Top mass measurement in the all hadronic channel at CDF II using $L=1.02\ fb^{-1}$

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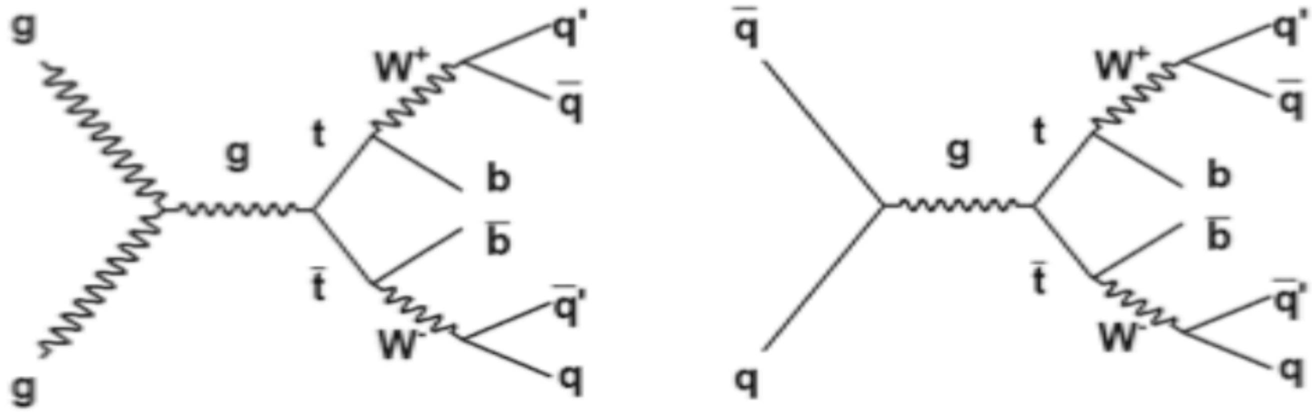
on behalf of the CDF collaboration

Top at the Tevatron



Looking at events with hadronic W decays
→ characteristic multijet signature

Advantages:
- Large BR=44%
- Fully reconstructed events

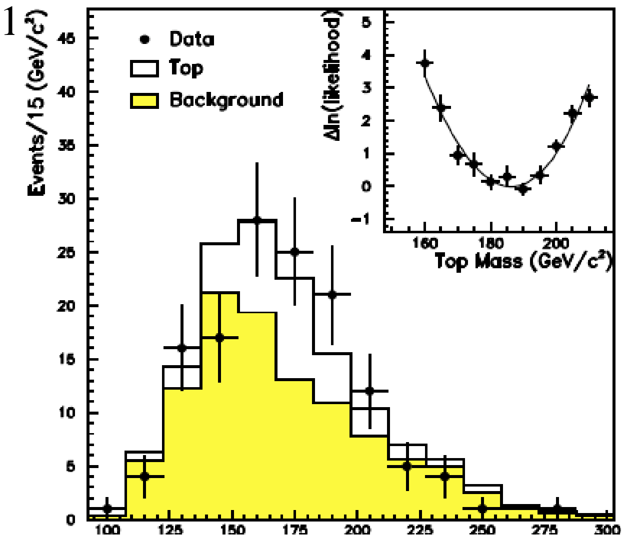
Disadvantages
- Huge QCD background
- Large jet-parton assignement ambiguity

Previous measurements

RunI all hadronic measurement L=110pb^{-1}

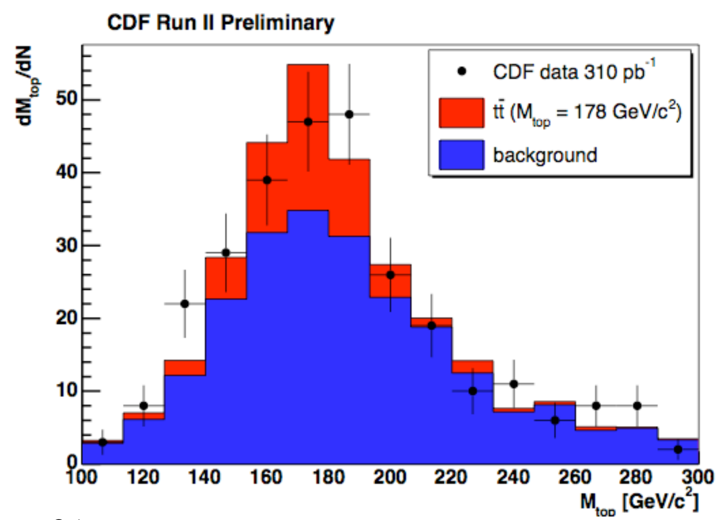
m_t=186 ± 10(stat.) ± 5(syst.) GeV/c^2

phys.rev.lett.79, (1997)

