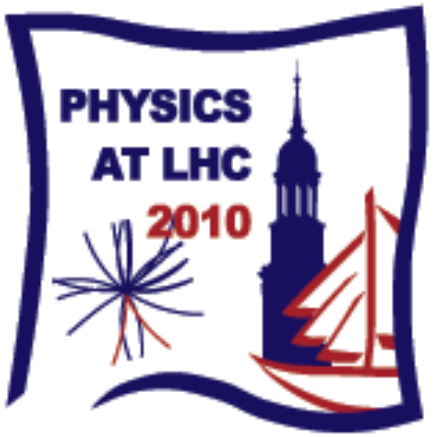


Charged Particle Multiplicities and Spectra with ALICE

Peter Hristov, CERN/PH

on behalf of the ALICE Collaboration

Outline

- Published results
  - $dN_{ch}/d\eta$ at 0.9 TeV. EPJC 65 (2010) 111

  Accepted by EPJC:
  - $dN_{ch}/d\eta$ and dN/dN_{ch} at 0.9 and 2.36 TeV. hep-ex:1004.3034(2010)
  - $dN_{ch}/d\eta$ and dN/dN_{ch} at 7.0 TeV. hep-ex:1004.3514(2010)
- New results
  - P_T spectra of charged particles at 0.9 TeV
- Summary

Event Classes

0.9 and 2.36 TeV

- Inelastic (INEL) = Single-diffractive (SD) + Double-diffractive (DD) + Non-diffractive (ND);
- Non-single diffractive (NSD)
- Use measured cross sections for diffractive processes
  - Change MC generator fractions (SD/INEL, DD/INEL) such that they match these fractions
  - Use Pythia and Phojet to assess effect of uncertainty in the kinematics of diffractive processes

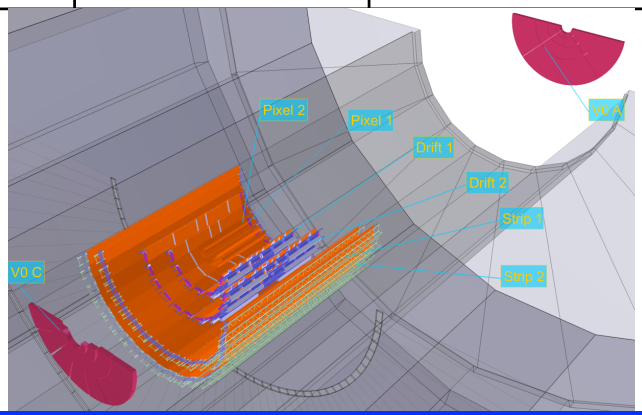
7 TeV

- Diffraction is quite unknown
- Hadron-level definition of events to minimize model dependence
  - All events that have at least one charged primary particle in $|\eta| < 1$: "INEL>0"

Data Samples

Energy, TeV	Mag. field, T	Online trigger	Events	Trig. Events: $\|z_V\|<5.5$cm
0.9	0	BPTX AND SPD	284	
0.9	-0.5	BPTX AND (V0A.OR.V0C.OR.SPD)	150000	47000
2.36	-0.5	BPTX AND SPD	40000	35000
7.0	-0.5	BPTX AND (V0A.OR.V0C.OR.SPD)	380000	240000

BPTX – Beam pick-up counters
V0 – scintillator detector,
2.8 <η< 5.1 and −3.7 <η< −1.7
SPD – ITS pixel layers (fast OR), |η|<2



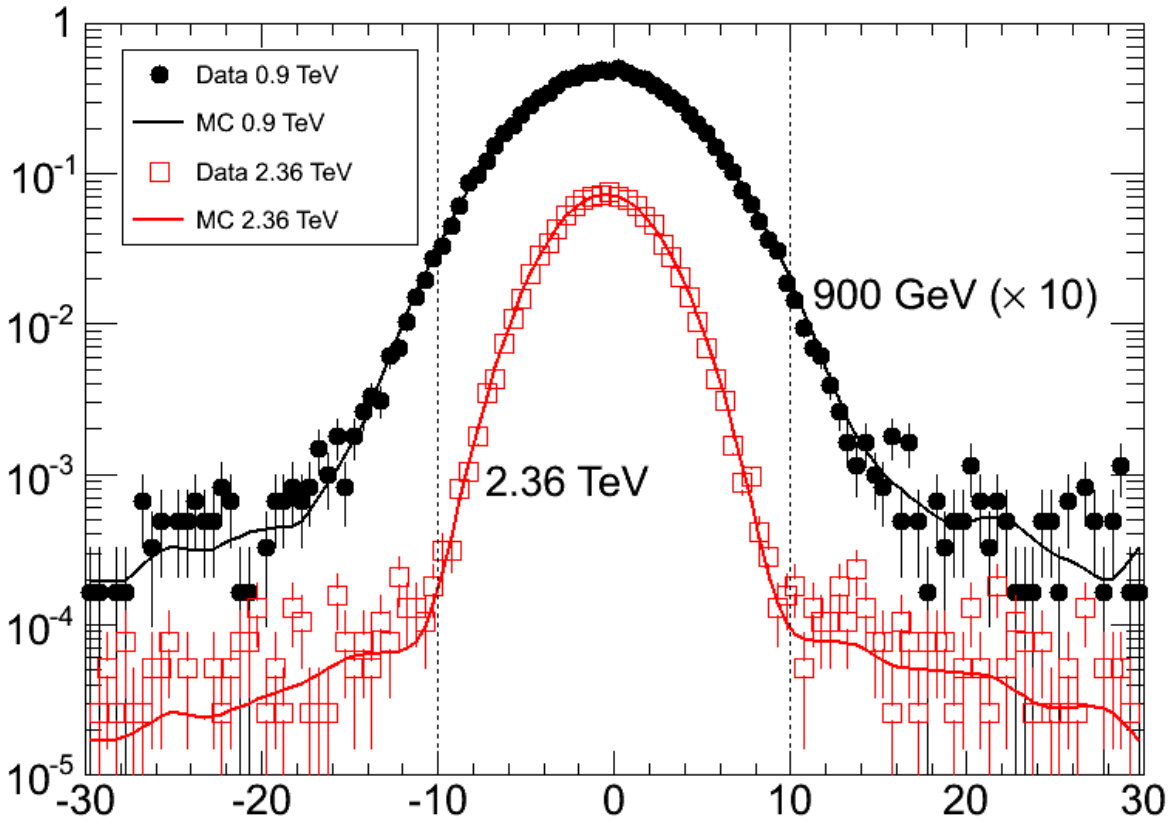
Vertex Reconstruction

The reconstruction correlates the hits in the two pixel layers.
Resolution:

longitudinal 0.1-0.3 mm
transverse 0.2-0.5 mm

Good agreement with MC

More details in the poster of Davide Caffarri



Pseudorapidity Density dN/dη

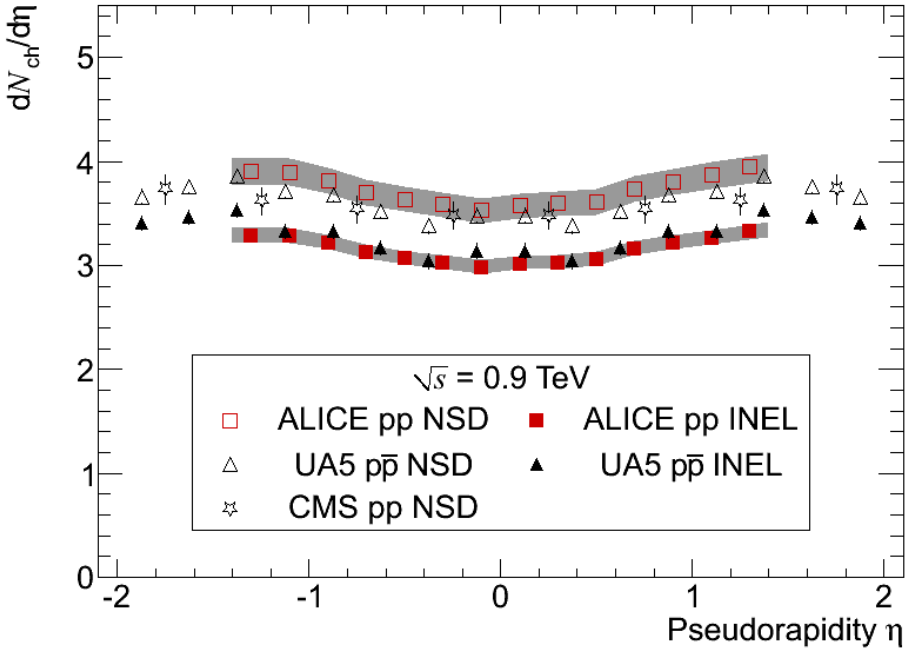
- Analysis:
  - Based on tracklets (hits in the two SPD layers that form short track segments): wider acceptance => smaller corrections
  - Triggered events with vertex
  - Select primary charged particles: matching with the primary vertex, quality cuts
  - Apply multidimensional (η, z_V, p_T) corrections

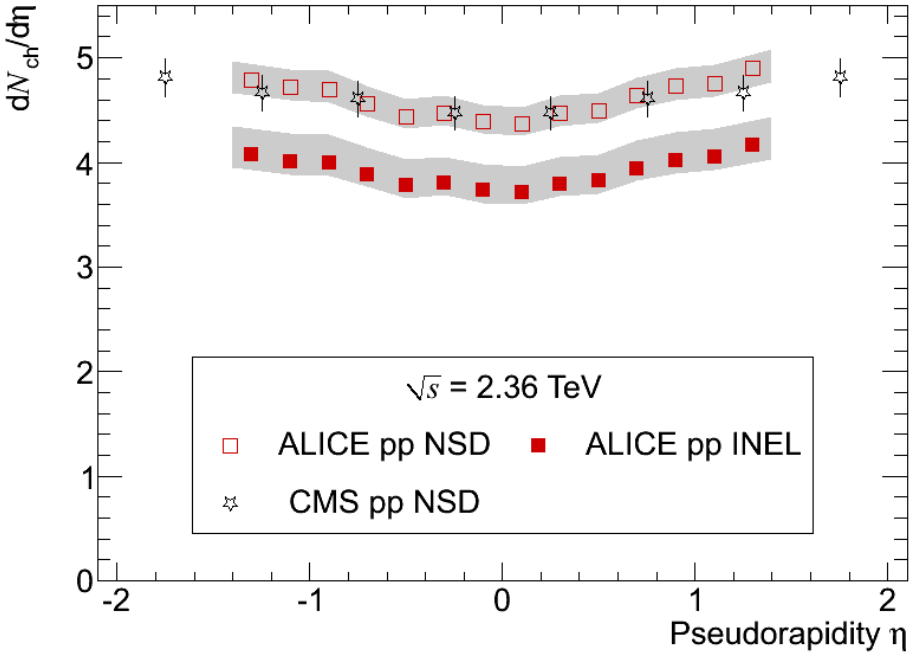
Primary particles = charged particles produced in the collision and their decay products excluding weak decays from strange particles

- Track-to-particle correction
  - Detector acceptance, tracking efficiency
  - Decay, conversions, stopping, etc.
  - Low momentum cut-off (B≠0)
- Correction for vertex reconstruction efficiency/ bias
- Trigger bias correction
  - Using control triggers
  - From MC
- For NSD: remove residual contamination from SD

$dN_{ch}/d\eta$ – Results & Comparison to Other Experiments

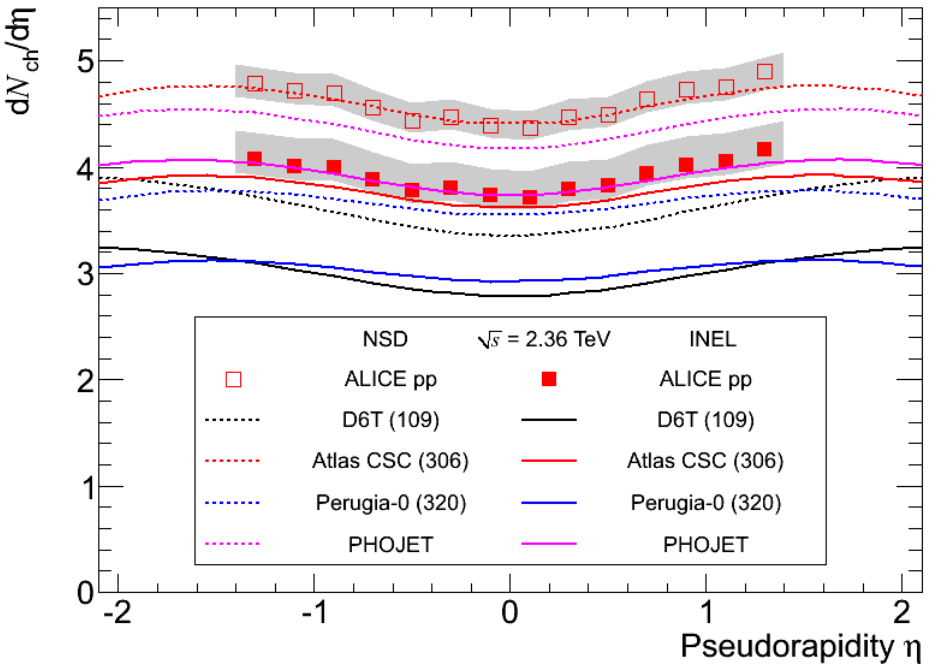
- Good agreement with UA5 (INEL at 0.9 TeV) and CMS (NSD at 0.9 TeV and 2.36 TeV)

