Sensitivity of CTA to dark matter annihilations in the Galactic Center

Enrico Maria Sessolo

National Centre for Nuclear Research (NCBJ)
Warsaw, Poland

EPS-HEP 2015
Vienna
July 24, 2015

L.Roszkowski, EMS, A.J.Williams, JHEP 1502 (2015) 014, 1411.5214
L.Roszkowski, EMS, A.J.Williams, JHEP 1408 (2014) 067, 1405.4289

Grants for innovation. Project operated within the Foundation for Polish Science "WELCOME" co-financed by the European Regional Development Fund

Outline

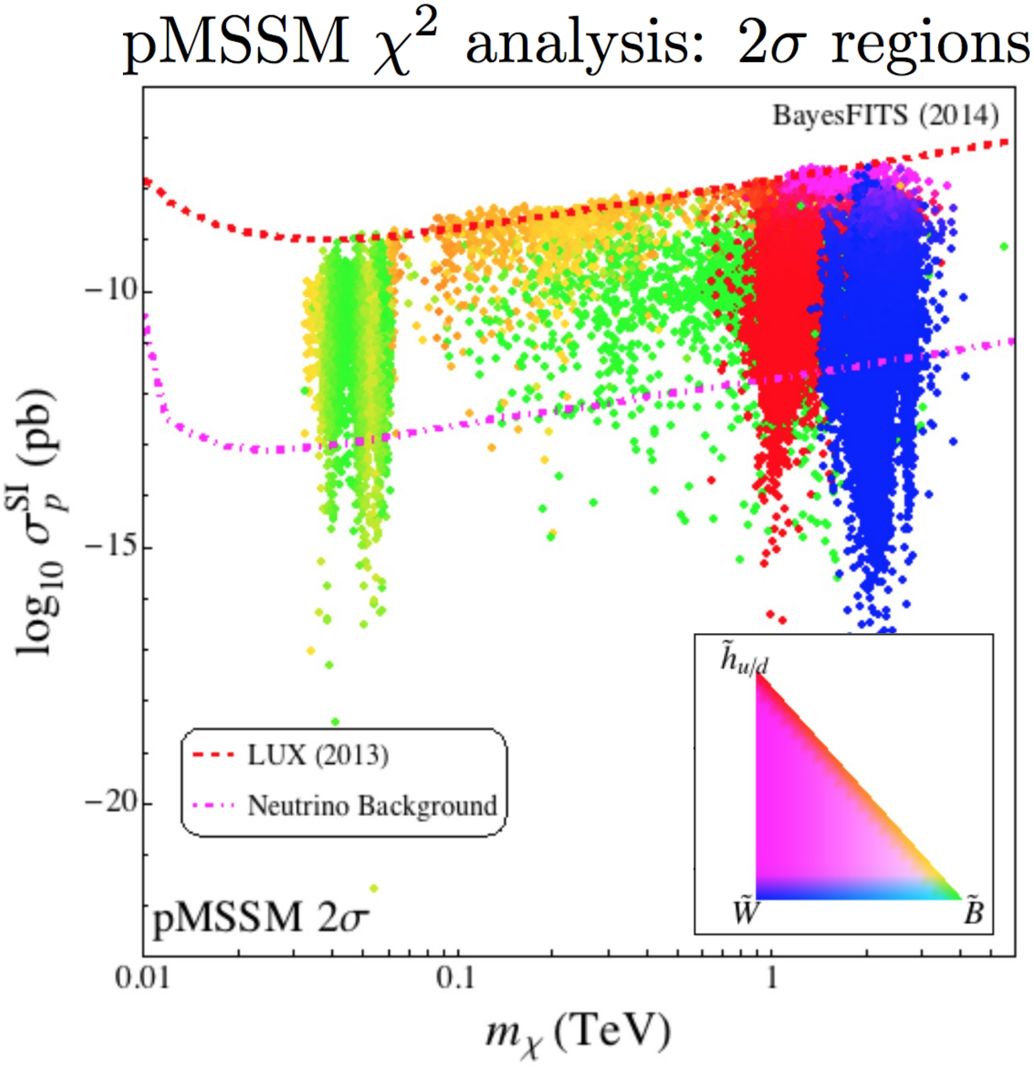
1. Motivation

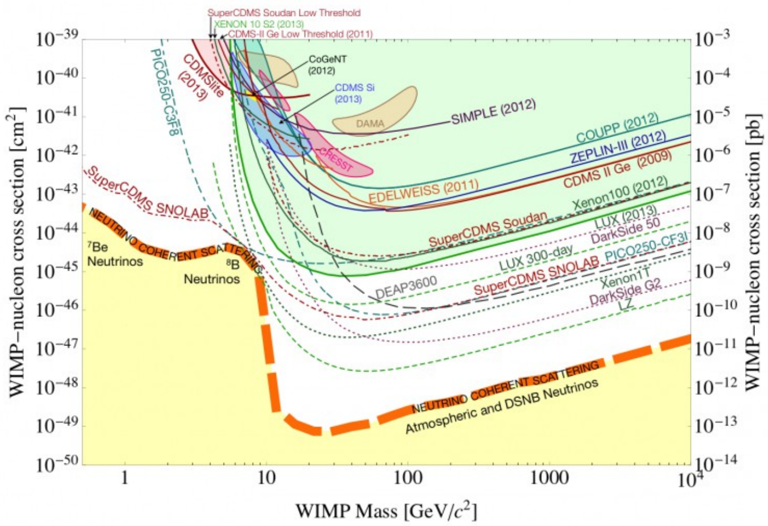
2. Summary of the calculation

2. Implications for SUSY

6. Summary

Direct detection: MSSM prospects

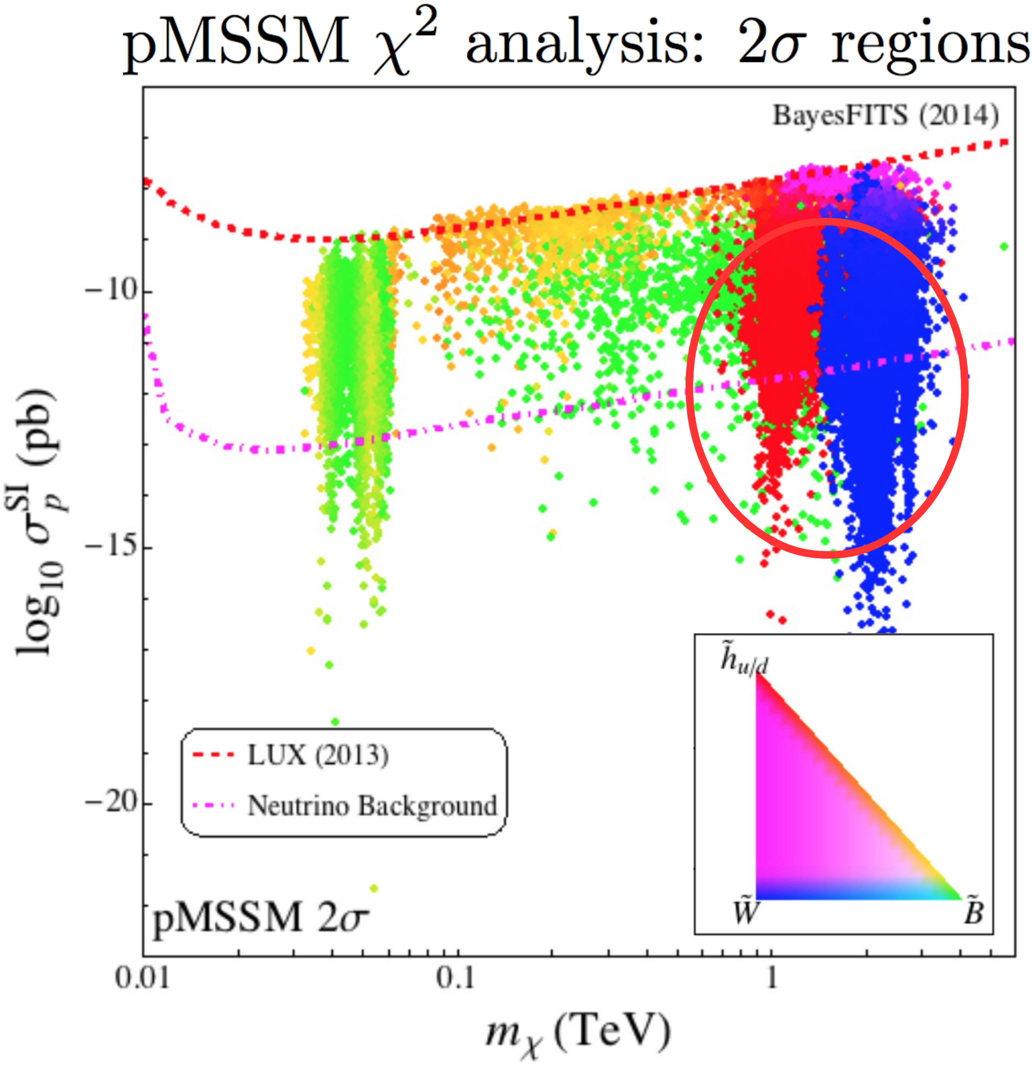


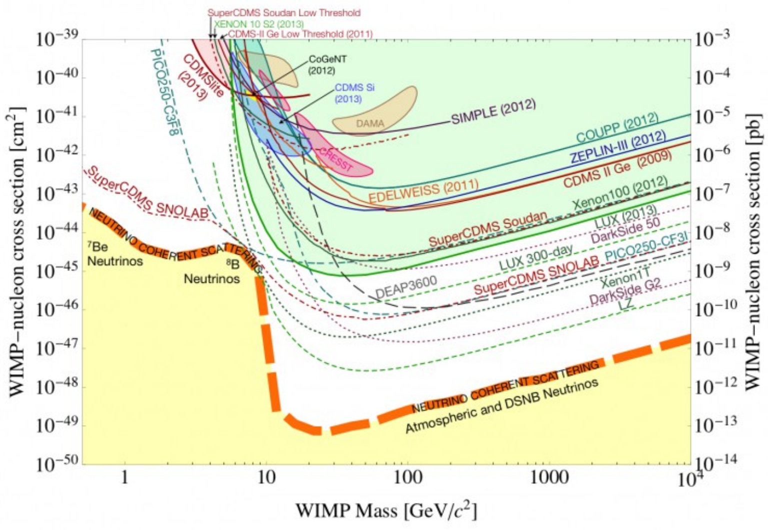


1 tonne (2017)