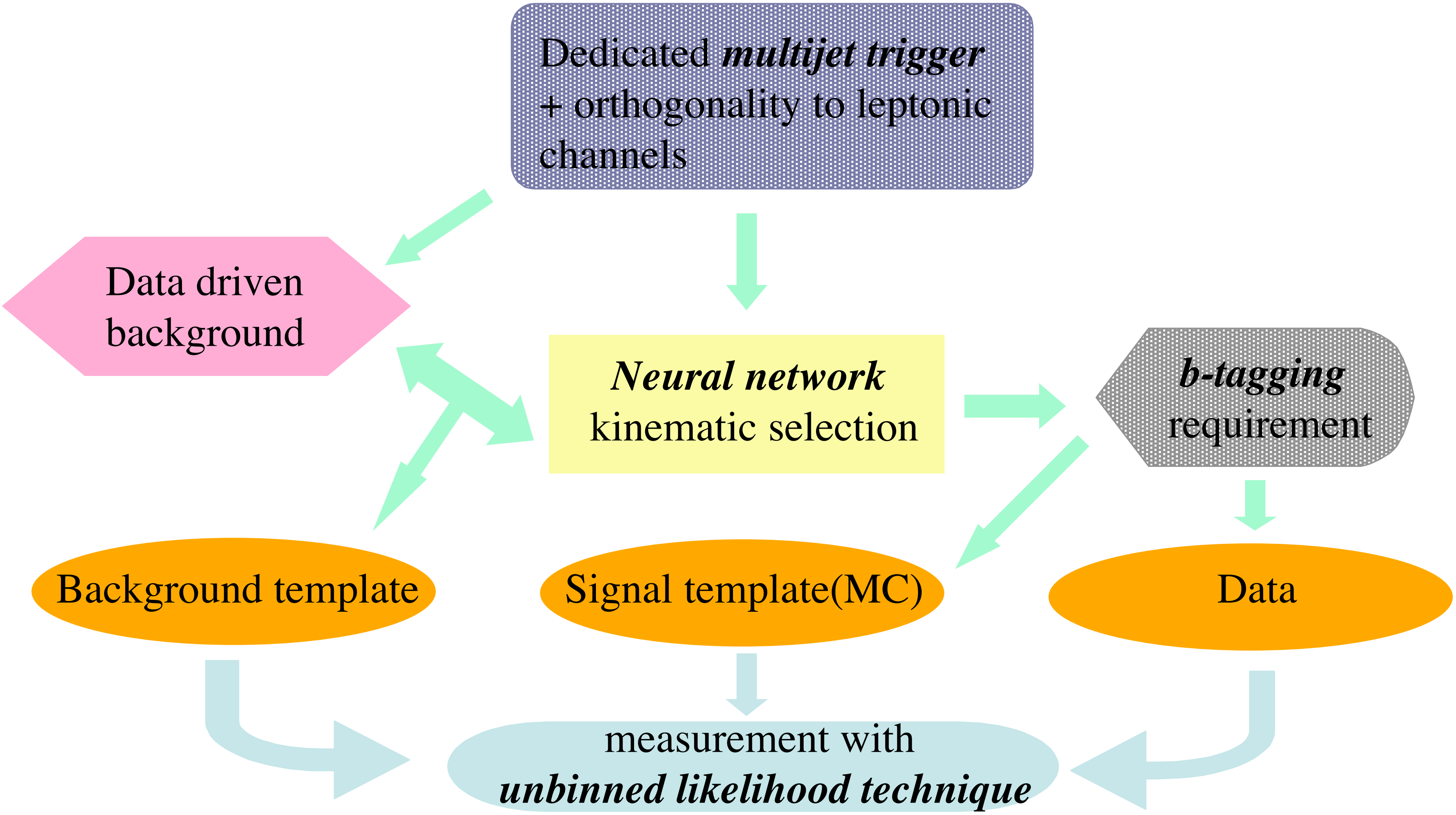


First Run II measurement (different technique) with L=310pb^{-1}

m_t=177.1 ± 4.9(stat.) ± 4.7(syst.) GeV/c^2



Analysis overview



Trigger & prereq's

Trigger requirements:

multijet topology, at least 4 jets and $\Sigma E_T \geq 175$ GeV

Prerequisites

At least 1 interaction vertex within fiducial region (60cm)

lepton rejection and missing E_T cuts to be orthogonal to leptonic channels

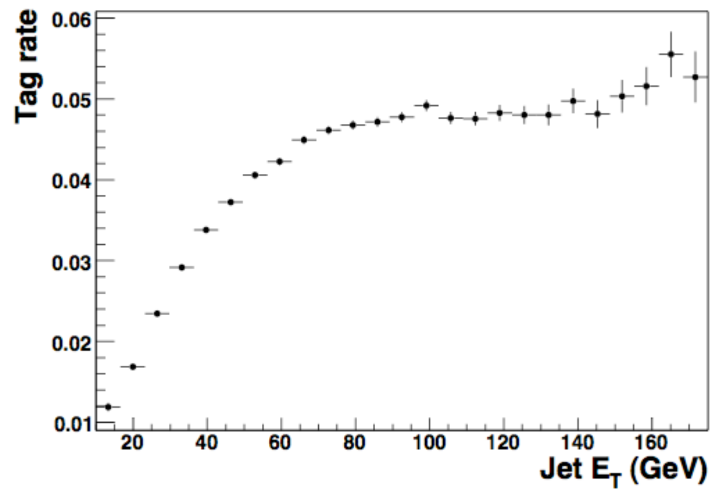
jets well separated in η-φ space

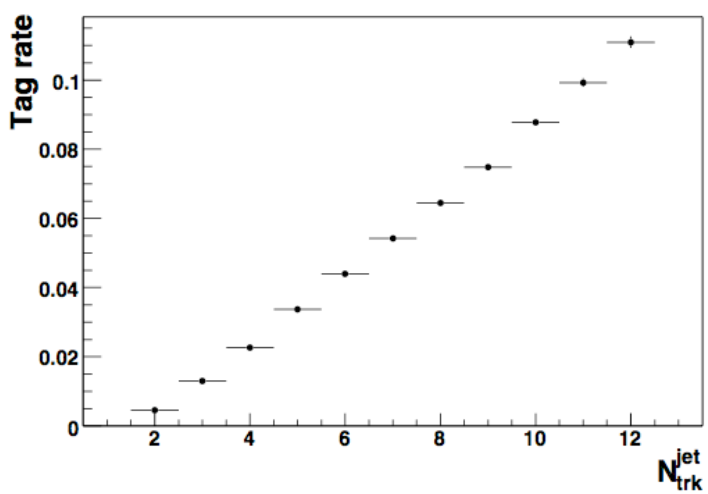
at this level S/B~1/1100

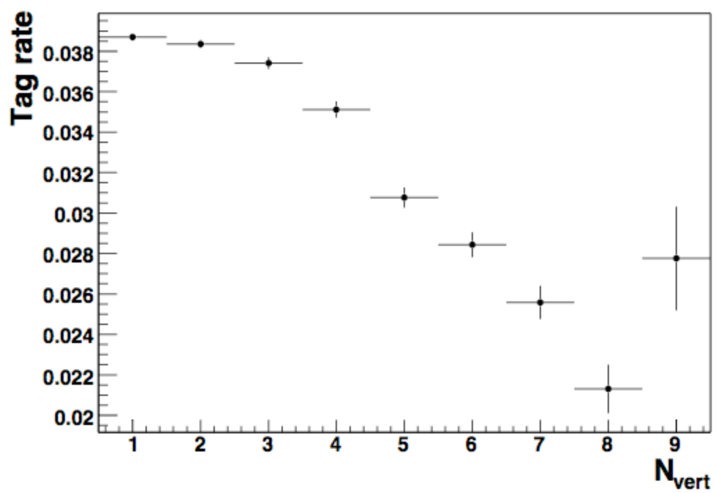
Data-driven background

Measurement will need *b-tags*

- **Tag rate parametrization**
  Matrix ($N_{vertices}$,N_{tracks}, E_T)
  built on a 4 jets sample
- Validated on sample with higher jet multiplicity





