What next for the CMSSM and NUHM

Improved prospects for superpartner and dark matter detection

arxiv:1405.4289 Leszek Roszkowski, Enrico Maria Sessolo, A.W.

update, improvement and extension of K. Kowalska, et al, arXiv:1302.5956

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Outline

- Experimental constraints
- Favoured regions in the CMSSM
- Prospects for colliders in the CMSSM
- Different favoured regions in the NUHM
- Prospects for DM detection
- Conclusions

Experimental Constraints

- HiggsSignals for Higgs mass and signal strengths
- Resumed top/stop contributions to higgs mass beyond 2-loops via FeynHiggs 2.10.0
- LHC SUSY searches likelihood map (8TeV ~20fb^{-1} ATLAS searches via CheckMate)
- LUX dark matter direct detection likelihood map

Constraint	Mean	Exp. Error	Th. Error	Ref.
$\Omega_\chi h^2$	0.1199	0.0027	10%	[12]
$\sin^2\theta_{\rm eff}$	0.23155	0.00015	0.00015	[42]
$\delta\,(g-2)_\mu \times 10^{10}$	28.7	8.0	1.0	[16, 17]
$\mathrm{BR}\left(\overline{\mathrm{B}} \to \mathrm{X_s}\gamma\right) \times 10^4$	3.43	0.22	0.21	[13]
$\mathrm{BR}\left(\mathrm{B_u} \to \tau\nu\right) \times 10^4$	0.72	0.27	0.38	[14]
ΔM_{B_s}	17.719 ps^{-1}	0.043 ps^{-1}	2.400 ps^{-1}	[42]
M_W	80.385 GeV	0.015 GeV	0.015 GeV	[42]
$\mathrm{BR}\left(\mathrm{B_s} \to \mu^+\mu^-\right) \times 10^9$	2.9	0.7	10%	[15]

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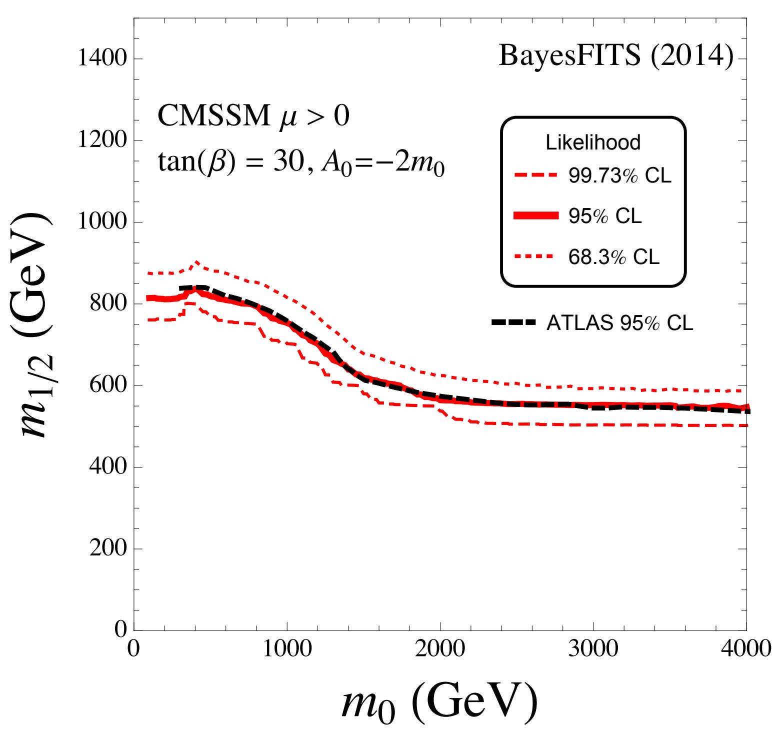
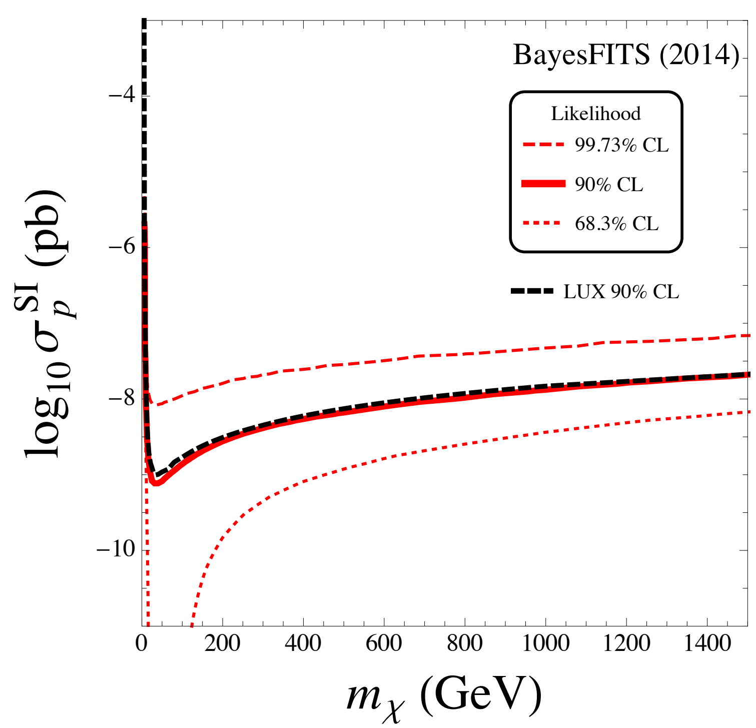
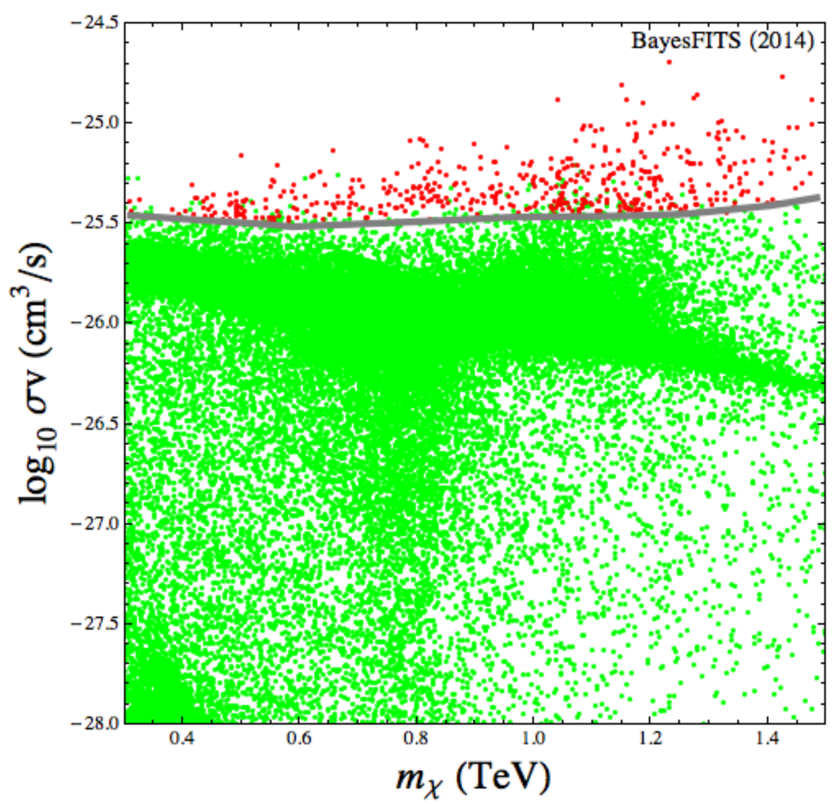




Future reach of CTA

- Cherenkov Telescope Array: The next generation ground based high energy gamma ray telescope.
- Projected limits available for individual final states
  (Mathias et.al arxiv:1401.7330)
- We apply these to the MSSM to generate an indicative limit for σv



CMSSM: model and priors

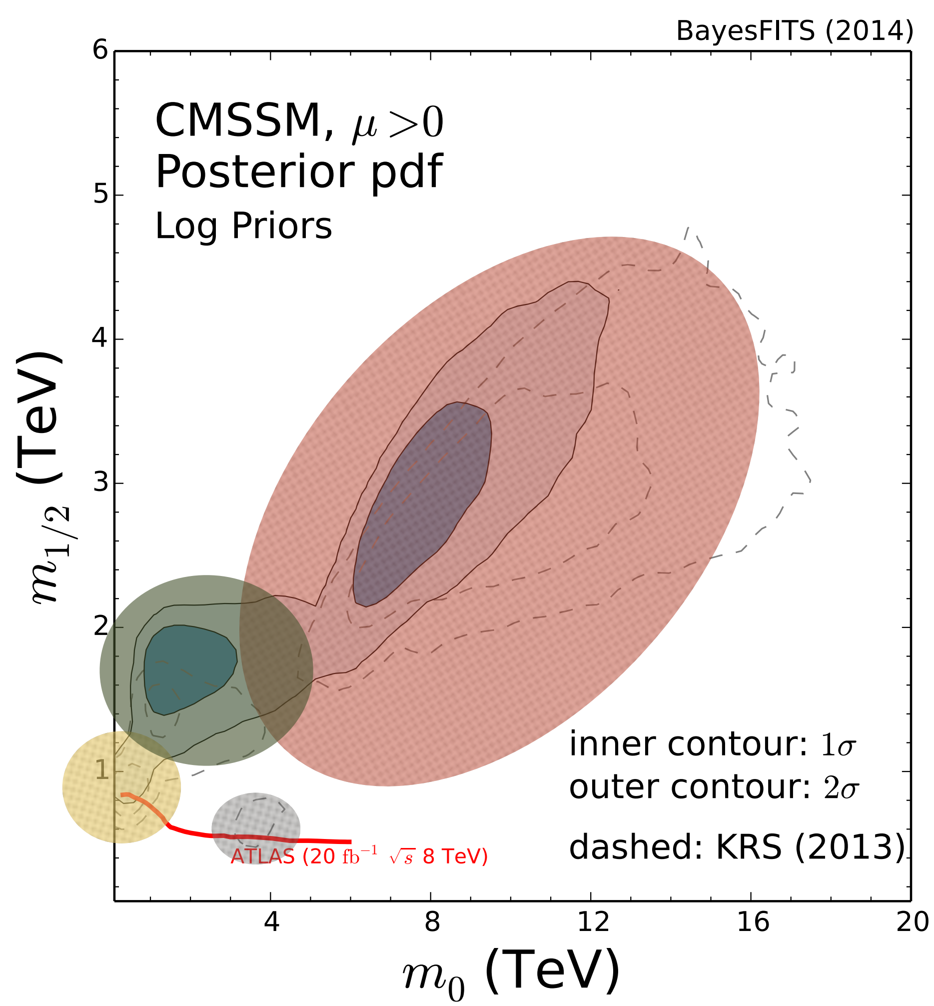
- Minimal Supersymmetric Standard Model
- Universal soft SUSY breaking terms at GUT scale.

