Projekt SPA

SUSY Parameter Determination

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Plan seminarium:

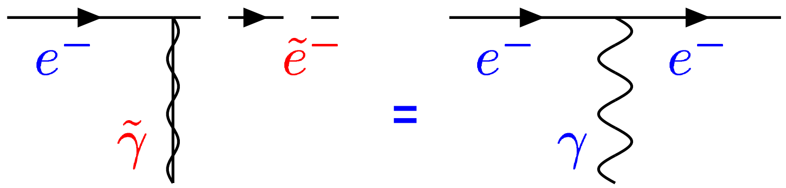
- Wprowadzenie
- Projekt SPA
- Sektor neutralin i chargin
- Badania przy LC
- Analiza danych z LC i LHC

Supersymmetry – a well motivated extension of the SM:

- stabilizes the electroweak scale
- leads to unification of gauge couplings
- accommodates large top quark mass
- provides dark matter candidate

Exact SUSY – no new parameters:

- we know spartners
- and their couplings

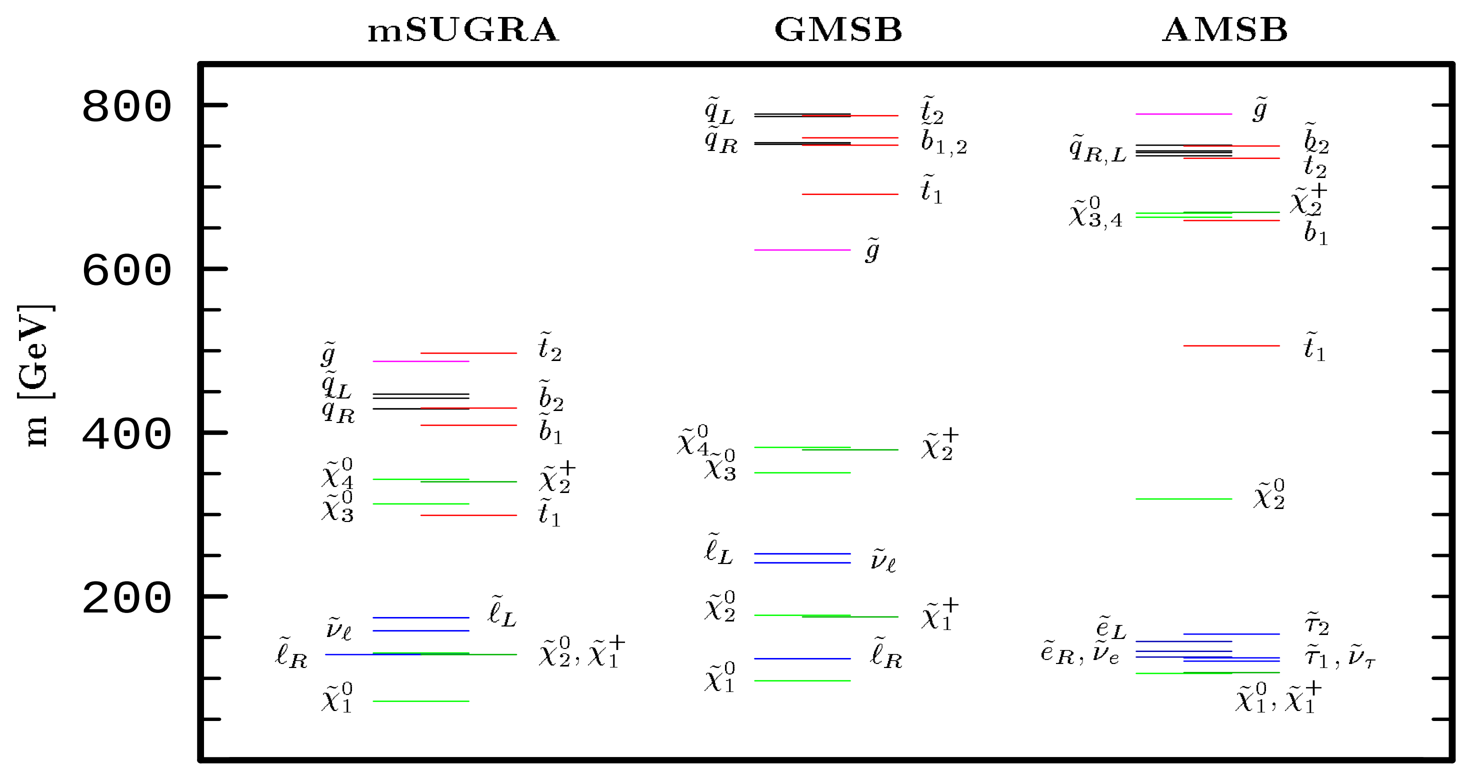


However SUSY – must be broken: soft breaking

- its mechanism unknown ($>$ 100 parameters in MSSM)
- many models: SUGRA, GMSB, AMSB, $\tilde{g}$MSB, . . .
- each model has a few parameters (at high scale)

  $\Longrightarrow$ different phenomenology

SUSY Breaking



How can one experimentally determine the SUSY parameters?

- Lagrangian parameters are not observables
- observables: σ, distributions, BRs, asymmetries, ...
- need unfolding procedure to determine masses, partial widths, couplings etc. from measured cross sectione ...

$\Longrightarrow$ not possible to measure Lagrangian parameters in a strictly model-independent way

In practice: comparison of data – Monte Carlo

$\Rightarrow$ dependence on other model parameters

Even in the SM

- masses: relatively small model dependence $\Leftarrow$ closely related to one observable
- couplings, mixing angles, ...: more model dependent

In the MSSM:

- many relations between particle masses
- many parameters are not closely related to one particular observable, like $\tan\beta$, μ, complex phases, ...
- masses of unstable particles: different definitions possible
- no obvious ’best’ choice for renormalization conditions
- already many different definitions in the literature
  $\Rightarrow$ have to convert between them when comparing theoretical predictions
- ultimately a global fit to many observables, like in the SM
  $\Rightarrow$ should we better converge to one (or at most only few) commonly accepted standard(s)??

Example: Les Houches Accord #3

Projekt SPA – Supersymmetry Parameter Analysis

A lot of results already available:

On the theoretical side:

- **two-loop for Higgs sector**
- **one-loop for sfermion and gaugino masses and couplings**
- **partial results for cross sections and decay widths**

On the experimental side

- **MC simulations for the LHC**
- **some experimental analyses performed for the LC**

Different pieces done in different schemes, and for different SUSY scenarios.

Goals of the SPA project

1st step: Collect consistent set of tools for

- masses, mixings, couplings, ...
- cross sections, BR, ...
- low-energy constraints, e.g. $b \to s\gamma$, $(g-2)_\mu$, $\Omega_{CDM}h^2$, ...

2nd step: Analyse one scenario $\Rightarrow$ SPS1a point chosen

- experimental error analyses for LHC + LC
- extract Lagrange parameters
- extrapolate them to high scale

One example: Analysis of the chargino/neutralino sector at LC + LHC

with Desch, Moortgat-Pick, Nojiri and Polesello

Existing simulations and estimates

	m [GeV]	Δm [GeV]	Comments
$\tilde{\chi}_1^\pm$	176.4	0.55	simulation threshold scan, 100 fb^{-1}
$\tilde{\chi}_1^0$	96.1	0.05	combination of all methods
$\tilde{\chi}_2^0$	176.8	1.2	simulation threshold scan $\tilde{\chi}_2^0\tilde{\chi}_2^0$, 100 fb^{-1}
$\tilde{e}_R$	143.0	0.05	e^-e^- threshold scan, 10 fb^{-1}
$\tilde{e}_L$	202.1	0.2	e^-e^- threshold scan 20 fb^{-1}
$\tilde{\nu}_e$	186.0	1.2	simulation energy spectrum, 500 GeV, 500 fb^{-1}
$\tilde{\mu}_R$	143.0	0.2	simulation energy spectrum 400 GeV, 200 fb^{-1}
$\tilde{\tau}_1$	133.2	0.3	simulation energy spectra, 400 GeV, 200 fb^{-1}

