WG5 - Physics at highest Q^2 and p_T^2 summary

DIS2002

Gudrid Moortgat-Pick, Simona Rolli,
Aleksander Filip Zarnecki

The big questions...

Origin of electro–weak symmetry breaking	Precision Higgs Physics (if Higgs exists) Precision SM Measurements (if no/very heavy Higgs exists)
Unification of the fundamental forces Hierarchy of scales	Precision Supersymmetry Extra Dimensions New Gauge Bosons
CP Violation and Flavour	Higgs? SUSY? ...?
Gravity	Extra Dimensions

Overview

- The status of Standard Model tests
  - EW parameters
  - high E_t jets
  - EW symmetry breaking
- Beyond the SM
  - SUSY
  - LQ,CI,LED
  - zoo
- Future : HERA upgrade, TeVatron II, LHC, LC, VLHC

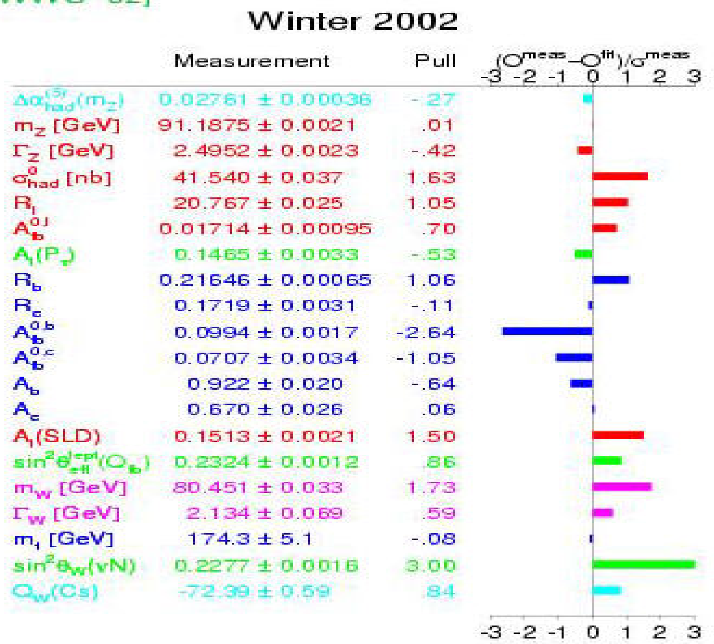
Status of SM

In general data agree very well with the SM:

LEP EW parameters precision measurements
T. Saeki

Basic assumption in global fit:
SM provides correct description of experimental data

Comparison of SM prediction with the data:
[LEPEWWG '02]



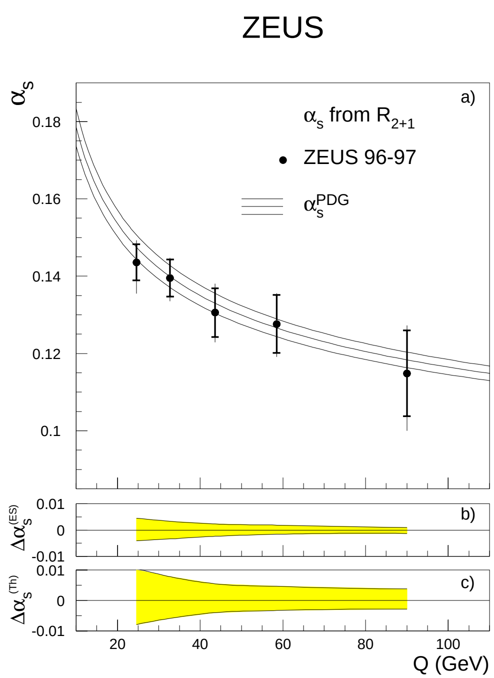
Winter 2002

	Measurement	Pull
$\Delta\alpha_{had}^{(5)}(m_Z)$	0.02761 ± 0.00036	-.27
m_Z [GeV]	91.1875 ± 0.0021	.01
Γ_Z [GeV]	2.4952 ± 0.0023	-.42
σ_{had}^0 [nb]	41.540 ± 0.037	1.63
R_l	20.767 ± 0.025	1.05
$A_{fb}^{0,l}$	0.01714 ± 0.00095	.70
$A_l(P_\tau)$	0.1465 ± 0.0033	-.53
R_b	0.21646 ± 0.00065	1.06
R_c	0.1719 ± 0.0031	-.11
$A_{fb}^{0,b}$	0.0994 ± 0.0017	-2.64
$A_{fb}^{0,c}$	0.0707 ± 0.0034	-1.05
A_b	0.922 ± 0.020	-.64
A_c	0.670 ± 0.026	.06
A_l(SLD)	0.1513 ± 0.0021	1.50
$\sin^2\theta_{eff}^{lept}(Q_{fb})$	0.2324 ± 0.0012	.86
m_W [GeV]	80.451 ± 0.033	1.73
Γ_W [GeV]	2.134 ± 0.069	.59
m_t [GeV]	174.3 ± 5.1	-.08
$\sin^2\theta_W(\nu N)$	0.2277 ± 0.0016	3.00
Q_W(Cs)	-72.39 ± 0.59	.84

Overall fit probability (quality of the fit): 1.7%

Jet at high E_t at HERA

C. Foudas

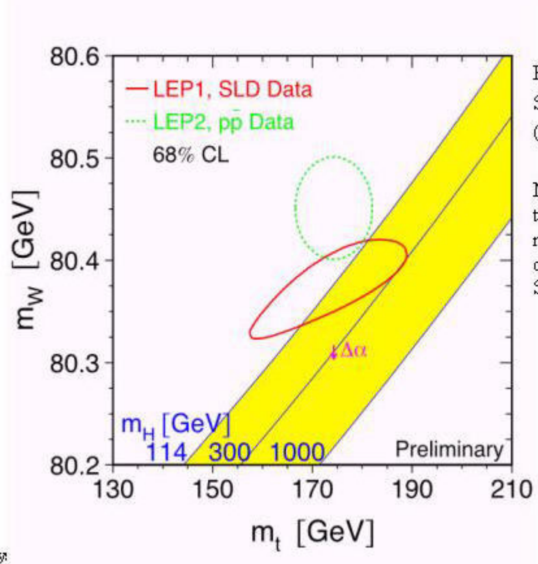


- Jet data at high E_T have been used at HERA-I to test QCD and make precise measurements of the gluons and α_S
- The detector and theory systematic errors have been well understood and we have learned that jet measurements can be made to better than 10% level if the E_T is high enough (high Q^2 is needed also)
- Low Q^2 regime is rich but require more precise theoretical calculations.
- HERA II will start soon !! One can expect a large increase of the high E_T high Q^2 samples which will enable us to tag the proton PDFs at higher x, measure α_S, BFKL, search for new physics.

Top physics

K. Sliwa

SM consistency checks: W mass vs M_{top}



Results of LEP EWWG SM consistency fits (Spring 2002)

Measurements of W and top mass constrain Higgs mass. Fundamental consistency tests of Standard Model

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SUMMARY OF TEVATRON RUN-I RESULTS

TOP MASS AND CROSS SECTION

combined CDF results from Run-I:

$M_t = 176.0 \pm 6.5$ GeV/c^2

$\sigma_{tt} = 6.5+1.7-1.4$ pb (for M_t=175 GeV/c^2)

combined D0 results from Run-I:

$M_t = 172.1 \pm 7.1$ GeV/c^2

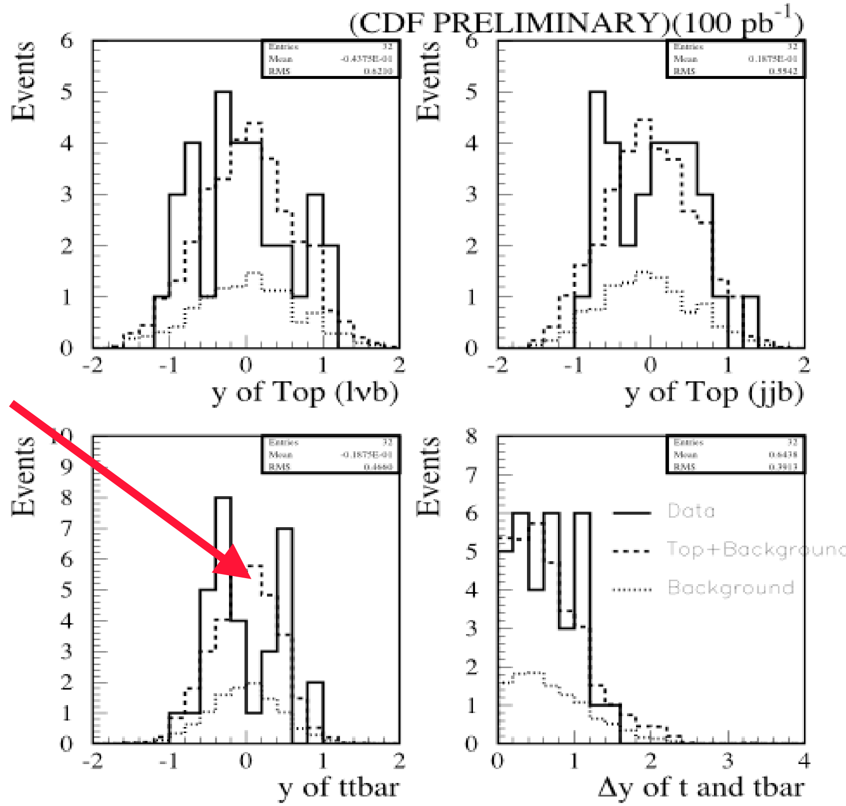
$\sigma_{tt} = 5.9 \pm 1.7$ pb (for M_t=172.1 GeV/c^2)

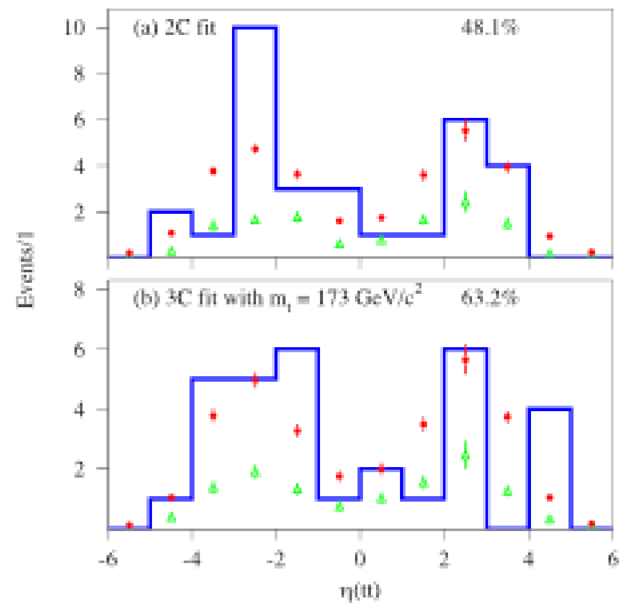
combined CDF and D0 result from Run-I:

$M_t = 174.3 \pm 5.1$ GeV/c^2

krzysztof.sliwa@tufts.edu DIS2002 Krakow, Poland April 30-May 4, 2002 28

IS IT ONLY TOP ?



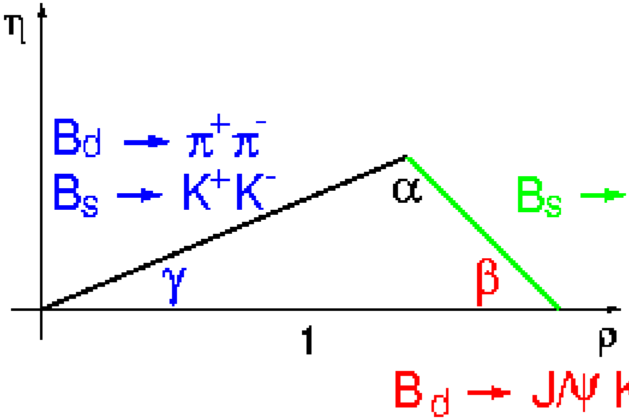


Rapidity (CDF) and pseudorapidity (D0) distributions of tt system

Run II CDF B-physics prospects

- CP violation
- Improved measurement of sin(2β) in $B^0 \to J/\psi K^0_{S}$: ≈20000 events
  $\sigma(\sin 2\beta) \approx 0.05$
- B_S mixing in $B_S \to D_S \pi^+$ sensitivity up to about
  $x_S \approx 60$ (≈23000 events)
  $x_S \approx 30$ in semileptonic decays

$x_S = \Delta m_S / \Gamma_S$



- Measurement of γ in
  $B^0_d \to \pi^+\pi^-$ and $B^0_S \to K^+K^-$ decays.
- Use of both decays reduces the influence of penguins.
- Assuming S/B=1/2 and $\Delta m_S = 30\ ps^{-1}$; events: $5000(\pi^+\pi^-)/10000(K^+K^-)$:
  $\sigma(\gamma) \approx 7^0$

NuTev puzzling result

P.Spenziouris

NuTeV

Results

Phys.Rev.Lett.88

$$\sin^2\theta_W^{(\text{on-shell})} = 0.2277 \pm 0.0013\,(\text{stat}) \pm 0.0009\,(\text{syst}) - 0.00022 \cdot \left(\frac{M_{\text{top}}^2 - (175\text{ GeV})^2}{(50\text{ GeV})^2}\right) + 0.00032 \cdot \ln\left(\frac{M_{\text{Higgs}}}{150\text{ GeV}}\right)$$

$$\sin^2\theta_W^{(\text{on-shell})} \equiv 1 - \frac{M_W{}^2}{M_Z{}^2}$$

- In good agreement with previous νN: $\sin^2\theta_W = 0.2277 \pm 0.0036$

NuTeV measures:

$$(g_L^{\text{eff}})^2 = 0.3001 \pm 0.0014$$
$$(g_R^{\text{eff}})^2 = 0.0308 \pm 0.0011$$
$$\rho_{\text{corr}} = -0.02$$

$$R^\nu = g_L^2 + r\, g_R^2$$
$$R^{\bar\nu} = g_L^2 + \frac{1}{r}\, g_R^2$$
$$g_L^2 \equiv u_L^2 + d_L^2$$
$$g_R^2 \equiv u_R^2 + d_R^2$$

Assuming predicted ν coupling, $(g_L^{\text{eff}})^2$ appears low

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NuTeV (cont'd)

Asymmetric strange sea (?)

- Our PDF model assumes xs=xs bar
  - constrained by our dimuon production data, within our LO model
- Recent (almost) global PDF NLO analysis finds $\int x(s\ s\ \text{bar})dx = 0.002$ *(Barone et al., hep ph/9904512)*
  - suggested as explaining half of the NuTeV effect *(Davidson et al., hep ph/0112302)*

➔ BUT: inconsitent with our dimuon x section (model independent); driven by high x CDHSW data

- ➢ even s sbar=0.002 DOES NOT explain half the effect if experimental cuts, etc included

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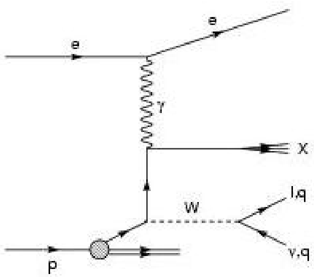
Isolated lepton final states @HERA

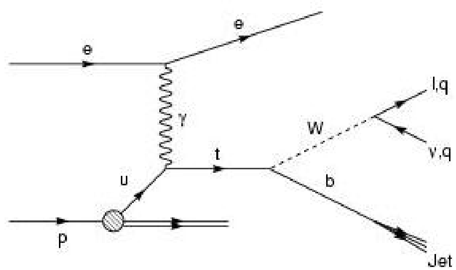
N.Malden

Nick Malden, Manchester University, DIS 2002

Introduction



SM W Production



FCNC Single top Production

Each processes has the same final state:

3 Jets in the hadron channel

Isolated high p_T lepton and missing total p_T in the lepton channel

Anomalous FCNC coupling parameterized by $k_{tu\gamma}$

Isolated Leptons, W and top at HERA — Page 4

H1 Results 94-00 Isolated Leptons

Electron and Muon	H1 Prel. e^+p Data	SM expectation	W	Other SM processes
$P_T^X > 0$ GeV	18	10.48 ± 2.53	8.19 ± 2.46	2.29 ± 0.59
$P_T^X > 12$ GeV	13	5.14 ± 1.31	4.22 ± 1.27	0.92 ± 0.33
$P_T^X > 25$ GeV	10	2.82 ± 0.73	2.34 ± 0.70	0.48 ± 0.18
$P_T^X > 40$ GeV	6	0.99 ± 0.28	0.93 ± 0.28	0.06 ± 0.04

ZEUS Results 94-00 - Isolated Leptons

ZEUS preliminary 1994-2000	Electrons Observed/expected (W)	Muons Observed/expected (W)
e^+p 114 pb^{-1}	7 / 9.9 $\pm$ 1.6 (2.4)	7 / 4.6 $\pm$ 0.6 (1.1)
e^-p 16 pb^{-1}	3 / 1.1 $\pm$ 0.4 (0.3)	0 / 0.8 $\pm$ 0.1 (0.2)
Total 130 pb^{-1}	10 / 11.0 $\pm$ 1.6 (2.7)	7 / 5.4 $\pm$ 0.7 (1.3)

Final selection isolating W component:

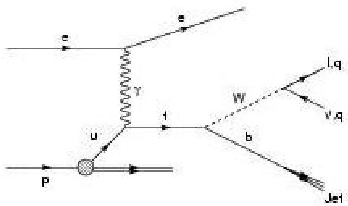
ZEUS preliminary 1994-2000 $e^{\pm}p$ 130 pb^{-1}	Electrons Observed/expected (W)	Muons Observed/expected (W)
$P_T^X > 25$ GeV	1 / 1.14 $\pm$ 0.06 (1.10)	1 / 1.29 $\pm$ 0.16 (0.95)
$P_T^X > 40$ GeV	0 / 0.46 $\pm$ 0.03 (0.46)	0 / 0.50 $\pm$ 0.08 (0.41)

Isolated leptons (cont'd)

Nick Malden, Manchester University, DIS 2002

Single top production

Interpret these kind of events as single top?



