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Interpretation of Dark Matter particles with LHC and direct detection data

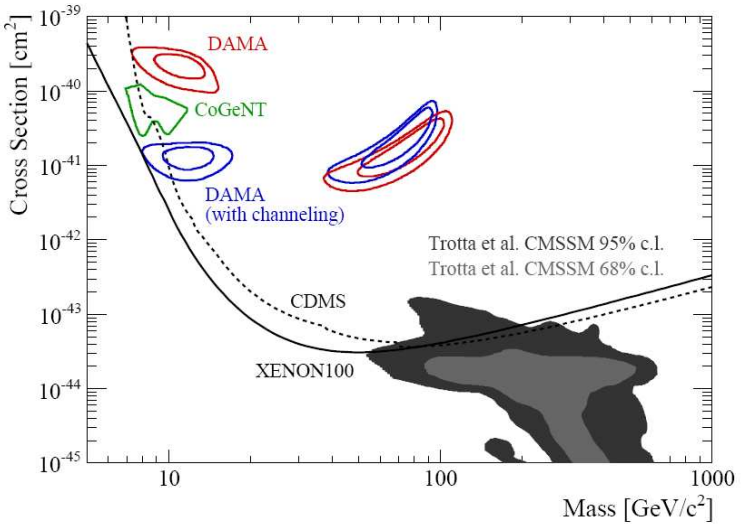
based on Bertone, Cerdeño, Fornasa, Ruiz de Austri and Trotta, arXiv:1005.4280

Direct Detection of DM

- DM particles scattering off nuclei of detectors hidden underground
- very few detected events
- upper limits

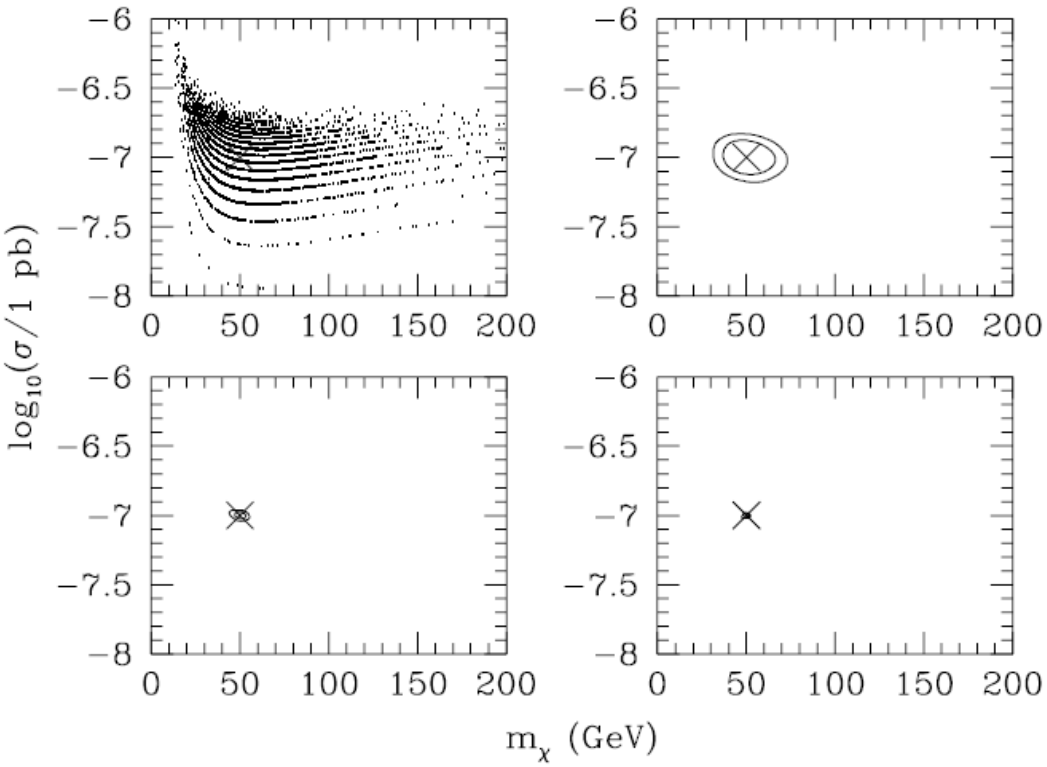
$$\frac{dR_\chi}{dE} = c_1 R_0 e^{-E/(E_0 c_2)} F^2(E)$$

$$R_0 = \frac{\sigma^{\rm SI}_{\chi-{\rm p}} \rho_\chi A^2 c^2 (m_\chi + m_p)^2}{\sqrt{\pi} m^3 m_p^2 v_0} \qquad E_0 = \frac{2 m_\chi^2 v_0^2 A m_p}{(m_\chi + A m_p)^2 c^2}$$



