New Results From DØ Presented at DPF

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For the DØ Collaboration

Fermilab Wine and Cheese Seminar

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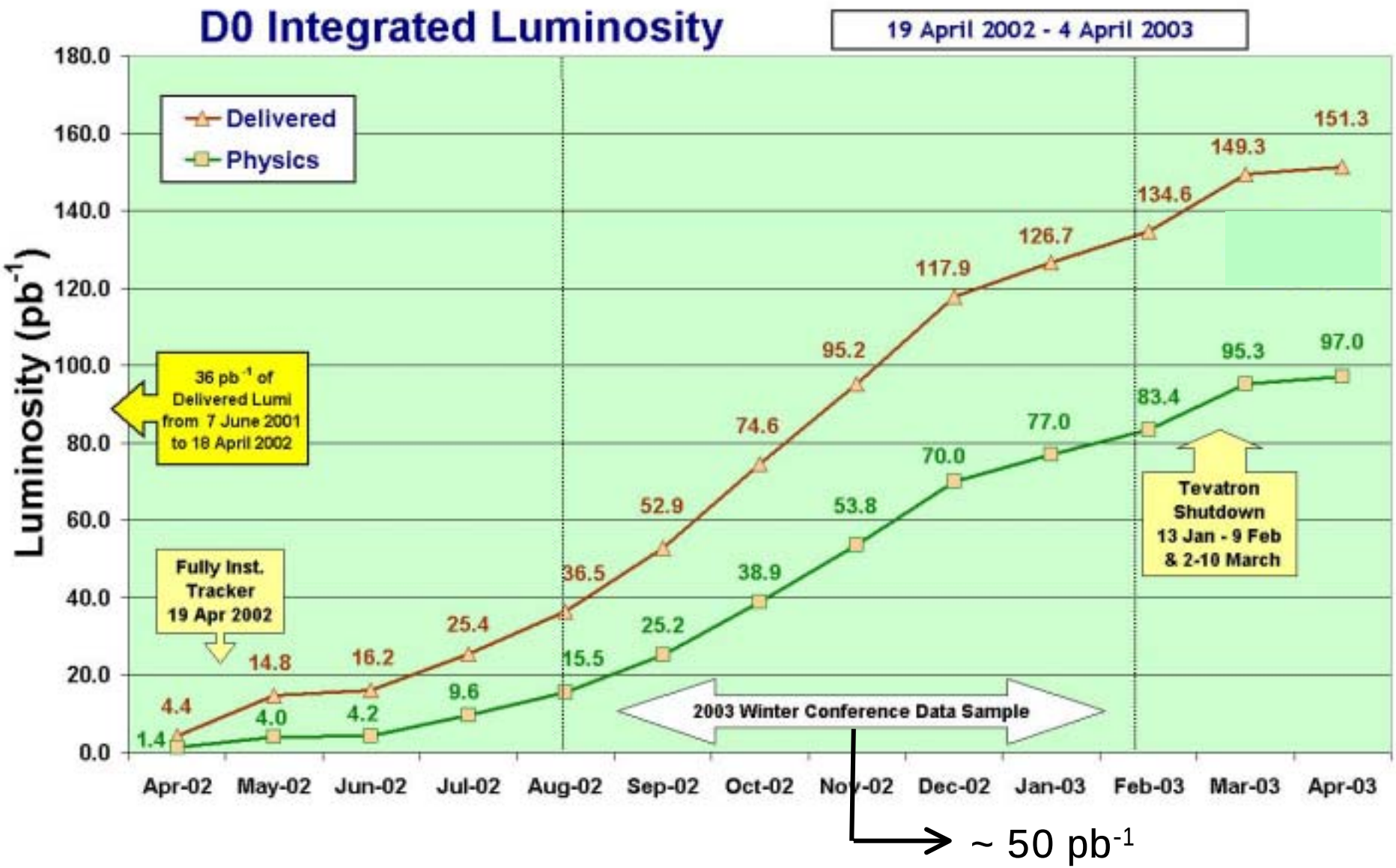
DØ Integrated Luminosity



~ 50 pb^{-1}

DØ Detector Performance

New Results for DPF

- QCD: inclusive jet cross-section
- B Physics: B_s and Λ_b
- Higgs: $H \rightarrow \gamma\gamma$, background for $H \rightarrow WW^* \rightarrow \mu\nu\ \mu\nu$
- New Phenomena: RunI search for 3,4-body decays of stop
- New Phenomena: Search for first generation Leptoquarks
- W/Z cross-section measurements
- Top cross-section measurement updates

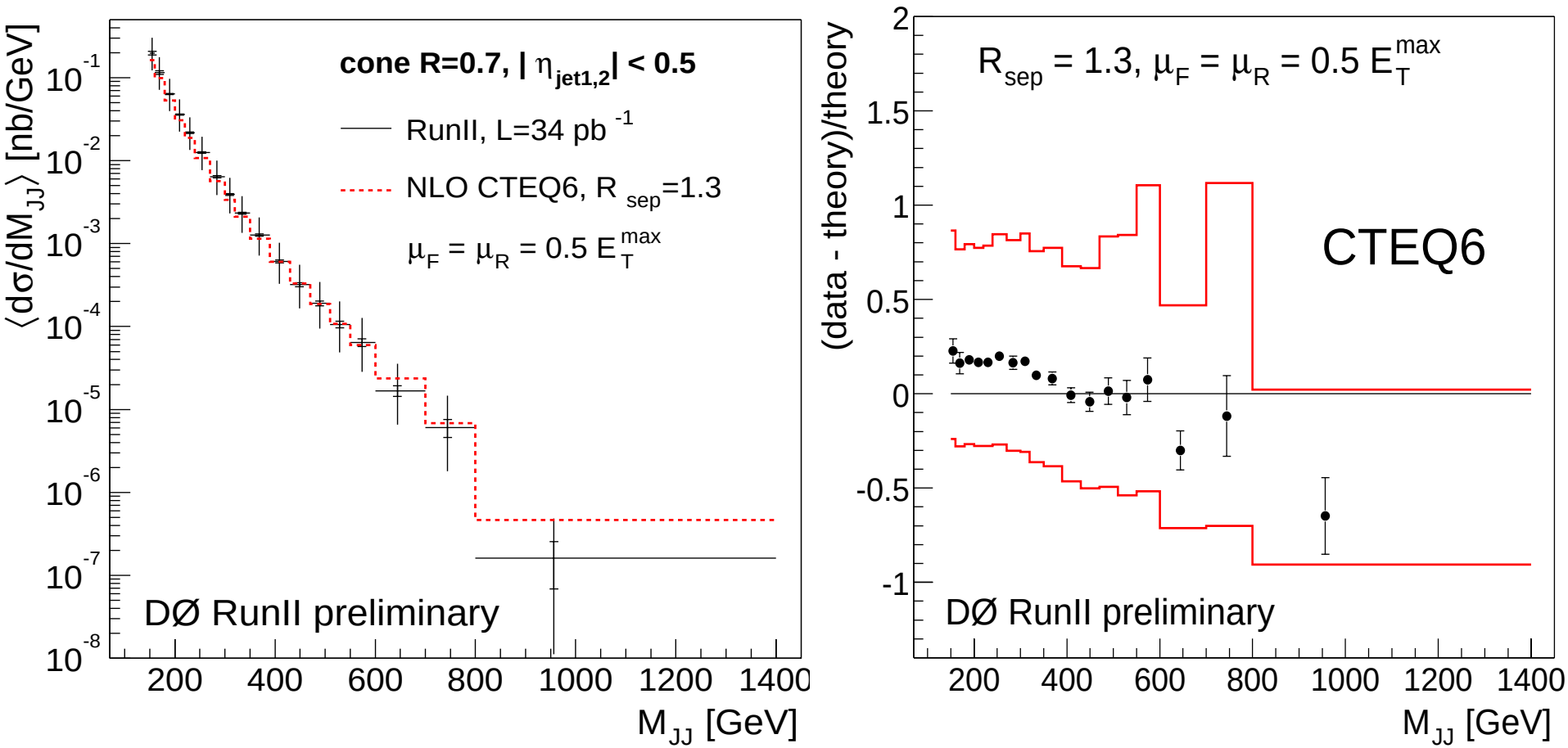
- many other new results already presented at Moriond:

  $\rightarrow$ Wine and Cheese: S. Protopopescu (March 7)

  $\rightarrow$ Wine and Cheese: B. Abbott (March 14)

QCD result presented at Moriond

- Dijet mass cross-section:



Inclusive Jet Cross-Section

- Jet cross-section:

  → understanding of QCD (proton structure)

  → search for new physics at high Q^2

- Data sample and selection:

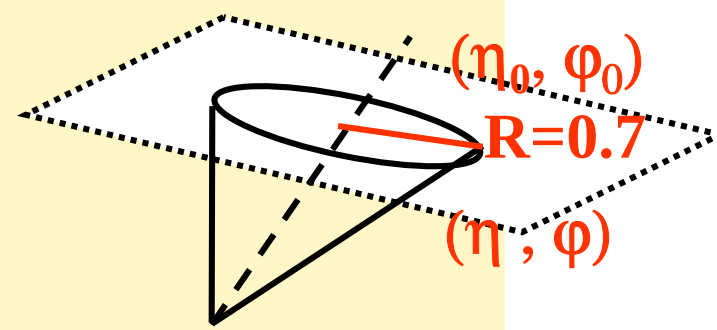
  → $\mathscr{L} \approx 34\ pb^{-1}$

  → $|\eta| < 0.5$, $60 < P_T < 560$ GeV (0.7 cone jet)

  → vertex constraints: $|z_{vtx}| < 50$ cm, $N_{trk} > 4$

  → $\not{E}_T / Pt_{lead\ jet} < 0.7$

  → jet quality cuts



Jet Energy Scale Corrections

- Correct the measured energy:

$$E_{corr} = \frac{E_{meas} - E_O}{R_{jet} S_{cone}}$$

Offset: electronic noise, uranium noise, underlying event

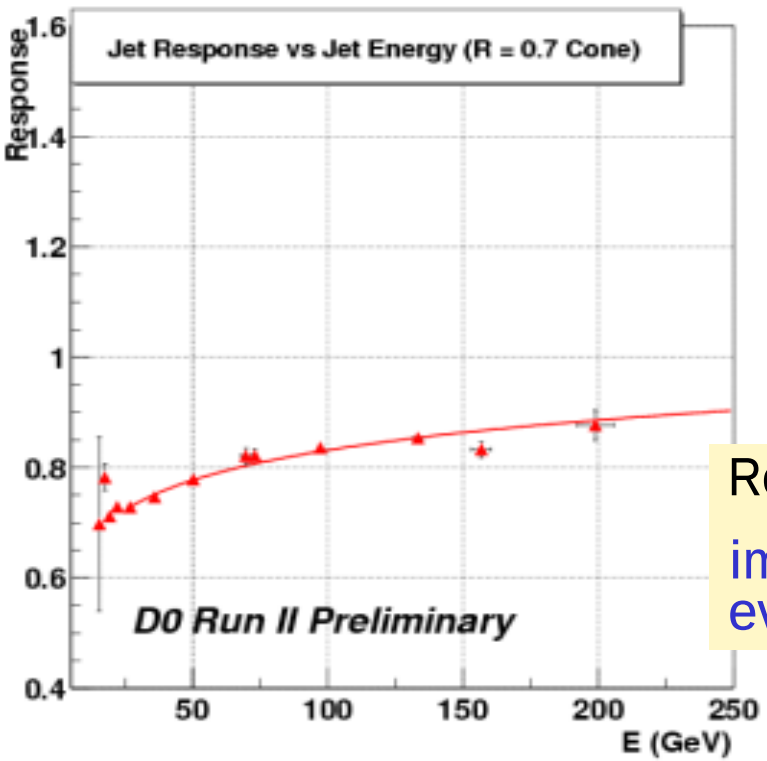
zero bias and minimum bias events (data)

out of cone Showering:

energy density in ring around the jet axis (data)

Response: $E_{meas}/E_{deposit} \neq 1$

imbalance energy in γ+jet events (data)

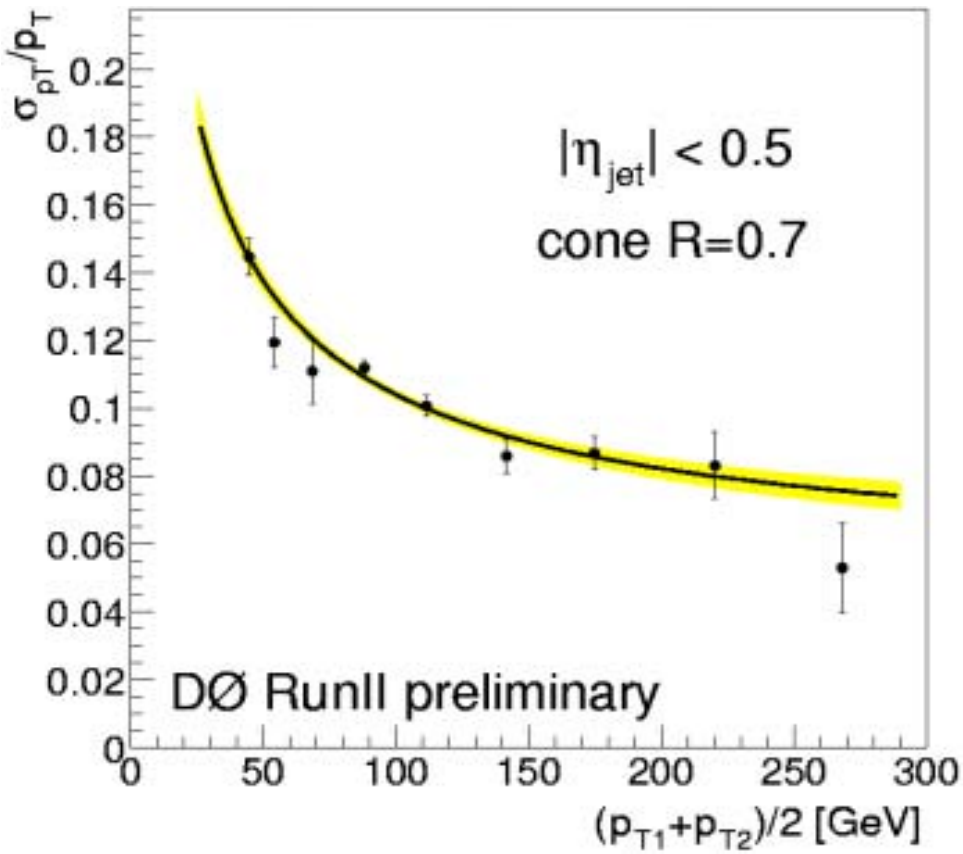


Jet Resolution

- Jet P_T resolution:

→ using energy asymmetry in dijet events

Jet p_T Resolution



$$A = \frac{p_T^{jet1} - p_T^{jet2}}{p_T^{jet1} + p_T^{jet2}} \qquad \frac{\sigma_{p_T}}{p_T} = \sqrt{2}\sigma_A$$

parametrized as:

$$\frac{\sigma_{p_T}}{p_T} = \sqrt{\frac{N^2}{P_t^2} + \frac{S^2}{P_t} + C^2}$$

N = 0.0 ± 2.2, S = 0.902 ± 0.045,
C = 0.052 ± 0.008

Inclusive Jet Cross-Section

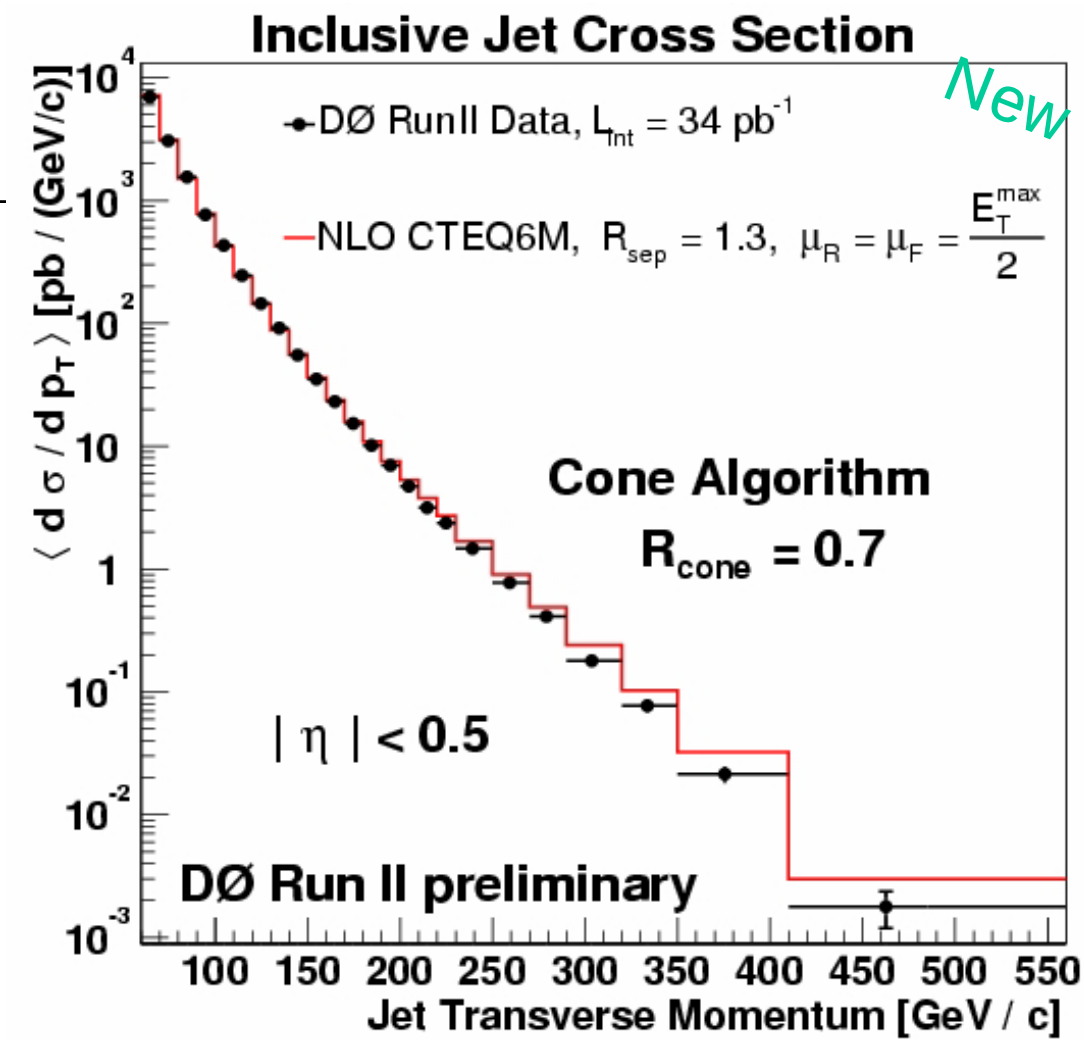
- For each P_T bin:

$$\left\langle \frac{d\sigma}{dp_t} \right\rangle = \frac{N_{event}}{L \cdot \Delta p_T} \times \frac{C_{unsmear}}{\varepsilon_{eff}}$$

