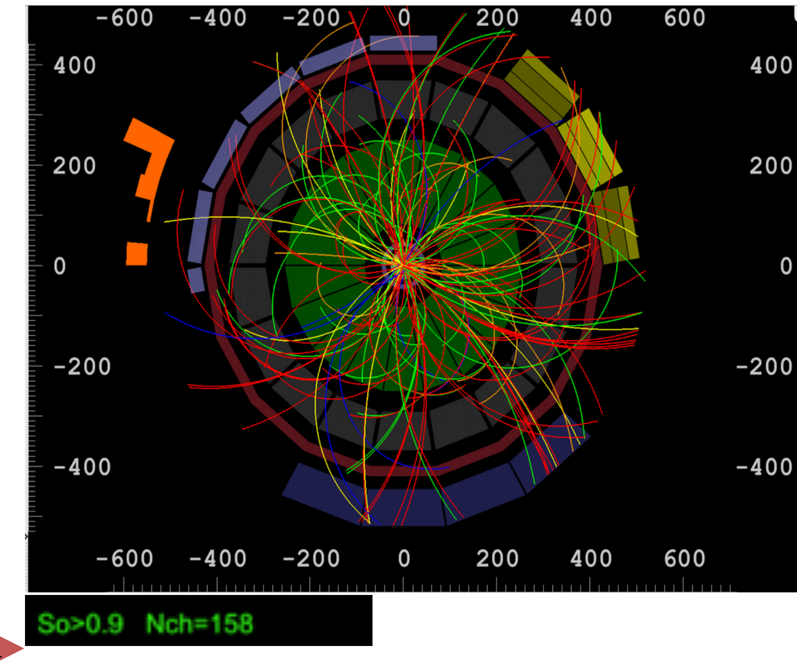
The spherocity is defined by: $S_{\mathrm{T}}^{pherocity} = \frac{\pi^2}{4} \min_{\vec{n}=(n_x,n_y,0)} \left(\frac{\sum_i |\vec{p}_{Ti} \times \vec{n}|}{\sum_i \vec{p}_{Ti}} \right)^2$

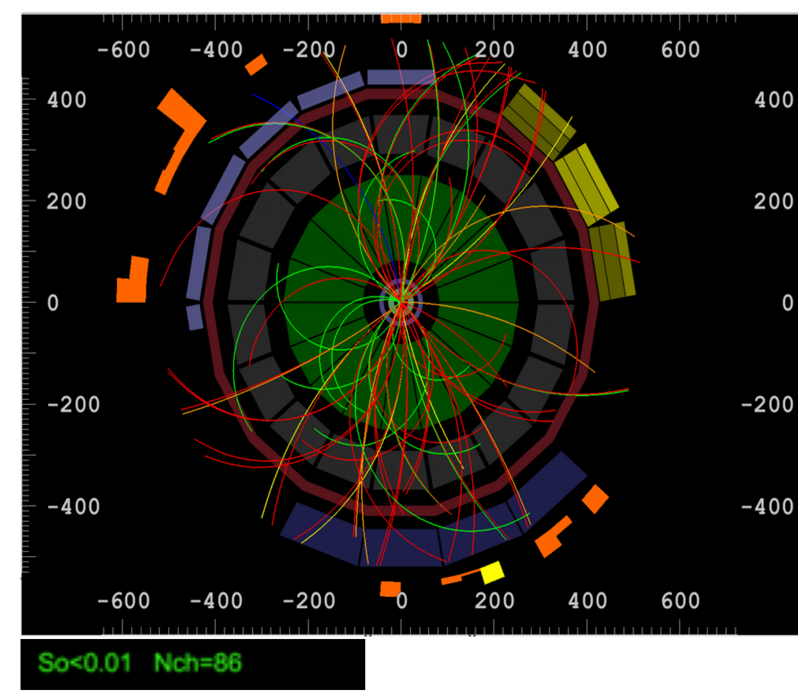
Where $\vec{n} = (n_x, n_y, 0)$ is the normal vector in the transverse plane that minimises this ratio. The limits are:

$$S_O = S_T^{pherocity} = \begin{cases} 1 \text{ isotropic} \\ 0 \text{ jetty} \end{cases}$$







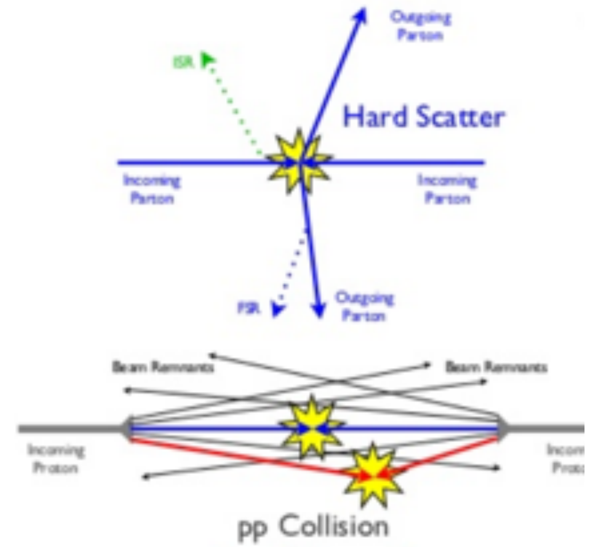


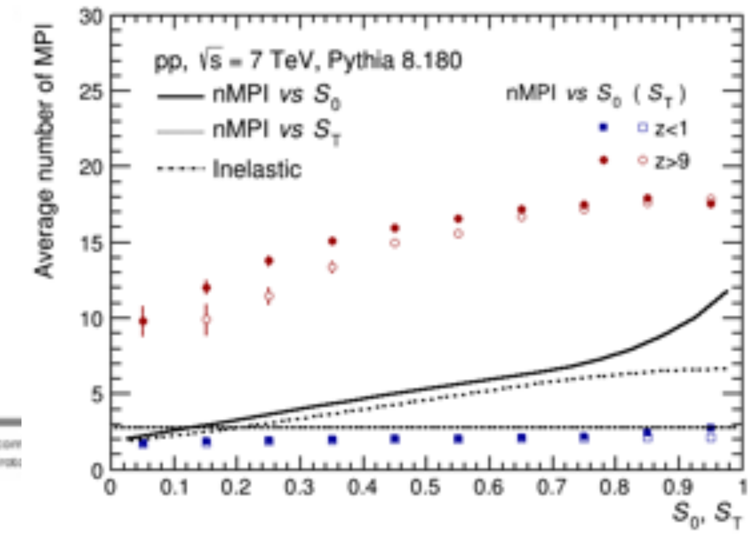
Spherocity is calculated event-by-event considering **more than 2 charged particles having p_{T} > 0.15 GeV/*c* and within |η|<0.8**.

Phenomenology of event shapes at hadron colliders
Andrea Banfi, Gavin P. Salam, Giulia Zanderighi
JHEP 1006:038,2010
A recent review on event shapes at hadron colliders.
Antonio Ortiz arXiv:1705.02056

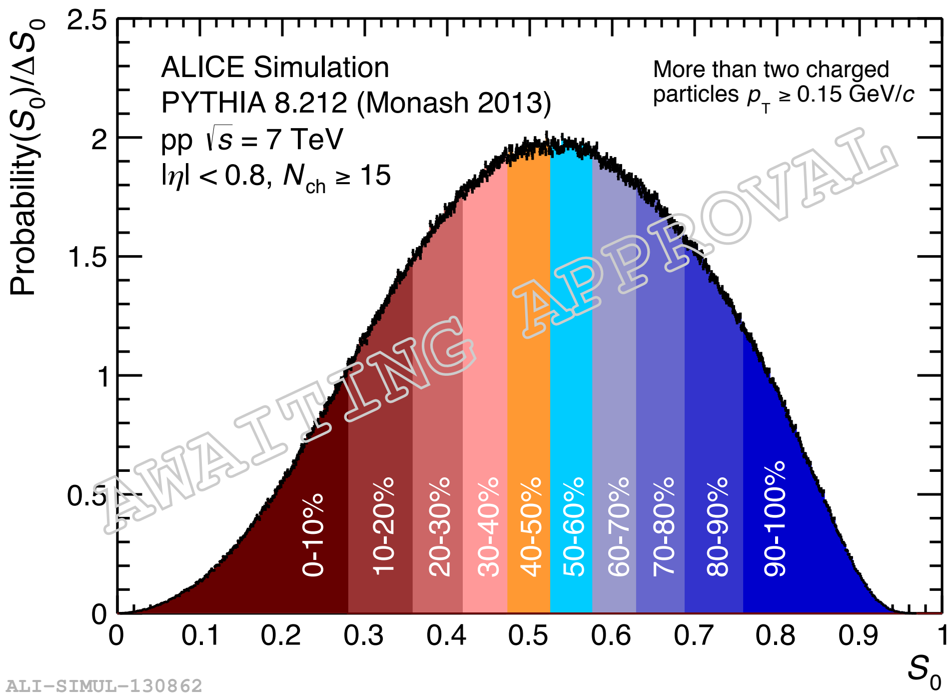
Motivation from Models

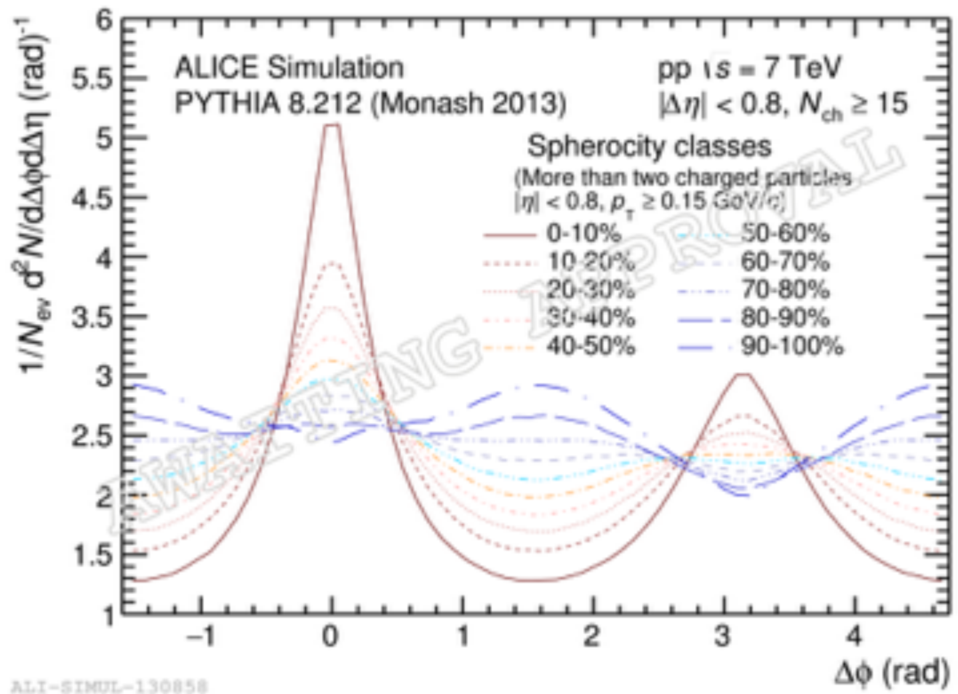
- Study features of High Multiplicity pp collisions using spherocity event by event will allow to separate "**soft**" (**no-pQCD**) from **"hard"** (**pQCD**) physics.
- With spherocity **MPI** could be studied.
- According to **PYTHIA 8**, spherocity allows the separation of events where **UE event** can be enhanced or suppressed.
- Comparing models and data will help us to get more information about high multiplicity events, for example if flow or other mechanisms as CR predominates in jets or in events without them.



