Non-SUSY Searches at the Tevatron

Jonathan Hays
Imperial College London
(on behalf of the CDF and DØ collaborations)

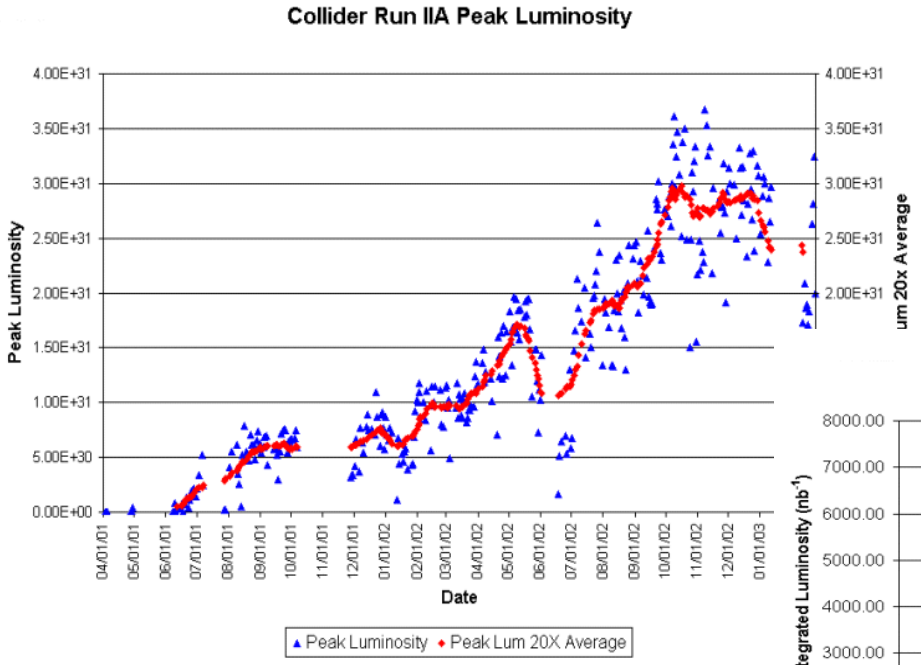
XXXVIII Rencontres de Moriond
Les Arcs, 22nd-29th March 2003

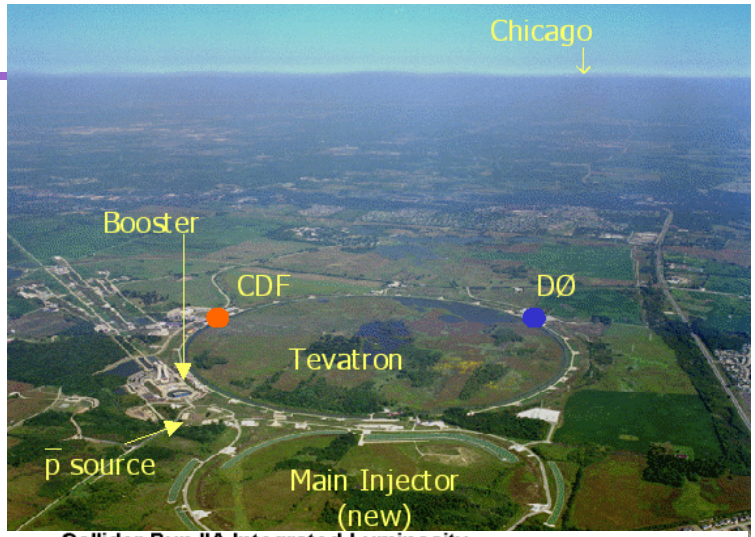
Outline

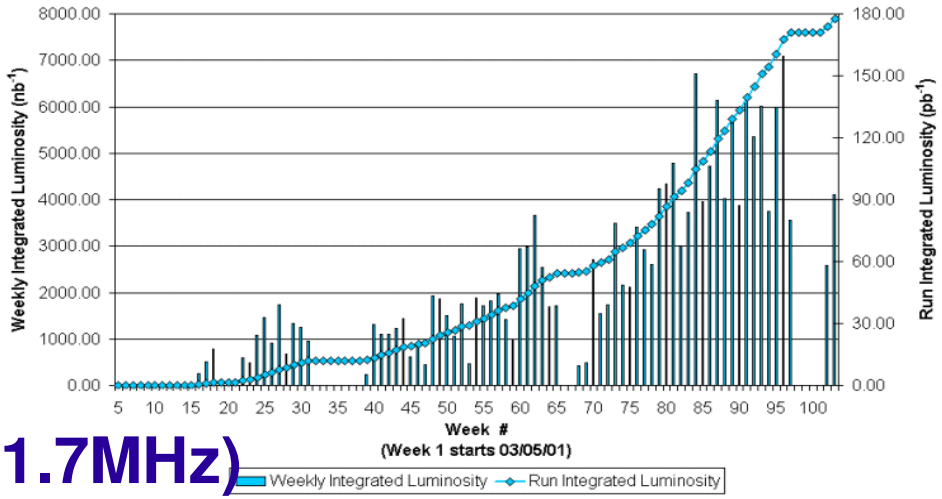
- Tevatron, DØ and CDF
- Leptoquarks
  - 1st Generation Scalar Leptoquarks (CDF)
  - 2nd Generation Scalar Leptoquarks (DØ)
- High mass searches
  - Large extra dimensions in the di-EM and di-muon channels (DØ)
  - Randal-Sundrum graviton search in di-lepton channel (CDF)
  - Z' searches (CDF & DØ)
  - Di-jet searches (CDF)
- eμ searches (DØ)
- CHArged Massive Particles (CHAMPs) (CDF)
- Conclusions

Tevatron

$L \sim 3 \times 10^{31}\ cm^{-2}s^{-1}$ (record = 4.06×10^{31})





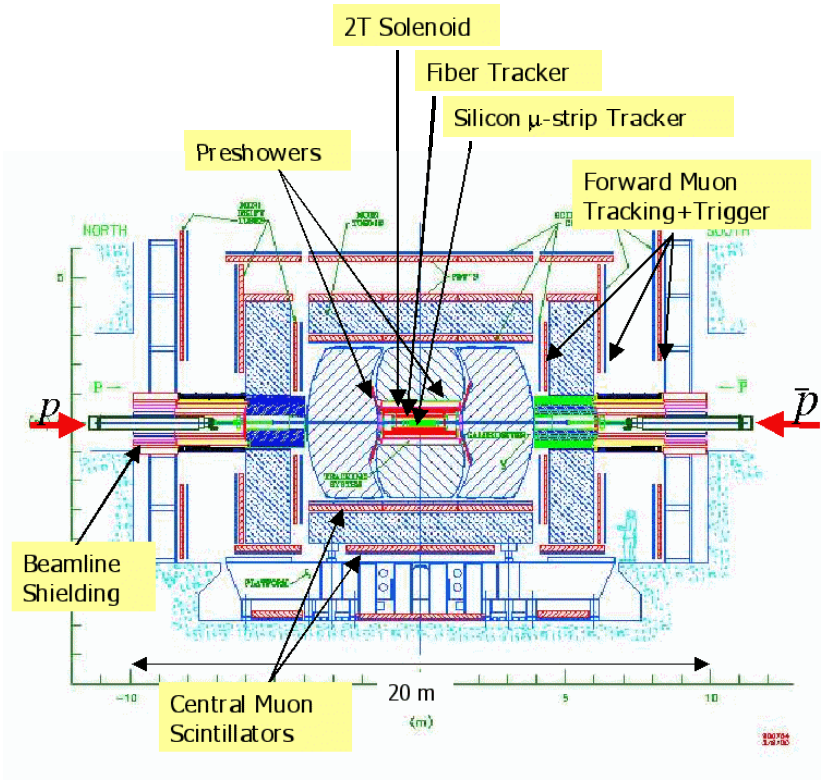


$L_{int} = 180\ pb^{-1}$

p-pbar collisions at 1.96 TeV (1.7MHz)

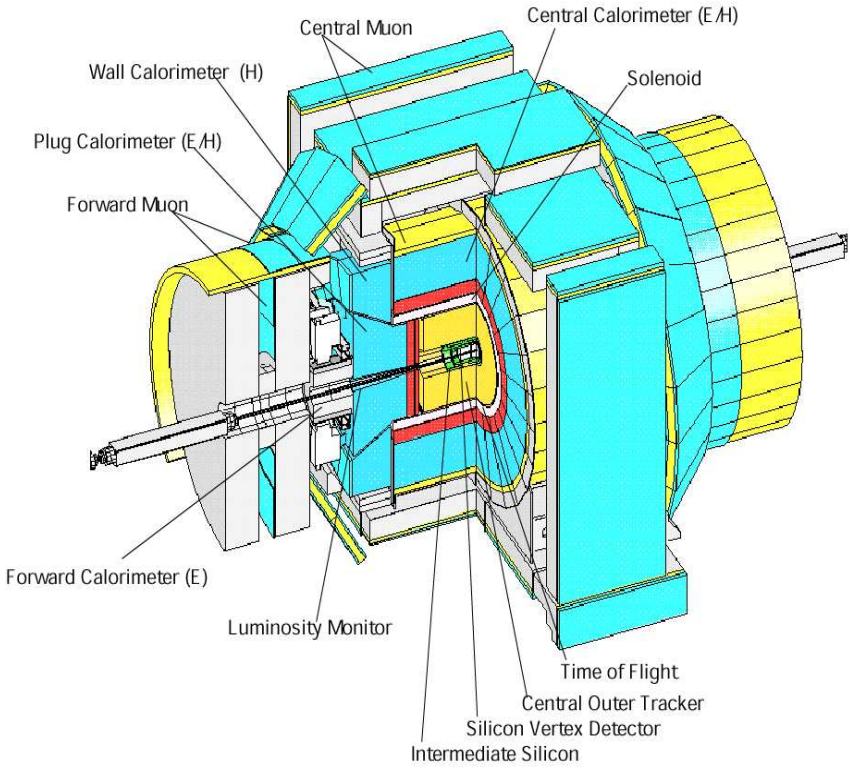
- **significantly increased x-section for high mass particle production**

