SUSY parameter fits in stau coannihilation scenarios

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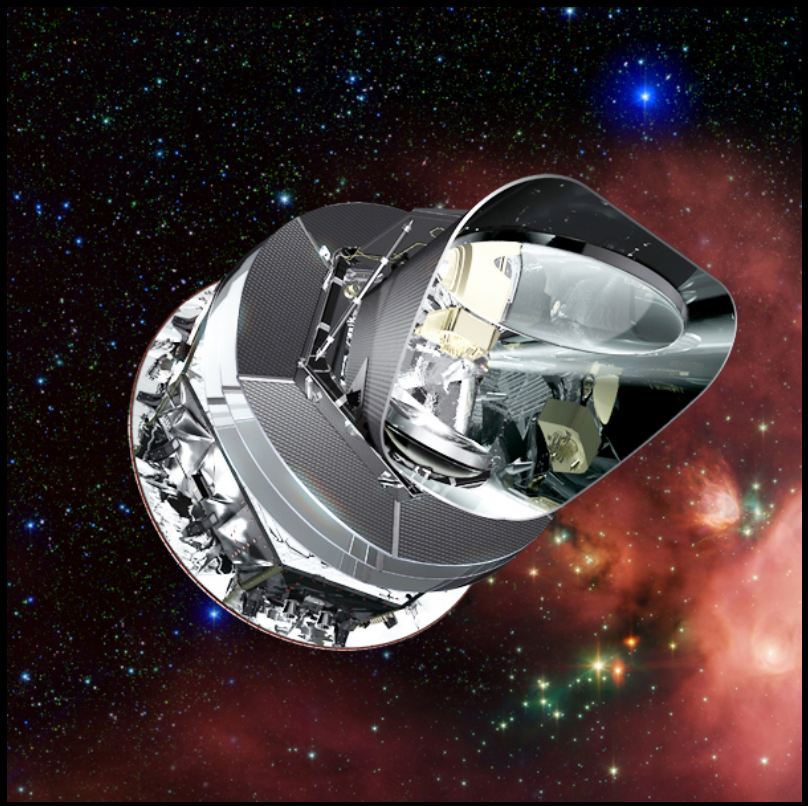
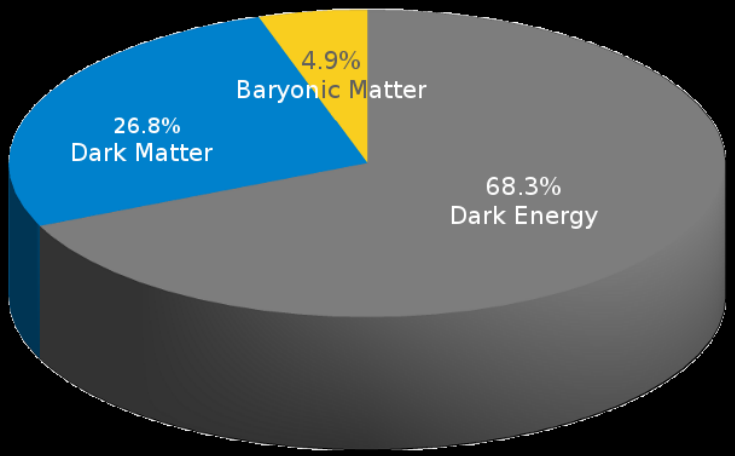


