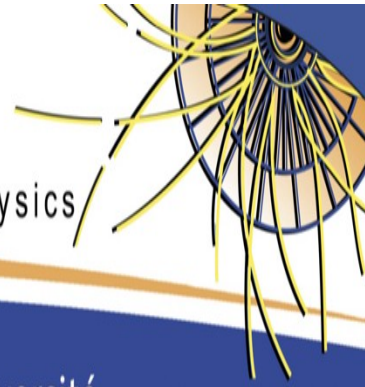


D. Longhena LHCsb 2021

# LHCP2021

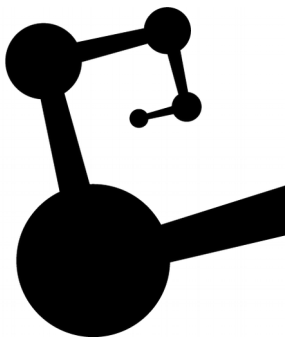
The Ninth Annual Conference on Large Hadron Collider Physics

7-12 June 2021 ~~Paris (France), Sorbonne Université (IN2P3/CNRS, IRFU/CEA)~~



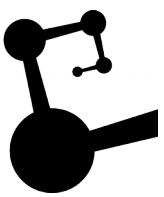
## Extraction of the multiplicity dependence of Multiparton Interactions from LHC pp data using Machine Learning techniques

Instituto de Ciencias Nucleares UNAM



Erik Zepeda and Antonio Ortiz

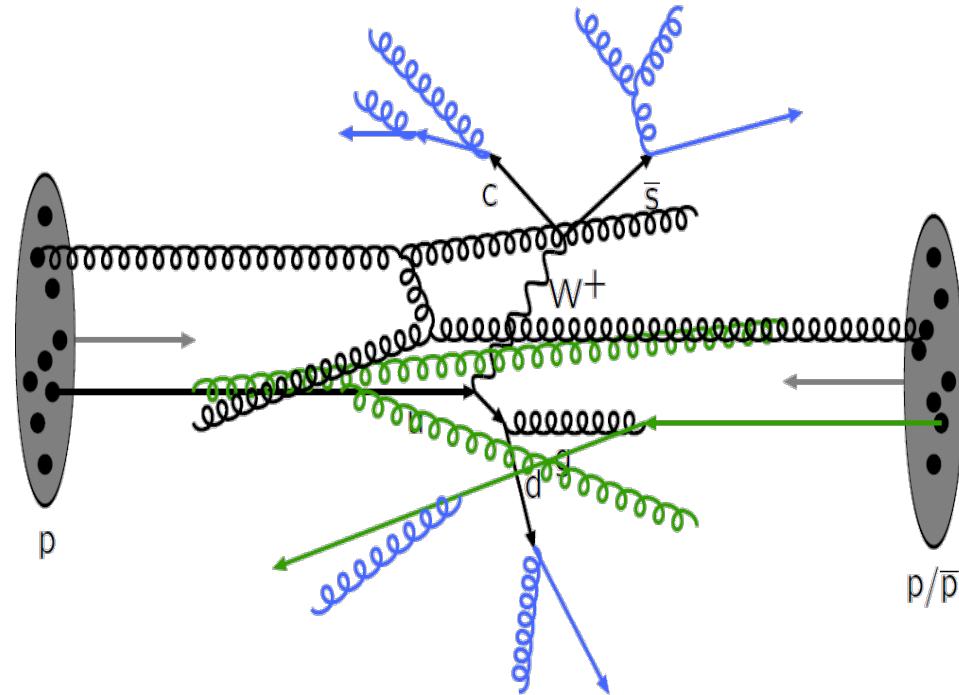
Based on: [J. Phys. G: Nucl. Part. Phys. 2021](#)



# Introduction



- Given the composite nature of hadrons, several parton-parton interactions (MPI) can occur within the same proton-proton collision (T. Sjöstrand, M. Zijl., *Phys.Rev. D* 36 (1987) 2019)



- MPI can help to elucidate the origin of collectivity in pp collisions (A. Ortiz et al., *Phys. Rev. Lett.* 111, 2013 4, 042001)

