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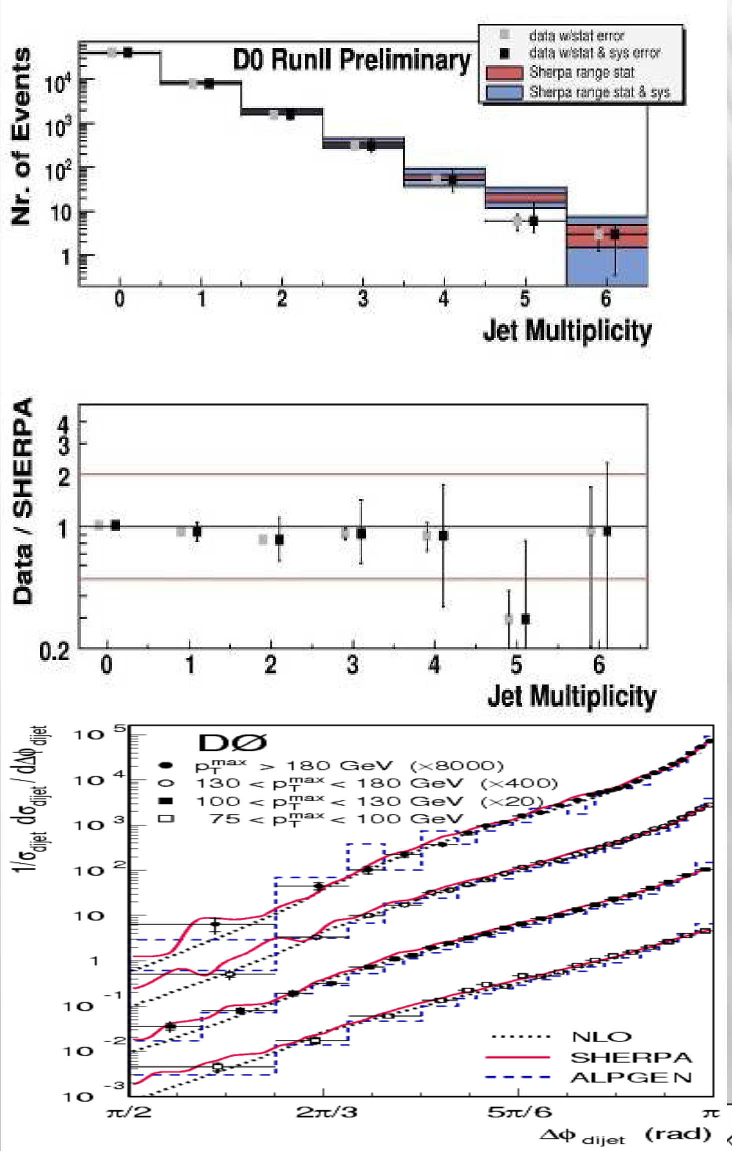
GENERATOR COMPARISON IN CMS AT 10 TEV

INTRODUCTION

- Introduction
  - General concepts of the MC generators
  - The paths towards discoveries : Matching Schemes and predictions
  - Discoveries at hadron colliders
- Generator Comparison at 10 TeV
  - Datasets and Selection cuts
  - Comparison selections from various MC generators at 10 TeV scenario
  - Systematical effects on theoretical predictions
- Summary
  - Differences and systematical effects on MC estimation of distributions

GENERATORS FOR LHC

- What we learn from Tevatron to LHC.
  - Physics process simulation:
  - PYTHIA, HERWIG
  - Working horses but limitations at high jet multiplicity
    - “ME generators”: ALPGEN, MADGRAPH, SHERPA
    - Better modeling at high number of jets
    - Some processes only available properly in dedicated MC
    - NLO generators (MC@NLO)
    - Not widely used yet but often used for cross-checks
  - Detector simulation
- Neither physics nor detector simulation can generally be trusted!



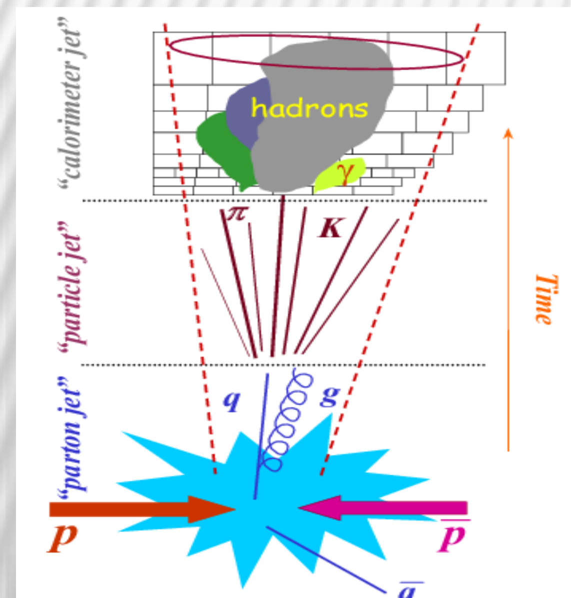
Central question: Do we understand and are we able to predict SM physics (QCD+EW) well enough to make discoveries at the LHC?

CONCEPTS OF THE MC GENERATORS

	Pythia-6.4	Herwig-6.5	MC@NLO-3.3	Sherpa-1.1.3	Alpgen-2.13
Matrix Element	LO(2->2)	LO(2->2)	NLO(2->2)	LO (2->4)	LO(2->6)
Parton Shower	P_T ordered	Angular Ordered	Herwig	Virtuality ordered*	Pythia/Herwig*
Matching Scheme	-	-	NLO	CKKW	MLM
Underlying Event	Pythia	Jimmy	Herwig	Pythia-like	Pythia/Herwig*
Hadronization	Lund	k_T clustered	Herwig	Pythia/Herwig like*	Pythia/Herwig*
Processes	SM,MSSM,etc.	SM,MSSM,etc	SM	SM,MSSM,ADD	SM
Standalone Generator	yes	yes	no	yes	no
Programming	Fortran	Fortran	Fortran	C++	Fortran

Madgraph : LO 2->n , Pythia interface, MLM matching

Sherpa and Madgraph : Feynmann diagrams + Helicity ampl. / Alpgen : Recursion relations



Parton showers (*):

- ➢Based on collinear approximation
- ➢Strict ordering of emissions in ordering variable
  - Q2 (Pythia <6.3 - Sherpa)
  - PT (Pythia >6.3 - Madgraph, Alpgen)
  - θE (Herwig-6.5 – MC@NLO)

matching

Hadronization(*):

- ➢ Lund Model (Madgraph, Alpgen, *Sherpa*)
- ➢ Clustered Hadronization (*Sherpa*, MC@NLO)

Underlying Event

- ➢ Pythia (Madgraph, Alpgen, Sherpa(basic pythia model))
- ➢ Herwig/Jimmy (MC@NLO)

MATCHING : MLM / CKKW / NLO

MLM matching : Madgraph and Alpgen

- Generate multi-parton event with cut on jet kT :
- **Pt > Ptgen , ΔRj1j2 > Rgen , |η|< ηgen**

three parameter for matching

- Cluster event and use kT^2 for **αs** scale : reject the event if the number of clusters is not equal to the number of ME partons

- Showering event starting from hard scale
- Collect showered partons in kT jets with kTcut > kTmin

- Keep event only if each jet matched to one parton
- For highest mult. sample, allow extra jets softer than kTmin

NLO matching: MC@NLO

- it describes the hard emission like a NLO calculation, including **NLO normalization**. It simulates additional collinear particle emission using **Sudakov form factor**. This is precisely what the parton shower does. It avoids double counting and describes entire PT range emission for **the first and hardest jet** consistently

CKKW matching : Sherpa

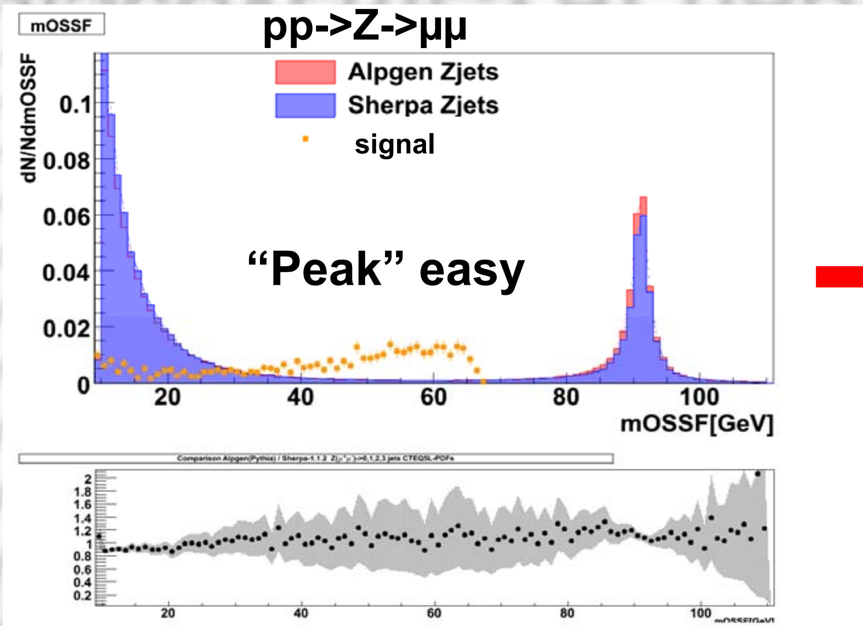
- Defined events with the distance (kT alg.) between a parton and the incoming partons (the beam) with **Y_{sep}**

