NLO+PS predictions for Wjj at the Tevatron

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in collaboration with

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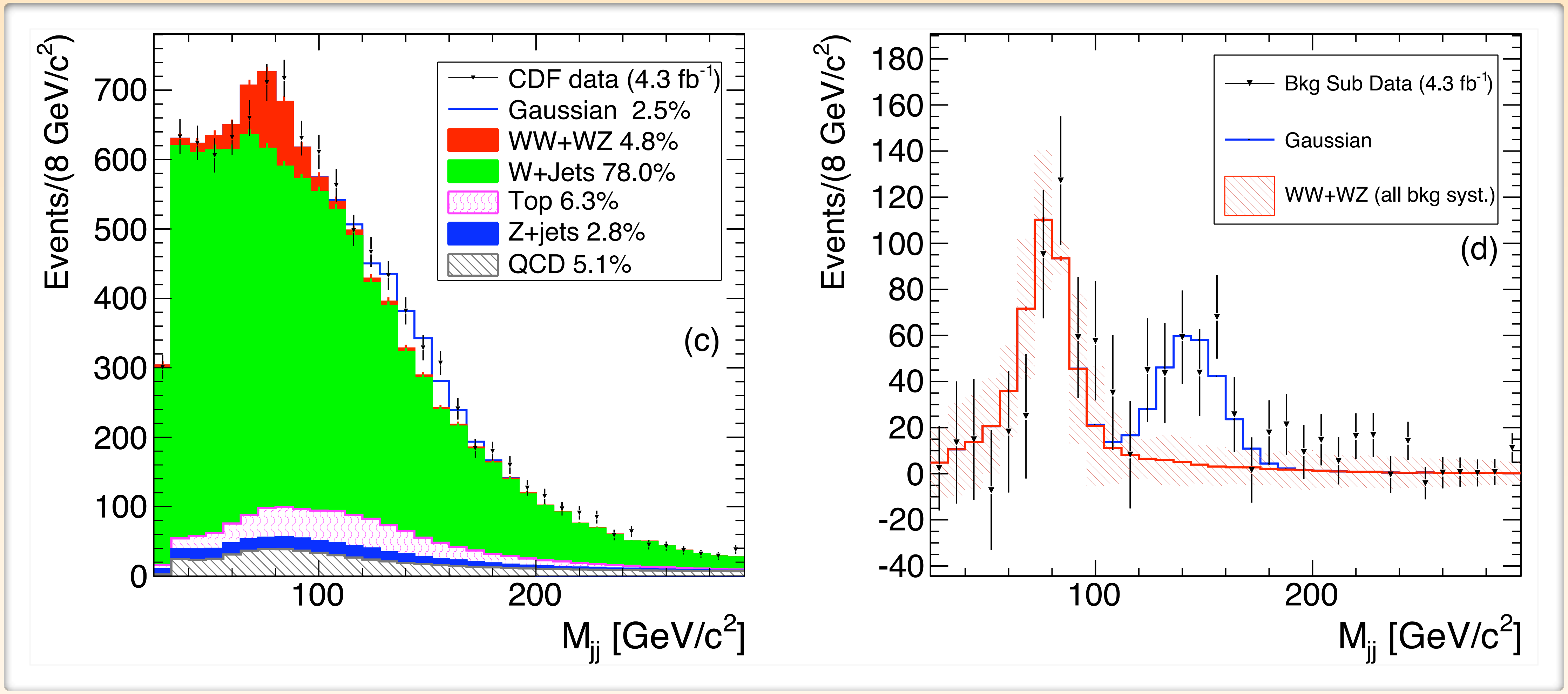
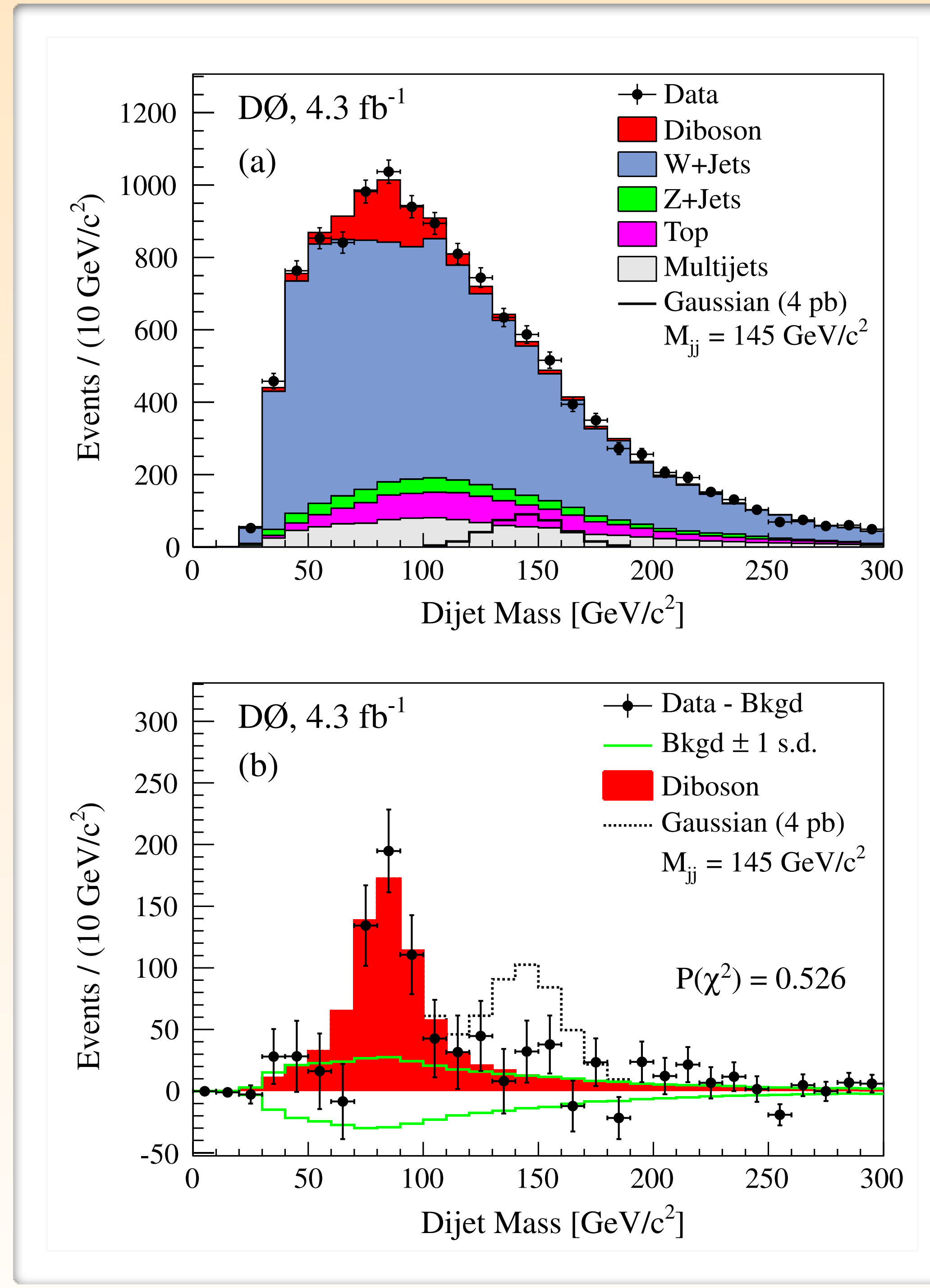
Wjj at CDF

