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UCL

Minimum bias and Underlying Event studies with Monte Carlo tune for pp events with the ATLAS detector

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(for the ATLAS collaboration)

ICHEP, Paris

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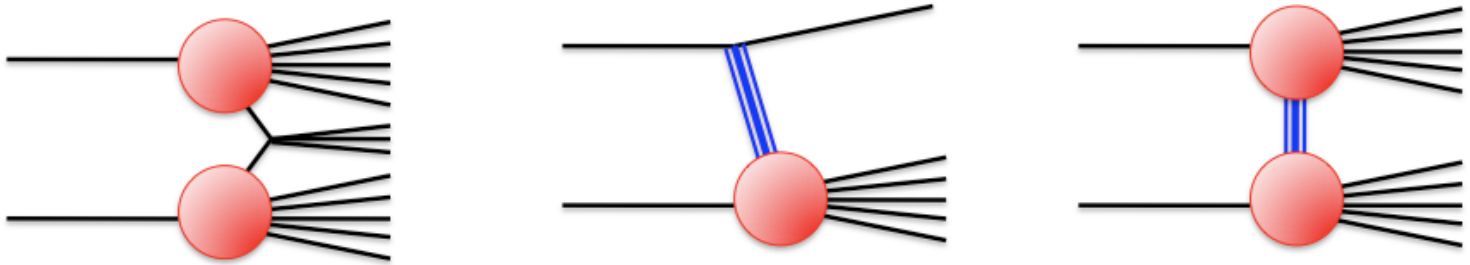
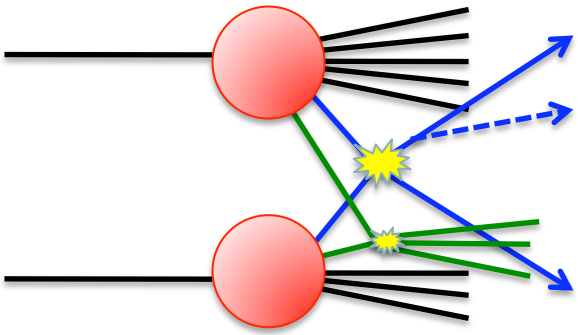
Minimum Bias and Underlying Event

Non-Diffractive (~50 mb) Single-Diffractive (~14 mb) Double-Diffractive (~9 mb) @7TeV

"Minbias"



"Underlying Event"

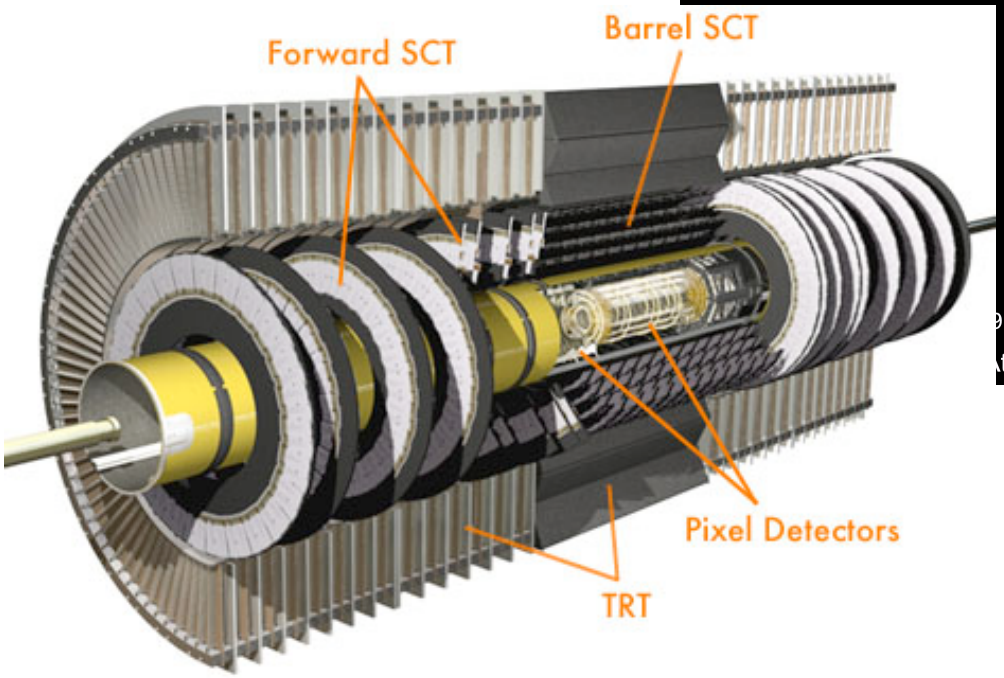


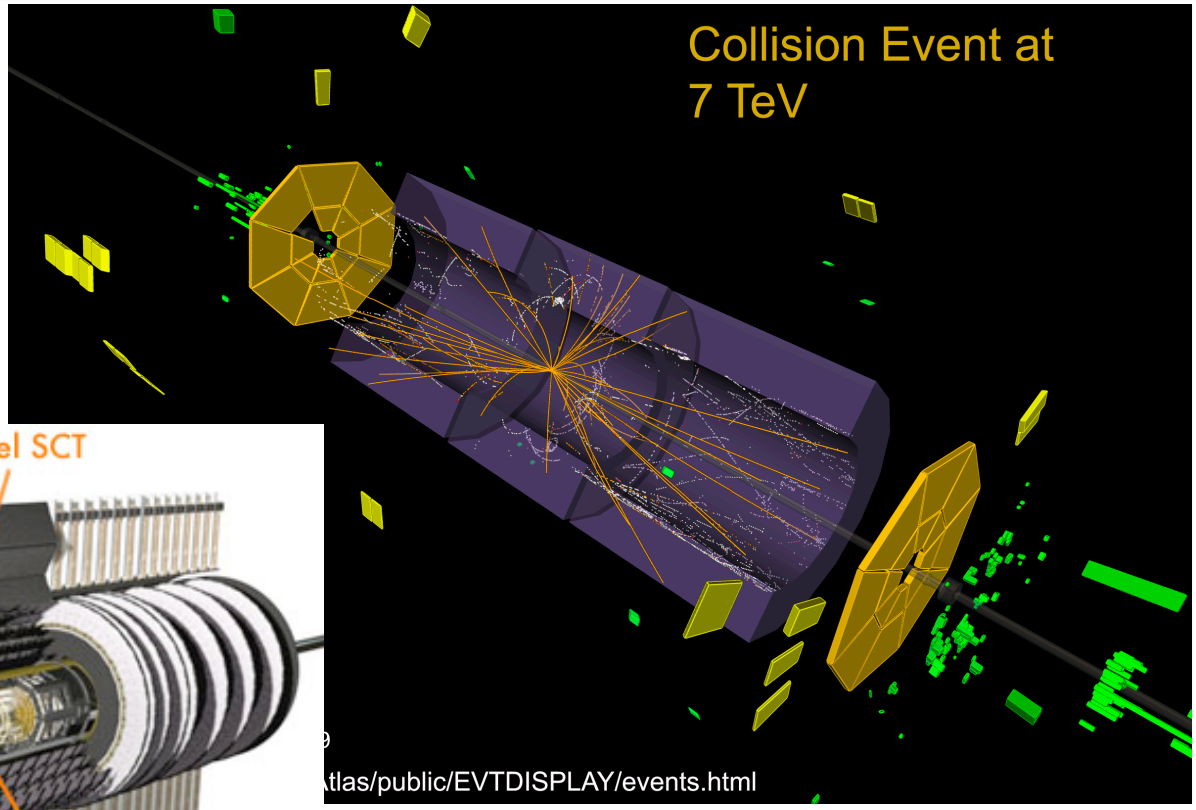
Hard scatter +
Initial/Final State Radiation,
Multiple Parton Interactions,
beam remnants

- Low energy QCD, requires MC models tuned to data
- A good MC description is essential for hadron collider physics!
- UE and pileup affect jets, E_T^{miss}, rapidity gaps, lepton ID, …

Detecting minbias events

Inner Detector in 2 T magnetic field reconstructs charged particle "tracks" with $|\eta| < 2.5$





Minimum Bias Trigger Scintillator (MBTS) disks trigger on any hit on either side $2.09 < |\eta| < 3.84$

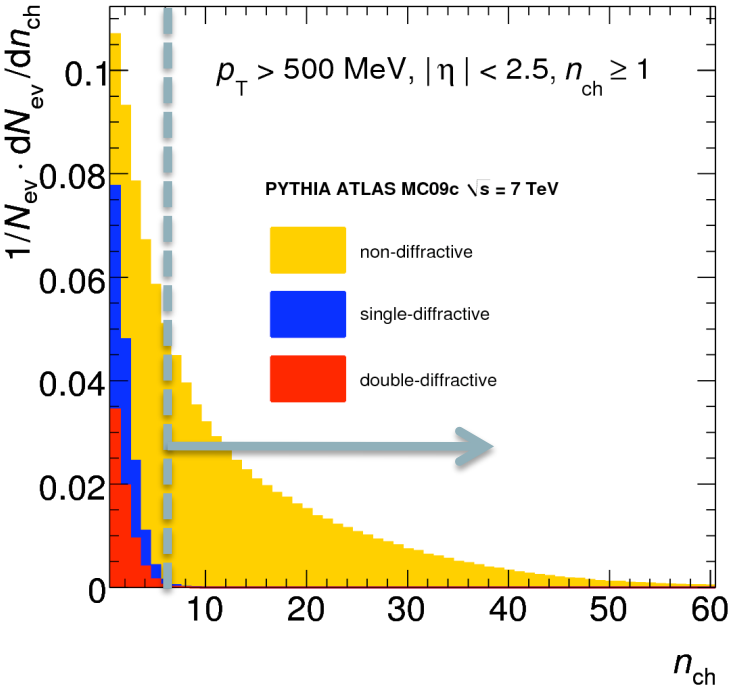
Minbias distributions

UCL

Charged particle distributions

1. multiplicity
2. p_T distribution
3. η distribution
4. Mean p_T vs multiplicity

For inclusive distributions, p_T > 100 MeV see Alison Lister's talk [Thursday, HI&soft physics session]



- Define a *diffraction suppressed* sample for MC tuning : $n_{ch} \geq 6$ {p_T > 500 MeV, |η| < 2.5}

√s	lumi.	N_{ev}
0.9 TeV	9 μb^{-1}	157,896
7 TeV	6.8 μb^{-1}	231,665

- Define a *diffraction enhanced* sample :
  - $n_{ch} \geq 1$ {p_T > 500 MeV, |η| < 2.5}
  - veto activity in *one* forward scintillator disk

√s	lumi.	N_{ev}
7 TeV	23 μb^{-1}	52,801

Minbias distributions

Charged particle distributions

1. multiplicity
2. p_T distribution
3. η distribution
4. Mean p_T vs multiplicity