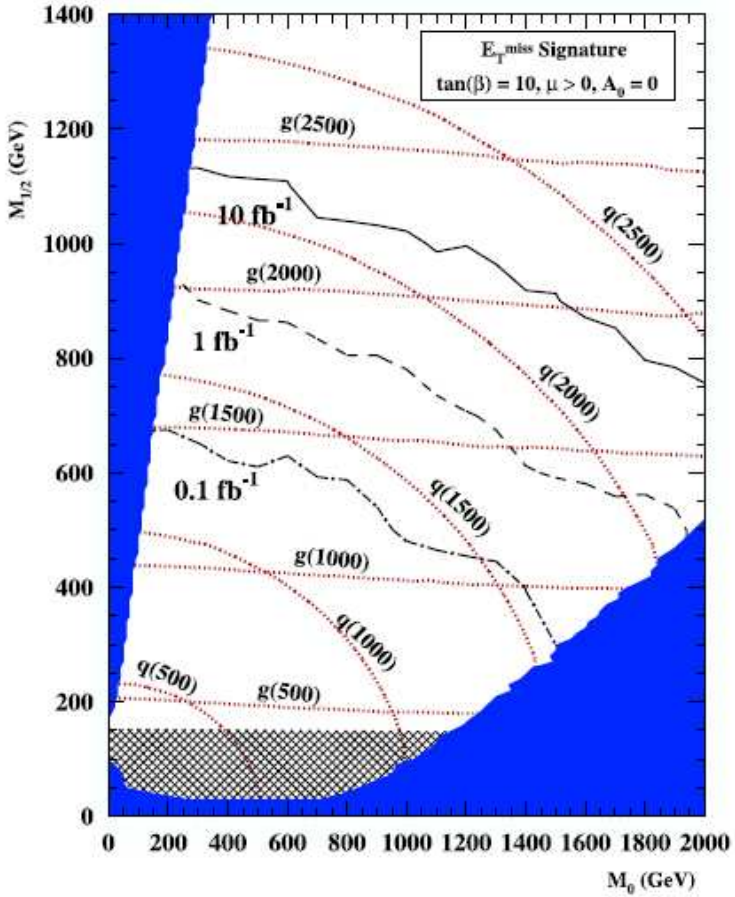
Reconstructing DM properties from DD

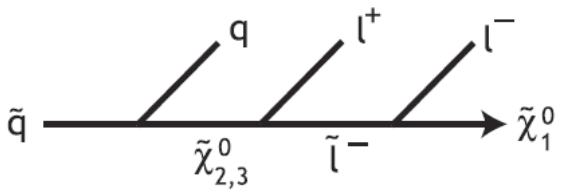
- a certain number of events (λ,{E_i}) are assumed for a future DD detector
- DM mass and cross section are derived with maximum likelihood technique
- reconstruction is better for the cross section than for the mass

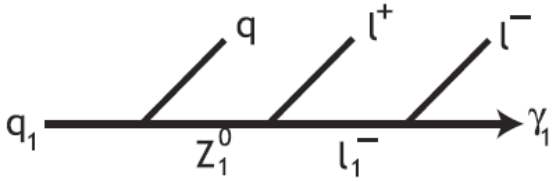


DM at colliders

- possibility of accessing an unexplored range of energy
- and detecting new particles
- difficulty in distinguishing among different models for new physics

