Electroweak and Top Physics at CDF in Run II

XVII Rencontres de Physique de la Vallée d'Aoste

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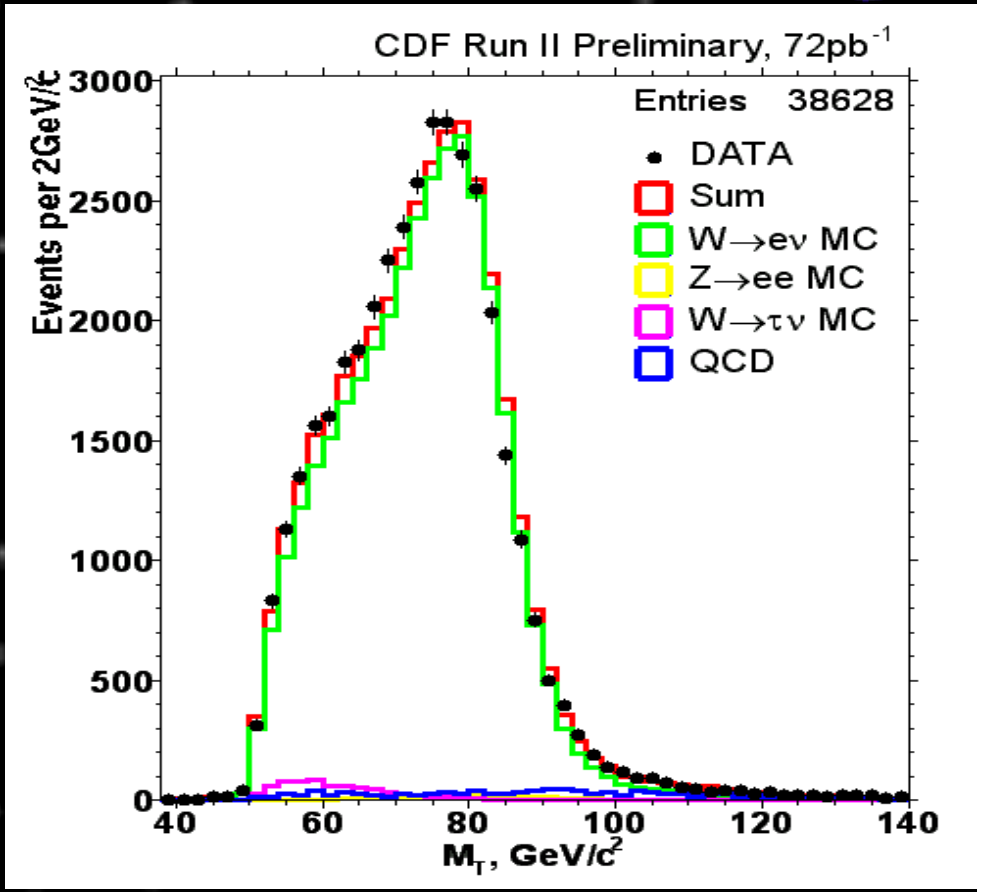
Electroweak Physics

- Cross section measurements
  - ✔$W \to l\nu$ (e,μ,τ)
  - ✔$Z^0 \to l^+l^-$ (e,μ)
- Forward-Backward asymmetry: A_{FB}
- Diboson: $W^+W^- \to ll\nu\nu$
- Standard Model consistency checks
  - ✔$R = \sigma(W \to l\nu)/\sigma(Z^0 \to l^+l^-)$ (e, μ)
    - ➤ extract $\Gamma(W)$
  - ✔$\sigma(W \to \tau\nu)/\sigma(W \to e\nu)$
    - ➤ extract g_τ/g_e

$\sigma.BR(W\rightarrow e\nu_e)$

- Event selection
  - ✔ One isolated high p_T central e
  - ✔ $\not\!\!E_T$>25 GeV
- 38628 candidates in ~72 pb^{-1}
- Backgrounds ~ 6%
  - ✔ dominated by QCD



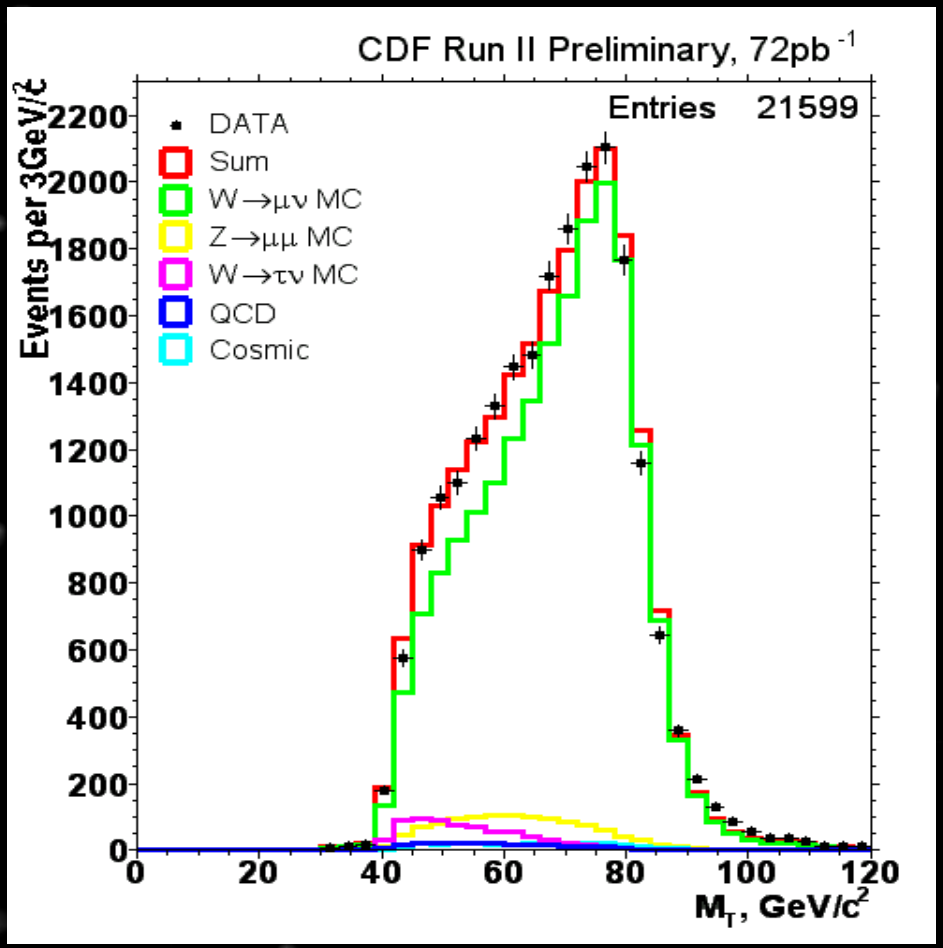
$\sigma\cdot BR(W\rightarrow e\nu) = 2.64\pm0.01_{stat}\pm0.09_{sys}\pm0.16_{lum}$ nb

NNLO @ $\sqrt{s}$=1.96 TeV[‡]: 2.69 ± 0.10 nb

[‡] Nucl. Phys. B359,343 (1991)
Phys.Rev. Lett. 88,201801 (2002)

$\sigma.BR(W\rightarrow\mu\nu_\mu)$

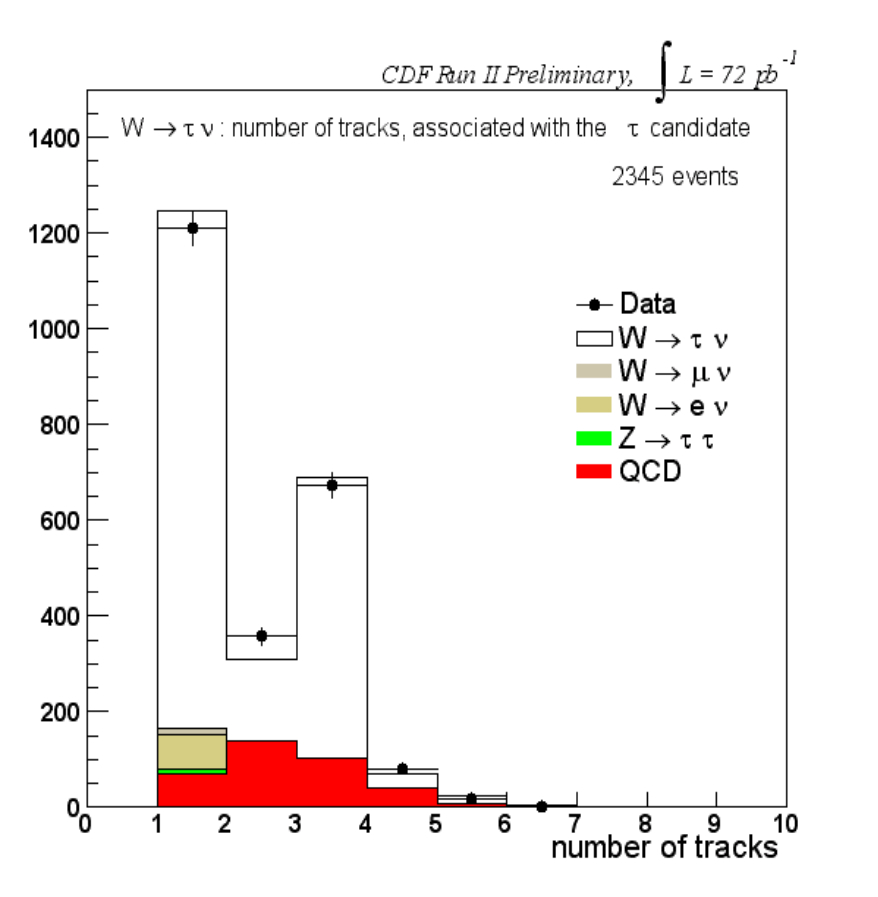
- Event selection
  - ✔ Isolated high p_T central μ
  - ✔ $\not\!\!E_T$>20 GeV
  - ✔ Z veto
  - ✔ Cosmic veto
- 21599 candidates in ~72 pb^{-1}
- Backgrounds ~ 11%
  - ✔ dominated by $Z\rightarrow\mu^+\mu^-$:



$$\sigma\cdot BR(W\rightarrow\mu\nu) = 2.64\pm0.02_{stat}\pm0.12_{sys}\pm0.16_{lum}\ nb$$

