

# Measurement of the Mass of the Top Quark in the $l+ Jets$ Channel Using the Matrix Element Method



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## Introduction

Top quark at the Tevatron.

## The Matrix Element Method

Basics of the method used.

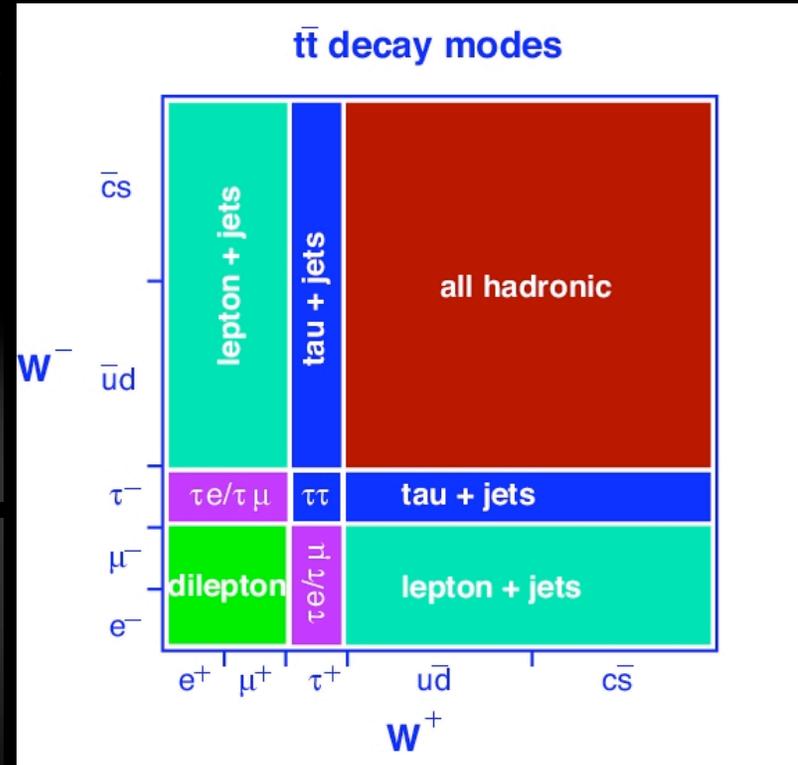
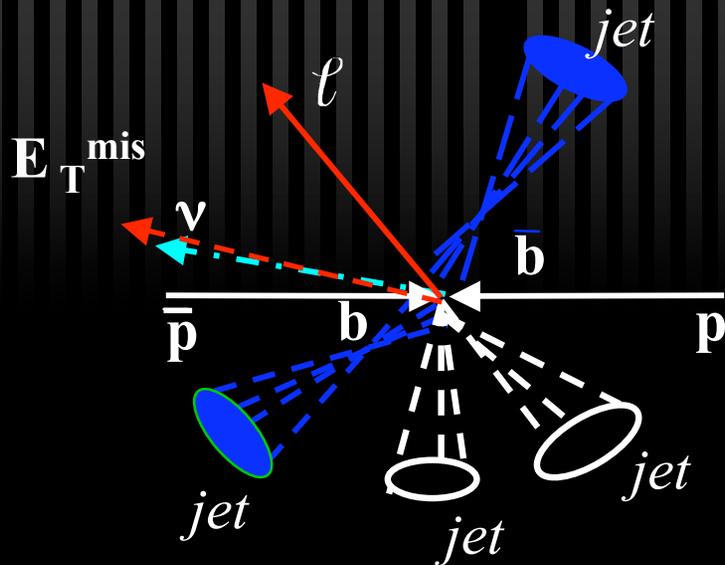
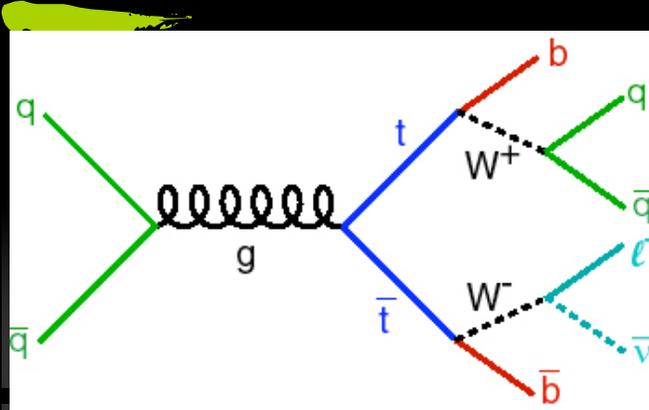
## Top Quark Mass Measurement in the $l+Jets$ Channel

Results from the  $900 \text{ pb}^{-1}$  of data.

# Top Quark

At the Tevatron, top quarks are primarily produced in pairs via the strong interaction. Since  $|V_{tb}| \sim 1$ , the top quark almost always decays to  $Wb$  ( $W_s, W_d$  CKM suppressed)

Event topology depends on the  $W$  decay mode



Experimental signature in the lepton+jets channel:

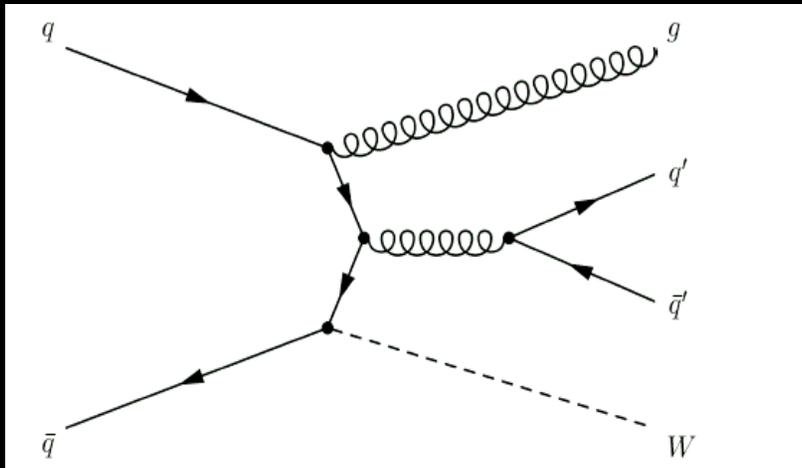
- 1 high  $p_T$  lepton
- 4 jets (2 b-jets)
- large  $E_T^{\text{mis}}$

# Top Quark Identification

## Background Processes:

● **W+jets**  
● **ttbar**

Multi-jet background



W+jets production.

Multi-jet events:

leading to fake or mis-characterized lepton  
and fake missing transverse energy

- Exactly 4 Calorimeter Jets  
 $p_T > 20 \text{ GeV}$   
 $|\eta| < 2.5$
- Isolated Lepton  
 $p_T > 20 \text{ GeV}$   
 $|\eta^e| < 1.1, |\eta^\mu| < 2.0$
- Missing Transverse Energy  
 $E_T^{\text{mis}} > 20 \text{ GeV}$

**W+jets**  
● **ttbar**

# The Basics of the Analysis I

We calculate a probability per event to be signal or background as a function of the top mass and the Jet Energy Scale (JES).

If we had all the parton level information 'y' this probability would be just proportional to the differential cross section.

In reality is a bit more complicated:

**Differential cross section,**  
based on LO Matrix Element  
(  $q\bar{q} \rightarrow t\bar{t}$  ) only

**Transfer Function:**  
probability to **measure x**, when  
**parton-level y** was produced.

**Initial state**

$$P_{t\bar{t}}(x; m_{top}, JES) = \frac{1}{\sigma(m_{top})} \int dq_1 dq_2 f(q) f(\bar{q}) d\sigma(y; m_{top}) Prob(x, y, JES)$$

**Normalization:**

Overall JES is a free parameter in the fit, constrained in situ by the mass of the W decaying hadronically

**Measurements (x):**  
**jets and leptons**

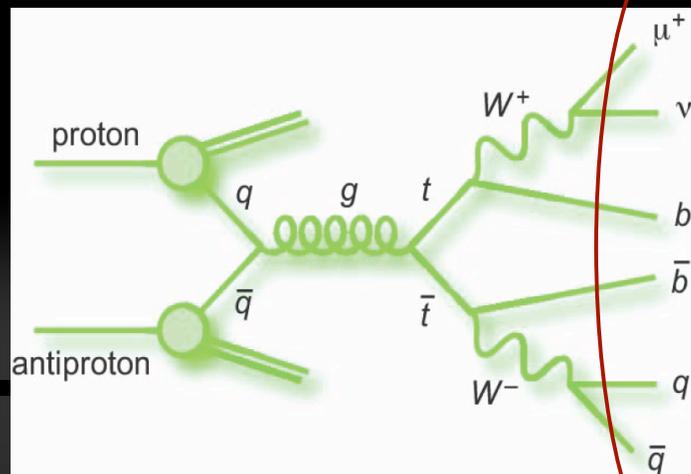
Background probability is conceptually the same but flat in  $m_{top}$  and  $JES$ .