Parameter	Description	Range	Distribution
m_0	Universal scalar mass	$0.1, 20$ TeV	Log
$m_{1/2}$	Universal gaugino mass	$0.1, 10$ TeV	Log
A_0	Universal trilinear coupling	$-20, 20$ TeV	Linear
$\tan\beta$	Ratio of the Higgs vevs	$3, 62$	Linear
$\mathrm{sgn}\,\mu$	Sign of the Higgs/higgsino mass parameter	$+1$ or -1	

- Nuisance Parameters

Nuisance parameter	Description	Central value	Distribution
M_t	Top quark pole mass	$173.34 \pm 0.76\,\mathrm{GeV}$	Gaussian
$m_b(m_b)^{\overline{MS}}$	Bottom quark mass	$4.18 \pm 0.03\,\mathrm{GeV}$	Gaussian
$\alpha_s(M_Z)^{\overline{MS}}$	Strong coupling	0.1185 ± 0.0006	Gaussian
$1/\alpha_{\mathrm{em}}(M_Z)^{\overline{MS}}$	Reciprocal of electromagnetic coupling	127.944 ± 0.014	Gaussian
$\Sigma_{\pi N}$	Nucleon sigma term	$34 \pm 2\,\mathrm{MeV}$	Gaussian
σ_s	Strange sigma commutator	$42 \pm 5\,\mathrm{MeV}$	Gaussian

CMSSM: Preferred regions



Decreased m0 in higgsino region due to new higgs corrections

Posterior in A-funnel increases due to better fit to higgs mass

Focus point region disfavoured by LUX

Reduced posterior in stau-coannihilation region due to LHC constraints

Dark matter mechanisms: stau-coannihilation, A-funnel, focus point, 1TeV Higgsino[1]

[1]L. Roszkowski, et al, arXiv:0903.1279 TeV higgsino DM in unified models, K. Kowalska, et al, arXiv:1302.5956 TeV higgsino DM in the CMSSM

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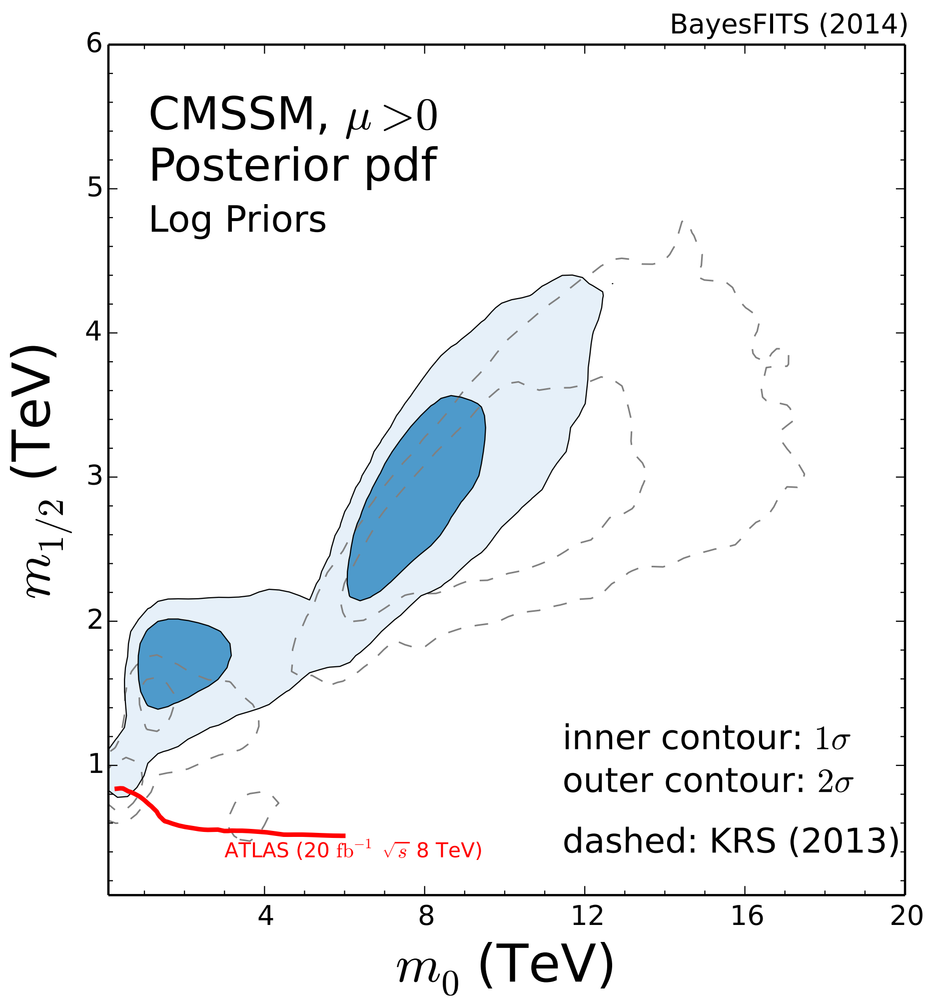

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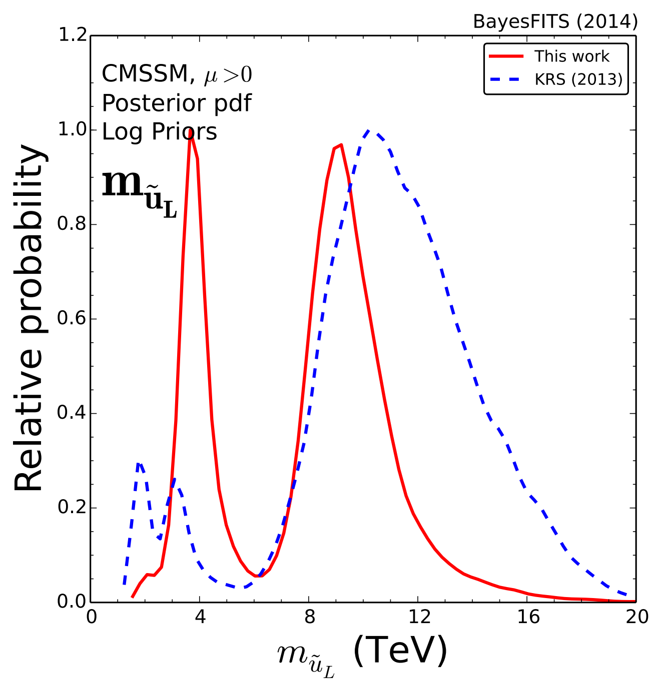
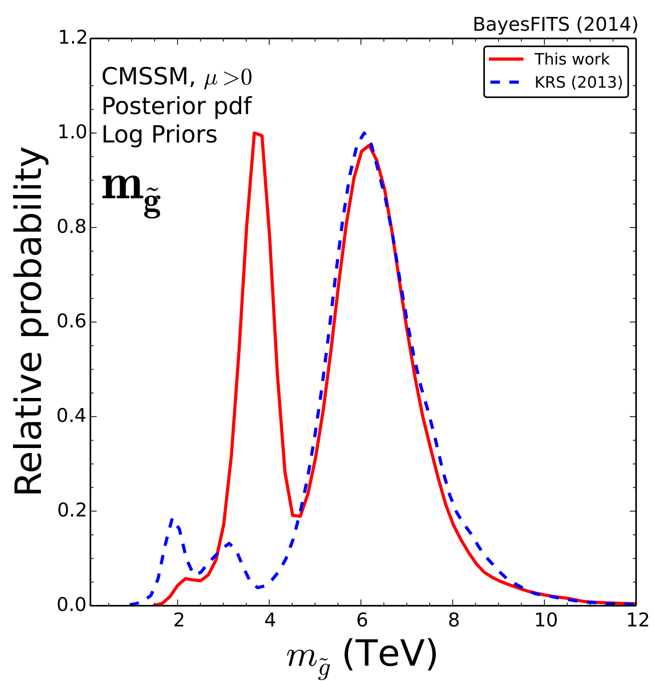
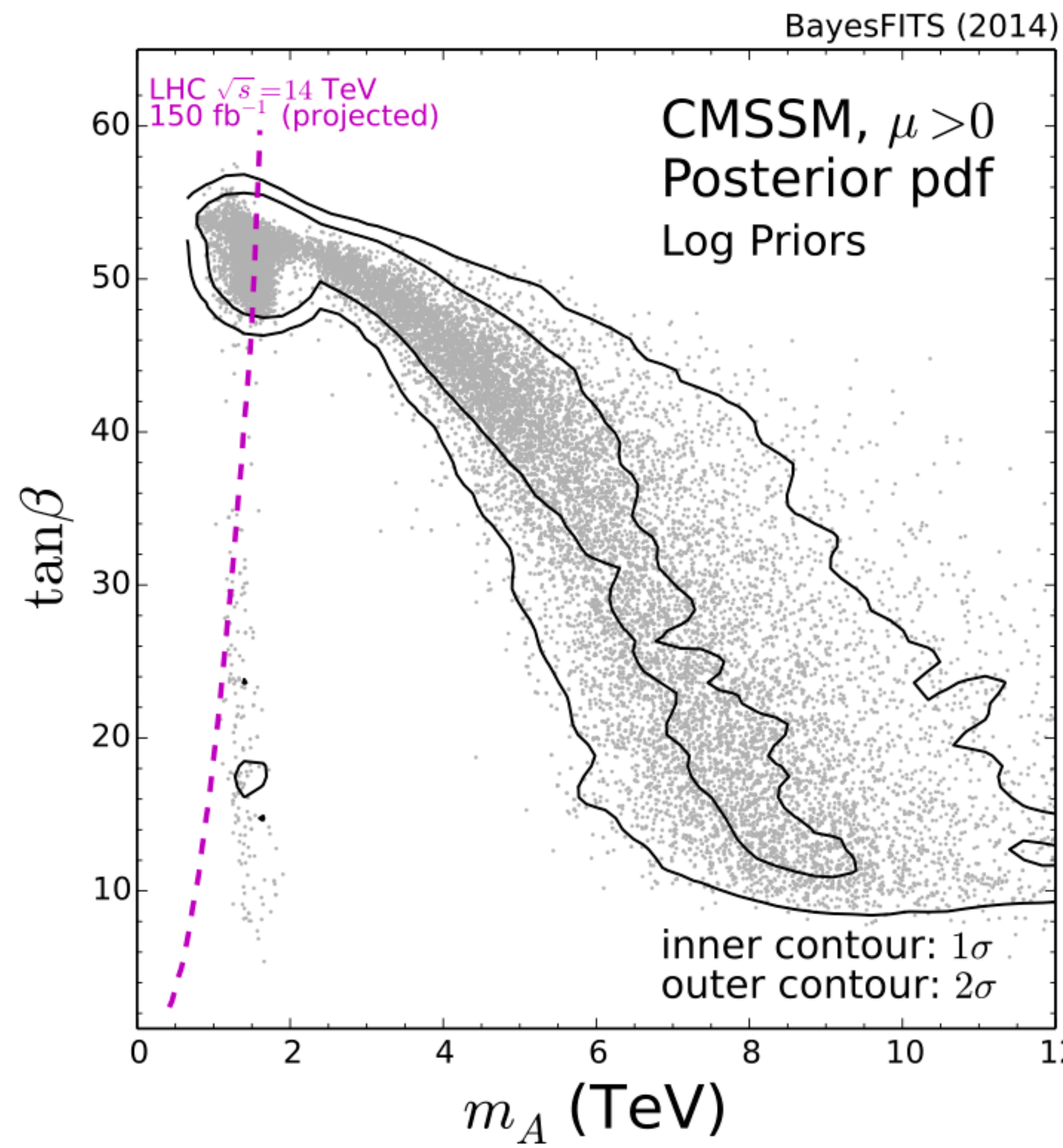
Prospects for colliders





Shift to A-Resonance region puts squarks and gluinos in reach of future colliders