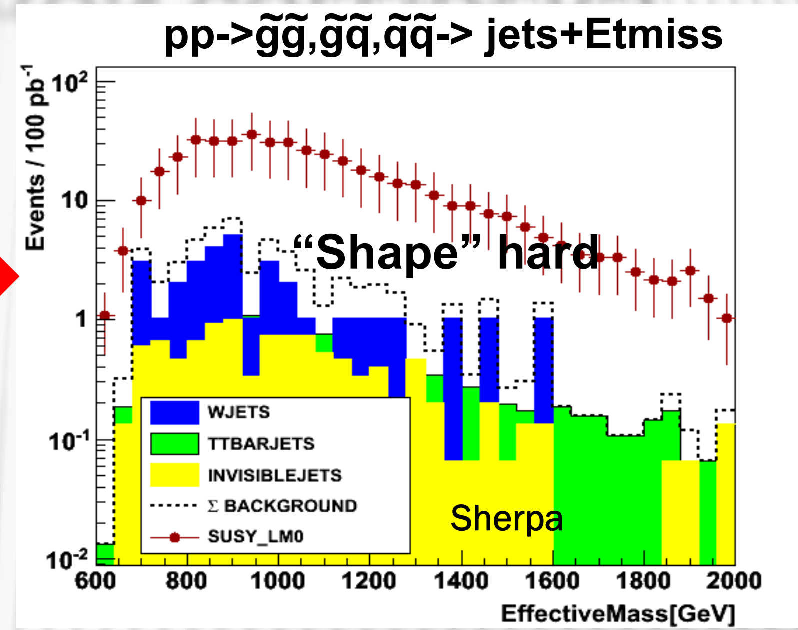
one parameter for matching

- **@ y_cut > y_sep** : choose the n-parton configuration with probability to the three level matrix elements squared $|Mn|^2$
- distribute all momenta according to $|Mn|^2$
- recontruct a probabilistic diagram by using the kT
- Reweight $|Mn|^2$ by product of **Sudakov from factors**
- The argument of the form factors and the running coupling are computed at the typical scales
- **@ y_cut < y_sep:** one uses instead a parton shower subjected to a veto procedure which cancels the **Y sep**. dependence - avoids double counting

	MC@NLO	CKKW - MLM
Hard Jets	first jet correct	all jets correct
Collinear Jets	all jets correct, tuned	all jets correct, tuned
Normalization	correct NLO	correct to LO plus real emission
others	POWHEG,etc.	MadEvents,Ariadne

DISCOVERIES AT HADRON COLLIDERS





Background **directly** measured from data. TH needed only for parameter extraction (Normalization, acceptance,…)

Background **shapes** needed. Flexible MC for both signal and background tuned and validated with data

Background **normalization** and **shapes** known very well. Interplay with the best theoretical predictions (MC) and data

Theory : Focus on the high Q2 -> Final description only in terms of partons and calculation of IR safe observables – cannot be directly employed in experimental studies

Experiment : Fully exclusive final state description for simulations more important -> Describe final states with high multiplicities starting from 2->1 , 2->2,…, using parton shower, and then hadronization model

DATASETS AND SELECTIONS

- Madgraph(Pythia)
  Zjets (PtJet30 GeV, ScaleDown/Up)
  Wjets(PtJet30 GeV, ScaleDown/Up)
  Ttbarjets(PtJet10/30/40 GeV, ScaleDown/Up,
  Larger/SmalerISRFSR)
- Sherpa
  Zjets (PtJet15/30 GeV, ScaleDown/Up)
  Wjets(PtJet30 GeV, eweak 1/2)
  Ttbarjets(PtJet10/30/40 GeV, ScaleDown/Up)
- MC@NLO(Herwig) - > Ttbarjets , Z+X
- Alpgen(Pythia) -> ttbarjets, Zjets , Wjets

All samples – UE/MI switch on
SisCone05 Jet Algorithm/ Generator Level
Selection cuts
Ptμ>10 GeV - | η μ | <2.5,
PtElec>15 GeV - | η e | <2.5,
PtJet>30 GeV - | η j | <3.0

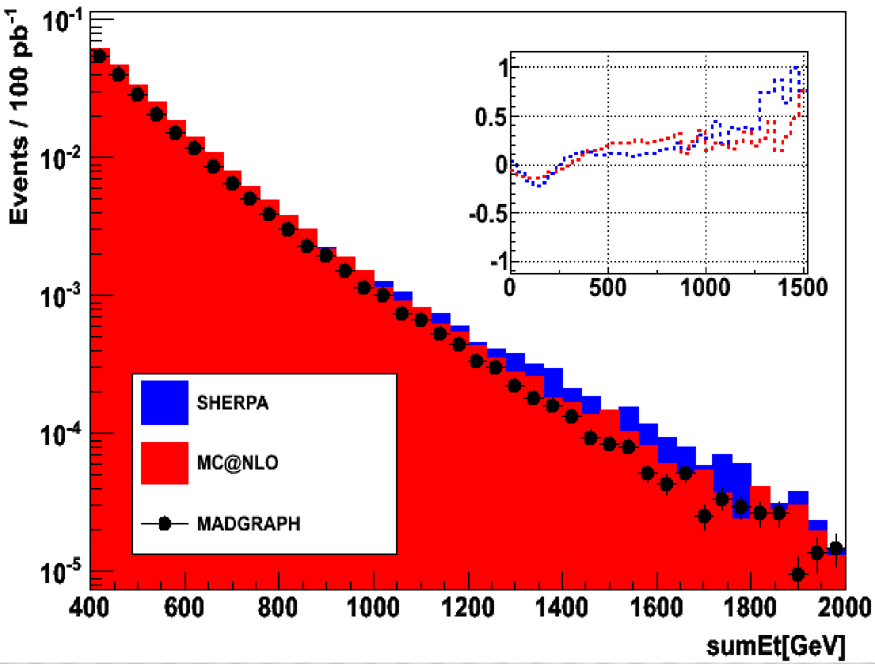
PtJet10/30/40 - cut on parton level – seperation between ME and PS
ScaleDown/Up – Multiplication factor (1/2 - 2) on factorization/renormalization scales
Smaller/Larger ISR -FSR – Low ISR – High ISR
Eweak – (first(1)/second(2)) order of electroweak corrections on matrix element calculation

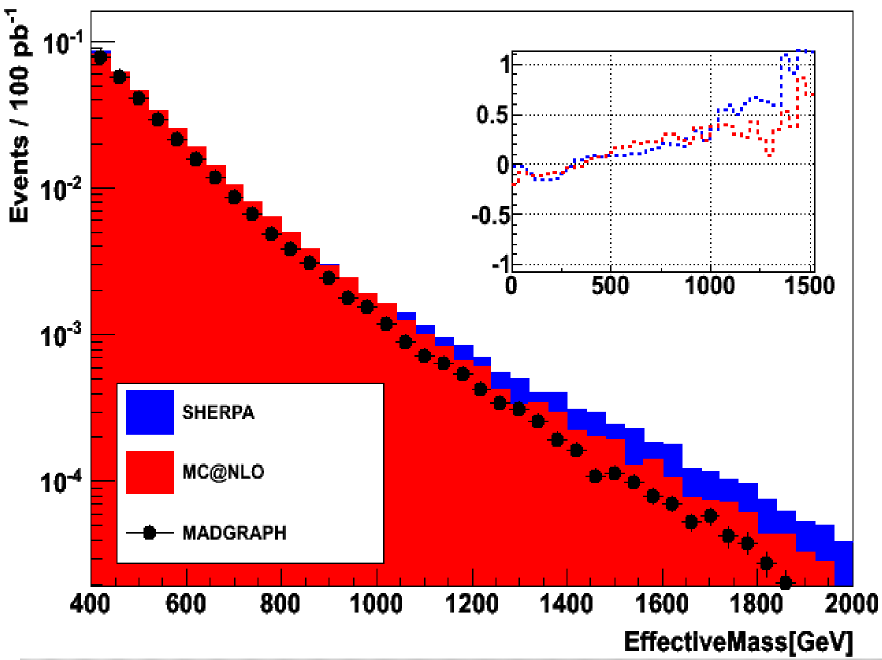
TTBARJETS

Xsections(Pb)	Sherpa (n=1)	Madgraph (n=5)
Ptjet10 GeV	163	296
PtJet30 GeV	206	317
PtJet40 GeV	196	304
Scale Up	178	292
Scale Down	230	336
Larger ISR		317
Smaller ISR		317
MC@NLO(n=1)	369	

Sherpa gives correct NLO shape estimation with CKKW matching schemes. Sherpa xsection has LO accuracy but its shape agree with NLO.