# The Basics of the Analysis II

## *b*-tagging:

Weight each jet to parton assignment with *b*-tagging probabilities.

24 possible weighted assignments between jets and partons



Six particle final state

Parameterized tagging efficiencies

$$P_{t\bar{t}}^{N-tag}(x; m_{top}, JES) = \sum_{c=1;24} W_c^{t\bar{t}} P_{t\bar{t}}^c(x; m_{top}, JES)$$

$$W_c^{t\bar{t}} = \prod_{J=1;4} P_J$$

If jet J was tagged:

If jet J was not tagged:

$$P_J = \varepsilon_J(\text{flavor}, \eta, p_T)$$

$$P_J = 1 - \varepsilon_J(\text{flavor}, \eta, p_T)$$

## The Basics of the Analysis III

Probability per event:

$$P_{evt}^{N-tag}(x; m_{top}, JES, f_{top}) = f_{top} P_{\bar{t}t}^{N-tag}(x; m_{top}, JES) + (1 - f_{top}) P_{bkg}(x, JES)$$

Probability per sample:

$$P^{N-tag}(x; m_{top}, JES) = \prod_{evt} P_{evt}^{N-tag}(x; m_{top}, JES)$$

$f_{top} = f_{top}^{best}(m_{top}, JES)$

To combine the three  $b$ -tagged samples the 2D probabilities are multiplied:

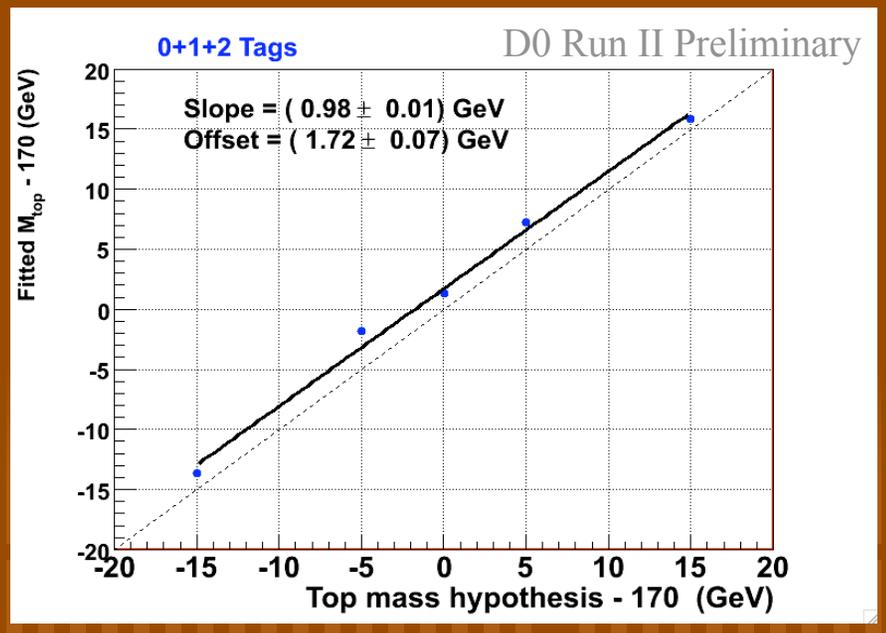
$$P^{comb}(x; m_{top}, JES) = P^{0-Tags}(x; m_{top}, JES) P^{1-Tag}(x; m_{top}, JES) P^{2-Tags}(x; m_{top}, JES)$$

To use an external constraint in  $JES$  we convoluted the original likelihood with the measure in the  $photon + Jet$  sample which is represented as a Gaussian likelihood centred at  $JES = 1$  with a width of 3.7% (this width is estimated from  $t\bar{t}$  MC sample).

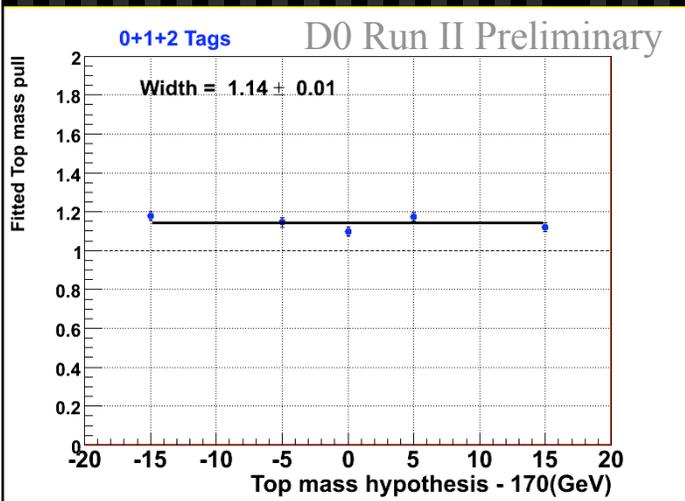
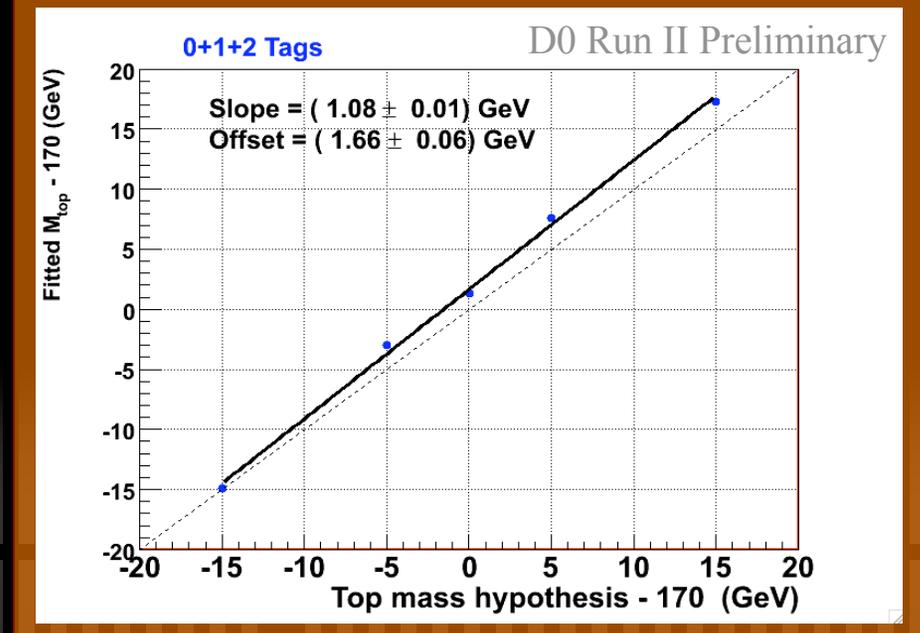
$$P(x; m_{top}, JES) = P^{comb}(x; m_{top}, JES) G(JES)$$

# Calibration

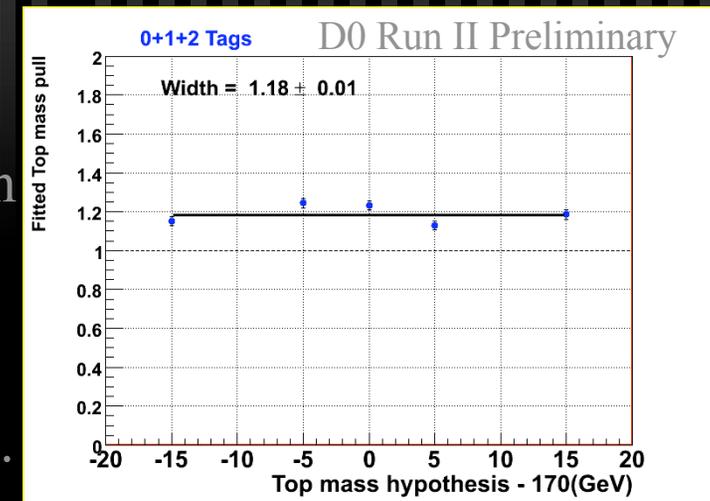
## Mass Calibration and Pull for Muons



## Mass Calibration and Pull for Electrons



Before applying to data, the method is calibrated for shifts in the mean and uncertainties using ensemble tests on simulated MC events.



