



# MPI@LHC 2011

## Experimental results: status & perspectives

**Arthur M. Moraes**  
**University of Glasgow**



# MPI@LHC - advancing the debate on Multiple Partonic Interactions.



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## MPI@LHC 2011

3rd International Workshop on Multiple Partonic Interactions at the LHC

21 - 25 November 2011  
DESY, Hamburg

**Topics:**

- Phenomenology of MPI processes and multiparton distributions
- Theoretical considerations for the description of MPI
- Measuring multiple partonic interactions
- Experimental results on inelastic hadronic collisions: underlying event, minimum bias, forward energy flow
- Monte Carlo development and tuning
- Connections with diffraction, heavy-ion physics and cosmic rays

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<http://mpi11.desy.de>

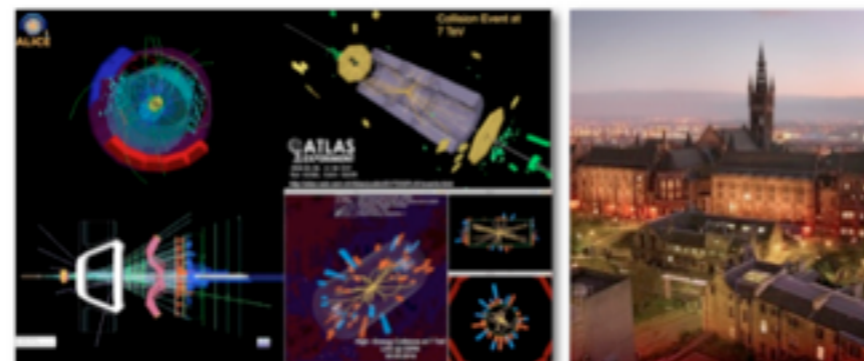


Home Proceedings Travel & Lodging Scientific programme Organising Committee Social



### MPI@LHC 2010: 2nd International Workshop on Multiple Partonic Interactions at the LHC

Glasgow, 29th of November to the 3rd of December 2010.



Welcome to MPI@LHC 2010

Welcome to the second International Workshop on Multiple Partonic Interactions at the LHC "2nd MPI@LHC".

The aim of this workshop on Multiple Partonic Interactions (MPI) at the LHC is to raise the profile of MPI studies, summarising the legacy from the older phenomenology at hadronic colliders, reviewing the early results from the LHC and favouring further specific contacts between the theory and experimental communities.

The MPI are experiencing a growing popularity and are currently widely invoked to account for observations that would not be explained otherwise: the activity of the Underlying Event, the cross sections for multiple heavy flavour production, the survival probability of large rapidity gaps in hard diffraction, etc. At the same

MPI@LHC 2010 on Indico

- Registration
- Scientific Programme
- Timetable
- Talk submission
- Organising Committee
- Travel & Lodging
- Social Events
- Contact e-mail

**1<sup>st</sup> International Workshop on Multiple Partonic Interactions at the LHC**  
**MPI@LHC'08** October 2-3, Perugia, Italy

The objective of the workshop is to raise the profile of MPI studies, the legacy from the older phenomenology and favouring contacts between theory and experimental communities.  
The ultimate ambition is to promote the MPI as unification of seemingly heterogeneous research lines and to profit of experimental picture in order to constrain their implementation evaluating the spin offs on the LHC physics program.

**Scientific Advisory Committee:**  
P. Bartalini (National Taiwan University, TW)  
J. Butterworth (University College London, UK)  
L. Fano (Istituto Nazionale di Fisica Nucleare, IT)  
R. Field (University of Florida, US)  
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M. Strikman (Pennsylvania State University, US)  
D. Treleani (Università degli Studi di Trieste, IT)

**Local Advisory Committee:**  
F. Andronico, G. M. Bilei, G. Chiochi, E. Gotsi, A. Santocchia (Università di Perugia and Istituto Nazionale di Fisica Nucleare, Perugia, IT)

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# MPI@LHC - advancing the debate on Multiple Partonic Interactions.

## MPI@LHC 2011

3rd International Workshop on Multiple Partonic Interactions at the LHC

This workshop series attempts to connect **theory-phenomenology-experiment** to better understand MPI related phenomena.

- ▶ several advances in theory predictions;
- ▶ new physics components added to MC models;
- ▶ remarkable advance on MC tuning;
- ▶ experimental results discussed in these workshops have come from various sources:

**Tevatron, RHIC, HERA and LHC.**

25th November - 1st December 2011  
DESY, Hamburg

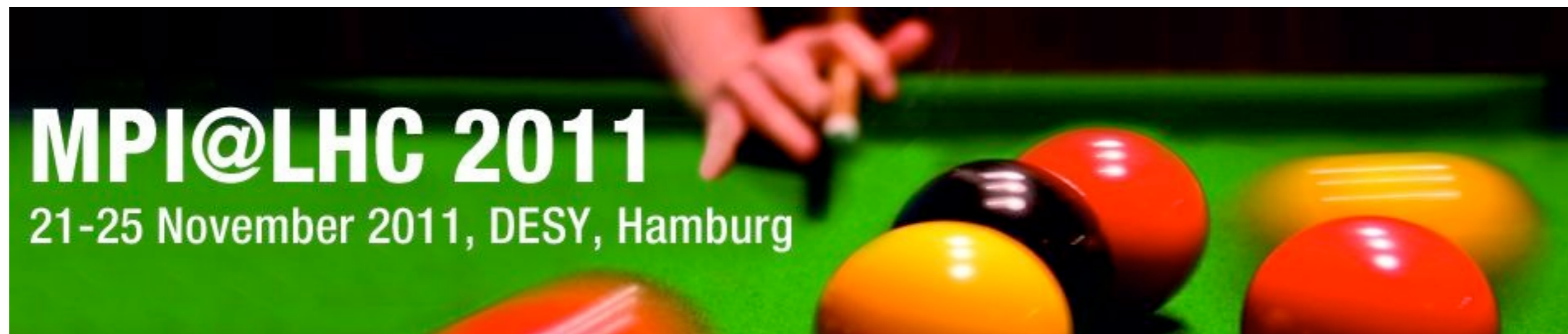
- Theoretical considerations for the description of MPI
- Measuring multiple partonic interactions
- Experimental results on inelastic hadronic collisions: underlying event, minimum bias, forward energy flow
- Connections with diffraction, heavy-ion physics and cosmic rays

Advisors: R. Engel (International Centre for Theoretical Physics, Trieste), G. Gustafson (University of Glasgow), J. Huston (University College London), L. Fano (INFN / Perugia), R. Field (University of Florida), I. Hinchliffe (LBNL), H. Jung (DESY), F. Krauss (University of Durham), S. Lam (INFN / Pisa), M. Mangano (CERN), A. Moraes (University of Glasgow), A. Moroni (CERN), G. Pascher (INFN / Roma), M. Schmeling (MPI Heidelberg), T. Sjostrand (Lund University), J. Skilling (University of Cambridge), Y. Srivastava (INFN / Perugia), M. Stikman (Pennsylvania State University), D. Treleani (INFN / Trieste)

Organized by: M. Medina, K. Mönig, Z. Nagy, S. Platzer, G. Stenlund, M. Stenlund, K. Stemmer, G. Weiglein

<http://mpi11.desy.de>





● (...some) **Highlights of experimental results presented this year...**

**(just a small selection of plots/slides)**

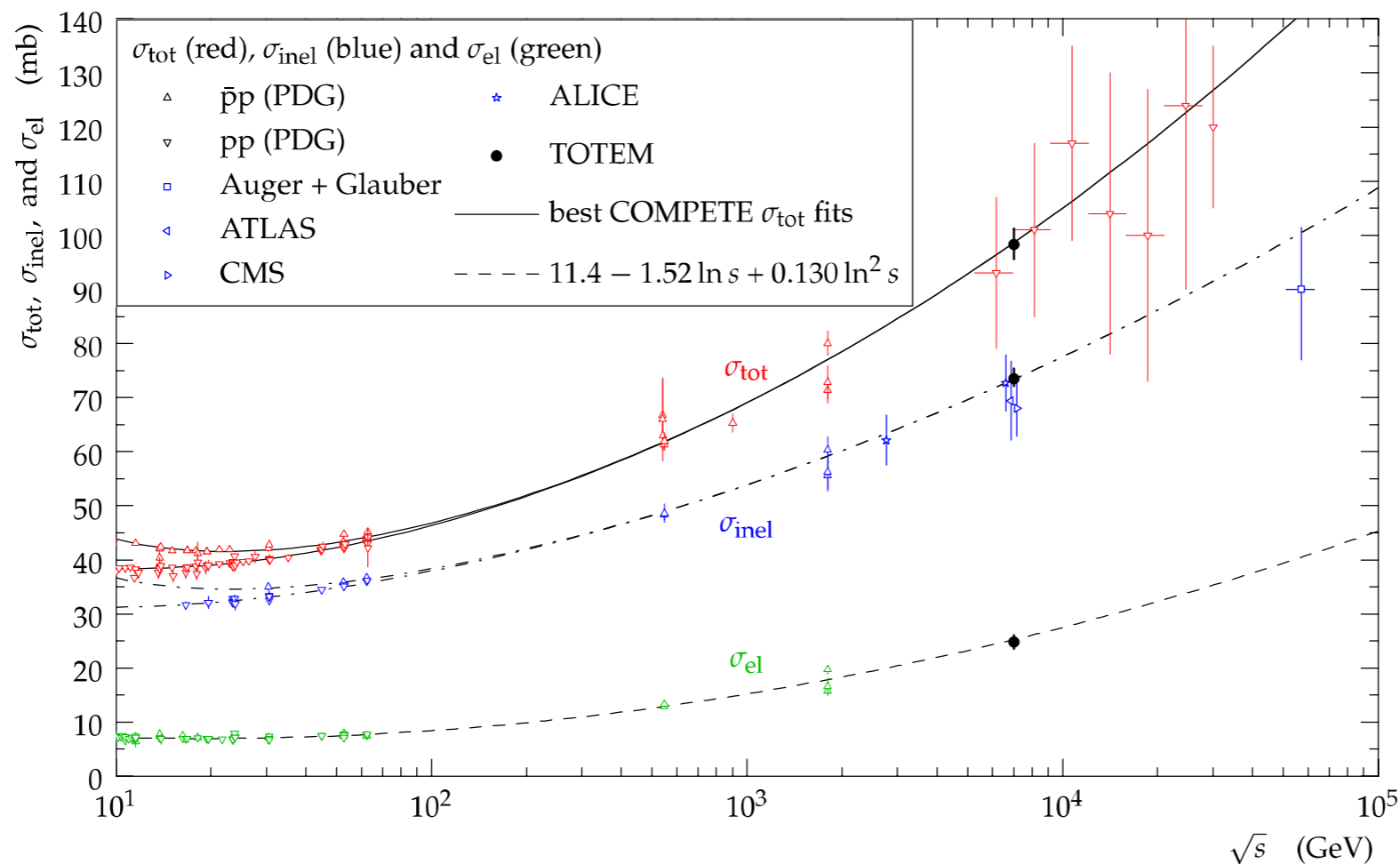


## TOTEM results & comparison

$$\sigma_{\text{tot}} = 98.3 \pm 0.2^{(\text{stat})} \pm 2.8^{(\text{syst})} \text{ mb}$$

