XXI International Symposium on Lepton and Photon Interactions at High Energies
Fermilab, 11-16 August 2003

Searches for New Phenomena at Current Colliders : Status and Prospects

Emmanuelle PEREZ
CEA-Saclay, DSM / DAPNIA / Spp

- Not Higgs, not SUSY (cf M. Schmitt's talk)…
- Emphasis on recent results
- Selected topics …

"Exotic" Physics : Why ?

- SM works so far, but raises a crucial question :

Where/what is the Higgs boson ?

Fundamental scalar field ??

yes → Hierarchy pb → Supersymmetry / Extra-dimensions / "Little" hierarchy

no → Dynamical Breaking of EW → technicolor, topcolor

- Questions which the SM (or SM + SUSY) does not answer :
  - Quantization of EM charge — Symmetry leptons-quarks ? Magnetic Monopoles ?
  - Mass terms for ν's ? — ν_R, Higgs triplets, RpV SUSY ?
  - "Replication" of three families ? — Compositeness ? Superstrings ?
  - Additionnal source of CP ? — SUSY (phases), additionnal quarks ?
  - Extra-dimensions ?
  - Particle masses & their hierar — Axions, $m_u = 0$?
  - Strong CP problem ? — Horizontal Symmetries ?
  - Flavor ? ……………

Where to look for ?

- In rare meson decays
- In Lepton Flavor Violating processes (e, e conversion in nuclei ...)
- In the sky (Cold Dark Matter, SN, red giants...)
- Various other places, amongst which : High Energy Colliders

The subject of this talk

LEP

e^+e^-, s = 91 – 209 GeV, ended in nov 2000

ALEPH, DELPHI, L3, OPAL

"tail" of analyses

 900 pb^{-1} per experiment

HERA

$e^{\pm}p$, s = 300 – 320 GeV

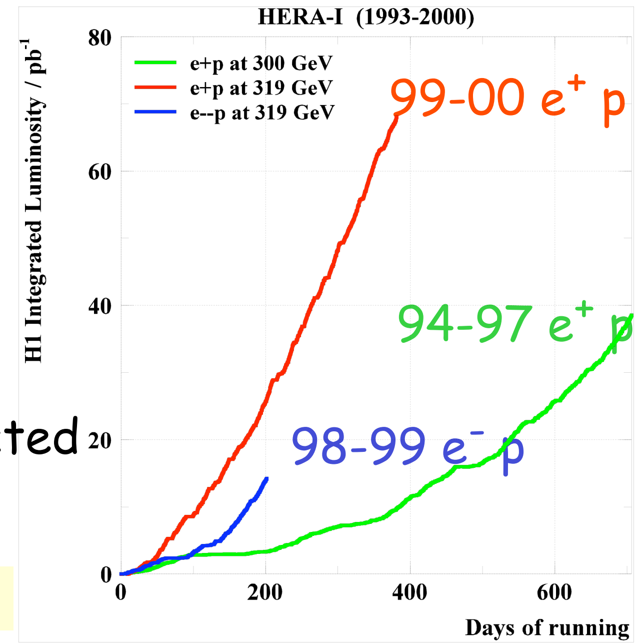
H1 / ZEUS (colliding experiments)

until summer 2000 : 120 pb^{-1} / expt

Restart (fall 01) more difficult than expected

Expect high $\mathcal{L}$ (high I_e/I_p) back in sep 03

1 fb^{-1} till 2006



Tevatron

$p\bar{p}$, s = 1800 – 2000 GeV

see previous talks

CDF / D0

Run I (92 – 96) : 110 pb^{-1} / expt

Restart in may 2001   300 pb^{-1} delivered by Tevatron.

> 210 pb^{-1} delivered (mid-July) since detectors are fully operationnal

Run II analyses presented here based on 100-130 pb^{-1}

2 fb^{-1} in 06-07

Any Hints for New Physics ?

Yes. Neutrinos do oscillate ! But no strong implication in the charged sector…

- Atomic Parity Violation : weak charge in Cs measured to 0.6 % (1997)

  > 2σ discrepancy with expectation until last spring

  SM prediction revised – now very good agreement

  Latest : Kuchiev & Flambaum, hep-ph/0305053

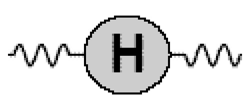
- $\sin^2\theta_W$ at NuTev ? Differs by $\approx 3\sigma$ from global SM analysis

  Not clear… theoretical uncertainty ? e.g. asymmetry in s-$\bar{s}$, violaton of isospin in parton distributions ?

- Excess in $b\bar{b}$ production ? May be not as large as initially suspected…

  Tevatron & HERA : discrepancy reduced… Still excess in $\gamma\gamma \to b\bar{b}$ at LEP…

- $(g-2)_\mu$?



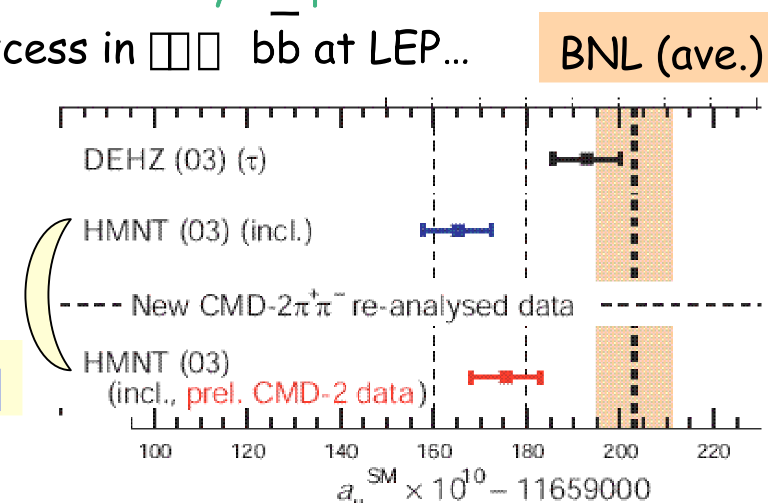
?

KLOE & BaBar enter the game via radiative return data

from $\tau \to \nu$ had

from $e^+e^- \to$ had

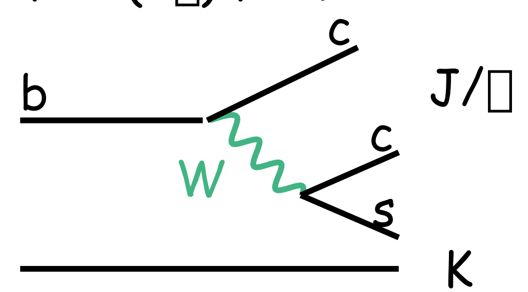
$\approx 2.5\sigma$



- Some interesting events / measurements at colliders … Some examples shown in the next slides…

New Physics in $B \to \phi K_s$?

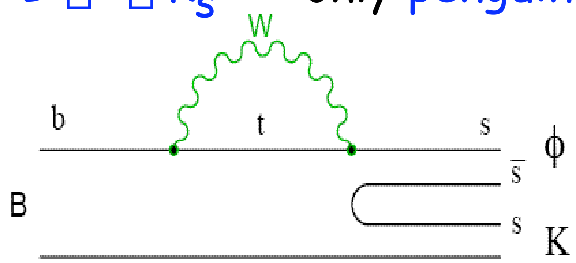
At ICHEP '02 BaBar & Belle reported a measurement of $\sin(2\beta)$ from :



- $B \to J/\psi K_s$ dominated by a tree-level amplitude

  Average (2002) : $\sin(2\beta) = 0.734 \pm 0.054$

- $B \to \phi K_s$ only penguin contributions



BaBar : $\sin(2\beta) = -0.19\ ^{+0.52}_{-0.50} \pm 0.09$

Belle : $\sin(2\beta) = -0.73 \pm 0.64 \pm 0.22$

(2002)

Average : $\sin(2\beta) = -0.39 \pm 0.41$

In the SM both should be the same within < 4 %

Discrepancy of $\sim 2.7\ \sigma$

Hint of new physics in $B \to \phi K$? (NP effects might be large in loop induced processes)

Triggered various speculations...

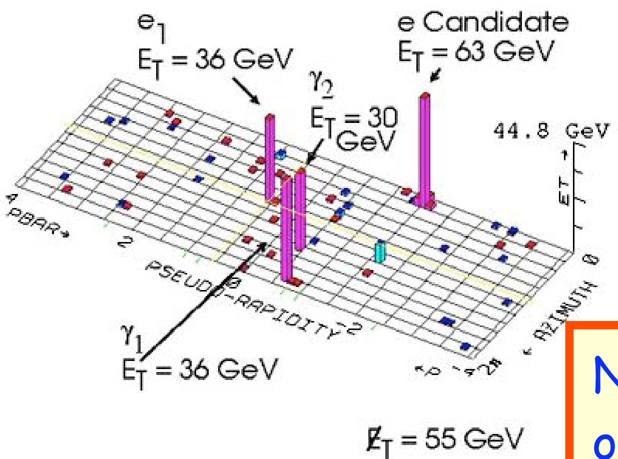
SUSY (non-universality), some 2HDM models, extra down quark...

Constrained by B mixing and $b \to s\gamma$...

Looking forward to reducing stat. error in $\sin(2\beta)_{\phi K}$!

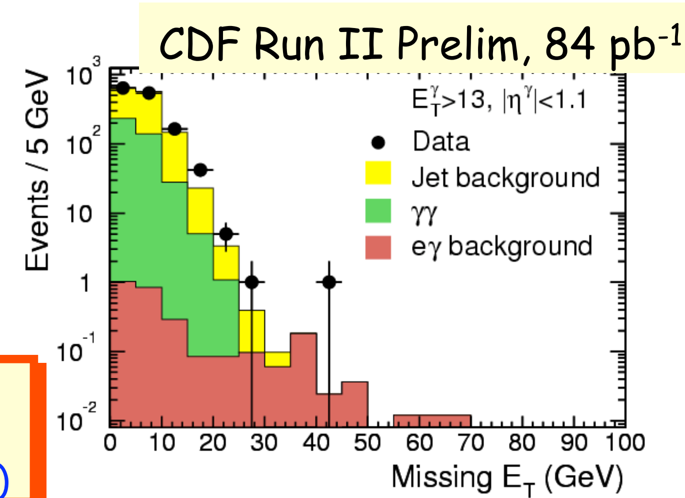
(Run I) CDF events with γ + $E_{T,miss}$ + X

- Run I eeγγ + $E_{T,miss}$ event : triggered a lot of activity... (10^{-6} evt expected !)



Run II data : look for events with two central γs

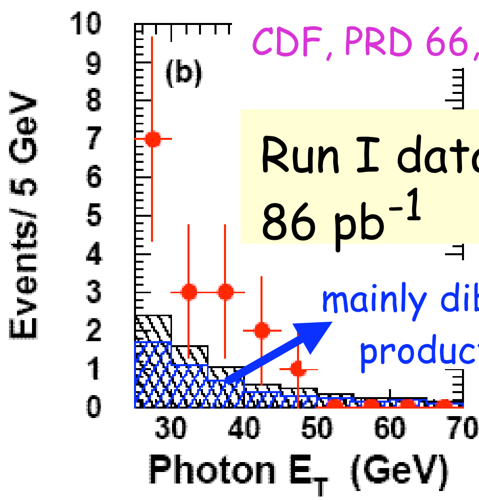
⚠ Better hermiticity of Run II detector !



No such spectacular evt observed so far ! (CDF & D0)

- Run I data : slight excess of evts with high E_T lepton & γ + large $E_{T,miss}$

CDF, PRD 66, 012004 (02)



Run I data, 86 pb^{-1}

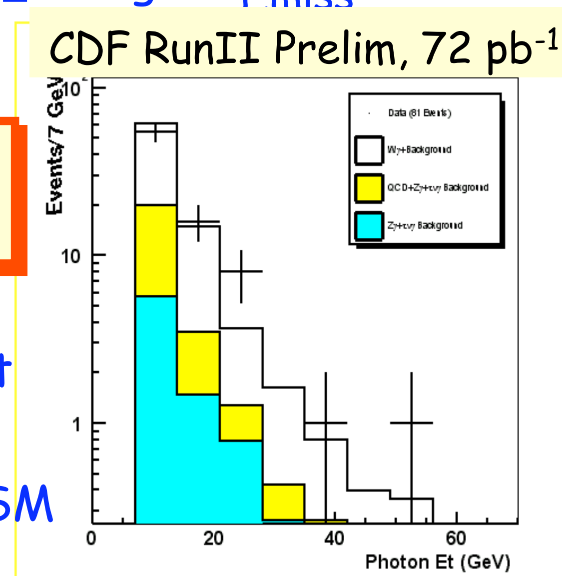
mainly diboson production

	e+γ
Obs.	16
Exp.	7.6 ± 0.7

(excess mainly in γ channel)

Not confirmed by RunII data

W γ production at Run II : good agreement with SM

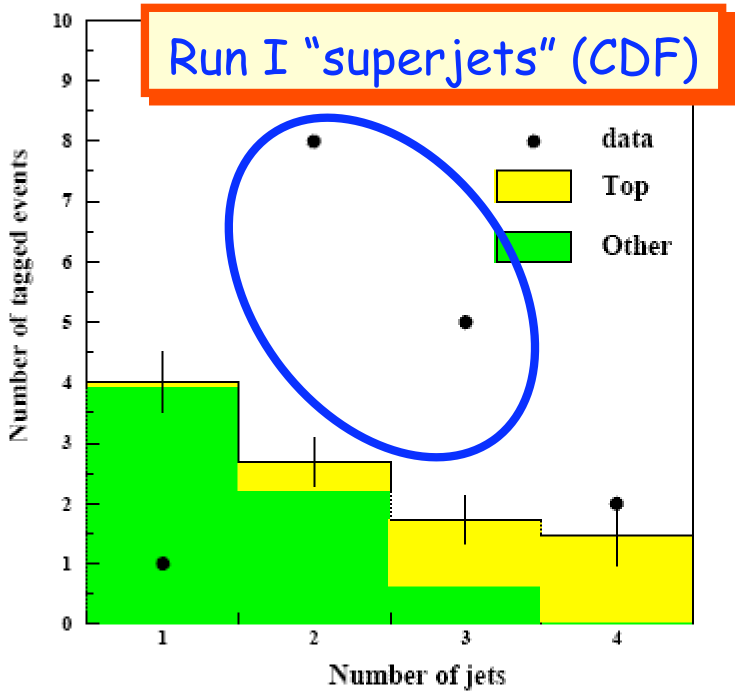


CDF "superjets" Events

Run I CDF data : excess of W + 2,3 jets where both a secondary vertex and a soft lepton are found in one jet ("superjets")

CDF Collab, PRD 65 (2002) 052007

13 evts observed, 4.4 ± 0.6 expected



- atypical kinematic properties
- SM reproduces well closely related data samples
- many, many checks; e.g. that the correlation of SVX and SLT taggers are well described by simulation

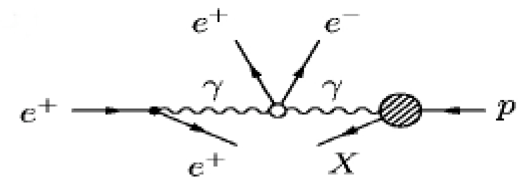
No explanation for this excess.
Probability (stat. fluctuation) ≈ 0.1 %

No statement yet from Run II. Good performance of b-tagging in both experiments, but correlations between taggers not yet studied. Work is going on in both experiments.