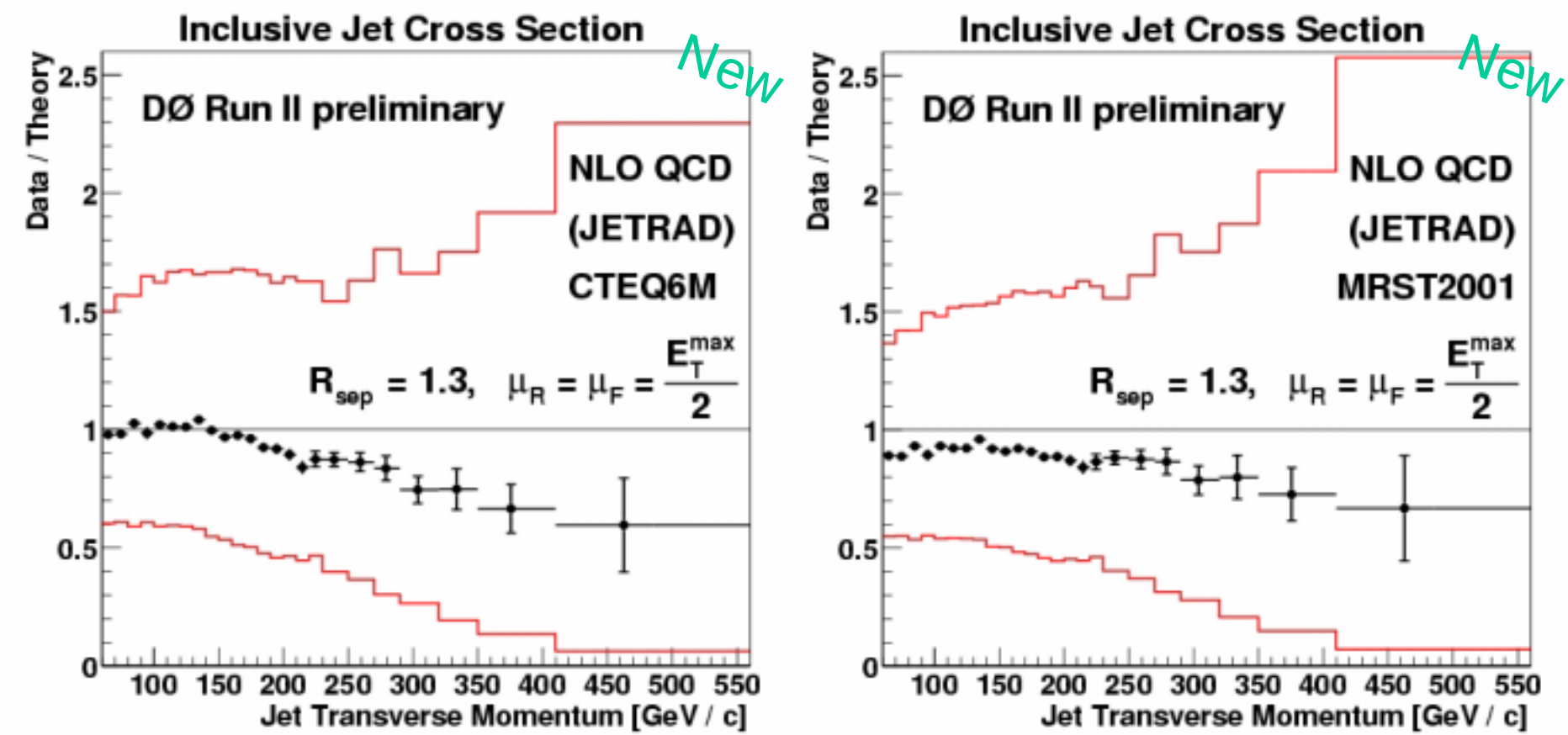
→ ε_{eff} estimated from data

→ theory: NLO pQCD (JETRAD)

→ here data points: only statistical errors



Data-Theory Comparison



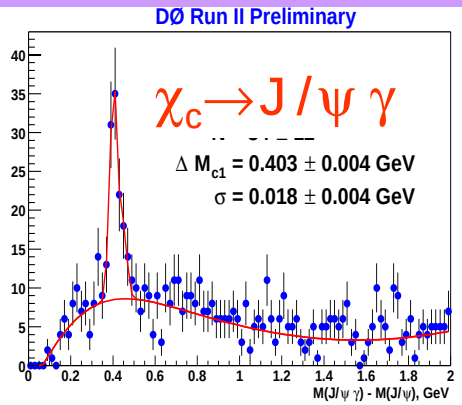
error on luminosity not shown (10%)

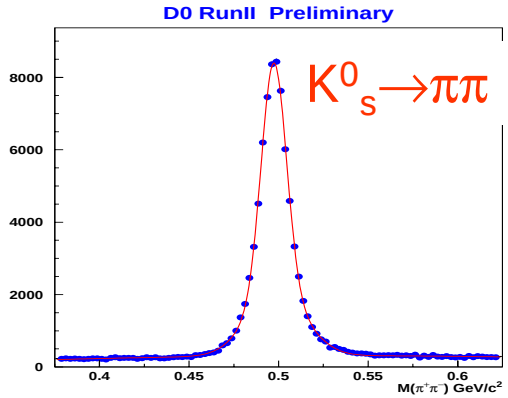
- Dominant error: energy scale

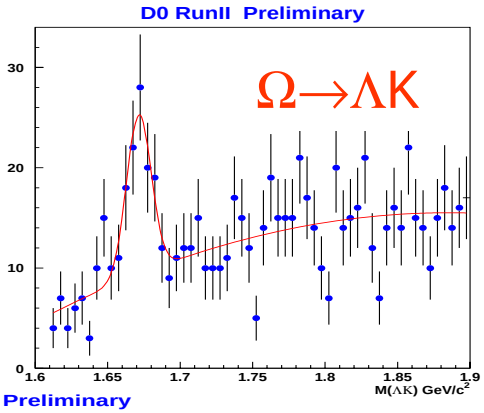
  → ~9% for central jets, P_T< 200 GeV

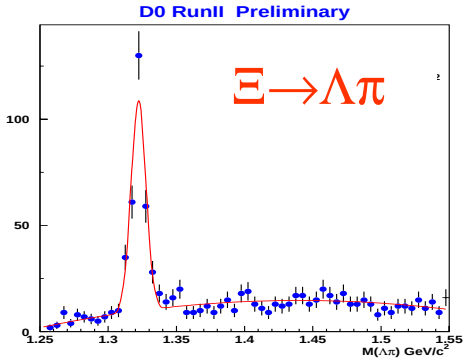
  → reduced statistics, extrapolation to higher P_T

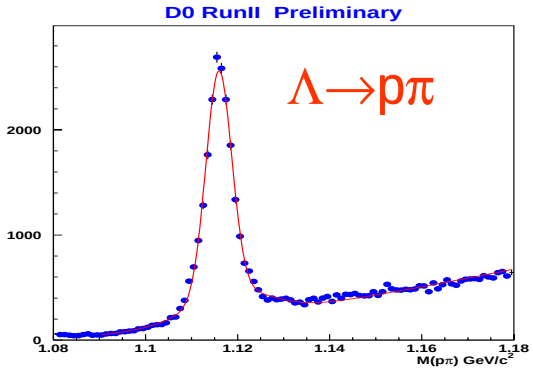
B Physics Results Shown At Moriond

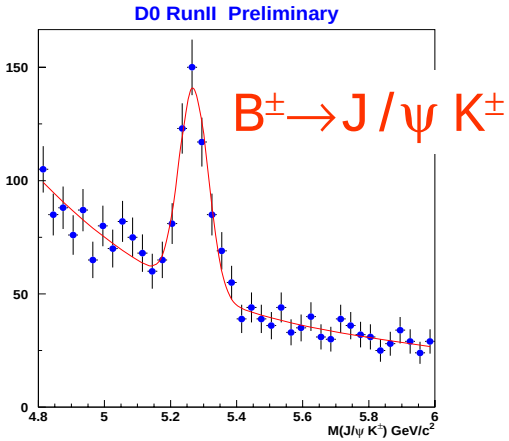


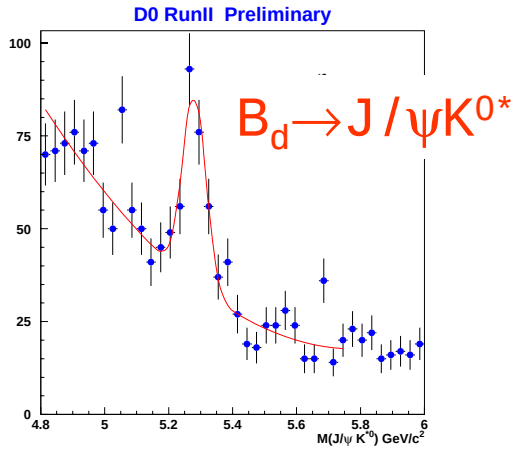


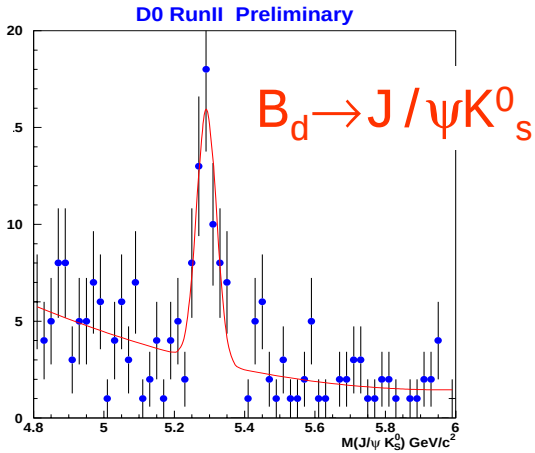




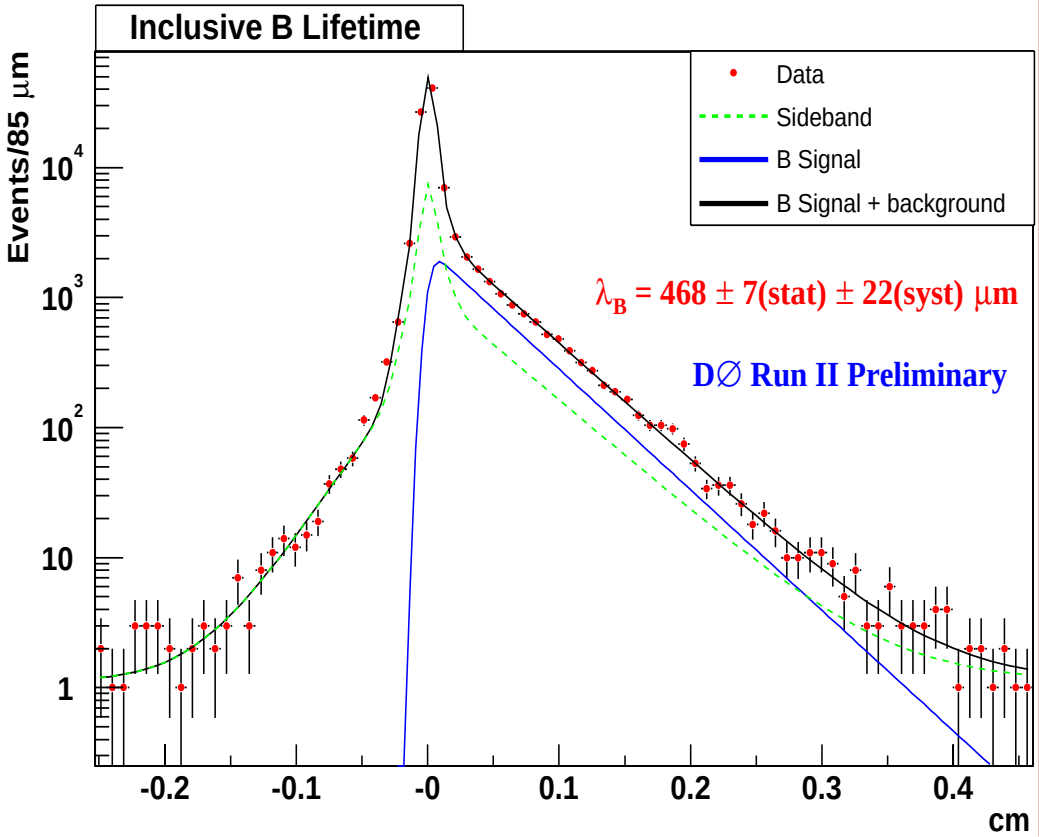


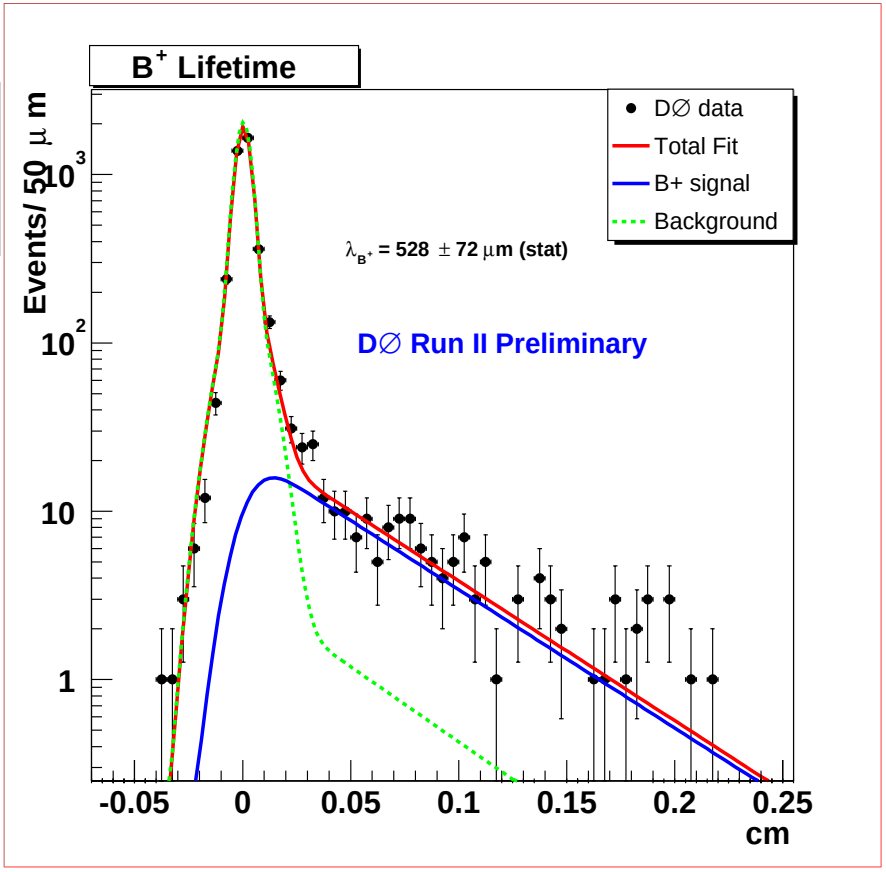






B lifetimes





→ inclusive: <τ> = 1.561 ± 0.024 (stat) ± 0.074 (sys) ps

→ charged B: <τ> = 1.76 ± 0.24 (stat) ps

New B Physics Results

- DØ has improved its tracking algorithm (low pt tracks, large impact parameter)

- Another B hadron new at DØ:

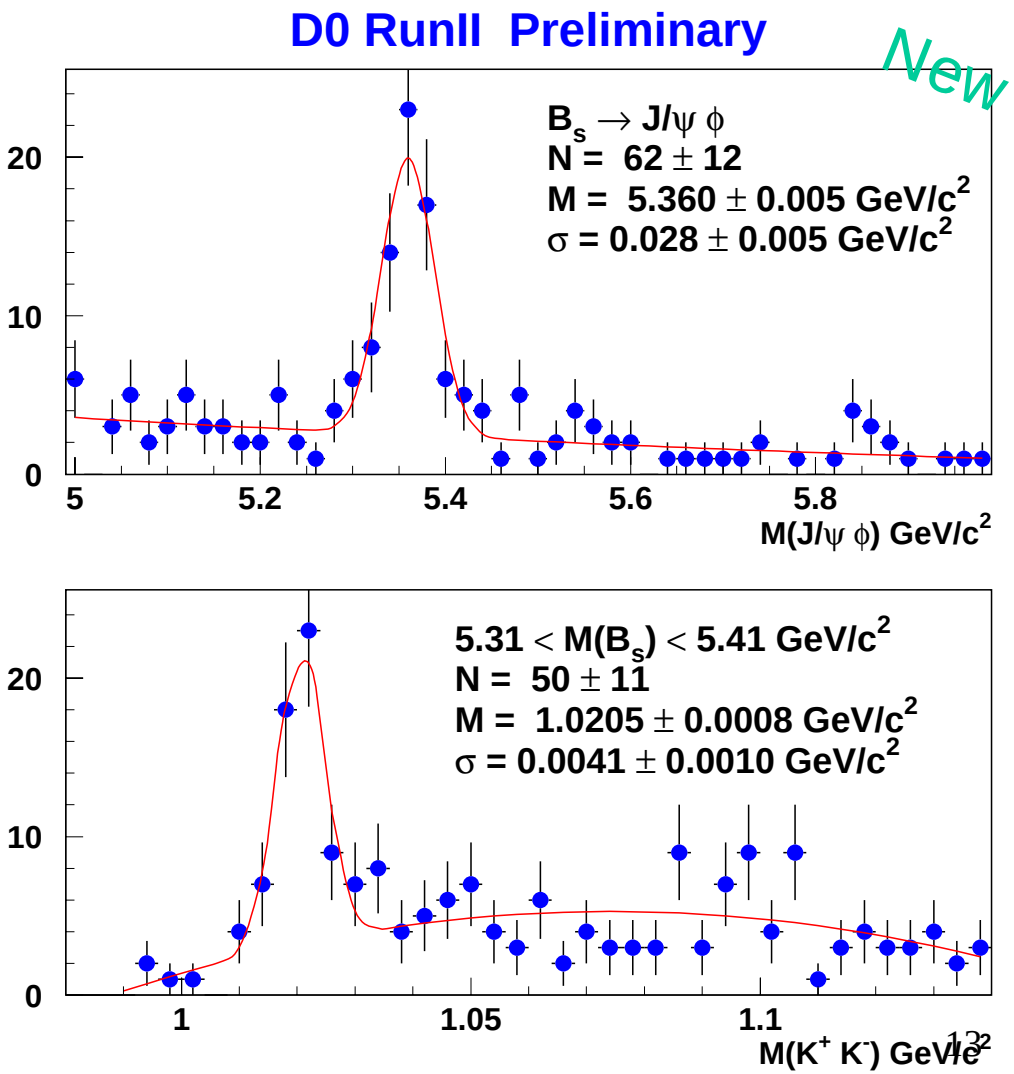
62 fully reconstructed

$B_s \to J/\psi\ \phi$

$\to$ not accessible at B factories

$\to$ golden channel for CP violation in B_s system (very small in the SM)

$\to$ B_s oscillation ($B_s \to D_s \ell \nu$, $B_s \to D_s \pi$)



B Physics

- B baryon:

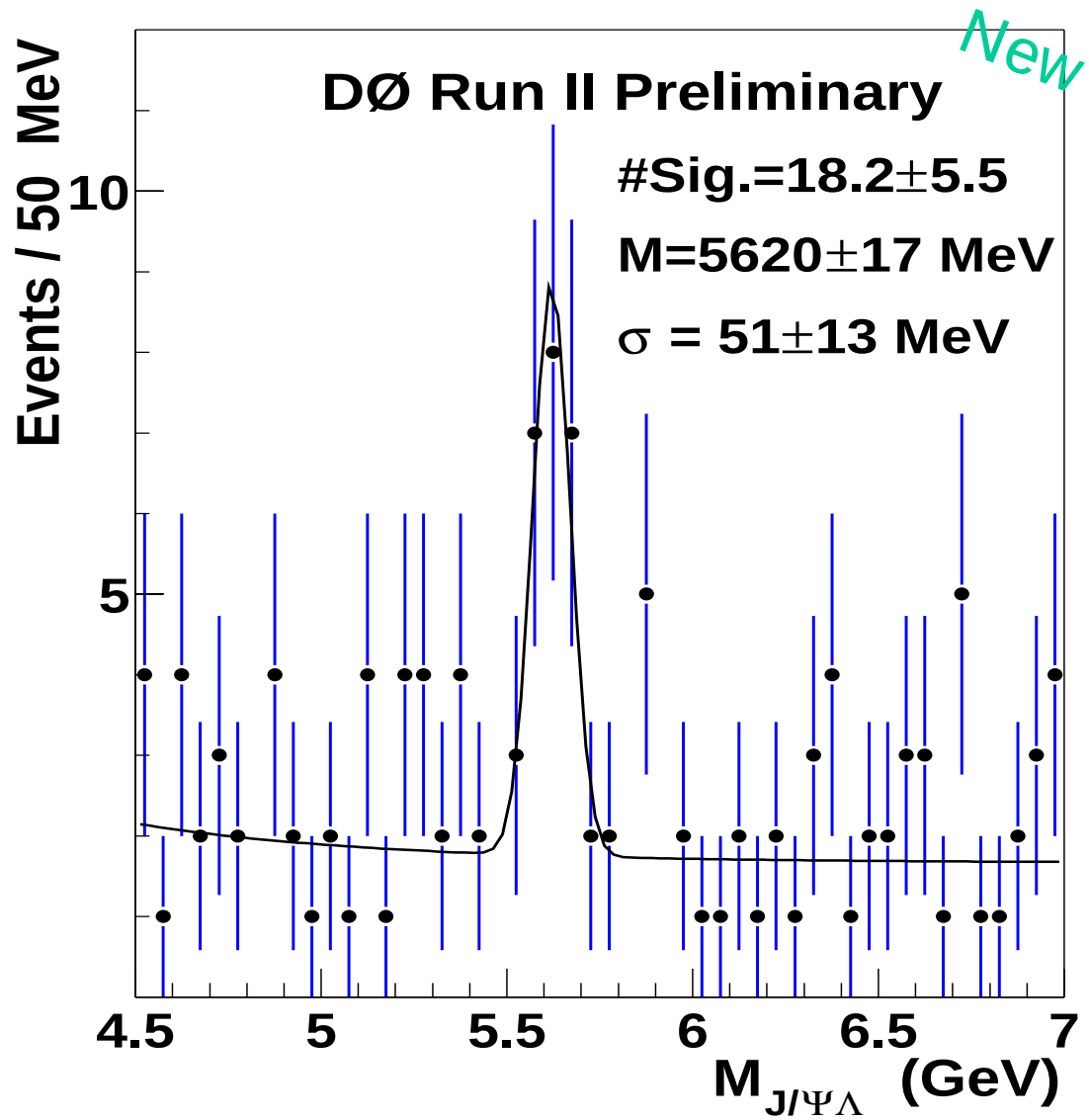
Fully reconstructed

$\Lambda_b \rightarrow J/\psi\ \Lambda$

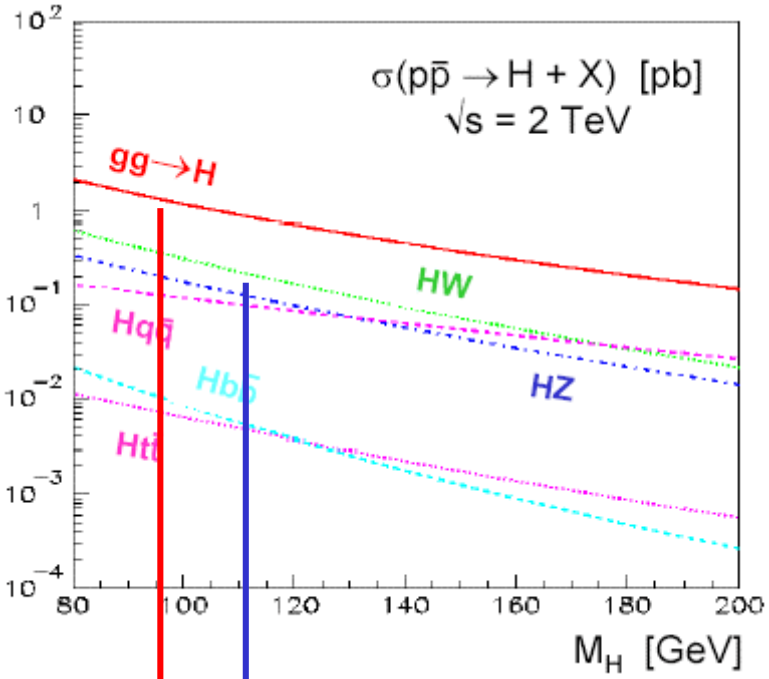
$\rightarrow$ not accessible at B factories

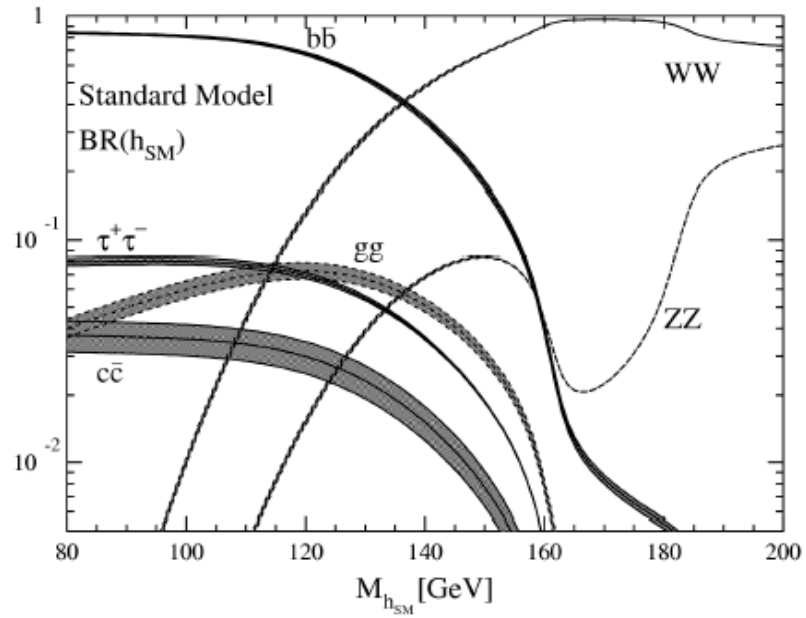
$\rightarrow$ lifetime: discrepancy with theory for $\frac{\tau(\Lambda_b)}{\tau(B^0)}$

