

Simulations of minimum bias and the underlying event, MC tuning and predictions for the LHC

Craig Buttar, Arthur Moraes, Ian Dawson
University of Sheffield

Outline

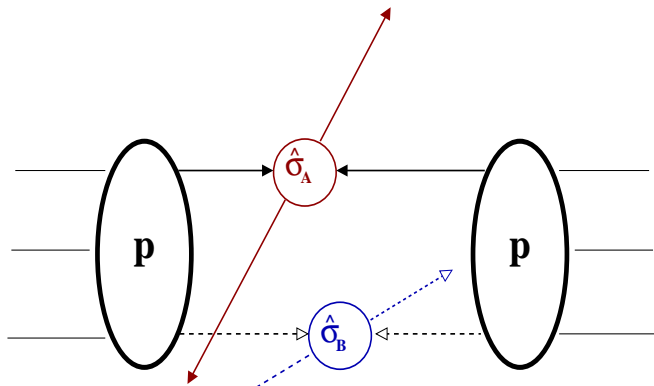
- Multi-parton scattering
- Tuning of PYTHIA
- Tuning using Jetweb
- LHC predictions
- Energy extrapolation and comparison with PHOJET
- Application to central jet veto in Higgs searches
- Summary+future work



How to describe low-pt behaviour ?

$$\sigma_{2 \rightarrow 2} > \sigma_{pp} \text{ at } p_T \sim 5 \text{ GeV}$$

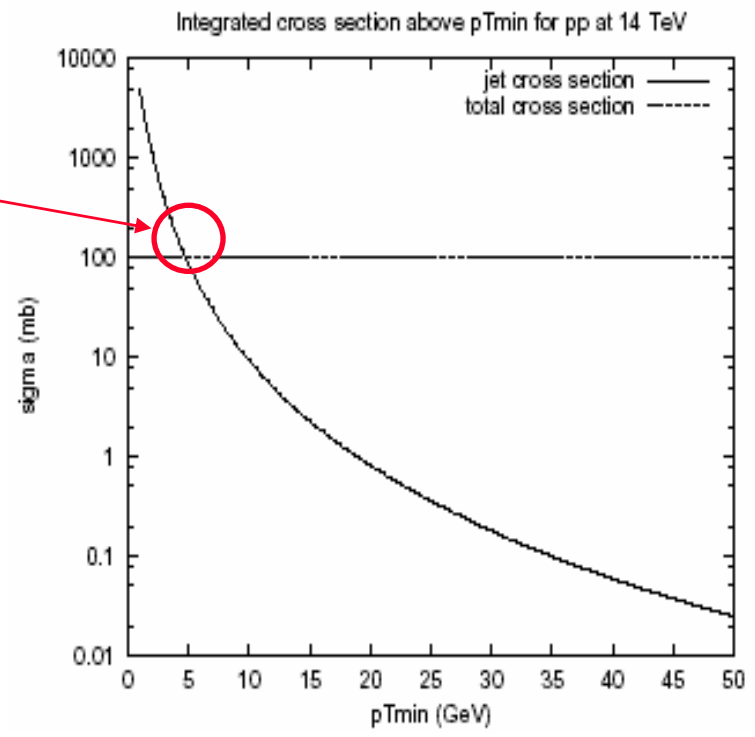
Different approaches but all many to multi-parton scattering



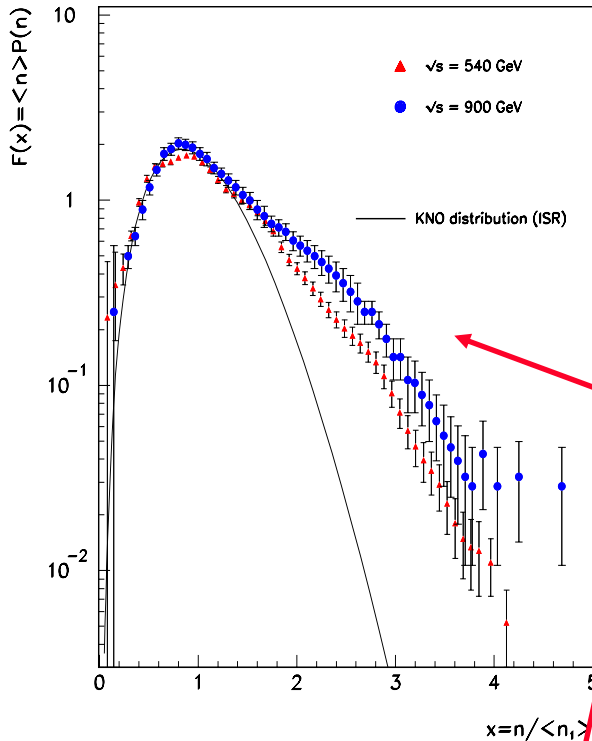
$$\bar{n} = \frac{\sigma_{hard}}{\sigma_{pp}}$$

$$\sigma_{hard} = \int_{p_{T-min}}^{s/4} \frac{d\sigma}{dp_t^2} dp_t^2$$

(simple scenario with sharp cut-off)



Evidence for multi-parton interactions



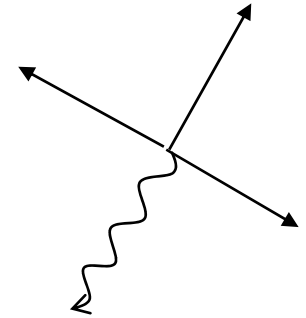
UA5 KNO distributions

D0 multijet analysis
HERA photoproduction

Direct

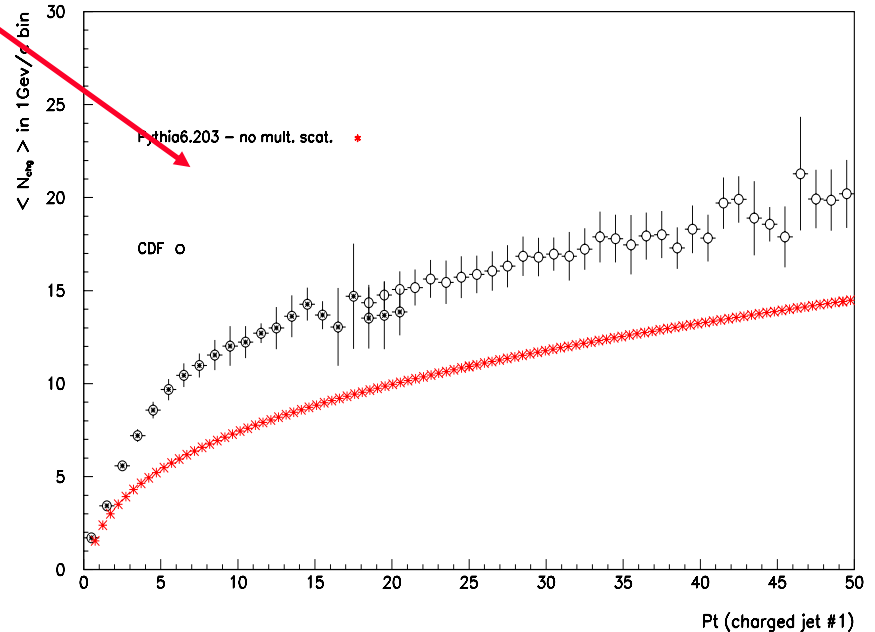
$$p\bar{p} \rightarrow \gamma / \pi^0 + 3 \text{ jets} + X$$

CDF



indirect

N_{ch} versus Pt (jet #1)



CDF underlying event



PYTHIA model

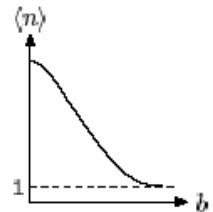
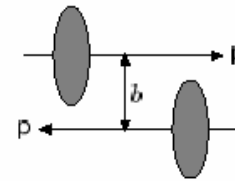
Multiple interactions solve total xsect problem
 Need to tame the PT divergence over QCD cross-section

Parameters of the model:

• p_T -min \longrightarrow Abrupt vs smooth cut-off \longrightarrow Number of interactions

Impact parameter \longrightarrow Matter distribution \longrightarrow Number of interactions and fluctuations

• energy dependence \longrightarrow $p_{t0} = 1.9 \text{ GeV} \left(\frac{\sqrt{s}}{1 \text{ TeV}} \right)^{0.16}$



Parameters not looked at: string drawing, effect of ISR (CDF)