Color code gives neutralino composition: bino, higgsino, wino

Direct detection: MSSM prospects

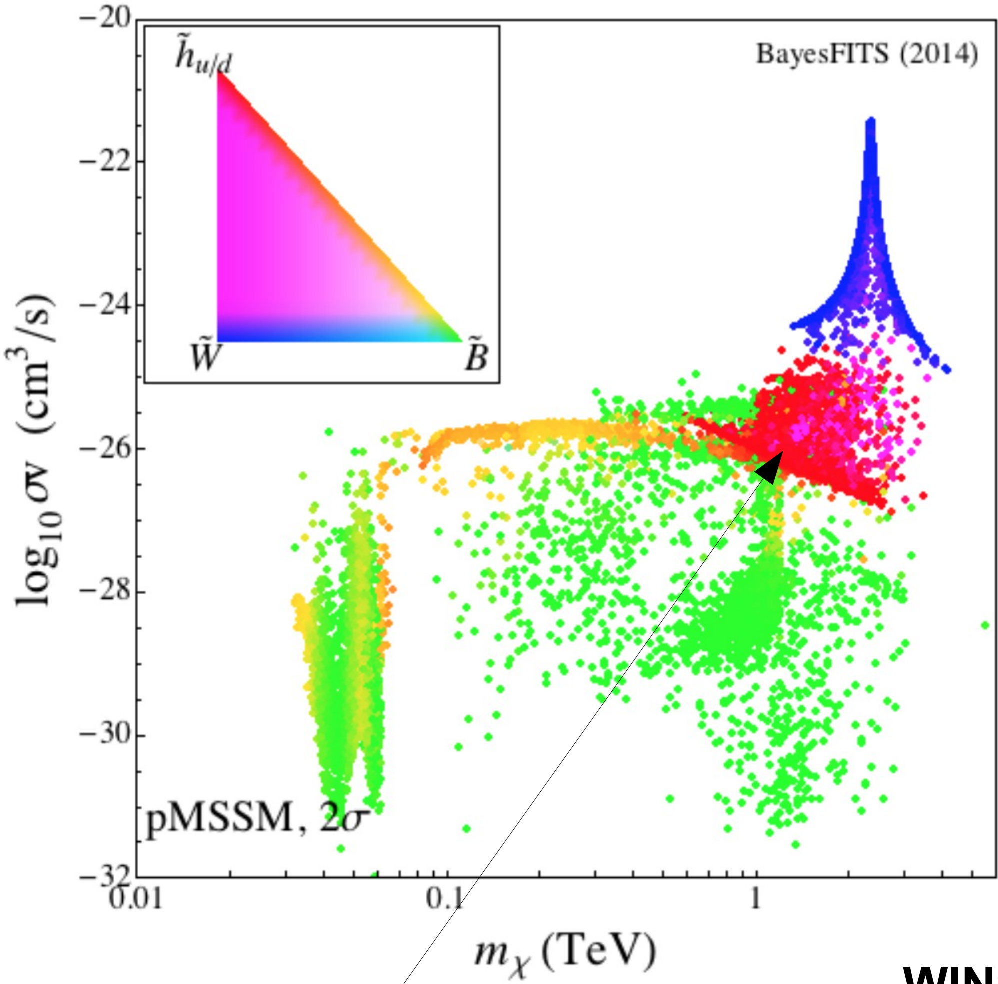


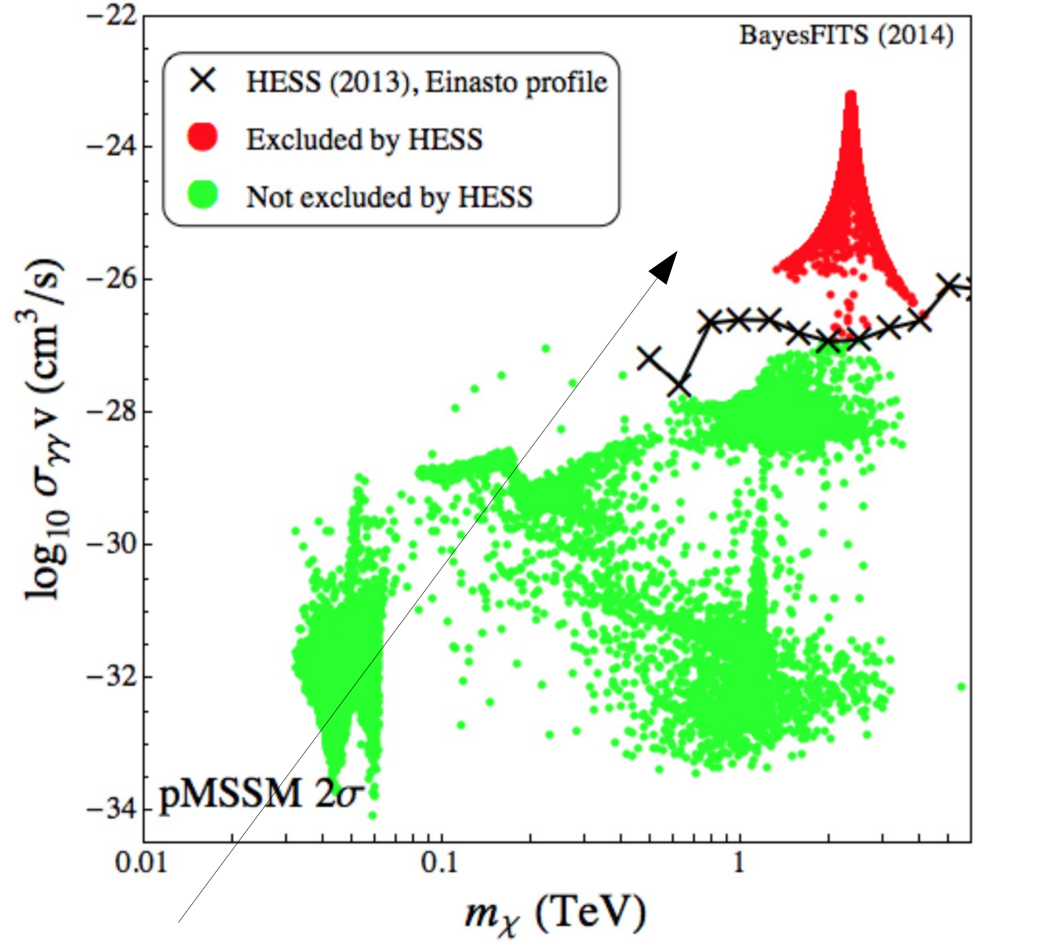


1 tonne (2017)

Area <u>strongly favored after Higgs discovery</u> (dark matter **higgsino** or **wino**)
not entirely covered / even below neutrino background

Indirect detection is complementary





WINO possibly 90% CL excl. by HESS (Sommerfeld)

