Improving W Boson Event Generation for Run 2a

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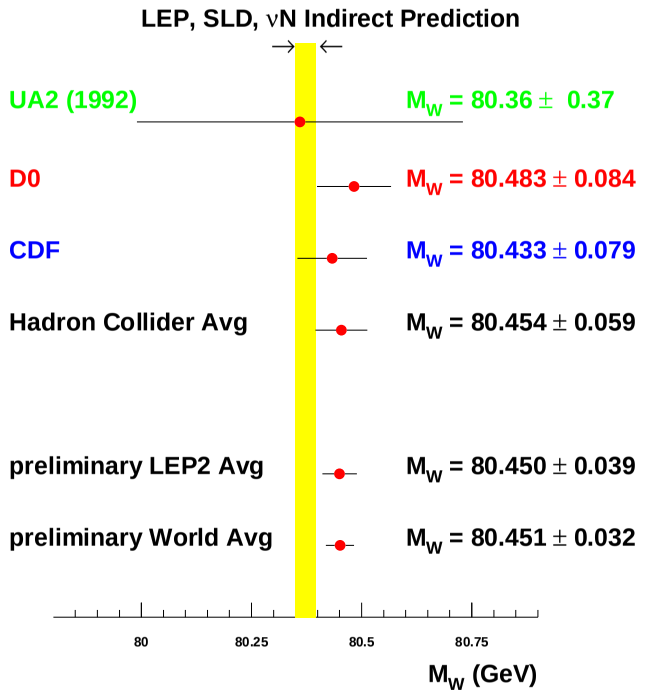
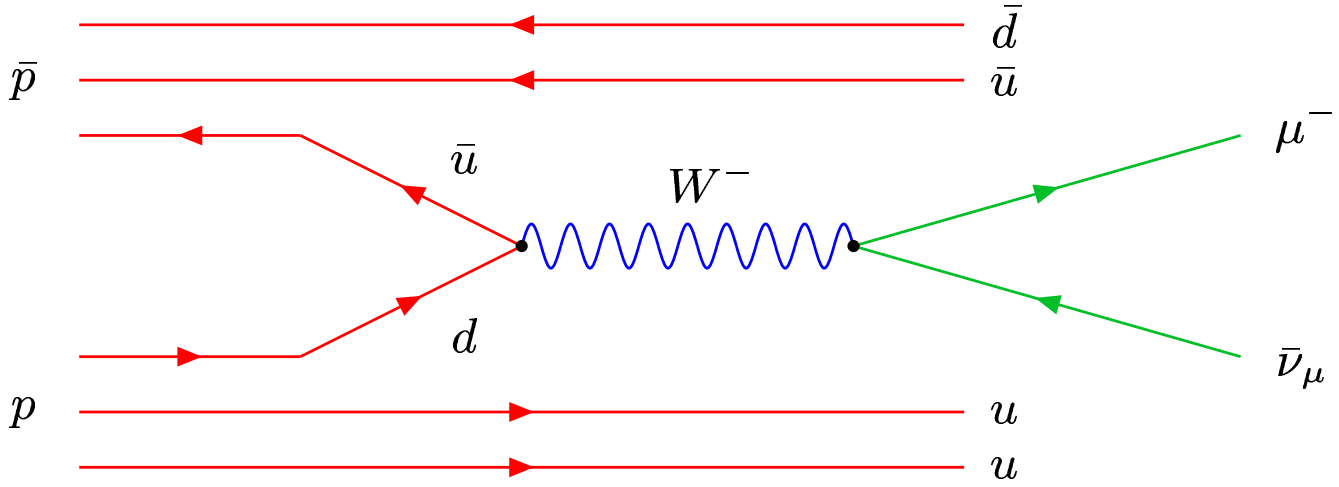
Introduction

- Measuring M_W constitutes a test of the Standard Model
- Measuring M_W and M_{top} constrain M_{Higgs}

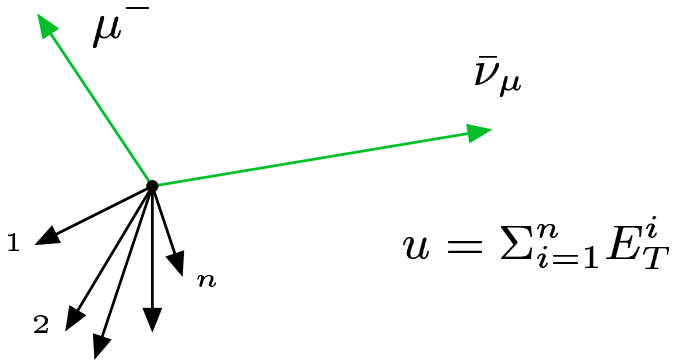
- In Run 2a will measure M_W with a precision of $40 - 80$ GeV
- Currently pushing experimental limits to obtain more precise measurements



