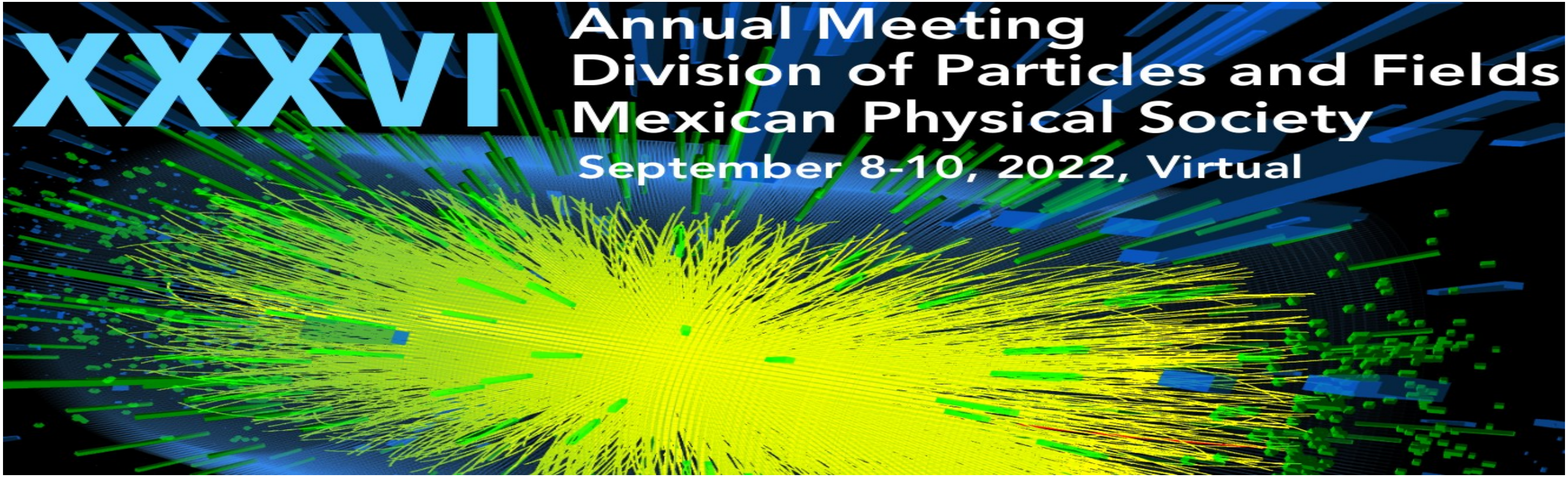

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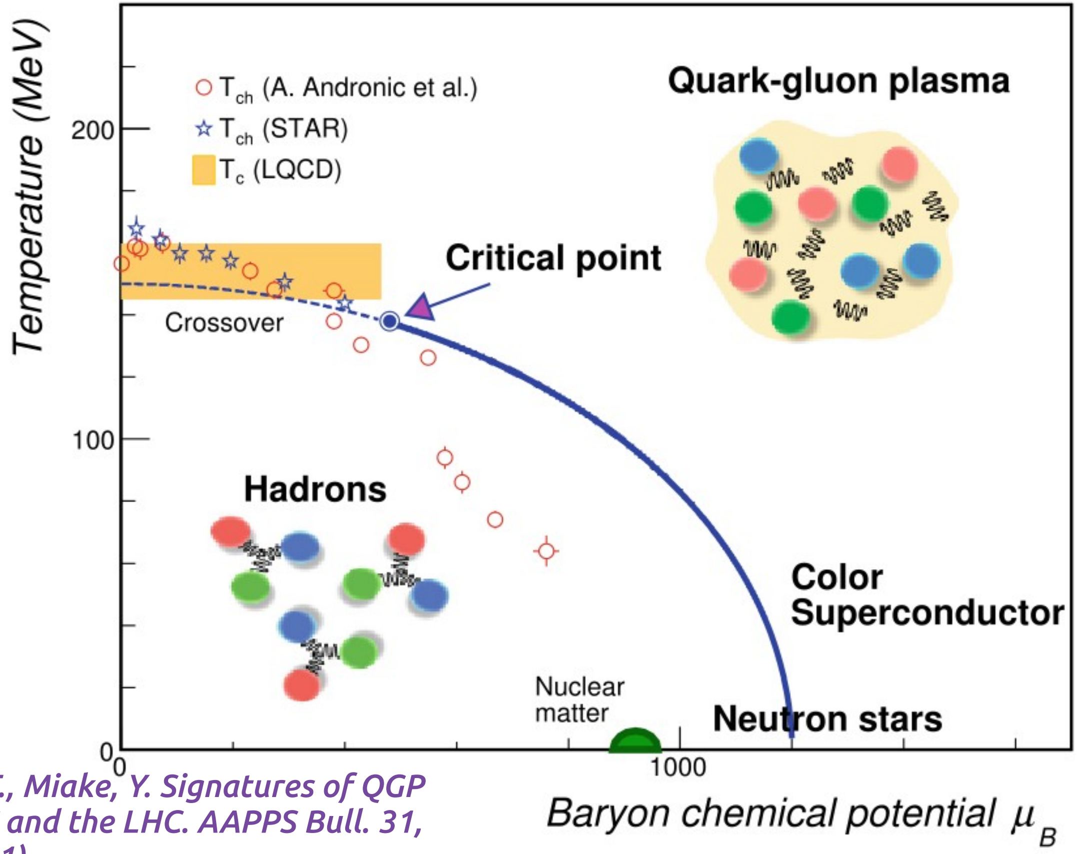
Extraction of Multiparton Interactions from ALICE pp collisions data using Machine Learning

Erik Zepeda and Antonio Ortiz

Motivation

Quantum Chromodynamics: the QGP



Niida, T., Miake, Y. Signatures of QGP at RHIC and the LHC. AAPPS Bull. 31, 12 (2021)

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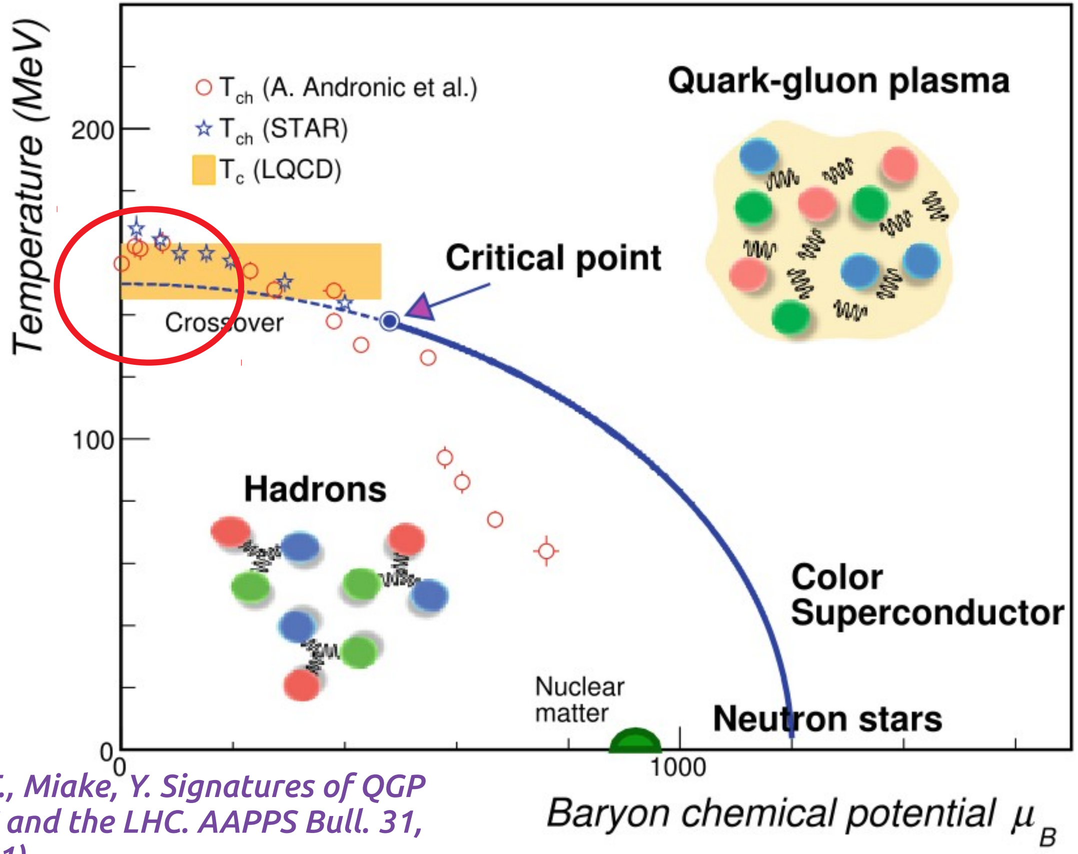

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Lattice QCD predicts a phase transition around $T_c \approx 155$ MeV

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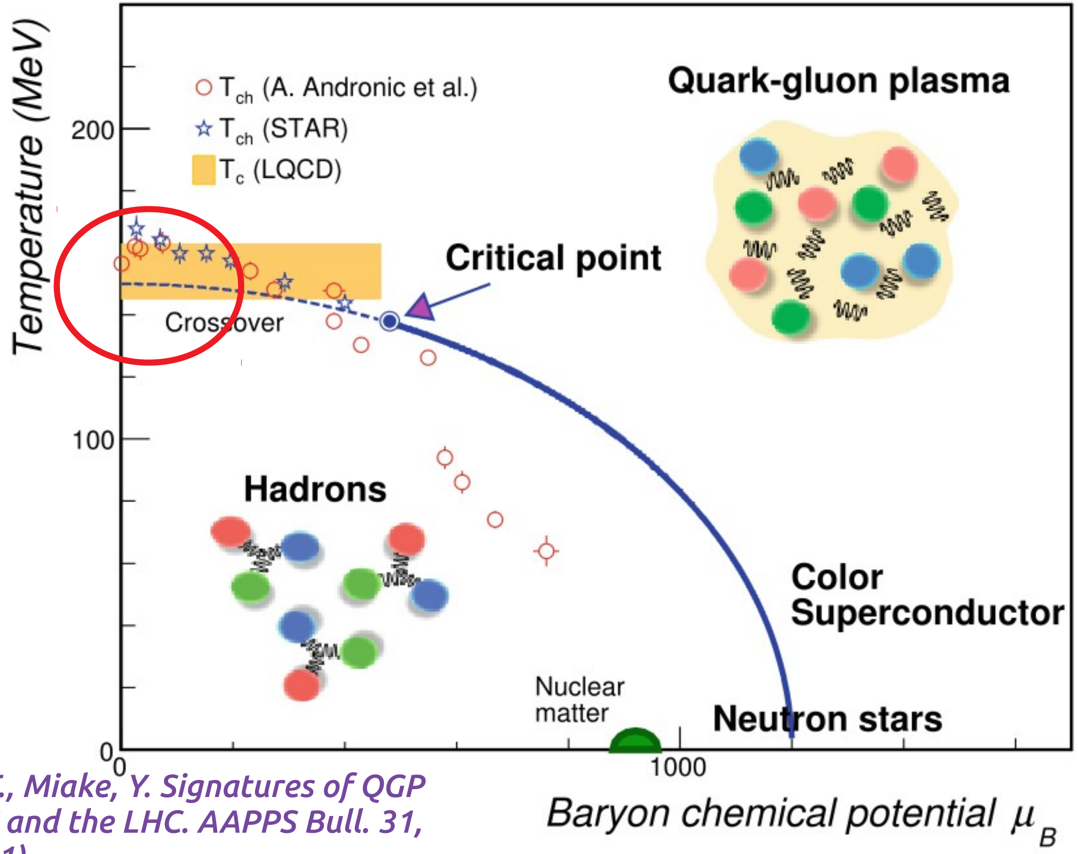

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Lattice QCD predicts a phase transition around $T_c \approx 155$ MeV

Direct photons measurement contains information of initial temperature ($T_{eff} \approx 297$ MeV)

ALICE Collaboration, Phys. Lett. B 754 (2016) 235-248

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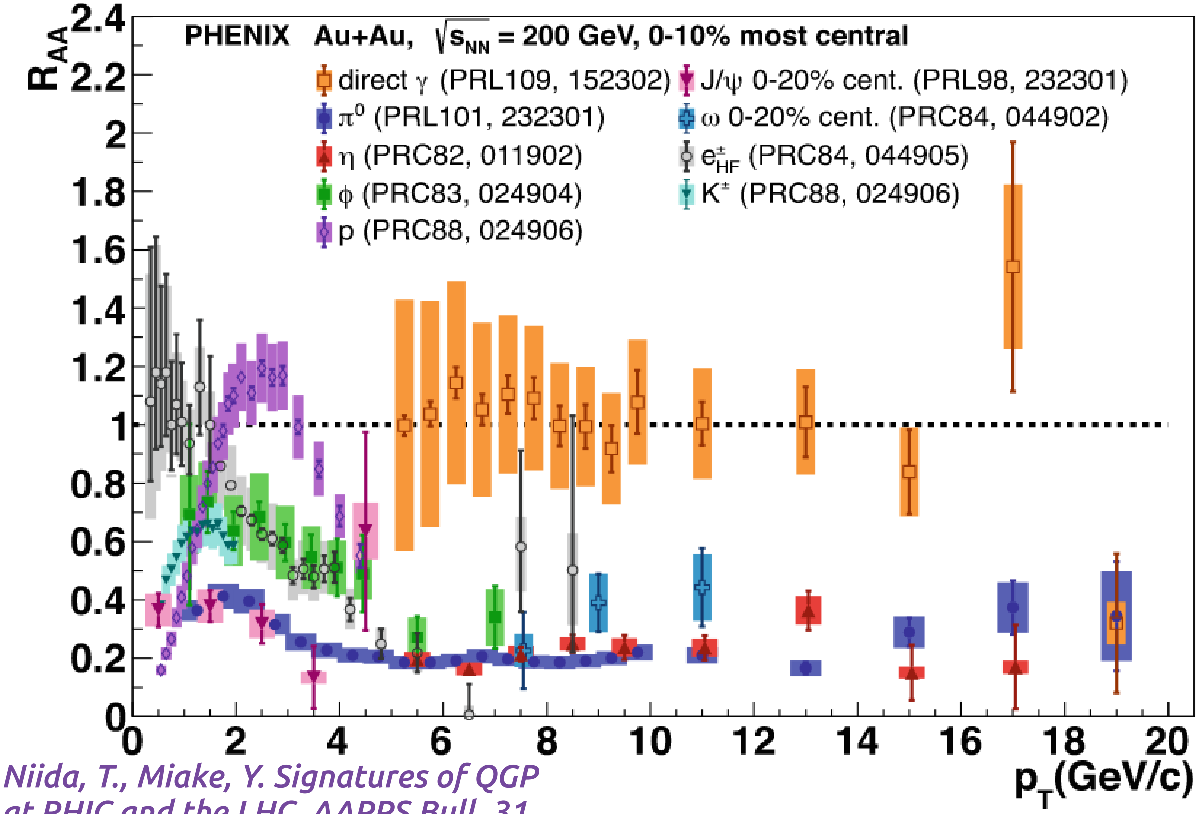
Motivation

Small MB collisions systems as reference to heavy-ions



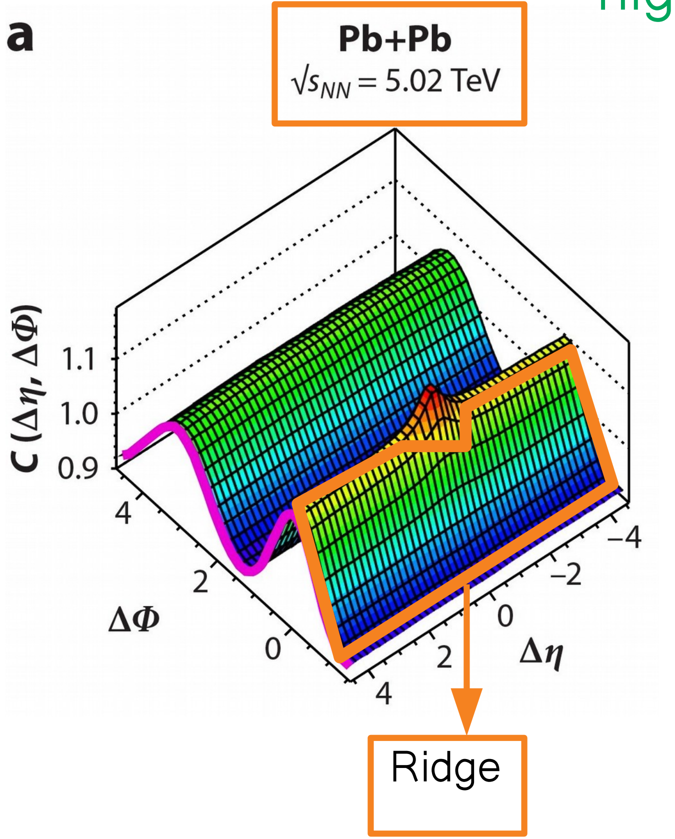
Niida, T., Miake, Y. Signatures of QGP at RHIC and the LHC. AAPPS Bull. 31, 12 (2021)

$$R_{AA} = \frac{d^2N_{AA}/dp_T/dy}{\langle N_{coll}\rangle d^2N_{pp}/dp_T/dy}$$

The R_{AA} behavior shows a significant energy loss of partons due the QGP

Motivation

New phenomena observed in high multiplicity small systems



Nagle JL. Zajc WA. 2018 Annu. Rev. Nucl. Part. Sci. 68:211-35

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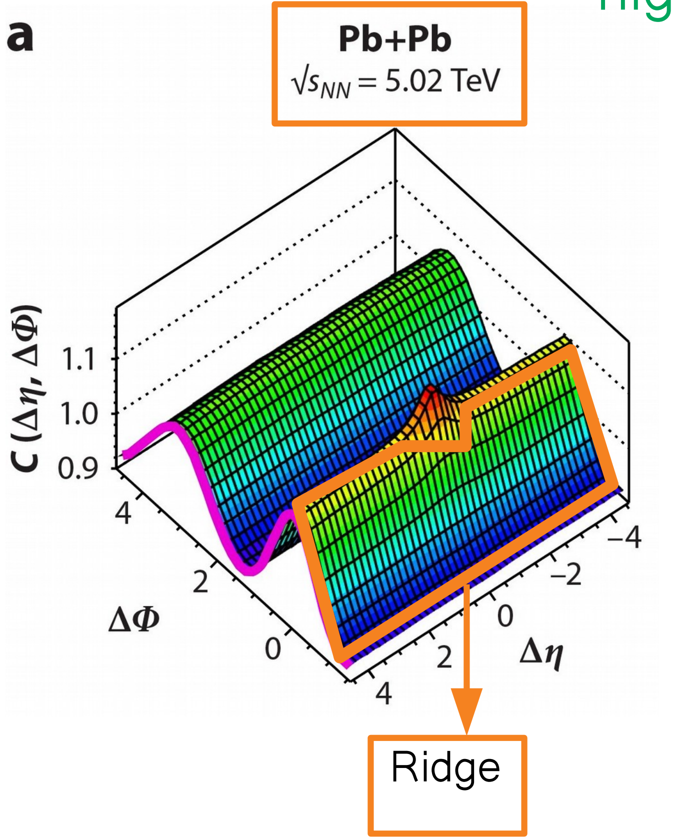

