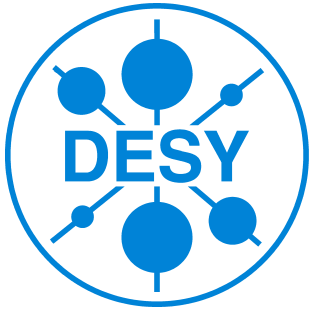
The physics chapters in the GDE documents

Klaus Mönig



On behalf of Abdelhak Djouadi, Joe Lykken, Klaus Mönig, Yasuhiro Okada, Mark Oreglia and Satoru Yamashita

Introduction

Documents to be produced by end 2006:

- GDE ILC Reference Design Report (incl. a short physics chapter)
- Detector Concepts Report (incl. a longer physics chapter)

Editors of the physics chapters (1 exp., 1 theo. / region):

- America: Mark Oreglia, Joe Lykken
- Asia: Satoru Yamashita, Yasuhiro Okada
- Europe: Klaus Mönig, Abdelhak Djouadi

Timescale

- Bangalore: Presentation and discussion of outline
- Vancouver (July): Detailed discussion with the community
- Valencia (November): Presentation of final draft

Proposed Outline

- Introduction
  - Physics landscape in 2015 (incl. possible outcome from LHC) (JL)
  - Important open questions in particle physics (JL)
  - Possible running scenario for ILC (KM)
  - Physics signals at the ILC (MO)
- The Higgs system (SY)
- Couplings of gauge bosons (KM)
- Top quark physics and QCD (MO)
- Supersymmetry (AD)
- Alternatives to SUSY (YO)
- Connections to cosmology
  New item suggested by the WWS

(In () assigned editor)

