Electroweak and Related Physics at CDF

Tim Nelson
Fermilab

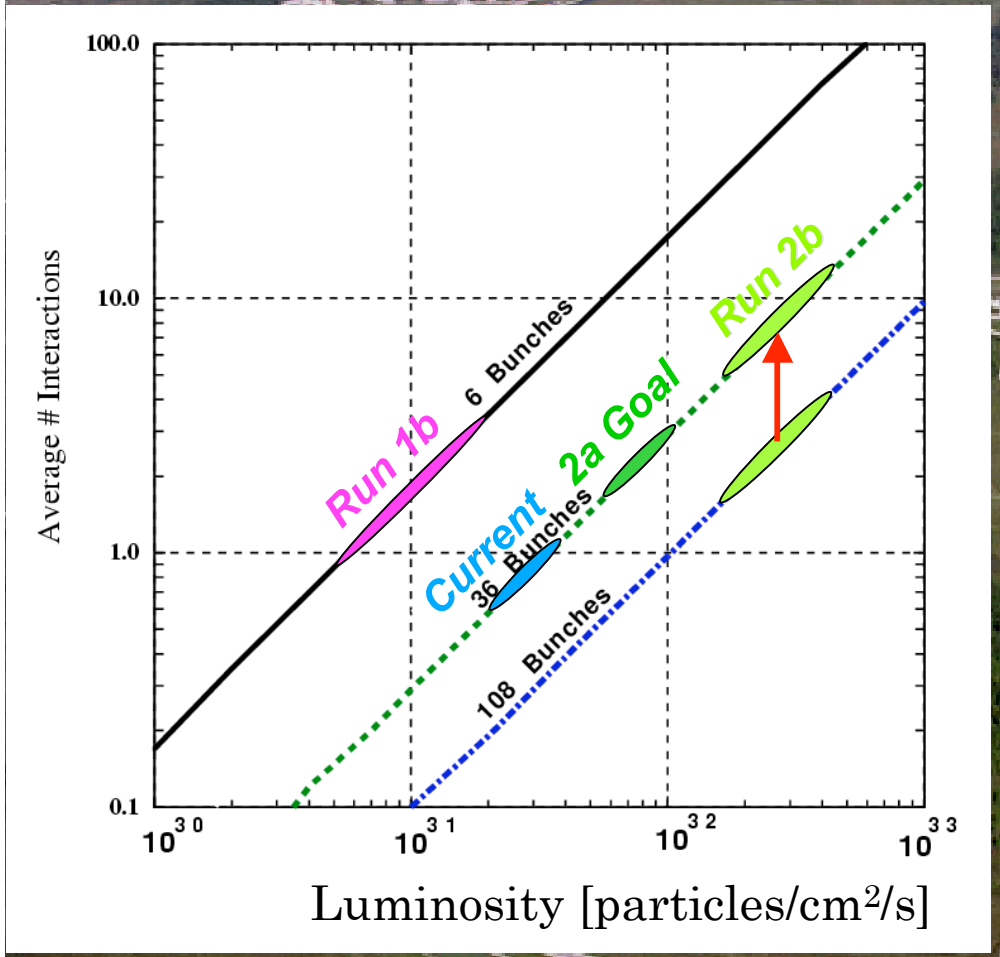
on behalf of the CDF Collaboration

DIS 2003
St. Petersburg
April 2003

Outline

- Experimental Status
- Electroweak
- Top
- Precision Searches
- Outlook

Tevatron Status



Upgrades:

- E_{CM}: 1.8 → 1.96 TeV
- Luminosity: 10^{31} → 10^{32}
- Run 2b (396 ns)

Making progress…

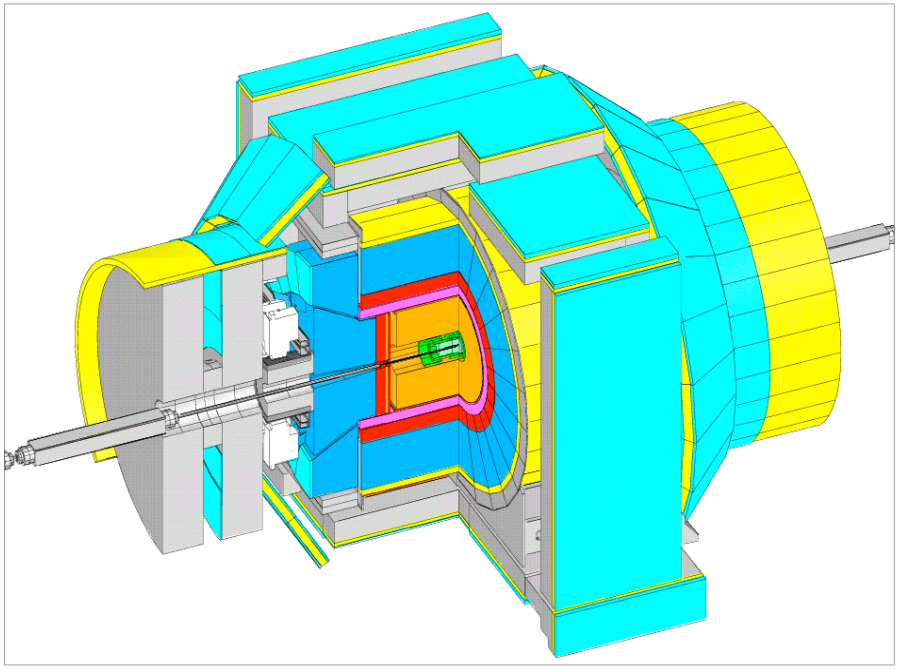
Currently less data approved for analysis than Run I

- 72 pb^{-1}
- 57 pb^{-1} w/ silicon

The CDF-II Detector

Major Upgrade:

- *New Silicon Tracking*
  - Extended coverage
  - 3-D reconstruction
- *New Drift Chamber*
  - Faster (2 □s □ 396 ns)
  - 96 *dE/dx* samples/track
- *New Forward Calorimeter*
  - 1.3 <|□|<3.5,
    same technology as central
- *Added Time-Of-Flight*
  - ~ 100 ps resolution
- *Extended muon coverage*
  - |□| < 1 □ |□|<1.5
- *New Trigger*
  - Tracks at L1
    (p_T>1.5 GeV/c)
  - Silicon Tracks at L2
    (p_T>2.0 GeV/c)