DØ and CDF



DØ

CDF



1st Generation Leptoquarks

- LQ pair production assuming no cross generational couplings with BF(LQ→eq) = 100%
- Selection:
  - 2 central electrons $E_T > 25$ GeV
  - 2 jets $E_T^{(j1)} > 30$ and $E_T^{(j2)} > 15$ GeV
  - reject events where $76 < M_{ee} < 110$ GeV
  - $E_T^{(j1)} + E_T^{(j2)} > 85$ GeV and $E_T^{(e1)} + E_T^{(e2)} > 85$ GeV
  - $\sqrt{((E_T^{(j1)} + E_T^{(j2)})^2 + (E_T^{(e1)} + E_T^{(e2)})^2)} > 200$ GeV

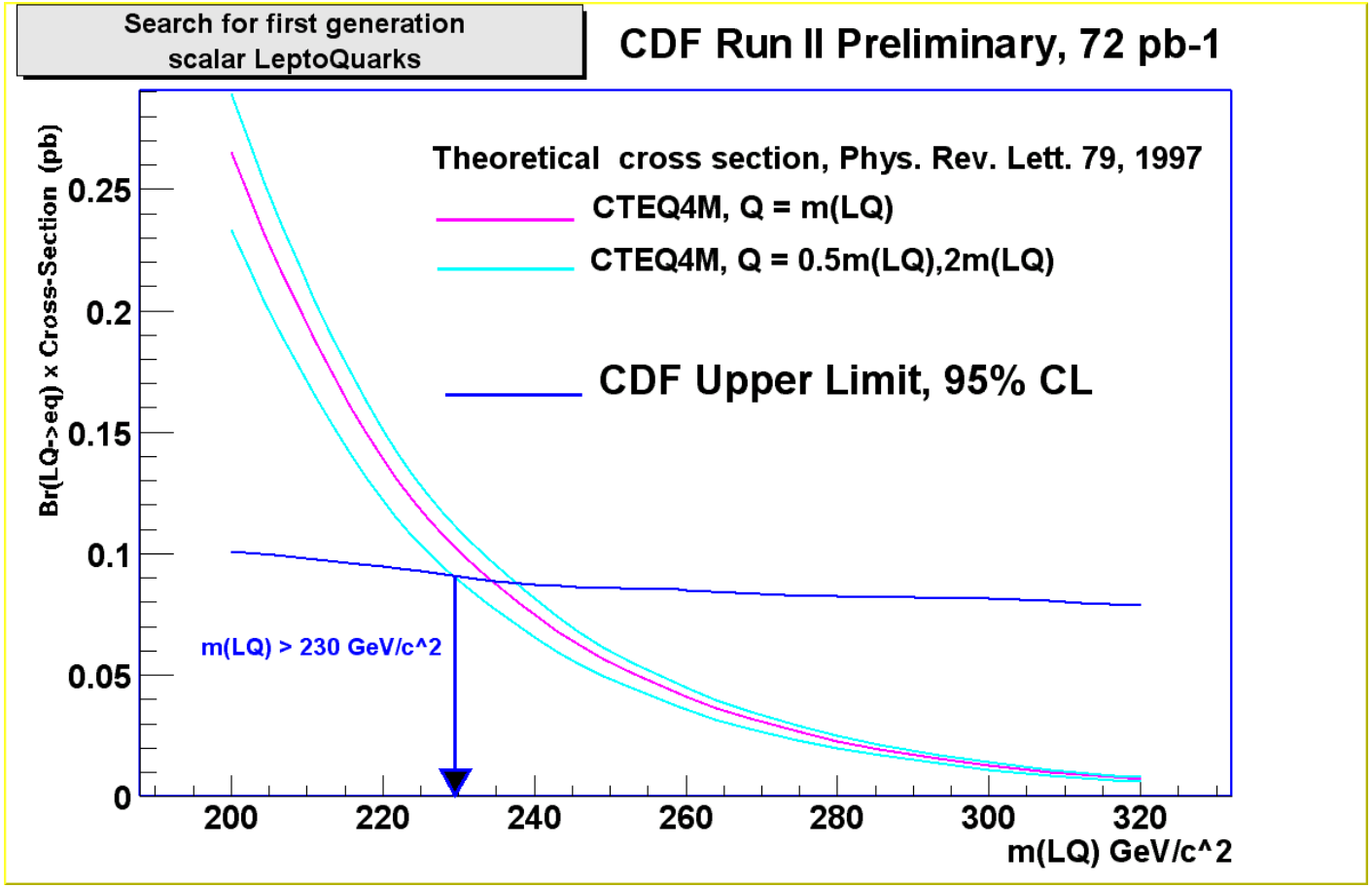
1st Generation Leptoquarks

- 25 % increase in x-section
- acceptances are slightly higher
- ~1/3 less lumi

M_{LQ} > 230 GeV @ 95 % CL

(Run I limit 220 GeV)

0 events observed

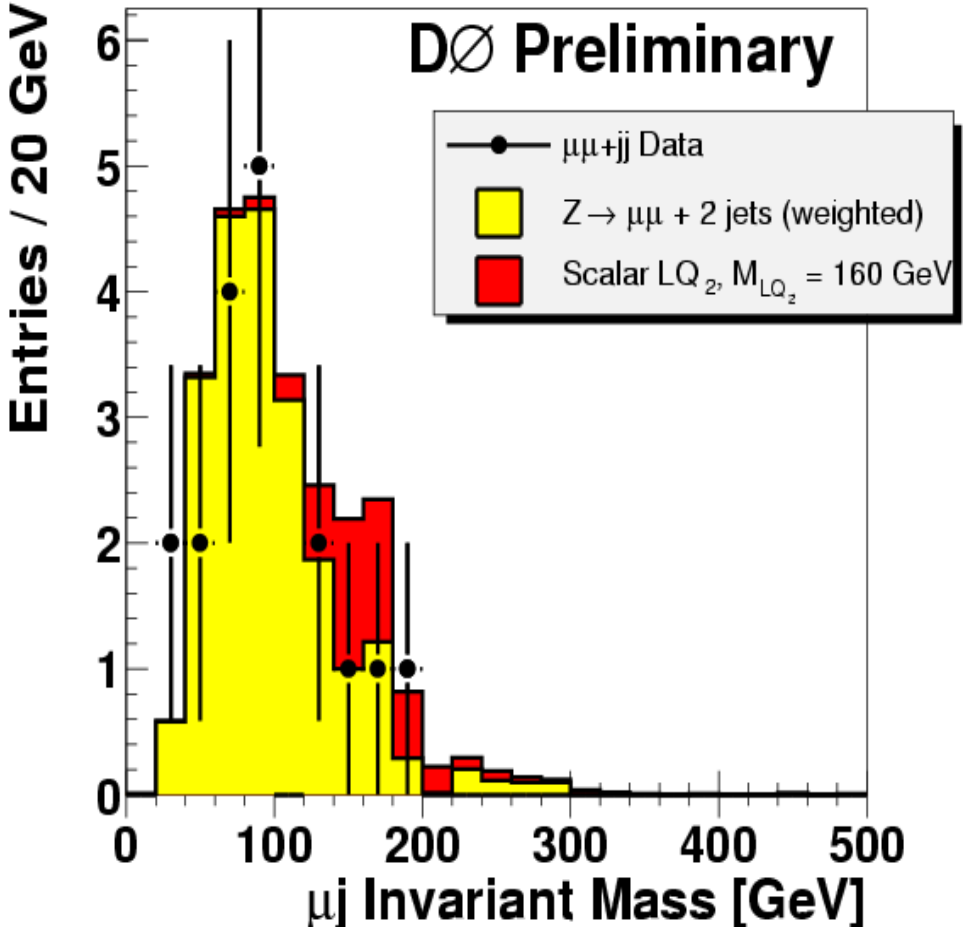


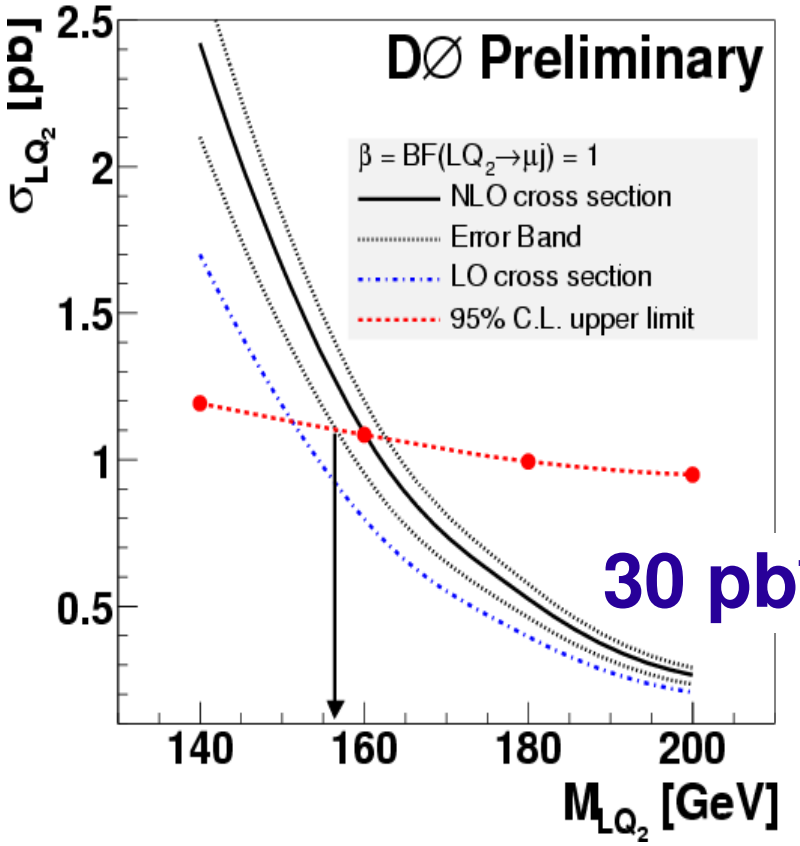
2nd Generation Leptoquarks

- Scalar LQ pair production assuming no cross generational couplings – BF(LQ $\rightarrow \mu q$) = 100%
- Signature: 2μ + 2jets and no missing E_T
- Trigger: single and di-muon triggers
- Offline selection:
  - 2 opposite signed muons p_T > 15 Gev,
  - 2 jets > 20 GeV
  - $M_{\mu\mu}$ > 110 GeV

