Dijet angular distributions from pp collisions at $\sqrt{s} = 14$TeV

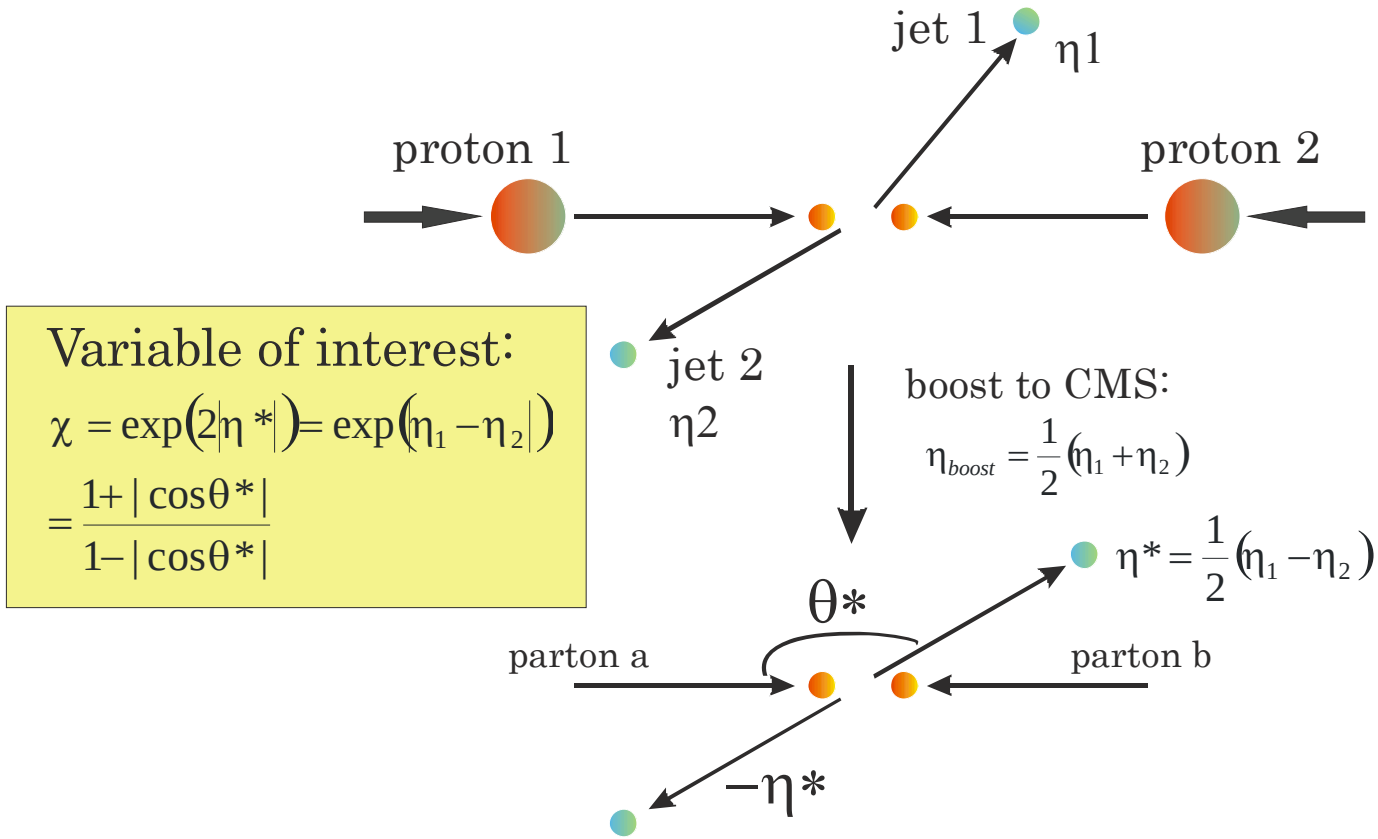
Nele Boelaert

Outlook

- Introduction: dijet angular distributions
- L0 + NLO QCD
- ATLAS MC study
- Summary and conclusions

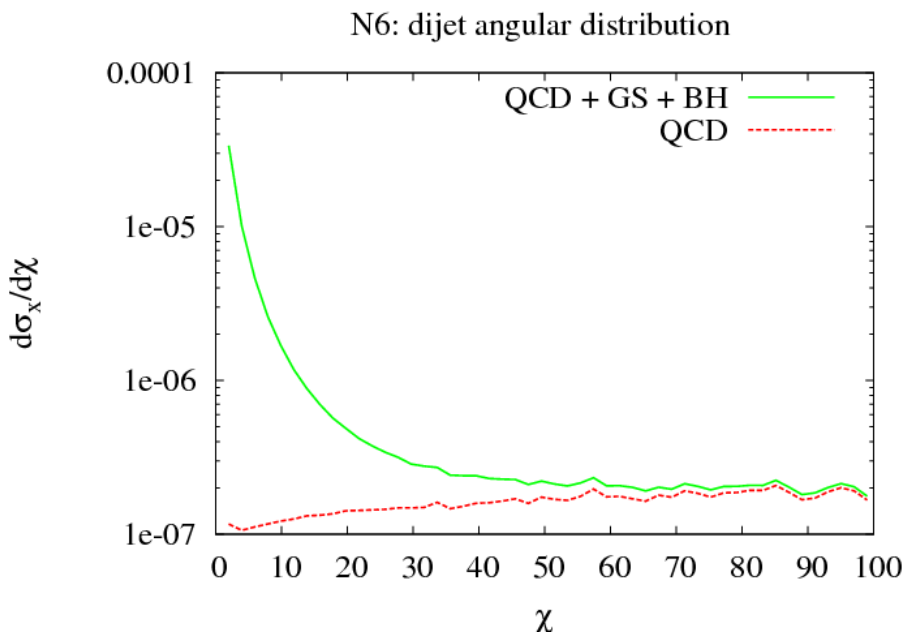
Dijet angular distributions

Dijet final state, in pp-collisions through qq, qg and gg interactions.