Deviation from Madgraph

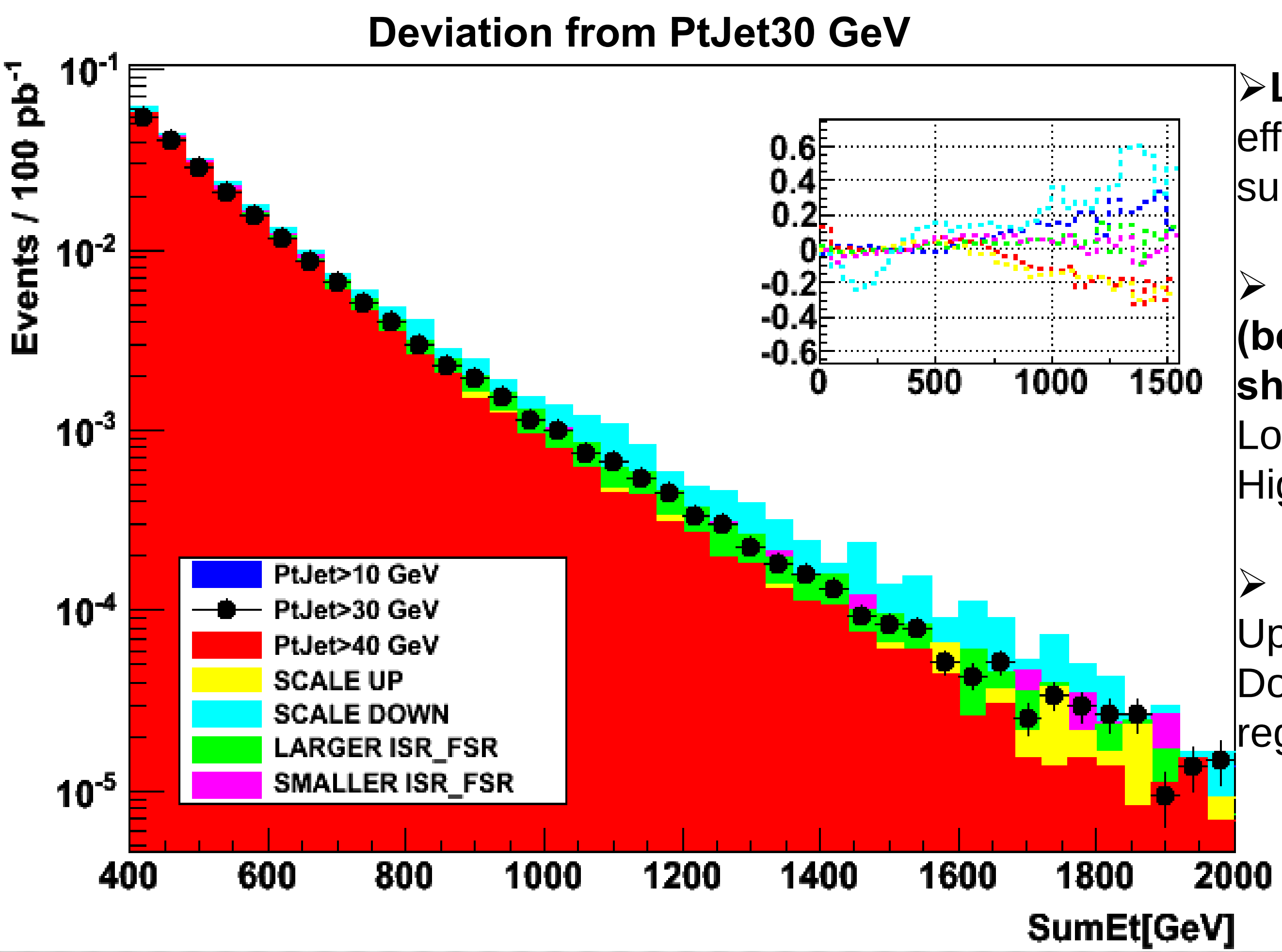




$\text{SumET} = \Sigma_i \text{JetsEt}_i$

$\text{EffectiveMass} = \Sigma_{i=5} \text{Etmiss} + \text{JetsEt}_i$

TTBARJETS -MADGRAPH SYSTEMATICS

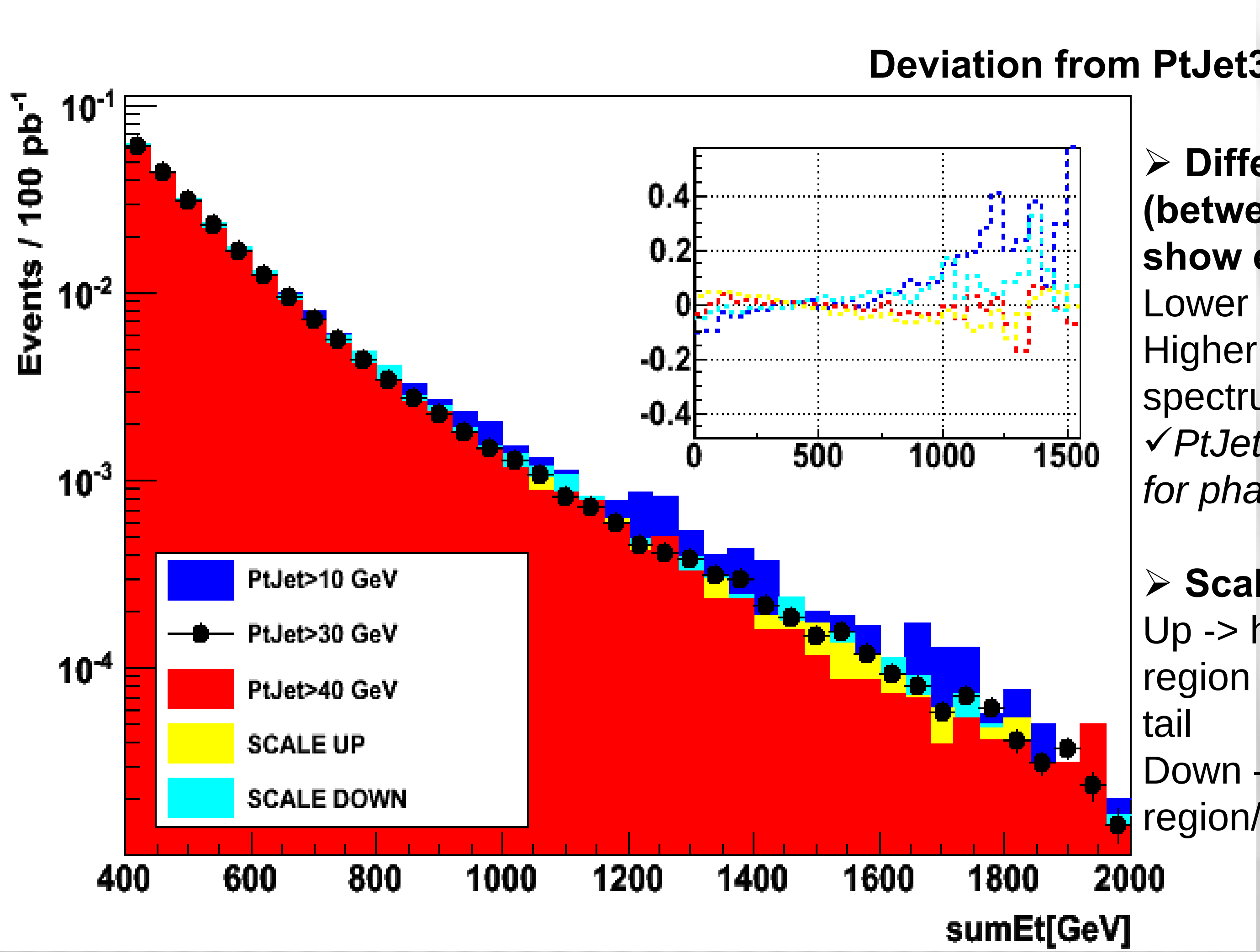


- **Larger/Smaller ISR** radiation effect is almost negligible on sumEt.