2nd Generation Leptoquarks

(Run I M_{LQ} > 200 GeV)





30 pb^{-1}

M_{LQ} > 157 GeV

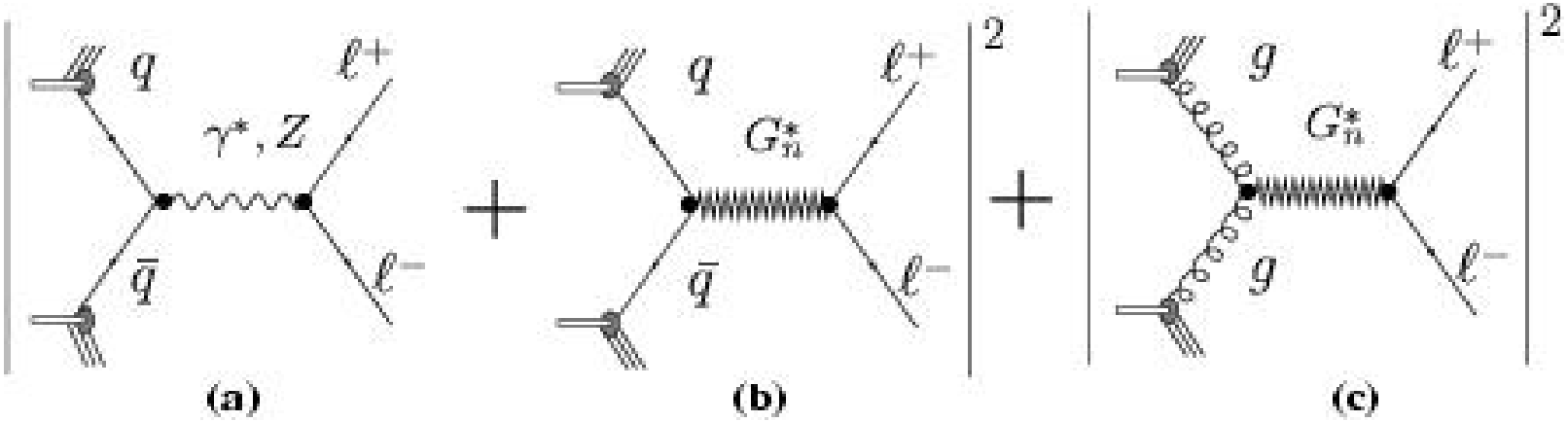
High Mass Searches

- Di-lepton, di-jet final states can be used in searches for:
  - large extra dimensions
  - new gauge bosons (eg Z')
  - technicolor
  - ...

Large Extra Dimensions

- Assume SM particles are confined to 3-brane
- Gravity propagates in the extra dimensions
- Signature is an excess of high mass di-lepton and di-photon events from virtual graviton diagrams

$$\frac{d^2\sigma}{dM\, d\cos\theta^*} = f_{SM} + f_{inter}\,\eta_G + f_{KK}\,\eta_G^2$$

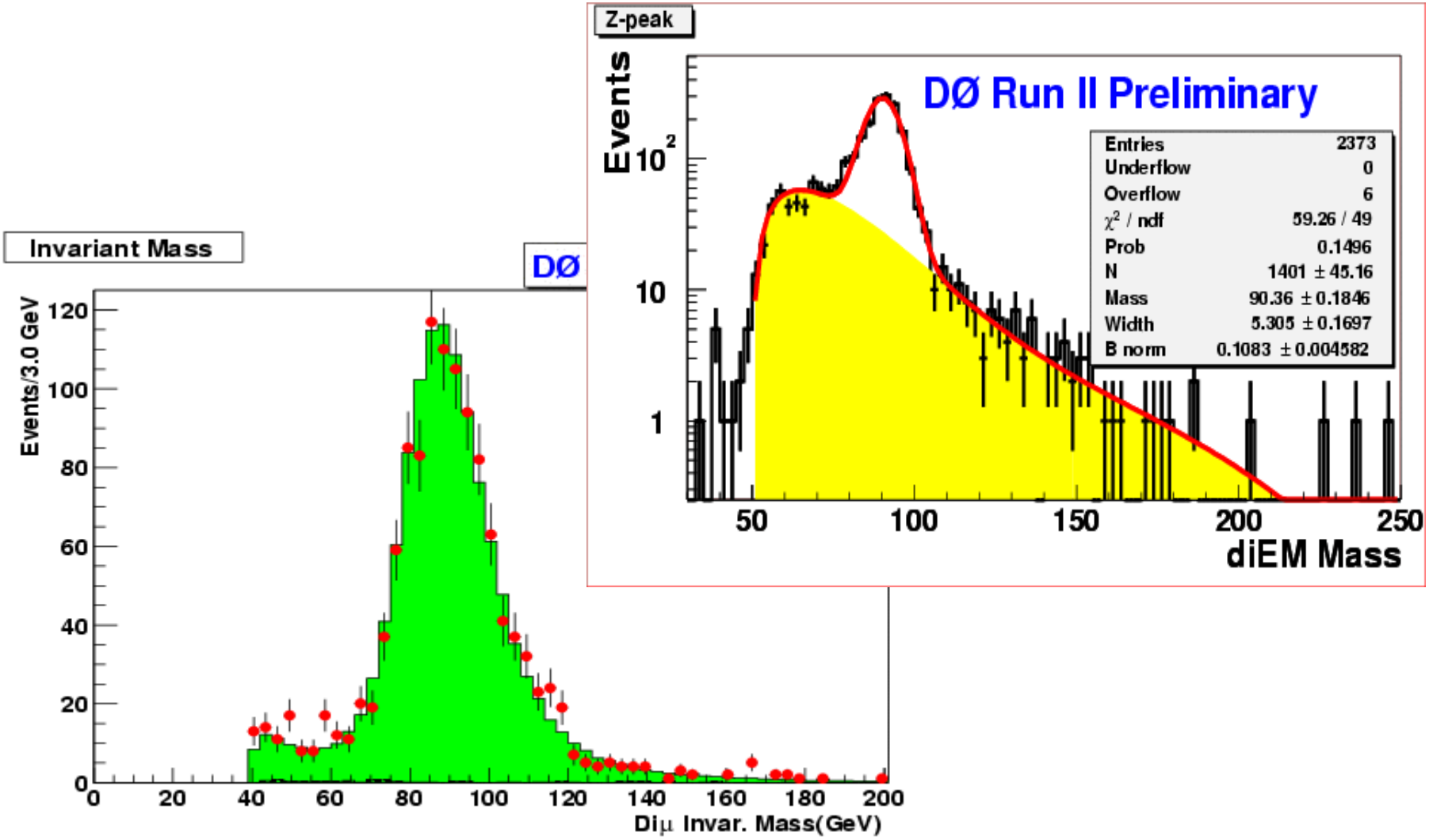


LED: di-electron + di-photon and di-muon

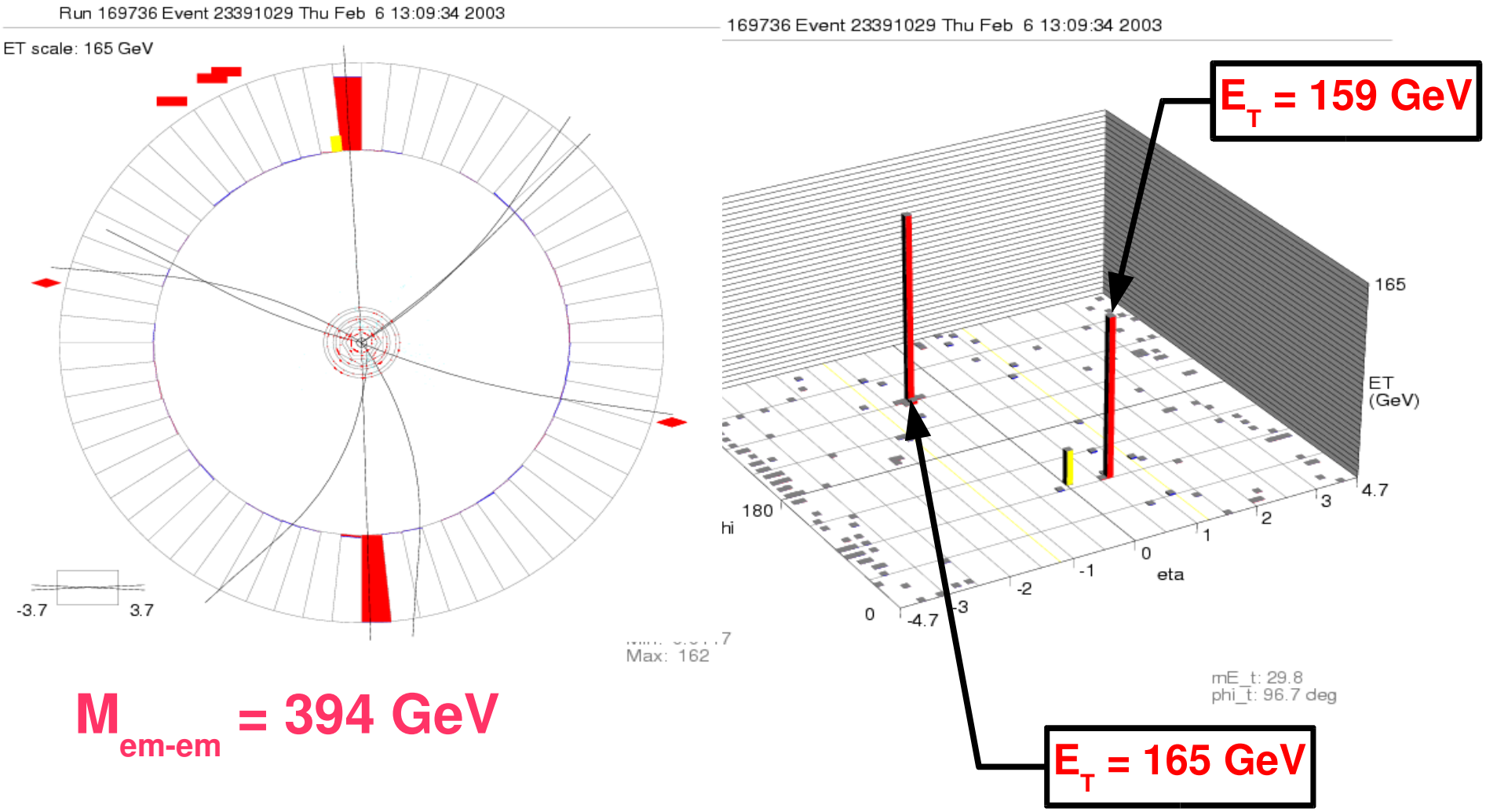
- **Di-electron + di-photon**
  - trigger on single and di-EM objects
  - 2 EM objects $E_T > 25$ GeV
  - Missing $E_T < 25$ GeV
- **Di-muon**
  - trigger on single and di-muon events
  - 2 muons matched with central tracks and $P_T > 15$ GeV
  - $M_{\mu\mu} > 140$ GeV

