

# LIP measurement of the top quark mass in the dilepton channel at CMS

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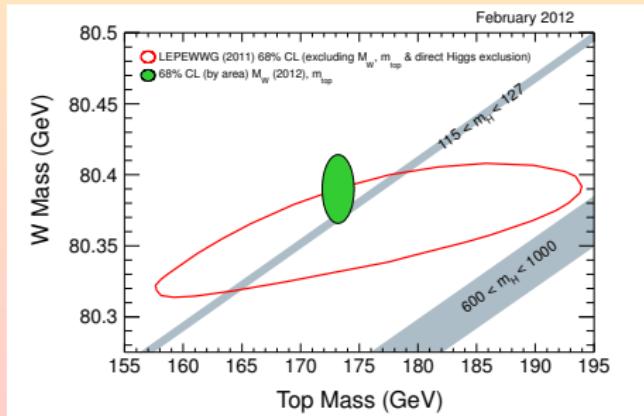
Jornadas do LIP, April 22st, 2012

# Outline

- Active LIP program in the top quark mass measurement
- Focus on the dilepton channel
- Focus on the KINb mass reconstruction algorithm
- Documented results
  - TOP-10-006 → first mass distribution ( $3.1 \text{ pb}^{-1}$ )
  - JHEP 07(2011)049 → first complete result ( $36 \text{ pb}^{-1}$  - 2010)
  - TOP-11-016 → most recent result ( $2.3 \text{ fb}^{-1}$  - 2011)
- Will show the latest result

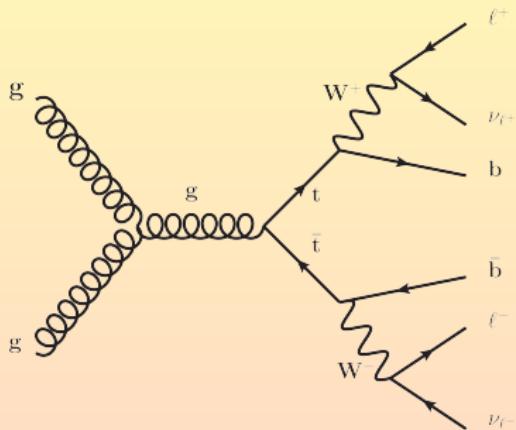
# Why is top mass measurement important

- $m_{top}$  is a fundamental parameter of the SM
  - Provides indirect constraint on the Higgs boson mass
  - Top decays promptly without hadronizing  $\Rightarrow$  direct measurement
  - Independent cross-check of the Tevatron results
  - Independent cross-check in the different top decay channels
- Reconstruction techniques are useful for top discrimination from BSM



# The dilepton channel

- $t\bar{t} \rightarrow (l^+\nu_l b) (l^-\bar{\nu}_l \bar{b})$
- Smallest branching fraction (**BR = 6.5%**)
- The least contaminated by background processes
  - Main ones: Drell-Yan and single top ( $tW$ )
- Top pair kinematics:  **$2 \times (4 \times 3)$**  quantities
- Two neutrinos in the final state:  
under-constrained system

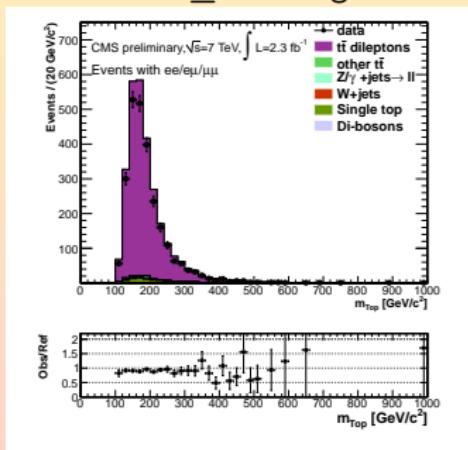


Object	Parameter	Type	N <sub>parameters</sub>	Total
jets	(E, p̄)	measurement	2×4	8
charged leptons	(E, p̄)	measurement	2×4	16
neutrinos	E <sub>T</sub> <sup>miss</sup>	measurement	2	18
	m <sub>ν</sub> = 0	constraint	2	20
W boson mass	m <sub>W</sub> = 80.398 ± 0.025 GeV	constraint	2	22
t mass	m <sub>t</sub> = m <sub>t̄</sub>	constraint	1	23
t̄t longitudinal balance	p <sub>z</sub> ∼ Gaus(0, σ)	hypothesis (MC)	1	24

