Measurements of the top quark mass using 9.7 fb^{-1} of DØ Run II data

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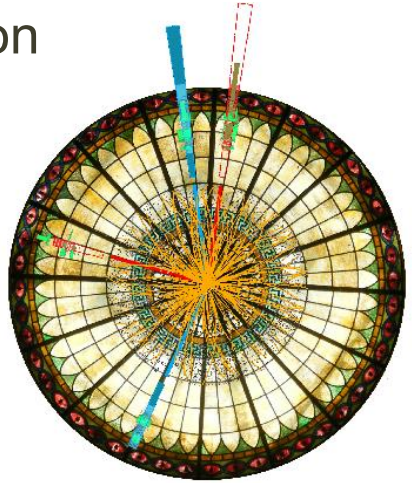
On behalf of the D0 Collaboration

DIS2015

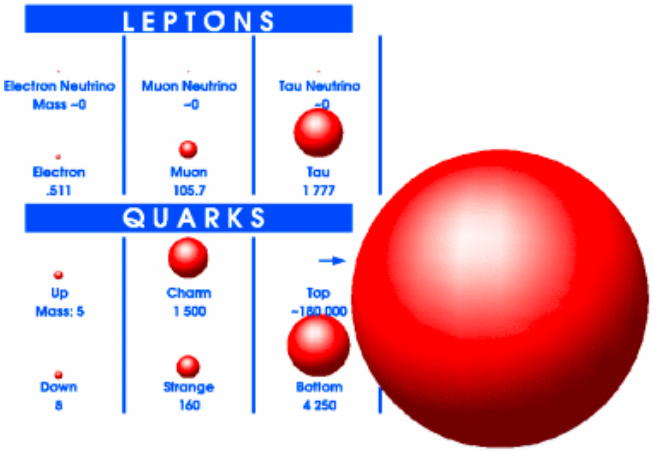
4/29/2015



Outline

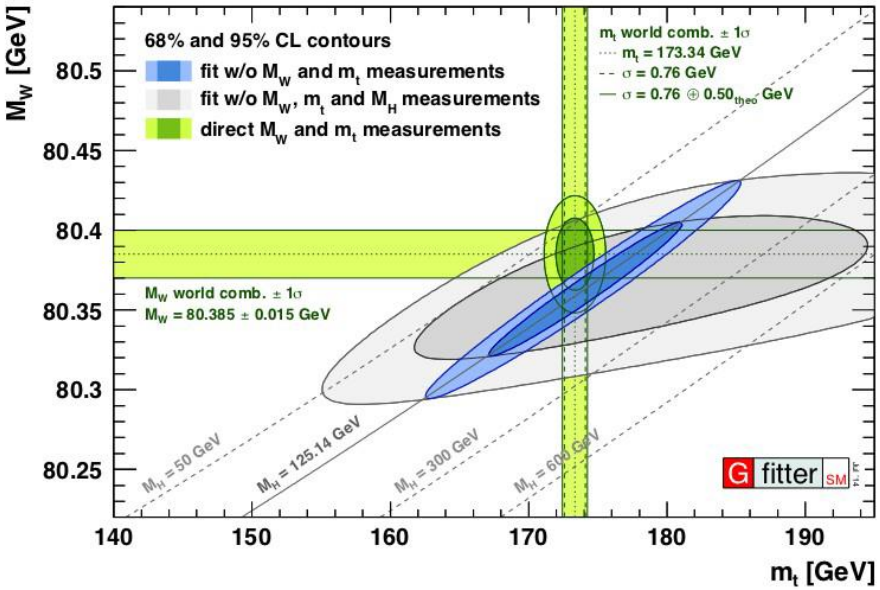
- motivation
- matrix element method
- l+jets measurement
- additional JES
- template method
- dilepton measurement
- systematic uncertainty
- summary & Outlook

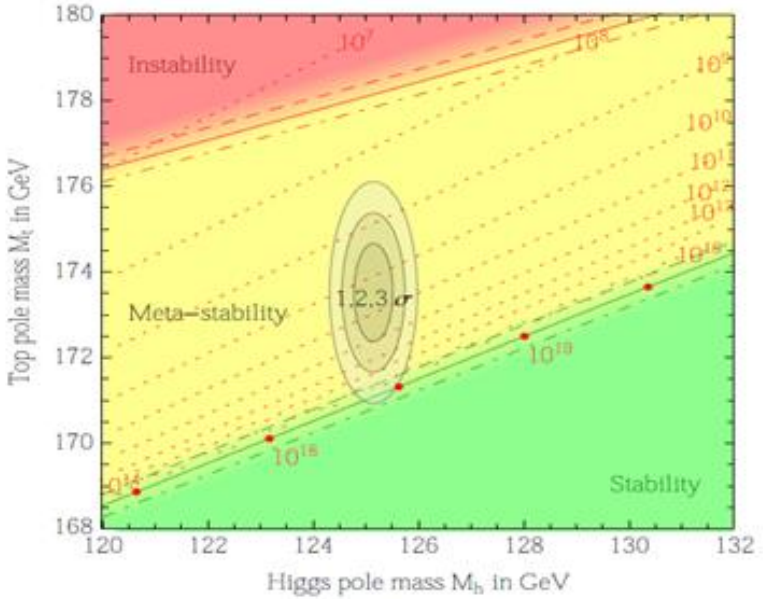
Motivation



Top quark in the Standard Model (SM)

- Most heavy fundamental particle
- The top Yukawa coupling is very close to **unity**, indicating that the top quark may play a special role in ESWB
- Self-consistency test of the SM
- Relates to the stability of Higgs potential