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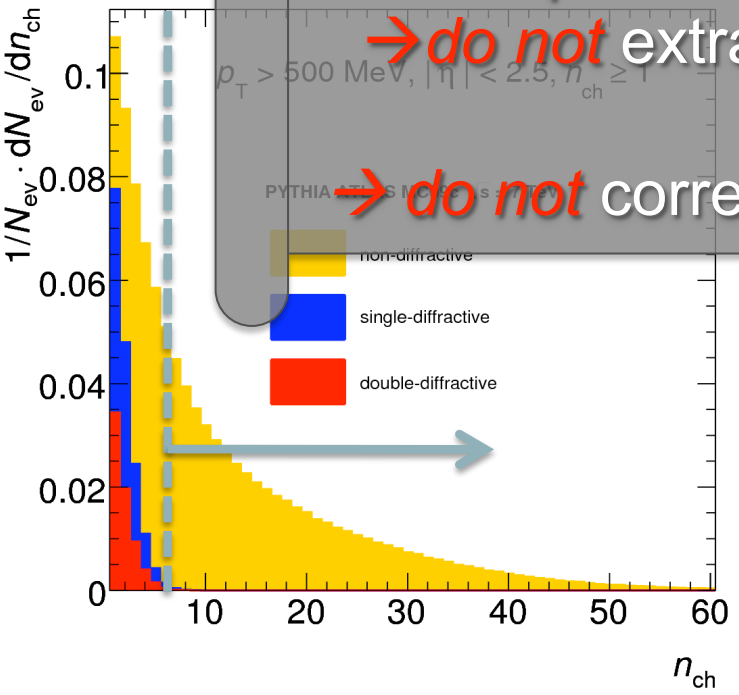
Our philosophy :

Results presented in a well defined phase space, -

→ *do not* extrapolate to full coverage with some MC model!

→ *do not* correct data for "diffractive background"!



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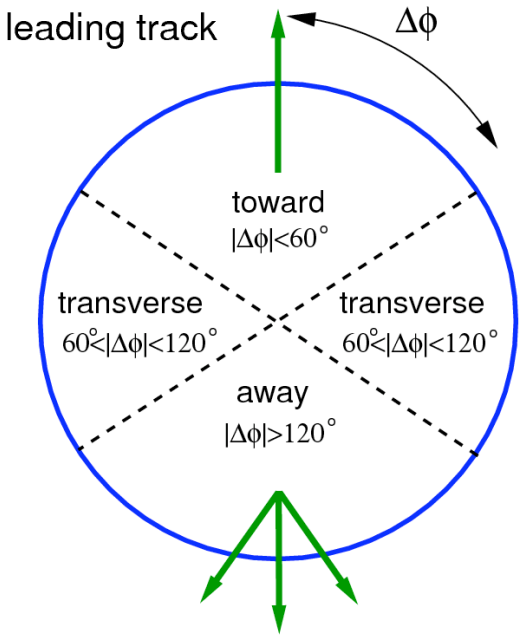
√s	lumi.	N_{ev}
7 TeV	23 μb^{-1}	52,801

UE distributions

- Select events with ≥1 charged particles, p_T > 1 GeV
- Direction of hard scatter = leading charged particle
- Define a region *transverse* to the hard scatter
- Study charged particle and p_T density as a function of the lead p_T in different regions.



√s	lumi.	N_{ev}
0.9 TeV	9 μb^{-1}	202,285
7 TeV	6.8 μb^{-1}	265,622

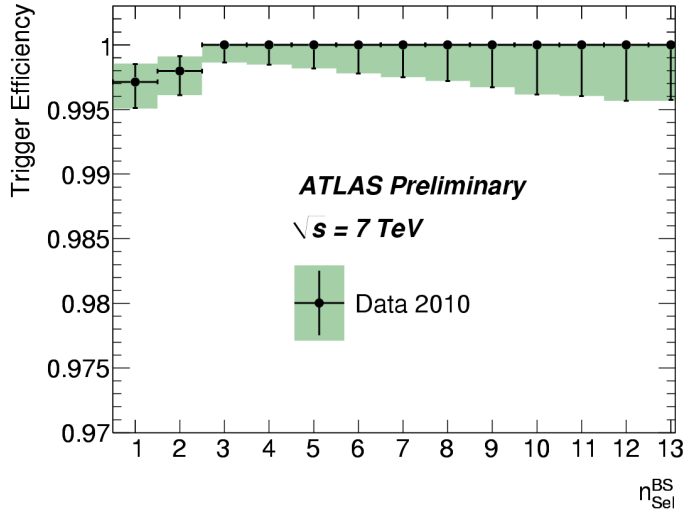
Pythia (v6.4.21) tune to diffraction suppressed MB and UE data

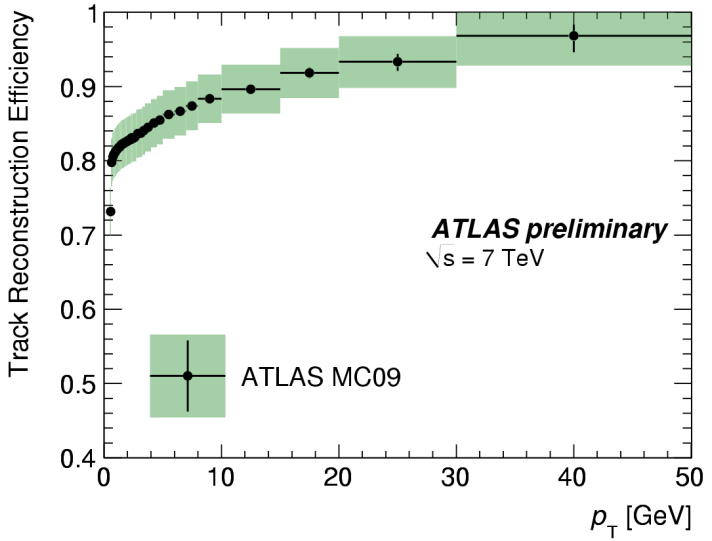
Start with MC09c (ATLAS tune to CDF minbias+UE data and D0 dijet angular correlations with LO* PDFs [PHYS-PUB-2010-002]).

Detector corrections

For details see Alison Lister's talk [Thursday, HI&soft physics session]

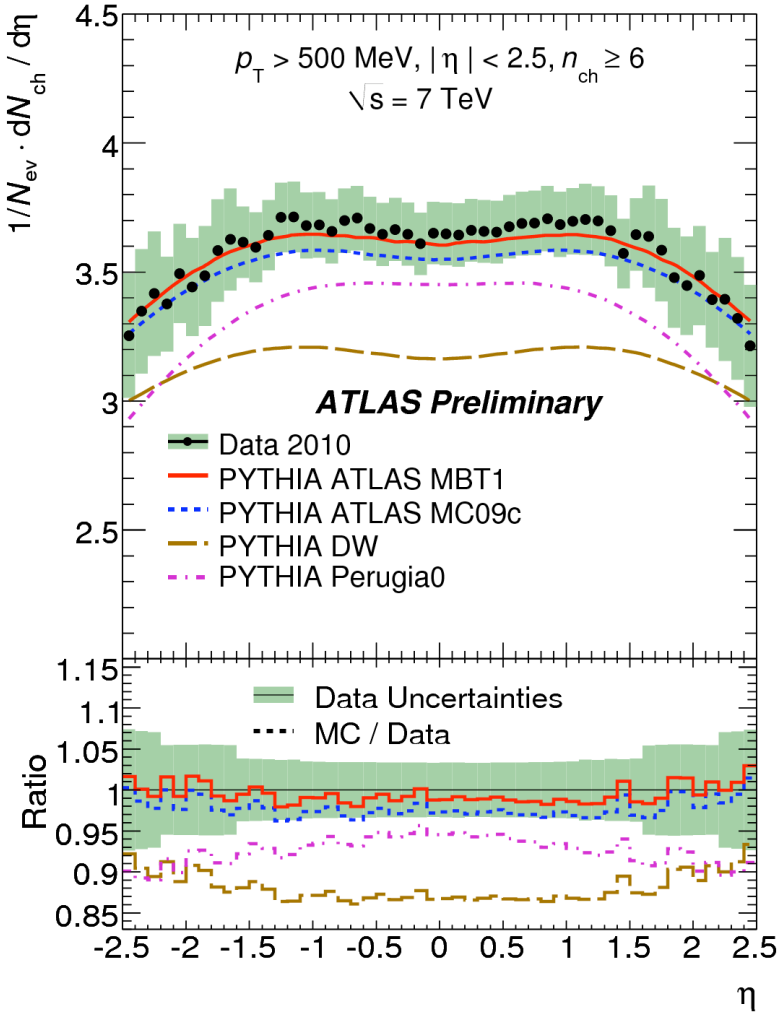
- Trigger and vertex efficiencies derived from data
  - Trigger > 99.5% efficient (obtained from a control trigger)
- Tracking efficiency from MC (various data ⟷ MC comparisons to set systematic)
  - The dominant systematic comes from knowledge of the material



