



Electroweak and **E**xotic session **E**

Cristinel Diaconu
CPPM/DESY

36 Talks+ joint session (A)

Convenors: Bruce Straub, Michael Spira, CD

Hera:8

Tevatron:6

Lep:9

LHC:3

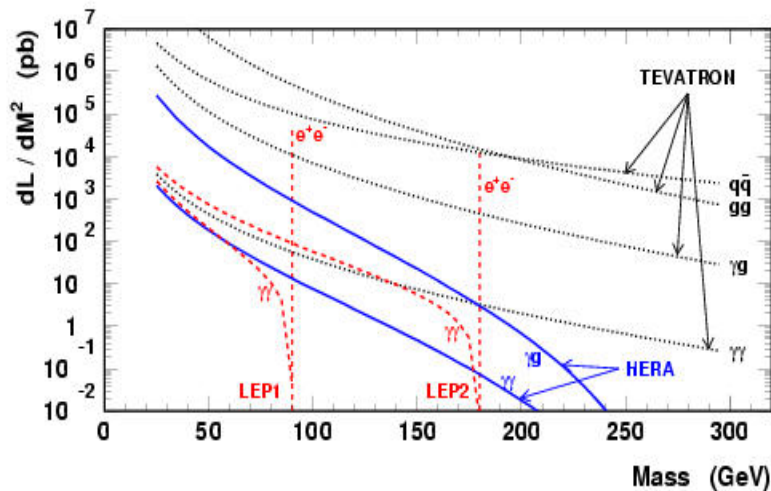
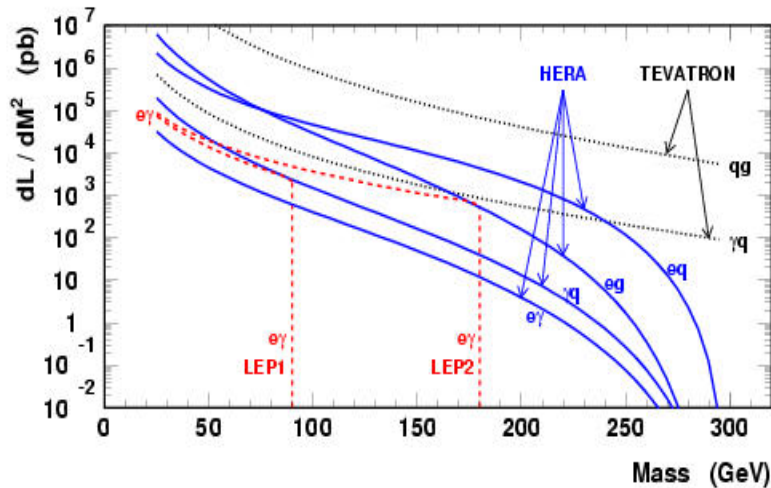
B-fact.: 2

Theory: 8

covered by Michael Spira

Thanks to all speakers!
Apologies for omissions, biases,
distorsions or low resolution plots

- Sebastien Greder (Strasbourg) Top results at the Tevatron
- Stano Tokar (Comenius Univ. / CERN) Top Physics in ATLAS
- Susana Cabrera (Duke) Electroweak results at the Tevatron
- Raimund Strohmer (Munich) W mass, WW and ZZ cross-sections
- Agustin Sabio Vera (Hamburg) W-boson production at large transverse momentum
- Emmanuel Sauvan (CPPM Marseille) Events with several high PT leptons at HERA
- Stephanie Beauceron (LPNHE-Paris) Higgs search at the Tevatron
- Andre Sopczak (Lancaster) Searches for Higgses beyond the Standard Model
- Christophe Delaere (Universite Catholique de Louvain) Fermiophobic Higgs
- Leonardo Carminati (INFN - Milano) H-> gamma gamma with the ATLAS detector
- Michael Spira (Paul Scherrer Institut) NLO results on bb+Higgs production at hadron colliders
- Nikolaos Kidonakis (Cambridge) Charged Higgs production with a top quark at the LHC
- Anja Vest (RWTH, Aachen/H1) Searches for squarks with H1 at HERA
- Nick Malden (Manchester/H1) Search for Superlight Gravitinos at HERA
- Tibor Kurca (IPN /CCIN2P3 Lyon) Susy results at the Tevatron
- Lorenzo Bellagamba (INFN/ZEUS) Lepton Flavor Violation and FCNC
- David South (DESY/H1) Events with high P_T leptons and missing P_T and anomalous top at HERA
- Gerhard Brandt (Heidelberg) Events with high PT tau's with H1 at HERA
- Nikolaos Kidonakis (Cambridge) Anomalous tqV couplings and FCNC top quark production
- Paolo Checchia (Padova) 2-fermion production at LEP
- Guillaume Leibenguth (Universite Catholique de Louvain) Single vector boson production at LEP
- Paul Bell (CERN) Quartic Gauge Couplings
- Frank Krauss (TU Dresden) Construction of new Tools for automatic Calculation of Cross Sections
- M. Moretti ALPGEN
- Tobias Haas (DESY) Physics at a Future Linear Collider
- Luigi LiGioi (INFN/ Rome La Sapienza) CP violation - overview of angles
- Marek Szczekowski (Warsaw/LHCb) Effect of new physics from the CP violation measurement
- Ivan Melo (Univ. of Zilina) Vector resonances from strong electroweak symmetry breaking at e+e- colliders
- Vitaliano Ciulli (INFN Firenze) Electroweak B physics at LEP
- Mousumi Datta (Wisconsin) Rare B decays
- Daniel Ryan (Tufts) Leptoquark searches at the Tevatron
- Arnold Pompos (Oklahoma) Other particle searches at the Tevatron
- Matti Peez (LLR - Ecole Polytechnique/H1) General Search for New Phenomena
- Ulrich Parzefall (Freiburg) Triple Gauge Couplings at LEP
- Thomas Teubner (Liverpool) g-2
- Philip Bechtle (DESY) Searches at LEP
- Jolanta Sztuk (Warsaw) Leptoquarks and Contact Interactions at HERA



1. flux of colliding matter

"secondary" beams of "partons"

2. EW/BSM: cross section of the hard process
unknown, allow to compare

LEP, Tevatron, HERA

3. (SM) background

low- \rightarrow unexpected events

2007 : LEP: 0.8 fb^{-1} HERA: 1 fb^{-1} TEVATRON: $1.2\text{-}2 \text{ fb}^{-1}$

(2009:4-8)

...or detect high energy effects in the loops: rare decays

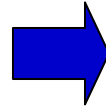
Outline

- SM status from precision measurements
- Top Mass
- Boson production
- High PT leptons
- Higgs searches
- SUSY
- Rare Decays

The Electroweak Fit

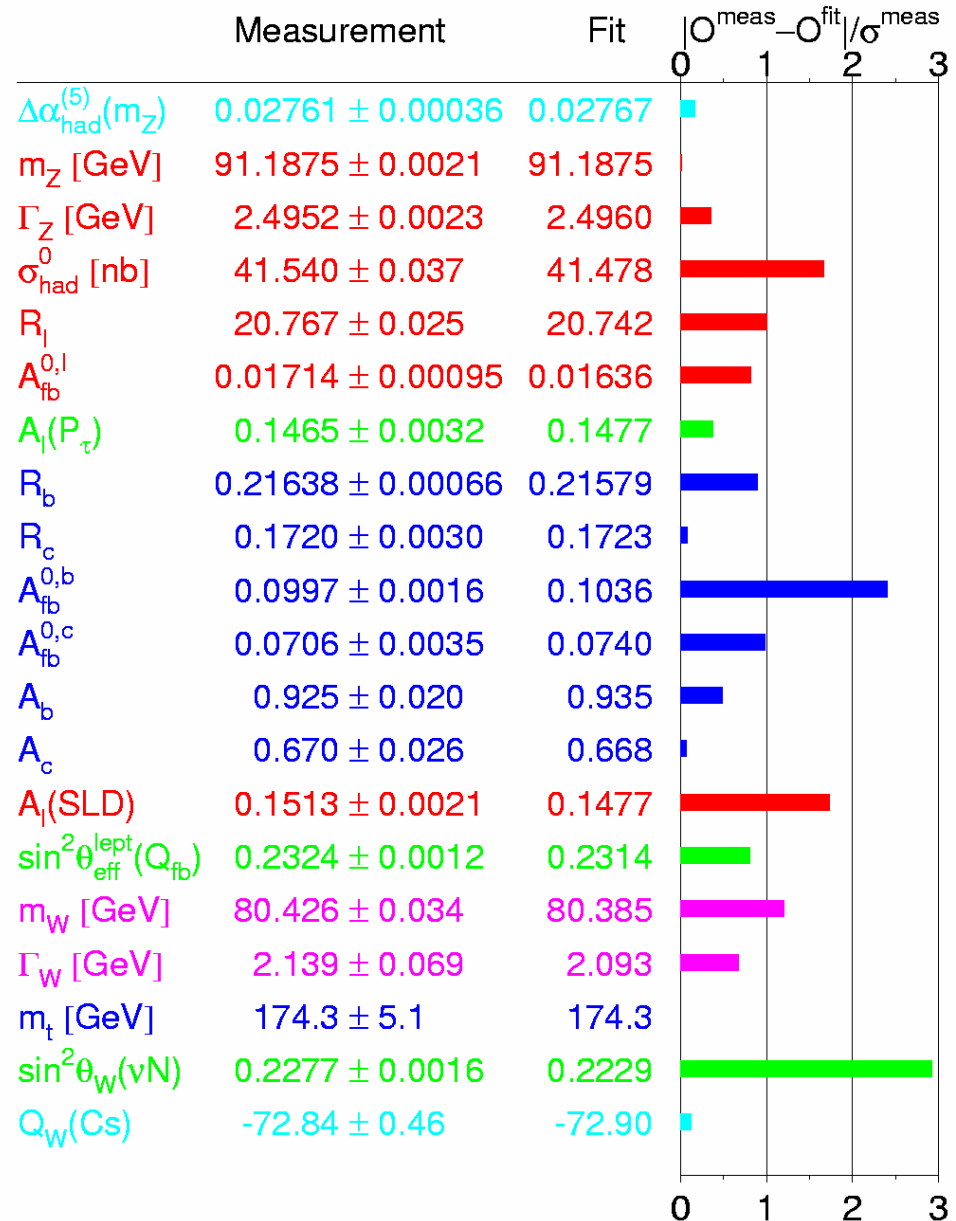
Global fit probability $\sim 4.5\%$
(28% without NuTeV)

Measurements using
 $Z \rightarrow Q\bar{Q}$ decays

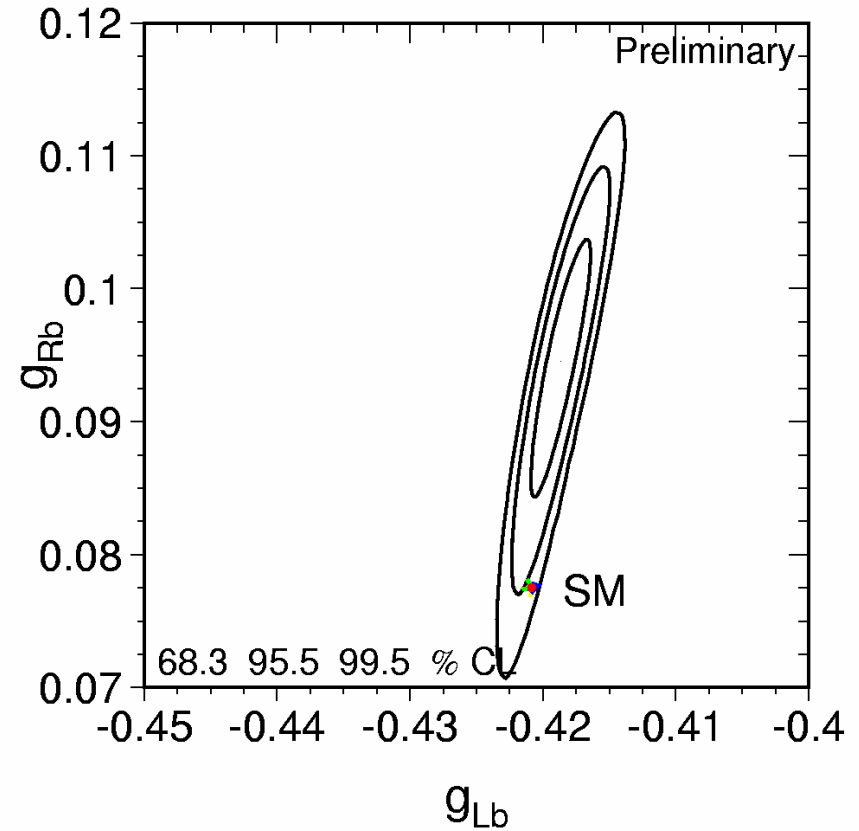
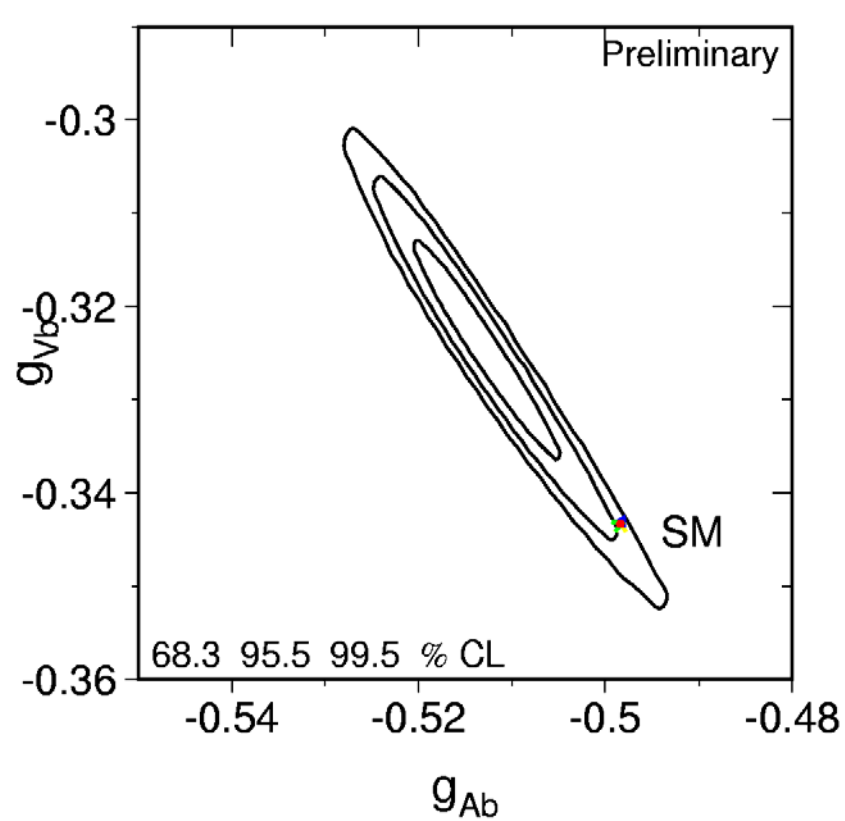


- R_b anomaly solved long ago...
- Forward-backward b asymmetry pull $> 2 \sigma$

Summer 2003

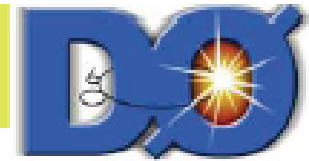


b-quark couplings anomaly?



Large deviations in the right coupling g_{Rb} only!