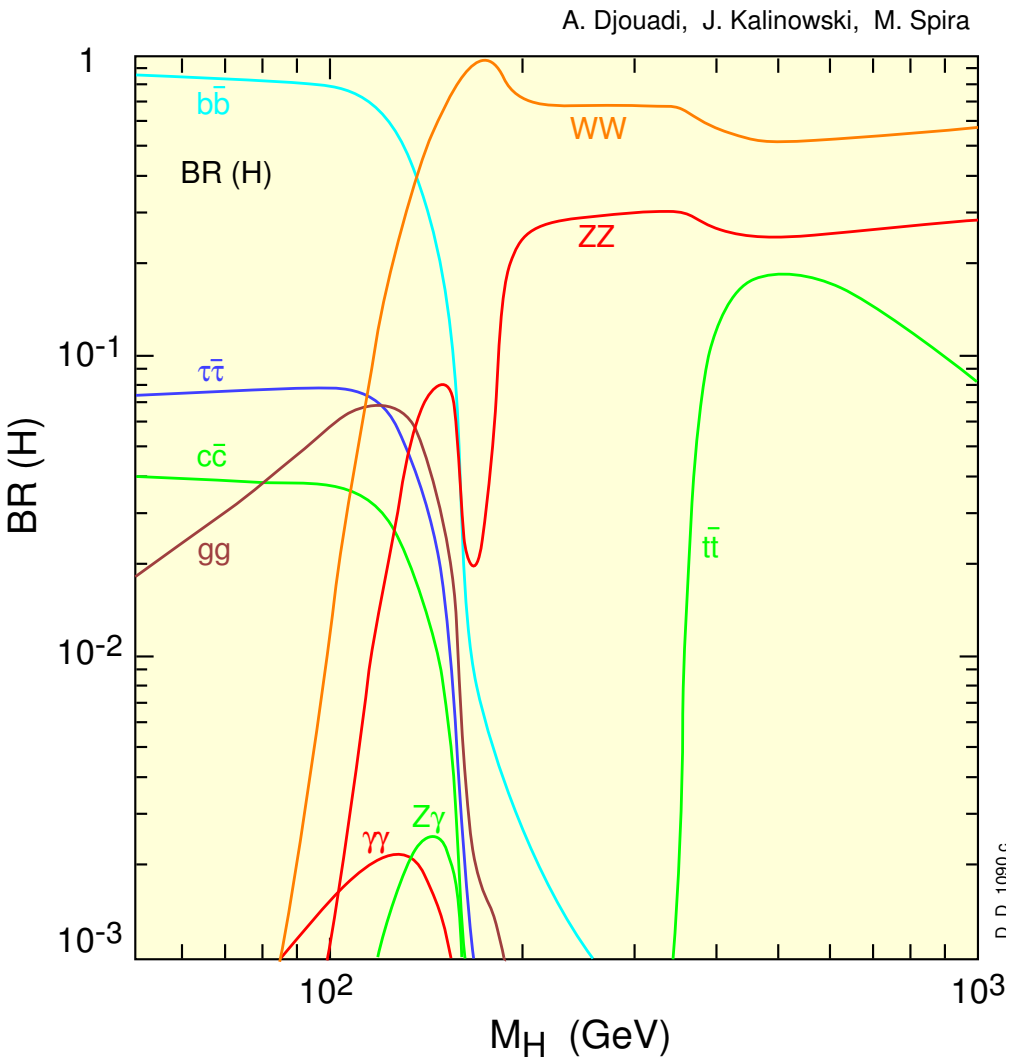
Remarks on the outline

- The outline is strictly physics driven
  - "Signals" like Z' appear in different places
  - The main ones are collected in the "Physics signals" subsection of the introduction and then referred to later
    (This section also motivates the need for a superb detector and the corresponding requirements for R&D)
- The chapter has to justify 500 GeV as a machine worthwhile on its own whatever LHC finds and the need for a 1 TeV upgrade
- The connections to LHC, cosmology etc. have to be stressed
- What about simultaneous running with LHC?
- "Standard physics" including Higgs will be described in detail
- "New physics" will be described in form of a few examples
- The gain from "options" will be mentioned when appropriate

The Higgs section

Some personal introductory comments:

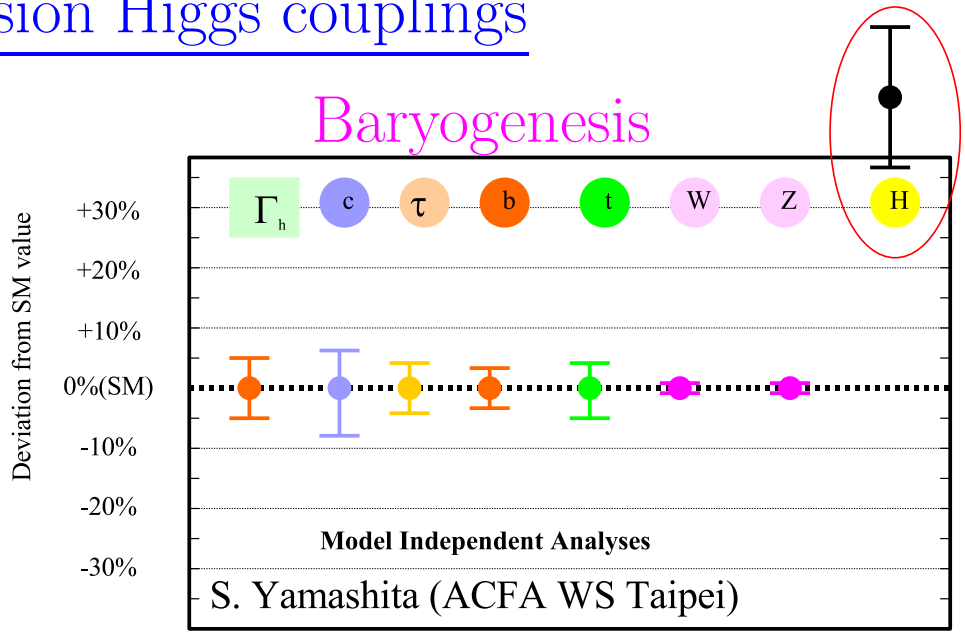
- For me the Higgs is the key motivation of ILC at least before light SUSY is seen
- The physics case is rather simple if $H \to b\bar{b}$ is large
- We have to phrase very carefully the possibility $m_H \sim 200\,\mathrm{GeV}$ where $H \to$ fermions decays are invisible and LHC can do a lot using spin correlations



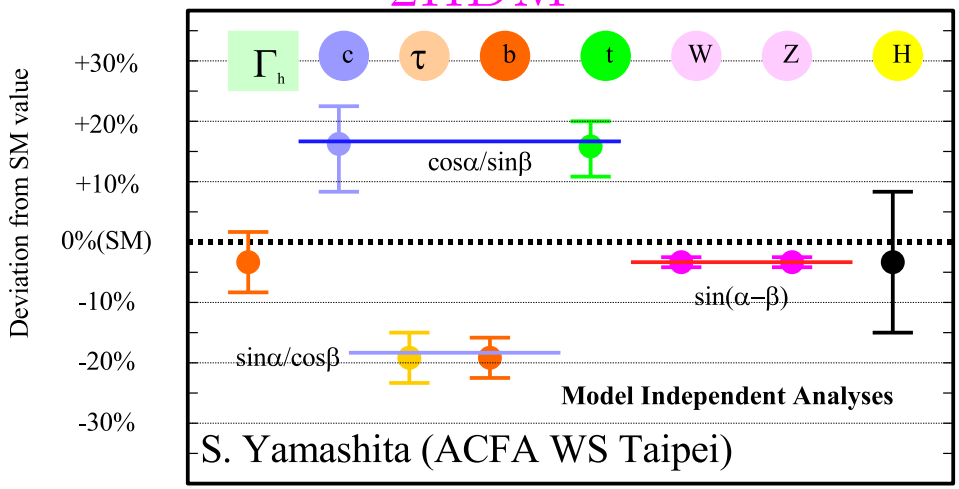
Applications of precision Higgs couplings

Especially the Higgs-coupling measurements are a powerful test of the model that LHC cannot do