## Data Sample

Electrons channel ( $971 \text{ pb}^{-1}$ ): 249 events (28% purity)

173 events in 0 Tags

57 events in 1 Tag

19 events in 2 Tags

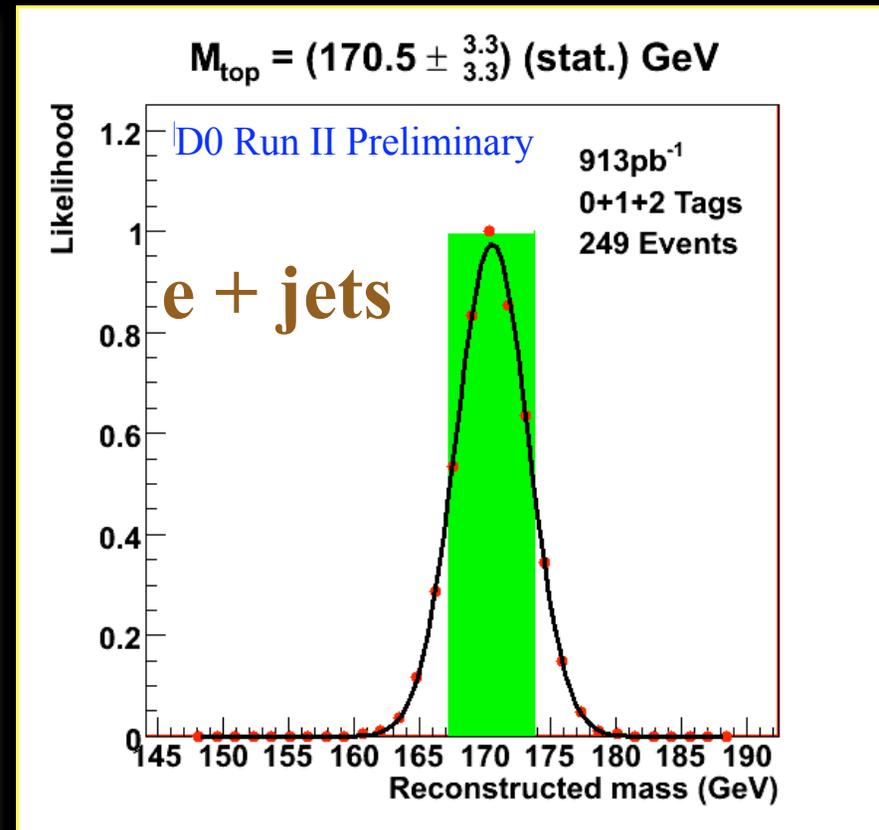
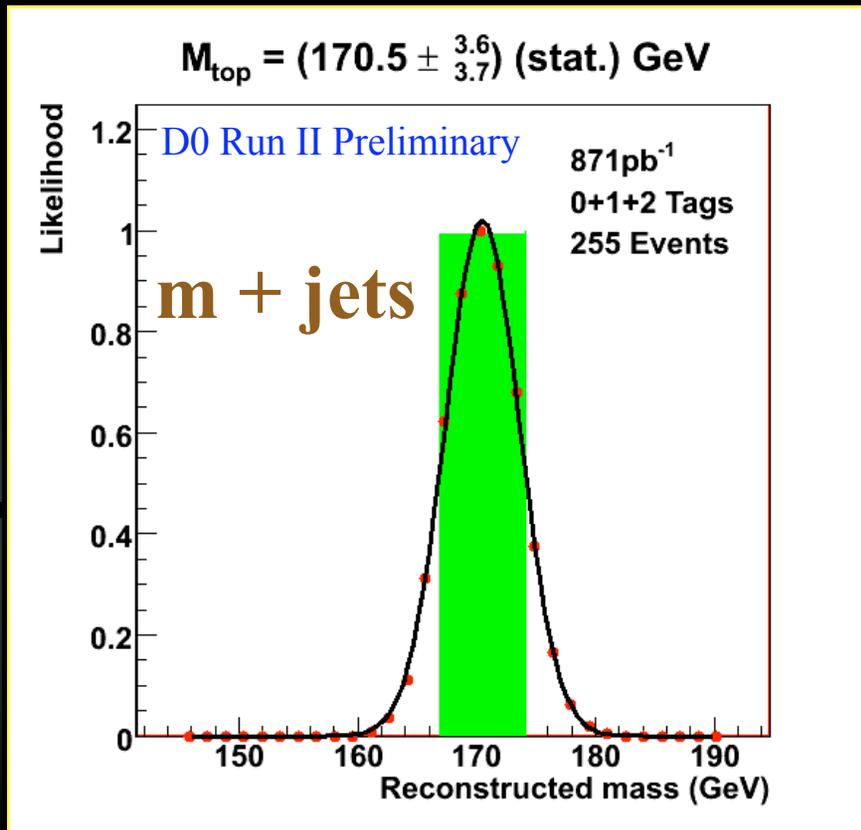
Muons channel ( $813 \text{ pb}^{-1}$ ): 255 events (25% purity)