$\sigma.BR(W\rightarrow\tau\nu_\tau)$

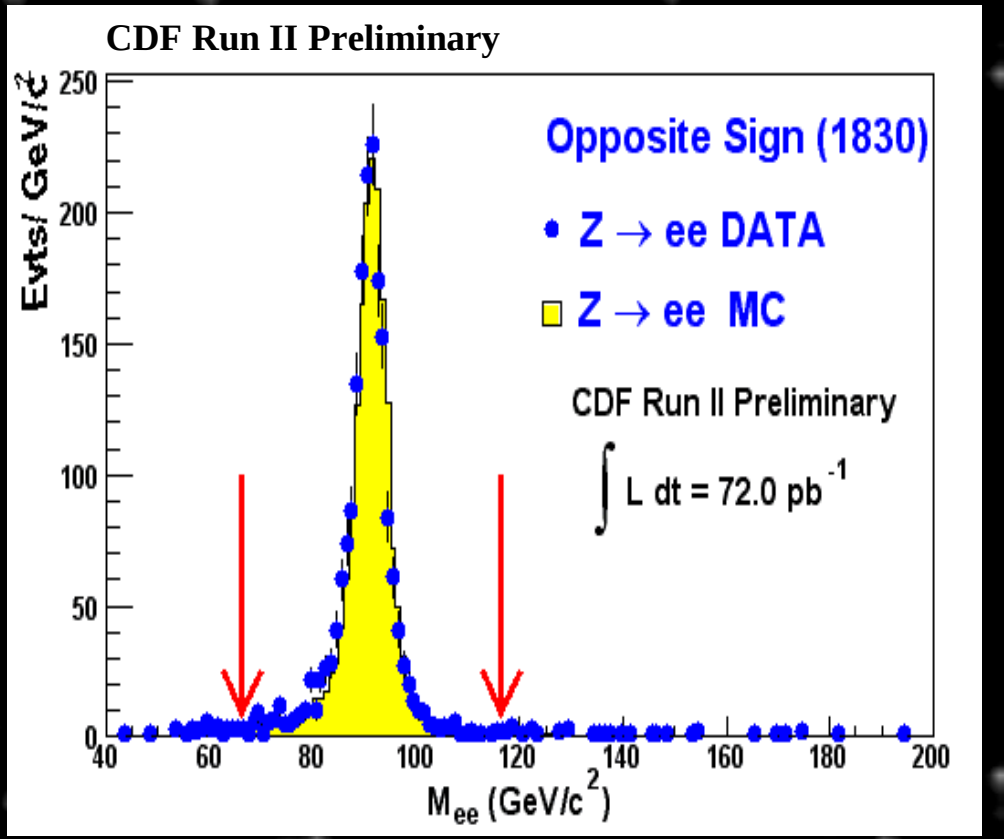
- Event selection
  - ✔ One isolated (calo+track) central τ
  - ✔ $\not\!\!E_T$>25 GeV
  - ✔ e removal
- 2345 candidates in ~72 pb^{-1}
- Backgrounds ~ 26%
  - ✔ dominated by QCD & $W\rightarrow e\nu$



$$\sigma\cdot BR(W\rightarrow\tau\nu) = 2.62\pm0.07_{stat}\pm0.21_{sys}\pm0.16_{lum}\ nb$$

$\sigma.BR(Z^0 \rightarrow e^+e^-)$

- Event selection
  - ✔ Two isolated high p_T central e
- 1830 candidates in ~72 pb^{-1}
- Backgrounds ~ 0.5%



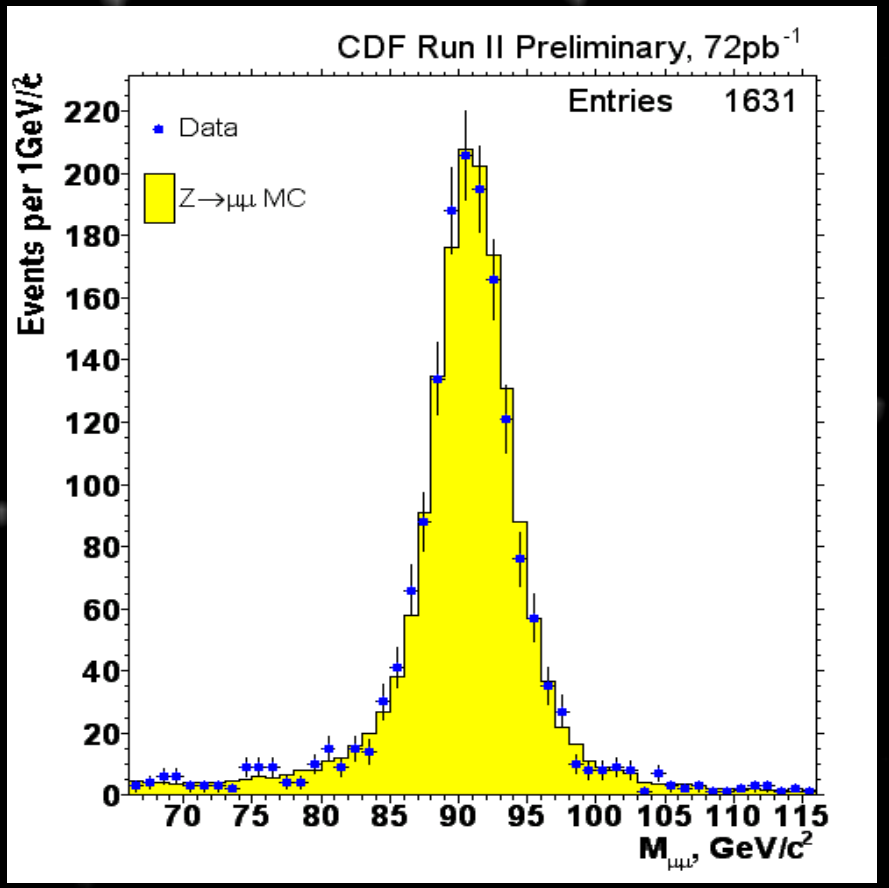
$\sigma \cdot BR(Z^0 \rightarrow e^+e^-) = 267 \pm 6_{stat} \pm 15_{sys} \pm 16_{lum}$ pb

NNLO @ $\sqrt{s}$=1.96 TeV‡: 252 ± 9 pb

‡ Nucl. Phys. B359,343 (1991)
Phys.Rev. Lett. 88,201801 (2002)

$\sigma.BR(Z^0 \rightarrow \mu^+\mu^-)$

- Event selection
  - ✔ One isolated high p_T central μ
  - ✔ A second isolated high p_T track:
    - ➤ E_{em} <2 GeV & E_{had}<6 GeV
  - ✔ Cosmic veto
- 1631 candidates in ~72 pb^{-1}
- Backgrounds ~ 0.5%

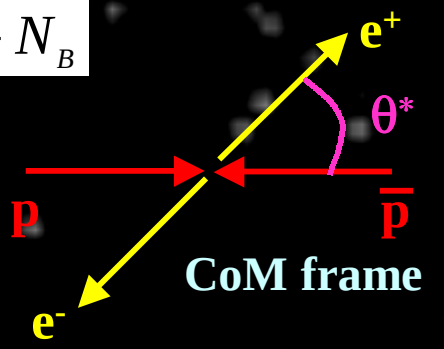


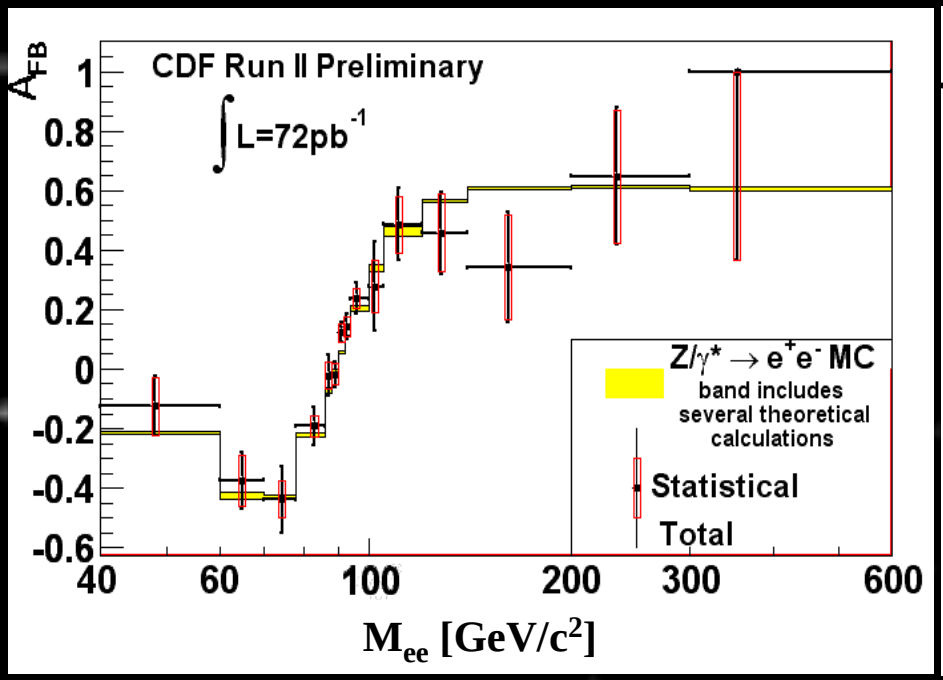
$$\sigma \cdot BR(Z^0 \rightarrow \mu^+\mu^-) = 246 \pm 6_{stat} \pm 12_{sys} \pm 15_{lum}\ pb$$