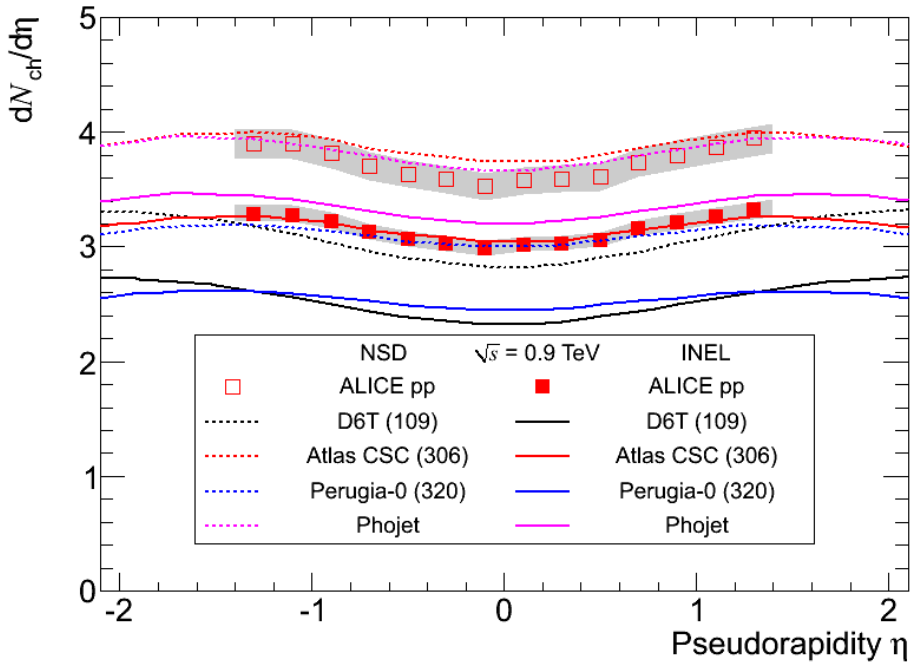


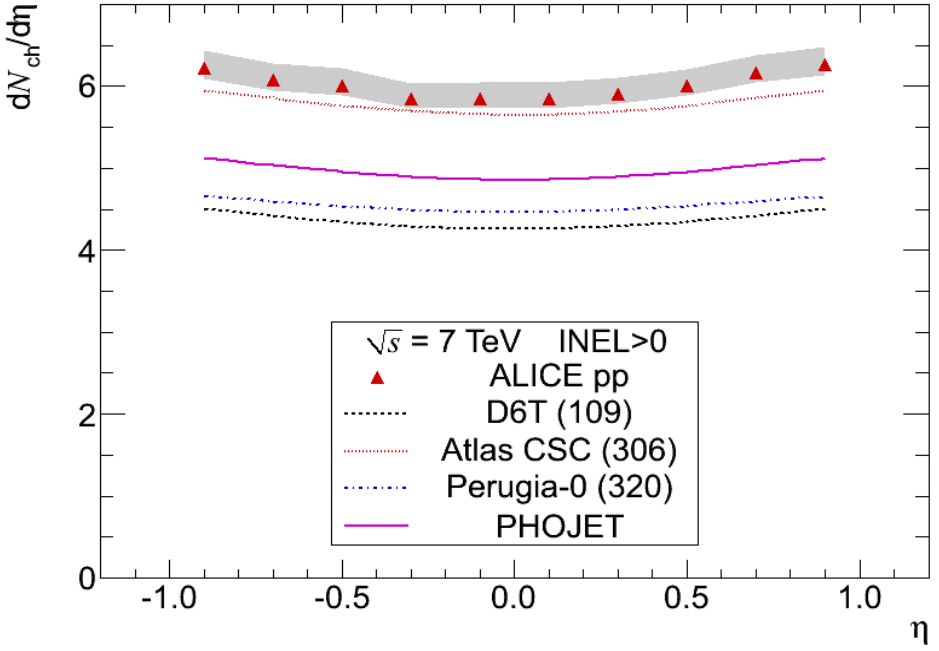


$dN_{ch}/d\eta$ – Comparison to Models

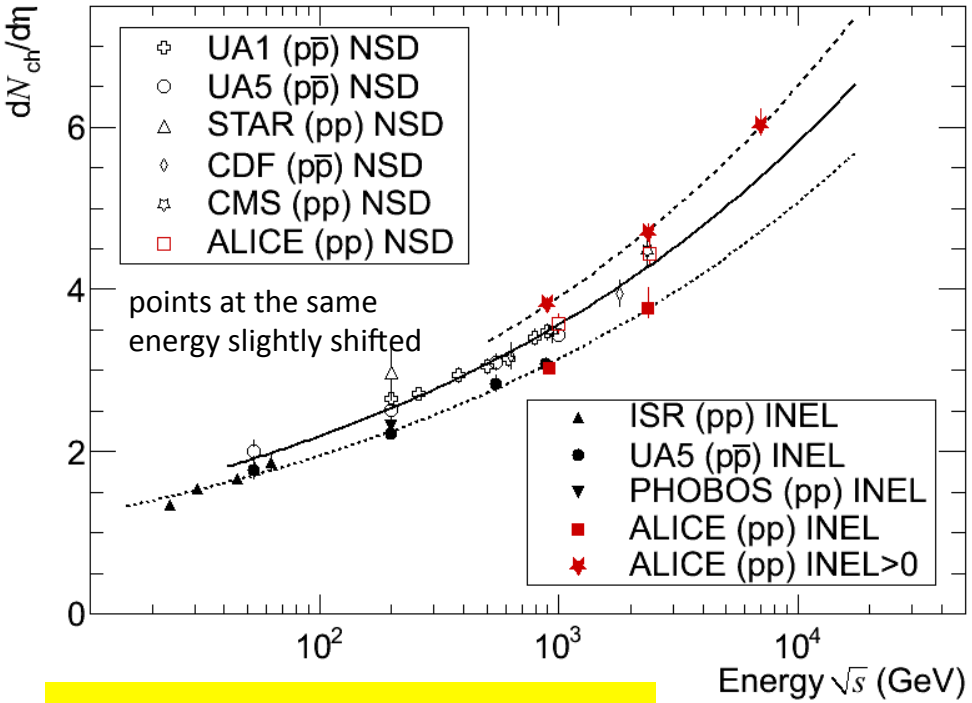
- Pythia D6T and Perugia-0 match neither INEL, NSD, INEL>0 at all three energies
- Pythia Atlas CSC and Phojet reasonably close with some deviations at 0.9 and 2.36 TeV
- Only Atlas CSC close at 7 TeV



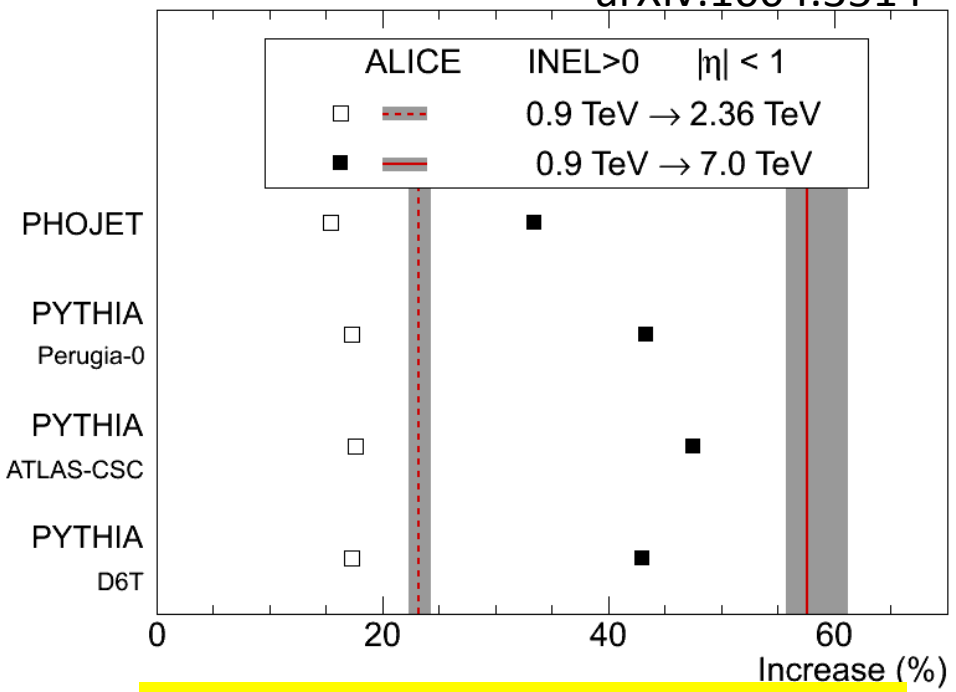




$dN_{ch}/d\eta$ – Energy Dependence



arXiv:1004.3514



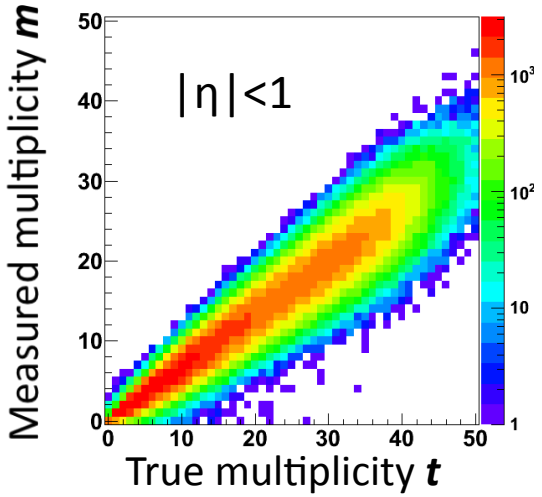
Power law dependence fits well

Significantly larger increase from 0.9 to 7 TeV than in MCs

Increase in $dN_{ch}/d\eta$ in $\|\eta\| < 1$ for INEL > 0 arXiv:1004.3514	**√s**	**ALICE (%)**	**MCs (%)**
	0.9 → 2.36 TeV	**$23.3 \pm 0.4\ ^{+1.1}_{-0.7}$**	**15 – 18**
	0.9 → 7 TeV	**$57.6 \pm 0.4\ ^{+3.6}_{-1.8}$**	**33 – 48**