163 events in 0 Tags

70 events in 1 Tag

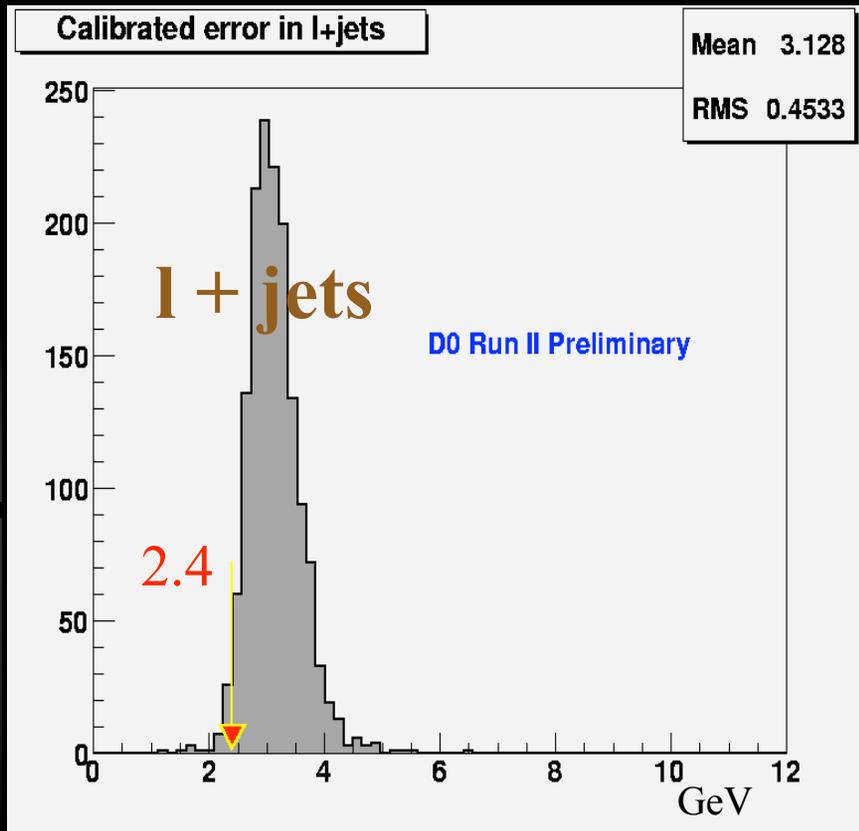
22 events in 2 Tags

# Result combining 0 + 1 + 2 Tags, Calibrated



**l + jets:**  $M_{top} = 170.5 \pm_{2.4}^{2.4} \text{ (stat. + JES) GeV}$

## Result combining 0 + 1 + 2 Tags, Calibrated

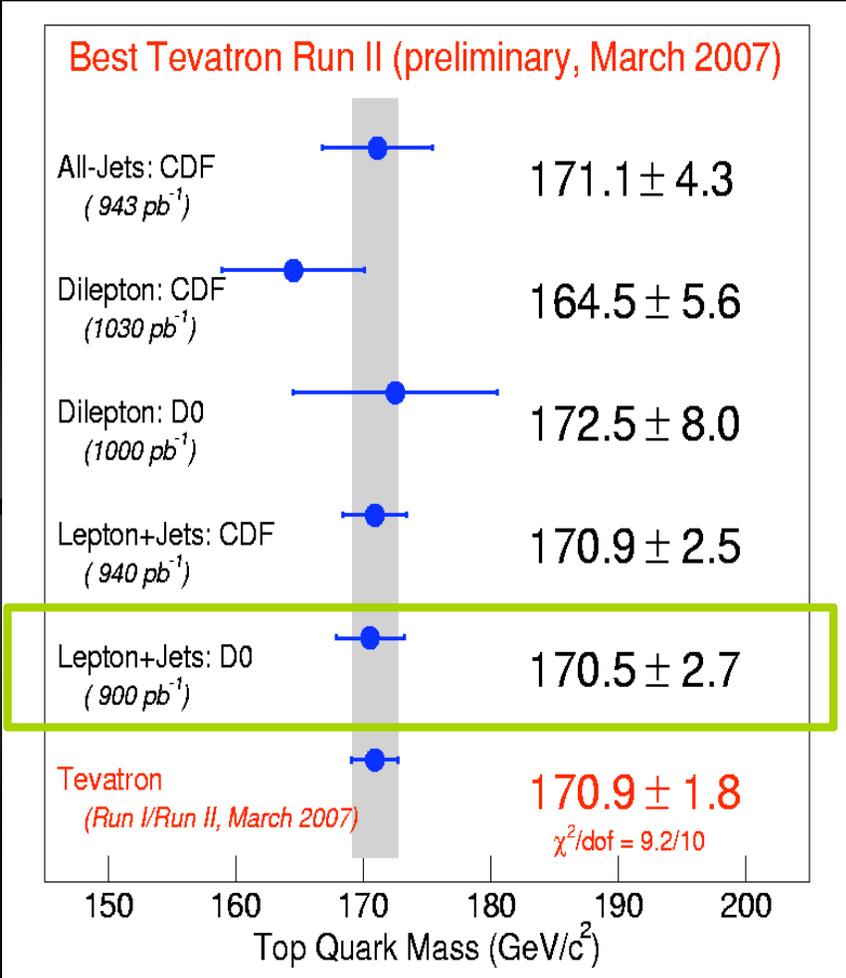


### Most Significant Systematic Errors

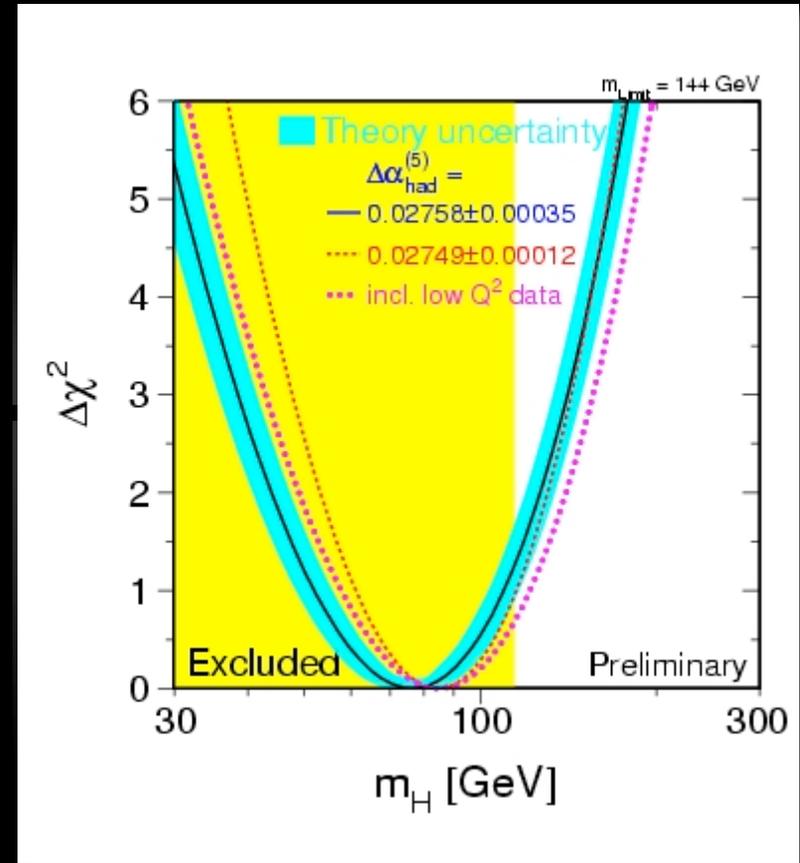
	(+)	(-)
Signal modeling	0.45	0.45
b fragmentation model	0.54	0.54
b/l ratio (1.5%)	0.57	0.57
JES pt dependence	0.23	0.23
TRF-Tagging MC	0.29	0.29
Signal fraction	0.53	0.24
QCD Contamination	0.21	0.21

**l + jets:**  $M_{top} = 170.5 \pm_{2.4}^{2.4} (stat. + JES) \pm_{1.1}^{1.2} (syst.) GeV$

# Top Mass Current Status



## Impact on Standard Model Higgs boson:



$$M_H = 76_{-24}^{+33} \text{ GeV}; \quad M_H < 144 \text{ GeV} @ 95\text{CL}$$

## CONCLUSIONS

D0 Run II Preliminary result for 0+1+2 Tags from 900 pb<sup>-1</sup>:

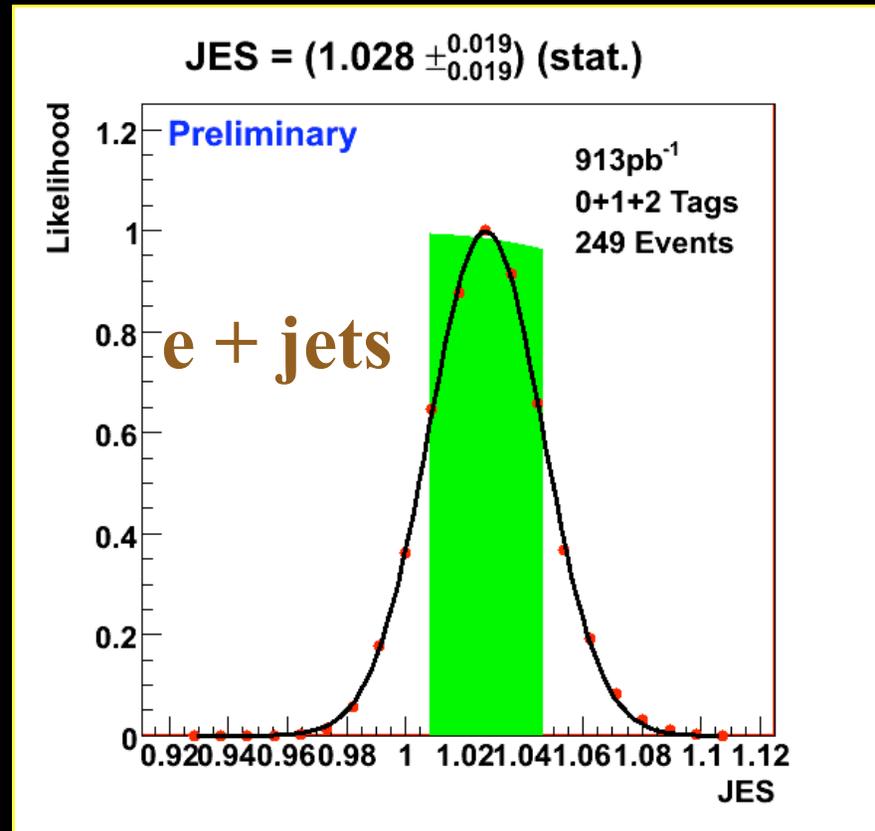
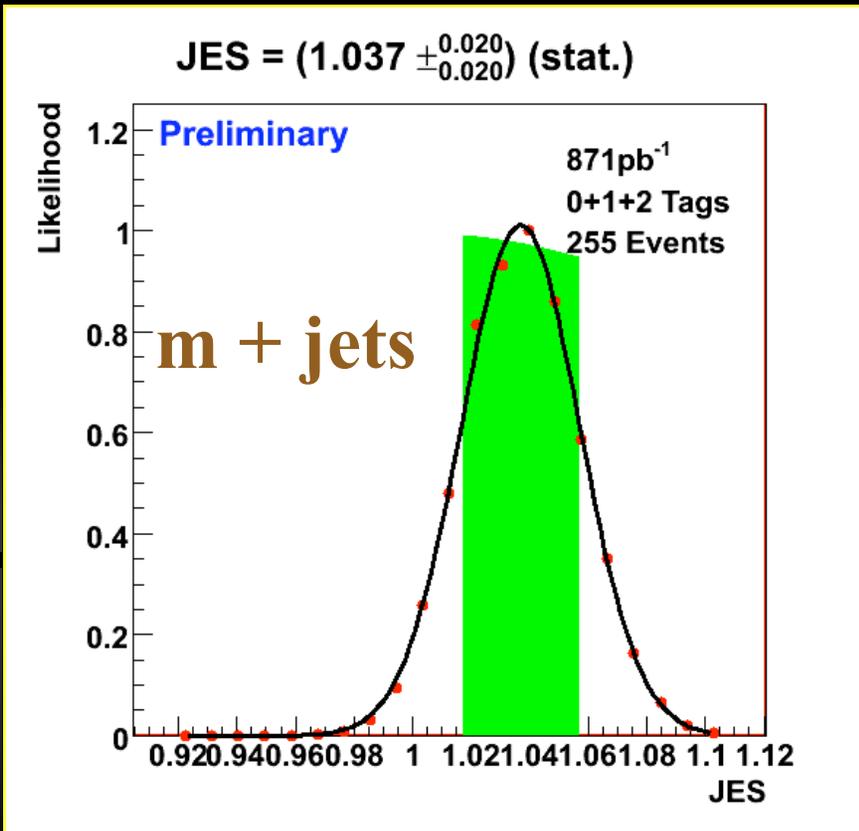
$$M_{top} = 170.5 \pm_{2.4}^{2.4} (stat. + JES) \pm_{1.1}^{1.2} (syst.) GeV$$

A new improved measurement of the top quark mass allow us to reach the 1% precision (Combined DØ + CDF measurement).

The precise measurement of top quark mass helps constrain the mass of the SM Higgs boson, and it is one of the most important measurements at the Tevatron.

