Transverse Momentum Spectra of Charged Particles Measured with ALICE

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5th Workshop on High p_T Physics at LHC
Mexico City

ALICE

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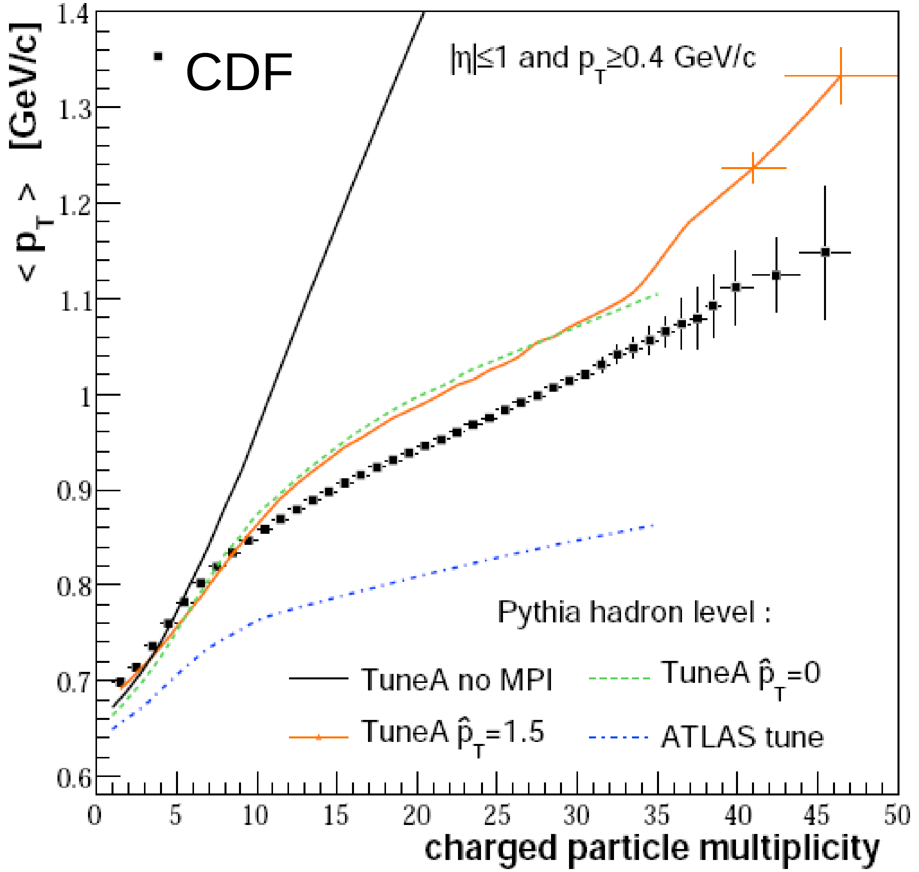
Interesting in many ways…

- Bulk particle production still challenge for (non-perturbative) QCD
- *pp* data as reference for heavy ion collisions
- Transverse momentum spectra crucial to understand soft QCD
- Here:
  - different multiplicities
  - as function of energy

CDF: Phys. Rev. D 79/2009, 112005

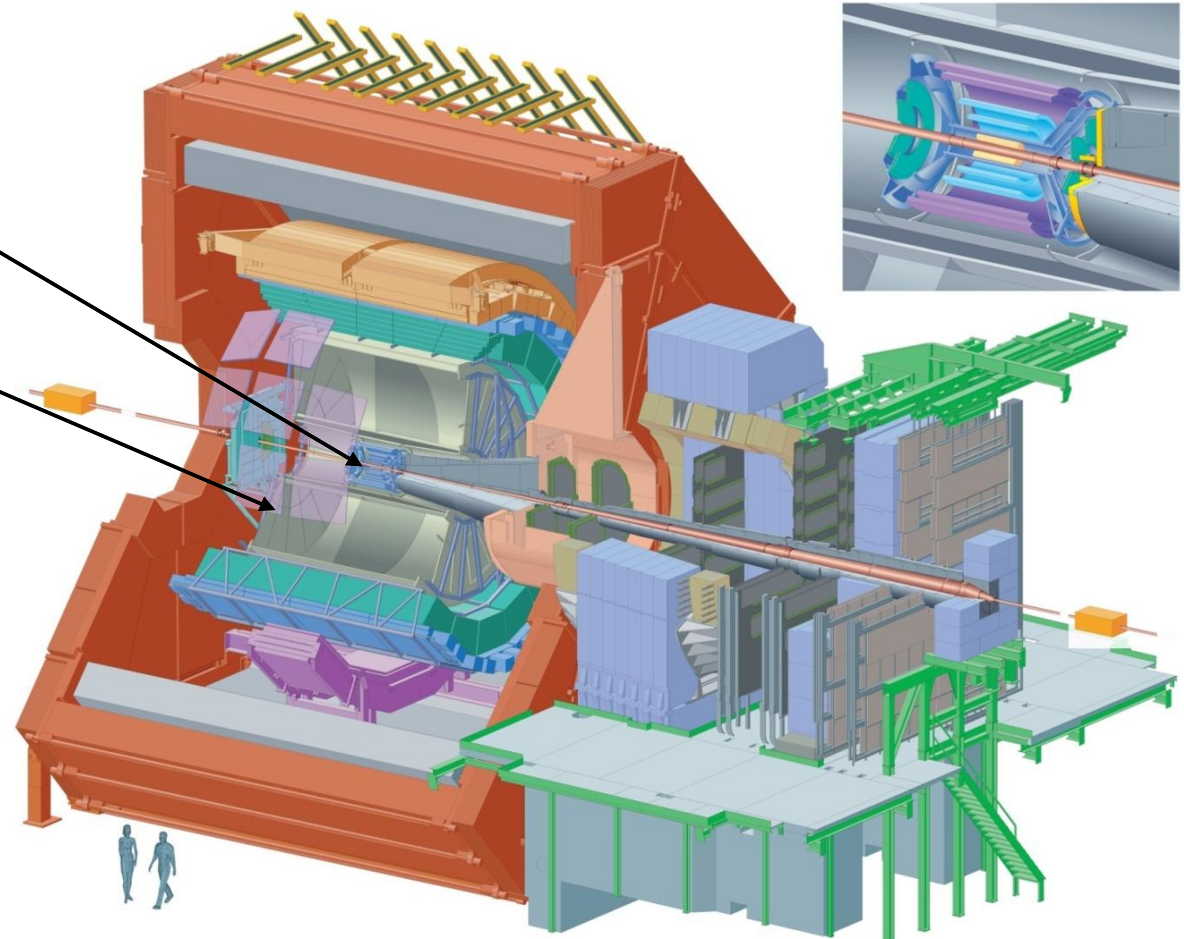


Analysis

ALICE – setup

Inner Tracking System

Time Projection Chamber

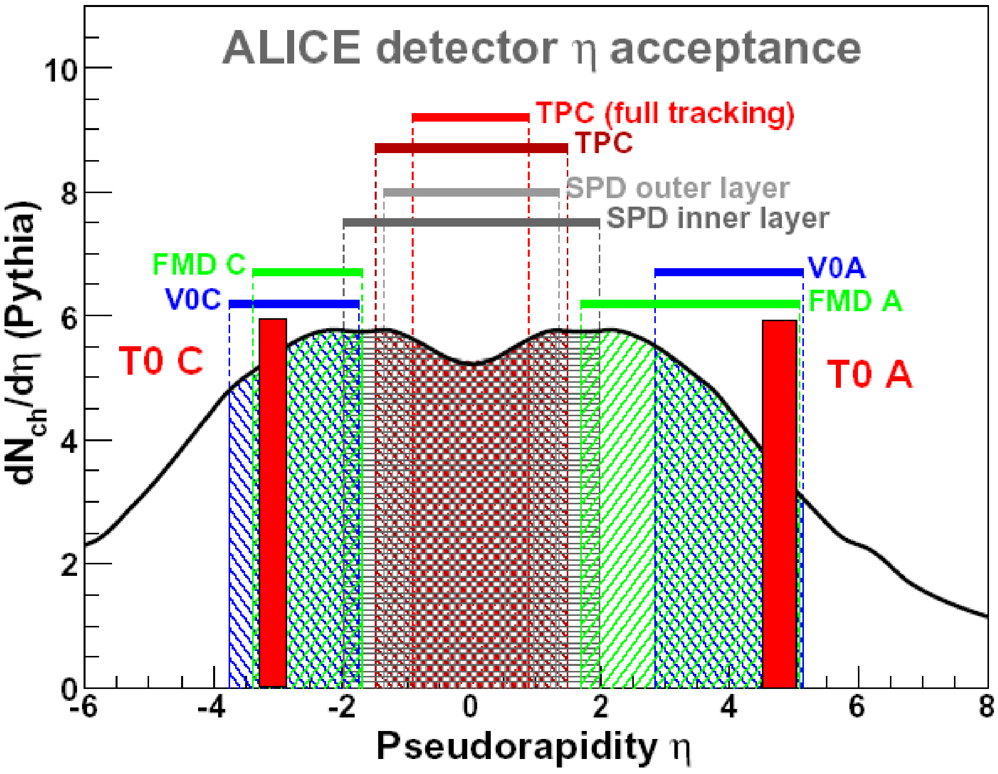


ITS and **TPC** detectors used in present analysis of p_T spectra.

