Searches Before LHC

a snapshot

Cristinel DIACONU

Centre de Physique des Particules de Marseille

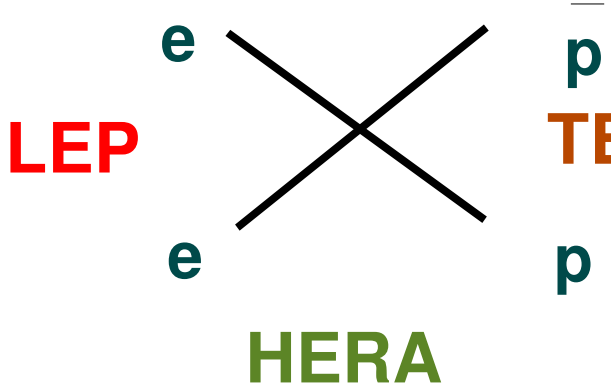
and Deutsches Elektronen Synchrotron Hamburg

- Introduction
- Standard Model and Higgs
- Signature based searches
- Generic searches
- Low energy results
- Conclusions

Colliders at Fermi Scale

before LHC (pp, 14 TeV)

209 GeV



1.96 TeV

320 GeV

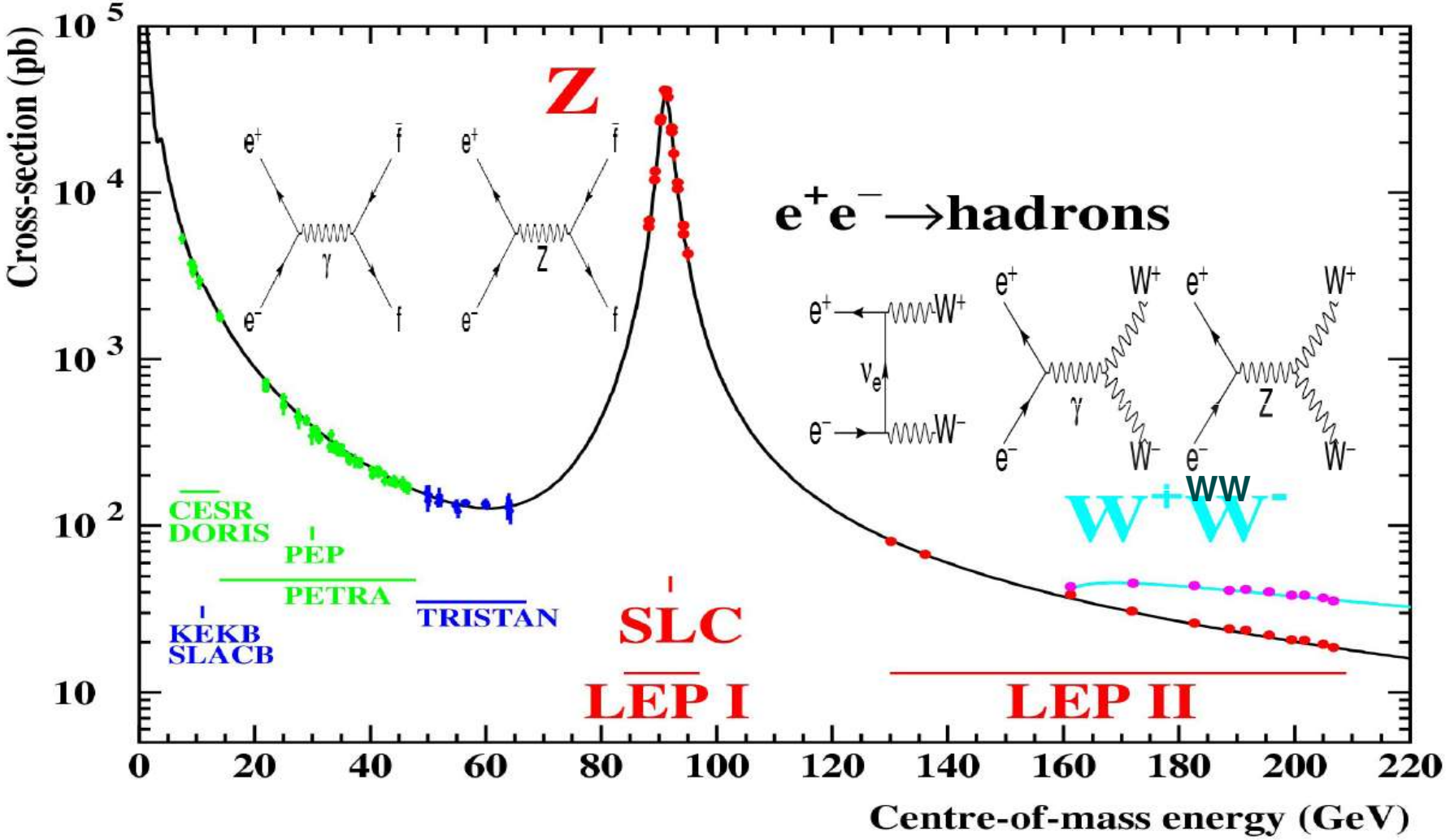
Low energy contraints can also access these scales: precision can beat decoupling

LEP/SLC

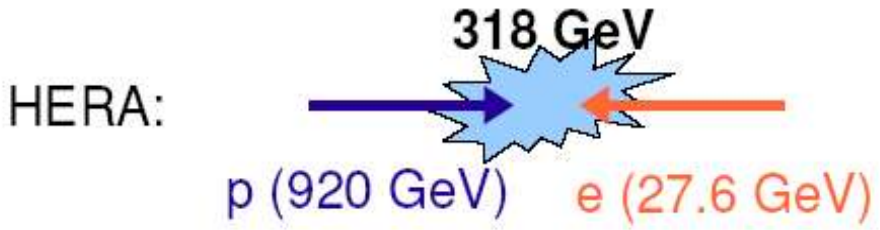
ALEPH, DELPHI, L3, OPAL

L~=900 pb^{-1}/expt.

SLC (SLD): polarized e^+e^- at Z peak



HERA



- **HERA 1: 1992-2000 ~120 pb^{-1}/expt**
- **HERA 2: 2003-2007 luminosity upgrade**

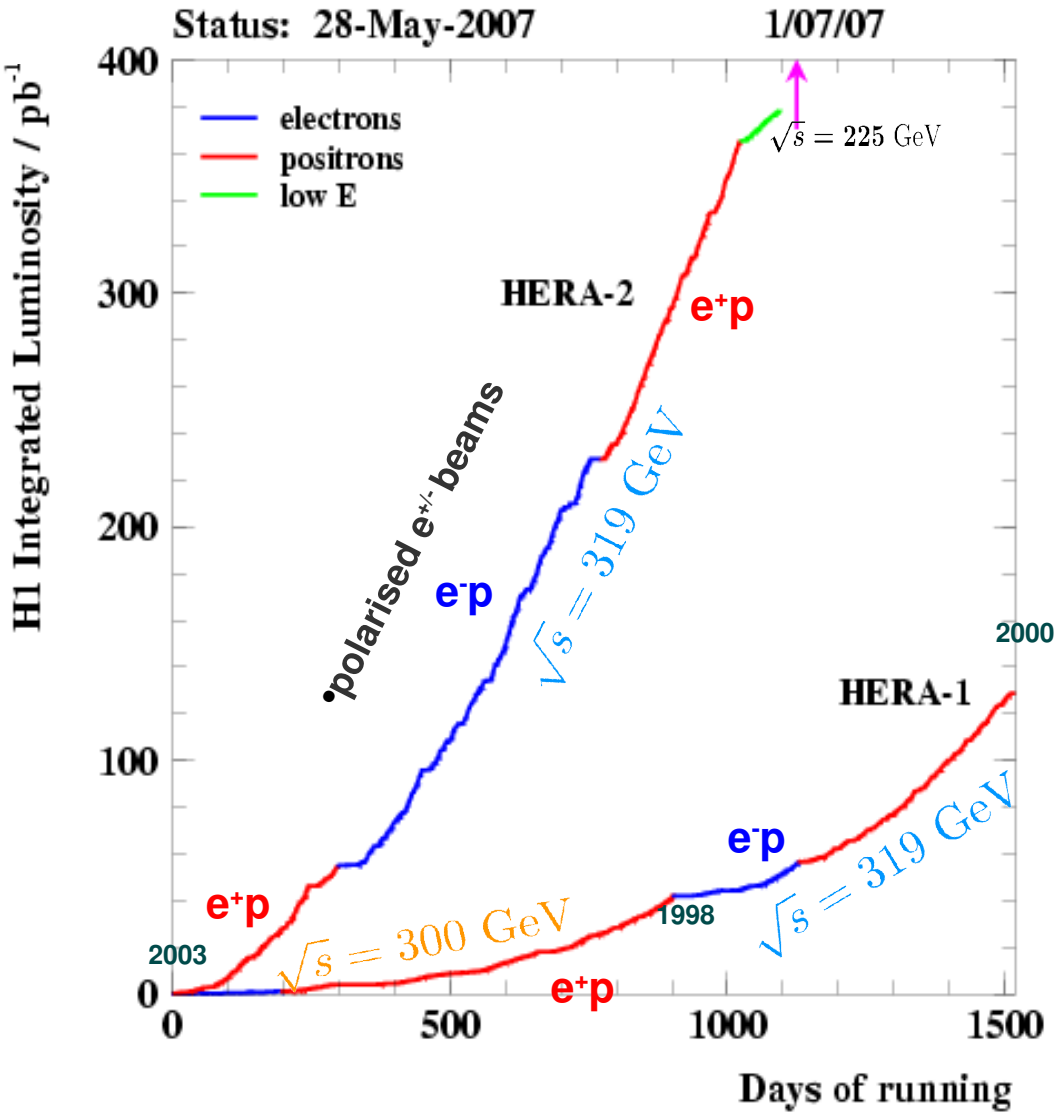
H1 Harvest at HERA 1+2: ~0.5fb^{-1}

- **~200 pb^{-1} e$^-$p**
- **~300 pb^{-1} e$^+$p**

Since April 2007: Low Energy Run

E_p=460 GeV

HERA program entering an exciting period: final analyses



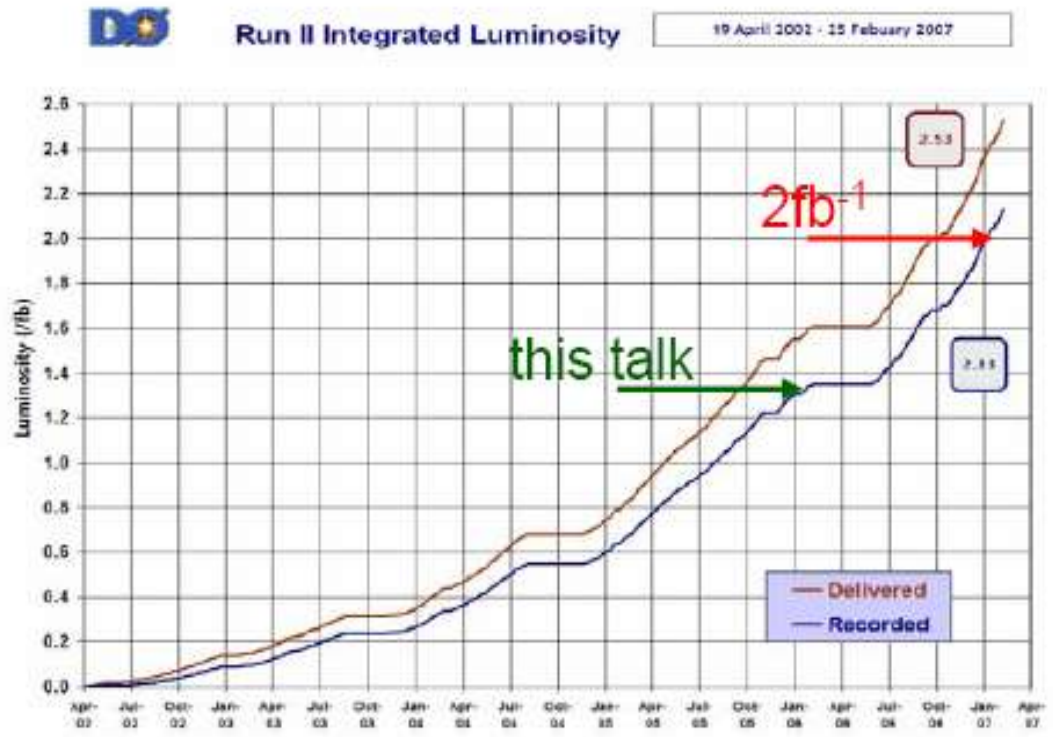
Tevatron

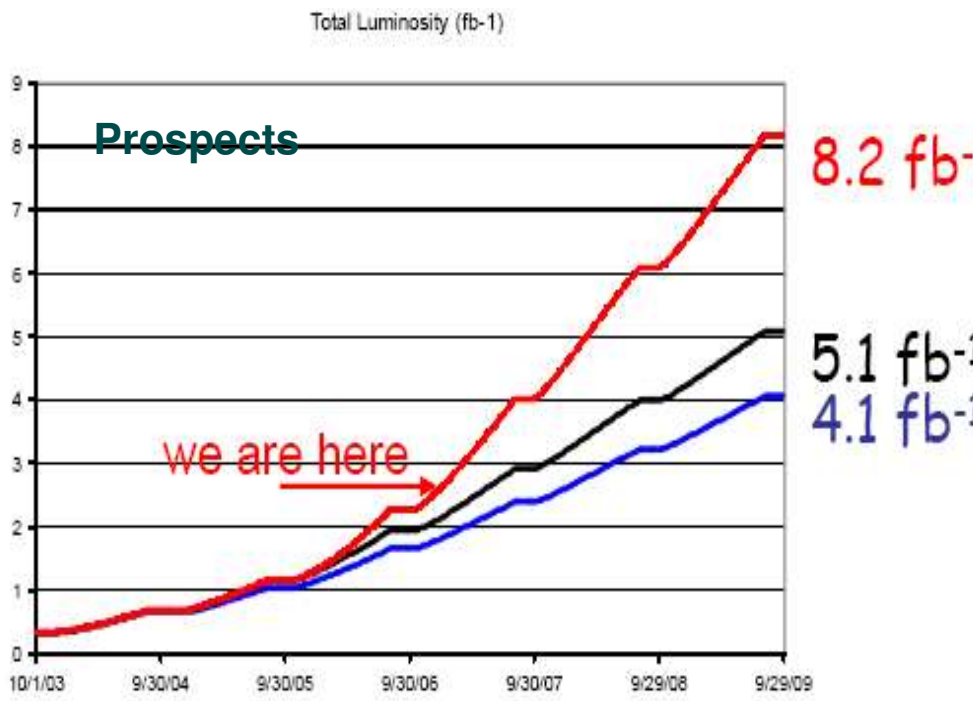
-> $p\bar{p}$ collider: CDF, D0

Run I E_{cm}=1.8 TeV

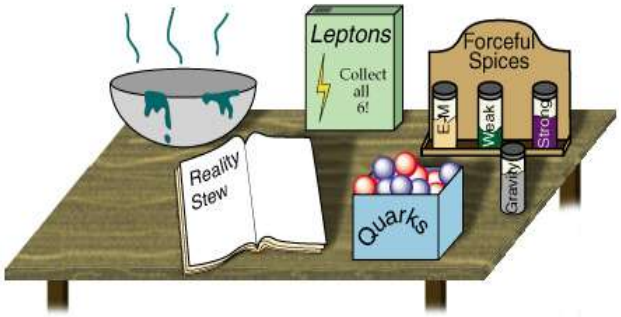
130 pb^{-1}/exp.(phys.)

