Measurement of the top quark mass in the eμ channel with a Matrix Element Method in ATLAS

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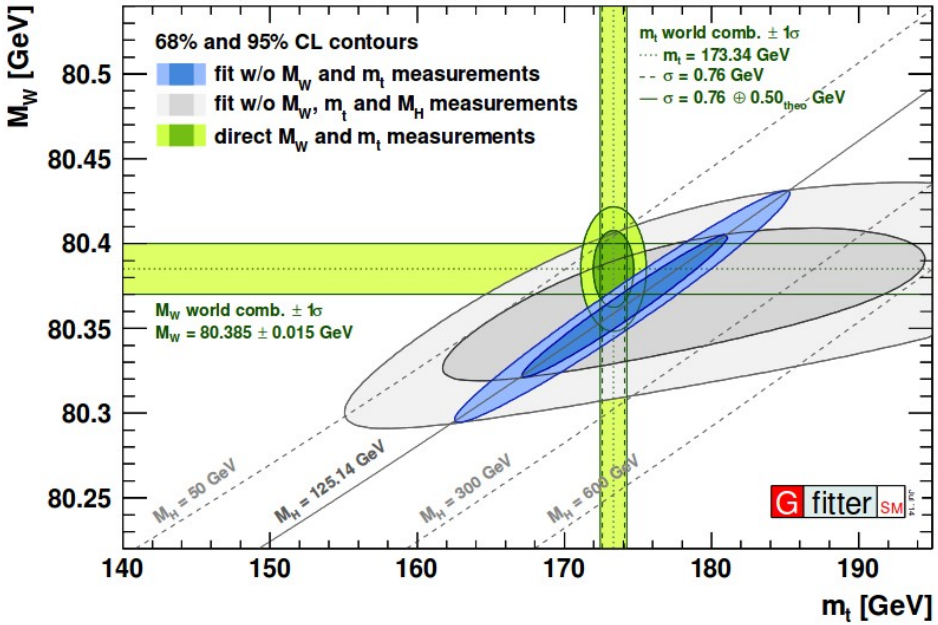
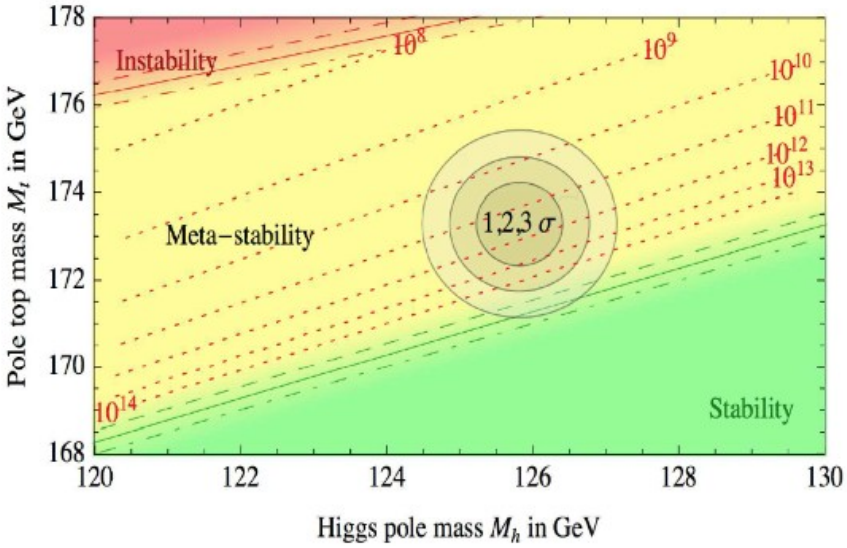
Measurement of the top quark mass