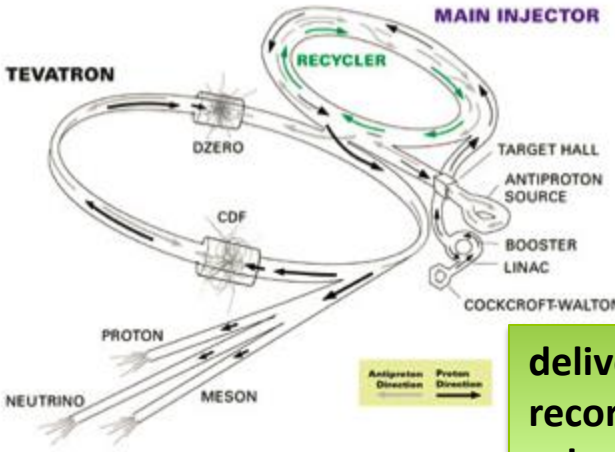


Buttazzo et al **arXiv:1307.3536**

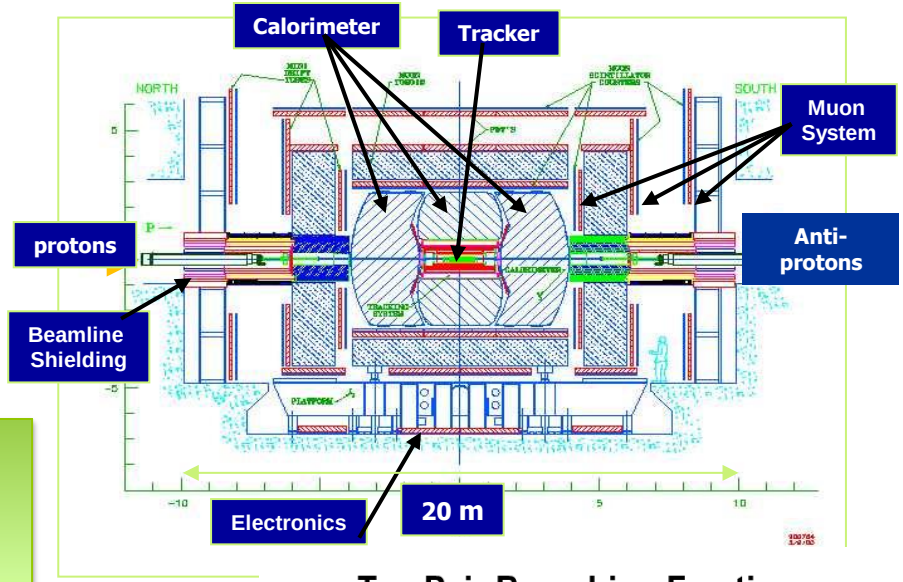
Tevatron, DØ and top production

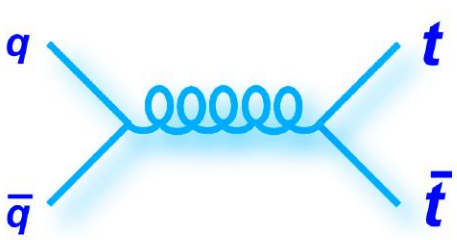
DØ experiment is one of the two experiments at Tevatron Hadron Collider, Fermilab

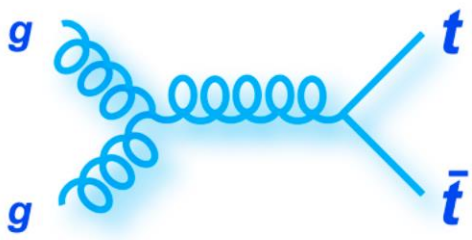
Tevatron Run II 2001-2011



delivered 11.9 fb^{-1}
recorded 10.7 fb^{-1}
selected 9.7 fb^{-1}

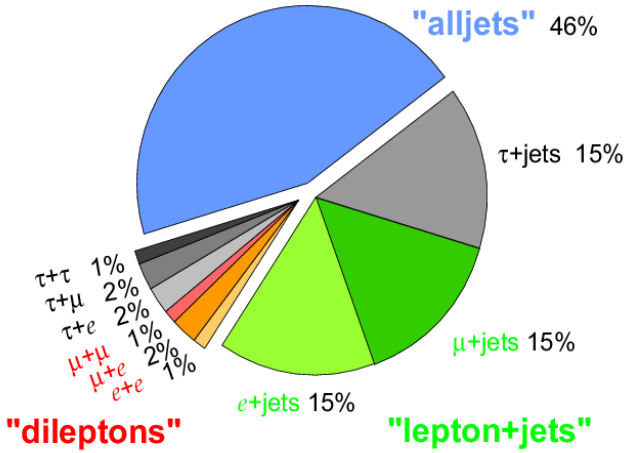






Tevatron Run II: σ (mt=173GeV) ~ 7.5 pb (arXiv:1112.5675)
85% qqbar annihilation, 15% gg fusion

Top Pair Branching Fractions



Matrix Element Method in lepton+jets channel

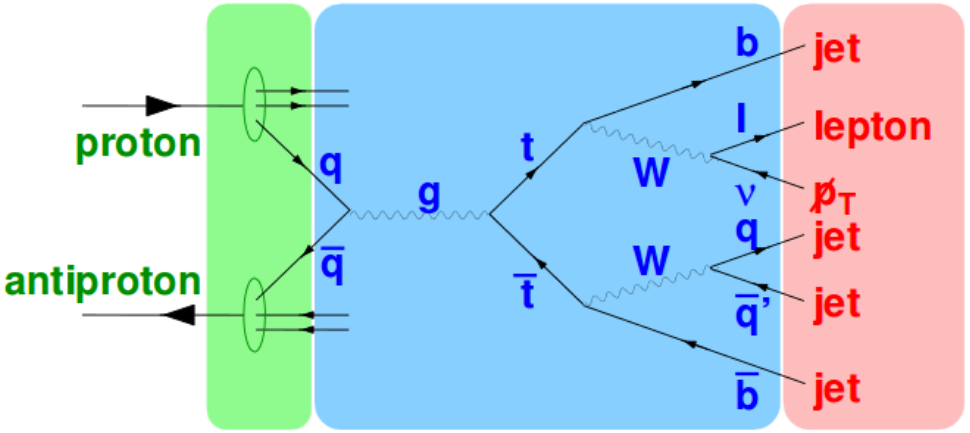
l+jets: Matrix Element method + in-situ jet energy scale (k_{JES})