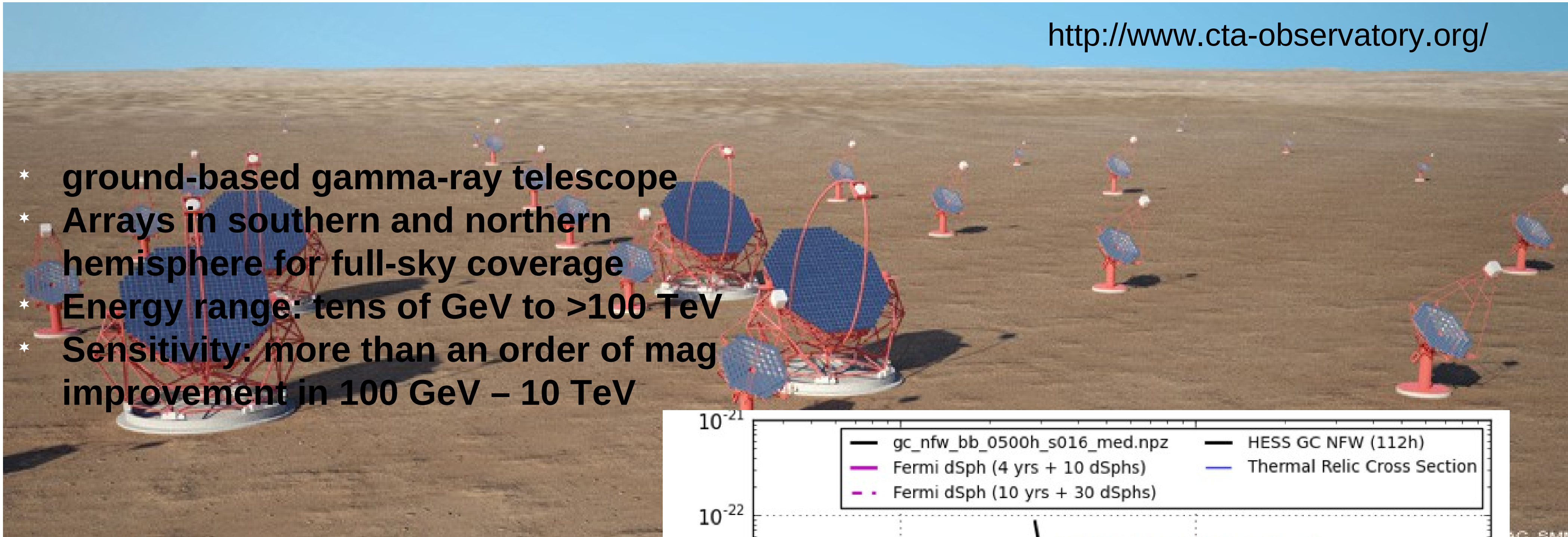
HIGGSINO just beyond reach

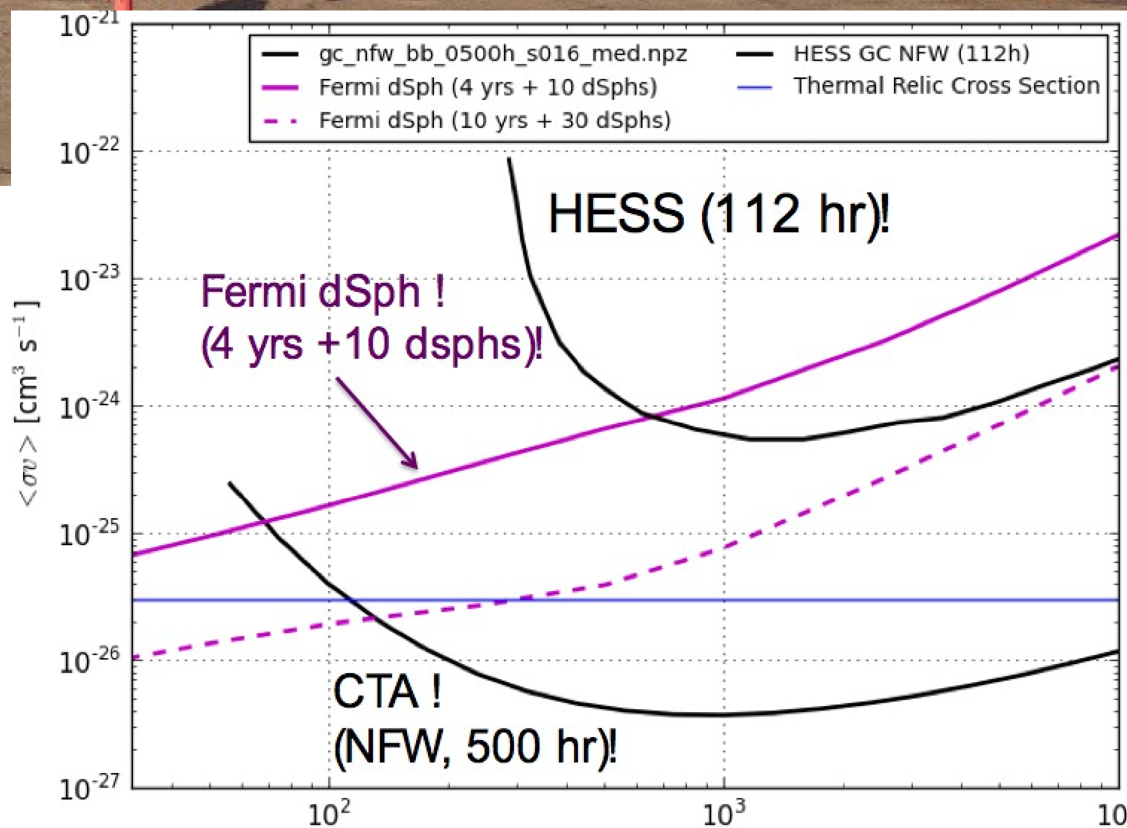
[First pointed out in
Cohen, Lisanti, Pierce, Slatyer (2013);
Fan, Reece (2013); Hryczuk *et al.* (2014)]

CTA – New guy in DM hunt race

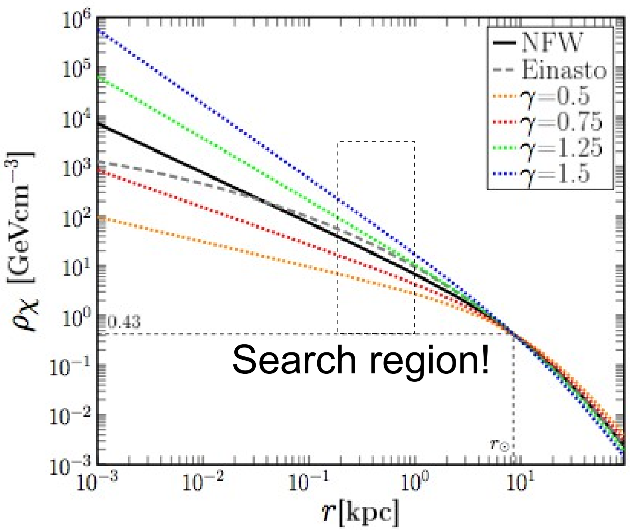
http://www.cta-observatory.org/

* **ground-based gamma-ray telescope**
* **Arrays in southern and northern hemisphere for full-sky coverage**
* **Energy range: tens of GeV to >100 TeV**
* **Sensitivity: more than an order of mag improvement in 100 GeV – 10 TeV**