Recall : $P_T^X > 25$ GeV H1 report 10 cf. 2.82

and at $P_T^X > 40$ GeV ZEUS report 0 cf. 0.46

ZEUS observe no candidates for single top production and correspondingly set an upper limit (at 95% C.L.) of $k_{tu\gamma} < 0.257$ (leptonic decays only)

H1 add further cuts to separate top production from SM W:

$P_T^{\mathrm{Jet}} > 25$ GeV, $M_T^{l\nu} > 10$ GeV and only positive leptons!

(Hard b-jet) (Real W) (Very little $\bar{u}$ in proton)

Isolated Leptons, W and top at HERA

Page 14

H1 Single top - leptonic decay

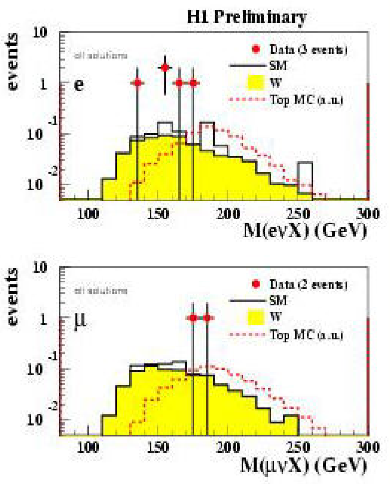
	Electron Channel	Muon Channel
Data	3	2
Total SM	0.75 ± 0.18	0.77 ± 0.21
W only	0.51 ± 0.16	0.68 ± 0.19
Efficiency	37%	45%

No events in small e^-p data set (13.6 pb^{-1})

cf. 0.25 ± 0.05 expected

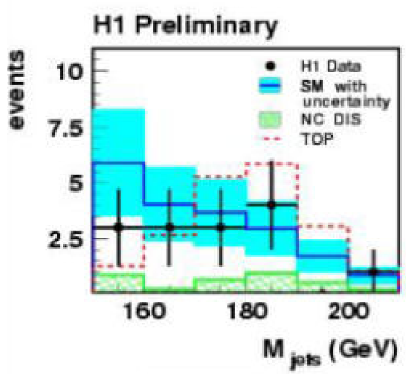
$\rightarrow \sigma(920\text{ GeV}) < 0.95$ pb

$k_\gamma < 0.32$



Isolated leptons (cont'd)

Single top - Hadronic decay - (H1)



After all top cuts

After top cuts:

14 events selected cf. 19.6 ± 7.8

Efficiency ($t \longrightarrow 3$ jets) 27%

Exclusion limits at 95% C.L.:

Hadronic Channel :	σ_{top} (320 GeV) < 0.40 pb
Hadronic and Leptonic Channel :	σ_{top} (320 GeV) < 0.43 pb
	$k_{tu\gamma} < 0.22$

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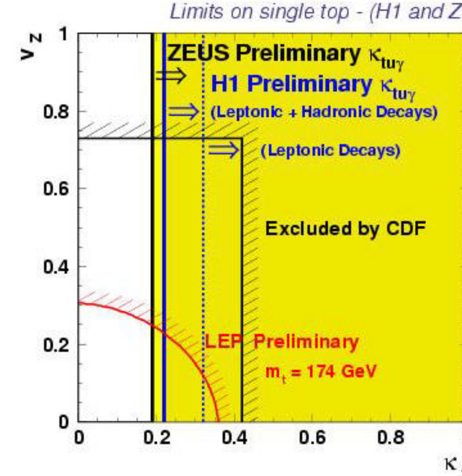
Limits on single top - (H1 and ZEUS)



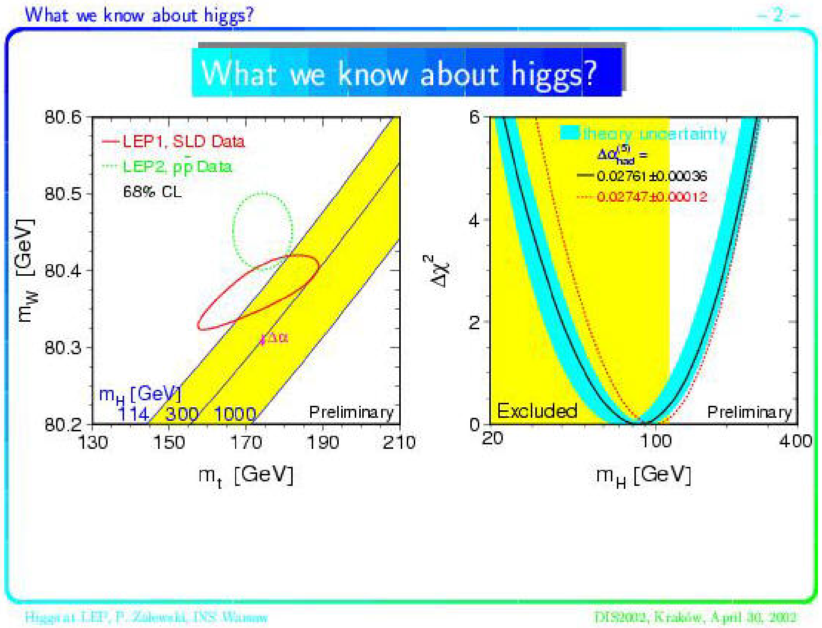
$k_{tu\gamma} < 0.22$ (H1)

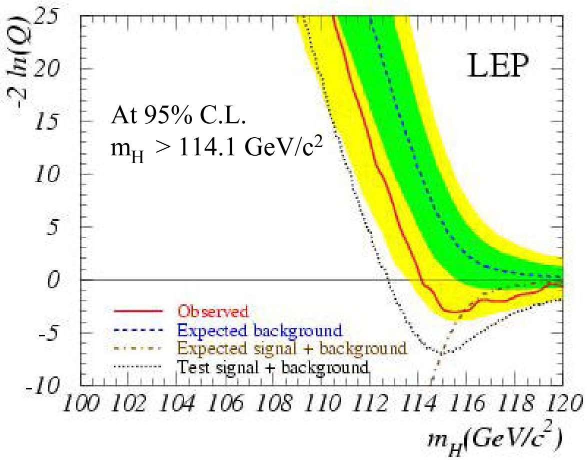
$k_{tu\gamma} < 0.19$ (ZEUS)

Isolated Leptons, W and top at HERA — Page 22

EW symmetry breaking

Higgs at LEP
P.Zalewski





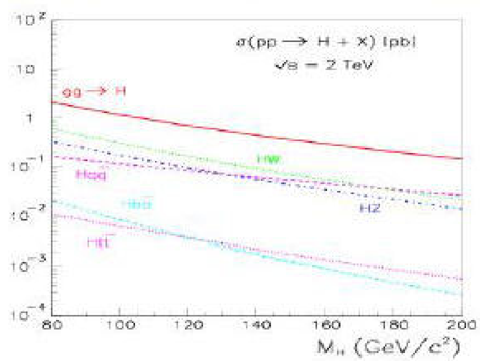
Despite the excellent perfomance of LEP the Higgs boson has not been found (yet) searches have been conducted in many sophisticated way. Some analysis still ongoing...

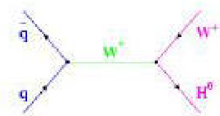
⇒ 2.1σ excess over background expectation

Prospect for Higgs at TeVatron

M. Petteni

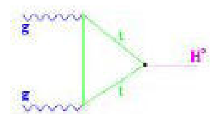
Production Mechanism





Associated production

Gluon fusion

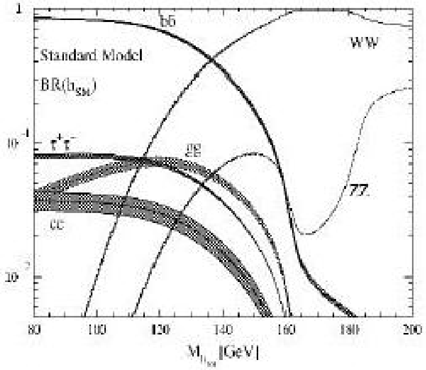


- Main mode of production difficult to trigger on and also to reconstruct. Swamped by QCD dijet production.
- More promising channel is the associated production where the gauge boson can be used as a trigger.
- Look for leptons, missing E_T and jets at trigger level.

Michele Petteni, Imperial College DIS 2002

Prospects for Higgs at the TeVatron

Higgs Boson Decay



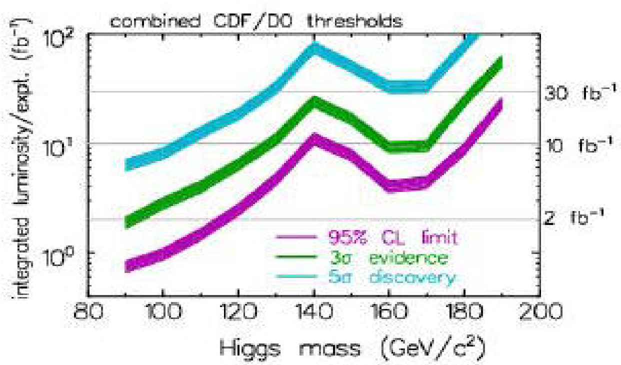
- Higgs decays to bb for $m_H < 135$ GeV.
- $\tau^+ \tau^-$ difficult at hadron collider.
- Above 135 GeV look for ZZ and WW decays.

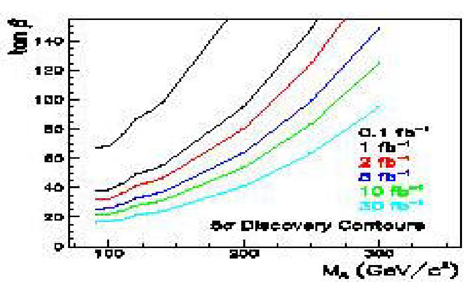
- Two search strategies:
  - Below 135 GeV look for associated production with 2 bjets from the Higgs decay.
  - Above this limit exploit gluon fusion and reconstruct the two gauge bosons.

Michele Petteni, Imperial College — DIS 2002

Higgs at the TeVatron

SUSY Higgs Workshop





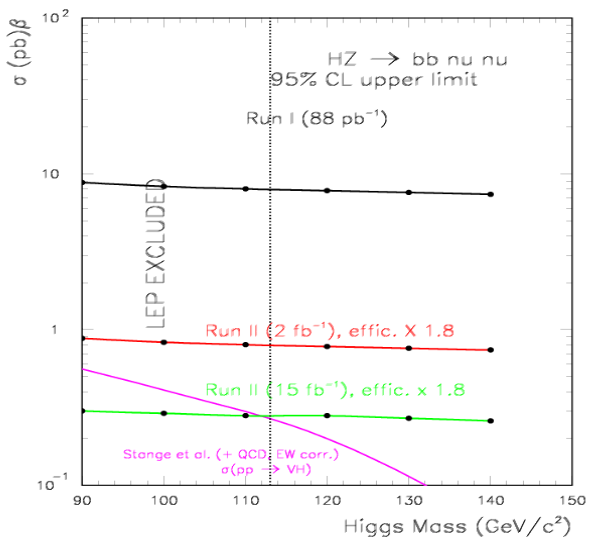
- Workshop used parametrised MC.
- Jet reconstruction, lepton id implemented at some level.
- 5 σ discovery looks possible for low mass higgs, exclusion up to about 180 GeV with 10 fb^{-1}.
- Luminosity is critical.
- Room for improvement.

Michele Petteni, Imperial College

DIS 2002

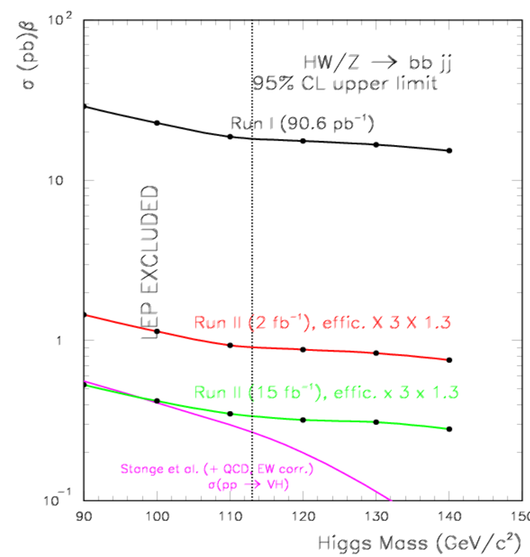
Run II extrapolations

Snowmass 2001



MET + bb:
In respect to run I, factor 1.4 (turn-on) x 1.3.
(improved geometrical acceptance)

Multijets:
in respect to runI factor 3
(double b-tag efficiency)x1.3.



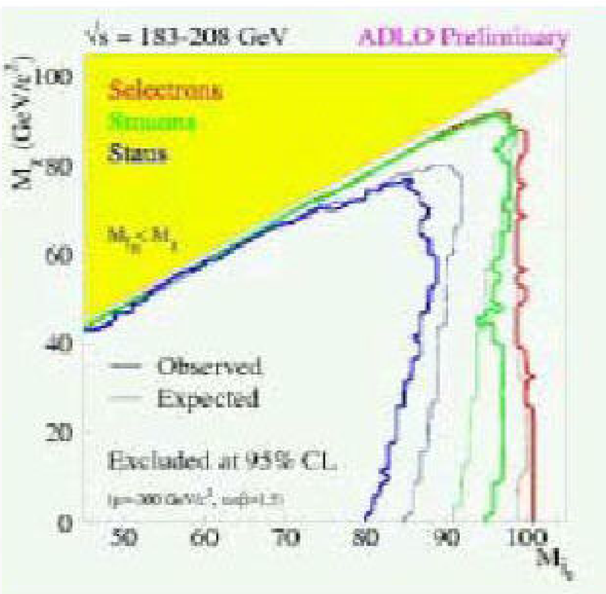
- Assuming the same Signal to Background ratio as in RUN-I, the cross section limit at 95 % confidence level has been scaled as

$$Eff_{RI} / Eff_{RII} \ x \ \sqrt{(L_{R-I} / L_{R-II})}$$

SUSY at LEP

N. De Filippis

LSP vs slepton limits



Conclusions

No excess was found at LEP experiments compatible with the productions of SUSY particles ($N_{obs} \cong N_{exp}$)

The absence of a signal is interpreted in terms of 95 % C.L. upper limits on the mass of the SUSY particles in the MSSM

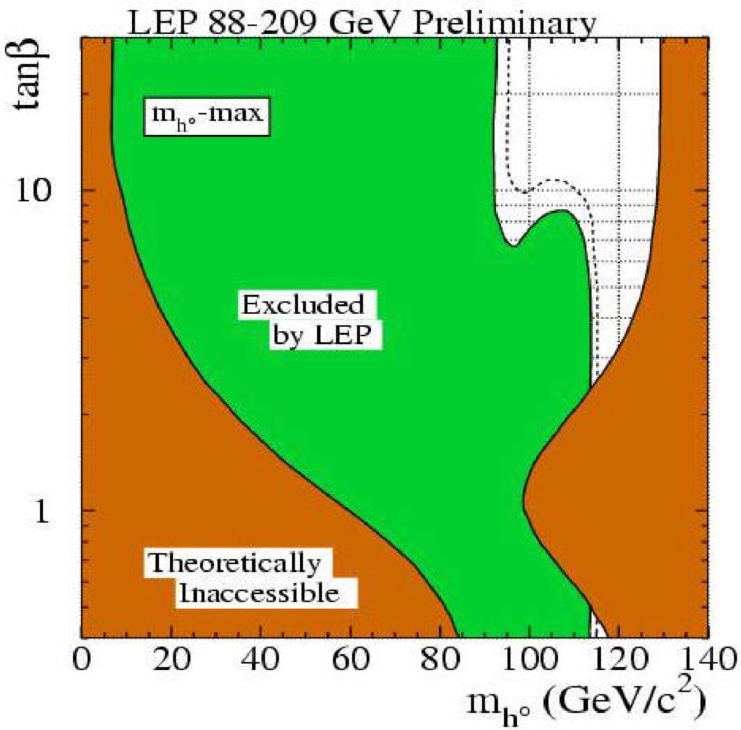
We are waiting for physics beyond Standard Model from Tevatron and LHC experiments

Nicola De Filippis DIS 2002, Cracow, 30 April - 4 May 28

SUSY Higgs

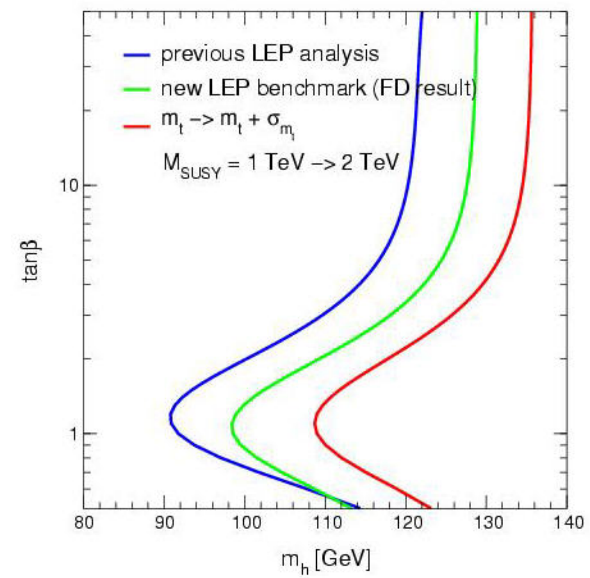
G. Weiglein

m_h^{max}-scenario:



Effect of: $m_t \to m_t + \sigma_{m_t}$, $M_{SUSY} = 1$ TeV $\to$ 2 TeV

[S. Heinemeyer, W. Hollik, G. W. '00]



$\Rightarrow$ precise knowledge of m_t important!

tanβ ~ 1 not excluded

m_h > 91.0 GeV (expected: 94.6 GeV), 95% C.L.