- **Different matching scales (between ME+PS) with MLM show effects on tail**
  Lower scale > harder spectrum
  Higher scale > softer spectrum

- **Scale Up/Down effect**
  Up -> softer spectrum on tail
  Down -> softer lower energy region/ harder spectrum on tail

TTBARJETS – SHERPA SYSTEMATICS



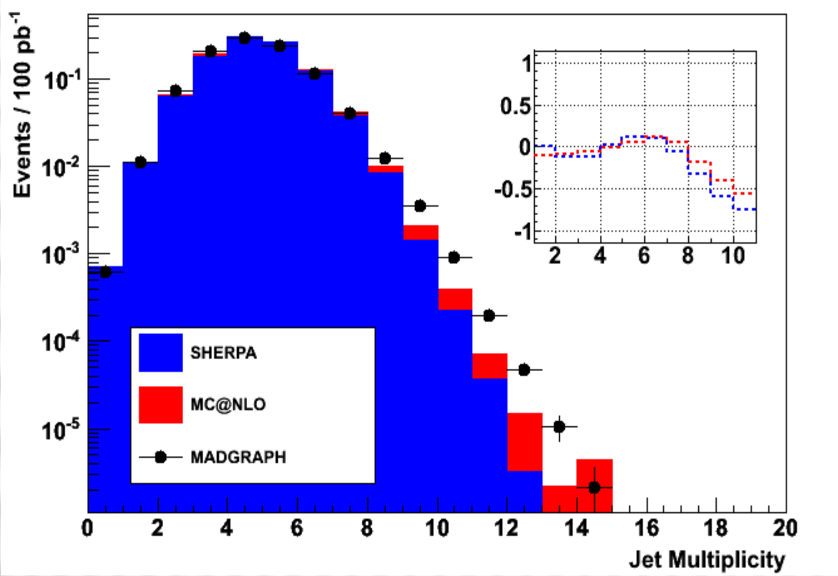
- **Different matching scales (between ME+PS) with CKKW show effects on tail**

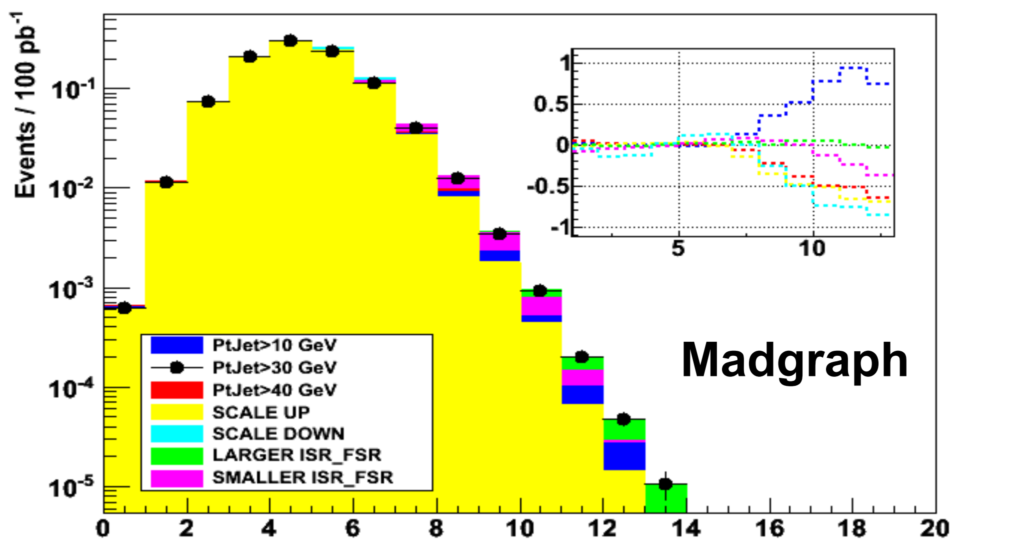
Lower scale > harder spectrum
Higher scale > slightly softer spectrum
✓*PtJet30/40 GeV convenient cuts for phase space*

- **Scale Up/Down effect**

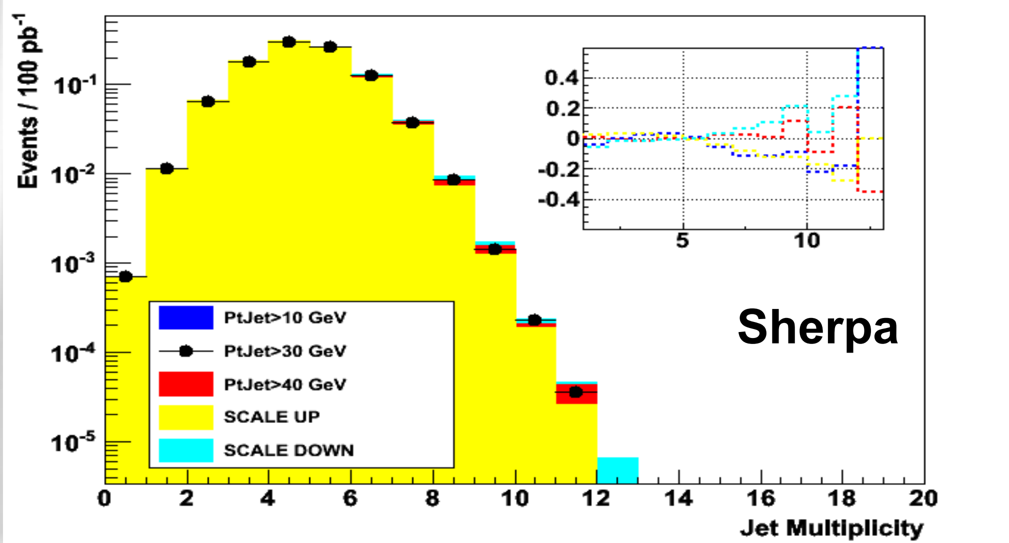
Up -> harder spectrum lower region /slightly softer spectrum on tail
Down -> softer spectrum lower region/ harder spectrum on tail

TTBARJETS – JET MULTIPLICITY

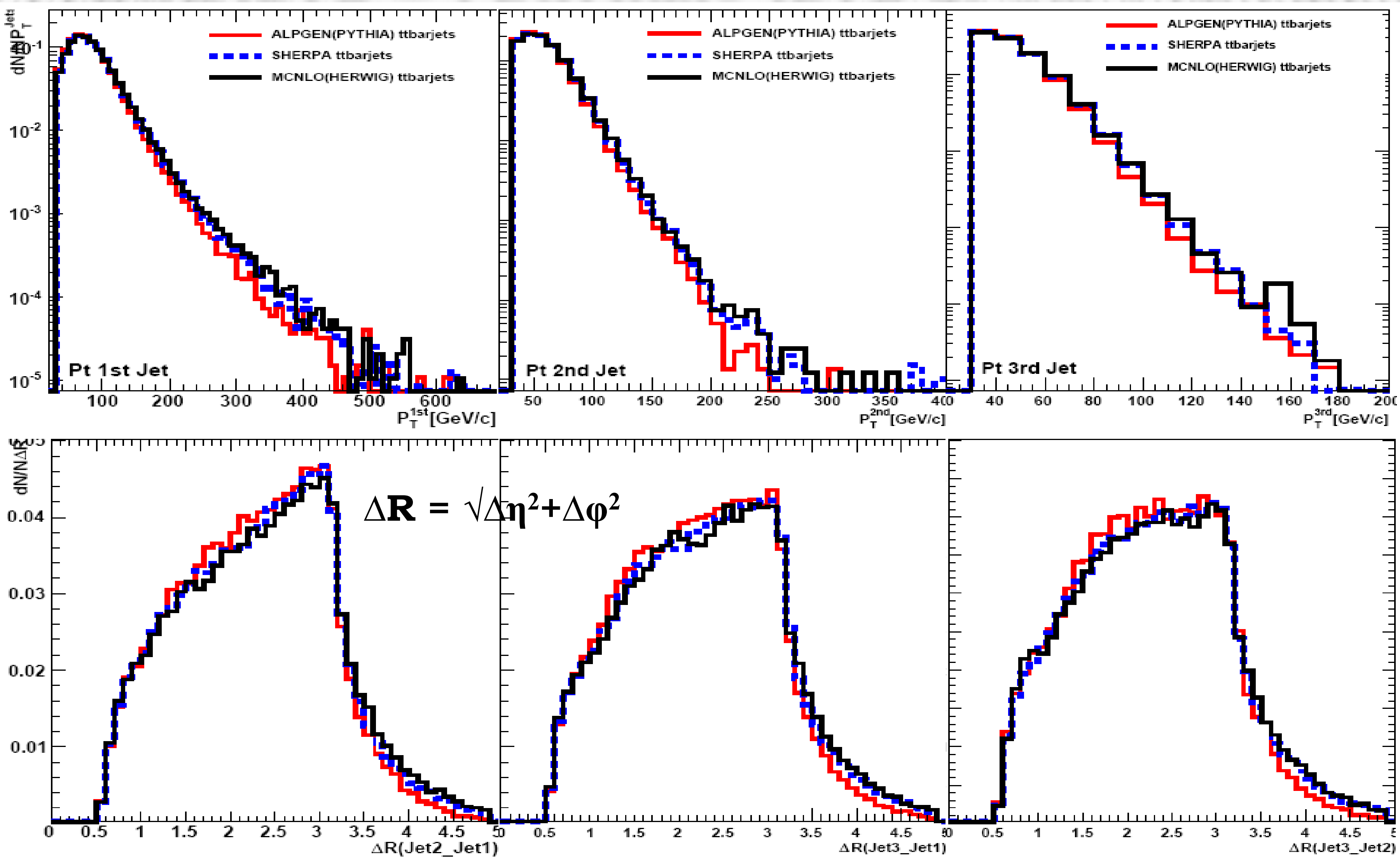




- ➢**Sherpa and MC@NLO** agree up to the eight jets
- ➢**Madgrapgh** has more jets – it seems more jets More jets on parton level – Sherpa less
- ➢**Magraph and MCNLO** are agree each other up to 10 jets
- ➢**Madgraph** Scales Up/Down ,Smaller ISR and PtJet scales are **large** effects on higher jet multiplicity
- ➢ **Sherpa** Scales Up/Down and PtJet are effects on higher jet multiplicity (less than MG)



TTBARJETS – LEADING JETS & ΔR (JETS)



