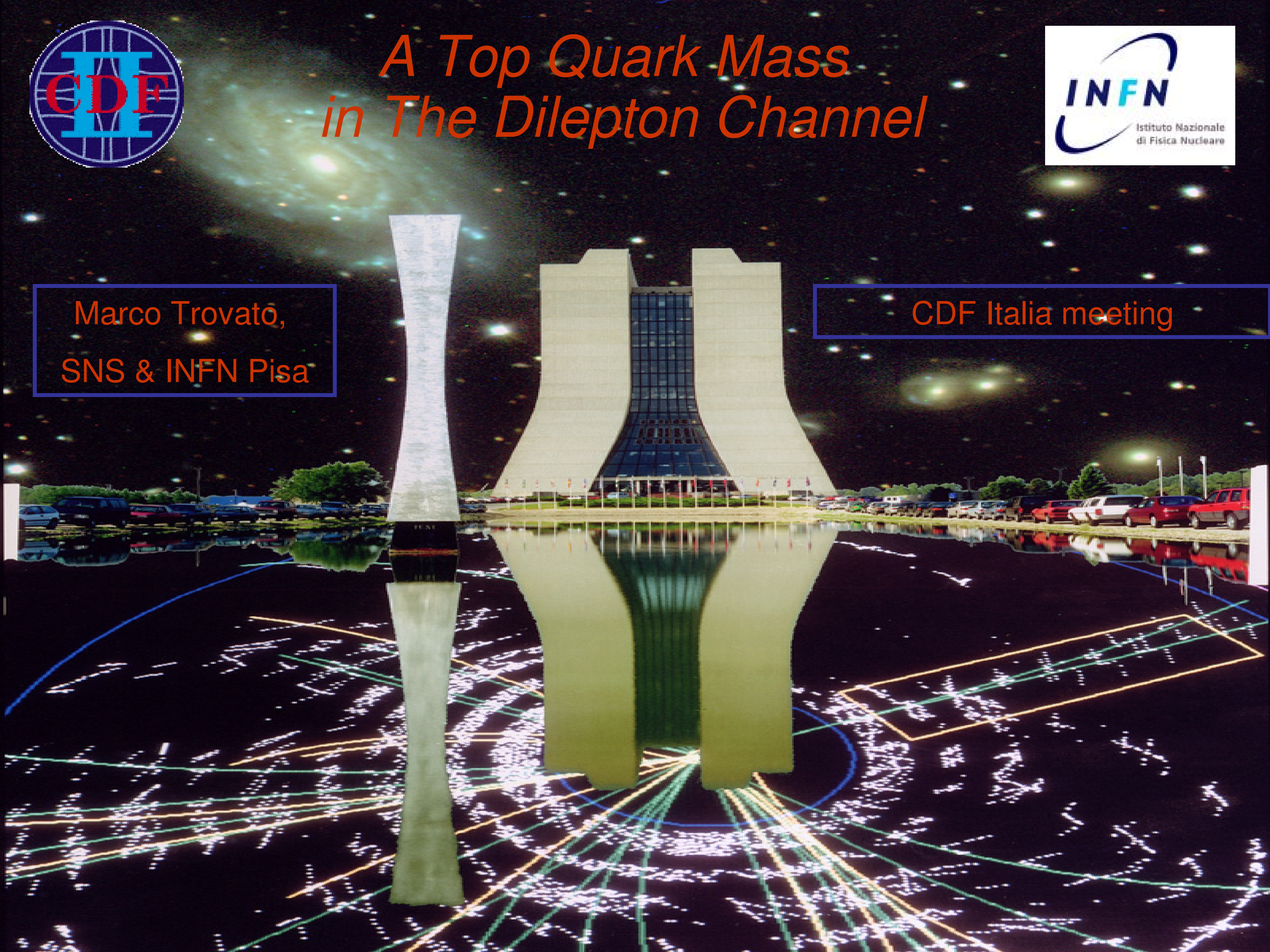
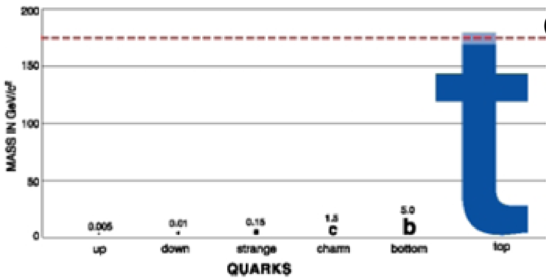
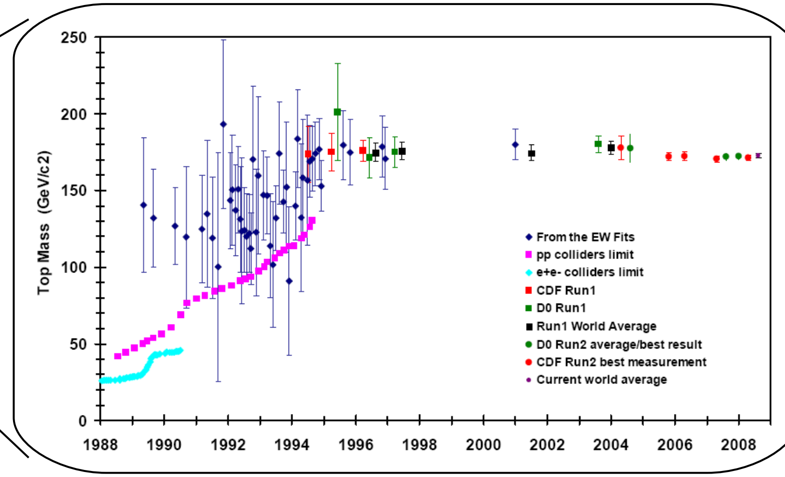