Event Selection

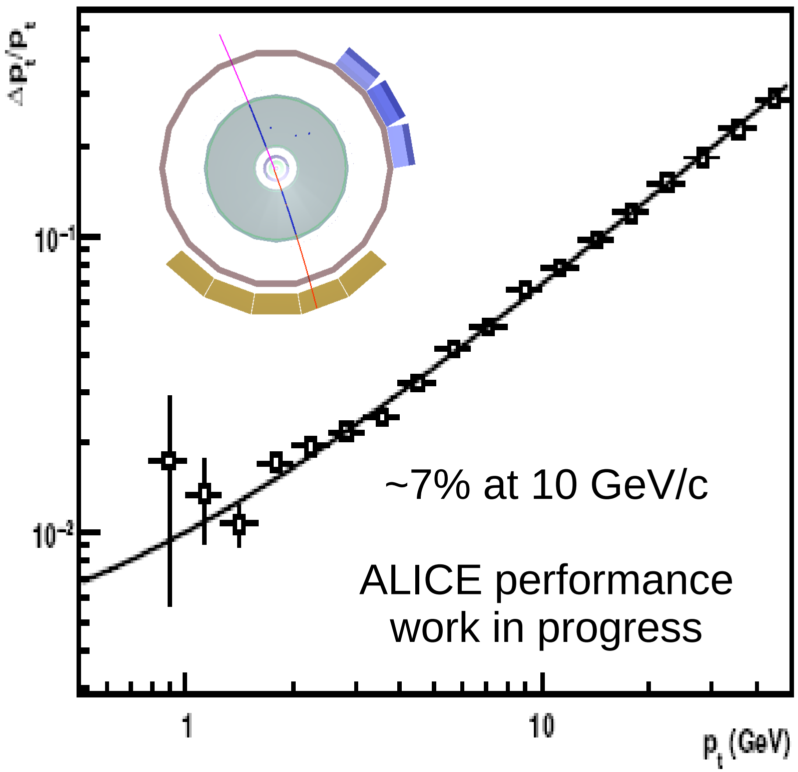
- Min Bias Trigger
  - SPD or V0A or V0C
- Beam background rejection
  - SPD and V0
- Event and track selection
  - ITS + TPC

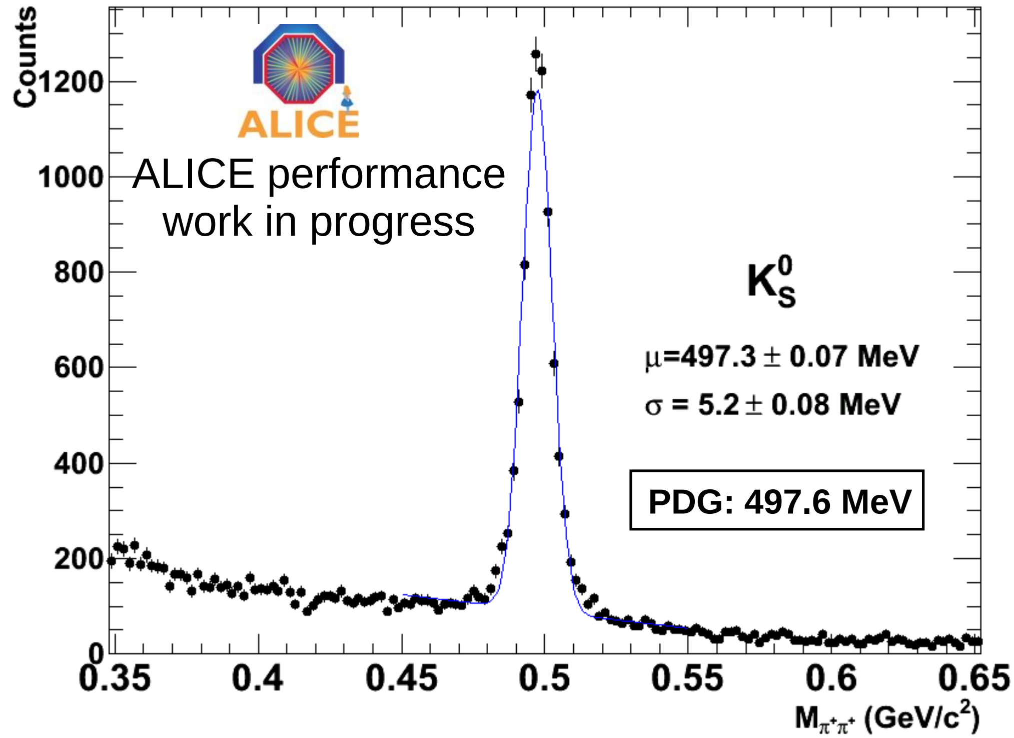
(full tracking, |η| < 0.8)
2.67 x 10^5 *pp* events
$\sqrt{s}$ = 900 GeV



TPC calibration

momentum resolution (from matching of two segments of cosmic track)

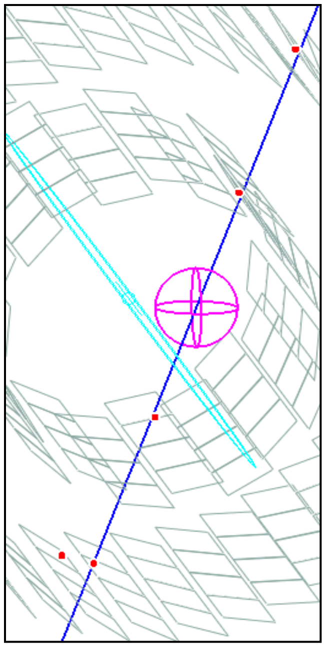


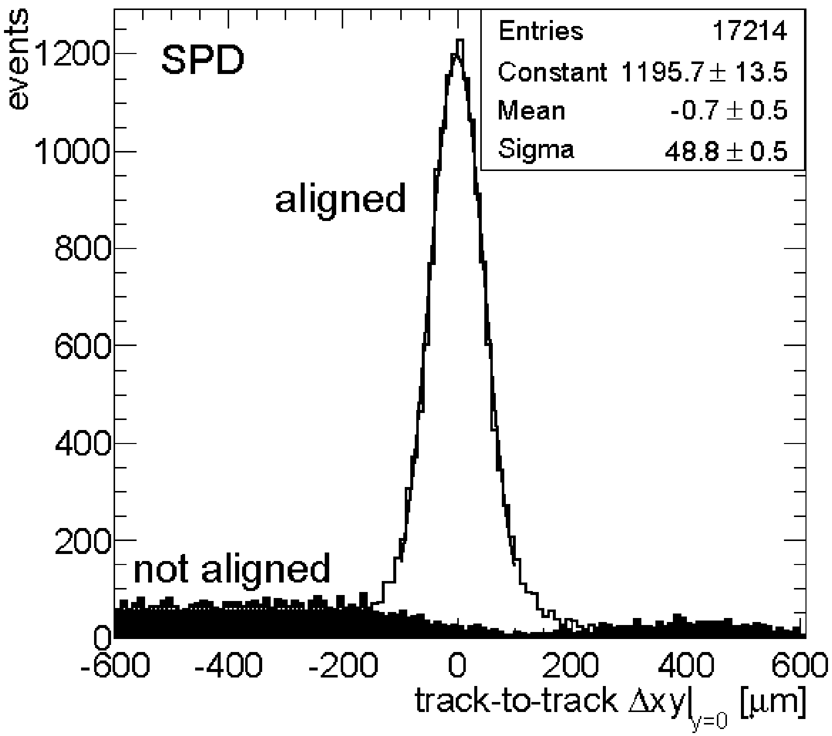


- → **present p_T resolution**
- **7% at 10 GeV/c**
- **below 1% at p_T<1 GeV/c**
- **confirmed by K^0_s measurements**

ITS alignment

alignment with cosmic tracks





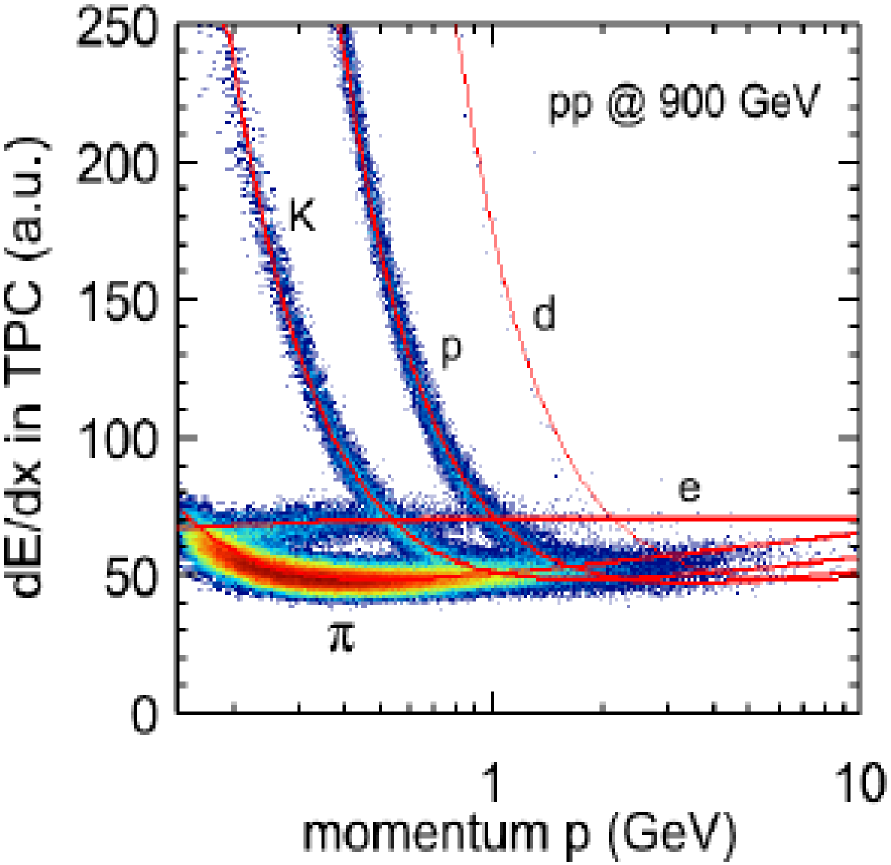
SPD alignment:

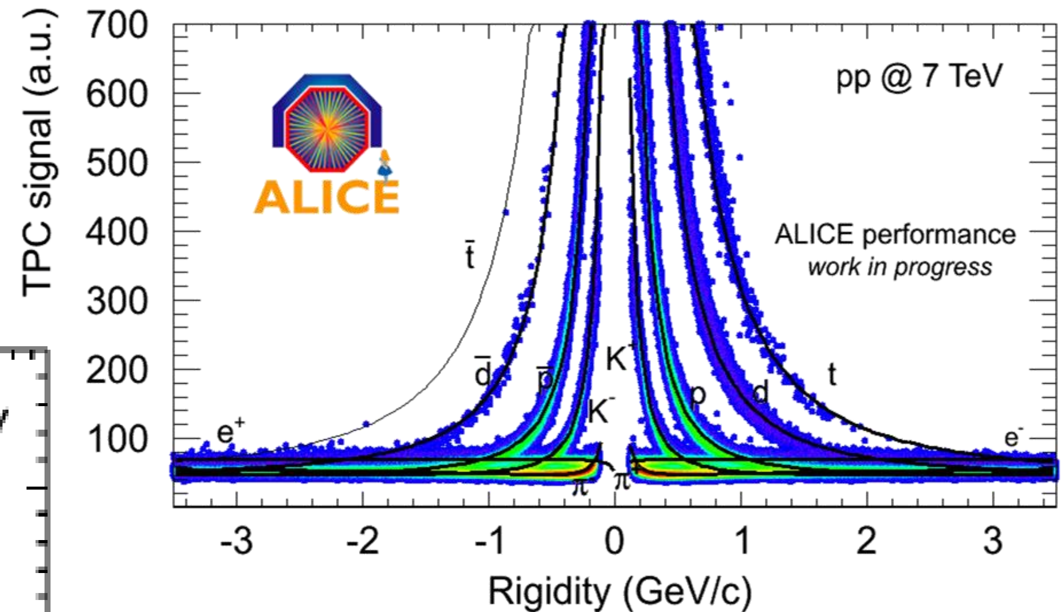
- $\sigma_{r\varphi} \approx 14\ \mu m$
- impact parameter resolution $\sigma \sim 50\ \mu m$
- misalignment < 10 μm

→close to design values

alignment with pp data ongoing

TPC dE/dx



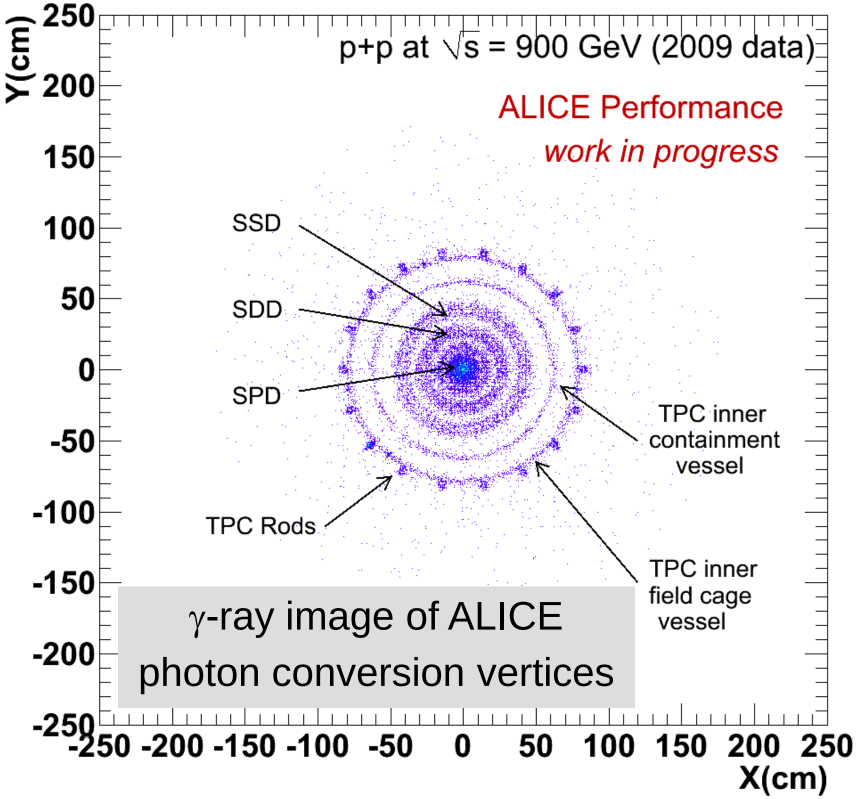


TPC dE/dx resolution:

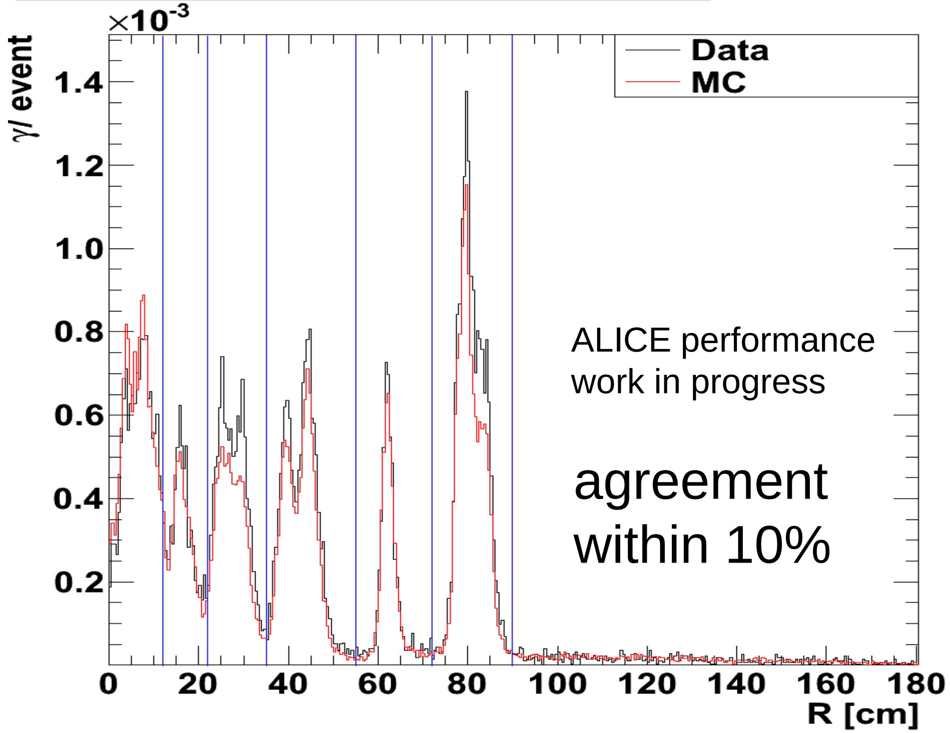
5.5% (= design value!)

TPC particle ID used for track propagation through material and p_T reconstruction.

Material Budget

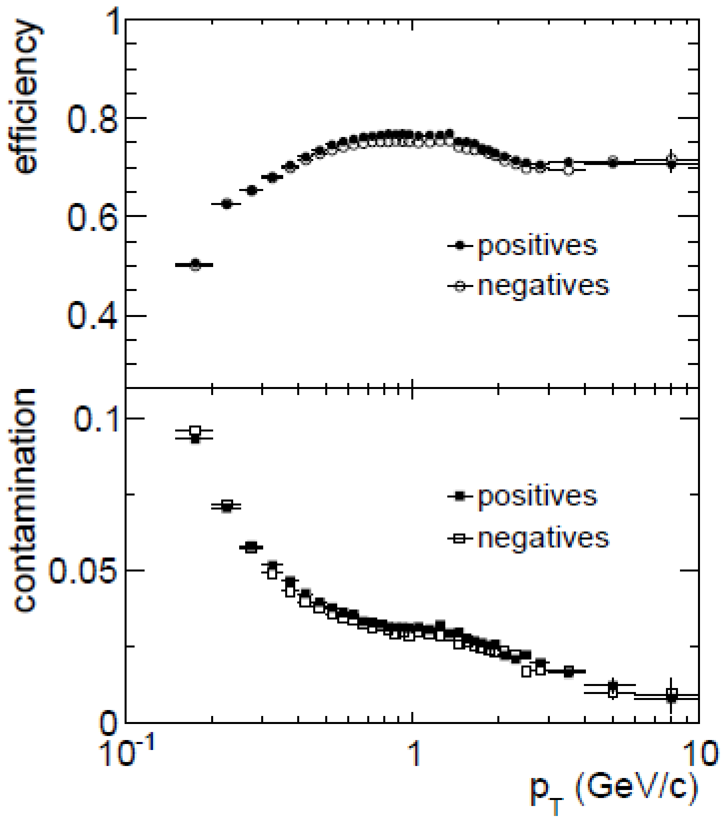


γ-ray image of ALICE – R distribution



- MC corrections rely on detailed knowledge of material budget
  - Efficiency correction (particle absorption)
  - Contamination correction (γ conversion, protons, ...)
  - Energy loss corrections (10% for 0.2 GeV/c pions)
- **Agreement between MC and Data within 10%.**

