Bundesministerium für Bildung und Forschung

Top Mass Measurements at the Tevatron

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for the CDF and D0 collaborations

Today's Menu

- Why are top mass measurements so interesting?
- The Tevatron
- Experimental challenges
- Measurements of the top mass:
  - The methods en bref
  - Flagship measurements in the semileptonic channel
  - All-hadronic channel
  - Dilepton channel
- Finita la comedia!

Top Mass Measurement Motivation

- The top is special:
  - Heaviest particle of the SM
  - Yukawa coupling is ~1
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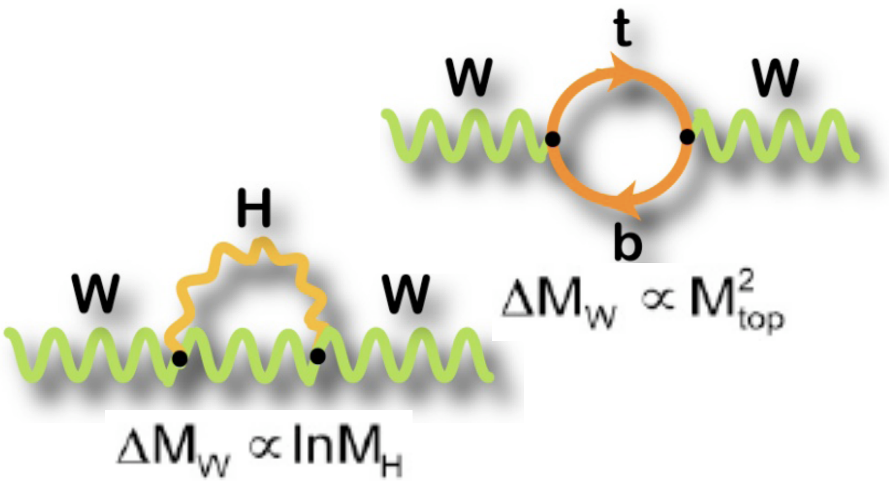

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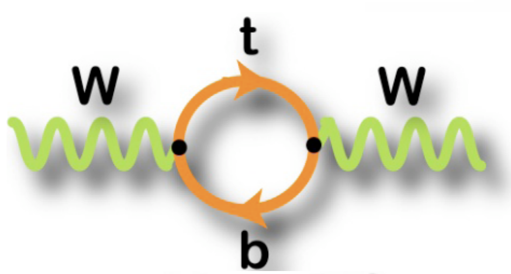
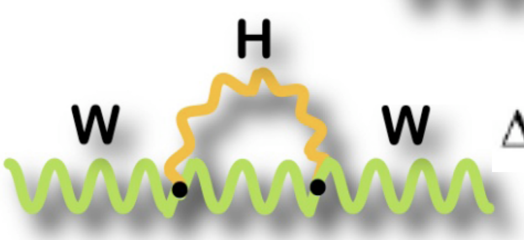
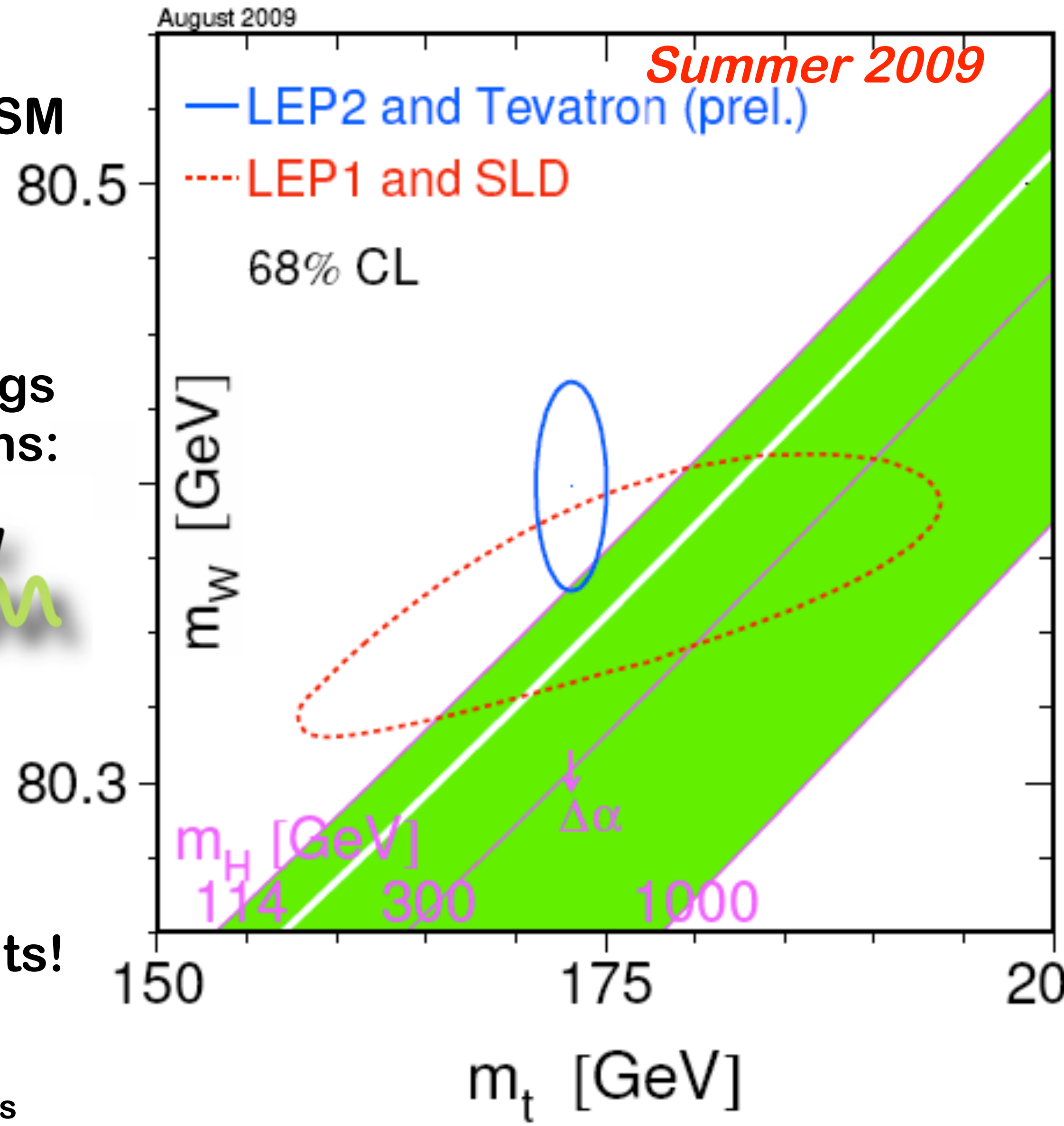


$\Delta M_W \propto M_{top}^2$



$\Delta M_W \propto \ln M_H$

  - Waiting for newest EW fits!
  - 1GeV change in m_{top} → ~10 GeV change in m_{higgs}



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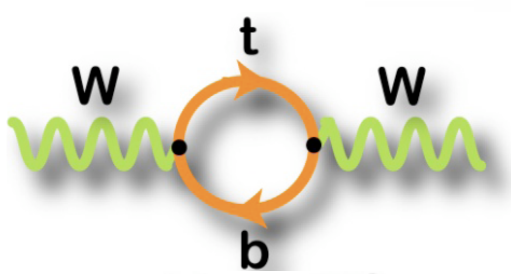

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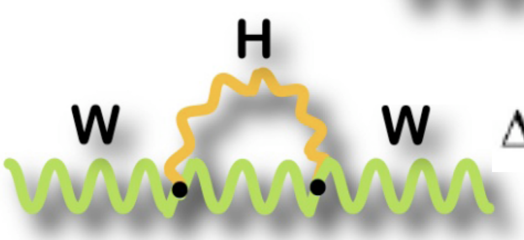

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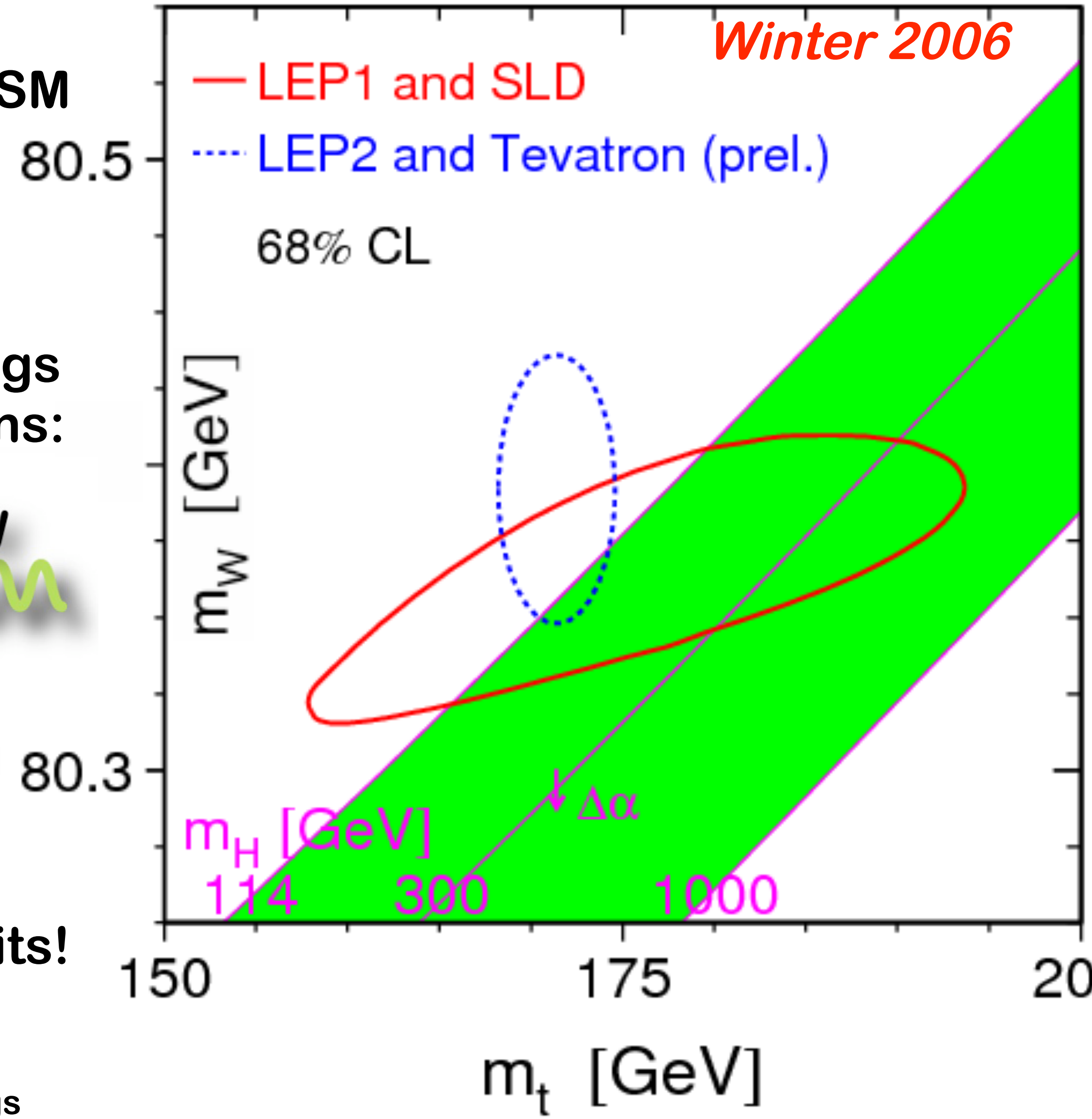
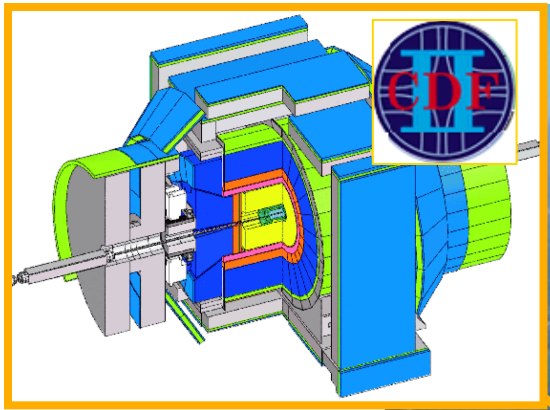
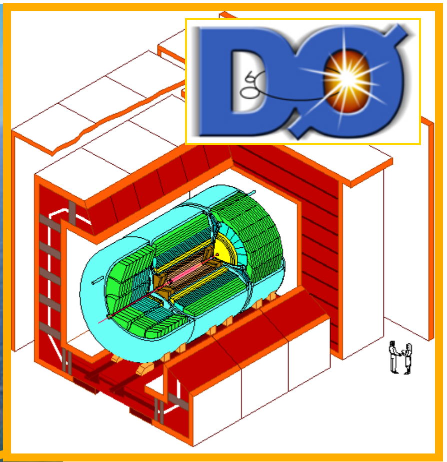
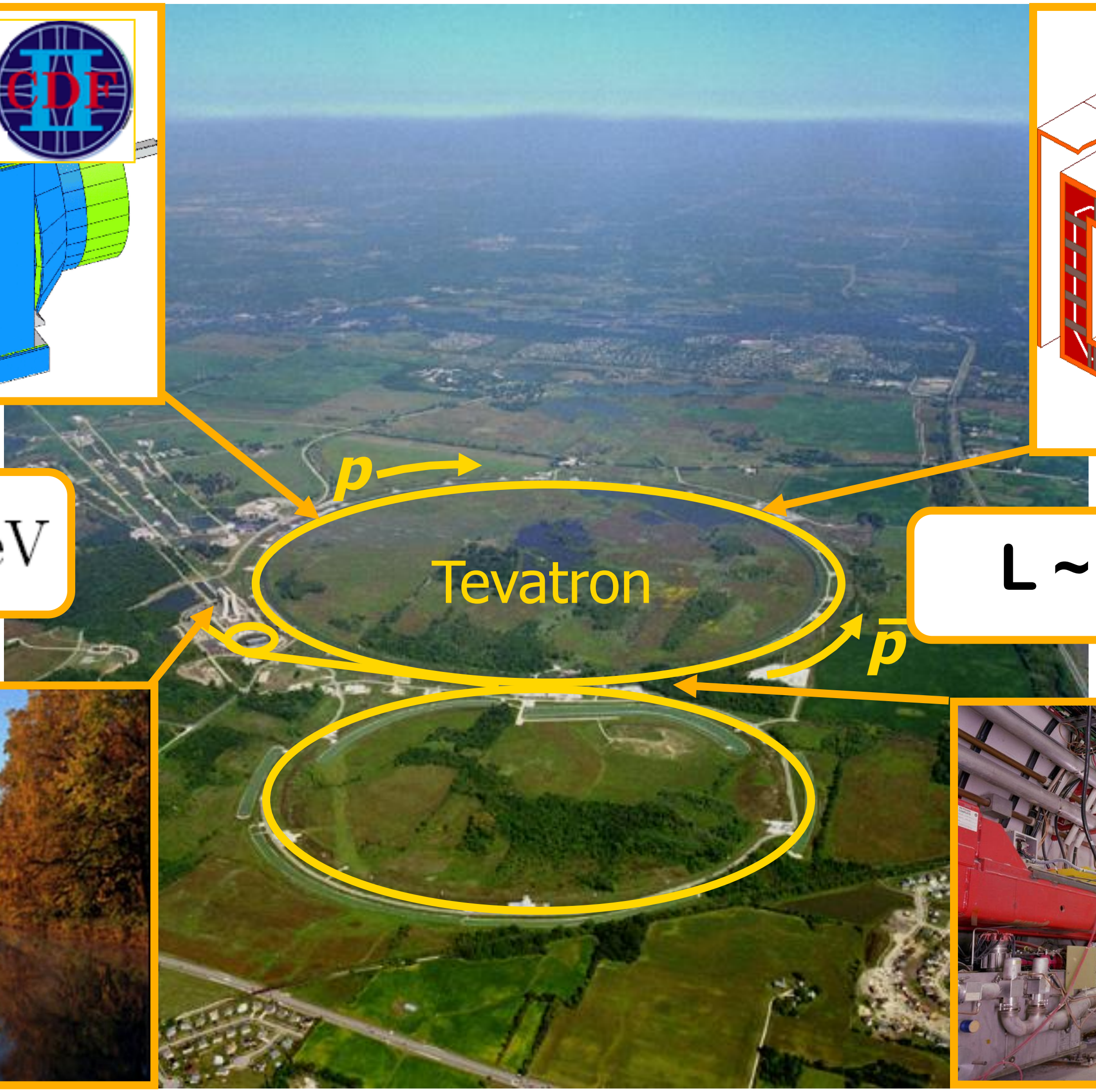


The Tevatron: a Top Factory

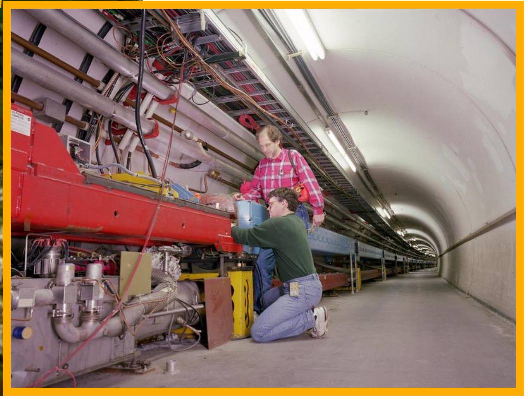




$$\sqrt{s} = 1.96\,\text{TeV}$$

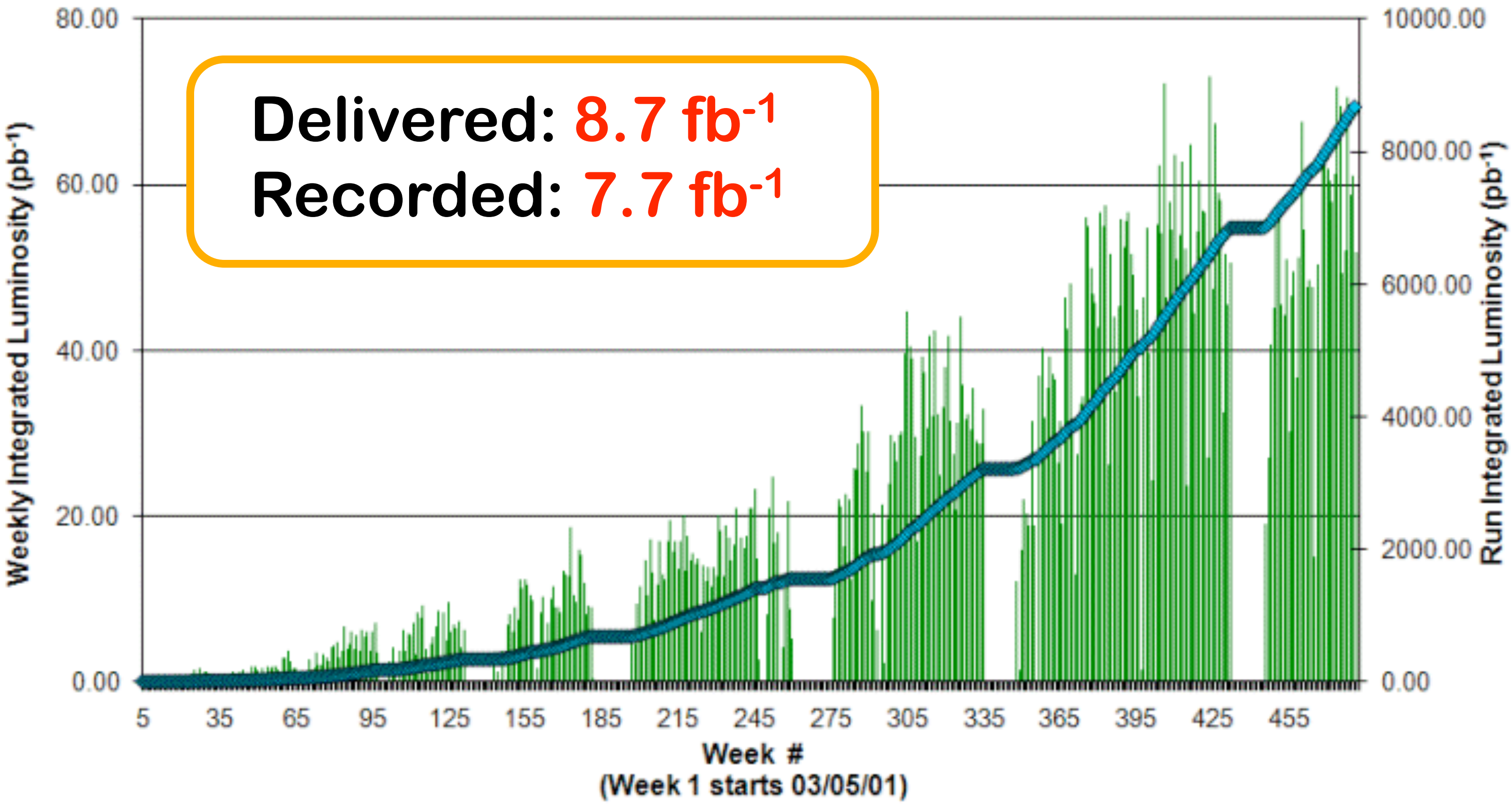


L ~ 7.5 fb^{-1} p.e.