Dijet angular distributions: dσ/dχ vs χ

- Binned in dijet invariant mass (Mjj), one can show that dσ/dχ vs χ is approximately flat for QCD
  → dσ/dχ test of QCD + sensitivity probe for new physics
- Strategy with ATLAS data:
  - Low integrated luminosity: study QCD
  - Later on: effects beyond the Standard Model (eg. gravitational scattering in large extra dimensions)



Selection cuts for dσ/dχ

- Atlas calorimeters: η–coverage up to 4.9
- Make sure full jet is fully seen by detector, i.e. for cone 0.7 jets only η-coverage up to η_{max} = 4.2

$$\begin{cases} \eta_{boost} = (\eta_1 + \eta_2)/2 \\ \eta^* = (\eta_1 - \eta_2)/2 \end{cases} \longrightarrow \begin{cases} -\eta_{\max} < \eta_1 = \eta^* + \eta_{boost} < \eta_{\max} \\ -\eta_{\max} < \eta_2 = -\eta^* + \eta_{boost} < \eta_{\max} \end{cases} \longrightarrow \begin{cases} 2\,|\,\eta_{boost}\,| < 2\eta_{\max} \\ 2\,|\,\eta^*\,| < 2\eta_{\max} - 2\,|\,\eta_{boost}\,| \end{cases} \xrightarrow{\exists c \in [0, \eta_{\max}]} \begin{cases} 2\,|\,\eta_{boost}\,| < c \\ 2\,|\,\eta^*\,| < 2\eta_{\max} - c \end{cases}$$

- $\chi = \exp(|\,2\eta^*\,|) = \exp(|\eta_1 - \eta_2|)$
- Suppose you want to measure dσ/dχ up to χ_{max} or equivalently $|\,2\eta^*\,|$ $(= \log(\chi))$ up to $X \equiv 2\eta_{\max} - c$ ➔ Can be done without loss in acceptance by requiring: $2\,|\,\eta_{boost}\,| < c$ $\exists c$

> Require: $2|\eta_{boost}| = |\eta_1 + \eta_2| < c$,
> $2|\eta^*| = |\eta_1 - \eta_2| < 2\eta_{max} - c$
> and measure χ up to $\exp(2\eta_{max} - c)$

ATLAS: c = 1.5, η_{max} = 4.2
➔ $|\Delta\eta| < 6.5$ or $\chi < 600$

Selection cuts

- Require: $|\eta_1+\eta_2|<c$, $|\eta_1-\eta_2| < 2\eta_{max} - c$ ($\chi<\chi_{max}$) and Mjj in bin [Mjj_{min}, Mjj_{max}]

Minimum pT of both jets for which the dijet passes the selection cuts?

- For 2 partons in final state (LO, NLO virtual) : $Mjj = p_T(\sqrt{\chi} + \frac{1}{\sqrt{\chi}})$

  → for events in bin [Mjj_{min}, Mjj_{max}] and $\chi<\chi_{max}$:

$$p_T \geq Mjj_{\min} /(\sqrt{\chi_{\max}} + \frac{1}{\sqrt{\chi_{\max}}}) = p_{T\min 2}$$

- For 3 partons in final state (NLO real), it can be shown that for events with Mjj in [Mjj_{min}, Mjj_{max}] and $\chi<\chi_{max}$:

$$p_T \geq Mjj_{\min} / 2 / \sqrt{1+0.5\chi_{\max} + 0.5/\chi_{\max}} = p_{T\min 3}$$

minimum pT:

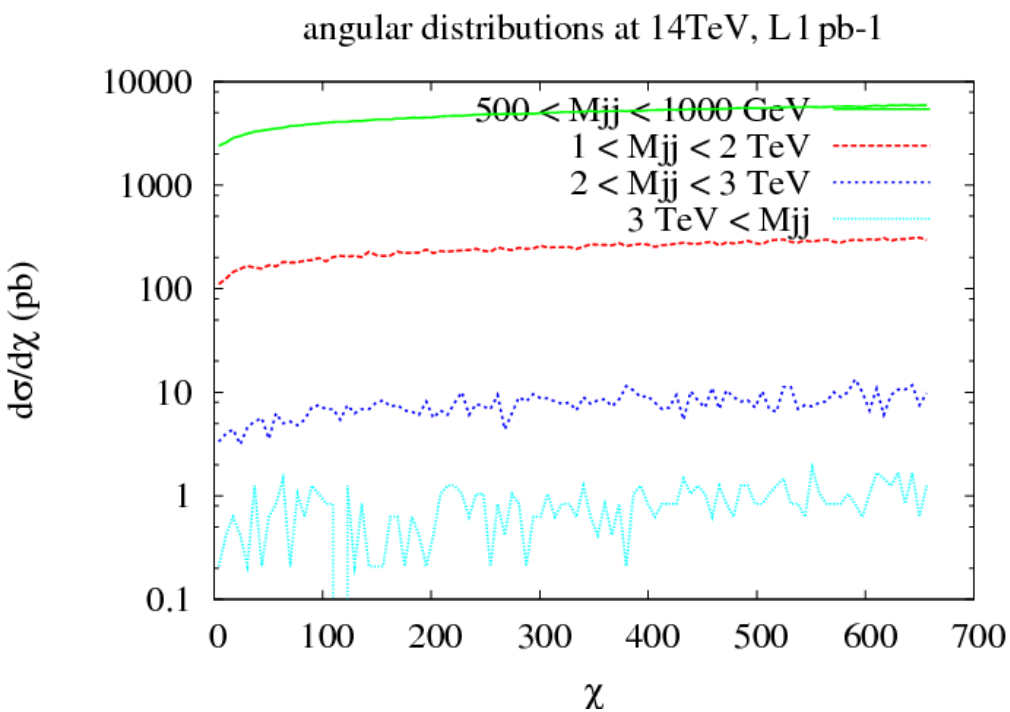
$$p_{T\min} = p_{T\min 3} \leq p_{T\min 2}$$