RunI Top Mass update

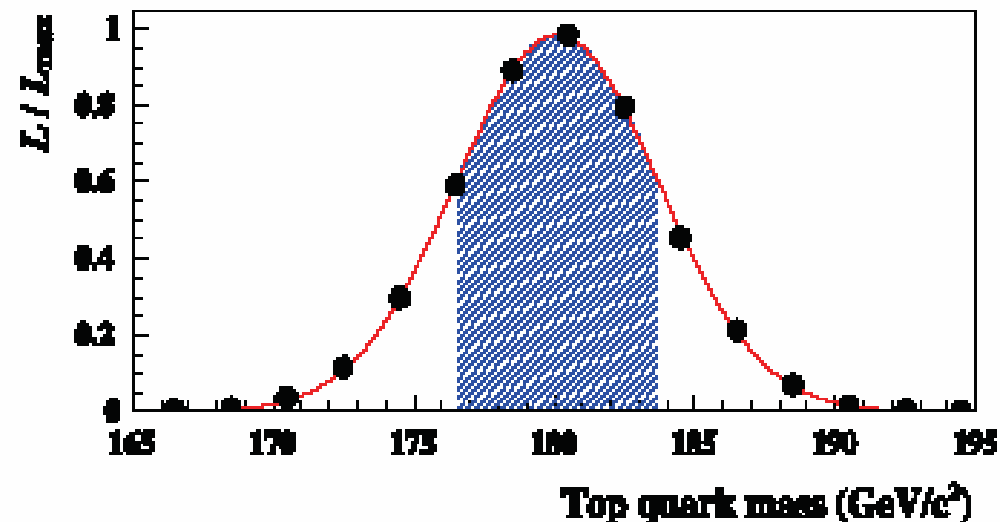


- Old approach :

- Topological discriminant used to separate signal from background
- Mass estimate made with 2D fit in fitted mass and discriminant and compared to MC templates

- New improved approach :

- Calculate **event probability** to be a tt event (σ^{LO} , pdf, trans. function)
- Consider all combinations, assign each a weight and sum their probabilities
- Increase purity by cutting on background probability



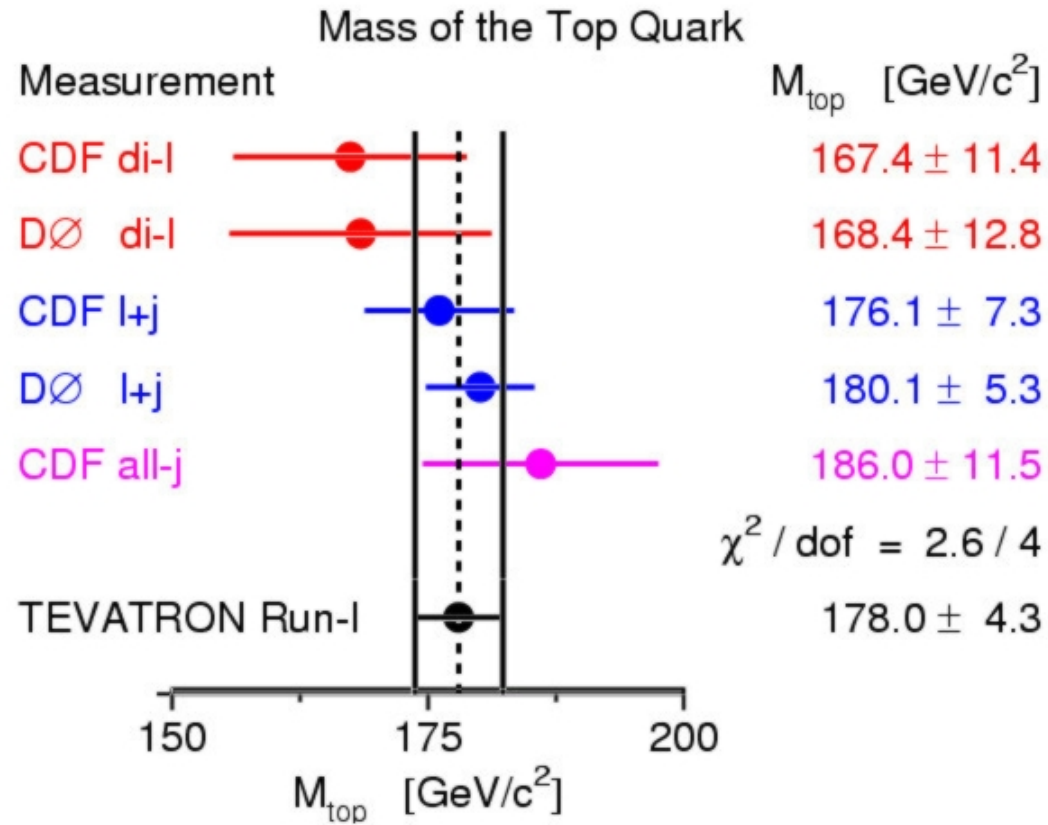
Combined with previous dilepton mass measurements, the new DØ average mass is :

New DØ averaged top mass : $179.0 \pm 5.1 \text{ GeV}$ (2003)

(previously : $172.1 \pm 7.1 \text{ GeV}$ (1998))

- Improvement in statistical errors equivalent to 2.4 more data !
- Dominant systematics from jet energy scale (3.3 GeV)

Top Mass Measurement



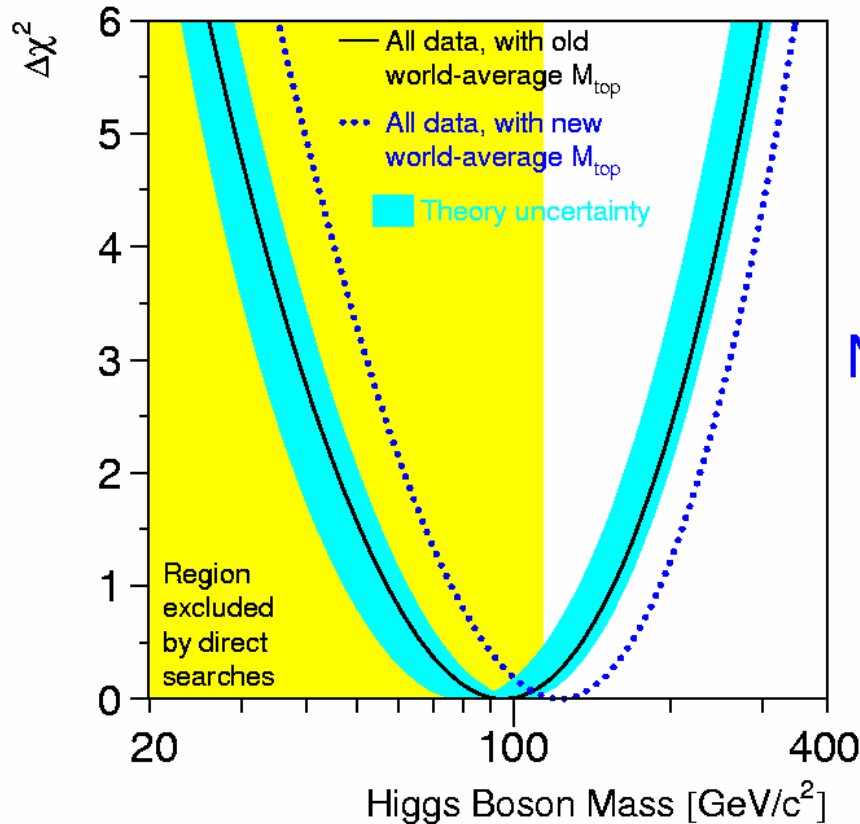
CDF RunII Preliminary :

$$M_t = 177.8^{+4.5}_{-5.0} (\text{stat.}) \pm 6.2 (\text{syst.}) \text{ GeV}$$

Consequences of new top-mass combination

Precision electroweak data:

Constrain M_H in the MSM



Old:

$$M_{\text{top}} = 174.3 \pm 5.1 \text{ GeV}$$

$$\log M_H = 1.98^{+0.21}_{-0.22}$$

$$M_H = 96^{+60}_{-38} \text{ GeV}$$

$$\text{or } < 219 \text{ GeV (95\% CL)}$$

New:

$$M_{\text{top}} = 178.0 \pm 4.3 \text{ GeV}$$

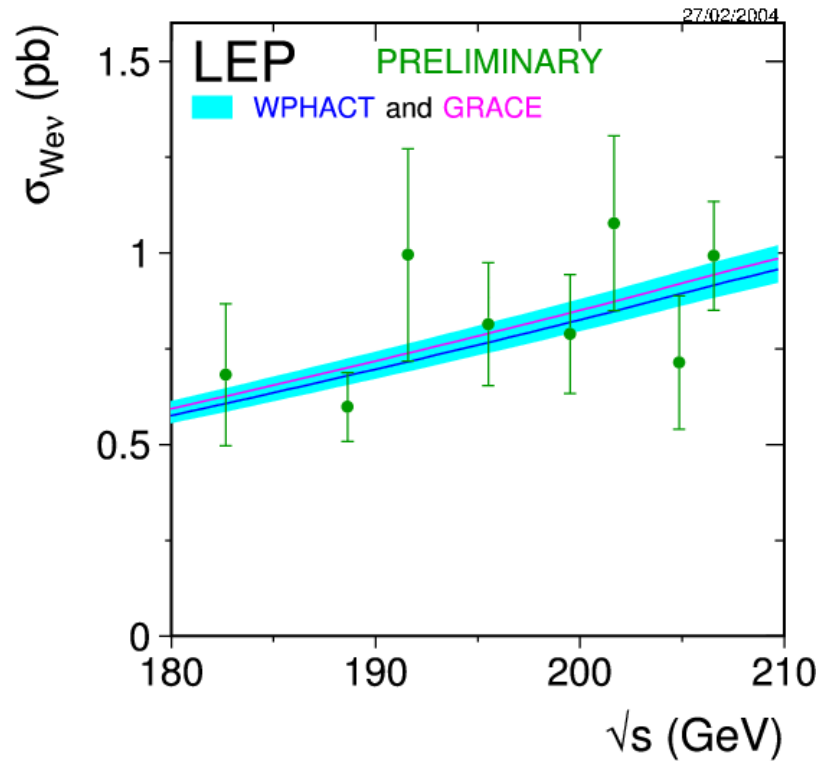
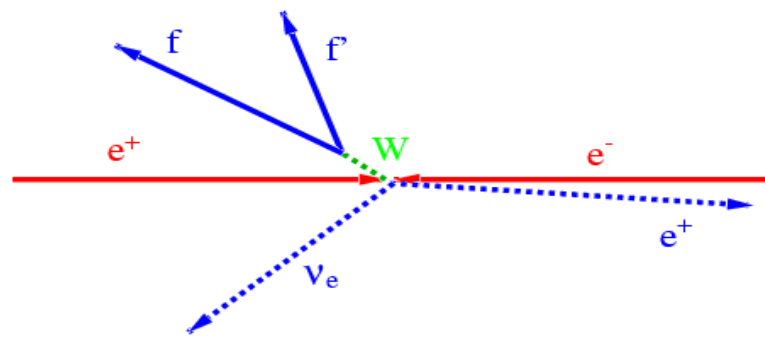
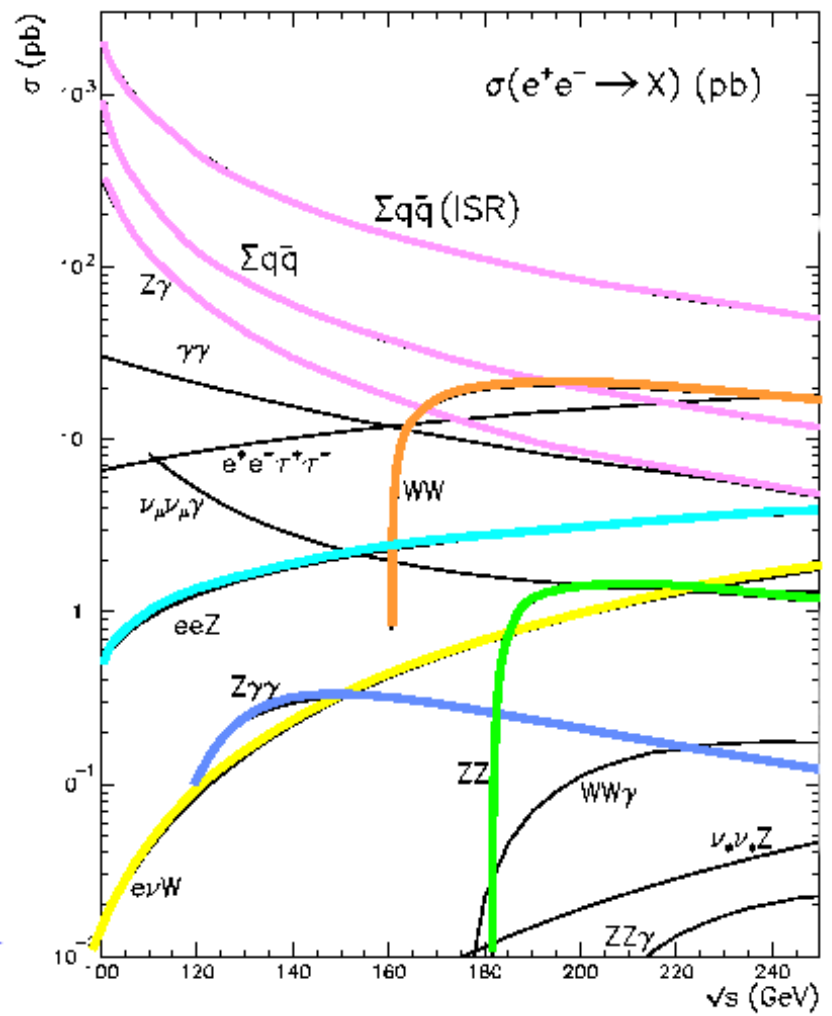
$$\log M_H = 2.07^{+0.20}_{-0.21}$$

$$M_H = 117^{+67}_{-45} \text{ GeV}$$

$$\text{or } < 251 \text{ GeV (95\% CL)}$$

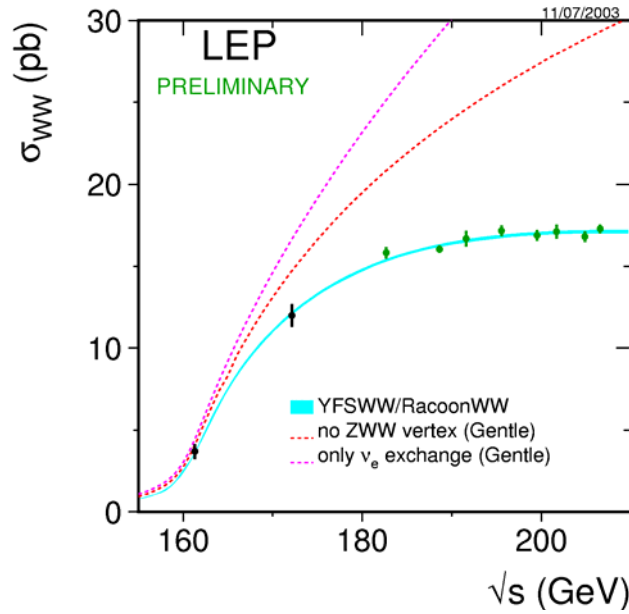
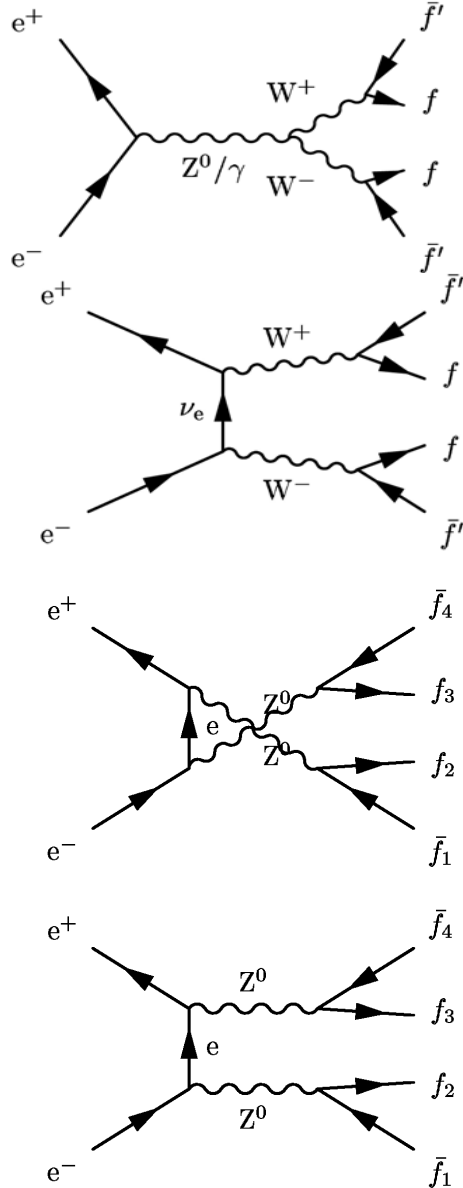
(Procedure as in hep-ex/0312023!)

Weak Boson Production at LEP

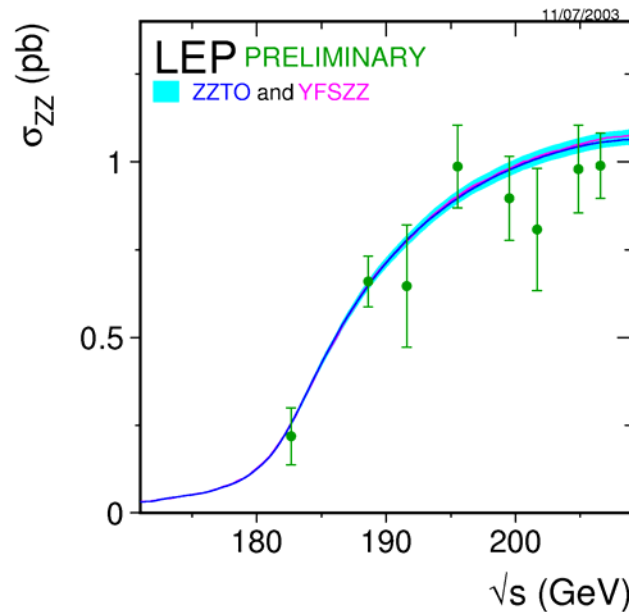
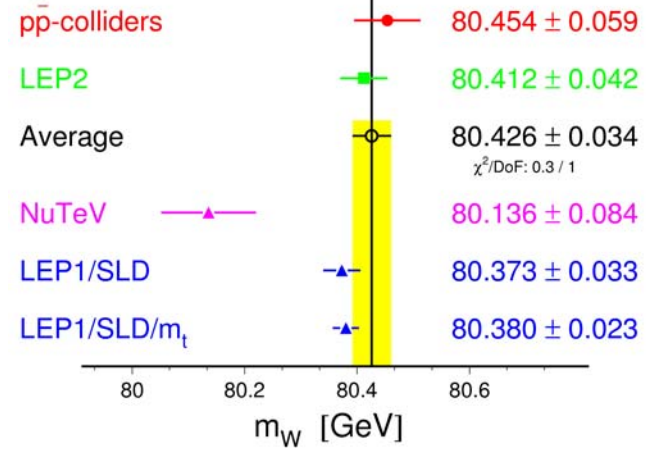


Guillaume Leibenguth

W/Z pair production at LEP



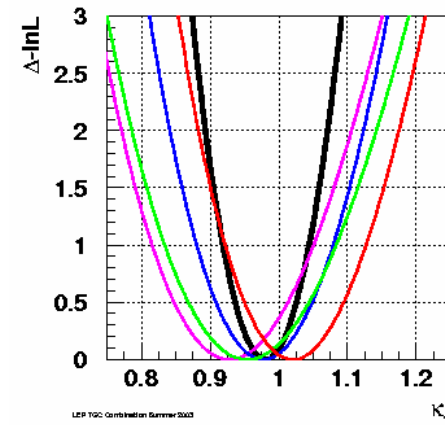
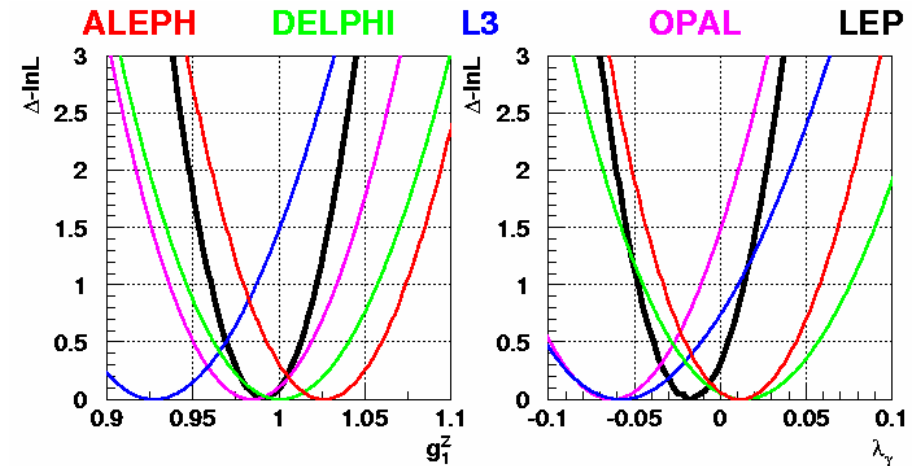
W-Boson Mass [GeV]