Possibility to discover heavy pseudo scalar at run 2 of the LHC

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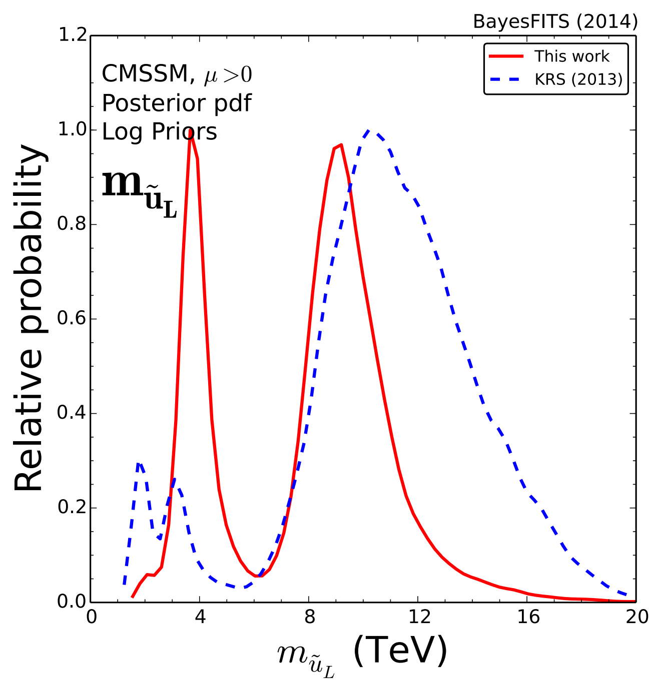
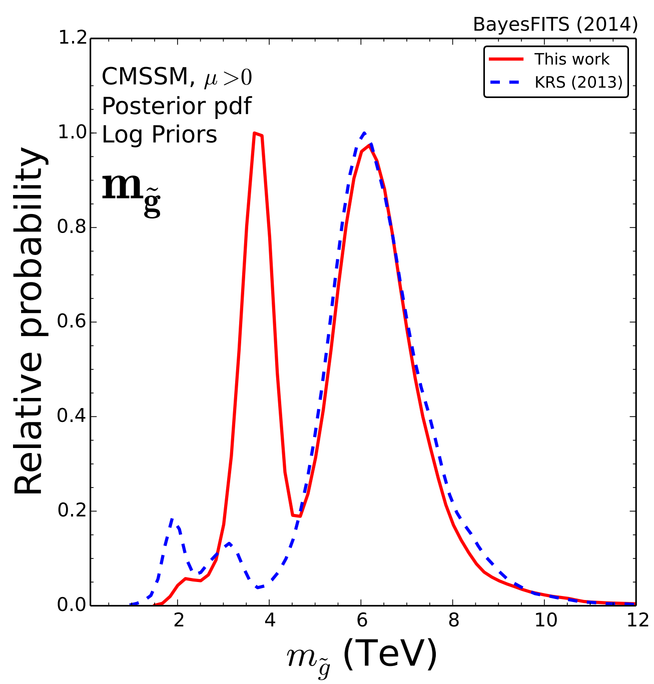
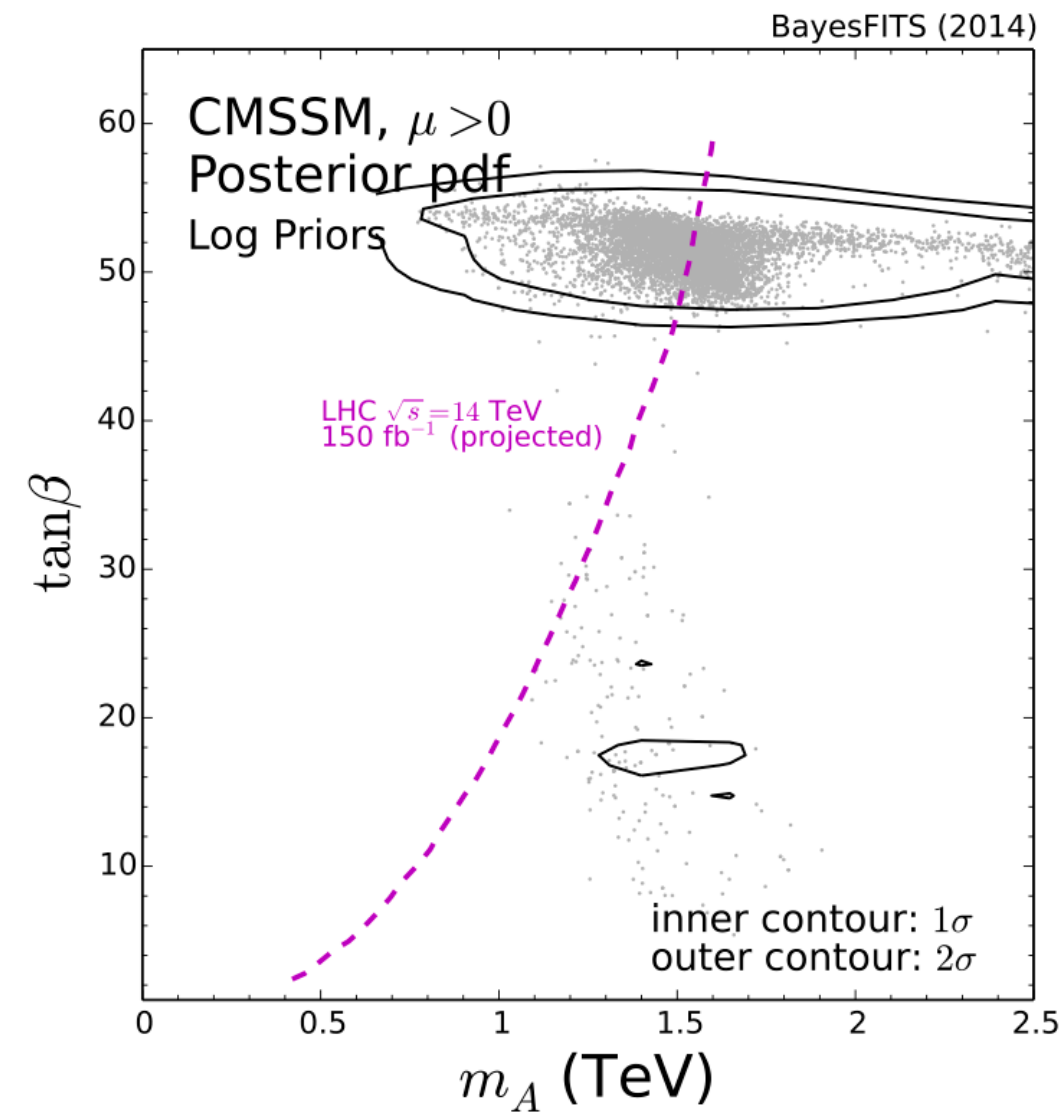






Possibility to discover heavy pseudo scalar at run 2 of the LHC

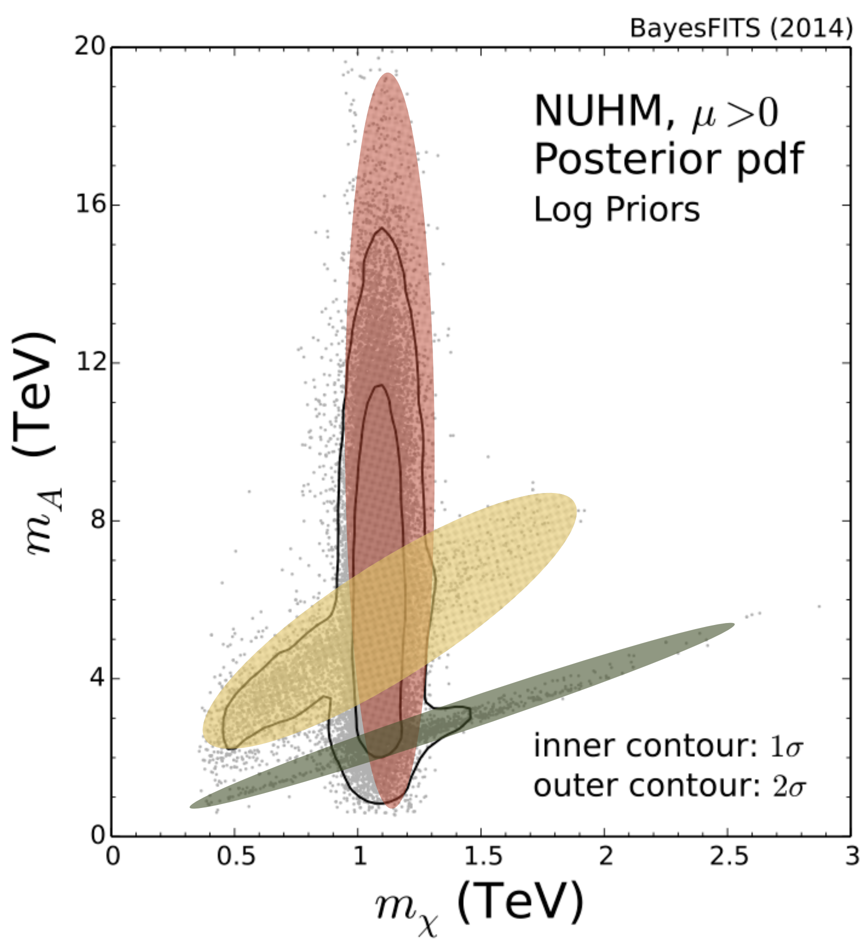
NUHM: Model and priors

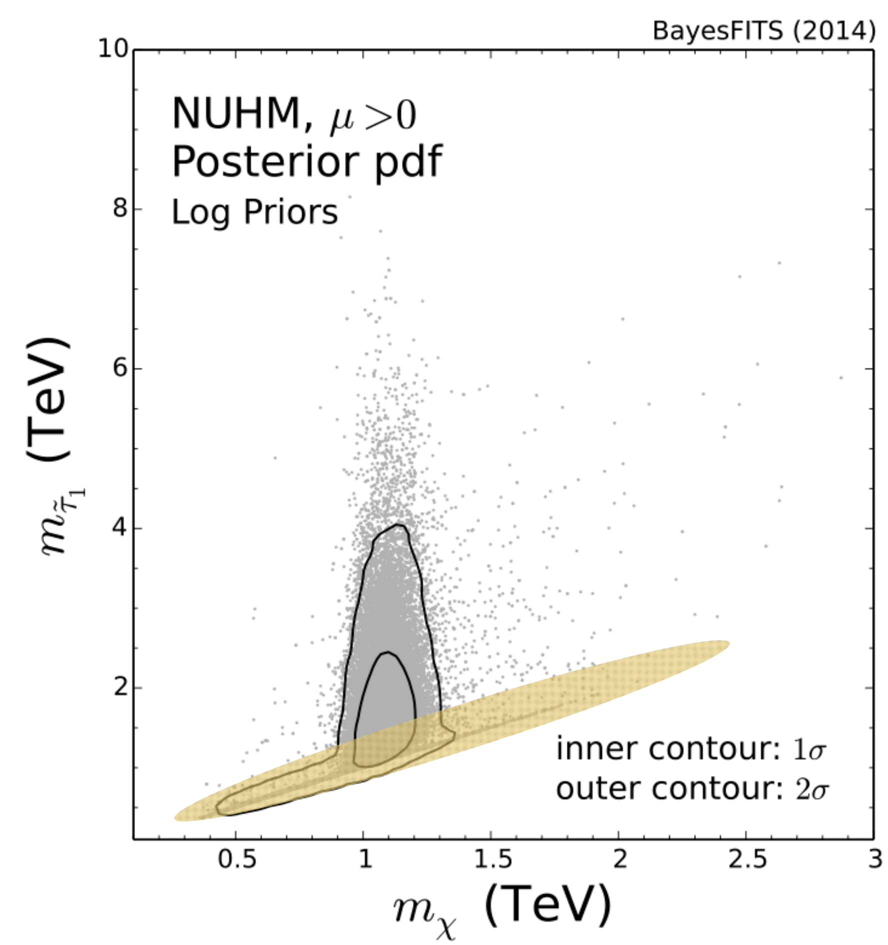
- Independently vary the Higgs mass soft parameters at the GUT scale
- Allow the squared mass terms to be positive or negative

$m^2_{H_d}/\sqrt{\lvert m^2_{H_d}\rvert}\,^{(*)}$	Signed GUT-scale soft mass of H_d	$-20, 20$ TeV	Linear
$m^2_{H_u}/\sqrt{\lvert m^2_{H_u}\rvert}\,^{(*)}$	Signed GUT-scale soft mass of H_u	$-10, 10$ TeV	Linear