Run II E_{cm}=1.96 TeV





Analyses with $1fb^{-1}$, a lot more to go still



Standard Model Status

- **Consistency check of the SM based on high precision measurements**
- **More than 1000 data points combined in 17 observables calculated in the SM from:**
  - **α_{em} (precision $3\cdot10^{-9}$) the critical part $\Delta\alpha_{had}$ (from e+e-->hadrons)**
  - **G_F (precision 9.10^{-6}) (->MW)**
  - **M_Z (precision 2.10^{-5}) from lineshape (LEP-1)**
  - **$\alpha_s(M_Z)$ (precision 2.10^{-2}) hadronic observables**
  - **M_{top} and M_{Higgs}**
- **Zfitter 6.42, precision at 2 loop (M_W , $\sin^2\theta_W$) 3-loop for ρ**

M^{top} and M^{W}

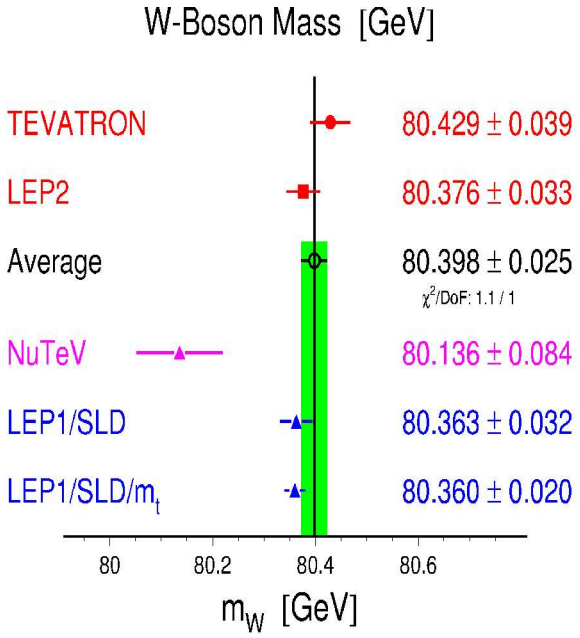
CDF M_W: 80413 ± 48 MeV

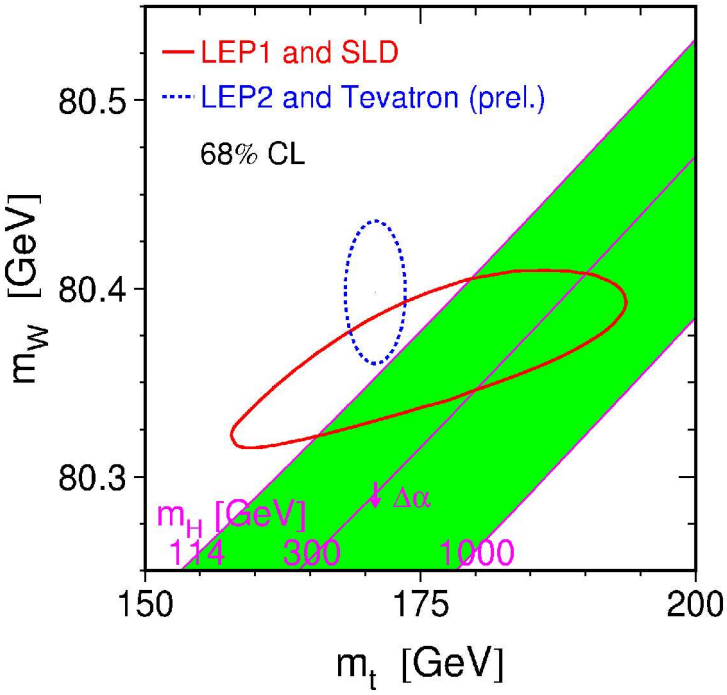
Tremendous progress in direct mesurements at Tevatron

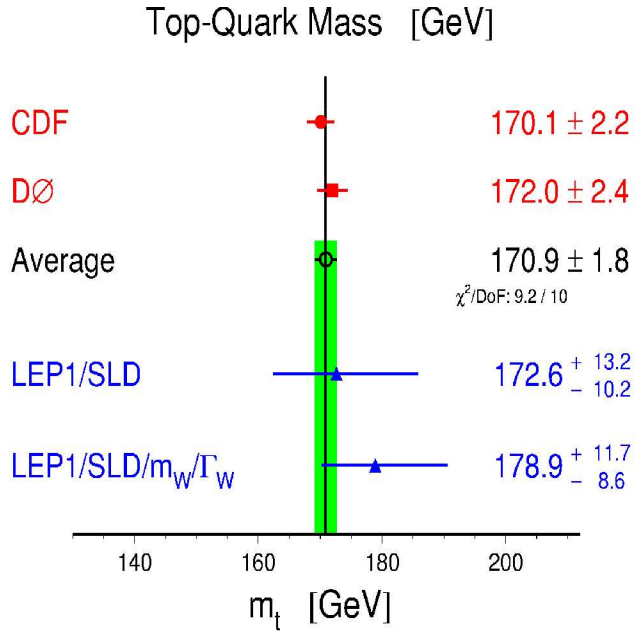
Higgs particle may be round the corner (or not)

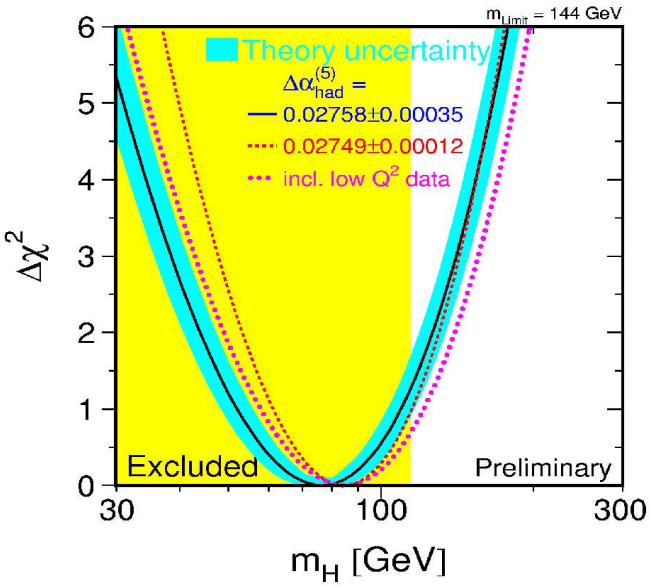
M^{higgs}=76+33-24 GeV

M^{higgs}<144 (182) GeV

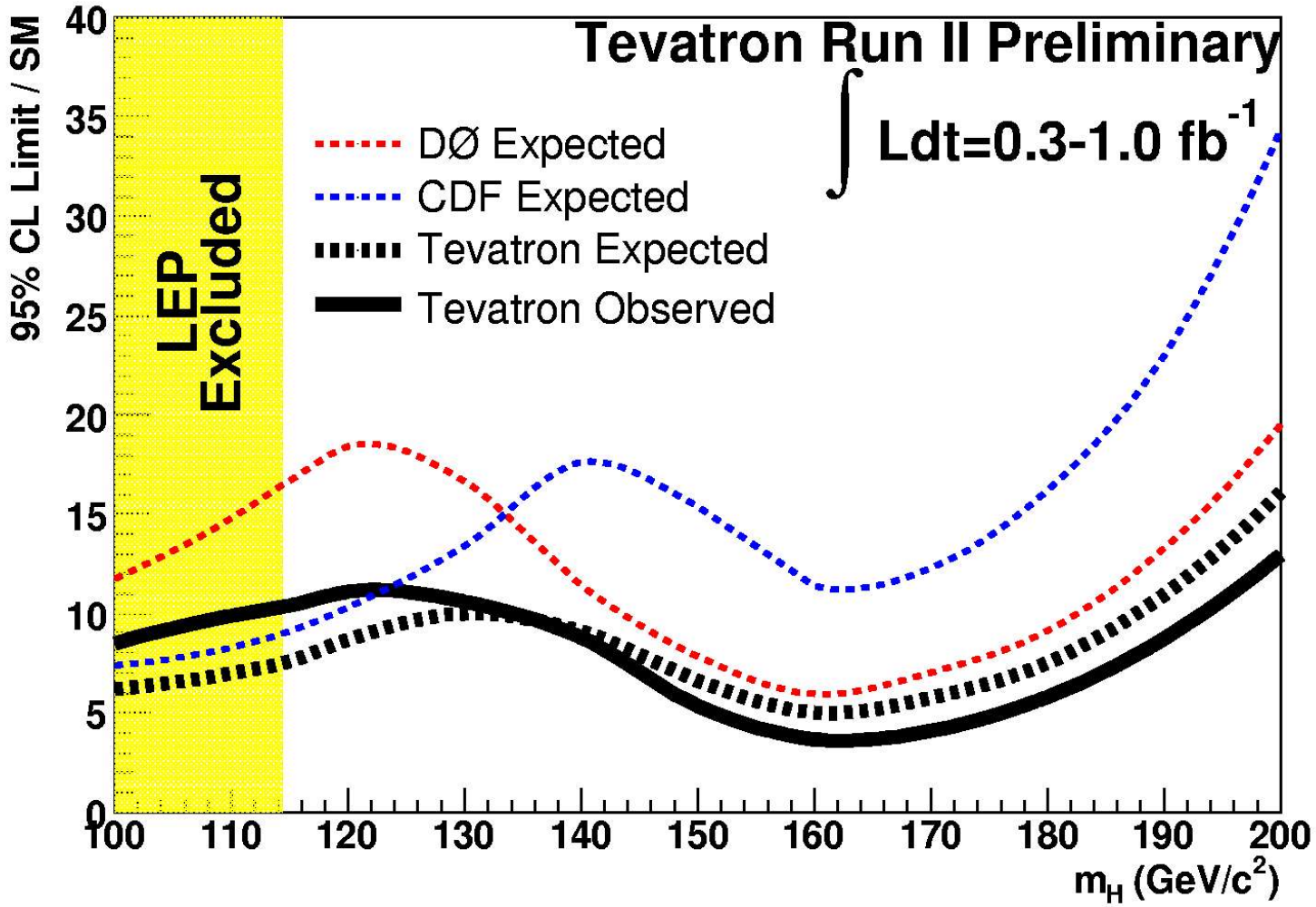








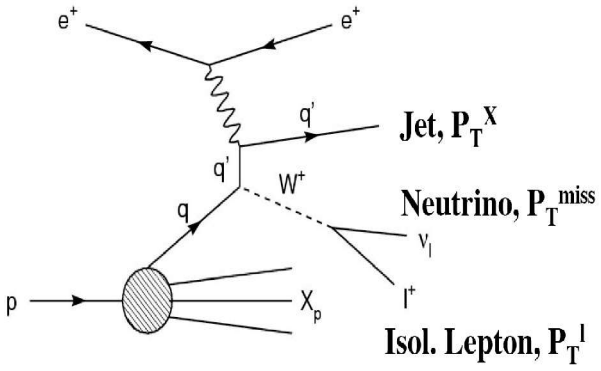
Direct Higgs Searches at Tevatron

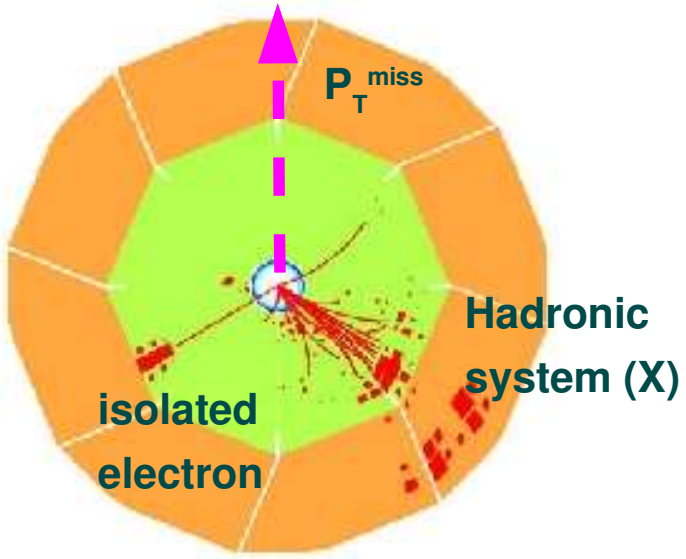


Event with isolated e or μ and P_T^{miss}

SM W: Total Cross Section ~1.3 pb

=> ~5 events/100pb^{-1}with e or μ

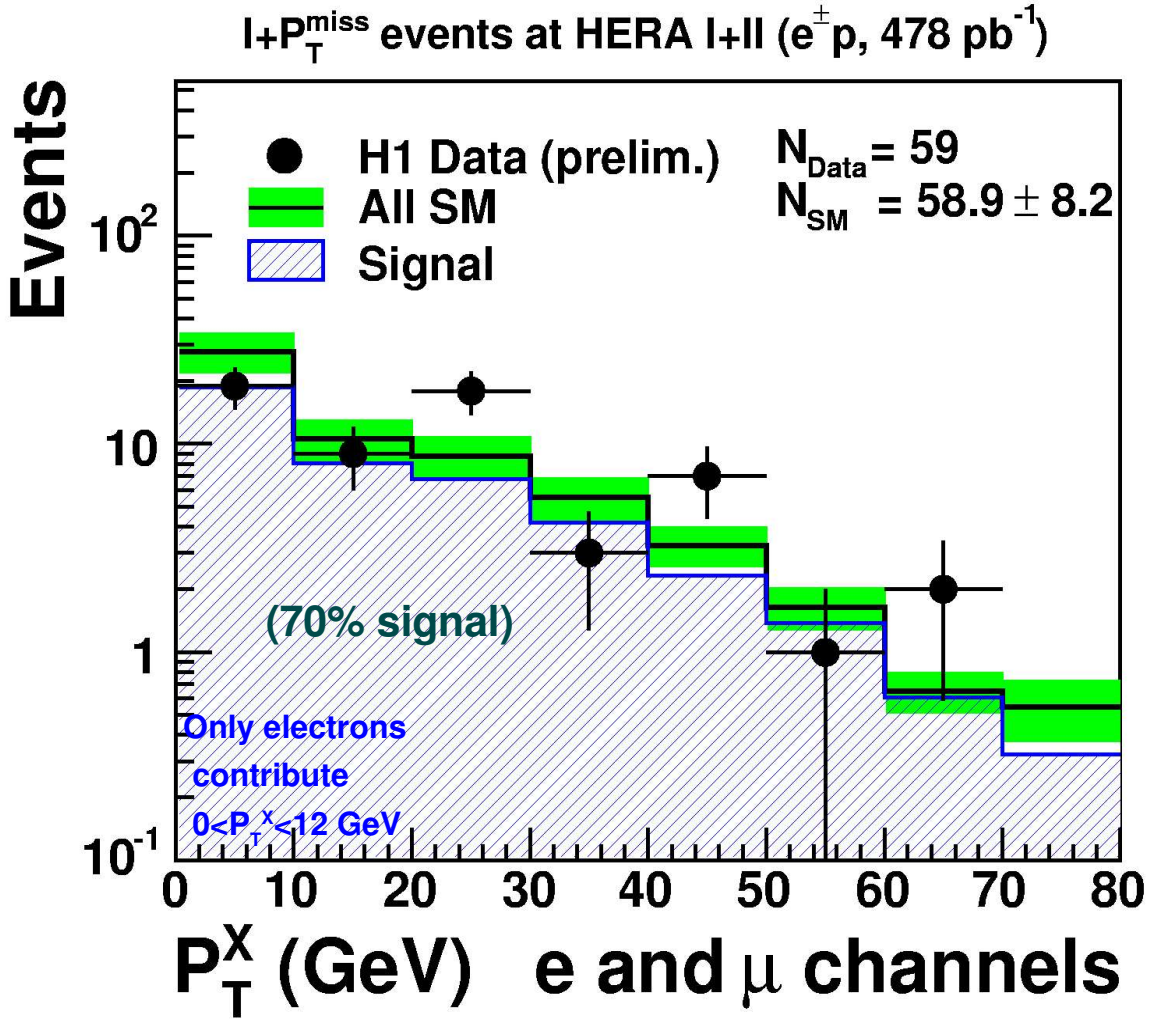




H1 HERA 1 (118 pb^{-1}, mainly e$^+$p)