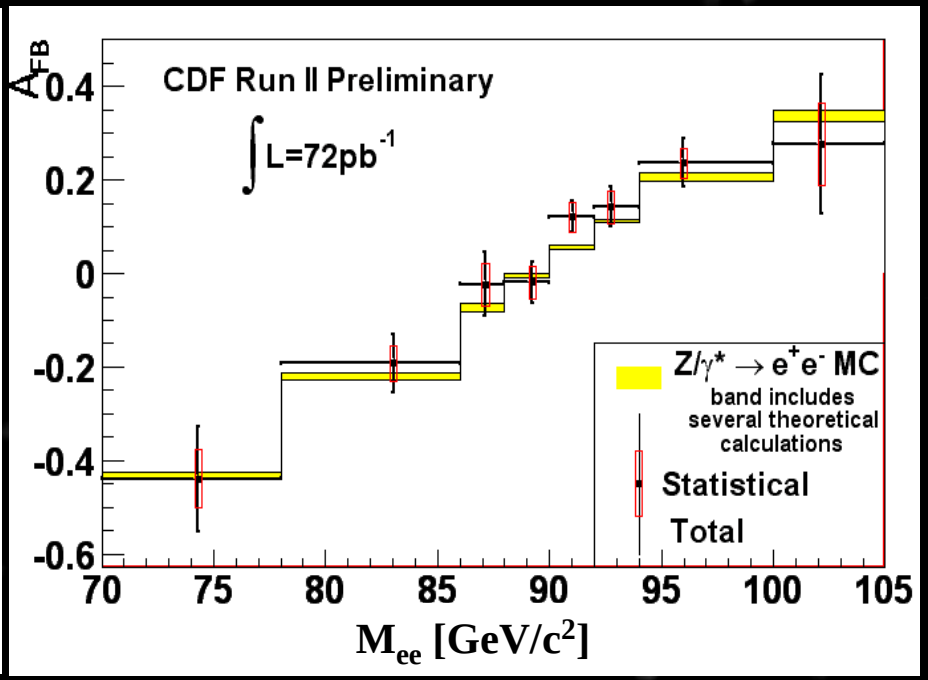
A_{FB} with $Z^0 \rightarrow e^+e^-$

- Forward-Backward asymmetry A_{FB}:
  - ✔ Direct probe V,A ⇨ Extract $\sin^2\theta_W$
  - ✔ Constrains the properties of any hypothetical heavy neutral gauge boson not in SM (e.g. Z')

$$A_{FB} = \frac{N_F - N_B}{N_F + N_B}$$







SM Consistency Checks

• electron • muon

R	$9.88 \pm 0.24_{stat} \pm 0.47_{sys}$ $10.69 \pm 0.27_{stat} \pm 0.33_{sys}$
$\Gamma(W)$ [GeV]	$2.29 \pm 0.06_{stat} \pm 0.10_{sys}$ $2.11 \pm 0.05_{stat} \pm 0.07_{sys}$

Measure *Theoretical prediction* *PDG SM* *PDG combined Exp*

$$R = \frac{\sigma(pp \to W)\,\Gamma(W \to e\nu)\,\Gamma(Z)}{\sigma(pp \to Z)\,\Gamma(W)\,\Gamma(Z \to ee)}$$

Extract

R = 10.67 ±0.15 NNLO(1.96 TeV) [Nucl. Phys. B359,343 (1991)] [Phys.Rev. Lett. 88,201801 (2002)]

Γ(W) : 2.118 ± 0.042 GeV [Phys. Rev. D66, 2002 (PDG fit)]

Γ(W) : 2.067 ± 0.021 GeV [Phys. Rev. D49, 2002]

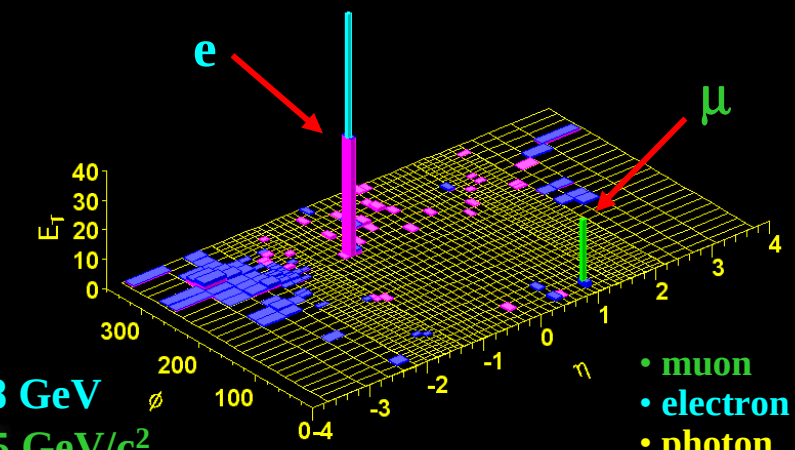
$$\frac{BR(W \to \tau\nu)}{BR(W \to e\nu)} = 0.99 \pm 0.04_{stat} \pm 0.07_{sys} \Rightarrow \frac{g_\tau}{g_e} = 0.99 \pm 0.02_{stat} \pm 0.04_{sys}$$

Diboson: $W^+W^- \to l\,l\nu\nu$

Event selection

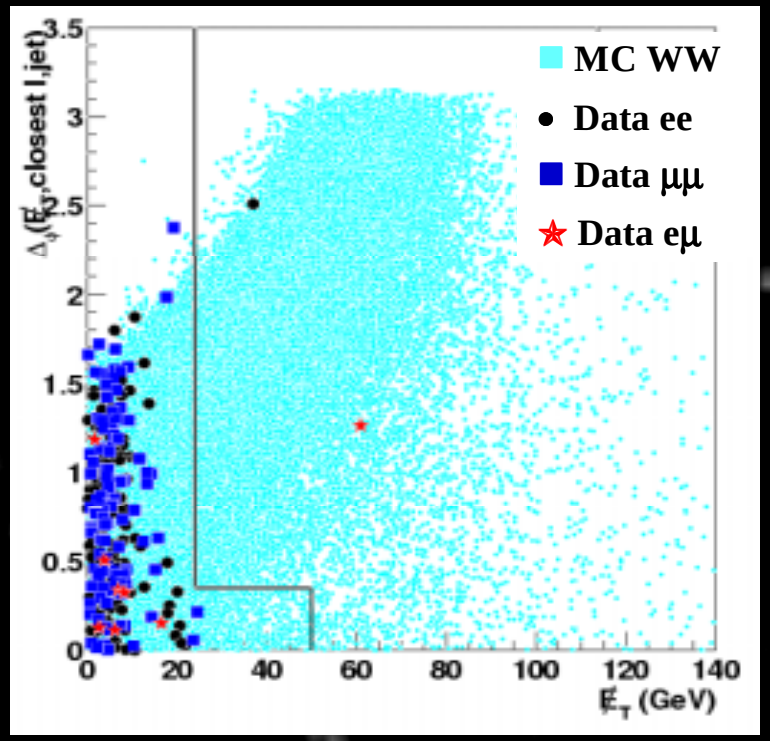
- ✔ Two high p_T isolated μ or e with opposite charge
- ✔ $\not\!\!E_T$>25 GeV
- ✔ $\Delta\phi(\not\!\!E_T, l/j)>20^0$
- ✔ Z veto
- ✔ Jet veto to reject $t\bar{t}$

Source	ee	μμ	eμ	ll
Background	0.29±0.13	0.46±0.18	0.77±0.60	1.52±0.64
WW→llνν	0.54±0.12	0.65±0.14	1.55±0.34	2.74±0.59
Data	1	0	1	2



$E_T(e)$=41.8 GeV
$P_T(\mu)$=20.5 GeV/c^2
$\not\!\!E_T$=60.2 GeV

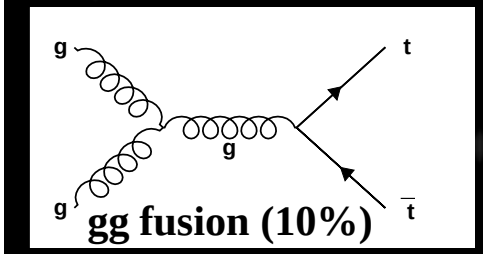
• muon
• electron
• photon

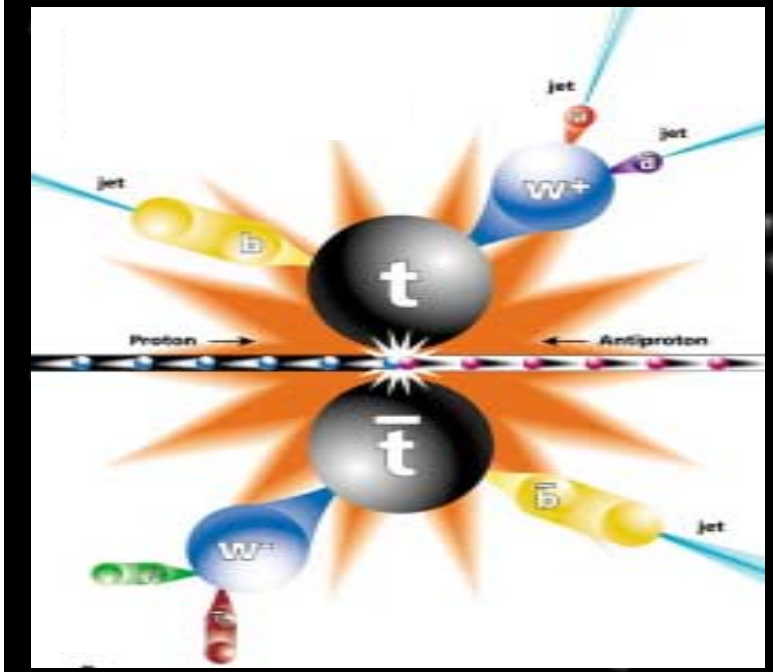


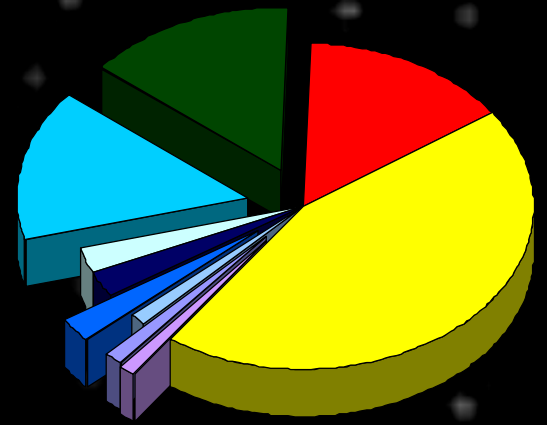
Cross section to come with more statistics