- In *Phys. Rev. D*, 102, 076014 (2020) we have proposed the extraction of MPI from minimum-bias pp data using Machine Learning (ML) methods

- In this work, we extract the multiplicity dependence of the number of MPI ( $N_{\text{mpi}}$ ) from the available ALICE data at the LHC

Figure taken from: Oxana Smirnova's Computing in High Energy Physics slides

# Machine Learning method



- Our approach relies on a multivariate regression technique based on Boosted Decision Trees (BDT)

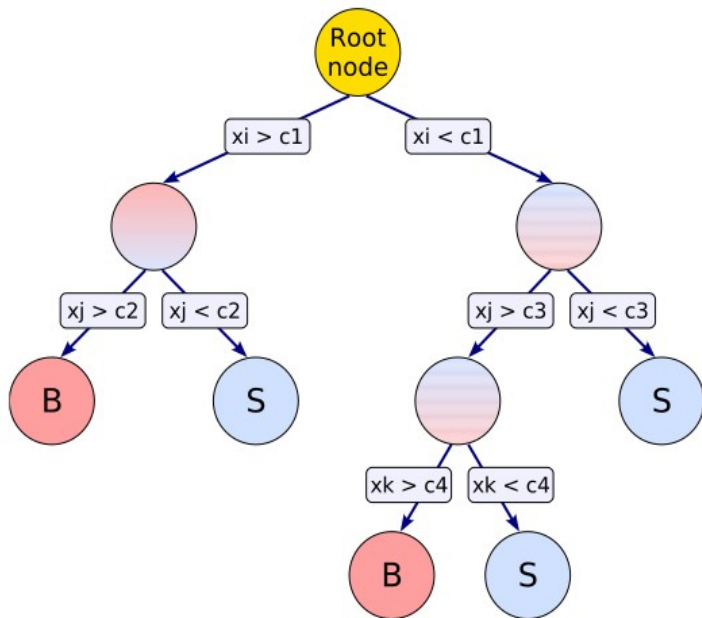


Figure taken from: A. Hocker, TMVA - Toolkit for Multivariate Data Analysis, Users Guide

- For training we consider event-by-event average transverse momentum and multiplicity  $N_{ch}$