# RESULT + PRIOR

## Combined 0 + 1 + 2 Tag analysis , Calibrated + Prior



**1 + jets:**

$$JES = 1.032 \pm_{0.014}^{0.014} (stat.)$$

## Systematic Errors

Error Source	up(+)	down(-)
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### Physics modeling:

Signal modeling	0.45	0.45
b fragmentation model	0.54	0.54
PDF uncertainty	0.16	0.39
Background modeling	0.15	0.15
b/c semileptonic decay	0.05	0.05

### Detector Modeling

b/l ratio (1.5%)	0.57	0.57
JES pt dependence	0.23	0.23
Trigger	0.08	0.13

### b tagging

TRF-Tagging MC	0.29	0.29
TRF (signal)	0.04	0.04
TRF (background)	0.03	0.06

### Method:

Signal fraction	0.53	0.24
QCD contamination	0.21	0.21
MC calibration mass	0.05	0.05
MC calibration JES	0.05	0.05

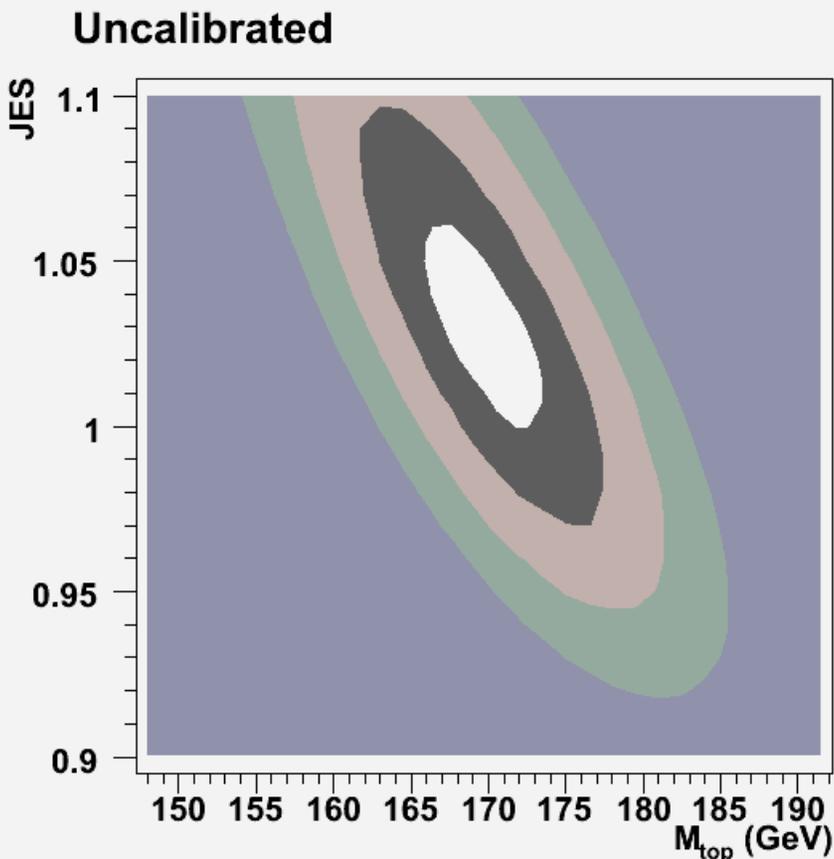
Total Systematic Errors	1.159956896	1.123343224
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Total Errors (Stat.+JES+Sys.)	2.665614376	2.64988679
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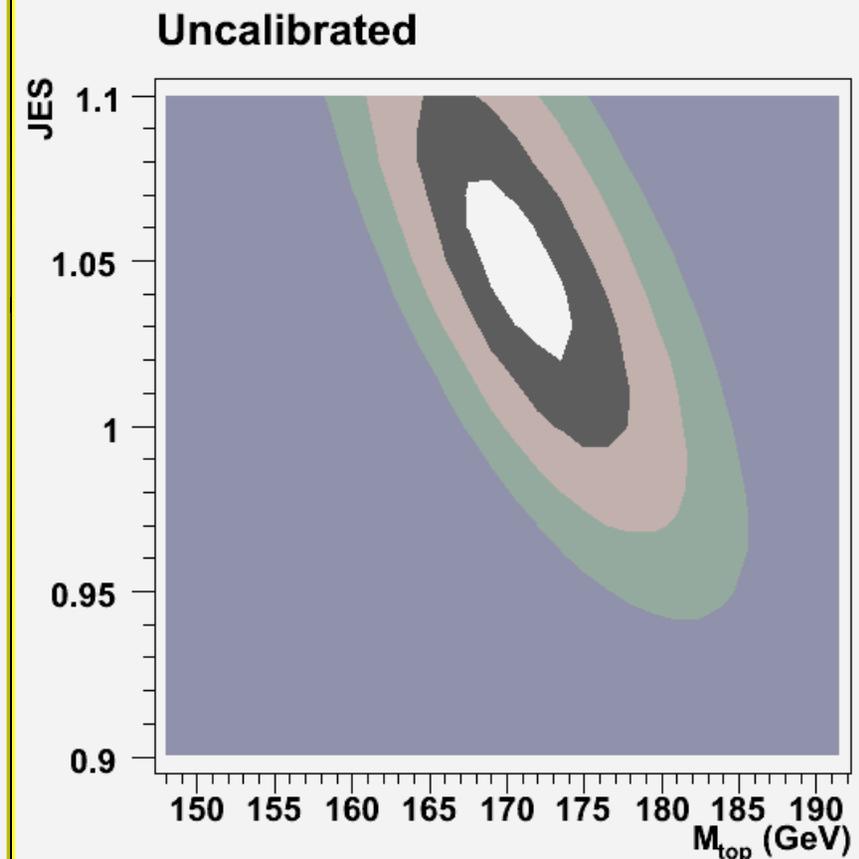
# DATA

2D likelihood before calibration. Each color represents one sigma. After projection in the two dimensions we apply the calibration curves and adjust the errors using the final pulls.

## Electrons channel

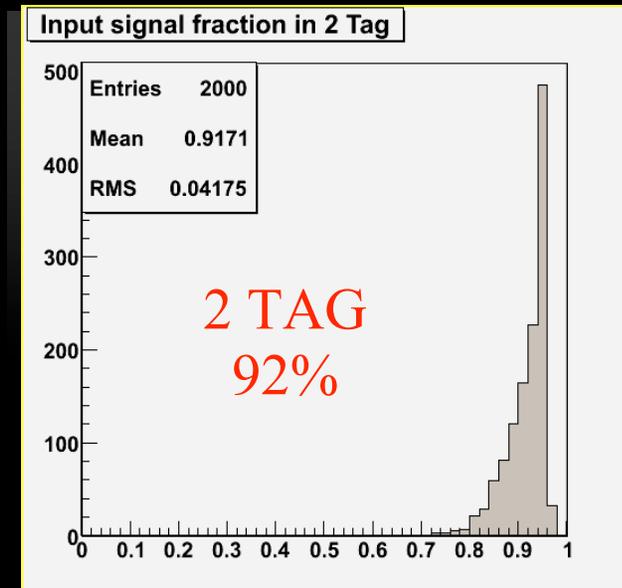
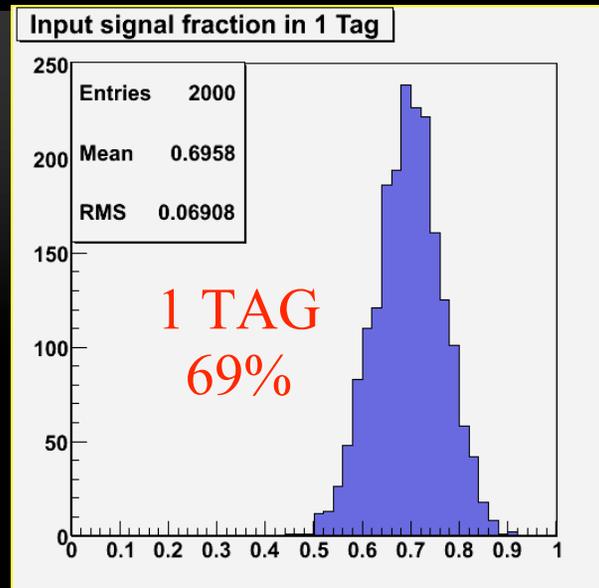
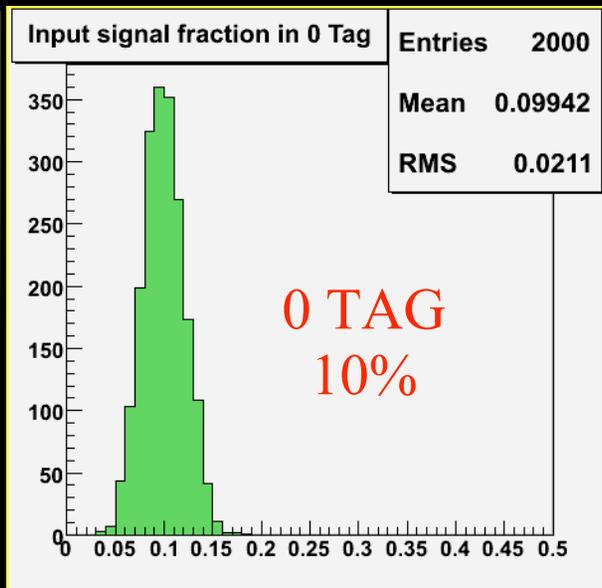
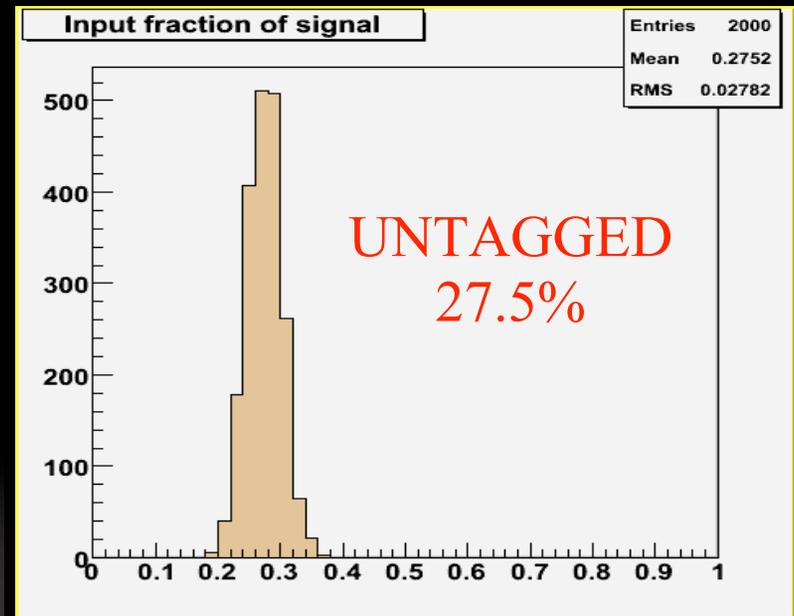