$$L(x_1,..,x_n; m_t, k_{\mathrm{JES}}, f) = \prod_{i=1}^{n} P_{\mathrm{evt}}(x_i; m_t, k_{\mathrm{JES}}, f)$$

$$P_{\mathrm{evt}}(x; m_t, k_{\mathrm{JES}}, f) = f \cdot P_{\mathrm{sig}}(x; m_t, k_{\mathrm{JES}}) + (1-f) \cdot P_{\mathrm{bkg}}(x; k_{\mathrm{JES}})$$

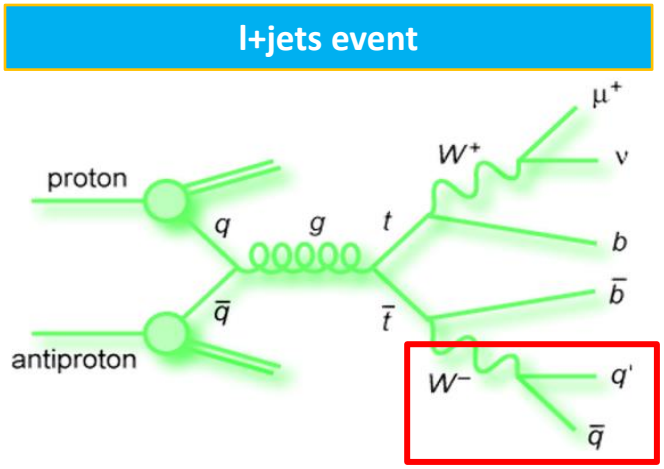
$$P_{\mathrm{sig}}(x; m_t, k_{\mathrm{JES}}) = \frac{1}{\sigma_{\mathrm{obs}}(p\bar{p} \to t\bar{t}; m_t, k_{\mathrm{JES}})} \times \sum_{perm} w_i \int_{q_1,q_2,y} \sum_{flavors} \mathrm{d}q_1 \mathrm{d}q_2 f(q_1) f(q_2) \frac{(2\pi)^4 |\mathscr{M}(q\bar{q} \to t\bar{t} \to y)|^2}{2q_1 q_2 s} \mathrm{d}\Phi_6 W(x,y; k_{\mathrm{JES}})$$

CTEQ6L PDF | LO Matrix Element | Detector Resolution



in-situ Jet energy calibration in lepton+jets channel

- in-situ JES calibration
  - 2 light quarks from W boson decay (W->qq')
  - provides a way to measure light quark JES
  - constraining the invariant mass to world average value of the W boson mass
  - This greatly reduces the uncertainty on JES absolute scale



- k_{JES} - additional JES factor that corrects measured jet energy to particle level

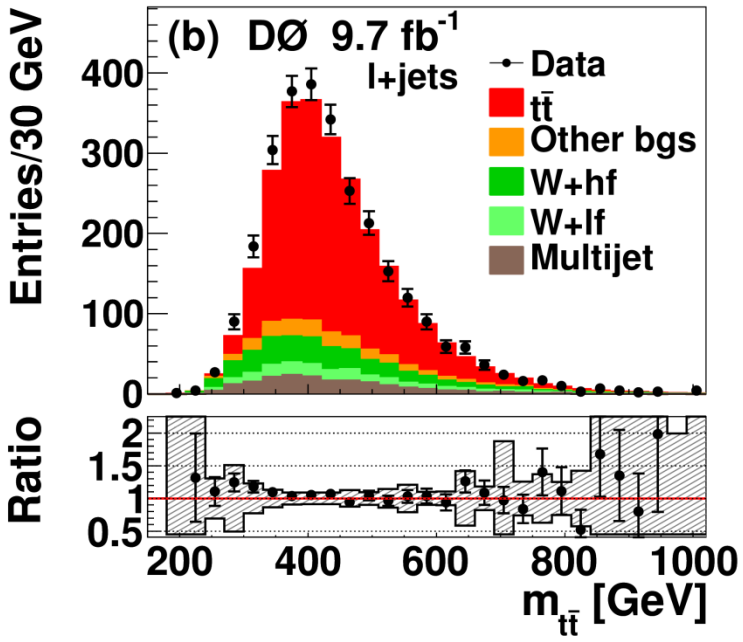
$$k_{JES} = 1.0250 \pm 0.0046 \text{ *}$$

