Search for excited quarks and leptons in D0 RunII

Thomas Millet
On behalf of D0 Collaboration

APS – DPF 2006 & JPS 2006
Honolulu, October 29 – November 3,2006

Outline

I. Fermions substructure : a compositeness model

II. Two searches of excited fermions in D0 RunII

III. Search for excited muons produced by four-fermion contact interaction

IV. Search for excited quark decaying into a Z+q final state

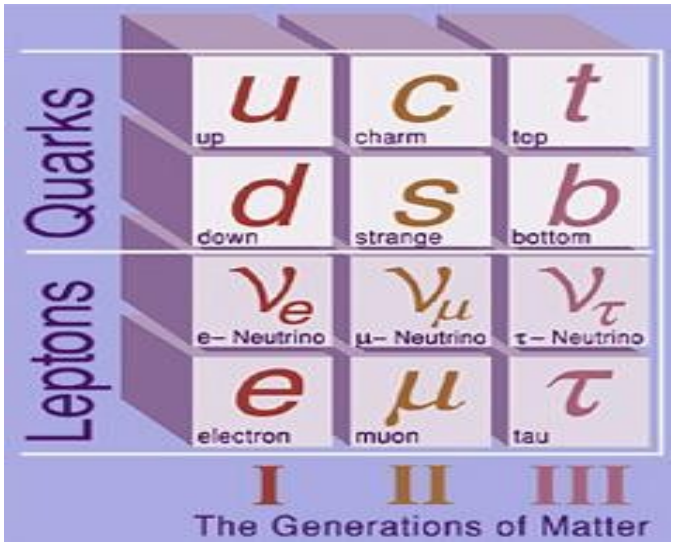
V. Conclusion

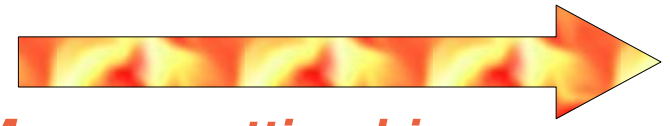
Fermions substructure : a compositeness model

- Motivation :
  - Explanation for the three generations
    - Excited fermion is a composite of a scalar and spin-1/2 constituent

