LHC / LC Study Group Report

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Oxford 01/2004

Worldwide Study of the Physics and Detectors for Future Linear e^+e^- Colliders

www.ippp.dur.ac.uk/~georg/lhclc

1. Introduction

- Physics case is well established both for LHC and LC
- LHC: $\gtrsim 2007$, expected to run for $\mathcal{O}(20)$ years

  LC: $\gtrsim 2015$?
- LHC and LC physics is complementary in many respects, similarly to previous generations of hadron and lepton colliders

  $\Rightarrow$ expect mutual benefits for physics program at both machines
- Qualitatively obvious,

  more quantitative analyses require detailed case studies, close collaboration of experts from LHC and LC as well as from theorists and experimentalists

LHC / LC Study Group

www.ippp.dur.ac.uk/~georg/lhclc

- Investigation of LHC / LC interplay:

  How can analyses at the LHC profit from results obtained at the LC and vice versa?

  Which synergy effects arise from concurrent running of LHC and LC?

- World-wide working group, started in spring 2002

  Collaborative effort of Hadron Collider and Linear Collider communities

How far are we?

- We had six working group meetings so far (most at CERN)
- Draft of first working group report exists:

  $\gtrsim 400$ pages, ≈ 40 individual contributions, $\gtrsim 100$ authors
- Currently going through editorial process

  Editors: T. Barklow, E. Boos, A. De Roeck, D. Denegri, K. Desch, H. Haber, F. Gianotti, R. Godbole, J. Gunion, S. Heinemeyer, J. Hewett, K. Kawagoe, K. Mönig, M. Nojiri, F. Paige, G. Polesello, F. Richard, S. Riemann, H. Schellman, W.J. Stirling P. Zerwas, G. W.
- Next meeting (study group $+$ editorial meeting):

  Feb. 27, CERN

2. Examples

Determination of SUSY parameters at LHC / LC

[*M. Chiorboli, B.K. Gjelsten, J. Hisano, K. Kawagoe, E. Lytken, U. Martyn, D. Miller, M. Nojiri, P. Osland, G. Polesello, A. Tricomi '03*]

Production of SUSY particles at LHC $\Rightarrow$ complicated final states,

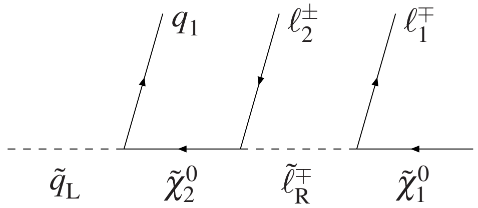
e.g.: $\tilde{g} \to \bar{q}\tilde{q} \to \bar{q}q\tilde{\chi}_2^0 \to \bar{q}q\tilde{\tau}\tau \to \bar{q}q\tau\tau\tilde{\chi}_1^0$

Production of uncolored particles via cascade decays in general much more promising than direct production (small rates, large backgrounds)

