Top Quark Mass from TEVATRON & LHC

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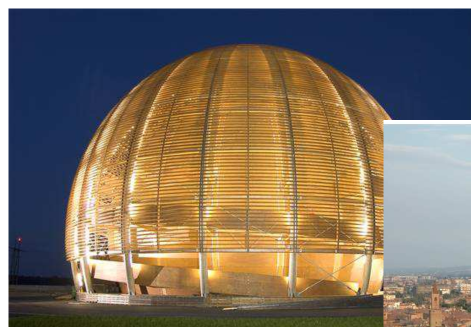
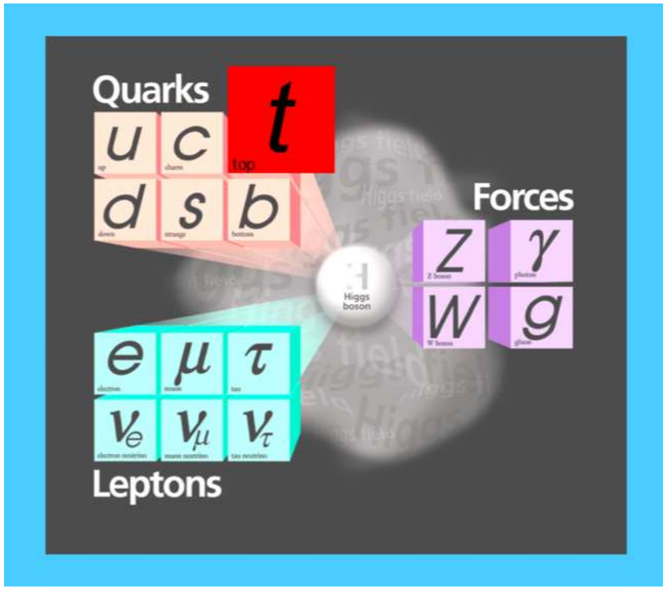
OUTLINE

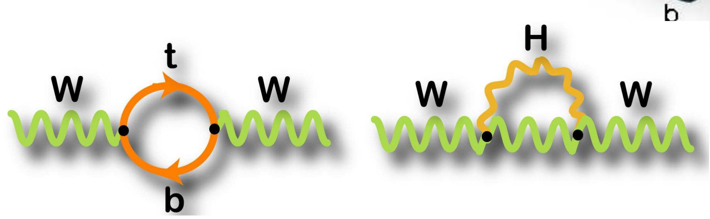
- **The Top Quark**
- **The Experiments**
- **Measurement Strategies**
- **Recent Results**
- **M_{top} Combinations & World Average**
- **Summary**



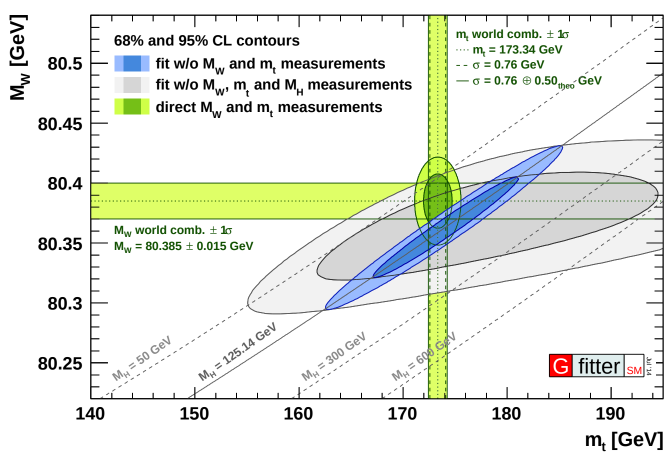
The Top Quark

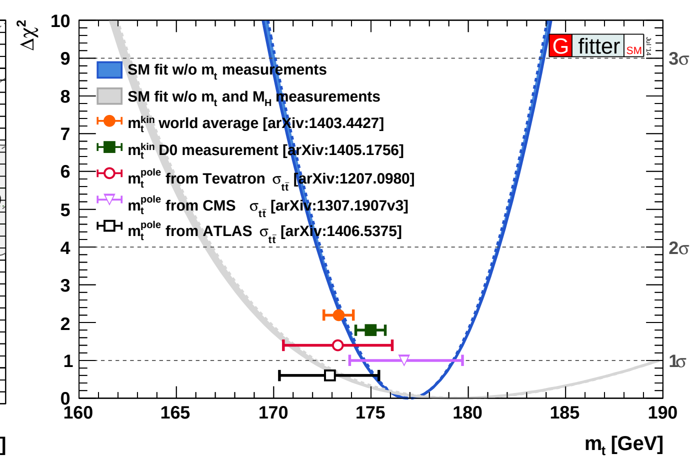


- Observed in 1995 at Fermilab....
  ... not a big surprise (...if we trust the SM...)
- ... but M_{top} striking large!

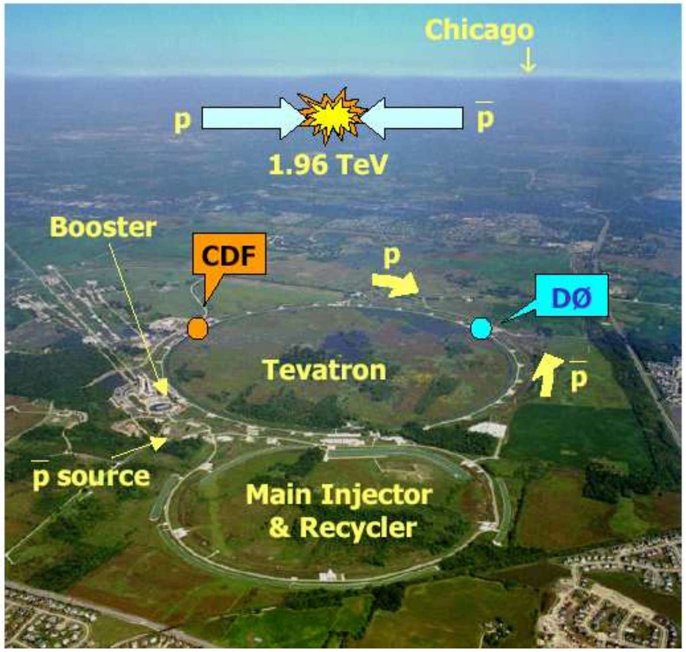


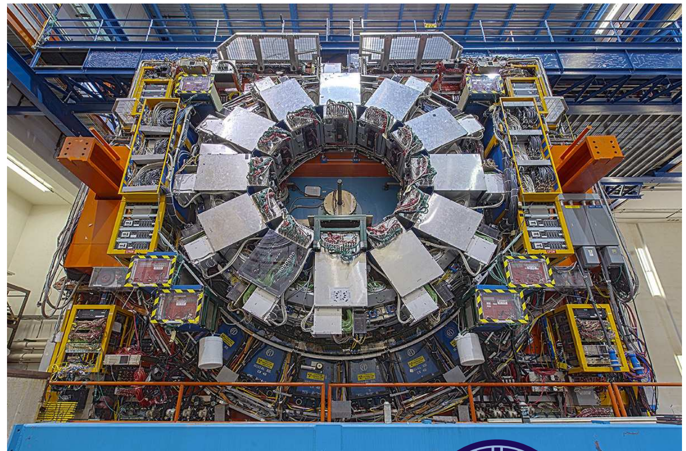
- **Why (keeping on) to measure M_{top} ?**
  - **Inside the SM :**
    - ∗ Test SM predictions
    - ∗ Test SM consistency
  - **Beyond the SM :**
    - ∗ Constraints on New Physics
    - ∗ Hints on EWSB?





