Single-top MC generator studies at CDF

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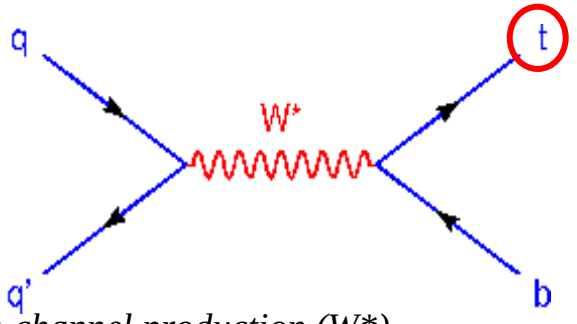
- Short Introduction
- MadEvent vs TopReX
- MadEvent vs ZTOP
- MadEvent vs MC@NLO

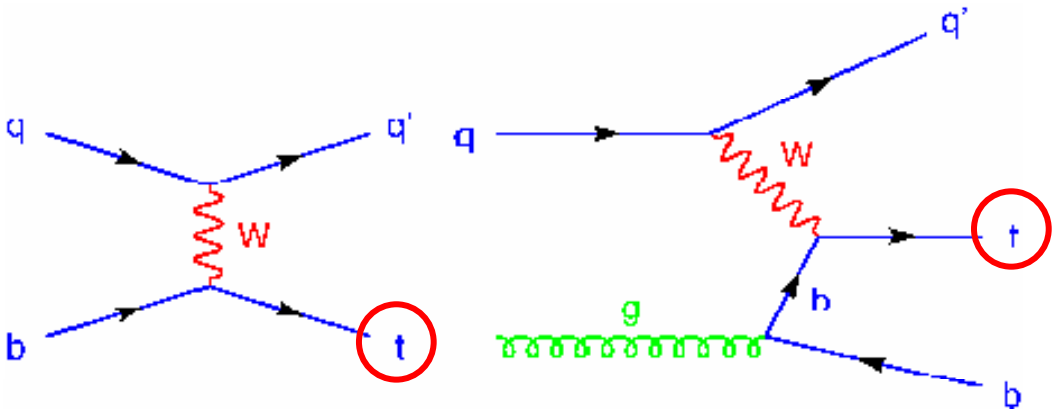
Workshop on Top Physics:
from the Tevatron to the LHC
LPSC Grenoble, October 19, 2007

Single Top Production

- At the Tevatron, top quarks are:
  - Mostly produced in pairs (7pb):
    - qq annihilation (85%)
    - gg fusion (15%)
  - Also electroweak (single-top):
    - s-channel
    - t-channel
    - Wt associated production



s-channel production (W)*



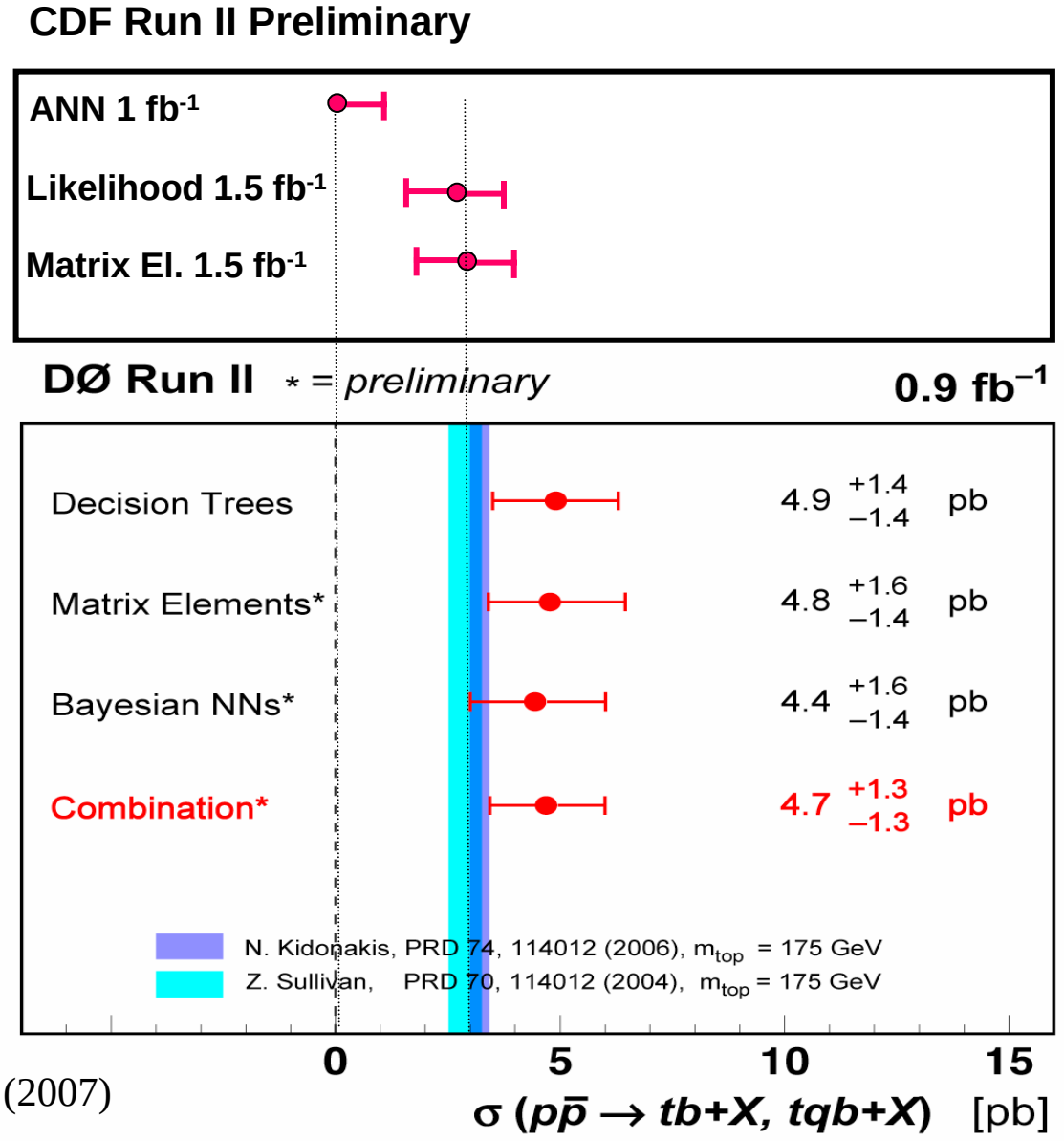
t-channel production (Wg fusion)

$s^{1/2}$ =*1.96TeV*	NLO Cross-sections
t-channel	1.98±0.25 pb
s-channel	0.88±0.11 pb

M_{top} = 175 GeV/c^2

- ***B.W. Harris et al.: Phys. Rev. D 66, 054024, Z. Sullivan hep-ph/0408049***
- ***Compatible results: Campbell et al, Phys. Rev. D 70, 094012 (2004).***
- ***N. Kidonakis, Phys.Rev. D 74, 114012 (2006)***