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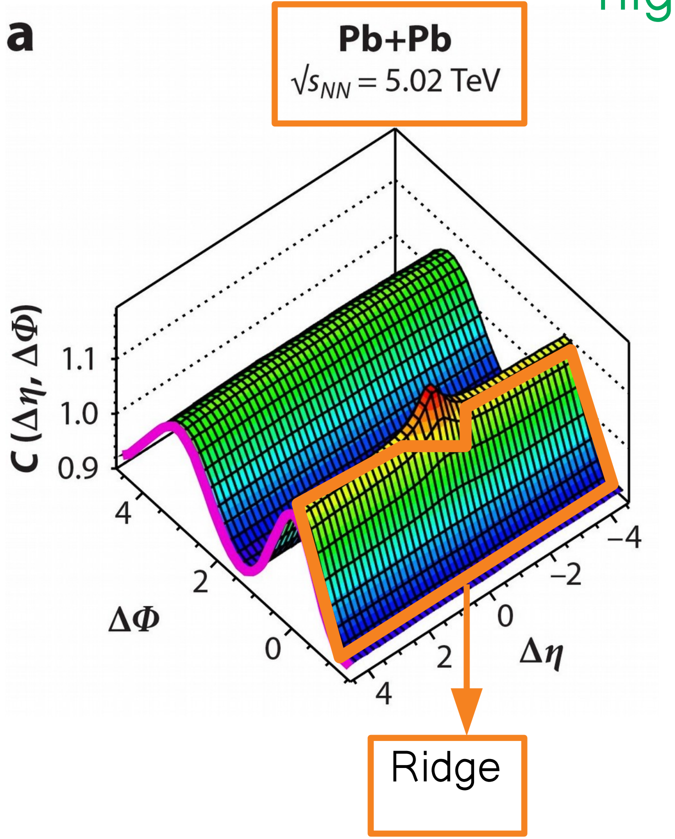

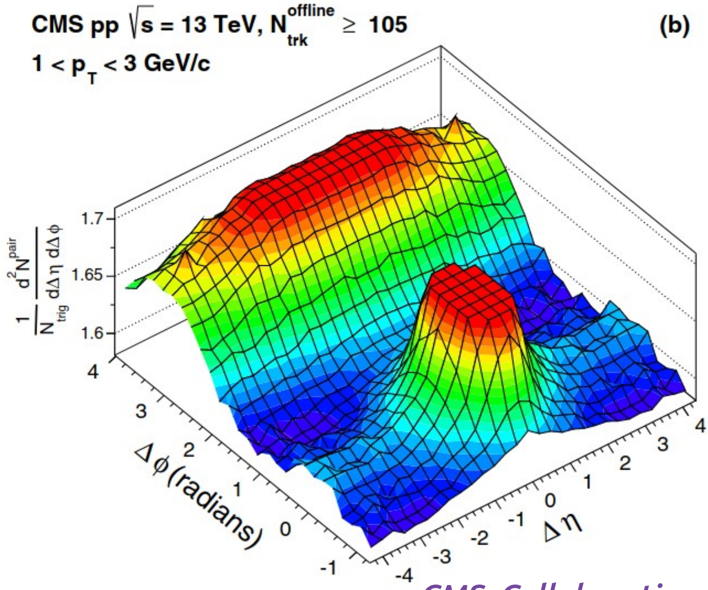

CMS Collaboration, Phys. Rev. Letts., 2016,116, 172302

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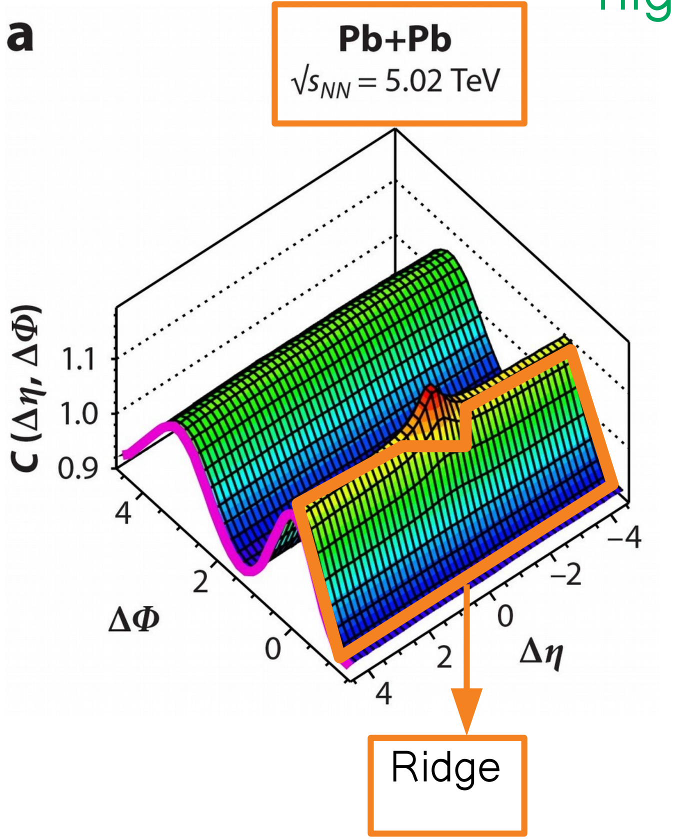

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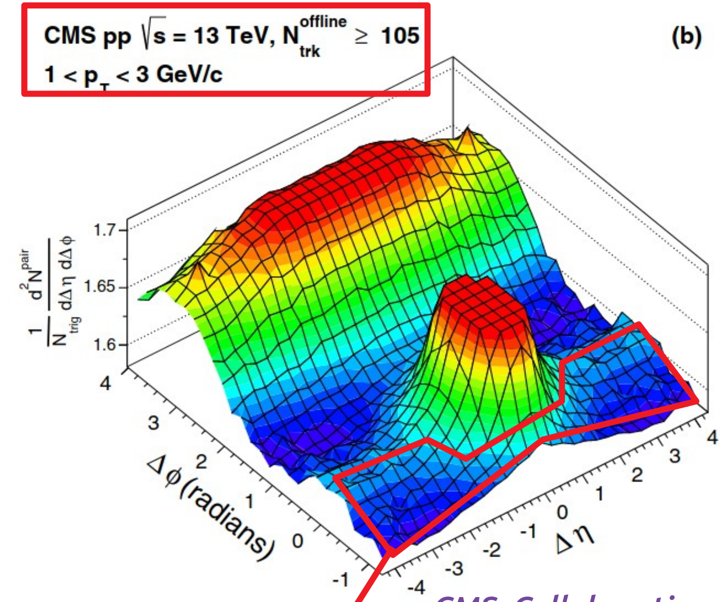

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Ridge is observed in high multiplicity pp collisions!

Motivation

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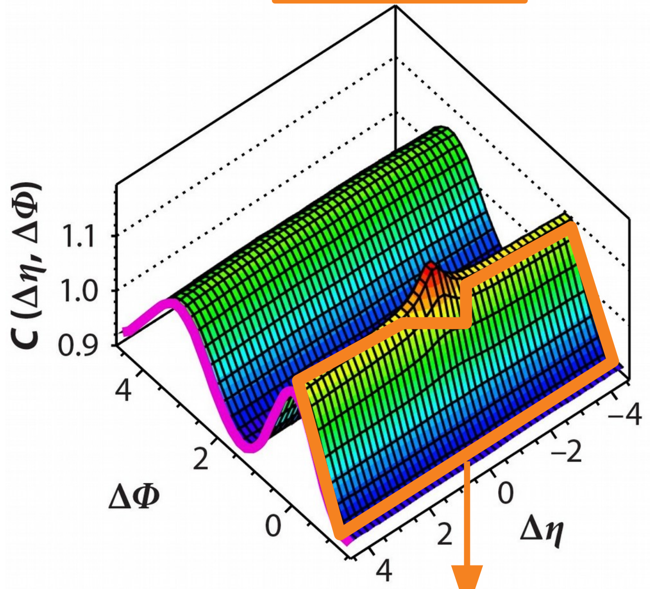
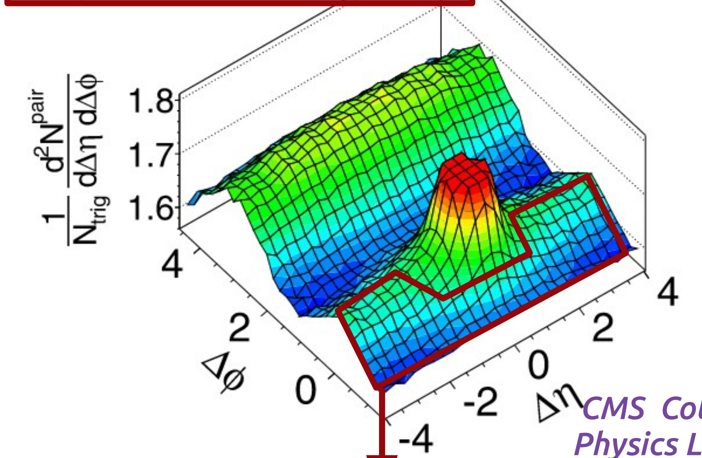
Pb+Pb
$\sqrt{s_{NN}} = 5.02$ TeV



Ridge

Nagle JL. Zajc WA. 2018 Annu. Rev. Nucl. Part. Sci. 68:211-35

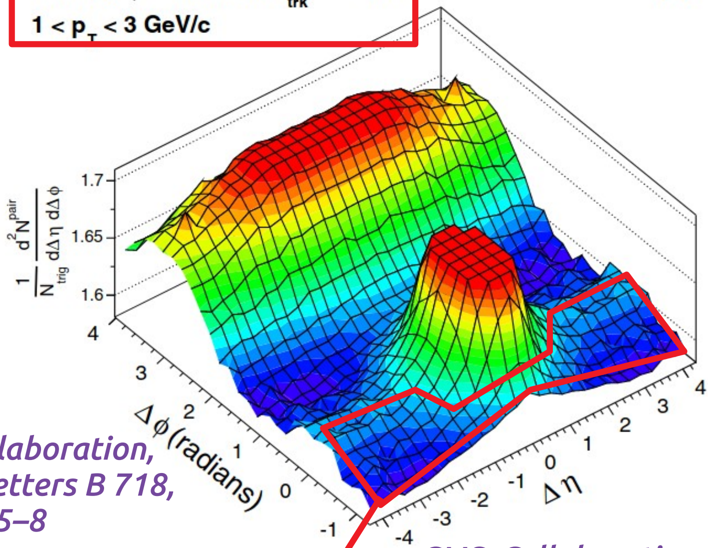
CMS pPb $\sqrt{s_{NN}} = 5.02$ TeV, $N_{trk}^{offline} \geq 110$
$1 < p_T < 3$ GeV/c



CMS Collaboration, Physics Letters B 718, no. 3, 795–8

Also observed in p-Pb collisions

CMS pp $\sqrt{s} = 13$ TeV, $N_{trk}^{offline} \geq 105$
$1 < p_T < 3$ GeV/c



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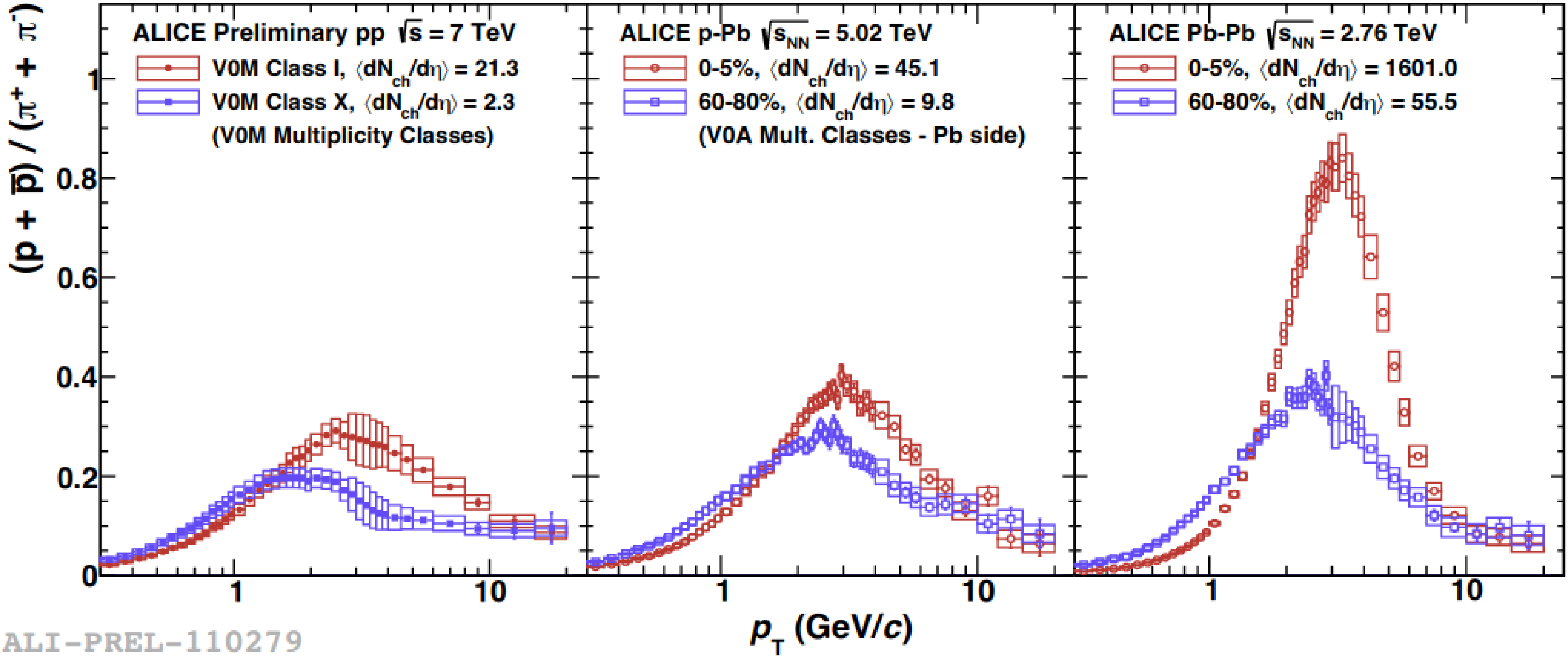

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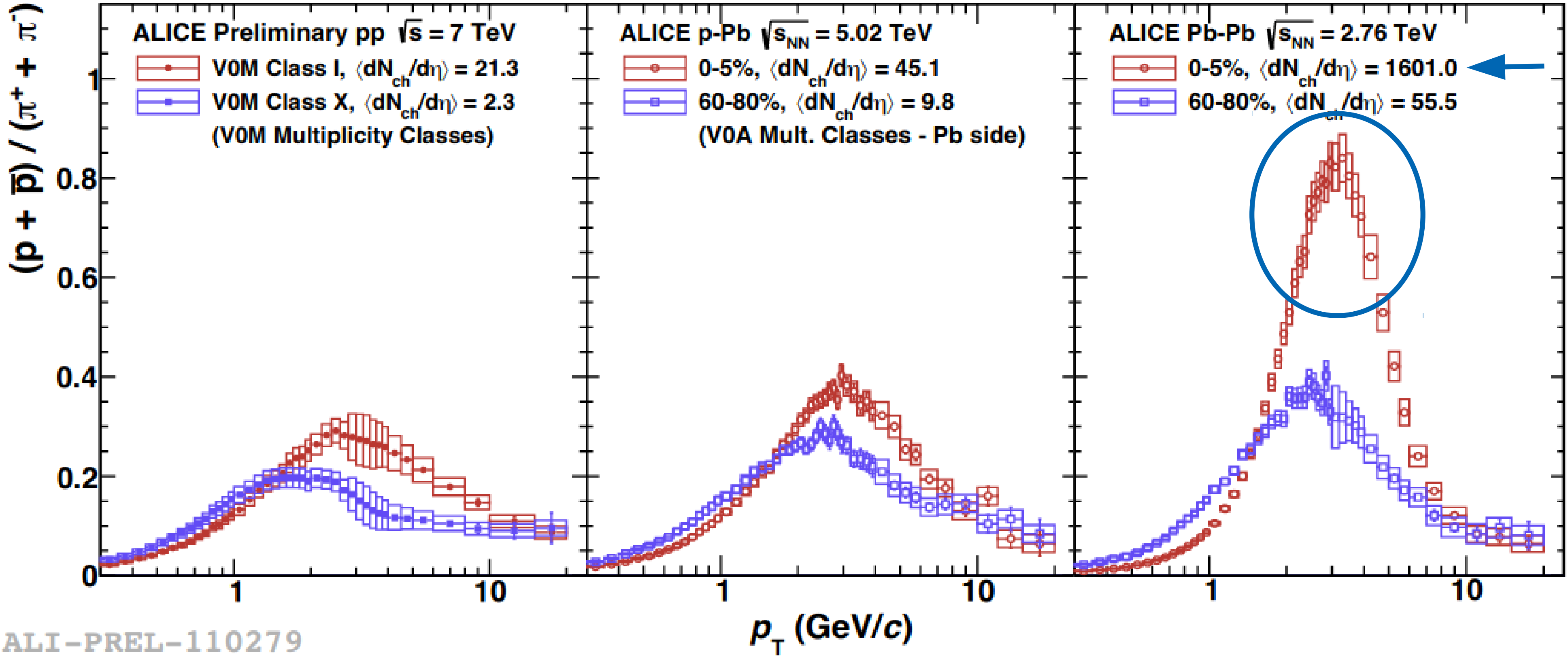

