Modeling Uncertainties on Mtop (CDF summary)

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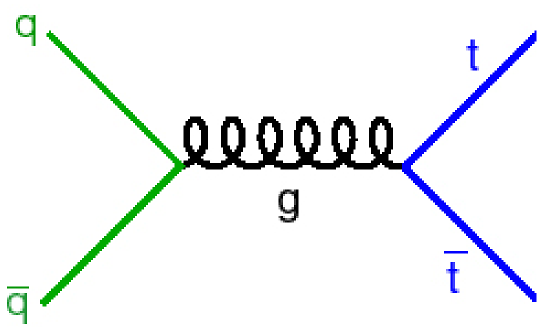
Signal modeling

Hard Scattering



$$f(x_1,u) \otimes f(x_2,u) \otimes \hat{\sigma}(q\bar{q} \rightarrow t\bar{t}(\alpha_s(u/\Lambda))$$

- PDFs, scales, qq vs gg, LO vs NLO

Signal modeling

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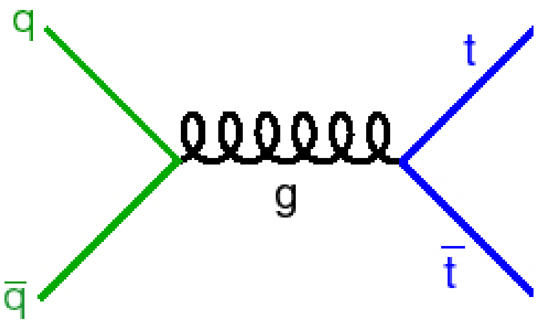

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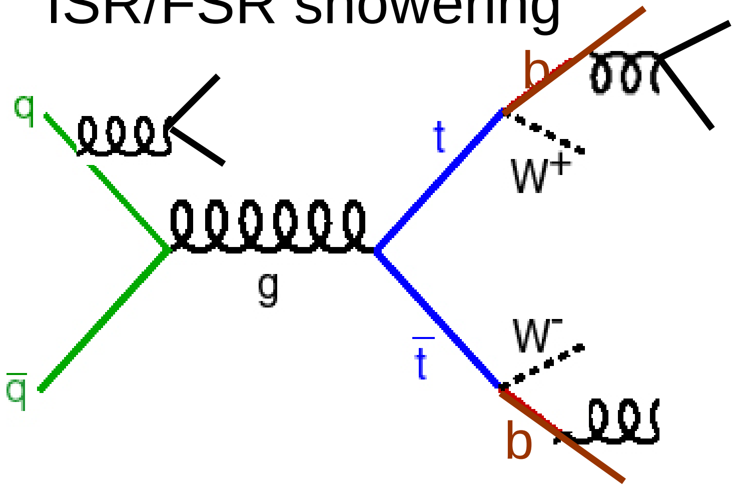
- PDFs, scales, qq vs gg
  LO vs NLO

ISR/FSR showering



$$\alpha_s(u/\Lambda)P_{q\rightarrow qg}(x/y,u)\otimes f(x,u)$$

- PDFs, scales, extra jets, modified b & W daughter jets due to FSR

Hadronization & jets

- Jet response (light, b-jets)

See Florencia & Pekka's talks

Signal modeling

Sources	Effects	
PDFs	hard-scattering	ISR showering
NLO	hard-scattering	extra hard jets
Q^2 Scale (fac/ren)	hard-scattering	ISR & FSR
Parton-showering		ISR & FSR
Hadronization (fragmentation)		Jet response (not in this talk)

Top Signal MCs

	PYTHIA	HERWIG	ME	MC@NLO
Hard scatt.	LO tt	LO tt	LO tt+njet	NLO tt
PS shower (ISR/FSR)	coherent branching	coherent branching	Pythia or Herwig interface (double counting problem, can be fixed by the CKKW)	Herwig v.6.505
Hadronization	LUND string	cluster model		
Underlying evts	beam-beam remnants, MPI	Beam-beam remnants. MPI(Jimmy)		
Spin corr	NO	Yes	Yes	No

- Default: HERWIG 6.505 LO
- Syst.: PYTHIA, MC@NLO, ALPGEN

CDF Methodology

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- PDFs: reweighting method at hard-scattering level

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- Data driven ISR/FSR syst.: ISR/FSR shower algorithm itself , but also different ISR/FSR due to PDFs and scale, a part of the NLO effect
- PDFs: reweighting method at hard-scattering level
- NLO: MC@NLO vs HERWIG LO
- Generator difference (including hadronization) HERWIG vs PYTHIA

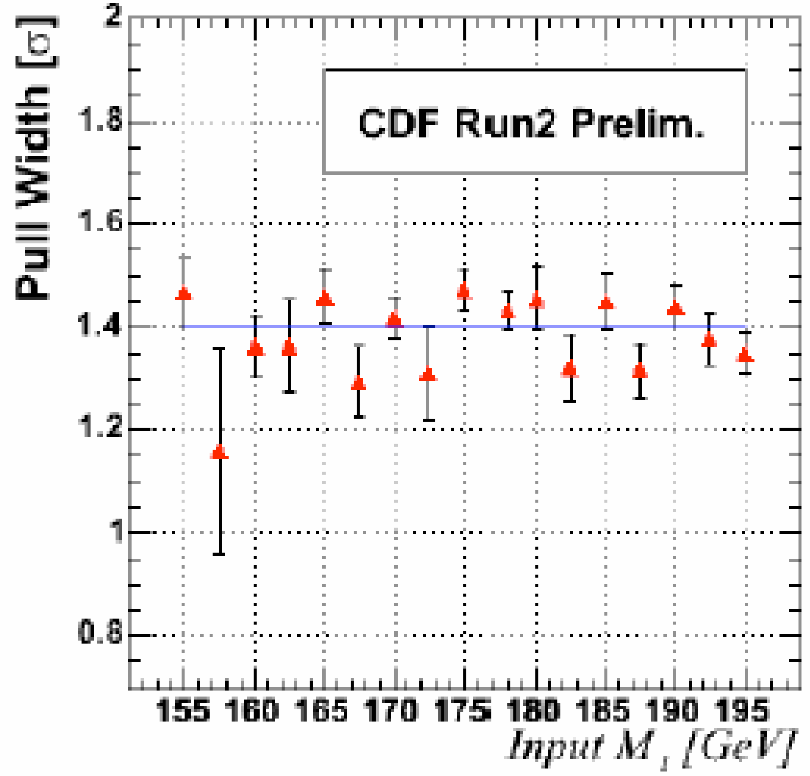
Summary on syst. errors

Systematic	Lepton+Jets		Dilepton
	Template	ME	ME
JES	(2.5)	3.0	2.5
b-jet modeling	0.6	0.6	0.5
ISR	0.4	0.4	0.5
FSR	0.6	0.5	0.5
PDFs	0.3	0.5	1.1
Generators	0.2	0.3	1.0
Bkgd shape	0.5	0.6	0.8
b-tagging	0.1	0.2	
MC statistics	0.3		1.5(bkgd)
Method	0.5	0.2	0.6
Total	1.3 (2.8)	3.2	3.6

- No additional syst. due to the NLO effect
- Template vs ME in lepton+jets: very similar

Side effect of the imperfect ME calculation (Matrix Element Method)

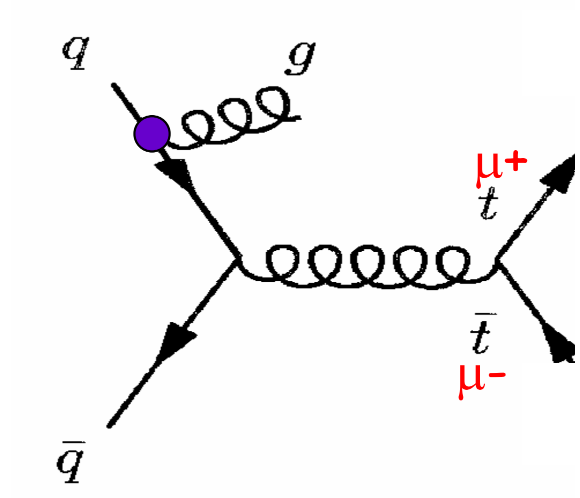
- Imperfect ME calculations
  - No initial state radiation (pt(ttbar)=0)
  - Final state: lepton & jet directions are well measured
  - No extra FSR jets (lepton+jet)
  - Jets are b-jets (dilepton)
- Final error is scaled up by 1.4 (dilepton ME)



Pull width: dilepton ME

ISR syst. in $t\bar{t}$ system?