LP 07 Status



Single Top Evidence at D0

Phys. Rev. Lett 98, 181802 (2007)

Monte Carlo Issues

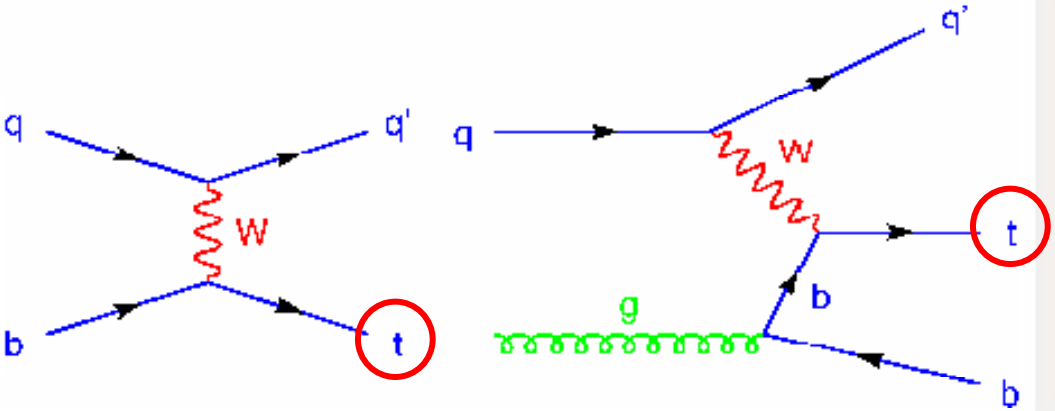
- Obviously, background modeling and estimation comes first!

- What about signal modeling?
  - At CDF, we studied MadEvent, TopRex, and MC@NLO (Run I single-top analyses used Pythia signal samples)
  - Remarkable progress in MC generators since the beginning of Run II…
  - Generous help from the MC/pheno/theory community

- Test different generators against each other:
  - Look at final state particle distributions:
    - At generation level
    - After parton showering (PS)
    - After detector simulation and reconstruction
  - Look at event yields

t-channel samples

- MadEvent, TopRex:
  - Mix LO (initial state b-quark) and NLO (initial state gluon) samples
  - Manually matching the two samples (a la CMS 2000/065, PRD 70, 114012)
    - Why need matching (what is different between LO and NLO)?



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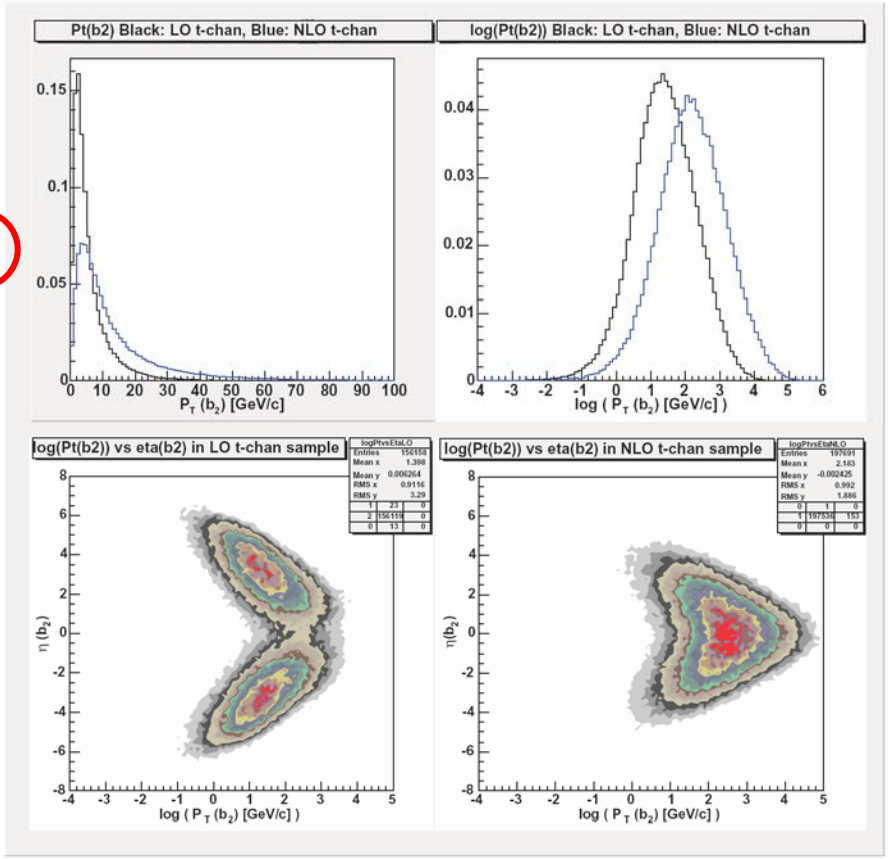

- Matching based on Pt(b2):
  - Pt(b2)<K use LO events
  - Pt(b2)>K use NLO events
  - By definition imperfect

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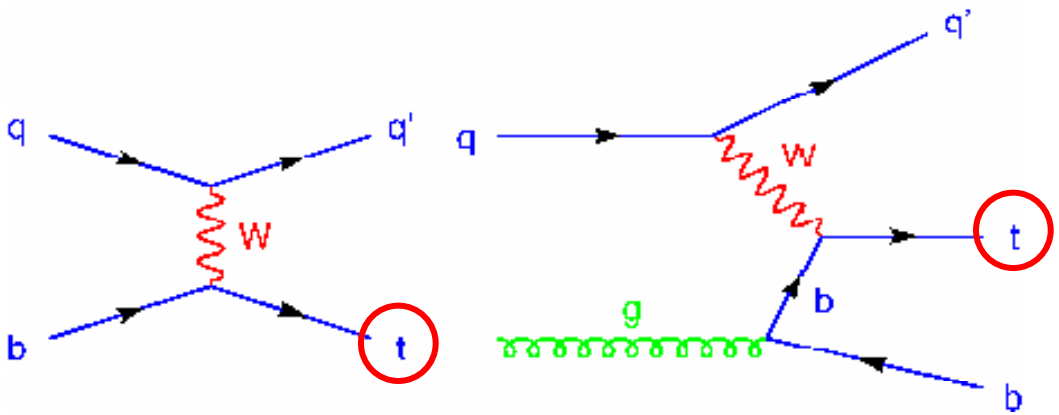