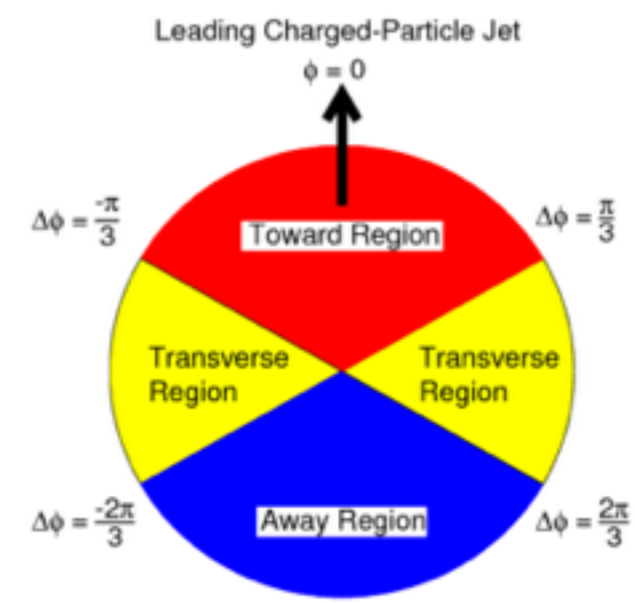


Disentangling the soft and hard components of the pp collisions using the sphero(i)city approach. Eleazar Cuautle, Raul Jimenez, Ivonne Maldonado, Antonio Ortiz, Guy Paic, Edgar Perez arXiv:1404.2372





For more of collectivity on Lund Monte Carlo see C. Bierlich's talk

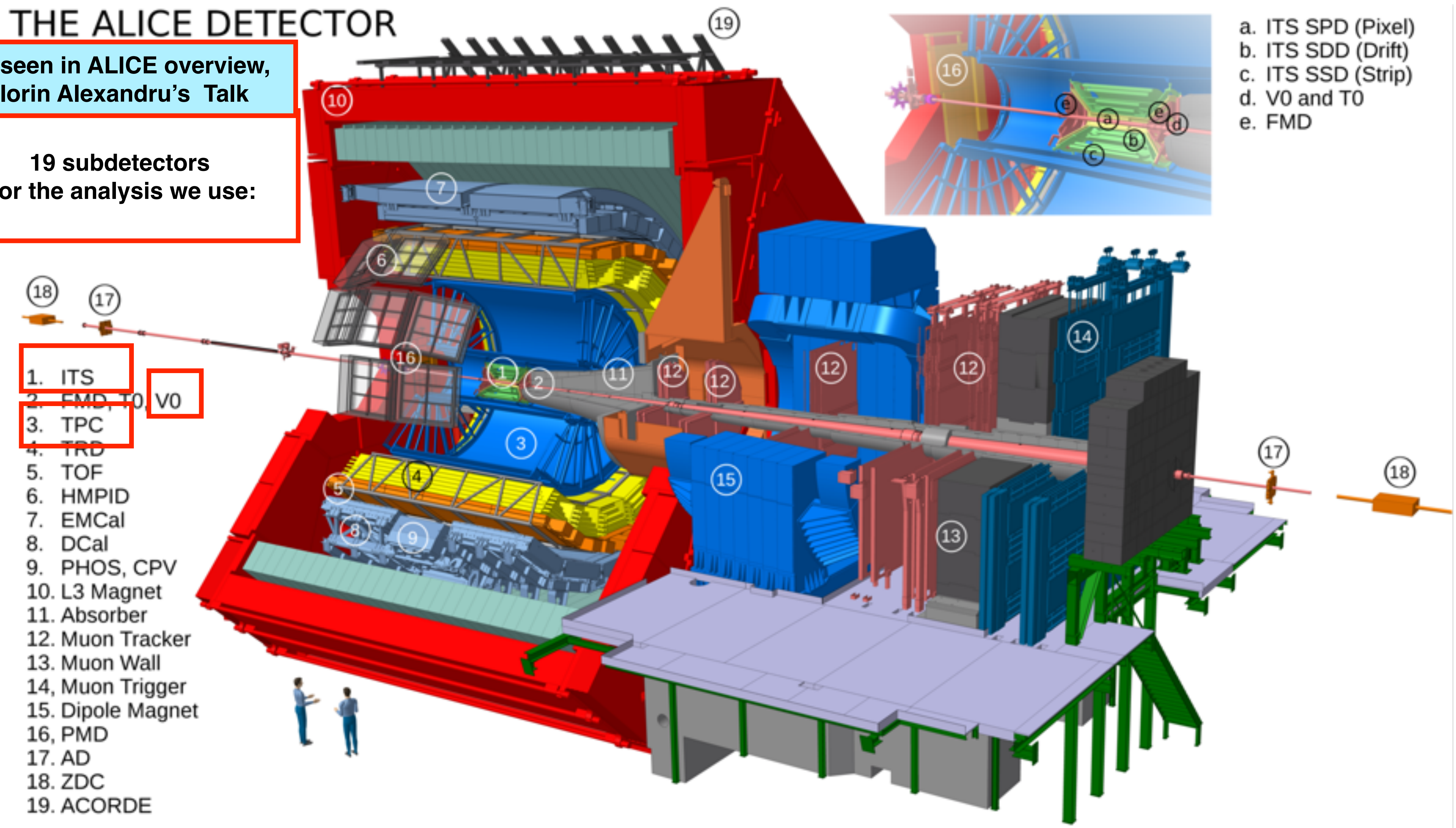


ALICE at LHC

ALICE at LHC (Run 2)

As seen in ALICE overview, Florin Alexandru's Talk

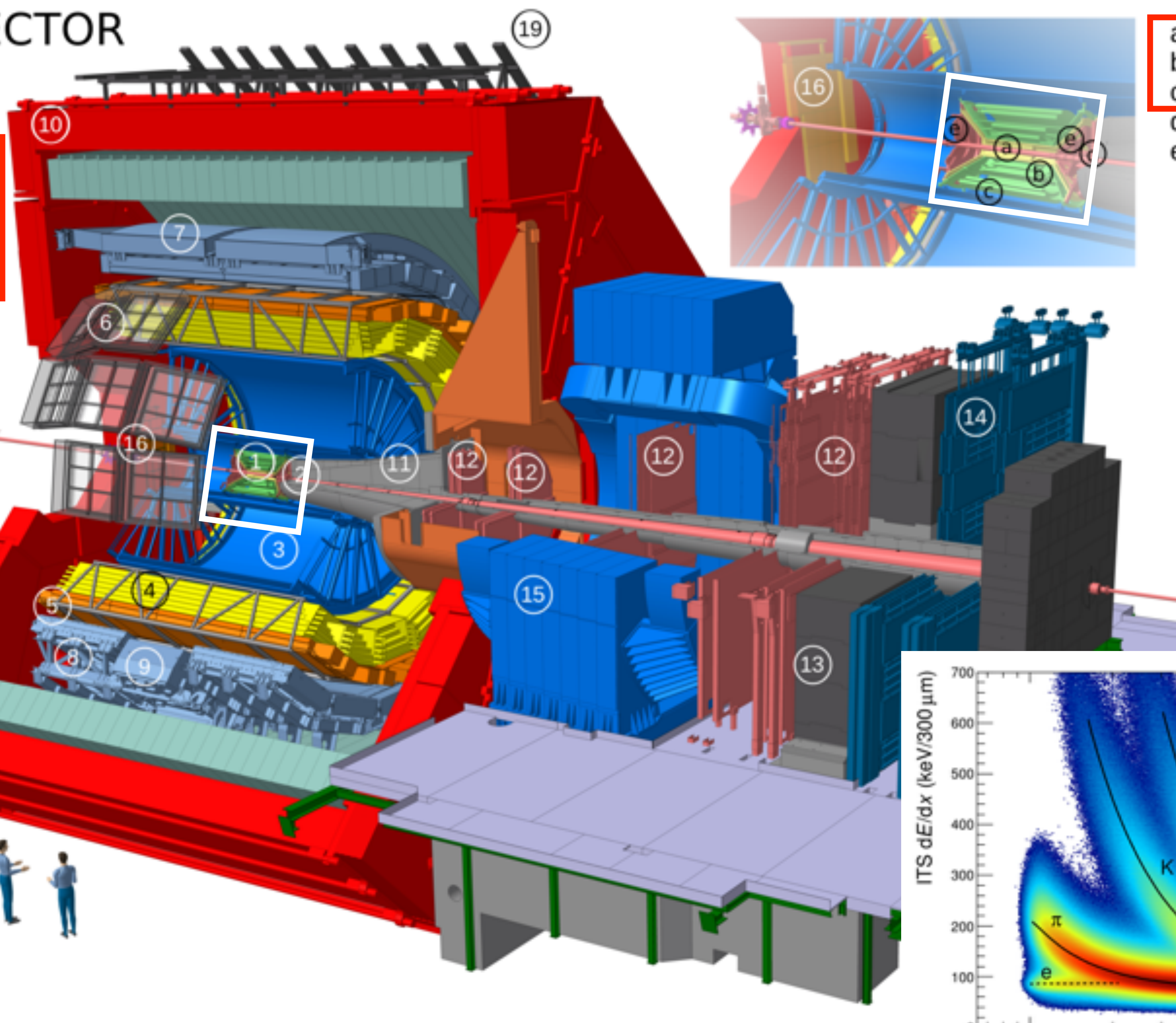
19 subdetectors
For the analysis we use:



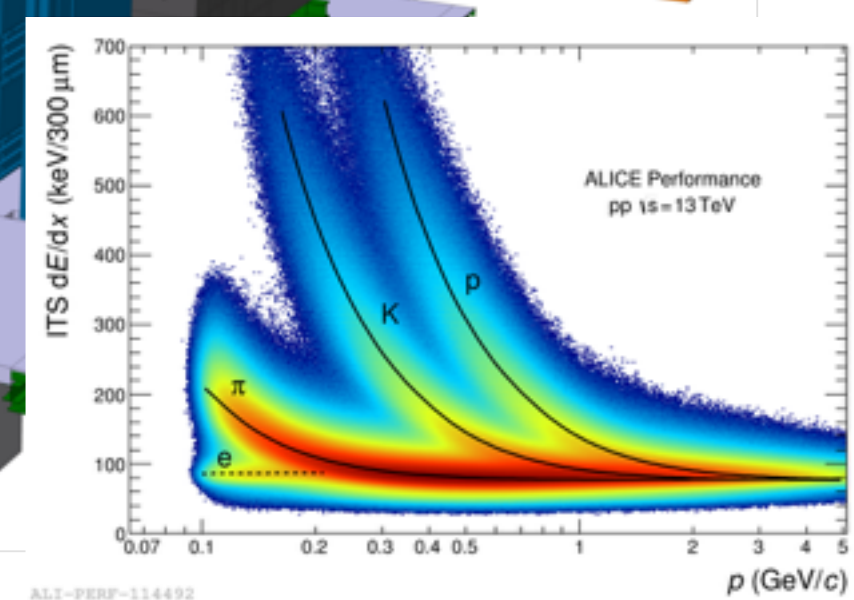
ALICE at LHC (Run 2)

