Imperial College London

Electroweak and Beyond the Standard Model Working Group - Experimental Summary

Alex Tapper & Beate Heinemann

Introduction

30 talks + joint sessions!

10 hours of talks + joint sessions!

10 theory talks C.-P. summary

20 experimental talks

Collider breakdown:

LEP 1
Tevatron 7
HERA 8
B-factory 1
LHC 3

Disclaimer:

Only a small personal selection of many results. Apologies for omissions, biases and mistakes!

Conveners:

C.-P. Yuan, B. Heinemann, A. Tapper

Split into six sessions:

- Electroweak precision
- Top Production
- Higgs
- Supersymmetry
- Leptoquarks, LFV, etc.
- Flavour physics

Joint sessions with SF

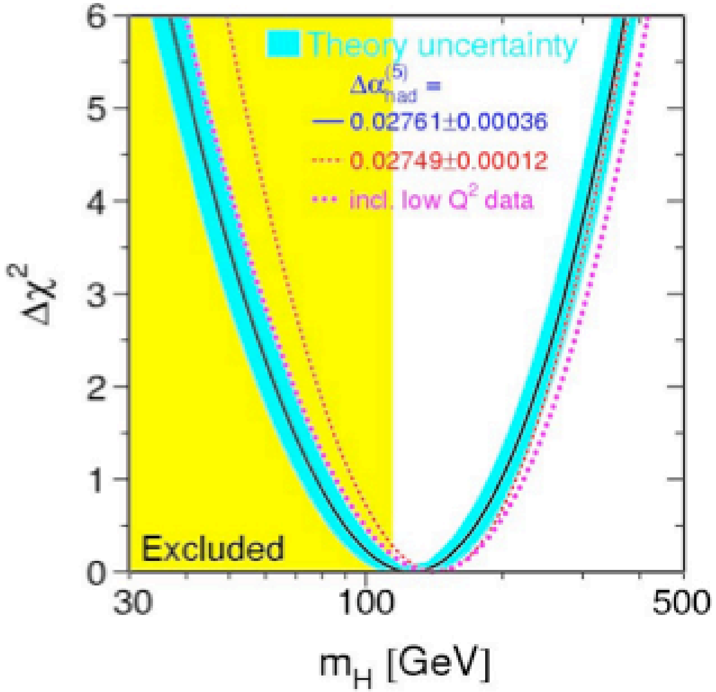
Talk follows this structure

Electroweak precision

P. Renton

Fits to electroweak precision data

THE BLUE BAND PLOT



Global electroweak fit – high Q^2 data

$$m_t = 178.4 \pm 3.9 \text{ GeV}$$

$$\alpha_S(M_Z) = 0.1188 \pm 0.0027$$

$$\Delta\alpha^{(5)}_{had}(M_Z) = 0.02770 \pm 0.00035$$

$$m_H = 126^{+73}_{-48} \text{ GeV}$$

$$\chi^2 = 18.3/13 \text{ df} \quad (\text{prob} = 15\,\%)$$

$$m_H < 280 \text{ GeV} \quad (95\% \text{ cl})$$

for $\Delta\alpha^{(5)}_{had}(M_Z) = 0.02749 \pm 0.00012 \quad m_H \Rightarrow 143$ GeV

2004 'blueband' from uncertainties of 2 (& leading 3) loops for M_W & $\sin^2\vartheta_{eff}$ (main effect for m_H)

Awramik,Czakon,Freitas,Weiglein hep-ph/0311148,0407317 &refs therein

Faisst,Kuhn,Seidensticker,Veretin N Phys B665,649(2003) + many more!

since Summer 2003 (Aachen EPS)

new top mass increases m_H by ~20 GeV

new 2-loop terms etc increase m_H by ~6 GeV

updated heavy flav. res. increases m_H by ~12 GeV

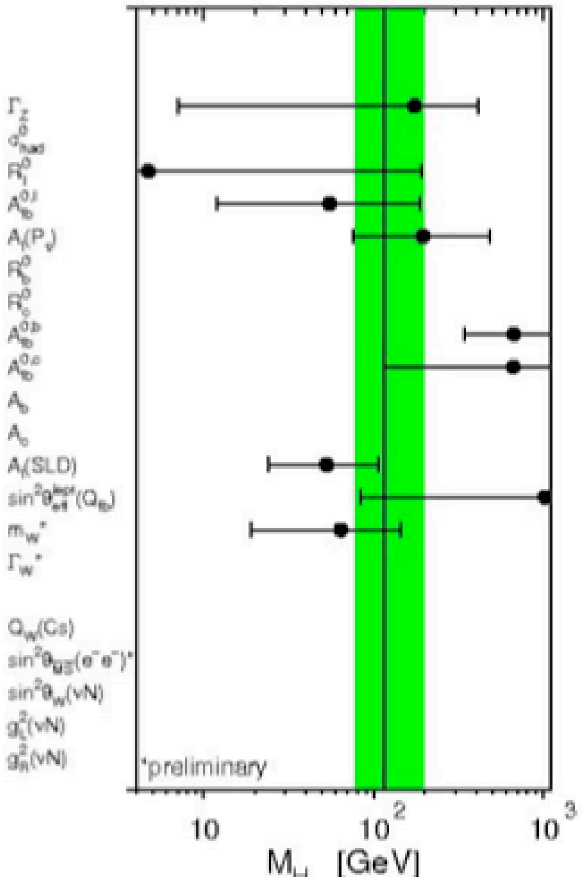
P. Renton

Fits to precision electroweak data

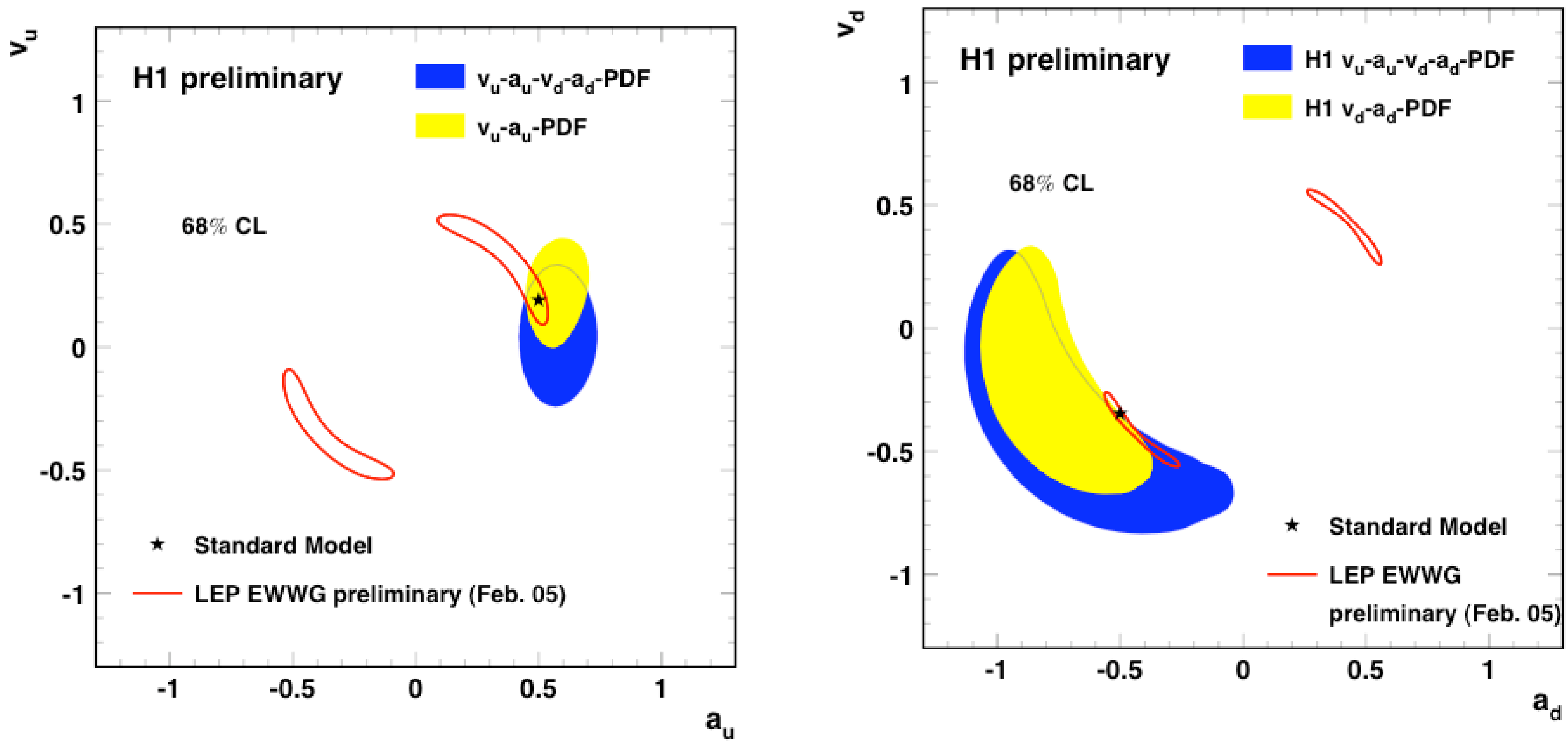
pulls

	Measurement	Fit
$\Delta\alpha^{(5)}_{had}(m_Z)$	0.02761 ± 0.00036	0.02770
m_Z [GeV]	91.1875 ± 0.0021	91.1874
Γ_Z [GeV]	2.4952 ± 0.0023	2.4965
σ^0_{had} [nb]	41.540 ± 0.037	41.481
R_l	20.767 ± 0.025	20.739
$A^{0,l}_{fb}$	0.01714 ± 0.00095	0.01642
$A_l(P_\tau)$	0.1465 ± 0.0032	0.1480
R_b	0.21630 ± 0.00066	0.21562
R_c	0.1723 ± 0.0031	0.1723
$A^{0,b}_{fb}$	0.0992 ± 0.0016	0.1037
$A^{0,c}_{fb}$	0.0707 ± 0.0035	0.0742
A_b	0.923 ± 0.020	0.935
A_c	0.670 ± 0.027	0.668
A_l(SLD)	0.1513 ± 0.0021	0.1480
$\sin^2\theta^{lept}_{eff}(Q_{fb})$	0.2324 ± 0.0012	0.2314
m_W [GeV]	80.425 ± 0.034	80.390
Γ_W [GeV]	2.133 ± 0.069	2.093
m_t [GeV]	178.0 ± 4.3	178.4