$$\sigma_{\text{ele}} = 8.3 \text{ mb}^{(\text{extrapol.})} + 16.5 \text{ mb}^{(\text{measured})} = 24.8 \pm 0.2^{(\text{stat})} \pm 1.2^{(\text{syst})} \text{ mb}$$

$$\sigma_{\text{inel}} = \sigma_{\text{tot}} - \sigma_{\text{ele}} = 73.5 \pm 0.6^{(\text{stat})} \pm 1.8^{(\text{syst})} \pm 1.3^{(\text{syst})} \text{ mb}$$



$$\sigma_{\text{inel}} (\text{CMS}) = 68.0 \pm 2.0^{(\text{syst})} \pm 2.4^{(\text{lumi})} \pm 4.0^{(\text{extrap})} \text{ mb}$$

$$\sigma_{\text{inel}} (\text{ATLAS}) = 69.4 \pm 2.4^{(\text{exp})} \pm 6.9^{(\text{extrap})} \text{ mb}$$

$$\sigma_{\text{inel}} (\text{ALICE}) = 72.7 \pm 1.1^{(\text{model})} \pm 5.1^{(\text{lumi})} \text{ mb}$$

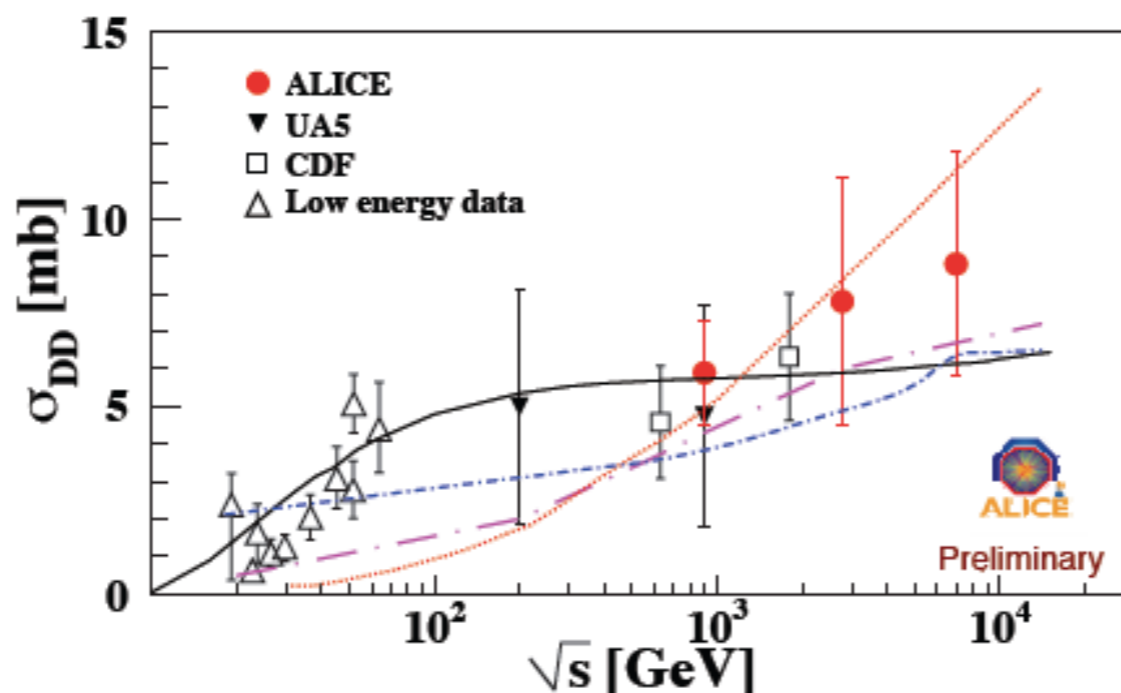
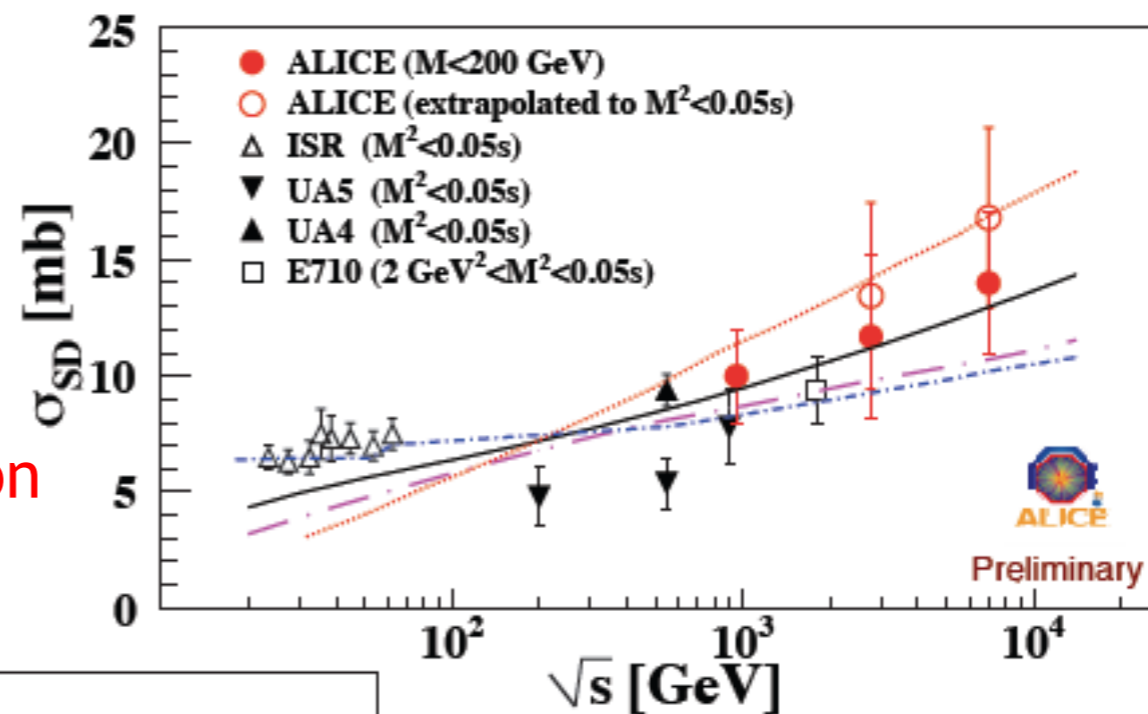
**K. Österberg (Wed.)**





## ALICE: Total SD and DD Cross Sections

ALICE: Unfold integrated SD and DD cross sections at all three CMS energies based on gap rates and topologies.  
 [implies some extrapolation into lowest  $\xi$  regions]



