Report from the workshop
The LHC Early phase for the ILC

at Fermilab April 12-14,07

Klaus Desch • Universität Bonn • 30/05/07 • LCWS07 Hamburg

universitätbonn

Interplay and Synergy

$$HC + LC > HC$$

$$HC \oplus LC > HC + LC$$

$$HC \otimes LC > HC \oplus LC$$

LCWS Korea 2002

LHC/ILC Study group
Phys. Rept. 426 (2006) 47

Conclusion 2002-2006:

Terascale physics needs both LHC and ILC

Many examples for

- joint interpretation (added value from ILC)
- joint analyses (feedback from ILC to LHC)

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Physics interplay of the LHC and the ILC☆

The LHC/ILC Study Group

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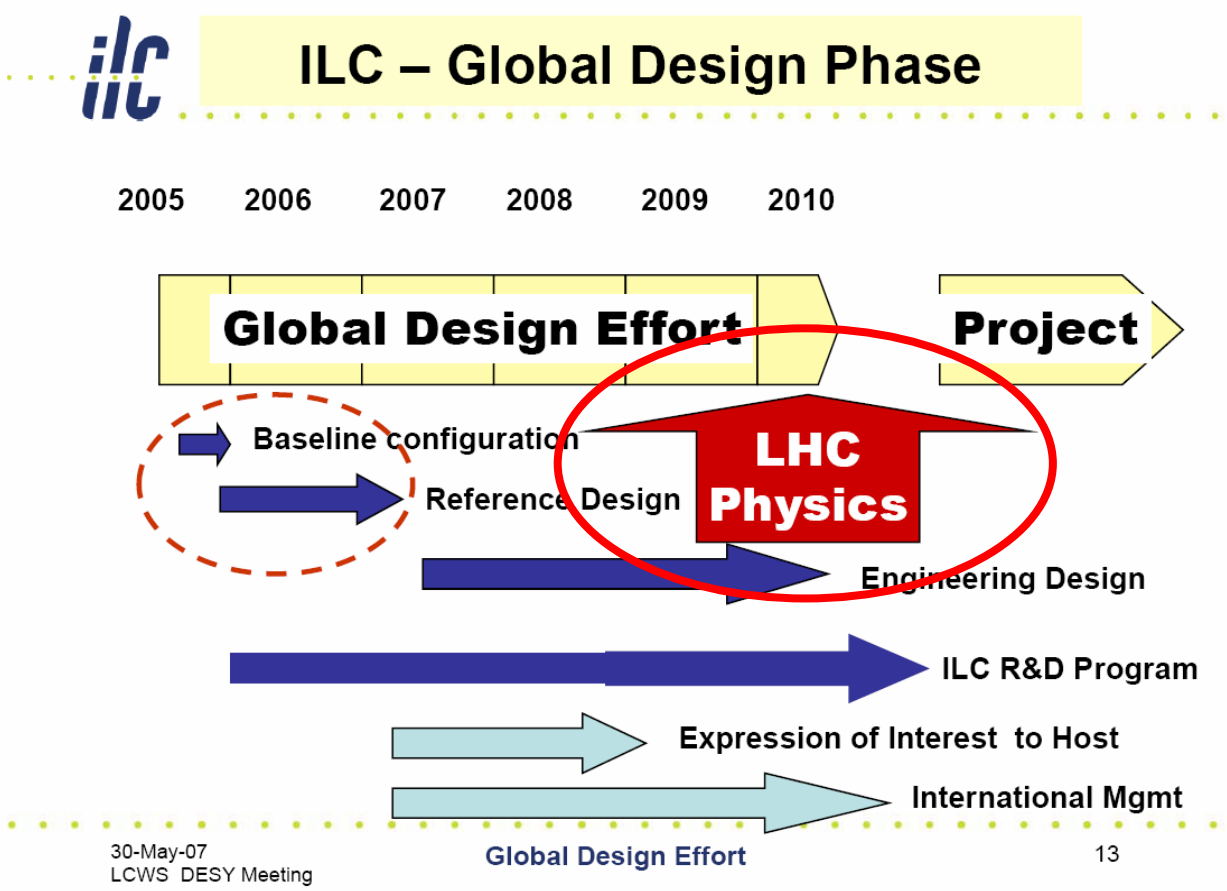
Getting Excited



With first pp collisions at 14 TeV next year, it is obvious that we have to start understanding implications of LHC discoveries for the ILC in much more detail

Workshop Charge

Workshop OC

What could be the impact of early LHC results on the choice of the ultimate ILC energy range and the ILC upgrade path?

