SUSY and Cosmo WG: summary

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LAPTH

Status of CMSSM

ILC measurements

DM and ILC

Conclusion

SUSY

- One attractive extension of SM
- Symmetry fermion -boson
- Solution to gauge hierarchy problem
- Radiative EW symmetry breaking –light Higgs

- Gauge coupling unification
- Could be link to string theories

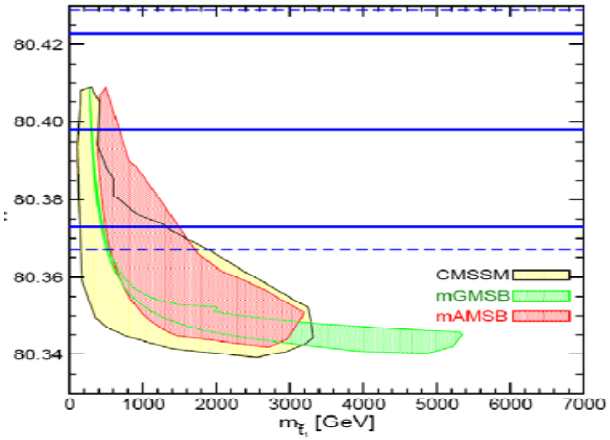
- Cold dark matter candidate if R-parity conservation
- MSSM, CMSSM, extensions…

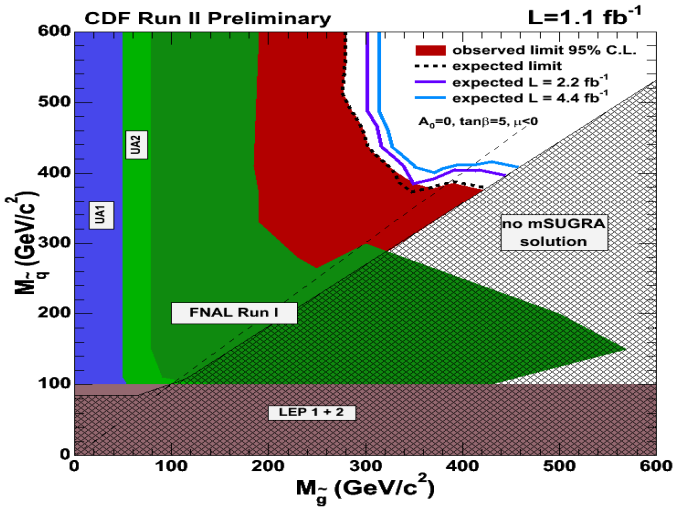
Constraints on SUSY – status

- EWPO : $M_{w,}$ $\sin^2\theta^l_{eff}$
  - M_w prefers light stops
- B observables :
  - $Br(B_s\text{--}\mu\mu)<5.8\times10^{-8}$ disfavours very large tanβ and light H/A
  - b –sγ constrain m_0-$m_{1/2}$, tanβ dependent
- $(g\text{-}2)_{\mu:}$ prefers light smuons/gauginos

$$a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{theo}} = (27.5 \pm 8.4) \times 10^{-10},$$

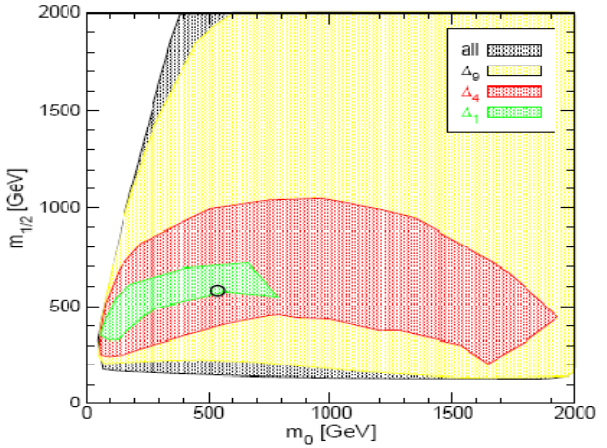
- Tevatron lower limits : squarks/gluino