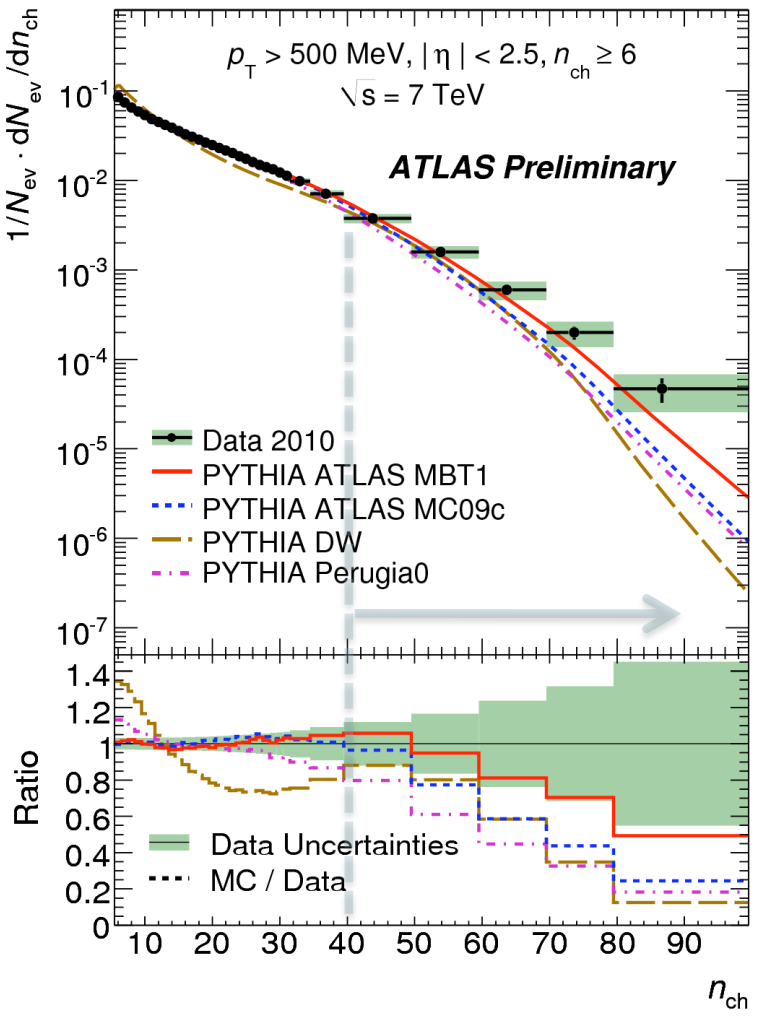


n^{BS}_{sel} = # of tracks with IP cuts w.r.t. BS

η spectra and particle multiplicity



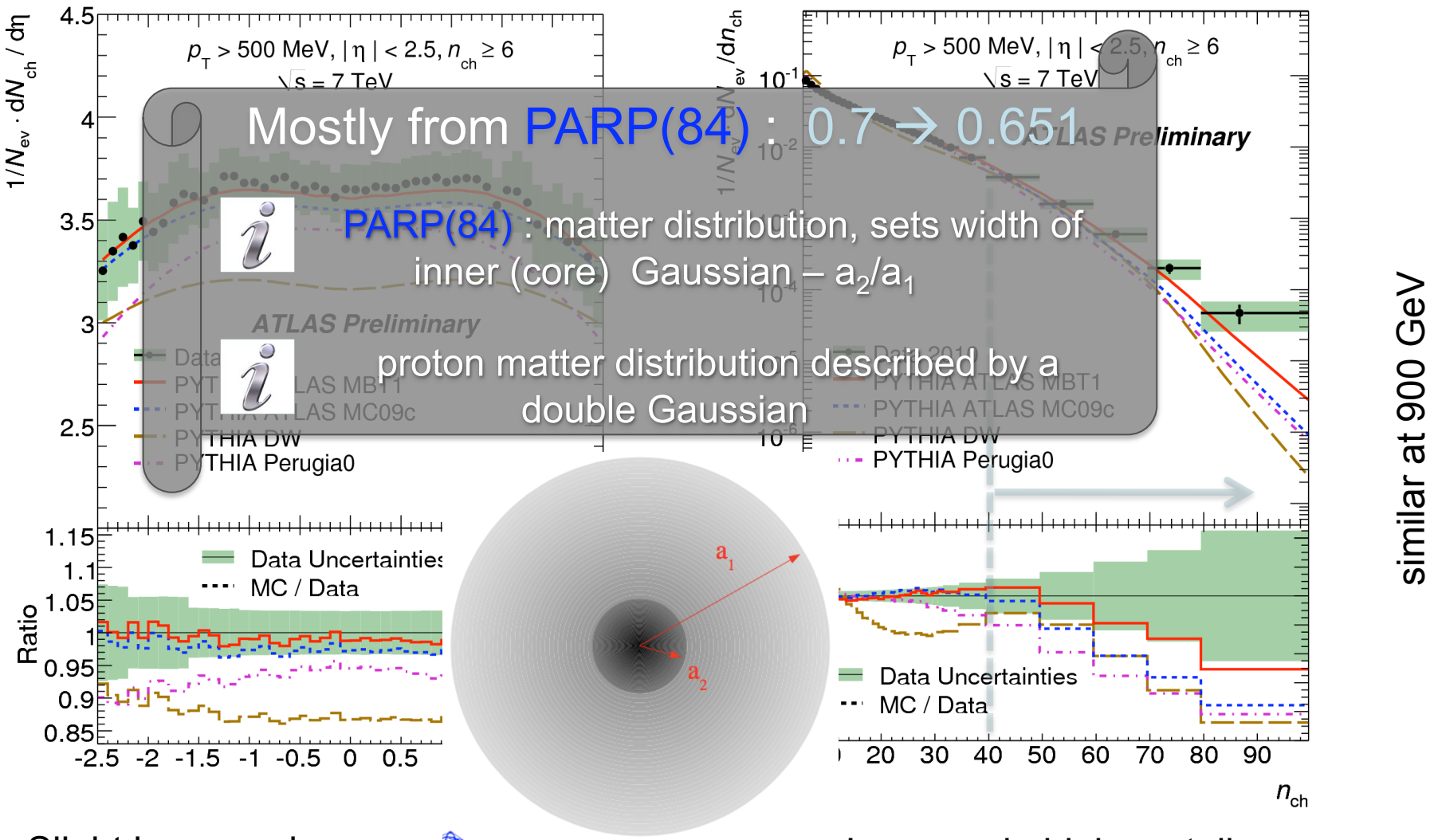
Slight increase in average multiplicity



Increase in high n_{ch} tails

similar at 900 GeV

η spectra and particle multiplicity

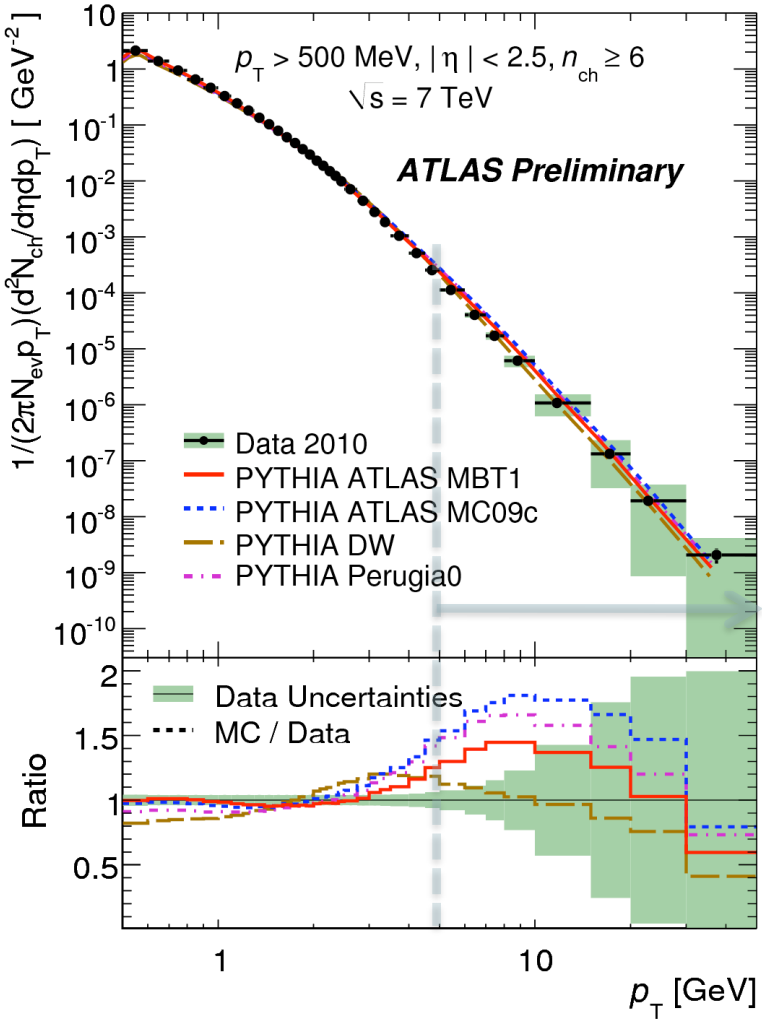


similar at 900 GeV

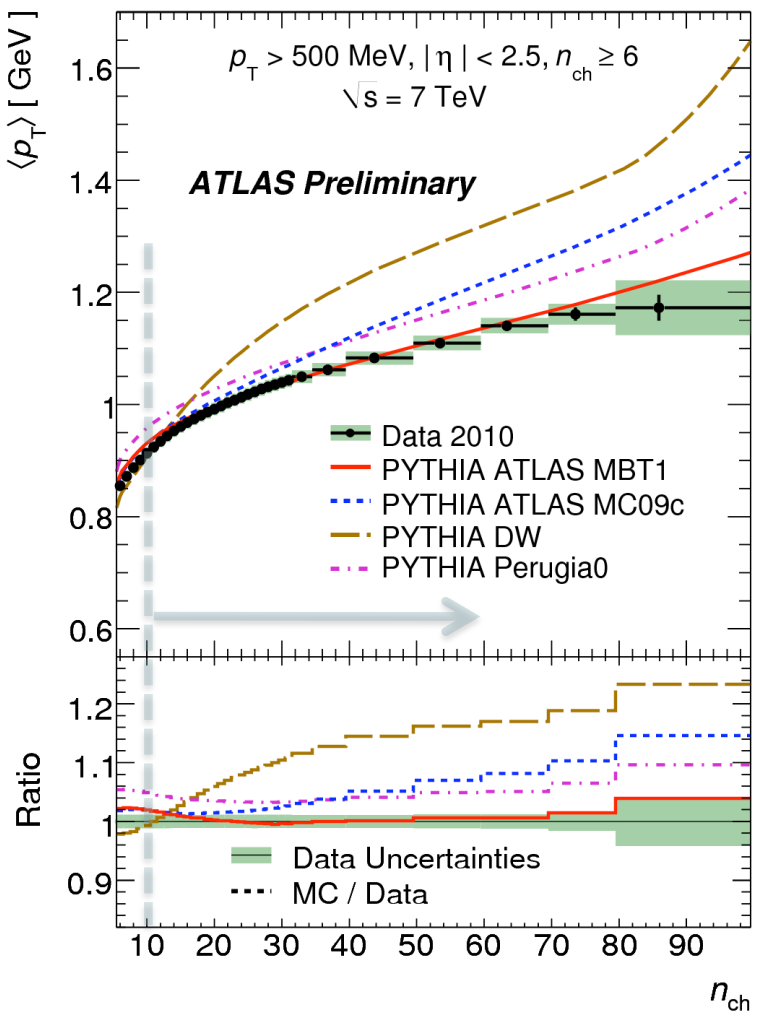
Slight increase in average multiplicity

Increase in high n_{ch} tails

