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DØ RunII Top Mass Measurement with the Matrix Element Method

for the DØ collaboration

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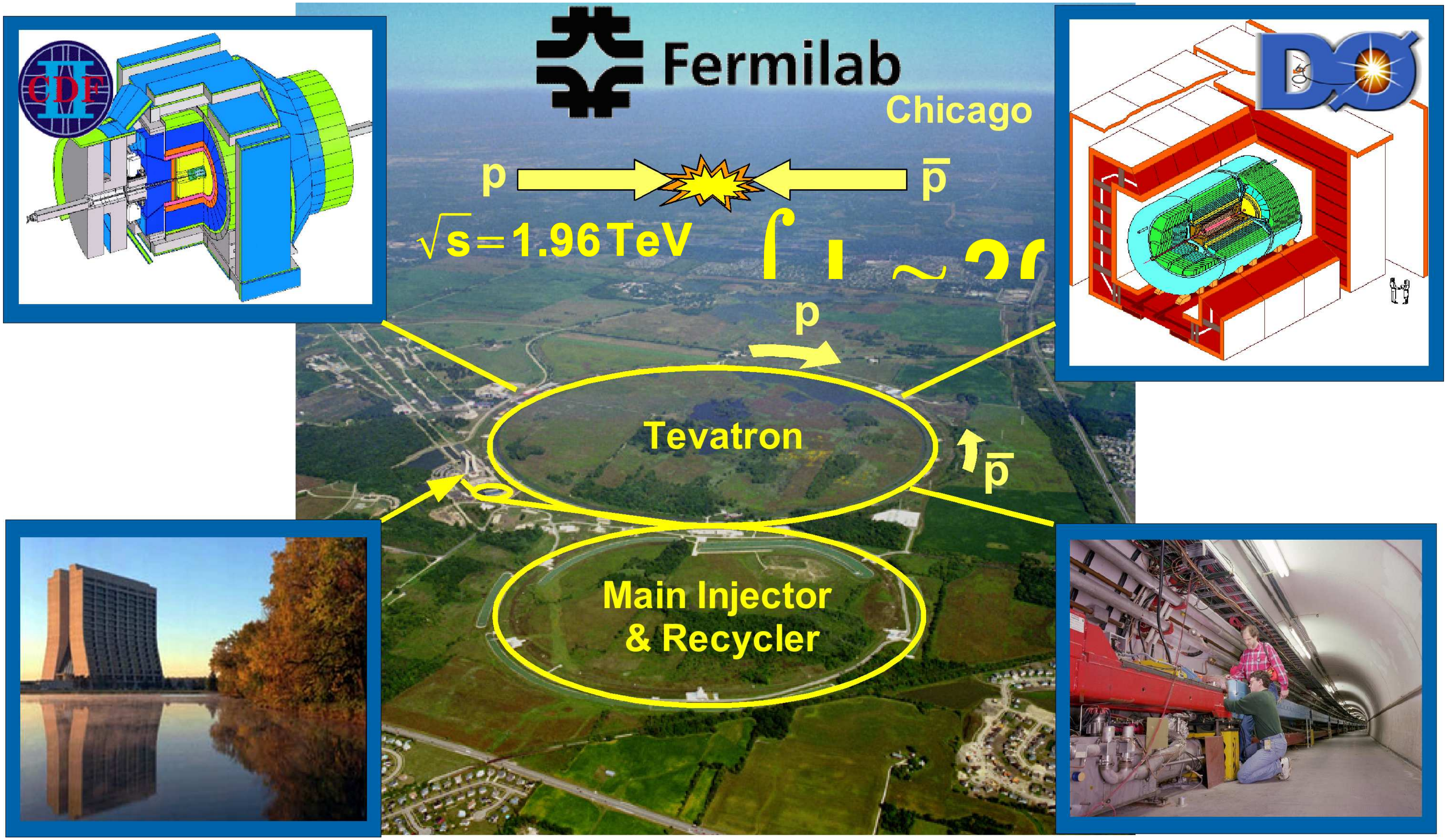
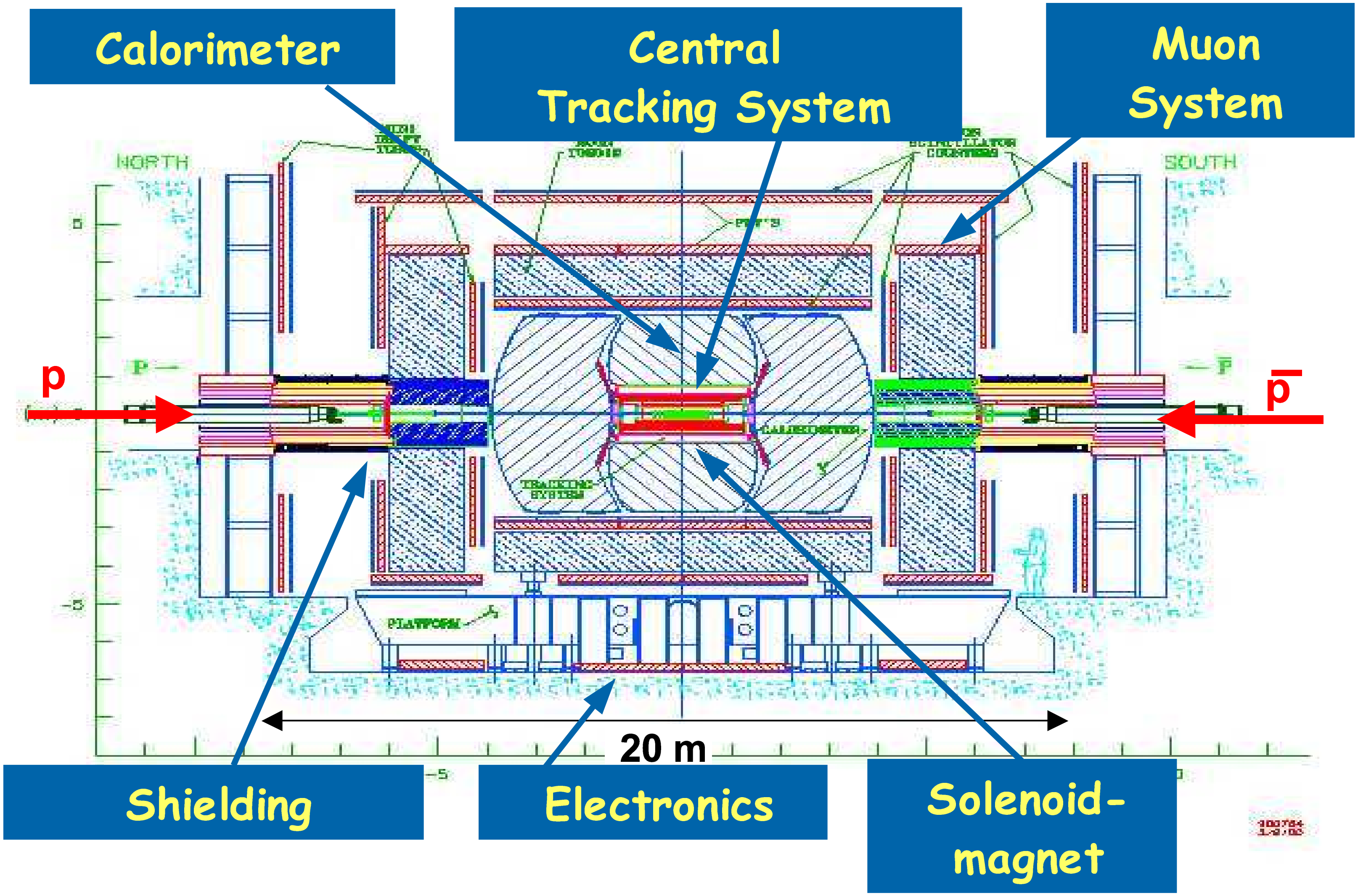
Tevatron: Run II