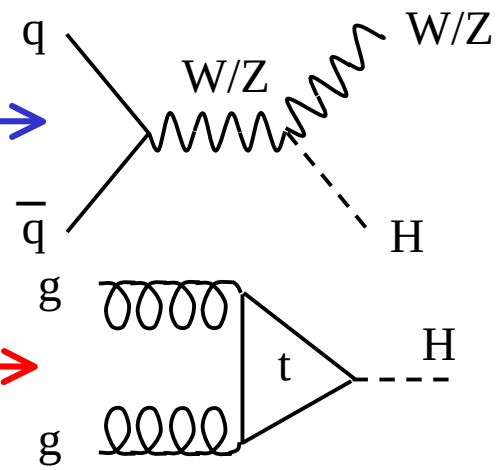
$\rightarrow$ mass measurement

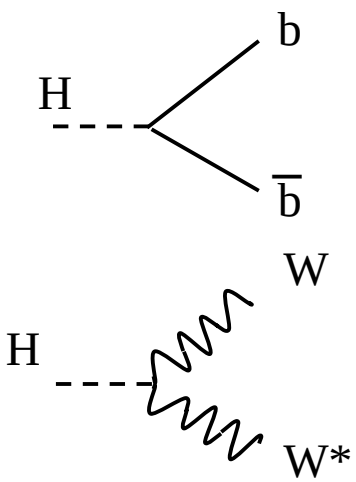


Higgs Searches









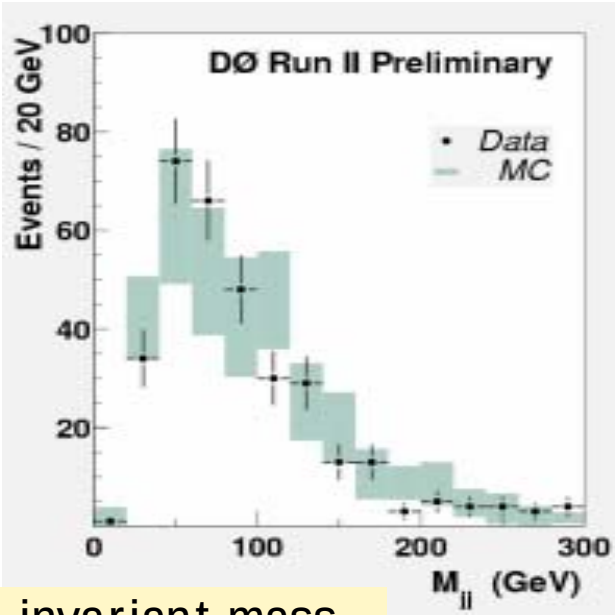
low mass

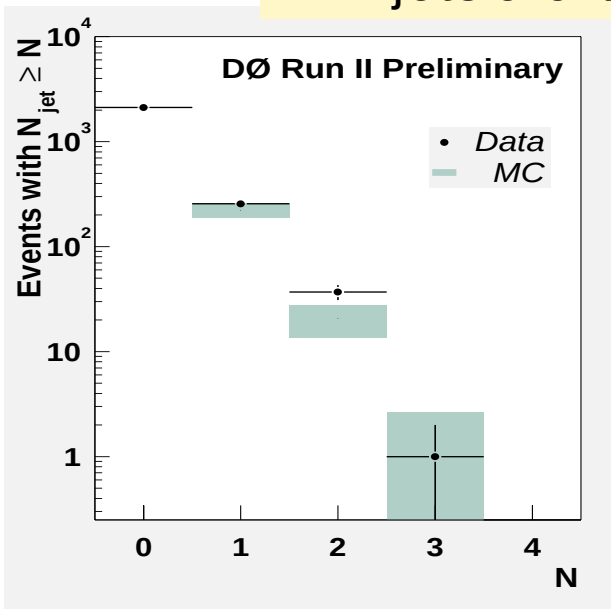
high mass

Low Mass Region

- Understand W/Z + jet production

Jet multiplicity in Z+jets events



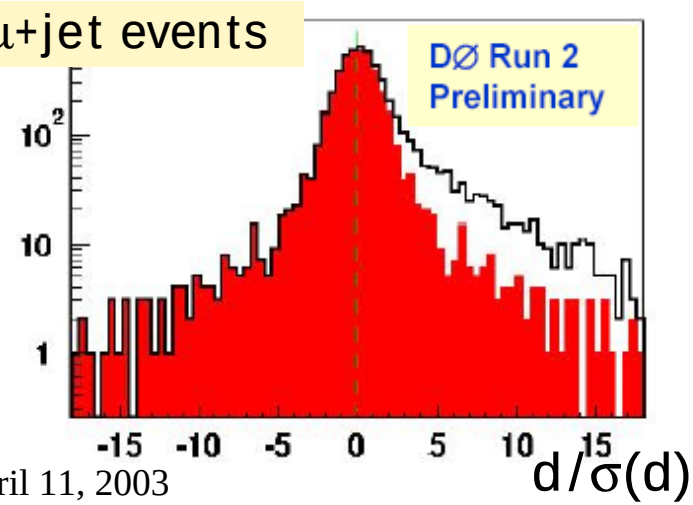


dijet invariant mass in W+jets events

- b-tagging

→ impact parameter tag

μ+jet events



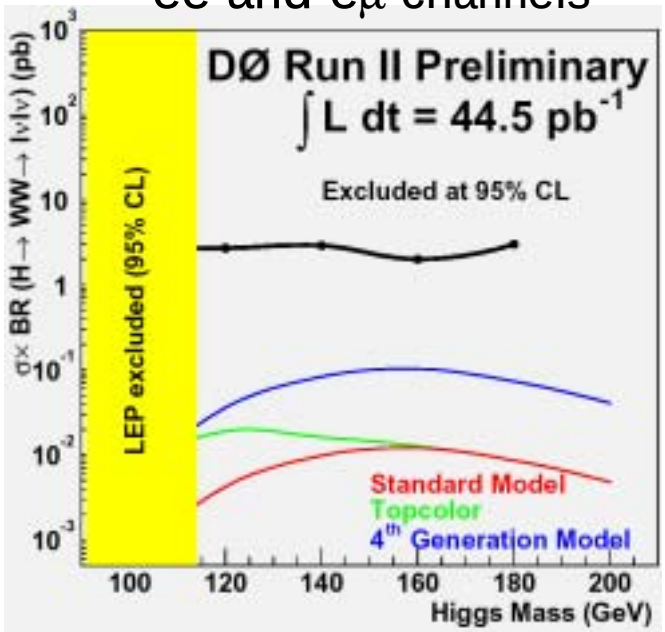
High Mass Region

- $H \rightarrow WW^* \rightarrow \ell^+ \ell^- \nu \bar{\nu}$

  $\rightarrow$ signature: ee, e μ, $\mu\mu$ + $\not{E}_T$

  $\rightarrow$ background: Z/y*, WW, $t\bar{t}$, W/Z+jets, and QCD

ee and eμ channels



- Dimuon channel

$\mathscr{L} \approx 48$ pb^{-1}

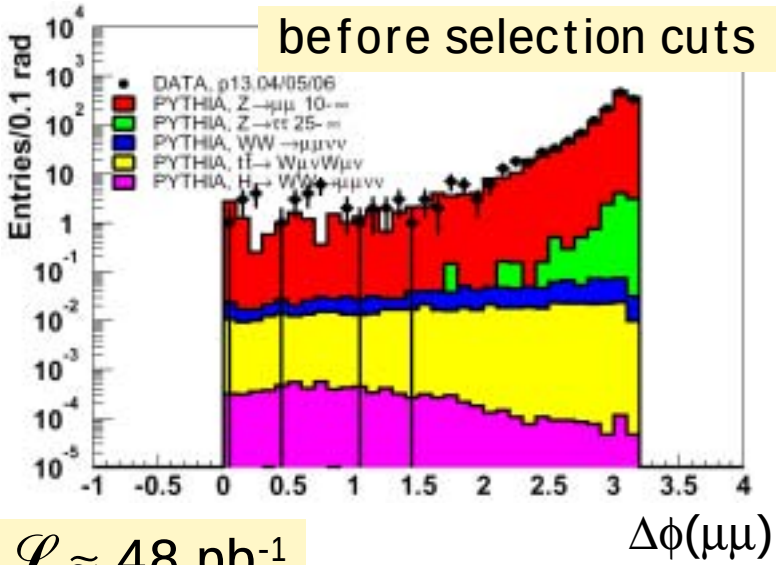
	Expected Background	Data New
μ-ID / P_T > 15GeV	1419 ± 19 (stat)	1414
20 < $m_{\mu\mu}$< 75 GeV	264 ± 10 (stat)	266
$\not{E}_T$ > 20 GeV	66.1 ± 4.7 (stat)	68
$\Delta\phi$(Jet, $\not{E}_T$) > 0.5	60.6 ± 4.6 (stat)	66
50 < $m_T(\mu\mu, \not{E}_T)$ < 200 Gev	3.6 ± 1.3 (stat)	5
$\Delta\phi$ ($\mu\mu$) < 2	0.32 ± 0.01 (stat)	1

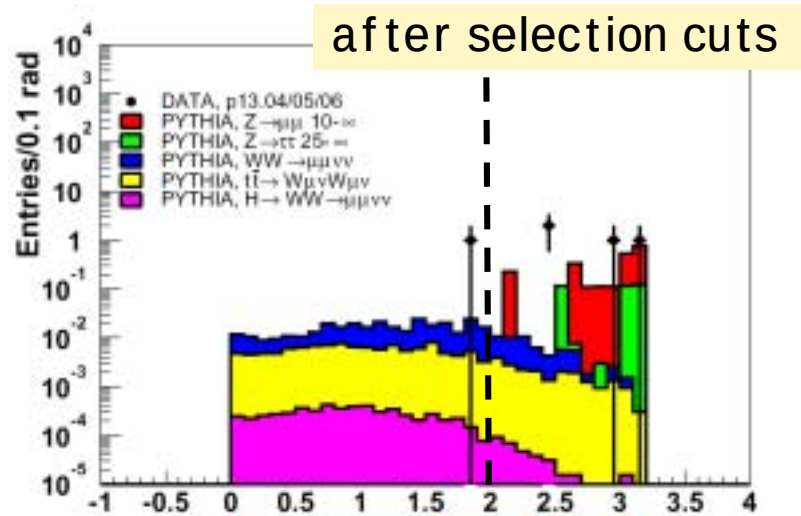
$H \rightarrow WW^* \rightarrow \mu^+ \mu^- \nu \bar{\nu}$

- $\Delta\phi(\mu\mu)$ cut

  → Higgs: spin correlation: $\ell\ell$ parallel

  → Z/y and QCD: $\ell\ell$ back to back



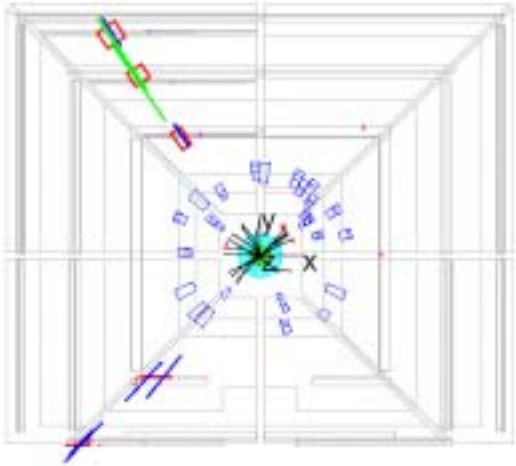


$\mathscr{L} \approx 48\ pb^{-1}$

- 1 candidate:

  → $P_T(\mu_1)$=33.7 GeV, $P_T(\mu_2)$=23.7 GeV, $\not{E}_T$ = 45.7 GeV

  → $\Delta\phi(\mu\mu)$ = 1.84, $m(\mu\mu)$ = 52.5 GeV, m_T = 60.3 GeV

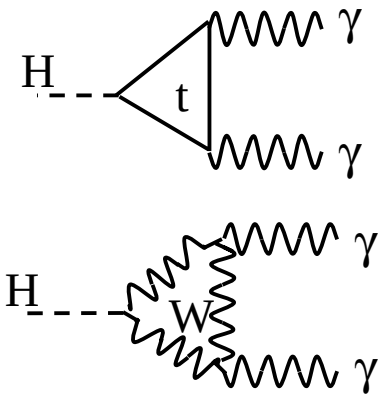


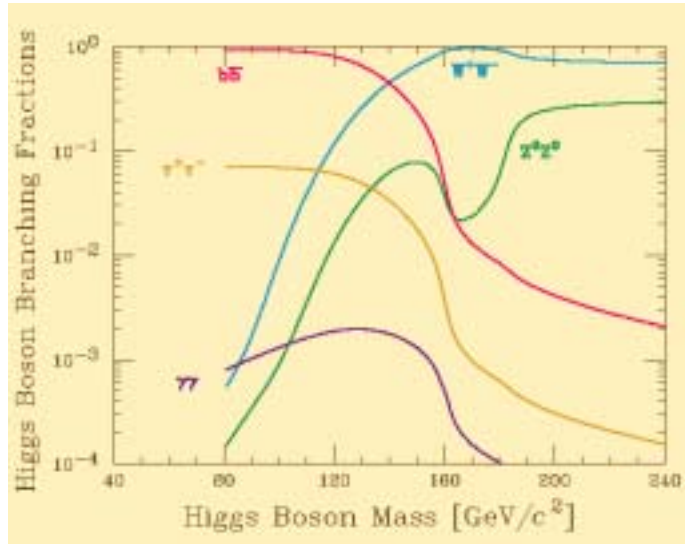
$H \rightarrow \gamma\gamma$

- Branching ratio in $\gamma\gamma$:

$\rightarrow$ in SM, very low: ~ 10^{-3}-10^{-4}

$\rightarrow$ enhance in extensions like Fermiphobic, Topcolor Higgs





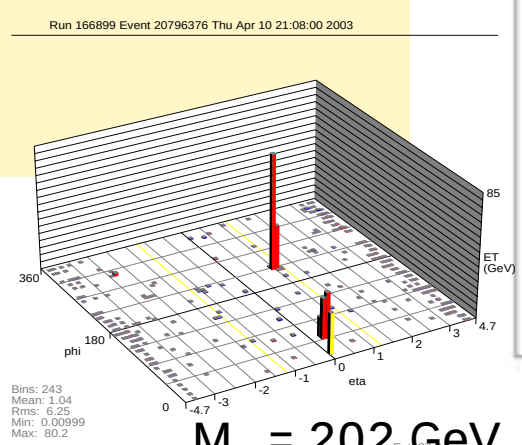
- Search for Topcolor Higgs:

$\rightarrow \mathscr{L} \approx 52$ pb^{-1}

$\rightarrow$ 2 isolated EM, E_T > 25 GeV, no track matched, mass window cut

$\rightarrow$ SM background: Z/γ, QCD

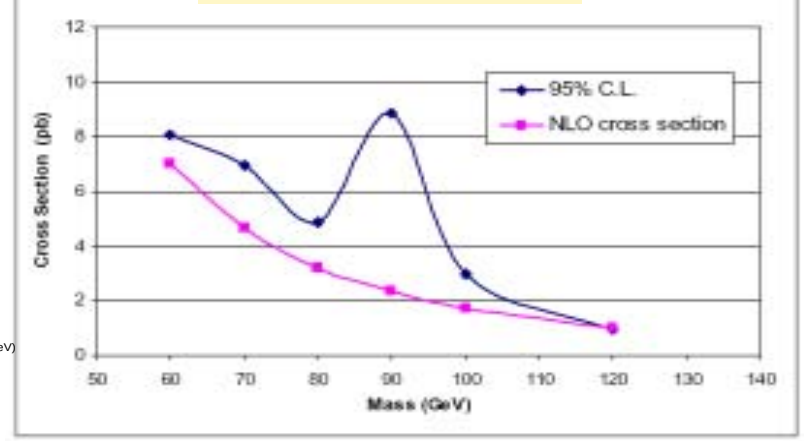
approaching region of interest



$M_{\gamma\gamma}$ = 202 GeV

New

Br ($h \rightarrow \gamma\gamma$) = 1



Searches for New Phenomena

- Deviations from SM:

→ Supersymmetry:

- e, μ + $\not{E}_T$: 3,4-body decays of the stop (RunI)
- Jets + $\not{E}_T$
- Di-Trilepton (eeℓ, $\mu\mu$, τ channels, ...)
- GMSB: $\gamma\gamma$ + $\not{E}_T$

→ Exotics

- first generation leptoquarks (ee +jets)
- second generation leptoquarks ($\mu\mu$ +jets)

→ Extra-dimensions:

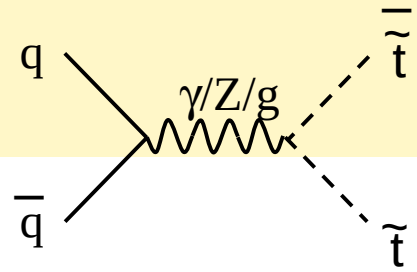
- Dielectrons and Diphotons
- Dimuons

Search for 3,4-Body Decays of the Stop at RunI

- MSSM:

→ due to the high top mass, the *scalar top* can naturally be lighter than the other squarks

→ produce by pairs



- Stop decay:

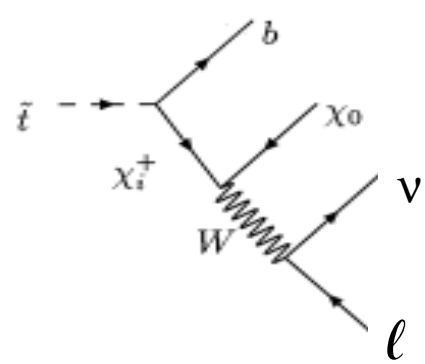
→ if heavy enough: $\tilde{t} \to b\, \chi^+_1$

→ moderate mass: $\tilde{t} \to c\, \chi^0_1$, $\tilde{t} \to b\, ff' \chi^0_1$ (via virtual χ^+_1)

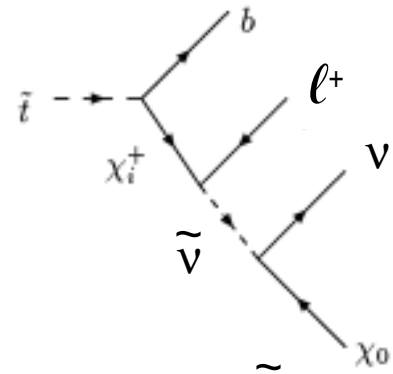
- Signature:

→ assume 4-body decay dominant (low tanβ)

→ channel: electron + muon + $\not{E}_T$



W exchange



light $\tilde{\nu}$

Data Selection

- Event selection:

→ electron Et > 15 GeV within $|\eta| < 2.5$

→ muon $P_T(\mu) > 15$ GeV within $|\eta| < 1.7$

→ $\not{E}_T > 20$ GeV

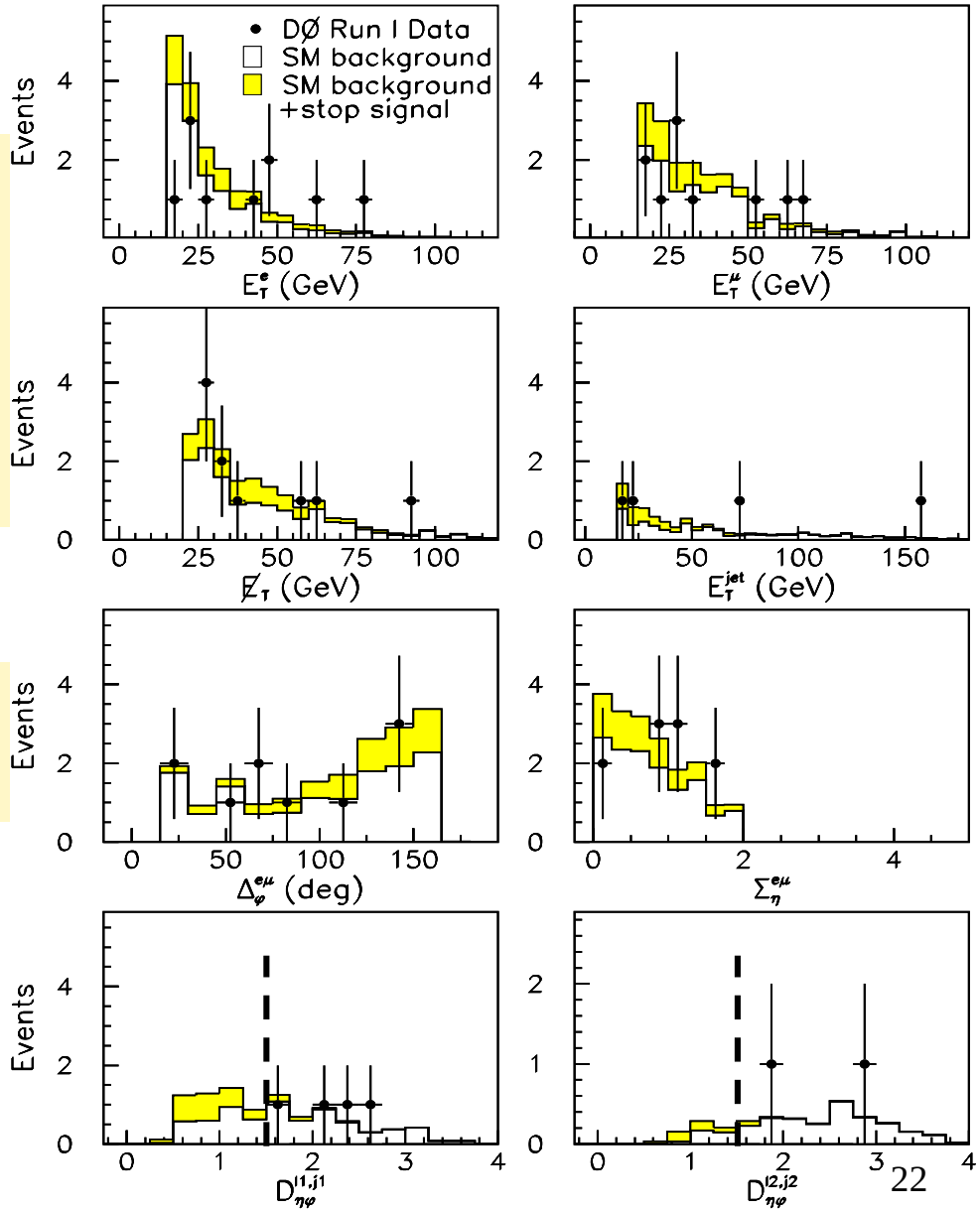
→ $|\eta_e + \eta_\mu| < 2$, $15^o < |\phi_e - \phi_\mu| < 165^o$

→ leptons separated from jets (if any)

- Background:

→ QCD (fake, heavy flavor)