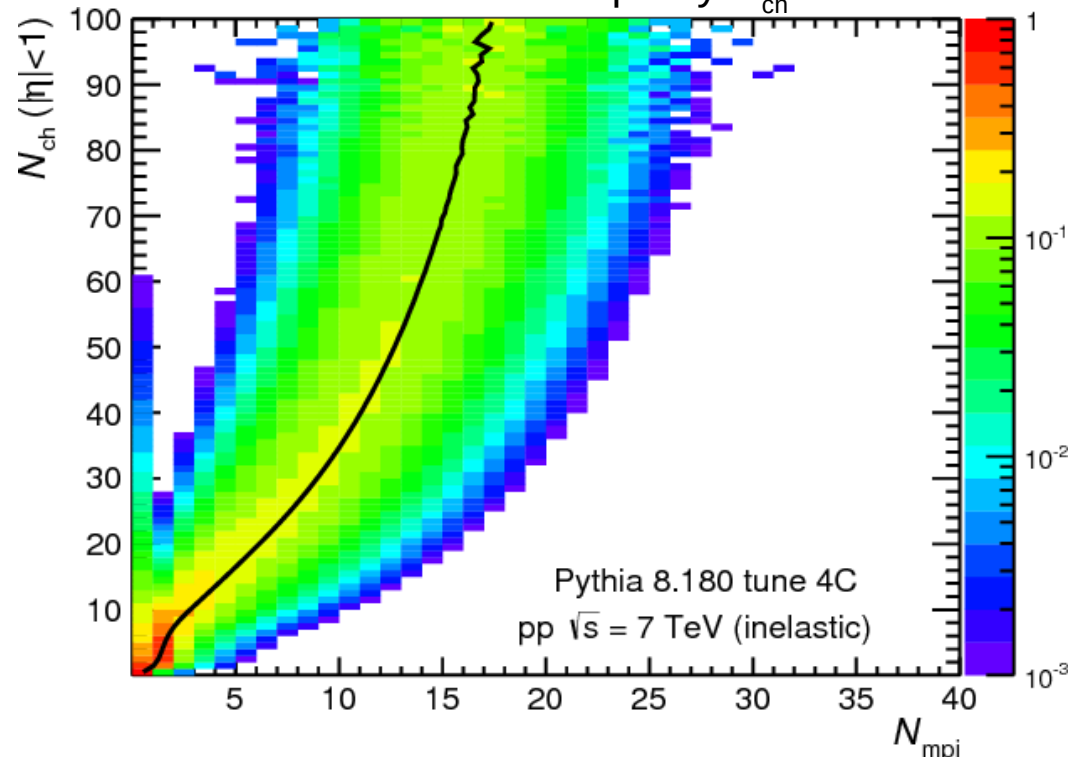


Figure taken from: A. Ortiz et al. Nucl. Phys. A, 941: 78-86 (2015)