Minimum bias data:

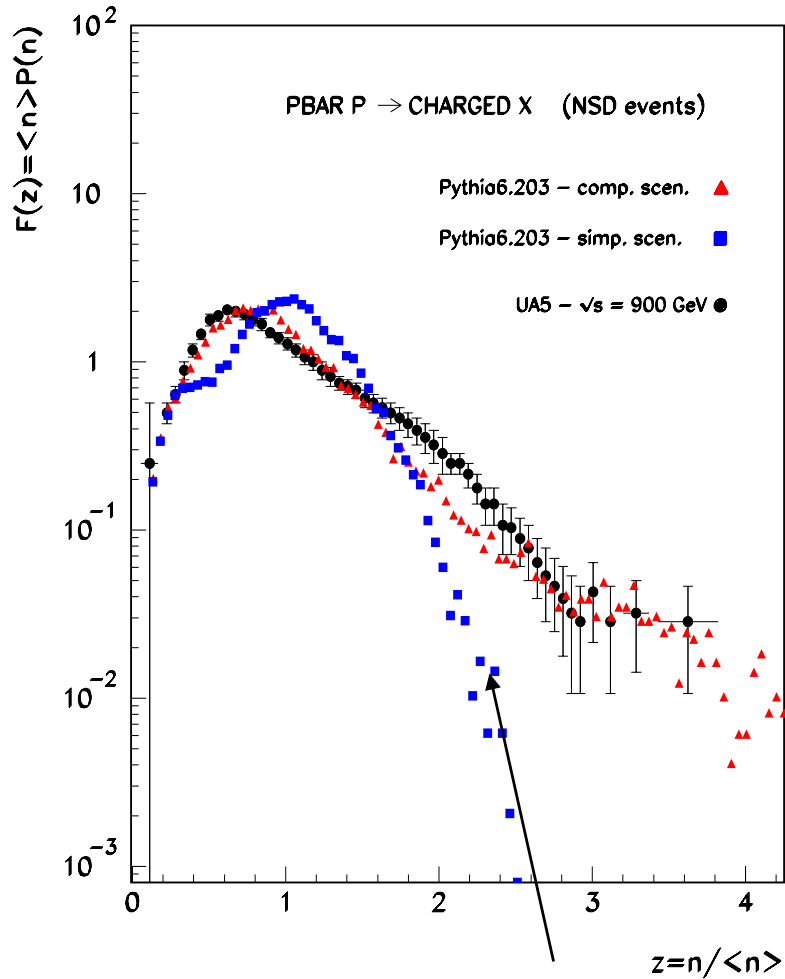
Multiplicity information:
 $\langle n_{ch} \rangle$, $dN/d\eta$, KNO, FB, etc.

Set π^0 , K^0_s and Λ^0 stable

Experiment	References	Colliding beams
CERN – ISR	Phys. Rev. D 30 528 (1984)	pp at $\sqrt{s} = 30.4, 44.5, 52.6$ and 62.2 GeV
UA5 – SPS	Phys. Rep. 154(5,6) 247 (1987) Z. Phys. C 37, 191 (1988) Z. Phys. C 43, 357 (1989)	$p\bar{p}$ at $\sqrt{s} = 200, 546$ and 900 GeV
CDF - Tevatron	Phys. Rev. D 41 2330 (1990)	$p\bar{p}$ at $\sqrt{s} = 1.8$ TeV
E735 - Tevatron	Phys. Lett. B 435 453 (1998)	