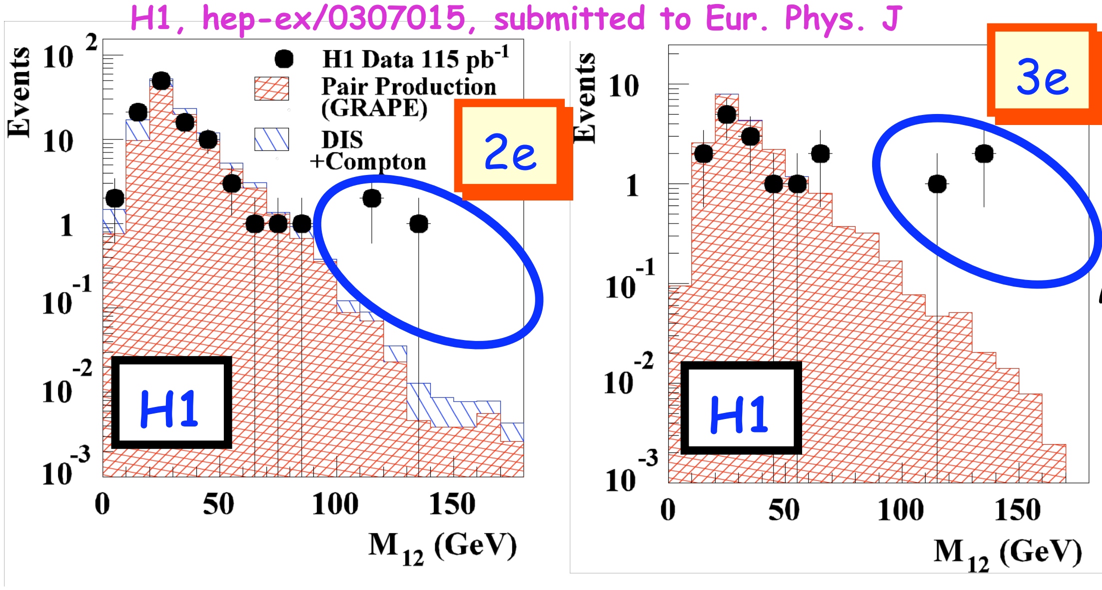
HERA multilepton events

Search for events with several leptons in final state

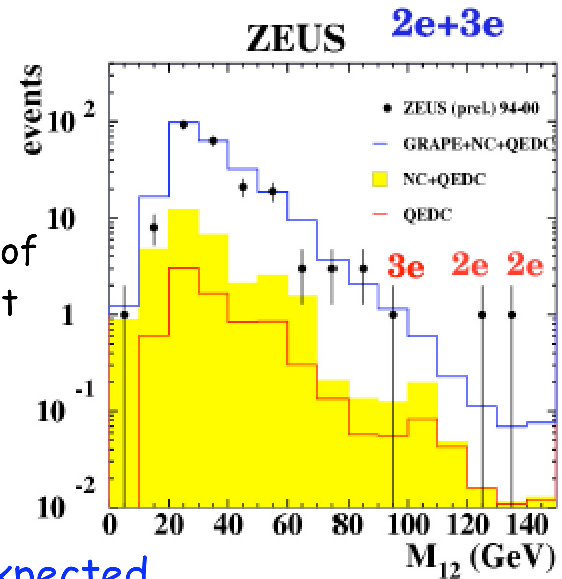
Mainly produced via γγ collisions

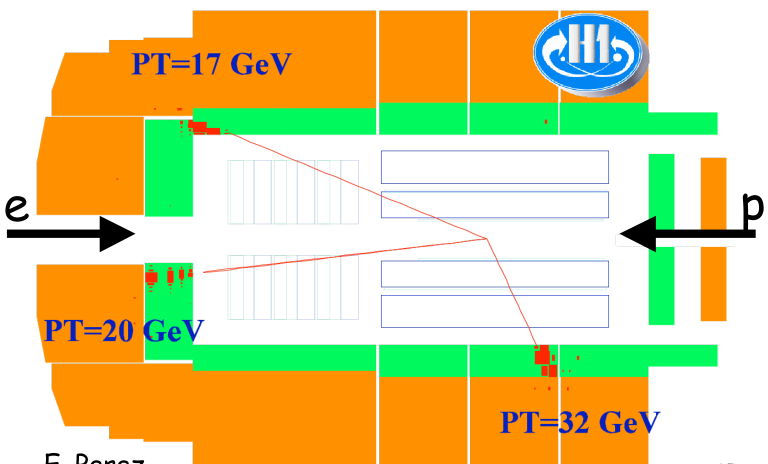


H1, hep-ex/0307015, submitted to Eur. Phys. J



M_{12} = mass of two highest P_T e





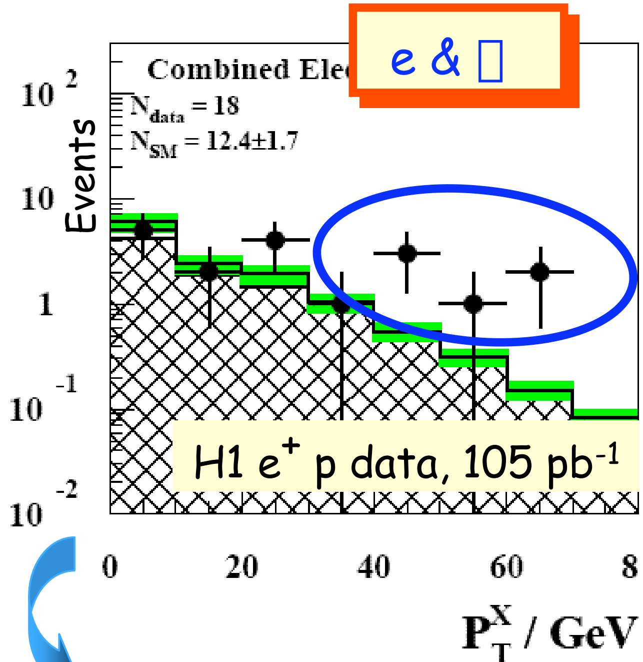
observed / expected

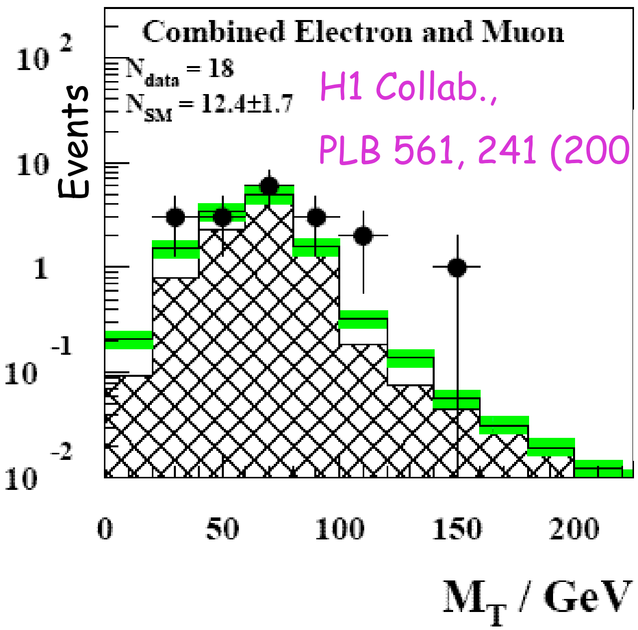
selection \ expt	H1 (115 pb^{-1})	ZEUS (130 pb^{-1})
2e, M > 100 GeV	3 / 0.30 ± 0.04	2 / 0.77 ± 0.08
3e, M > 100 GeV	3 / 0.23 ± 0.04	0 / 0.37 ± 0.04

(different angular ranges in H1 / ZEUS analyses)

No excess in ep → ee X

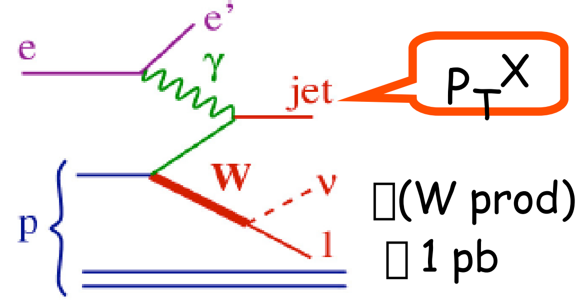
HERA events with isolated lepton + $P_{T,miss}$





e p □ l + jet + $P_{T,miss}$

Main SM contribution :

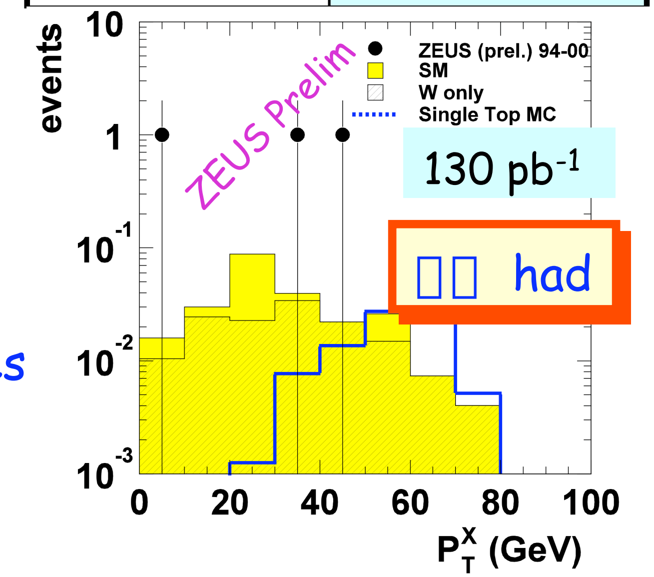


□(W prod) □ 1 pb

ZEUS $e^{\pm}$ p data	□ channel
$P_T^X > 25$ GeV	2 / 0.12 ± 0.02
$P_T^X > 40$ GeV	1 / 0.06 ± 0.01

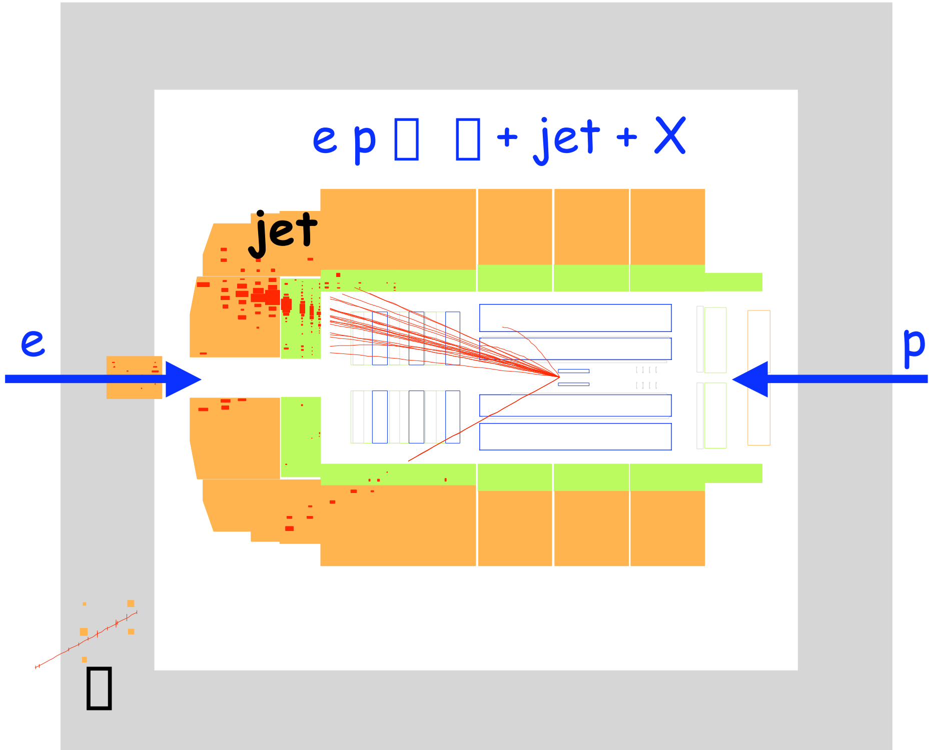
observed / expected

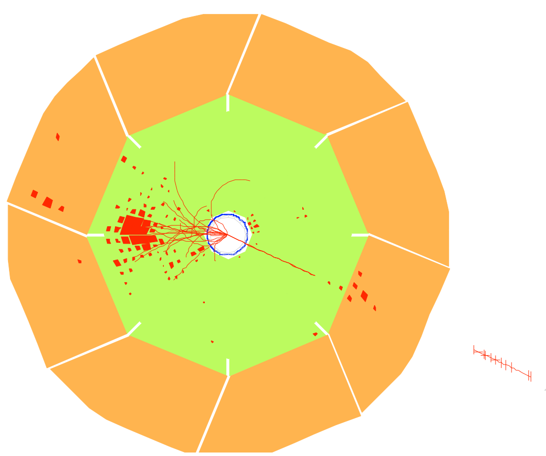
H1 e^+ p data	e channel	□ channel	Combined e & □
$P_T^X > 25$ GeV	4 / 1.48 ± 0.25	6 / 1.44 ± 0.25	10 / 2.92 ± 0.49
$P_T^X > 40$ GeV	3 / 0.54 ± 0.11	3 / 0.55 ± 0.12	6 / 1.08 ± 0.22