p_T spectra and $\langle p_T \rangle$ vs n_{ch}



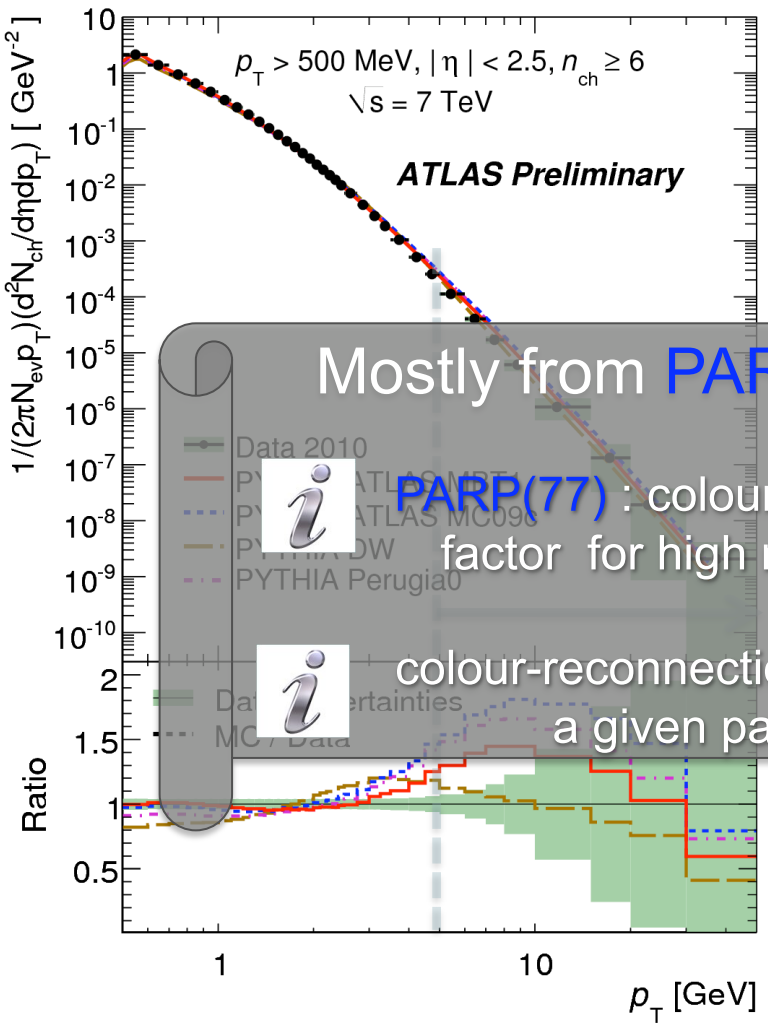
Decrease in high p_T tails

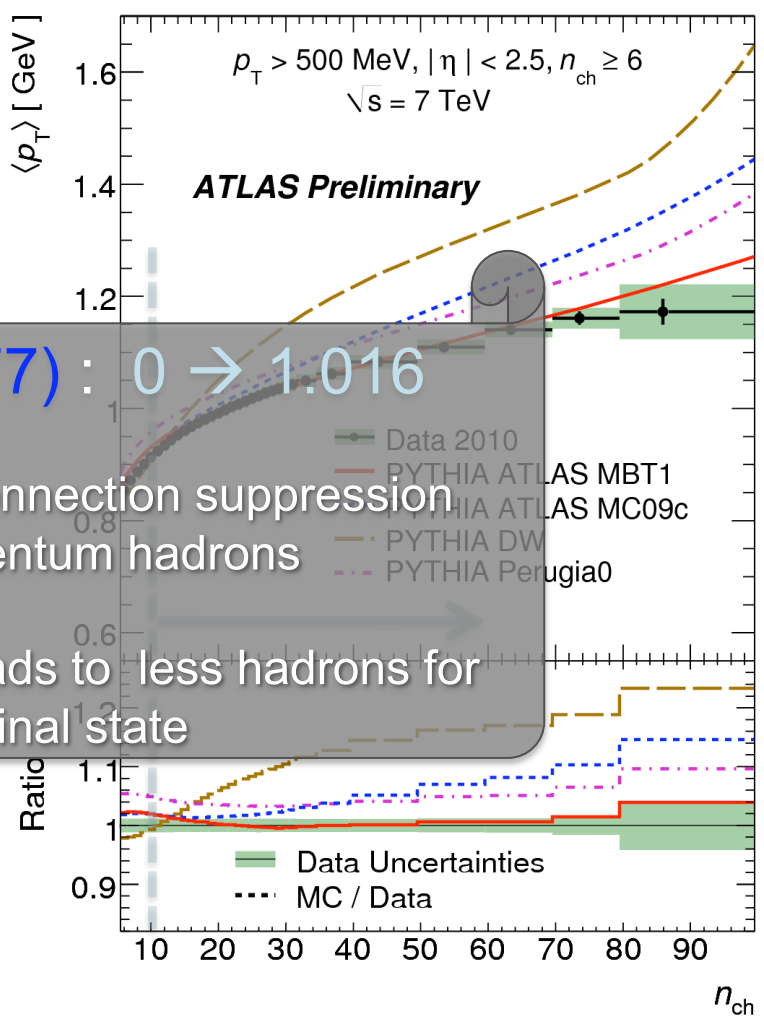


Decrease in $\langle p_T \rangle$ at high n_{ch}

similar at 900 GeV

p_T spectra and $\langle p_T \rangle$ vs n_{ch}





Mostly from PARP(77) : 0 → 1.016

PARP(77) : colour-reconnection suppression factor for high momentum hadrons

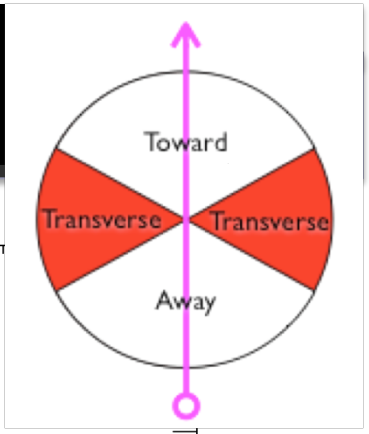
colour-reconnection leads to less hadrons for a given parton final state

