Search for heavy resonances in dielectron, diphoton, electron + photon and electron + MET final states

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on behalf of the DØ Collaboration

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Overview

- Introduction
- Featured Analyses :

most recent Run IIa DØ results

(1) Search for Randall-Sundrum Gravitons in dielectron and diphoton final states

(2) Search for excited electrons e* in the electron + photon final state

(3) Search for a W´ Boson in electron + MET final state

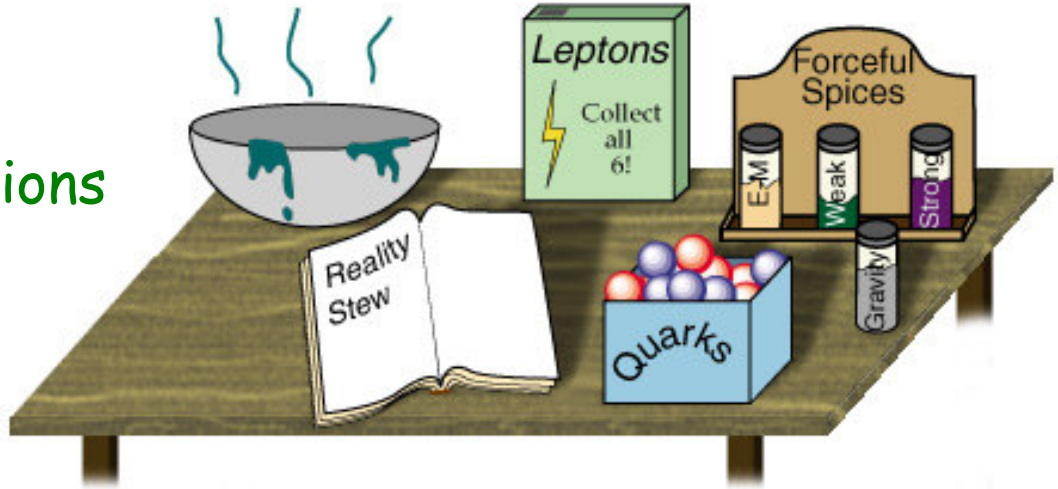
- o Data Selection
- o Backgrounds
- o Result
- o Limit

- Conclusion & Outlook

Introduction

Standard Model

Describes the fundamental fermions and their interactions

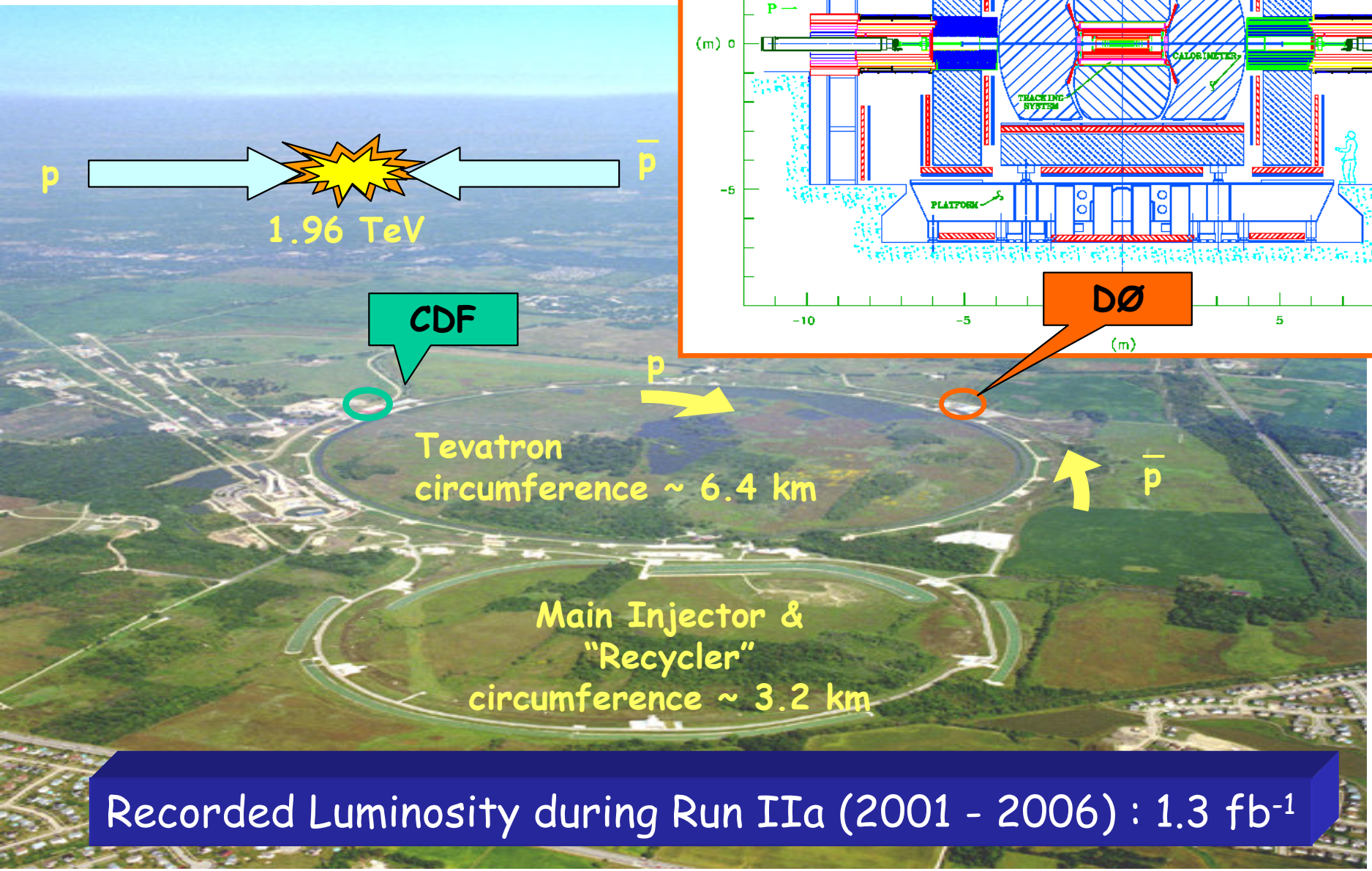


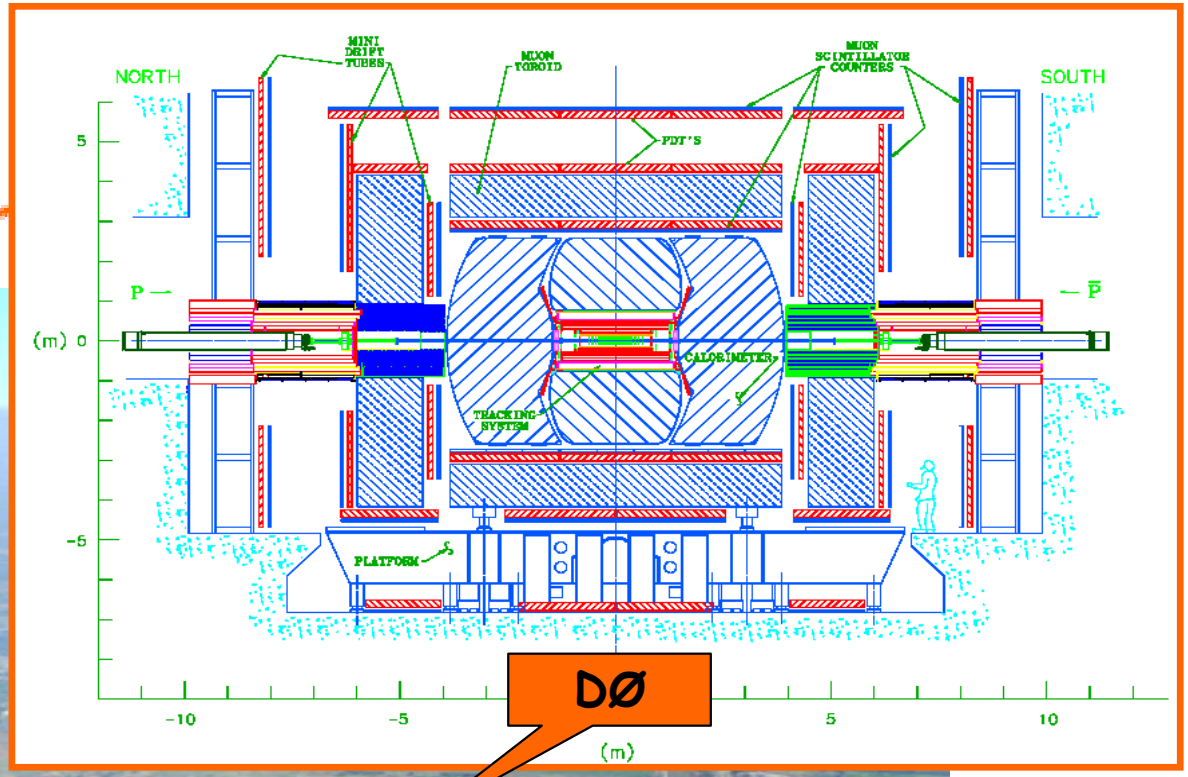
Prediction of
- W, Z production cross section
- top quark
- Δm_s

. . . **But** it is not considered to be a complete theory

What about
- number of fermion families ?
- hierarchy of fermion masses ?
- fine tuning ?

Tevatron & DØ





Recorded Luminosity during Run IIa (2001 - 2006) : 1.3 fb^{-1}

Extension (I) : Extra Dimensions (ED)

Hierarchy problem :

EW scale « GUT scale « Planck scale (~10^2 GeV « ~10^{16} GeV « ~10^{19} GeV)

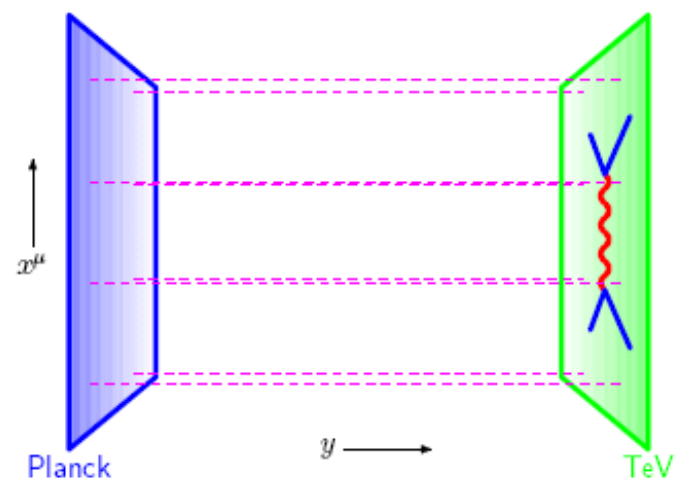
Idea :

1 fundamental scale (~ tens TeV) with 1 + 3 + δ time-space structure

Randall-Sundrum Extra Dimensions (RS ED)

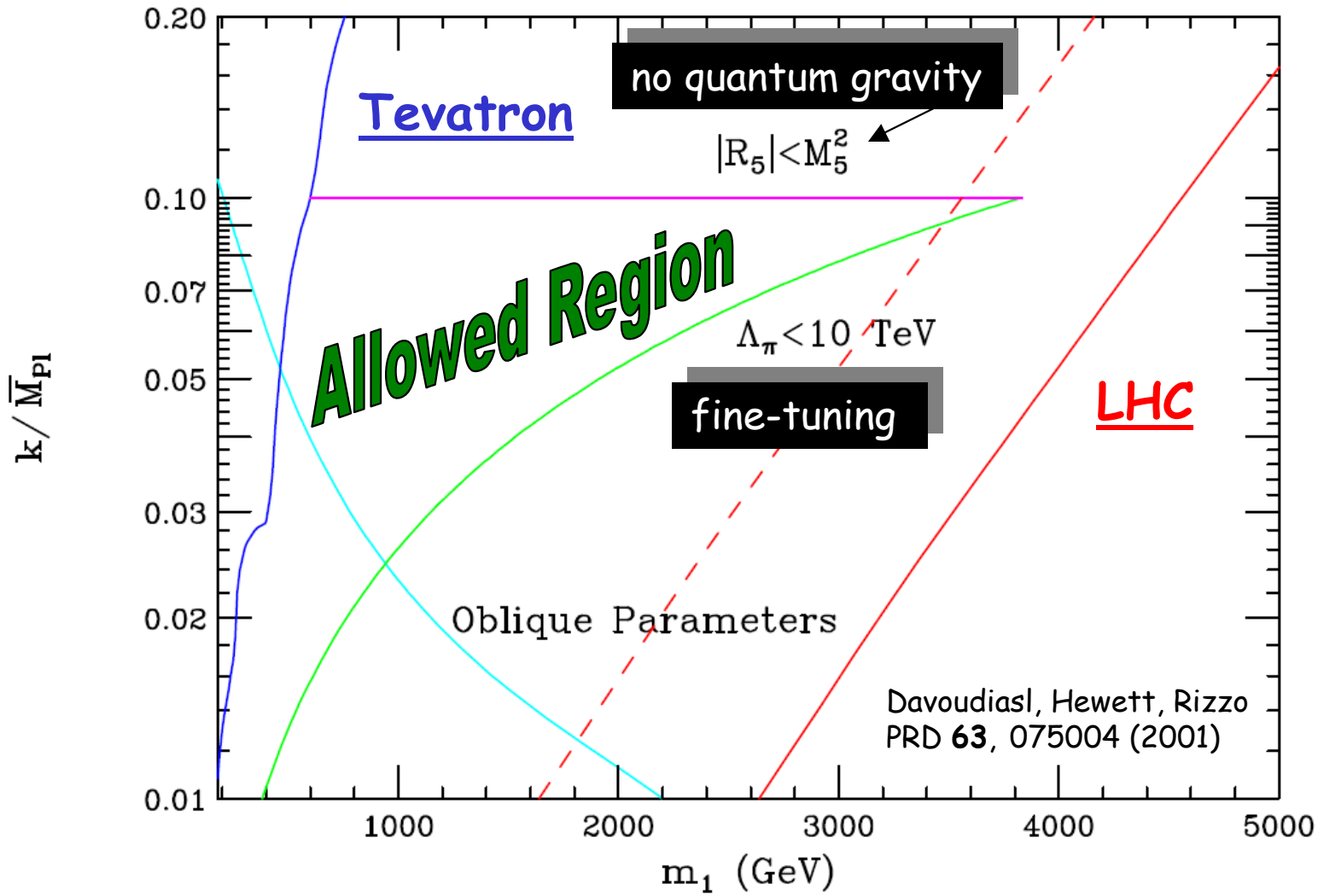
- one (5th) extra dimension (δ = 1)
- 2 branes : Planck (y = 0) and TeV/SM (y = πr_C)
- ‚warped' metric $ds^2 = e^{-2k|y|}\eta_{\mu\nu}dx^\mu dx^\nu - dy^2$
- SM brane $\Lambda_\pi = M_{Planck} e^{-k\pi r_C} \sim 1\,TeV \Rightarrow kr_C \sim 11$ (‚natural')
- KK gravitons $m_n = x_n k e^{-k\pi r_C} = x_n \cdot \Lambda_\pi \cdot \frac{k}{M_{Planck}}$ ~ O(GeV) – O(TeV)