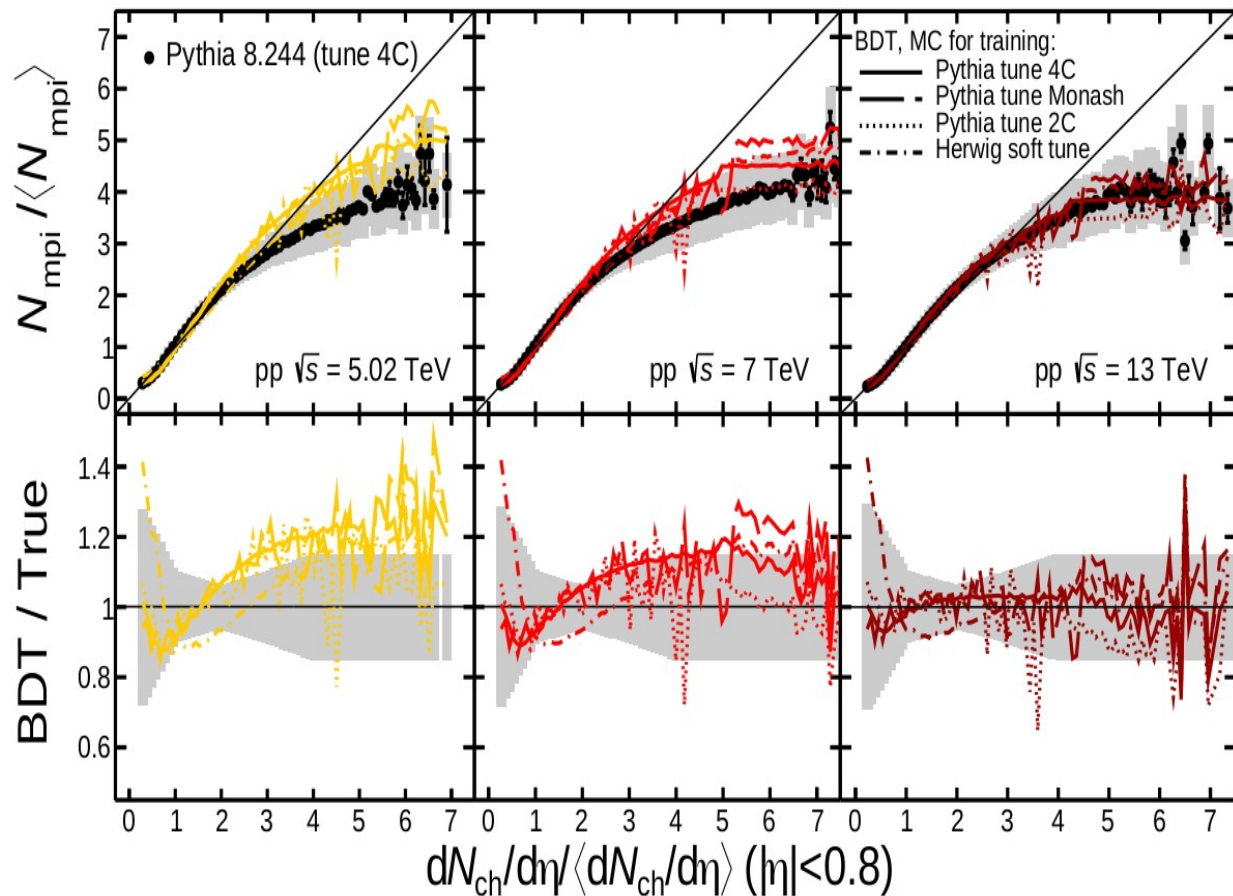
# Monte Carlo closure test



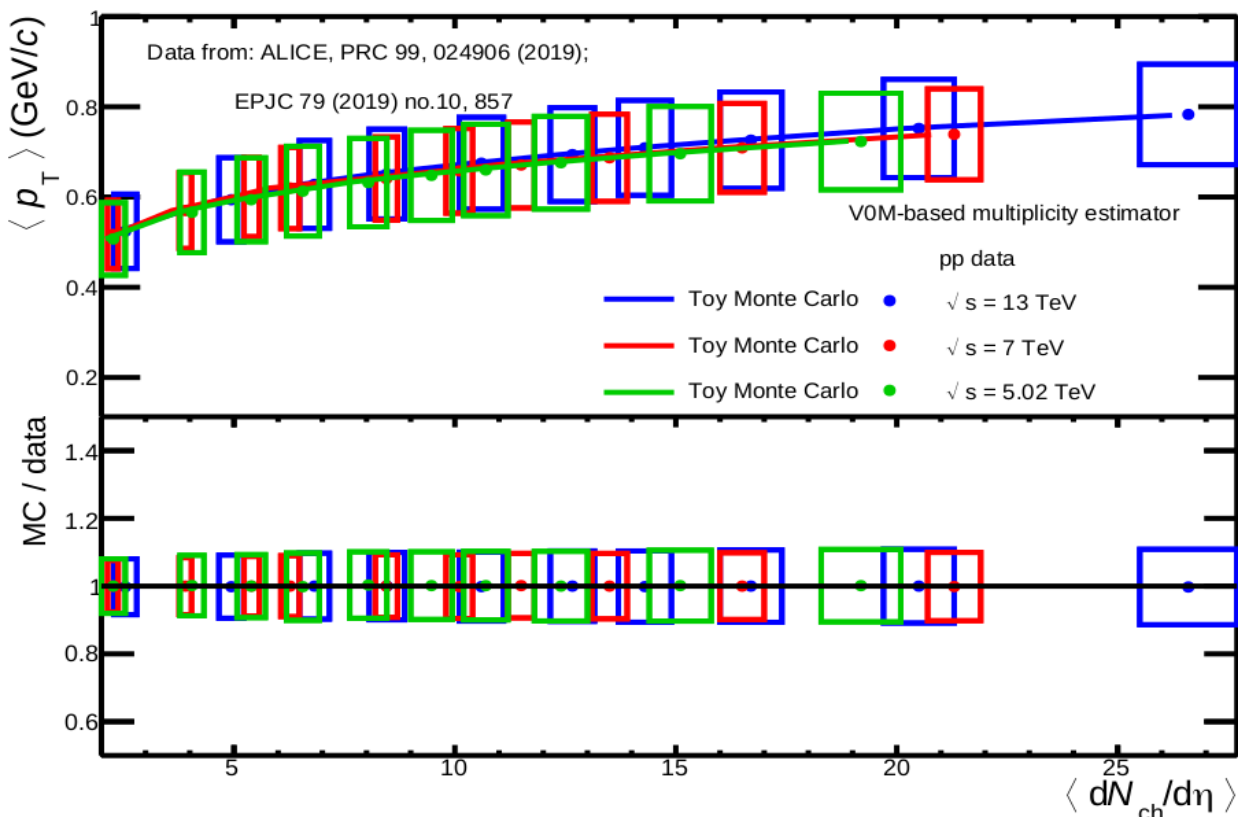
► Correlation obtained using PYTHIA 8 tune 4C shows that for higher multiplicities, a deviation of the self normalized  $N_{\text{mpi}}$  with respect to the linear trend