Multiplicity Distributions

- Analysis:
  - Select z_V interval where the η acceptance is uniform (MC): $|z_V|<5.5$cm
  - Efficiency, acceptance => Detector response function (MC): Probability that a collision with the true multiplicity ***t*** is measured as an event with the multiplicity ***m***



- Unfolding
  - Regularization: $\chi^2(U)$-> min

$$\chi^2(U) = \sum_m \left(\frac{M_m - \sum_t R_{mt} U_t}{e_m} \right)^2 + \beta R(U)$$

  - Bayesian: iterative

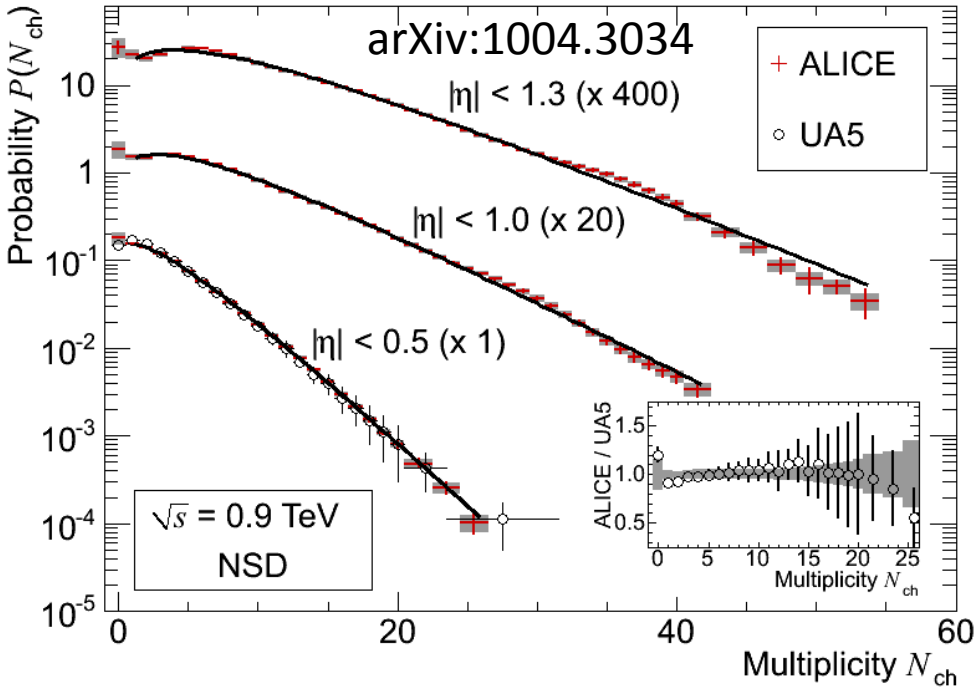
$$\tilde{R}_{tm} = \frac{R_{mt} P_t}{\sum_{t'} R_{mt'} P_{t'}}, \quad U_t = \sum_m \tilde{R}_{tm} M_m$$

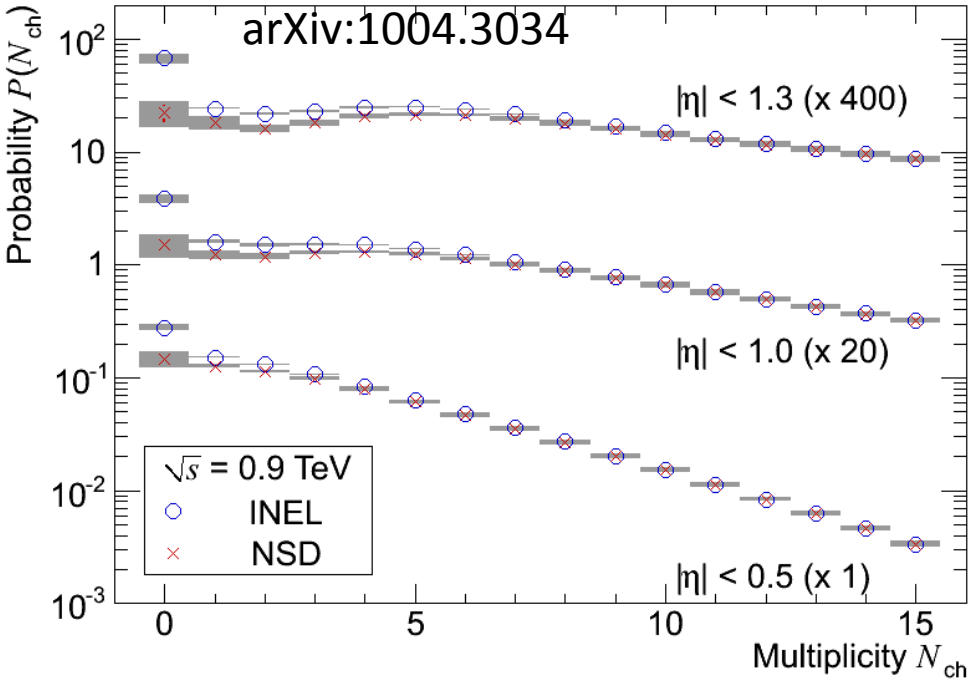
Smooth (or not) U_t and use it as P_t

- Corrections for vertex reconstruction and trigger bias
  - Like for $dN_{ch}/d\eta$, but in unfolded variables (true multiplicity) because it is applied after unfolding

Multiplicity Distributions at 0.9 TeV

- Distributions in limited η-regions
- Consistent with UA5
- Fits with one NBD work well in limited η-regions
- Difference between INEL and NSD in low-multiplicity region