Top Production & Decay

- BR(t→Wb)≈ 100 %
  - ✔ Both W's decay via W→lν (l = e or μ; 5%)
    - ➤ final state lν lν $b\bar{b}$: dilepton
  - ✔ One W decays via W→lν (l = e or μ; 30%)
    - ➤ final state lν $q\bar{q}$ $b\bar{b}$: lepton+jets
  - ✔ Both W decays via W→$q\bar{q}$ (44%)
    - ➤ final state: $q\bar{q}$ $q\bar{q}$ $b\bar{b}$: all hadronic







Top Physics

- $\sigma_{t\bar{t}}$ measurement
  - ✔Precision test of QCD
  - ✔Probe for physics beyond SM:
    - Non-SM production:
      - $X \rightarrow tt$
      - $X \rightarrow ll + jets + \not{E}_T$
    - Non-SM decay: $t \rightarrow Xb$

- Channels:
  - ✔dilepton channel ($l\nu\ l\nu\ b\bar{b}$)
    - Good S/B≈7:1
    - Low statistics
    - More difficult to measure M_{top} accurately
  - ✔l+jets channel ($l\nu\ q\bar{q}\ b\bar{b}$)
    - Lower S/B≈1:6 for W+≥ 3 jets
      - b-tagging improve S/B≈3:1
    - Higher statistics
    - Essential for M_{top}(2 b-tags jets)

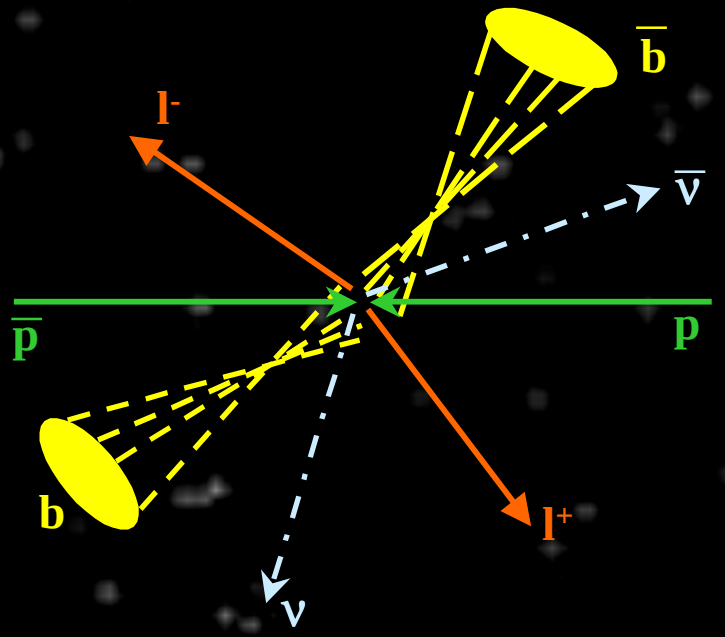
⇒ Top mass ?

Dilepton Channel

- Event selection (similar to Run I)
  - ✔ Two high p_T isolated μ or e with opposite charge
  - ✔ $\Delta\phi(\not\!\!E_T, l/j) > 20^0$
  - ✔ Z veto
  - ✔ $\not\!\!E_T > 25$ GeV
  - ✔ Jets $\not\!\!E_T > 10$ GeV & $|\eta| < 2.0$

  use ≥ 2 jets for $\sigma_{t\bar{t}}$
  - ✔ $H_T > 200$ GeV ($\Sigma \not\!\!E_T, E_T^l, E_T^j$)

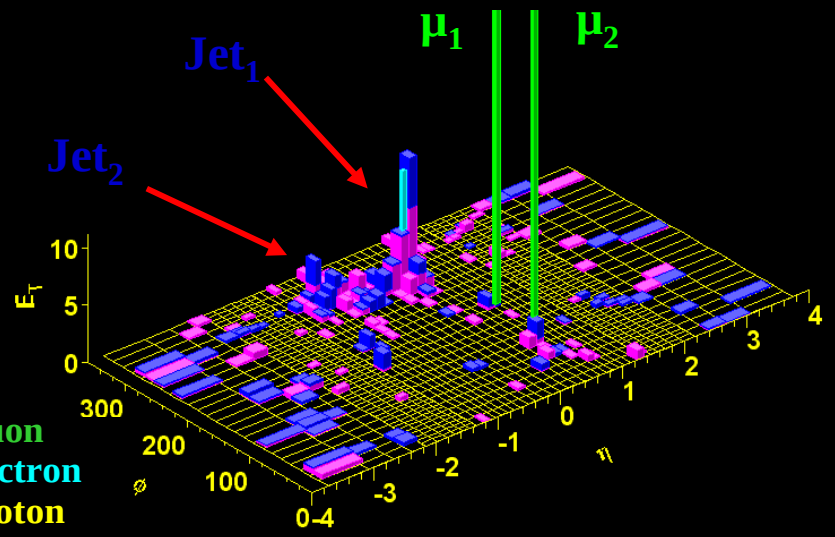
- Backgrounds
  - ✔ WW/WZ,
  - ✔ $Z \rightarrow \tau\tau$, Drell-Yan
  - ✔ fake lepton



72 pb^{-1} : 5 candidates in $\geq$ 2 jets bin (1 ee, 1 $\mu\mu$, 3 eμ)

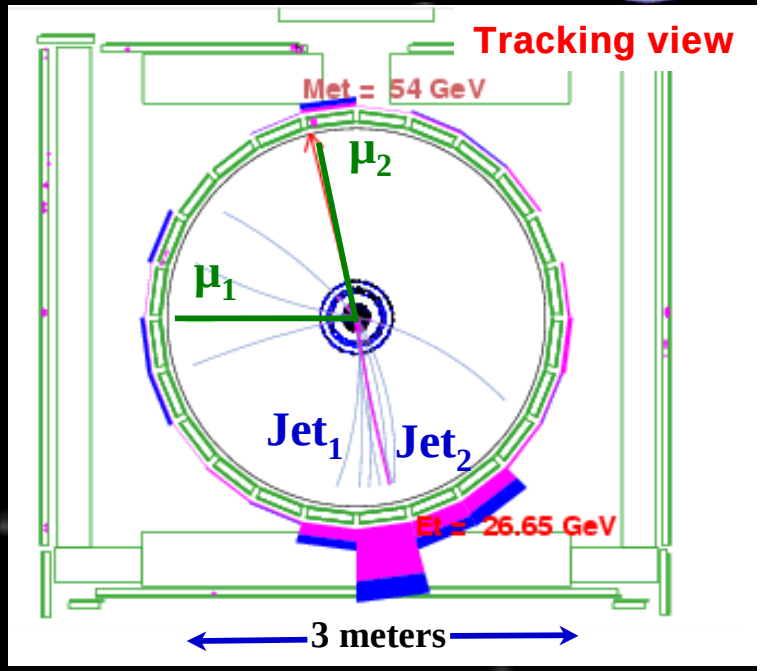
$t\bar{t}$ Dilepton Candidate

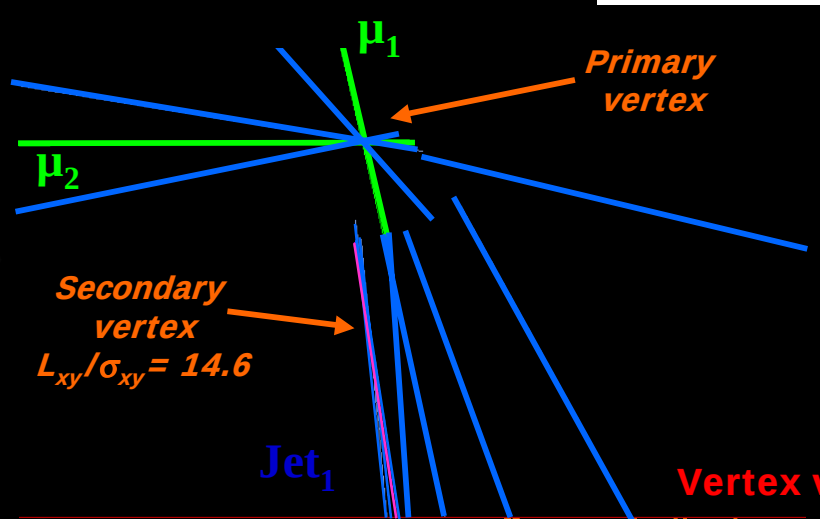
$t\bar{t}$ dilepton candidate:
Nov 26 2002 run: 154654 event: 7344016
$\mu^+\mu^-$ (CMUP-CMX) + 2 jets