## Muons channel



# The Ensembles

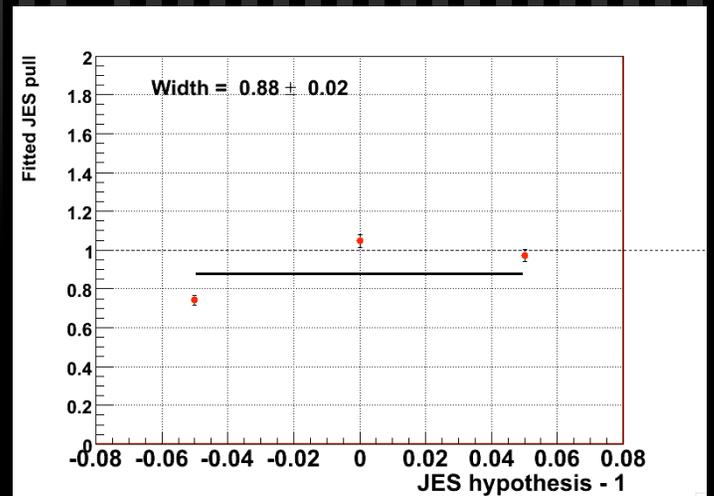
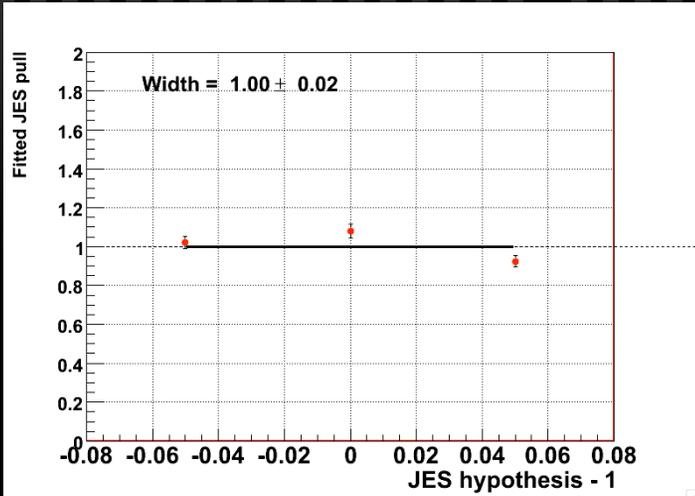
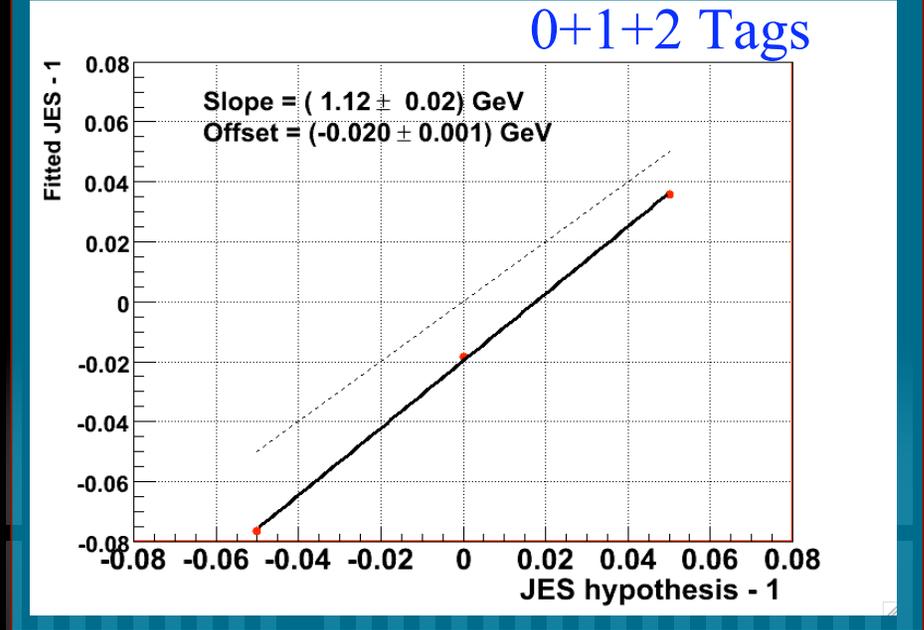
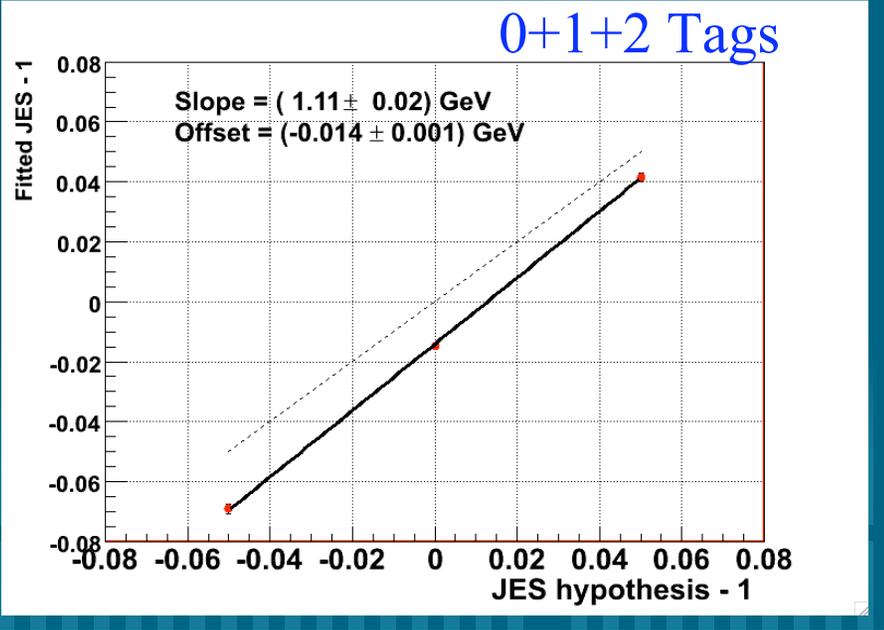
Example of composition and fluctuations in the ensembles (inputs). Electrons channel composition:  
251 events 27.6% purity.  
Below are the purities for the different Tag samples.