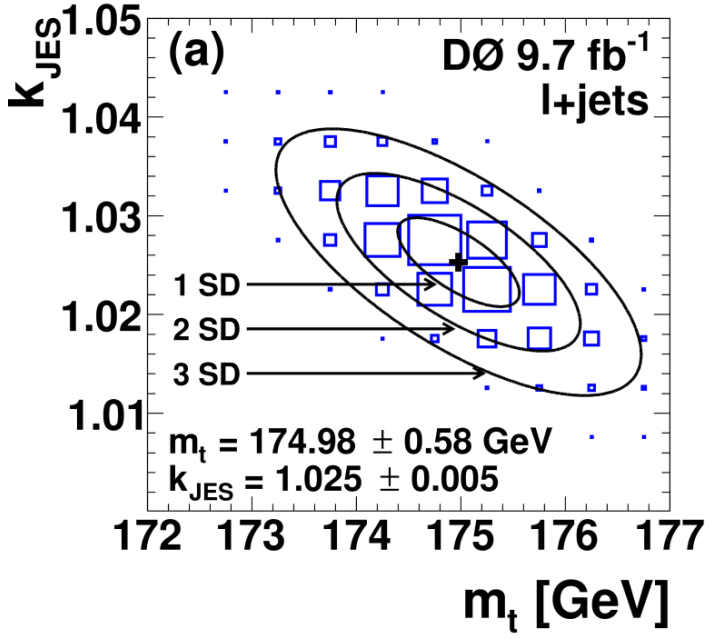
(typical JES uncertainty is ~2%)

- k_{JES} can also be adopted in the dilepton channel
- By adopting k_{JES} , the JES systematic uncertainty in dilepton channel is reduced by a factor ~4

* Phys. Rev. Lett. **113**, 032002 (2014)

Precise measurement of the top quark mass in l+jets final states using 9.7fb^{-1} of D0 data





m_t = 174.98 ± 0.76 GeV

m_t = 174.98 ± 0.58 (stat + JES) ± 0.49 (syst) GeV

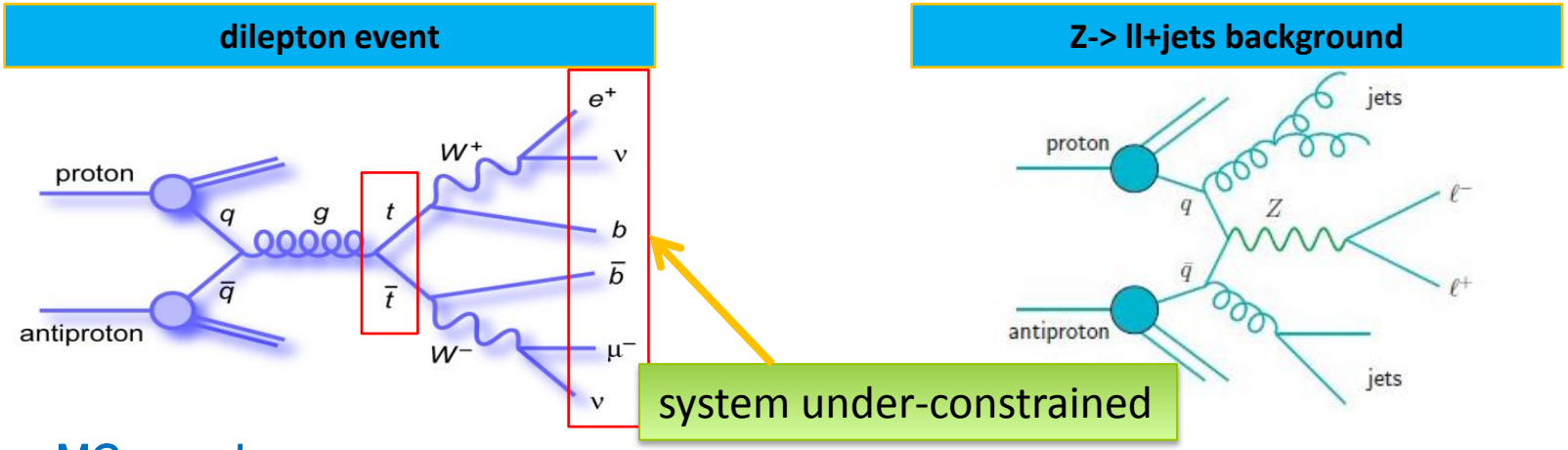
0.43% precision

most precise single channel measurement

submitted to Phys. Rev. D

(Phys. Rev. Lett. **113**, 032002 (2014))

Data sample and event yields for dilepton final states



- ttbar MC sample:
  130 – 200 GeV with 5 GeV increment & 172.5 GeV sample (ALPGEN+PYTHIA)
- backgrounds:
  Z->ll+jets (ALPGEN+PYTHIA), diboson (PYTHIA), instrumental (data)
- Kinematic selection:
  two isolated leptons with opposite charge: pT > 15 GeV, |η| < 2.5
  at least two jets with: pT > 20 GeV, |η| < 2.5
  additional topological requirement *
- At least one jet originates from b quark