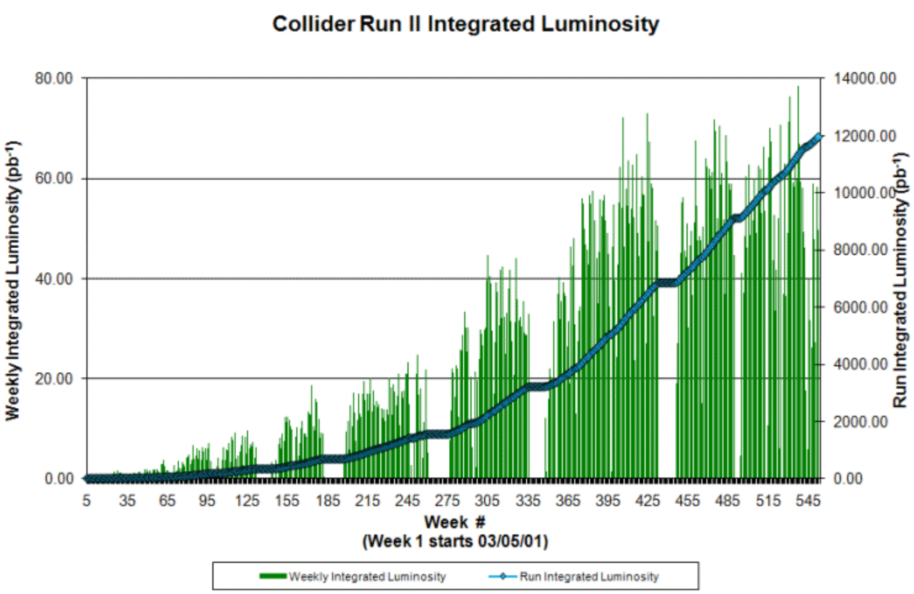
The Tevatron Experiments





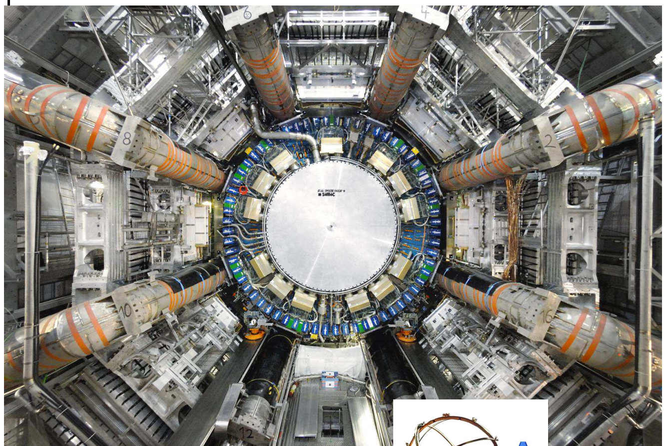
CDF

DØ

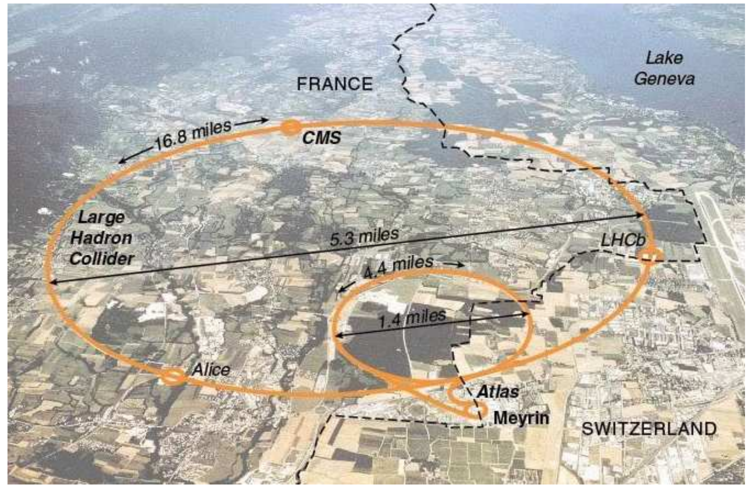


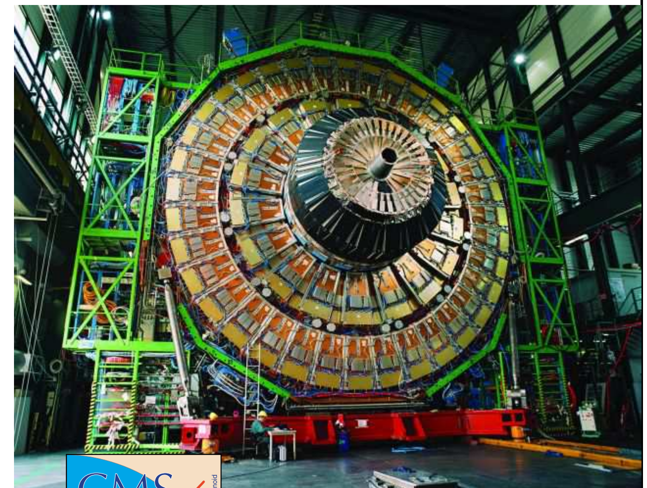
- $p\bar{p}$ collisions at 1.96 TeV (Run II, 2001-2011).
- Peak lumi $\approx 4 \cdot 10^{32} \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- About $12\,\mathrm{fb}^{-1}$ delivered to experiments. Acquired $10\,\mathrm{fb}^{-1}$ / experiment
- Collaborations :
  - Currently 400 + 400 members
  - 60 (CDF) + 70 (DØ) Institutions

The LHC Experiments

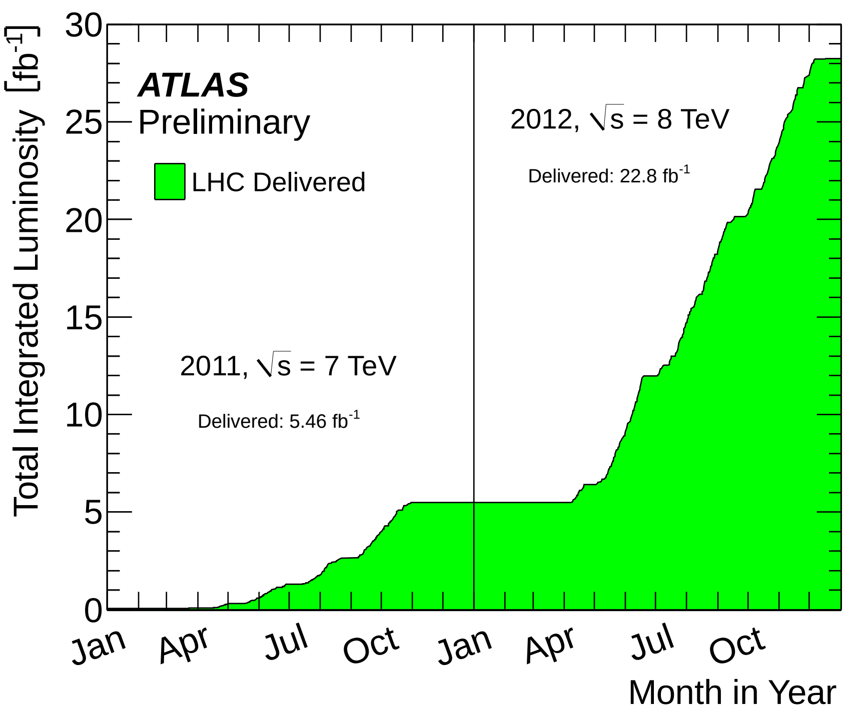


ATLAS





CMS

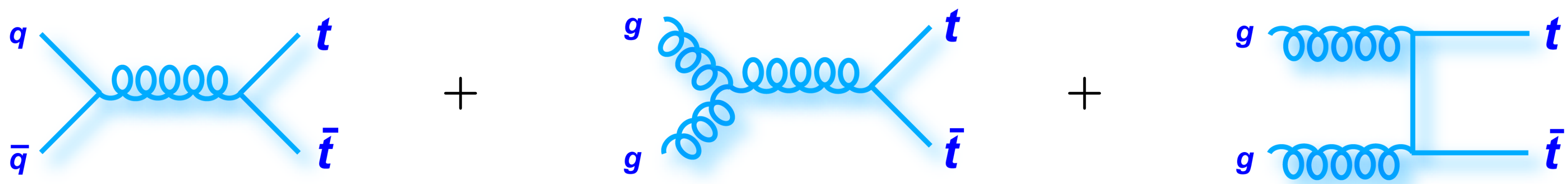


- pp **collisions at 7 (2011) & 8 TeV (2012).**
- **Peak lumi** $\approx 7.5 \cdot 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$
- **About** $6 + 23\,\mathrm{fb}^{-1}$ **delivered to experiments.**

  Acquired $\approx 5 + 21\,\mathrm{fb}^{-1}$ **/ experiment**
- **Collaborations :**
  - **Currently 2500/3000 members from about 180 Institutions each.**

Top Quark Production

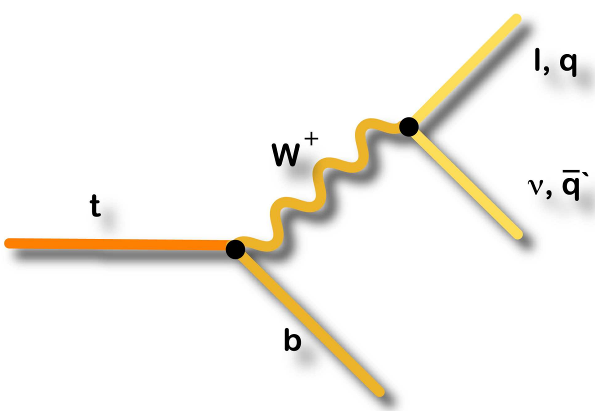
$t\bar{t}$ production via strong interaction

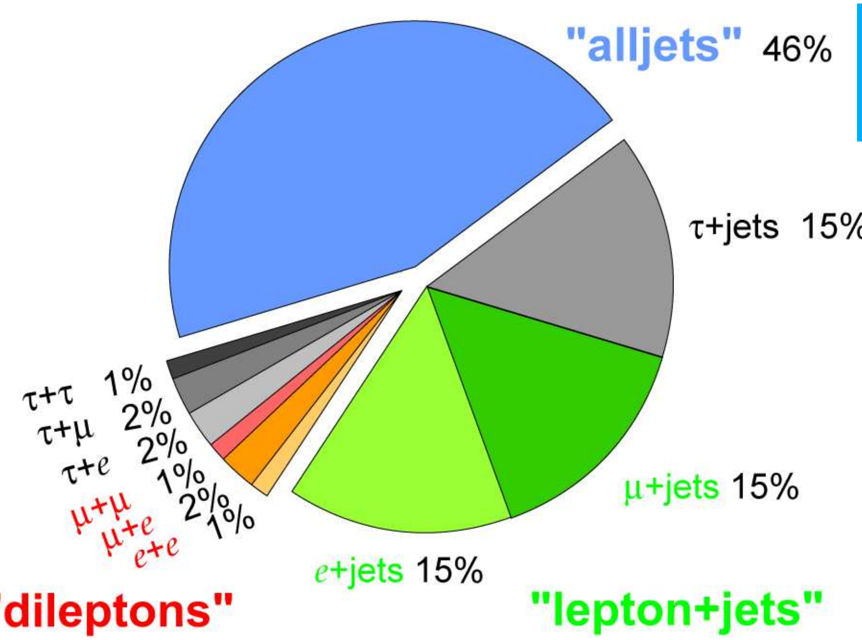


TEV $\sim 85\%$
LHC $\sim 10\%$

TEV $\sim 15\%$
LHC $\sim 90\%$

In the SM : $BR(t \to Wb) \simeq 100\%$ $\Rightarrow$ **$t\bar{t}$ final states defined by Ws' decays**