Raimund Stohmer

LEP-Combined TGC Results

- Single-parameter fit combination
 - Precision of 0.02 – 0.05
 - Consistent with SM
 - Sensitive to radiative corrections



LEP preliminary

$$\begin{aligned} \kappa_\gamma &= 0.984^{+0.042}_{-0.047} \\ \lambda_\gamma &= -0.016^{+0.021}_{-0.023} \\ g_1^Z &= 0.991^{+0.022}_{-0.021} \end{aligned}$$

	LEP2	Tevatron (projected)	LHC	TESLA
κ_γ	0.05	0.1	0.08	$\sim 5 \cdot 10^{-4}$
λ_γ	0.02 5	$3 \cdot 10^{-3}$	$1 \cdot 10^{-3}$	$\sim 5 \cdot 10^{-4}$
g_1^Z	0.02 5			$\sim 5 \cdot 10^{-4}$

Ulrich Parzefall

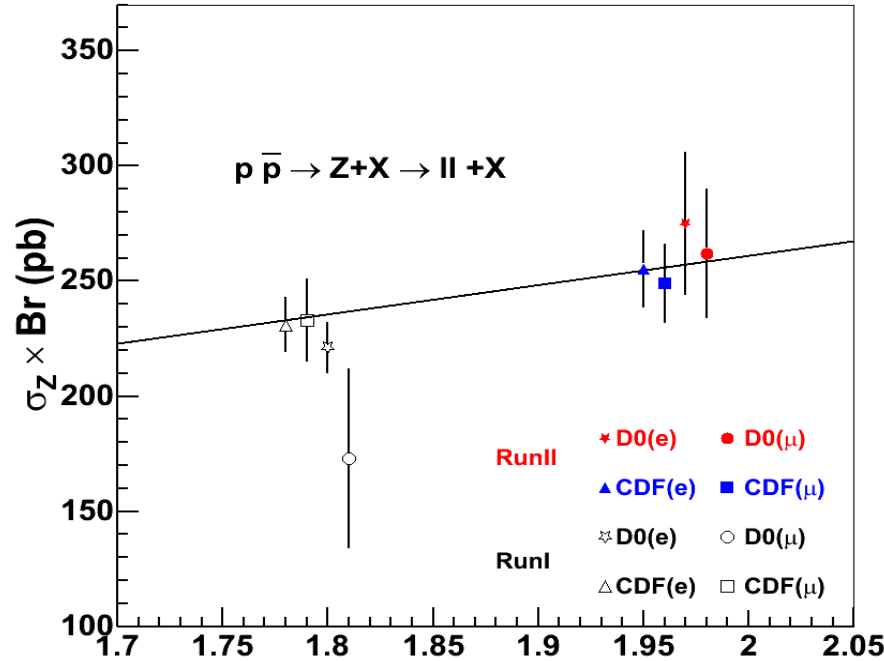
Paul Bell



CDF & DØ $\sigma \times \text{BR}(Z \rightarrow l^+ l^-)$, $\sigma \times \text{BR}(W \rightarrow l \nu)$

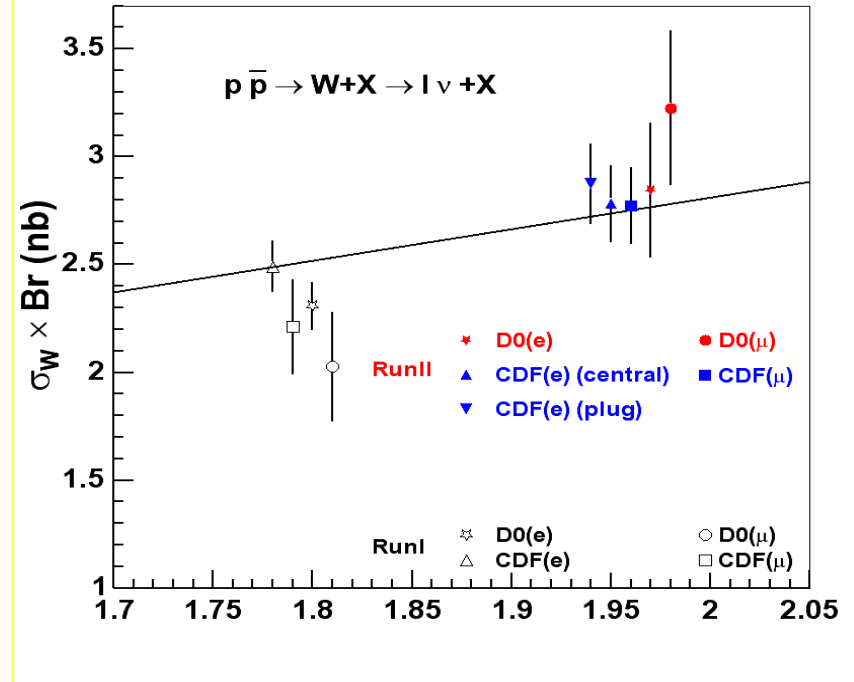


CDF and DØ RunII Preliminary



CDF: e&μ combined

CDF and DØ RunII Preliminary



$$\sigma \text{BR}(Z \rightarrow ee) = 250.5 \pm 3.8 \text{ pb (NNLO theory: Martin, Roberts, Stirling, Thorne)}$$

$$\sigma(p\bar{p} \rightarrow Z / \gamma^* \rightarrow \ell\ell) = 254.3 \pm 3.3(\text{stat}) \pm 4.3(\text{syst}) \pm 15.3(\text{lum}) \text{ pb}$$

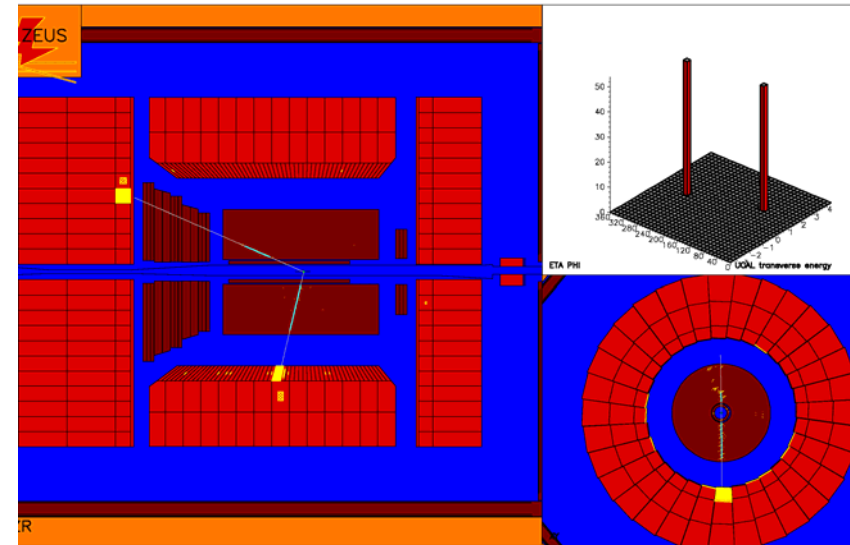
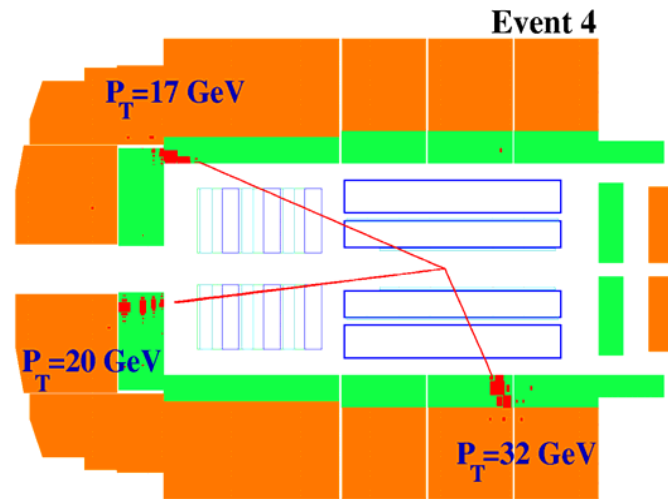
$$\sigma \text{BR}(W \rightarrow l\nu) = 2687 \pm 40 \text{ pb (NNLO theory: Martin, Roberts, Stirling, Thorne)}$$

$$\sigma(p\bar{p} \rightarrow W \rightarrow \ell\nu) = 2777 \pm 10(\text{stat}) \pm 52(\text{syst}) \pm 167(\text{lum}) \text{ pb}$$

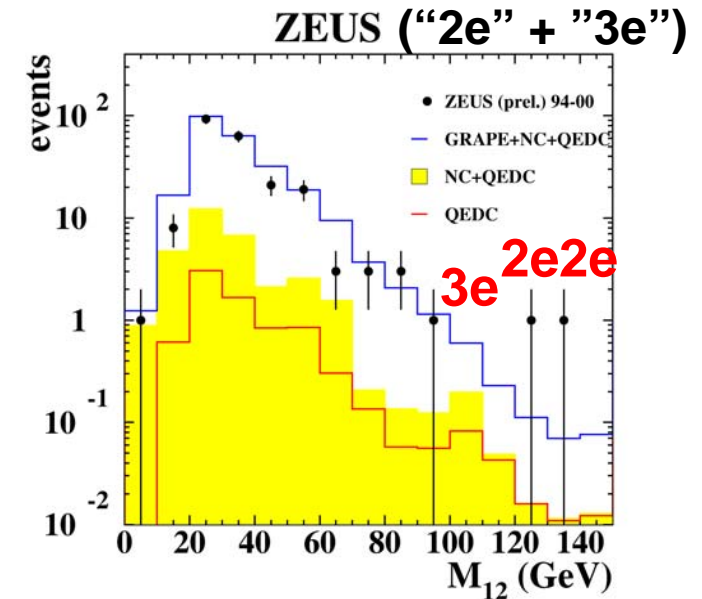
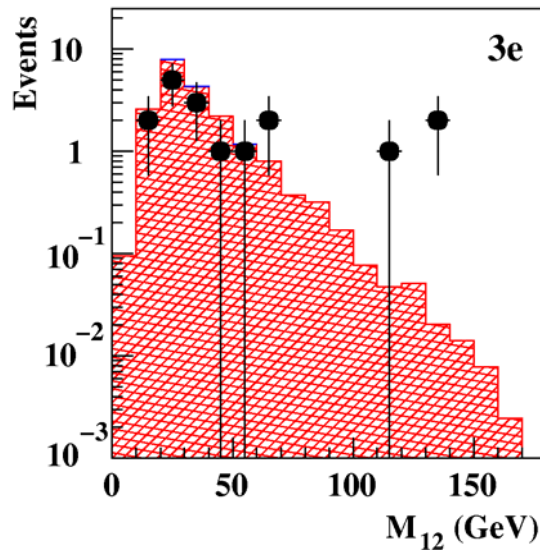
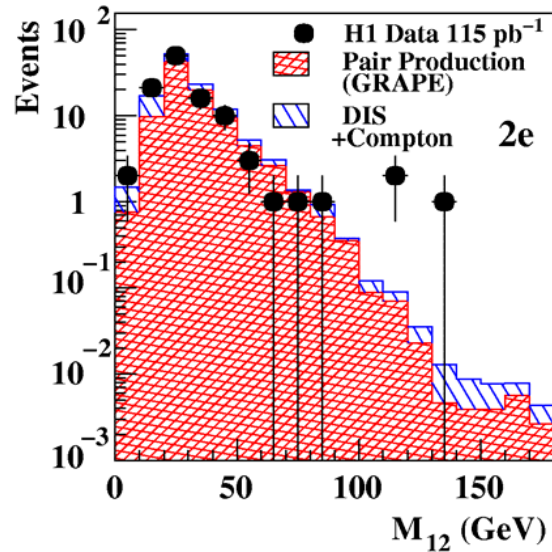
Boson pair production also studied

Suzanna Cabrera

Events with several leptons at HERA



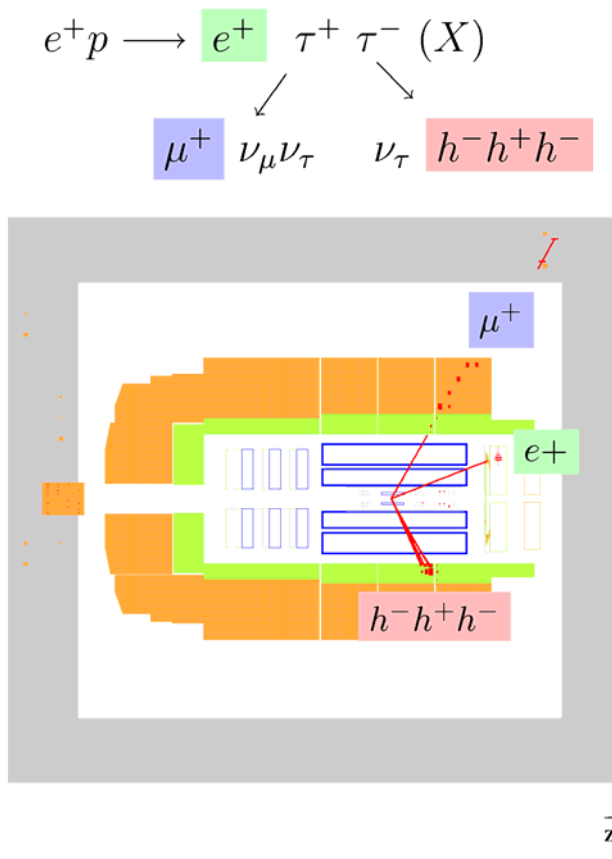
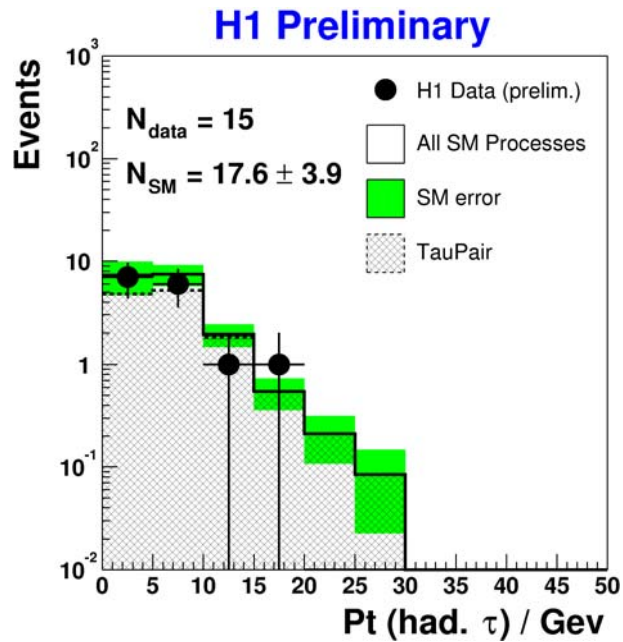
[H1, Eur. Phys. J. C31(2003),17]



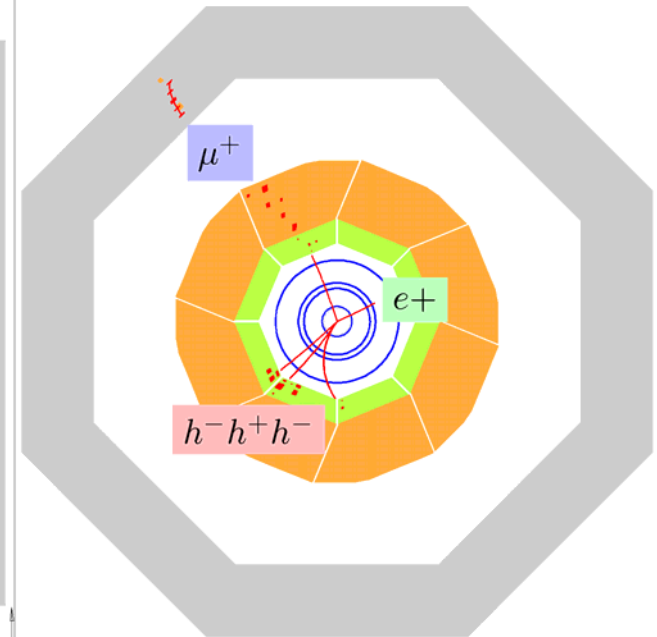
Multi-muons: [H1, Phys. Lett. B583 (2004), 28]