$x_0 = 0;\ x_1 = 3.83\ldots$



Extension (I) : Extra Dimensions (ED)

2 free parameters : mass of lightest KK excitation m_1 and k/M_{Planck}



5d curvature scalar in AdS_5 :

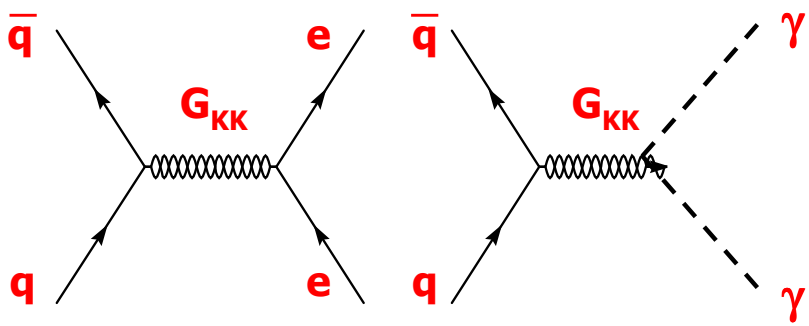
$$R_5 = -20k^2$$

5d Planck scale :

$$M_5^3 \approx kM_{Planck}^2$$

Many other types of ED : Large ED, TeV^{-1} ED, ...

RS ED : Data Selection



Note : Br(G → γγ) = 2 Br(G → ee)

Idea : do not distinguish in final state between electrons and photons

Event selection :

- triggered by EM or diEM triggers
- 2 electromagnetic objects (diEM) in the DØ Calorimeter
  - no track match required (γ !!!)
  - energy deposition patterns consistent with electromagnetic showers (isolation, shape, ...)
  - both in central calorimeter : $|\eta| < 1.1$
  - $E_T > 25$ GeV
  - $m_{diEM} > 50$ GeV

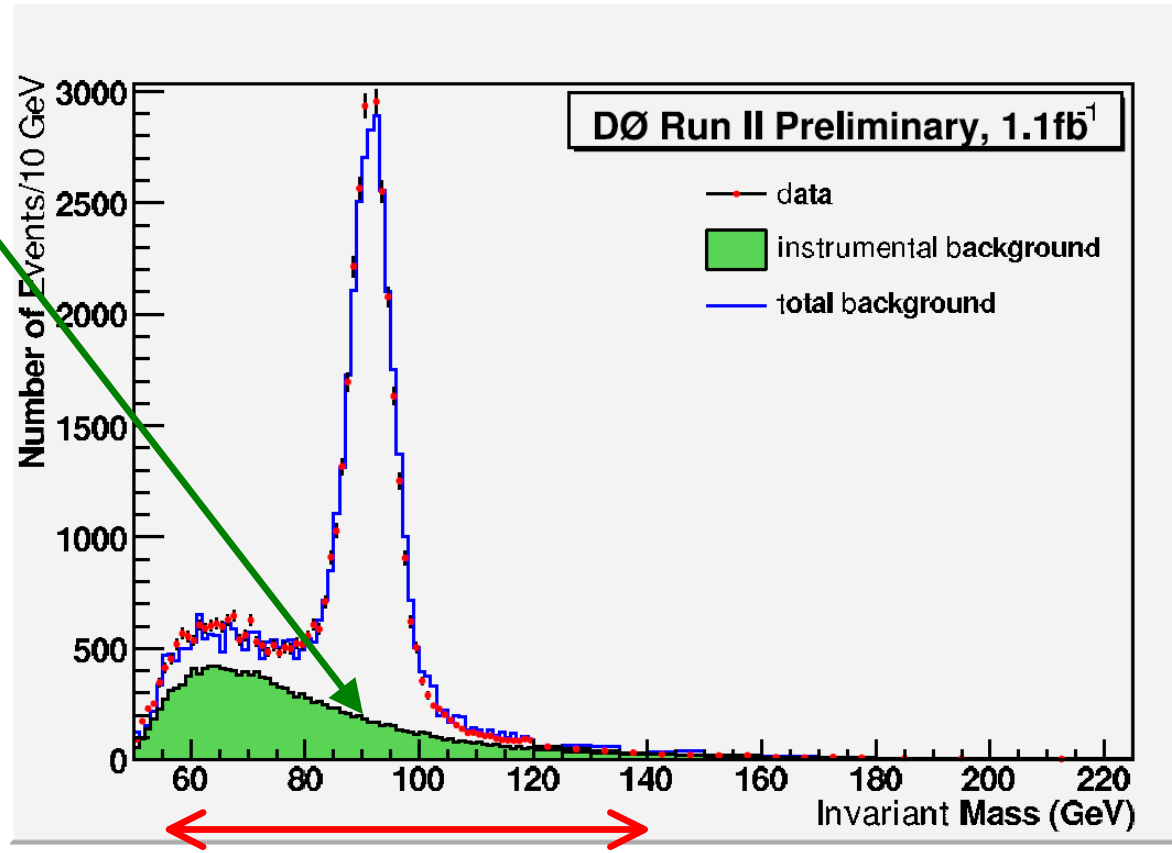
⇨ 50354 Events

RS ED : Backgrounds

Backgrounds :

- physics : Drell-Yan / Z & direct diphoton from Pythia MC
- instrumental : from Data

Select diEM objects *failing* the tight shower criteria
-> gives an estimate for the shape of misidentified electrons/photons
-> fit the invariant mass distribution around the Z peak with sum of physics and instrumental background



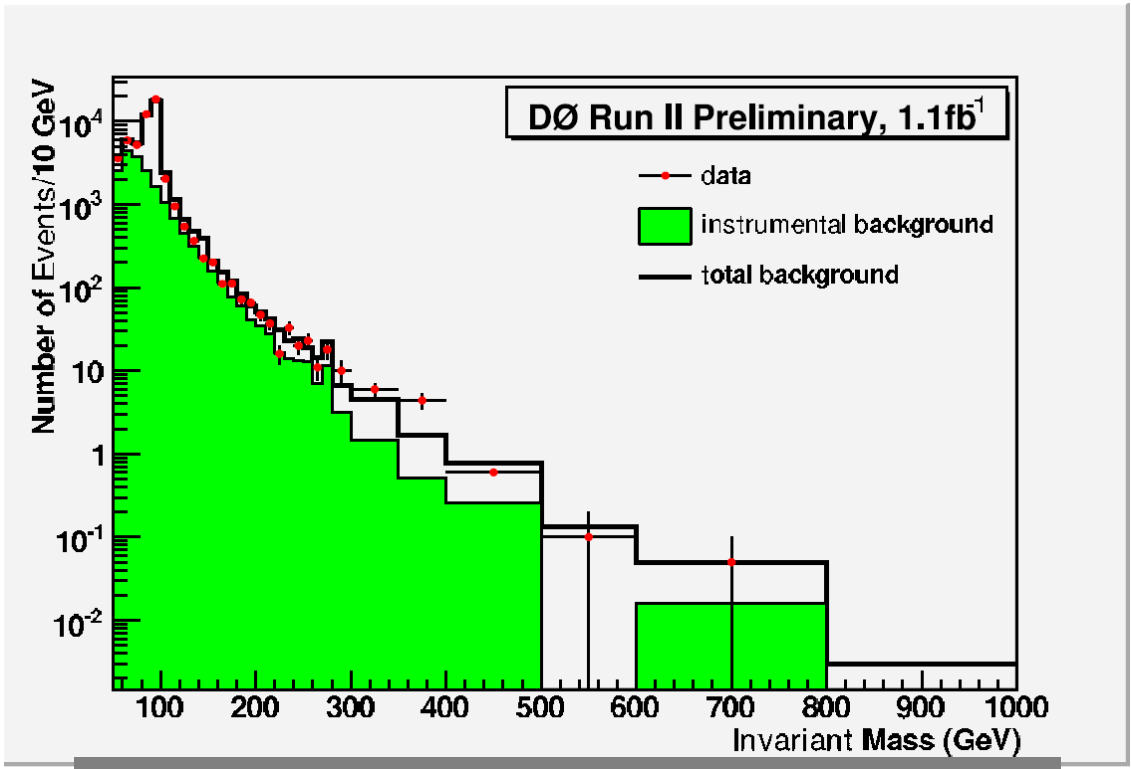
Fit : 60 GeV < m_{diEM} < 140 GeV

RS ED : Result

For different Graviton masses we make use of an optimized mass window in invariant mass distribution

Some Examples :

Mass [GeV]	Window [GeV]	Data	Background
240	230 - 250	53	47.0 ± 6.1
330	310 - 350	23	15.9 ± 3.2
400	370 - 430	12	7.0 ± 1.2
500	460 - 540	3	3.38 ± 0.76
600	550 - 650	0	0.78 ± 0.10
700	630 - 770	1	0.76 ± 0.33
800	710 - 890	0	0.15 ± 0.03
900	790 - 1010	0	0.08 ± 0.02



Good agreement between data and sum of backgrounds

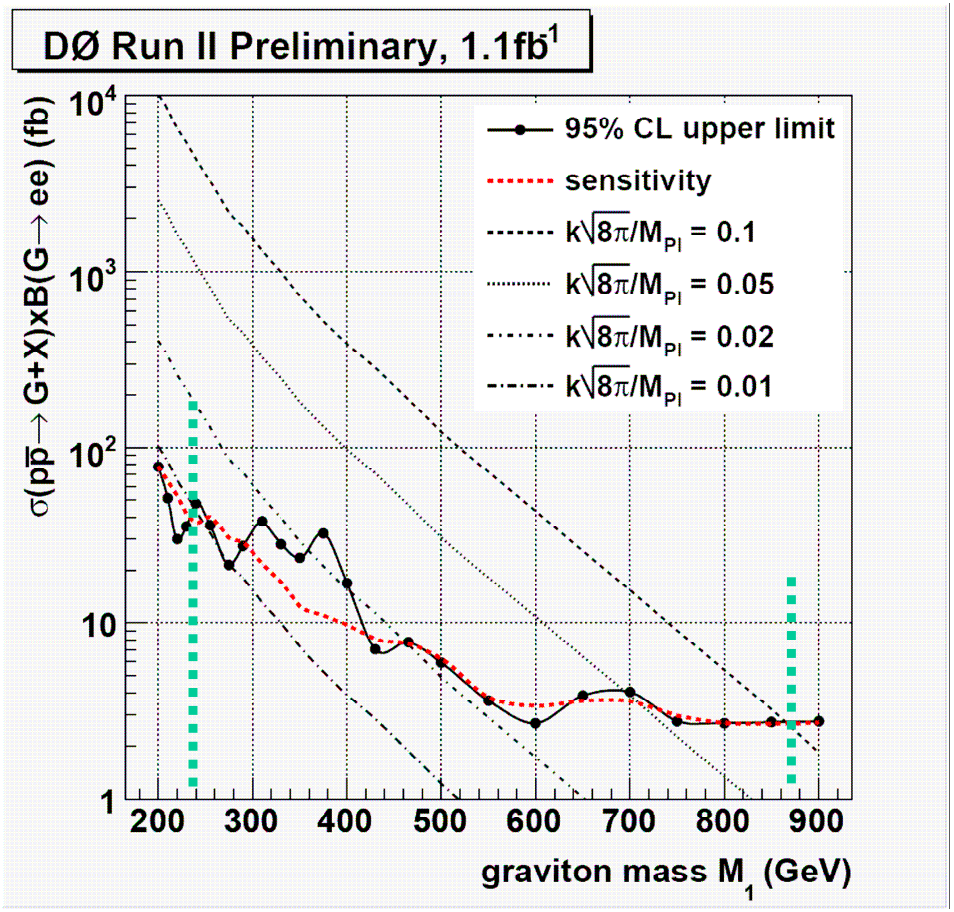
Uncertainties :