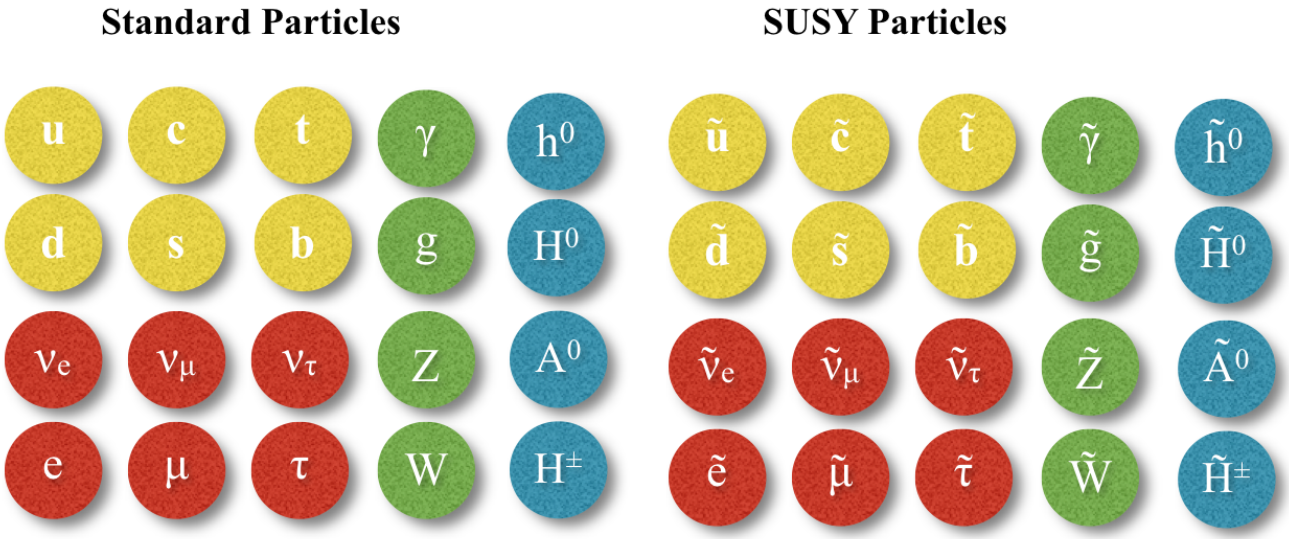

4.9%
Baryonic Matter
26.8%
Dark Matter
68.3%
Dark Energy

What properties should dark matter have?

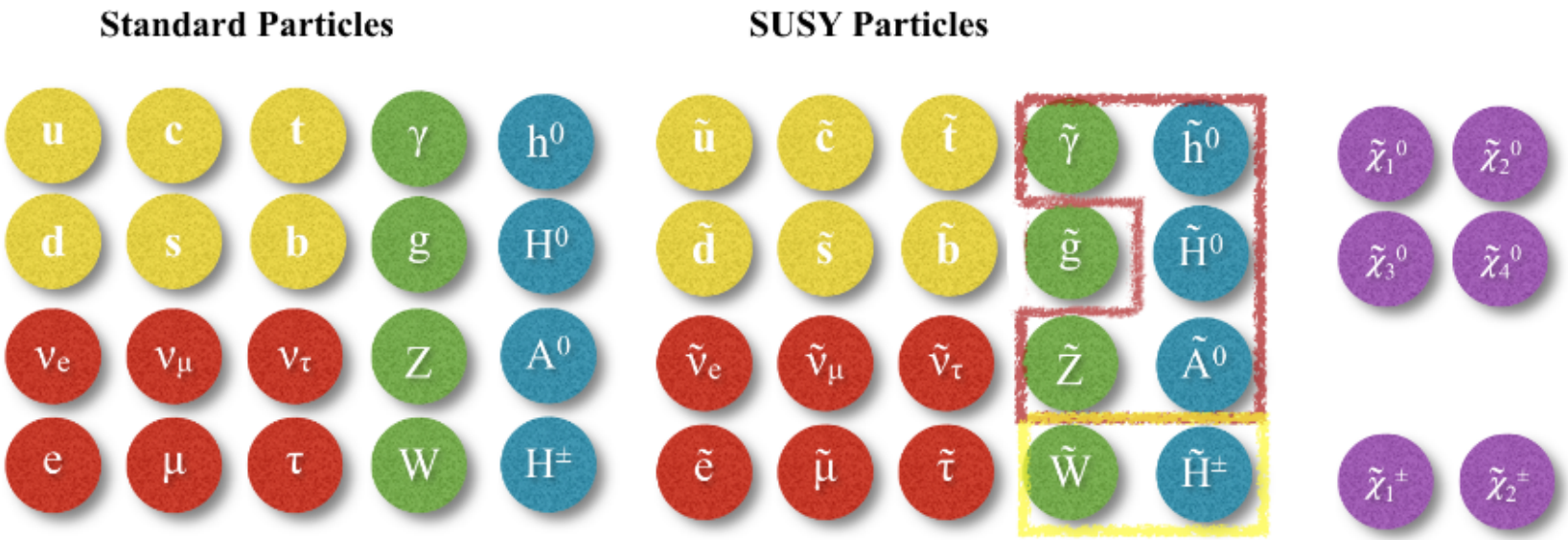
1. Electrically neutral
2. Weakly interacting
3. Stable

Supersymmetry can provide us with a candidate

Particles in supersymmetry



Particles in supersymmetry



Lightest neutralino has the right properties to be DM

Lightest supersymmetric particle (LSP)

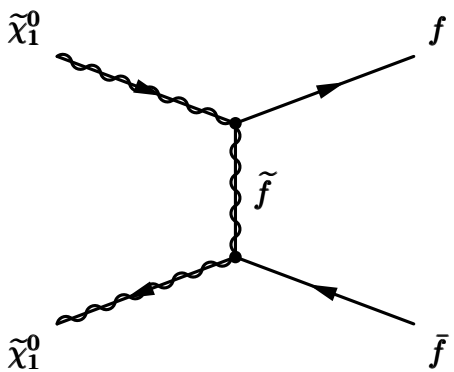
1. Electrically neutral ✓
2. Weakly interacting ✓
3. Stable if impose R-parity* in interactions ✓

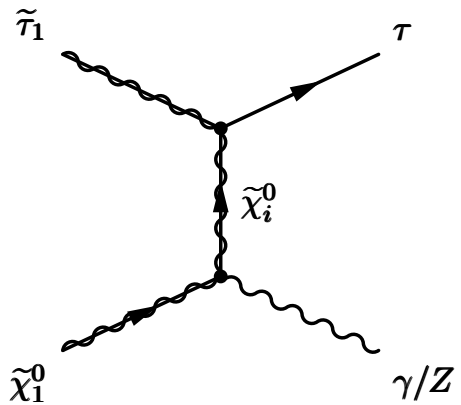
*R-parity: multiplicatively conserved, $R_{SM} = 1$, $R_{SUSY} = -1$

Correct amount of dark matter?