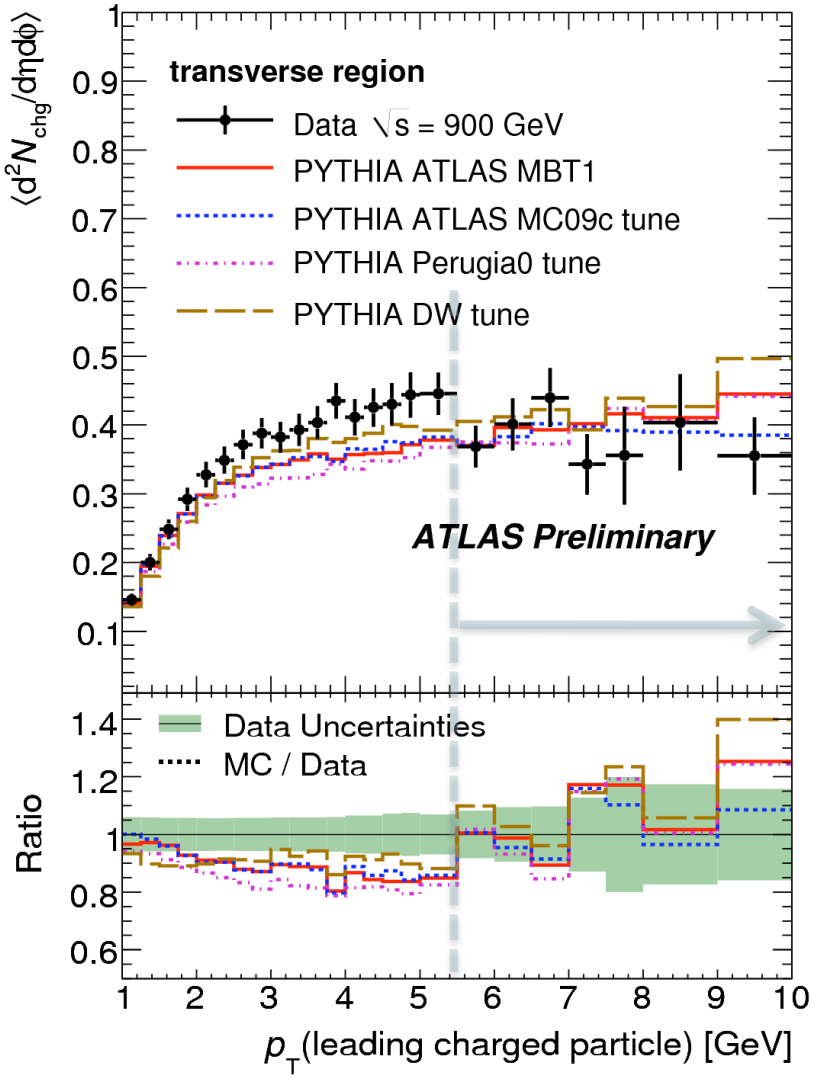
similar at 900 GeV

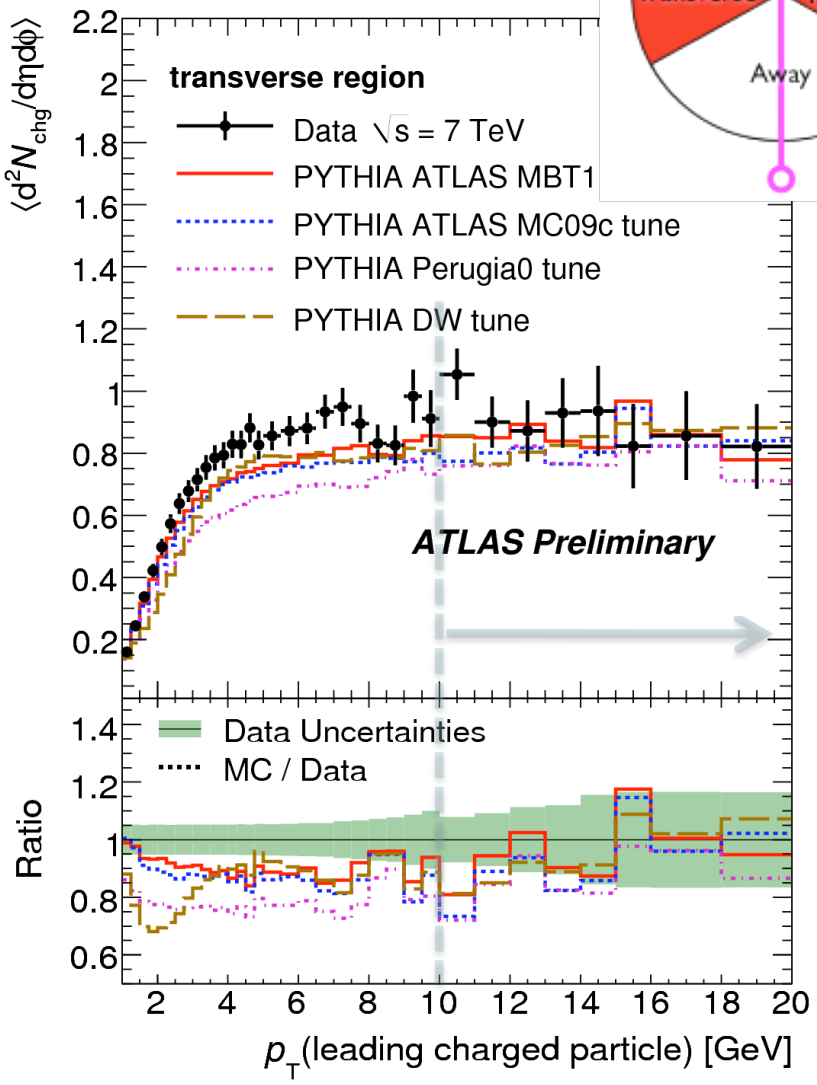
Decrease in high p_T tails

Decrease in $\langle p_T \rangle$ at high n_{ch}

UE distributions

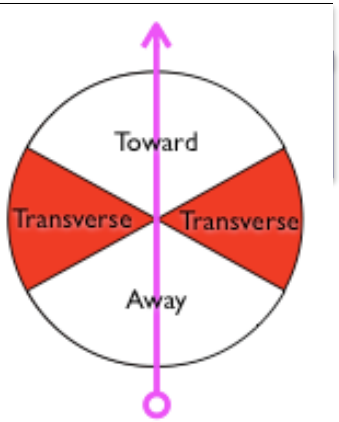


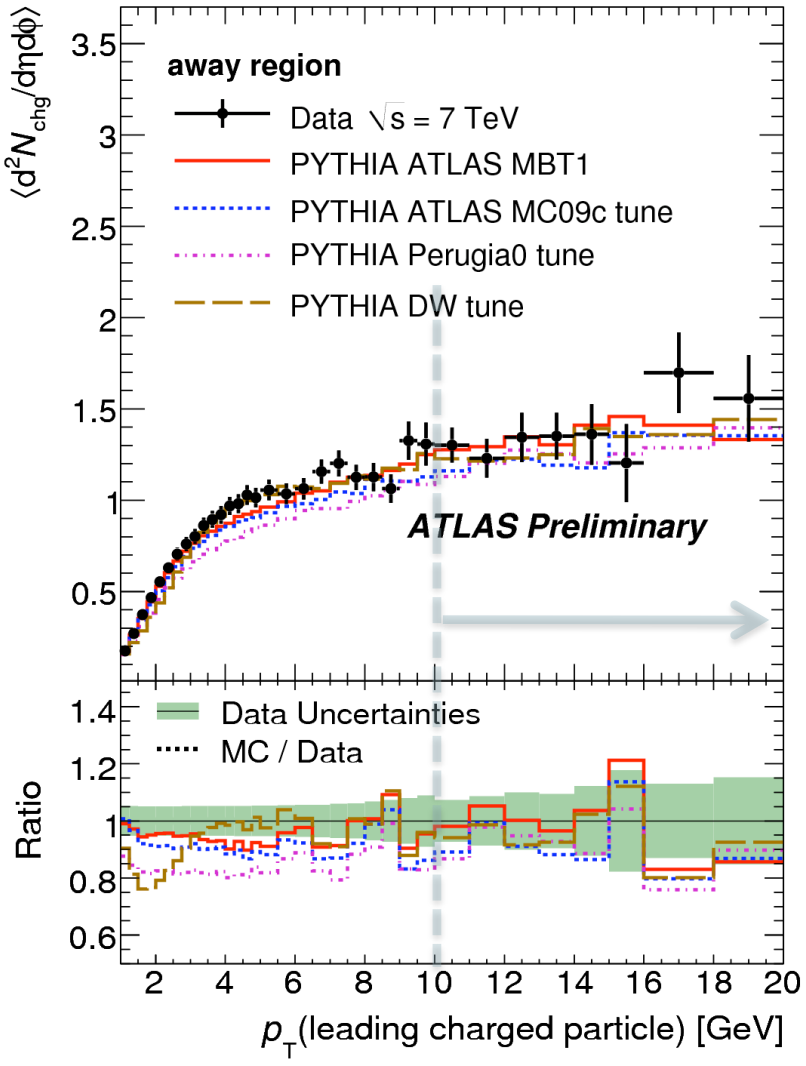


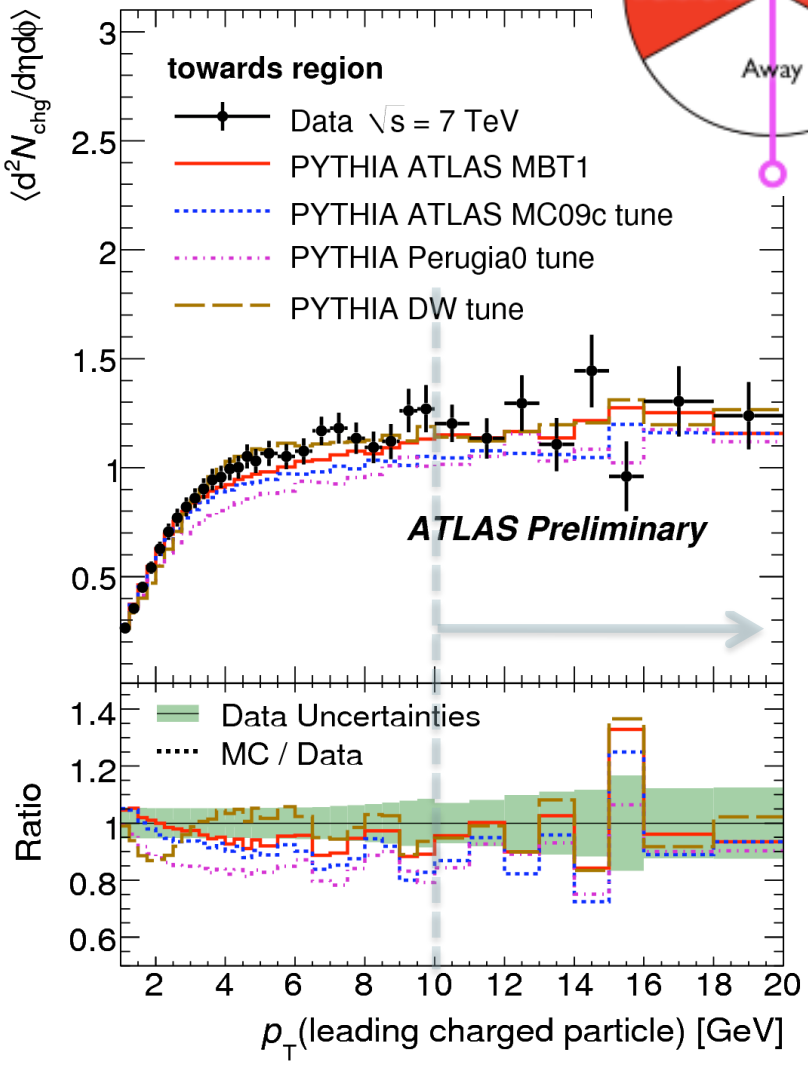


similar for Σp_T density

UE distributions



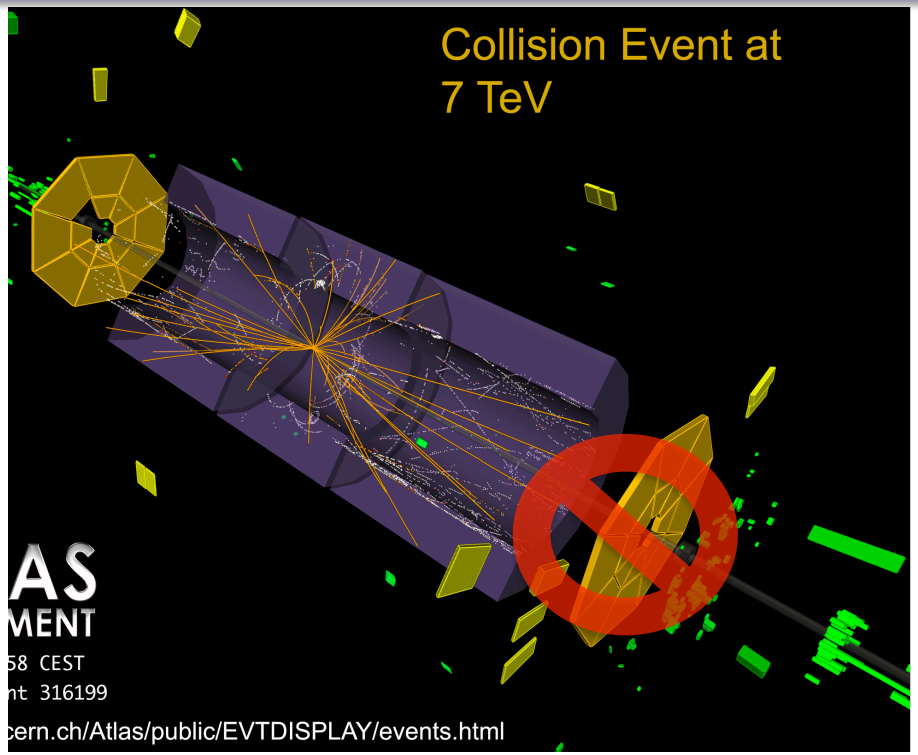




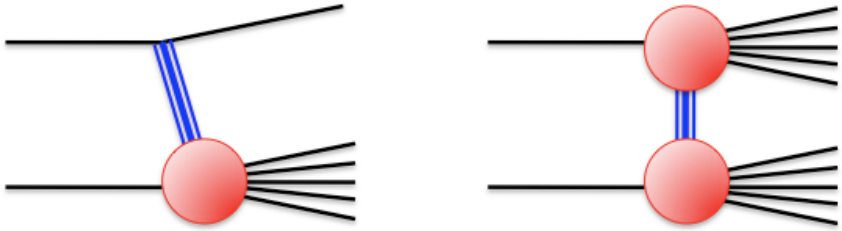
similar at 900 GeV

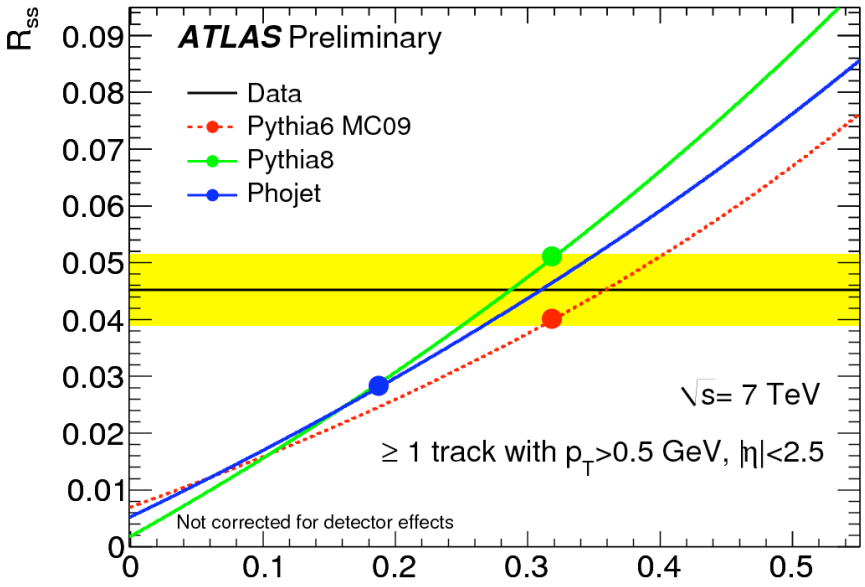
Diffraction enhanced sample

no detector corrections yet! compared to full Sim MC!