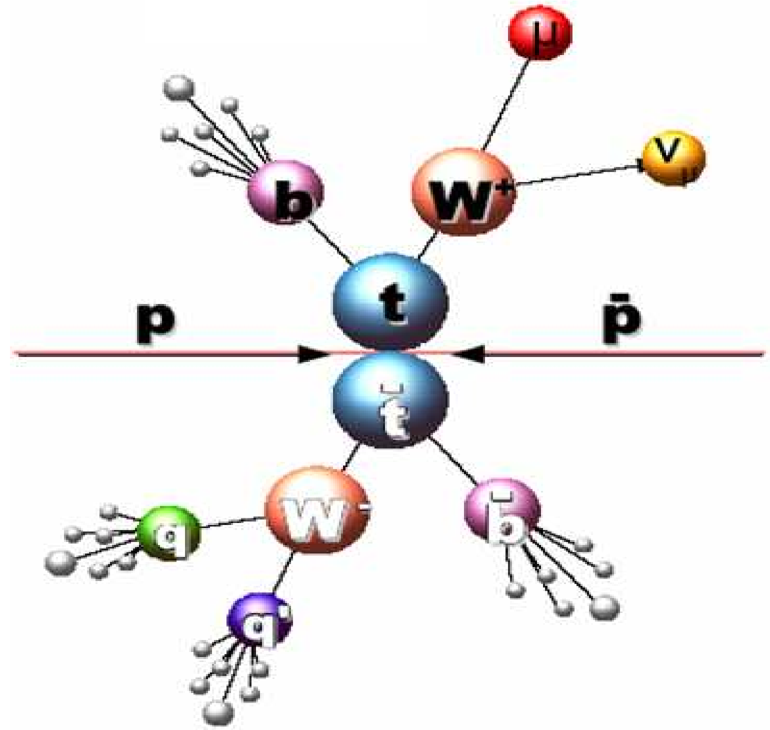


DØ Detector



Calorimeter
Central Tracking System
Muon System
p
p̄
NORTH
SOUTH
20 m
Shielding
Electronics
Solenoid-magnet

Top Quark Physics



Production:

- pair production
- 85% Annihilation
- 15% Gluon-Fusion

Decay:

- top decays exclusively to W+b
- W decays to qq' or lν

Channels:

- di-lepton
- **lepton+jets** signature →
- all-jets

1 isolated letpon (e or μ)
Missing Transverse Energy
4 Calorimeter Jets

Backgrounds:

- W+jets
- Multijet (QCD)

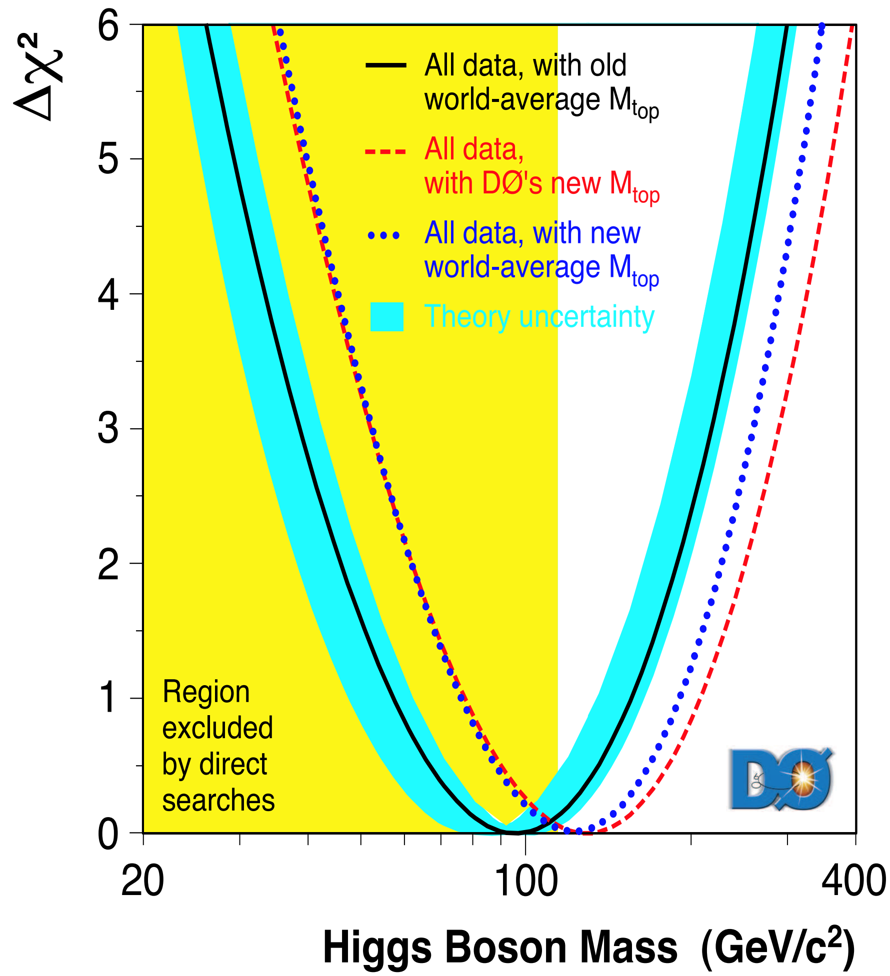
Top Quark Mass

- Top-quark mass not predicted by SM (free parameter)
- Best known relative quark mass ($\Delta m/m \approx 0.03$)
- m_{top} input to EW fits $\longrightarrow$ m_{Higgs}
- <u>Run I Tevatron Result:</u>