W Events at the Tevatron



- W bosons are produced via $q\bar{q}' \rightarrow W$
- Event signature is a high p_T charged lepton and large $\not{E}_T$



Generating W Mass Templates

- Mass templates are constructed from (i) event generation and then (ii) detector simulation
- Event generators contain little or no QCD corrections and QED corrections are plugged in at the end

Need to improve W event generation for Run 2a M_W measurement

- Recently, several programs have become available that deal well with either QCD or QED effects
- Best ones are: **WGRAD** for QED and **RESBOS** for QCD

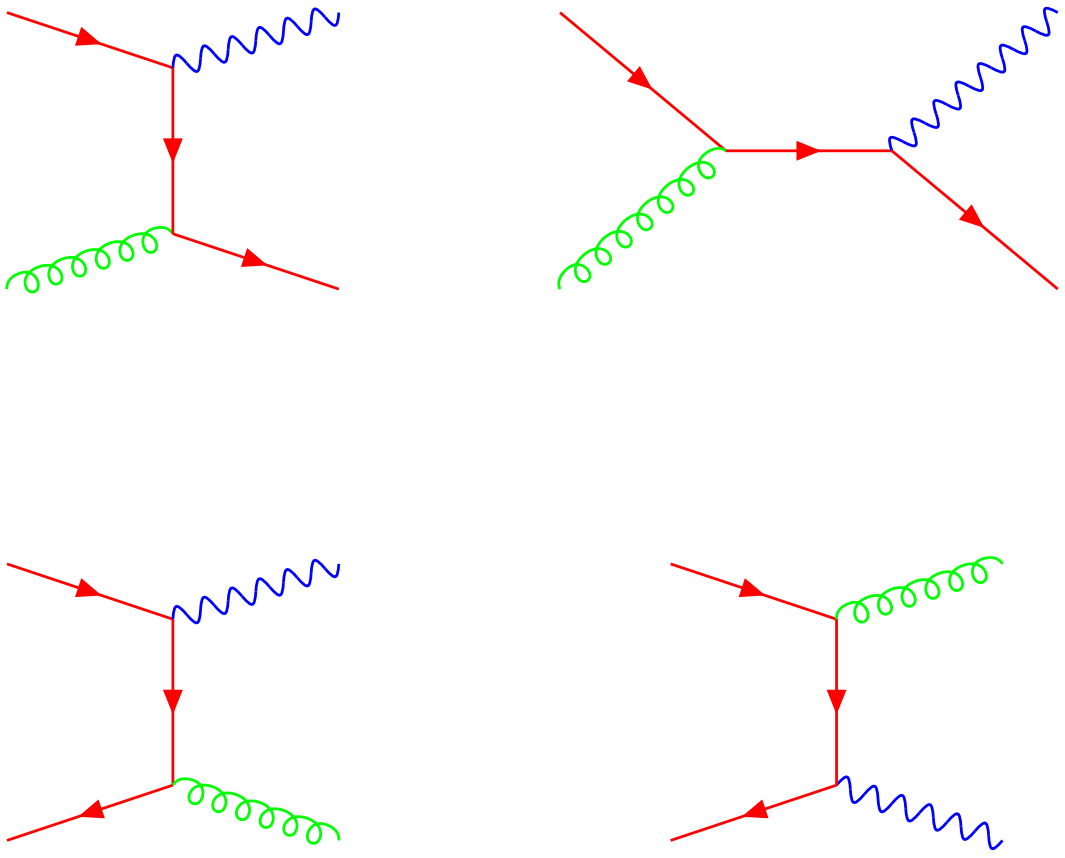
QCD with **RESBOS** [C. Balazs *et al.*, Phys. Rev. D **56**, 5558 (1997)]

- **RESBOS** is a fortran program that computes the fully differential cross section $d\sigma/dp_T\,dy\,dp^2\,d\Omega_l$ for $p\bar{p} \to W \to l\nu$
- Uses exact matrix elements for W production and decay
- Contains LO and NLO initial state QCD corrections