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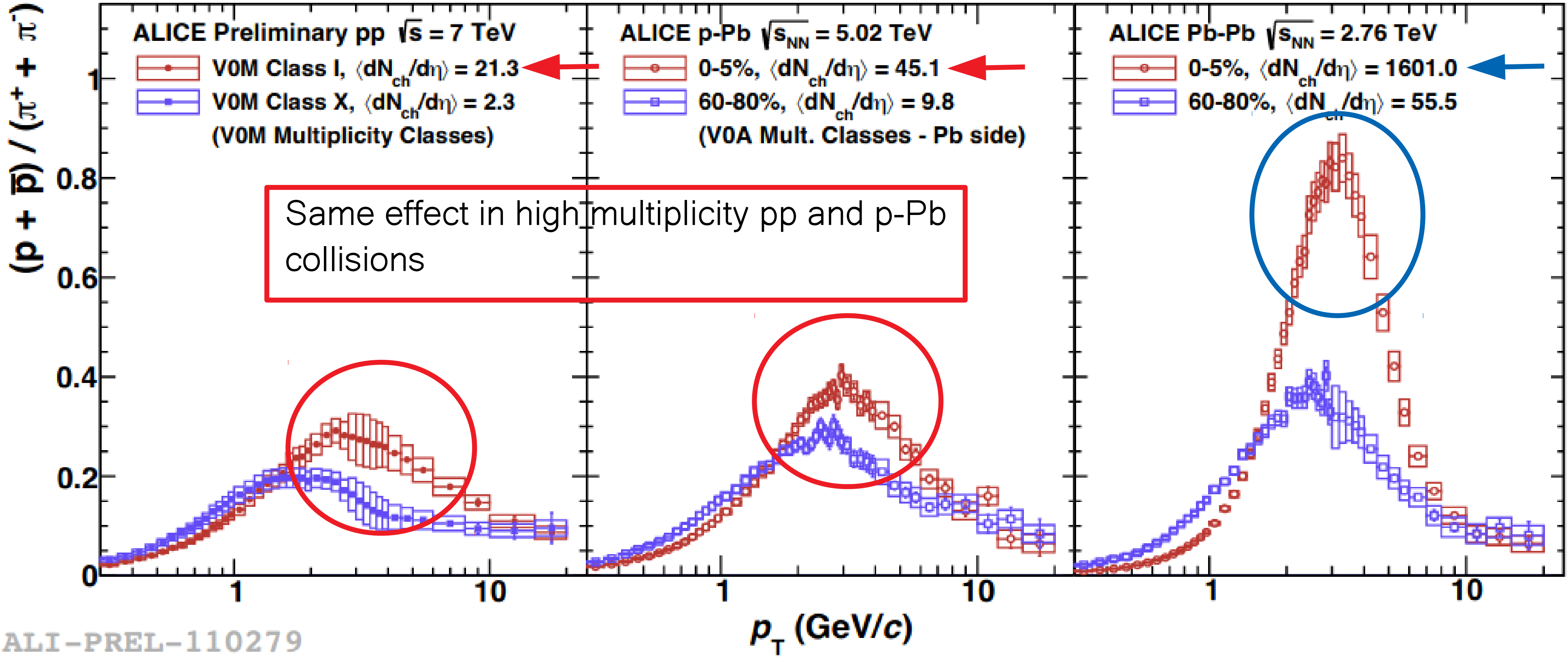

Motivation

New phenomena observed in high multiplicity small systems

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- Models as interactions between strings are also capable to simulate collective effects

Christian Bierlich et al. Collectivity without plasma in hadronic collisions. Physics Letters B, 779:58–63, 2018.

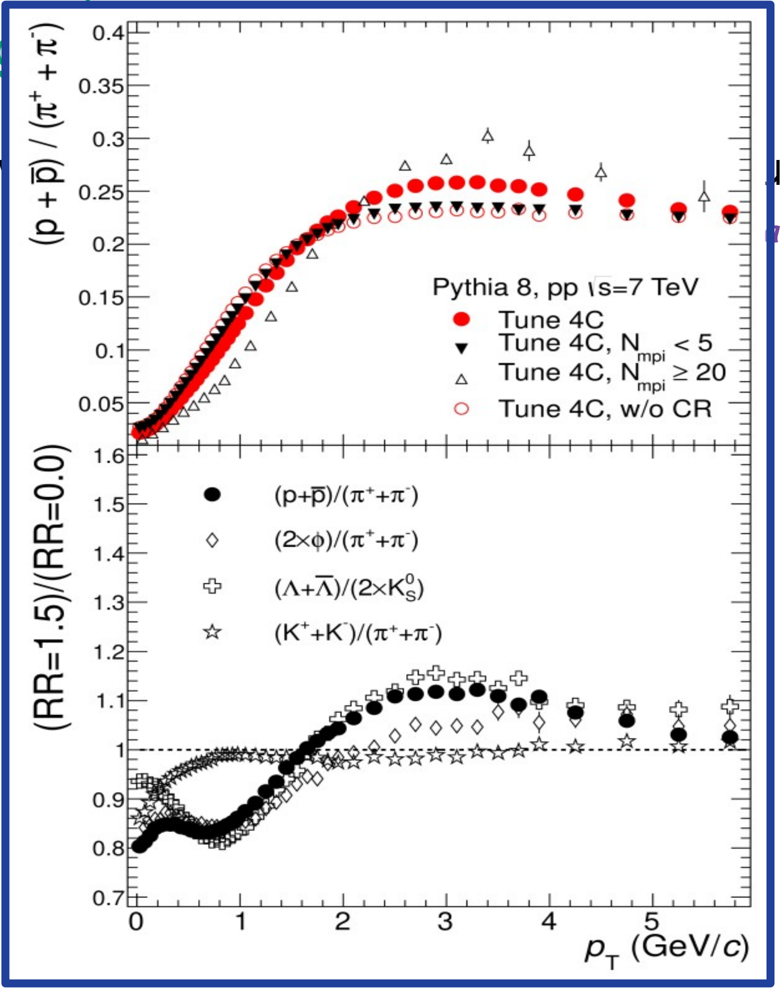
Motivation

New phenomena observed in hi

- Models as interactions betw… ulate collective effects

… in hadronic

- Alternative: CR and **Multiparton Interactions**



A. Ortiz, Guy Paic et al.
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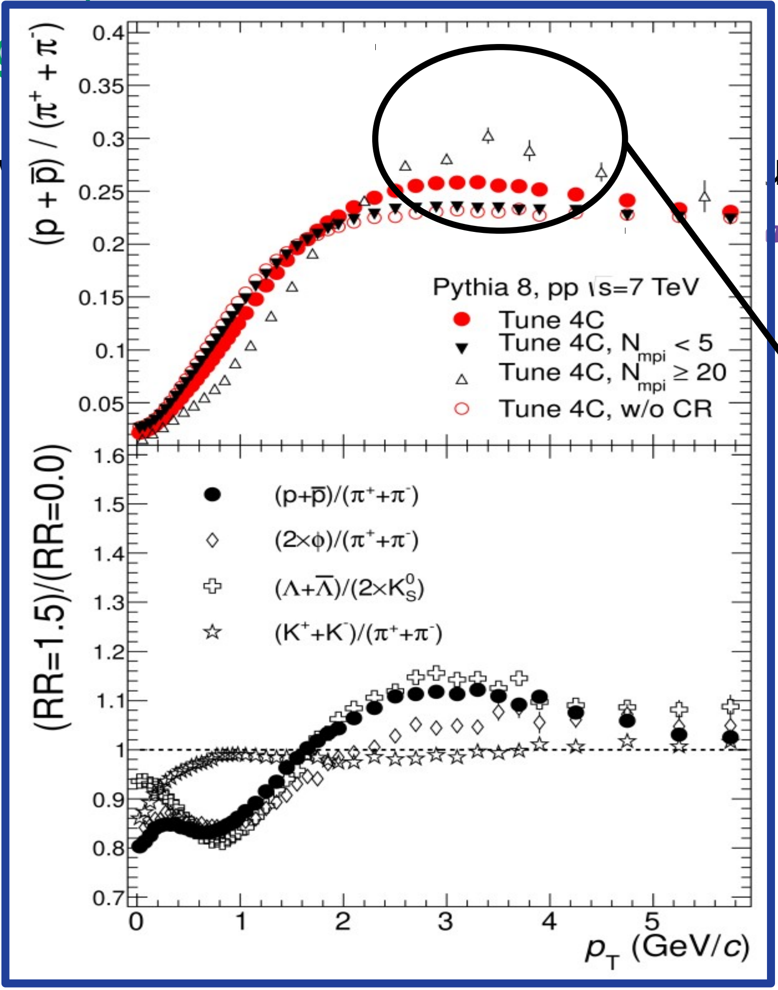

Maximum around 3 GeV/*c*,

A. Ortiz, Guy Paic et al.
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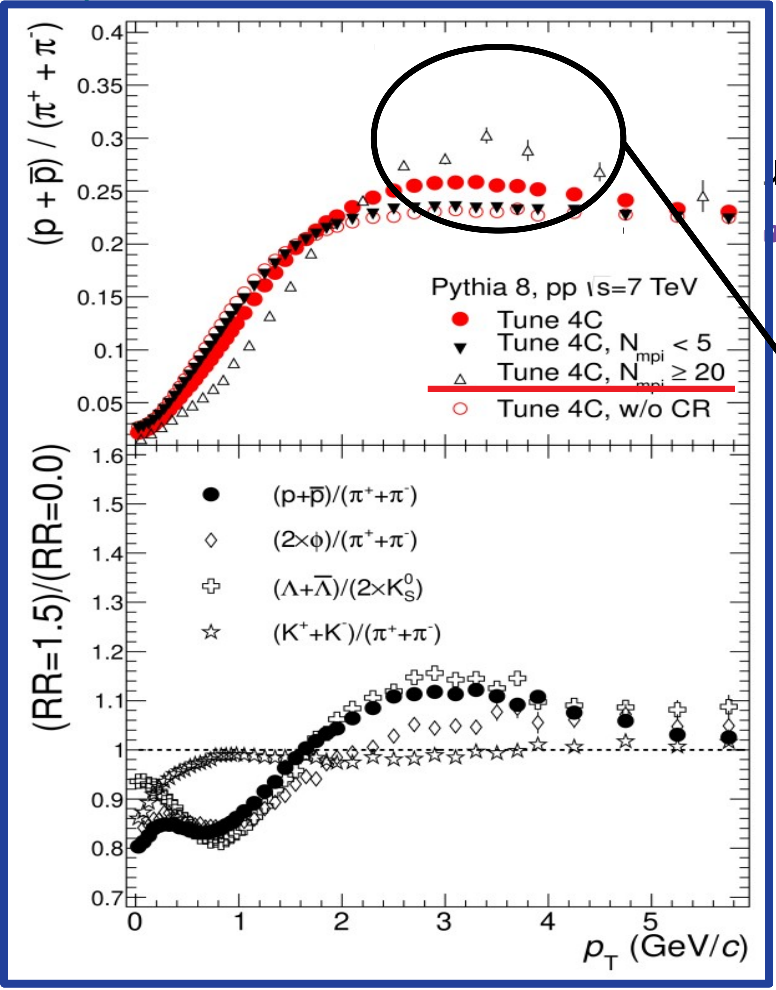

Maximum around 3 GeV/c, this peak increases considering events with high number of MPI

A. Ortiz, Guy Paic et al.
Phys. Rev. Lett. 111, 042001

We propose to extract
MPI from the available ALICE pp collisions data
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Based on:

Antonio Ortiz and Erik A Zepeda 2021 J. Phys. G: Nucl. Part. Phys. 48 085014

Erik Alfredo Zepeda Garcia and Antonio Ortiz, PoS LHCP2021 (2021) 347

Antonio Ortiz, Antonio Paz, José D. Romo, Sushanta Tripathy, Erik A. Zepeda, and Irais Bautista, Phys. Rev. D 102, 076014 (2020)

Analysis: decision trees

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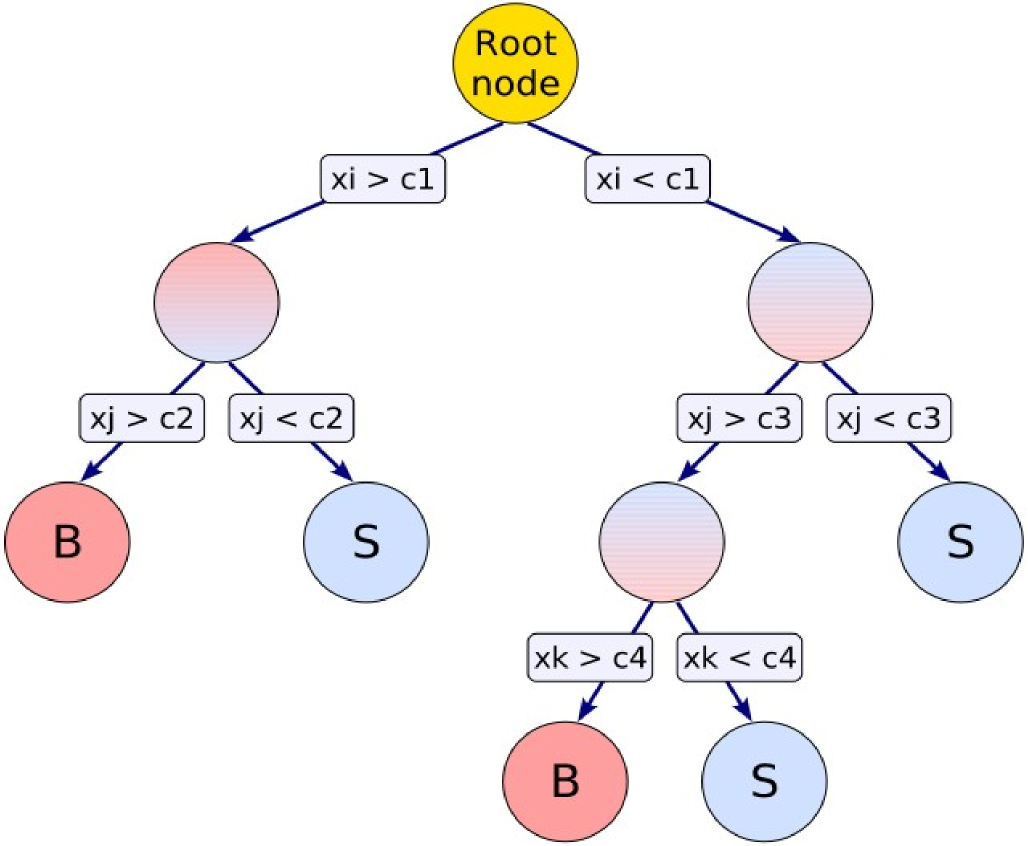

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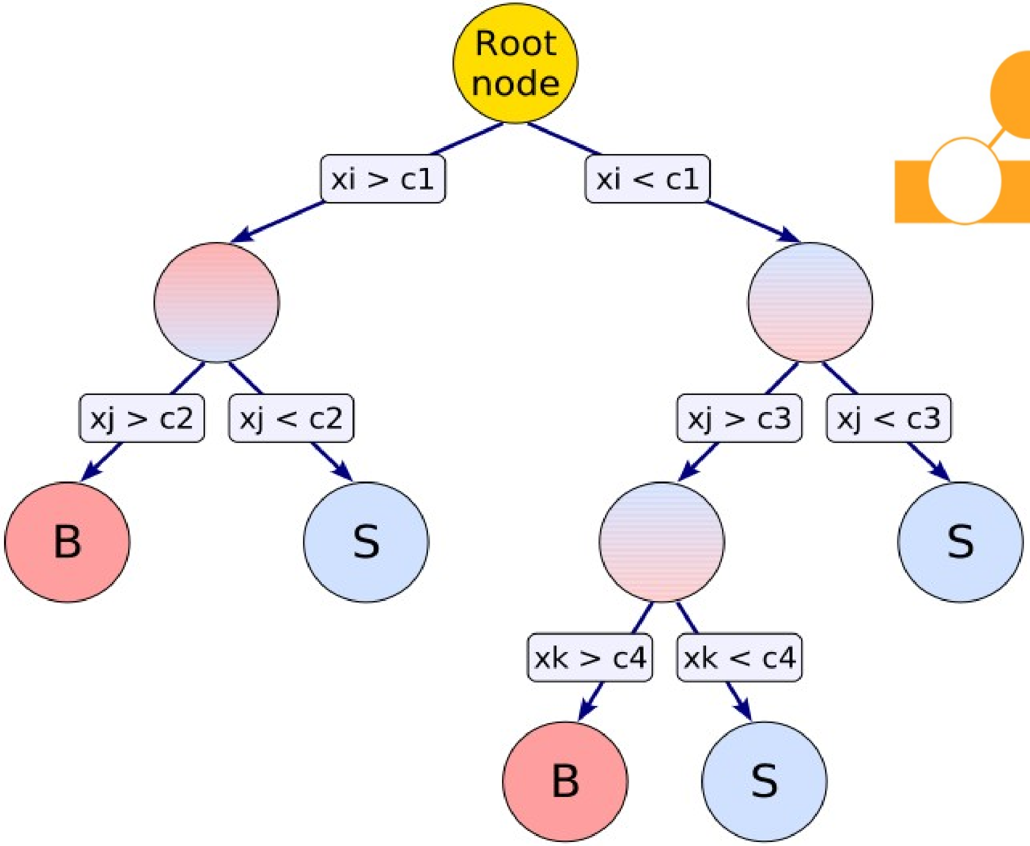