P_T^X>25 GeV 11 (Data) / 3.5±0.6 (SM) (3σ)

Full HERA Luminosity

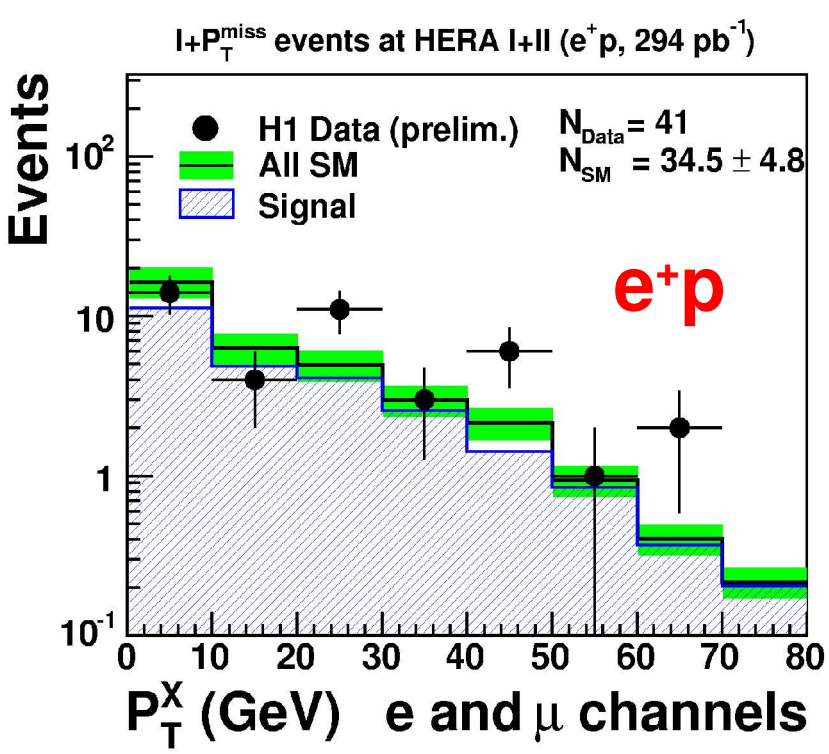


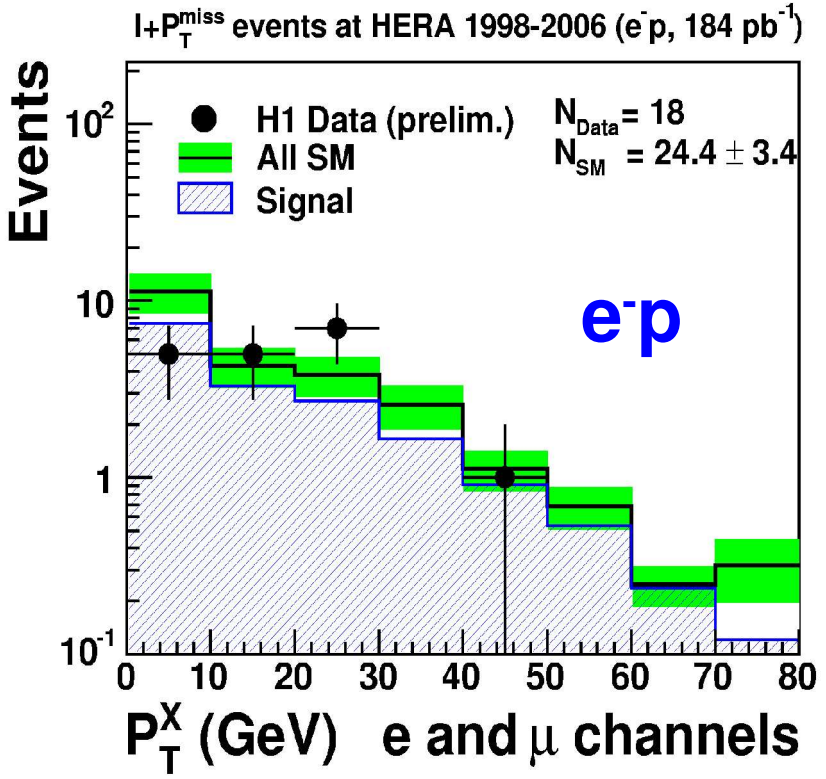
Evidence for W production at HERA

Continue to observe events at high P_T^X

=>Look more differentially in e$^+$p/e$^-$p data samples

H1 Results (e and μ) e^+p vs. e^-p data





Different observations
in e^+p and e^-p.
ZEUS do not support this observation

P_T^X > 25 GeV		electrons **Data/SM**	muons **Data/SM**
H1	294 pb^{-1}	11/4.7±0.9	10/4.2±0.7
ZEUS	228 pb^{-1}	1/3.2±0.4	3/3.1±0.5

3sigma

Events with leptons and photons

Search for $\ell\gamma + X$ in 929 pb^{-1}

Motivation

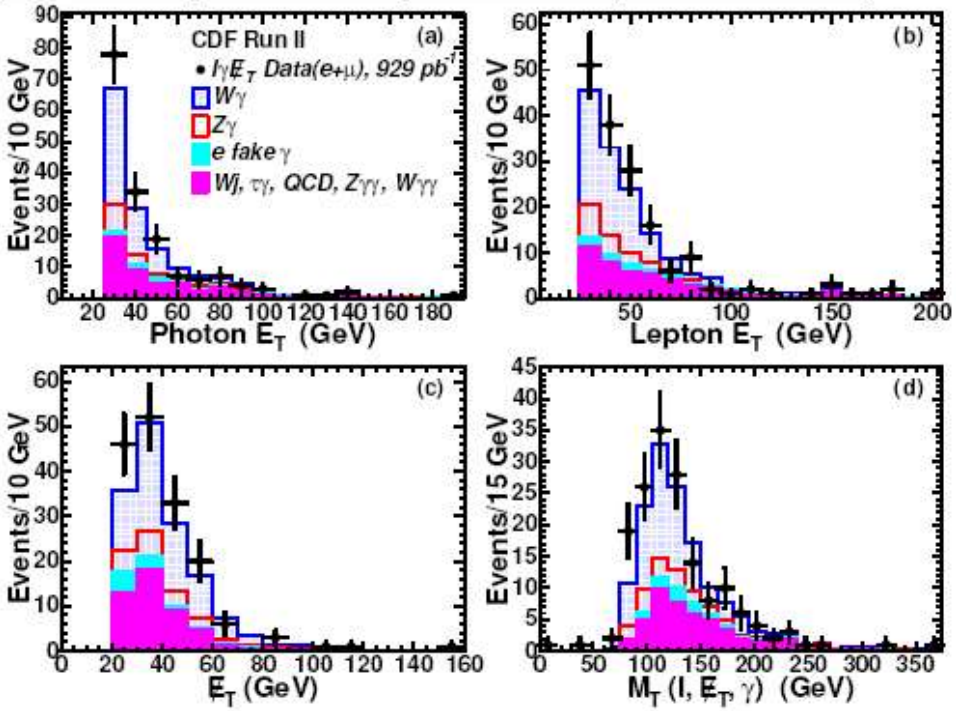
- Run I $ee\gamma\gamma\not\!\!E_T$ (10^{-6} expected, 1 observed)
- $\ell\gamma\not\!\!E_T$: 7.6±0.7 expected, 16 observed, 2.7σ

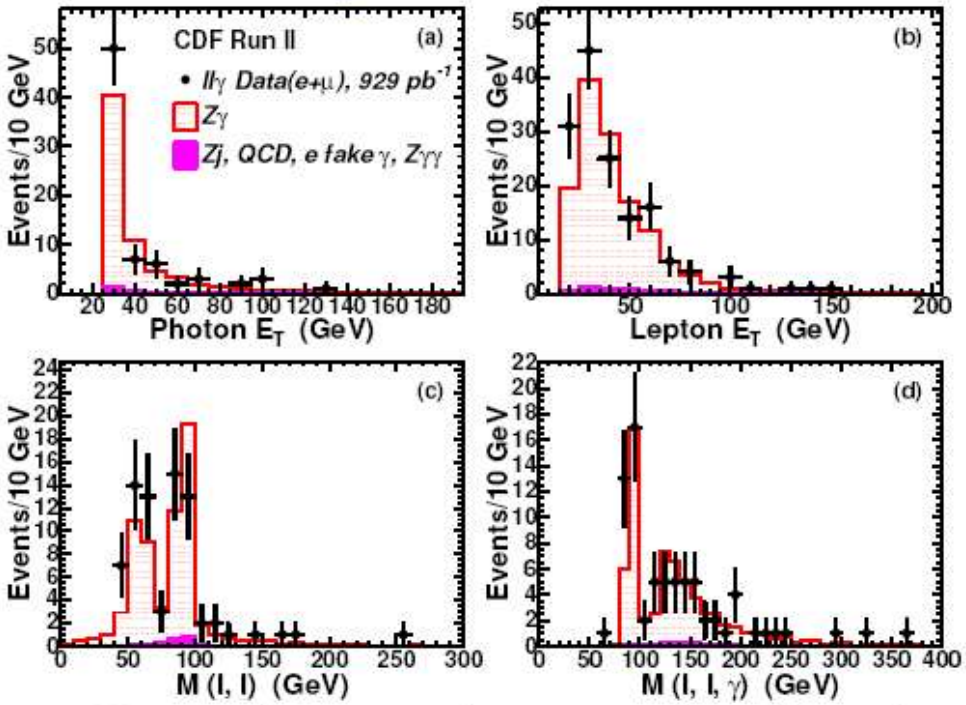
Analysis

- Signature-Based search
- *a priori* defined cuts (same as in Run I)
- MadGraph, CompHep and Baur MC

Results

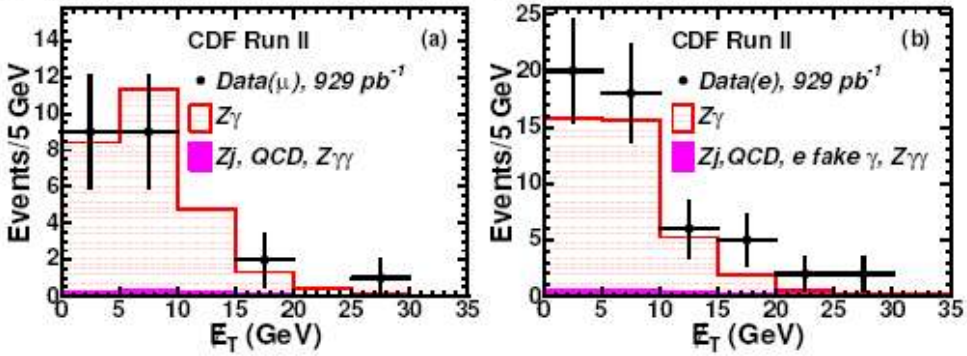
$\ell\gamma\not\!\!E_T$	$e\gamma\not\!\!E_T$	$\mu\gamma\not\!\!E_T$	$(e+\mu)\gamma\not\!\!E_T$
Predicted	94.8 ± 8.1	55.7 ± 7.1	150.6 ± 13.0
Observed	96	67	163





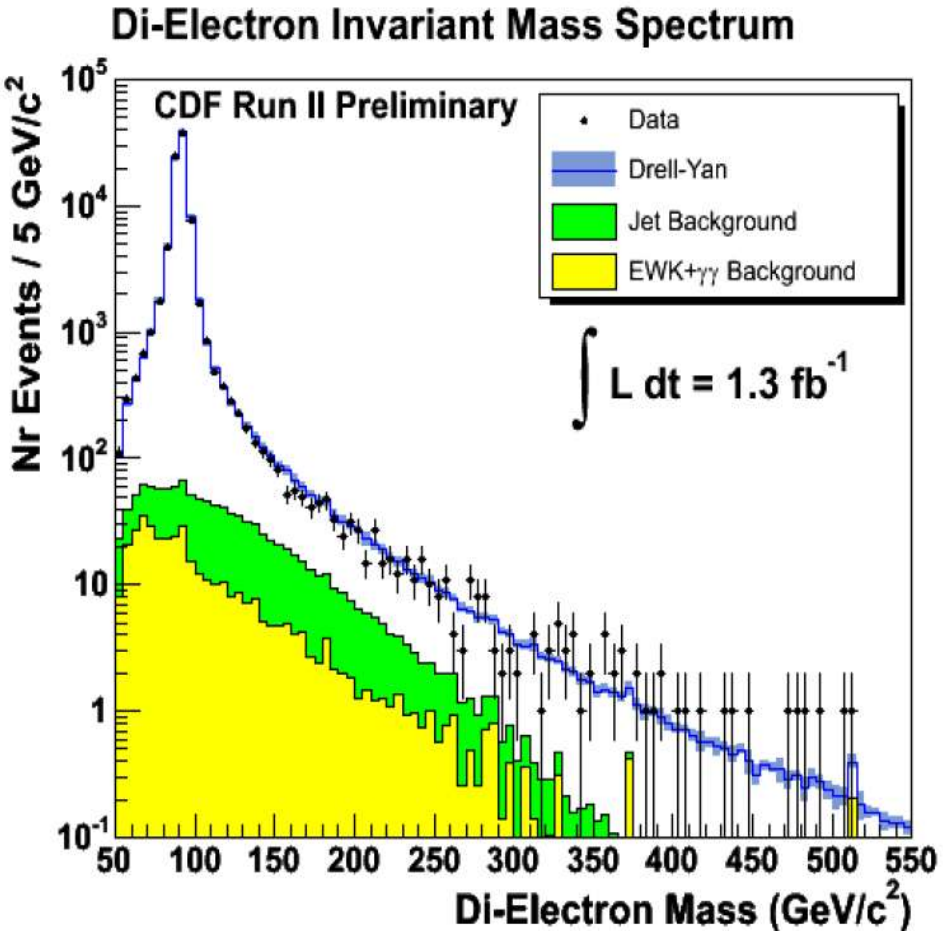
$\ell\ell\gamma$	$ee\gamma$	$\mu\mu\gamma$	$\ell\ell\gamma$
Total	39.0 ± 4.8	26.1 ± 3.1	65.1 ± 7.7
Observed	53	21	74