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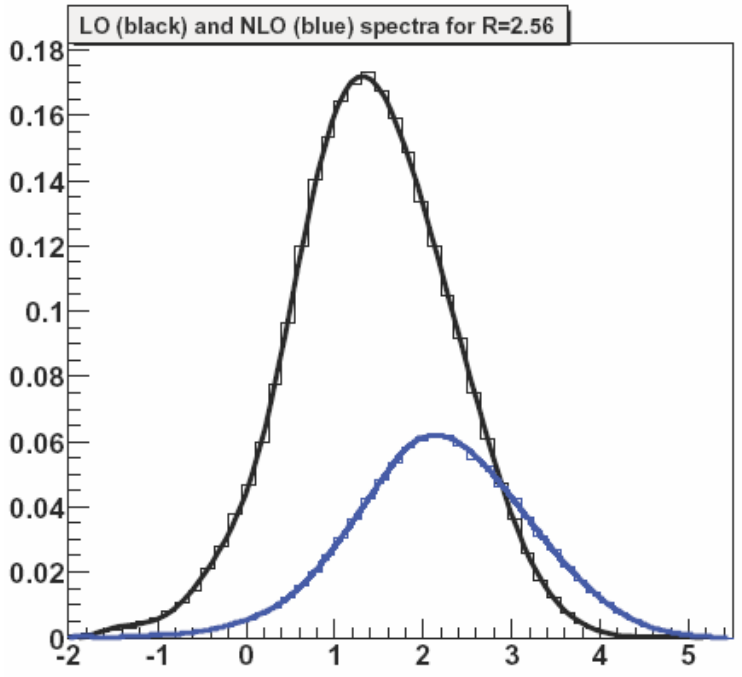

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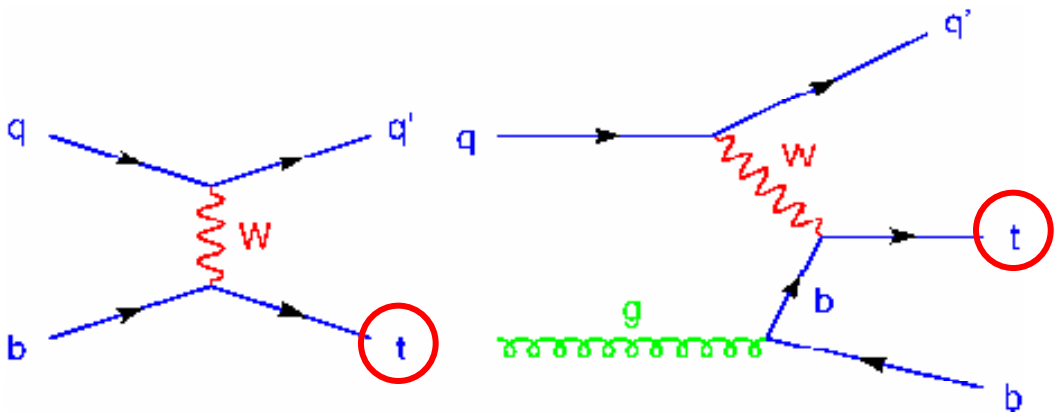

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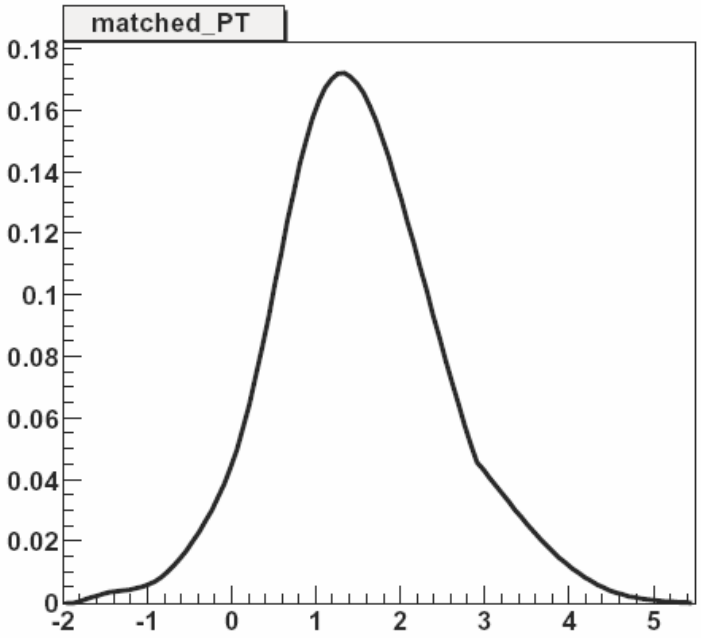

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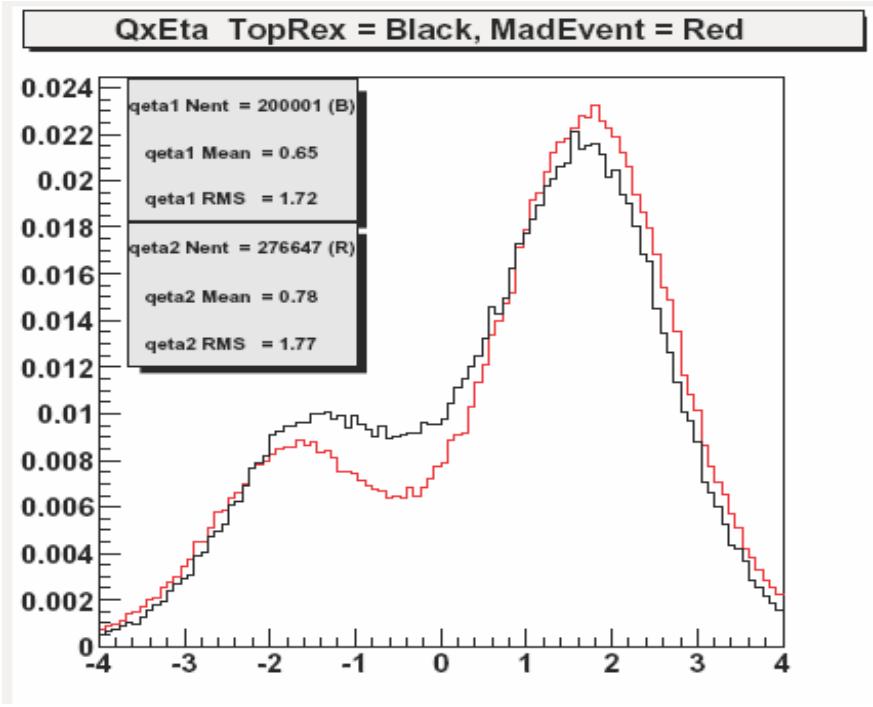
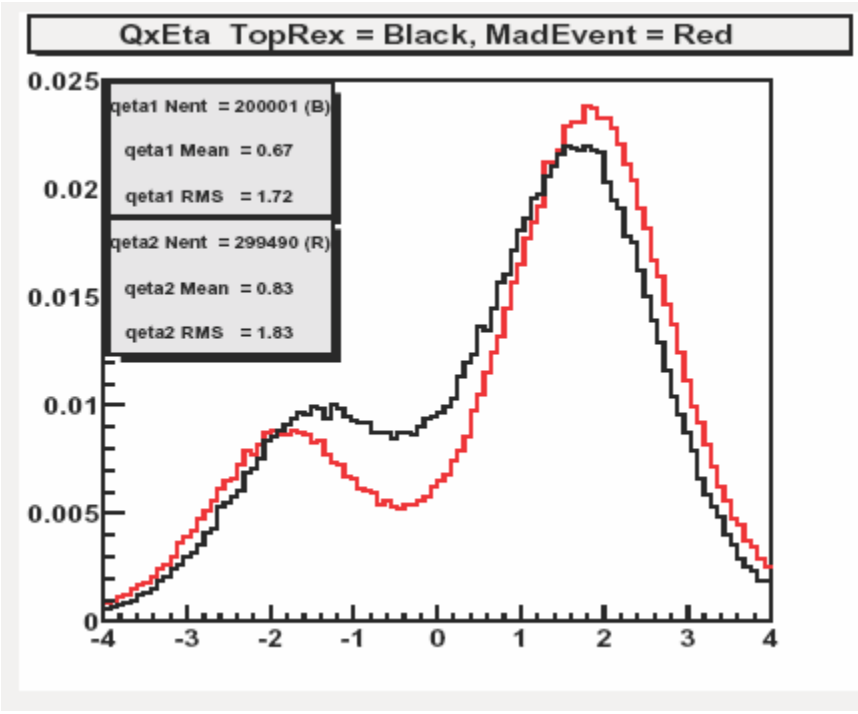
I. MadEvent vs TopRex

