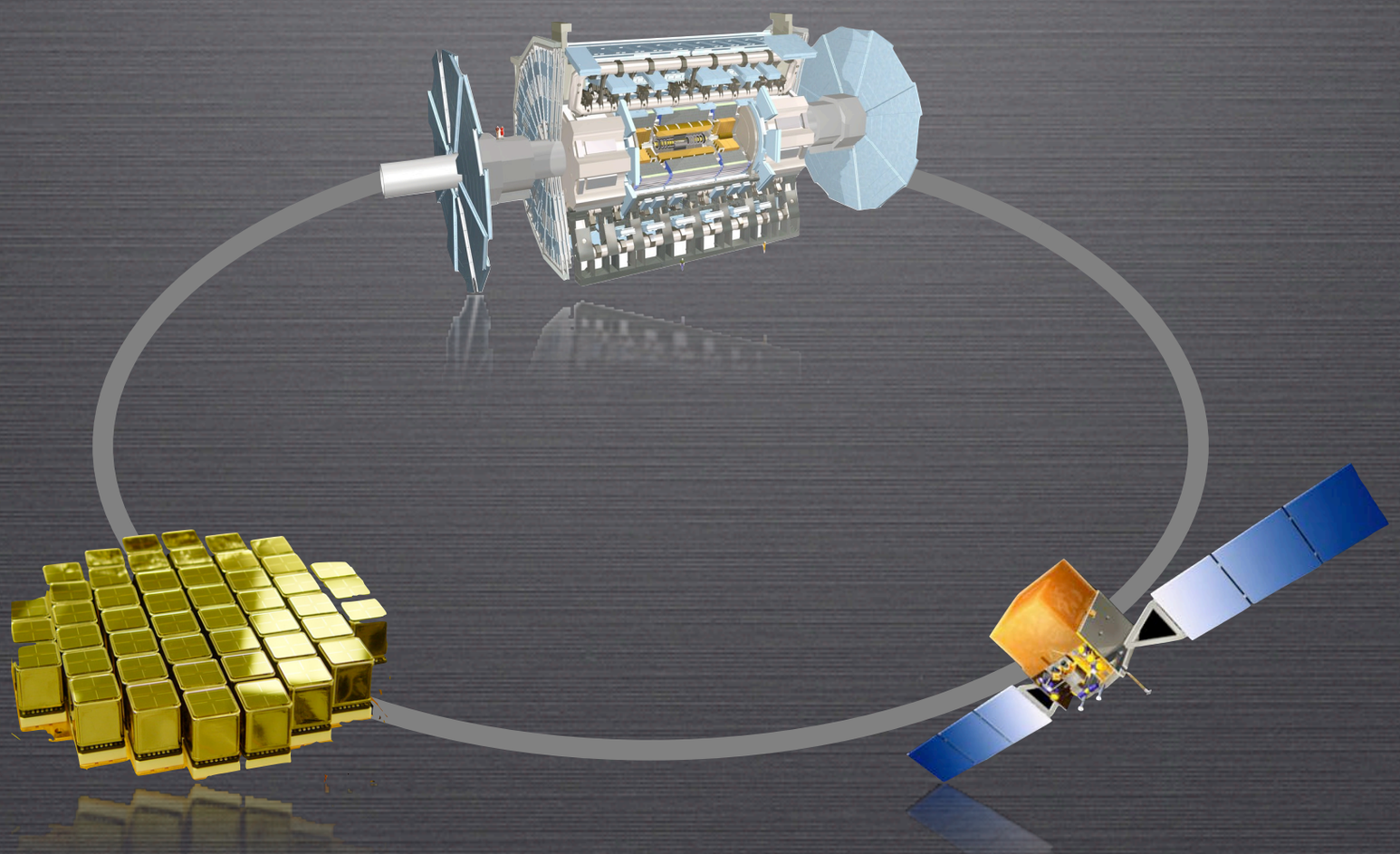
Identification of Dark Matter Candidates

Gianfranco Bertone



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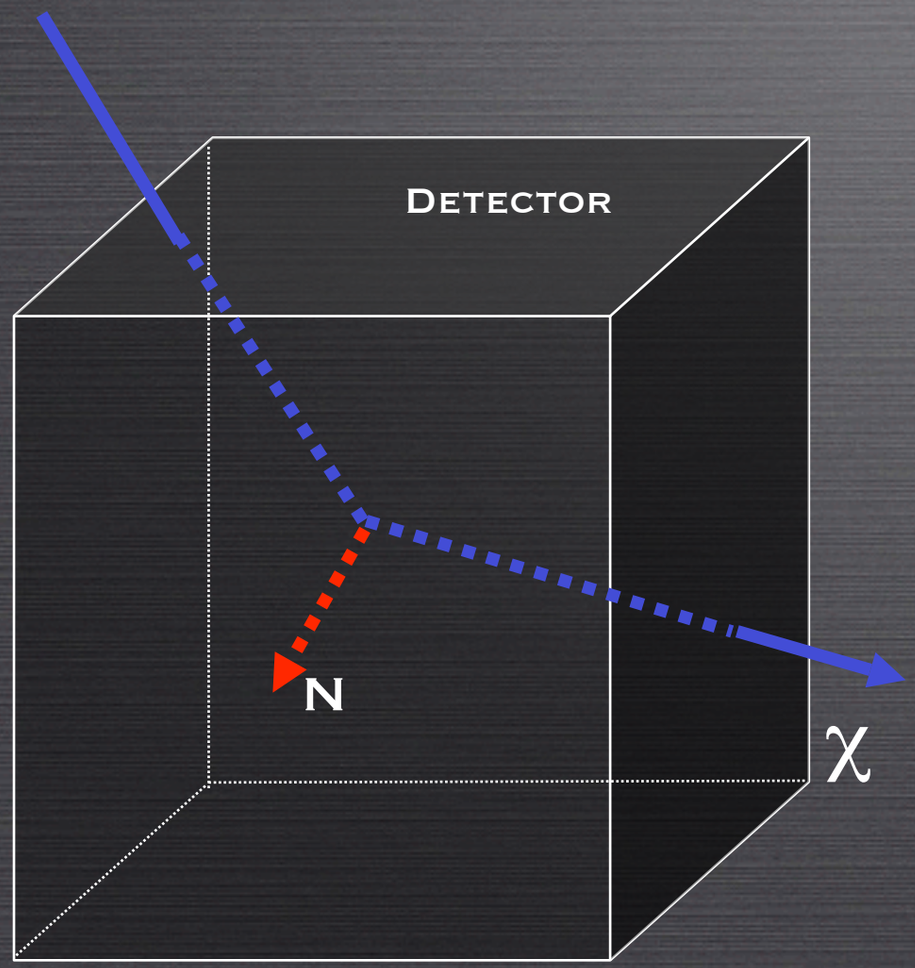
Direct Detection

Basics

DM Scatters off nuclei in the detector



Differential Event Rate

$$\frac{\mathrm{d}R}{\mathrm{d}E}(E) = \frac{\sigma_{\mathrm{p}}\rho_{\chi}}{2\mu_{\mathrm{p}\chi}^2 m_{\chi}} A^2 F^2(E) \langle \int_{v_{\mathrm{min}}}^{\infty} \frac{f^{\mathrm{E}}(v,t)}{v} \mathrm{d}v \rangle$$

Theoretical Uncertainties

Ellis, Olive & Savage 2008; Bottino et al. 2000; etc.

Uncertainties on f(v)

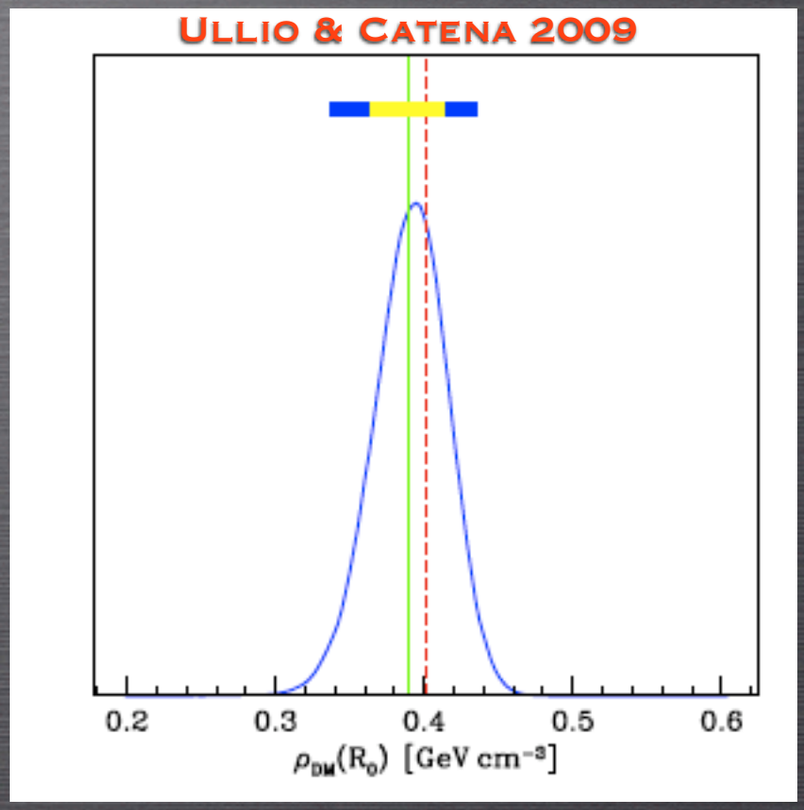
Ling et al. 2009; Widrow et al. 2000; Helmi et al 2002 (cfr. next talk!)