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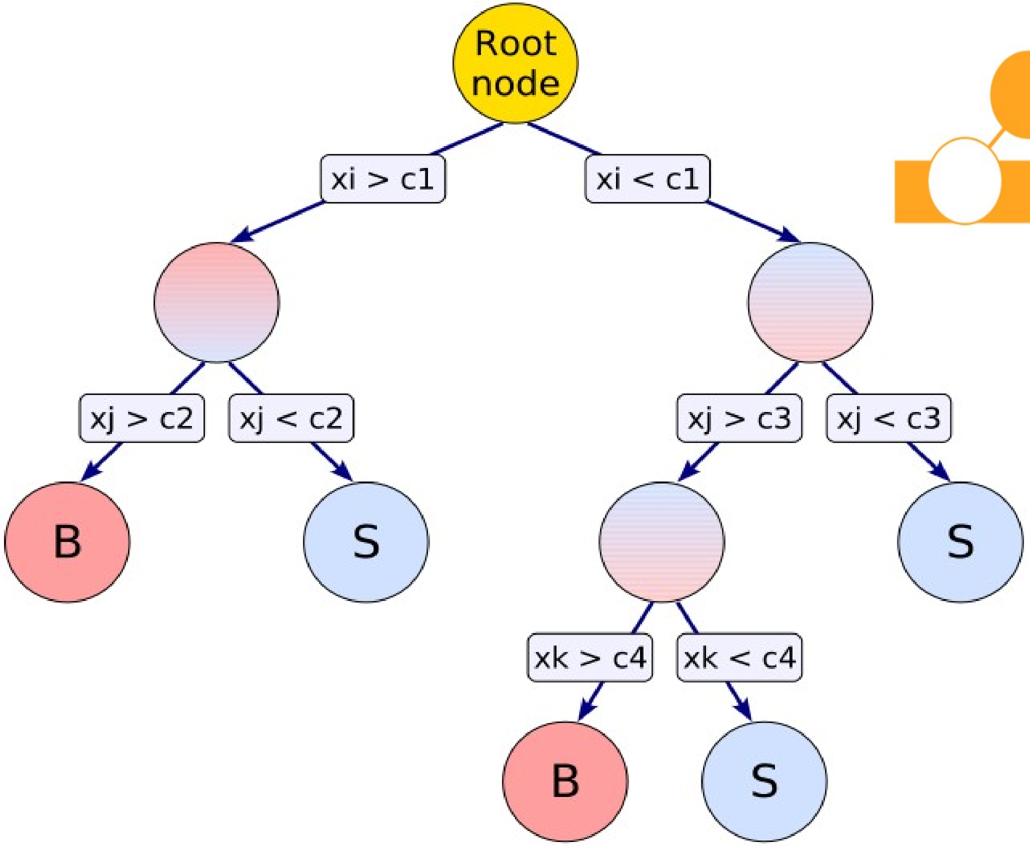

R. Brun and F. Rademakers. Nucl. Instrum. Meth. A, 389:81–86, 1997

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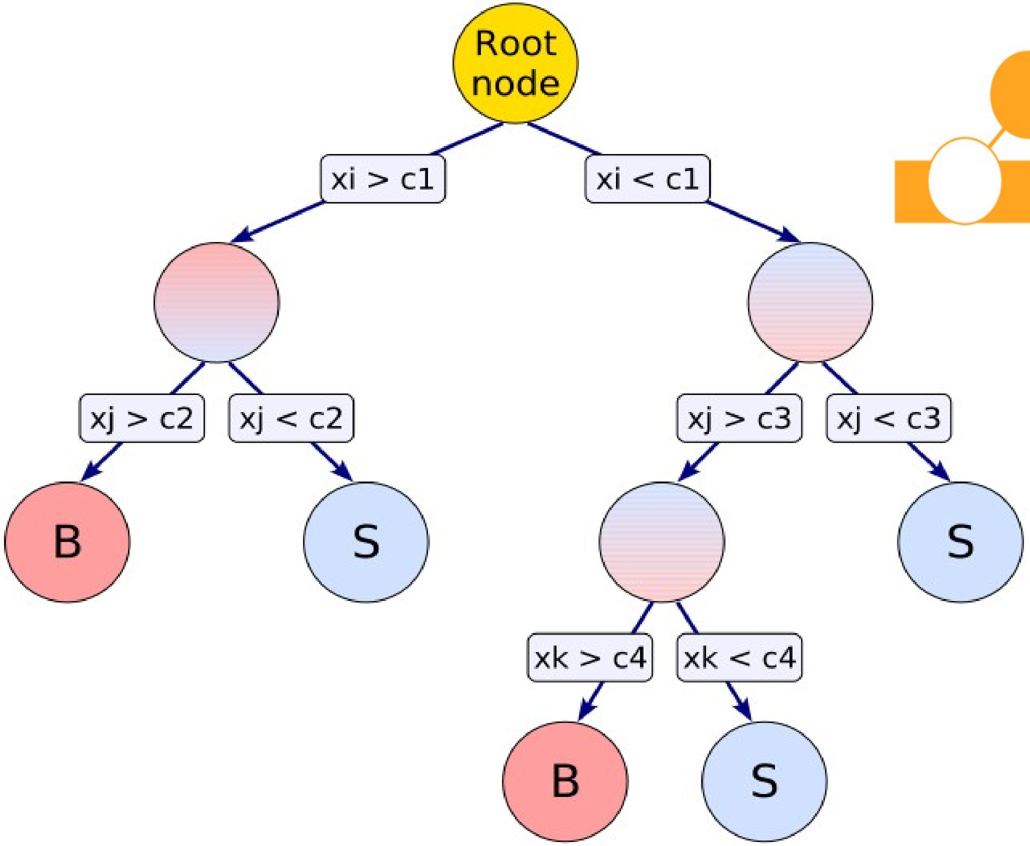

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TMVA provides an environment for the processing, evaluation and application of regression and classification multivariate tecniques

Analysis: extraction of N_{mpi}

- The extraction of N_{mpi} is considered a regression problem where given a set of input variables we try to minimize a loss function

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Strategy for the extraction of N_{mpi} :

1. Training and Test
2. Monte Carlo validation
3. Data processing

Analysis: extraction of N_{mpi}

Training and Test

- Training of BDT: simulated events of pp collisions at $\sqrt{s}$ = 13 TeV using Pythia 8 Tune 4C

Analysis: extraction of N_{mpi}

Training and Test

- Training of BDT: simulated events of pp collisions at $\sqrt{s}$ = 13 TeV using Pythia 8 Tune 4C

    - We trained two BDT sets: for $|\eta| < 0.8$ and $|\eta| < 0.5$ ranges, with $p_T > 0.15$ GeV/c

Analysis: extraction of N_{mpi}

Training and Test

- Training of BDT: simulated events of pp collisions at $\sqrt{s}$ = 13 TeV using Pythia 8 Tune 4C

Input variables

- Mid-pseudorapidity charged particle multiplicity (N_{ch})

  Average transverse momentum ($\langle p_T \rangle$)

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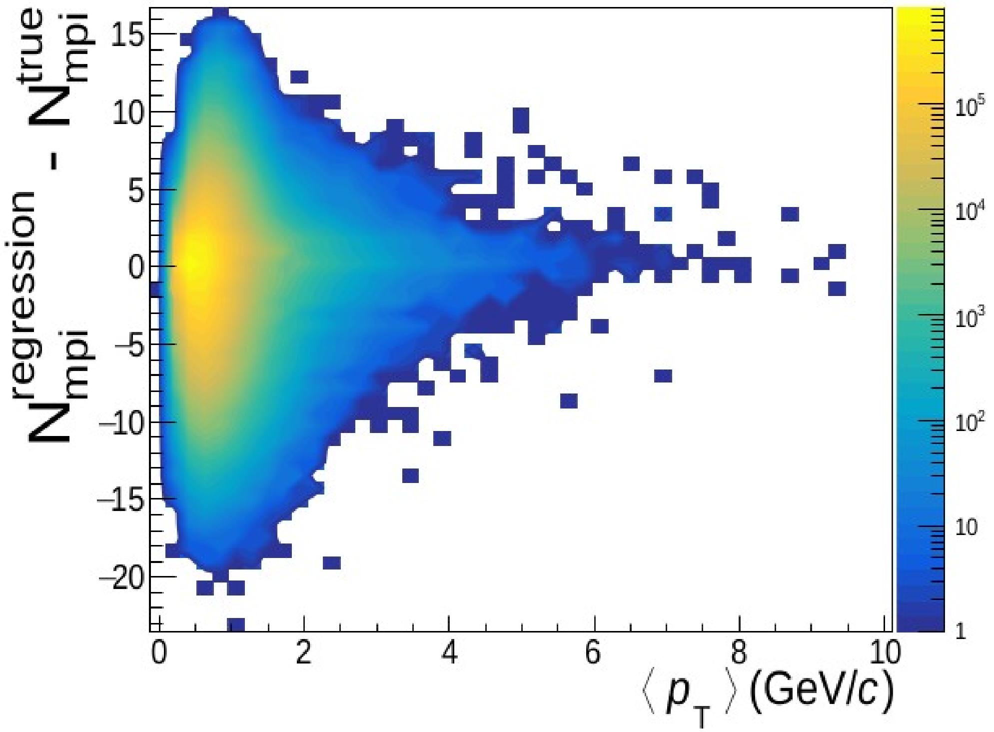
Based on their correlation with N_{mpi}

E. Cuautle et al. Nuclear Physics A, 956:749–752, Dec 2016

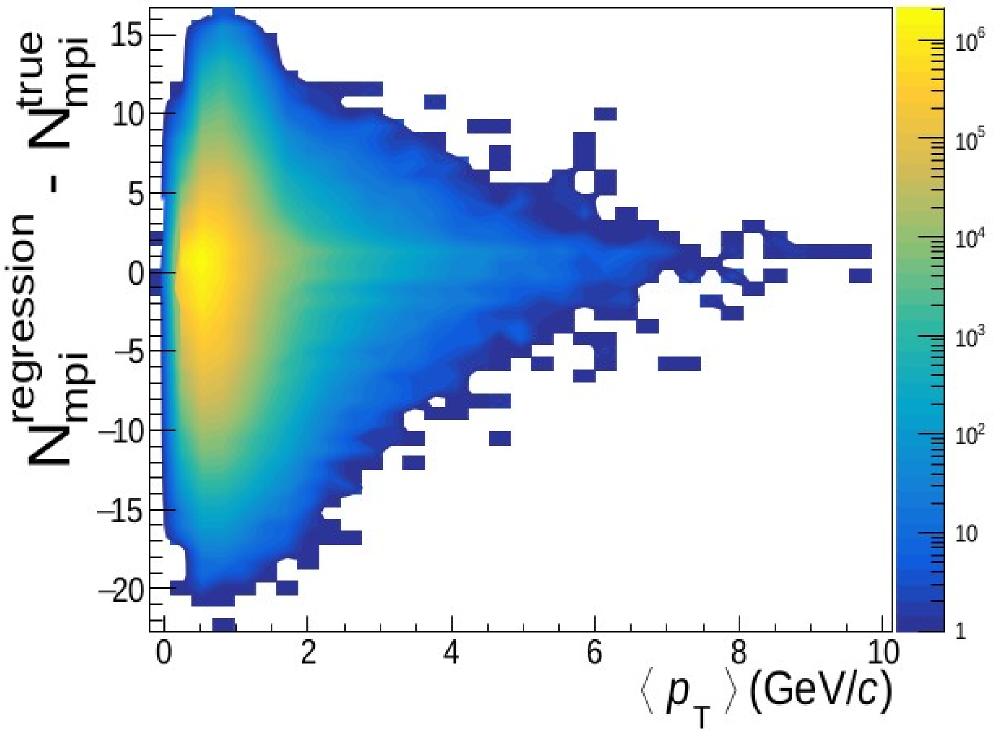
Analysis: extraction of N_{mpi}

Training and Test

Deviation between target variable and true value



(a) Entrenamiento



(b) Prueba

Analysis: extraction of N_{mpi}

Training and Test

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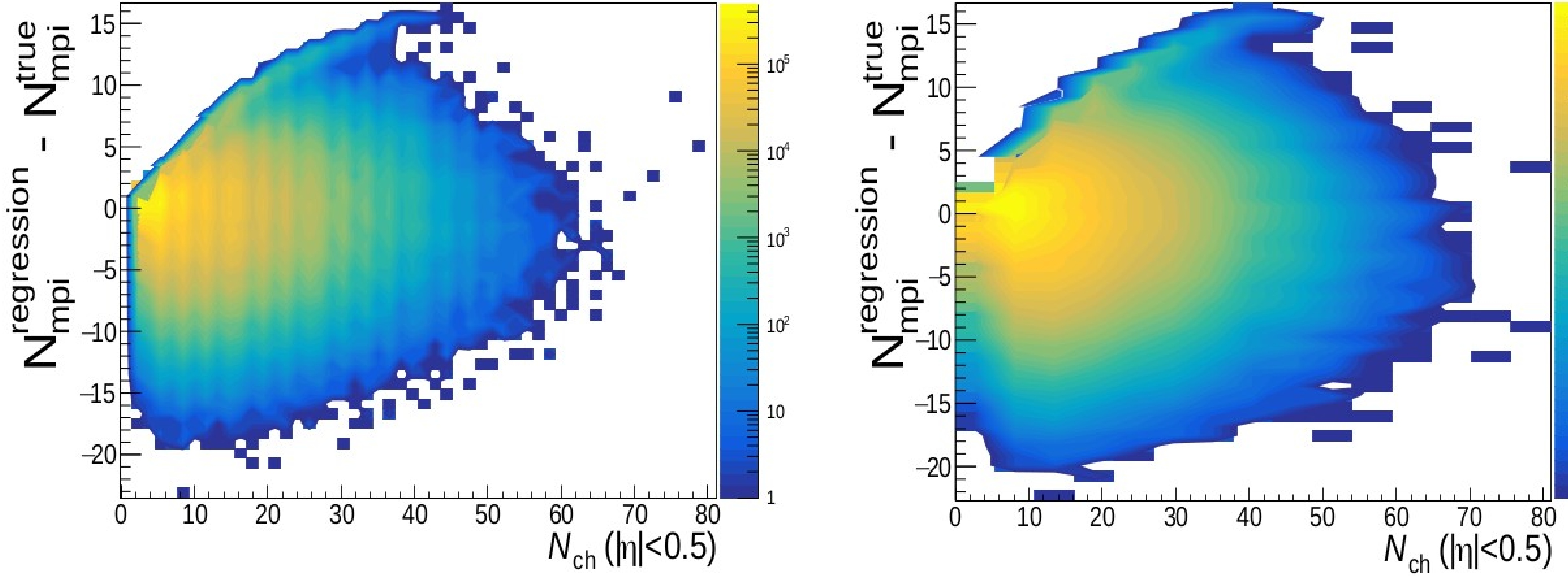

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Analysis: extraction of N_{mpi}

Monte Carlo Validation

- BDT were trained with the 2C, 4C and Monash 2013 PYTHIA 8 models, and HERWIG 7 Soft Tune

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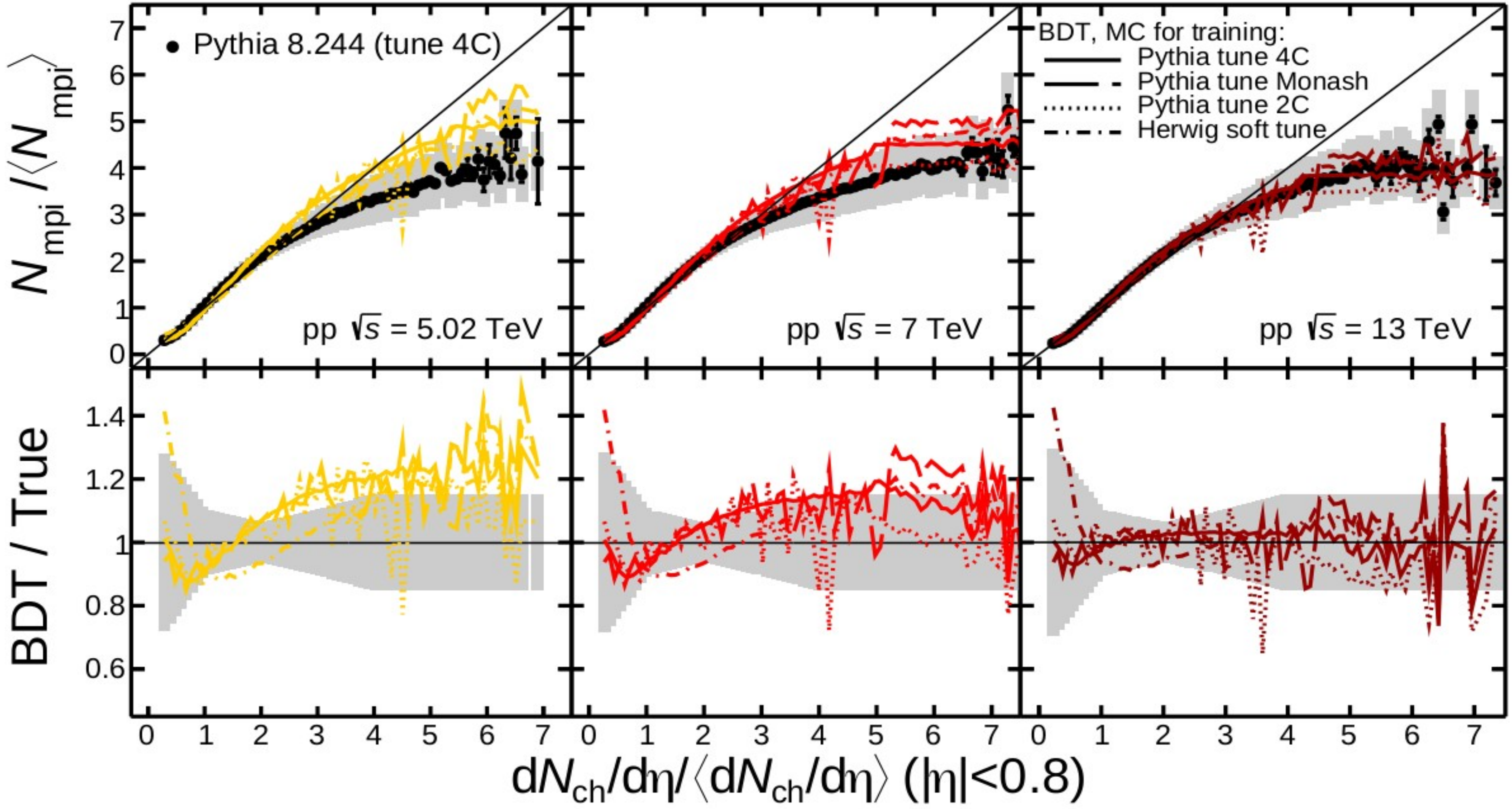
Validation consisted in comparing the BDT results with the information provided by PYTHIA 8 Tune 4C

