Benchmarks for the ILC/CLIC physics study with polarization

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- **New initiative**
- **Requirements for polarized beams**
- **Benchmark strategy**
- **Outlook**

New initiative: ILC/CLIC polarization group

- Goal: requirements on polarized beams
  - **Physics case(s):**
    - what's important for <1 TeV
    - What's important for >1 TeV

    Different physics cases!
  - **Spin-tracking, depolarization**
  - **Needs for systematics: helicity flipping**
  - **Accuracy needs for polarimetry (up+down)**
  - Effects on luminosity, crossing angle, etc.

Benchmark scenarios discussed

Expected depolarization

Bailey, Hartin et al, EPAC'08

- Rather large depolarization at CLIC, small at ILC
- Precise spin tracking required !
- Still under work

Parameter set	Depolarization ΔP_{tw}		
	ILC 100/100	ILC 80/30	CLIC-G
T-BMT	0.17%	0.14%	0.10%
S-T	0.05%	0.03%	3.4%
incoherent	0.00%	0.00%	0.06%
coherent	0.00%	0.00%	1.3%
total	0.22%	0.17 %	4.8%

Impact of polarized beams

- **`analysing' character:** prove kind of interaction/test of chirality and spin
- **`statistical character':** suppress background processes with suitable configuration
- **'precision' character:** reduce systematics
- **'compensating' character (?):** improve design 'shortcomings' (lower √s@ILC, large # of photons@CLIC,...)

➢ **different priorities for both machines but large overlap concerning requirements + simulations**

Polarized beams summary table

- **See hep-ph/0507011:** Gain (80%,0) -> (80%,60%)

Case	Effects	Gain& Requirement
Statistics:		
$P_{\rm eff}$	(axial)vector interactions	95%
$\Delta A_{\rm LR}/A_{\rm LR}$	due to error propagation	$\times 3$
Standard Model:		
top threshold	Electroweak coupling measurement	factor 3
$t\bar{q}$	Limits for FCN top couplings reduced	factor 1.8
CPV in $t\bar{t}$	Azimuthal CP-odd asymmetries give access to scalar- and tensor-currents up to 10 TeV	$P^{\rm T}_{e^-}P^{\rm T}_{e^+}$ required
W^+W^-	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$	up to a factor 2
	TGC: error reduction of $\Delta\kappa_\gamma$, $\Delta\lambda_\gamma$, $\Delta\kappa_Z$, $\Delta\lambda_Z$	factor 1.8
	Specific TGC $\tilde{h}_+ = {\rm Im}(g_1^{\rm R}+\kappa^{\rm R})/\sqrt{2}$	$P^{\rm T}_{e^-}P^{\rm T}_{e^+}$ required
CPV in γZ	Anomalous TGC $\gamma\gamma Z, \gamma ZZ$	$P^{\rm T}_{e^-}P^{\rm T}_{e^+}$ required
HZ	Separation: $HZ \leftrightarrow H\bar{\nu}\nu$	factor 4 with RL
	Suppression of $B = W^+\ell^-\nu$	factor 1.7
$t\bar{t}H$	Top Yukawa coupling measurement at $\sqrt{s} = 500$ GeV	factor 2.5

Supersymmetry:		
$\tilde{e}^+\tilde{e}^-$	Test of quantum numbers L, R	P_{e^+} required
	and measurement of $e^\pm$ Yukawa couplings	
$\tilde{\mu}\tilde{\mu}$	Enhancement of S/B, $B = WW$	factor 5-7
	$\Rightarrow m_{\tilde{\mu}_{L,R}}$ in the continuum	
HA, $m_A > 500$ GeV	Access to difficult parameter space	factor 1.6
$\tilde{\chi}^+\tilde{\chi}^-$, $\tilde{\chi}^0\tilde{\chi}^0$	Enhancement of $\frac{S}{B}$, $\frac{S}{\sqrt{B}}$	factor 2–3
	Separation between SUSY models,	
	'model-independent' parameter determination	
CPV in $\tilde{\chi}^0_i\tilde{\chi}^0_j$	Direct CP-odd observables	$P^{\mathrm{T}}_{e^-}P^{\mathrm{T}}_{e^+}$ required
RPV in $\tilde{\nu}_\tau \to \ell^+\ell^-$	Enhancement of S/B, $S/\sqrt{B}$	factor 10 with LL
	Test of spin quantum number	
Extra Dimensions:		
$G\gamma$	Enhancement of S/B, $B = \gamma\nu\bar{\nu}$,	factor 3
$e^+e^- \to f\bar{f}$	Distinction between ADD and RS models	$P^{\mathrm{T}}_{e^-}P^{\mathrm{T}}_{e^+}$ required
Z′:		
$e^+e^- \to f\bar{f}$	Measurement of Z' couplings	factor 1.5
Contact-Interactions:		
$e^+e- \to q\bar{q}$	Model independent bounds	P_{e^+} required
Precision measurements of the Standard Model at GigaZ:		
Z-pole	Improvement of $\Delta \sin^2\theta_W$	$\sim$ factor 10
	Improvement of Higgs bounds	$\sim$ factor 10
	Constraints on SUSY parameter space (in CMSSM)	factor 5
CPV in $Z \to b\bar{b}$	Enhancement of sensitivity	factor 3