ITS:
Usefull for tracking and vertex determination
Used for: p_T, N_{ch}

THE ALICE DETECTOR

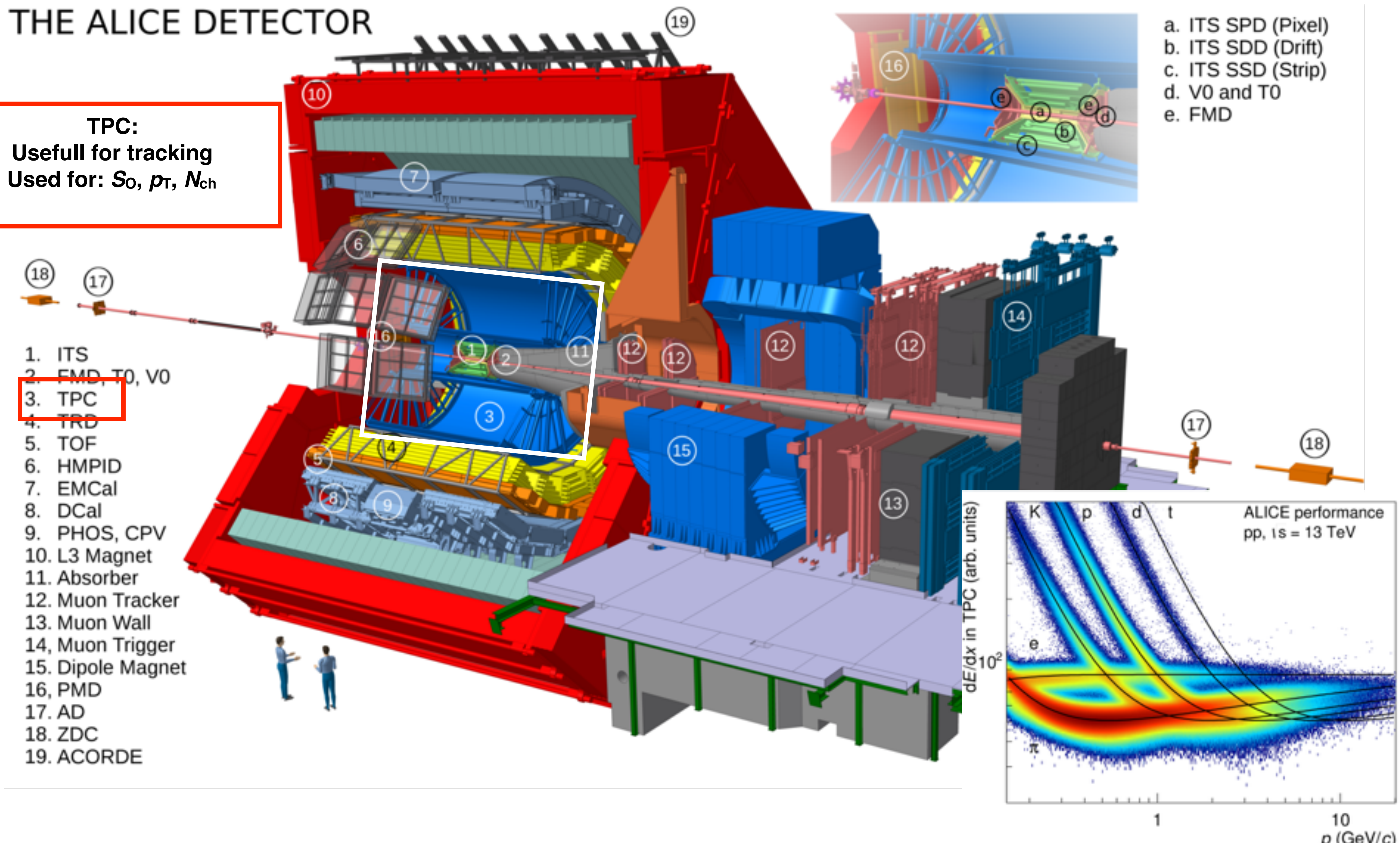


1. ITS
2. FMD, T0, V0
3. TPC
4. TRD
5. TOF
6. HMPID
7. EMCal
8. DCal
9. PHOS, CPV
10. L3 Magnet
11. Absorber
12. Muon Tracker
13. Muon Wall
14, Muon Trigger
15. Dipole Magnet
16, PMD
17. AD
18. ZDC
19. ACORDE



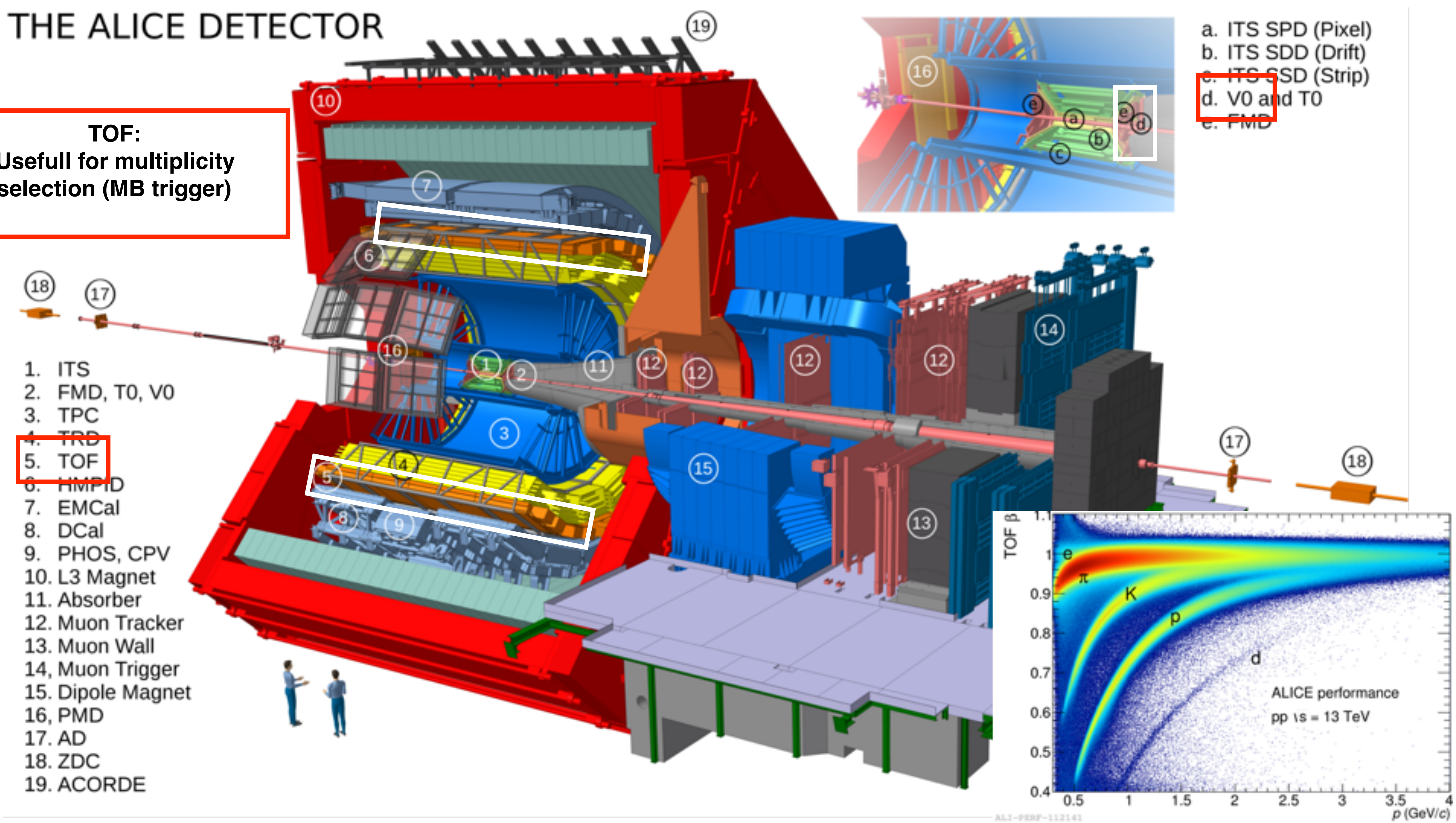
ALICE at LHC (Run 2)

TPC:
Usefull for tracking
Used for: S_O, p_T, N_{ch}



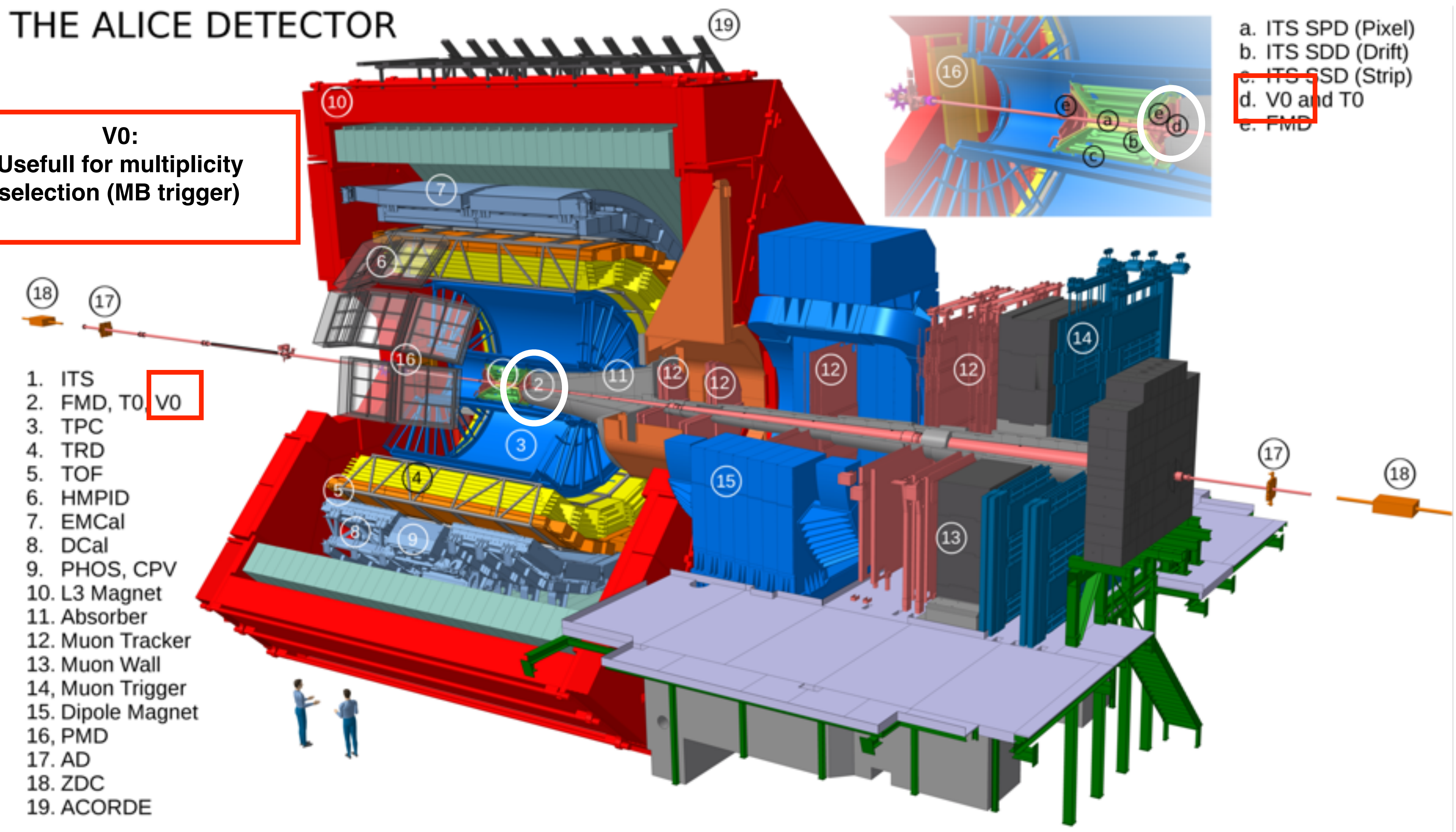
ALICE at LHC (Run 2)

TOF:
Usefull for multiplicity selection (MB trigger)



ALICE at LHC (Run 2)

V0:
Usefull for multiplicity selection (MB trigger)

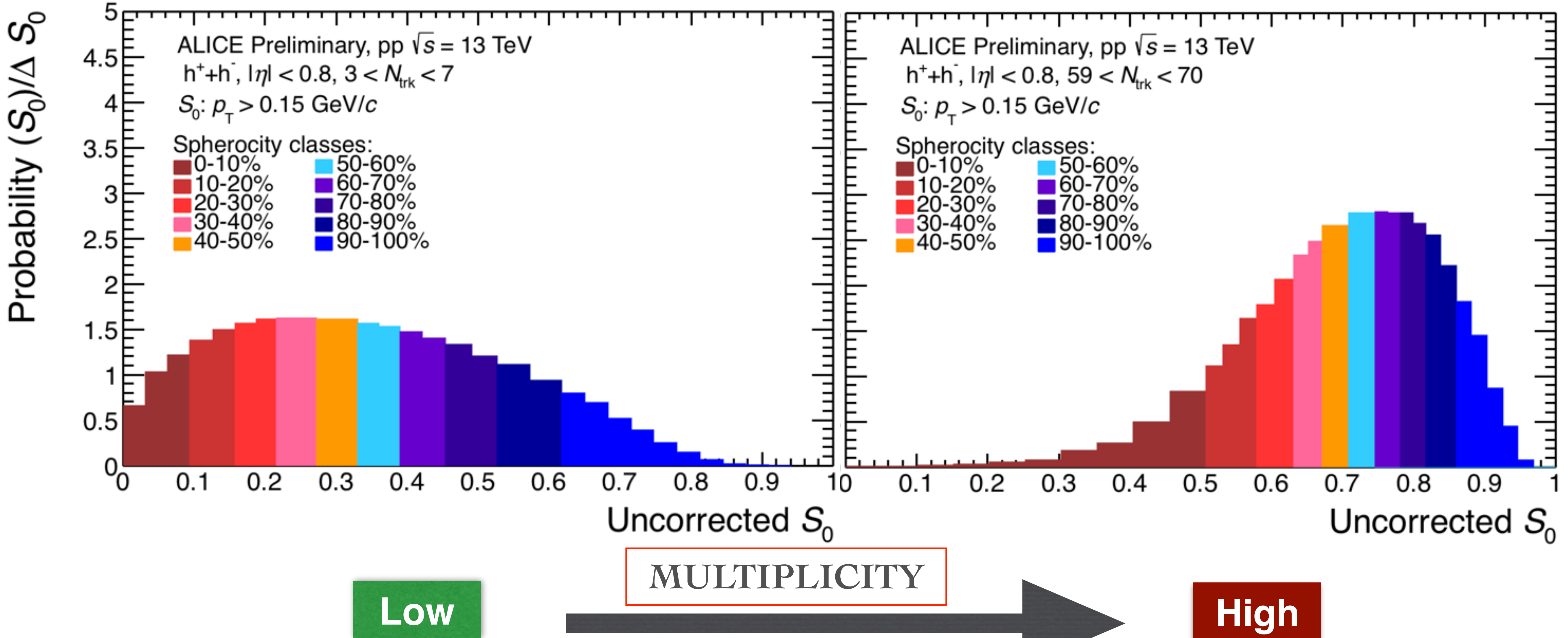


Results
Data from pp $\sqrt{s}$=13 TeV

Spherocity percentile selection (within N_{ch} selection)

Analysis details:

- Data: pp $\sqrt{s}$ = 13 TeV
- Multiplicity selection: primary charge tracks with $p_T > 0$, in $|\eta| < 0.8$.
- Spheroctiy selection: more than 3 tracks for $p_T > 0.15$ GeV/c in $|\eta| < 0.8$.