- Keep other priors the same as the CMSSM

NUHM: preferred regions

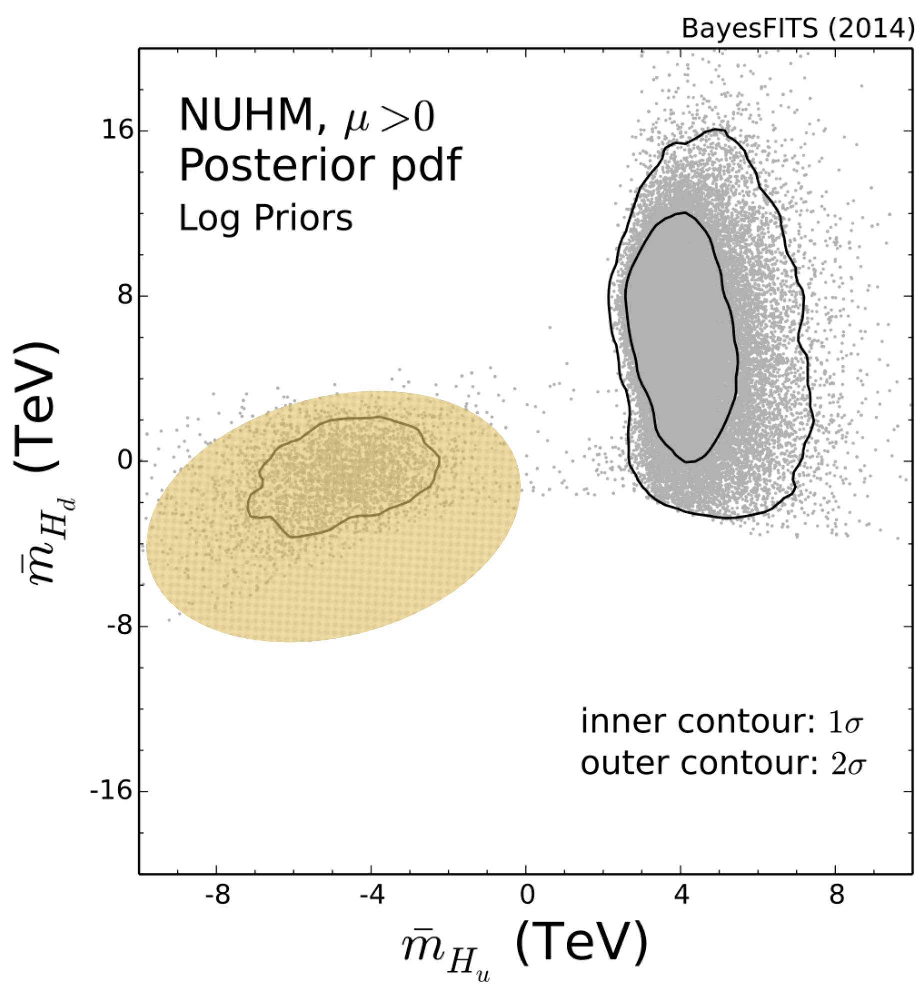


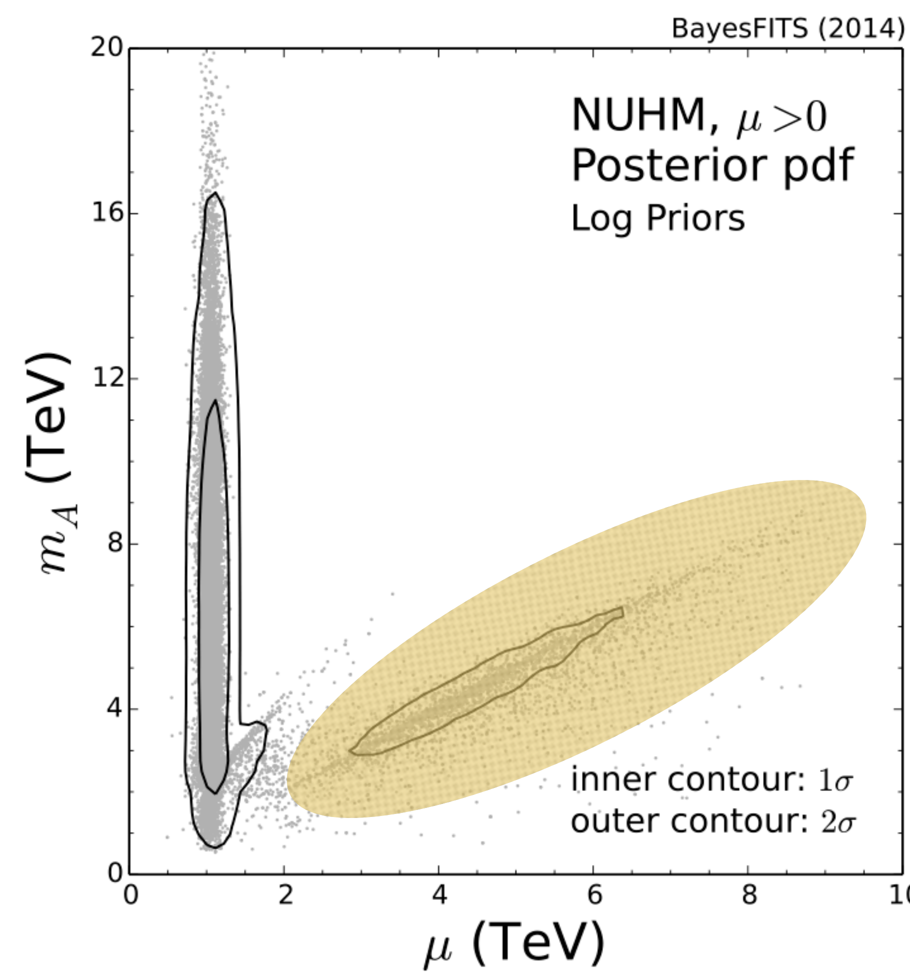


Dark matter mechanisms: stau-coannihilation, A/H-funnel, 1TeV Higgsino

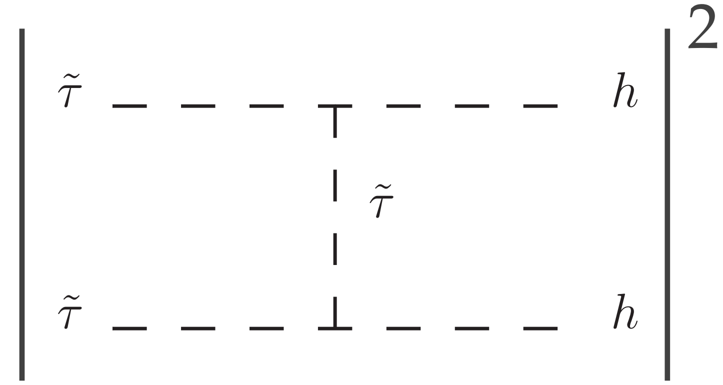
Stau-coannihilation region extends to large masses

Extended stau-coannhiliation strip



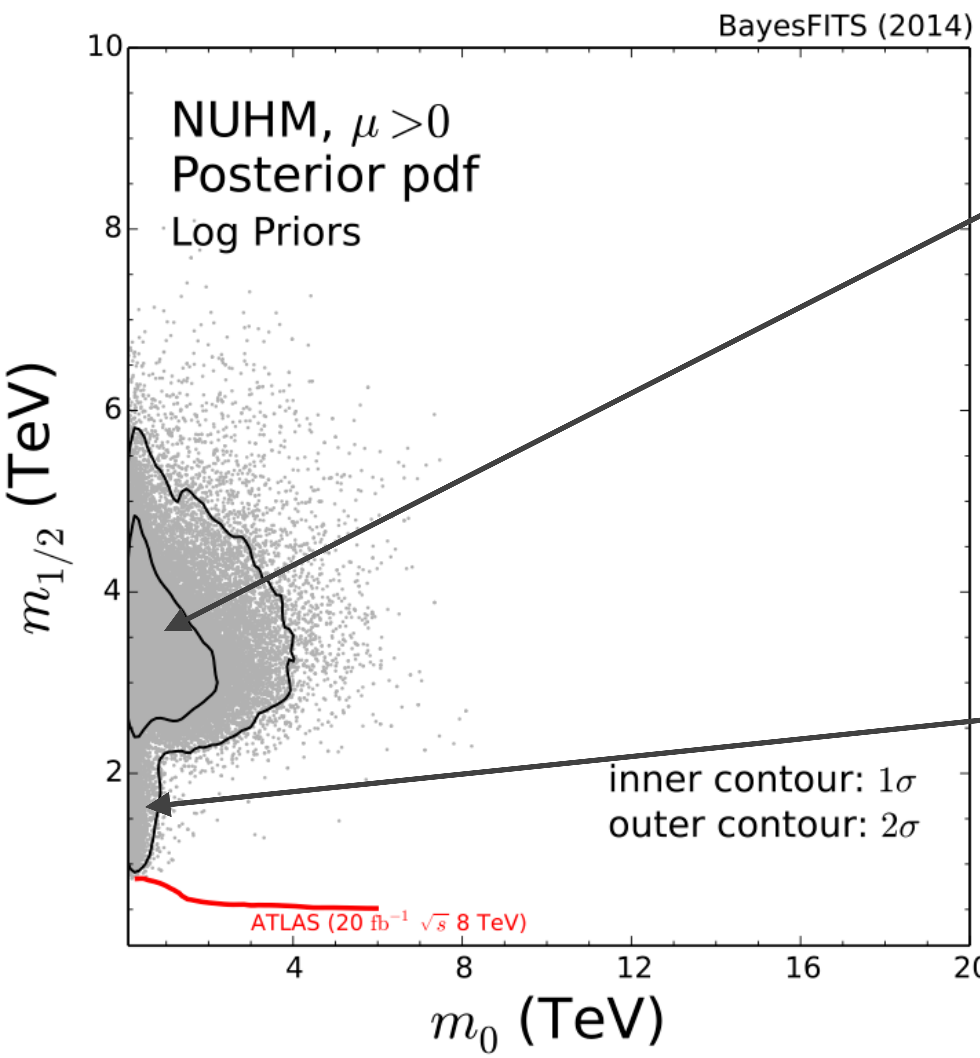


Large negative m_{H_u} leads to large μ at EW scale



$\propto \mu^4$

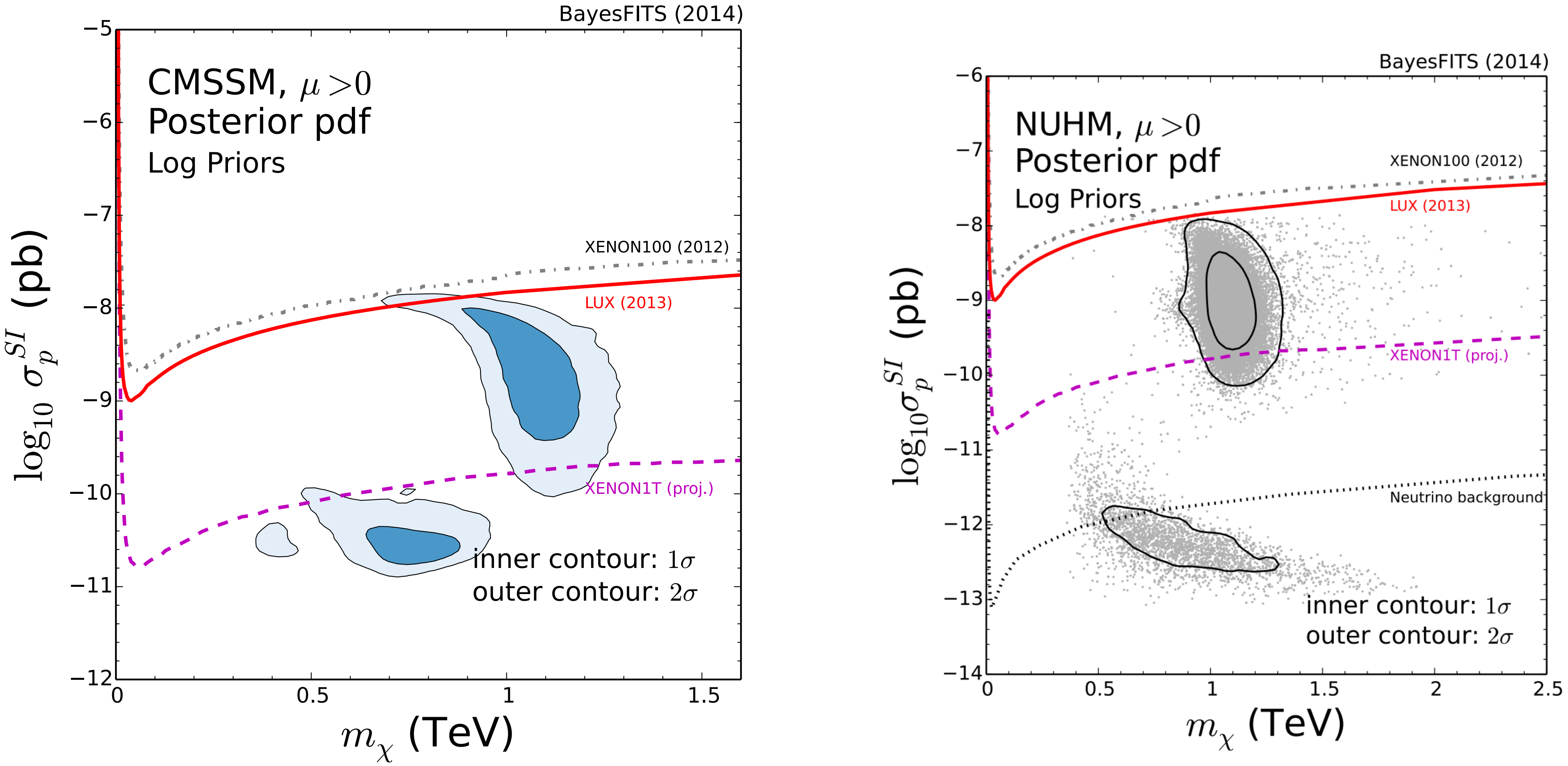
NUHM: preferred regions



Higgsino region no longer constrained to large m_0

Stau co-annihilation region extends to larger $m_{1/2}$. Less tension with the LHC