Silicon Tracking Detectors

Central Drift Chamber

Solenoid Coil /TOF

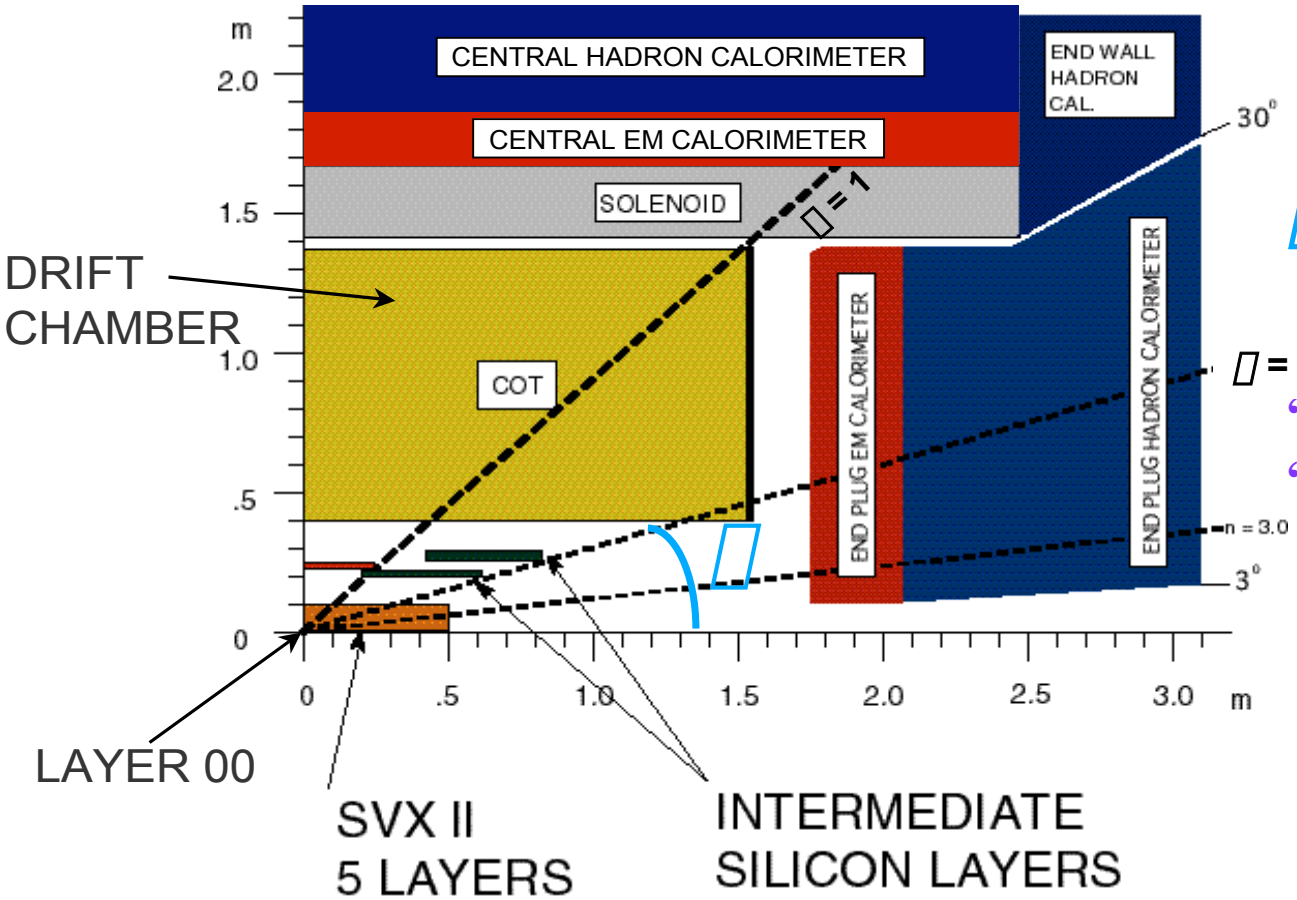
EM Calorimeter

Hadronic Calorimeter

Muon Drift Chambers

Muon Scintillator Counters

Tracking Upgrades



$= -ln(tan(/2))$

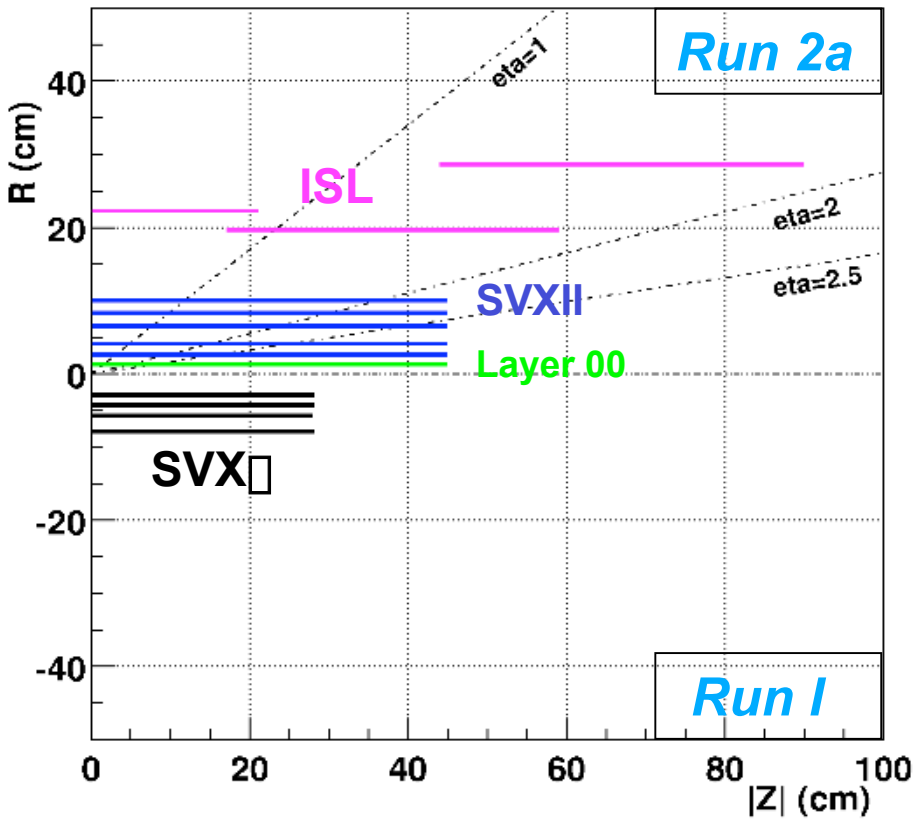
"central": $|| < 1.1$

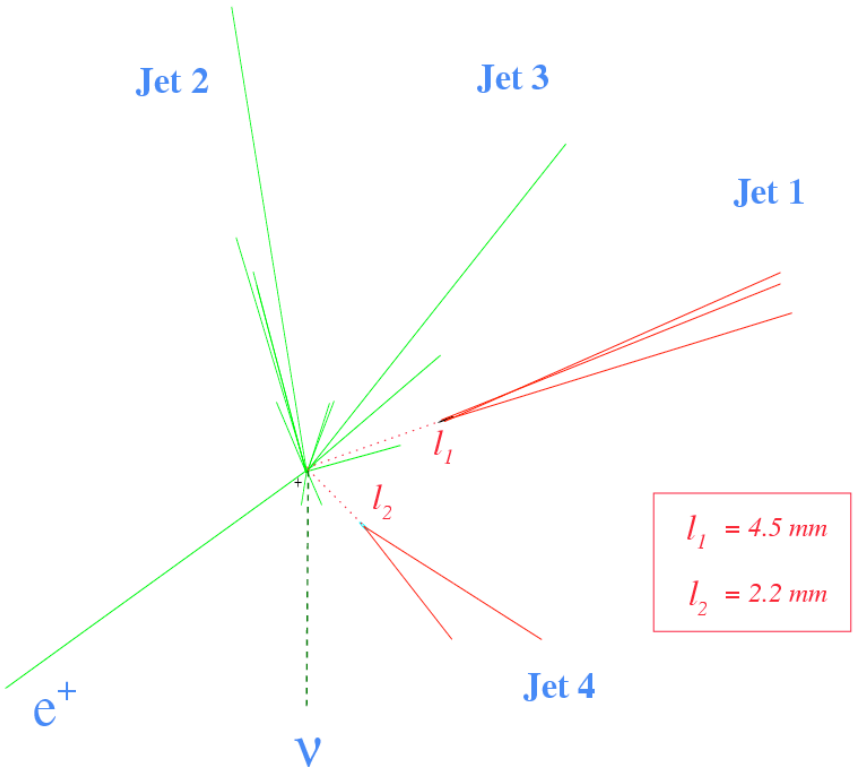
"forward": $|| > 1.1$

Tracking is fundamental to lepton identification

Silicon Upgrade

$\eta = -ln(tan(\theta/2))$

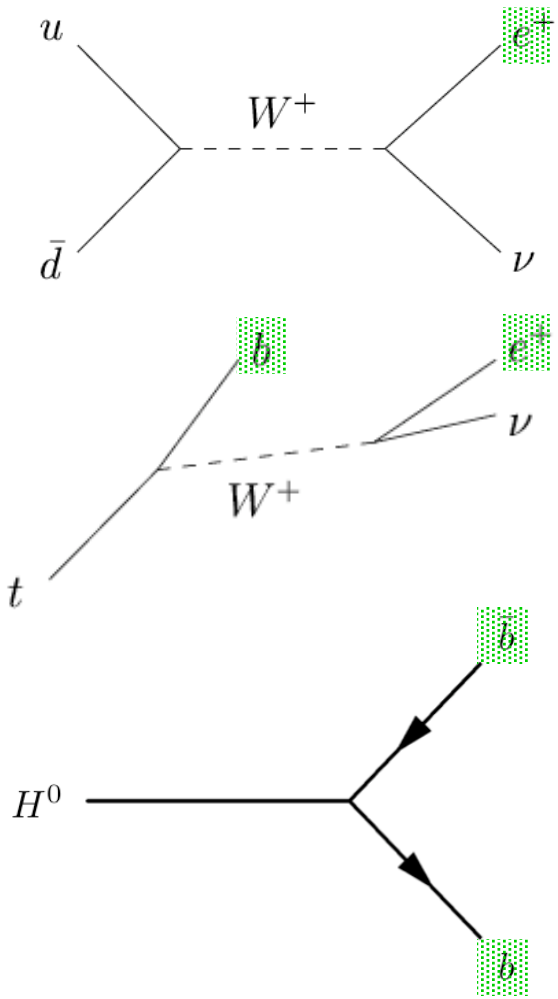


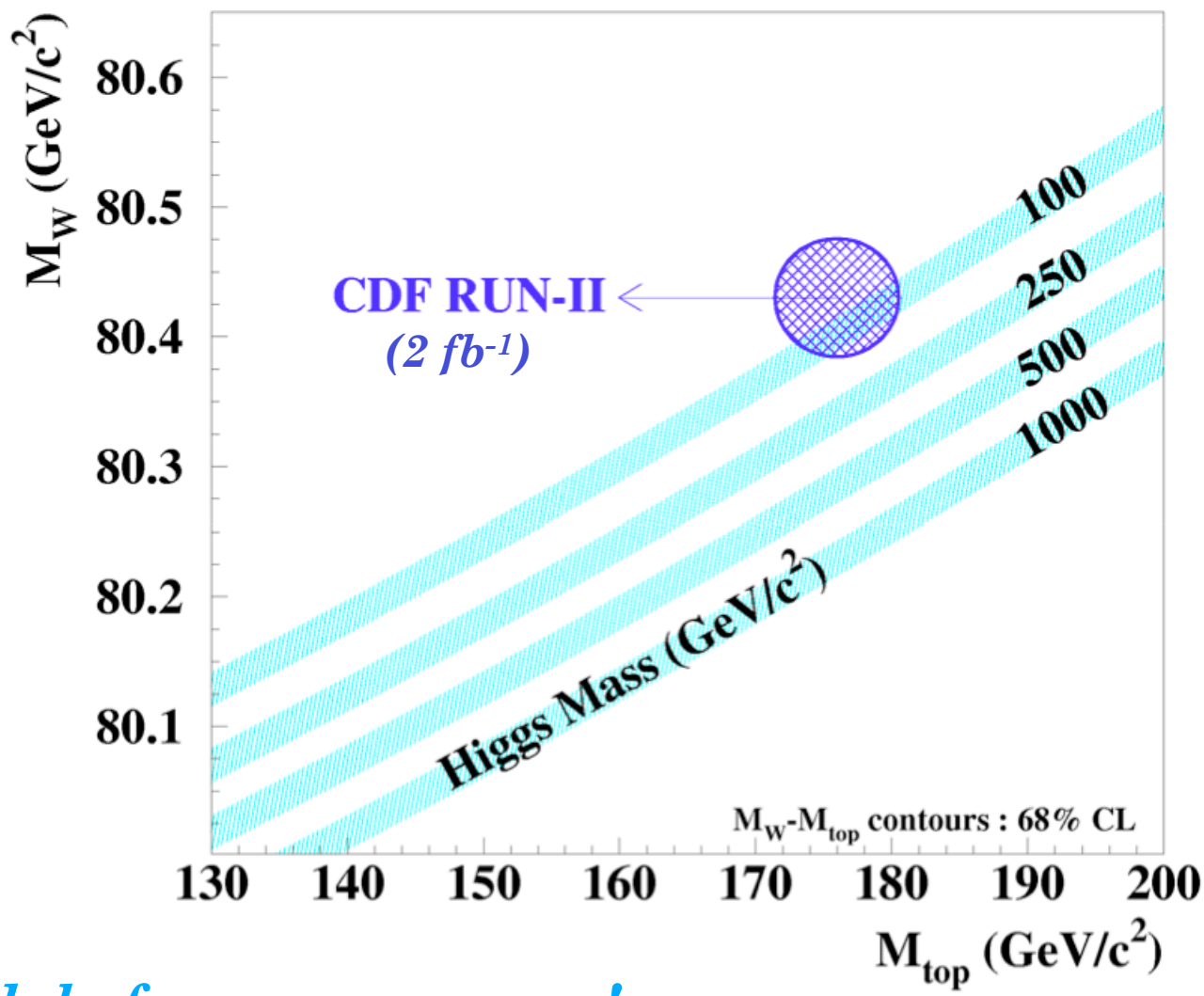


tt̄ e+jets

***Silicon* tracking is fundamental to tagging *b*-jets**

Precision Electroweak





Must walk before we can run!

$\sigma_W \cdot B(W \to e\nu)$

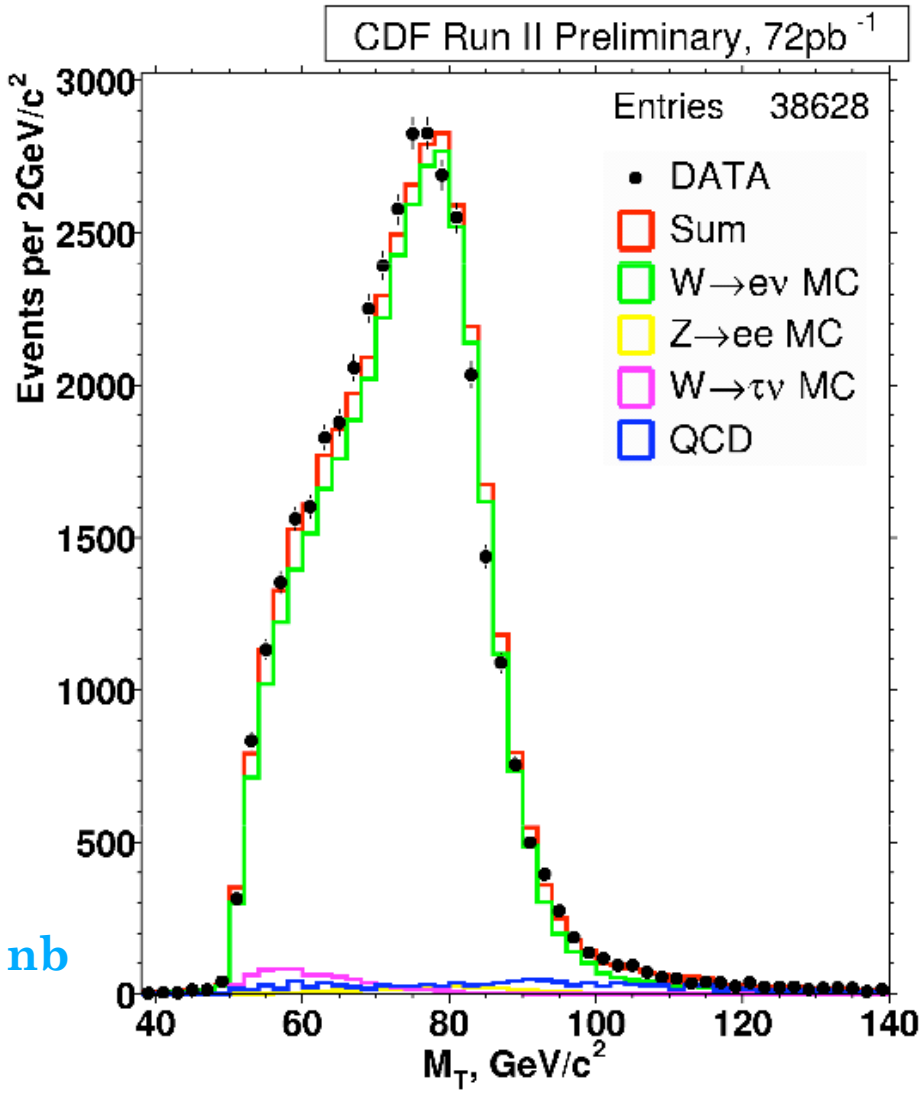
Selections: (*acc* $\cdot$ ϵ = 19.3%)

- Electron (central only)
  - Isolated EM Calorimeter cluster
  - $E_T > 25$ GeV
  - Matched track, $P_T > 10$ GeV
- Missing $E_T > 25$ GeV

Sample: (*72 pb^{-1} Run II*)

- 38628 events
  - QCD: 3.5%
  - $W \to \tau\nu$: 2.0%
  - $Z \to ee$: 0.9%

$\sigma_W \cdot B = 2.64 \pm 0.01_{stat} \pm 0.09_{sys} \pm 0.16_{lum}$ nb



$\square_W \square B(W \square \square\square)$

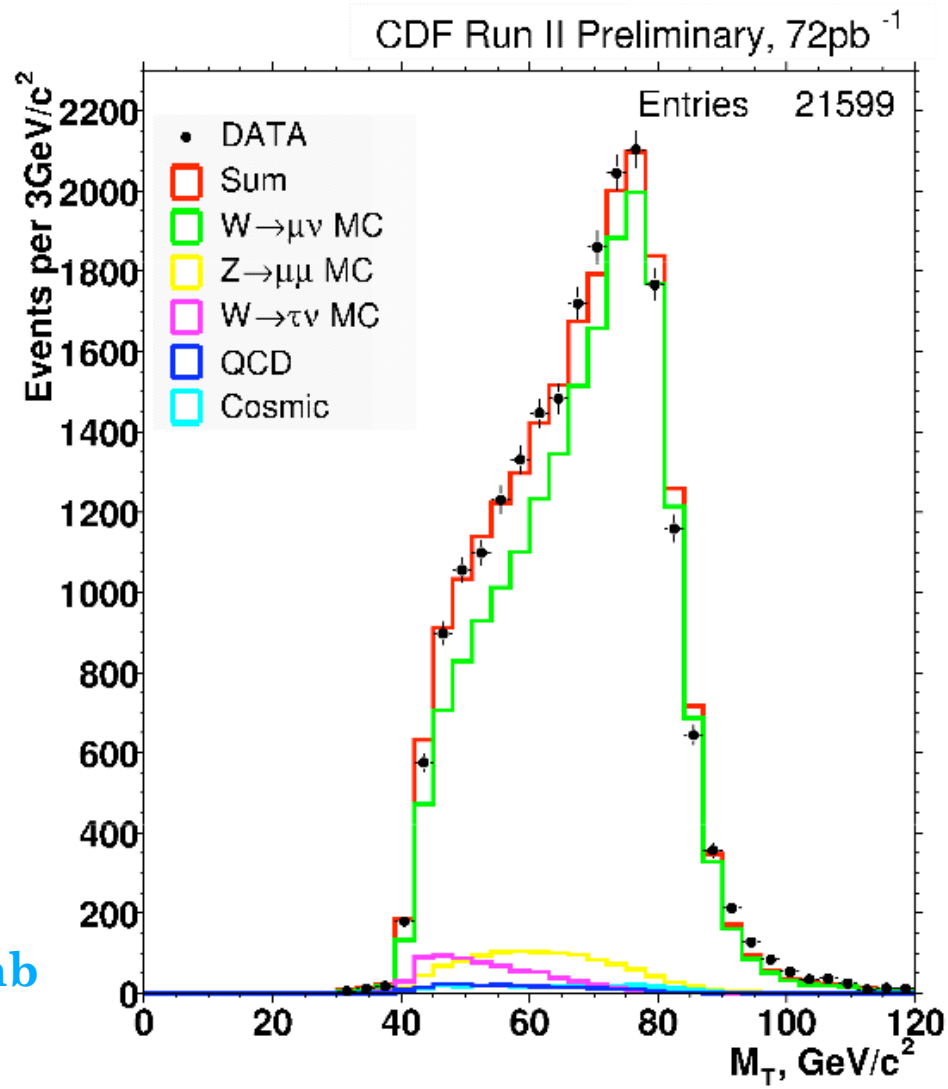
Selections: (*acc* $\square \square$ = 10.1%)