The Tevatron Performance for the Top!

- Tevatron has shown a great performance in FY 2010!
- We keep enlarging our calibration samples
  - Better handles on experimental uncertainties:
    - e.g. Jet Energy Scale (JES), Jet Energy Resolution, etc.



Top Mass: Experimental Challenges

- The Tevatron is a hadron collider
  - Very high backgrounds!
- Backgrounds can bias the top mass measurement

Typical Backgrounds:

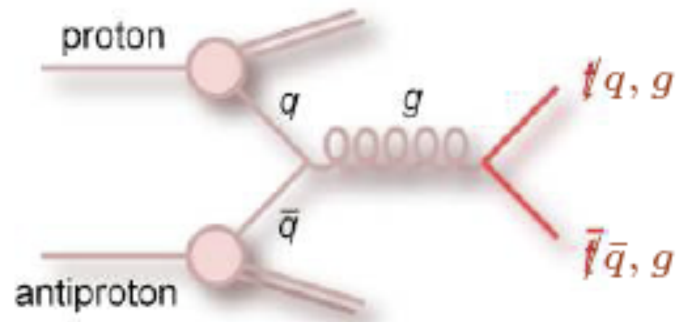
W+jets

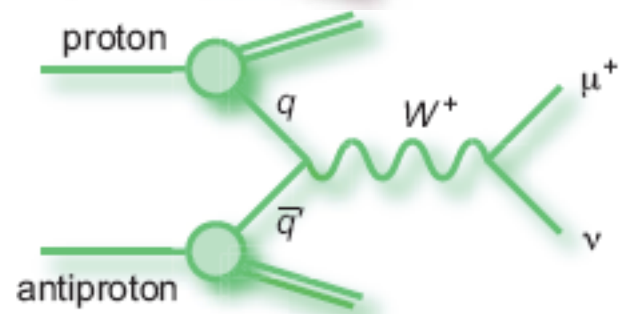
Z+jets

QCD multijet prod’n

Diboson prod’n

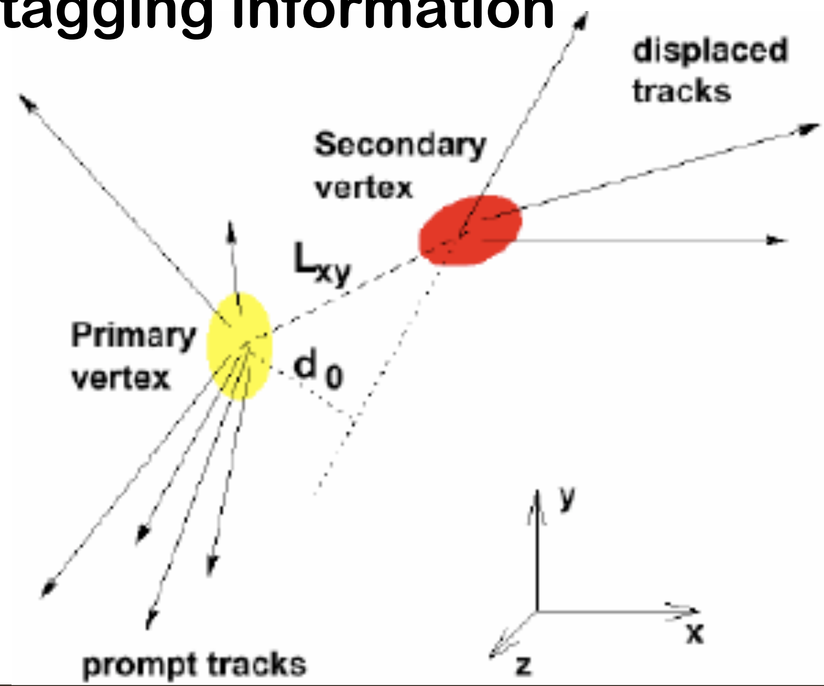
Single top prod’n





See talk by F. Deliot (top Xsec)

- The Tevatron is a hadron collider
  - Very high backgrounds!
- Backgrounds can bias the top mass measurement
- Control backgrounds using b-tagging information

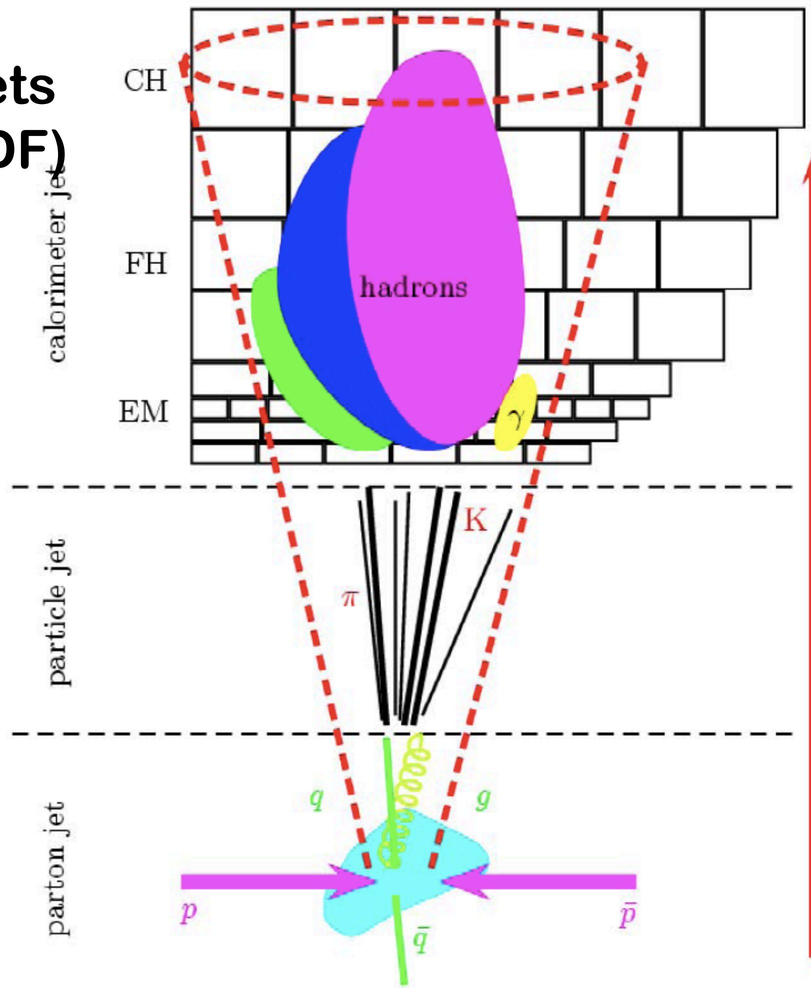


Channel	B-tags	S:B	Perm.
Dilepton	≥ 0	1:4	2
	≥ 1	4:1	2
Lepton+jets	≥ 0	< 1:1	12
	≥ 1	2.5:1	6
	≥ 2	10:1	2
All-hadronic	≥ 1	1:4	30
	≥ 2	4:1	6

At the same time:
→ help combinatorics!

Top Mass: Experimental Challenges

- We are interested in parton-level quantities for our top mass measurement
  - Map the energies of reco-level jets to particle jets (D0) / partons (CDF)
  - This is referred to as a Jet Energy Scale (JES) corr'n
  - With the current size of calibration samples:
    - σ(JES)/JES ~ 1.5% (D0)
    - σ(JES)/JES ~ 3% (CDF)



- And many more:
  - Lepton ID, p_T scale
  - Signal, background model
  - ISR, FSR
  - …
  - → cover some in the systematics discussion

Top Mass Measurement: Methods

- The measurements shown today are based on:
  - Template method
  - Matrix Element method

Top Mass Measurement: Methods

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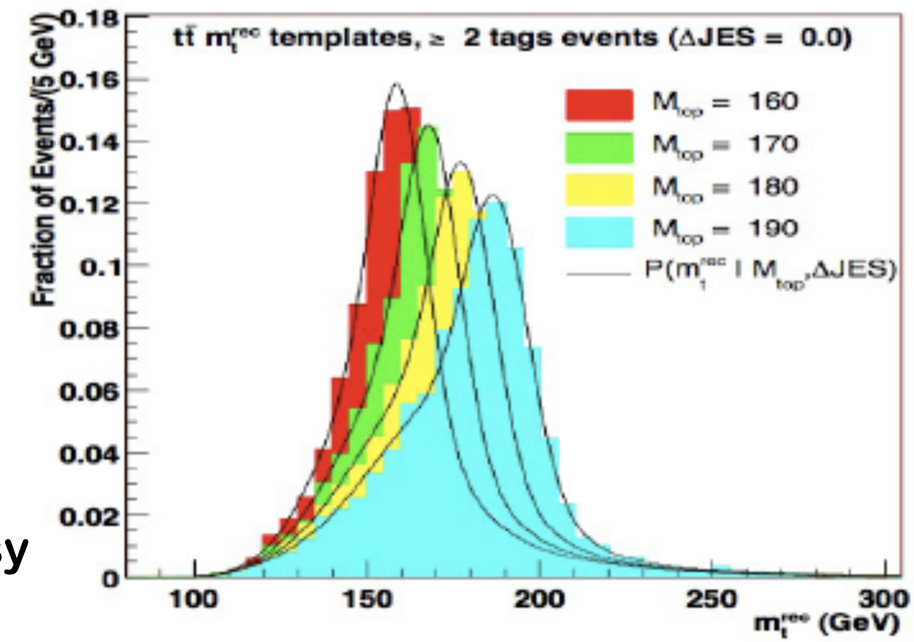
  - Template method
  - Matrix Element method
- Template method:
  - Pick a set of variables x_i sensitive to m_{top}
  - Create "templates" = distributions of x_i using MC
    - For signal: $x_i = x_i(m_{top})$
    - For background
  - Maximise the likelihood of their consistence with the observation
  - Advantages:
    - Few assumptions
    - fairly straight forward
    - Combination of channels easy



Top Mass Measurement: Methods

- The measurements shown today are based on:
  - Template method
  - Matrix Element method
- Matrix Element method:
  - Calculate p.d.f. on an event-by-event basis, pdf = pdf(m_{top}):

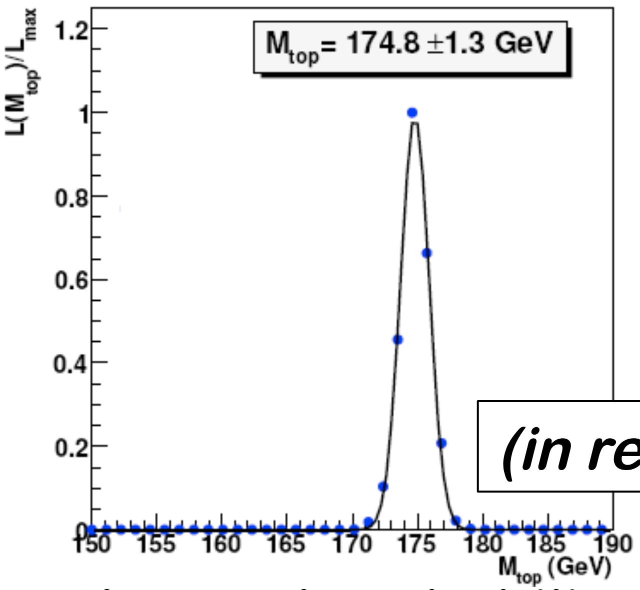
$$P_i(\vec{x}_i) = \frac{1}{N}\int \mathrm{TF}(\vec{x}_i \,|\, \vec{y}_i)\, d\sigma(\vec{y}_i, m_t)$$

  - The clue: calculate $d\sigma$ with a LO matrix element: $d\sigma \propto |\mathcal{M}|^2(m_t)$
  - Use Transfer Functions (TF) to map parton level quantities $\vec{y}_i$ to reco level quantities $\vec{x}_i$
  - Key advantage:
    - We are calculating the probability for an event to be consistent with a tt decay for a given m_{top}
      - 4-vectors with maximal topological information + correlations
    - This is the maximally possible use of the event information
      - → maximal statistical power

Top Mass in the Lepton+Jets Channel (I)

- Matrix Element method, D0 (3.6 fb^{-1})
- Extract m_{top} by maximising the likelihood for n events x_1…

$$\text{Likelihood} = \prod_{i=1}^{n} P_{\rm evt}(x_i; m_{\rm top}, JES, f_{\rm top})$$



(in reality, it's a 2D-fit: m_{top} vs JES)

- Define the total probability for each event (f_{top}=sig. frac'n)

$$P_{\rm evt}(x; m_{\rm top}, JES, f_{\rm top}) = f_{\rm top} \cdot P_{\rm sig}(x; m_{\rm top}, JES) + (1 - f_{\rm top}) \cdot P_{\rm bkg}(x; JES)$$

Top Mass in the Lepton+Jets Channel (I)

- The Matrix Element method in its full beauty:
  - The signal probability is the interesting bit!

LO Matrix element

$$P_{sig}(x; m_{\mathrm{top}}, JES) = \frac{1}{\sigma_{\mathrm{obs}}(p\bar{p} \to t\bar{t}; m_{\mathrm{top}}, JES)} \times \sum_{\mathrm{perm}} w_n \int_{q_1, q_2, y} \sum_{\mathrm{flavors}} dq_1 dq_2 f(q_1) f(q_2) \frac{(2\pi)^4 \left|\mathcal{M}(q\bar{q} \to t\bar{t} \to y)\right|^2}{2 q_1 q_2 s} d\Phi_6 W(x, y; JES)$$

Transfer Function

Permutation weight, b-tag based

  - (Background probability similar → but ME for W+jets, no m_{top} dependence!)

Top Mass in the Lepton+Jets Channel (I)

- The **Matrix Element** method in its full beauty:
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$$P_{sig}(x; m_{\text{top}}, JES) = \frac{1}{\sigma_{\text{obs}}(p\bar{p} \to t\bar{t}; m_{\text{top}}, JES)} \times \sum_{\text{perm}} w_n \int_{q_1,q_2,y} \sum_{\text{flavors}} dq_1 dq_2 f(q_1) f(q_2) \frac{(2\pi)^4 \left|\mathcal{M}(q\bar{q} \to t\bar{t} \to y)\right|^2}{2 q_1 q_2 s} d\Phi_6 W(x, y; JES)$$

LO Matrix element

pdfs

Bjoerken-x of incoming partons

Transfer Function

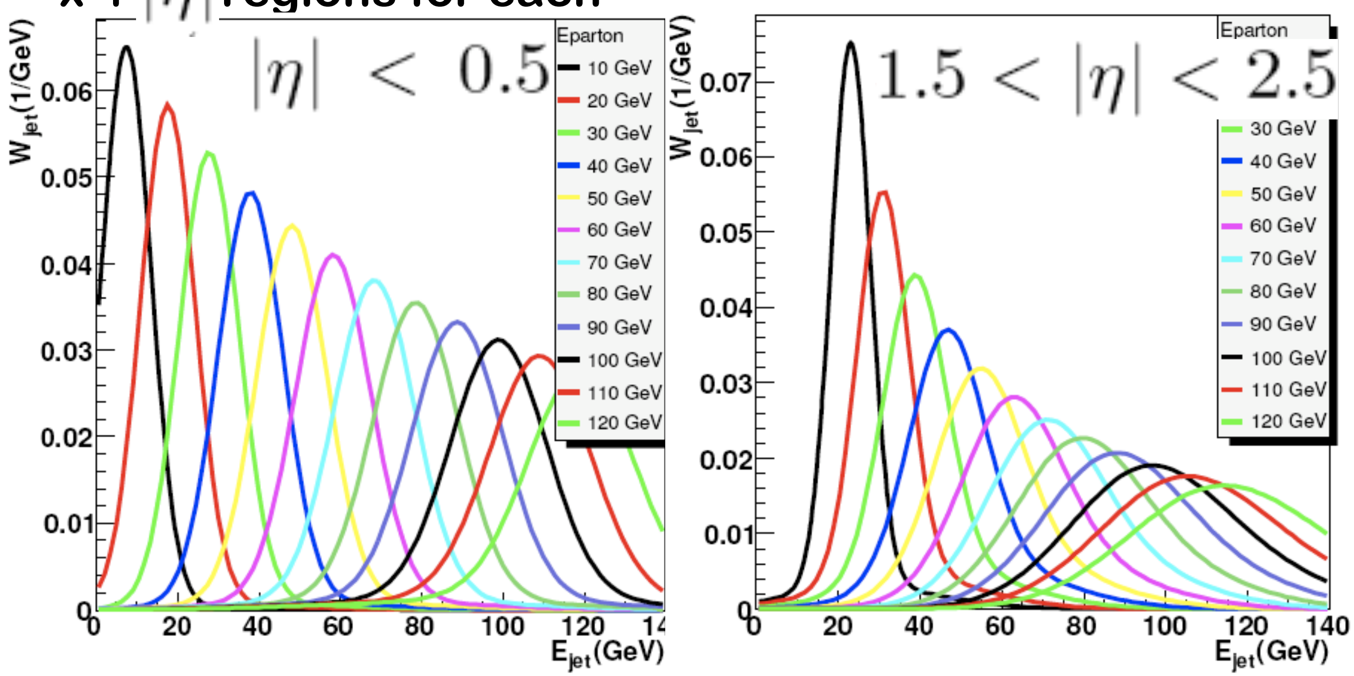
Differential phase space

Permutation weight, b-tag based

  - (Background probability similar
    → but ME for W+jets, no m_{top} dependence!)