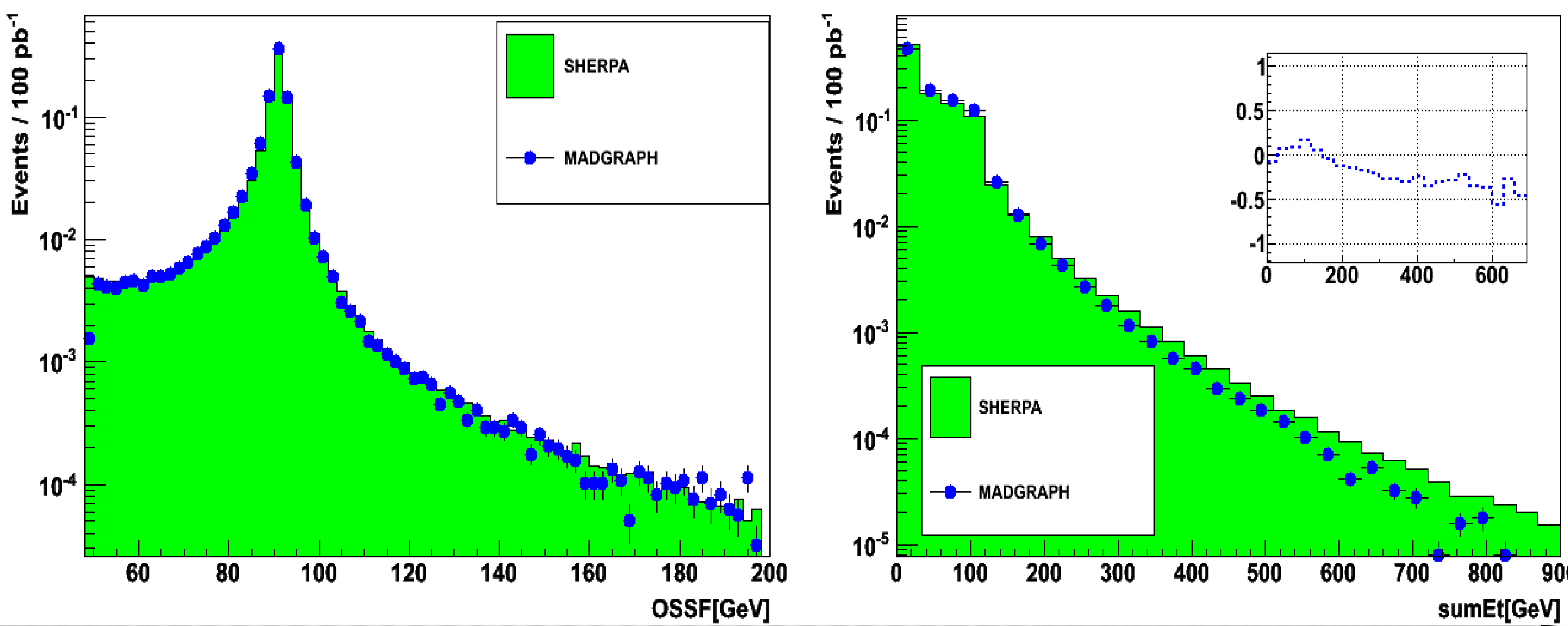
ZJETS

Xsections(Pb)	Sherpa (n=3)	Madgraph (n=5)	Alpgen(n=3)
PtJet30 GeV	3900	3700	3650
Scale Up	3800	3600	---
Scale Down	4100	3900	----

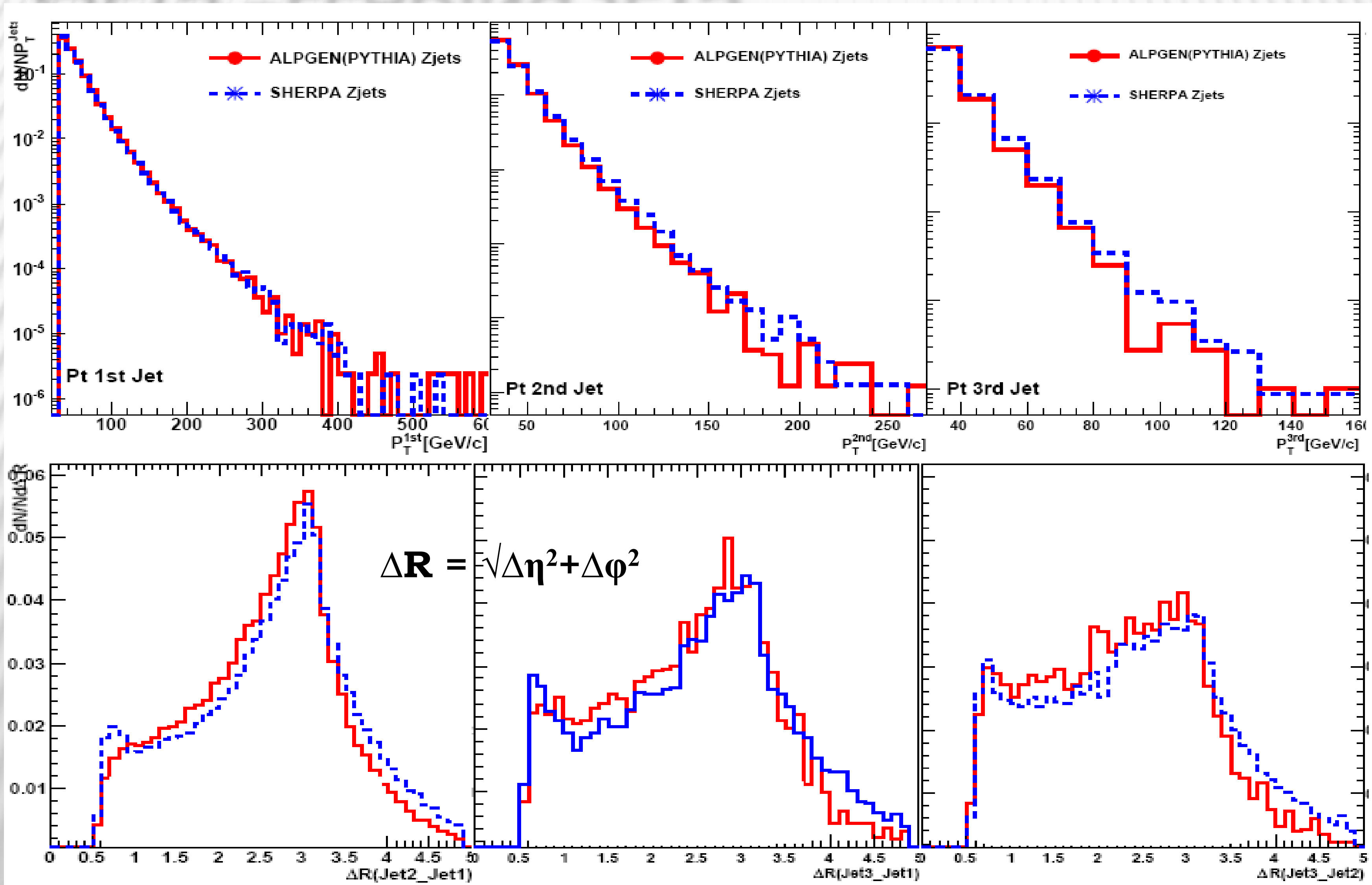
Backup!

OSSF (Opposite Same Sign Flavour) distribution are agree well on Sherpa and Madgraph. Sherpa SumEt distribution is harder than Madgraph spectrum – NLO shape?