M_A > 91.9 GeV (expected: 95.0 GeV)

SUSY at HERA

R-parity violating ($R\!\!\!/_p$) SUSY

J. Haller

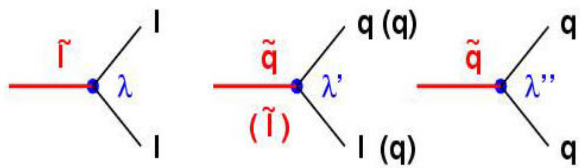
But: most general theory that is supersymmetric, gauge-invariant and renormalizable **has additional term:**

$R\!\!\!/_p$ part of SUSY superpotential:

$$W_{R\!\!\!/_p} = \lambda_{ijk} L_i L_j \bar{E}_k + \lambda'_{ijk} L_i Q_j \bar{D}_k + \lambda''_{ijk} \bar{U}_i \bar{D}_j \bar{D}_k$$

$$\hookrightarrow L\!\!\!/ \qquad \hookrightarrow L\!\!\!/ \qquad \hookrightarrow B\!\!\!/$$

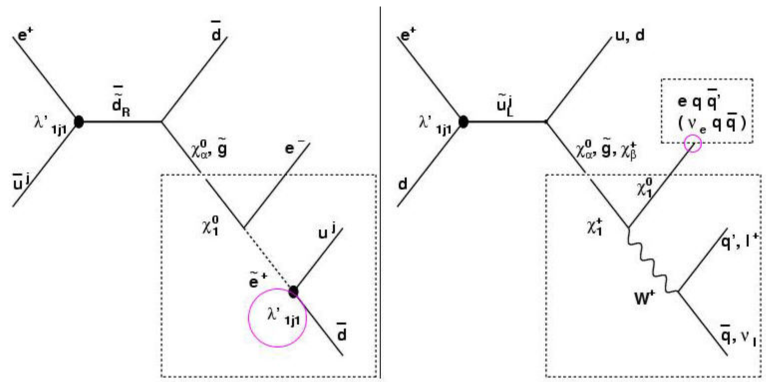
$\Longrightarrow$



- **Resonant production of single SUSY particles**
- **SUSY particles can decay into standard particles**

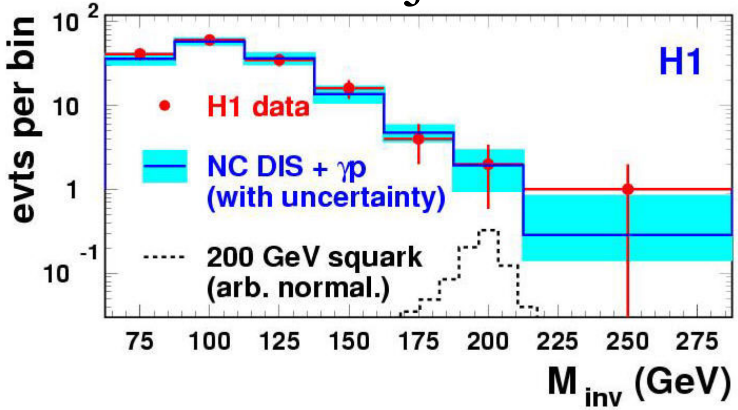
(⇒ LSP no more stable)

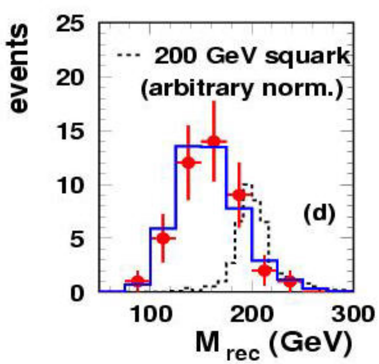
Cascade decays



SUSY at HERA (cont'd)

e + jets + X





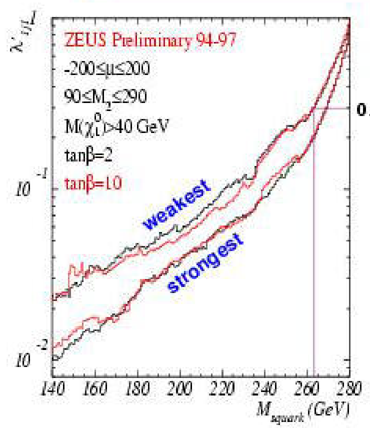
ν + jets + X

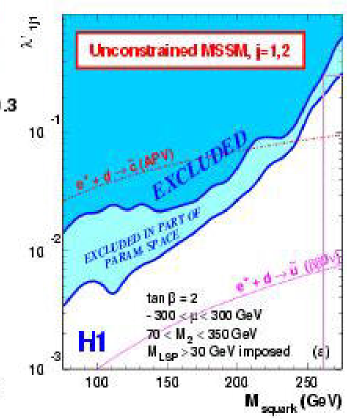
Exclusion limits in the phenomenological MSSM

Unconstrained (phenomenological) MSSM:

- gaugino masses depend on MSSM soft terms : $\tan\beta, \mu, M_2$
- BR and R_p–conserving couplings depend on : $\tan\beta, \mu, M_2$
- but: sfermion masses are free

⟹ **Scan in SUSY parameter space:**





- Limits are widely model independent
- masses $M_{\tilde{q}}$ up to 260 GeV excluded for $\lambda'_{1j1} = 0.3$
- HERA's sensitivity extends beyond the indirect limits from low energy experiments for $\tilde{c}, \tilde{t}$ (see e.g.: Dreiner, hep-ph/9707435)

Johannes Haller 8 DIS 2002

SUSY at HERA (cont'd)

Results in Constrained MSSM Models

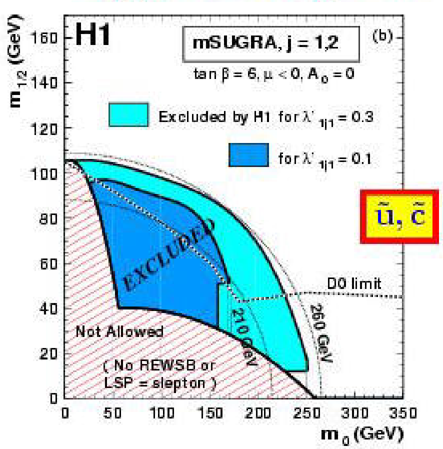
H1 gives limits in constrained models:

- common sfermion (gaugino) mass m_0 ($m_{1/2}$) at GUT scale
- masses at EW scale given by RGE
- Sfermion and gaugino sector are related

  $\Rightarrow$ completely determined by : $m_0, m_{1/2}, \mu, \tan\beta, A_0$
- minimal supergravity (mSUGRA):

  in addition: radiative EW symmetry breaking (REWSB)

  $\Rightarrow |\mu|$ is related to other parameters



- HERA sensitivity follows isomass curve
- HERA's constraints depend on λ'

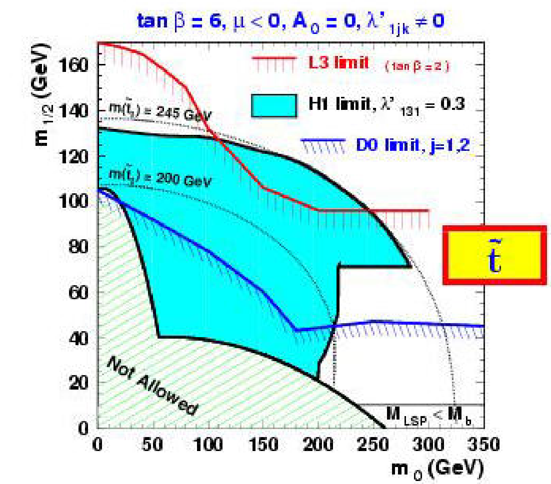
$\Rightarrow$ HERA and Tevatron complement each other

Results in Constrained MSSM Models (cont.)

Special interest in stop production:

- $\tilde{t}_1$ may be the lightest squark

$\Longrightarrow$ larger part of $(m_0, m_{1/2})$-plane covered by HERA (compared to λ'_{1j1} , $j \neq 3$)



- Masses $M_{\tilde{t}_1}$ up to 245 GeV can be ruled out for $\lambda'_{131} = 0.3$

$\Rightarrow$ HERA competitive to LEP at intermediate m_0 for λ'_{131}

Limits competitive with LEP and TeVatron

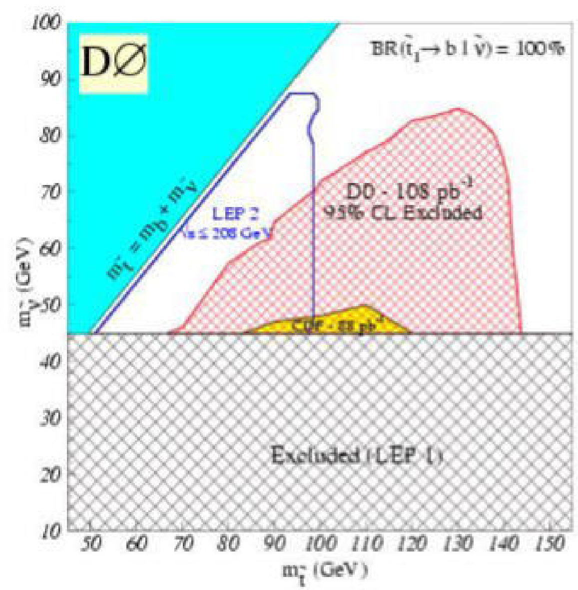
SUSY at the TeVatron

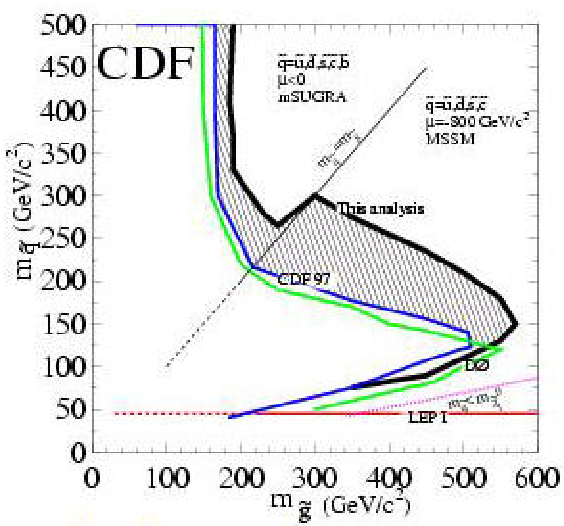
R. Stroehmer

- run I analysis are almost all finalized

- improved result on searches for gluinos and squarks

Stop pair production



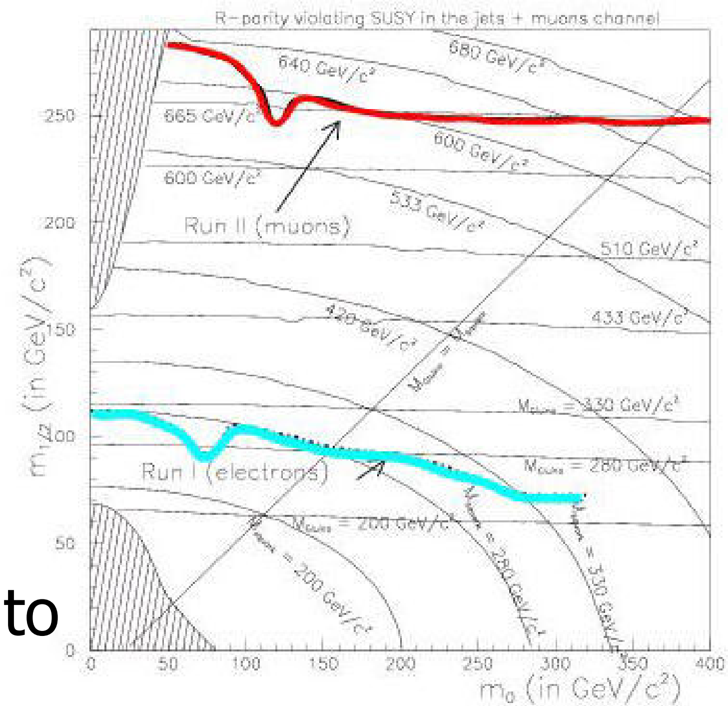


Multijets + MET

SUSY at the TeVatron

R. Stroehmer

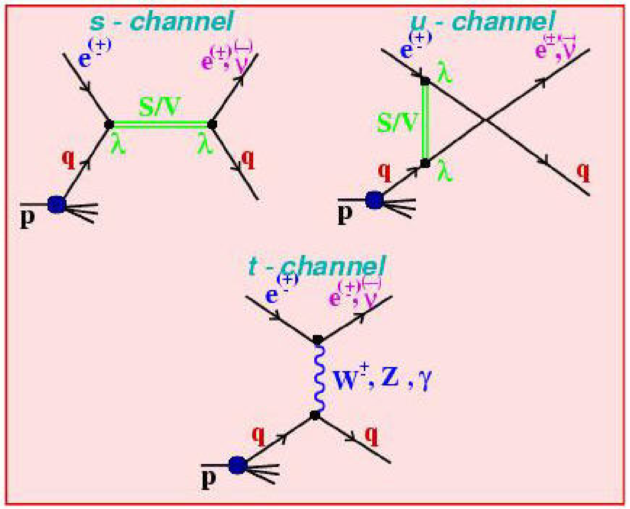
Many new results
for RPV SUSY



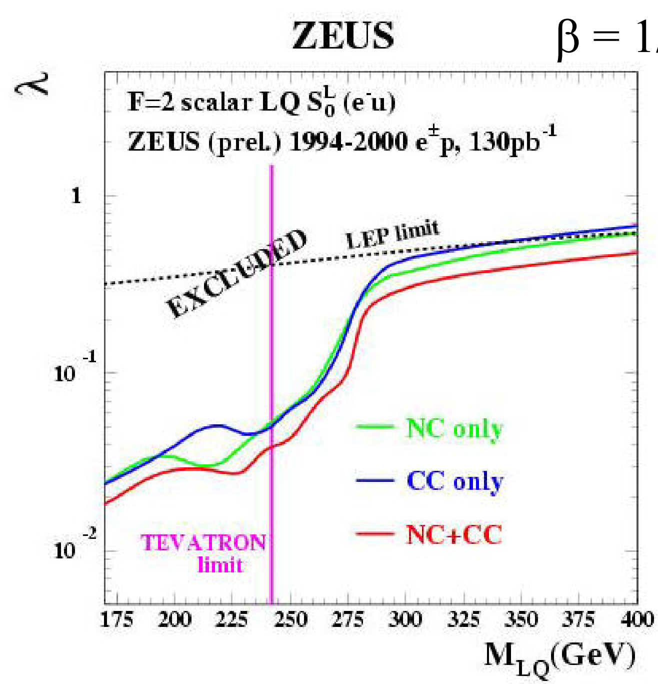
Searches for LSP decaying into
letpon + 2 jets

