# W/Z+jets MC and constraints from data

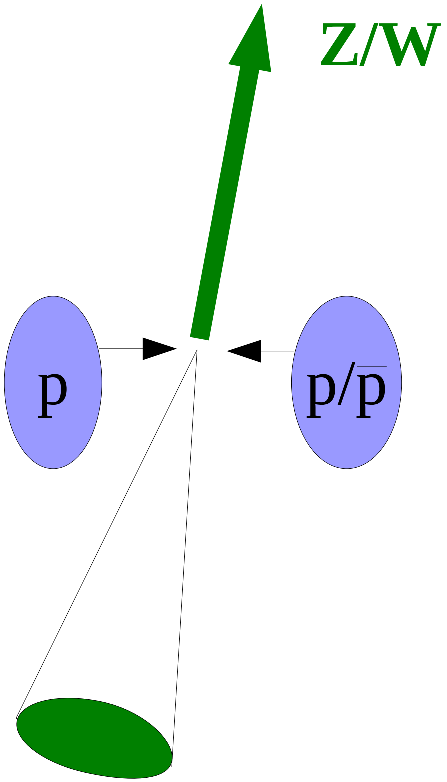
Samuel Calvet

December 4th 2008

# The issue

**Hard scattering**

+ ISR, FSR

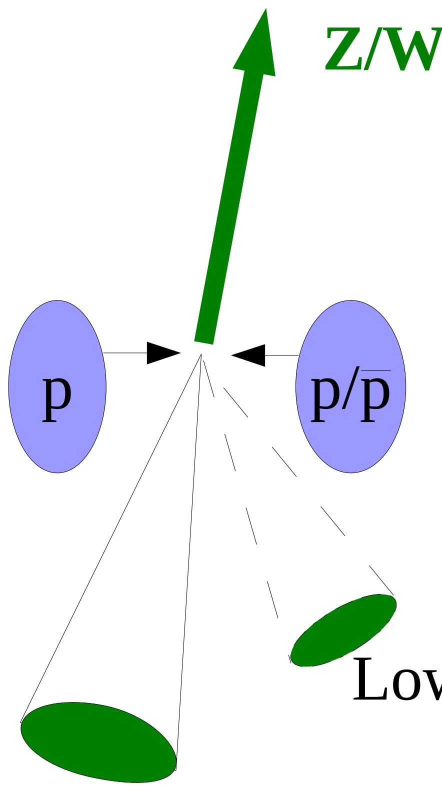



Jet, pT>15/20 GeV

# The issue

**Hard scattering**

+ ISR, FSR




Low pT jet → not reconstructed

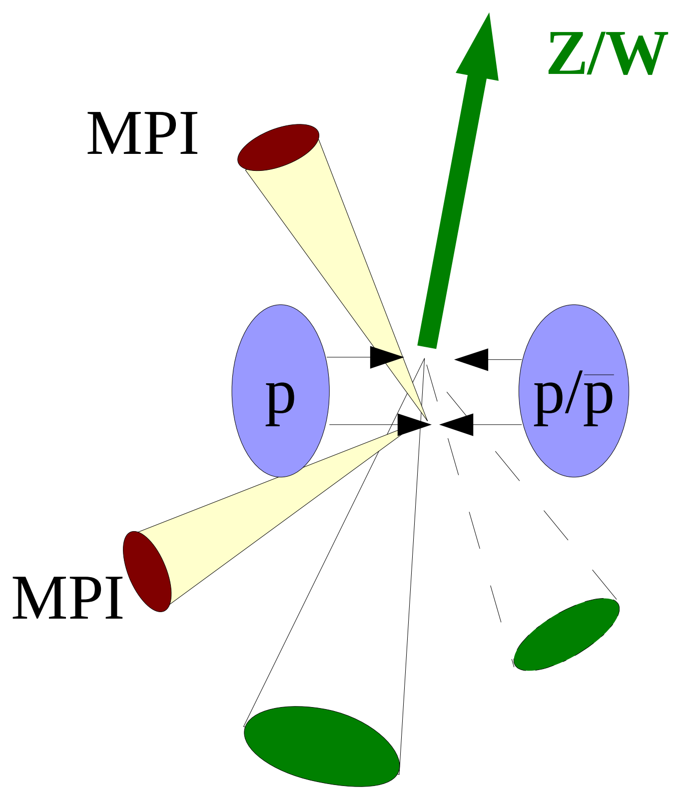
Jet, pT>15/20 GeV

# The issue

**Hard scattering** + **Pile up**

Multiple Parton Interaction,...
Minimum biais

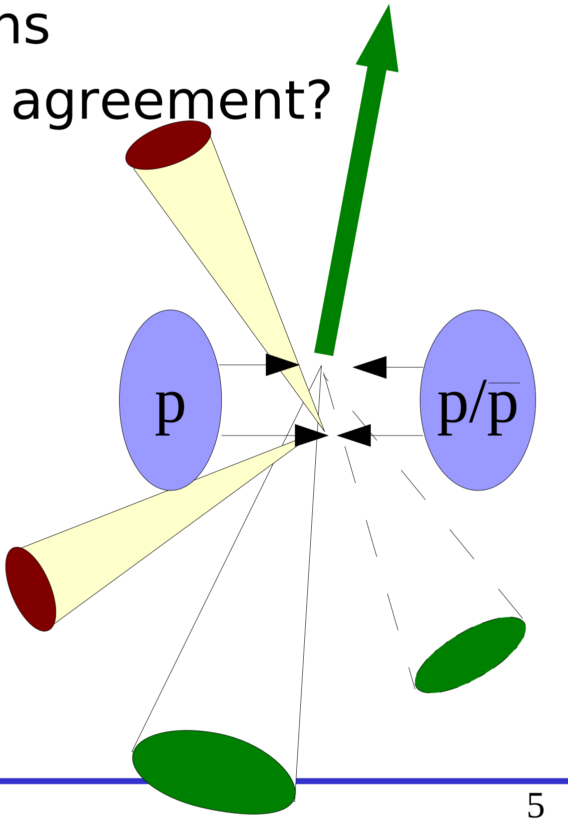
+ ISR, FSR



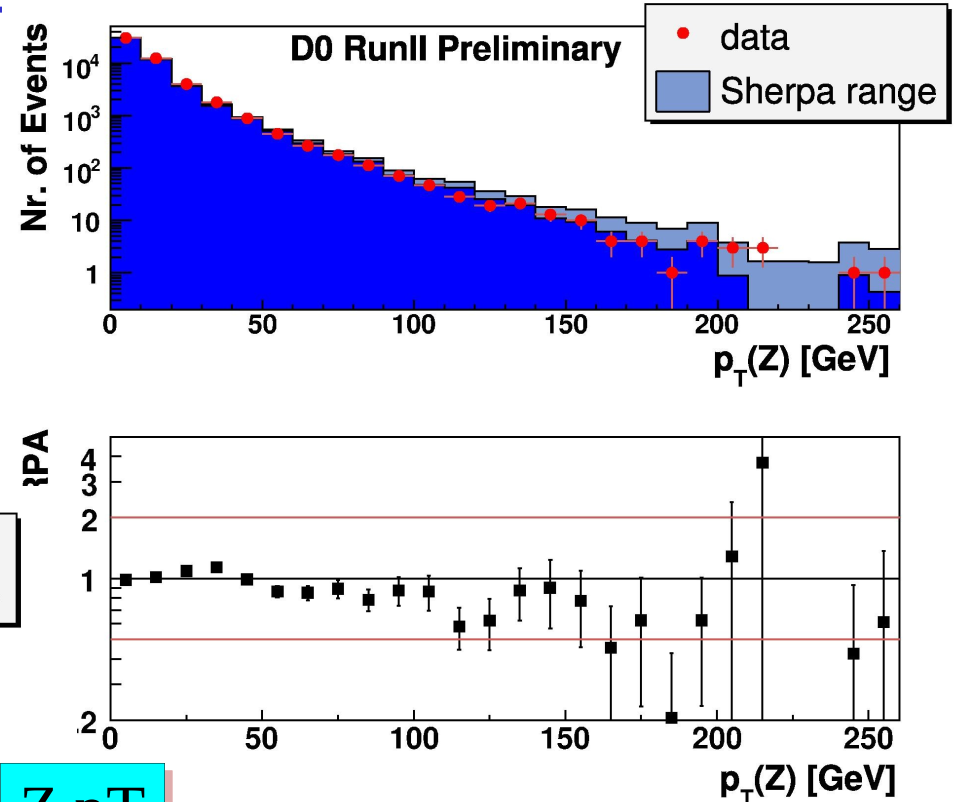
# Outline

- Experiments can use LO or ~LL (ME+PS) MC to simulate these main signals/backgrounds
  - NLO not yet available for large jet multiplicity

- Today :
  - State of the art : some data/MC comparisons
  - How can we try to improve our data vs MC agreement?
  - A precise measurement
    - Future MC would benefit from that

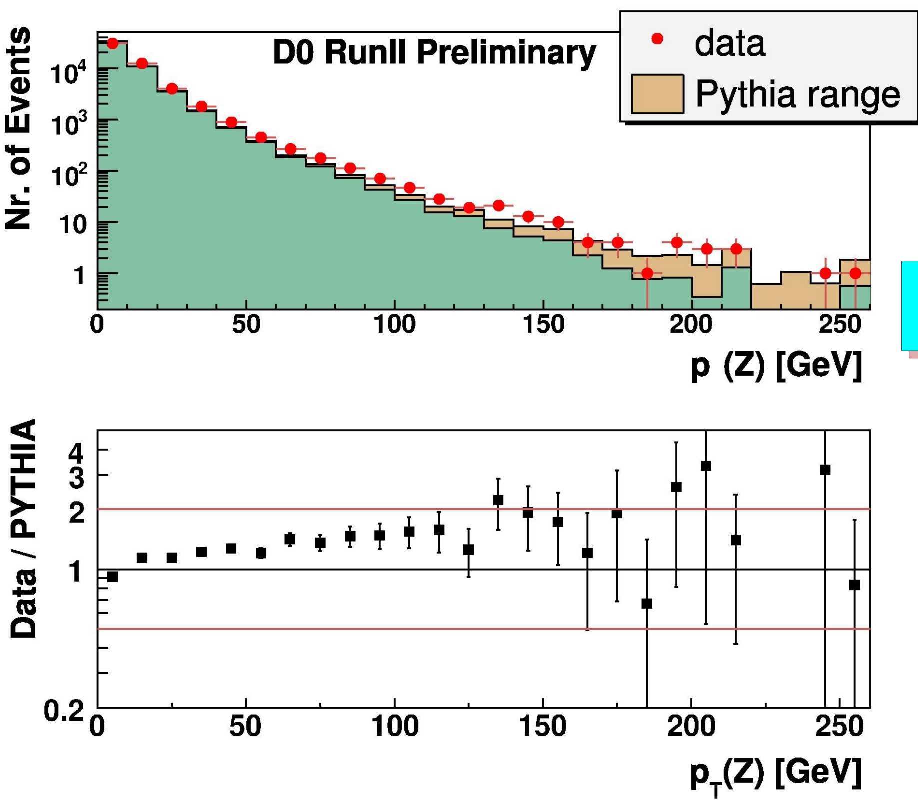


# Z→ee pT, detector level




**PYTHIA too soft**
**(As expected)**

## PYTHIA v6.314 tune A




Z pT

## SHERPA v1.0.6

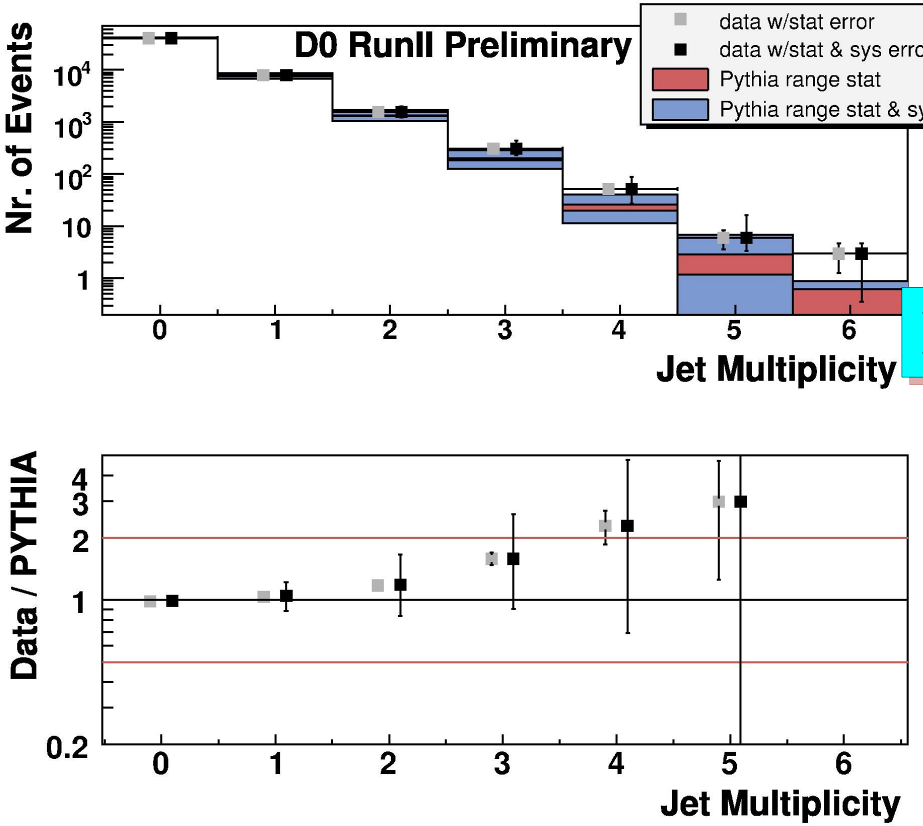
**SHERPA**
**a bit too hard at high pT**