Could there be issues that would need to be implemented into the ILC machine and detectors design from the start?

Could there be cases that would change the consensus about the physics case for an ILC with an energy of about 500 GeV? (e.g. faster energy upgrade path)

What are the prospects for LHC/ILC interplay based on early (for the workshop: early=10fb^{-1}) LHC data?

Strategy: Largely signal-driven (not so much model driven)

Workshop statistics

http://conferences.fnal.gov/ilc-lhc07/

- 101 registered participants
- 13 plenary talks + WG summaries
- 27 parallel talks + lots of discussion
- 4 Working Groups

WG 1: Only one state, SM-like Higgs boson, at the early stage of LHC
Convenors: Howard Haber, Laura Reina, Alexei Raspereza, Markus Schumacher

WG 2: No Higgs boson at the early stage of the LHC
Convenors: Tim Barklow, Jack Gunion, Wolfgang Kilian

WG 3: BSM: Leptonic resonances and Multi-Gauge-Boson signals
Convenors: Tao Han, Sabine Riemann, Tom Rizzo

WG 4: BSM: Missing energy (+nothing, leptons, jets) and everything else
Convenors: Filip Moortgat, Jose Santiago, James Wells, Graham Wilson

Good balance of experiment (LHC and ILC) and theory

WG 1: Higgs-like state at the LHC

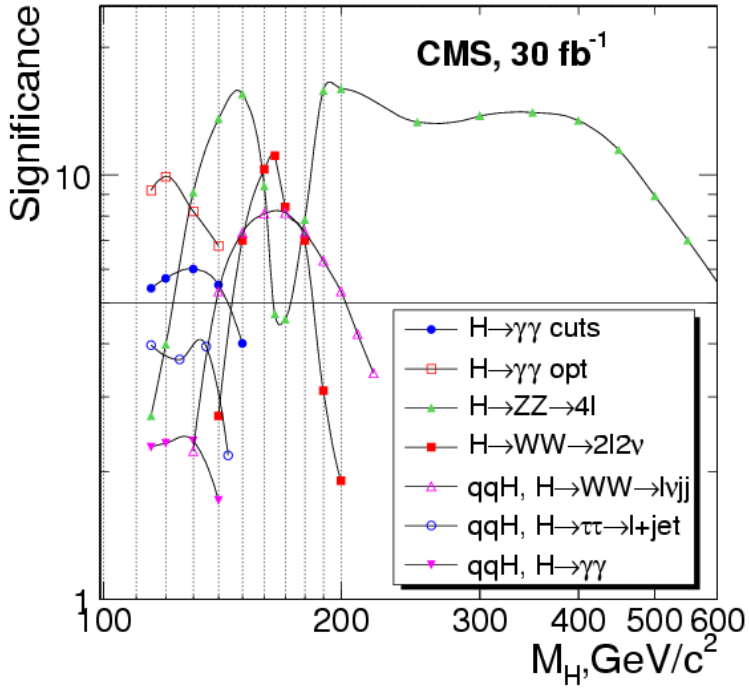
Contributions

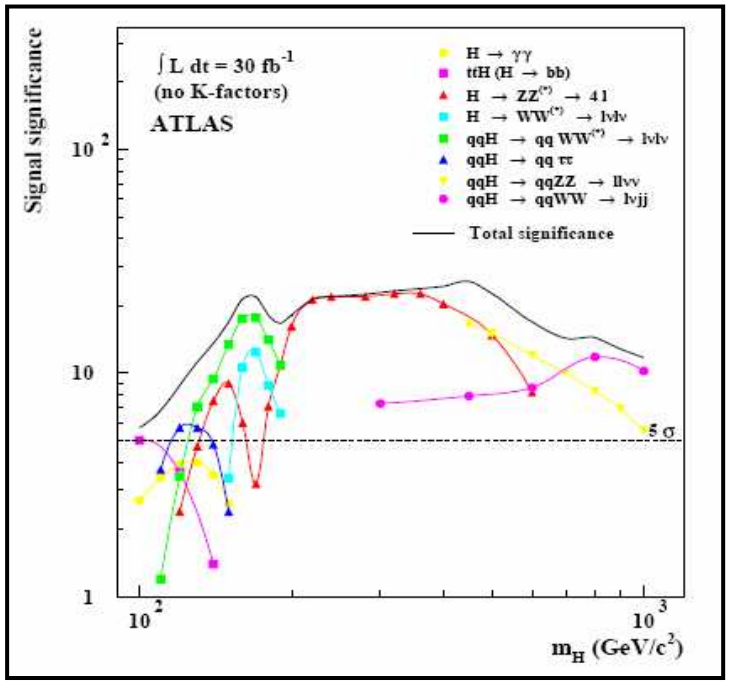
Plenary:
K. Cranmer, Higgs signals at the LHC
H. Logan, Higgs Theory
R. van Kooten, Higgs at ILC