  $m_{top} = 178.0 +/- 4.3\ GeV/c^2$

  TevEW/Top working group hep-ex/0404010

  -> Matrix Element Method!
- <u>Run II Goal:</u>
  reduce uncertainty to ~3 GeV



Matrix Element Method I

- Use full kin. information to calculate probability for each event being a top event as a function of the top mass
- Probability is proportional to differential cross section
- Calculate background probability in a similar way and build event probability

$$\rightarrow \boxed{P(x;M_{top}) = c\,P_{t\bar{t}}(x;M_{top}) + (1-c)\,P_{bkg}(x)}$$ x: kin. variables

- Combine all event probabilities to likelihood
- Extract top mass by minimizing the negative likelihood w.r.t. the top mass hypothesis

Matrix Element Method II

- **Signal Probability:**

$$P_{t\bar{t}}(x;M_{top}) = \sum_{comb+\nu} \int d\rho_1 dp_z^{\nu} dm_{qq}^2 dM_{bqq}^2 dM_{bl\nu}^2 |\mathbf{M}|^2 \frac{f(q_1)}{|q_1|}\frac{f(q_2)}{|q_2|} \Phi_6 \prod_{i=1}^{4} W_{jet}(E_i^{parton}, E_i^{jet})$$

all jet permutations and neutrino solutions taken into account!

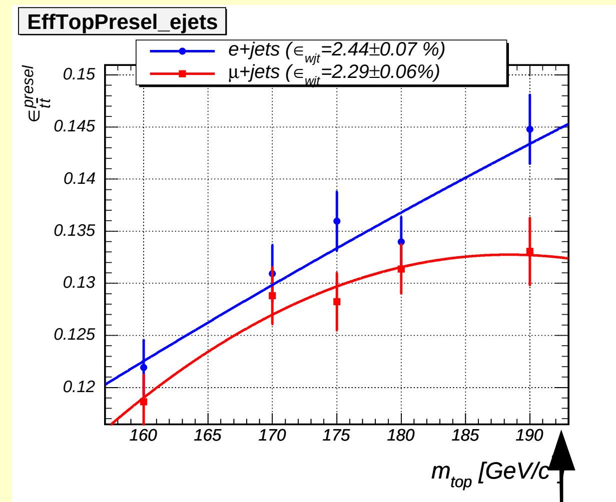
- LO MatrixElement $|M|^2$ x Flux Factor
- Phase space Φ_6 x PDFs $f(q_i)$
- Transfer Functions $W_{jet}(x,y)$ (energy resolution):
  - Prob. to measure E'=y (jet) if E=x (parton) was produced
  - Derived from Monte Carlo
  - All jet angles assumed to be perfectly measured

- Acceptance Corrections
- 5 integrations -> very CPU intensive analysis

Event Selection

Topological Selection

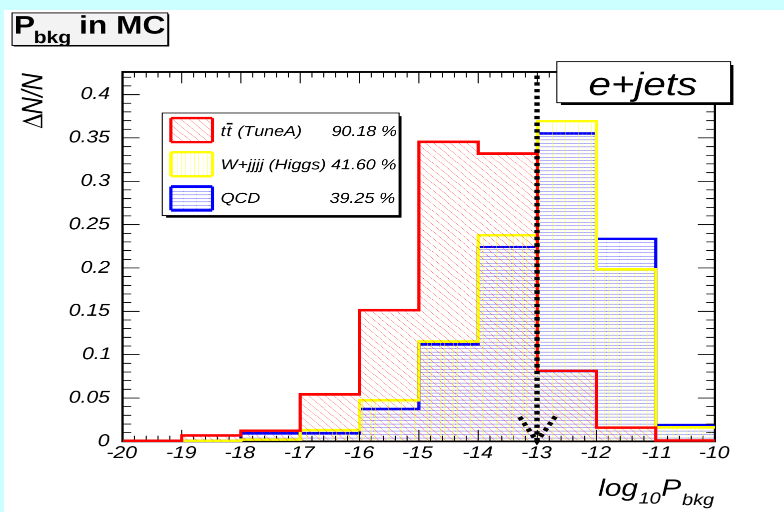
- 1 isolated lepton, p_T>20 GeV/c
- Missing Transverse Energy
- Exactly 4 calorimeter jets, p_T>15 GeV/c, |η|<2.5
- Three leading jets: p_T>20 GeV/c