- Background estimates:
  - fast MonteCarlo for Drell-Yan and di-photon production
  - instrumental and reconstruction fake rates estimated from data

LED: Di-EM and Di-muon



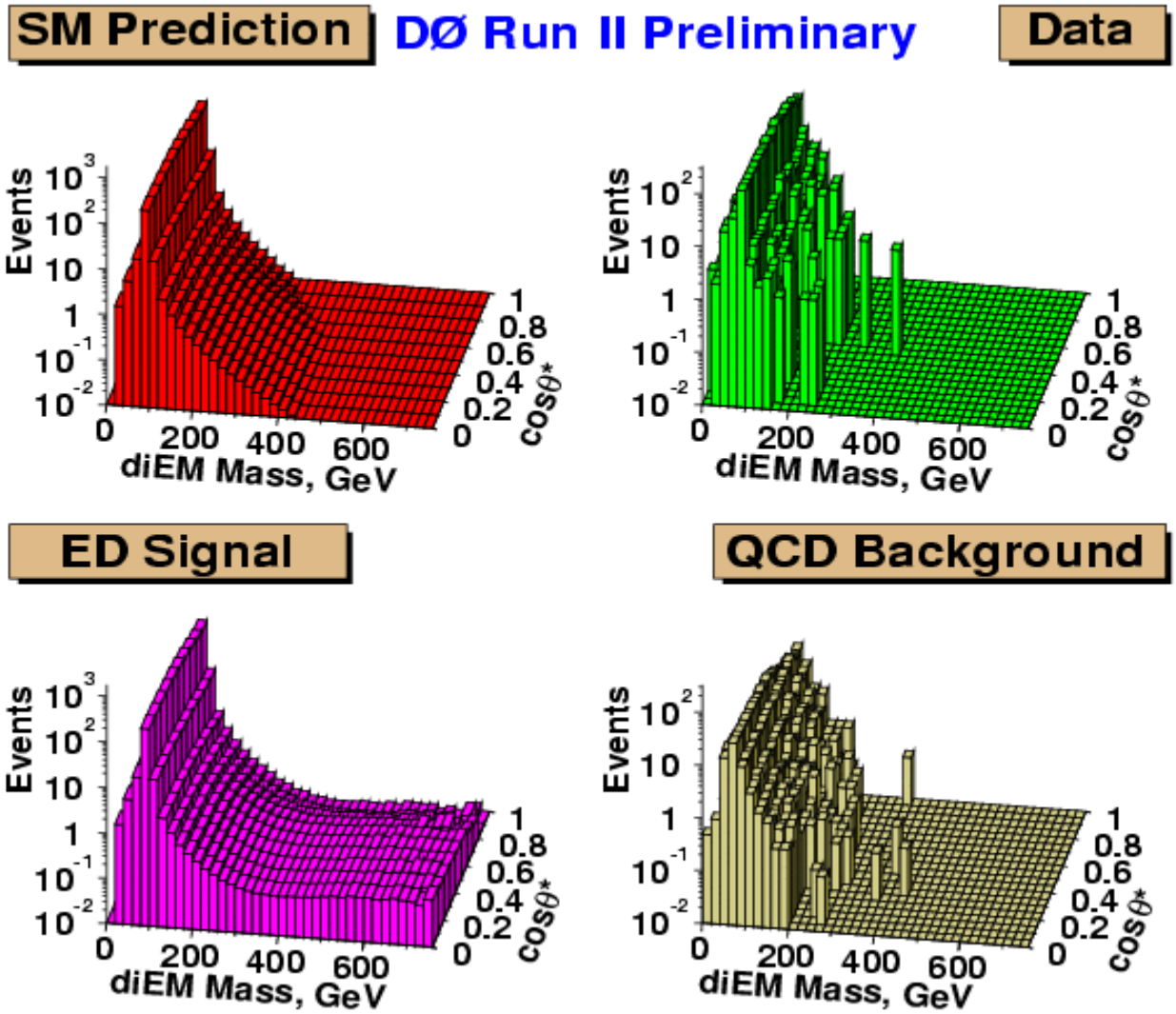
LED: di-electron + di-photon



$M_{em\text{-}em}$ = 394 GeV

LED: Limits

Fit in the $M_{em\text{-}em}$, $|\cos(\theta^*)|$ plane



LED : Limits

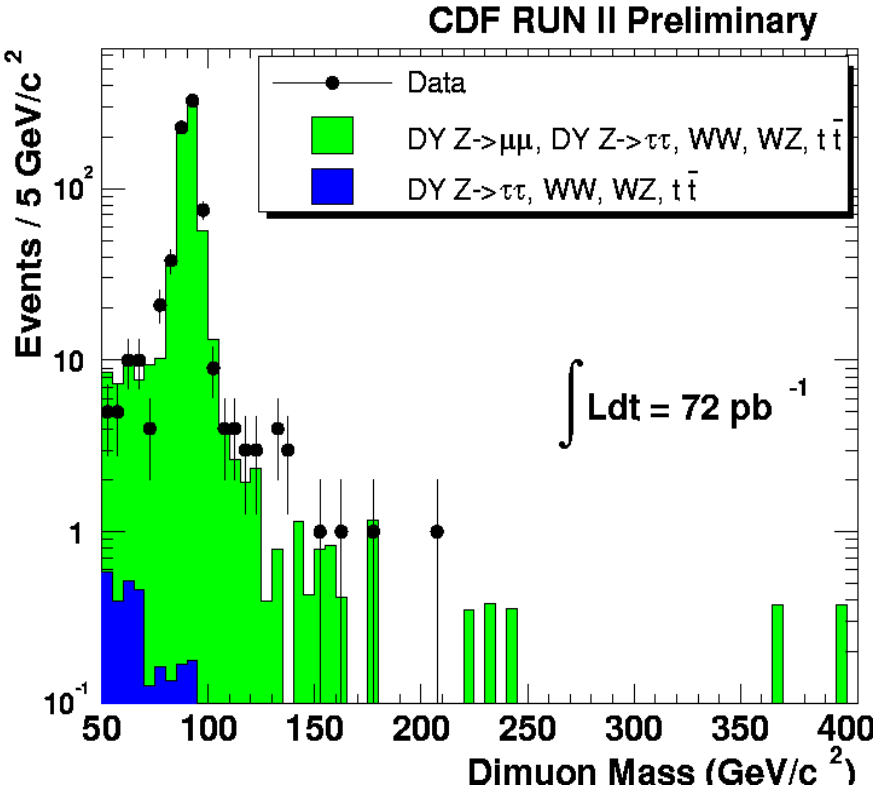
- Translate the limit on η_G into a lower limit on M_s
  - the fundamental Planck scale (in TeV)

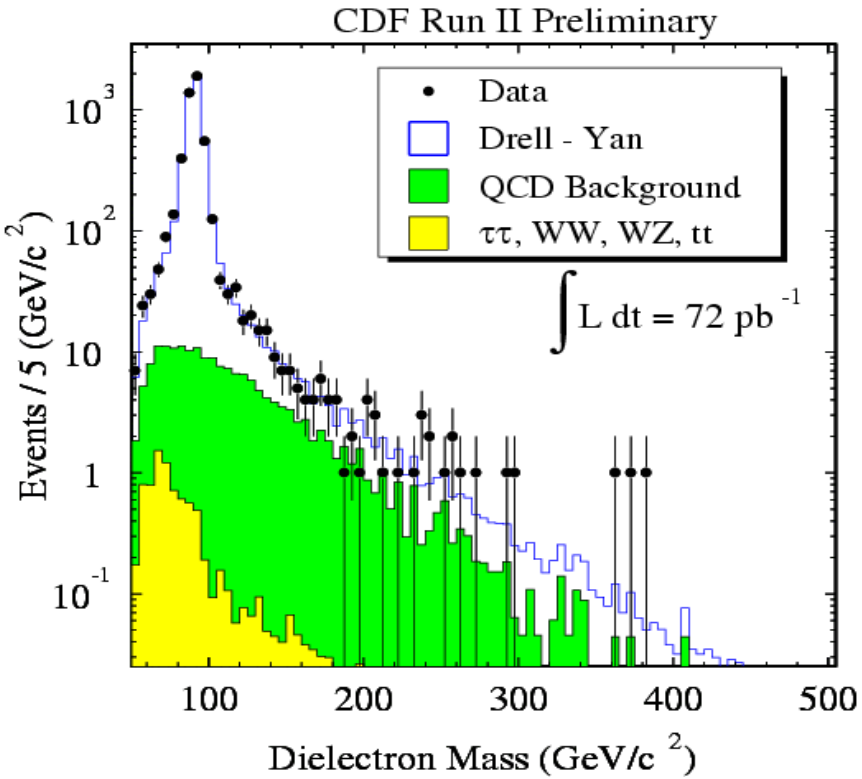
Formalism	GRW	HLZ, n=2	HLZ, n=7	Hewett, $\lambda = +1$
di-EM	1.12	1.16	0.89	1.00
di-muon	0.79	0.68	0.63	0.71