Production of τ pairs at HERA

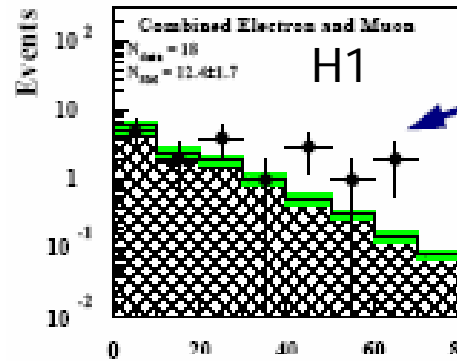
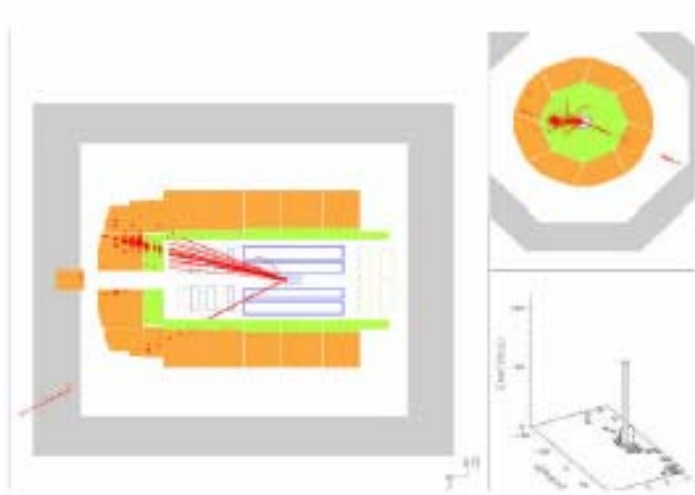
First glimpse, semi-leptonic $\tau\tau$ final state



TAU-PAIR CANDIDATE



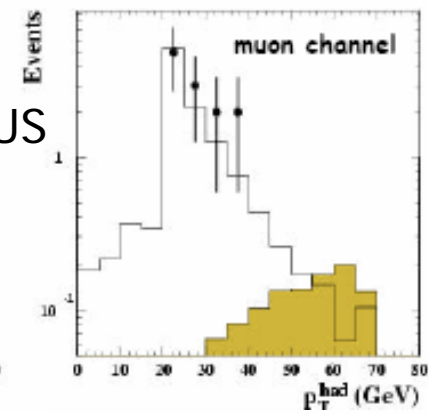
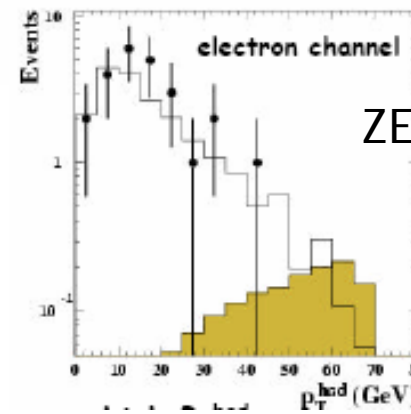
Events with isolated leptons and P_T^{miss}



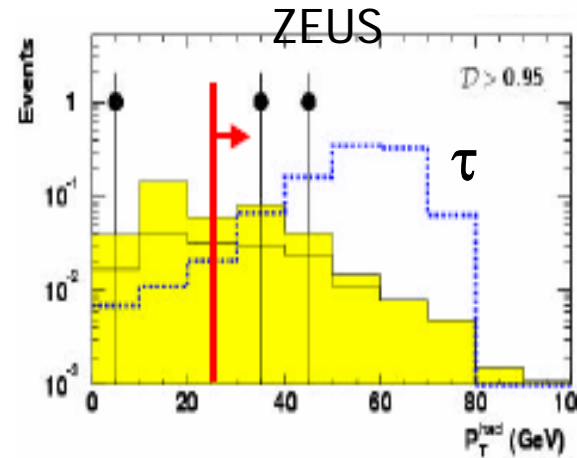
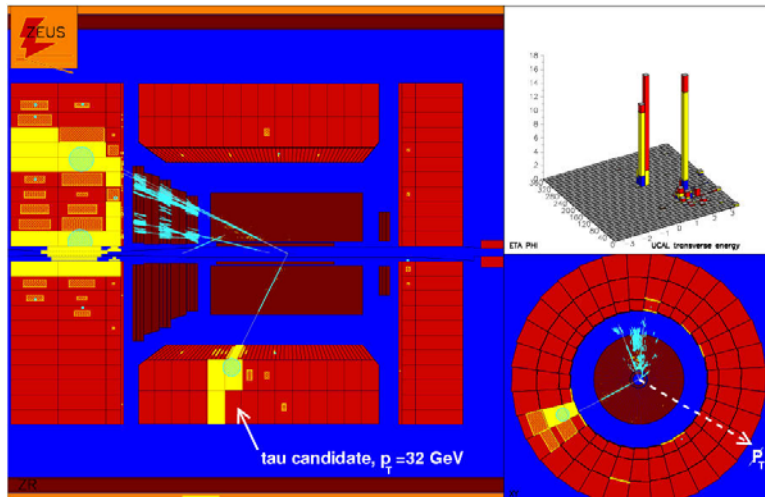
$P_T^X > 25 \text{ GeV}$:

$$N_{\text{data}} = 10$$

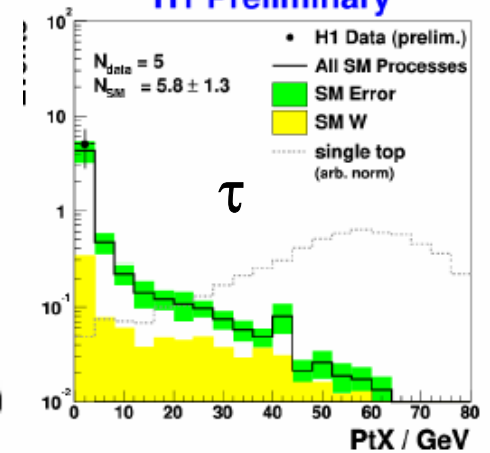
$$N_{\text{SM}} = 2.92 \pm 0.49$$



ZEUS



H1 Preliminary



Summary Tables of all Isolated Lepton Searches at HERA-I



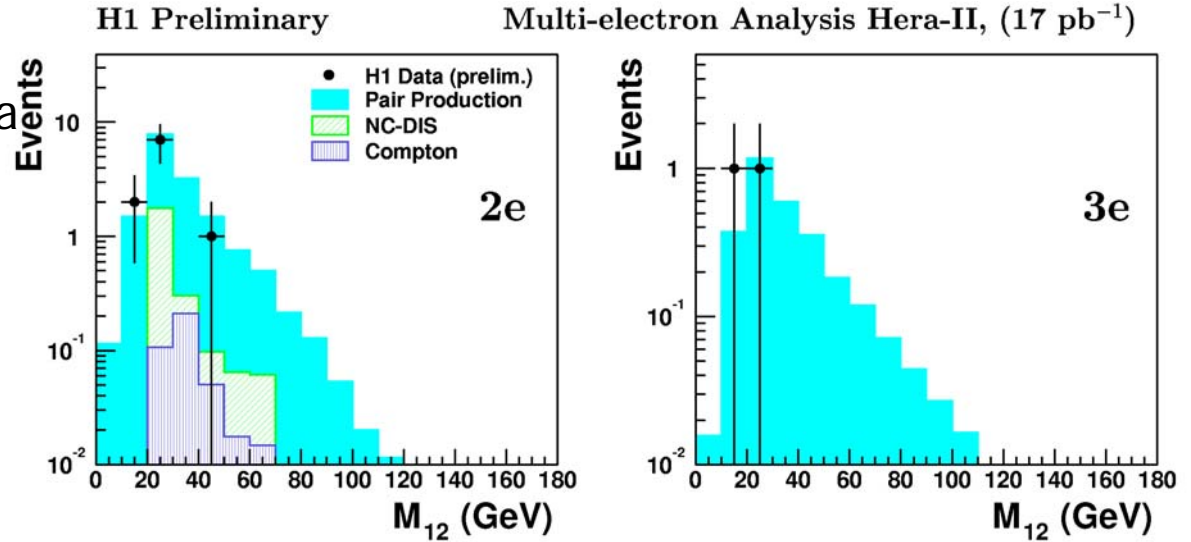
1994-2000 ep 118 pb^{-1}	Electron observed / expected	Muon observed / expected	Tau (108 pb^{-1}) observed / expected
Full Sample	11 / 11.54	8 / 2.94	5 / 5.81
$P_{TX} > 25$ GeV	5 / 1.76	6 / 1.68	0 / 0.53
$P_{TX} > 40$ GeV	3 / 0.66	3 / 0.64	0 / 0.22



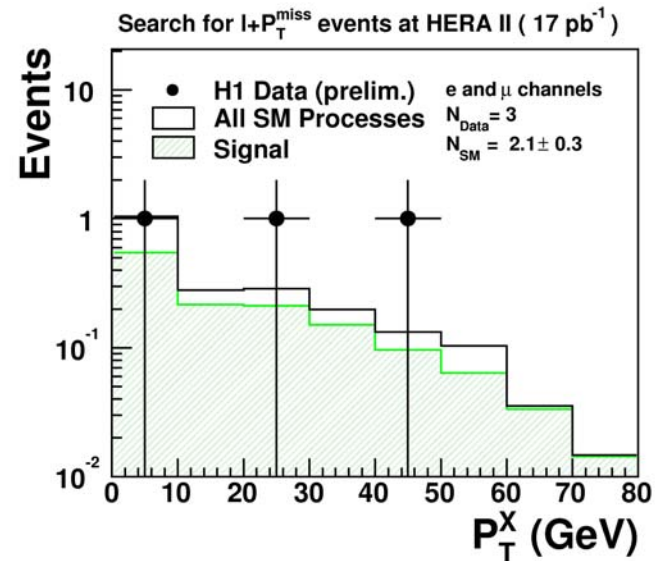
1994-2000 ep 130 pb^{-1}	Electron observed / expected	Muon observed / expected	Tau observed / expected
Full Sample	24 / 20.6	12 / 11.9	3 / 0.40
$P_{TX} > 25$ GeV	2 / 2.9	5 / 2.75	2 / 0.20
$P_{TX} > 40$ GeV	0 / 0.94	0 / 0.95	1 / 0.07

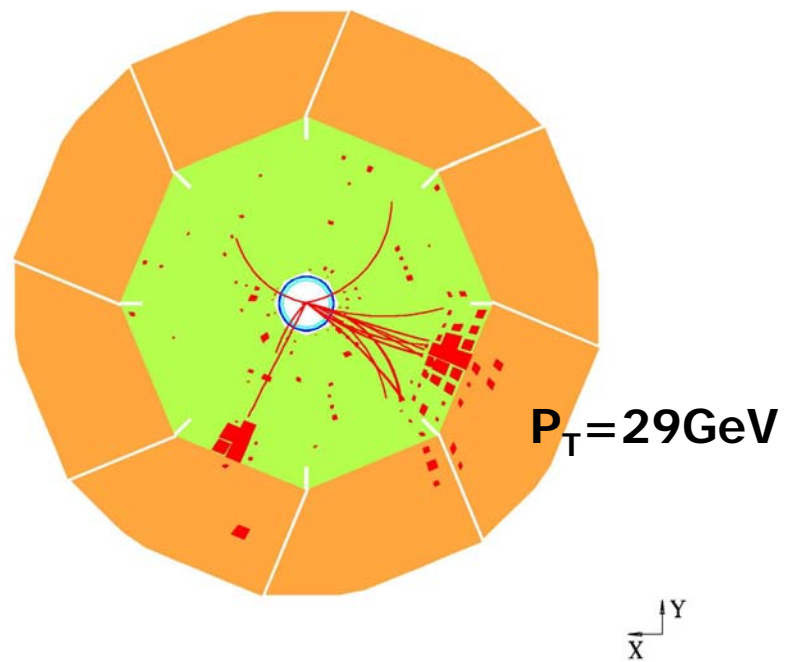
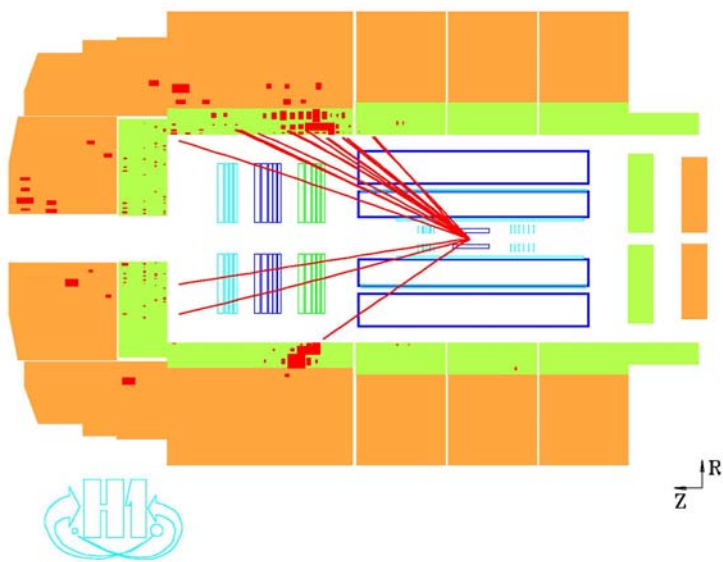
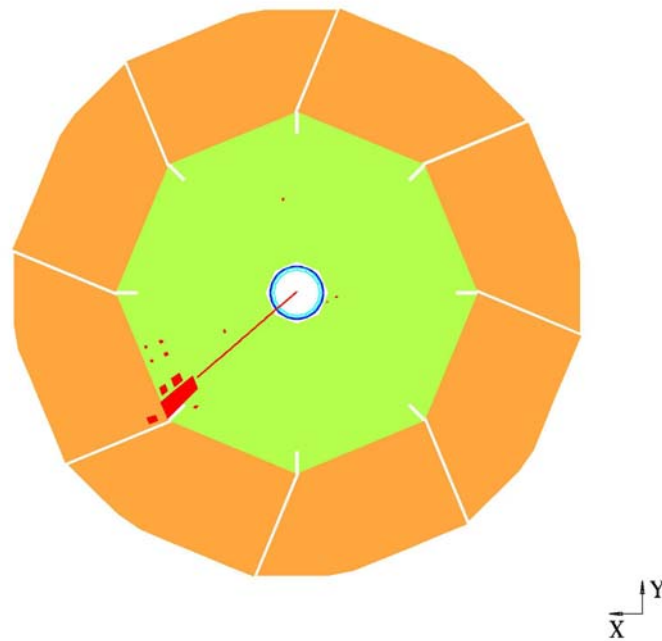
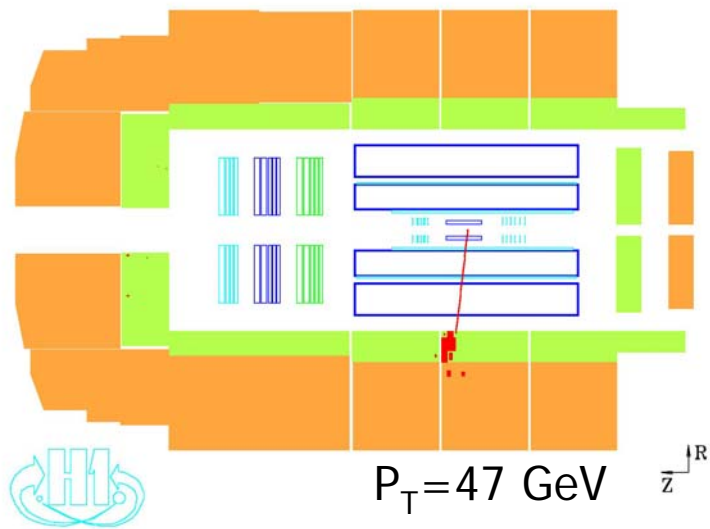
HERA II data (H1)

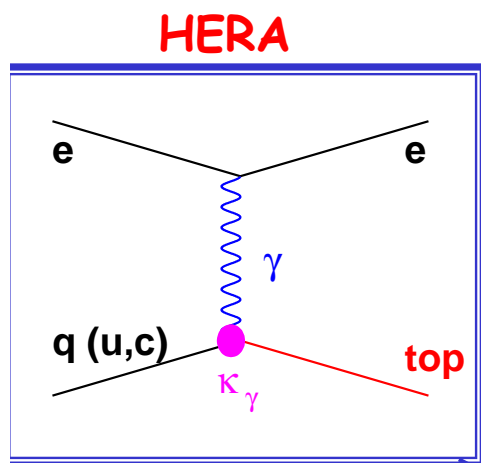
Recent 2003/2004 data
 $L=17 \text{ pb}^{-1}$



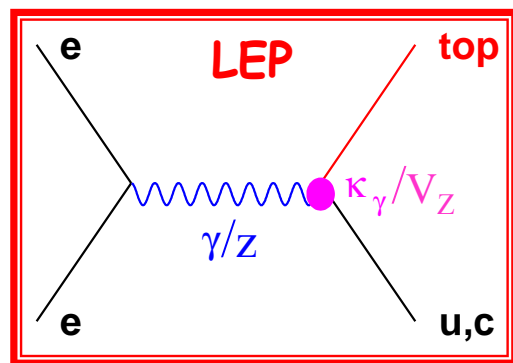
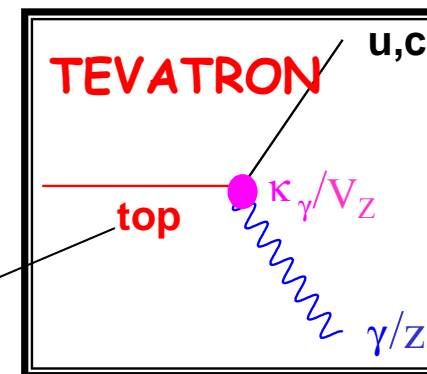
$P_T^X > 25 \text{ GeV}$: 2/0.6