LeptoQuarks at HERA

J. Sztuk



BRW model
β = 1/2



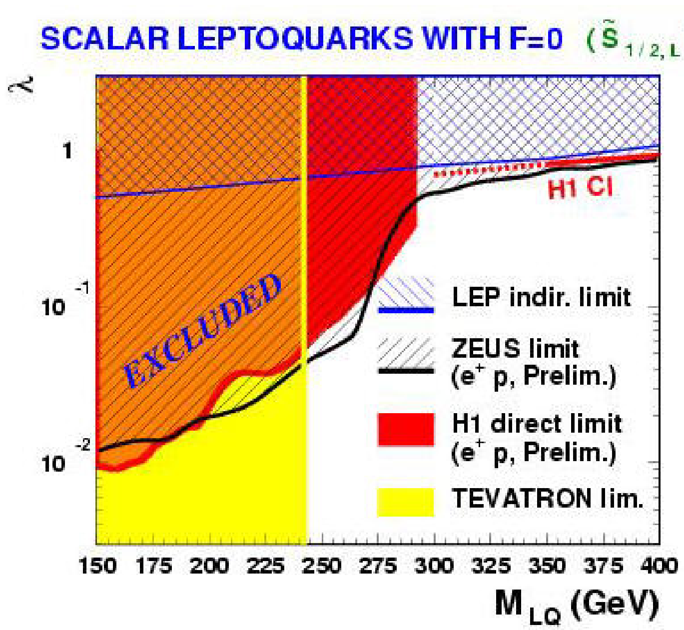
M ≤√s s-channel production
M >√s s and u-channel exchange + interference
(CI approximation)

Both NC and CC channels considered

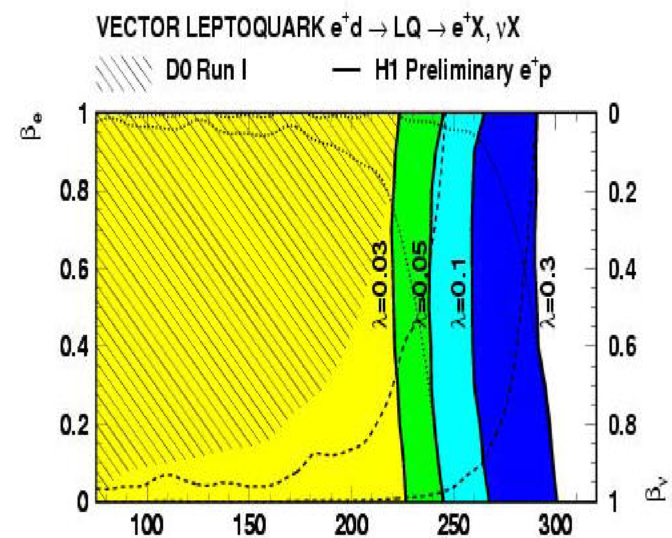
LeptoQuarks at HERA

J. Sztuk

BRW model



Generic model

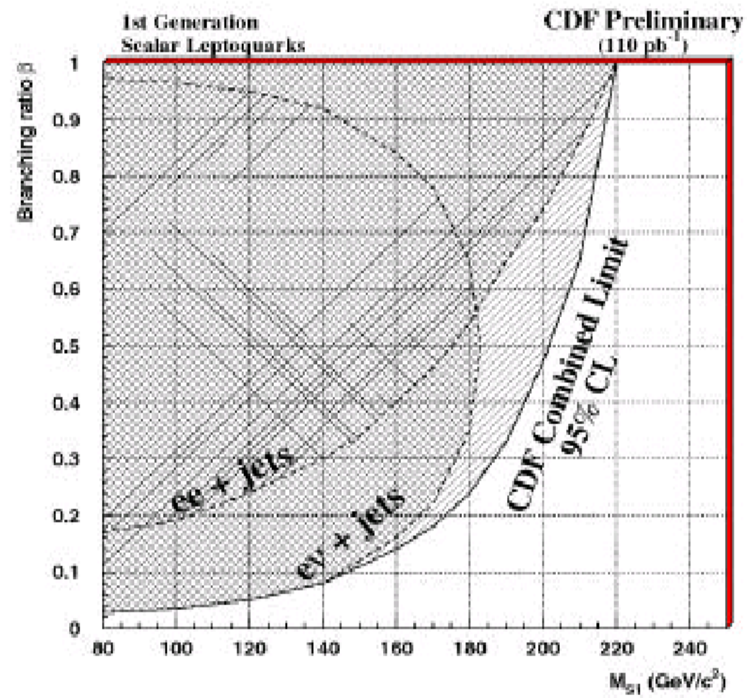


Tevatron Leptoquark Limits

S. Mattingly

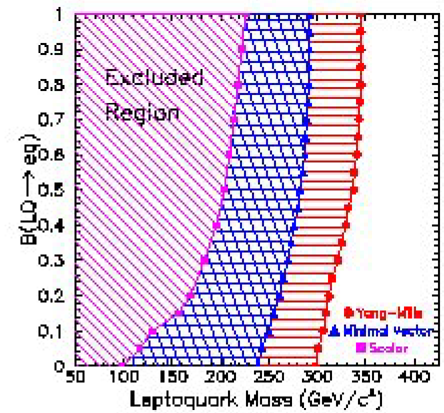
- Existing Tevatron LQ Searches
  - pp → gg → LQ LQ → l^+l^-qq, $l^\pm\nu qq$, $\nu\nu qq$
    - Limits depend on type of LQ (scalar/vector, generation), LQ-q-l couplings and β=BR(LQ → $l^\pm q$)
- 1st generation LQ mass limits

1st Gen.	β	Scalar (GeV/c)	Vector Minimal Coupling (GeV/c)	Vector Yang-Mills Coupling (GeV/c)
DZero	1	225(242)	292	345
	0.5	204	282	337
	0	98	238	298
CDF	1	220(242)	280	330
	0.5	202	265	310

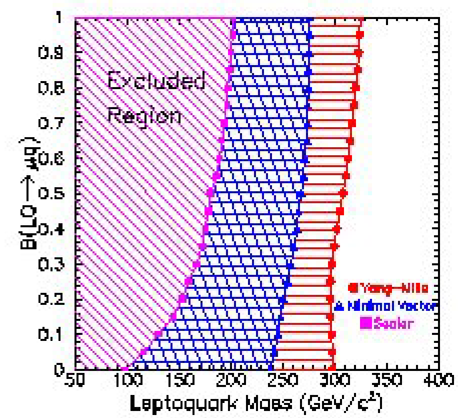


Tevatron Leptoquark Limits

2nd Gen	β	Scalar (GeV/c)	Vector Minimal Coupling (GeV/c)	Vector Yang-Mills Coupling (GeV/c)
DZero	1	200	275	325
	0.5	180	260	310
	0	98	238	298
CDF	1	202		
	0	123	171	222

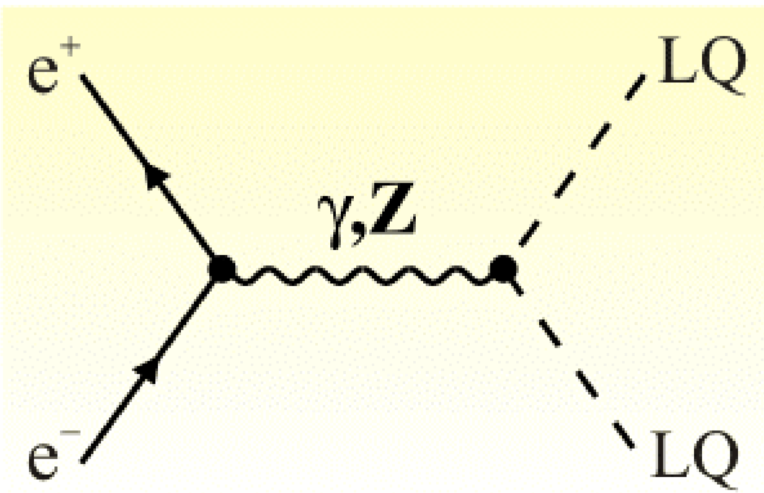


3rd Gen	β	Scalar (GeV/c)	Vector Minimal Coupling (GeV/c)	Vector Yang-Mills Coupling (GeV/c)
DZero	0.5			209
	0	98	238	298
CDF	1	99	170	225
	0	148	199	250



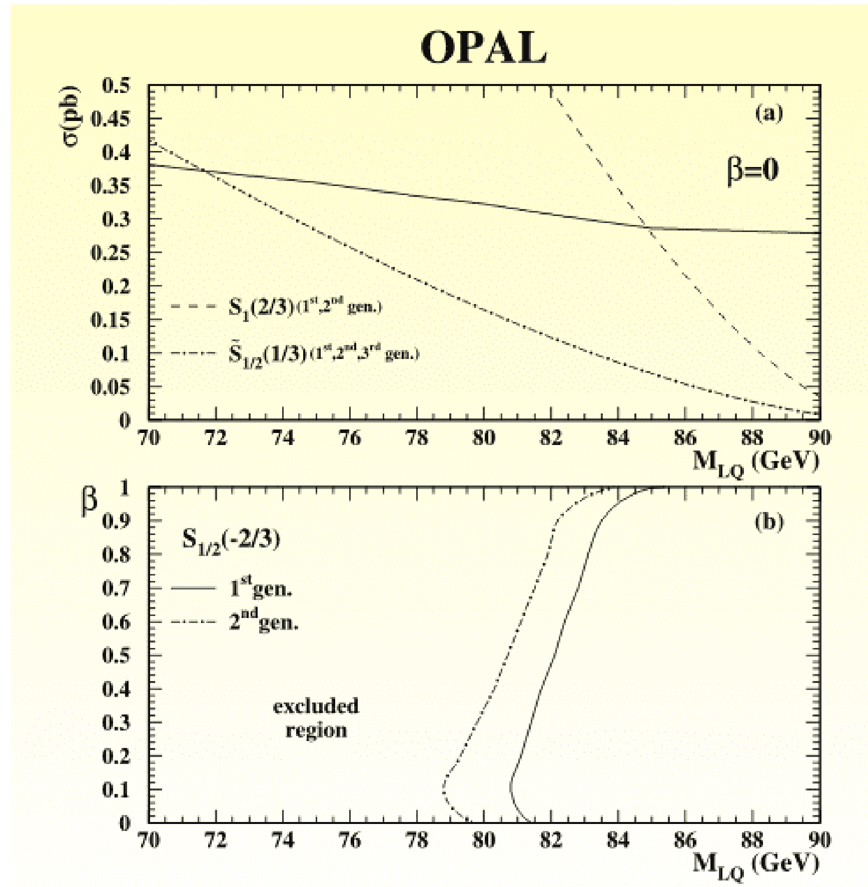
LEP LQ limits

Pair production $M \leq \sqrt{s}/2$

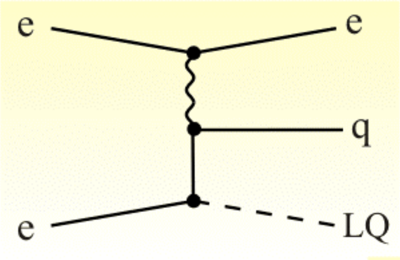


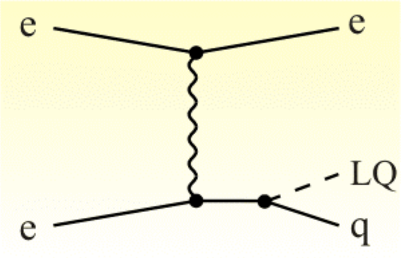
Decay mode :

- ♦ $LQ\ LQ \rightarrow llqq$
- ♦ $LQ\ LQ \rightarrow l\nu qq$
- ♦ $LQ\ LQ \rightarrow \nu\nu qq$

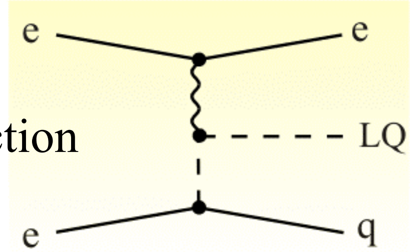


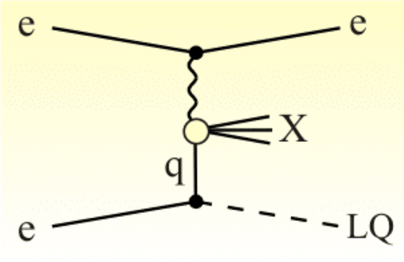
LEP LQ limits

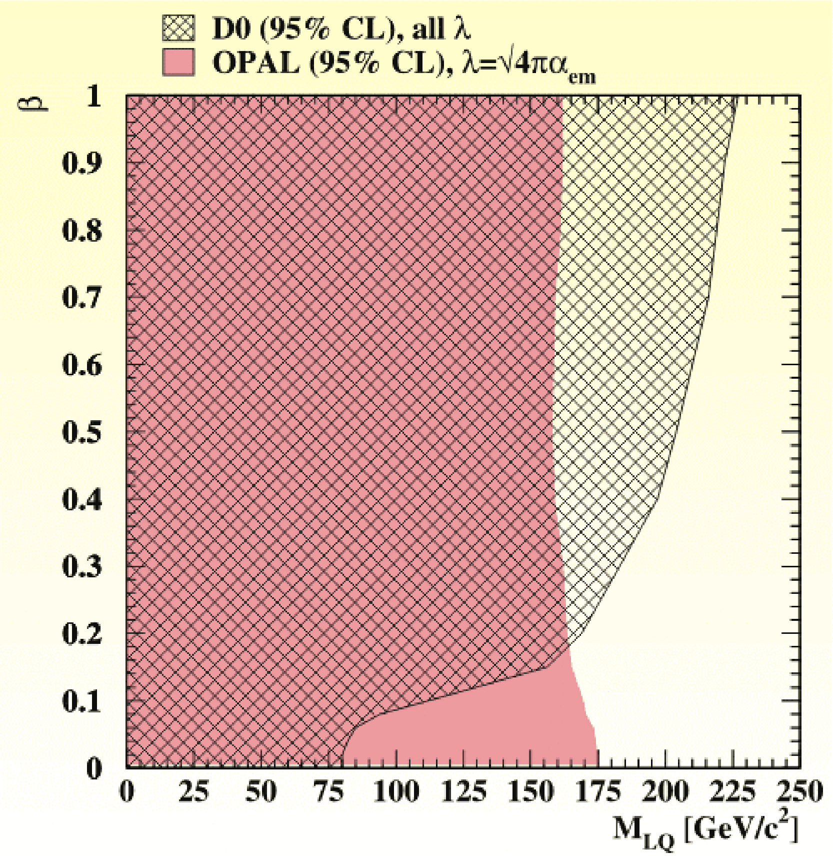




Single LQ production
M < √s



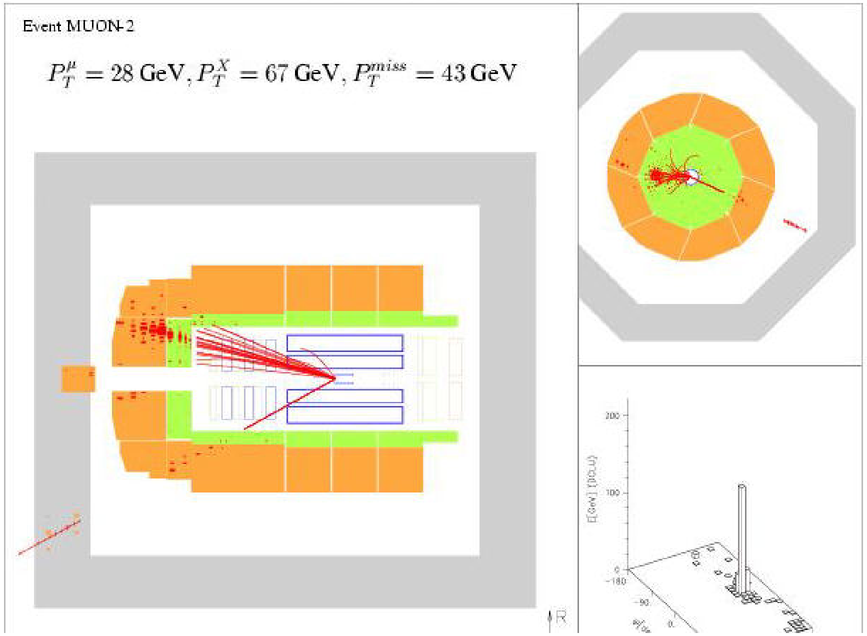


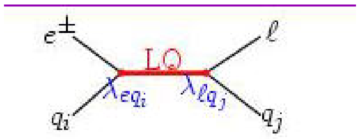


LFV at HERA

C. Genta

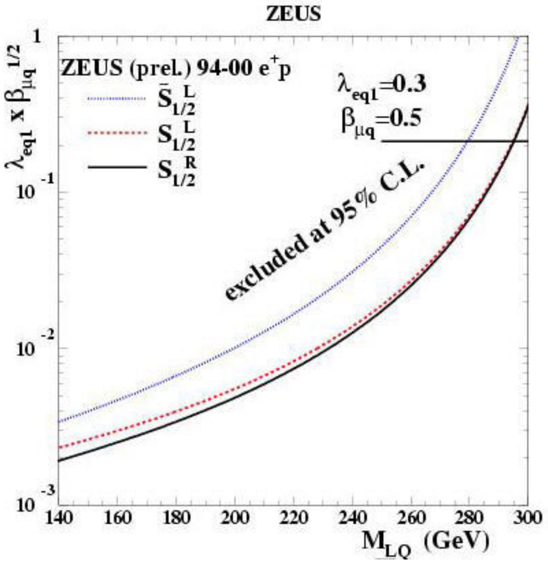
$e^+p \rightarrow \mu^+X$





No evidence found

limits on Youkawa coupling/mass for generation mixing LQ



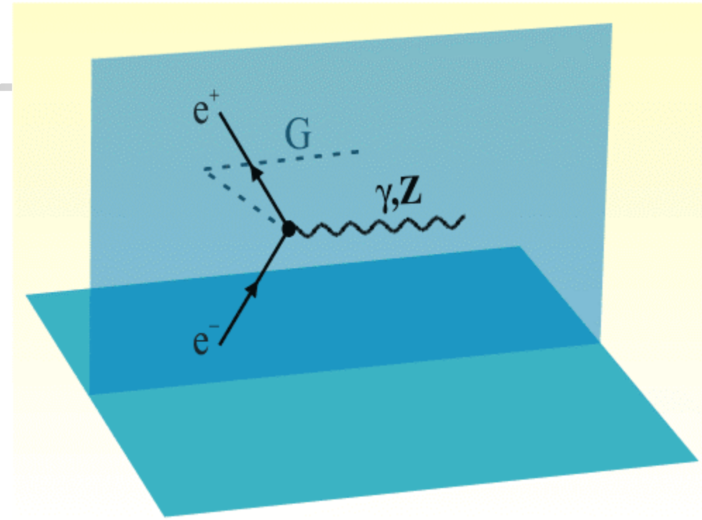
For λ =0.3 M > 280-300GeV

LED search at LEP

P.Deglon

$e^+e^- \rightarrow G\gamma$ cross-section goes as :

$$\sigma \approx \frac{\sqrt{s}^{\,n}}{M_D^{n+2}}$$



Signature :