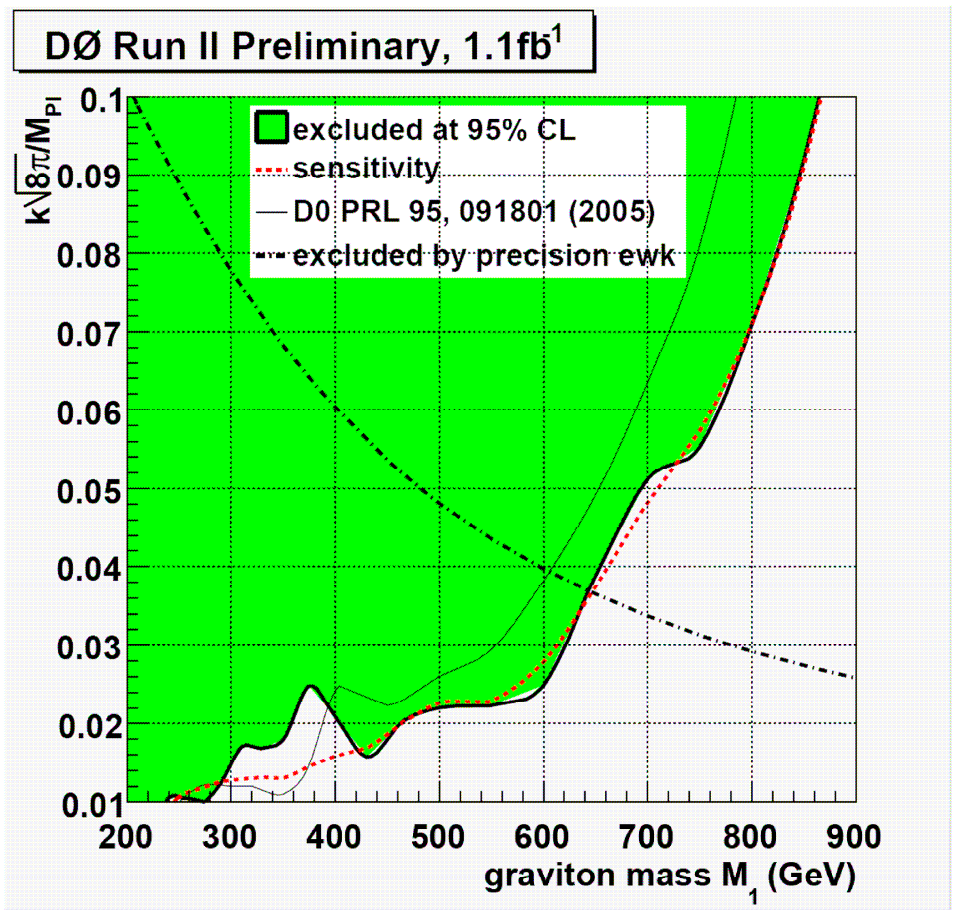
Cross sections, efficiency corrections, PDF, acceptance

~ 10%

RS ED : Limit

- Bayesian approach with a flat prior
- Systematic uncertainties are represented by Gaussian priors





For $k\sqrt{8\pi} / M_{Planck} = 0.1(0.01)$ mass limit on RS Graviton is 865 (240) GeV

Extension (II) : Excited Electrons e*

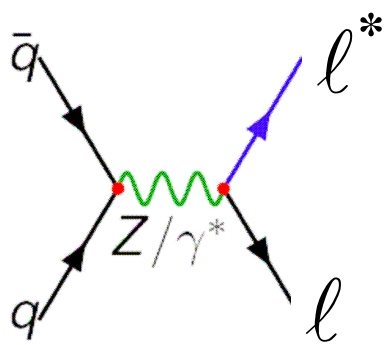
Possible explanation for hierarchical structure of fermions :

Substructure of fermions ??

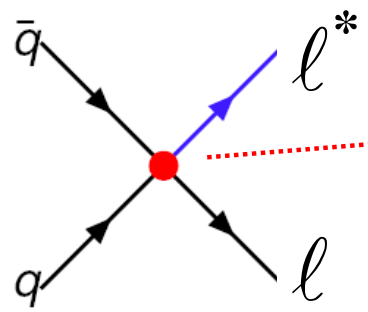
observable : radiative decays

Production :

EW
(here: neglected)



Contact Interaction CI



Effective theory :

$$\mathcal{L} = \frac{4\pi}{2\Lambda^2} j^\mu j_\mu$$

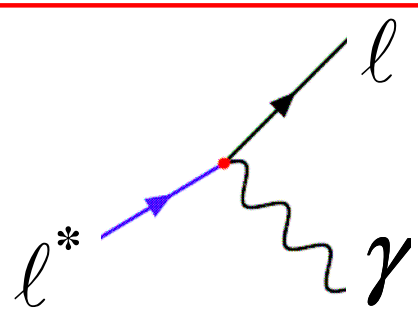
„Compositeness Scale Λ"

Decay :

$\ell^* \to \nu W$ (EW)

$\ell^* \to \ell Z$

$\ell^* \to f f \ell$ (CI)

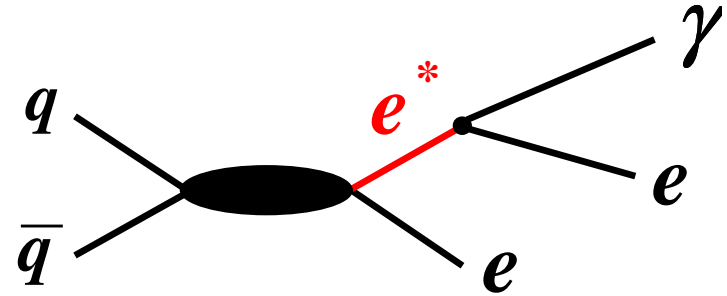


$\ell^* \to \ell \gamma$

„golden"
(EW)

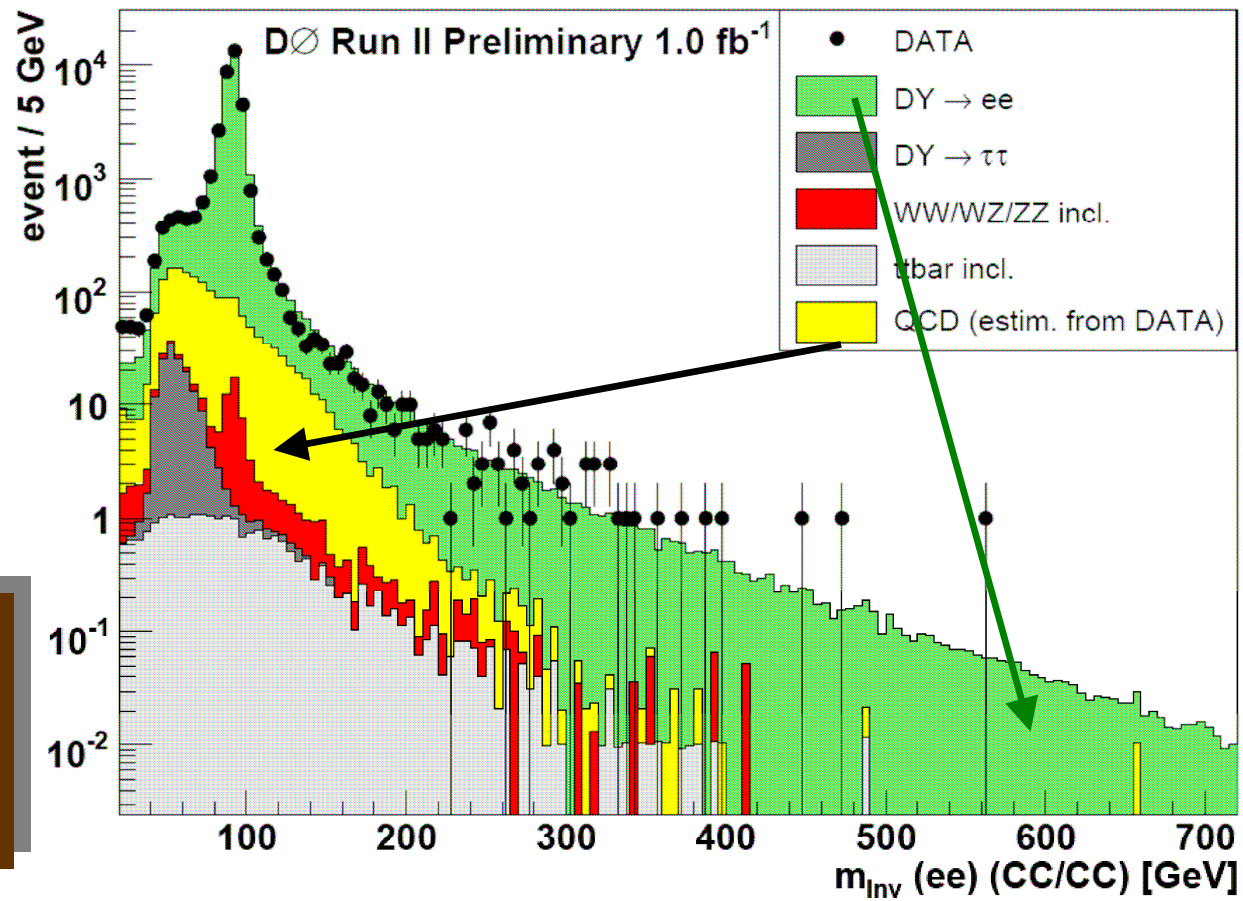
Parameters :
Mass m(l*)
Scale Λ

e* : Data Selection (ee)



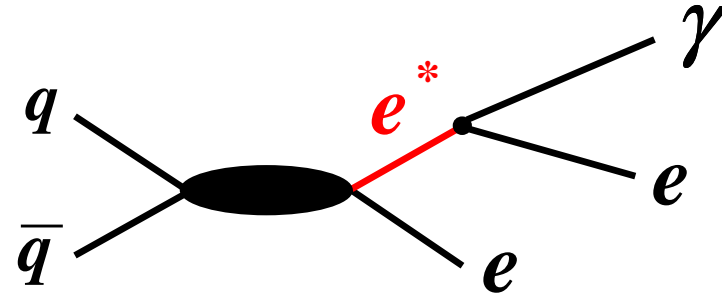
Event selection :

- triggered by EM or diEM triggers
- 2 electromagnetic objects in the DØ Calorimeter
  - energy deposition patterns consistent with EM showers
  - associated tracks
  - $E_T(e_1) > 25$ GeV
  - $E_T(e_2) > 15$ GeV
  - $|\eta| < 1.1$ or $1.5 < |\eta| < 2.5$
  - separated $\Delta R > 0.4$



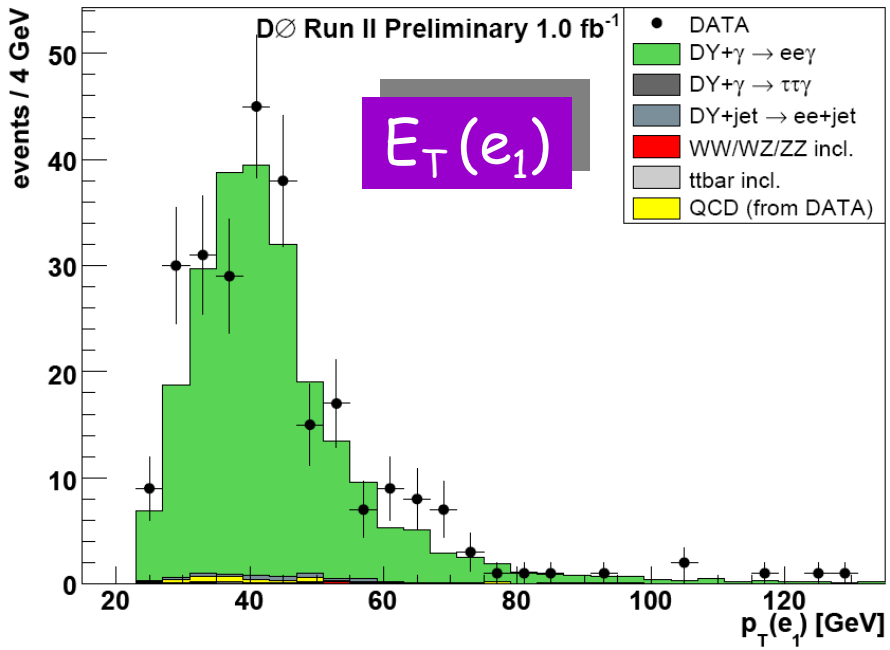
Data :
62930
Background :
61560 ± 120 (stat) ± 6553 (sys)

