EWSB : Experimental Summary



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THANKS to our speakers :

Paolo Azzurri, Lorenzo Bellagamba, Alain Blondel, Dhiman Chakraborty, Caroline Colard, Frank Filthaut, Eva Halkiadakis, Amit Klier, Hinrich Meyer, Filip Moortgat, Carlos Sanchez, Vladislav Simak, Iacopo Vivarelli

EWSB : Big Picture

- $SU(2)_L \otimes U(1)_Y$
- Why are M_w and $M_z O(100)$ GeV, yet $M_y = 0$?
- SM : spontaneous symmetry breaking via the Higgs mechanism.



- Direct searches for the quanta of the Higgs field.
 - Discover the means by which the Higgs mass is stabilised :
 - Supersymmetry
 - Extra-dimensions, etc.
 - Other agents for EWSB.

Electroweak Symmetry Breaking



Tevatron Enters its Stride



W Mass Measurement



Electroweak Symmetry Breaking

W Mass @ LEP-II



W Mass @ Hadron Colliders

Difficult :

- ► limited Z→l⁺l⁻ statistics to set energy scale – have to use low mass resonances and detailed physics knowledge.
- production uncertainties : recoil, PDF's etc.



Source of uncertainty (MeV)	W → ev (Run 1b)	<i>W</i> →μν (Run 1b)
Lepton E scale, p resolution	70 (80)	30 (87)
Recoil E scale and resolution	50 (37)	50 (35)
Background	20 (5)	20 (25)
Production & decay model	30 (30)	30 (30)
Statistics	45 (65)	50 (100)
Total	105 (110)	85 (140)

World's best single measurement with data on tape.

- CDF & D0 combined with 2 fb^{-1} : $\Delta M_w = 30 \text{ MeV}$
- LHC : 15-25 MeV ???



WIN'05

Electroweak Symmetry Breaking

Top Mass Measurement



Top Mass Measurement : New Ideas

Jet Energy Scale

- Impose W mass constraint and fit for an in-situ jet energy scale determination.
- 20% improvement in JES systematic.



ISR/FSR :

 Use collider data itself (DY) to define range of parameter variation.



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Top Mass Measurement : New Results



LHC:

► $R(t\bar{t}) \approx 1$ Hz @ low luminosity.

Will still require detailed understanding of jet energy scales, but many cross-checks possible with high statistics. △m_{top} ≈ 1 GeV seems feasible.
Precision measurements of top properties.

WIN'05

Precision Measurements : Asymmetries





Electroweak Symmetry Breaking

Precision Measurements : Branching Ratios

Br(W $\rightarrow \mu\nu$)/Br(W $\rightarrow e\nu$) = 0.994 ±0.021 Br(W $\rightarrow \tau\nu$)/Br(W $\rightarrow e\nu$) = 1.069 ± 0.029 Br(W $\rightarrow \tau\nu$)/Br(W $\rightarrow \mu\nu$) = 1.075 ± 0.028

tau BR is three sigmas larger than e/mu !

 $g_{\mu}/g_{e} = 0.997 \pm 0.010$ $g_{\tau}/g_{e} = 1.036 \pm 0.015$ $g_{\tau}/g_{\mu} = 1.039 \pm 0.014$

Direct test of W lepton universality at the 1% precision level

Electroweak Symmetry Breaking

Winter 2005 - LEP Preliminary





Light Higgs Searches

► Low mass : $H \rightarrow b\bar{b}$ dominates.

Production in association with gauge bosons provides distinctive signatures but with much smaller cross-sections.



Z(→vv̄)H(→bb̄) also being analysed.
Still some work required to reach anticipated sensitivity.



Heavy Higgs Searches

- \triangleright High mass : H \rightarrow WW dominates.
- ► Take advantage of largest σ_{PROD} : gg→H
- Direct WW production a serious background.
- Use scalar decay spin correlations to separate signal from background.





BSM Higgs Searches

MSSM : enhanced \u00f6bb coupling can give large production cross-sections.

► Decay predominantly to $b\bar{b}$, $\tau^+\tau^-$.





Higgs Searches @ LHC

So, what's new ?

- Many studies being re-done with improved understanding of :
 - signal & background (k-factors)
 - detector performance (full GEANT simulations)
- Renewed emphasis on VBF; utilising the colour structure of the events to suppress backgrounds.



WW, ZZ fusion

Tests using Tevatron (VB+n-jet) data

N.Z

Jet

⁹ Jet



Electroweak Symmetry Breaking

Supersymmetry

Solves hierarchy problem.
Natural dark matter candidate (R_P)
Gauge coupling unification.

124 parameters in MSSM
Concentrate on a few schemes; and parameter sets within those schemes.





Electroweak Symmetry Breaking



- Search for trileptons & like-sign dileptons.
- Very careful control of backgrounds required.
- Chargino mass limits in the range 115-130 GeV for large branching ratio mSUGRA scenarios.
- Significantly extending LEP limits.



Squark/Gluino Searches

175

75



- LSP no longer necessarily stable : loose dark matter candidate.
- Sparticles can be singly produced.
- HERA :





M_{SQUARK} > 275 GeV excluded for EM strength coupling. Similar limits for stop.
Highly complementary to Tevatron.

SUSY @ LHC

Recent progress : Inclusive signatures. "SUSY Scale" Variable : Fully include tau decay channels. Mass reconstruction in cascade $E_T^{sum} = E_T^{miss} + \sum_{T} p_{T,i}$ decays. Determination of new particle properties. 10⁵ Events/50 GeV/10 fb⁻¹ SM background 1200 10 **SUSY (700 GeV)** 1000 Msusy (GeV) 800 10^{3} 600 400 10 200 Warning: model dependent plot! 10 0 500 1000 1500 2000 500 1000 1500 2000 2500 0 ET sum (GeV) E_T^{sum} (GeV)

Electroweak Symmetry Breaking

SUSY @ LHC

- SUSY spin determination.
- Make use of spin correlations in decay of squark :



- Measure asymmetry between $d\sigma(l^+q)/dm$ and $d\sigma(l^-q)/dm$.
- Exploit fact that $\sigma(pp \rightarrow \tilde{q}) > \sigma(pp \rightarrow \tilde{\bar{q}})$.
- Visible asymmetry at high L (~500/fb)

\neg SUSY







Electroweak Symmetry Breaking

In a Lab Far Far Away



Physics :

- \triangleright Higgs mass to 1 part in 10^6
- **Direct** measurement of $\Gamma(H)$
- Resolve degenerate Higgses

<u>Recent progress</u> : new cooling ideas.

Helical rather than ring cooling combines ionisation cooling with emittance exchange to provide "6D" cooling.



Outlook

<u>WIN'07 :</u>

- New era of precision measurements.
- Higgs discovery :
 - ►SM (unlikely)
 - **BSM** ??? A decent shot.
- Tevatron will still be doubling its luminosity annually – very interesting for searches.
- LHC activities ramping up.
- Clearer ideas for the next experimental steps.



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- Precision EWK Measurements at LEP-II
- SUSY Searches at HERA
- PLENARY

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- **EWK Precision Measurements at the Tevatron**
- : New Physics Searches at the LHC
- Higgs Searches at the Tevatron
- **Top Mass Measurements at the Tevatron**
- Physics at a Future Muon Collider
- Electroweak Measurements at HERA
- SUSY Searches at the LHC
- Searches for New Physics at the Tevatron
- **Top Quark Properties & Physics at the LHC**
- Higgs Searches at the LHC