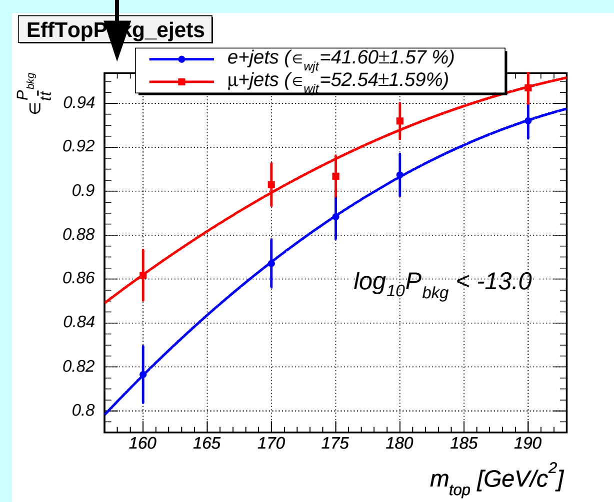


Selection efficiencies

$\log_{10}P_{bkg}$<-13

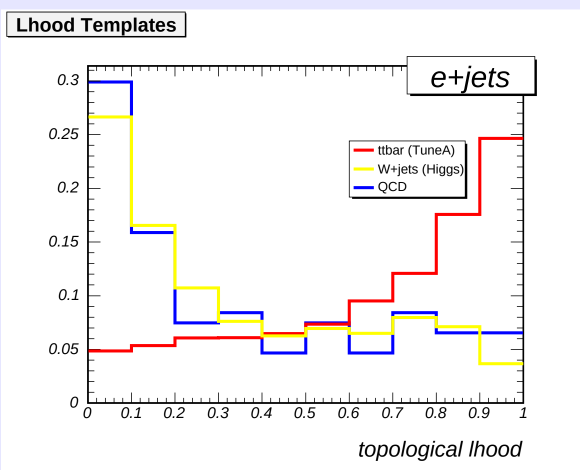
- increasease purity of sample



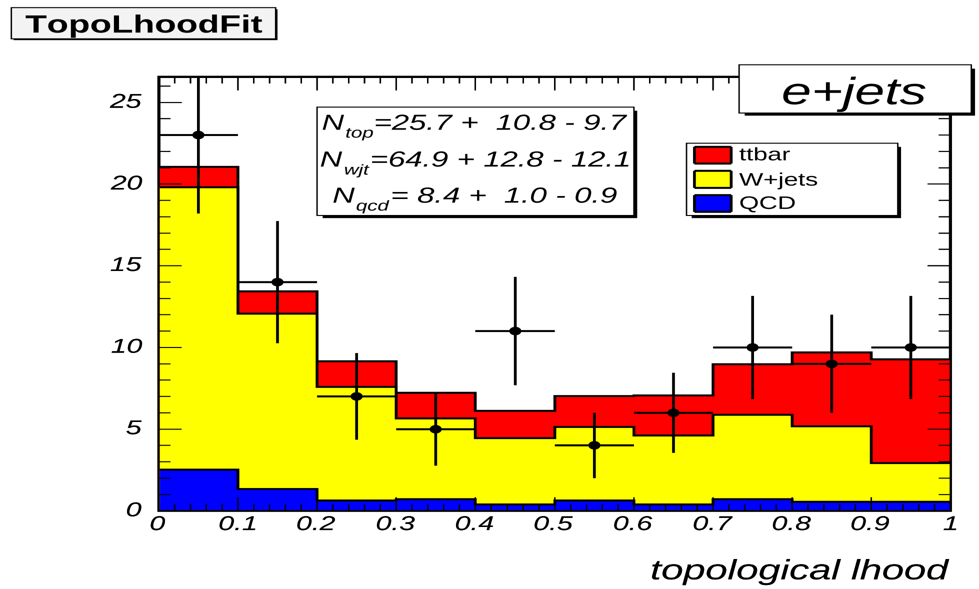


Sample composition

Topological likelihood template



fit



P_{bkg} efficiencies (MC)