► Using ML-based regression, one can recover the energy and multiplicity dependence of the self normalized  $N_{\text{mpi}}$

► Tunes 2C, 4C and Monash 2013 of PYTHIA 8, and HERWIG 7.2 were used for training, then the effects of the MPI and hadronization models are considered in the systematic uncertainties



# Analysis of data



In this analysis, we have used the published ALICE data on  $p_T$  spectra as a function of event multiplicity. The data are available for pp collisions at 5.02, 7 and 13 TeV

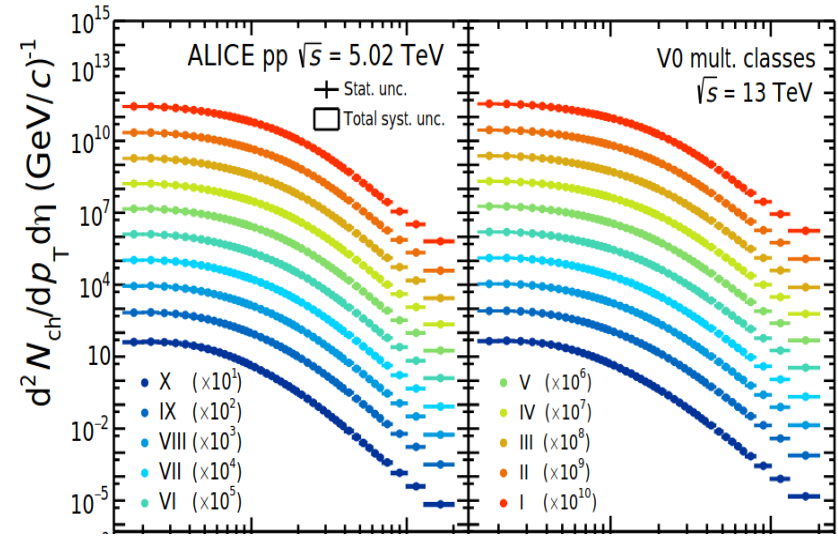


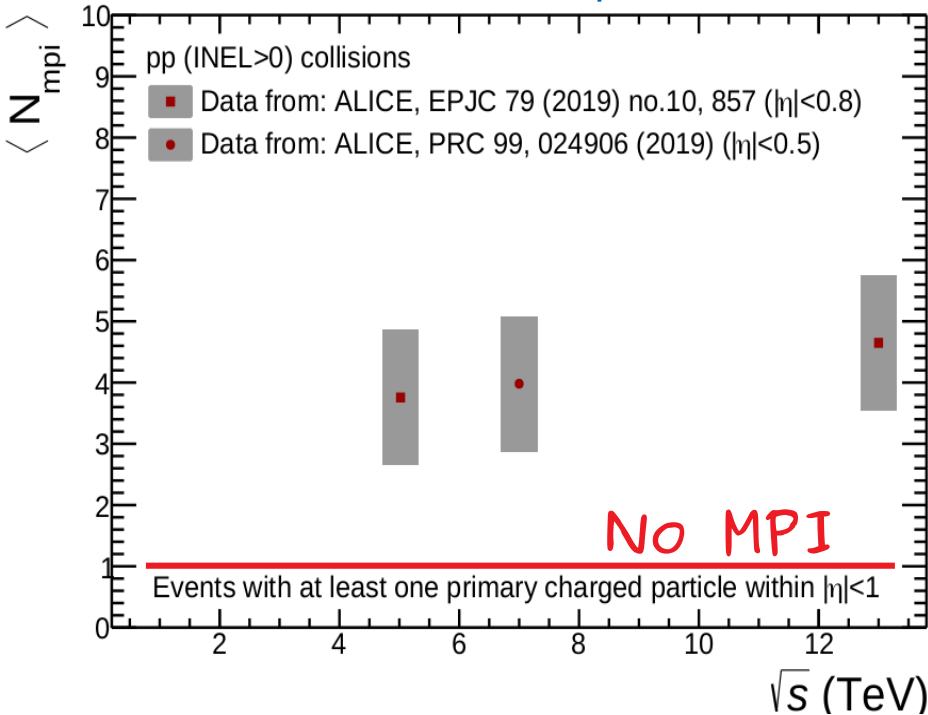
Figure taken from: ALICE Collaboration, Eur. Phys. J.C 79 (2019) 10, 857

