Future Impact of CTA on SUSY models

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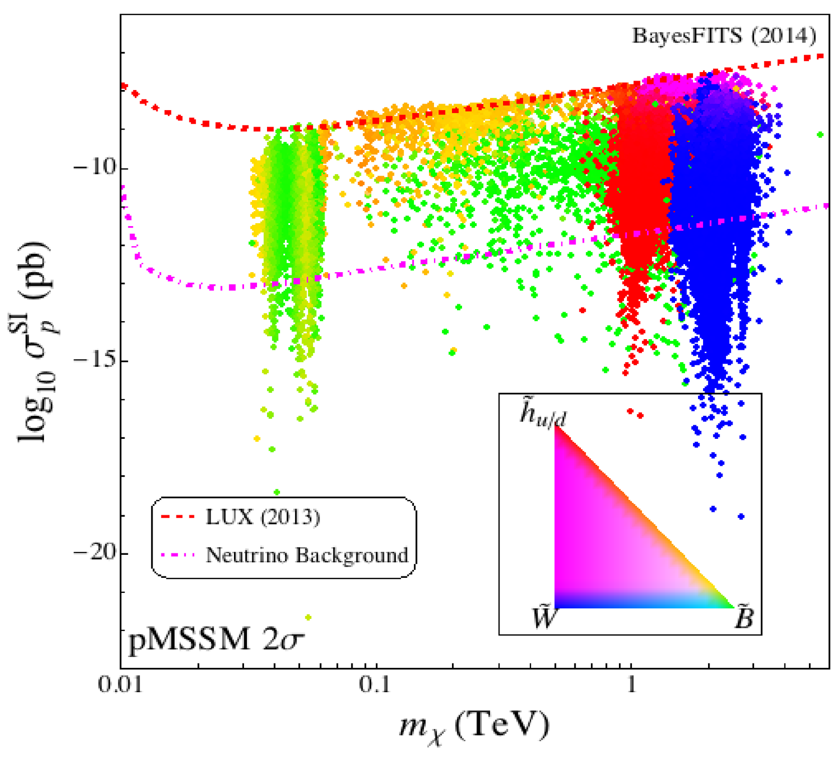
Abstract

We analyse the sensitivity of the future Cherenkov Telescope Array (CTA) experiment to dark matter annihilations in the galactic centre. We systematically examine the different statistical methods for setting limits using CTA and provide a realistic assessment of the sensitivity of CTA to gamma ray fluxes from dark matter annihilation by means of a binned likelihood analysis for the Einasto and Navarro-Frenk-White halo profiles. Applying these projections to the phenomenological minimal supersymmetric standard model (pMSSM) we show that CTA is bound to exclude at the 95% C.L. almost all of the phenomenologically favoured ~1 TeV higgsino region of the pMSSM. We show that for the constrained MSSM (CMSSM) CTA will play a key role in probing the parameter space out of reach of direct detection experiments and the LHC.

pMSSM favouring heavy dark matter

The combination of the discovery of a standard model like Higgs boson with mh~125 GeV, and the exclusion bounds on squarks and gluinos now favours heavier dark matter candidates in global fits of the pMSSM.

