Charged Particle Production in Proton-Proton Collisions at $\sqrt{s}$ = 13 TeV with ALICE at the LHC

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Outline of the talk

- **Motivation**
- **The ALICE Detector**
- **Event selection and systematic uncertainties**
- **The pseudorapidity-density distribution of charged-particles**
- **The transverse-momentum (p_T) spectra of charged particles**
- **Comparison with Monte-Carlo (MC) generators**
- **Summary and conclusions**

Motivation

- Pseudorapidity density and transverse-momentum spectra are key observables to characterize the global properties of the collision.

- Measurements provide constraints for better tuning of models and MC event generators for hadron-collider and cosmic-ray physics.

- Valuable reference data from proton-proton collisions to study nuclear effects in nucleus-nucleus and proton-nucleus collisions.

The ALICE Detector at LHC

ALICE Detector
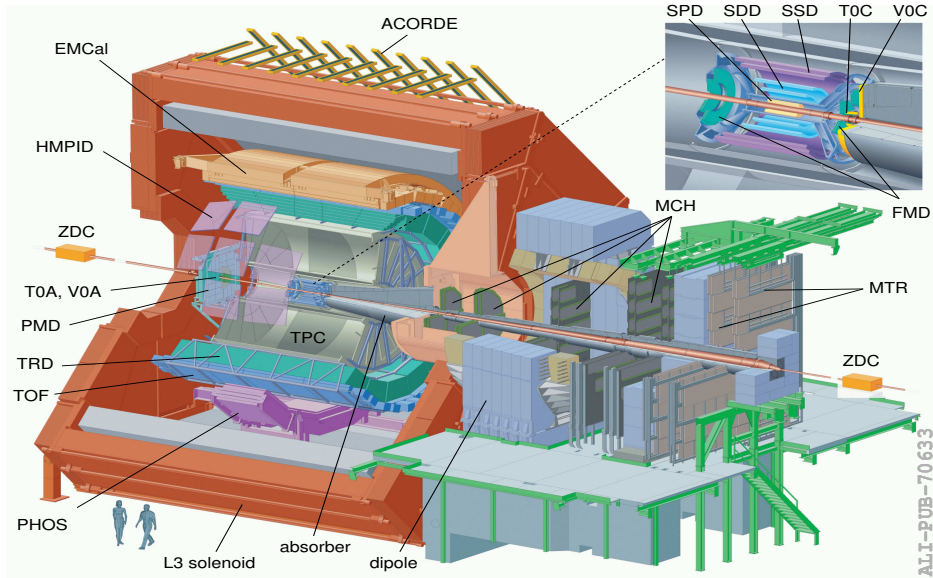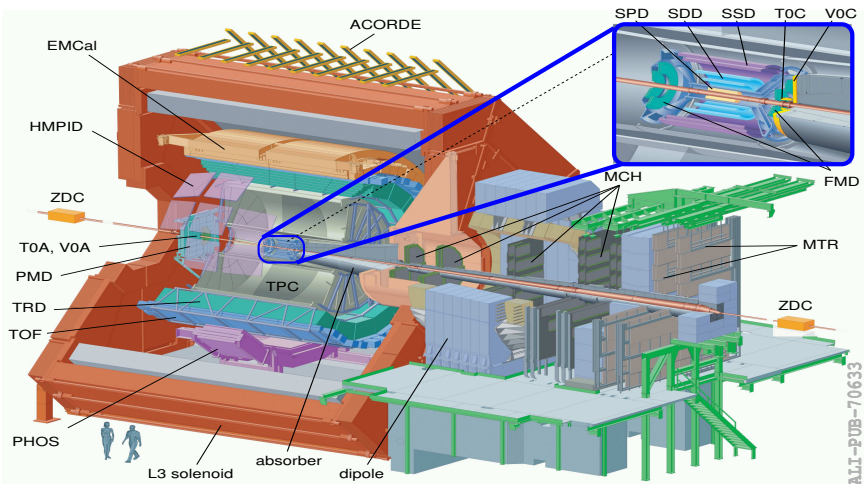
- Tracking Detectors: Inner Tracking System (ITS) and TPC.
- Triggering Detectors: V0 Detectors.

Event Selection and Analysis Criteria

- About 1.5 million minimum bias events are selected from the data collected during the June 2015 run.
- The reconstructed vertex is within $|z| < 10$cm.
- The transverse momentum is above 50 MeV/c.

The pseudorapidity density is given by:

$$\mathrm{d}N_{\mathrm{ch}}/\mathrm{d}\eta = \alpha(1 - \beta)\mathrm{d}N_{\mathrm{tracklets}}/\mathrm{d}\eta.$$

$\alpha = 1.5$ accounts for the acceptance and efficiency correction.

$\beta = 0.01$ is the contamination of reconstructed tracklets.