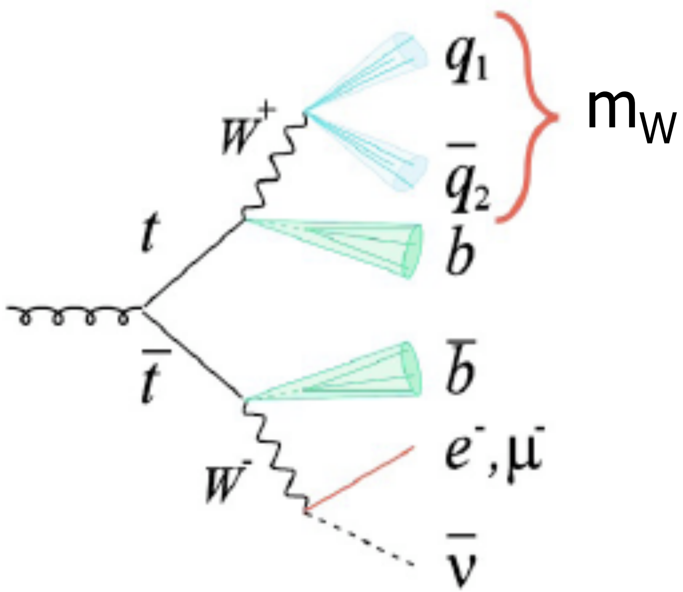
Top Mass in the Lepton+Jets Channel (I)

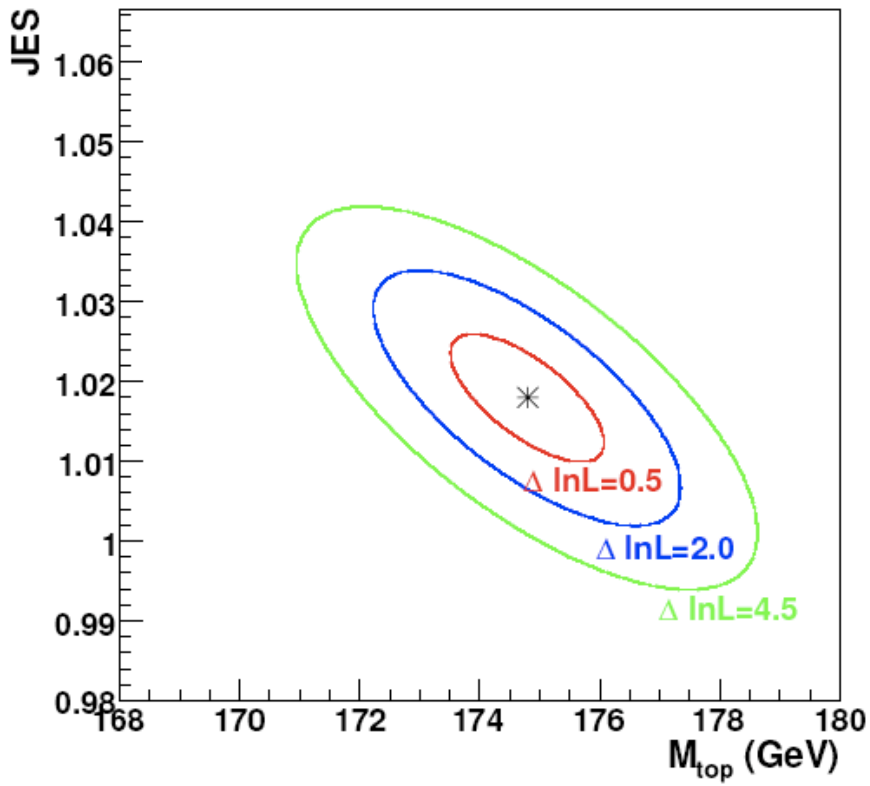
- The **Transfer Functions** $W(x, y; JES)$ relate parton-level quantities to reconstruction-level ones
  - By definition: normalised to unity
  - D0 uses a double-Gaussian to parametrise them
  - Treat separately:
    - Light / b-tagged jets with soft muon tag / other b-jets
    - x 4 $|\eta|$ regions for each



Top Mass in the Lepton+Jets Channel (I)

- Play **experimental trick**:
  - **Largest experimental uncertainty** is the **JES**
  - perform an **in-situ calibration of the JES**:
    - Constrain the two jets from W decay to m_W
    - This allows a simultaneous extraction of m_{top} and JES!

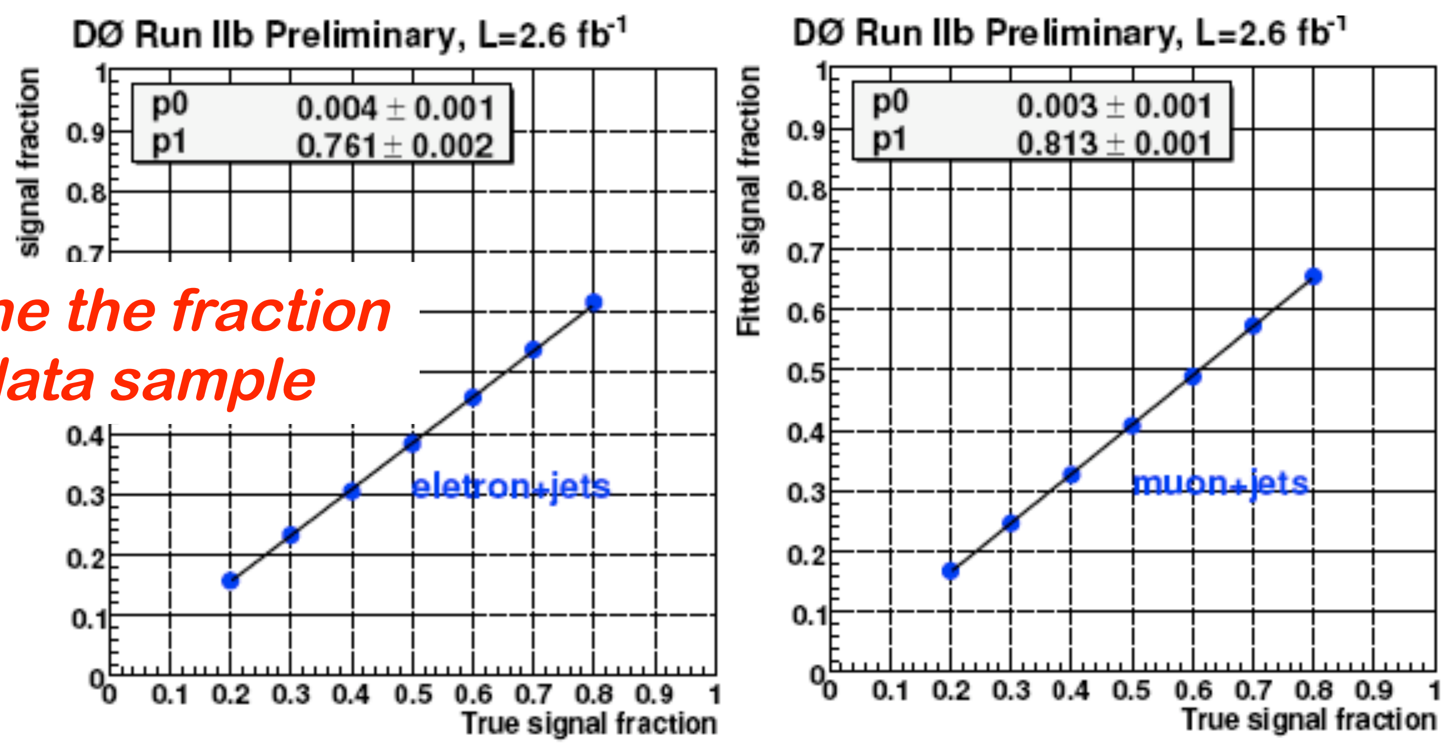




Top Mass in the Lepton+Jets Channel (I)

- Behold! We need to calibrate the method:
  - Is the extracted central value not biased?
  - Is the statistical uncertainty over/underestimated?
- Study this using pseudo-experiments:
  - Draw ensembles of pseudo-experiments from MC

Step 1: determine the fraction of signal f_{top} in data sample



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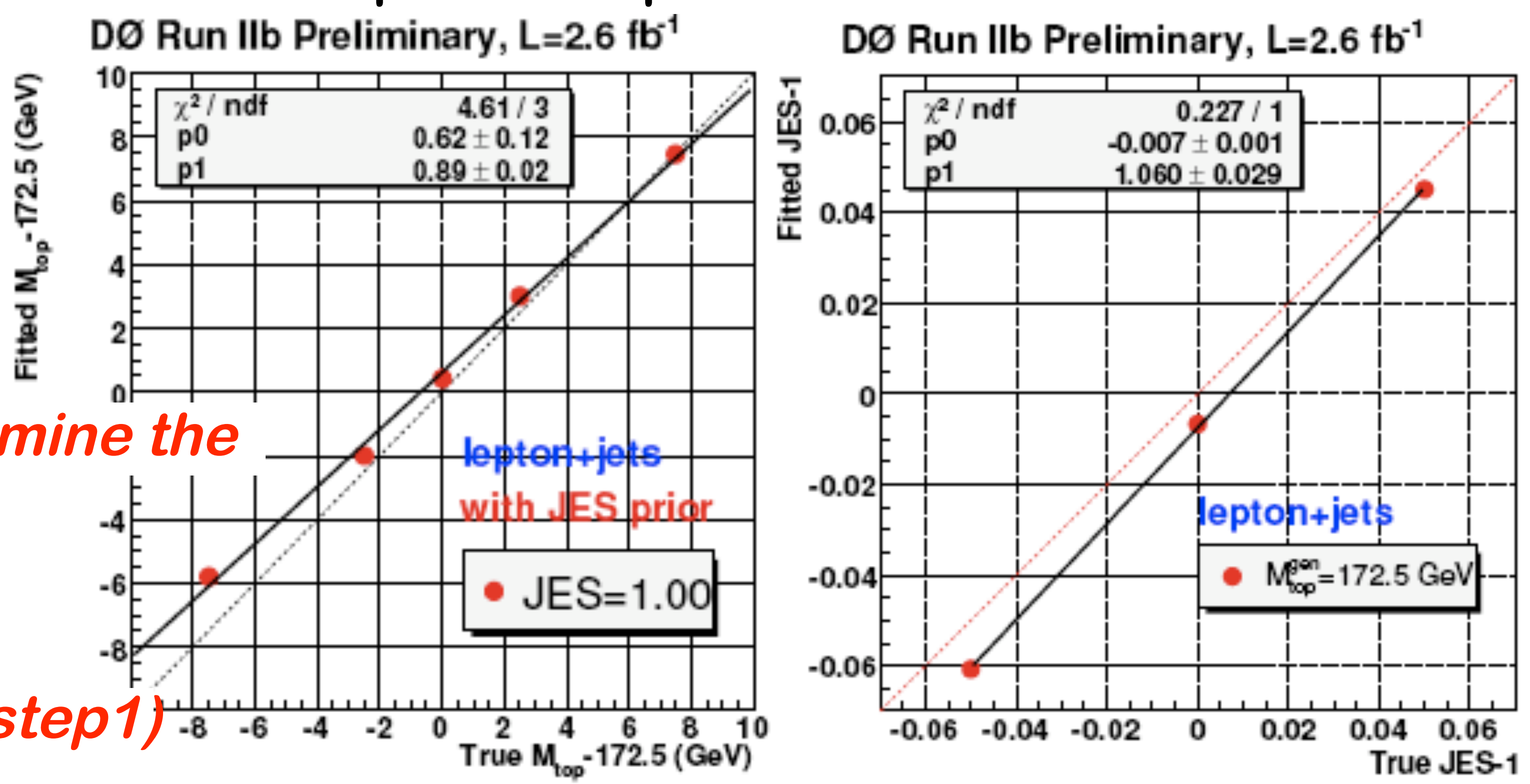
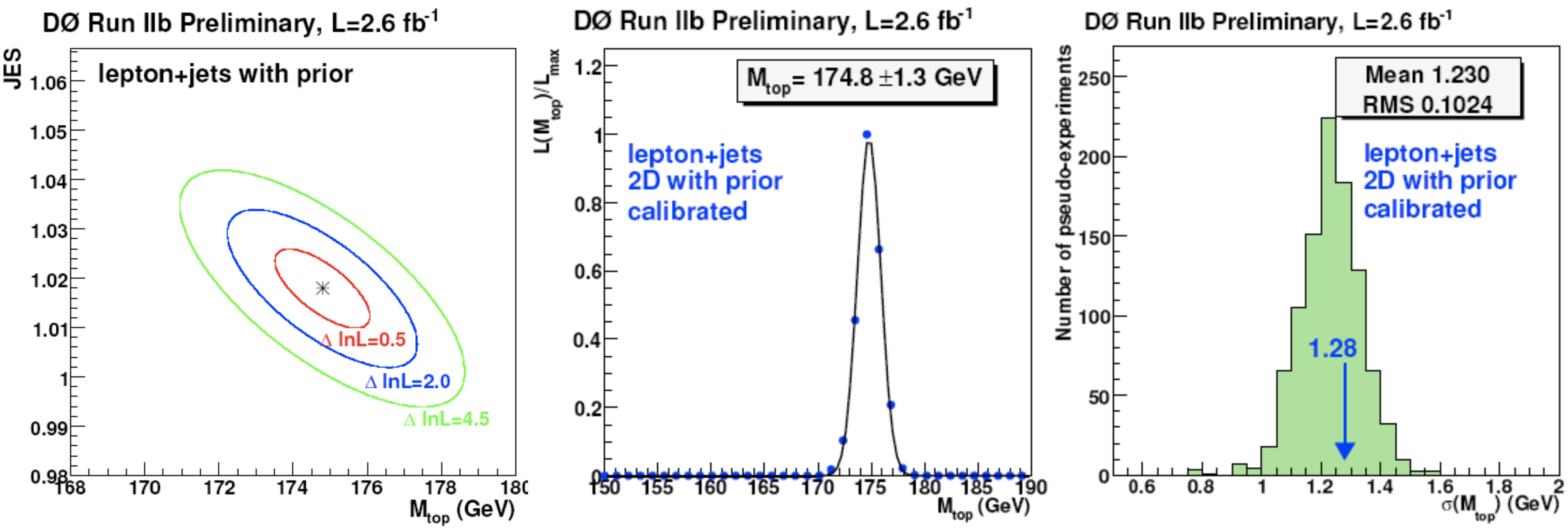


Step 2: determine the m_{top} and JES calibration + pull width (for f_{top} from step1)

Top Mass in the Lepton+Jets Channel (I)

- Final result (systematics dominated!)
  - Combined (3.6 fb^{-1}):

$$m_{top} = 173.748 \pm 0.83(\text{stat}) \pm 1.62(\text{syst}) = 173.7 \pm 1.8\,\text{GeV}$$



Top Mass in the Lepton+Jets Channel (I)

Systematics

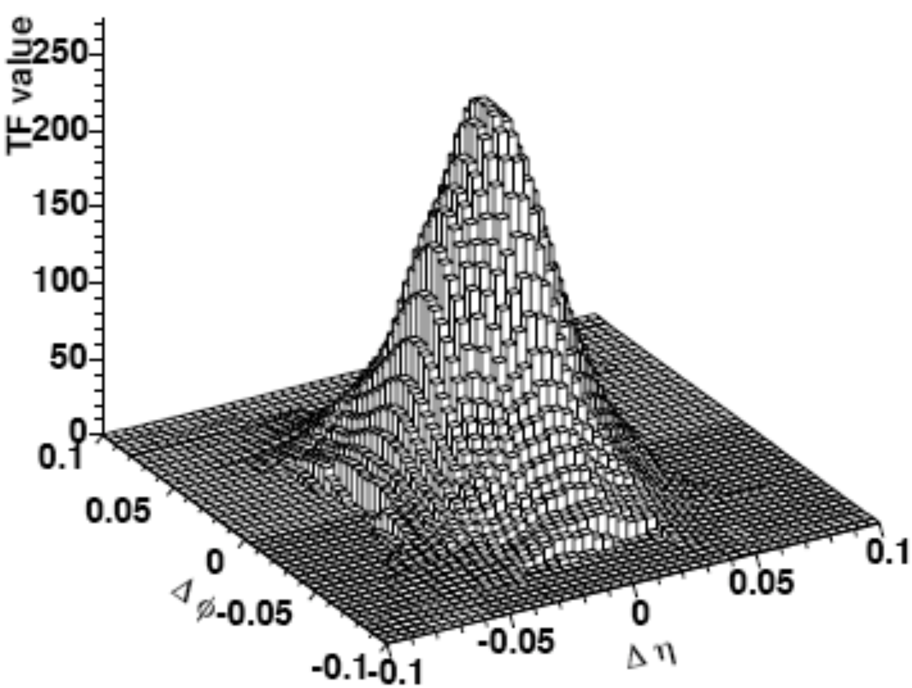
Source	Run IIb (GeV)	Run IIa (GeV)
Higher Order Effects	±0.25	±0.25
ISR/FSR	±0.26	±0.40
Hadronization and UE	±0.58	±0.58
Color Reconnection	±0.40	±0.40
Multiple Hadron Interactions	±0.07	±0.01
Background Modeling	±0.03	±0.04
W HF factor	±0.07	±0.09
b-Modeling	±0.09	±0.03
PDF Uncertainty	±0.24	±0.14
Residual JES Uncertainty	±0.21	±0.10
Relative b/Light Response	±0.81	±0.83
Sample-Dependent JES	±0.56	±0.56
b-Tagging Efficiency	±0.08	±0.15
Trigger Efficiency	±0.01	±0.19
Lepton Momentum Scale	±0.17	±0.17
Jet Identification Efficiency	±0.26	±0.26
Jet Energy Resolution	±0.32	±0.03
QCD Background	±0.14	±0.14
Signal Fraction	±0.10	±0.09
Muon Resolution	-	±0.10
Signal Contamination	-	±0.13
MC Calibration	±0.20	±0.26
Total	±1.41	±1.43

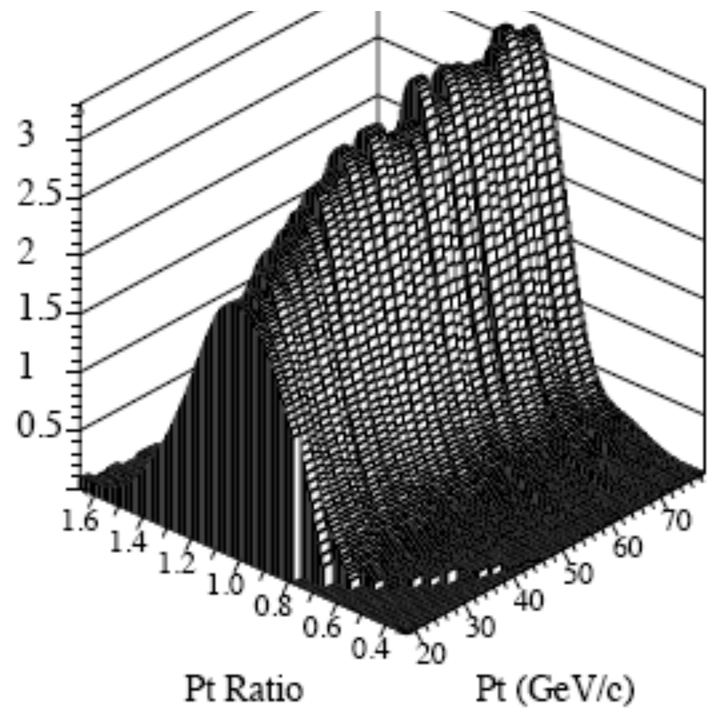
(will revisit later)

Top Mass in the Lepton+Jets Channel (II)

- **Matrix Element Method, 4.8 fb^{-1}, CDF**
  - Conceptually fairly similar to the D0 measurement
  - Focus only on the major differences in the following
- **More integration variables ("quasi-MC integration"):**
  - Not only energies, but also η x ϕ for jets (small effect)
  - TRFs are not fitted