- Commissioned TopRex for the Tevatron
- Looked at distributions of Pt and Eta of:
  - Lepton, neutrino, b-quark from top decay, 2nd b-quark (b2), light q
  - Other variables providing good S/B discrimination
    - eg Q x η

LO t-channel

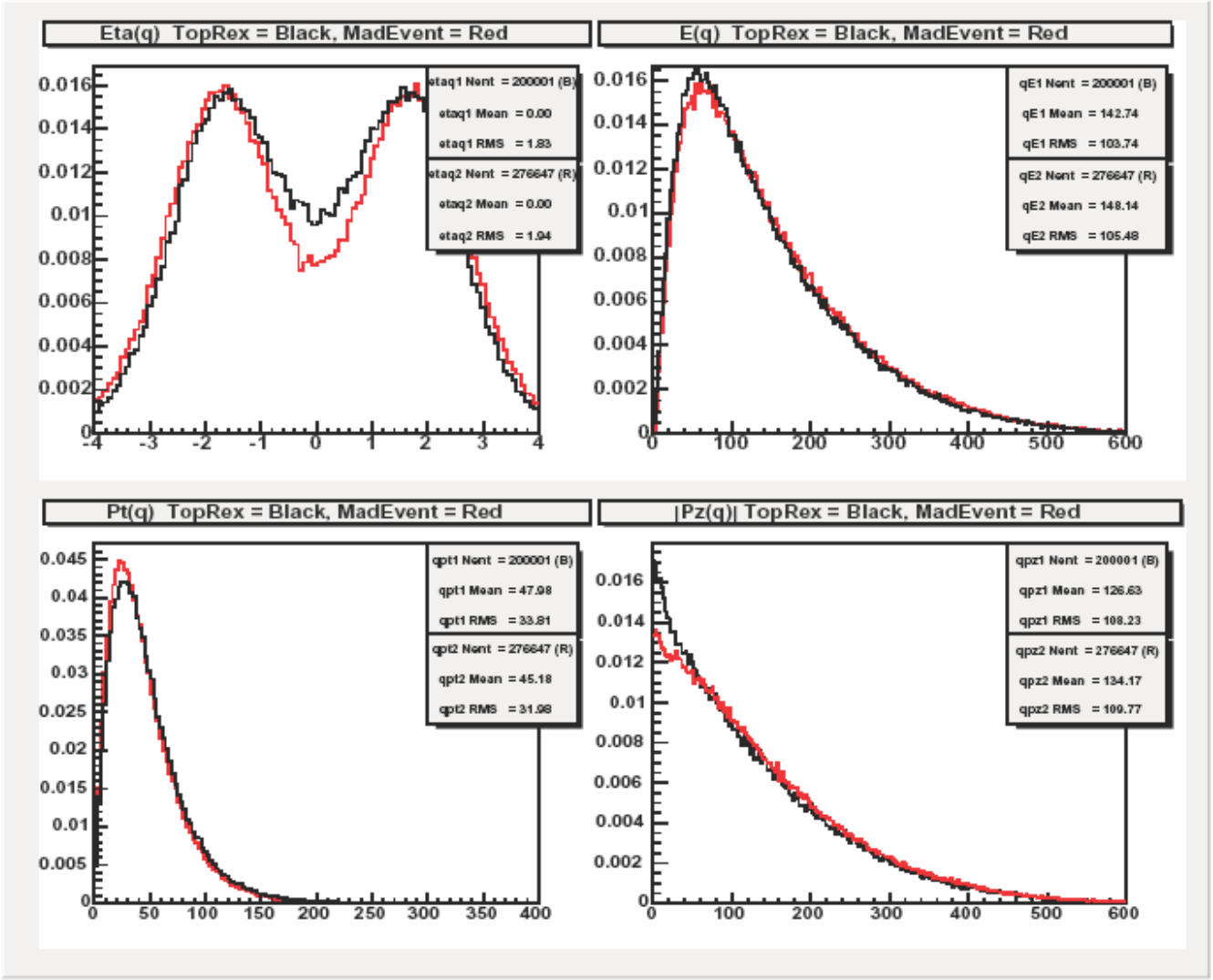


NLO t-channel



MadEvent (red) vs TopReX (black)

- Light quark (generator level) in the LO t-channel samples:



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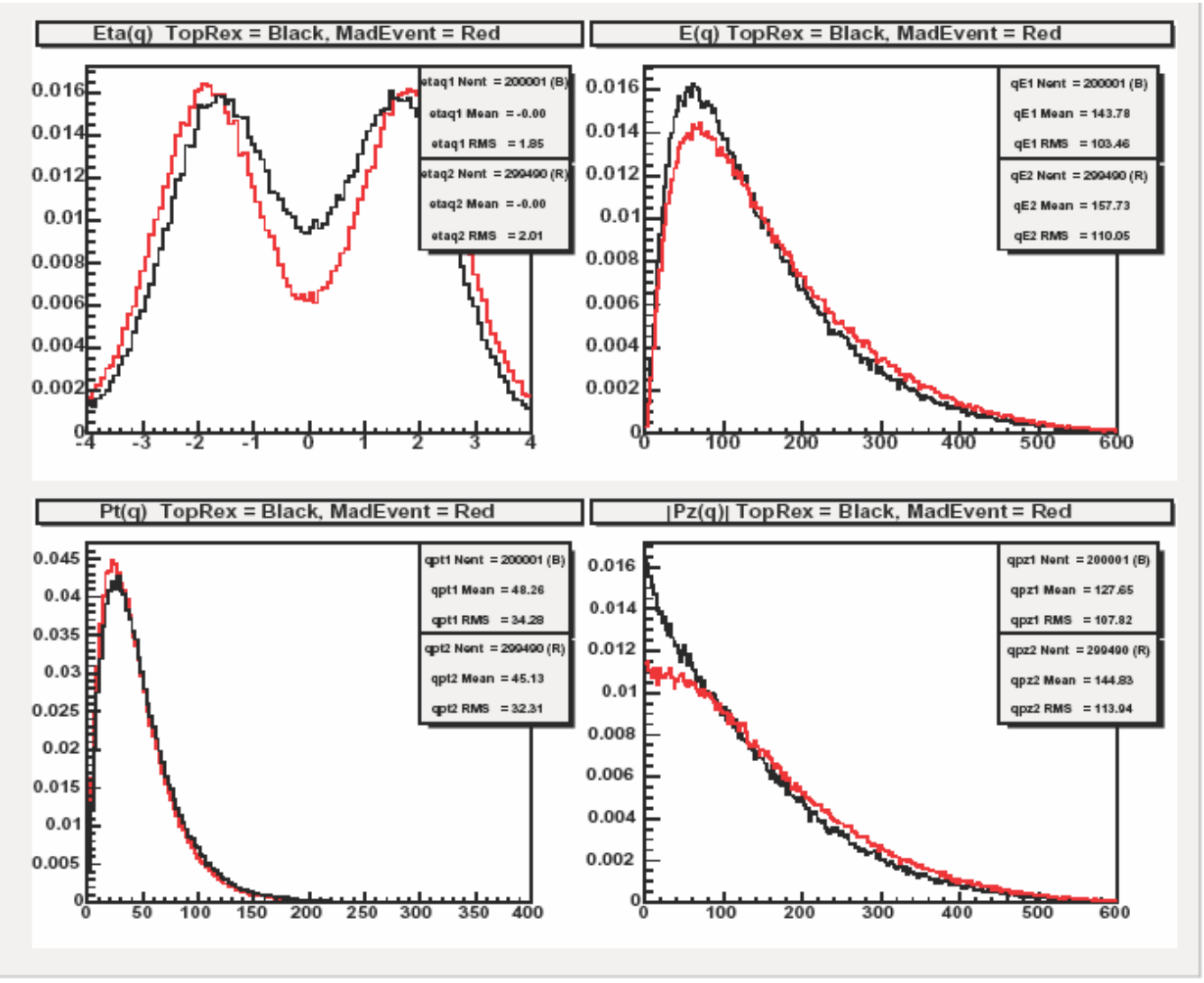
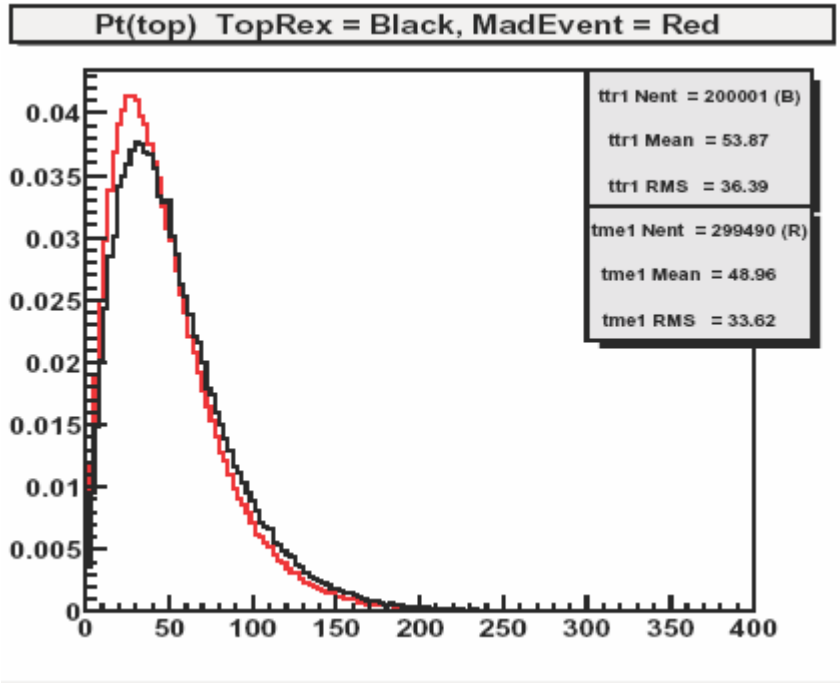
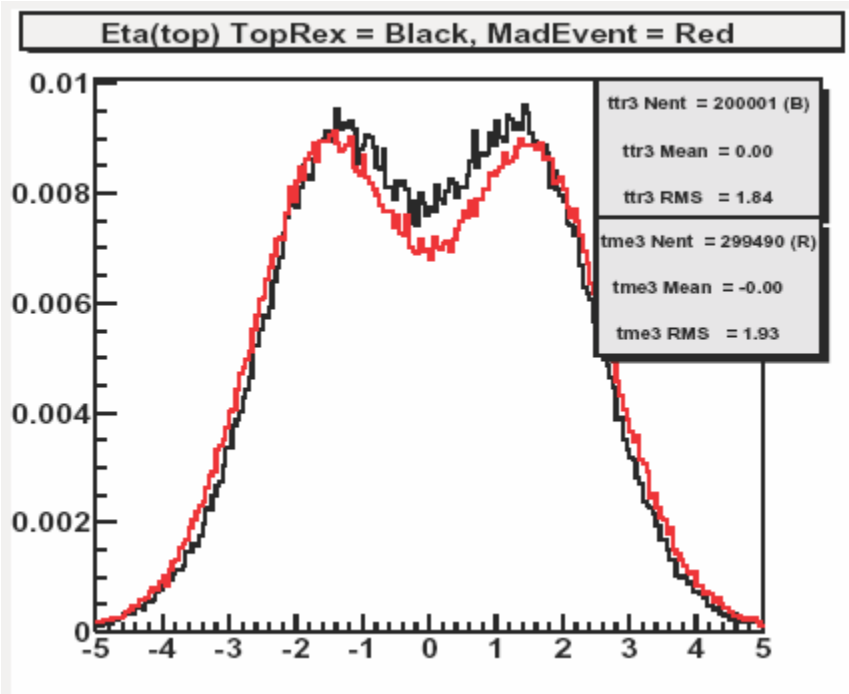
- Light quark (generator level) in NLO t-channel samples:



MadEvent (red) vs TopReX (black)