- Single photon
- Missing energy

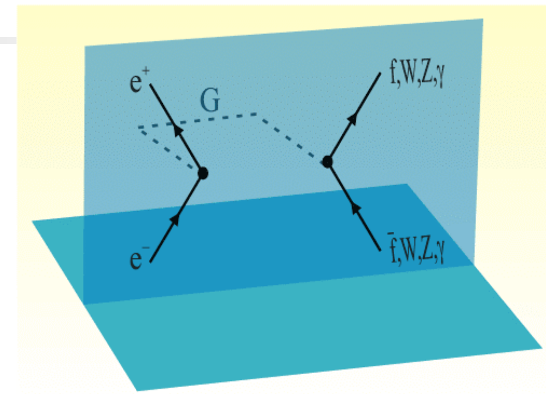
95% lower limits on M_D (TeV):

	Number of extra dimensions					
	2	3	4	5	6	7
Aleph (189-209 GeV)	**1.28**	0.97	0.78	0.66	0.57	—
Delphi (181-209 GeV)	**1.38**	—	0.84	—	0.58	—
L3 (189 GeV)	**1.02**	0.81	0.67	0.58	0.51	0.45
Opal (189 GeV)	**1.09**	0.86	0.71	0.61	0.53	0.47

[hep-ex/0201029]

LED search @LEP

P.Deglon



Aleph + Delphi + L3 + Opal
130 GeV – 209 GeV

M_S (TeV)

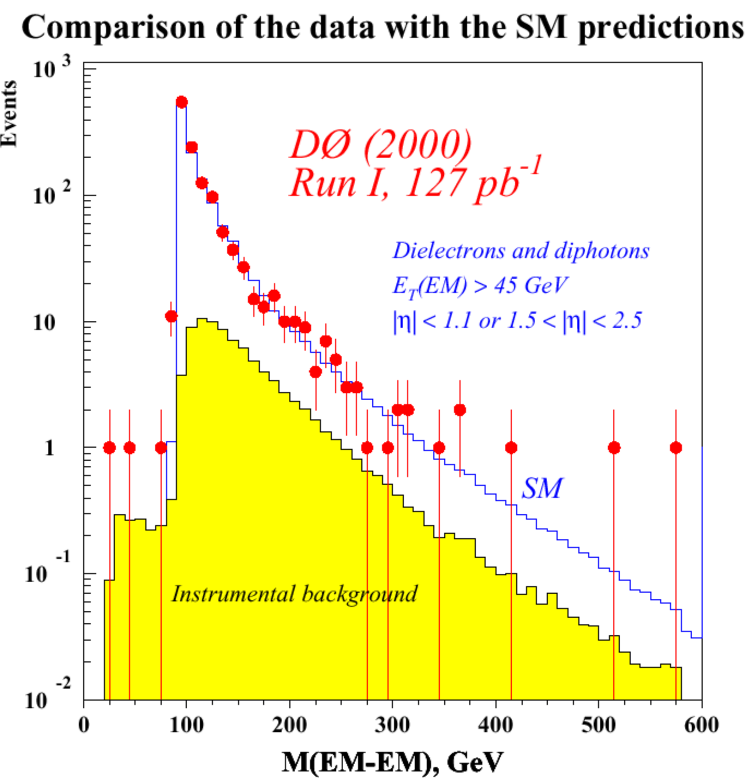
95% CL lower limit :	λ = −1	λ = +1
$e^+e^- \rightarrow e^+e^-$	1.28	1.13
$e^+e^- \rightarrow \gamma\gamma$	1.14	0.95
Combined	**1.39**	**1.13**

[hep-ex/0103039]

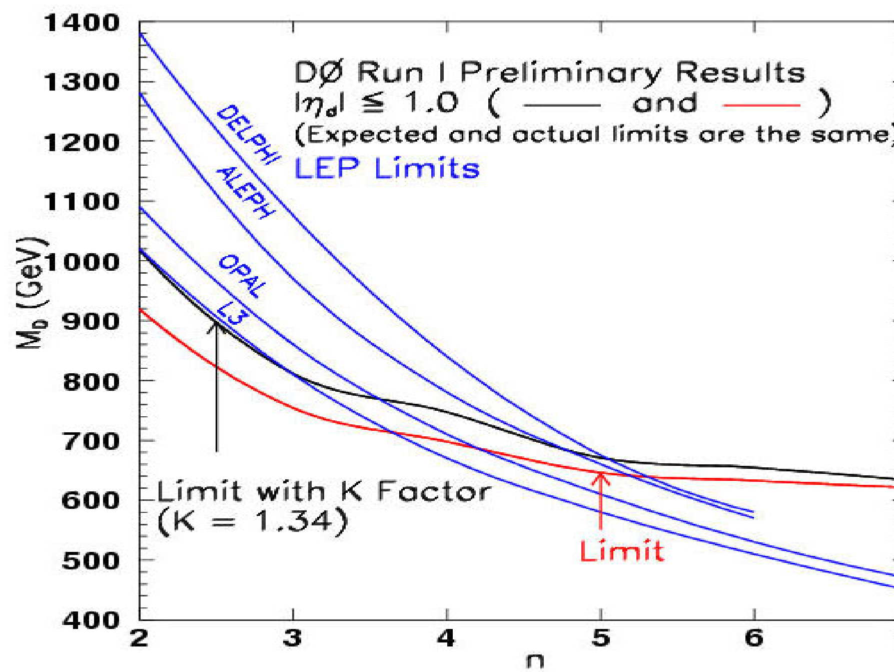
LED @ TeVatron

S.Mattingly

Searches for virtual graviton exchange



pp→eeX,γγX



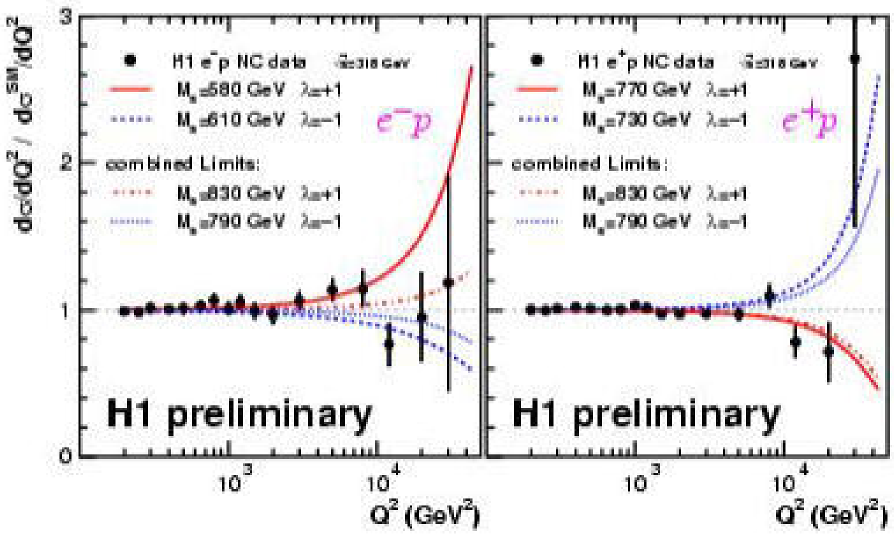
Direct graviton production

pp→gG

LED searches at HERA

S. Schmitt

Limits on large extra dimensions



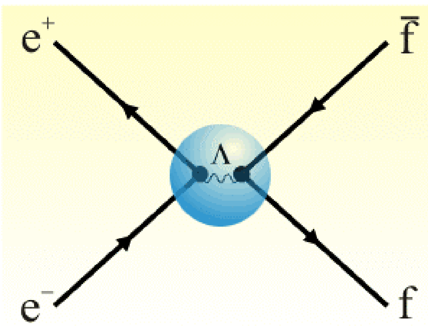
H1 limits on M_S
$\lambda = +1$: 0.83 TeV
$\lambda = -1$: 0.79 TeV

ZEUS limits on M_S
$\lambda = +1$: 0.81 TeV
$\lambda = -1$: 0.82 TeV

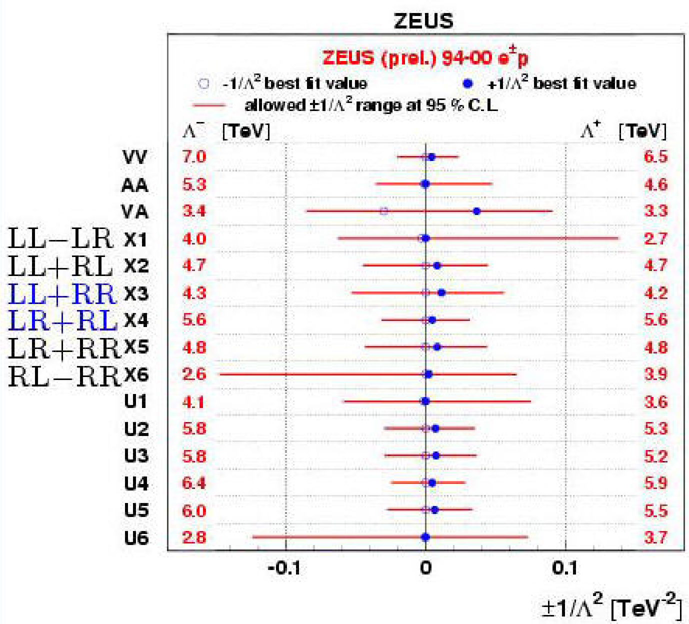
$\lambda = +1$: 1.13 TeV $\lambda = -1$: 1.39 TeV LEP

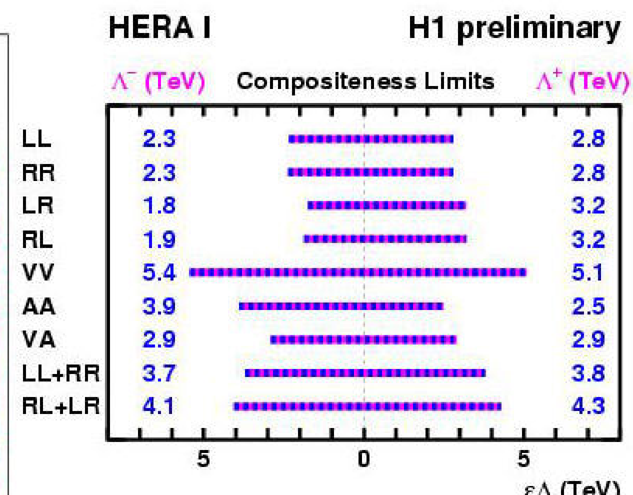
$\lambda = +1$: 1.1 TeV $\lambda = -1$: 1.0 TeV TeVatron, D0

Contac Interactions



Limits on Compositeness models from HERA





LL, LR, RL, RR: stringent limits from atomic $\not{P}$

U1–U6: assume only u quark couples

Limits of order 2 – 7 TeV, depending on the model

Contact interactions @ HERA

Summary and conclusions

- HERA is sensitive to physics far beyond its center-of-mass energy, probing the structure of the eu and ed systems
- Explore light quarks $\leftrightarrow$ complementary to LEP
- Limits on the contact interaction scale Λ up to 7 TeV
- Limits on leptoquark masses (coupling $\lambda = 1$) up to 1.4 TeV
- Limits on Squarks in $R\!\!\!/_p$ SUSY (coupling $\lambda = 1$) up to 0.75 TeV
- Probe quark radius down to $0.7 \cdot 10^{-3}$ fm
- Rule out large extra dimensions up to scales $M_S \lesssim 0.8$ TeV

HERA II has just started:

- Collect factor of 10 more data
- Use polarized $e^{\pm}$ to disentangle left and right-handed couplings

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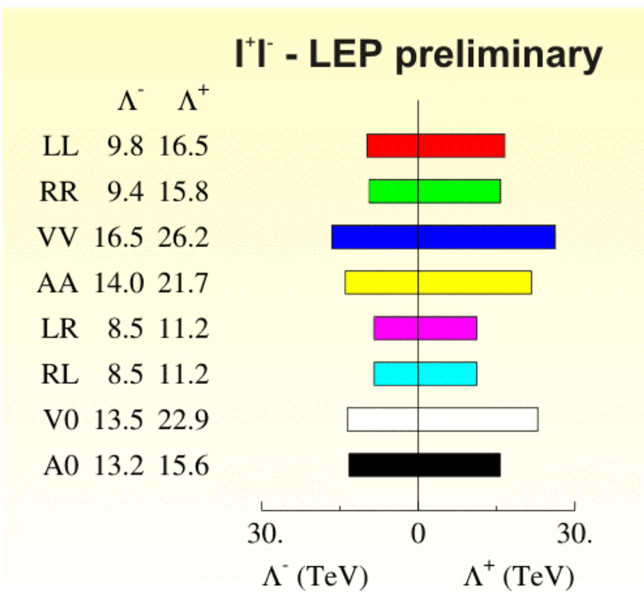
P.Deglon

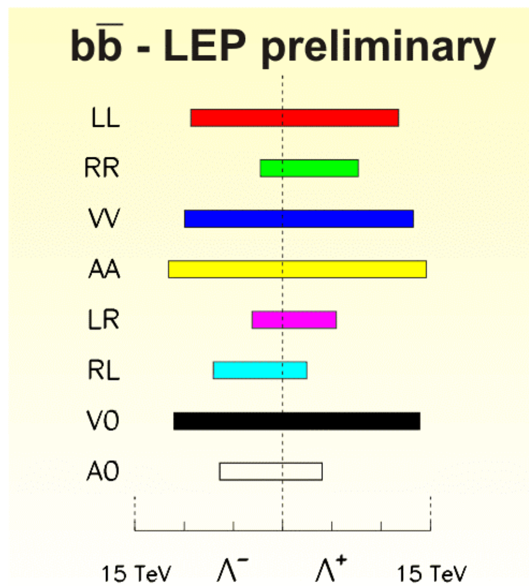
Contact Interaction Limits @LEP

Aleph + Delphi + L3 + Opal 130 GeV - 209 GeV

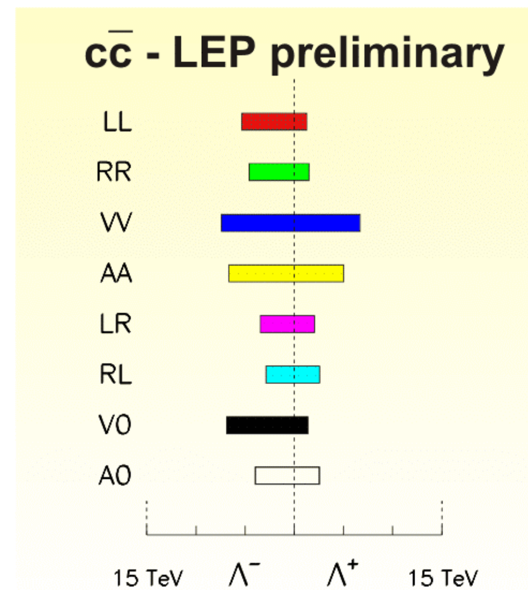
$e^+e^- \to \mu^+\mu^-$ or $\tau^+\tau^-$