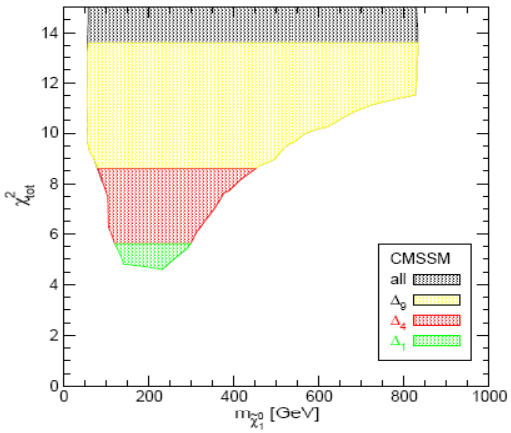




Constraints on CMSSM

- CMSSM: MSSM with GUT scale universal condition (4 1/2 parameters- m_0,$m_{1/2}$, A_0, tanβ, sign(μ)) and MFV
- χ^2 fit: Large area of parameter space allowed
- Constraint on mass scale : $\Delta\chi^2<4$ -- LSP<450GeV, other sparticles could be in reach of ILC500 or 1000





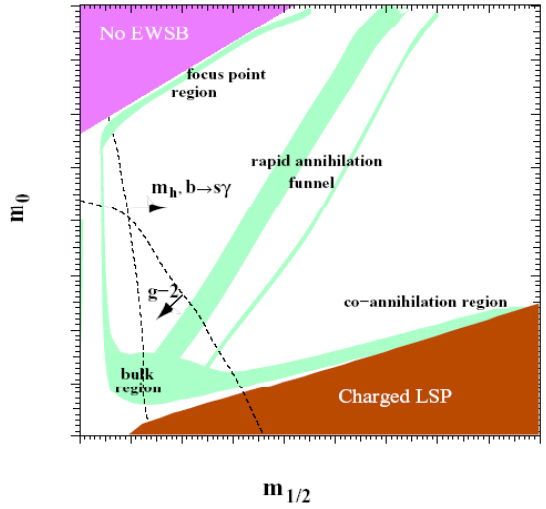
Heinemeyer et al., 0805.2359

Including DM

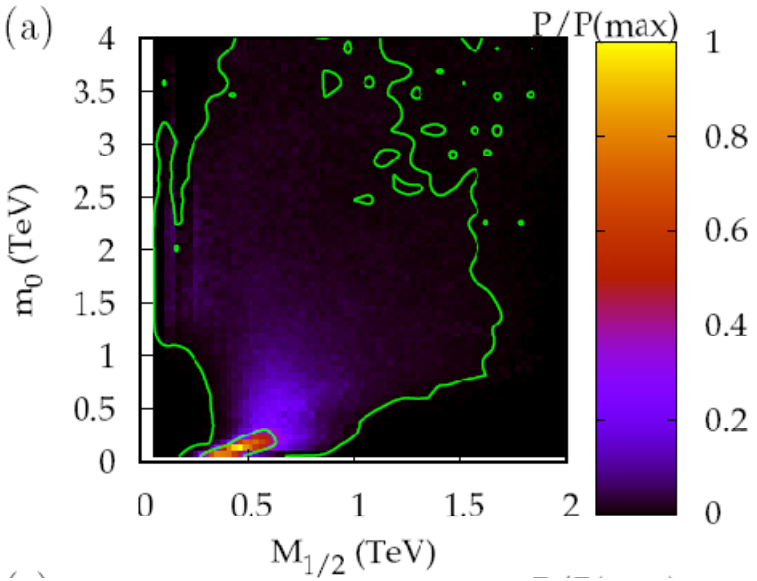
- Assume R parity conservation
- Include WMAP/SDSS and DM relic density