- Muon (central only)
  - Muon hits
  - Matched track, $P_T > 20$ GeV
  - Min. Ionization in calorimeter
- Missing $E_T > 20$ GeV
- Cosmic & $Z\square \square\square$ vetos

Sample: (*72 pb^{-1} Run II*)

- 21599 events
  - $Z \square \square\square$: 5.3%
  - $W \square \square\square$: 3.2%
  - Cosmics: 1.3%
  - QCD: 1.0%

$\square_W \square B = 2.64 \pm 0.02_{stat} \pm 0.12_{sys} \pm 0.16_{lum}$ nb



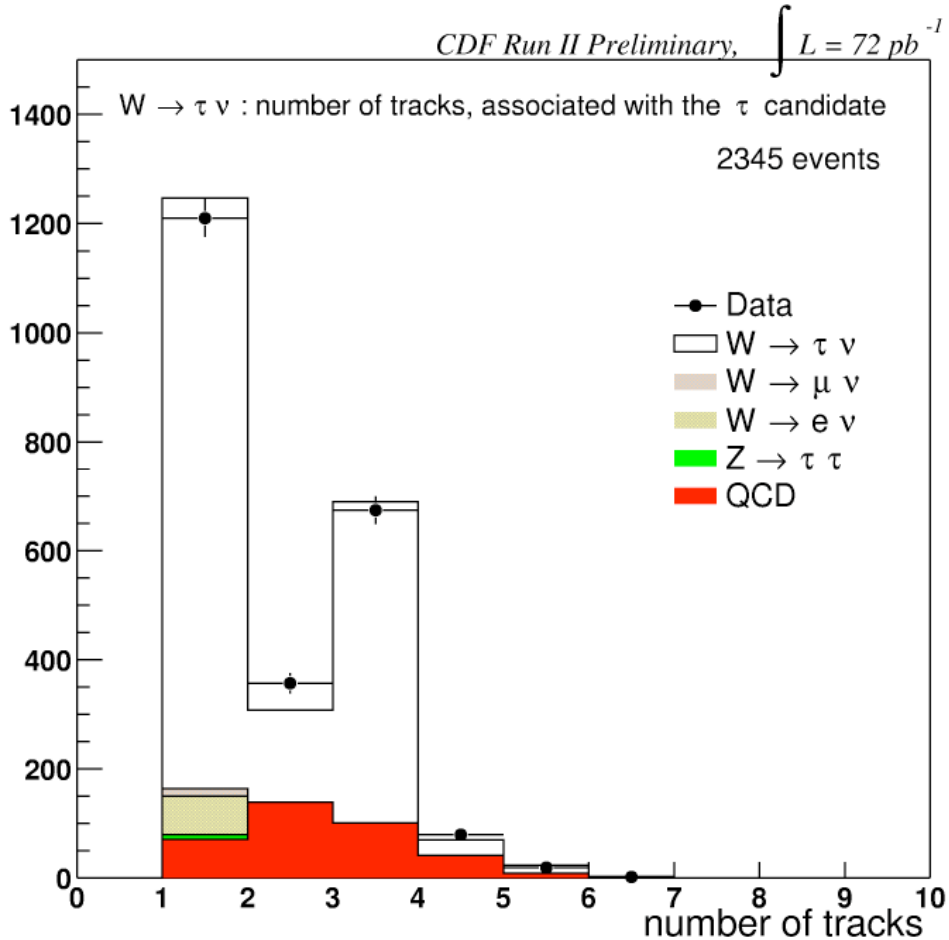
$\sigma_W \cdot B(W \to \tau\nu)$

***Selections*: (*acc* $\cdot$ ϵ = 0.92%)**

- **Tau (central only)**
  - **Isolated Hadronic Calorimeter cluster**
  - **P_T & number of tracks in 10°/30° cones**
  - **E_T > 25 GeV**
- **Missing E_T > 25 GeV**
- **Dijet veto**

***Sample*: (*72 pb^{-1} Run II*)**

- **2345 events**
  - **QCD: 15%**
  - **$W \to e\nu$: 4.4%**
  - **$W \to \mu\nu$: 3.9%**
  - **Cosmics: 1.5%**
  - **$Z \to \tau\tau$: 0.9%**

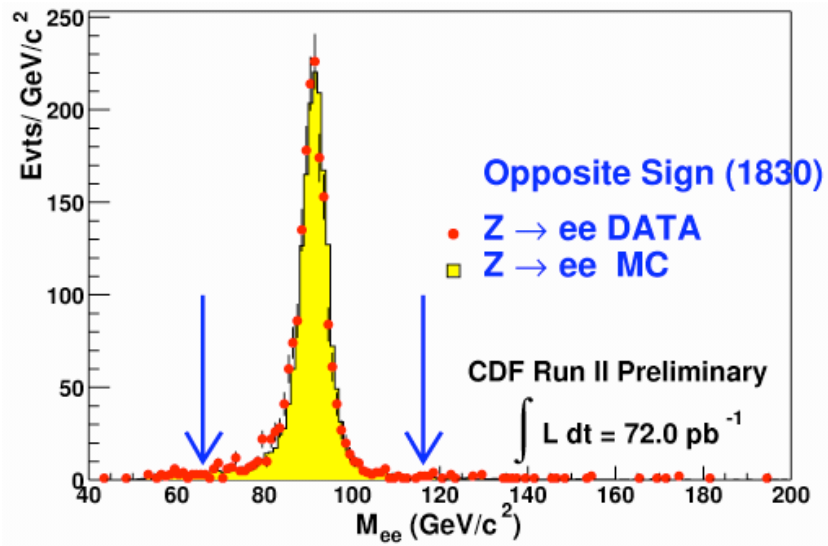


$\sigma_W \cdot B = 2.62 \pm 0.07_{stat} \pm 0.21_{sys} \pm 0.16_{lum}$ nb

$\square_Z \square B(Z \square ee)$

Selections: (*acc* $\square \square$ = 9.5%)

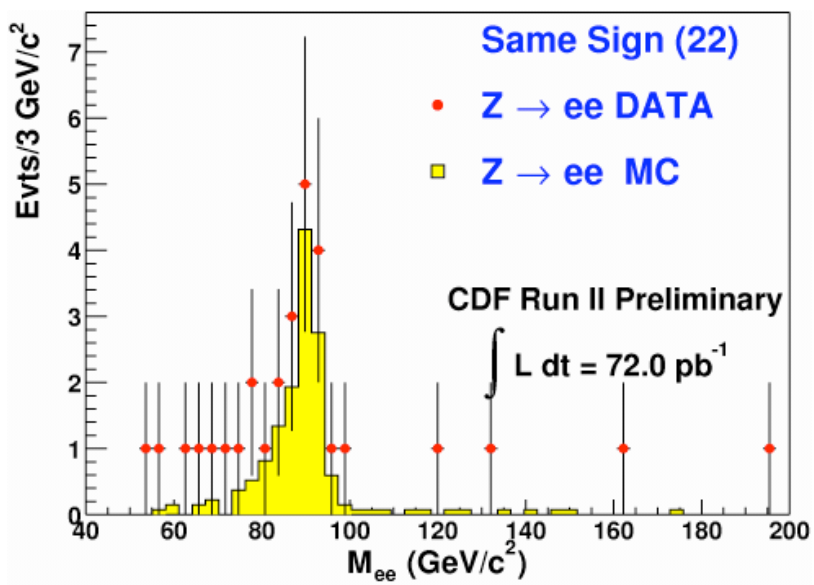
- 2 Electrons (central only)
  - Isolated EM Calorimeter clusters
  - $E_T > 25$ GeV
  - Opp-sign matched tracks, $P_T > 10$ GeV
- $66 < M_{ee} < 116$ GeV



Sample: (*72 pb^{-1} Run II*)

- 1830 opposite-sign events
  - QCD: 0.5%
  - $Z \square \square$: 0.05%

$\square_Z \square B = 267 \pm 6_{stat} \pm 15_{sys} \pm 16_{lum}$ pb



$\sigma_Z \cdot B(Z \to \mu\mu)$

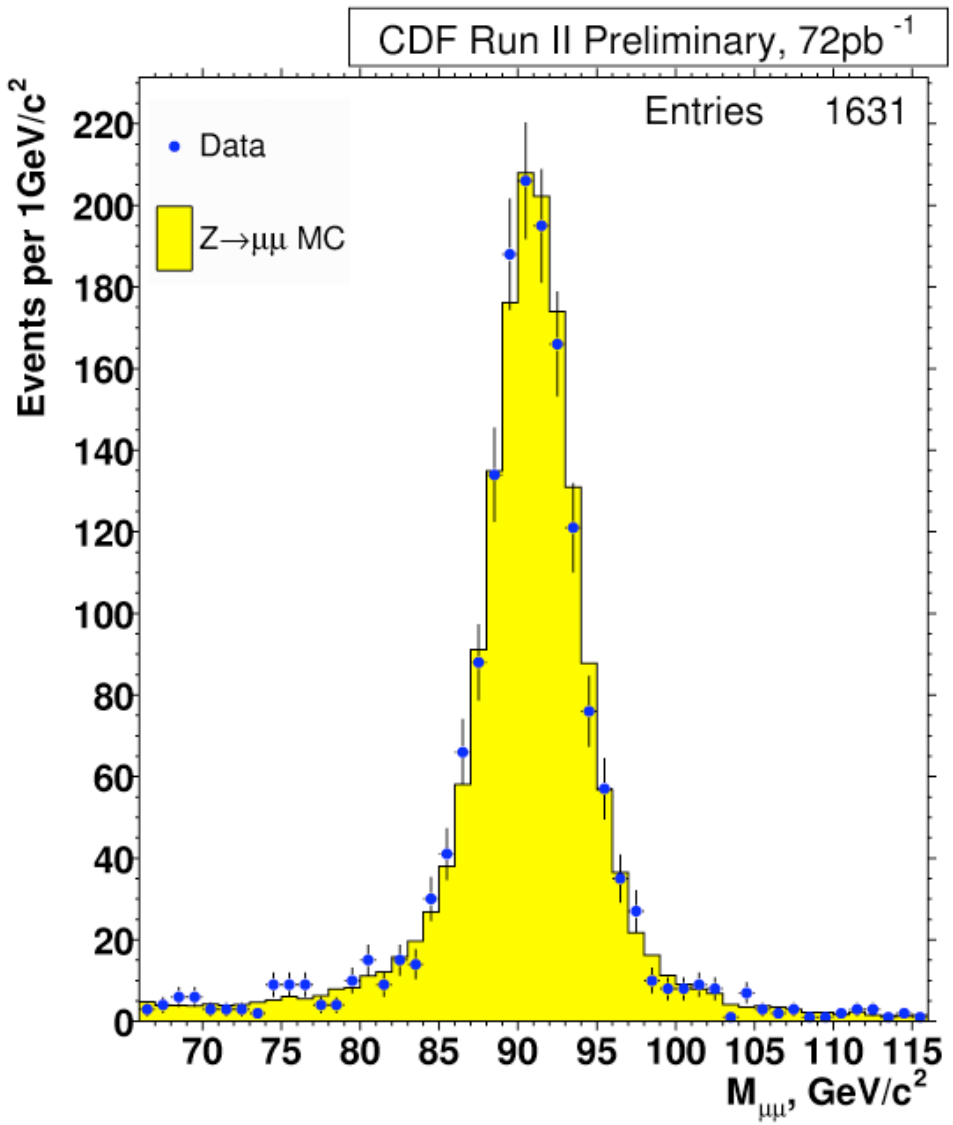
Selections: (*acc* $\cdot \varepsilon$ = 9.2%)

- 2 Muons (central only)
  - At least one with muon hits
  - Opp-sign matched tracks, $P_T > 20$ GeV
  - Min. Ionization in calorimeter
- Cosmic veto
- $66 < M_{ee} < 116$ GeV

Sample: (*72 pb^{-1} Run II*)

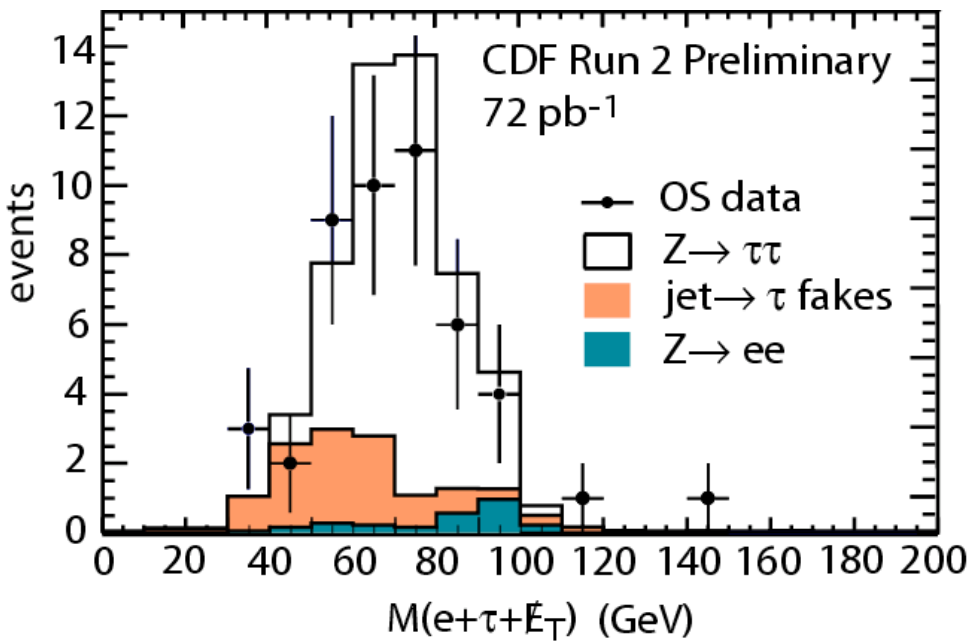
- 1631 opposite-sign events
  - Cosmics: 0.8%
  - QCD: < 0.2%