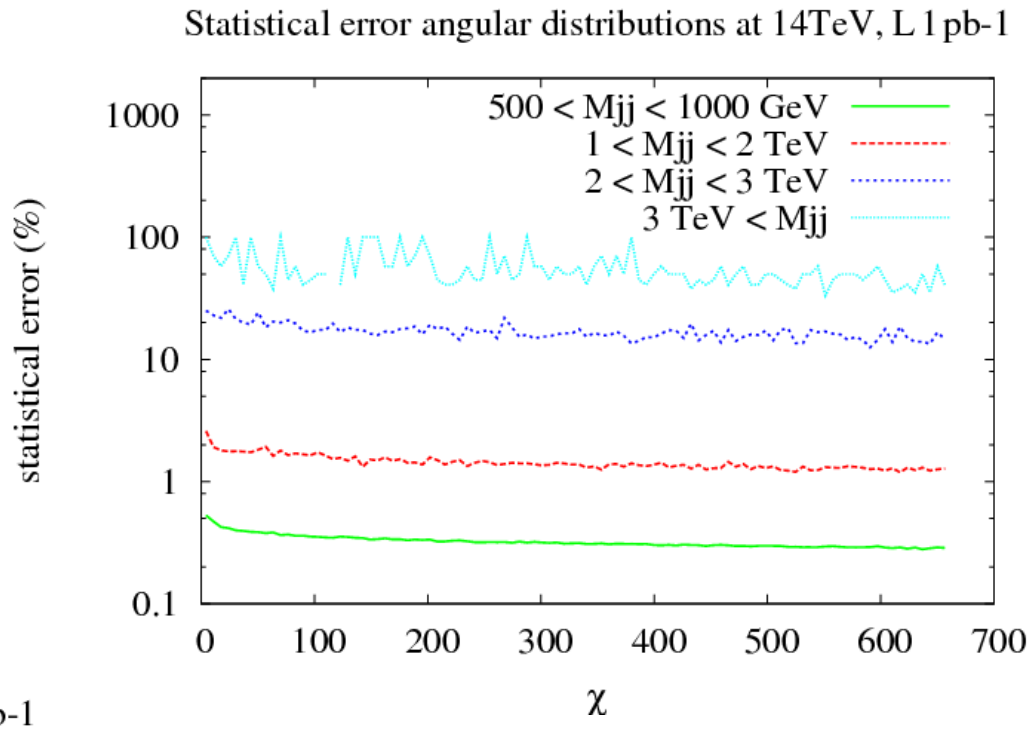
Trigger selection

$\|\eta_1+\eta_2\|<1.5$ Mjj-bin	χ_{max} =100 p_{Tmin}	χ_{max} =600 p_{Tmin}
0.5-1 TeV	35 GeV	14 GeV
1-2 TeV	70 GeV	28 GeV
2-3 TeV	140 GeV	55 GeV
3-14TeV	210 GeV	84 GeV

LO QCD: dσ/dχ

- pythia 6.4, √s =14TeV
- 4 Mjj bins:
  0.5<Mjj<1TeV, 1<Mjj<2TeV,
  2<Mjj<3TeV & 3TeV<Mjj
- L ~ 1pb-1