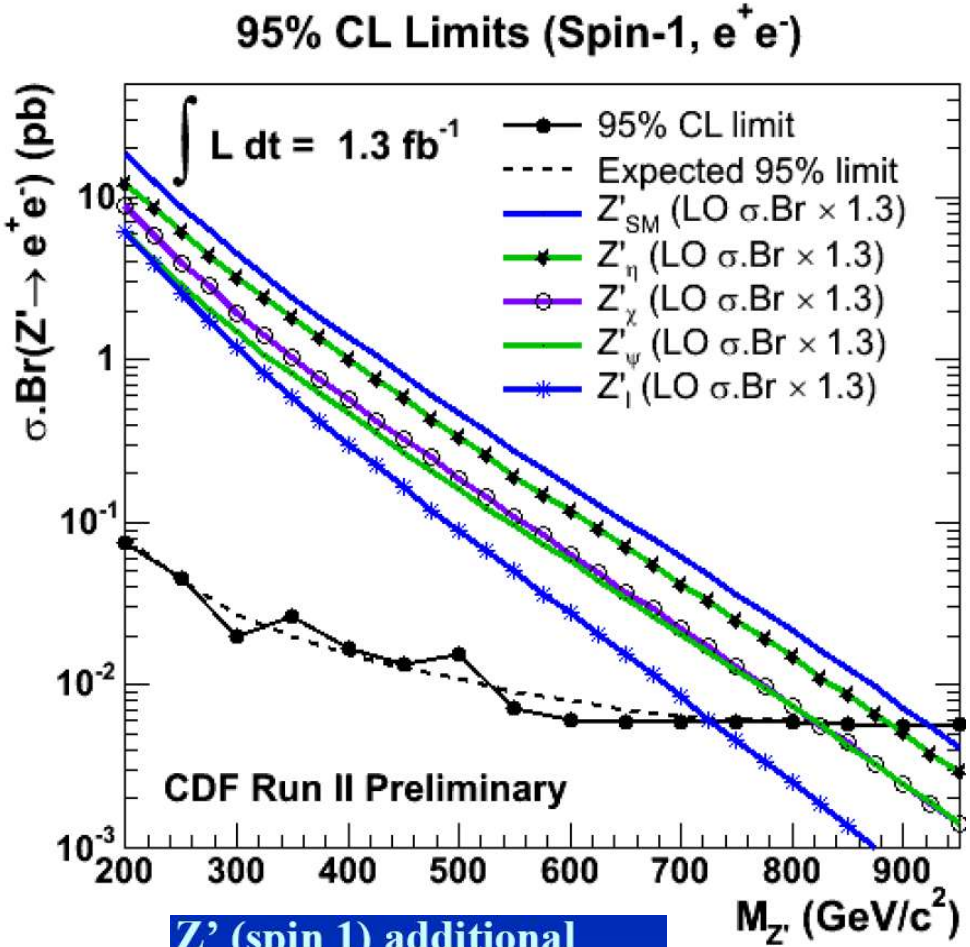
0 $e\mu\gamma$ vs. 1.0 ± 0.3, 0 $\ell\gamma\gamma$ vs. 0.62 ± 0.15



Di-leptons searches (Tevatron)

Two electrons with P_T>25 GeV





Z' (spin 1) additional neutral gauge boson

Z'_{SM}>923 GeV Z'_{I}>729 GeV
Z'_{ψ}>822 GeV Z'_{χ}>822 GeV
Z'_{η}>891 GeV

New Result
Full HERA statistics

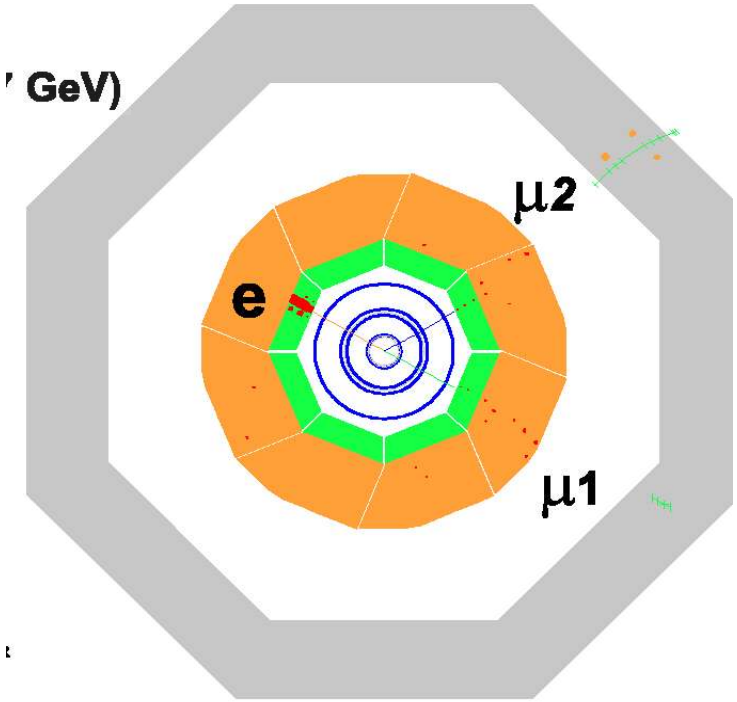
Multilepton events at HERA

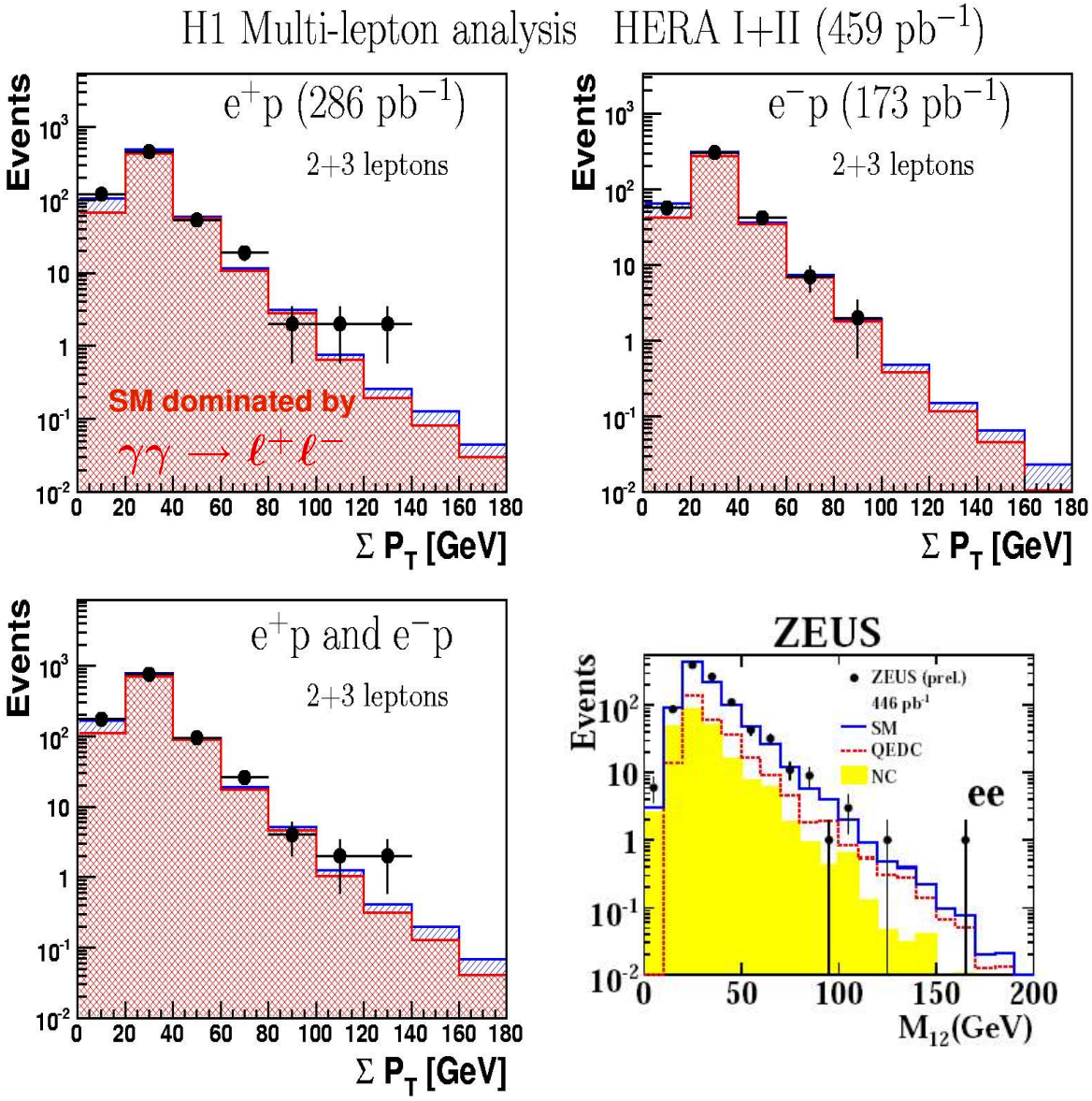
H1/HERA I: observation of multi-electrons at high mass

Include muons; combinations:

ee, eμ, μμ, eee, eμμ

ΣP_T: "hardness" of the events





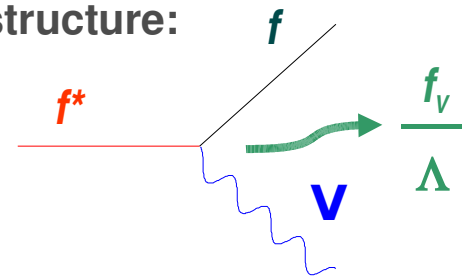
For ΣP_T>100 GeV, e^+p data: 4/1.2±0.

Search for lepton-boson resonances

full HERA E_{cm}=320 GeV luminosity

Unambiguous signature for matter substructure:

direct observation of excited states



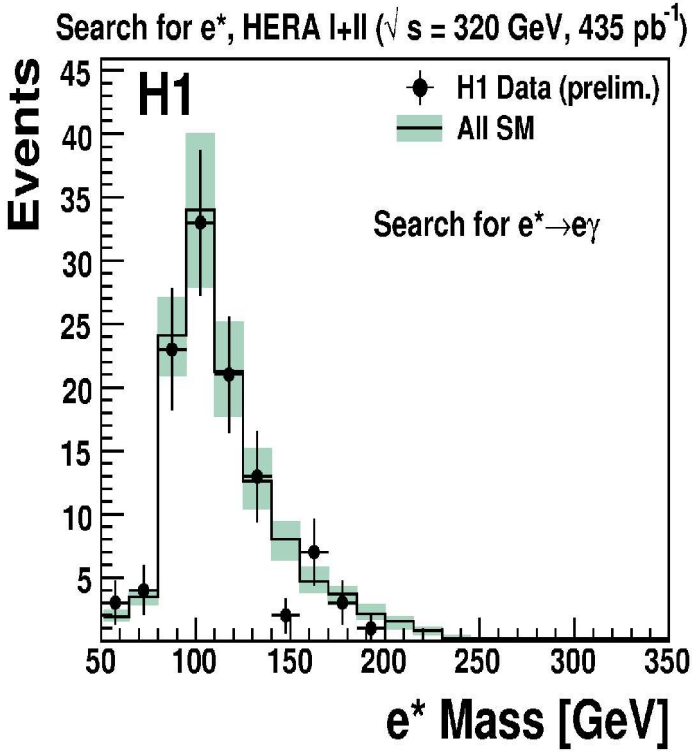
$\Lambda \approx$ compositeness scale

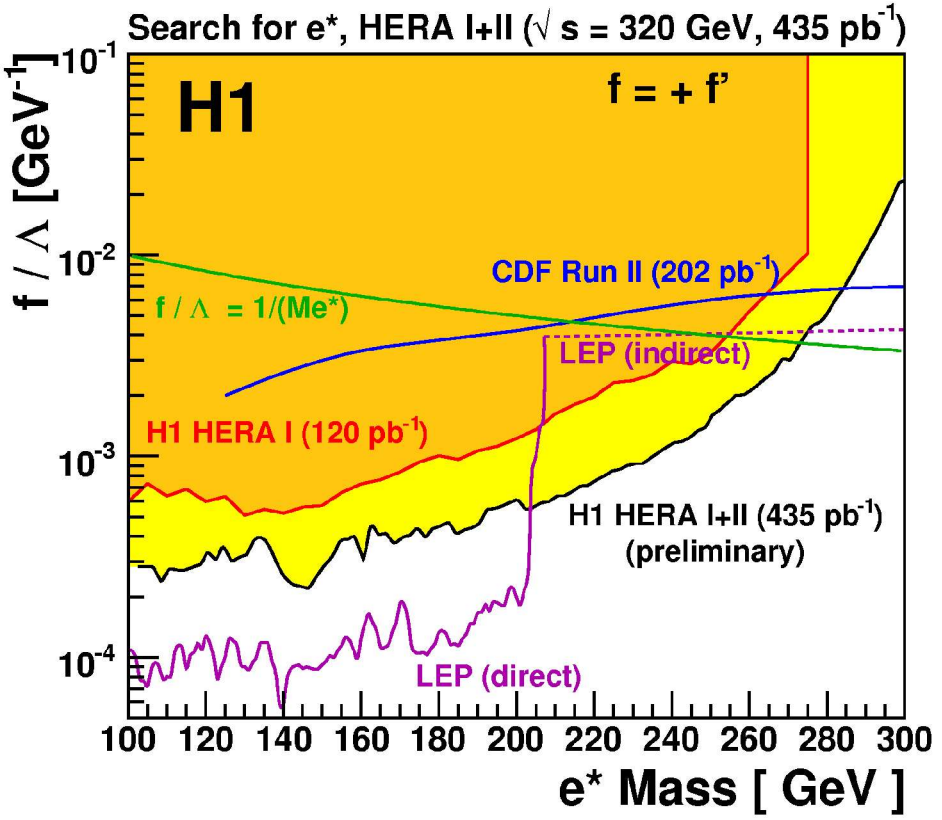
Relative strength γ, Z,g :