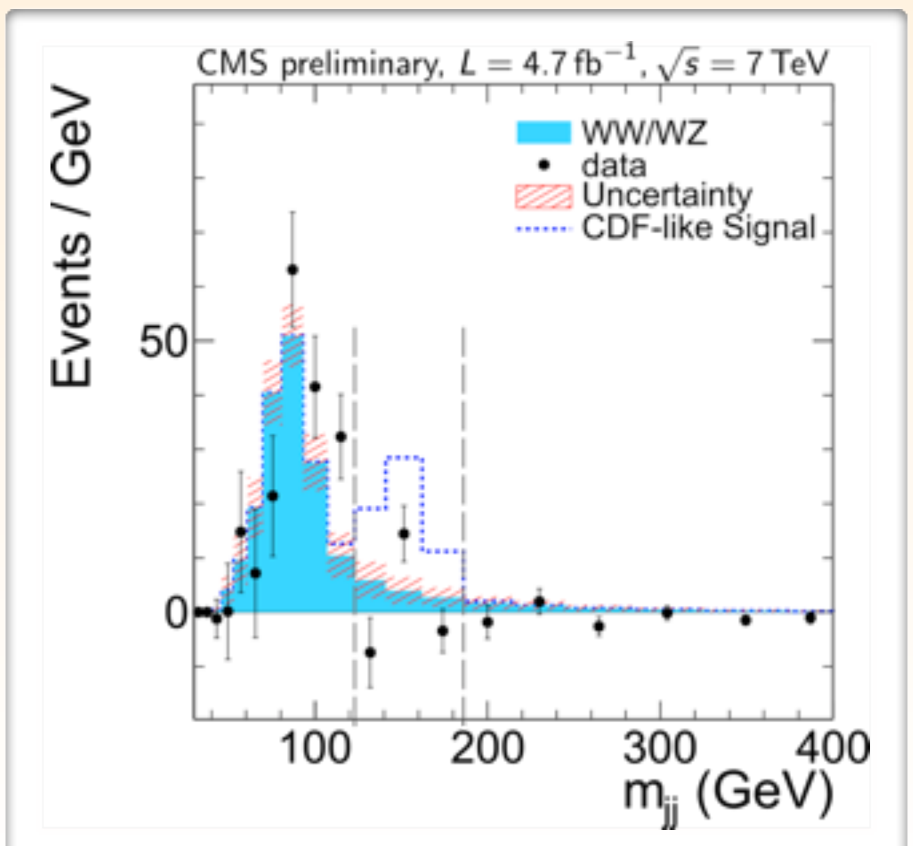


- In April 2011 CDF reported an excess of events with 3.2 standard deviation significance in the dijet invariant mass distribution (with invariant mass 130-160 GeV) for Wjj events
- The update in June (using 7.3 fb^{-1} of data) increased significance of the excess to 4.1 standard deviations

Response...