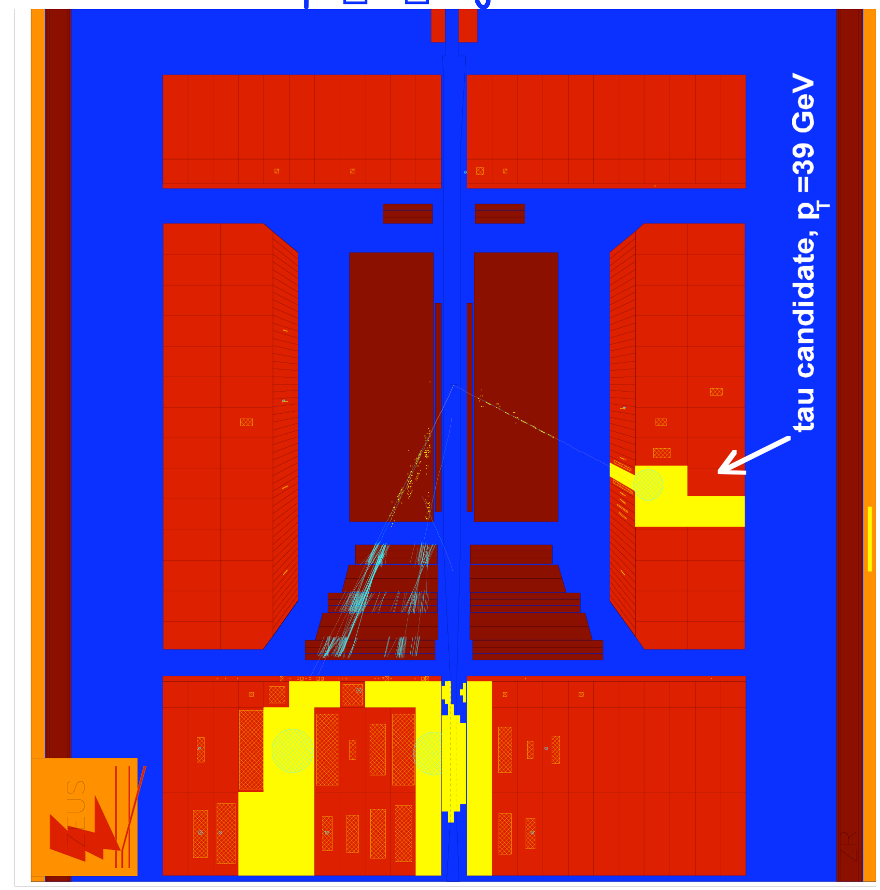
- No excess in H1 e^- p data
- No excess in ZEUS data in e & □ channels, □ candidates
- Agreement in the had. channel (but large bckgd)
- W prod : full NLO corrections included (recently available)

HERA events with isolated lepton + $P_{T,miss}$





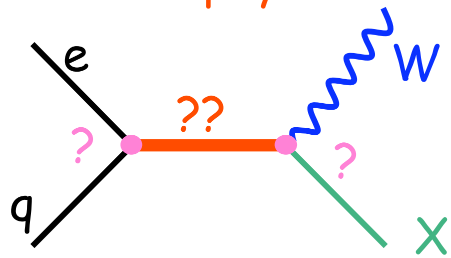
e p □ □+ jet + X



Complementarity of Experiments

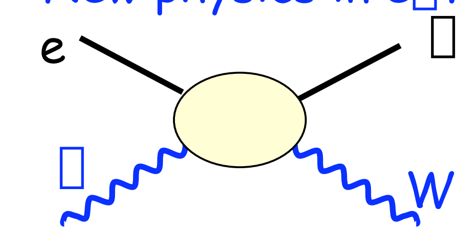
Statistical fluctuation in H1 / ZEUS data ? The answer should come soon !
Meanwhile, possible hint for new physics ? i.e. should other expts see something ?

- e-q resonance ?



- not a lot of phase space
- but possibilities exist…
- if ?? can be pair produced at Tevatron, could look like tt

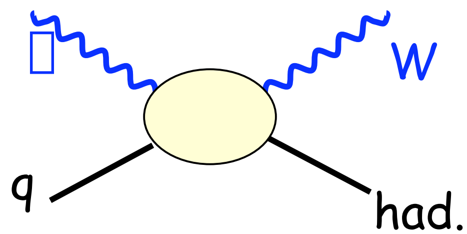
- New physics in e□?



Most likely, something should have been seen at LEP !

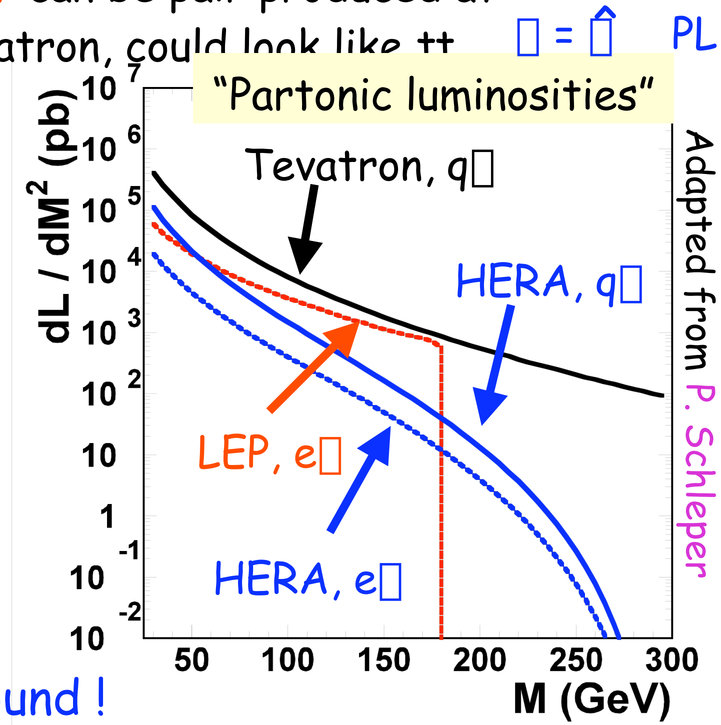
(NB: unlikely to produce large $P_{T,had}$ at HERA)

- New physics in □q ?



May have large x-section at the Tevatron …

But huge W + jets background !



Illustrates the complementarity between the 3 colliders

To go further in such comparisons, one needs specific models …

Models for New Physics

Try to address one/several question(s) not solved by the SM...

Extend the SM by :

- More symmetry
  - SUSY - the only sym. which prevents to add $m^2 H^+H$ in $\mathcal{L}$
  - enlarge the gauge symmetry - unification of couplings, restore the parity symmetry at high energies, add some symmetry between the lepton & quark sectors ...
- Enlarged/modified matter field content - neutrino masses, new fermions to cancel m^2_h divergences up to ~ 10 TeV ...
  - may arise in GUTs
  - possibly together with some new interaction(s) - dynamical EWSB
- Enlarged space-time - hierarchy problem, fermion masses, links with cosmology; links with string theories

Build models taking into account precision measurements & bounds from low E

Covered :

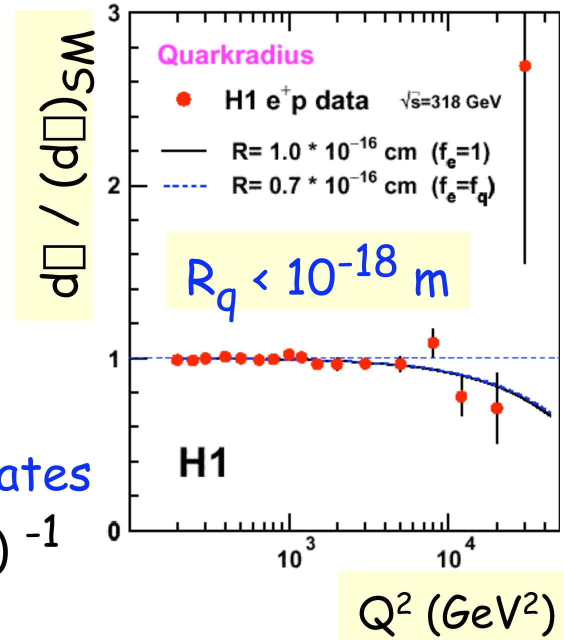
- Composite fermions
- Technicolor resonances (a bit...)
- Leptoquarks
- Z ' (W ') gauge bosons
- Models with extra dimensions

Not covered :

- Extra generations of leptons or/and quarks
- Lepton Flavor Violation
- some models with extra dim.
- ...

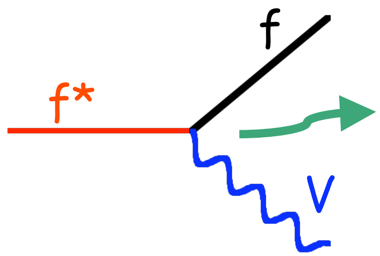
A new scale of matter ?

- First approach : assign a finite size to the EW charge distributions. E.g. in DIS at HERA, where $Q^2_{max} \sim 10^5$ GeV^2 $\quad f(Q^2) = 1 - \frac{<r^2>}{6} Q^2$



- Interaction between fermion constituents can be parameterized as a Contact Interaction (ff → ff)

- Unambiguous signature : direct observation of excited states



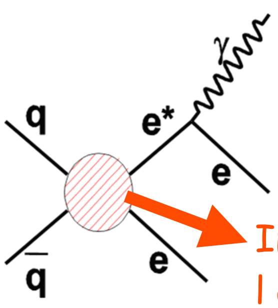
$\frac{f_V}{\Lambda}$ (chiral) magnetic coupling ~ (GeV)$^{-1}$

$\Lambda \sim$ compositeness scale

Relative strength of γ, Z and g couplings → f, f ', f_s

Hagiwara et al, ZPC 29 (1985) 115.
Boudjema et al, ZPC 57 (1993) 425.

⇒ Pair production of f* in e^+e^- and pp ; single production depends on coupling



Other possible approach IF leptons & quarks have common constituents : $\mathcal{L} \sim \frac{4\pi}{\Lambda^2} (\bar{e^*} \gamma^\mu e)(\bar{q} \gamma_\mu q)$

Baur et al, PRD 42 (1990) 815.

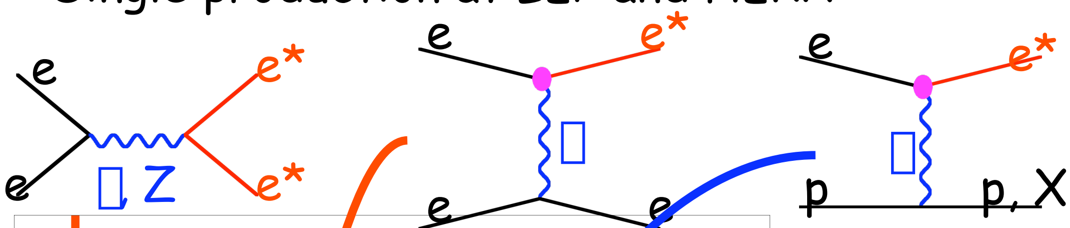
Experimentally ~ similar, mainly ≠ normalization

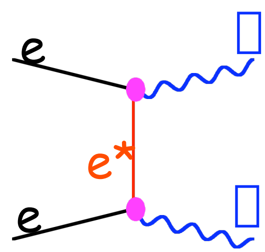
Excited Electrons : e + V Resonances

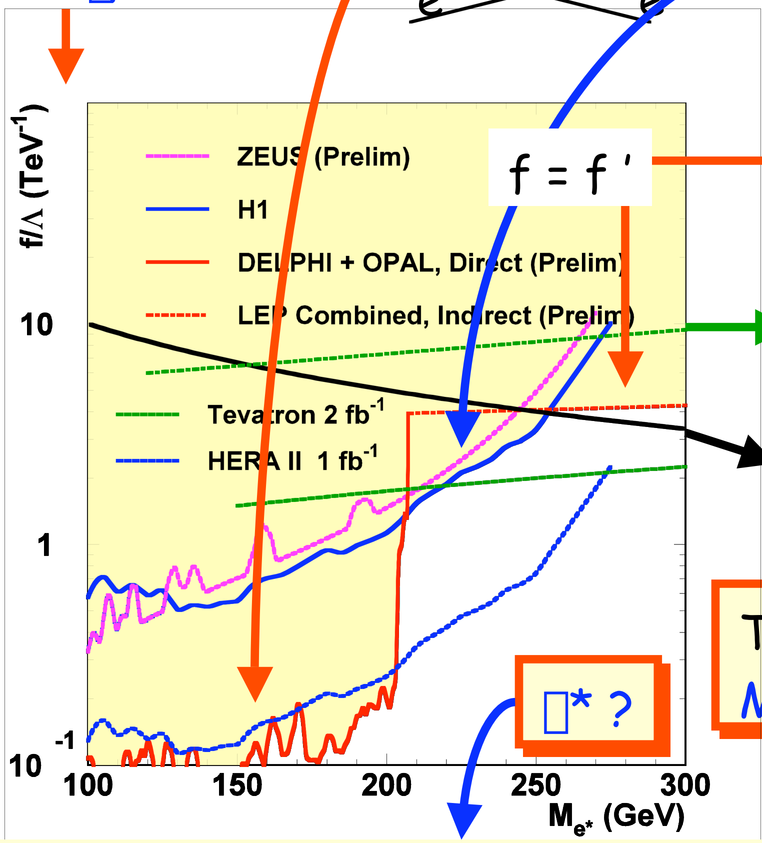
- Pair production at LEP ⇒ masses below ~ 100 GeV ruled out
- Single production at LEP and HERA

All e* decay modes considered at LEP & HERA

Branching ratios of eγ, eZ, νW depend on f vs f '







f = f '

My interpretation of CDF bounds

$f/\Lambda = 1/M(e^*)$

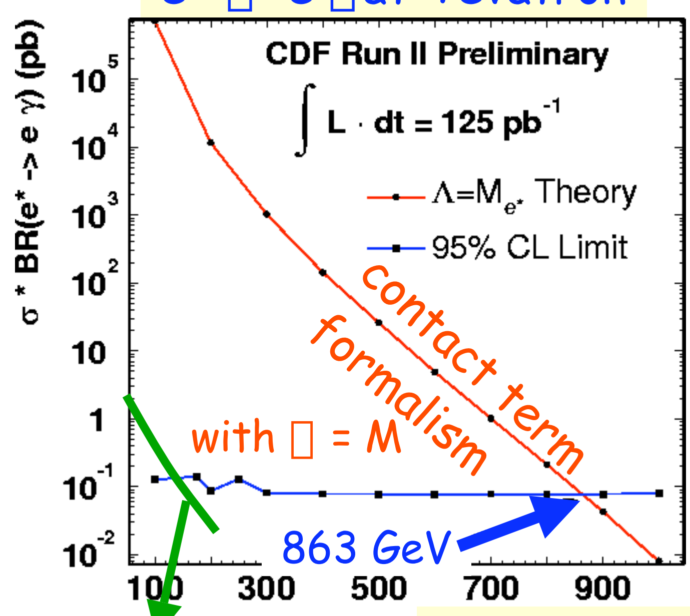
To fix the ideas : $M(e^*) > 250$ GeV

ν* ?

