SFITTER: Impact of TeVatron data

Remi Lafaye, Tilman Plehn, Dirk Zerwas
CERN and LAPP, MPI Munich, LAL Orsay

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Introduction

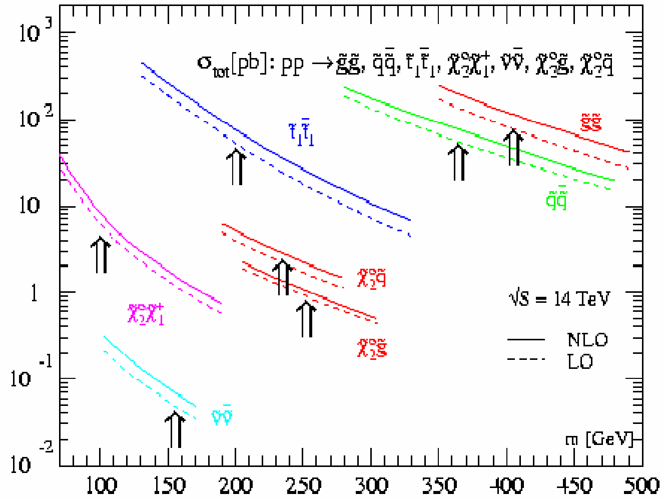
SFITTER: tool to determine supersymmetric parameters from measurements
Models: MSUGRA, MSSM, GMSB, AMB

The workhorses:
- **Mass spectrum generated by SUSPECT (new version interfaced) or SOFTSUSY**
- **Branching ratios by MSMLIB**
- **NLO cross sections by Prospino2.0**
- **MINUIT**

The Technique:
- **GRID (multidimensional to find a non-biased seed, configurable)**
- **subsequent FIT**

Other approaches:
- **Fittino (Bechtle et al)**
- **Interpolation (Polesello)**
- **Analytical calculations (Kneur et al, Kalinowski et al)**
- **Hybrid (Porod)**

Beenakker et al

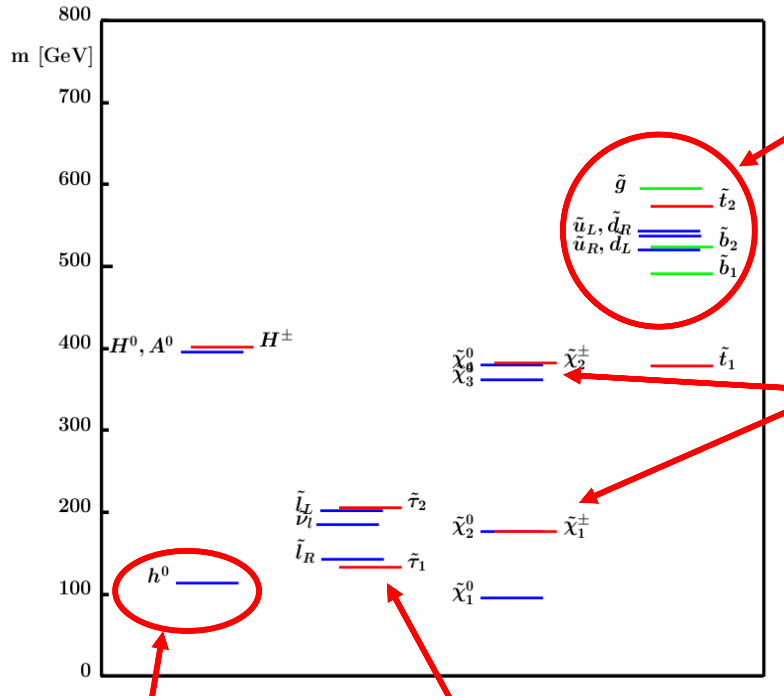


Assumptions for the following:

- **SUSPECT used to generate central mass values**
  - **χ^2 meaningless, will not be quoted**
- **SUSPECT mode:**
  - **high precision Higgs**
  - **sfermion masses 0.01% (? acc to manual)**
- **nominal theoretical errors:**
  - **Higgs mass ±3GeV (S. Heinemeyer et al.)**
  - **sfermion see above, but 3% between versions possible**
  - **ignored for the new work presented today**
- **The model:**
  - **a restricted number of measurements will be available, restrict number of parameters → MSUGRA**
- **Study errors only for the time being**
  - **FIT only**
  - **SMEAR (Gaussian of measurements) not yet used**
  - **correlations technically implemented, but not used**