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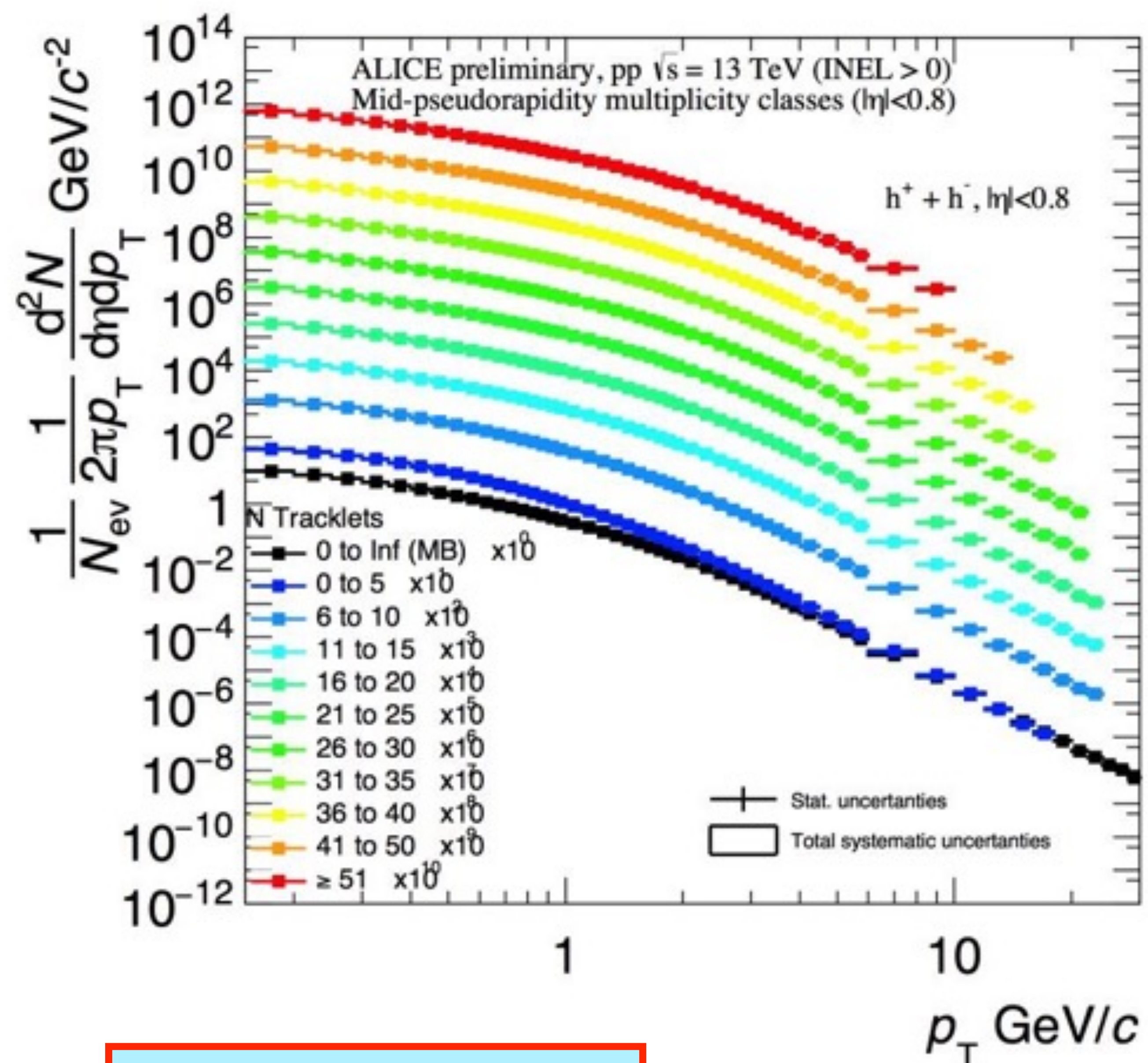
Getting the mean transverse momentum

- From the invariant yield in multiplicity bins one gets the $<p_T>$ vs multiplicity for the inclusive case as expressed in the equation:

$$\langle p_T \rangle = \frac{\sum_i y_i \cdot p_T}{\sum_i y_i}$$

- Applying the same method, for the yields now selected by spherocity percentile, one can get the corresponding average transverse momentum.
- The p_T spectra were corrected by efficiency (with real particle composition) and contamination from secondaries (from multi template fit to DCAxy distributions).



As seen in Sergio's Iga Talk

Corrections by multiplicity and spherocity

- Due to reconstruction efficiency in multiplicity and spherocity some corrections were done.
- For correction of multiplicity we based on:

$$\langle p_{\mathrm{T}}\rangle(N_{\mathrm{ch}}) = \sum_{\mathrm{m}} \langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}) R(N_{\mathrm{ch}}, N_{\mathrm{m}})$$

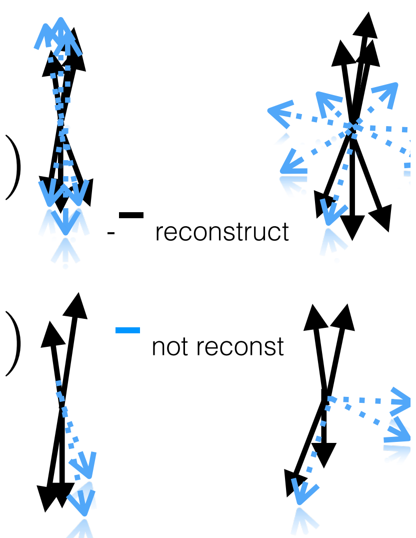
- For spherocity correction was made in 2 steps:

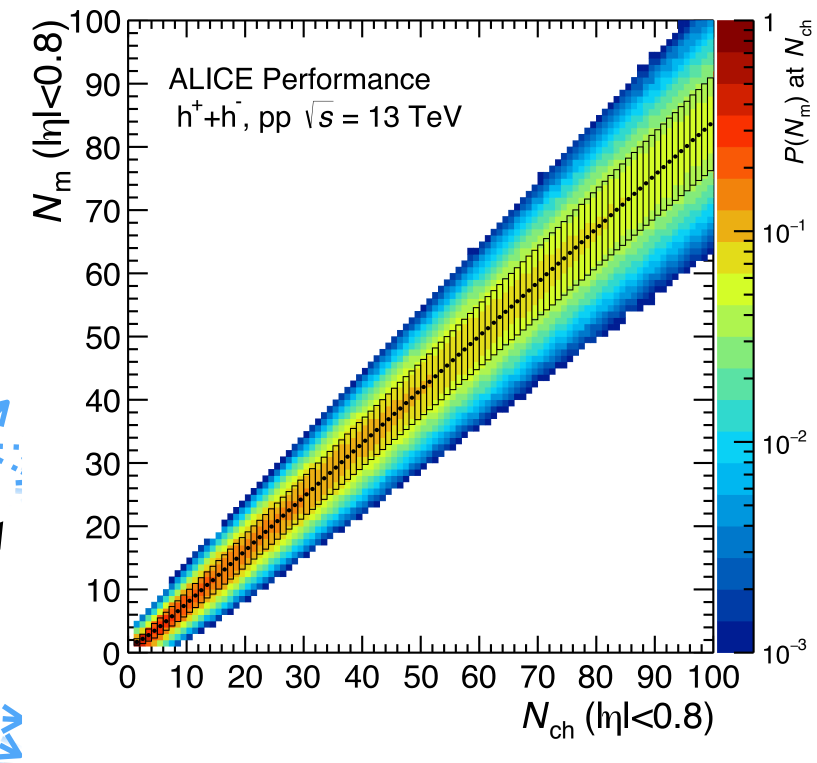
To correct the $\langle p_{\mathrm{T}}\rangle$ in the S_{O} bin

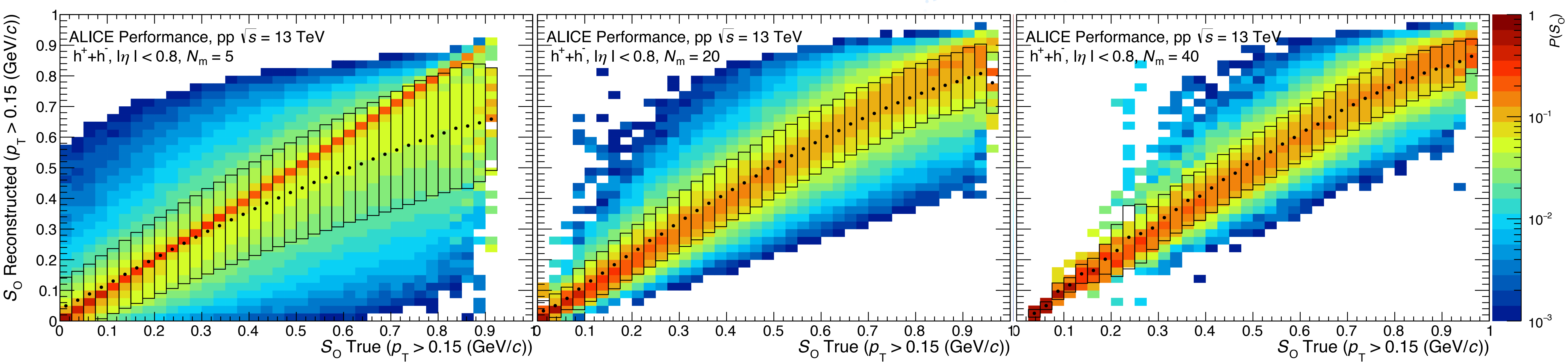
$$\langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}, S_{0,\mathrm{t}}) = \sum_{\mathrm{m}} \langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}, S_{0,\mathrm{m}}) R(S_{0,\mathrm{t}}, S_{0,\mathrm{m}})$$