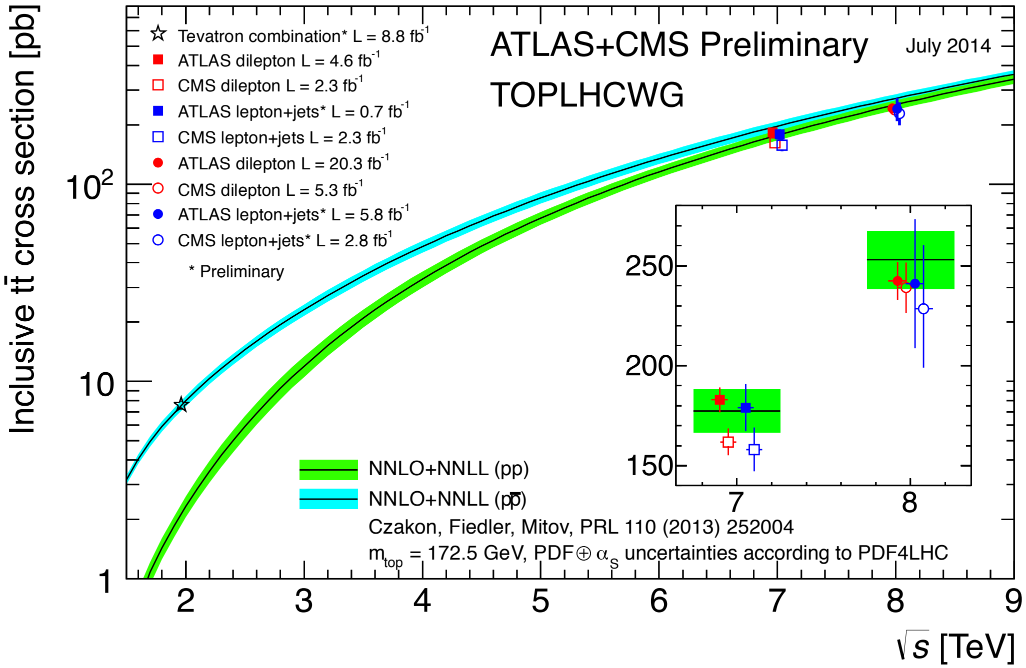


4 q-jets,
2 b-jets

2 high p_T charged leptons,
2 b-jets, $\not{E}_T$

1 high p_T charged lepton,
2 q-jets, 2 b-jets, $\not{E}_T$

$t\bar{t}$ production x-section



$\sigma_{t\bar{t}}\ (p\bar{p},\ 1.96\ \text{TeV}) \simeq 7.5\ \text{pb}$

$\sigma_{t\bar{t}}\ (pp,\ 7\ \text{TeV}) \simeq 175\ \text{pb}$

$\sigma_{t\bar{t}}\ (pp,\ 8\ \text{TeV}) \simeq 250\ \text{pb}$

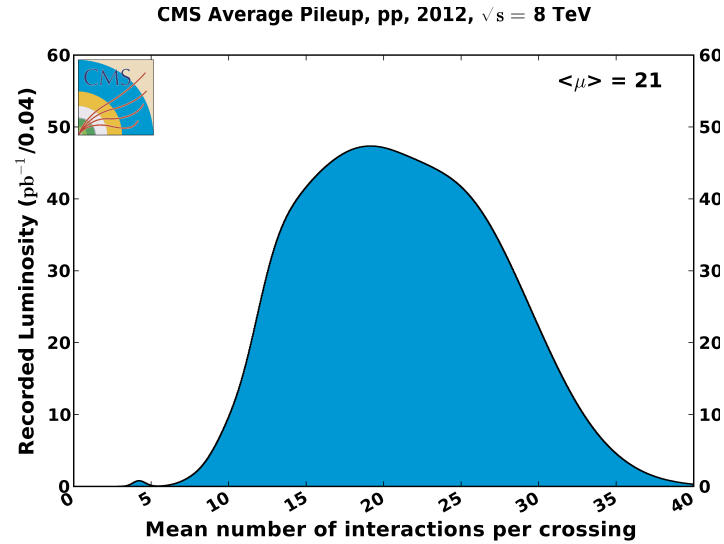
TEV : $\approx$ **75 000** $t\bar{t}$ **pairs / experiment** **(Run II)**

LHC : $\approx$ **6 000 000** $t\bar{t}$ **pairs / experiment** **(Run 2011 + Run 2012)**

.... but... $\sigma_{t\bar{t}}/\sigma_{\text{inel}} \sim 10^{-9}$

Top Mass Challenges

- $\sigma_{t\bar{t}} \,/\, \sigma_{inel} \sim 10^{-9}$!!!
  - **... Event Selection :**
    - **Triggers**
    - ***b*-tagging algorithms.**
    - **High E_T and "central" Jets.**
    - **Lepton Id (Dilepton, Lepton + jets).**



- **Reconstruction :**
  - **Jets-to-partons assignments**

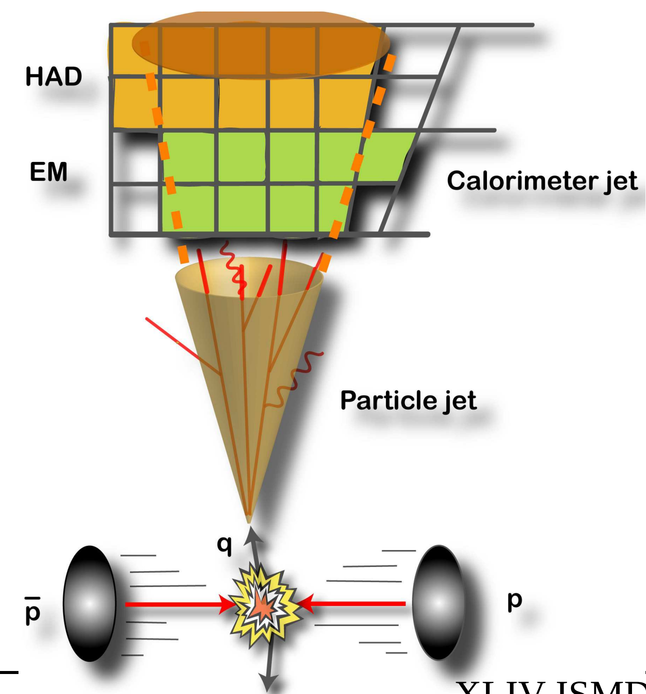
    Which jet comes from which interaction / particle?
    PILEUP. Combinatoric problem

  - **Measure "Jets" and not partons**

    Need corrections to obtain parton energy
    ⇒ **J**et **E**nergy **S**cale (..or **JSF**)
    ⇒ Important contribution to $\sigma_{\mathrm{M_{top}}}(syst)$

  - **Undetected ν's (Dilepton, Lepton + jets).**

    Need assumptions. Multiple solutions.



Measurement Strategies

- **Matrix Element (ME)**

  – Define the probability, P_{ev}, that the *observed* kinematics $\vec{y}$ arise from any possible signal or bkg kinematics $\vec{x}$ at parton level:

  * $d\sigma(\vec{x})$ LO differential x-section of a final state $\vec{x}$ at parton level. Depending on $\mathrm{M_{top}}$ for $t\bar{t}$ events, but not for bkg.
  * $\mathcal{W}(\vec{y}, \vec{x})$ "Transfer function", i.e. probability to measure the observed set of variables $\vec{y}$, given $\vec{x}$ at parton level. Depends on JES.
  * $f_{t\bar{t}}$ Fraction of signal events expected in the data.

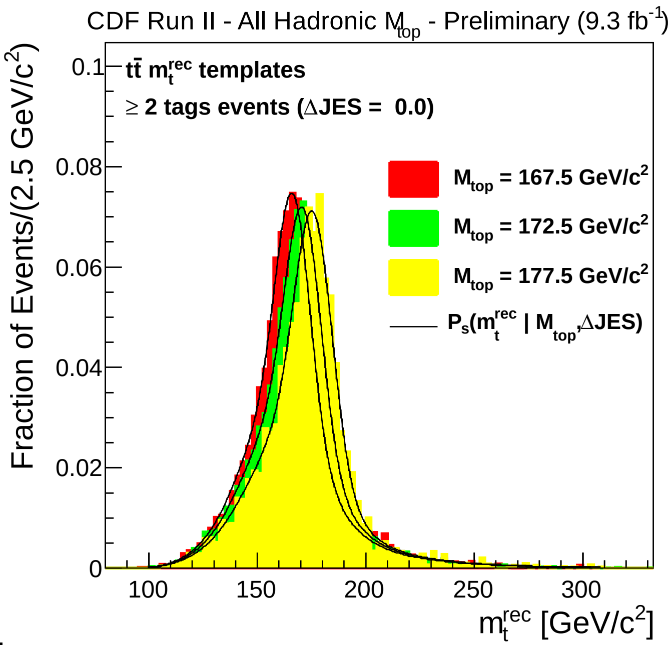
  – Maximize $\mathcal{L}_{sample} \propto \prod_{events} P_{ev}(\vec{y}, f_{t\bar{t}}, \mathrm{M_{top}})$ evaluated for observed data

- **Template Method**

  – Consider a set of observables, $\vec{x}$, sensitive to $\mathrm{M_{top}}$. Evaluate and plot the set for each event $\Rightarrow$ "Templates"

  – Maximize a likelihood where *observed* distributions are compared to expectations for different $\mathrm{M_{top}}$ and signal fractions, $f_{t\bar{t}}$.

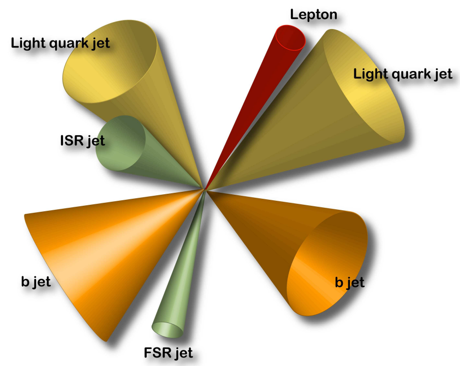
$$\mathcal{L}_{\mathrm{sample}} \propto \prod_{events} \prod_{\vec{x}} \mathcal{L}_{\mathrm{shape}}(x_i | f_{t\bar{t}}, \mathrm{M_{top}})$$



Measurement Channels

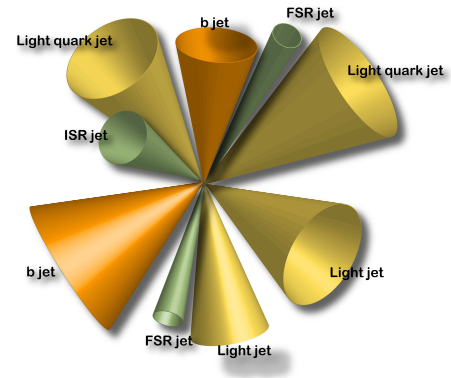
Lepton + Jets

Reasonable Bkg,
Good Statistics....
The Golden Channel!



- Jets-to-Partons assignment ambiguity
- Well reconstructed kinematics (but p_z^ν ambiguity)

All-Jets

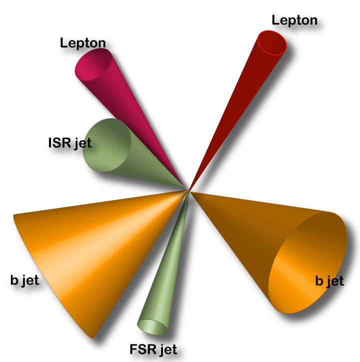


Huge QCD Bkg...
Large Statistics
Challenging!