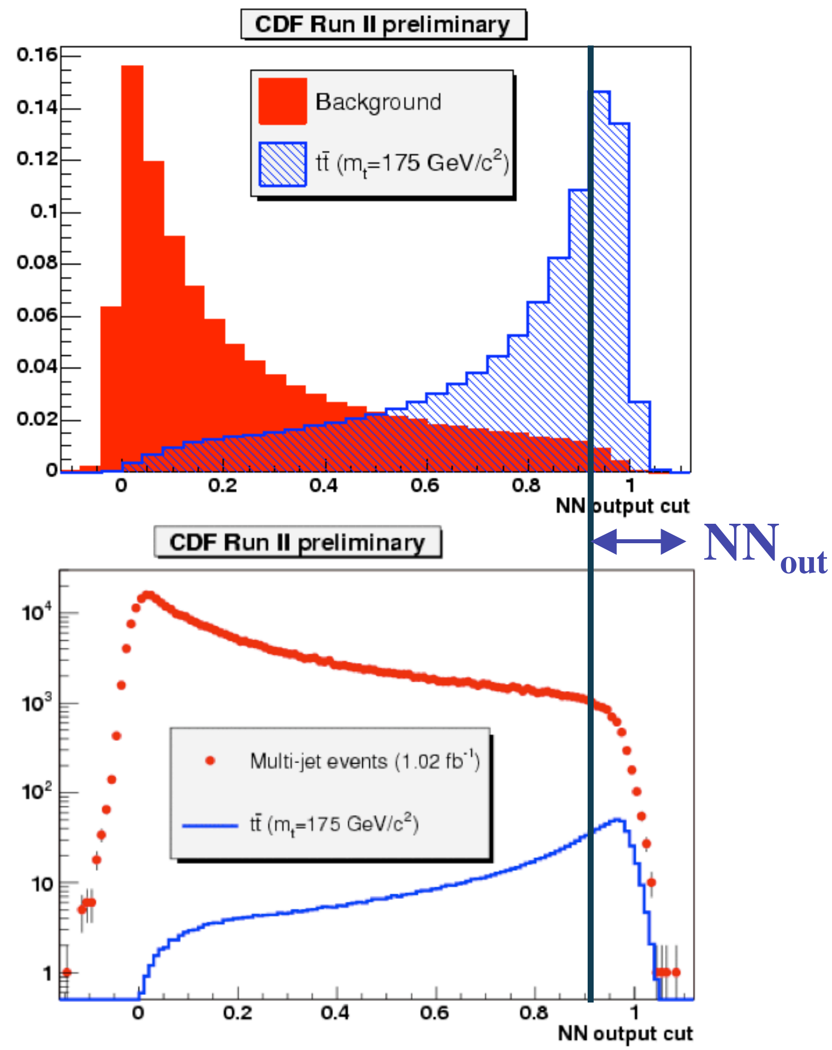


Reducing background

Neural network 11 inputs - 1 output

- **SumEt** Scalar sum of transverse energies
- **SumEt3** as above, expect the two leading j's
- **C** centrality
- **A** aplanarity
- **min mjj** minimum dijet mass
- **max mjj** maximum dijet mass
- **min mjjj** minimum trijet mass
- **max mjjj** maximum trijet mass
- **$E_T{}^*{}_1$** $E_T \sin\theta^*$ for the leading jet
- **$E_T{}^*{}_2$** $E_T \sin\theta^*$ for the sub-leading jet
- **$\langle E_T{}^* \rangle$** geometric mean over remaining jet

Optimized cut: $NN_{out} \geq 0.91$



Mass extraction technique

- **Reconstruct the event kinematics looking for a variable strongly correlated with top mass**
- **Apply it to signal and background events to build probability distribution functions (templates)**
- **Use unbinned likelihood technique to extract the top mass measurement**

Fitter definition

- For ***each tagged jet*** we reconstruct event kinematics according to $t\,\bar{t} \rightarrow b\,b\,q_1\bar{q}_2\,q_3\bar{q}_4$ hypothesis.
- Assume b-tagged jets come from b quarks (reduce combinatories)

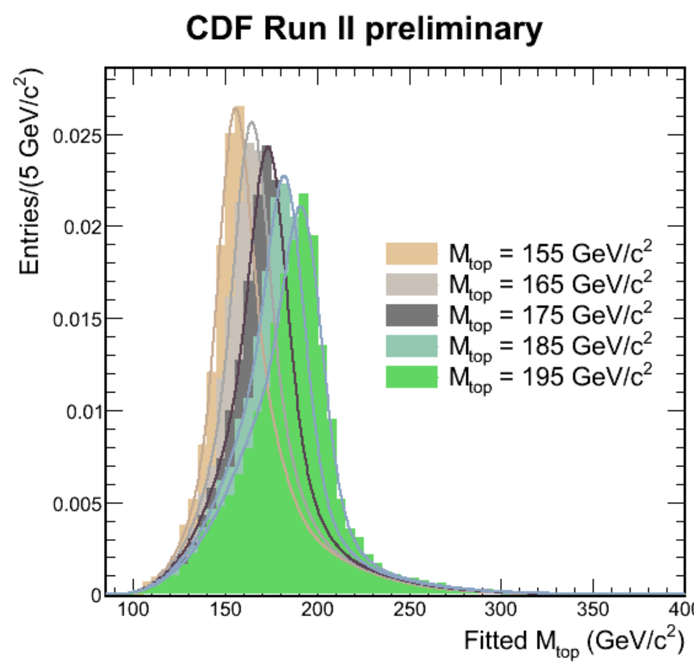
$$\chi^2 = \frac{(m_{jj1} - m_W)^2}{\Gamma_W^2} + \frac{(m_{jj2} - m_W)^2}{\Gamma_W^2} + \frac{(m_{jjj1} - m_t)^2}{\Gamma_t^2} + \frac{(m_{jjj2} - m_t)^2}{\Gamma_t^2} + \Sigma \frac{(p_i^{fit} - p_i^{data})^2}{\sigma_i^2}$$

m_W , Γ_W , Γ_t fixed to known values

m_{top} - p_T^{fit} fit parameters

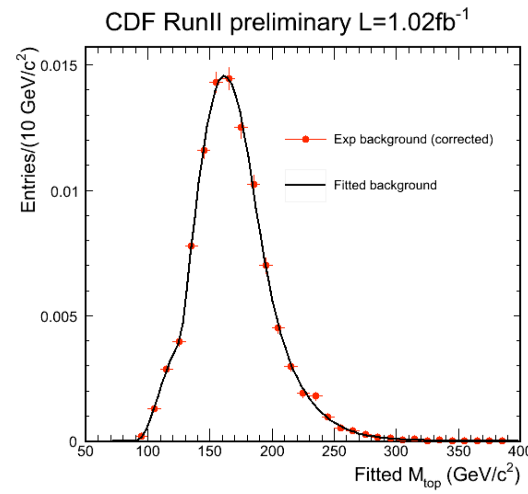
- ONLY the best combination (lowest χ^2) enters an invariant mass distribution, i.e. our template