  => Large spectrum of excited states

  => Search for heavy resonances





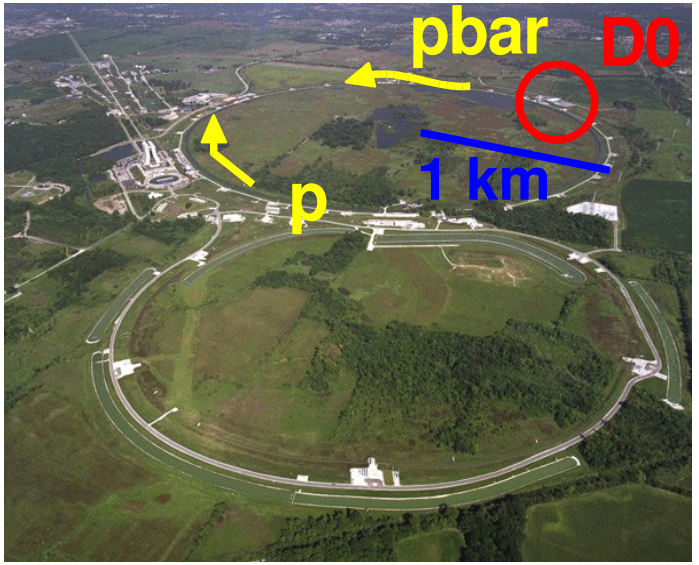
Masses getting bigger

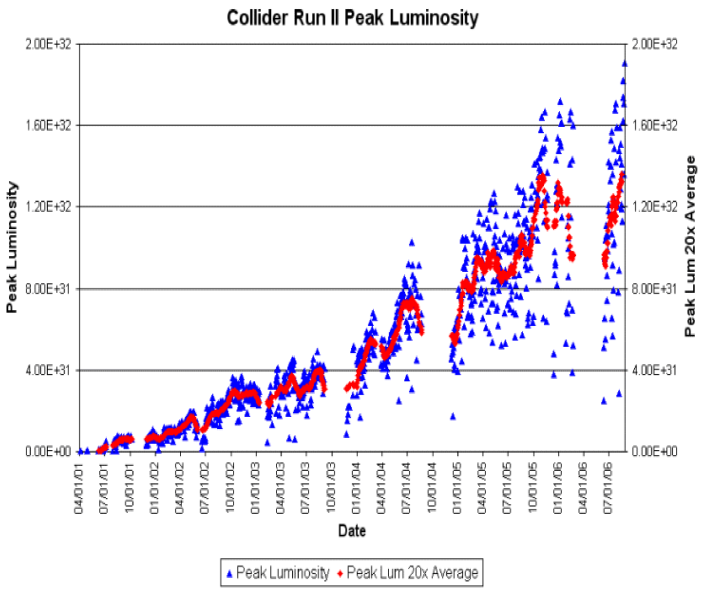
- Production of **excited fermions** :
  - Two parameters : **M(f*)**, Λ (compositeness scale)
    - Effective lagrangian for Gauge Interaction :

$$L_{eff} = \frac{1}{2\Lambda} F_R^x \sigma^{\mu\nu} \left(g f \frac{\tau^a}{2} \underbrace{W^a_{\mu\nu}}_{SU(2)} + g' f' \frac{Y}{2} \underbrace{B_{\mu\nu}}_{U(1)} + g_s f_s \frac{\lambda^a}{2} \underbrace{G^a_{\mu\nu}}_{SU(3)} \right) F_L + h.c.$$

Two searches of excited fermions in D0 RunII

- Protons-antiprotons collisions :
  - $\sqrt{s} = 1.96$ TeV
- Integrated luminosity :
  - ~ ***380 pb^{-1}*** (Aug 2002 - Sep 2004) for excited muons search
    - Phys. Rev. **D73**, 111102 (2006)
  - ~ ***370 pb^{-1}*** (Apr 2002 - Aug 2004) for excited quarks search
    - Phys. Rev. **D74**, 011104 (2006)
  - Fraction of the total luminosity of the RunII (Apr 2001 – Mar 2006) : ~**1.2 fb^{-1}**

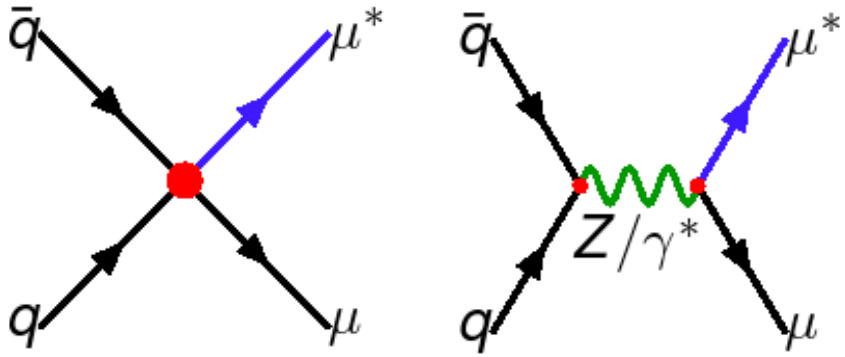




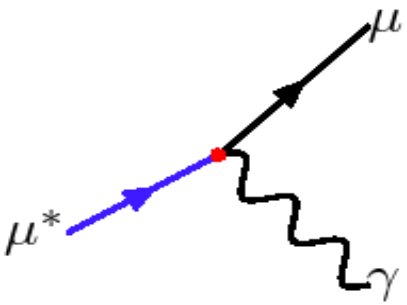
Search for excited muons produced by four-fermion contact interaction