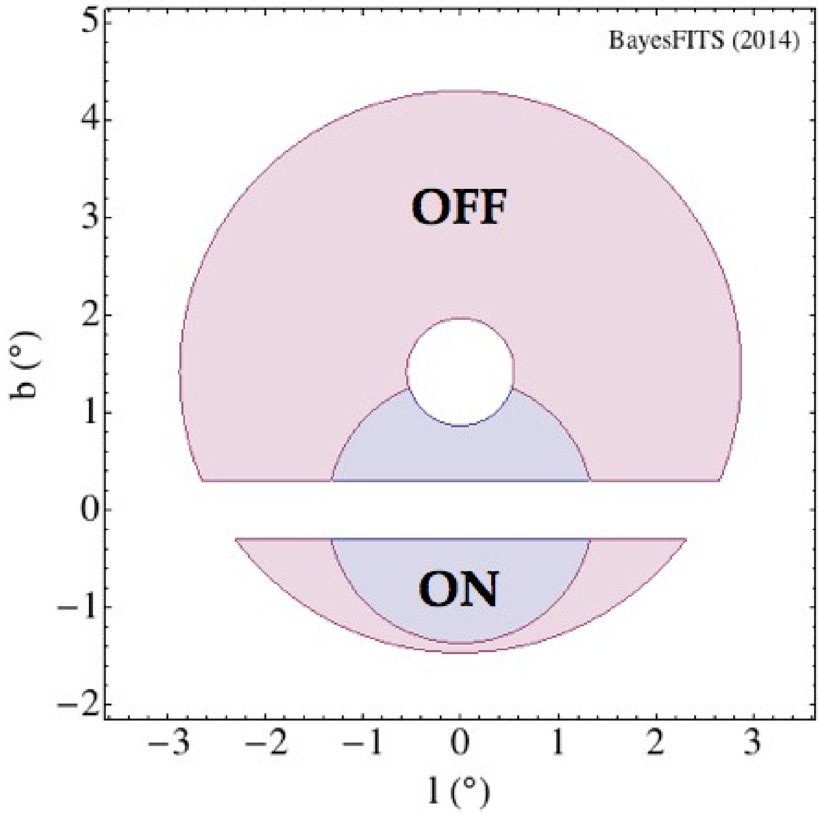
Galactic Center DM Halo



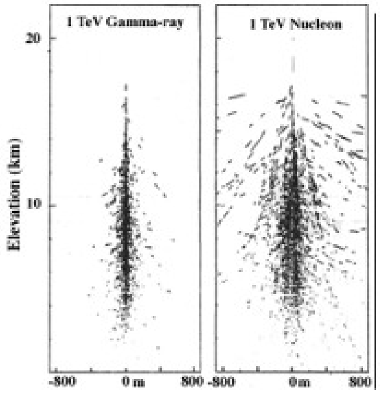
diffuse gamma radiation from WIMP pair annihilation

The observational setup

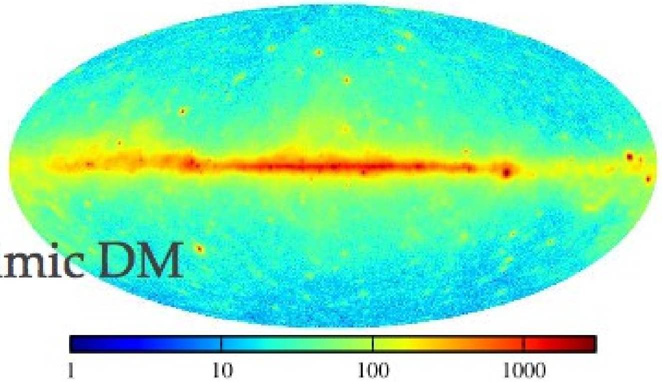
- Mask galactic plane to reduce backgrounds
- OFF region rich in background
- ON region rich in signal
- Integrate over entire energy range or split into energy bins for spectral information.



The backgrounds



1. Cosmic rays
   - Isotropic
   - Can discriminate based on shower
   - Estimated by MC from collaboration
2. Diffuse gamma-rays
   - Measured by FERMI-LAT below 100 GeV
   - Need to extrapolate to higher energies
   - Larger in ON region that OFF region! Can mimic DM signal DGE background: Silverwood et al. arxiv:1408.4131



The signal

$$\frac{d\Phi}{dE} = \underbrace{\frac{\sigma v}{8\pi m_\chi^2} \frac{dN_\gamma}{dE}}_{\Phi_{PP}} \underbrace{\int_{\Delta\Omega} \int_{l.o.s} \rho^2 \left[r(\theta)\right] dr(\theta) d\Omega}_{J}$$

Particle Physics Factor
Parameterises DM properties
Depends on annihilation final state

J factor
Parameterises DM halo and observation region
Astrophysical uncertainties
Halo model

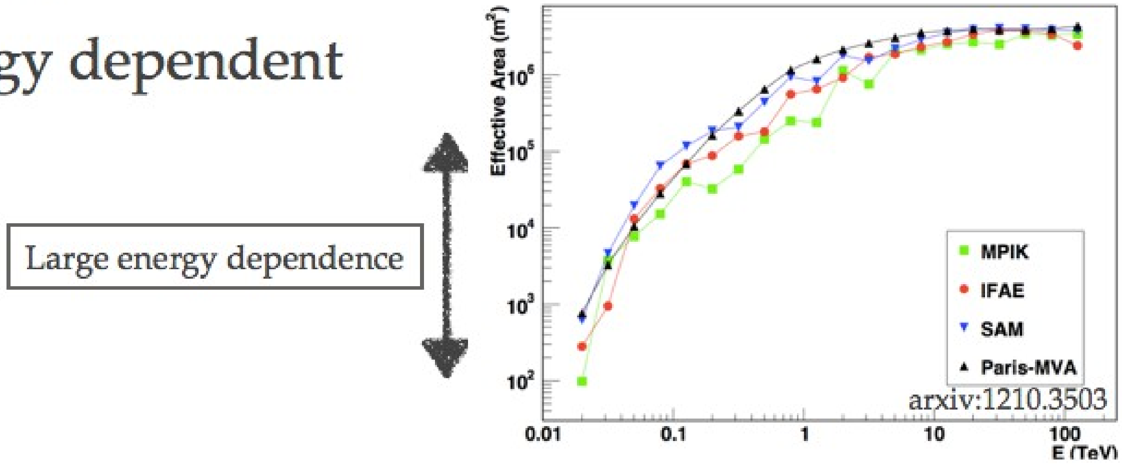
NFW: $$\rho(r) = \rho_s \frac{(r/r_s)^{-\alpha}}{(1 + r/r_s)^{-3+\alpha}}$$

Einasto: $$\rho(r) = \rho_s e^{-\frac{2}{\alpha}((\frac{r}{r_s})^\alpha - 1)}$$

The observed signal

$$N_i^{\mathrm{ann}} = t_{\mathrm{obs}}.J.\frac{\sigma v}{8\pi m_\chi^2}\int_{\Delta E_i} dE\left(\frac{1}{\sqrt{2\pi\delta(E)^2}}\int_{26\mathrm{GeV}}^{m_\chi} d\bar{E}\frac{dN_\gamma(\bar{E})}{d\bar{E}}A_{\mathrm{eff}}(\bar{E})e^{-\frac{(E-\bar{E})^2}{2\delta(E)^2}}\right)$$

- Separate into energy bins
- Marginalise over energy resolution
- Effective area is energy dependent