Analysis: extraction of N_{mpi}
Monte Carlo Validation



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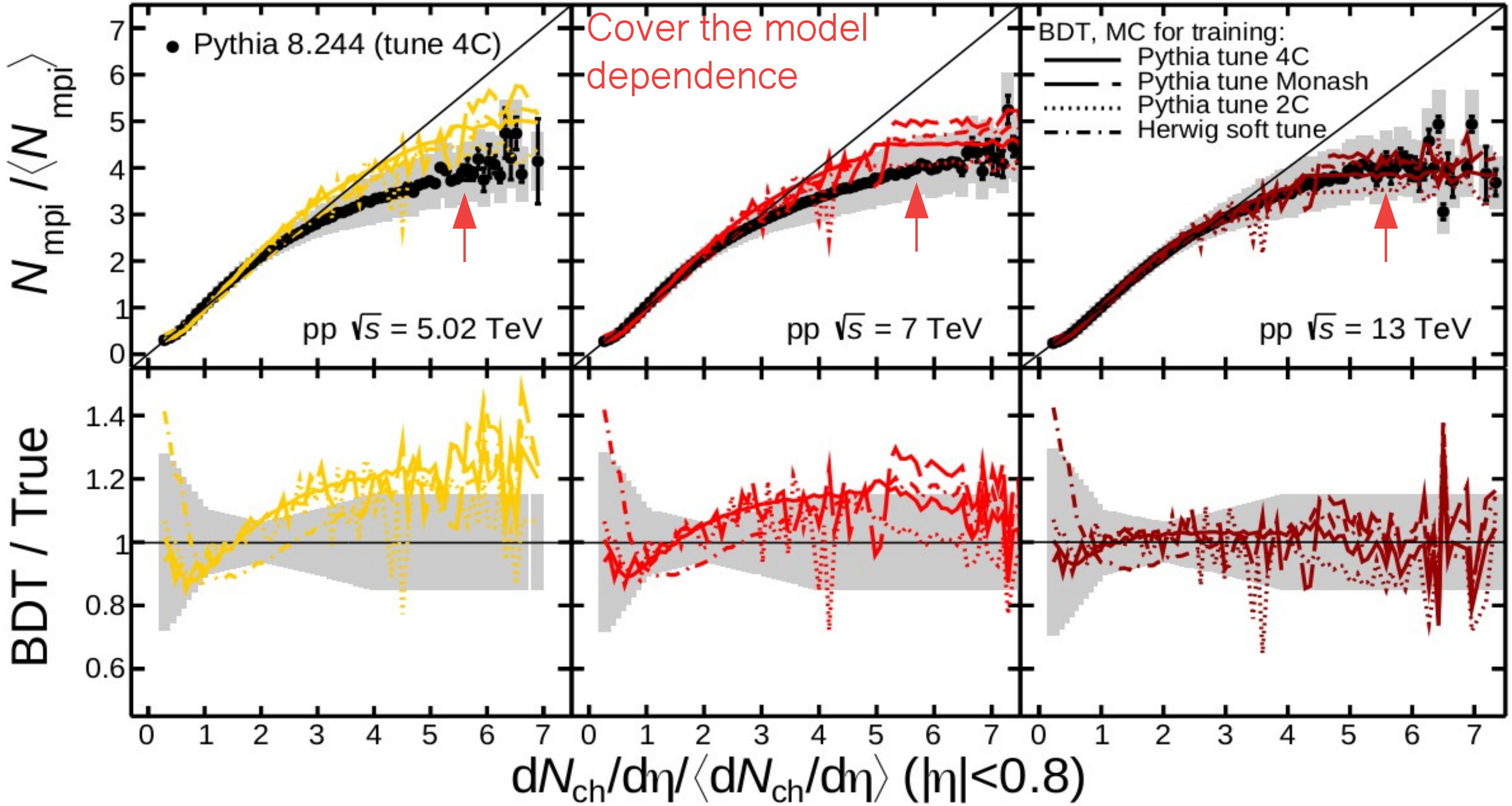

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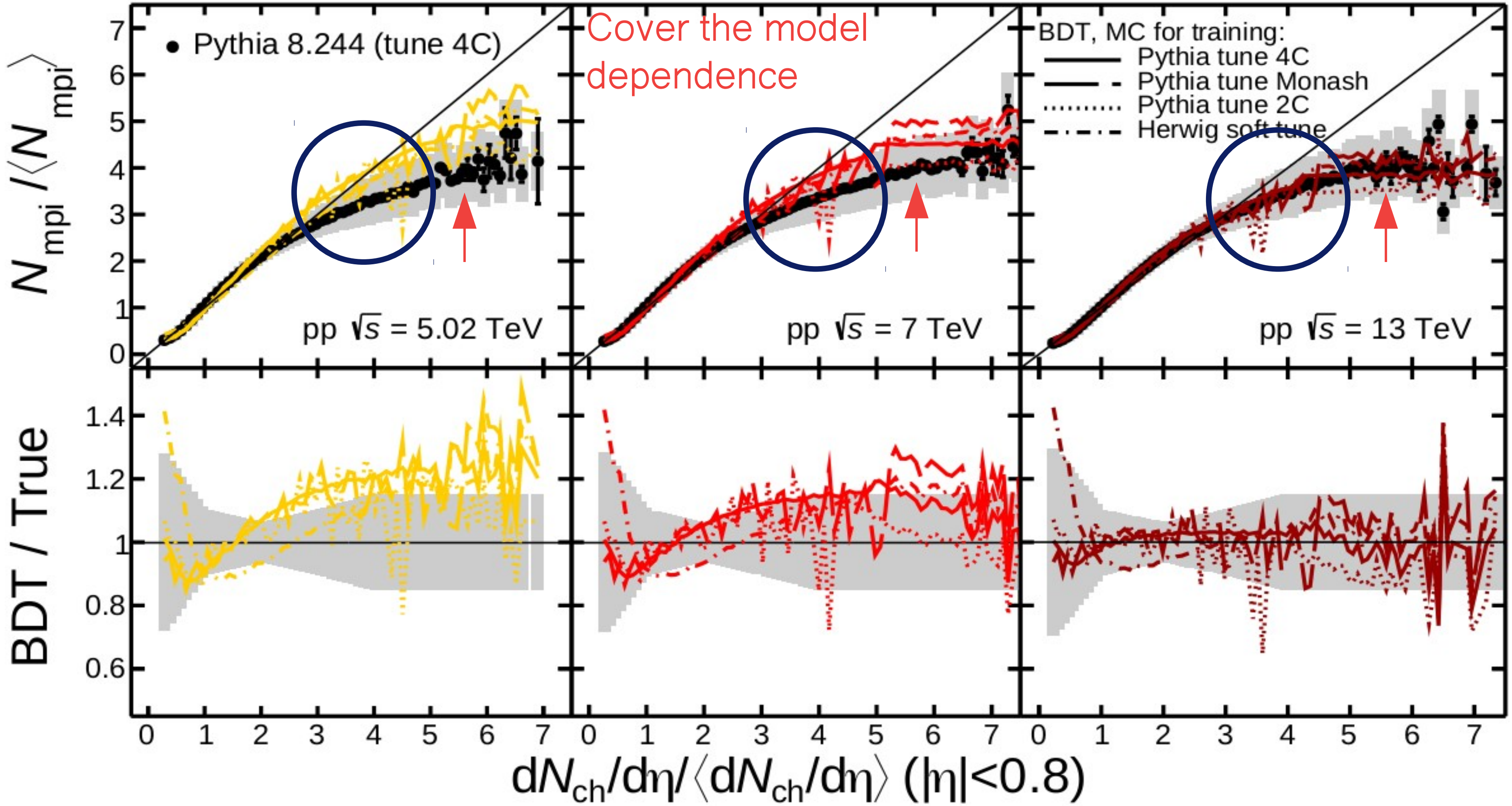

For higher multiplicities, we observe a deviation with respect to the linear trend

Analysis: extraction of N_{mpi}
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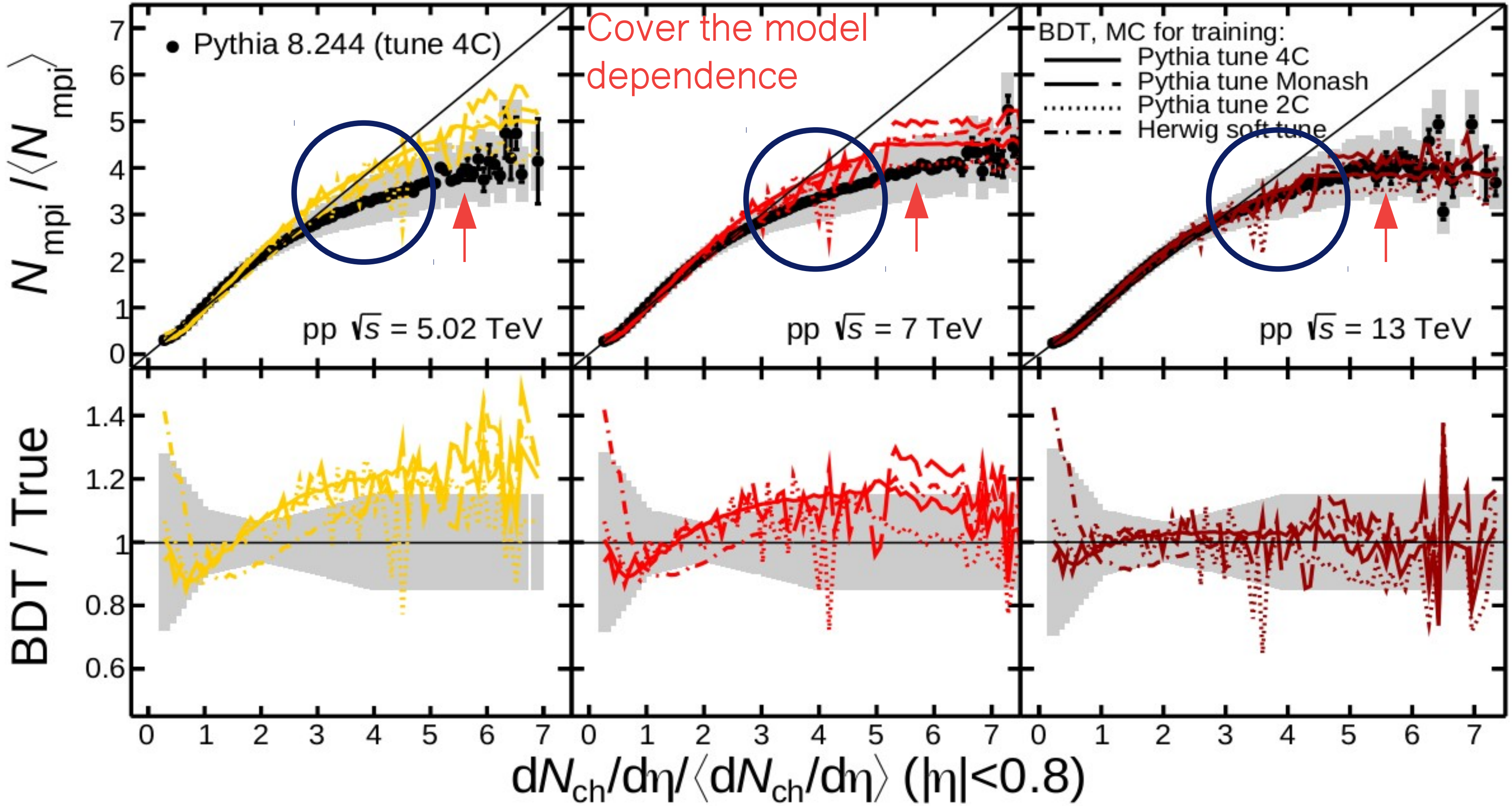

For higher multiplicities, we observe a deviation with respect to the linear trend

Compatible with

A. Ortiz et al.Journal of Physics G: Nuclear and Particle Physics, 44(6):065001, Apr 2017

High multiplicity pp collisions can only be produced selecting high multiplicity jets

Analysis: extraction of N_{mpi}
Data processing

MC generator: C++ program inside ROOT

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1. Each event class was simulated considering its multiplicity spectrum following a Poisson distribution

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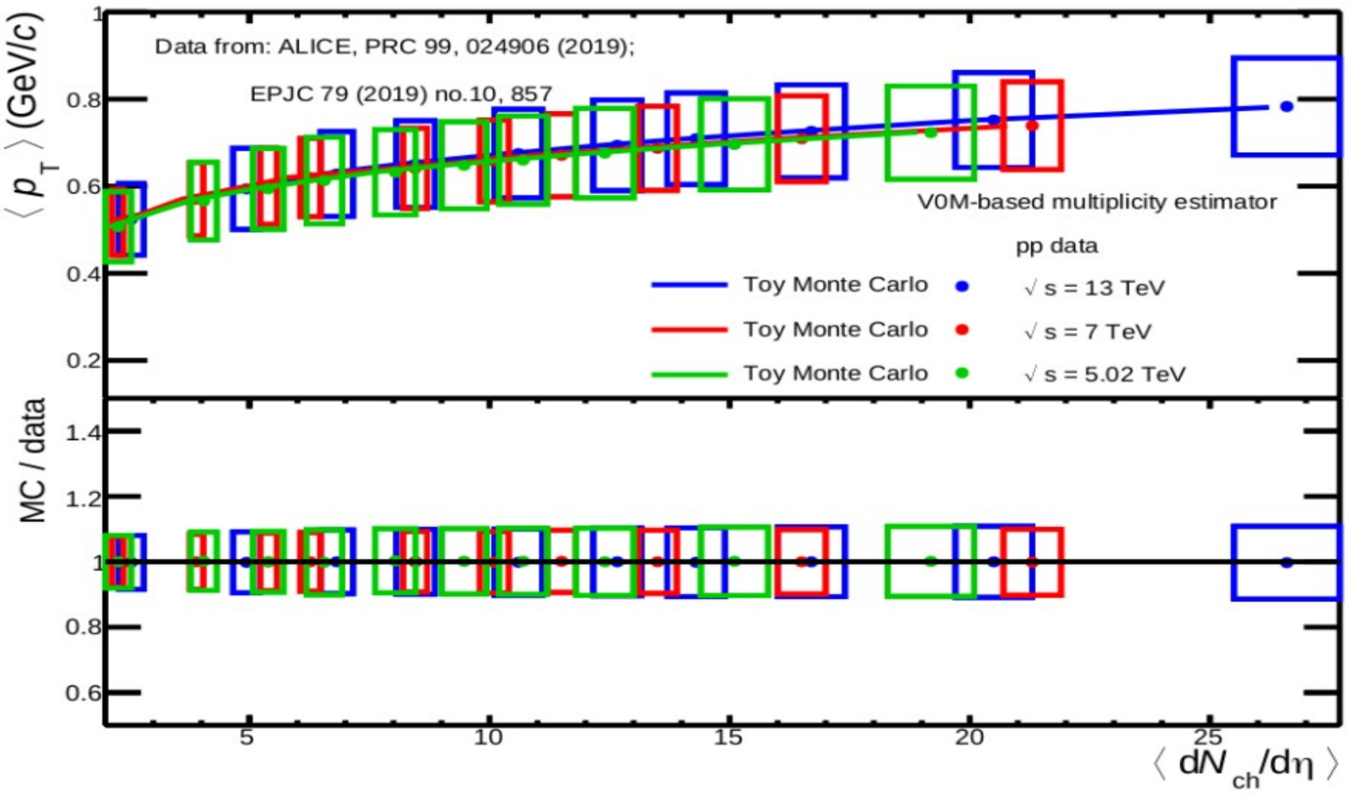
3. In a particle loop the p_T was randomly extracted

4. In each event the $\langle p_T \rangle$ was calculated

Analysis: extraction of N_{mpi}

Data processing



Results: average number of MPI

Using the BDT, we estimated the average number of multiparton interactions $\langle N_{mpi} \rangle$ from ALICE pp collisions data at $\sqrt{s}$ = 7 TeV.