Studies & simulations to be done

$\tilde{\chi}_1^\pm$		$\sigma_{L,R}(\tilde{\chi}_1^\pm \tilde{\chi}_1^\mp)$
$\tilde{\chi}_2^\pm$	m, Γ, B	$\sigma_{L,R}(\tilde{\chi}_1^\pm \tilde{\chi}_2^\mp)$, $\sigma_{L,R}(\tilde{\chi}_2^\pm \tilde{\chi}_2^\mp)$
$\tilde{\chi}_2^0$	$\Delta m_{12} = m_{\tilde{\chi}_2^0 - \tilde{\chi}_1^0}$	m_{ee}, $m_{\mu\mu}$ spectra
$\tilde{\chi}_3^0$	m, Γ	Z, W spectra, thresholds
$\tilde{\chi}_4^0$	m, Γ	Z, W spectra,thresholds
$\tilde{e}_L$	m, Γ, B in e^+e^-	E_e spectra from $\tilde{e}_R\tilde{e}_L$, $\tilde{e}_L\tilde{e}_L$
$\tilde{\nu}_\mu$	m, Γ	
$\tilde{\mu}_L$	m, Γ, B	continuum, threshold
$\tilde{\nu}_\tau$	m, Γ	
$\tilde{\tau}_2$	$m, \Gamma, B, \mathcal{P}_\tau$	
$\tilde{t}_1$	m, $\cos\theta_{\tilde{t}}$, Γ	jet spectra, min. mass

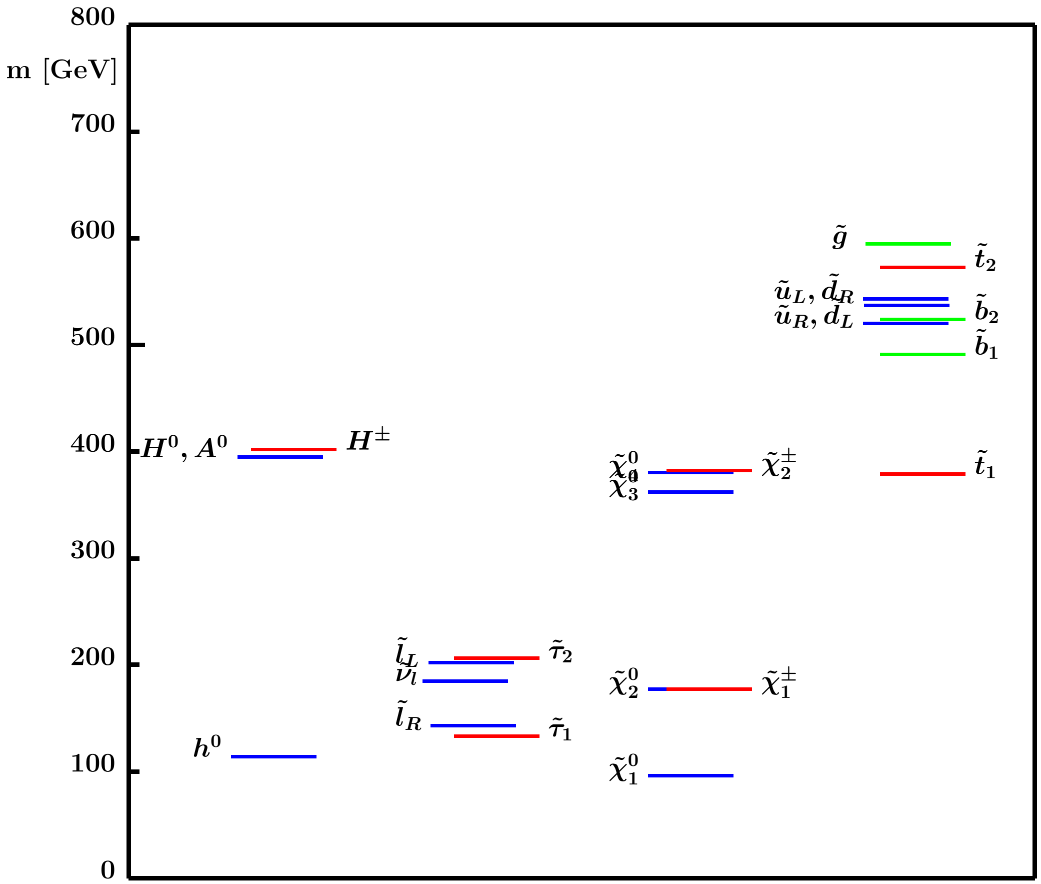
Scenario: [Desch, Moortgat-Pick, Nojiri, Polesello, JK]

- The SPS1a SUSY point for analysis
- The first phase of a LC with $\sqrt{s} \leq 500$ GeV could overlap with the LHC
- only light $\tilde{\chi}_1^+$, $\tilde{\chi}_1^0$ and $\tilde{\chi}_2^0$ accessible at the LC
- $\tilde{e}_{\rm L}$, $\tilde{e}_{\rm R}$ and $\tilde{\nu}_e$ measured
- polarized beams with $P(e^-) = \pm 0.80$ and $P(e^+) = \mp 0.6$
- integrated luminosity of 100 fb^{-1} per process

Goals of the exercise: at tree level

- how well can the SUSY parameters be determined from LC
- with additional info from the LHC
- joint analysis

Example: charginos/neutralinos



m_0	100 GeV
$m_{1/2}$	250 GeV
A_0	-100 GeV
$\tan\beta$	10
sign μ	$+$

SPS1a – 'typical' mSUGRA parameters and spectrum

```
ISAJET 7.58 equivalent input:
MSSMA:   595.19  352.39  393.63   10.00
MSSMB:   539.86  519.53  521.66  196.64  136.23
MSSMC:   495.91  516.86  424.83  195.75  133.55 -510.01 -772.66 -254.20
MSSMD: SAME AS MSSMB (DEFAULT)
MSSME:    99.13  192.74
```

The chargino sector:

- chargino mass matrix in the $(\tilde{W}^-, \tilde{H}^-)$ basis

$$\mathcal{M}_C = \begin{pmatrix} M_2 & \sqrt{2} m_W \cos\beta \\ \sqrt{2} m_W \sin\beta & |\mu| e^{i\Phi_\mu} \end{pmatrix}$$

- to diagonalize, two unitary matrices parameterized by two mixing angles $\phi_{L,R}$ and three CP phases $\beta_{L,R}$ and γ

$$U_L = \begin{pmatrix} c_L & s_L^* \\ -s_L & c_L \end{pmatrix}, \qquad U_R = \begin{pmatrix} 1 & 0 \\ 0 & e^{i\gamma} \end{pmatrix} \begin{pmatrix} c_R & s_R^* \\ -s_R & c_R \end{pmatrix}$$

where $c_{L,R} = \cos\phi_{L,R}$, $\quad s_{L,R} = e^{i\beta_{L,R}} \sin\phi_{L,R}$

From $\{M_2, \mu, \tan\beta\} \Longrightarrow \{m_{\tilde{\chi}^\pm_{1,2}}, \cos 2\phi_{L,R}\}$

- **the chargino masses**

$$m^2_{\tilde{\chi}^\pm_{1,2}} = \frac{1}{2}\left[M_2^2 + |\mu|^2 + 2m_W^2 \mp \Delta_C\right]$$

- **the mixing angles**

$$\cos 2\phi_{L,R} = -\left[M_2^2 - |\mu|^2 \mp 2m_W^2 \cos 2\beta\right] / \Delta_C$$

where

$$\Delta_C = [(M_2^2 - |\mu|^2)^2 + 4m_W^4 \cos^2 2\beta + 4m_W^2 (M_2^2 + |\mu|^2) + 8m_W^2 M_2 |\mu| \sin 2\beta \cos \Phi_\mu]^{1/2}$$

Experimentally masses and mixing angles will be measured

- **chargino masses** $\Leftarrow$ **threshold scans, or in continuum**
- **mixing angles** $\Leftarrow$ **cross sections with polarized beams**

Inverting [Choi et al. ’98-’02, Kneur, Moultaka ’99,’00]

From $\{m_{\tilde{\chi}_1^\pm},\, m_{\tilde{\chi}_2^\pm},\, \cos 2\phi_L,\, \cos 2\phi_R\} \Longrightarrow \{M_2, |\mu|, \cos\Phi_\mu, \tan\beta\}$

- **the mass parameters**

$$M_2 = [(m^2_{\tilde{\chi}_2^\pm} + m^2_{\tilde{\chi}_1^\pm} - 2m^2_W)/2 - \Delta_C(c_{2L} + c_{2R})/4]^{1/2}$$

$$|\mu| = [(m^2_{\tilde{\chi}_2^\pm} + m^2_{\tilde{\chi}_1^\pm} - 2m^2_W)/2 + \Delta_C(c_{2L} + c_{2R})/4]^{1/2}$$

- $\tan\beta = \sqrt{\frac{4m_W^2 - \Delta_C(\cos 2\phi_L - \cos 2\phi_R)}{4m_W^2 + \Delta_C(\cos 2\phi_L - \cos 2\phi_R)}}$

- **and** $\cos\Phi_\mu$ **(or sign of μ in CP–invariant case)**

In our scenario $\tilde{\chi}_2^\pm$ is beyond the kinematical limit

Question:

How well M_2, μ and $\tan\beta$ can be determined from the LC data without the heavy chargino mass?