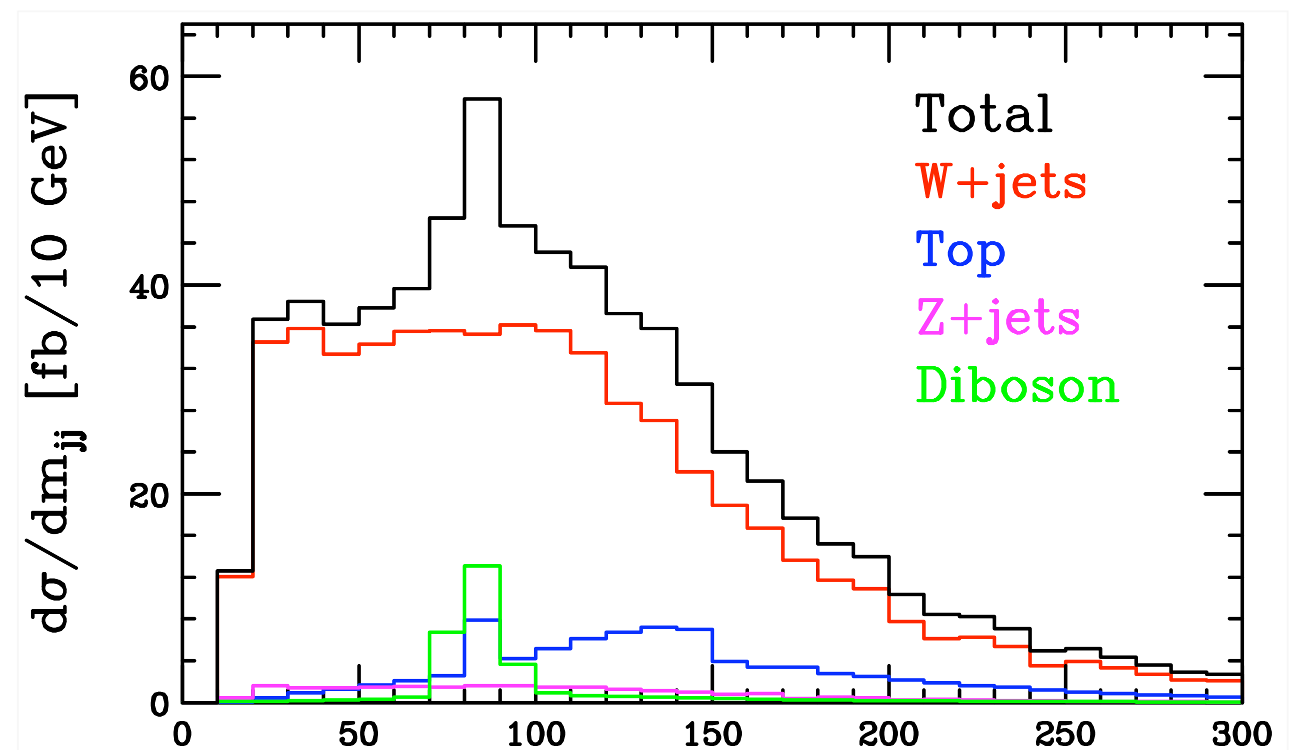
- By now ~100 papers have appeared trying to explain this excess by introducing BSM physics
- A handful of papers tried to explain the results within the SM (mostly by addressing issues in the top quark sector)
- CDF's results are not confirmed by DØ nor by CMS





NLO effects

- CDF estimates their backgrounds using LO SMC programs (Alpgen+Pythia & Sherpa) normalized to (N)NLO or to the data
- J. Campbell, A. Martin & C. Williams have looked at the same distribution at parton level to study the impact of NLO corrections on differential distributions



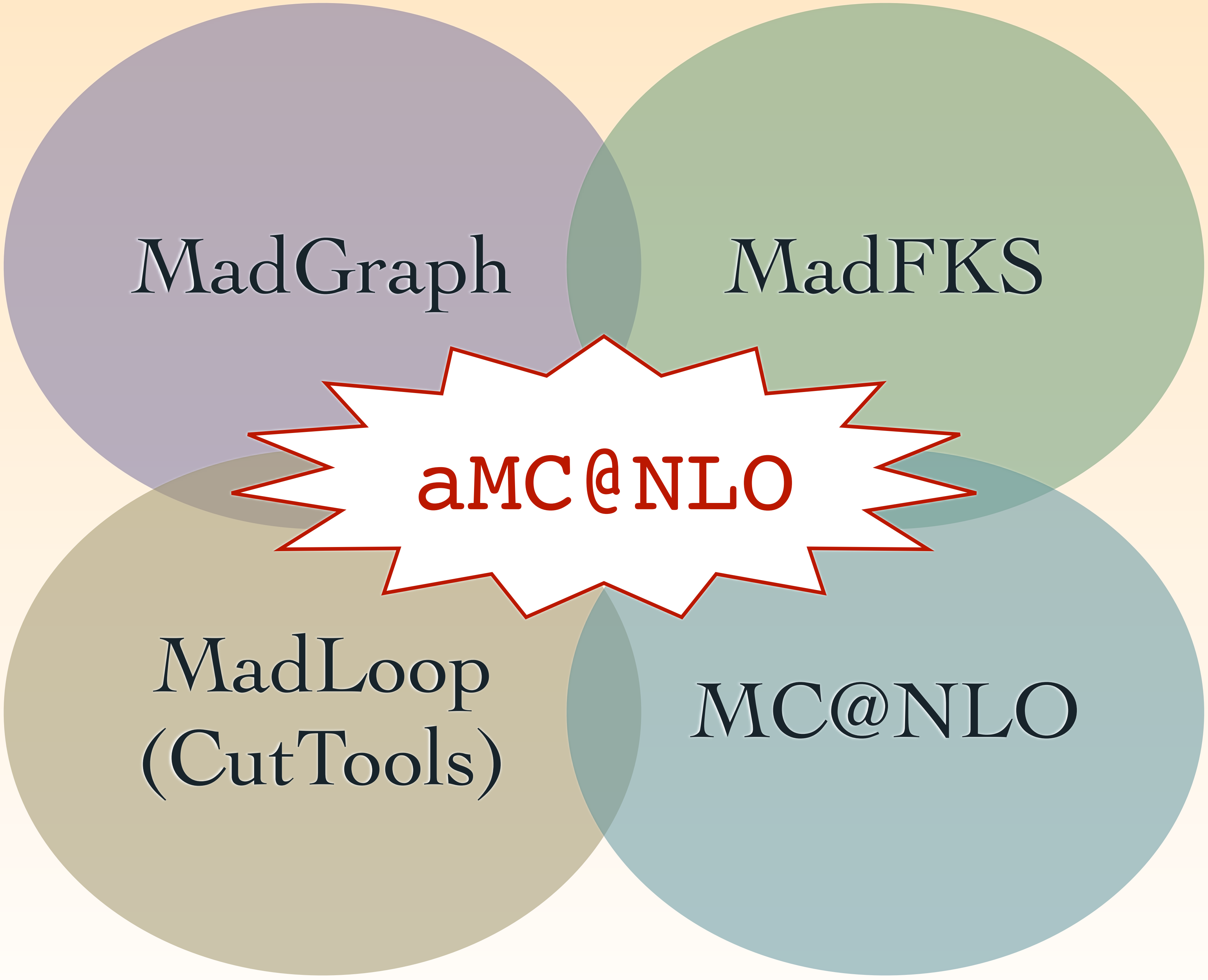
Campbell, Martin, & Williams; arXiv:1105.4594