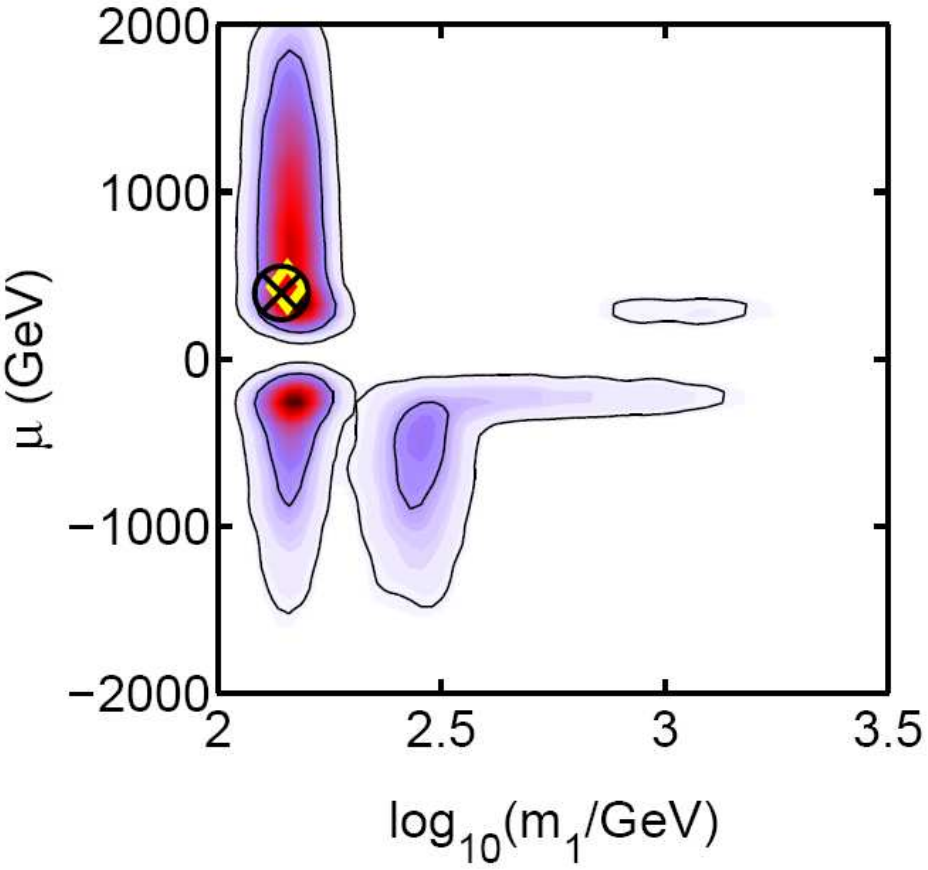






Internal degeneracies

- even if the model is correctly determined, collider data may not be enough to completely determine all the parameters of model
- possibility of residual degeneracies



Bayesian statistics

- "clever" way of scanning the parameter space ***m*** (24 dimensions)
- a certain amount of data is assumed ***d***