- Need “fine tuned” selections to obtain good S/B
- Large Jets-to-Partons assignment ambiguity
- Fully reconstructed kinematics

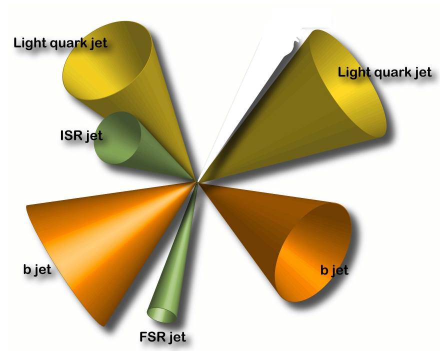
Dilepton

The cleanest sample...
The smallest statistics



- Small combinatoric problem
- Underconstrained kinematics (2 undetected ν’s)

Missing E_T + Jets



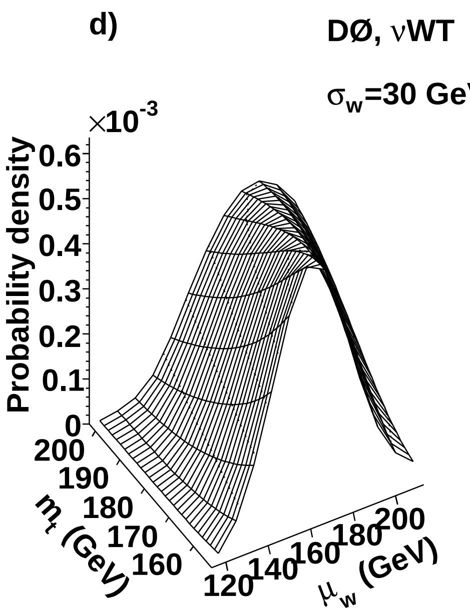
- Selection defined to be complementary to other channels.
- Mostly L + Jets with undetected lepton

Dilepton

DØ, Template by NWA, $4.3 + 1.0\,\text{fb}^{-1}$

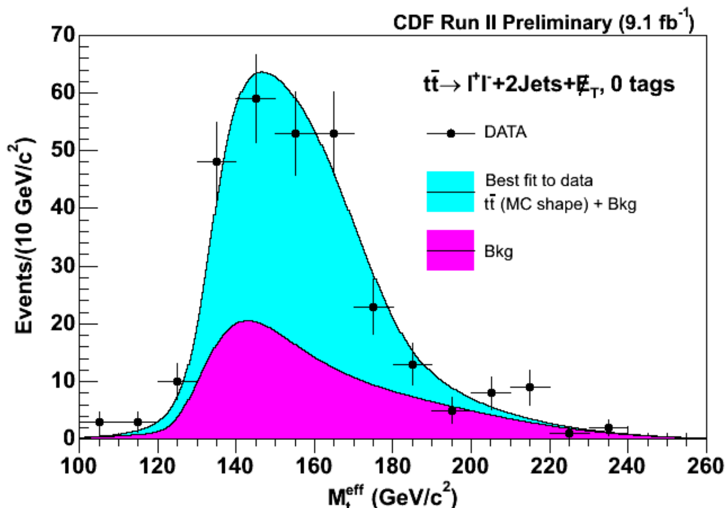
- Phys. Rev D86, 051103(R) (2012)
- **N**eutrino **W**eighting **A**lgorithm: templates based on an event weight for possible solutions of underconstrained kinematics.
- JES calibration from Lepton + Jets analysis is used.
- Combined with NWA + Matrix Weighting @ 1 fb^{-1}

$$\text{M}_{\text{top}} = 174.0 \pm 2.4\,(stat) \pm 1.4\,(syst)\,\text{GeV} \quad (1.6\%)$$



CDF, Templates, $9.1\,\text{fb}^{-1}$

- CDF conference note 11072, Jan 2014. Use full CDF dataset.
- "Hybrid" variable method to reduce JES uncertainty:
  - Templates by $M_t^{eff} = w \cdot M_t^{reco} + (1-w) \cdot M_t^{alt}$
  - M_t^{reco} sensitive to true M_{top}. Defined by NWA.
  - M_t^{alt} less sensitive to M_{top}, but not based on jet energies.
  - w defined to minimize expected (stat + JES) uncertainty
- Two independent samples: 0-tag, $\geq$ 1-tag



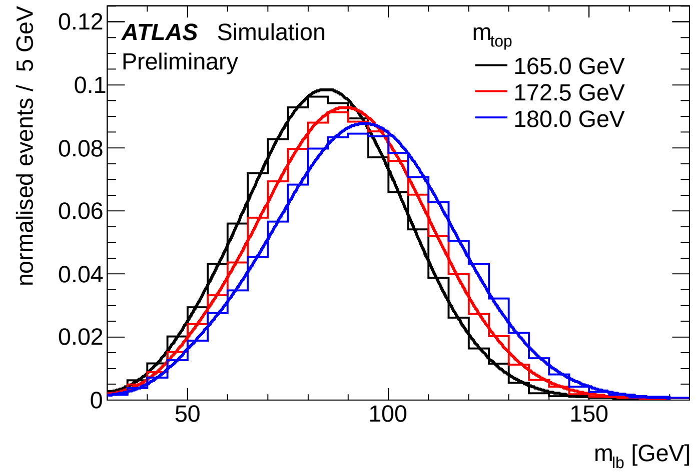
0-tag fitted templates

$$\text{M}_{\text{top}} = 170.8 \pm 1.8\,(stat) \pm 2.7\,(syst)\,\text{GeV} \quad (1.9\%)$$

Dilepton

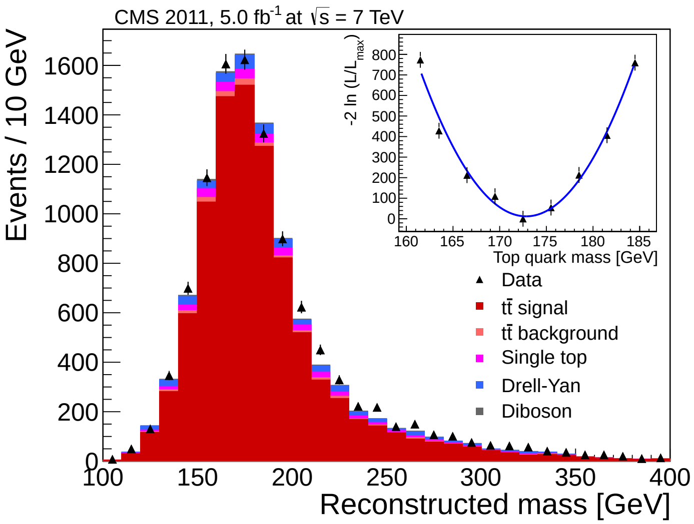
ATLAS, Templates, $4.7\,\text{fb}^{-1}$ @ $\sqrt{s} = 7$ TeV

- ATLAS Conference Note 2013-077, July 2013.
- Select events with $\ell_1^+ \ell_2^-$, ≥ 2 jets, $\equiv 2$ b-tags.
- Template method based on $m_{\ell b} = \min_{\ell \leftrightarrow b} \left(\frac{m_{\ell b}^{(1)} + m_{\ell b}^{(2)}}{2} \right)$
- 2913 Observed Events. Expected Purity $\simeq 96\%$.
  Main Bkg: Single t



$$M_{top} = 173.1 \pm 0.6\,(stat) \pm 1.5\,(syst)\ \text{GeV} \quad (0.94\%)$$

CMS, Templates, $5.0\,\text{fb}^{-1}$ @ $\sqrt{s} = 7$ TeV (EPJ C72 2012 (2202))



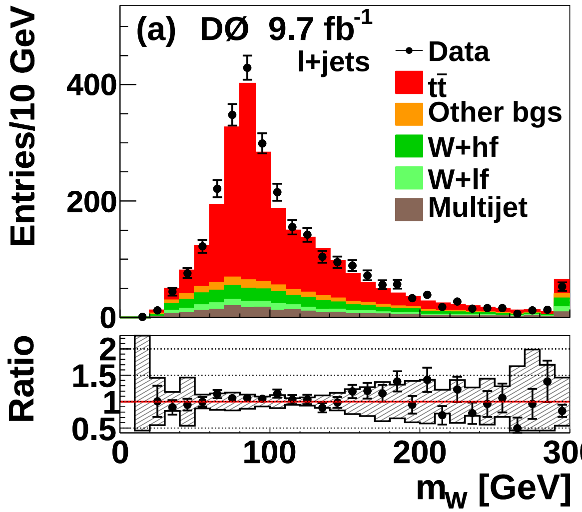
- Require $\ell_1^+ \ell_2^-$, ≥ 2 jets, ≥ 1 b-tag.
- Expected purity 78% (1-tag) / 93% ($\geq$ 2-tags)
- Use highest p_T ℓ_1^+, ℓ_2^-, (b-tagged) jets.
- **Matrix Weighting**:
  Assume m_t and weight possible p_ν's solutions.
  m_t yielding highest total weight chosen for templates.

$$M_{top} = 172.5 \pm 0.4\,(stat) \pm 1.5\,(syst)\ \text{GeV} \quad (0.93\%)$$

Lepton + Jets

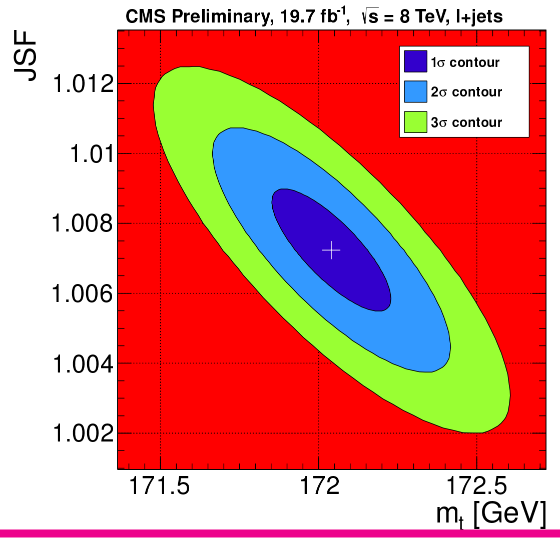
Best Single Measurements in the World Up to Date