  $\Omega h^2=0.104 +0.0073/-0.012$

- Strong relation m_0-$m_{1/2}$ for fixed values of A_0 and tanβ



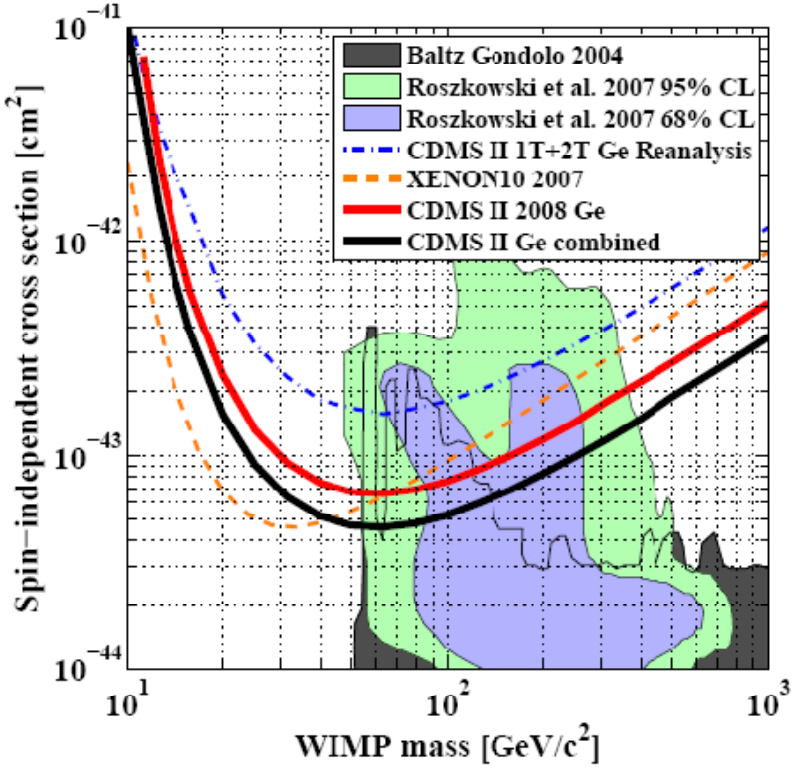
- MCMC approach+ Bayesian statistics : fits of CMSSM +SM parameters
- 90%CL – no constraint yet on SUSY spectrum – best fit at low m_0-$m_{1/2}$



Allanach et al. 0705.0487

Dark matter – Searches

- Direct detection – search for WIMPS interaction with nuclei in large detectors -- experiments are improving : new limits
- Xenon and CDMS – $\sigma^{SI} > 4x10^{-8}$pb
- Probe parameter space of MSSM
- Goal 10^{-10}pb in < 10 years
- SD limits also improving- COUPP and Kims ~ $\sigma^{SD} \sim 10^{-2}$pb -- Not yet probing the MSSM



SUSY at ILC

- Search for sparticles hard to see at LHC

- Determination of parameters :
  - Masses can be measured at per-mil level : threshold scans/endpoint measurements
  - Spin of particles
  - Determination of soft SUSY parameters
    - LHC/ILC : Phases from stop production and decay (G. Moortgat-Pich)
  - Underlying model, SUSY breaking mechanism..
  - DM properties

SUSY at ILC

- Determination of parameters :
- Sneutrinos – (T. Robens)
  - Mass measurement mass even when decay is invisible (e.g. SPS1A) Freytas'05 $e^+ e^- \longrightarrow \tilde{\chi}_1^+ \tilde{\chi}_1^- \longrightarrow (\tilde{\bar{\nu}}_e \tilde{\nu}_\mu e^- \mu^+ \longrightarrow) \tilde{\chi}_1^0 \tilde{\chi}_1^0 e^- \mu^+ \nu_\mu \bar{\nu}_e$

    signal: $e^- \mu^+ + \mathbf{E_{miss}}$

  - Full matrix element for both signal and background (interference effects)
  - Chargino mass from threshold scan, sneutrino mass from lepton energy spectrum ~ 1% precision
  - study is ongoing : improved cuts etc…

Precision

- To take advantage of high precision at ILC – must make theoretical predictions at one-loop level
  - Many processes computed in the last few years
  - Chargino pair production with CP violation (K. Rolbiecki)
  - Asymmetries induced at one-loop only – sensitive to phases, e.g. φ_t could be a few %

$$A_{12} = \frac{\sigma^{\text{loop}}(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_2^-) - \sigma^{\text{loop}}(e^+e^- \to \tilde{\chi}_2^+\tilde{\chi}_1^-)}{\sigma^{\text{tree}}(e^+e^- \to \tilde{\chi}_1^+\tilde{\chi}_2^-) + \sigma^{\text{tree}}(e^+e^- \to \tilde{\chi}_2^+\tilde{\chi}_1^-)}$$