- Using the newly developed tool, **aMC@NLO**, we addressed the main background, W+2j, at the NLOwPS level to see how well LOwPS or fixed order NLO describe this distribution

PP → WJJ CDF/DØ ANALYSIS CUTS

- minimal transverse energy for the lepton: $E_T(l) > 20$ GeV;
- maximal pseudo rapidity for the lepton: $|\eta(l)| < 1$;
- minimal missing transverse energy: $\not{E}_T > 25$ GeV;
- minimal transverse W-boson mass: $M_T(l\nu_l) > 30$ GeV;
- jet definition: JetClu algorithm with 0.75 overlap and $R = 0.4$;
- minimal transverse jet energy: $E_T(j) > 30$ GeV;
- maximal jet pseudo rapidity: $|\eta(j)| < 2.4$;
- minimal jet pair transverse momentum: $p_T(j_1 j_2) > 40$ GeV;
- minimal jet-lepton separation: $\Delta R(lj) > 0.52$;
- minimal jet-missing energy separation: $\Delta\phi(\not{E}_T j) > 0.4$;
- hardest jets close in pseudorapidity: $|\Delta\eta(j_1 j_2)| < 2.5$;
- jet veto: no third jet with $E_T(j) > 30$ GeV and $|\eta(j)| < 2.4$;
- lepton isolation: transverse hadronic energy smaller than 10% of the lepton transverse energy in a cone of $R = 0.4$ around the lepton.