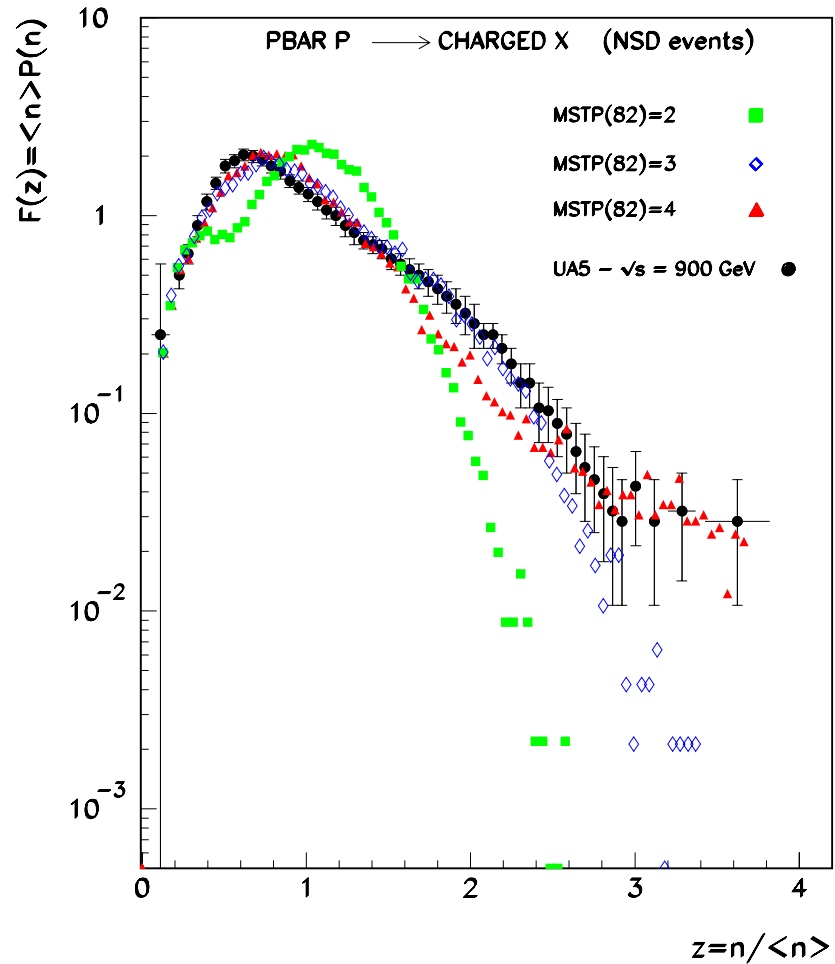


Use 'complex' scenario
with smooth cut-off

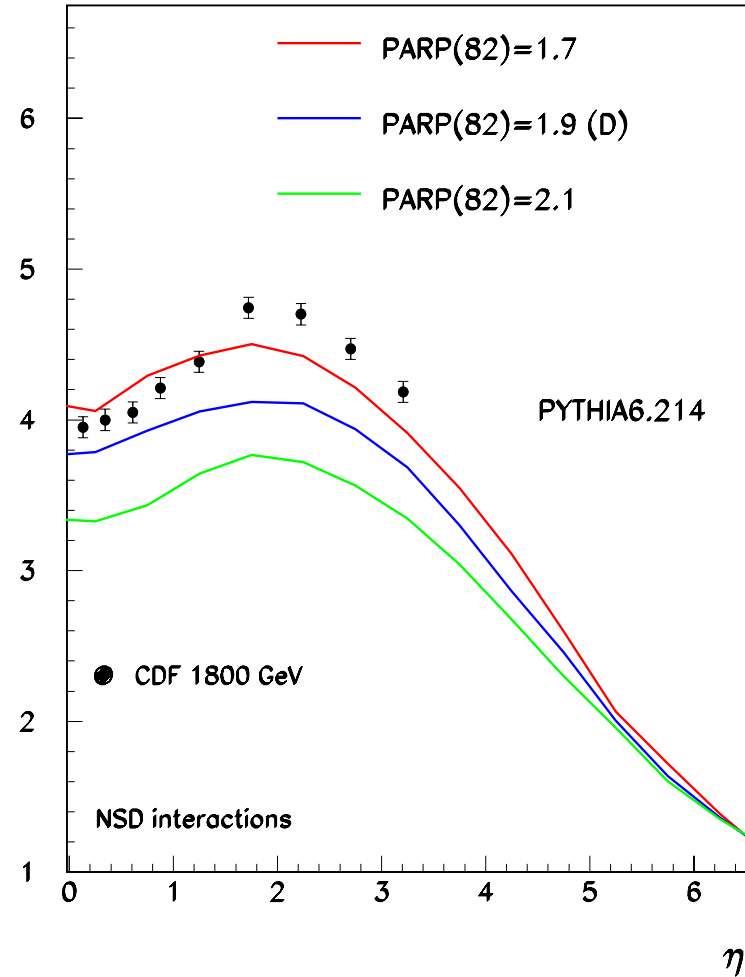
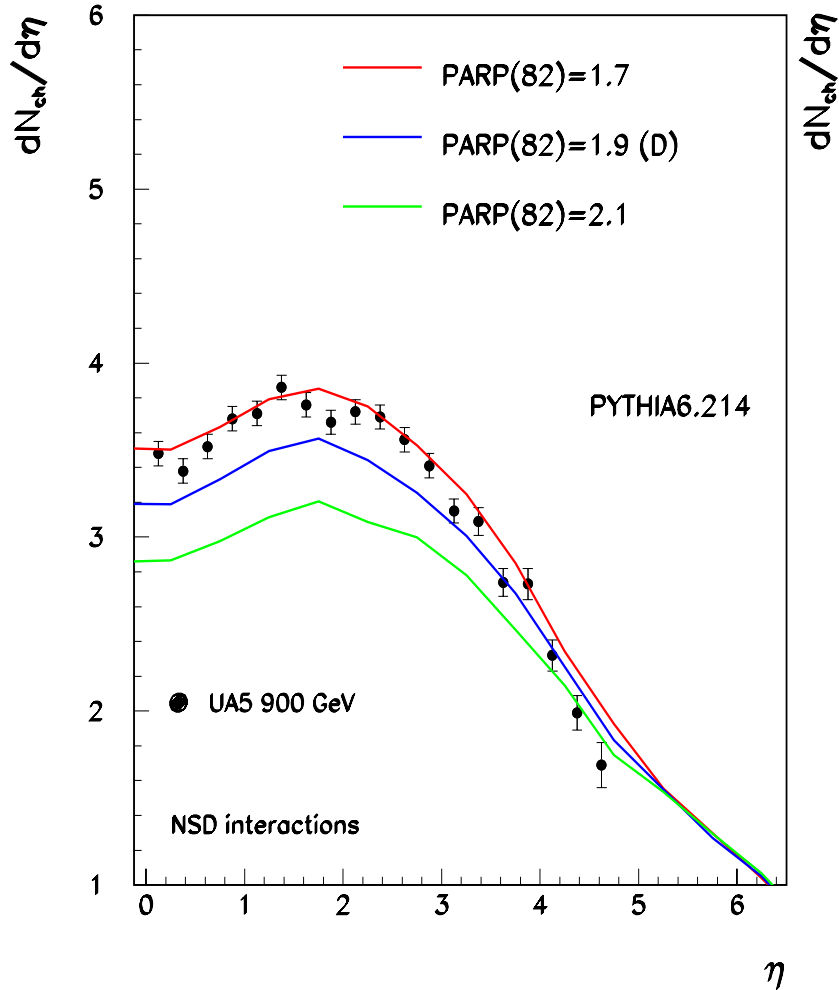


Abrupt cut-off generates
too few interactions

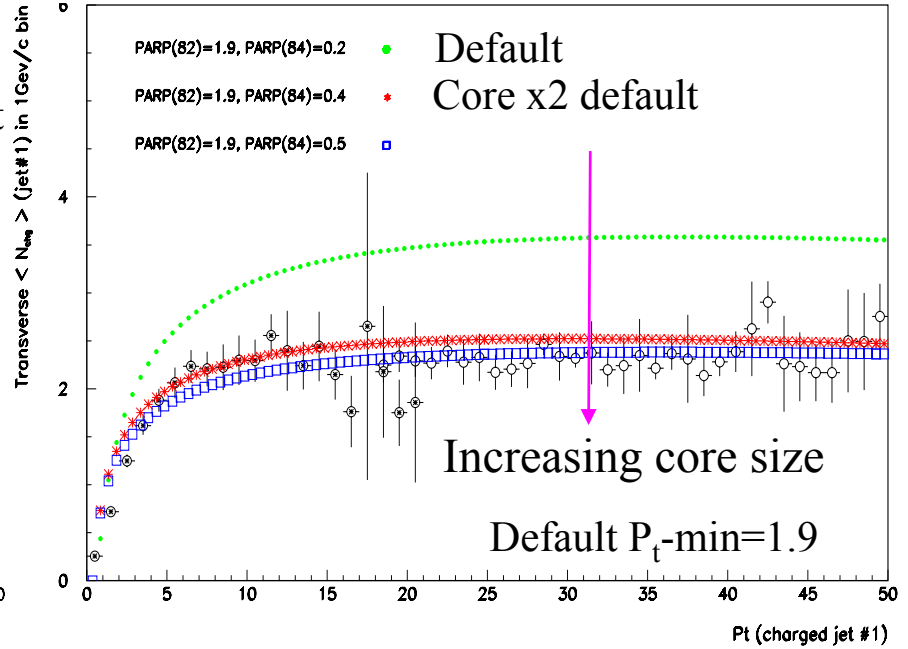
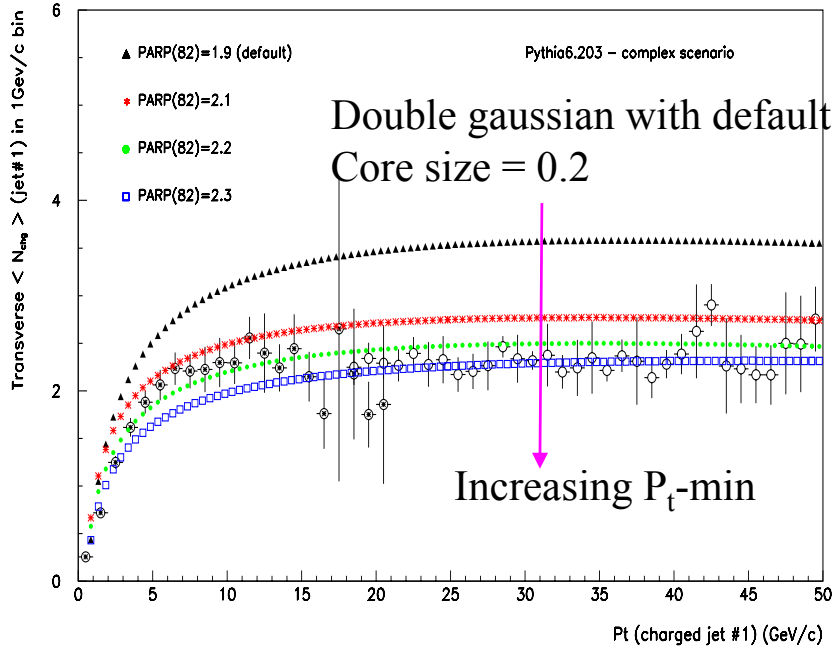
Use 'double-gaussian'
Matter distribution



Pt-min is $\sim 1.9\text{GeV}$ default value



Transverse $\langle N_{ch} \rangle$ vs jet p_T



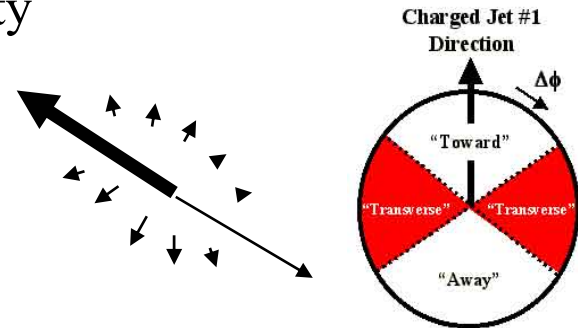
The underlying event requires less activity \Rightarrow higher pt
Lose ‘unification’ of min-bias and underlying event

Alternatively increase the core size
This reduces the core density-reducing activity