Parallel:
D. Rainwater, SM Higgs at the LHC with 10 fb−1
B. Mellado, SM Higgs searches in the early phase of the LHC with ATLAS
A.de Roeck, SM Higgs searches in the early phase of the LHC with CMS
B.Raspereza, Experimental aspects of Higgs searches at the ILC
M. Weber, Precision calculations for H → WW/ZZ → 4f with PROPHECY4f
P. Nadolsky, Resummation for Higgs signal and background in the diphoton decay mode
A. Belyaev, Light MSSM Higgs boson scenario and its test at hadron colliders
G. Shaugnessy, Phenomenology of the SM with a scalar singlet
G. Huang, Higgs to aa at the LHC

WG 1: Higgs-like state at the LHC

- SM-like Higgs discovery possible with ~10 fb^{-1}ud* at ATLAS and CMS



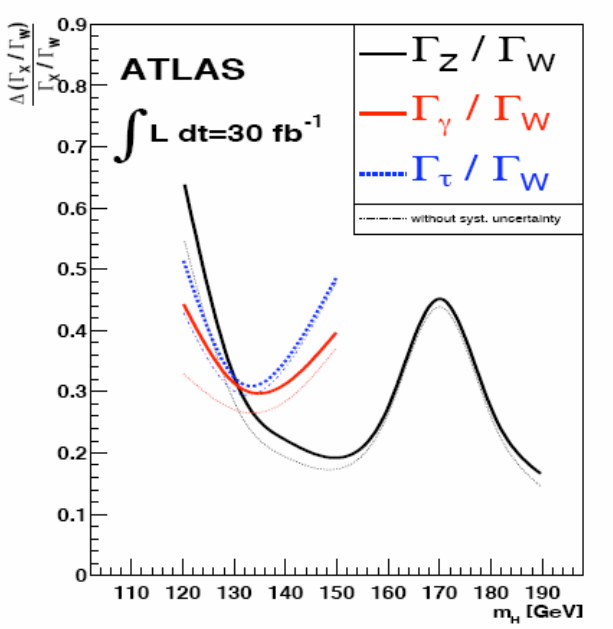


* ud = „understood data" F.Moortgat

WG 1: Higgs-like state at the LHC

- only rather little will be known about the new state at this early stage but probably enough for ILC decision/planning

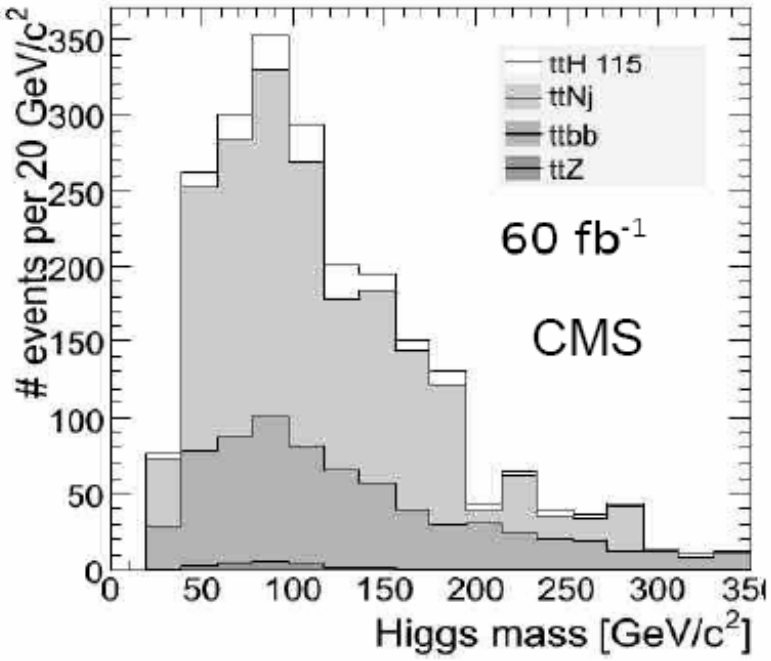
  - mass (from $\gamma\gamma$ or ZZ)
  - VBF or H->ZZ -> gauge coupling present (-> HZ production@ILC)
  - rough determination of partial width coupling ratios need at least 30 fb^{-1}