Efficiency and Contamination



Efficiency of the primary track selection

Contamination by secondary tracks

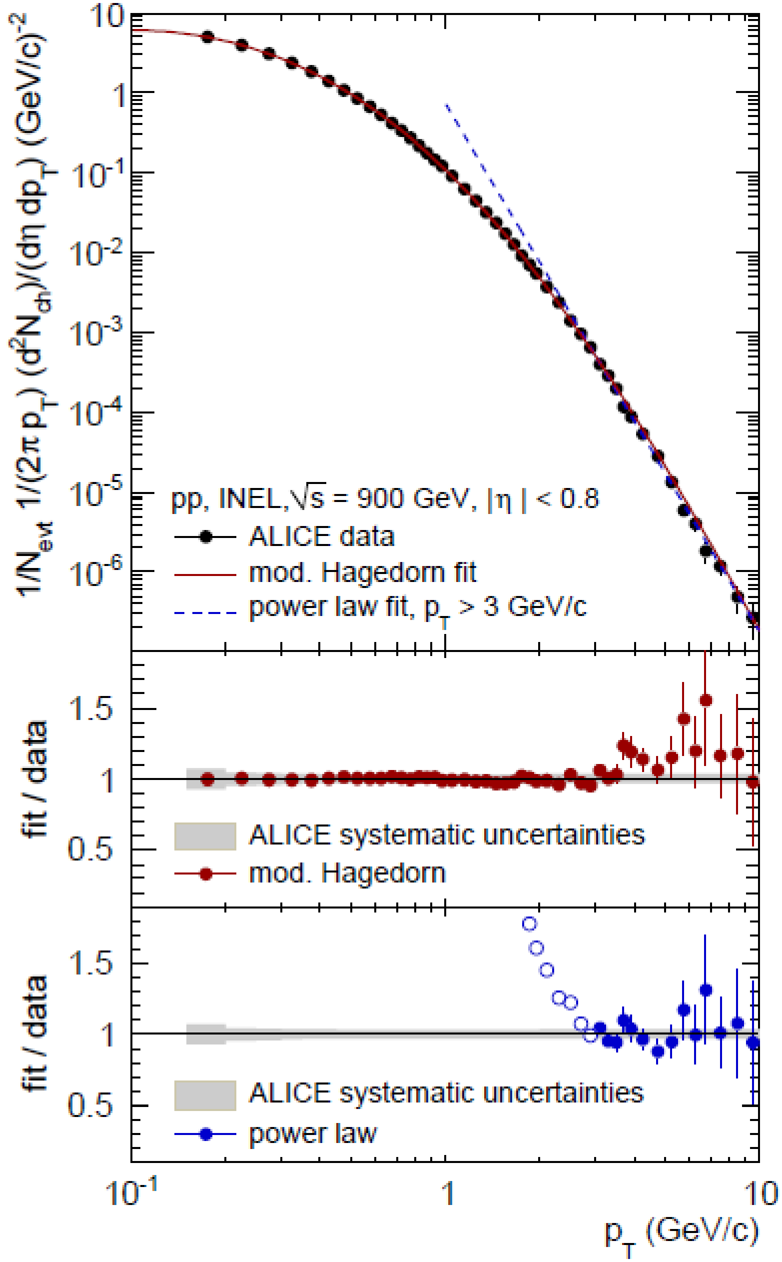
PYTHIA

Systematic Uncertainties

	$\frac{1}{N_{evt}}\frac{1}{2\pi p_T}\frac{d^2N_{ch}}{d\eta\, dp_T}$	$\langle p_T \rangle$		
p_T range (GeV/c)	0.15 – 10	0.5 – 4	0.15 – 4	0 – 4 (extrap.)
Track selection cuts	0.2-4%	negl.	0.3%	0.5%
Contribution of diffraction (INEL)	0.9-1%	negl.	negl.	negl.
Contribution of diffraction (NSD)	2.8-3.9%	-	-	-
Event generator dependence (INEL)	2.5%	negl.	negl.	negl.
Event generator dependence (NSD)	0.5%	-	-	-
Particle composition	1-2%	0.1%	negl.	0.1%
Secondary particle rejection	0.2-1.5%	negl.	0.1%	0.2%
Detector misalignement	negl.	negl.	negl.	negl.
ITS efficiency	0-1.6%	negl.	0.3%	0.5%
TPC efficiency	0.8-4.5%	negl.	0.5%	0.7%
SPD triggering efficiency	negl.	negl.	negl.	negl.
VZERO triggering efficiency (INEL)	negl.	negl.	negl.	negl.
VZERO triggering efficiency (NSD)	0.2%	-	-	-
Beam-gas events	negl.	negl.	negl.	negl.
Pile-up events	negl.	negl.	negl.	negl.
Total (INEL)	3.0-7.1%	0.1%	0.7%	1.0%
Total (NSD)	3.5-7.2%	-	-	-
R weighting procedure		3.0%	3.0%	3.0%
Extrapolation to $p_T = 0$		-	-	1.0%
Total		3.0%	3.1%	3.3%

p_T Spectra

dN_{ch}/dp_T



Fit by modified Hagedorn function
For extrapolation to p_T=0

$$\frac{1}{2\pi p_T}\frac{d^2N_{ch}}{d\eta\, dp_T} \propto \frac{p_T}{m_T}\left(1+\frac{p_T}{p_{T,0}}\right)^{-b}.$$

$p_{T,0}$ = 1.05 ± 0.01 (stat.)±0.05 (syst.) GeV/c
b = 7.92 ± 0.03 (stat.)±0.02 (syst.).

Fit by power law function for p_T>3 GeV/c

$$\frac{1}{2\pi p_T}\frac{d^2N_{ch}}{d\eta\, dp_T} \propto p_T^{-n},$$

n = 6.63 ± 0.12 (stat.) ±0.01 (syst.)

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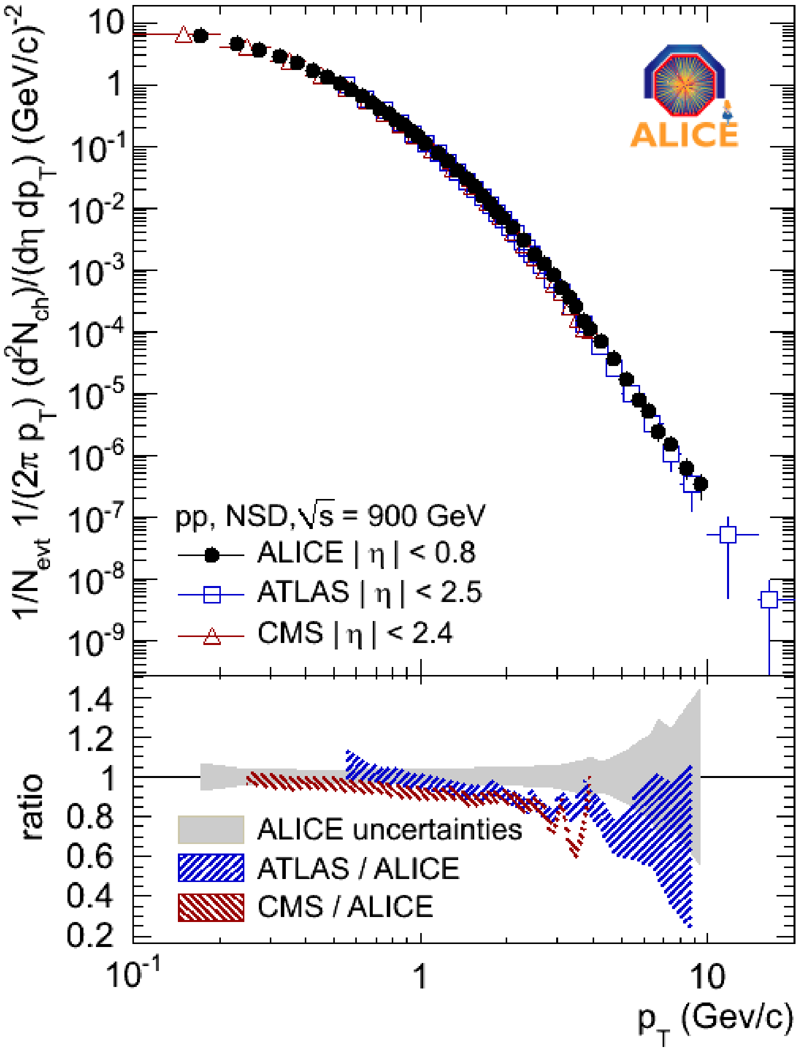
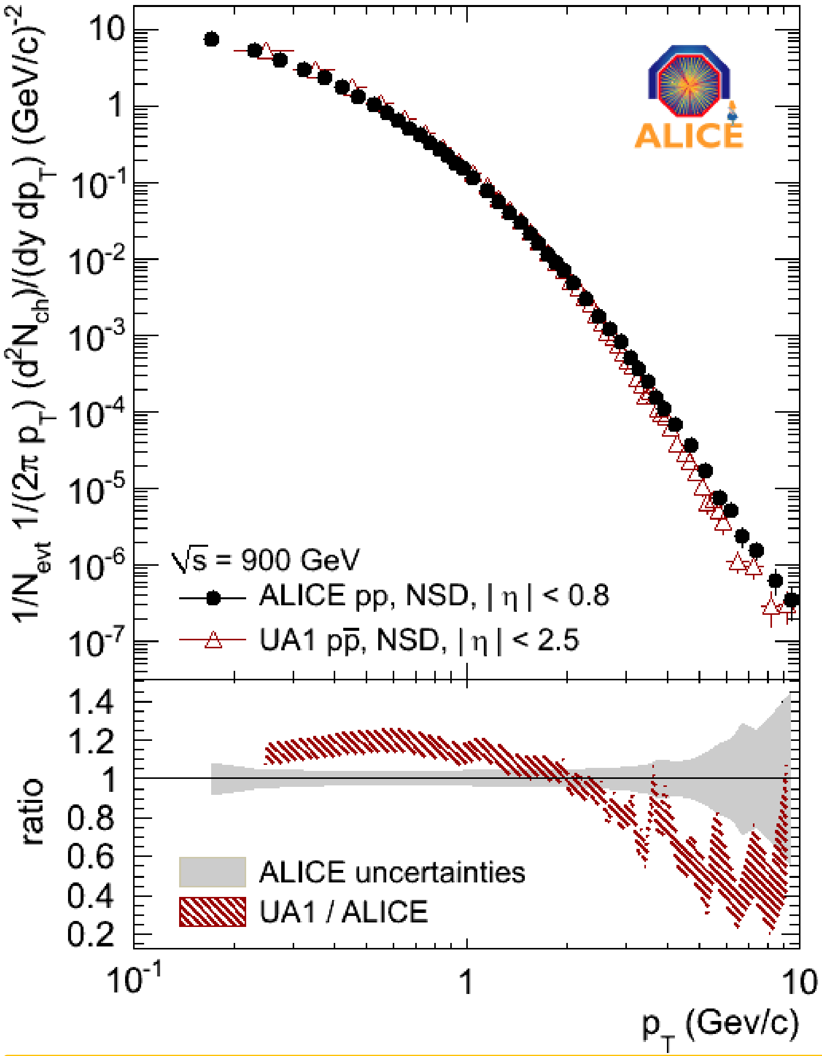
dN_{ch}/dp_T – comparison to experiments