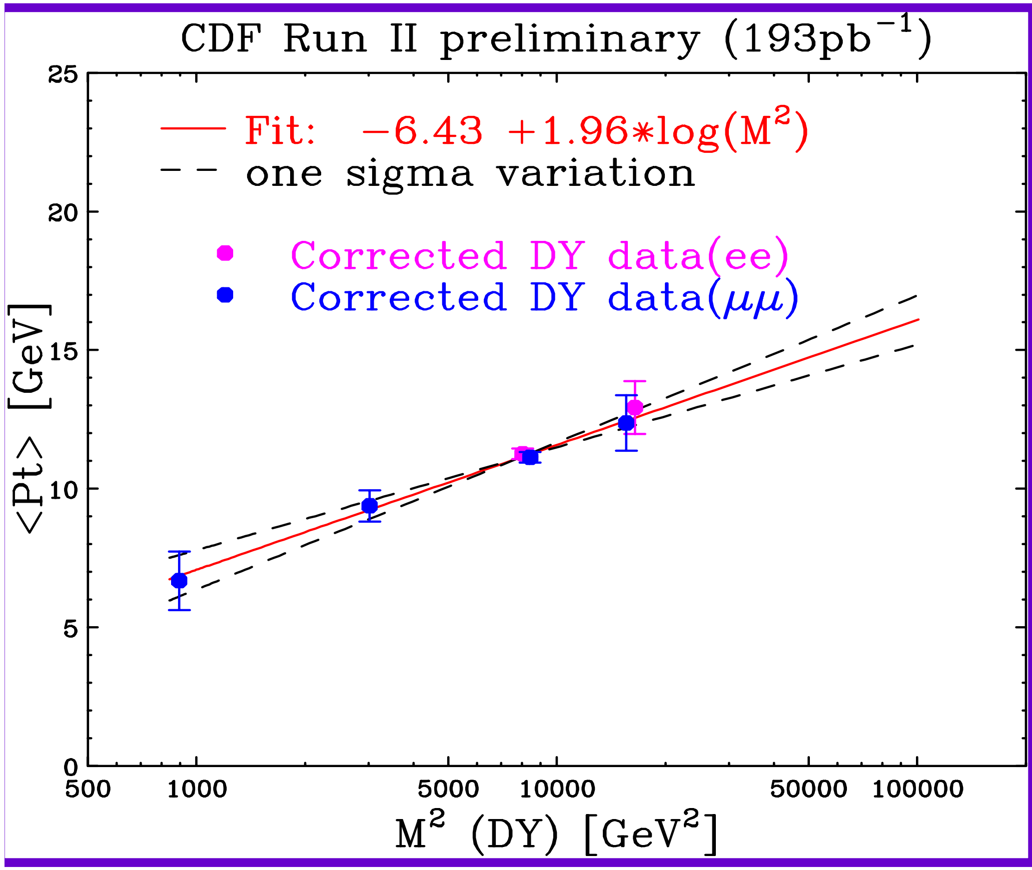
- New approach
  - ISR is governed by DGLAP eq.: Q^2, Λ_{QCD}, splitting functions, PDFs
  - Use DY data (no FSR): study Pt of the dilepton, Njets for different mass regions (~different Q^2)

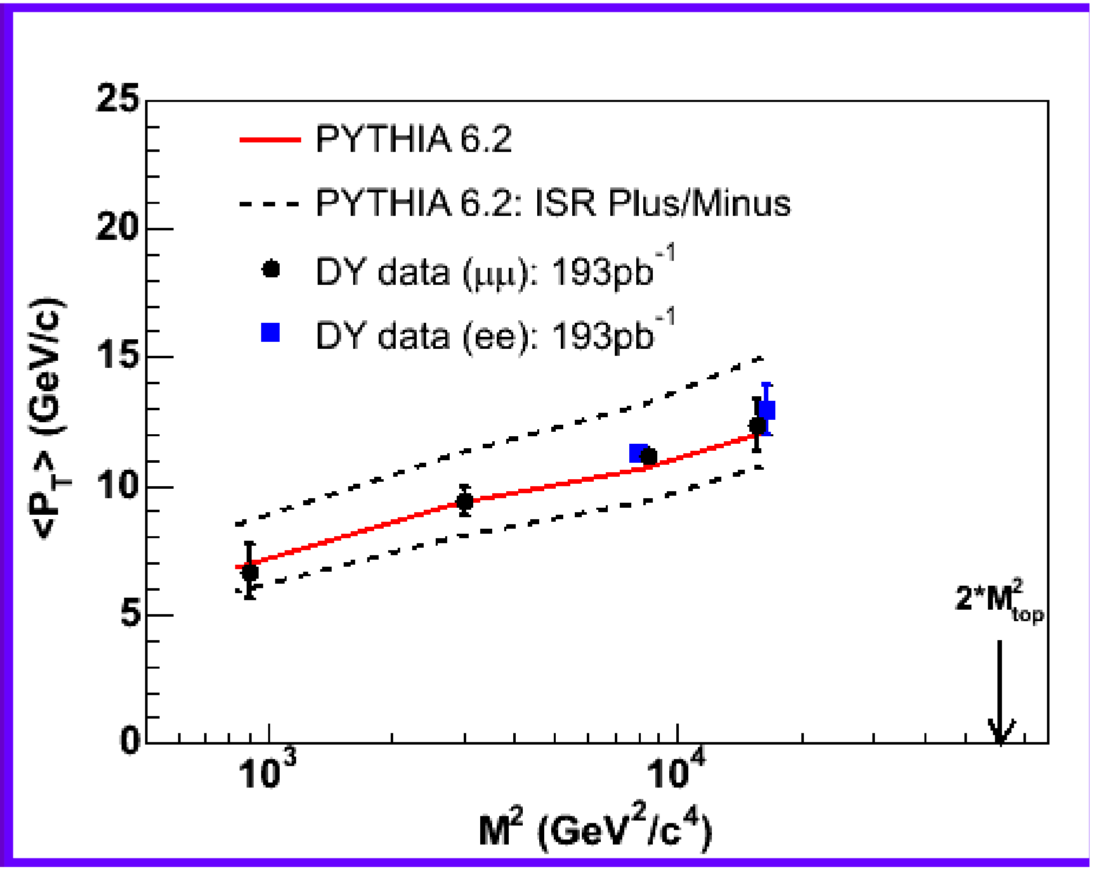


$q\bar{q}$ -> $t\bar{t}$(85%)

$$\frac{dq(x,Q^2)}{d\ln Q^2} = \int \frac{dy}{y}\alpha_s\left(\frac{Q^2}{\Lambda^2_{QCD}}\right) P_{q\to qg}\left(\frac{x}{y},Q^2\right) q(y,Q^2)$$

<Pt (dilepton)> as a function of M^2(ll)