- muon
- electron
- photon

Lego view





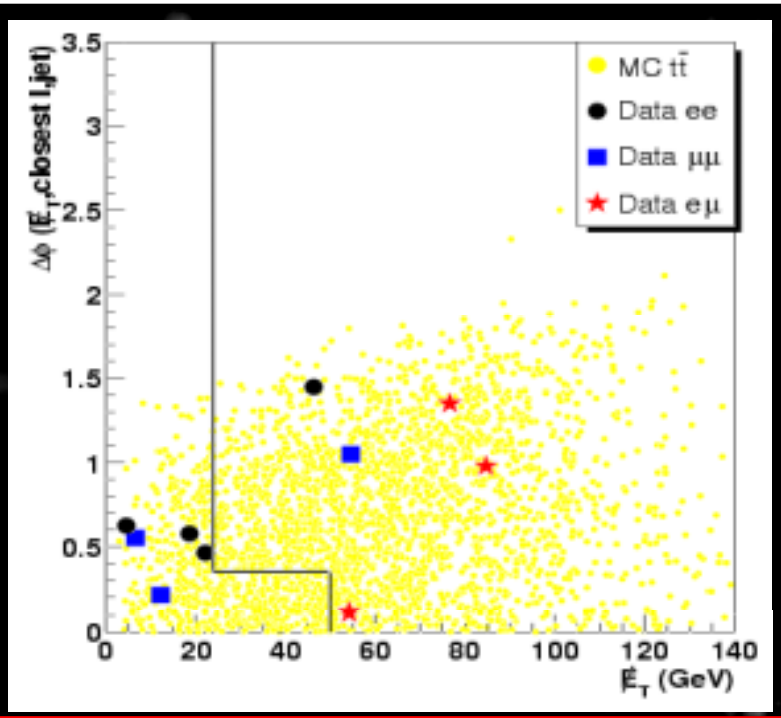
- muon
- electron
- hadron

Vertex view

$p_T(\mu_1) = 57$ GeV/c^2
$p_T(\mu_2) = 53$ GeV/c^2
$M_{\mu\mu} = 69$ GeV/c
$E_T^j = 32{,}15$ GeV
$\not\!\!E_T = 54$ GeV
$H_T = 212$ GeV

$\sigma_{t\bar{t}}$ in Dilepton Channel

Source	ee	μμ	eμ	ll
Background	0.103±0.056	0.093±0.054	0.100±0.037	0.30±0.12
tt→lνlνbb	0.47±0.05	0.59±0.07	1.44±0.16	2.5±0.3
SM expectation	0.57±0.08	0.68±0.09	1.5±0.2	2.8±0.3
Data	1	1	3	5



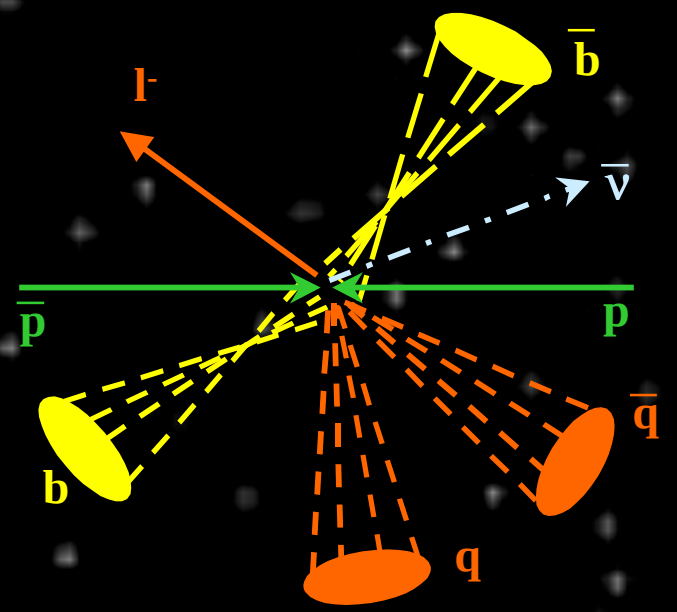
$\sigma_{t\bar{t}} = 13.2 \pm 5.9_{stat} \pm 1.5_{sys} \pm 0.8_{lum}$ pb

NLO @ $\sqrt{s}$=1.96 TeV for M_{top} = 175 GeV‡: $6.70^{+0.71}_{-0.88}$ pb

‡ MLM

Lepton+Jets Channel

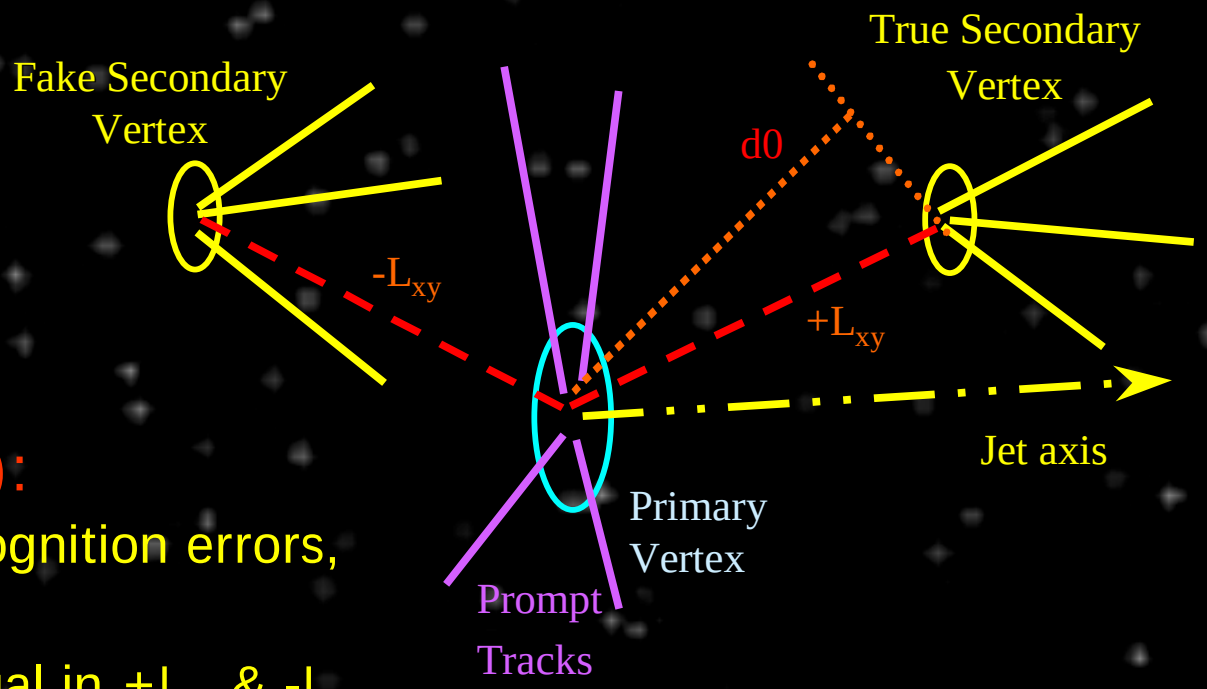
- Event selection (same as Run I)
  - ✔ One isolated high p_T central e or μ
  - ✔ $\not\!\!E_T$>20 GeV
  - ✔ Jets E_T>15 GeV & $|\eta|$<2.0
  - ✔ Z veto
  - ✔ use W+≥ 3 jets for $\sigma_{t\bar{t}}$



- Reduce background with b-tagging
  - ✔ Secondary Vertex Tagging (SECVTX)
    - ➤ Only 2% W+jets expected to have b quarks
- Backgrounds
  - ✔ W+jets ($g \to b\bar{b}$, $c\bar{c}$)
  - ✔ Mistags from light quarks and gluon jets
  - ✔ W+charm
  - ✔ Non W background (fake lepton), diboson, Drell-Yan, single top (small)

Lepton+Jets: b - tagging

- b-quarks have a long lifetime: $c\tau \sim 450\ \mu m$
  - ✔ B hadrons travel L_{xy}~3mm before decay
- Jet is tagged as b-jet if $L_{xy}/\sigma_{xy} > 3$ (typical σ_{xy}~150μm)

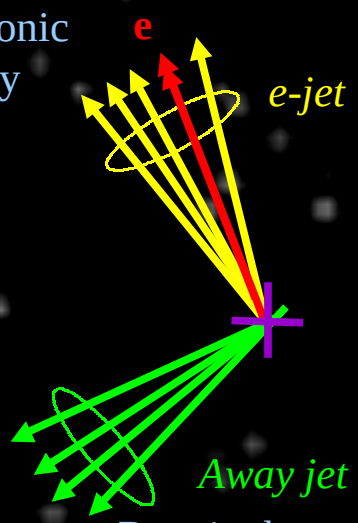


- Mistags ($g \to d\bar{d}$, $u\bar{u}$):
  - ✔ Due to pattern recognition errors, resolution etc...
  - ✔ Assume mistag equal in $+L_{xy}$ & $-L_{xy}$

b - tagging Efficiency

- Jet b-tagging efficiency
  - ✔ $\varepsilon_B = r/F_B$
    - Tagging rate: $r = (N_+ - N_-)/N_{tot}$
    - F_B: Fraction of e-jets containing heavy flavour
  - ✔ Done with few different methods:
    - results all consistent with each other
  - ✔ Measured in data & $b\bar{b}$ MC
    - Determine Scale Factor