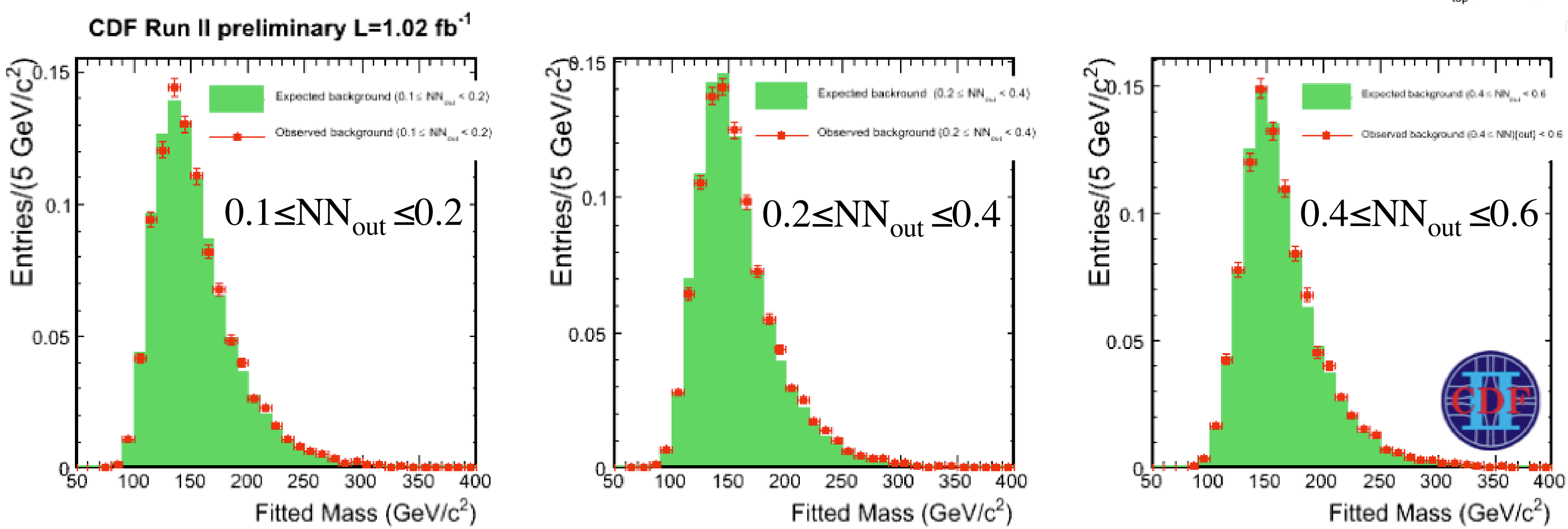
Optimized cut χ^2 <16 → S/B ~ 1/2



Background template

- For each fiducial jet in the pre-tag sample we run the kin fitter and weight the resulting mass with jet tag rate.
- Resulting distribution is validated in data samples in NN_{out} control regions





Likelihood fit

Finally compare the data invariant masses to signal and background templates

$$L_{sample} = L_{norms} \cdot L_{shapes}$$

$$L_{sample} = e^{-\frac{(n_b - N_b)^2}{2\sigma^2_{N_b}}} \cdot e^{-\frac{(n_b + n_s - N)^2}{2\sigma^2_N}} \cdot \prod_{i=1}^{N} \frac{n_b P_b(m_i) + n_s P_s(m_i, M_{top})}{n_b + n_s}$$

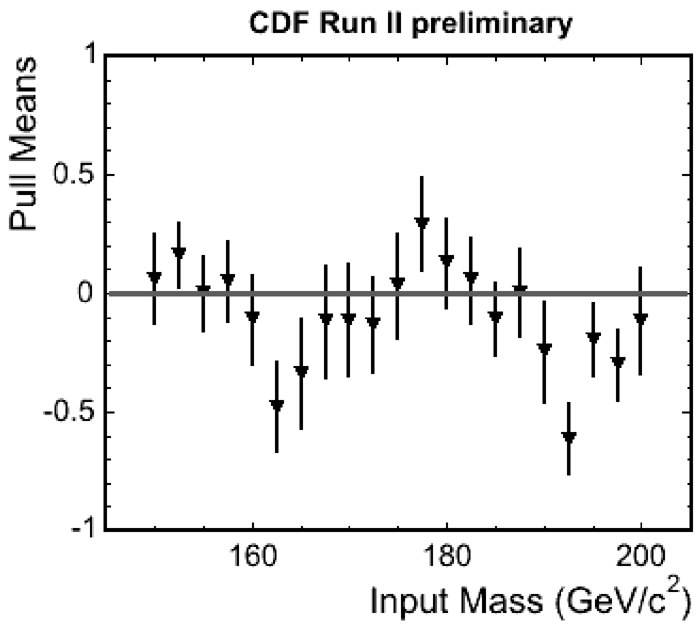
Find a maximum for L_{sample} with respect to n_s, n_b, M_{top}

