

Determination of SuSy parameters:  
CLIC and gluino  
GDR SuSy meeting

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## pMSSM, mSUGRA and SPS1a

- MSSM

- mSUGRA and SPS1a

## LHC, ILC and CLIC

### Parameter determination

- mSUGRA fit

- MSSM fit

- Parameter fixing @ LHC

### Gluinios @ CLIC

- Production modes

- Cross section

## Conclusions

# 1.1 MSSM

- ▶ MSSM : Minimal SuSy extension of the SM
- ▶  $R$ -parity conservation

105 param.

But for a phenomenologically viable model : pMSSM  $\rightarrow$  24 param.

$\tan \beta$	$M_1$	$M_2$	$M_3$	$M_A$	$\mu$
$A_{\tilde{\tau}}$	$A_{\tilde{t}}$	$A_{\tilde{b}}$	$m_{\tilde{T}R}$	$m_{\tilde{T}R}$	$m_{\tilde{\mu}R}$
$m_{\tilde{\mu}L}$	$m_{\tilde{e}R}$	$m_{\tilde{e}L}$	$m_{\tilde{q}L}^1$	$m_{\tilde{q}L}^2$	$m_{\tilde{q}L}^3$
$m_{\tilde{t}R}$	$m_{\tilde{b}R}$	$m_{\tilde{c}R}$	$m_{\tilde{s}R}$	$m_{\tilde{u}R}$	$m_{\tilde{d}R}$

## 1.2 mSUGRA and SPS1a

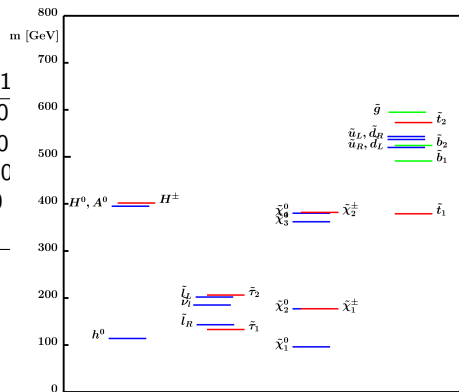
Minimal SuperGravity model, heavily constrained  $\rightarrow$  5 param. left!

Defined at the GUT scale

		SPS1
Unif. gaugino mass param.	$m_{1/2}$	100
Unif. $\tilde{f}$ mass param.	$m_0$	250
Unif. tri-lin. coupling	$A_0$	-100
Ratio of Higgs VEVs	$\tan \beta$	10
Sign of $\tilde{H}$ mass param.	$\text{sign } \mu$	+

For a detailed LHC/ILC comparison :

**SPS1a point** (Allanach *et al.* 2002)



## 2 LHC, ILC and CLIC

- ▶ **LHC** :  $pp$  ring @  $E_{CM} = 14$  TeV, in commissioning. Err  $\approx 5\%$
- ▶ **ILC** : linear  $e^+e^-$ , 1 TeV, in project. Err  $\approx 0.5\%$
- ▶ **CLIC** : linear  $e^+e^-$ , 3 to 5 TeV, in study

CLIC errors = ILC errors extended to larger spectrum

### Expected errors

$\Delta$	SPS1a	LHC	ILC	CLIC
$h$	110.76	0.25	0.05	0.05
$A$	398.93		1.5	1.5
$H$	399.32		1.5	1.5
$H^+$	407.26		1.5	1.5
$\chi_{1\pm}$	180.18		0.55	0.55
$\chi_{2\pm}$	382.15		3	3
$\tilde{g}$	606.26	8		
$\chi_1^0$	97.194	4.8	0.05	0.05
$\chi_2^0$	180.77	4.7	1.2	1.2
$\chi_3^0$	363.09		4	4
$\chi_4^0$	381.93	5.1	4	4
$\tilde{e}_1$	142.86	4.8	0.05	0.05
$\tilde{e}_2$	200.86	5	0.2	0.2
$\tilde{\mu}_1$	142.86	4.8	0.2	0.2
$\tilde{\mu}_2$	200.83	5	0.5	0.5
$\tilde{\tau}_1$	133.2	6.5	0.3	0.3
$\tilde{\tau}_2$	204.98		1.1	1.1
$\tilde{t}_1$	399.57		2	2
$\tilde{t}_2$	586.03			2.8
$\tilde{b}_1$	516.33	14		2.6
$\tilde{b}_2$	546.38	14		2.7
$\tilde{u}_1, \tilde{c}_1$	546.08	19		5.5
$\tilde{u}_2, \tilde{c}_2$	562.44	17.4		5.5
$\tilde{d}_1, \tilde{s}_1$	544.8	19		5.5
$\tilde{d}_2, \tilde{s}_2$	567.94	17.4		5.5