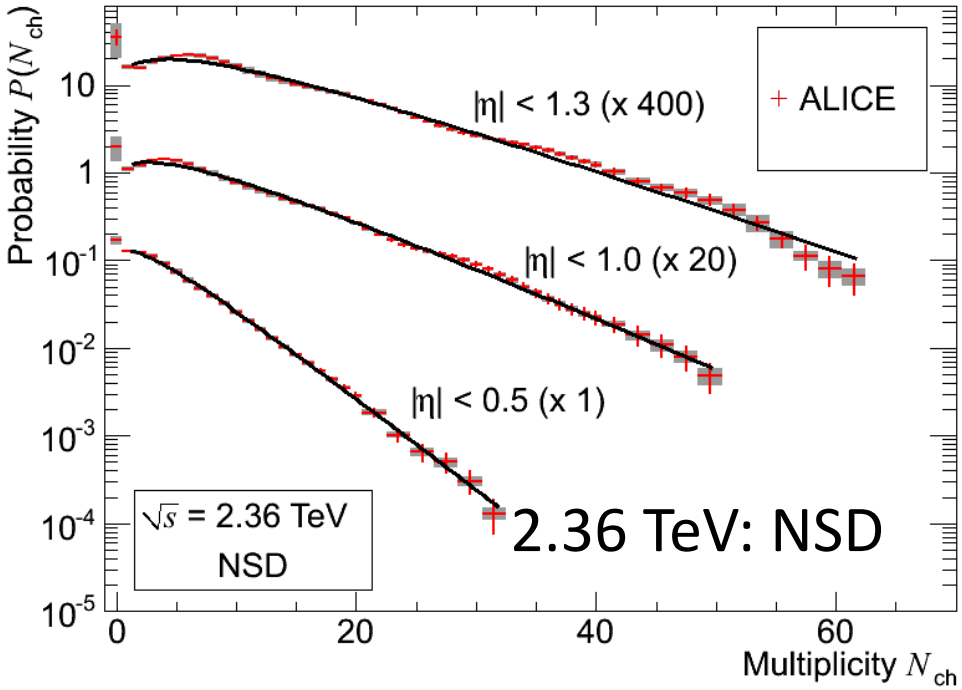




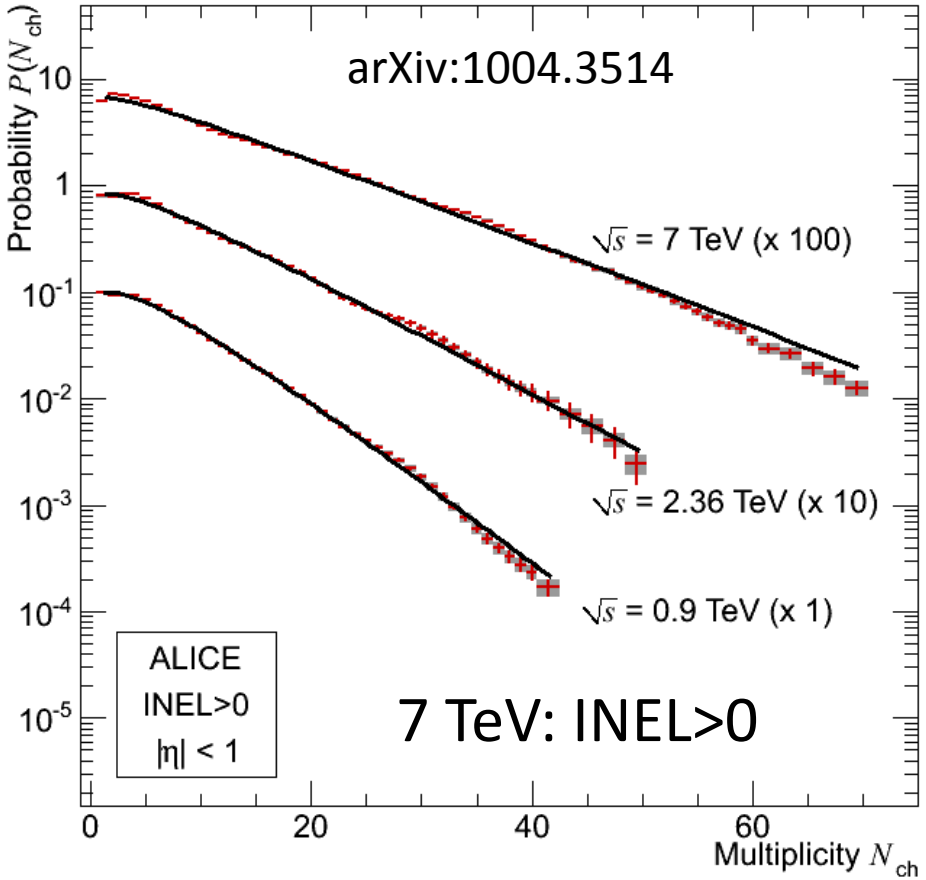
Multiplicity Distributions at 2.36 and 7 TeV

- Fits with one NBD work also at 2.36 and 7 TeV

arXiv:1004.3034

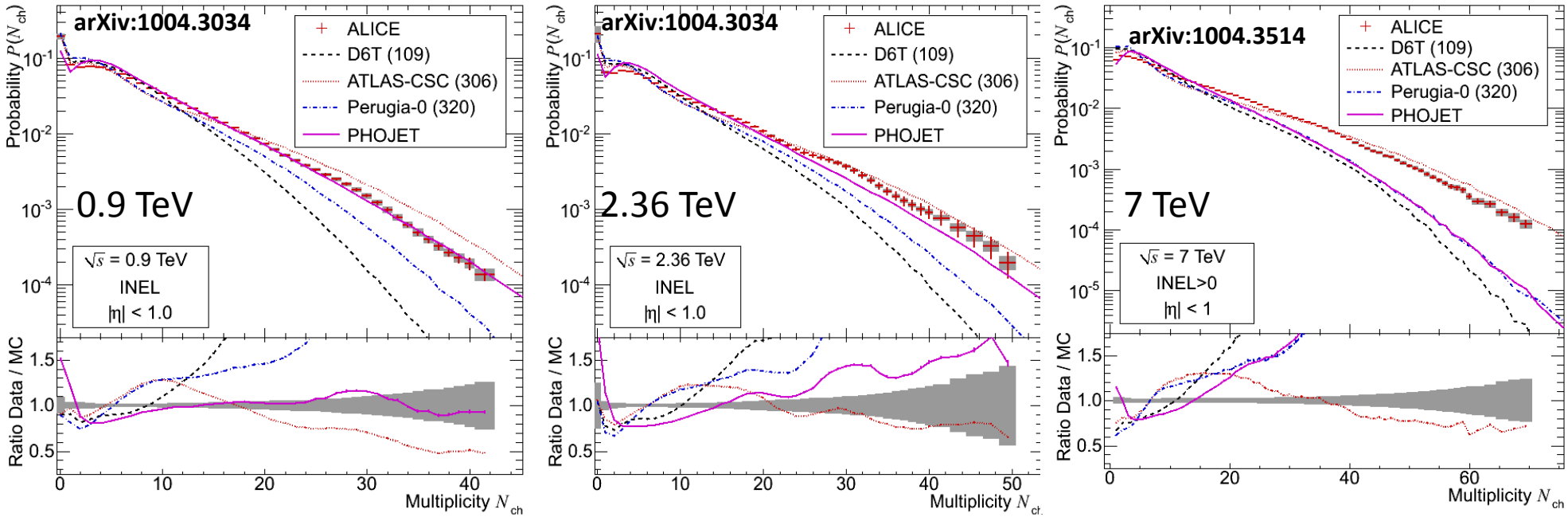


arXiv:1004.3514

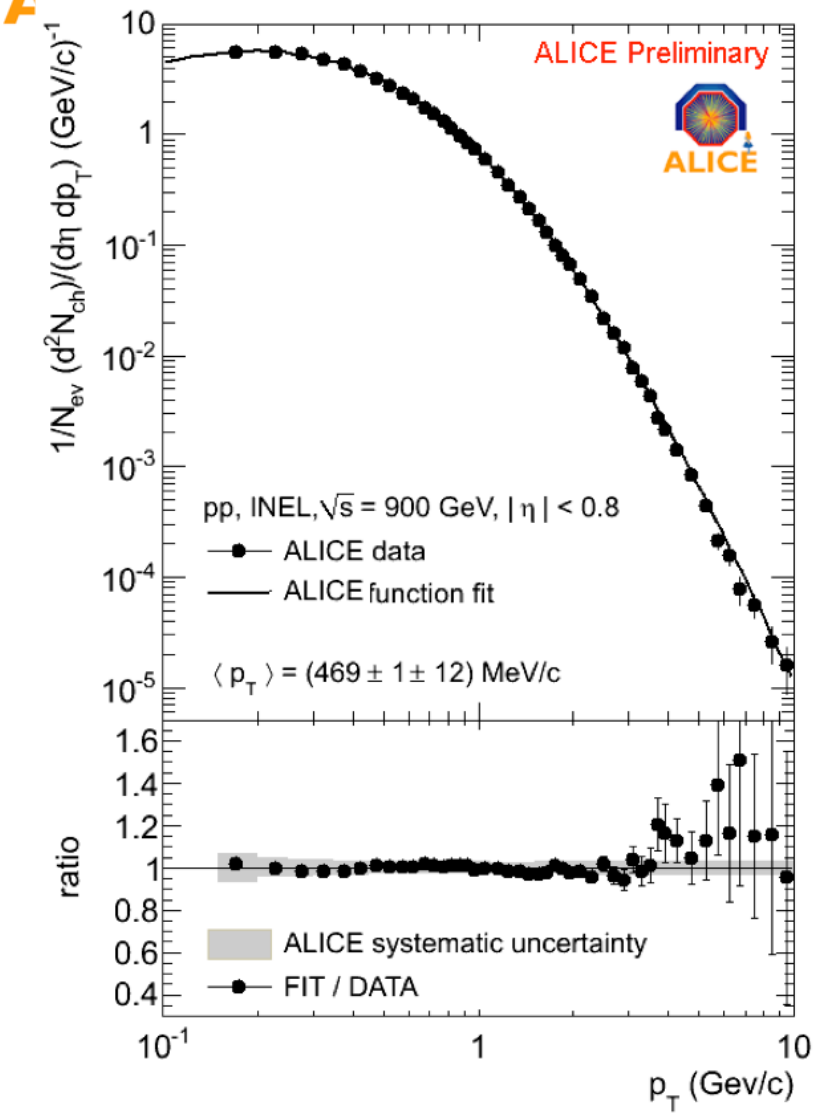


Multiplicity Distributions: Comparison to MC

- Phojet
  - provides a good description at 0.9 TeV
  - fails at 2.36 and 7 TeV
- Pythia: Atlas CSC
  - fails at 0.9 TeV
  - reasonably close at 2.36 and 7 TeV but deviations around 10-20
- Pythia: D6T and Perugia-0 far from the distribution at all energies