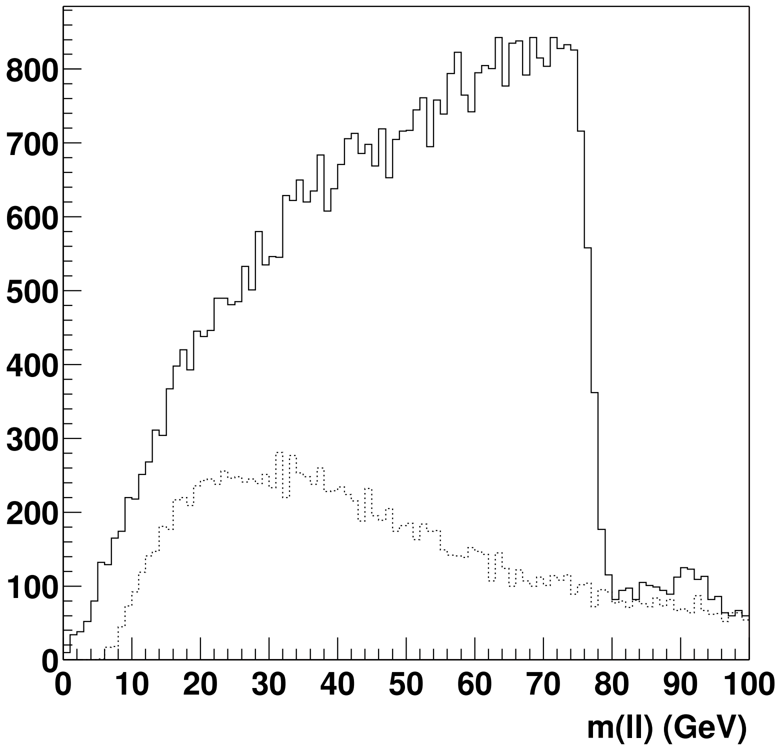
Many states are produced at once

Reconstruction of sparticle masses at the LHC

Cascade decays: complicated decay chains for squarks and gluinos



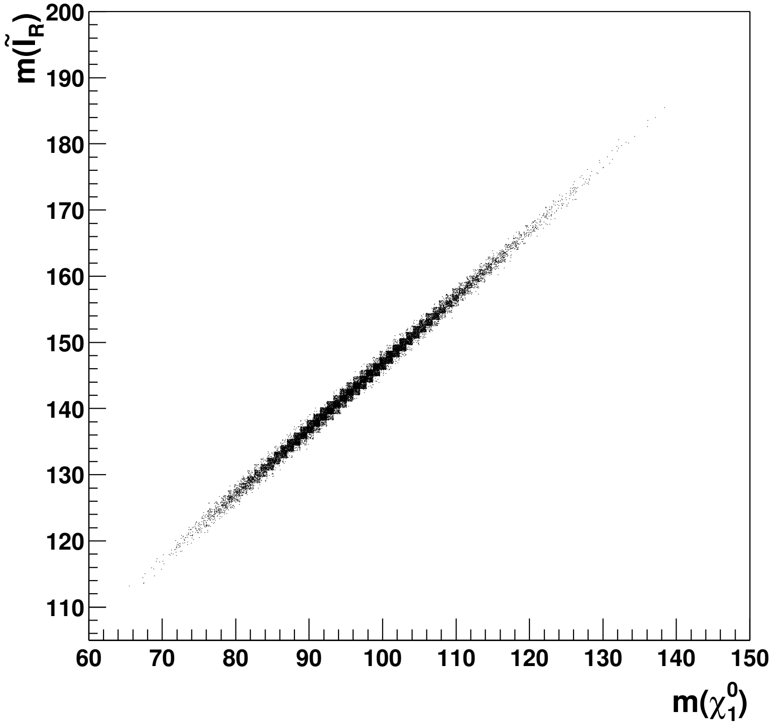
Main tool: dilepton "edge" from $\tilde{\chi}_2^0 \to \ell^+\ell^-\tilde{\chi}_1^0$



Examples worked out from ATLAS and CMS for SPS1a (favourable scenario for both LHC and LC)

LHC analysis with LC input: mass of lightest SUSY particle (LSP)

Reconstruction of the states in decay chain requires precise knowledge of LSP mass



$\Rightarrow$ Precision measurement of $m_{\rm LSP}$ at LC leads to significant improvement in determination of slepton, squark and gluino masses at the LHC

Search for the heaviest neutralino at LHC following the prediction from LC

[K. Desch, J. Kalinowski, G. Moortgat-Pick, M. Nojiri, G. Polesello '03]