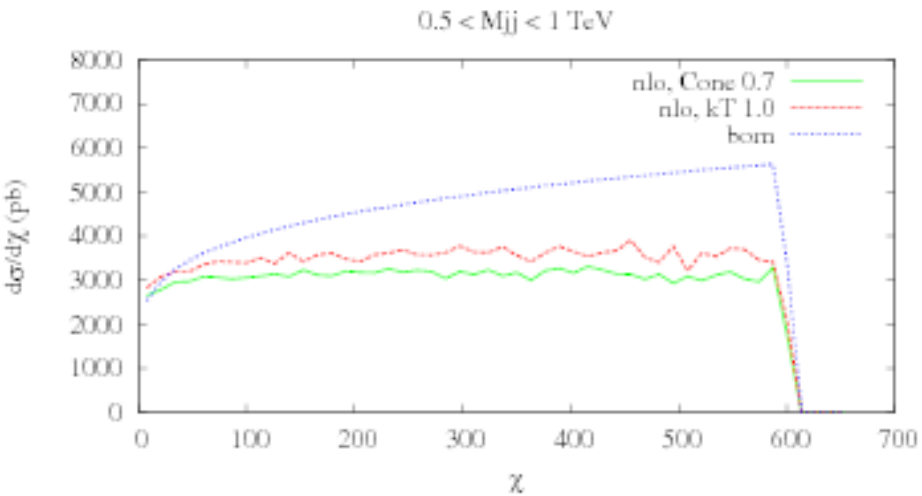


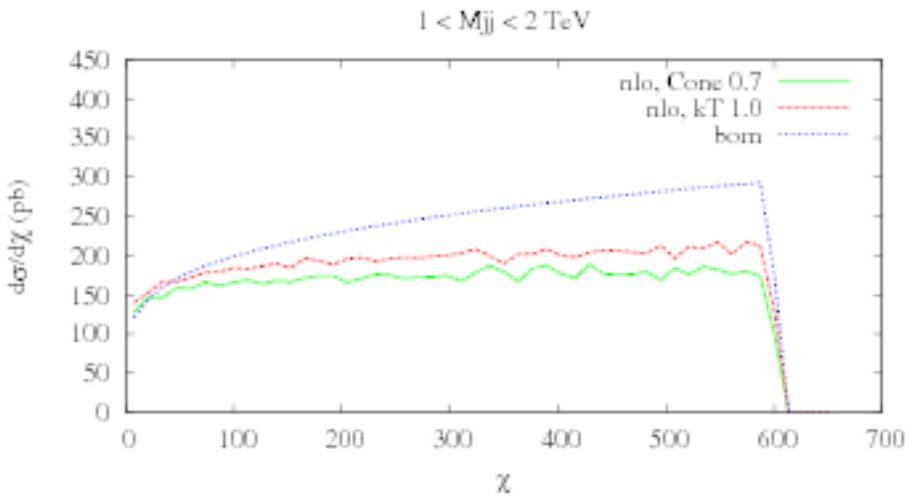


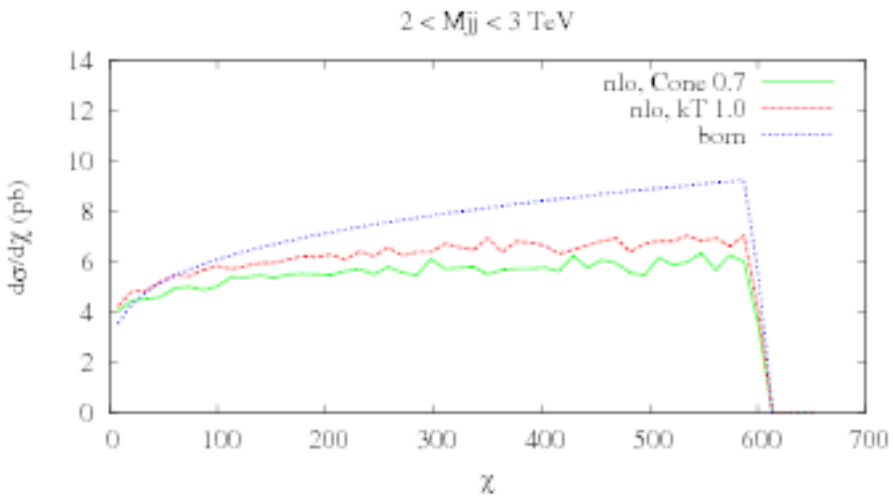
Already reasonable statistics with 1pb-1!

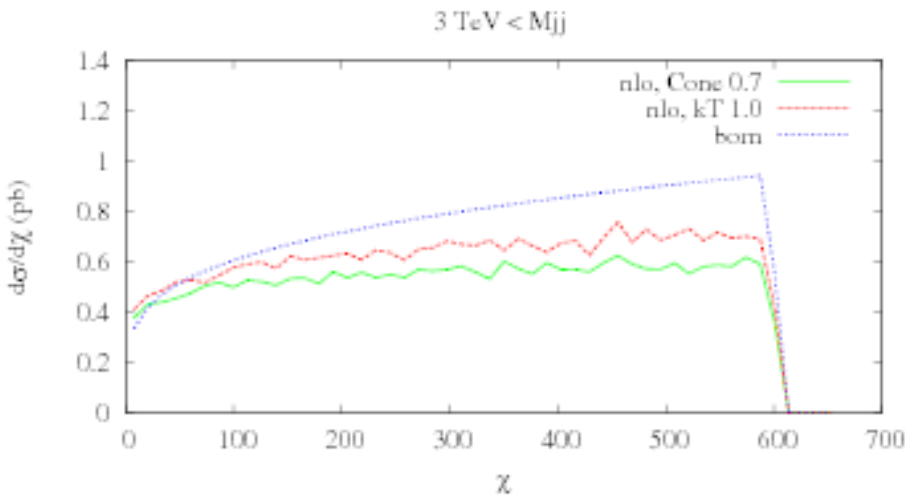
QCD up to NLO

- jetrad [HEP-PH 9302225] for NLO calculations at 14TeV
- no hadronization, clustering at the parton level: Cone 0.7 or kT 1.0



