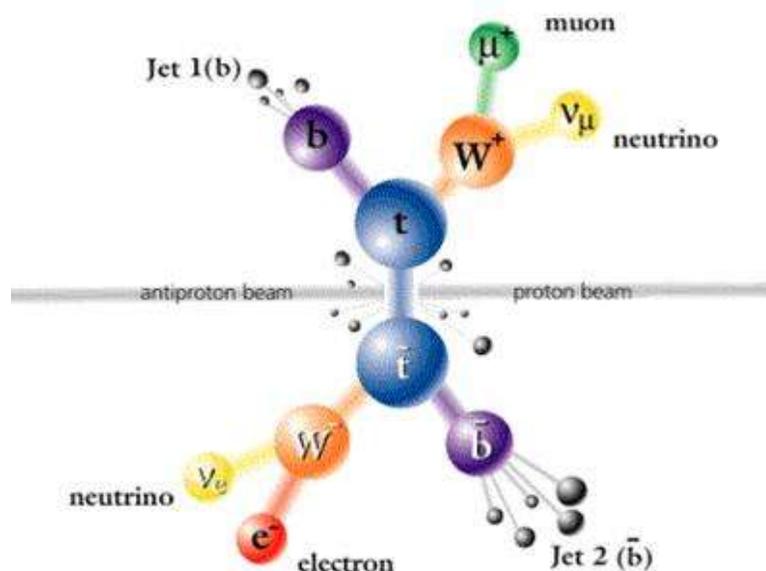


# Top Quark Results at the Tevatron

*Sébastien GREDER*  
*IReS-ULP*

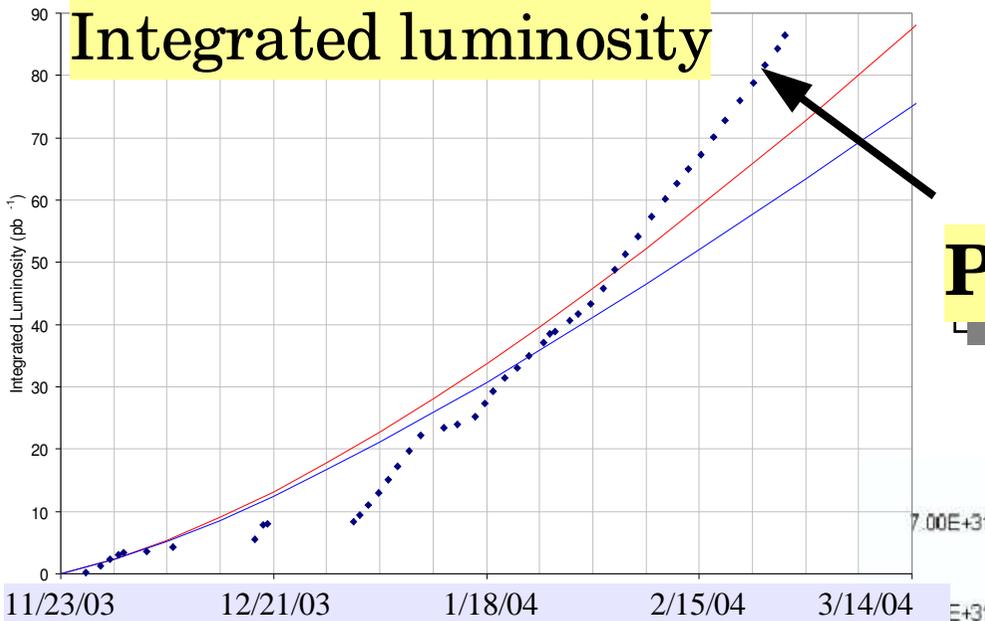


On behalf of **DO** and **CDF**  
collaborations



*Greder Sébastien*

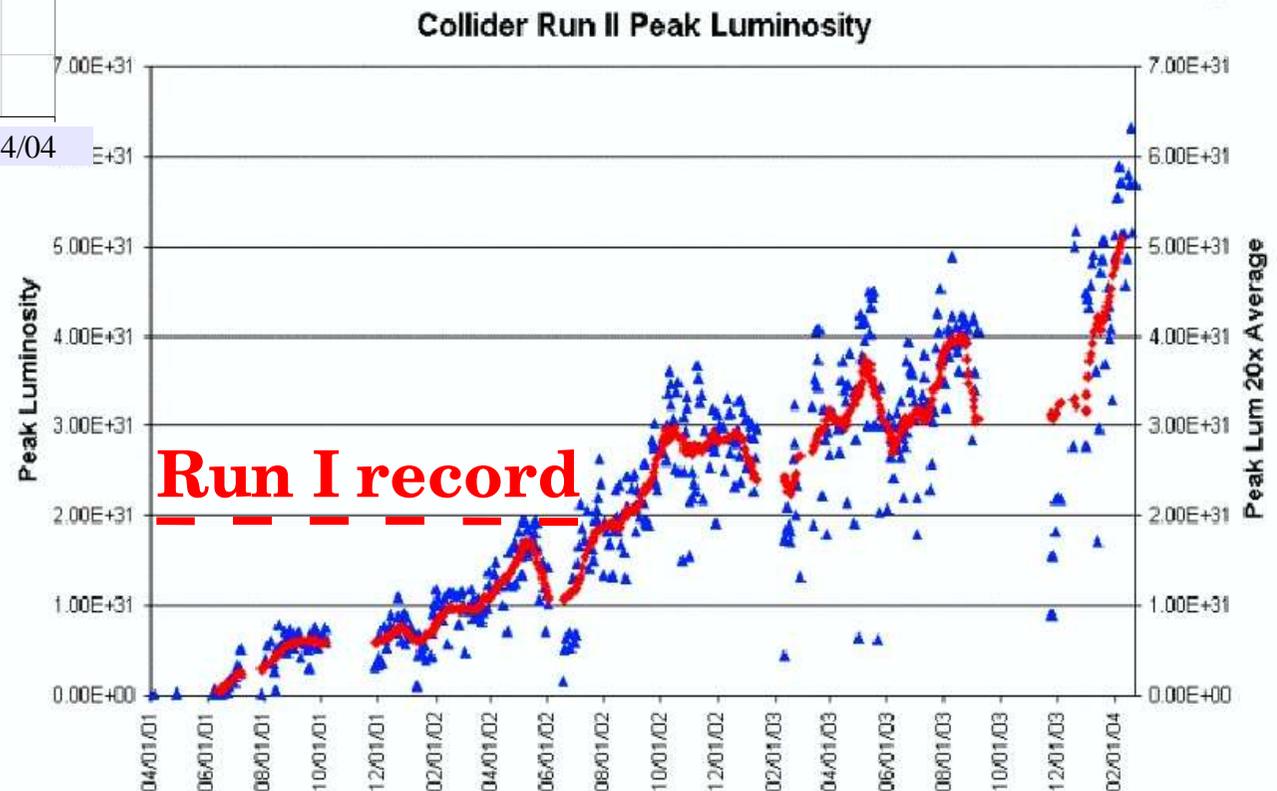
# Tevatron Performance



Performance above **design/base** !

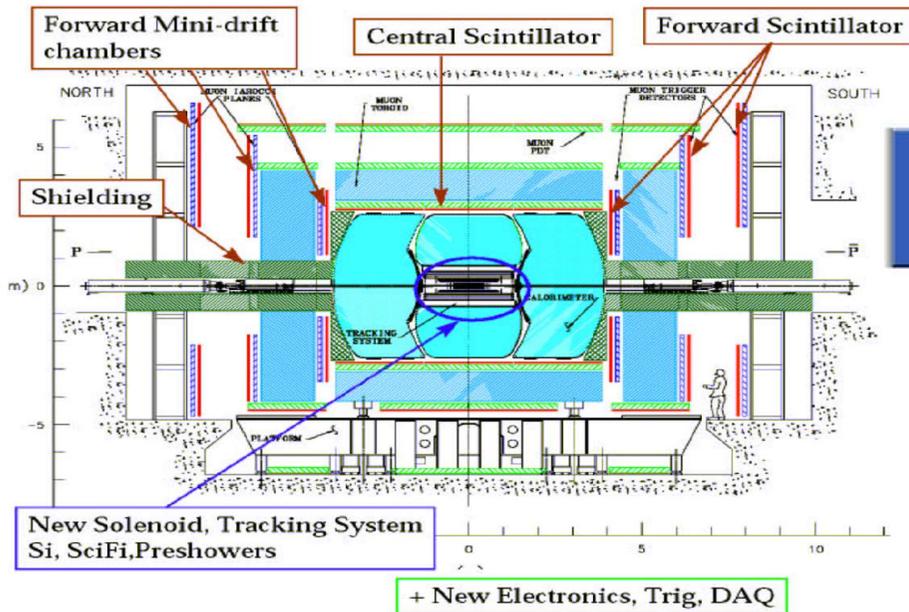
- Peak luminosity :  $6.3 \times 10^{31}$
- First store with anti-proton recycler
- Almost  $350 \text{ pb}^{-1}$  to tape

120-200  $\text{pb}^{-1}$  used for this talk



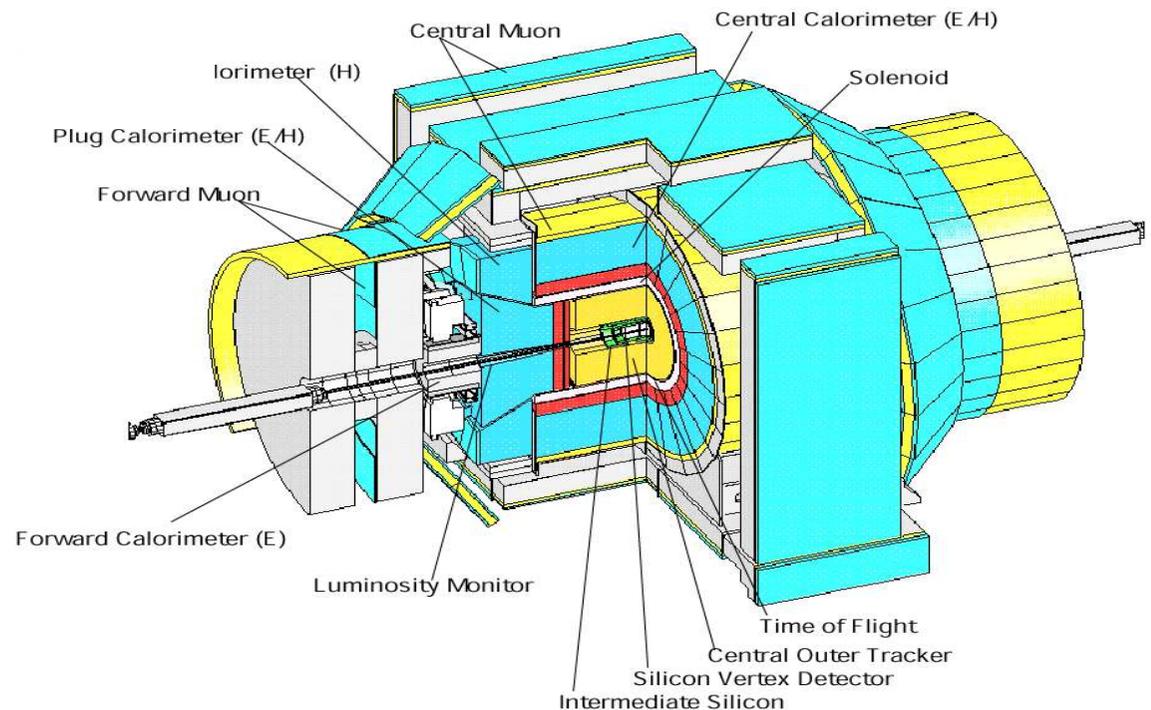
*Greder Sébastien*

# RunII Detectors Upgrades



- New tracking system :
  - silicon micro-vertex tracker (SMT)
  - central fiber tracker (CFT)
  - Solenoid : 2T magnetic field
- Preshowers added to calorimeter
- Improved muon system

- Upgraded Silicon Vertex Detector (SVX) and faster tracking drift chambers
- New scintillating tile end-plug calorimeters
- Increased muon detectors eta-phi coverage
- New scintillator time-of-flight system



*Greder Sébastien*

# Top Studies motivations

## A rich physics menu :

- Large  $M_t$  ( $\sim 175$  GeV) :