The di-EM limit is approaching the DØ Run I limit
(Run I GRW limit = 1.2 TeV)
The di-muon analysis is new at DØ

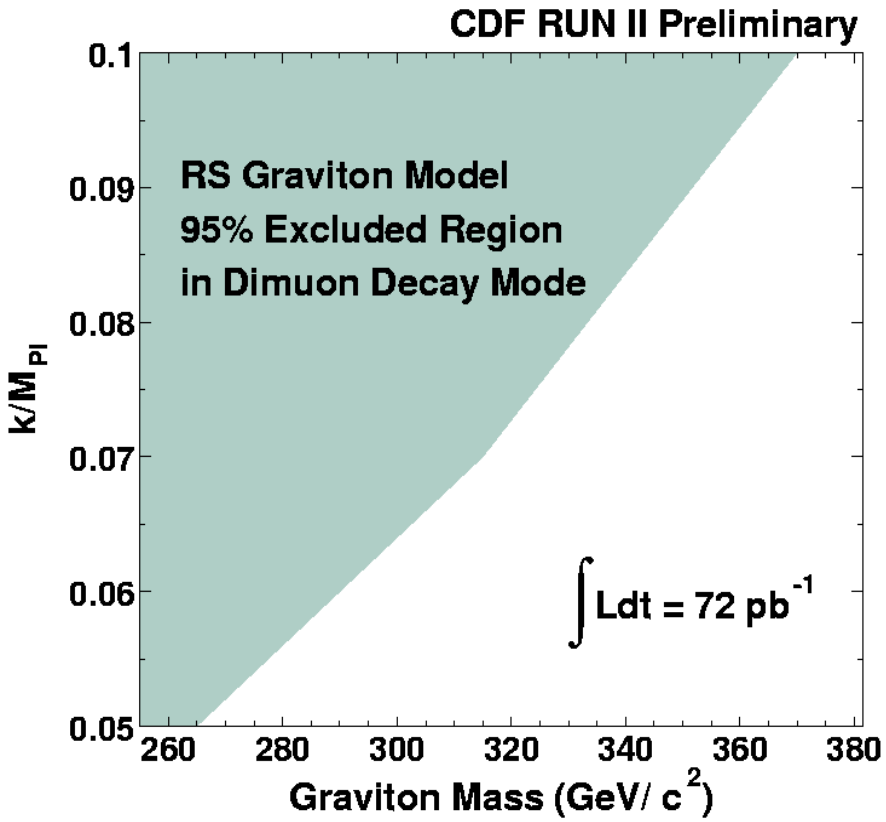
RS-Graviton Searches

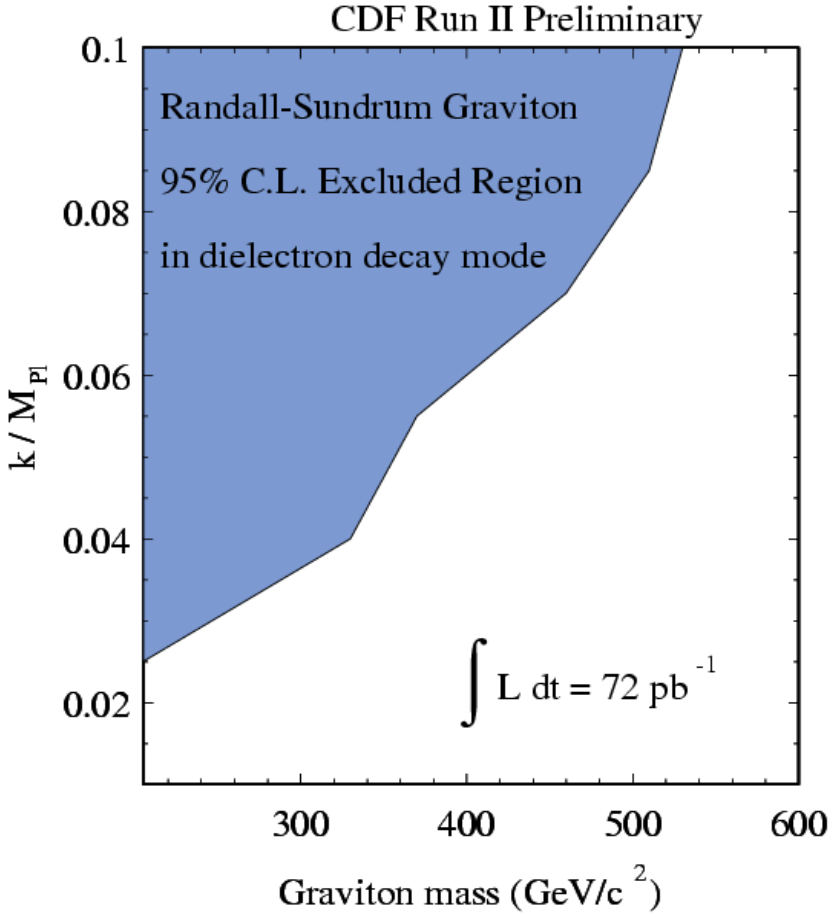
- Excited graviton in 5 dimensions
- Free parameters: mass M_G and coupling k/M_{PL}
- Look for high mass excess in D-Y di-lepton events





RS : Graviton Searches



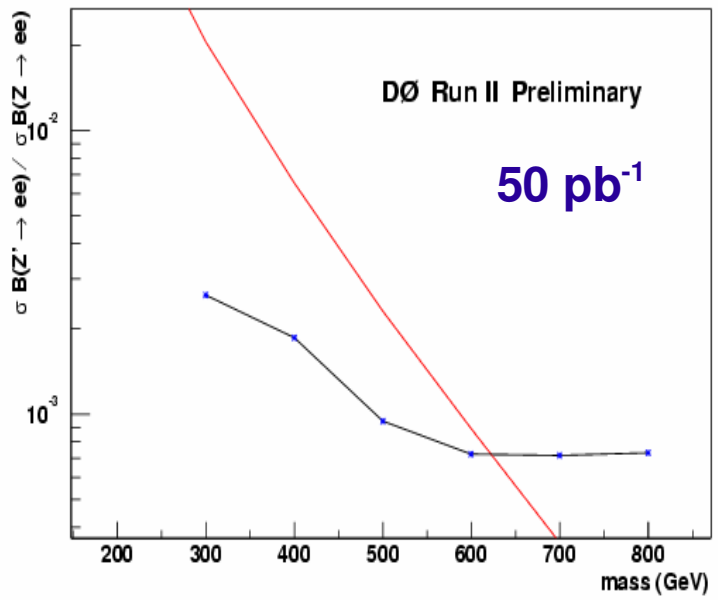


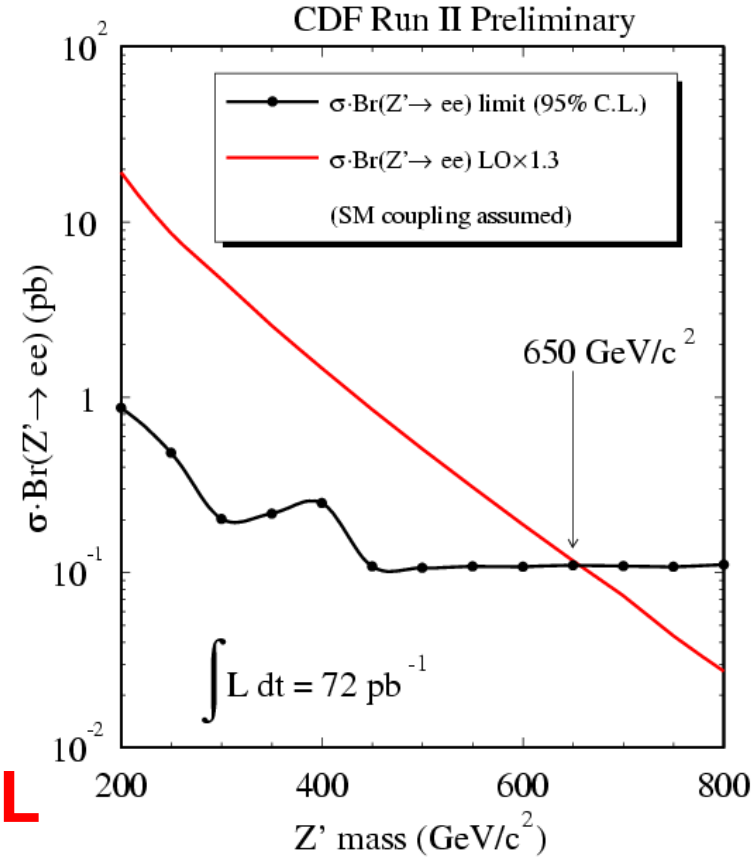
Z' searches

- Drell-Yan production $qq \rightarrow Z' \rightarrow e^+e^-$ (CDF & DØ)
- Selection
  - At CDF
    - 2 good electrons (at least one central) $E_T > 25$GeV
    - Missing $E_T / \sqrt{(\Sigma E_T)} < 2.5$
  - At DØ
    - 2 good electrons $E_T > 25$ GeV

Z' Searches (e^+e^-)

No excess observed





(Run I DØ: $M_{Z'} > 670$ GeV @ 95% CL)