A Top Quark Mass
in The Dilepton Channel
Marco Trovato,
SNS & INFN Pisa
CDF Italia meeting

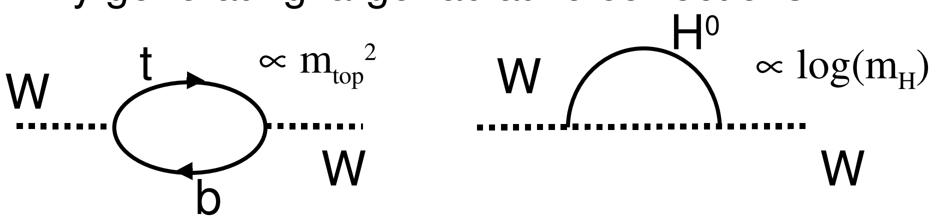
Top mass measurement: Motivation

- **_Enormous mass_**
  - Same scale as EWSB
  - Yukawa coupling of ~ 1

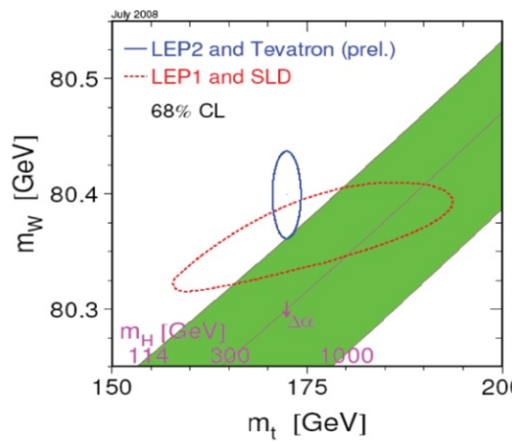




- **_Within the SM_**
  - By generating large radiative corrections



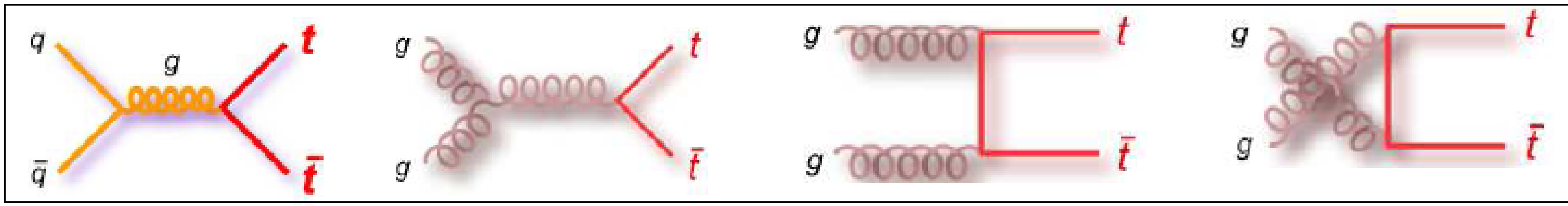
helps constraining the Higgs mass



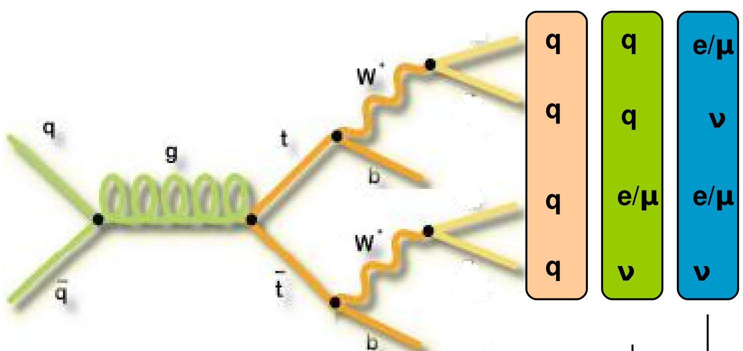
- **_Beyond the SM_**
  - discrepancies in the results across different decay channels could provide hints of new physics

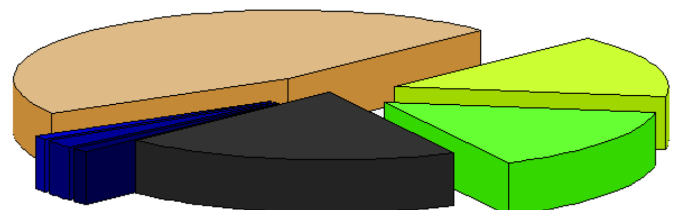
Top Production and Signature

Produced in pairs mainly via strong interactions → ~ 6.7 pb (Mtop =175 GeV)



Decaying in Wb ~ 100 % of the times → 3 possible signatures depending on W's products