MC normalized to data

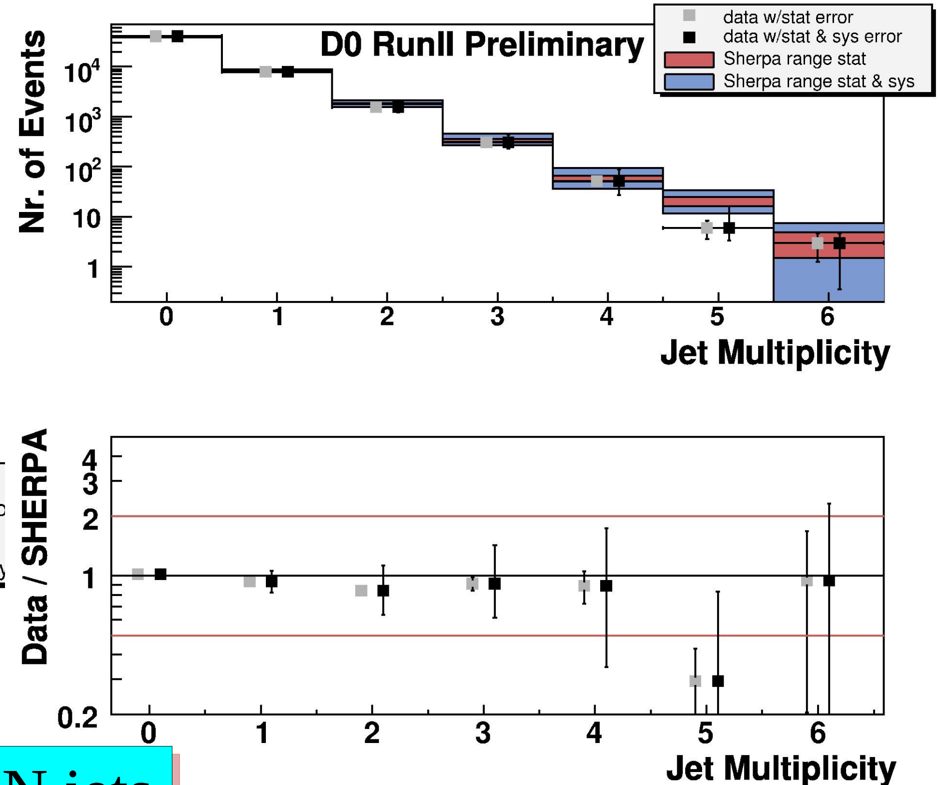
# Z→ee, jet pT>15GeV, detector level

**PYTHIA too soft**
**(As expected)**

## PYTHIA v6.314 tune A




N jets




## SHERPA v1.0.6

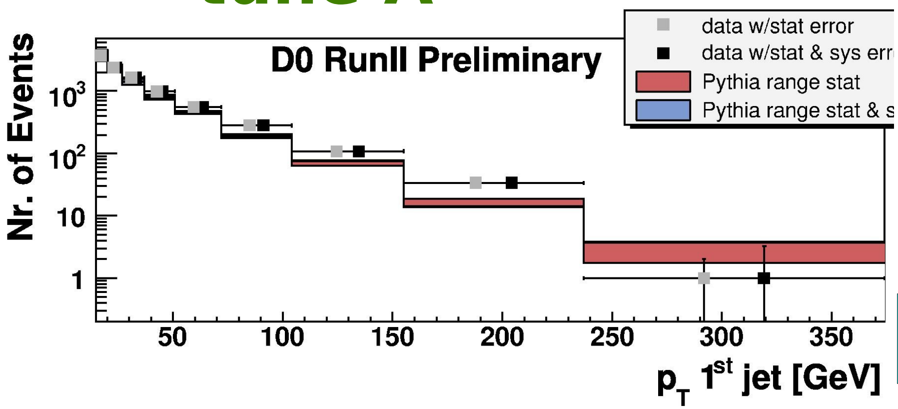
**SHERPA**
**a bit too hard**

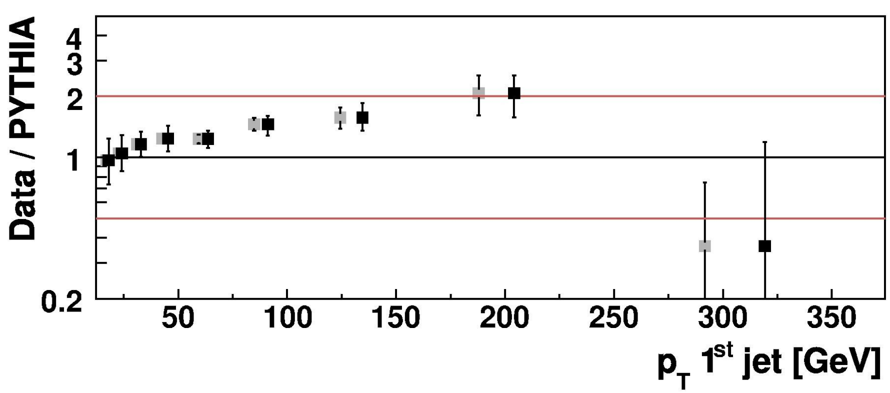
MC normalized to data

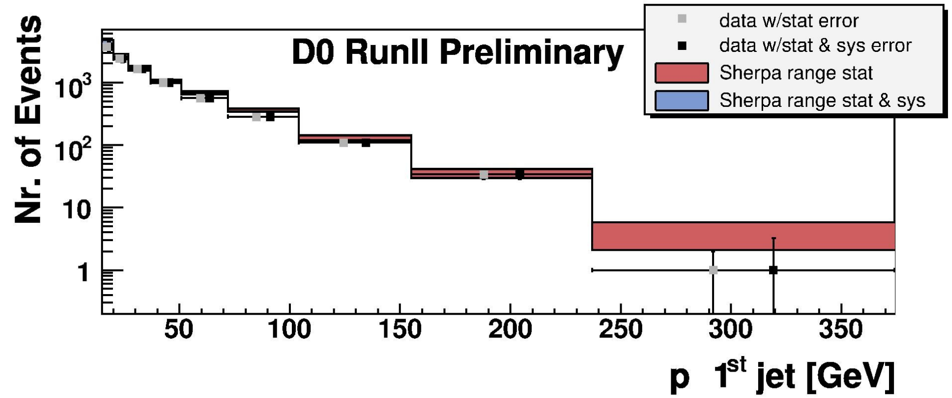
# Z→ee, jet pT>15GeV, detector level

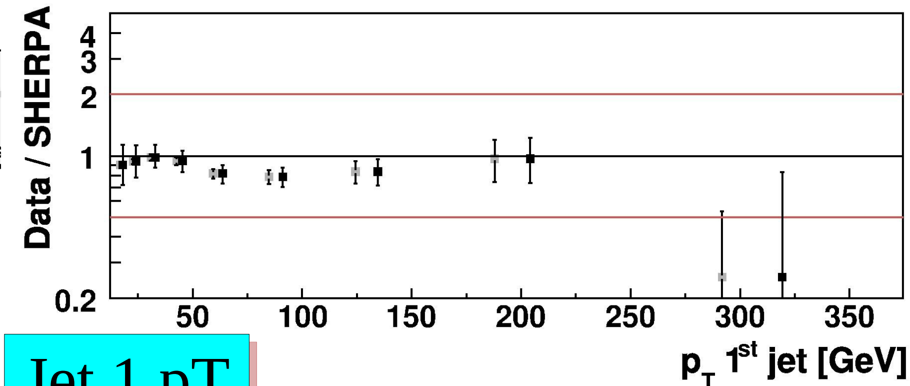
**PYTHIA too soft**
**(As expected)**

## PYTHIA v6.314 tune A



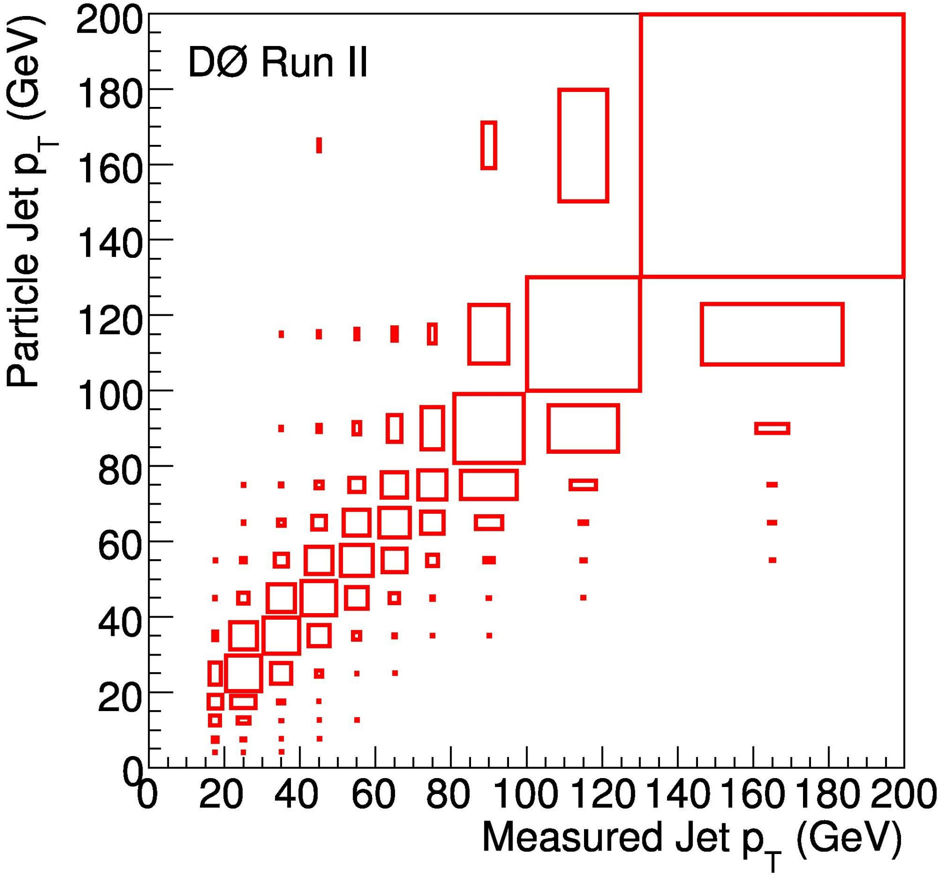

Jet 1 pT

## SHERPA v1.0.6

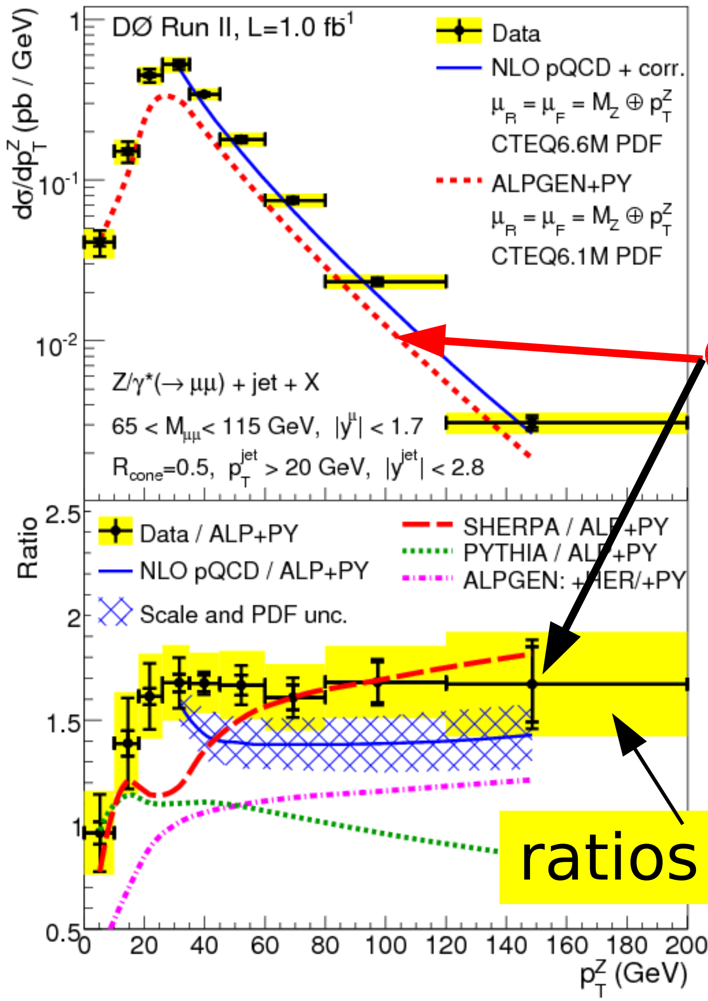
**~ok**
**1.3 more jets @80GeV**

- The distributions on the previous slides were at the detector level.

- One can unfold the data in order to come back to the particle level :
  - Use a migration matrix to bring back the jets to particle level, cone size 0.5 →
  - Leptons after QED FSR



# Z→$\mu\mu$, ≥1jet, jet pT>20GeV, unfolded




Z pT

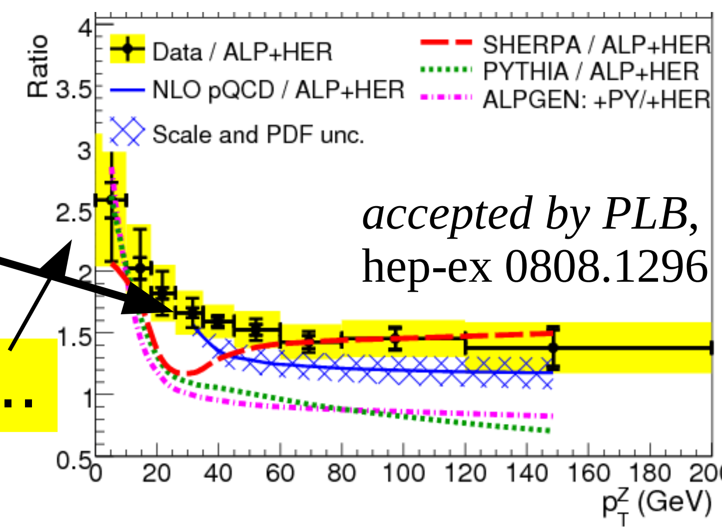
**PYTHIA v6.418**
**ALPGEN v2.13 +PYTHIA v6.323**
**ALPGEN v2.13 +HERWIG v6.510**
**SHERPA v1.1.1**

alpgen+pythia

*PLB 669 278 (2008)*, hep-ex 0808.1296

alpgen+herwig

*accepted by PLB*, hep-ex 0808.1296




ratios data/alpgen+...

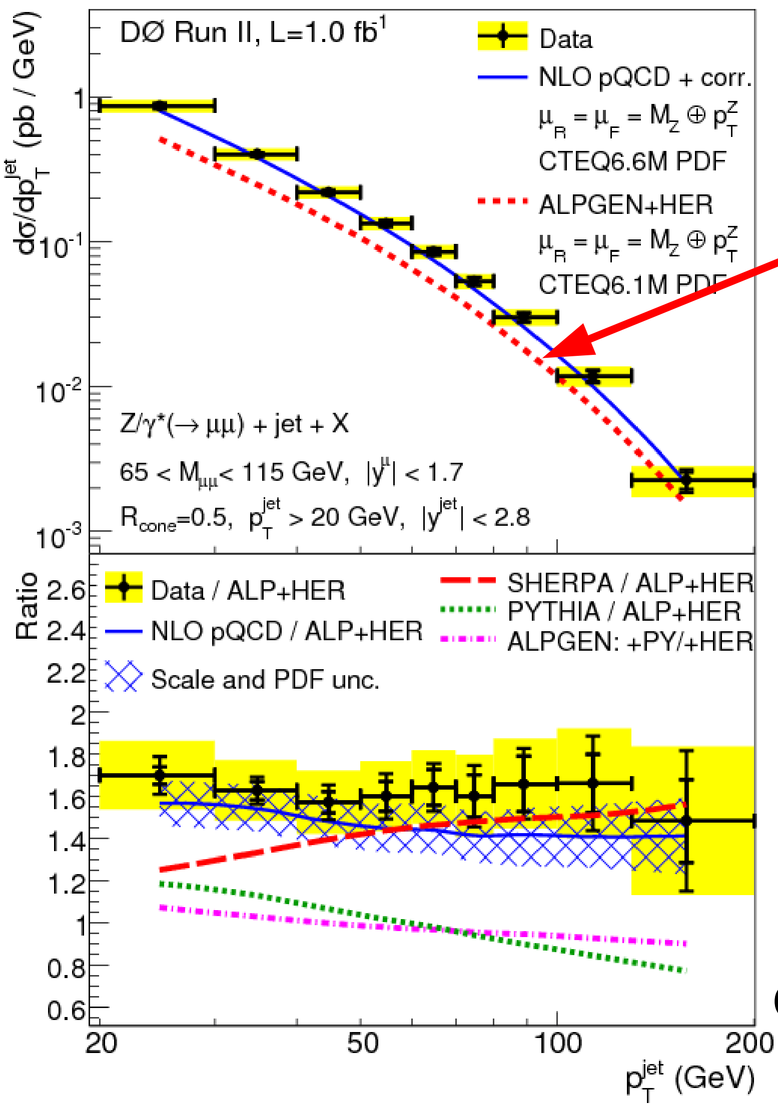
- At low pT, data are in between alpgen+pythia and alpgen+herwig
- Above 40 GeV the ratio is flat