- used to compute a likelihood function $p(\mathbf{d}|\xi(\mathbf{m}))$ that updates our knowledge about the particular point encoded in the prior $\pi(\mathbf{m})$

$$p(\mathbf{m}|\mathbf{d}) = \frac{p(\mathbf{d}|\xi(\mathbf{m}))\pi(\mathbf{m})}{p(\mathbf{d})}$$

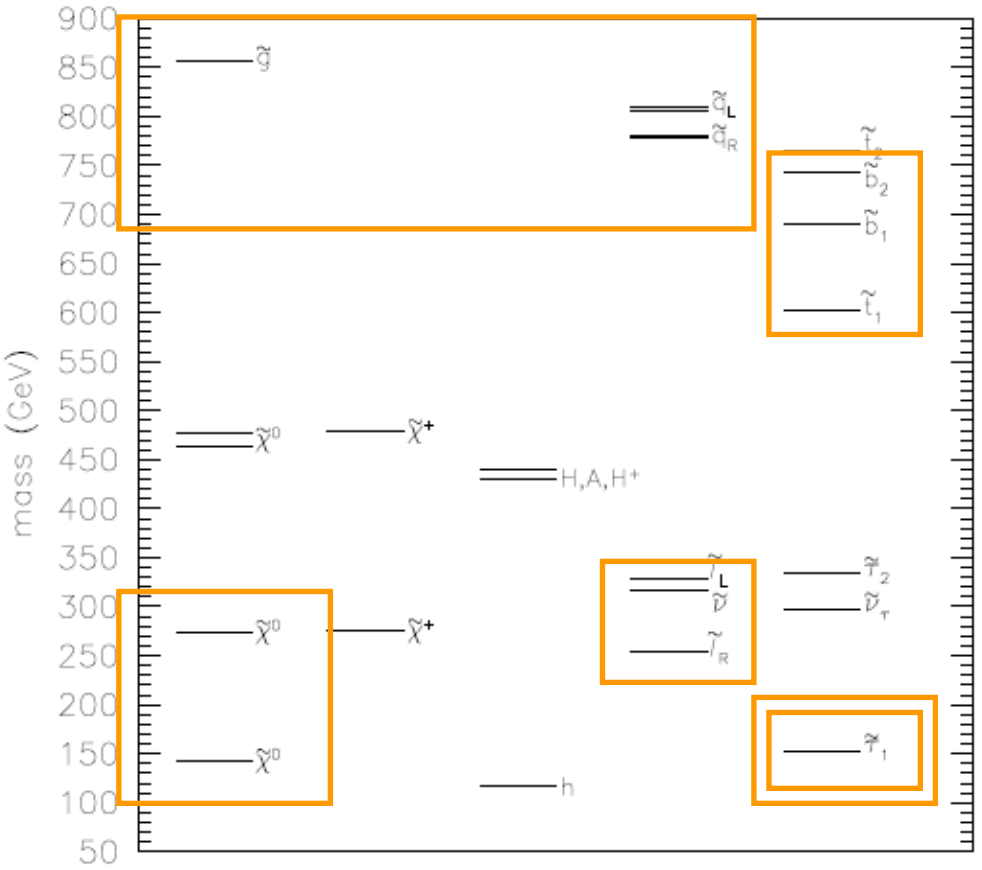
- MultiNest algorithm implemented in SuperBayeS has been used