*=subject of optimization for this analysis

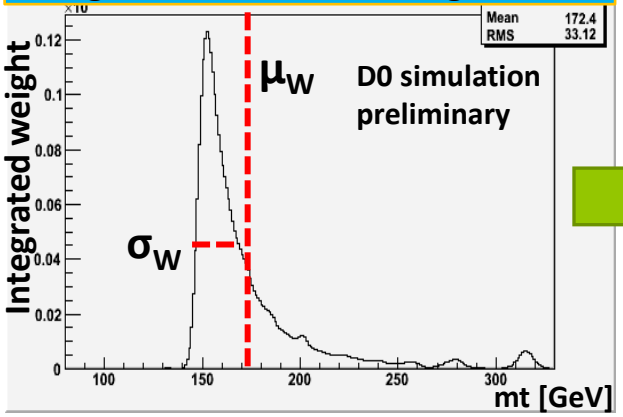
Event yields after selection

Channel	expected	data
eμ	298.1 ± 24.6	336
ee	106.5 ± 11.0	113
μμ	103.5 ± 8.3	109

Neutrino Weighting + Template Method in dilepton final states

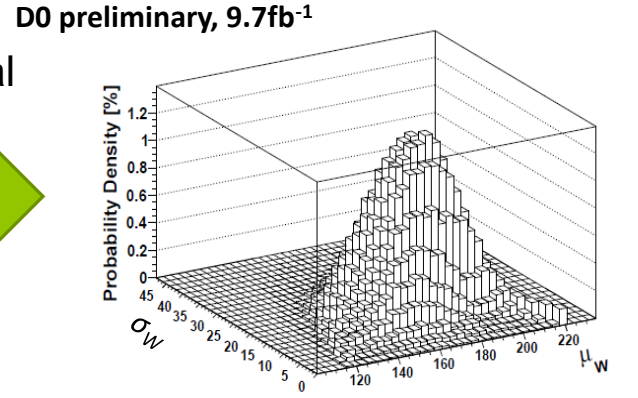
- Event can be reconstructed for given mtop and two neutrino rapidities
- The agreement between calculated MET and observed MET is quantified by a weight ω
- For each given mtop, Integrate ω over all possible combinations of the two neutrino η's and jet-lepton assignments

weight distribution of a single event



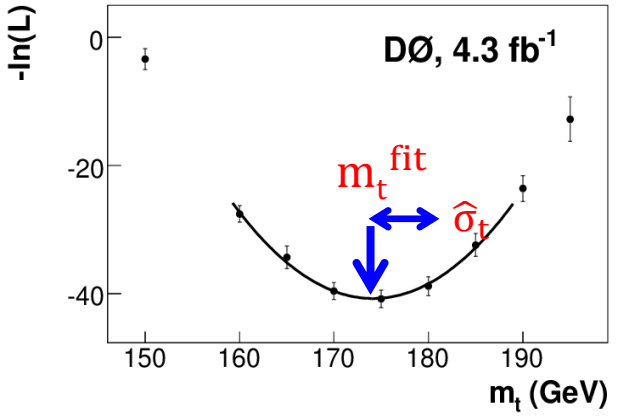
Use the first two moments (μ_W, σ_W) to build templates for signal and backgrounds

signal template – m_t=172.5 GeV



Iteratively fit negative log likelihood with parabola

- fitted m_{top} = minimum of parabola
- estimated statistical uncertainty = deviation from minimum of parabola to minimum + 0.5



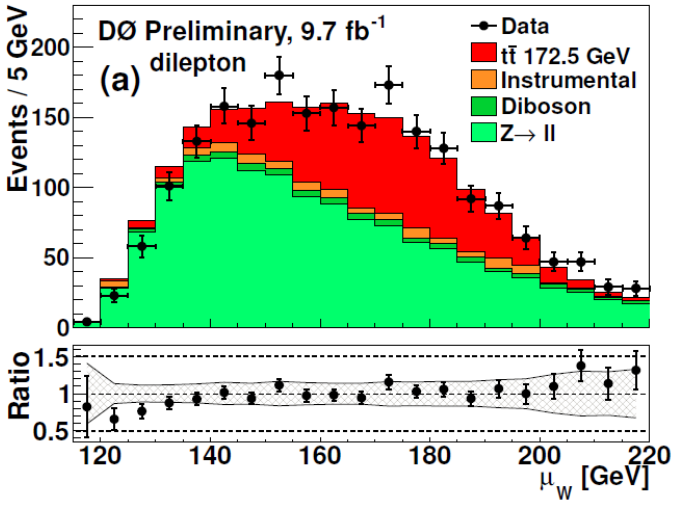
Optimization in dilepton final states using template method

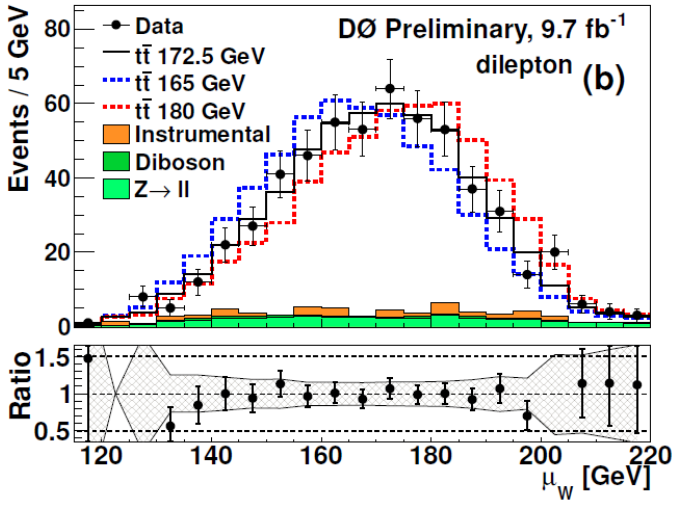
Category	Parameters	Expected improvement
Event Selection	Kinematic cuts:	~3% in stat.uncert.
	H_T (eμ)	
	E_T significance (ee / μμ)	
	E_T (μμ)	
	E_T in Zmass Window (ee)	
	Btagging maxMVA cut (ee/eμ/μμ)	
weight calculation	Unclustered missing E_T resolution	~5% in stat.uncert.
	Scanned mass range	~6% in stat.uncert.
Likelihood Calculation	Template bin size (μ_w,σ_w) (ee/eμ/μμ)	~10% in stat.uncert.
	Number of pseudo-experiments	stablize syst.uncert.