Higgs mass from individual measurements



Determination of electroweak parameters at HERA with the H1 experiment



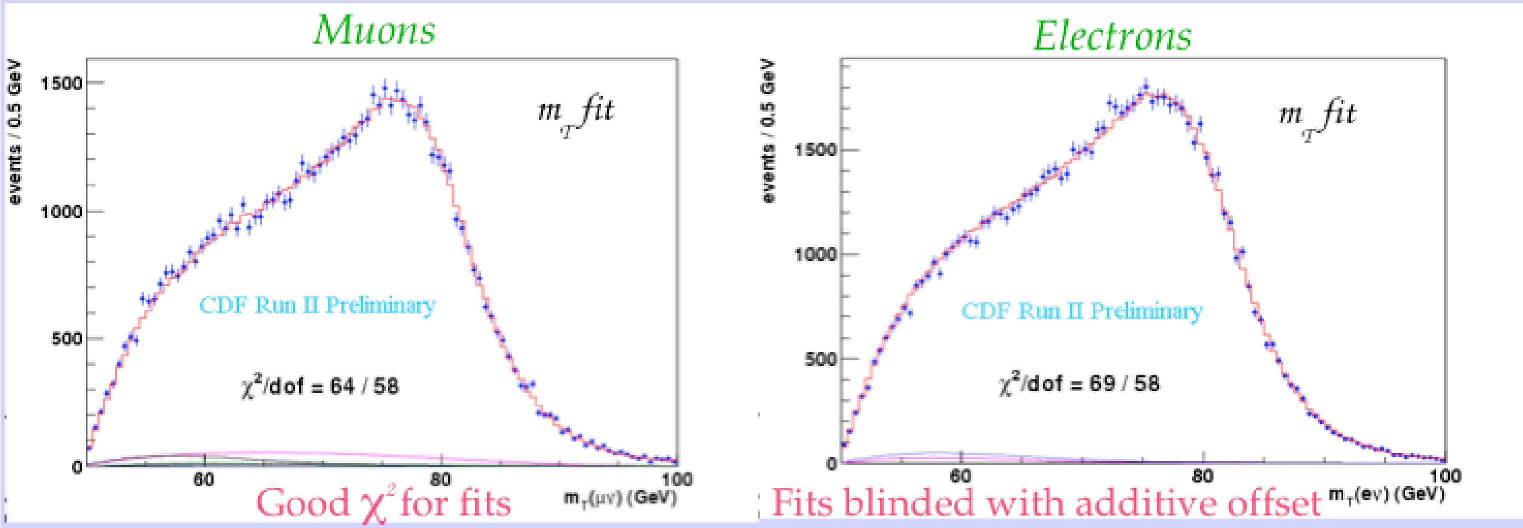
Precision will improve with HERA II high luminosity data

Precision in vector couplings will also improve with long. polarised data

C. Hays

W mass at the Tevatron

CDF *W* Mass Fits and Systematics



Systematic	Electrons (Run 1b)	Muons (Run 1b)	Common (Run 1b)
Production and Decay Model	30 (30)	30 (30)	25 (16)
Lepton Energy Scale and Resolutic	70 (80)	30 (87)	25 (0)
Recoil Scale and Resolution	50 (37)	50 (35)	50 (0)
Backgrounds	20 (5)	20 (25)	
Statistics	45 (65)	50 (100)	
Total	105 (110)	85 (140)	60 (16)

Total uncertainty 76 MeV (cf Run 1: 79 MeV)

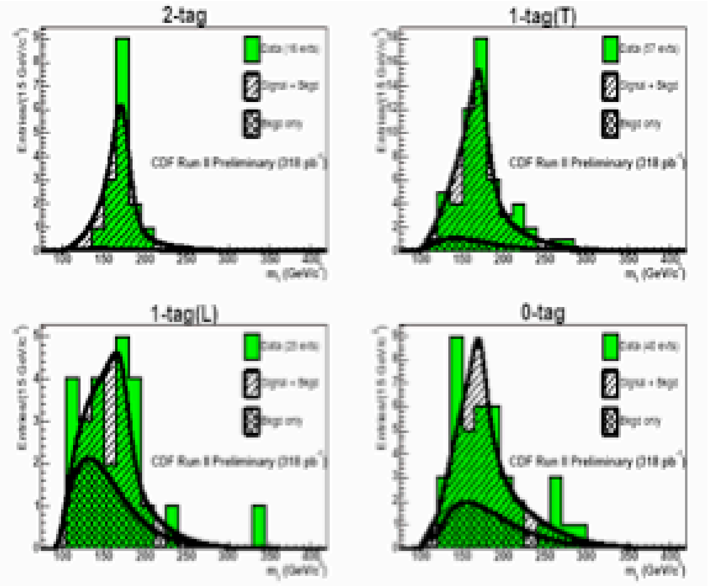
Top mass at the Tevatron

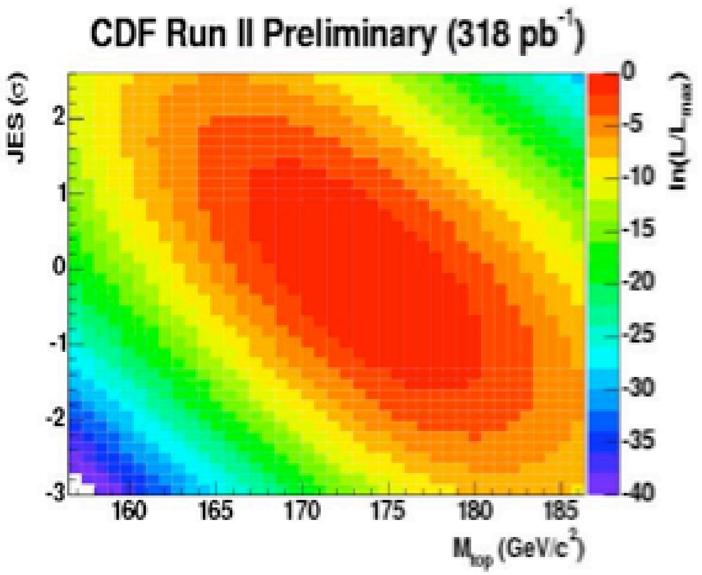
- Use 318 pb^{-1} of data
- 2-D fit: best single top mass measurement in the world:

$$M_{top} = 173.5^{+2.7}_{-2.6}(stat.) \pm 2.5(JES) \pm 1.7(syst.) GeV/c^2$$

- Cross-check using traditional 1-D fit:

$$M_{top} = 173.2^{+2.9}_{-2.8}(stat.) \pm 3.1(JES) \pm 1.5(syst.) GeV/c^2$$





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K. Mazumdar

Electroweak precision measurements at the LHC

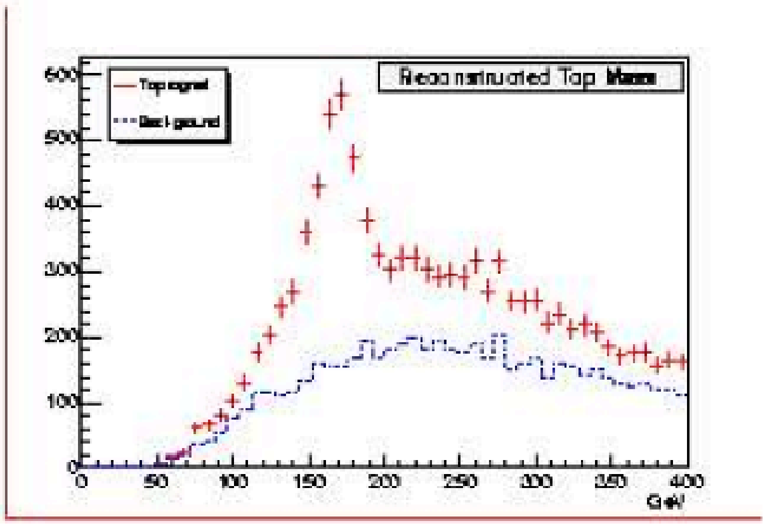
Electroweak Precision: Status

- W/Z production at LHC will be considered as luminosity monitor.
- Current parton cross-sections are known to 5 - 10%.
- Need to know to a level of 2% $\Longrightarrow$ requires calulations to 1st order in $\alpha_{\rm EW}$ and to 2nd order in α_s atleast.

exp. error	$\delta sin^2\theta_{eff}(\times 10^5)$	δM_W [MeV]	δm_t [GeV]	δM_H [MeV]
today	17	34	5.1	-
LHC	14-20	15	1-2	200

ILC will do better, of course.

150 pb^{-1} -> a few months running

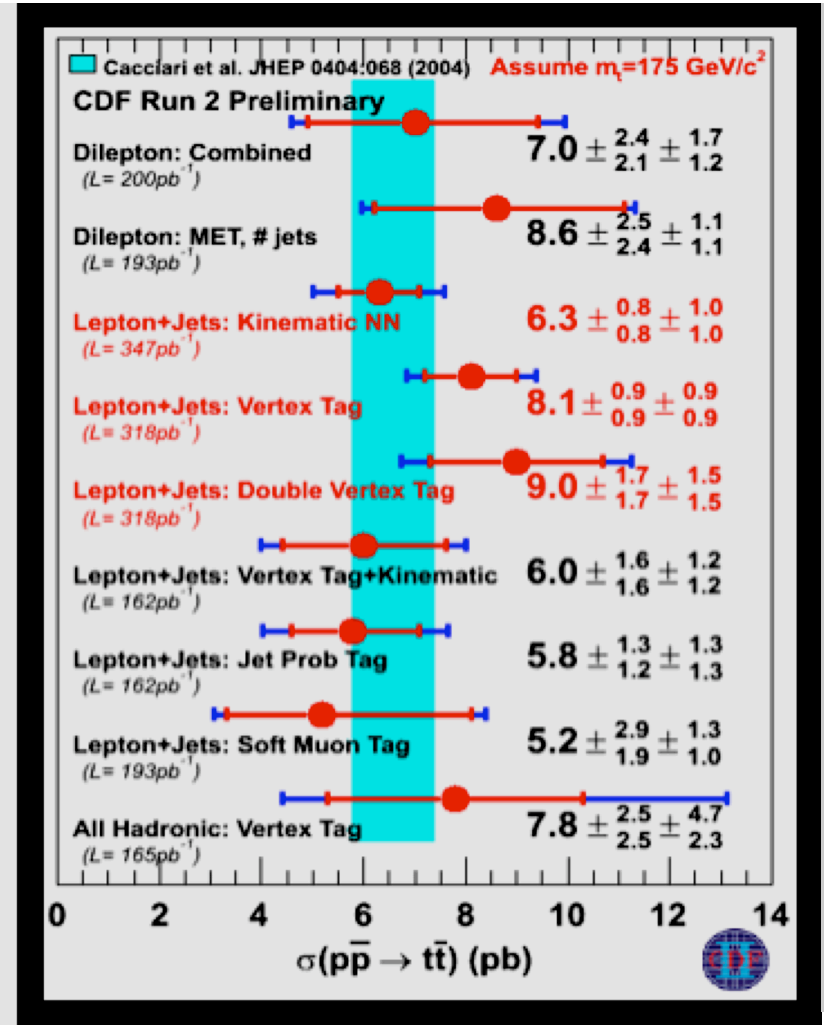


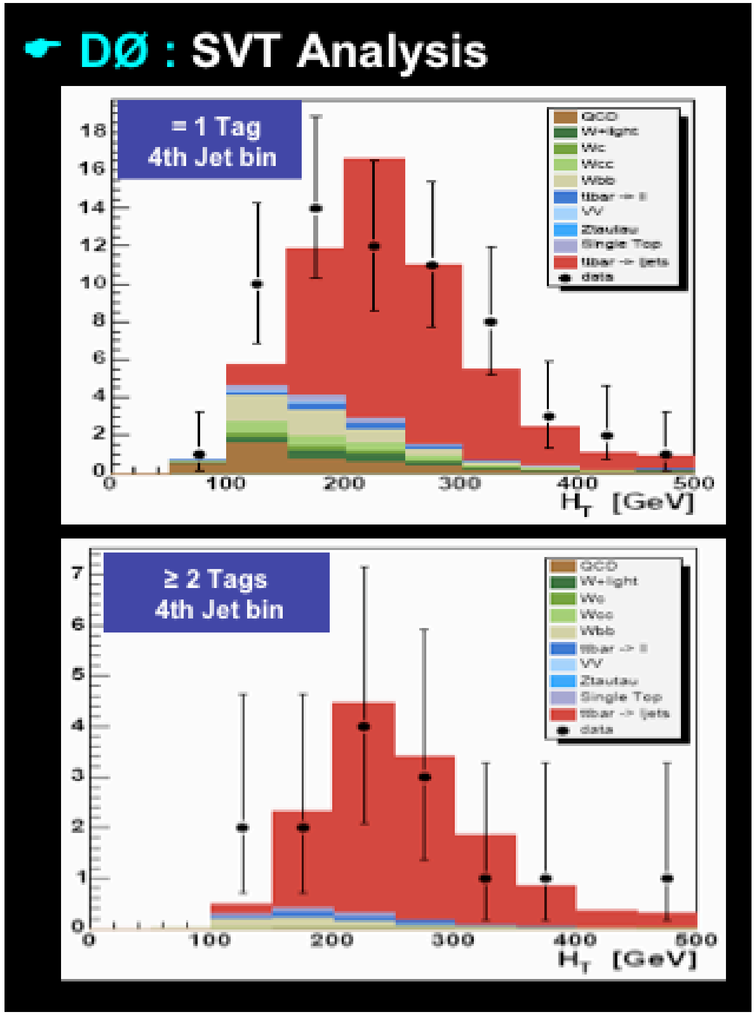
- Measure of $\sigma(t\bar{t})$ to $\sim$ 20% accuracy.
- With b-tagging expect error $\sim$ 10%