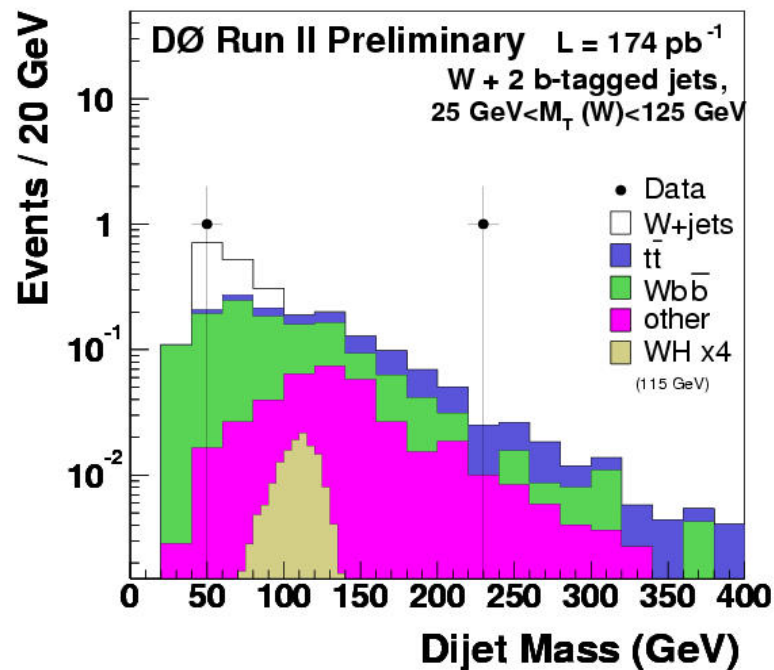
H1 +



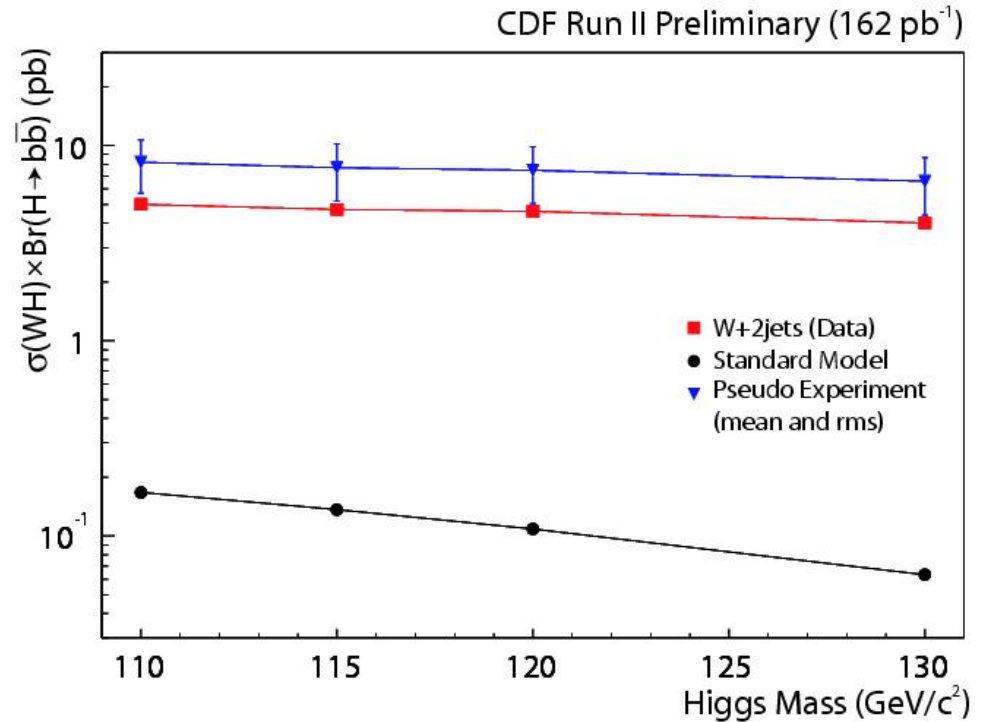
Also hadronic channel used in the limit setting

Higgs searches at Tevatron

$W(\rightarrow ev)bb$ production



DØ: $\sigma(WH)B(H \rightarrow bb) < 12.4 \text{ pb}$
 for $M_H = 115 \text{ GeV}$ at 95% C.L.

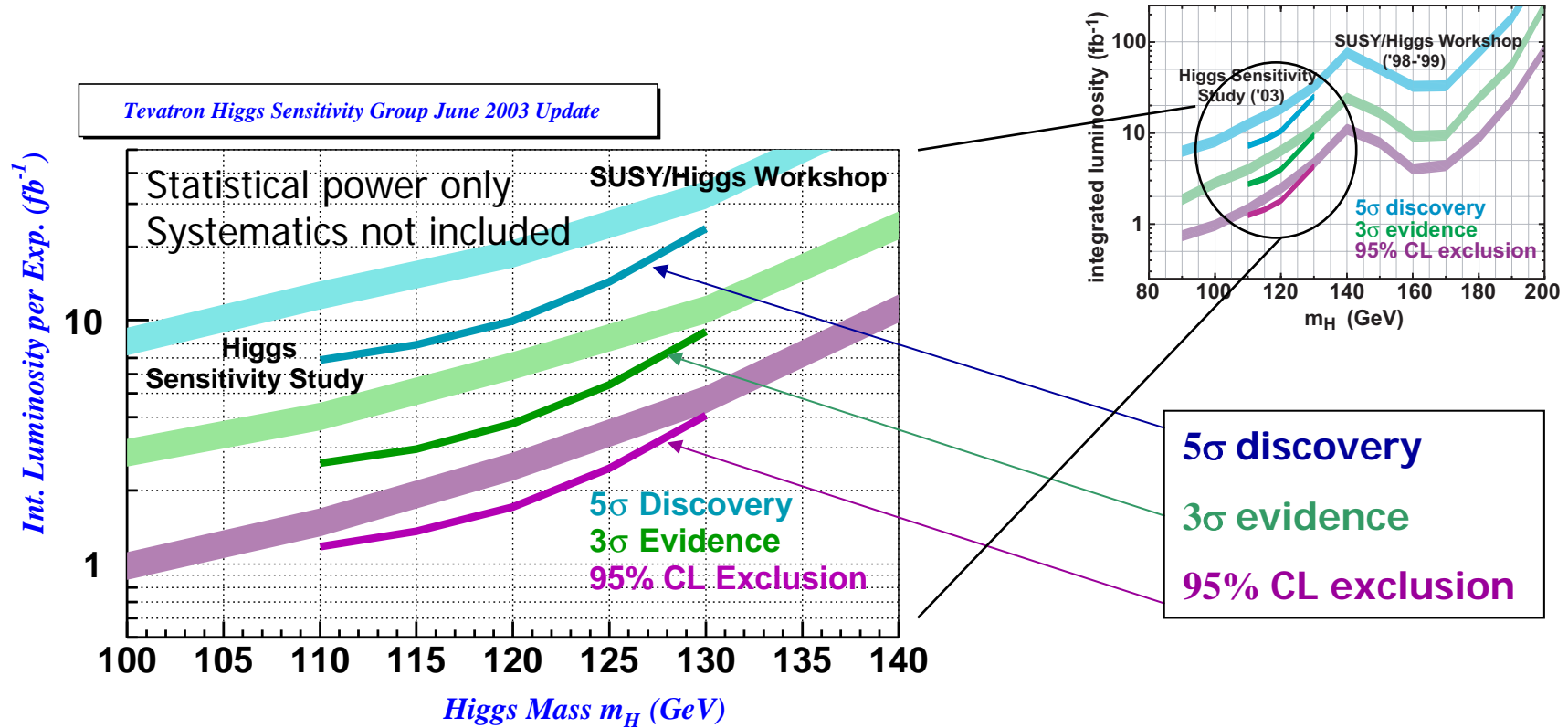


CDF: $\sigma \times B < 14 - 19 \text{ pb}$
 for $M_H = 70 - 120 \text{ GeV}$
 Exceeds CDF's Run I limit [PRL 79, 3819(1997)]

More on Higgses:

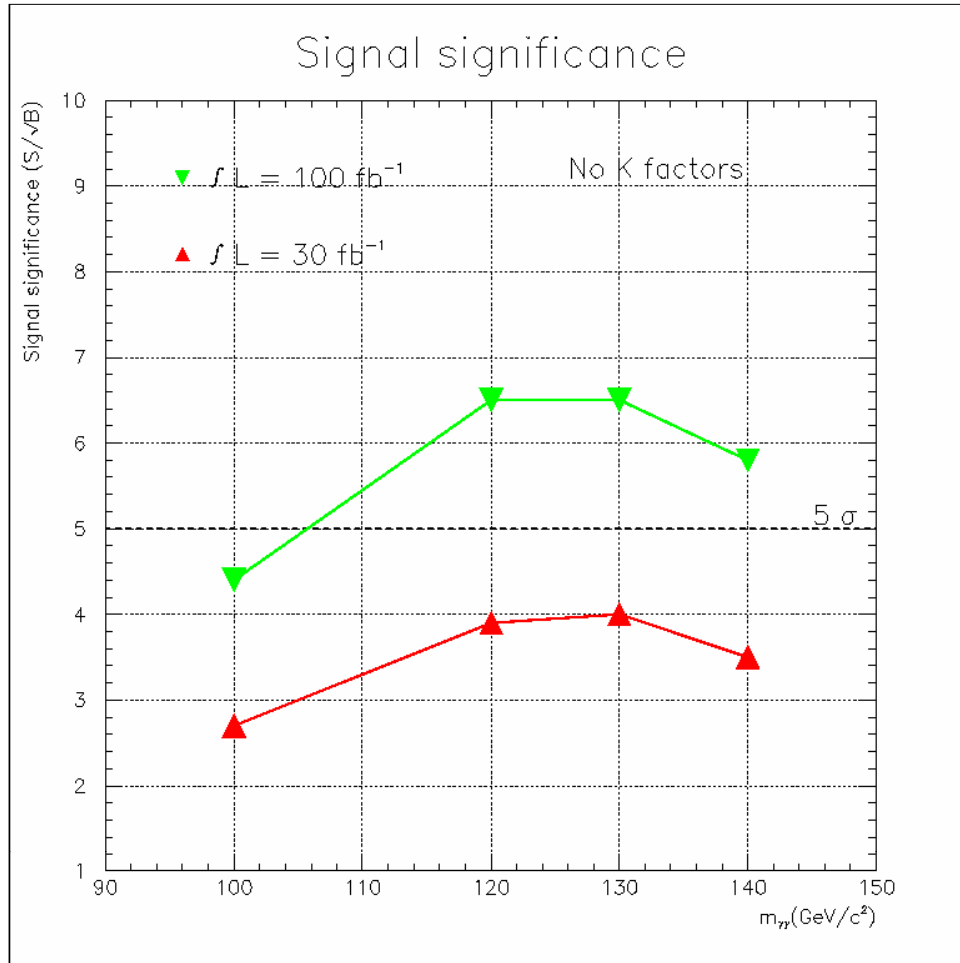
Stephanie Beauceron, Andre Sopczak, Christophe Delaere

Prospectives for Higgs search



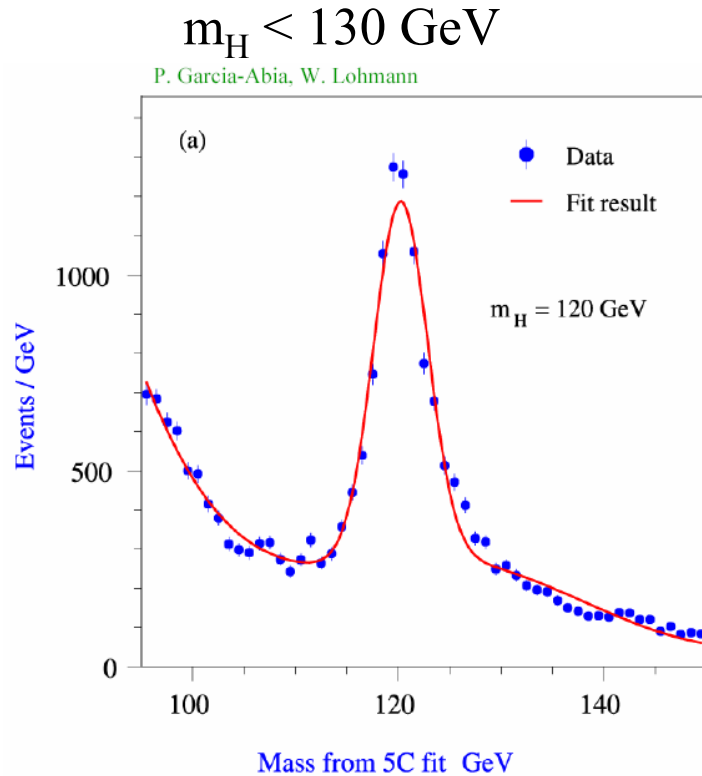
- New study from CDF + DØ :

ATLAS: discovery potential $H \rightarrow \gamma\gamma$

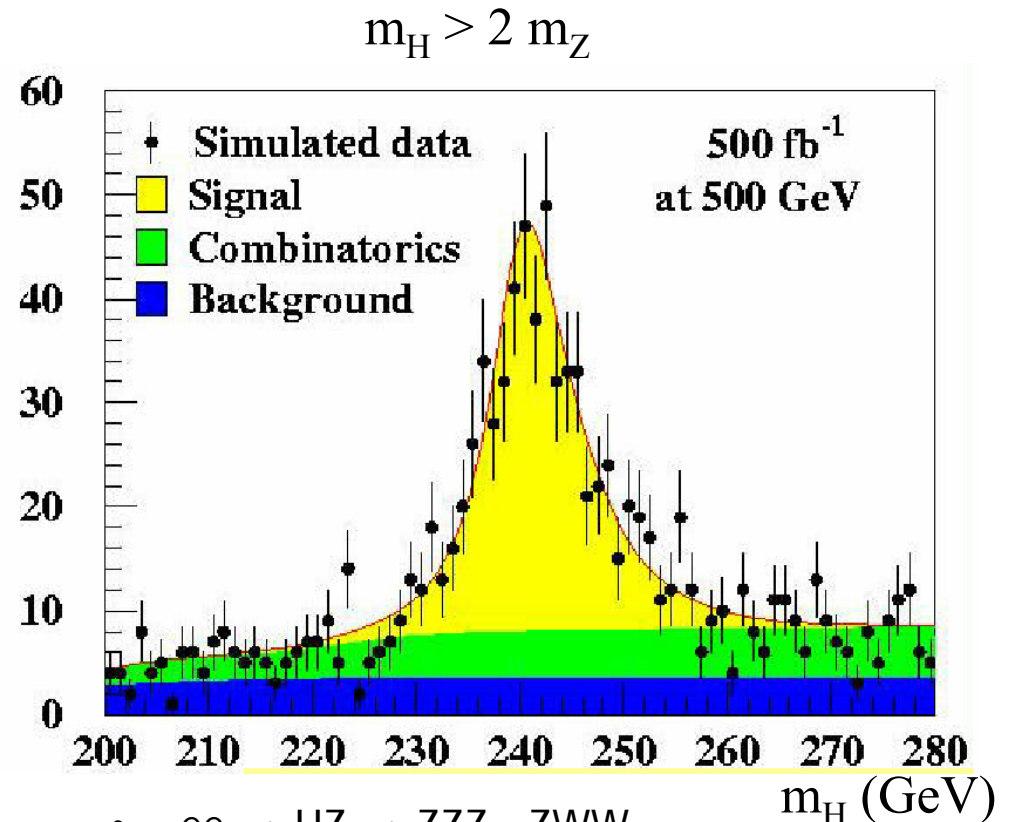


- 100 fb^{-1} collected in high luminosity conditions ($10^{34} \text{ cm}^{-2} \text{ s}^{-1}$)
- 30 fb^{-1} collected in low luminosity conditions ($(2) \cdot 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$)
- Last official results reported in physics TDR (PYTHIA 5.7 with CTEQ2L)
- Latest simulations (PYTHIA 6.2 and CTEQ5L) and analysis confirms the published results with a slight degradation ($< 10\%$)

Next Linear Collider



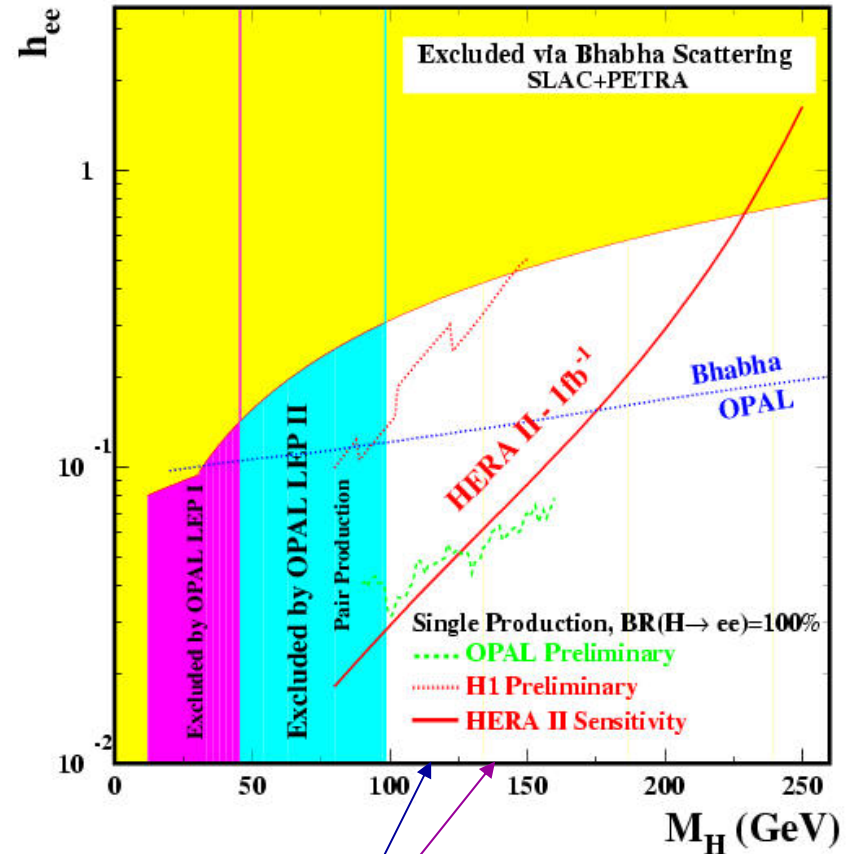
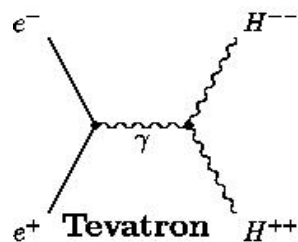
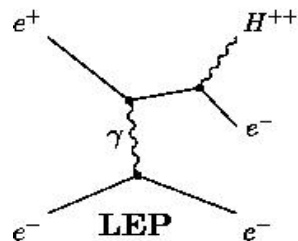
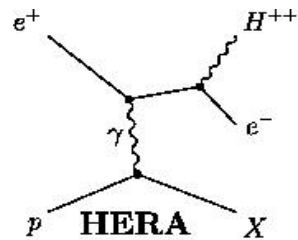
- $ee \rightarrow HZ \rightarrow bbqq$
 - Use 5C fit to signal on top of bg
 - $\Delta m_H = 40 \dots 70 \text{ MeV}$