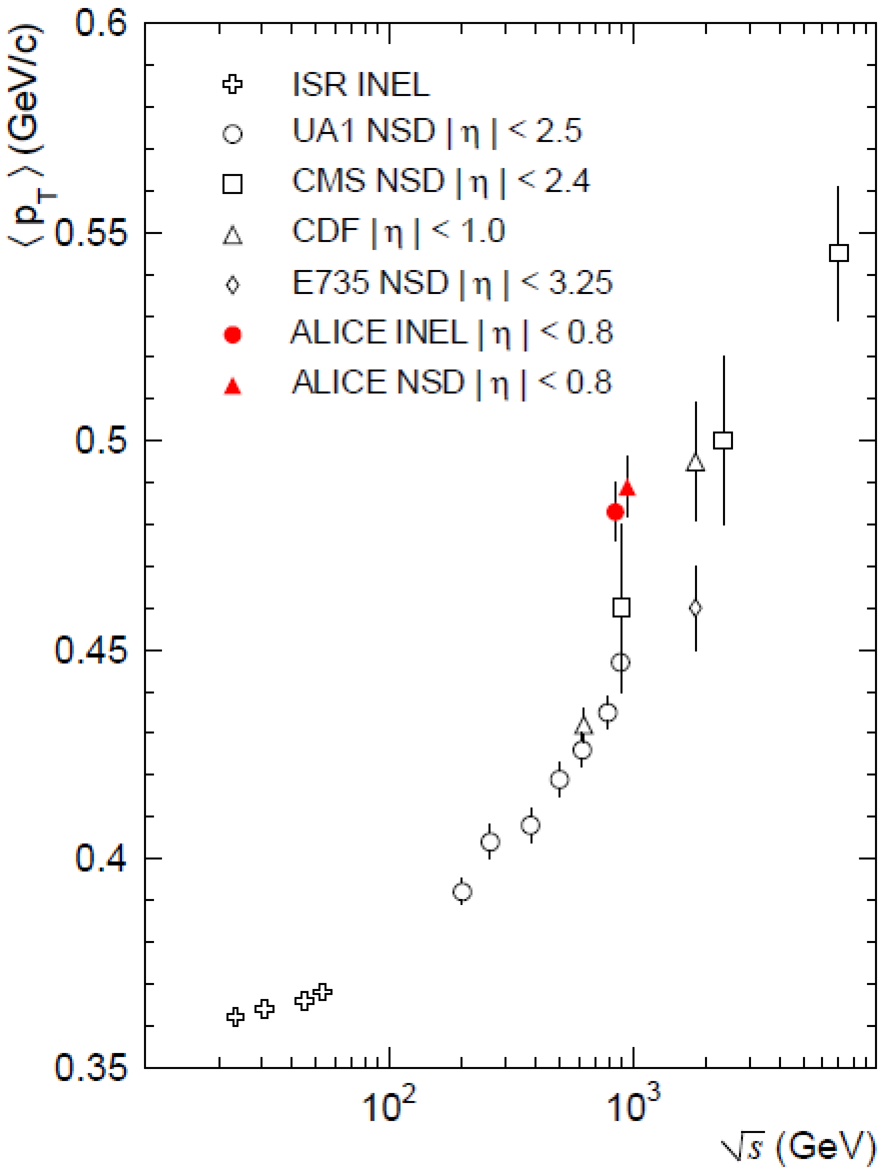




- good agreement at p_T<1 GeV/c
- ALICE spectrum harder at higher p_T

- UA1 sees higher yield at low p_T

$\langle p_T \rangle$ - energy dependence



- ALICE sees larger $\langle p_T \rangle$ than other experiments with larger η acceptance at 900 GeV

- similar trend also observed
  - at Tevatron
  - in η bins of CMS data
  - in PYTHIA

$\langle p_T \rangle_{INEL} = 0.483 \pm 0.001\ (stat.)$
$\pm 0.007 (syst.)\ GeV/c.$

$\langle p_T \rangle_{NSD} = 0.489 \pm 0.001\ (stat.)$
$\pm 0.007 (syst.)\ GeV/c.$