Test of the Internal coherence of the Standard Model

Linked to the Higgs potential and stability of the Universe

arXiv:1407.3792



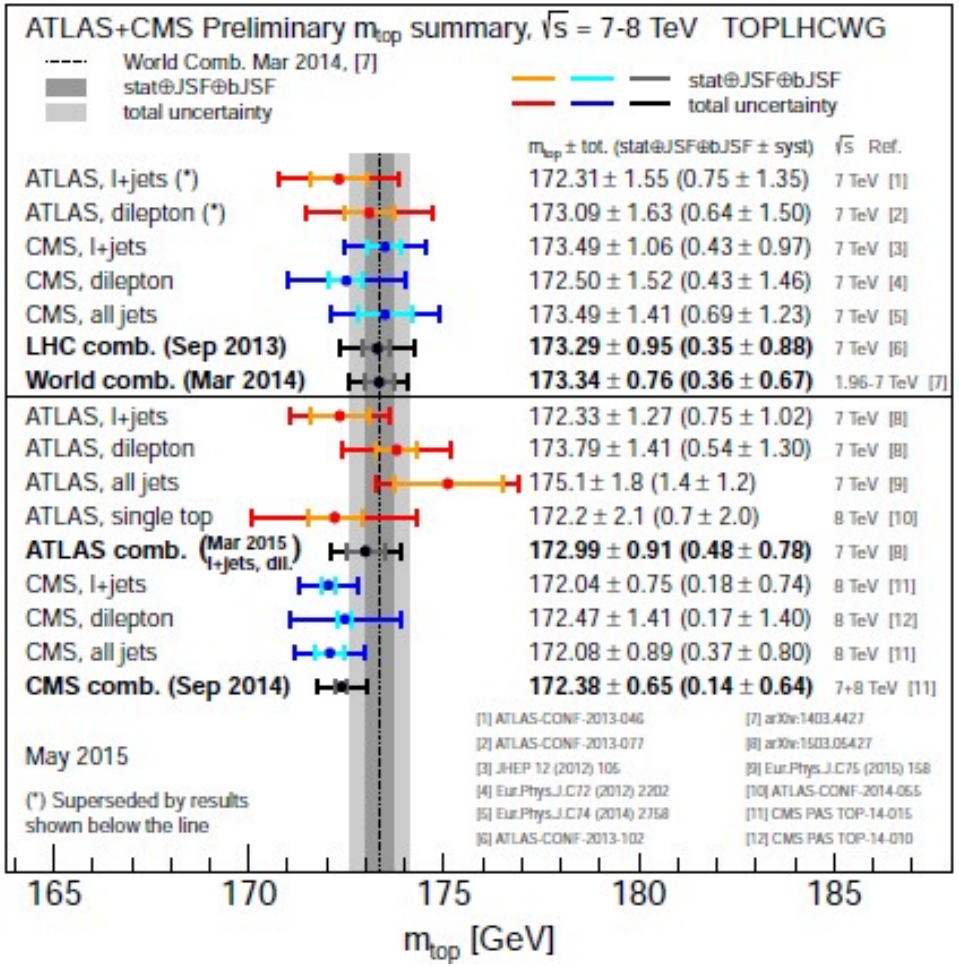


From an experimental point of view the top quark mass can be measured in different final states with several techniques, all with good precision

At LPNHE, we are working on a measurement with ttbar events with two leptons in the final state (the mass cannot be directly reconstructed because of the presence of two neutrinos), with the matrix element method

Measurement of the top quark mass

Top quark mass measurements at Run I



Reconstructing all the top quark decay products:

- total uncertainty dominated by **systematic uncertainties**
  - strongly **correlated** between decay channels, methods, and experiments
  - mostly due to **b-jet energy scale, color reconnection,** and ISR
- need of "**alternative**" **measurement** methods

E. Bouvier (IPN Lyon, https://indico.in2p3.fr/event/12491

Matrix Element Method (overview)

- For each event a probability is defined as a function of the probabilities to be signal like (P_{sig}) or background like (P_{bkg}) :

$$P_{evt}(m_{top} \mid x) = f_{t\bar{t}} P_{sig}(m_{top} \mid x) + (1 - f_{t\bar{t}}) P_{bkg}(m_{top} \mid x) \qquad f_{t\bar{t}} \equiv \frac{N_{sig}}{N_{sig} + N_{bkf}}$$

- The probability to be signal or background like is related to the differential cross section $\frac{d\sigma}{dx}(m_{top})$ through :

$$P_i(m_{top} \mid x) = \frac{1}{\sigma^i_{obs}(m_{top})} \frac{d\sigma^i}{dx}(m_{top} \mid x) \quad \text{with } i = \text{signal or background}$$

$$\sigma^i_{obs}(m_{top}) = \varepsilon^i(m_{top}) \sigma^i_{th}(m_{top})$$

- Computing the differential cross section is the heart of the method :

k : observables of the final state at the reconstructed level

$|M_{t\bar{t}}(p_1, p_2, x, m_{top})|$: Matrix element e.g. $p_1 p_2 \to t\bar{t} \to b\bar{b}e\mu\nu_e\nu_\mu$

f_{pdf} : parton density function

$$\frac{d\sigma^i}{dx}(m_{top} \mid k) \propto \sum_i \int dp_1 dp_2 d\Phi |M_i(p_1, p_2, x, m_{top})|^2 f_{pdf}(p_1) f_{pdf}(p_2) TF(x \mid k)$$