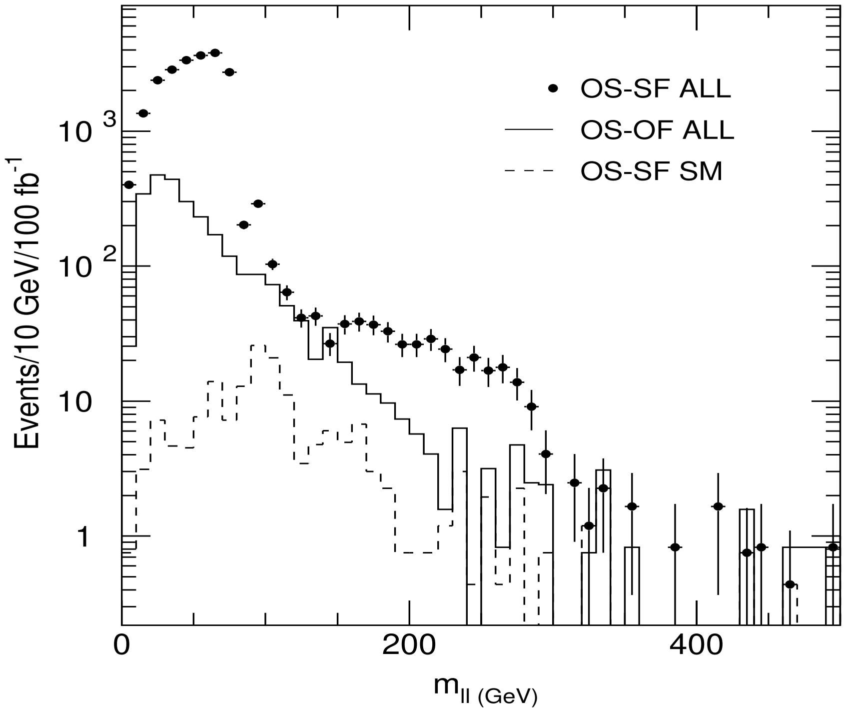
Assumption: lightest neutralino and chargino states $(\chi_1^0, \chi_2^0, \chi_1^\pm)$ accessible at LC

$\Rightarrow$ Determination of all parameters in neutralino/chargino sector possible

$\Rightarrow$ Prediction of masses and decay properties of all neutralinos and charginos, e.g. $m_{\tilde{\chi}_4^0} = 378.3 \pm 8.8$ GeV

$\Rightarrow$ With this information the heaviest neutralino can be identified at the LHC using a dilepton "edge"

Search for the heaviest neutralino at LHC following the prediction from LC



$\Rightarrow$ Determination of $m(\tilde{\chi}_4^0)$ at LHC with high precision

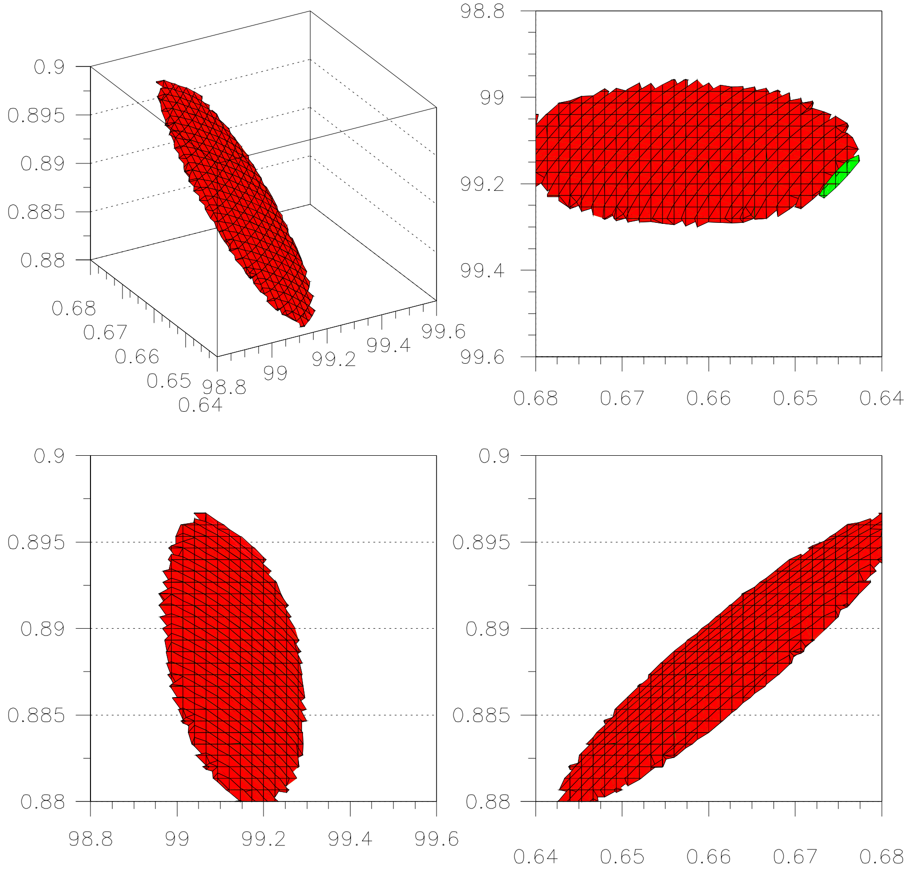
$\Rightarrow$ Feeding $m(\tilde{\chi}_4^0)$ back into LC analysis provides additional information