SuperBayeS
Supersymmetry Parameters Extraction Routines for Bayesian Statistics

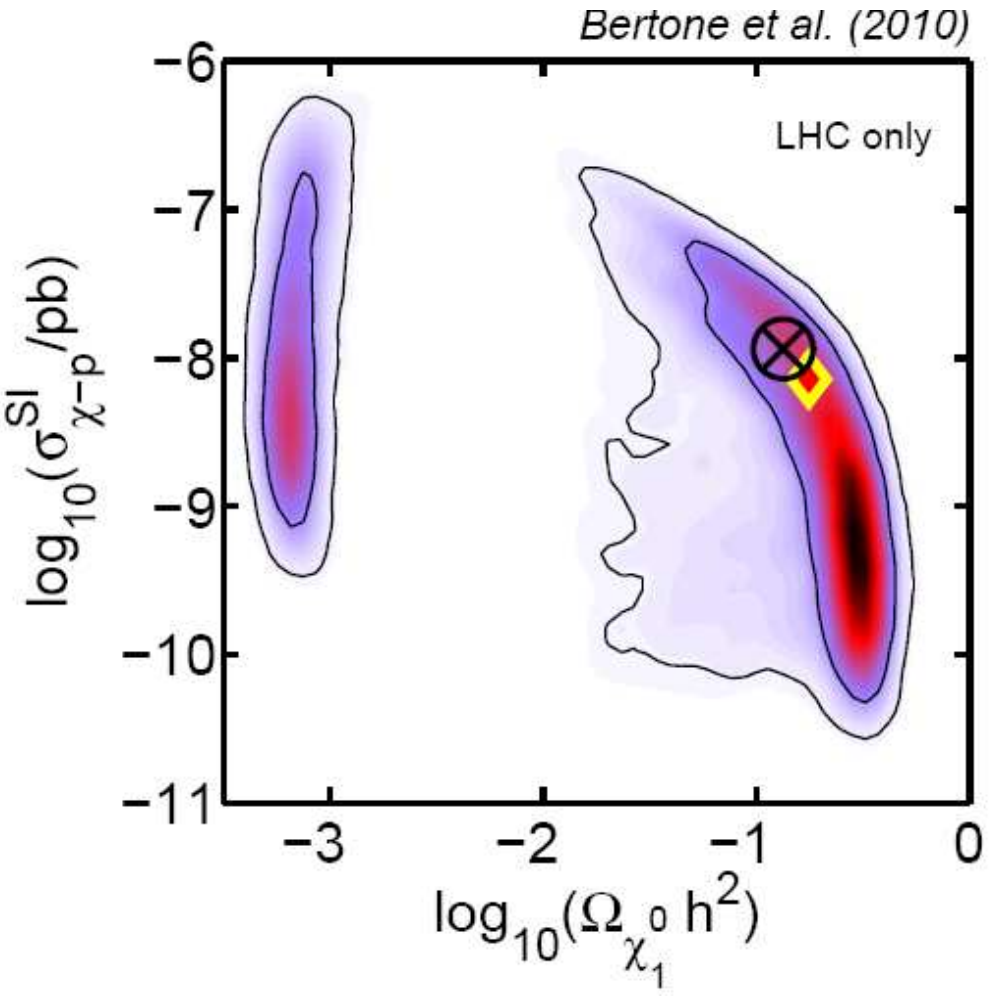
http://superbayes.org

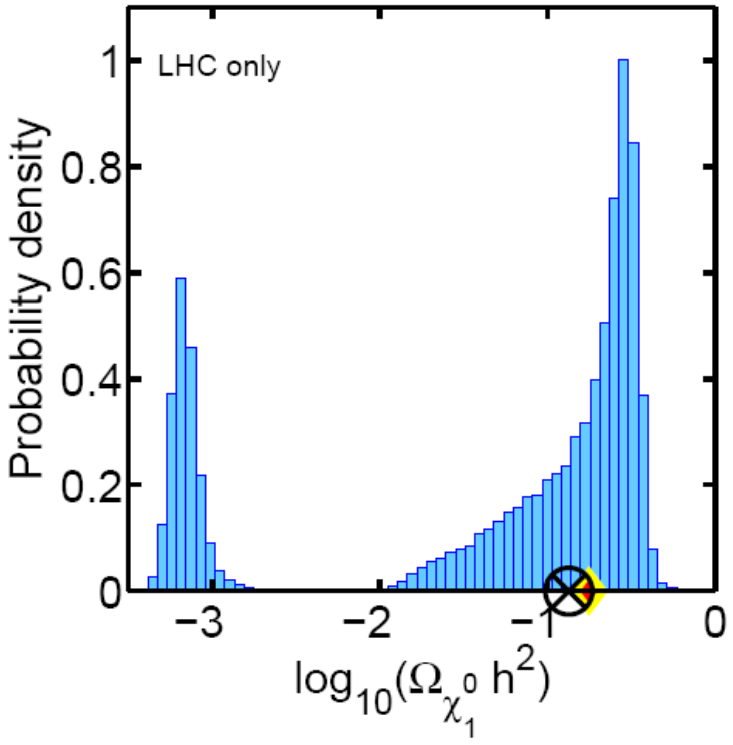
Reference point (Nature)

- SUSY model in the co-annihilation region
- LHC data includes first and second neutralinos
- and a measurement of the mass difference with the lightest stau



LHC only


Bertone et al. (2010)
LHC only
$\log_{10}(\sigma^{SI}_{\chi-p}/pb)$
$\log_{10}(\Omega_{\chi_1^0} h^2)$
−6
−7
−8
−9
−10
−11
−3
−2
−1
0