Prospects for dark matter direct detection



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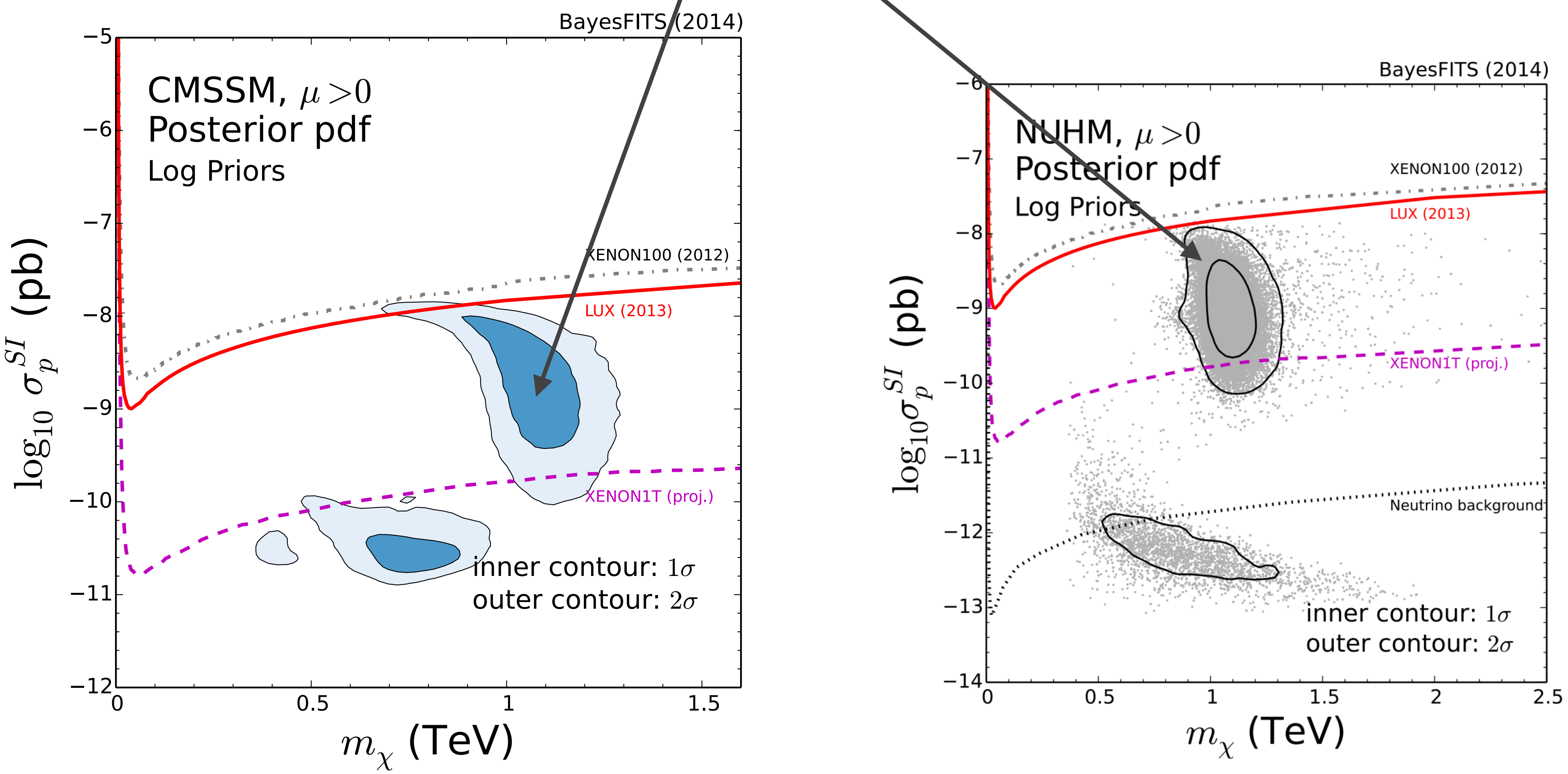
Higgsino region can be probed by XENON1T



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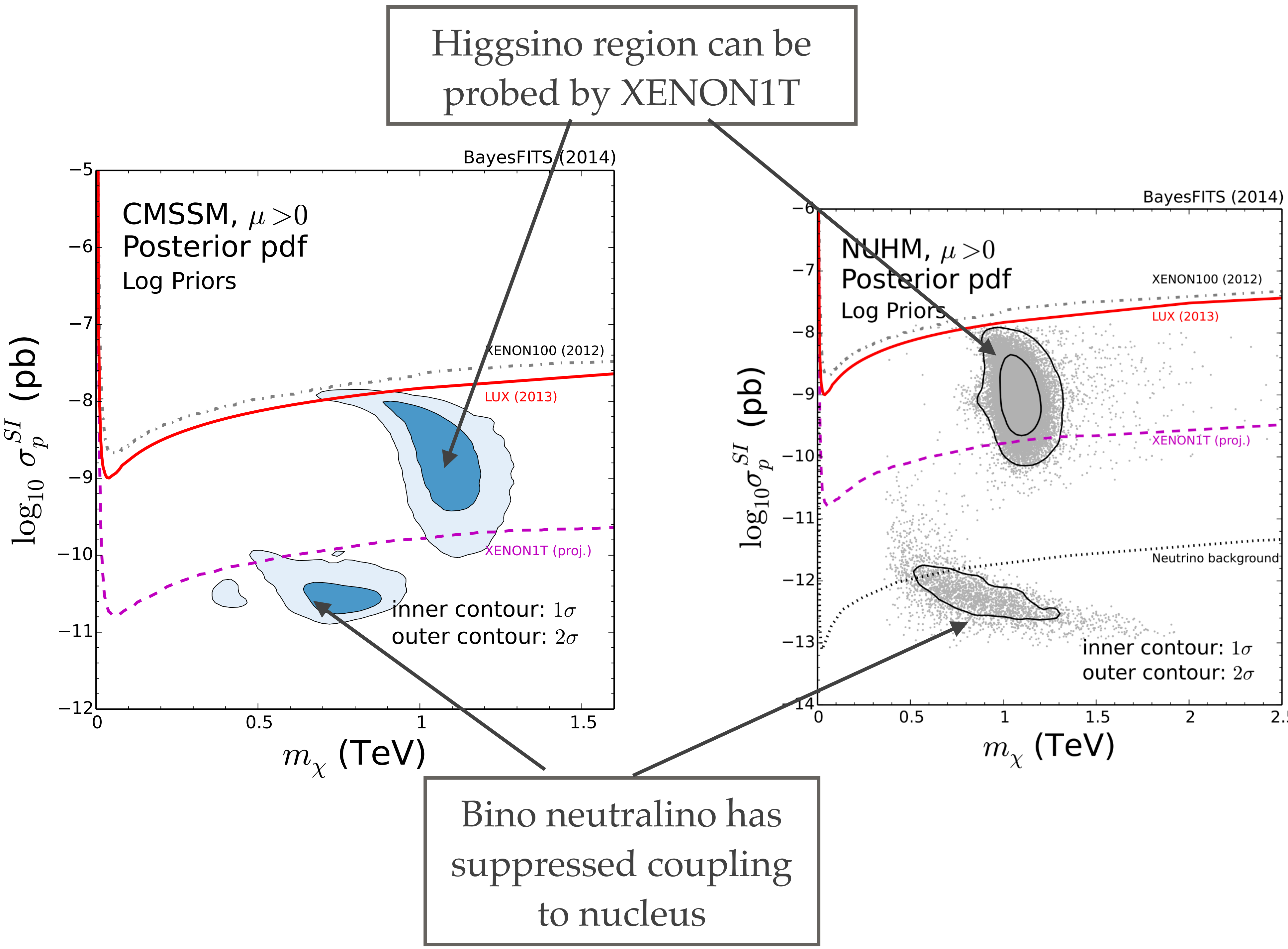

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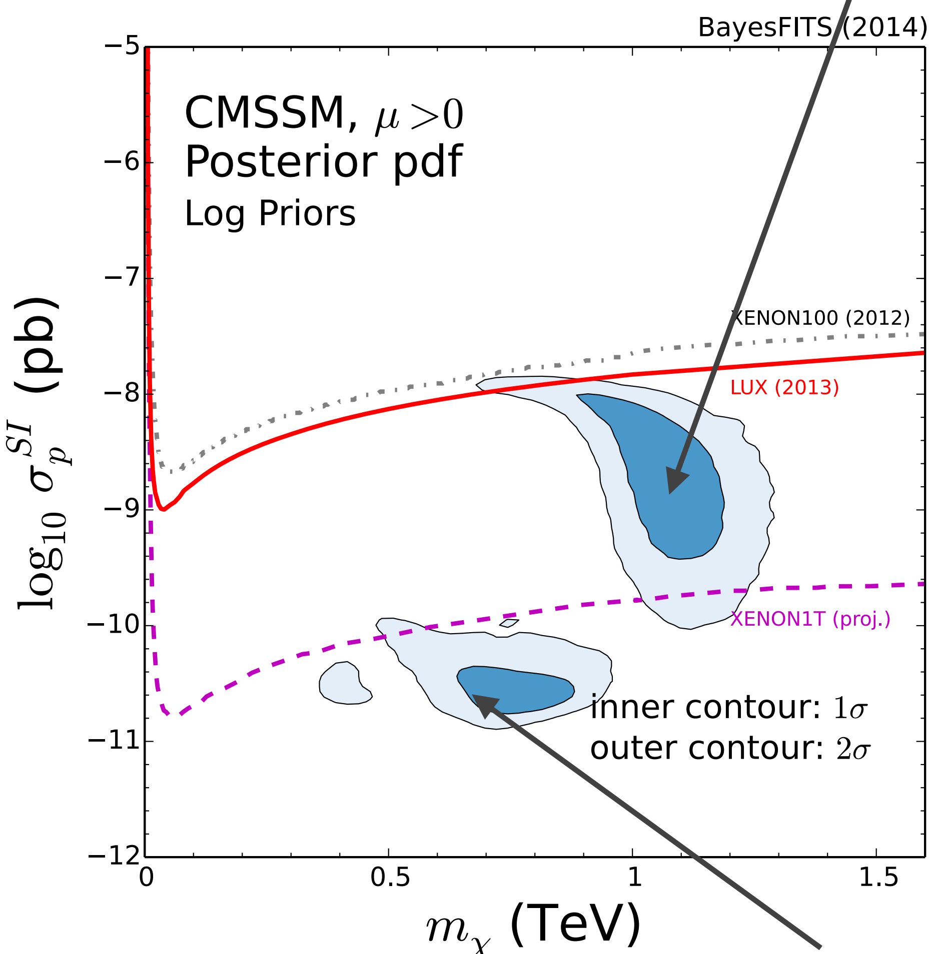
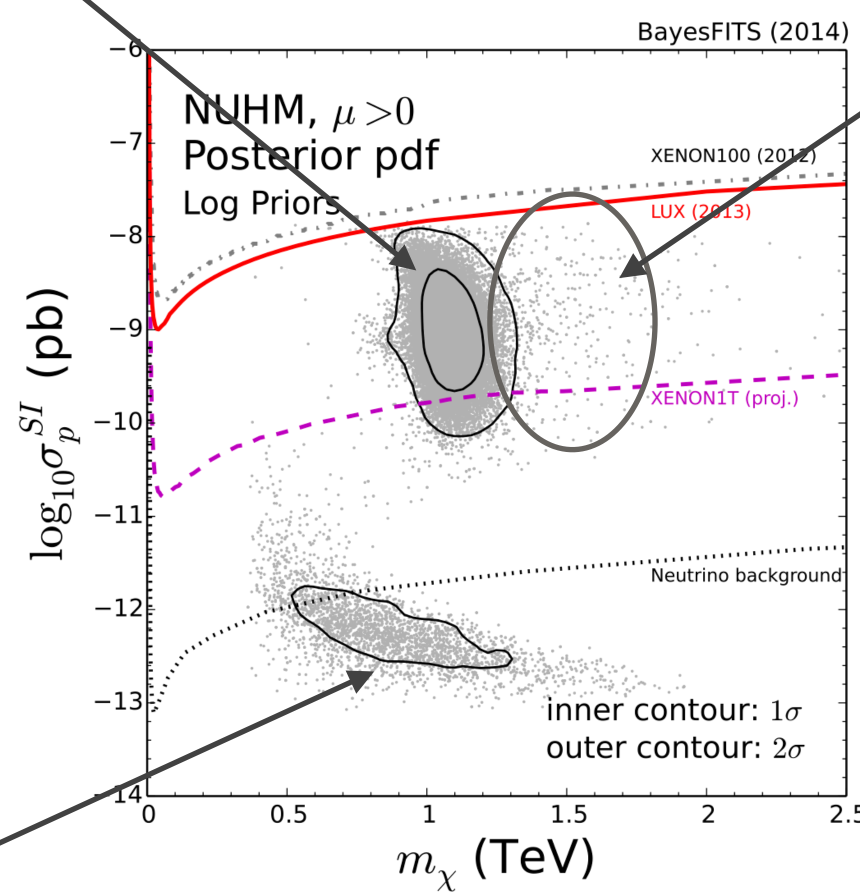
Mixed bino-higgsino A/H-funnel