No QED corrections

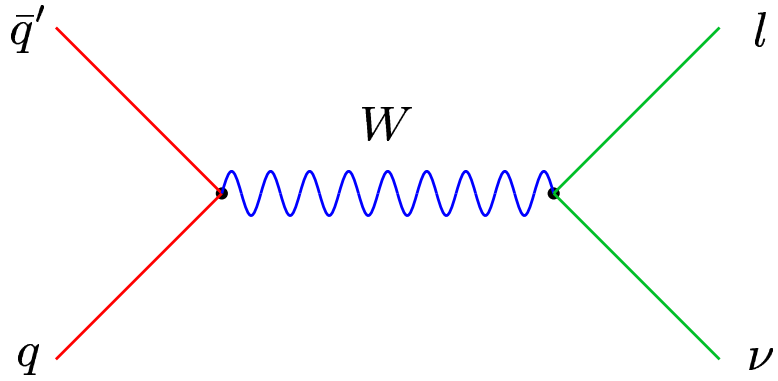
- Includes soft and collinear gluon emission (dominant contribution to cross-section at small p_T)
- Events can be unweighted for event generation

LO QCD Corrections to W Production



QED with **WGRAD** [U. Baur *et al.*, Phys. Rev. D. **59**, 013992 (1999)]

- **WGRAD** is a fortran program that calculates $\mathcal{O}(\alpha)$ radiative corrections to $q\bar{q}' \to W \to l\nu$
- Includes ISR, FSR, and interference terms



No QCD corrections

- Includes real photon in the final state
- Events can be unweighted for event generation

Unweighting Process (in **WGRAD**)

- During precision calculation maximum weight is stored
- For event generation: event is stored if its weight, w, satifies:

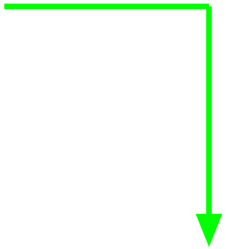
$$w/w_{max} > \text{Random[0,1]}$$

- If $w > w_{max}$ subtract 1 from w and repeat above test ... outcome is some events stored multiple times
- On average w/w_{max} is very small thus unweighting is slow
- Events with negative weight $\sim 0.005\%$
- Events with negative weights get weight of -1

Merging **RESBOS** and **WGRAD**

Idea: numerically merge output of programs in a way that preserves the QCD and QED corrections from each

1. Match kinematics of the W bosons from each
2. Boost **WGRAD** W boson with **RESBOS** p_T^W
3. Boosted **WGRAD** W is our final W



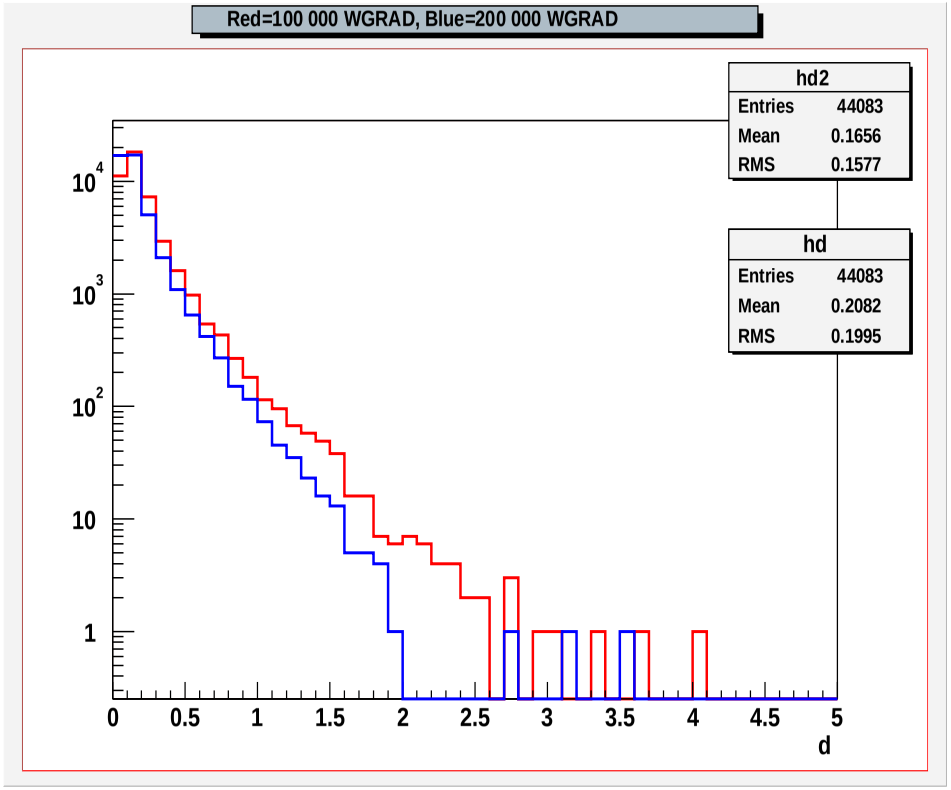
- **RESBOS** M_T^W and p_T^W contain QCD effects
- M_T^W gets correction of order $(p_T^W/M_W)^2$