$\Rightarrow$ Improved accuracy of parameter determination at LC

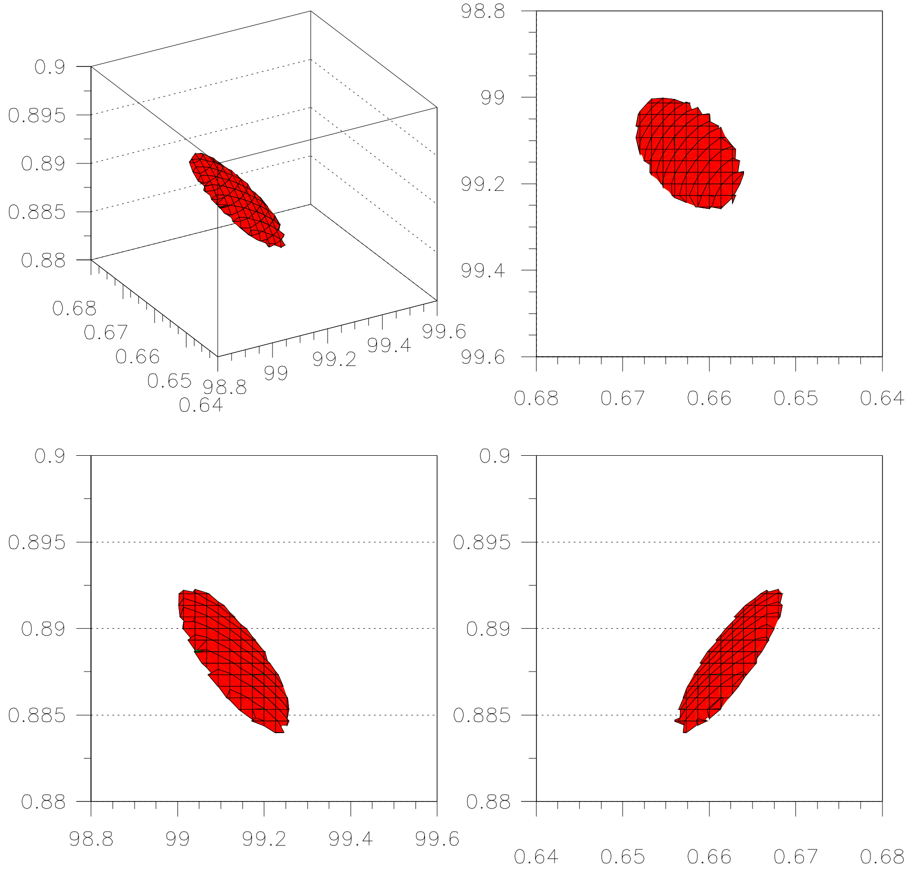
LC analysis with LHC input

Determination of neutralino parameter M_1 and chargino mixing angles $\cos\phi_{\rm L}$, $\cos\phi_{\rm R}$:

LC information alone



LHC + LC information



LHC / LC synergy

Search for heaviest neutralino at LHC is typical example for possible LHC / LC synergy effects:

If statistically marginal signal appears at the LHC right where it was predicted from LC information

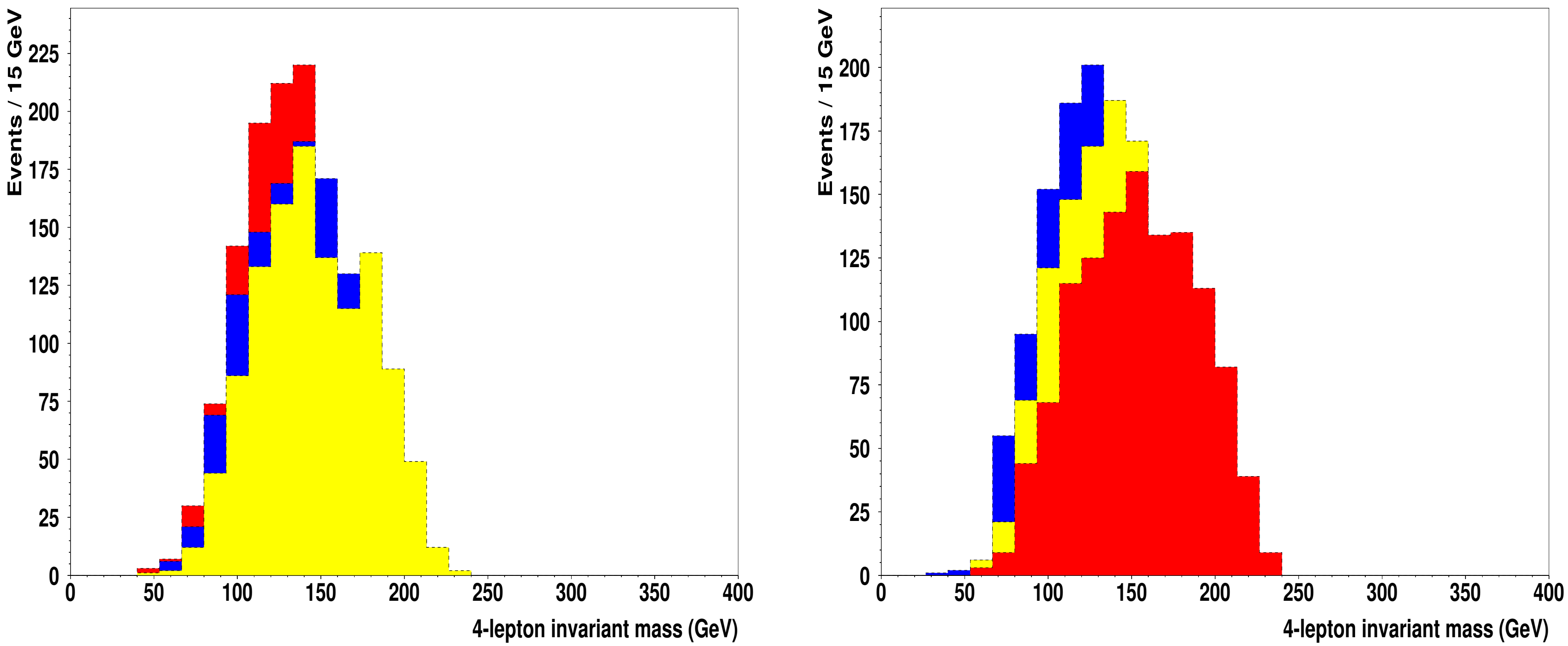
$\Rightarrow$ LC input can be crucial for optimised searches and possible upgrades at the LHC

- LC prediction leads to increase of LHC statistical sensitivity!
- Improved cuts, modified triggers
- Call for higher luminosity
- ...