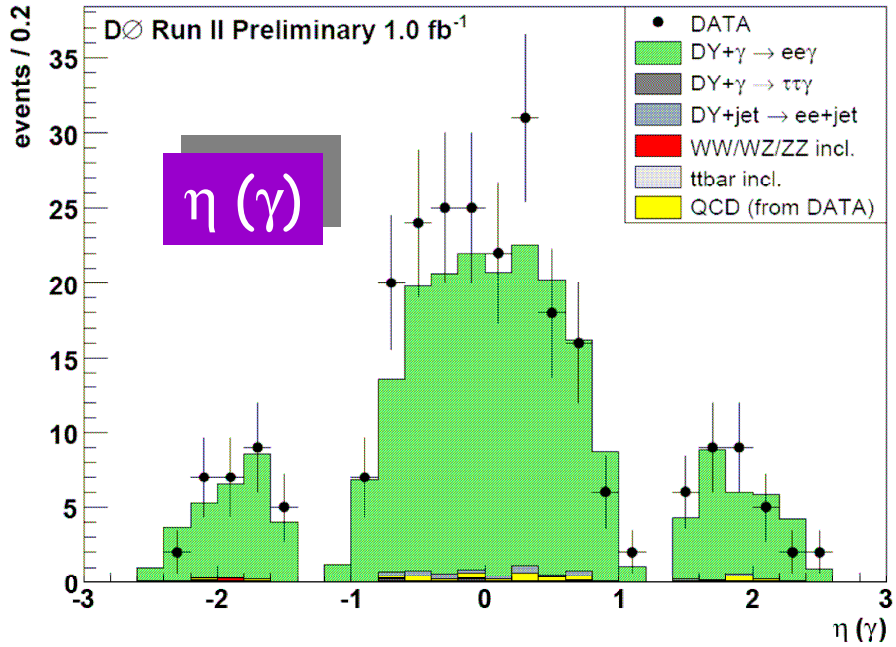
e* : Data Selection (eeγ)



Photon Identification

- electromagnetic object in the DØ Calorimeter
  - energy deposition patterns consistent with EM showers
  - no associated track, isolated
  - $E_T > 15$ GeV and $|\eta| < 1.1$ or $1.5 < |\eta| < 2.5$





Data : 259
Background : 232 ± 3 (stat) ± 29 (sys)

Good agreement between data and background

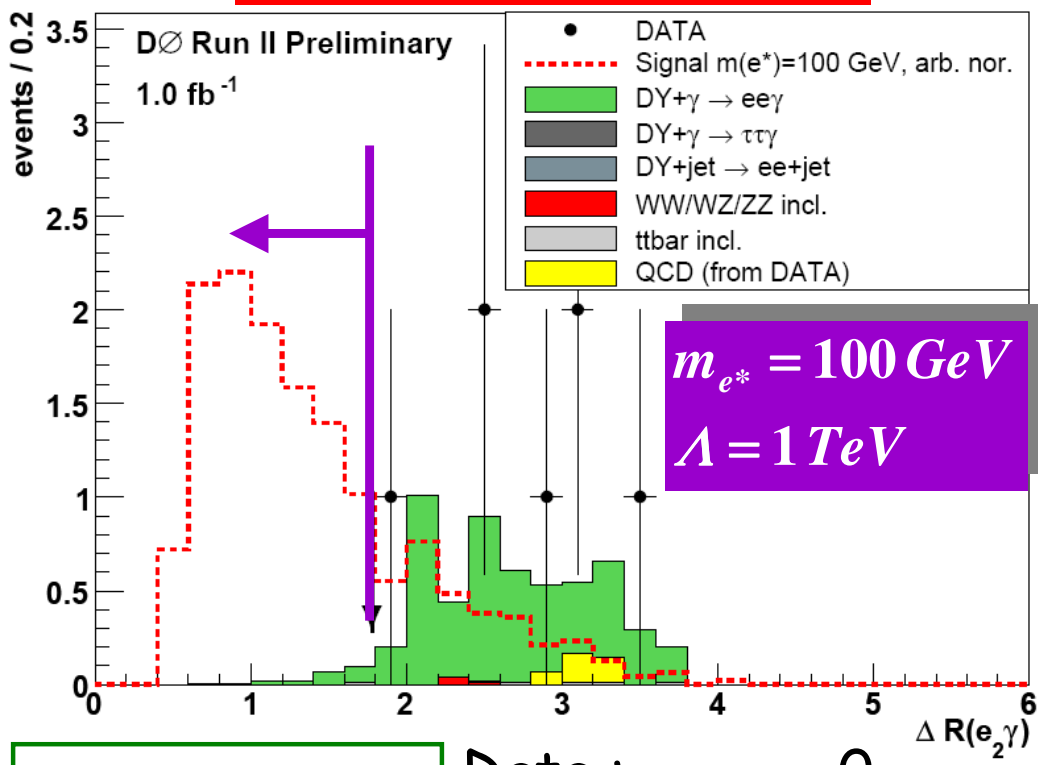
e* : Limit

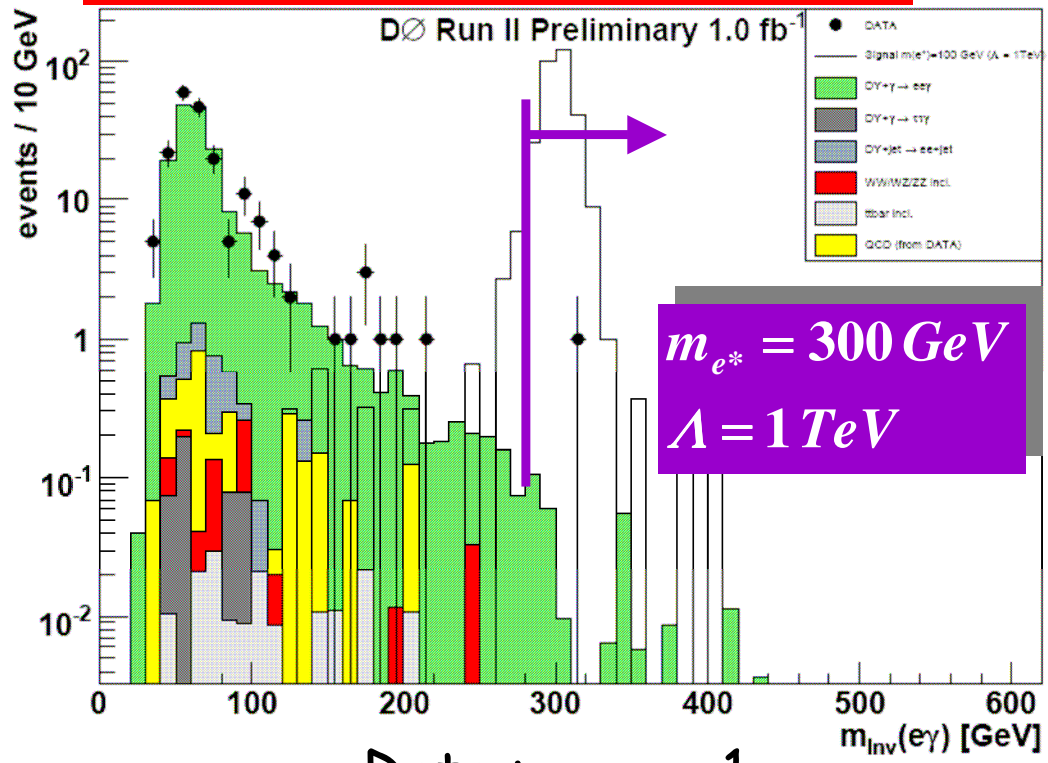
Optimize cut on m(eγ) wrt the expected limit

How to combine electron and photon ??

For m(e*) < 300 GeV :
$e_2 + \gamma$

For m(e*) ≥ 300 GeV :
Combination closest to m(e*)



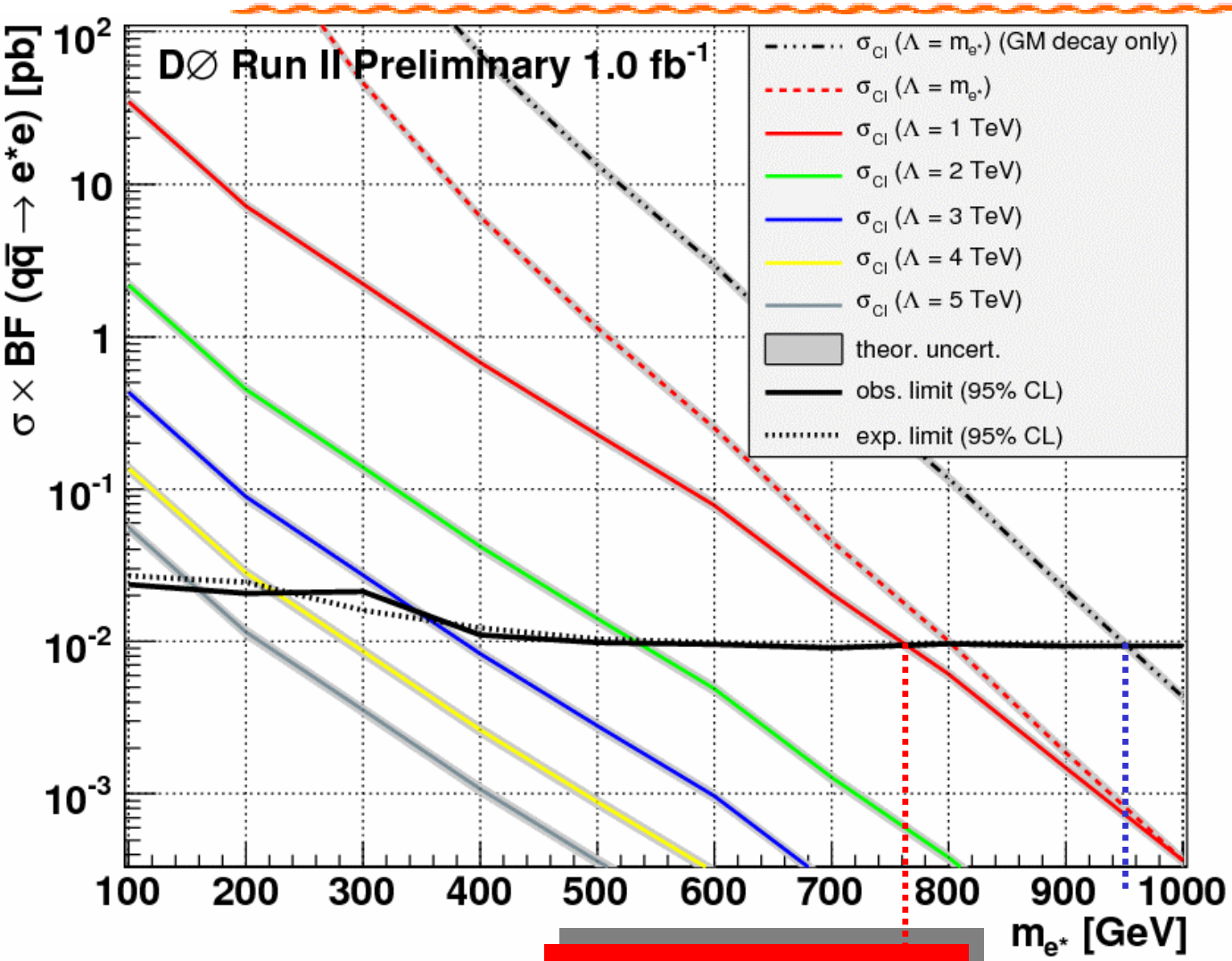


$\Delta R\,(e_2, \gamma) < 1.8$

Data : 0
Background : 0.31 ± 0.09

Data : 1
Background : 0.28 ± 0.10

e* : Result



$m_{e^*} > 756\,GeV$

$\Lambda = 1\,TeV$

Uncertainties :
Efficiency corrections, cross sections, PDF luminosity, misID, QCD

~ 10%

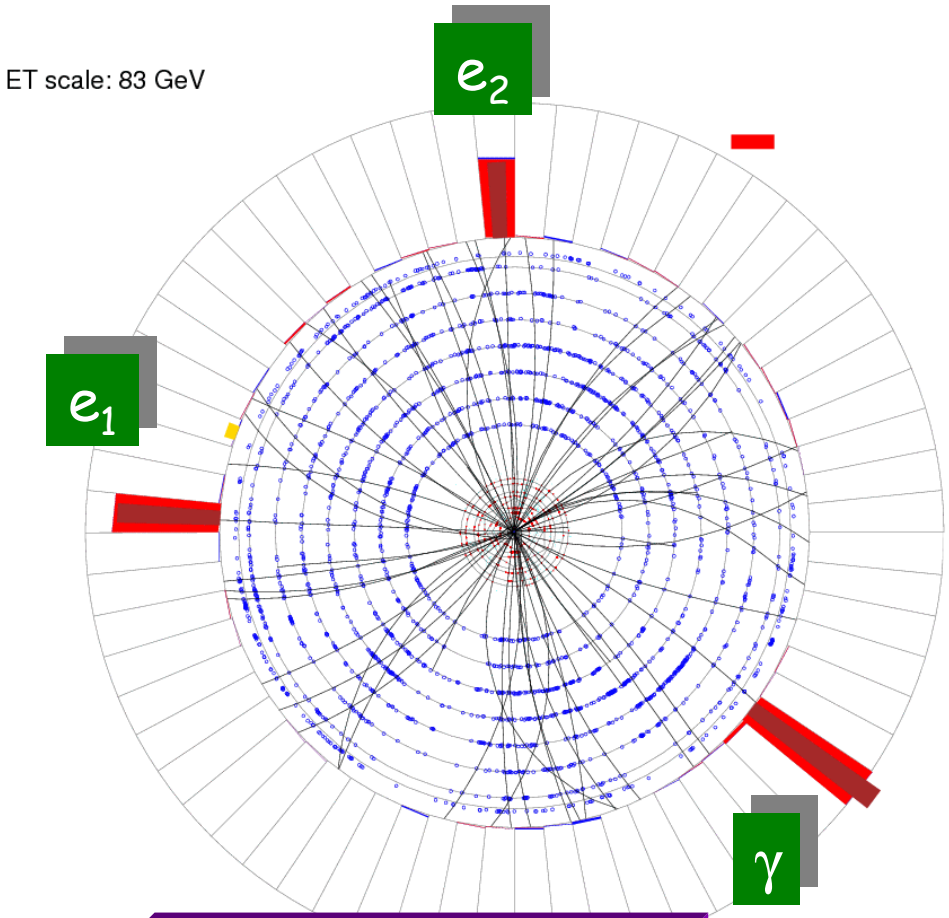
Neglect decays via Contact Interaction :