veto activity in one forward scintillator disk
{2.09<η < 3.84 OR -2.09 > η > -3.84 }





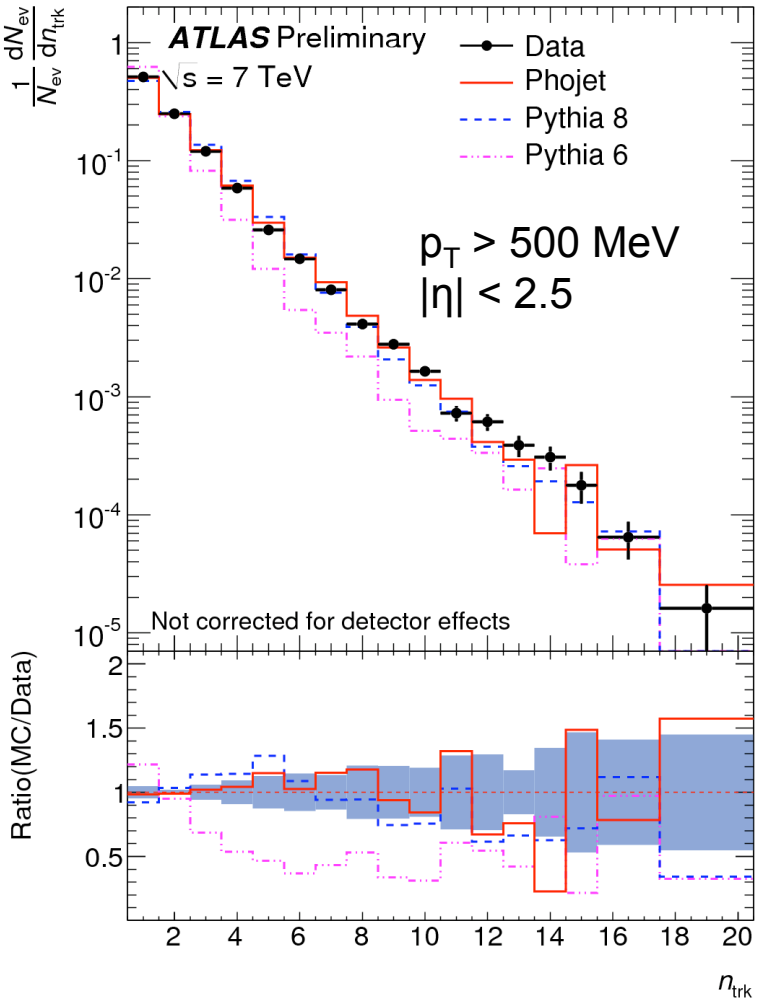
$n_{trk} \geq 1$ {$p_T > 500$ MeV, $|\eta| < 2.5$}

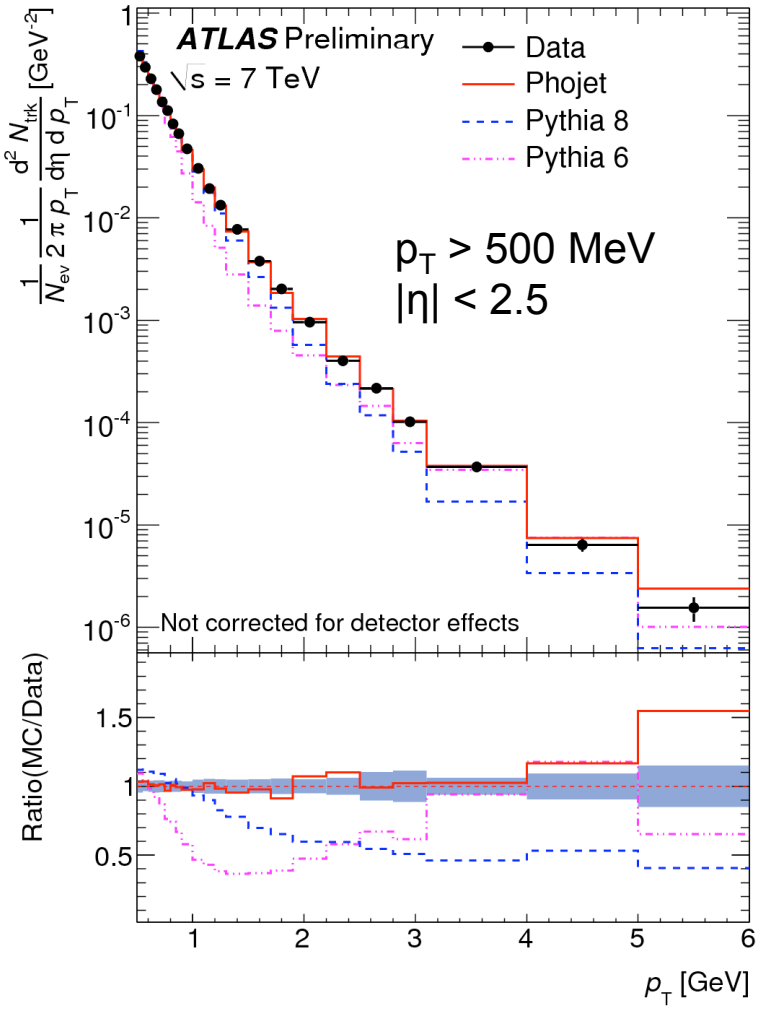
$$R = \frac{\#\ \text{single-sided}}{\#\ \text{single-sided} + \#\ \text{double-sided}}$$

sensitive to relative diffractive cross-section → $\sigma_{diff} / \sigma_{inel}$

Diffraction enhanced sample

no detector corrections yet! compared to full Sim MC!





Excellent agreement with Phojet!

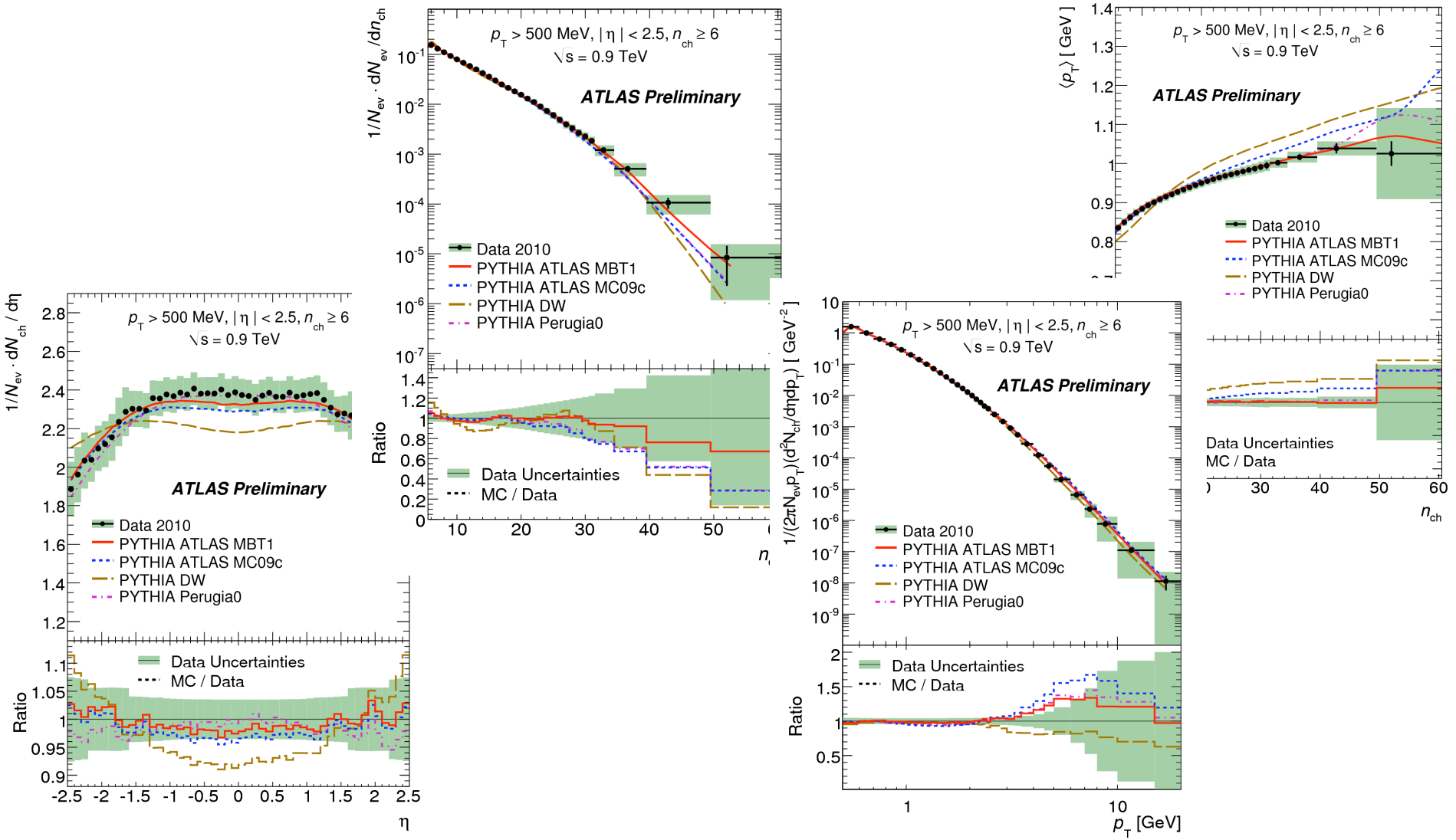
Summary

- ATLAS minbias and UE results at 900 GeV and 7 TeV in different phase space regions "completing the picture"
- New Pythia 6 tune to a diffraction suppressed minbias and UE data samples
  - improved description of minbias data
  - hints of tension with UE data ?
- Diffraction enhanced minbias sample (not yet detector corrected) favours Pythia's relative diffractive cross-sections and Phojet particle spectra

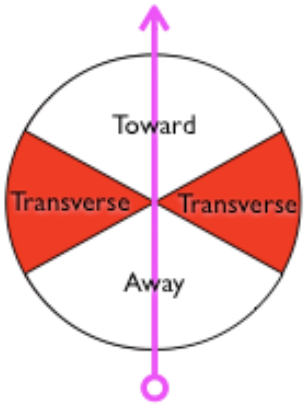
For the interested listener:
ATLAS-CONF-2010-031 : "*Charged particle multiplicities in pp interactions at sqrt(s) = 0.9 and 7 TeV in a diffractive limited phase-space measured with the ATLAS detector at the LHC and new PYTHIA6 tune*"
ATLAS-CONF-2010-029 : "*Track-based underlying event measurements in pp collisions at sqrt(s) = 900GeV and 7 TeV with the ATLAS Detector at the LHC*"
ATLAS-CONF-2010-048 : "Studies of Diffractive Enhanced Minimum Bias Events in ATLAS"