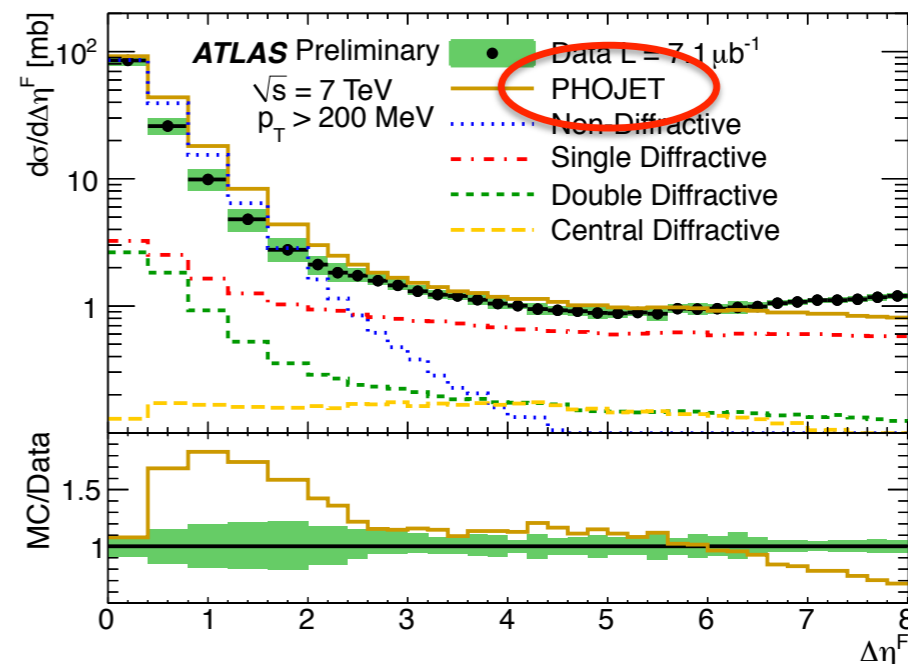
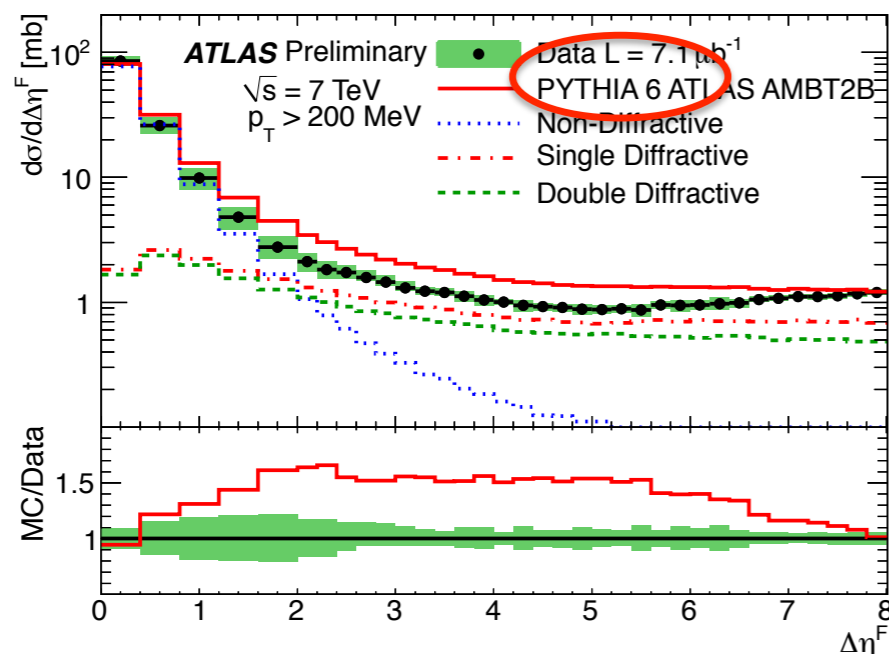
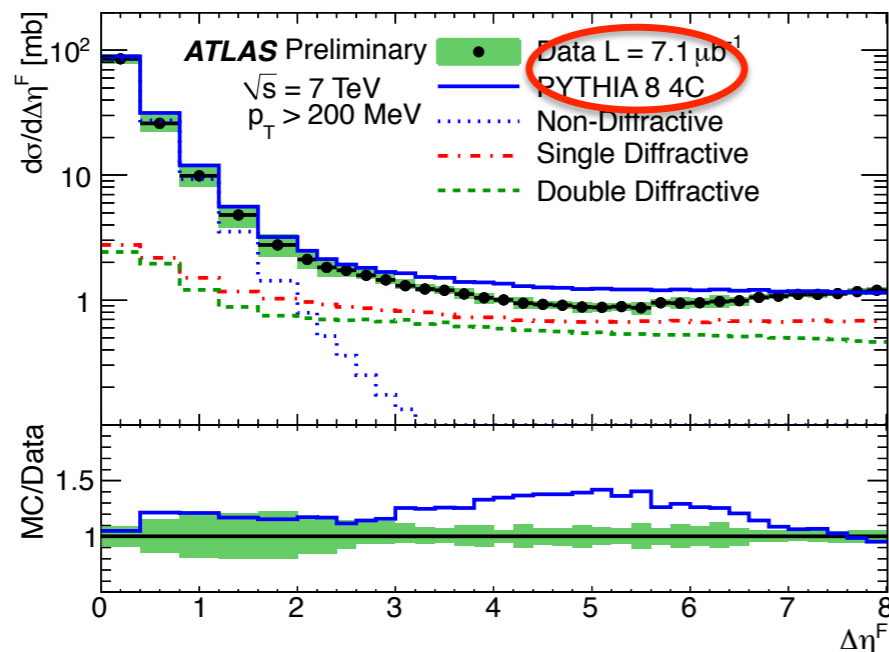
$\sigma(\text{SD})$  with  $\xi < 0.05$

$\sigma(\text{DD})$  with gap  $\Delta\eta > 3$

Good agreement with SPS data and wide range of model predictions

## Small Gaps and Hadronisation

- Big variation between MCs in small non-zero gap production via ND  $\rightarrow$  fluctuations / UE
- PYTHIA8 best at small gaps
- PHOJET > 50% high at  $\Delta\eta^F \sim 1.5$

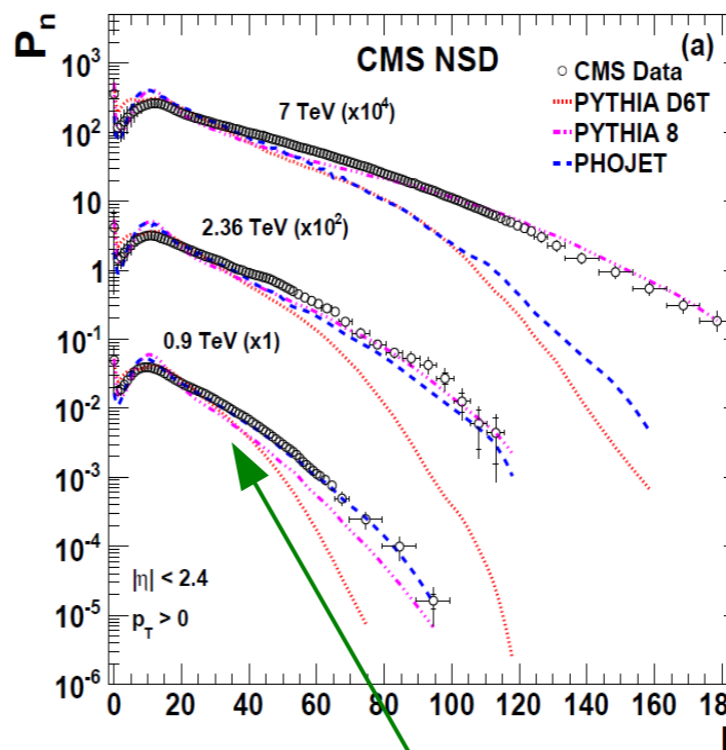
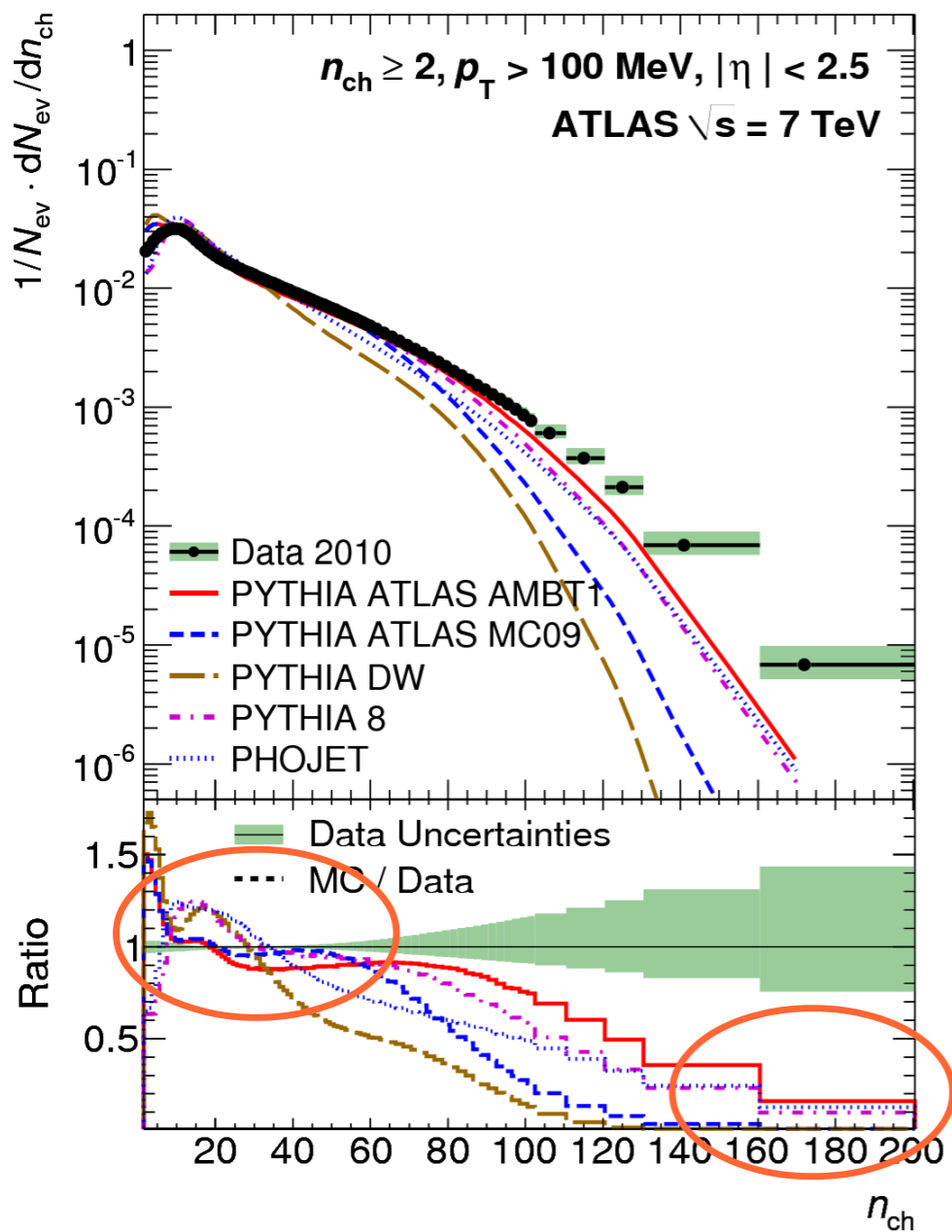