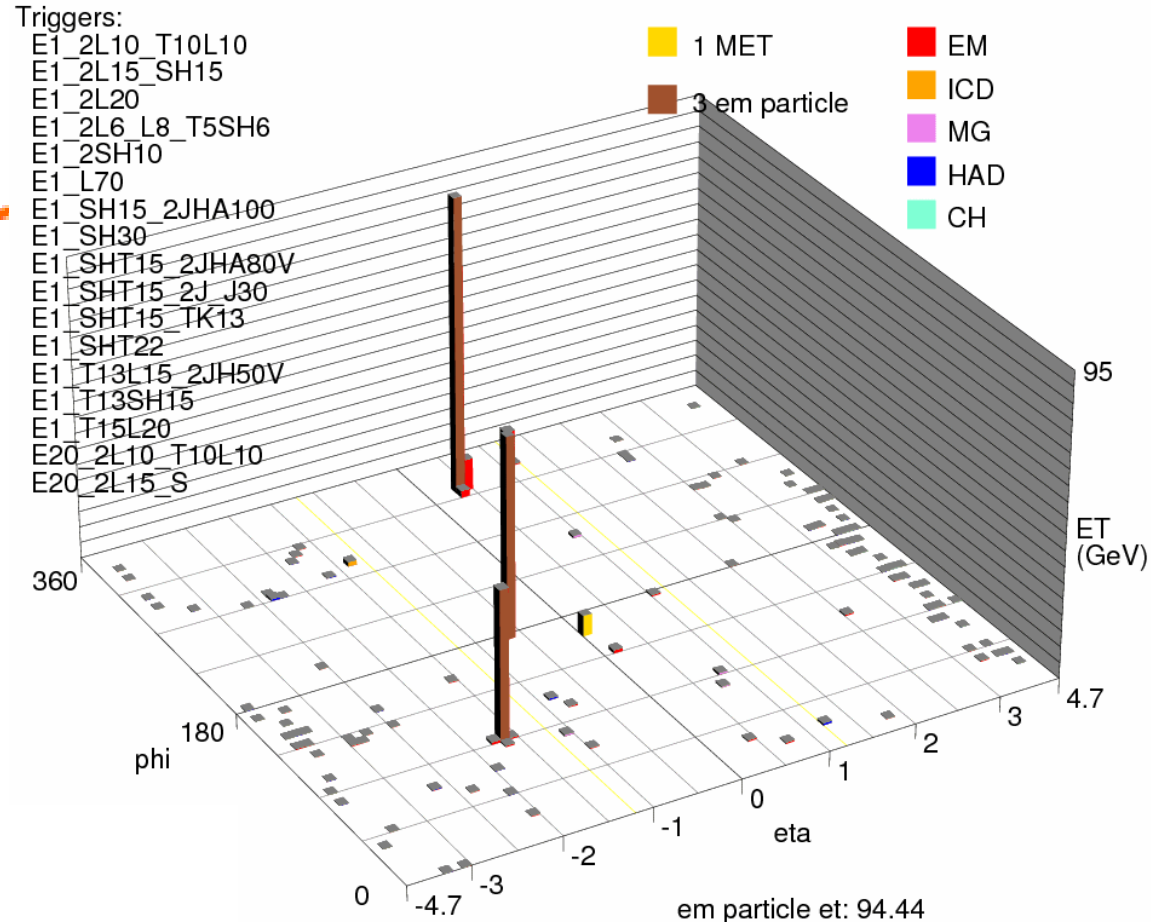
$$m_{e^*} > 946\,GeV$$

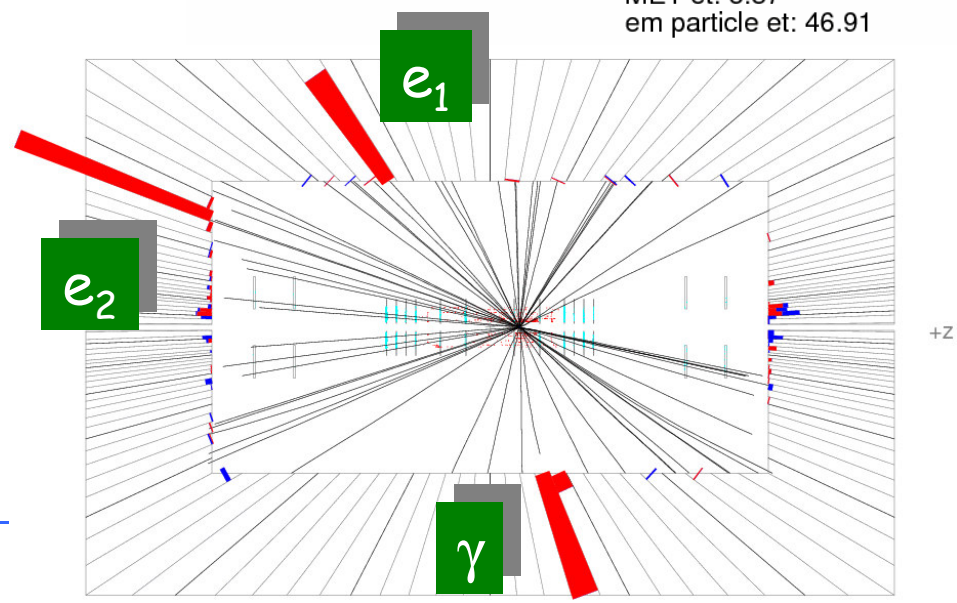
$$\Lambda = m_{e^*}$$

CDF II (202 pb^{-1}) :
m(e*) > 879 GeV

e* : Event Display







$m(e_2, \gamma) = 195$ GeV

$m(e_1, e_2) = 90.1$ GeV → $Z + \gamma$

Extension (III) : Heavy Gauge Bosons

Additional gauge bosons (W´ , Z´) are introduced in

many extensions to the SM : $\cancel{SU(5)}, \; SO(10), \; E_6, \; \ldots$

Parameters :

- mass, width

In addition :

- mixing (mass eigenstates ≠ group eigenstates) ξ
- new fermion – boson – couplings g'
- new CKM – Matrix U'

Make **assumptions** to reduce number of parameters :

⇨ $\xi \equiv 0 \;, \quad g' \equiv g_{SM} \;, \quad U' \equiv U_{SM}$

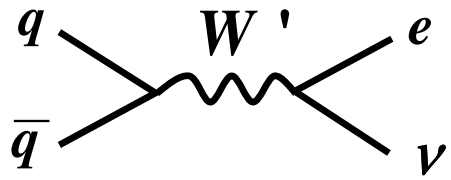
⇨ width ~ mass

$$m_{W'} < 180\,GeV : \Gamma_{W'} = \frac{m_{W'}}{m_W} \cdot \Gamma_W$$

$$m_{W'} > 180\,GeV : \Gamma_{W'} = \frac{4}{3} \cdot \frac{m_{W'}}{m_W} \cdot \Gamma_W$$

Decay tb allowed

W´: Data Selection



Event selection :

- triggered by inclusive single EM triggers
- missing transverse energy MET > 30 GeV
- contains 1 electron candidate
  - energy deposition patterns consistent with electromagnetic showers (isolation, shape, ...)
  - in central calorimeter : $|\eta| < 1.1$
  - $E_T > 30$ GeV
  - track match in z and ϕ direction (**no E/p**)

Further cleaning cuts :

- $0.7 < E_T/\mathrm{MET} < 1.3$
- no jet activity in opposite direction of electron/MET

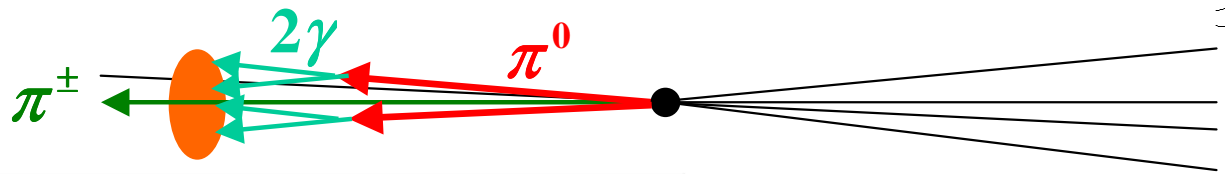
-> Reject fake MET

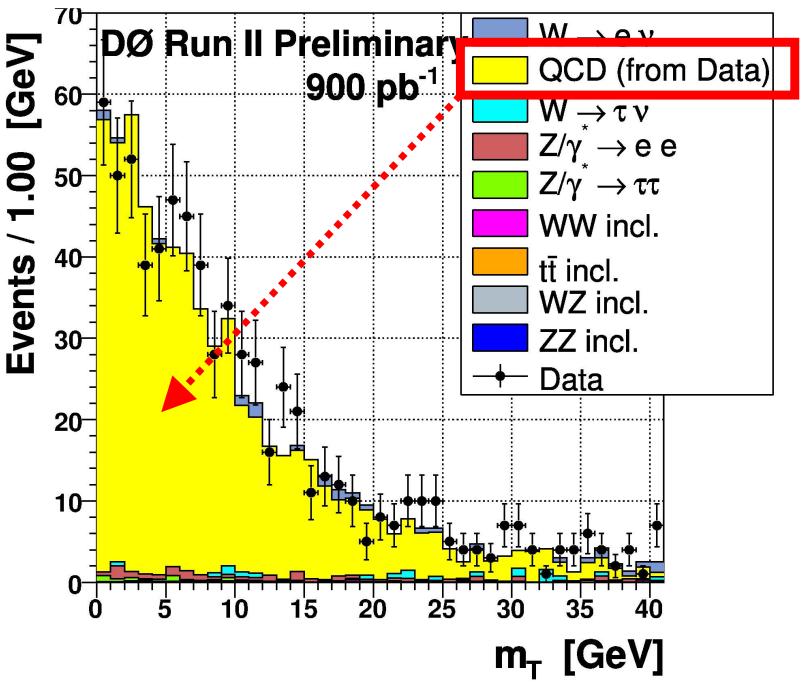
W´: Backgrounds

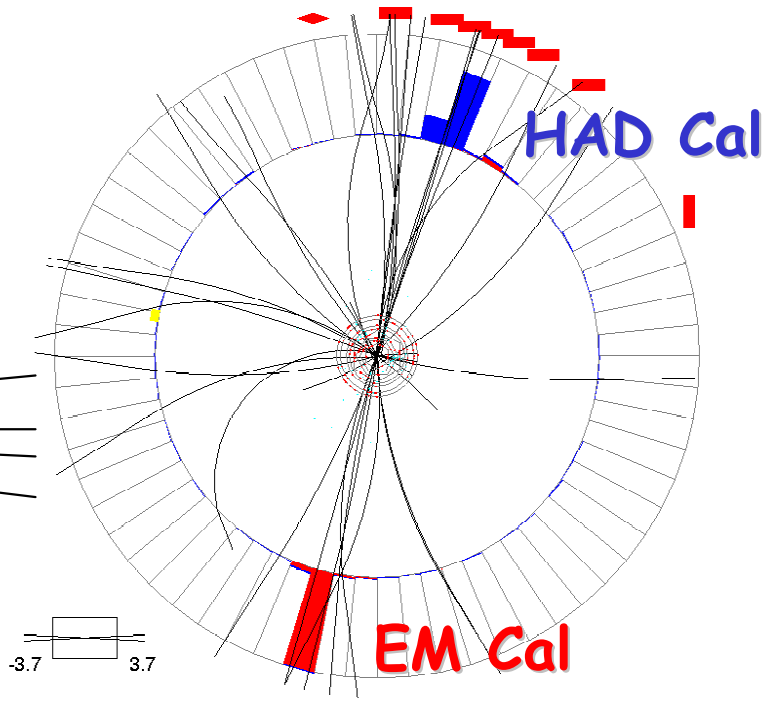
Backgrounds :

- dominant : W from Pythia MC
- minor : WW, ZZ, WZ, Z from Pythia MC

- QCD multijet from Data (‚fake electrons')