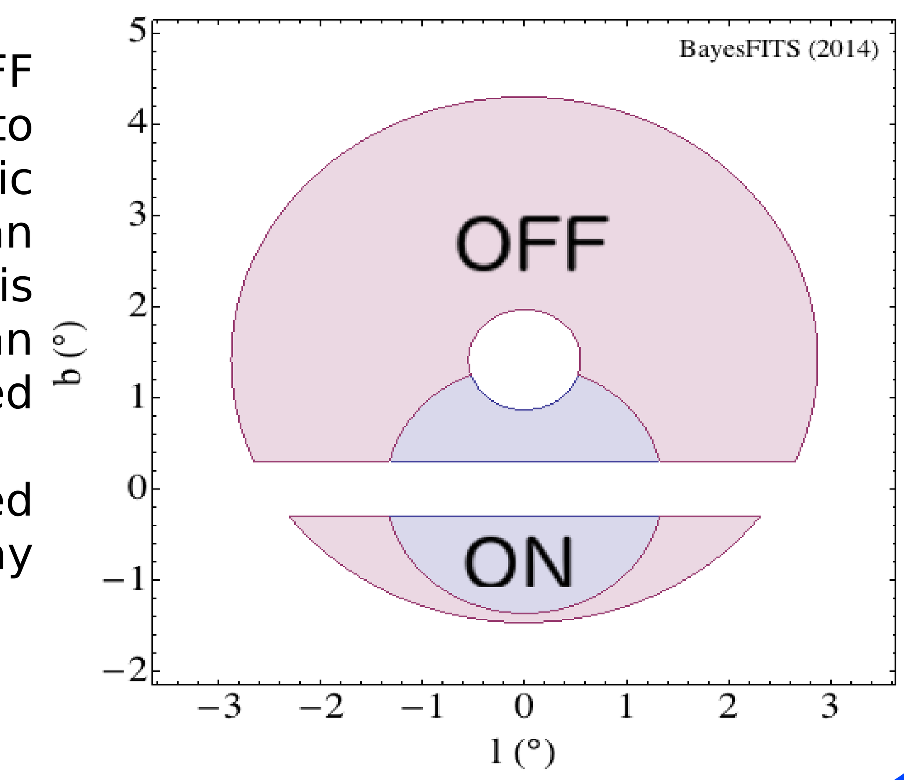
The dark matter relic abundance constraint can be satisfied by a nearly pure higgsino with $m_\chi \approx 1\,\mathrm{TeV}$ or a wino with $m_\chi \approx 3\,\mathrm{TeV}$. The spin-independent cross section limit for these regions can lie beyond the sensitivity of future direct detection experiments. **Indirect detection** offers a window to probe these heavy dark matter candidates



Observing the galactic centre with CTA

CTA will be the next generation ground based air Cherenkov gamma ray telescope. It will exceed the current sensitivity to dark matter annihilations in the range of 100 GeV to several TeV.

We perform an ON/OFF analysis of the sensitivity to annihilations in the galactic centre. The analysis defines an ON region where the signal is expected to appear and an OFF region that is dominated by the background.
The galactic plane is masked to reduce the gamma ray background.



Statistical Analysis

We define the limit in terms of a likelihood function, when -2 ln(L) > 2.75 the annihilation rate is excluded at the 95% CL. We compare three different definitions of the likelihood function. Written in terms of observed number of gamma rays in energy range i and region j, n_{ij}, and expected number μ_{ij}.

Li and Ma Method: $$-2\ln\mathcal{L} = 2\left[n_{\mathrm{ON}}\ln\left(\frac{1+\alpha}{\alpha}\frac{n_{\mathrm{ON}}}{n_{\mathrm{ON}}+n_{\mathrm{OFF}}}\right)+n_{\mathrm{OFF}}\ln\left((1+\alpha)\frac{n_{\mathrm{OFF}}}{n_{\mathrm{ON}}+n_{\mathrm{OFF}}}\right)\right]$$

Skellam Distribution: $$\mathcal{L}(\{\theta_{\mathrm{diff},i}\}) = \prod_i e^{-(\mu_{i,\mathrm{ON}}+\alpha\mu_{i,\mathrm{OFF}})}\left(\frac{\mu_{i,\mathrm{ON}}}{\alpha\mu_{i,\mathrm{OFF}}}\right)^{\frac{\theta_{\mathrm{diff},i}}{2}} I_{|\theta_{\mathrm{diff},i}|}\left(2\sqrt{\alpha\mu_{i,\mathrm{ON}}\mu_{i,\mathrm{OFF}}}\right)$$