The aMC@NLO code



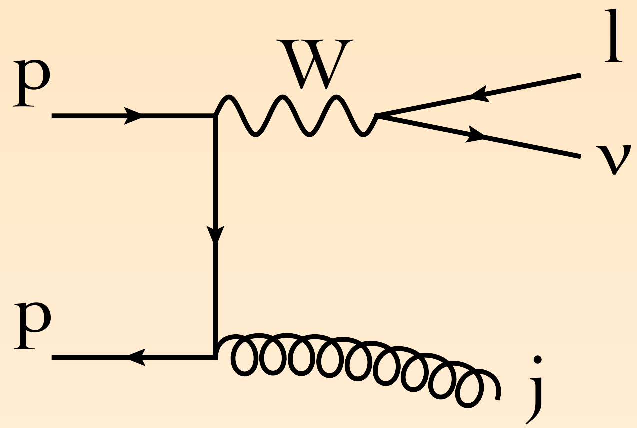
http://amcatnlo.cern.ch

Computational challenge

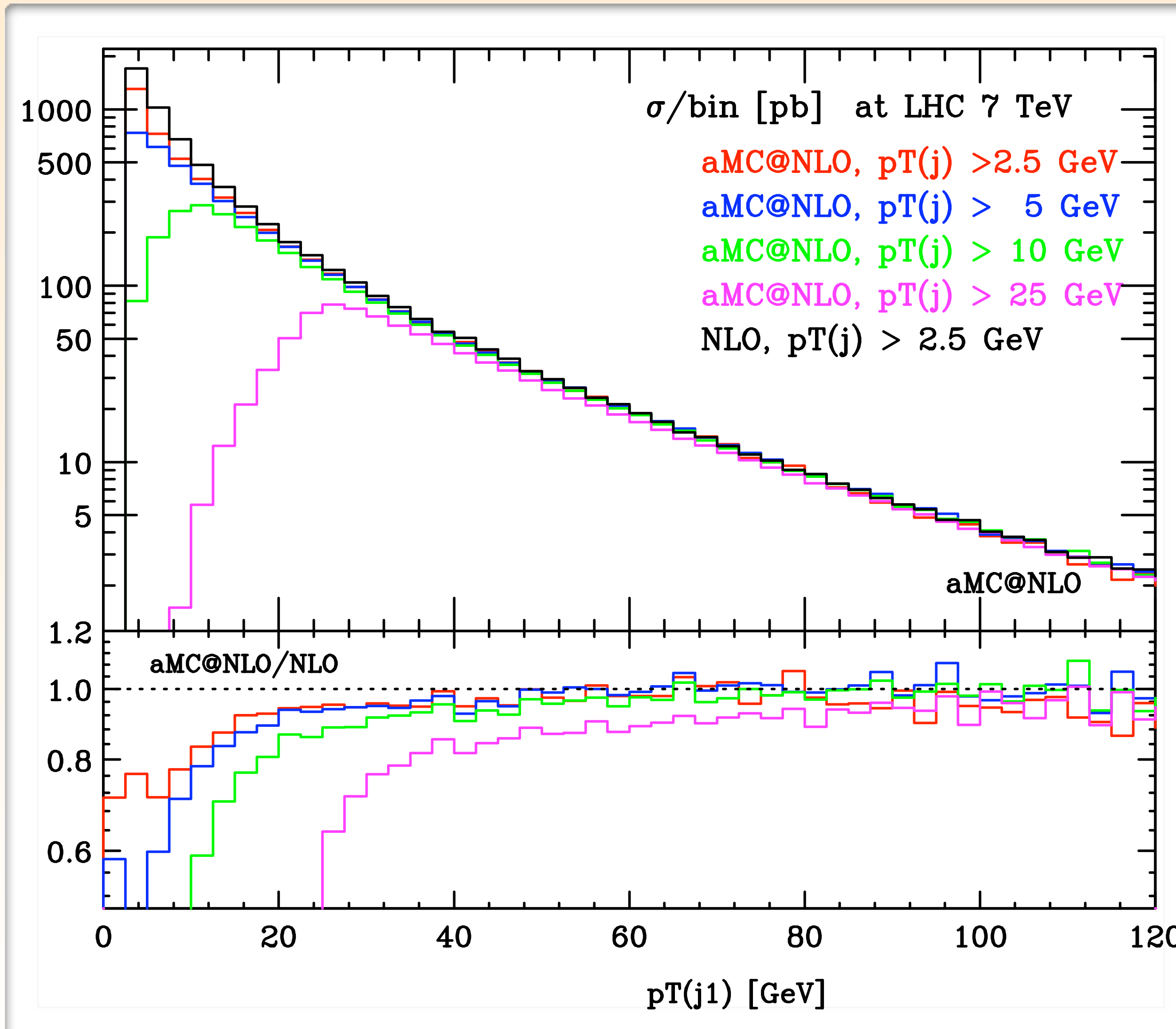
- This is the first time that such a process with so many scales and possible (IR) divergences is matched to a parton shower at NLO accuracy*
- Start with W+1j production to validate processes which need cuts at the matrix-element level
- To check the insensitivity to this cut:
  - generate a couple of event samples with different cuts and show that the distributions after analysis cuts are statistically equivalent

* Recently also the following have been studied at the NLO+PS accuracy
- Wjj & Wjjj [*Hoeche, Krauss, Schonherr & Siegert, arXiv:1201.5882*]
- Zjj [*Re arXiv:1204.5433*]
- Hjj [*Campbell, Ellis, RF, Nason, Oleari, Williams arXiv:1202.5457*]

PP → WJ



- For W+1j the easiest cut would be in on the p_T of the W boson
- However, for validation purposes it is more appropriate to apply this cut on the jet instead (because that is what we'll be doing in W+2j). Same at LO, but different at NLO
- Different cuts at generation level yield the same distributions at analysis level if the analysis level cut is 3-4 times larger



pp → Wjj Set-up

[RF, Frixione, Hirschi, Maltoni, Pittau, Torrielli (2011)]

- Two event samples with 5 GeV and 10 GeV p_T cuts on the jets at generation level, respectively, each with 10 million unweighted events
- Renormalization and factorization scales equal to $\mu_R = \mu_F = H_T/2$