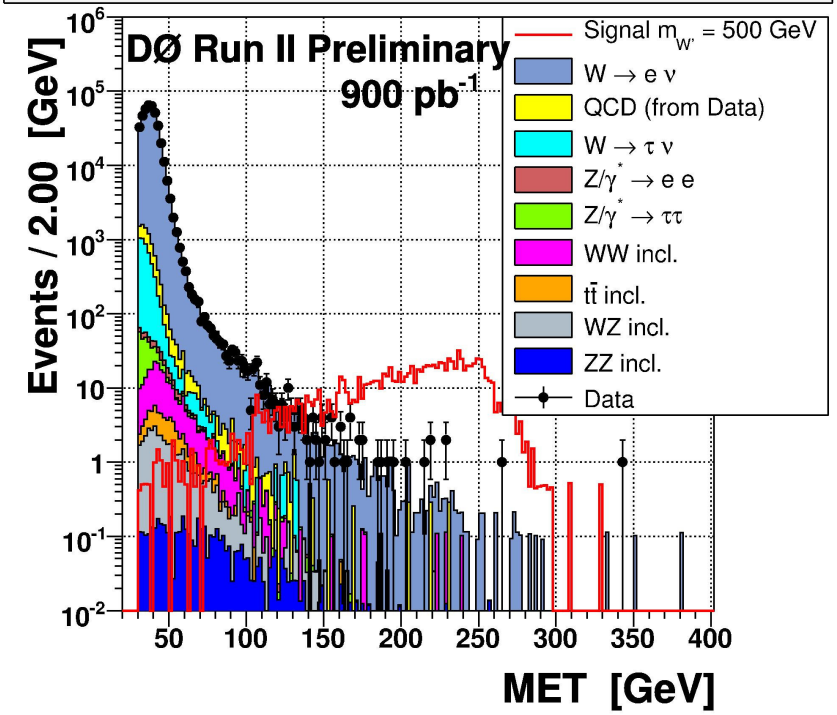




Method similar to diEM analysis :
- electron candidate *failing* tight shower criteria
- scale to data + SM PYTHIA MC in low m_T region

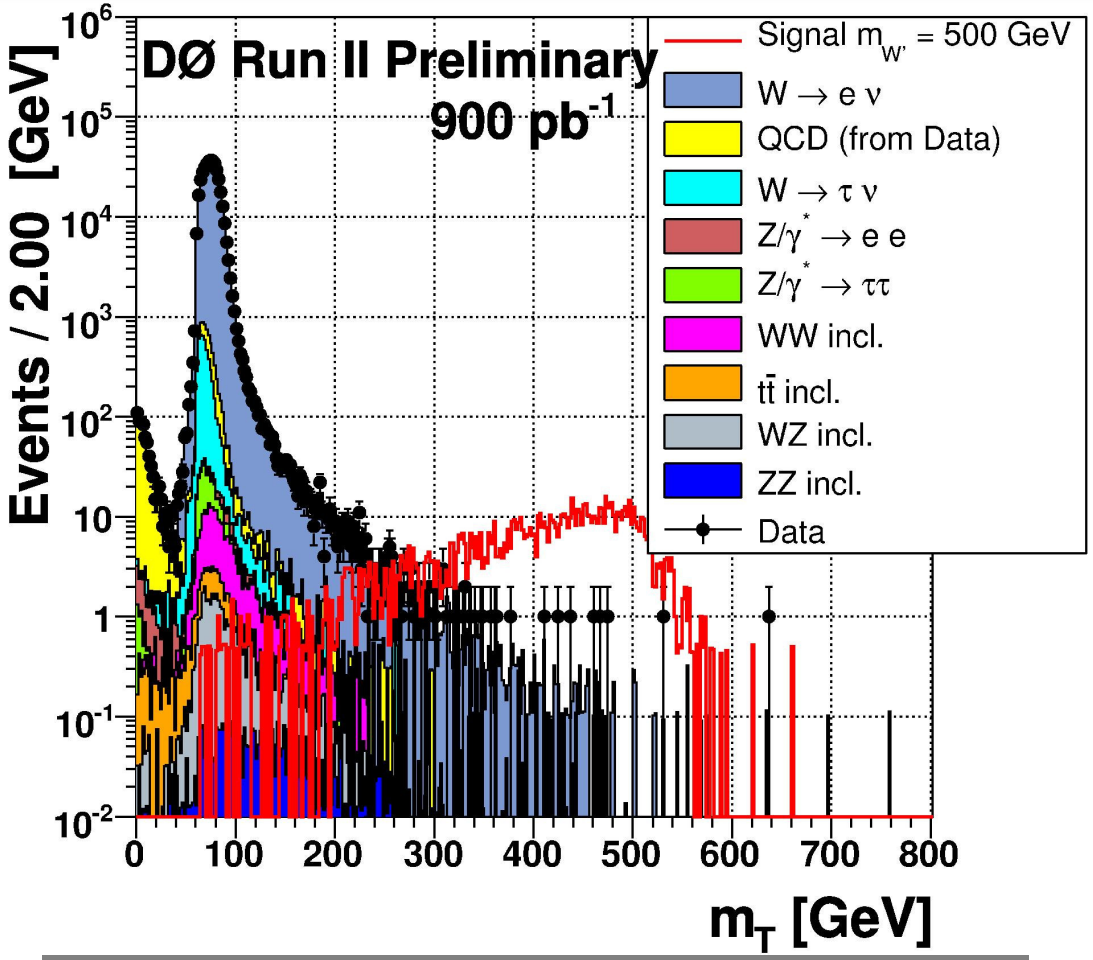
W′ : Result

MET



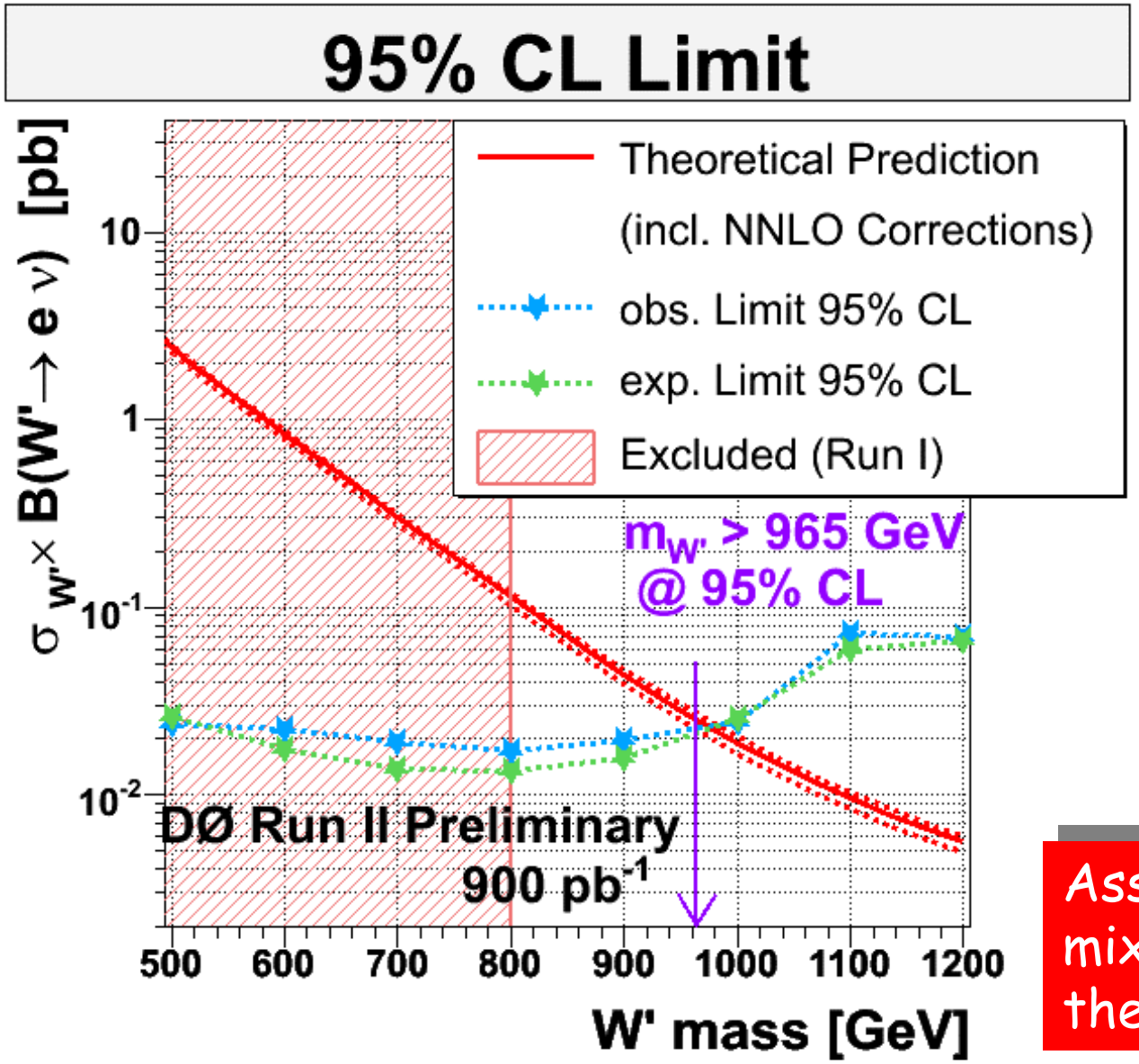
m_T >	Data	MC
150 GeV	630	623 ± 18 (stat) ± 79 (sys)
200 GeV	199	211 ± 9 (stat) ± 28 (sys)
300 GeV	31	31 ± 2 (stat) ± 6 (sys)
400 GeV	8	8 ± 1 (stat) ± 2 (sys)
500 GeV	2	2 ± 1 (stat) ± 1 (sys)

Transverse Mass m_T



Good agreement between data and sum of backgrounds

W´ : Limit



Limit :

Use m_T distribution
(m_T > 150 GeV)
→ **shape information**

Uncertainties :

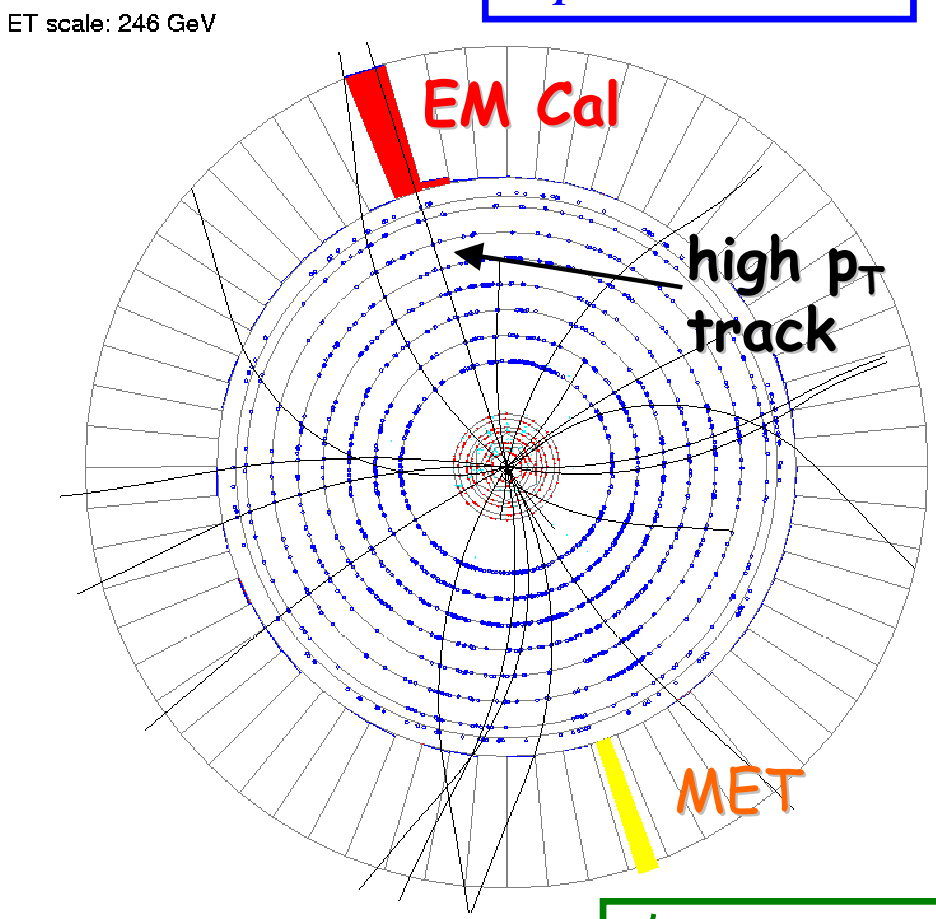
Cross sections, normalization, QCD scaling, efficiency corrections, PDF, electron energy scale