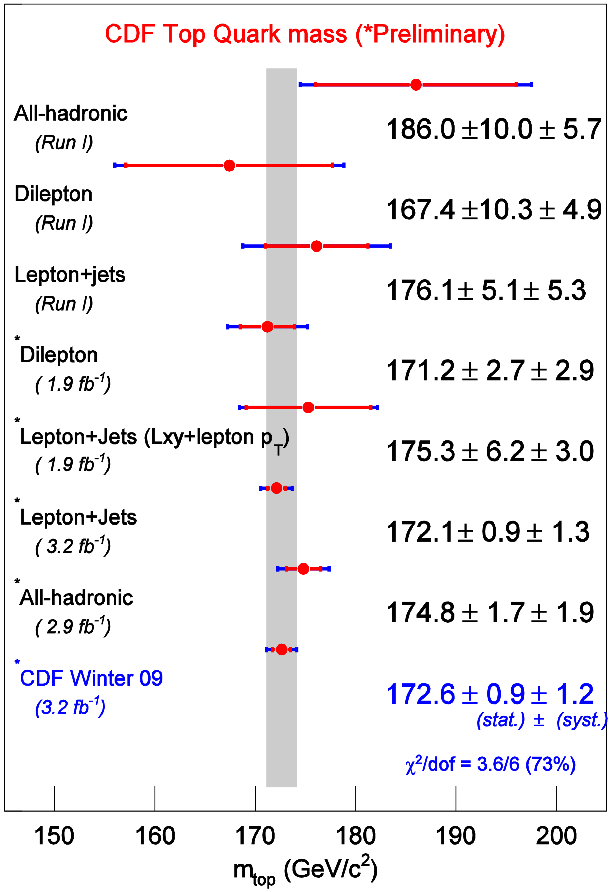


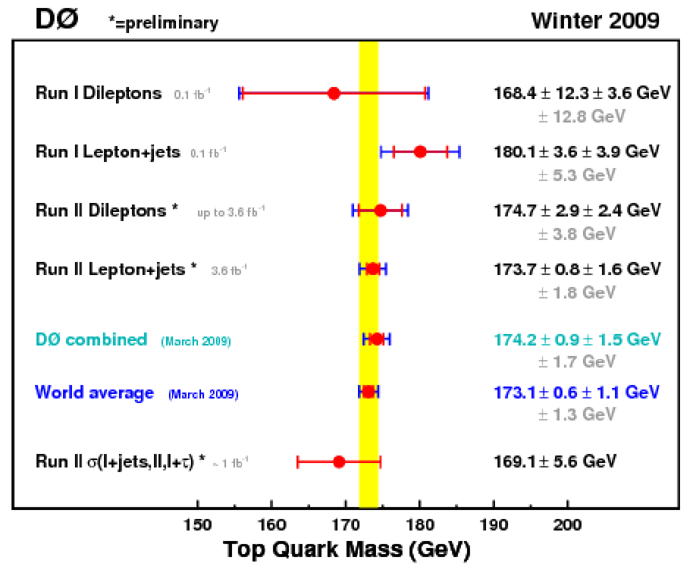
all jets 44%
→ 2 b-jets
→ 4 q-jets

dilepton 5%
→ 2 b-jets
→ 2 high PT e/ μ
→ large missing transverse energy (MET)

l+jets 30%
→ 2 b-jets, 2 q-jets
→ high PT e/ μ
→ large MET

State of the art @ Tevatron





arXiv:0903.2503

Tevatron world average (March '09)

$$M_{top} = 173.1 \pm 0.6\,(stat.) \pm 1.1\,(syst.)\ GeV$$

$$(\delta M_{top} / M_{top} = 0.75\%)$$

Dilepton channel

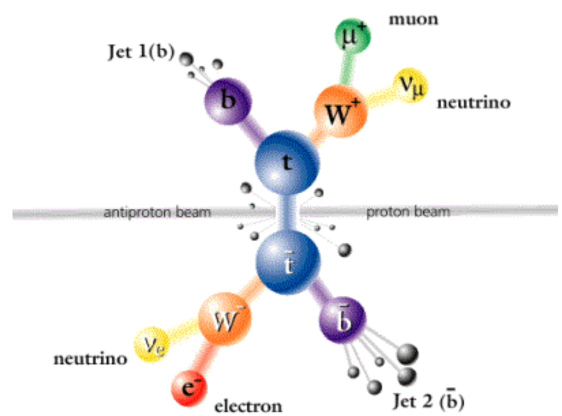
❑ Features

→ Very clean sample (S:B ~ 3:1)

→ Less affected from JES systematic (2 jets)

→ Low statistics

→ Unconstrained kinematics (2 neutrinos)



❑ Importance

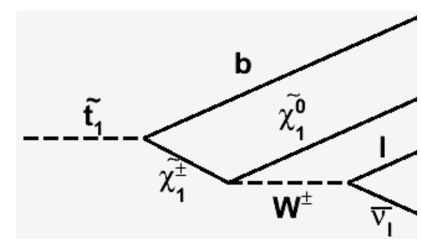
- As uncorrelated sample:

  → contribute to improve overall resolution on M_{top}

- Due its unique bg:

  → helps including/excluding other non-SM signal processes (stop)

  → sensitive to non-SM background processes



A particular top mass measurement

Documentation for this work:

- 340/pb: PRD 73 112006, CDF note 7641
- 2.9/fb: CDF notes 9048, 9433, 9505, **arXiv:0901.3773**

Authors: *I. Suslov, M. Trovato, G. Velev, V. Glagolev, Oleg Pukhov, G. Bellettini, G. Chlachidze, J. Budagov, Alexei Sissakian*

Selection of the events: LTRK algorithm

General cuts

✓ A well identified isolated lepton ("tl")

electron { Cluster E_T > 20 GeV

muon { P_T >20 GeV

✓ A well isolated track lepton (trkl)

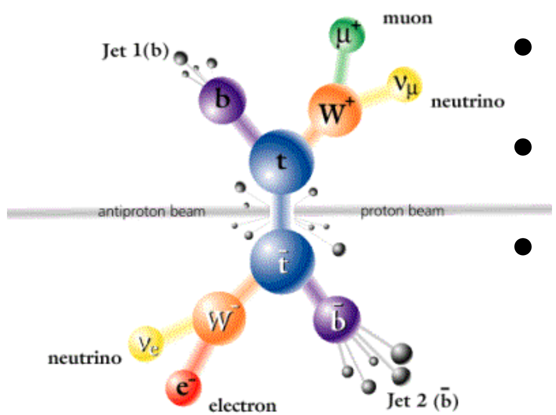
→ P_T > 20 GeV

✓ Two or more jets

→ $E_T^{@L5}$ > 20 GeV

✓ Missing energy

→ $\not{E}_T > 25$ GeV



Vetoes

- MET < 40 GeV
  $(\text{if } 76\ \text{GeV}/c^2 < M_{tl-trkl} < 106\ GeV/c^2)$
- Cosmic
- Same sign dilepton ltrk
- Δφ(tl, MET) < 5°;> 175°
- Δφ(trkl, MET) < 5°
- Δφ(MET, jet) < 25°
  (if MET<50GeV)