dN_{ch}/dp_T – Results



- The selection of primary tracks is based on the transverse impact parameter from ITS (7σ) + quality criteria in ITS and TPC
- The momentum is estimated by TPC (the ITS-TPC alignment is not final)

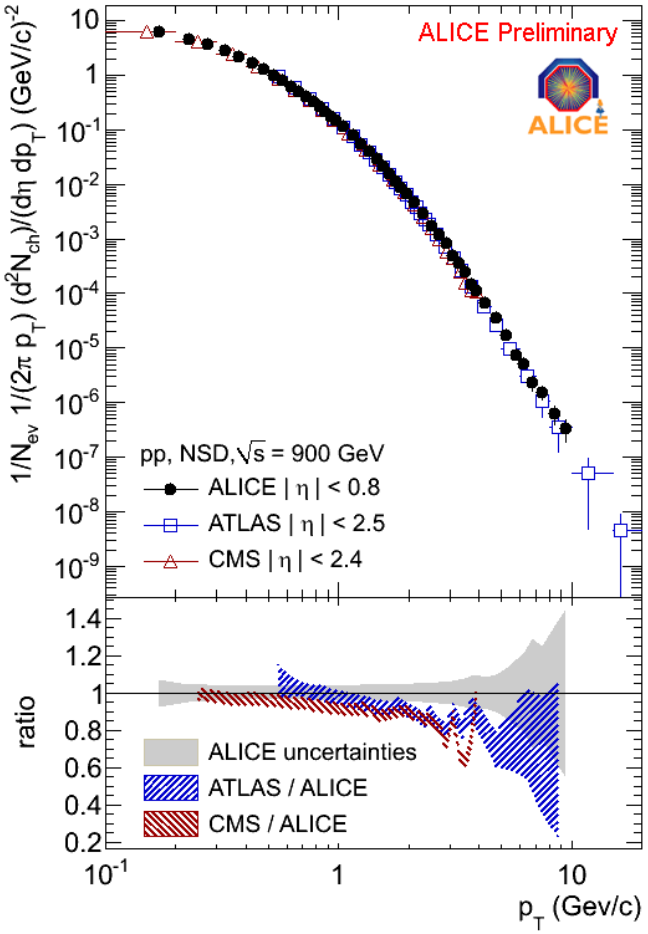
$$\sigma(p_T)/p_T = 0.01 \oplus 0.007\, p_T,\ p_T \text{ in } GeV/c$$

- A fit is used to extrapolate the distribution to p_T=0

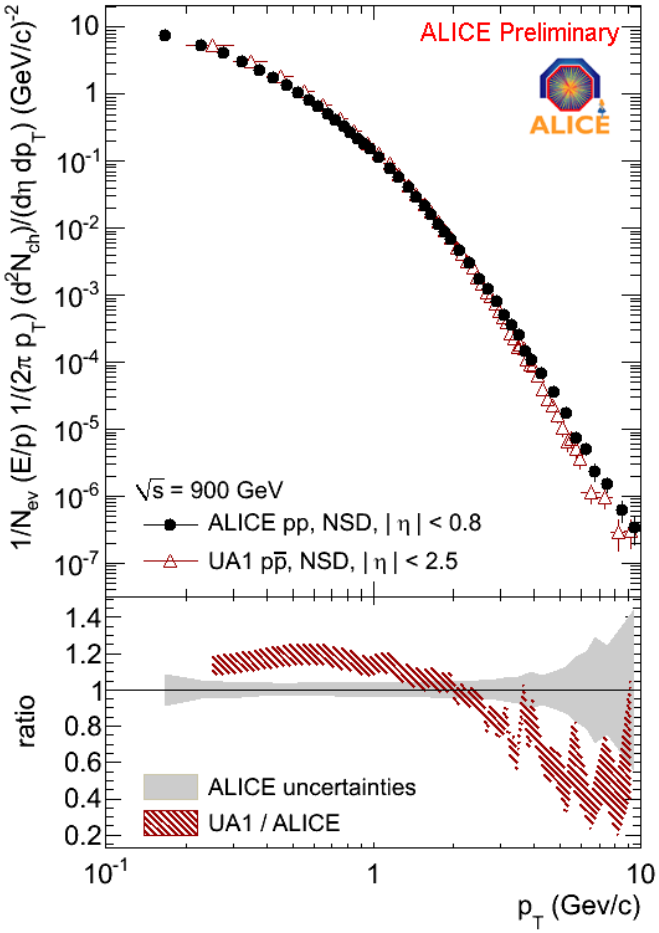
$$\frac{d^2N_{ch}}{d\eta dp_T} \propto p_T \left(1 + \frac{E_T}{nT}\right)^{-n}$$

dN_{ch}/dp_T – Comparison to Other Experiments

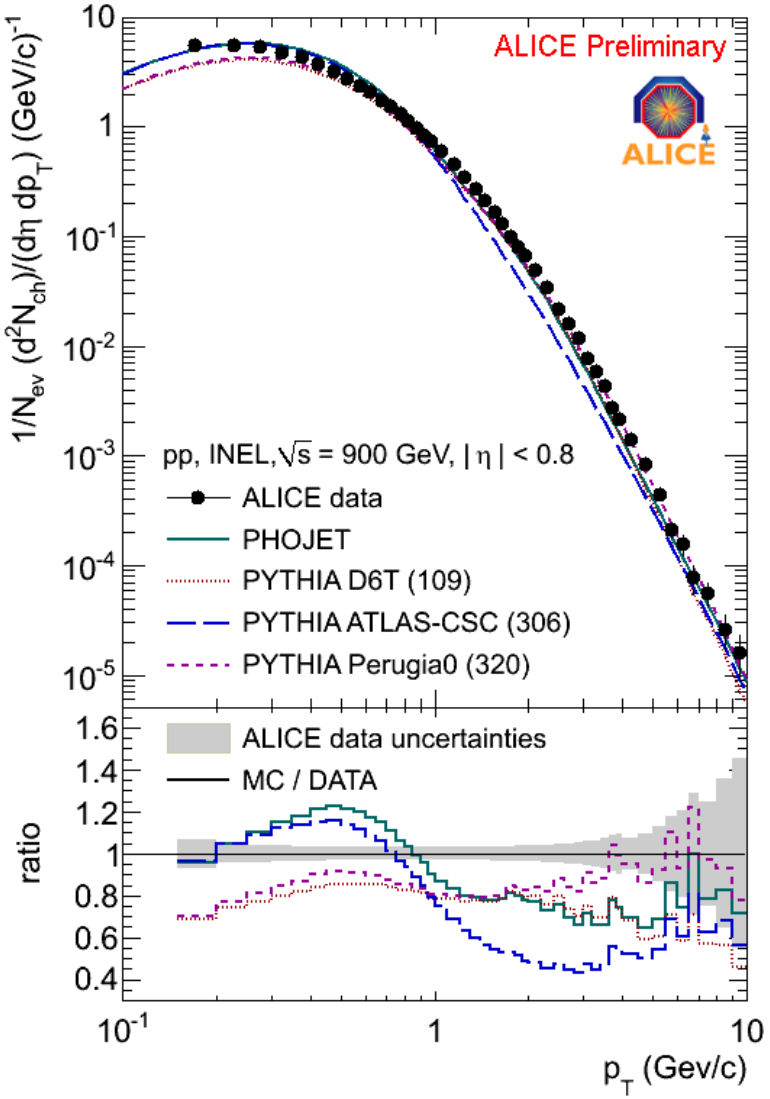
- Good agreement at p_T<1 GeV/c
- ALICE spectrum harder at higher p_T