→ equivalent to a scale factor ~1.7/1.5

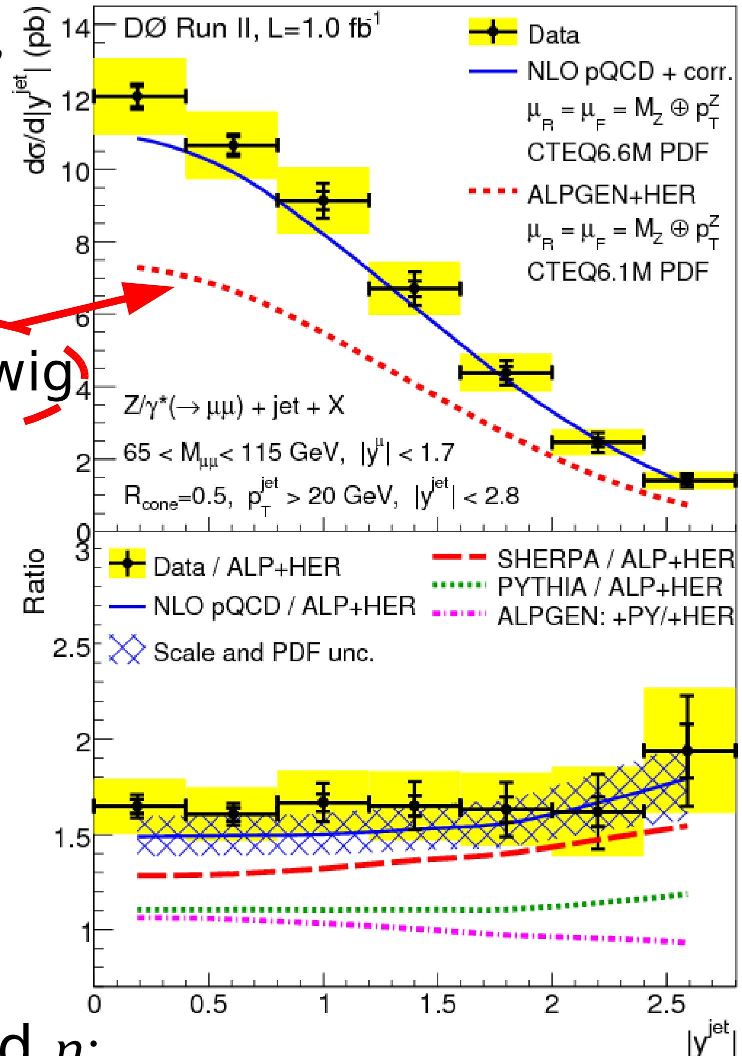
# DataZ→$\mu\mu$, ≥1jet, jet pT>20GeV, unfolded

*PLB 669 278 (2008)*,
hep-ex 0808.1296

jet 1 pT




alpgen+herwig




jet 1 pT and $\eta$:
Alpgen+herwig in fairly good agreement with data

jet 1 $|\eta|$

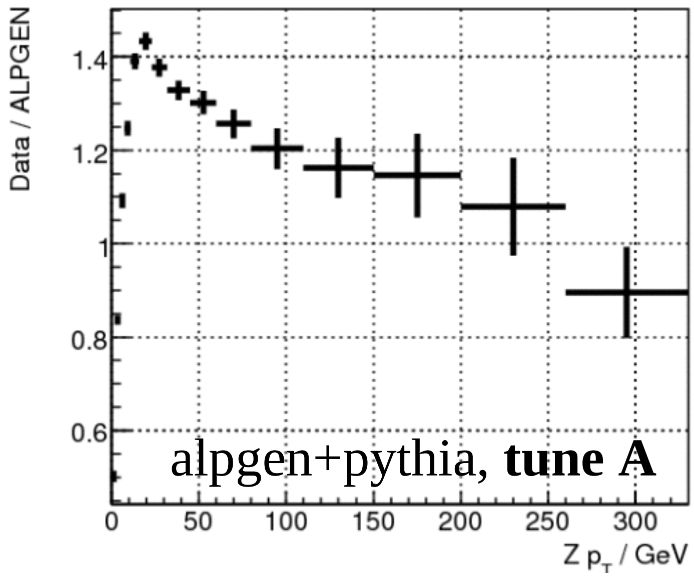
# Various MC tunes...

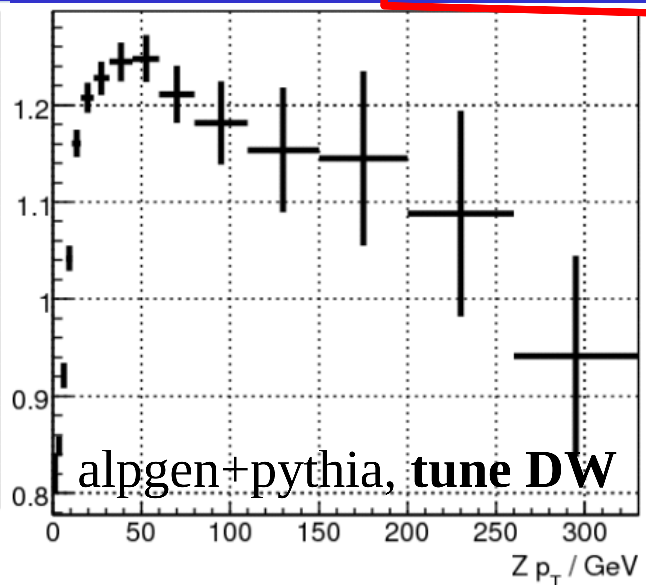
- The underlying event (UE) is really not negligible for the generators ME+PS

- An other test: varying the tune of pythia in alpgen+pythia
  - Tune A: based on underlying event studies at CDF
    - Developed using CTEQ5L: LO PDF & LO $\alpha_s$
  - Tune DW: same as A + the intrinsic kT adjusted to describe CDF RunI Z pT + small tune to describe D0 RunII di-jet $\Delta\varphi$
    - CTEQ5L
  - Tune QW: same as DW
    - CTEQ6M: NLO PDF, NLO $\alpha_s$

# Various MC tunes...

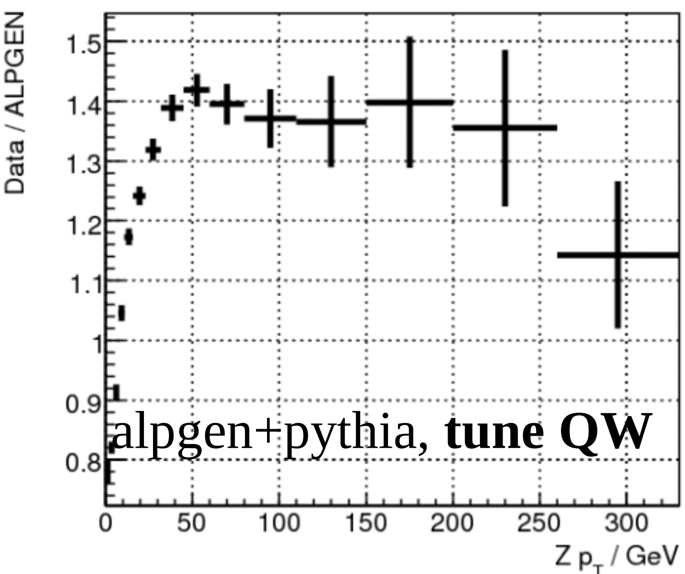
DØ WORK IN PROGRESS




Tunes A and DW: LO
Tune QW: NLO

Z pT : ratio “unfolded data (Z → mumu) / MC”




Z pT (but other kinematic variables too) is very dependent on tunes of UE, ISR, FSR, ...

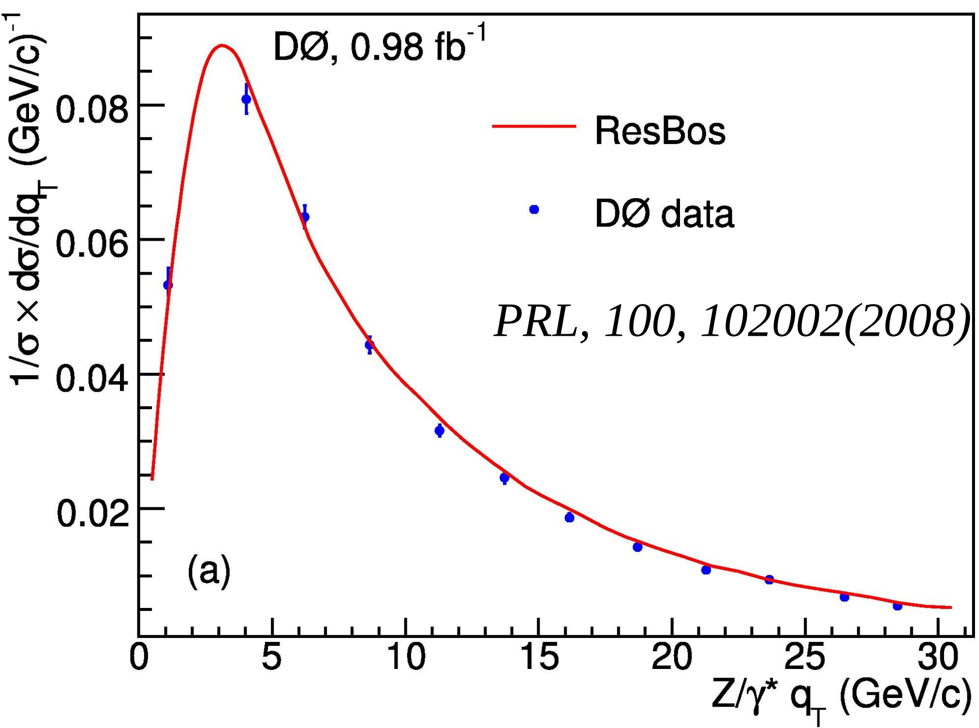
Large Z pT appears better described using NLO PDF (I am not saying it is correct)

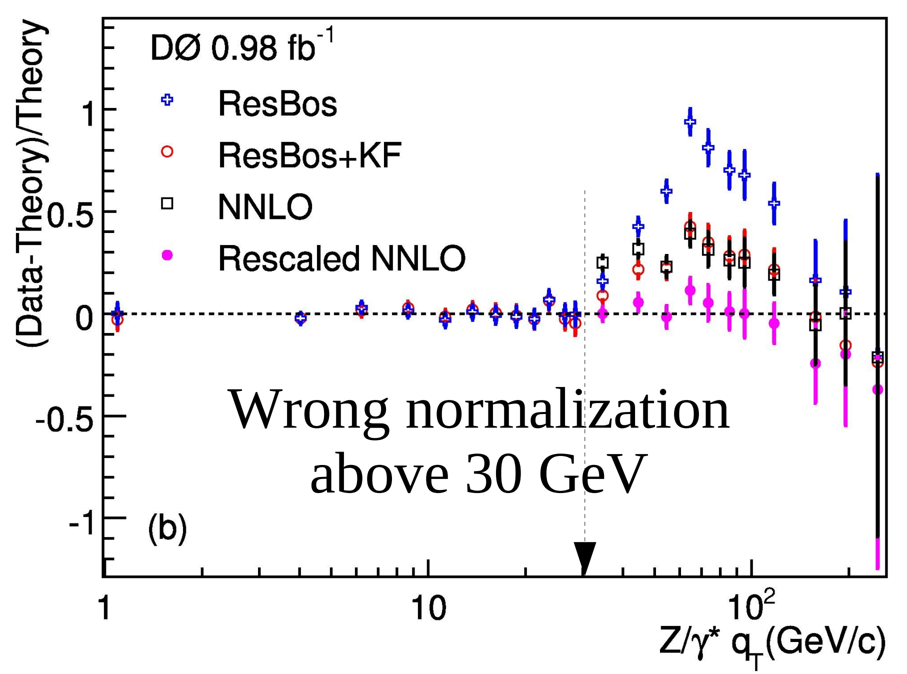
# How do we improve our MC ?

# How do we improve our MC ?

- Sherpa, Alpgen+... are "improved LO" (almost LL) MC
- It is not surprising they can not describe perfectly the data

- Fix : include NLL information into our LO MC
  - ResBos gives a resummed differential cross-section of the Z boson in agreement to the data, in the low Z pT region



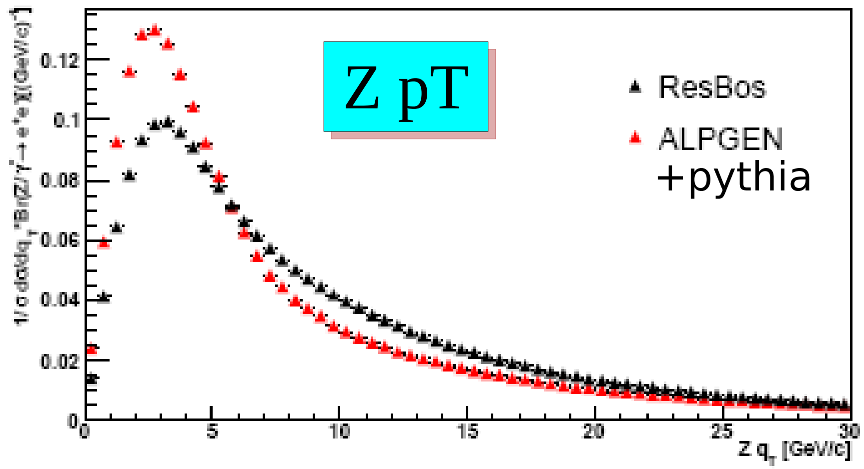



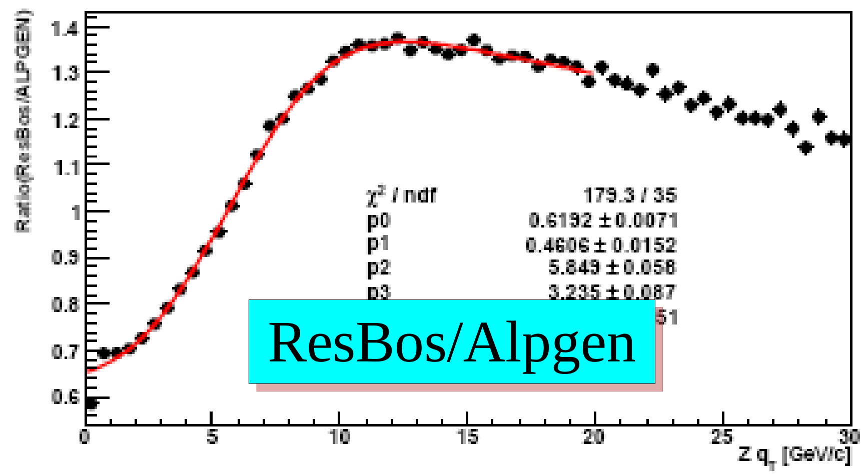
# How do we improve our MC ? (here, alpgen+pythia)