$e^+e^- \to b\bar{b}$



$e^+e^- \to c\bar{c}$

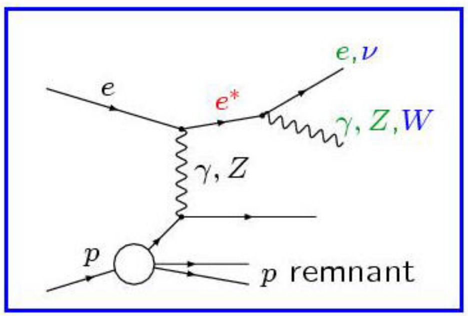


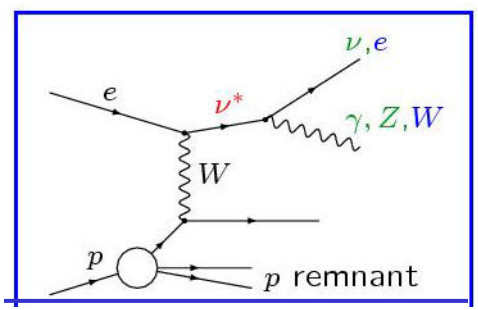
for μ,τ : **$\Lambda > 8.5$ TeV … 26.2 TeV**

[LEP2FF/01-01]

Beyond the SM (cont'd)

- Excited fermions at HERA A. Weber





NC-like final state:
high-energy electron

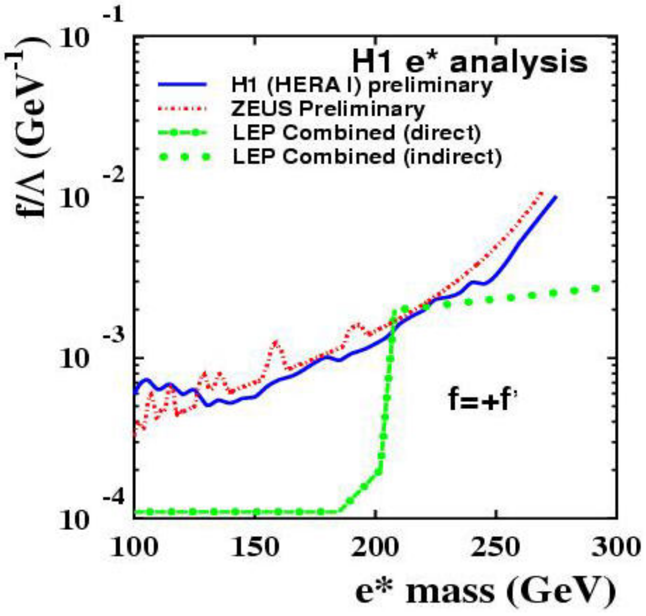
- $\nu^* \longrightarrow eW \longrightarrow eq\bar{q}'$
- $e^* \longrightarrow eZ \longrightarrow eq\bar{q}$
- $e^* \longrightarrow e\gamma$

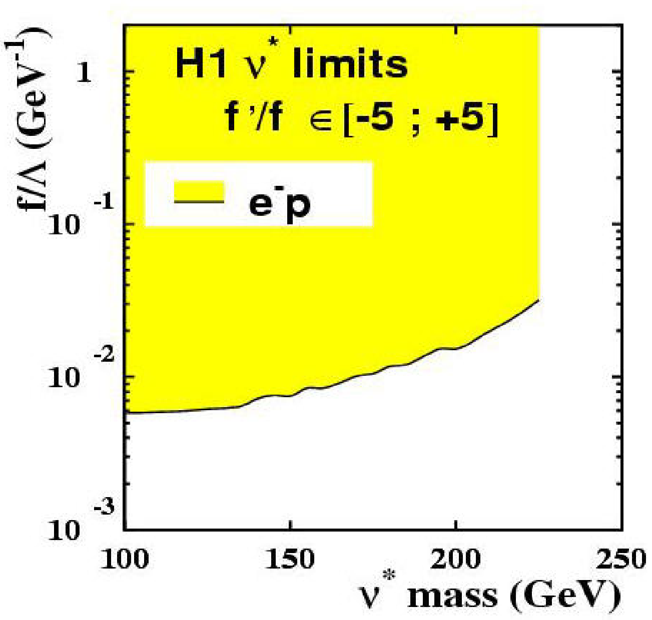
CC-like final state:
final-state $\nu \Rightarrow \not{P}_T$

- $\nu^* \longrightarrow \nu Z \longrightarrow \nu q\bar{q}$
- $e^* \longrightarrow \nu W \longrightarrow \nu q\bar{q}'$
- $\nu^* \longrightarrow \nu\gamma$

Excited Fermions at HERA

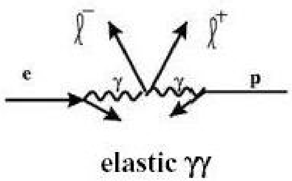
No evidence for any excited fermions



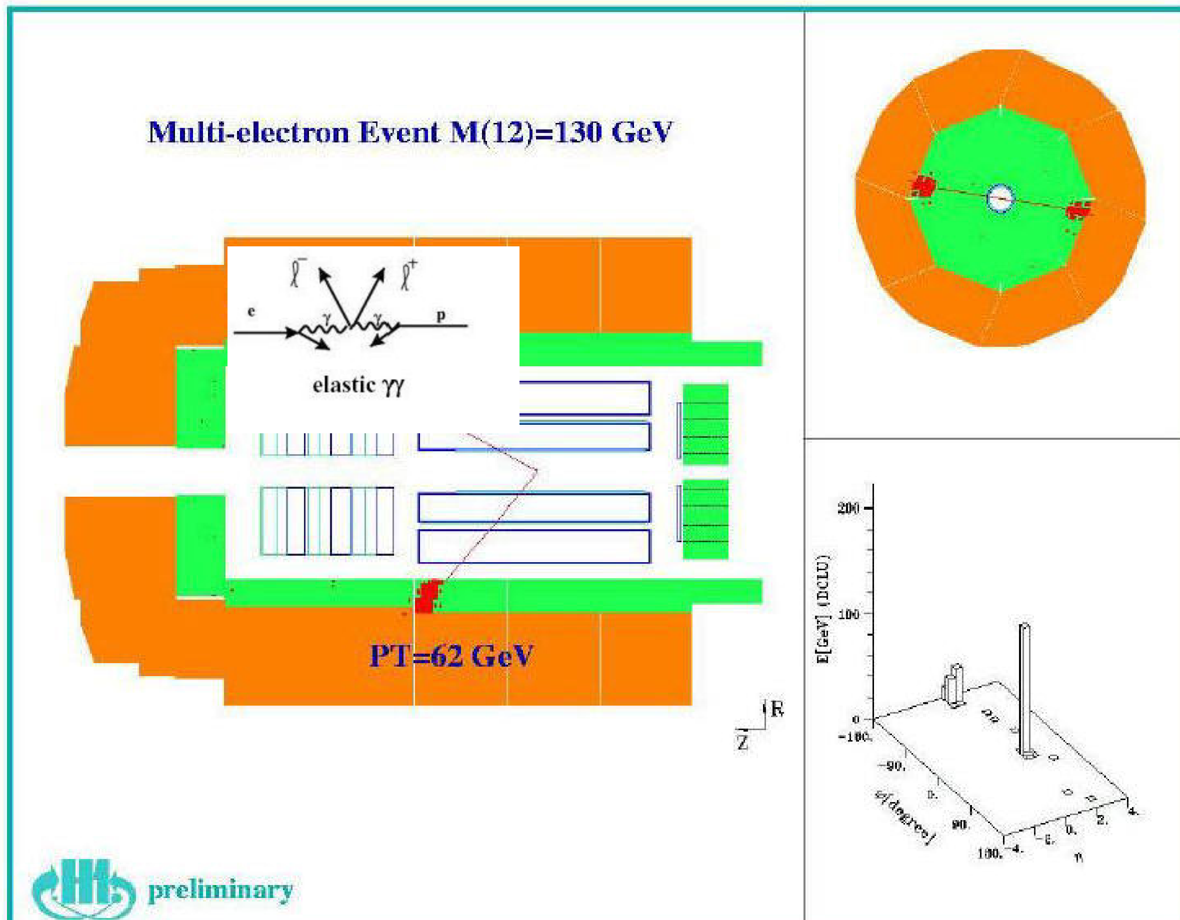


Multileptons final states at HERA

C. Vallee



Elastic γγ
Inelastic γγ
ee (resolved γ from p)
DY (resolved γ from e)

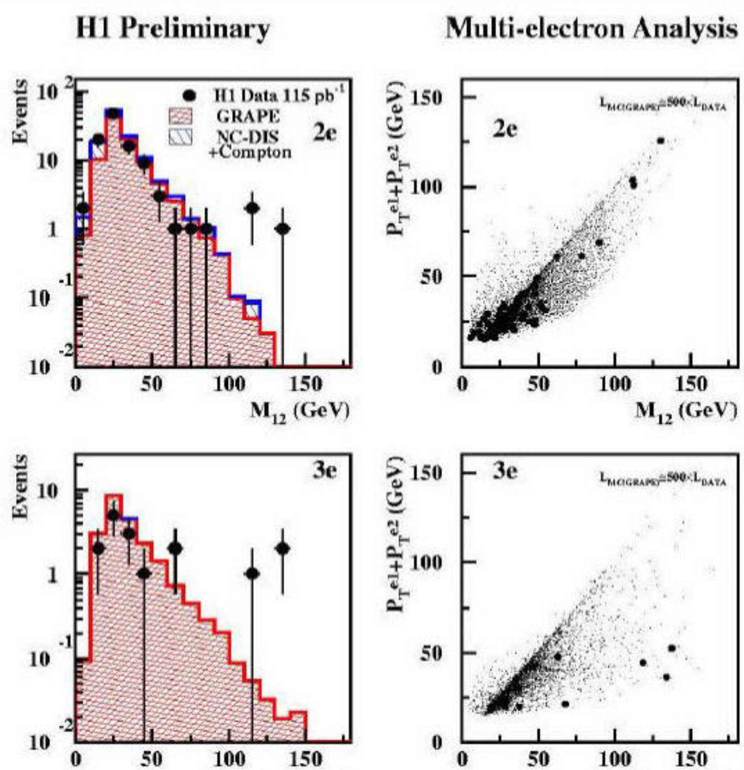


Multileptons final states at HERA

MASS OF THE 2 HIGHEST-P_T ELECTRON PAIR

2e →

3e →



← the 3 high-mass pairs have also high P_T

the 3 high-mass pairs have a bwd-fwd topology ←

Multileptons final states at HERA

- Multileptons final states at HERA
  - C. Vallee

SUMMARY

multi-electron production has been measured in e-p collisions for electron P_T's up to ~50 GeV and electron pair masses up to ~100 GeV

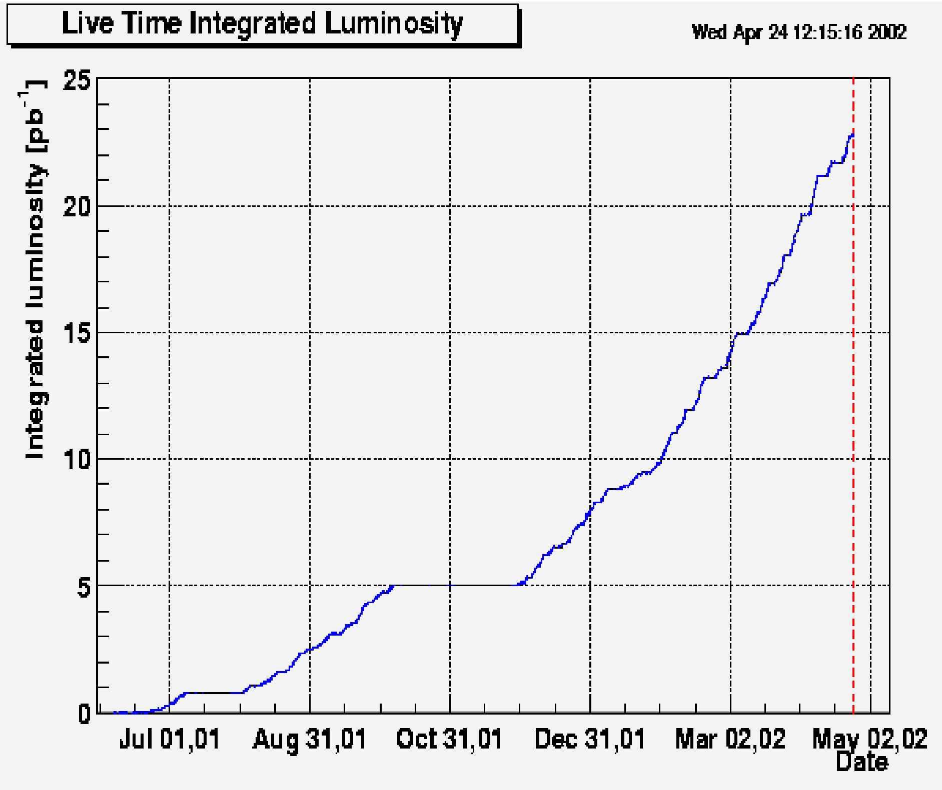
good overall agreement is found with the Standard Model

6 events are seen with electron pair masses above 100 GeV

	data	SM
visible 2e $M_{12} > 100$ GeV :	3	0.25 ± 0.05
" 3e " :	3	0.23 ± 0.04

LOOKING FORWARD TO HIGHER LUMINOSITY AND FURTHER INVESTIGATION OF THE EXCESS

TeVatron Run II status



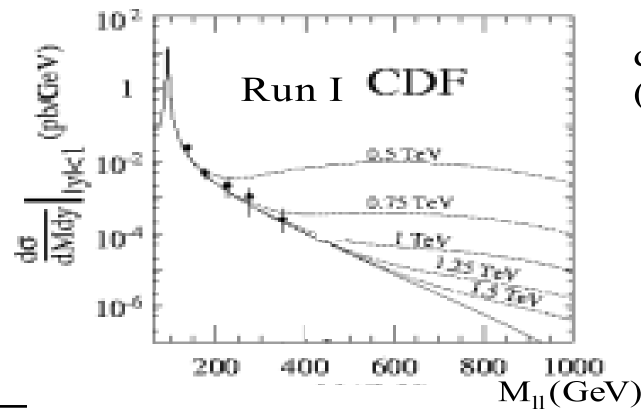
- Tevatron is planning to deliver 80pb^{-1} by the end of September (200 pb^{-1} by the end of 2002), but up to now ~40 pb^{-1} delivered.

M.Wolter

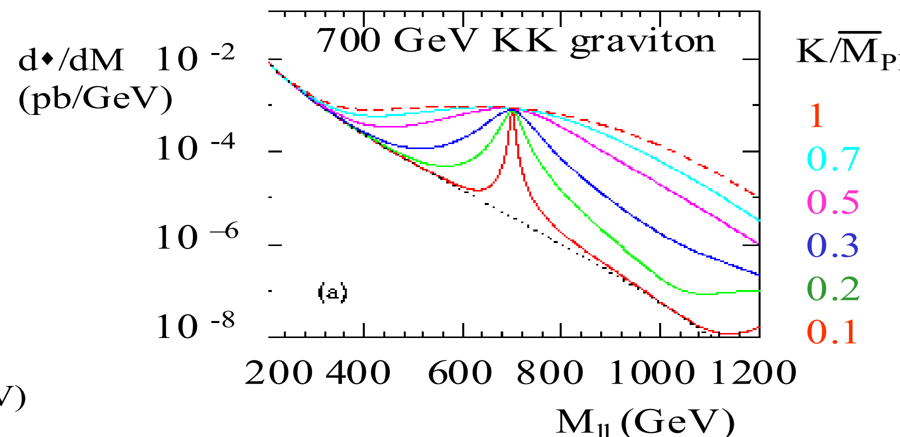
LED at TeVatron II

T.Pratt

ADD model and RS model limits



——
- - - - Quantum Gravity Model for M_s values
● CDF results for dimuon samples



Effective Planck Scale lower limit (95% C.L.)
0.9-1.5 TeV Run I
1.3-2.5 TeV Run IIa, 1.7-3.5 TeV LHC
Range corresponds to number of extra dimensions n=7-2. (hep-ph/9904234, hep-ph/9909218)

Compactification scales R^{-1} (TeV)
≙ 0.9 Run 1 at 95% C.L.,
1.2 Run II, 6.7 LHC
(hep-ph/9905311)

Tracey Pratt DIS 2002, Poland April 02

HERA upgrade

A.Metha

Integrated luminosity will be ~1000 pb^{-1}

Luminosity will be shared equally between $e^{+}p$ and $e^{-}p$ and L and R polarizations
Some data taken at lower CMS energy for F_l and high x measurements

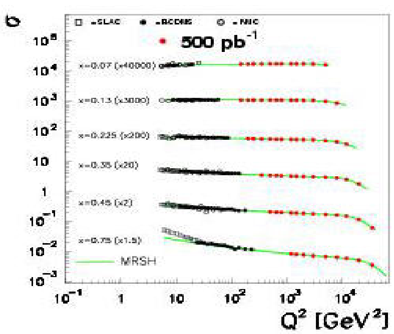
High P_T Physics at HERA 2

- $e^{+}p$ NC + CC Cross sections
- $e^{-}p$ NC + CC Cross sections
- Longitudinally Polarised $e^{\pm}$ measurements
- W production
- Z^{0} and $l^{+}l^{-}$ production
- High P_T jet production
- CC with γ
- CC with dijets
- Heavy Flavour at high Q^2