Top Production

K. Ranjan

Top production at the Tevatron

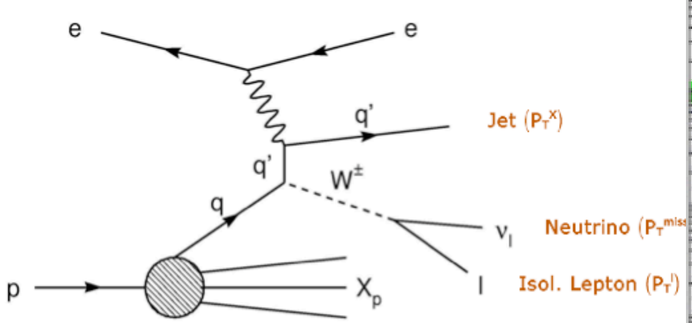




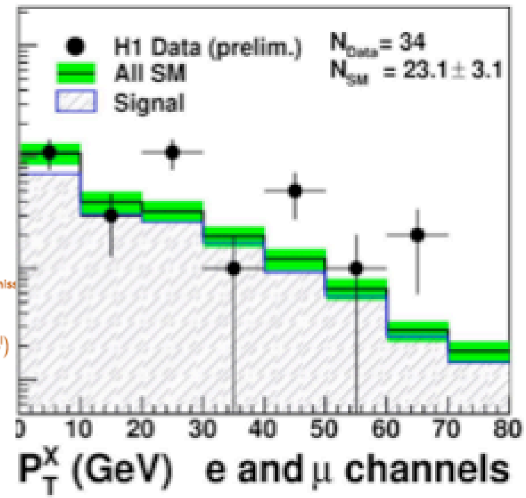
C. Veelken

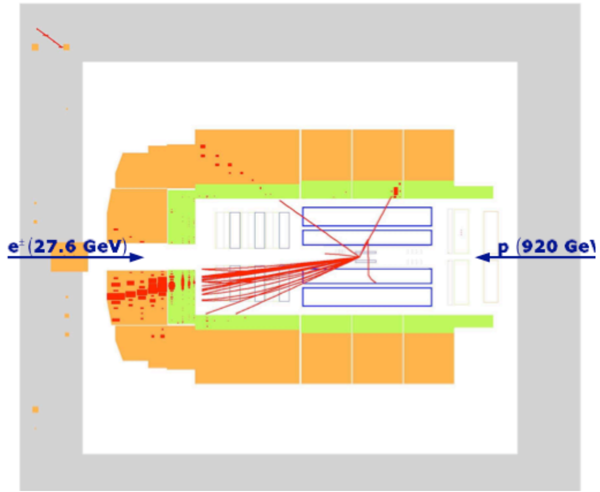
Isolated lepton search and single top at H1

SM Signal: Production of real W Bosons



- Cross-Section $\sigma(ep \to eWX) \approx 1$pb (at NLO)
- Branching Fraction $W \to l\nu \approx 10\%$ each for e,μ,τ





$e^{\pm}p$ data (1994-2005) 192 pb^{-1}	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau[①] obs./exp. (W)
All P_T^X	25/18.3 ± 2.5 (70%)	9/4.8 ± 0.8 (85%)	5/5.8 ± 1.4 (15%)
P_T^X > 25 GeV	11/3.0 ± 0.6 (81%)	6/3.0 ± 0.6 (86%)	0/0.5 ± 0.1 (49%)

① $e^{\pm}p$ (1996-2000) 108 pb^{-1}

K. Piotrzkowski

Single W boson production at ZEUS

H1 — $e^{\pm}p$ data (1994-2005) 192 pb^{-1}

	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau[①] obs./exp. (W)
All P_T^X	25/18.3 ± 2.5 (70%)	9/4.8 ± 0.8 (85%)	5/5.8 ± 1.4 (15%)
P_T^X > 25 GeV	11/3.0 ± 0.6 (81%)	6/3.0 ± 0.6 (86%)	0/0.5 ± 0.1 (49%)

[①] $e^{+}p$ (1996-2000) 108 pb^{-1}

ZEUS — $e^{\pm}p$ data (1994-2000) 130 pb^{-1}

	Electron obs./exp. (W)	Muon obs./exp. (W)	Tau obs./exp. (W)
All P_T^X	24/20.6 $^{+1.7}_{-4.6}$ (17%)[②]	12/11.9 $^{+0.6}_{-0.7}$ (16%)[②]	3/0.40 ± 0.12 (43%)
P_T^X > 25 GeV	2/2.90 ± 0.6 (45%)	5/2.75 ± 0.21 (50%)	2/0.20 ± 0.05 (49%)

[②] **Preselection**

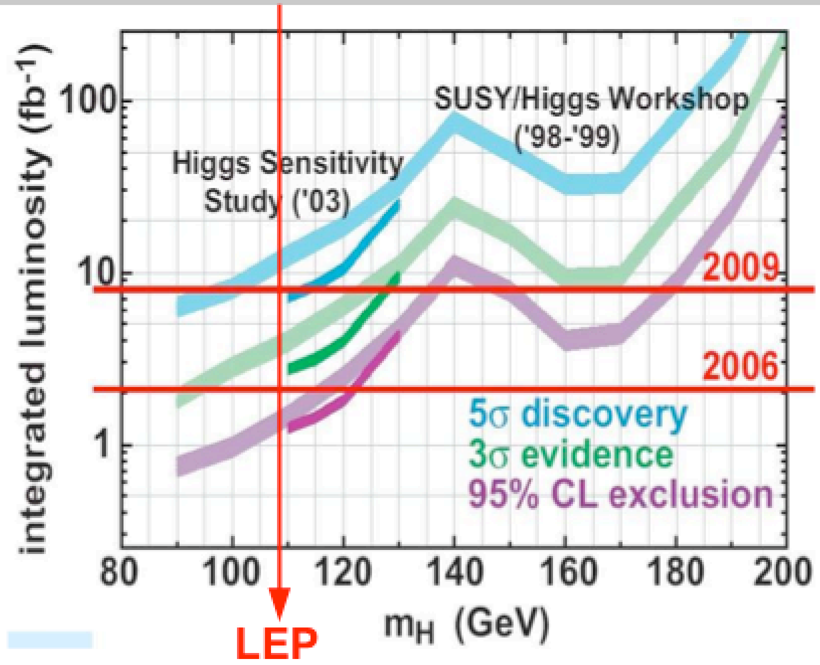
EPVEC LO MC predicts $3.2 \pm 0.1^{+1.1}_{-1.0}$ W events (with efficiency of 39%); other SM processes give $3.2 \pm 0.6^{+1.7}_{-1.6}$ events (mostly NC)

95% CL limit is $\sigma < 2.8$ pb

Higgs

Higgs searches at the Tevatron

Higgs Search Prospects at Tevatron

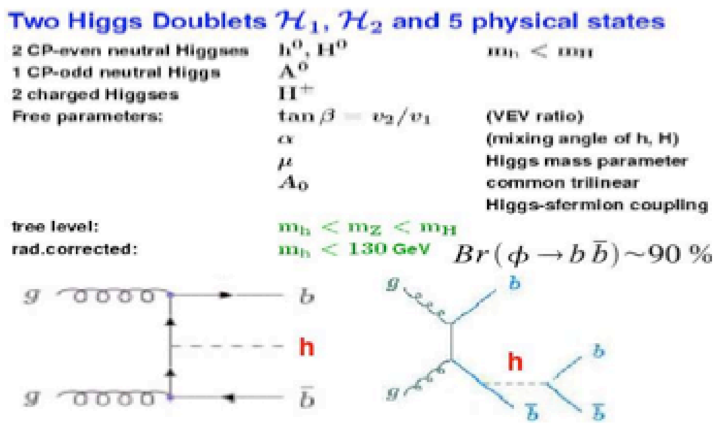


- Integrated luminosity required per experiment, to either exclude a SM Higgs at 95% C.L. or discover it the 3σ or 5σ level (no systematics).

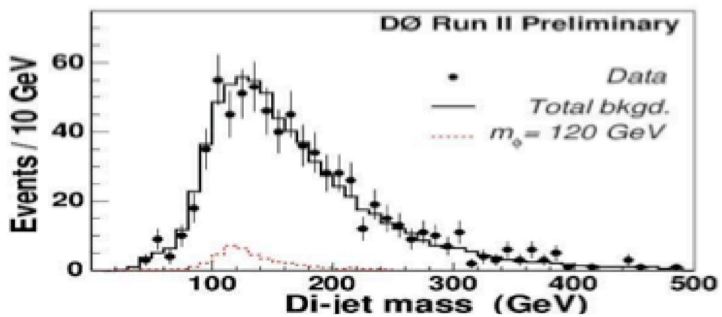
- sensitivity in the mass region above LEP limit starts above $2fb^{-1}$
- meanwhile:
  - optimize analysis techniques
  - improve understanding of detectors
  - search for non-SM Higgs with higher production cross-section

Higgs searches at the Tevatron

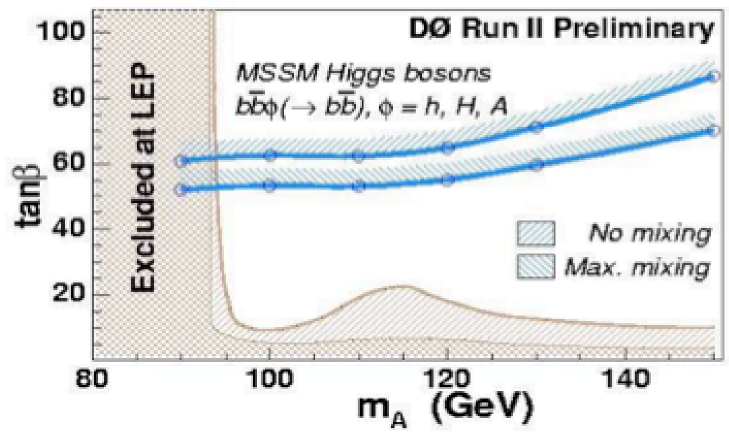
Search for MSSM Higgs: hbb (DØ)



- search for neutral Higgs in a Two-Higgs-doublet MSSM SUSY model
- do not distinguish between h, H and A
- DØ analysis based on 260pb^{-1}



- selection:
  - trigger on 3-jet events
  - off-line cut on leading jet E_T (optimized wrt m_H hypothesis)
  - ≥3 b-tagged jets
- main background:
  - QCD heavy flavor (bbjj, ccjj, cccc, bbcc, bbbb)
  - QCD fakes (jjjj)
  - Other (Z→bb,→cc; tt)
- no excess observed