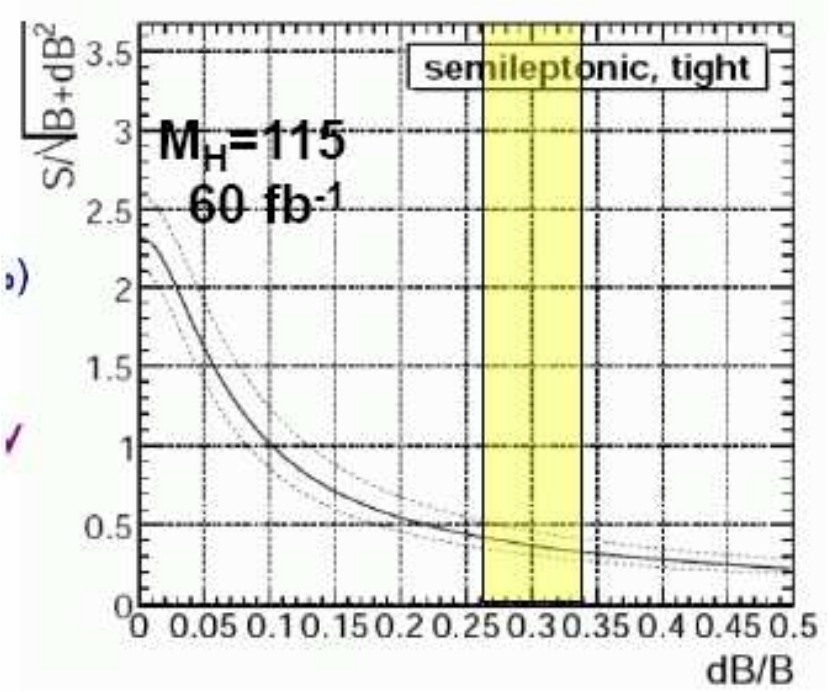


Dührssen et al

WG 1: Higgs-like state at the LHC

ttH at LHC appears to be increasingly difficult – stay tuned





de Roeck

WG 1: Higgs-like state at the LHC

Consequences for ILC:

Mh <~ 160 GeV
Full program of Higgs precision measurements can (and must) be done

Mh >~ 160 GeV
ILC action required!!

Shopping list:

- couplings to WW, ZZ still measurable (but how much better than LHC?)
  → improve precision (include hadronic Z?, more luminosity?)
- fully explore WW-Fusion, total width measurement from WW→H→WW
- Yukawa couplings hard to access
  → BR(H→bb) measurable up to ~ 220 GeV (redo with new vertex tag)
  → H→tt* below threshold ?
  → ttH needs high sqrt(s) (studied up to m_H= 200 GeV so far, go beyond?)
- total width from HZ threshold scan?
- selfcoupling from ννHH→ννWWWW (sqrt(s), luminosity)?
- stress importance of EW precision measurements (Giga-Z,…)

We need to continue with realistic ILC physics studies after DCR

WG 2: No Higgs (yet) at the early LHC

Contributions

Plenary:
C. Wagner, On the possible absence of Higgs signals at the LHC, Theory
S. Chivukula, No Higgs signals at the LHC, Theory

Parallel:
G. Cacciapaglia, No Higgs Models
T. Tait, No Higgs with 10 fb^{-1} at the LHC: Implications for Supersymmetric Models
J. Reuter, No Higgs Scenario in Little Higgs Models in the first 10 fb^{-1} at LHC
J. Gunion, Extra/Exotic Higgs Decay Channels

A fork on the road:

A. Truly no Higgs boson?

B. At least one Higgs boson but it escaped detection at LHC with 10 fb^{-1}

When you come to a fork in the road, take it. - Yogi Berra

WG 2: No Higgs (yet) at the early LHC

A. Truly no Higgs boson?

S. Chivukula
G. Cacciapaglia

1. Higgs-less models from XD (gauge boson (+fermion) towers
new GBs cannot be too heavy (unitarity) and not too light (prec EW)