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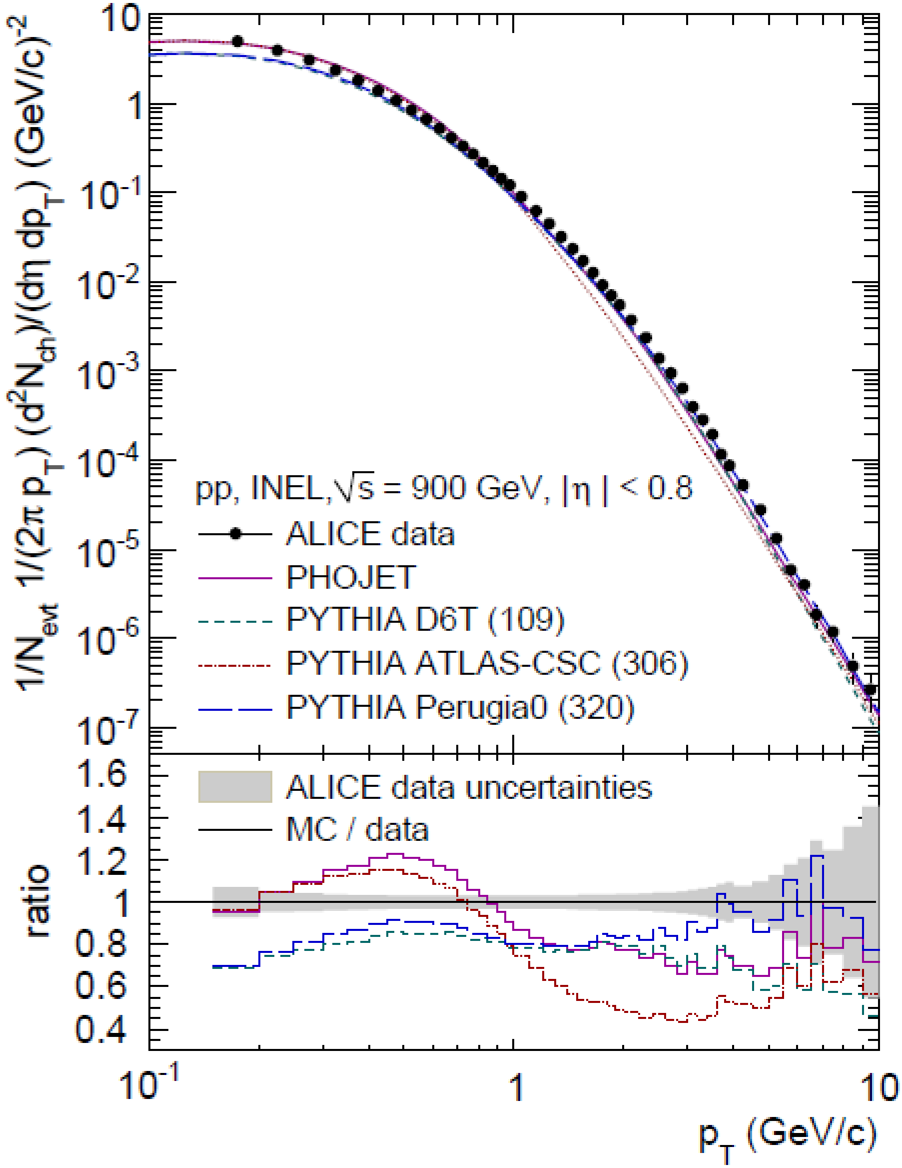
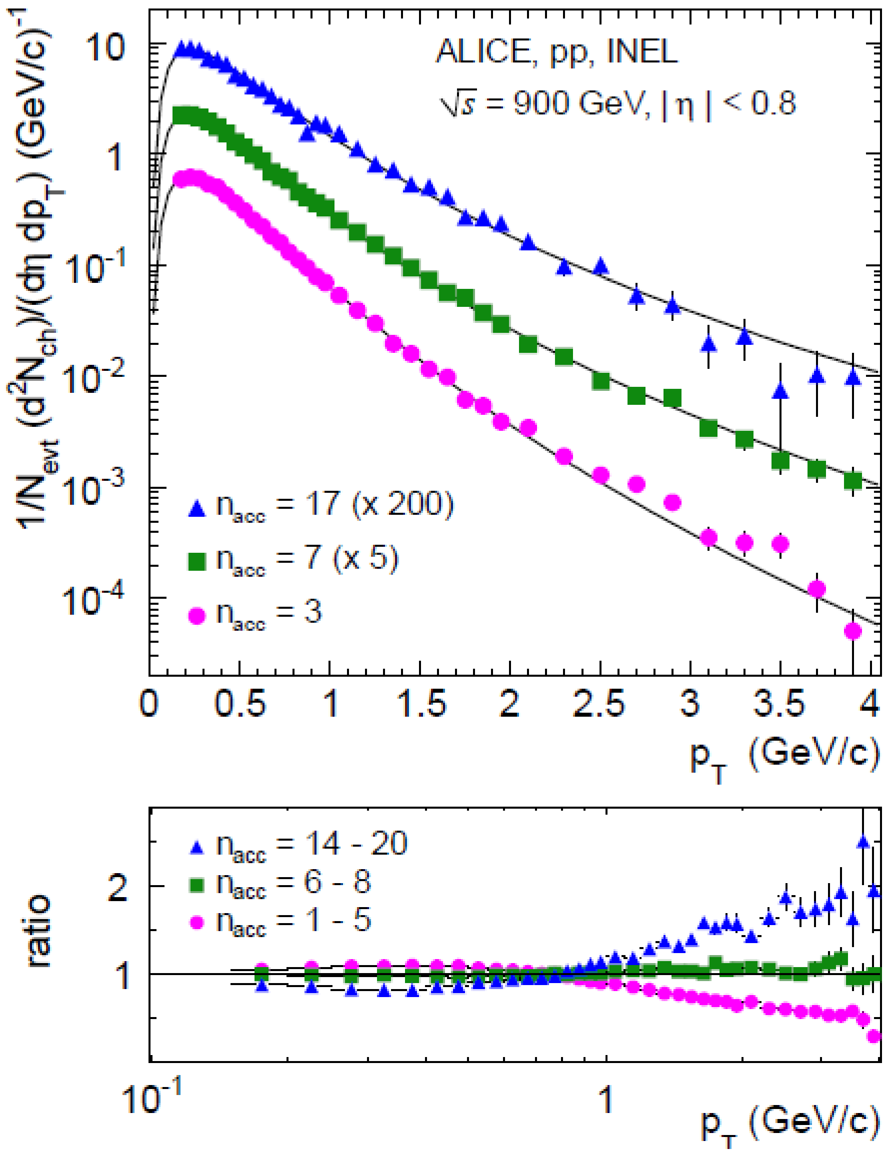
dN_{ch}/dp_T – comparison to MC



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

Multiplicity Dependence

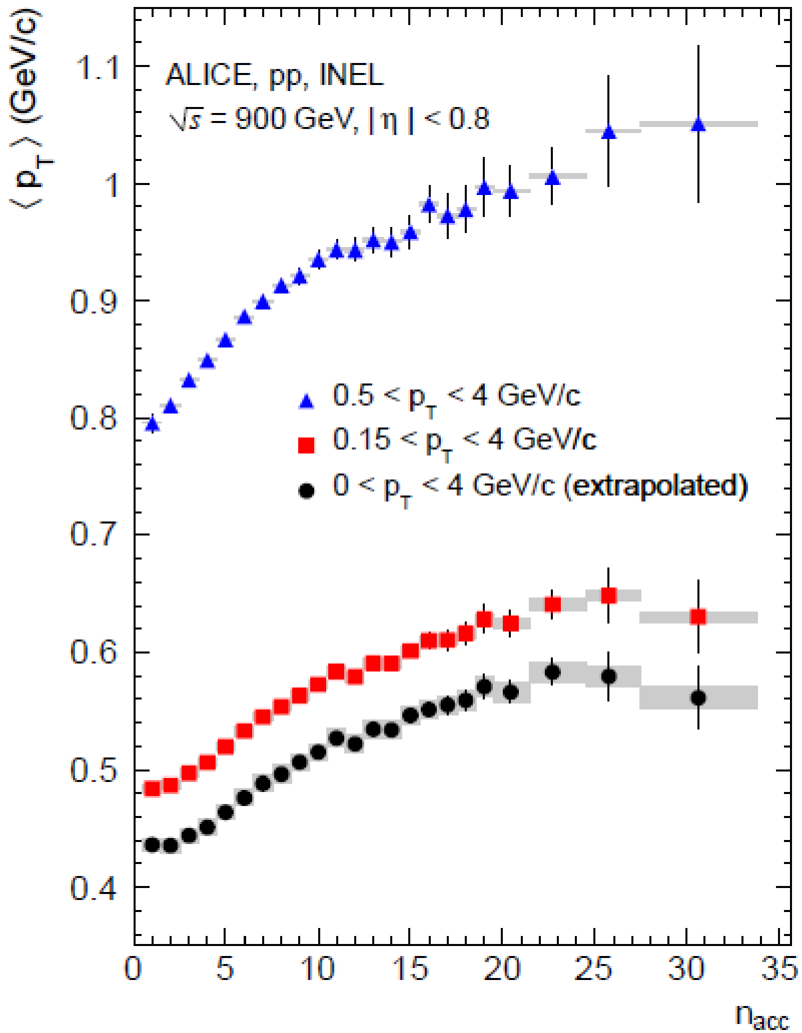
$<p_T>$ vs multiplicity



Fits of $$\frac{1}{p_T}\frac{d^2N_{ch}}{d\eta dp_T} \propto \frac{p_T}{m_T}\left(1+\frac{p_T}{p_{T,0}}\right)^{-n}$$

in bins of multiplicity

<pT> vs multiplicity

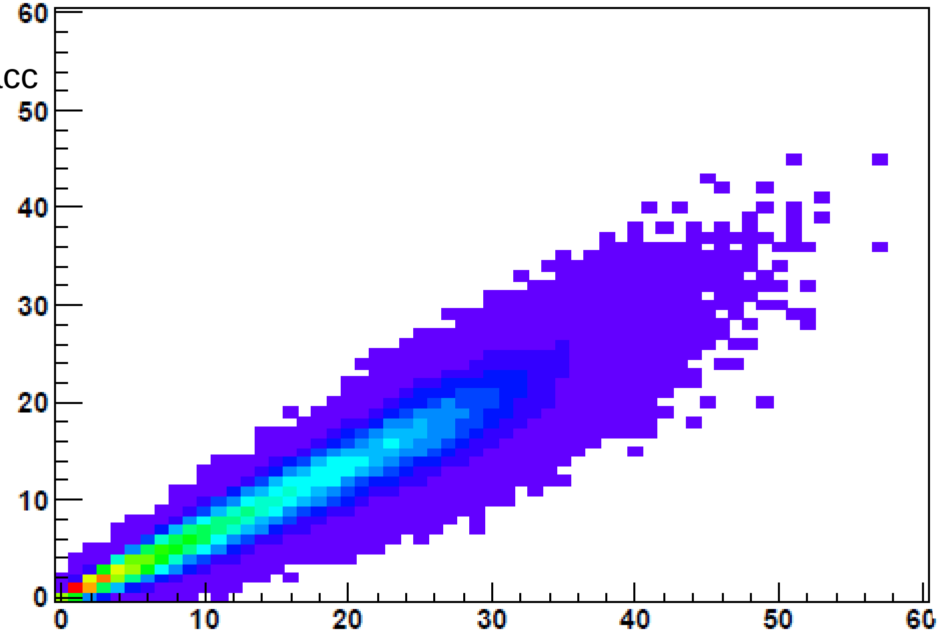


p_T > 500 MeV/c:
weighted average over data points $0.5<p_T<4$ GeV/c

p_T > 150 MeV/c:
weighted average over data points $0.15<p_T<4$ GeV/c

p_T >0:
weighted average over data points $0.15<p_T<4$ GeV/c, combined with result from fit at $p_T<0.15$ GeV/c