	e+jets	μ+jets
Top	0.889	0.915
Wjjjj	0.416	0.525
QCD	0.393	0.549

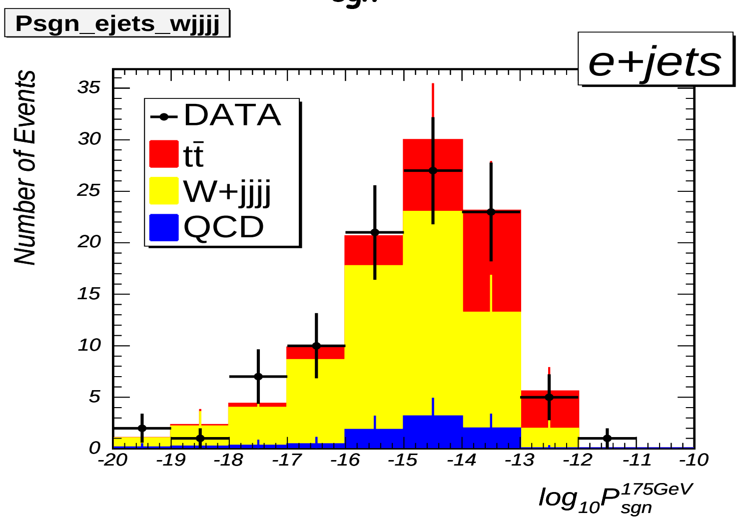
Sample composition

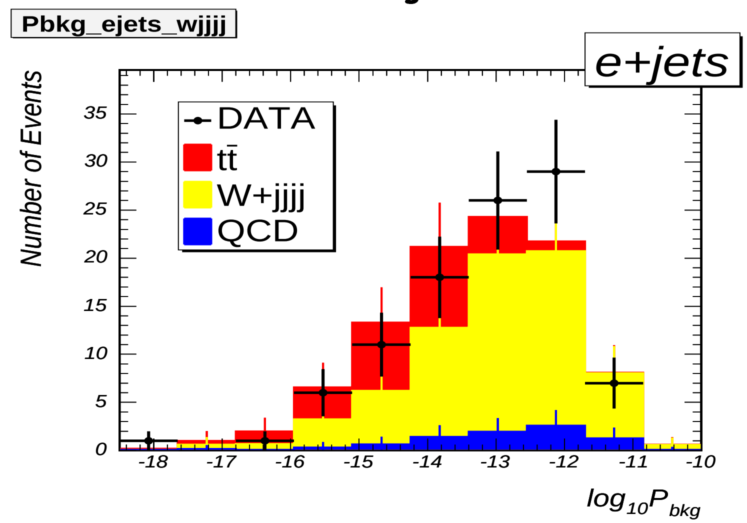
	e+jets	μ+jets
N_{events}	45	40
f_{top}	0.430	0.450
f_{QCD}	0.062	0.065
Lumi	$159pb^{-1}$	$148pb^{-1}$