- One can reweight alpgen events according to ResBos Z pT, in the low pT region

- Use the unfolded data to describe the pT above 30 GeV

DØ WORK IN PROGRESS

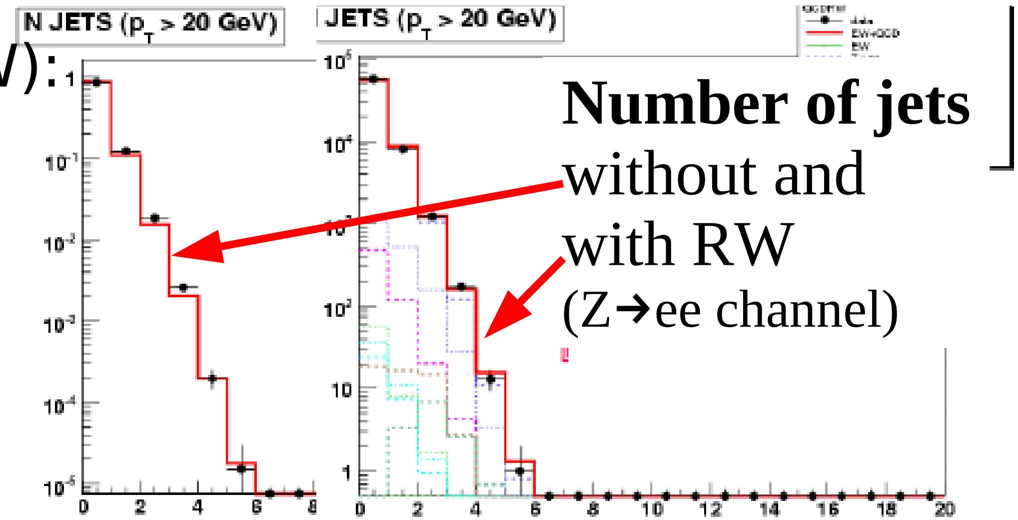


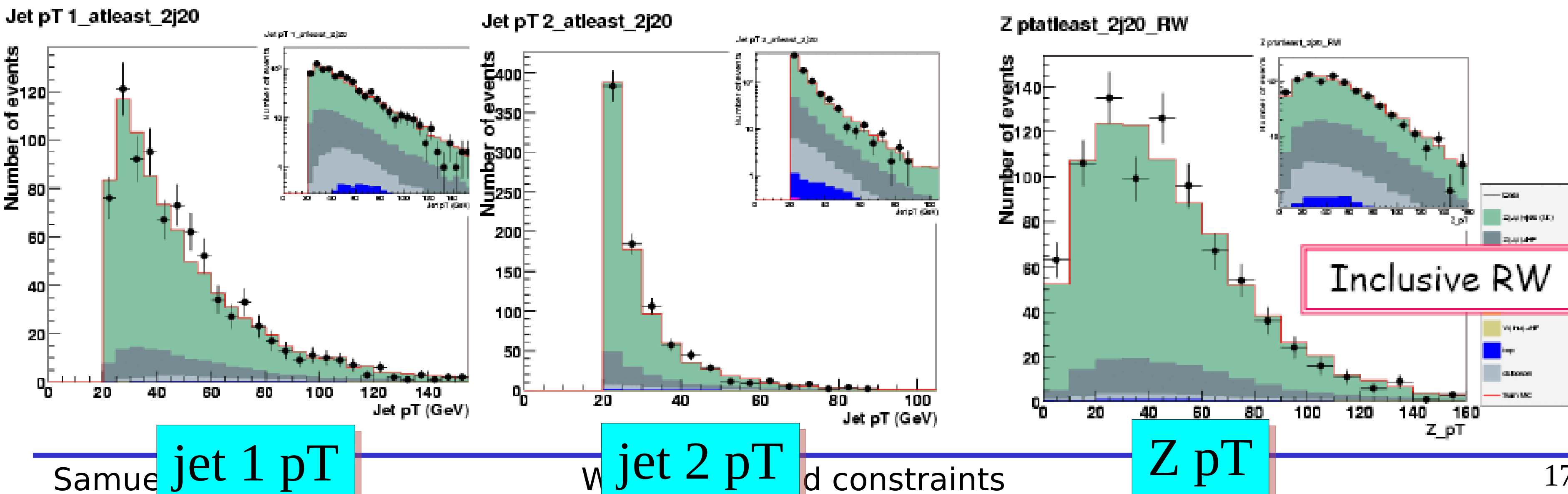
# How do we improve our MC ? (here, alpgen+pythia)

- After Z pT reweighting (RW):
  - Jet multiplicity improved
  - No additional scale factor needed

DØ WORK IN PROGRESS




- Z→$\mu\mu$+≥2jets : no additional scale factor (~1.2 before RW)

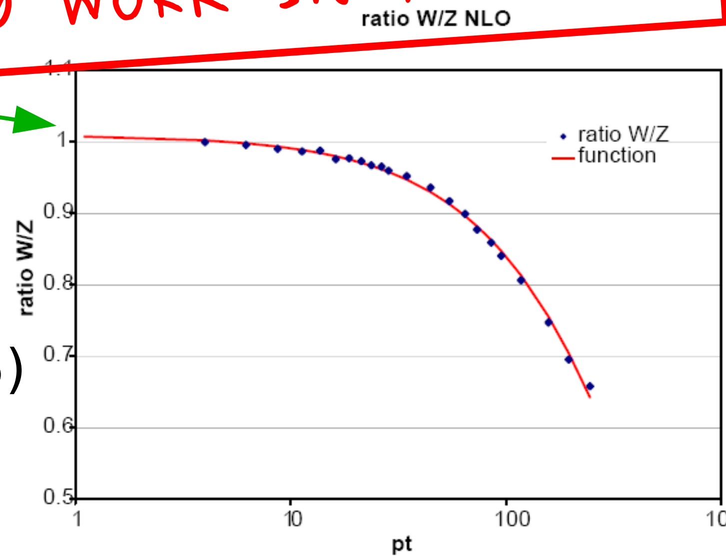


# From Z to W simulation

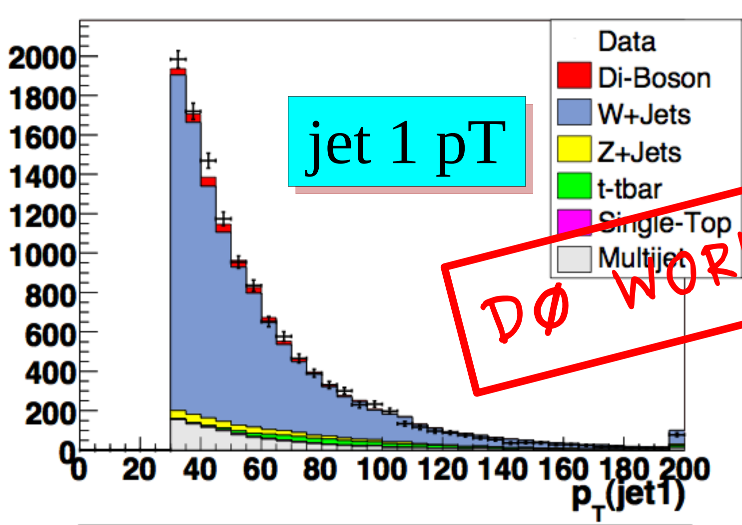
- We know the Z pT simulation is not perfect, so there is no reason to assume the W pT simulation to be correct

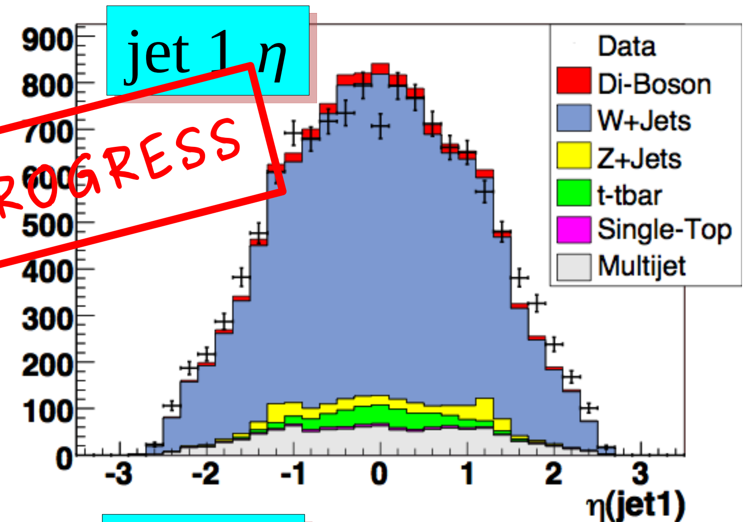
- Unfortunately there is not W pT measurement with similar precision as for Z→ee on the market
  - Rely on theory  for the W pT/Z pT ratio (NLO) :
    - use W pT from ResBos **at low pT**
    - **use (*unfolded data Z pT*)**
      x (*NLO ratio*) **at high pT**
      - Melnikov-Petriello code
      - NLO ratio in agreement with NNLO ratio
  - At the moment, an additional scale factor is needed for W+2jets (~1.25)
  - Hopefully the W pT RW will fix it

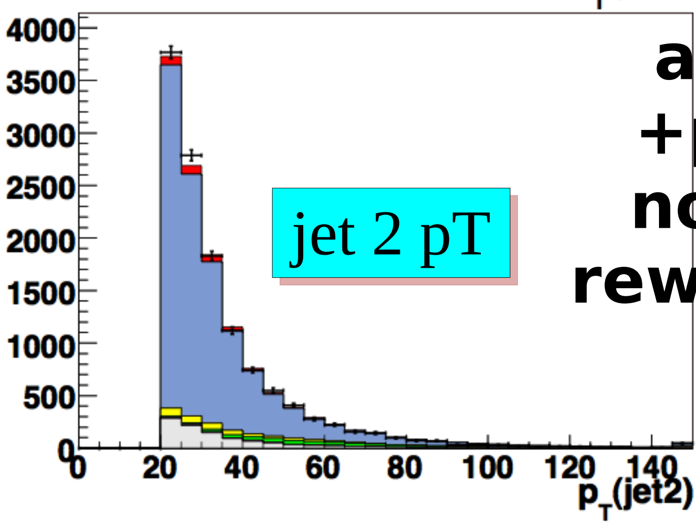
DØ WORK IN PROGRESS



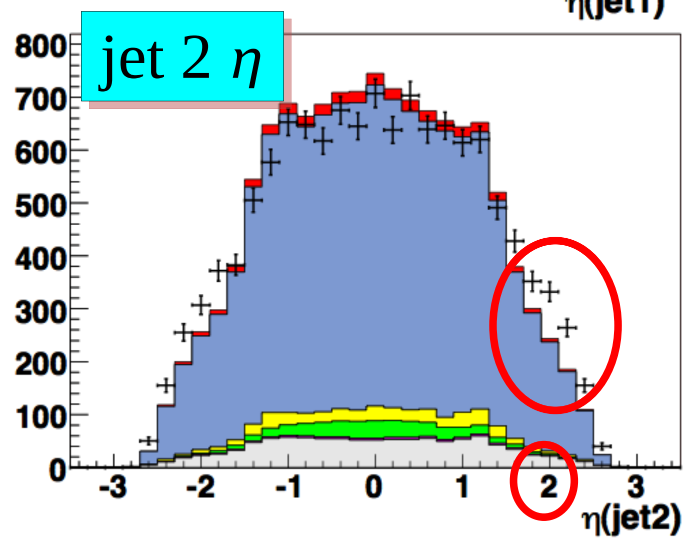
# W→eν, ≥2 jets, jet 1 (2) pT> 30 (20) GeV



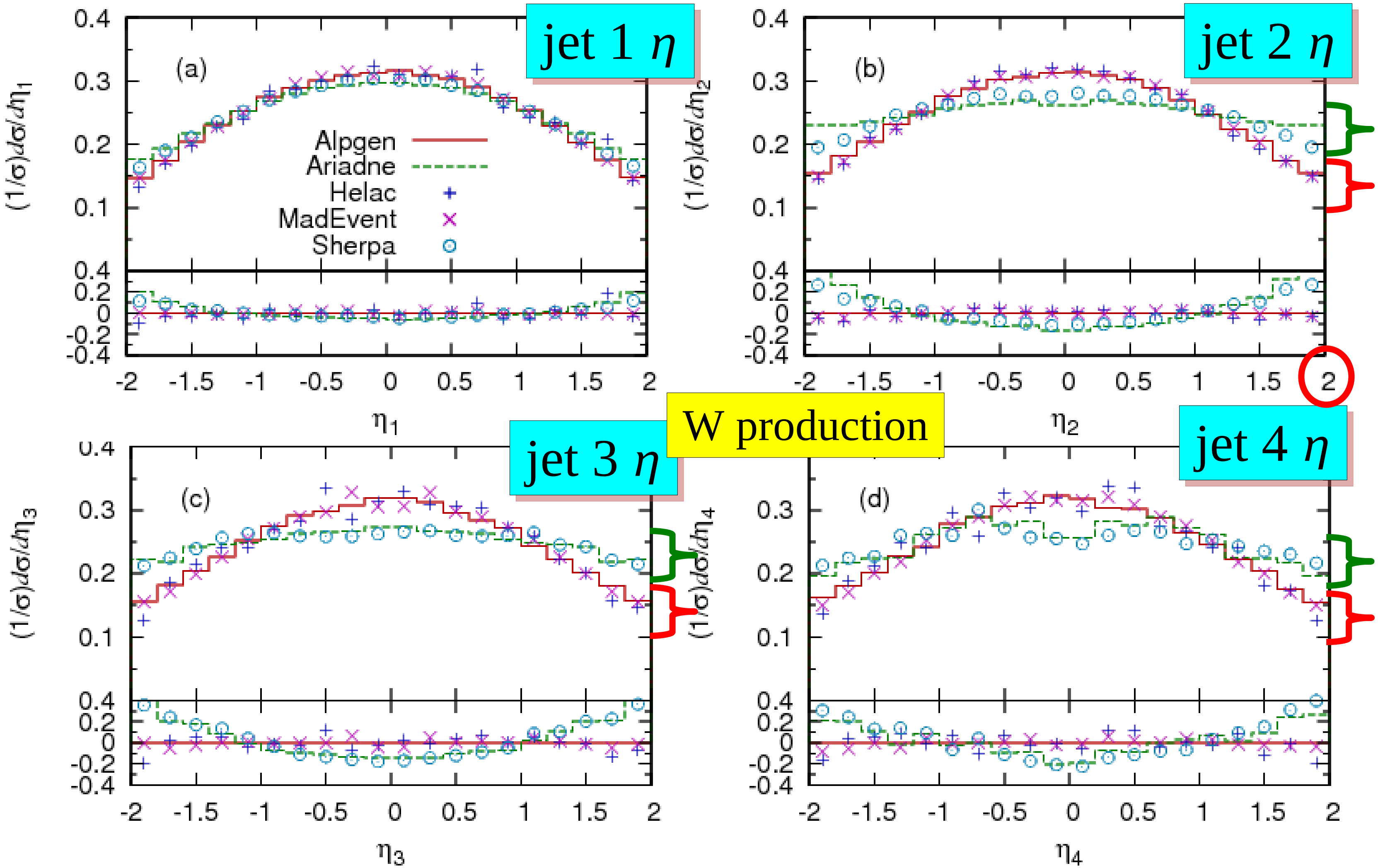

**alpgen +pythia, no W pT reweighting**




Good description of jet pT's

Jet η's broader in data than in MC (better in sherpa, see next slide)

# MC comparison : is there a matching effect ?




arXiv:0706.2569

Alpgen+Herwig, MadEvent+pythia → MLM

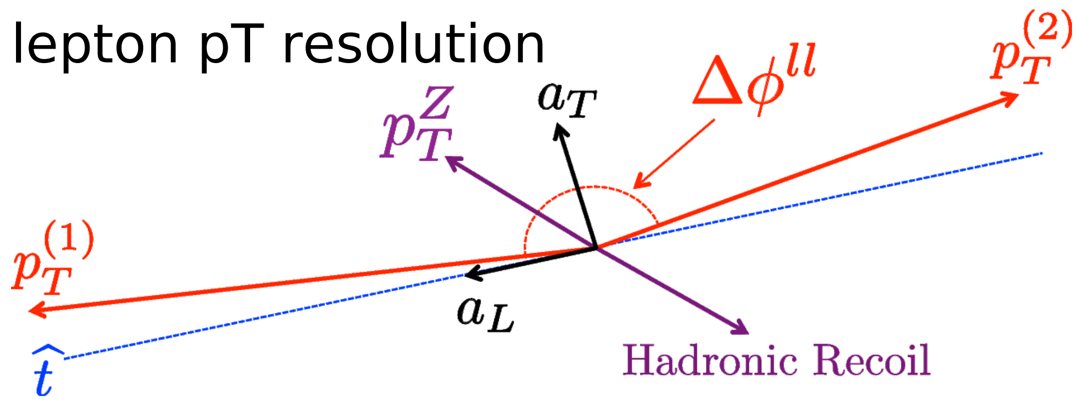
Sherpa, Ariadne+pythia → CKKW

# A precise measurement

# Low Z pT using a novel technique

- Z pT can be decomposed into 2 components $a_T$ and $a_L$
  - $a_T$ is ~insensitive to lepton pT resolution