Yes, if $m_{\widetilde{\chi}_1^0} \sim 100$ GeV, $\widetilde{\chi}_1^0 \sim \widetilde{B}$
And another particle near in mass $\Longrightarrow$ 

- Pair annihilation depends on LSP mixing and sfermion mass
- Coannihilation depends strongly on the stau-LSP mass difference

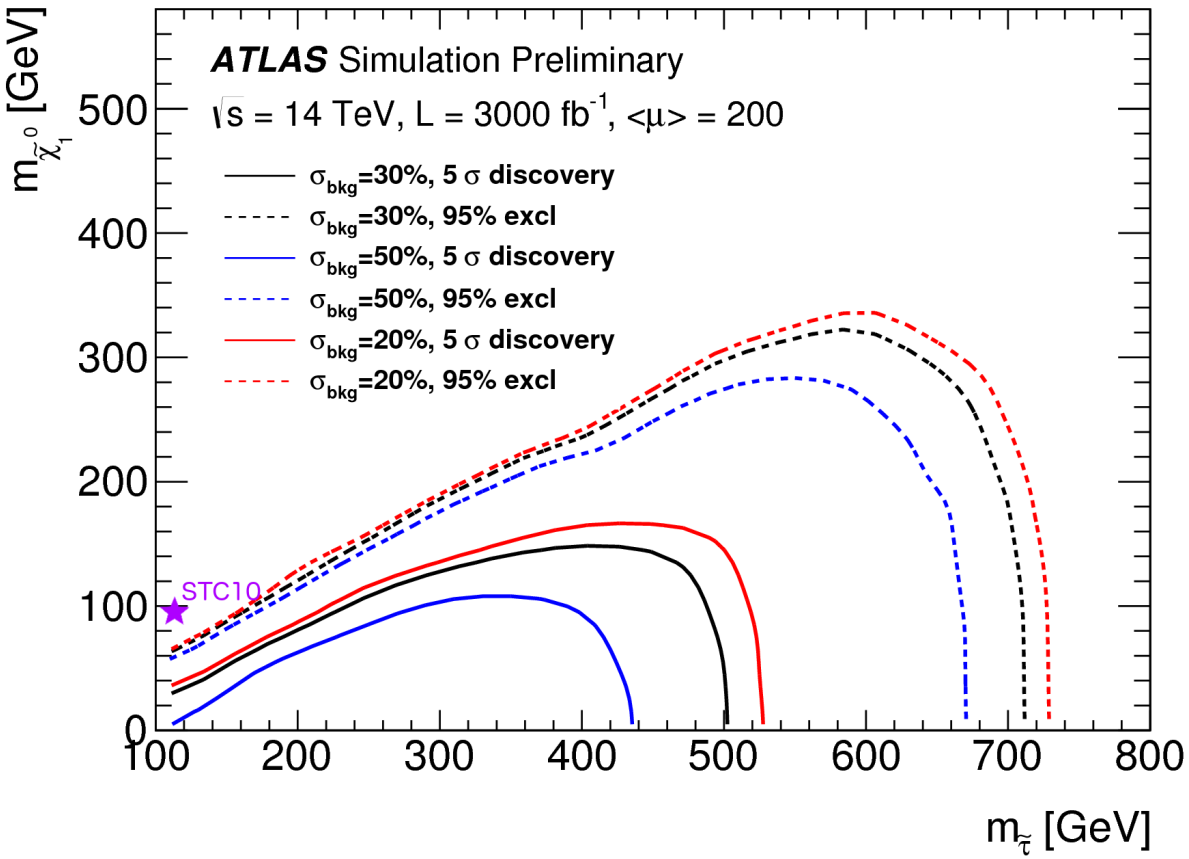




Prospects at HL-LHC

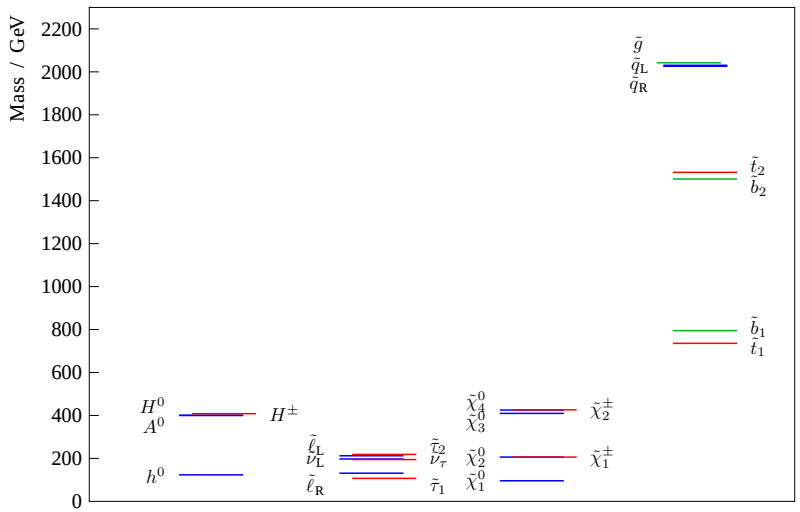
ATLAS-PHYS-PUB-2016-021

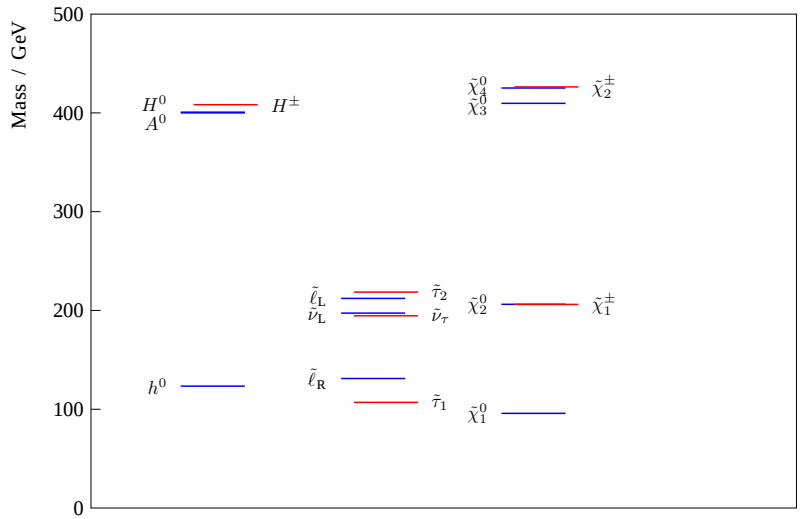
$pp \to \widetilde{\tau}\widetilde{\tau} \to \tau\tau + \text{MET}$