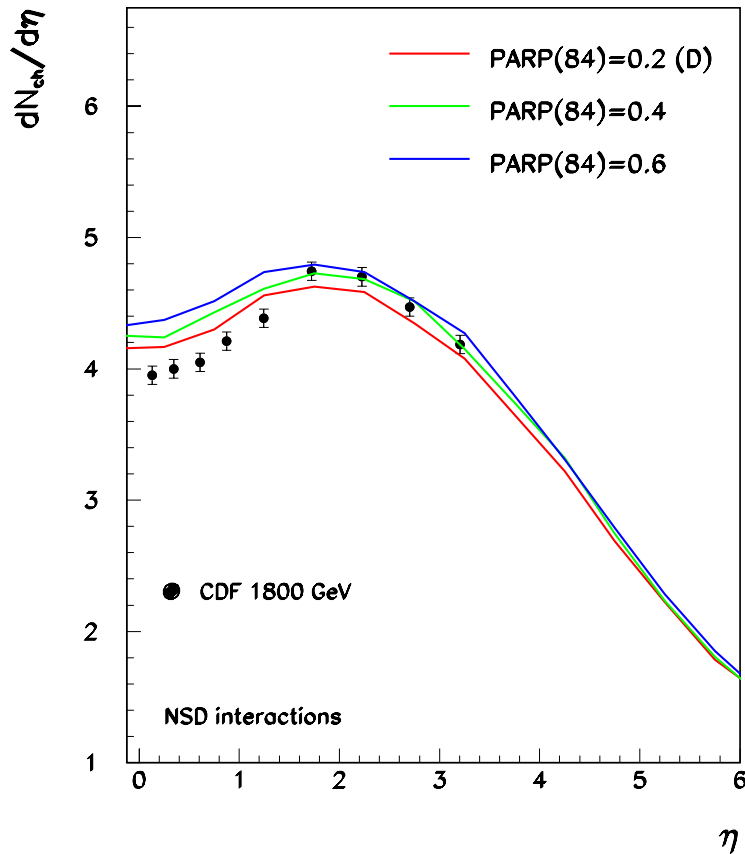
CDF Run 1 underlying event analysis

Phys. Rev. D, **65** 092002 (2002)

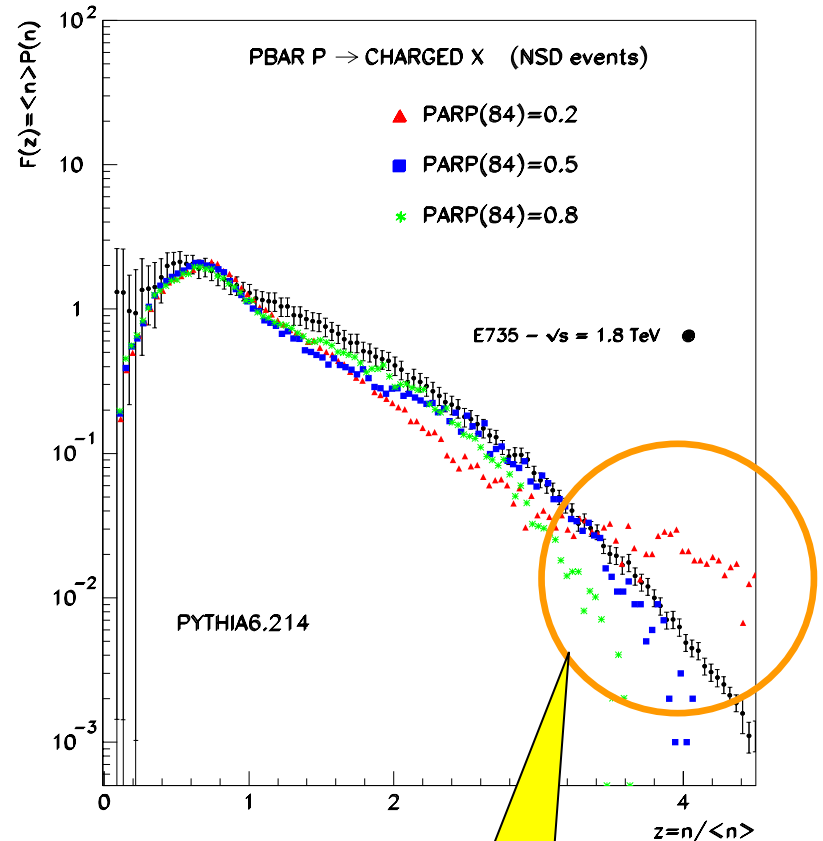
Craig Buttar ISMD 2003



The rapidity distributions are insensitive to the matter distribution



Agreement with KNO improves
As it reduces the large fluctuations in multiplicity



Effect on high multiplicity events.



PYTHIA Tuning (AM Tune)

"D" = PYTHIA's default

Minimum bias	Underlying event
MSUB(94)=1 (D=0) MSUB(95)=1 (D=1)	MSUB(95)=1 (D=1)
MSTP(51)=7 (D=7)	MSTP(51)=7 (D=7)
MSTP(81) = 1 (D=1)	MSTP(81) = 1 (D=1)
MSTP(82) = 4 (D=1)	MSTP(82) = 4 (D=1)
PARP(82) = 1.8 (D=1.9)	PARP(82) = 1.8 (D=1.9)
PARP(84) = 0.5 (D=0.2)	PARP(84) = 0.5 (D=0.2)
PARP(90)=0.16 (D=0.16)	PARP(90)=0.16 (D=0.16)
π^0 , K_s^0 and Λ^0 stable (D=decay's on!)	MC distributions corrected.

Non-diff. + d.diff.

CTEQ 5L

Multiple interactions

Double Gaussian

PT0

Core size

PT0 energy dependence

Primary vertex

Exclude 8% of chd. tracks

Required to compare to data



Jetweb



Jetweb is a database tool for tuning MCs

J Butterworth and S Butterworth:

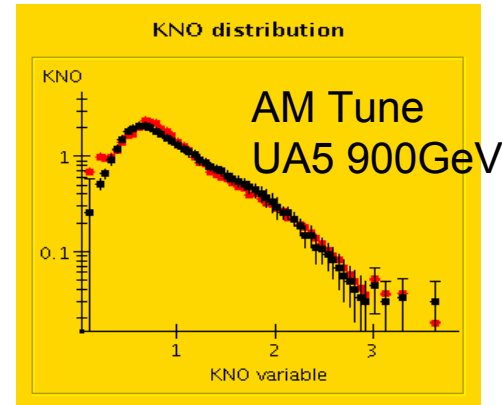
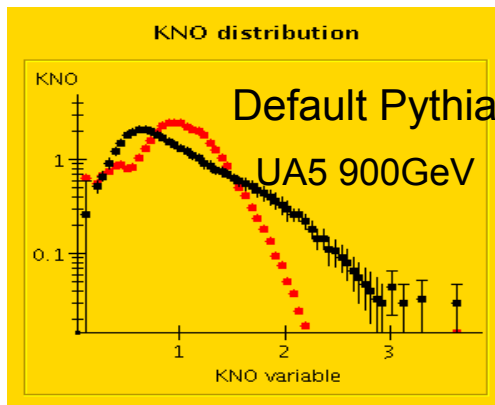
Comput. Phys. Commun. 153 (2003) 164-178

<http://jetweb.hep.ucl.ac.uk>

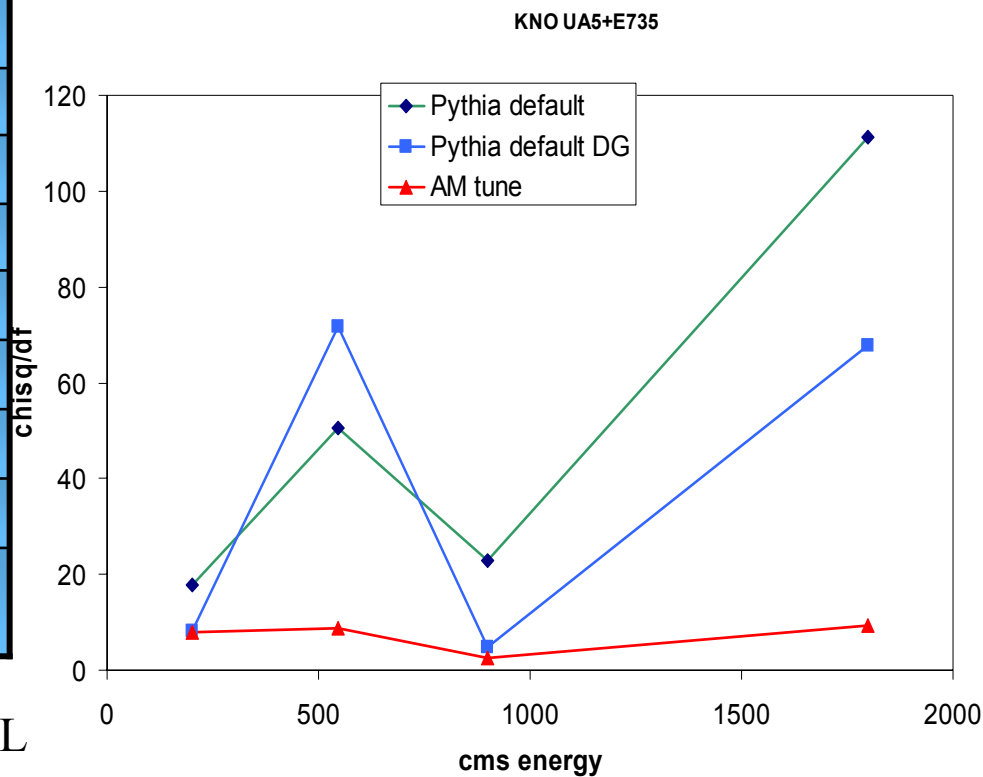
- Collection of plots from OPAL, H1, ZEUS, CDF, D0, UA5 publications, stored as distributions
- Generates events using (currently PYTHIA or HERWIG) and uses HBOOK to generate histograms to compare to data
- χ^2/\mathbf{DF} calculated for distributions
- Fits are stored for future reference and comparison to different