Inverting in the CP conserving case (SPS1a)

From $\{m_{\tilde{\chi}_1^\pm},\, \cos 2\phi_{L,R}\} \Longrightarrow \{M_2, \mu, \tan\beta\}$

- **define**

$$p = \pm\left|\frac{\sin 2\Phi_L + \sin 2\Phi_R}{\cos 2\Phi_L - \cos 2\Phi_R}\right|, \qquad q = \frac{1}{p}\,\frac{\cos 2\Phi_L + \cos 2\Phi_R}{\cos 2\Phi_L - \cos 2\Phi_R}$$

- **then**

$$\begin{aligned} M_2 &= \frac{m_W}{\sqrt{2}}\left[(p+q)\sin\beta - (p-q)\cos\beta\right] \\ \mu &= \frac{m_W}{\sqrt{2}}\left[(p-q)\sin\beta - (p+q)\cos\beta\right] \\ \tan\beta &= \left[\frac{p^2 - q^2 \pm \sqrt{r_{\tilde{\chi}}^2(p^2+q^2+2-r_{\tilde{\chi}}^2)}}{(\sqrt{1+p^2}-\sqrt{1+q^2})^2 - 2r_{\tilde{\chi}}^2}\right]^\eta \end{aligned}$$

where $\eta = 1$ **for** $\cos 2\phi_R > \cos 2\phi_L$**, and** $\eta = -1$ **otherwise**

Experimental input at the LC Ball, Desch, Martyn

	$\tilde{\chi}_1^\pm$	$\tilde{\chi}_2^\pm$	$\tilde{\chi}_1^0$	$\tilde{\chi}_2^0$	$\tilde{\chi}_3^0$	$\tilde{\chi}_4^0$	$\tilde{e}_R$	$\tilde{e}_L$	$\tilde{\nu}_e$
m	176.03	378.5	96.17	176.6	358.8	377.9	143.0	202.1	186.
δm	0.55		0.05	1.2			0.05	0.2	0.7

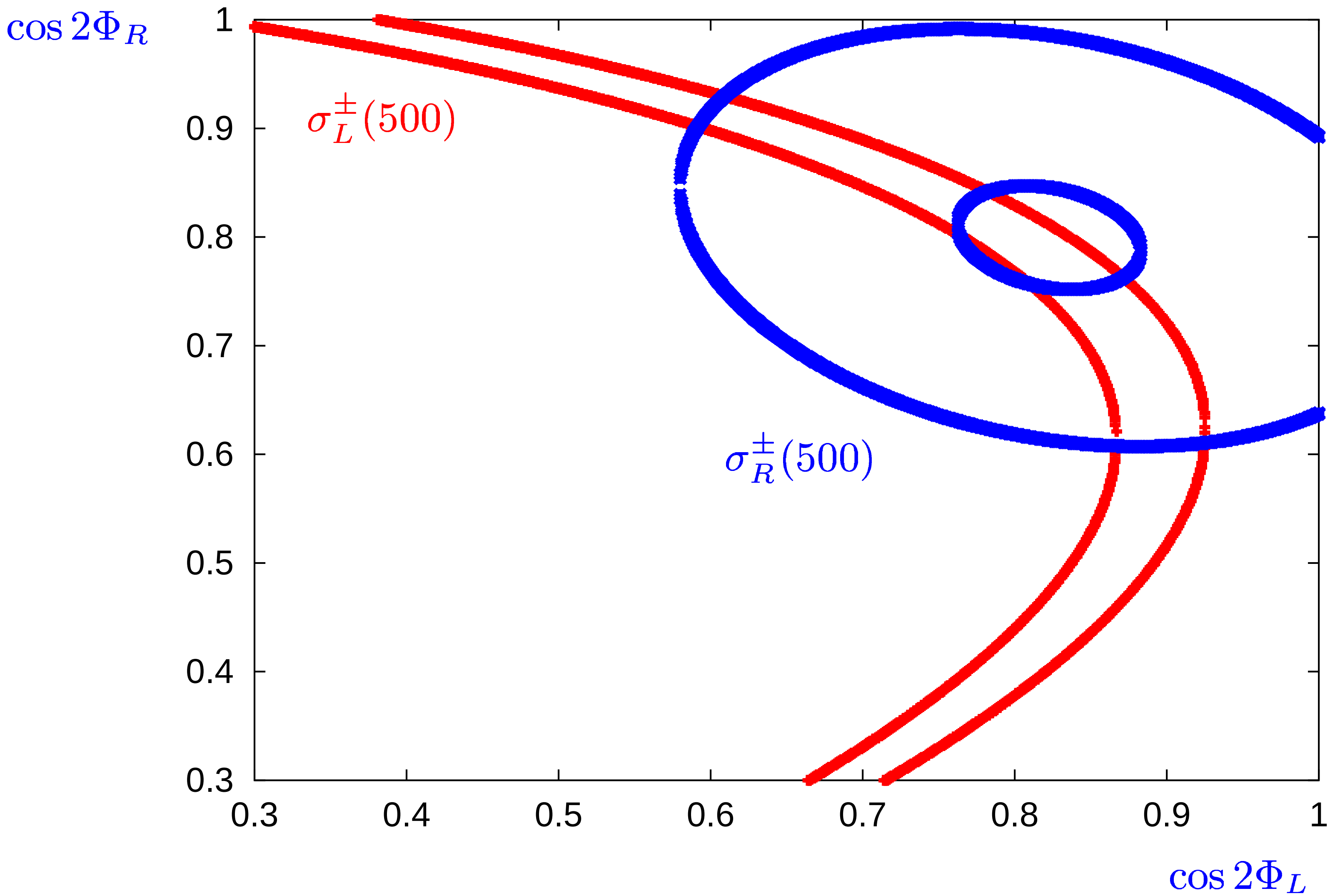
For the analysis we take

- chargino mass with error of 0.55 GeV
- polarised cross sections $\sigma_L^\pm\{11\}$ and $\sigma_R^\pm\{11\}$ at $\sqrt{s} = 400,\ 500$ GeV
- $\tilde{\chi}_1^\pm \to \tilde{\tau}_1^\pm \nu_\tau$ with 100% followed by $\tilde{\tau}_1^\pm \to \tau^\pm \tilde{\chi}_1^0$
- the signature: two τ jets in opposite hemispheres
- assume 100 fb^{-1} per each process and take 1σ statistical error
- include error of 0.7 GeV for $m_{\tilde{\nu}_e}$
- beam polarisation with $\Delta P(e^\pm)/P(e^\pm) = 0.5\%$