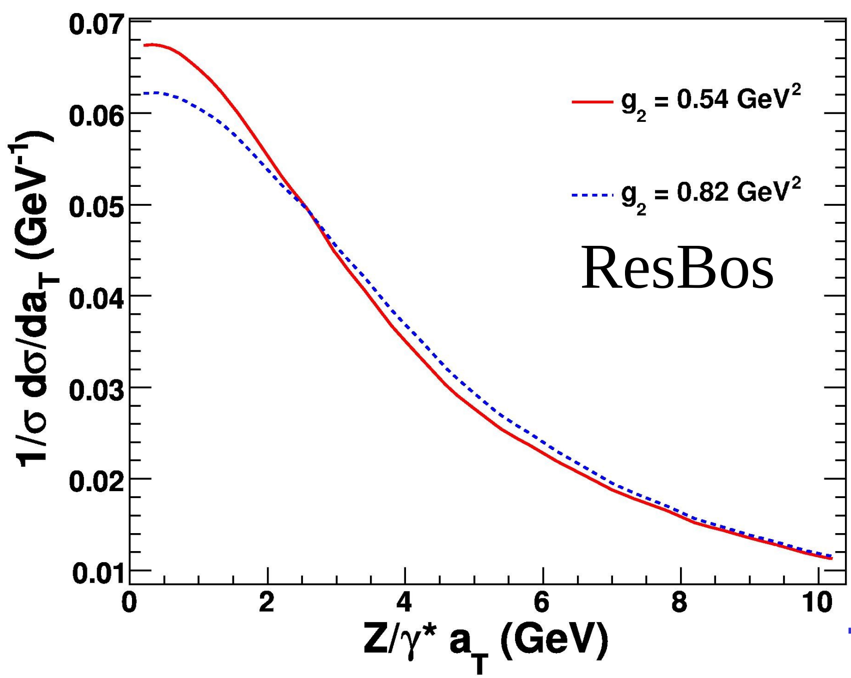
$$\hat{t} = \frac{\vec{p}_T^{(1)} - \vec{p}_T^{(2)}}{|\vec{p}_T^{(1)} - \vec{p}_T^{(2)}|}$$



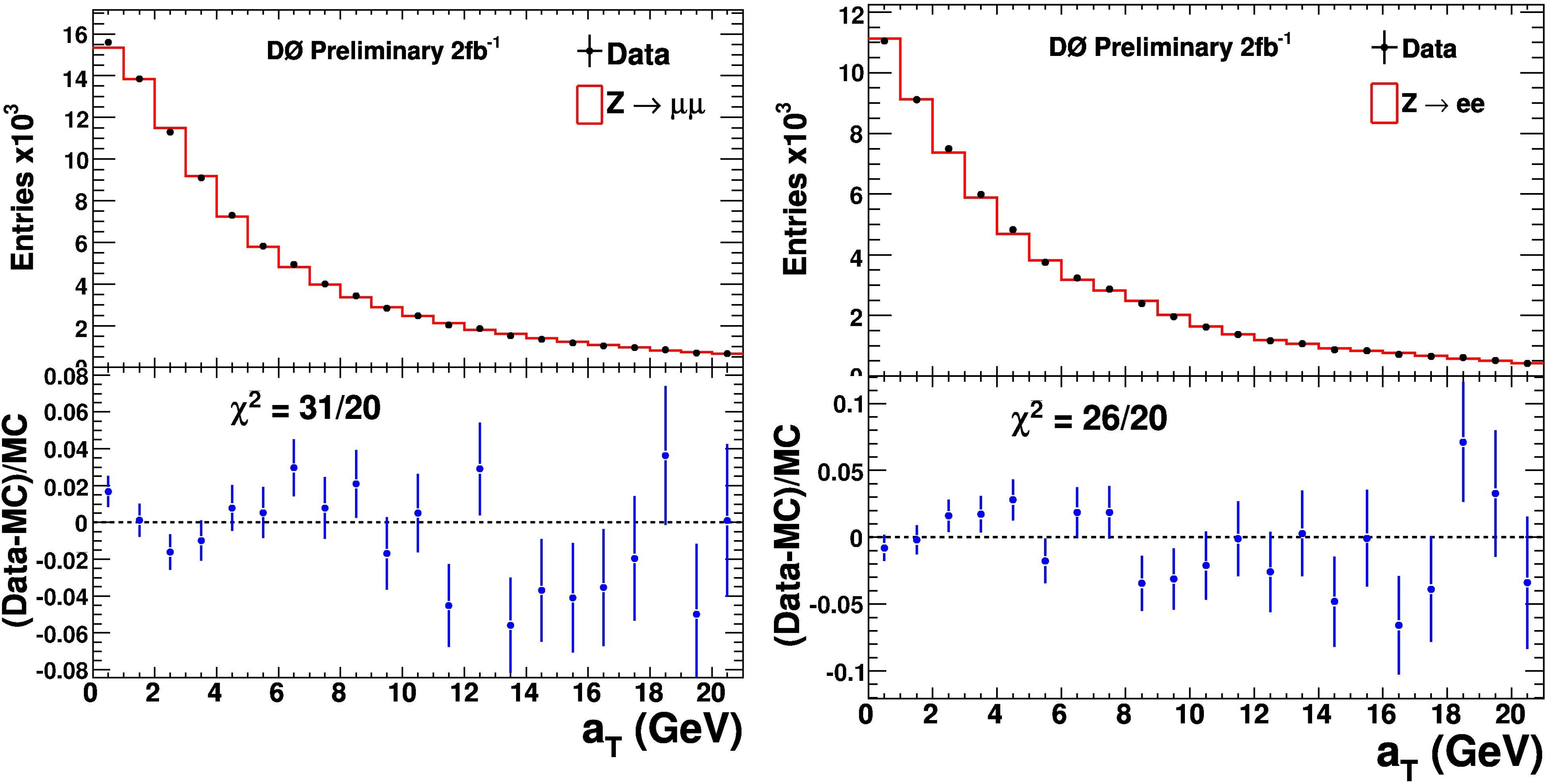

- Non-perturbative form factor (by BLNY ):

$$S_{NP}(b, Q^2) = \left[ g_1 + g_2 \ln\left(\frac{Q}{2Q_0}\right) + g_1 g_3 \ln(100 x_i x_j) \right] b^2$$

- Use $a_T$ and $a_L$ to measure $g_2$



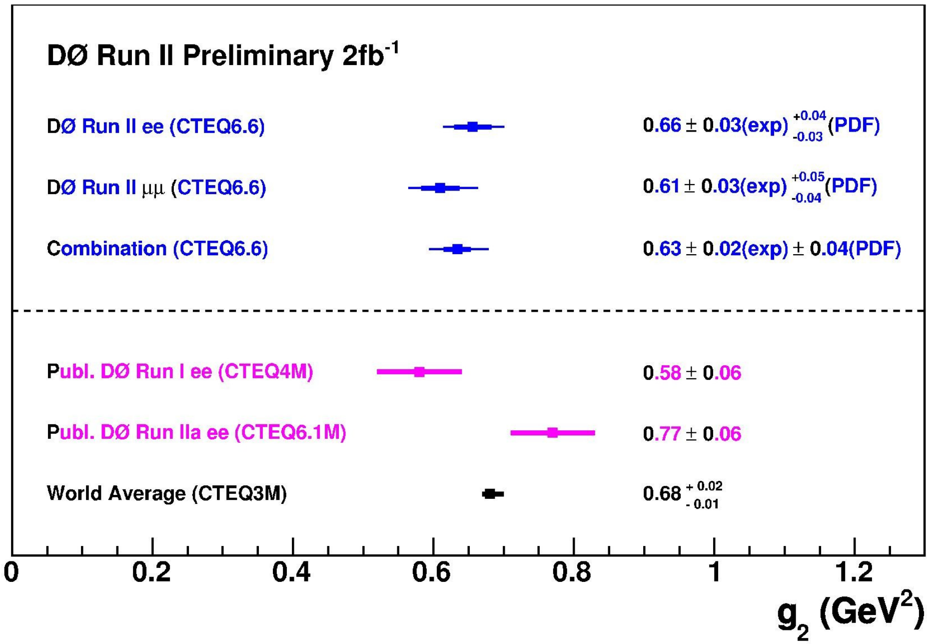
# Low Z pT using a novel technique

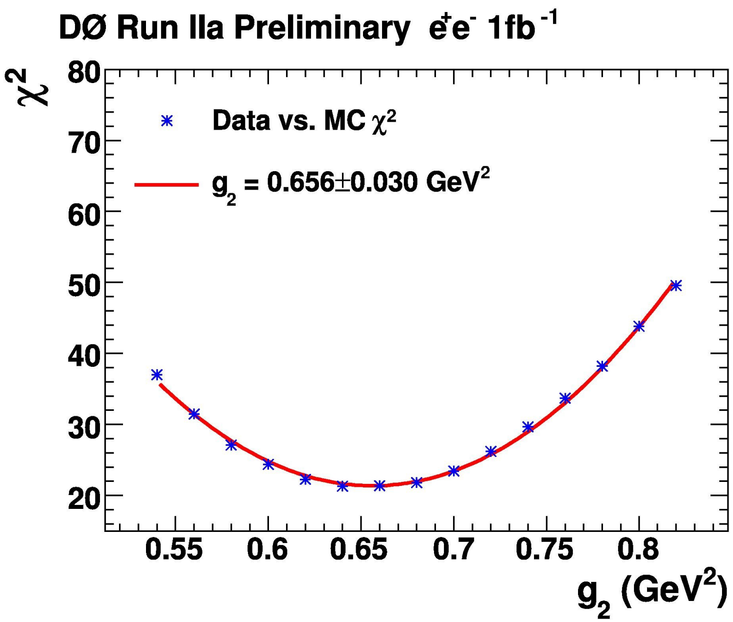


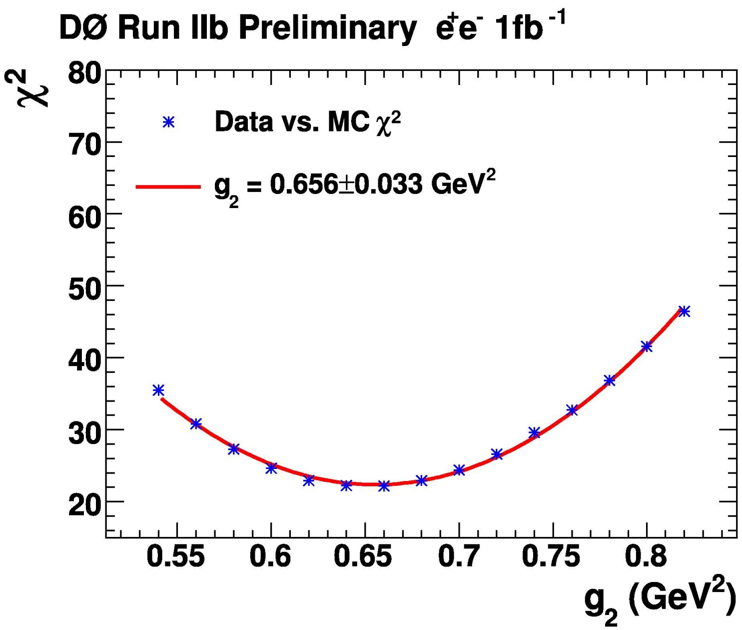

- This technique allows to use the muon channel @DØ.
- Reweight pythia samples with 15 ResBos predictions (corresponding to a grid of 15 $g_2$ parameters)

# Low Z pT using a novel technique

- Precise measure of $g_2$
  - 0.63 ±0.02(exp) ±0.04(pdf)
- Should help to tune the MC in the low pT region



# Conclusion

- Tevatron experiments get enough events to test precisely the prediction of V+jets signals backgrounds
  - It is an unavoidable step on the road to discoveries/ precision measurements
  - Manpower dedicated on the understanding/modeling of these backgrounds (for example, V+jets task force @ DØ)
  - The needed massages of the MC's are better and better understood
  - Measurements of boson + heavy flavor still statistic limited (see back up)

- → Recent precise measurements should help the tuning and comparisons of MCs

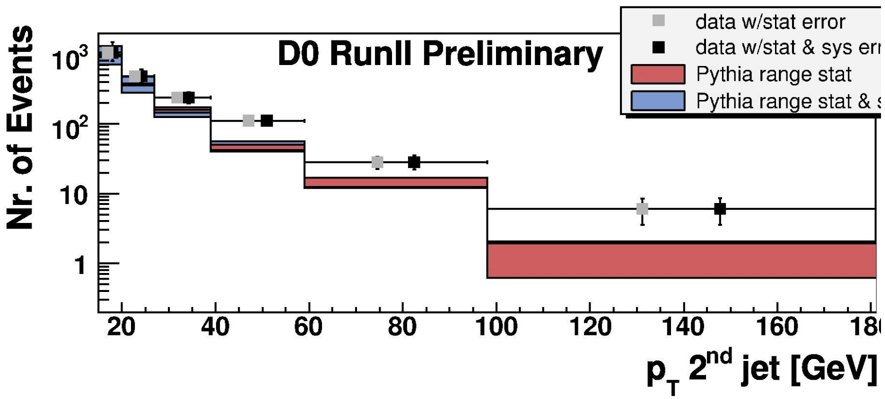
- LHC will reap the benefits from all these works