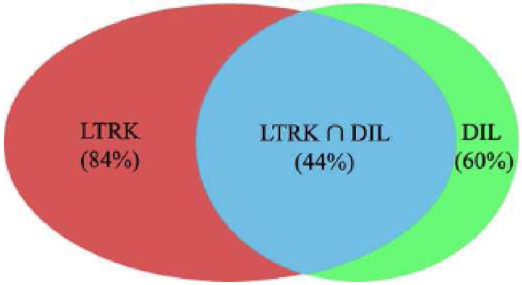
Why LTRK?

Compared to the other competive selection (DIL)

1) Statistics is increased at the price of higher (but well modeled) background rates

PRD 73 112006	DIL	LTRK
Luminosity	340 pb^{-1}	360 pb^{-1}
Expected $t\bar{t}$	15.7 ± 1.3	19.4 ± 1.4
Drell-Yan	5.5 ± 1.2	8.7 ± 3.3
$W(\to \ell\nu)$ + jets fakes	3.5 ± 1.4	4.0 ± 1.2
Diboson	1.6 ± 0.3	2.0 ± 0.4
Total background	10.5 ± 1.9	14.7 ± 3.6
Total expected	26.2 ± 2.3	34.1 ± 3.9
Observed	33	46

6) We investigate a sample otherwise unexplored



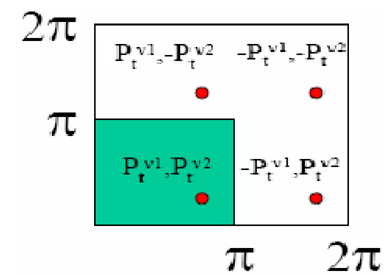
Percentaged normalized to LTRK U DIL

The method: event by event

- Constrain the kinematics – PHI method:

  Assume φ_1, φ_2 of the neutrinos as known

  → optimal 144 point grid created in $(0,\pi)\times(0,\pi)$



- Kinematical event reconstruction*:*

  → for each (φ_1,φ_2) we minimize χ^2 with respect to $\tilde{M}_t$

$$\chi^2 = \chi^2_{reso} + \chi^2_{constr}$$

$$\chi^2_{reso} = \sum_{l}^{2} \frac{(P_T^l - \tilde{P}_T^l)^2}{\sigma^2_{P_T^l}} + \sum_{l}^{2} -2\ln(\wp_{tf}(P_T^j \mid \tilde{P}_T^l)) + \sum_{i=x,y} \frac{(UE^i - \widetilde{UE}^i)^2}{\sigma^2_{UE^i}}$$

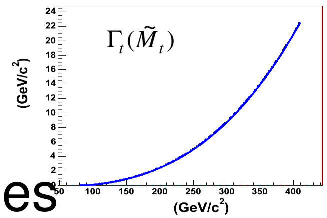
$$(P_T^{part} - P_T^{jet}) / P_T^{jet}$$

$$\chi^2_{constr} = -2\ln(BW(m_{inv}^{l_1\nu_1} \mid M_W, \Gamma_{M_W})) - 2\ln(BW(m_{inv}^{l_2\nu_2} \mid M_W, \Gamma_{M_W})) - 2\ln(BW(m_{inv}^{l_1\nu_1 j_1} \mid \tilde{M}_t, \Gamma_{\tilde{M}_t})) - 2\ln(BW(m_{inv}^{l_2\nu_2 j_2} \mid \tilde{M}_t, \Gamma_{\tilde{M}_t}))$$

$$BW = \frac{\Gamma^2 M^2}{(m_{inv}^2 - M^2)^2 + \Gamma^2 M^2}$$

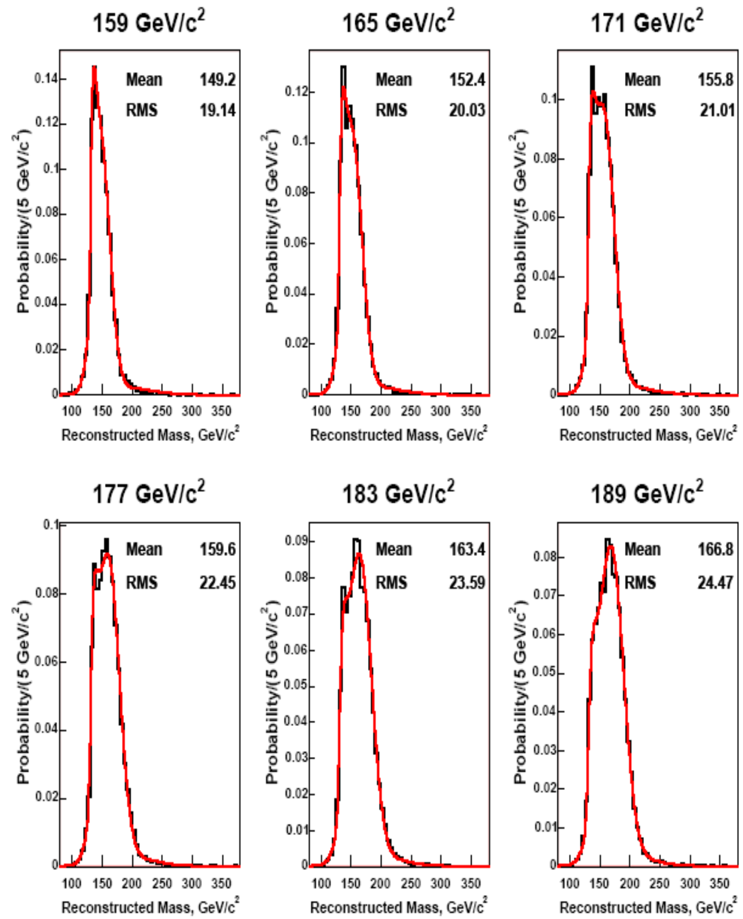
- Best event top mass (M_t^{reco})*:*

  → a weighted average of the 144 masses



The method: signal templates

A signal mass template defines the probability density function to renconstruct M_t^{reco} from a ttbar event generated with M_t