- UA1 sees higher yield at low p_T – larger η acceptance

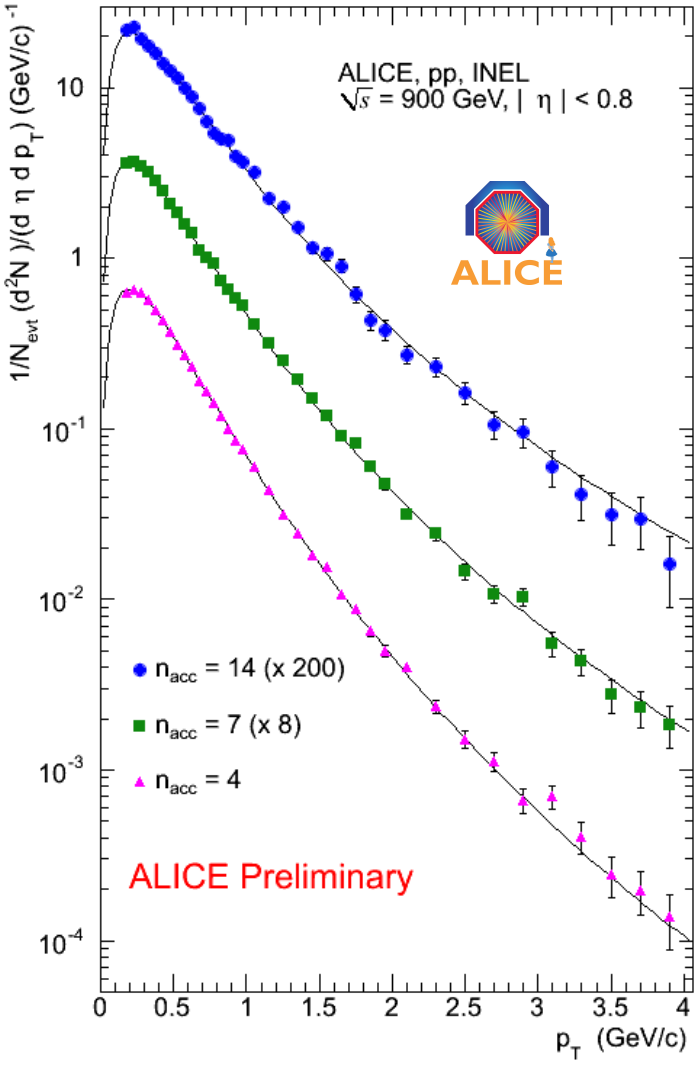


dN_{ch}/dp_T – Comparison to MC



- PYTHIA D6T and Perugia0 describe shape reasonably well but fail in the yield
- PHOJET and ATLAS-CSC are off

<p_T> Dependence on Multiplicity

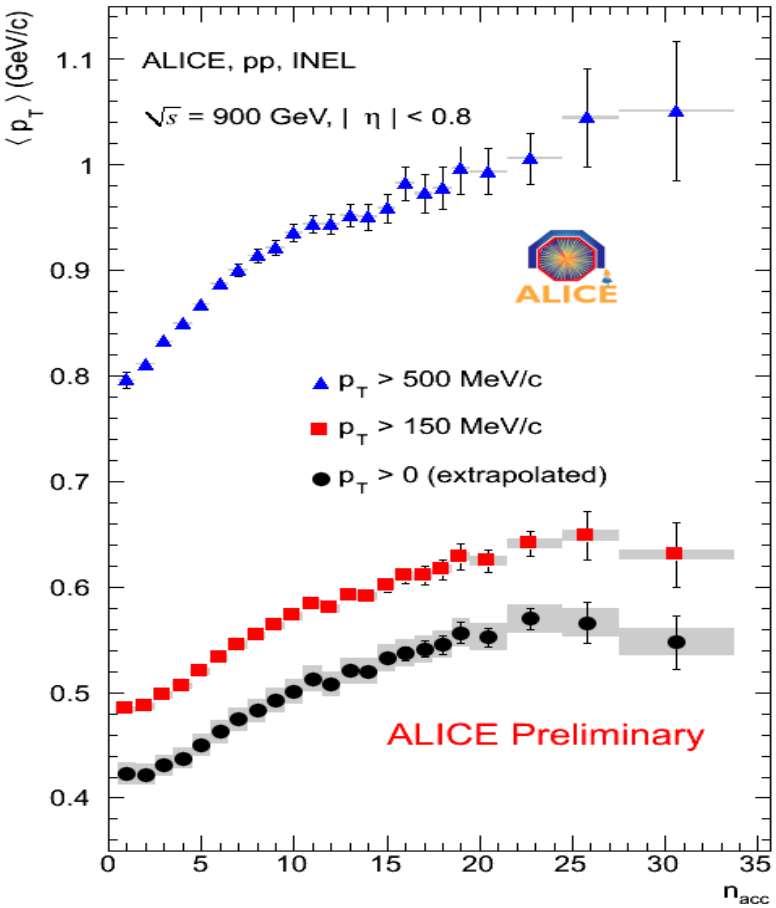


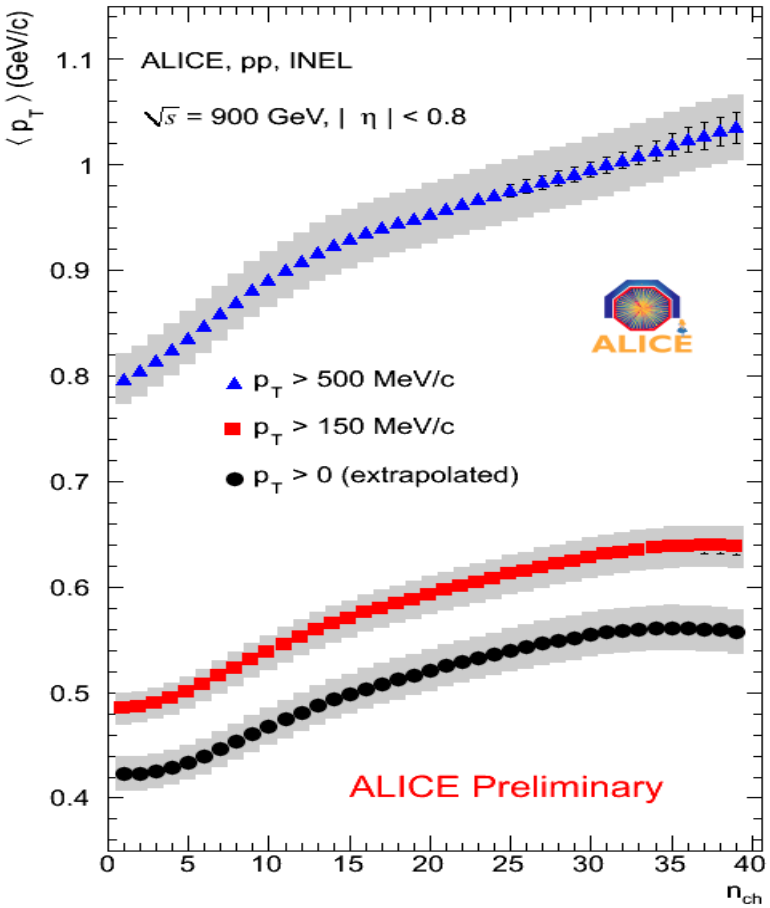
- In bins of observed multiplicity n_{acc}
  - Fits of p_T spectra and calculation of mean
  - Calculation of mean p_T in a "visible" interval: weighted average over data points
  - Calculation of mean p_T in a "visible "interval combined with extrapolation from a fit at low momenta