SPS1a

m_0 = 100GeV $m_{1/2}$ = 250GeV A_0 = -100GeV tanβ =10 sign(μ)=+
favourable for LHC and ILC (Complementarity)



Moderately heavy gluinos and squarks

Heavy and light gauginos

Higgs at the limit of LEP reach

light sleptons

$\tilde{\tau}_1$ lighter than lightest $\chi^\pm$:

- **$\chi^\pm$ BR 100% $\tilde{\tau}\nu$**
- **χ_2 BR 90% $\tilde{\tau}\tau$**
- **cascade:**

$\tilde{q}_L \rightarrow \chi_2\, q \rightarrow \tilde{\ell}_R\, \ell\, q \rightarrow \ell\, \ell\, q\chi_1$ visible

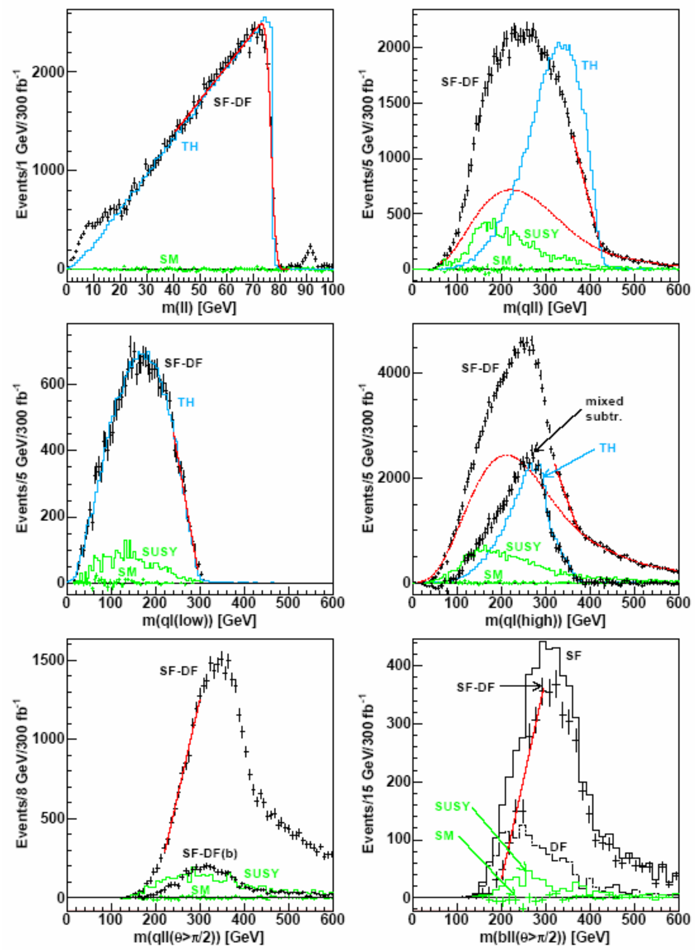
Examples of measurements at LHC

Gjelsten et al: ATLAS-PHYS-2004-007/29

$$
\begin{aligned}
(m^2_{ll})^{\mathrm{edge}} &= \frac{(m^2_{\tilde\chi^0_2} - m^2_{\tilde l_R})(m^2_{\tilde l_R} - m^2_{\tilde\chi^0_1})}{m^2_{\tilde l_R}} \\
(m^2_{qll})^{\mathrm{edge}} &= \frac{(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde\chi^0_1})}{m^2_{\tilde\chi^0_2}} \\
(m^2_{ql})^{\mathrm{edge}}_{\mathrm{min}} &= \frac{(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde l_R})}{m^2_{\tilde\chi^0_2}} \\
(m^2_{ql})^{\mathrm{edge}}_{\mathrm{max}} &= \frac{(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde l_R} - m^2_{\tilde\chi^0_1})}{m^2_{\tilde l_R}} \\
(m^2_{qll})^{\mathrm{thres}} &= [(m^2_{\tilde q_L} + m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde l_R})(m^2_{\tilde l_R} - m^2_{\tilde\chi^0_1}) \\
&\quad -(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})\sqrt{(m^2_{\tilde\chi^0_2} + m^2_{\tilde l_R})^2 (m^2_{\tilde l_R} + m^2_{\tilde\chi^0_1})^2 - 16 m^2_{\tilde\chi^0_2} m^4_{\tilde l_R} m^2_{\tilde\chi^0_1}} \\
&\quad +2m^2_{\tilde l_R}(m^2_{\tilde q_L} - m^2_{\tilde\chi^0_2})(m^2_{\tilde\chi^0_2} - m^2_{\tilde\chi^0_1})]/(4m^2_{\tilde l_R} m^2_{\tilde\chi^0_2})
\end{aligned}
$$