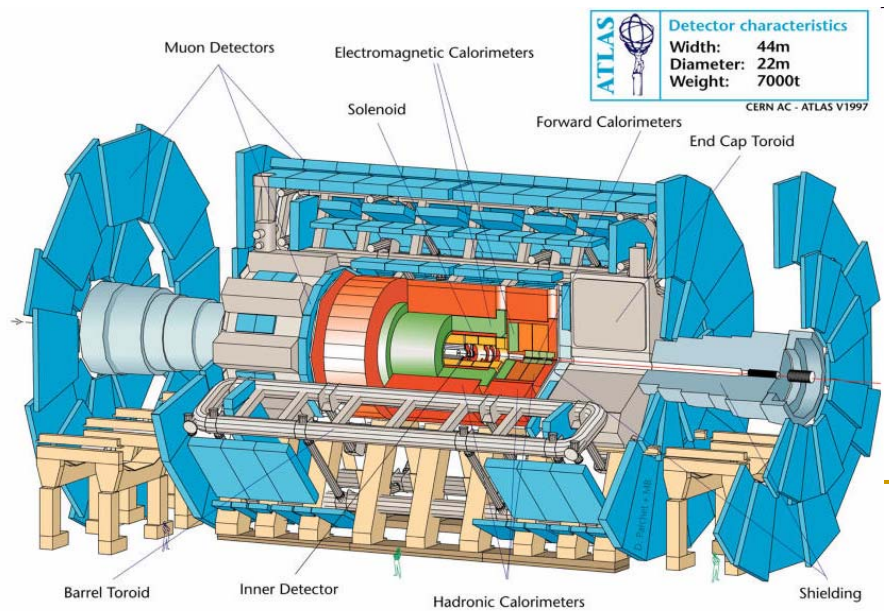


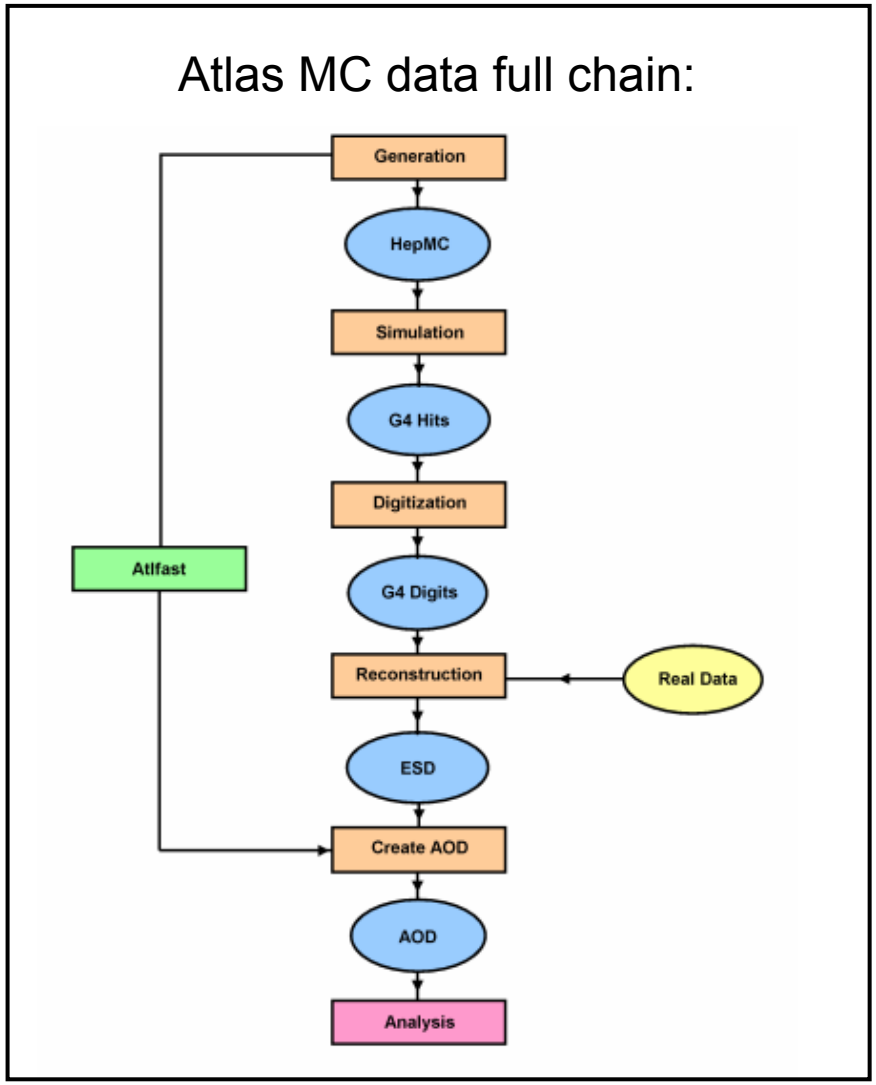




Measurement with ATLAS

- No real data yet!
- But we have ATLAS MC samples that include detector response (=**Full Chain MC**)
- We need Full Chain MC to study detector response and sensitivity, and estimate corrections in order to be able to compare measurement with theory