Signal templates are built from events generated within a top mass range 155-195 GeV/c2

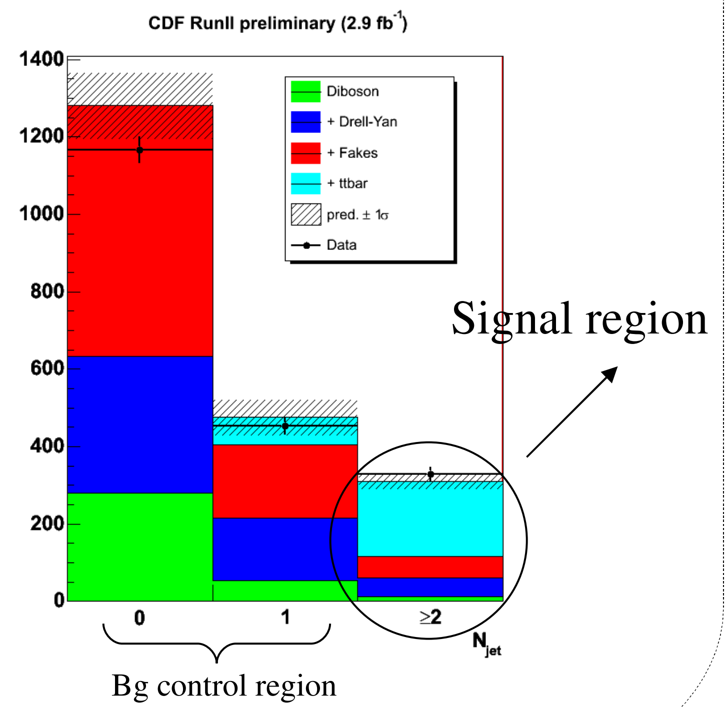
- Templates are parametrized with analytic functions (f_s) depending on M_t

Bg contamination

- LTRK sample is affected by three main bg processes: DY, Diboson, W+jets ("fakes")
  → DY & Diboson are simulated and weighted according to their cross-section
  → Fakes are obtained from data

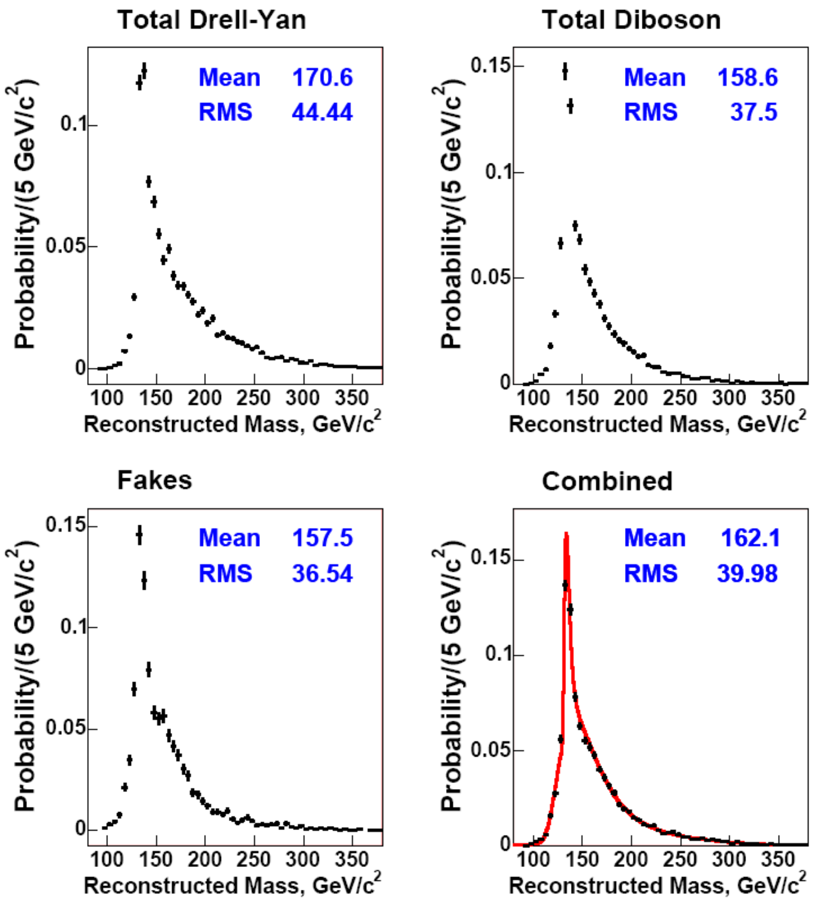
Reconstructed events are normalized to the expected rates

Process	Expected rate ($\int Ldt = 2.9/fb$)
Signal (ttbar)	162.6 ± 5.1
Diboson	15.2 ± 1.0
Drell-Yan	49.6 ± 7.2
Fakes	80.2 ± 15.7
Total background	145.0 ± 17.3



The method: bg templates

A bg mass template defines the probability density function to renconstruct M_t^{reco} from a non-ttbar event