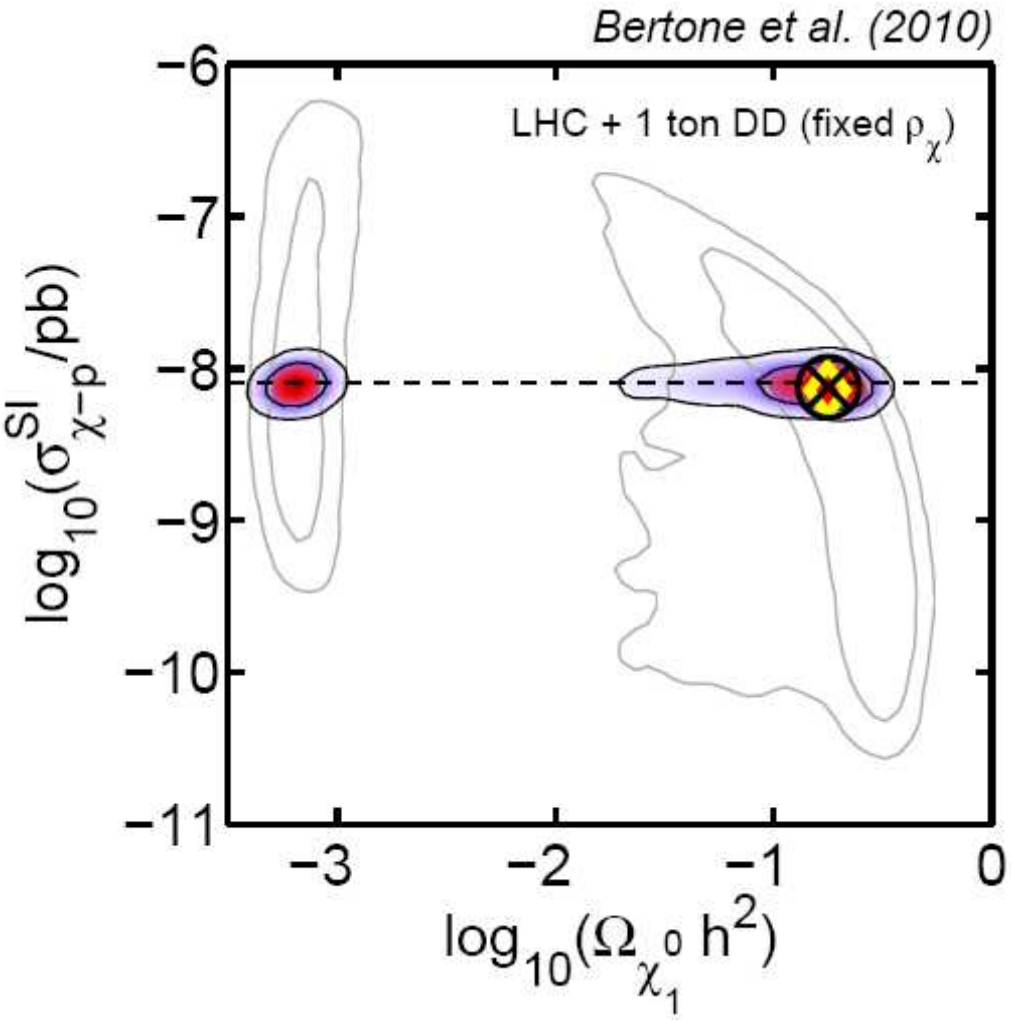

LHC only
Probability density
$\log_{10}(\Omega_{\chi_1^0} h^2)$
0
0.2
0.4
0.6
0.8
1
−3
−2
−1
0

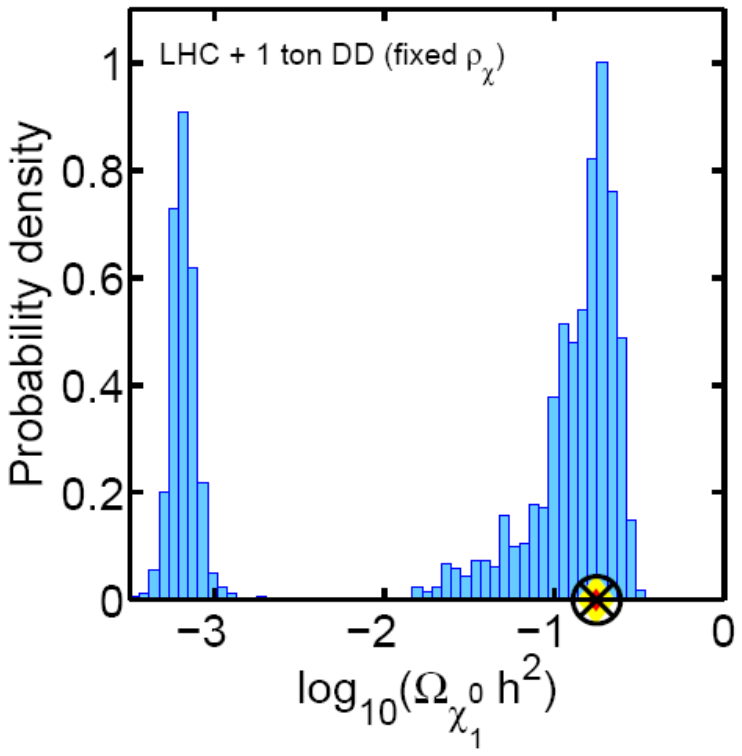
Including direct detection

- for all the scanned models compute the predicted number of events and include this observable in the likelihood
- reference value for the local DM density ρ_{DM} is 0.385 GeV cm^{-3} (Catena & Ullio)
- local DM density can be fixed to the reference value $\rho_\chi = \rho_{DM}$
- or scale with the relic density