HERA upgrade

e^+p NC Cross sections

$> 500\ \mathrm{pb}^{-1}$ needed to make significant improvements



- $2 - 10\%$ u quark precision up to $x = 0.65$
- 10% error for cross section $Q^2 = 20\,000\ \mathrm{GeV}^2$
- 5σ discovery for deviations DATA/SM> 1.5

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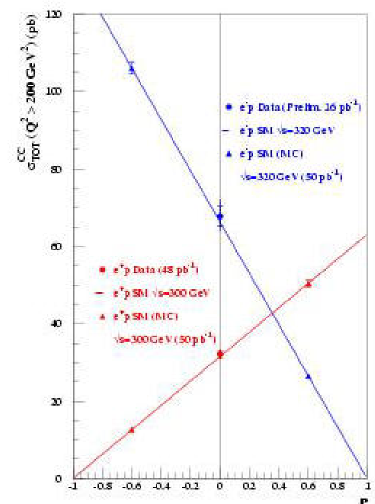
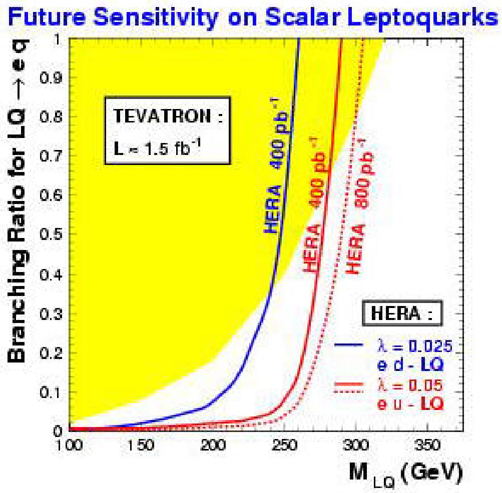
Polarised $e^{\pm}p$ CC Cross sections



- Look for right handed charge currents
- Any deviation from straight line $\Rightarrow$ New Physics! (no QCD or EW fits/parameters needed)
- Measurement can already be made with modest luminosity

HERA upgrade

Leptoquarks



- HERA will continue to have best limits, especially at low branching ratios

Searches at HERA2– Summary

model	beam charge	best polarization: left	best polarization: right
right handed currents (CC)	e^-	-	$e^-_R \to \nu_R$ (W_R)
SUSY R_P Violating	e^+		$e^+_R \to \bar{u}_L, \bar{c}_L, \bar{t}_L$
	e^-	$e^-_L \to \bar{d}_R, \bar{s}_R, \bar{b}_R$	
anomalous top	$e^\pm$	$t_{L,R}$	
$F = 0$ Leptoquarks	e^+	$S_{1/2}, V_0$: $e^+_L \to \overline{V^R_0}$	$e^+_R \to \overline{V^L_1}$, $e^+_R \to \overline{S^L_{1/2}}$
$F = 2$ Leptoquarks	e^-	$S_0, V_{1/2}$: $e^-_L \to S^L_1$, $e^-_L \to \bar{V}^L_{1/2}$	$e^-_R \to \bar{S}^R_0$
Contact Interaction	$e^\pm$	various	
Quark Radius	$e^\pm$	any	
Large Extra Dimens.	$e^\pm$	any	
Excited Fermions	$e^\pm$	$e^-_L \to f^*_R$	$e^+_R \to f^*_L$
Excited Neutrinos	e^-	$e^-_L \to \nu^*_R$	

- e^+p or e^-p L or R ? ⇒ We need it all!

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Polarization at HERA

E. Gianfelice

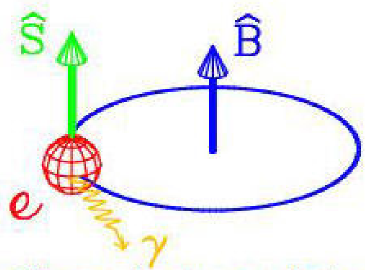
Polarisation in electron rings

1/2 spin particle in a homogeneous magnetic field

$\rightarrow$ 2 stable states:

$\vec{S} \uparrow\uparrow \vec{B}$

$\vec{S} \downarrow\uparrow \vec{B}$



Sokolov-Ternov (1964): spin-flip synchrotron radiation.

- Equilibrium polarisation:

$$P_{ST} = \frac{W_{\uparrow\downarrow} - W_{\downarrow\uparrow}}{W_{\uparrow\downarrow} + W_{\downarrow\uparrow}} = 92.4\%$$

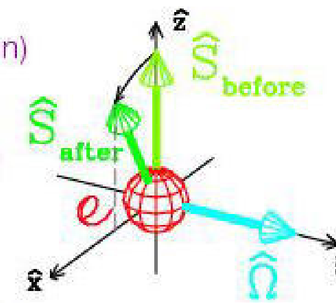
Spin kinematics

Polarisation (*if any*) builds up in the vertical direction, but polarisation along the particle motion direction is of interest for physics. Thomas-BMT equation (1959):

$$\frac{d\vec{S}}{dt} = \vec{\Omega} \times \vec{S} \quad \text{(precession)}$$

spin tune $\equiv$

# of precessions / turn $\simeq a \times \gamma$



where (MKS)

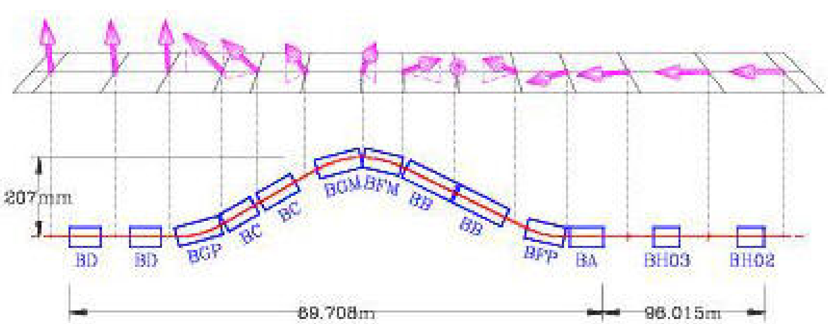
$$\vec{\Omega} = -\frac{e}{m_0}\left[\left(a + \frac{1}{\gamma}\right)\vec{B} - \frac{a\gamma}{\gamma+1}\vec{\beta}\cdot\vec{B}\vec{\beta} - \left(a + \frac{1}{\gamma+1}\right)\vec{\beta}\times\vec{E}\right]$$

$a \equiv (g-2)/2 \simeq 0.00116.$

Polarization at HERA

Polarisation at HERA

$e^{\pm}$ beam longitudinal polarisation has been an integral part of the HERA design. The spins are rotated into the longitudinal direction by an interleaved sequence of vertical and horizontal bends (Buon-Steffen, 1985).



- HERA proved the possibility of getting longitudinal polarisation in a high energy electron ring.
- High longitudinal beam polarisation was routinely delivered to HERMES

Polarization measurements

J.Boehme

Charged currents

Charged current cross–section depends linearly polarisation:

- electrons: $\sigma_{CC}(P) = (1-P)\,\sigma_{CC}(0)$
- positrons: $\sigma_{CC}(P) = (1+P)\,\sigma_{CC}(0)$

=> precise knowledge of polarisation as important as of luminosity!
In order to...

- test SM cross–section,
- extrapolate to $P = \pm 1$
- search for right–handed charged currents

... we need $\delta P/P < 1\%$, otherwise dominant syst. error at high Q^2!

Neutral currents

x–section polarisation dependent due to Z^0 exchange and $Z^0-\gamma-$interference

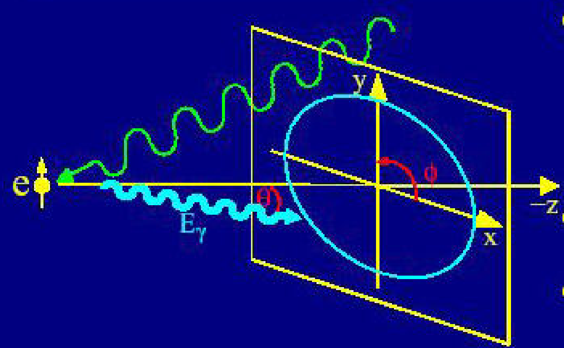
=>vector & axialvector couplings of Z^0 to u and d quarks:

- ~250 pb^{-1} for each lepton charge & polarisation sign
- a_u, a_d also with P=0
- $P \geq 0.5$ allows precise extraction of v_u, v_d

...highly sensitive to systematic polarisation deviations!

Polarization measurements (cont'd)

Compton Scattering



- Kinematics described by 2 variables:
  - polar angle θ <=> E_γ (photon energy)
  - azimutal angle ϕ => y (vert. coordinate)
- S1, S3: lin. & circ. laser polarisation
- P_Y, P_Z: transv. & long. e polarisation

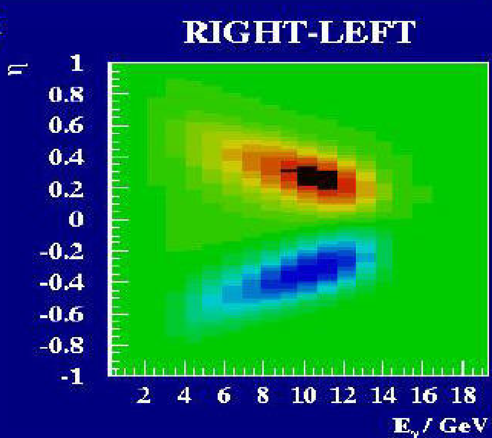
$$\frac{d^2\sigma}{dE\,d\phi} = \Sigma_0(E) + S_1\,\Sigma_1(E)\cos 2\phi + S_3\left(P_Y \Sigma_{2Y}(E)\sin\phi + P_Z \Sigma_{2Z}(E)\right)$$

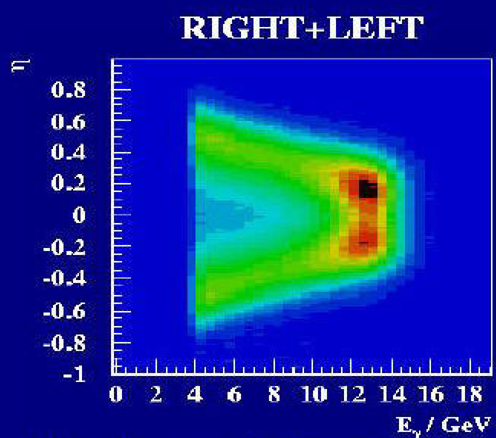
- LPOL: needs only energy dependence
- TPOL: needs energy and y, i.e. full 2D cross section

Polarization measurements (cont'd)

TPOL: Analysis Upgrade

- Idea: fit double differential x–section => no assumptions about:
  - linear laser polarisation
  - η–y–transformation
  - calibration, alignment, resolution ...



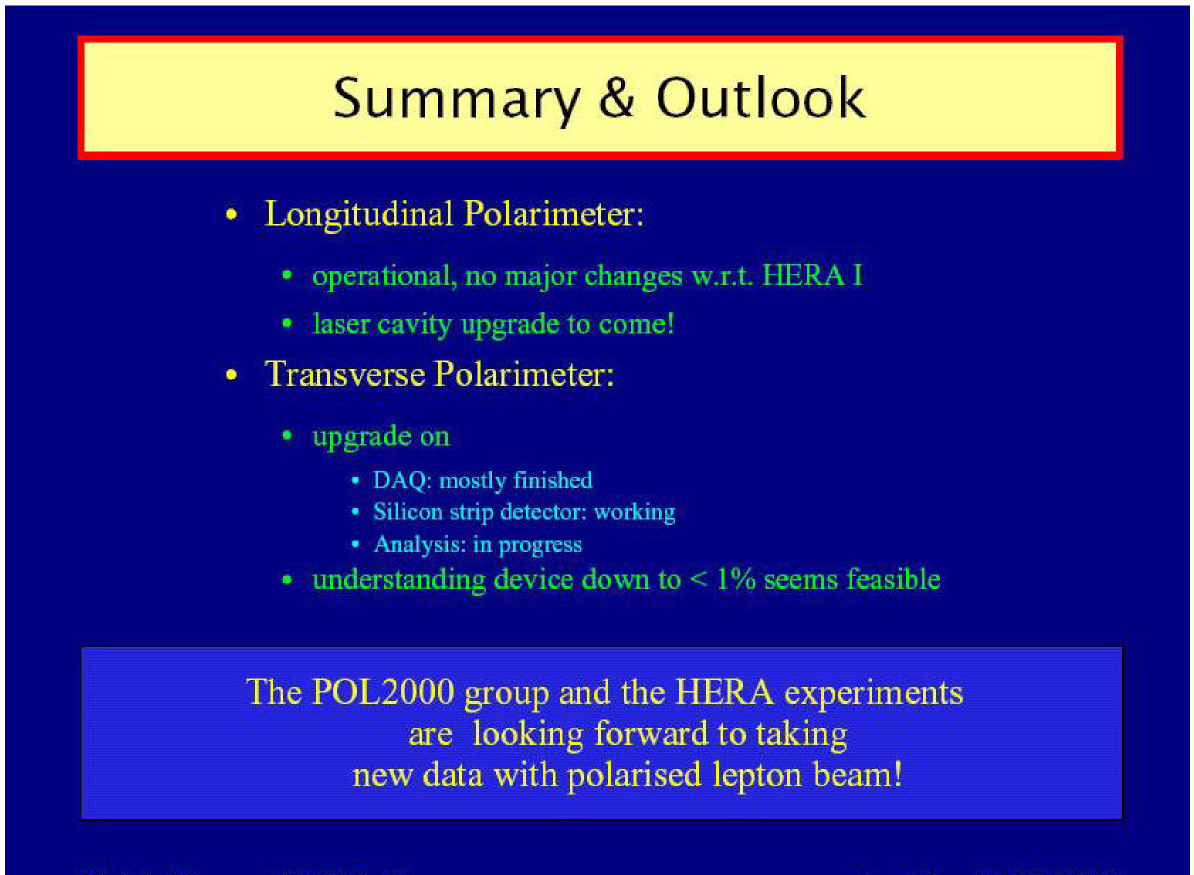


- First step : fit sum of spectra for laser both helicities => calibration
- Second step: fit difference => polarisation
- analysis not final yet
- no final systematic error yet

Polarisation Measurement @ HERA II – 12

Jenny Böhme, DIS 2002, 05/02/02

Polarization measurements (cont'd)



The future: LHC status

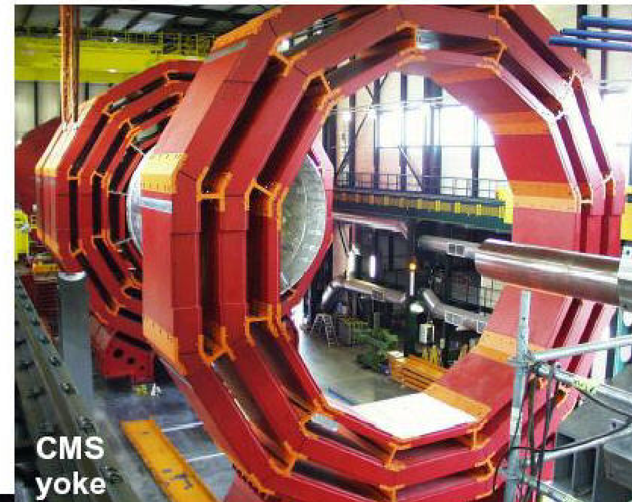
G. Wrochna

LHC Status

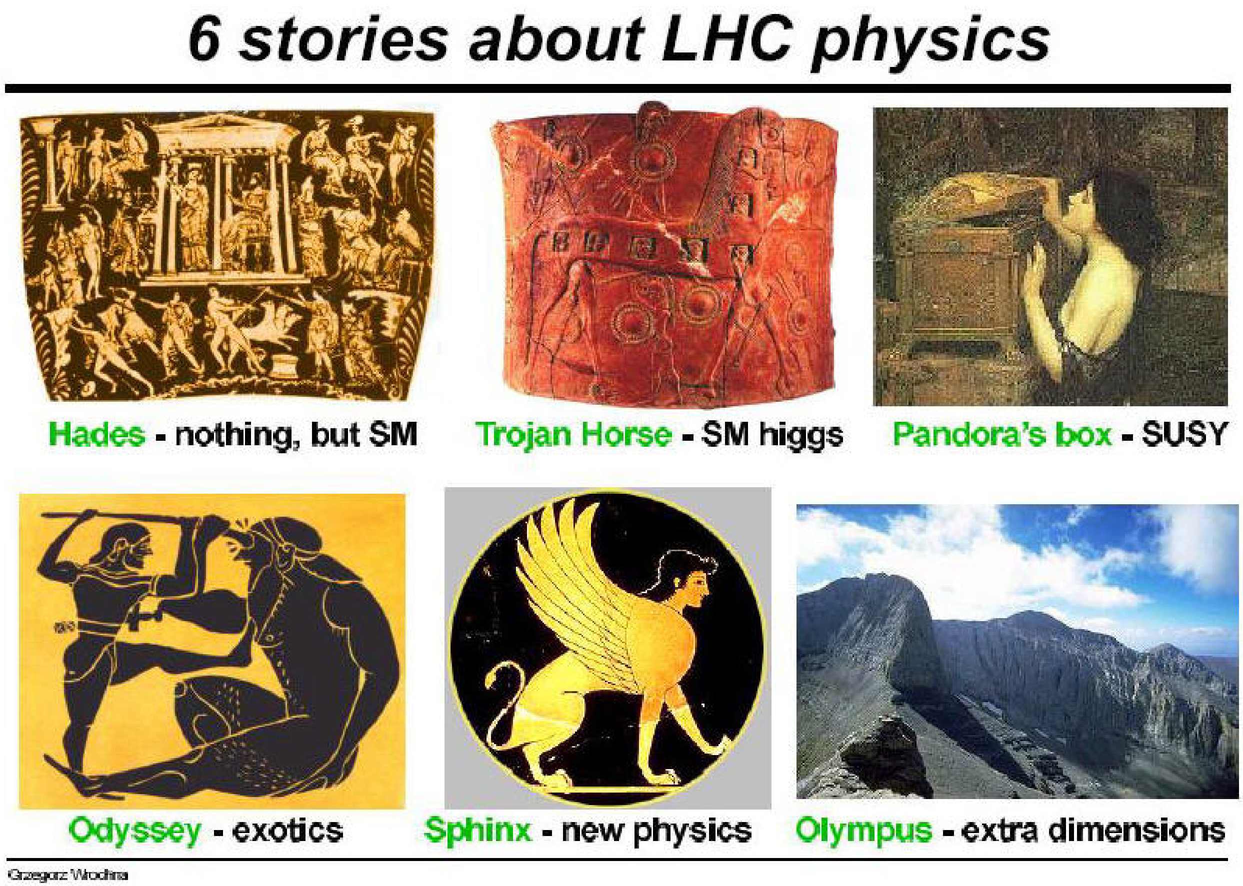
- LHC magnets in production
- Exp. caverns well advanced
- Detector pre-assembly on surface going on
- Detector elements in mass production
- First detector elements (some muon chambers, calorimeter modules) delivered to CERN