DØ: $M_{Z'} > 620$ GeV @ 95% CL

CDF: $M_{Z'} > 650$ GeV @ 95% CL

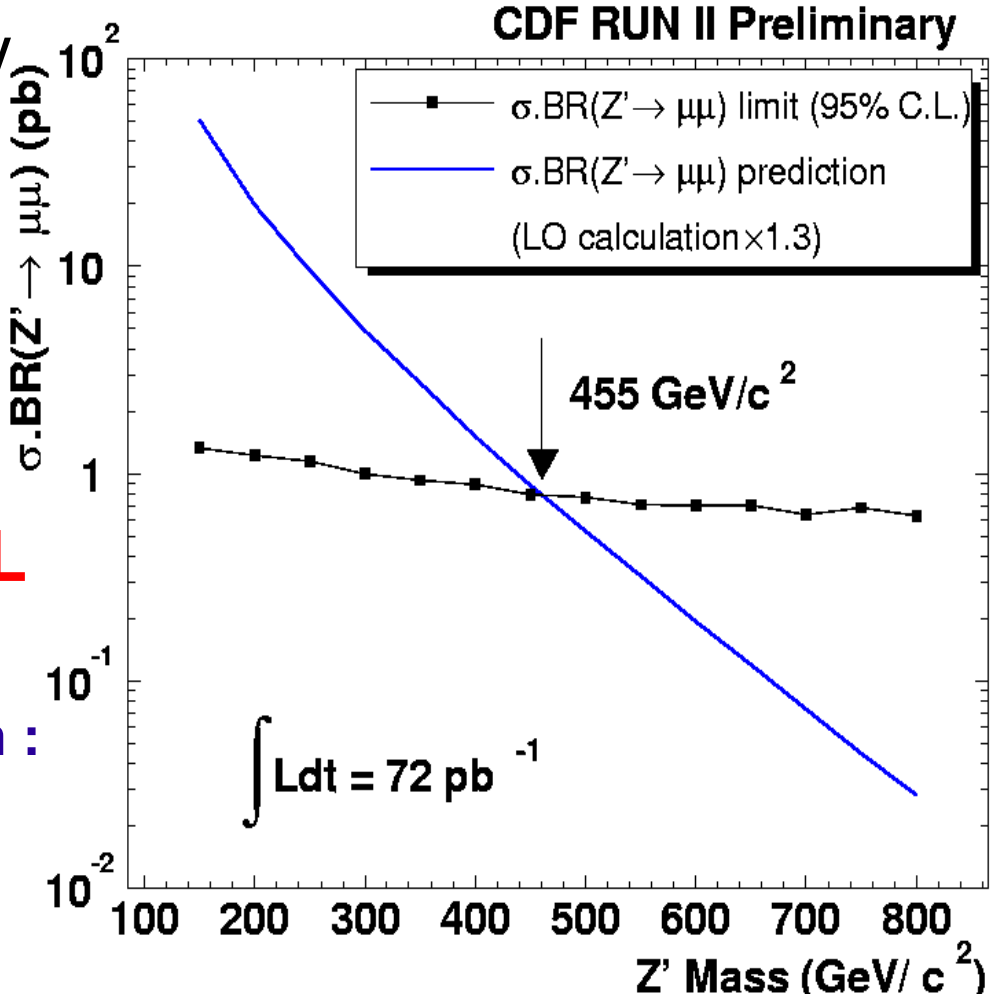
Z' Searches ($\mu^+\mu^-$)

- Drell-Yan production $qq \rightarrow Z' \rightarrow \mu^+\mu^-$ (CDF)
- 2 muons $P_T > 20$ GeV

No excess observed

$M_{Z'} > 455$ GeV @ 95% CL

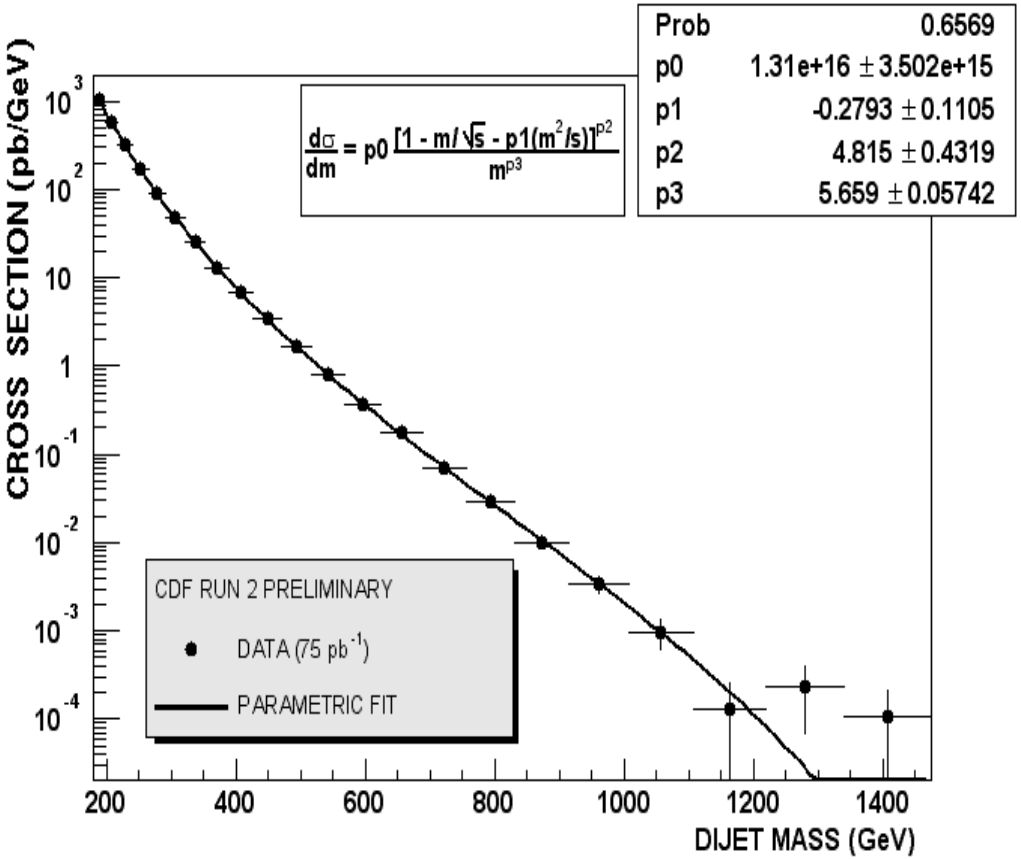
(Run I CDF combined di-lepton : $M_{Z'} > 690$ GeV @ 95% CL)



Di-Jet Mass

Selection: Inclusive jet sample (75 pb^{-1})

take 2 highest E_T jets with $|\eta| < 2$ & $|\tanh(\Delta\eta/2)| < 2/3$



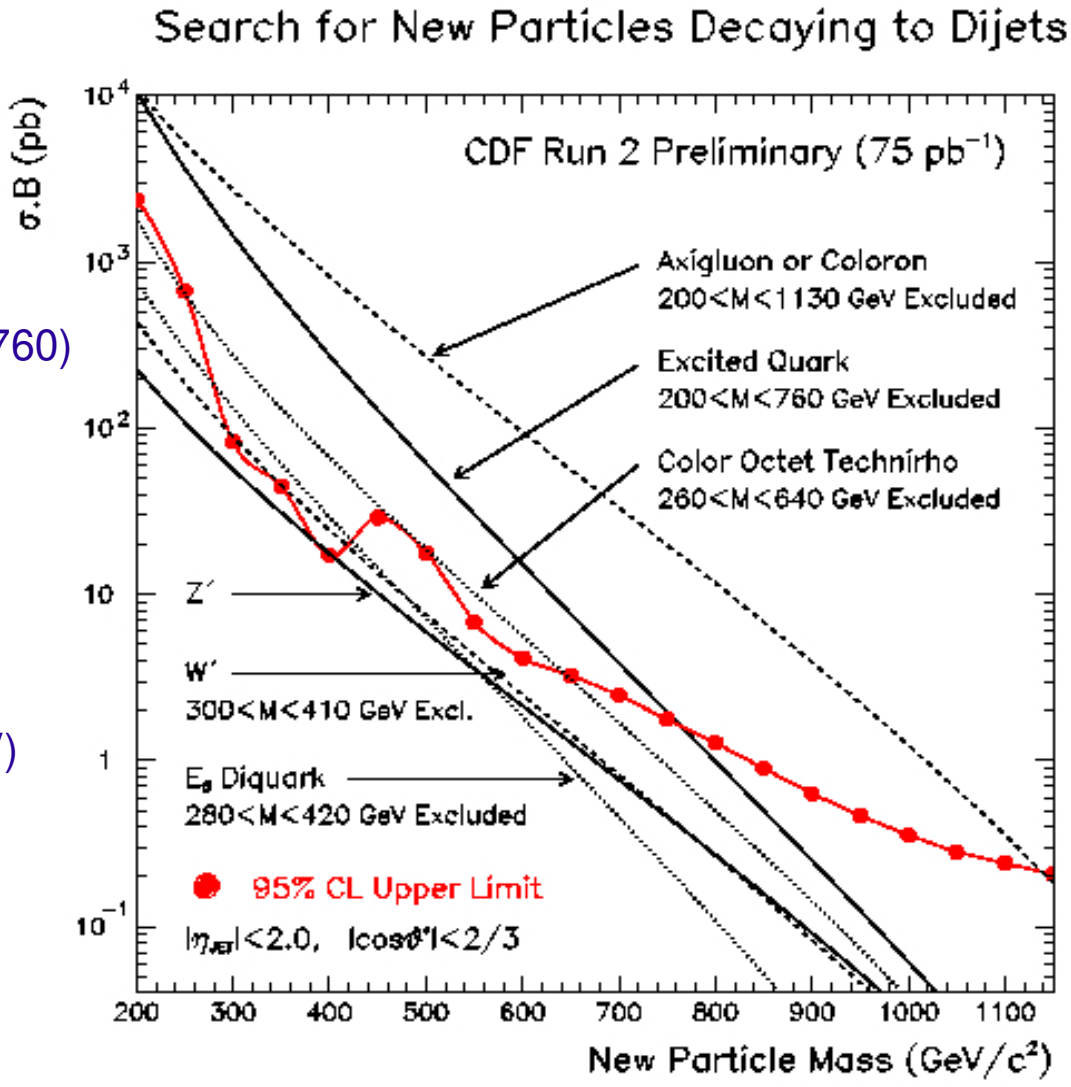
Fit the mass spectrum with a simple parametrisation of the background and look for *bumps* comparable with the mass resolution.