Deviation from Sherpa

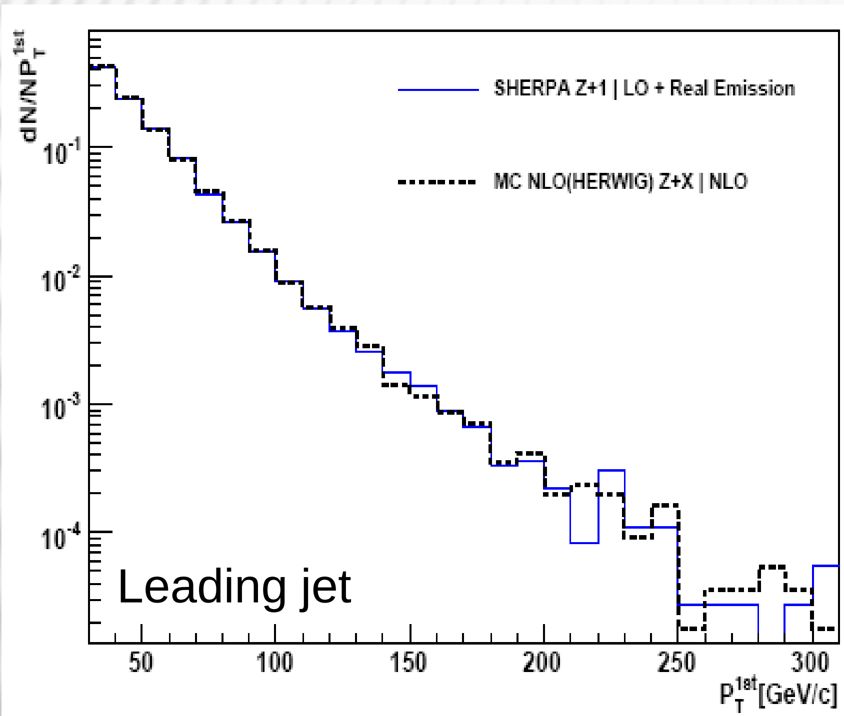


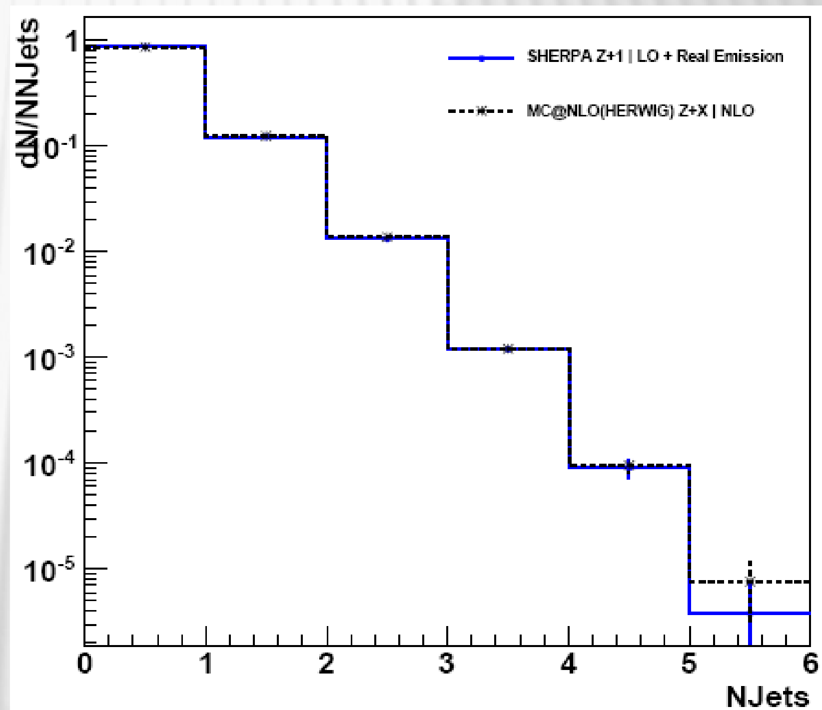
ZJETS – LEADING JETS



Z+X LEADING JET – NLO NORMALIZATION

- The Sherpa-MC method seems to reproduce the NLO shapes for W/Z plus jets production at LHC. It defines first jet correctly. Sherpa and MC@NLO have **one jet** on matrix element. Sudakov rescaling works perfectly on Sherpa.





LO + Real Emission vs NLO normalization

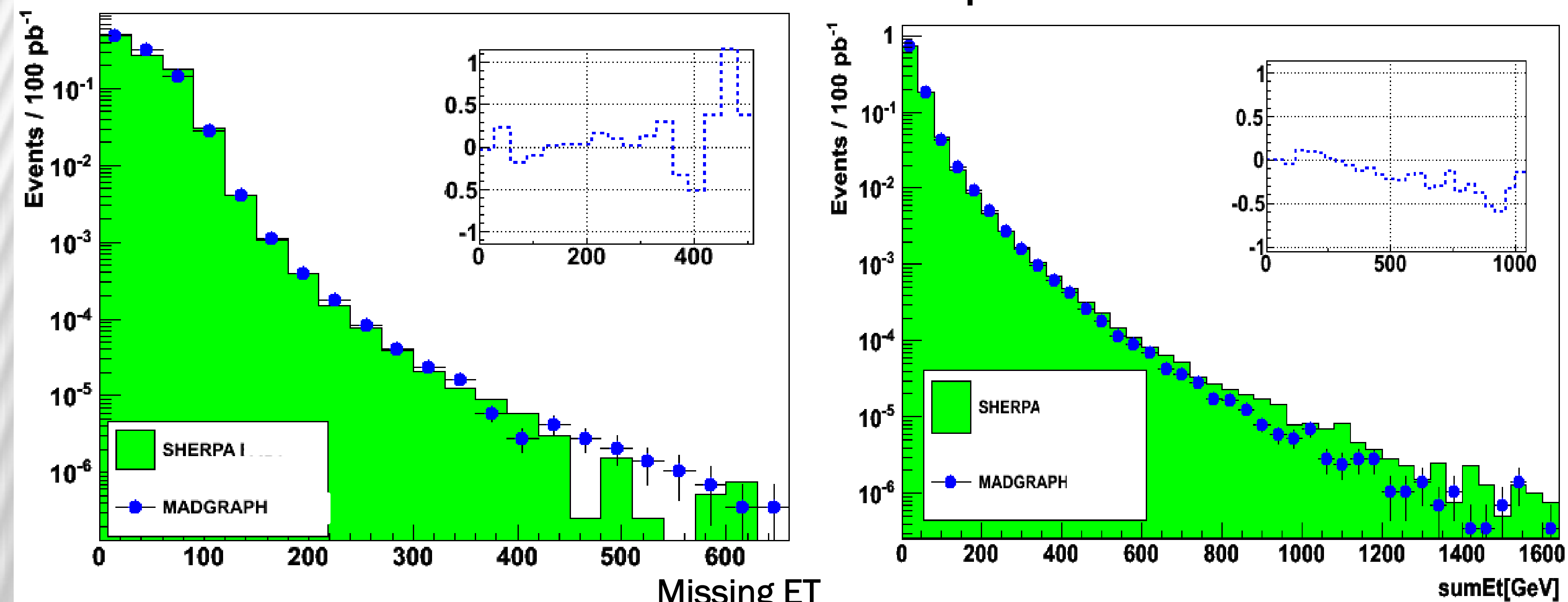
WJETS

Xsections(nb)	Sherpa (n=3)	Madgraph (n=5)	Alpgen(n=3)
PtJet15 GeV	42.1	--	---
PtJet30 GeV	40.9	40	39.4
Scale Up	39.6	38.7	---
Scale Down	42.6	41.5	----

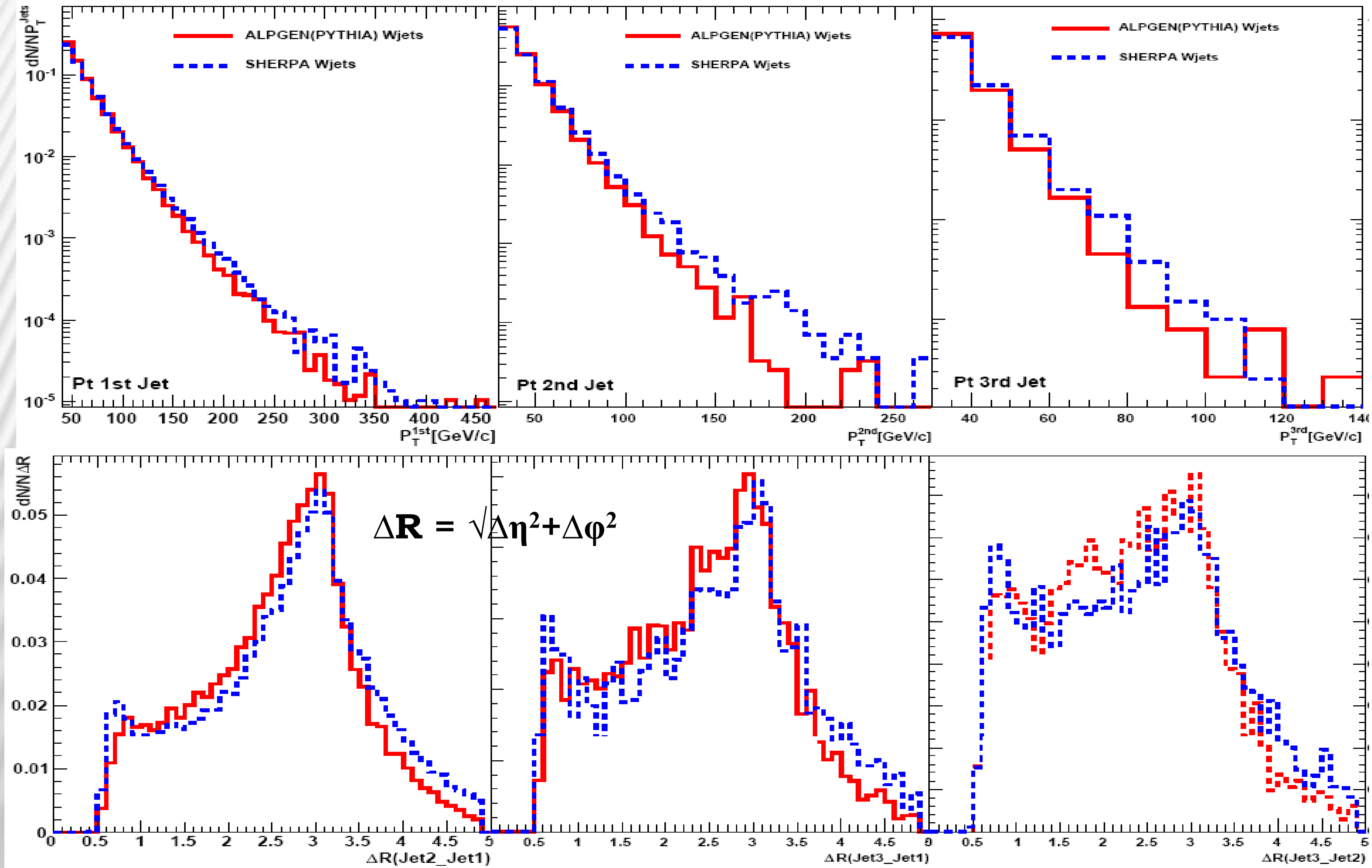
Backup!