Quantity	**WGRAD**	**RESBOS**
M_W	$l\,\nu\,\gamma$	$l\,\nu$
y_W	$l\,\nu\,\gamma$	$l\,\nu$
M_T^W	$l\,\nu$	$l\,\nu$

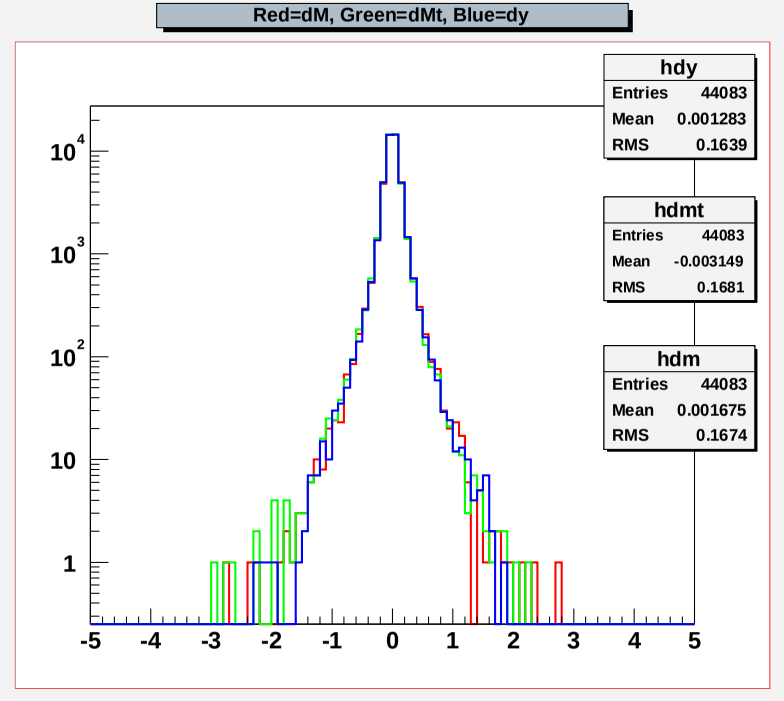
Merging **RESBOS** and **WGRAD** (con't)

- Generated 44 083 unweighted **RESBOS** events
- Matched using 100 000 and 200 000 unweighted **WGRAD** events
- For each **RESBOS** event found closest **WGRAD** event in (M_W, M_T^W, y_W) space by minimizing $d = \sqrt{\frac{\delta^2 M}{\sigma_M^2} + \frac{\delta^2 M_T}{\sigma_{M_T}^2} + \frac{\delta^2 y}{\sigma_y^2}}$
- Boosted **WGRAD** event with **RESBOS** p_T