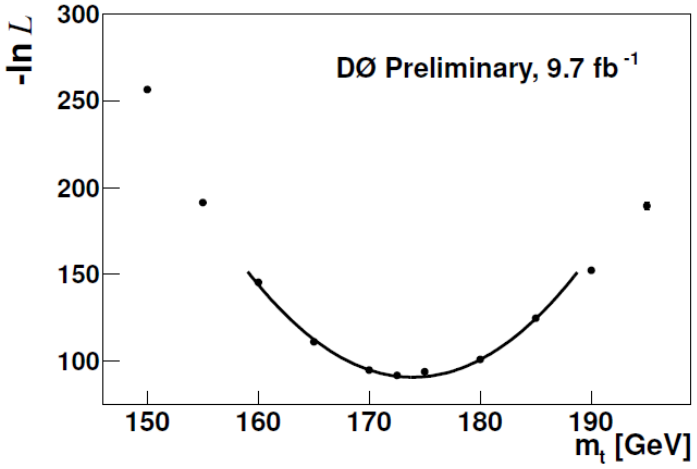
- Using 9.7 fb^{-1} of data, the expected improvement in expected statistical uncertainty is > 25% on top of 2X more data

Data result in dilepton final states

Distribution of μ_W before and after all selections and kinematic reconstruction







preliminary data measurement in the dilepton channel

m_t = 173.3 ± 1.4 (stat)

Systematic Uncertainty and result in dilepton final states

D0 preliminary, 9.7fb^{-1}

Source	σ_{m_t} [GeV]
Jet energy calibration	
Absolute scale	± 0.5
Flavor dependence	± 0.3
Residual scale	± 0.4
b quark fragmentation	± 0.1
Signal modeling	
ISR/FSR	± 0.2
Color reconnection	$+0.2$
Higher order effects	$+0.3$
Hadronization	-0.1
PDF uncertainty	-0.1
Signal fraction	< 0.05
Object reconstruction	
Electron p_T resolution	< 0.05
Muon p_T resolution	< 0.05
Electron energy scale	< 0.05
Muon p_T scale	< 0.05
Jet resolution	± 0.1
Jet identification	< 0.05
Method	
Calibration	± 0.1
Template statistics	± 0.2

In the dilepton channel, the top quark mass measured using template method is

D0 preliminary, dilepton

$m_t = 173.3 \pm 1.6$ GeV

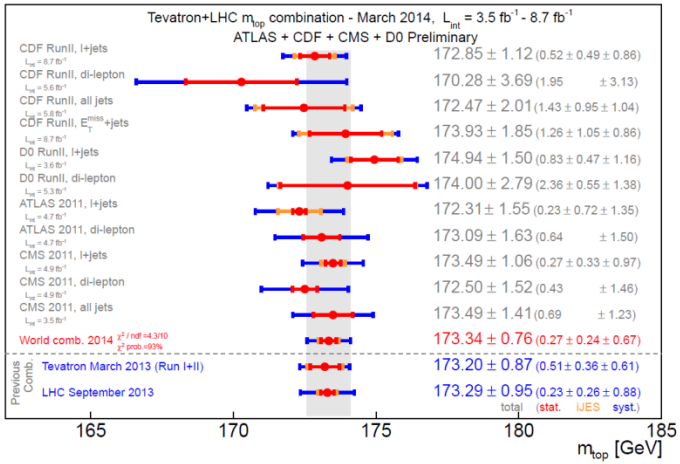
$m_t = 173.3 \pm 1.4$ (stat) $\pm$ 0.8 (syst) GeV

0.9% precision

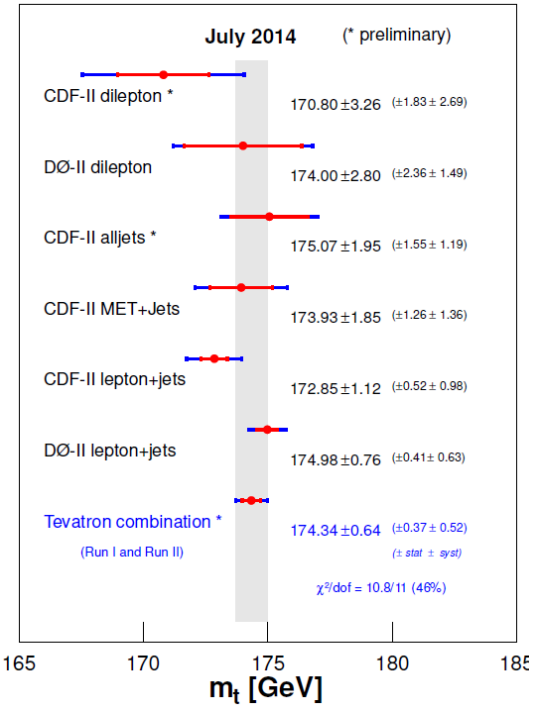
- Smallest systematic uncertainty in dilepton channel
- Consistent with current world average

Recent headlines on the top quark mass

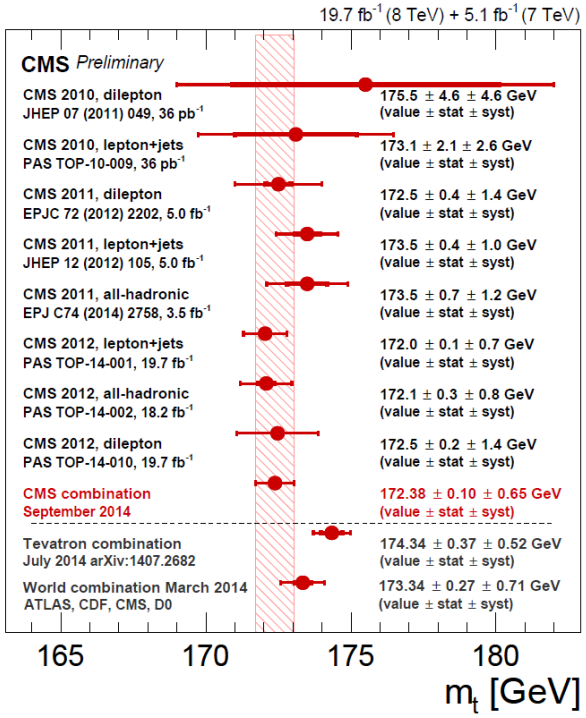
First World combination
March 2014
arXiv:1403.4427