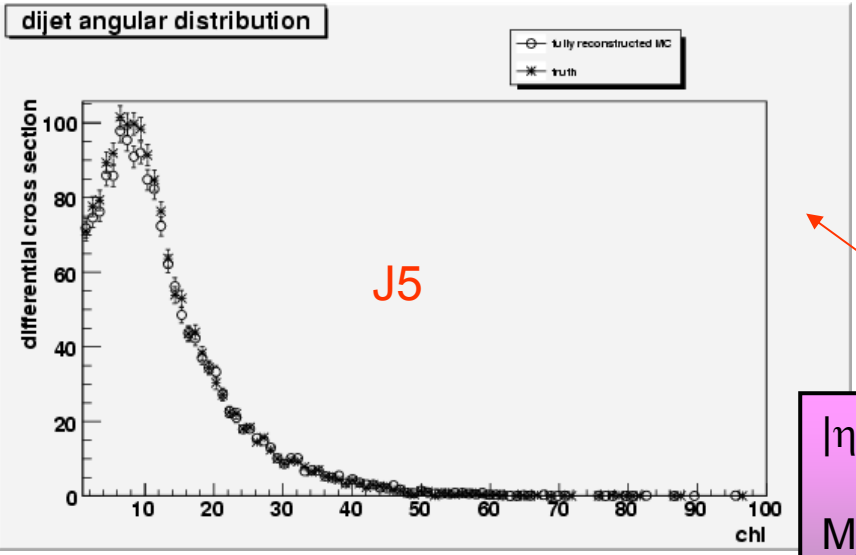
ATLAS Monte Carlo study

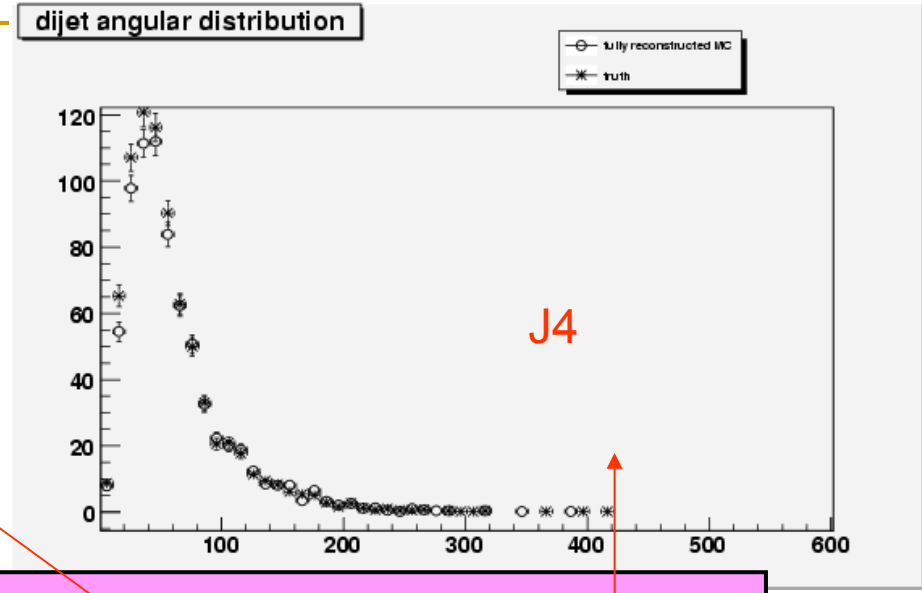
- ATLAS Jx samples, binned in partonic Pt:

Event sample	J2	J3	J4	J5	J6	J7	J8
Pt range (GeV)	35-70	70-140	140-280	280-560	560-1120	1120-2240	>2240
σ (mb)	9.3E-2	5.9E-3	3.14E-4	1.3E-5	3.6E-7	5.3E-9	2.22E-11

- QCD Only
- O(100k) events for each Jx
- Each reconstructed event has a corresponding truth event:
  truth: particles at generator level, no detector ⇔ **reco(nstructed)**: particles at from generator through detector simulation and reconstruction
- Cone 0.7 Jets
- Need to combine samples to get full Pt range, weight events with σ/N (N number of events in sample)