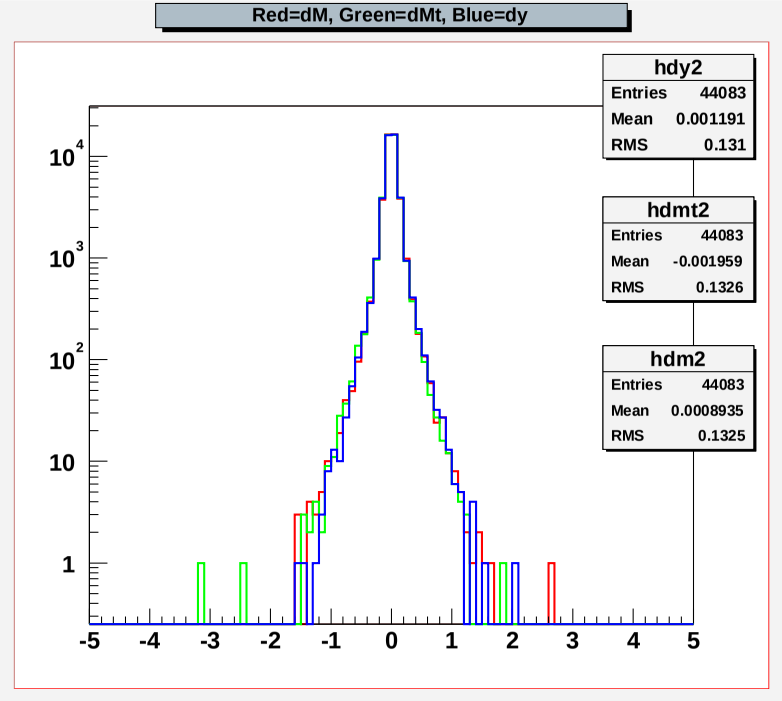
Minimized distance $\rightarrow$ $d = \sqrt{\delta^2 M + \delta^2 M_T + \delta^2 y}$