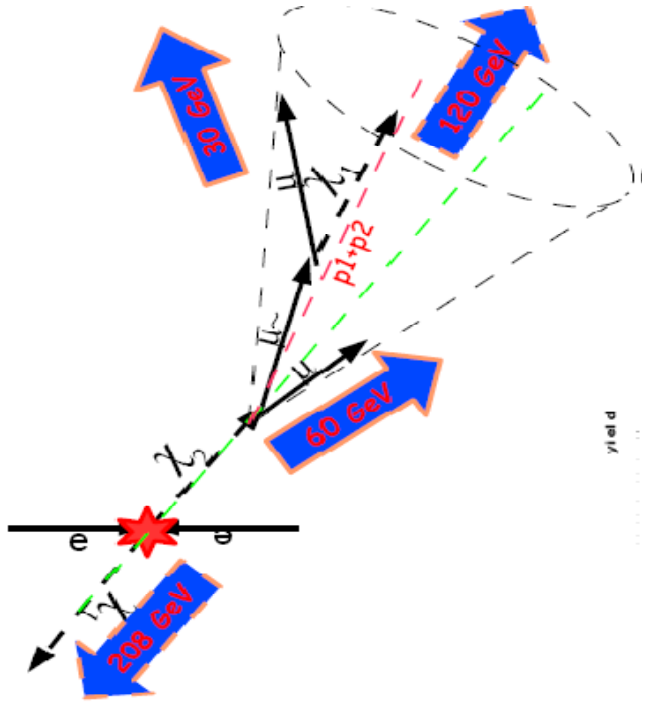
- Experimental level : studies with full simulation
  - Di-muon decay of neutralino2 (N. D'Ascenzo)
  - Smuon pair production (Chen)

Di-muon decay of neutralino 2

- Muon channel has small BR (2.5% for SPS1a) but di-muon signature is clean and easy to detect at ILC
- Signal is small, background is huge (more than 2 orders of magnitude)

- Optimisation, extended Likelihood method for enhancing signal vs background for small signals

- Full background + full simulation on the way



- Two isolated muons with :
  Missing energy >300 GeV
- Transversal momentum > 40 GeV
- Acoplanarity > 0.5 π

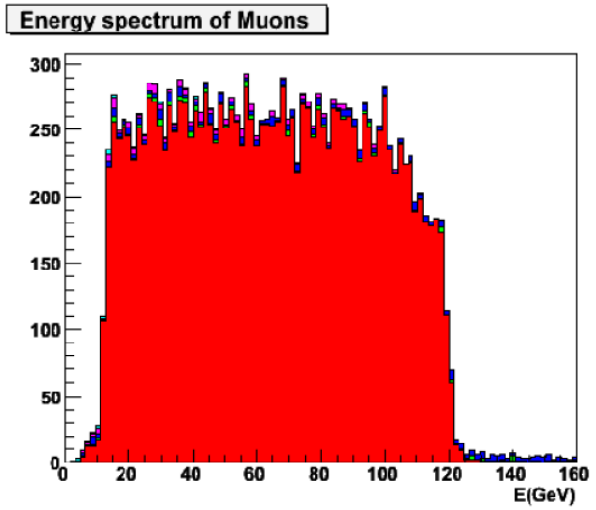
RH- Smuon pair production

- Determine mass and spin of smuon
- Full simulation
- Signal: 2 muons +missing energy
- Background small after cuts
- Masses from endpoint energy : precision <1%
- Determination of spin
- Angular distribution

$$\frac{d\sigma}{d\cos\theta} \propto \sin^2\theta$$

- Shows that smuon has spin zero

$$e_L^+ e_R^- \rightarrow \tilde{\mu}_R \tilde{\mu}_R \rightarrow \mu^+ \mu^- \tilde{\chi}_1^0 \tilde{\chi}_1^0$$



Calculated: $m_{\tilde{\mu}_R} = 142.89 \pm 0.33\ GeV$

$m_{\tilde{\chi}_1^0} = 97.63 \pm 0.22\ GeV$

Dark Matter

- Evidence for BSM physics?
- Many candidates for DM (SUSY and non-SUSY) - neutralino

Models can have special DM properties and face different challenges for measurement of sparticles at colliders/ILC

- MSSM, CPVMSSM
- CMSSM, GMSB, AMSB, NUHM,VCMSSM (GUT scale conditions and symmetry breaking mechanism)

- NMSSM, nMSSM, MNSSM, CNMSSM, VCNMSSM, USSM – μ problem
- SO10SSM, E6SSM…

- MNSSM (S. Hesselbach)
  - Extra neutralino (singlino) can be light
  - Extra scalars possibly light
- USSM (J. Roberts)
  - Extra neutralinos, Z'