P_{sgn}/P_{bkg} : Data vs MC

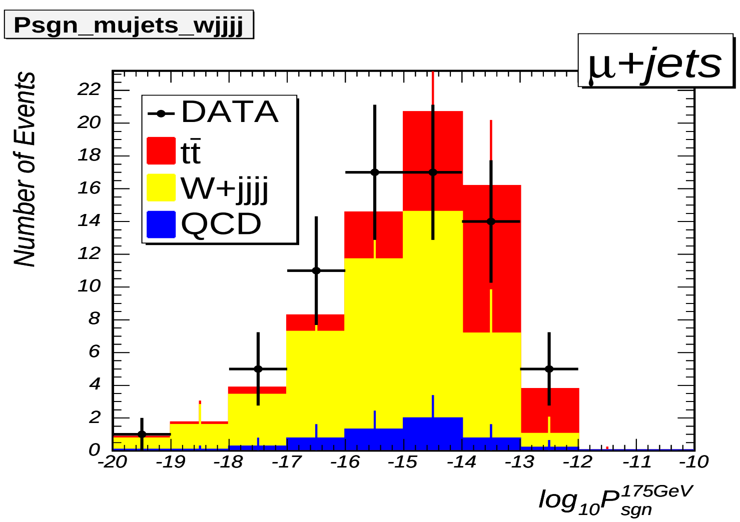
P_{sgn} P_{bkg}

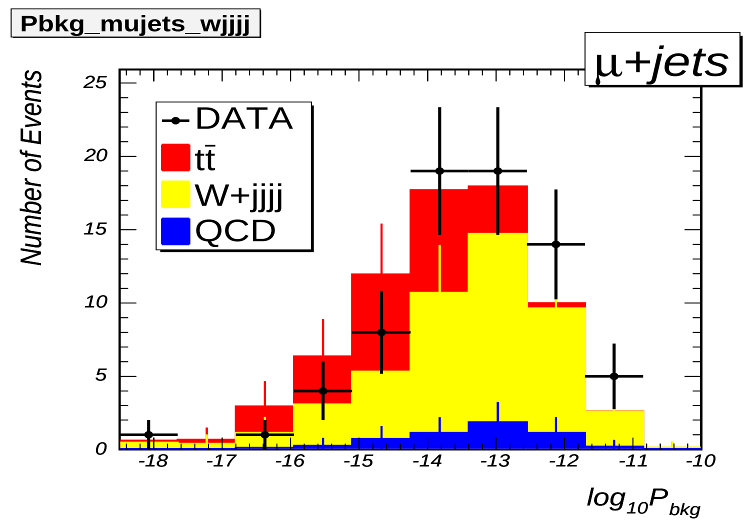
e+jets





μ+jets





Mass Calibration I

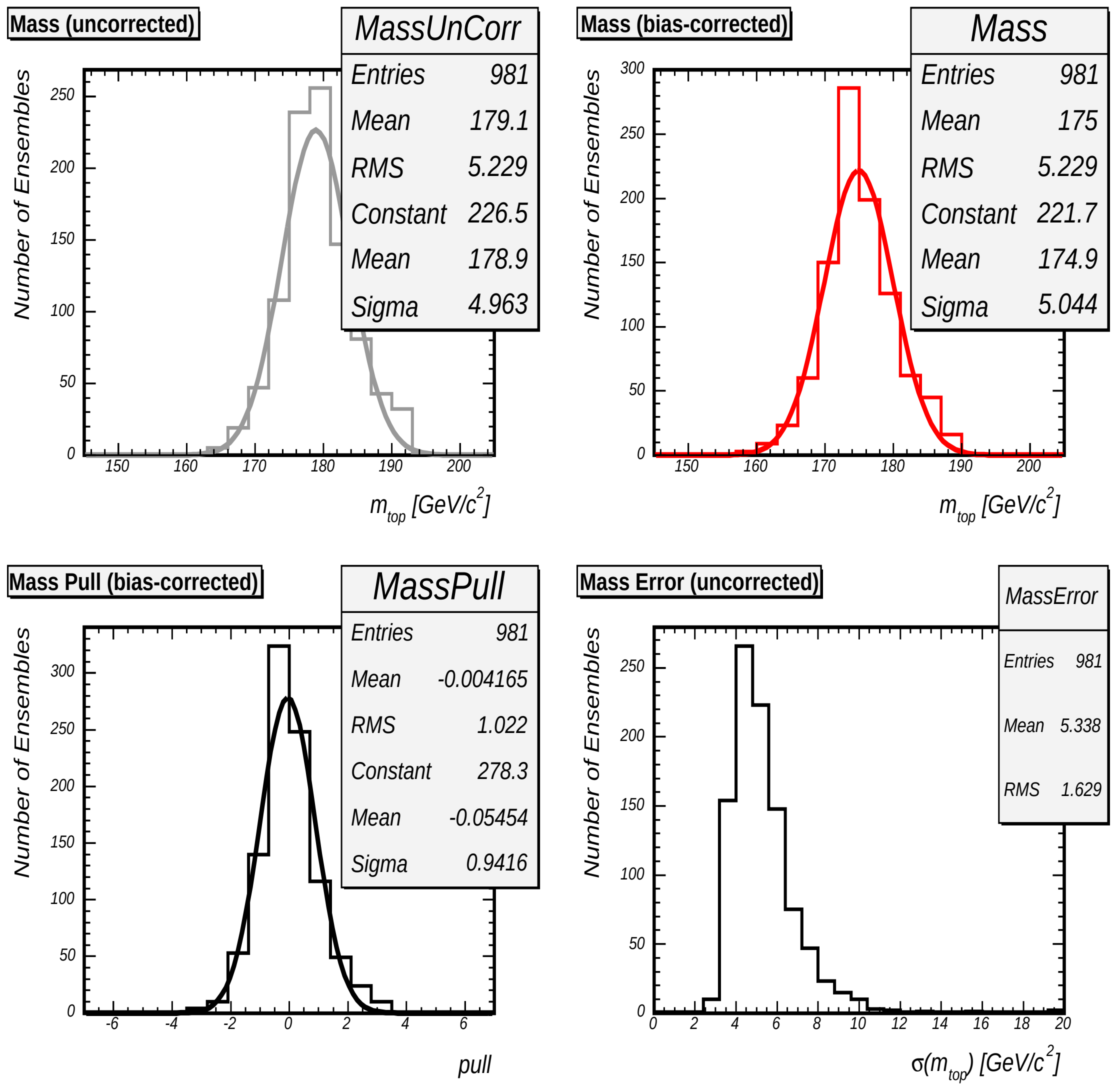
- Ensemble Tests
- 1000 ensembles
- 5 mass points
  (160 GeV/c^2 - 190 GeV/c^2)
- Events drawn from pool multiple times in different ensembles