Binned Poisson Likelihood: $$\mathcal{L} = \prod_{i,j}\frac{\mu_{ij}^{n_{ij}}}{n_{ij}!}$$

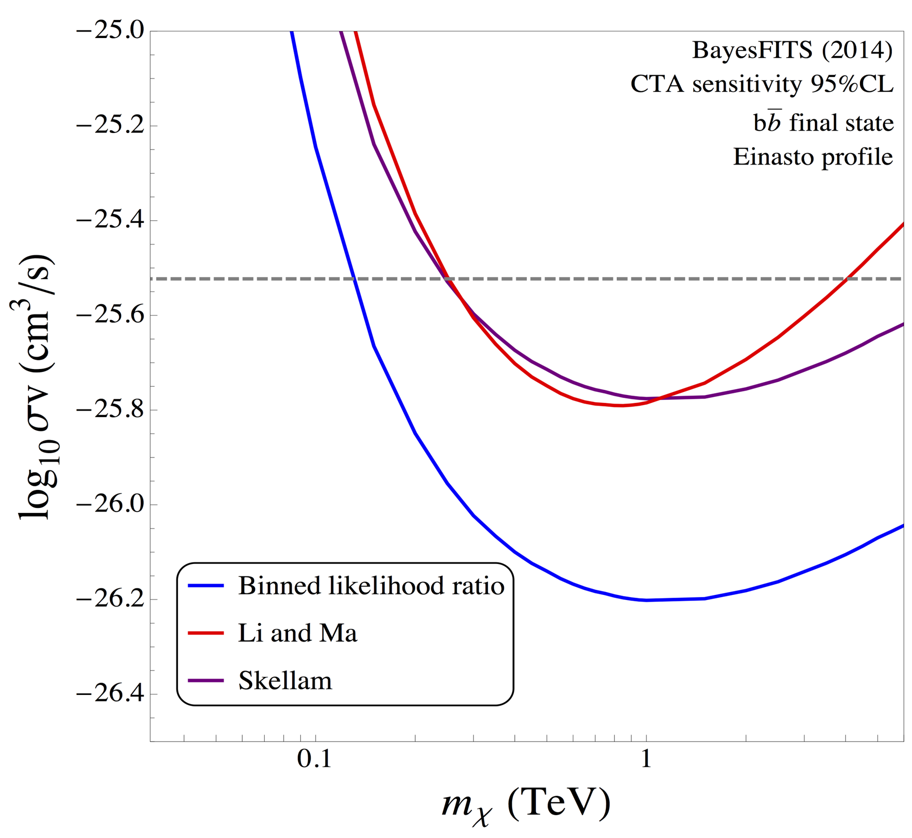
$$\theta_{\mathrm{diff},i} = n_{i,\mathrm{ON}} - \alpha\, n_{i,\mathrm{OFF}}$$