We found $\langle N_{mpi} \rangle = 3.98 \pm 1.01$

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Complements our result for
$\sqrt{s}$ = 5.02 and $\sqrt{s}$ = 13 TeV

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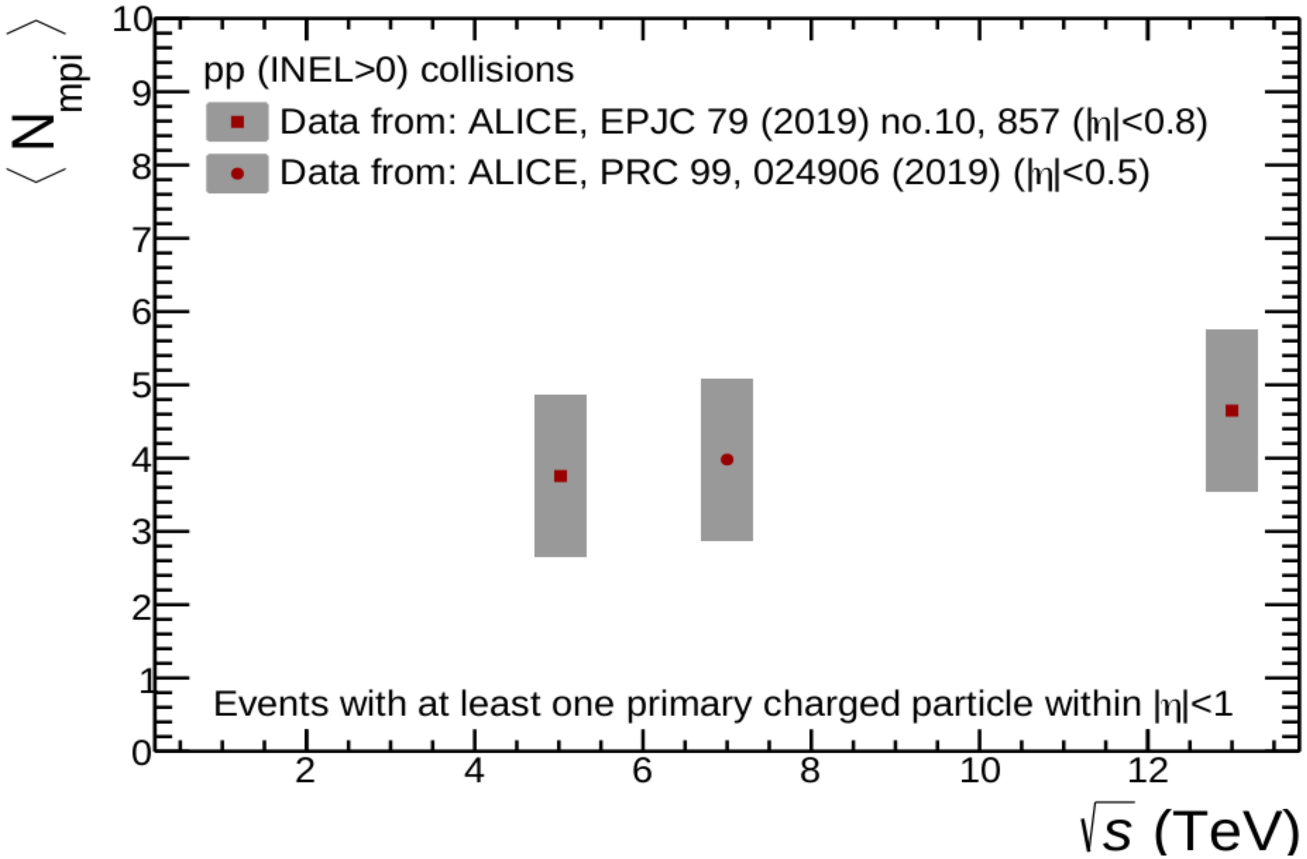

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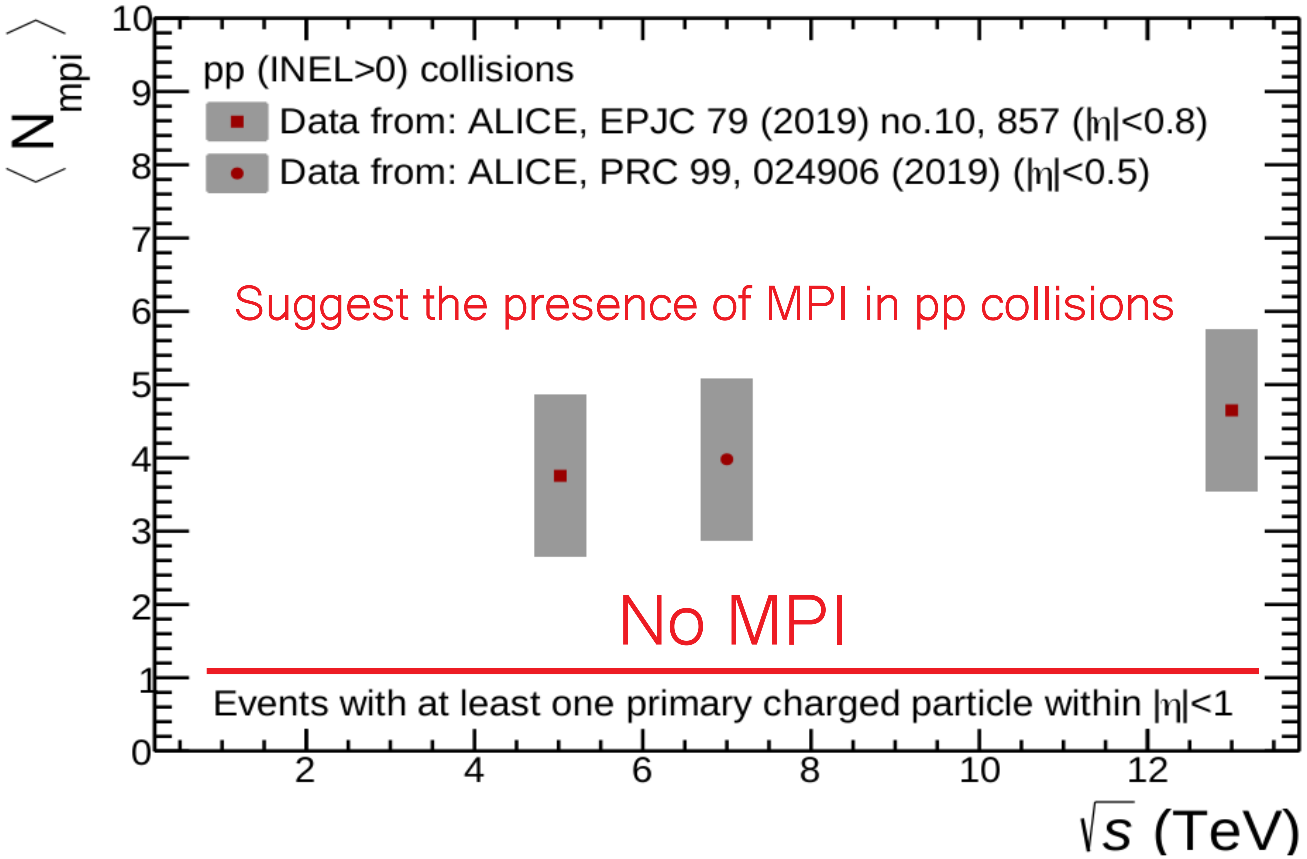

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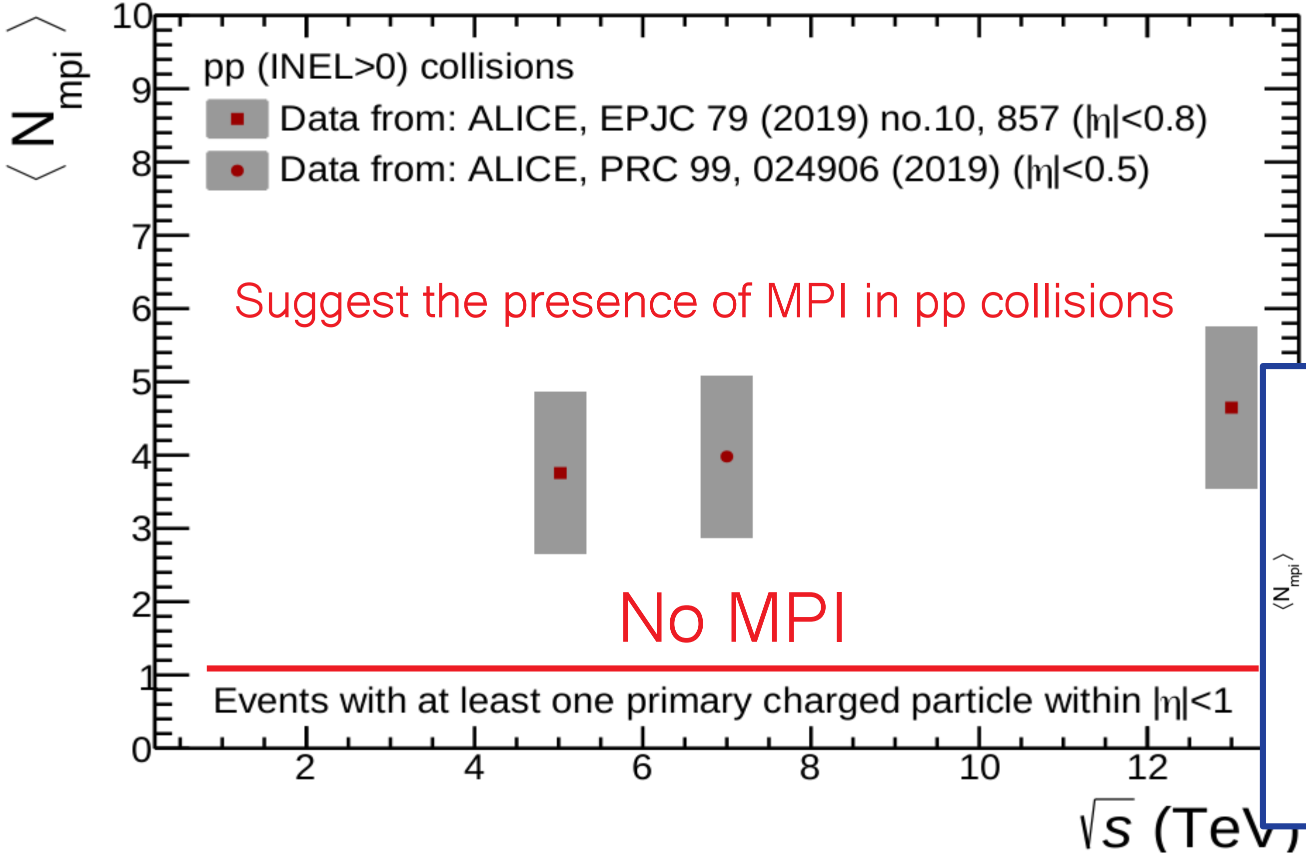
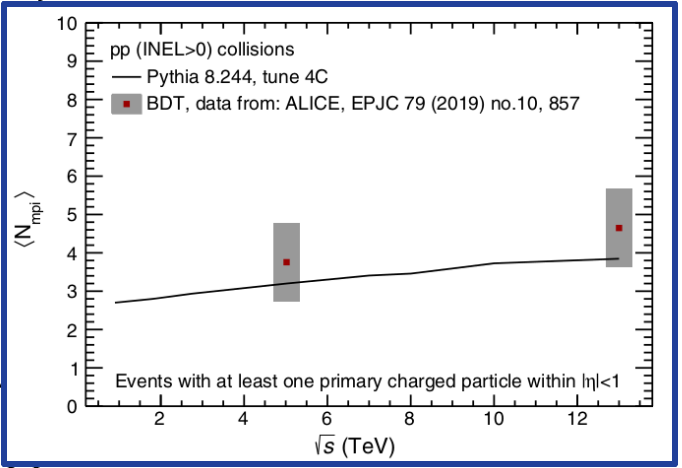


Energy dependence similar to PYTHIA 8 Tune 4C



Results: multiplicity dependence of $\langle N_{mpi} \rangle$

We extend our last study reported on

Antonio Ortiz, Antonio Paz, José D. Romo, Sushanta Tripathy, Erik A. Zepeda, and Irais Bautista, Phys. Rev. D 102, 076014

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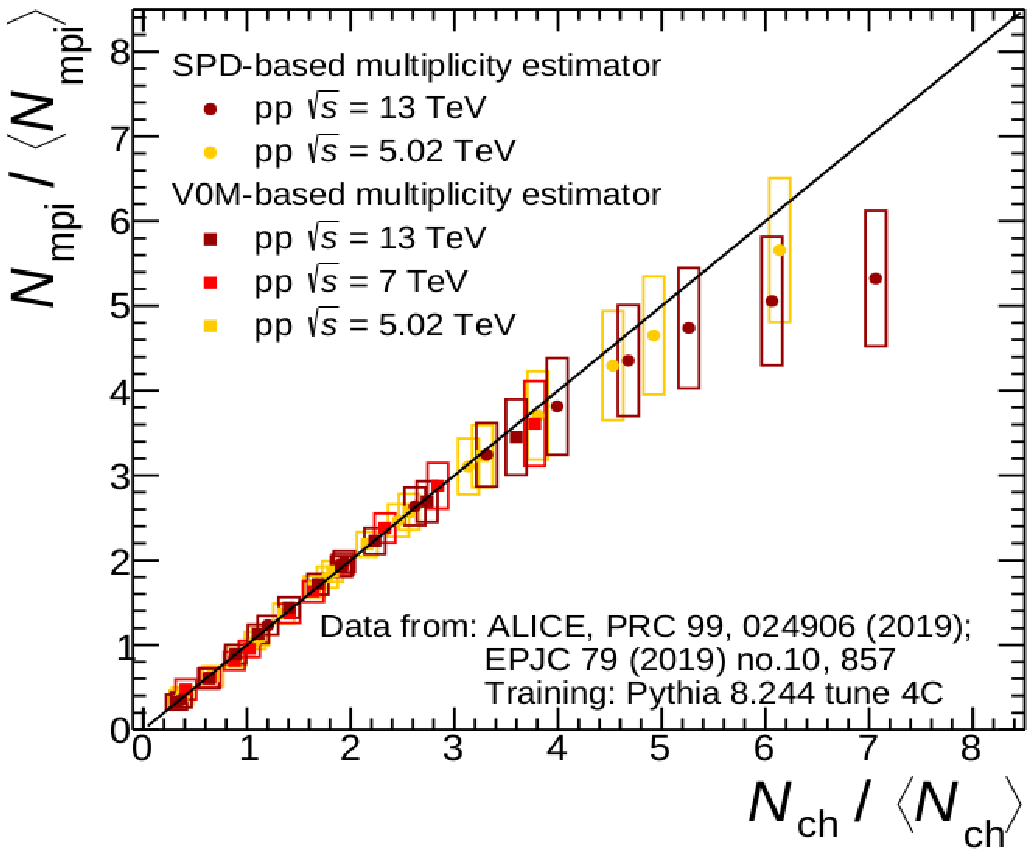

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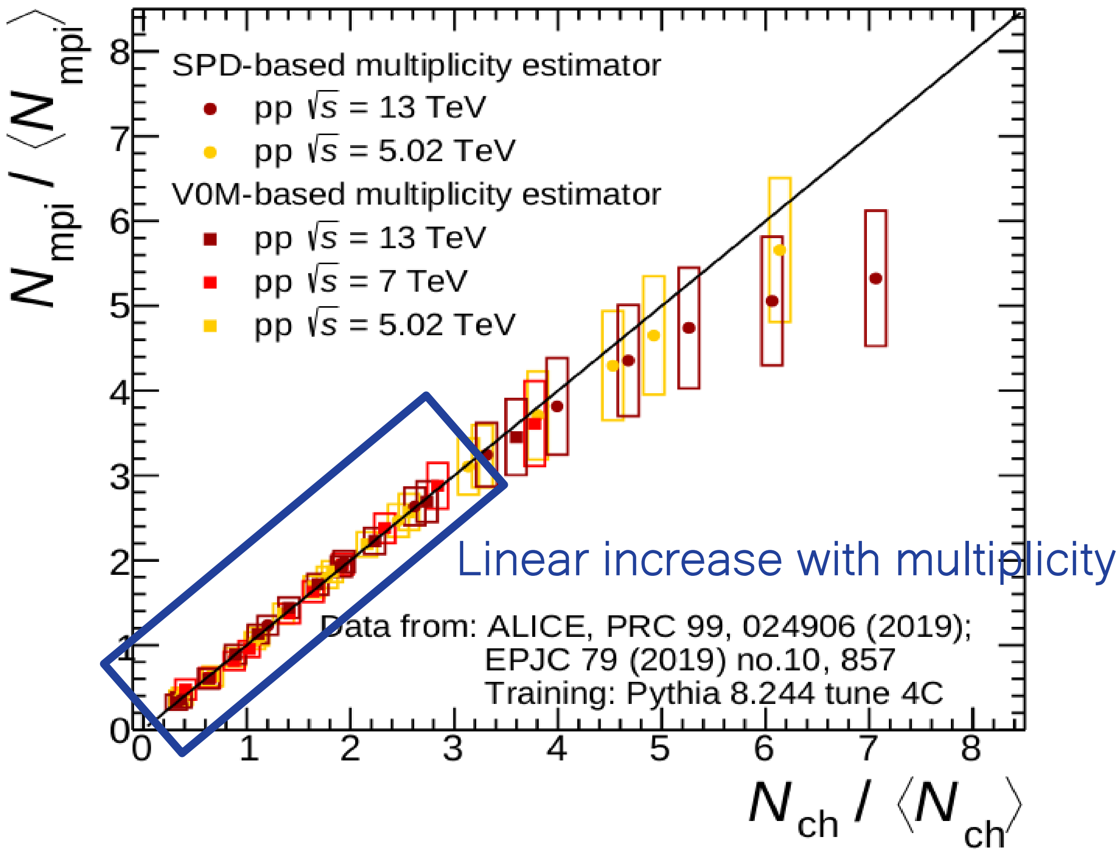