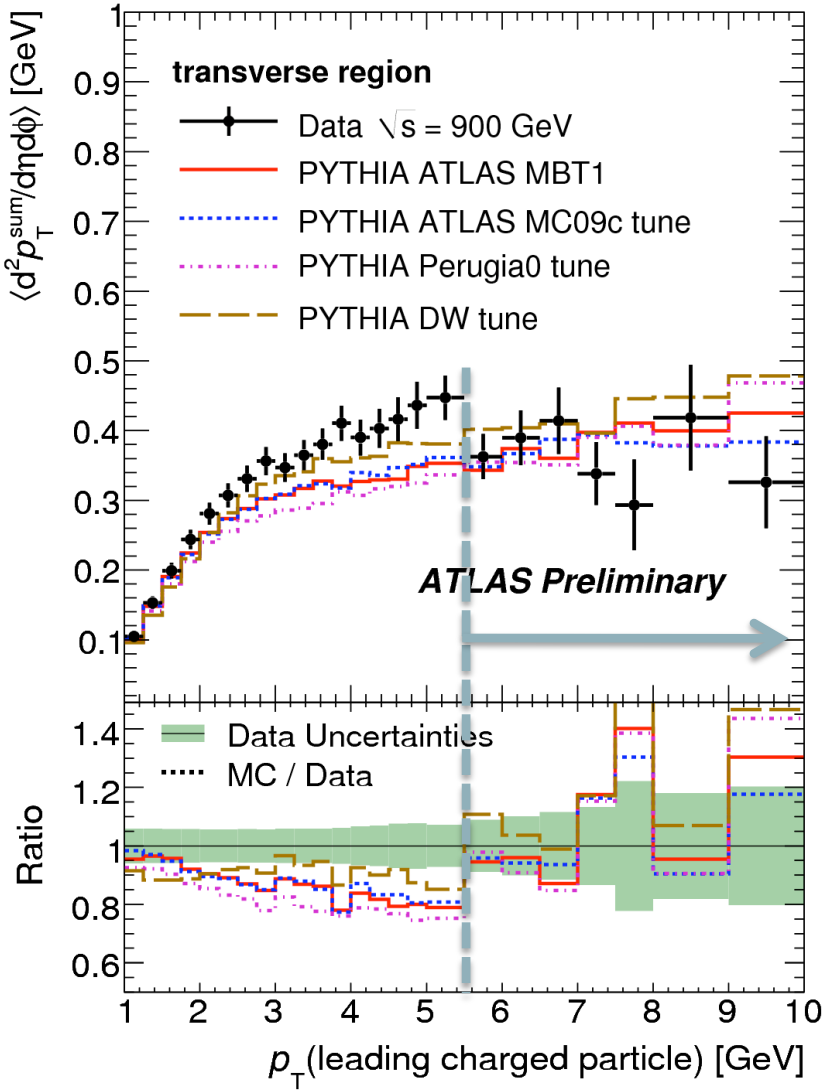
BACKUP

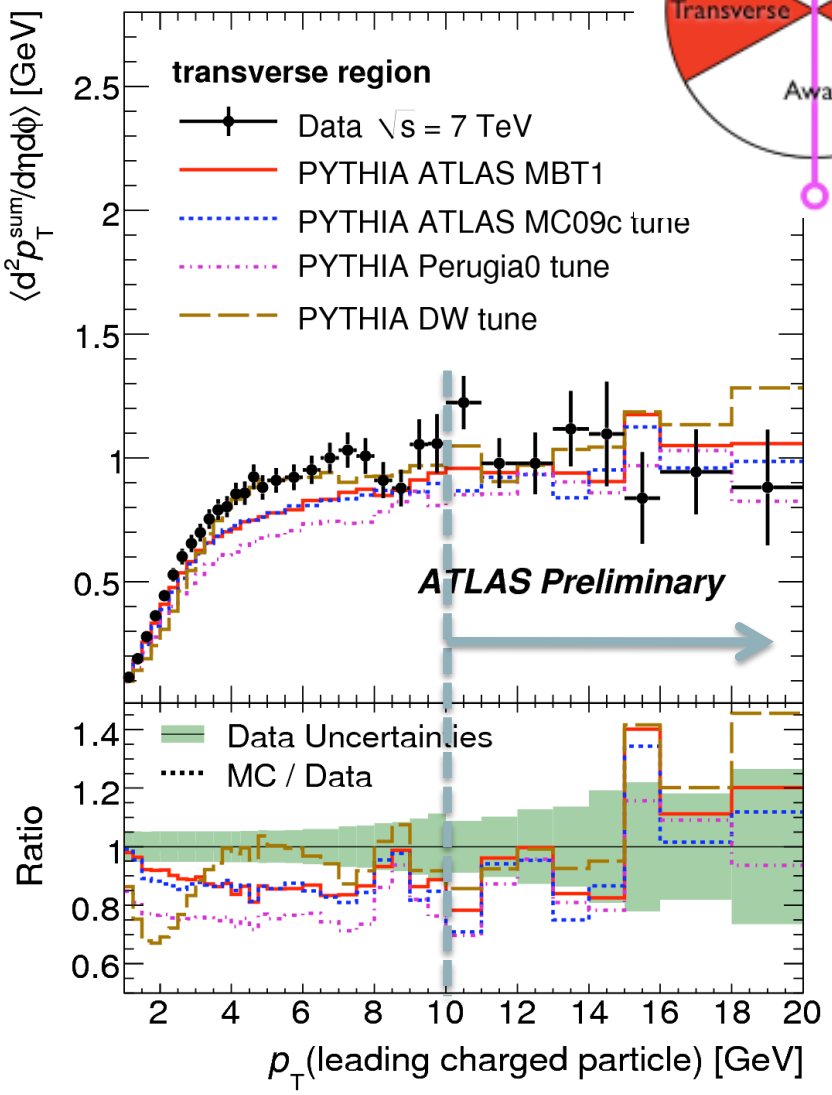
900 GeV MB data



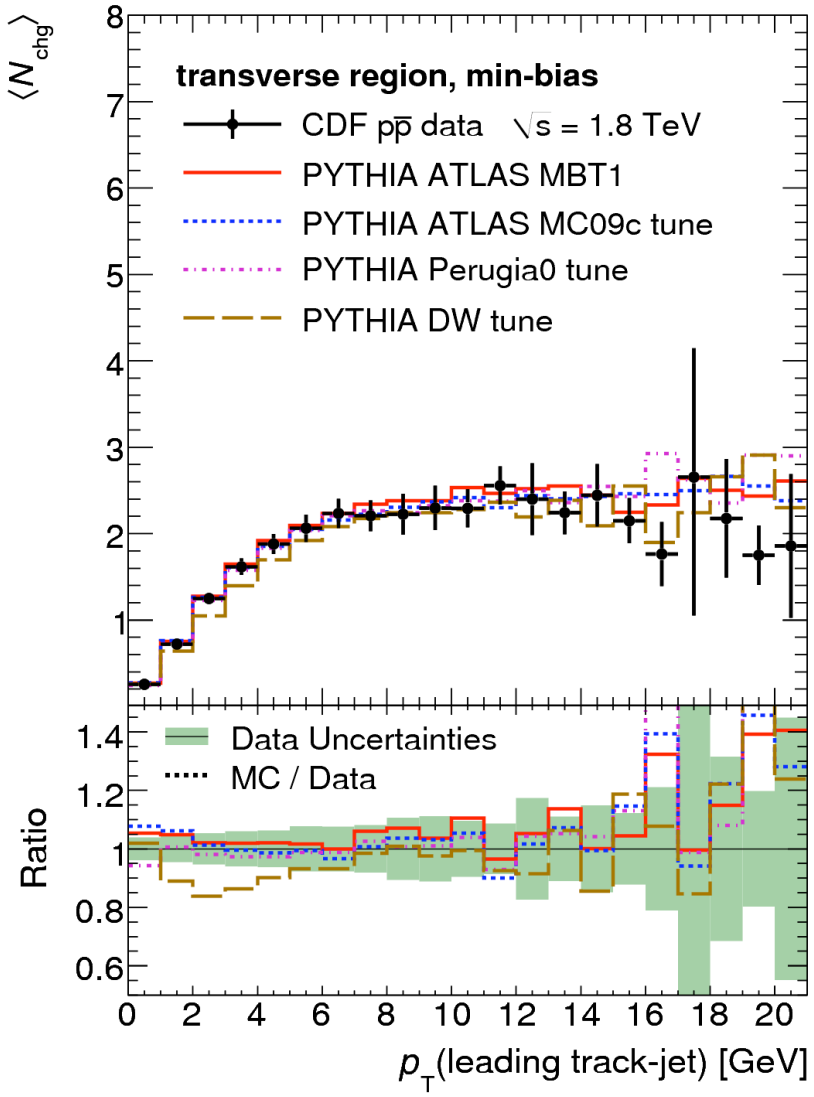
UE distributions

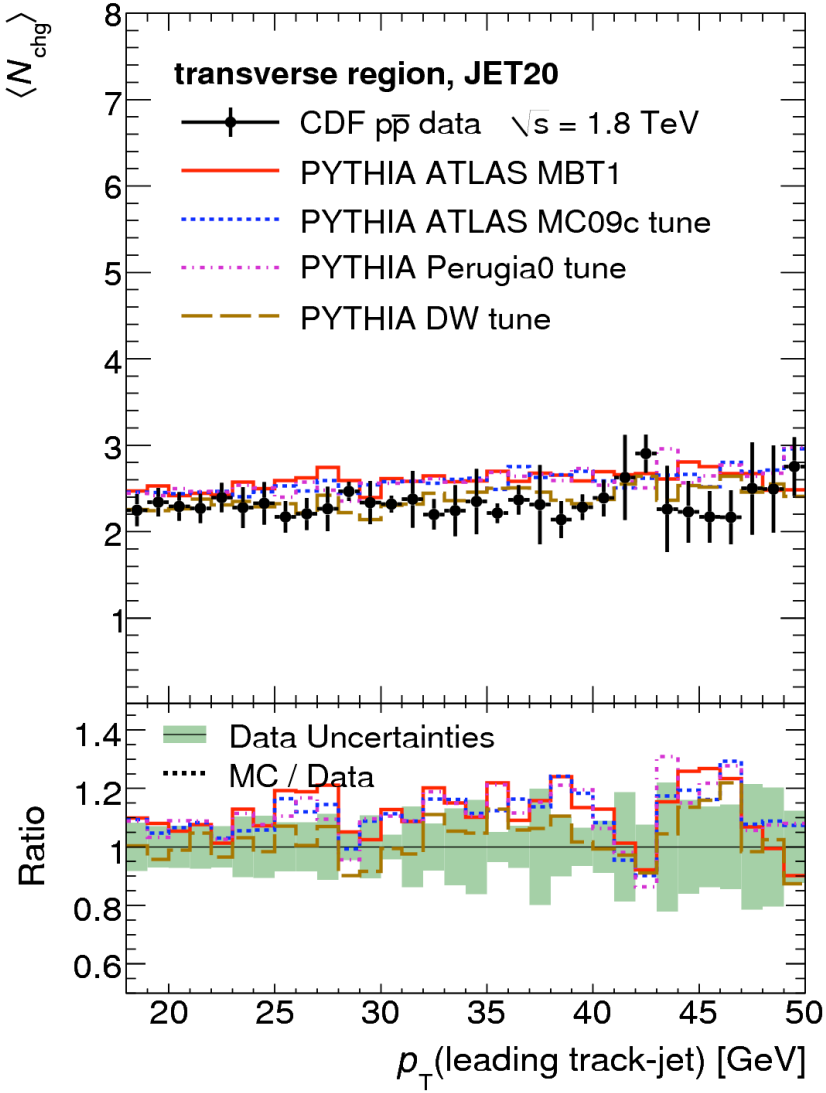




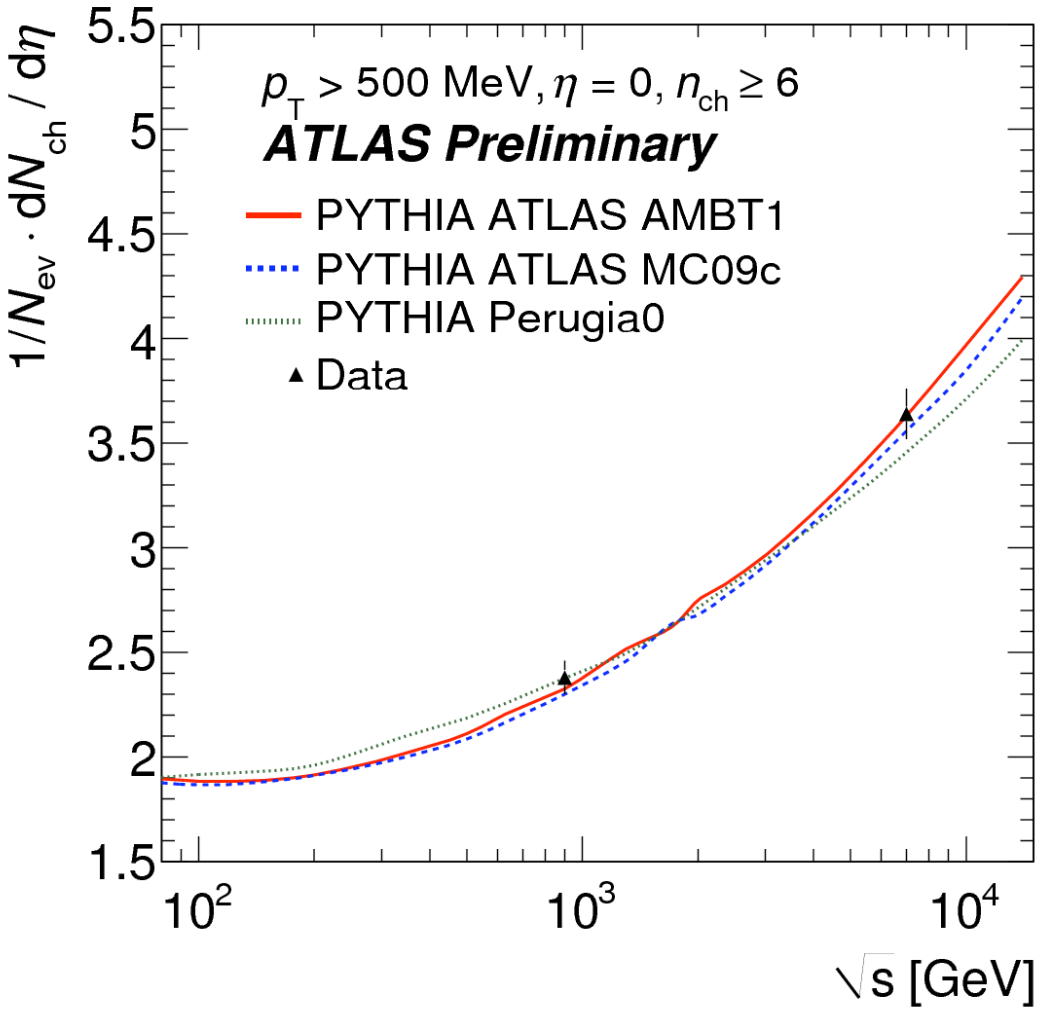


CDF data


transverse region, min-bias
CDF pp̄ data √s = 1.8 TeV
PYTHIA ATLAS MBT1
PYTHIA ATLAS MC09c tune
PYTHIA Perugia0 tune
PYTHIA DW tune
⟨N_chg⟩
Data Uncertainties
MC / Data
Ratio
p_T(leading track-jet) [GeV]

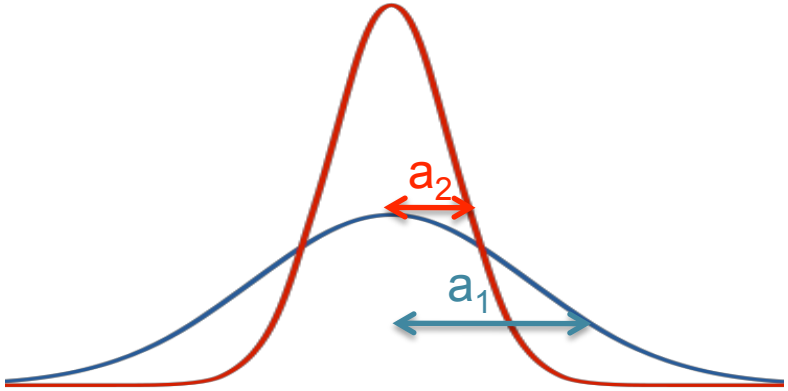

transverse region, JET20
CDF pp̄ data √s = 1.8 TeV
PYTHIA ATLAS MBT1
PYTHIA ATLAS MC09c tune
PYTHIA Perugia0 tune
PYTHIA DW tune
⟨N_chg⟩
Data Uncertainties
MC / Data
Ratio
p_T(leading track-jet) [GeV]

Charged particle distributions



Pythia 6 tune [AMBT1]

Matter distribution of protons described by double Gaussian



PARP(83) = fraction in core Gaussian
PARP(84) = a_2 / a_1

Regularisation of divergence in 2→2 scattering via $1/p_T^4 \rightarrow 1/(p_T^2 + p_{T0}^2)^2$

p_{T0} = PARP(82) (E_{COM} / 1.8 TeV) PARP(90)

	MC09c	AMBT1	Approximate effect
PARP(83)	0.8	0.356	Less fluctuations in n_{ch}
PARP(84)	0.7	0.651	Increase n_{ch} tails, more activity