- Templates are parametrized with analytic functions (f_b) M_t - undependent

The method: Likelihood

- *The likelihood expresses the probability that a M_t^{reco} distribution be obtained from a sample of N events composed of n_s signal events and n_b background events*

$$\mathscr{L} \equiv \mathscr{L}_{shape} \cdot \mathscr{L}_{backgr} \cdot \mathscr{L}_{param}$$

$$\mathscr{L}_{shape} \equiv \frac{e^{-(n_s+n_b)} \cdot (n_s+n_b)^N}{N!} \cdot \prod_{n=1}^{N} \frac{n_s \cdot f_s(m_n|M_{top}) + n_b \cdot f_b(m_n)}{n_s+n_b}$$

Fit parameters

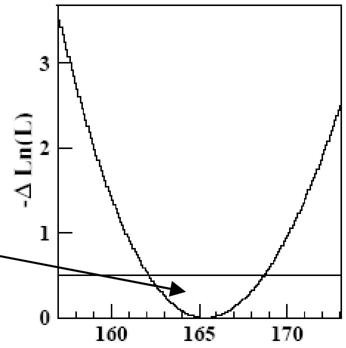
$$\mathscr{L}_{backgr} \equiv exp(\frac{-(n_b - n_b^{exp})^2}{2\sigma^2_{n_b^{exp}}})$$

Expected background rate and its uncertainty

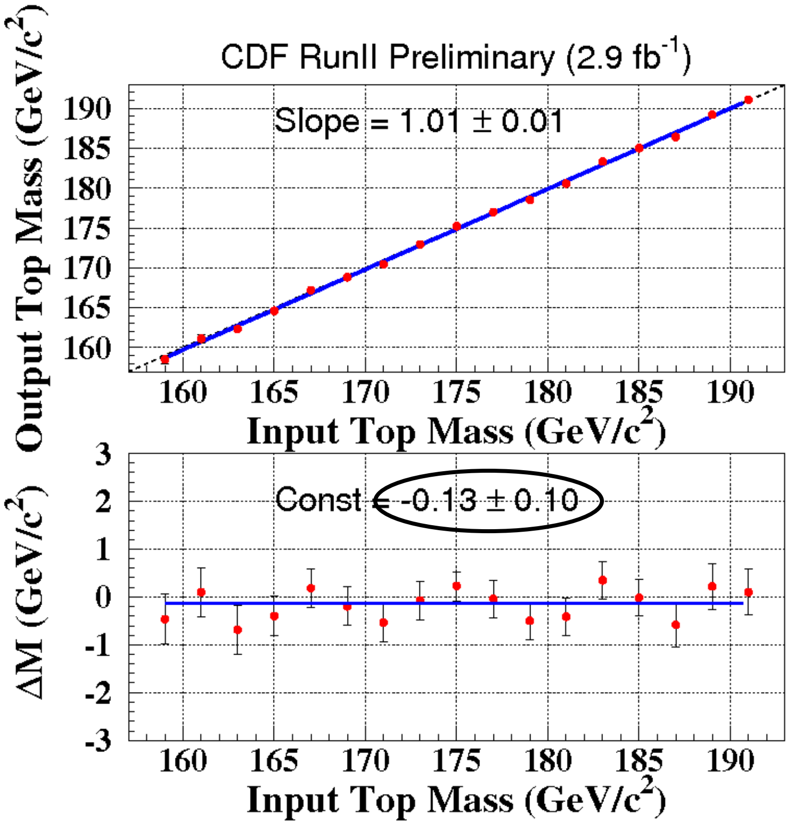
$$\mathscr{L}_{param} \equiv exp\{-0.5[(\vec{\alpha} - \vec{\alpha_0})^T U^{-1}(\vec{\alpha} - \vec{\alpha_0}) + (\vec{\beta} - \vec{\beta_0})^T V^{-1}(\vec{\beta} - \vec{\beta_0})]\}$$

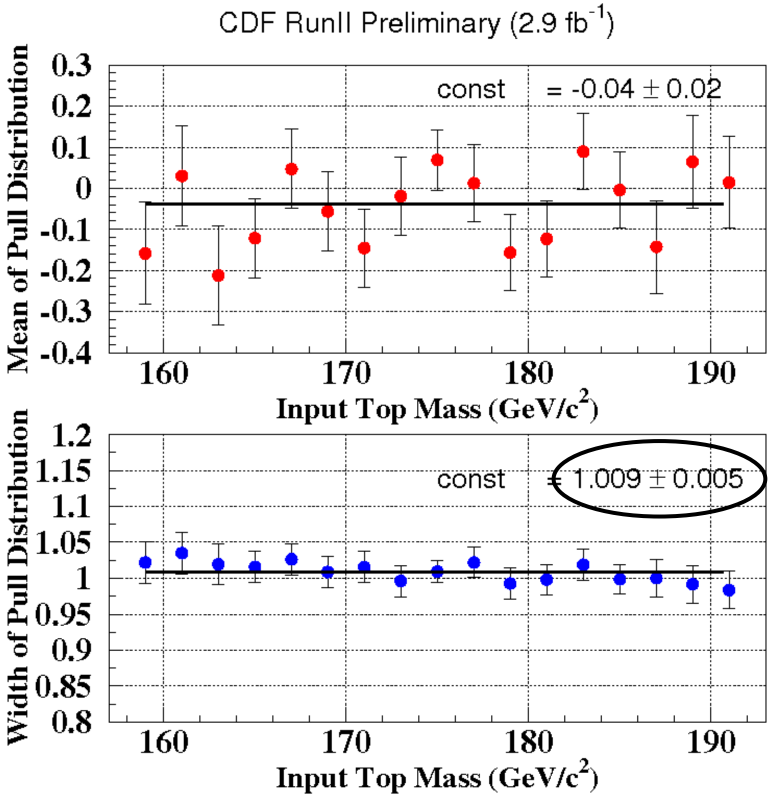
Template parametrizations and covariance matrices