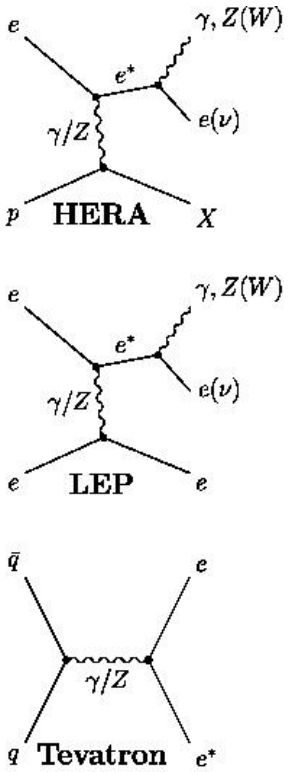
couplings f, f ', f_s

Lepton-Boson Resonances

eγ, νW, eZ



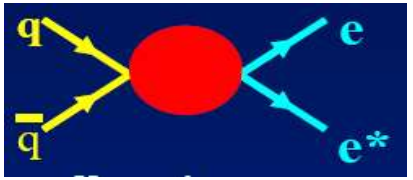


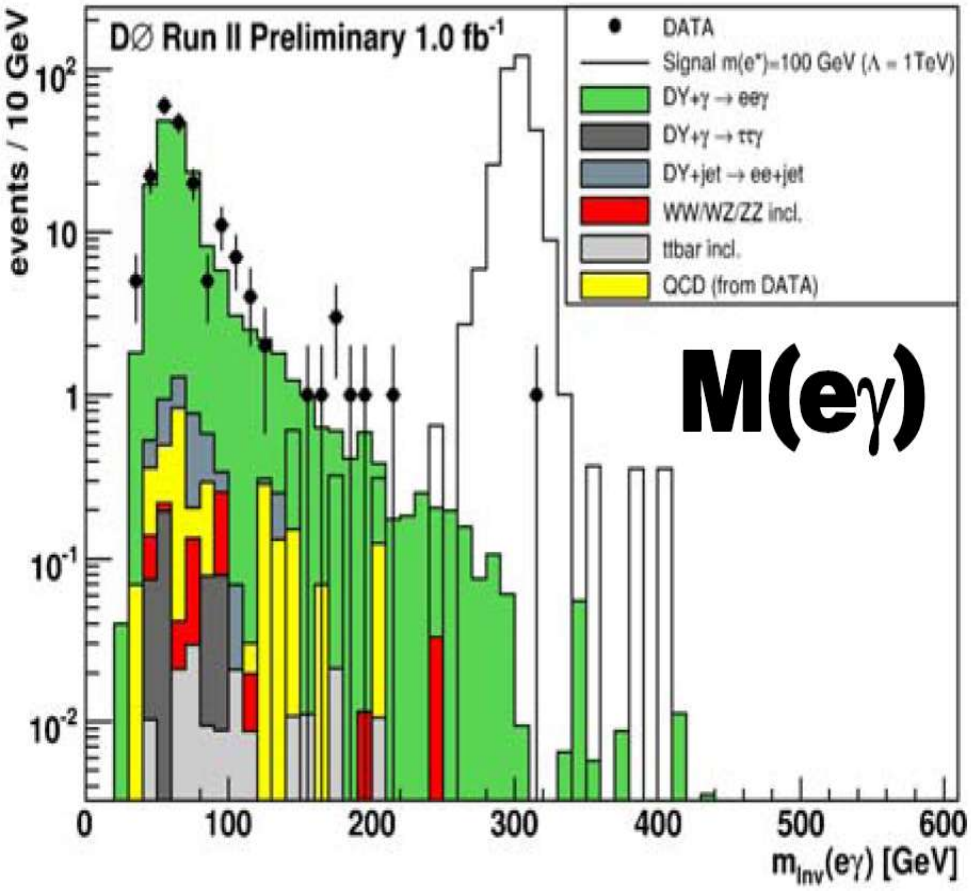


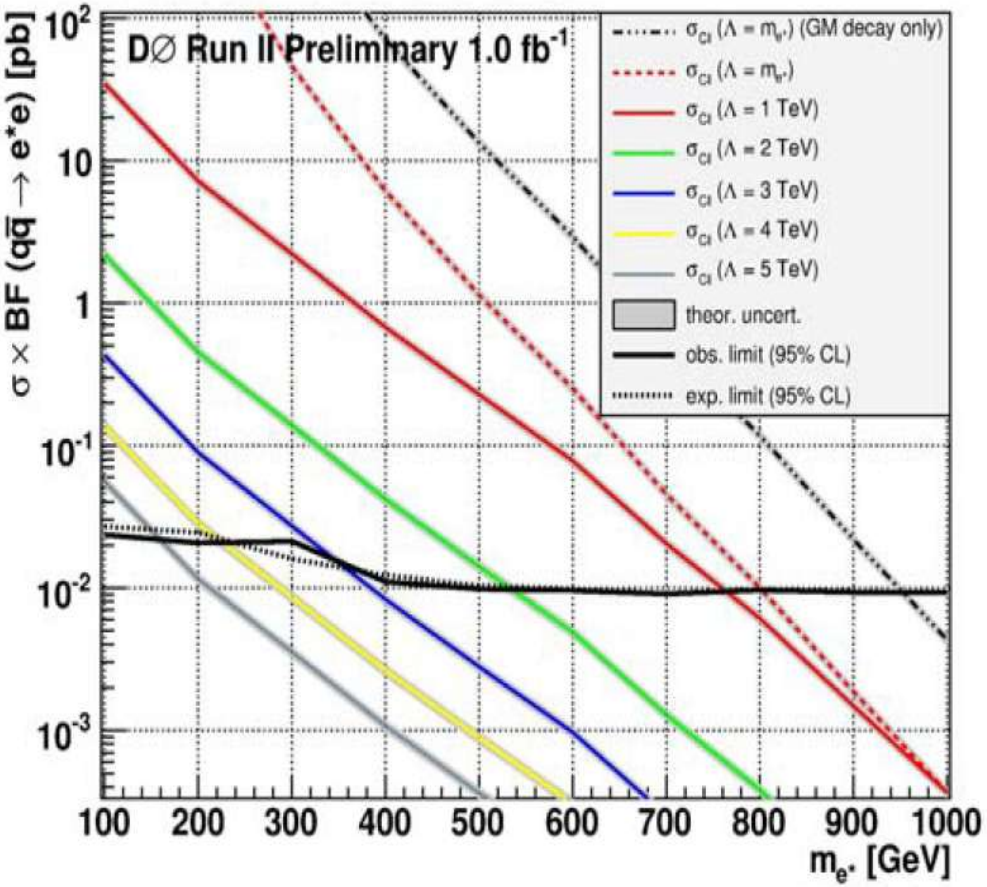
$f/\Lambda = 1/M_{e*}$

$M_{e*} < 273$ GeV excluded @ 95% C.L.

Excited electrons(Tevatron)







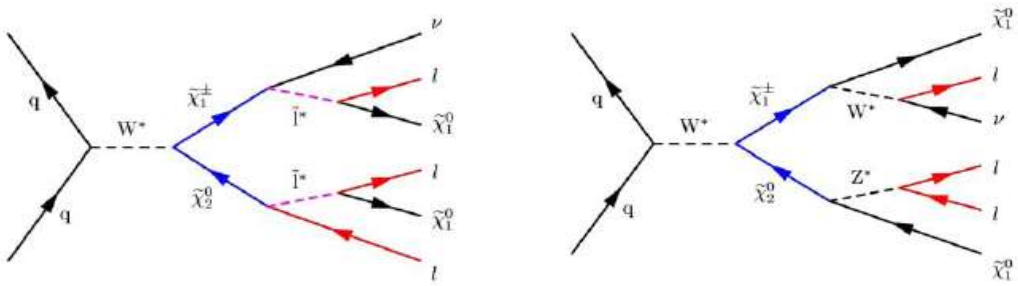
Λ=M(e*) M(e*)<800 GeV excluded @ 95% CL (CI formalism)

Multi-leptons at Tevatron

Trileptons: very small background

spectacular signature

Can come from SUSY cascades



CDF: 14 topologies (e,μ, tracks)

3lep	ee+l CEM	ee+l plug	eμ+l	μμ+l high p_T	μe+l CEM	μe+l plug	ee + track	μμ+l low p_T
Lumi (pb^{-1})	1034	954	1034	745	745	680	1013	976
Bkgd	0.44 ± 0.08	0.34 ± 0.10	0.28 ± 0.09	0.64 ± 0.18	0.42 ± 0.08	0.36 ± 0.07	0.97 ± 0.28	0.42 ± 0.12
Data	0	0	0	1	0	0	3	1

LS lep	ee LS	ee_{si} LS	$e_{si}e_{si}$ LS	e_{si}μ LS	eμ LS	μμ LS
Lumi (pb^{-1})	993	993	993	971	971	1087
Bkgd	0.10 ± 0.10	0.50 ± 0.30	1.30 ± 0.30	1.70 ± 020	2.30 ± 0.50	0.90 ± 0.10
Data	1	2	1	4	4	1

LS=likesign

D0:4 topologies

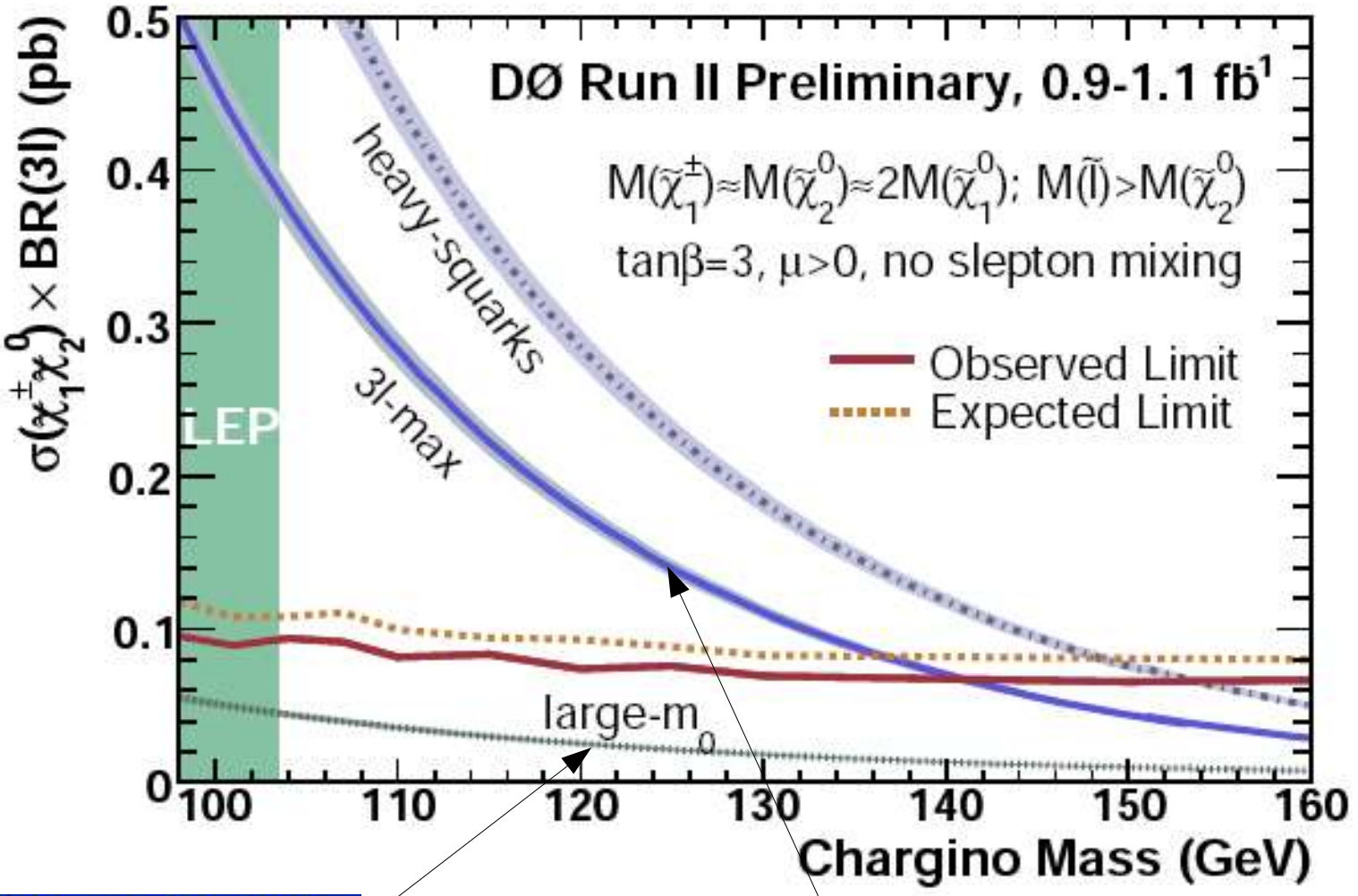
	Lumi (pb^{-1})	Bkgd	Data
eel	1000	0.76 ± 0.67	0
μμl	1100	0.32 ± 1.34	2
μel	1100	0.94 ± 0.40	0
LS *μμ*	1000	1.1 ± 0.4	1