Then

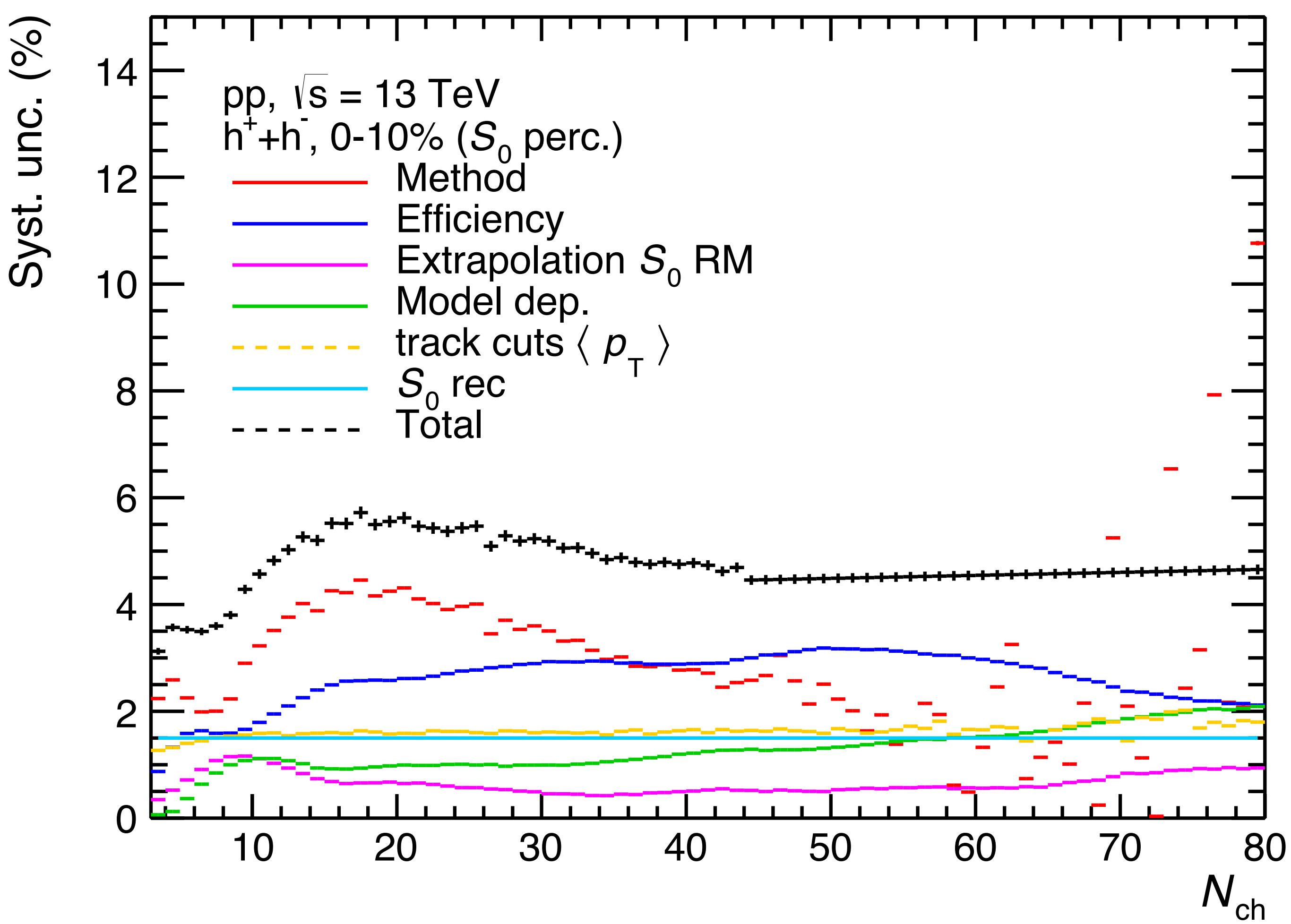
$$\langle p_{\mathrm{T}}\rangle(N_{\mathrm{ch}}) = \sum_{\mathrm{m}} \langle p_{\mathrm{T}}\rangle(N_{\mathrm{m}}) R(N_{\mathrm{ch}}, N_{\mathrm{m}})$$

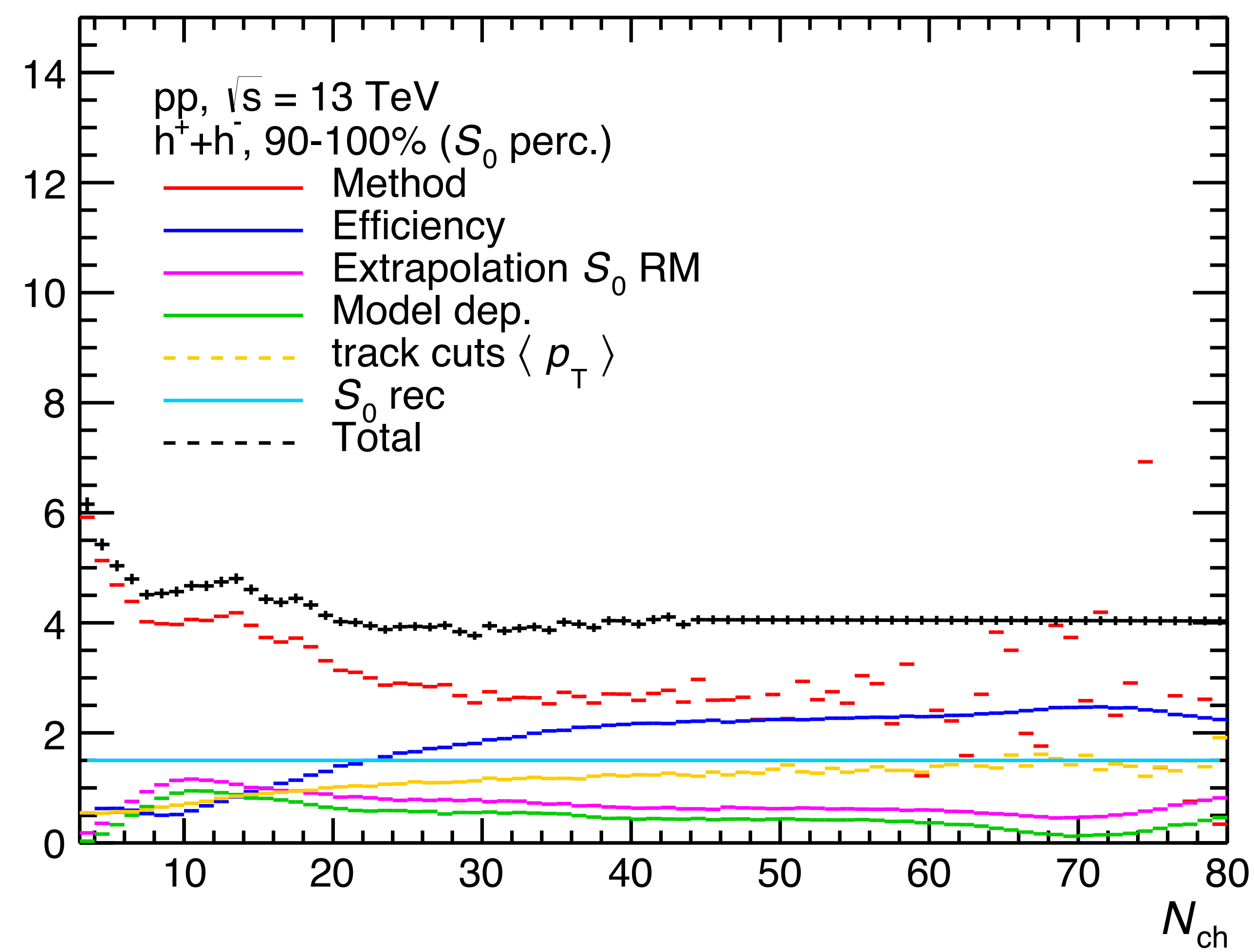






Summary of systematic uncertainties

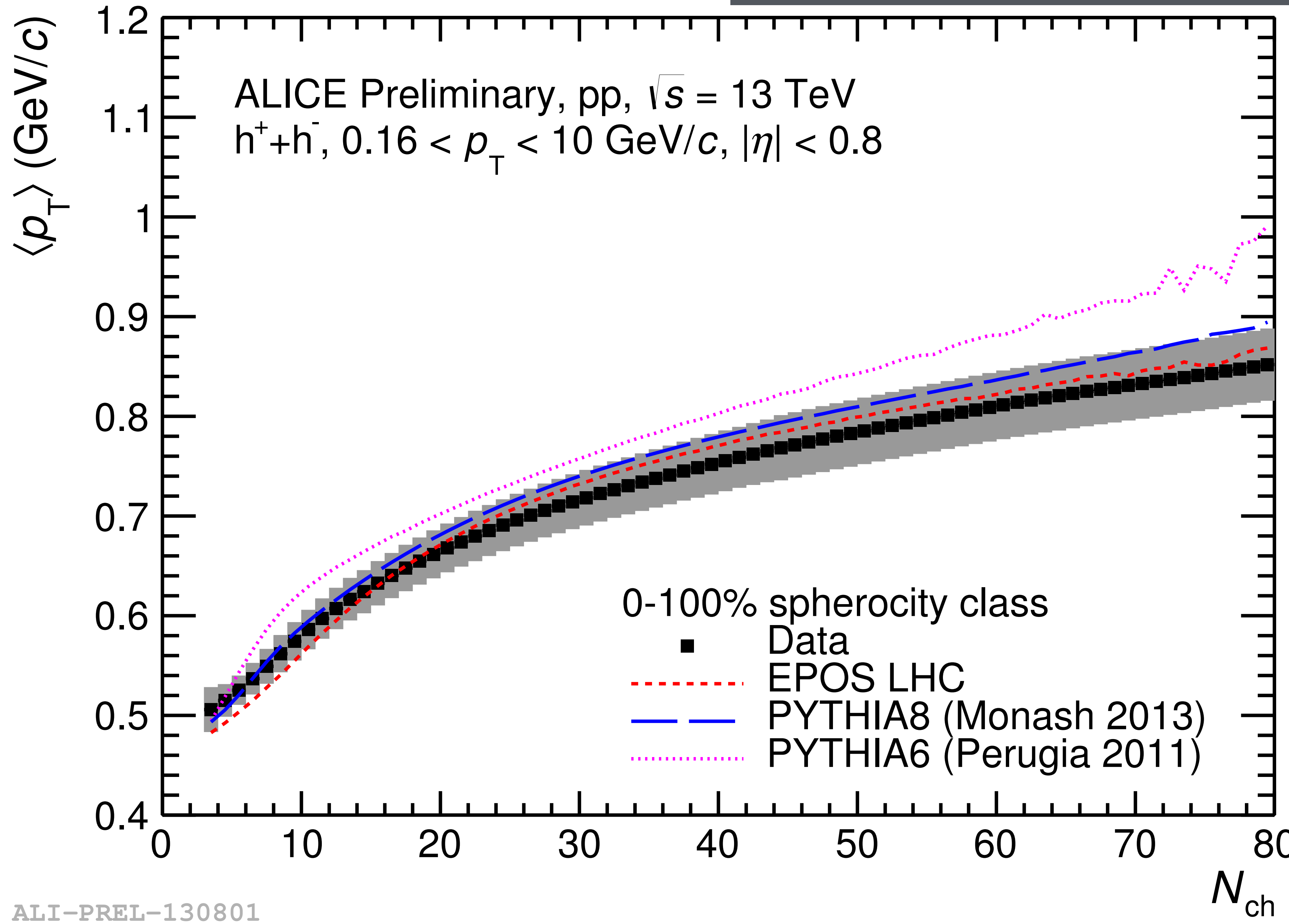




Track cut	Nominal value	Lower value	Higher value
Min. number of crossed rows	70	60	100
Min. ratio crossed rows over findable TPC clusters	0.8	0.7	0.9
Max. χ^2 per cluster in TPC	4	3	5
Max. χ^2 per cluster in ITS	36	25	49
SPD point	required	not required	not required
DCA_{xy}	7σ	4σ	10σ
DCA_z	2	1	5

Average transverse momentum (Inclusive case)