- $ee \rightarrow HZ \rightarrow ZZZ, ZWW$
 - $H \rightarrow ZZ, WW$ with hadronic decay, so no missing energy
 - Use 4C kin fit
 - $\Delta m_H \approx 400 \text{ MeV}$ (0.2%)
 - $\Delta \Gamma_H \approx 800 \text{ MeV}$ (25%)

New Bosons: H^{++}

- H^{++} predicted in LR symmetric models
- Only lepton couplings, do not “couple to the mass”

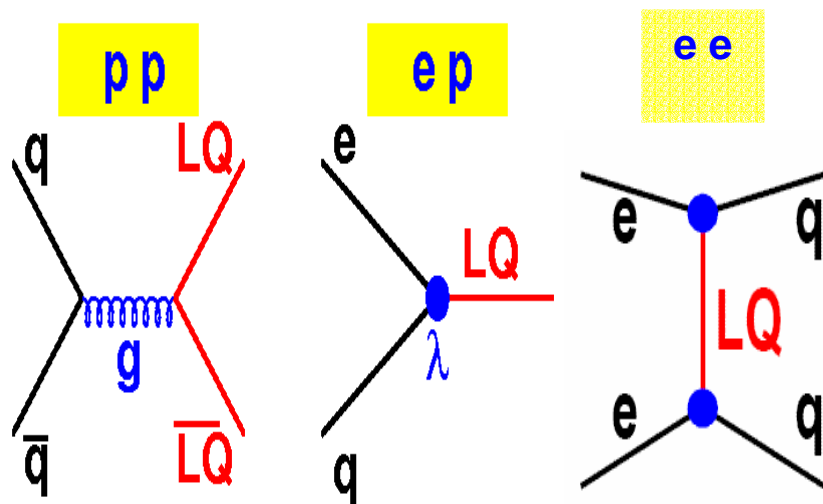


RUN2

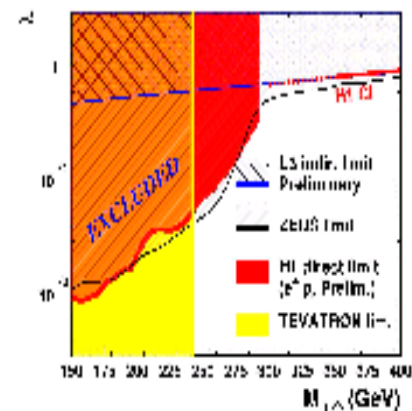
Mass Limit	CDF 240 pb ⁻¹		DØ 106 pb ⁻¹	
	H_L^{++}	H_R^{++}	H_L^{++}	H_R^{++}
ee	135	~102-113		
$\mu\mu$	135	113	116	95
$e\mu$	115			

Other new bosons: Leptoquarks

Comparison with LEP and TEVATRON

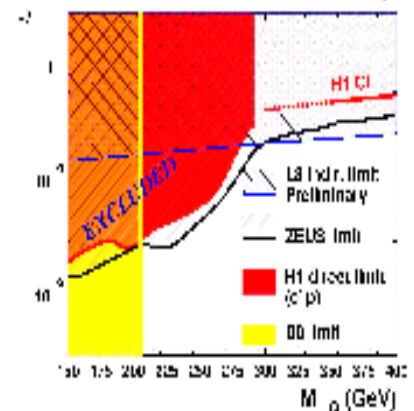


SCALAR LEPTOQUARKS WITH $F=0$ ($\tilde{S}_{LQ,1}$)



- TeVatron: LQ pair production λ independent

SCALAR LEPTOQUARKS WITH $F=2$ ($\tilde{S}_{LQ,2}$)



- LEP: indirect channel effect in quark-pair production

$$e^+e^- \rightarrow q\bar{q}$$

More on LQ, LFV: Jola Sztuk, Lorenzo Bellagamba

LQ at Tevatron

Run 1

Run 2



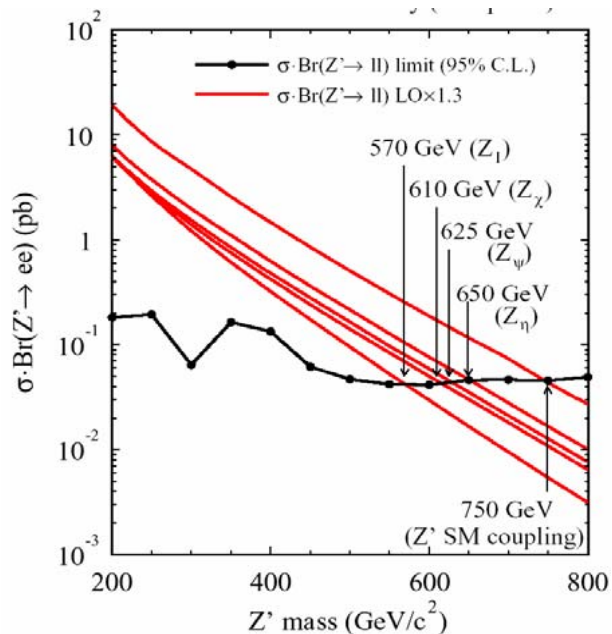
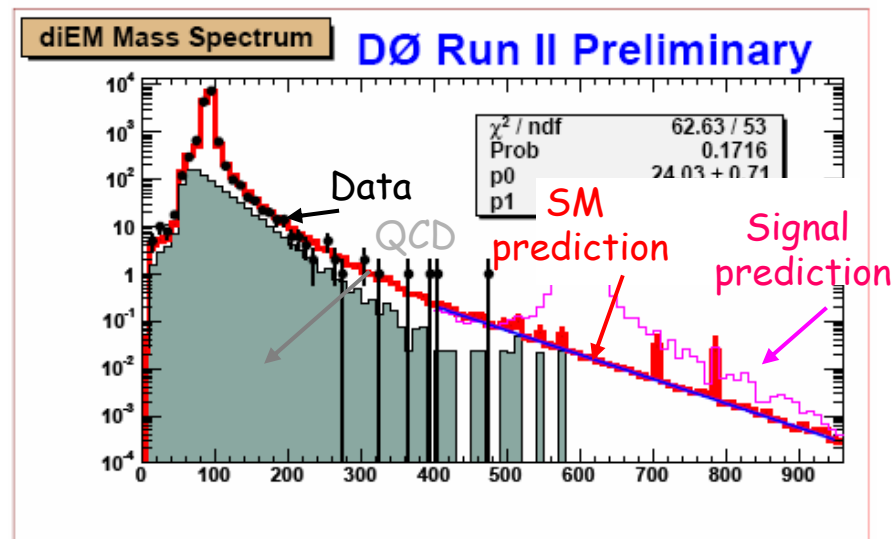
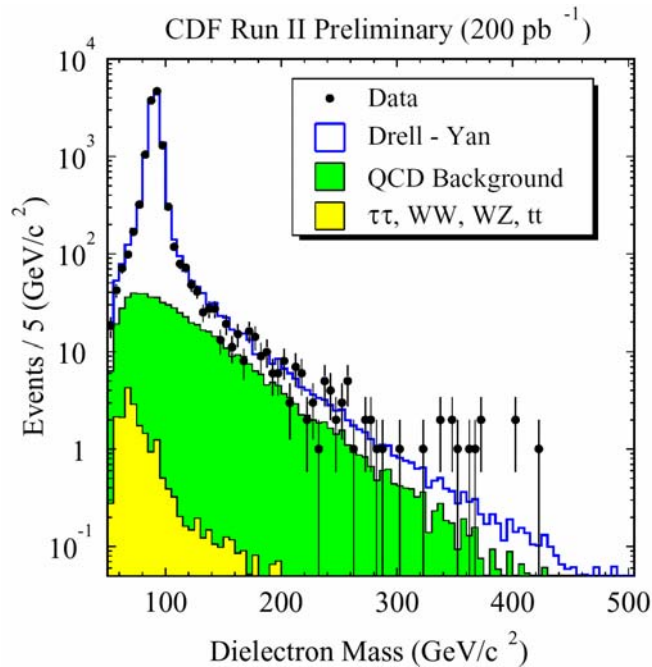
Beta	I	II
1	225	200
1/2	204	180
0	98	98
1	220	202
1/2	182	164
0		123 ¹

Beta	I	II
1.0	238	200
0.5	213	<i>in progress</i>
0.0	<i>in progress</i>	<i>in progress</i>
1.0	230	240
0.5	197	<i>in progress</i>
0.0	117	117

¹ v v c c

Z' in ee channel

$D\mathcal{O} \int L dt = 200 \text{ pb}^{-1}$

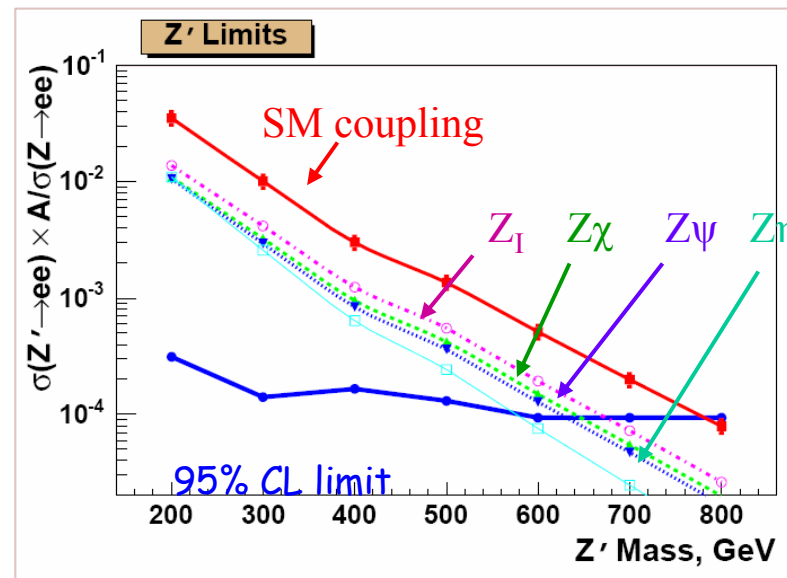


Limits (in GeV)

SM Couplings

CDF : 750
 DØ: 780

E_6	Z_1	Z_χ	Z_ψ	Z_η
CDF:	570	610	625	650
DØ:	575	640	650	680



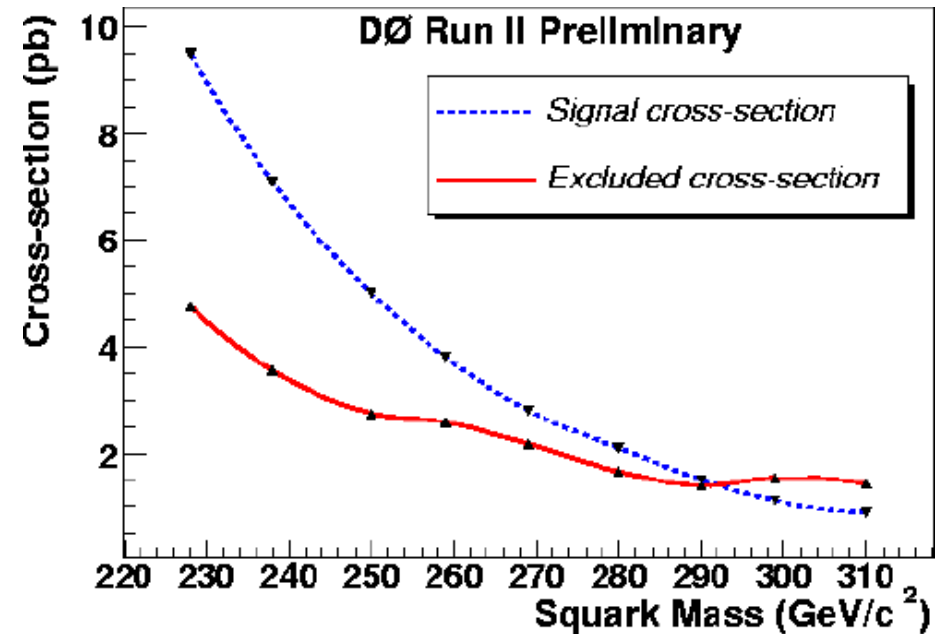
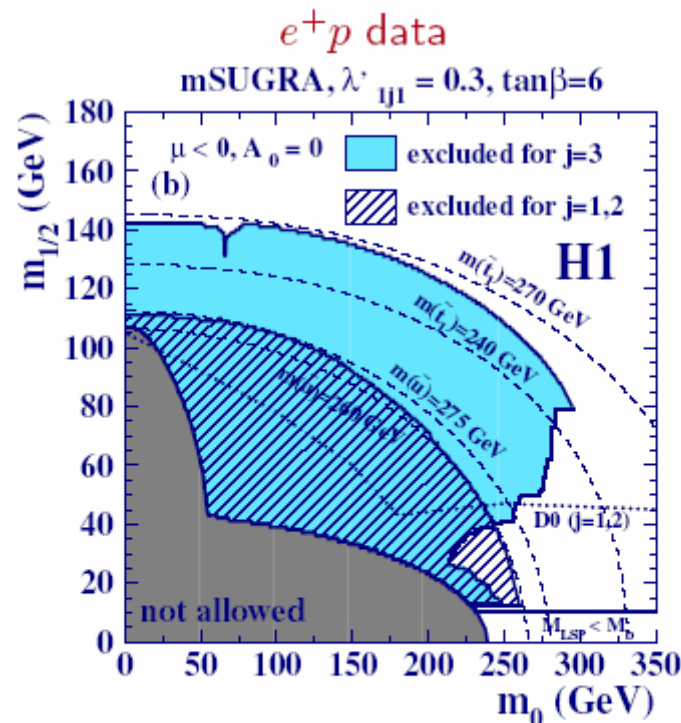
More exotics: A.Pompos, T.Kurca, P.Bechtle

SUSY : squark production

MSUGRA

Only five parameters: $\tan\beta$, $m_{1/2}$, m_0 , A_0 , $\text{sign}\mu$

HERA: Rp-violation, squarks single produced
Tevatron: pair production



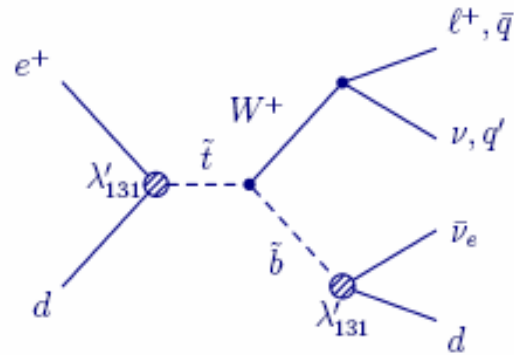
HERA sensitivity follows isomass curve:

\tilde{u} , \tilde{c} , \tilde{t} excluded up to 275 GeV;

Anja Vest, Tibor Kurca

Search for bosonic stop decay

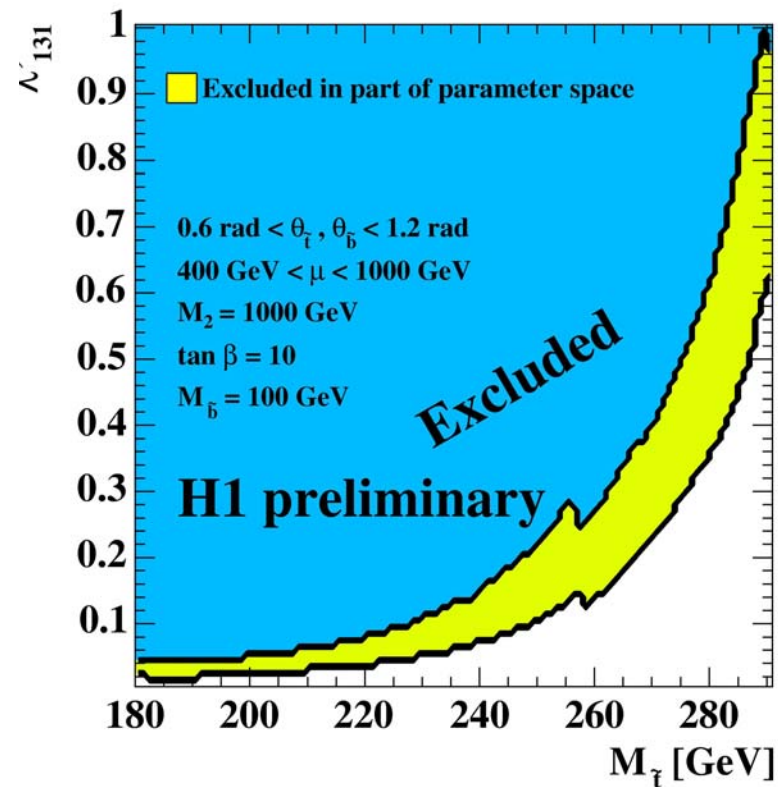
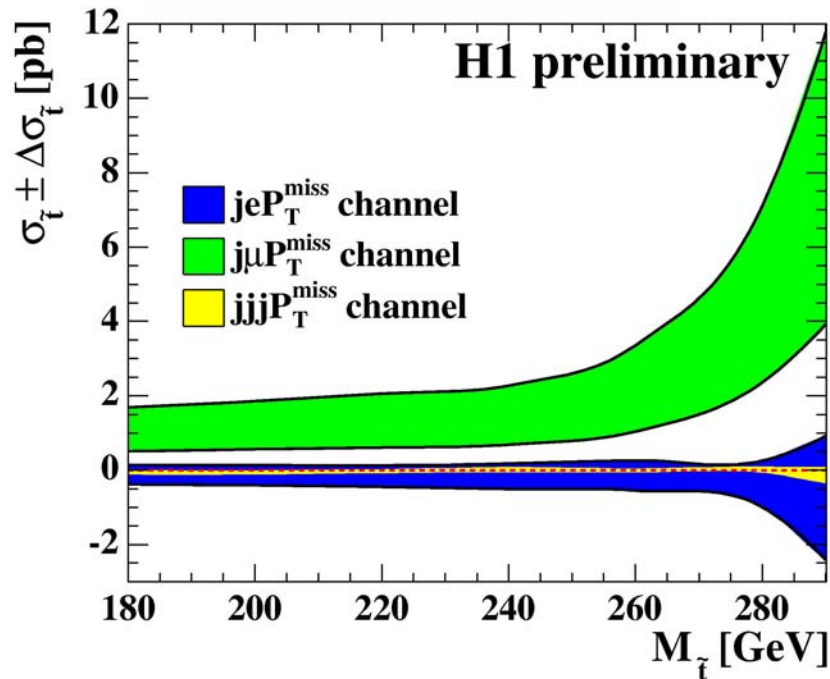
→ bosonic stop decay $\bar{t} \rightarrow bW$