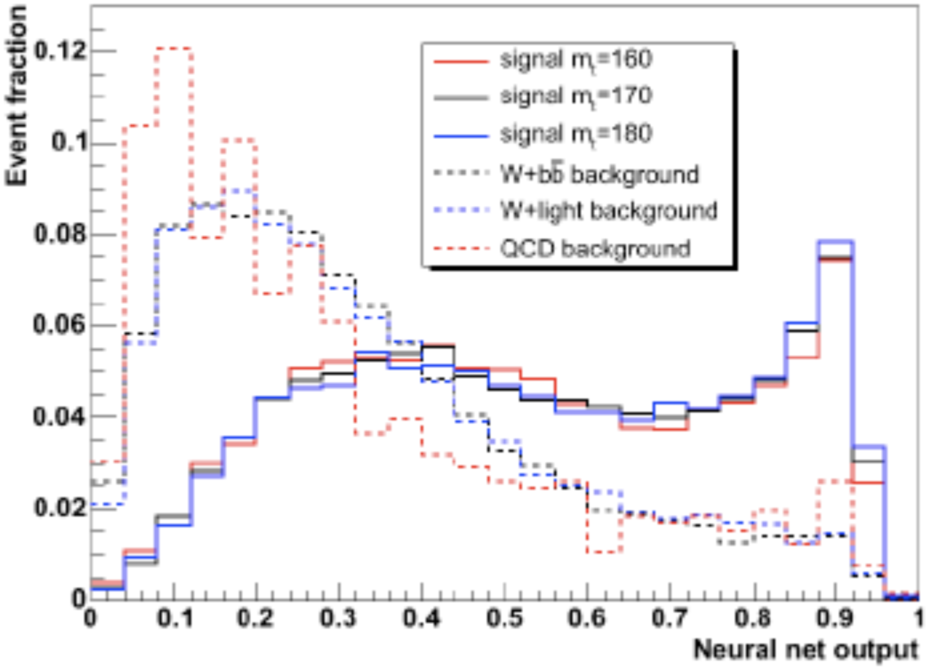
Light quark angular transfer function, η = 0, m = 5





Top Mass in the Lepton+Jets Channel (II)

- **Background fitting is done using a NN selection:**



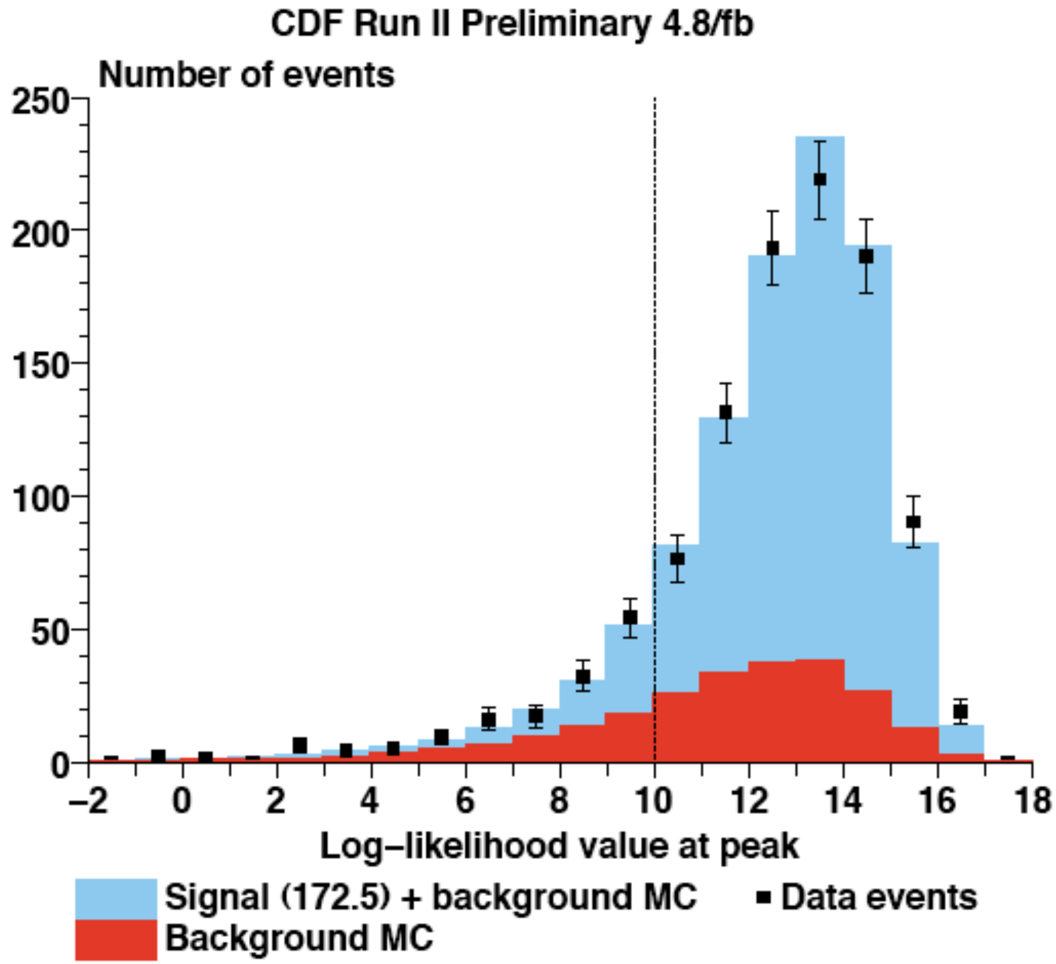
Trained for m_{top}=170 GeV and Wbb

Careful check for any m_{top} dependence!

- **Form total likelihood by subtracting average background likelihood scaled by f_{bkg} for the NN value of that event**

Top Mass in the Lepton+Jets Channel (II)

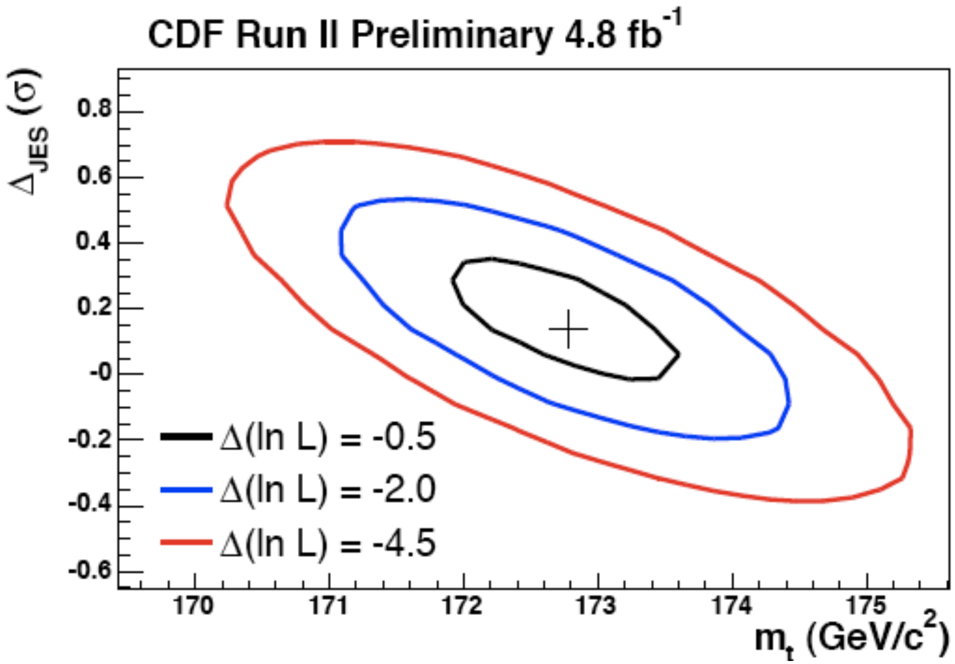
- For a notable fraction of signal events (~30%):
  - One of the physics objects does not correspond to truth
  - Remove those misreconstructed events:
    - Require minimum LH value at peak
    - ~80% efficient
    - (~96% for good)
    - (~70% for bgr.)

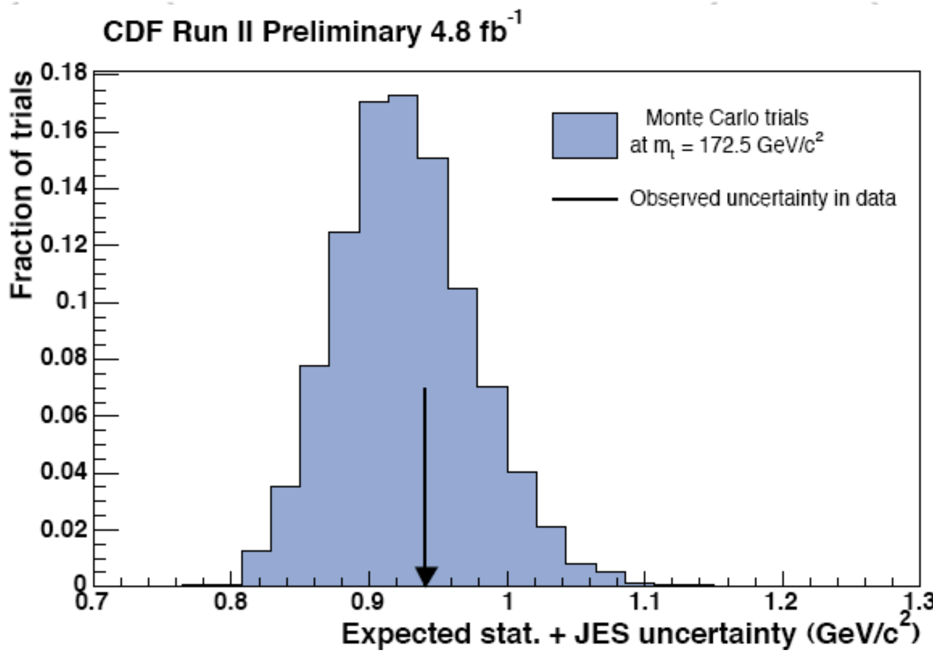


Top Mass in the Lepton+Jets Channel (II)

- **CDF obtains:**

$$m_t = 172.8 \pm 0.7\ (\text{stat.}) \pm 0.6\ (\text{JES}) \pm 0.8\ (\text{syst.})\ \text{GeV}/c^2$$





- **World's most precise m_{top} measurement!**
- **Similar statistical uncertainty to the D0 measurement**

Top Mass in the Lepton+Jets Channel (II)

Systematics

Systematic source	Systematic uncertainty (GeV/c^2)
Calibration	0.11
MC generator	0.25
ISR and FSR	0.15
Residual JES	0.49
b-JES	0.26
Lepton P_T	0.14
Multiple hadron interactions	0.10
PDFs	0.14
Background modeling	0.33
Gluon fraction	0.03
Color reconnection	0.37
Total	0.84

(will revisit later)

Top Mass In the All-Hadronic Channel

- Template method, CDF (2.9 fb-1):
  - Highly challenging due to immense QCD background!
  - Consider final states with $6 \leq N_{\text{jets}} \leq 8$
    - After multijet trigger req't: 1.4 x 10^7 events, S:B ~ 1:1200
    - After offline preselection: 1.7 x 10^6 events, S:B ~ 1:430

Top Mass In the All-Hadronic Channel

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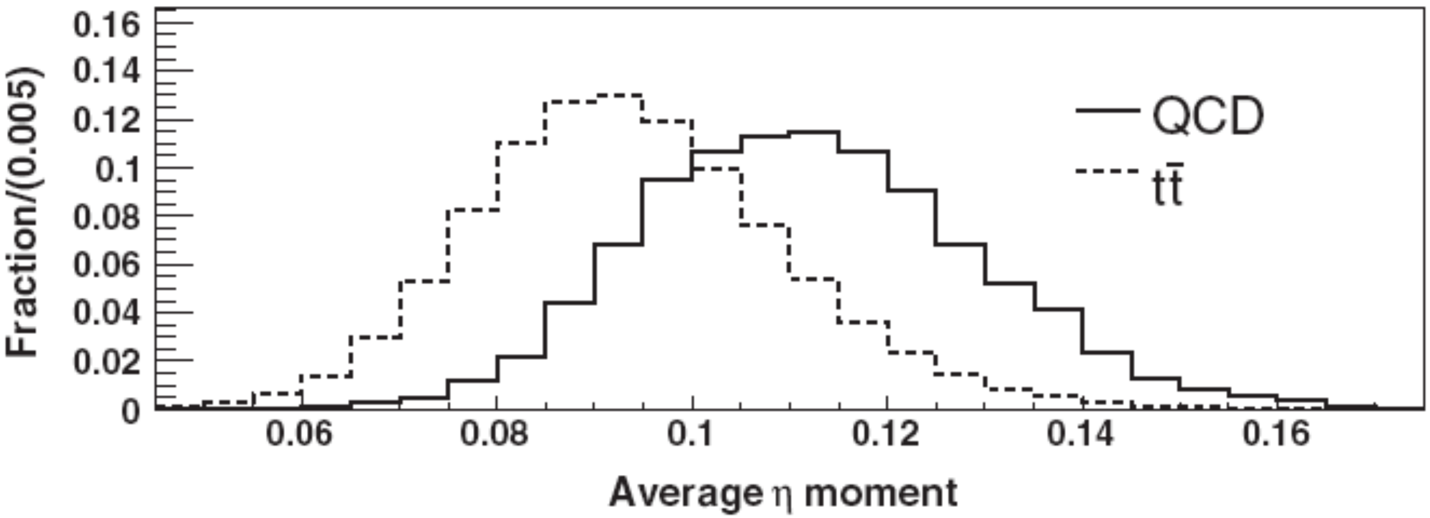
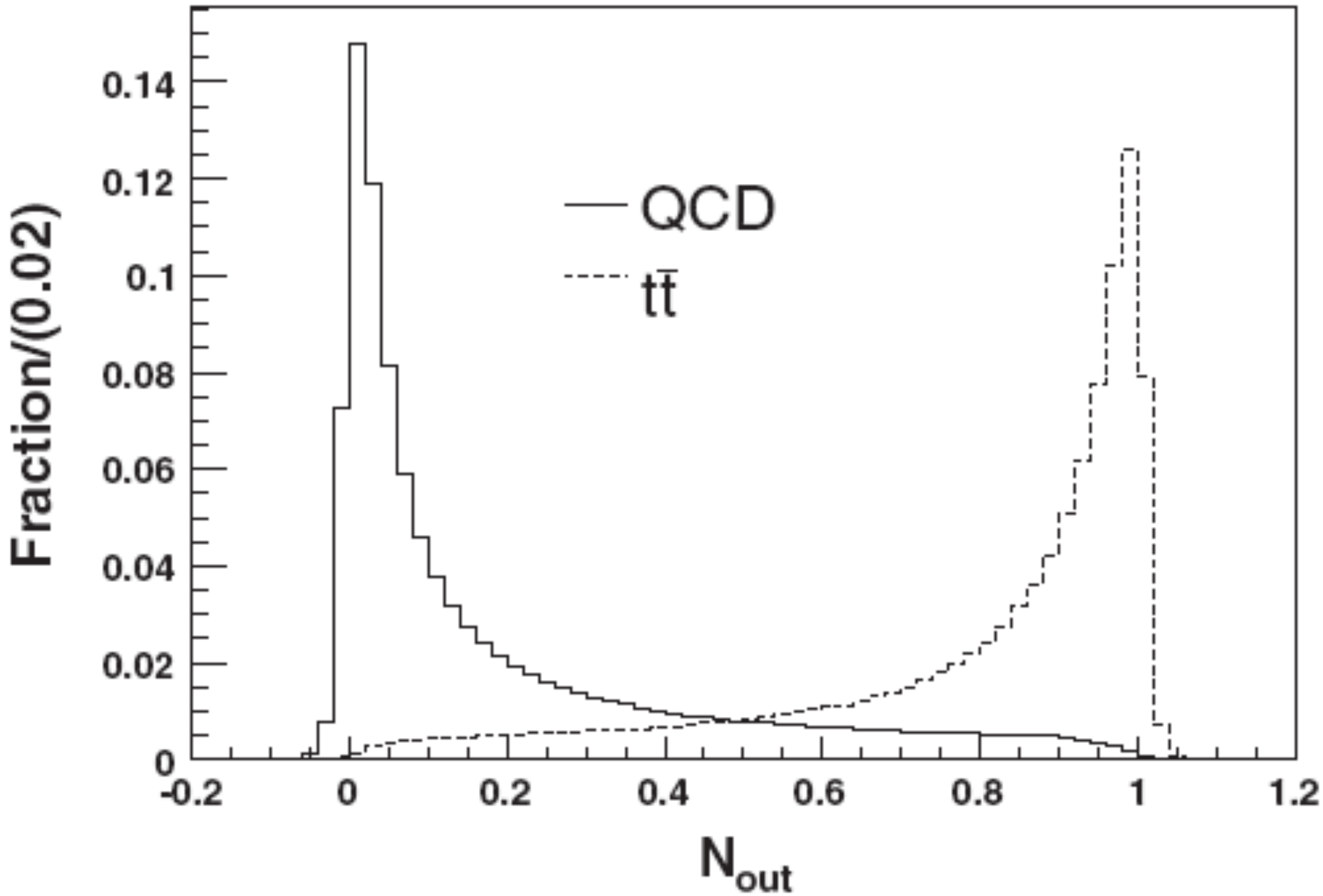
    - After multijet trigger req't: 1.4 x 10^7 events, S:B ~ 1:1200
    - After offline preselection: 1.7 x 10^6 events, S:B ~ 1:430
  - Use multilayered NN (MLPFIT) with inputs:
    - "traditional" selection variables like $\sum E_T, M_{3j}^{\rm min}, M_{3j}^{\rm max}$...
    - specific variables, e.g. 2^{nd} moments of jets in η and ϕ
      - Good discrimination between quark and gluon jets:



Top Mass In the All-Hadronic Channel

- **Powerful tool constructed:**



- **Define control region $N_{out} < 0.25$**
  - **Derive corrections for tag rate (correl'ns for multiple tags)**

Top Mass In the All-Hadronic Channel

- Use b-tagging to refine S:B and improve combinatorics:
  - 30 jet-parton assignments with 1 b-tag
  - 6 assignments with 2 b-tags
- For each assignment minimise:

$$\chi^2 = \frac{(m_{jj}^{(1)} - M_W)^2}{\Gamma_W^2} + \frac{(m_{jj}^{(2)} - M_W)^2}{\Gamma_W^2}$$

Double m_W constraint for JES

$$+ \frac{(m_{jjb}^{(1)} - m_t^{\mathrm{rec}})^2}{\Gamma_t^2} + \frac{(m_{jjb}^{(2)} - m_t^{\mathrm{rec}})^2}{\Gamma_t^2}$$

Constraint on m_{top}

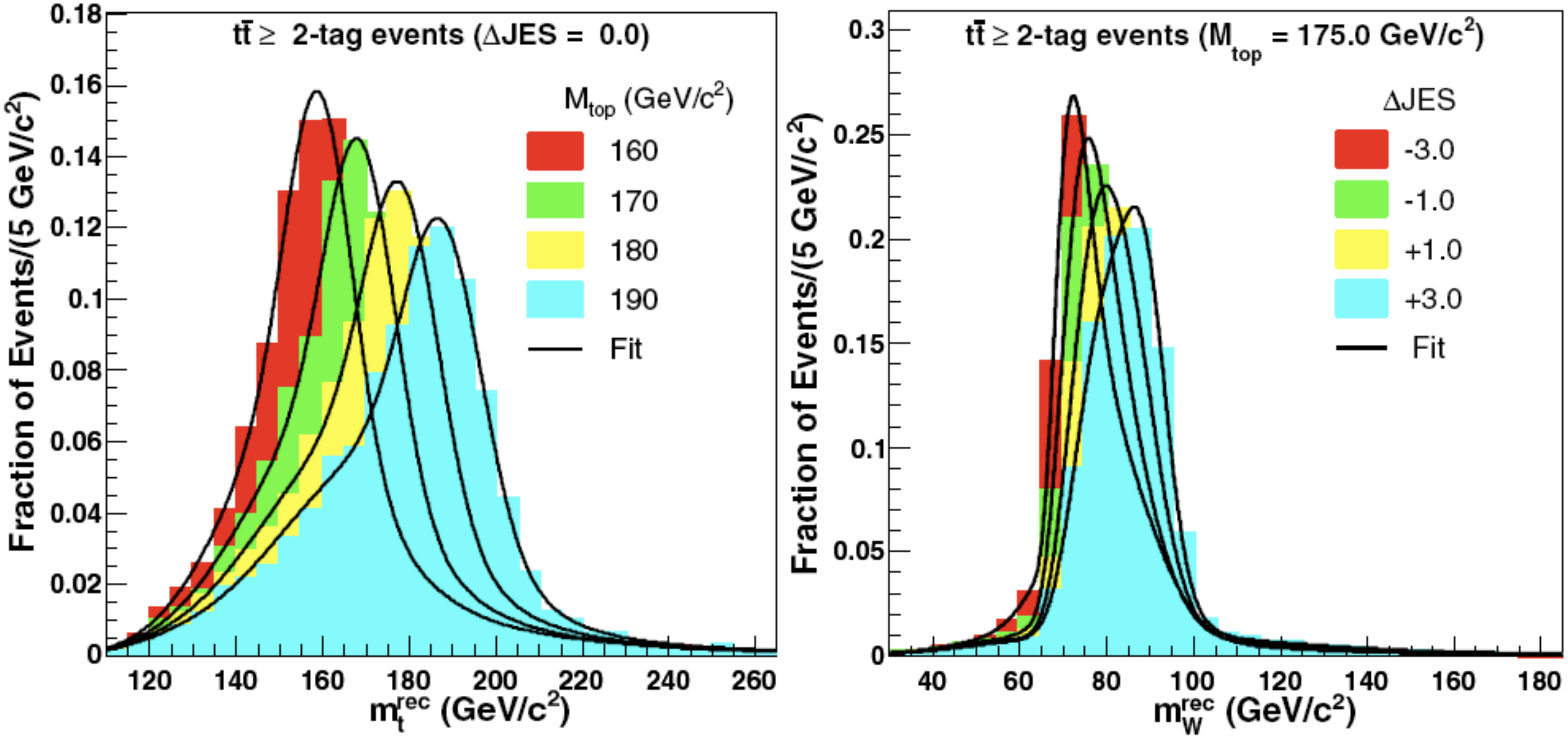
$$+ \sum_{i=1}^{6} \frac{(p_{T,i}^{\mathrm{fit}} - p_{T,i}^{\mathrm{meas}})^2}{\sigma_i^2}$$

Consistence of fitted 4-momenta with measured ones

- Pick assignment with minimal χ^2
- Now we are able to reconstruct m_{top} and m_W!