G. Weiglein *et al.* [LHC/LC Study Group Collaboration] (2004)

## 3.1 mSUGRA fit

**Aim:** Compare precision of parameter determination @ LHC/ILC/CLIC.

**Tools:**

- ▶ SuSpect generates observable spectrum at SPS1a point
- ▶ Sfitter fits parameter space to observable spectrum and computes errors

### mSUGRA fit

	SPS1a	LHC	ILC	CLIC
$m_0$	100	4.0	0.08	0.08
$m_{1/2}$	250	1.8	0.13	0.10
$\tan \beta$	10	1.3	0.12	0.12
$A_0$	-100	31.8	4.79	3.79

errors on parameters

- ▶ LHC precision  $\approx 10\%$
- ▶ ILC precision 1-2 oom better
- ▶ CLIC  $< 10 \times$  better
  - ▶  $m_{1/2}$  better by 30%
  - ▶  $A_0$  better by 20%

## 3.2 MSSM fit

24 free parameters: less precision

- ▶ Partial determination at LHC
- ▶ ILC better up to 1 oom but fixing required
- ▶ ILC silent on squarks
- ▶ CLIC req. no fix. but not 1 oom <
- ▶ Wiser to compare CLIC/LHC+ILC

What is the influence of fixing?

	nom.	LHC	ILC	LHC+ILC	CLIC	CLIC+ $\tilde{g}$
$\tan \beta$	10	79	1.45	1.16	1.16	1.94
$M_1$	101.4	16	0.23	0.18	0.18	0.30
$M_2$	191.6	47	0.92	0.50	0.88	1.14
$M_3$	586.7	33	FIXED	8.14	658.31	8.10
$m_{\tilde{\tau}_L}$	194.7	FIXED	1.92	3.09	2.42	4.24
$m_{\tilde{\tau}_R}$	133.5	8.9	2.20	4.04	2.98	5.84
$m_{\tilde{\mu}_L}$	195.5	5.7	0.51	0.51	0.51	0.51
$m_{\tilde{\mu}_R}$	136.0	6.0	0.21	0.21	0.21	0.22
$m_{\tilde{e}_L}$	195.5	5.7	0.20	0.20	0.20	0.21
$m_{\tilde{e}_R}$	136.0	6.0	0.07	0.06	0.06	0.08
$m_{\tilde{q}_L^3}$	497.1	32	60.2	24.36	6.53	9.02
$m_{\tilde{t}_R}$	421.6	FIXED	33.8	14.48	12.76	11.31
$m_{\tilde{b}_R}$	522.5	43	FIXED	24.54	8.25	9.03
$m_{\tilde{q}_L^2}$	545.9	13.6	FIXED	8.78	6.84	3.99
$m_{\tilde{c}_R}$	527.9	20	FIXED	16.36	6.44	5.61
$m_{\tilde{s}_R}$	525.8	20	FIXED	16.40	6.49	5.63
$m_{\tilde{q}_L^1}$	545.9	13.6	FIXED	7.12	6.57	3.98
$m_{\tilde{u}_R}$	527.9	20	FIXED	16.23	6.69	5.59
$m_{\tilde{d}_R}$	525.8	20	FIXED	16.27	6.23	5.62
$A_{\tilde{\tau}}$	-251.7	FIXED	539	748.3	851.33	1386.3
$A_{\tilde{t}}$	-494.6	1547	17.5	13.88	23.33	23.14
$A_{\tilde{b}}$	-795.3	FIXED	FIXED	12040	3348.2	3750.1
$m_A$	398.93	FIXED	0.87	0.87	0.87	0.87
$\mu$	357.0	45	2.31	1.93	2.45	2.36

### 3.3 Parameter fixing @ LHC

We fix less sensitive parameters *a priori*.