Within uncertainties, the toy MC reproduces the correlation between the  $\langle p_T \rangle$  and  $\langle dN_{ch}/d\eta \rangle$

# Results

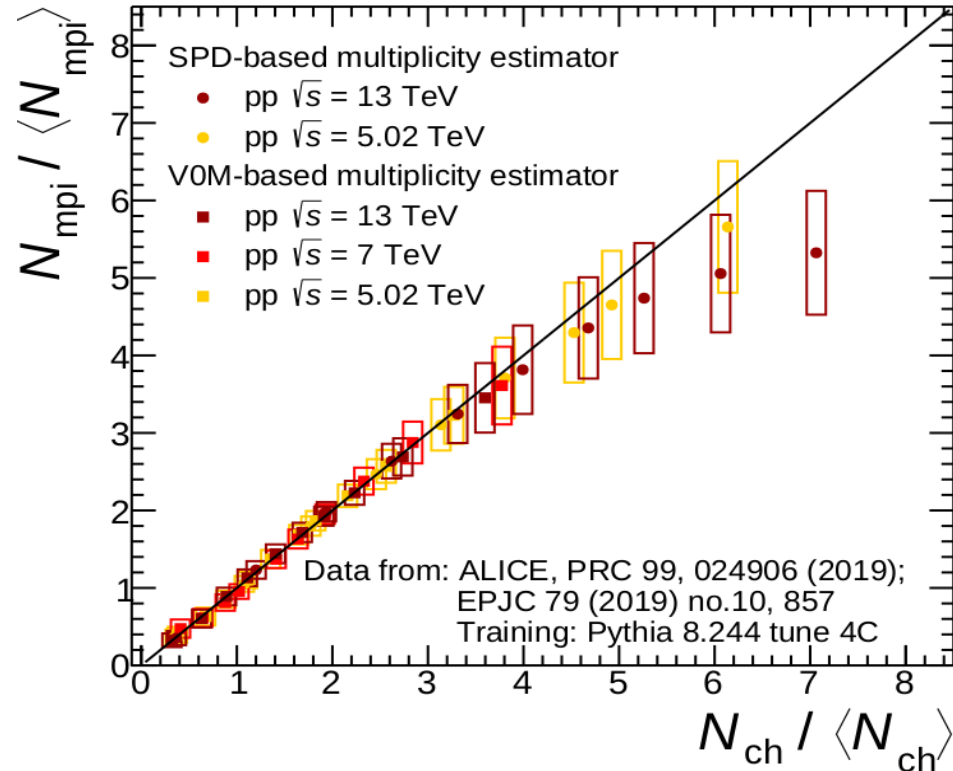


► Data are consistent with the presence of MPI

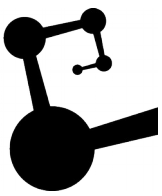


► Results of  $N_{mpi} / \langle N_{mpi} \rangle$  vs.  $N_{ch} / \langle N_{ch} \rangle$

qualitatively agrees with Pythia 8



► For higher multiplicities, we observe a deviation of the self normalized  $N_{mpi}$  with respect to the linear trend. This result is fully compatible with the so-called “mini-jet analysis” [ALICE Collaboration, JHEP09, 049 \(2013\)](#)



# Summary



- We report the extraction of the average number of MPI from pp data at the LHC energies
- We found  $\langle N_{\text{mpi}} \rangle = 3.98 \pm 1.01$  for minimum-bias pp collisions at 7 TeV
- Our results provide experimental evidence of the presence of MPI in hadronic interactions
- Our results are fully consistent with the so-called “mini-jet analysis” of ALICE, high multiplicities can only be reached by selecting events with many high-multiplicity jets