N_{meas} to N_{true}



n_{acc}

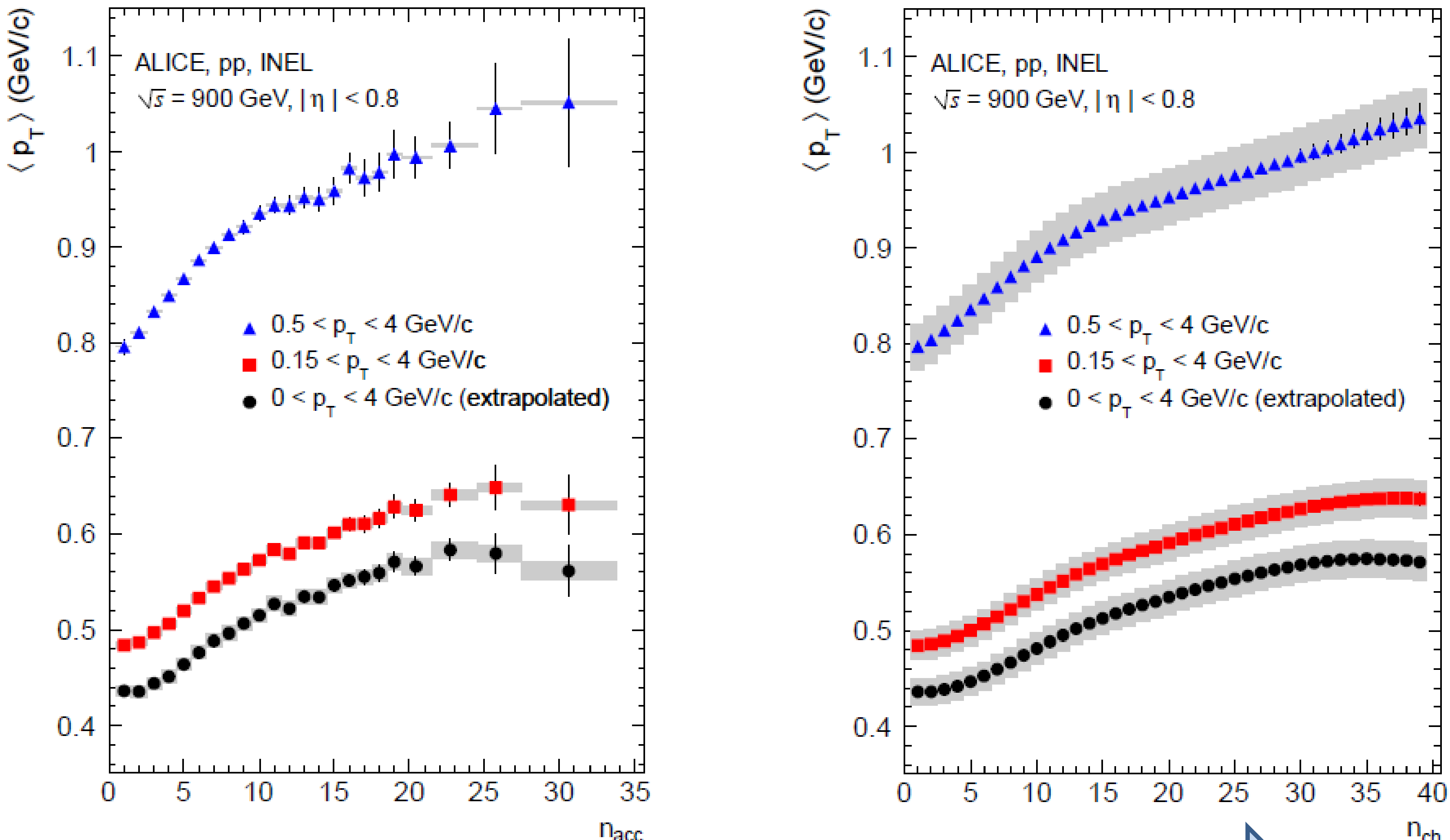
n_{ch}

PYTHIA

- Transition not trivial
- Cross checks:
  - PYTHIA
  - PHOJET
  - Unfolding of matrix
- Edge effects to be considered

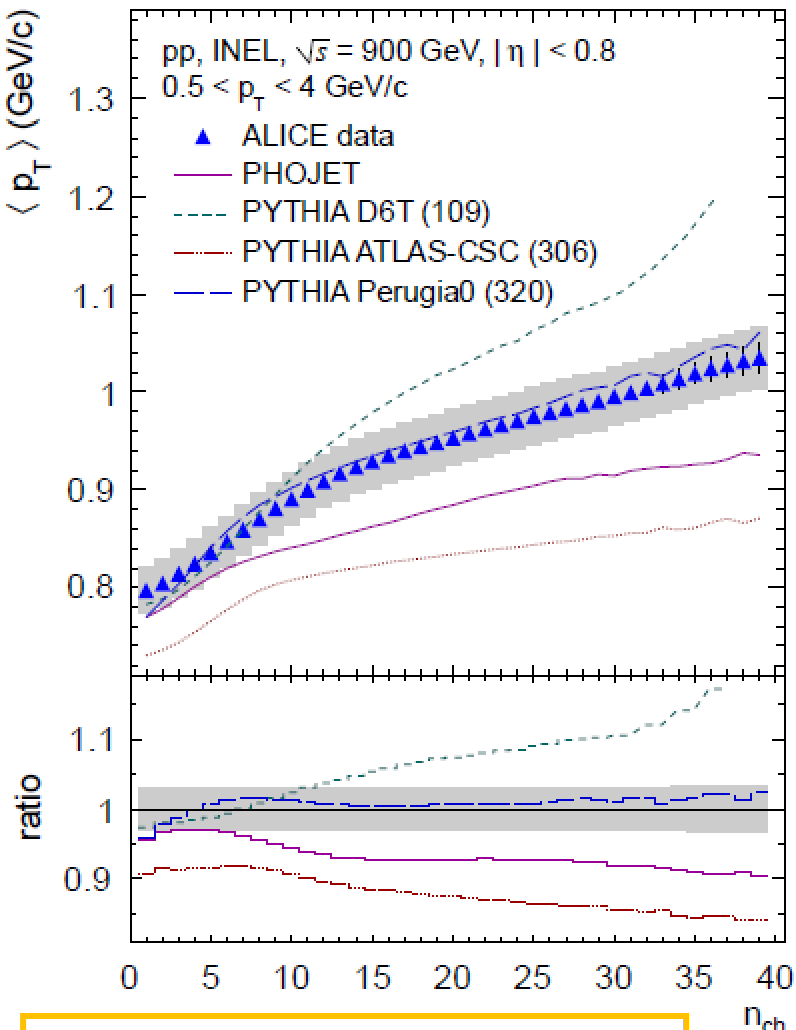
$$\langle p_T \rangle (n_{ch}) = \sum_{n_{acc}} \langle p_T \rangle (n_{acc}) \cdot R(n_{ch}, n_{acc})$$

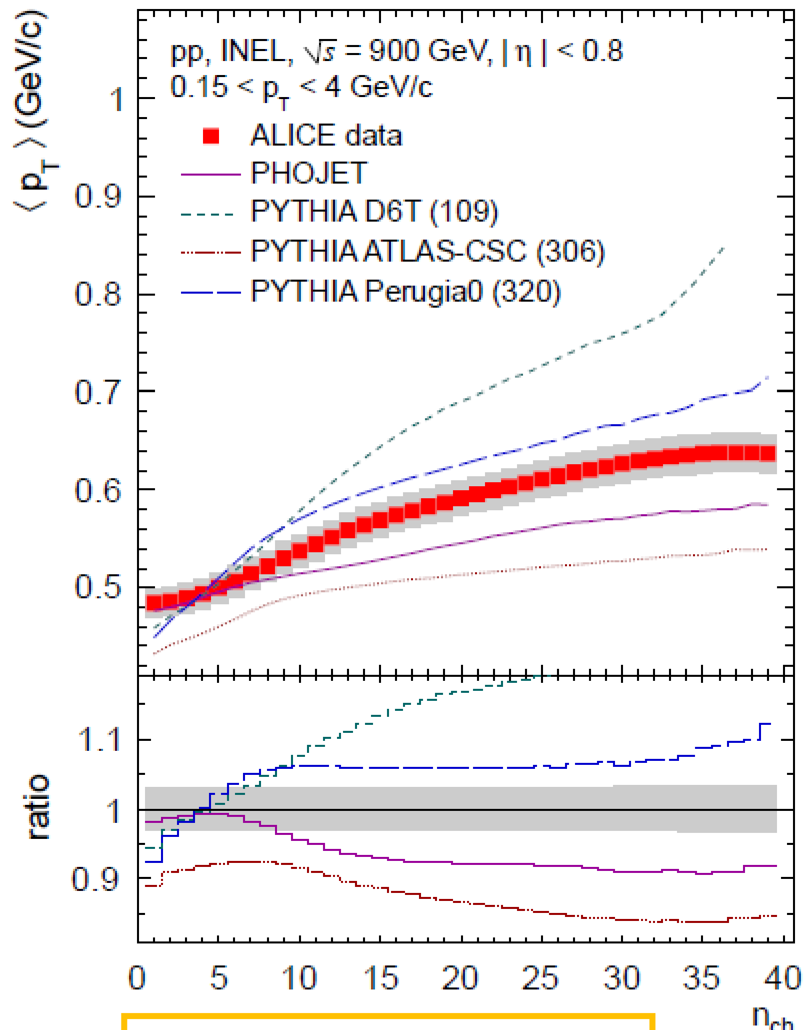
<pT> vs multiplicity



from measured to true multiplicity (employing MC)