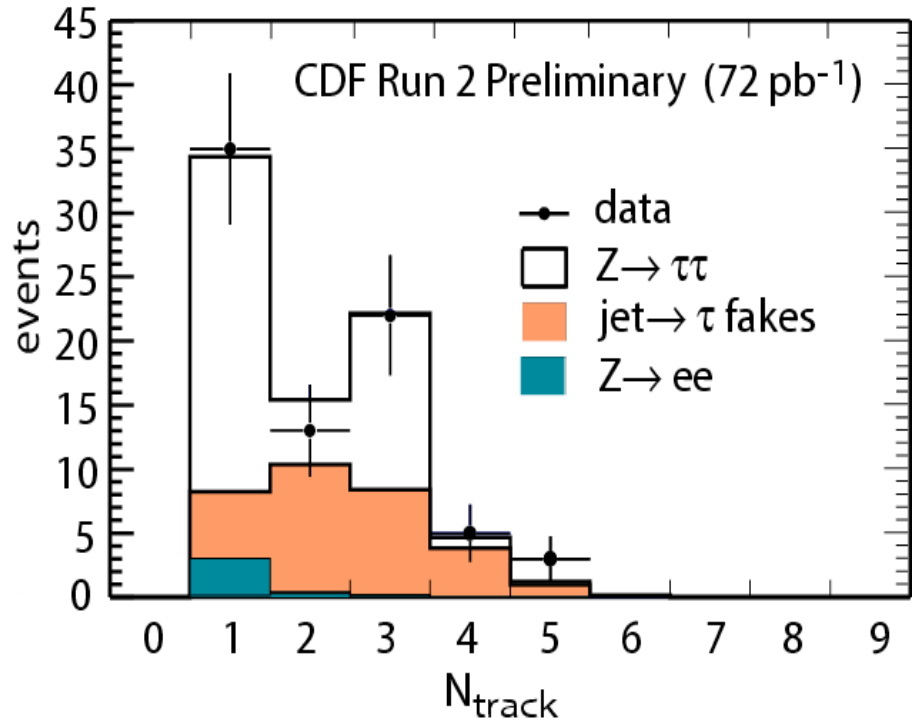
$$\sigma_Z \cdot B = 246 \pm 6_{stat} \pm 12_{sys} \pm 15_{lum} \text{ pb}$$



$Z \to \tau\tau$

- Clear $Z \to \tau\tau \to e\tau_h$ signal
- Background needs further study

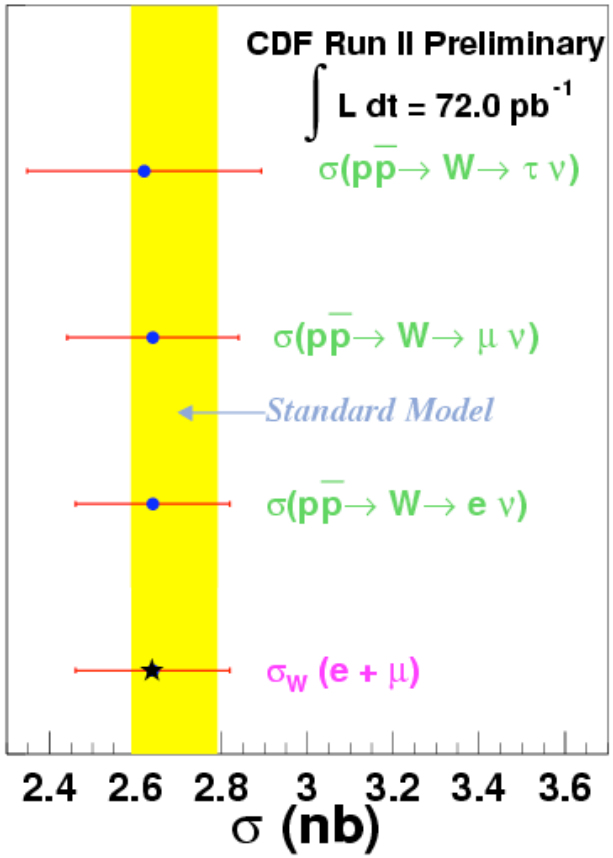




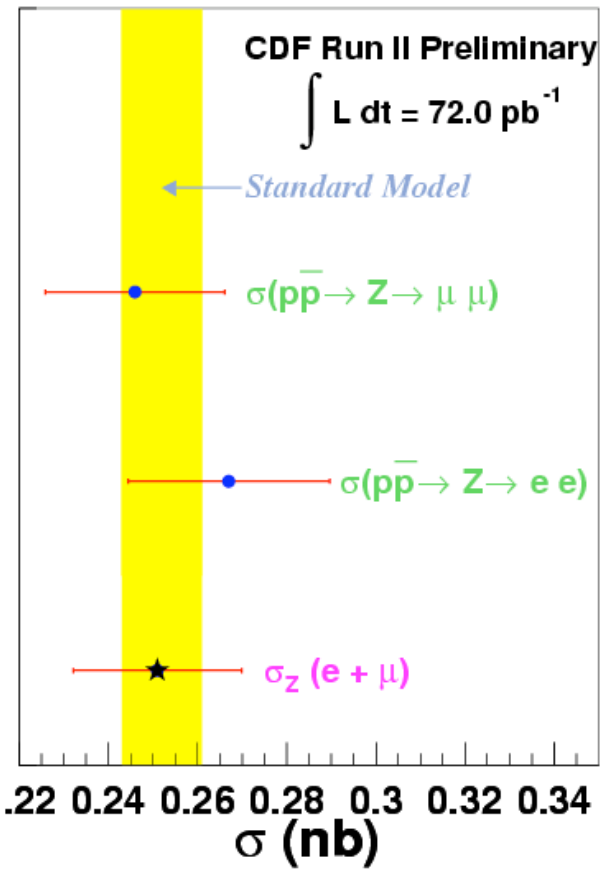
Goal of preliminary cross section by summer

σ_W , σ_Z Summary

W cross section measurements



Z cross section measurements



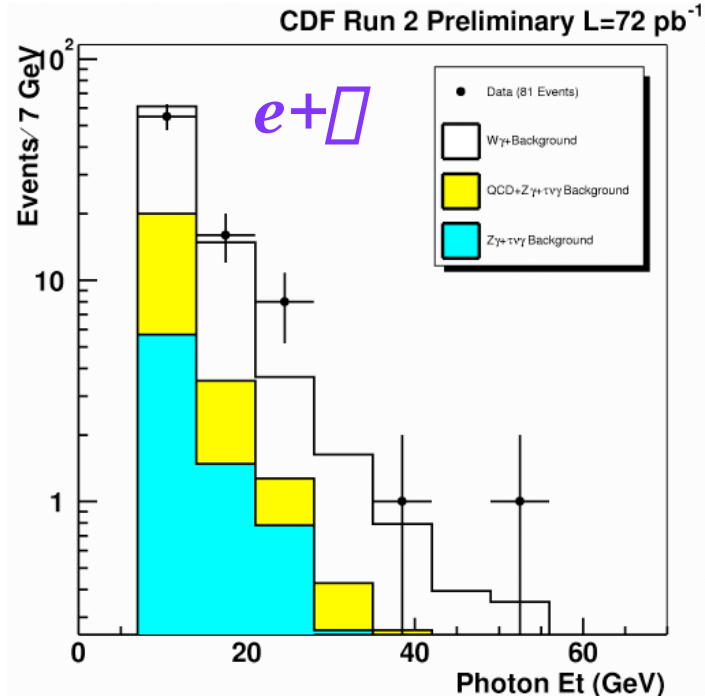
combined $\sigma_W \cdot B(W \to l\nu) = 2.640 \pm 0.012_{stat} \pm 0.093_{syst} \pm 0.158_{lum}$ nb

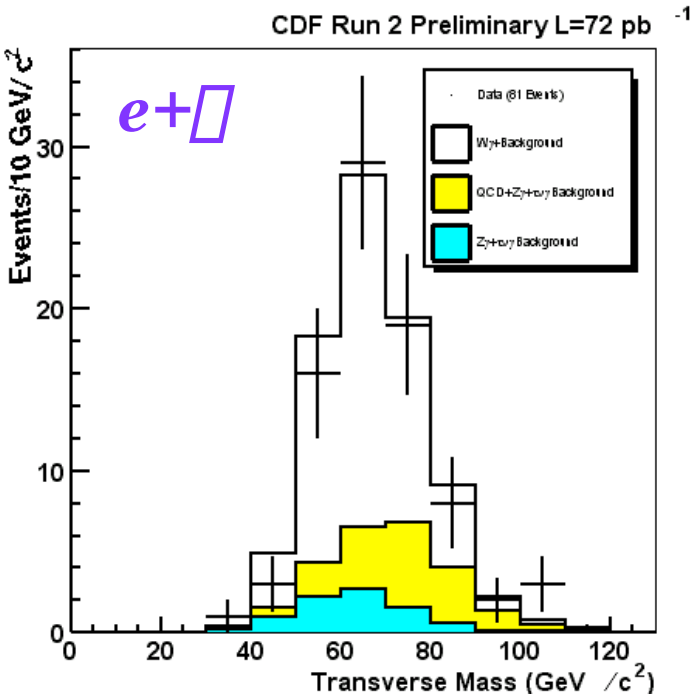
combined $\sigma_Z \cdot B(Z \to ll) = 251.5 \pm 4.3_{stat} \pm 10.6_{syst} \pm 15.1_{lum}$ pb

$\sigma_{W\gamma} \cdot B(W \rightarrow e\nu, \mu\nu)$

Selections:

- **Electron or Muon (central only) + Missing E_T**
  - **Same selections as used for σ_W**
- **1 Photon (central only)**
  - **$E_T > 7$ GeV, $\Delta R(\gamma, l) > 0.7$ ***
  - **Isolated EM calorimeter cluster**
  - **Tracking isolation cuts**
- **$Z \rightarrow ll$ & Cosmic(γ) vetos**





Sample: (72 pb^{-1} Run II)

- **43 (38) events in $e\gamma$ ($\mu\gamma$)**
  - **$W \rightarrow e\nu$ ($\mu\nu$) + jet:** 11.5 (5.6) events
  - **$Z \rightarrow ee$ ($\mu\mu$) + γ:** 2.4 (5.1) events
  - **$W \rightarrow \tau\nu$ + γ:** 0.5 (0.7) events

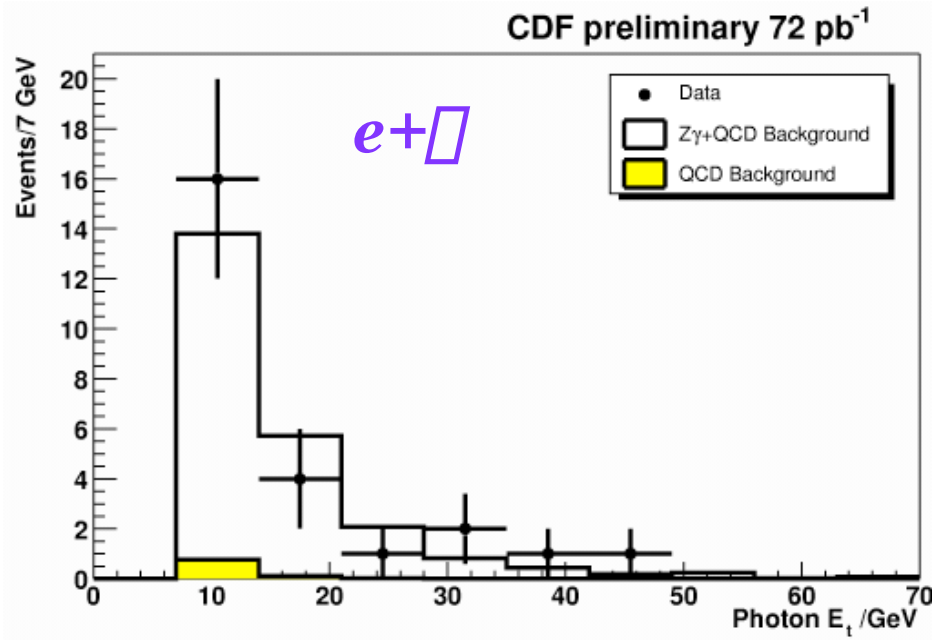
$$\sigma_{W\gamma}(W \rightarrow e\nu)^* = 17.2 \pm 3.8_{stat} \pm 2.8_{sys} \pm 1.0_{lum} \text{ pb}$$
$$\sigma_{W\gamma}(W \rightarrow \mu\nu)^* = 19.5 \pm 4.5_{stat} \pm 2.4_{sys} \pm 1.2_{lum} \text{ pb}$$