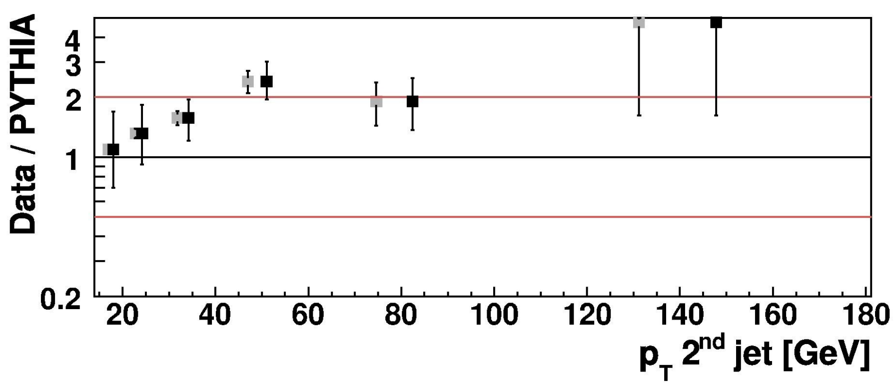
# Backup

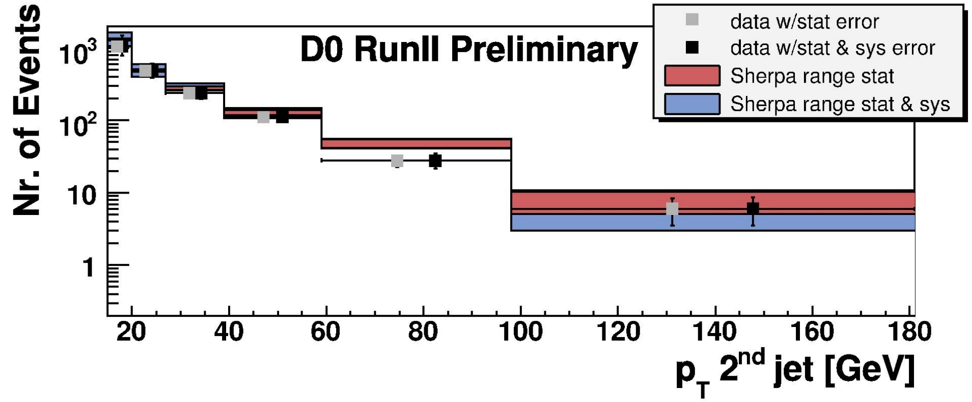
# Z→ee, jet pT>15GeV, detector level

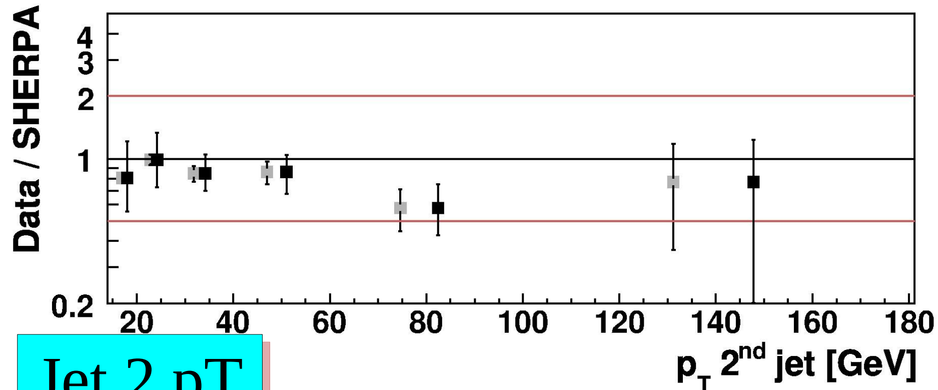
**PYTHIA too soft**
**(As expected)**

## PYTHIA v6.314 tune A



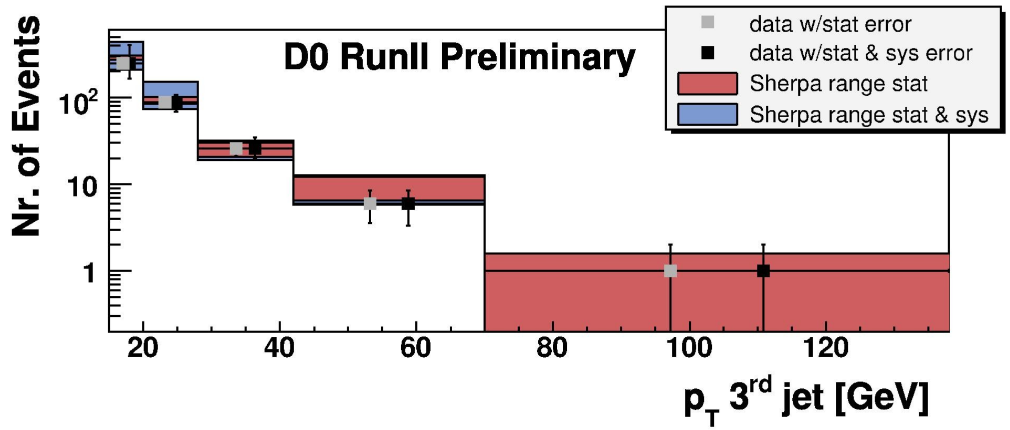




Jet 2 pT

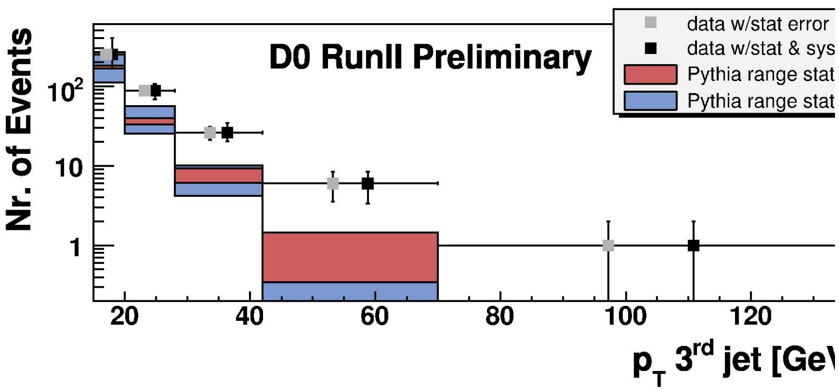
## SHERPA v1.0.6

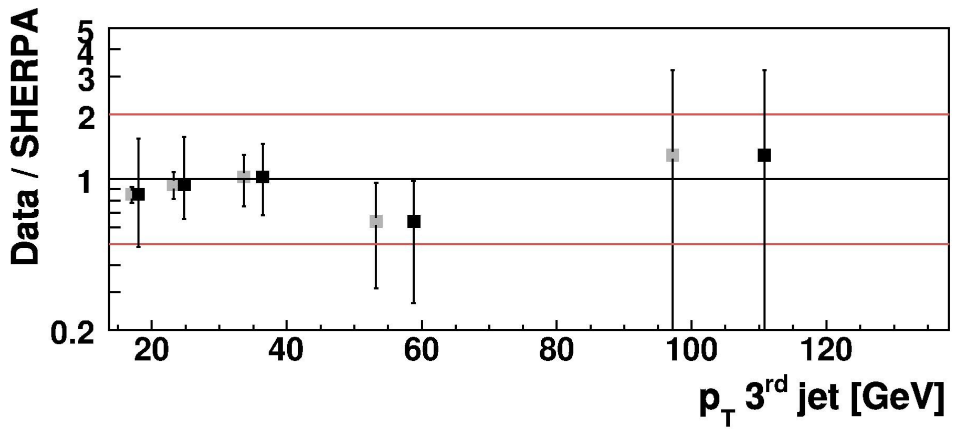
**~ok**
**1.7 more jets @80GeV**

# Z→ee, jet pT>15GeV, detector level

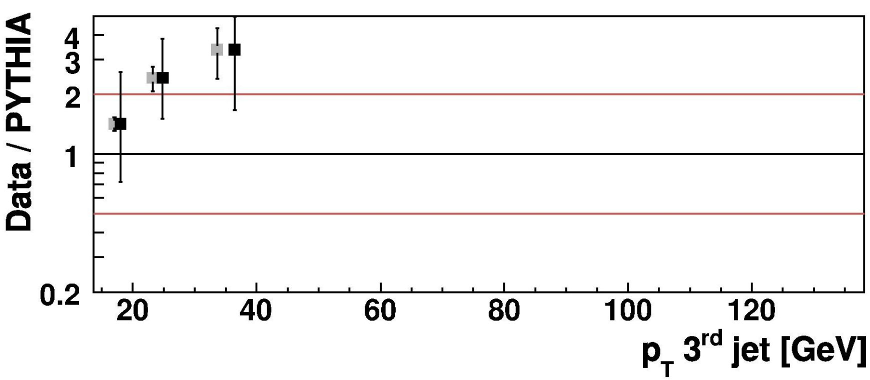



**PYTHIA v6.314 tune A**

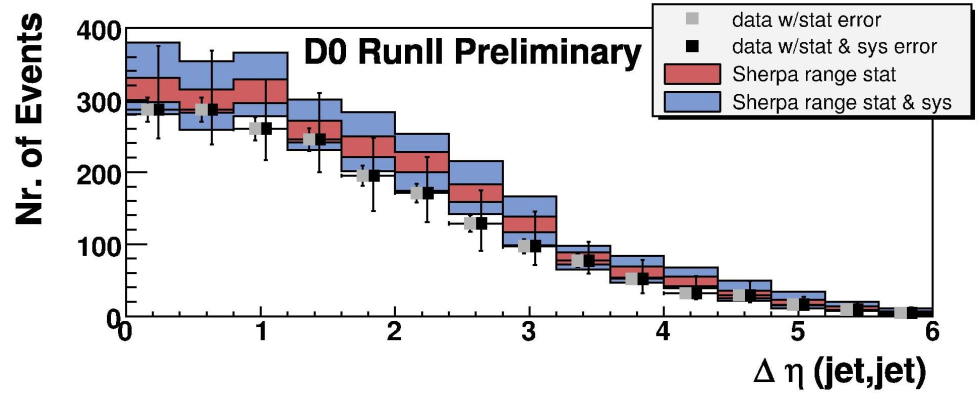


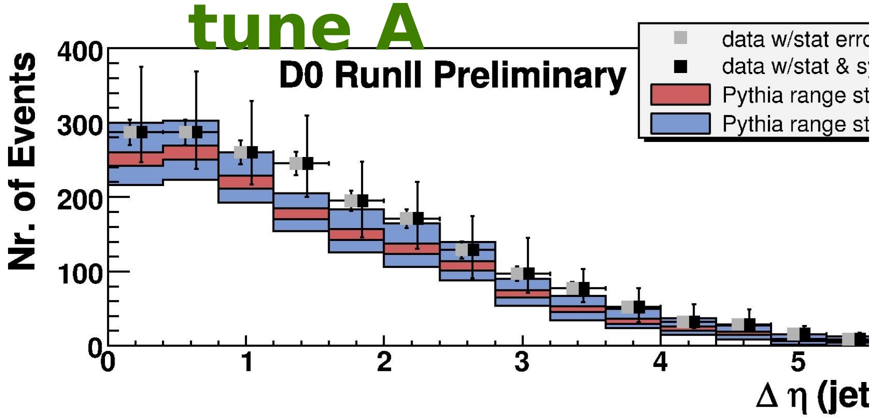

**SHERPA v1.0.6**

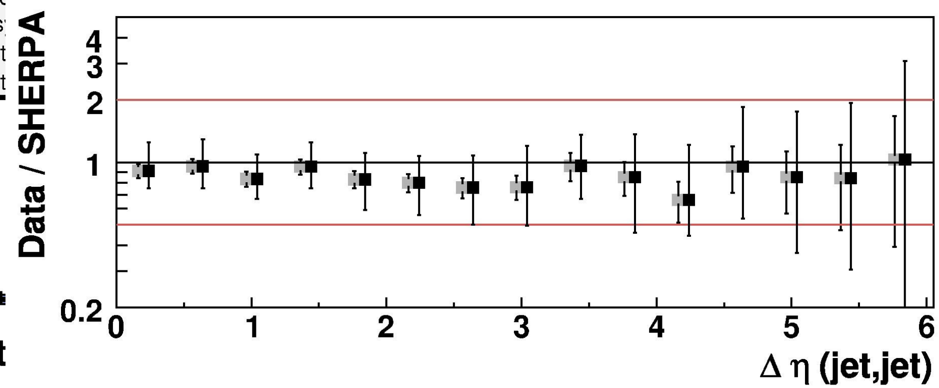


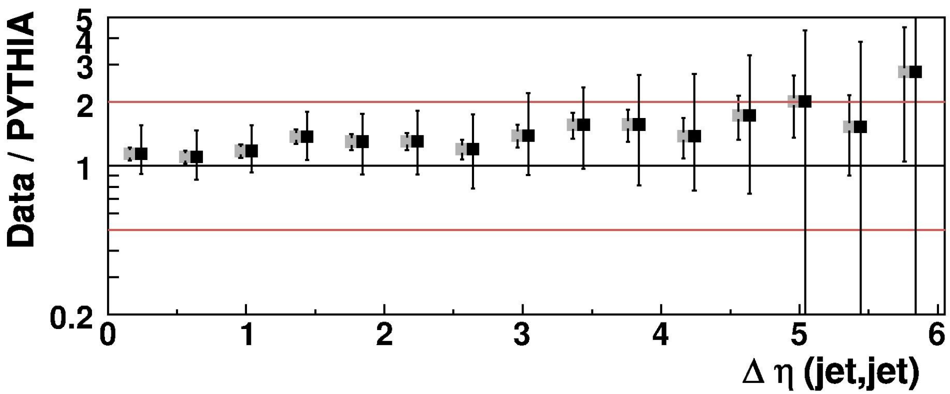
# Z→ee, jet pT>15GeV, detector level




PYTHIA v6.314
tune A

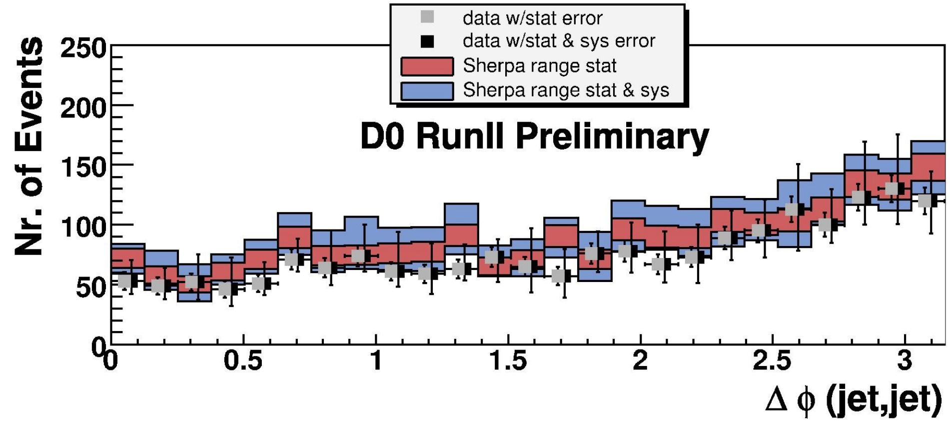


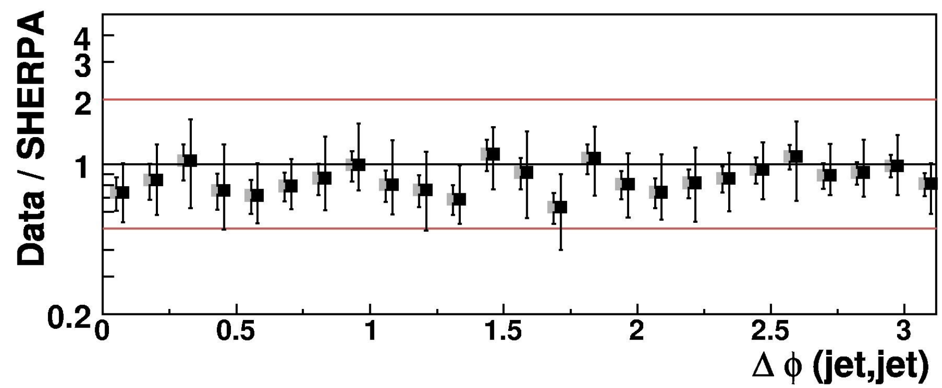



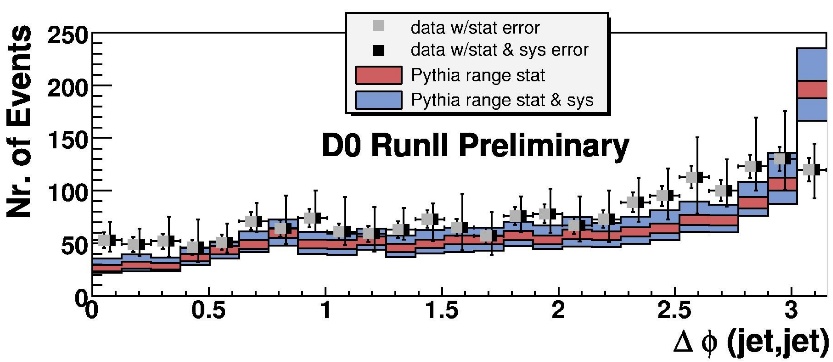

SHERPA v1.0.6

# Z→ee, jet pT>15GeV, detector level

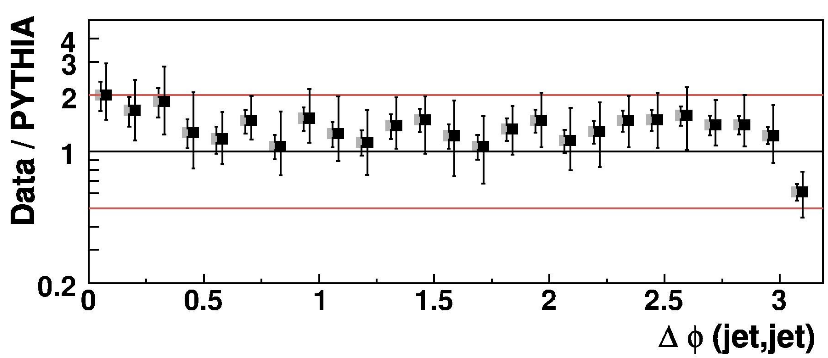



**PYTHIA v6.314 tune A**

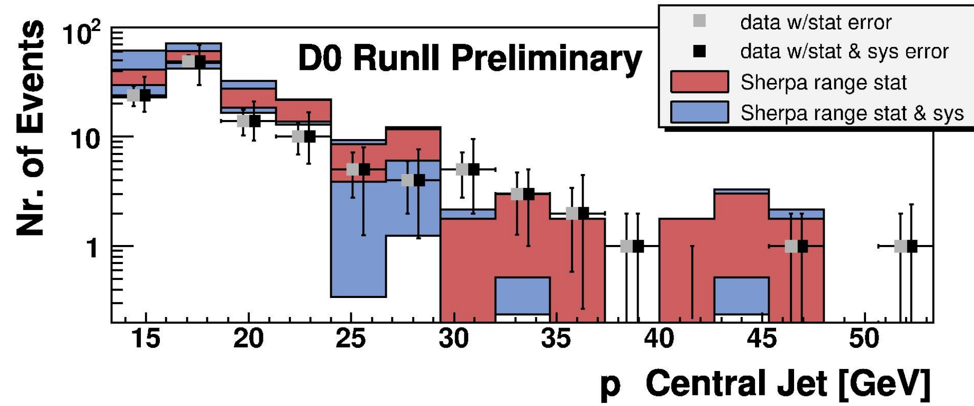


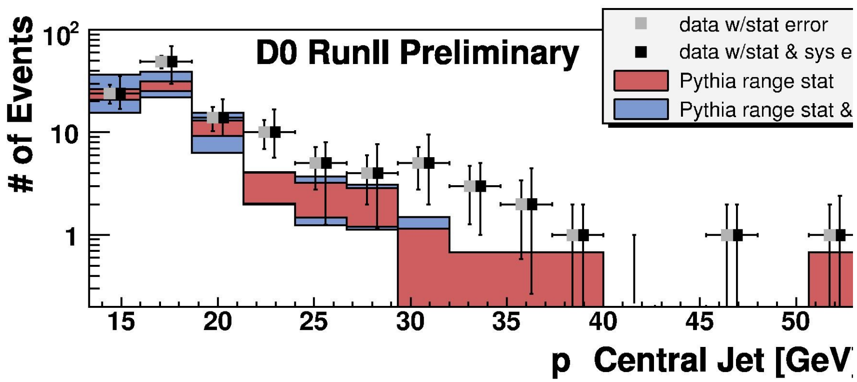