Event Selection and Analysis Criteria

- Tracklets used for pseudorapidity-density measurement are the short track segments reconstructed by using the position of the reconstructed primary vertex and two hits, one on each Silicon Pixel Detector (SPD) layer.

- Tracks used for transverse-momentum measurement are reconstructed using the information from the ITS and TPC detectors.

- The tracks are selected with the requirements on the number of space points used for tracking, quality of the track fit, and the distance of closest approach to the reconstructed vertex.

Event Selection and Analysis Criteria

Two normalization classes are used, INEL and INEL > 0

- Inelastic event selection (INEL):
  - ▸ Events are selected with Minimum Bias trigger with logical OR of detector hits defined as (V0A || V0C || ADA || ADC).
- Inelastic event with at least one charged particle (INEL > 0):
  - ▸ Events selected with at least one reconstructed SPD tracklet (charged particle) in an event within the region $|\eta| < 1.0$.
- Pseudorapidity distribution of charged particles is measured for both INEL and INEL > 0 normalization classes.
- The transverse-momentum distribution of charged particles is measured for INEL > 0 normalization class.

Systematic Uncertainties

- Normalization of the results
- Detector acceptance and efficiency
- Material budget
- Tracklets and tracks selection criteria
- Particle composition
- Contamination from weak decays of strange hadrons

Summary of Systematic Uncertainties

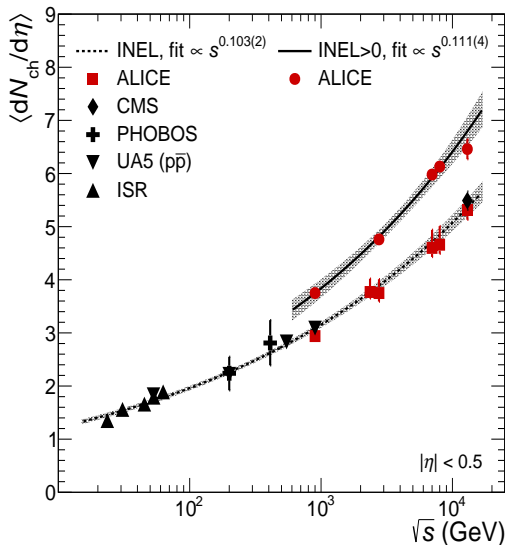| Sources (expressed in %)	$dN_{ch}/d\eta$		dN_{ch}/dp_T	
	INEL	INEL>0	0.15	20 GeV/c
Background events and pileup	negligible		negligible	
Normalisation	2.8	2.3	2.3	
Detector acceptance and efficiency	1.5		1.8	5.6
Material budget	0.1		1.5	0.2
Track(let) selection criteria	negligible		1.5	3.0
Particle composition	0.2		0.3	2.4
Weak decays of strange hadrons	0.5		3.4	0.4
Zero-p_T extrapolation	1.0		NA	
Total (η, p_T dependent)	1.9		4.4	6.8
Total	3.4	3.0	5.0	7.2

Average Pseudorapidity Density of Charged Particles

- The results are shown in the normalisation classes INEL and INEL>0.

- PYTHIA6 calculations are in better agreement with the data than the ones of PYTHIA8 and EPOS LHC in both INEL and INEL>0.

- Agrees with the CMS results (Phys. Lett. B751 (2015) 143, arXiv:1507.05915) for inelastic collisions within the uncertainties.
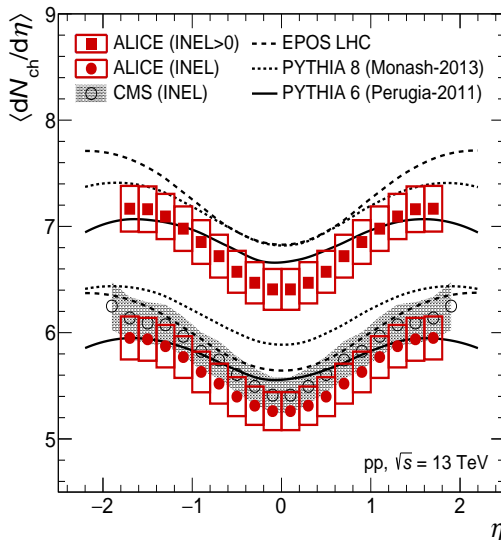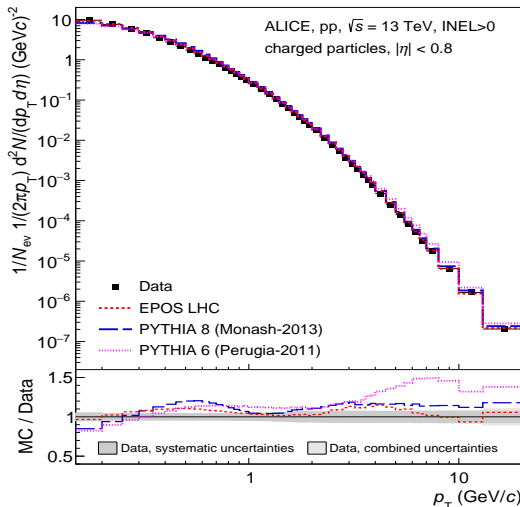
arXiv:1509.08734

Colliding Energy Dependence

arXiv:1509.08734

- Energy dependence of charged-particle pseudorapidity density for INEL and INEL>0.