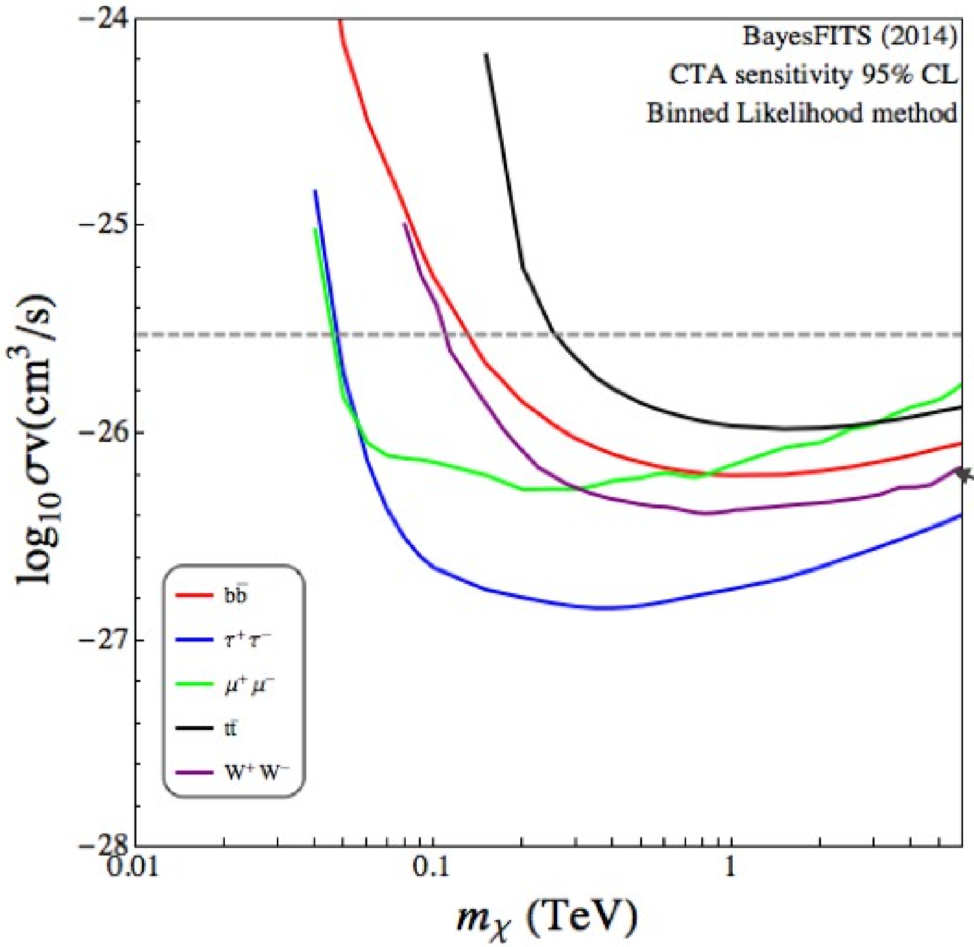


Binned likelihood

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

- Likelihood function for poisson distribution
- Uses full spectral information
- Can be adapted to a full morphological analysis