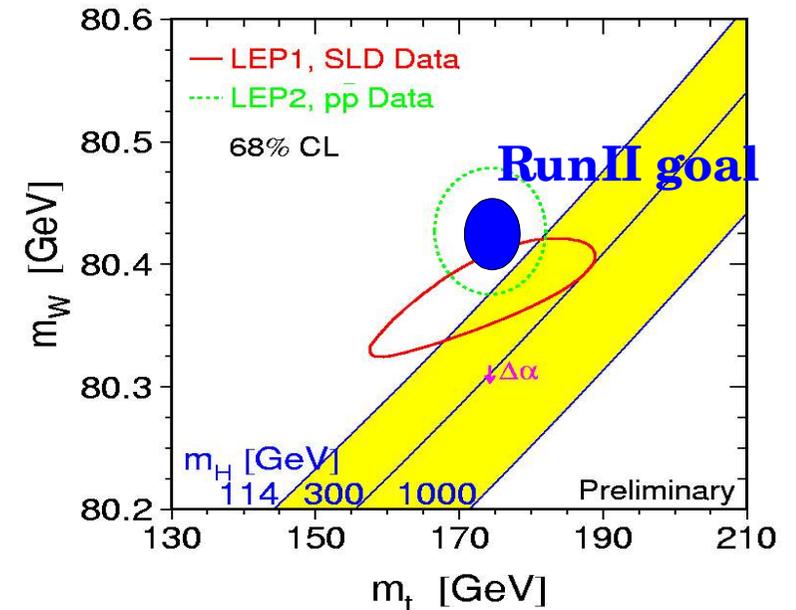
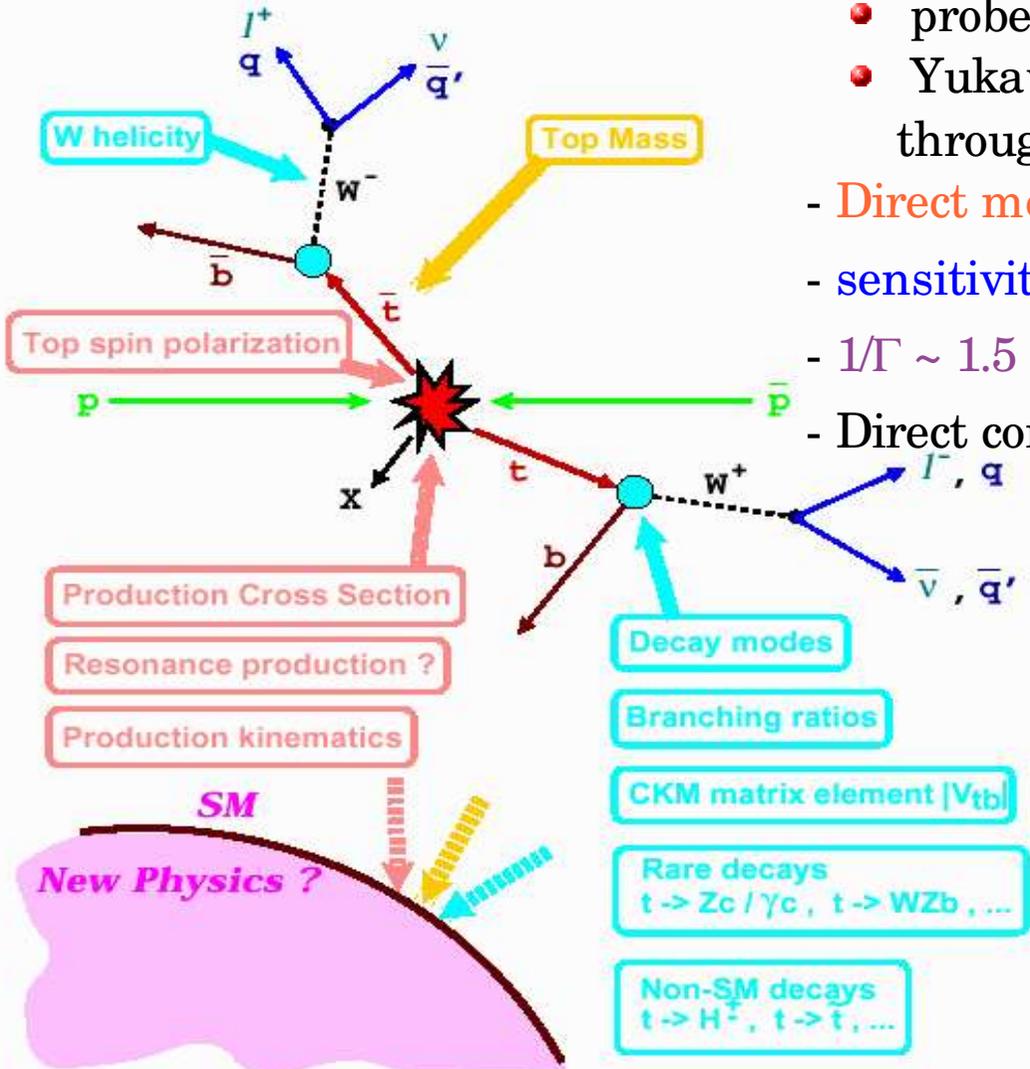
- probe to the EWSB scale
- Yukawa coupling  $\sim 1$ . ; does top acquire its mass through the Higgs mechanism ?

- Direct measurement of  $V_{tb}$

- sensitivity to non-SM physics

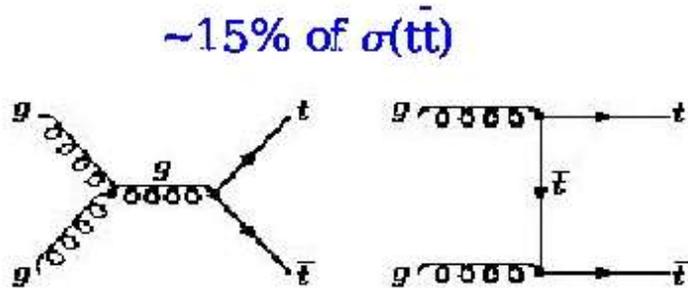
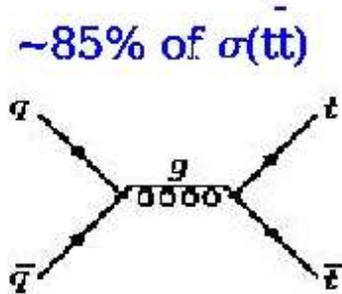
-  $1/\Gamma \sim 1.5$  GeV  $< \tau_{\text{hadro}}$  : opportunity to study a bare quark !

- Direct constraints on Higgs mass, ...



# Top Production at Tevatron

Strong production : top pairs

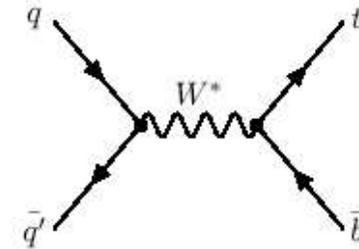


(Process rates are reversed at LHC)

EW production : single-top

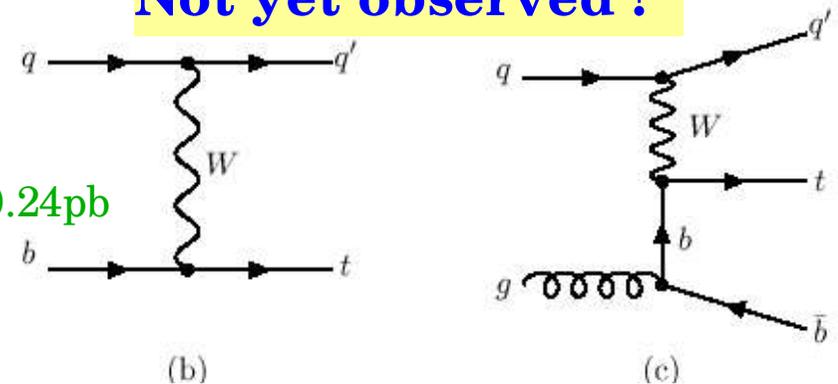
( $\sim 40\% \sigma_{tt}$ )

s-channel  
 $\sigma = 0.88 \pm 0.11 \text{ pb}$



**Not yet observed !**

t-channel  
 $\sigma = 1.98 \pm 0.24 \text{ pb}$



- ◆ Cross-section increased by 30% w.r.t RunI center-of-mass energy
  - ◆  $\sigma_{tt} = 6.77 \pm 0.4 \text{ pb}$
- (Kidonakis, Vogt, Phys.Rev. D 68, 114014, 2003))

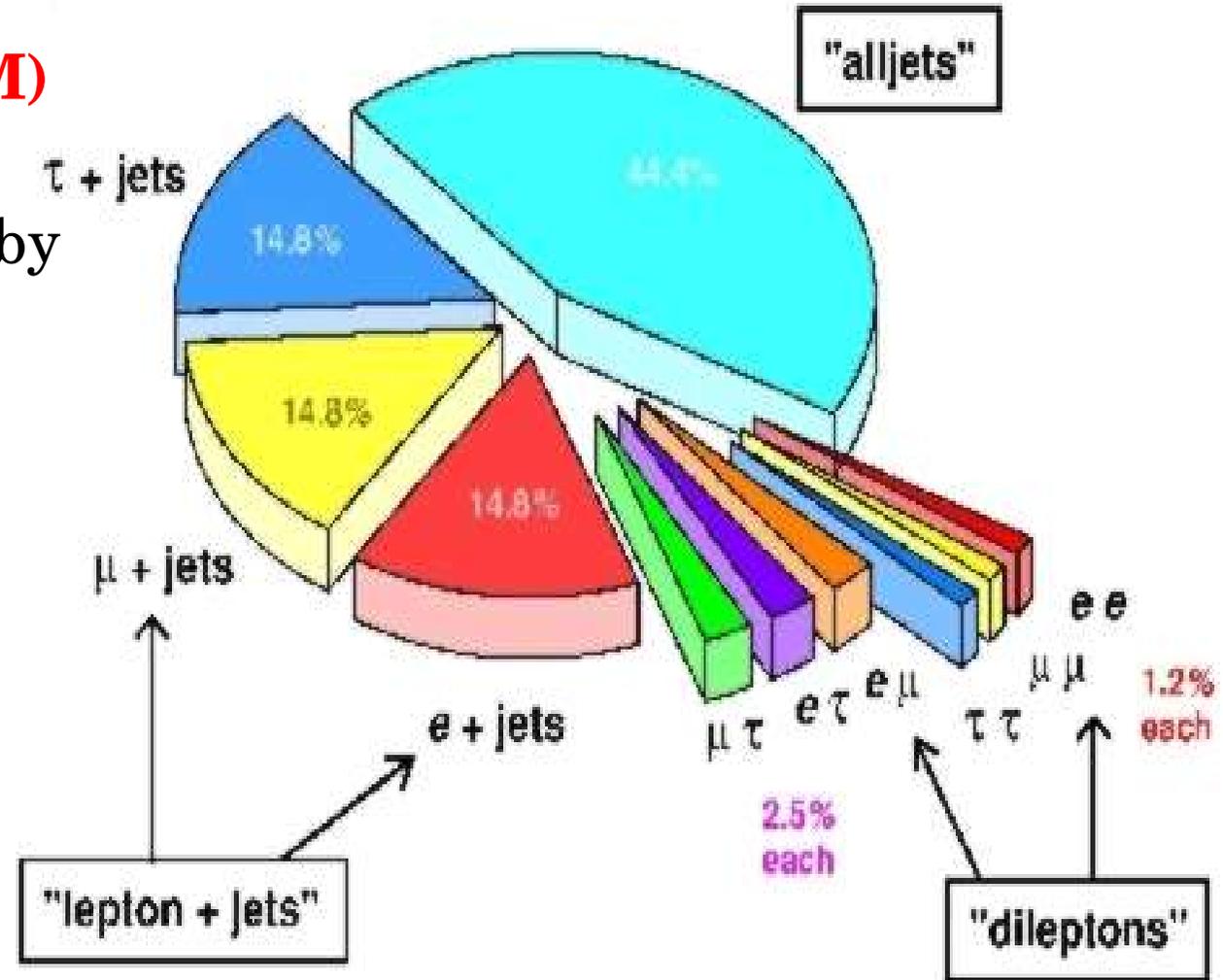
- RunI limits :
- CDF :  $\sigma_s < 18 \text{ pb}$  ,  $\sigma_t < 13 \text{ pb}$  ,  $\sigma_{st} < 14 \text{ pb}$
  - DØ :  $\sigma_s < 17 \text{ pb}$  ,  $\sigma_t < 22 \text{ pb}$

# Top decays

**BR( $t \rightarrow Wb$ )  $\sim 1$  (within SM)**

Signatures are hence labeled by  
*W final states* :

- $\rightarrow$  **dilepton** (BR  $\sim 5\%$ )  
ee, e $\mu$ ,  $\mu\mu$  + 2 b-jets
- $\rightarrow$  **lepton + jets** (BR  $\sim 30\%$ )  
e,  $\mu$  + 4 jets (2 b-jets)
- $\rightarrow$  **all hadronic** (BR  $\sim 44\%$ )  
6 jets (2 b-jets)





# Outline of results

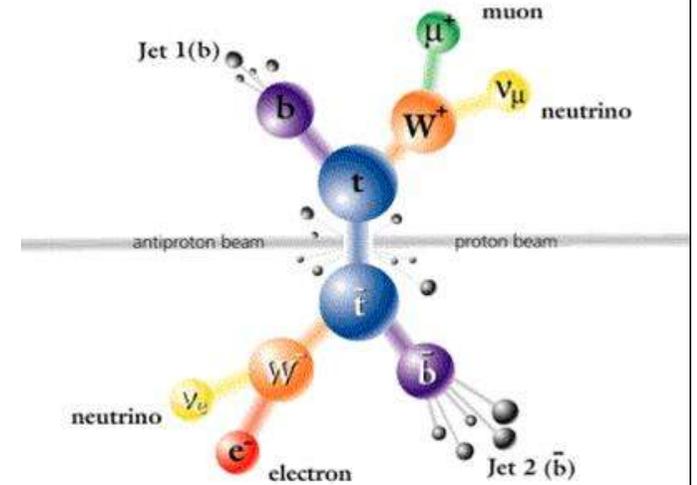


- $t\bar{t}$  cross-sections measurements
  - Dilepton
  - Lepton + jets
  - All hadronic
- Single -Top search
- Top mass