For LHC we fix  $m_{\tilde{t}_L}$ ,  $m_{\tilde{t}_R}$ ,  $A_{\tilde{t}}$ ,  $A_{\tilde{b}}$  and  $m_A$  at SuSpect nominal values :  
unsatisfying.

- ▶ Scan through possible values for fixed parameters
- ▶ Check deviation of unfixed parameters from nominal values

	$m_{\tilde{t}_L}$	$m_{\tilde{t}_R}$	$A_{\tilde{t}}$	$A_{\tilde{b}}$	$m_A$
range	0:2000	0:2000	-4000:4000	-4000:4000	0:2000
$\Delta \tan \beta$	1.68	5.95	0.64	2.5	0.55

- ▶  $m_{\tilde{t}_L}$ ,  $m_A$  and  $A_{\tilde{t}}$  : no sensitivity  $\rightarrow$  harmless fixation.
- ▶  $m_{\tilde{t}_R}$  and  $A_{\tilde{b}}$  : obvious sensitivity.

Bias introduced by parameter fixing  
Too few observable to determine MSSM  
 $\rightarrow$  Search for new SuSy observable @ LHC



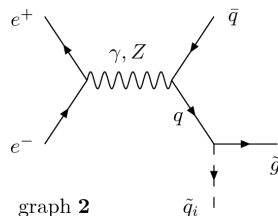
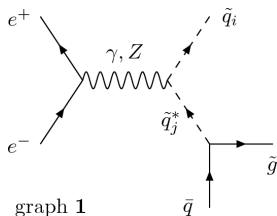
## 4 Gluinios @ CLIC

### Aim

Increase precision on MSSM determination at CLIC  
Measure gluino mass with precision  $>$  LHC (1.3%)

# 4.1 Production modes

4 graphs for  $e^+e^- \rightarrow \bar{q}\tilde{q}\tilde{g}$



## 4.2 Cross section

$E_{CM}(\text{CLIC}) \approx 3 - 5 \text{ TeV}$

$\sigma_{\text{max}} \approx 2.5 \text{ fb}$

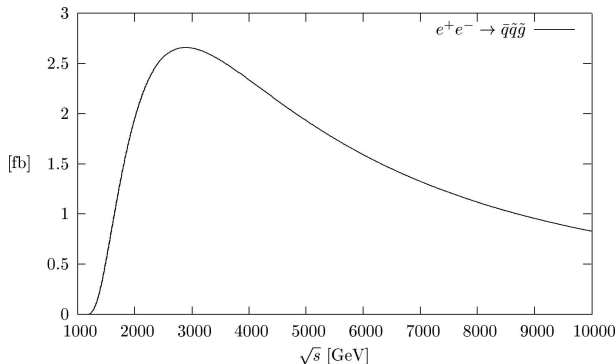
We need  $\Delta m_{\tilde{g}} < 1.3\%$

$\Rightarrow \geq 6000 \text{ events}$

$\Rightarrow \int L \geq 2500 \text{ fb}^{-1}$  (peak)

$\Rightarrow \int L \geq 5000 \text{ fb}^{-1}$  (thr.)

(with 100% eff.)



In accordance with Datta and Djouadi (2002)

Expected int. luminosity :  $2500 \text{ fb}^{-1} \text{ y}^{-1}$  at the peak (Aguillar-Saavedra *et al.* (2002))

$\Rightarrow$  Interesting for more detailed analysis with background noise

# Conclusions

- ▶ **Parameter determination @ LHC/ILC/CLIC**
  - ▶ MSSM can be determined at LHC
  - ▶ ILC/CLIC → precision measurements
- ▶ **MSSM parameters fixing at LHC**
  - ▶ Obvious bias introduced by parameter fixing
  - ▶ New SuSy observable required
- ▶ **Gluinos @ CLIC**
  - ▶ Measure of the gluino mass at CLIC is interesting for MSSM determination
  - ▶ Need to perform detailed analysis with noise

Thank you.