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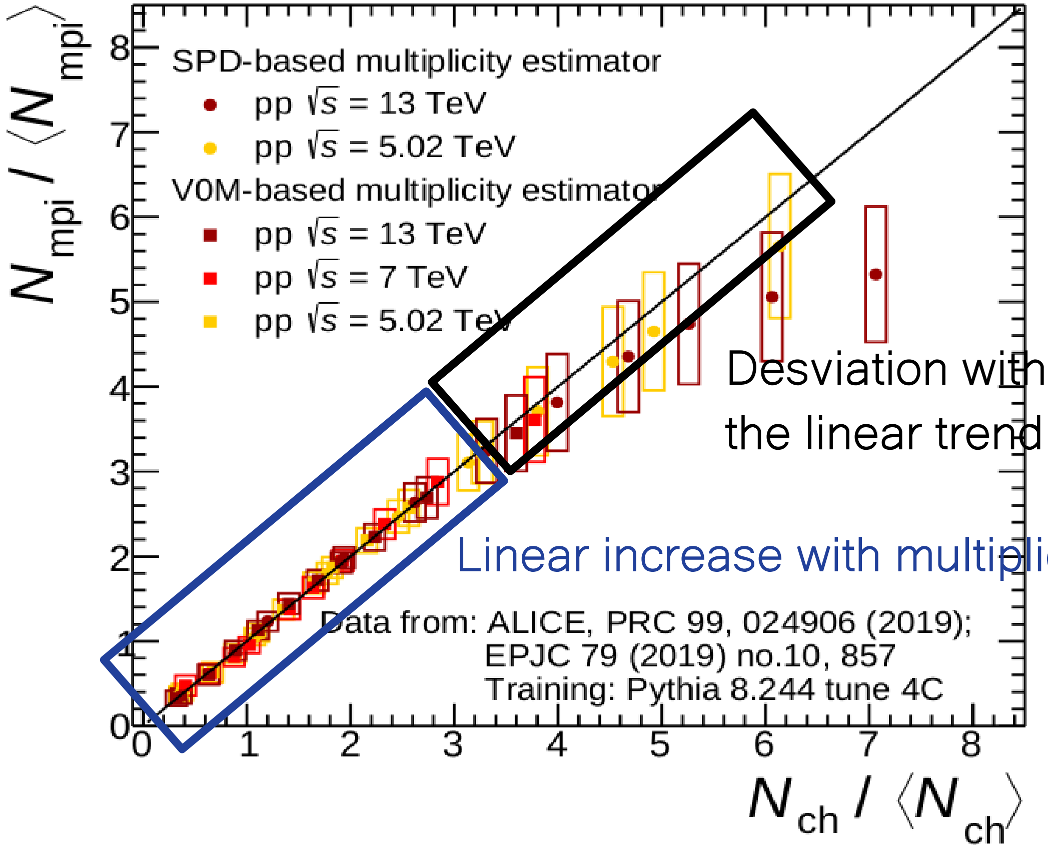
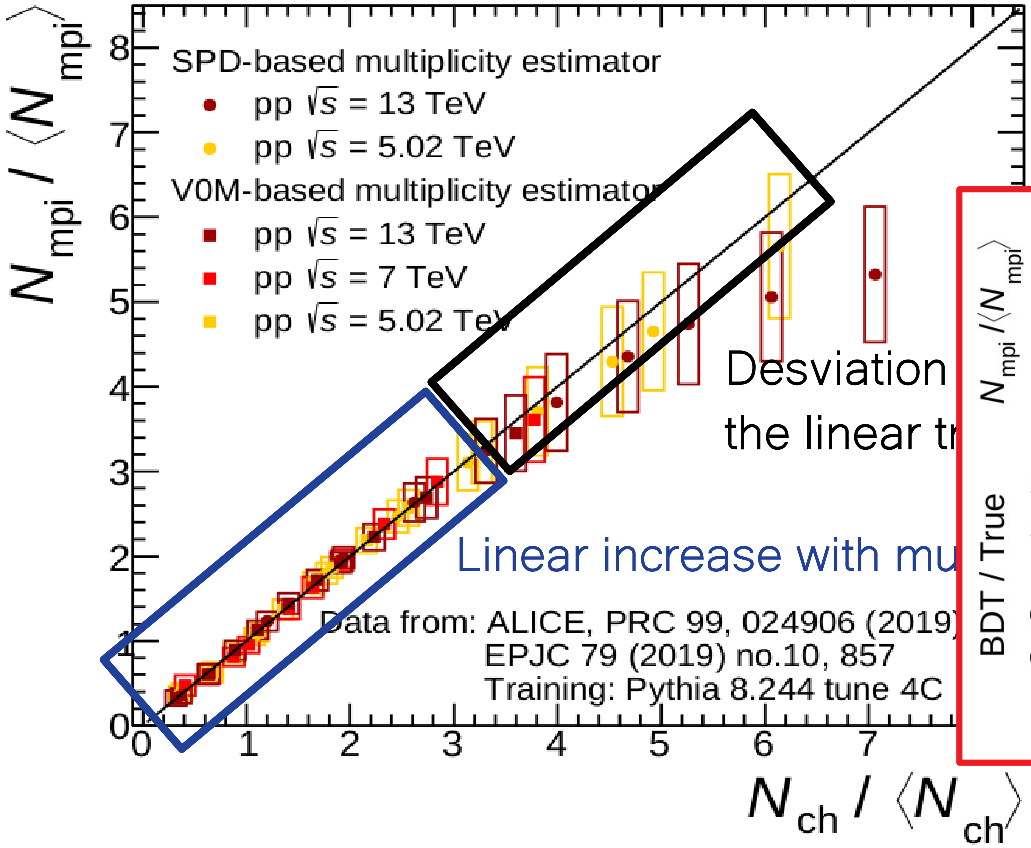


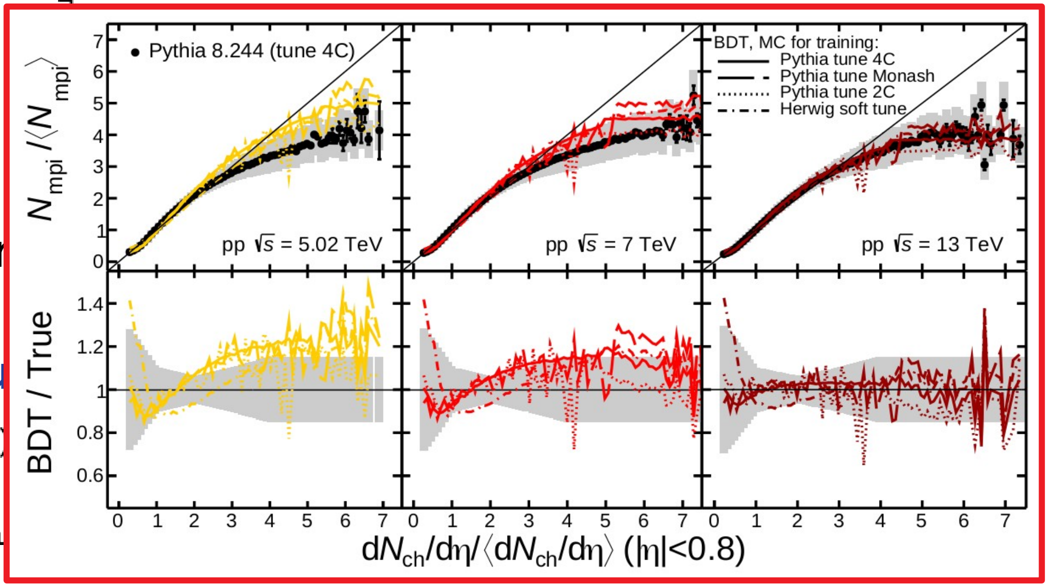
Desviation with respect to the linear trend

Linear increase with multiplicity

Results: multiplicity dependence of $\langle N_{mpi} \rangle$



Consistent with PYTHIA simulations



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Results: multiplicity dependence of $\langle N_{mpi} \rangle$

Our result is compared with
the ALICE collaboration analysis

B. Abelev et al.
JHEP, 09:049, 2013.

In Pythia context $N_{\text{uncorrelated seeds}}$ is defined, which provides information about the number of semi-partonic interactions by event

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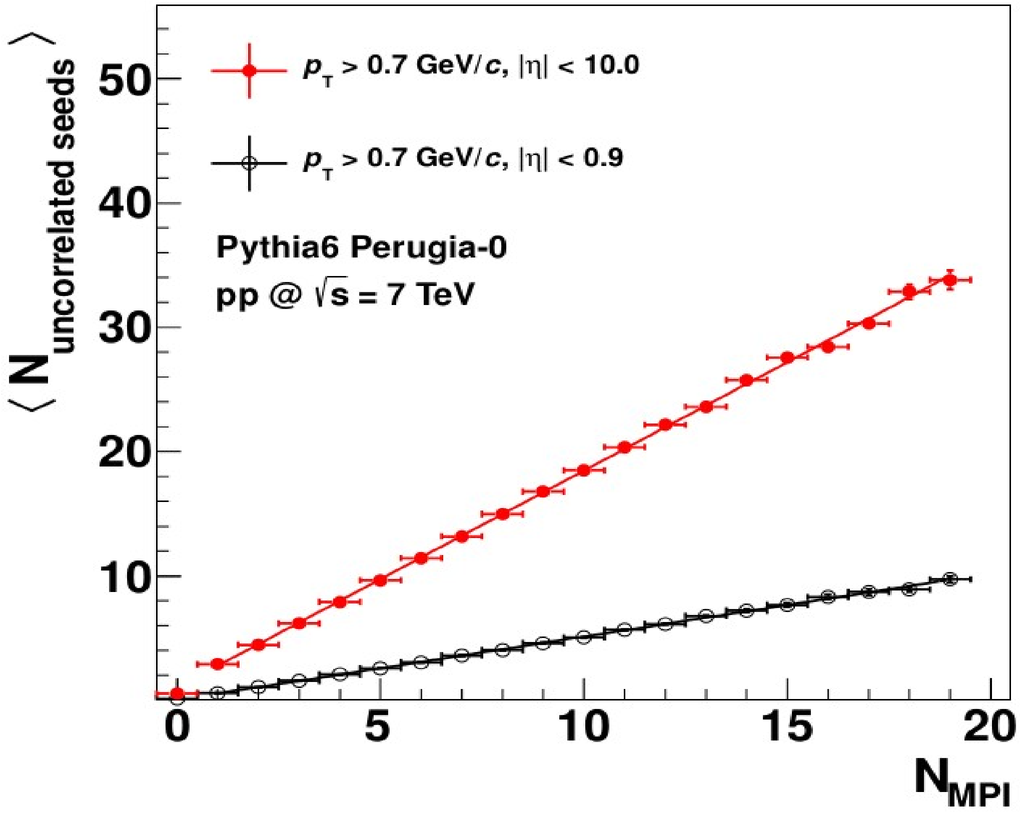

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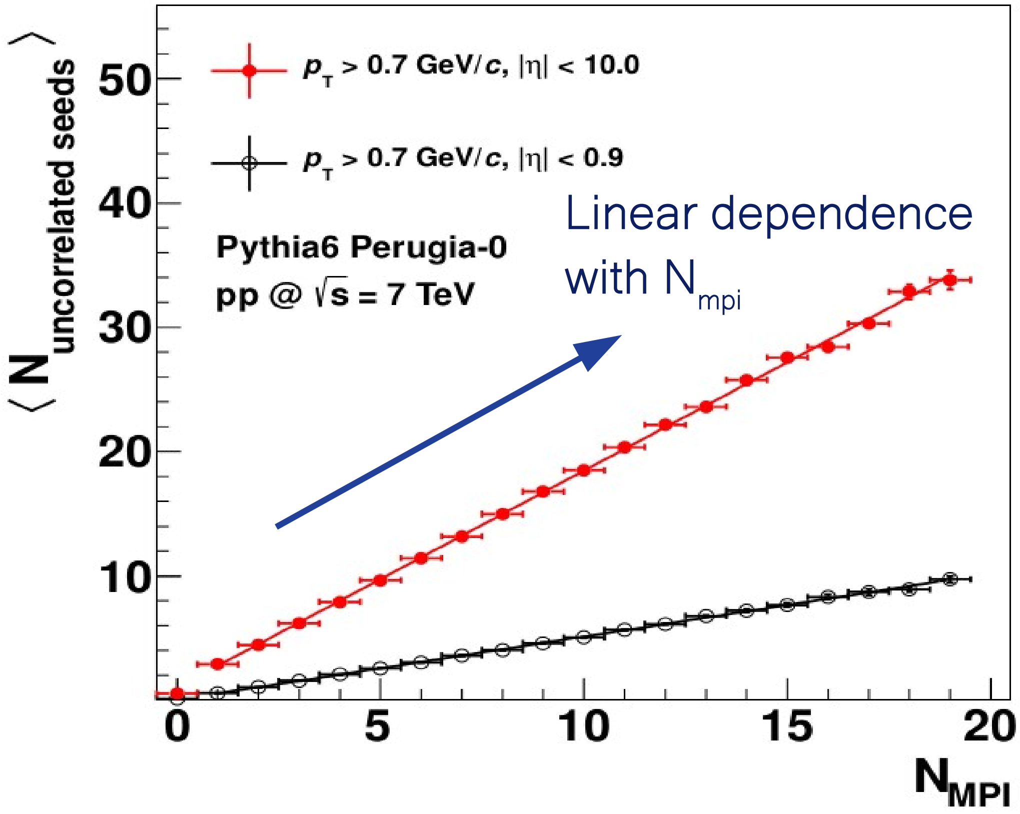

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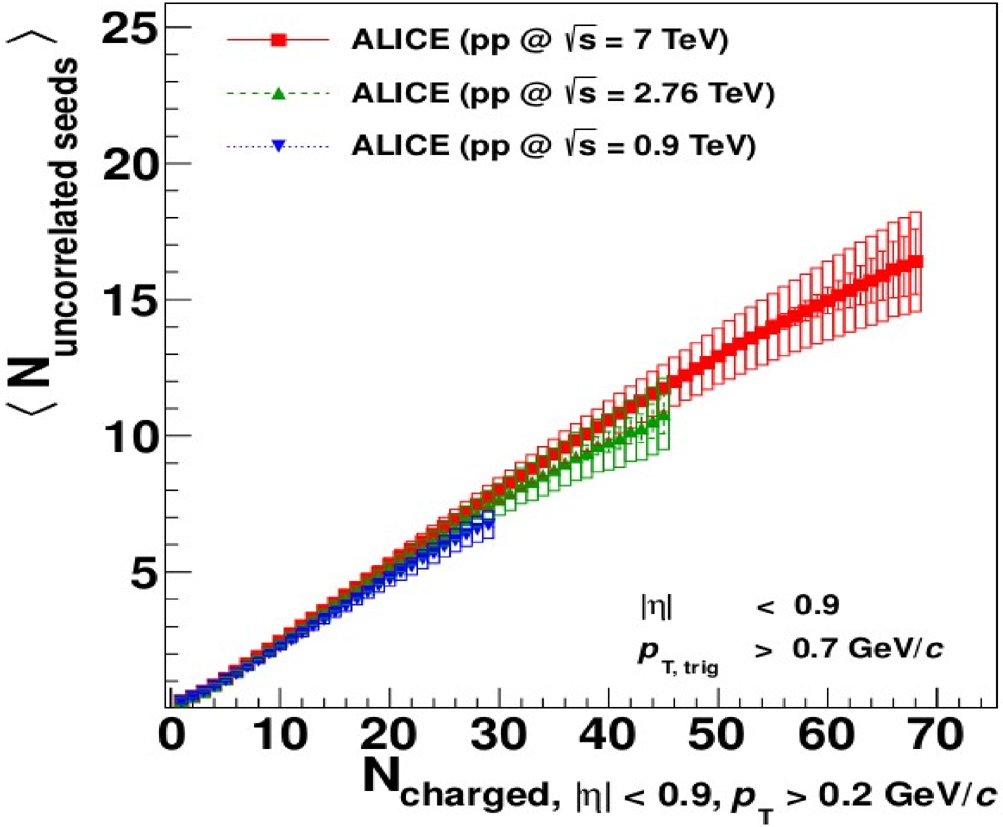

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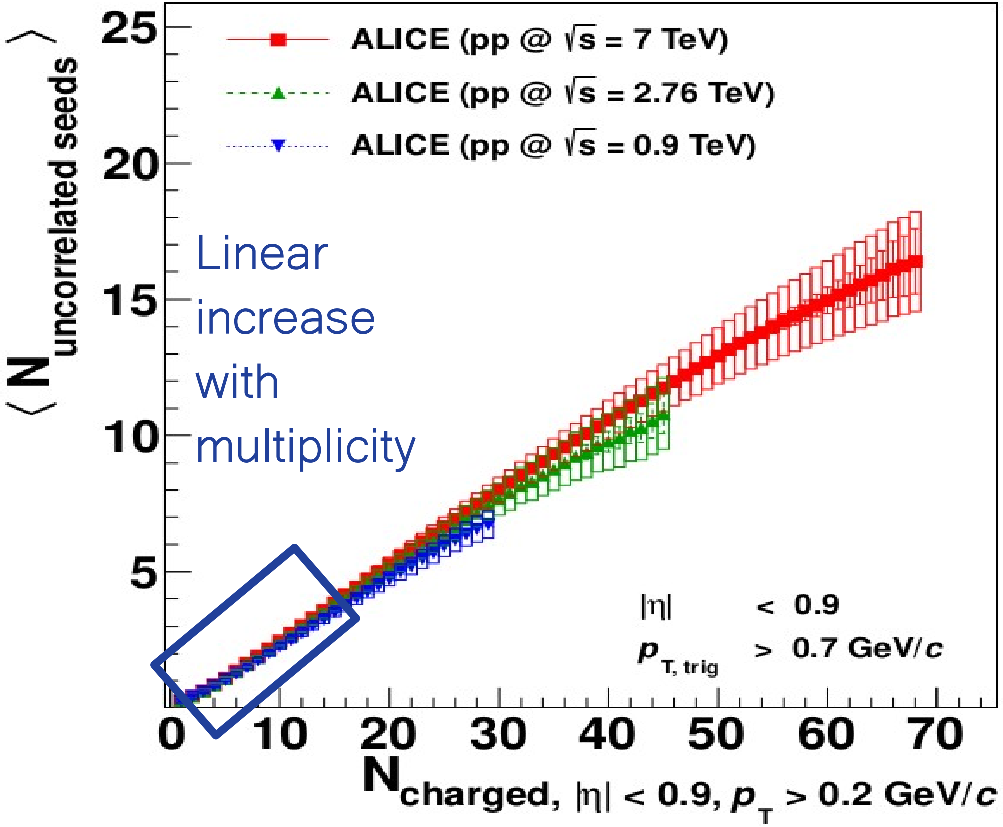

