From HERA to the LHC

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HERA-LHC Workshop 2004 - 2005

- Parton distribution functions
 - X-sections, DGLAP, BFKL and resummation
- Multijet final states & energy flow
 - Rapidity-gap events
- Heavy quarks
 - Input for LHCb
- Diffraction
 - An interesting way to measure the Higgs?
- Monte Carlo tools



Open Questions beyond the Standard Model

- What is the origin of particle masses?
 due to a Higgs boson?
- Why so many flavours of matter particles LHC
- What is the dark matter in the Universe?
- Unification of fundamental forces?
- Quantum theory of gravity?



Why do Things Weigh?

Newton:

Weight proportional to Mass Einstein:

Energy related to Mass Neither explained origin of Mass

Where do the masses come from?

Are masses due to Higgs boson? (the physicists' Holy Grail)



Without Higgs ...

- ... there would be no atoms
 - Electrons would escape at the speed of light
- ... weak interactions would not be weak
 - Life would be impossible: there would be no nuclei, everything would be radioactive

How does the Higgs trick work?





A Phenomenological Profile of the Higgs Boson

• First attempt at systematic survey

A PHENOMENOLOGICAL PROFILE OF THE HIGGS BOSON

John ELLIS, Mary K. GAILLARD * and D.V. NANOPOULOS ** CERN, Geneva

Received 7 November 1975

A discussion is given of the production, decay and observability of the scalar Higgs boson H expected in gauge theories of the weak and electromagnetic interactions such as the Weinberg-Salam model. After reviewing previous experimental limits on the mass of

We should perhaps finish with an apology and a caution. We apologize to experimentalists for having no idea what is the mass of the Higgs boson, unlike the case with charm [3,4] and for not being sure of its couplings to other particles, except that they are probably all very small. For these reasons we do not want to encourage big experimental searches for the Higgs boson, but we do feel that people performing experiments vulnerable to the Higgs boson should know how it may turn up.



























The Particle Higgsaw Puzzle

Is LHC finding the missing piece? Is it the right shape? Is it the right size?



Does the 'Higgs' have Spin Zero?

- Decays into $\gamma\gamma$, so cannot have spin 1
- Spin 0 or 2?
- If it decays into ττ or b-bar: spin 0 or 1 or orbital angular momentum
- Can diagnose spin via
 - angular distribution of $\gamma\gamma$
 - angular correlations of leptons in WW, ZZ decays
- Does selection of WW events mean spin 0?



Does the 'Higgs' have Spin Zero?











Theoretical Constraints on Higgs Mass

- Large $M_h \rightarrow$ large self-coupling \rightarrow blow up at low-energy scale Λ due to renormalization Ξ^{350} exclusion
- Small: renormalization due to t quark drives quartic coupling < 0 at some scale Λ
 - \rightarrow vacuum unstable



• Vacuum could be stabilized by **Supersymmetry**

Elementary Higgs or Composite?

• Higgs field:

 $<0|H|0> \neq 0$

• Quantum loop problems



- Fermion-antifermion condensate
- Just like QCD, BCS superconductivity
- Top-antitop condensate? needed m_t > 200 GeV

New technicolour force?

- Heavy scalar resonance?
- Inconsistent with
 - precision electroweak data?











Combination of LHC & Tevatron

Diffractive MSSM Higgs Production

Diffractive MSSM Higgs Production

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Potentially useful discriminator between different Higgs models

Conversation with Mrs Thatcher: 1982

Think of things for the experiments to look for, and hope they find something different

> Then we would not learn anything!

Wouldn't it be better if they found what you predicted?