- **DØ, Matrix Element, $9.7\,\text{fb}^{-1}$** (Phys. Rev. Lett. 113, 032002 (July 2014))
  - Improved detector calibration and JES corrections to reduce syst
  - For each event evaluate ME-based probability as a weighted sum over possible parton-jet combinations
  - Dependence on JES given by Transfer Functions $\mathcal{W}(\vec{y},\,\vec{x})$
  - Simultaneous JES calibration by jets assigned to W boson.



$$M_{\text{top}} = 175.0\ \pm 0.4\,(stat)\ \pm 0.6\,(syst)\ \text{GeV} \quad (0.43\%)$$

- **CMS, $19.7\,\text{fb}^{-1}$ @ $\sqrt{s} = 8\,\text{TeV}$** (CMS Physics Analysis Summary TOP-14-001, March 2014)
  - Template Analysis based on Ideogram Method
  - Reconstruct m_t^{reco}, m_W^{reco} for all possible jets-to-partons assignments
  - All values included in P_{evt} with proper weight
  - m_W^{reco} used for *in situ* JES calibration

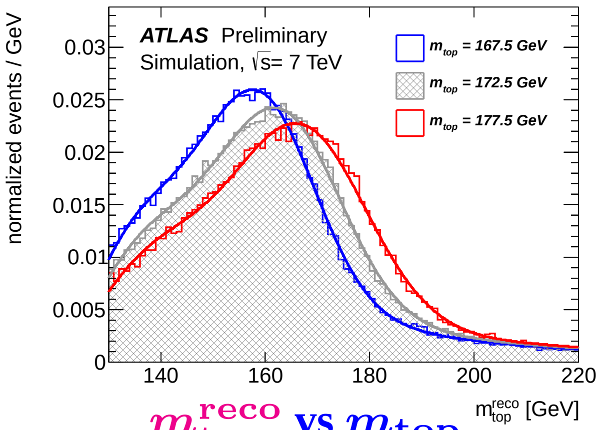


$$M_{\text{top}} = 172.0\ \pm 0.2\,(stat + \text{JSF})\ \pm 0.8\,(syst)\ \text{GeV} \quad (0.45\%)$$

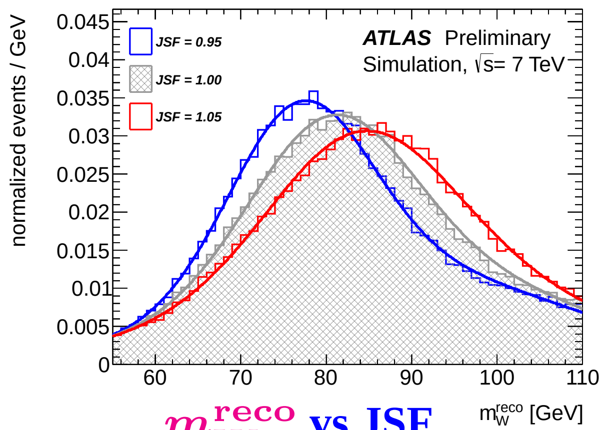
Lepton + Jets

ATLAS, $4.7\,\mathrm{fb}^{-1}$ @ $\sqrt{s} = 7\,\mathrm{TeV}$ (ATLAS Conference Note 2013-046, May 2013)

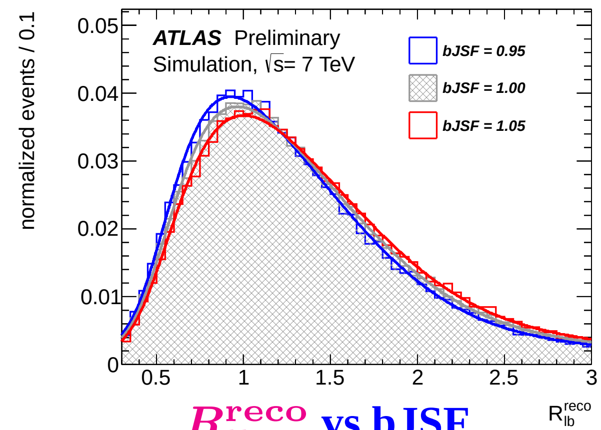
- **3-dimensional Template analysis $\Rightarrow$ JSF AND bJSF *in situ* calibration**



$m_{\mathrm{top}}^{\mathrm{reco}}$ vs m_{top}



$m_{\mathrm{W}}^{\mathrm{reco}}$ vs JSF



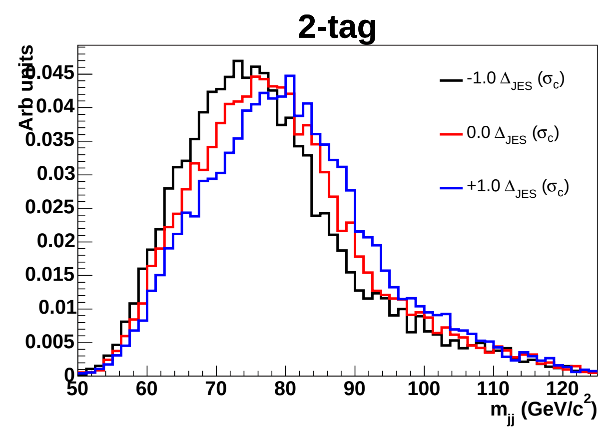
$R_{\mathrm{lb}}^{\mathrm{reco}}$ vs bJSF

$M_{\mathrm{top}} = 172.3 \pm 0.2\,(stat) \pm 1.5\,(syst)$ GeV (0.89%)

CDF, Templates, $8.7\,\mathrm{fb}^{-1}$ (Phys. Rev. Lett. 109 (2012) 152003)

- **3D templates : m_t^{reco} vs $m_t^{\mathrm{reco}\,(2)}$ vs m_{jj}**
- **m_{jj} used for *in situ* JES calibration**
- **5 independent data samples (based on *b*-tag) combined**

$M_{\mathrm{top}} = 172.8 \pm 0.7\,(stat) \pm 0.8\,(syst)$ GeV (0.64%)

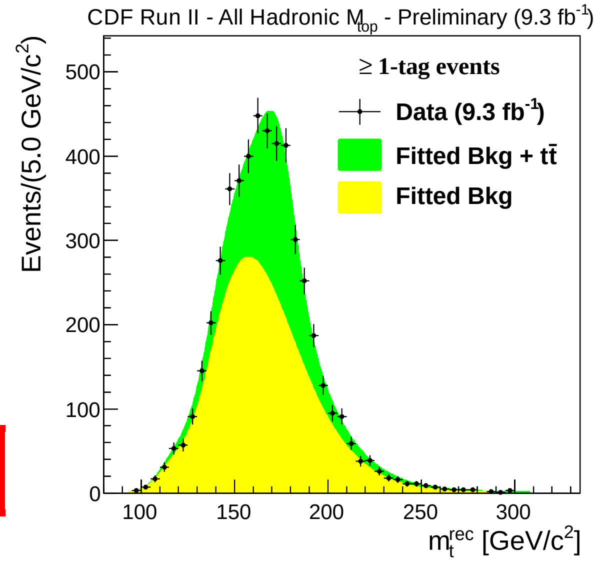


m_{jj} dependence on JES

All-Hadronic

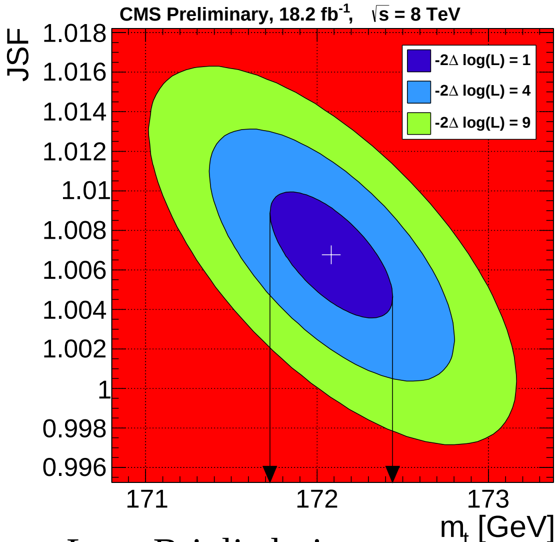
CDF, Templates, $9.3\,\mathrm{fb}^{-1}$ (CDF public note 11084, February 2014)

- Tuned event selection based on Neural Net, b-tag
- Data driven bkg modeling
- S/B larger than $1/1$ for $\geq$ 2-tag events.
- In each event reconstruct (χ^2 minimization) :
  - a "top mass", m_t^{rec}
  - a "W mass", m_W^{rec} $\Rightarrow$ JES calibration



$$M_{top} = 175.1 \pm 1.2\,(stat) \pm 1.6\,(syst)\,\mathrm{GeV} \quad (1.1\,\%)$$

CMS, $18.2\,\mathrm{fb}^{-1}$ @ $\sqrt{s} = 8\,\mathrm{TeV}$ (CMS Physics Analysis Summary TOP-14-002, July 2014)



- Same method (ideogram) and templates used for CMS L+Jets
- Require large Jet multiplicity, 2 b-tags, good event reconstruction
- High purity (78%) in a difficult channel

$$M_{top} = 172.1 \pm 0.4\,(stat + \mathrm{JSF}) \pm 0.8\,(syst)\,\mathrm{GeV} \quad (0.53\%)$$