Jetweb comparison



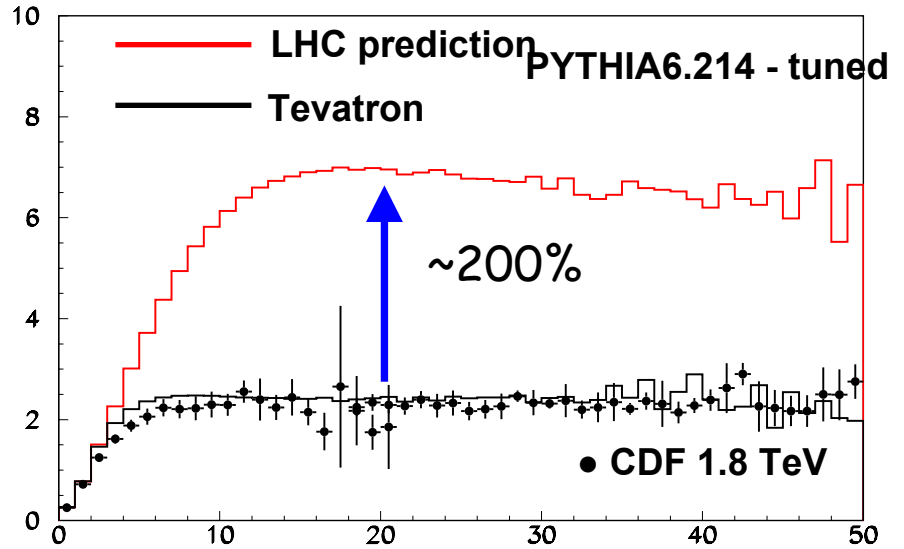
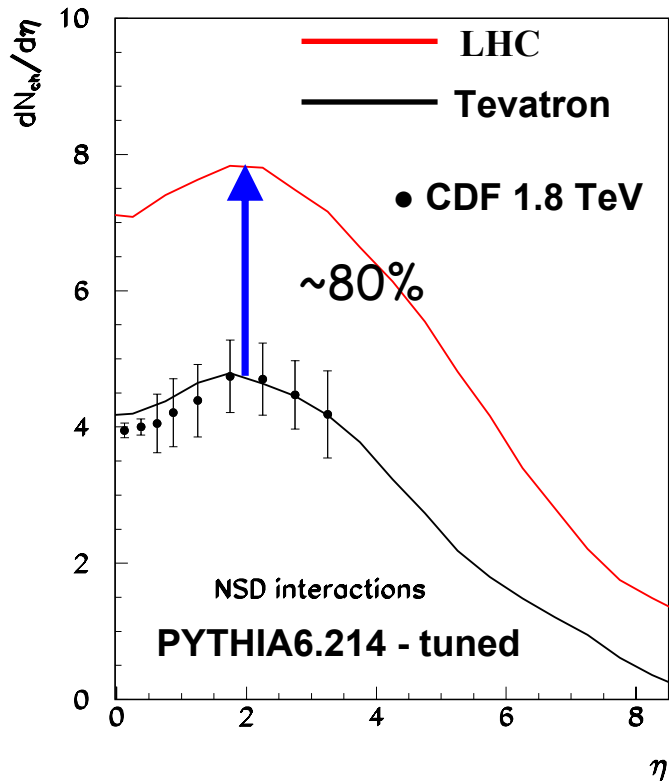
	dN/deta fit χ^2/DF		
Energy	Default	Def. DG	AM tune
200 (UA5)	16.9	18.5	6.8
900 (UA5)	11.3	16.3	1.3
	KNO fit χ^2/DF		
200 (UA5)	17.7	8.0	8.0
546 (UA5)	50.5	71.6	8.7
900 (UA5)	22.9	7.7	2.5
1800 (E735)	27.2	26.2	6.0



Jetweb fits generated by B. Waugh, UCL



LHC predictions

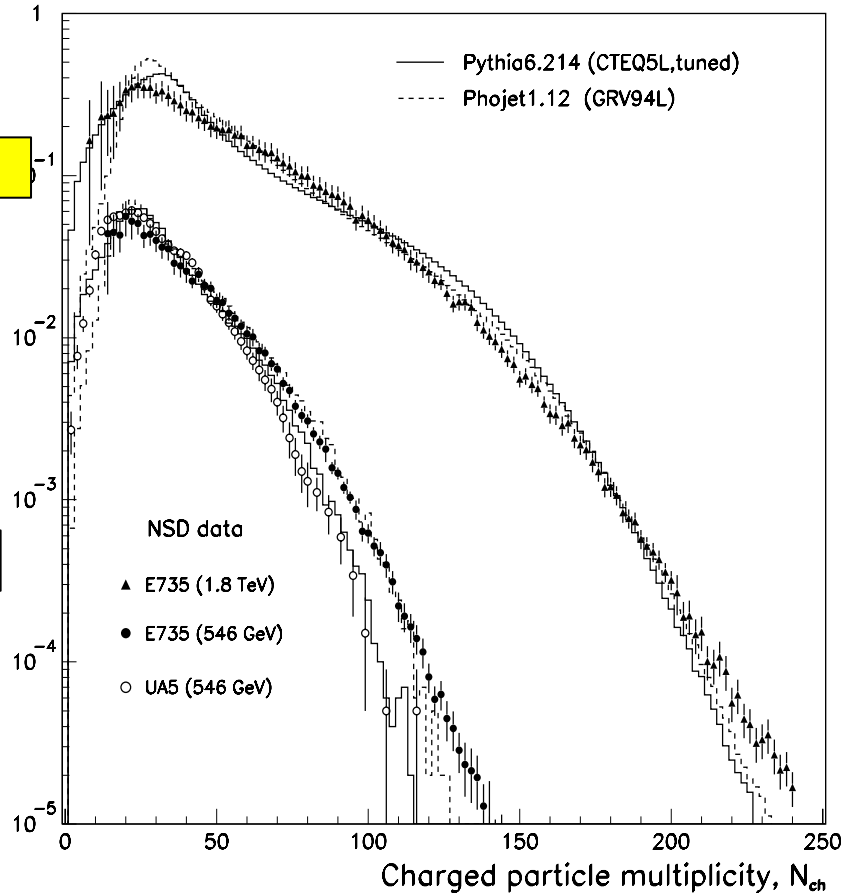
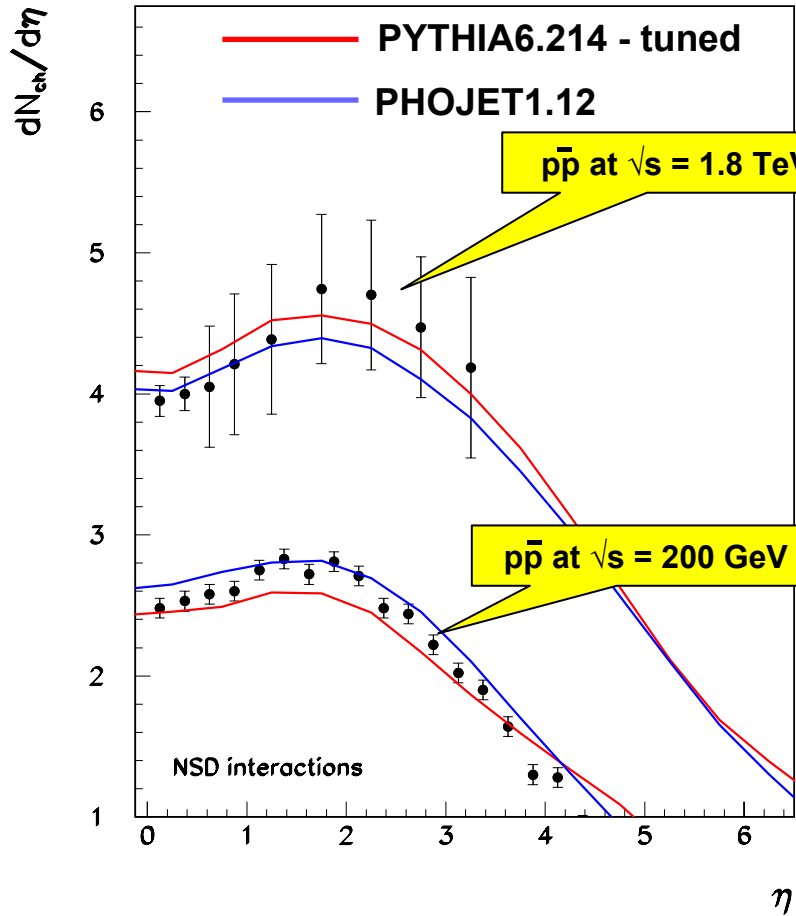