Direct Detection

Local Density

Dynamical Constraints

- Terminal Velocity of Gas Clouds
- Blue Horizontal-Branch (BHB) halo stars from the SDSS
- Estimates of Oort's constants
- Motion of stars perpendicular to the Galactic plane
- Velocity distribution of MW satellites



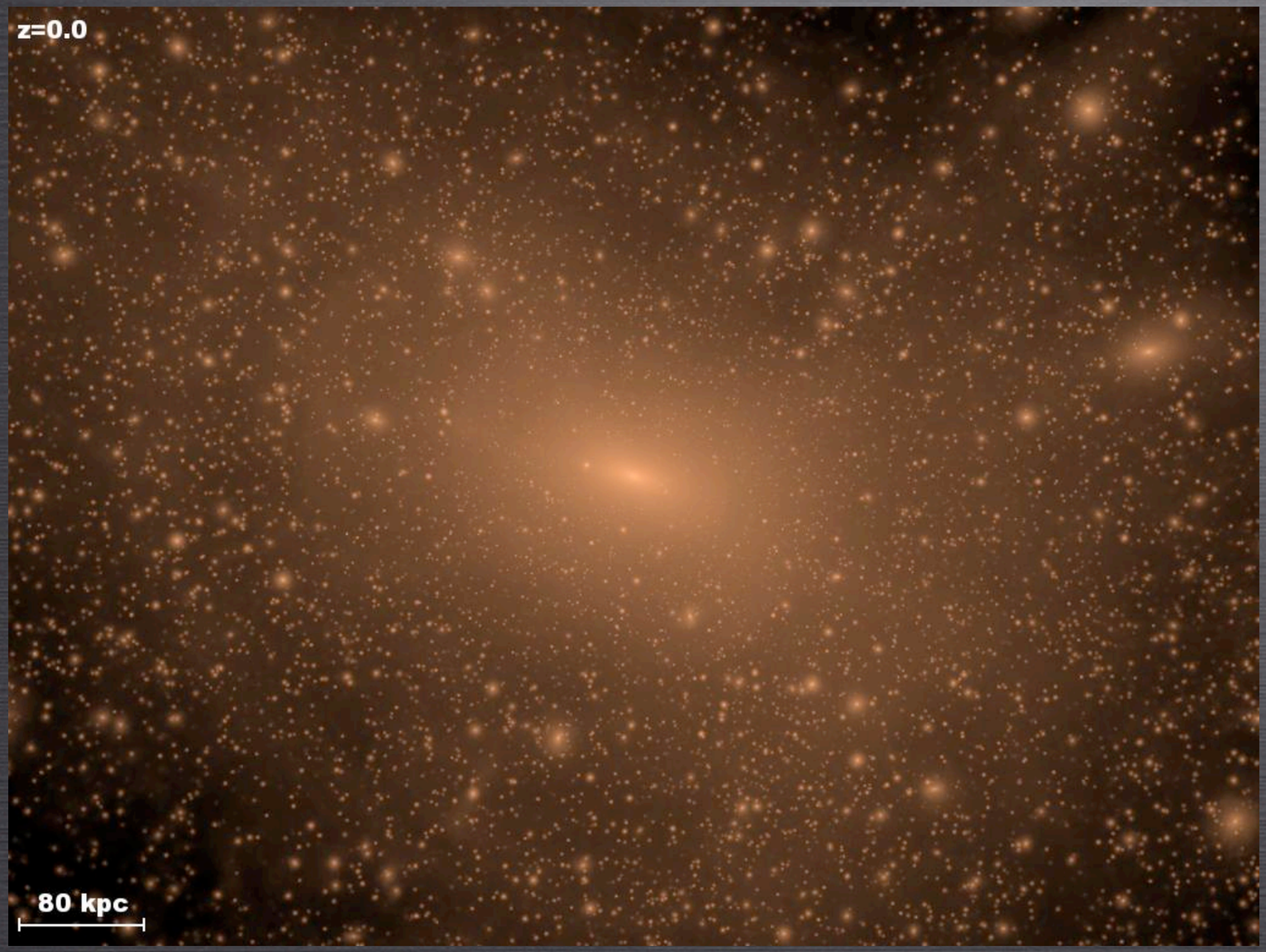
$$\rho_{DM}(R_0) = 0.389 \pm 0.025\,\mathrm{GeV\,cm^{-3}}$$