Interesting for Tevatron, esp. if $(g-2)_\mu$!

Take care of ≠ conventions !

e* → e γ at Tevatron



contact term formalism

with Λ = M

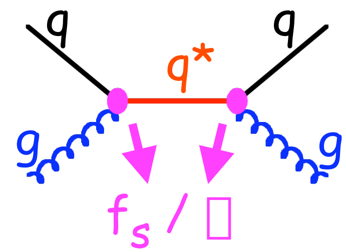
863 GeV

M(e*) GeV)

Hagiwara,
$f/\Lambda = 1/M$
⇒ M > 150 GeV

Excited quarks & other j-j resonances

- Dijet resonances predicted in various models
  - New fermions, e.g. excited quarks
    - ⇒ expect signal in q γ/Z, q W depending on f_s vs f & f'
  - new gauge bosons, Z', W' (but signal mainly in the dilepton channels)
  - new massive colored bosons, e.g. $SU(3)_1 \times SU(3)_2 \rightarrow SU(3)_{QCD}$ (chiral color, colorons, topgluons…)



Narrow resonances compared to $\Gamma(M_{jj}) \lesssim 10\%\ M_{jj}$

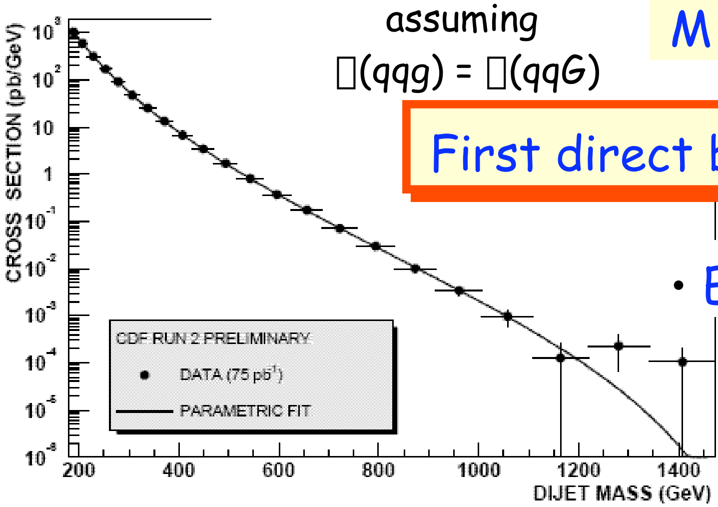
- Look for a narrow resonance in the di-jet spectrum : use a simple background parametrization for dσ/dM and search for bumps ≈ resolution

- Axigluon & (flavor univ.) colorons :

assuming Γ(qqg) = Γ(qqG)

M > 1130 GeV

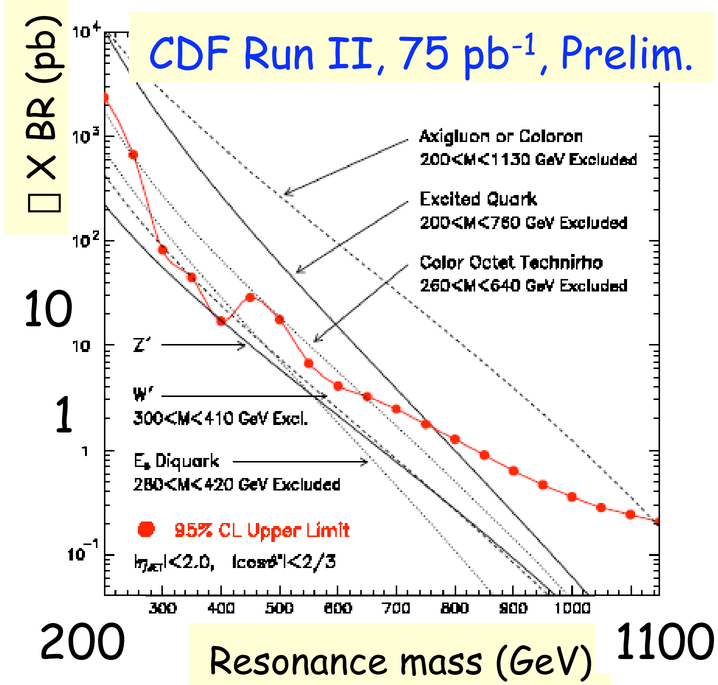
First direct bound > 1 TeV !!



- Excited quarks :

M > 760 GeV

(f=f'=fs=1, Λ = M)



New Physics in the Top Quark Sector ?

Large top mass… Might expect first hints of new physics in the top sector

- Topcolor : introduced in DEWSB models to account for large M_{top}

$SU(3)_1 \times SU(3)_2 \rightarrow SU(3)_{QCD}$ with e.g. $SU(3)_2$ coupling strongly to 3rd gene only

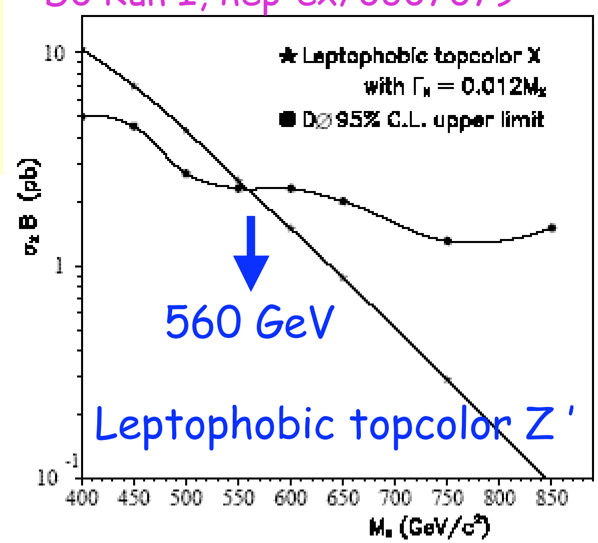
→ Topgluons coupling mainly to bb, tt

Avoid a large mass for b ?

→ e.g. a new Z boson, attractive to tt & repulsive to bb i.e. no bb condensate

Might expect – some tt resonances

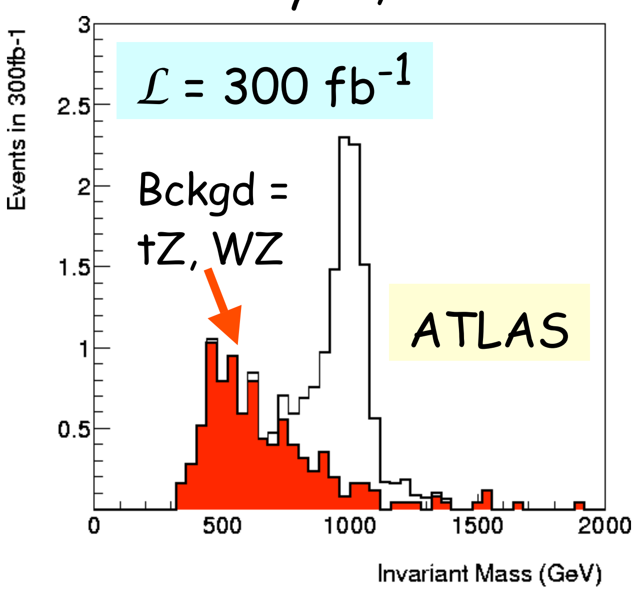
D0 Run I, hep-ex/0307079



- " Little Higgs" models

New heavy T , could be observed in q b → q' T

+ T → tZ → 3 leptons



Look for a tZ resonance

NB : "recent" model… experimental studies have already started !

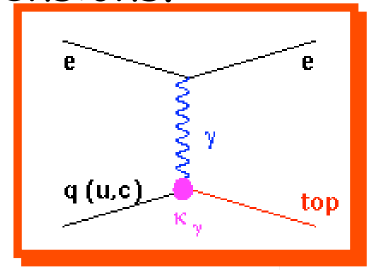
- Single Top production @ Tevatron

Should be observed with ~ 2 fb^{-1}

Might bring surprises, eg V_{tb}, anomalous couplings

FCNC couplings involving the top quark ?

Anomalous couplings between top, γ/Z and u/c may arise in SM extensions.
Would lead to:



- enhanced single top production @ Tevatron
- single top production at LEP & HERA (tiny rate within the SM)
  (HERA has ≈ no sensitivity on couplings top-c)
- t → u/c + γ/Z @ Tevatron

Possible explanation of HERA's events ?

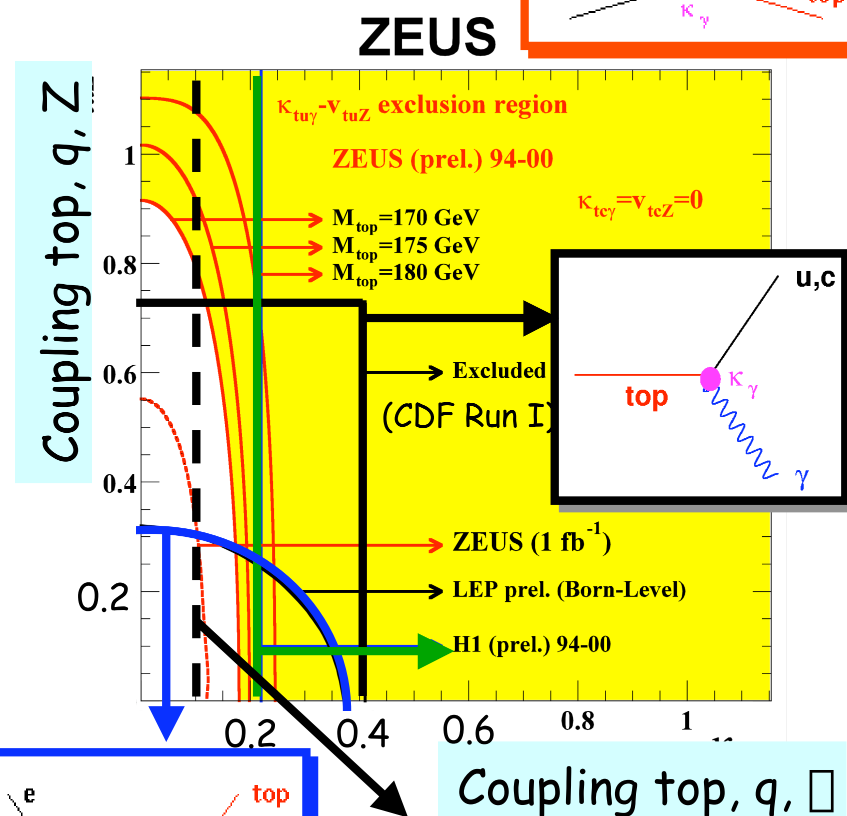
e q → (e) t → (e) + b + lepton + $E_{T,miss}$

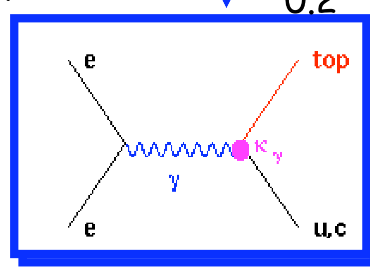
H1 : 5 candidates, 1.7±0.4 expected (Prelim.)

- not excluded by LEP & Run I data
- ZEUS vs H1 : too few events so far…
  ⇒ looking forward to doubling $\mathcal{L}$!

Sensitivity @Tevatron :

- mainly via radiative top decays
- u/c γ → t : σ quite large but huge bckgd !
  for κ ≈ 0.2, σ ~ σ(SM single t) ~ 2 pb…





t → uγ, 2 fb^{-1}

H1 Prelim., Contrib. Paper #181
ZEUS Collab., PLB 559, 153 (2003)
Final DELPHI results, Contrib. Paper #53
L3, PLB 549 (2002) 290

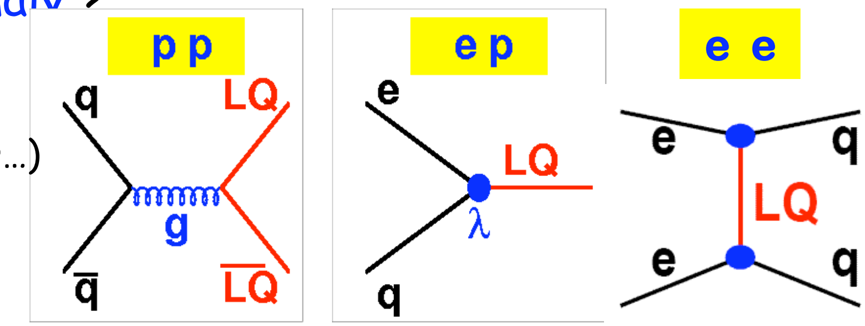
Lepton + Quark Resonances : Leptoquarks

Apparent symmetry between the lepton & quark sectors ?
Exact cancellation of QED triangular anomaly ?