Top Mass In the All-Hadronic Channel

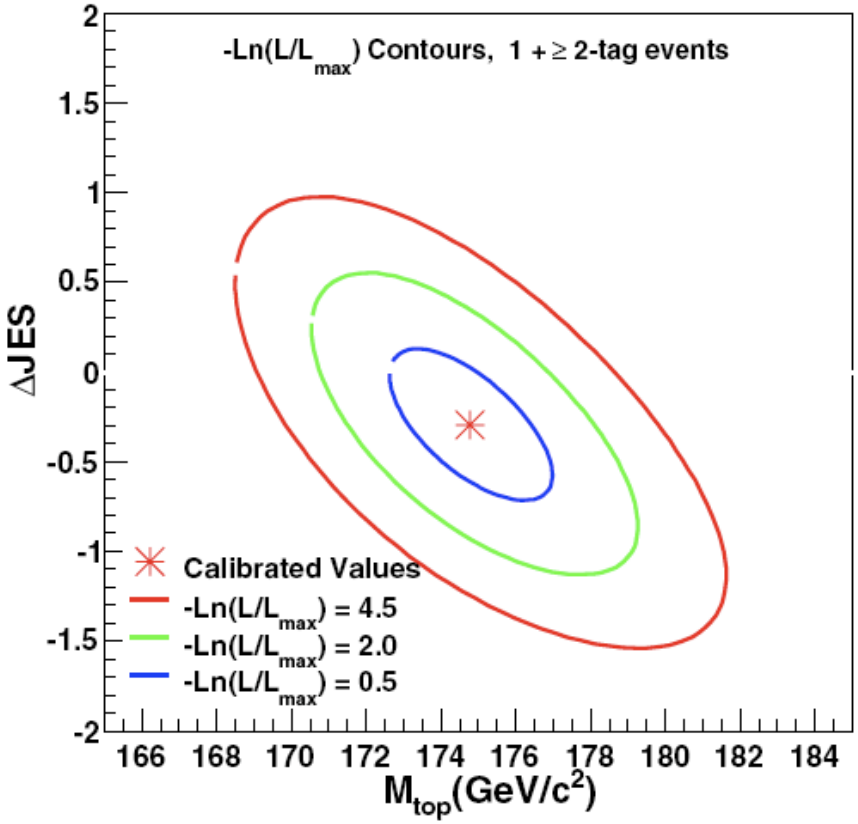
- Select events for the measurement:
  - With $N_{out} > 0.90$ and $\chi^2 < 6$ for 1 b-tag (S:B ~ 1:4)
  - With $N_{out} > 0.88$ and $\chi^2 < 5$ for 2+ b-tags (S:B ~ 1:1)
- **Maximise binned likelihood** for (+ tons of crosschecks):
  - m_{top}, m_W, n_{signal} events, $n_{background}$ events (+ Xsec meas't)

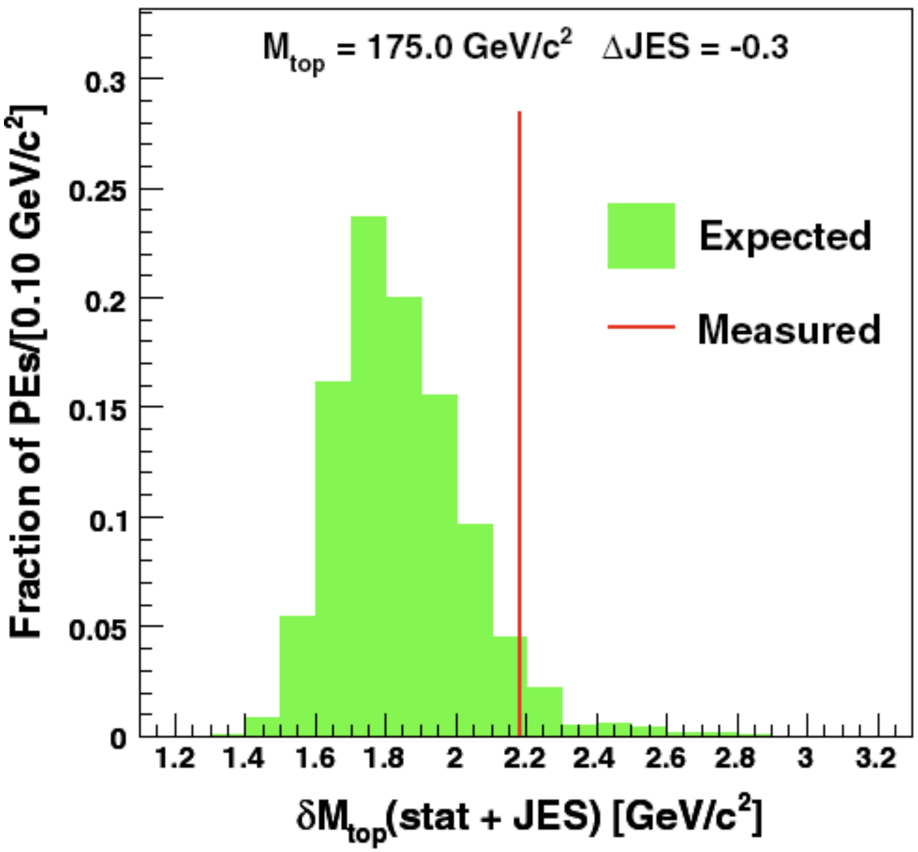


Top Mass In the All-Hadronic Channel

- After calibration with ensemble testing techniques:

$$M_{top} = 174.8 \pm 1.7(\text{stat}) \pm 1.6(\text{JES})\,^{+1.2}_{-1.0}(\text{syst})\ \text{GeV}/c^2$$

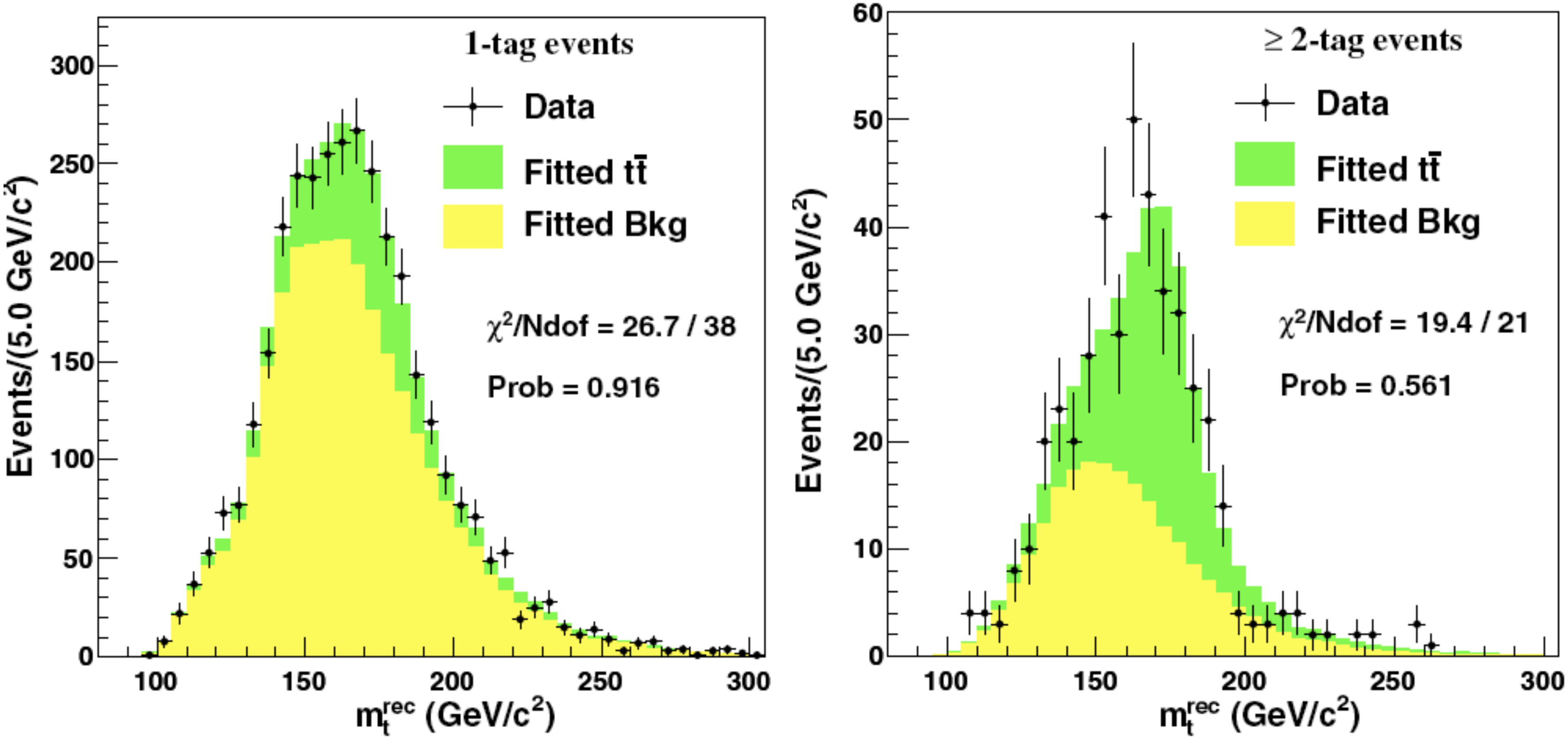




- **Strongest contribution to world average after l+jets!**

Top Mass In the All-Hadronic Channel

- Overall crosscheck looks good:



- Extract top cross section of:

$$\sigma_{t\bar{t}} = 7.2 \pm 0.5(\mathrm{stat}) \pm 0.4(\mathrm{lum})\ \mathrm{pb}$$

  - (For $M_{top} = 175\ \mathrm{GeV}/c^2 \quad \Delta\mathrm{JES} = -0.3$)

Top Mass In the All-Hadronic Channel

Systematics

Source	δM_{top}^{syst} (GeV/c^2)	$\delta \Delta JES^{syst}$
Residual bias	$^{+0.8}_{-0.4}$	$^{+0.18}_{-0.24}$
2D calibration	<0.1	<0.01
Generator	0.3	0.25
ISR/FSR	0.1	0.06
b-jet energy scale	0.2	0.04
b-tag SF E_T dependence	0.1	0.01
Residual JES	0.5	···
PDF	$^{+0.3}_{-0.2}$	$^{+0.05}_{-0.04}$
Multiple $p\bar{p}$ interactions	0.2	0.01
Color reconnection	0.4	0.08
Statistics of templates	0.3	0.07
Background shape	0.1	0.02
Total	$^{+1.2}_{-1.0}$	$^{+0.34}_{-0.37}$

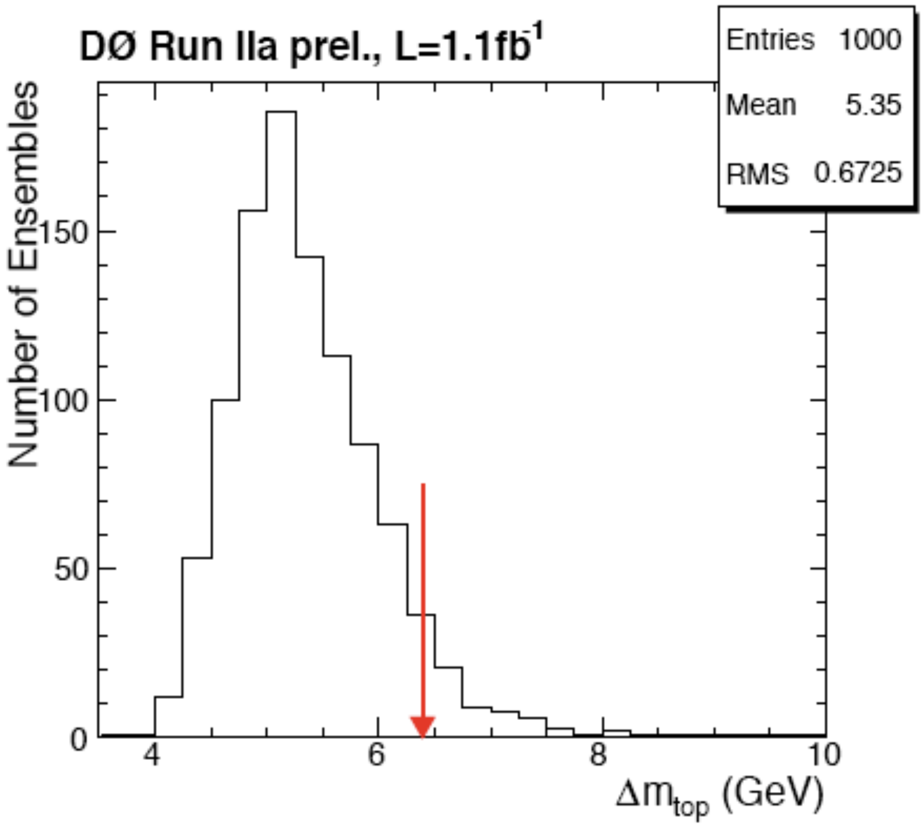
Top Mass in the Dilepton Channel

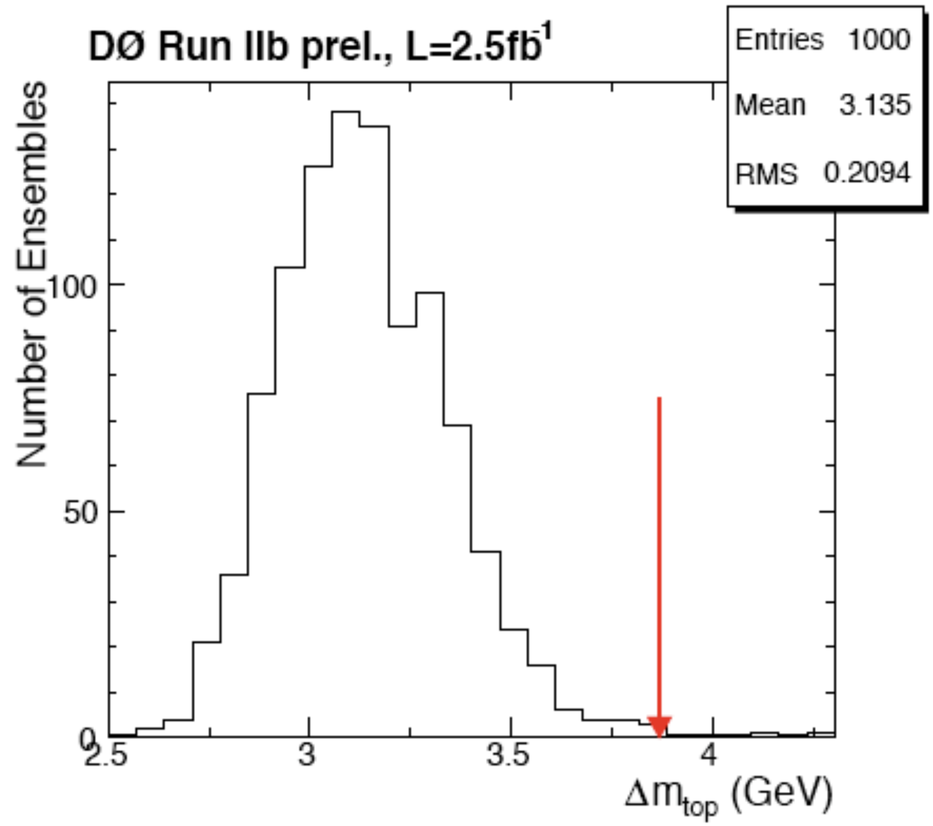
- **Matrix Element method, D0 (3.6 fb^{-1})**
  - **Similar approach to l+jets channel**
  - **However, the kinematics is not overconstrained**
  - **Cannot fit for JES simultaneously**
  - **D0 obtains (ll for Run IIa, emu for Run IIb):**

$$m_{\mathrm{top}}^{\ell\ell} = 174.7 \pm 2.9\,(\mathrm{stat.}) \pm 2.4\,(\mathrm{sys.})\,\mathrm{GeV}$$