Tevatron Combination
July 2014
arXiv:1407.2682



CMS Combination
September 2014
CMS-PAS-TOP-14-015



	World comb.	Tevatron comb.	CMS comb.
m_t [GeV]	173.34 ± 0.76	174.34 ± 0.64	172.38 ± 0.66
Precision	0.44 %	0.37 %	0.38 %

Summary and outlook

l+jets

m_t = 174.98 ± 0.58 (stat + JES) ± 0.49 (syst) GeV

0.43% precision

dilepton preliminary

m_t = 173.3 ± 1.4 (stat) ± 0.8 (syst) GeV

0.9% precision

- In the dilepton channel, the precision is improved by about a factor of two compared to previous template result for 5.3 fb^{-1}
- We look forward to updated Tevatron combination (and World combination)

Thank you for your attention !

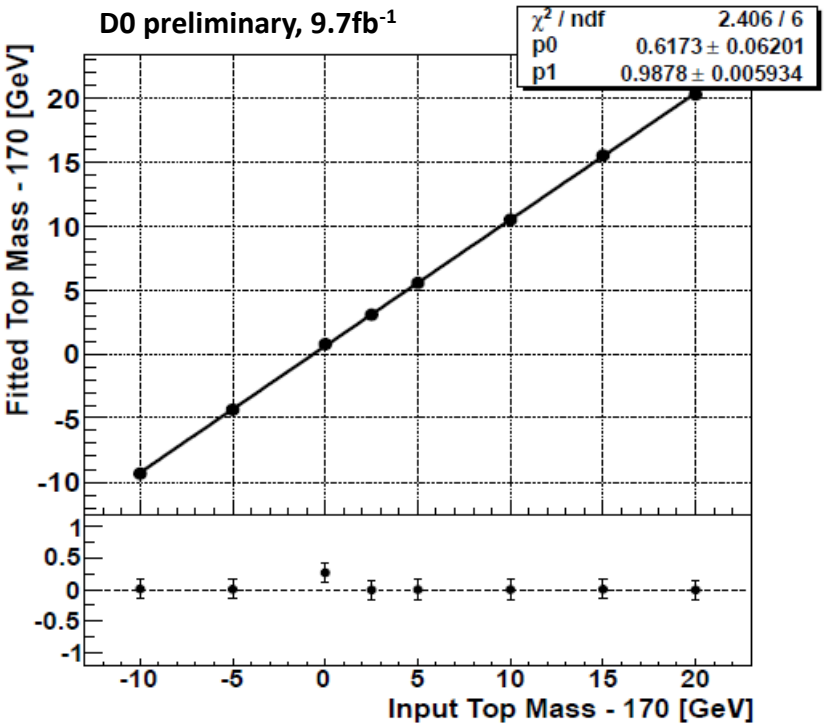
Backup

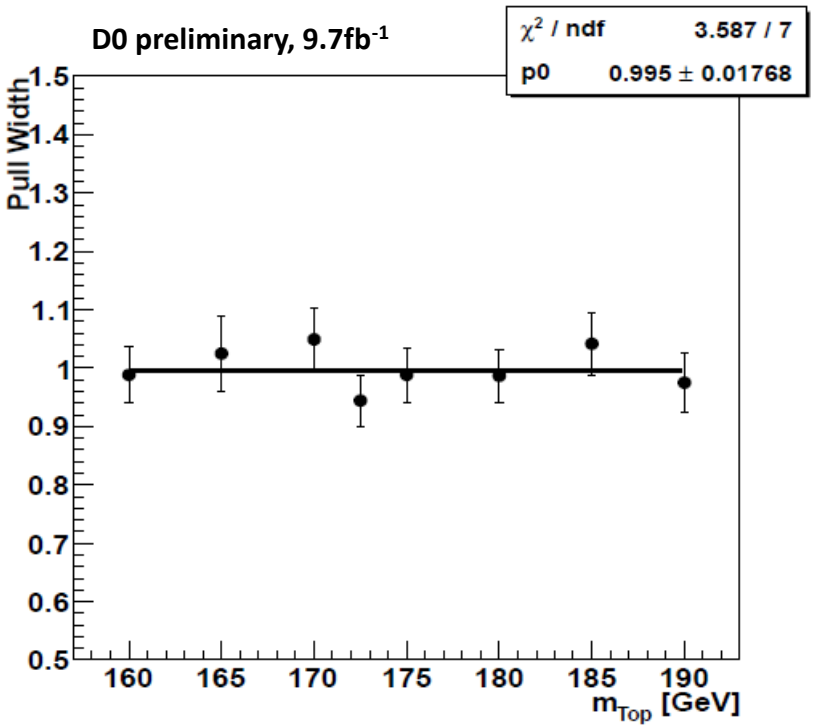
Calibration and expected stat.uncert. in dilepton channel