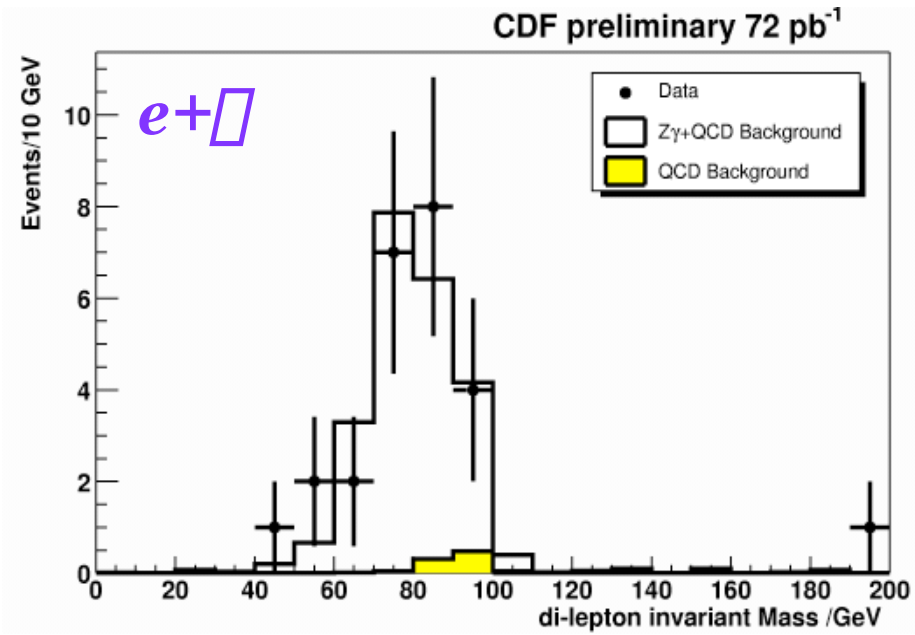
SM Expected: ~19 pb

$\sigma_{Z\gamma} \cdot B(Z \rightarrow ee, \mu\mu)$

Selections:

- 2 Electrons or Muons (central only)
  - Same selections as used for σ_Z
- $M_{ll} > 40$ GeV
- 1 Photon (central only)
  - $E_T > 7$ GeV, $\Delta R(\gamma, l) > 0.7$ *
  - Isolated EM calorimeter cluster
  - Tracking isolation cuts
- $Z\gamma \rightarrow ll$ & Cosmic(γ) vetos





Sample: (*72 pb^{-1} Run II*)

- 11 (14) opposite-sign ee ($\mu\mu$) events
  - $Z\gamma \rightarrow ee$ ($\mu\mu$) + *jet*: 0.5 (0.5) events

$\sigma_{Z\gamma} \cdot B(Z\gamma \rightarrow ee)^* = 5.5 \pm 1.7_{stat} \pm 0.6_{sys} \pm 0.3_{lum}$ pb

$\sigma_{Z\gamma} \cdot B(Z\gamma \rightarrow \mu\mu)^* = 6.0 \pm 1.6_{stat} \pm 0.7_{sys} \pm 0.4_{lum}$ pb

SM Expected: ~5 pb

Adding Forward Acceptance

QCD backgrounds are many times larger without tracking requirements

Tracking is critical

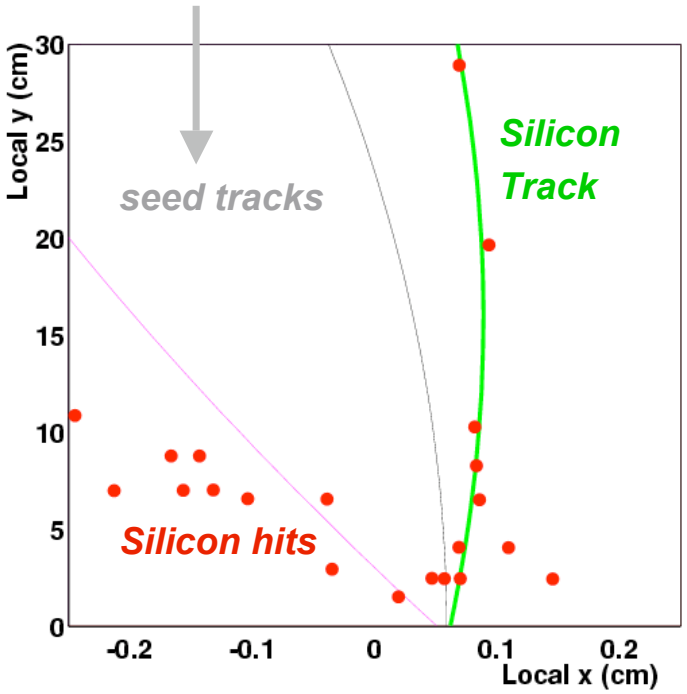
Have standalone silicon tracking in forward region: much less efficient and clean than central drift chamber + silicon

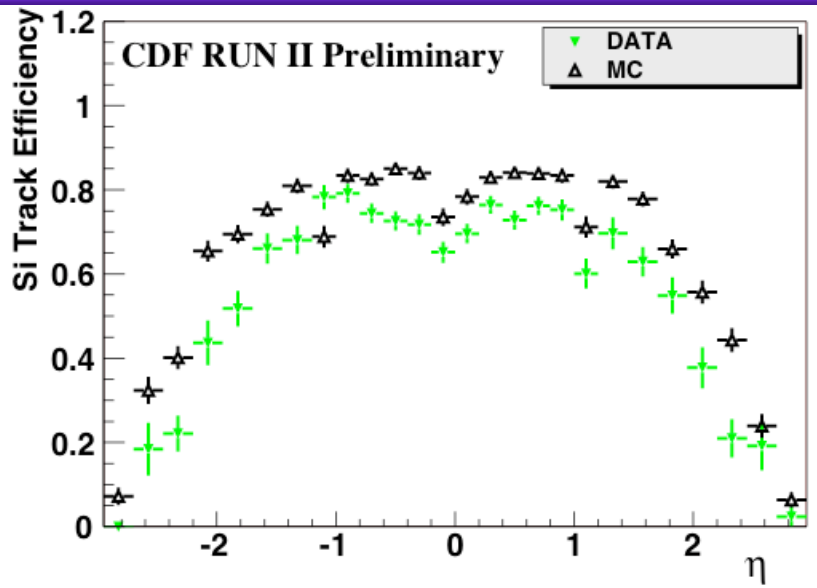
Need a way to reduce the problem!

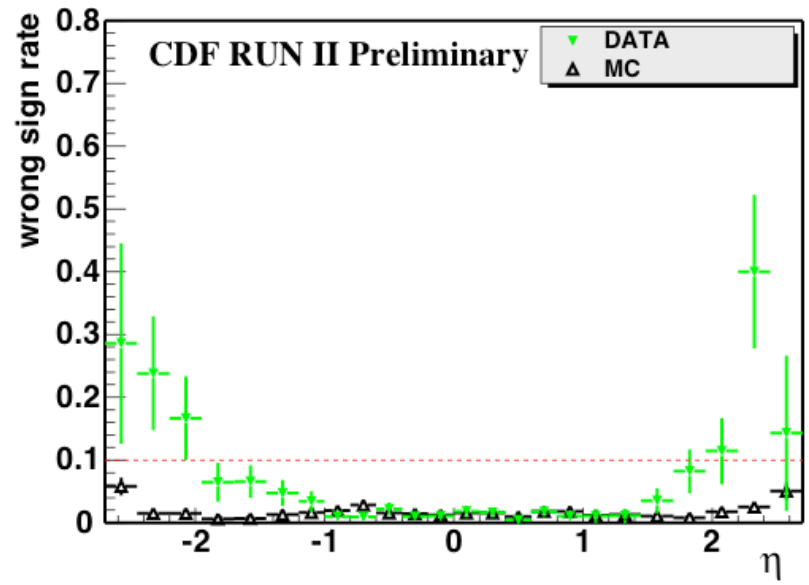
Calorimeter-seeded $e^{\pm}$ tracking

***Two points** and a **curvature** define a unique helix…*

- **Primary vertex**
  - *x-y*: beamspot (~40 um)
  - *z*: event vertex (~100 um)
- **Calorimeter shower-maximum hit**
  - ~1 mm
- **Calorimeter E_T | curvature |**







Forward $W \to e\nu$

Selections:

- Electron (forward only)
  - Isolated EM Calorimeter cluster
  - $E_T > 20$ GeV
  - Calorimeter-seeded track
- Missing $E_T > 25$ GeV

Sample: (*60 pb^{-1} Run 2 data*)

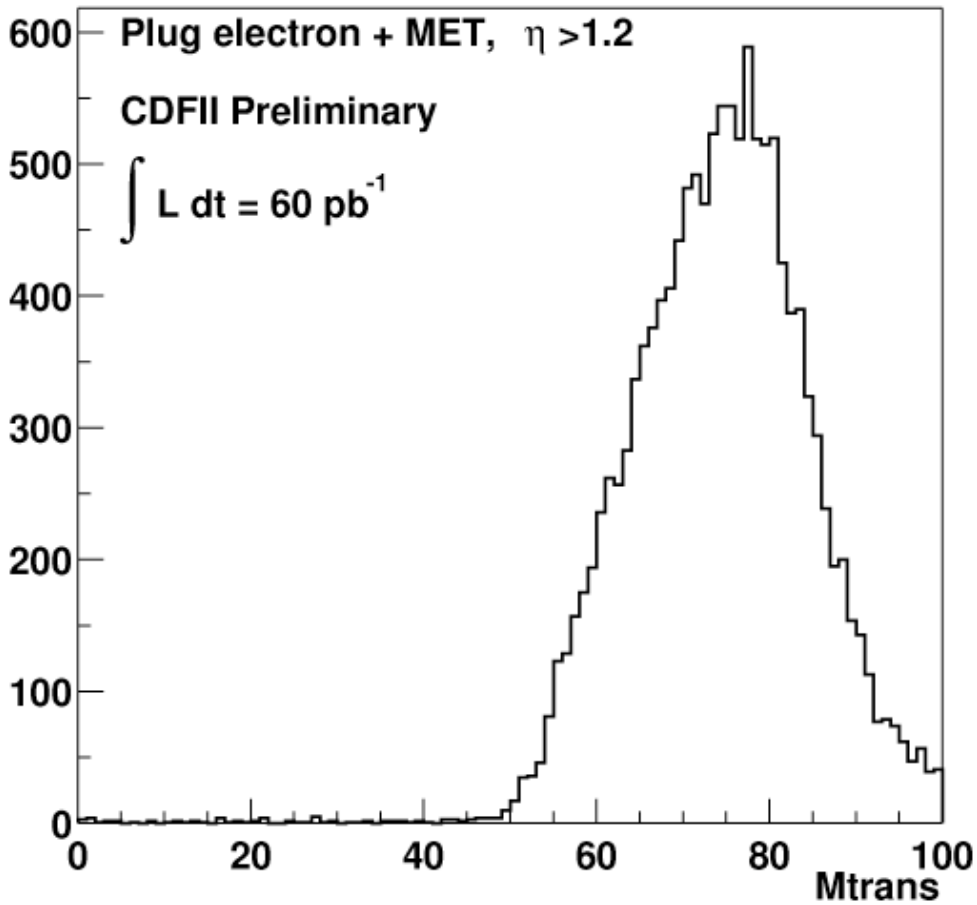
- ~20,000 events

QCD background:

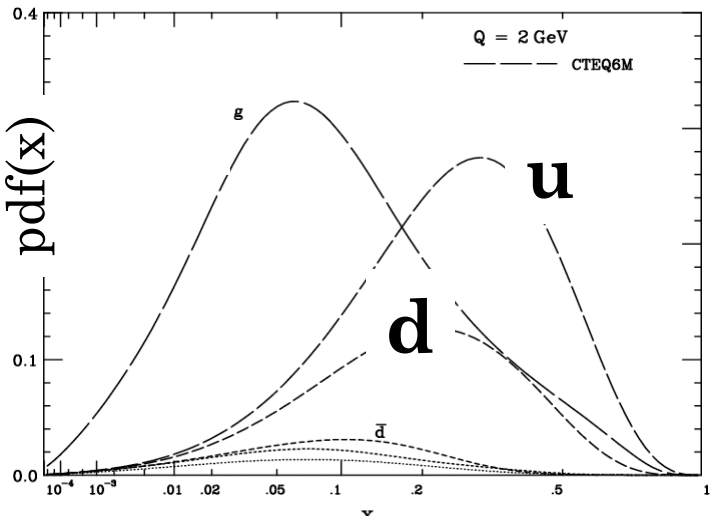
without forward tracking: ~18%

with forward tracking: ~3%

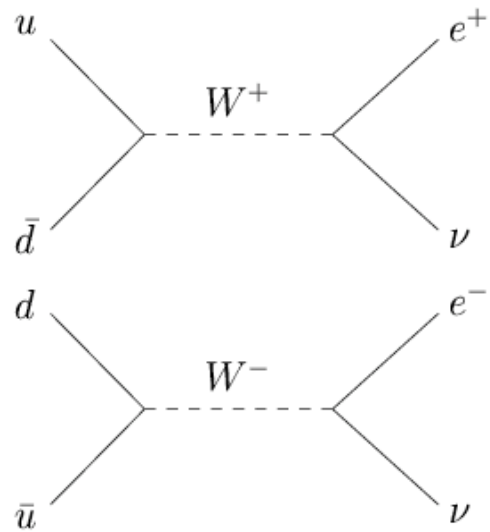
Similar to central background

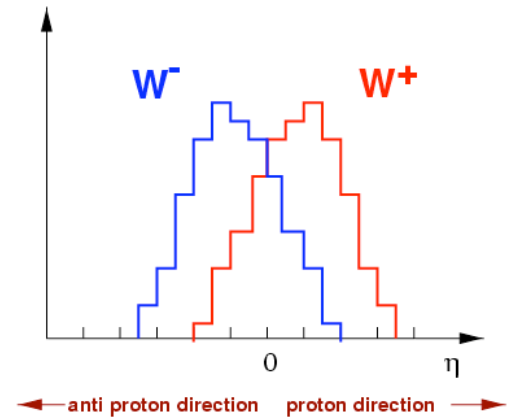


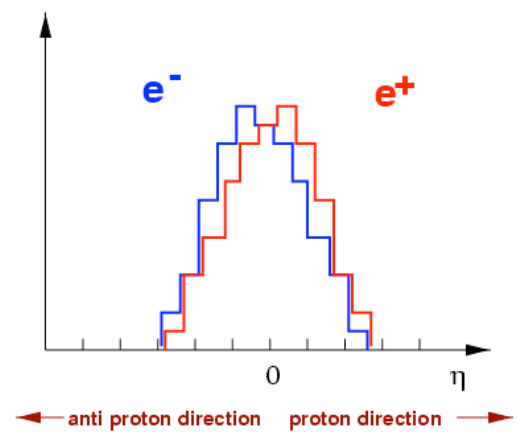
W→ e→ Charge Asymmetry



x = **p**(parton)/**p**(proton)







$$A_l(\eta) = \frac{d\sigma(e^+)/d\eta - d\sigma(e^-)/d\eta}{d\sigma(e^+)/d\eta + d\sigma(e^-)/d\eta} \simeq \frac{\mathrm{d(x)}}{\mathrm{u(x)}}$$

Forward tracking is critical here!