- Top quark slightly harder in P_T (and more central) in TopReX

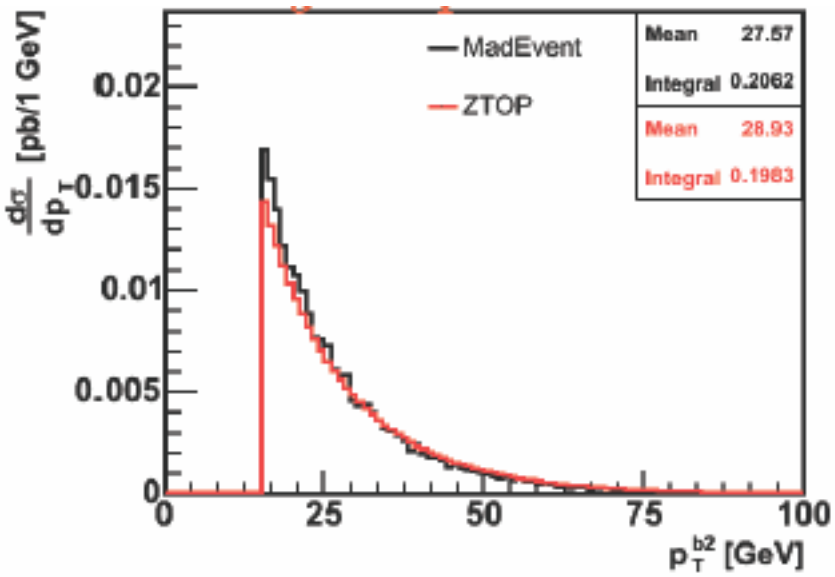


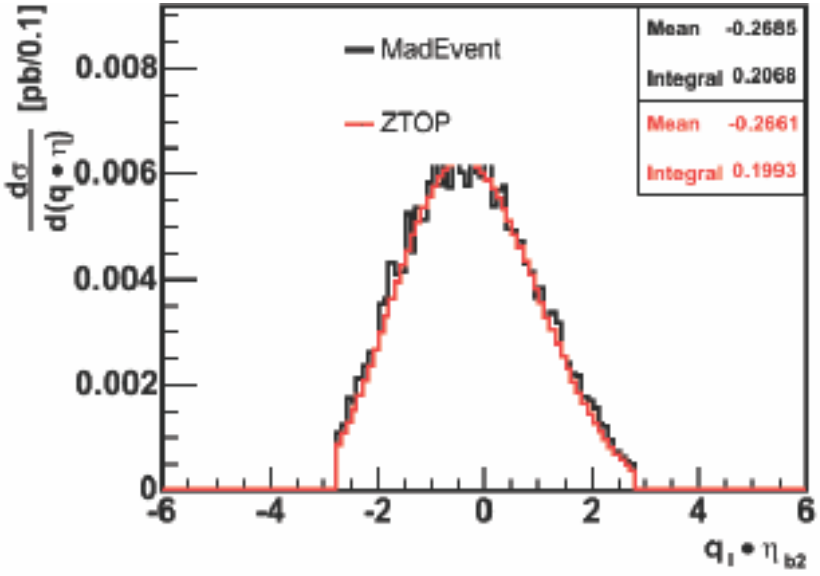


- Conclusion: t-channel samples (esp NLO) somewhat different:
  - NLO fraction of events is small compared to LO
  - Light quark more central in TopReX; top quark also, to a smaller extent

II. Comparisons to ZTOP

- Also compared the MadEvent distributions against the NLO kinematic distributions (no events) given by the ZTOP program.
- ZTOP gives pt and η of top and the leading jets (top was not decayed)
- For the most part, shapes agree well, eg 2nd b-jet in t-chan:

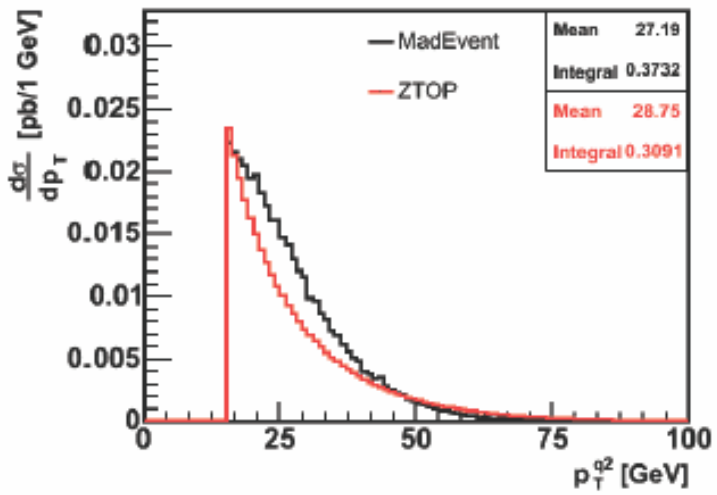


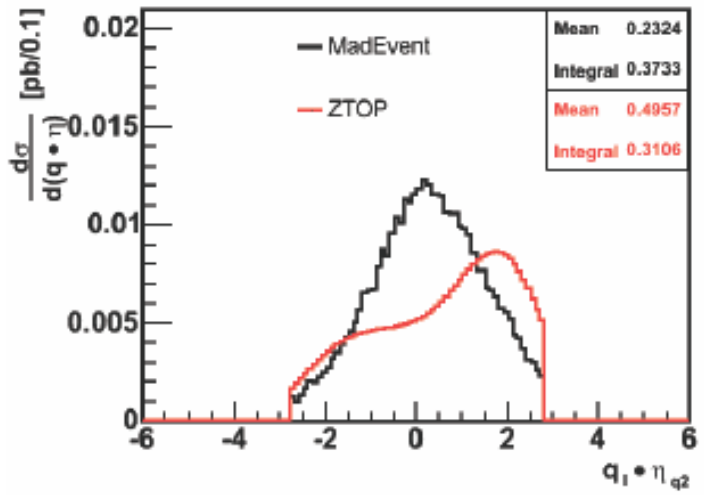


- Worst agreement: Second leading light jet distributions (next page)

Comparisons to ZTOP

- 2nd leading light jet (few ME processes not included our MC)





- Acceptance agreement looks good:

	2-Jet-Bin	3-Jet-Bin	2+3-Jet-Bin
t-channel	-2.5 %	-0.6 %	-2.2 %
s-channel	-0.2 %	-0.3 %	-0.2 %

III. Comparisons to MC@NLO

- MC@NLO single-top code available relatively recently – we used v3.3:
  - Includes spin correlation between FS top and bottom quarks
  - Matching is not done by hand!
  - HERWIG used for PS (our default sample was MadEvent+Pythia)

- Same procedure as before:
  - Look at final state particles and record the agreement
  - Look at acceptances in different jet bins