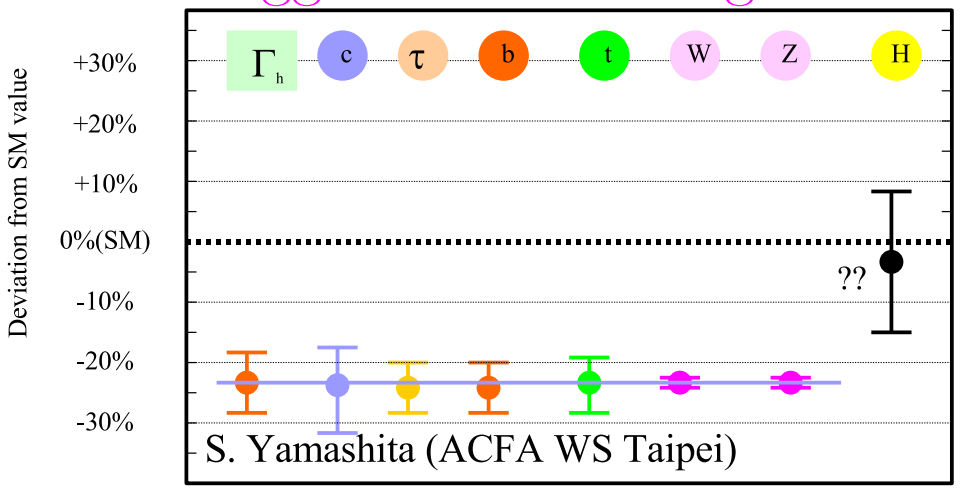
Baryogenesis



2HDM



Higgs-Radion mixing



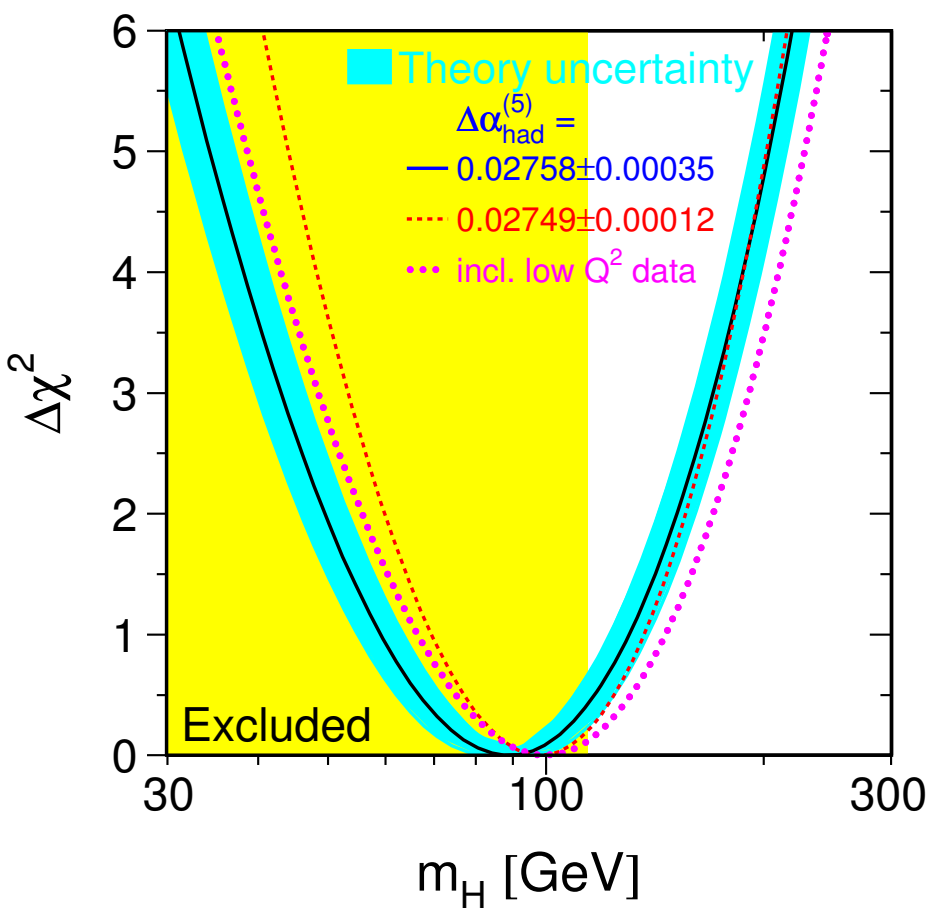
Outline of the Higgs section

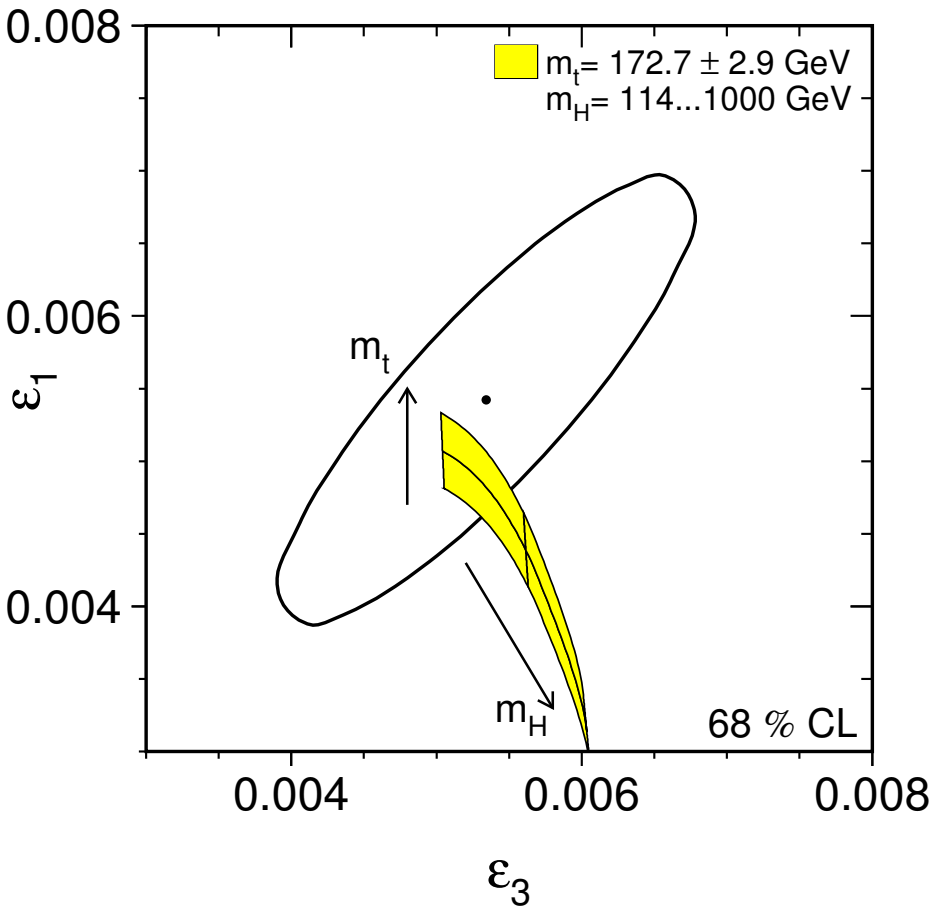
- Introduction: Why is the Higgs important, what makes it unique
  - general: The mystery of the vacuum an the model of mass generation
  - concrete: The Higgs sector in specific models (SM, (N)MSSM, CP violation)
  - expectations from Tevatron, LHC
- Higgs production at ILC
  - Higgsstrahlung and fusion
  - Yukawa processes
  - Higgs self coupling and multi-Higgs production