Top Mass in the Dilepton Channel

- **D0 was rather unlucky with its data:**





Tevatron Top Mass Combination

- **Lepton + jets mass measurements dominate world average**

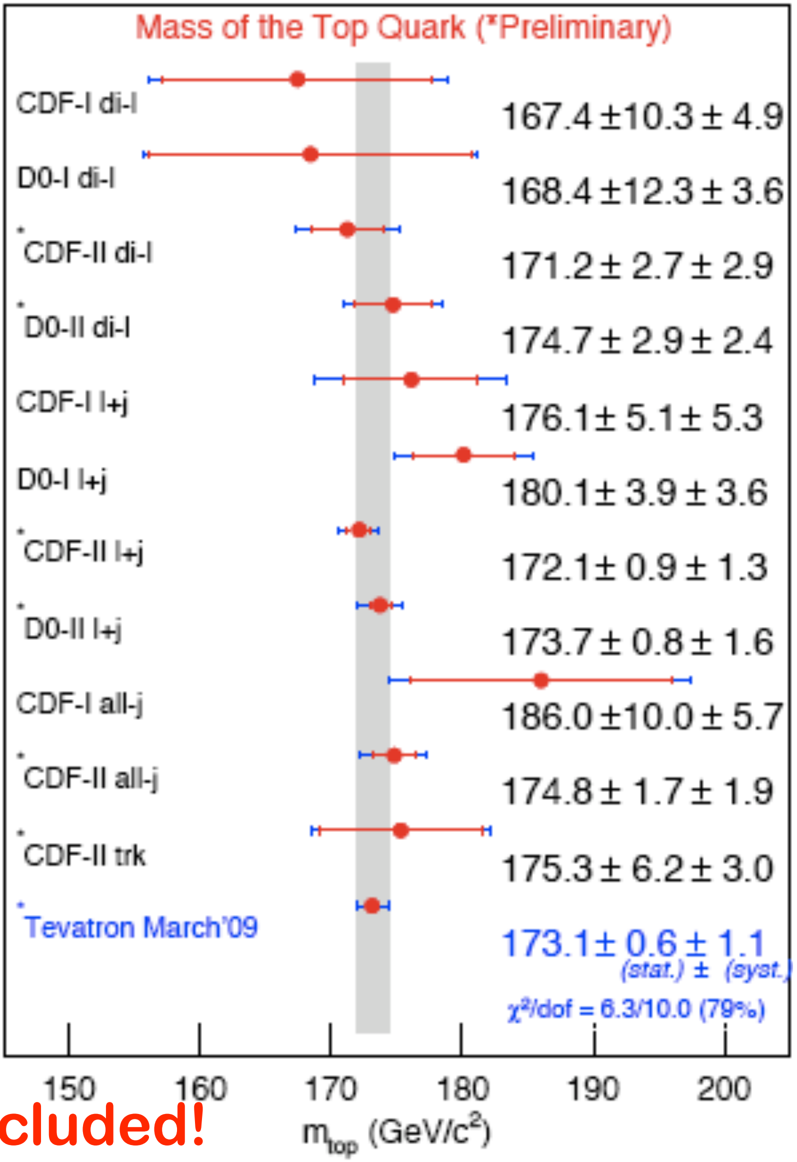
Parameter	Value (GeV/c^2)	Correlations		
M_t^{all-j}	175.1 ± 2.6	1.00		
M_t^{l+j}	172.7 ± 1.3	0.20	1.00	
M_t^{di-l}	171.4 ± 2.7	0.19	0.50	1.00

- **Results are consistent**
  - (χ^2 probability = 76%)
- **World average:**

$$M_t = 173.1 \pm 0.6 \text{ (stat.)} \pm 1.1 \text{ (syst.) GeV}/c^2$$

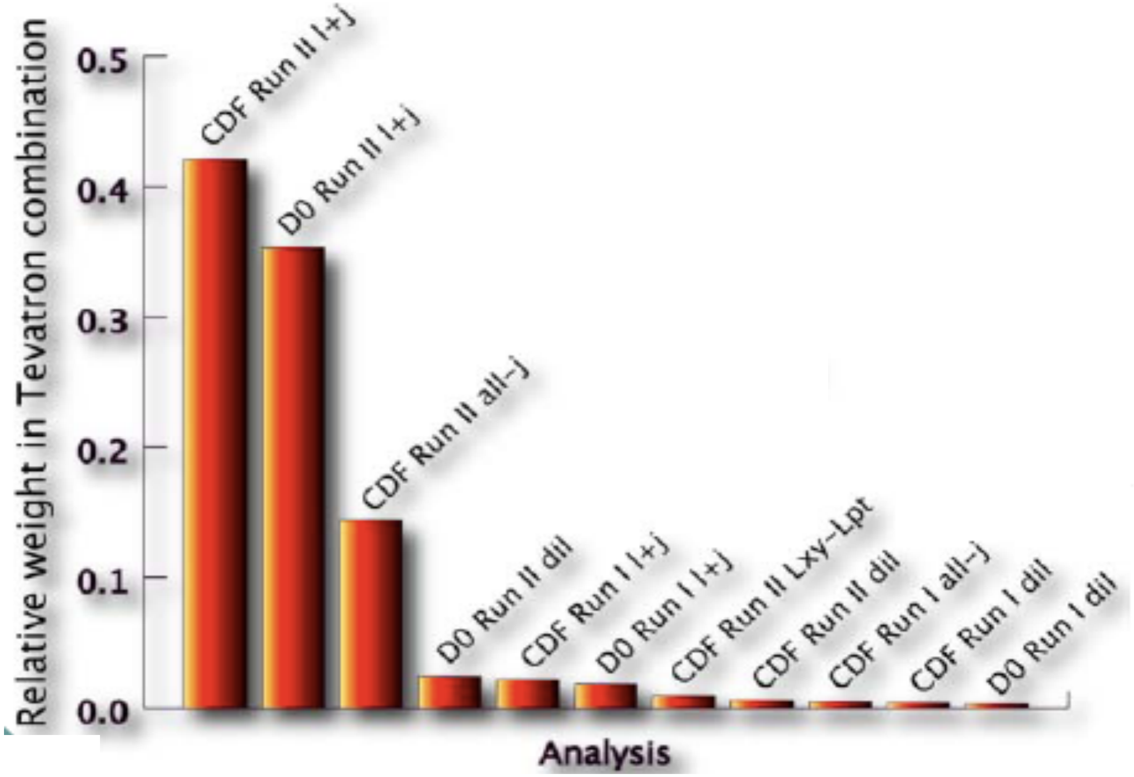
$$M_t = 173.1 \pm 1.3 \text{ GeV}/c^2$$

  - Top mass known to 0.75% prec'n
  - Approaching 1 GeV!
- **World's most precise meas't NOT included!**



Tevatron Top Mass Combination

	Run I published					Run II preliminary					
	CDF			DØ		CDF				DØ	
	l+j	di-l	all-j	l+j	di-l	l+j	di-l	all-j	trk	l+j	di-l
Pull	+0.4	−0.5	+1.1	+1.4	−0.4	−0.9	−0.5	+0.7	+0.3	0.5	+0.4
Weight [%]	−2.4	−0.5	−0.6	+2.0	+0.3	+47.4	+0.7	+16.2	−0.1	+39.8	−2.7



Top Quark Mass Systematics

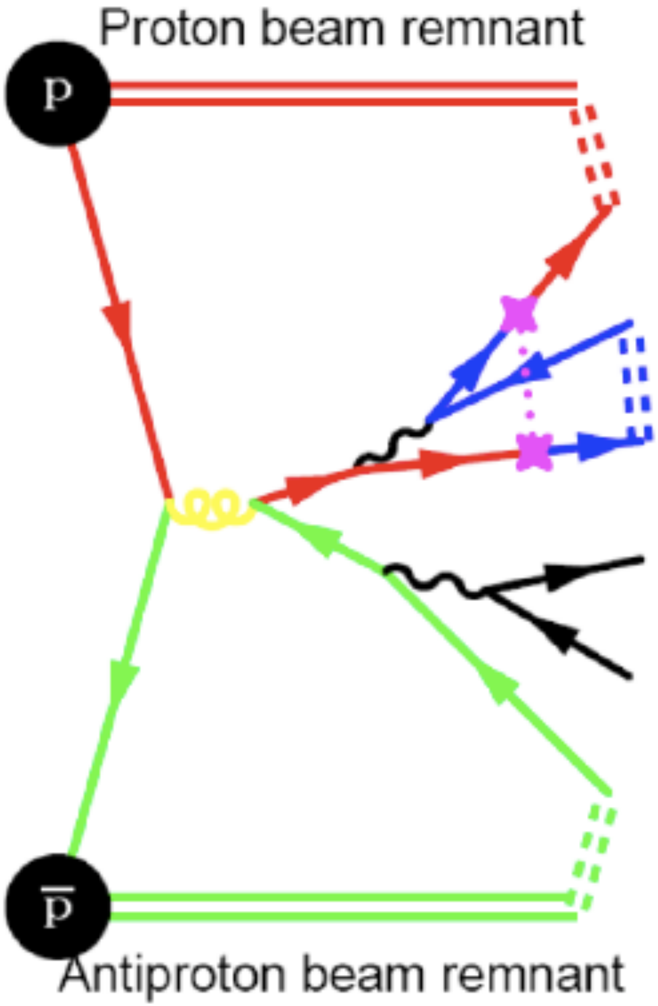
Source	Run IIb (GeV)	Run IIa (GeV)
Higher Order Effects	±0.25	±0.25
ISR/FSR	±0.26	±0.40
Hadronization and UE	±0.58	±0.58
Color Reconnection	±0.40	±0.40
Multiple Hadron Interactions	±0.07	±0.01
Background Modeling	±0.03	±0.04
W HF factor	±0.07	±0.09
b-Modeling	±0.09	±0.03
PDF Uncertainty	±0.24	±0.14
Residual JES Uncertainty	±0.21	±0.10
Relative b/Light Response	±0.81	±0.83
Sample-Dependent JES	±0.56	±0.56
b-Tagging Efficiency	±0.08	±0.15
Trigger Efficiency	±0.01	±0.19
Lepton Momentum Scale	±0.17	±0.17
Jet Identification Efficiency	±0.26	±0.26
Jet Energy Resolution	±0.32	±0.03
QCD Background	±0.14	±0.14
Signal Fraction	±0.10	±0.09
Muon Resolution	-	±0.10
Signal Contamination	-	±0.13
MC Calibration	±0.20	±0.26
Total	±1.41	±1.43

Discuss most significant systematic uncertainties for ME analyses in l+jets in the following…

Systematic source	Systematic uncertainty (GeV/c^2)
Calibration	0.11
MC generator	0.25
ISR and FSR	0.15
Residual JES	0.49
b-JES	0.26
Lepton P_T	0.14
Multiple hadron interactions	0.10
PDFs	0.14
Background modeling	0.33
Gluon fraction	0.03
Color reconnection	0.37
Total	0.84

Systematics: Colour Reconnection

- **Colour reconnection is a recent addition**
  - See paper by P. Skands and D. Wicke [arXiv:0807.3248]
  - Hadronisation regions of jets from W and b decay can overlap:
    - Possible effect on m_{top} due to colour reconnection
  - Evaluate by comparing signal with colour reconnection on/off
  - Systematic about 0.4 GeV
    - Both D0 and CDF



Systematics: ISR / FSR

- Initial and final state radiation (ISR/FSR) may bias the top mass measurement
  - It is partly the source for “misreconstructed” events
- ISR and FSR can be separated in Drell-Yan processes
- CDF did a study to determine the amount of ISR / FSR (CDF note 6804)
  - Derived Pythia tunes with amount of ISR is central +/- Δ
  - Evaluate systematics as the difference of m_{top} for those
  - Both D0 and CDF obtain a systematic of a similar magnitude
    - Likely to be larger at the LHC

Systematics: Hadronisation and UE

- Pythia and Herwig have different models for
  - Hadronisation
  - Underlying Event (UE)
- In general: rerun MC with Pythia and Herwig showering
- D0:
  - "Hadronisation and UE":
    - Compare alpgen signal samples
      - Hadronised with Pythia
      - Hadronised with Herwig
- CDF:
  - "MC Generator":
    - Compare:
      - Pythia signal samples hadronised with Pythia
      - Herwig signal samples hadronised with Herwig

Systematics: Residual JES

- Besides the global JES factor (which is fitted) there could remain a JES dependence differential in η x ϕ
  - The JES corrections are parametrised in η x ϕ
  - Scale the individual jet energies by the uncertainty sqrt(data^2 + MC^2)(η,ϕ) on the JES parametrisation
  - Preserve overall correction magnitude
    - Only differential changes "simulated"
- D0:
  - "Residual JES Uncertainty"
- CDF:
  - "Residual JES"

Systematics: b-jet JES

- The JES of light quark jets and heavy flavour jets does not need to be the same
  - For b-jets the response may be different:
    - higher mass → out of cone corrections different?
    - Shower particle composition different
    - escaping neutrinos
- D0:
  - “Relative b/light response”
- CDF:
  - “bJES”

  - *N.B.: in CDF’s bJES also the b-jet fragmentation is included (in the table on slide 38)*

Systematics: Sample-dependent JES

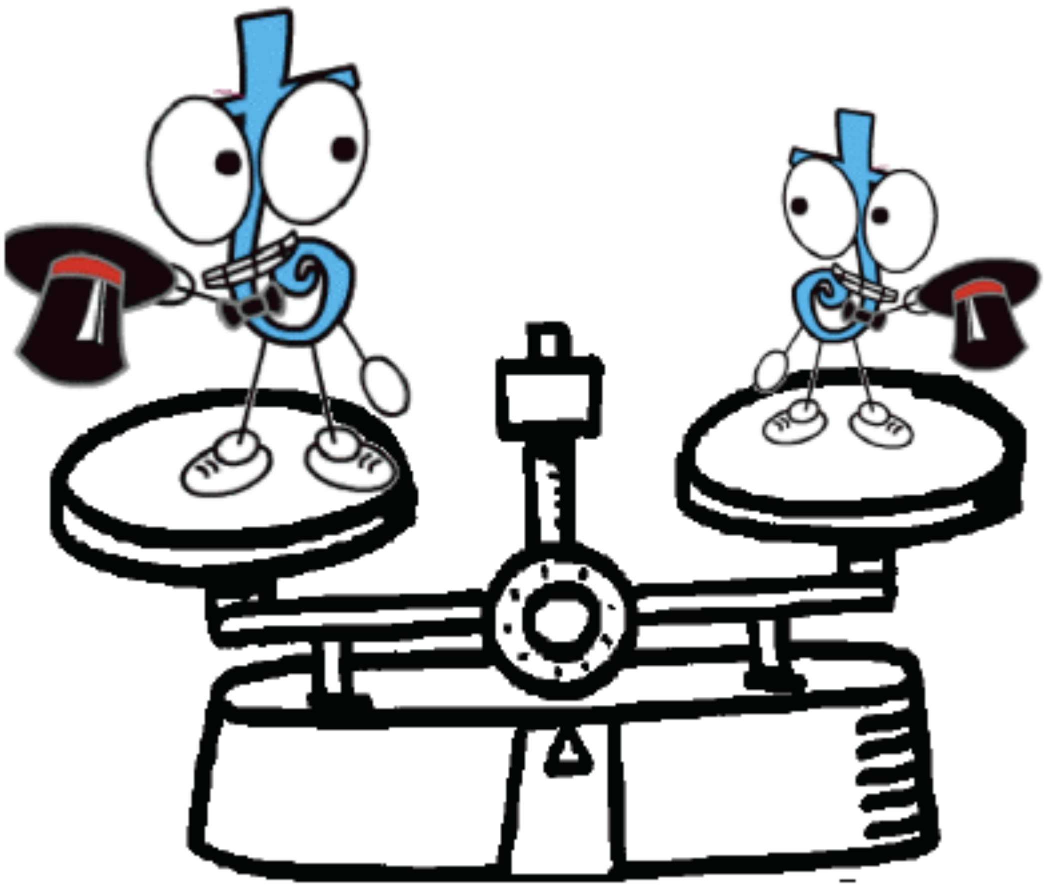
- The JES does not need to be the same for jets from light quarks and gluons
  - JES corr's derived in a sample dominated by quark jets
  - In signal MC: predominantly quark jets
  - In W+jets background: predominantly gluon jets
  - Systematic: evaluate m_{top} with background sample JES shifted or not
- Currently, only D0 evaluates this systematic (AFAIK)
  - Magnitude: 0.56 GeV
  - However, we have indications that the current evaluation scheme is somewhat pessimistic
  - Stay tuned…

Summary

- The top quark mass is a very intriguing SM parameter!
- The Tevatron and its experiments are in a great shape
- We keep refining the precision of our top quark mass measurements!
  - Most precise measurements with the Matrix Element method in the l+jets channel
  - Followed by the all-hadronic channel + the Template Method
  - Notable contribution from the dilepton channel
  - Interesting alternative methods on the market *(not shown)*
- Our measurements are systematically limited since years
  - Lots of work went into the understanding the systematics
  - And unifying their treatment across experiments!

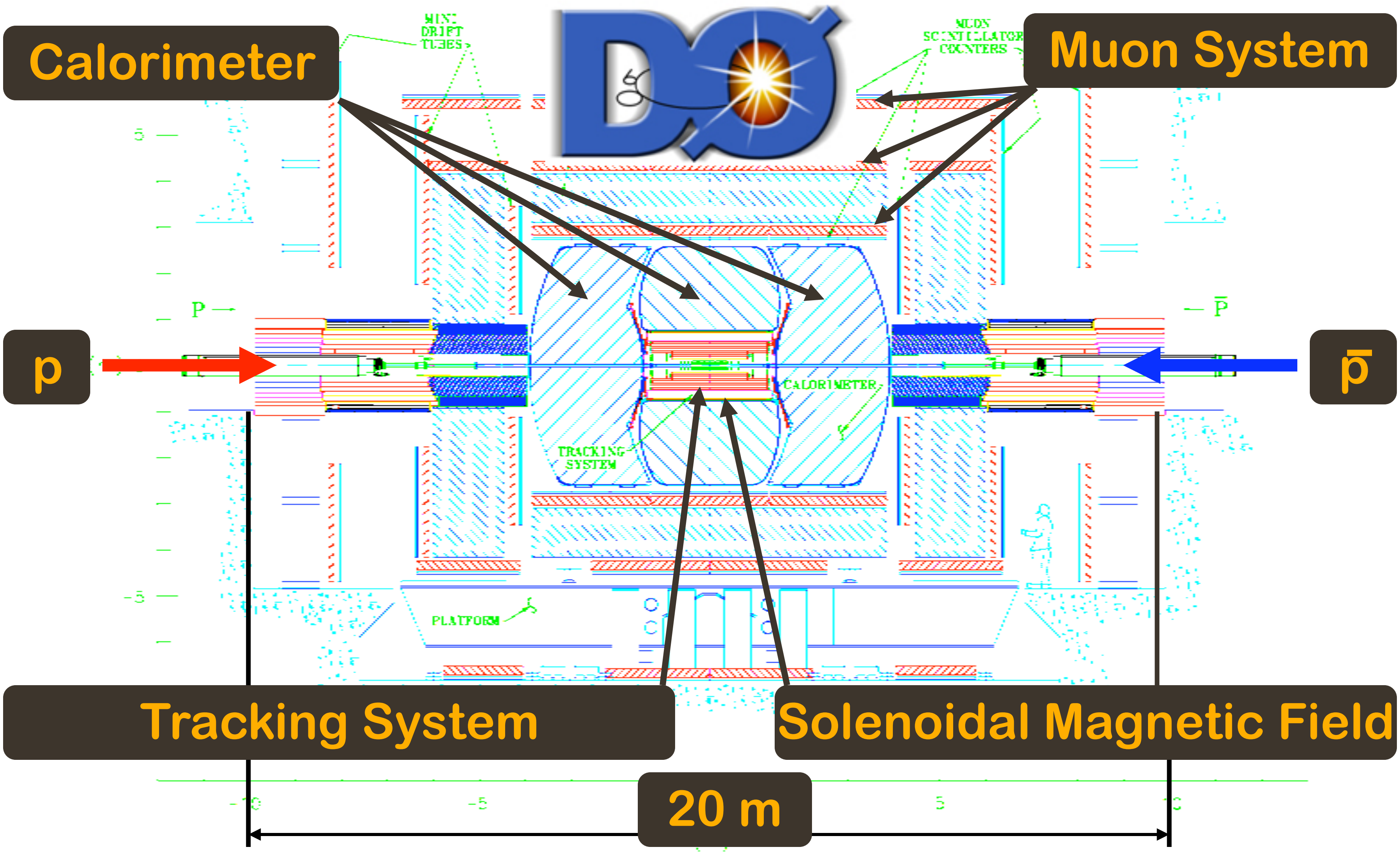
Outlook

We are looking ahead to more exciting measurements from the Tevatron!