$$\frac{\left(\frac{UE(LHC)}{MB(LHC)} \right)_{\rho_{particle}}}{\left(\frac{UE(CDF)}{MB(CDF)} \right)_{\rho_{particle}}} = \frac{4.4}{2.6} = 1.7$$

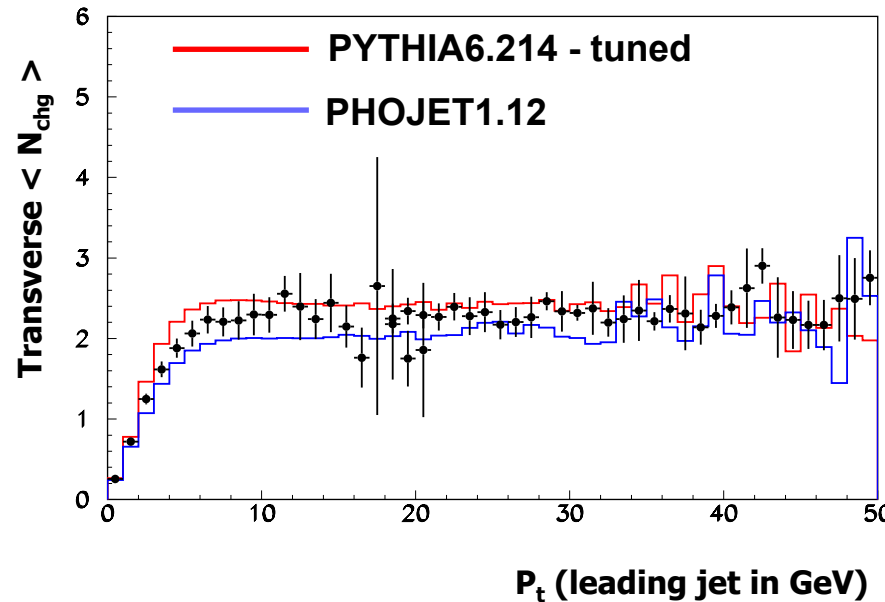
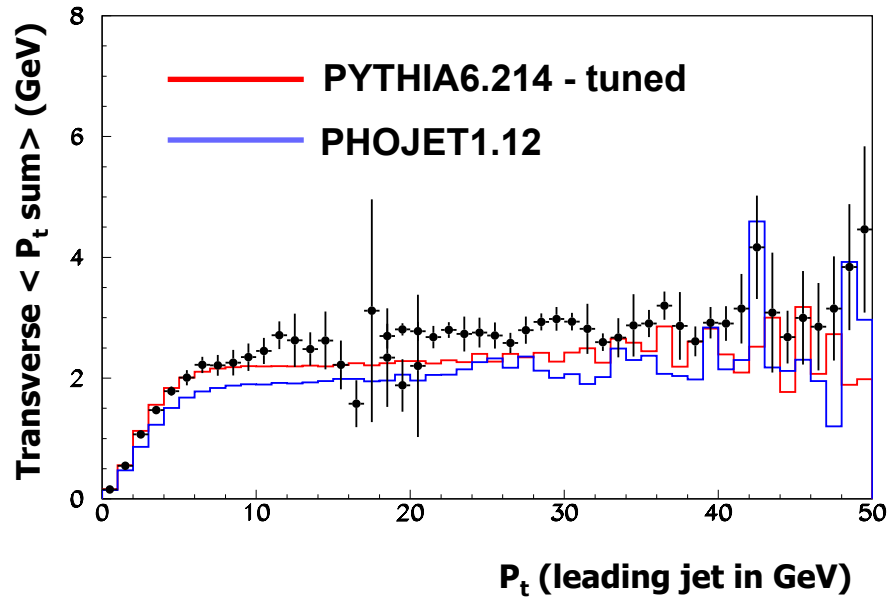
	$dN/d\eta$ ($\eta=0$)	N_{ch} jet- $p_t=20\text{GeV}$
1.8TeV (pp)	4.1	2.3
14TeV (pp)	7.0	7.0
increase	~x1.8	~x3



PYTHIA vs PHOJET: Minimum bias

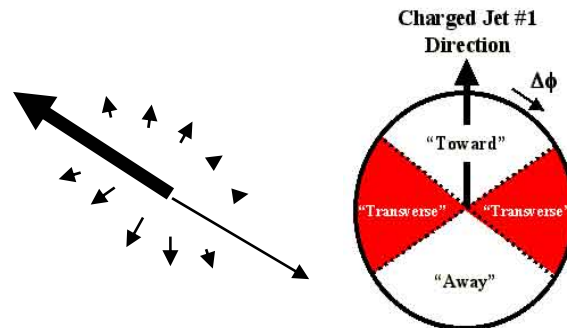


PYTHIA vs PHOJET: Underlying event

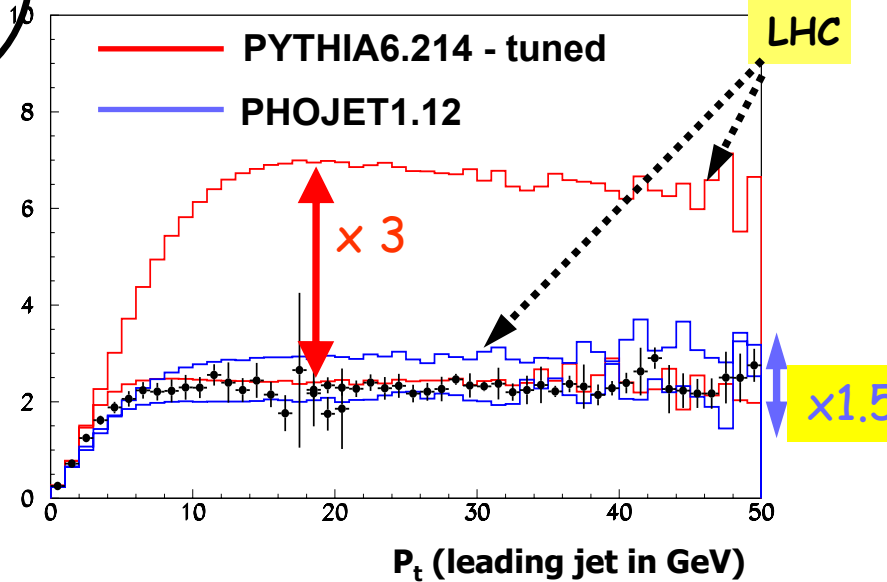
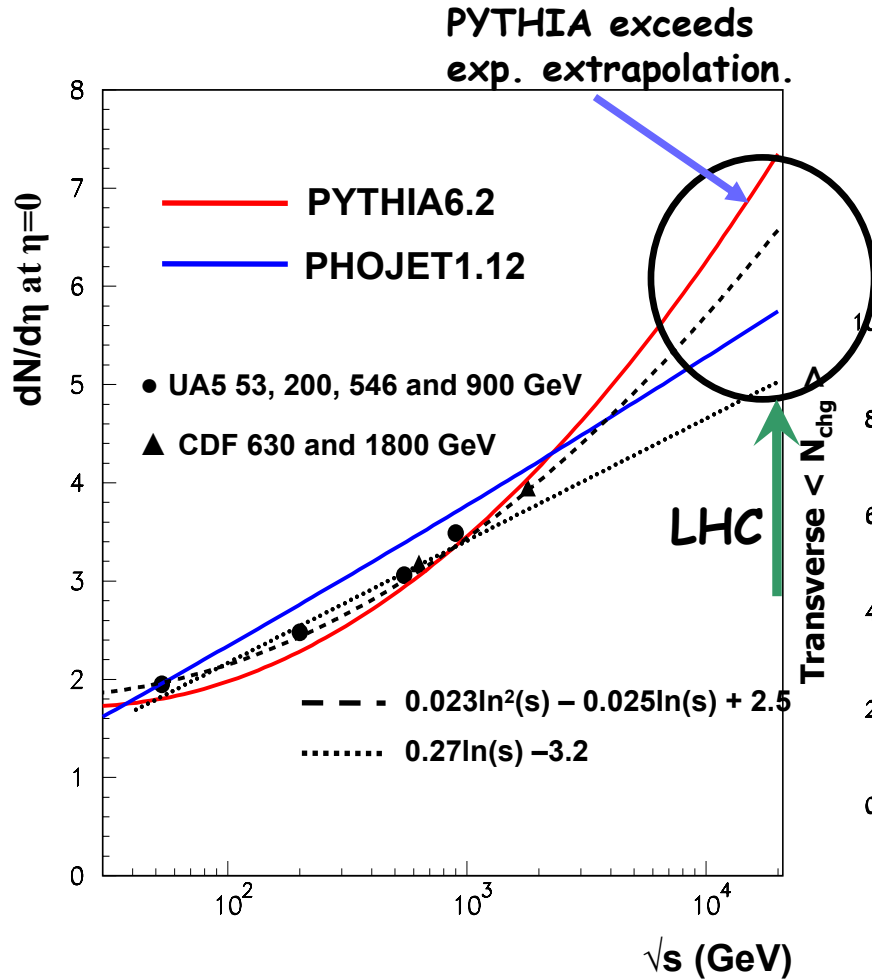