# Dilepton channel

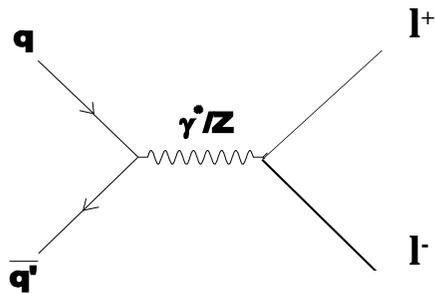
- Analysis requirements :

- 2 high Pt isolated leptons, missing  $E_t$  and  $\geq 2$  jets (CDF & DØ)
- 1 high Pt lepton + 1 high Pt isolated track (CDF) : sensitive to  $\tau$  lepton final state

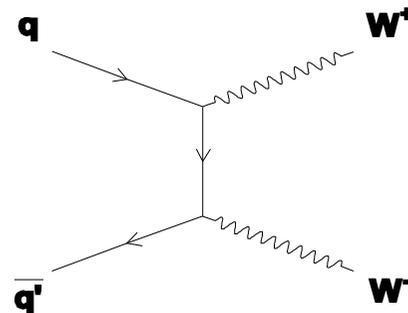


- Physical backgrounds (from Monte-Carlo)

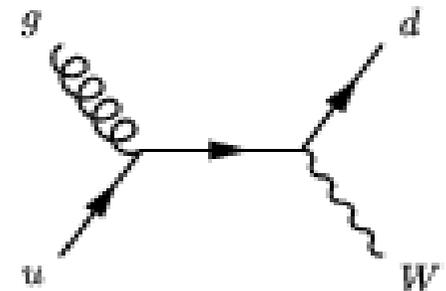
$Z/\gamma^* \rightarrow l^+l^-$



Vector bosons pairs (WW, WZ, ZZ)



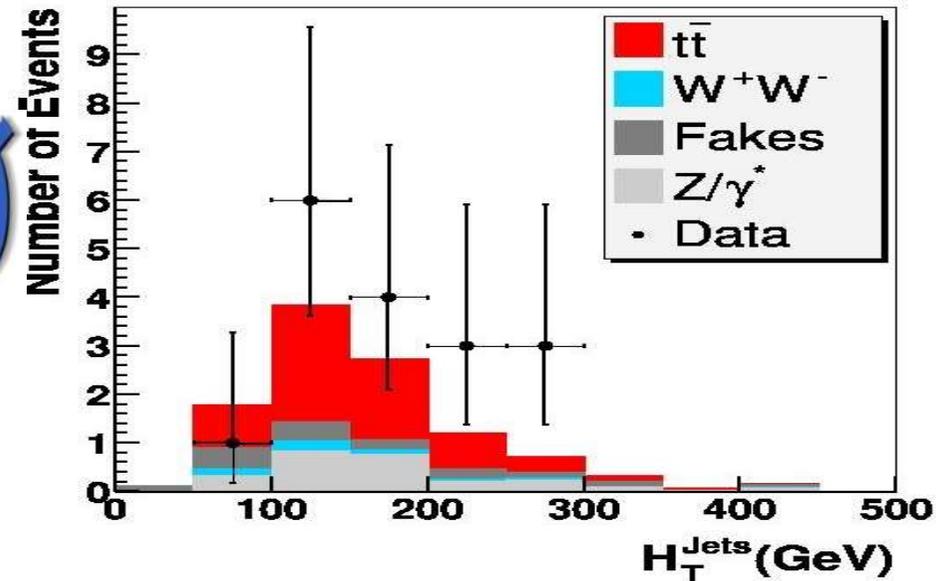
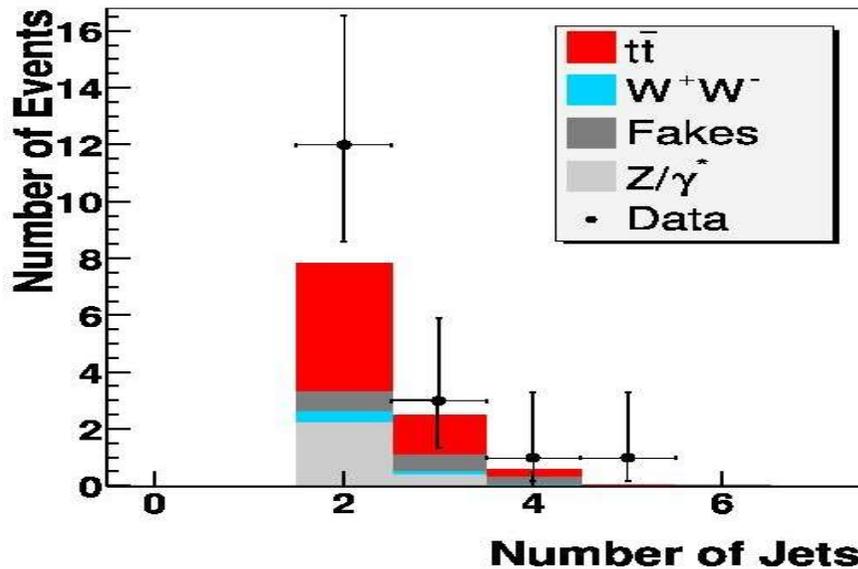
W+ jets



- Instrumental backgrounds (from Data) :

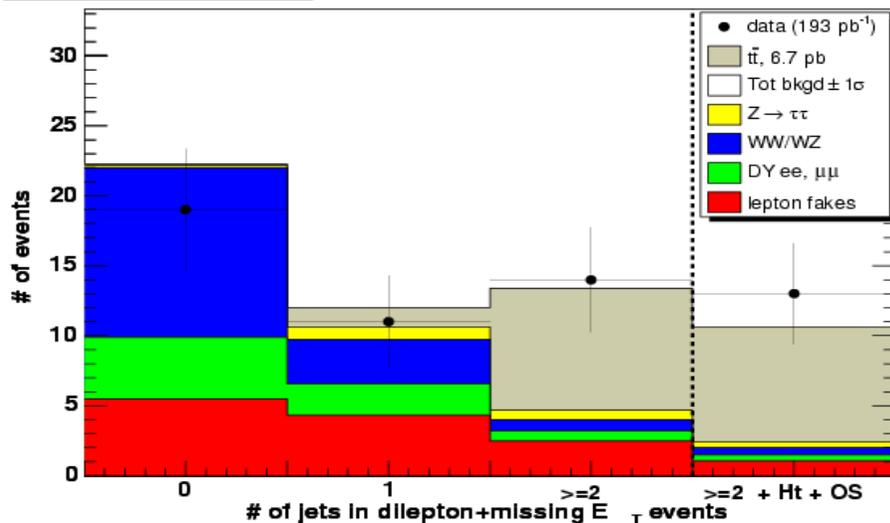
- fakes : from missing  $E_t$ , isolated  $e/\mu$

# Dilepton channel

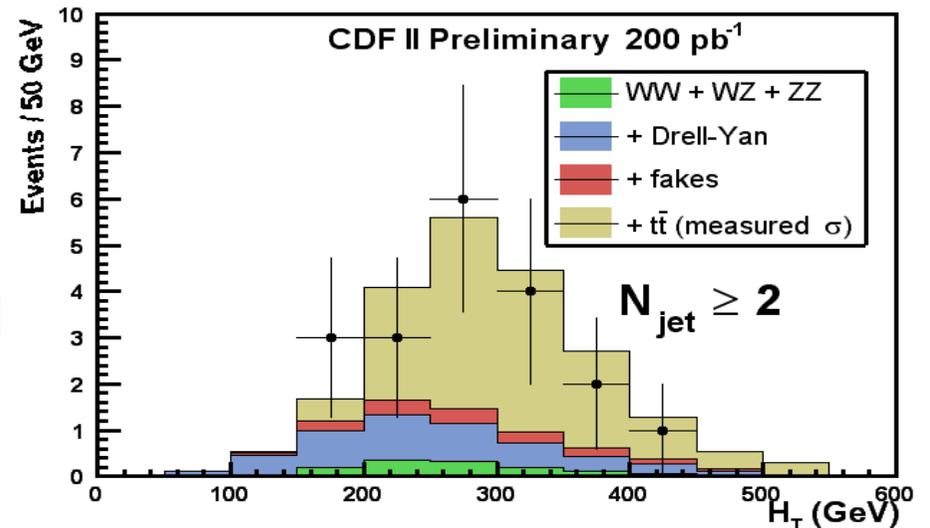


Small statistics but benefits from high S/B

CDF II preliminary

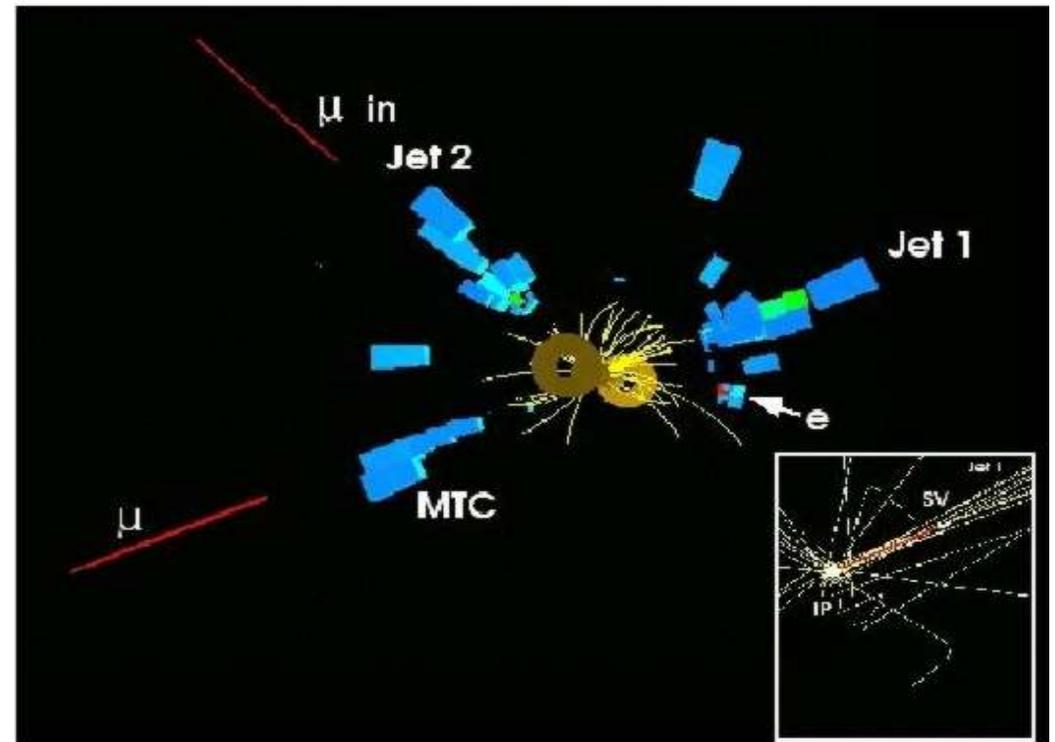
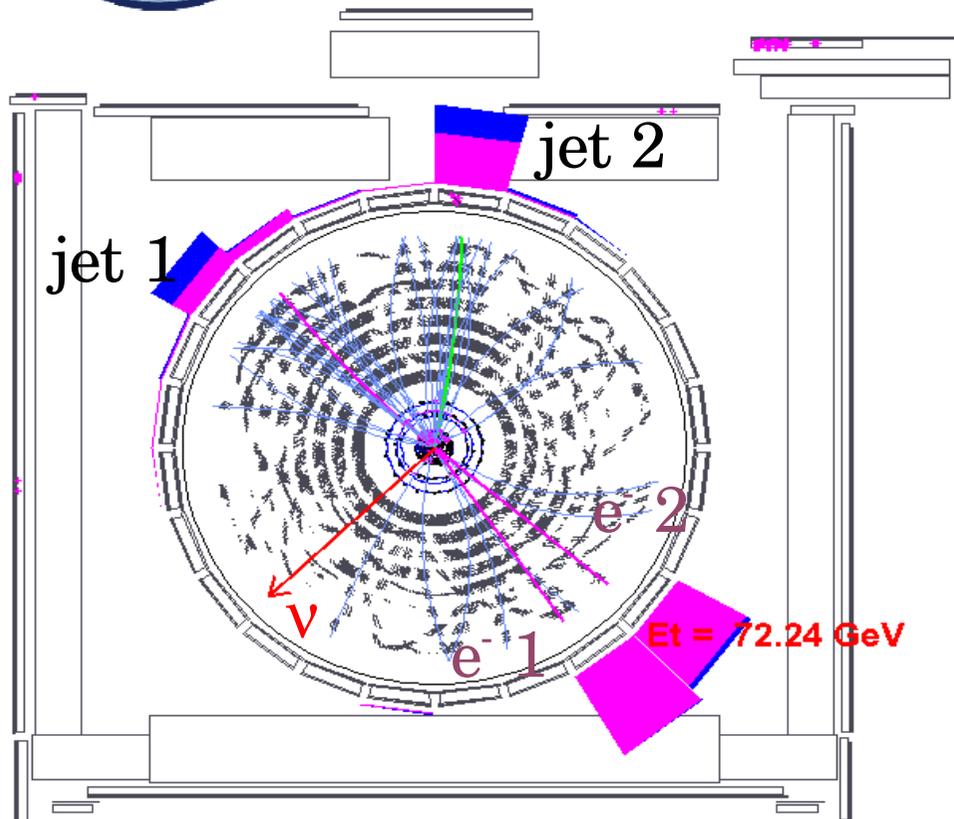


Total Transverse Energy (scalar sum)



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# Dilepton candidate events



# Lepton+jets channels

Lower S/B than dilepton but higher BR (30%)

- Analysis requirements :

1 high Pt isolated lepton, missing Et and  $\geq 3$  or 4 jets

- *Topological approach* :

- Neural Network
- Event likelihood fit
- Kinematical fit

- *Counting approach* :

Use b-taggers.