Bino neutralino has suppressed coupling to nucleus

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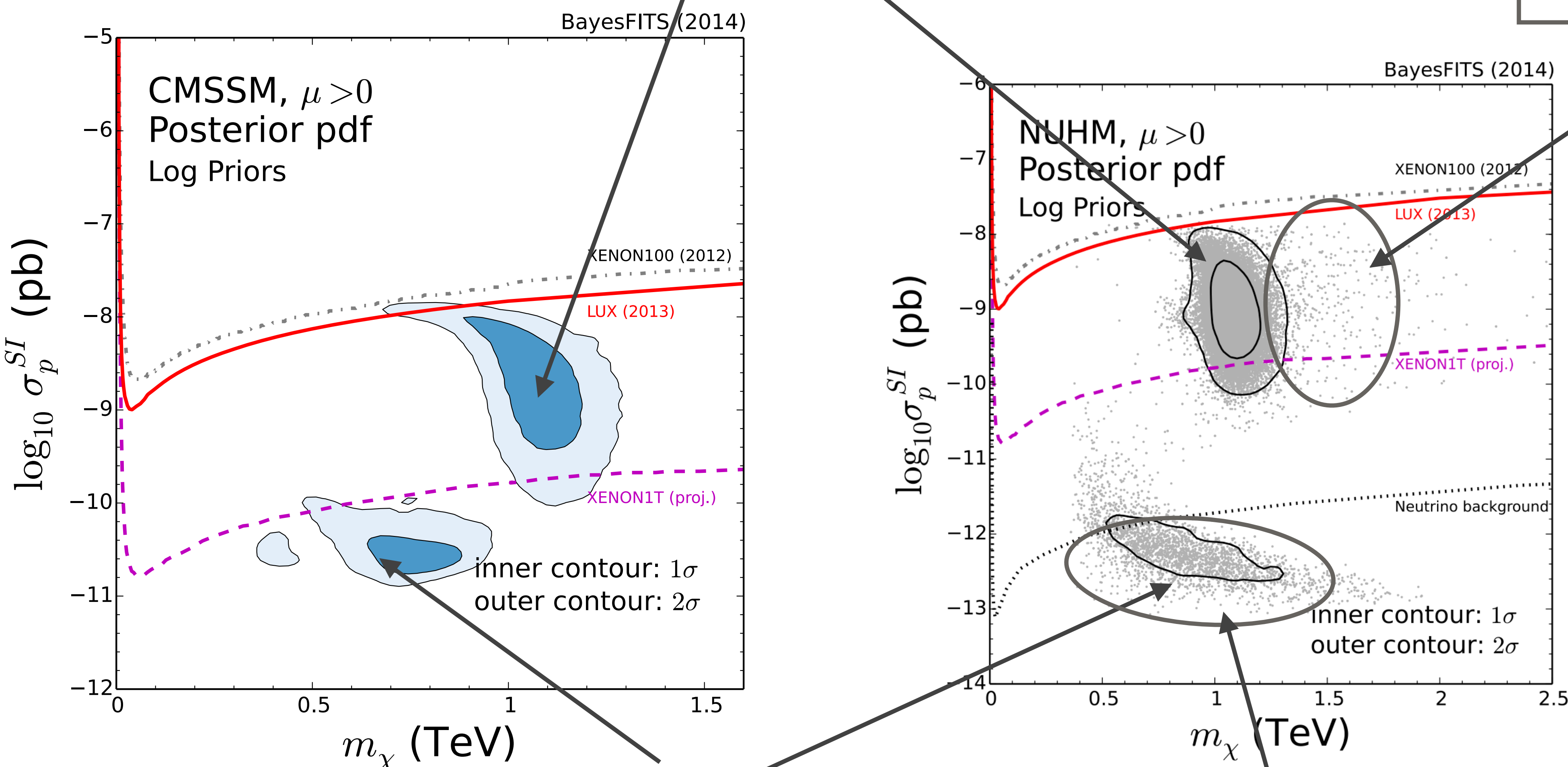
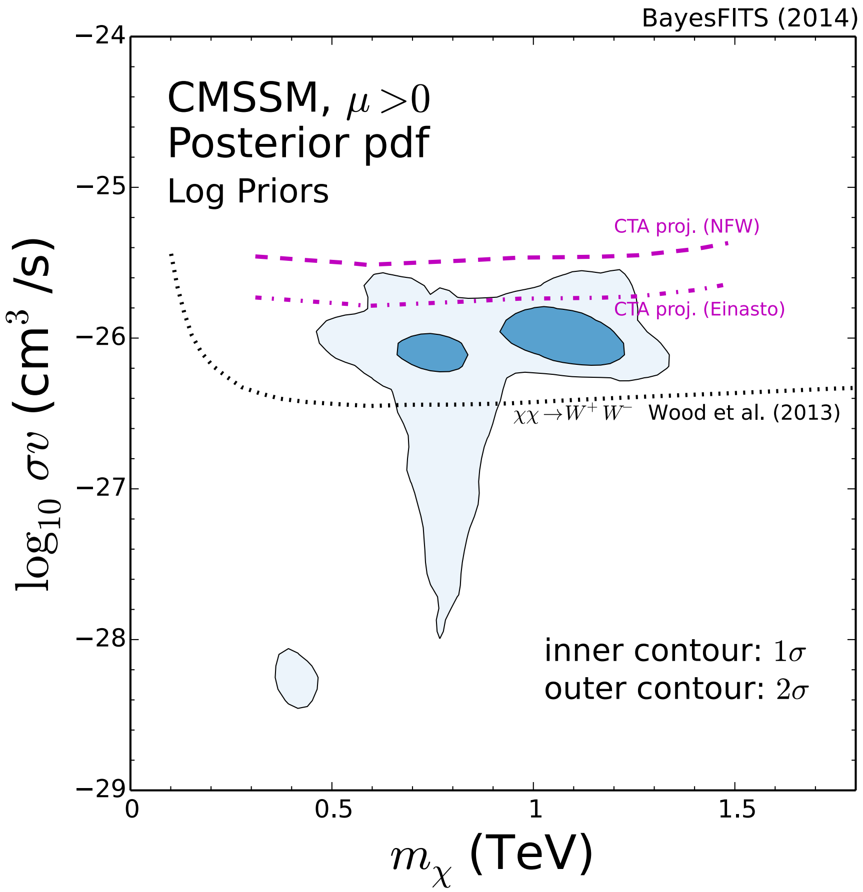
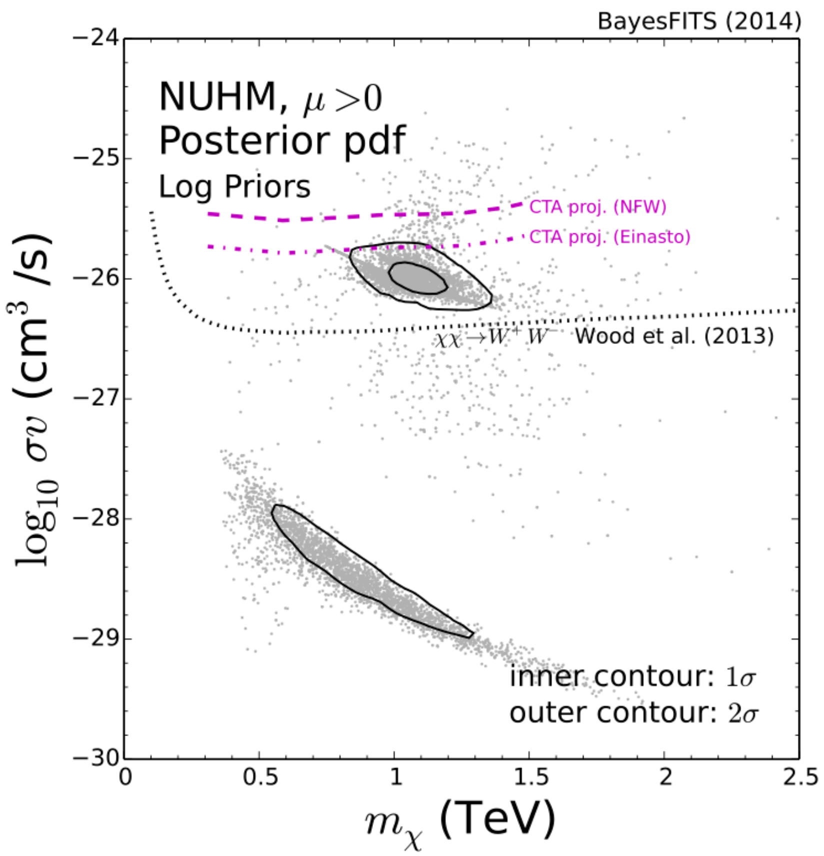