Results: Projections for CTA

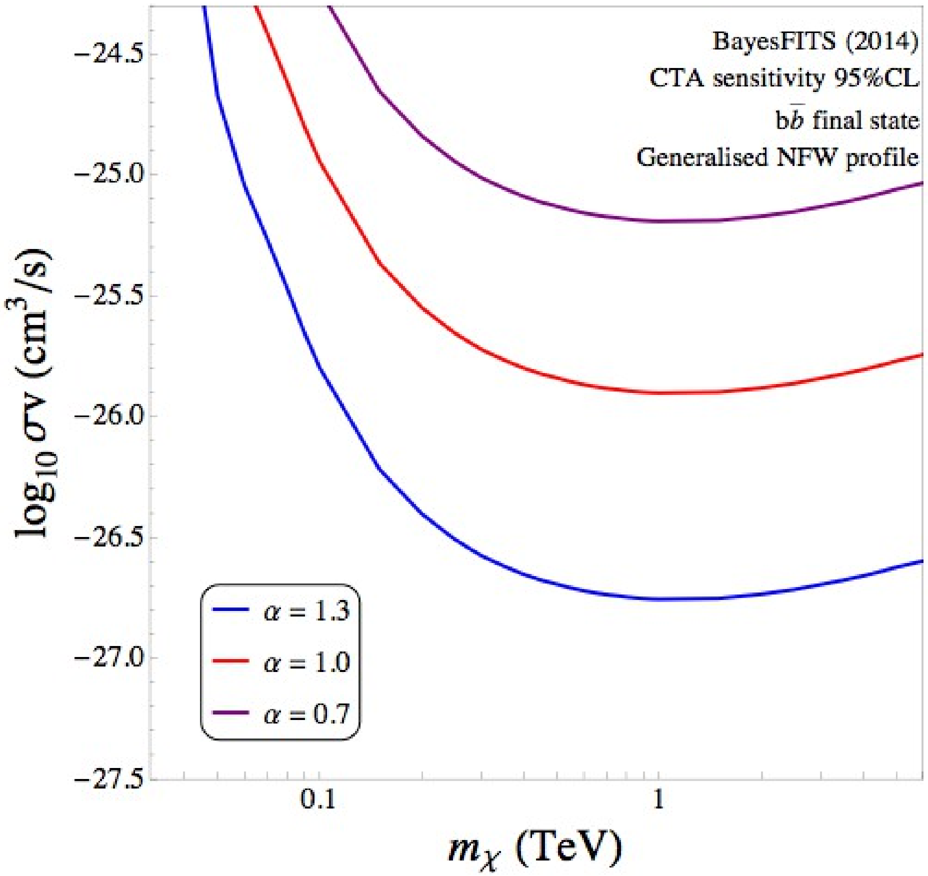


Below "thermal relic" level for many final states

Difference between bb and WW mostly EW corrections

Excellent sensitivity to TeV scale DM candidates

Results: Projections for CTA



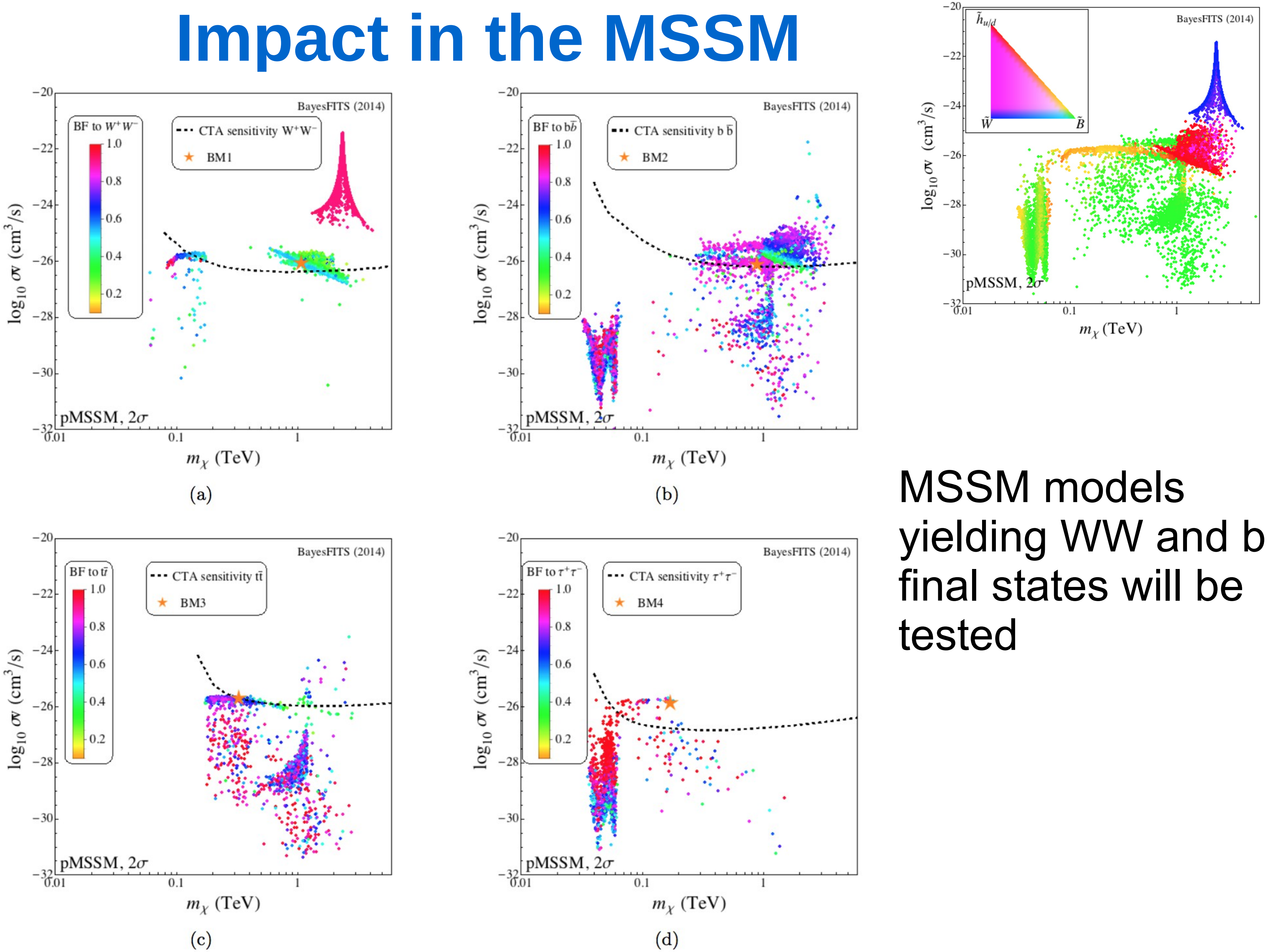
NFW profile:

$$\rho(r) = \rho_s \frac{(r/r_s)^{-\alpha}}{(1 + r/r_s)^{-3+\alpha}}$$

Uncertainty due to parameterisation of halo

ON/OFF or morphological analysis allows halo profile to be constrained if a signal is seen