- Analyses at ILC
  - experimental techniques
  - model dependent and model independent analyses
  - combination with other findings
- Expectations at ILC
  - Higgs properties and quantum numbers
  - rare decays and self couplings
  - limits in specific models
  - general answers to the Higgs mysteries
  - combination with LHC results

Coupling of gauge bosons

We know exactly which couplings can be measured with which precision

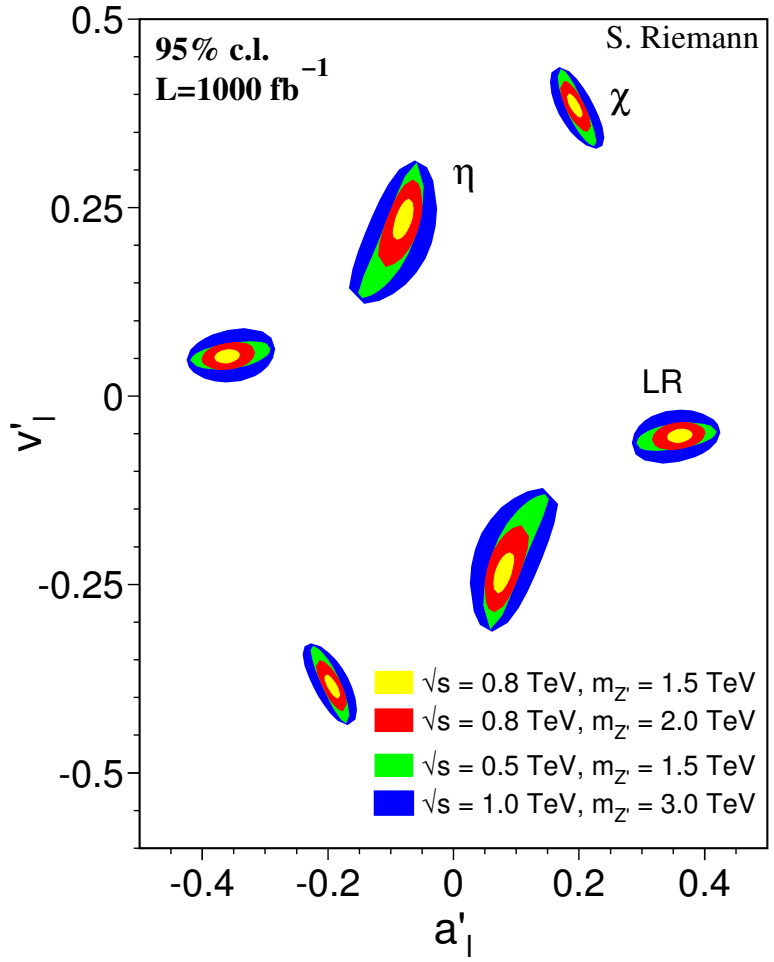
For the Z→fermions couplings on resonance we have the full machinery from LEP/SLC