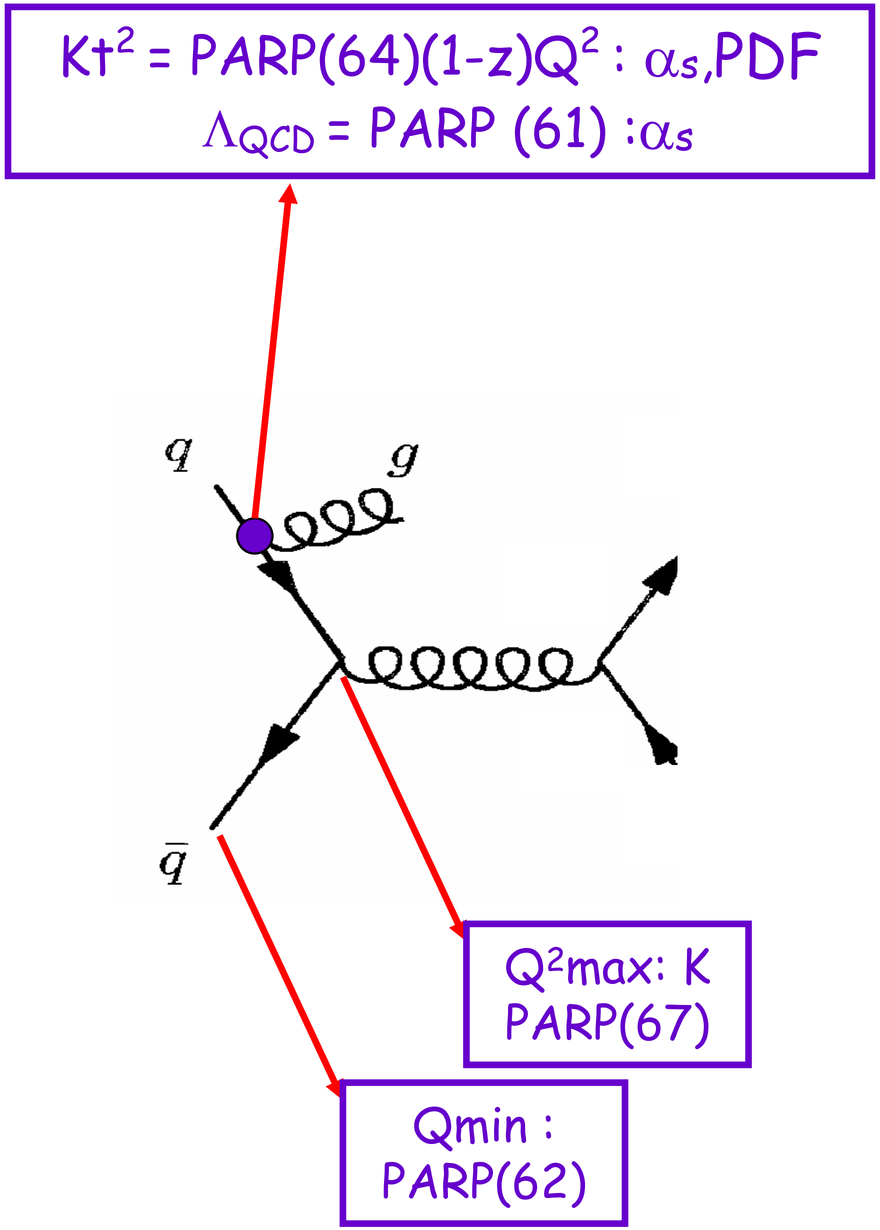




- A good logarithmic Q^2 ($\sim M^2$) dependence is observed.
- Conservative ISR syst. (plus/minus) for ttbar are established
  - <Pt(dilepton)>: sensitive to only total size of ISR, but missing Njet
  - Extrapolate to top pair production region using LO MC

ISR uncertainty

Pythia	ISR more	ISR less
PARP(61) (D=0.146)	0.292 (5 flavour)	0.073
PARP(64) (D=1.0)	0.25	4.0
PARP(67) (D=1.0)	4.0 (Tune-A)	



FSR syst. in $t\bar{t}$ system

- FSR syst. is based on the ISR syst. studies
  - Both ISR and FSR have same parton shower process (DGLAP), except that the PDF evolution is only involved in ISR showering.

Pythia	FSR plus (Top std)	FSR minus (Top std)
PARP(72)	0.292 (5fl: LO)	0.073
PARP(71) D=4	8	2.0

Default FSR syst:
No change in color singlet
(including resonance decay)
Constrained by LEP data

Pythia	FSR plus (Top cntrl)	FSR minus (Top cntrl)
PARP(72)	0.292	0.073
PARJ(81) D=0.290	0.580 (4fl: LO)	0.145
PARP(71)	8	2.0

Even allow variation
in color singlet
(conservative)

NLO effect on top pair production

- Use MC@NLO: Parton shower MC (like PYTHIA, HERWIG), but the partonic hard processes are calculated up to the full NLO QCD corr.
  - Only sensible way to compute K factor event by event.
  - Pythia and HERWIG LO MC are poor for multi-jets
  - ME (ALPGEN, MadGraph) are fine for multi-jets, once double counting problem is removed using CKKW or MLM, but still LO accuracy (K factor still necessary)

- Size of the extra hard gluon emission due to NLO?

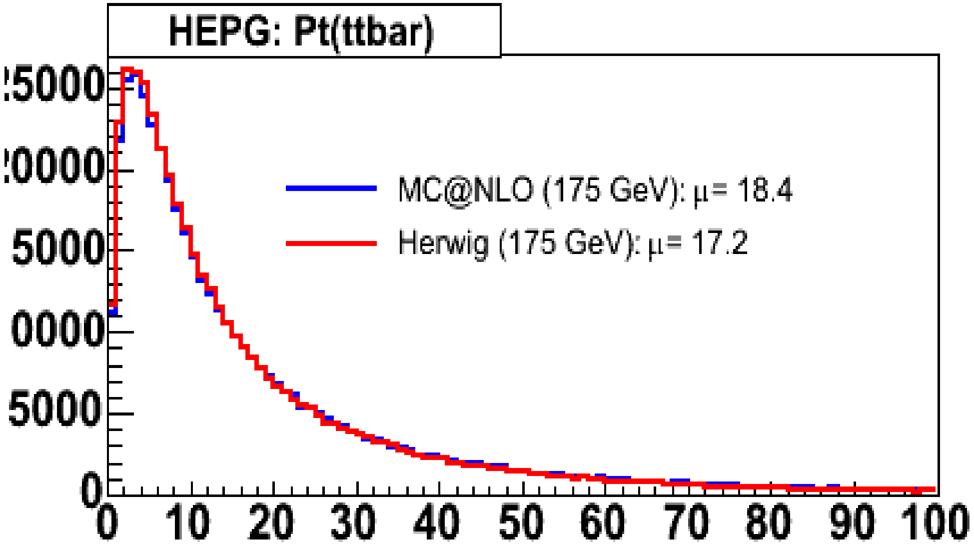
  - How much is the NLO effect covered by the ISR/FSR syst?

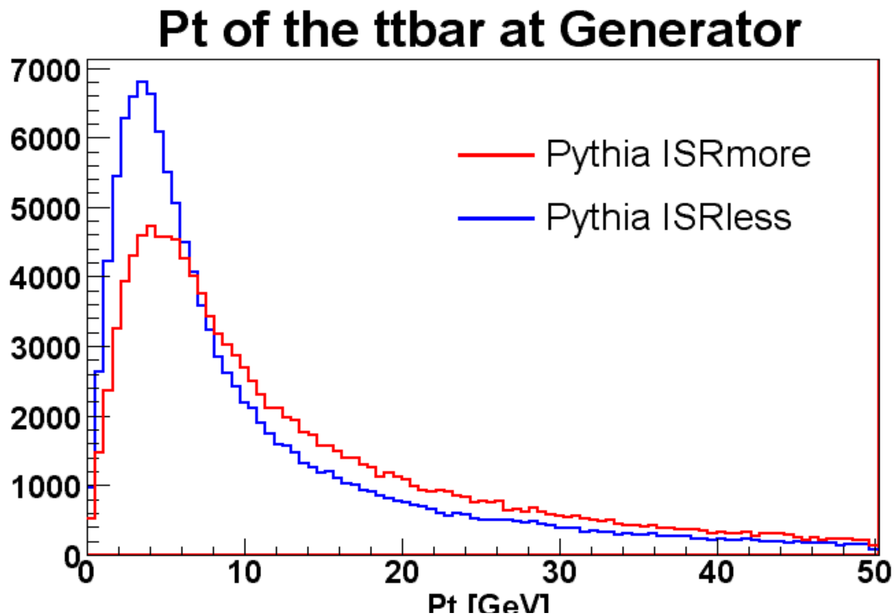
- Different production rate for qq vs gg, but gg has a higher acceptance (more ISR jets)
  - CTEQ5 LO (5.5% gg fraction) :
  - CTEQ5 NLO (14.3% gg)

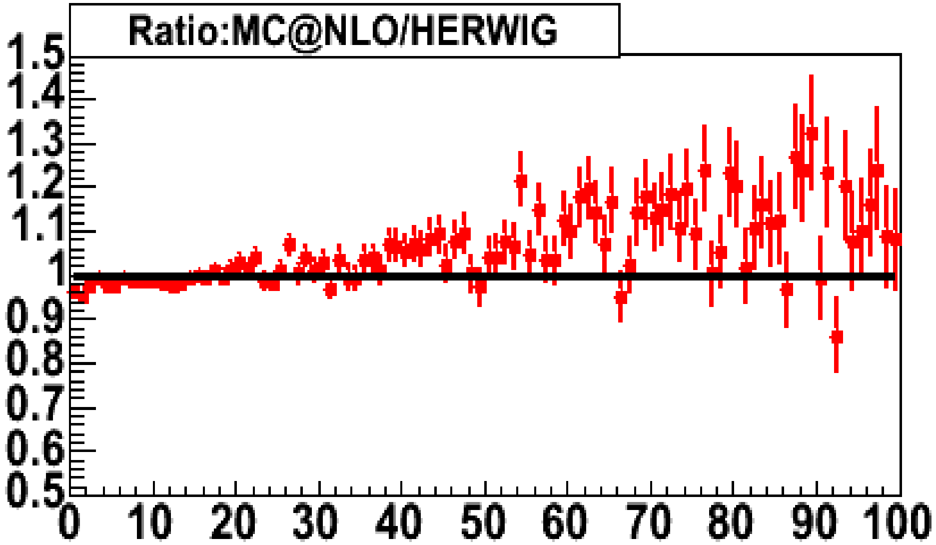
A brief summary on the comparison of MC@NLO and HERWIG