Signature: 3 jets + P_T or jet + ℓ + P_T

→ high P_T lepton events observed at H1

Interpretation of these events as decay products from bosonic stop decays (T. Kon et al., Mod. Phys. Lett. A12 (1997) 3143)



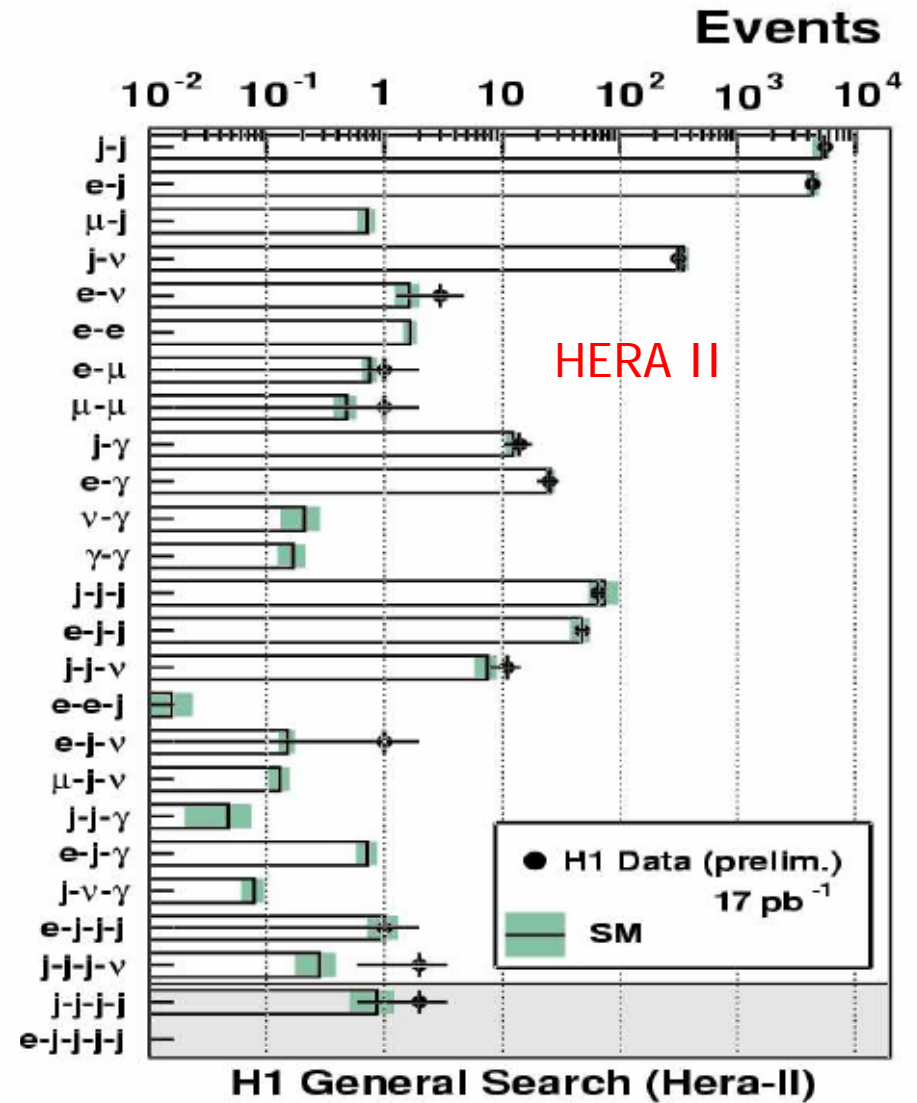
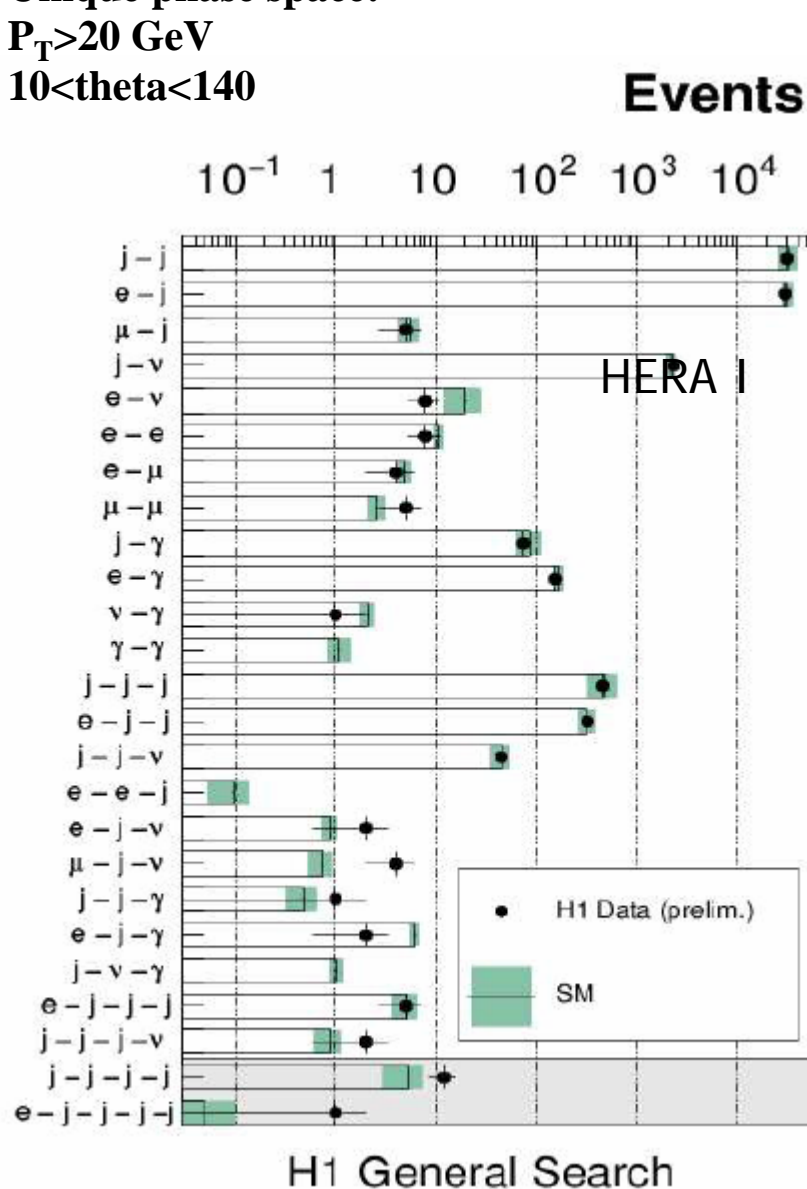
GMSB: Nick Malden, Tibor Kurca

General Search for New Phenomena

Unique phase space:

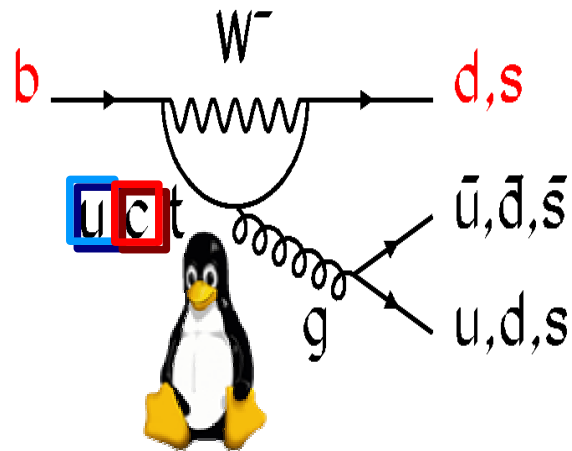
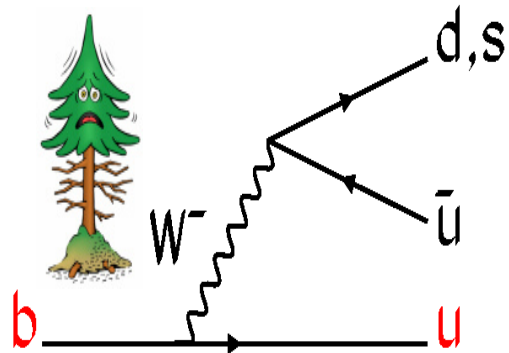
$P_T > 20$ GeV

$10 < \theta < 140$

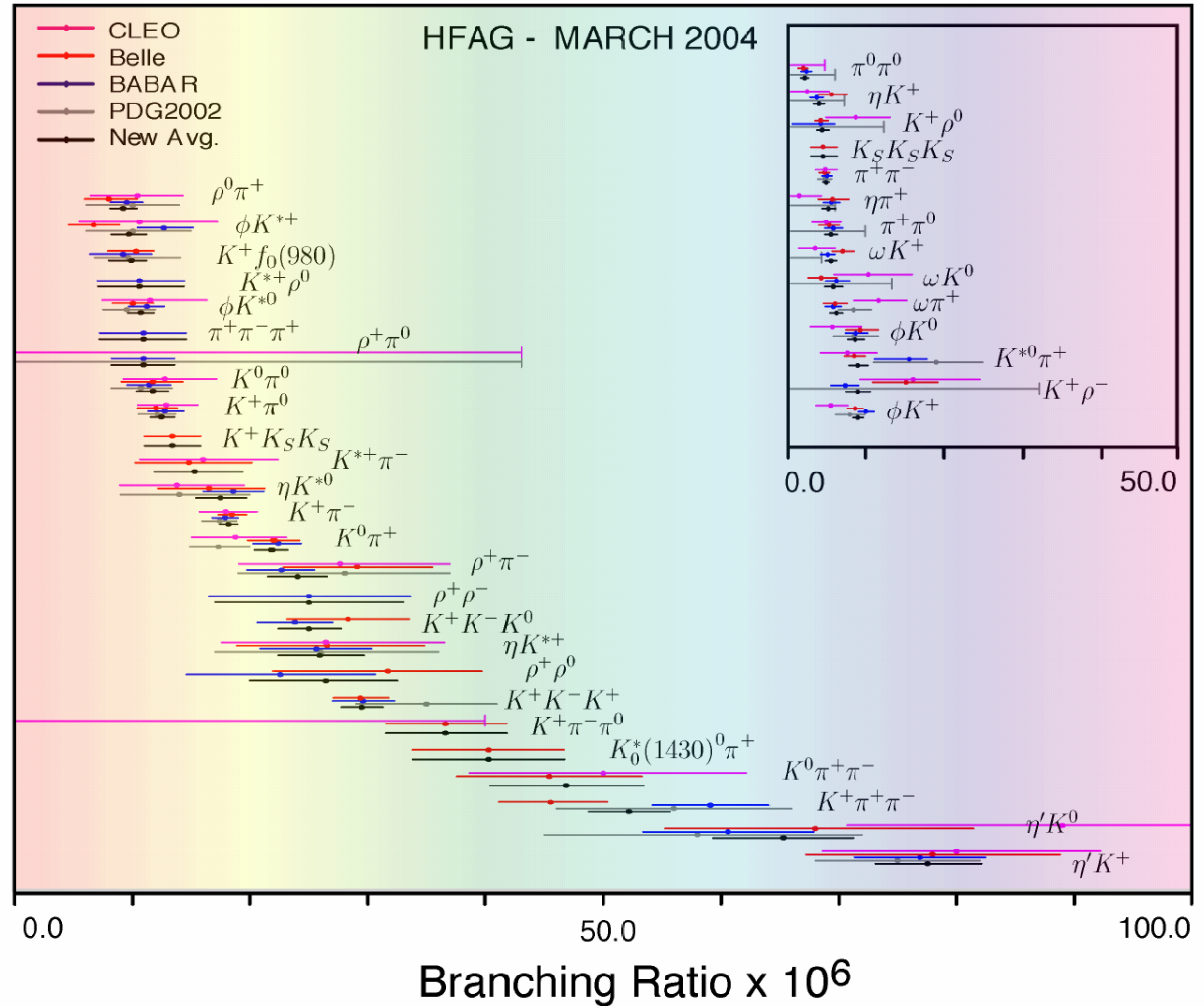


Matti Peetz

Rare decays aren't so "rare" (PEP3=665pb⁻¹/24h)



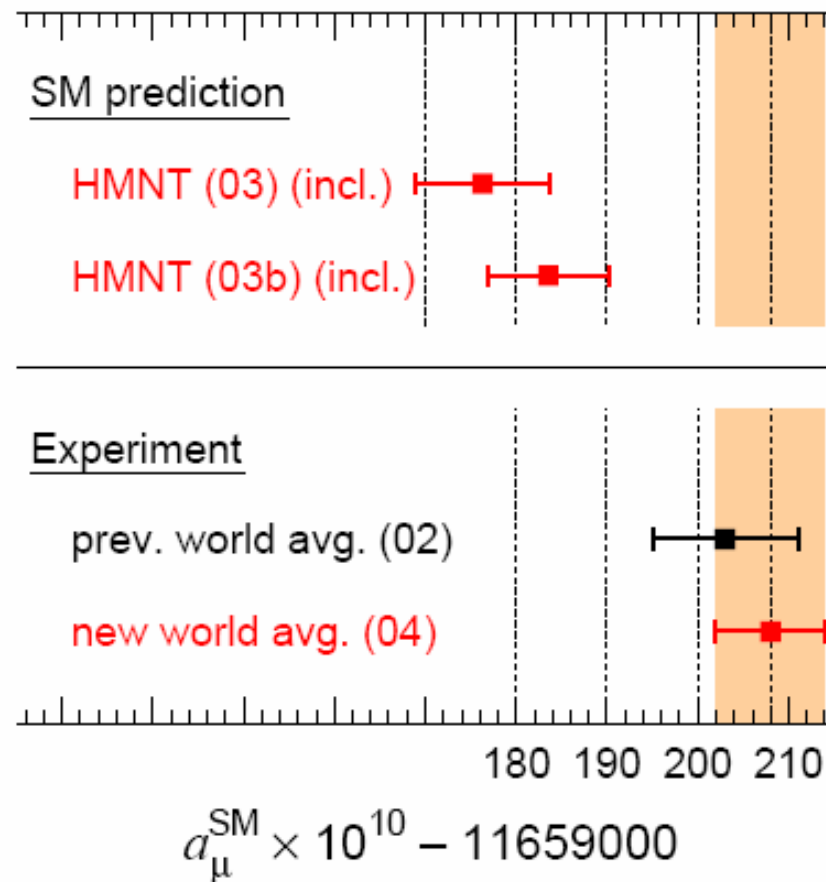
Charmless B Branching Ratios



Flavour Physics:
Luigi DiGiola, Marek Szczekowski

$(g-2)_\mu$

a_μ^{SM} comp. to new BNL 04 world av.:



Summary and Outlook

- LEPxSU(2)xU(1) is perfect, within the errors.
- Tevatron :2xLumi(Run1)
 - 2007: 1-2 fb⁻¹
 - Run1->2:factor ~40 in lumi by 2009 Ecm=1.9 TeV
- HERA: Upgrade delayed, recent good news
 - Need to fullfill the promised program 1 fb⁻¹
- Impressive exploration of rare phenomena at B factory (660 pb-1/24h PEP)
- New generation of colliders pp, ee expected to take over from LEP,HERA,TEVATRON



DiBoson Production: $W\gamma, Z\gamma, WW$: TGC



$$\sigma \cdot \text{BR}(pp \rightarrow W\gamma \rightarrow \ell\nu_\ell\gamma) = 19.3 \pm 1.3 \text{ pb}$$

NLO prediction (U. Baur)

CDF

$$\sigma(W\gamma) \times \text{BR}(W \rightarrow \ell\nu) = 19.7 \pm 1.7 \text{ (stat)} \pm 2.0 \text{ (sys)} \pm 1.1 \text{ (lumi)} \text{ pb}$$

D0

$$\sigma(W\gamma) \times \text{BR}(W \rightarrow \ell\nu) = 19.3 \pm 2.7 \text{ (stat)} \pm 6.1 \text{ (sys)} \pm 1.2 \text{ (lumi)} \text{ pb}$$

NLO prediction (U. Baur): (LO + ET(γ) dependent k factors):

$$\sigma \cdot \text{BR}(pp \rightarrow Z\gamma \rightarrow \ell\ell\gamma) = 5.4 \pm 0.4 \text{ pb}$$

$$\sigma(Z\gamma) \times \text{BR}(Z \rightarrow \ell\ell) = 5.3 \pm 0.6 \text{ (stat)} \pm 0.4 \text{ (sys)} \pm 0.3 \text{ (lumi)} \text{ pb}$$

$$\text{NLO (MFCM, Ellis \& Campbell)} \quad \sigma^{WW} = 12.5 \pm 0.8 \text{ pb}$$