- Plenty of room for ILC discoveries in mass-degenerate region

Stau coannihilation: STC10 scenario

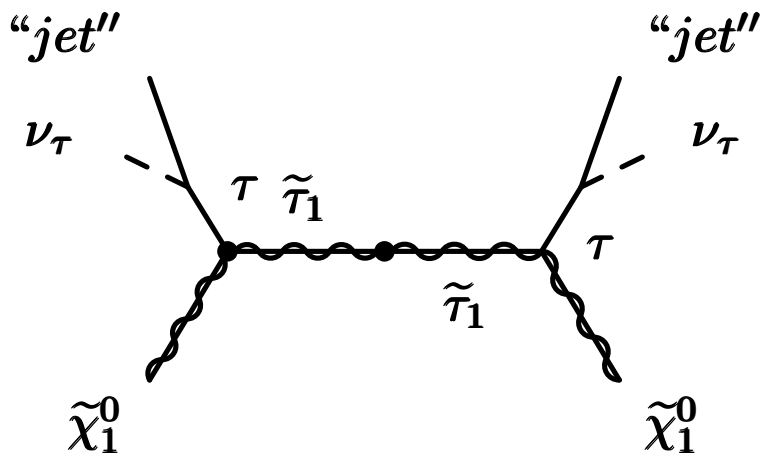


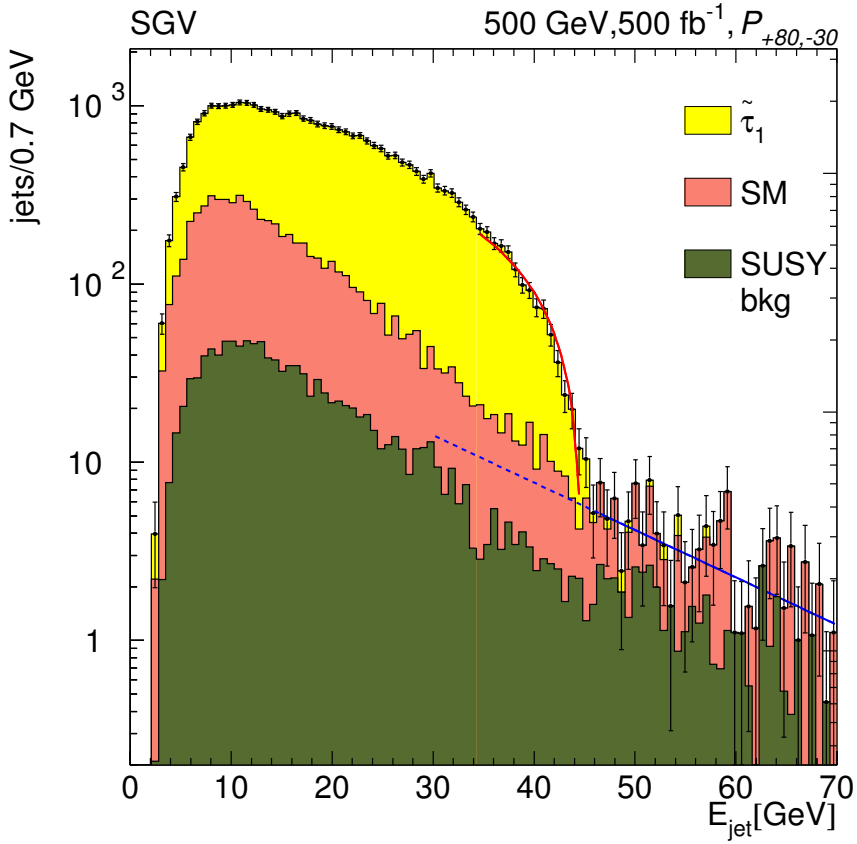


- Many particles accessible at $\sqrt{s} = 500$ GeV: important are $\widetilde{\chi}_1^0, \widetilde{\chi}_2^0, \widetilde{\chi}_1^\pm, \widetilde{\tau}_1, \widetilde{e}_R, \widetilde{\mu}_R$
- Stau-LSP mass difference 11 GeV
- Analysis paper Berggren et al arXiv:1508.04383, relic density study arXiv:1602.08439

Measurements at $\sqrt{s} = 500$ GeV: example $\widetilde{\tau}_1$ endpoint

- $\widetilde{\tau}_1 \to \widetilde{\chi}_1^0 \tau$ endpoint $\implies$ $\Delta m_{\widetilde{\tau}_1} = 0.15\%$ (160 MeV)





[arXiv:1508.04383v1]

Measurements at $\sqrt{s} = 500$ GeV ILC

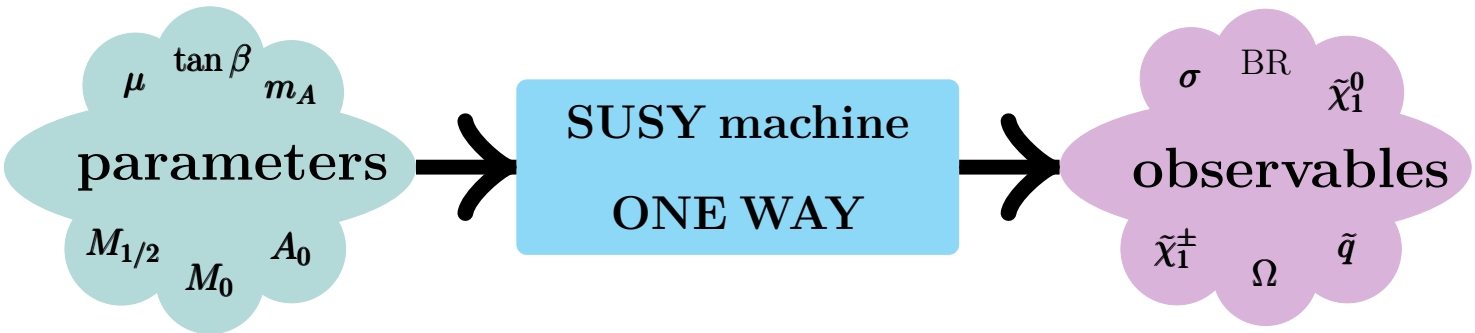
- Can discover all sleptons, sneutrinos, $\widetilde{\chi}_1^0, \widetilde{\chi}_2^0$ and $\widetilde{\chi}_1^\pm$
- Precisions on masses after 500 fb^{-1} for both $\mathcal{P}(\pm 0.8, \mp 0.3)$:

analysis [1508.04383v1]	$m_{\widetilde{\chi}_1^0}$	0.15%	$m_{\widetilde{\chi}_2^0}$	0.5%
	$m_{\widetilde{\tau}_1}$	0.16%	$m_{\widetilde{\tau}_2}$	2.5%
	$m_{\widetilde{e}_R}$	0.17%	$m_{\widetilde{\mu}_R}$	0.4%
estimate [1508.04383v1]	$m_{\widetilde{e}_L}$	1%	$m_{\widetilde{\mu}_L}$	1%
	$m_{\widetilde{\nu}_e, \widetilde{\nu}_\mu, \widetilde{\nu}_\tau}$	1%	$m_{\widetilde{\chi}_1^\pm}$	1%

What predictions can be made from these hypothetical observations?

Fit SUSY parameters to ILC $\sqrt{s} = 500$ GeV SUSY mass measurements and Higgs measurements

What are SUSY parameters and why study them?