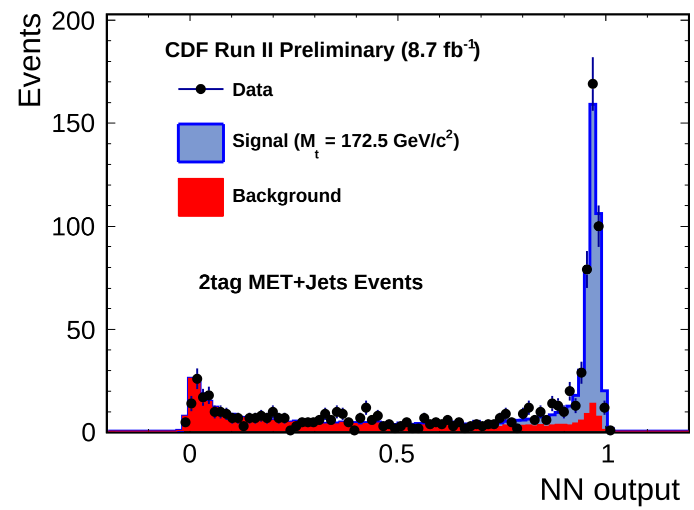
Missing E_T + Jets

- **CDF, Templates, $8.7\,\mathrm{fb}^{-1}$**

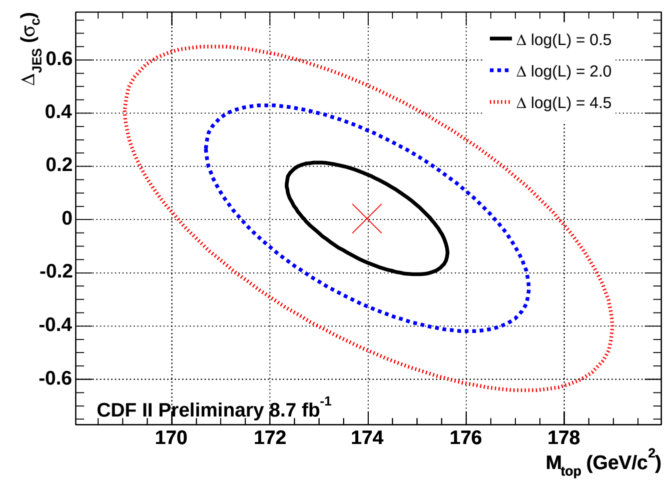
  - **Phys. Rev D88 (2013) 011101**
  - **Require large $\not\!\!E_T$, no tight lepton**

    $\Rightarrow$ **independent of All-Had, L+jets, Dilepton**
  - **Exploiting NN selection and bkg modeling similar to All-Had analysis**
  - **$\not\!\!E_T$ treated as due to $W \to \ell\nu$ with "lost" charged lepton in event reconstruction**
  - **Same technique used in CDF L+jets :**
    - **3D templates using m_t^{reco}, $m_t^{reco(2)}$, m_{jj}**
    - **m_{jj} used for *in situ* JES calibration**

$$\mathrm{M_{top}} = 173.93 \pm 1.26\,(stat) \pm 1.36\,(syst)\,\mathrm{GeV}$$
$$\sigma_{\mathrm{M_{top}}}/\mathrm{M_{top}} \simeq 1.1\%$$



Neural Net Output



$\mathbf{M_{top}}$ from $\sigma_{t\bar{t}}$

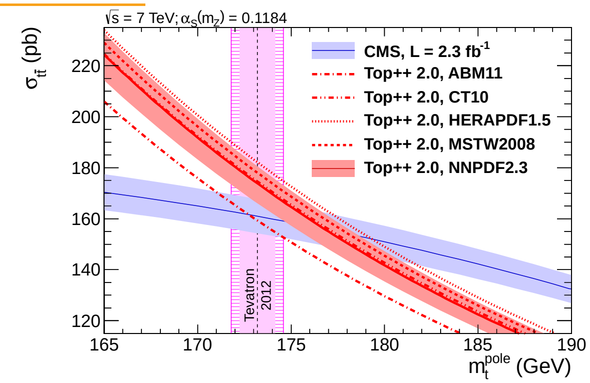
- ★ $\sigma_{m_t} \simeq 0.8\,\mathrm{GeV}$ (relative 0.4%) $\longrightarrow$ **precision measurement!**
- ★ ...but quarks are confined $\longrightarrow$ m_t not uniquely defined in QCD... (e.g m_t^{pole}, $m_t^{\overline{MS}}$,...)
- ★ So.. what are we measuring??? $\longrightarrow$ m_t^{MC} (.. it should be close to m_t^{pole})
- ★ Using $\sigma_{t\bar{t}}^{theo}(m_t)$ and $\sigma_{t\bar{t}}^{meas}$ allows extraction of m_t in a well defined renormalization scheme

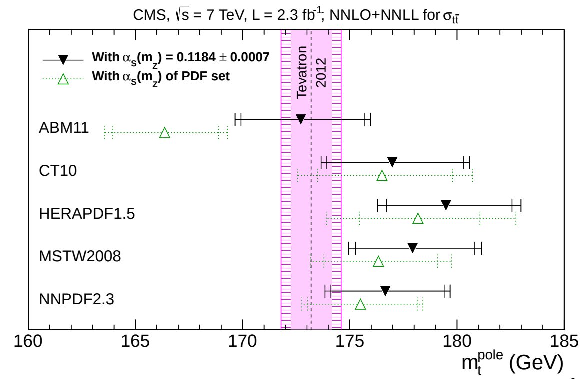
CMS, $2.3\,\mathrm{fb}^{-1}$ @ $\sqrt{s} = 7\,\mathrm{TeV}$ (arXiv:1307.1907v4, August 2014)

- Measurement of m_t^{pole} (relation with $m_t^{\overline{MS}}$ known at $\mathcal{O}(\alpha_s^3)$)
- Use :
  - NNLO + NNLL calculations of $\sigma_{t\bar{t}}^{theo}$
  - $\sigma_{t\bar{t}}^{meas}$ from dilepton channel
- Assume m_t^{MC} = $m_t^{pole} \pm 1\,\mathrm{GeV}$
- Consider maximum of

$$P(m_t) = \int P^{meas}(\sigma_{t\bar{t}}|m_t) \cdot P^{theo}(\sigma_{t\bar{t}}|m_t)\, d\sigma_{t\bar{t}}$$

$$m_t^{pole} = 176.7^{+3.0}_{-2.8}\,\mathrm{GeV}$$

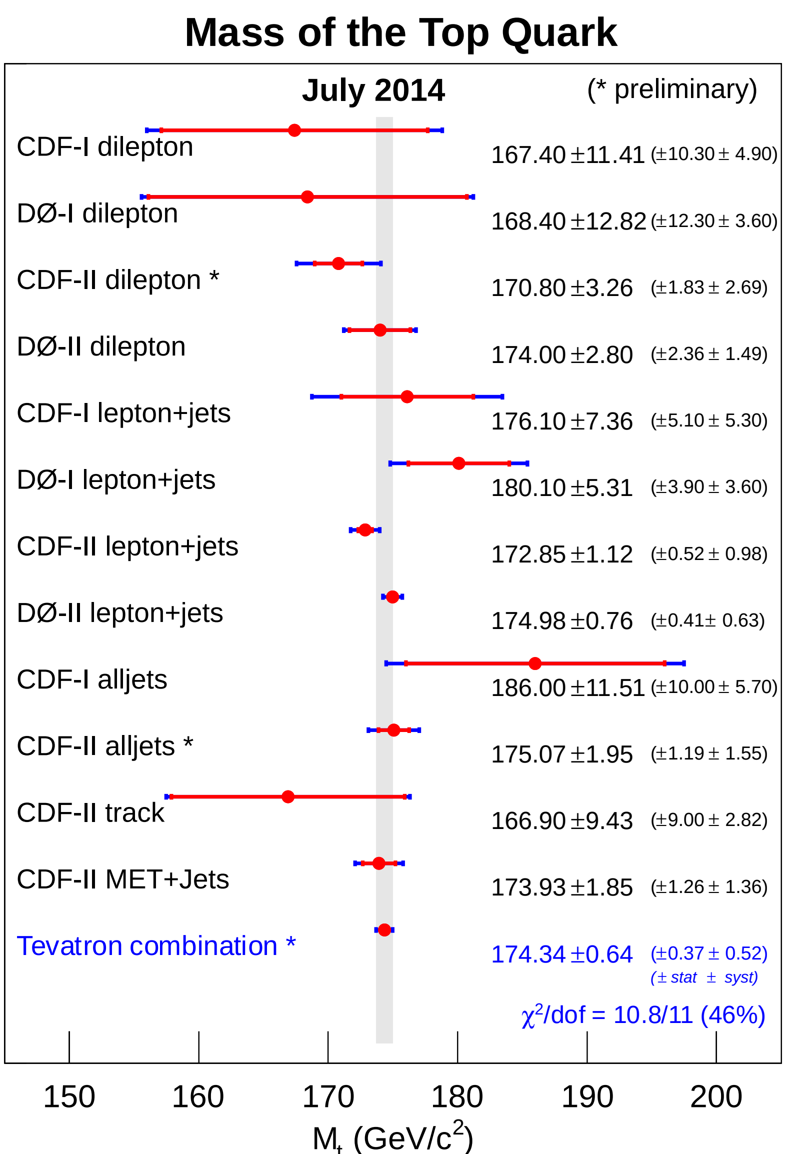


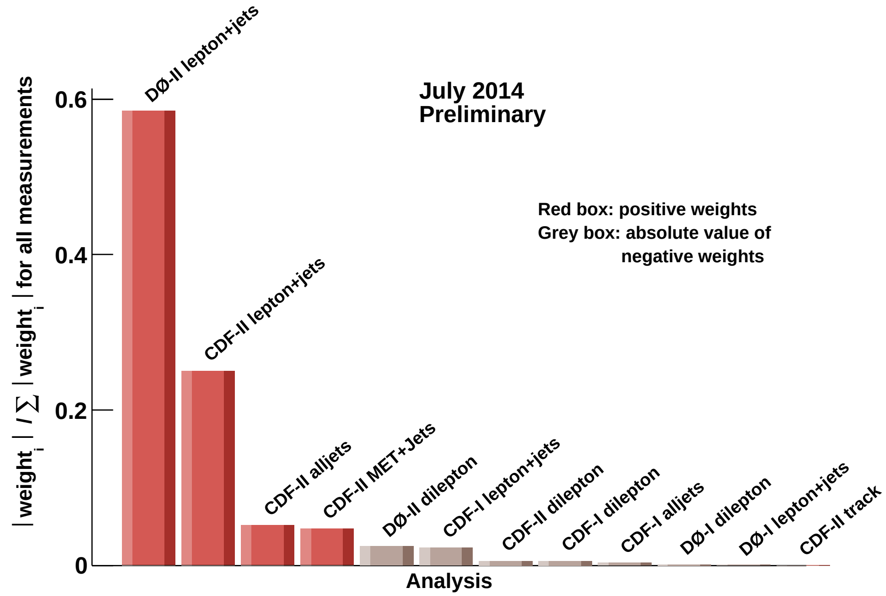


Tevatron Top Quark Mass

CDF + DØ, July 2014 (arXiv:1407.2682)