P. Newman (Wed.)

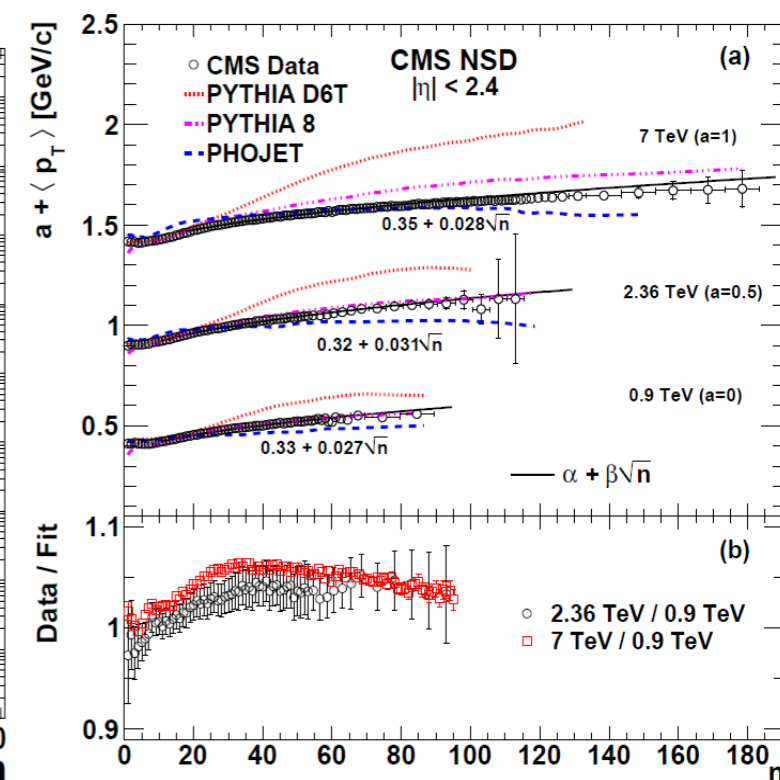




# Charged particle multiplicities: minimum bias events



Change in slope: multi-component structure



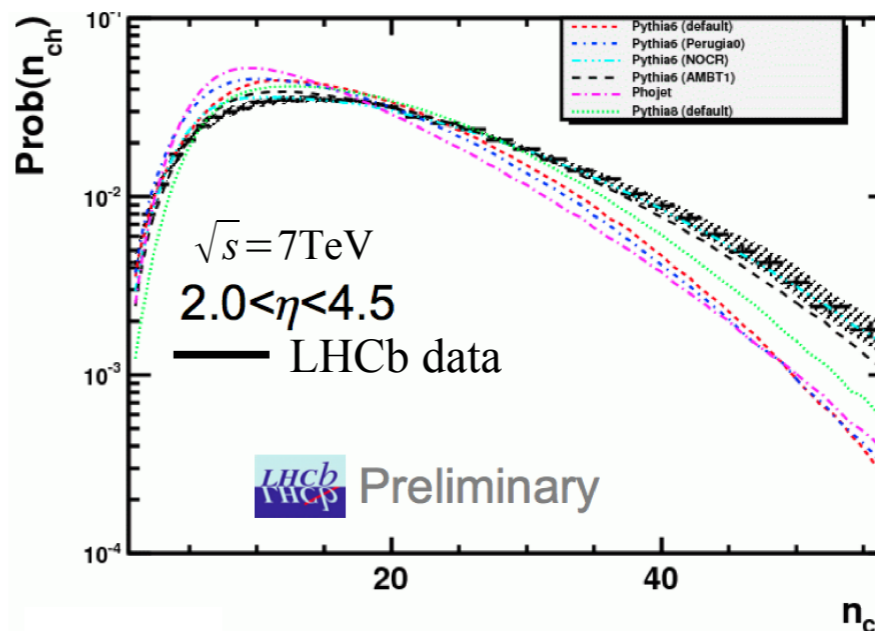
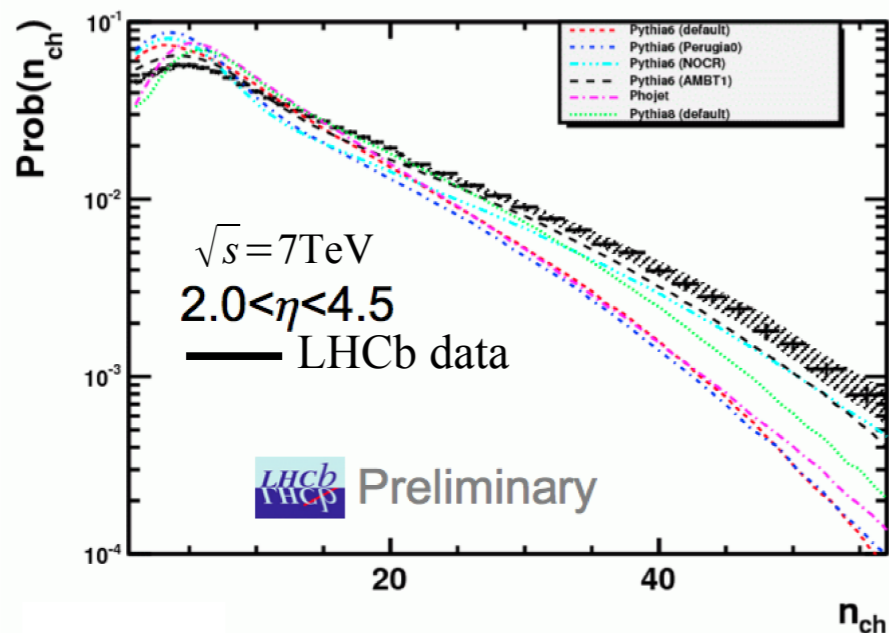
**S. Bansal (Mon.)**

**M. Leyton (Mon.)**



-> probability to have  $n_{ch}$  in an unbiased event

-> probability to have  $n_{ch}$  in a hard interaction event (at least one track with  $p_T > 1$  GeV)



-> good agreement between Perugia NOCR prediction and real data (black solid line)

S. Bansal (Mon.)

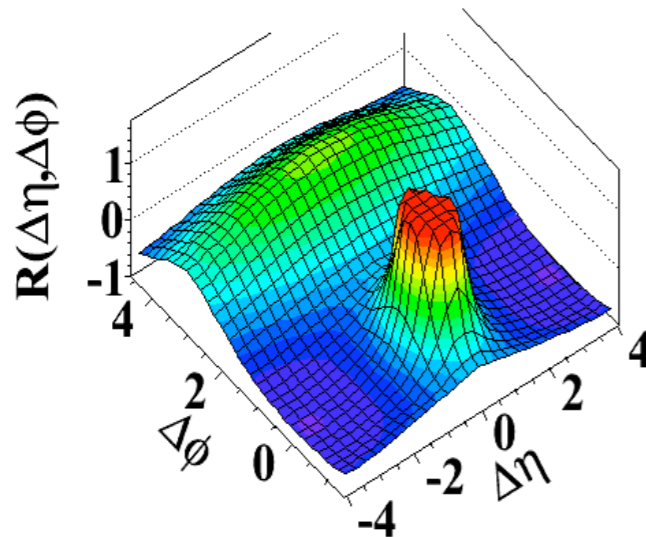


## High Multiplicity Results at $\sqrt{s} = 7$ TeV

Intermediate  $p_T$  :  $1 < p_T < 3$  GeV/c

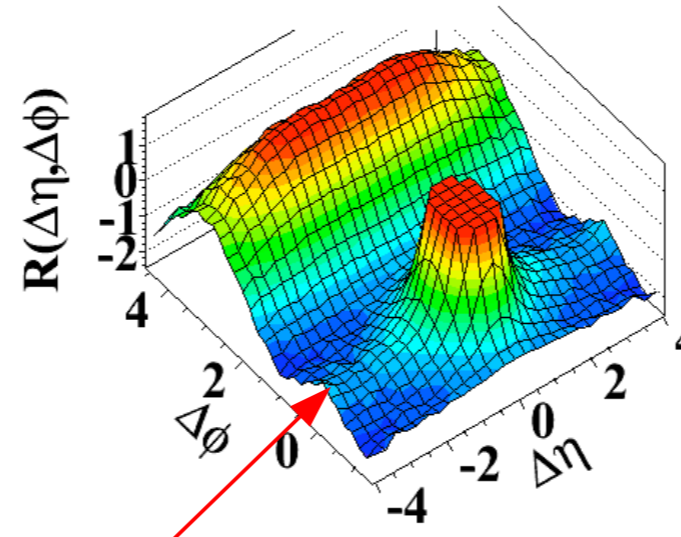
MinBias

(b) MinBias,  $1.0 \text{ GeV/c} < p_T < 3.0 \text{ GeV/c}$



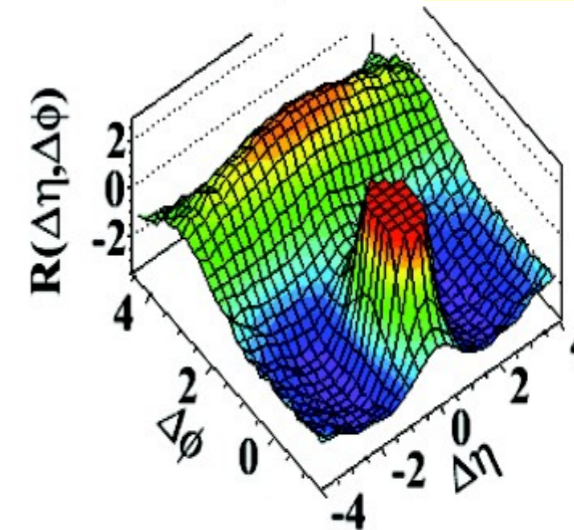
High Multiplicity:  $N > 110$

(d)  $N > 110$ ,  $1.0 \text{ GeV/c} < p_T < 3.0 \text{ GeV/c}$



(d)  $N > 110$ ,  $1.0 \text{ GeV/c} < p_T < 3.0 \text{ GeV/c}$

PYTHIA 8



→ **Observation of a Long-Range, Near-Side angular correlations at high multiplicity in pp events at intermediate  $p_T$  (Ridge at  $\Delta\phi \sim 0$ )**

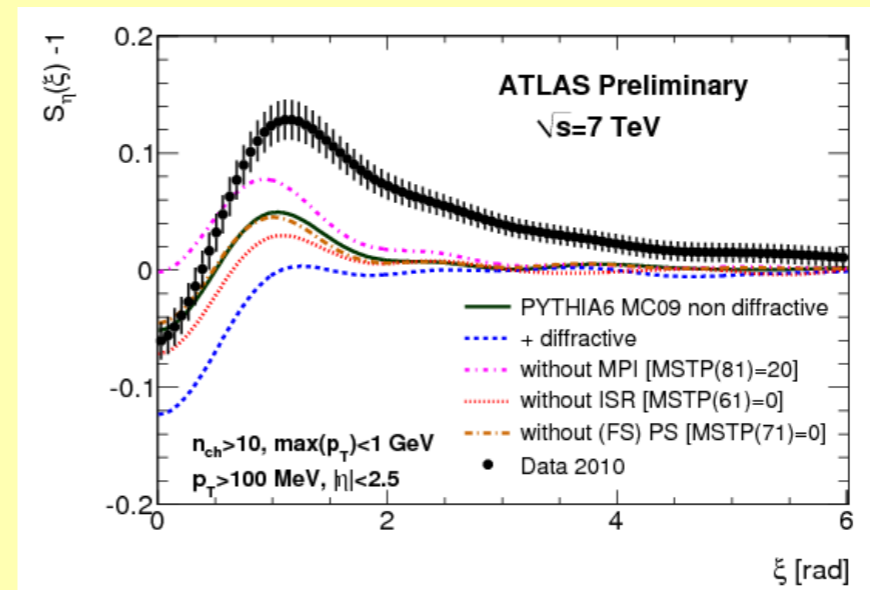
... not reproduced in PYTHIA 8 (and PYTHIA 6, HERWIG++, madgraph)