- Physical backgrounds

W+jets, QCD multijet, single top, VV (WW, WZ, ZZ), Z+jets, ...



# Leptons+jets using NN or Likelihood fit

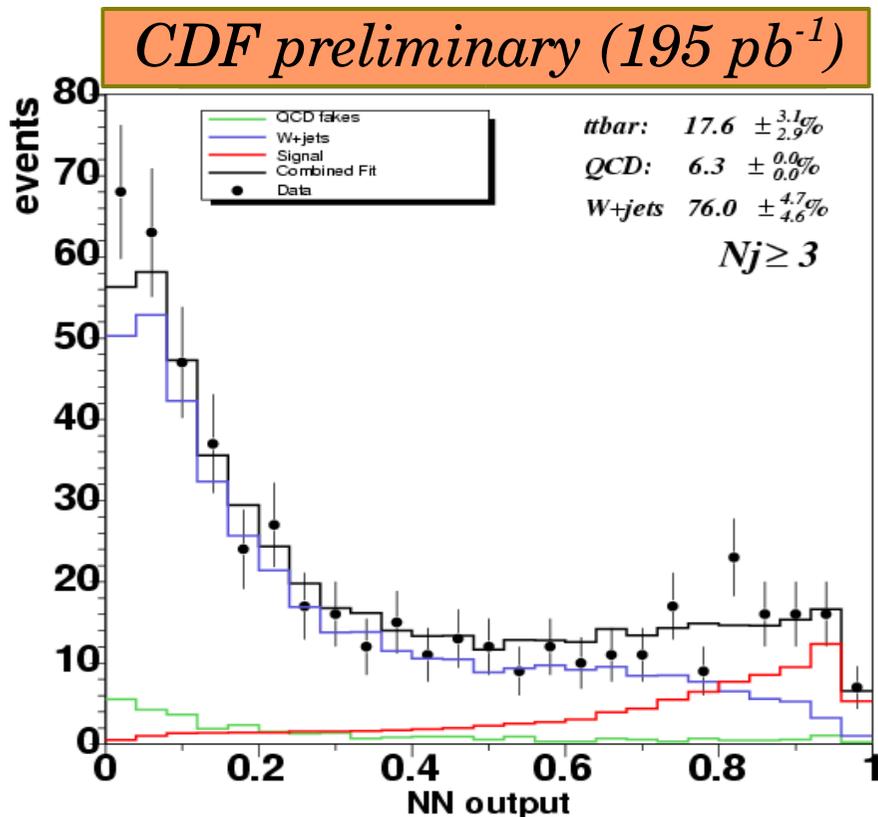


*Top and W+jets kinematics and topology differ slightly but for many variables*

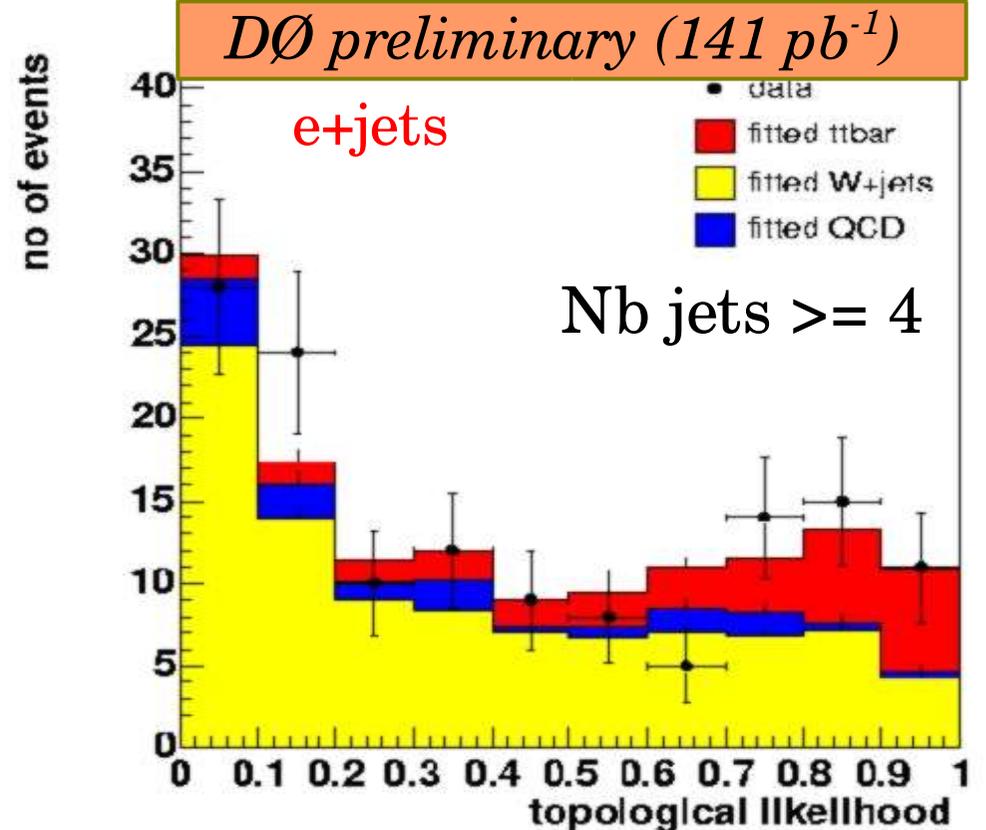
Use neural net (with 7 input variables) to optimize information treatment

Build an event likelihood (using 4 variables)

Fit data from MC templates to extract signal/background fractions



$$\sigma_{t\bar{t}} = 6.7 \pm 1.3(\text{stat.}) \pm 1.5(\text{syst.})$$



$$\sigma_{t\bar{t}} = 7.2^{+2.6}_{-2.4}(\text{stat.})^{+1.6}_{-1.7}(\text{syst.}) \pm 0.47(\text{lumi.})$$

# Leptons+jets : using b-taggers



*Top pairs decays contain 2 b quarks in the final state !*

- ◆ B hadrons fly over 3mm
- ◆ Hadronization produces a lot of displaced tracks w.r.t primary vertex
- ◆ Semi-leptonic decay :  
 $BR(b \rightarrow lvc) + BR(b \rightarrow c \rightarrow lvs) \sim 40\%$

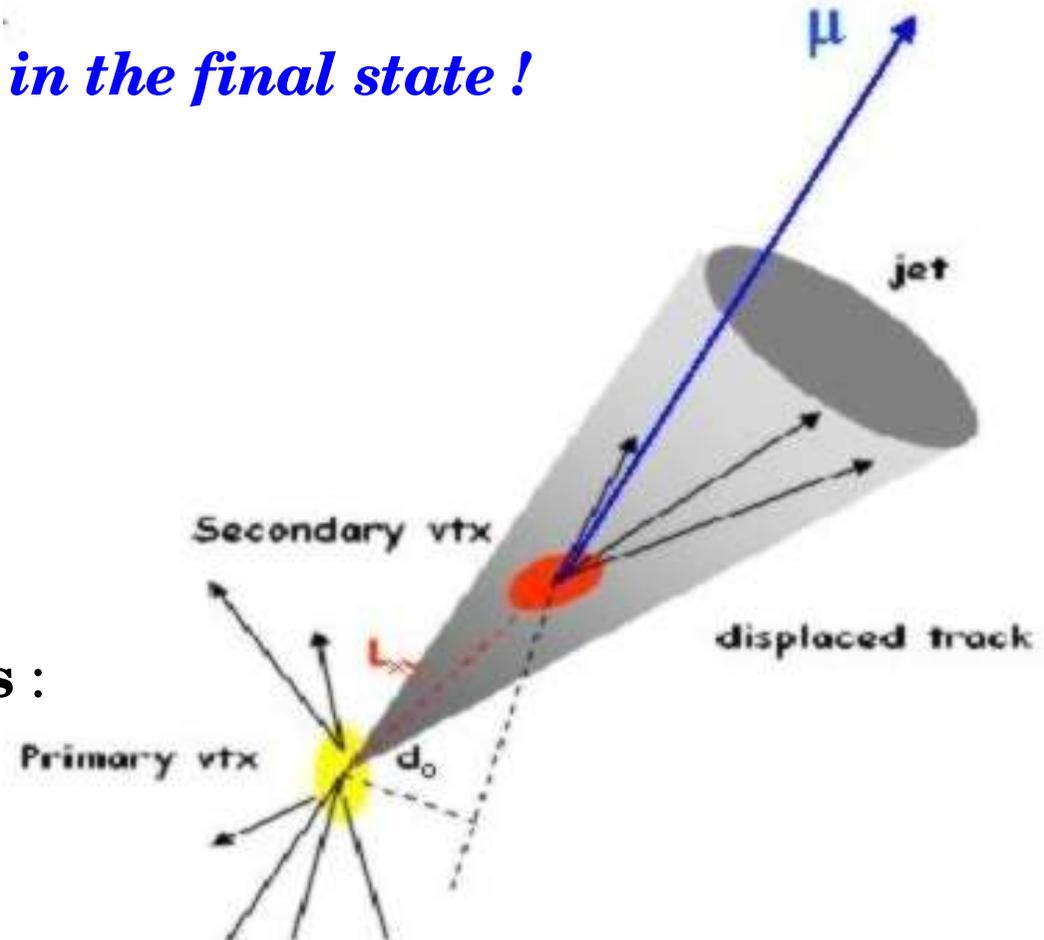
➡ Tag event with **secondary vertices** :

$$\varepsilon_b(tt) \sim 55\%, \text{ mistag} \sim 0.5\%$$

(CDF : SVX , DØ : SVT)

➡ or with **muon matched in jets** :