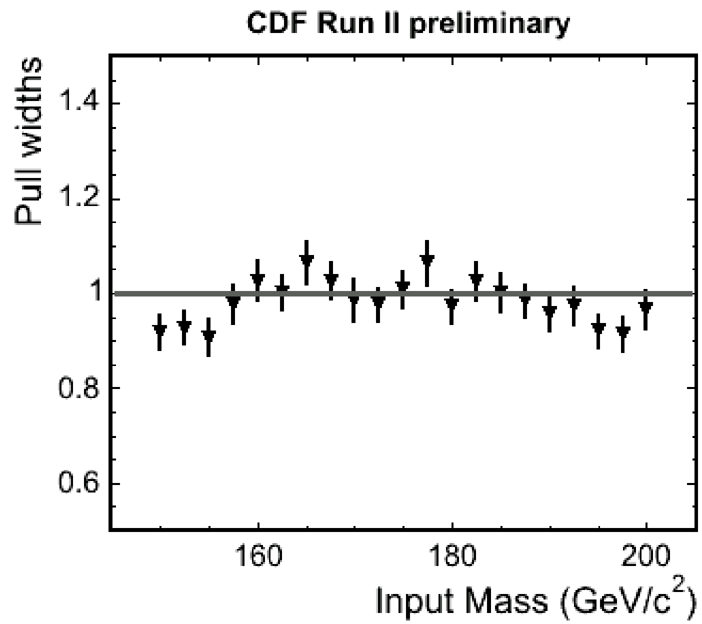
Pseudo-experiments

Plot ***pull*** $\frac{M_{fit} - M_{input}}{\sigma_{M_{fit}}}$

means to check if method is biased

widths to check if statistical sensitivity prediction is accurate





Method unbiased - stat error prediction accurate

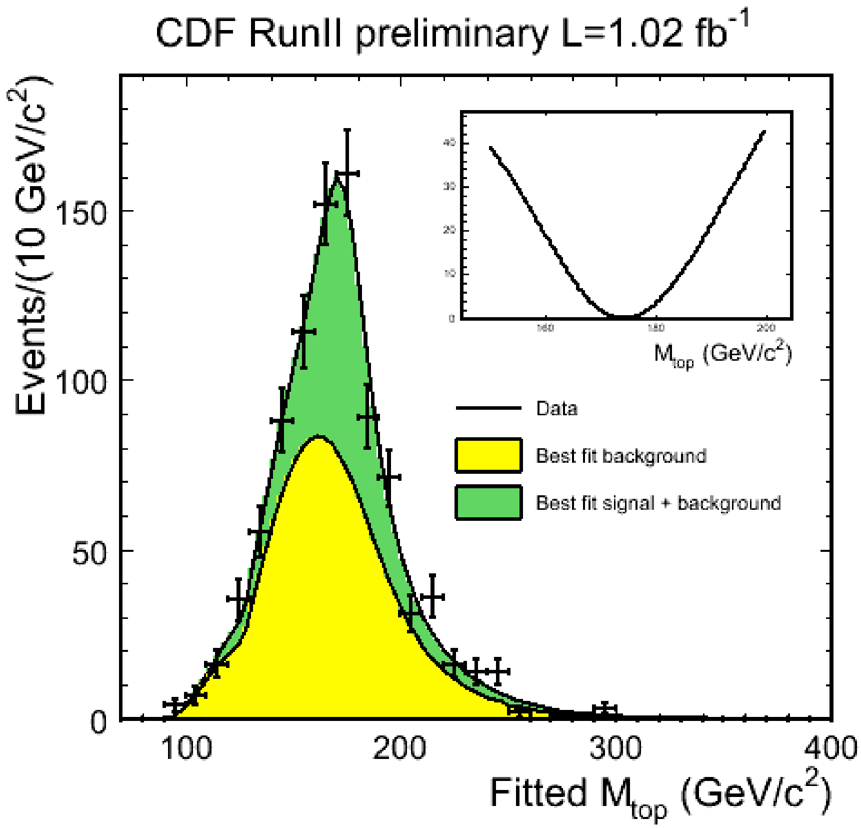
Systematic uncertainties

Source	Systematics (GeV/c^2)
Jet energy scale	4.5
Generator	1.0
b-jet energy scale	0.5
Parton Distribution Function	0.5
Background shape	0.5
Background fraction	0.5
ISR	0.5
FSR	0.5
b-tag	0.5
MC statistics	0.1
Template parametrization	0.1
Total	4.8

Results

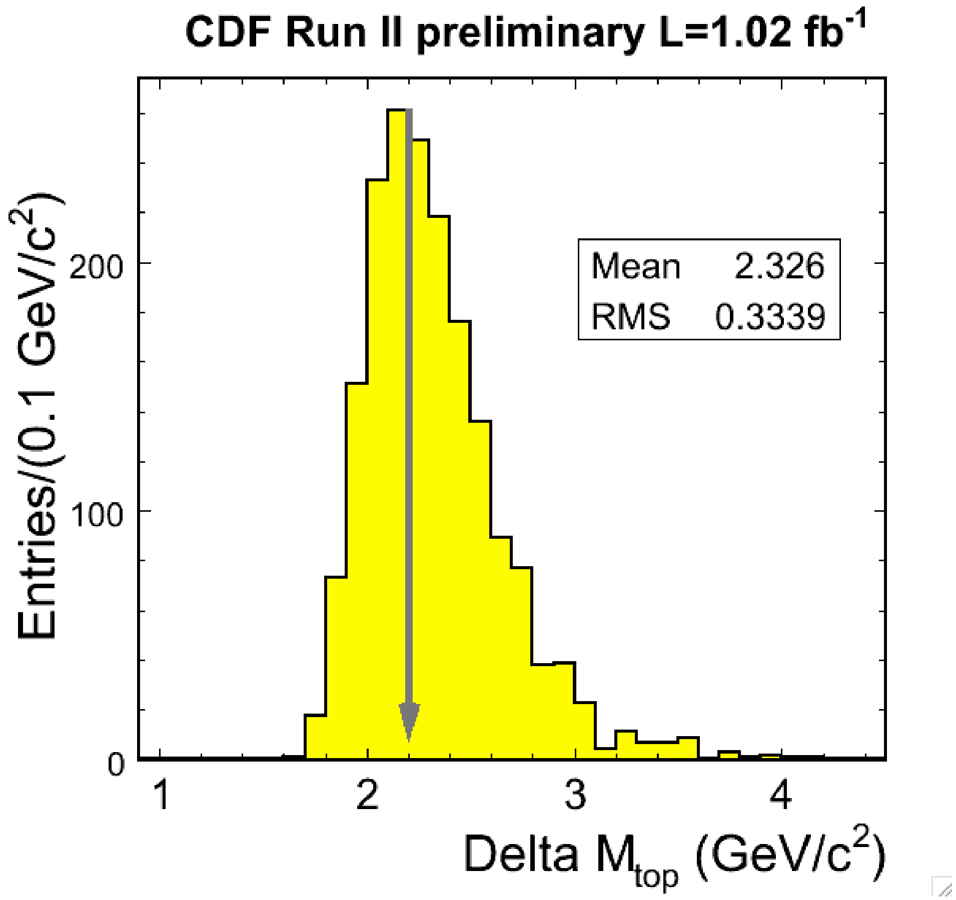
Apply to L=1.02 fb^{-1} of data where we find 926 tags in 772 events. We measure:

m_{top}=174.0 ± 2.2 (stat.) ± 4.8 (syst.)