δM, δM_T, δy for 100 000 and 200 000 WGRAD events

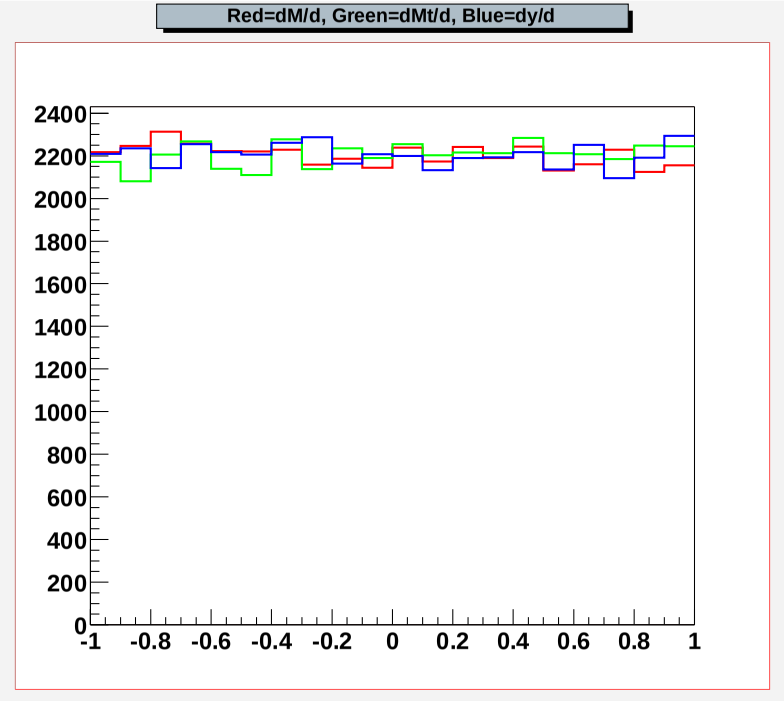


100 000

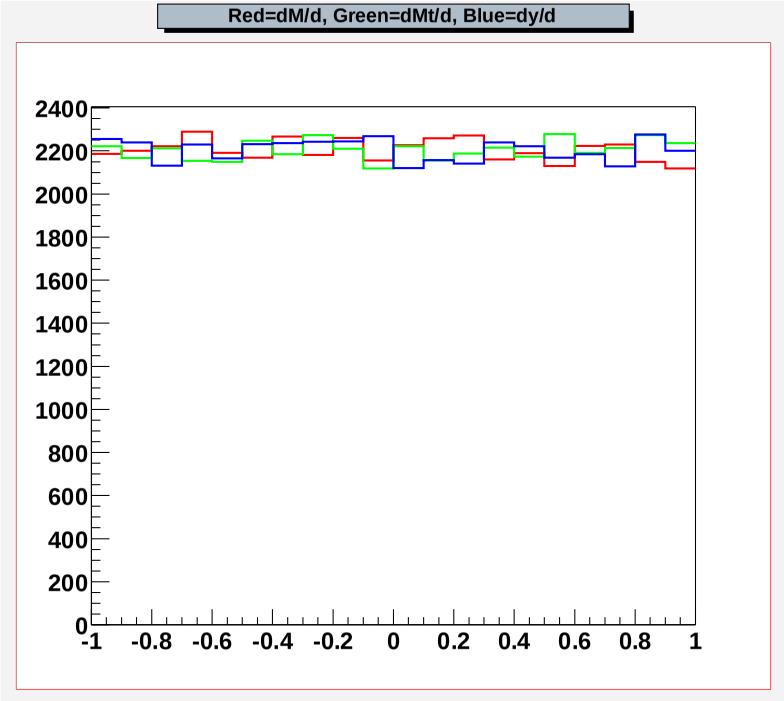


200 000

$\delta M/d$, $\delta M_T/d$, $\delta y/d$ for 100 000 and 200 000 WGRAD events

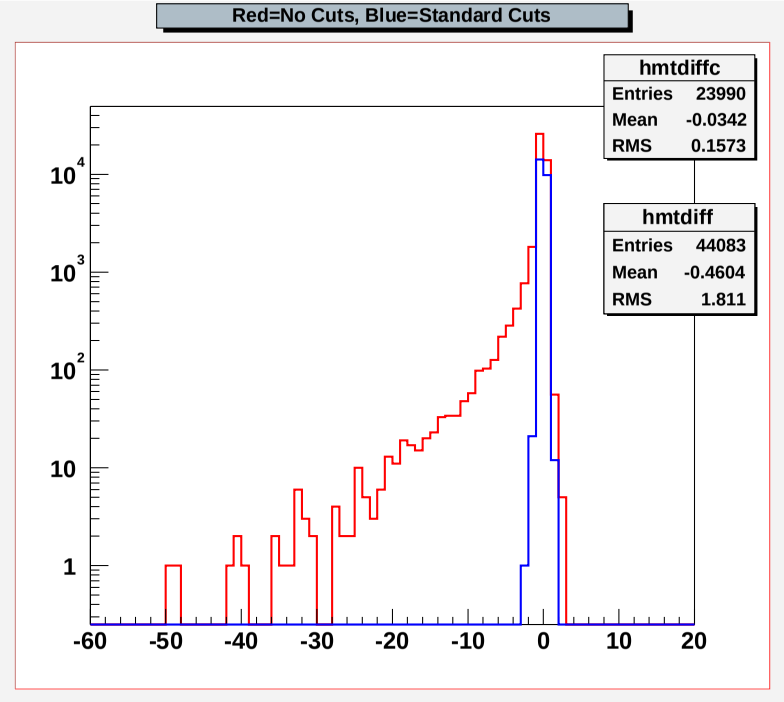


100 000

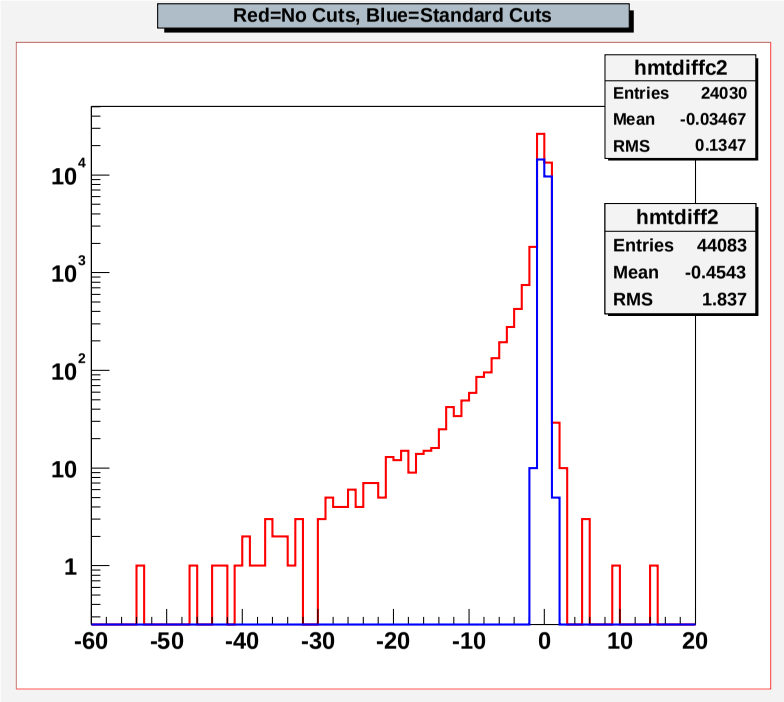


200 000

δMt after boost for 100 000 and 200 000 WGRAD events