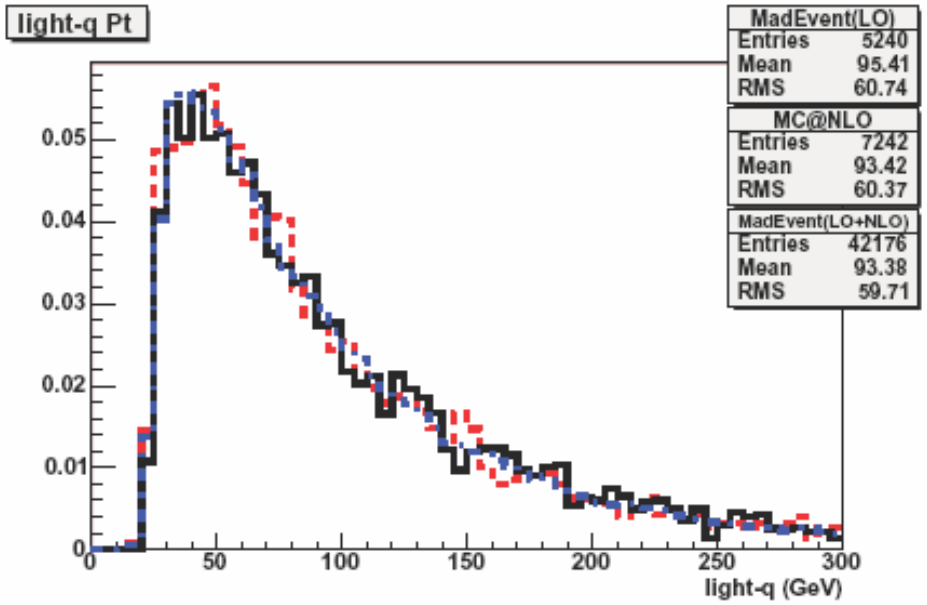
MadEvent vs MC@NLO

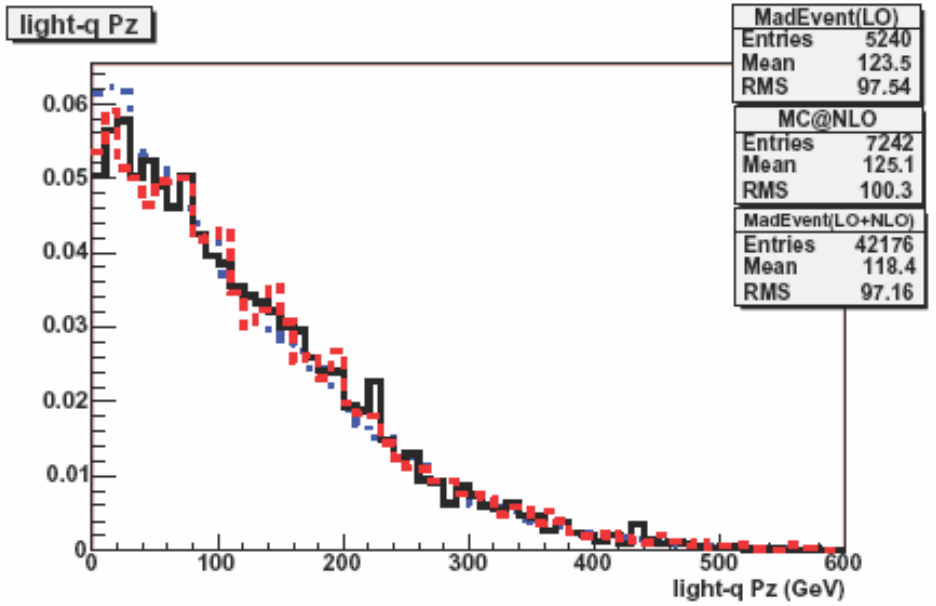
- Nice agreement. It can be seen that (after PS+full simulation)
  - In general MC@NLO means lower by ~1 GeV

Particle	Sample	P_T		$\|P_Z\|$	
		MadEvent	MC@NLO	MadEvent	MC@NLO
lepton	s-chan	44.55	45.02	31.07	31.42
	LO t-chan	42.24	41.9	30.93	29.79
	Matched t-chan	42.74		31.22	
neutrino	s-chan	53.77	53.32	33.23	32.4
	LO t-chan	52.82	52.62	31.83	30.98
	Matched t-chan	52.64		31.29	
b from t	s-chan	63.04	62.17	41.49	40.48
	LO t-chan	57.57	56.49	37.83	36.75
	Matched t-chan	57.45		37.41	
other b	s-chan	92.73	89.47	60.98	59.26
light q	LO t-chan	95.41	93.42	123.5	125.1
	Matched t-chan	93.38		118.4	
top	s-chan	61.35	59.97	73.83	72.67
	LO t-chan	54.45	53.01	71.32	65.66
	Matched t-chan	54.03		69.56	

MadEvent vs MC@NLO

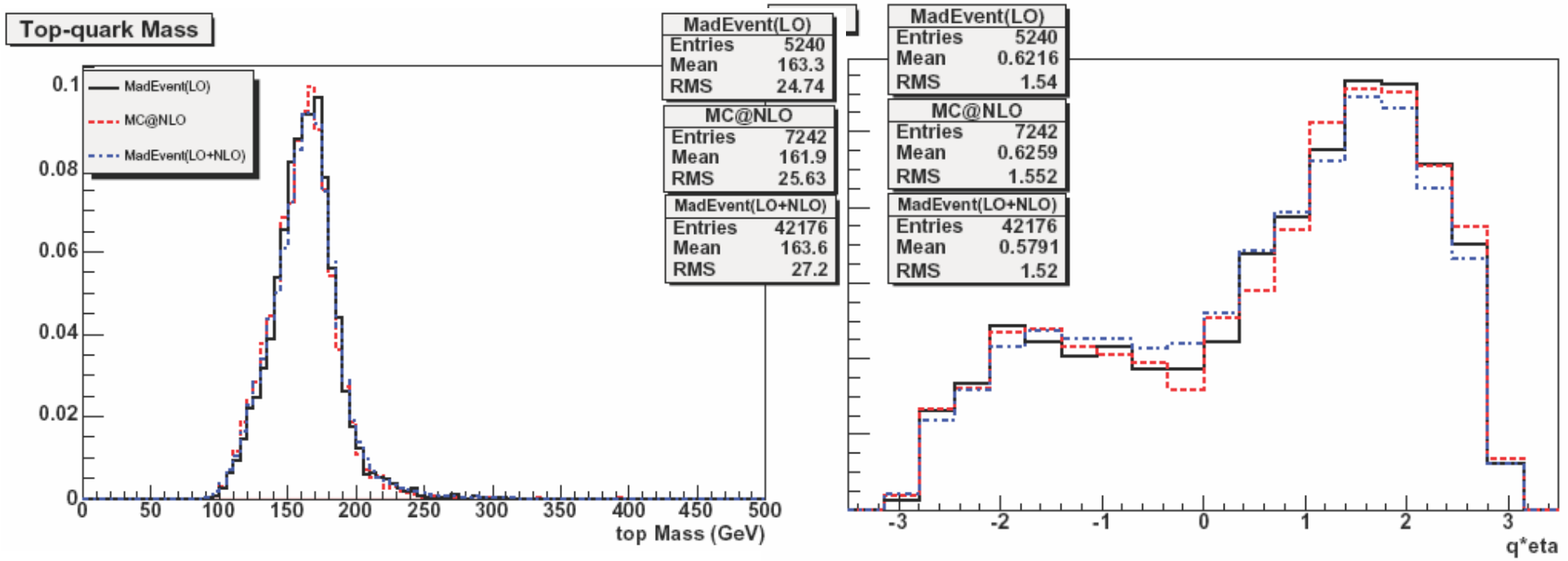
- Very good agreement in all kinematic distributions, before and after detector simulation
- For example, light quark jet in t-chan events:





MadEvent vs MC@NLO

- Reconstructed top and Q x Eta in t-channel events:



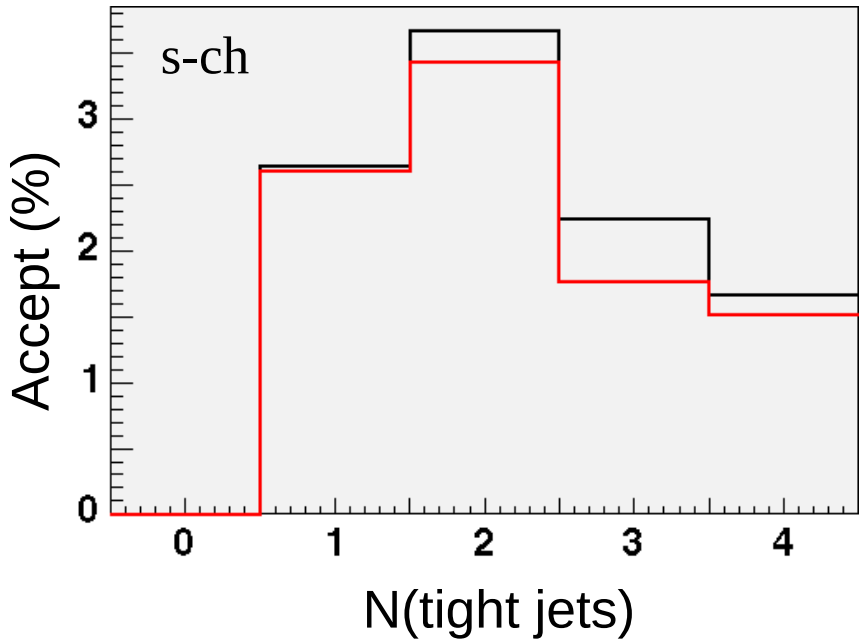
- Acceptances?
- In the 2 jet bin the agreement is good:
  - s-channel: 3.43% (ME) vs 3.67% (MC@NLO)
  - t-channel: 2.41% (ME) vs 2.43% (MC@NLO)
  - Across all jet bins – satisfactory agreement (next page)

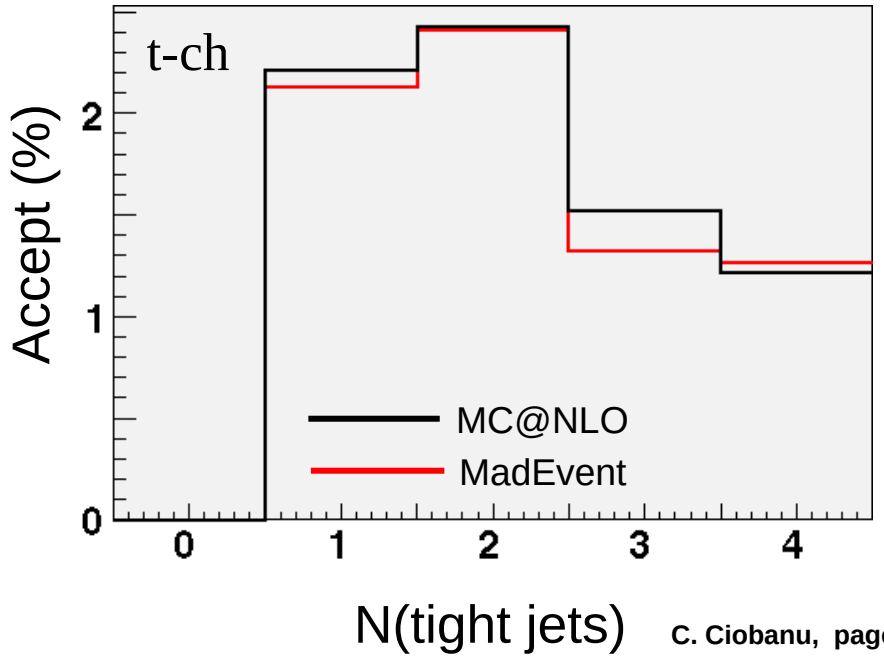
MadEvent vs MC@NLO

- Acceptances by jet bin are slightly different – esp. 3 jet bin
- All jet bins together: s-chan: 9%, t-chan 4%
- Understand the size of this effect on the cross section measurements for the next round – when the 3 jet bin will be included.

Tight jets: Et > 20 GeV, |η| < 2.8

Require at least one b-tagged jet



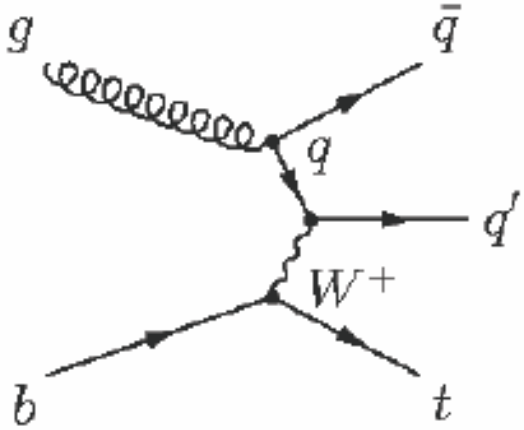


Summary

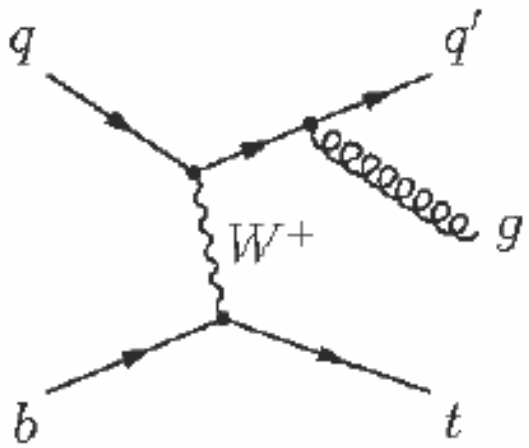
- Several generators studied for single-top samples at CDF:
- MadEvent, TopRex, with manual matching for t-channel:
  - Phys. Rev. D, 71 012005(R) (2005)
- Agreement with ZTOP NLO distributions reasonably good
- MC@NLO versus MadEvent comparisons:
  - Very similar distributions
  - Slightly different distribution of acceptance by Njet bin (especially 3jet bin)
- Many thanks to the theo/pheno/MC people – Tim Stelzer, Fabio Maltoni, Scott Willenbrock, Steve Mrenna, Zack Sullivan, Sergey Slabospitsky, Stefano Frixione, Bryan Webber, and others for providing expertise and support

parton level 2nd-leading light quark ≠ 2nd-leading light jet

- following NLO matrix elements not included in the matched MadEvent sample:



IS gluon splitting



IS + FS gluon radiation

- contribution especially to soft p_T-2nd-leading light jets

- FS gluon radiation modeled by PYTHIA => not visible at parton level
  => jet-clustering of stable particles (k_T cluster algorithm)

- Similar circumstances for the light jet in the *s*-channel