M_{top} corresponds to –ln[L]$_{min}$



Calibrations





$M_{top} \rightarrow M_{top} = M_{top} - 0.13\, GeV/c^2$ to correct for the bias

$\sigma(M_{top}) \rightarrow \sigma(M_{top}) = \sigma(M_{top}) * 1.009$ to correct for error underestimation

Systematic uncertainty

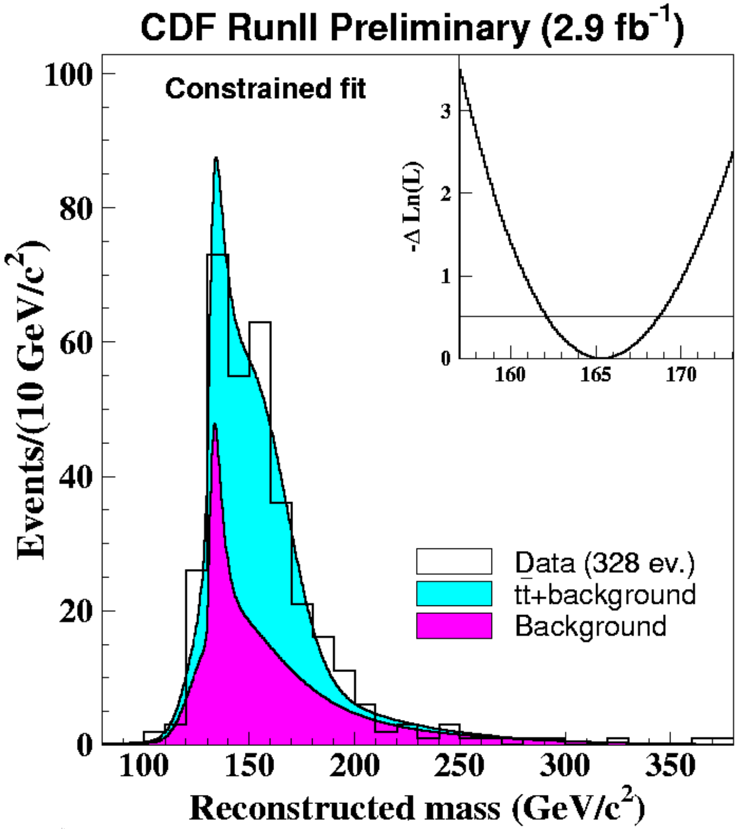
Source	Uncertainty (GeV/c^2)
Jet energy scale	2.9
b-jet energy scale	0.4
Lepton energy scale	0.3
Monte Carlo generators	0.2
Initial and final state radiation	0.2
Parton distribution functions	0.3
Luminosity profile (pileup)	0.2
Background composition	0.5
Fakes shape	0.4
Drell-Yan shape	0.3
Total	**3.1**

❖ JES is ~94% of the overall systematic uncertainty

Results in Data: Constrained Fit

$$\int L dt = 2.9 / fb$$

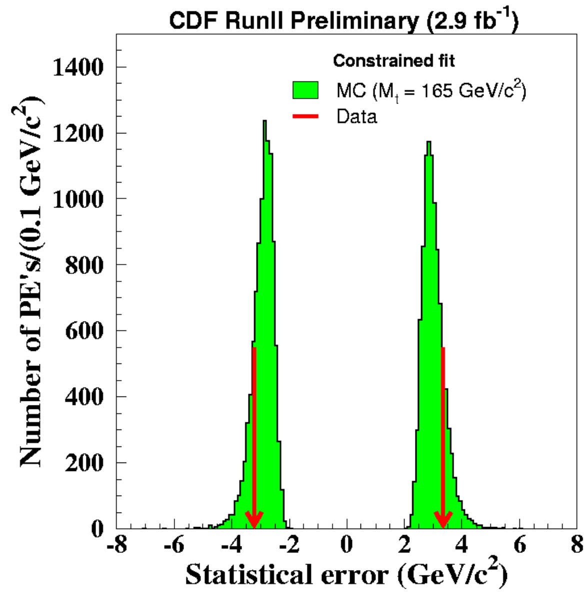
$$\rightarrow N_{bg}^{\exp} = 145.0 \pm 17.3$$