$$\varepsilon_b(tt) \sim 15\%, \text{ mistag} \sim 3.6\%$$

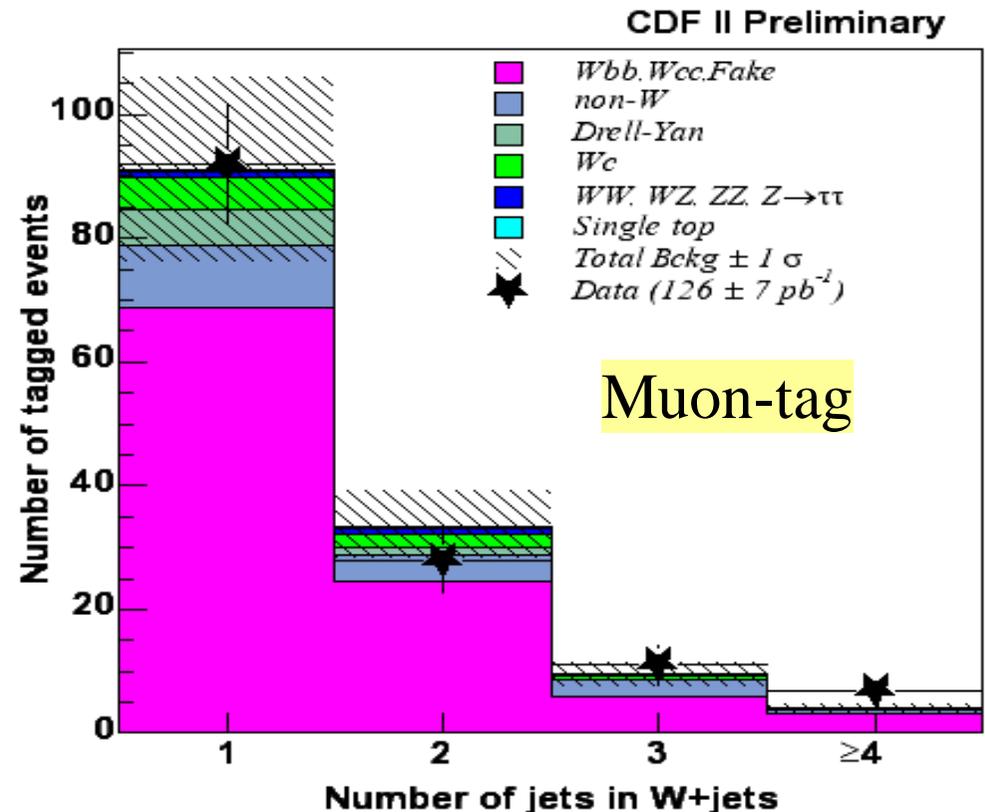
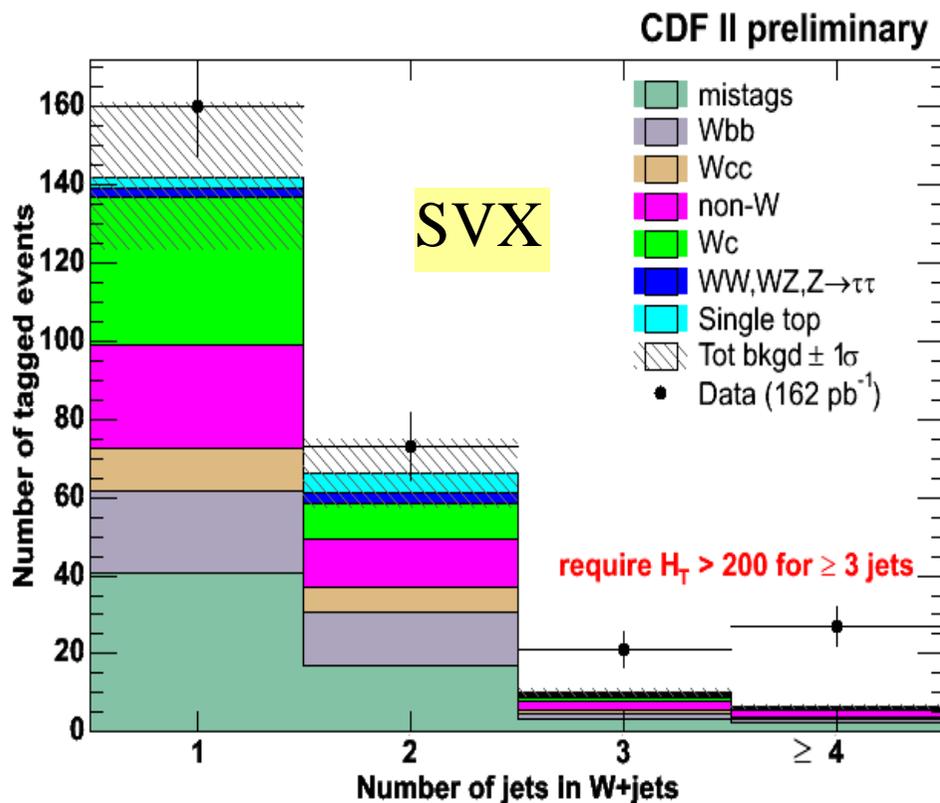


# Leptons+jets : using b-taggers



## Counting analysis

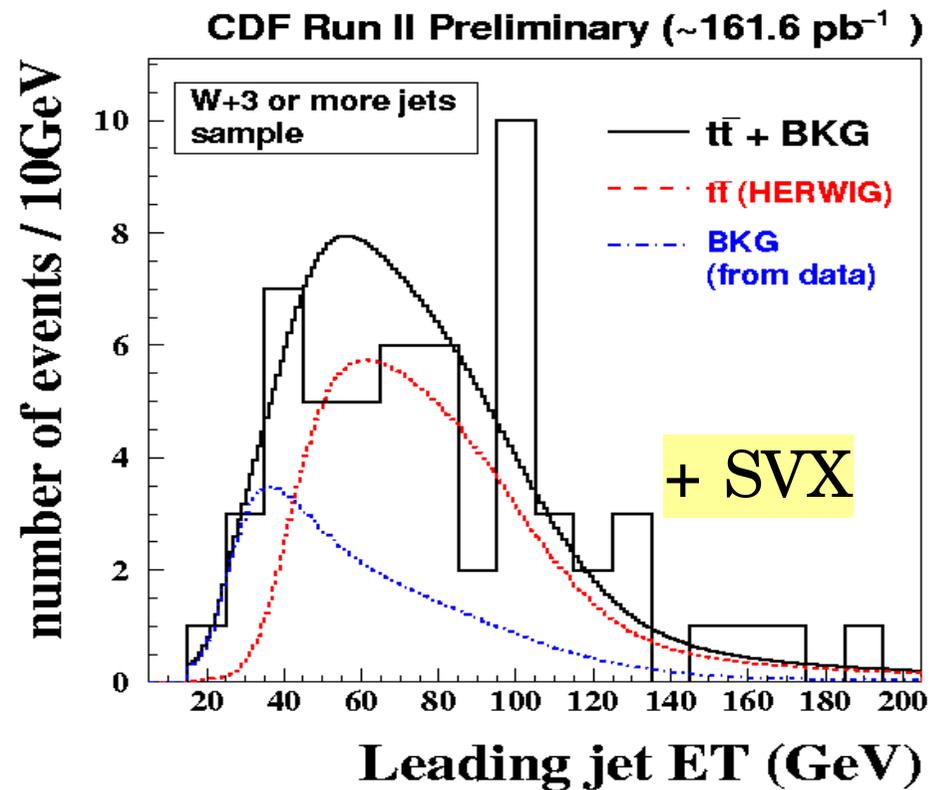
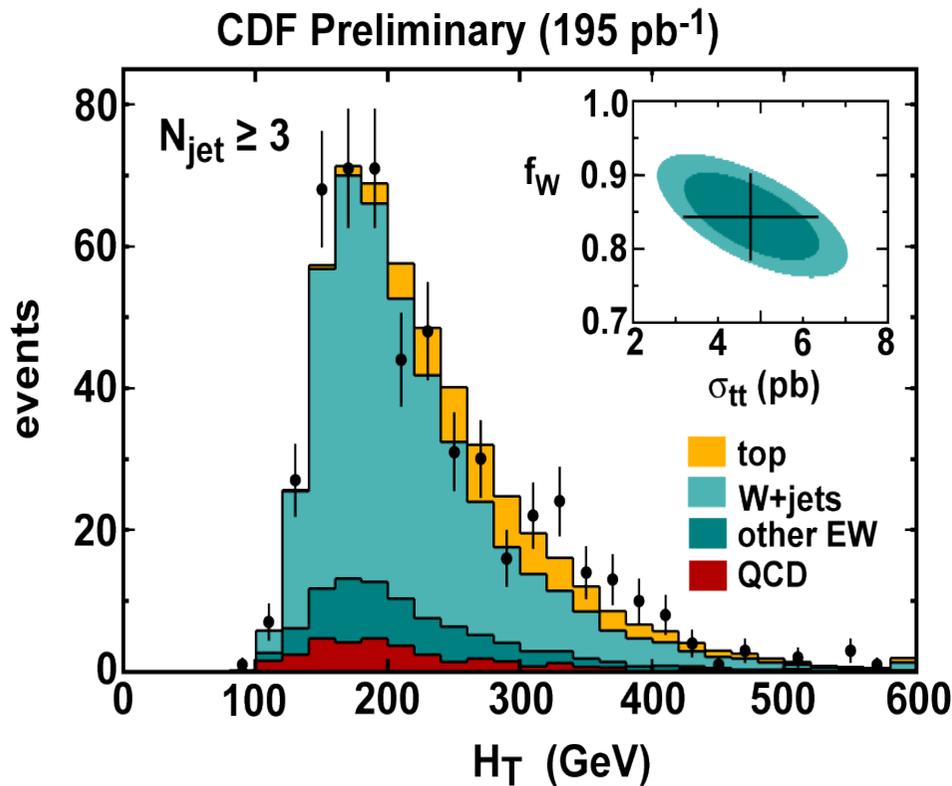
- Use data as much as possible for non-W (QCD), fake tags
- Use MC for W+heavy flavour and VV expectations
- ➔ Top candidates correspond to the excess of events with **3 and  $\geq 4$  jets**



# Leptons+jets : kinematical fit (+ SVX)



- Separate signal/background in tagged event by exploiting event shape information
- Fit templates signal (from MC) and background (from data) to data to get fractions for different kinematical variables distributions ( $H_T$ ,  $E_T$  leading jet, ...)



$$\sigma_{t\bar{t}} = 6.0^{+1.5}_{-1.8} (stat.)^{+0.8}_{-0.8} (syst.)$$

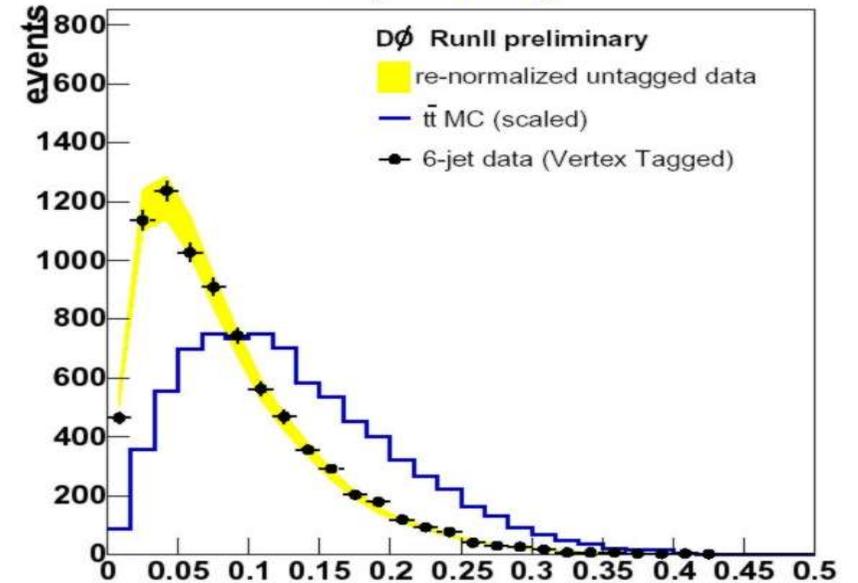
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$$\sigma_{t\bar{t}} = 4.7 \pm 1.6 (stat.) \pm 1.8 (syst.)$$

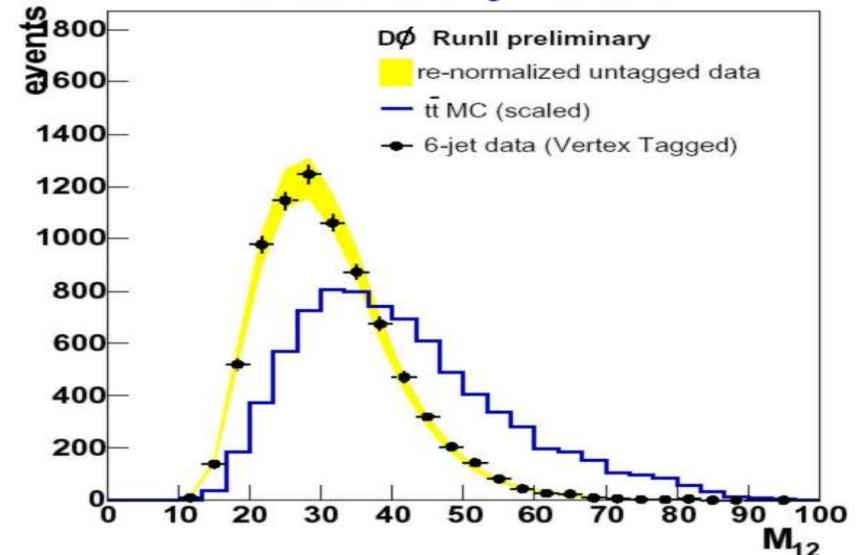
# All Jets channel + SVT/SVX

- **Signature** :  
6 jets, 2 being b-jets
- **Background** :  
QCD multijet is overwhelming signal; **need of b-tagging**
- **Analysis** :
  - $D\phi$ 
    - Use secondary-vertex tagger (SVT)
    - Combine various kinematical variables as inputs for 3 NNs
  - CDF
    - Kinematical selection completed by requiring  $\geq 1$  b-tagged jet ;