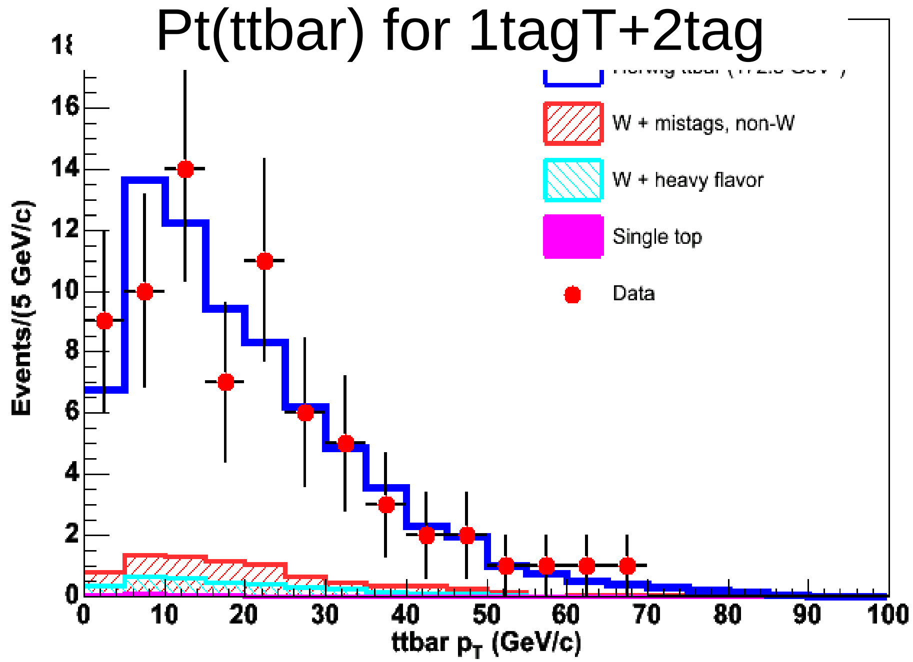
- MC@NLO (Mtop=175 GeV, no spin-corr) vs HERWIG (spin-corr on)
- NLO vs ISR/FSR syst.?
  - Pt(ttbar), Njets(loose): most of effects seem to be covered by the ISR/FSR syst.
- Comparison at HEPG level
  - NLO effect at the Tevatron is small.
  - Pt(ttbar): good agreement, but harder at Pt~100 GeV by 10%
  - Njets (loose jets): increased by 10% at Njet~7.
  - Pt(top): good agreement except very low Pt and high Pt regions
  - Pt of W,b and leading jet Et: all good agreement
  - More tops from gg channel are produced in plug region

Pt of $t\bar{t}$: NLO vs ISR syst.