## Pythia variations

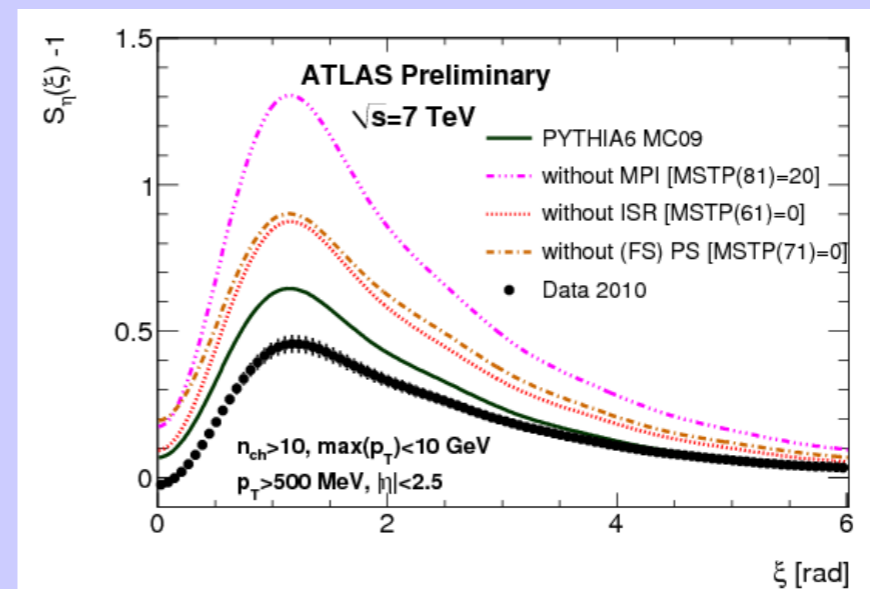
### Low-pT enhanced:

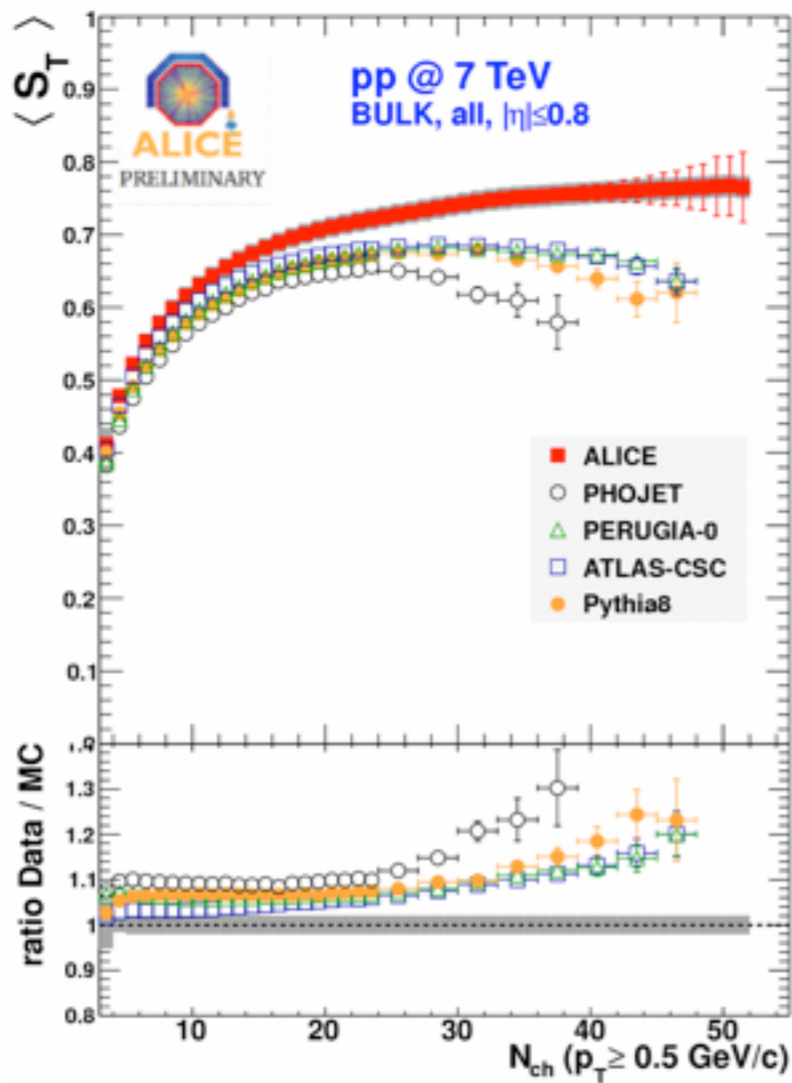
- Extreme variation of model parameters cannot provide reasonable description of data
- Modeling of diffractive events is major source of discrepancy between data and models
- MPI scheme pulls model prediction away from data



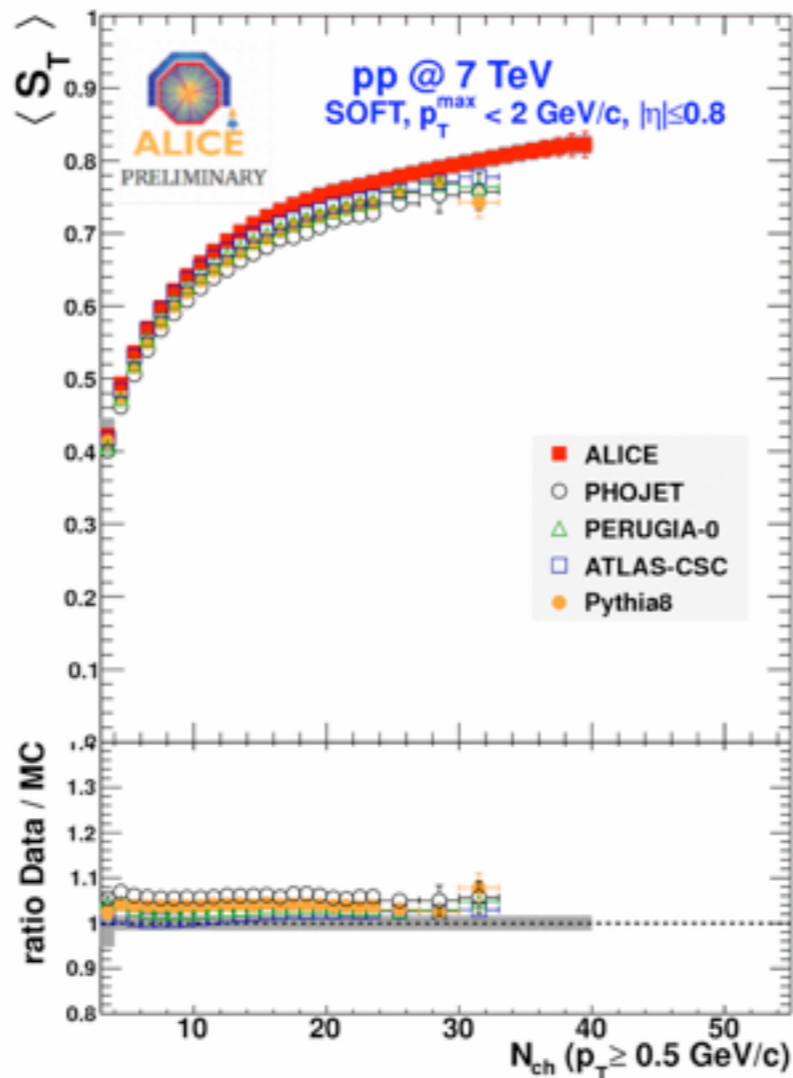
### Low-pT depleted:

- Higher rate of MPI is required to describe the data

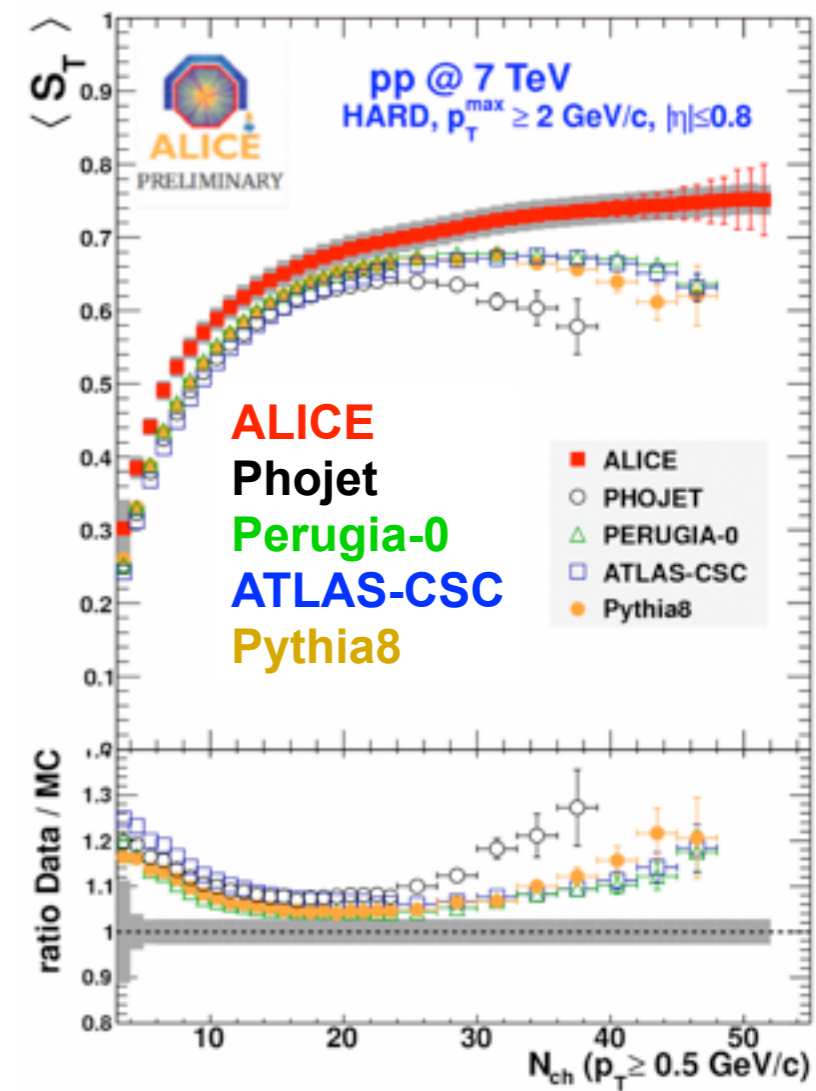




ALI-PREL-2668



ALI-PREL-2695



ALI-PREL-2677

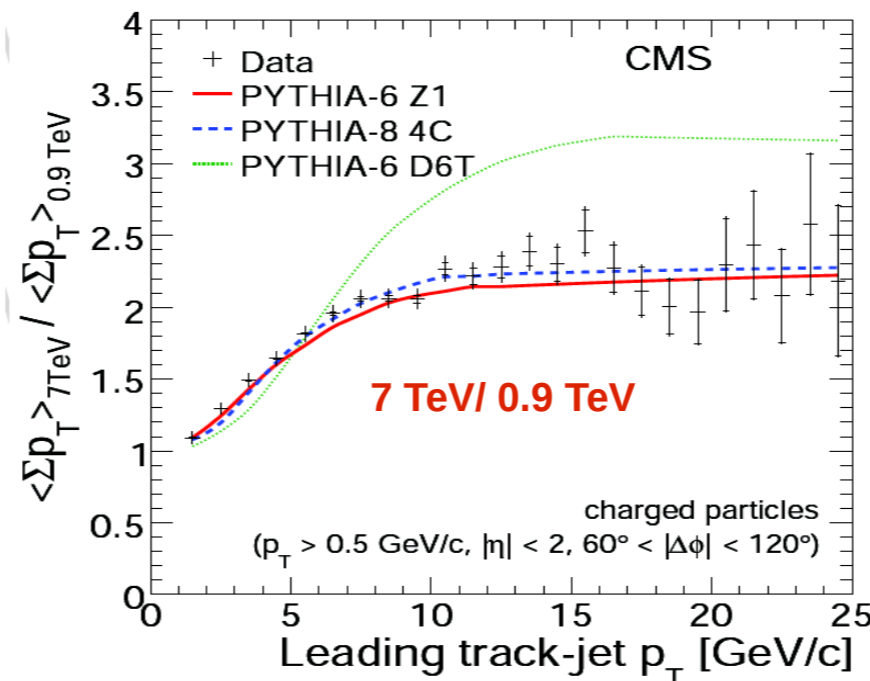
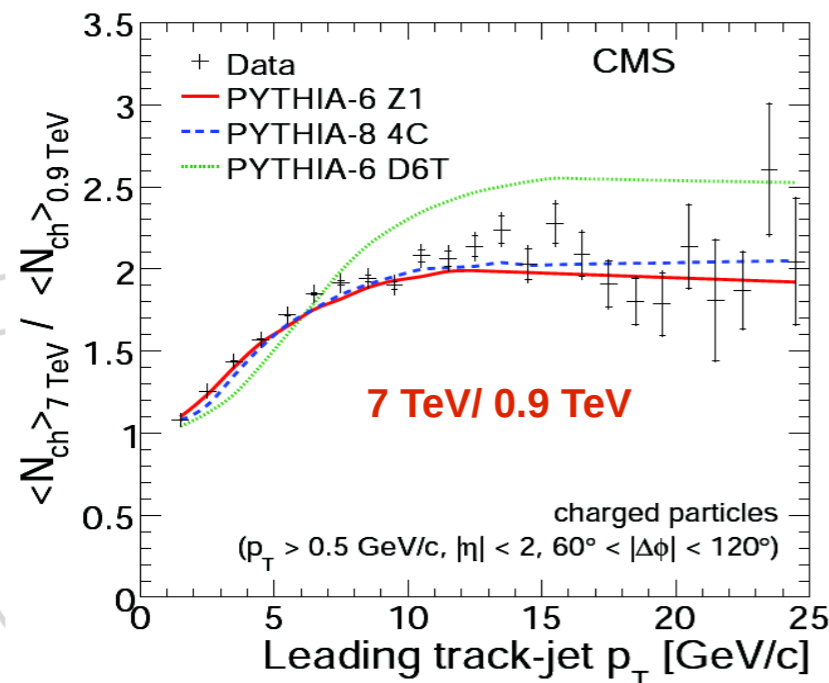
**J. F. Grosse-Oetringhaus (Mon.)**





## Comparison between 7 TeV and 900 GeV

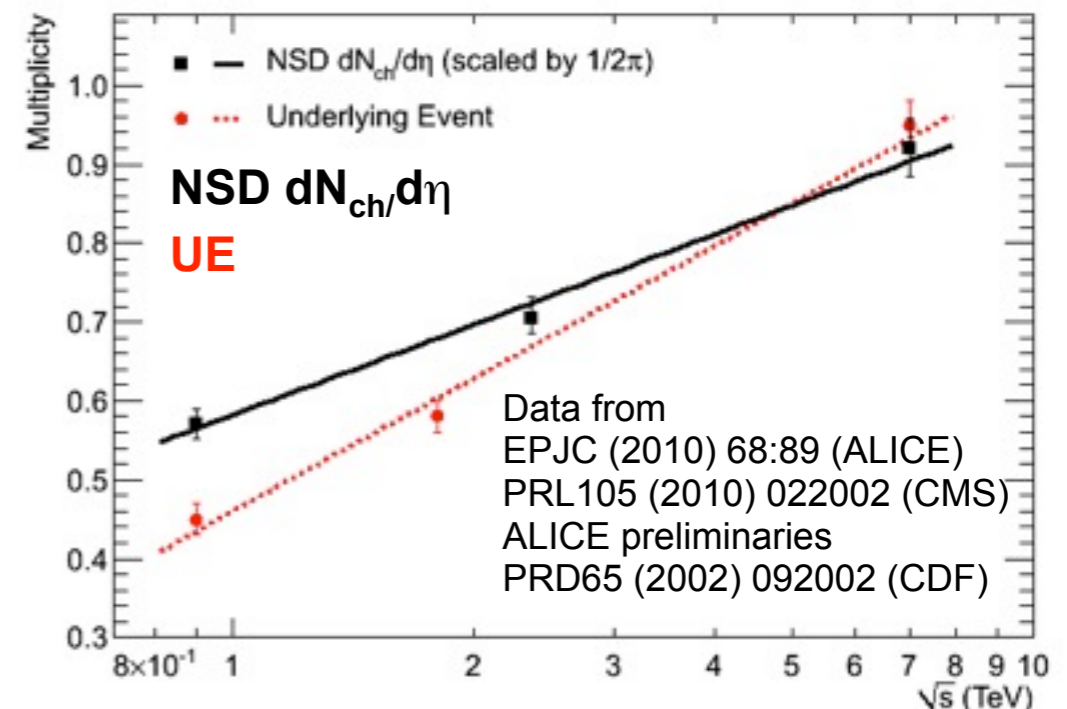
S. Bansal (Mon.)



- In the presence of a large energy scale, UE grows significantly with  $\sqrt{s}$
- A factor 2 going from 900 GeV to 7 TeV to be compared with 1.7 for MB.
- MPI growth with  $\sqrt{s}$  well described by Z1 and 4C, too pronounced in D6T.