Inclusive techniques deployed

Very low number of events

No significant deviation found

SUSY constraints from multi-leptons



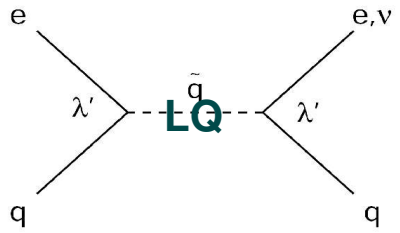
MSUGRA

- W/Z decays dominate
- no sensitivity

- m(slepton) slightly larger than m(χ_2^0)
- $M(\chi_1^{\pm}) > 141$ GeV

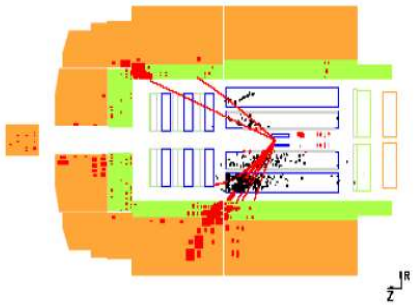
Search for lepton-jet resonances

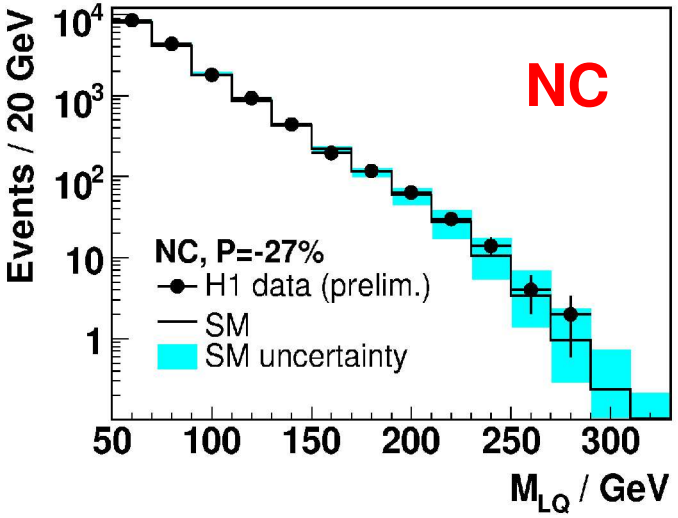
Lepton-jet resonance



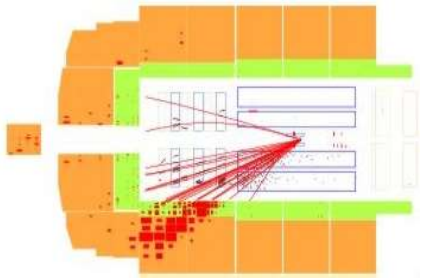
HERA II, e^-p, 92 pb^{-1}

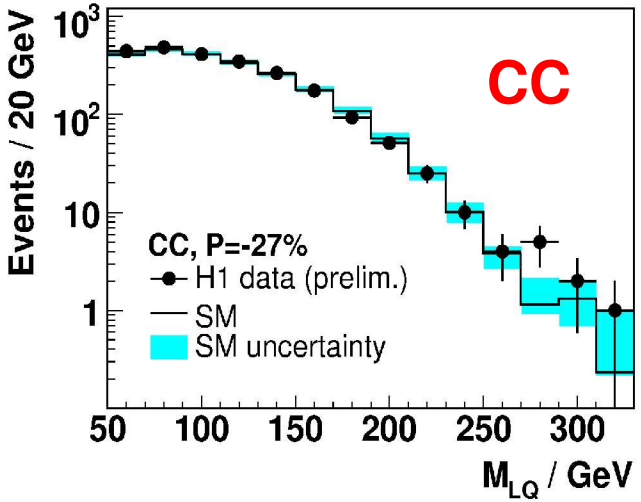
e+jet

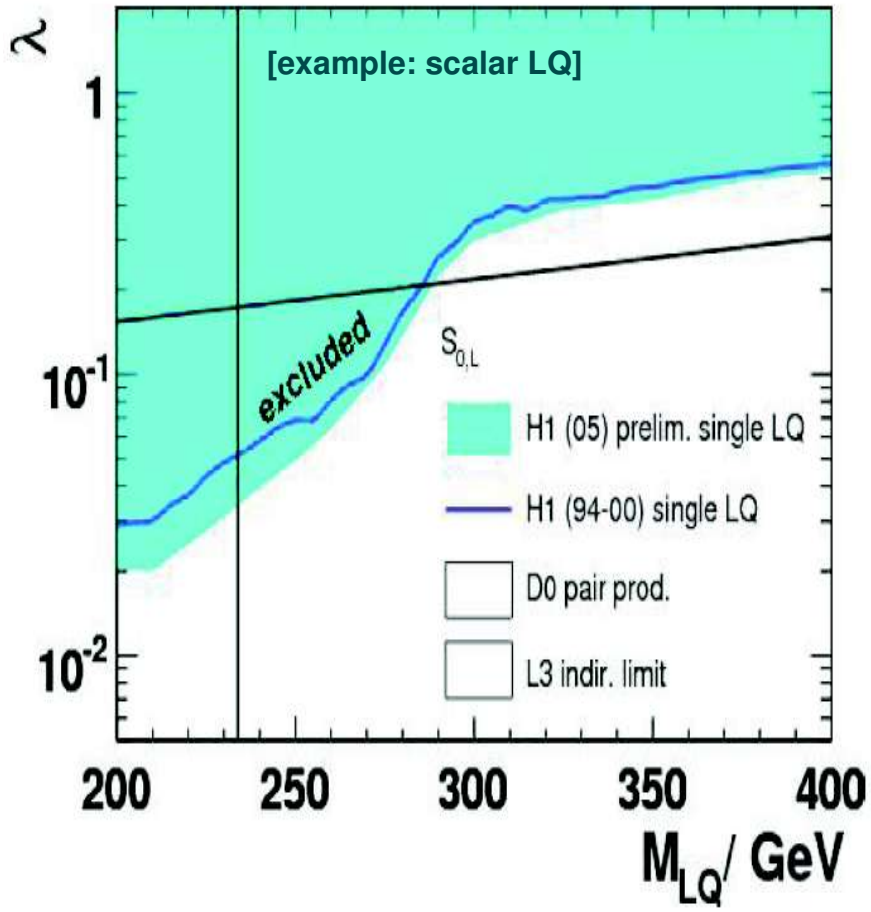




P_T^{miss}+jet



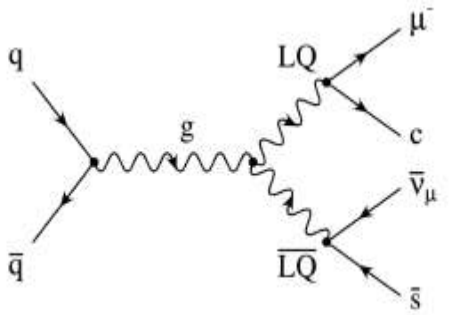




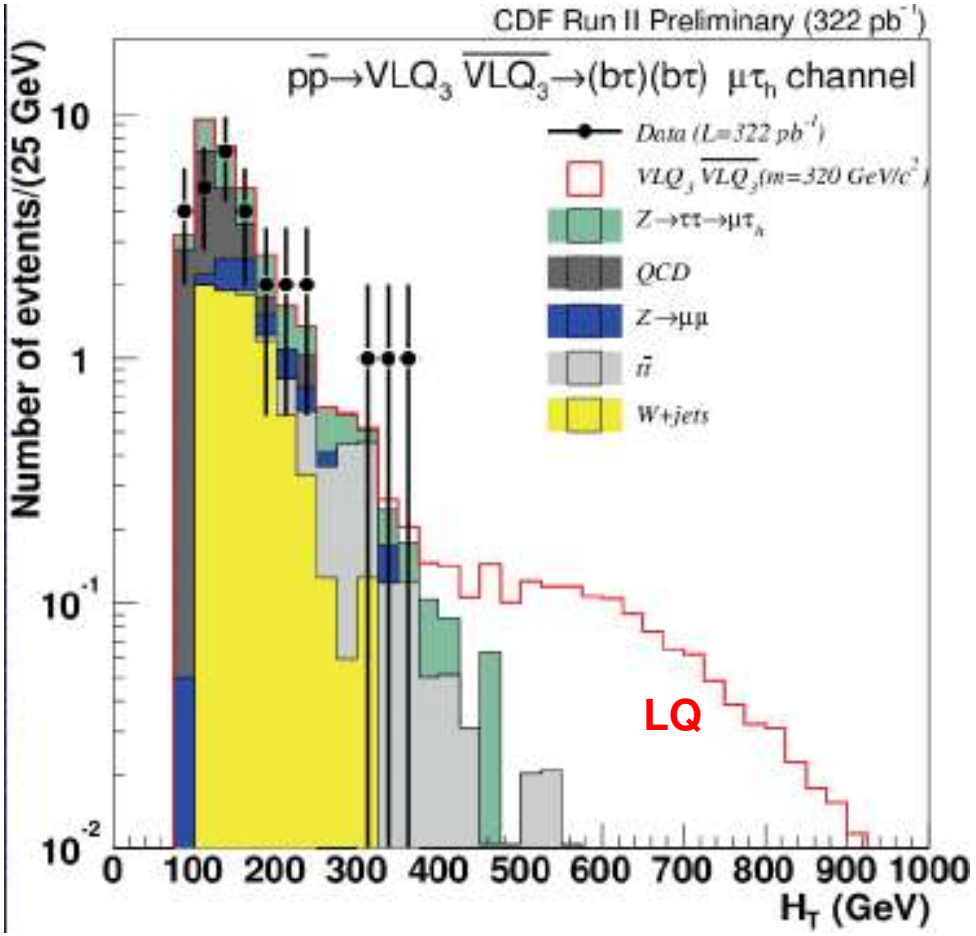
More data, e^+/e^-p, (x2)

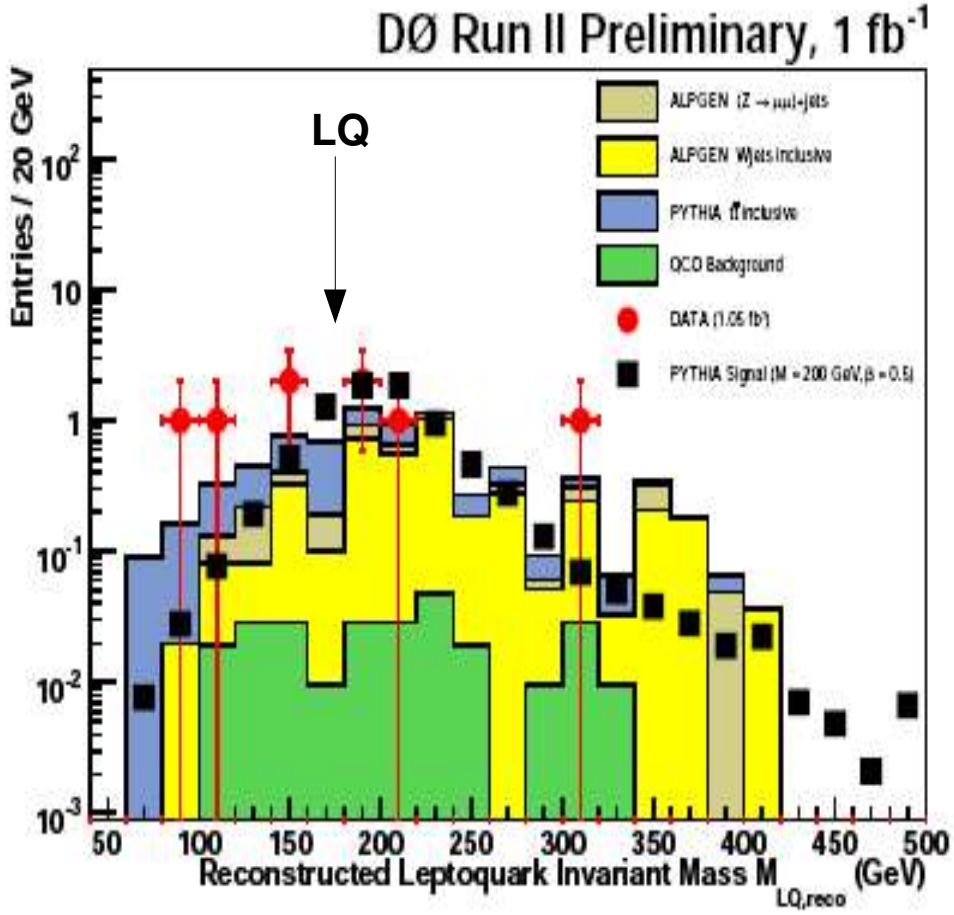
final domain to explore

Leptoquarks at Tevatron



Complex particle identification: LQ 2nd and 3rd generations

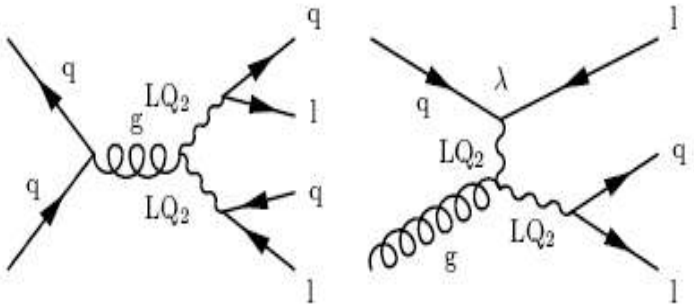


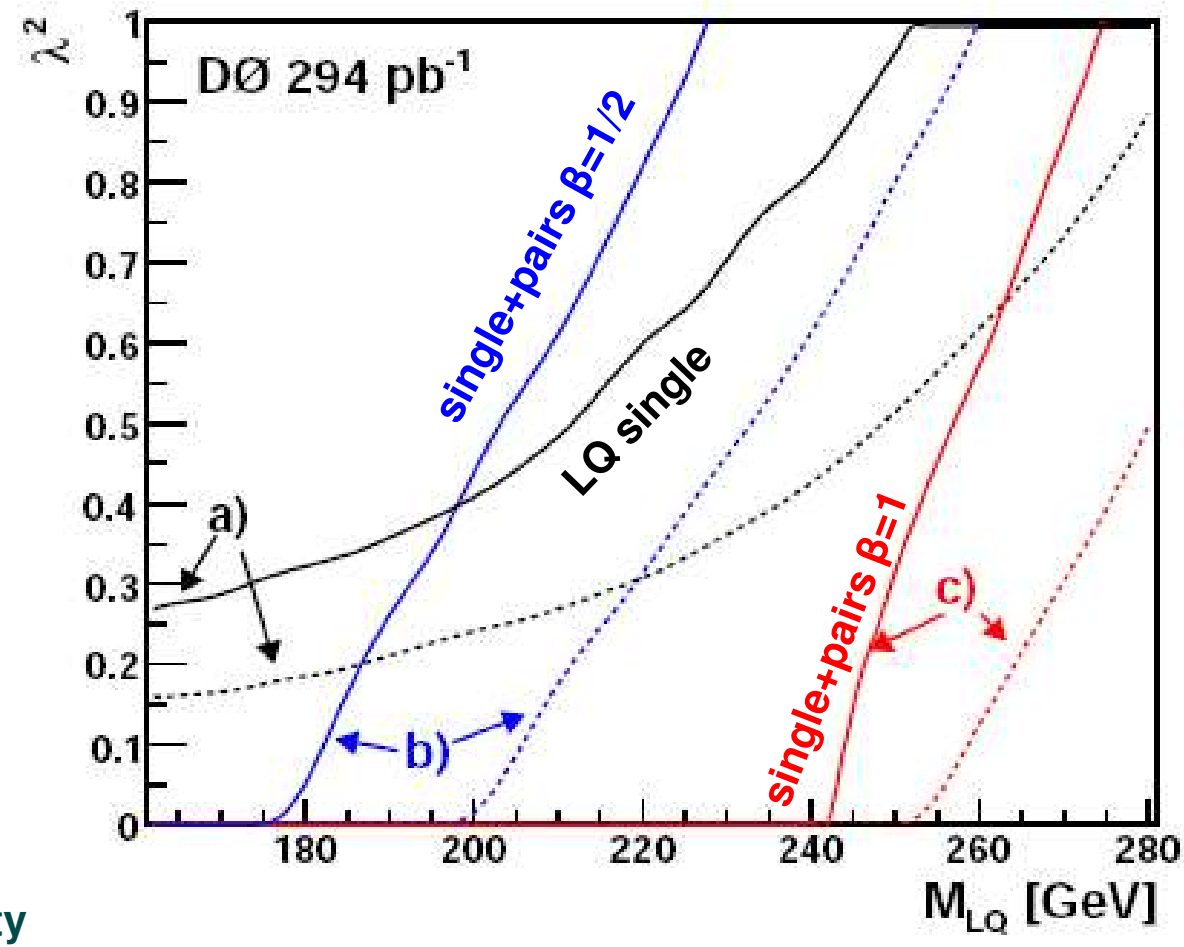


Single production at Tevatron

PLB 647, 74 (2007)