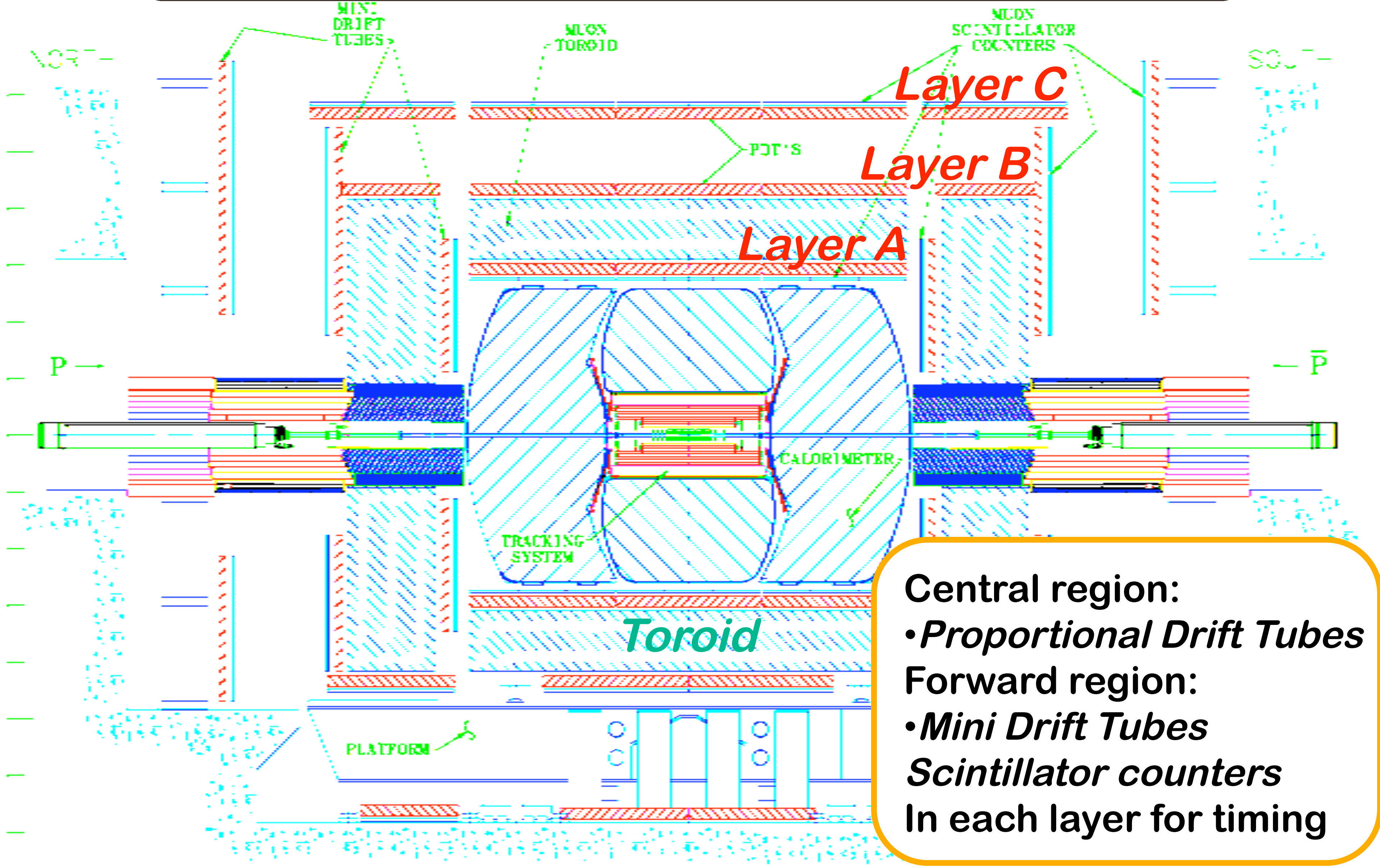


Bonus slides

The DØ Detector

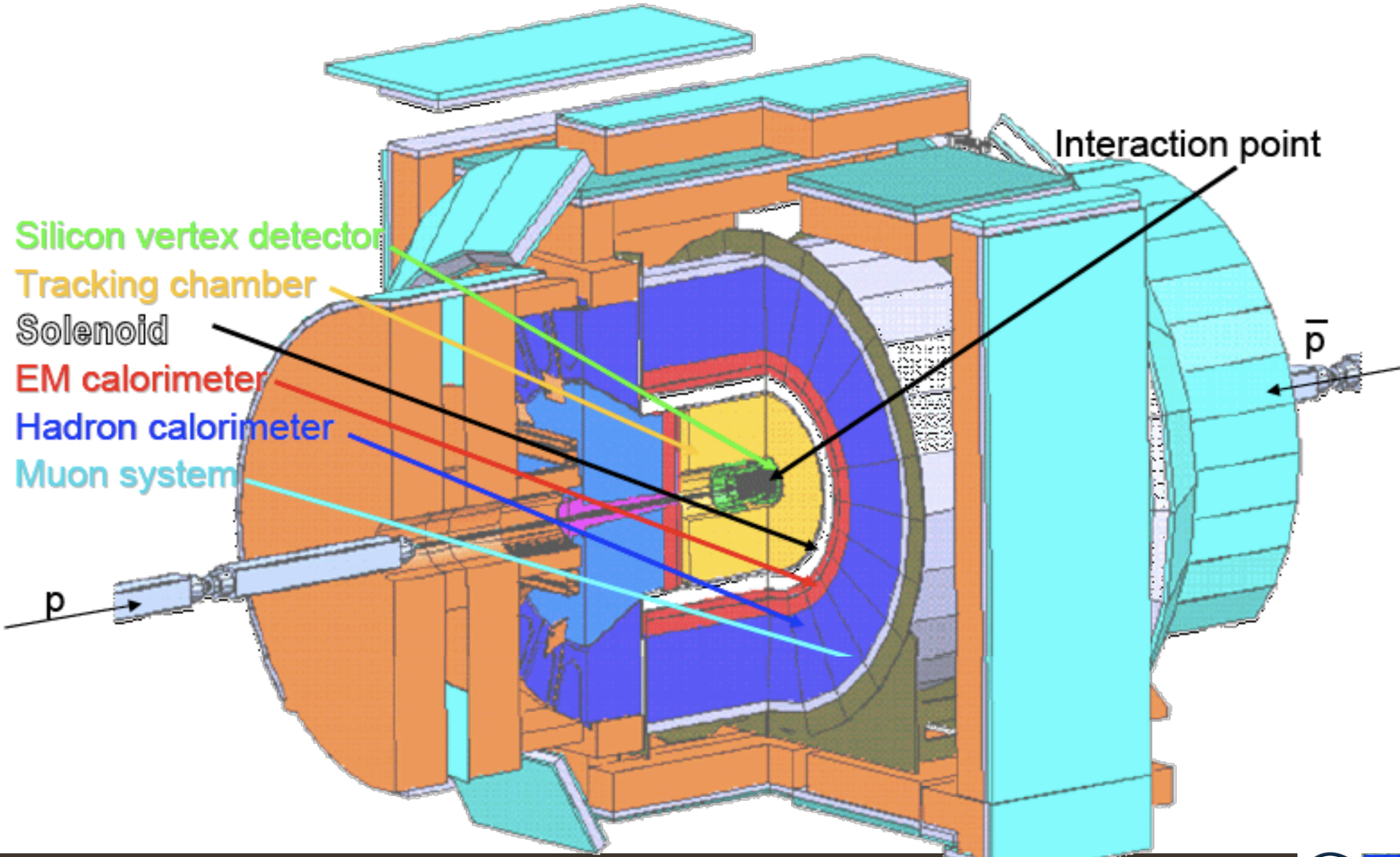


The Muon System of the DØ Detector



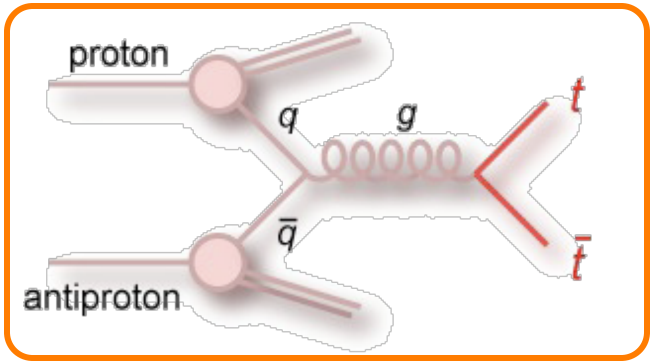
Central region:
•*Proportional Drift Tubes*
Forward region:
•*Mini Drift Tubes*
Scintillator counters
In each layer for timing

The CDF Detector



tt Production ...

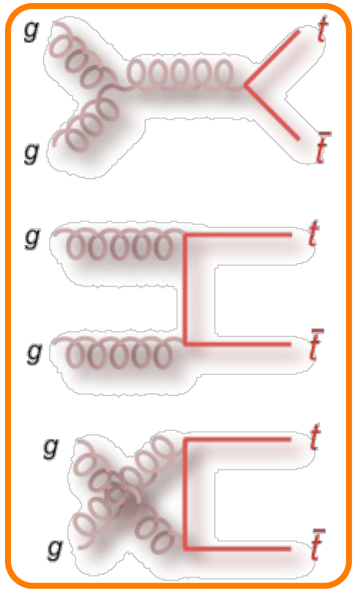
- **tt pairs produced via strong interaction at the Tevatron:**

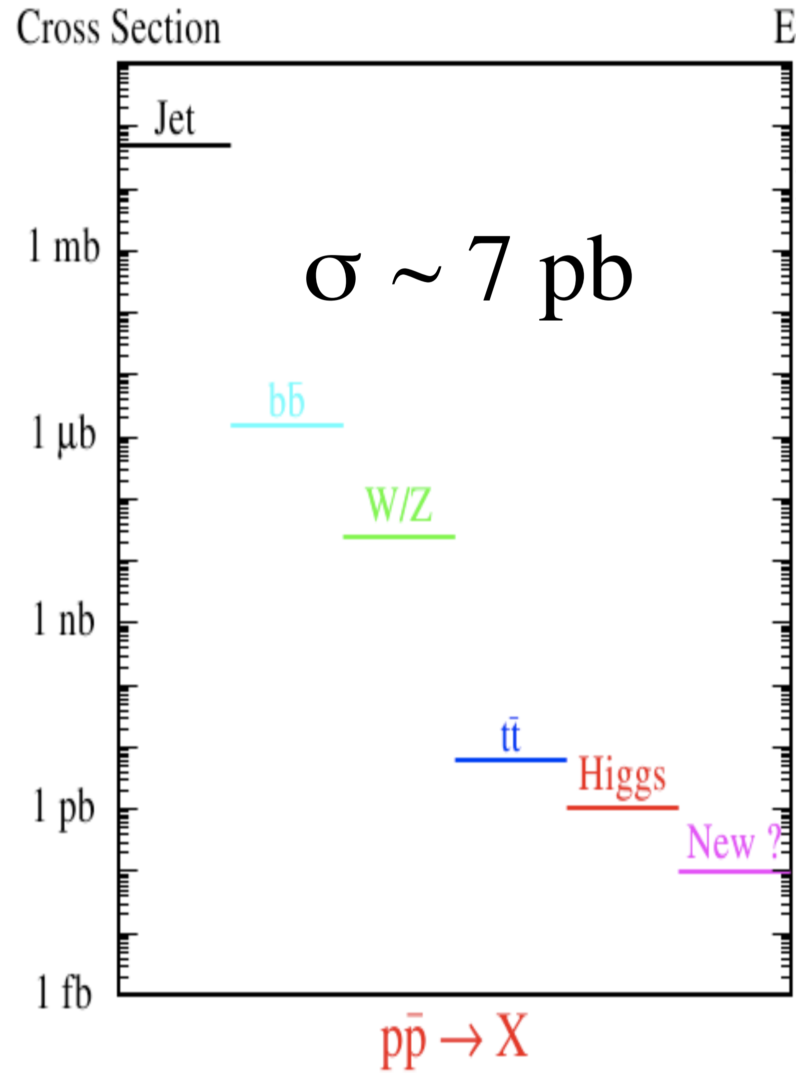


85%

+

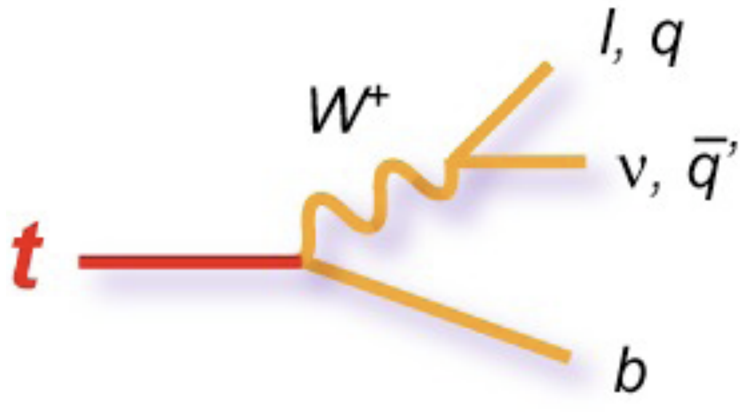
15%





… and Decay

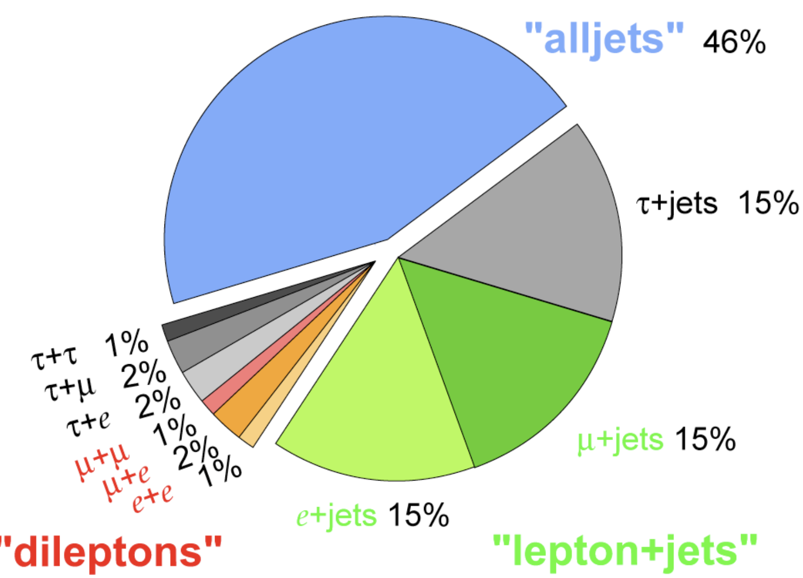
- In the SM:
  - $|V_{tb}| = 0.9990\text{-}0.9992$ @ 95% C.L. assuming 3 CKM generations
- Characterise tt final states by top decays!

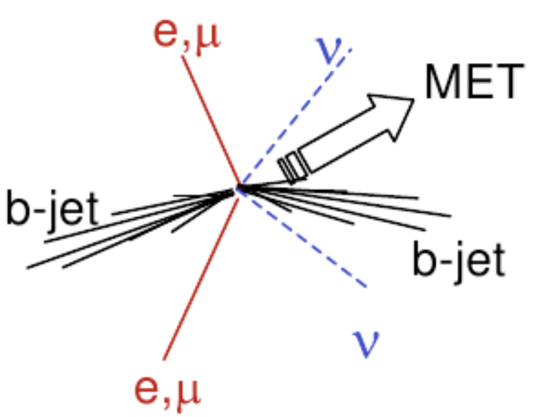


… and Decay

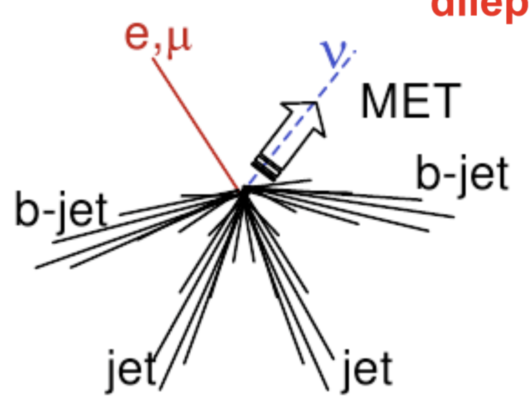
- **In the SM:**
  - **$|V_{tb}|$ = 0.9990-0.9992 @ 95% C.L. assuming 3 CKM generations**
- **Characterise tt final states by top decays!**

Top Pair Branching Fractions

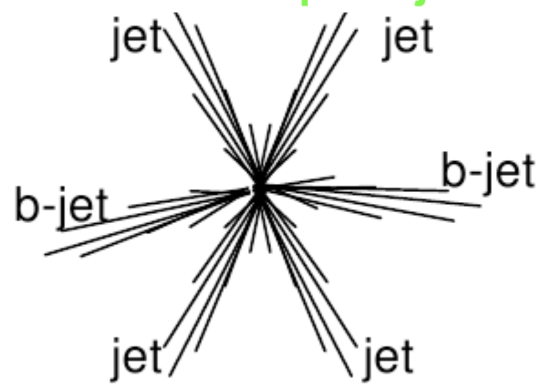




Dilepton
(BR~5%, low bckg)



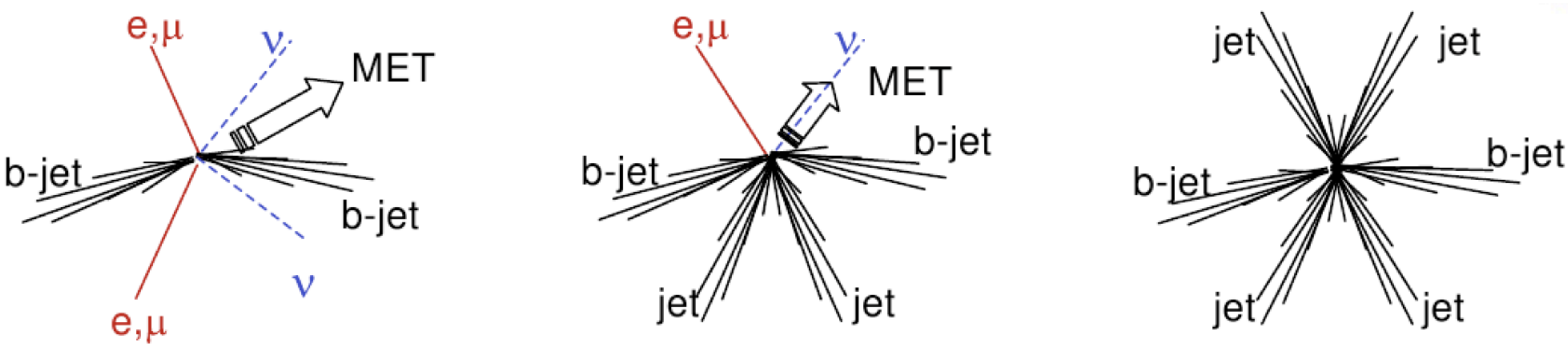
Lepton+jets
(BR~30%, moderate bckg)



All-hadronic
(BR~46%, huge bckg)