- LQs appear in many extensions of SM

(enlarged gauge structure, compositeness, technicolor…)

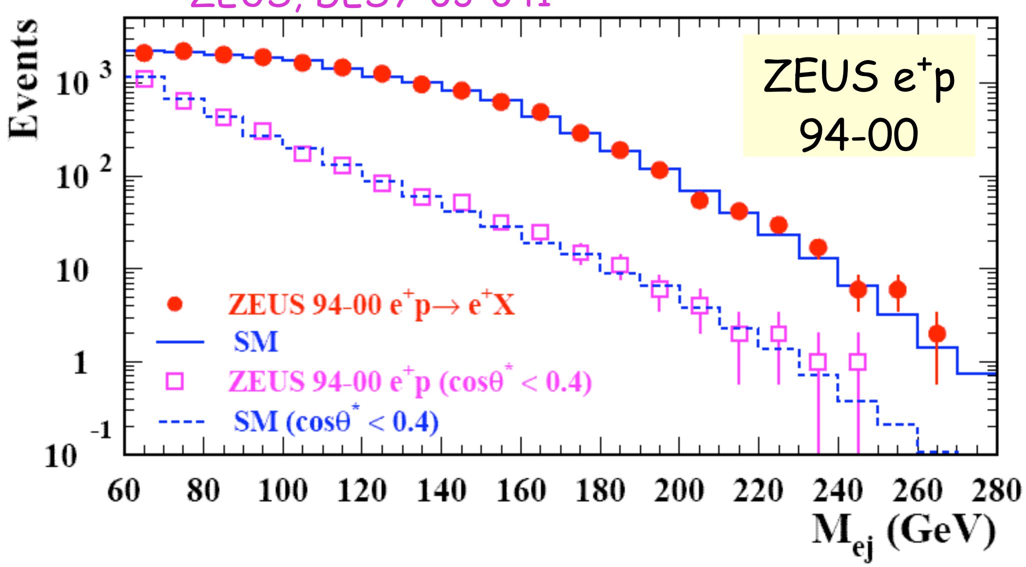
- Connect lepton & quark sectors



- Scalar or Vector color triplet bosons
- Carry both L and B, frac. em. charge

 (unknown) Yukawa coupling lepton-quark-LQ

ZEUS, DESY-03-041



- Single LQ prod at HERA

Topologies	SM Background
e + jet	Neutral Current DIS Exploit specific angular distribution of LQ decay products
+ jet	Charged Current DIS

Look for a resonant peak in M spectra

 reduced background

No excess observed in both channels

First Generation Leptoquarks at Tevatron

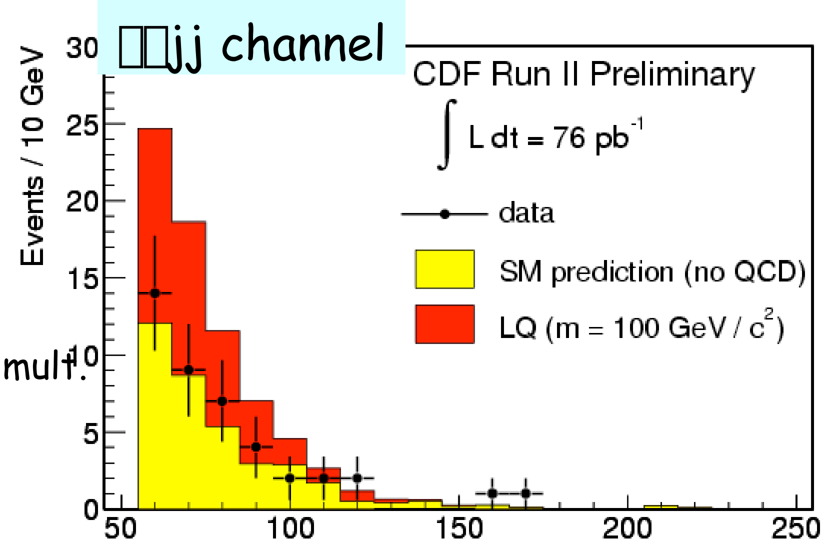
• Pair production at Tevatron

Mainly from the data

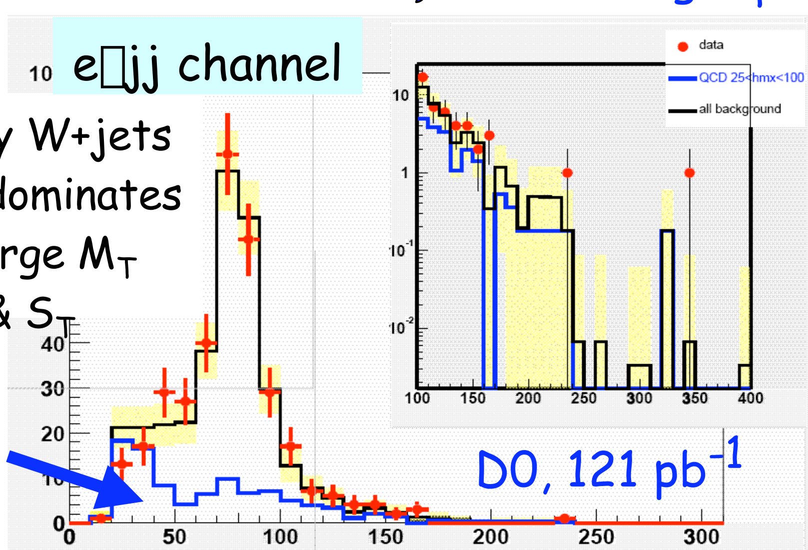
Topol.	SM Background
eejj	DY + jets, QCD “fake”, top
e□jj	QCD, W + jets, top
□□jj	W (□ □/□) + jets Z (□ □□) + jets QCD

• rate for a jet to “fake” an e
• use of control / bckgd enriched samples
• correct the $O(\alpha_s^0)$ MC to reproduce the observed jet mult.

Require a good understanding of missing E_T !



Missing E_T (GeV)



Mainly W+jets
QCD dominates at large M_T & S_T

QCD

Transverse mass (e, □) (GeV)

No attempt to reconstruct the LQ mass
Make use of $S_T = \Sigma E_T$

	D0	CDF
eejj	0 / 0.45 ± 0.12 (135 pb^{-1})	0 / 3.4 ± 3.2 (72 pb^{-1})
e□jj	3 / 4.19 ± 1.00 (121 pb^{-1})	2 / 1.73 ± 1.40 (72 pb^{-1})
□□jj	—	42 / 42.5 ± 10.7 (76 pb^{-1})

Bckgd well controlled

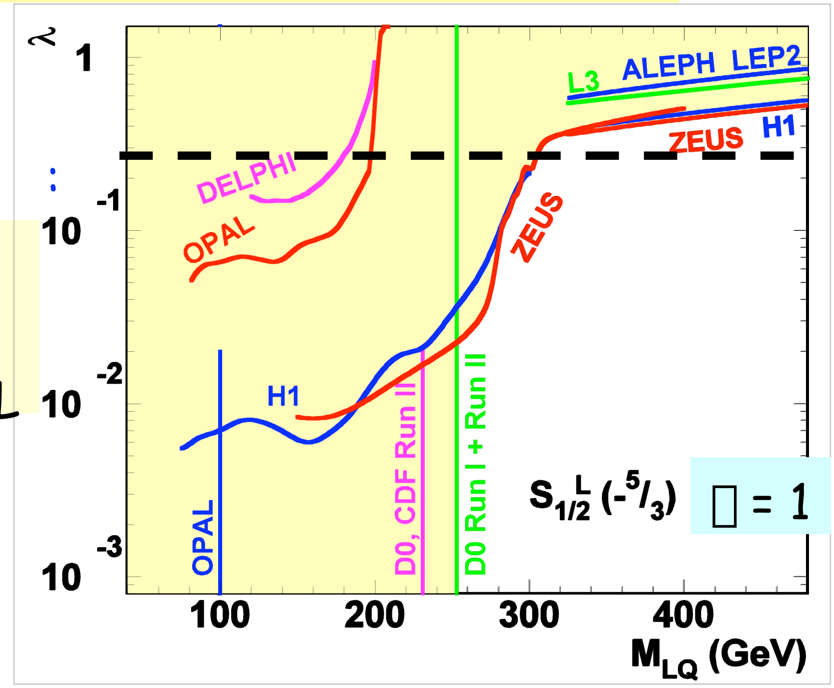
Existing Bounds on 1st Generation LQs

β = BR(LQ → eq)

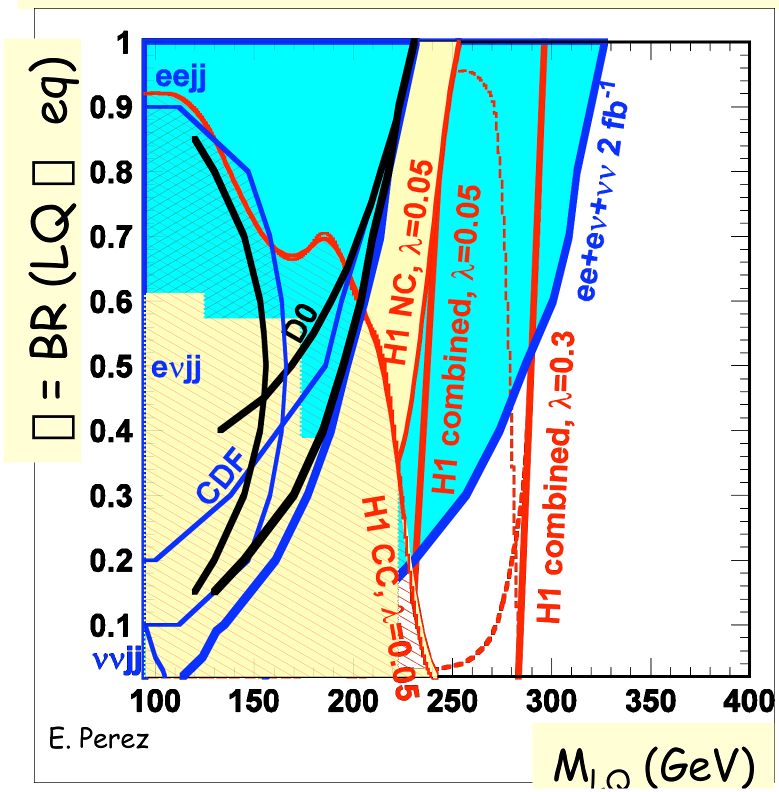
β_e	Run II bounds	
1	231	D0
1	230	CDF
0.5	166	CDF (eνjj)
0.5	169	D0 (eejj)
0.5	156	D0 (eνjj)
0	107	CDF

For $\lambda = \sqrt{4\pi\alpha_{em}} \sim 0.3$:

HERA rules out LQ masses < ~ 290 GeV @ 95 % CL



D0 Run II + D0 Run I : M > 253 GeV for β=1



- Tevatron probes large masses for large β (LQ → eq) independently of λ
- HERA better probes LQs with small β provided that λ not too small

⇒ Complementarity of both facilities

NB : at HERA, e^+ / e^- + polarisation could help in disentangling the LQ quantum nbs

Second and Third Generation Leptoquarks

So far, $LQ_{2,3}$ with M > 100 GeV can be probed → exclusively at the Tevatron !

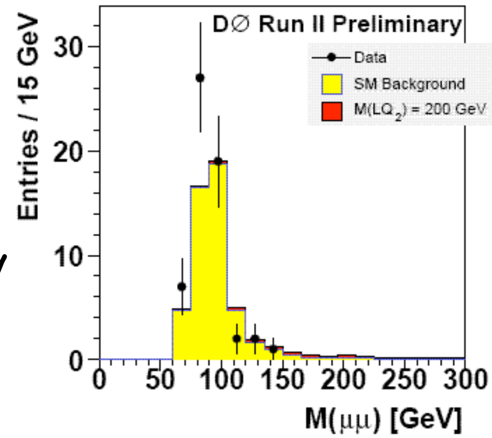
- Search for LQ_2 in D0 Run II data :

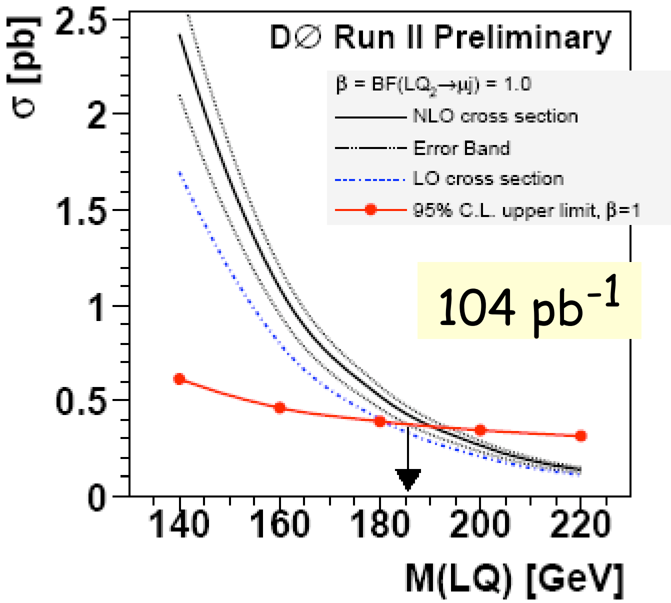
$\mu\mu$ + at least 2 jets

Signal at large $M_{\mu\mu}$ & S_T

SM bckgd → only DY

M > 186 GeV for $\beta(LQ \to \mu q) = 1$





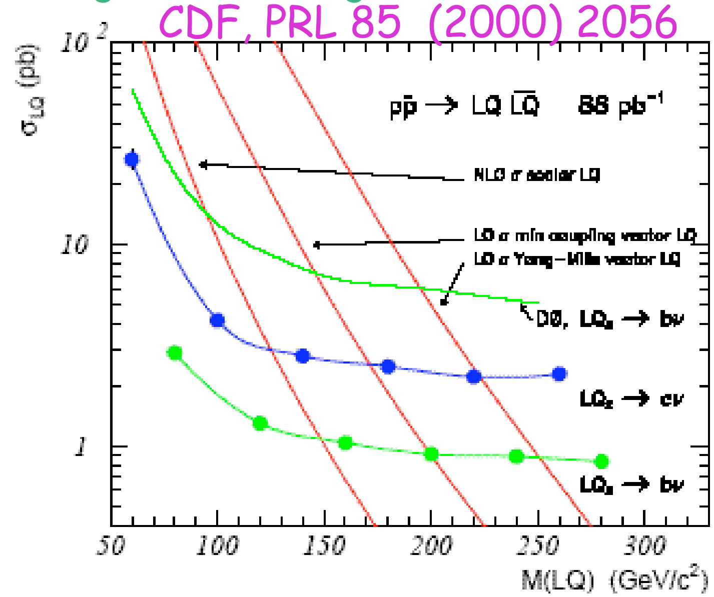
Already competitive with Run I result (200 GeV) obtained from a NN analysis

- Search for LQ_2 & LQ_3 using heavy flavor tagging (Run I results) :

$LQ_2 \to \nu c$

$LQ_3 \to \nu b$, $LQ_3 \to \tau b$

CDF, PRL 85 (2000) 2056



... New physics might couple mainly to 3rd gene fermions

β_ν	Scalar	
1	99	(bν)
0	149	(bτ)

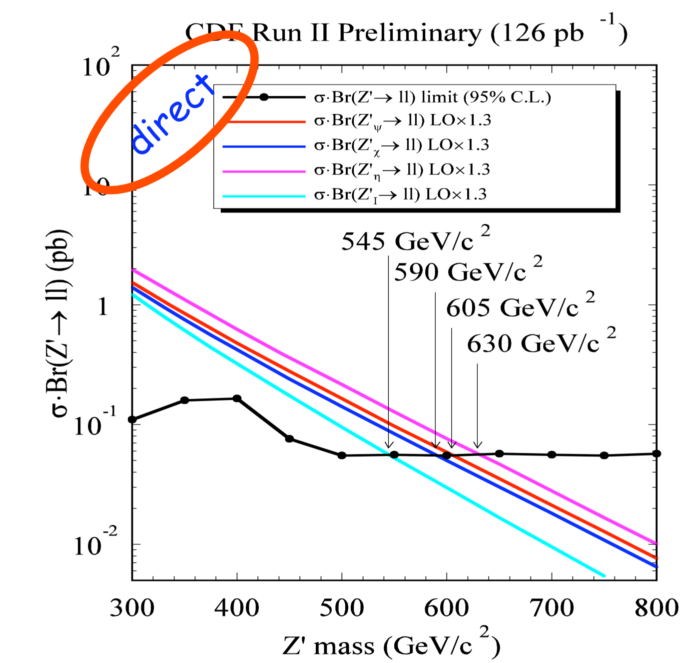
Run II will bring much more sensitivity (improved SVX)

Dilepton resonances

- New heavy gauge boson Z ', e.g. models with L-R symmetry or E_6 GUT inspired
- Kaluza-Klein gravitons in some extra-dim. models
- (Color-singlet) technirho in Technicolor models ...