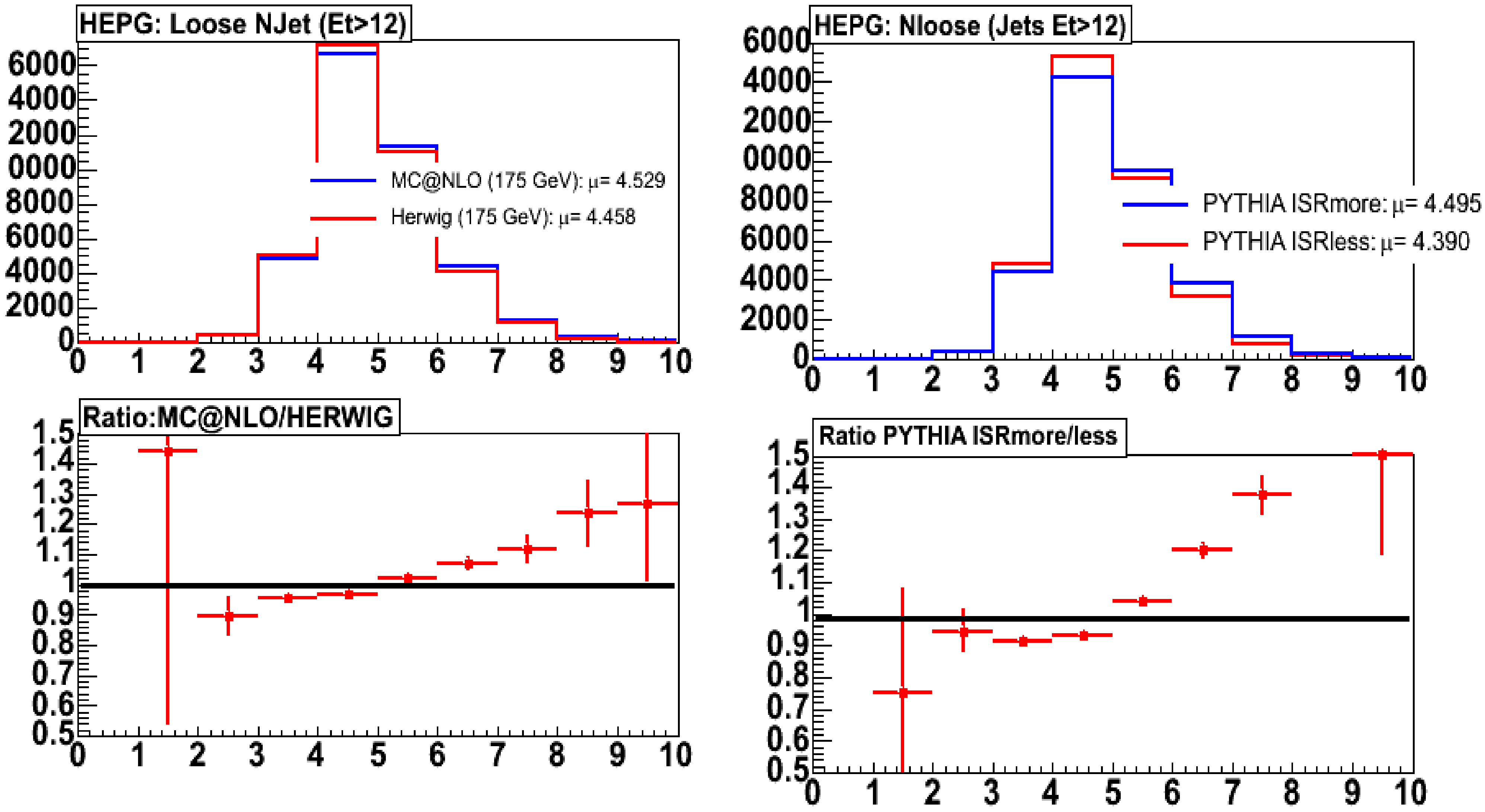




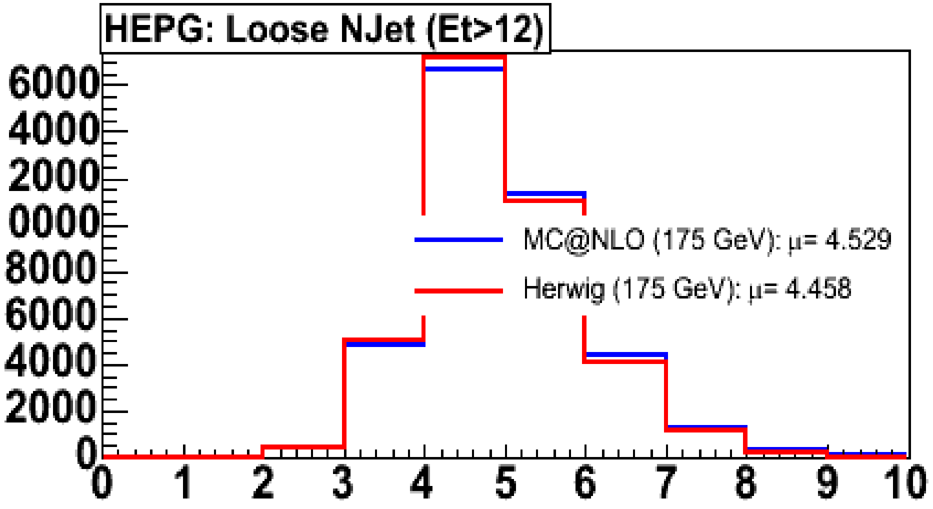


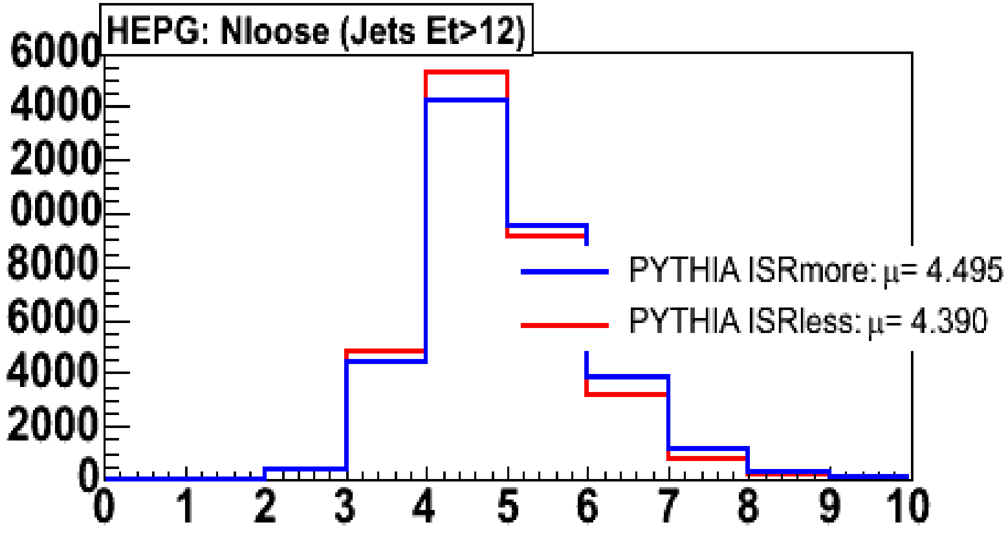


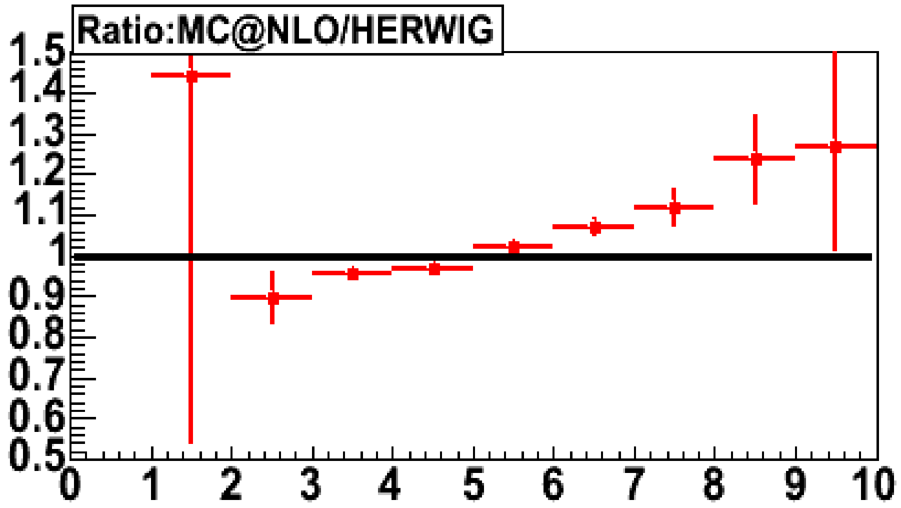
Njets (Et>12 GeV at HEPG particles)
NLO vs ISR syst.



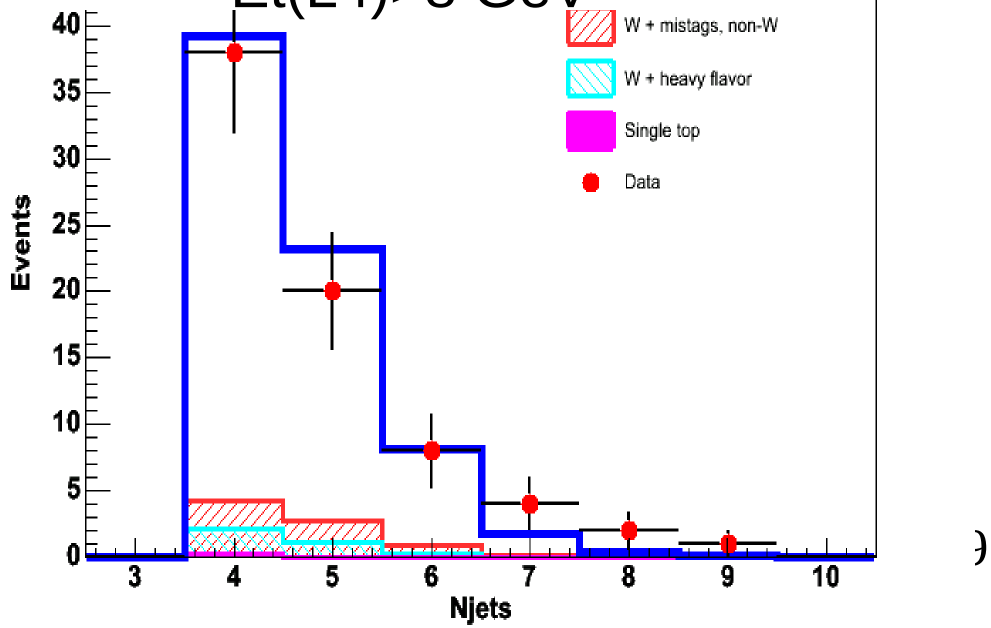
Njets (Et>12 GeV ~ 8 GeV at L4)
NLO vs ISR syst.