$$\alpha = \Delta\Omega_{\mathrm{ON}}/\Delta\Omega_{\mathrm{OFF}}$$

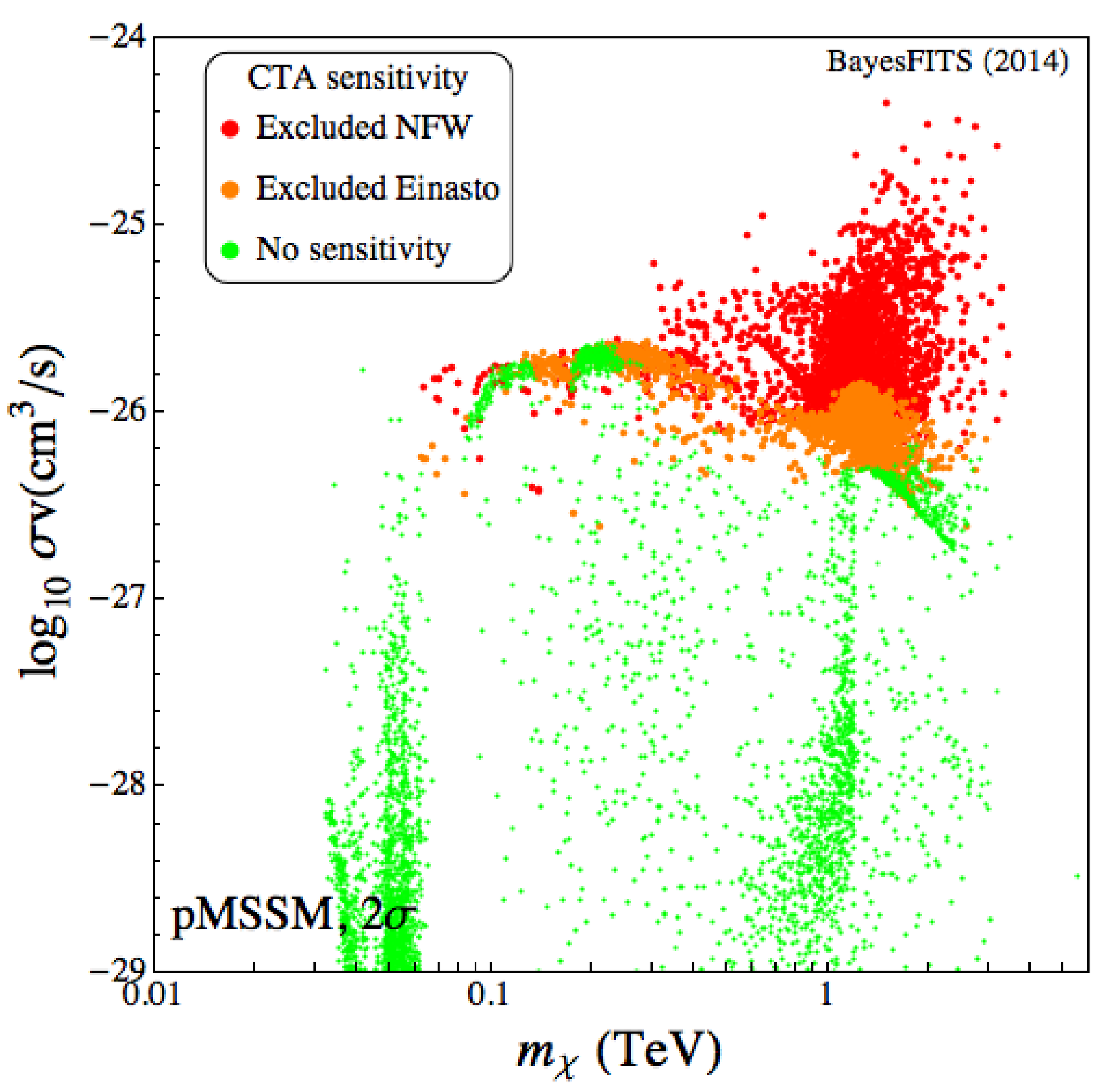
We calculate a projected limit by setting the observed number of gamma rays to be equal to the background only.

Projected Limits

For low masses the limits obtained using the Skellam distribution and the Li and Ma method are comparable. For larger masses the Li and Ma method loses sensitivity compared to the other two methods as they benefit from the data being binned by energy. The binned likelihood method produces the strongest limits. At 1 TeV the limit is stronger that the canonical thermal annihilation rate for a WIMP



Impact on the MSSM and CMSSM



In the pMSSM CTA will have the sensitivity to constrain part of or the vast majority of the 1TeV higgsino region depending on the dark matter halo profile. CTA can constrain points in the parameter space that lie below the irreducible neutrino background for direct detection experiments