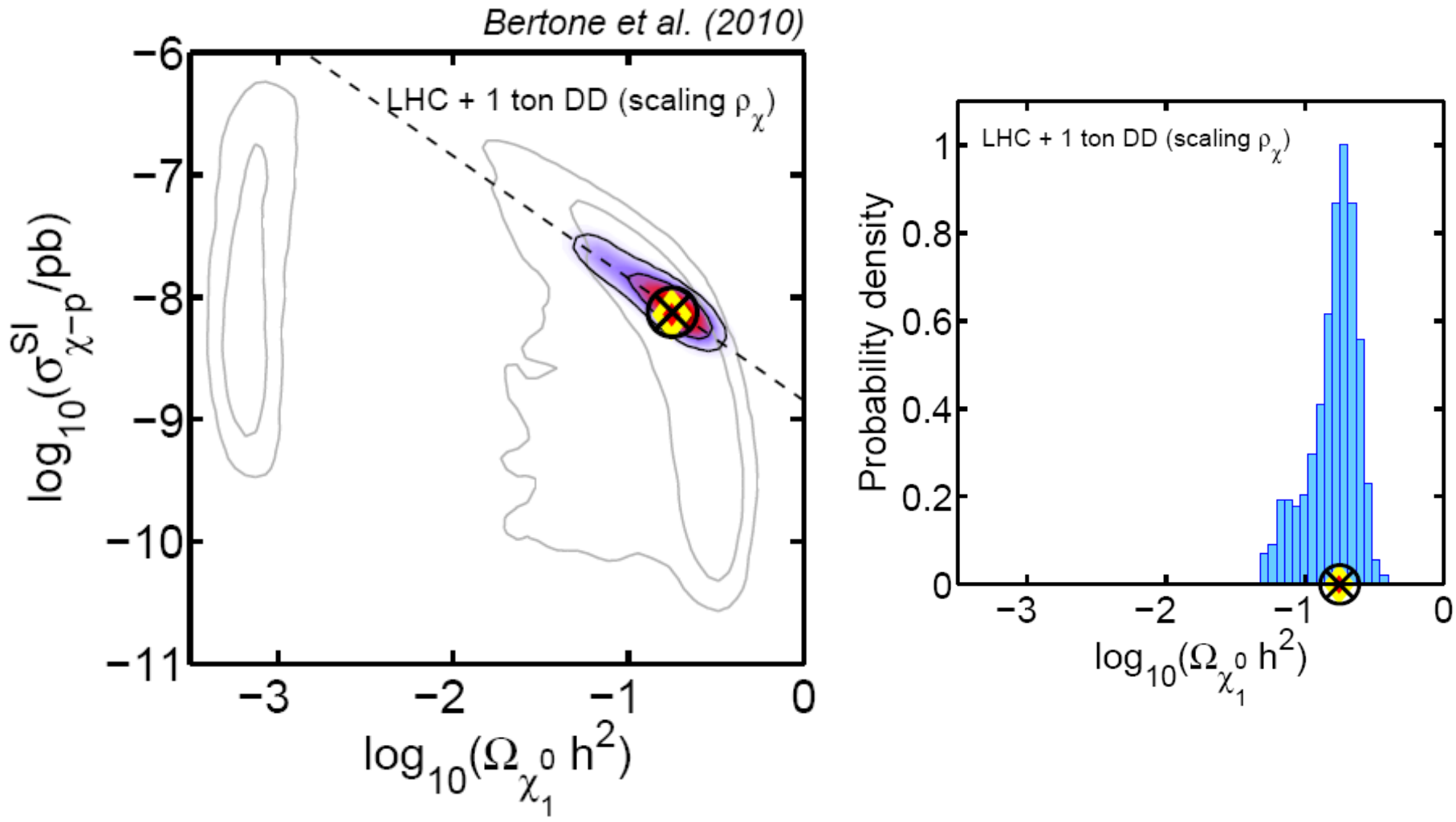
$$\frac{\rho_{\tilde{\chi}_1^0}}{\rho_{\mathrm{DM}}} = \frac{\Omega_{\tilde{\chi}_1^0}}{\Omega_{\mathrm{DM}}}$$

LHC and direct detection (fixed local density)





LHC and direct detection (scaling local density)



Conclusions

- study the reconstruction capability of direct detection and colliders

- direct detection may be not able to constrain much the DM mass

- colliders may be affected by internal degeneracies

- under a particular assumption on the local density the combination of the two breaks the degeneracies and allows for an interpretation of the neutralino as the DM particle

- LHC may be used as a DM experiment

Nature of neutralino

- parameters m_1, m_2 and μ mainly determine the nature of neutralinos and charginos
- the only information available is the mass of the first and the second neutralinos
- different scenarios are possible