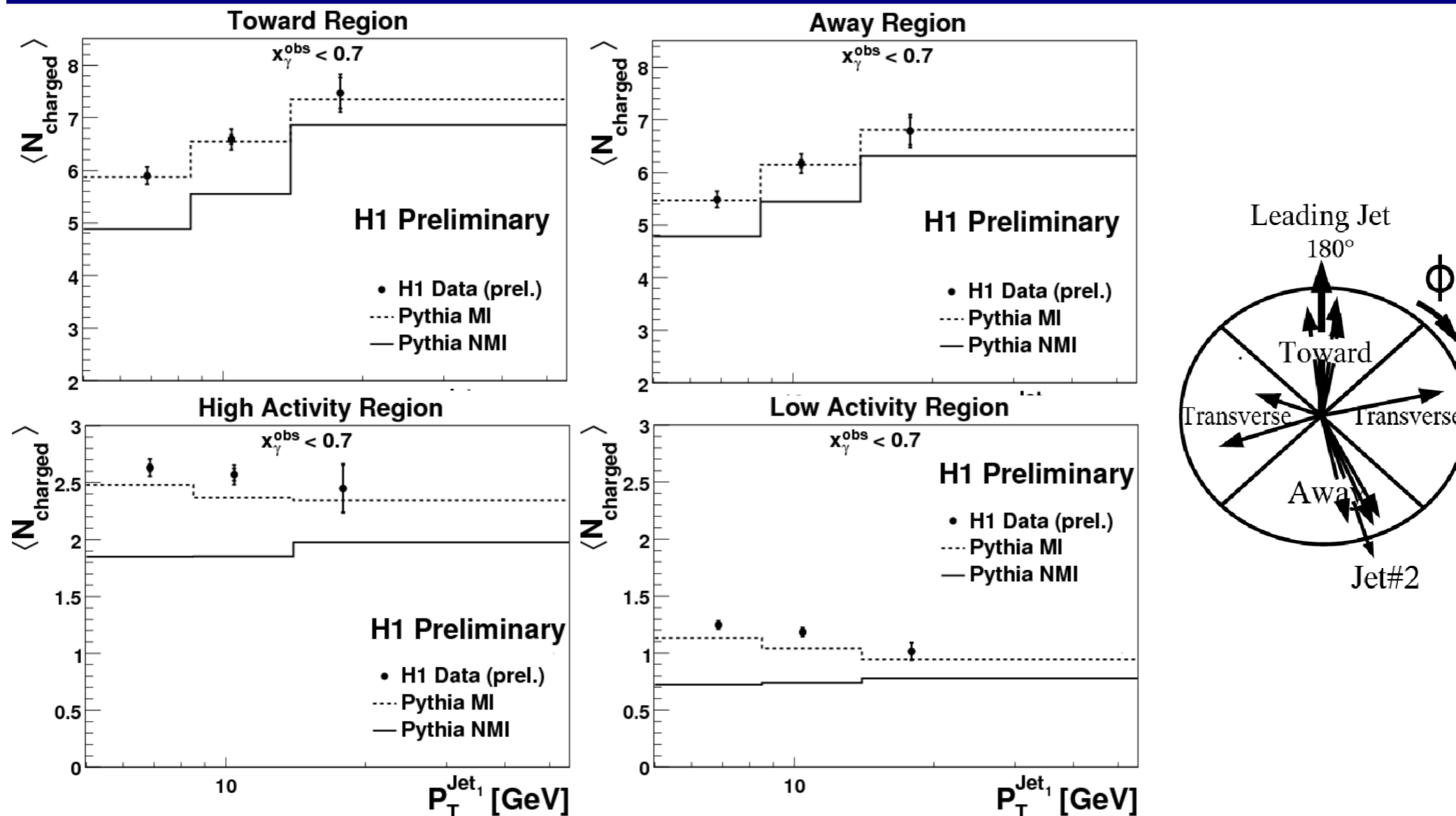
11/21/11

Sunil Bansal, MPI@LHC





# Charged Particle Flow in Photoproduction

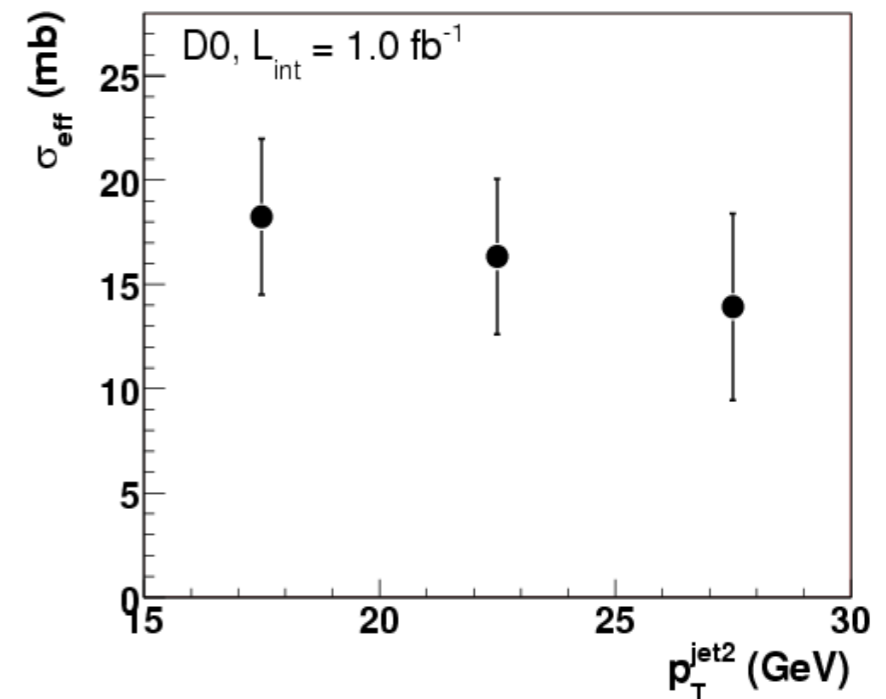
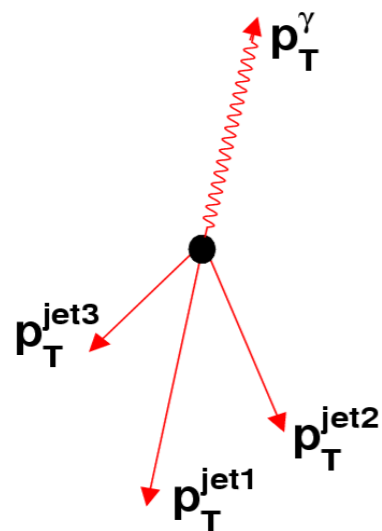
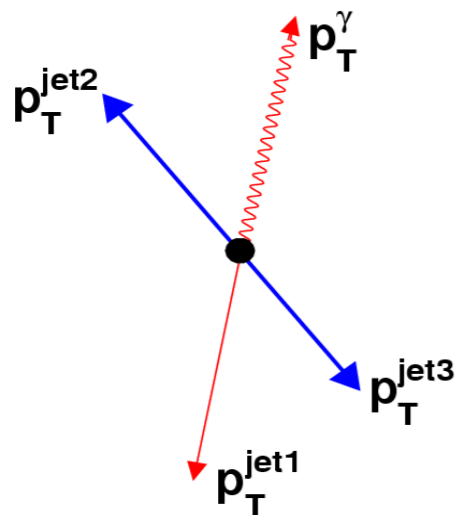


- **Charge particle multiplicity in hard region very well described by MI.**
- **Low  $P_t$  jet - MI contributes slightly more  $\rightarrow$  not only pedestal effect**
- **MI important in transverse regions**
- **... but no perfect description of data... but tuning is possible...**

Double parton interactions in  $\gamma+3\text{jet}$  events in  $p\bar{p}$  collisions at  $\sqrt{s}=1.96$  TeV in D0

**G. Golovanov (Tue.)**

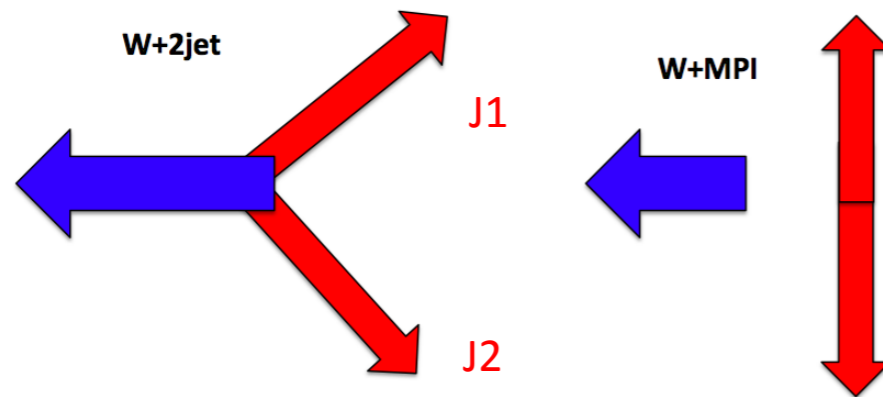
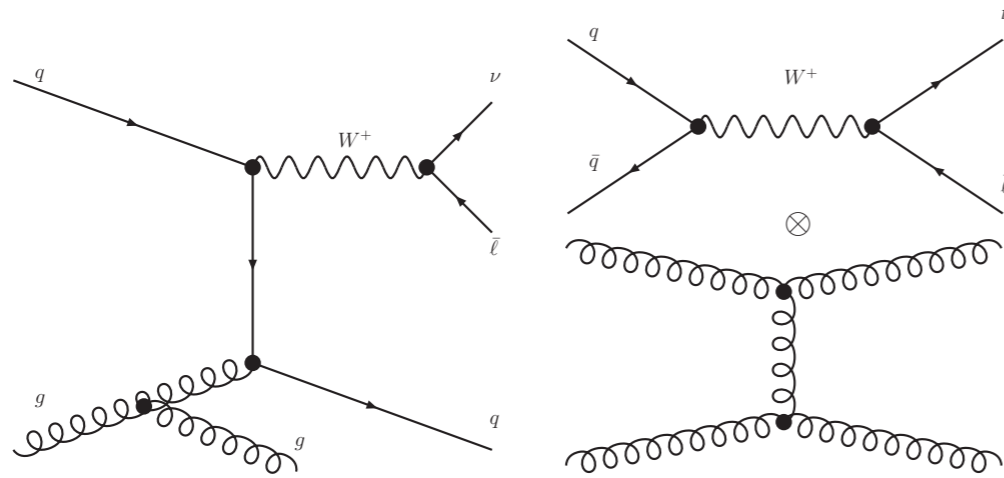
Phys. Rev. D81, 052012(2010)  
arXiv:0912.5104



$$\sigma_{\text{eff}}^{\text{ave}} = 16.4 \pm 0.3(\text{stat}) \pm 2.3(\text{syst}) \text{ mb}$$

Found DP fractions are pretty sizable: they drop from  $\sim 46\text{-}48\%$  at  $2^{\text{nd}}$  jet  $p_T$  15-20 GeV to  $\sim 22\text{-}23\%$  at  $2^{\text{nd}}$  jet 25-30 GeV with relative uncertainties  $\sim 7\text{-}12\%$ .