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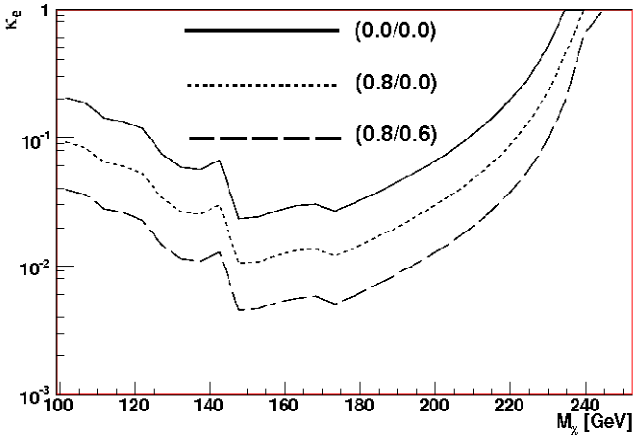
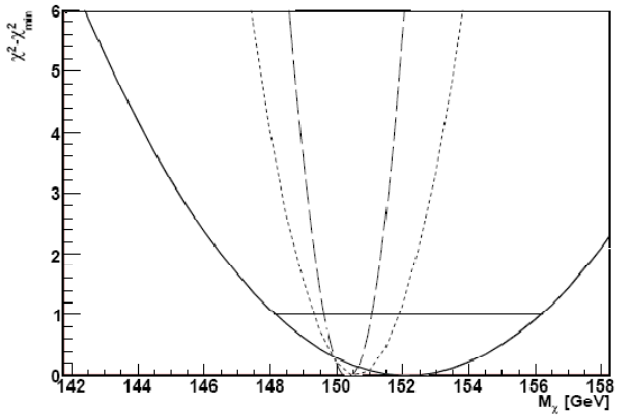
Model independent approach

Model independent WIMP search

- WIMP pair with single photon (Bartels)
- One of physics analyses of ILD detector concept –optimisation
- Could be only SUSY signal at 500GeV
- Simple and clean signature
- Estimate cross-section from Ωh^2 assuming a certain fraction of annihilation DM in e+e-pairs
- Reach in coupling+ mass determination (2007)
- Improved analysis going on





DM at colliders

- WMAP and SDSS gives precise information on the amount of dark matter
- "Doing cosmology at colliders" : discovery of new particles and measurement of their properties→
  - "collider prediction" for the relic density of DM
  - Matches what has been measured in the sky/confront cosmological model
- Precision measurements at colliders are needed
- How difficult strongly depends on the details of the new physics model – which SUSY scenario, what is the dominant DM annihilation process
- Studies exist for both LHC and ILC in CMSSM and MSSM – bulk scenario, stau coannihilation- focus point scenario
  - Polesello, Tovey, Nojiri, Martyn, Bambade et al, Baltz et al,
  - Some scenario, with precision expected at ILC could match the precision of PLANCK

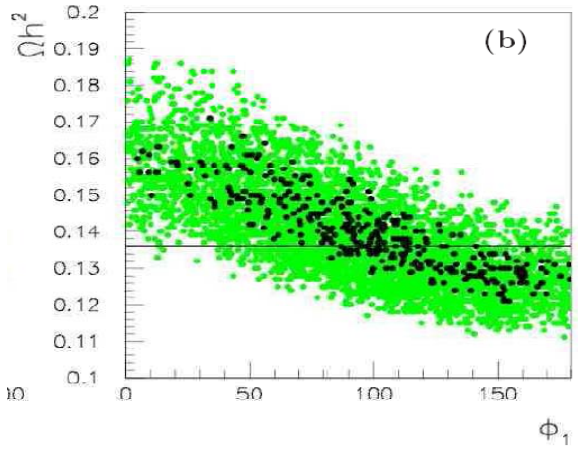
CPVMSSM and ILC

- New study within CPVMSSM in specific scenario with light stau τ_1, τ_2, χ_1, χ_2, χ^+ accessible at ILC
- Staus are mixed and both contribute to annihilation of LSP into tau pairs

- All signals in $\tau\tau E_{miss}$ - disentangle sources –

- Use measurement of masses + θ_τ +P_τ to determine model parameters and infer Ωh^2
- $0.116 < \Omega h^2 < 0.19$

- WMAP: $0.094 < \Omega h^2 < 0.136$



- Need to know couplings of LSP not only masses

Conclusion

- ILC can be exploited for precise determination of parameters –
  - Underlying model – supersymmetry breaking mechanism
  - Dark matter properties

- Experimental studies with full simulation of signal and background are going on