No significant excess beyond the Standard Model

Di-Jet Mass

Excluded:

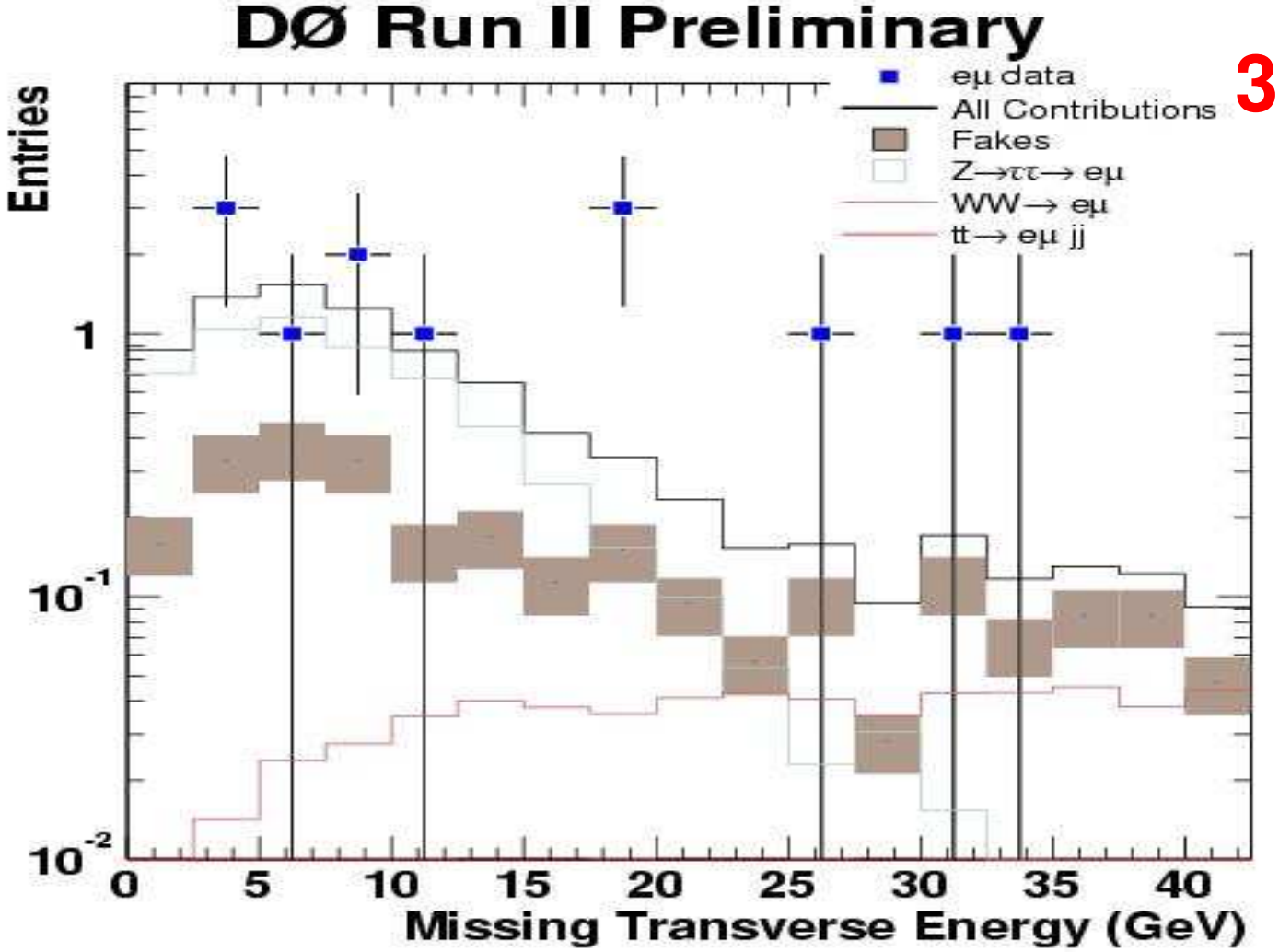
- axigluons (200 < M < 980)
  - **200 < M < 1130 GeV**
- excited quarks
  - (580 < M < 570, 580 < M < 760)
  - **200 < M < 760 GeV**
- colour octet technirhos
  - (260 < M < 640 GeV)
  - **260 < M < 480 GeV**
- E6 diquarks (280 < M < 420 GeV)
  - **290 < M < 420 GeV**
- W' (300 < M < 420)
  - **300 < M < 410 GeV**
- Run I results : **Run II results**



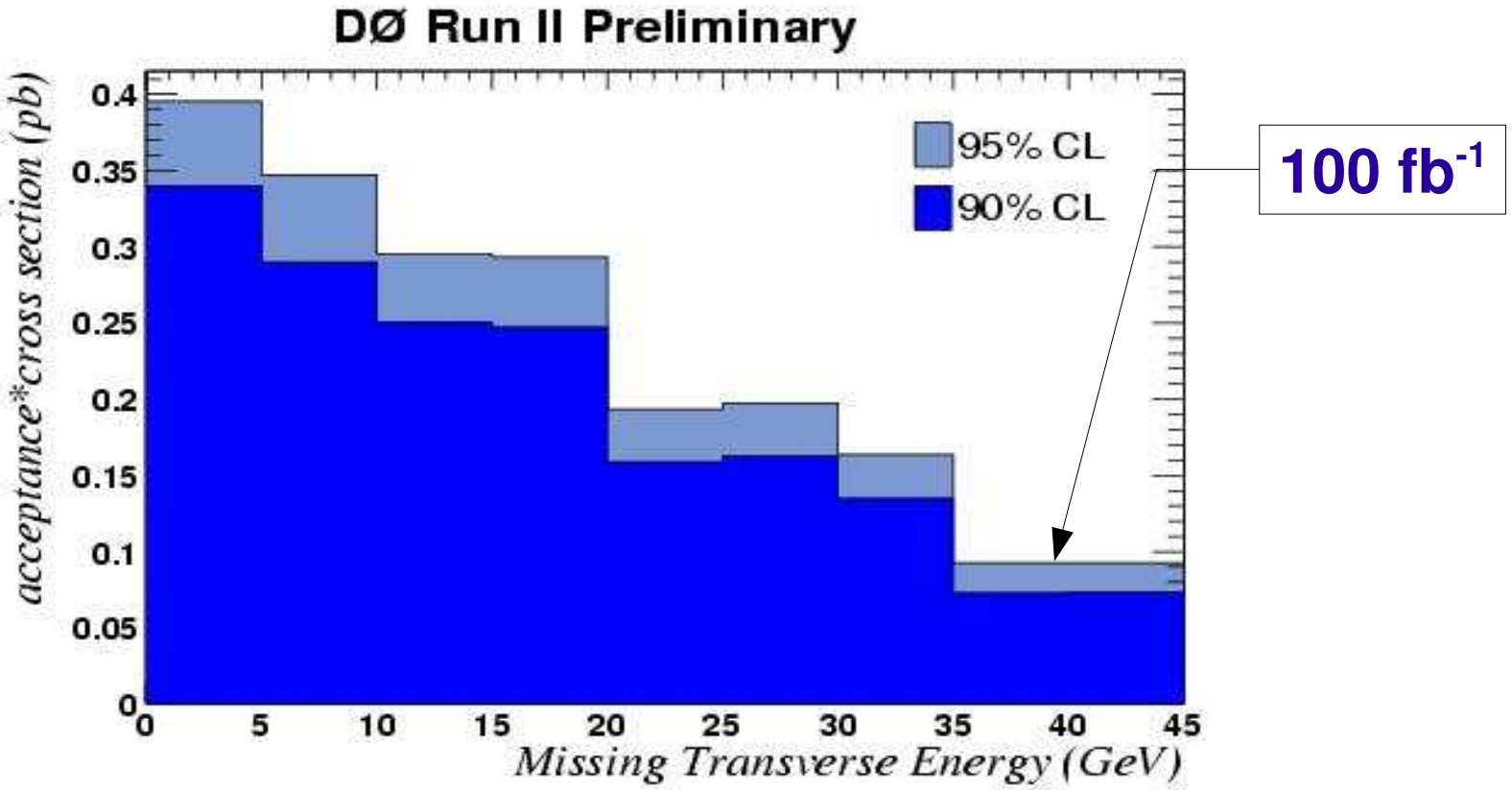
"eμ" analysis

- Very low SM backgrounds allow a model independent approach
- Estimate fake rates from data
- Physics backgrounds from simulation
- Trigger : single muon + single electron
- Offline selection:
  - ≥ 1 muon and ≥ 1 electron with p_T > 15GeV,
  - no reconstructed jets

“eμ” analysis


DØ Run II Preliminary
33 pb-1
eμ data
All Contributions
Fakes
Z→ττ→ eμ
WW→ eμ
tt→ eμ jj
Entries
1
10-1
10-2
0
5
10
15
20
25
30
35
40
Missing Transverse Energy (GeV)