CDF Run 1 underlying event analysis

Phys. Rev. D, **65** 092002 (2002)



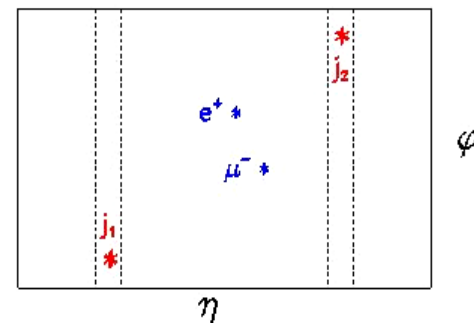
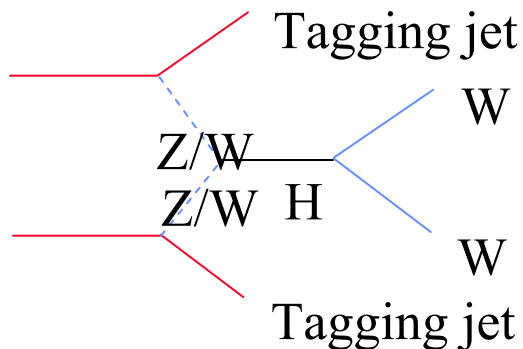
Extrapolation to the LHC-Comparison with PHOJET



VBF Signal ($H \rightarrow WW \rightarrow l\nu l\nu$)

Prospects for the search for a standard model Higgs boson in ATLAS using VBF, S.Asai et al, SN-ATLAS-2003-024 -> EPJ

- forward tagging jets
- correlated leptons
- **low hadronic activity in central region**
- central Higgs production



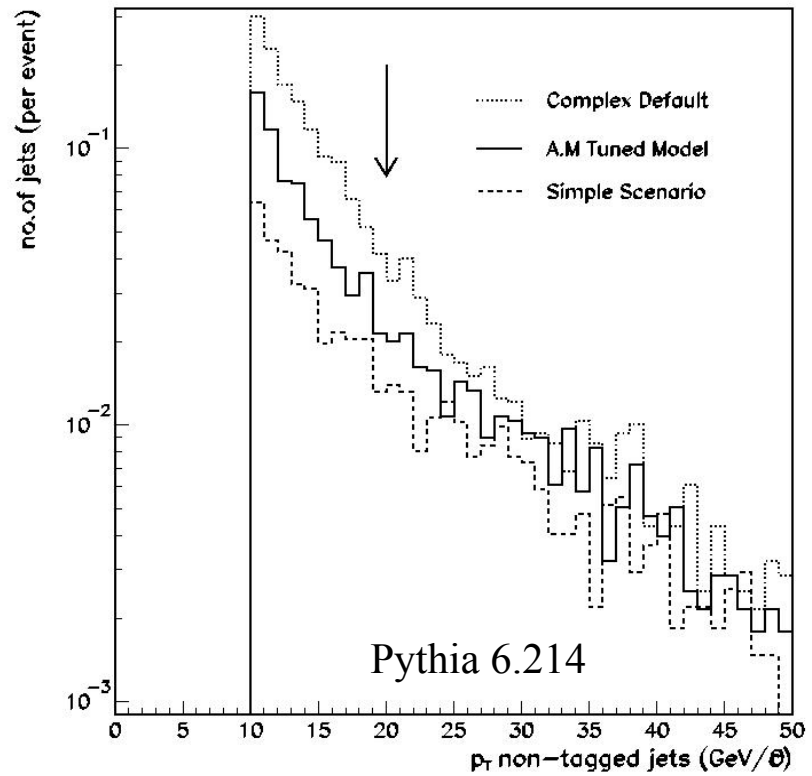
Tag jet cuts

- Candidates are two highest P_T jets in opposite hemispheres; $|\Delta\eta| > 3.8$
- $P_T^1 > 40\text{GeV}$; $P_T^2 > 20\text{GeV}$
- $M_{jj} > 550\text{GeV}$

**Important discovery channel
For Higgs in mass range
120-200GeV**



Central-jet veto:
 Cut non-tag jets in
 $|\eta| < 3.2$
 $P_T > 20 \text{ GeV}$



Model	CJV efficiency	Significance
Default pythia	82%	8.1
Default DG	71%	7.5
AM tuning	76%	7.6
Paper	86%	8.2

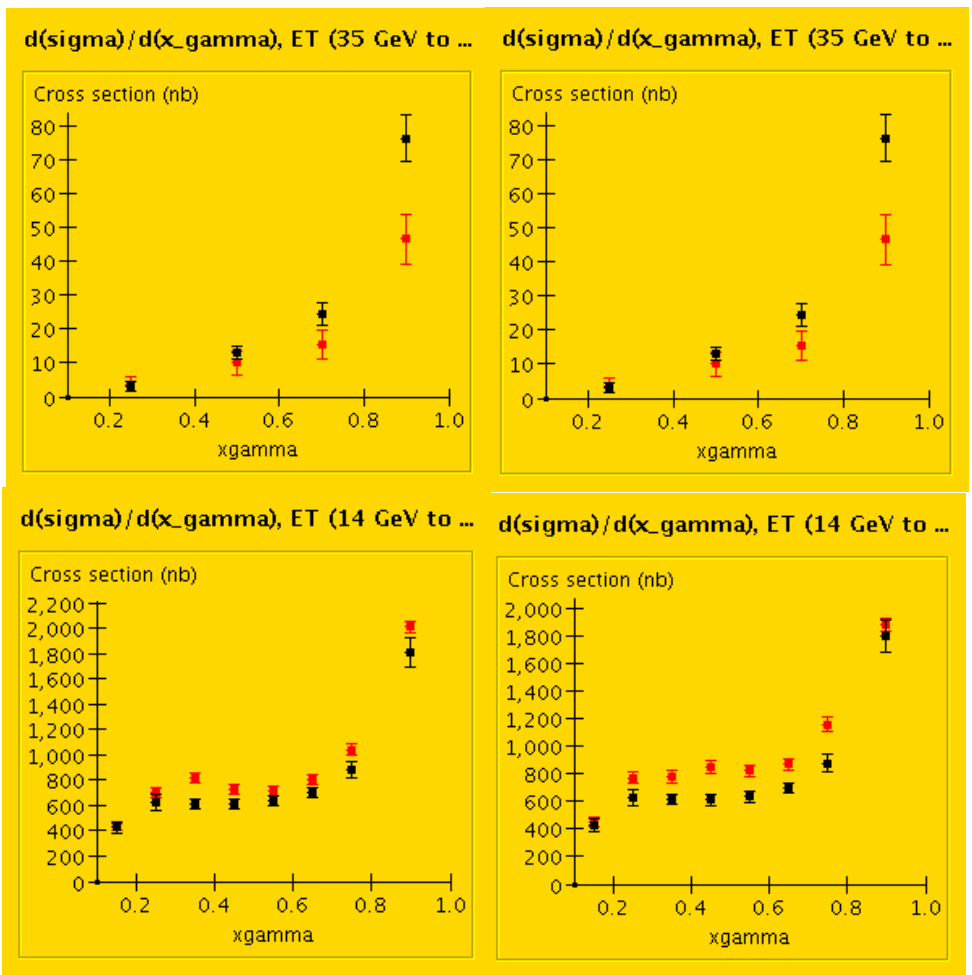
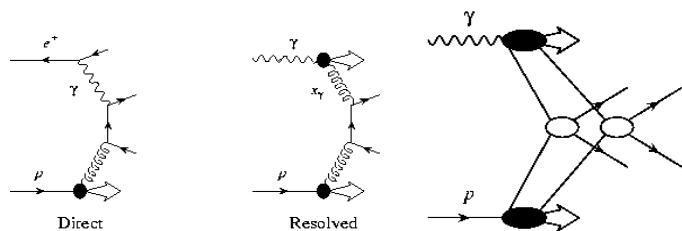