$W \to e\nu$ Charge Asymmetry

Selections:

- Electron (central+forward)
  - Isolated EM Calorimeter cluster
  - $E_T > 20$ GeV
  - Calorimeter-seeded track
- Missing $E_T > 30$ GeV

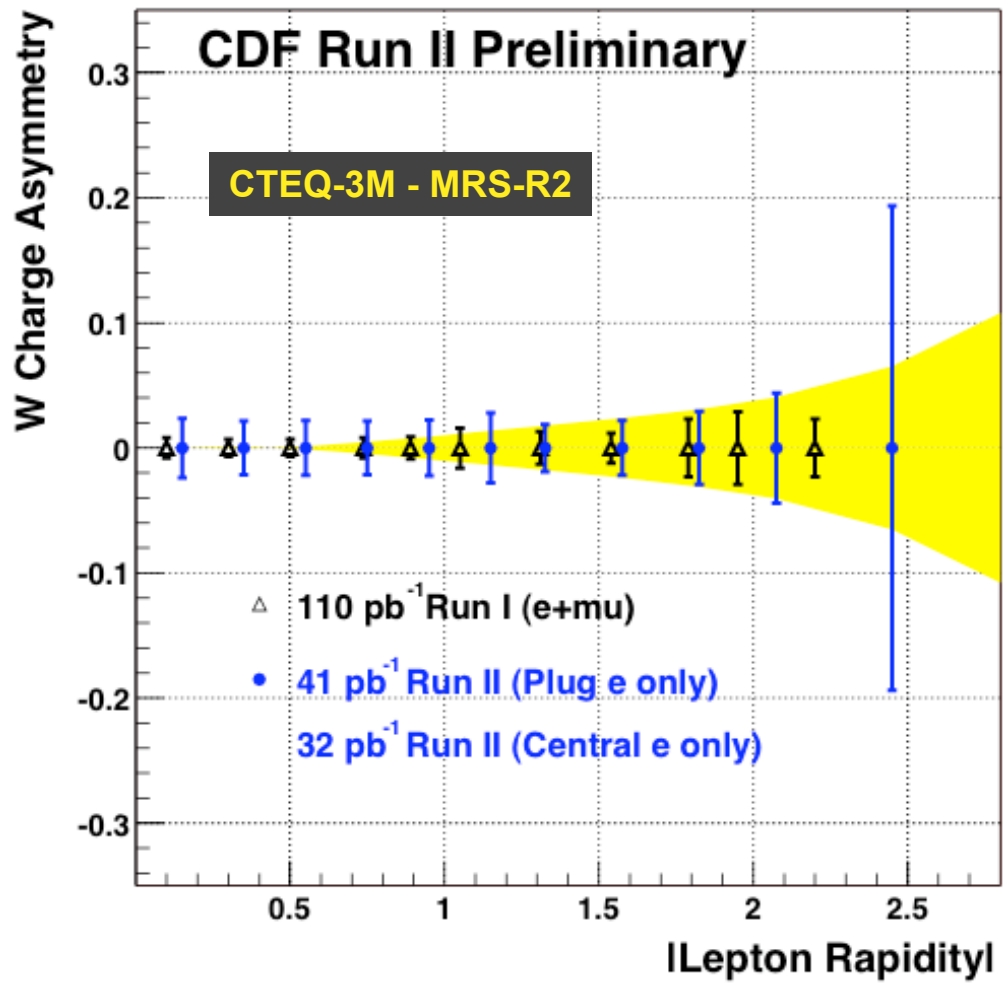
Sample:

- 21317 events

Blind analysis:

- Plotting sensitivity only
- Higher "specific sensitivity" in forward region than Run 1

results to be unblinded for summer



σ_{WW} ($WW \rightarrow ll$)

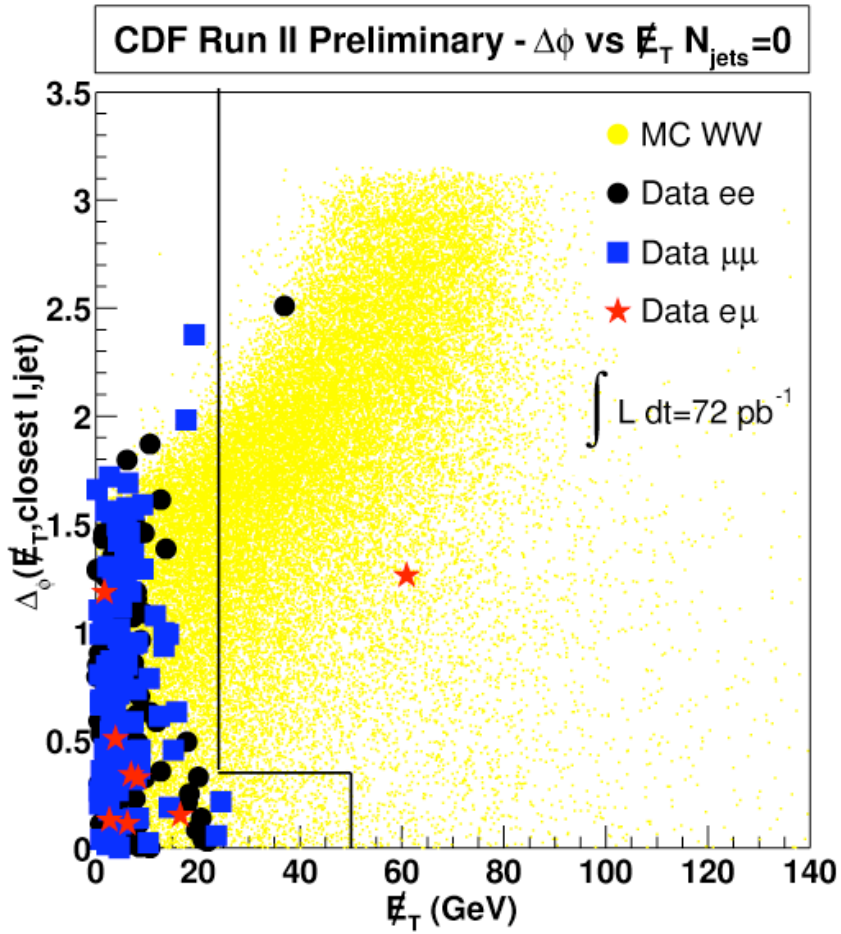
Selections:

- 2 Electrons / Muons (central only)
  - Same cuts as EWK measurements
- Veto $76 < M_{ll} < 106$ GeV, cosmics & conversions
- Missing $E_T > 25$ GeV
- $\Delta\phi$ (missing E_T, nearest lepton)
- $N_{jets} = 0$ ($E_t > 10$ GeV, $\Delta\phi < 2.0$)

Sample: (*72 pb^{-1} Run II*)

- 2 events
  - Background: 1.5 ± 0.6 events (QCD + DY + *WZ* + *tt*)

SM Expected: 2.8 ± 0.6



just the appetizer…

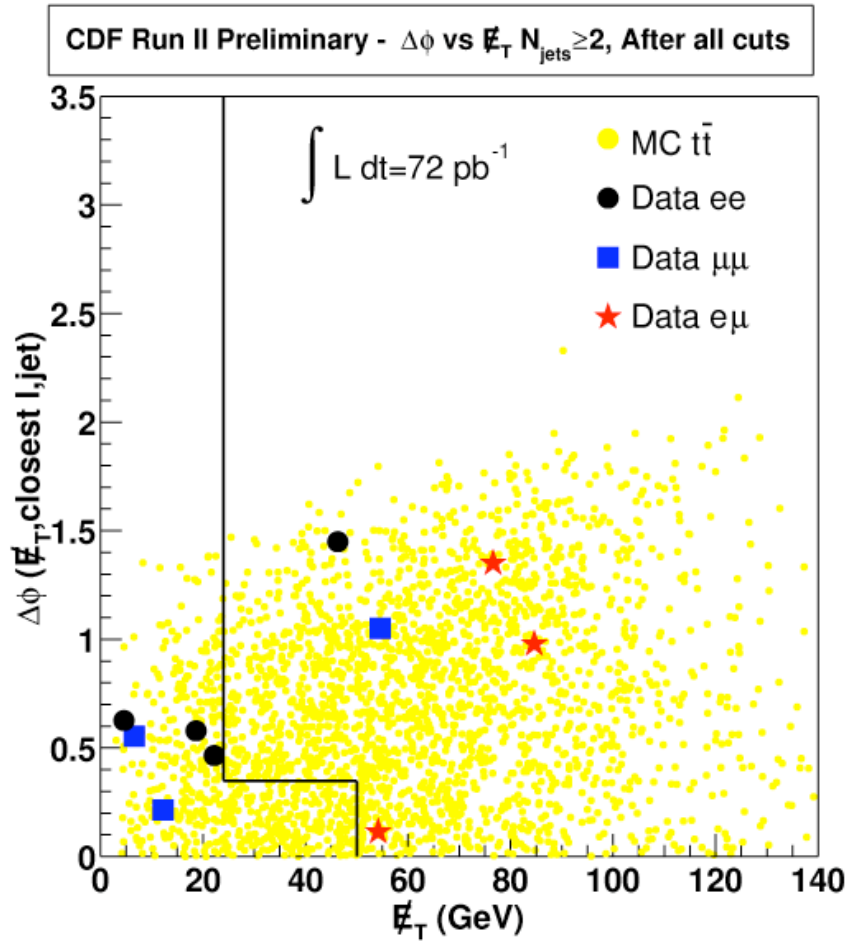
$\square_{tt}$ ($tt\square$ ll)

Selections:

- 2 Electrons / Muons (central only)
  - Same cuts as EWK measurements
- Veto 76 < M_{ll} < 106 GeV, cosmics & conversions
- Missing E_T > 25 GeV
- $\square\square$ (missing E_T, nearest lepton)
- $H_T = \square E_T$ + Missing E_T > 200 GeV
- $N_{jets} \geq 2$ (E_t > 10 GeV, $\square$ < 2.0)

Sample: (*72 pb^{-1} Run II*)

- 5 events
  - Background: 0.30 ± 0.12 events (DY + WW/WZ + $\square\square$ + QCD)



$$\square_{tt} = 13.2 \pm 5.9_{stat} \pm 1.5_{sys} \text{ pb}$$

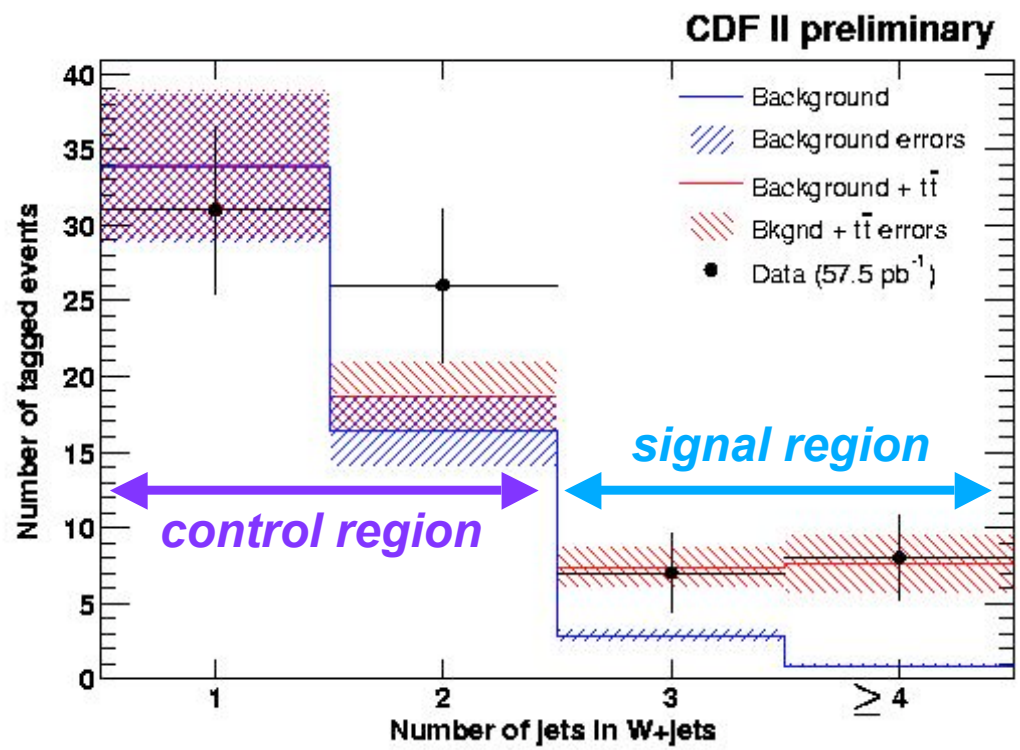
σ_{tt} ($t\bar{t} \rightarrow$ l+jets)