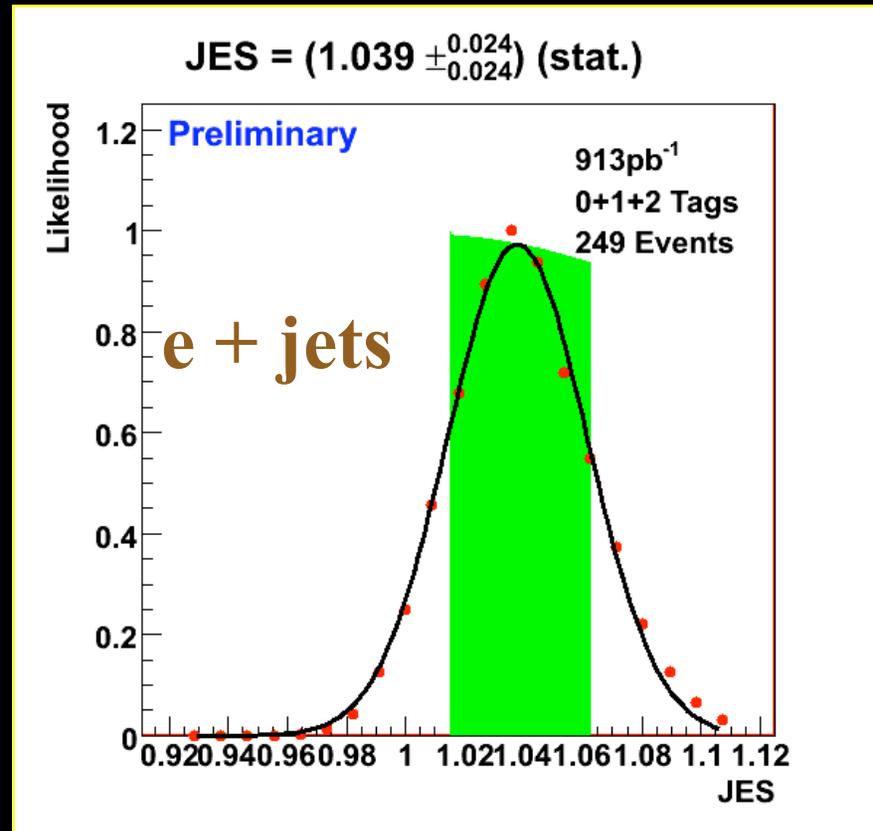
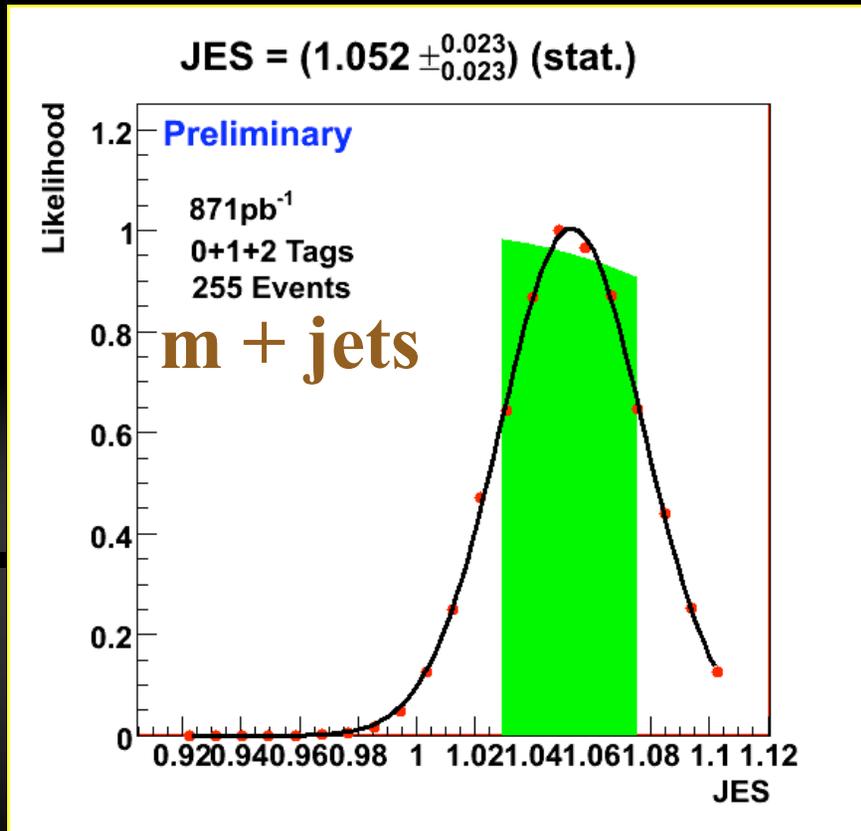
# JES Calibration

## JES Calibration for Muons

## JES Calibration for Electrons



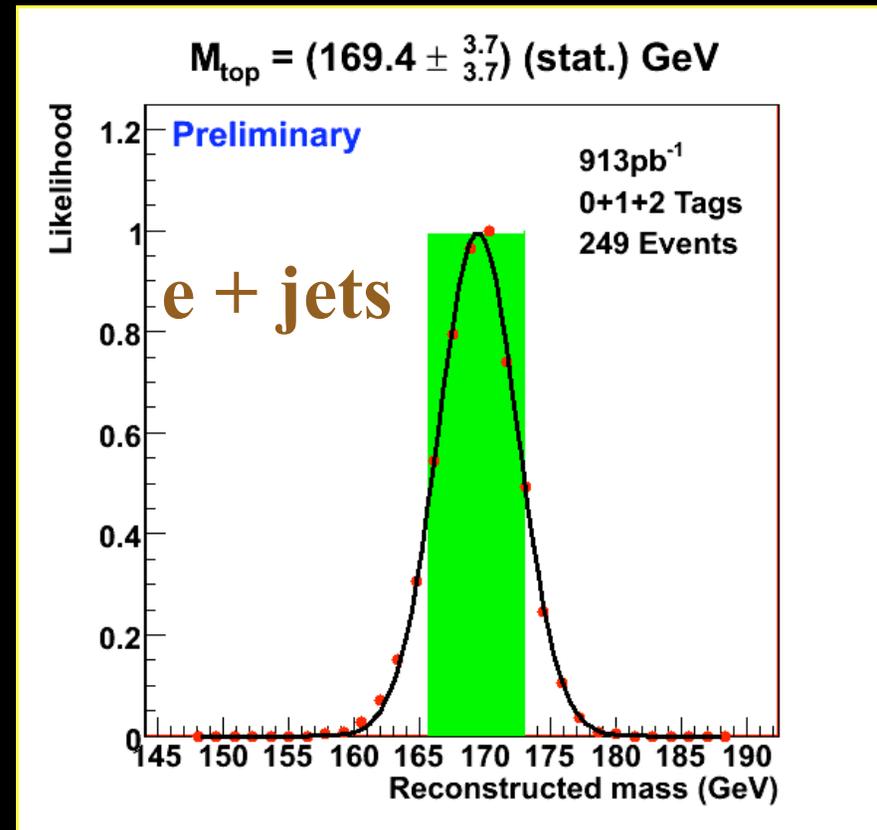
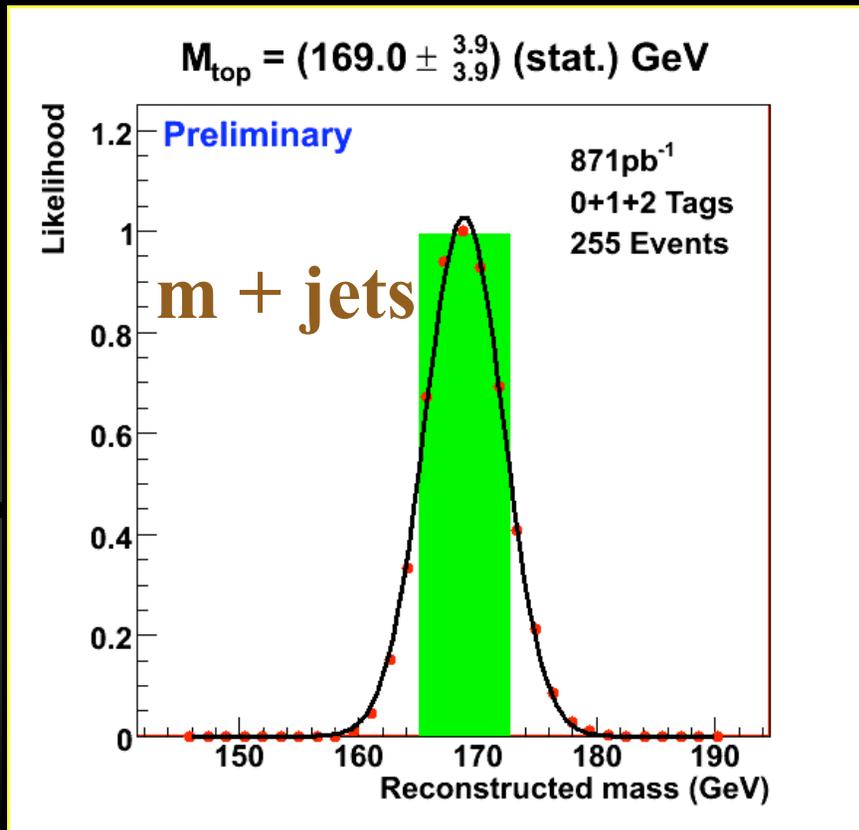
## Combined 0 + 1 + 2 Tag analysis - Calibrated