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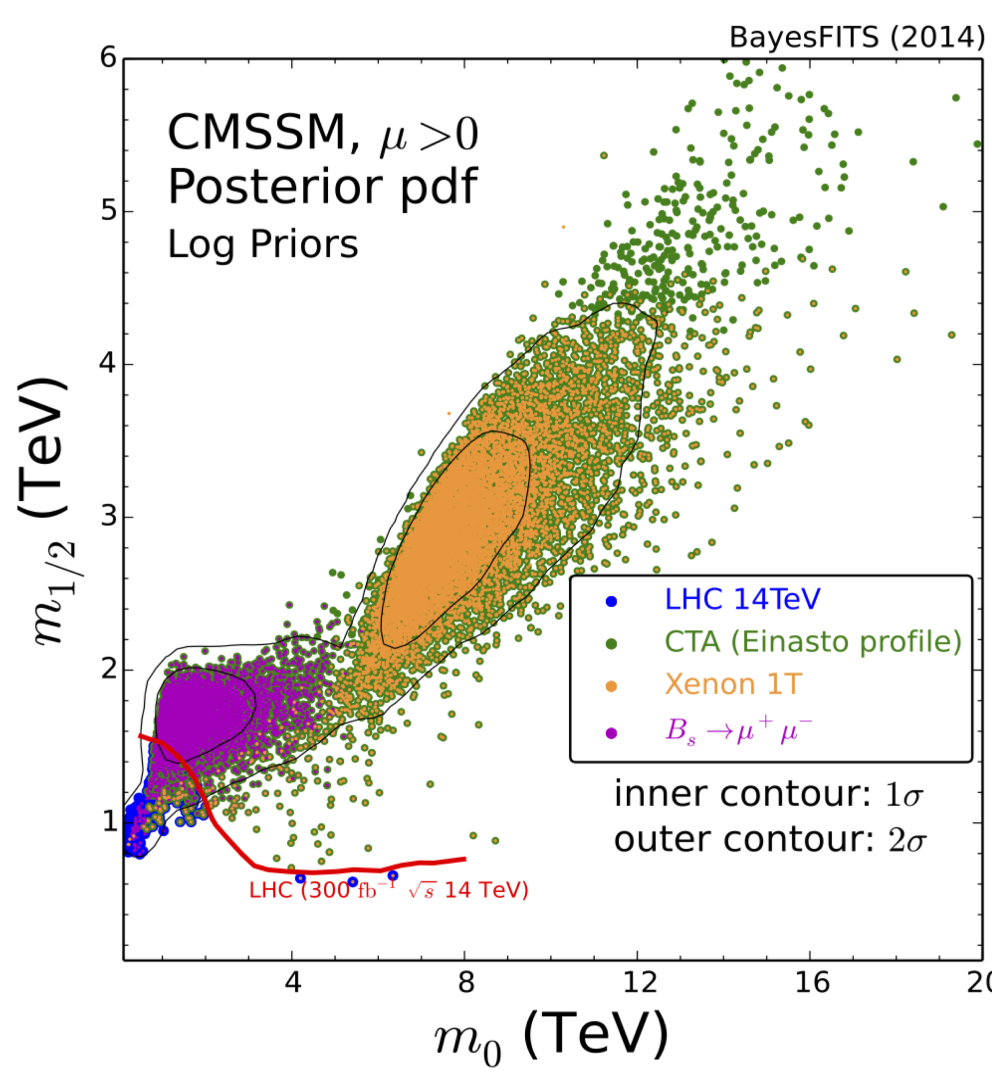
For the CMSSM CTA will provide an additional means of constraining models across most of the parameter space that will be covered by the LHC and direct detection. CTA will close the remaining gaps not covered by the other experiments leading to complete coverage of the parameter space by a combination of CTA, tonne scale direct detection experiments, measurement of $B_s \to \mu\mu$ and searches for squarks and gluinos as the LHC run II.



BayesFITS project "*The Bayesian approach to multi-parameter problems in physics and beyond involving parallel computing and large data-sets*" within the framework of the FNP WELCOME programme.
BayesFITS Group http://www.ncbj.gov.pl/bayesfits

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