Determination of M_{A} from heavy Higgs decays into SUSY particles at the LHC

[*F. Moortgat ’03*]

$H, A \to \tilde{\chi}_2^0 \tilde{\chi}_2^0$: Four lepton invariant mass distribution for $M_{\mathrm{A}} = 350 \pm 20$ GeV (left) and $M_1 = 60 \pm 10$ GeV (right)



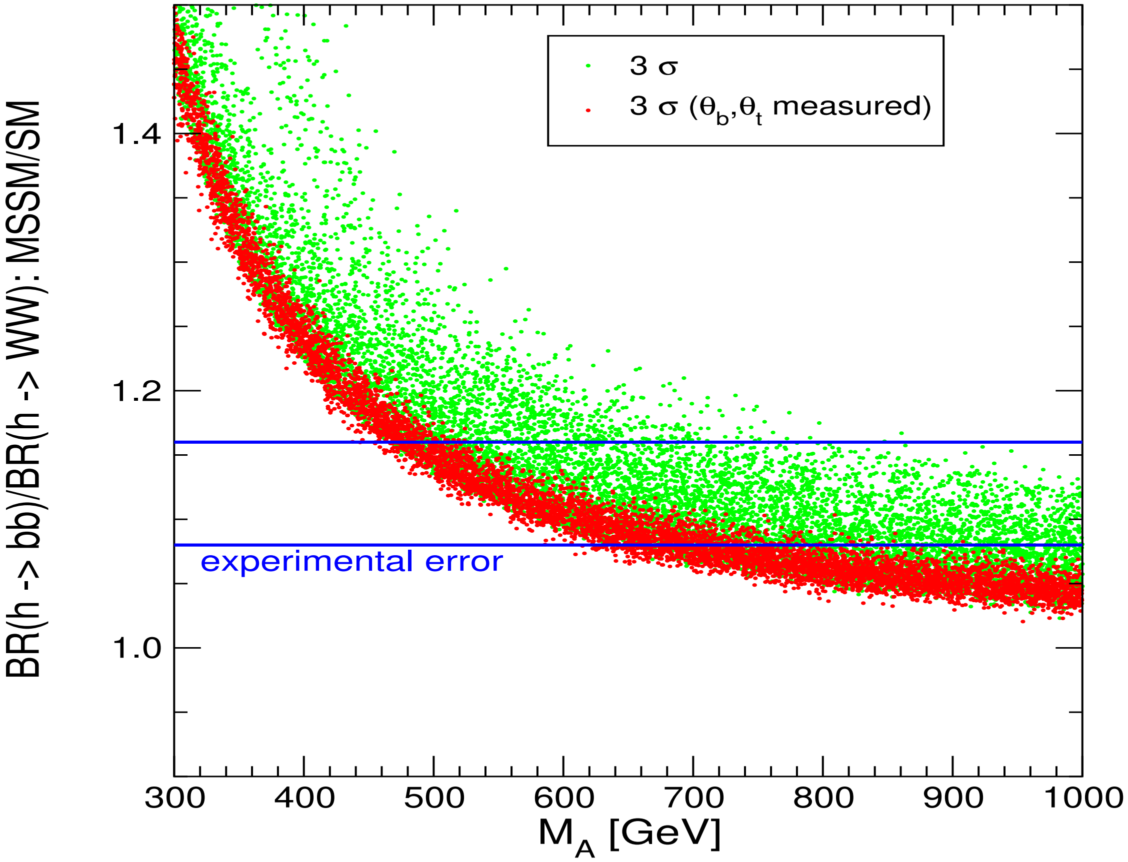
$\Rightarrow$ Precise knowledge of LSP mass from LC crucial for determination of M_{A}

Indirect constraints on M_A from Higgs BR measurements at the LC using LHC / LC input

[*K. Desch, E. Gross, S. Heinemeyer, G.W.*]

LC measurement of

$$\left[\mathrm{BR}(h \to b\bar{b})/\mathrm{BR}(h \to WW^*)\right]_\mathrm{MSSM} / \left[\mathrm{BR}(h \to b\bar{b})/\mathrm{BR}(h \to WW^*)\right]_\mathrm{SM}$$