Chargino production cross sections and errors

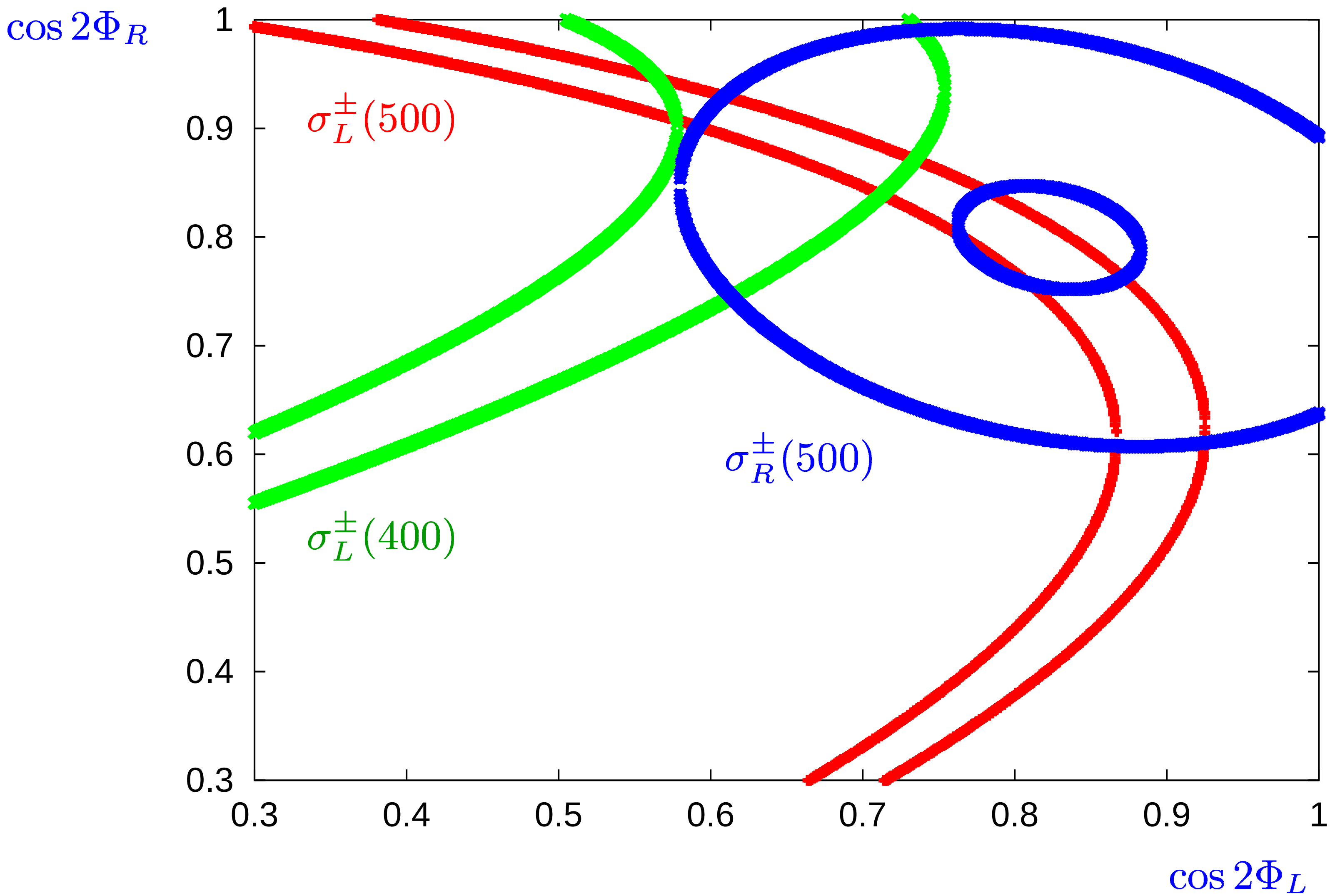
$\sqrt{s}$	400 GeV		500 GeV	
$(P(e^-), P(e^+))$	$(-.8, +.6)$	$(+.8, -.6)$	$(-.8, +.6)$	$(+.8, -.6)$
$\sigma(e^+e^- \to \tilde{\chi}_1^+ \tilde{\chi}_1^-)$	215.84	6.38	504.87	15.07
$\delta\sigma_{\text{stat}}$	1.47	0.25	2.25	0.39
$\delta\sigma_{P(e^-)}$	0.48	0.12	1.12	0.28
$\delta\sigma_{P(e^+)}$	0.40	0.04	0.95	0.10
$\delta\sigma_{m_{\tilde{\chi}_1^\pm}}$	7.09	0.20	4.27	0.12
$\delta\sigma_{m_{\tilde{\nu}_e}}$	0.22	0.01	1.57	0.04
$\delta\sigma_{\text{total}}$	7.27	0.35	5.28	0.51

plot cross sections in the $\cos 2\Phi_L$ and $\cos 2\Phi_R$ plane



$\cos 2\Phi_R$
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
$\sigma_L^{\pm}(500)$
$\sigma_R^{\pm}(500)$
$\cos 2\Phi_L$

SPA: charginos



$$\Rightarrow \cos 2\phi_L \in [0.62, 0.71], \quad \cos 2\phi_R \in [0.87, 0.91]$$

An attempt to solve for M_2, μ and $\tan\beta$

- $\Delta M_2 = 10$ **GeV**
- $\Delta\mu = 40$ **GeV**
- **no limit on** $\tan\beta$

$\Longrightarrow$**include neutralinos**

The neutralino sector:

- **neutralino mass matrix in the $(\tilde{B}, \tilde{W}^3, \tilde{H}_1^0, \tilde{H}_2^0)$ basis**

$$\mathcal{M}_N = \begin{pmatrix} M_1 & 0 & -m_Z c_\beta s_W & m_Z s_\beta s_W \\ 0 & M_2 & m_Z c_\beta c_W & -m_Z s_\beta c_W \\ -m_Z c_\beta s_W & m_Z c_\beta c_W & 0 & -\mu \\ m_Z s_\beta s_W & -m_Z s_\beta c_W & -\mu & 0 \end{pmatrix}$$

$M_1 = |M_1|\, \mathrm{e}^{i\Phi_1}$, $\mu = |\mu|\, \mathrm{e}^{i\Phi_\mu}$

- **the diagonalization matrix N: 6 angles and 10 phases**

$$N = \mathrm{diag}\left\{\mathrm{e}^{i\alpha_1}, \mathrm{e}^{i\alpha_2}, \mathrm{e}^{i\alpha_3}, \mathrm{e}^{i\alpha_4}\right\} \mathrm{D}$$

$$\mathrm{D} = \mathrm{R}_{34}\, \mathrm{R}_{24}\, \mathrm{R}_{14}\, \mathrm{R}_{23}\, \mathrm{R}_{13}\, \mathrm{R}_{12}$$

R_{jk}: **2-dim complex rotation by** $(\cos\theta_{jk}, \sin\theta_{jk}\, \mathrm{e}^{i\varphi_{jk}})$

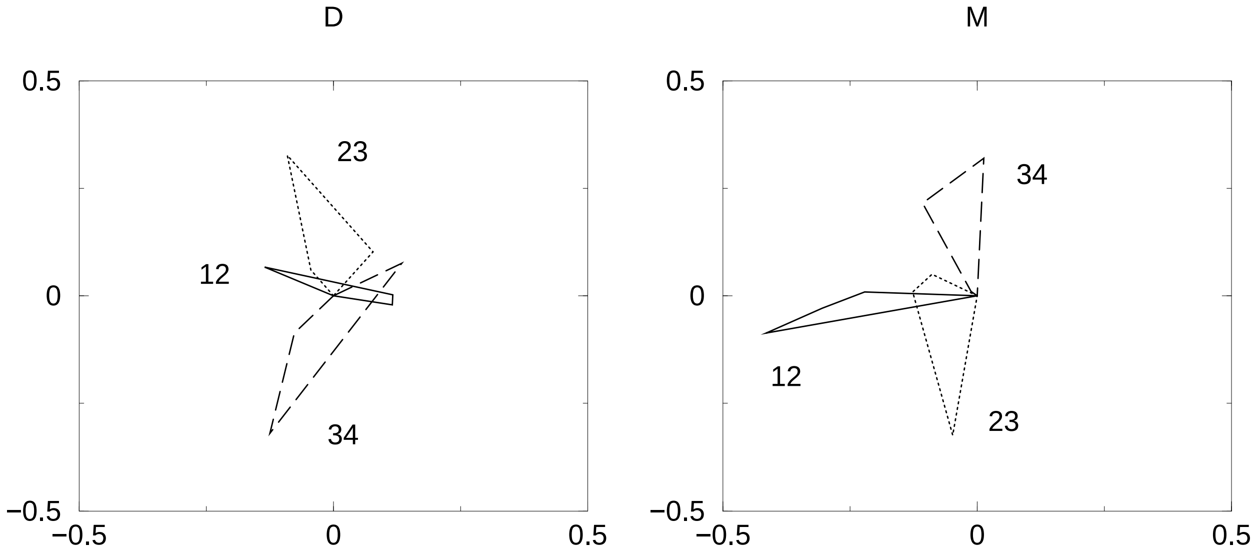
- **if $\varphi_{ij} = 0$ and $\alpha_i = 0$, CP conserved**

- **unitarity constraints $\longrightarrow$ quadrangles of two types**

⊕ **multiply rows i and j** $\qquad M_{ij} = \Sigma_k N_{ik} N_{jk}^*$

⊕ **multiply columns i and j** $\qquad D_{ij} = \Sigma_k N_{ki} N_{kj}^*$

- **unlike in the CKM or MNS cases of quark and lepton mixing, the orientation of all quadrangles is physical and determined by the phases**