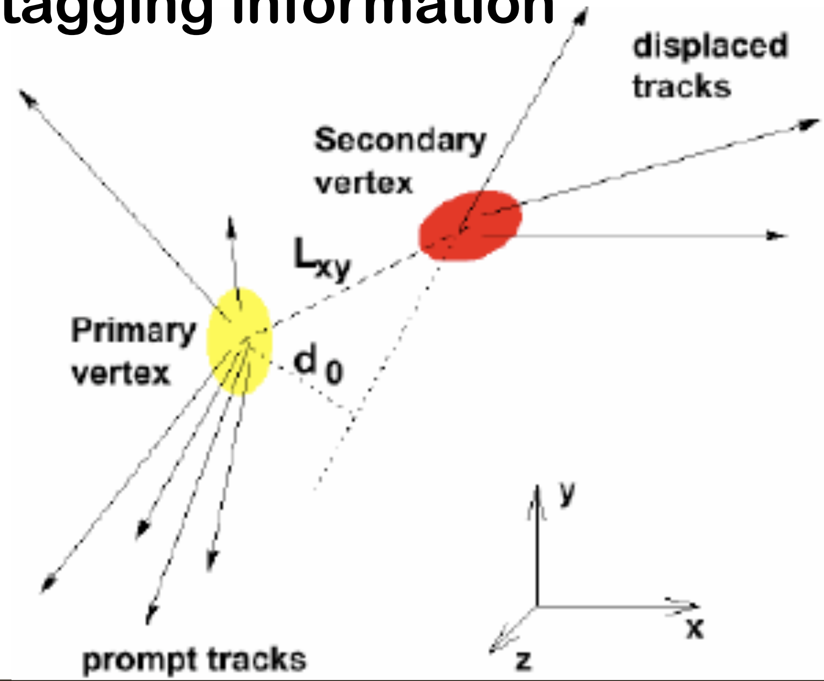
Typical ttbar preselection

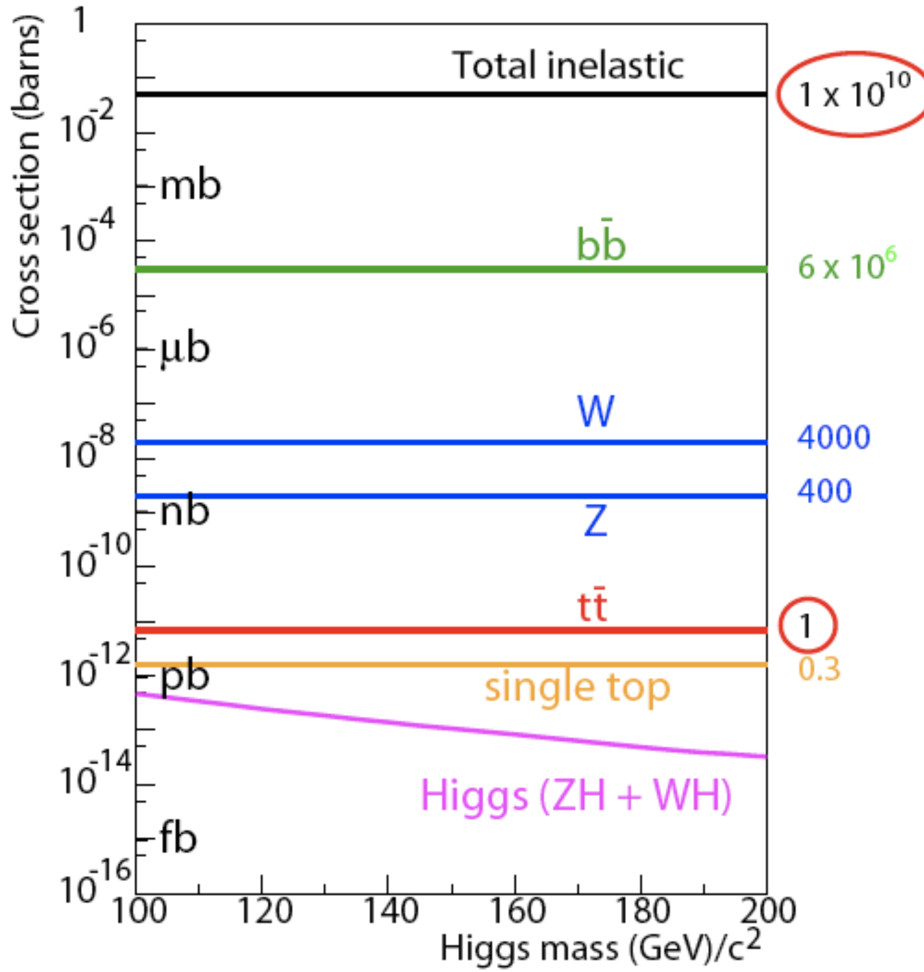
Dilepton	Lepton+jets	All-hadronic
2 high-p_T leptons	1 high-p_T lepton (>20 GeV)	No leptons
Missing E_T	Missing E_T (>40 GeV)	No missing E_T
2 jets	4 jets (> 20GeV)	6 jets
$\geq$ 0 b-tags	$\geq$ 1 b-tag	$\geq$ 1 b-tag
S/B:		



Dilepton (BR~5%, low bckg) ***Lepton+jets*** (BR~30%, moderate bckg) ***All-hadronic*** (BR~46%, huge bckg)

- The Tevatron is a hadron collider
  - Very high backgrounds!
- Backgrounds can bias the top mass measurement
- Control backgrounds using b-tagging information





See talk by F. Deliot (top Xsec)

Top Mass in the Lepton+Jets Channel (I)

- Template method, CDF (4.8 fb-1)
  - Use two observables to maximise sensitivity to top mass:
    - $m_{top}(1)$ → top mass of best chi^2 fit
    - $m_{top}(2)$ → top mass of second best chi^2 fit
  - Define the chi^2 as:

Consistency w/ meas'd p_T values

Consistency w/ underlying event

$$\chi^2 = \Sigma_{i=\ell,4jets} \frac{(p_T^{i,fit} - p_T^{i,meas})^2}{\sigma_i^2} + \Sigma_{j=x,y} \frac{(U_j^{fit} - U_j^{meas})^2}{\sigma_j^2}$$

$$+ \frac{(M_{jj} - M_W)^2}{\Gamma_W^2} + \frac{(M_{\ell\nu} - M_W)^2}{\Gamma_W^2} + \frac{(M_{bjj} - m_t^{\rm reco})^2}{\Gamma_t^2} + \frac{(M_{b\ell\nu} - m_t^{\rm reco})^2}{\Gamma_t^2}$$

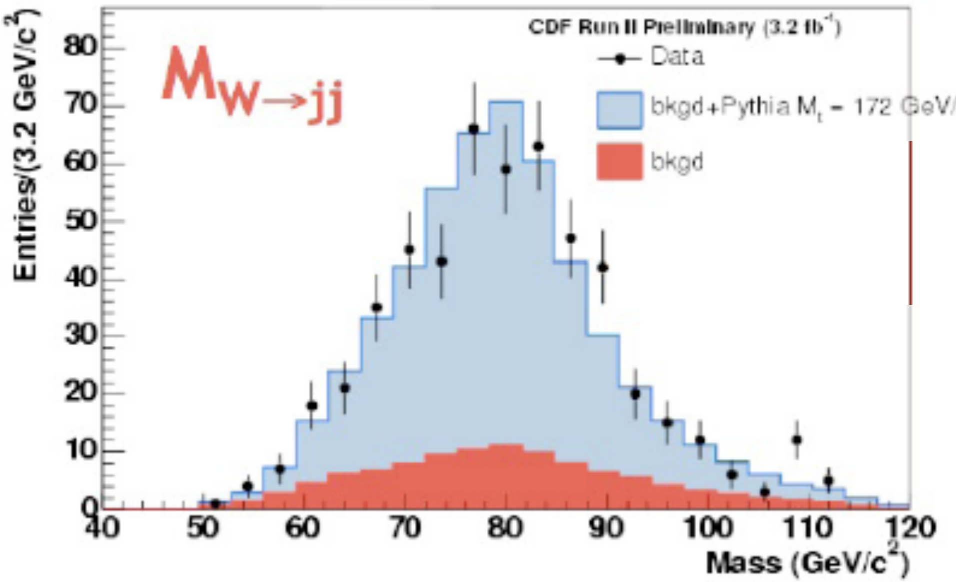
Consistency w/ reconstructed m_{top} within experimental resolution

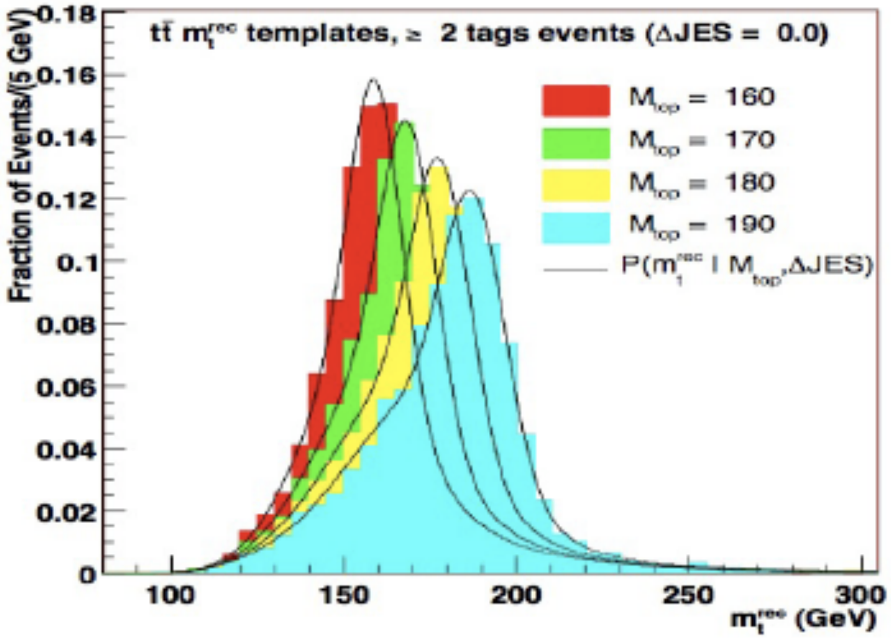
Consistency w/ known W mass w/I exp. resol'n

  - chi^2 = chi^2(m_{reco}(top), JES)
  - Drop events with chi^2 > 9!

Top Mass in the Lepton+Jets Channel (I)

- Play experimental trick:
  - Largest experimental uncertainty is the JES
  - perform an in-situ calibration of the JES via the chi^2 fit

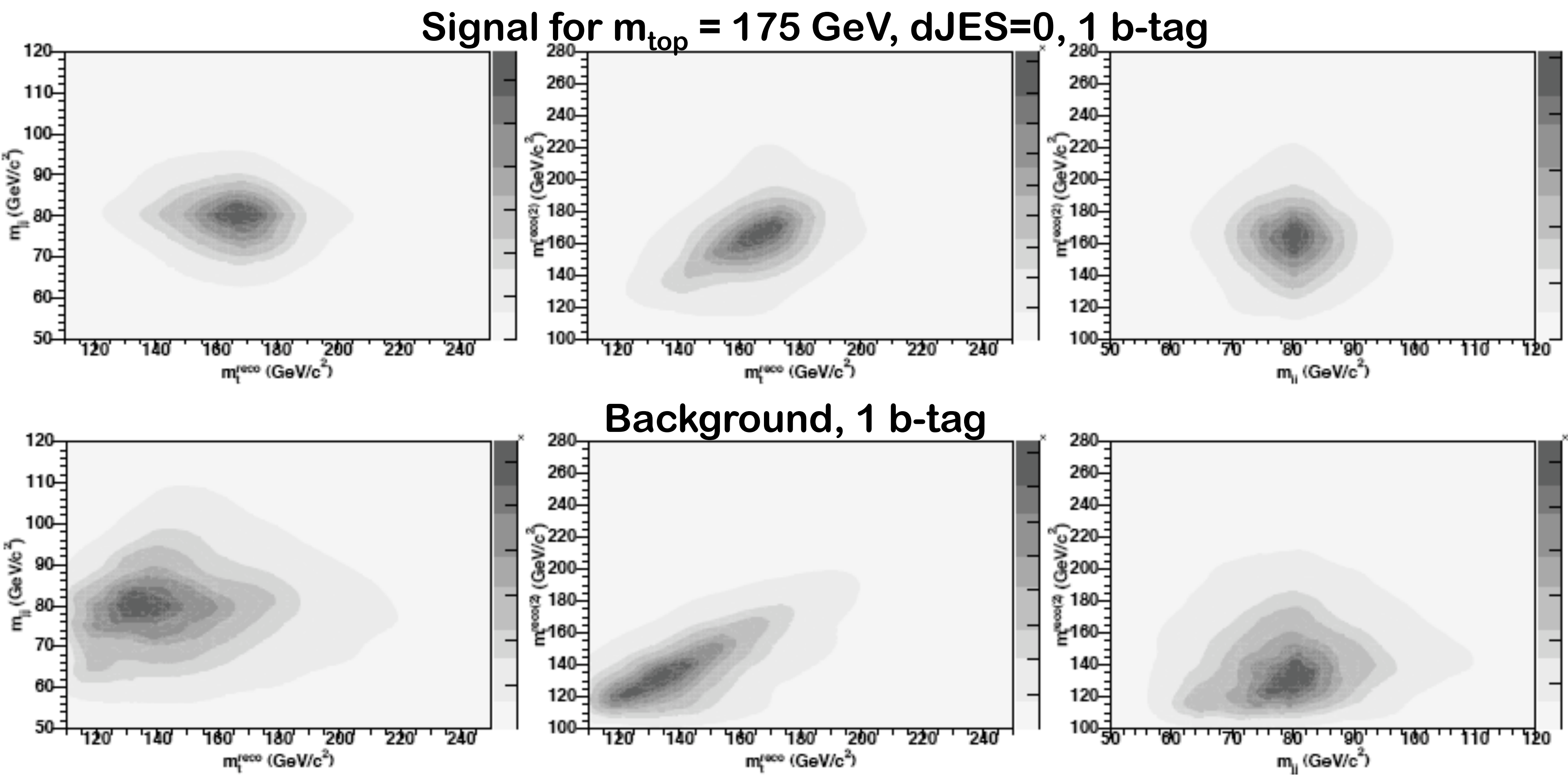




- Construct m_{top}-dependent → templates

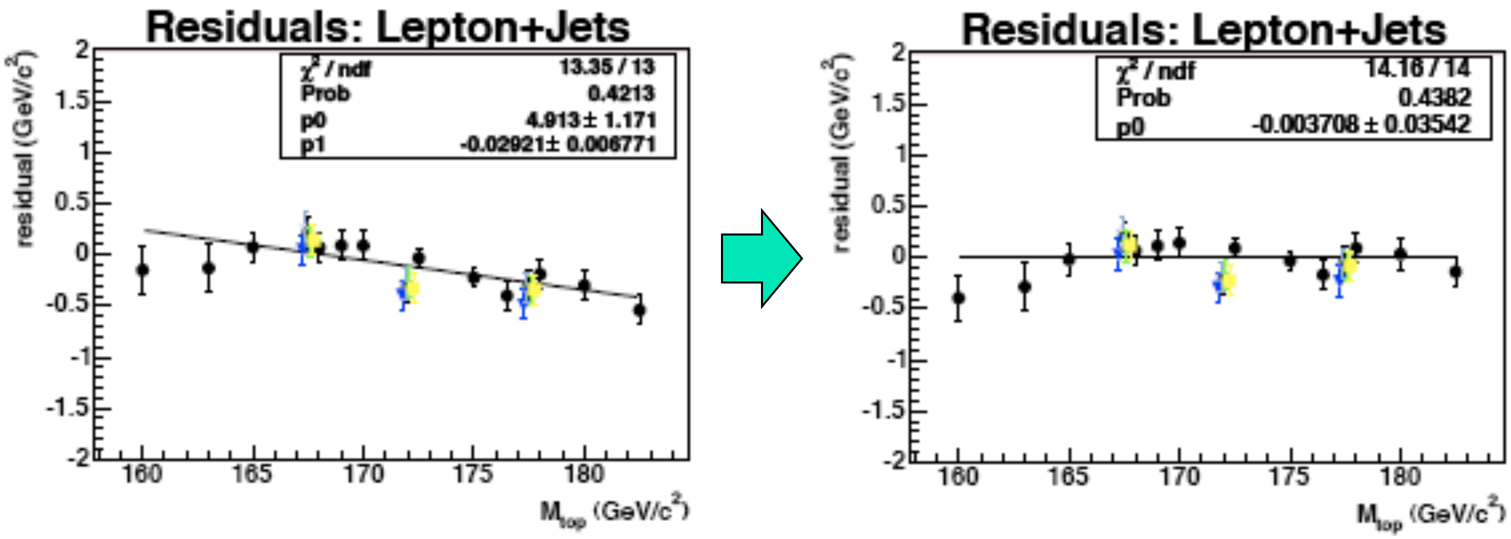
Top Mass in the Lepton+Jets Channel (I)

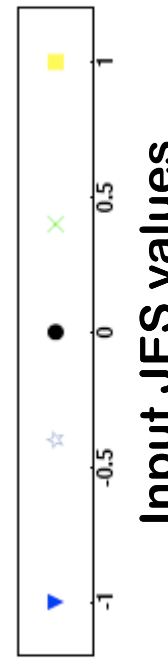
- In reality, matters with 3D-pdf are a bit more complicated:
  - Look at 2D projections of 3D pdf:



Top Mass in the Lepton+Jets Channel (I)

- Not quite ready to extract the top mass yet
  - Need to calibrate the method (ensemble tests):
    - Possible biases due to simulation, acceptance, … effects
    - Over/underestimation of statistical uncertainty



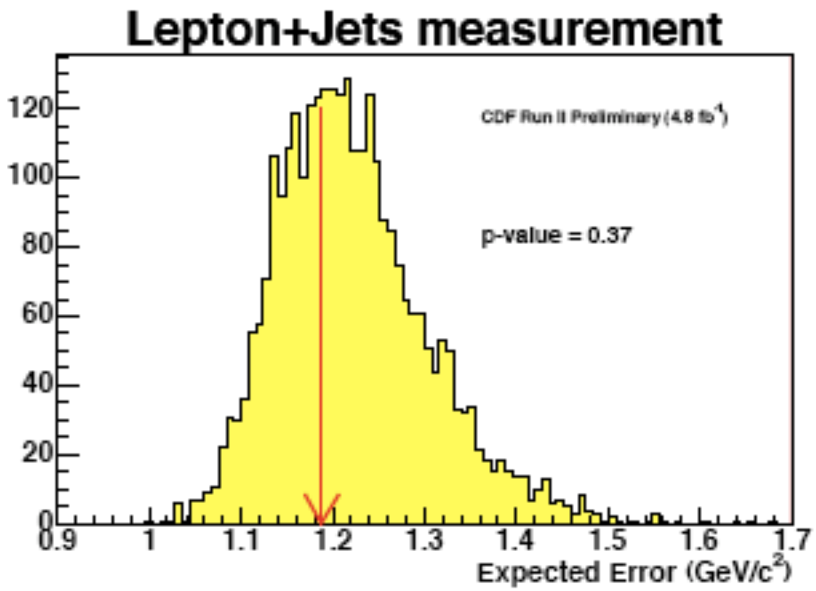


    - Correct for residual slope: +3%
    - Inflate statistical uncertainties by 4.1%
- We obtain:

$$M_{top} = 172.2 \pm 1.2\ (\text{stat.}) \pm 1.0\ (\text{syst.})\ \text{GeV}/c^2 = 172.2 \pm 1.5\ \text{GeV}/c^2$$

Top Mass in the Lepton+Jets Channel (I)

- **Did we get lucky?**



Systematic Uncertainties

CDF II Preliminary 4.8 fb^{-1}

Systematic	LJ
Residual JES	0.6
Generator:	0.7
PDFs	0.1
b jet energy	0.2
Background shape	0.1
gg fraction	<0.1
Radiation	0.1
MC statistics	0.1
Lepton energy	<0.1
MHI	0.1
Color Reconnection	0.2
Total systematic	1.0