Constraints on M(<R) -> contraints on Q_X

See also Strigari and Trotta 2009; Weber and De Boer 2009; Salucci et al. 2010

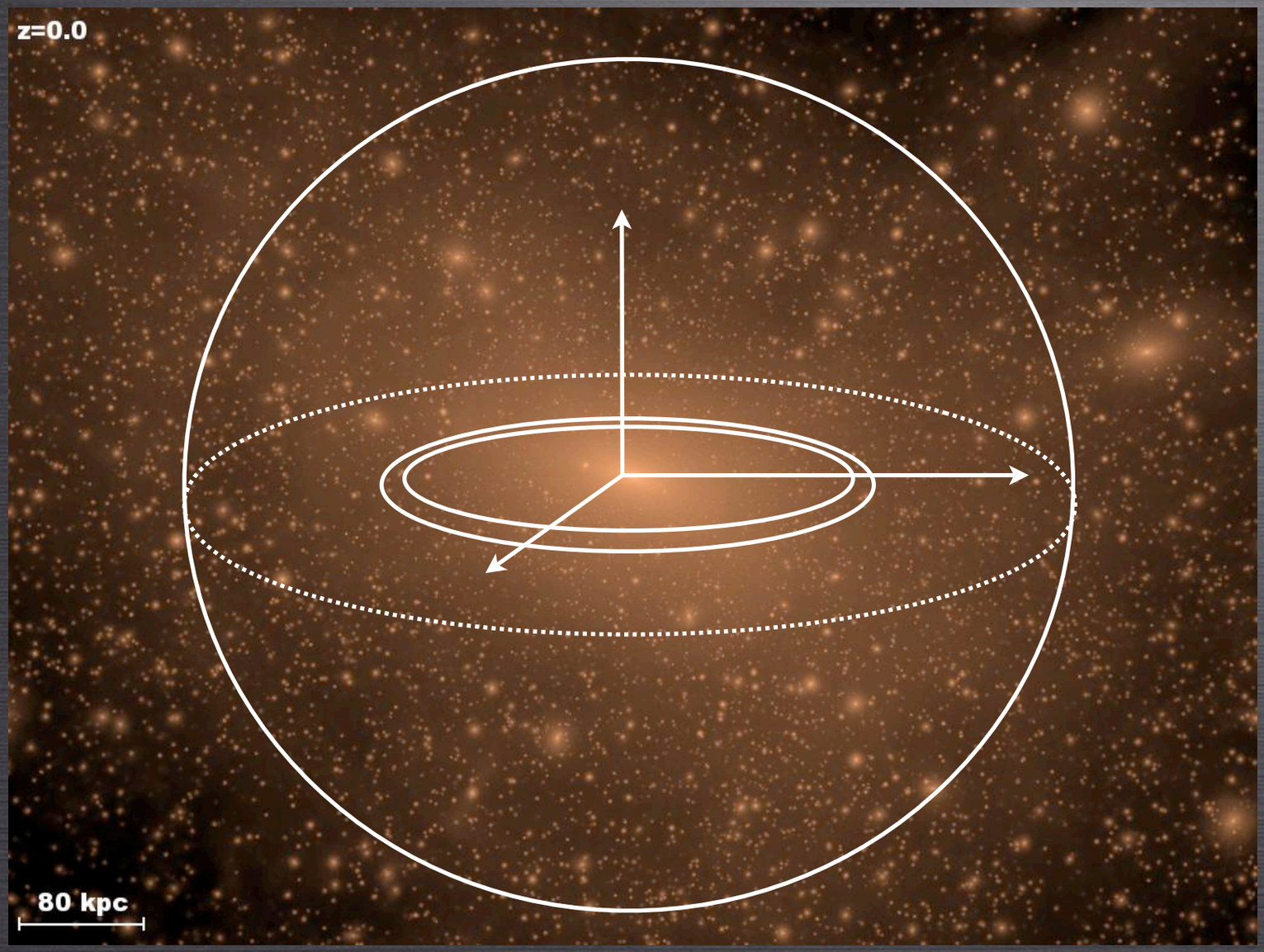
Triaxial Halos

Pato, GB, Agertz, Teyssier, Moore 2010



Triaxial Halos

Pato, GB, Agertz, Teyssier, Moore 2010

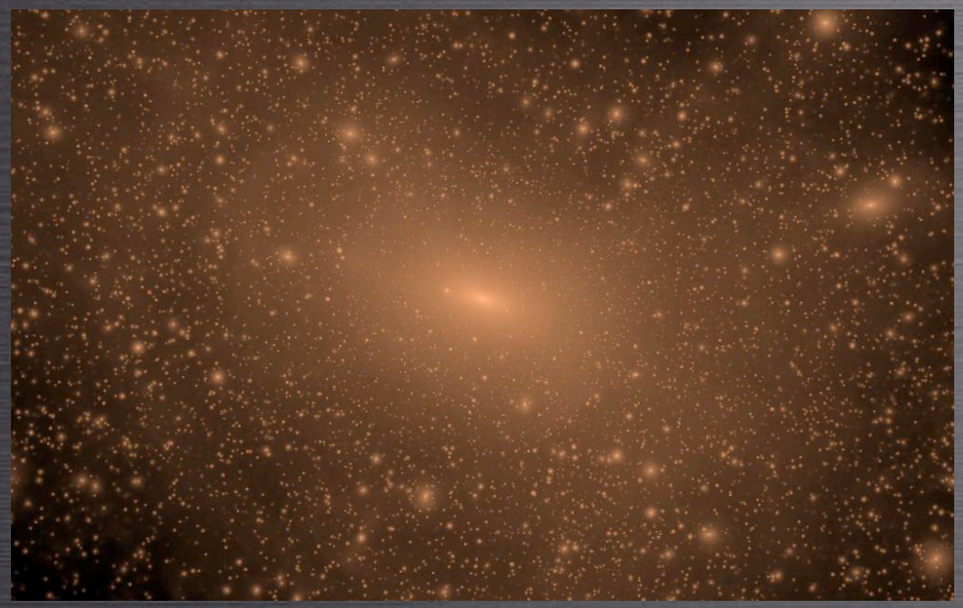


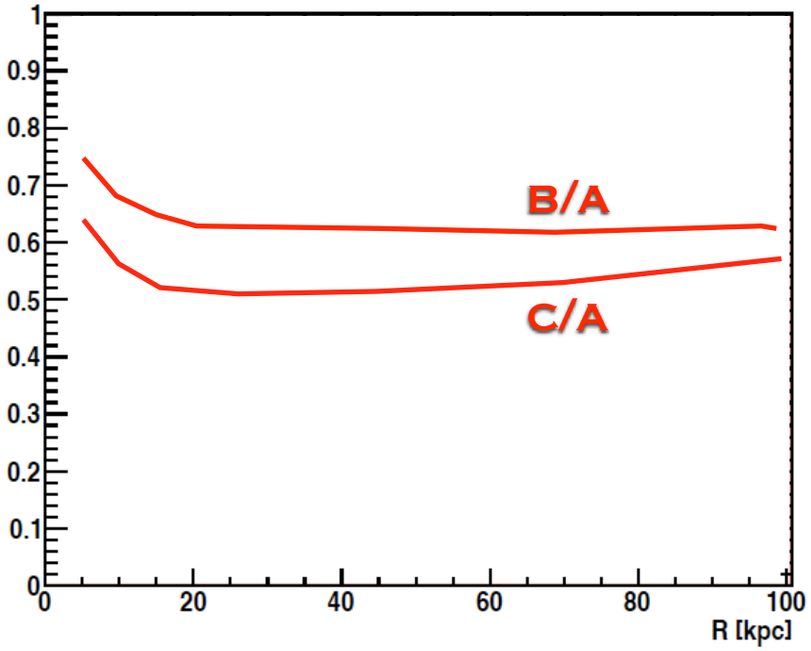
Moment of Inertia Tensor

$$I_{ij} = \frac{\sum_{k=1}^{N} m_k r_{i,k} r_{j,k}}{\sum_{k=1}^{N} m_k}.$$

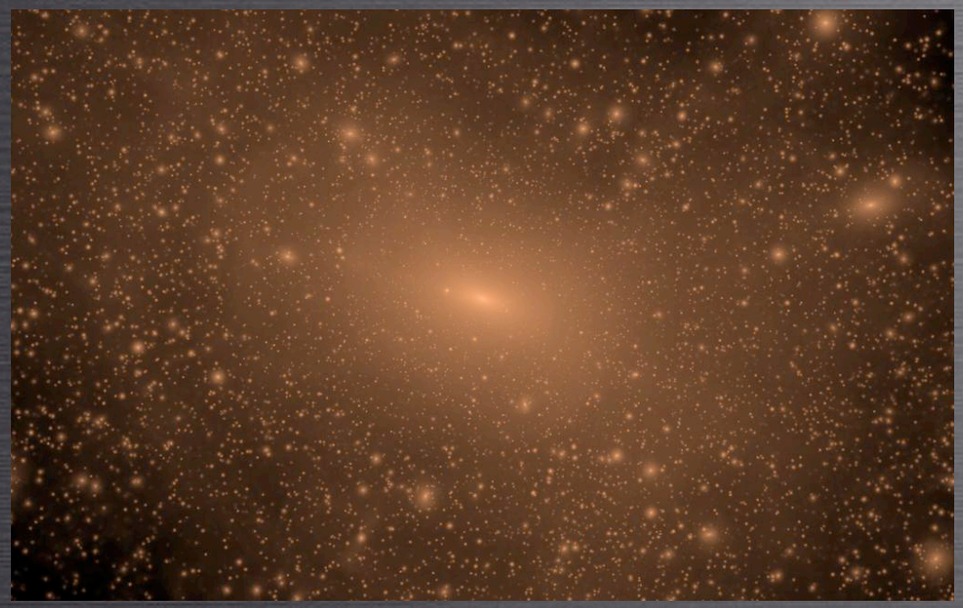
Rotation Axes
(a,b,c)