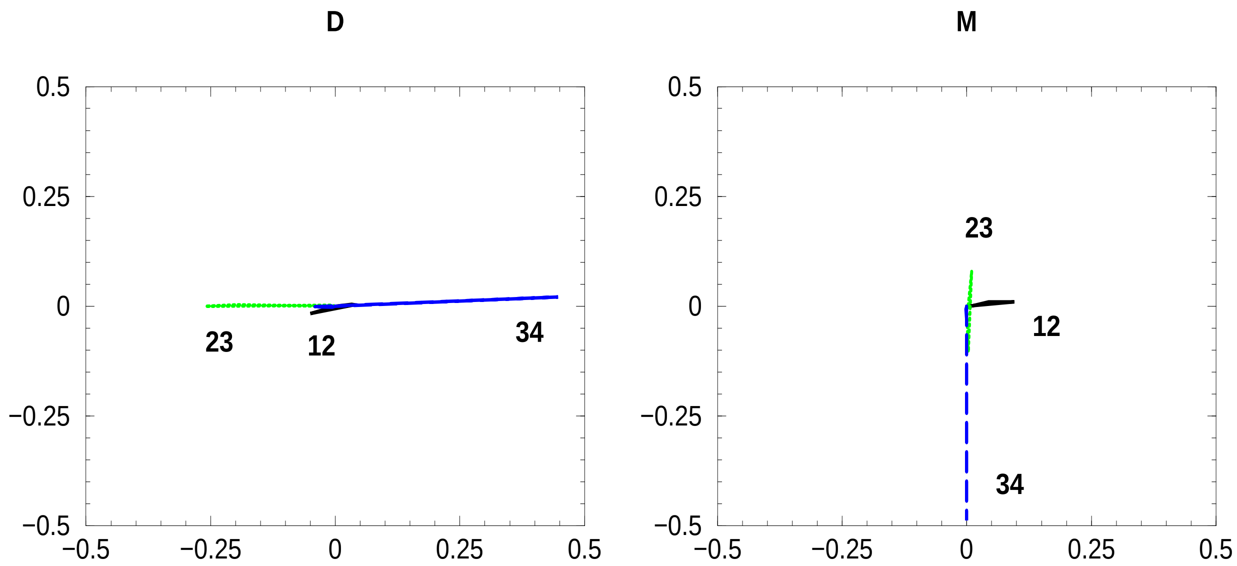
$$(M_1,\ M_2,\ |\mu|, \tan\beta) = (100\,GeV,\ 150\,GeV,\ 200\,GeV,\ 3), \quad \Phi_\mu = \pi/2.$$

- **CP conserved if all quadrangles collapse and parallel to axes**

If CP-violating phases small, small effects for CP-odd quantities [JK]

example: $\tan\beta = 10$, $M_2 = 190.8$ **GeV,** $\mu = 365.1$ **GeV,** $|M_1| = 100.5$ **GeV,** $\Phi_1 = \pi/5$

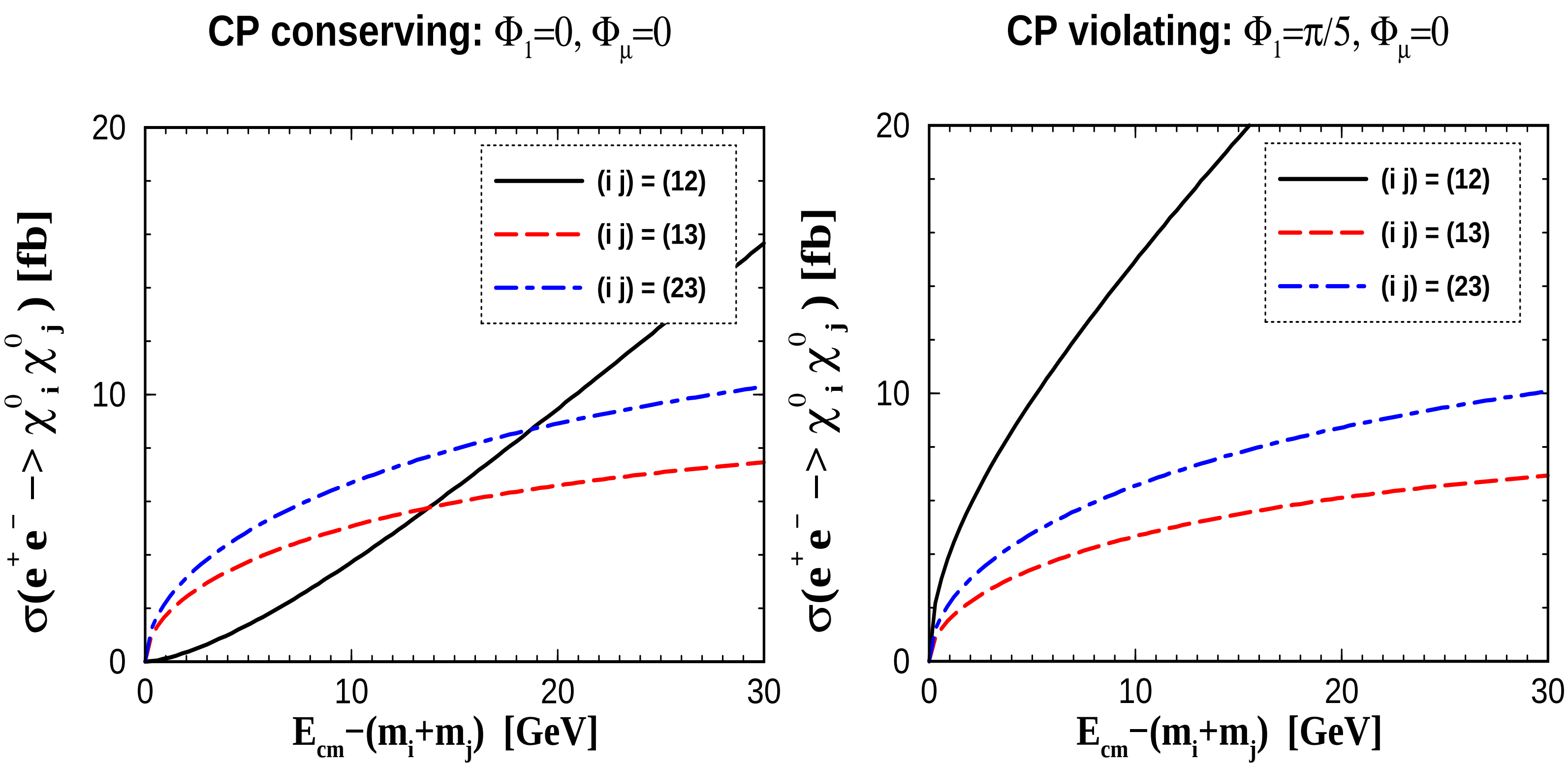
unitarity quadrangles:



If energy above the heavy -inos,

- **threshold behavior of non-diagonal neutralino production – clear signal of nontrivial CP phases**

- **in CP-conserving:**
  - **S-wave excitation only if $\tilde{\chi}_i^0$ and $\tilde{\chi}_j^0$ have opposite CP-parities**
  - **if (ij) and (ik) pairs in S-wave $\Longrightarrow$ (ik) pair in P-wave**
- **In CP-violating: all pairs can be in S-wave**



The neutralino sector: new parameter M_1

Observables and errors

- two light neutralino masses with $\delta m_{\tilde\chi^0_1} = 0.05$ GeV, $\delta m_{\tilde\chi^0_2} = 1.2$ GeV
- $\tilde\chi^0_1\tilde\chi^0_3$ and $\tilde\chi^0_1\tilde\chi^0_4$ pairs kinematically accessible at $\sqrt{s} = 500$ GeV, but rates small and complicated $\tilde\chi^0_{3,4}$ decays $\Longrightarrow$ neglected
- $\sigma^0_{L,R}\{12\}$ and $\sigma^0_{L,R}\{22\}$ at $\sqrt{s} = 400$ GeV and $\sqrt{s} = 500$ GeV
- $\tilde\chi^0_2 \to \tilde\tau^\pm_1\tau^\mp$ with almost 90%, followed by $\tilde\tau^\pm_1 \to \tau\tilde\chi^0_1$
- efficiency of about 25% for $\tilde\chi^0_1\tilde\chi^0_2$ production
- 1σ statistical error at 100 fb^{-1}, including 25% efficiency
- errors on $m_{\tilde\chi^\pm_1}, m_{\tilde e_L}, m_{\tilde e_R}$ and beam polarization

$\tilde{\chi}^0_1\tilde{\chi}^0_2$ **production cross section and errors**

$\sqrt{s}$	400 GeV		500 GeV	
$(P(e^-), P(e^+))$	$(-.8, +.6)$	$(+.8, -.6)$	$(-.8, +.6)$	$(+.8, -.6)$
$\sigma(e^+e^- \to \tilde{\chi}^0_1\tilde{\chi}^0_2)$	148.38	20.06	168.42	20.81
$\delta\sigma_{\text{stat}}$	2.82	2.63	2.95	2.54
$\delta\sigma_{P(e^-)}$	0.32	0.05	0.37	0.06
$\delta\sigma_{P(e^+)}$	0.28	0.001	0.31	0.01
$\delta\sigma_{m_{\tilde{\chi}^\pm_1}}$	0.21	0.30	0.16	0.26
$\delta\sigma_{m_{\tilde{e}_L}}$	0.20	0.01	0.17	0.01
$\delta\sigma_{m_{\tilde{e}_R}}$	0.00	0.01	0.00	0.01
$\delta\sigma_{\text{total}}$	2.87	2.65	2.99	2.55