## KINb method

- Solve several times the equations for kinematics ( $5 \cdot 10^4$ )
- Each time vary jet kinematics according to resolution
- $\cancel{E}_T$  constrains the neutrinos' momenta
- $\mathbf{p}_z^{t\bar{t}}$  constrains the  $t\bar{t}$  system (minimal dependence on  $m_{top}$ )
- Repeat for each lepton-jet combination
  - use the two jets with leading b-tag discriminator value
  - require at least one b-tagged jet
- $m_{top}$  estimated from the peak of the combination with largest number of solutions

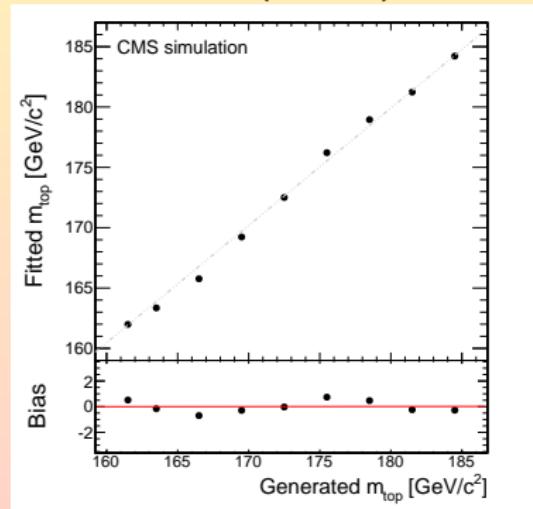
→ Events with  $\geq 2$  b-tags



# Fit and Calibration

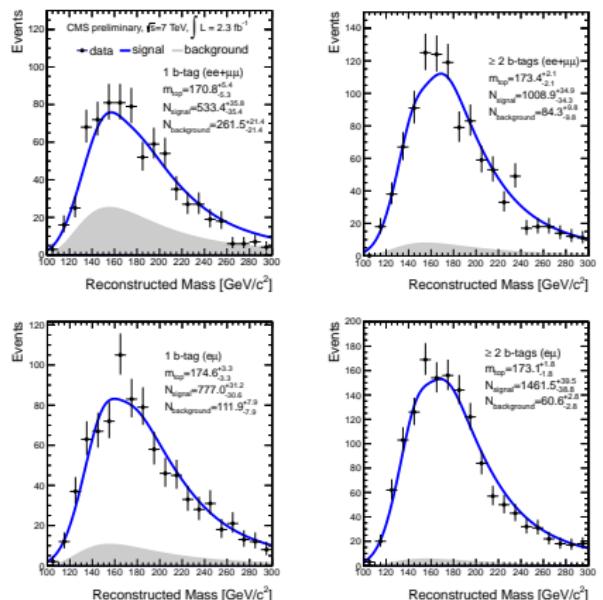
- Signal and background templates are derived from dedicated MC samples or data
- Unbinned fit likelihood is used to extract  $m_{\text{top}}$ ,  $N_{\text{signal}}$ ,  $N_{\text{background}}$   
 $\mathcal{L}(m_t) = \mathcal{L}_{\text{shape}}(m_t) \times \mathcal{L}_{\text{nb}}$
- Fit is calibrated from pseudo-experiments using different top mass hypothesis
- Final residual bias is within **0.4  $\frac{\text{GeV}}{c^2}$**  (envelope)

→ After calibration (residual)