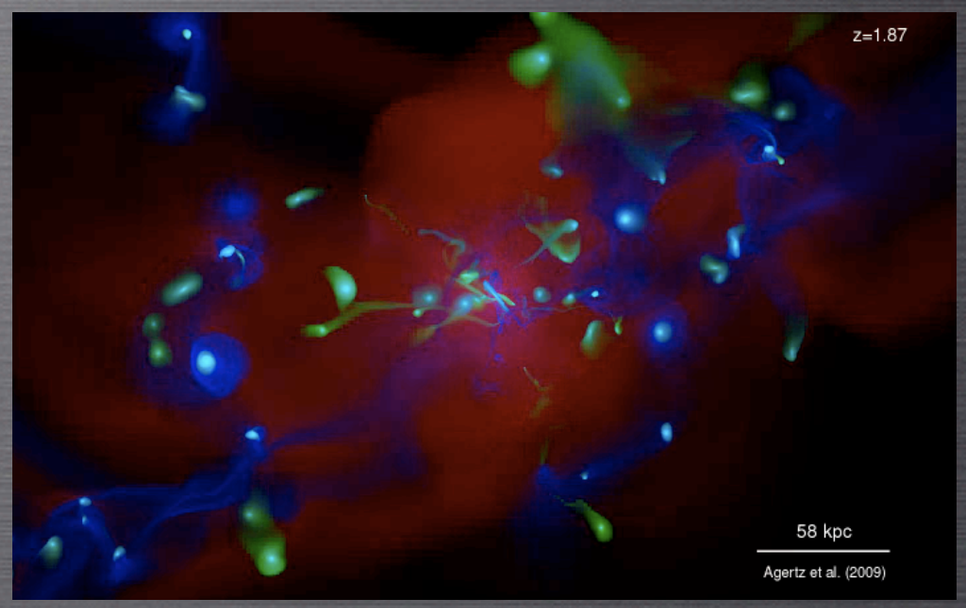
Triaxial Halos

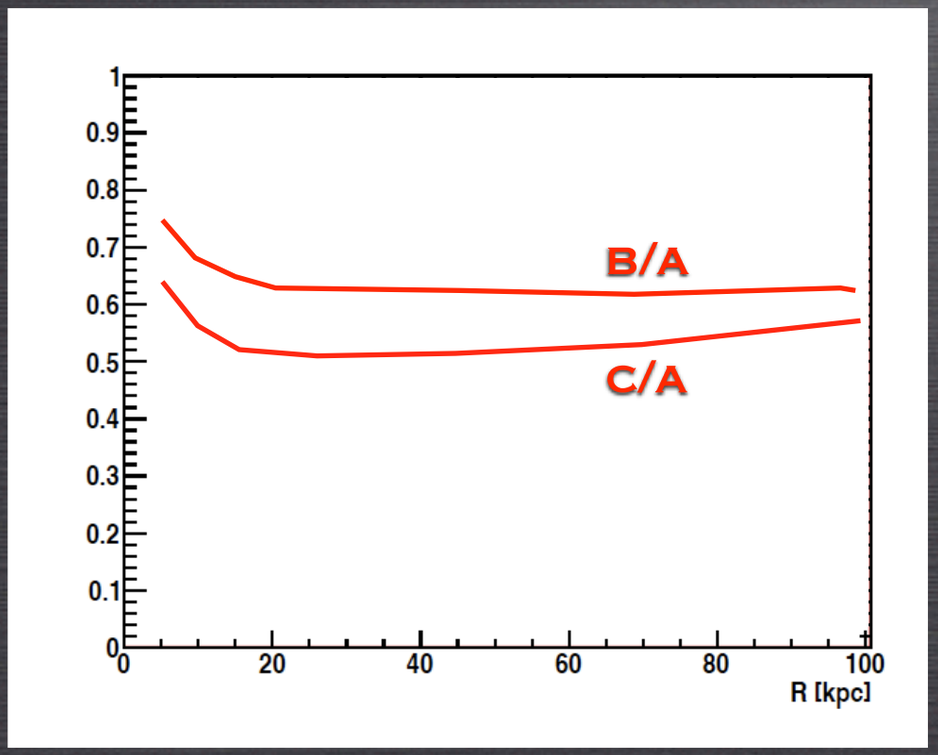


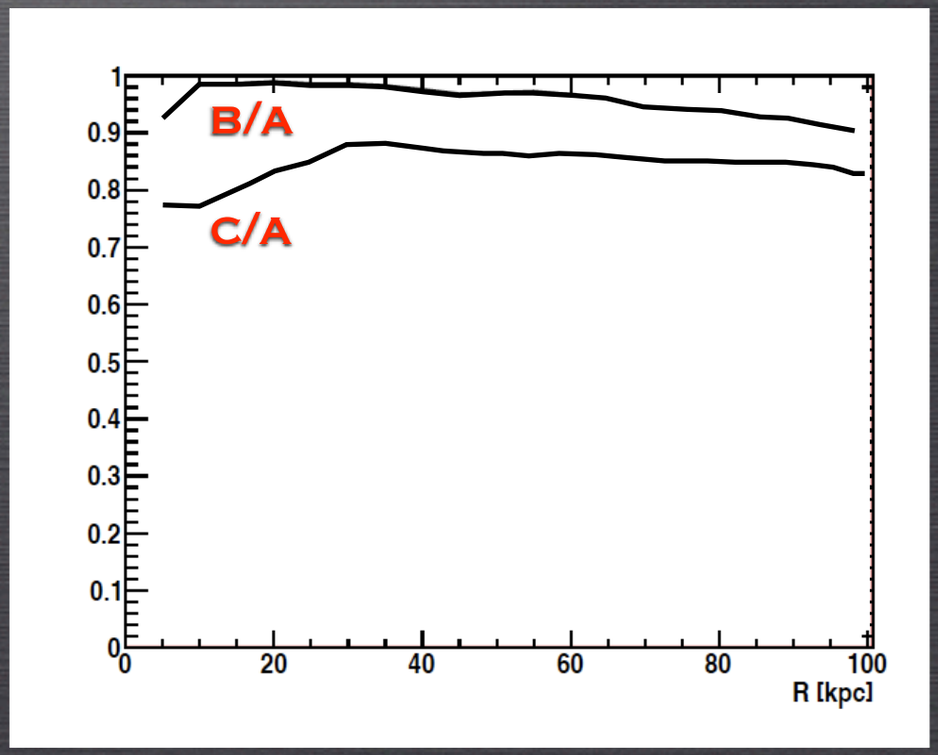


Triaxial Halos



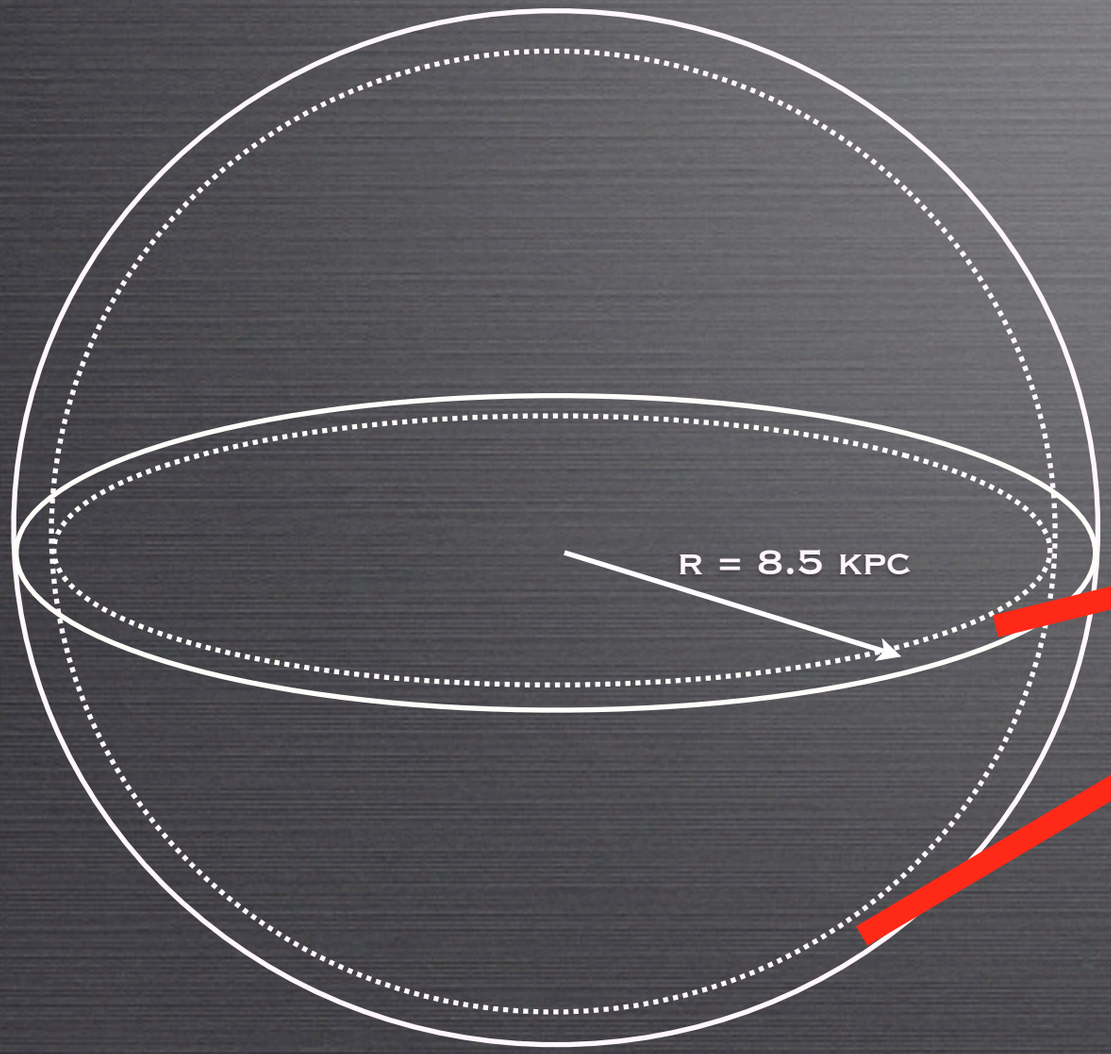


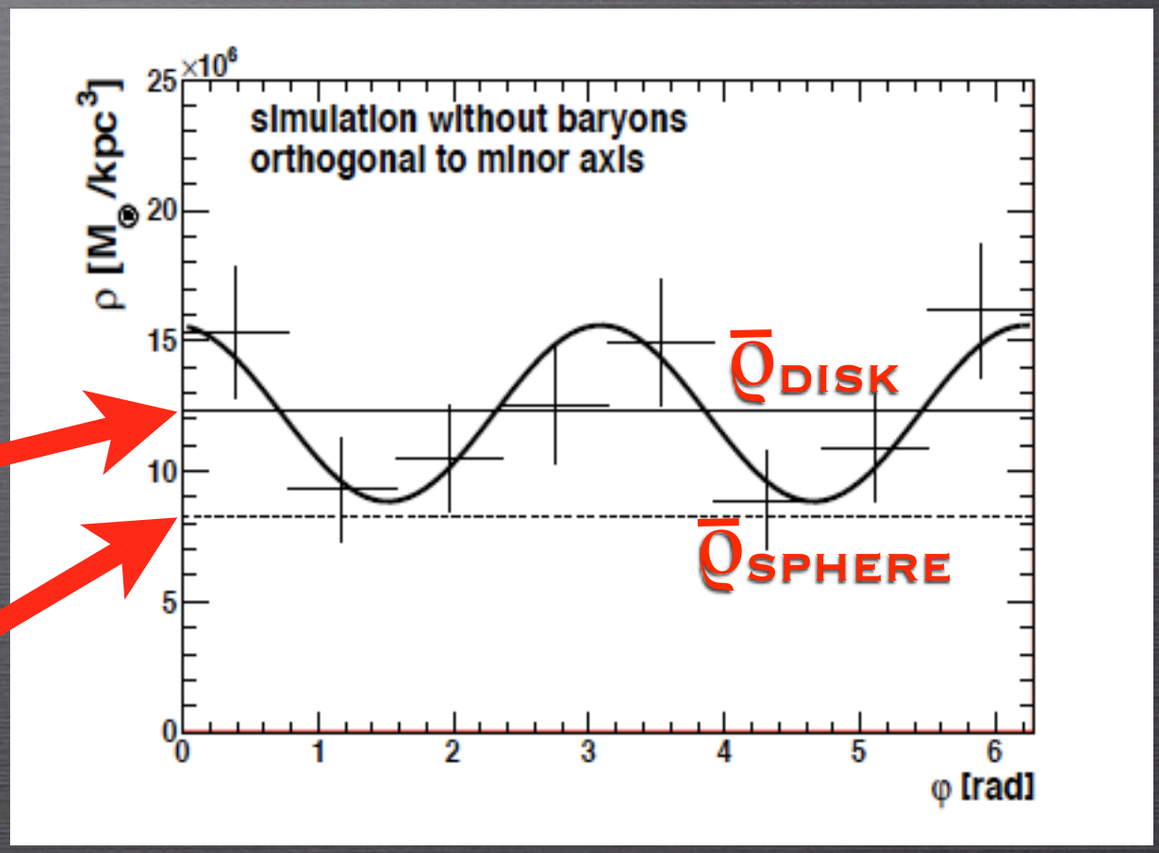




Modulation of DM density

at fixed GC-distance





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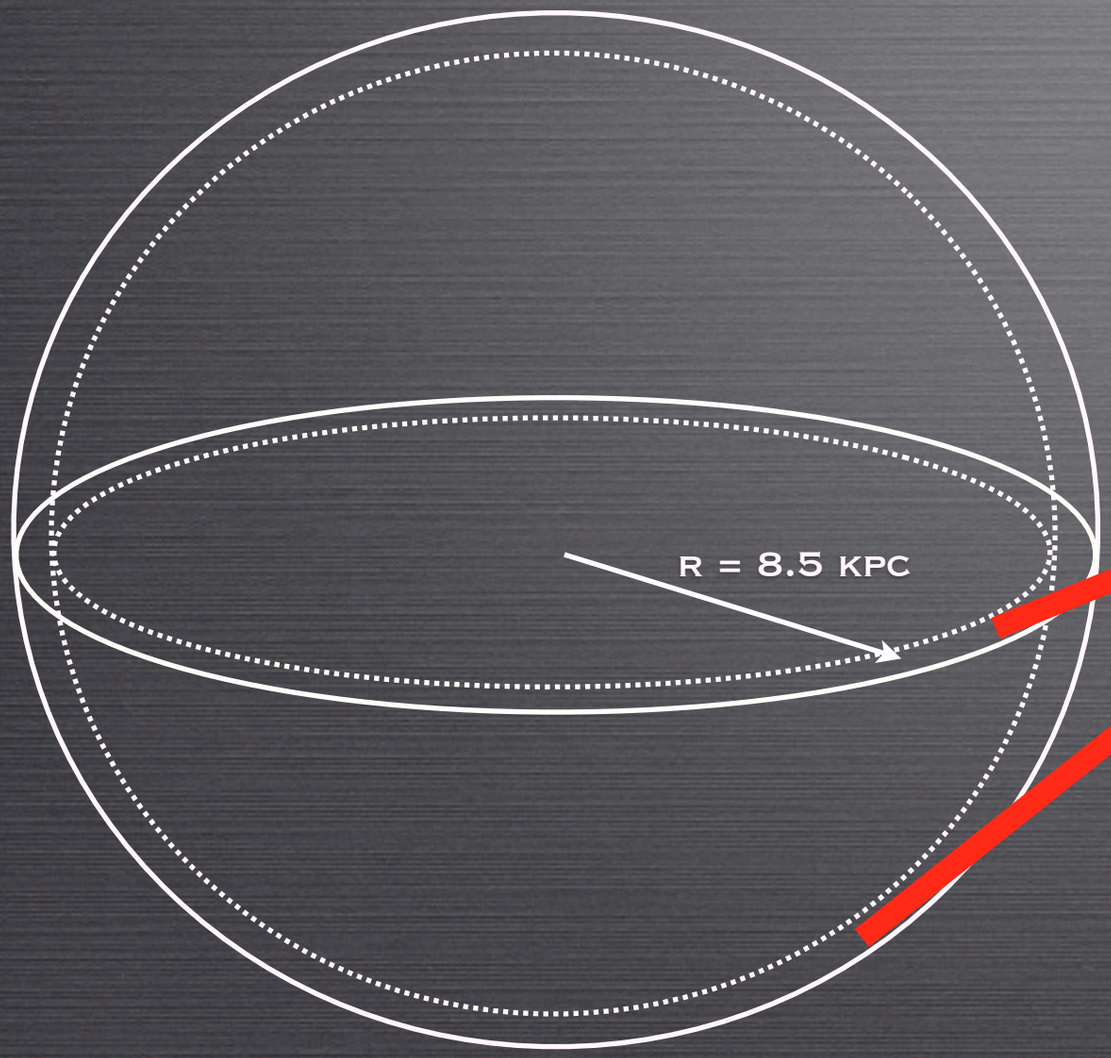
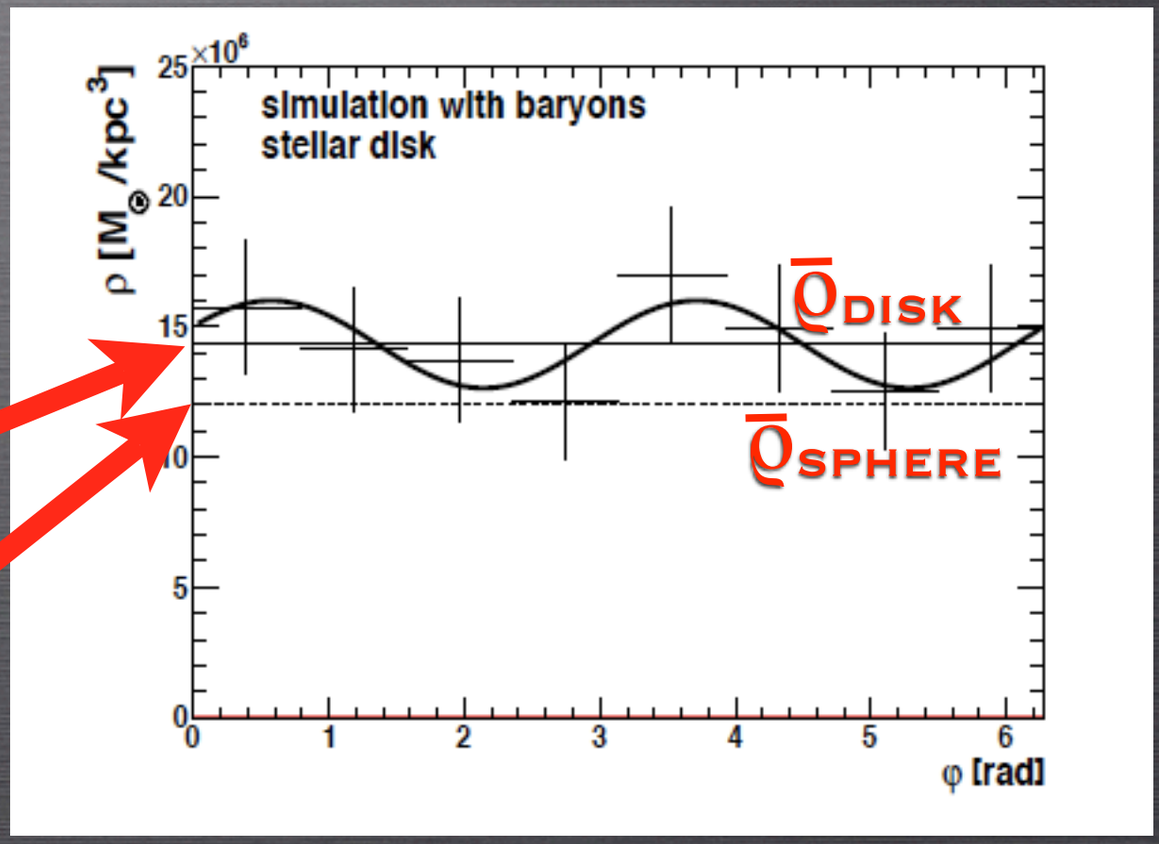
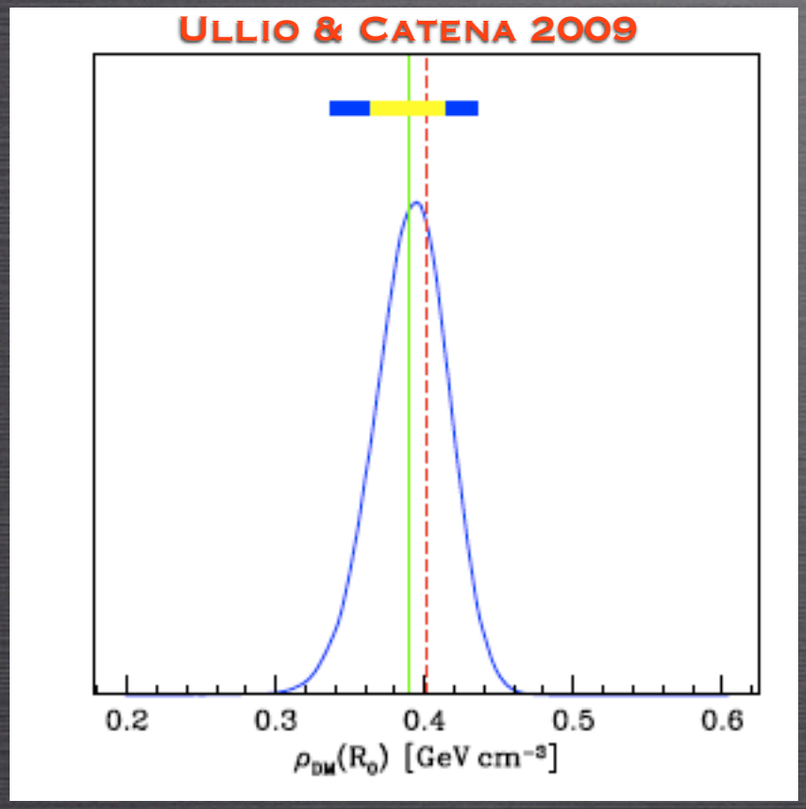