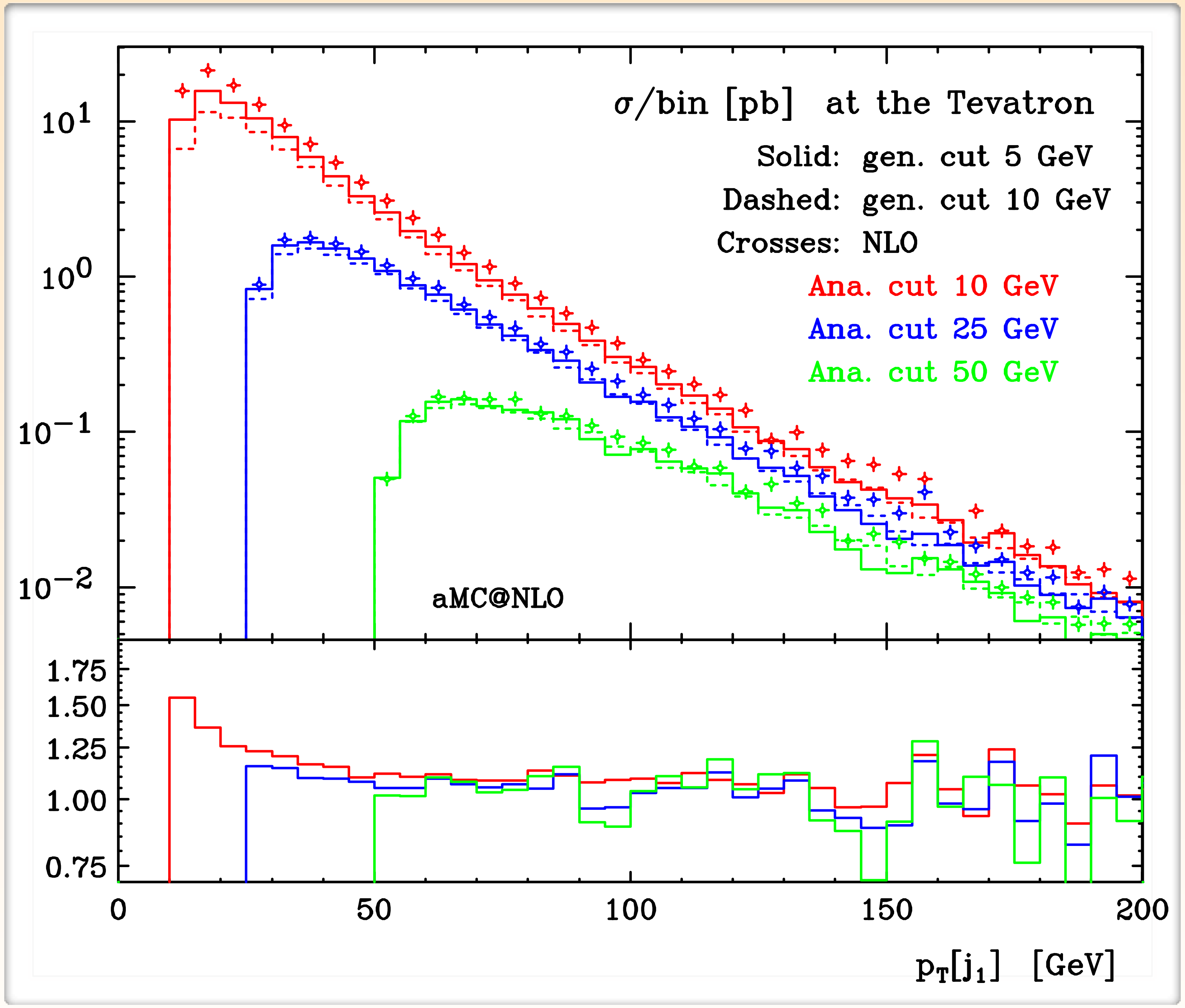
$$2\mu_R = 2\mu_F = H_T = \sqrt{(p_{T,l\nu}^2 + m_{l\nu}^2)} + \sum |p_{T,i}|$$

where sum is over the 2 or 3 partons (at the matrix element level)

- Jets are defined with anti-k_T and R=0.4
- MSTW2008(N)LO PDF set for the (N)LO predictions (with $\alpha_s(m_Z)$ from PDF set using (2)1-loop running)
- m_W = 80.419 GeV,
  $G_F = 1.16639 \cdot 10^{-5}$ GeV^{-2},
  α^{-1} = 132.507,
  Γ_W = 2.0476 GeV