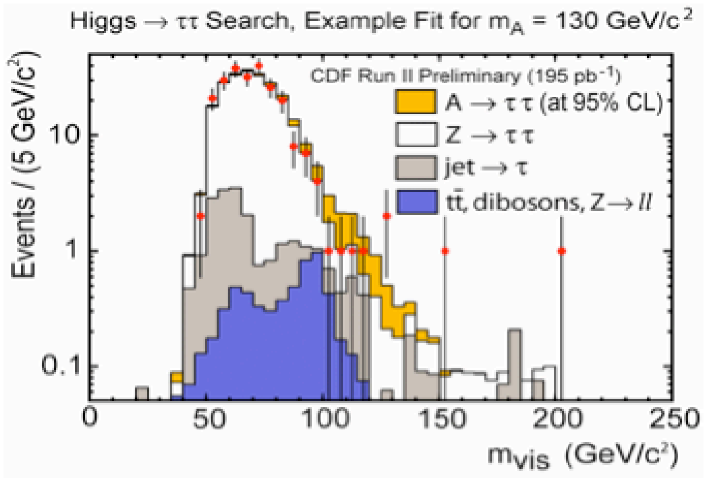


C. Hensel

Higgs searches at the Tevatron

Search for MSSM Higgs: h → ττ (CDF)

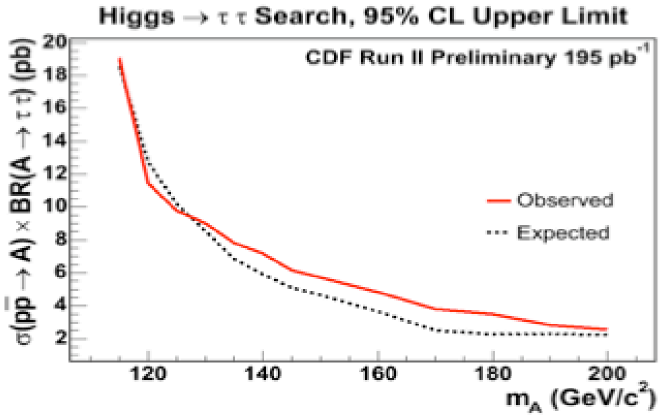
- require two τ's:
  τ→ν+hadrons, τ→ννe/μ
- τ triggers (lepton + isolated track)
- Background:
  - multi-jet events
  - W→lν
  - Z→ll
- remove light quark bkgnd:
  $H_T=|p_T(\tau_1)|+|p_T(\tau_2)|+ME_T>50$GeV
- limit extracted from binned likelihood fit on mass-like discriminating variable $m_{vis}(l,\tau,ME_T)$



MSSM Higgs → ττ Search, final events

	$\tau_h\tau_e$	$\tau_h\tau_\mu$	Combined
$Z\to\tau\tau$	132.3 ± 17.1	104.1 ± 13.3	236.4 ± 29.5
$Z\to ll$	1.8 ± 0.2	4.9 ± 0.4	6.7 ± 0.6
$t\bar{t}, VV$	0.7 ± 0.1	0.8 ± 0.1	1.5 ± 0.1
$jet\to\tau$	12.0 ± 3.6	7.0 ± 2.1	19.0 ± 5.7
Total predicted	146.8 ± 17.5	116.8 ± 13.5	263.6 ± 30.1
Data	133	103	236

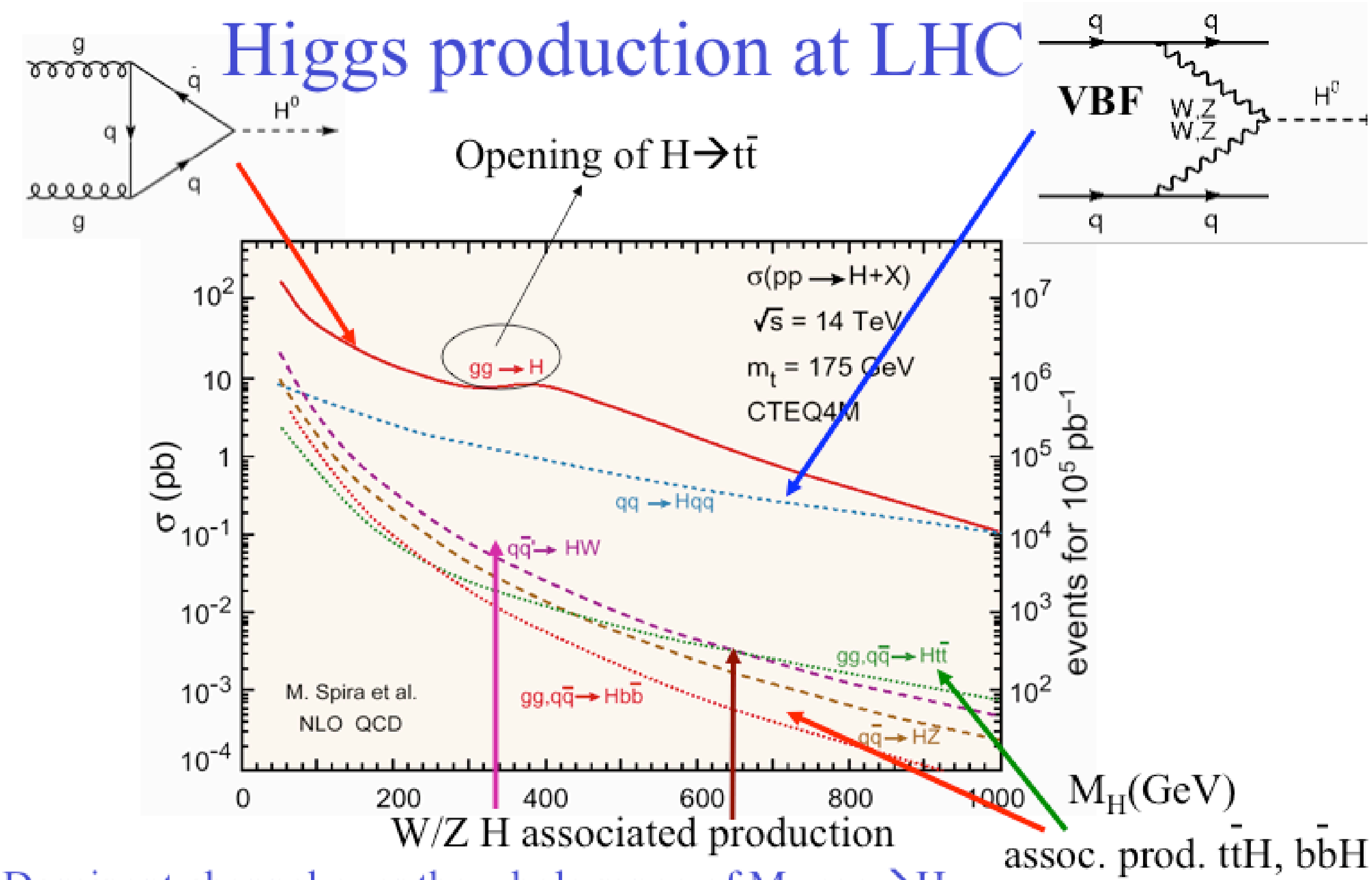
CDF Run II Preliminary



M. Escalier

Higgs searches at the LHC

Higgs production at LHC



Dominant channel over the whole range of M_H :gg→H

VBF and assoc. prod. : distinct signatures→↑S/B, ↓statistics

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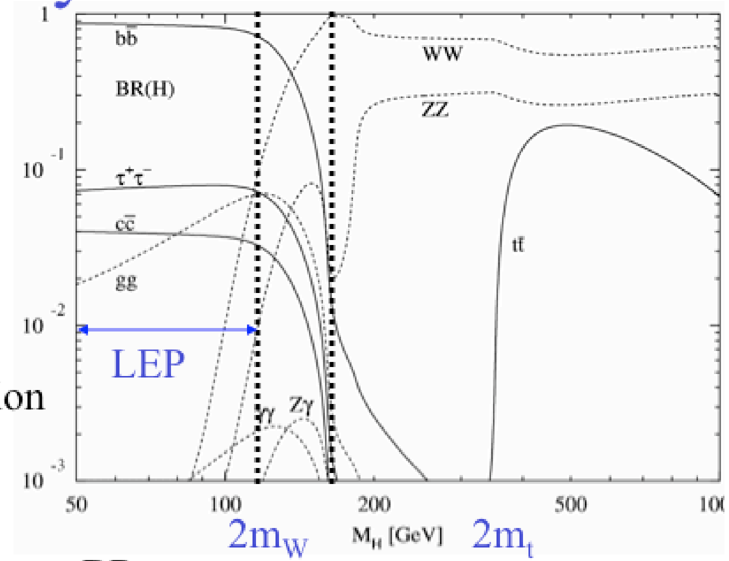
Higgs seaches at the LHC

Higgs decay at LHC

• M_H<140 GeV:
dominant decay mode $b\bar{b}$ and $\tau\tau$
overwhelmed by bck (inclusive)
$\sigma(gg \rightarrow H \rightarrow b\bar{b})$~20 pb; $\sigma(b\bar{b})$~500 μb
Accessible channels :
ttH(H→bb), VBF (H→ττ)
rare decay mode H→γγ
cleaner signature, inclusive production



• 140<M_H<180 GeV
WW^* and ZZ^* channels have significant BR
$H \rightarrow ZZ^* \rightarrow 4l$ good mass reconstruction possible, but low stat.
$H \rightarrow WW^* \rightarrow l\nu l\nu$ either inclusive or VBF production (better S/B)

• M_H>180 GeV
H→ZZ→4l gold-plated channel « easy »

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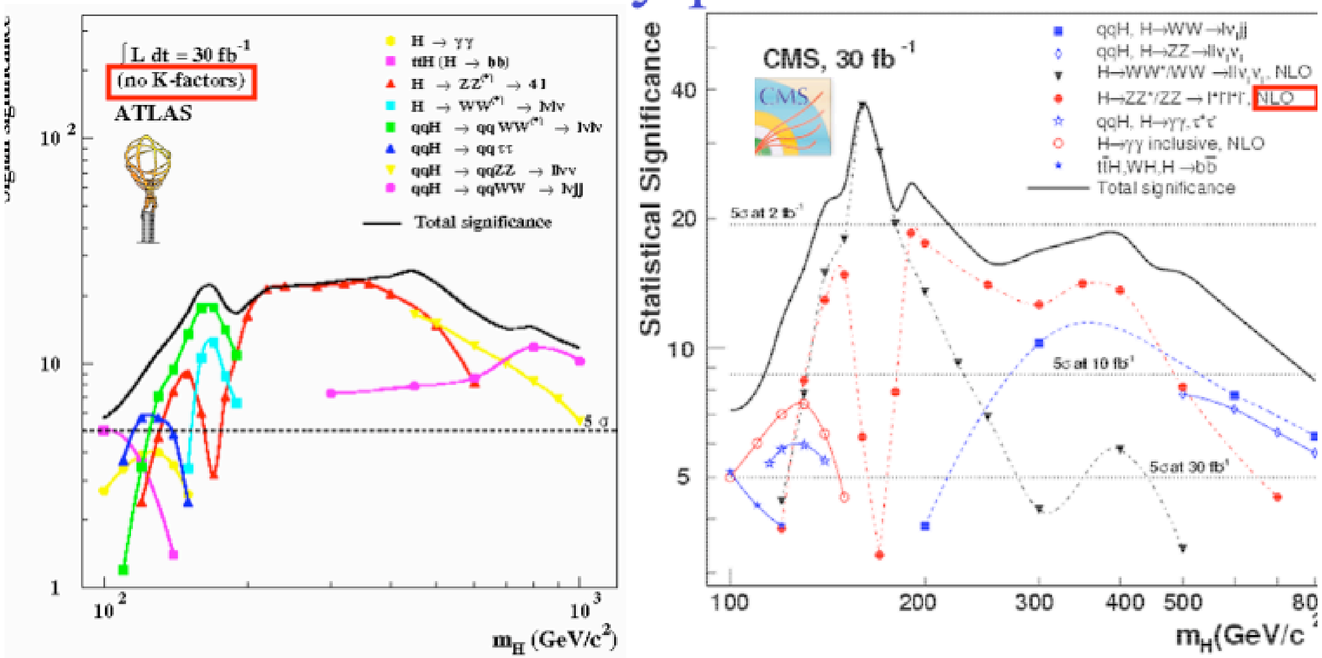
M. Escalier