Fit result

$$N_{bg} = 146.1 \pm^{15.1}_{15.0}$$

$$M_{top} = 165.35 \pm^{3.35}_{3.22} \text{ (stat.) } GeV / c^2$$



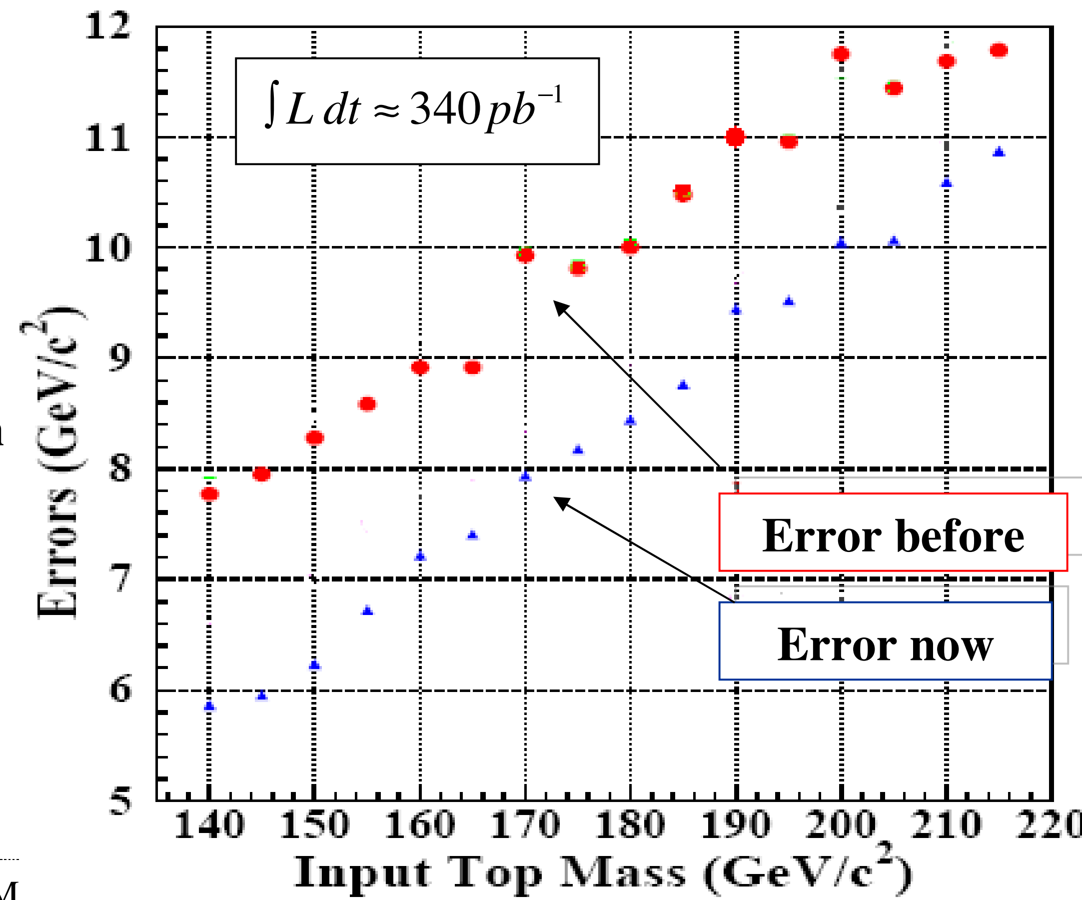
18% PE's with larger error

Previous Result and Improvement

With respect to the previous published result

$$(M_{top} = 169.7^{+8.9}_{-9.0}(stat) \pm 4.1(syst)\ GeV/c^2),\ \text{PRD 73 2006}$$

we note:



A ~ 20% improvement in mass sensitivity due to the introduction in the χ^2 of a BW instead of a Gaussian distribution

Conclusions

$$M_{top} = 165.5 \pm^{3.4}_{3.3} (stat) + 3.1 (\mathrm{Syst})\, GeV / c^2$$

- First dilepton mass measurement with ~ 3/fb data

→ first to investigate the LTRK sample at high luminosities (50% overlap with DIL sample)

→ first to use relativistic Breit-Wigner distribution function and top-mass dependent top width in the kinematical event reconstruction

- Plans at nex step:
  - Analysing separately b-tagged and untagged events
  - Exploiting event by event probability
  - Increasing statistics

BACKUP

DØ: Orthogonal measurement

Based on m_t-dependence of σ_{tt}

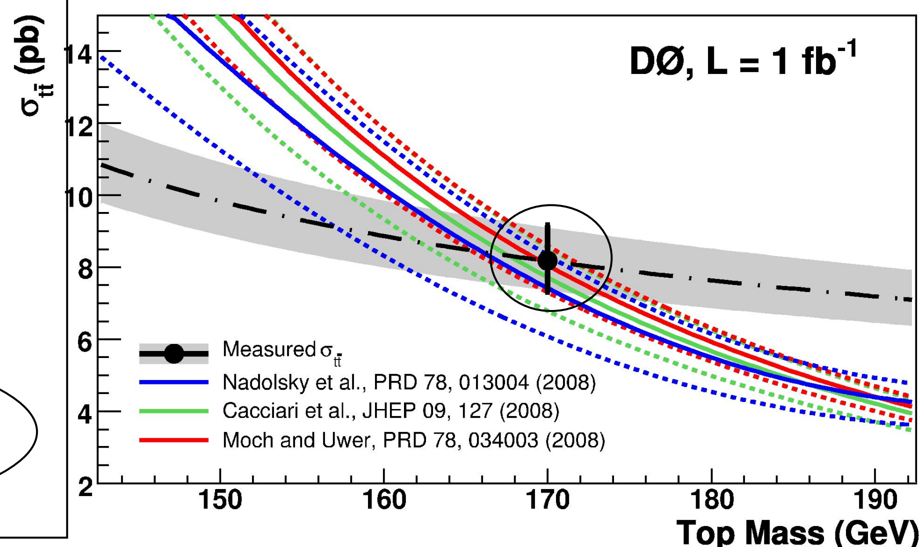
- ❑ l+jets, dilepton samples

→ τ included

→ ≥3 jets (l+jets), ≥2 jets (dilepton)

→ 1 b-tag

$$\sigma_{t\bar{t}}^{measured}(M_{top} = 170\,\text{GeV}) = 8.18 \pm^{0.98}_{0.87}\ (stat. + syst.)\ \text{pb}$$



Depending on the input from theory we obtain

$$M_{top} = ۱۶۵.۵ \pm^{۶.۱}_{۵.۹}\ \text{GeV (NLO QCD)}$$

$$M_{top} = 167.5 \pm^{5.8}_{5.6}\ \text{GeV (NLO + NLL QCD)}$$

$$M_{top} = 169.1 \pm^{5.9}_{5.4}\ \text{GeV (approximate NNLO QCD)}$$

- ✓ Less accurate than direct easurements
- ✓ Does not heavily rely on (LO) simulated ttbar

→ less sensitive to difference between MC and pole masses