Direct Detection

Uncertainties on the Local Density

"Statistical"

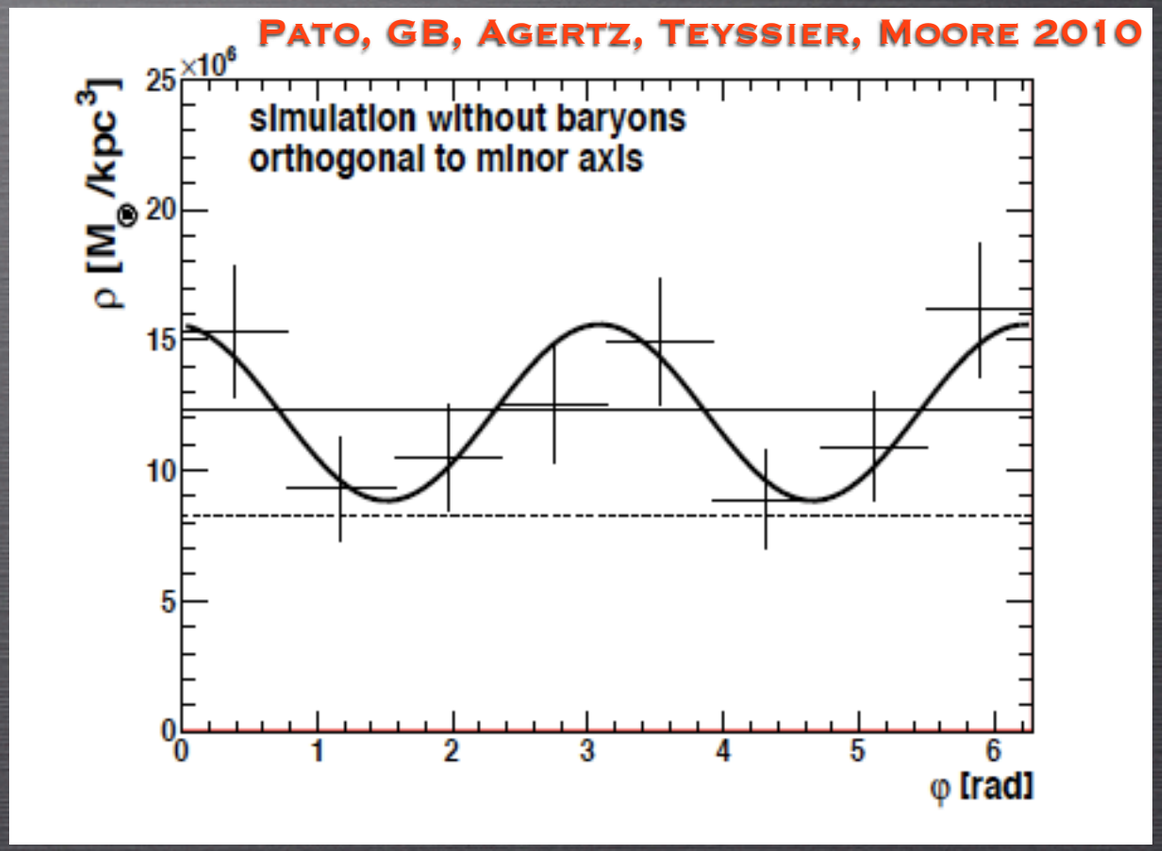


$$\rho_{DM}(R_0) = 0.389 \pm 0.025\,\mathrm{GeV\ cm^{-3}}$$

From dynamical Observables (see also Strigari & Trotta 2009)

+

"Systematic"



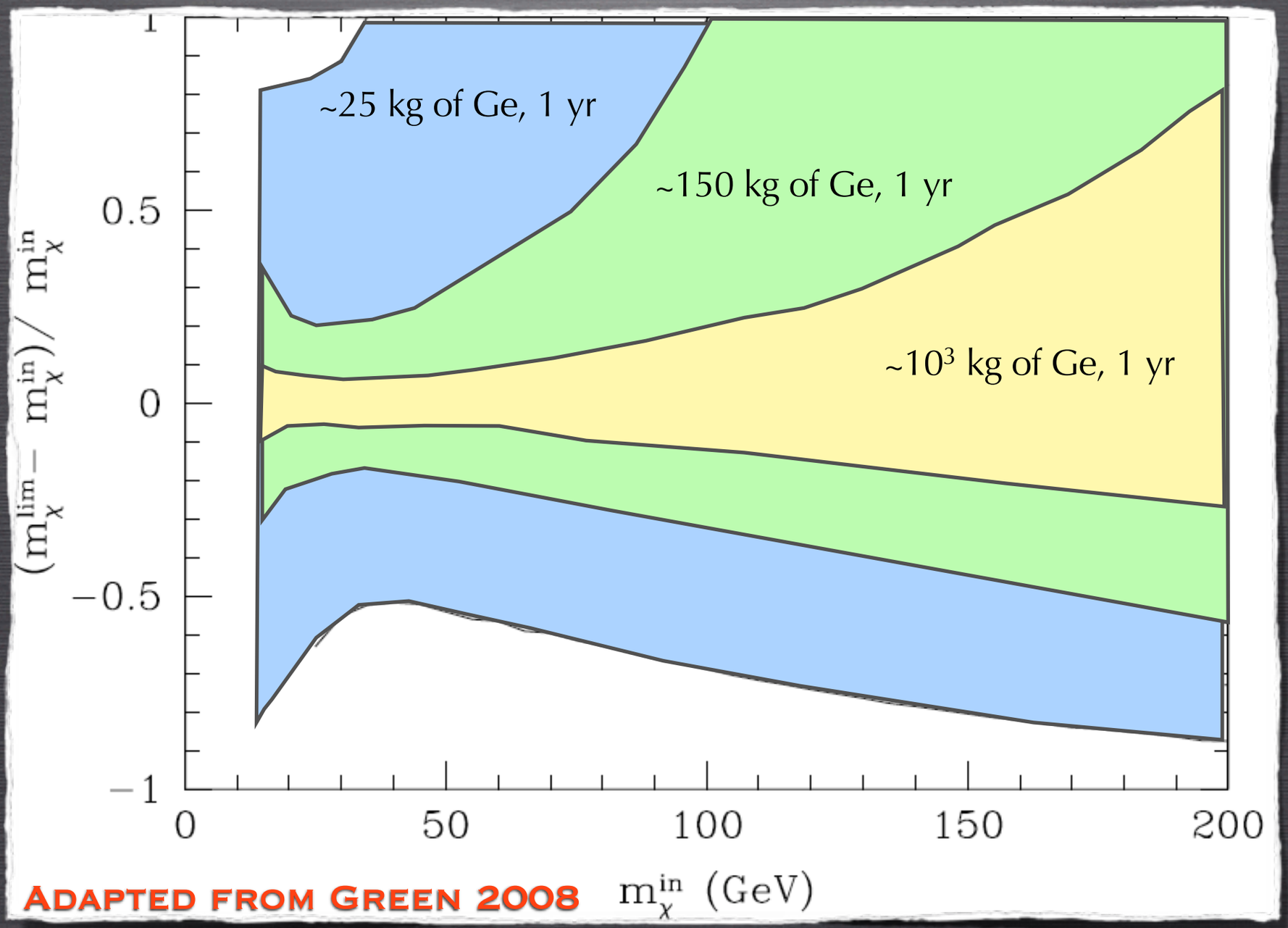
$$\rho_0/\bar{\rho}_0 = 1.01 - 1.41$$ w/ Baryons