↓

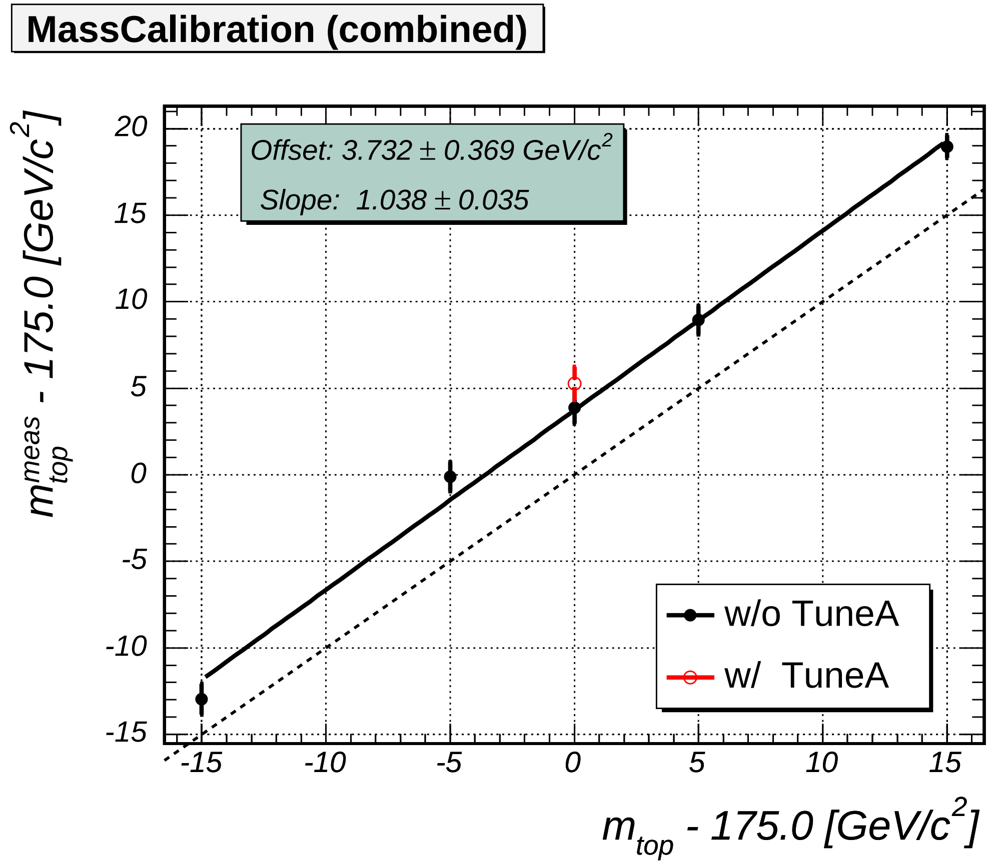
Mass Bias:	~ 3.5 GeV/c^2
Exp. Stat. Err.:	~ 5.0 GeV/c^2
Pull (RMS):	~ 1.0

e+jets/μ+jets combined)

→ **Calibration**



Mass Calibration II



Note:

The simulation of the underlaying event was found not optimal in the MC samples generated for this study.

This is currently treated as a systematic uncertainty by comparsion to an optimized MC sample for m_{top}=175 GeV/c^2

Offset: 3.7 +/- 0.4 GeV/c^2
Slope: 1.04 +/- 0.04 GeV/c^2

Systematic Uncertainties

- Systematic uncertainties derived from Monte Carlo
- Dominated by systematic uncertainty from Jet Energy Scale
- Improvement of DØ JES measurement highest priority for top group!

Syst. Uncertainty	Combined [GeV/c^2]	
Jet Energy Scale	+5.0	-3.7
Calibration	+0.5	-0.5
Signal Modelling	+2.2	-2.2
Background Modelling	+2.0	-2.0
Jet Energy Resolution	+2.0	-2.0
P_{bkg} cut vartiation	+1.0	-1.0
Multi Parton Interactions	+1.2	-1.2
Transfer Functions	+1.0	-1.0
top fraction c_1	+0.5	-0.5
trigger turn on	+0.5	-0.5
likelihood fit procedure	+0.5	-0.5
acceptance corrections	+0.1	-0.1
TOTAL	**+6.5**	**-5.6**

preliminary

Summary and Outlook

Summary:

- Matrix Element Method established for RunII
- Extensively studied and fully calibrated on Monte Carlo
- Application to Data currently under collaboration review

Outlook:

- Fix mass bias caused by signal probability calculation
- Improve Jet Energy Scale measurement
- Include b-tagging to
  - improve signal-to-background ratio
  - reduce combinatoric background (jet-parton permutations)