Bino neutralino has suppressed coupling to nucleus

Stau-coannihilation region extends below neutrino background

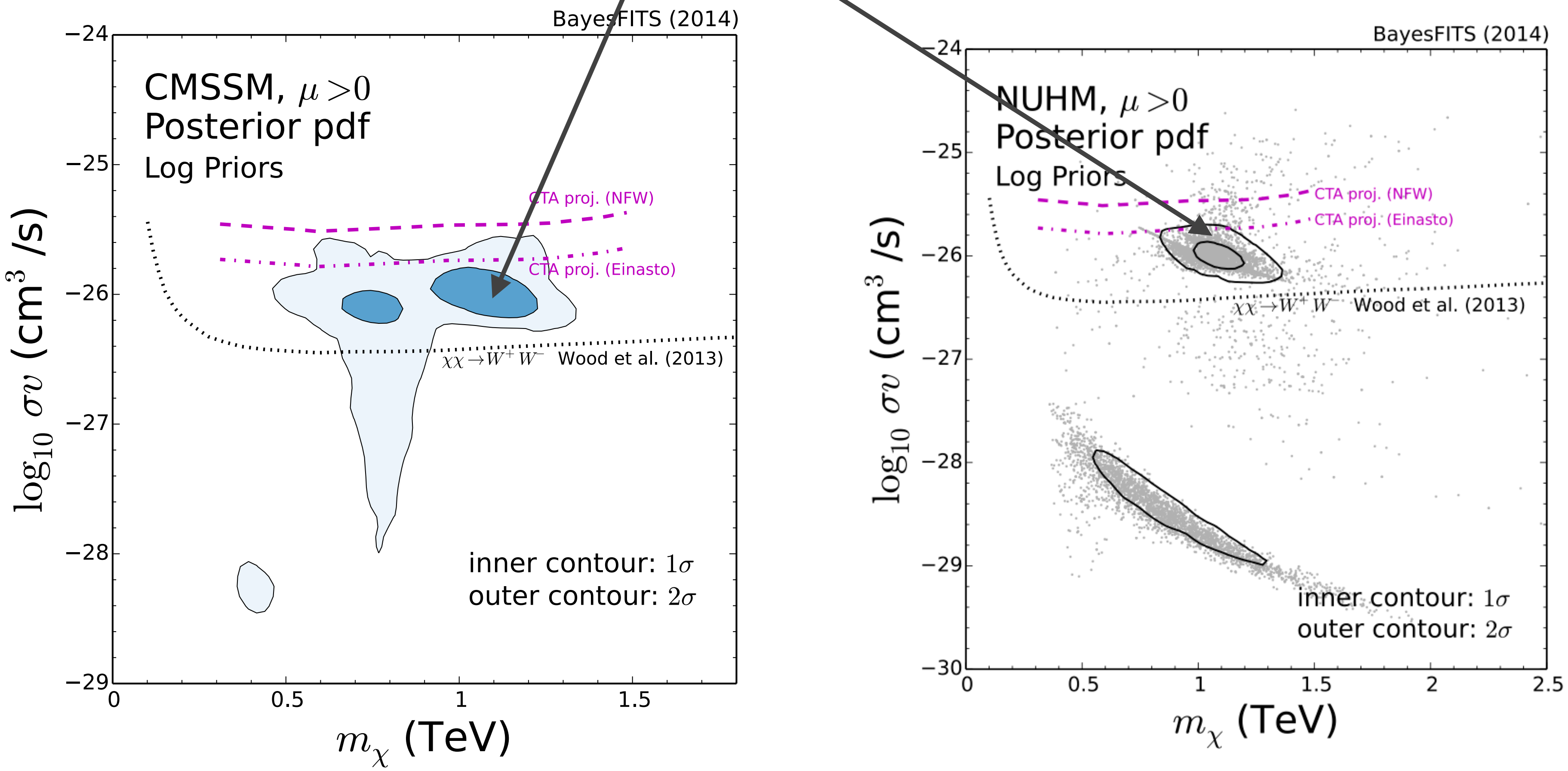
Prospects for DM detection at CTA





Prospects for DM detection at CTA

Factor 5 improvement required
in this set up to probe entire higgsino region



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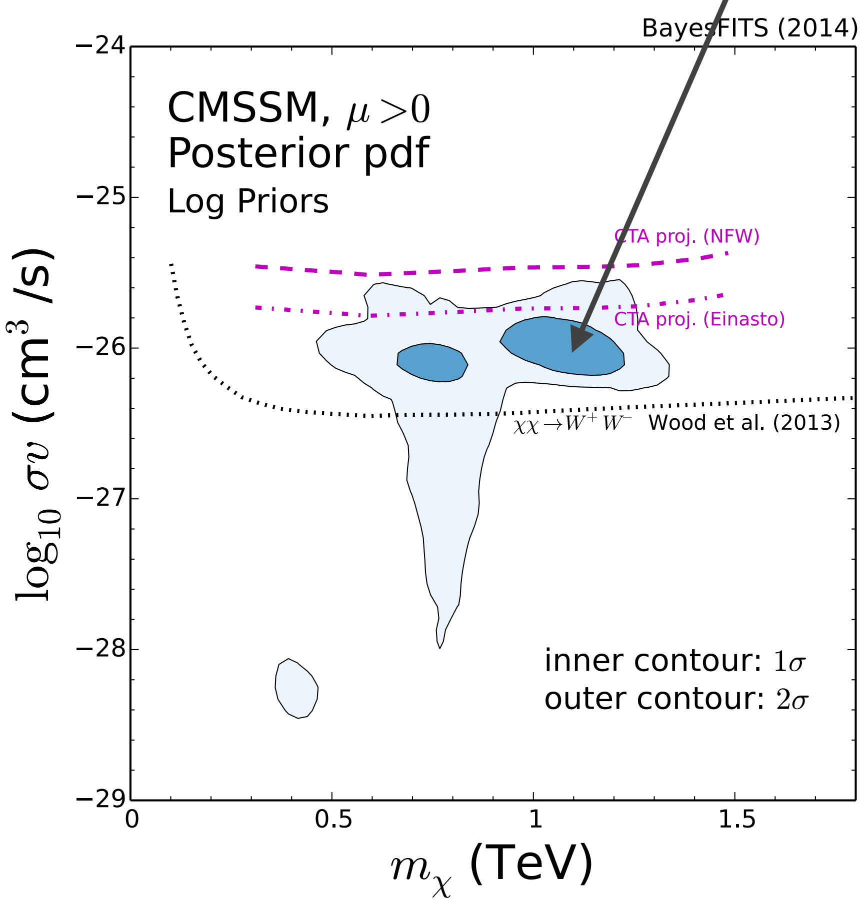

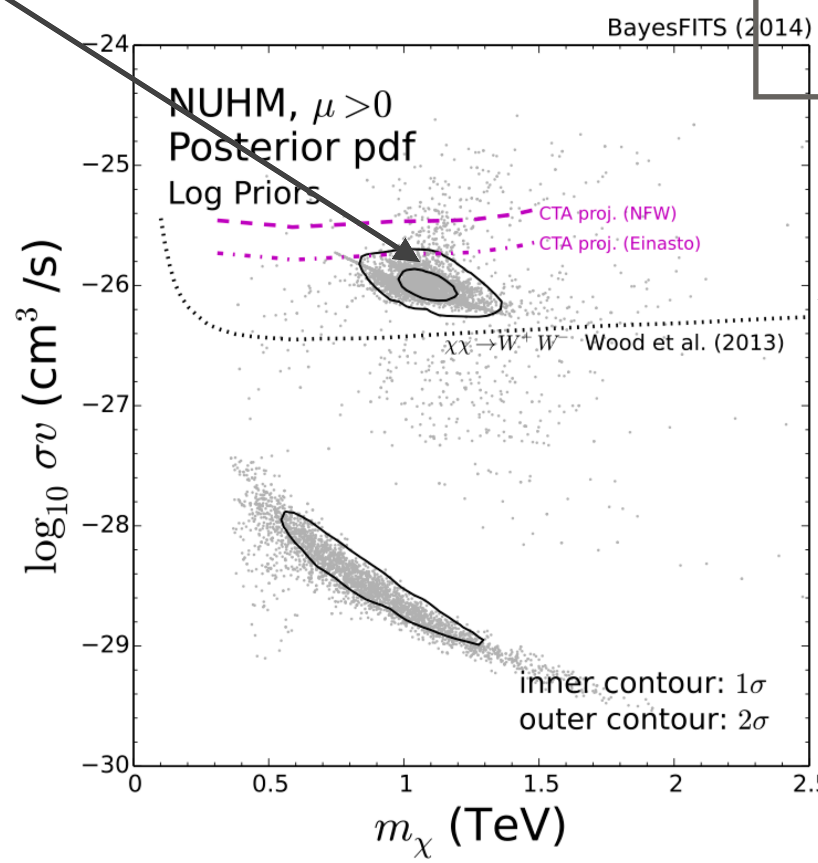

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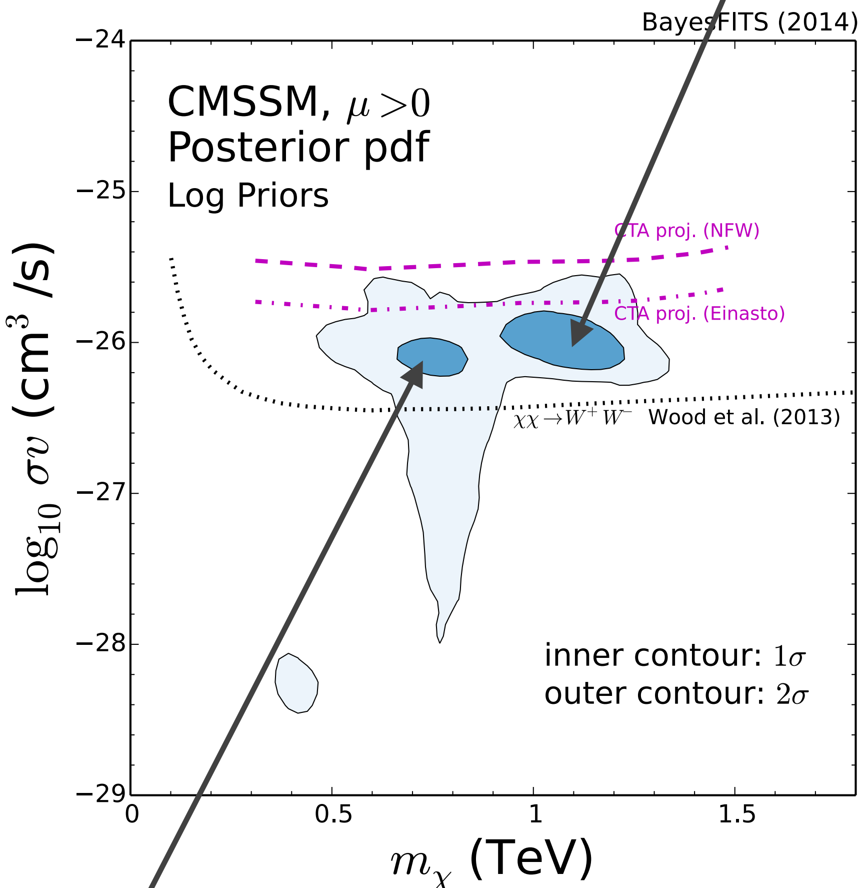