- The energy dependence of $\langle dN_{ch}/d\eta \rangle$ is parametrised by the power law Cs^b fitted to data.

- Fit results gives:
  $b = 0.103 \pm 0.002$ for INEL
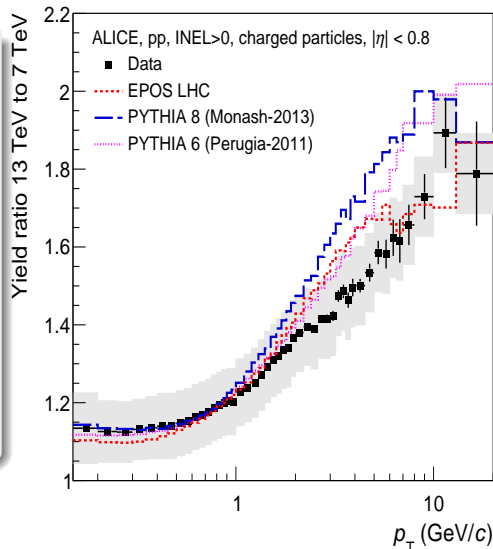 $b = 0.111 \pm 0.004$ for INEL > 0

Transverse Momentum Spectrum

arXiv:1509.08734

ALICE, pp, $\sqrt{s}$ = 13 TeV, INEL>0
charged particles, $|\eta| < 0.8$

- Data
- EPOS LHC
- PYTHIA 8 (Monash-2013)
- PYTHIA 6 (Perugia-2011)

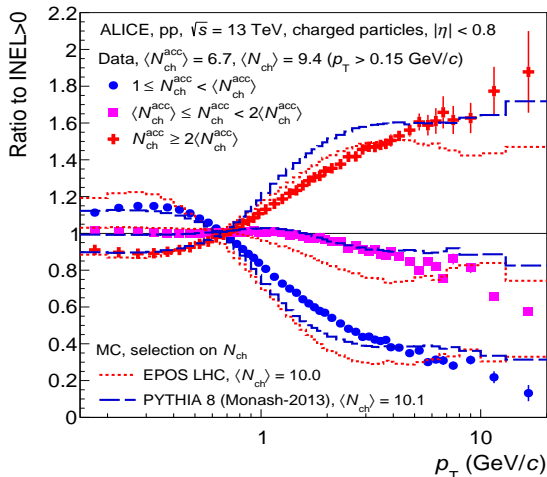Data, systematic uncertainties   Data, combined uncertainties

- The invariant charged-particle yield as a function of p_T agrees well
  ($< 25\%$ for $p_T < 4$ GeV/c) with PYTHIA6, PYTHIA8 and EPOS LHC models.

Comparison with MC

- Ratio of transverse-momentum spectra in INEL> 0 events at $\sqrt{s}$ = 13 and 7 TeV.

- The spectrum at $\sqrt{s}$ = 13 TeV is significantly harder than at $\sqrt{s}$ = 7 TeV.

- PYTHIA6, PYTHIA8 and EPOS LHC show a similar trend as observed in the data but slightly more pronounced in higher p_T region.

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ALICE, pp, INEL>0, charged particles, $|\eta|$ < 0.8
- Data
- EPOS LHC
- PYTHIA 8 (Monash-2013)
- PYTHIA 6 (Perugia-2011)

Yield ratio 13 TeV to 7 TeV

p_T (GeV/c)

Comparison with MC

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- The correlation of the spectrum with multiplicity is prominent and it is stronger at high p_T.

Summary and Conclusions

- Measured the pseudorapidity and transverse-momentum distributions of charged particles produced in proton-proton collisions at $\sqrt{s}$ = 13 TeV.

- The charged-particle densities in $|\eta| < 0.5$ are 5.31 $\pm$ 0.18 and 6.46 $\pm$ 0.19 for INEL and INEL > 0 respectively.

- The transverse-momentum spectrum is significantly harder at $\sqrt{s}$ = 13 TeV than at $\sqrt{s}$ = 7 TeV, and shows features where spectrum is correlated with the charged-particle multiplicity measured in the same kinematic region.

- The results are found to be in fair agreement with the expectations from lower energy extrapolations and with the calculations from PYTHIA and EPOS Monte Carlo generators.

THANK YOU!