Model □ couplings of Z ' to fermions;
mixing with the Z □ 0 (mainly Z peak data)

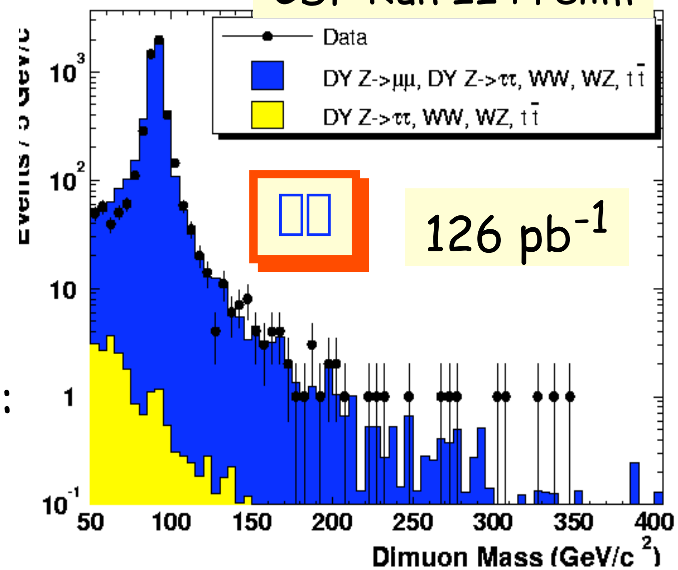
D0 & CDF searched for ee & μμ resonances :

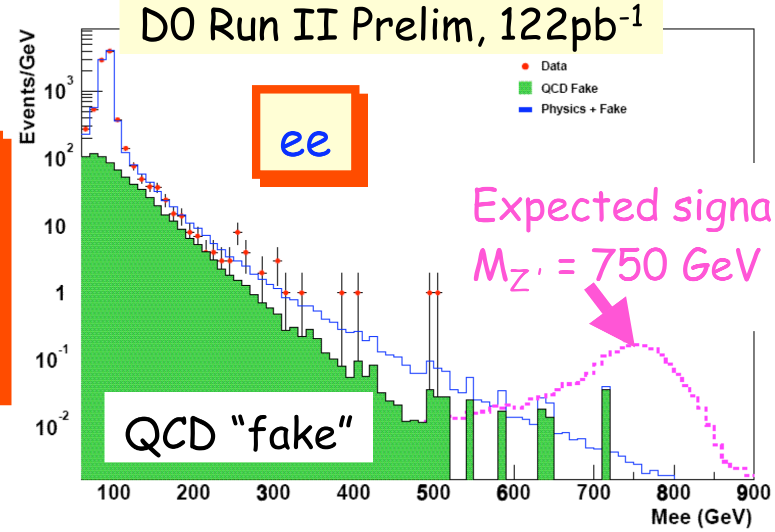


Main bckgds @ high M :

ee	DY, QCD "fake"
μμ	DY

Run II direct bounds between 545 and 730 GeV





Already competitive with indirect LEP bounds

Status & Prospects on New Z' Bosons

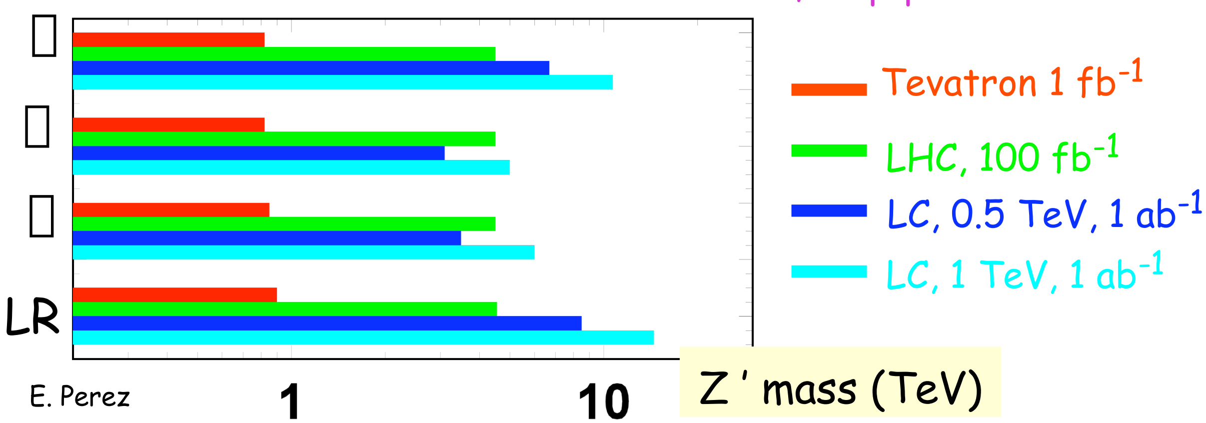
Limits & sensitivities on Z ' bosons often expressed in :

- SSM : Z ' couples to fermions like the SM Z
- E_6 inspired models : E_6 □ SO(10) x U(1)□ and SO(10) □ SU(5) x U(1)□

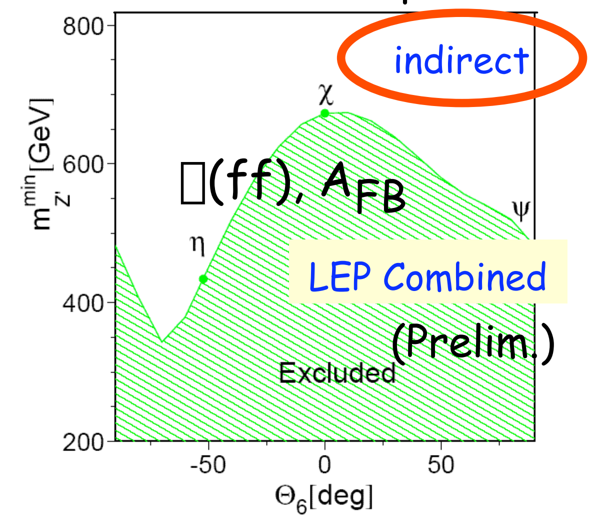
$Z' = Z_{□} \sin□_6 + Z_{□} \cos□_6$ different models depending on mixing angle $□_6$

	Indirect bounds		Run II prelim. results		
	LEP Combined	APV (*)	CDF ee+□□ ($126\ pb^{-1}$)	D0 □□ ($100\ pb^{-1}$)	D0 ee ($122\ pb^{-1}$)
SSM	**1787**	**835**	730	610	719
□	673	740	**590**	my estimations from D0 bounds on □ x BR :	
□	481	-	**605**		
□	434	540	**630**	□ 530	□ **605**

(*) my estimations using Casalbuoni et al, PLB 460, 135
& Kuchiev & Flambaum, hep-ph/0305053



Indirect bounds from LEP much more model dependent



APV ? Q_W would need to be measured within □ 0.1% to compete with LHC

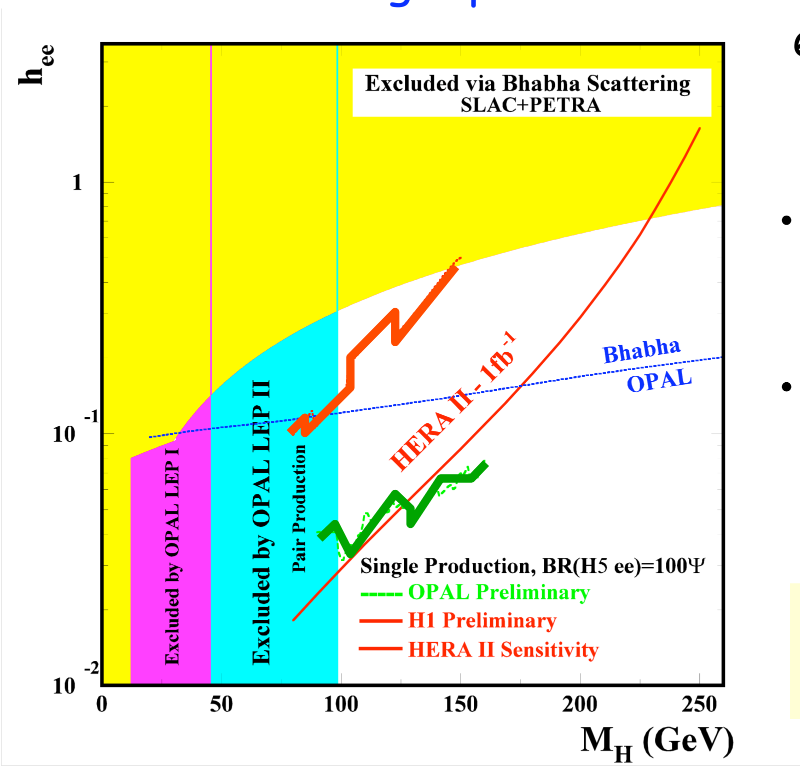
l^+l^+ Resonances ? E.g. Doubly Charged Higgs

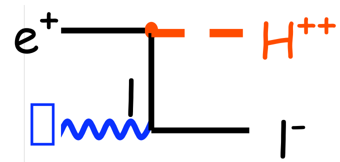
Appear in L- R symmetric models : $SU(2)_L \times SU(2)_R$ broken by Higgs triplet
(or extended Higgs sector by a triplet with Y=2). Might explain small (Majorana) ν masses.
H^{++} couples to fermions via unknown Yukawa couplings h_{ij}, not related to masses
SUSY L – R models predict low H^{++} masses, below $\sim$ 1 TeV

- Pair production at LEP : H $\rightarrow$ ee, $\mu\mu$, $\tau\tau$, $e\mu$, $e\tau$, $\mu\tau$ considered

M_H > 98.5 GeV

- LEP & Hera : single production via $e^+ \gamma \rightarrow e^- H^{++}$





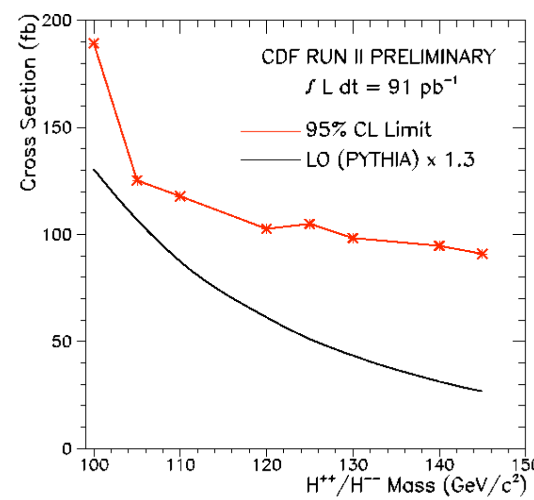
H1 2e & 3e events at high M : only one 2e evt fulfils charge requirement

- Influence on Bhabha scattering at LEP
$\Rightarrow$ Constraints at M > 200 GeV

- Tevatron : pair production dominates

No sensitivity yet !

Run II should probe masses up to 180 GeV



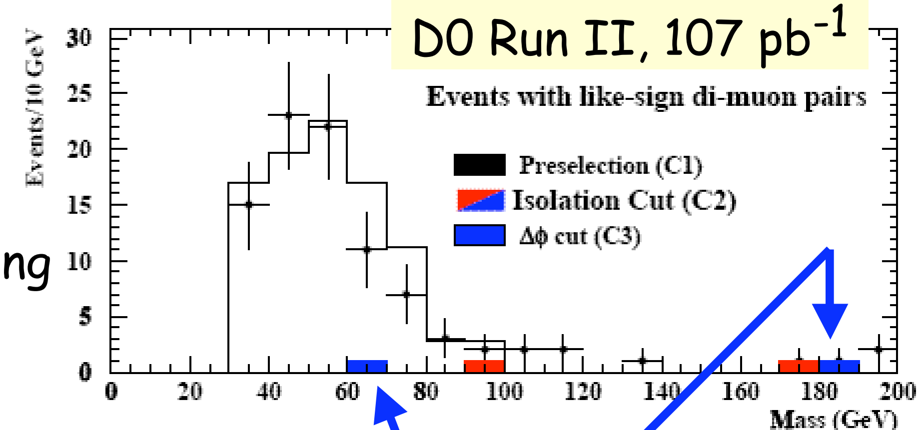
Search for H±± □ □□ at Tevatron

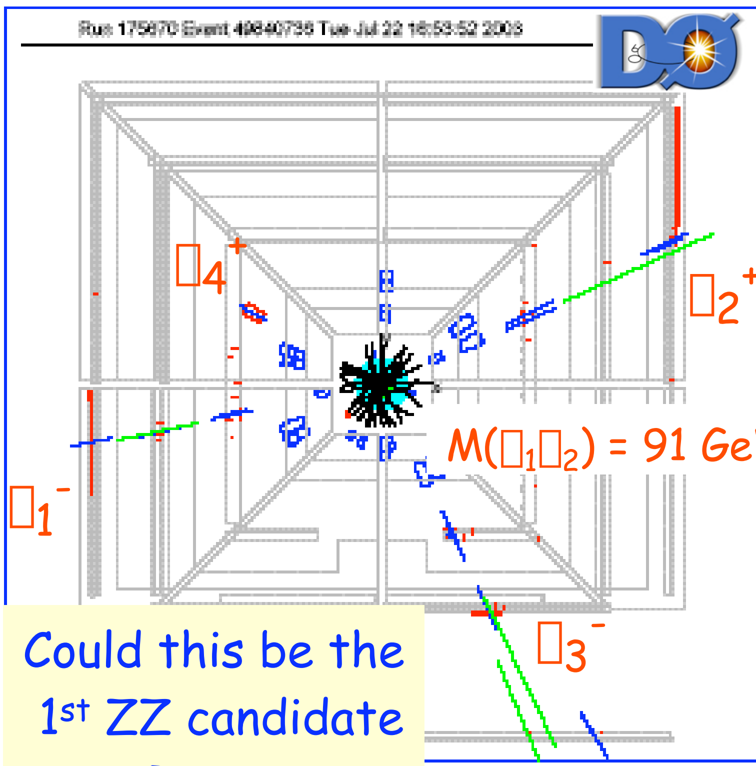
Look for events with at least 2 □ and one pair of □ with like-sign charges

- Basic □□ like-sign selection :

  Mainly bb events

  Rate well described by SM prediction when bb expectation is rescaled following Run I □(bb inclusive) measurement





Could this be the 1st ZZ candidate in Run II ?