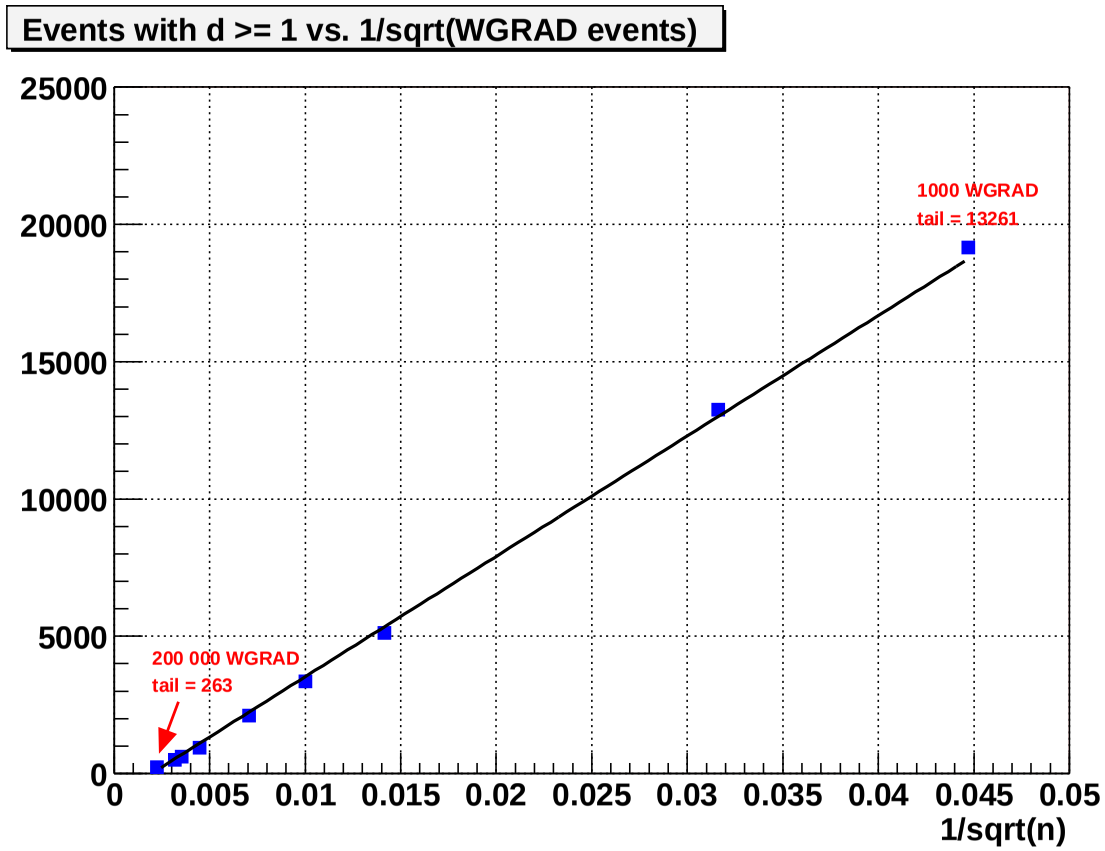
100 000



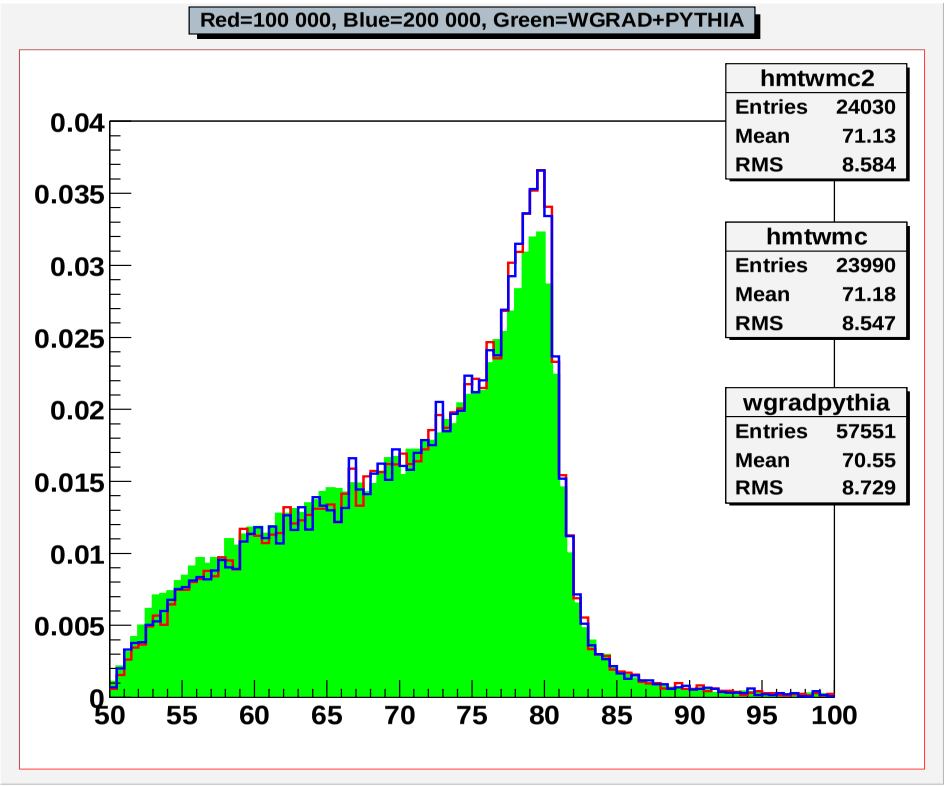
200 000

- Standard cuts: p_T^l, $p_T^\nu > 25$ GeV, $u < 20$ GeV improve matching

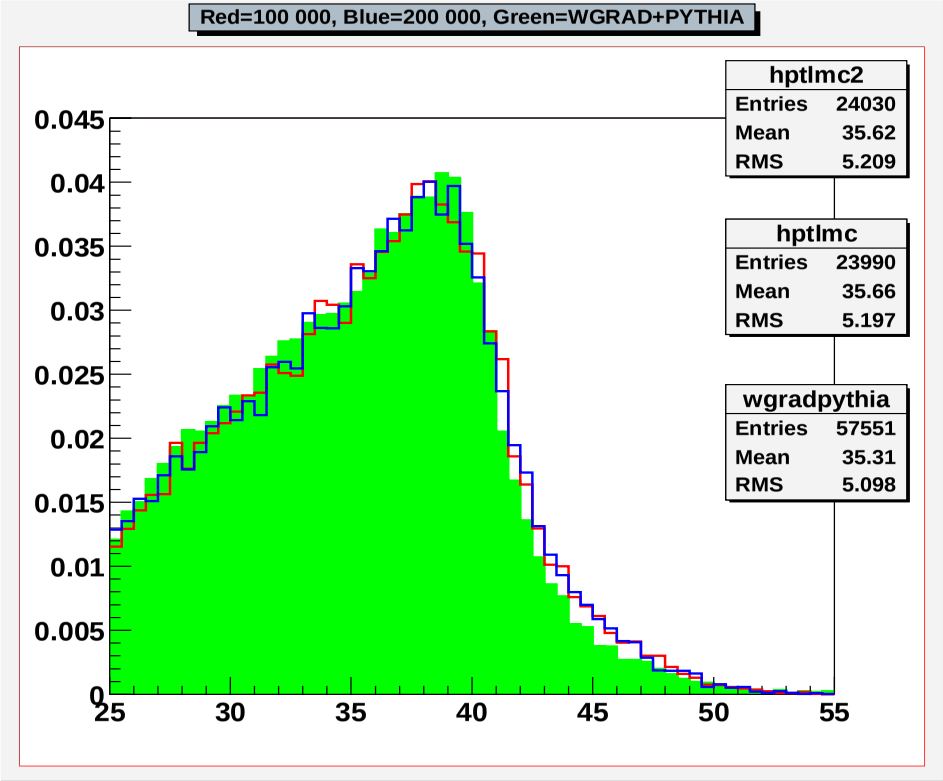
Matching scales with $\sqrt{\text{WGRAD events}}$



Transverse Mass



Charged Lepton Transverse Momentum



Conclusions

- For Run 2a mass measurement need improved W boson generation
- Numerical merger of **RESBOS** and **WGRAD** is the most promising start
- Need to unambiguously identify presence of QED and QCD corrections in M_T^W and p_T^l distributions

  $\rightarrow$ Template fitter (see changes in M_W from various effects)
- May need to find faster matching algorithm for Run 2a templates ($\sim$20M events)
- CDF note on the way
- Will show results at upcoming EWK meeting