Semi-leptonic b decay

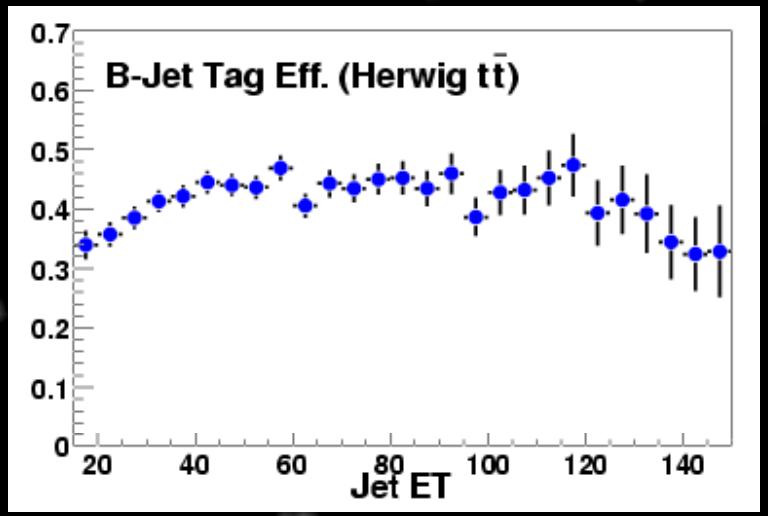


Require b-tag to enhance b-flavour

ε (Data)	ε (MC)	Scale Factor
0.20±0.01	0.22±0.01	0.89±0.07

- Efficiency of b-tagging a $t\bar{t}$ event
  - ✔ measure in $t\bar{t}$ MC, apply SF

ε(event tag) = 45 ± 1 ± 5 %

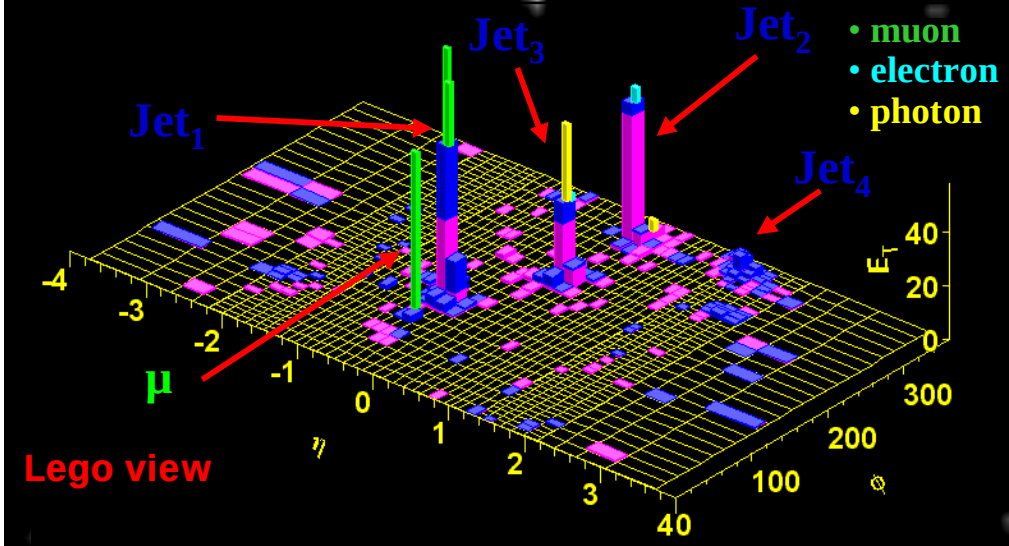


l+jets: Main Backgrounds

- Mistags measured from data
- $Wb\bar{b}$ & $Wc\bar{c}$ measured from MC
  - ✔ Relies on simulation of heavy flavour content
  - ✔ For now take $b\bar{b}$ & $c\bar{c}$ fraction in $Wb\bar{b}$ & $Wc\bar{c}$ from Run I
    - ➤ RunI & Run II fractions agree within uncertainties
  - ✔ b-tagging efficiency from Run II corrected with SF

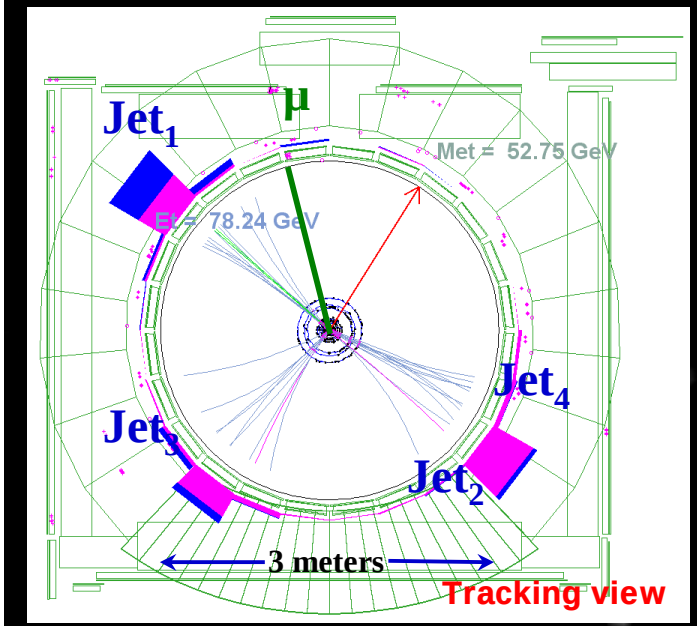
Njet	1	2	3	≥ 4
$-L_{xy}$	7.4 ± 0.77	2.9 ± 0.33	0.7 ± 0.1	0.25 ± 0.046
$Wb\bar{b}$	6.3 ± 2.3	3.9 ± 1.3	0.8 ± 0.3	0.30 ± 0.11
$Wc\bar{c}$	2.3 ± 1.0	1.5 ± 0.7	0.2 ± 0.1	0.07 ± 0.03
Total	16.0 ± 3.4	8.4 ± 2.0	1.7 ± 0.4	0.6 ± 0.2

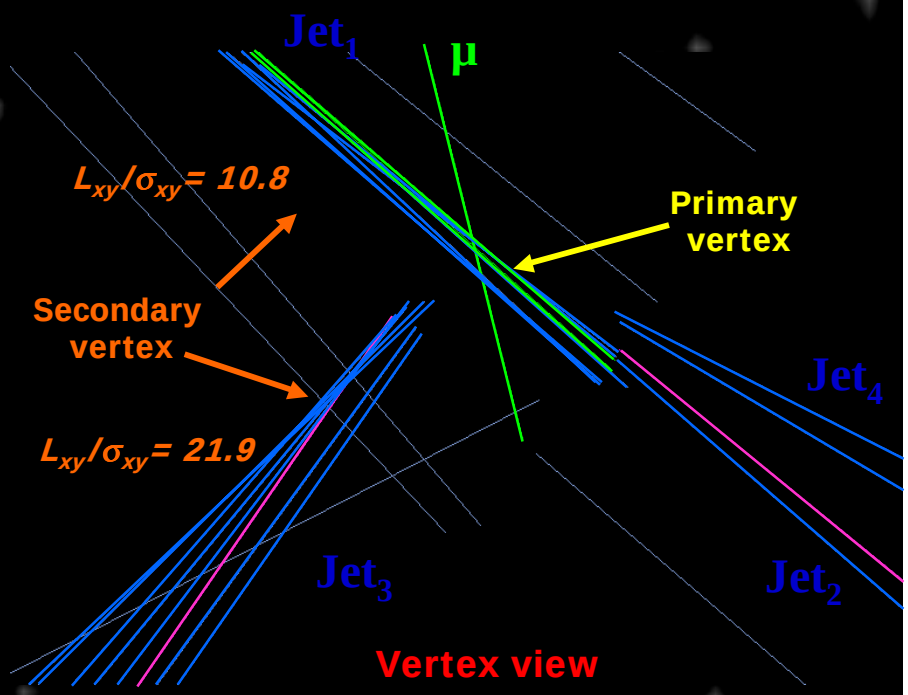
$t\bar{t}$ l+jets Candidate



$\bar{t}t$ l+jet candidate:
Nov 02 2002 run: 153693 event: 799494
μ (CMUP) + 4 jets

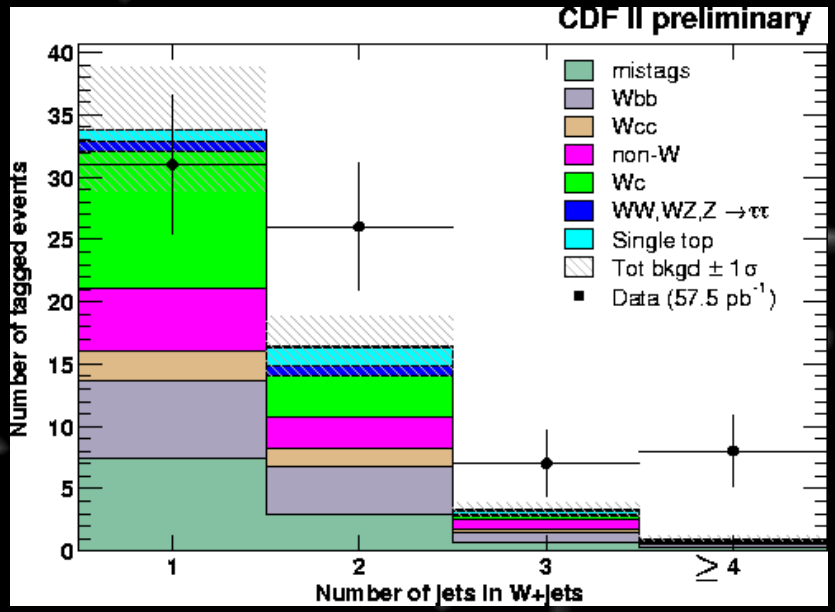
$p_T(\mu) = 54.4$ GeV/c^2
$E_T^j = 96.7, 65{,}8, 54.8, 33.8$ GeV
$\not{E}_T = 40.8$ GeV