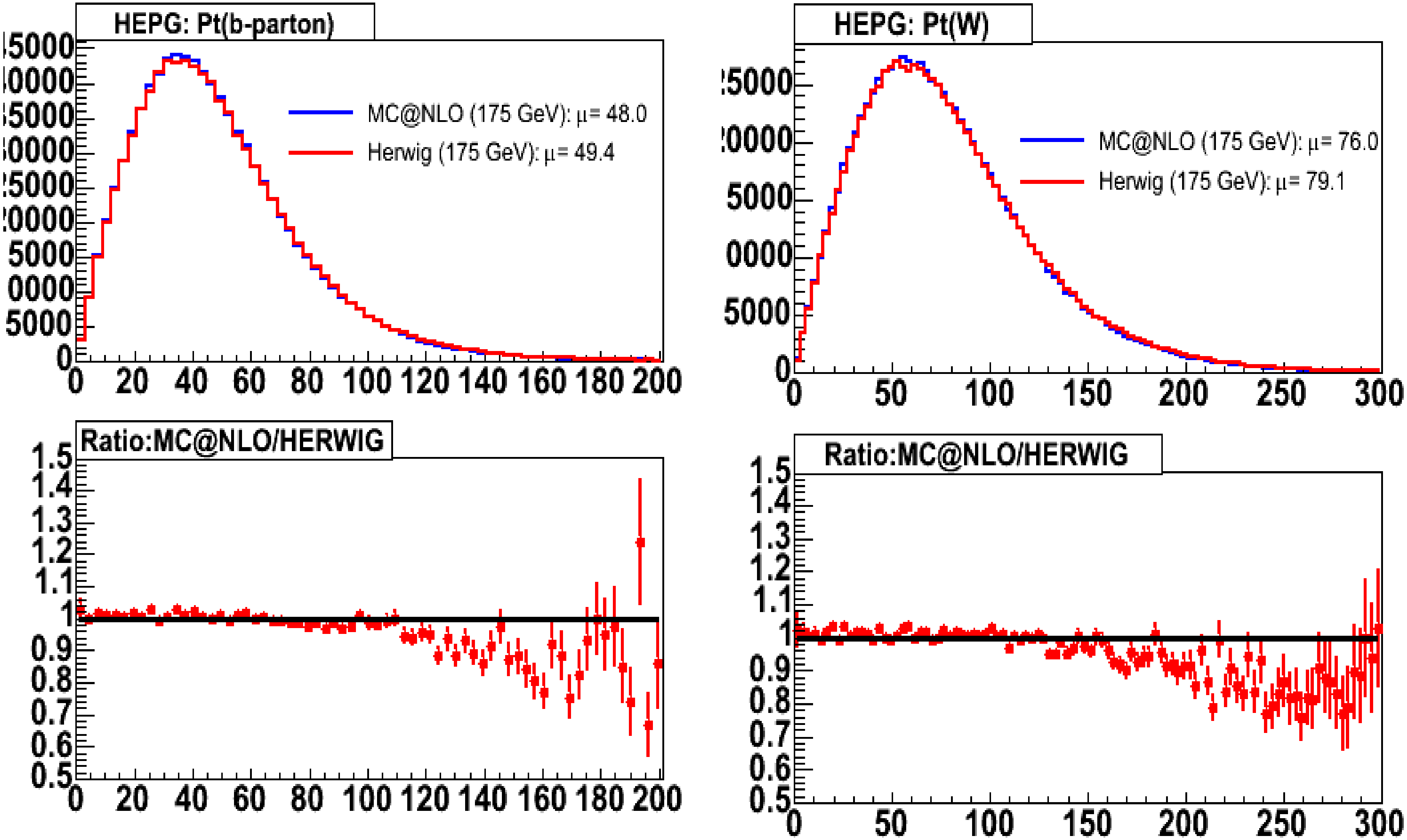




Njets for 1tagT+2tag:
Et(L4)>8 GeV



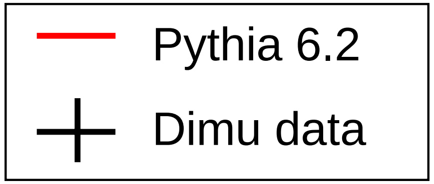
Pt of b-parton and W



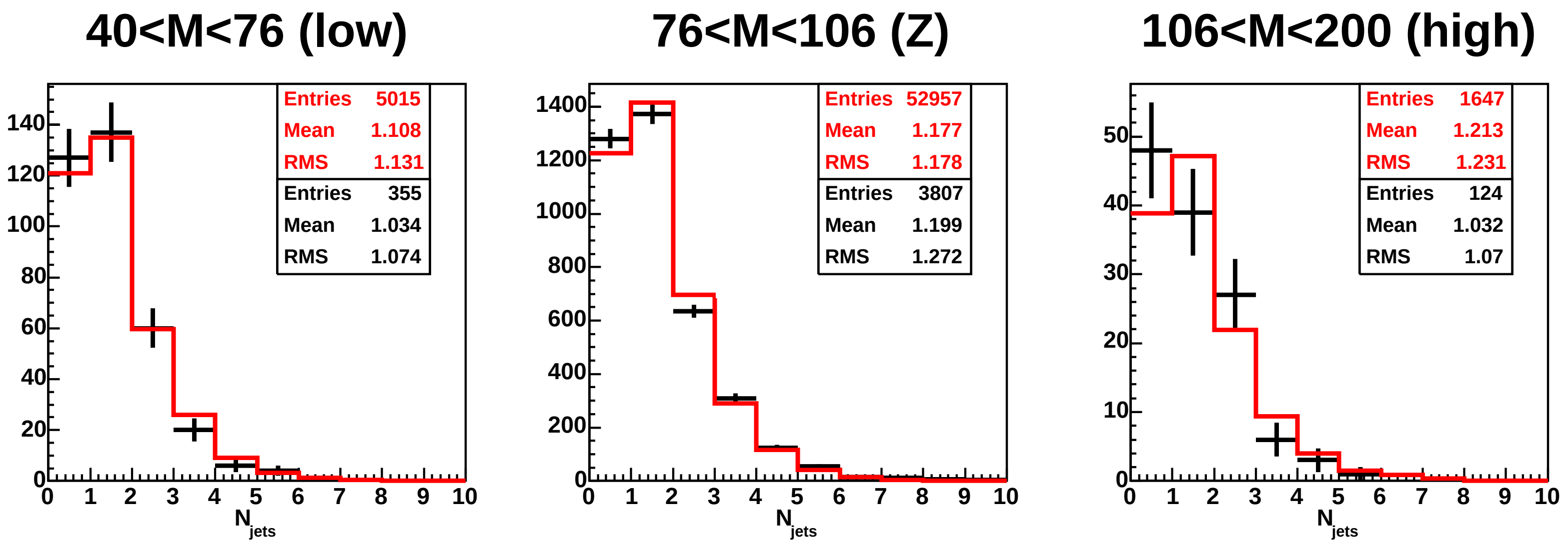
How can we improve the ISR/FSR/NLO syst.?

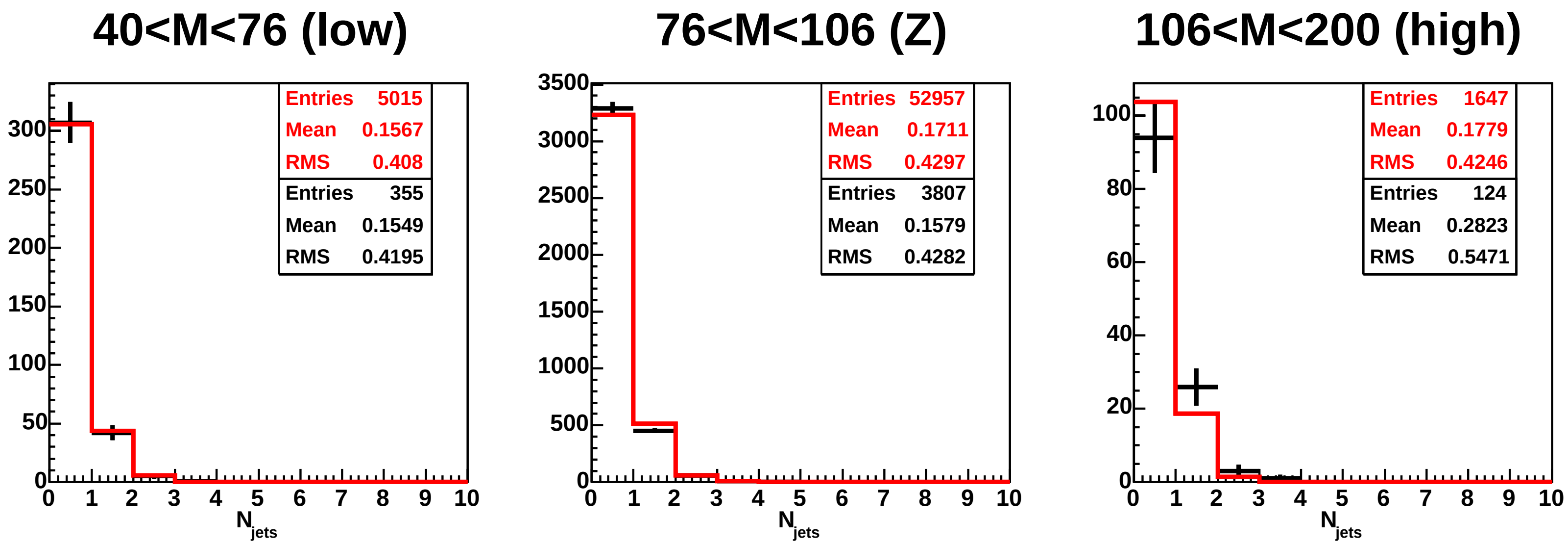
- Update on the ISR studies
  - More DY data are added. (total 340pb-1)
  - Njet, $\delta\phi$(ll) distributions are included: good agreement with Pythia and data
  - Q^2 dependences on Njet, $\delta\phi$(ll) are under studies.
  - Low-pt DY data need to be added
- Future improvement
  - Comparison of the ttbar data (with 1fb-1 data) with various MCs (MC@NLO, CKKW ALPGEN, MadGraph ttbar + Njets)
  - Especially helpful in pinning down FSR syst.
  - FSR uncertainty (outside cone) is a double counting with another jet syst. (out-of-cone correction)
  - Study with Pythia 6.3

N_{jets} Distribution



$4 < E_T < 15$ GeV
(Soft Jets)