Higgs searches at the LHC

Discovery potential



Almost all allowed mass range explored in 1st year (10 fb^{-1}) for ATLAS-CMS

With 30 fb^{-1}, more than 7 σ for the whole range (provided systematics on the background are under control)

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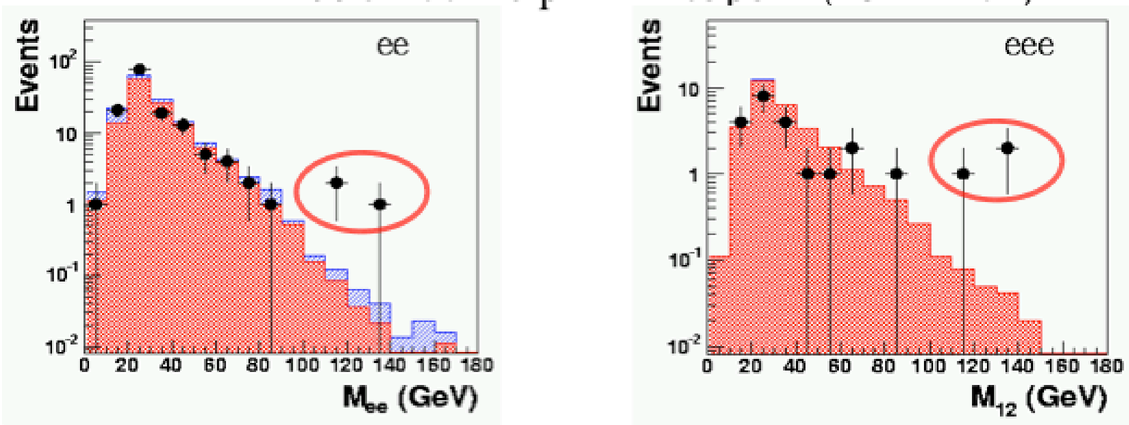
A. Schoening

Multi leptons and Higgs at H1

HERA II Preliminary

1996-2004 $e^{\pm}p$ L=163pb^{-1} (ICHEP 04)



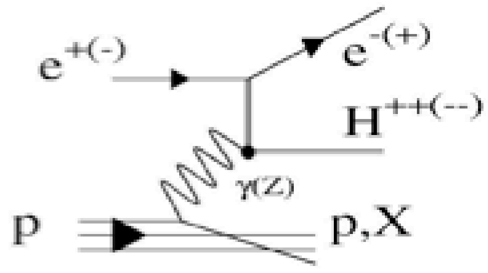
(HERA I+II)	data(L=163pb^{-1})	SM	Pair Production (Grape)
ee	147	149.8 ± 24.8	125.5
eee	24	30.4 ± 3.9	30.4

⇒ good agreement with SM

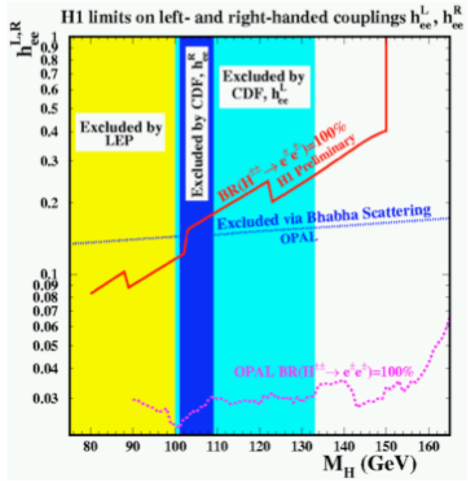
M_{12}>100 GeV

(HERA I+II)	data(L=163pb^{-1})	SM	Pair Production (Grape)
ee M_{12}>100 GeV	3	0.44 ± 0.01	0.32
eee M_{12}>100 GeV	3	0.31 ± 0.08	0.31

⇒ excess at high invariant mass



HERA I 1996-2000



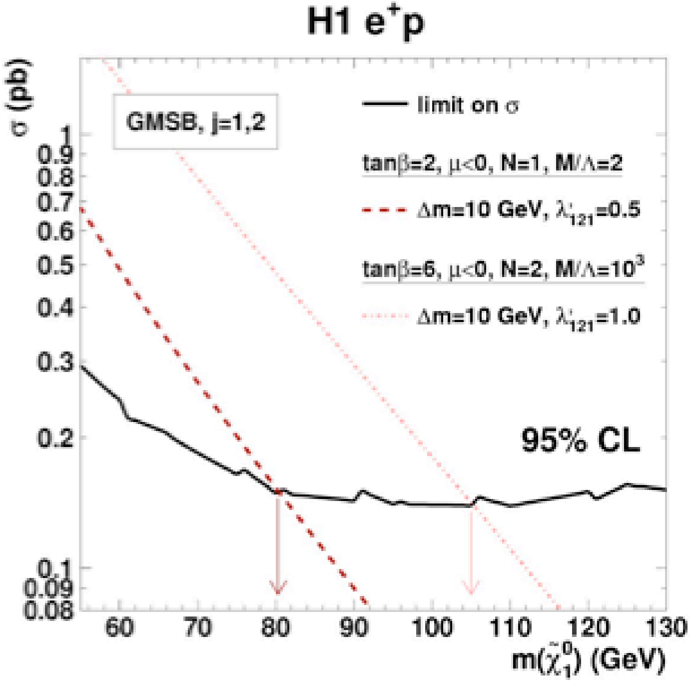
excess of high mass multi-electrons cannot be explained by doubly charged Higgs hypothesis

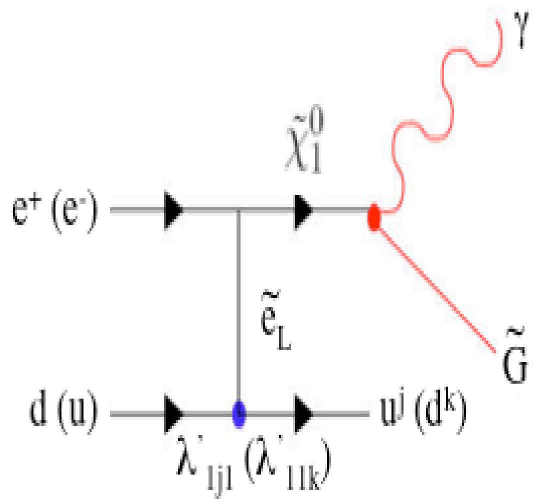
Supersymmetry

D. South

SUSY searches at H1

Gravitino Cross Section Limits

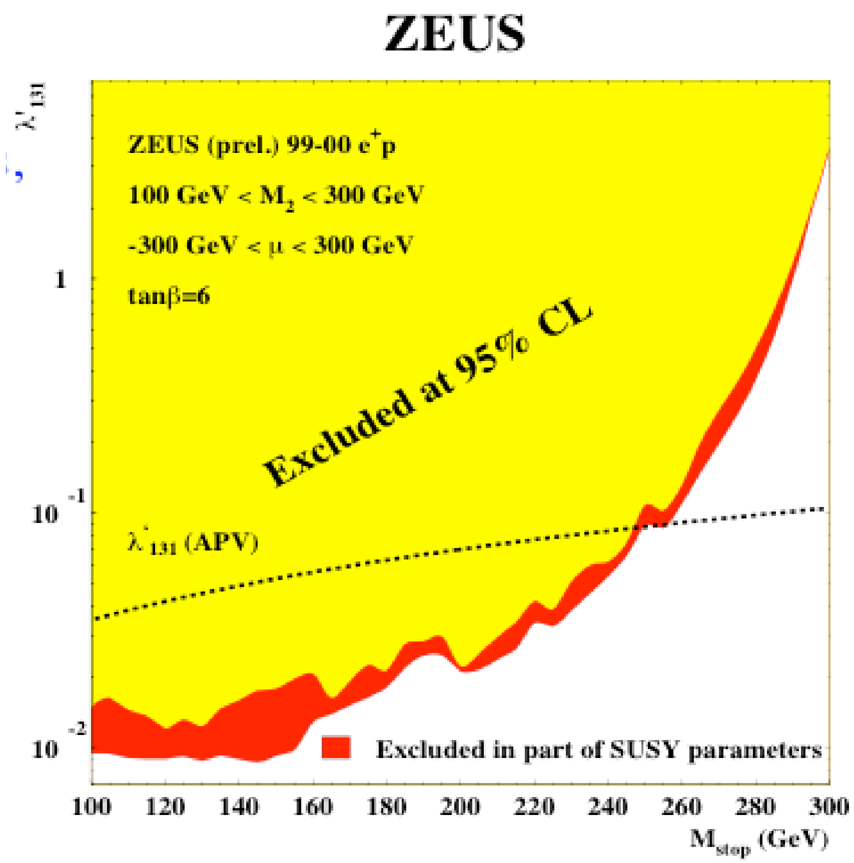


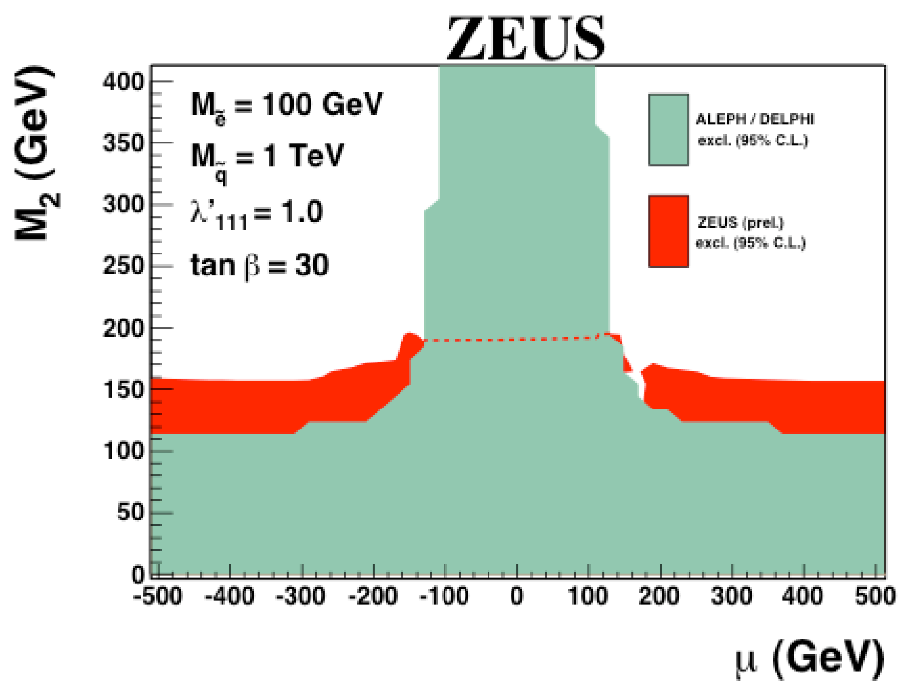


- No significant deviation from SM : derive limits on GMSB model at 95% CL
- Limits less stringent at low neutralino masses due to lower detection efficiency
- For comparison, GMSB cross sections for different couplings λ'_{121} and λ'_{112} with fixed values of tanβ, N and μ

C. Horn

SUSY searches at ZEUS





Search for bosonic stop decay in NC and CC like channels in RPV MSSM

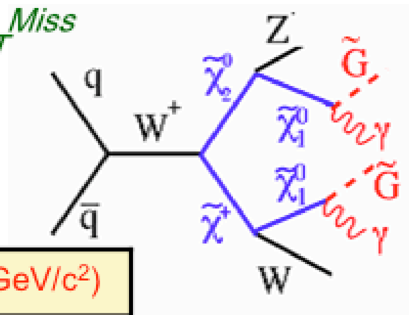
Search for gaugino production in RPV MSSM