- Can get information about unobserved sparticles
- Can test types of SUSY model (e.g. GUT scale models)

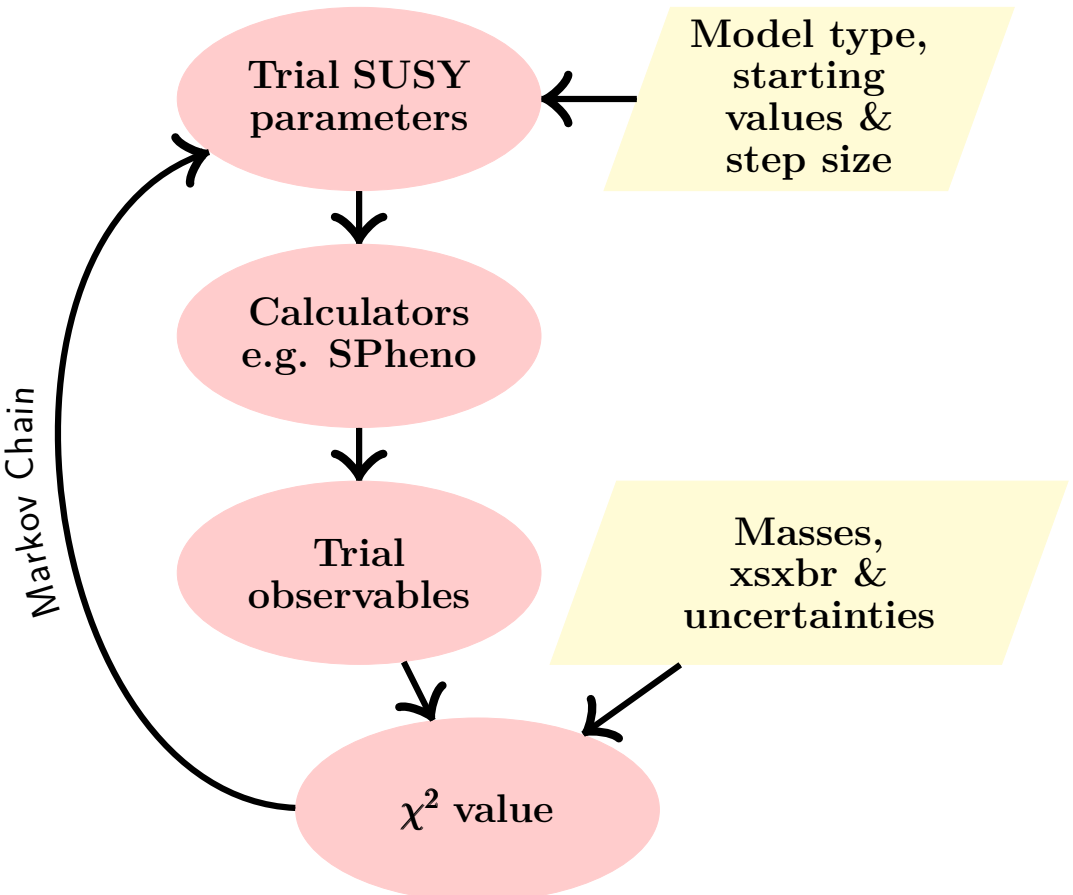
Fitting parameters to observables with Fittino

Fittino minimises

$$\chi^2 = \left(\frac{\mathcal{O}(ILC) - \mathcal{O}(theory)}{\Delta\mathcal{O}(ILC)}\right)^2$$

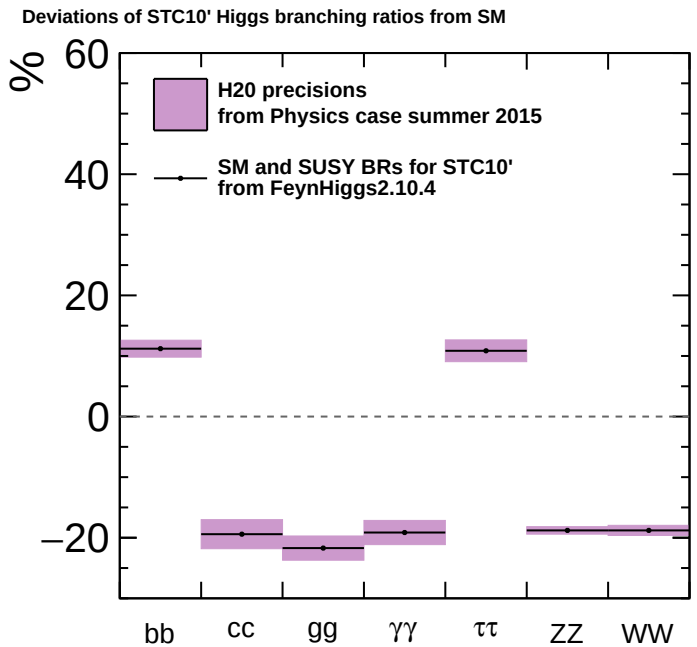
(arXiv:hep-ph/0412012)

SUSY SPheno3.3.9beta3,
Higgs mass and BRs
FeynHiggs2.10.2,
DM MicrOMEGAs and
Astrofit



Fits to SCT10' scenario

- Observables
  - Slepton, sneutrino, $\widetilde{\chi}_1^0, \widetilde{\chi}_2^0, \widetilde{\chi}_1^\pm$ masses - uncert. from slide 10
  - Higgs mass and coupling measurements from H20 operation