- 3000 pseudo-experiments
- fitted top mass vs. input top mass
- good slope and pull

$$m_t^{fit} = \alpha(m_t^{MC} - 170) + \beta + 170$$

$$p = \frac{m_t^{meas,calib} - m_t^{MC}}{\sigma^{meas,calib}}$$

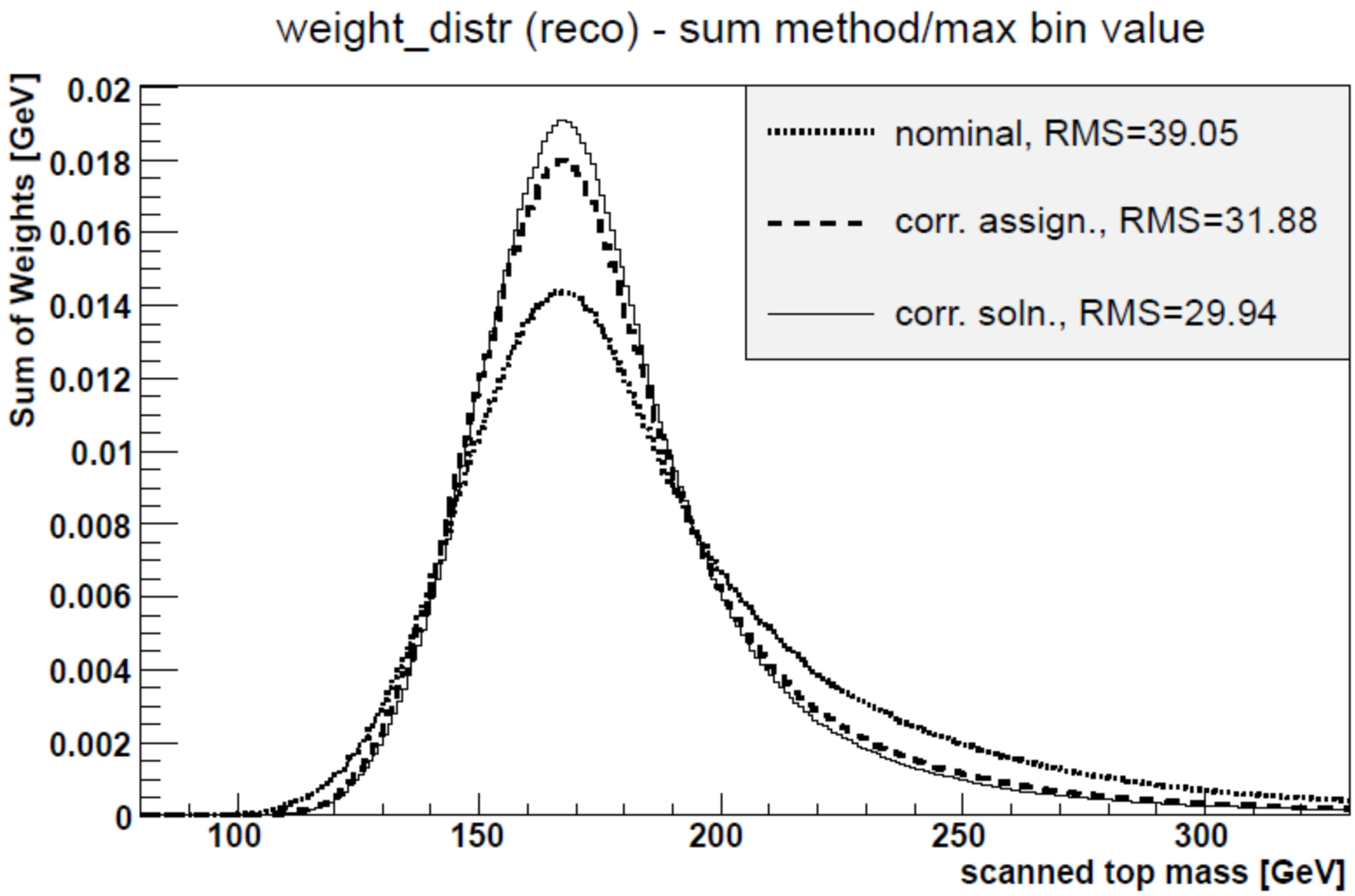




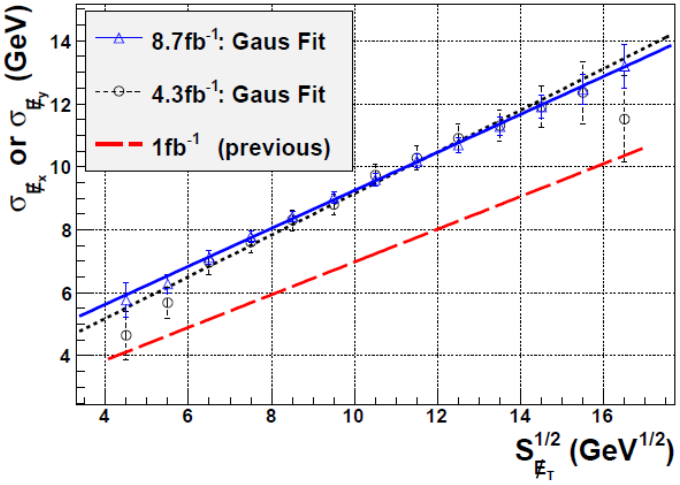
Systematic Uncertainty in the lepton+jets channel

Source of uncertainty	Effect on m_t (GeV)
Signal and background modeling:	
Higher order corrections	$+0.15$
Initial/final state radiation	± 0.09
Hadronization and UE	$+0.26$
Color reconnection	$+0.10$
Multiple $p\bar{p}$ interactions	-0.06
Heavy flavor scale factor	± 0.06
b-jet modeling	$+0.09$
PDF uncertainty	± 0.11
Detector modeling:	
Residual jet energy scale	± 0.21
Flavor-dependent response to jets	± 0.16
b tagging	± 0.10
Trigger	± 0.01
Lepton momentum scale	± 0.01
Jet energy resolution	± 0.07
Jet ID efficiency	-0.01
Method:	
Modeling of multijet events	$+0.04$
Signal fraction	± 0.08
MC calibration	± 0.07
Total systematic uncertainty	± 0.49
Total statistical uncertainty	± 0.58
Total uncertainty	± 0.76

Weight distribution



MET resolution



DØ detector has very good MET resolution
Important for measurement in dilepton channel using template method