MC results: dσ/dχ vs χ



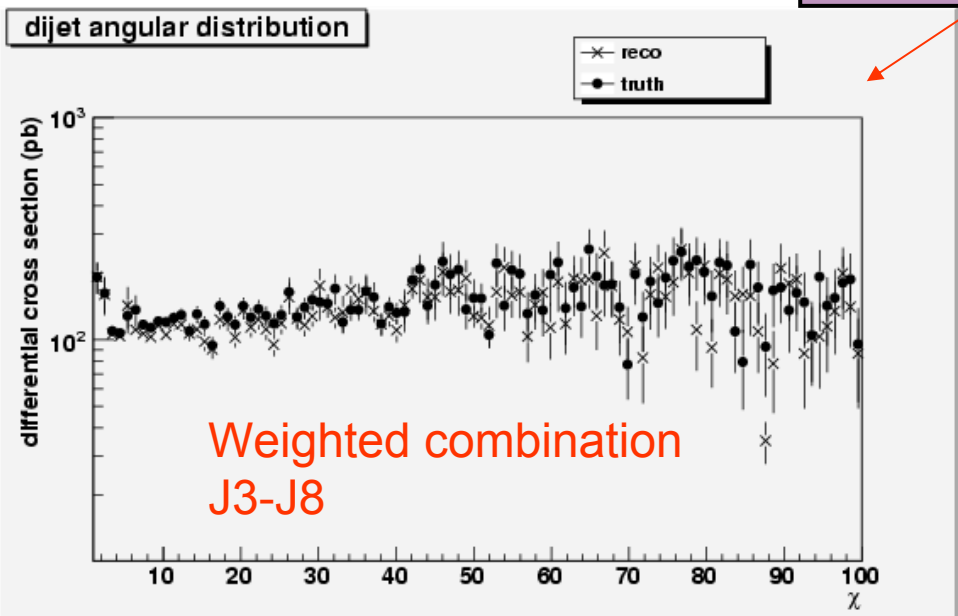


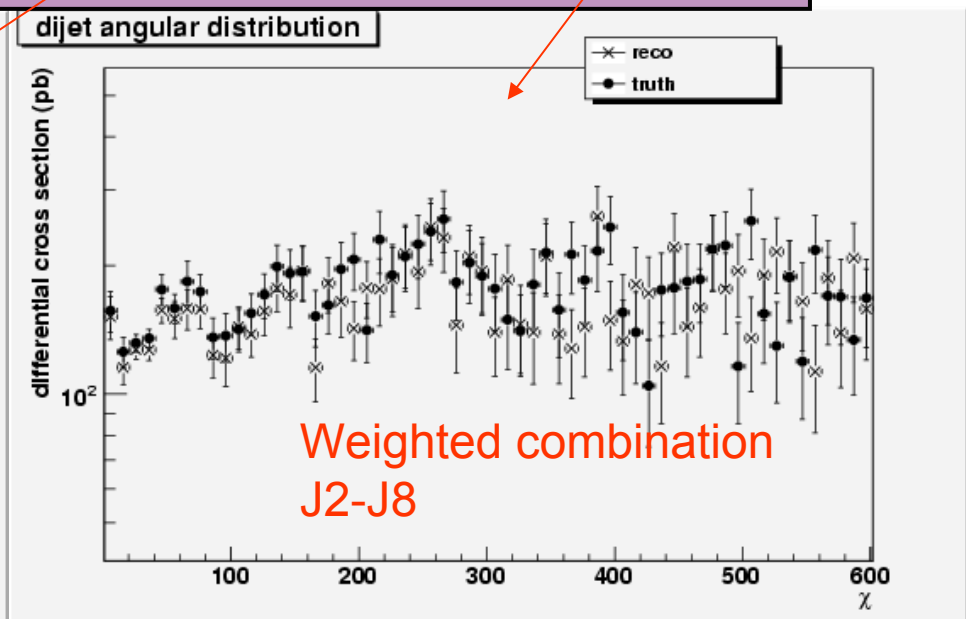
$|\eta_1+\eta_2|<1.5$

Mjj-bin
1-2 TeV

χ_{max} =100
p_{Tcut}
70 GeV

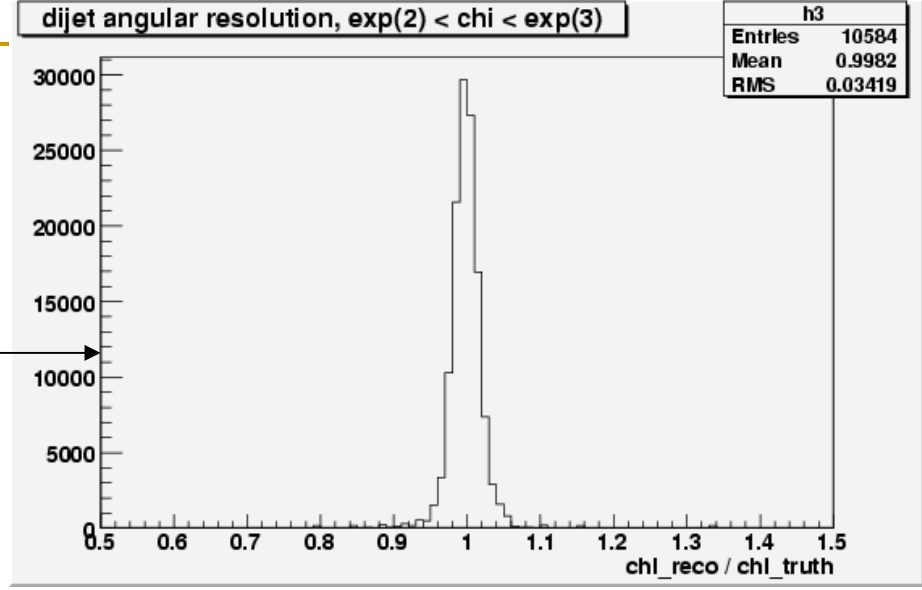
χ_{max} =600
p_{Tcut}
28 GeV

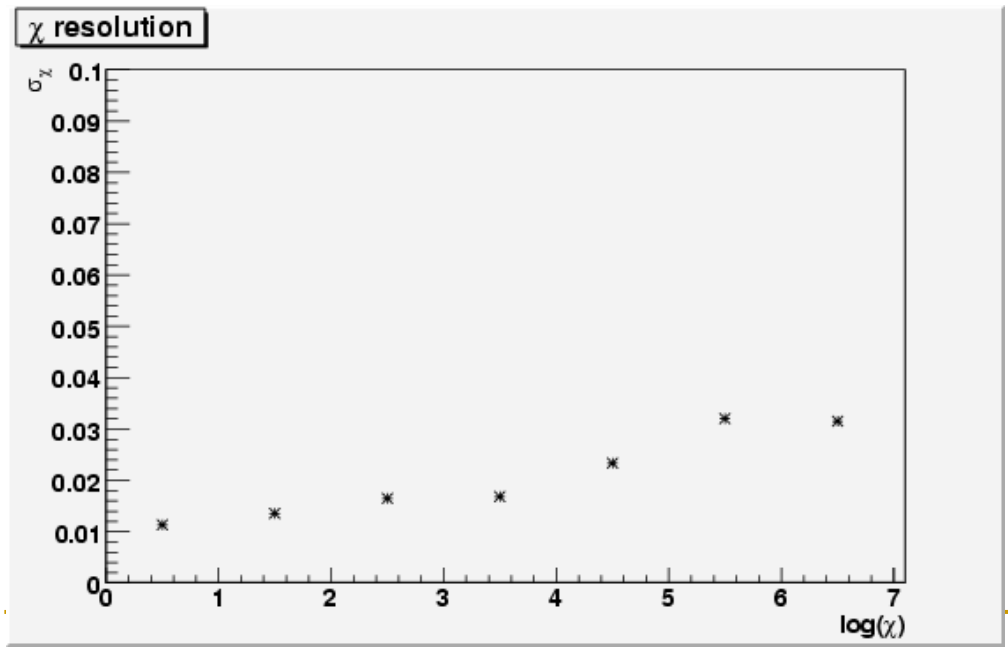




Resolution in χ

- Study bins in χ (eg. 1< χ <exp(1)) and Mjj: take ratio (χ reco) / (χ truth); should be Gaussian around 1. Perform Gaussian fit in each bin→ σ_χ is resolution in χ.





Good resolution in χ over whole χ-range!