- Length of Markov Chain 500 000 points non-continuous
- Fit pMSSM-13 parameters with Fittino

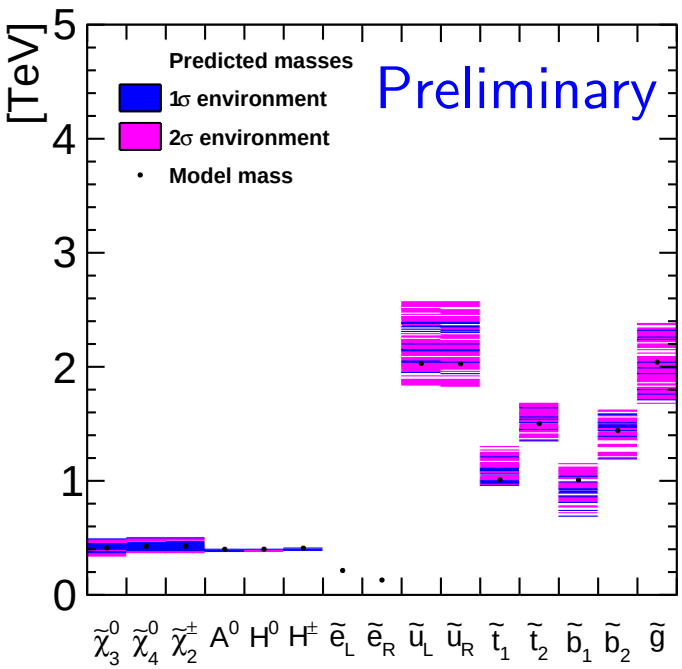
Fitted parameters. Preliminary

parameter	STC10'	fitted value
$\tan\beta$	10	9.7 ± 0.7
μ	400	411 ± 36
M_1	100	100.0 ± 0.3
M_2	210	209.5 ± 3.1
M_3	2000	$[1580, 2337]$
m_A	400	398 ± 5
$A_t = A_b = A_\tau$	-2850	$[-3097, -2670]$
$M_Q(1,2) = M_U(1,2) = M_D(1,2)$	2000	$[1922, 2383]$
$M_Q(3)$	1450	$[1218, 1602]$
$M_U(3)$	1100	$[1023, 1305]$
$M_D(3)$	1000	$[671, 1034]$
$M_L(1,2,3)$	207	206.9 ± 0.9
$M_E(1,2,3)$	118	118.7 ± 0.8

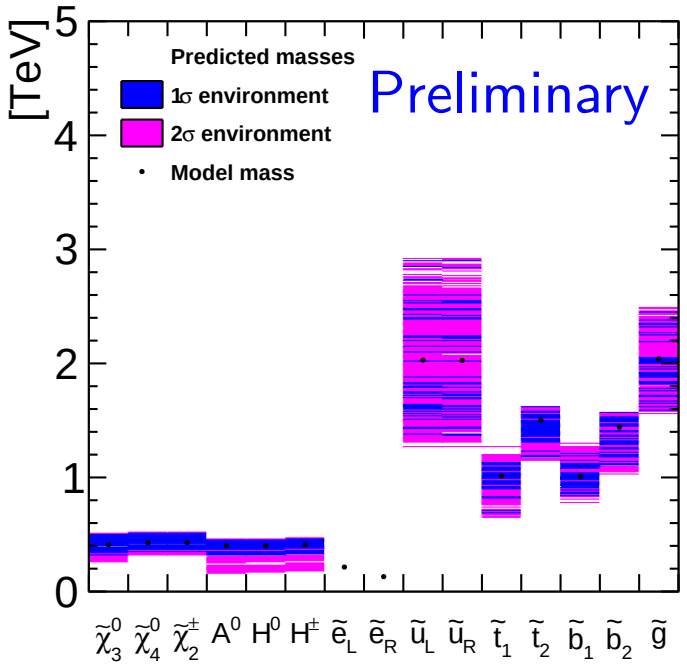
Predicted masses of unobserved sparticles