J. Zhou

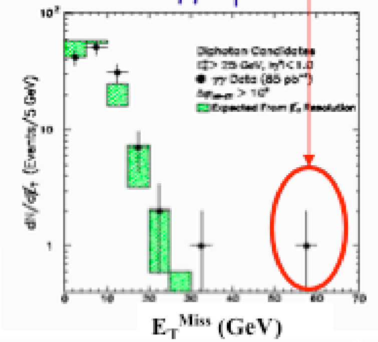
SUSY searches at the Tevatron

Chargino-Neutralino in $\gamma\gamma+E_T^{Miss}$

In GMSB: 2 photons+E_T^{Miss}



Motivated from CDF-I $ee\gamma\gamma E_T^{Miss}$ event

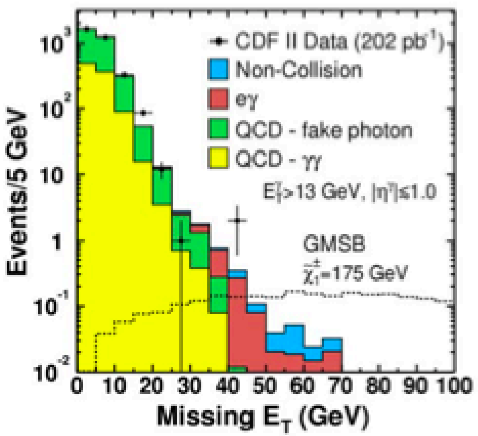


CDF/DØ Event selection:

-2 photons E_T > 13/20 GeV

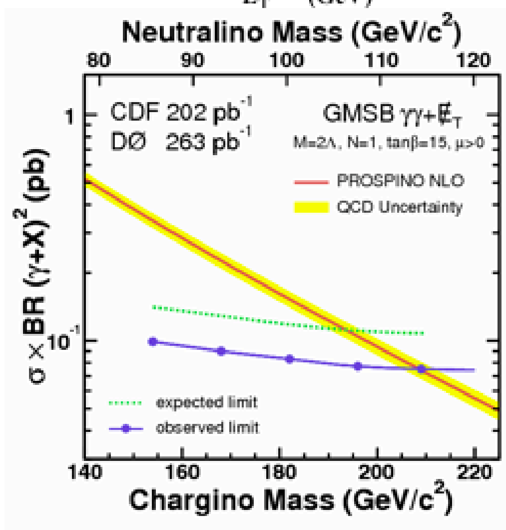
-E_T^{Miss}>45/40 GeV

	Bkgd Exp.	Obs	Limit $m_{\tilde{\chi}^+}$ (GeV/c²)
D0	3.7±0.6	2	195
CDF	0.3±0.1	0	167



CDF and D0 combined result: $m(\tilde{\chi}_1^\pm)$>209 GeV/c²

hep-ex/0504004



N. Ozturk

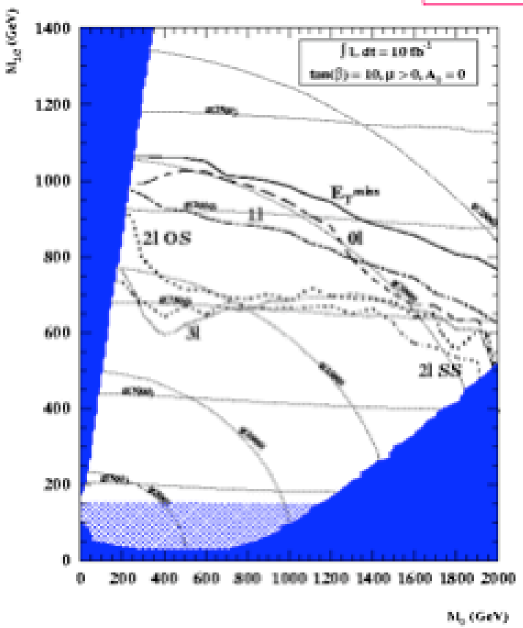
SUSY searches at the LHC

mSUGRA Reach

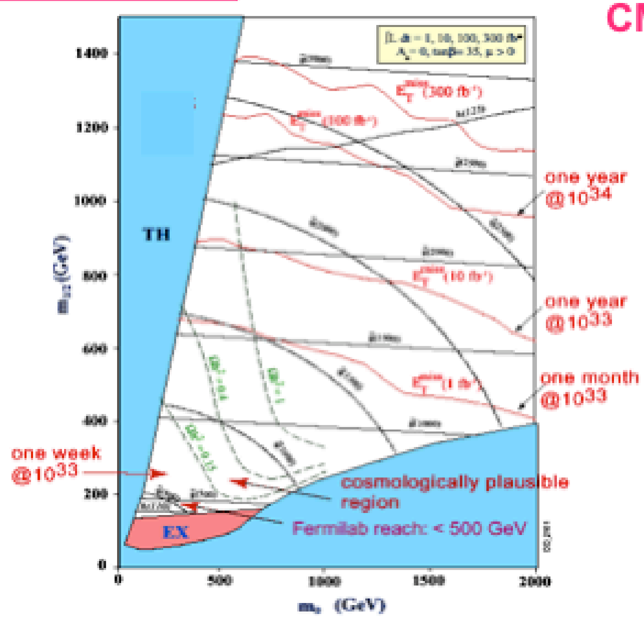
- mSUGRA framework: five free parameters: m_0, $m_{1/2}$, A_0, $\tan(\beta)$, $\mathrm{sgn}(\mu)$
- Reach sensitivity only weakly dependent on A_0, $\tan(\beta)$, $\mathrm{sgn}(\mu)$
- Multiple signatures on most of parameter space: E_T^{miss} (dominant signature), E_T^{miss} with lepton veto, one lepton, two leptons same sign (SS), two leptons opposite sign (OS)

5σ exclusion contours

ATLAS

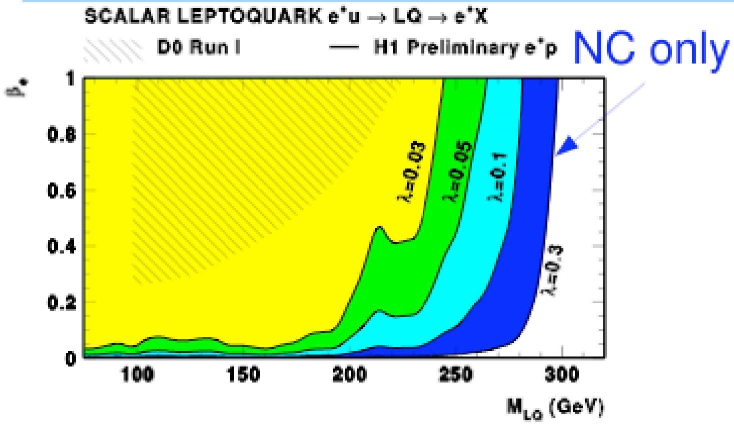


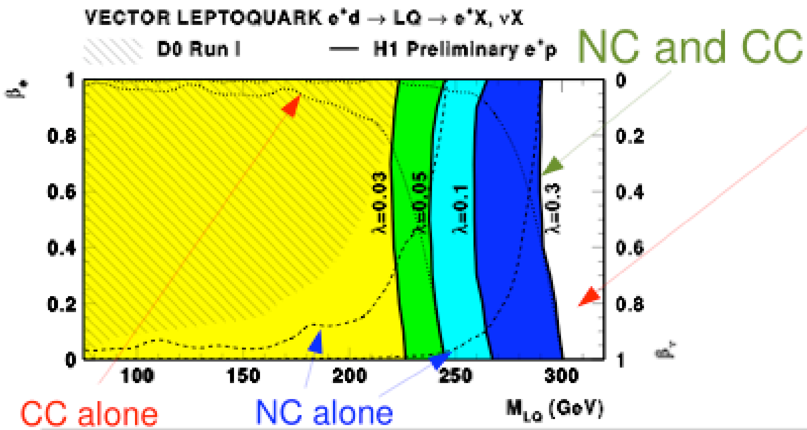
CMS



Leptoquarks, Lepton Flavour Violation, Extra Dimensions, New Gauge Bosons etc.

Extended model: free β





LQ → eq, νq with

- relaxed assumption w.r.t. BRW
- β is free parameter

LQs up to 300 GeV at λ=0.3 can be excluded

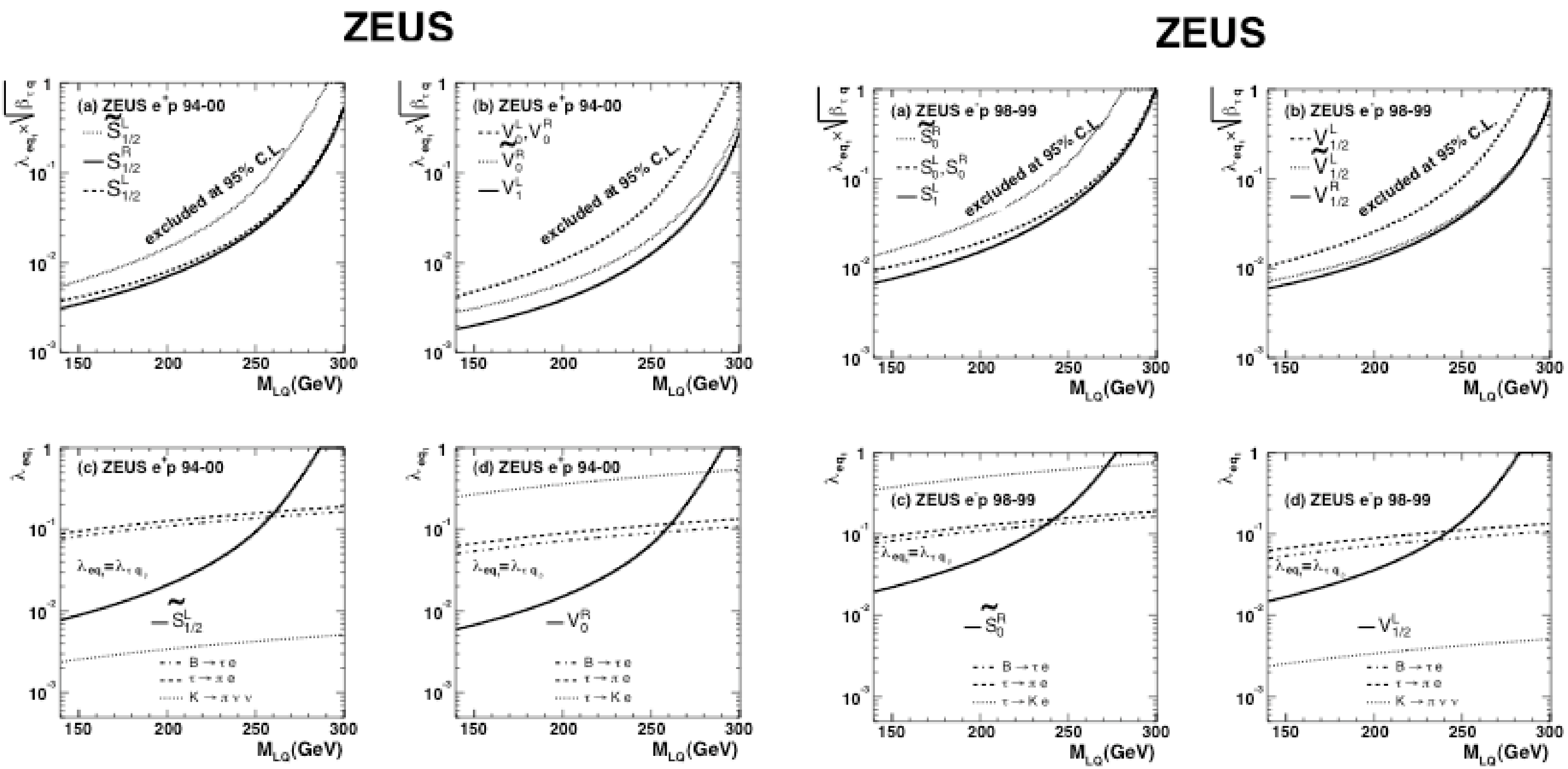
CC channels as sensitive as NC channels, combined limit independent of β

Compare to DØ Run I+II (hep-ex/0412029):

- $M_{LQ,\ sca}$ > 256 GeV at β_e=1
- $M_{LQ,\ sca}$ > 206 GeV at β_e=0.2
- limited sensitivity at low β_e

G. Barbagli

Search for lepton flavour violation at ZEUS



Use LFV results to place limits on leptoquark masses and couplings.