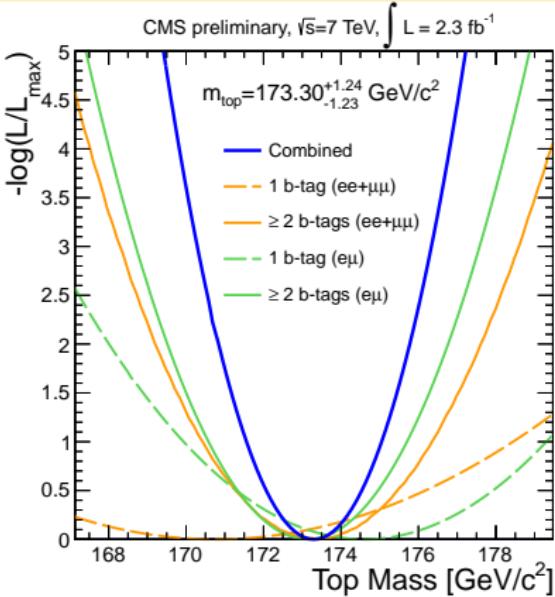


# Fit Results

## → Exclusive mass fits



## → Combined likelihood fit



# Systematic uncertainties computation

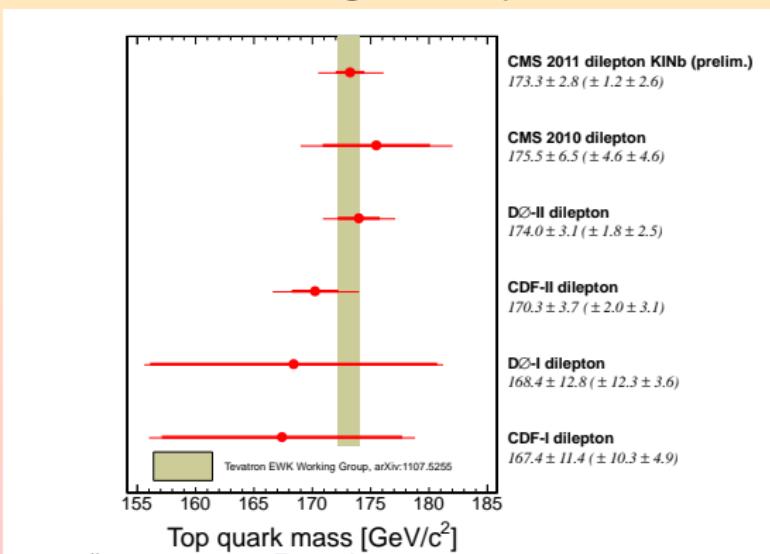
- Two main sources of systematics:
  - Physics object calibration:  
jet/lepton energy scale, resolution,  
 $b$ -tagging performance
  - Modeling of the signal:  $Q^2$  scale,  
PDF uncertainty, contamination  
from ISR/FSR, pileup scenario, MC  
generator (MADGRAPH vs. POWHEG)
- Systematics are estimated from  
pseudo-experiments

Source	$\Delta m_{\text{top}} \left( \frac{\text{GeV}}{\text{c}^2} \right)$
JES	+1.90
flavor-JES	-2.00
JER	+1.08
	-1.13
Fit calibration	$\pm 0.30$
DY normalization	$\pm 0.40$
Factorization scale	$\pm 0.4$
Jet parton matching scale	$\pm 0.41$
Pile-up	$\pm 0.65$
<b>b</b> -tagging uncertainty	$\pm 0.19$
mis-tagging uncertainty	$\pm 0.30$
LES	$\pm 0.43$
MC generator	+0.12
	-0.18
PDF	$\pm 0.14$
<b>Total</b>	$\pm 0.4$
	+2.49
	-2.59

# Conclusion

In the past two years LIP-CMS was active in Top mass measurement

- $173.3 \pm 1.2(\text{stat.}) \pm 2.6(\text{syst.}) \frac{\text{GeV}}{c^2}$  (CMS PAS TOP-11-016)
- Robust and precise measurement
- In good agreement with world average and dilepton measurements from Tevatron