**Aplanarity**



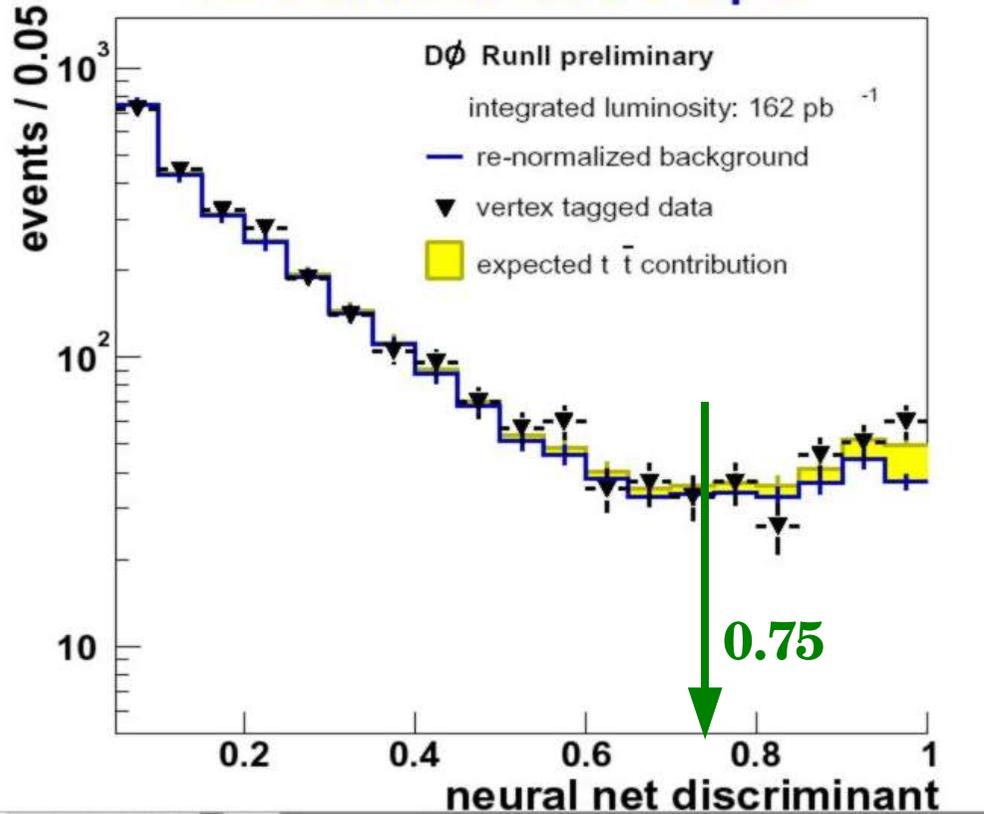
**smallest di-jet mass**



# All Jets channel + SVT/SVX



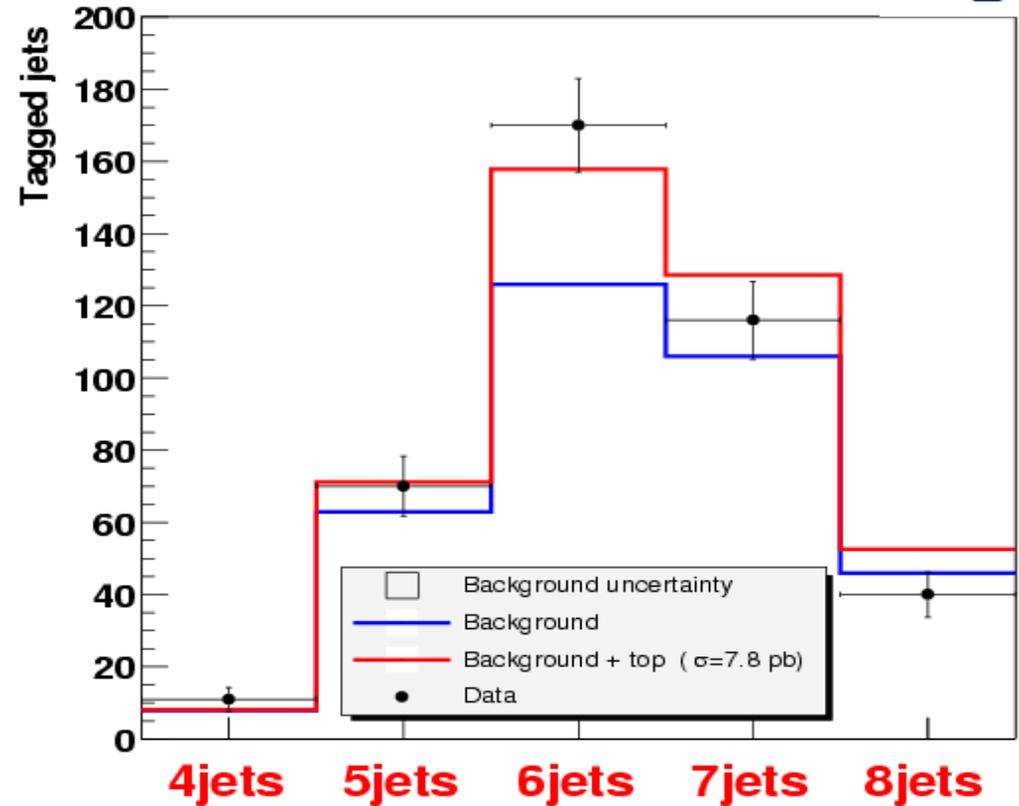
Neural Network 2 output



$$\sigma_{t\bar{t}} = 8.3 \pm 3.8(\text{stat.})_{-2.1}^{+2.3}(\text{syst.}) \pm 0.5(\text{lumi.})$$



CDF Run II preliminary, L=165 pb<sup>-1</sup>



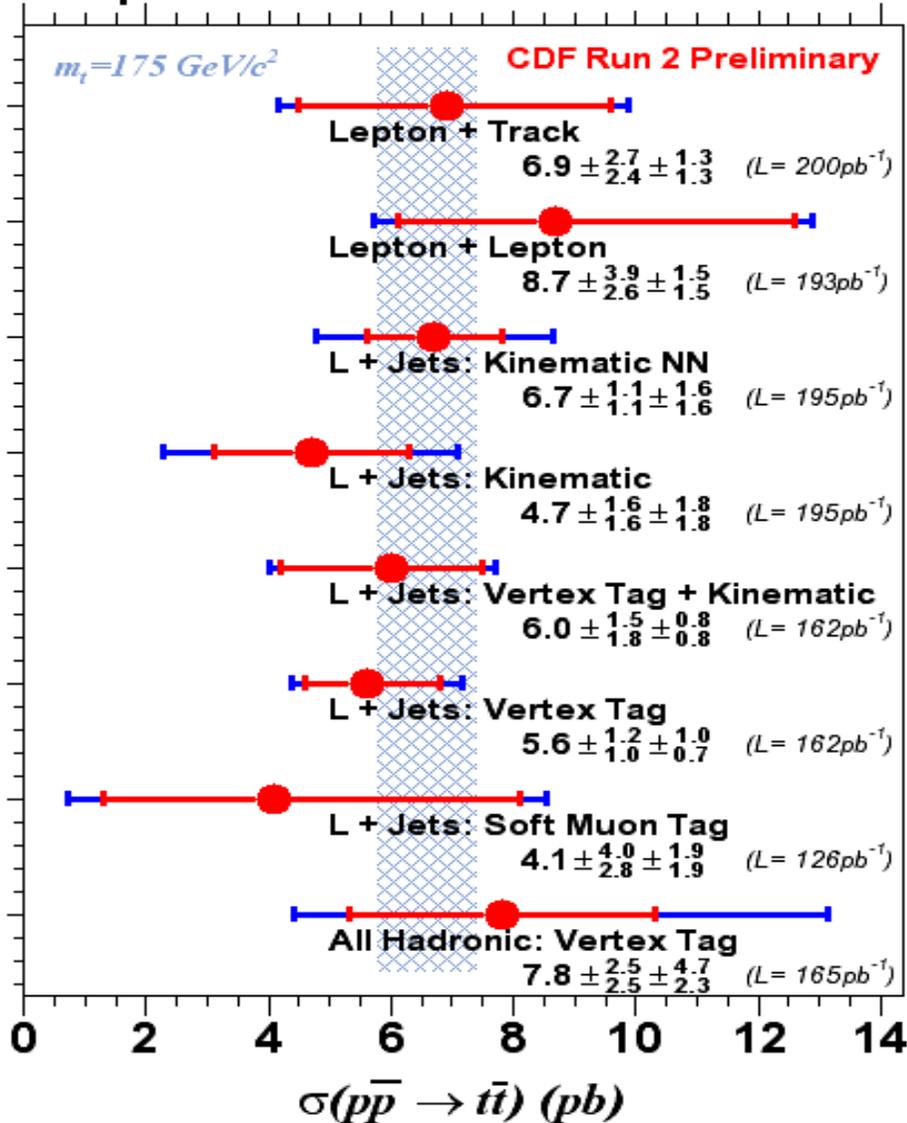
$$\sigma_{t\bar{t}} = 7.8 \pm 2.5(\text{stat.})_{-2.3}^{+4.7}(\text{syst.})$$



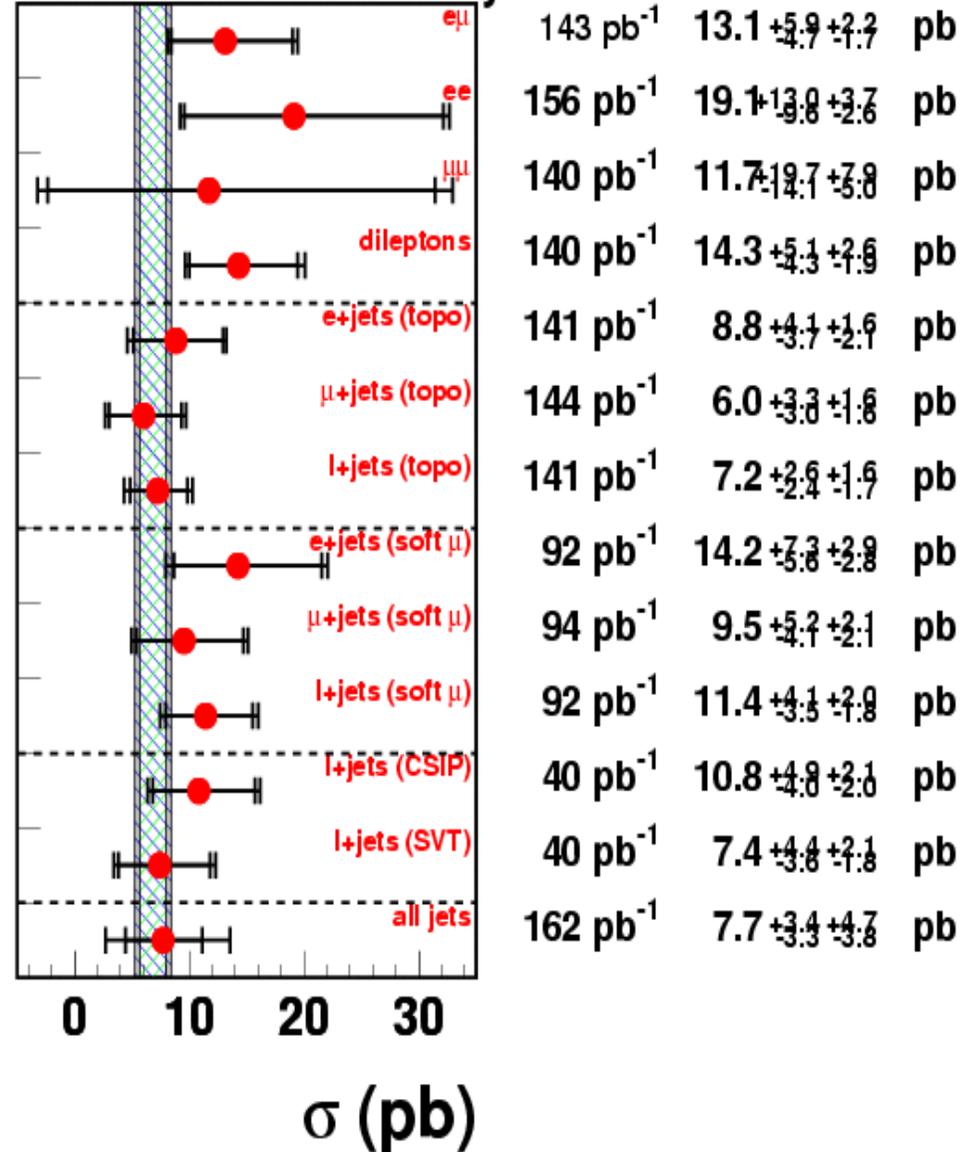
# Top pair production x-section summary



## Top Pair Production Cross Section



## DØ Run II Preliminary



# Single-Top search

## • Motivation :

- only way to measure directly  $V_{tb}$  ( $\sigma \sim |V_{tb}|^2$ )
- sensitivity to non-SM physics

## • Signature :

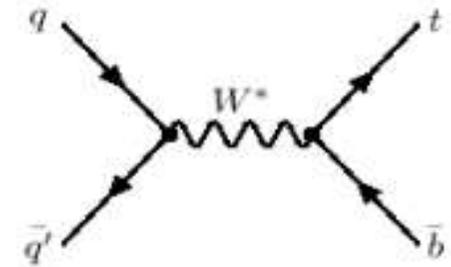
same as lepton+jets but with a lower jet multiplicity

## • Background :

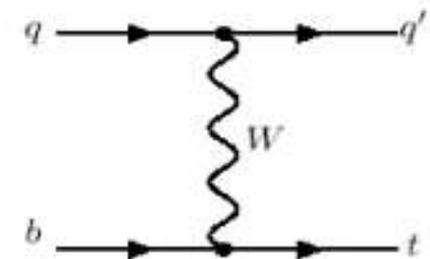
top pairs, W+jets, VV (from data/MC) ,  
QCD multijet (from data)