FULL SYSTEMATIC UNCERTAINTY



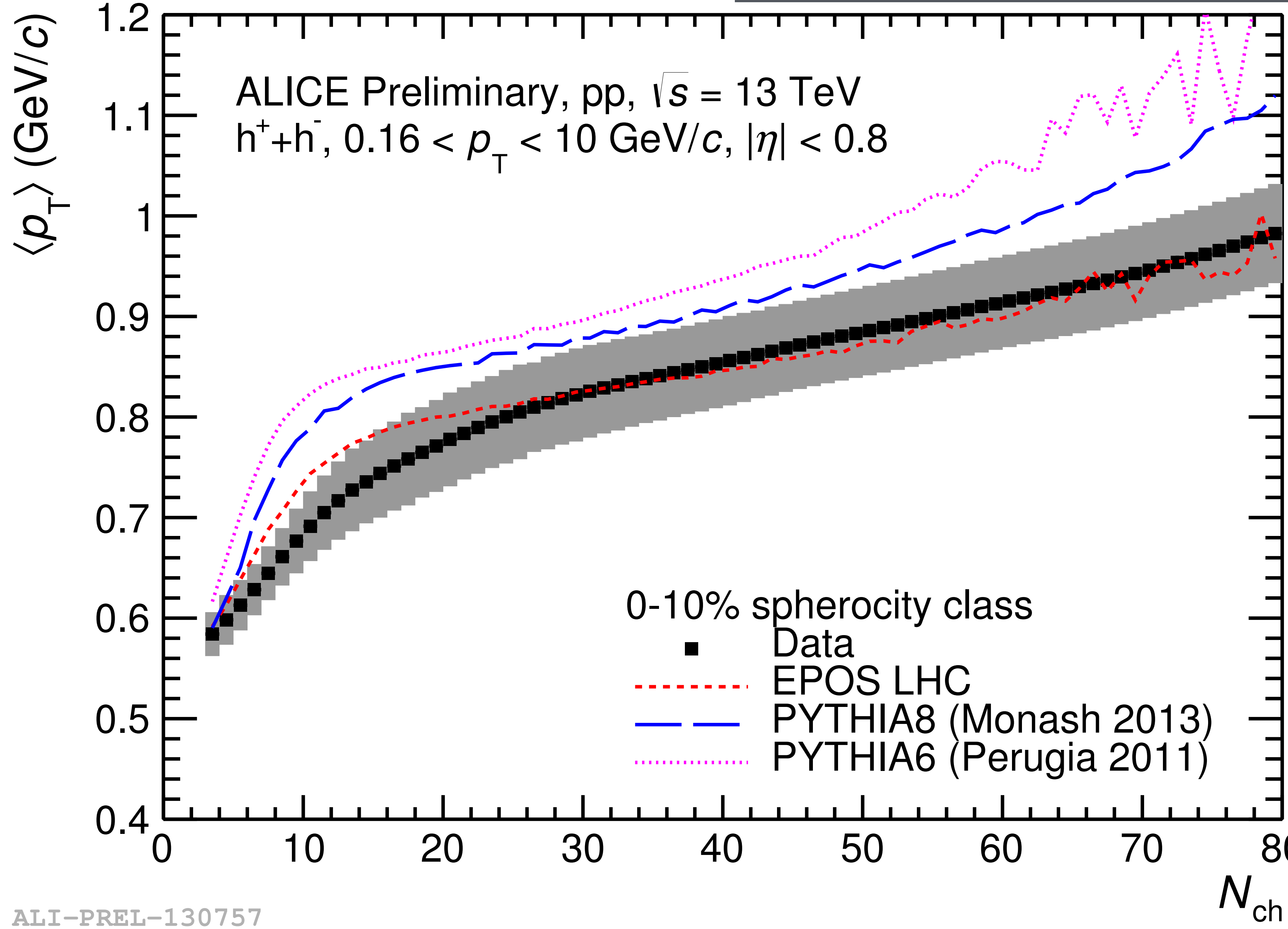
ALI-PREL-130801

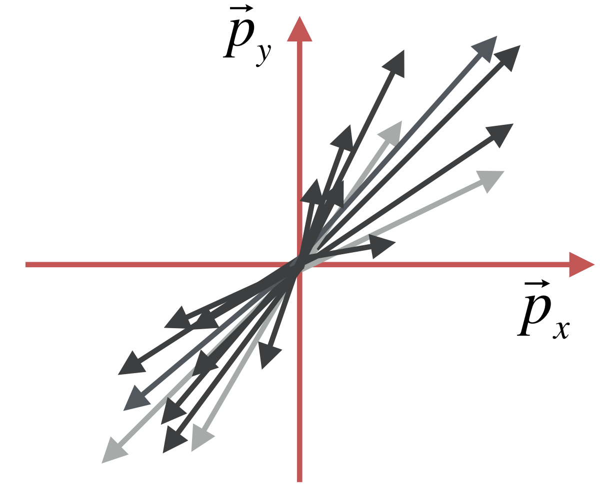
No spherocity selection: models describe well the data
N_{ch}<10: EPOS LHC underestimates the <p_T>
N_{ch}>30: PYTHIA 6 overestimates the <p_T>

Hector Bello Martinez

Average transverse momentum (Jetty events)

FULL SYSTEMATIC UNCERTAINTY

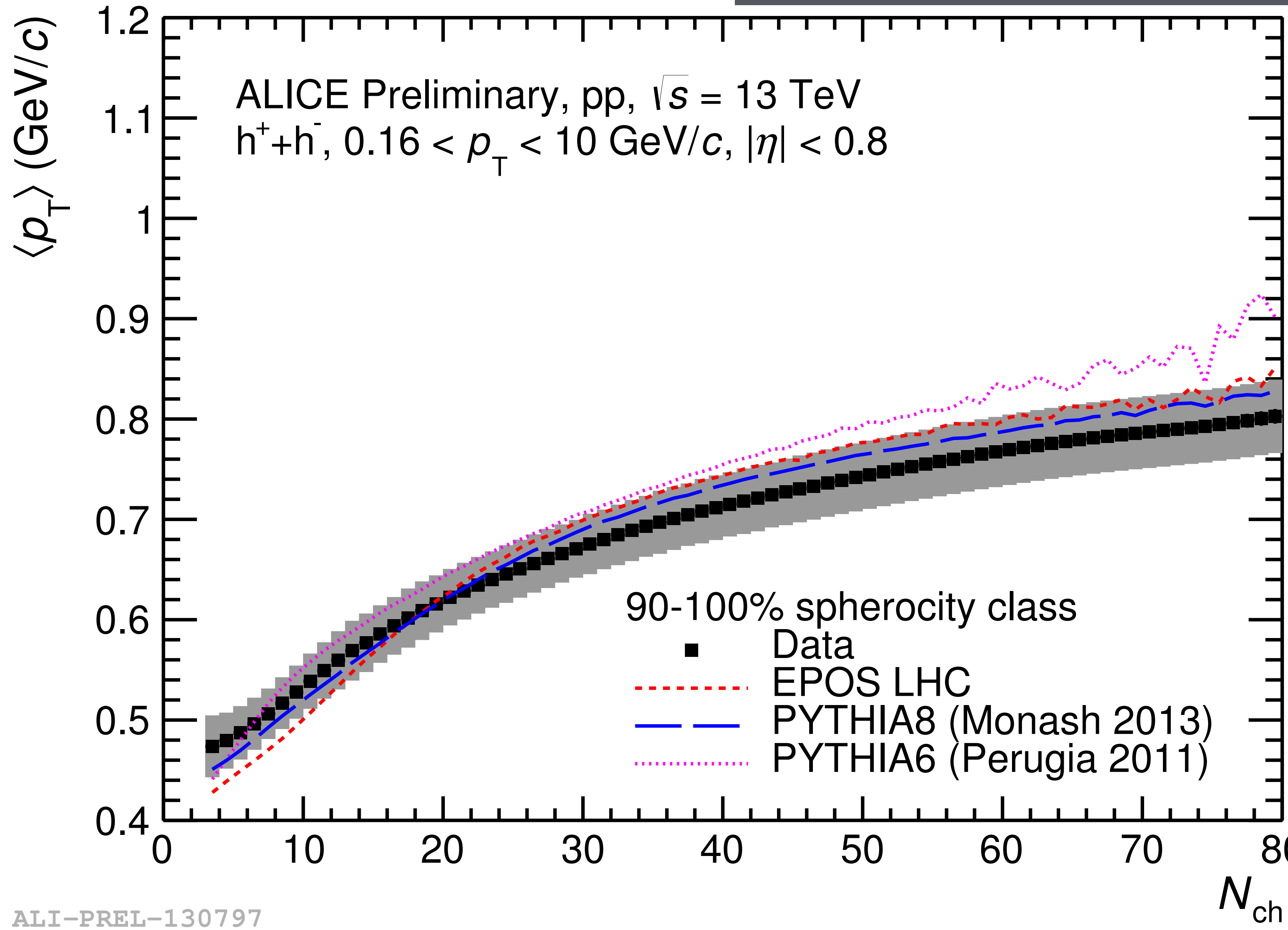


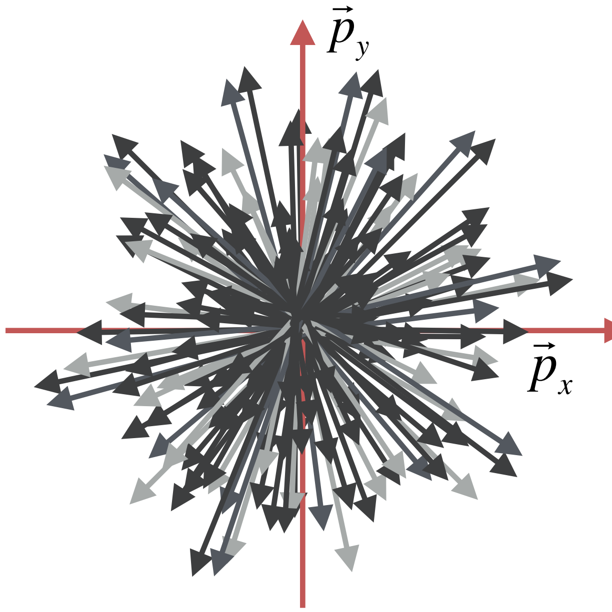


Non-isotropic events: LARGER DIFFERENCES WITH MODELS THAN IN THE INCLUSIVE CASE
PYTHIA 6 and PYTHIA 8 overestimate the <p_T> (input to improve the CR models: soft-hard interaction)
EPOS LHC describes well the data

Average transverse momentum (Isotropic events)

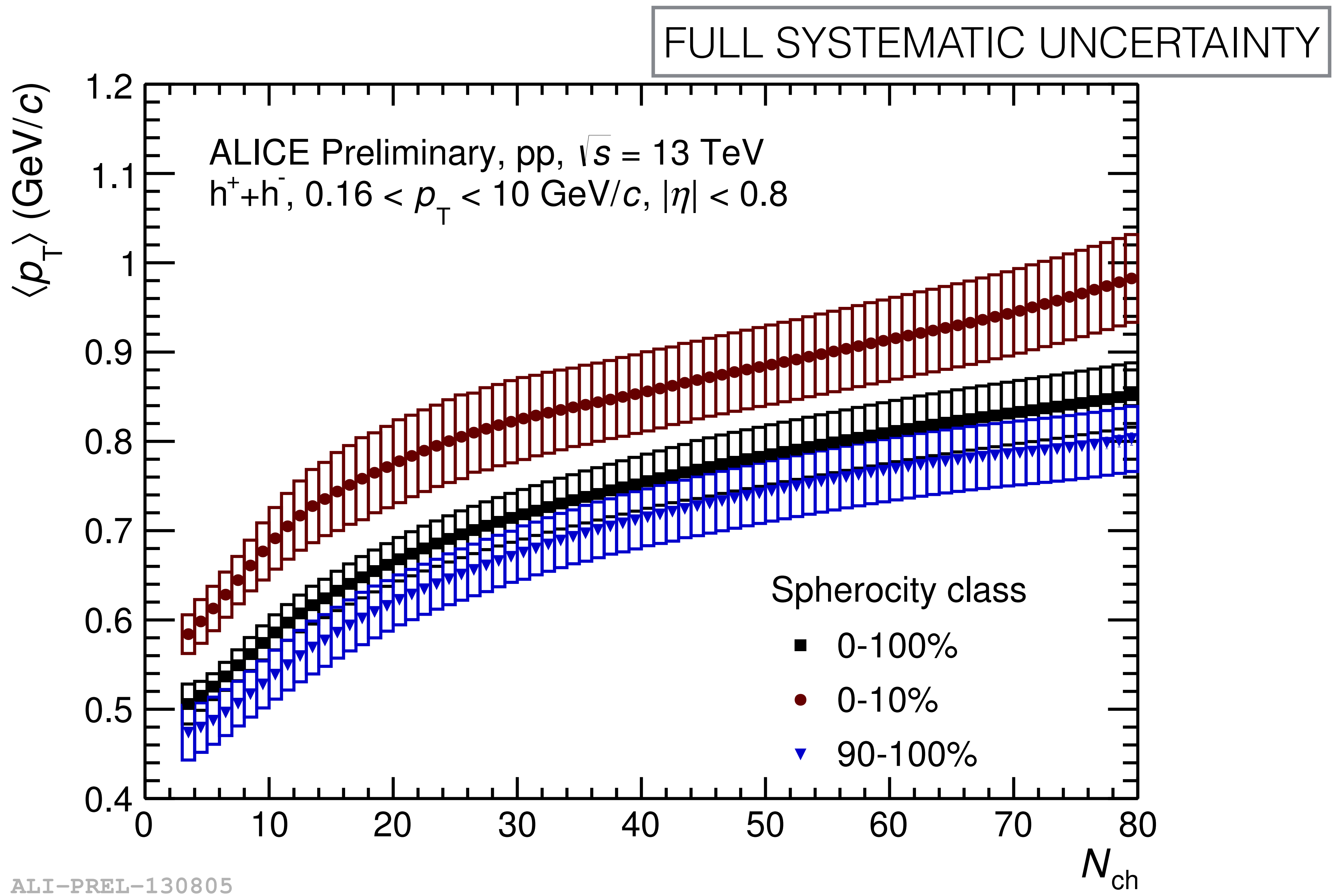
FULL SYSTEMATIC UNCERTAINTY





BETTER AGREEMENT WITH MODELS (except EPOS LHC [low N_{ch}] and PYTHIA 6 [high N_{ch}])

Average transverse momentum (comparison)



Conclusions

- Mean p_T vs multiplicity is a measurement which is useful to constrain the phenomenological models of particle production, e.g. color reconnection models can be tuned.