Here: second generation LQ_2

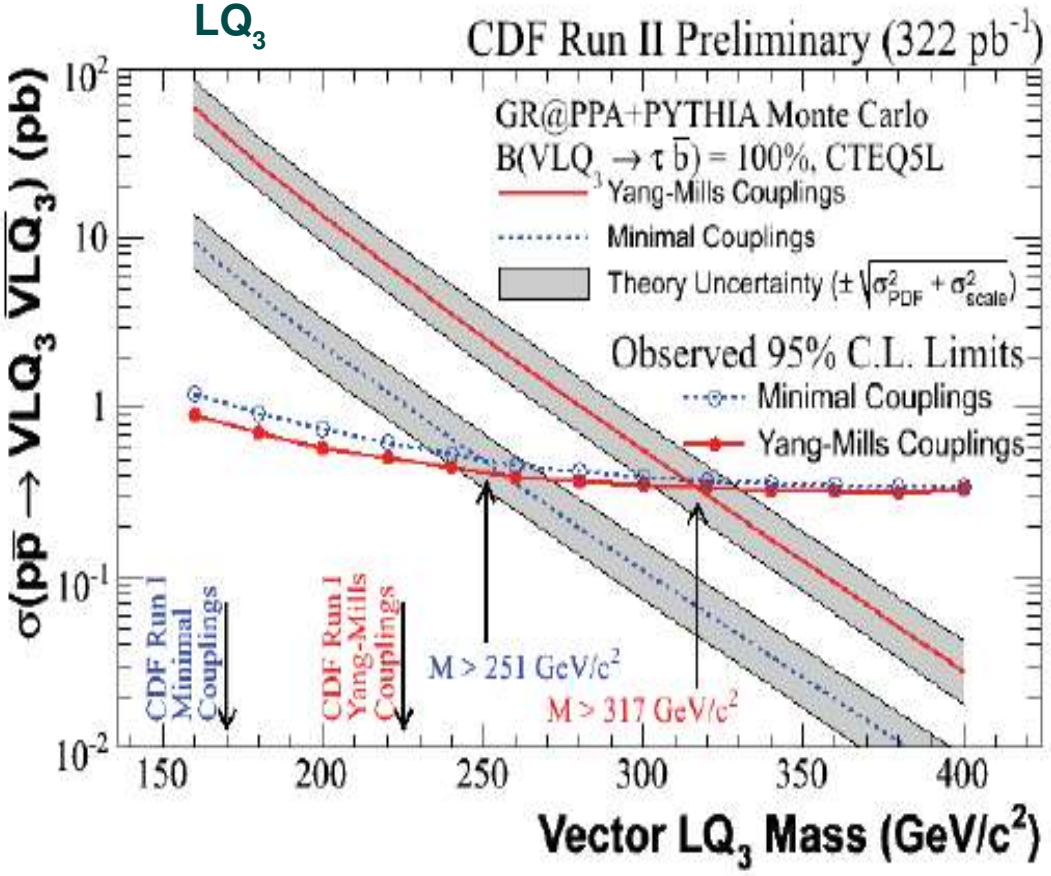


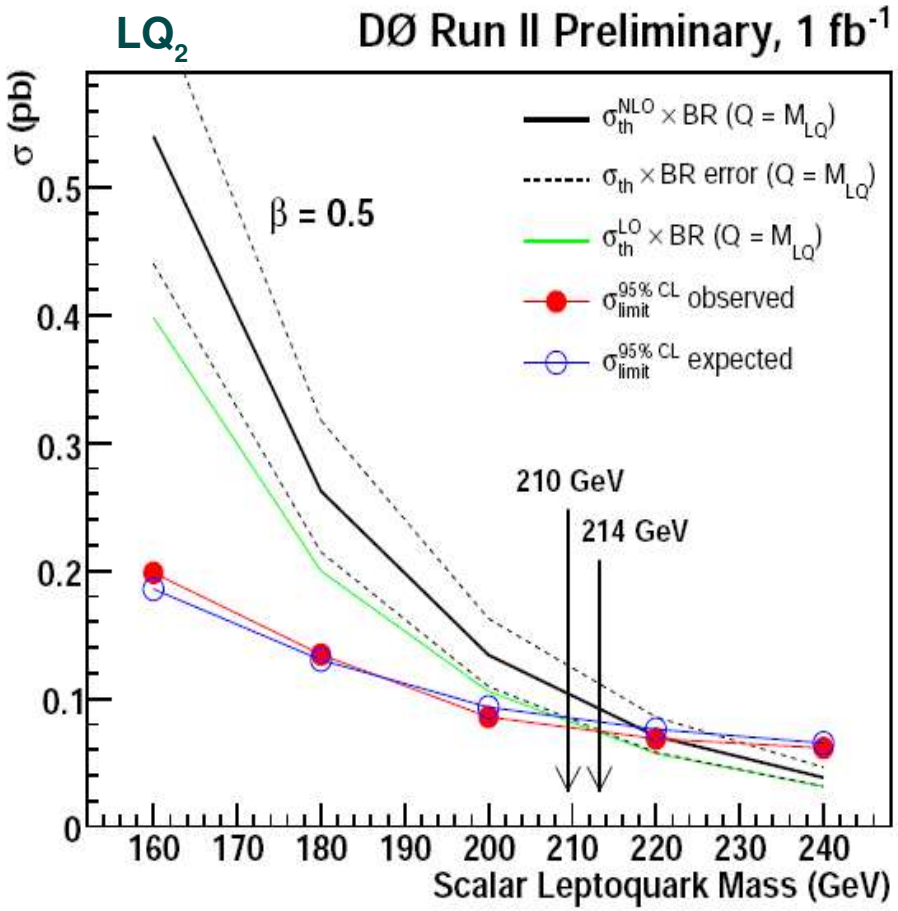


More mechanisms, more sensitivity

single production: gain for larger couplings

Mass-coupling limits



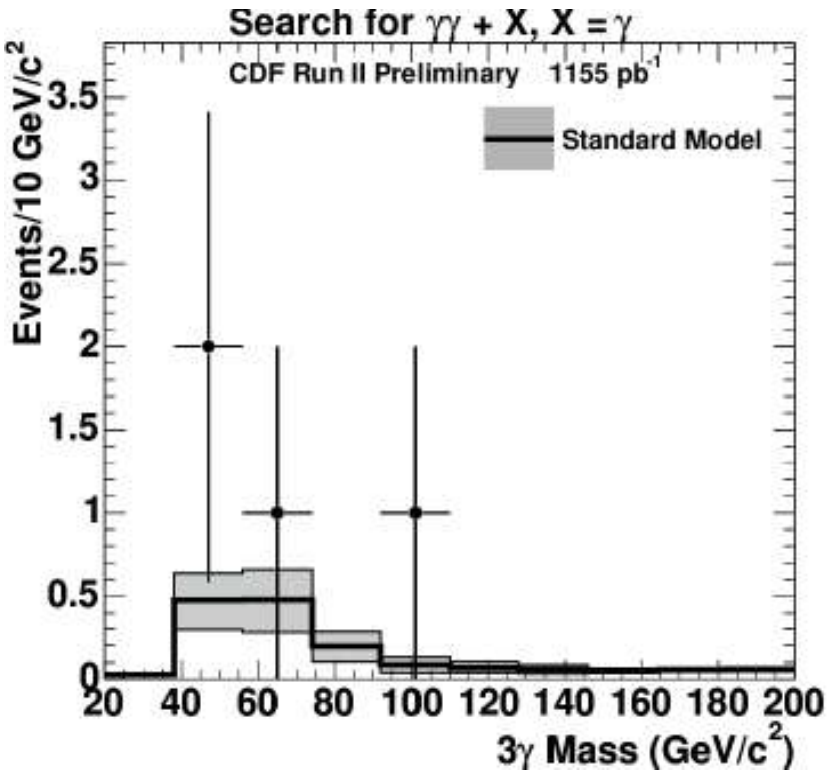


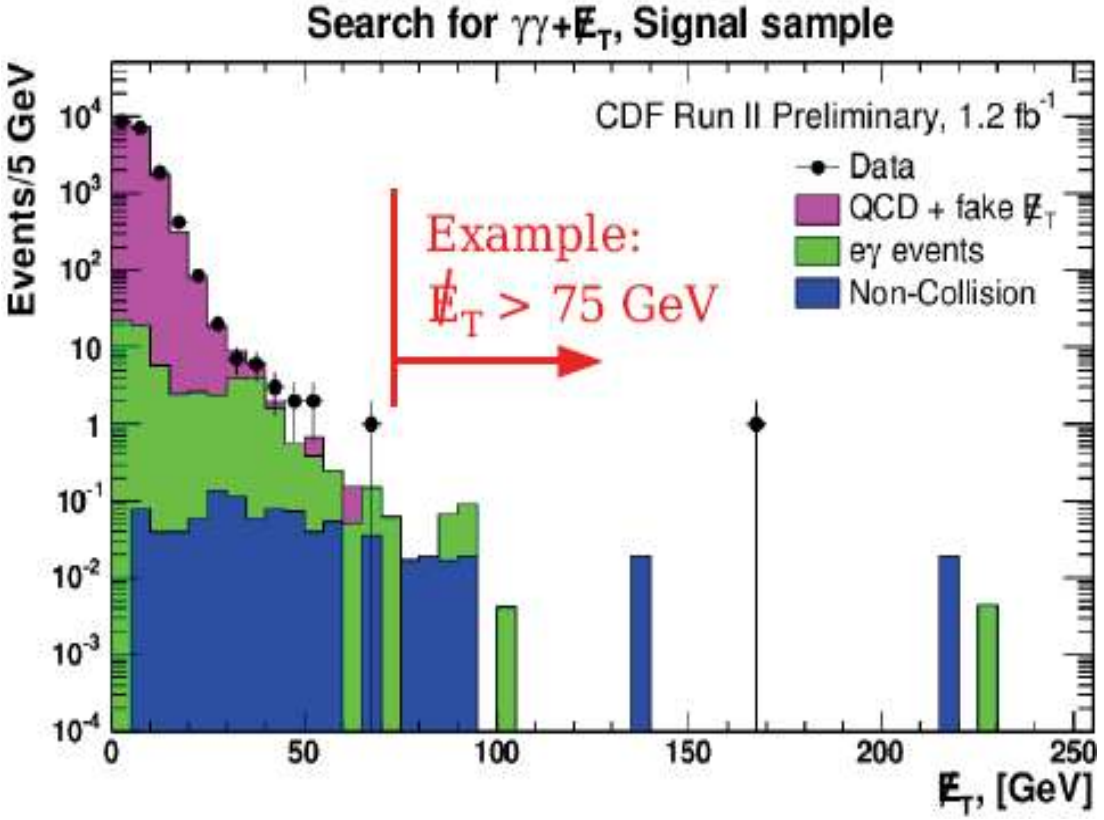
M>317 GeV @ 95% CL

M>214 GeV @95% CL

Multi-photon events at Tevatron

Motivated by the anomalous eeγγ E^t_{miss} event (run I)





	γγγ	γγ$\not\!\!E_T$	γγe	γγμ
SM	2.2	0.24	6.8	0.7
Data	4	1	3	0

Good agreement with the Standard Model

General Searches

New result
Full HERA II

- Search for isolated particles at high P_T
- Electrons ,Photons, Muons, Hadronic Jets, Neutrinos

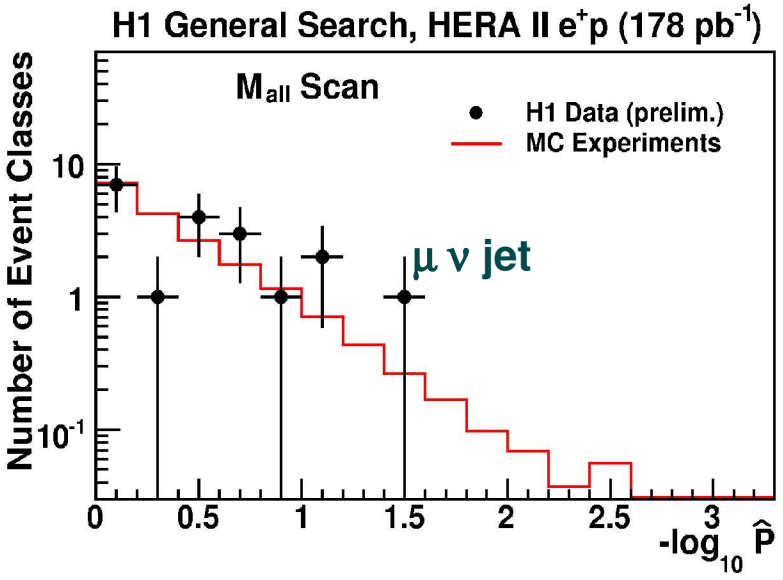
- Unique phase space:

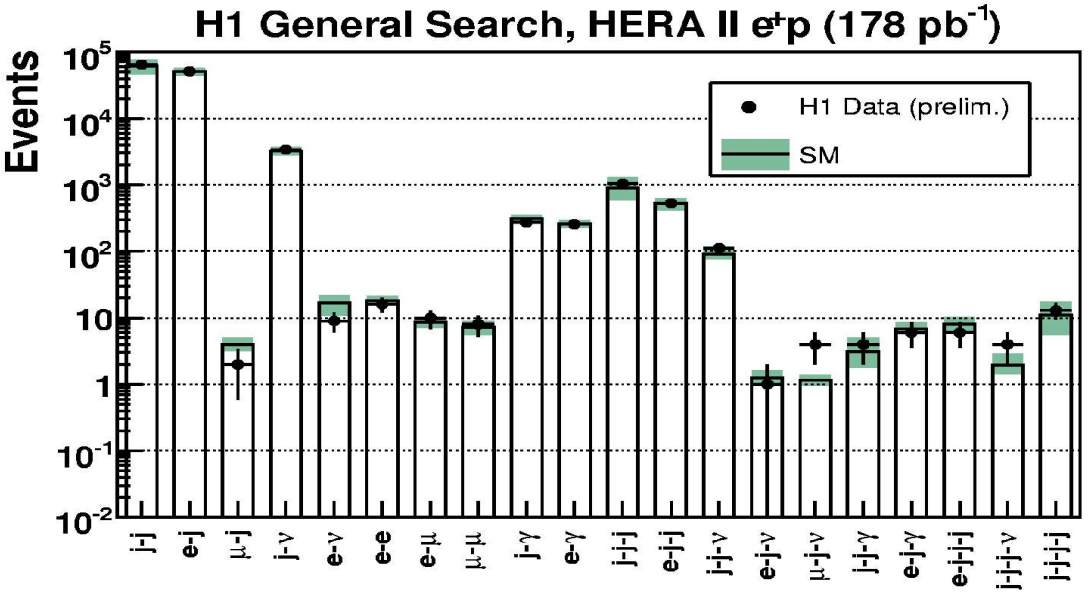
P_T >20 GeV

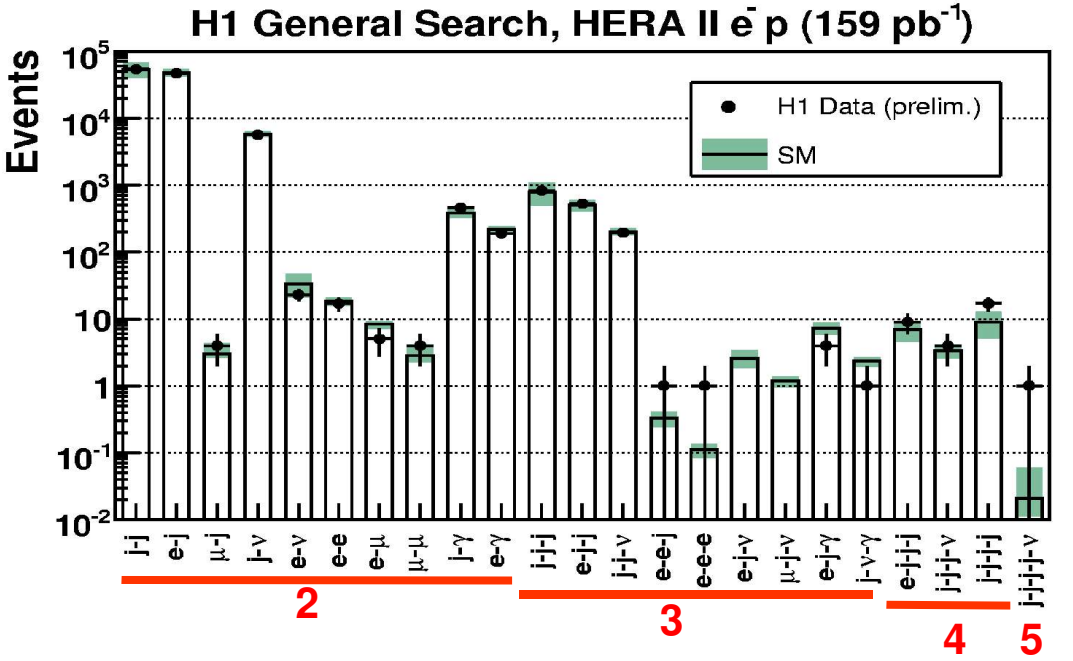
$10^o<\theta<140^o$

D0, PRD64, 012004 (2001)
H1, Phys Lett B602 (2004) 14

- Investigate Mass and ΣP_T
- Statistical Analysis (search for deviations)





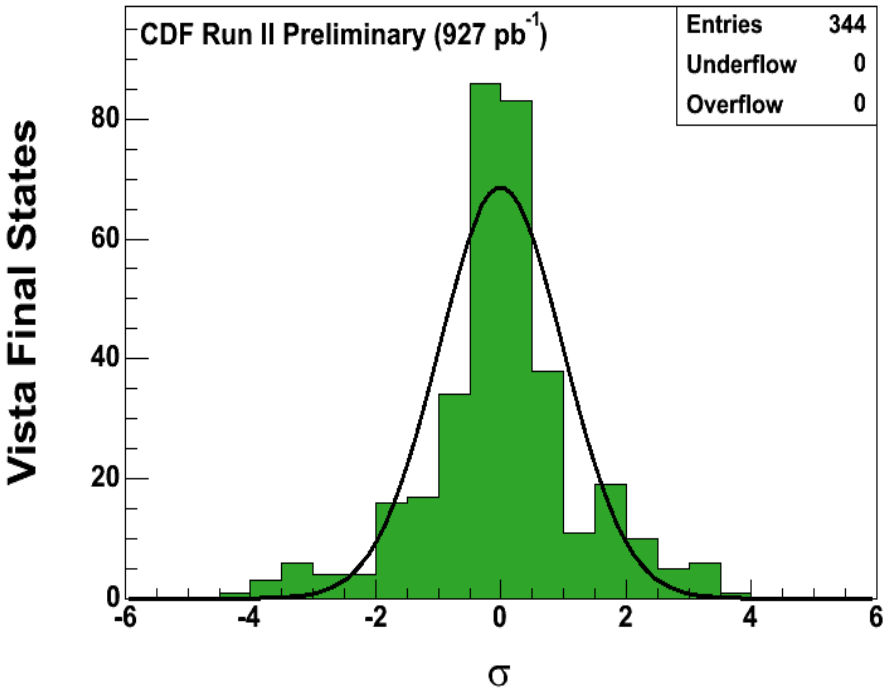


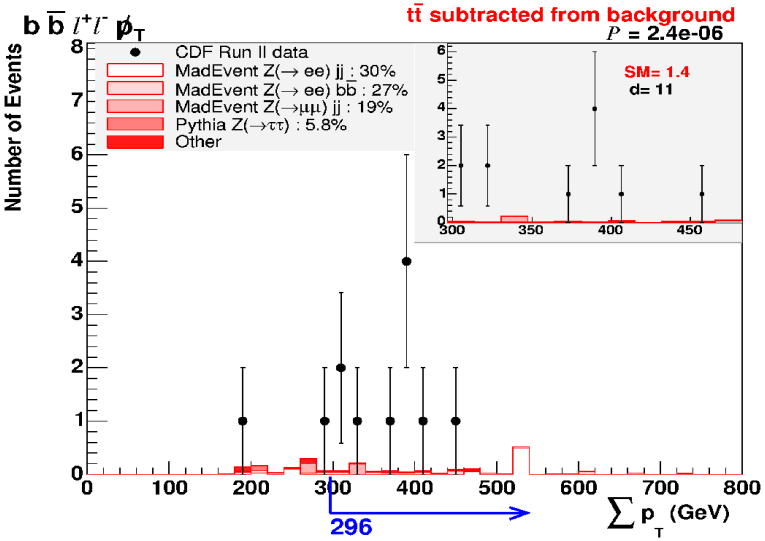
Vista and Sleuth @ CDF

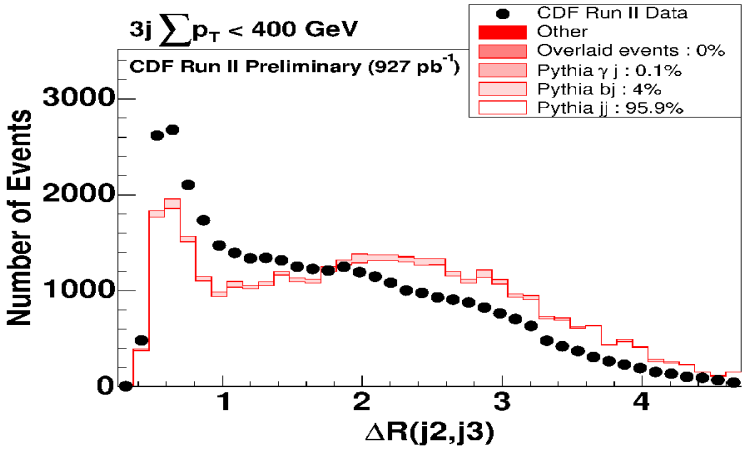
D0 also recently involved

Similar general search,

but phase space adjusted on background







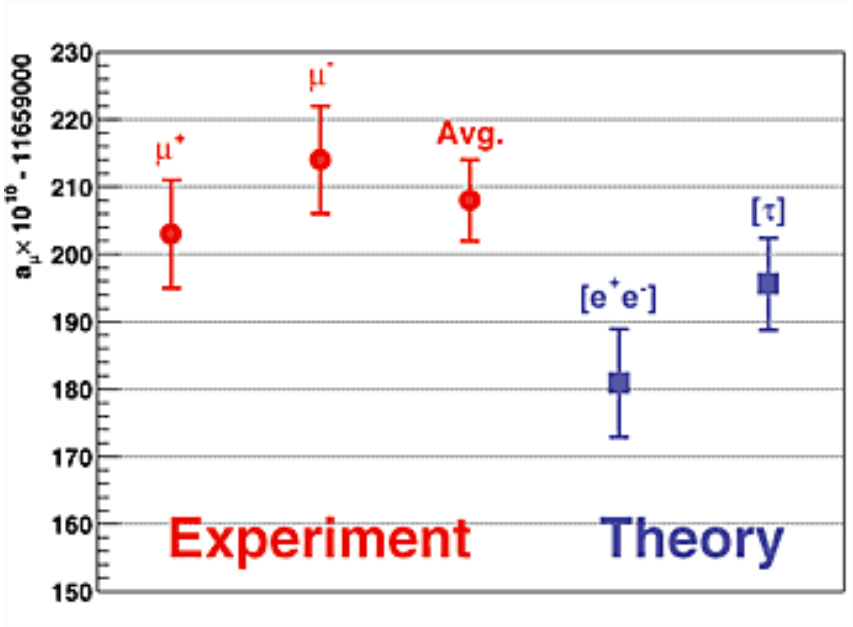
Experimental effort is huge, but worth

Security belt for the unexpected

Low Energy, high precision

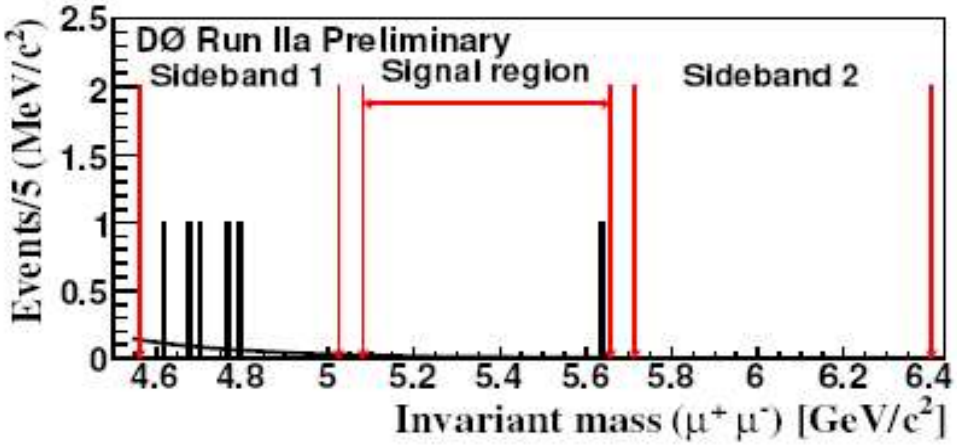
Beat Decoupling?

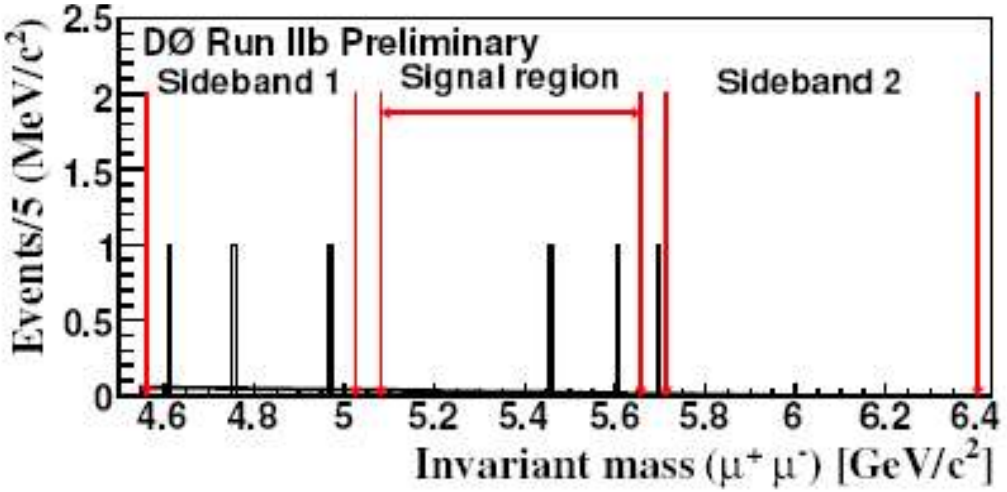
$a_\mu=(g_\mu-2)/2$



a_{μ^-} (BNL'01) = 11 659 214 (8)(3) × 10^{-10} (0.7 ppm)

$B_s \rightarrow \mu^+\mu^-$



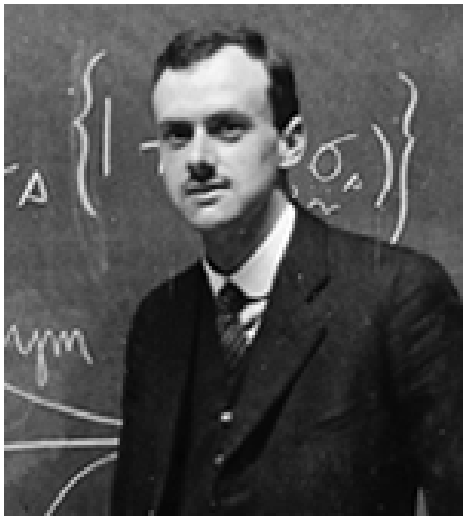


$$\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)_{2fb^{-1}} < 7.5\,(9.3) \times 10^{-8}$$

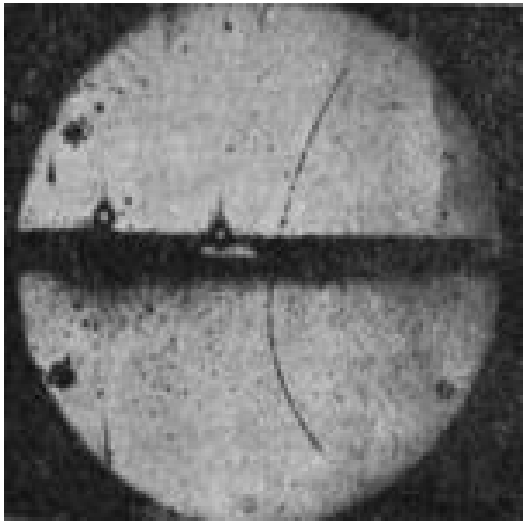
(SM 3.4 10^{-10})

A celebration: positron is 75

Dirac equation 1928



Positron discovery Anderson 1932



Heisenberg (1960's)*:

“Up till that time, I had the impression that, in quantum theory, we had come to a harbour. [This discovery] threw us into the sea again.”

LHC -> Four Seas?

*from F.Wilczek's “Fantastic realities”

Conclusions and outlook

- Standard Model in best shape ever
- Present fronteer colliders continue to explore new teritory before LHC
  - In the last 2 year the luminosity at HERA and Tevatron x2
  - HERA data in the can, scrutinise, discover, report
  - Tevatron still large factors (~5-8) to go, high hopes
- The start of the LHC will be an interesting period,
  - a surprise can occur however before