⇨ observable at LHC with 10 fb^{-1}
⇨ clear case for ILC (-> WG3 „leptonic resoncanes")

2. technicolor-like strong interaction (~ traditional)

⇨ multi-gauge boson signals at LHC
generic signal: deviations in high-mass VV→VV

LHC action required:
more expt. studies + phenomenolgy (realistic generators!) needed
exclusion potential at LHC? What Luminosity needed?
(excluding strong VV-scattering means
that a weak EWSB signal has been missed!) ⇨ ILC

WG 2: No Higgs (yet) at the early LHC

B. Higgs escaped detection so far… (with ~10fb^{-1})

⇨ Higgs is not SM-like
⇨ Higgs is probably also not „standard" MSSM-like

Possibilities:

SUSY implications **Tait, Wagner**

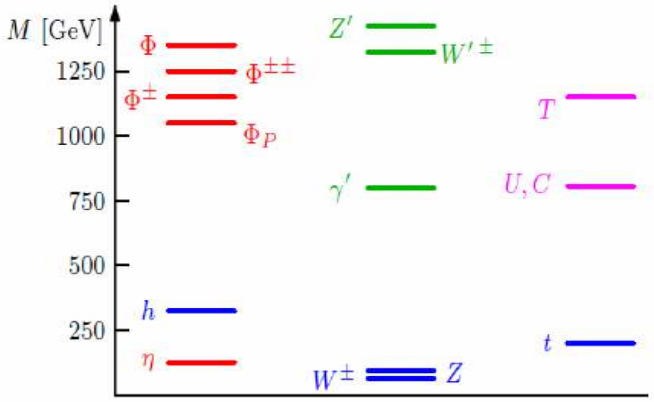
- if no Higgs seen, but evidence for SUSY particles
  - ⇨ more complex Higgs sector (NMSSM, …)
  - ⇨ light (< 114 GeV) e.g. $h \to aa \to 4\tau$ tough at LHC
  - ⇨ invisible Higgs decays?

ILC can discover all of these!
Evidence for SUSY particles w/o light Higgs should be enough motiviation for ILC…

WG 2: No Higgs (yet) at the early LHC

Little Higgs Model **Reuter**

- „standard" Higgs may be (very) heavy and broad ⇨ delayed LHC discovery
- light and (very) narrow pseudoscalar ⇨ delayed (or non-) discovery at LHC
- extra gauge bosons and fermions



Arkani-Hamed et al, Littlest Higgs

- Lots of motivation for ILC
  But when is there enough evidence? ⇨ Action!

Extra/Exotic Decay Channels **Gunion**

- extra/exotic Higgs decays are possible in extended Higgs models even w/o SUSY
- light (<114 GeV) Higgs which evaded LEP bounds is tough at LHC
- invisible+broad state? **van der Bij**
- consequence for ILC?
  How to convince ourselves that such a scenario is present?
  Exclude strong EWSB scenario?