Physics cases for pol. beams

- **$\sqrt{s}$<1 TeV:**
  - Direct searches: light SUSY particles, Higgs coupling (ew, triple), ttH, access to heavy Higgs, CP-violating effects
  - Indirect searches: Hints for extra dimensions, structure of Z' couplings
- **$\sqrt{s}$>1 TeV:**
  - Direct searches: heavy SUSY, triple Higgs couplings,extra dimensions, etc.

But keep in mind: all these topics should be discussed w.r.t. LHC prospects/results!

Current status of 'new' group

- First discussion started
  - Choice of suitable benchmark scenarios
  - Definition of common task list ILC/CLIC
  - Discussion on interesting physics cases
- 'Core' group consists:
  - CERN: M. Battaglia, L. Linsen, J. Wells
  - DESY: J. List, S. Riemann, myself
- Plans:
  - Provide first reliable results at the ECFA in 10/10

Challenges in benchmark scenarios

- Aim: need for a few scenarios
  - Should be in concordance with current bounds
  - Should provide a spectrum of different experimental topologies
  - Should `probe' specific design features, as e.g. beamstrahlung
    - E.g. 'probe' mass degeneration in (heavy) SUSY
- A CLIC benchmark ≠ ILC benchmark
  - Intersection at 1 TeV
- Should provide 'add-on' s to LHC expectations!

Free parameters in the MSSM

- mass matrices are 3 x 3 hermitian

  → m_Q^2 , m_u^2 , m_d^2 , m_L^2 , m_e^2 : 45 parameters

- gaugino masses M_1, M_2, M_3 are complex numbers: 6
- trilinear couplings a_u, a_d, a_e are 3 x 3 complex matrices: 54
- bilinear coupling b is 2 x 2 matrix: 4
- Higgs masses m^2_{Hu}, m^2_{Hd} : 2

→ altogether 111 parameter ???

Symmetries (lepton + baryon number, Peccei-Quinn, R symmetry) lead to'rotations':

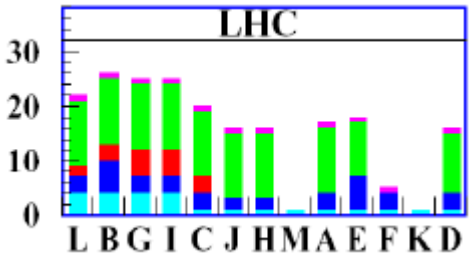
-4 non-trivial field redifinitions

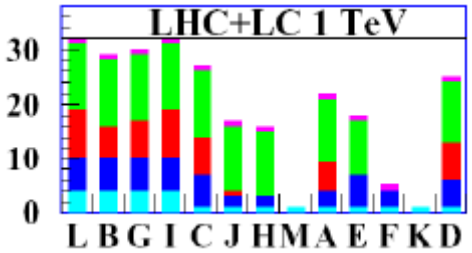
-2 in the Higgs sector (since minimal model only 2 parameters in the Higgs sector)

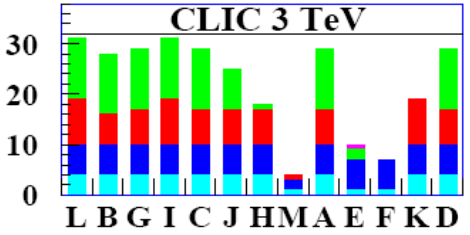
→ remain 105 free new parameters in the MSSM!

DisneyWorld of SUSY scenarios

'Available' benchmarks (2003):







Criticism:

- **13 SUSY 'benchmarks' scenarios out of millions …**
  really a true representative choice ?
- **heavy masses often mass degenerated: no resolution (beamstrahlung!) has been taken into account…**
  really a reliable 'counting' ?
- **many of these scenarios contradict bounds from gμ – 2 !**
  really a useful basis for future decisions?
- **multi-fit programmes (Mastercode, Fittino, Gfitter etc.) predict 'light' SUSY**
  use of such extreme scenarios is debatable

Where do we expect SUSY?