$\tilde{\chi}_2^0\tilde{\chi}_2^0$ production cross section and errors

	400 GeV		500 GeV	
$(P(e^-), P(e^+))$	$(-.8,+.6)$	$(+.8,-.6)$	$(-.8,+.6)$	$(+.8,-.6)$
$\sigma(e^+e^- \to \tilde{\chi}_2^0\tilde{\chi}_2^0)$	85.84	2.42	217.24	6.10
$\delta\sigma_{\text{stat}}$	2.33	2.5	3.26	2.44
$\delta\sigma_{P(e^-)}$	0.19	0.05	0.48	0.12
$\delta\sigma_{P(e^+)}$	0.16	0.02	0.41	0.05
$\delta\sigma_{m_{\tilde{\chi}_1^\pm}}$	2.67	0.08	1.90	0.05
$\delta\sigma_{m_{\tilde{e}_L}}$	0.15	0.004	0.28	0.01
$\delta\sigma_{m_{\tilde{e}_R}}$	0.00	0.00	0.00	0.00
$\delta\sigma_{\text{total}}$	3.56	2.5	3.83	2.45

We perform a simple $\Delta\chi^2$ test defined as

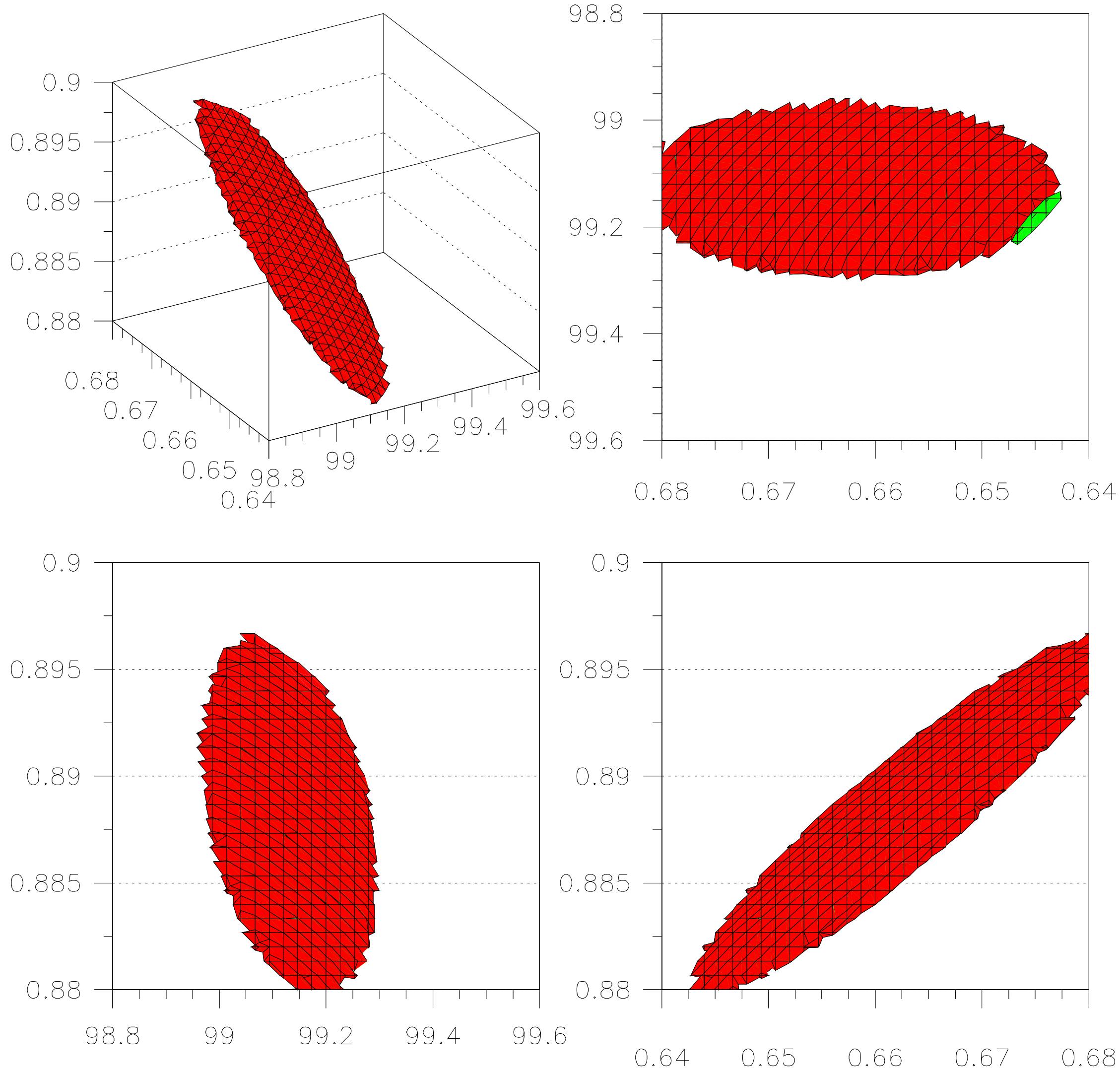
$$\Delta\chi^2 = \sum_i \left|\frac{O_i - \bar{O}_i}{\delta O_i}\right|^2$$

The sum over physical observables O_i includes

- $m_{\tilde{\chi}^0_1}$ **and** $m_{\tilde{\chi}^0_2}$
- $\sigma^0_{L,R}\{12\}, \sigma^0_{L,R}\{22\}$ **measured at 400 and 500 GeV**

$\Delta\chi^2$ **is a function of unknown** M_1, $\cos 2\Phi_L$ **and** $\cos 2\Phi_R$**, with** $\cos 2\Phi_L$ **and** $\cos 2\Phi_R$ **restricted from the chargino sector**

Derive 1σ errors from $\Delta\chi^2 = 1$



LC data

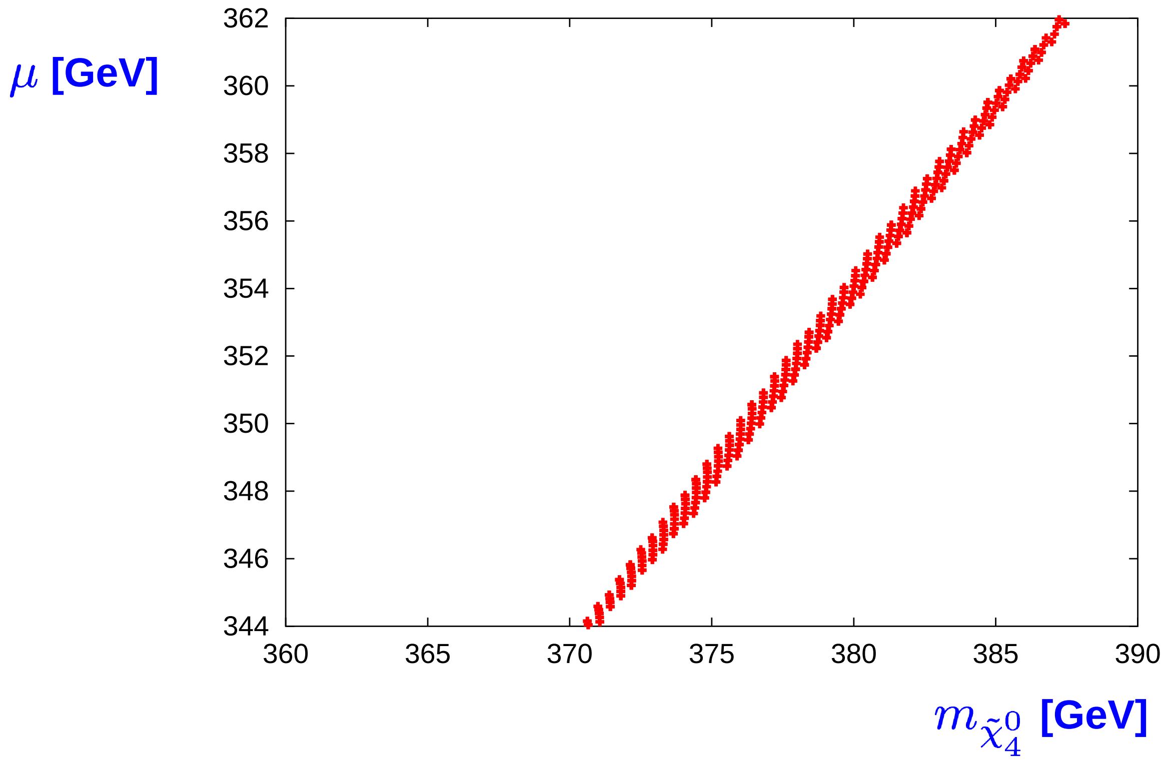
$\Delta\chi^2 = 1$ *contours in the* $M_1, \cos 2\Phi_L, \cos 2\Phi_R$ *parameter space*

Results from the LC data:

SUSY Parameters			
M_1	M_2	μ	$\tan\beta$
99.1 ± 0.15	192.7 ± 0.7	$\mu = 352.8 \pm 8.1$	$[8.6 - 11.8]$