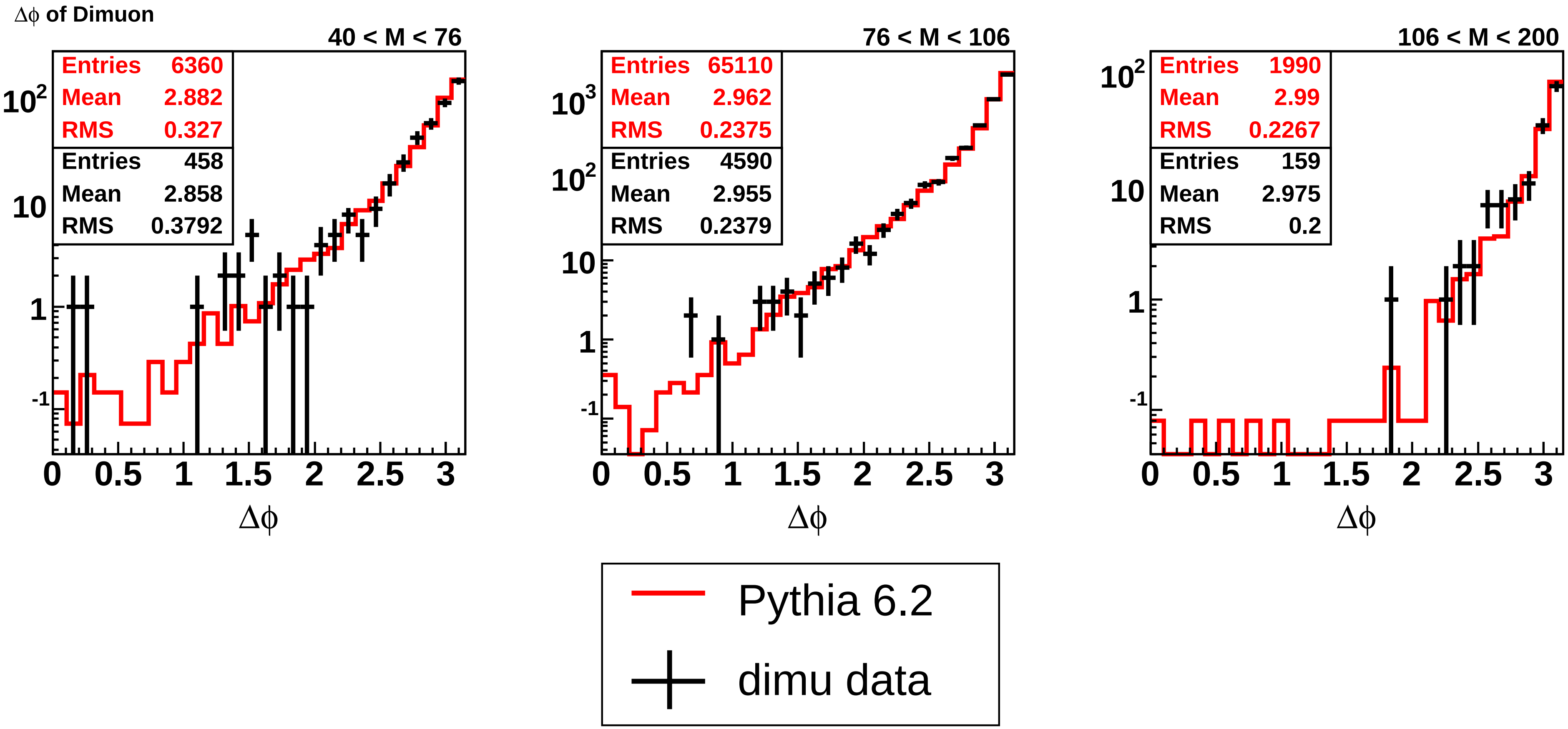




$E_T > 15$ GeV
(Hard Jets)

Updated studies by Sasha Rahlin (Chicago REU student)

Δφ(μμ) Distribution



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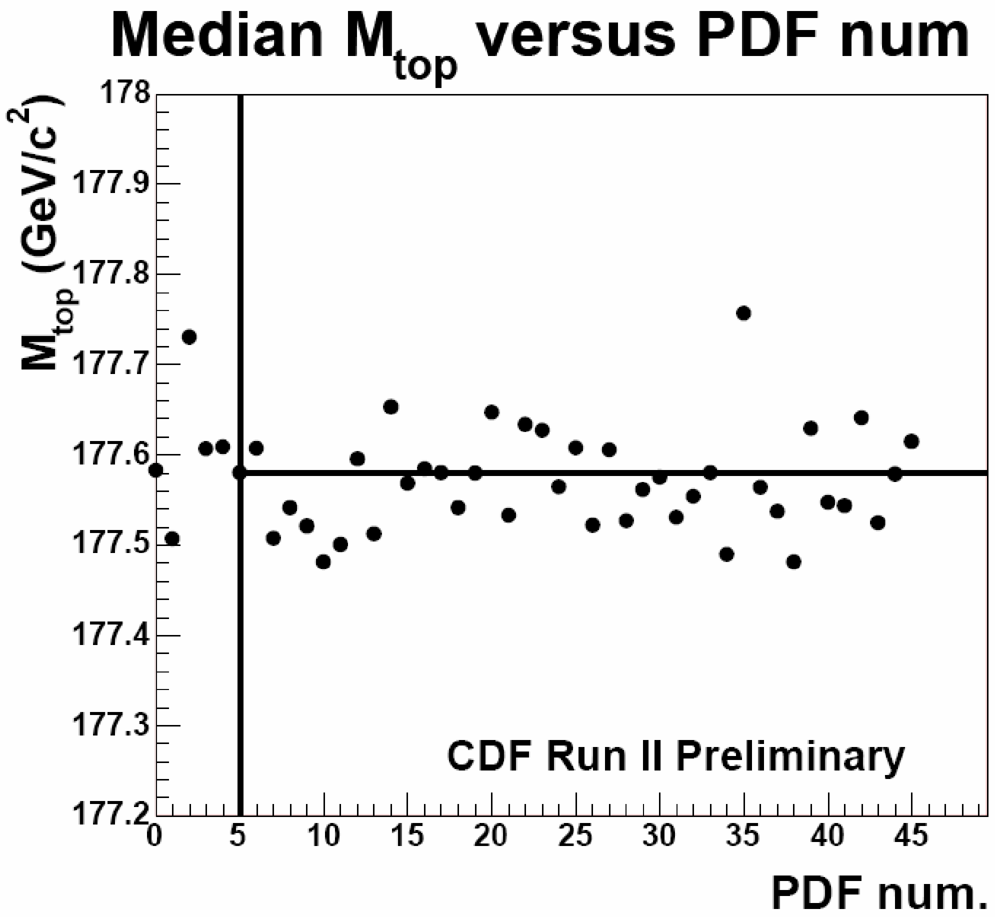
PDFs systematic



Syst.	ΔM_{top} (lepton+jet)
MRST72 -CTEQ5L	-0.08+-0.03
MRST75 -MRSR72	+0.22+-0.03
20 Eigen CTEQ6M	+0.20+-0.09

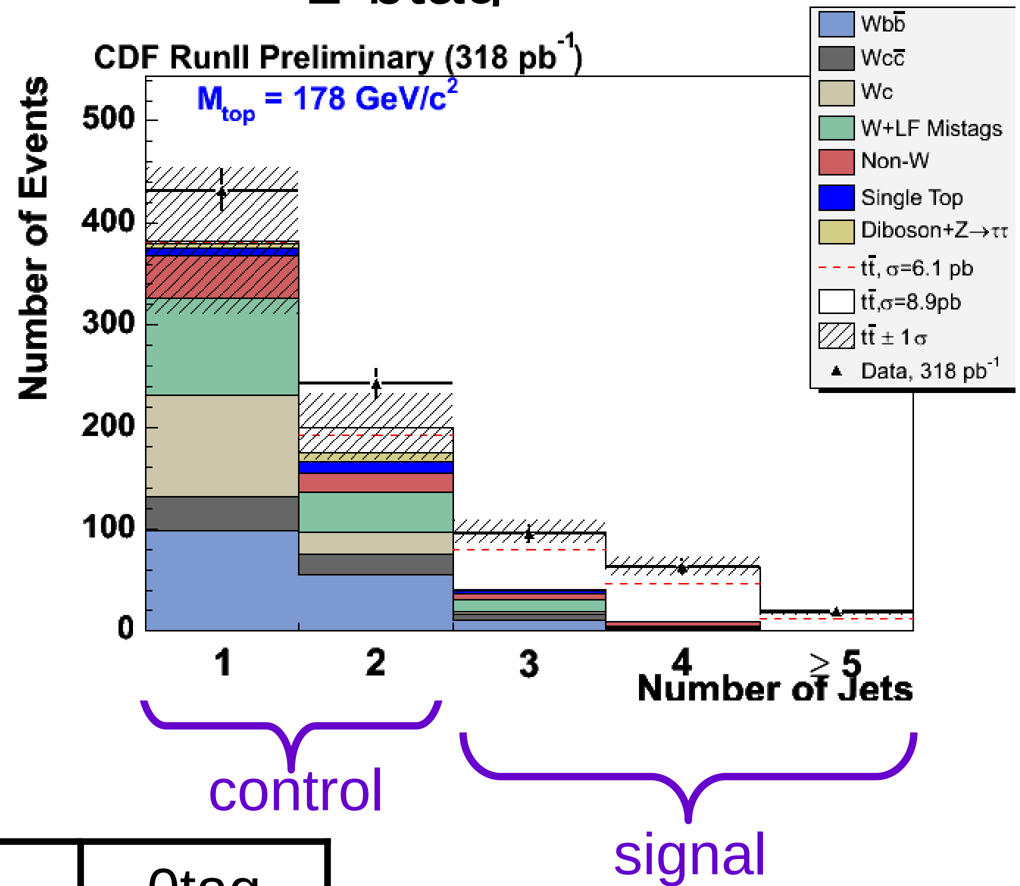
$$f_1(x_1)\otimes f_2(x_2)\otimes\sigma(q\bar{q}/gg\rightarrow t\bar{t})$$