$\langle p_T \rangle$ vs Multiplicity: from n_{acc} to n_{ch}

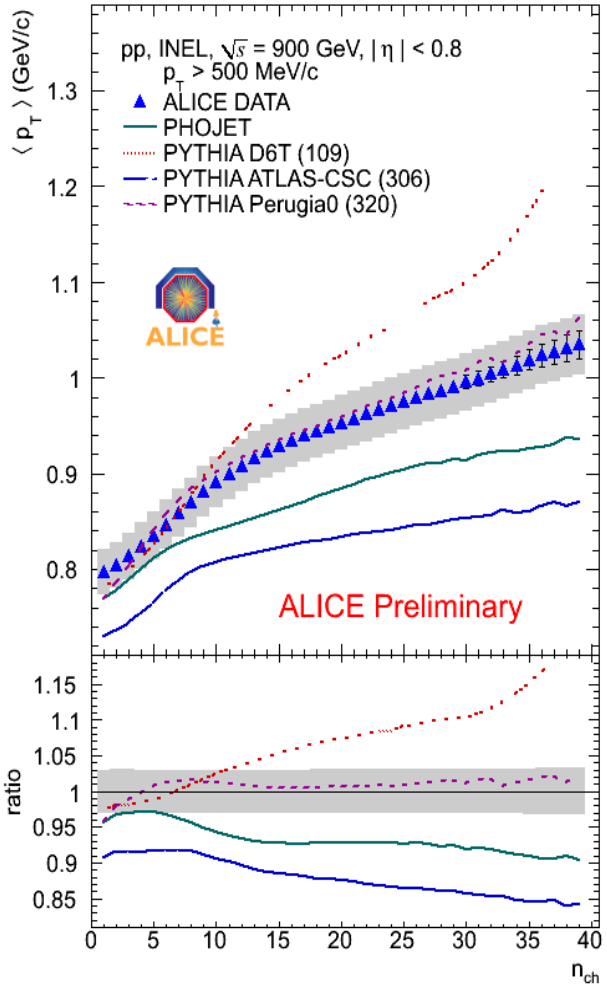
- n_{acc}: number of accepted particles in $|\eta|<0.8$, $p_T>0.15$ GeV/c
- n_{ch}: number of all primaries in $|\eta|<0.8$, $p_T>0$

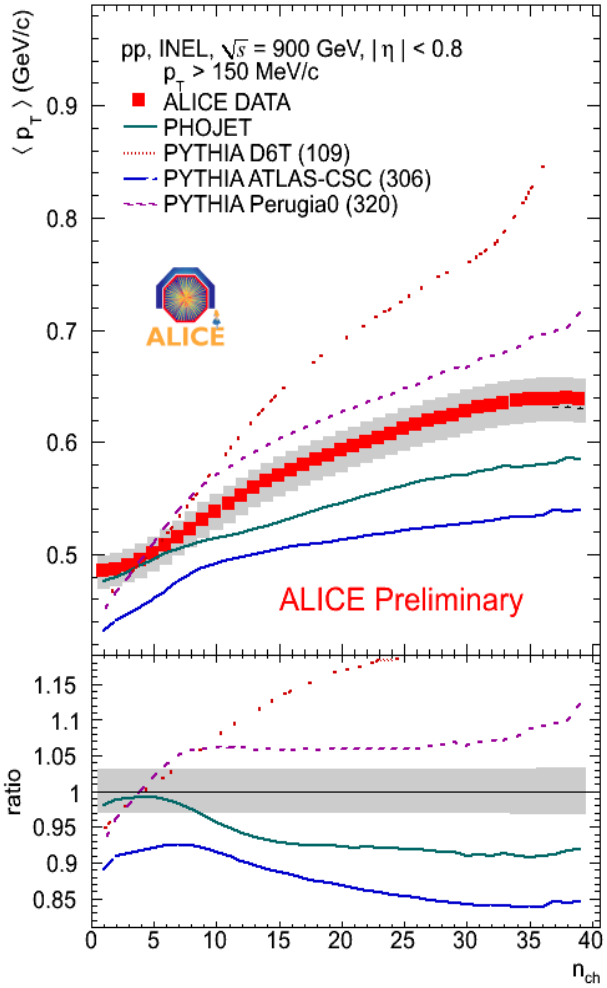
$\langle p_T \rangle(n_{ch}) = \Sigma p_T(n_{acc}) R(n_{acc}, n_{ch})$, where $R(n_{acc}, n_{nch})$: response matrix from MC





<p_T> vs multiplicity – comparison to MC





- p_T>500 MeV/c: PYTHIA Perugia0 gives good description of the data
- p_T>150 MeV/c: all models fail

Summary

- The average multiplicity increases significantly faster than predicted by Pythia and Phojet
- The multiplicity and transverse momentum distributions are not described satisfactory by MC generators. Tuning needed!
- More new results to come soon!

Many thanks to Jan Fiete Grosse-Oetringhaus, Harald Appelshaeuser, Jacek Otwinowski, Andrea Dainese, Boris Hippolyte, Federico Antinori, Luciano Ramello, Karel Safarik

Backup

Systematics

Systematic uncertainties at 900 GeV in %	INEL	NSD
Fractions ND/DD/SD	0.6	2.8
MC dependence	2.0	1.0
Detector efficiency	1.5	
Particle composition*	0.5 - 1.0	
Material budget	negl.	
p_T spectrum	0.5	
SPD triggering efficiency	negl.	
V0 triggering efficiency	negl.	0.5
Background	negl.	
Total	2.7	3.4

Systematics

Uncertainty	$dN_{ch}/d\eta$ analysis		$P(N_{ch})$ analysis	
	0.9 TeV	2.36 TeV	0.9 TeV	2.36 TeV
Tracklet selection cuts	negl.	negl.	negl.	negl.
Material budget	negl.	negl.	negl.	negl.
Misalignment	negl.	negl.	negl.	negl.
Particle composition	0.5–1.0 %	0.5–1.0 %	included in detector efficiency	
Transverse-momentum spectrum	0.5 %	0.5 %	included in detector efficiency	
Contribution of diffraction (INEL)	0.7 %	2.6 %	3–0 % (0–5)	5–0 % (0–5)
Contribution of diffraction (NSD)	2.8 %	2.1 %	24–0 % (0–10)	12–0 % (0–10)
Event-generator dependence (INEL)	+1.7 %	+5.9 %	8–0 % (0–5)	25–0 % (0–10)
Event-generator dependence (NSD)	−0.5 %	+2.6 %	3–5–1 % (0–10–40)	32–8–2 % (0–10–40)
Detector efficiency	1.5 %	1.5 %	2–4–15 % (0–20–40)	3–0–9 % (0–8–40)
SPD triggering efficiency	negl.	negl.	negl.	negl.
VZERO triggering efficiency (INEL)	negl.	n/a	negl.	n/a
VZERO triggering efficiency (NSD)	0.5 %	n/a	1 %	n/a
Background events	negl.	negl.	negl.	negl.
Total (INEL)	$^{+2.5}_{-1.8}$ %	$^{+6.7}_{-3.1}$ %	9–4–15 % (0–20–40)	25–0–9 % (0–10–40)
Total (NSD)	$^{+3.3}_{-3.3}$ %	$^{+3.7}_{-2.7}$ %	24–5–15 % (0–10–40)	32–8–9 % (0–10–40)