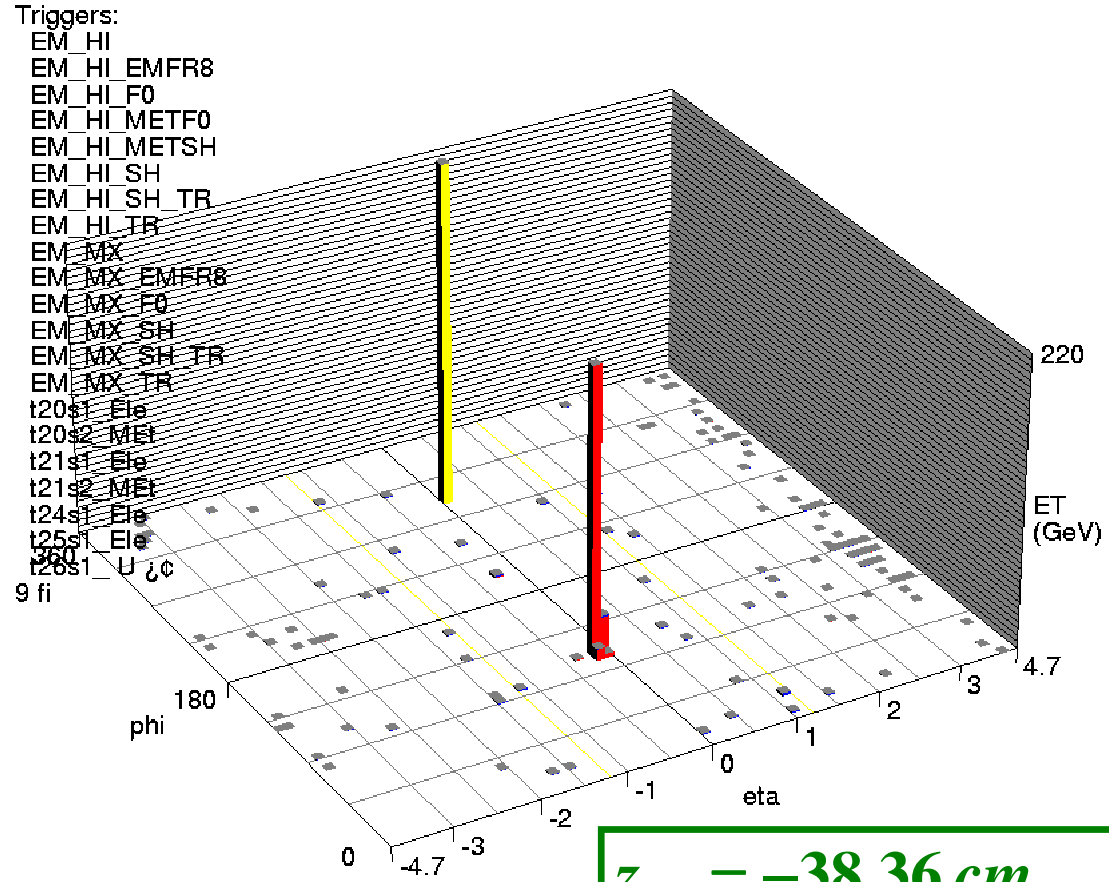
~ 15%

Assuming SM couplings and no mixing with new gauge groups the mass limit is **965 GeV**

W´: Event Display

$$m_T = 530\,GeV$$



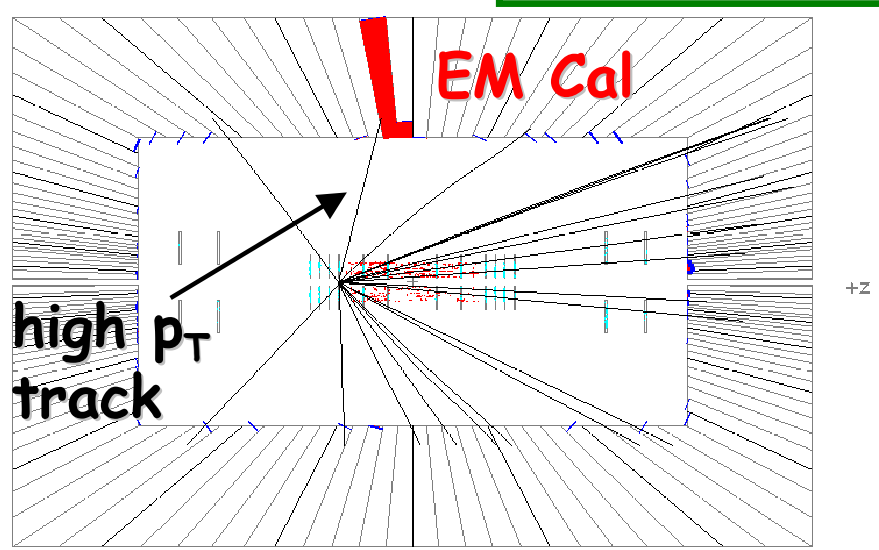


$$z_{vtx} = -38.36\,cm$$

$$|z_{vtx} - z_e| = 0.04\,cm$$

$$\not{E}_T = 265\,GeV$$

$$E_T^{el} = 265\,GeV$$



Conclusion and Outlook

- interesting signatures to look for at the Tevatron
- presented 3 new analyses :
  - Search for Randall-Sundrum Gravitons in diEM spectrum
  - Search for excited electrons
  - Search for W´ in electron + MET final state
- in 1 fb^{-1} no evidence for ‚New Physics' found -> new restrictive limits

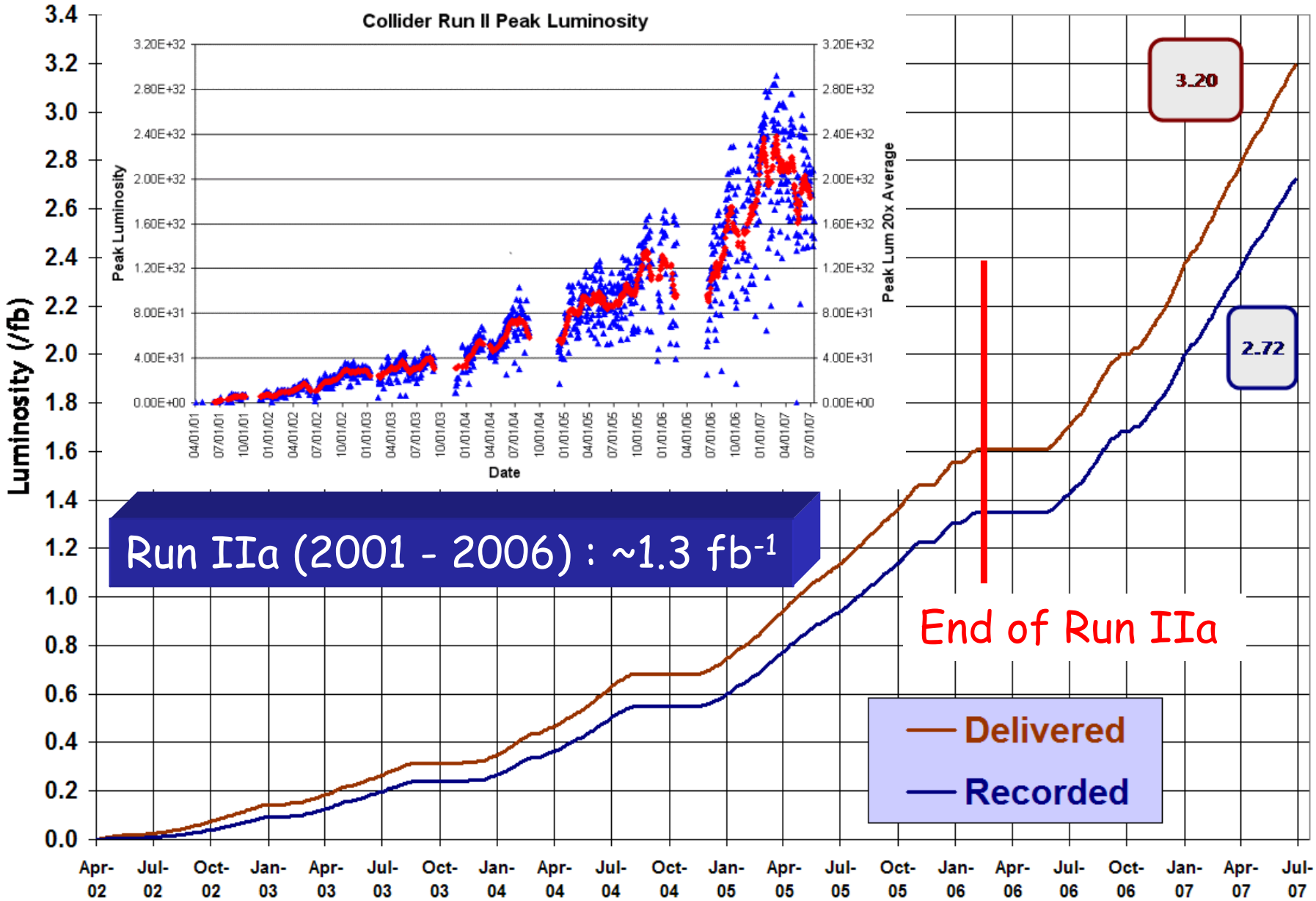
- ✓ For $k\sqrt{8\pi}/M_{Planck} = 0.1$ mass limit on RS Graviton is 865 GeV
- ✓ For Λ = 1 TeV the mass limit on e* is 756 GeV
- ✓ Mass limit for W´ is 965 GeV (SM couplings, no mixing)

Run IIb ongoing with improved accelerator & detector

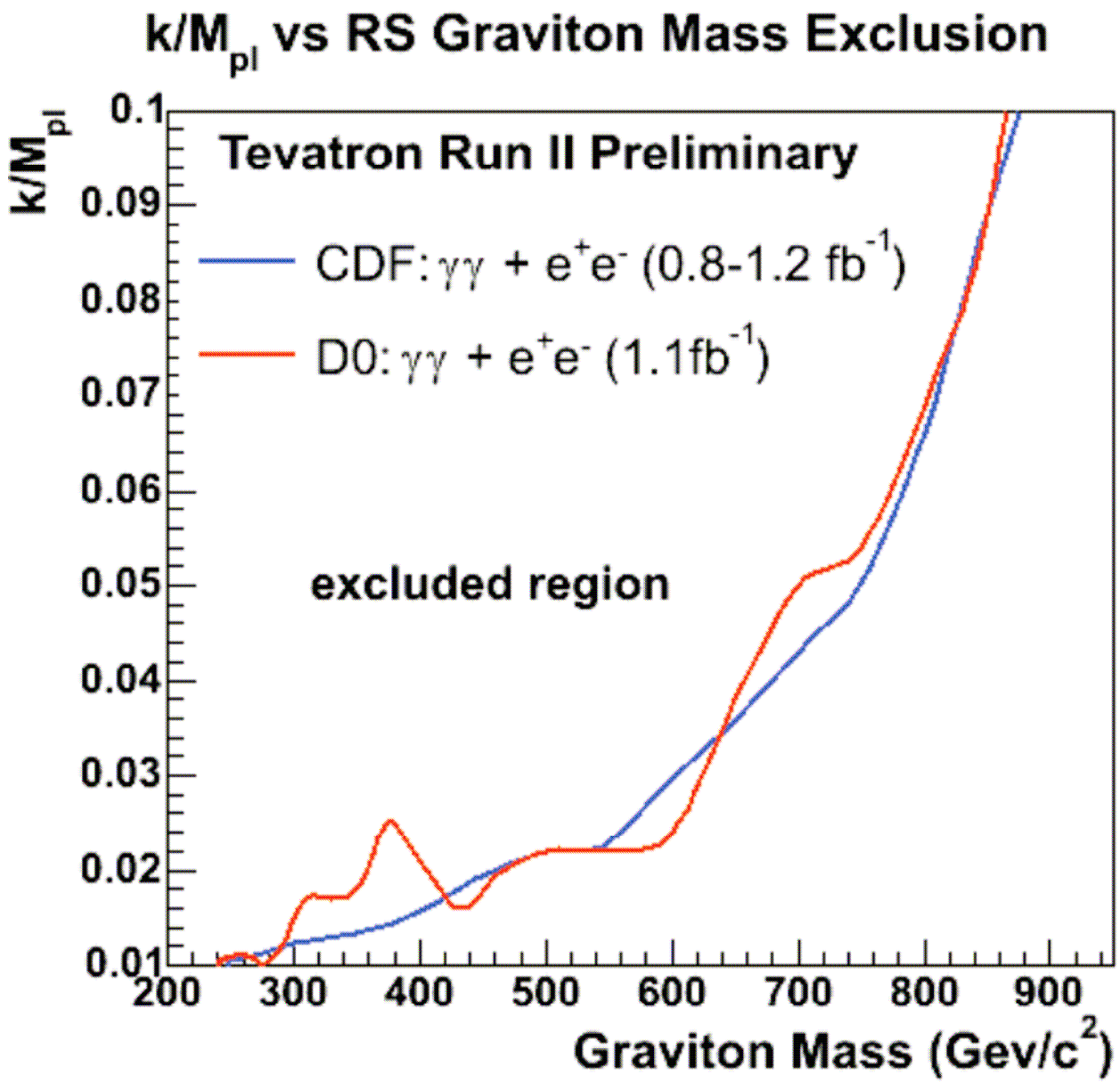
→ Reveal ‚New physics' with higher luminosity ???