What did we expect?

About 40% of the pseudo-experiments have lower σ_{stat}



Addressing jet energy scale issue

All-hadronic channel traditionally affected statistically by poor S/B (now good) and systematically by JES

Jet energy can be calibrated *in situ* using jets from hadronic W decays

CDF & D0 already use W→jj in the lepton+jet channel to reduce Jet Energy Scale (JES) systematics

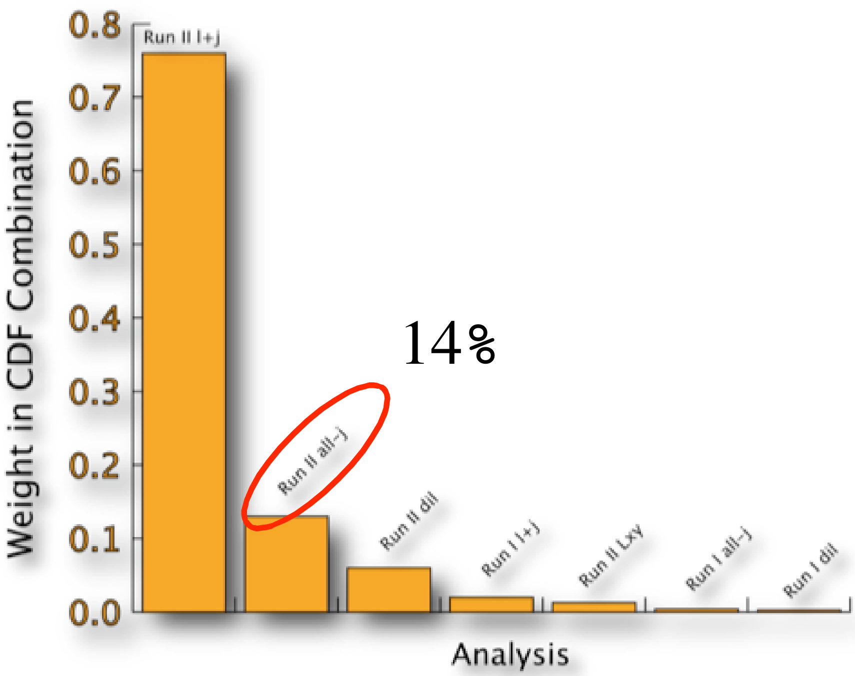
We have two hadronic W decays

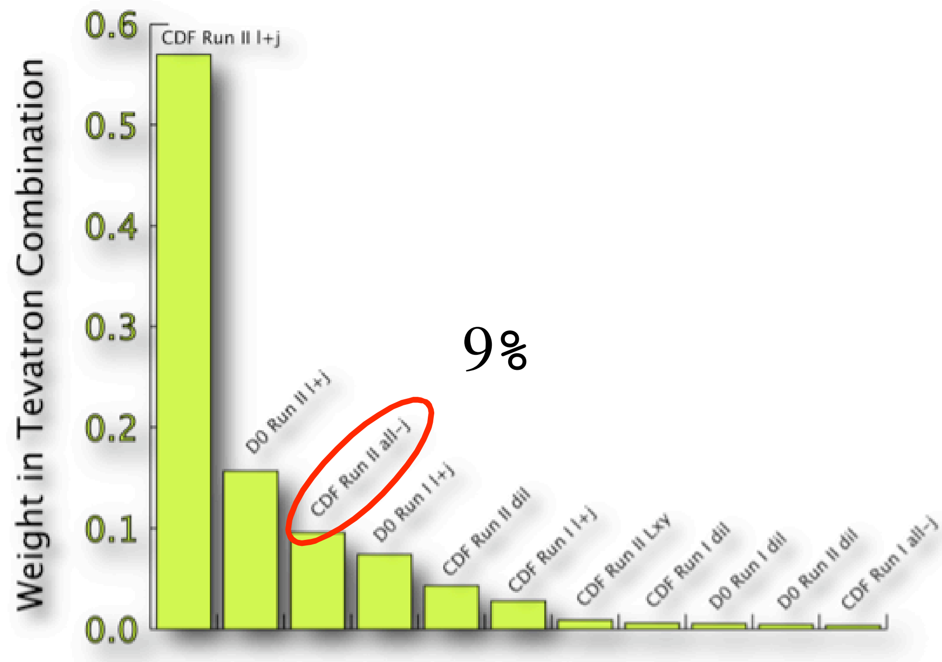
↓

more sensitive to the jet energy scale!

All-hadronic mass and world average

- This measurement enters the most recent Tevatron combination





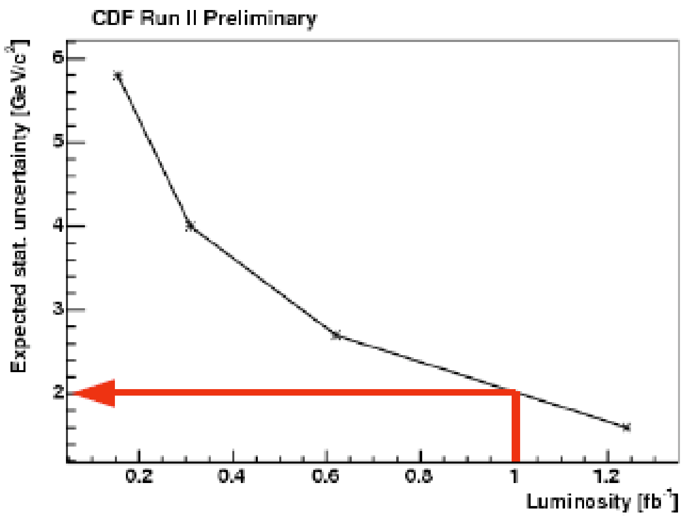
- **Big enhancement** expected when calibrating the jet energy scale *in situ* with hadronic W decays

Other measurements ongoing

"Ideogram"

- Cascade cuts
- Different tagging algorithm
- Mixed background: MC+data-driven

Sensitivity with $L=1\ fb^{-1}$ assuming no improvements to the technique: **stat~2GeV/c^2**



"*FLAME*": Mixed technique

- Cascade cuts
- Data-driven background
- Templates weighted by Matrix Element event probabilities

- Already using $W \rightarrow jj$ *in situ* calibration to measure the jet energy scale