Higgs BRs from LC measurements

Parameters of $\tilde{\mathrm{t}}$ / $\tilde{\mathrm{b}}$ sector from LHC / LC analysis

Comparison:

no experimental information on $\theta_{\tilde{\mathrm{b}}}$, $\theta_{\tilde{\mathrm{t}}}$

$\Delta\theta_{\tilde{\mathrm{b}}} = 20\%$, $\Delta\theta_{\tilde{\mathrm{t}}} = 10\%$

$\Rightarrow$ Knowledge of $\tilde{\mathrm{t}}$ / $\tilde{\mathrm{b}}$ sector parameters is crucial

Higgs coupling measurements at LHC and LC

Top Yukawa coupling:

[*S. Dawson, A. Juste, L. Reina, D. Wackeroth, K. Desch, M. Schumacher; D. Rainwater et al.*]

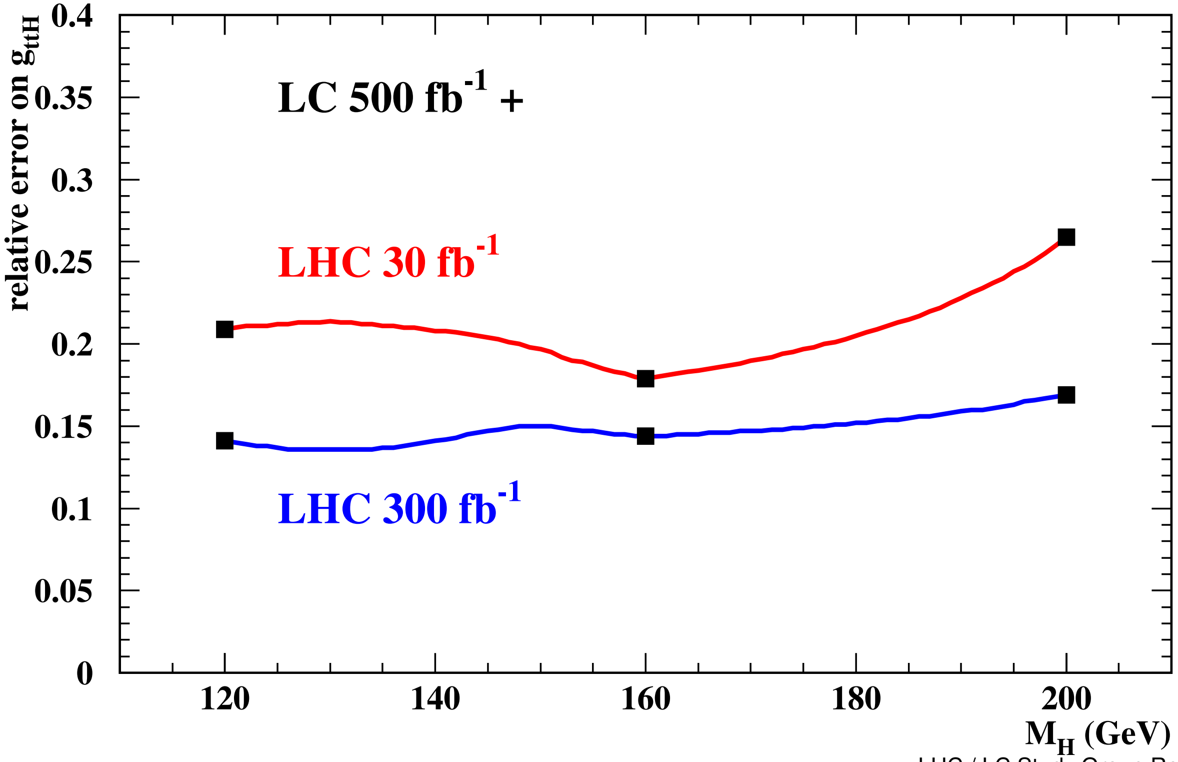
Only preliminary measurement of tth coupling at 500 GeV LC for light Higgs