PARP(82)	2.31 GeV	2.292 GeV	More activity
PARP(90)	0.2487	0.250	More(less) activity at 0.9(7) TeV

overall increase in n_{ch} tail

overall increase in activity

Pythia 6 tune [AMBT1]

Start with MC09c (ATLAS tune to CDF minbias+UE data and D0 dijet angular correlations with LO* PDFs [PHYS-PUB-2010-002]).

Initial State Radiation :

- Proton intrinsic p_T distribution cut-off (PARP(93))
- Cut-off in initial state radiation (PARP(62))

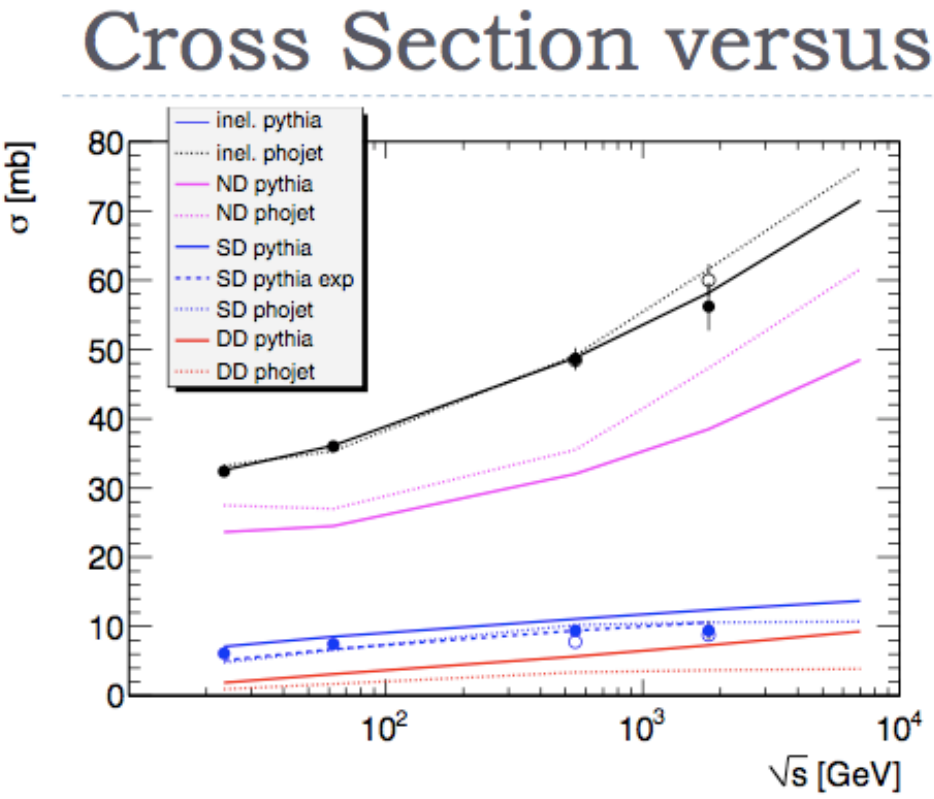
Colour reconnection :

- Probability that a string piece *does not* participate in colour annealing : $(1 - \text{PARP(78)})^{n_{MI}}$ (n_{MI} =# of MPI)
- Suppression factor for colour annealing : $1 / (1 + \text{PARP(77)}^2 \bullet p_{avg}^2)$

	MC09c	AMBT1	Approximate effect
PARP(62)	1.0	1.025	Very little affect
PARP(93)	5.0	10.0	Very little affect
PARP(77)	0.0	1.016	Decrease $<p_T>$ and p_T tail
PARP(78)	0.224	0.538	Increase $<p_T>$ and p_T tail

} overall decrease in p_T tail and $<p_T>$ vs n_{ch}

Diffractive cross-sections



√s (TeV)		Pythia6 MC09	Phojet
0.9	ND	34.4 mb	40.0 mb
	SD	11.7 mb	10.5 mb
	DD	6.4 mb	3.5 mb
7.0	ND	48.5 mb	61.6 mb
	SD	13.7 mb	10.7 mb
	DD	9.3 mb	3.9 mb

Plot from Beate Heinemann