Most stringent to available in some cases, particularly in the tau channel

Magnetic monopoles

Dirac magnetic monopoles have a large magnetic charge

- Highly ionizing, produce many delta rays
- Bend in *r-z* plane, not *r-φ* plane

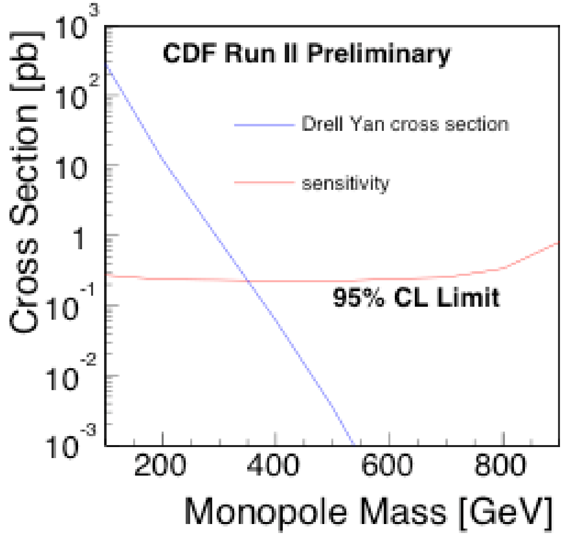
CDF took 36pb^{-1} of data with a special monopole trigger

- require large light pulses from time-of-flight scintillator bar
- reconstruct in central-outer-tracker with special tracking algorithm

Unusual properties of monopoles mean background is effectively zero

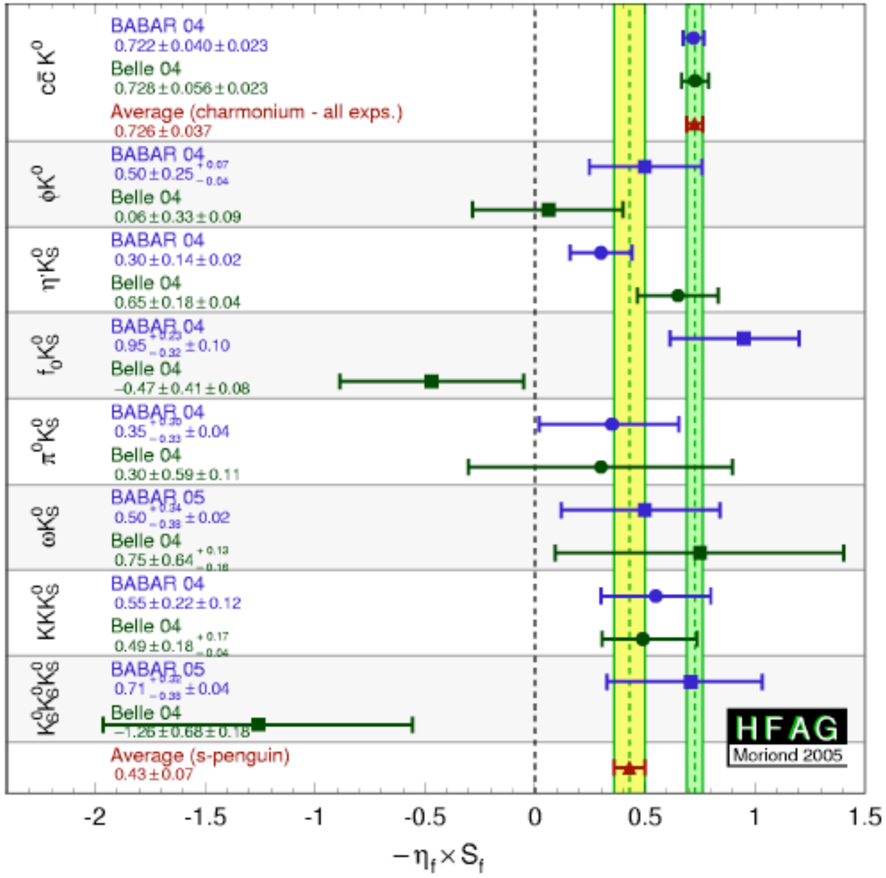
No events found

Mass limit of M > 350 GeV for Drell-Yann pair production



Flavour Physics

Combined "sin2β" Results



BABAR+Belle:
$\Delta S \sim -3.7\,\sigma$

BaBar only:
$\Delta \sin 2\beta \approx -2.9\sigma$

Belle only:
$\Delta \sin 2\beta \approx -2.9\sigma$

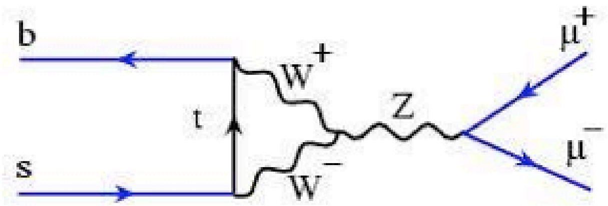
…but comparison ignores subleading diagrams !

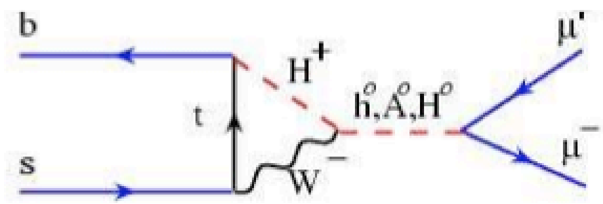
$B_s \rightarrow \mu\mu$: Beyond the SM

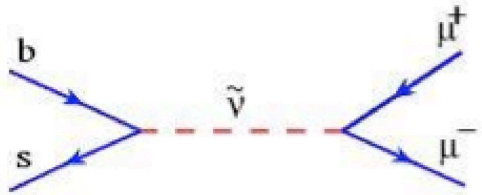
- Look at decays that are suppressed in the Standard Model: $B_{s(d)} \rightarrow \mu^+\mu^-$
  - Flavor changing neutral currents(FCNC) to leptons
    - No tree level decay in SM
    - Loop level transitions: suppressed
    - CKM , GIM and helicity(m_l/m_b): suppressed
    - SM: $BF(B_{s(d)} \rightarrow \mu^+\mu^-) = 3.5\text{x}10^{-9}(1.0\text{x}10^{-10})$

    G. Buchalla, A. Buras, Nucl. Phys. B398,285
- New physics possibilities
  - Loop: MSSM: mSugra, Higgs Doublet
    - 3 orders of magnitude enhancement
    - Rate $\propto \tan^6 / (M_A)^4$

    Babu and Kolda, Phys. Rev. Lett. 84, 228
  - Tree: R-Parity violating SUSY







One of the best indirect search channels at the Tevatron

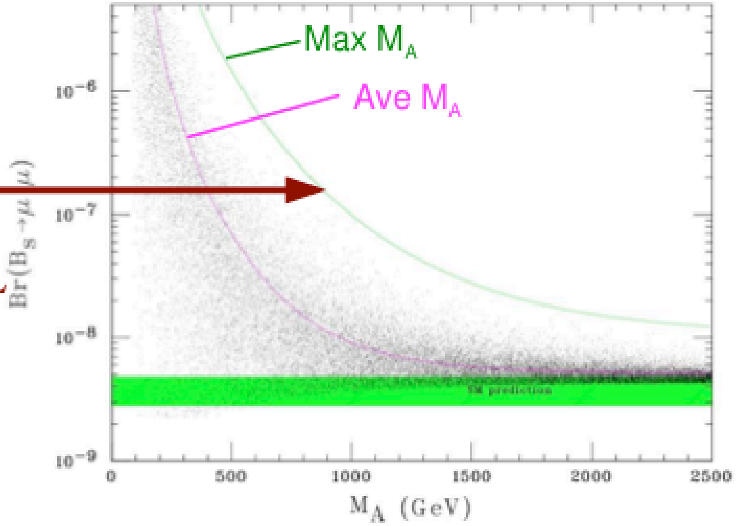
$B_s \rightarrow \mu\mu$: MSSM

- Combined $B_s \rightarrow \mu^+\mu^-$ result:

  Bayesian approach with a flat prior.
  Systematic errors on fs and
  BF($B^+ \rightarrow J/\psi K^+$) correlated.

$$BF(B_s \rightarrow \mu^+\mu^-) < 1.6 \times 10^{-7}\ 95\%\ \mathrm{CL}$$

- SM Prediction
  - SM: $BF(B_s \rightarrow \mu^+\mu^-) = 3.5\text{x}10^{-9}$
  - No sensitivity for SM rate



Dedes, Huffman hep-ph/0407285,2004

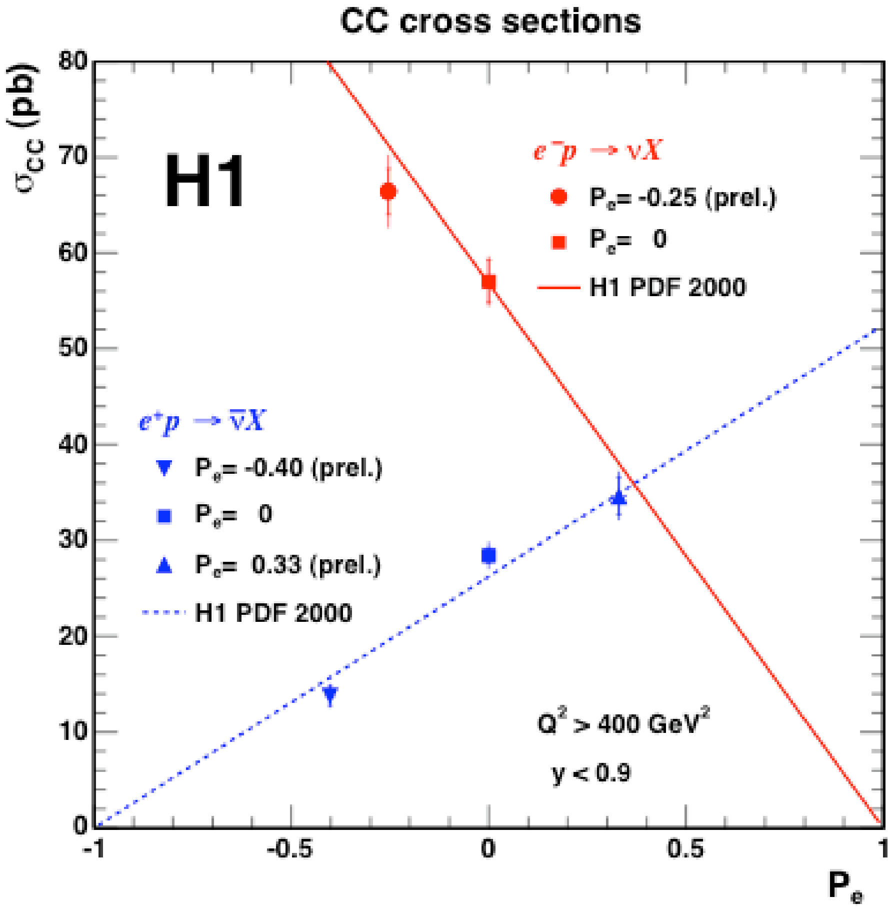
- No strong SUSY:MSSM limits from $B_s \rightarrow \mu^+\mu^-$
  - Too many MSSM parameters
  - If $B_{s(d)} \rightarrow \mu^+\mu^-$ observed: M_A < 800GeV
  - $\tan\beta = 50$