No results yet but very promising technique

Conclusions

We implemented a neural network + b-tagging selection to reduce background in the all-hadronic channel and use template method to extract a mass

We measure the top quark mass to be

$$m_{top}=174.0 \pm 2.2 \text{ (stat.)} \pm 4.8 \text{ (syst.)} GeV/c^2$$

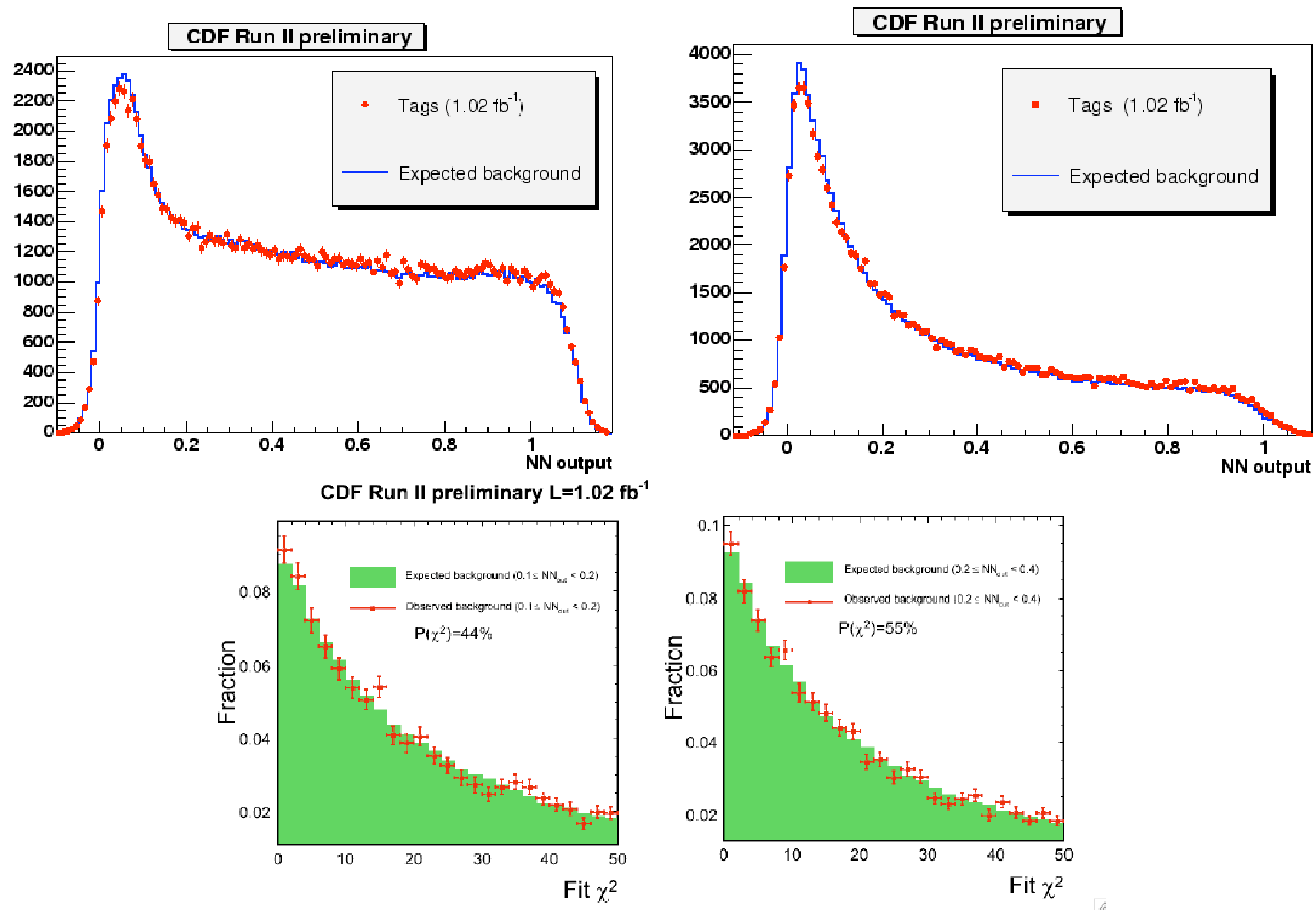
best measurement up to date in this channel (planning to publish)

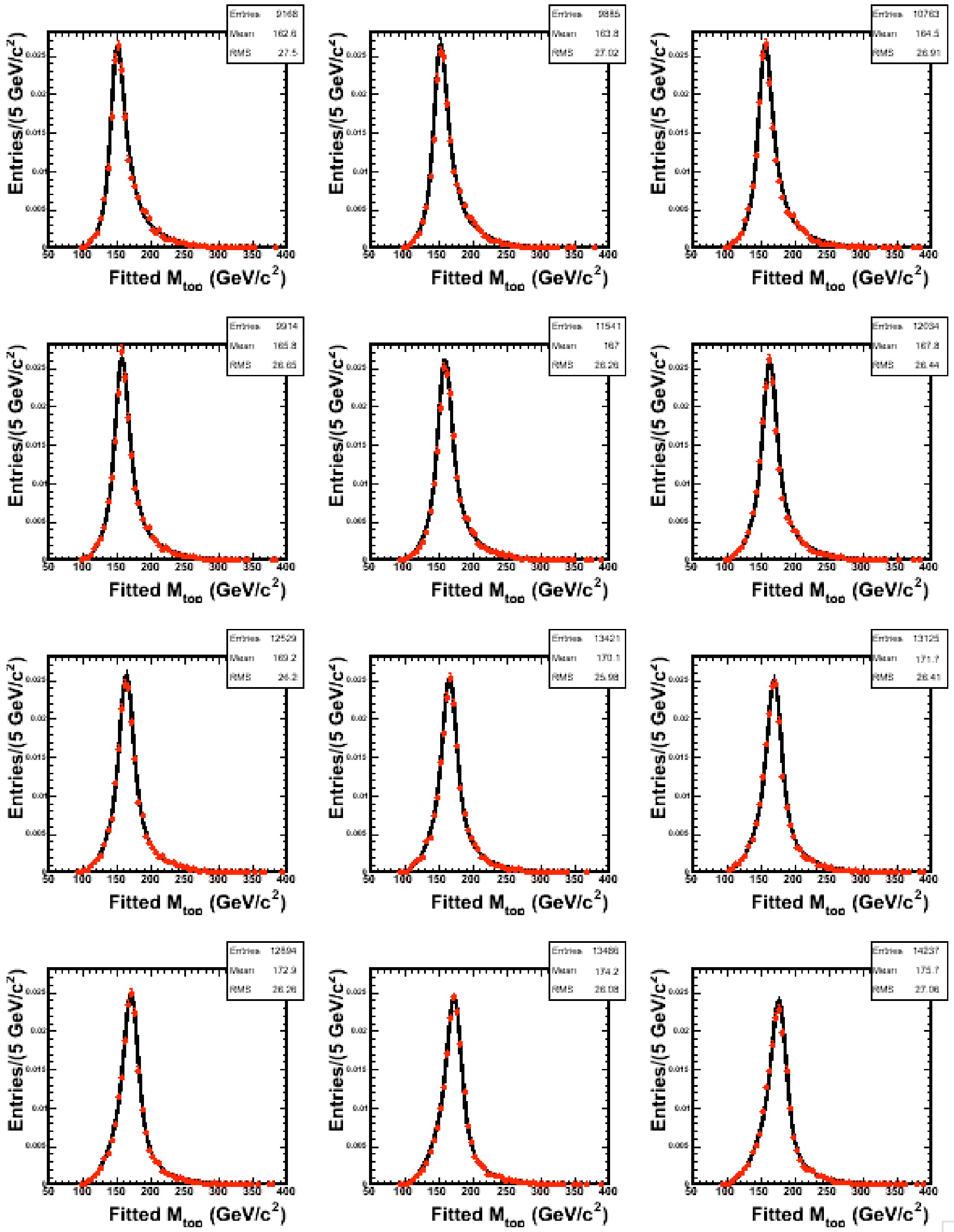
All-hadronic uncertainties tradionally dominated by