- The double differential analysis shown here allows to test the models where underlying event (or core contribution) is enhanced or suppressed with respect to the multiplicity dependent case.
  - The average p_T exhibits a steeper rise with N_{ch} going from isotropic (90-100%) to non-isotropic (0-10%) events.
  - The largest tension between data and PYTHIA (6 and 8) is observed for non-isotropic events, where color reconnection can affect the low p_T part of the spectrum due to the presence of a hard parton.
  - This can be used to study the soft-hard interaction.

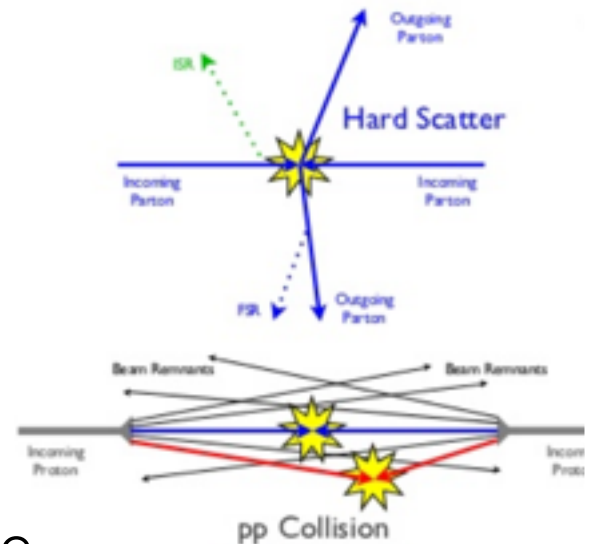
Dziękuję!

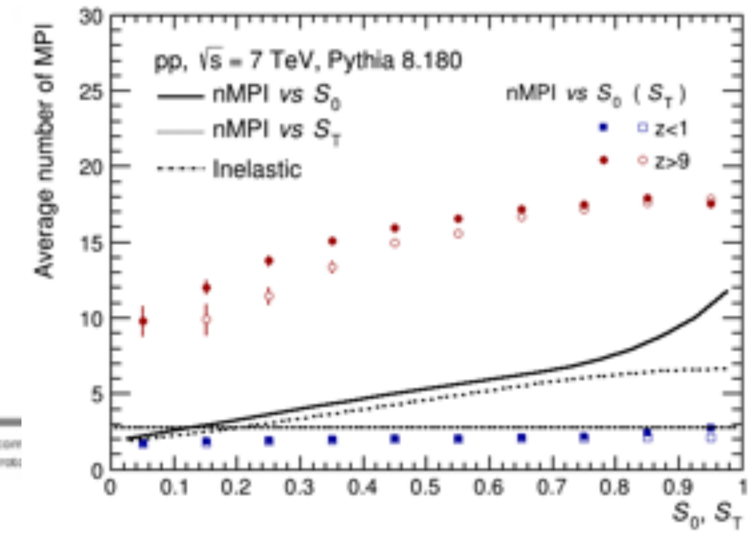
Thank you!

Backup

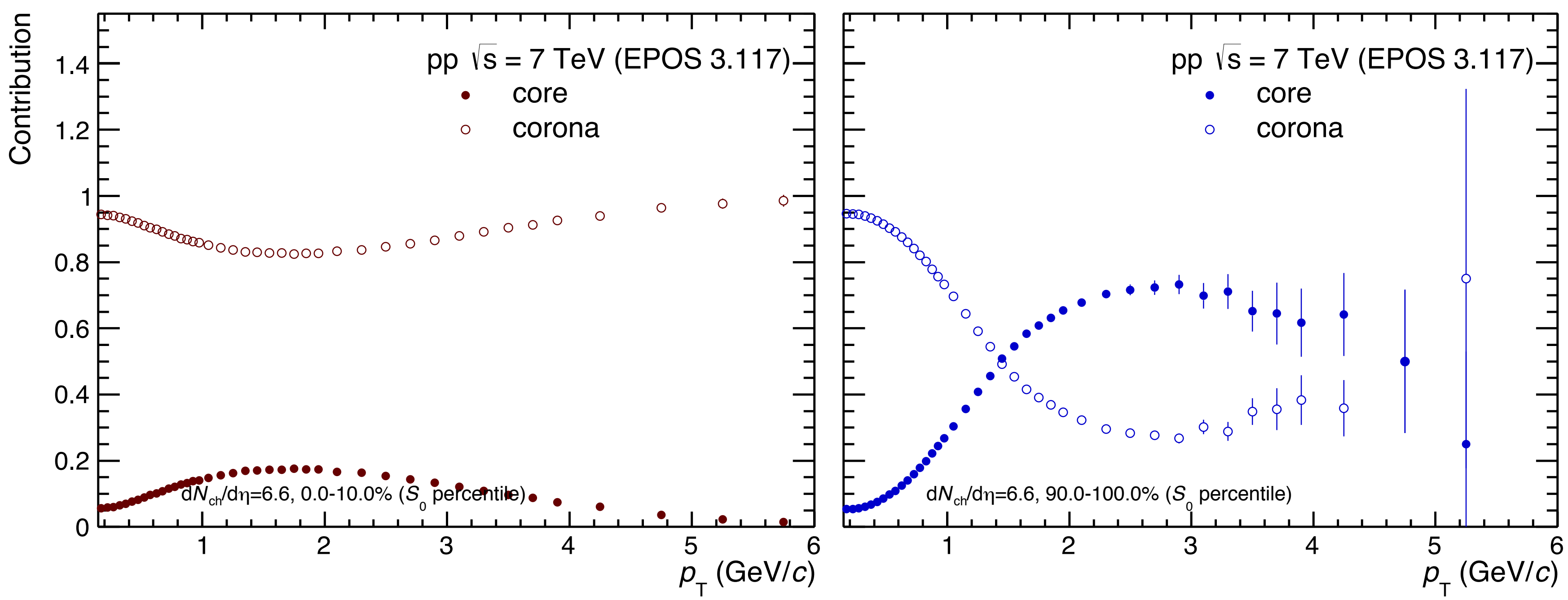
Motivation from Models

- Study features of High Multiplicity pp collisions using spherocity event by event will allow to separate “**soft**” (**no-pQCD**) from **“hard”** (**pQCD**) physics.
- With spherocity **MPI** could be studied.
- According to **PYTHIA 8**, spherocity allows the separation of events where **UE event** can be enhanced or suppressed.
- In **EPOS 3.1**, using spherocity one can achieve samples with enhanced or suppressed core contribution.



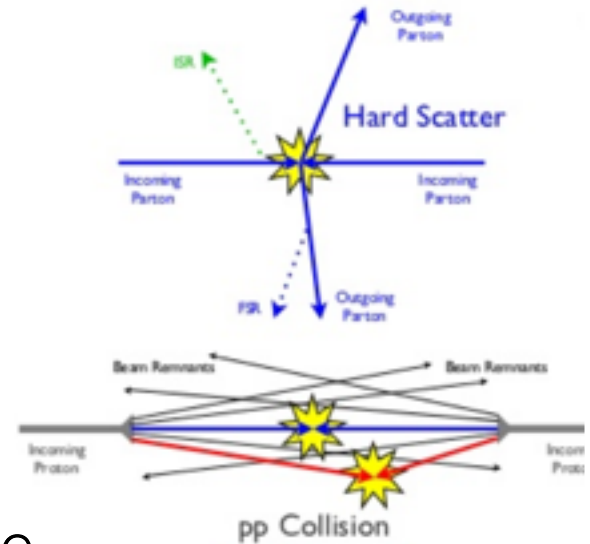


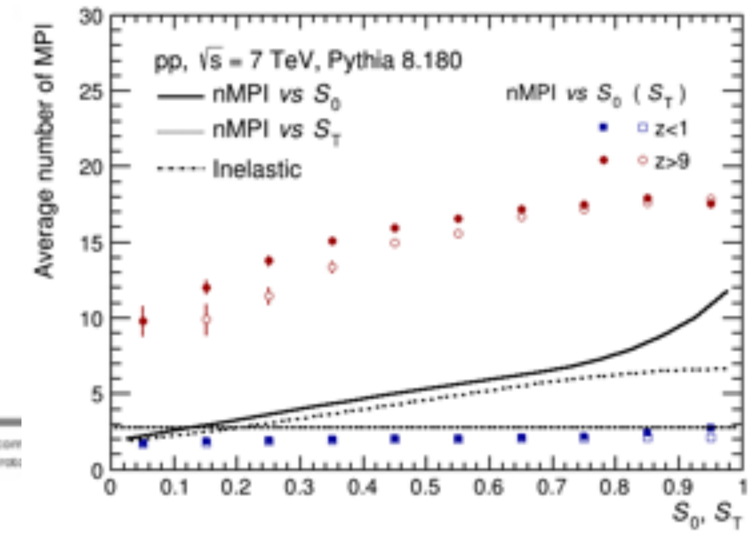
Disentangling the soft and hard components of the pp collisions using the sphero(i)city approach. Eleazar Cuautle, Raul Jimenez, Ivonne Maldonado, Antonio Ortiz, Guy Paic, Edgar Perez arXiv:1404.2372



Motivation from Models

- Study features of High Multiplicity pp collisions using spherocity event by event will allow to separate "**soft**" (**no-pQCD**) from **"hard"** (**pQCD**) physics.
- With spherocity **MPI** could be studied.
- According to **PYTHIA 8**, spherocity allows the separation of events where **UE event** can be enhanced or suppressed.
- In **EPOS 3.1**, using spherocity one can achieve samples with enhanced or suppressed core contribution.
- Comparing models and data will help us to get more information about high multiplicity events, for example if flow or other mechanisms as CR predominates in jets or in events without them.





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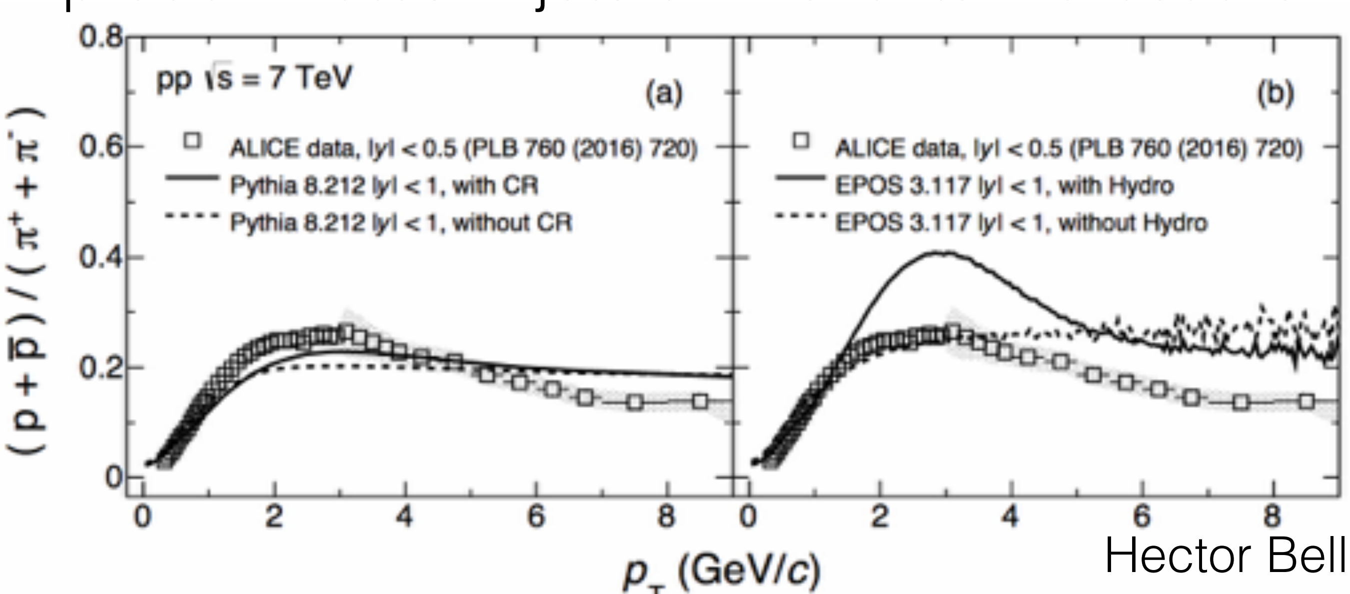
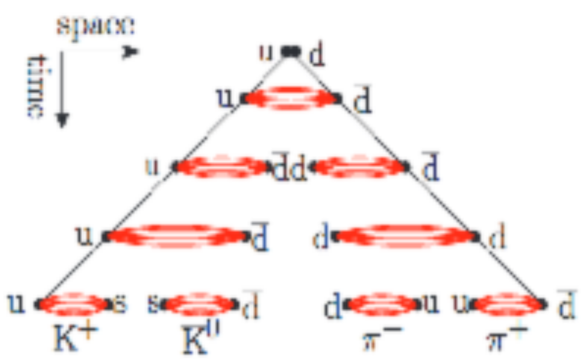


Revealing the source of the radial flow patterns in proton--proton collisions using hard probes, Antonio Ortiz, Gyula Bencédi, Héctor Bello, J. Phys. G: Nucl.Part.Phys.44 (2017) .