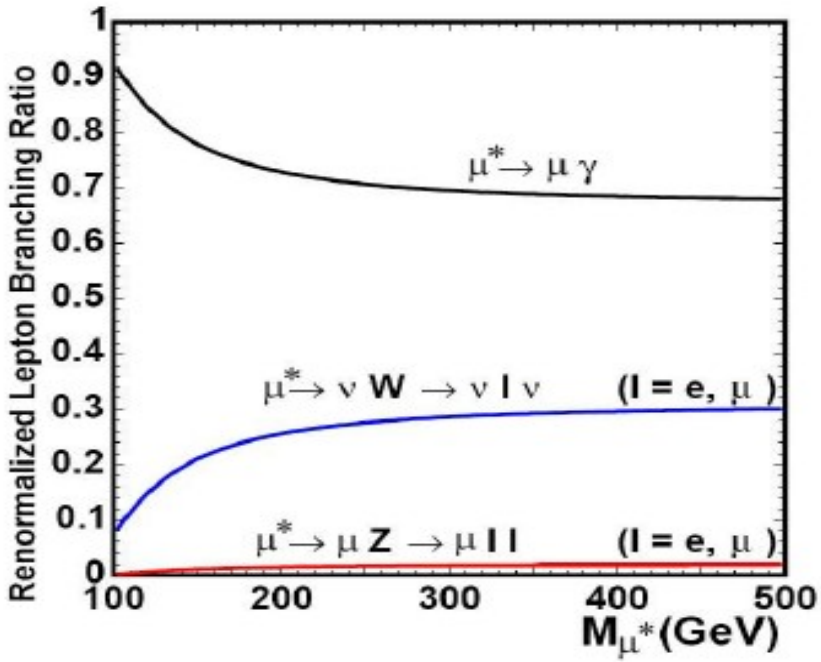
- Production :
  - The *CI* is dominant

$$L_{CI} = \frac{g^2}{2\Lambda^2} j^{\mu} j_{\mu}$$

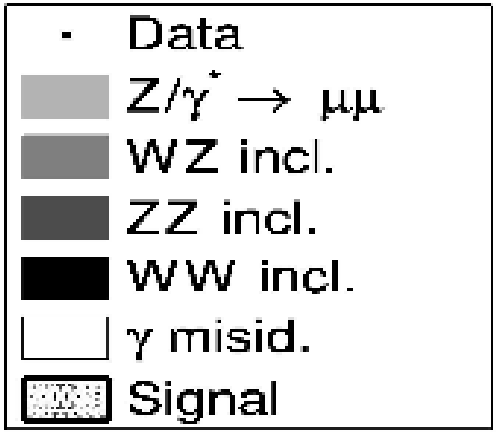


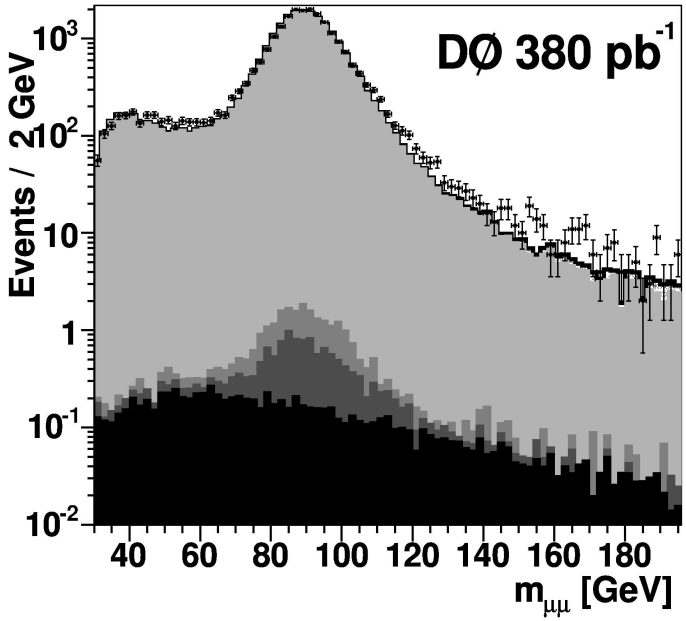
- Decay :
  - **Leptonic decay** prefered (better S/B and easier trigger and ID in an hadronic collider)
  - Signature : ***μμγ***