- All masses predicted correctly

SUSY inputs + h



SUSY inputs only

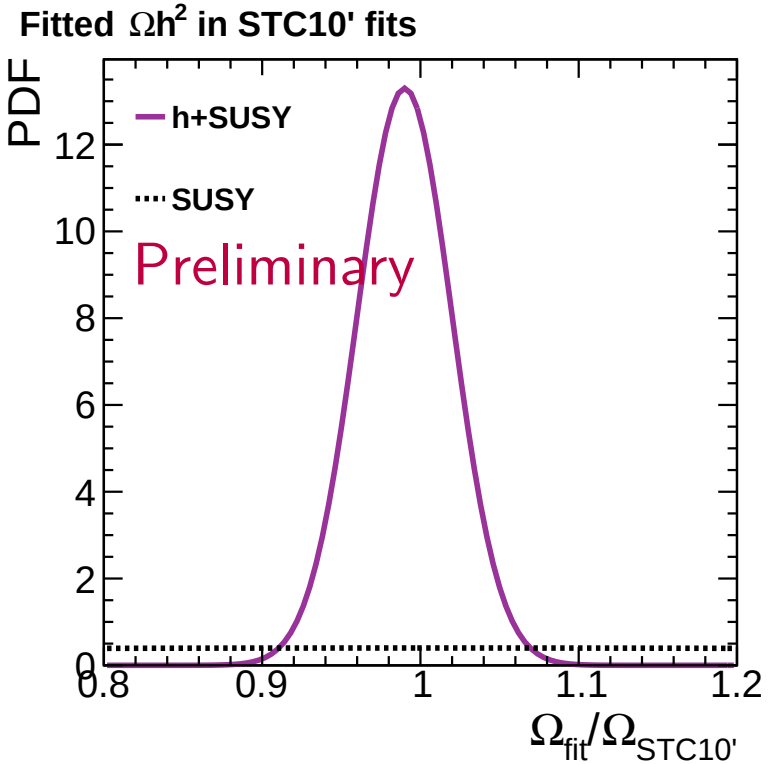


- Motivation for ILC or LHC upgrades

Dark matter predictions

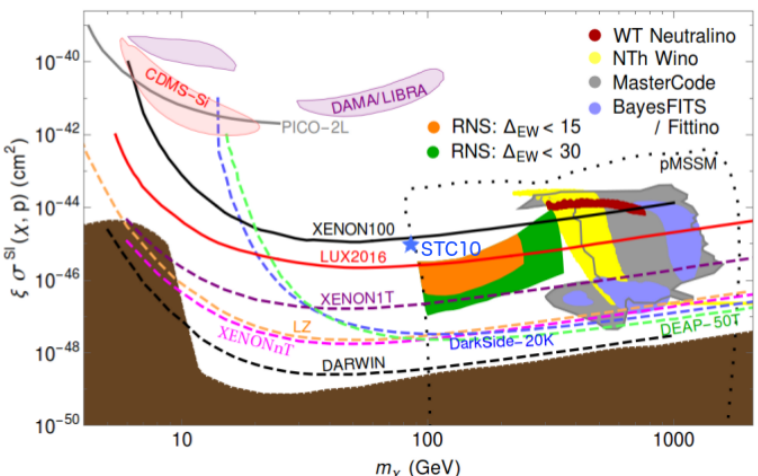
- Dark matter relic density is fitted correctly as long as Higgs inputs are used ($\delta\Omega$=3%)

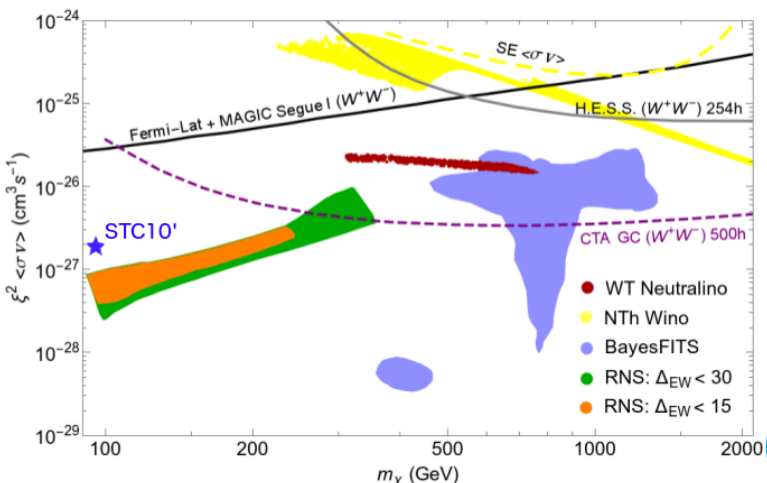
Flatness caused by allowed low values of m_A



Dark matter predictions continued

- Have compared three benchmarks
  - STC10' $\rightarrow$ 100% of observed relic density Ω_{Planck}
  - STC10'-Ω75 $\rightarrow$ 75% of Ω_{Planck}
  - STC10'-Ω50 $\rightarrow$ 50% of Ω_{Planck}
- Work in progress: relic density is fitted correctly
  $\Longrightarrow$ if true, then $\Omega_{fit} < 100\%$ is a hint of non-SUSY DM
- WIMP-nucleon scattering and WIMP annihilation cross sections predicted by fit
  $\Longrightarrow$ Competition and complementarity w/ DM experiments





Conclusions

- Stau coannihilation scenarios motivated by dark matter
- ILC precision measurements would allow fitting pMSSM-13 SUSY parameters
- Expected precisions from ILC $\sqrt{s} = 500$ GeV enable predictions for masses of unobserved sparticles
- Dark matter relic density can be determined correctly provided the permille-level SUSY mass measurements and Higgs measurements from ILC
- Outlook: Comparisons of results for different benchmarks and input data sets coming

Backup

Higgs BRs if mA = 1 TeV