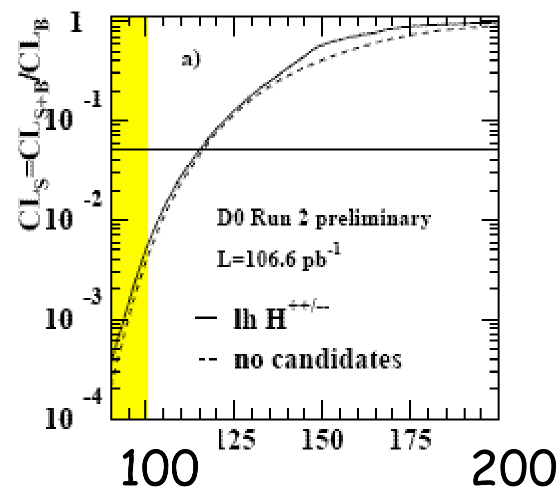
- Signal selection □ 2 candidates (exp. 0.34 ± 0.1)

M_H > 116 (95) GeV for L (R) H±± □ □□ ← D0, Preliminary

(similar result from CDF)

- CDF also looked at non-diagonal coupling H±± □ e □

  M_H > 110 GeV



Kaluza-Klein Gravitons

Why is the gravity so weak, i.e. $M_{Pl} >>> M_{EW}$?

All attempts □ higher dim. space, with n compactified extra dimensions

- "Localized gravity" on a "brane" at d ≠ 0 from our brane; propagation of gravity in the extra dim is exponentially damped due to the (tuned) space-time metric
  Randall & Sundrum models; "usual" version : n=1, R_c □ Planck length
  PRL 83 (1999) 3370;
  PRL 83 (1999) 4690
- "Strong gravity" ; fundamental scale ~ TeV; gravity appears weaker in 4d because flux lines are "diluted" in large extra dimensions
  Large R_c □ 0.1 mm. Not excluded by gravity measurements
  Arkani-Hamed, Dimopoulos, Dvali, PLB 429 (1998) 263
  revived ideas in Antoniadis, PLB 246 (1990) 377.

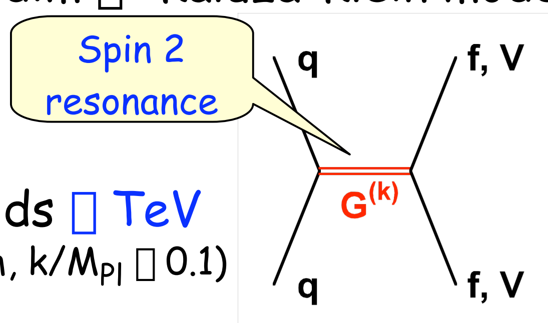
Graviton propagate in extra dim □ Kaluza-Klein modes

In localized gravity :

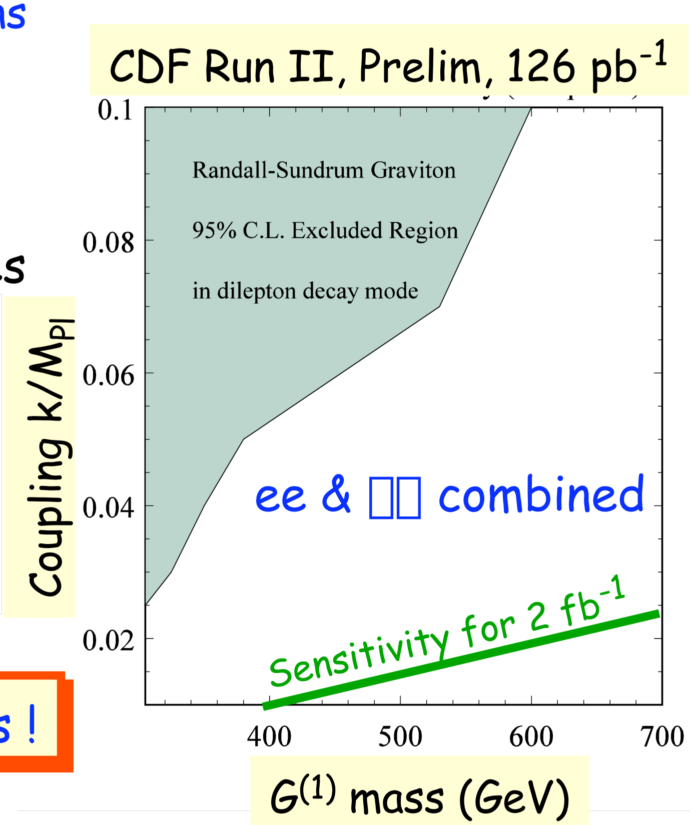
$G^{(k)}$ heavy, $G^{(1)}$ □ TeV

Coupling of $G^{(k)}$ to SM fields □ TeV

(determined by some model param, k/M_{Pl} □ 0.1)



CDF : qq, gg □ ee, □□, jj



First direct constraints on Randall-Sundrum models !

Kaluza-Klein Gravitons in Large Extra Dim

Very different phenomenology if "large" extra dimensions.

$G(k)$ with quantized momentum $q_T = k/R$ in extra dim : $m^2 = 0 = (E^2 - p_{4d}^2) - q_T^2 \Rightarrow m_{4d}^2 = q_T^2$

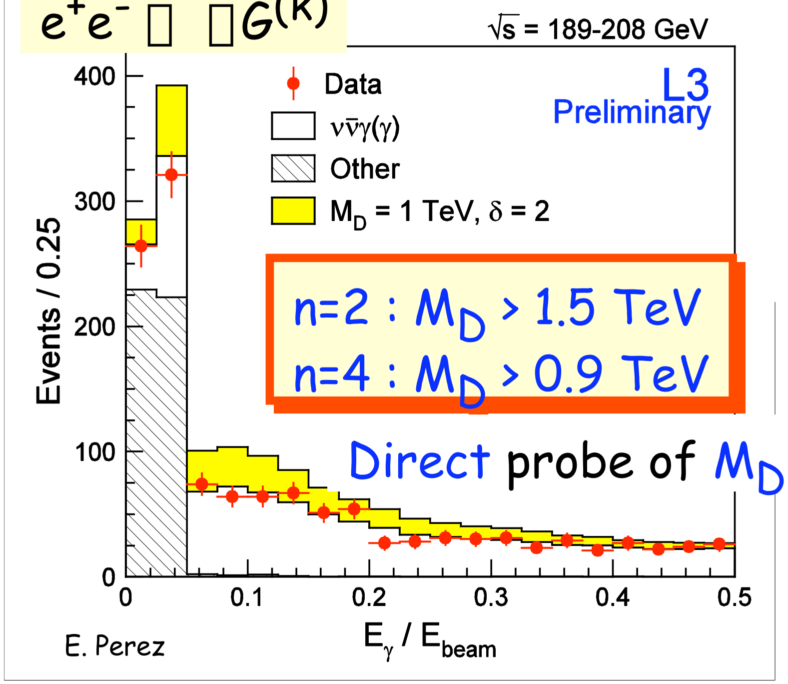
4+n dim	4 dim
Massless graviton $G^{(k)}$ with momentum $q_T = k/R$	Massive graviton $G^{(k)}$ with $m^2 = k^2/R^2$

$R \sim 0.1$ mm i.e. $1/R \sim 1$ meV $\Rightarrow$ Mass "continuum", "first" states very light !!

Coupling of $G^{(k)}$ to SM fields $\propto 1 / M_{Pl} \Rightarrow G^{(k)}$ stable !

May be copiously produced at colliders

$e^+e^- \to \gamma G^{(k)}$

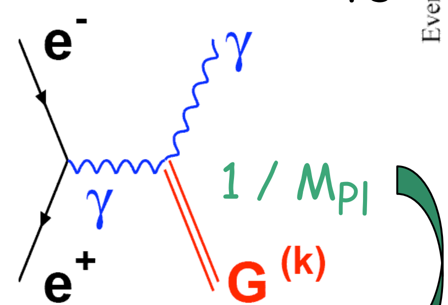


$n=2$: $M_D > 1.5$ TeV

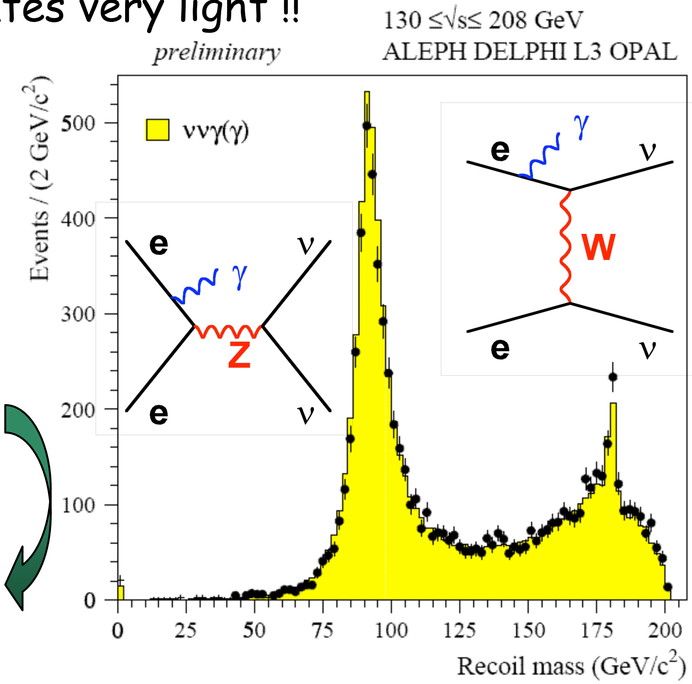
$n=4$: $M_D > 0.9$ TeV

Direct probe of M_D

E. Perez



compensated by huge multiplicity of states

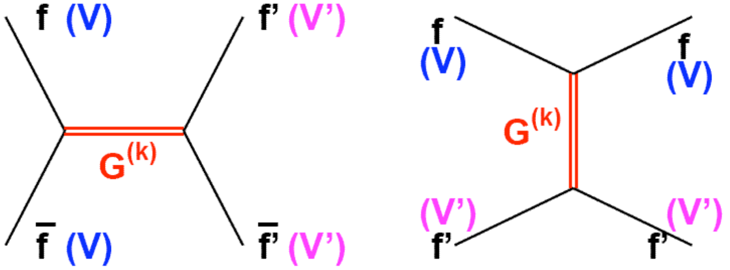


- Hadronic colliders : mainly jet + Missing Et

⇒ D0 & CDF (Run I) : bounds ~ 1 TeV (n=2)

⇒ LHC (100 fb^{-1}) : reach ~ 7 - 8 TeV

Kaluza-Klein Gravitons in Large Extra Dim



Interference of $G^{(k)}$ exchange with SM processes affects observables

$$\frac{1}{M_{Pl}^2} \sum \frac{1}{s/t/u - m_k^2} \rightarrow \frac{\lambda}{M_S^4}$$

divergent for n > 1…

($\propto$ 1 / ($i^2+j^2+\ldots$) ΔV)

Effective coupling with

$\lambda = O(1)$, $M_S = O(M_D)$

(various formalisms…)

i.e. not a direct probe of M_D

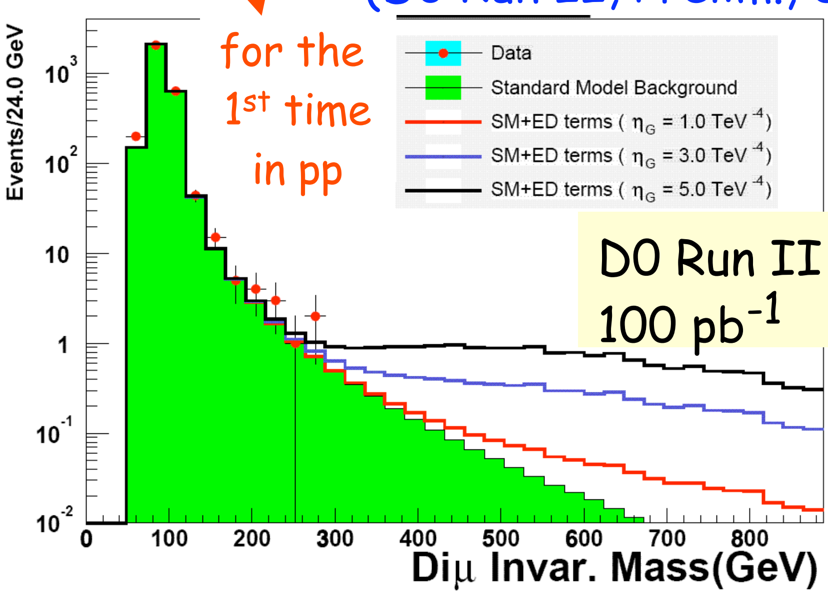
"GRW" formalism :

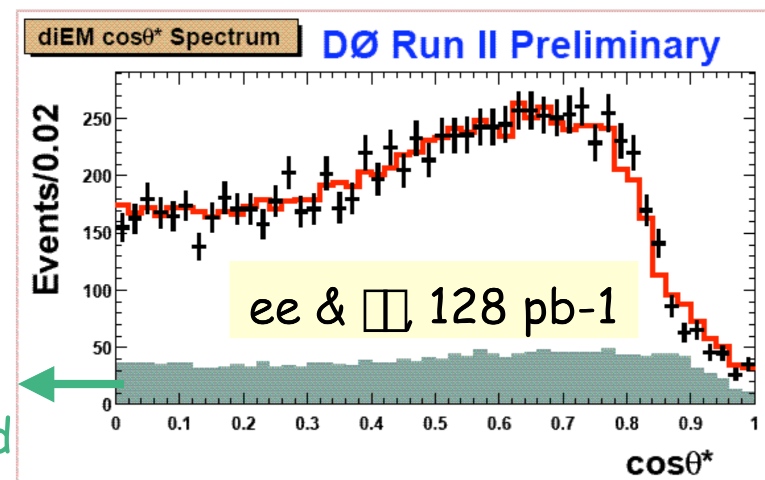
- Bhabha & γγ at LEP — M_S > 1.35 TeV (LEP combined, Bhabha)
- NC DIS at HERA — M_S > 0.82 TeV
- ee & γγ, μμ at Tevatron — M_S > 1.28 TeV (D0 Run II, Prelim., ee & γγ)

1.38 TeV combined with Run I

(also CDF, ee & γγ, Run I)

for the 1^{st} time in $p\bar{p}$





instr. bckgd

With 2 fb^{-1}, M_S up to ≈ 2 TeV can be probed at the Tevatron

New ED Searches from LEP: Branons & Radions

• LED : Remind the DV problem in (tree-level) amplitudes involving $G^{(k)}$ exchange…

Allow the SM brane to "vibrate" in the extra dim, on a length 1/f

Emission/absorption of KK modes □ brane deformation; larger deformations □ higher modes

Large 1/f (small tension) □ Strong suppression of $G^{(k)}$ emission for large |k| !