$<p_T>$ vs multiplicity – comparison to MC

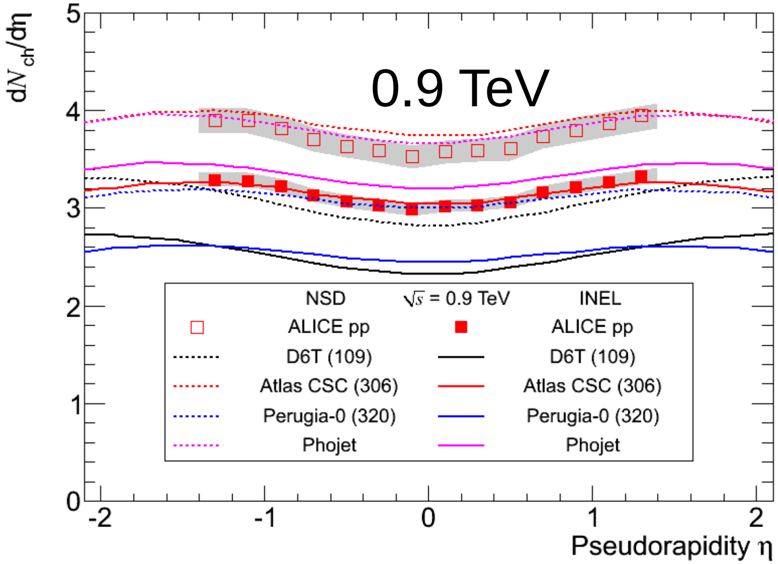


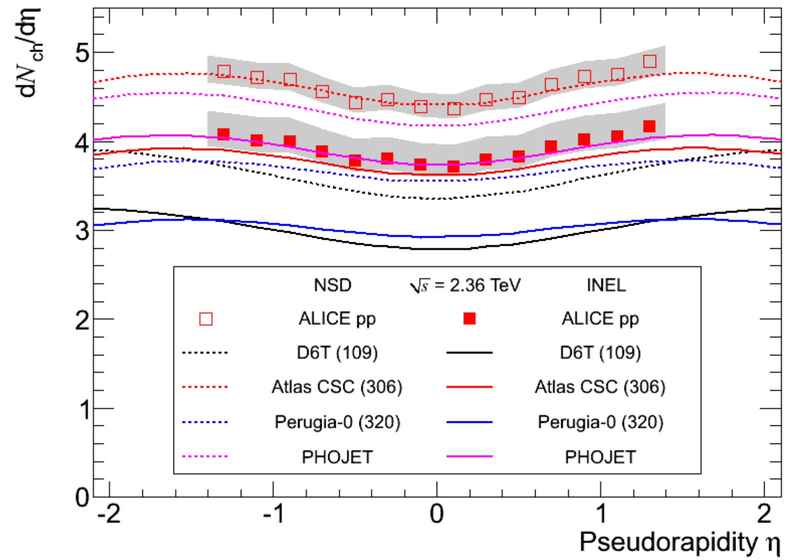


- p_T>500 MeV/c:
  PYTHIA Perugia0 gives good description of the data

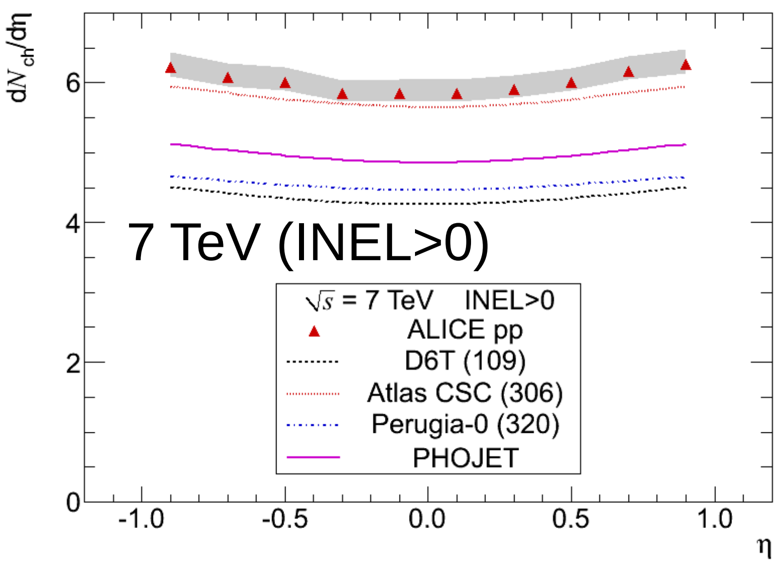
p_T>150 MeV/c:
all models fail
(Perugia0 is still best)

Reminder: $dN_{ch}/d\eta$



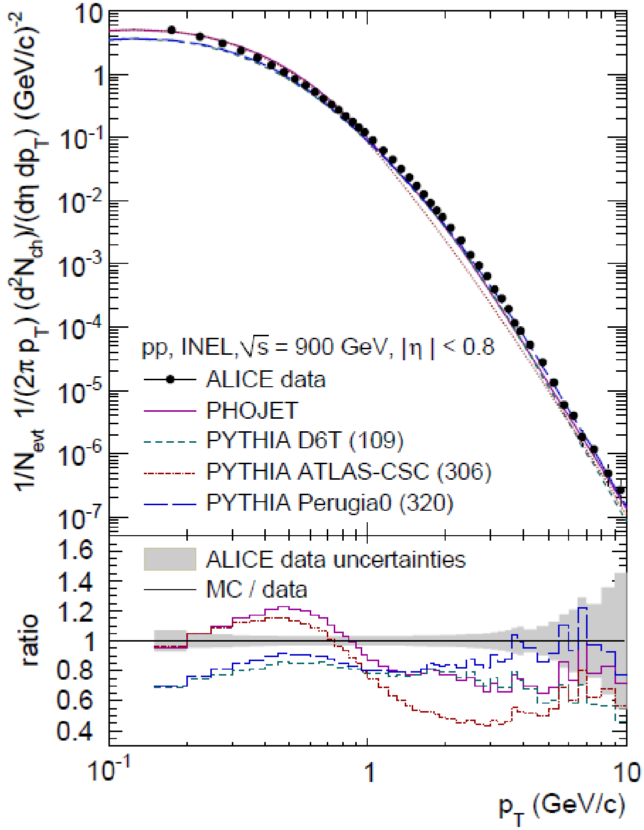


2.36 TeV

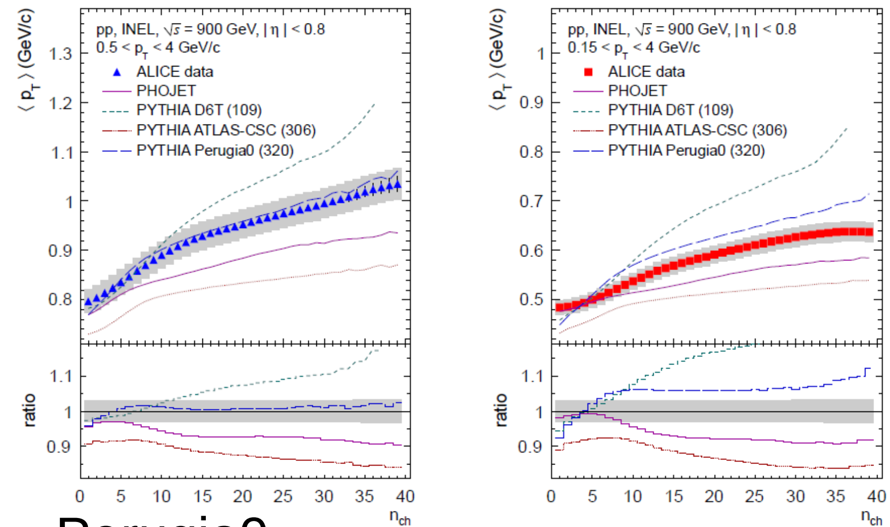


- PYTHIA D6T and Perugia-0 don't match at any energy
- Pythia ATLAS-CSC and PHOJET reasonably close at 0.9 and 2.36 TeV
- only ATLAS-CSC close at 7 TeV

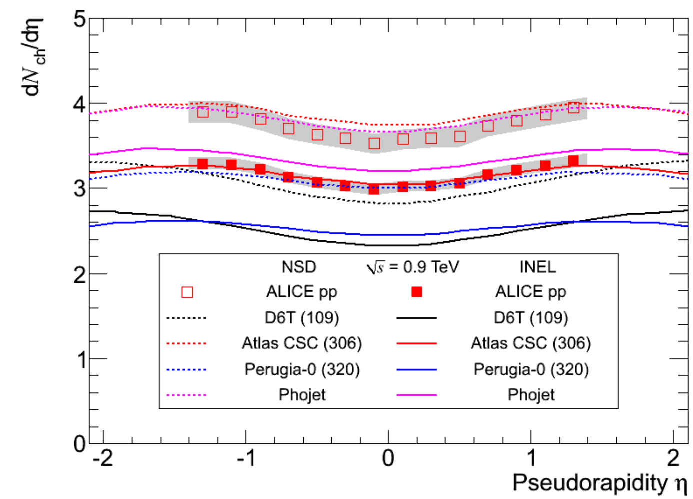
Monte Carlo



PYTHIA D6T and Perugia0



~Perugia0



ATLAS-CSC and PHOJET

None of the MC's do really well

Summary

•Primary charged particle transverse momentum spectrum
•Mean transverse momentum
for pp collisions at $\sqrt{s}$ = 900 GeV

•Good agreement with previous results from LHC up to p_T = 1 GeV/c
•At higher p_T , harder momentum spectrum than other measurements at same energy -> different pseudorapidity intervals

•None of models and tunes describe p_T spectrum and correlation between $\langle p_T \rangle$ and n_{ch}

•In low p_T region, where the bulk of the particles are produced, the models require further tuning

Outlook and Questions

- Data will be used as baseline for heavy ion measurements
- Need for good energy scaling
- What do we learn on soft QCD rather than only modifying parameters?
- What are the implications on HI predictions?