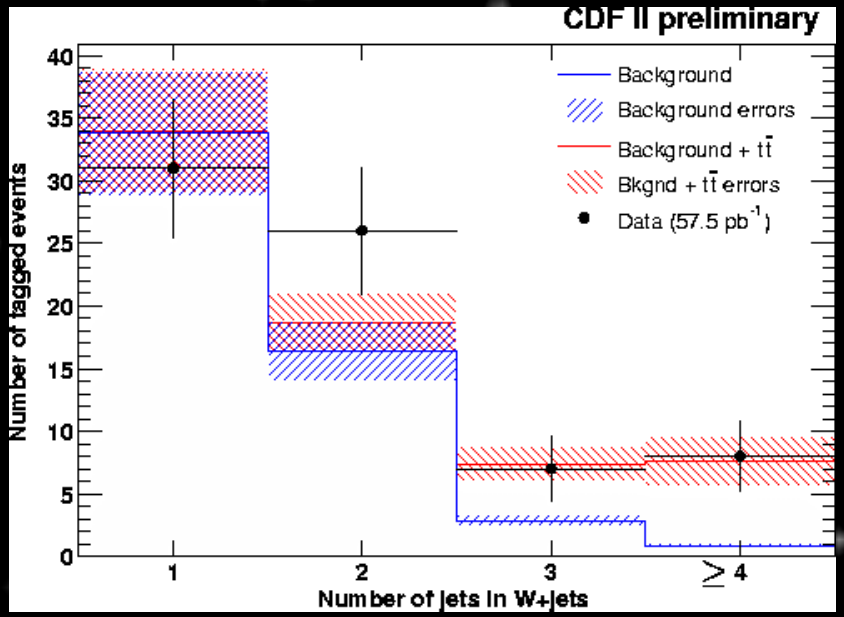




$\sigma_{t\bar{t}}$ Measurement: l+jets channel

Source	W + 1jet	W + 2jets	W + 3jets	W + ≥4jets
Background	33.8±5.0	16.4±2.4	2.88±0.05	0.87±0.2
SM Bkgnd + $t\bar{t}$	34.0±5.0	18.65±2.4	7.35±1.4	7.62±2.0
Events before tagging	4913	768	99	26
Events after tagging	31	26	7	8



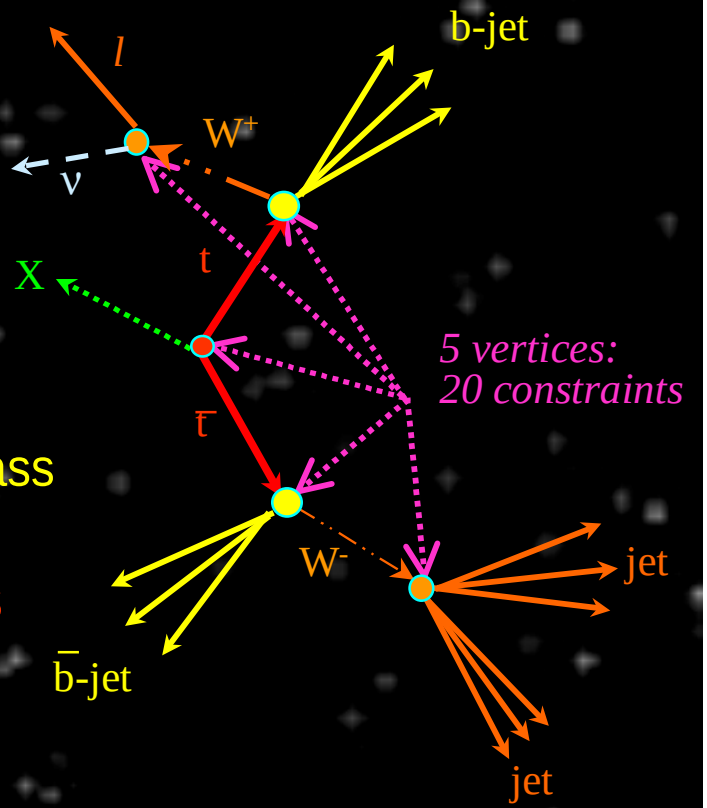


$\sigma_{tt} = 5.3 \pm 1.9_{stat} \pm 0.8_{sys} \pm 0.3_{lum}$ pb

NLO @ $\sqrt{s}$=1.96 TeV for M_{top} = 175 GeV‡: $6.70^{+0.71}_{-0.88}$ pb

Top mass

- Sample: l+jets
  - ✔ 24 combinatorics
    - ➤ 12 correspond to the jet-parton match
    - ➤ every combination has two solutions for p_z^{ν}
  - ✔ with 1 b-tagged jet goes down to 12
  - ✔ with 2 b-tagged jets to 4
  - ✔ Impose $M_t = M_{\bar{t}}$, $M(j,j) = M(l,\nu) = M_W$,
    - ➤ PDG: M_W, Γ_W, Γ_t
  - ✔ 2-C fit applied, lower χ^2 is chosen for top mass
- Model the shape of reconstructed mass distribution for $t\bar{t}$ & background events
- Extract top quark mass using maximum Likelihood



Run II Top Mass uncertainties

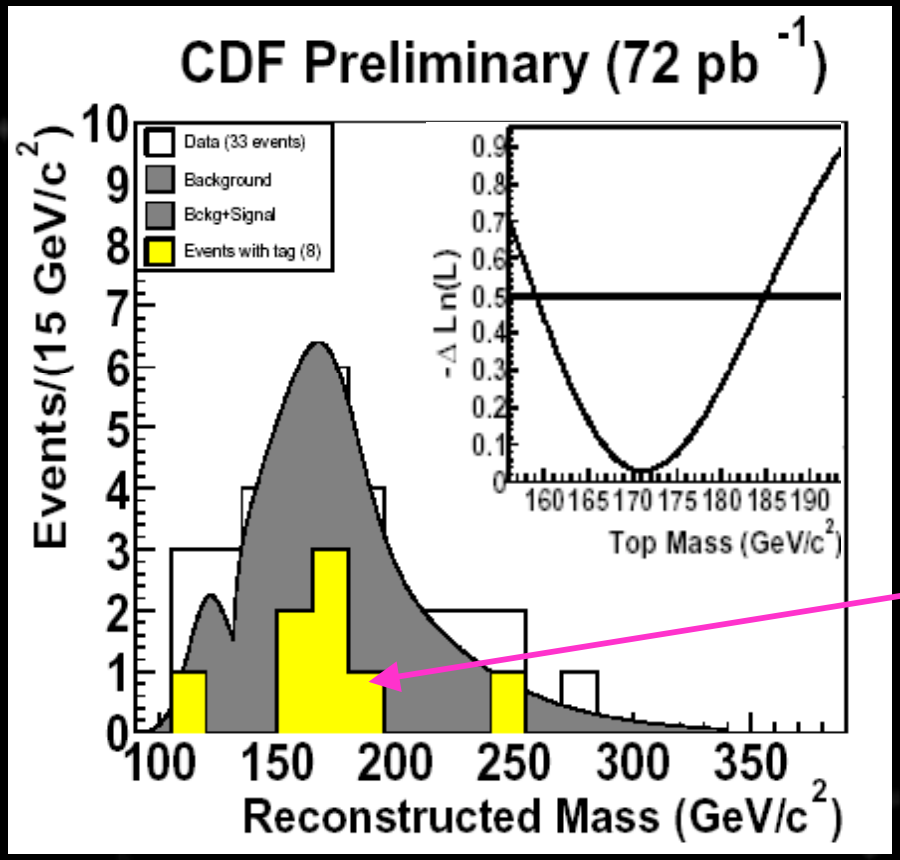
Run I uncertainty was 4.4
Need to understand CDF calorimeter better.

Run II Systematic uncertainties on M_{top}

Source	Uncertainty (GeV/c^2)
Jet Energy Measurement	9.3
Initial and Final State Radiation	2.4
Background Shape	0.3
Parton Distribution Functions	1.8
Monte-Carlo Generators	1.8
Total	9.9

We know how to do it !

How does it look ?

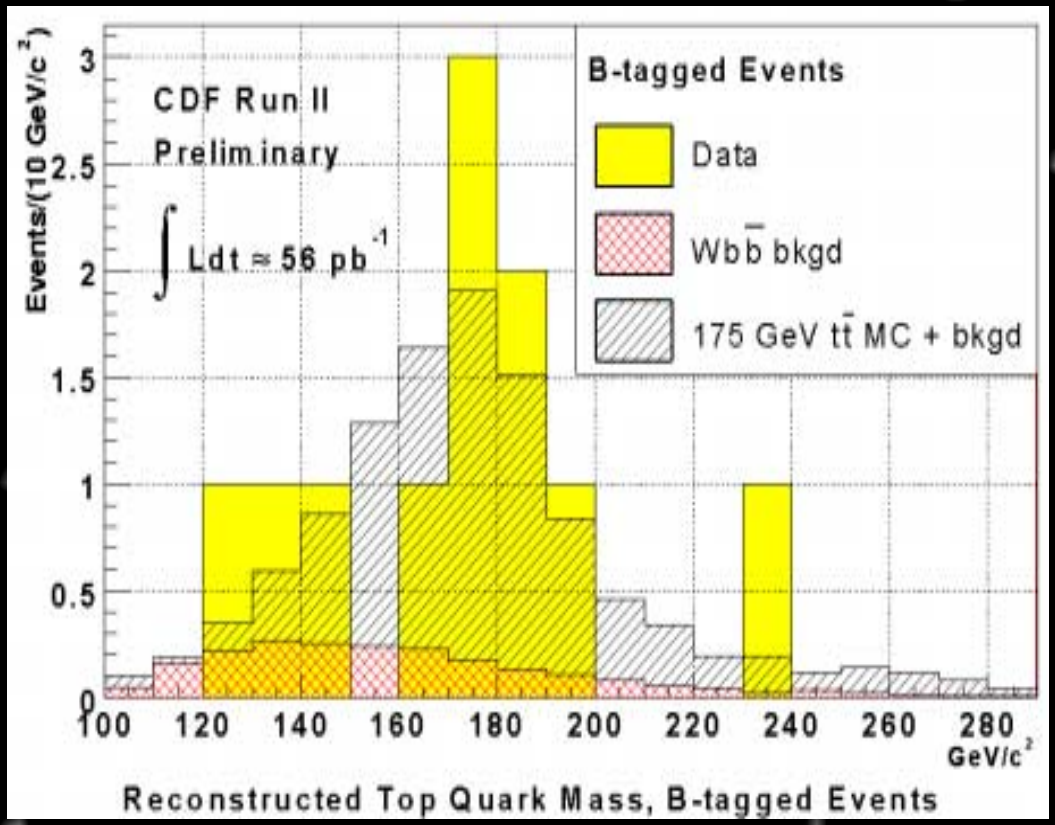


- No b-tag requirement on the jets ...
  - ✔≥4 jets with E_T>15 GeV

Event with at least 1 b-tagged jet
Not used in the fit!