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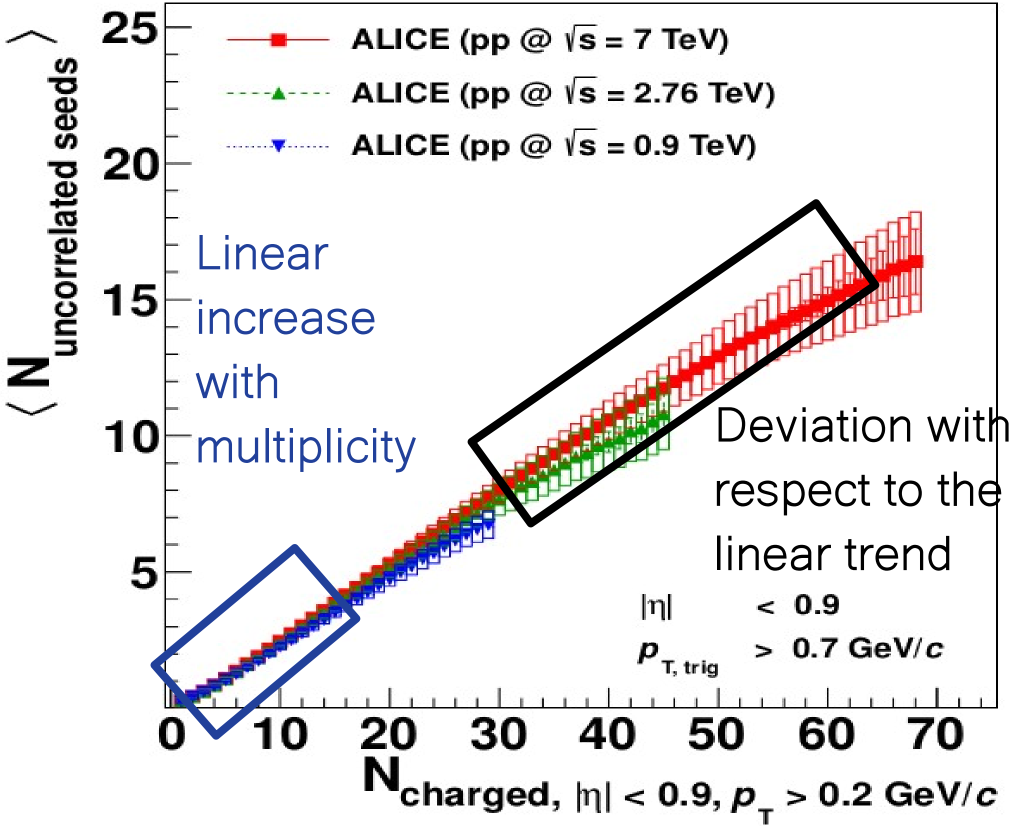
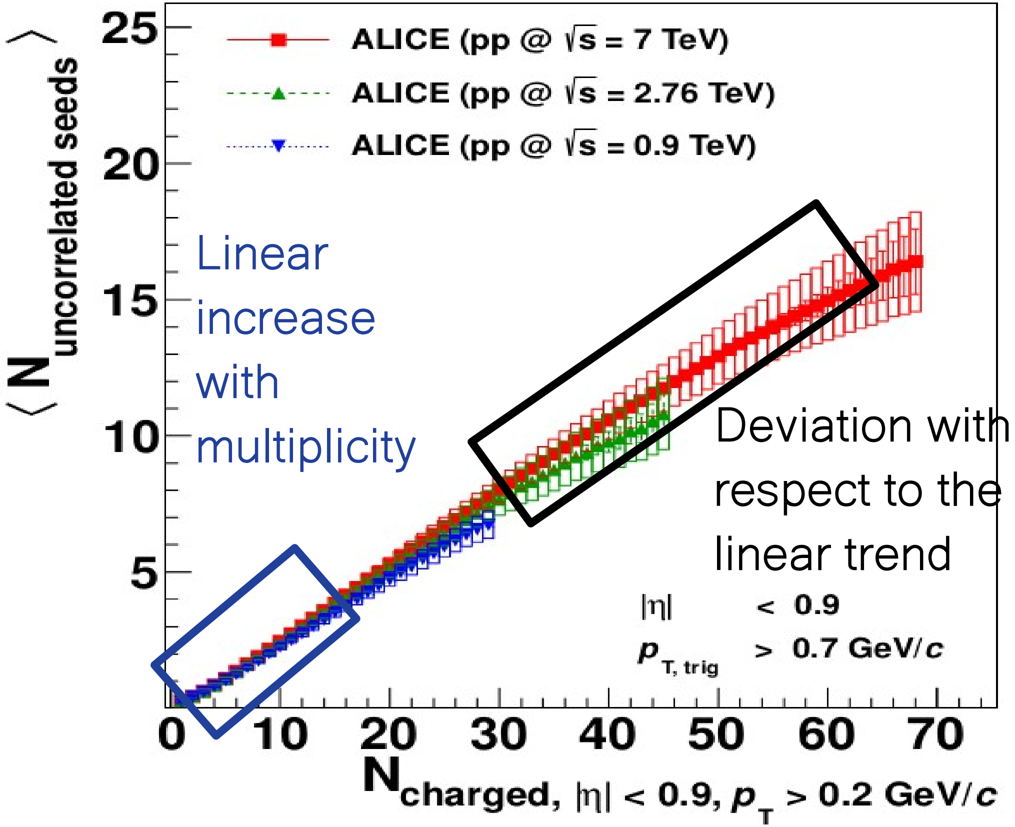


Results: multiplicity dependence of $\langle N_{mpi} \rangle$



Completely compatible with our results!

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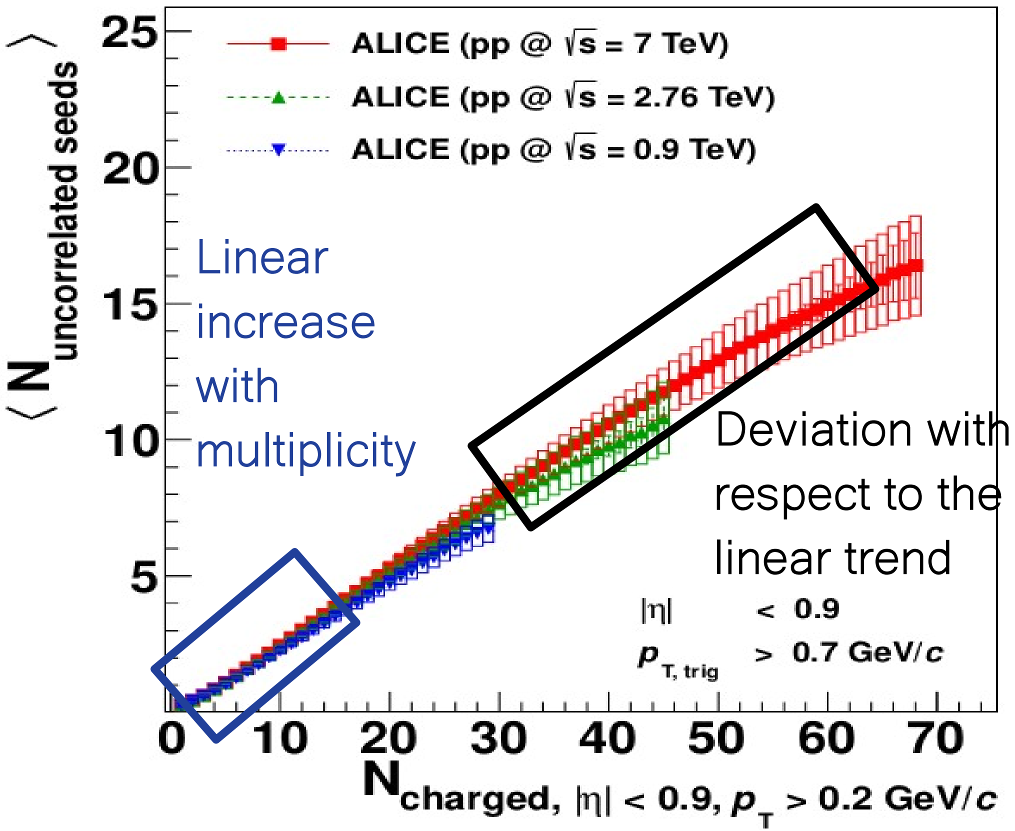

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High multiplicity can only be reached selecting events with high multiplicity jets

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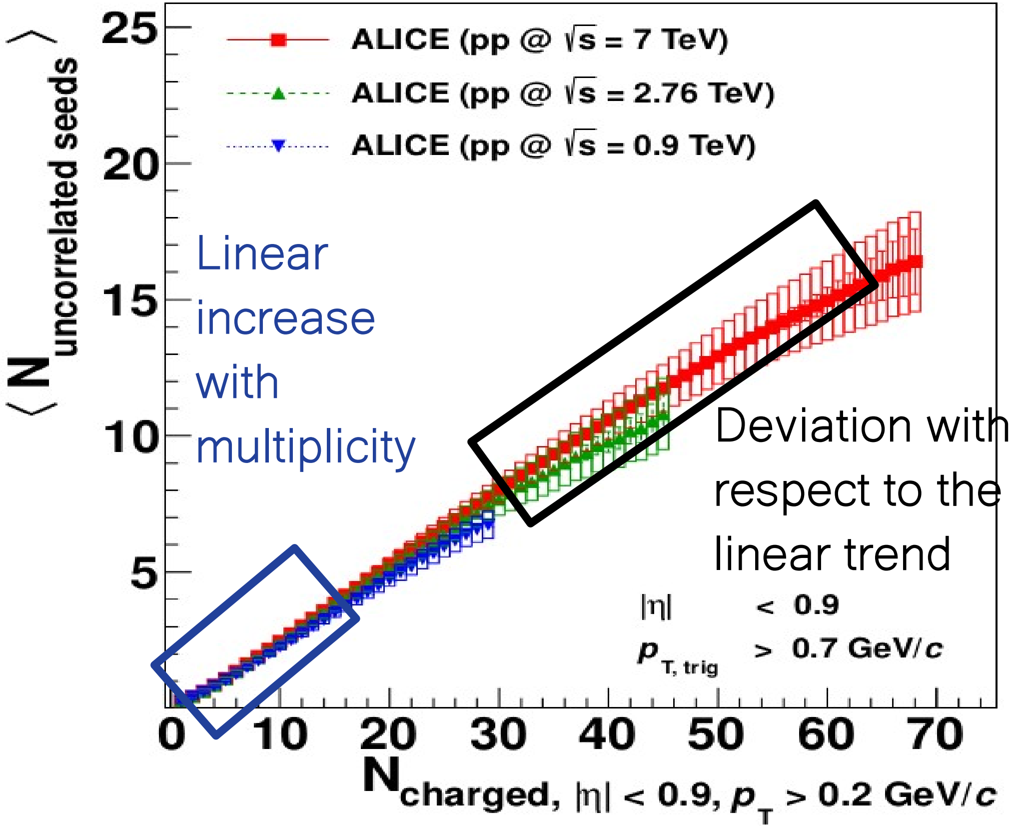

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High multiplicity can only be reached selecting events with high multiplicity jets

This characteristic is explained as a selection bias.

Results: future outlook

- We propose to include more information in the BDT training, in order to determine if the N_{mpi} extraction improves

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W. Henryk. New ALICE detectors for run 3 and 4 at the CERN LHC. 958:162116, 2020

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ALICE Run3 MFT+V0+: Multiplicity computed in the forward regions $-3.6 < \eta < -2.45$ and $2.2 < \eta < 5.1$ which cover the MFT and VZERO+ detectors

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  if the N_{mpi} ext

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  collisions da
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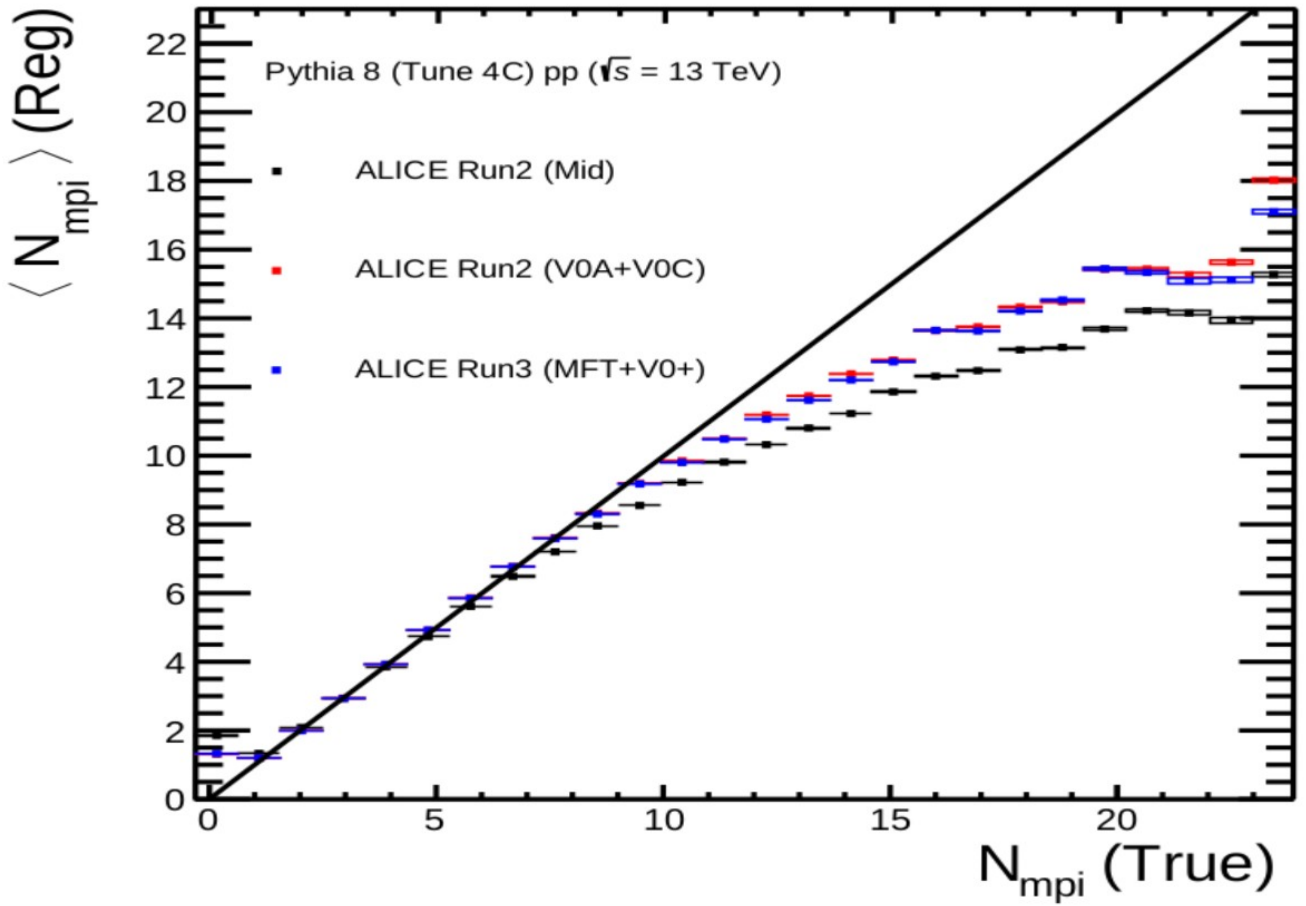

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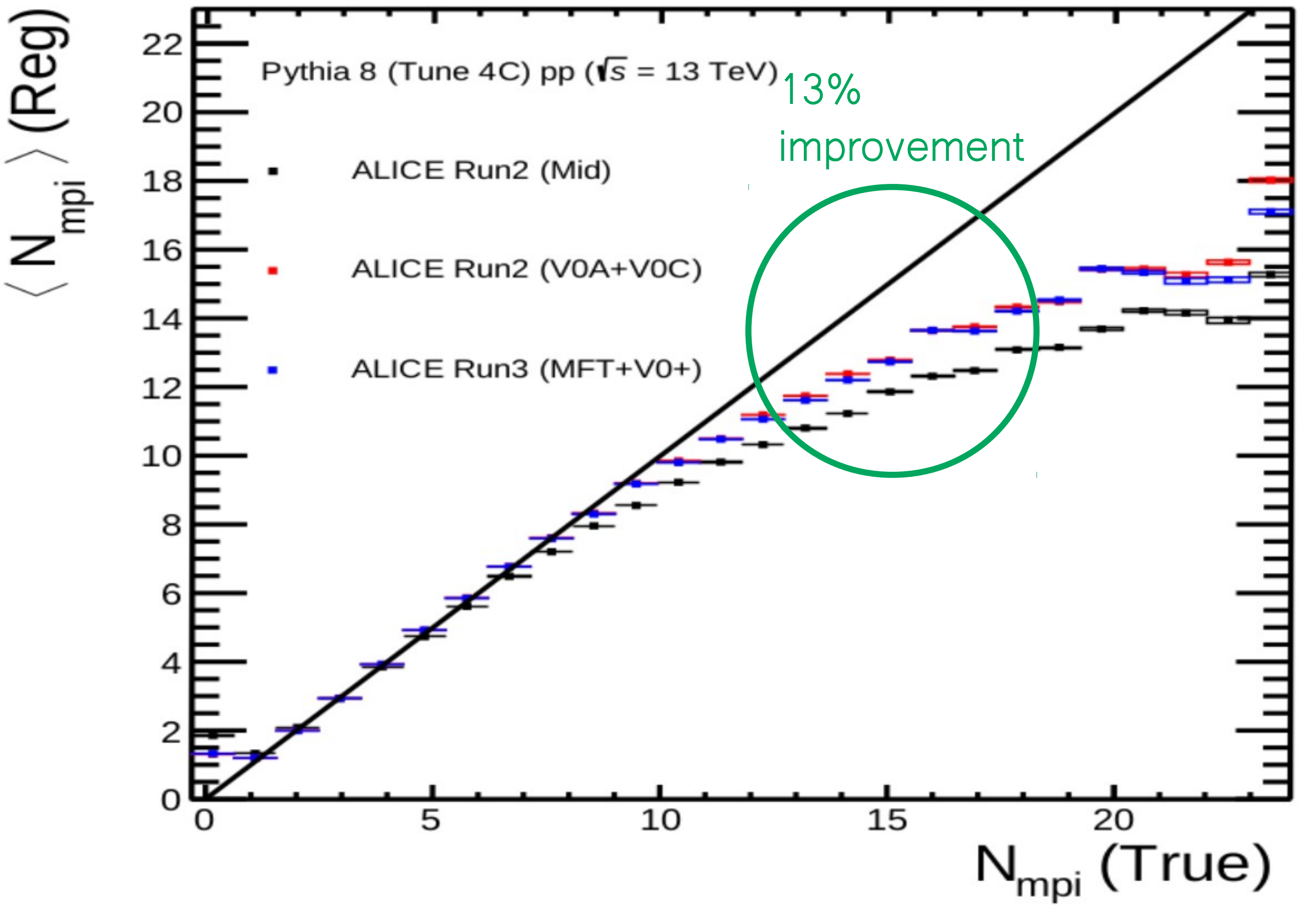

The extraction of N_{mpi} improves considering more information in the training

Conclusions

- Using the ALICE data which consist on transverse momentum spectra as a function of event multiplicity for pp collisions at $\sqrt{s}$ = 7 TeV, we report $\langle N_{mpi} \rangle = 3.89 \pm 1.01$. Result being compared with $\langle N_{mpi} \rangle = 3.76 \pm 1.01$ and 4.65 ± 1.01 for $\sqrt{s}$ = 5.02 and 13 TeV, which shows low energy dependence consistent with PYTHIA. This result provides experimental evidence of MPI in hadronic interactions.

- Using the available ALICE pp collisions data, we reported $N_{mpi} / \langle N_{mpi} \rangle$ as a function of $N_{ch} / \langle N_{ch} \rangle$ for $\sqrt{s}$ = 5.02, 7 and 13 TeV. For $N_{ch} / \langle N_{ch} \rangle < 3$ we observe a linear increase , while for $N_{ch} / \langle N_{ch} \rangle > 4$ a deviation with respect to the linear trend. This result is consistent with the ALICE collaboration analysis.

Conclusions

- The extraction of N_{mpi} improves considering more information in the BDT training, computing the multiplicity in the forward region. Which opens the posibility to extract the number of MPI event by event and in this way, study the particle production as a function of MPI.

- Based on verifications performed with Monte Carlo event generators, and in the agreement of our results with the ALICE collaboration measurements. Our approach is robust and can be used by experiments in order to study the particle production as a function of MPI. This can help to the understanding of heavy ion-like features observed in pp collisions data.