Selections:

- Electron / Muon (central only)
  - Same cuts as EWK measurements
- Veto $76 < M_{ll} < 106$ GeV, cosmics and conversions
- Missing $E_T > 20$ GeV
- $N_{jets} \geq 3$ (jet $E_T > 15$ GeV)
- *At least one jet with secondary vertex tag from silicon*

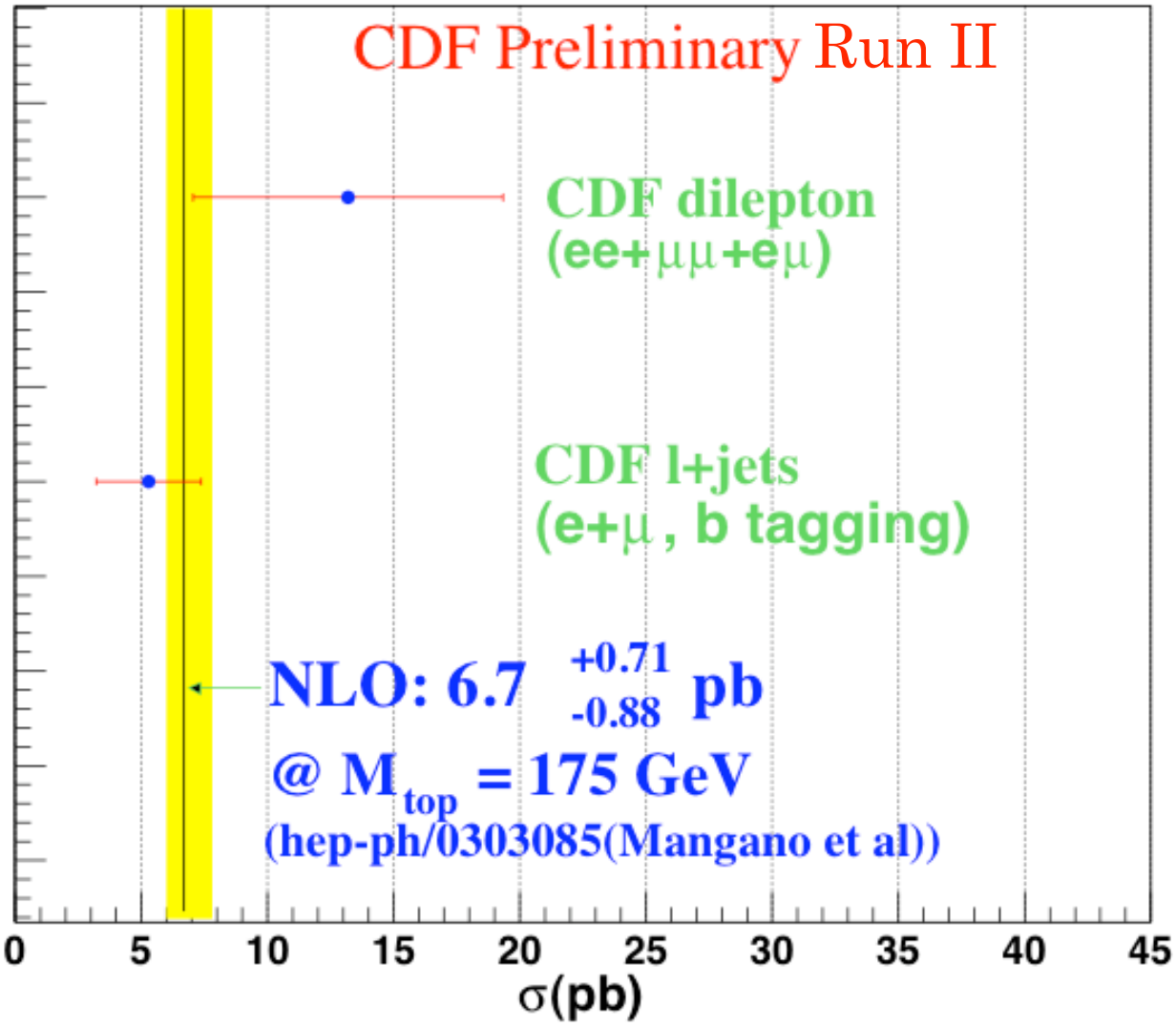
Sample: (57.5 pb^{-1} *Run 2 data*)

- 15 events
  - Background: 3.8 ± 0.5 events (W+jets & mistags dominant)

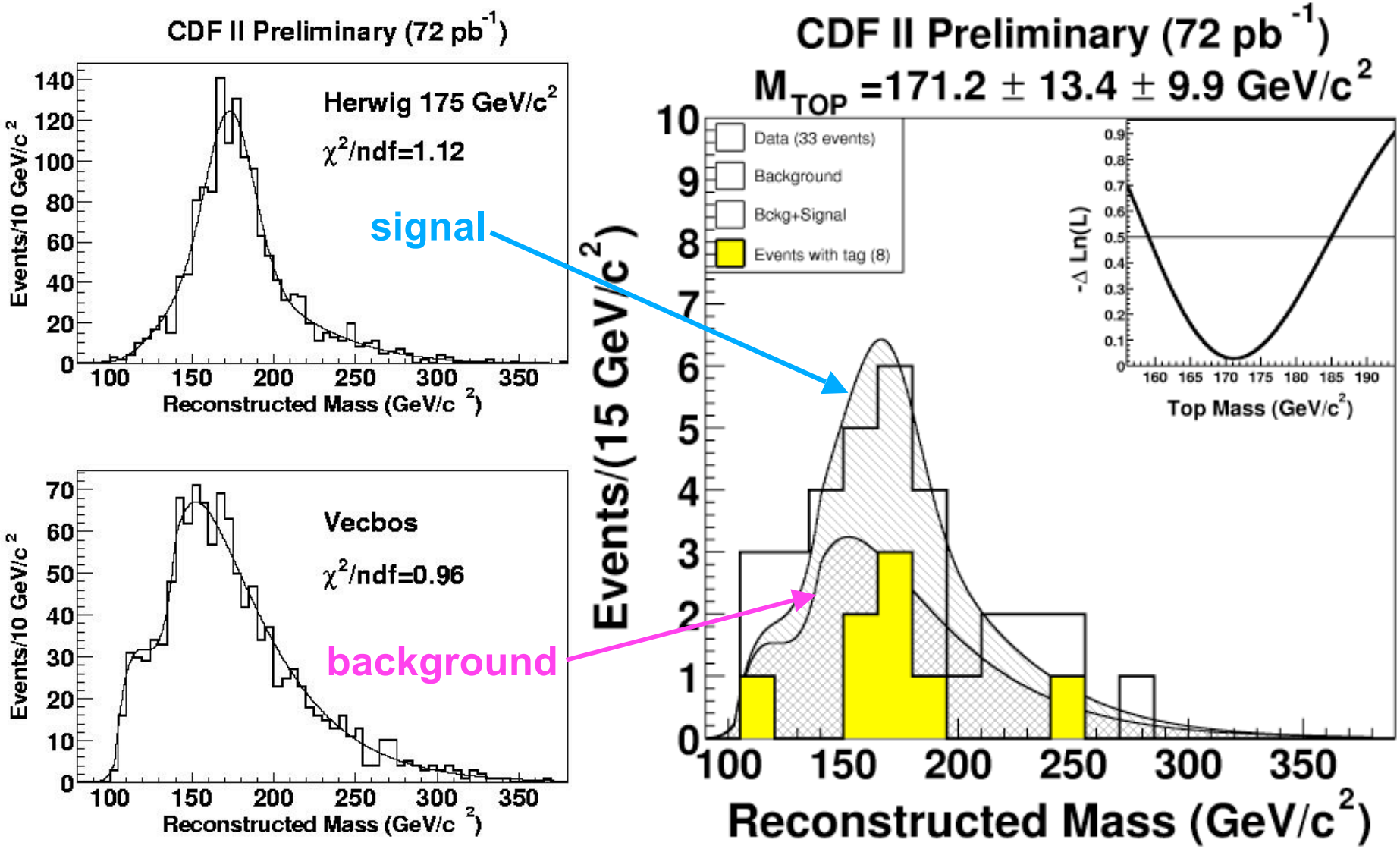


$$\sigma_{tt} = 5.3 \pm 1.9_{stat} \pm 0.8_{syst} \text{ pb}$$

σ_{tt} Summary



M_t (*l+jets*)


CDF II Preliminary (72 pb^{-1})
Herwig 175 GeV/c^2
χ^2/ndf=1.12
signal
Events/10 GeV/c^2
Reconstructed Mass (GeV/c^2)
Vecbos
χ^2/ndf=0.96
background
Events/10 GeV/c^2
Reconstructed Mass (GeV/c^2)
CDF II Preliminary (72 pb^{-1})
M_{TOP} =171.2 ± 13.4 ± 9.9 GeV/c^2
Data (33 events)
Background
Bckg+Signal
Events with tag (8)
-Δ Ln(L)
Top Mass (GeV/c^2)
Events/(15 GeV/c^2)
Reconstructed Mass (GeV/c^2)

Electroweak-related Searches

***A Challenging Goal*:**

Model-independent, "signature-based" searches

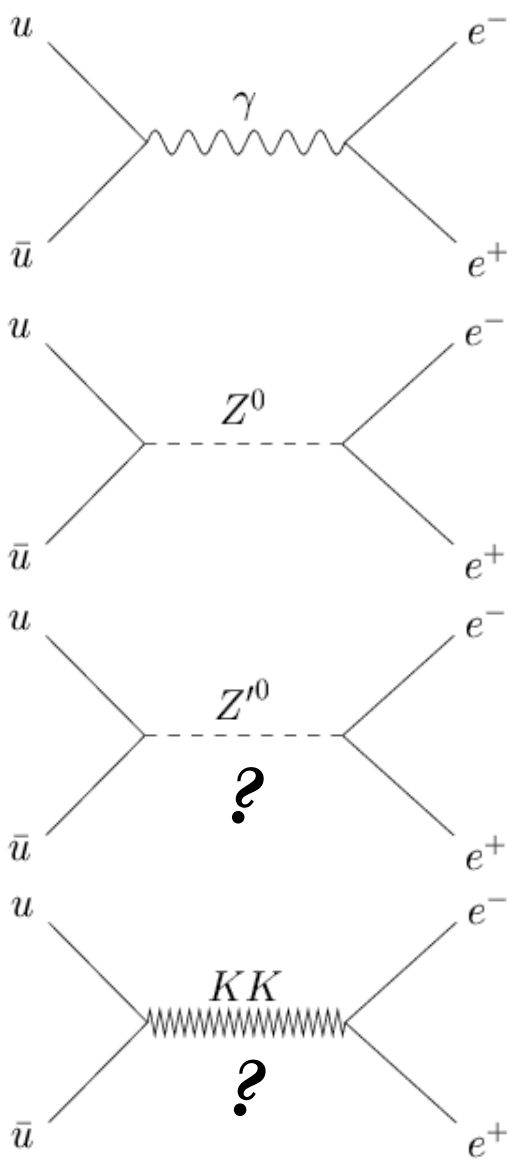
***Focus on Final States*:**

- **Many possibilities for new physics**
- **Very simple**
- **Backgrounds are "precision physics"**

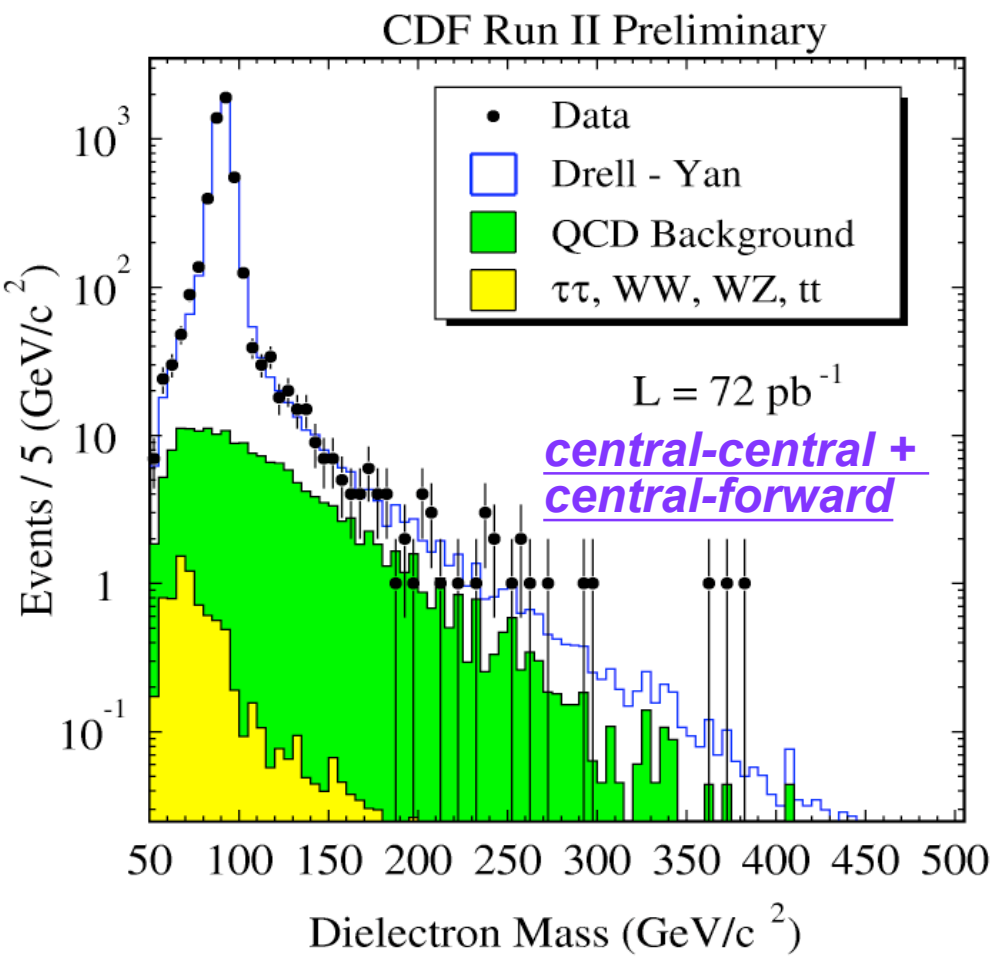
"Precision Searches"