Edge	Nominal Value	Fit Value	Syst. Error Energy Scale	Statistical Error
$m(ll)^{\mathrm{edge}}$	77.077	77.024	0.08	0.05
$m(qll)^{\mathrm{edge}}$	431.1	431.3	4.3	2.4
$m(ql)^{\mathrm{edge}}_{\mathrm{min}}$	302.1	300.8	3.0	1.5
$m(ql)^{\mathrm{edge}}_{\mathrm{max}}$	380.3	379.4	3.8	1.8
$m(qll)^{\mathrm{thres}}$	203.0	204.6	2.0	2.8
$m(bll)^{\mathrm{thres}}$	183.1	181.1	1.8	6.3

plus other mass differences and edges…



From edges to masses:
System overconstrained

Coherent set of "measurements"
for LHC (and ILC)
"Physics Interplay of the LHC and ILC"
Editor G. Weiglein hep-ph/0410364

Results for 300fb^{-1} (thus 2014):

- **energy scale leptons 0.1%**
- **energy scale jets 1%**

Polesello et al: use of χ_1 from ILC in LHC analyses improves the mass determination

	Mass, ideal	"LHC"	"LC"	"LHC+LC"
$\tilde{\chi}_1^\pm$	179.7		0.55	0.55
$\tilde{\chi}_2^\pm$	382.3	–	3.0	3.0
$\tilde{\chi}_1^0$	97.2	4.8	0.05	0.05
$\tilde{\chi}_2^0$	180.7	4.7	1.2	0.08
$\tilde{\chi}_3^0$	364.7		3-5	3-5
$\tilde{\chi}_4^0$	381.9	5.1	3-5	2.23
$\tilde{e}_R$	143.9	4.8	0.05	0.05
$\tilde{e}_L$	207.1	5.0	0.2	0.2
$\tilde{\nu}_e$	191.3	–	1.2	1.2
$\tilde{\mu}_R$	143.9	4.8	0.2	0.2
$\tilde{\mu}_L$	207.1	5.0	0.5	0.5
$\tilde{\nu}_\mu$	191.3	–		
$\tilde{\tau}_1$	134.8	5-8	0.3	0.3
$\tilde{\tau}_2$	210.7	–	1.1	1.1
$\tilde{\nu}_\tau$	190.4	–	–	–
$\tilde{q}_R$	547.6	7-12	–	5-11
$\tilde{q}_L$	570.6	8.7	–	4.9
$\tilde{t}_1$	399.5		2.0	2.0
$\tilde{t}_2$	586.3		–	
$\tilde{b}_1$	515.1	7.5	–	5.7
$\tilde{b}_2$	547.1	7.9	–	6.2
$\tilde{g}$	604.0	8.0	–	6.5
h^0	110.8	0.25	0.05	0.05
H^0	399.8		1.5	1.5
A^0	399.4		1.5	1.5
$H^\pm$	407.7	–	1.5	1.5

Masses versus Edges

Using masses ($300 fb^{-1}$):

m_0 = 100 ± 4 GeV

$m_{1/2}$ = 250 ± 1.7 GeV

$\tan\beta$ = 10 ± 1.1

A_0 = -100 ± 33 GeV

Using edges ($300 fb^{-1}$) new:

m_0 = 100 ± 1.2 GeV

$m_{1/2}$ = 250 ± 1.0 GeV

$\tan\beta$ = 10 ± 0.9

A_0 = -100 ± 20 GeV

- edges to masses is not a simple "coordinate" transformation:

- Δm_0=1GeV → shift $m\tilde{\ell}_R$ = 0.7GeV $\Delta m\tilde{\ell}_R$ =5GeV
  0.7GeV/5GeV ≈ 0.14
- Δm_0=1GeV → shift $m\ell\ell$ = 0.4GeV $\Delta m\ell\ell$ = 0.08GeV
  0.4GeV/0.08GeV ≈ 5
- $\Delta m_{1/2}$=1GeV → shift $m\chi_2$= 0.9GeV $\Delta m\chi_2$ =5GeV
  0.9GeV/5GeV ≈ 0.2
- $\Delta m_{1/2}$=1GeV → shift $m\ell\ell$ = 0.7GeV $\Delta m\ell\ell$ = 0.08GeV
  0.7GeV/0.08GeV ≈ 9

- probably need correlations to get back precision from masses

LHCmax scenario:

- all LHC measurements are available
- 10fb-1 (2008): statistical error ~ factor sqrt(30)
- systematic (e-scale) ~ factor 5.4

(5‰ lepton e-scale, 5% jet e-scale)

- top mass measurement from TeVatron
  - currently ± 4GeV
  - extrapolated begin of LHC ± 2GeV
- using the masses

mtop = 175GeV	mtop = 179GeV	mtop = 171GeV
$m0 = 100 \pm 22$ GeV	$m0 = 99 \pm 22$GeV	$m0 = 102 \pm 22$ GeV
$m_{1/2} = 250 \pm 9$ GeV	$m_{1/2} = 249 \pm 9$ GeV	$m_{1/2} = 250 \pm 9$ GeV
$\tan\beta = 10 \pm 6$	$\tan\beta = 7.4 \pm 3$	$\tan\beta = 13.7 \pm 9$
$A_0 = -100 \pm 181$ GeV	$A_0 = -22 \pm 226$ GeV	$A_0 = -174 \pm 145$ GeV

top mass precision 4GeV:

- m_0, $m_{1/2}$ unaffected
- $\tan\beta$ and A_0 shifted by up to 1σ

top mass precision 2GeV:

- shift reduced to less than 0.7σ

LHCmax scenario: edges

- all LHC measurements are available
- 10fb-1 (2008): statistical error ~ sqrt(30)
- systematic (e-scale) ~ 0.5% leptons, 5% jets

Variable	Value (GeV)	Errors		
		Stat. (GeV)	Scale (GeV)	Total
$m_{\ell\ell}^{max}$	77.07	0.03	0.08	0.08
$m_{\ell\ell q}^{max}$	428.5	1.4	4.3	4.5
$m_{\ell q}^{low}$	300.3	0.9	3.0	3.1
$m_{\ell q}^{high}$	378.0	1.0	3.8	3.9
$m_{\ell\ell q}^{min}$	201.9	1.6	2.0	2.6
$m_{\ell\ell b}^{min}$	183.1	3.6	1.8	4.1
$m(\ell_L) - m(\tilde{\chi}_1^0)$	106.1	1.6	0.1	1.6
$m_{\ell\ell}^{max}(\tilde{\chi}_4^0)$	280.9	2.3	0.3	2.3
$m_{\tau\tau}^{max}$	80.6	5.0	0.8	5.1
$m(\tilde{g}) - 0.99 \times m(\tilde{\chi}_1^0)$	500.0	2.3	6.0	6.4
$m(\tilde{q}_R) - m(\tilde{\chi}_1^0)$	424.2	10.0	4.2	10.9
$m(\tilde{g}) - m(\tilde{b}_1)$	103.3	1.5	1.0	1.8
$m(\tilde{g}) - m(\tilde{b}_2)$	70.6	2.5	0.7	2.6