WG 3: Leptonic Resonances and Multi-gauge boson signals

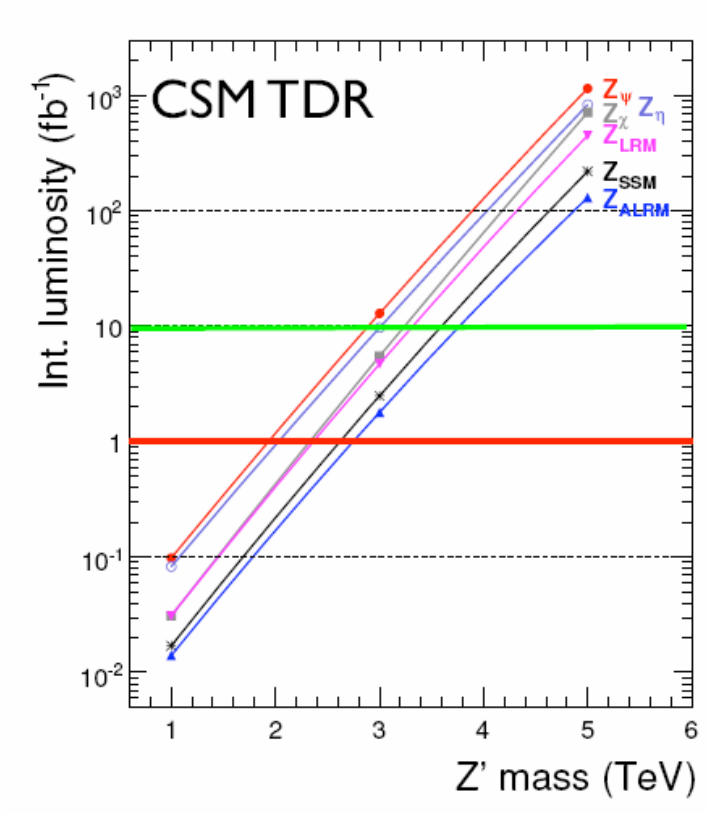
Contributions

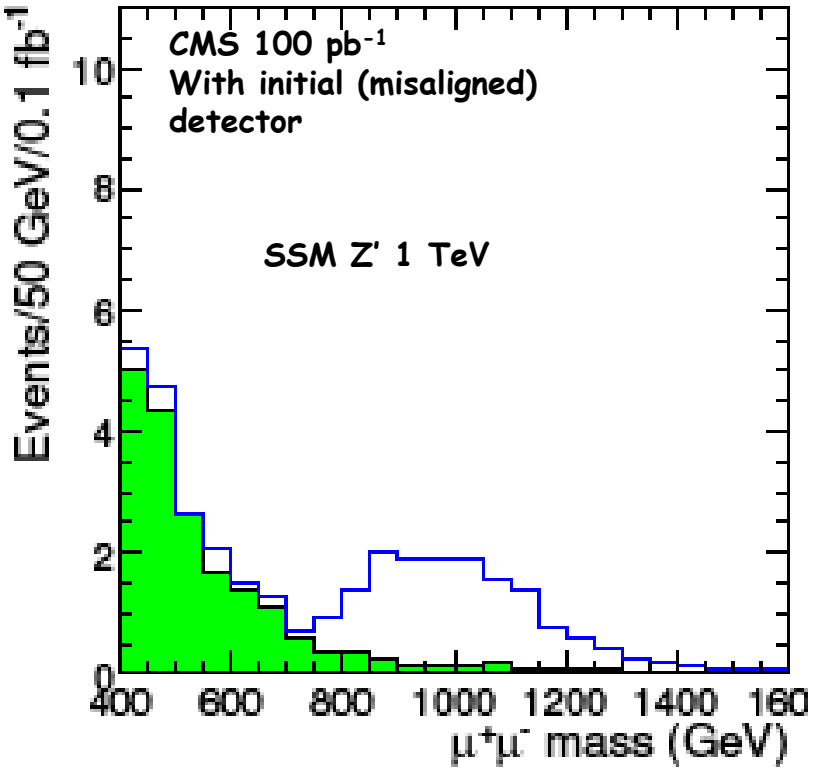
Plenary:
J. Mnich, Multi Gauge Bosons at the LHC
G. Azuelos, Leptonic Resonances at the LHC
D. Wackeroth, Leptonic Resonances and Multi Gauge Bosons, Theory
A.De Roeck, Beyond SM signals at the LHC
M. Oreglia, Beyond the Standard Model Signals at the ILC

Parallel:
K. Kong, Resonances in Universal Extra Dimensions
S. Riemann, Discoveries through ILC precision measurements
B. Lillie, Using top quarks to probe the Randall-Sundrum model
G. Landsberg, Search for Extra Dimensions and Leptoquarks in Early LHC data
T. Tait, New (and Not So New) Z' Gauge Bosons and the LHC/ILC Connection
G. Brooijmans, New and old gauge boson discoveries in early LHC data
T. Scott, Using object correlations to extract new physics from the LHC