## • Analysis :

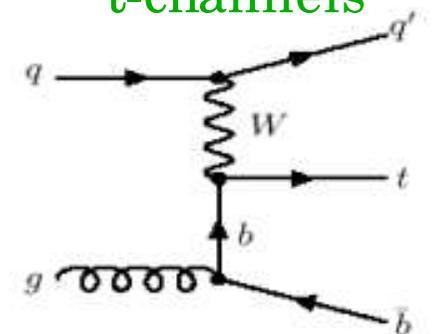
- preselect 1 high Pt lepton + missing  $E_t$  + 2-4 jets
- Require  $\geq 1$  tagged jet
- Apply topological cuts
- Treat separately combined and t-channel



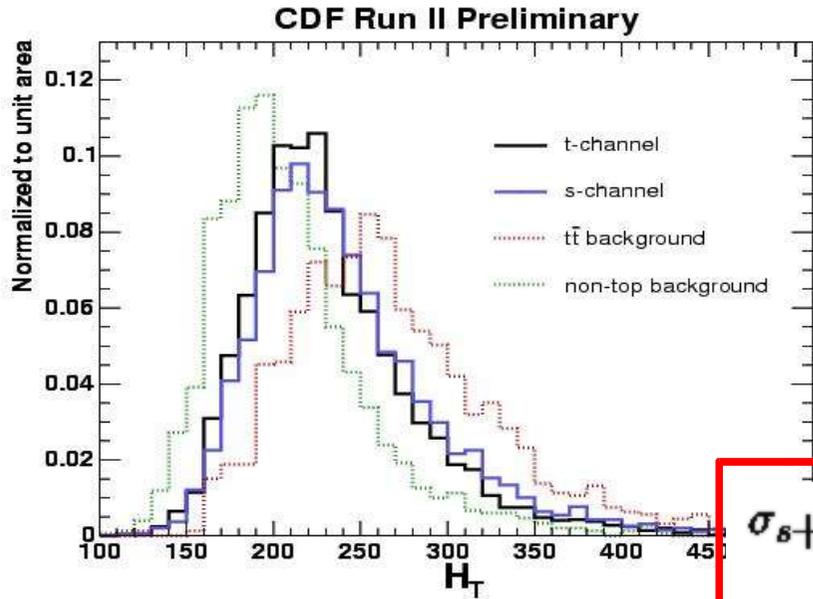
s-channel



t-channels

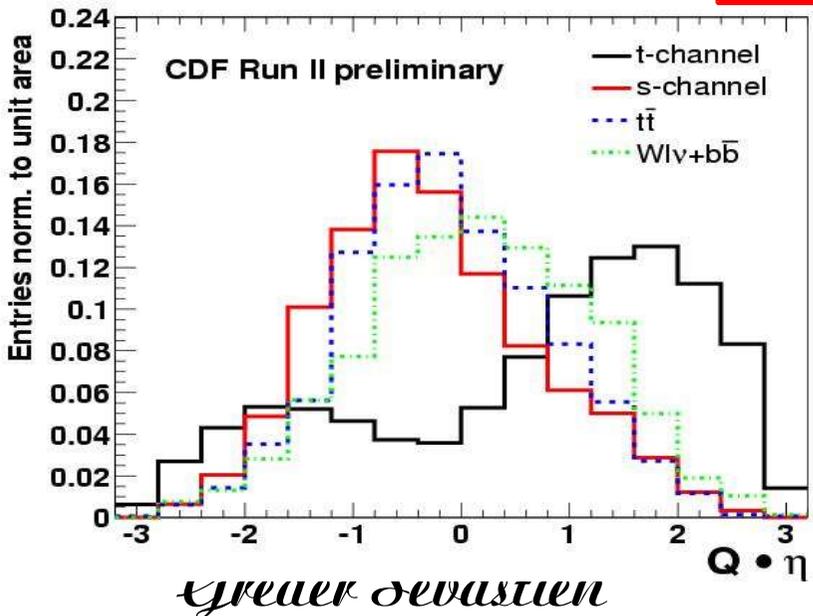
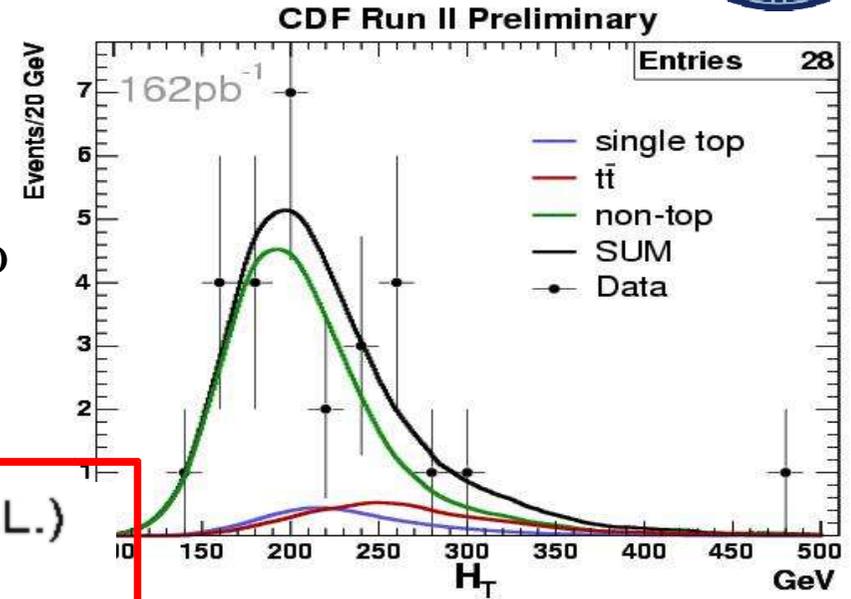


# Single-Top search

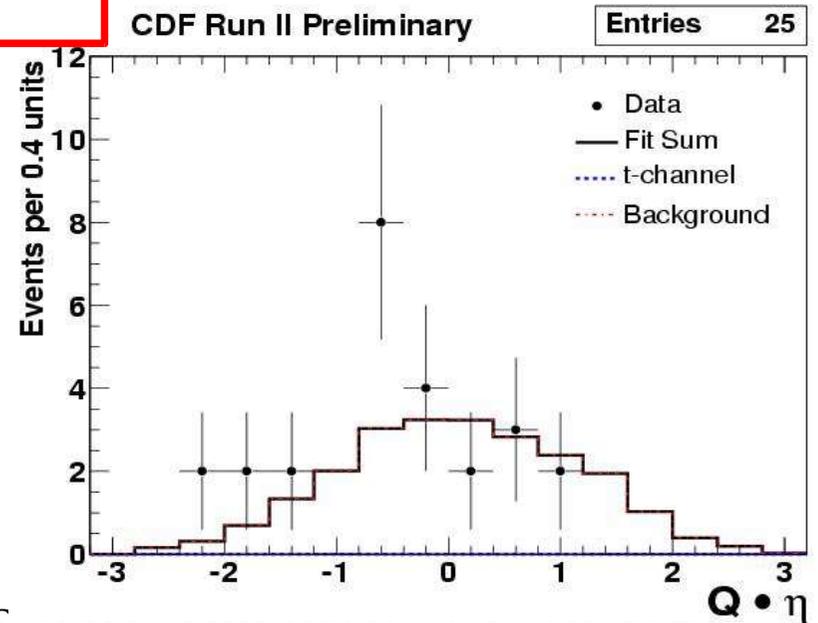


Combined channels  
Likelihood fit to H<sub>T</sub> from MC templates

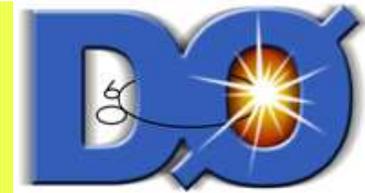
$\sigma_{s+t} < 13.7 \text{ pb (95\% CL.)}$   
 $\sigma_t < 8.5 \text{ pb (95\% CL.)}$



t-channel  
Likelihood fit to Q\*eta from MC templates



# Single-Top search



- Use 2 types of b-tagging algorithm :
  - Lifetime based (sec. vertex (SVT) and jet lifetime (JLIP))
  - Soft-muon tag (SLT)
- Nice agreement between predicted and observed distributions
- W+ jets estimated from data

## Expected limits :

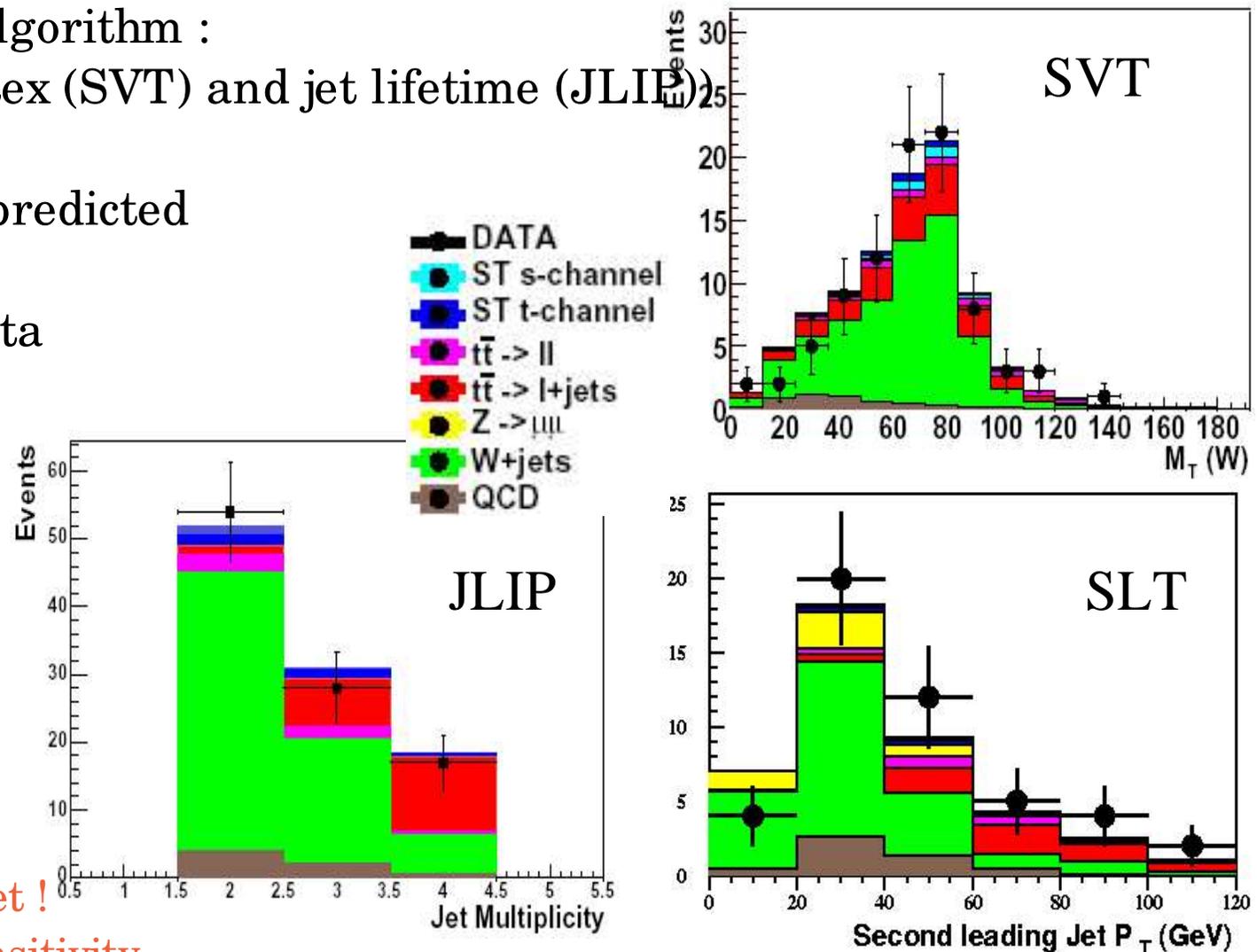
(including systematics)

$$\sigma_s < 13.8 \text{ pb}$$

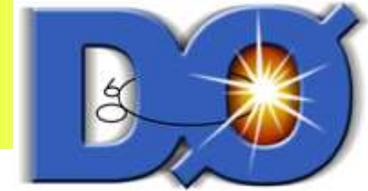
$$\sigma_t < 19.8 \text{ pb}$$

$$\sigma_{s+t} < 15.8 \text{ pb}$$

➡ No topological cuts applied yet !  
It will increase statistical sensitivity



# RunI Top Mass update

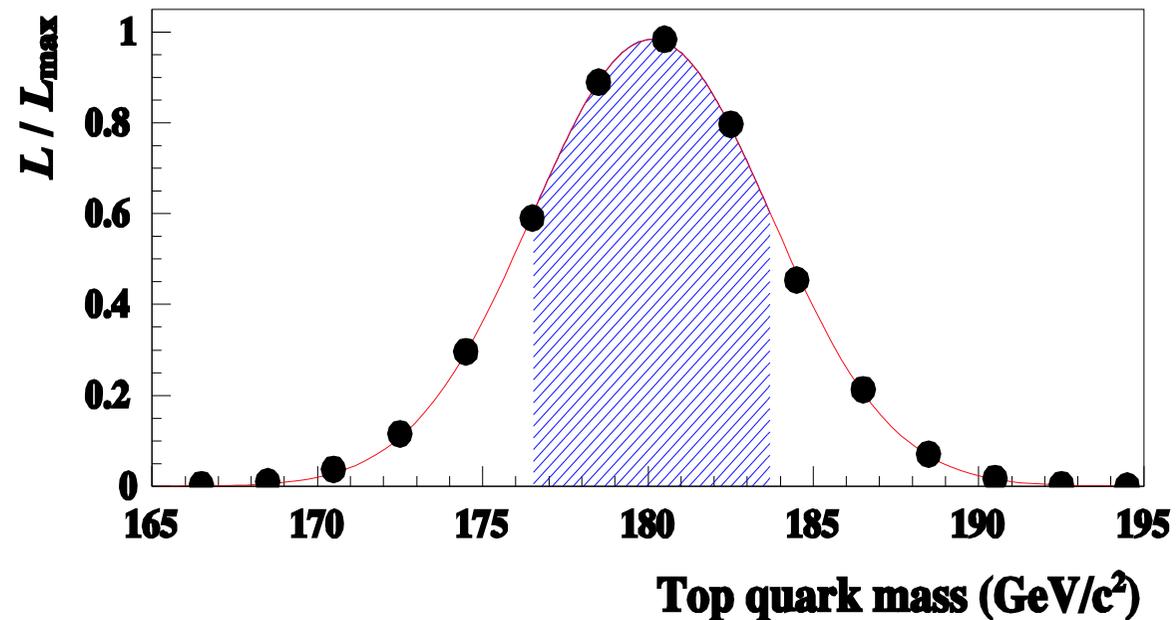


- **Old approach :**

- Topological discriminant used to separate signal from background
- Mass estimate made with 2D fit in fitted mass and discriminant and compared to MC templates