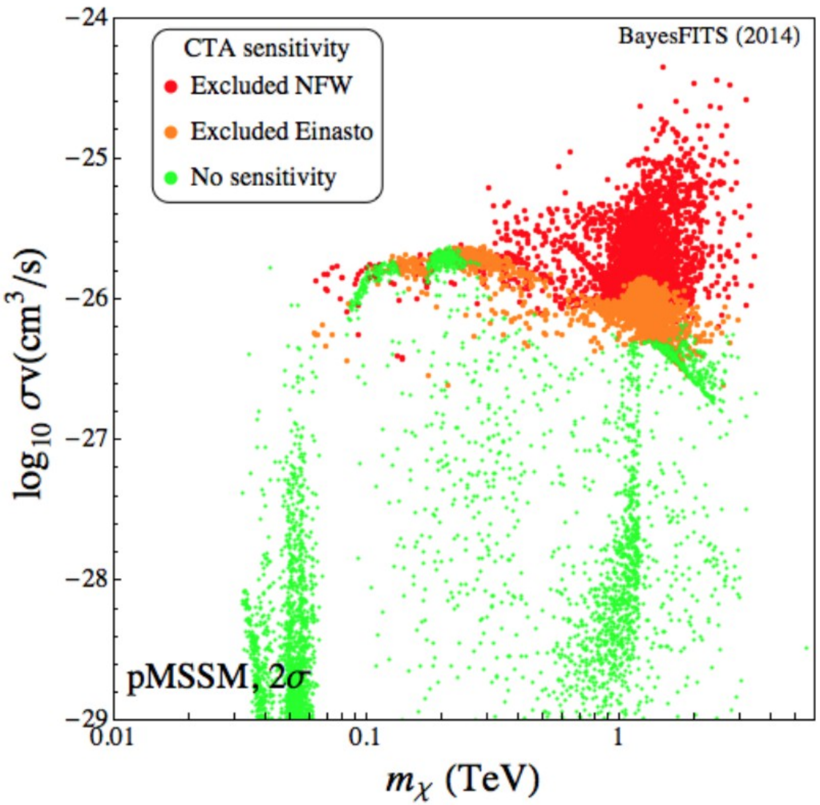
Impact in the MSSM

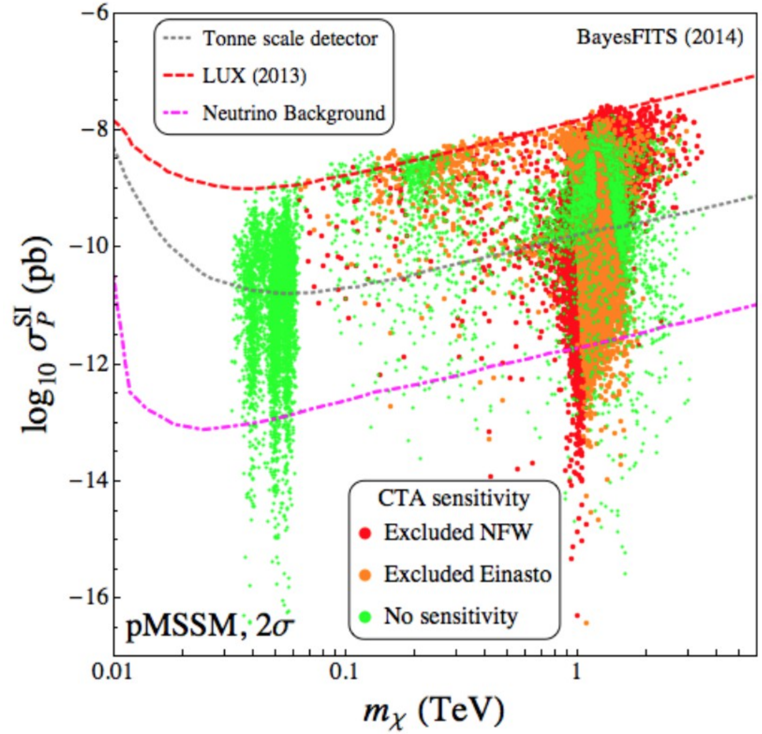


MSSM models yielding WW and bb* final states will be tested

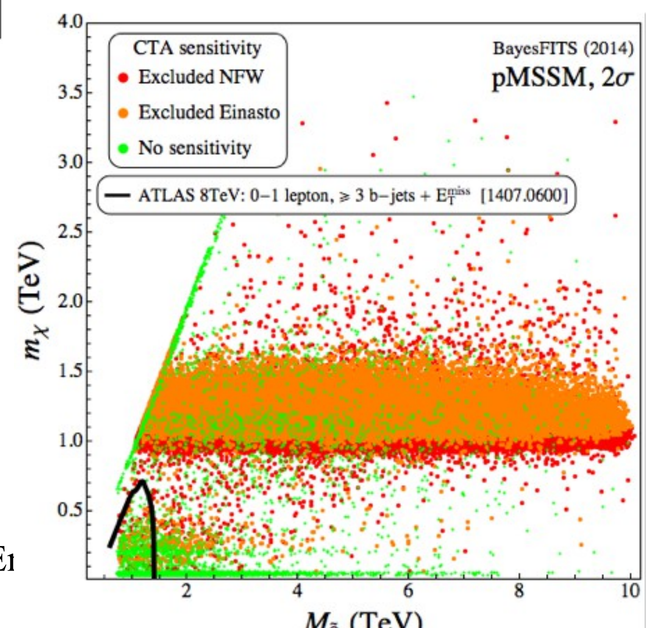
Impact in the MSSM

Orthogonal and complementary to direct detection and the LHC





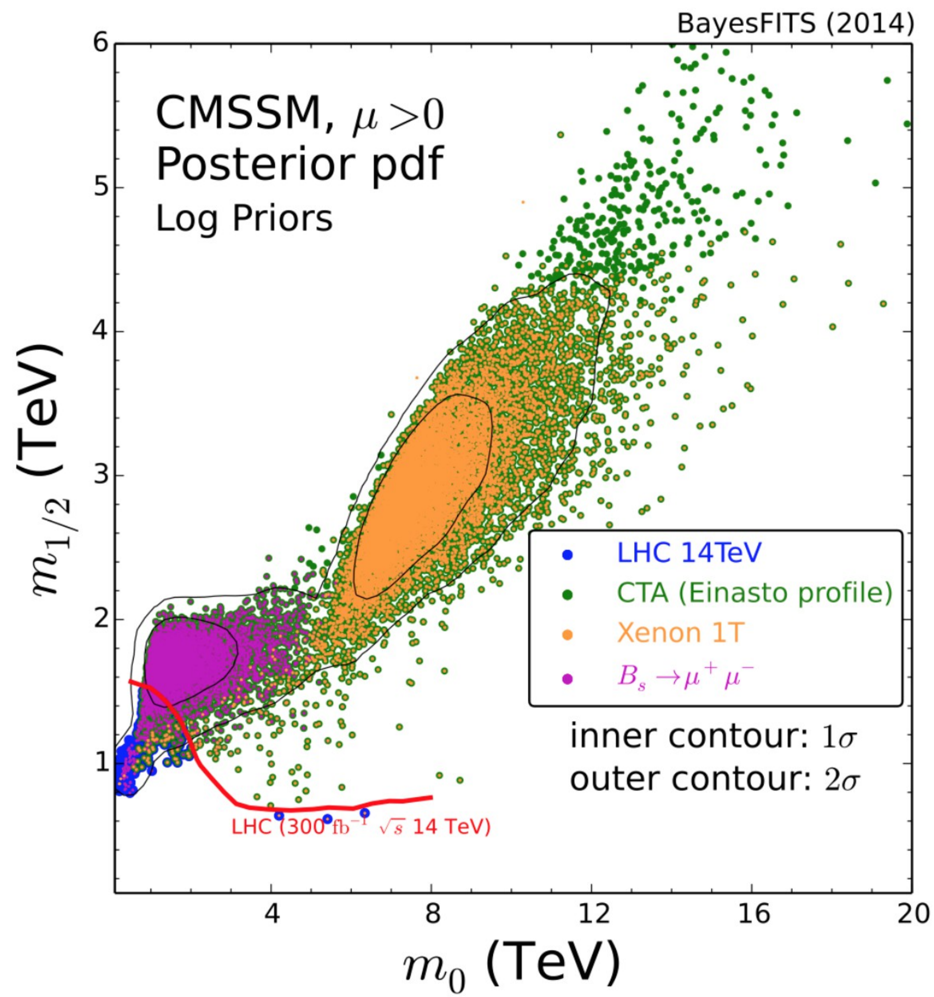
Under Einasto and NFW profile all (or significant part) of higgsino region in reach with 500 hours.



No problem w/ neutrino floor

Probes high mass neutralinos unreachable by LHC

The special case of CMSSM / mSUGRA



CTA key to covering entire parameter space of the CMSSM

To take home:

- LHC + Higgs point to multi-TeV SUSY:

  heavier dark matter candidates emerge as likely
- CTA will improve limits on heavy annihilating dark matter
- CTA will provide complementarity to direct detection experiments and the LHC
- CTA can close the gaps on the parameter space of the CMSSM