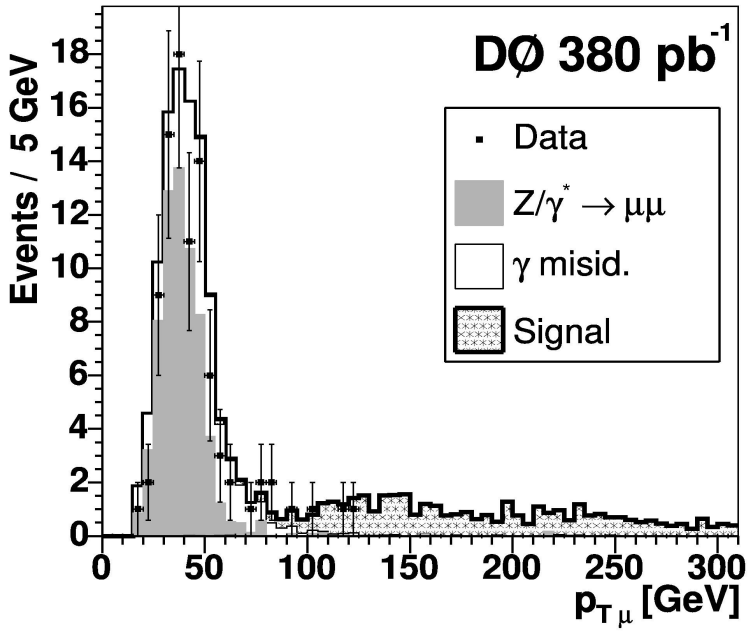


- Clear signal with very small QCD background
- The largest SM background :
  - Drell-Yan : $p\,\bar{p} \rightarrow Z/\gamma* \rightarrow \mu\,\mu(\gamma)$
- Muons selection :
  - Dimuon triggers
  - 2 isolated muons (p_T > 15 GeV) in the muon system with a matched track in the central tracking system

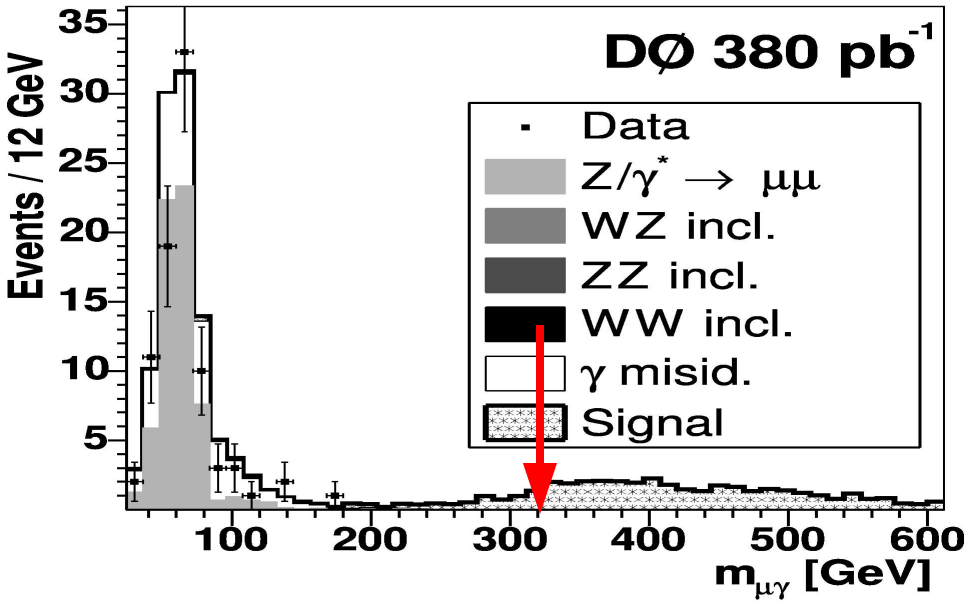




- Photon selection :
  - Isolated photon (E_T > 16 GeV) in the central part of the calorimeter ($|\eta|$<1.1)
  - Separated from the muons candidates