- **New improved approach :**

- Calculate **event probability** to be a tt event ( $\sigma^{\text{LO}}$ , pdf, trans. function)
- Consider all combinations, assign each a weight and sum their probabilities
- Increase purity by cutting on background probability



Combined with previous dilepton mass measurements, the new DØ average mass is :

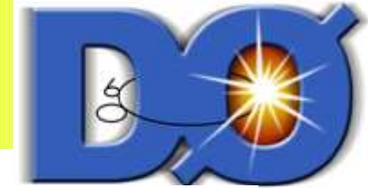
**New DØ averaged top mass : 179.0  $\pm$  5.1 GeV (2003)**

**(previously : 172.1  $\pm$  7.1 GeV (1998))**

- Improvement in statistical errors equivalent to 2.4 more data !
- Dominant systematics from jet energy scale (3.3 GeV)

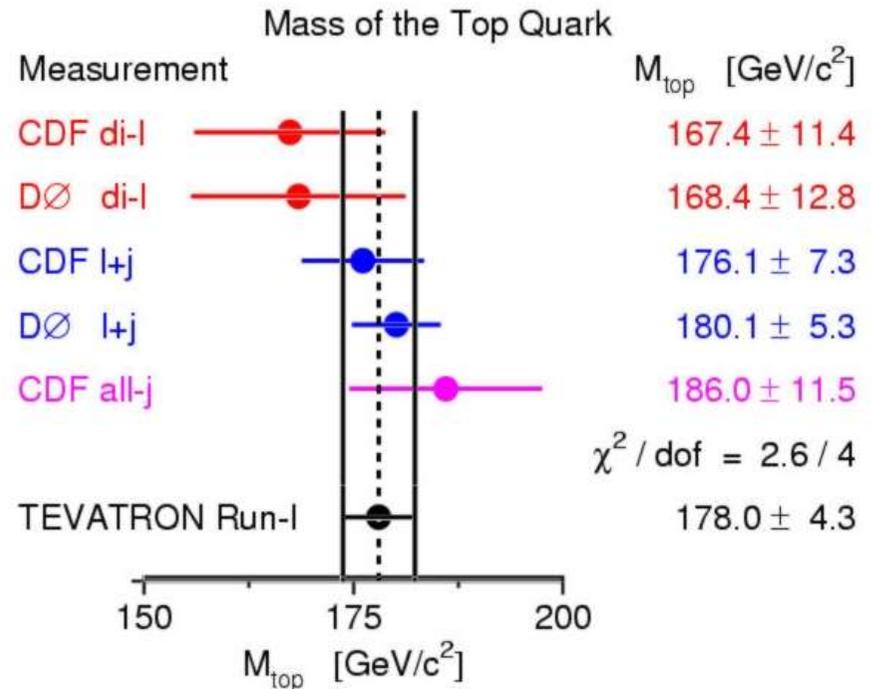
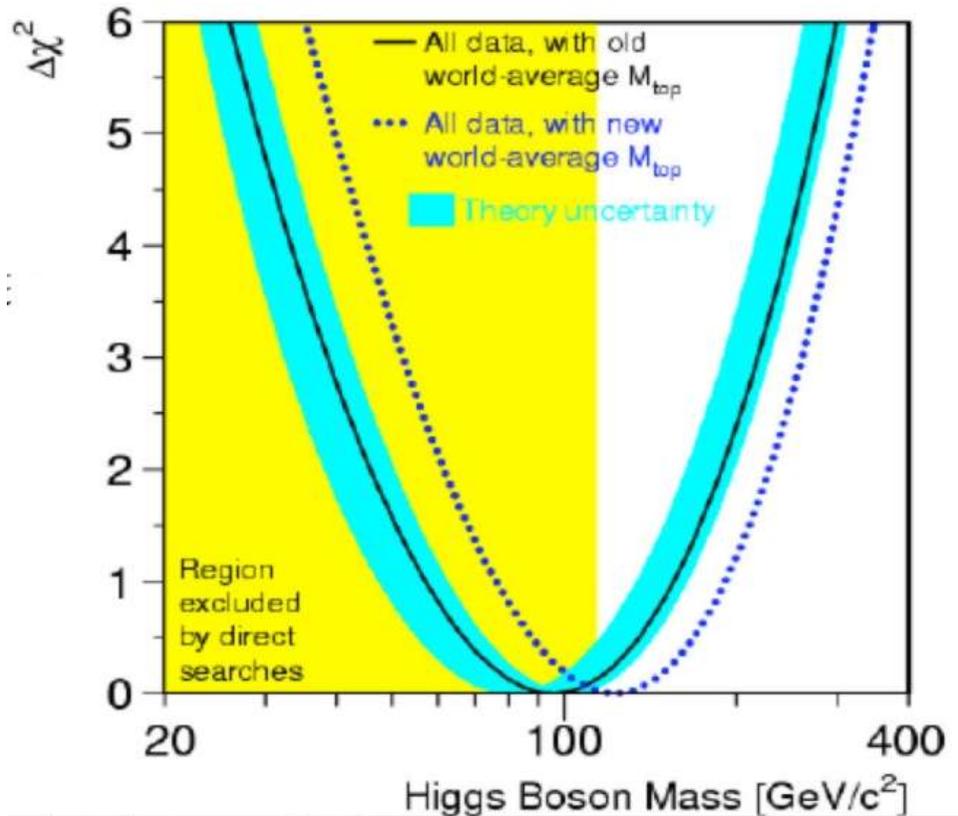


# RunI Top Mass update



New world averaged Top mass :

## New Higgs Mass constraint



$M_{top} = 178.0 \pm 4.3 \text{ GeV}$

$\log M_H = 2.07^{+0.20}_{-0.21}$

$M_H = 117^{+67}_{-45}$

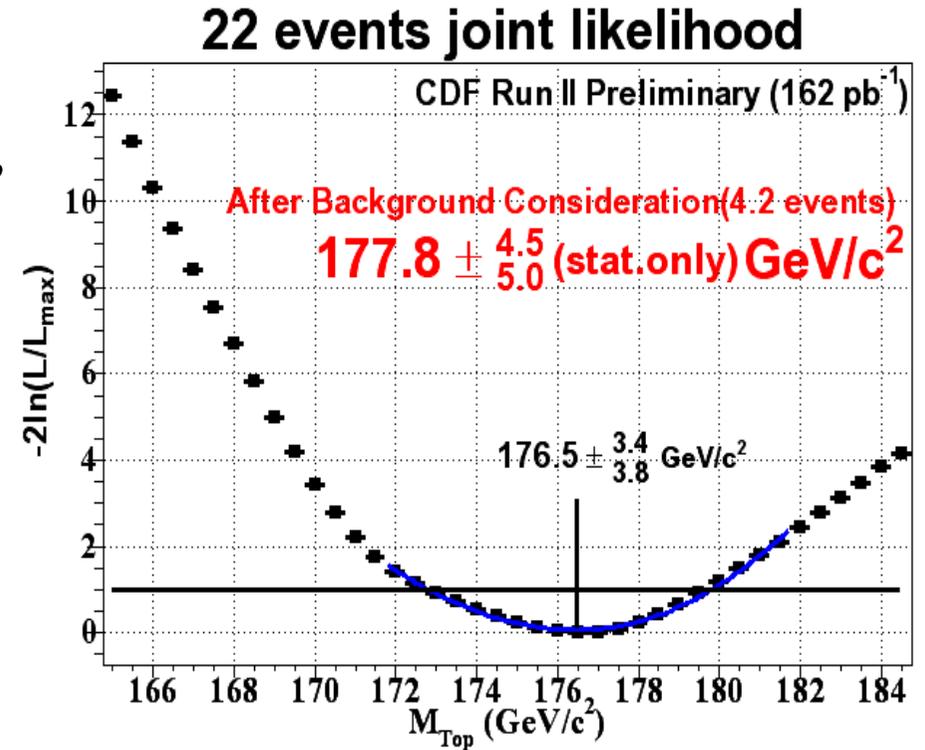
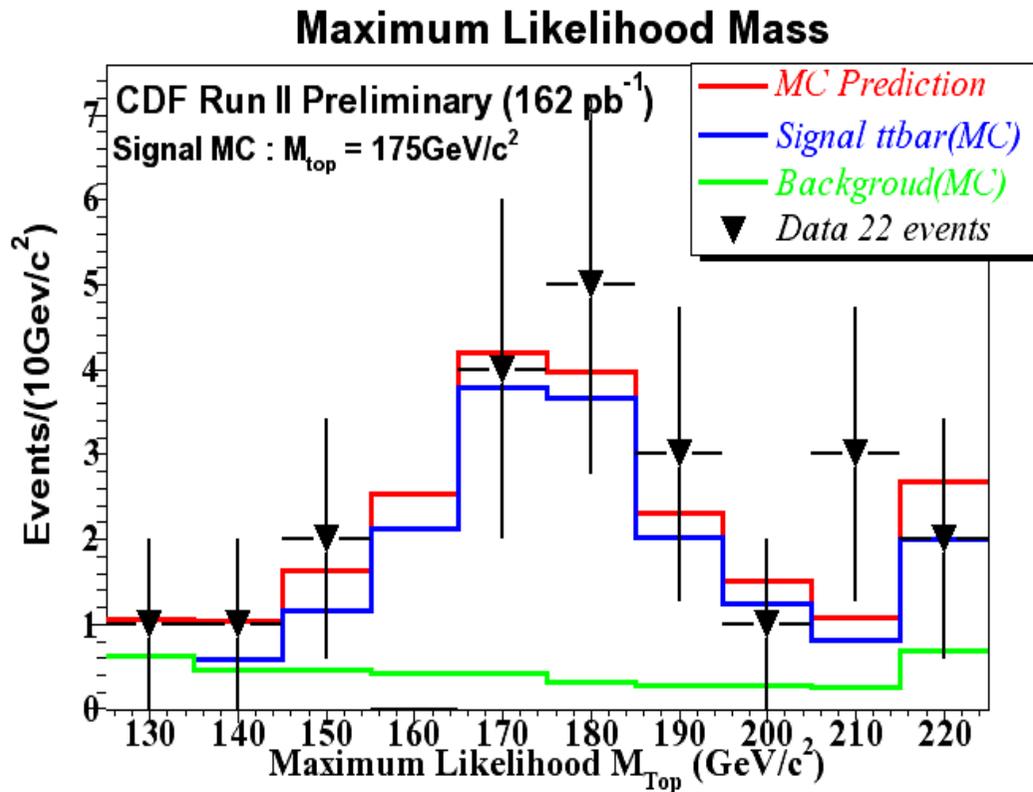
$M_H < 251 \text{ GeV (95\% CL.)}$

# RunII Top Mass



## New Dynamical likelihood method :

- Define an event likelihood (ME, pdf,  $f^{tt}(Pt)$ , transf. function(partons  $\leftrightarrow$  observables)
- Take into account all combinations



*CDF RunII Preliminary :*

$$M_t = 177.8^{+4.5}_{-5.0} \text{ (stat.)} \pm 6.2 \text{ (syst.) GeV}$$



# Conclusion - Outlook



- Top quark signal has been seen in several channels using a great variety of approaches (NN, likelihood, kinematic fit, b-tagging, ...)
- All results are consistent with theoretical predictions.
- Improved RunI measurement of the top mass, RunII results coming soon
- Statistics are still limited but quickly increasing :

**time for precise measurements is coming ...**

- On-going/future analysis :  
top mass, single-top, BR,  $|V_{tb}|$ , W helicity, spin correlations, ...