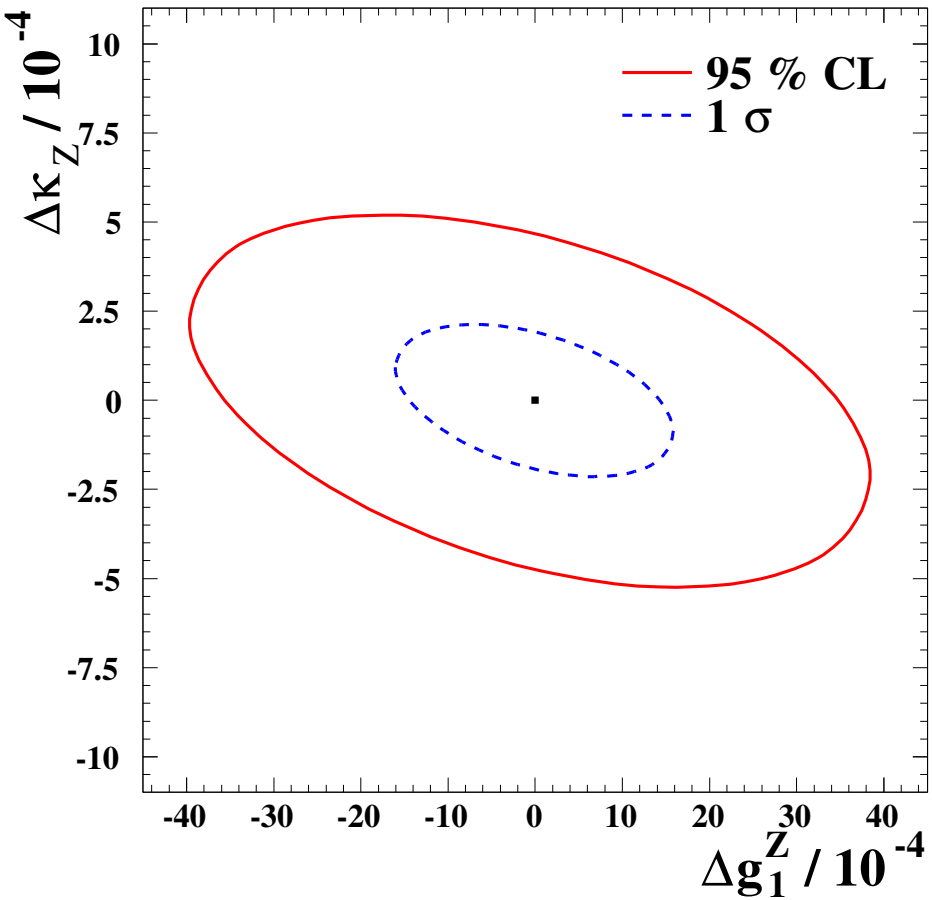




For the Z→fermions couplings above resonance we have detailed BSM interpretations but we have to think how to phrase them in a model independent way

For gauge-boson self couplings we have the model independent parameterisations but we largely miss the interpretations





Detailed outline

- Couplings of gauge bosons to fermions
  - couplings of fermions to the Z (GigaZ)
    - experimental possibilities
    - expected gain from GigaZ
  - couplings of fermions to gauge bosons at high energies
- Couplings amongst gauge bosons
  - triple gauge boson couplings
  - quartic gauge boson couplings

Top quark physics an QCD

Also for the top we know that it is there

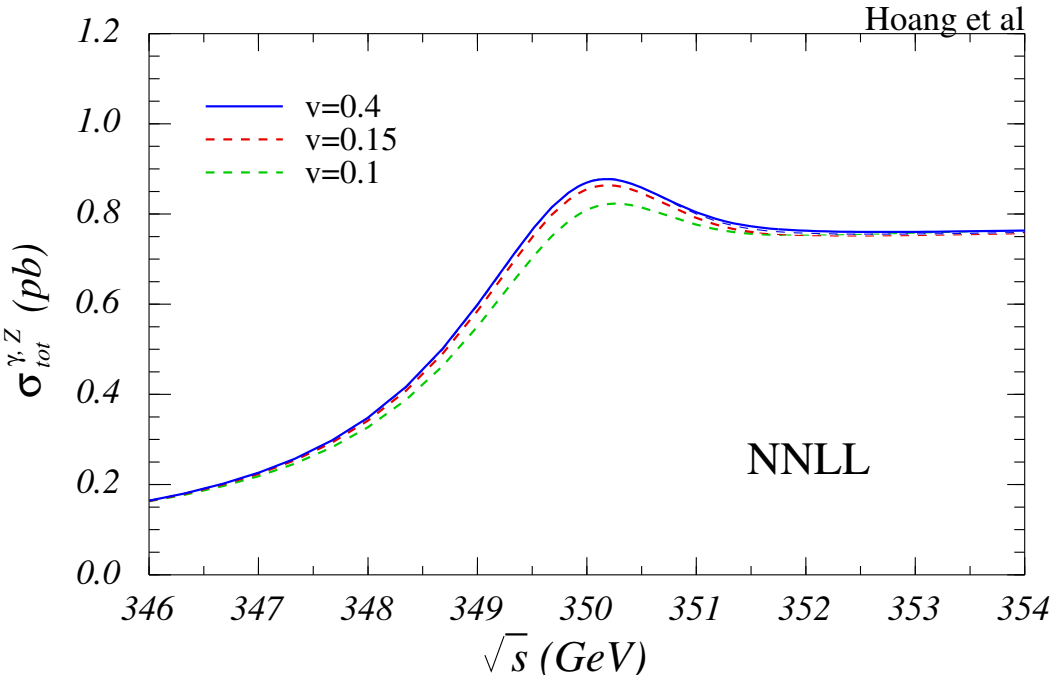
In many models (e.g. little Higgs) the top-quark plays a special role