x : observables of the final state at the parton level

p_1 and p_2 : incoming parton

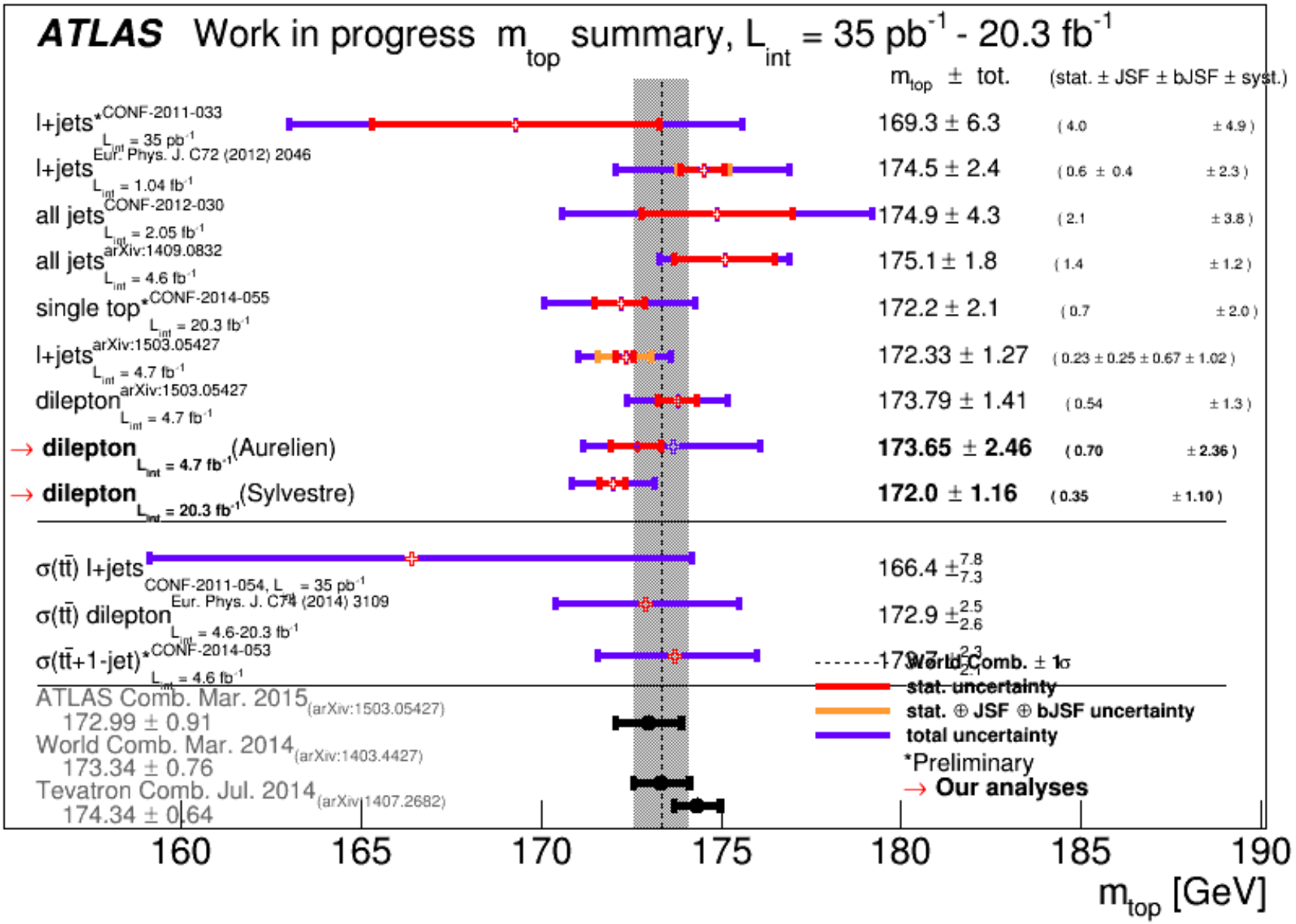
$d\Phi$: phase space for process

$TF(x \mid k)$: Transfer Function from k to x

See slides of Sylvestre on 4th June 2015 (https://indico.cern.ch/event/398044/)

Results

ATL-COM-PHYS-2015-546/547



Limitations of the method

Use of MadWeight2 program based on MadGraph

- MadGraph4 : ME Leading Order only, this version is no more maintained, not pecific for top physics and not easy to parallelize
- integration based on VEGAS

- 1 event, for one mass hypothesis with ~10000 integration steps = ~30s
  we need ~30 hypothesis masses ===> 15 mn par événement
- selection of 2000 dilepton events at 7 TeV, 10000 events at 8 TeV
  + Monte Carlo (~20 times data stat) + all systematic uncertainties (>100), signal vs signal+bkg hypotheses, background events

====> >10^7 computing hoursl
millions of small files spread on grid to be retrieved
Result = ~4 months on grid (computing, retrieving etc)
If calibration changes (and it does !) need to redo all !

New tools

New tools are available

- MadGraph 5 (https://cp3.irmp.ucl.ac.be/projects/madgraph/wiki/MadWeight)
  Next to Leading Order, new possibilities (ISR) +
  much faster by factor ~60 to get the Matrix Element
- MadWeigh 5 : small gain (~2) in the integration of the Matrix Element !
  (we are currently working to make it work in the analysis chain)

- MeMTk : developped in ATLAS by the Berlin group, NLO,
  integration based also on CUBA/VEGAS

MeMTk : 2000 evts in 120 mn on 1 coeur (gain ~100 wrt MadGraph4)
14 mn on 8 cores
7 mn on 16 cores
5 mn on 32 cores
4 mn on 128 cores (extra gain de ~30)

==> but not integrated to our analysis chain

- GPU/XeonPhi (see slides of Tristan)
  See also developments done at LLR for ME calculation on GPU,
  OpenCL, GridCL platforms (was the core of a WP for past LPaso ANR)