LHC schedule

- First beam circulating **April 2007**
- First pp collisions **June 2007**



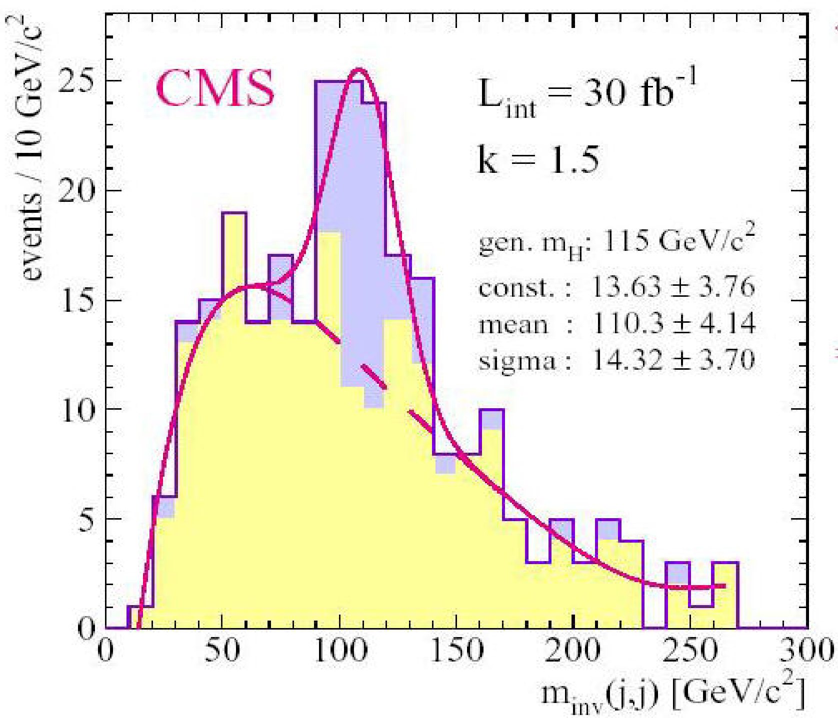
The LHC mythology



Higgs at LHC

$$t\bar{t}H^0_{SM} \rightarrow l^{\pm}\nu q\bar{q}b\bar{b}b\bar{b}$$

$$m_{H^0} = 115\ GeV/c^2$$



◇ $90 < m < 130\ GeV/c^2$:

N_{H115}	=	38
$N_{t\bar{t}Z^0}$	=	3
$N_{t\bar{t}b\bar{b}}$	=	23
$N_{t\bar{t}jj}$	=	26
N_{BG}	=	52

$\Rightarrow$ results (stat.):

$S/B = 73\%$

$S/\sqrt{B} = 5.3$

$\Delta y_t / y_t = 13\%$

$\Delta m / m = 3.8\%$

The future: Linear Collider

K. Desch

What is so special about a Linear Collider?

clean well defined initial state kinematics

electro-weakly interacting initial state

large S/B for possible signals

tiny beam spot $\longrightarrow$ flavour tag

flexible tunable beam energy 90 – $\sim$ 1000 GeV

beam polarisation

runnning options ($\gamma\gamma, e\gamma, e^-e^-$) $\longrightarrow$ M. Krawczyk's talk

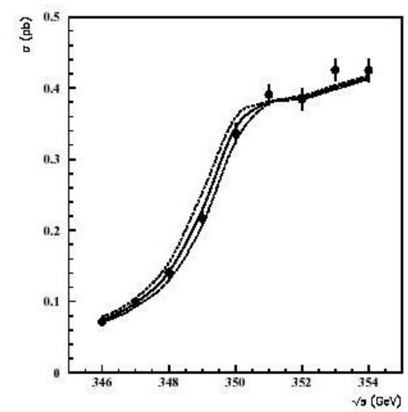
precise high luminosity (several 100 fb^{-1}/year)

excellent detector resolution (focus on physics, not on survival)

precise theory predictions (backgrounds,signals at loop level)

1. Precision measurement of top quark properties

- mass and width – threshold scan:



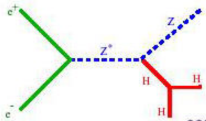
$\Delta m_{top} \approx 100 MeV$ | $\Delta\Gamma_{top}/\Gamma_{top} \approx 0.05$

for 100 fb^{-1} around threshold

Linear Collider

Higgs Self Coupling

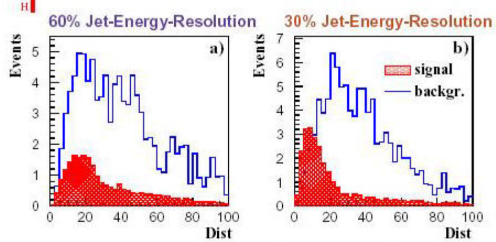
The "holy grail":



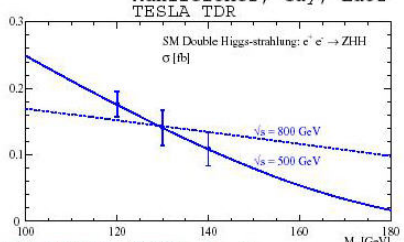
- tiny cross section
  → need highest luminosity
- multi-jet reconstruction
  → energy flow calorimeter
- use angular distributions
  for best sensitivity

$\Delta\lambda/\lambda \approx 20\%$

for 1000 fb^{-1} at 500 GeV



Mühlleitner, Gay, Lutz
TESLA TDR



K. Desch Physics at a Linear Collider, DIS02 Krakow, 02/05/2002 Page 12

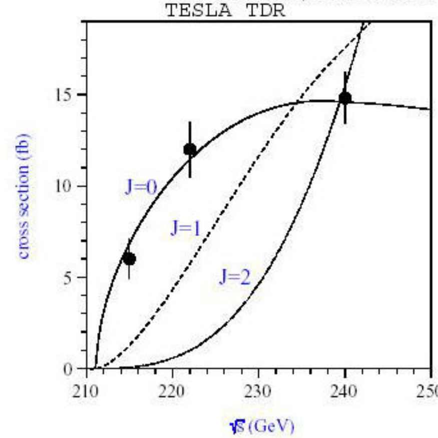
Higgs Bosons: Spin and CP

Is it really a "Higgs"?

Spin from threshold scan

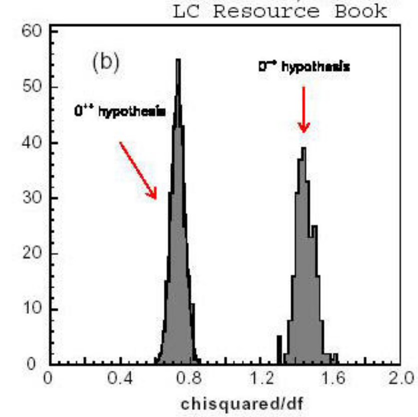
10 fb^{-1}/point:

D.J.Miller, W.Lohmann
TESLA TDR



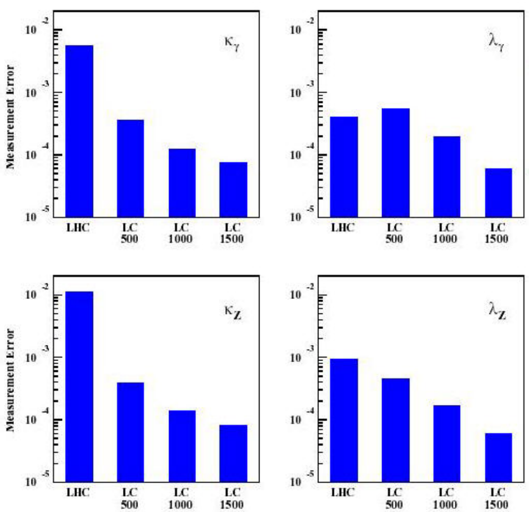
CP from angular distribution of ZH:

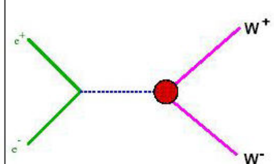
P.Derwent, A.Para
LC Resource Book



Linear Collider

Triple Gauge Couplings





TGC's are a universal precision probe for new physics

Strong EWSB Scale Sensitivity:

$\alpha_1 = 0$	80%+0%	80%+60%
Λ_2^*	5.4 TeV	8.8 TeV
Λ_3^*	8.2 TeV	10.7 TeV

$\sqrt{s} = 500$ GeV, 500 fb^{-1}

K. Desch Physics at a Linear Collider, DIS02 Krakow, 02/05/2002 Page 30

CP Violation

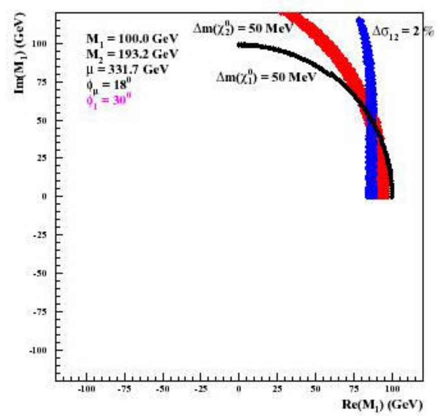
SUSY mass parameters may be complex $\Rightarrow$ CP-violating phases:

$$\mu = |\mu| e^{i\phi_\mu}, M_1 = |M_1| e^{i\phi_1}$$

Phases affect various observables:

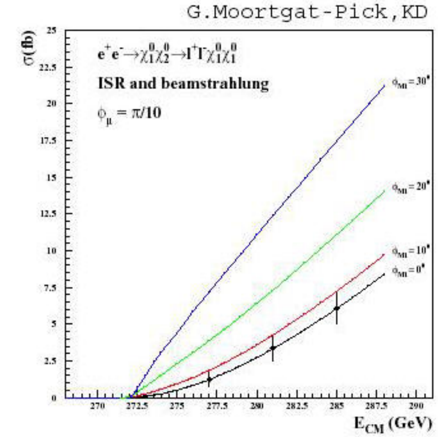
$\sigma(\tilde{\chi}_1^0 \tilde{\chi}_2^0)$, BR($\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 e^+ e^-$), $m_{\tilde{\chi}_1^0}$ etc.

Isocontours in complex M_1 plane:



Production threshold for $\chi_2^0 \chi_1^0$ production:

G.Moortgat-Pick,KD

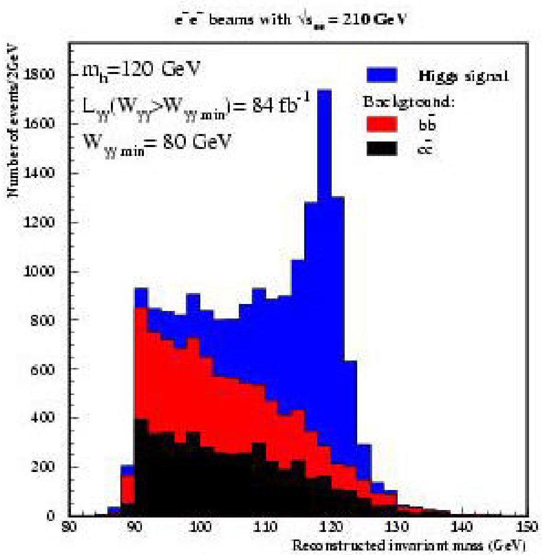


(see also Barger et al,hep-ph/0101106,LC Resouce Book)

K. Desch Physics at a Linear Collider, DIS02 Krakow, 02/05/2002 Page 19

Gamma-Gamma option at LC

M.Krawczyk



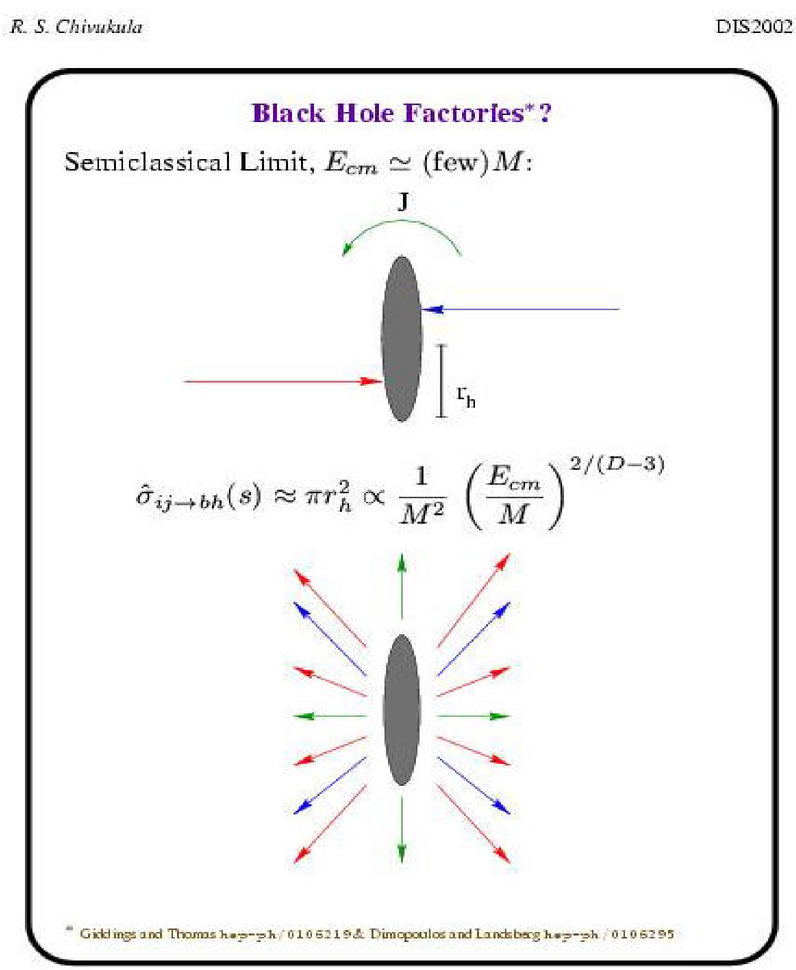
Process	Number of events	Efficiency
$\gamma\gamma \to h^\circ \to b\bar{b}$	7663	40.3%
$\gamma\gamma \to b\bar{b}$		
$J_z = 0$	412	8.9%
$J_z = 2$	4690	5.2%
$\gamma\gamma \to c\bar{c}$		
$J_z = 0$	37	0.5%
$J_z = 2$	4493	0.3%

$$\frac{\Delta\left[\Gamma(h \to \gamma\gamma) BR(h \to b\bar{b})\right]}{\left[\Gamma(h \to \gamma\gamma) BR(h \to b\bar{b})\right]} = \frac{\sqrt{N_{obs}}}{N_{obs} - N_{bkgd}} \approx 1.7\%$$

Without higher-order corrections.

A photon collider based on laser beams back-scattered from high energy electrons offers a unique opportunity to study resonant production of the Higgs boson in the process $\gamma\gamma \to$ H

Physics beyond the TeV scale...



S. Chivukula, Z.Lalak

Black holes production (LHC) through extra dimensions (n=6)

M_{BH} > 5 TeV -> 1BH/sec
M_{BH} > 10 TeV -> 3BH/day

Signatures :

10% hard leptons

2% hard protons

Conclusions

- It has been a very interesting session
- we thank all our speakers
- and we look forward to new data from HERA2 and the Teavtron!