Jetweb comparison

Preliminary

ZEUS precision di-jet
Photoproduction data

	$d\sigma/dxy$	χ^2/DF
Jet ET-range	Default	AM tune
35-90	1.4	3.1
25-35	6.8	2.0
17-25	0.9	1.0
14-17	4.0	7.5



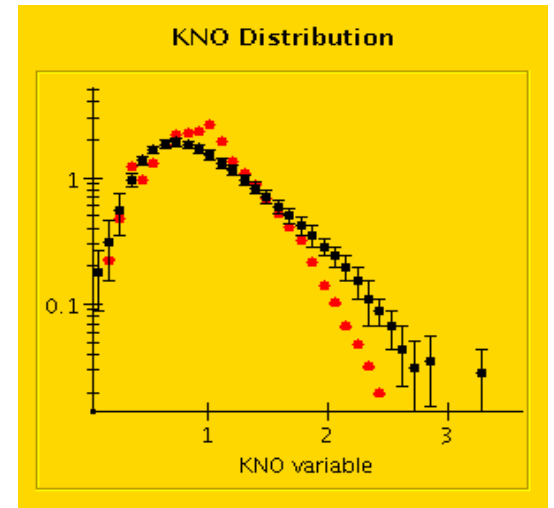
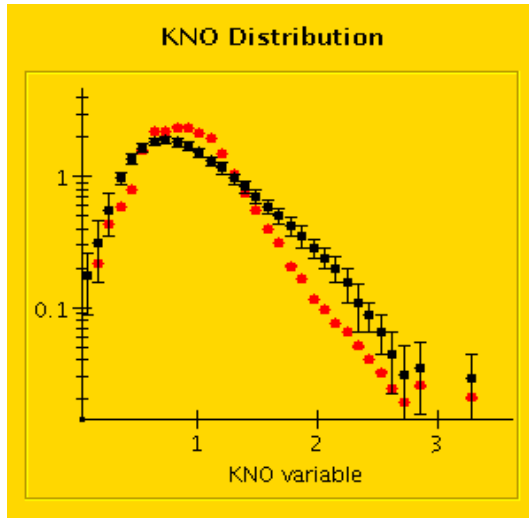
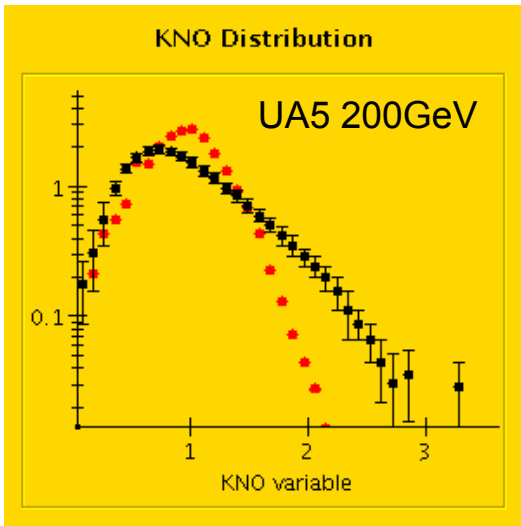
← Increasing sensitivity to Underlying event



Summary and conclusions

- PYTHIA(+PHOJET) can be ‘tuned’ to give a good description of minimum bias and underlying event data from 200GeV-1800GeV
main parameters are: p_T -min and the proton matter distribution
- PYTHIA overestimates particle multiplicities predicted by extrapolations of data, and predictions from PHOJET at LHC energies
- Underlying event activity at the LHC greater than at Tevatron by $\sim x3$ using tuned PYTHIA
- Compare to tunings using initial state radiation (suggested by R Field (CDF))
- Use Jetweb to compare to wider range of data: HERA, other Tevatron data

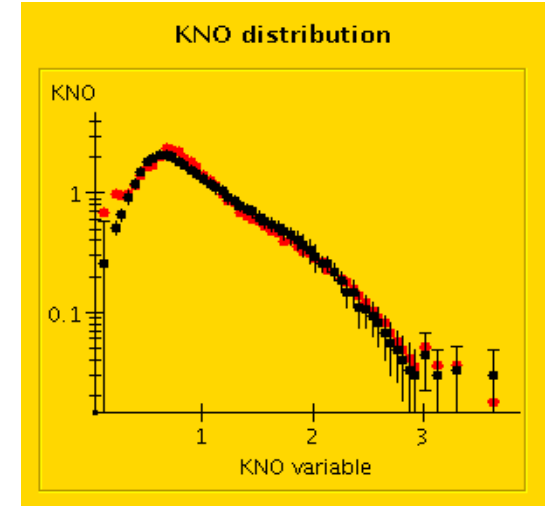
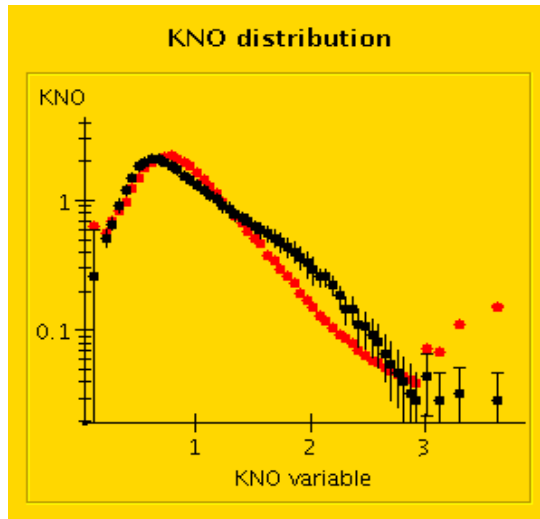
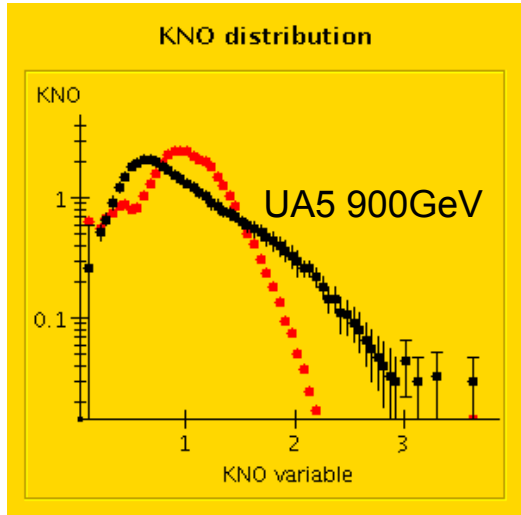




Default Pythia

Default DG

AM Tune



PHOJET

- Developed mainly for soft and semi-hard particle production.
- Implements ideas of **Dual Parton Model** for low- p_T processes.
- **Multiple Pomeron** exchanges (sea-quark multi-chains) enhances the event activity.
- Limited to production mechanisms of strong interactions.
- However, useful tool for **MB** and **UE** studies where jets are involved.