Very detailed work (experimental and theoretical) for the mass from the threshold scan exists

Also the $t\bar{t}H$ Yukawa coupling has been studies carefully

We still miss a careful experimental study on $t\bar{t}Z$ including all observables (polarised cross sections, polarised asymmetries, top polarisation)

How interesting are the standard α_s measurements from jet rates?



Detailed outline

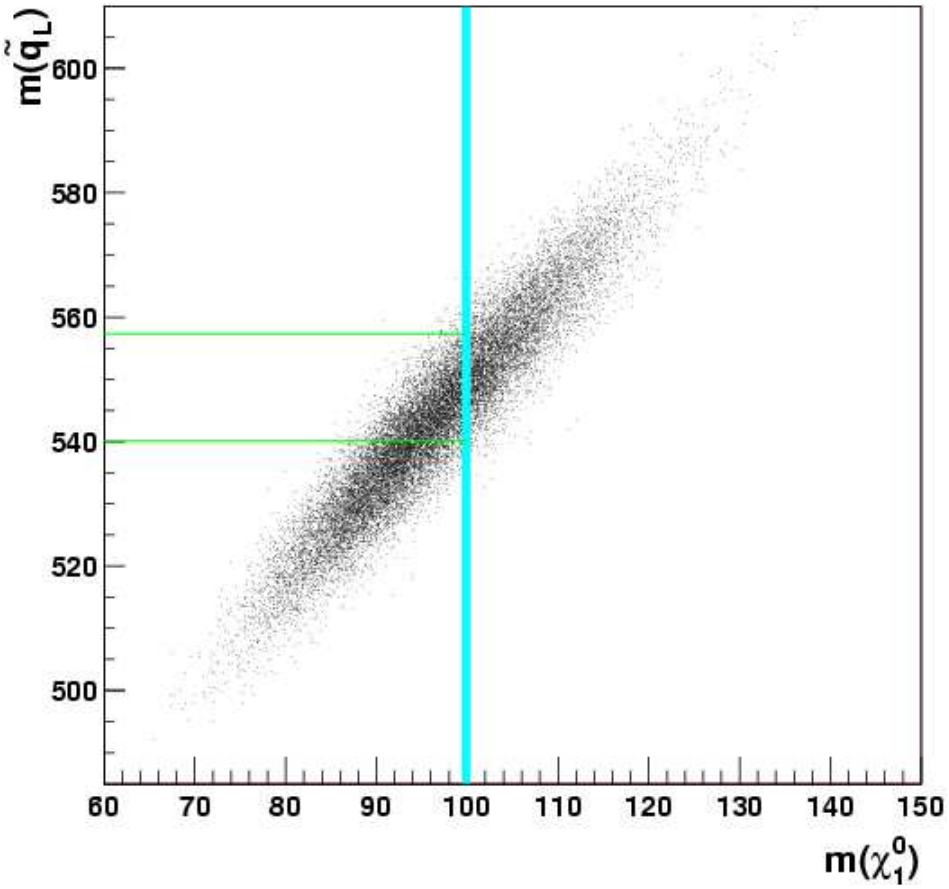
- Precision measurement of top mass, width; threshold scans
- Top and QCD; α_s measurement
- Top decay modes; couplings
  - physics of anomalous couplings
  - $t\bar{t}H$ Yukawa coupling
- Top form factors