$$\rho_0/\bar{\rho}_0 = 0.39 - 1.94$$ DM only

Triaxiality, Baryons, etc.

Direct Detection

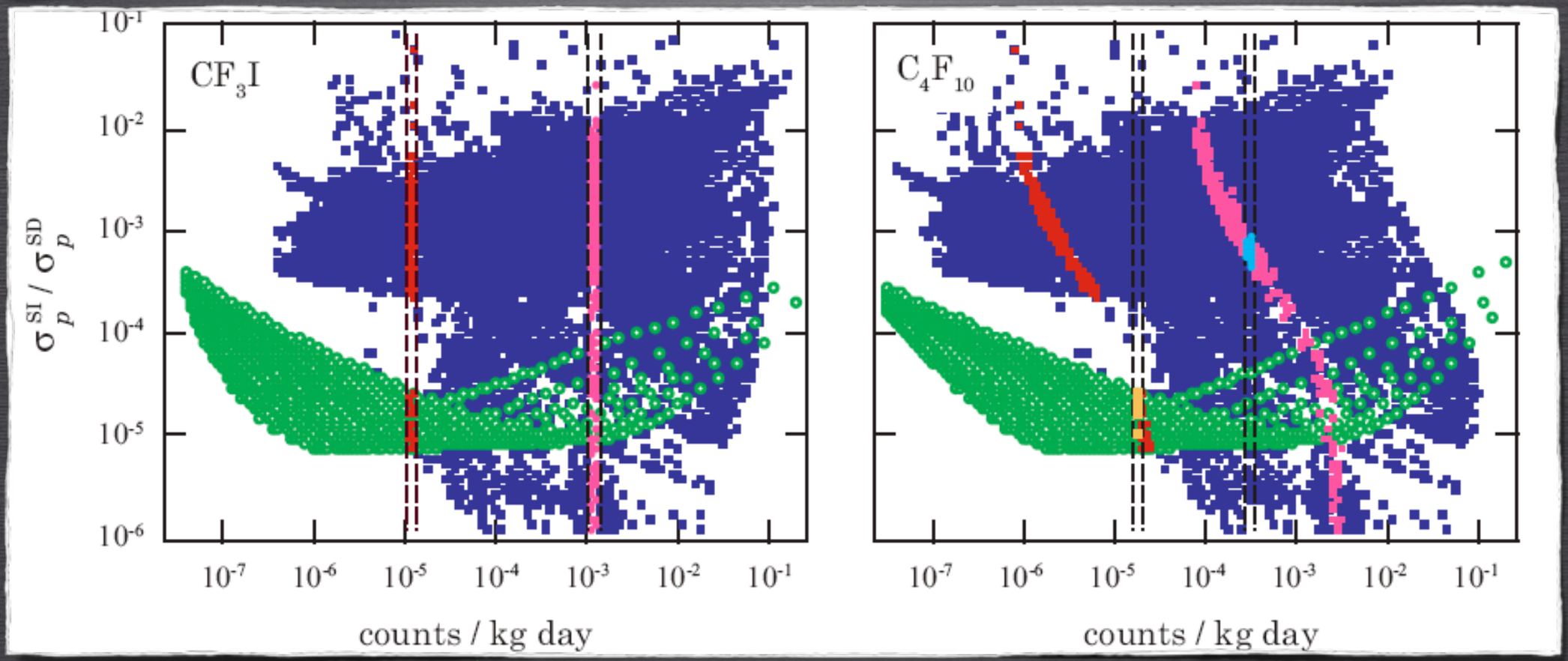
95% C.L. constraint on the reconstructed DM mass



Adapted from Green 2008

Direct Detection

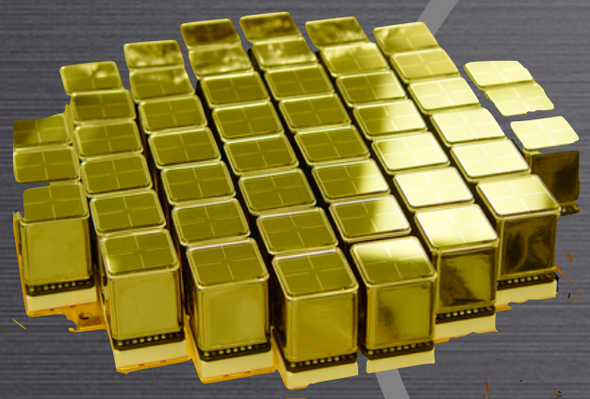
Better constraints combining results from different targets

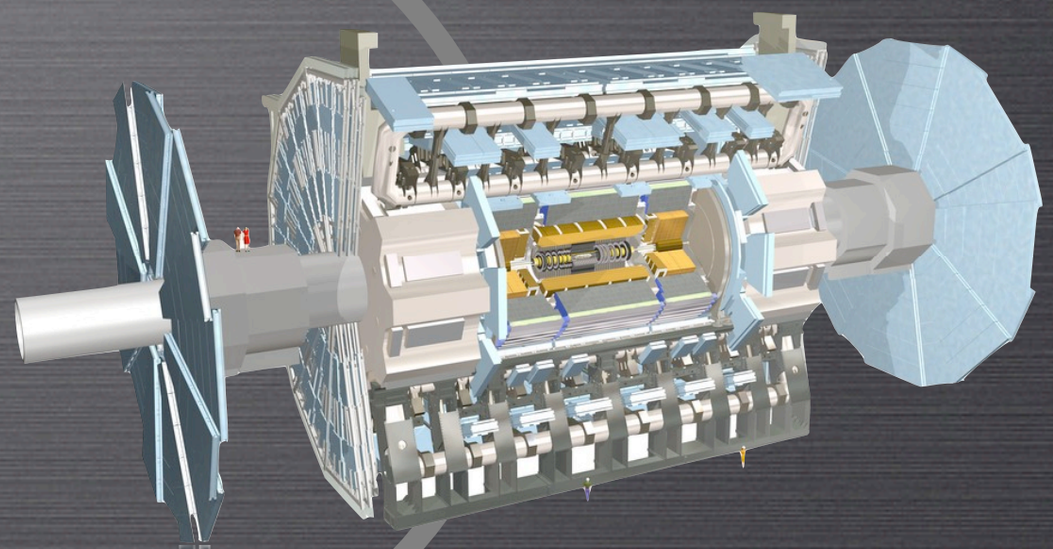


The case of COUPP. GB, Cerdeno, Collar & Odom 2007

Or combine with information from Accelerators...

DD + LHC





Example of Inverse problem at LHC

Inferring the relic density (thus the DM nature) of newly discovered particles from LHC data... What we would like:

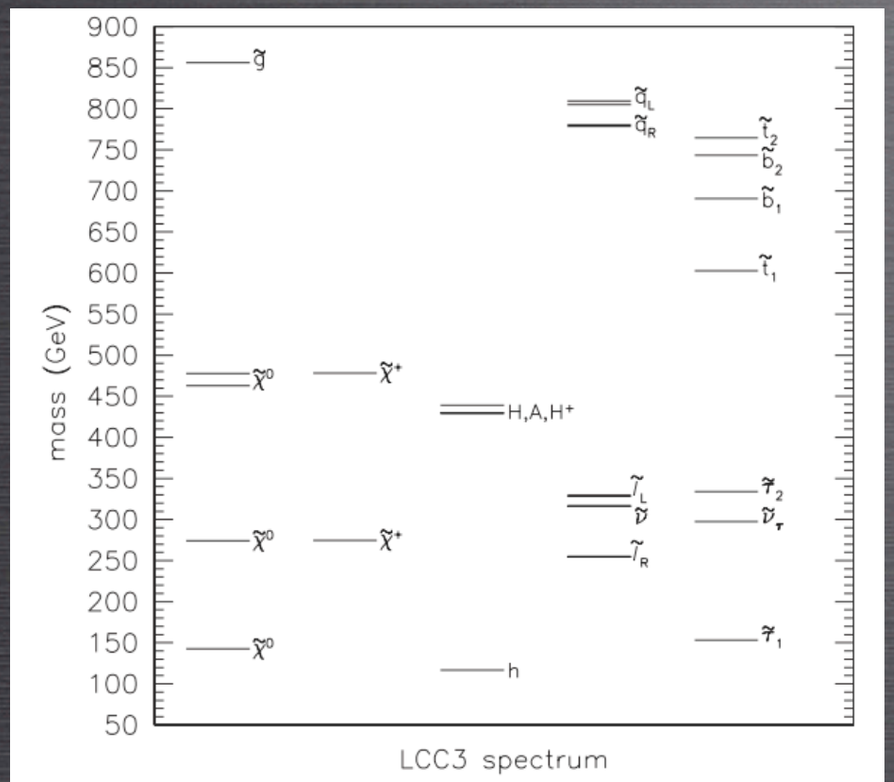
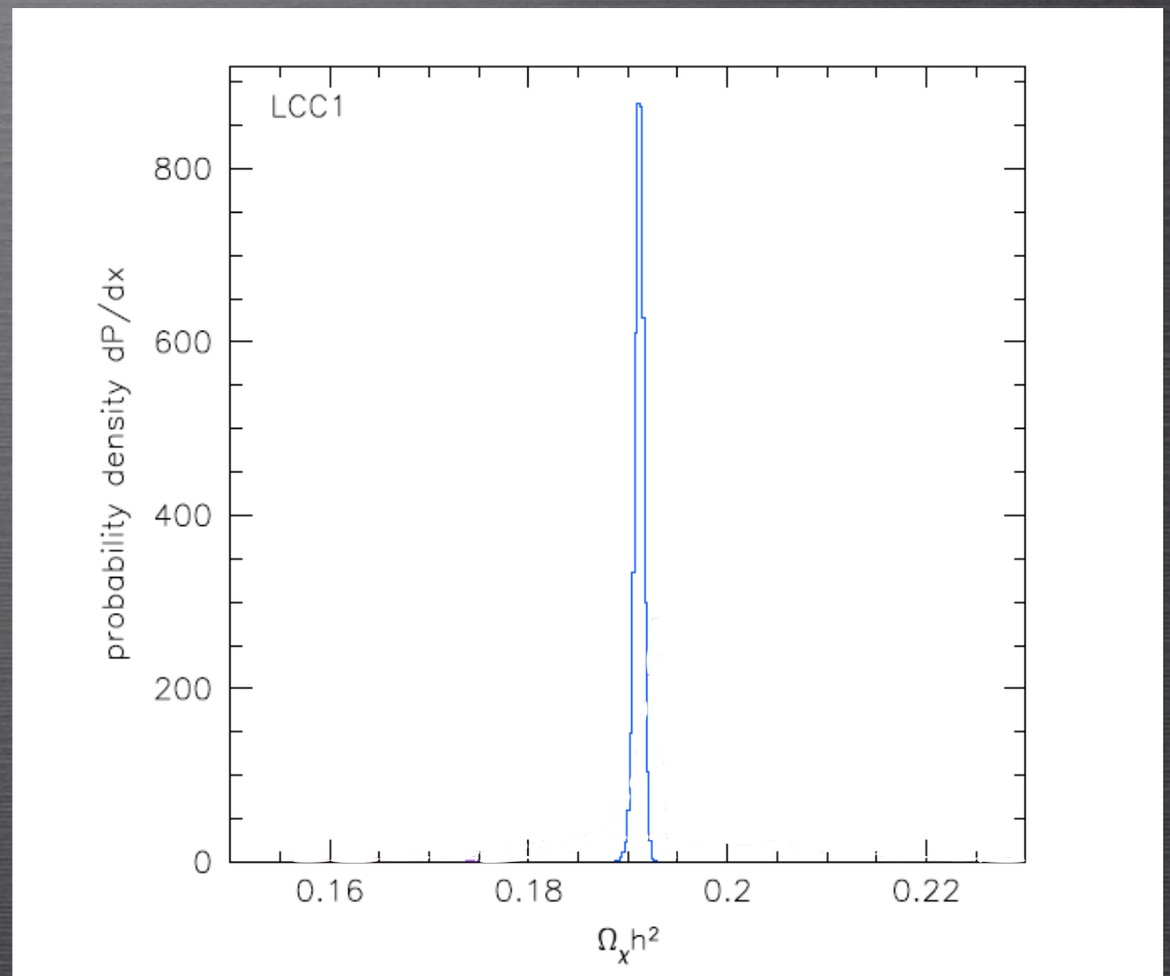
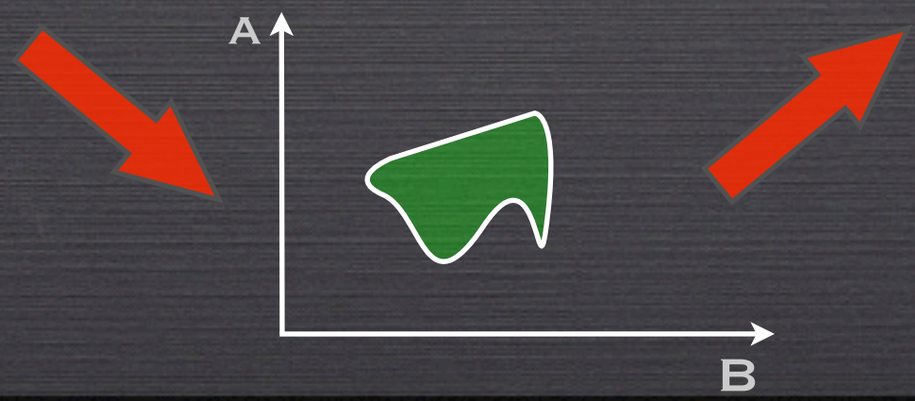


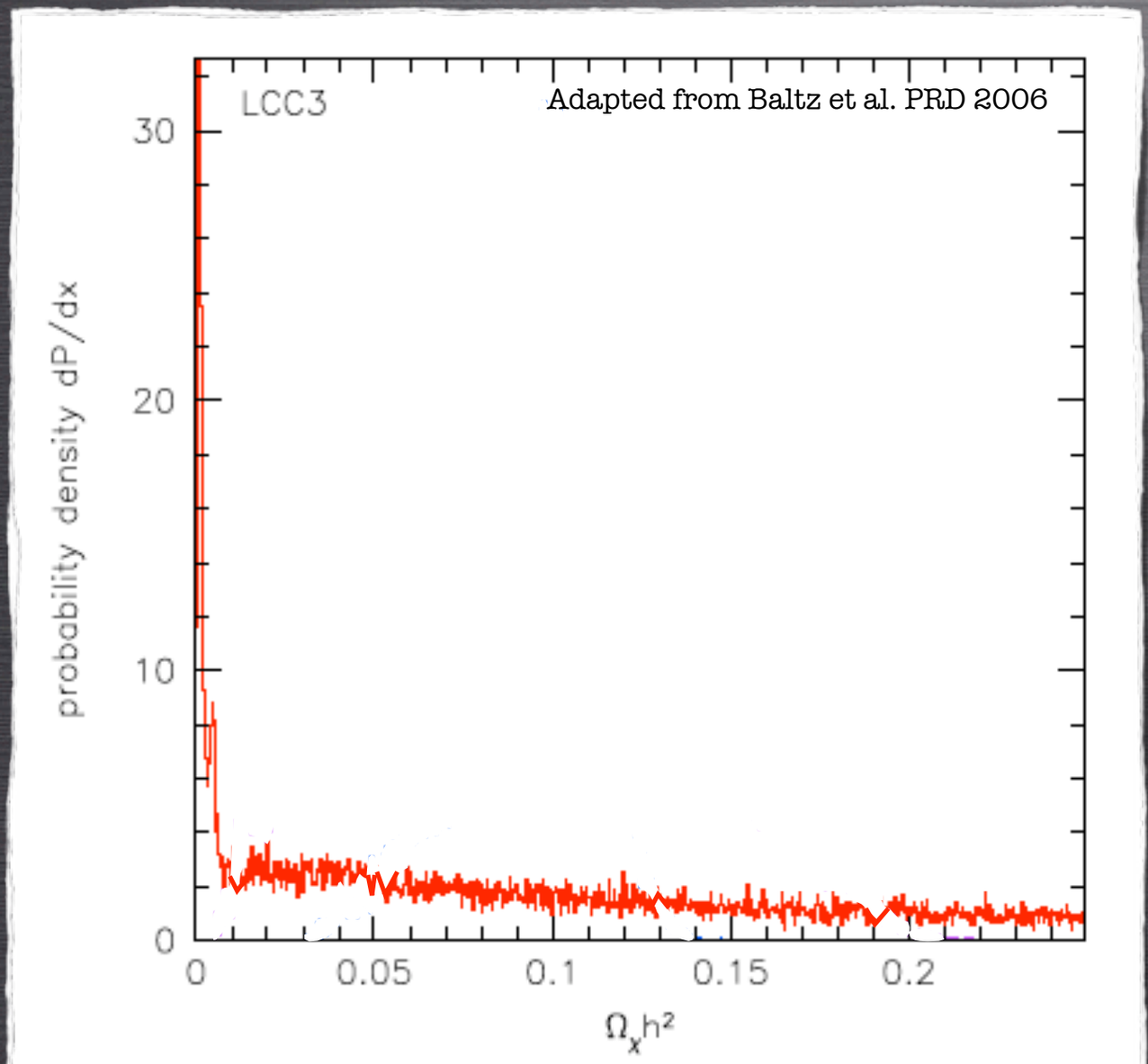
FIG. 34. Particle spectrum for point LCC3. The stau-neutralino mass splitting is 10.8 GeV. The lightest neutralino is predominantly *b*-ino, the second neutralino and light chargino are predominantly *W*-ino, and the heavy neutralinos and chargino are predominantly Higgsino.





Example of Inverse problem at LHC

Inferring the relic density (thus the DM nature) of newly discovered particles from LHC data... what we will most probably get:



Even if SUSY particles are discovered, it will be challenging to determine $\Omega_\chi h^2$ with good accuracy!