$$M_{top} = 171.2^{+14.4}_{-12.5\ stat} \pm 9.9_{sys}\ GeV/c^2$$

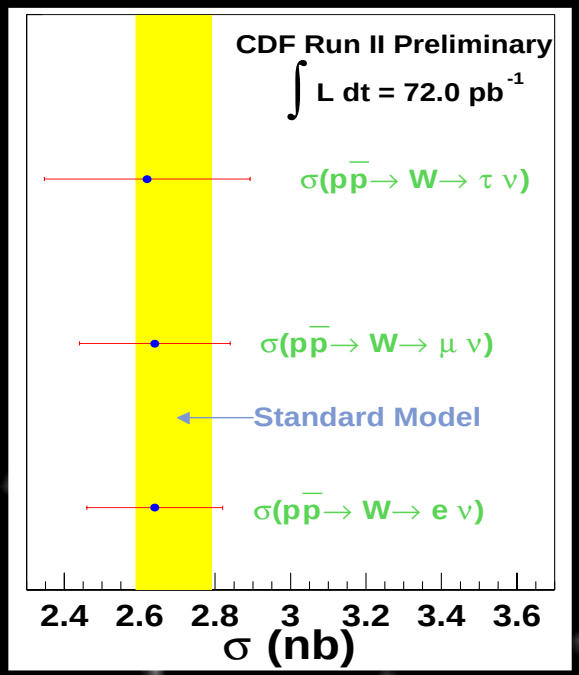
What about using b-tagging ?

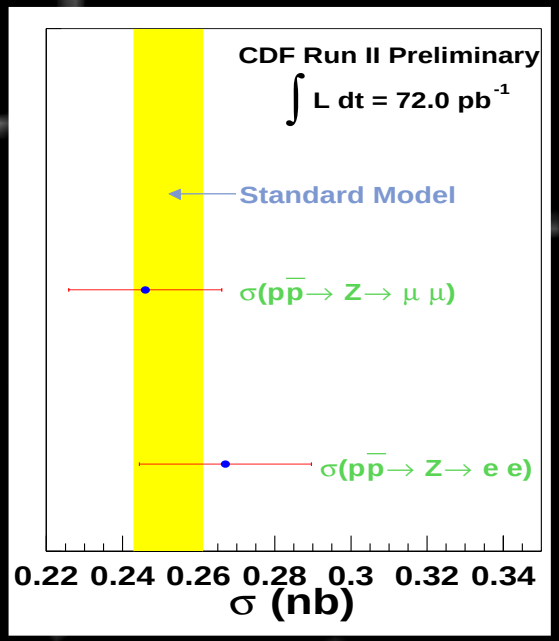


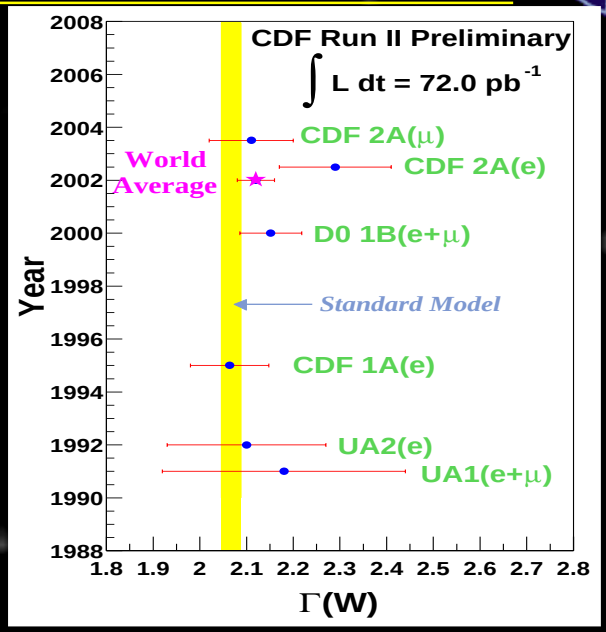
- **4** jets with $|\eta| < 2.0$,
  - ✔**3** with $E_T > 15$ GeV
  - ✔Require at least 1 b-tagged jet

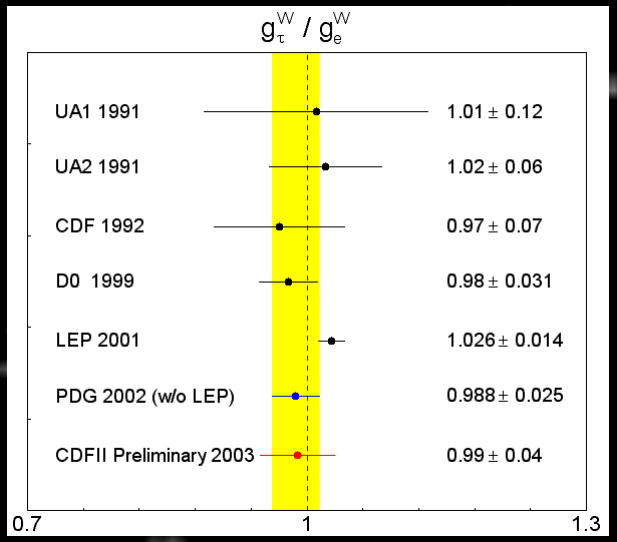
M_{top}= ??? soooonnnn

EWK summary



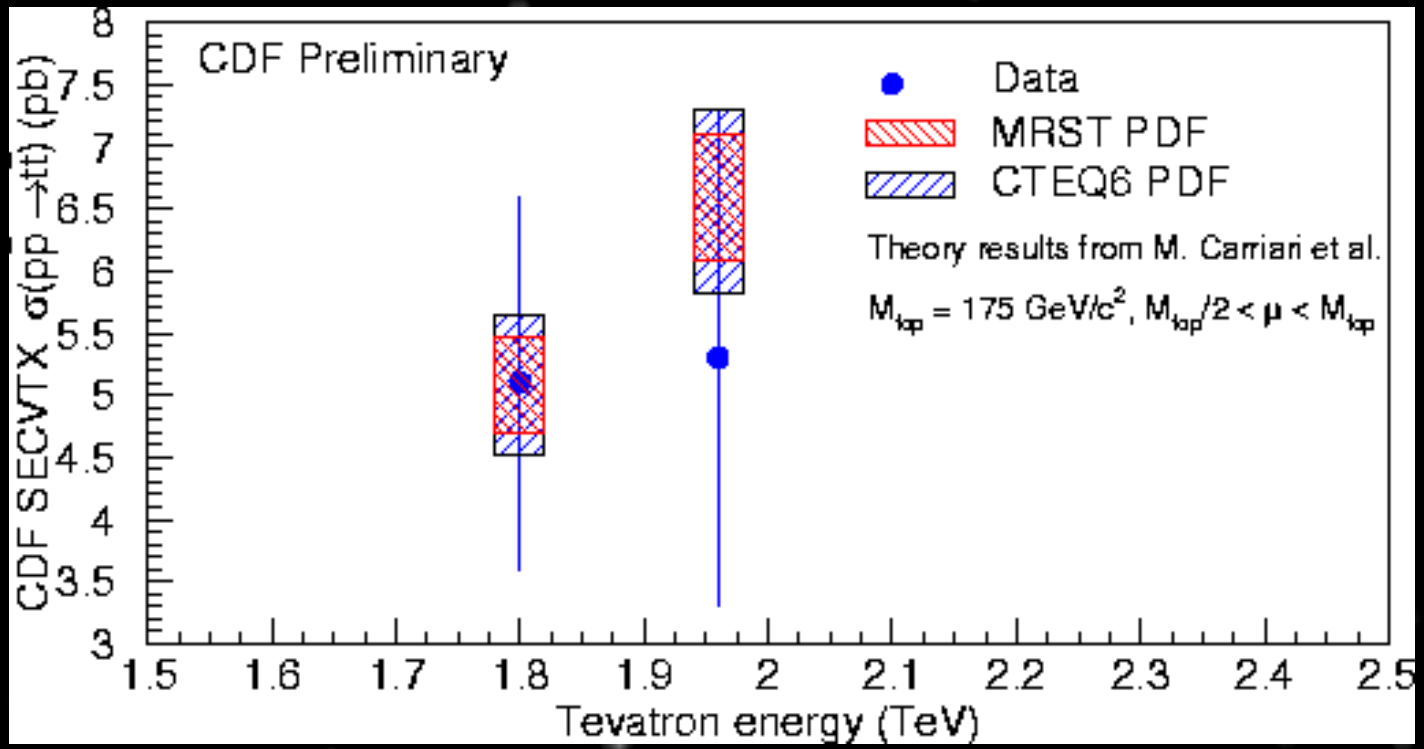






Many new results already competitive

Top summary



Run I like cross section analyses in good shape

Top mass measurement on its way...

Stay tuned for exciting results from CDF ...