WG 3: Leptonic Resonances and Multi-gauge boson signals

Leptonic Z'-like resonance can be seen very fast at LHC

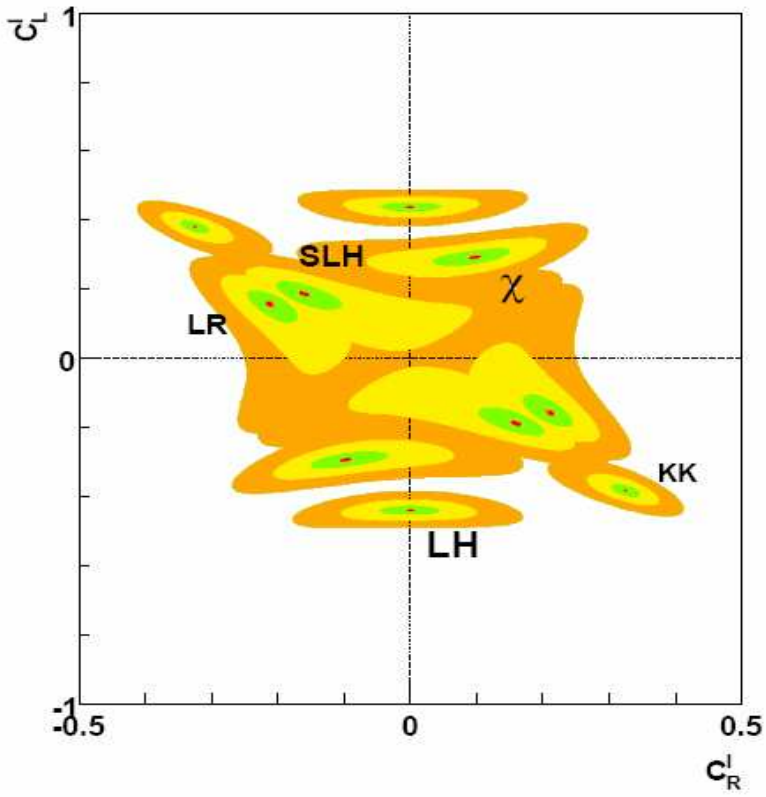




WG 3: Leptonic Resonances and Multi-gauge boson signals

- Not very likely, that a <500 GeV ll-Resonance appears (but ILC would of course study it in s-channel ☺)
- A resonance within the direct reach of an upgraded ILC would probably call for a fast upgrade path (still would like to do the precision Higgs (if there) and SM program)
- A resonance beyond the direct ILC reach: ILC+LHC can determine coupling structure from interference with γ/Z exchange to determine its nature
- also for W´ (ee->$\nu\nu\gamma$) S.Riemann

Godfrey et al, (also S.Riemann)



E6 χ model
LR symmetric
Littelest Higgs (LH)
Simplest Little Higgs (SLH)
KK excitations in ED

WG 4: Missing Energy (+ everything else)

Contributions

Plenary:
S. Asai, Missing Energy Signals at the LHC
J. Lykken, Missing Energy and other Signals, Theory
A.De Roeck, Beyond SM signals at the LHC
M. Oreglia, Beyond the Standard Model Signals at the ILC

Parallel:
R.Cavanaugh, Aspects of MET measurements at the LHC
G.Wilson, Experimental aspects of investigating missing energy signatures at the ILC
K.Wang, Nearly degenerate Gauginos at the LHC
B.Lillie, Breaking degeneracies in the MSSM- inverting the LHC with the ILC
R.Hill, T-parity in Little Higgs Models
S.Chang, Some Complications in Analyzing Missing Et Signals

WG 4: Missing Energy (+ everything else)

G. Wilson

- Suppose:
  - –A light Higgs is found. Consistent with SM, SUSY.
  - –Only a jets+MET signal is found at LHC.
- What is the minimum √shat involved in the signal ?
  - –Can we estimate the e^+e^- production threshold reliably ?
- Can the signal be produced in e^+e^- (does it couple to the γ, W, Z, h) ?
  - –Presumably no info will be available.
  - –If it's a gluino, e^+e^- is probably irrelevant for direct tests ...
- Is there ANY robust logical inference on the masses of lighter particles that can be made, e.g. M_{LSP} ???

Many people made this point!

Action required: need as model-independent as possible tools to interpret LHC Et-miss data w.r.t. involved masses of colored and colorless particles
- Full reconstruction of long cascades at LHC **(Gjelsten,Miller,Osland)**
- Global SUSY fits **(Fittino, SFITTER)**
- Likelihood maps **(Allanach, Plehn et al)**
- MARMOSET **(Arkani-Hamed et al)**
- ??? **(your name could be here)**

Summary and Plans

Very stimulating workshop
Good participation from LHC,ILC,Theory – all are important!

Lots of specific items identified
Needs and deserves more attention and (of course) more people!

This was not a one-time excercise
WGs continue to work

Next workshop at SLAC in 2nd week of November 07 (t.b.c.)