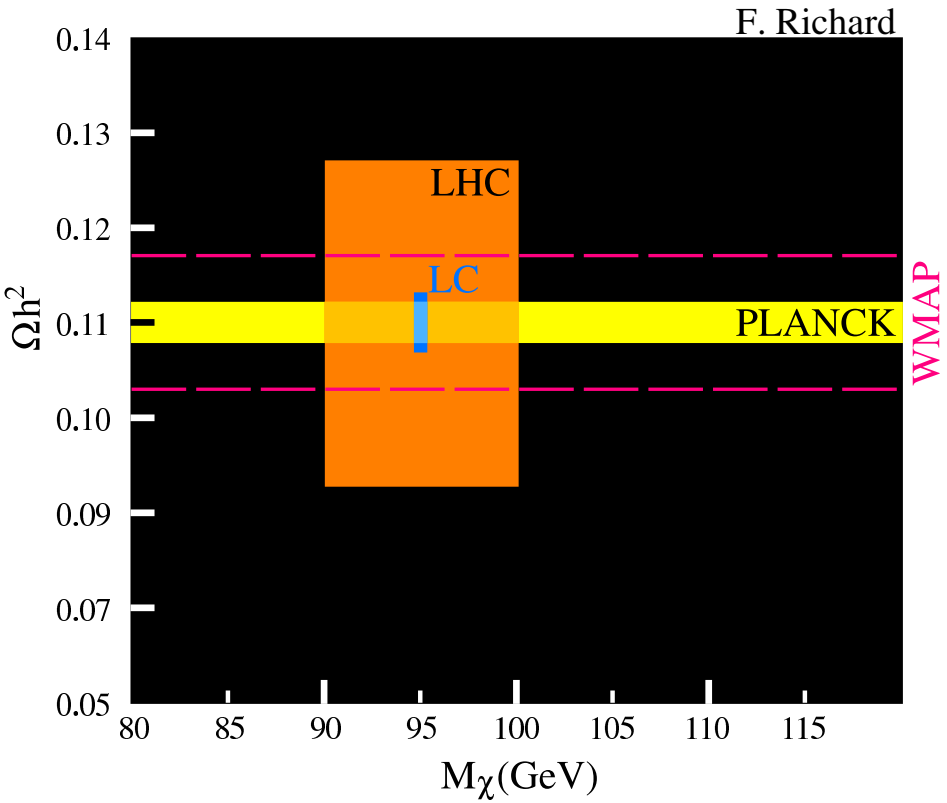
Supersymmetry

Supersymmetry is the most popular extension of the SM

It offers very good examples for ILC/LHC complementarity

It also has good concrete examples for the ILC impact on cosmology





Detailed outline

- Preliminaries:
  - Introduction and motivations for SUSY
  - Summary of MSSM and constrained/extended models
  - Summary of possible outcome of LHC (maybe in Intro section)
  - Possible signals at ILC
- Measurements to be performed at the ILC:
  - in slepton-pair production
  - in chargino/neutralino production
  - in stop production
  - measurements in other scenarios/extensions of the MSSM (light gravitinos, singlino NMSSM, RPV, Higgs in cascades, ..).
  - Summary of benefits of higher energy and other machine options
- Implication of the precision ILC measurements:
  - testing GUT relations
  - determination of Lagrangian parameters in constrained models
  - impact on Higgs physics (determination of $m_{\rm h}$, etc..)
  - implication for cosmology and determination of Ωh^2