Mass Predictions		
$m_{\tilde{\chi}_2^\pm}$	$m_{\tilde{\chi}_3^0}$	$m_{\tilde{\chi}_4^0}$
379.0 ± 7.2	359.0 ± 7.7	377.9 ± 7.3

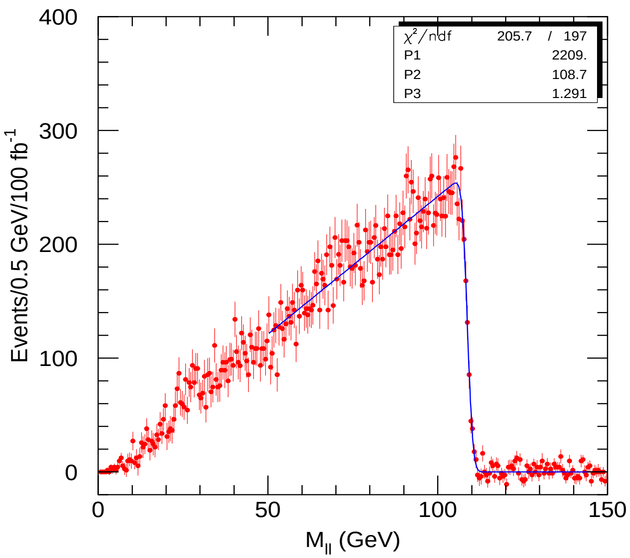
strong correlation between errors for μ and heavy chargino/neutralino masses



LC data supplemented by the LHC:

LHC will provide a first measurement of $m_{\tilde{\chi}_2^0}$ and $m_{\tilde{\chi}_4^0}$ the processes:

$$\tilde{\chi}_i^0 \to \tilde{\ell}\ell \to \ell\ell\tilde{\chi}_1^0, \qquad i = 2, 4$$



$$m_{l^+l^-}^{max} = m_{\tilde{\chi}_i^0}\sqrt{1 - \frac{m_{\tilde{\ell}}^2}{m_{\tilde{\chi}_i^0}^2}}\sqrt{1 - \frac{m_{\tilde{\chi}_1^0}^2}{m_{\tilde{\ell}}^2}}$$

The achievable precision:

$\delta m_{\tilde{\chi}_2^0} = 4.5$ **GeV and** $\delta m_{\tilde{\chi}_4^0} = 5.1$ **GeV at 300 fb^{-1}**

From the LC + $\delta m_{\tilde{\chi}^0_4} = 5.1$ **GeV**

SUSY Parameters			
M_1	M_2	μ	$\tan\beta$
99.1 ± 0.14	192.7 ± 0.5	352.4 ± 4.2	$[9 - 11.2]$

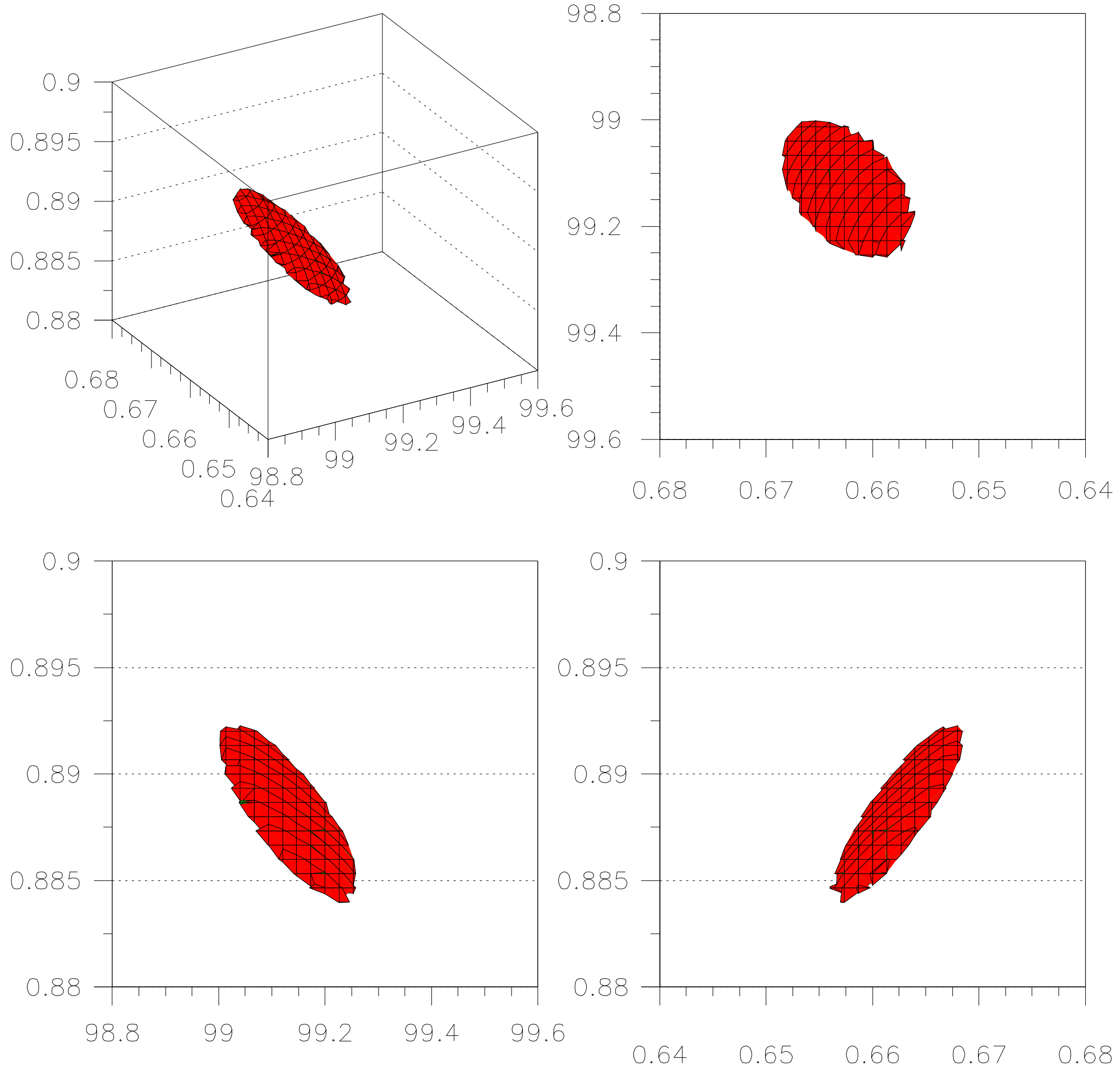
Mass Predictions	
$m_{\tilde{\chi}^\pm_2}$	$m_{\tilde{\chi}^0_3}$
378.5 ± 5.0	358.8 ± 5.1

Joint analysis of the LC and LHC data:

- At the LHC, $\delta m_{\tilde{\chi}_2^0}$ and $\delta m_{\tilde{\chi}_4^0}$ depend both on the experimental error on the position of $m_{l^+l^-}^{max}$, and on $\delta m_{\tilde{\chi}_1^0}$ and $\delta m_{\tilde{\ell}}$.
- from LHC alone, errors for $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\ell}}$ are of 4.8 GeV
- $m_{\tilde{\chi}_1^0}$ and $m_{\tilde{\ell}}$ measured at the LC with error of 0.05 GeV
- with this input $\delta m_{\tilde{\chi}_2^0} = 0.08$ GeV and $\delta m_{\tilde{\chi}_4^0} = 2.23$ GeV

Use these errors to determine SUSY parameters

Joint analyses of LC + LHC



$\Delta\chi^2 = 1$ *for the joint analysis of the LC + LHC*

Final results:

Susy Parameters			
M_1	M_2	μ	$\tan\beta$
99.1 ± 0.12	192.7 ± 0.35	352.4 ± 2.2	$[9.3 - 10.8]$

Mass Predictions	
$m_{\tilde{\chi}_2^\pm}$	$m_{\tilde{\chi}_3^0}$
378.5 ± 2.0	358.8 ± 2.2

The SPA project – a coordinated effort of theory & experiment

Short–term goals:

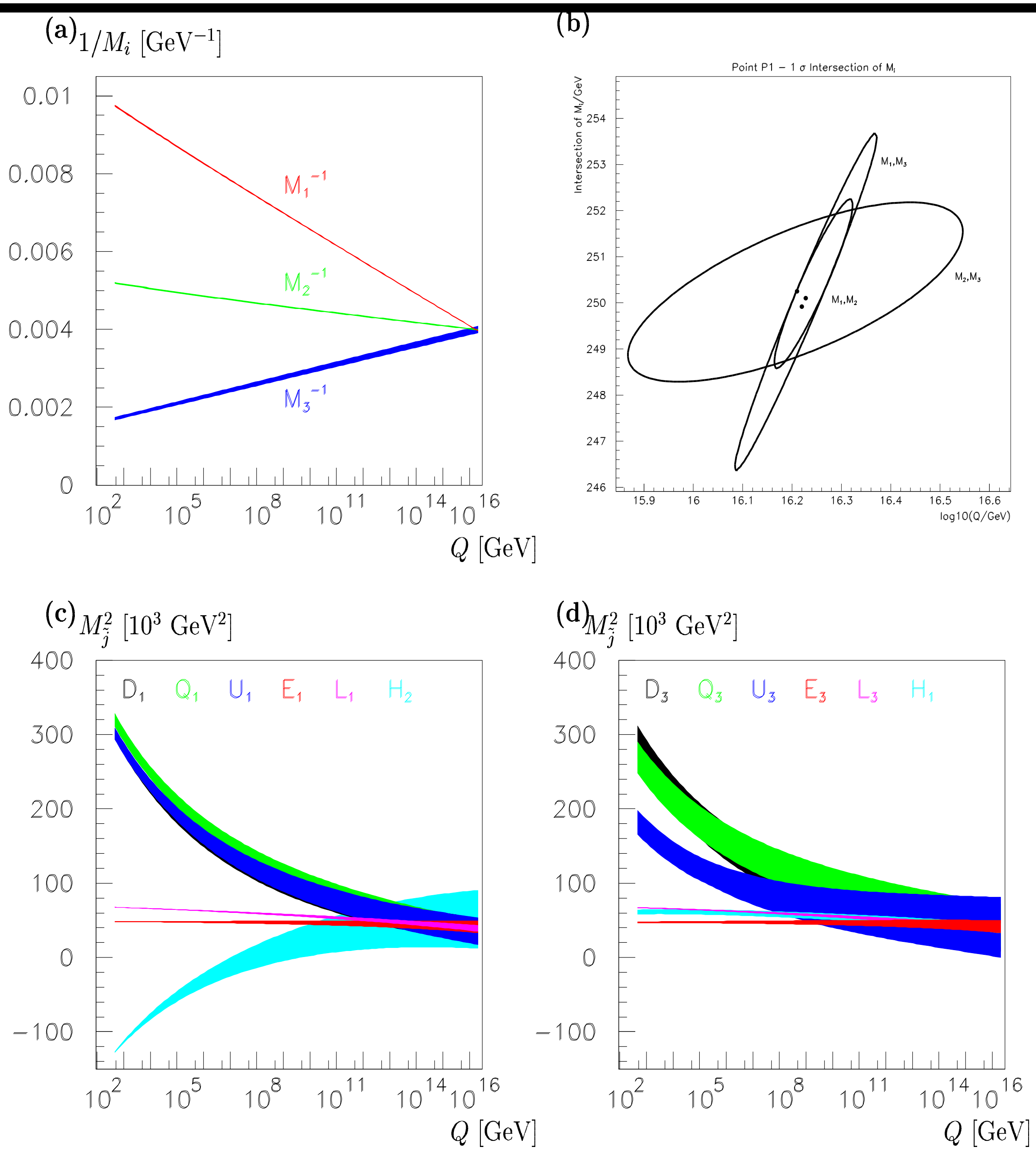
- reach a SPA Convention on parameter definitions
- collect all necessary tools

Long–term goals:

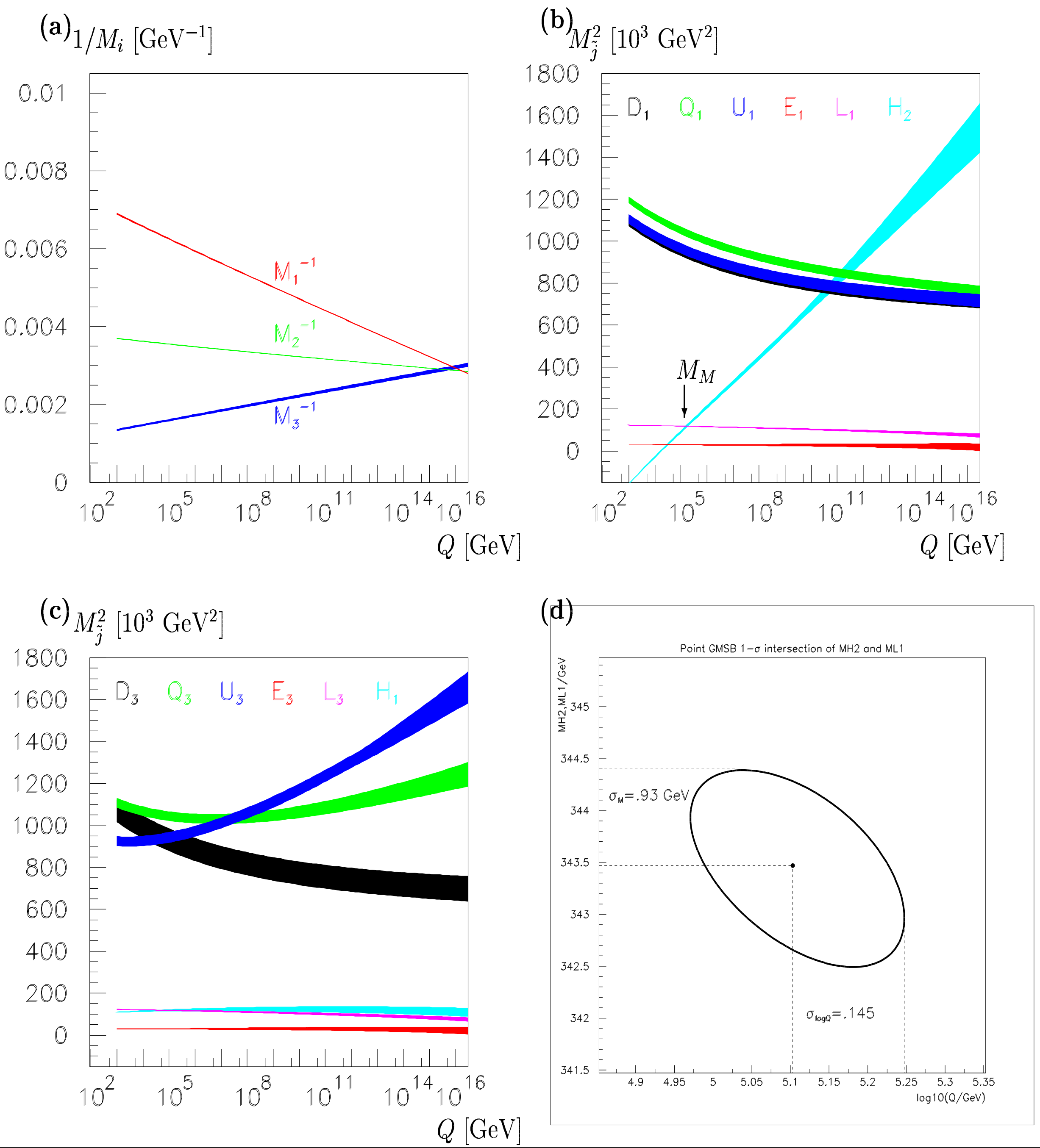
- assess experimental errors on mass, cross section, BR, ... measurements
- derive the low-energy SUSY parameters
- extrapolate them to the high scale to reveal, hopefully, the SUSY breaking mechanism

For practical reasons: one SPS1a SUSY point chosen.

Summary


(a) 1/M_i [GeV^-1]
M_1^-1
M_2^-1
M_3^-1
Q [GeV]
(b)
Point P1 – 1 σ Intersection of M_i
Intersection of M_i/GeV
log10(Q/GeV)
M_1,M_3
M_2,M_3
M_1,M_2
(c) M^2_j̃ [10^3 GeV^2]
D_1 Q_1 U_1 E_1 L_1 H_2
Q [GeV]
(d) M^2_j̃ [10^3 GeV^2]
D_3 Q_3 U_3 E_3 L_3 H_1
Q [GeV]

mSUGRA


(a) $1/M_i$ [GeV^{-1}]
M_1^{-1}
M_2^{-1}
M_3^{-1}
Q [GeV]
(b) $M_{\tilde{j}}^2$ [10^3 GeV^2]
D_1 Q_1 U_1 E_1 L_1 H_2
M_M
Q [GeV]
(c) $M_{\tilde{j}}^2$ [10^3 GeV^2]
D_3 Q_3 U_3 E_3 L_3 H_1
Q [GeV]
(d)
Point GMSB 1−σ intersection of MH2 and ML1
MH2,ML1/GeV
σ_M=.93 GeV
$\sigma_{\log Q}$=.145
log10(Q/GeV)