Sherpa has harder spectrum on SumEt. **Madgraph** has slightly harder spectrum on missing transverse energy – more partons from ME.

Deviation from Sherpa

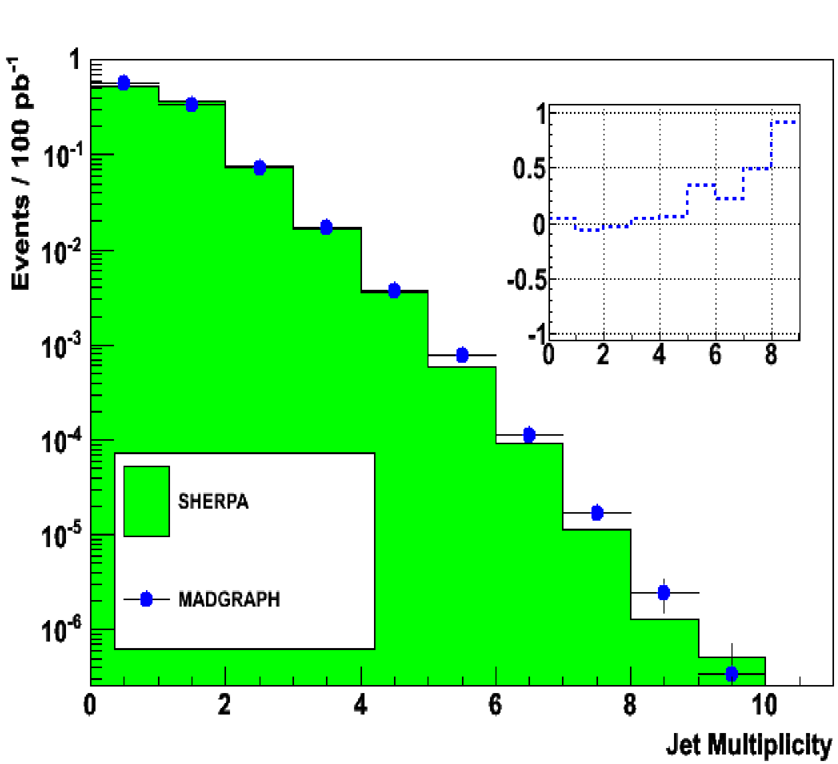


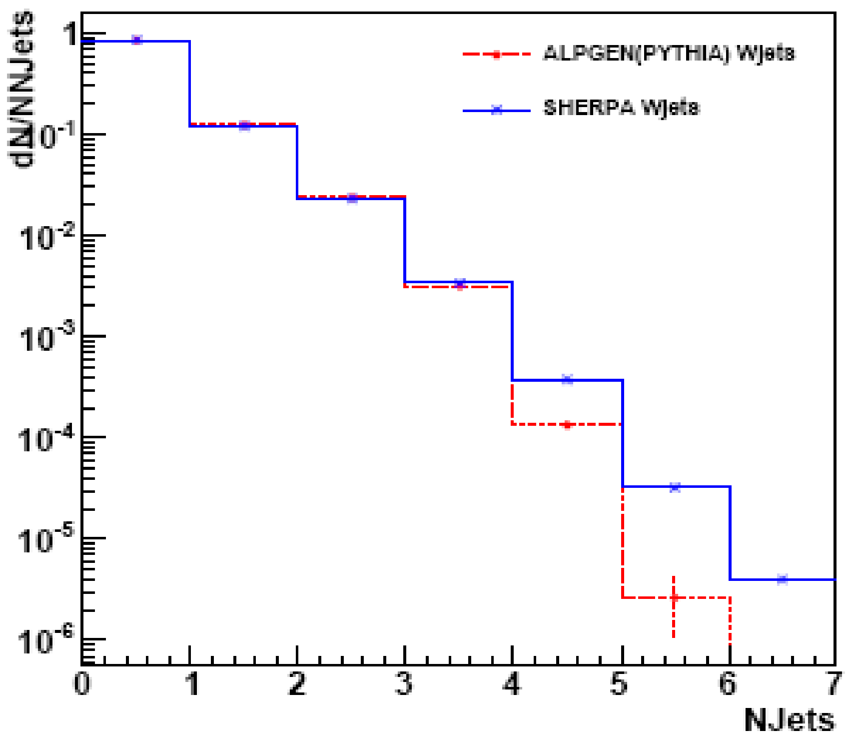
WJETS – LEADING JETS



WJETS – JET MULTIPLICITY

Sherpa , Alpgen and Madgraph are agree up to 4-5 jets (parton level jets) . Madgraph has harder spectrum comparing to the Sherpa and Alpgen MC generators since it has more partons at matrix element calculation. Sherpa has harder spectrum than Alpgen with same number of partons at matrix element.





WJETS –SYSTEMATICAL EFFECTS

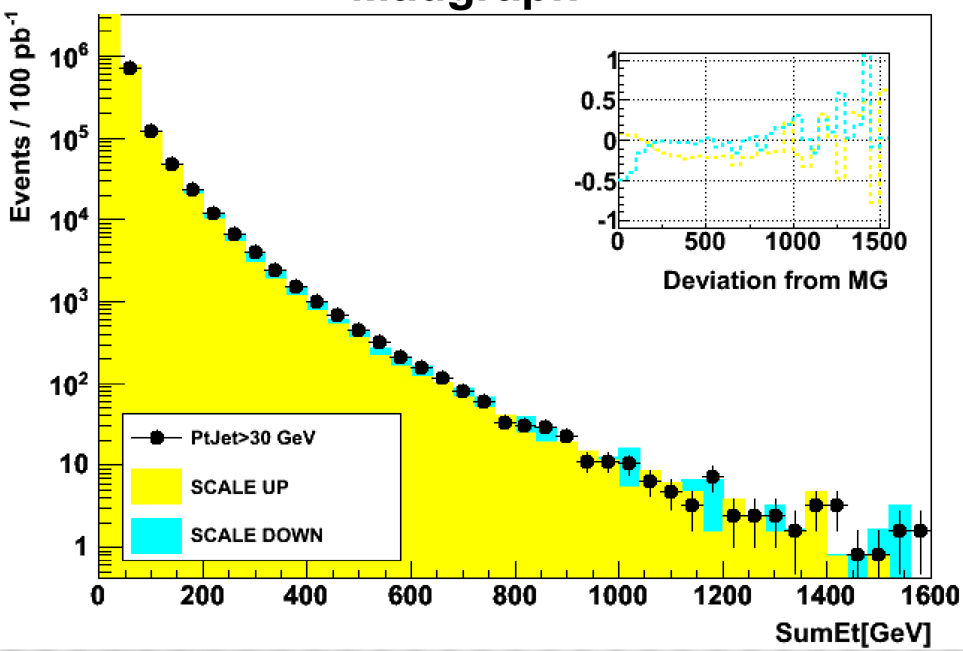
- **Scale Up/Down effect**

Up -> softer spectrum on tail
Down -> softer lower energy region/ harder spectrum on tail