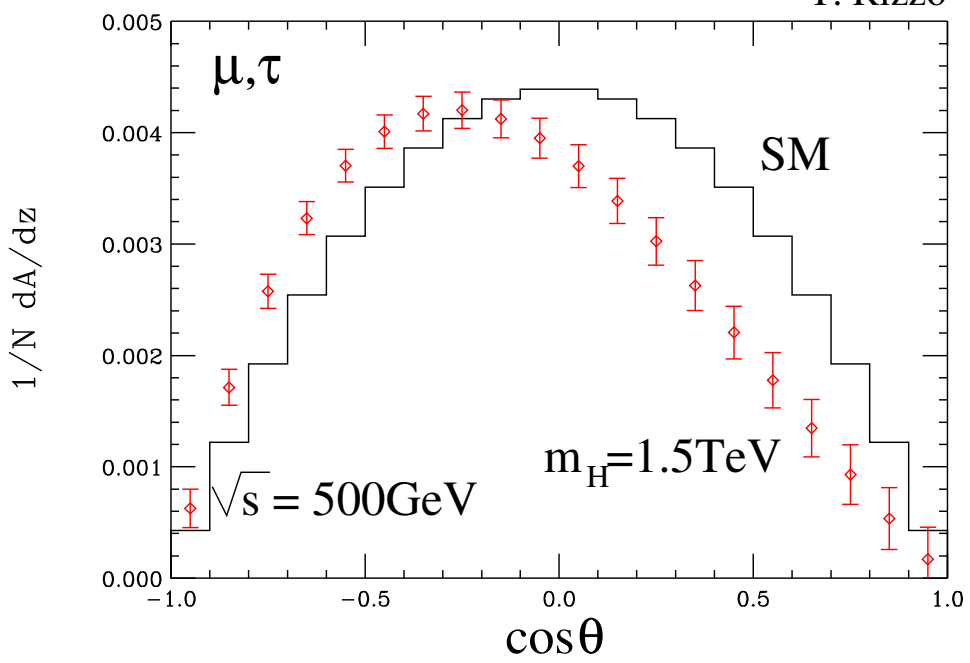
Alternatives to SUSY

There is a huge number of models

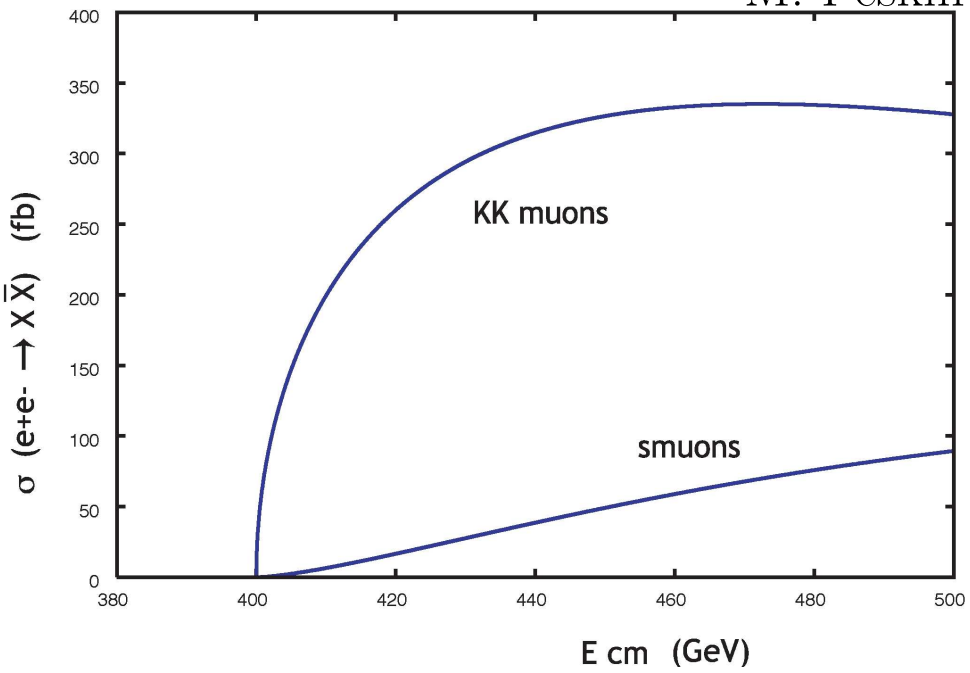
There is no way to study all within a limited space

We plan to concentrate on a few examples that are popular and ILC can contribute significantly

T. Rizzo



M. Peskin



Detailed outline

- Introduction
  - Motivation of alternative scenarios
  - Simple descriptions of various models (ADD, RS, UED, Little Higgs model, etc.)
  - Connection to dark matter problems
  - An example of LC study in the ADD model Determination of the number of extra dimensions Determination of the spin 2 property
- Examples
  - An example of LC study in the UED model Spin determination of 1st KK particles
  - An example of LC study in the Little Higgs model Indirect effects in $e^+e^- \to t\bar{t}Z$, Zh, and $f\bar{f}$ processes.
  - Discrimination of various Z' models from $e^+e^- \to f\bar{f}$ processes
- A discussion and a summary table of new physics models, which describes
  - what LHC can find,
  - what LC can find directly or indirectly (i.e. SM and Higgs processes),
  - what aspects LC can clarify in each case.

Connections to cosmology

- In the beginning we had two main sections (apart from the introduction)
  - Electroweak symmetry breaking
  - Connections to cosmology

  and the different physics topics below this structure
- In Bangalore it was decided to structure according to the physics and discuss cosmology inside the different chapters
- The WWS proposed now to keep this structure but add a short summary on cosmological connections
- We are happy to adopt this proposal if it is supported by the community

Simulation work

- We need to prove that we can do the physics we claim
- Ideally this is done with full simulation
- However the simulation has to be done with the detector we think to have for the ILC (i.e. $\Delta E/E = 30\%/\sqrt{E}$)
- If we don't reach this in time we have to stay with fast simulation
- Some difficult key channels not requiring particle flow may still be possible with full simulation, e.g.:
  - BR($H \to c\bar{c}$)
  - $\tilde{\tau}$ in low Δm SUSY
- Some other missing items:
  - Top weak couplings (which energy is needed?)
  - $q\bar{q}$ production: statistical and systematic errors on σ and A_{FB}

Requirements from theory

- For many items one can use available material.
- For a few points, one needs some updates:
  - Determination of quark masses, ...
  - Scalar Higgs potential with effects of New Physics
  - Chiral Lagrangian approach for the no Higgs scenario
  - Update/extend benchmark points (lines?) for SUSY ...
- For some points, one needs new studies:
  - Model independent study of Higgs production and decay
  - DM, CPV, Baryogenesis
  - KK Dark Matter at ILC? Other points with extra dims?...
- Joint experimental/theory new effort is needed:
  - Strongly interacting Higgs sector
  - Effect of τ polarisation in rejecting bkg for low $\Delta m_{\tilde{\tau}}$
  - Scenarios for complementarity between LHC and ILC

Community Input

- We encourage comments for all of you
- We have a Wiki page at http://www.linearcollider.org/wiki/doku.php
  Click at "DCR - Physics Chapter"
- All the outlines and first draft text is there
- Please check this page regularly
- Physics groups should keep us informed of new developments
- And you can reach each of us:
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