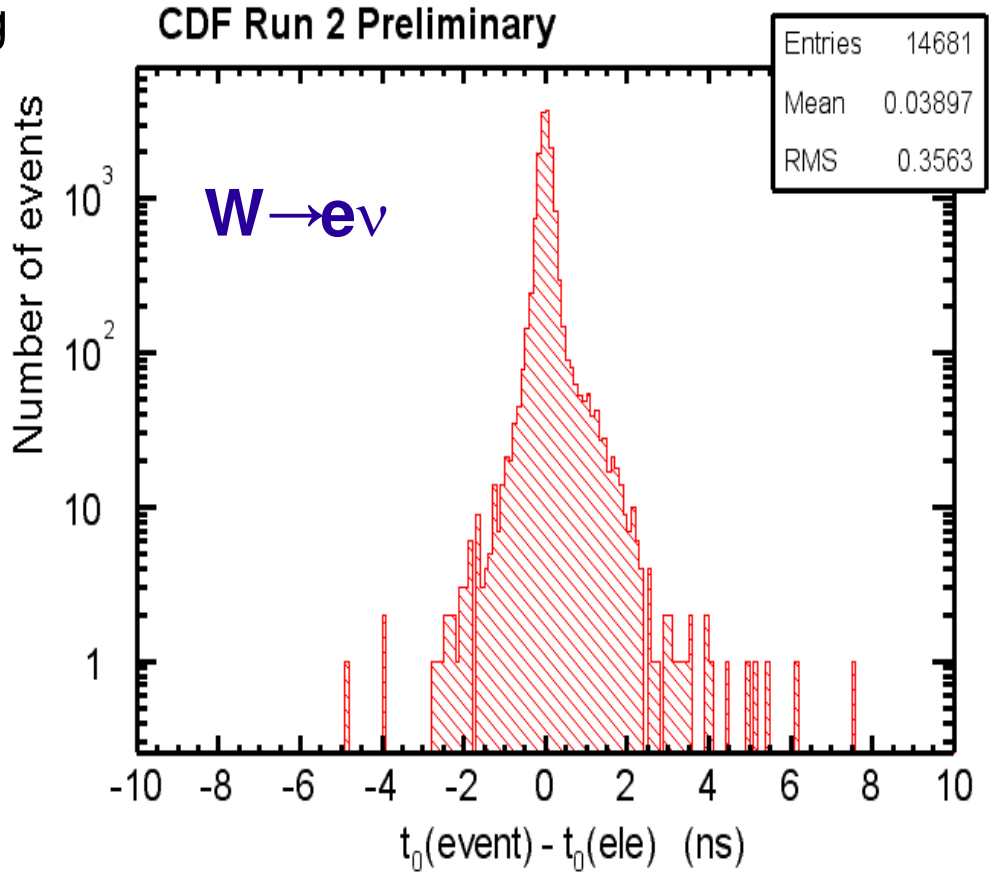
“eμ” analysis



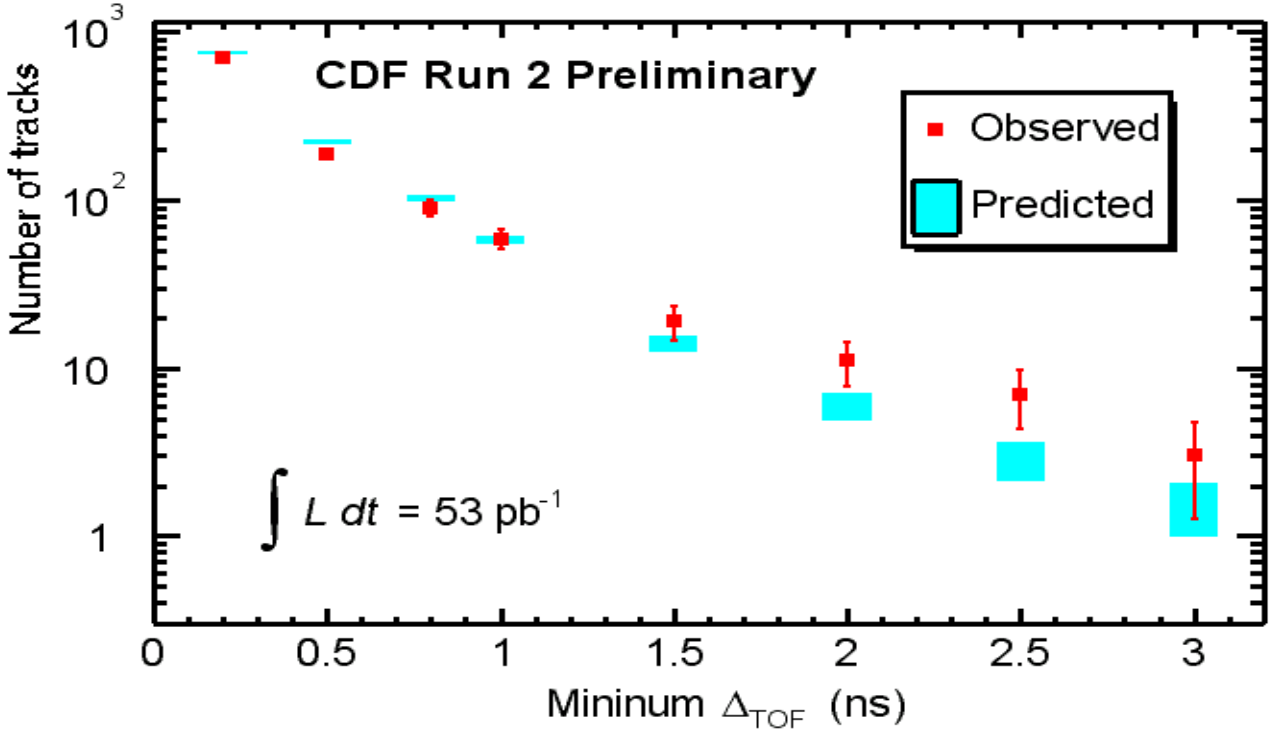
Upper limits on acceptance × production cross section for new phyiscs

CHAMPS

- CDF RunII TOF system provides higher sensitivity than dE/dx for higher $\beta\gamma$
- Long lived particles escaping the detector:
  - use high-p_T muon triggers
- Isolated and slow moving
  - p_T > 40 GeV to get full tracking efficiency
  - long time-of-flight
- establish t_0 from tracks p_T < 20 GeV
  - look for tracks with large (TOF - t_0)



CHAMPs



Select events where: **$(TOF_{track}$ -t0) > 2.5 ns**

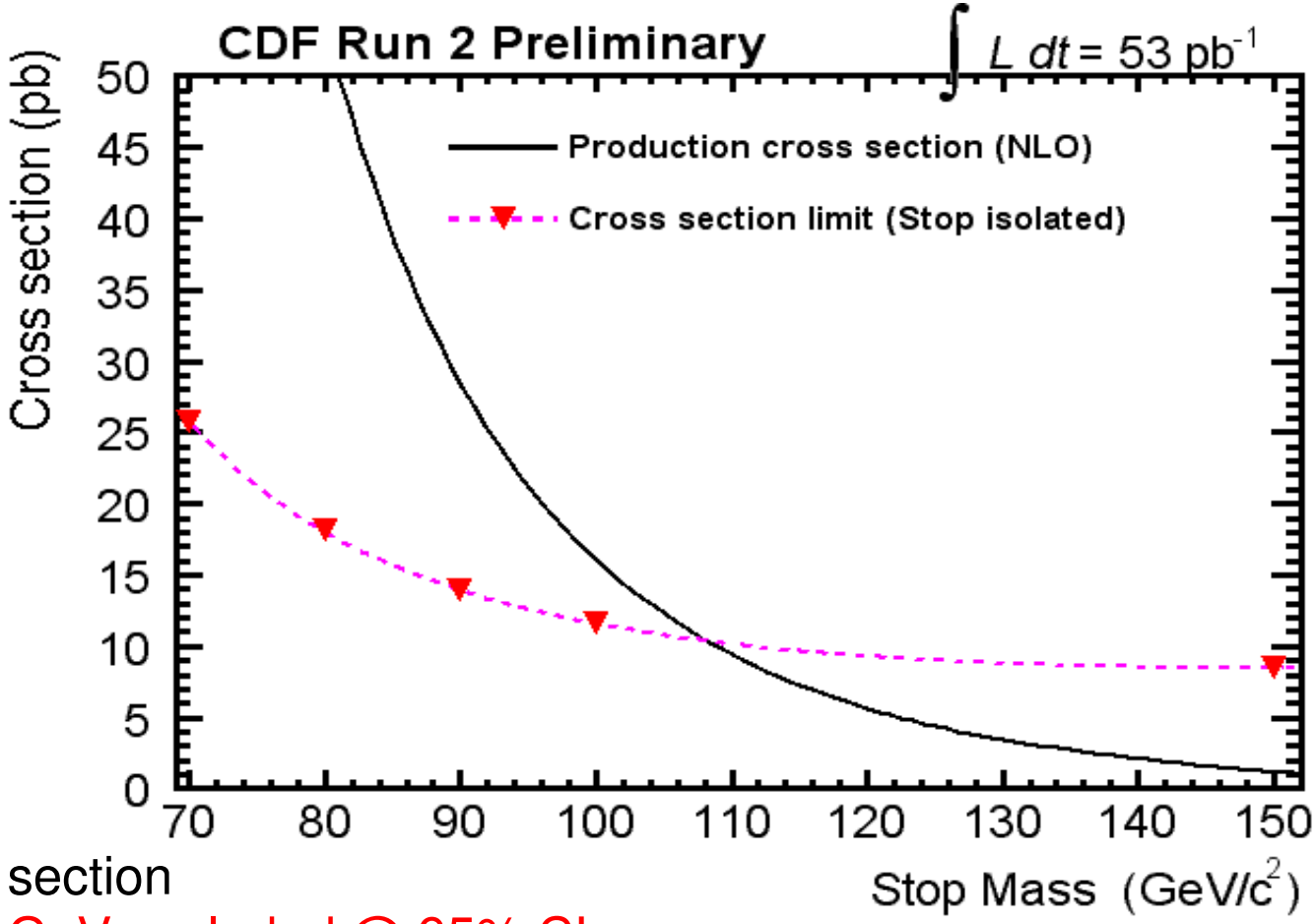
Background estimate from tracks **20 < P_T < 40 GeV**

Expect: **2.9 ± 0.7 (stat) ± 3.1 (sys) events**

Observed: **7 events**

CHAMPs

- Interpret in context of stable stop:



NLO cross section

$M_{stop} < 107$ GeV excluded @ 95% CL

Conclusions

- Both DØ and CDF continue to actively pursue searches for new phenomena
- Results are now approaching or improving on Run I sensitivities
- No new particles or physics have yet been discovered in Run II
- BUT : the discovery potential rises as the dataset accumulates
  - a new signal could be just around the corner!