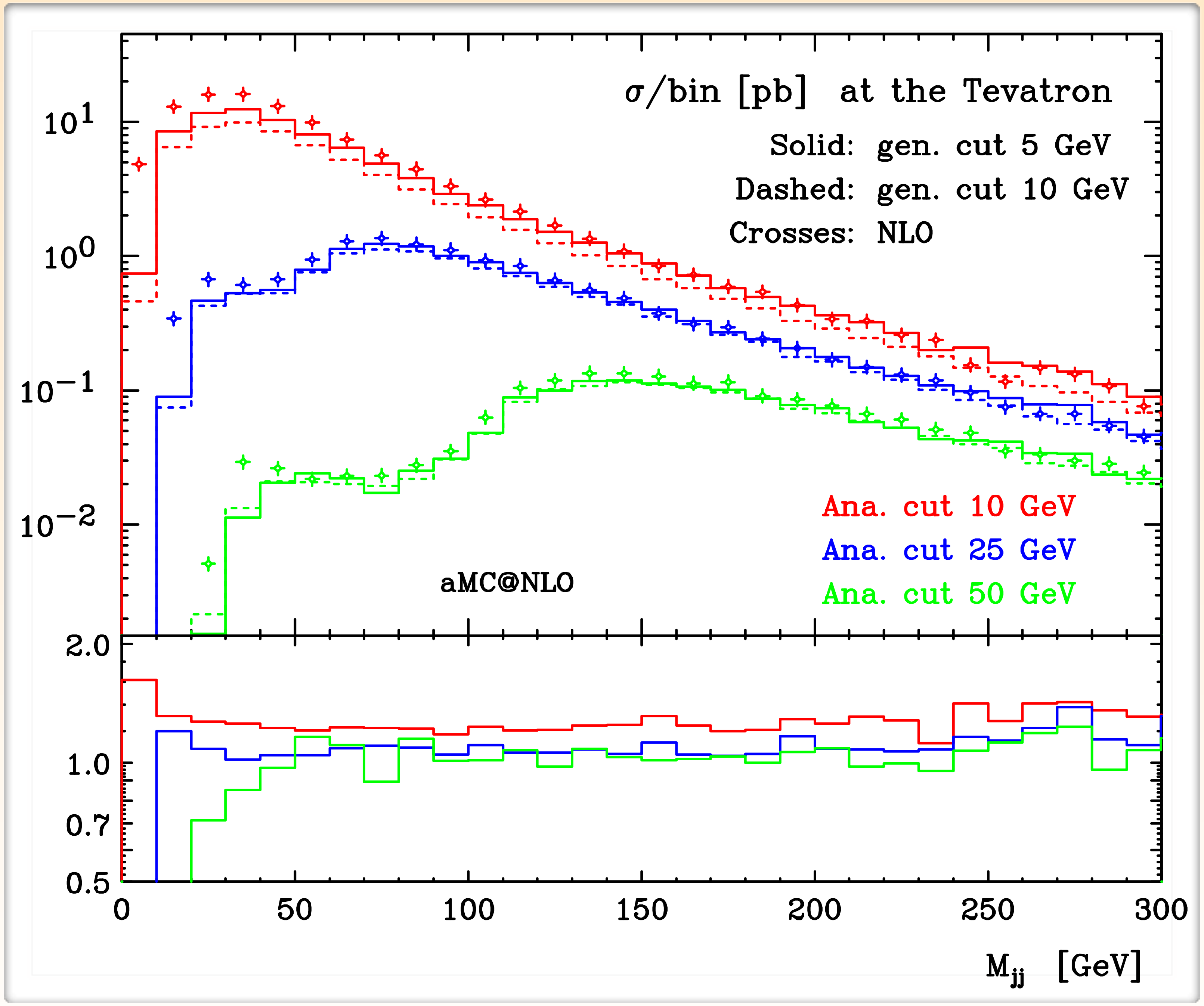
pp → Wjj Validation

- The two generation level cuts agree for high enough momenta (or harder analysis cuts)
- Good agreement with (N)LO, slight difference in shape
- Tails have low statistics, in particular for the 5 GeV generation cuts

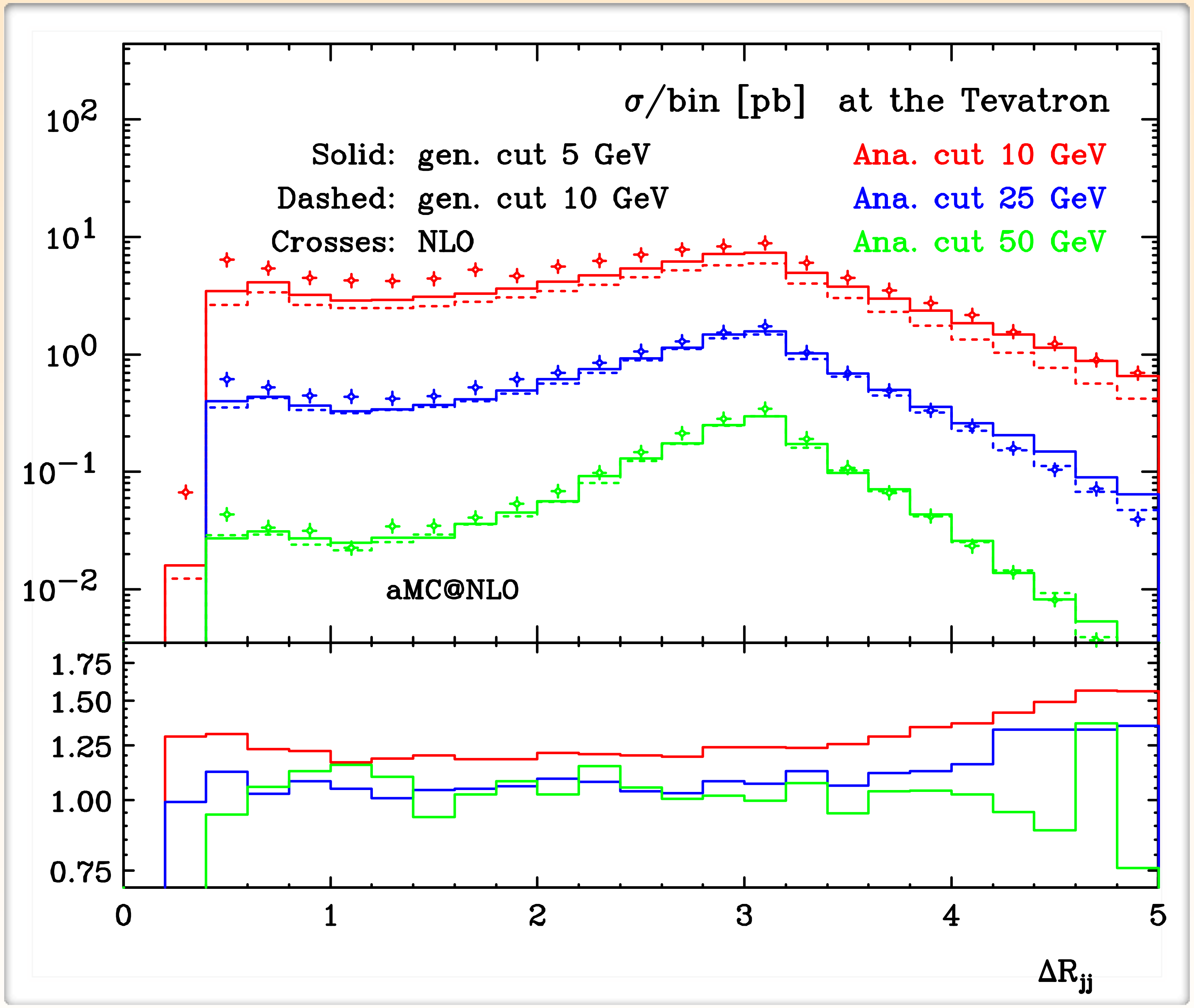


pp → Wjj Validation - II

- Dijet invariant mass
- For analysis cuts larger than 25 GeV the two event samples coincide (except for the very low mass region)
- For smaller analysis cuts the bias is flat in this distribution