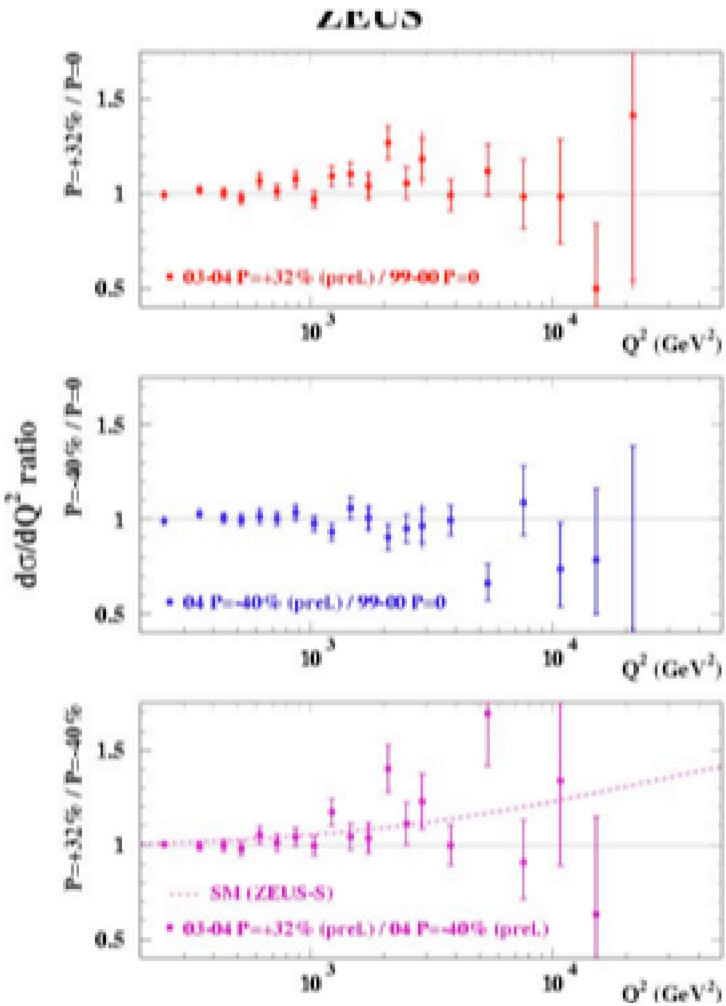
Does limit specific SUSY models

Joint Sessions with Structure Functions Working Group

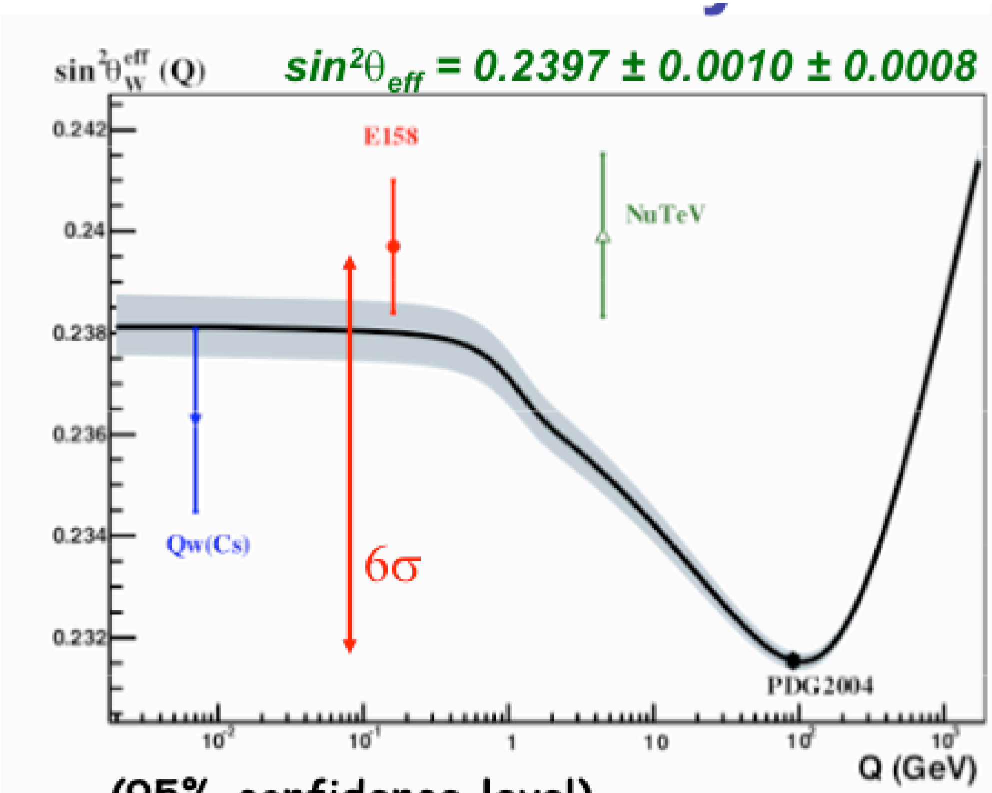
A. Nikiforov & A. Tapper

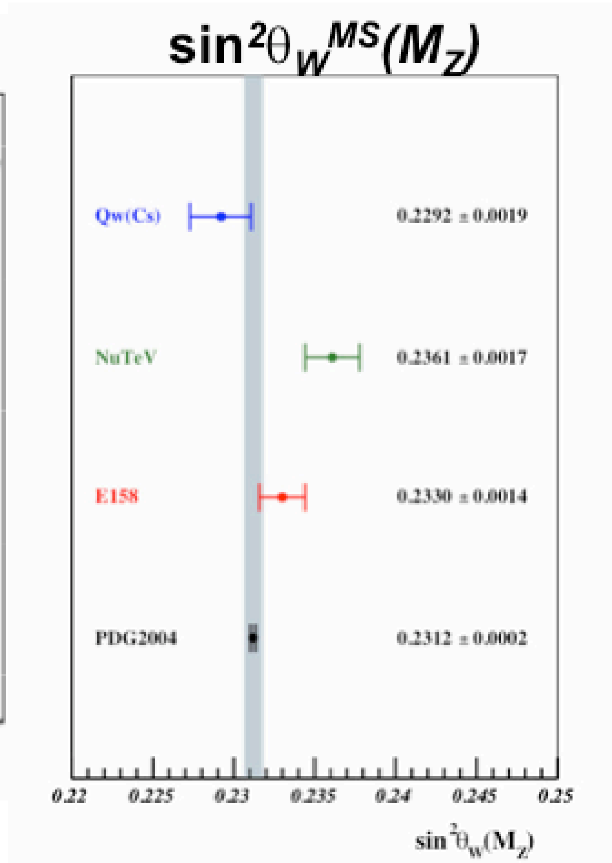
High Q^2 CC and NC DIS with polarised leptons





Mixing angle from parity violating Moller scattering (SLAC E158)





(95% confidence level)

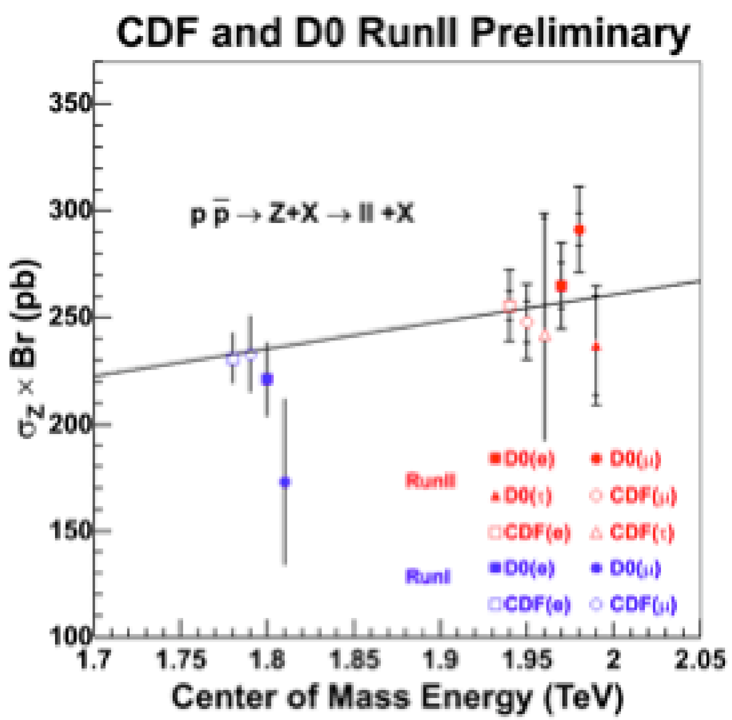
hep-ex/0504049 submitted Tuesday!

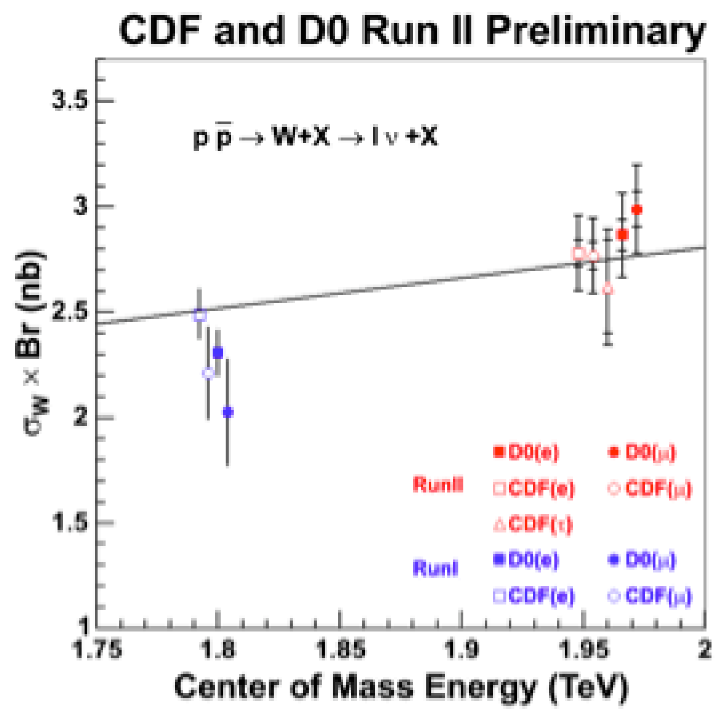
* Limit on Λ_{LL} ~ 7 or 16 TeV
* Limit on SO(10) Z' ~ 1.0 TeV
* Limit on lepton flavor violating coupling ~ $0.01G_F$

J. Hays

W and Z cross sections at the Tevatron

Benchmark analyses for all high pT lepton analyses





Systematics limited measurements ~2-3% level (excl luminosity)

Dominant contributions from acceptance (large contributions from PDF

Summary and future prospects

- Electroweak Standard Model provides an almost perfect picture of all our observations. Measurements still coming in from Tevatron, HERA and fixed target experiments.
- A few tantalising deviations from the Standard Model at B factories and H1. Watch this space for further developments.
- HERA still able to place competitive limits on many processes beyond the standard model (SUSY, LFV, Leptoquarks…)
- Tevatron should be sensitive to SM Higgs within the next year or so. Already able to place limits that restrict allowed phase space in many SUSY and other new physics scenarios.
- Vast discovery potential of the LHC to come.

Thanks to all the speakers for the fascinating talks and the organisers for a lively and stimulating workshop!