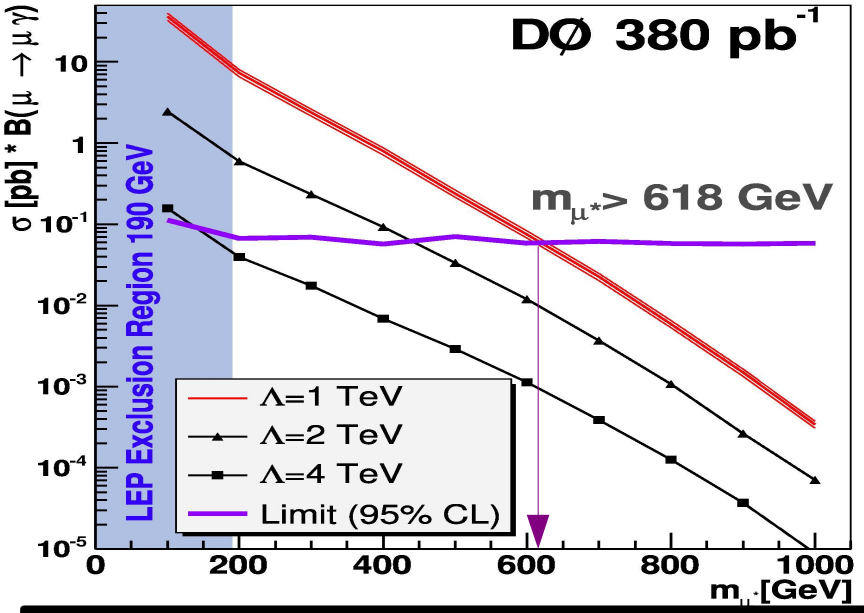


- Final selection : cut on M(μγ) depending on M(μ*) :
  - Example for 400 GeV (cut at 330 GeV)



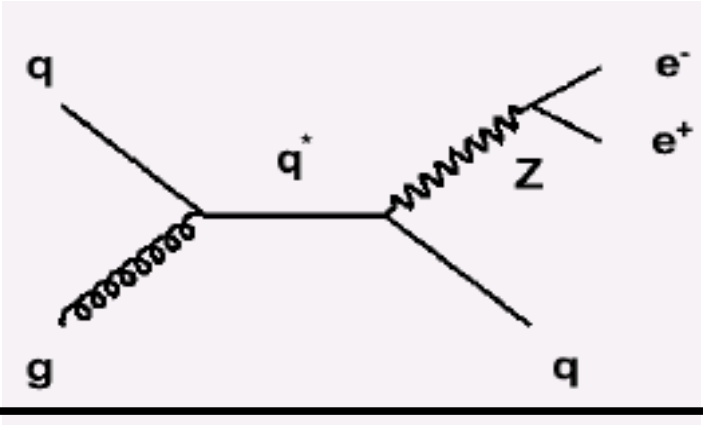
- Results :
  - No excess found in the data compared to the theoretical predictions

m(μ^*) (GeV)	Data	SM prediction	Signal eff (%)
100	0	0.170 ± 0.126	7.5 ± 1.0
200	0	0.170 ± 0.126	12.5 ± 1.5
300	0	0.041 ± 0.023	12.1 ± 1.5
400	0	0.016 ± 0.011	14.7 ± 1.8
500	0	0.003 ± 0.001	11.9 ± 1.5
600	0	0.003 ± 0.001	14.4 ± 1.8
700	0	0.003 ± 0.001	13.6 ± 1.7
800	0	0.003 ± 0.001	14.5 ± 1.8
900	0	0.003 ± 0.001	14.7 ± 1.8
1000	0	0.003 ± 0.001	14.4 ± 1.8



m(μ*) > 618 GeV for Λ = 1 TeV
m(μ*) > 688 GeV for Λ = m(μ*)