PP → WJJ VALIDATION - III



- Distance between the jets
- A small bias remains at 25 GeV analysis in the tail of the distribution, but reduced a lot from lower cuts analysis cuts
  - 5 GeV sample probably ok, 10 GeV gen. cut is a bit too hard
- Of all distributions we have looked at, this one shows the largest bias due to generation cut

pp → Wjj
CDF/DØ analysis cuts

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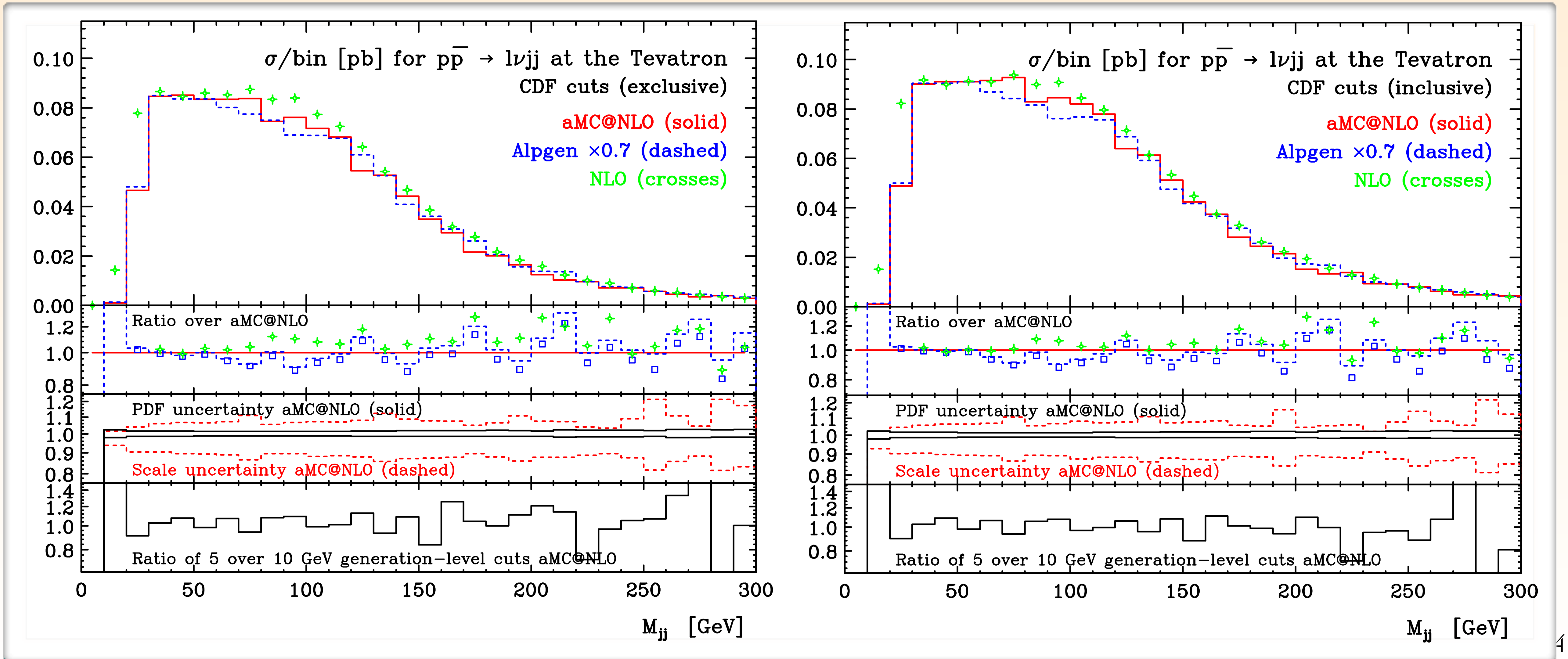
- To slightly simplify the analysis, the MC truth is used to assign the lepton to the W-boson decay
- Only W^+ events (simply a factor 2 for ppbar collisions)
- No underlying event

pp → Wjj
Dijet invariant mass

[RF, Frixione, Hirschi, Maltoni, Pittau, Torrielli (2011)]

- Dijet invariant mass with/without jet veto
- This is the distribution in which CDF found an excess of events around 130-160 GeV
- No differences in shape between the 5 and 10 GeV generation level cuts
- No sign of enhancement over NLO or LOwPS in the mass range 130-160 GeV



Conclusions

- The NLO effects on the shape of the di-jet invariant mass distribution (in association with a W-boson) are small and cannot explain the excess observed by CDF
- These results are obtained with the aMC@NLO package, which allows for event generation at NLO accuracy (NLO+PS) in a completely automated way
- aMC@NLO is being rewritten within the MadGraph v5 framework and is going to be made public soon
- NLO event files and latest news available from the aMC@NLO website

http://amcatnlo.cern.ch