$$M_{top} = 174.34 \pm 0.64\,\text{GeV} \quad (0.37\%)$$



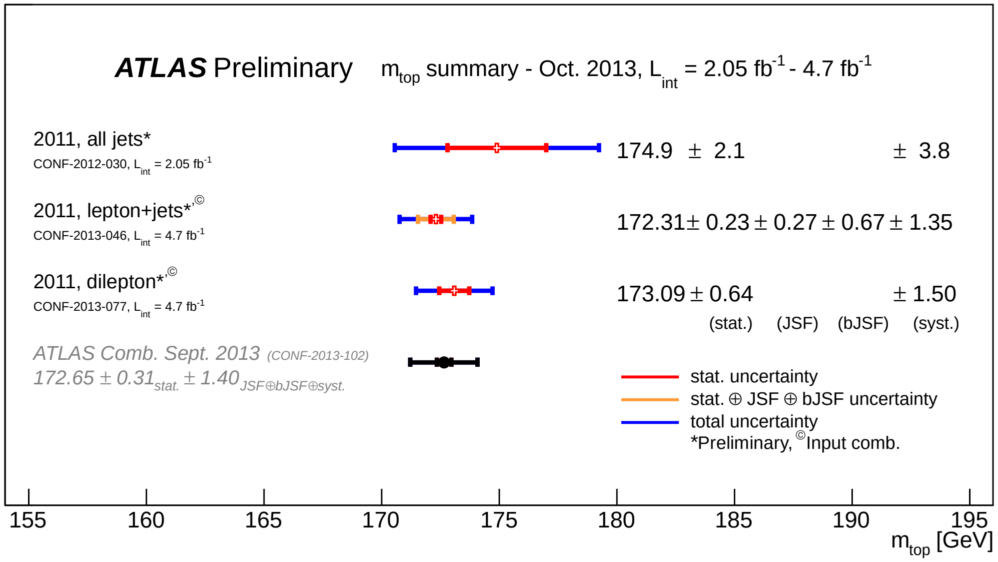


Best Measurement in the World up to Date

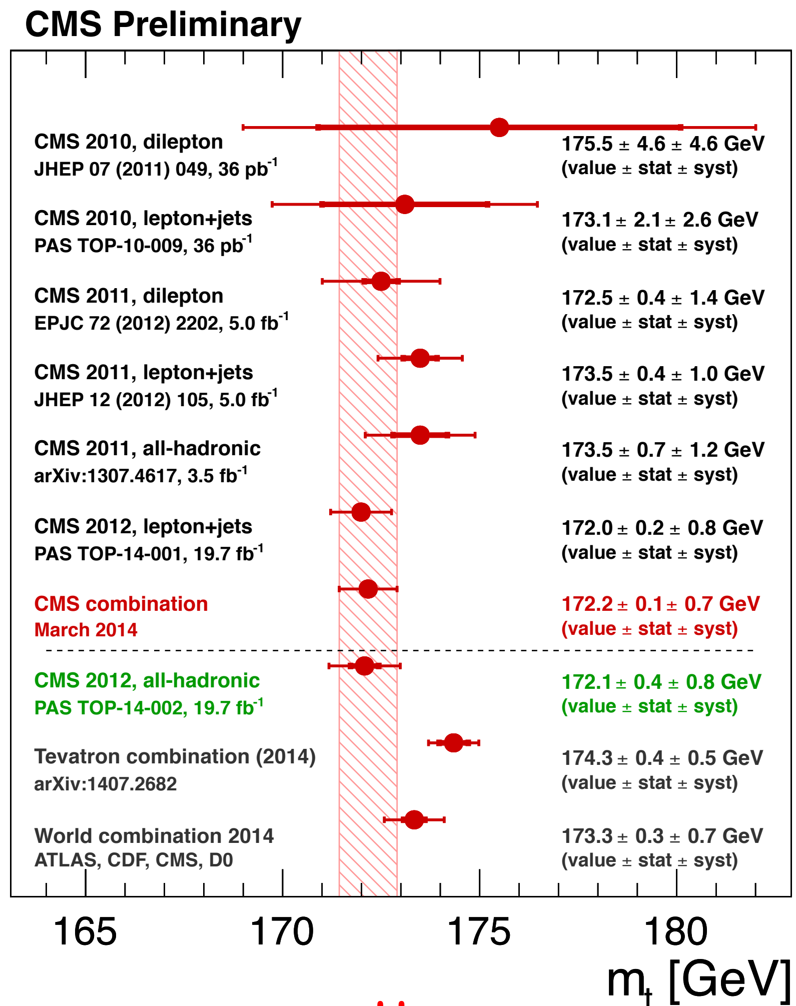
- **Best results of each experiment in each channel from Run I and Run II combined.**
- **All correlations taken into account.**
- **Precision limited by systematic uncertainties in all channels.**
- **Individual Experiments Combinations :**
  - **CDF :** $M_{top} = 173.16 \pm 0.93\,\text{GeV}$ **(March 2014)**
  - **DØ :** $M_{top} = 175.08 \pm 1.47\,\text{GeV}$ **(May 2011)**

LHC Top Quark Mass

ATLAS CONF-2013-102 (September 2013)



CMS PAS-TOP-14-001 (March 2014)



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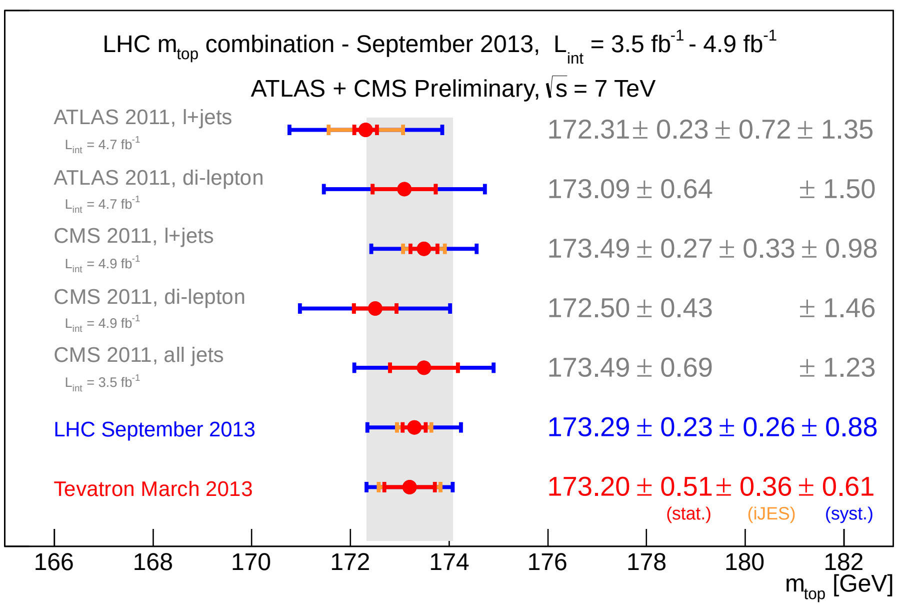
$$M_{top} = 172.22 \pm 0.73\,\mathrm{GeV} \quad (0.43\%)$$

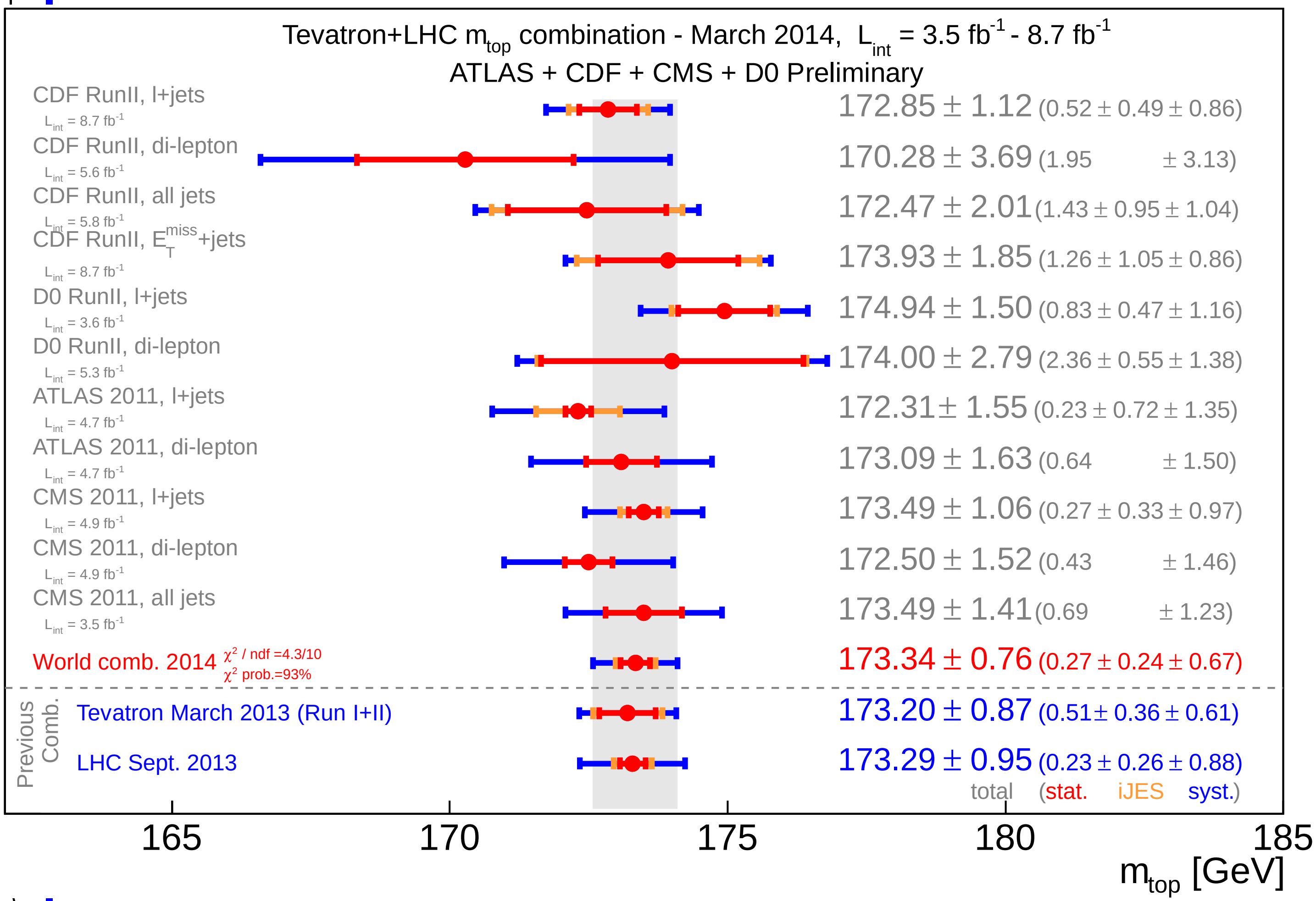
ATLAS + CMS (September 2013)