Search for excited quark decaying into a Z+jets final state

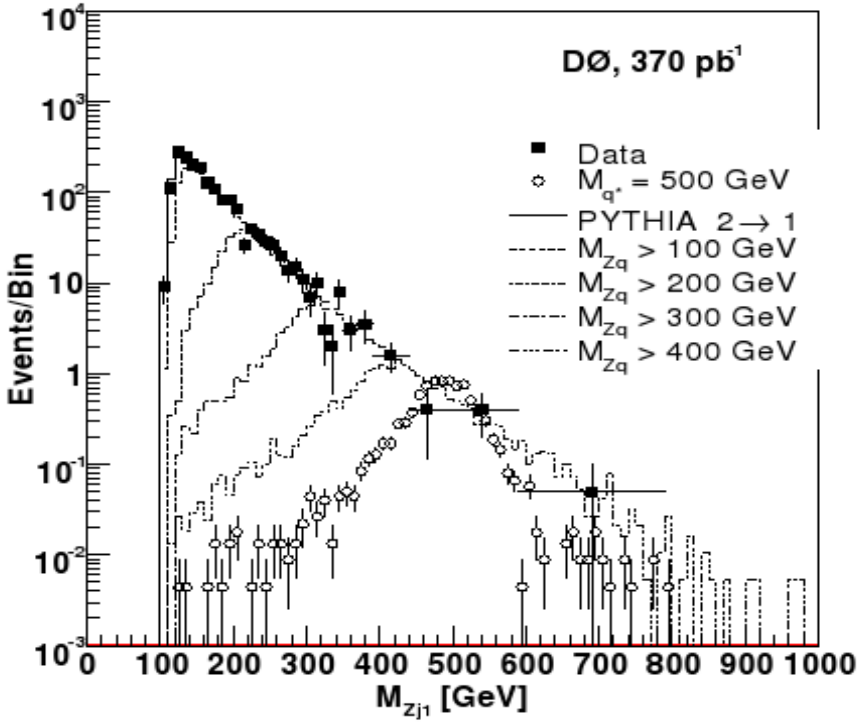


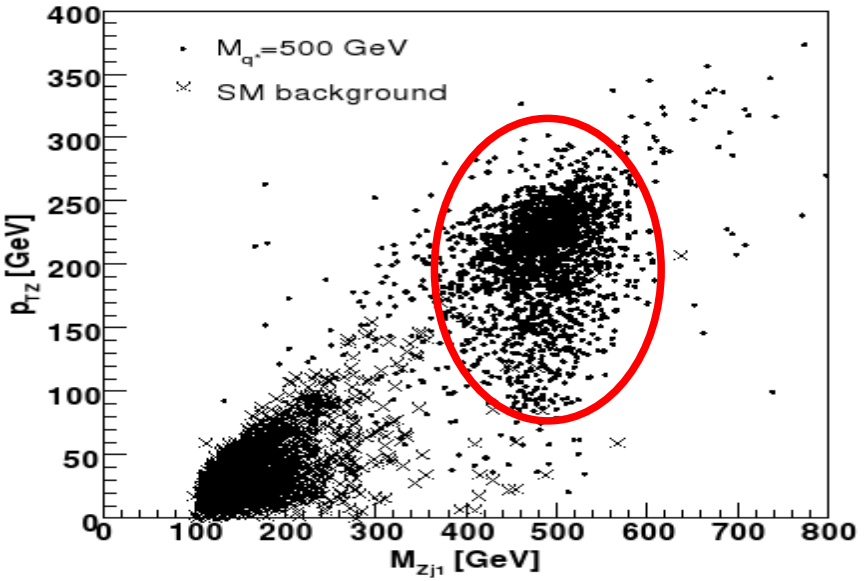
Feynman diagram for the signal (Gauge interaction)

- Search :
  - Model independent in **eeq**
- Motivation :
  - Search of massive resonance induced by new physics
  - The Z decay into a pair of electrons :
    - small branching ratio 3.36%
    - but : clear signature and low background + good mass resolution
    - Such a signal studied for the first time

- Preselection cuts :
  - 2 isolated electrons candidates (p_T > 30 GeV, p_T > 25 GeV)
    - at least one with matching track
  - Invariant electron pair mass :
    - 80 < M_{ee} < 102 GeV
- Background :
  - Instrumental background :
    - QCD events with hadronic jets misreconstructed as EM clusters: **(0.56 ± 0.02)%** of the selected events after preselection cuts
    - W+jets events where a hadronic jet is misidentified as an electron : an order of magnitude less than the QCD background
  - Dominant Physics background : **Z+jets**