Backup

Performance

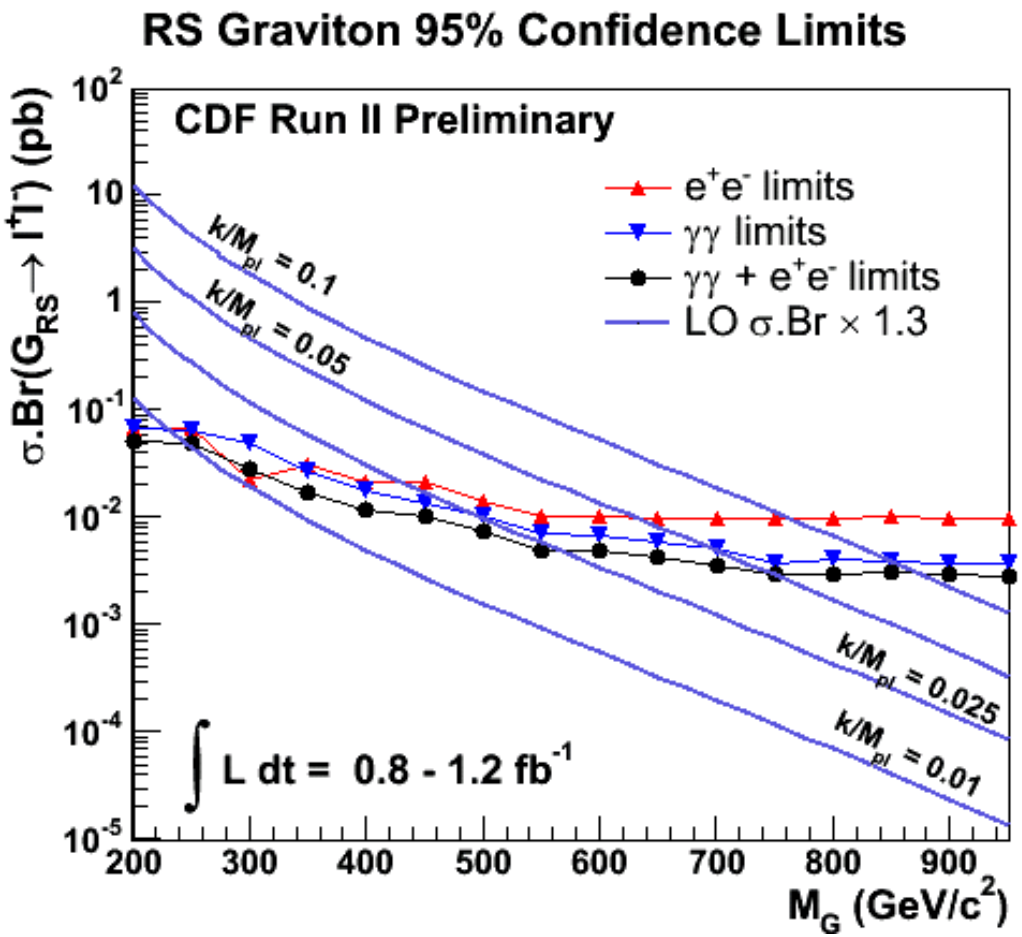


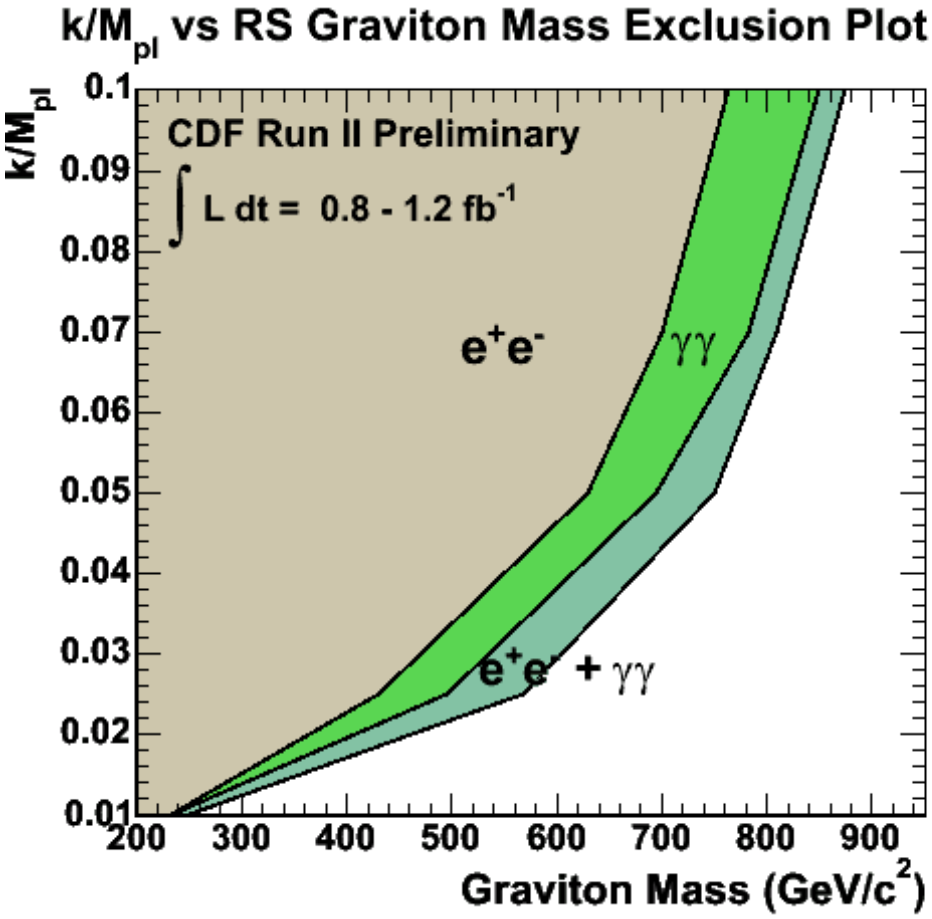
RS ED : CDF & DØ



P. Savard
ICHEP 2006

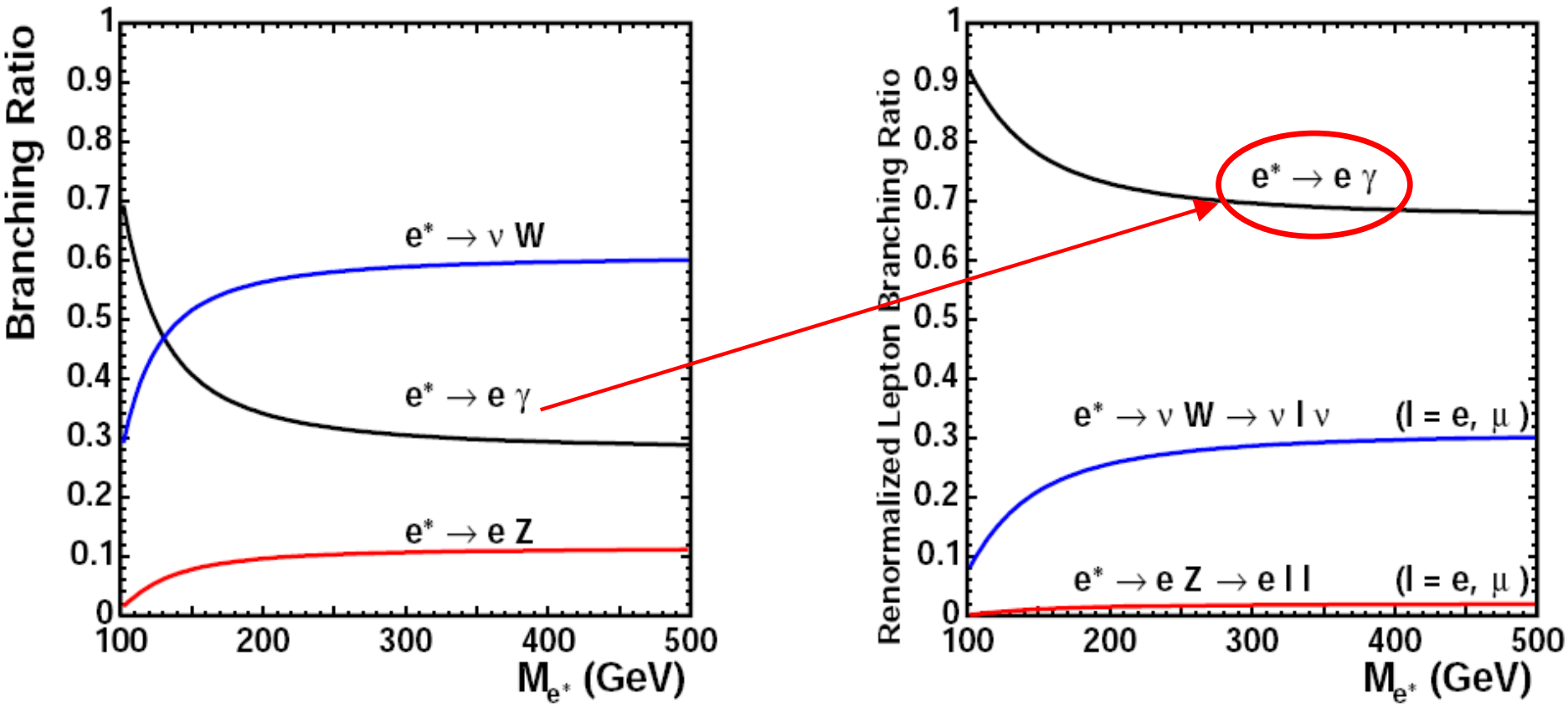
RS ED : CDF





For $k\sqrt{8\pi}\,/\,M_{Planck} = 0.1(0.01)$ mass limit on RS Graviton is 875 (242) GeV

Extension (II) : Excited Electrons e*



Lepton required for trigger, clean final state

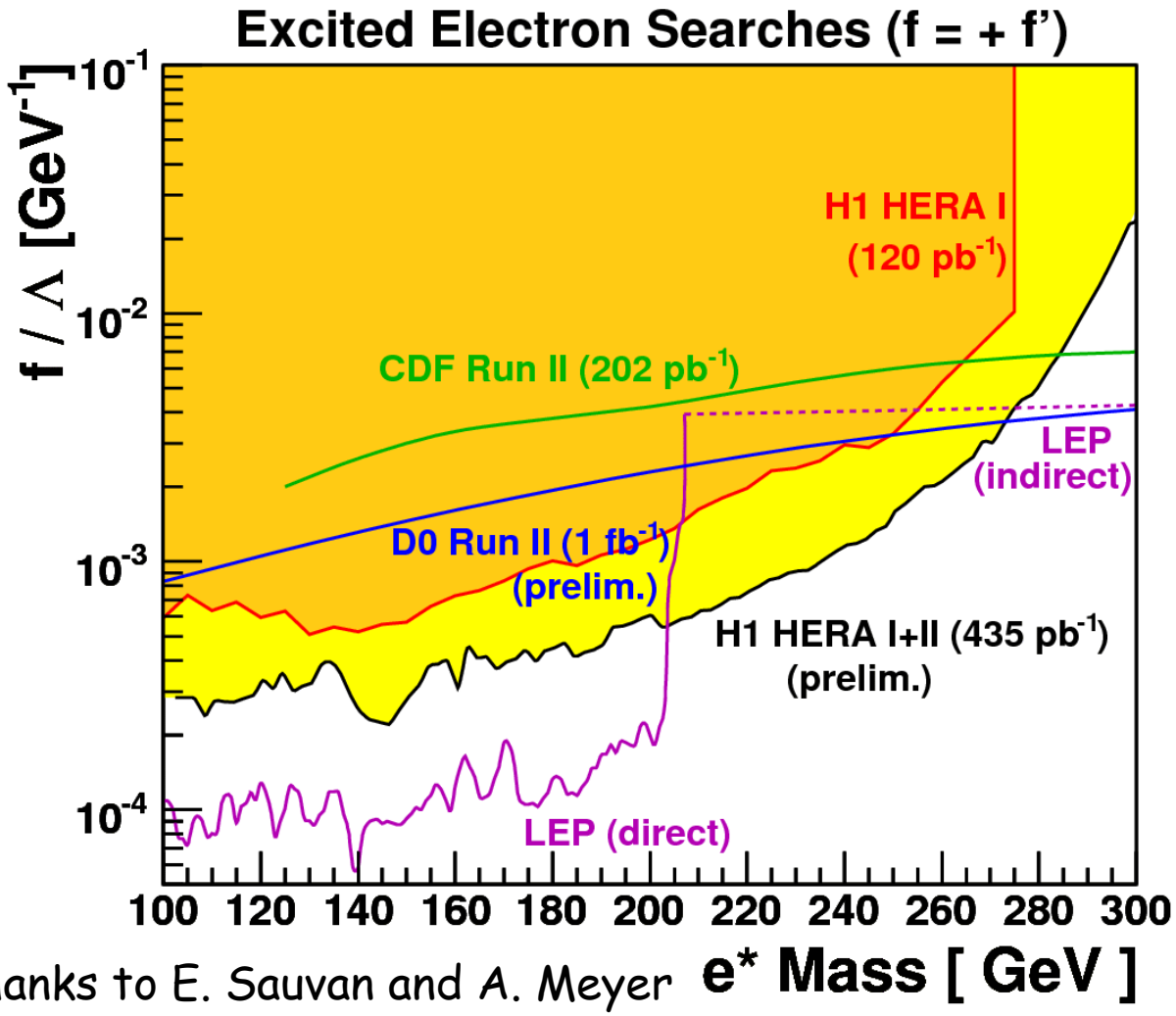
→ check BR für leptonic decays of W and Z

→ 70% of e* → lepton + X decays into ‚golden' channel $e^* \rightarrow e\gamma$

e* : Result

Gauge mediated Interaction :

$$\mathcal{L}_{GM} = \frac{1}{2\Lambda}\bar{F}^*_R\sigma^{\mu\nu}\left[gf\frac{\tau^a}{2}W^a_{\mu\nu} + g'f'\frac{Y}{2}B_{\mu\nu} + g_s f_s\frac{\lambda^a}{2}G^a_{\mu\nu}\right]F_L$$



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Note :
Contact Interaction contribution here neglected
Tevatron : CI ~ 100 * GM