M_{top} WORLD AVERAGE

March 2014 : the ATLAS, CDF, CMS and DØ Collaborations approved the very first Tevatron + LHC M_{top} combination

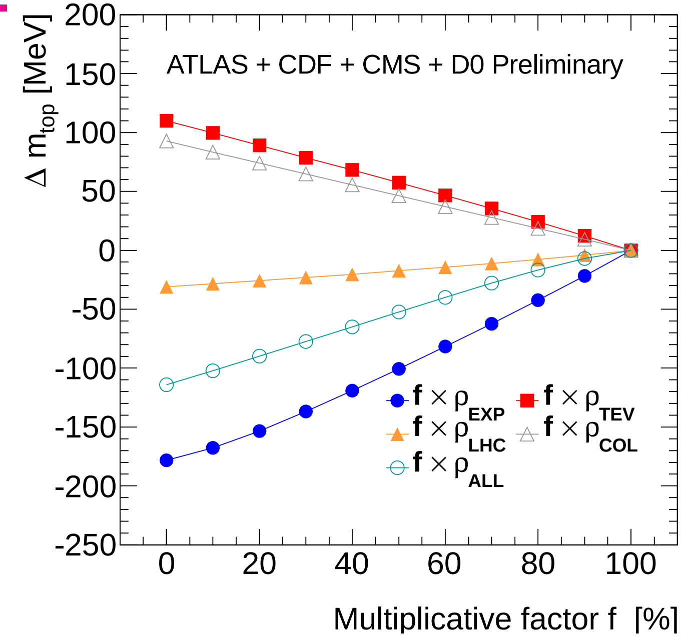
$$M_{top} = 173.34 \pm 0.76\,\text{GeV}$$

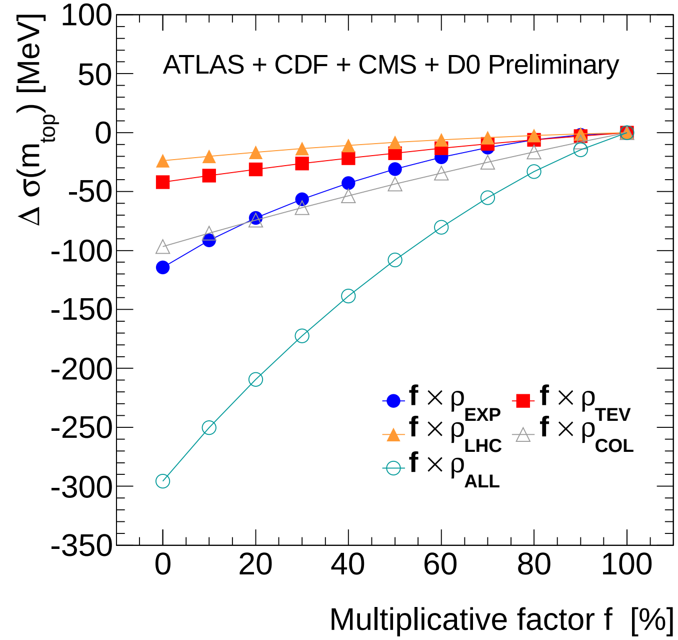


- * arXiv 1403.4427 [hep-ex]
- * **Tevatron : Run II data (up to 8.7 fb^1)**
- * **LHC : 2011 data (up to 4.9 fb^1)**
- * **Best single measurement in each channel from each experiment**
- * **13% improvement w.r.t. most precise single Collider combination**
- * **28% improvement w.r.t. most precise single input**

M_{top} WORLD AVERAGE

	ρ_{EXP}				ρ_{LHC}	ρ_{TEV}	ρ_{COL}	
	ρ_{CDF}	ρ_{D0}	ρ_{ATL}	ρ_{CMS}			$\rho_{ATL-TEV}$	$\rho_{CMS-TEV}$
Stat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
iJES	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
stdJES	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
flavourJES	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
bJES	1.0	1.0	1.0	1.0	0.5	1.0	1.0	0.5
MC	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Rad	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5
CR	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
PDF	1.0	1.0	1.0	1.0	1.0	1.0	0.5	0.5
DetMod	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
b-tag	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
LepPt	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0
BGMC†	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
BGData	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Meth	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
MHI	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0





- **First combination between the two Colliders**
- **Big effort performed in order to :**
  - * **classify uncertainties**
  - * **define correlations**
- **Various correlation scenarios have been checked**

M_{top} WORLD AVERAGE

- **M_{top} Uncertainties**
  - **Dominated by systematic effects**
  - **Leading contributions : MC signal modeling, JES**

	Input measurements and uncertainties in GeV											
	CDF				D0		ATLAS		CMS			World
Uncertainty	l+jets	di-l	all jet	E_T^{miss}	l+jets	di-l	l+jets	di-l	l+jets	di-l	all jet	Combination
m_{top}	172.85	170.28	172.47	173.93	174.94	174.00	172.31	173.09	173.49	172.50	173.49	173.34
Stat	0.52	1.95	1.43	1.26	0.83	2.36	0.23	0.64	0.27	0.43	0.69	0.27
iJES	0.49	n.a.	0.95	1.05	0.47	0.55	0.72	n.a.	0.33	n.a.	n.a.	0.24
stdJES	0.53	2.99	0.45	0.44	0.63	0.56	0.70	0.89	0.24	0.78	0.78	0.20
flavourJES	0.09	0.14	0.03	0.10	0.26	0.40	0.36	0.02	0.11	0.58	0.58	0.12
bJES	0.16	0.33	0.15	0.17	0.07	0.20	0.08	0.71	0.61	0.76	0.49	0.25
MC	0.56	0.36	0.49	0.48	0.63	0.50	0.35	0.64	0.15	0.06	0.28	0.38
Rad	0.06	0.22	0.10	0.28	0.26	0.30	0.45	0.37	0.30	0.58	0.33	0.21
CR	0.21	0.51	0.32	0.28	0.28	0.55	0.32	0.29	0.54	0.13	0.15	0.31
PDF	0.08	0.31	0.19	0.16	0.21	0.30	0.17	0.12	0.07	0.09	0.06	0.09
DetMod	< 0.01	<0.01	<0.01	<0.01	0.36	0.50	0.23	0.22	0.24	0.18	0.28	0.10
b-tag	0.03	n.e.	0.10	n.e.	0.10	<0.01	0.81	0.46	0.12	0.09	0.06	0.11
LepPt	0.03	0.27	n.a.	n.a.	0.18	0.35	0.04	0.12	0.02	0.14	n.a.	0.02
BGMC	0.12	0.24	n.a.	n.a.	0.18	n.a.	n.a.	0.14	0.13	0.05	n.a.	0.10
BGData	0.16	0.14	0.56	0.15	0.21	0.20	0.10	n.a.	n.a.	n.a.	0.13	0.07
Meth	0.05	0.12	0.38	0.21	0.16	0.51	0.13	0.07	0.06	0.40	0.13	0.05
MHI	0.07	0.23	0.08	0.18	0.05	<0.01	0.03	0.01	0.07	0.11	0.06	0.04
Total Syst	0.99	3.13	1.41	1.36	1.25	1.49	1.53	1.50	1.03	1.46	1.23	0.71
Total	1.12	3.69	2.01	1.85	1.50	2.79	1.55	1.63	1.06	1.52	1.41	0.76

Summary

- **Since its discovery, in 1995, the properties of the top quark have been measured in different channels and using many methods.**
- **The CDF and DØ Collaborations performed many measurements of M_{top} using data collected in the Tevatron Run II up to 2011...**
- **...they are now finalizing the analyses using full datasets.**
- **In 2010 the ATLAS and CMS Experiments started to measure M_{top} exploiting the large amount of data collected at the LHC.**
- **A partial selection of most recent results has been presented in this talk. Full details in**
  - **www-cdf.fnal.gov/physics/new/top/public_mass.html**
  - **www-d0.fnal.gov/Run2Physics/top/**
  - **https://twiki.cern.ch/twiki/bin/view/AtlasPublic/TopPublicResults**
  - **https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResultsTOP**

- **In March 2014 the first WORLD AVERAGE has been performed yielding**

LHC + TEVATRON, March 2014

$$M_{top} = 173.34 \pm 0.76\,\mathrm{GeV}$$

$$\sigma_{M_{top}}/M_{top} \simeq 0.44\%$$

Backup

Systematic Tables

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

TABLE I: Summary of uncertainties on the measured top quark mass. The signs indicate the direction of the change in m_t when replacing the default by the alternative model.

DØ L + Jets

Table 1: List of systematic uncertainties for the combined fit to the entire lepton+jets data set.

	δm_t^{2D} (GeV)	δJSF	δm_t^{1D} (GeV)
Experimental uncertainties			
Fit calibration	0.10	0.001	0.06
p_T- and η-dependent JES	0.18	0.007	1.17
Lepton energy scale	0.03	<0.001	0.03
MET	0.09	0.001	0.01
Jet energy resolution	0.26	0.004	0.07
b tagging	0.02	<0.001	0.01
Pileup	0.27	0.005	0.17
Non-$t\bar{t}$ background	0.11	0.001	0.01
Modeling of hadronization			
Flavor-dependent JSF	0.41	0.004	0.32
b fragmentation	0.06	0.001	0.04
Semi-leptonic B hadron decays	0.16	<0.001	0.15
Modeling of the hard scattering process			
PDF	0.09	0.001	0.05
Renormalization and factorization scales	0.12±0.13	0.004±0.001	0.25±0.08
ME-PS matching threshold	0.15±0.13	0.003±0.001	0.07±0.08
ME generator	0.23±0.14	0.003±0.001	0.20±0.08
Modeling of non-perturbative QCD			
Underlying event	0.14±0.17	0.002±0.002	0.06±0.10
Color reconnection modeling	0.08±0.15	0.002±0.001	0.07±0.09
Total	0.75	0.012	1.29

CMS L + Jets