Precision measurement requires LC with 800–1000 GeV

LHC measures $(\sigma \times \mathrm{BR})$

⇒ Yukawa coupling can be extracted if precise measurement of Higgs BR's from LC are used

Combination of measurements at LHC / LC running at $\sqrt{s} = 350$ GeV:

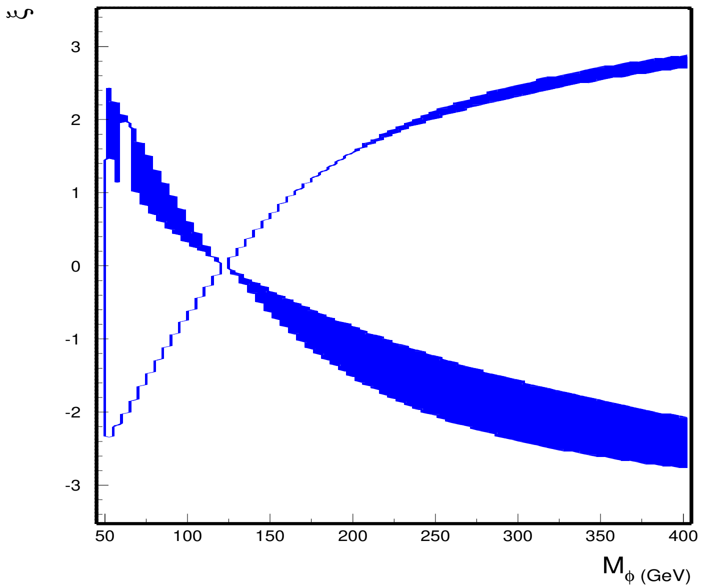


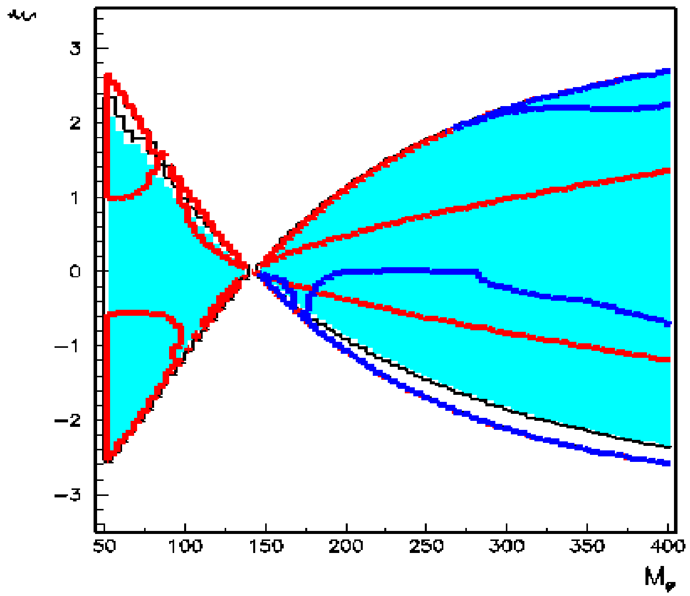
Higgs and radion searches at LHC and LC

[*M. Battaglia, S. De Curtis, A. De Roeck, D. Dominici, J. Gunion*]

Models with 3-branes in extra dimensions predict radion ϕ, can mix with the Higgs

Parameter regions where Higgs significance is below 5σ at the LHC with 30 fb^{-1} (left), regions where the precise measurements of the $hb\bar{b}$ and hWW couplings at the LC provide $> 2.5\sigma$ evidence for the radion mixing effect (right):





3. Conclusions

- LHC / LC interplay is a very rich field

  Extends physics potential of both machines

  Topics covered in this talk are just a small survey

- In order to investigate the interplay, we need detailed information about how well LHC and LC can measure a wide variety of observables in different scenarios

  $\Rightarrow$ need to stay tuned for input from LHC and LC simulations

- First LHC / LC working group document is on a good way:
  Full draft will be circulated soon

- Work doesn't stop with the completion of the present working group report – we have just scratched the surface so far