Impact from experimental uncertainties

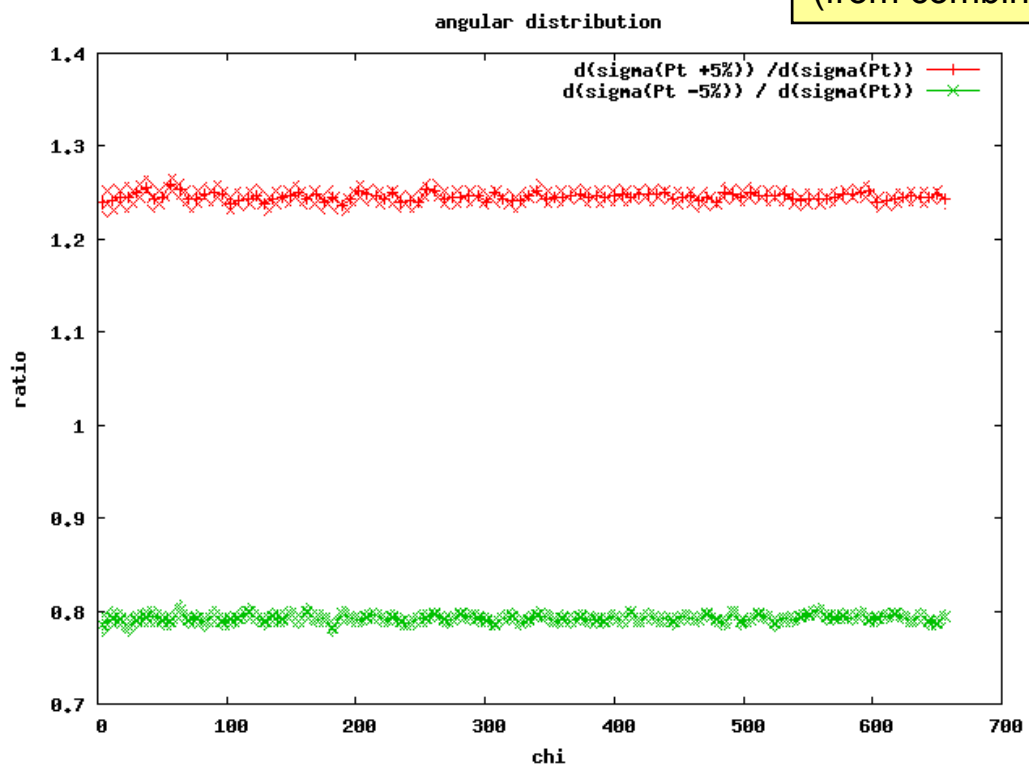
- Jet energy scale
- Jet energy resolution
- Resolution in η
- Resolution in ϕ

} Systematic error <4%

Impact of Jet Energy Scale (JES)

1. Generate events with pythia 6.4, no detector simulation
2. Calculate $d\sigma/d\chi$ vs χ for 1<Mjj<2 TeV
3. Increase jet pT with +5%: pT=pT+5%
4. Calculate $d\sigma_{increase}/d\chi$ for 1<Mjj<2 TeV
5. Take ratio of differential cross-sections: $(d\sigma_{increase}/d\chi) / (d\sigma/d\chi)$ (red curve)
6. Repeat steps 3.-4.-5. with pT-5% (green)

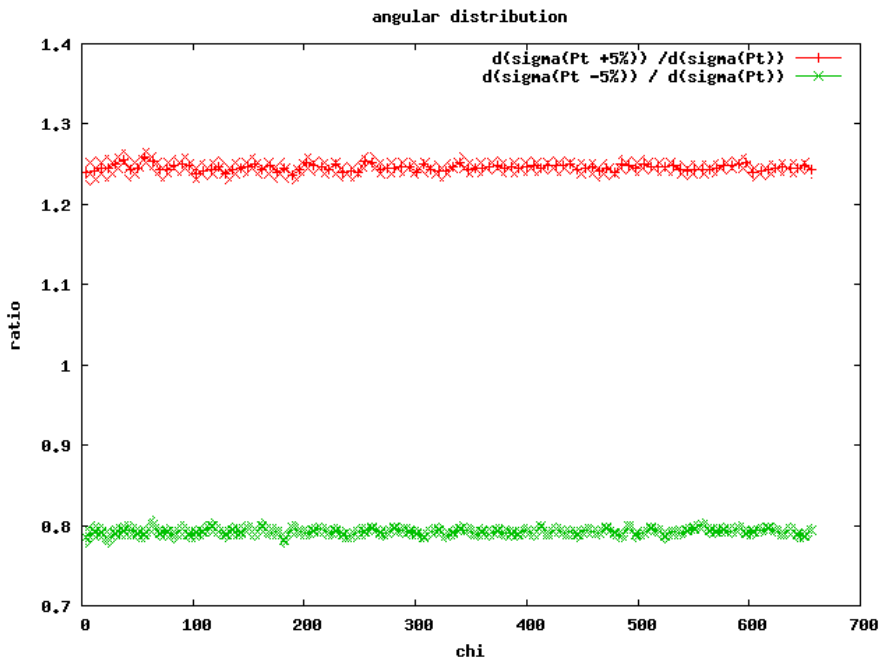
JES:
D0 [Phys. Rev. Lett. 80, 4, 666-671]: less than 4% and nearly independent of dijet invariant mass. (using photon + jet and dijet events)
ATLAS [Atlas Collaboration: Detector Level Jet Corrections, 2008]: expected around 5% (from combined test beam)



Impact Jet Energy Scale (JES)

- Effect due to binning in Mjj of $d\sigma/d\chi$
- Shape of distributions not effected by a global (η independent) error on JES

  → normalize distributions $d\sigma/d\chi/\sigma$ ($dN/d\chi/N$)
- Remaining η dependence of JES error needs to be investigated → systematic error on $d\sigma/d\chi/\sigma$



Summary and conclusions.

Dijet angular distributions:

- can be measured with ATLAS up to χ~600
- already good statistics with 1 pb-1
- QCD calculations up to NLO
- good experimental resolution in χ
- experimental uncertainties dominated by uncertainties in JES, normalize (= $d\sigma/d\chi/\sigma$) to get rid of global JES uncertainty, but a residual η-dependent error on JES still affects distributions