**E. Dobson (Tue.)**



$$\Delta_{jets} = \left| \vec{P}_T^{J1} + \vec{P}_T^{J2} \right|$$

$$\Delta_{jets}^n = \frac{\left| \vec{P}_T^{J1} + \vec{P}_T^{J2} \right|}{\left| \vec{P}_T^{J1} \right| + \left| \vec{P}_T^{J2} \right|}$$

$$f_{DP}^R = \frac{N_{W_0+2j_{MPI}}}{N_{W+2j}}$$

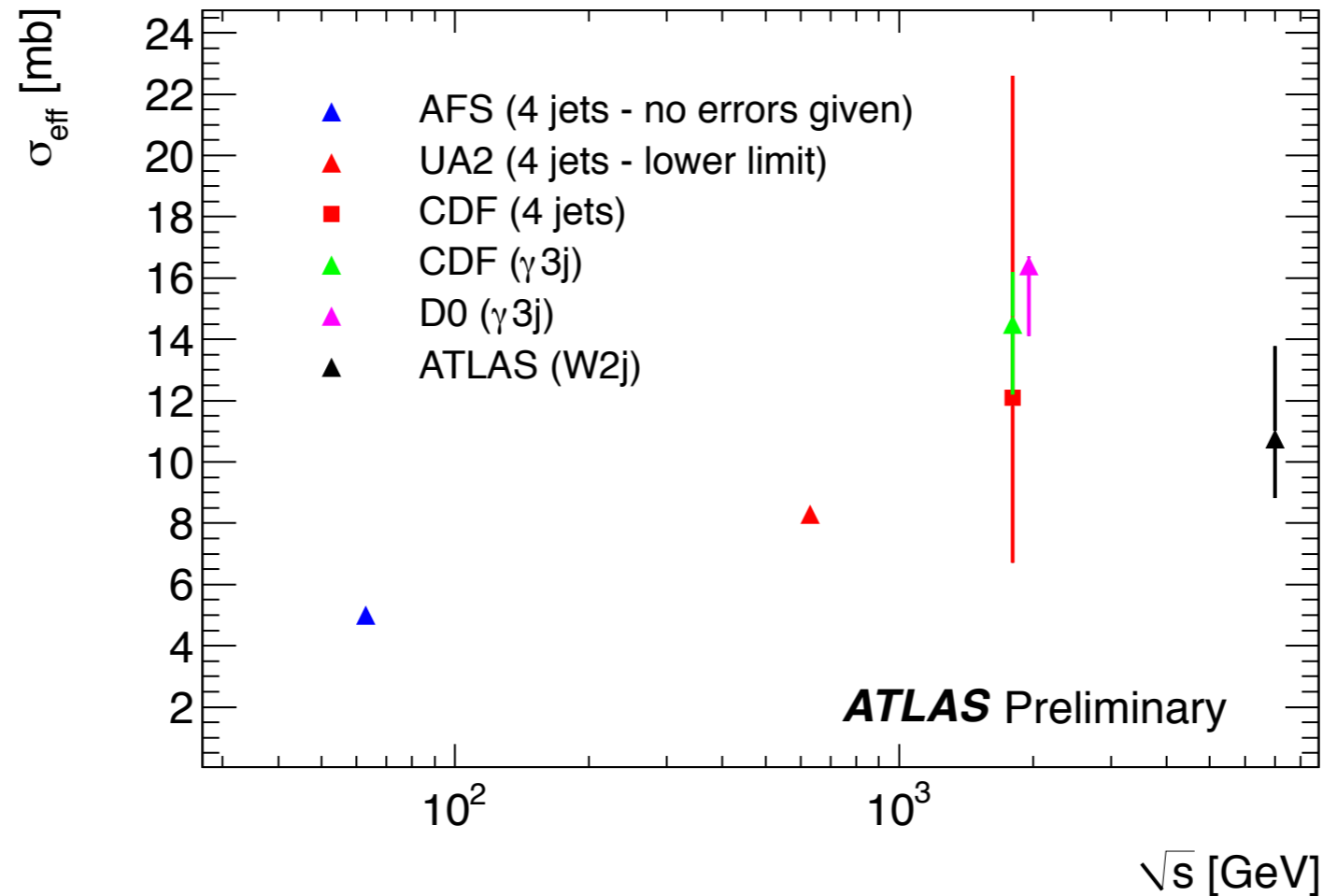
$$f_{DP}^R = 0.16 \pm 0.01 \text{ (stat.)} \pm 0.03 \text{ (sys.)}$$

$$\sigma_{\text{eff}} = \frac{1}{f_{DP}^R} \cdot \frac{N_{W_0} N_{2j_D}}{N_{W+2j}} \cdot \frac{1}{\epsilon_{2j_D}} \cdot \frac{1}{\mathcal{L}_{2j_D}}$$

$$\sigma_{\text{eff}}(7 \text{ TeV}) = 11 \pm 1 \text{ (stat.) } {}^{+3}_{-2} \text{ (sys.) mb.}$$



# Putting the result into context....

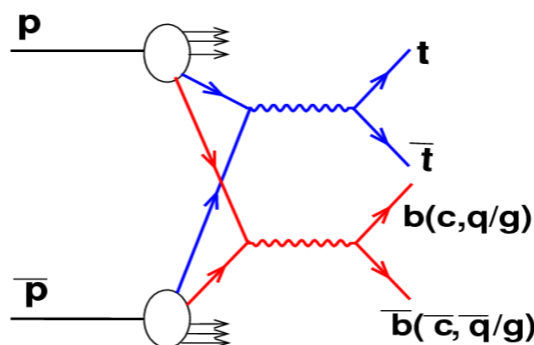
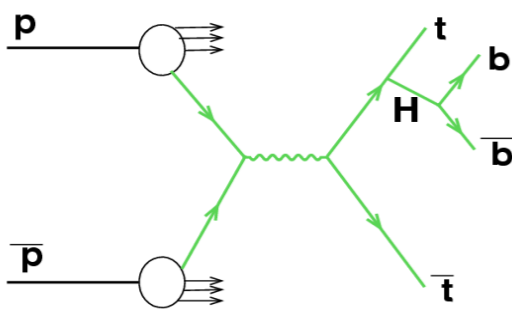
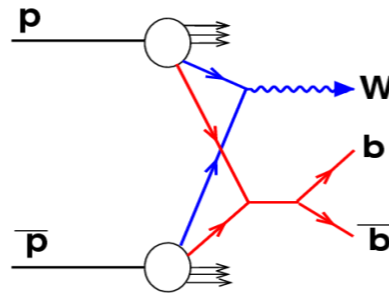
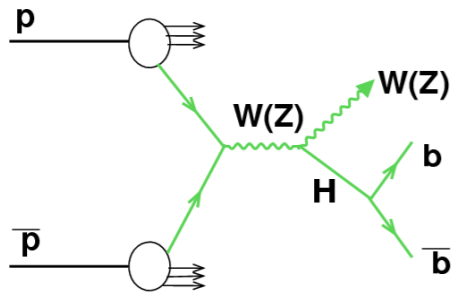


Results consistent with other measurements  
 - no real evidence for variation of  $\sigma_{\text{eff}}$  with channel or  $E_{\text{COM}}$

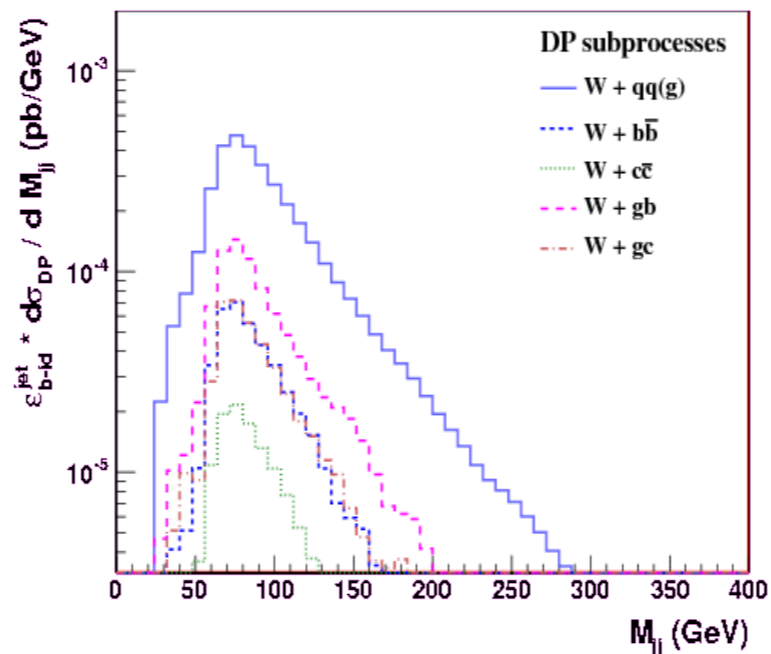
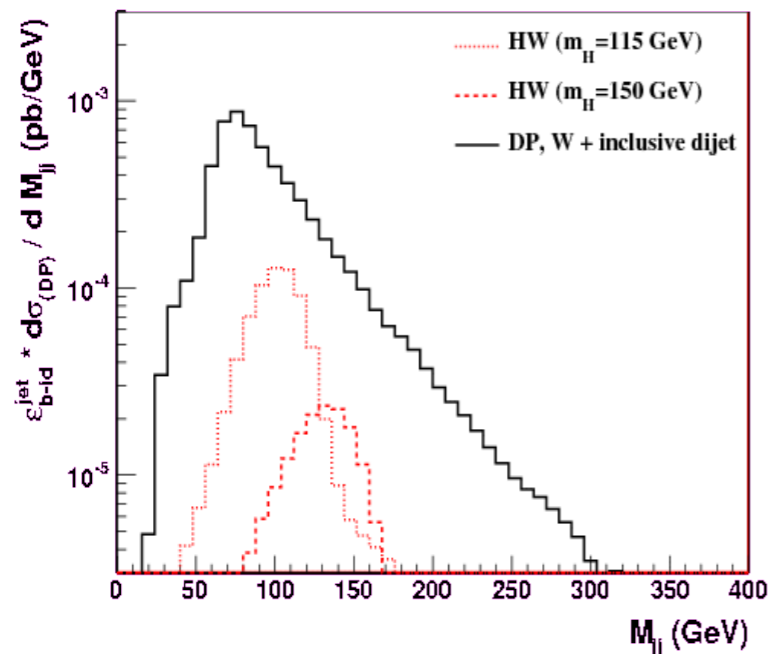
# Double parton interactions as a background to rare processes

Signal

Double Parton background



- Kinematic + bID selections are same as in actual D0 analyses.
- Dijet  $d\sigma/dM$  and W cross sections are normalized to D0 measurements.
- Higgs signal is suppressed even in the peak by a factor 2.5-5



**G. Golovanov (Tue.)**

...and many other interesting results!



...and many other interesting results!

Where do we go from here?



...and many other interesting results!

Where do we go from here?



- LHC will hopefully continue to deliver a lot of data...
- Correlations in MB events are on their way to be published...
- More UE event measurements will become available soon (DY, high  $E_T$  jets, ...)
- Direct measurements of MPI processes at the LHC

# MPI@LHC 2012

In addition to the work already in the pipeline, which measurements should we propose to our experimental collaborations?

How can we keep track of these studies so we can see them mature enough to be presented in 2012?