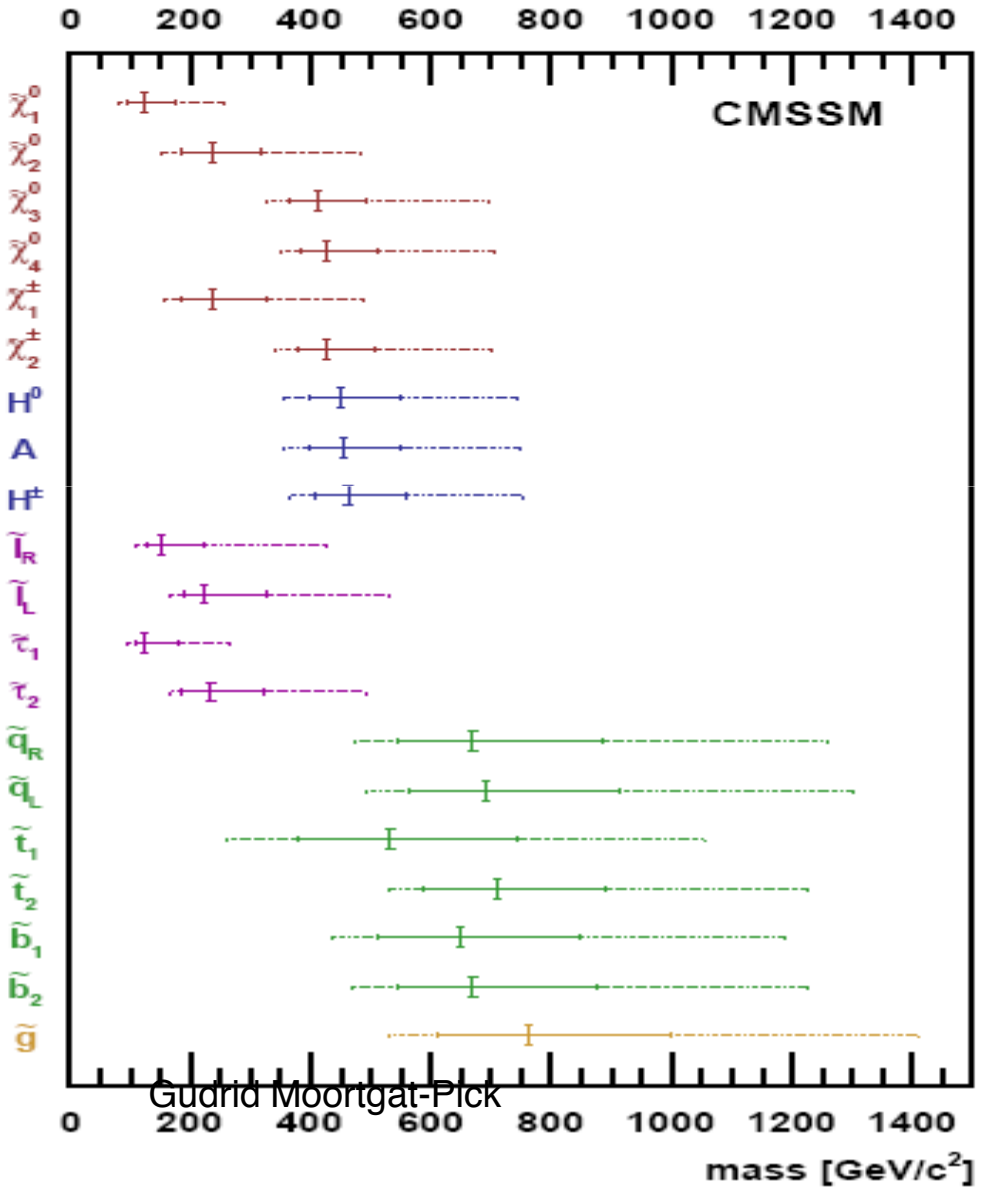
O. Buchmueller et al, '09

Multiparameter best fit:

Included: ew. prec. ob, Cosmological bounds, g_μ-2, etc.

➢**Rather light SUSY !**

General feature:
if g_μ-2 fulfilled, a few SUSY particles have to be light!!!



Different priorities

- Heavy SUSY particles:
  - Often close in mass
  - Difficult to separate (in particular with large beamstrahlung)
- Important at CLIC:
  - Use polarized beams to study S/B, including beamstrahlung, etc.
- Important at ILC:
  - Use pol. beams to analyse properties of low masses: predictions for heavy particles

Strategy

- Defining suitable scenarios …. *'status'*
- Study properties of low masses at both designs
- Study properties of heavy part at CLIC
- Fold in possible information from LHC
- Clarify 'add-on's achievable at a LC
- Define/check demands for the design to achieve these physics goals

Outlook

- Very optimistic: large overlap, constructive for physics studies at both machines
- Different criteria for physics of pol. beams at $\sqrt{s} < 1$TeV and > 1 TeV !
  - 'weighted via LHC results and expectations!'
- Hopefully 1st results at the ECFA meeting
- *Personal guess: we have to think about a staged approach*
  - *Unrealistic to have one single machine equally well performing from 90 GeV -> 3 TeV*
  - *ILC and CLIC fit perfectly together as 'staged approach'*