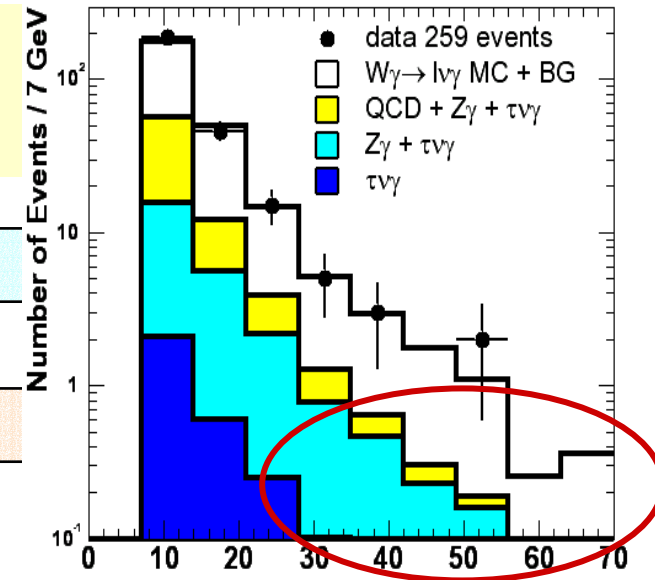
e, μ

$$\sigma(pp \rightarrow WW) = 14.3^{+5.6}_{-4.9} \text{ (stat)} \pm 1.6 \text{ (syst)} \pm 0.9 \text{ (lum)} \text{ pb}$$

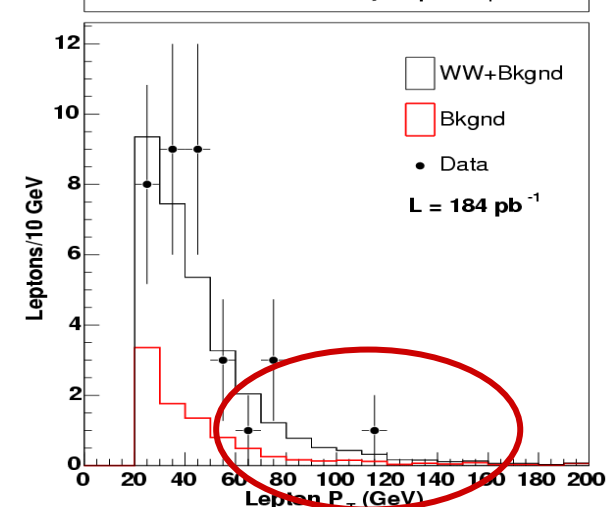
$l + \text{track}$

$$\sigma(pp \rightarrow WW) = 19.4 \pm 5.1 \text{ (stat)} \pm 3.5 \text{ (syst)} \pm 1.2 \text{ (lum)} \text{ pb}$$

CDF Run 2 Preliminary 202 /pb



CDF Run II Preliminary - Lepton P_T



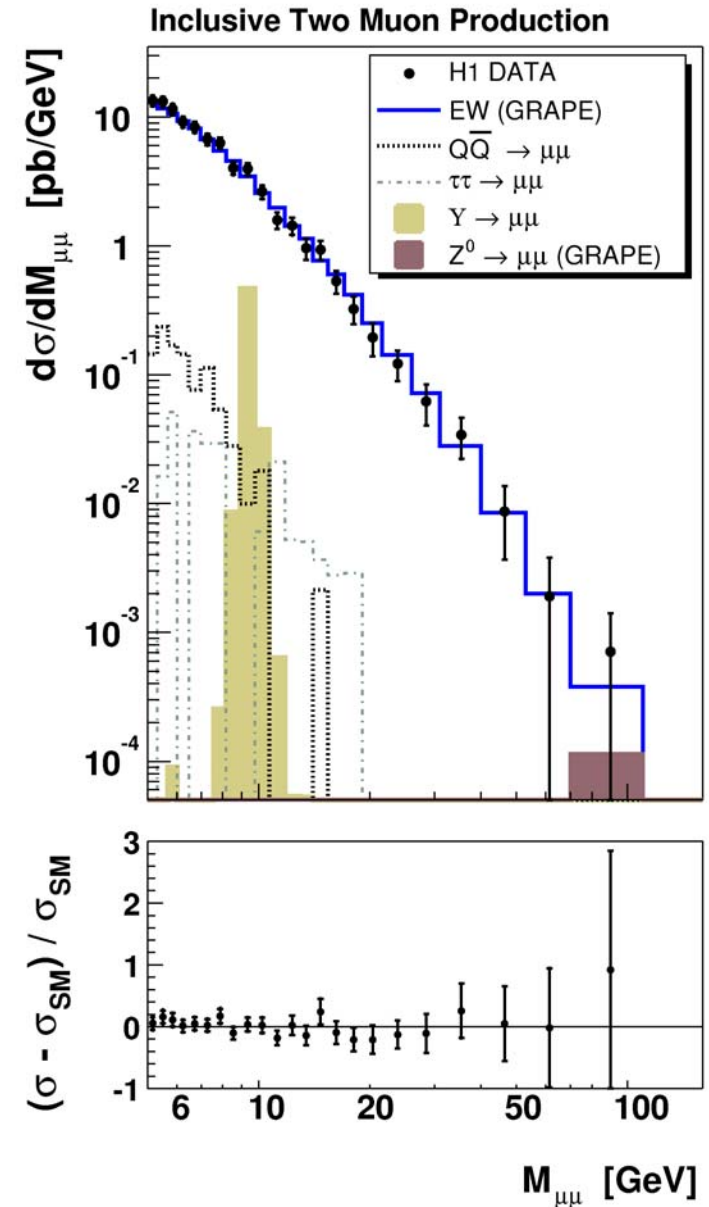
Di-muon events

[H1, Phys. Lett. B583 (2004), 28] H1: (71 pb⁻¹)

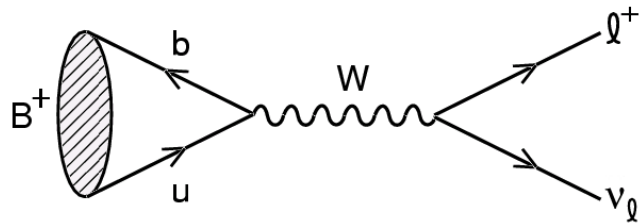
- Muons identified in central tracker, calorimeter and external muon chambers
- $P_{T}^{\mu 1} > 2 \text{ GeV}$, $P_{T}^{\mu 2} > 1.75 \text{ GeV}$
- $M_{\mu\mu} > 5 \text{ GeV}$
- $(20^\circ < \theta_{\mu} < 160^\circ)$

$$\sigma_{\mu\mu} = 46.4 \pm 1.3 \pm 4.5 \text{ pb}$$

SM prediction (GRAPE): $46.1 \pm 1.4 \text{ pb}$



$B^+ \rightarrow l^+ \nu$



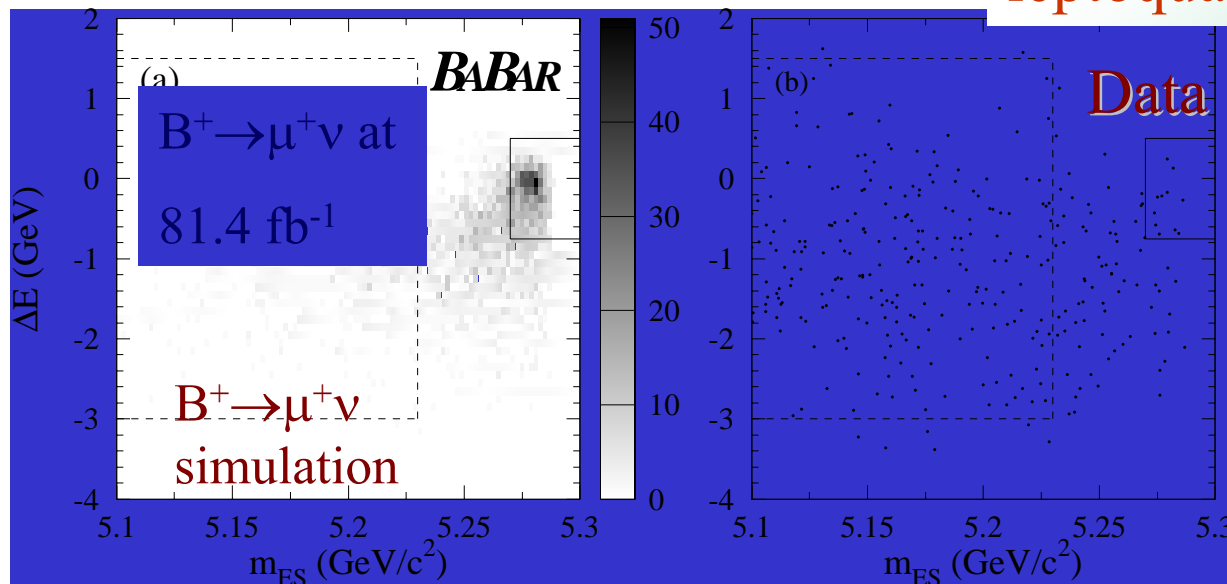
- Purely leptonic decay are helicity suppressed in SM

- $B^+ \rightarrow l^+ \nu$: SM expectation:

$$\text{BF}(B^+ \rightarrow \mu^+ \nu) \sim 4 \times 10^{-7}$$

$$\text{BF}(B^+ \rightarrow \tau^+ \nu) \sim 9 \times 10^{-5}$$

- Provide measurement of $f_B |V_{ub}|$
- Sensitive to charged Higgs, leptoquarks.

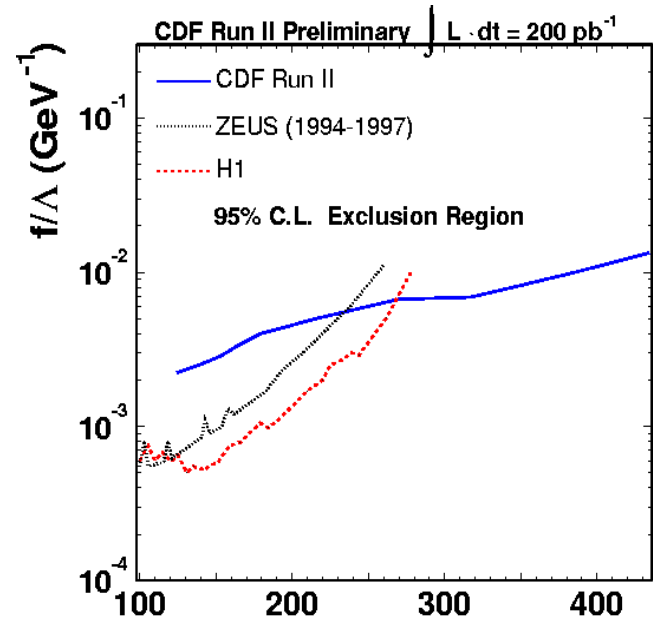
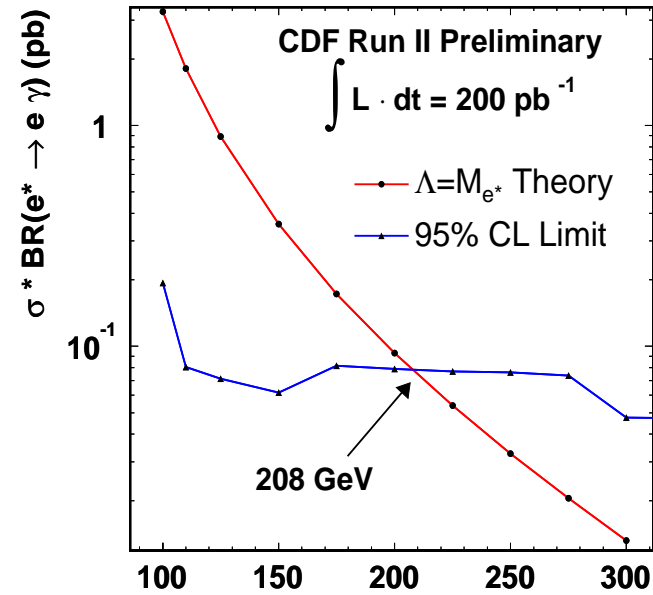
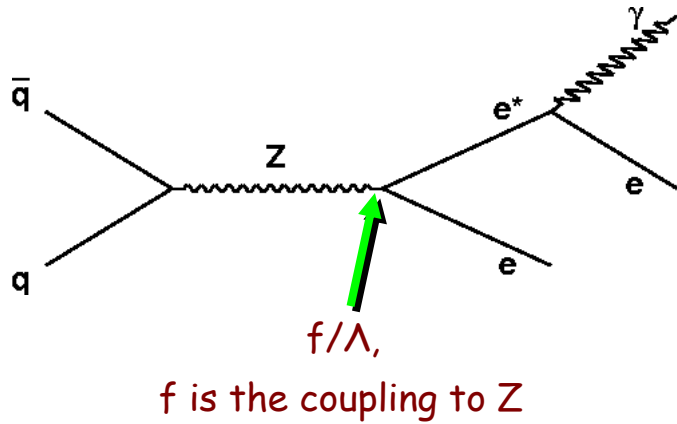


$L=81.4 \text{ fb}^{-1}$

$\text{BF}(B^+ \rightarrow \mu^+ \nu) < 6.6 \times 10^{-6} @ 90\% \text{ CL}$

(PRL)

Search for excited electrons at Tevatron

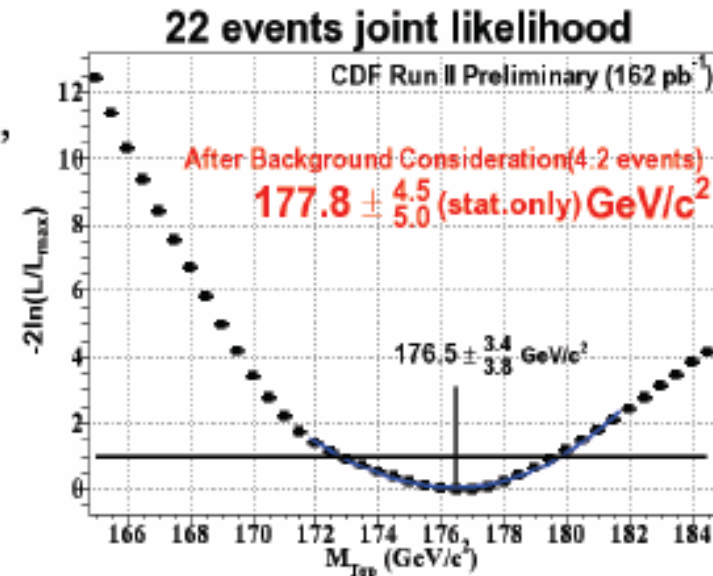
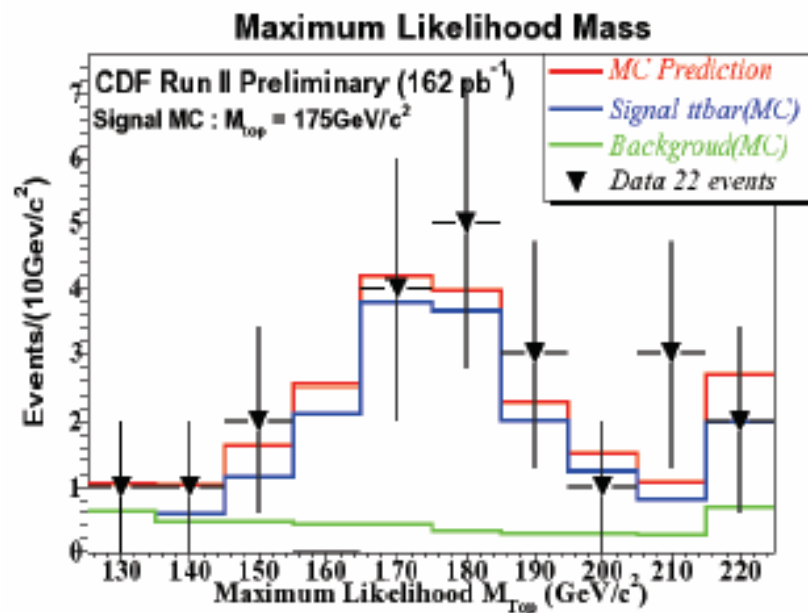


RunII Top Mass



New Dynamical likelihood method :

- Define an event likelihood (ME, pdf, $f^{tt}(Pt)$, transf. function(partons \leftrightarrow observables)
- Take into account all combinations



CDF RunII Preliminary :

$$M_t = 177.8^{+4.5}_{-5.0} \text{ (stat.)} \pm 6.2 \text{ (syst.) GeV}$$

Search for Superlight Gravitino at HERA

Neutralino Production via t channel selectron exchange at HERA

- Assume one Yukawa coupling ($\lambda'_{1,1}$ / $\lambda'_{1,2}$) dominates and $\tilde{\chi}_1^0 \rightarrow \gamma \tilde{G}$ has unobservably short lifetime ("superlight gravitino" $\approx eV$).
- Study \tilde{H}_p SUSY independent of squark mass, dependent on $m_{\tilde{L}}, m_{\tilde{R}}$.
- Experimental signal: $P_T^{miss}(\tilde{G})$, photon and jet.

Event Selection

- 64 pb⁻¹ of e^-p data and 14 pb⁻¹ of e^-p data – COM energy of 320 GeV.
- Basic selection:
 - Non e^+p rejection, timing and vertex requirements.
 - $(\tilde{G}) P_T^{miss} > 25$ GeV
 - (Jet) $P_T^{miss} > 5$ GeV and within good tracking acceptance.
 - (Photon) $P_T^{miss} > 5$ GeV, isolated and within good tracking acceptance.

GMSB Model Interpretations

- No significant deviation from SM → derive GMSB limits.
- Fix ratio β , N and sign(μ) and transform A and M into $m(\tilde{\chi}_1^0)$ and $m(\tilde{A})$.

H1 preliminary: e^-p

GMSB, $\beta = 1.2$
 $\tan\beta = 10, N = 1$

H1 preliminary: e^-p

GMSB, $\beta = 2.0$
 $\tan\beta = 10, N = 1$

- For $N = 1$ can exclude $m(\tilde{\chi}_1^0) < 108$ GeV, and $m(\tilde{A}) < 138$ GeV.

Nick Malden