→ $Z \to \tau\tau$, WW, $t\bar{t}$



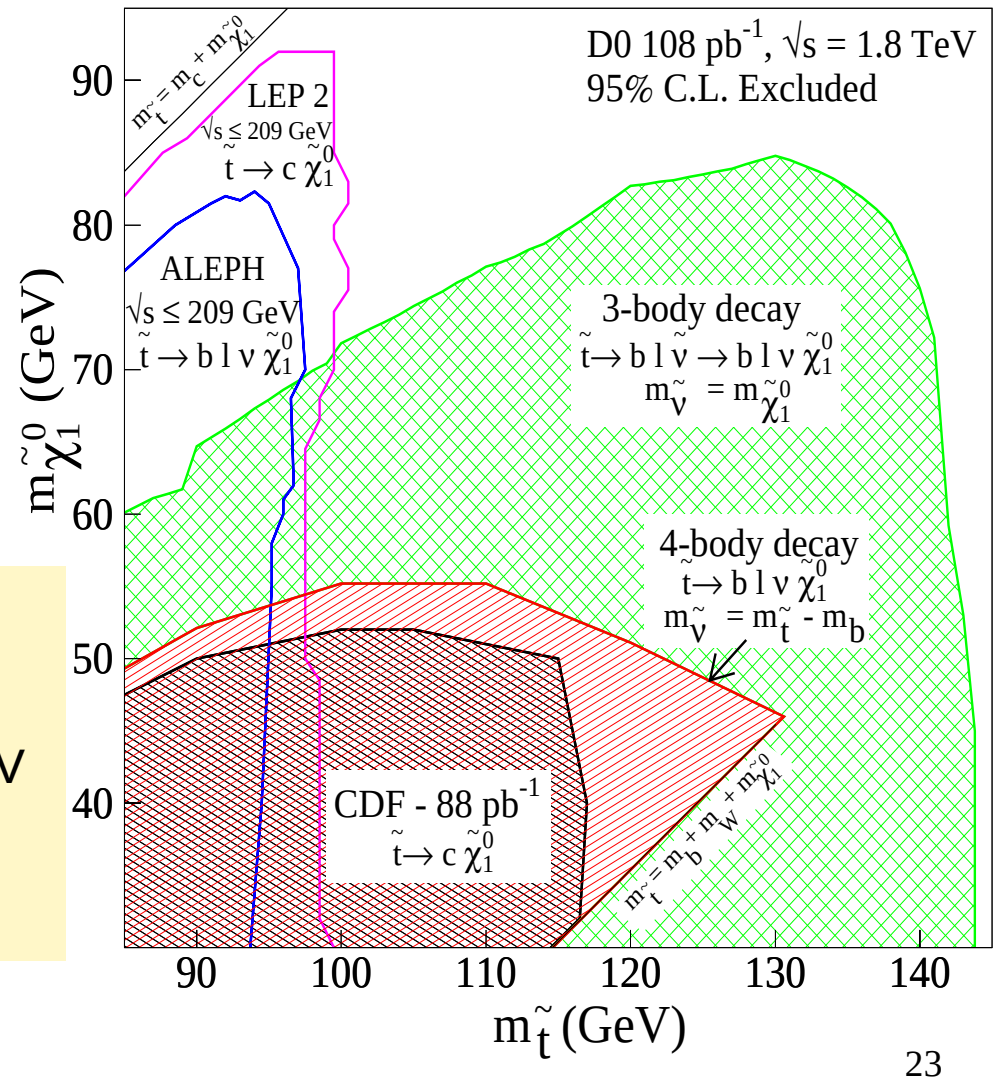
$m(\tilde{t}) = 120$ GeV

$m(\chi^0_1) = 60$ GeV

Results

QCD	4.3 ± 0.3
$Z \to \tau\tau$	0.5 ± 0.1
WW	2.8 ± 0.3
$t\bar{t}$	0.4 ± 0.1
Total expected	8.0 ± 0.8
Observed events	6

light $\tilde{\nu}$ scenario



→ new scenario allows to complete the $\tilde{t} \to c\,\chi^0_1$ result

→ for light $\tilde{\nu}$, exclude up to $m(\tilde{t})$=140GeV

→ need more luminosity for W exchange scenario

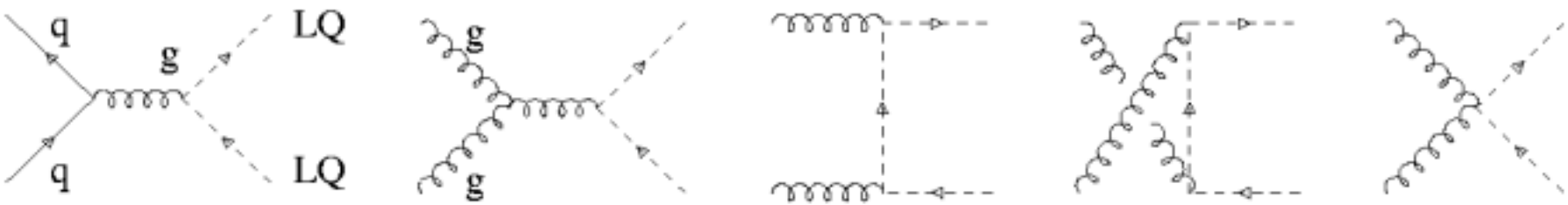
Search for first generation Leptoquarks

- Leptoquarks:

→ couple directly leptons and quarks

→ scalar or vector

→ carry color, fractional charge, baryonic and leptonic numbers



→ 3 generations but limits on FCNC: no intergeneration decays

→ first generation: LQ → eq or νq ⇒ search for ee+2jets final states

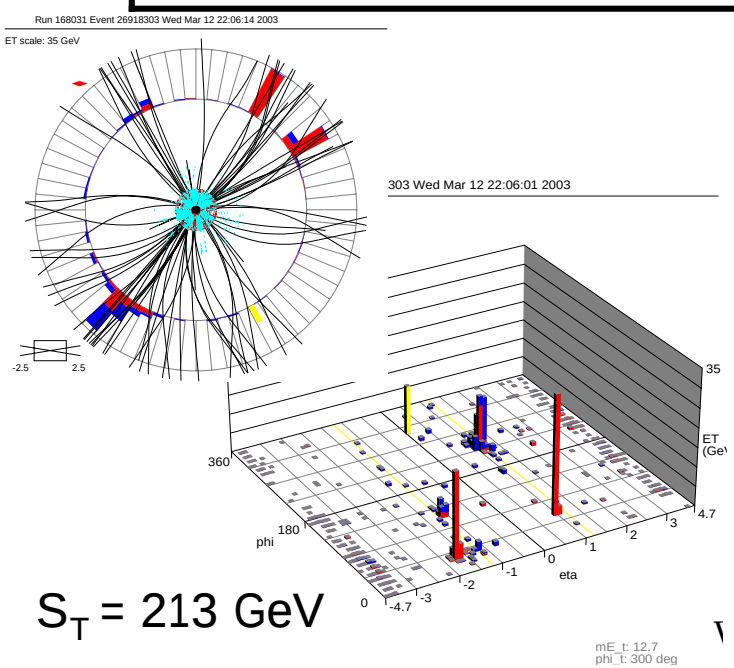
Dielectron + Dijet Channel

- Background:

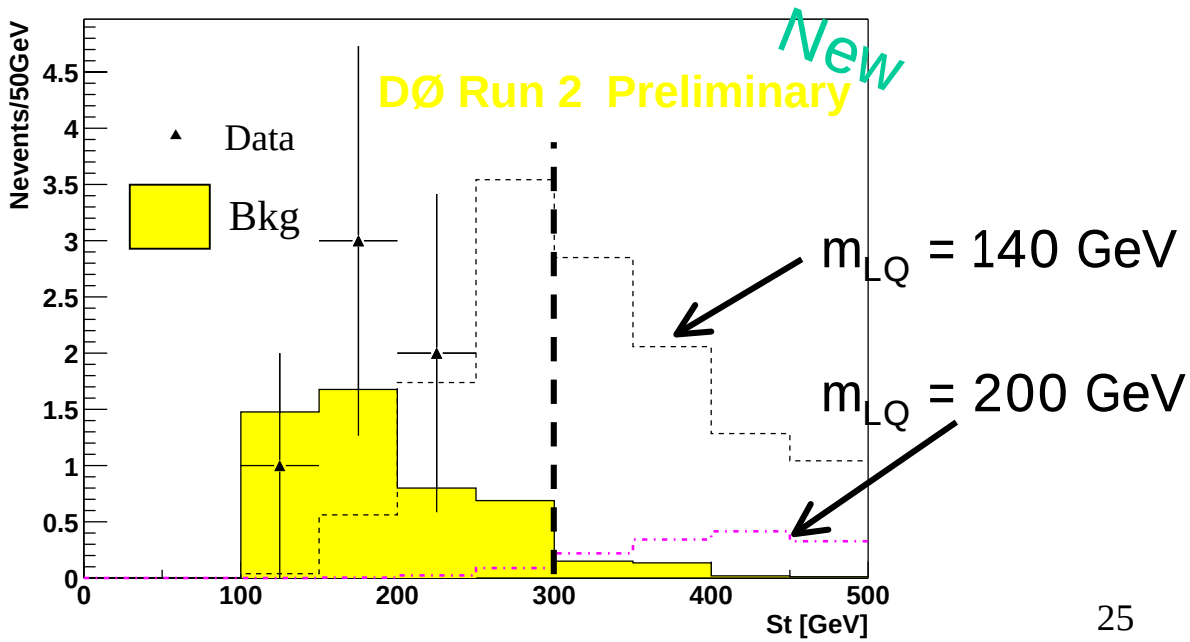
→ Drell-Yan/Z + jets, QCD (with 2 fakes EM), $t\bar{t}$

$\mathscr{L} \approx 43\ pb^{-1}$

	Expected Background	Data
2 EM Et > 15 GeV / one track	1989 ± 172	2093
2 jets Et> 20 GeV / ΔR>0.5	39 ± 10	37
Z veto (M_{ee}< 75 GeV, M_{ee}> 105 GeV)	5.0 ± 1.1	6
S_T= Σ Et(e,jets) > 300	0.34 ± 0.06	0

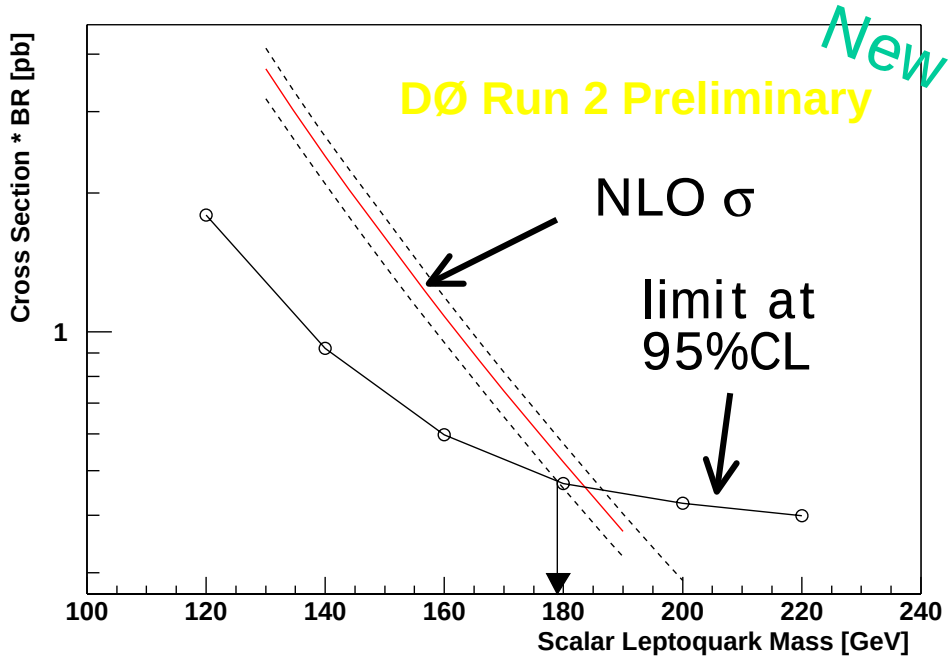


S_T = 213 GeV



Scalar LQ Search Results

- Data consistent with SM Background:



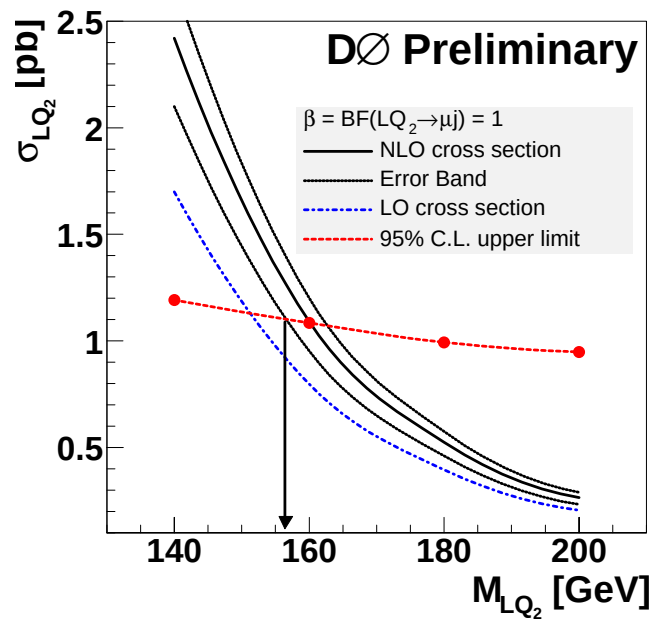
1st generation

→ σ(LQ) < 0.47pb @ 95% CL

→ for $Br(LQ_1 \rightarrow eq) = 1$:

$m_{LQ1} > 179$ GeV

approaching RunI limit:
$m_{LQ1} > 225$ GeV



2nd generation

→ for $Br(LQ_2 \rightarrow \mu q) = 1$:

$m_{LQ2} > 157$ GeV

Electroweak Physics

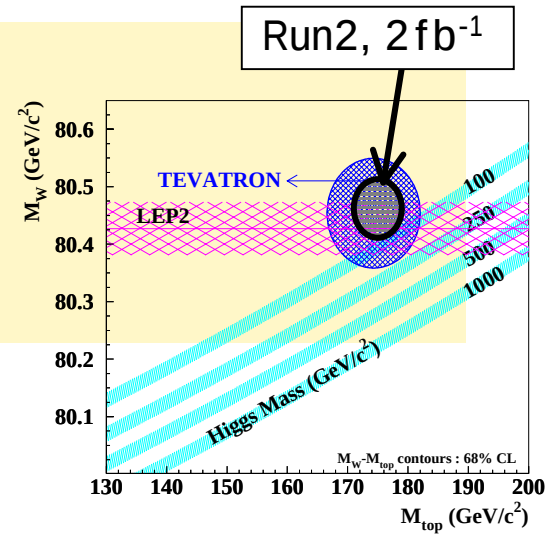
- W/Z production

→ W can be used to determine the luminosity

→ tune algorithms and triggers

→ test of the SM, precision EW measurement

→ W + jets: background for Top and Higgs signals



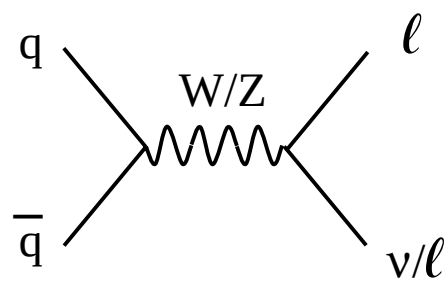
- Signal:

→ dominant production via $q\bar{q}$ annihilation

→ signature: high P_T e or μ + $\not{E}_T$ (W)

high P_T dilepton (Z)

→ background: QCD (fake leptons)



Electron Channel

- Selection:

→ EM cluster with Et > 25 GeV (isolated, large EM fraction, with shower shape consistent with MC expectation)

→ $|\eta| < 1.1$

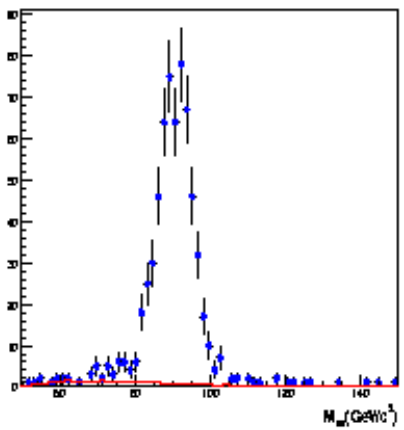
→ W: $\not{E}_T$ > 25 GeV, track match

→ Z: 70 < Mee < 110 GeV

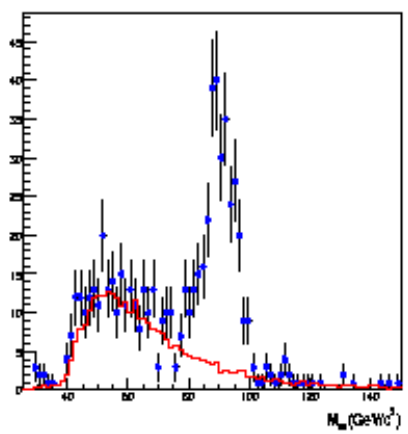
- Efficiencies:

→ evaluated on data: $\varepsilon_{tot}(Z) = 9.3$ %, $\varepsilon_{tot}(W) = 15.7$ %

pass shower shape cut



fail shower shape cut



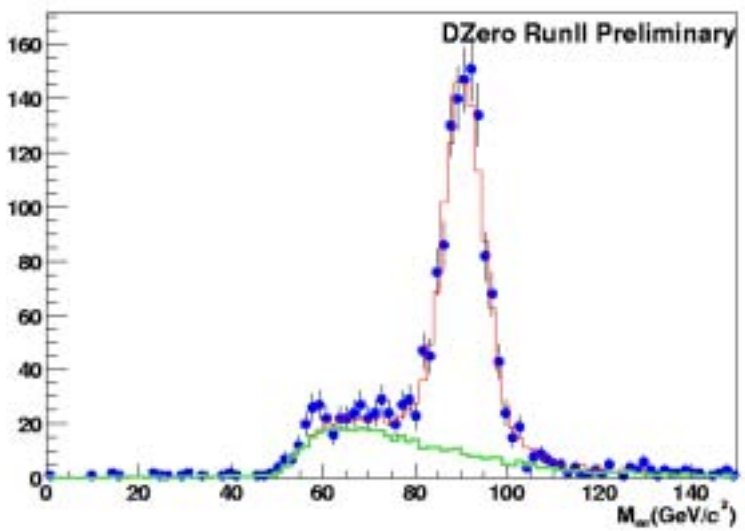
Z→ee signal

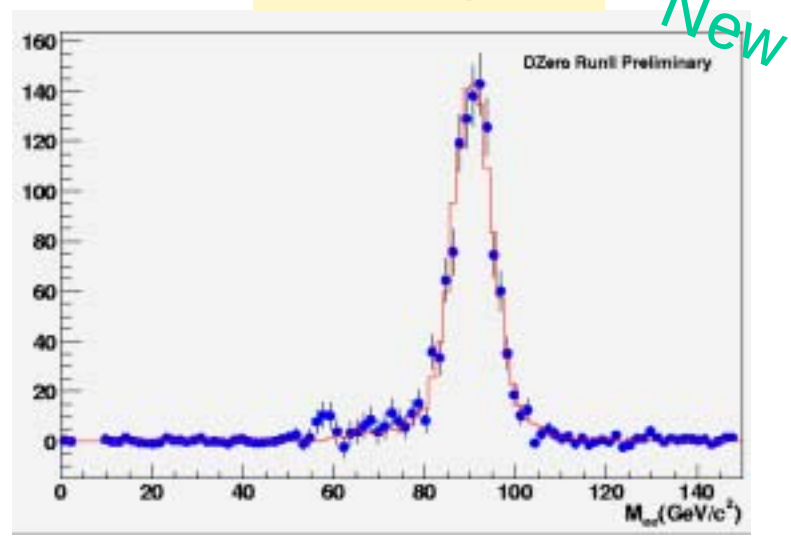
- Signal extraction:

→ background removed by fitting a scaled shape

→ contribution from Drell-Yan events: 1.7%

$\mathscr{L} \approx 42\ pb^{-1}$





→ Number of Z(ee) candidates: 1139 ± 42

$$\sigma(Z)Br(Z\rightarrow ee) = 294 \pm 11(N_z) \pm 8(sys) \pm 29(lumi)pb$$

Background estimation

- W→ eν:

→ QCD background evaluated from data

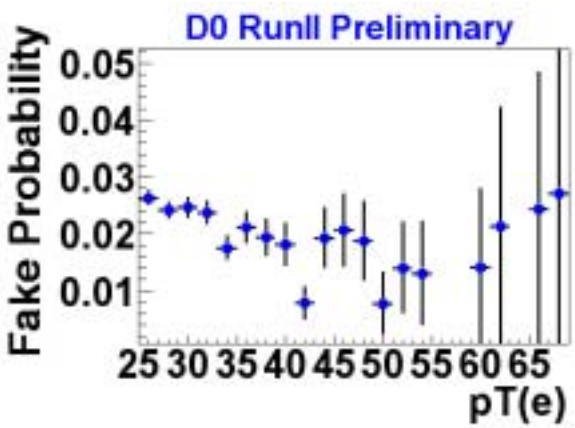
→ W →τν (MC), Z → ee (negligible)

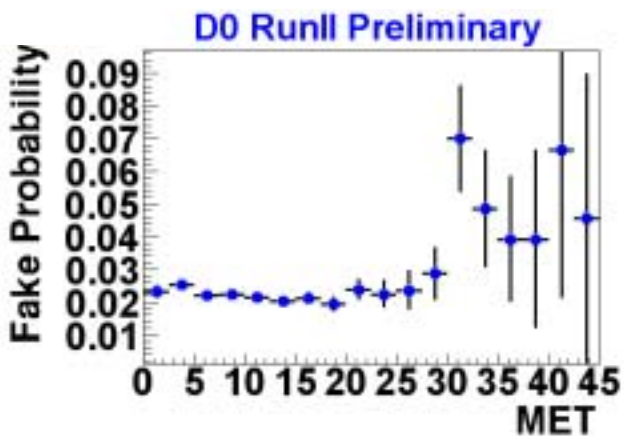
- "Matrix method":

1 additional requirement

$$\left.\begin{aligned} N_{base} &= N_W + N_{bkg} \\ N_{tight} &= \varepsilon_W N_W + f\, N_{bkg} \end{aligned}\right\} \quad N_W = \frac{N_{tight} - f\, N_{base}}{\varepsilon_W - f}$$

→ for W →eν: additional requirement = track match

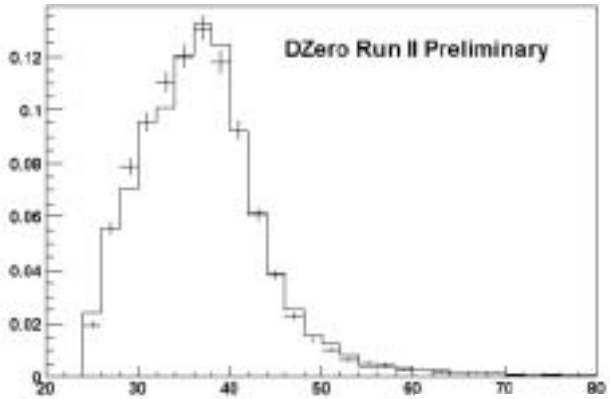




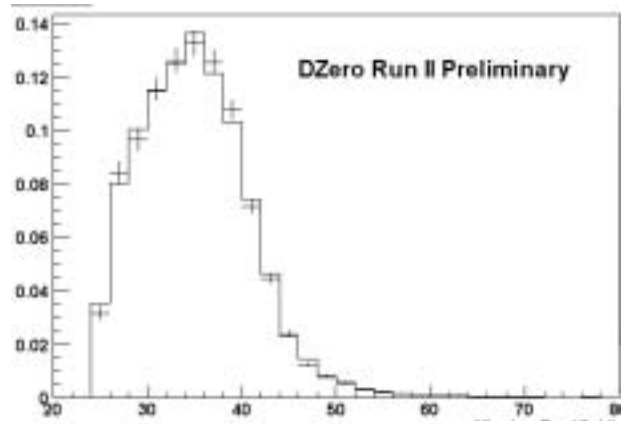
using QCD EM/jet events:

f = 2.3 ± 1 %

W→ eν signal

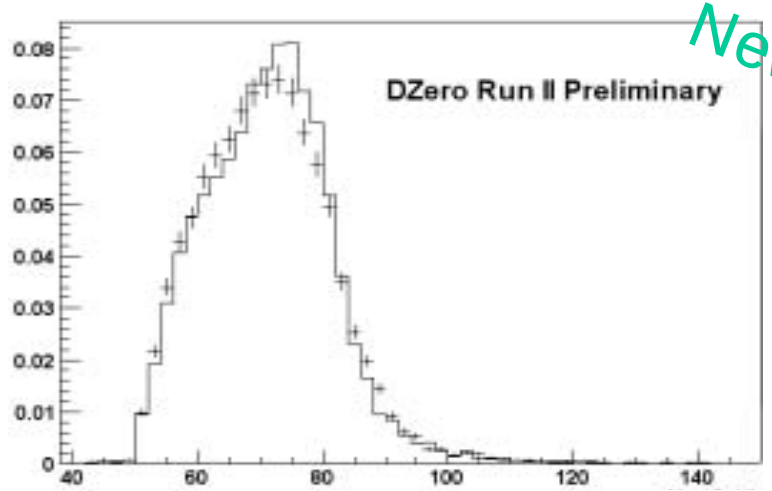


E_T (GeV)



$\not{E}_T$ (GeV)

New



m_T (GeV)

$\mathscr{L} \approx 42\ pb^{-1}$

→ Number of W(eν) candidates: 27370 ± 898

$$\sigma(W)Br(W \to e\nu) = 3054 \pm 100(N_w) \pm 86(sys) \pm 305(lumi)pb$$

Muon Channel

- W selection:

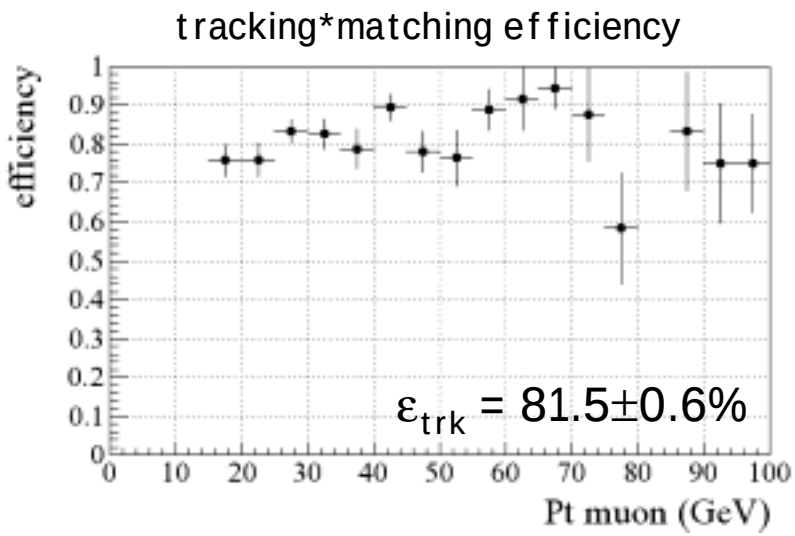
→ $P_T(\mu)$ > 20 GeV isolated and matched with a track

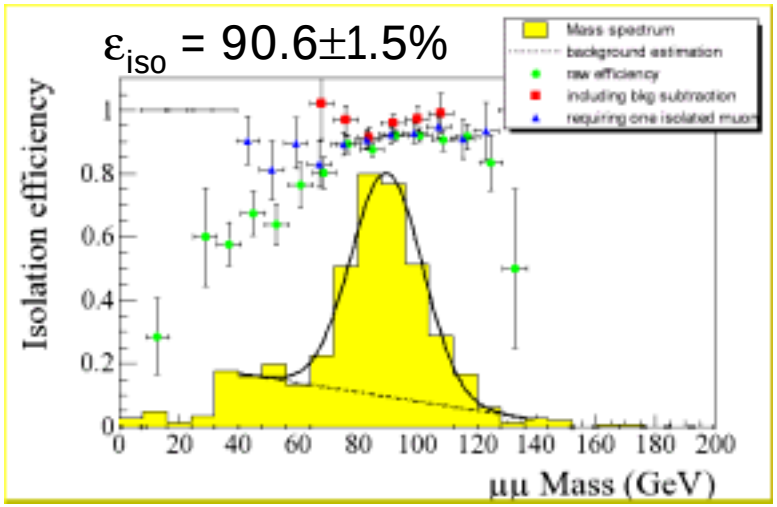
→ $\not{E}_T$ > 20 GeV (corrected from the muon Pt)

→ Z veto

- Efficiencies:

→ evaluated on data: $\varepsilon_{tot}(W)$ = 13.2 %





Background estimation

- $W \to \mu\nu$:

  $\to b\bar{b}$ background evaluated from data

  $\to W \to \tau\nu$, $Z \to \mu\mu$ (MC/data)

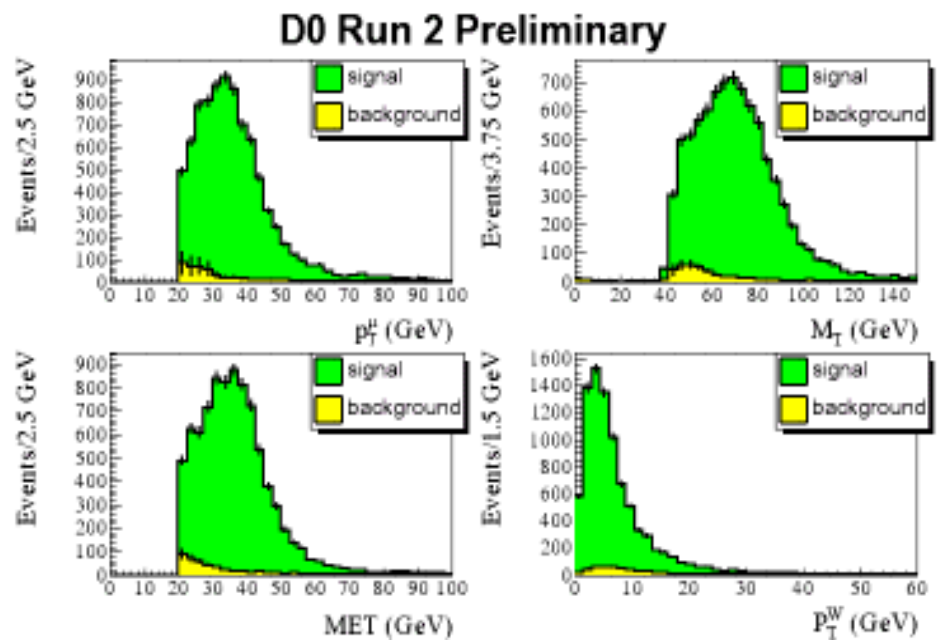
- "Matrix method":

1 additional requirement

$$\left.\begin{aligned} N_{base} &= N_W + N_{bkg} \\ N_{tight} &= \varepsilon_W N_W + f\, N_{bkg} \end{aligned}\right\} \quad N_W = \frac{N_{tight} - f\, N_{base}}{\varepsilon_W - f}$$

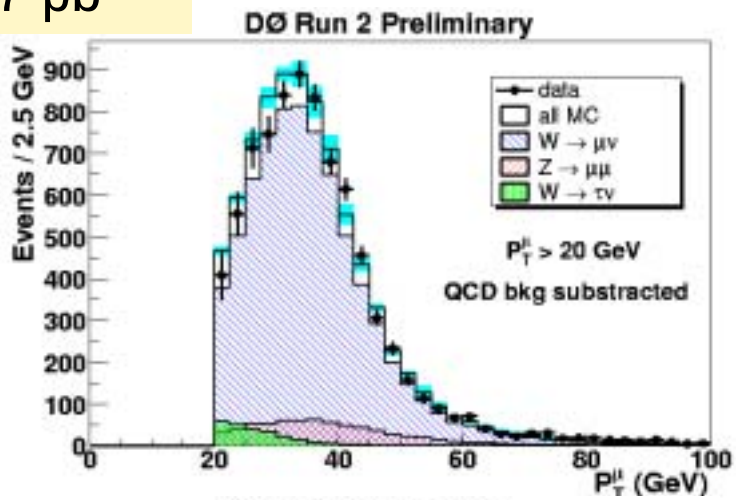
$\to$ for $W \to \mu\nu$: additional requirement = isolation (calorimeter+tracker)