# BACKUP SLIDES

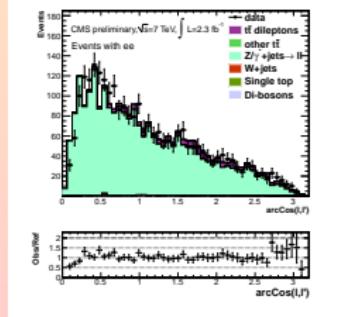
## Event selection strategy

- Events pass standard dilepton triggers and are reconstructed using Particle Flow
- Two isolated, oppositely charged leptons ( $e, \mu$ ) with  $\mathbf{p}_T > 20 \frac{\text{GeV}}{c}$ ,  $|\eta| < 2.4$
- $|m_{ll'} - 91| \geq 15 \frac{\text{GeV}}{c^2}$  (out of  $Z$  mass window) ( $ee, \mu\mu$  only)
- Dilepton mass  $m_{ll'} > 12 \frac{\text{GeV}}{c^2}$
- At least two jets reconstructed with AntiKt5 algorithm, with  $\mathbf{p}_T > 30 \frac{\text{GeV}}{c}$ ,  $|\eta| < 2.4$ 
  - Energy corrections and jet identification algorithms are applied
- Classify jets with an high efficiency b-tagging algorithm, and require at least 1 b-tagged jet in the event
- Selected leptons and jets required to originate from the same primary interaction vertex
- Missing transverse energy  $E_T > 30 \text{ GeV}$  ( $ee, \mu\mu$  only)

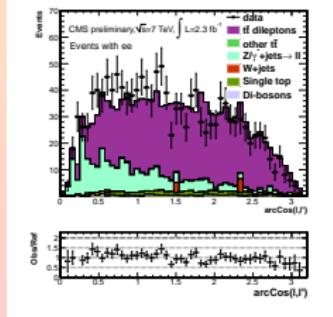
# Control of the Drell-Yan contamination in the selected sample

- Use angle between the two leptons ( $\theta_{\ell\ell'} = \arccos \left[ \frac{\vec{p}_\ell \cdot \vec{p}_{\ell'}}{|\vec{p}_\ell| |\vec{p}_{\ell'}|} \right]$ ): correlated for DY, random for other processes
- Use data-driven shapes taken from low  $E_T$  region ( $< 30 \text{ GeV}$ )
- Shape for  $t\bar{t}$  and other processes taken from MC
- Perform a fit of the templates in the signal region ( $E_T > 30 \text{ GeV}$ )

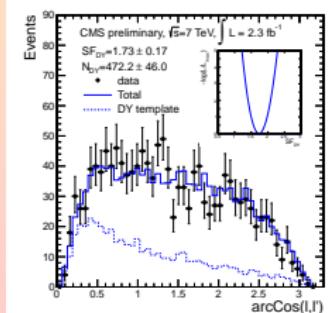
→ ee,  $E_T < 30 \text{ GeV}$  region



→ ee,  $E_T > 30 \text{ GeV}$  region



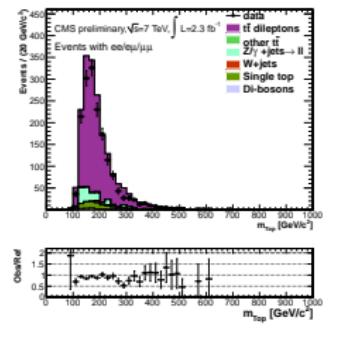
→ fit in  $E_T > 30 \text{ GeV}$  region



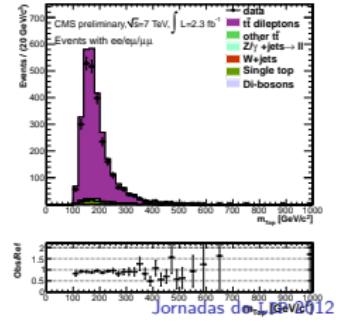
# Sample selected for the measurement

- Require  $\cancel{E}_T > 30 \text{ GeV}$  for all channels (similar resolution)
- KINb rejects 29% (17%) of background (signal) events (no solutions)
- Uncertainties contain both stat. and syst. ones
- Good agreement between data and expectations