mtop = 175GeV

m_0 = 100 ± 6 GeV

$m_{1/2}$ = 250 ± 5 GeV

$\tan\beta$ = 10 ± 5

A_0 = -100± 110 GeV

mtop = 179GeV

m_0 = 97.9 ± 6 GeV

$m_{1/2}$ = 250 ± 6 GeV

$\tan\beta$ = 7.5 ± 2

A_0 = -37 ± 140 GeV

mtop = 171GeV

m_0 = 101 ± 6 GeV

$m_{1/2}$ = 249 ± 5 GeV

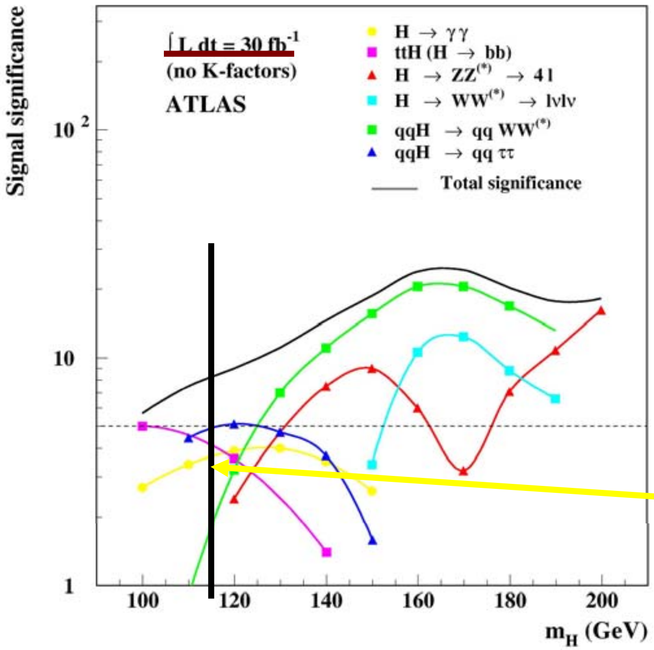
$\tan\beta$ = 12.6 ± 6

A_0 = -152 ± 88 GeV

Internal information in the edges leads to a higher precision

- ultimate top mass precision introduces less than 0.7σ uncertainty in SUSY parameter determination

LHCminimal scenario:



Higgs mass from γγ

- too early for Higgs to γγ with 10fb-1
- only central cascade SUSY measurements are available:

χ_1, χ_2, $\tilde{q}_L$, $\tilde{\ell}_R$

From the masses

m_0 = 100 ± 30 GeV

$m_{1/2}$ = 250 ± 26 GeV

tanβ = 10 ± 485

A_0 = -100 ± 9200 GeV

From the edges:

m_0 = 100 ± 14 GeV

$m_{1/2}$ = 250 ± 10 GeV

tanβ = 10 ± 144

A_0 = -100 ± 2400 GeV

No surprise: less information, less precision, even for mtop 4GeV error negligeable effect given the errors

LHCminimal plus Higgs scenario:

- Higgs is sitting on the edge of LEP exclusion
- WH+ZH 6 events per fb^{-1} and experiment
- end of Run: $\Delta m_h = \pm$ 2GeV
- adding background: ΔmHiggs = ± 4-5GeV
- minimal scenario LHC

plus TeVatron Higgs hint of 4.5GeV precision:

No Higgs, edges from the LHC:	Higgs hint plus edges from the LHC:
m_0 = 100 ± 14 GeV	m_0 = 100 ± 9 GeV
$m_{1/2}$ = 250 ± 10 GeV	$m_{1/2}$ = 250 ± 9 GeV
$\tan\beta$ = 10 ± 144	$\tan\beta$ = 10 ± 31
A_0 = -100.37 ± 2400 GeV	A_0 = -100 ± 685 GeV

A Higgs hint mass measurement would lead to an improvement of m_0, $\tan\beta$ and A_0 (but the latter two are still essentially undetermined)!

Conclusions

- SFITTER updated with new SUSPECT
- use of thresholds and masses now possible
- use of thresholds and mass differences improves significantly the determination of m_0
- SPS1a4TeVatron:
    - ultimate TeVatron top quark measurement (2GeV) will reduce uncertainties on the SUSY parameter determination due to the top quark mass measurement to less than 1σ ☺
    - if TeVatron can detect a hint of the Higgs and measure its mass with a precision of 4-5GeV a positive impact on the parameter determination can be observed

Thanks to Volker for the Higgs hint!