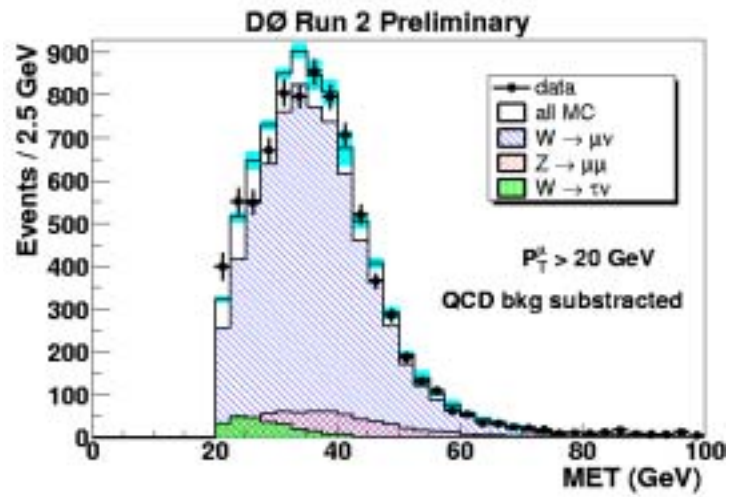
$\to$ Nb of candidates: 7352 ± 154

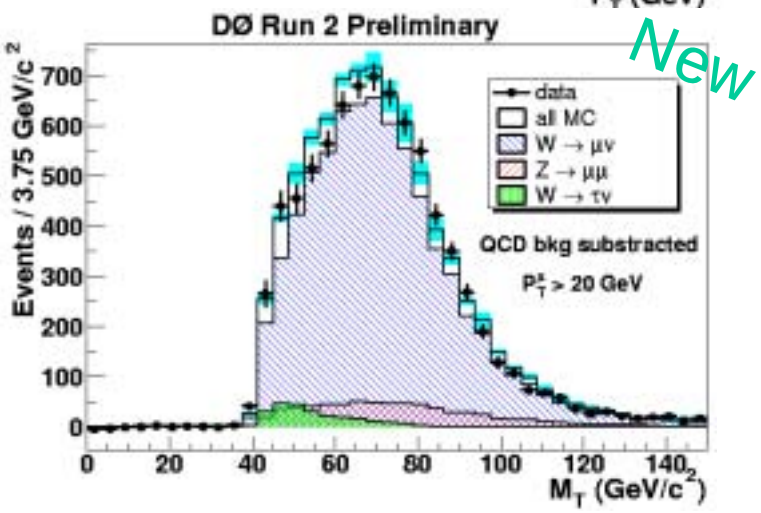


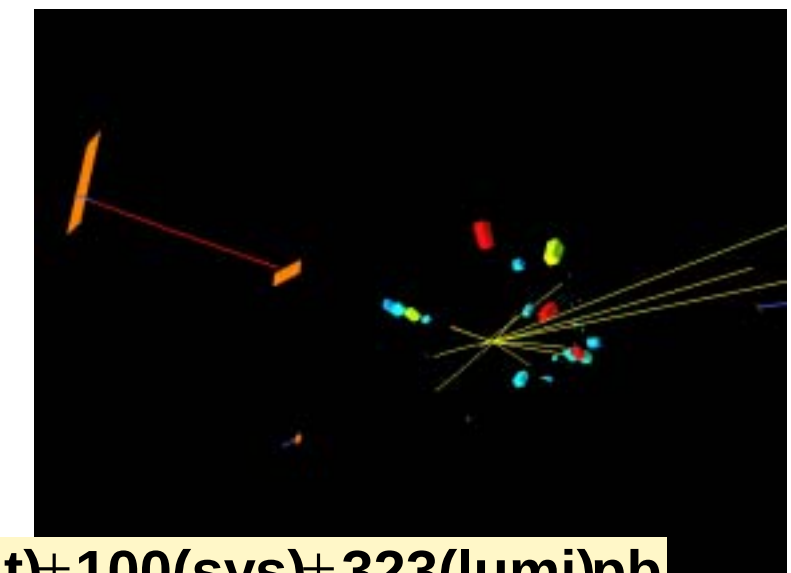
W→μν signal

$\mathscr{L} \approx 17\ pb^{-1}$









$$\sigma(W)Br(W\rightarrow\mu\nu) = 3226 \pm 128(stat) \pm 100(sys) \pm 323(lumi)pb$$

$Z \to \mu\mu$ signal

- Z selection:

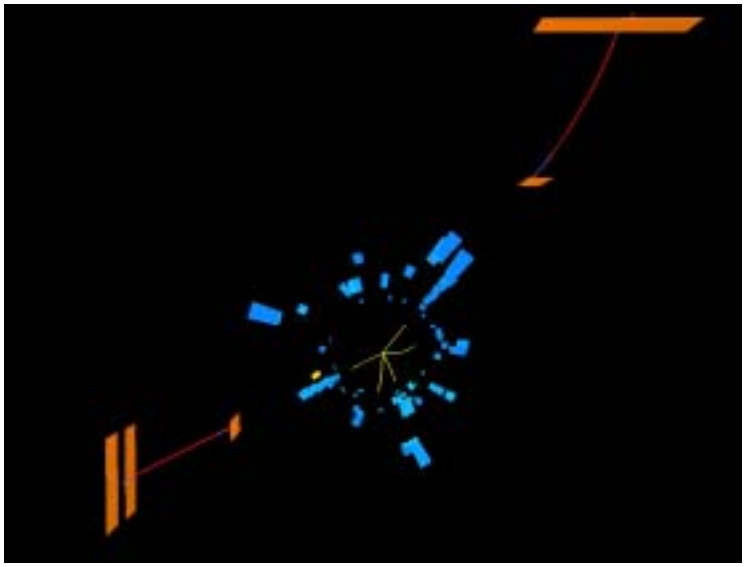
$\to$ 2 opposite charged muons P_T > 15 GeV

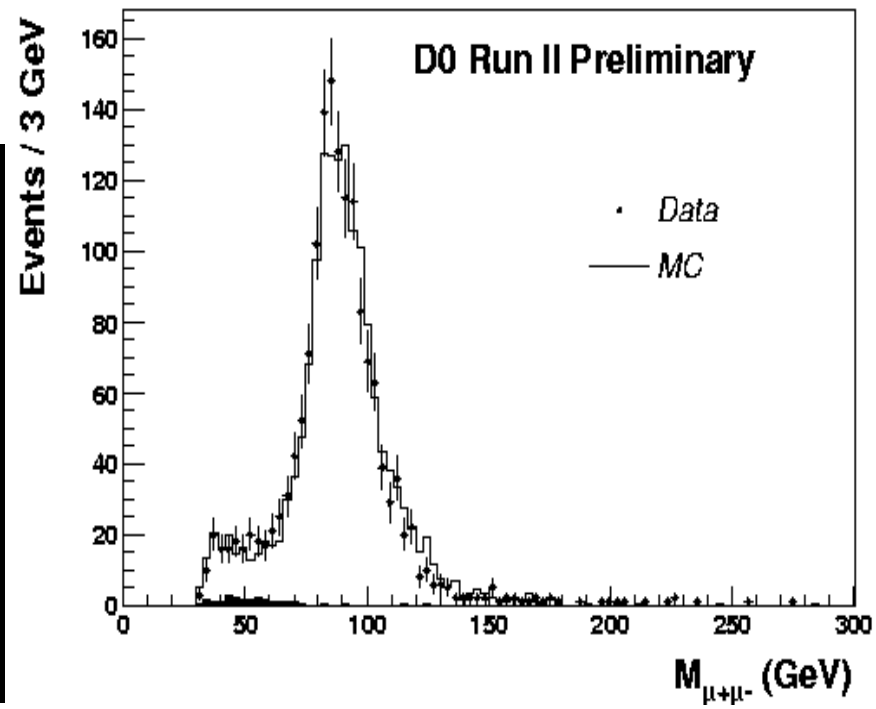
$\to$ one isolated (calorimeter+tracker)

$\to$ separated in (η,ϕ)

$\mathscr{L} \approx 32\ pb^{-1}$

$\varepsilon_{tot}(Z) = 16.3\ \%$





$\to$ Number of $Z(\mu\mu)$ candidates: 1585 ± 40

$$\sigma(Z)Br(Z \to \mu\mu) = 264 \pm 7(stat) \pm 17(sys) \pm 26(lumi)pb$$

W/Z Cross-Sections Summary

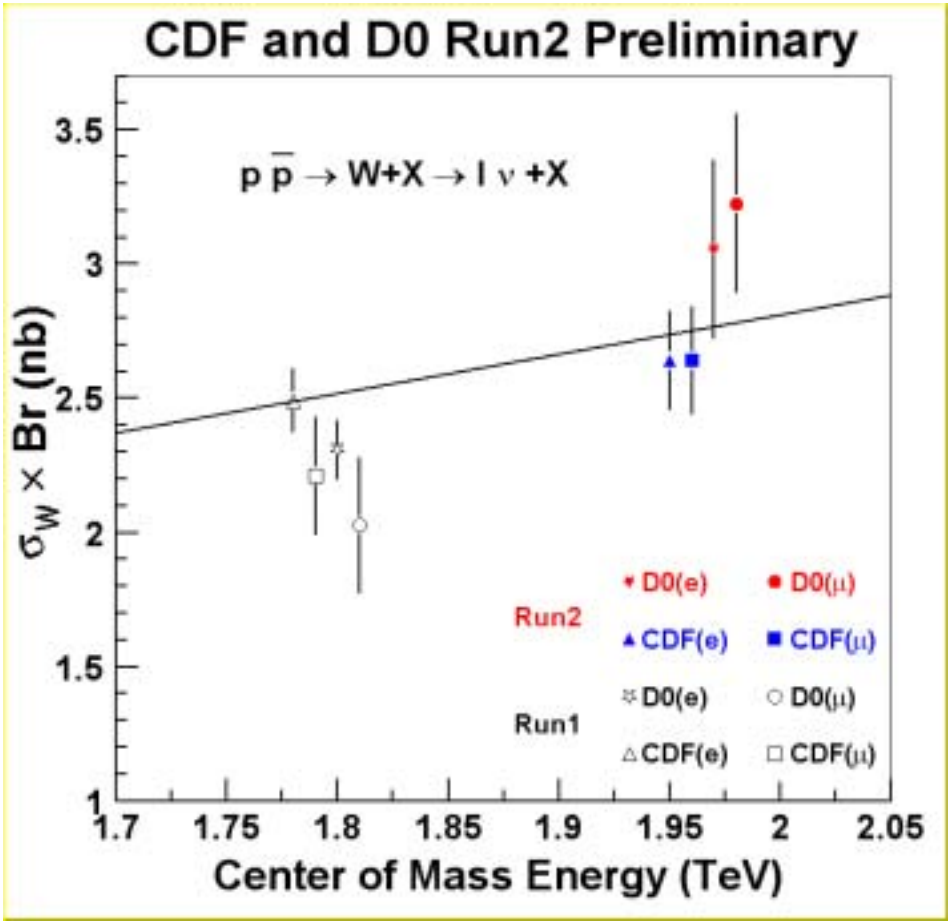
$\sigma(W)\ Br(W \rightarrow e\nu) = 3054 \pm 100\ (N_W) \pm 86\ (sys) \pm 305\ (lumi)\ pb$

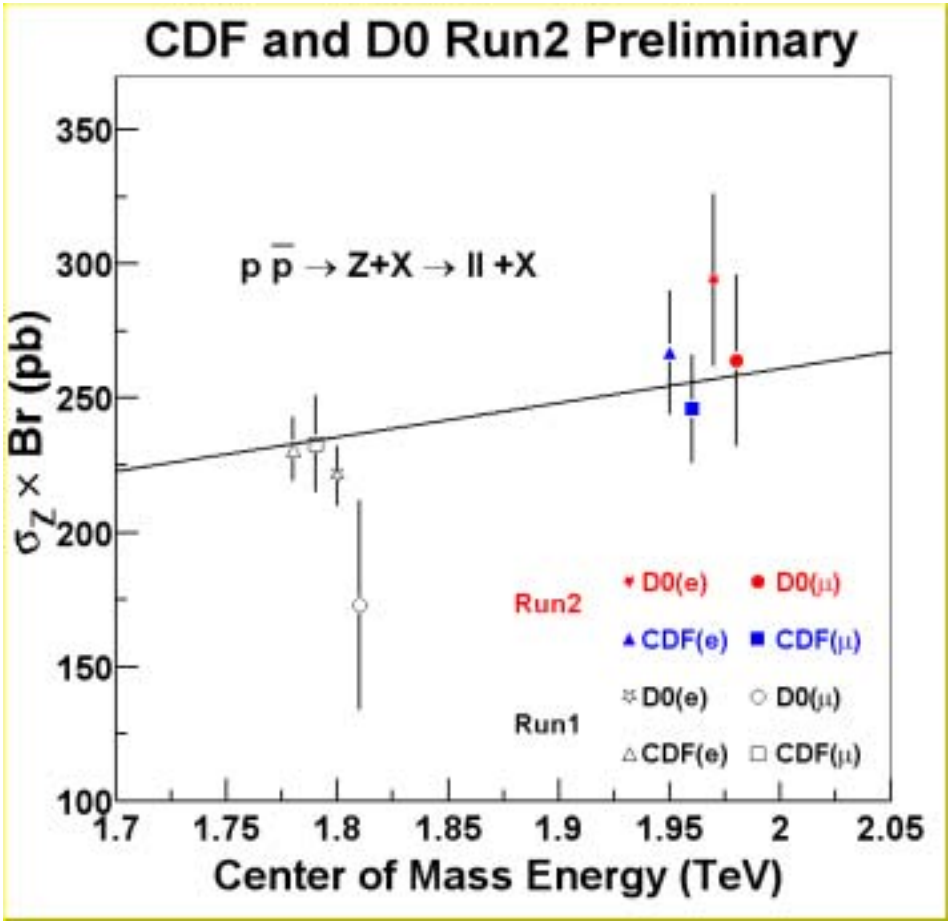
$\sigma(Z)\ Br(Z \rightarrow ee) = 294 \pm 11\ (N_z) \pm 8\ (sys) \pm 29\ (lumi)\ pb$

$\sigma(W)\ Br(W \rightarrow \mu\nu) = 3226 \pm 128\ (stat) \pm 100\ (sys) \pm 323\ (lumi)\ pb$

$\sigma(Z)\ Br(Z \rightarrow \mu\mu) = 264 \pm 7\ (stat) \pm 17\ (sys) \pm 26\ (lumi)\ pb$

W/Z Cross-Sections at Tevatron





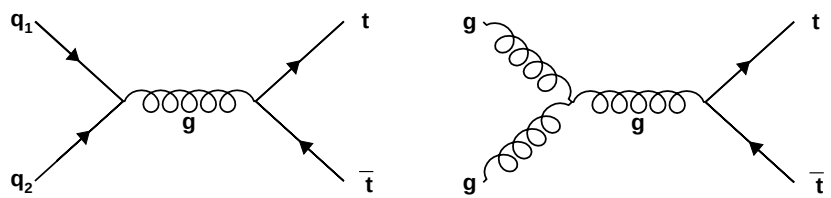
theoretical prediction: C. R. Hamberg, W.L. van Neerven and T. Matsuura, Nucl. Phys. B359 (1991) 343, CTEQ4M PDF

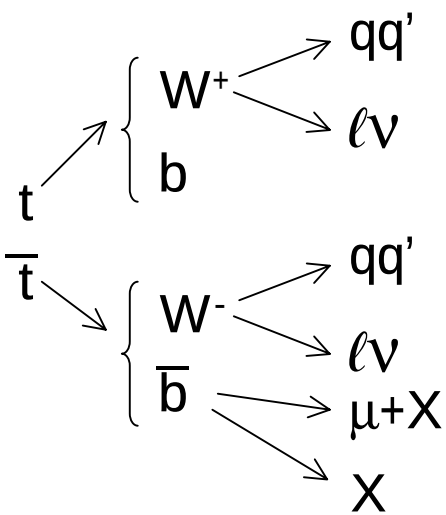
Top Production Cross-Section Measurement

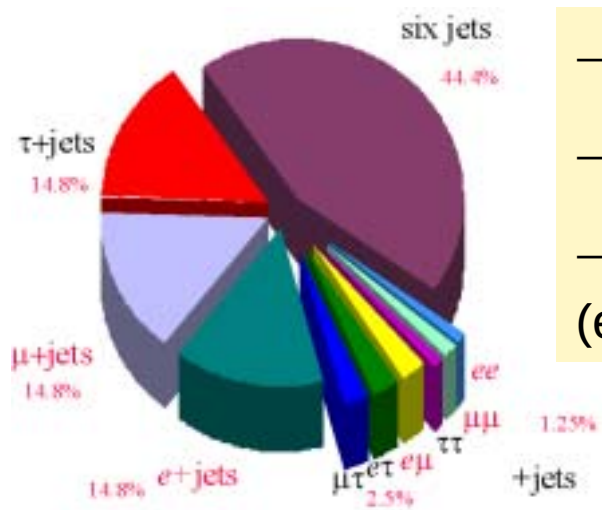
- Production and decays:

→ produced mostly in pairs: $\sigma(t\bar{t}) \approx 7$pb, ~ 30% higher cross-section than at Run I

→ decay: $Br(t \to Wb) = 100\%$







- 7 channels presented:

→ dileptons (ee, eμ, μμ)

→ lepton + jets (e or μ + ≥ 4 jets)

→ lepton + jets with soft muon tag (e or μ + ≥ 3 jets + SLT)

Dielectron Channel

- Background:

→ physics: $Z \to \tau\tau$ (MC), $WW \to ee$ (MC), $Z/\gamma \to ee$ (Data)

→ instrumental: heavy flavor QCD, W + jets with fake electrons (Data)

- Event selection:

→ 2 electrons Et > 20 GeV matched with a track

→ $\not\!\!E_T$ > 25 GeV (> 40 GeV in Z mass region)