→ Events with 1 b-tag

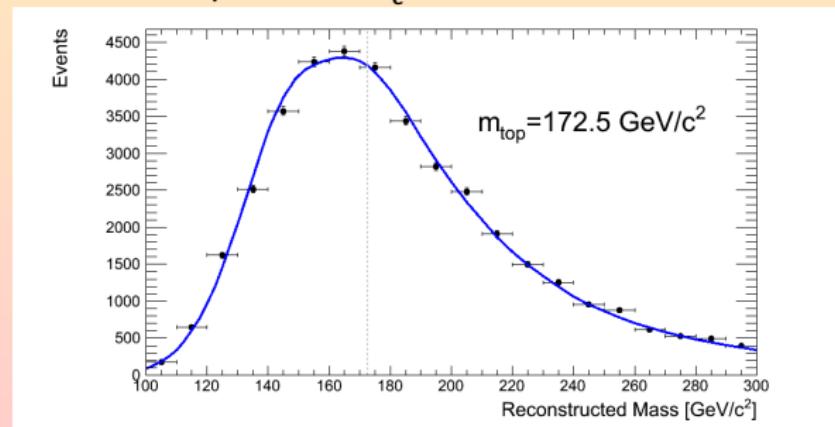


→ Events with  $\geq 2$  b-tags



## Modeling the signal component

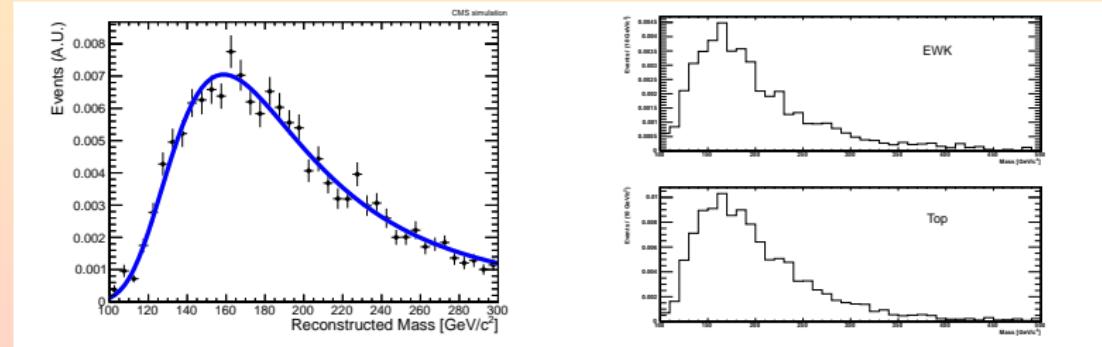
- Generated signal MCs, from  $161.5 \frac{\text{GeV}}{c^2}$  to  $184.5 \frac{\text{GeV}}{c^2}$
  - Mass reconstructed by using the KINb method
  - Categorizing by  $= 1$  and  $\geq 2\text{b} - \text{tags}$
  - Distributions fitted with a Gaussian+Landau template
  - Free parameters assumed to be linear functions of  $m_{\text{top}}$
  - $m_{\text{top}} \rightarrow (m_{\text{top}} - 172) \cdot \text{slope} + \text{intercept}$
- 2 b-tags  $m_{\text{top}}^{\text{gen}} = 172.5 \frac{\text{GeV}}{c^2}$



# Modeling the non-DY background component

- VV, W+jets, single-t and non-dilepton  $t\bar{t}$  fit together
  - Landau curves are used in a combined fit in all channels

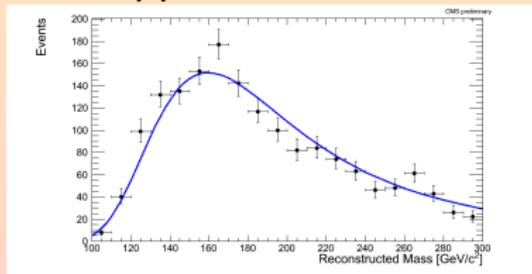
→ Non-DY



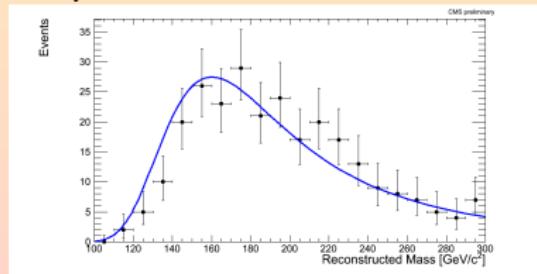
# Modeling the DY background component

- $e\bar{e} + \mu\bar{\mu}$ :  $Z \rightarrow ll$  events inside  $Z$  mass peak
- $e\mu$ : samples with  $\mu \rightarrow \tau$  replacement in  $Z \rightarrow \mu\mu$  data
- Landau curves are used to fit DY shape in all channels