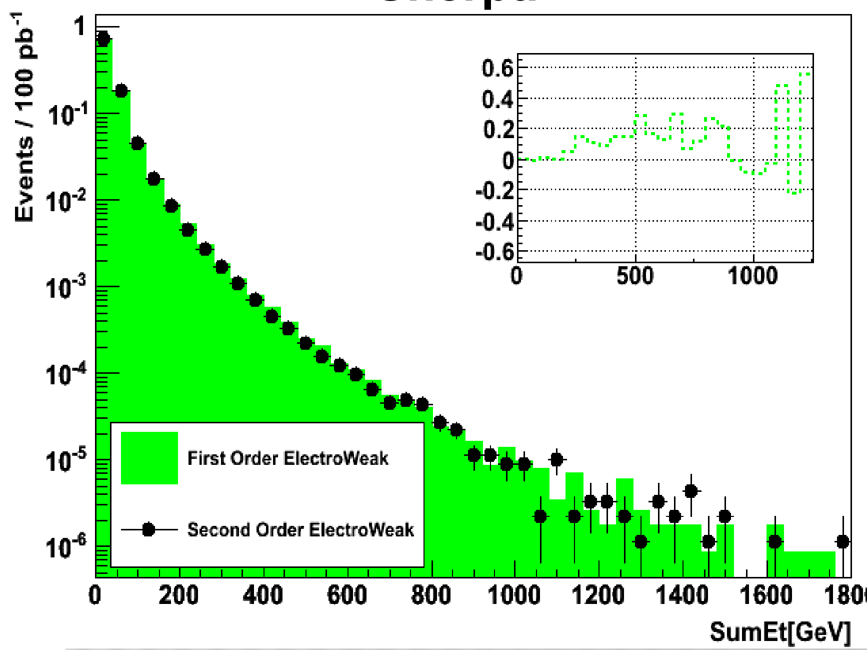
- **Electroweak correction**

First Order -> softer spectrum 10-20%

Madgraph



Sherpa

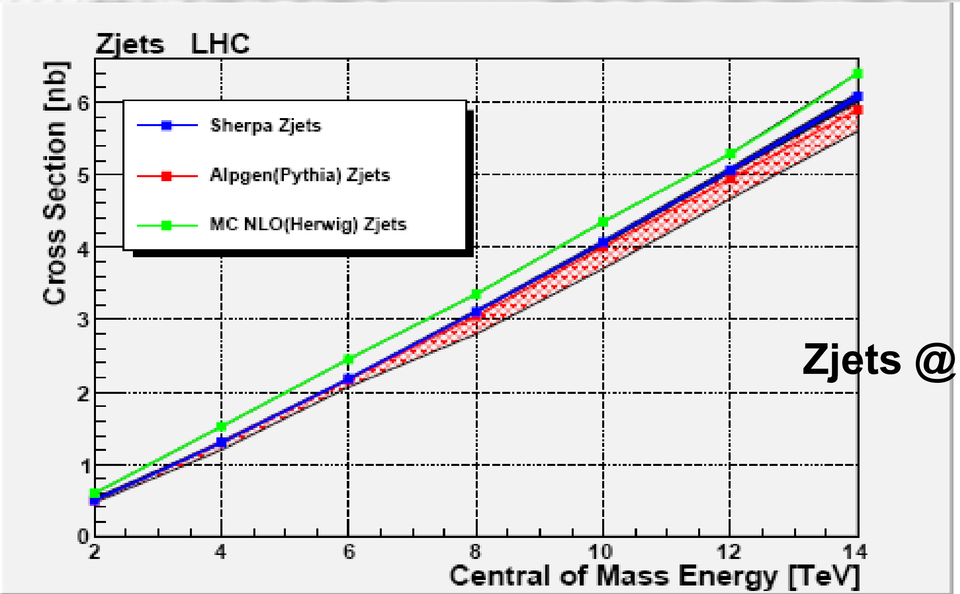


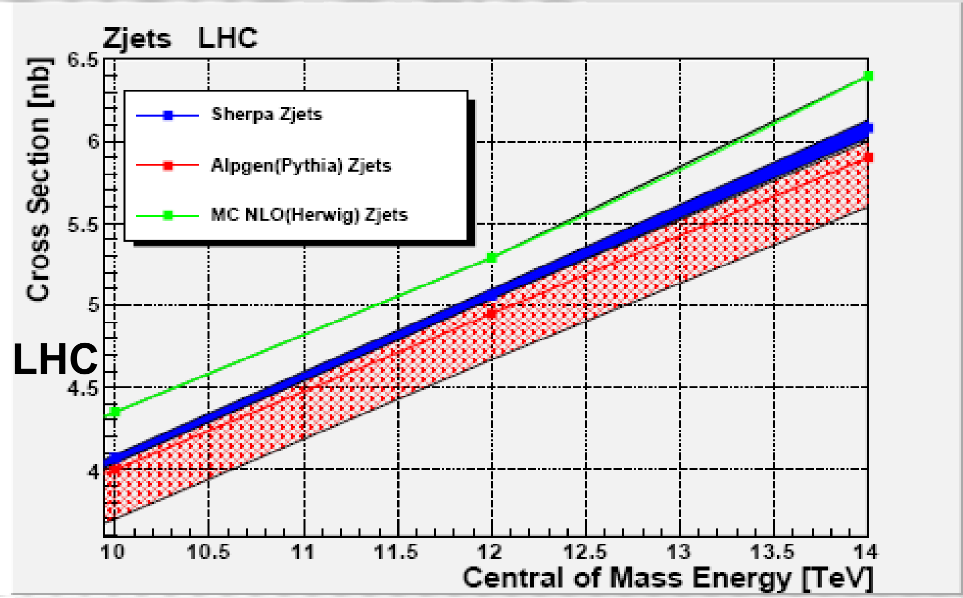
SUMMARY

- Starting with **ttbar/Z/W jets SumEt** distribution, we find trivial %10-30 effects of the different MC approaches, scale changes and ISR effects, with variation of scales leading to a softer/harder spectrum on tails. **The leading jets** for Alpgen/Madgraph and Sherpa agree on distributions for Z/W/ttbar jets. Sherpa has slightly harder jet spectrum than Alpgen/Madgraph. **Jet multiplicities** agree on MC –generators with small differences on higher jet multiplicities –showering effects. - Sherpa has NLO shape normalization comparing with NLO approach – LO + Real Emission / NLO normalization

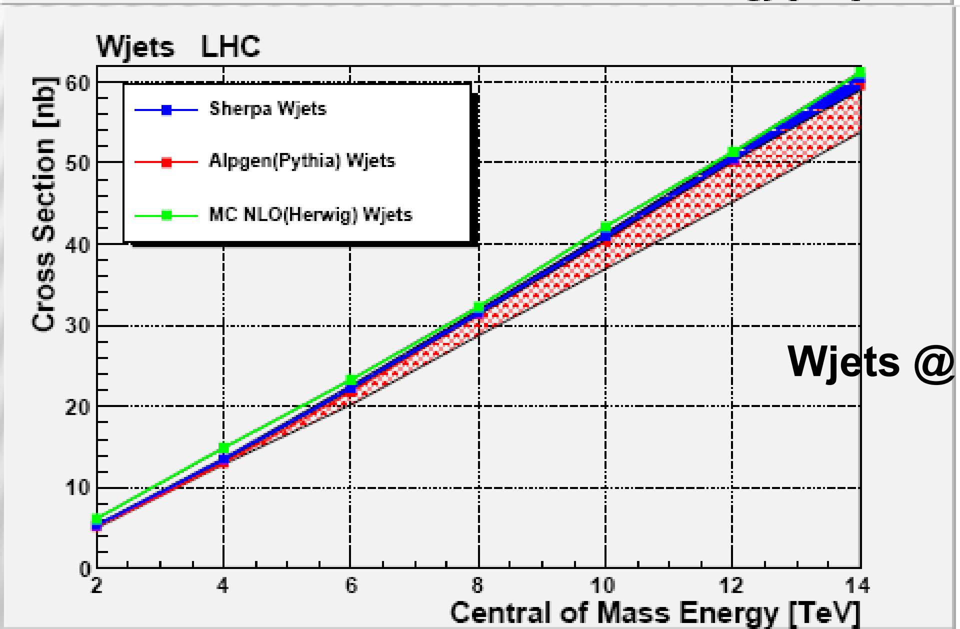
- **Systematical effects on distributions** – Sensitivity to scale changes in Madgraph/Alpgen larger than in Sherpa (presumably because Sherpa compensates scaling effects in α_s and cross sections using Sudakov rescaling for each event, while Madgraph/Alpgen compensate scaling effects in α_s only by a matrix reweighting)

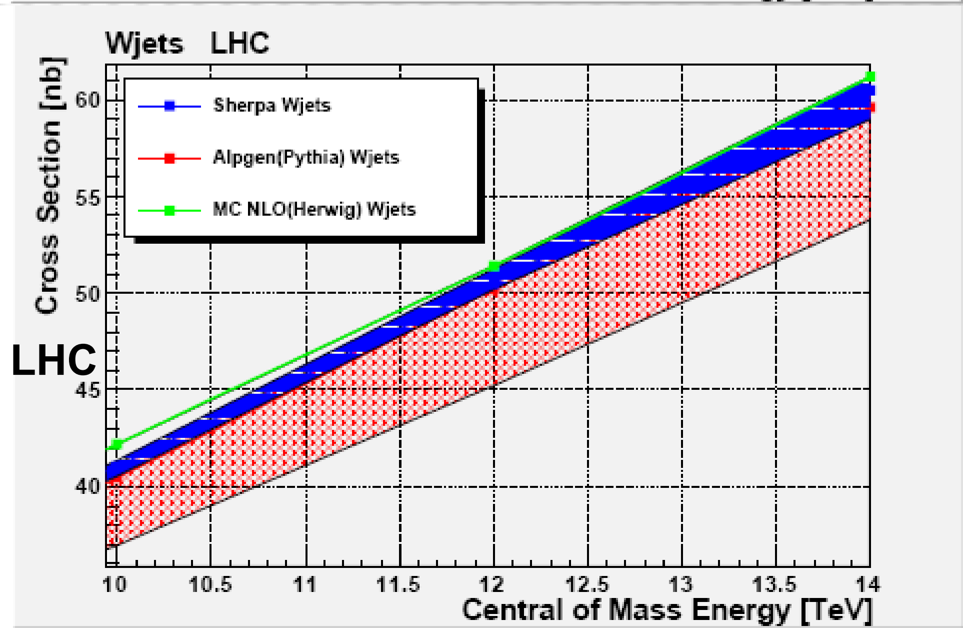
BACKUP – CROSS SECTIONS @ LHC





Zjets @ LHC





Wjets @ LHC