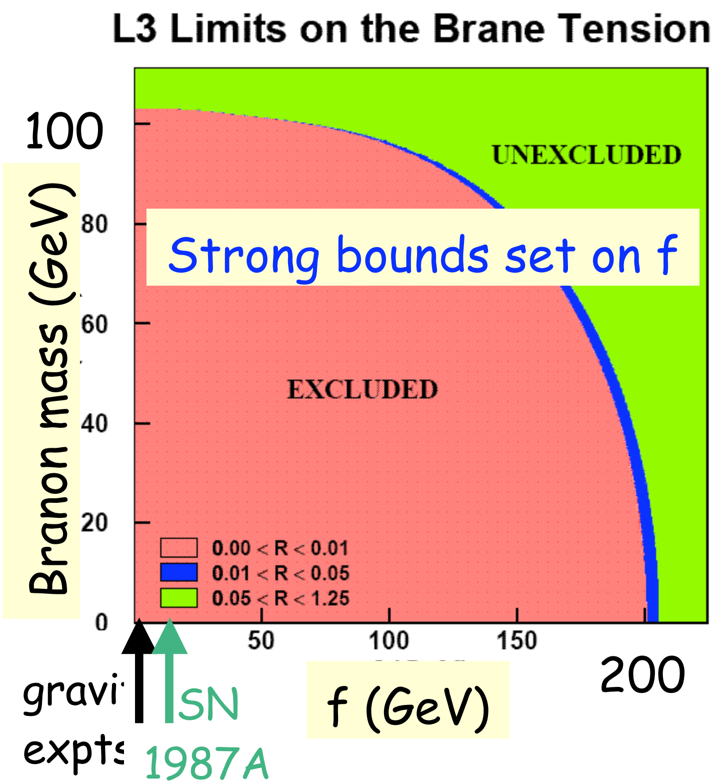
might regularize the DVs, but suppress the standard signal !!

Scalar field associated to the brane vibrations : "branon" □

May be pair produced, e.g. e^+e^- □ □□ □, coupling □ $1/f^4$

f << M_D : branon sig.

f >> M_D : graviton sig.



• Extra dim models : also new scalars

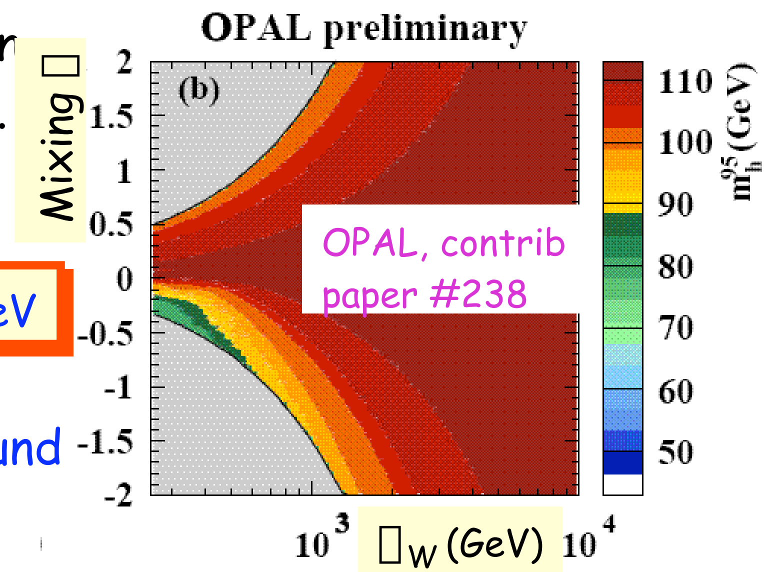
In RS model : only one, the radion R <R> = □$_W$

Mixes with the Higgs, large coupling to gg

Re-interpretation of the flavor ind. Higgs searches

M(h-like) > 58 GeV

First collider bound on Higgs-radion



"Signature Based" Searches for NP

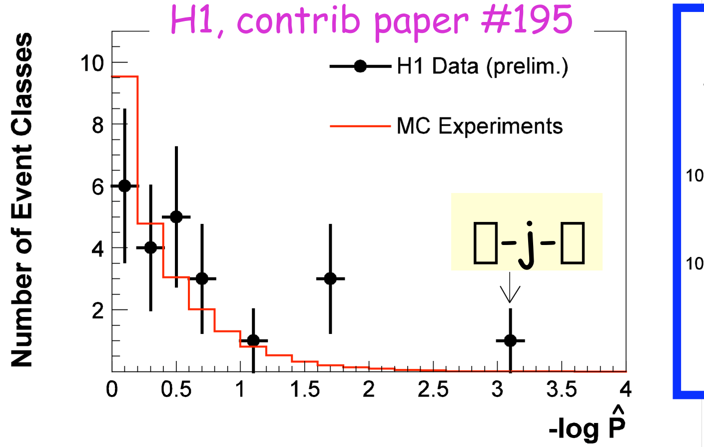
(Quasi) "model-independent" search for new physics :

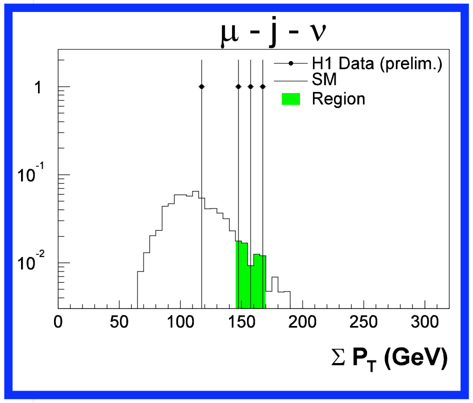
- definition of objects (e, □, □, □ jet, W, Z, ...)
- look at data vs SM in all "channels" with > 1 object
- in each channel, find the part of □ space with largest deviation (e.g. in M, □ p_T)
- quantify the agreement using "Gedanken" (Mock, MC) expts

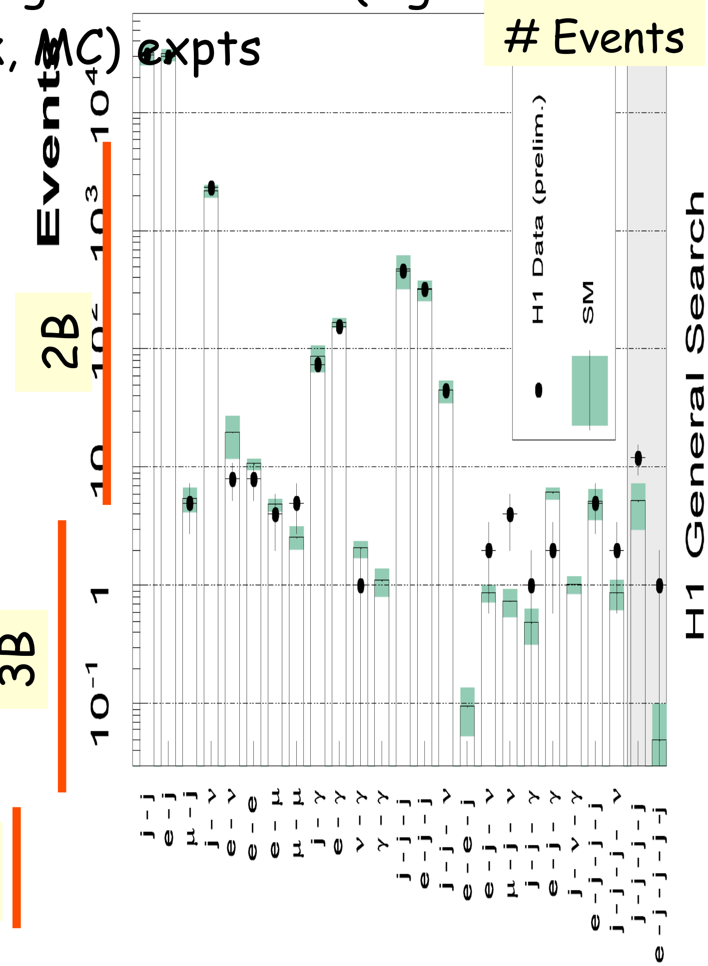
Pionnered by DZero with the full Run I sample
D0, PRD64, 012004 (2001)

Applied recently to the full sample of H1 data

H1, contrib paper #195







- overall very good agreement H1 data / SM
- retrieves the "lepton-jet-$E_{T,miss}$" and "multi-electron" anomalies

(dedicated analyses might be more sensitive)

Requires a very good understanding of detector & backgrounds !

Searches for Magnetic Monopoles

eg = nhc/4□

(Dirac) Magnetic Monopoles may explain the quantization of Q_{em}

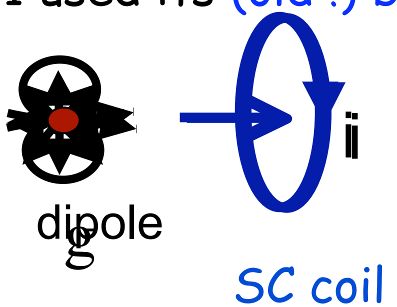
Might affect □□□ □□ via a Monopole (M) loop. Prediction ?? (non-perturbative…)

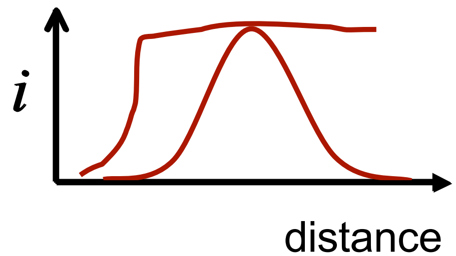
If light enough, could be produced at colliders: pp, ee, ep □ MM (via □□)

High energy loss □ might be stopped + trapped in material (e.g. beam pipe)

H1 Collab contributed paper #186

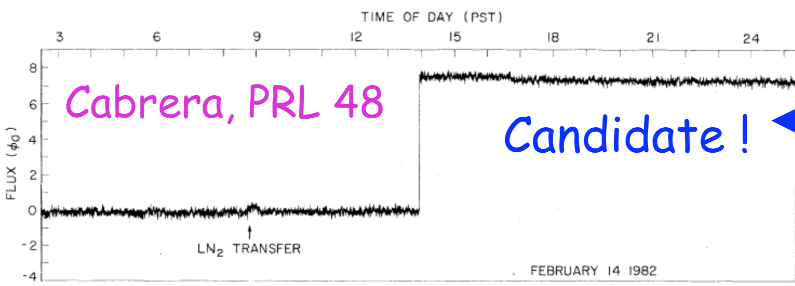
H1 used its (old !) beam pipe, cut it in strips & analyze with a SQUID



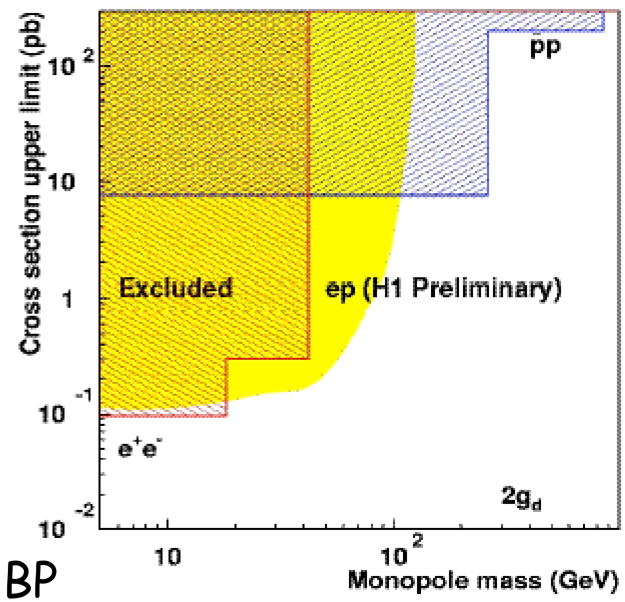


$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} - \mu_0 \vec{j}_m$$

$-i = \Phi/L + \mu_0\, g / L$



search in cosmic rays, SLAC (81-82)



Calibration using "pseudo-poles"; sensitivity of □ 0.2 g_D

No such signal in H1 BP !

Similar studies using pieces of D0 & CDF detectors & BP

Kalbfleisch et al, PRL 85 (2000) & hep-ex/0306045

Conclusions

- Many new results from Tevatron experiments using Run II data.
  No signal for new physics observed so far.
  Constraints set on many models, often the most stringent up to date.
  Established the good performances of key components of the detector.
  Good understanding of SM physics as seen in the detectors.

- "Puzzling" events observed at HERA. Clarification (or discovery ?) should come soon with HERA-II luminosity.

- We do not know what form "new physics" will take, but expect to see something at the TeV scale. Could happen soon :
  - at Tevatron & HERA, within models & beyond models
  - in precision measurements, rare decays and LFV processes
  - or a bit later with the Large Hadron Collider…

Within the next 10 years we should have a much deeper understanding of fundamental physics at the highest energy scales !

Apologies for results I did not present, for mistakes, for missing references.