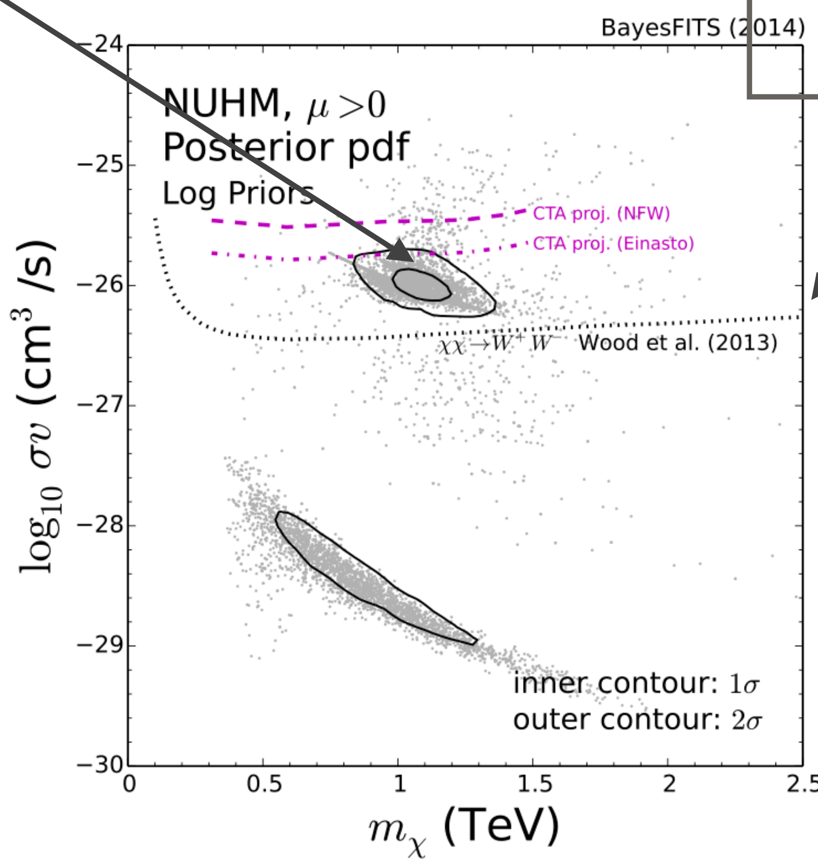

Possibility to probe a large part of the A-funnel region

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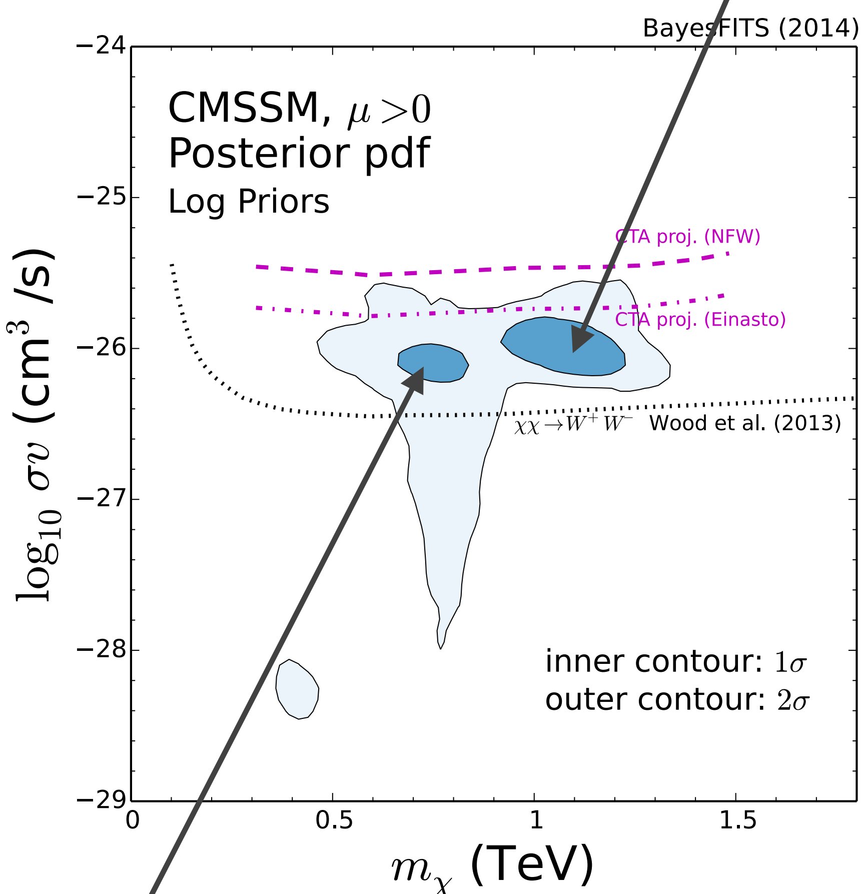

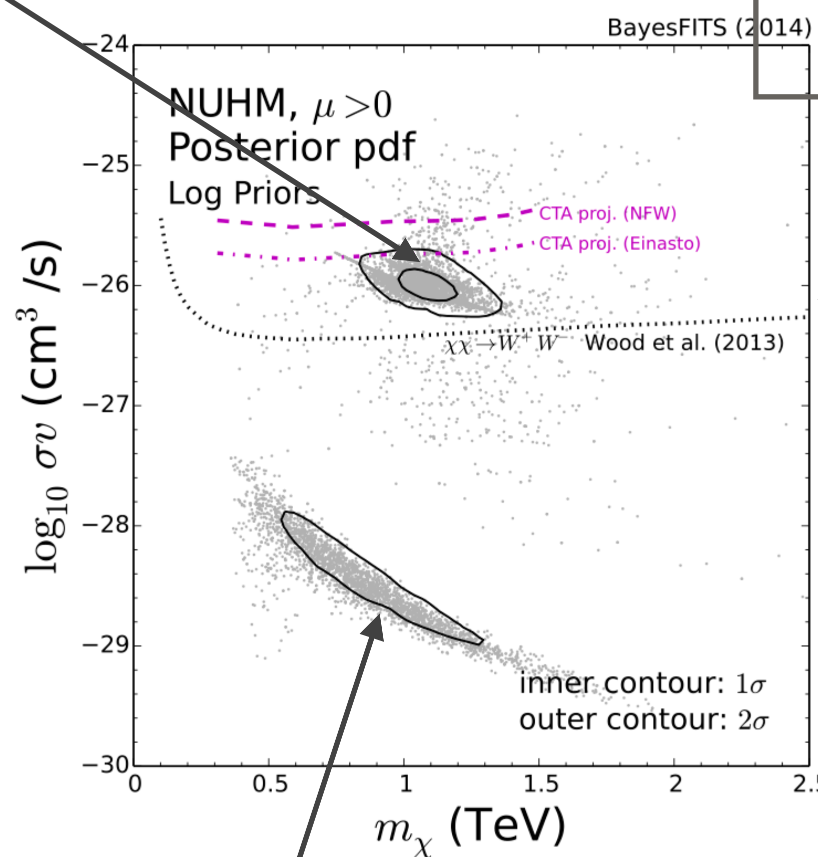

Possibility to probe a large part of the A-funnel region

Little chance to probe stau-coannihilation region

Conclusions

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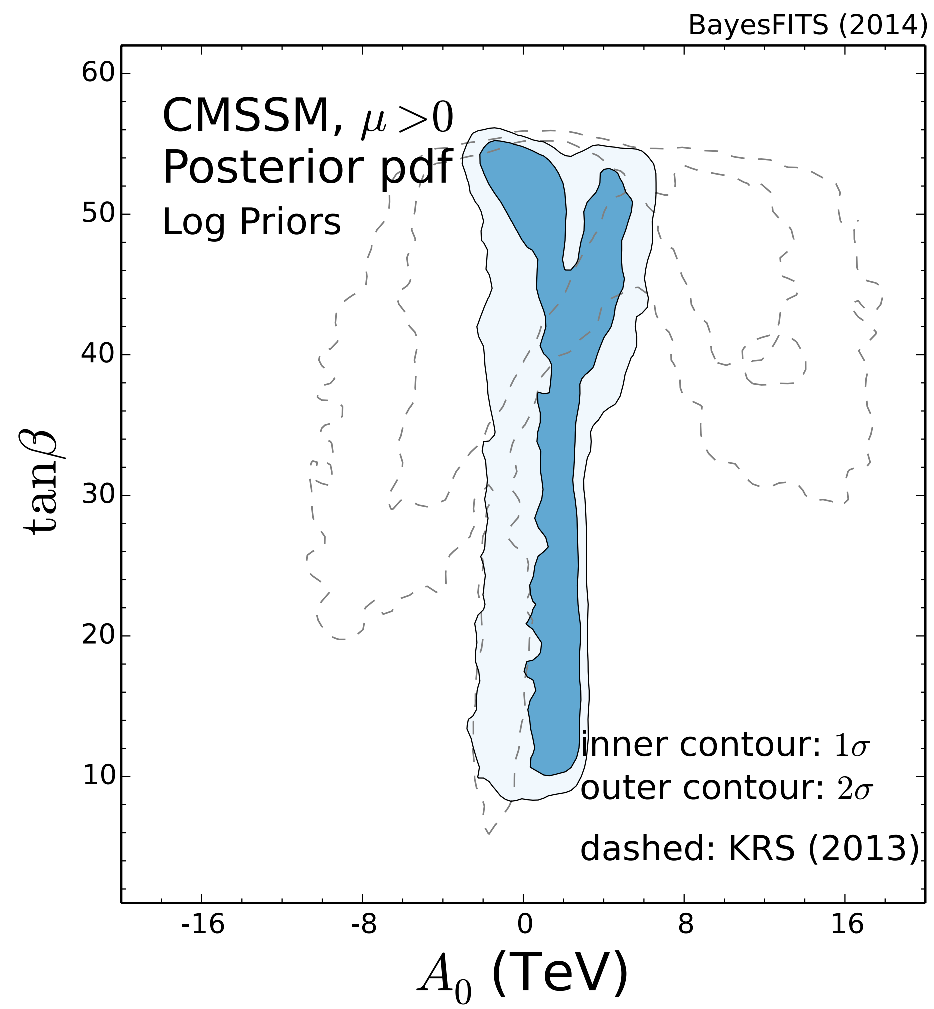
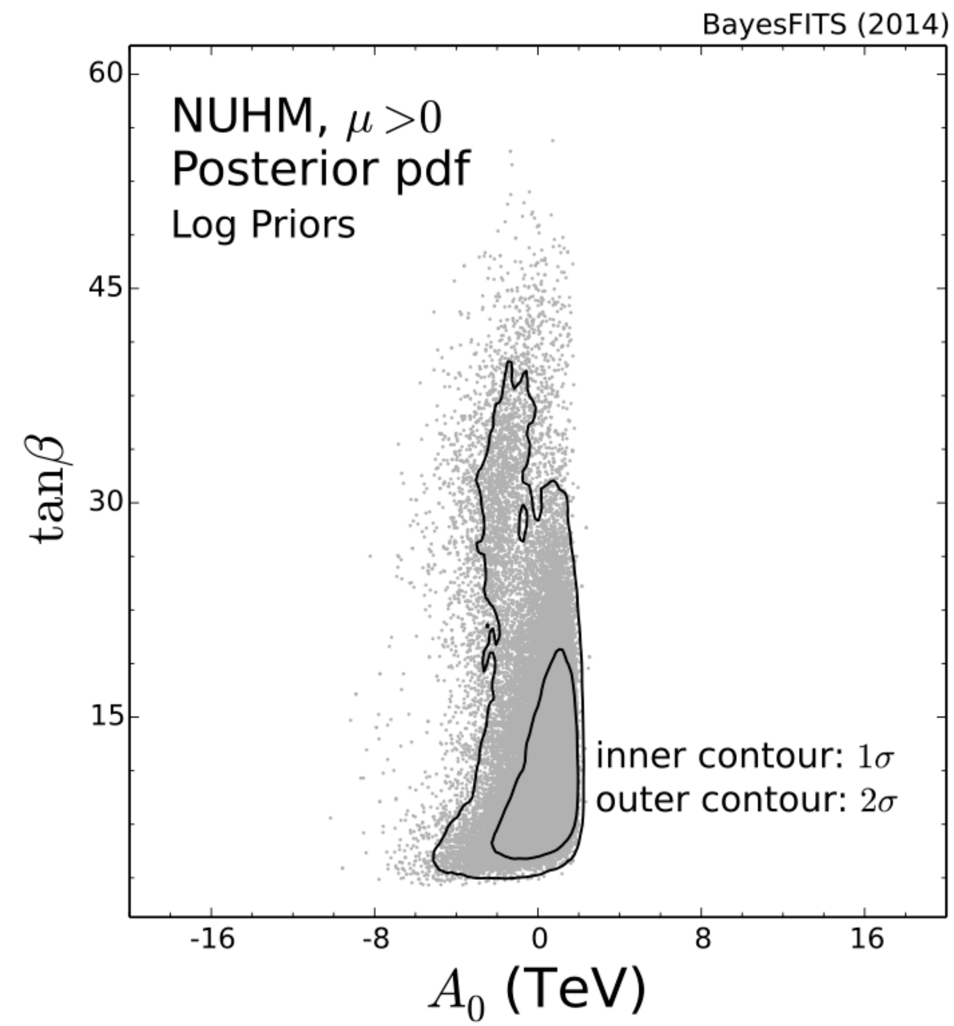
- 1 TeV Higgsino dark matter strongly motivates future dark matter analysis at CTA.

Backup: CMSSM and NUHM regions





General reduction in A0 due improved higgs mass calculation

Backup: Projected limits for CTA

- We take limits obtained for specific final states (Mathias et.al arxiv:1401.7330)
- This implies a limit on the flux of photons from annihilations

$$N_{\rm ann}^{95\%} = t_{\rm obs} \frac{\langle \sigma v \rangle^{95\%}}{8\pi m_\chi^2} N_{\gamma,{\rm obs}}\, J$$

$$N_{\gamma,{\rm obs}} = \int \frac{dN_\gamma(E)}{dE} A_{\rm eff}(E) dE$$

Dependence on final state