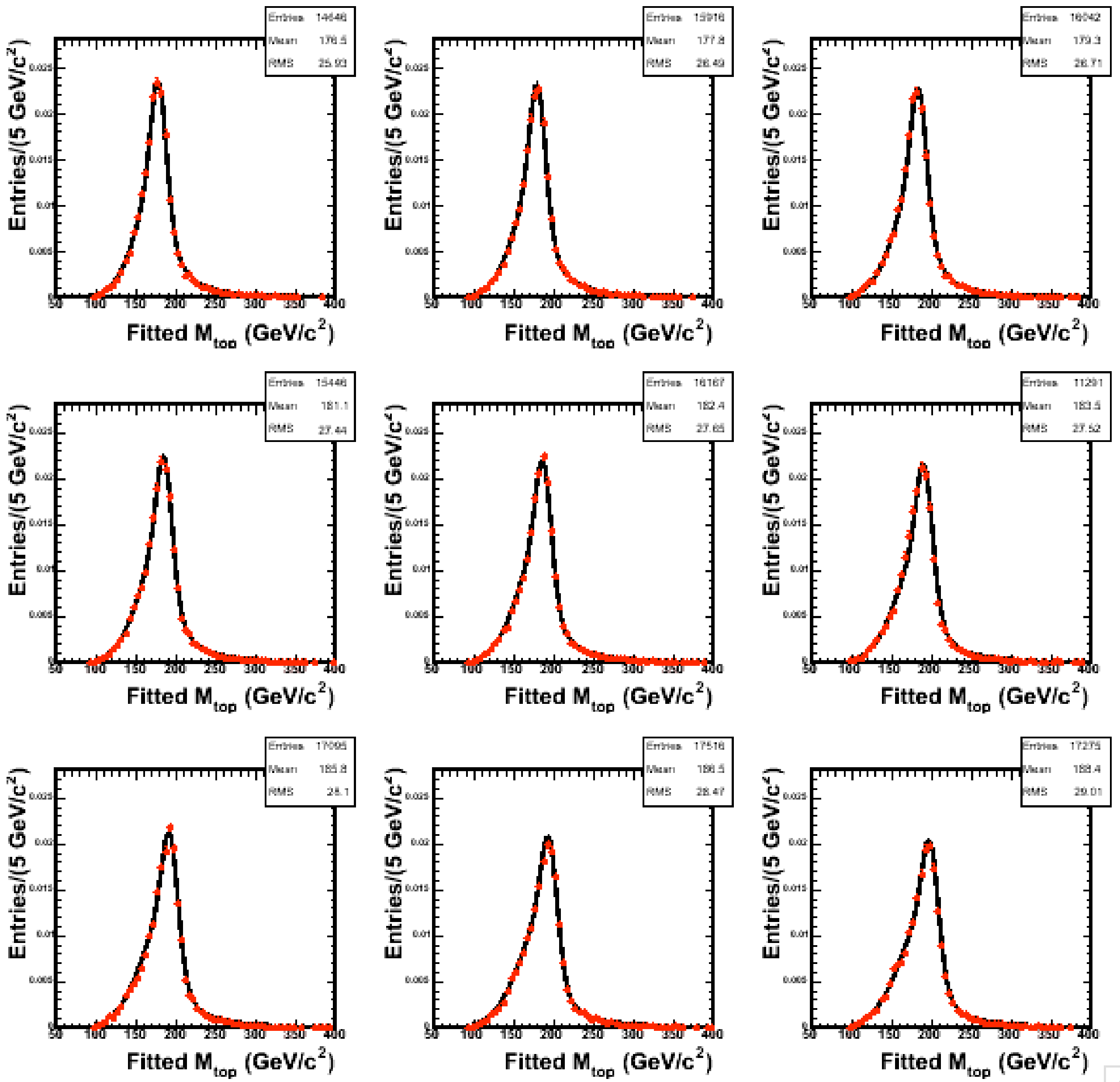
- ***statistics*** huge background → **dramatically reduced**
- ***systematics*** jet energy scale → **work in progress-results soon**

Back up slides

More background validation




Entries/(5 GeV/c²)
Fitted M_top (GeV/c²)



Entries 14646
Mean 176.5
RMS 25.93
Entries 15916
Mean 177.8
RMS 26.49
Entries 16042
Mean 179.3
RMS 26.71
Entries 15446
Mean 181.1
RMS 27.44
Entries 16167
Mean 182.4
RMS 27.65
Entries 11291
Mean 183.5
RMS 27.52
Entries 17095
Mean 185.8
RMS 28.1
Entries 17516
Mean 186.5
RMS 28.47
Entries 17275
Mean 188.4
RMS 29.01
Entries/(5 GeV/c^2)
Fitted M_{top} (GeV/c^2)