→ DY  $e\bar{e} + \mu\bar{\mu}$

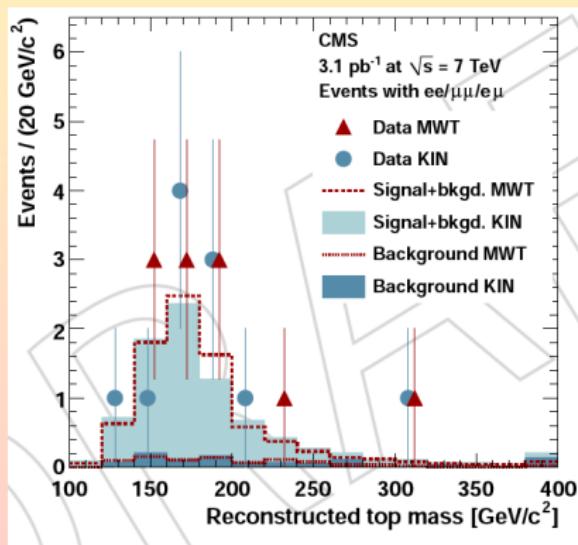


→ DY  $e\bar{\mu}$



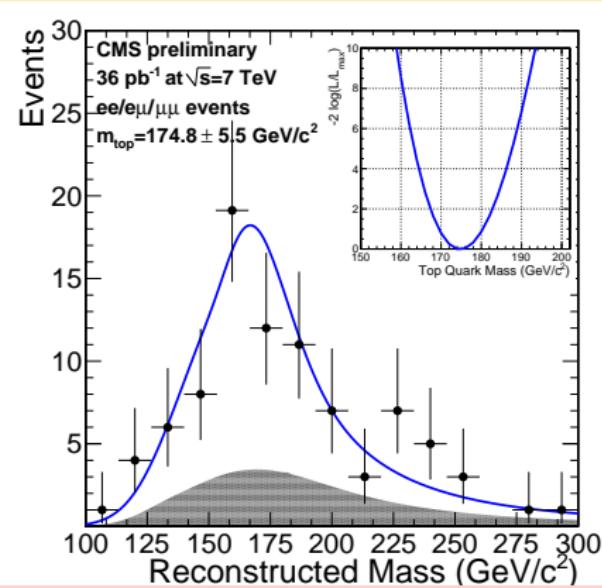
# First mass distribution

→ First mass distribution (TOP-10-006)



# 2010 Results

→ Combined mass fit



# Results

2010 ( $36 \text{ pb}^{-1}$ )

$$174.8 \pm 5.5(\text{stat.})^{+4.5}_{-5.0}(\text{syst.}) \frac{\text{GeV}}{\text{c}^2}$$

JHEP 07(2011)049

2011 ( $2.3 \text{ fb}^{-1}$ )

$$173.3 \pm 1.2(\text{stat.}) \pm 2.6(\text{syst.}) \frac{\text{GeV}}{\text{c}^2}$$

CMS PAS TOP-11-016

Source	$\Delta m_{\text{top}} (\frac{\text{GeV}}{\text{c}^2})$
JES	$+3.1$ $-3.7$
b-jet JES	$+2.2$ $-2.5$
Underlying event	$\pm 1.2$
Fit calibration	$\pm 0.5$
Factorization scale	$\pm 0.7$
Jet parton matching scale	$\pm 0.7$
Pile-up	$\pm 0.9$
<b>b</b> -tagging uncertainty	$\pm 0.3$
MC generator	$\pm 0.9$
PDF	$\pm 0.4$
<b>Total</b>	$+4.5$ $-5.0$

Source	$\Delta m_{\text{top}} (\frac{\text{GeV}}{\text{c}^2})$
JES	$+1.90$ $-2.00$
flavor-JES	$+1.08$ $-1.13$
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