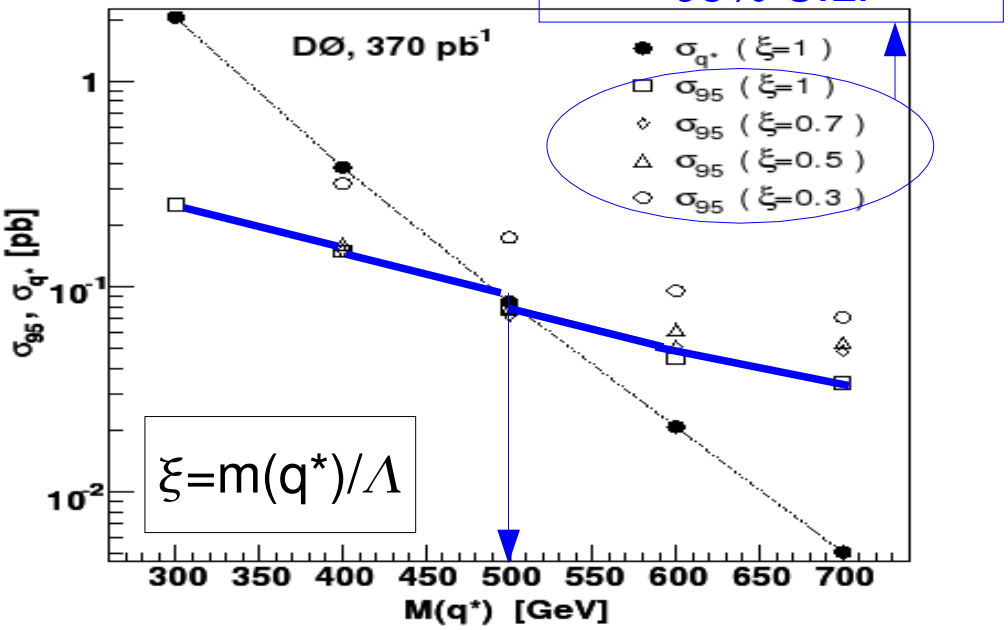
- Z+jets events simulation :
  - PYTHIA : 2→2 process with different thresholds of M_{zq} (used for different heavy resonance masses)
- Final cuts :
  - 2D cut on p_{Tz} vs M_{zj1} optimized as a function of the heavy resonance mass ($p_{Tz} \approx 0.5 \times M_{zj1}$ for the signal)





- Results
  - No evidence of heavy resonance

Upper limits on the cross section at the 95% C.L.



m(q*) = Λ (GeV)	Data	SM predictions	Signal Eff. (%)
300	31	32.8 ± 2.9	14.0 ± 0.9
400	9	7.5 ± 0.8	16.4 ± 1.0
500	3	2.9 ± 0.8	19.5 ± 1.2
600	1	1.6 ± 0.6	24.4 ± 1.4

Decay	Mass limits (GeV)	Collaboration
q*→qγ	460	CDF *Phys. Rev. Lett.* **72**, 3004 (1994)
q*→qW	530	CDF *Phys. Rev. Lett.* **72**, 3004 (1994)
q*→qg	775	D0 *Phys. Rev. D.* **69**, 111101(R) (2004)

m(q*) > 510 GeV for Λ = m(q*)

Conclusion

- The mass limits on the excited muons are **the most stringent** limits to date.
- The study on the excited quark is **complementary** to earlier searches and has sensitivity to hypothetical models with enhanced couplings to the Z boson.

BACKUP SLIDES

The D0 detector

- Several layered subdetectors :
  - Lar/U calorimeter
    - $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$ ($\eta = -\ln(\tan(\theta/2))$)
    - hermetic and fine granularity

    => E(jets), mE_T
  - Tracking system (B = 2T)
    - Silicon Microstrip Tracker
    - Central Fiber Tracker
  - Muon system (toroid)
    - Good rapidity coverage