**SHERPA v1.0.6**

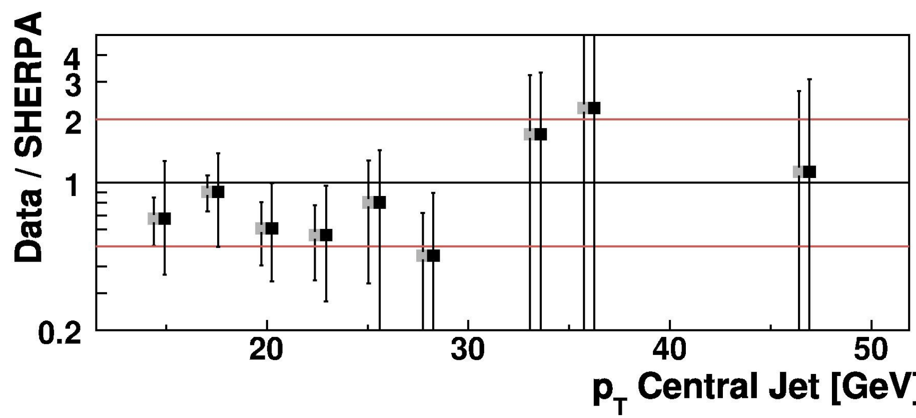


# Z→ee, jet pT>15GeV, detector level

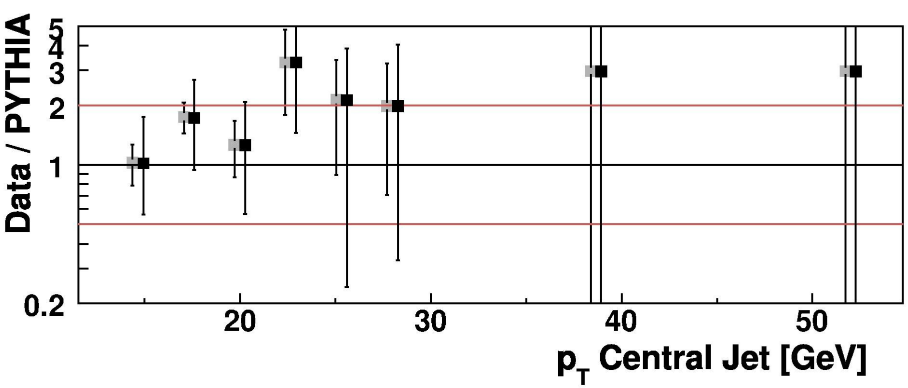



**PYTHIA v6.314 tune A**



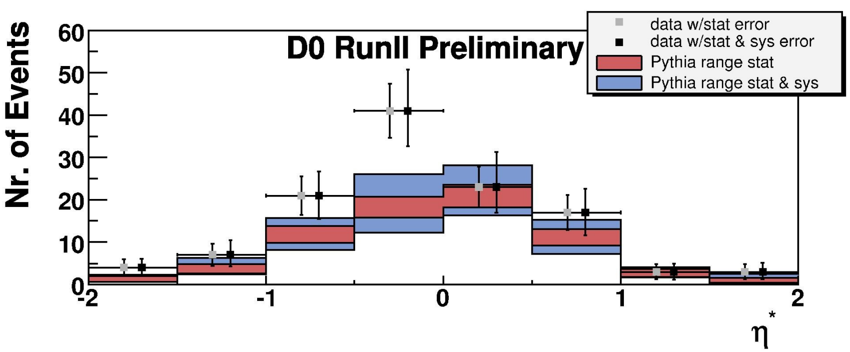



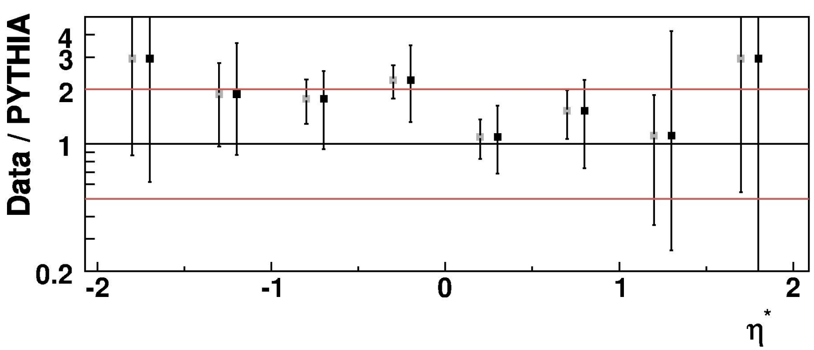

**SHERPA v1.0.6**



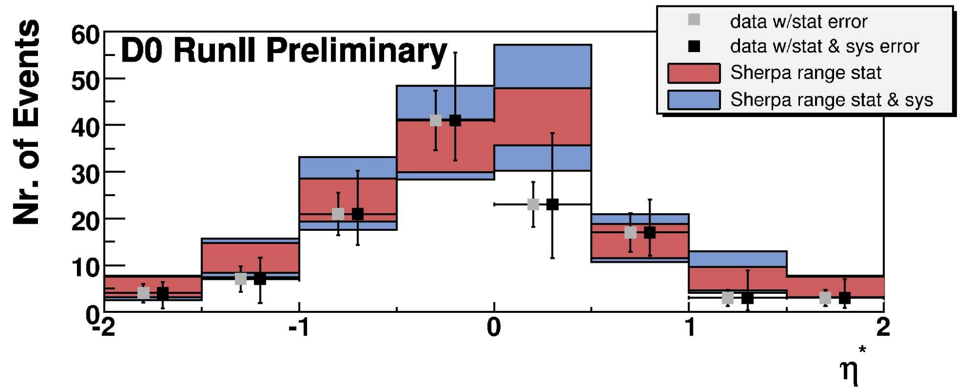
# Z→ee, jet pT>15GeV, detector level

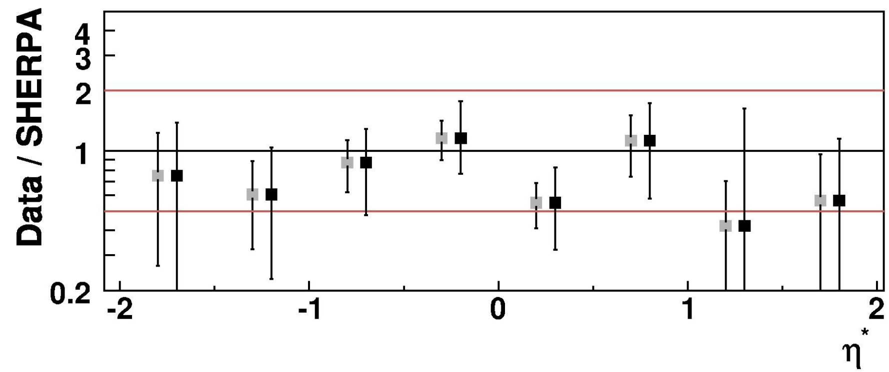
**PYTHIA v6.314 tune A**



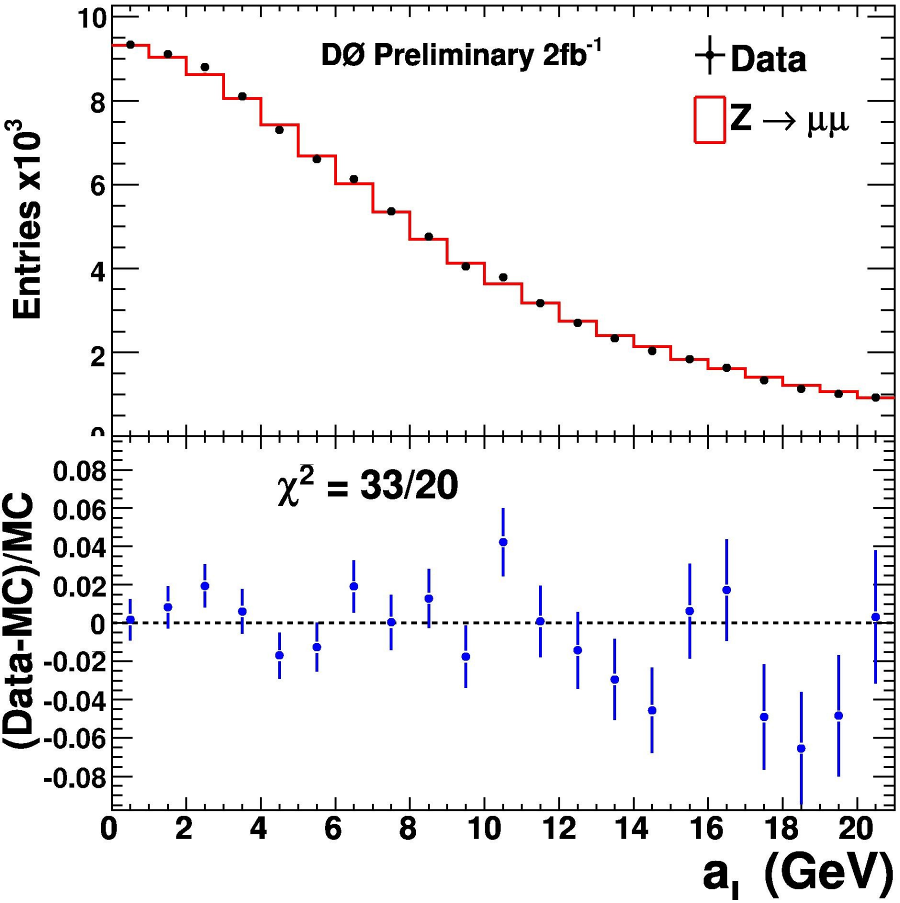



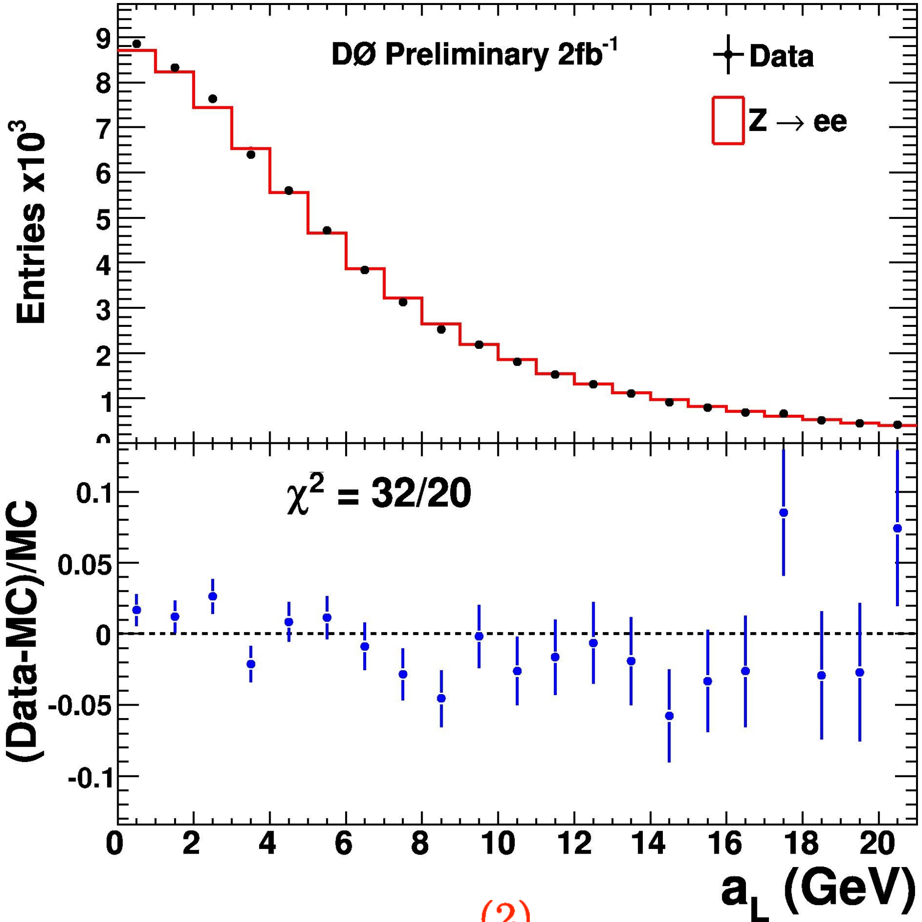

**SHERPA v1.0.6**

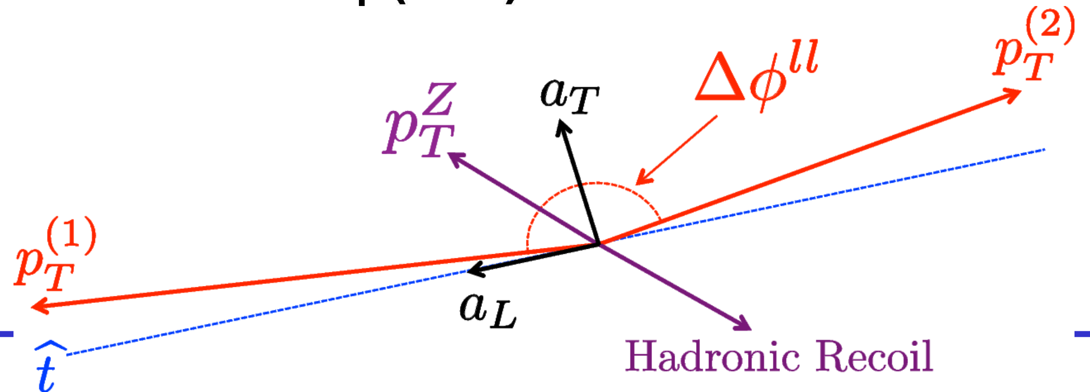


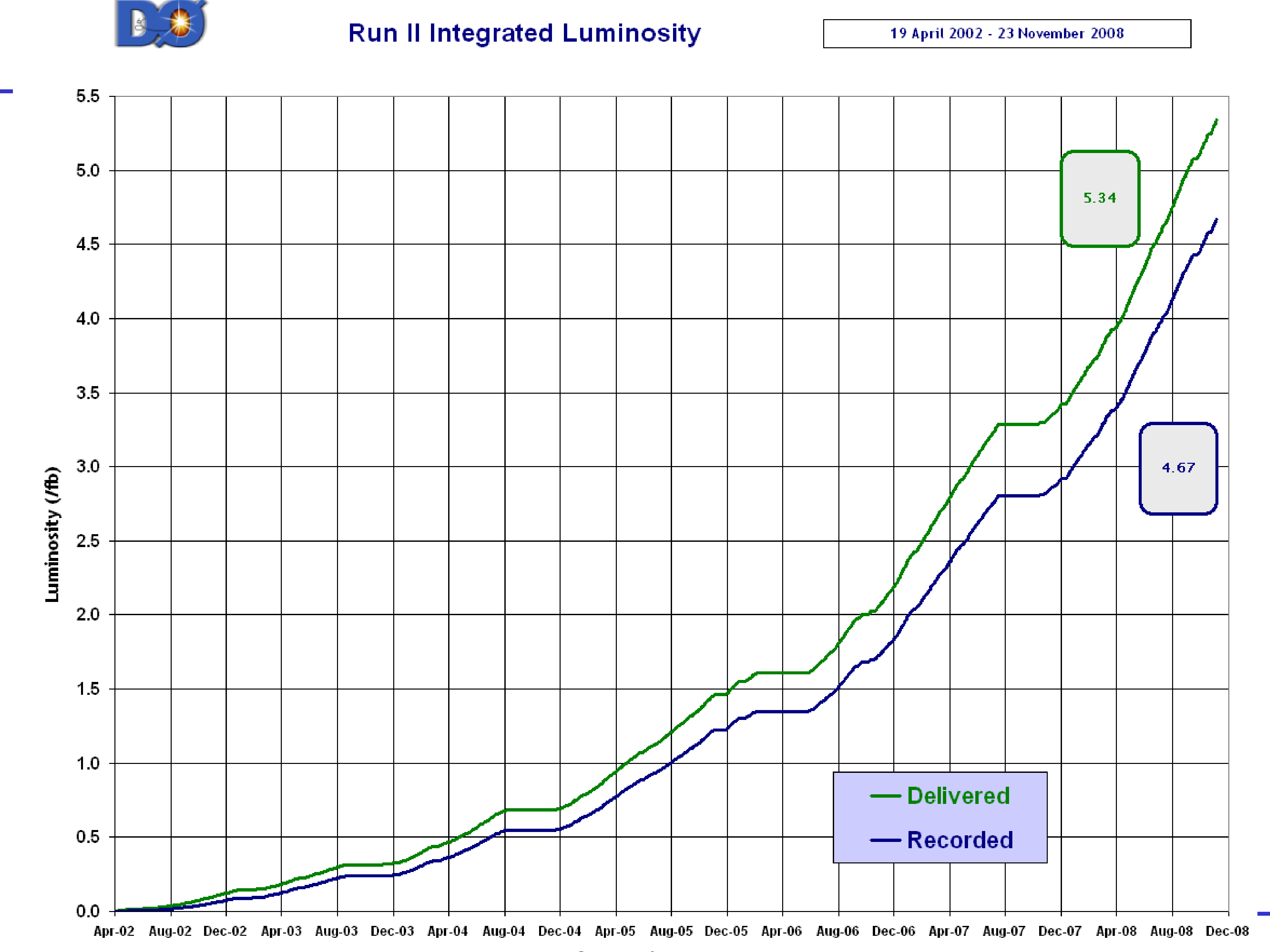



# Low Z pT using a novel technique



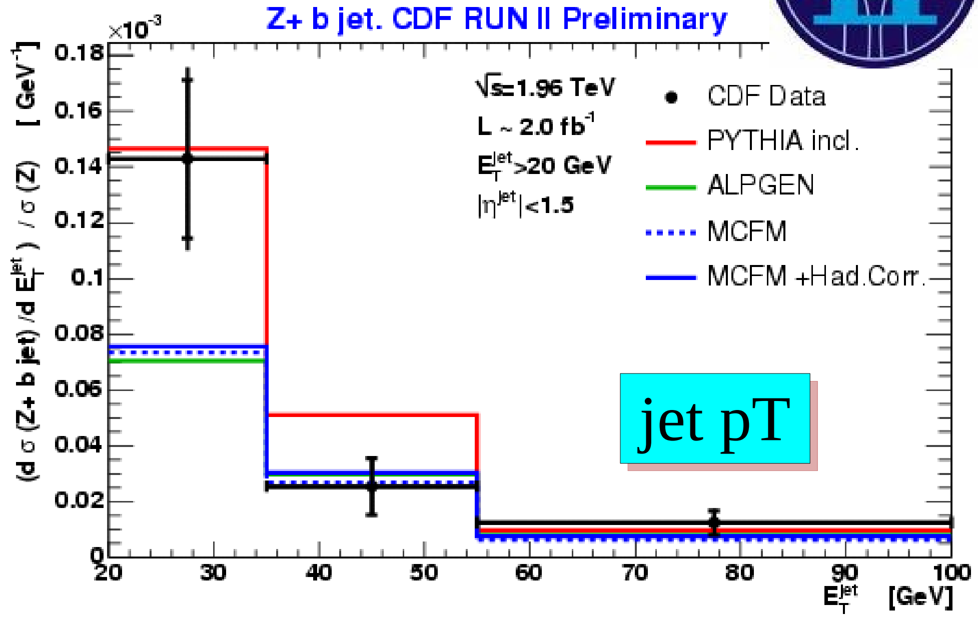



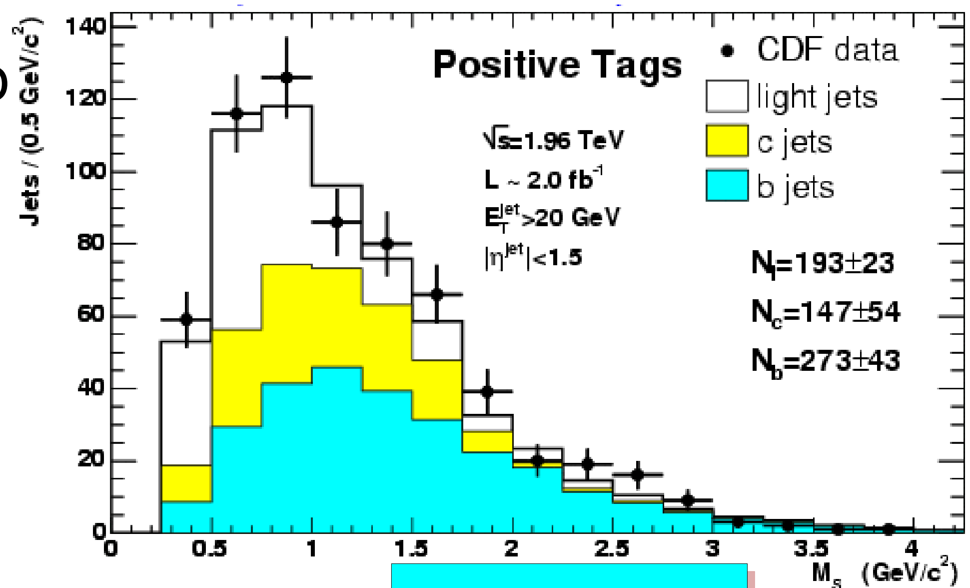


Run II Integrated Luminosity
19 April 2002 - 23 November 2008
Luminosity (/fb)
5.34
4.67
Delivered
Recorded
Apr-02
Aug-02
Dec-02
Apr-03
Aug-03
Dec-03
Apr-04
Aug-04
Dec-04
Apr-05
Aug-05
Dec-05
Apr-06
Aug-06
Dec-06
Apr-07
Aug-07
Dec-07
Apr-08
Aug-08
Dec-08

# Z+b-jets : Z→ee/$\mu\mu$+b

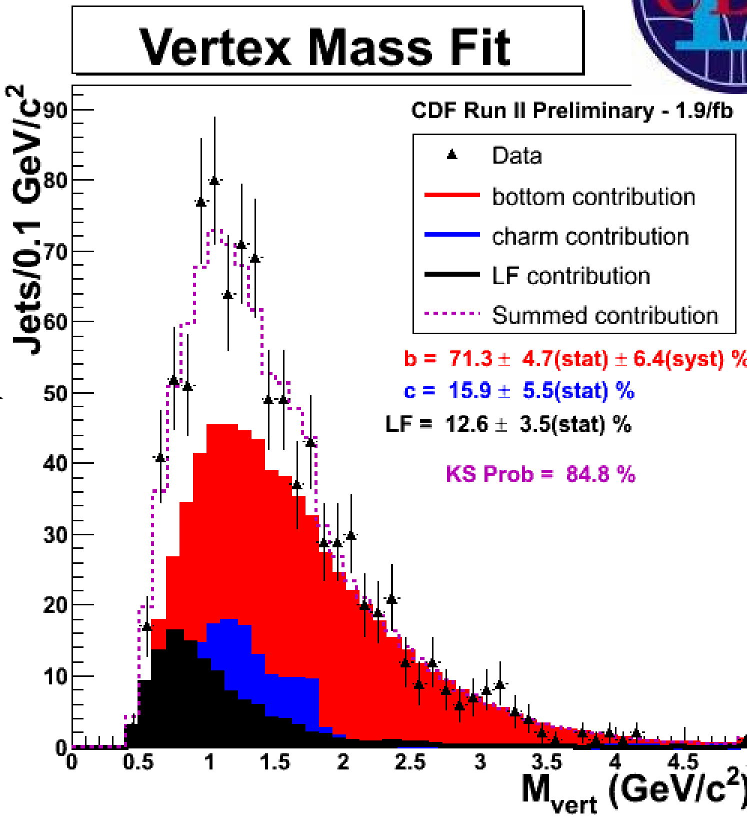
- Secondary vertex tagging
- Data corrected to hadron level (R=0.7 cone jets)