- Reweighting method: reweight the hard-scattering cross sections with new PDFs (f_1, f_2)
  - Lepton+jet: ΔM_{top} = 0.3 GeV (Template)
  - Dilepton: ΔM_{top} = 1.1 GeV (ME): due to a limited CPU power

Backgrounds (template: lepton+jets)

- W+heavy flavor jets(bb,cc,c)
  - HF fraction from ALPGEN MC
  - Normalized to data
- W+jets(mistag)
  - Use measured mistag rate, applied to the data
- Multijet:fake-W (jet->e, track->μ)
  - Estimated from data
- Single top, dibson (WW,WZ)
  - Estimated from MC

>=1-btag

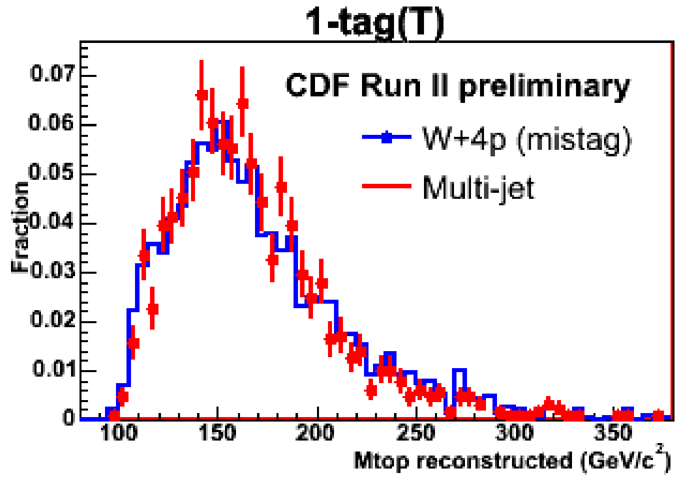


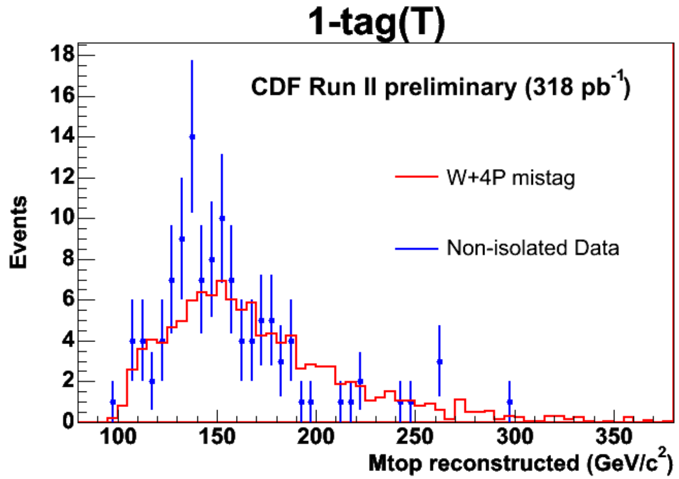
	2tag	1tagT	1tagL	0tag
bkgds	0.7+-0.2	7.6+-1.2	10.2+-1.7	no est
Data	16	57	25	40

Background Shapes

- Lepton+jets: major uncertainties by W+HF & W+4P modeling by ALPGEN
  - For W+HF/W+4P(mistag): replace entire background shape by individual major background, take ½ of largest difference as a syst. = 0.3 GeV
  - In addition, shapes due to diff. Q2 scales (4Mw Mw2, ¼Mw2, Mw2 + PtW2) is 0.4 GeV – ½ the largest difference
  - Non-W by W+4P(mistag) or non-iso data or multi-jet fake electron data: 0.1 GeV
- Dileptons major uncertainties by DY & Fake
  - Drell-Yann: 0.4+-0.6 GeV (ME)
  - Fake: 0.7 GeV (ME)
- More data and tunning Q^2 scale
  - $Q^2=a*Mw^2 + b*Pt\_w^2$

Non-W





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Bkgd shape	0.5	0.8
….	…	…
Total	1.3 (2.8)	3.6

Improves with more CPU power

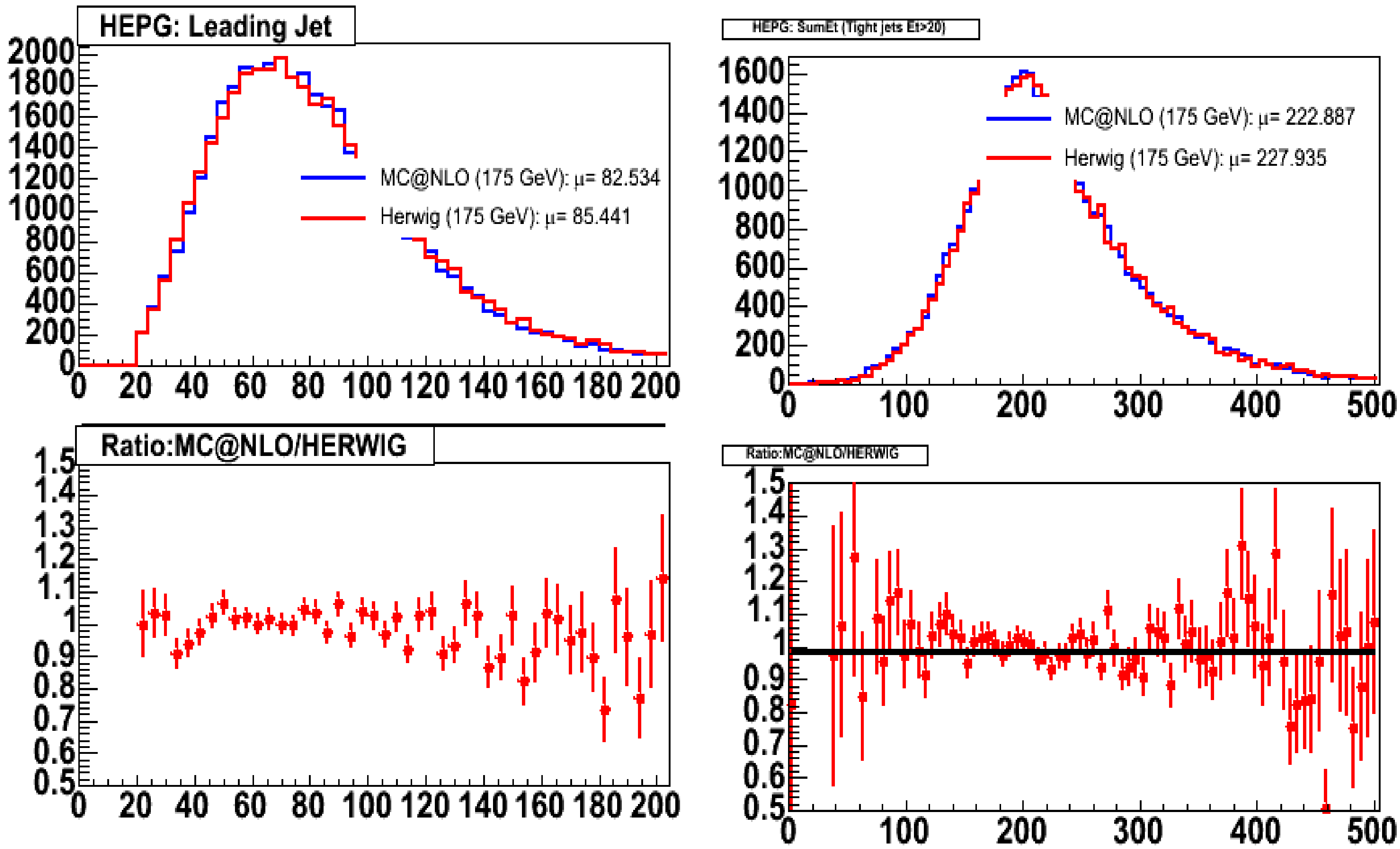
Improves with more data and smarter algorithm

Not much…

Things to do

- Signal modeling
  - Better constraints on ISR/FSR syst.
  - Tasks with MC@NLO
    - More validations on MC@NLO MC
    - Extra jets:
    - Extra jets from MC@NLO (mainly ISR) are covered by the ISR syst.
    - FSR jets from b-quark or light quark (from W): this is not handled by MC@NLO but by Herwigh PS: need to check with CKKW ALPGEN or MadGraph
  - Q2 scale dependence? (Q=0.5Mtop to 2*Mtop, never done)
- Background modeling
  - Better understanding of W+HF, W+4P, DY+2P ALPGEN MCs and tuning with data (Q2 scale etc)

Leading Jet and Sum Jet Ets



Eta of top (qq vs gg)