Electroweak final states are ideal here…

High-mass e^+e^-

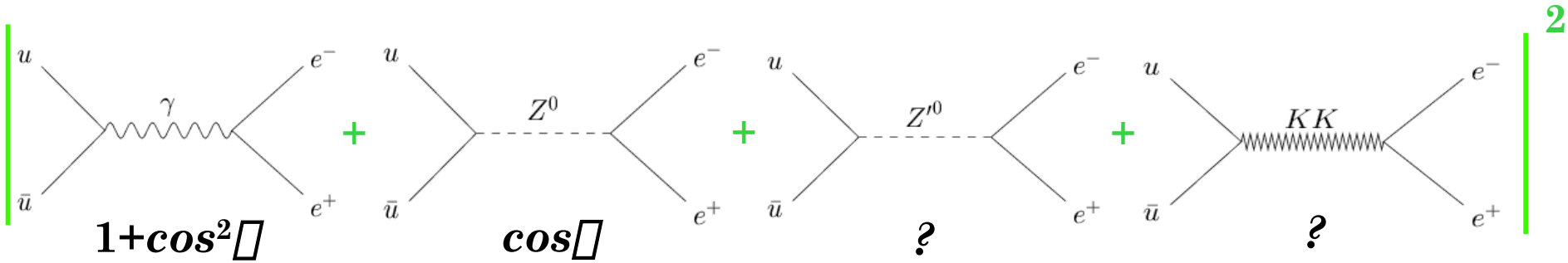


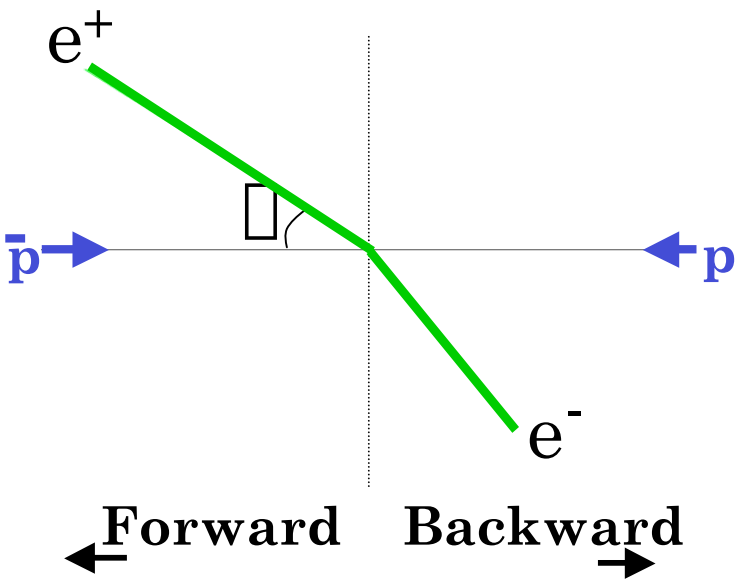
(see A. Munar's talk)



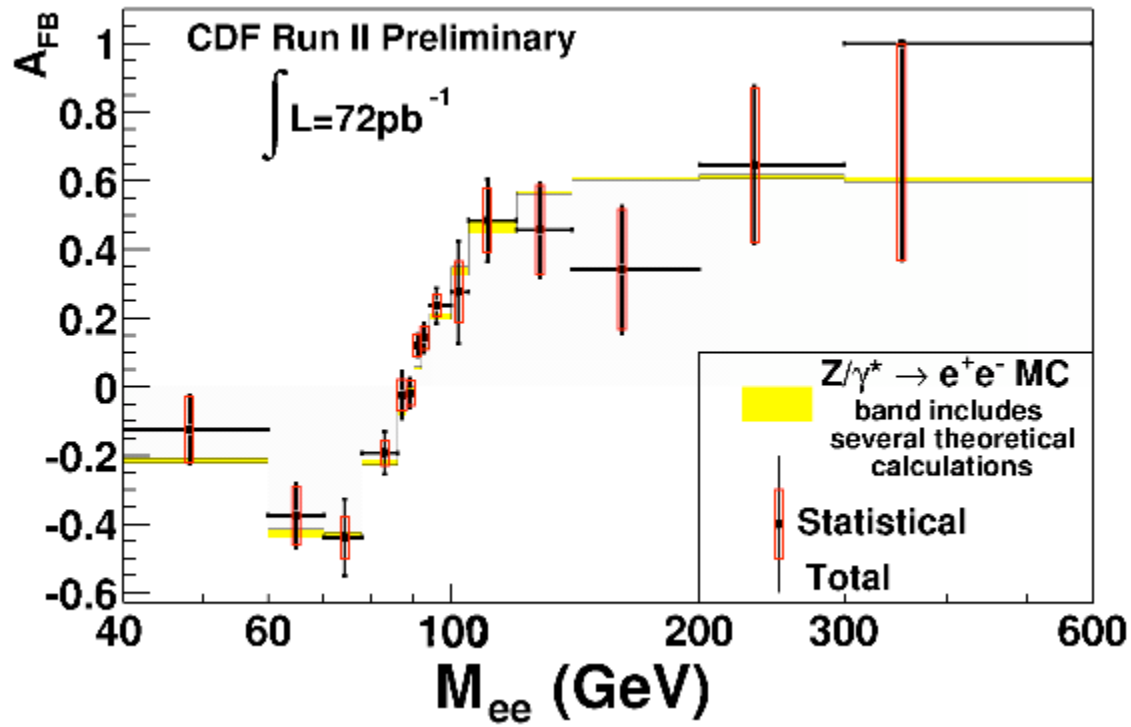
Z′, extra dimensions, compositeness

Angular Distributions: Interference





central-central + central-forward



Forward di-electrons

Selections:

- Electrons (forward only)
  - Isolated EM Calorimeter cluster
  - $E_T > 15$ GeV
  - Calorimeter-seeded track

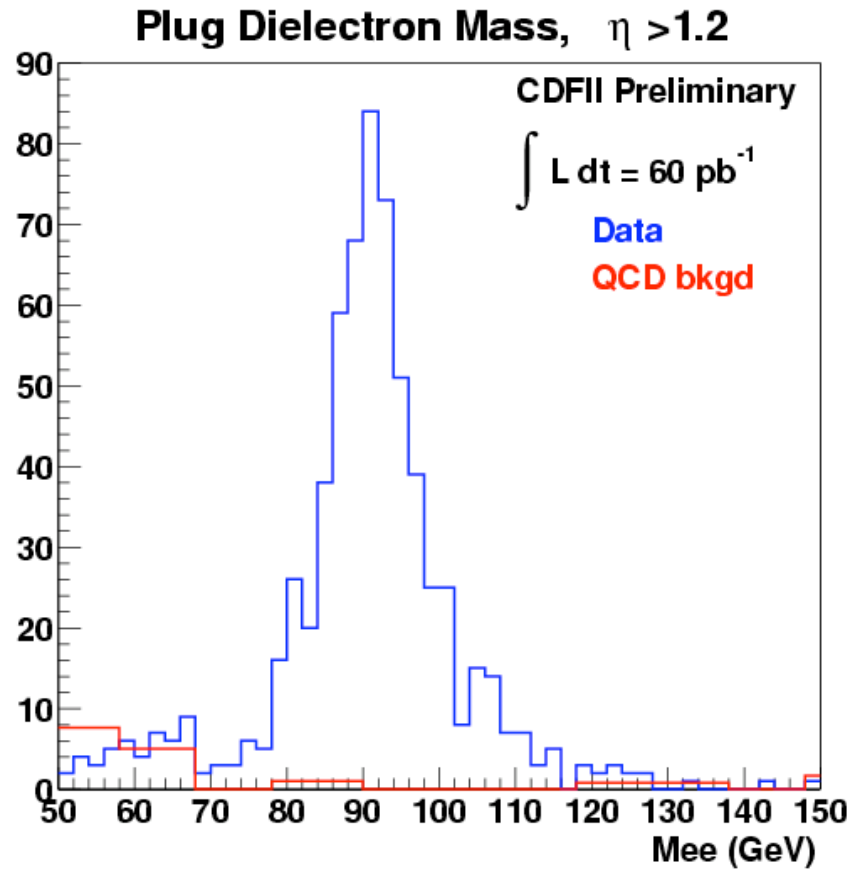
Sample: (*60 pb^{-1} Run 2 data*)

- 843 events

QCD background ($M_{ee} > 100$ GeV):

w/o tracking: $60 \pm 5_{stat}$ %

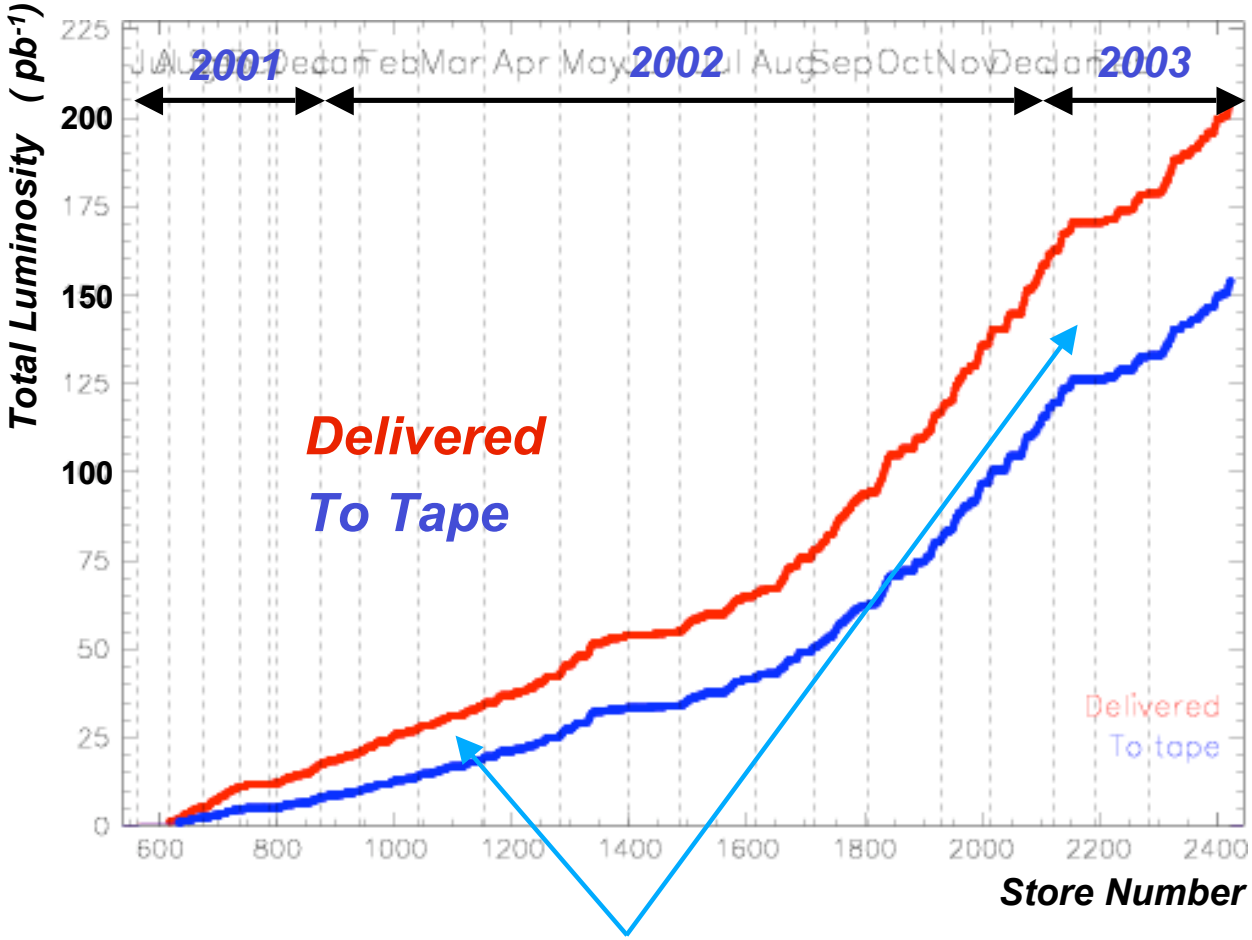
with tracking: $4 \pm 3_{stat}$ %



Similar to central-central background

Outlook

Goal: 200-320 pb^{-1} delivered in FY03



CDF efficiency continues to improve, as well

Conclusions

- **Preliminary results established for major electroweak benchmarks**
- **Broad top physics program is underway**
- **Promising searches in clean electroweak final states now match Run I sensitivity**
- **Improved detector, new techniques will extend reach beyond expected luminosity increases**