- Fit the vertex mass by 3 templates (b, c, light)
- Measurement $\sigma$(Z+b-jets)=0.93 ±0.36 pb consistent with the theory 0.45±0.07 pb
- Pythia does a good job to predict the Z+b fraction
- Statistic limited

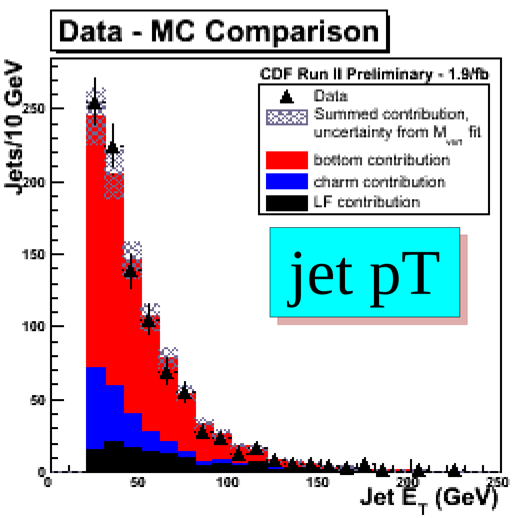


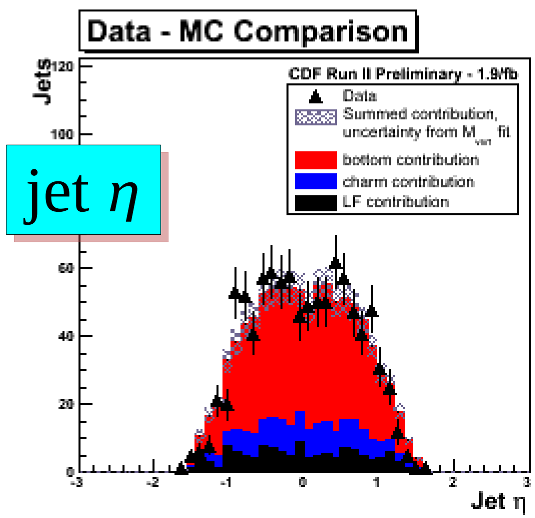



# W+b-jets : W→e/$\mu\nu$+b

- "Ultratight" secondary vertex tagging → high *b* purity
- Templates : **light**, ***b*** and ***c***
  - Fit the vertex mass distribution
  - NB: R=0.4 cone jets
- Measured cross-section 3.5 times larger than the prediction by Alpgen+herwig
  - Investigations are underway



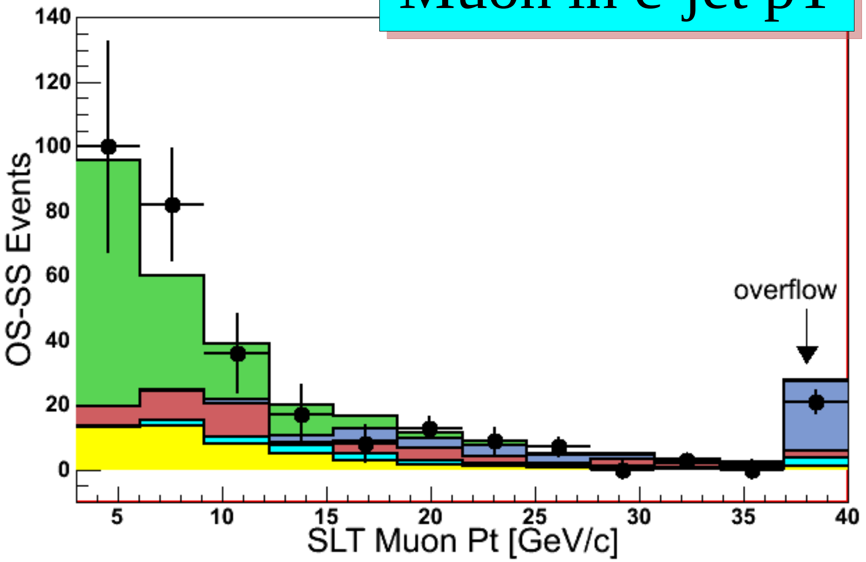




Check the fractions on other variables

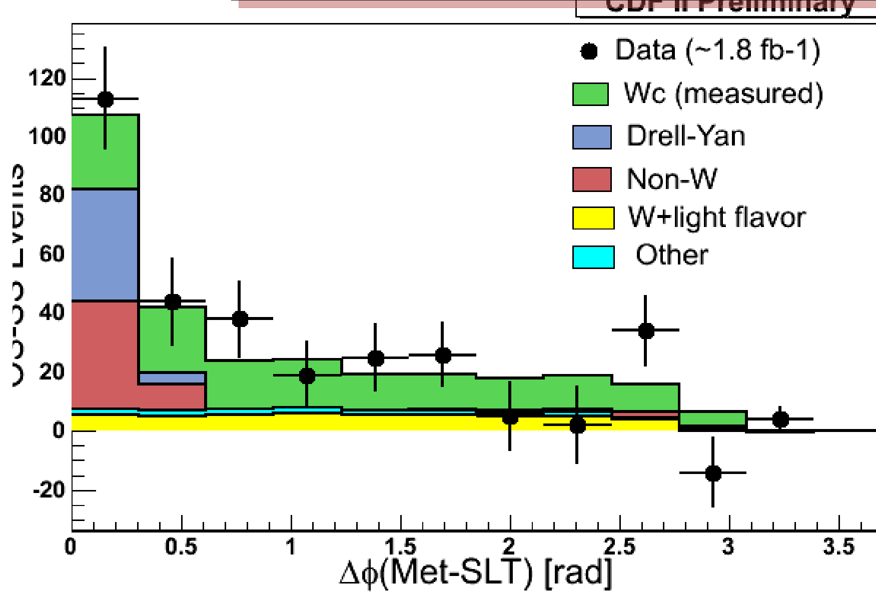
# W+c-jets : W→e/$\mu\nu$+c

- "Soft muon tagger" to select the c-jets
- $N(W+c) = N^{OS-SS}_{tot} - N^{OS-SS}_{bkg}$ → Considering the 2 leptons:
  OS : opposite sign
  SS: same sign
- Result:
  - $\sigma(W+1c) = 9.8 \pm 2.8(stat)^{+1.4}_{-1.6}(sys) \pm 0.6(lum)$ pb
  - In agreement with NLO prediction : $11^{+1.4}_{-3.0}$ pb

Muon in c-jet pT




$\Delta\phi$(MET,Muon in c-jet)




k(') and s-factors included