→ 2 jets P_T > 20 GeV

→ $H_T = \Sigma(P_{Tjet} + Et_e)$ > 120 GeV

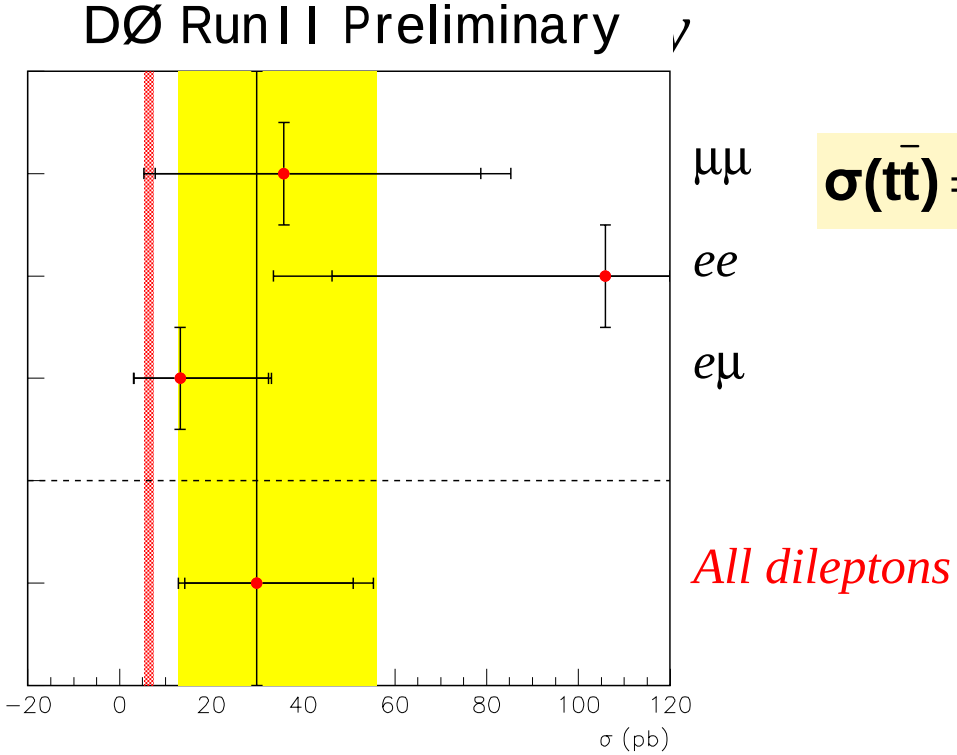
$\mathscr{L} \approx 48\ pb^{-1}$

New

	ee + $\not\!\!E_T$	+ 2 jets	+ H_T
physical background	8.29	1.16	0.98
fakes	0.42	0.02	0.02
Expected $t\bar{t}$ signal	0.40 ± 0.04	0.26 ± 0.02	0.25 ± 0.02
Total expected	9.11 ± 1.09	1.44 ± 0.47	1.25 ± 0.48
Observed events	9	4	4

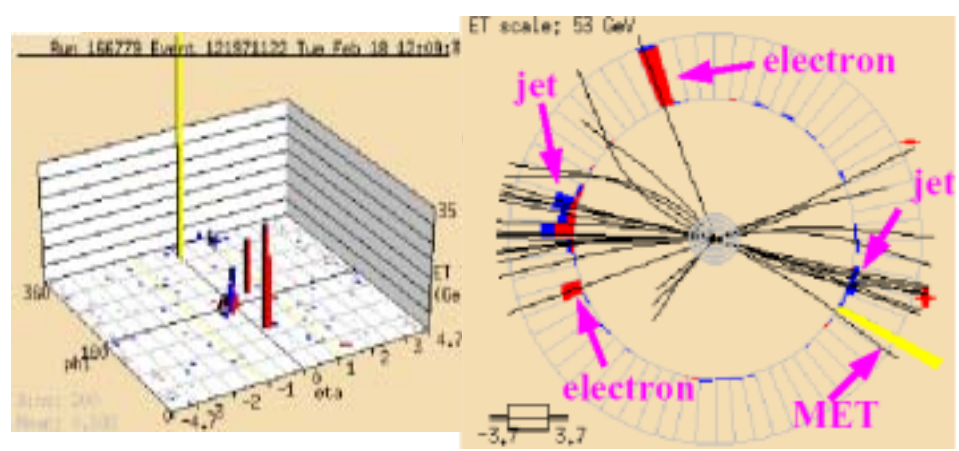
Dilepton Channel

	ee	eμ	μμ
$\mathscr{L}$ (pb^{-1})	48	33	43
Total Background	1.00 ± 0.49	0.07 ± 0.01	0.60 ± 0.30
Expected $t\bar{t}$ signal	0.25 ± 0.02	0.50 ± 0.01	0.3 ± 0.04
Observed events	4	1	2



dilepton combined:

$$\sigma(t\bar{t}) = 29.9^{+21.0}_{-15.7}(\text{stat})^{+14.1}_{-6.1}(\text{sys}) \pm 3.0(\text{lumi})\text{pb}$$



Lepton+Jets Channel

- Background:

→ μ+jets: heavy flavor QCD with semi-leptonic decays

→ e+jets: QCD with fake electron

→ both evaluated on data using the matrix method

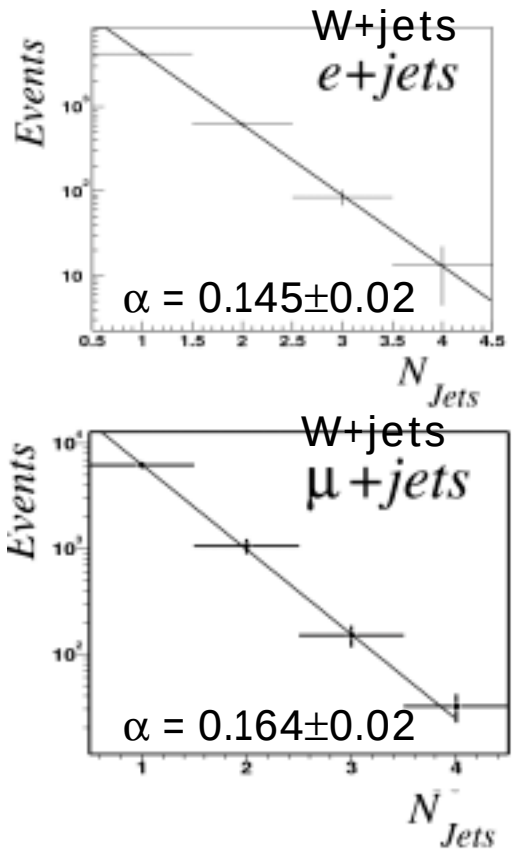
- Event selection:

→ sample enriched in W (e, μ P_T > 20GeV, $\not{E}_T$ > 20 GeV, soft μ veto)

→ estimate QCD background as a function of the number of jets

→ evaluate W+4jets using scaling law

→ topological cuts (4 jets, H_T, aplanarity)



Lepton+Jets Channel

	e+jets	μ+jets
$\mathscr{L}$ (pb^{-1})	50	40
Total Background	2.7 ± 0.6	2.7 ± 1.1
Expected $t\bar{t}$ signal	1.8	2.4
Observed events	4	4

5 jets:

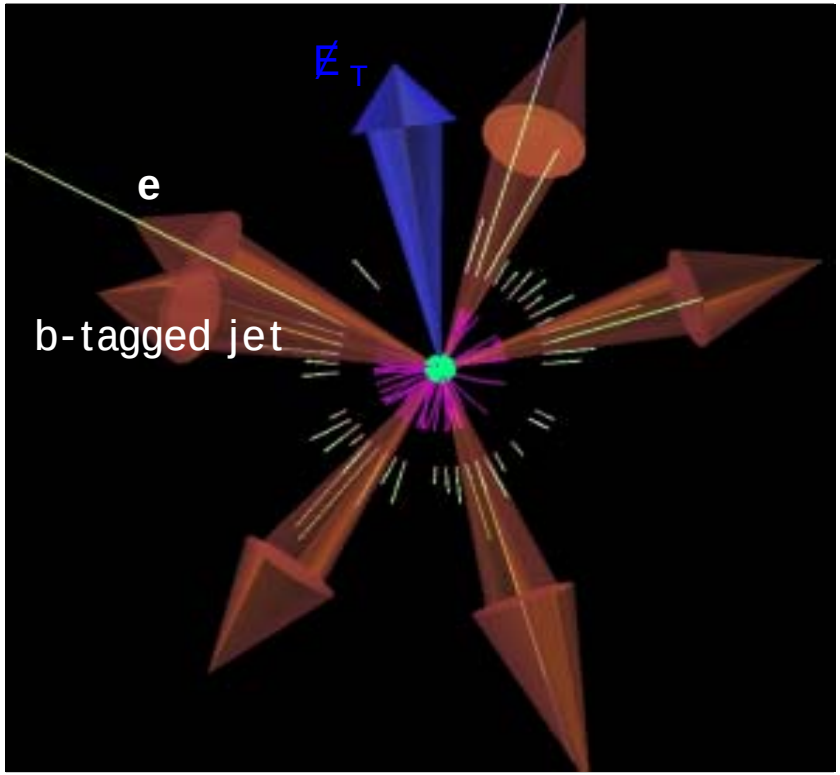
P_{T1} = 100.9 GeV, P_{T2} = 71.7 GeV,

P_{T3} = 70.3 GeV, P_{T4} = 69.6 GeV,

P_{T5} = 54.8 GeV (tagged)

$P_T(e)$ = 34.2 GeV, $\not{E}_T$ = 32.1 GeV

H_T = 422.6 GeV, aplanarity = 0.17



Lepton+Jets Channel with Soft Muon Tag

- Event selection:

→ same preselection as lepton+jets

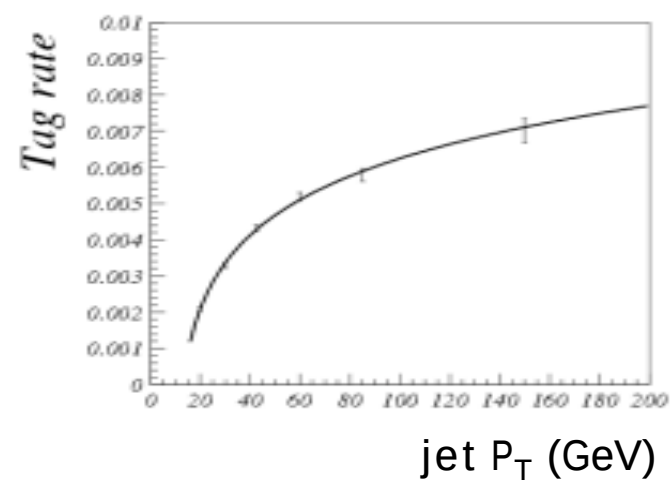
→ at least 3 jets

→ estimate QCD background with the matrix method

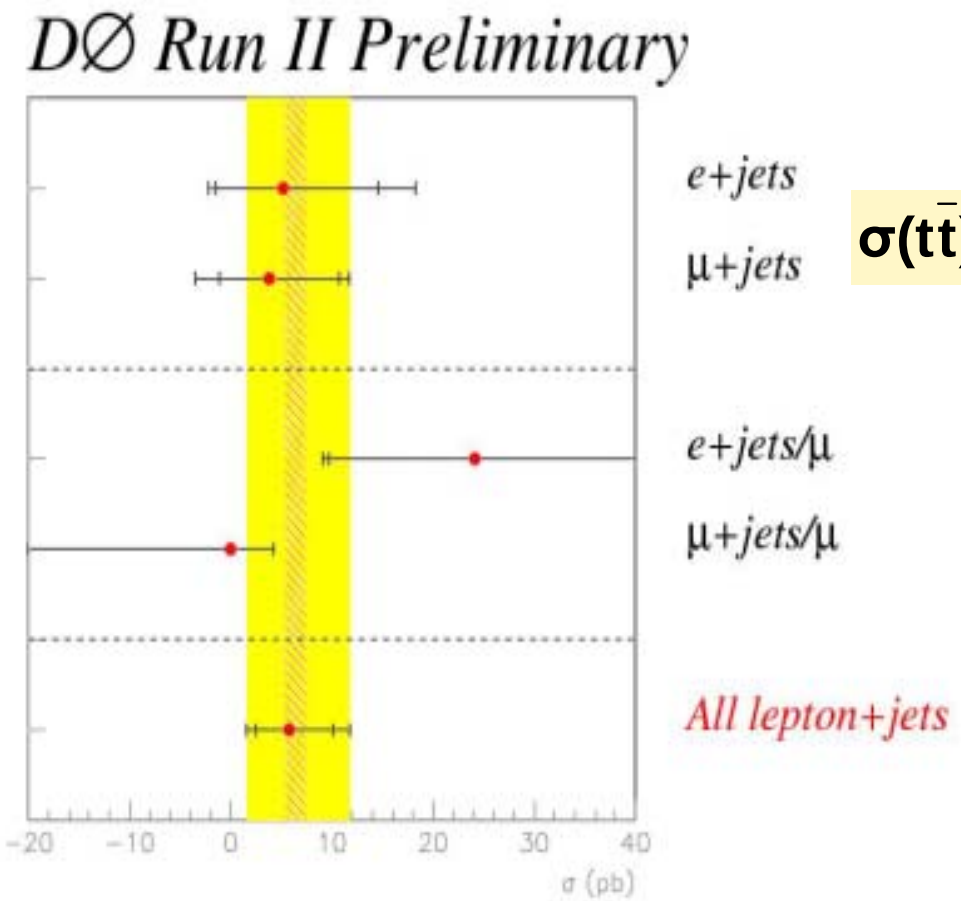
→ softer topological cuts

→ soft muon tag

	e+jets	μ+jets
$\mathscr{L}$ (pb^{-1})	50	40
Total Background	0.2 ± 0.1	0.7 ± 0.4
Expected $t\bar{t}$ signal	0.5	0.8
Observed events	2	0

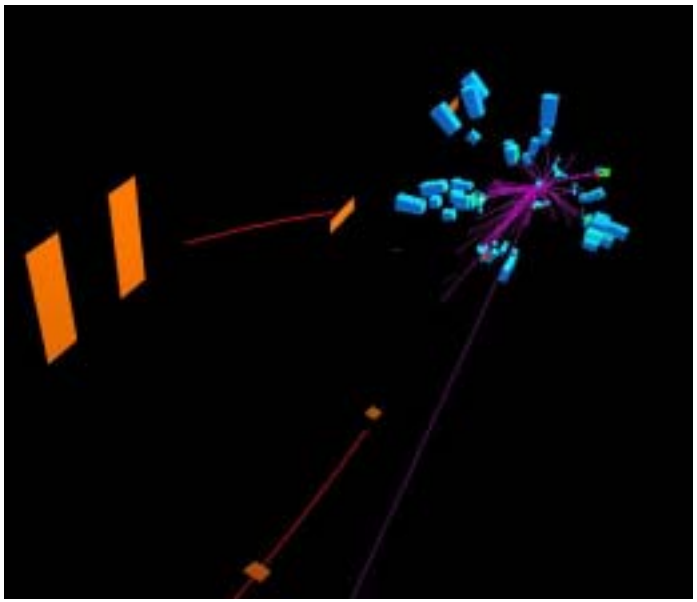


Lepton+Jets Channel Combined

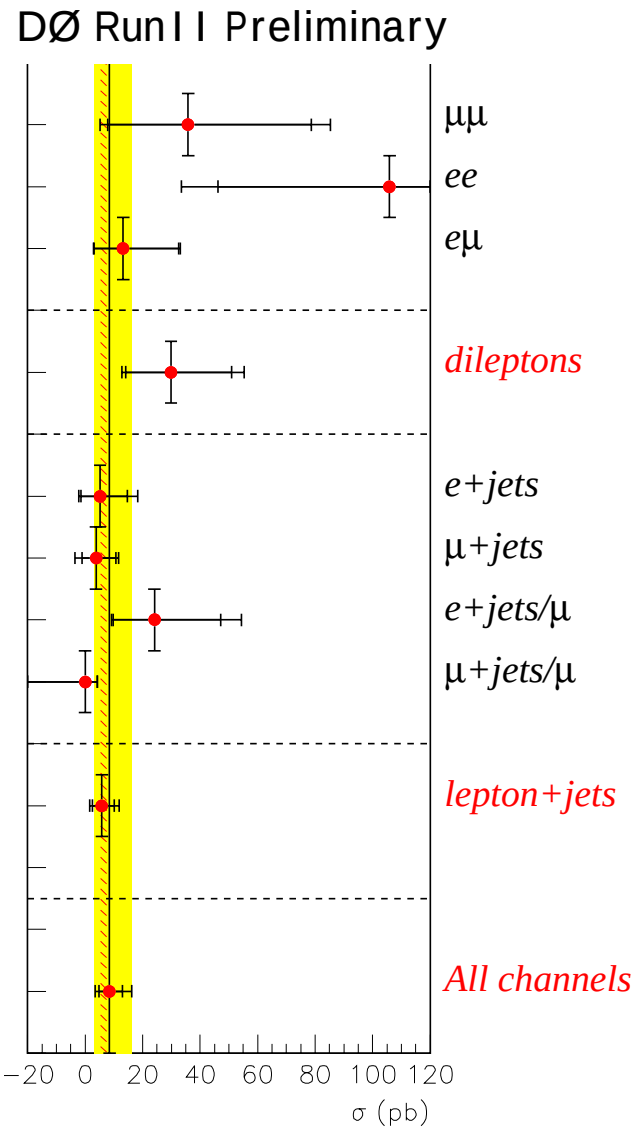


lepton+jets combined:

$$\sigma(t\bar{t}) = 5.8^{+4.3}_{-3.4}(\text{stat})^{+4.1}_{-2.6}(\text{sys}) \pm 0.6(\text{lumi})\ \text{pb}$$



DØ Run 2 Top Production Cross-Section Combined



all channels combined:

$$\sigma(t\bar{t}) = 8.5\,^{+4.5}_{-3.6}\,(\text{stat})\,^{+6.3}_{-3.5}\,(\text{sys}) \pm 0.8(\text{lumi})\ \text{pb}$$

theoretical prediction at 1.96 TeV:

$\sigma(t\bar{t}) \approx 6.7$ to 7.5 pb

Conclusion

- A lot of DØ Run 2 analyses in progress:

→ re-establishing signals

→ searches already approach Run I limits and will break new grounds soon

- Many more results to come:

→ with improved detector understanding

→ with improved object ID efficiencies

→ with increased statistics