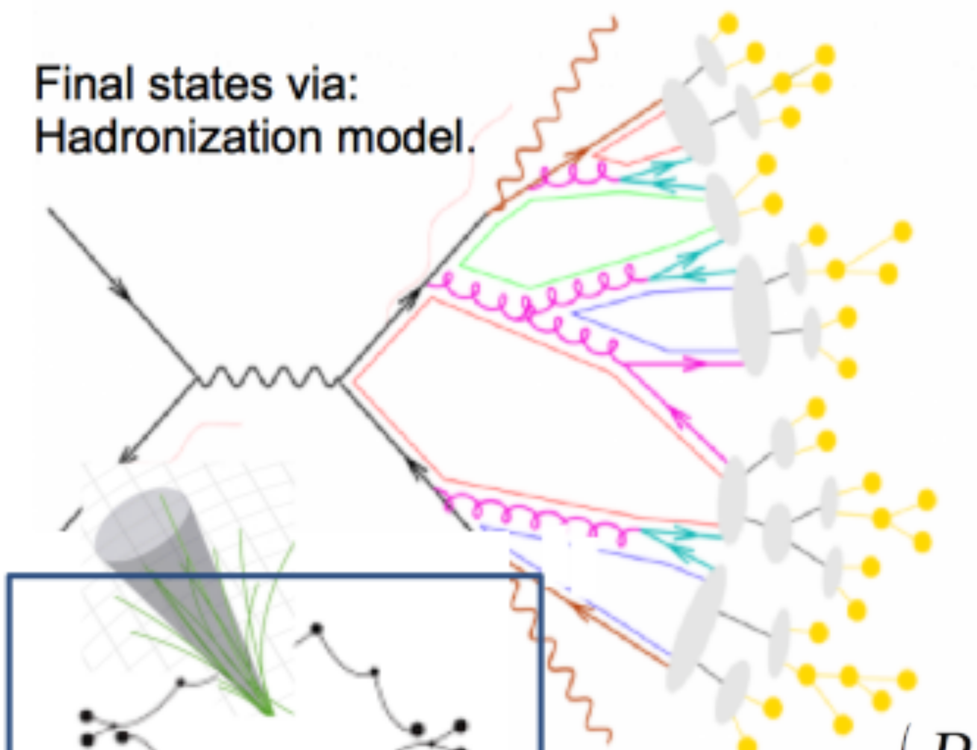
Reference to Pythia 8

Introduction Color Reconnection (PYTHIA8)

Production via:
Lund String fragmentation
Model



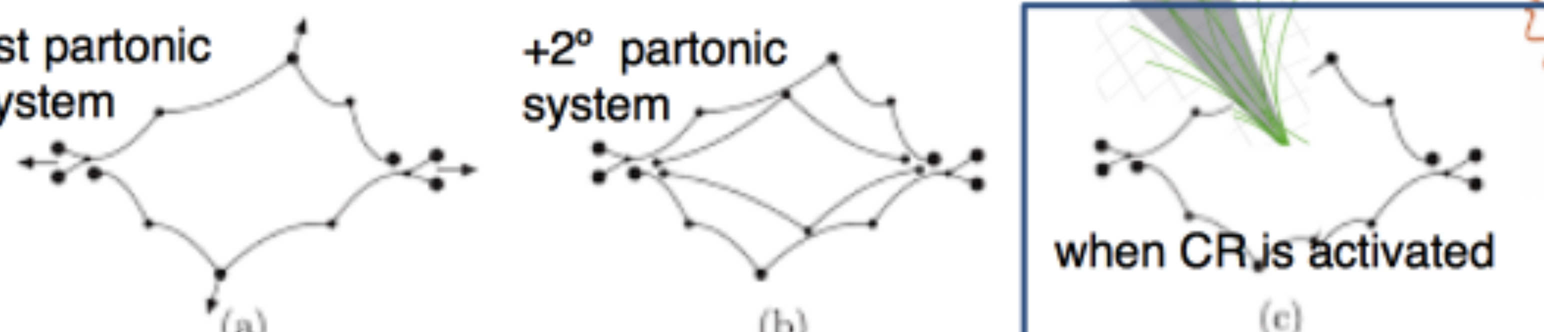
Final states via:
Hadronization model.



1st partonic system

+2° partonic system

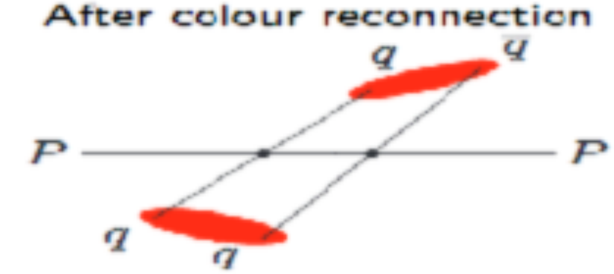
when CR is activated



$$P(p_T) = \frac{(RR \times p_{T0})^2}{(RR \times p_{T0})^2 + p_T^2}$$

- Figure taken from: G. Gustafson, Acta Phys. Polon. B40, 1981 (2009)
  Effects of CR on hadron flavor observables, C. Bierlich and J. R. Christiansen, PRD 92 (2015) 9, 094010

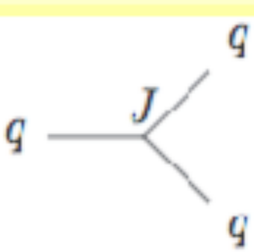
After colour reconnection



From: Jesper Roy Christiansen MPI@LHC 2014

QCD rules say how reconnection is allowed (epsilon color tensor)

$q^i q^j q^k \epsilon^{ijk} \rightarrow q$

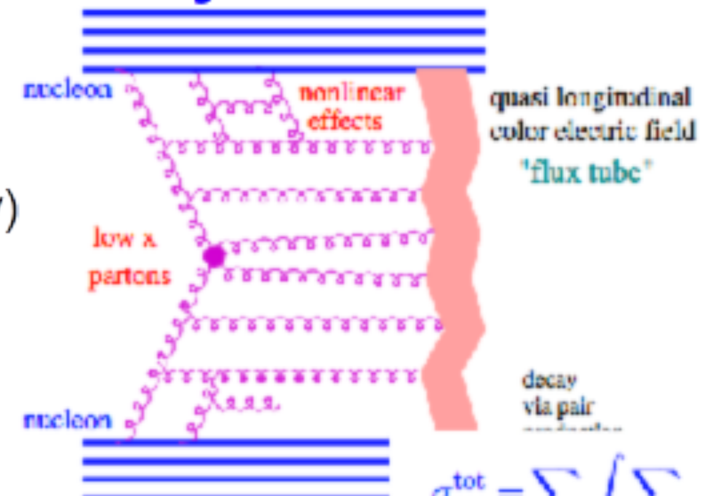


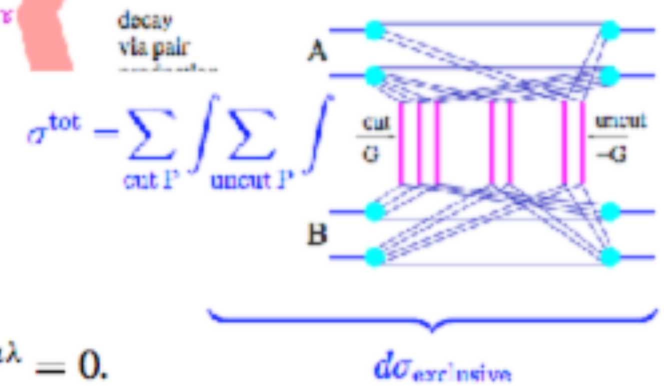
The minimum string length tell us the configuration

Reference to EPOS

Introduction   3+1D Hidrodynamics

Model with:
Energy conservation in multiple scattering
Parton modelled by (Gribov–Regge Theory)
Off-shell, remanents
Saturation



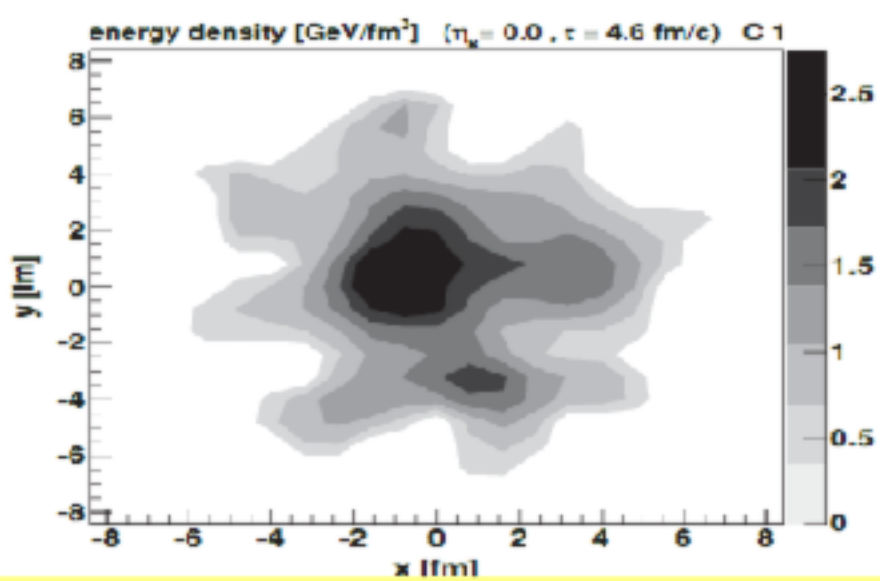


"Core-corona" separation

Core→high string density
Corona→low string density
with "Core"=Hidrodynamics
No "Core"=just string model

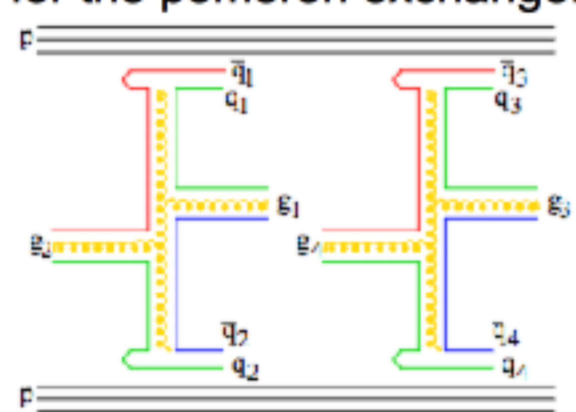
$$\partial_{;\nu} T^{\mu\nu} = \partial_\nu T^{\mu\nu} + \Gamma^{\mu}_{\nu\lambda} T^{\nu\lambda} + \Gamma^{\nu}_{\nu\lambda} T^{\mu\lambda} = 0.$$

K. Werner et al., PRC89 (2014) 6, 064903



K. Werner et al., PRC 82 (2010) 044904

Color flux tubes for the pomeron exchange.



K.Werner et al, PRC 92 (2015) 034906

3. **Thesis Draft**

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