**1 + jets:**

$$JES = 1.046 \pm_{0.017}^{0.017} \text{ (stat.)}$$

## Combined 0 + 1 + 2 Tag analysis - Calibrated



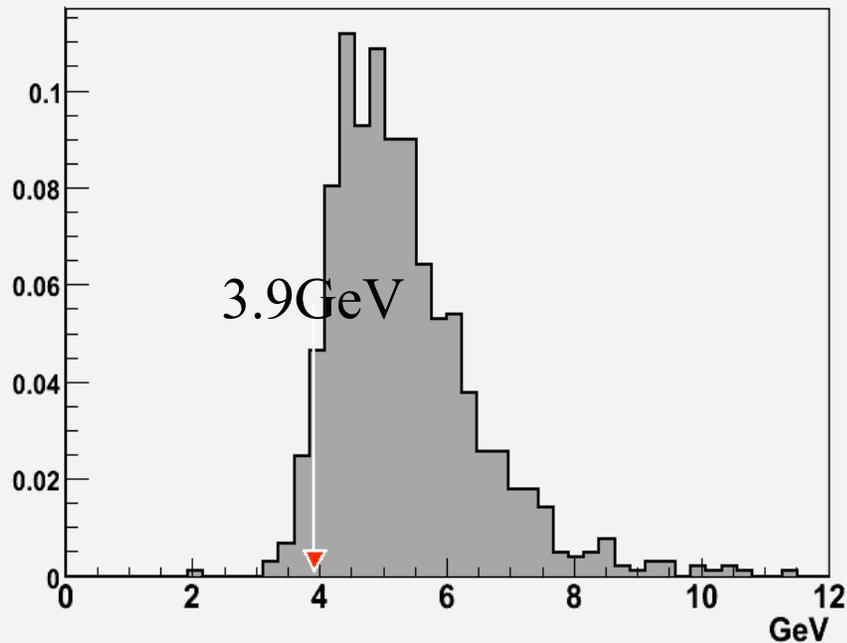
**1 + jets:**  $M_{\text{top}} = 169.2 \pm_{2.7}^{2.7} \text{ (stat. + JES)}$

# DATA RESULT

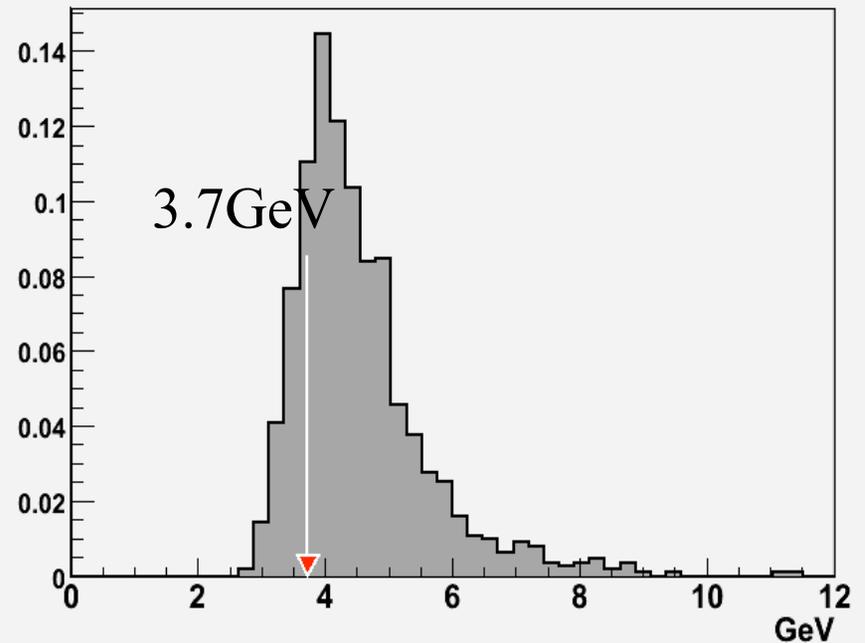
$$M_{top} = 169.2 \pm_{2.7}^{2.7} (stat. + JES) GeV$$

Combined 0 + 1 + 2 Tag analysis - Calibrated

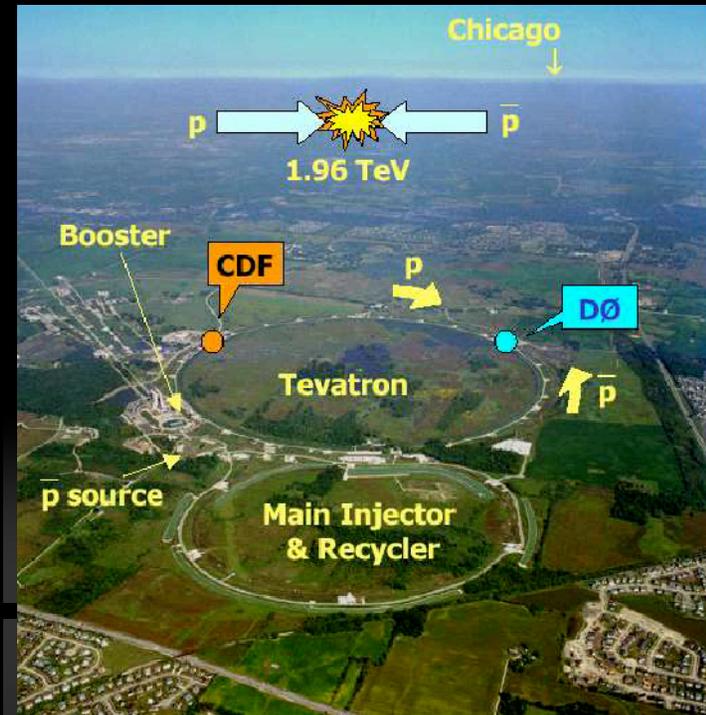
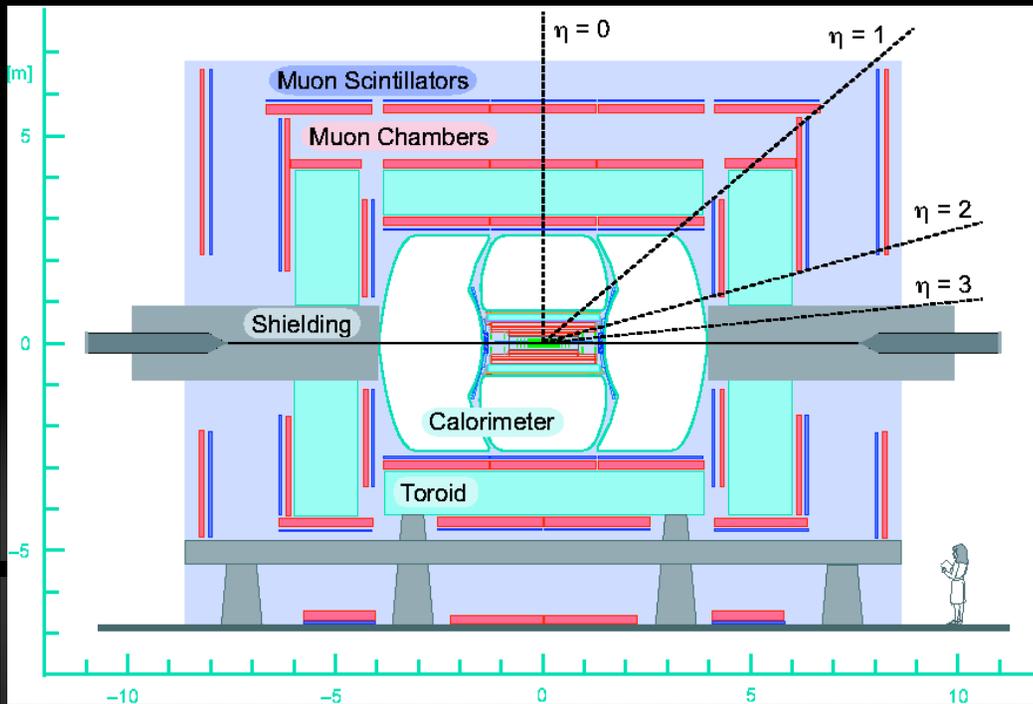
calibrated error m+jets



calibrated error in e+jets



# The DZero Detector and the Tevatron



## Tracking:

Silicon vertex detector (SMT)  
 Central Fiber Tracker (CFT)  
 2 T Superconducting Solenoid.  
 $|\eta| < 2.5$

## Preshowers

## EM/HAD Calorimeter:

Central,  $|\eta| < 1.1$   
 Forward,  $|\eta| < 4.2$

## Muon system:

1.8 T iron toroids.  
 $|\eta| < 2.0$

## 3-Level trigger system:

Level 1 (hardware): 2 kHz  
 Level 2 (hardware): 1 kHz  
 Level 3 (software): 50 Hz