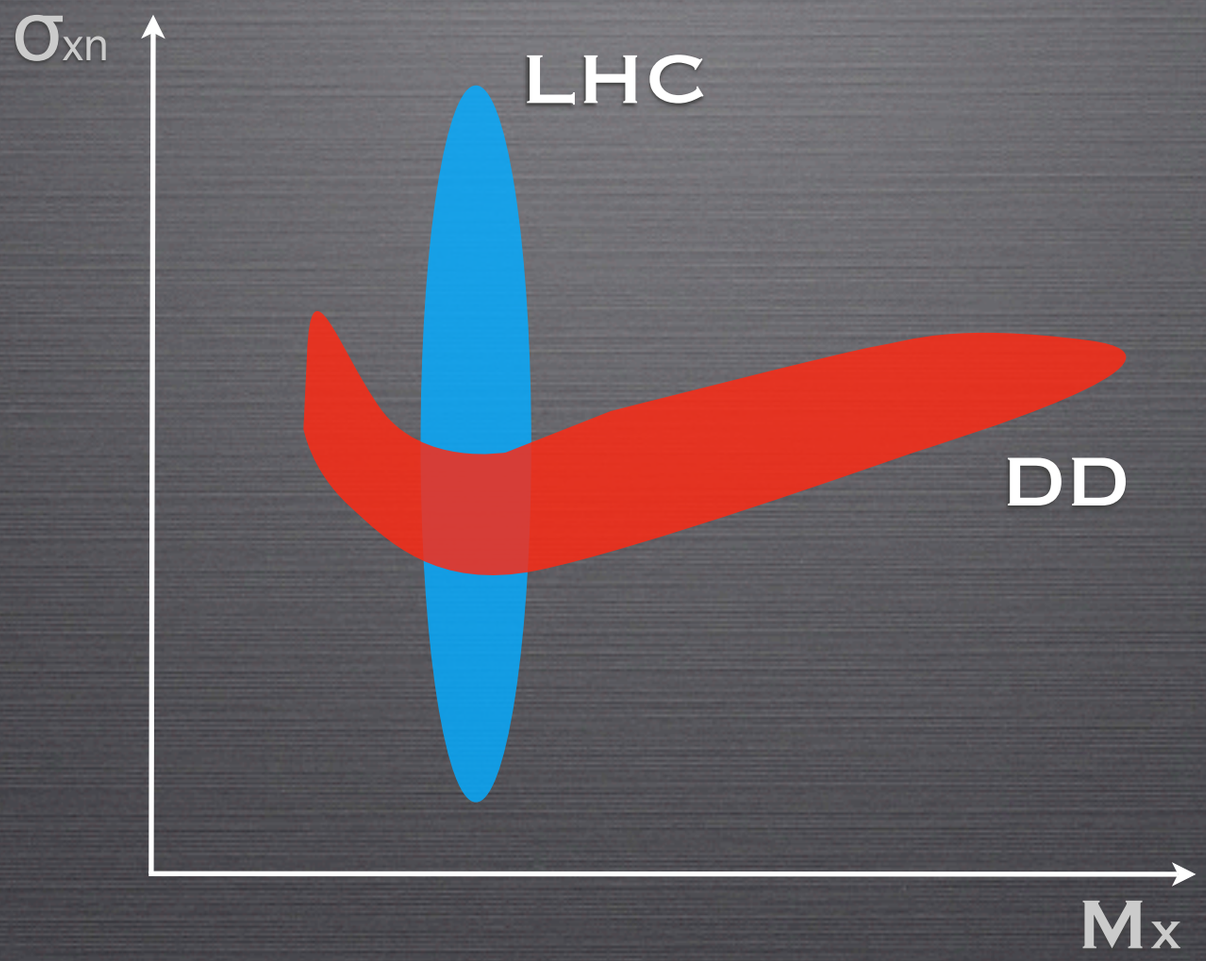
	Ωh^2	LHC
LCC1	0.192	7.2%
LCC2	0.109	82.%
LCC3	0.101	167%
LCC4	0.114	405%

New particles may then turn out to be too abundant (decaying DM?) or not enough (multi-component DM)...

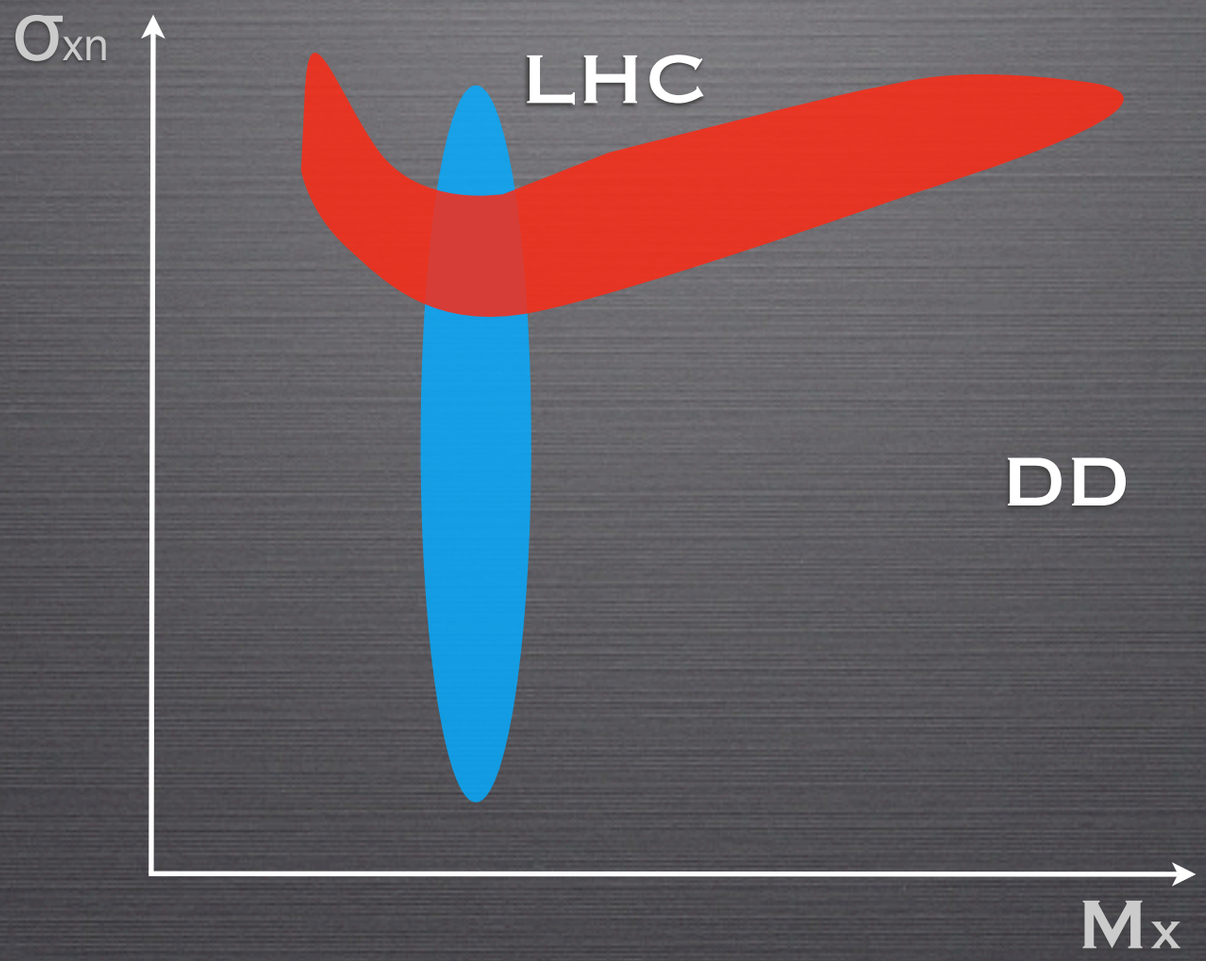
Need particle astrophysics (direct/indirect) experiments to prove that new particles = DM !!

See also B. C. Allanach et al. 2004, M. Nojiri et al. 2006, Roszkowski et al. 2009

LHC+DD

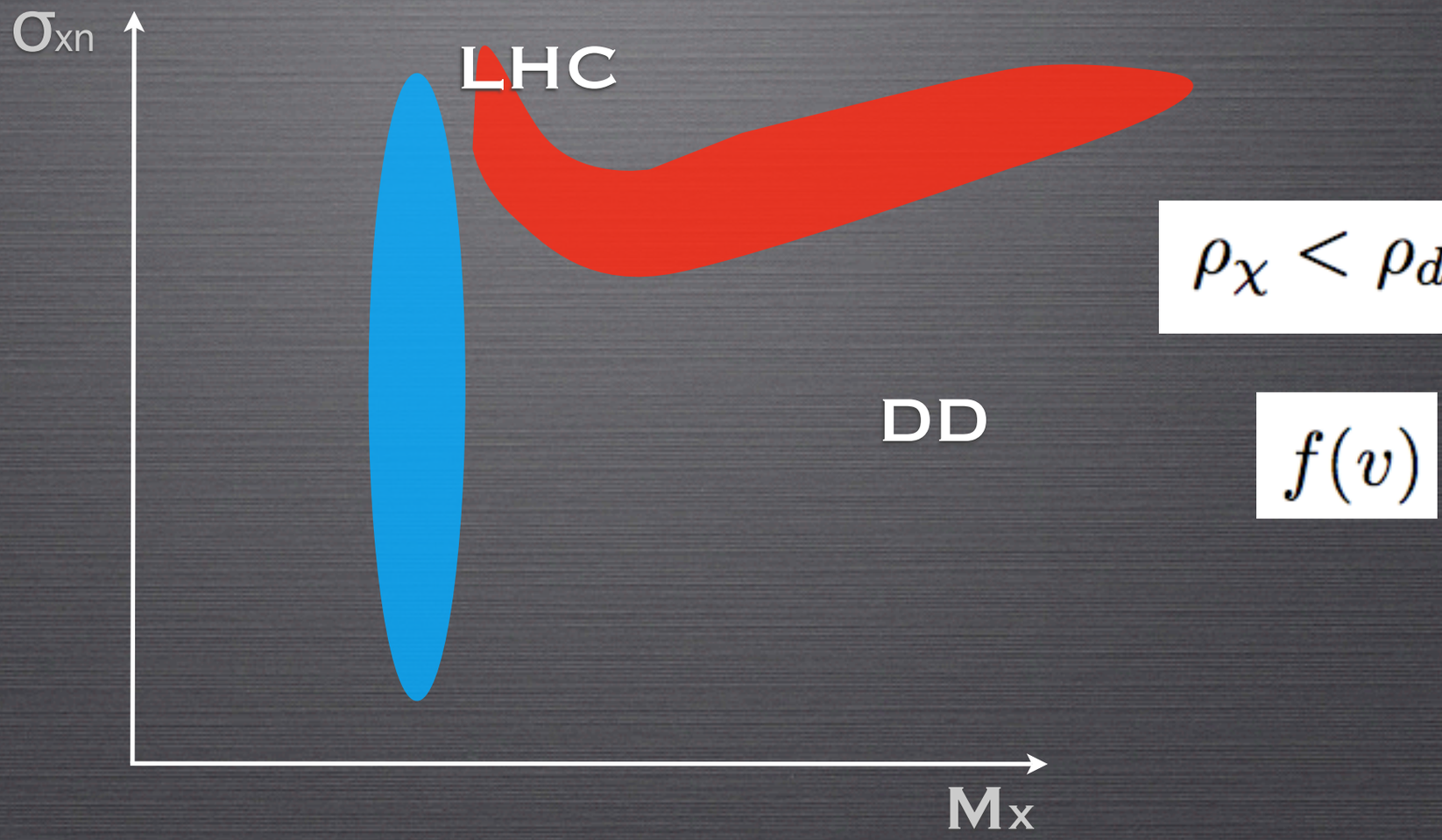


LHC+DD

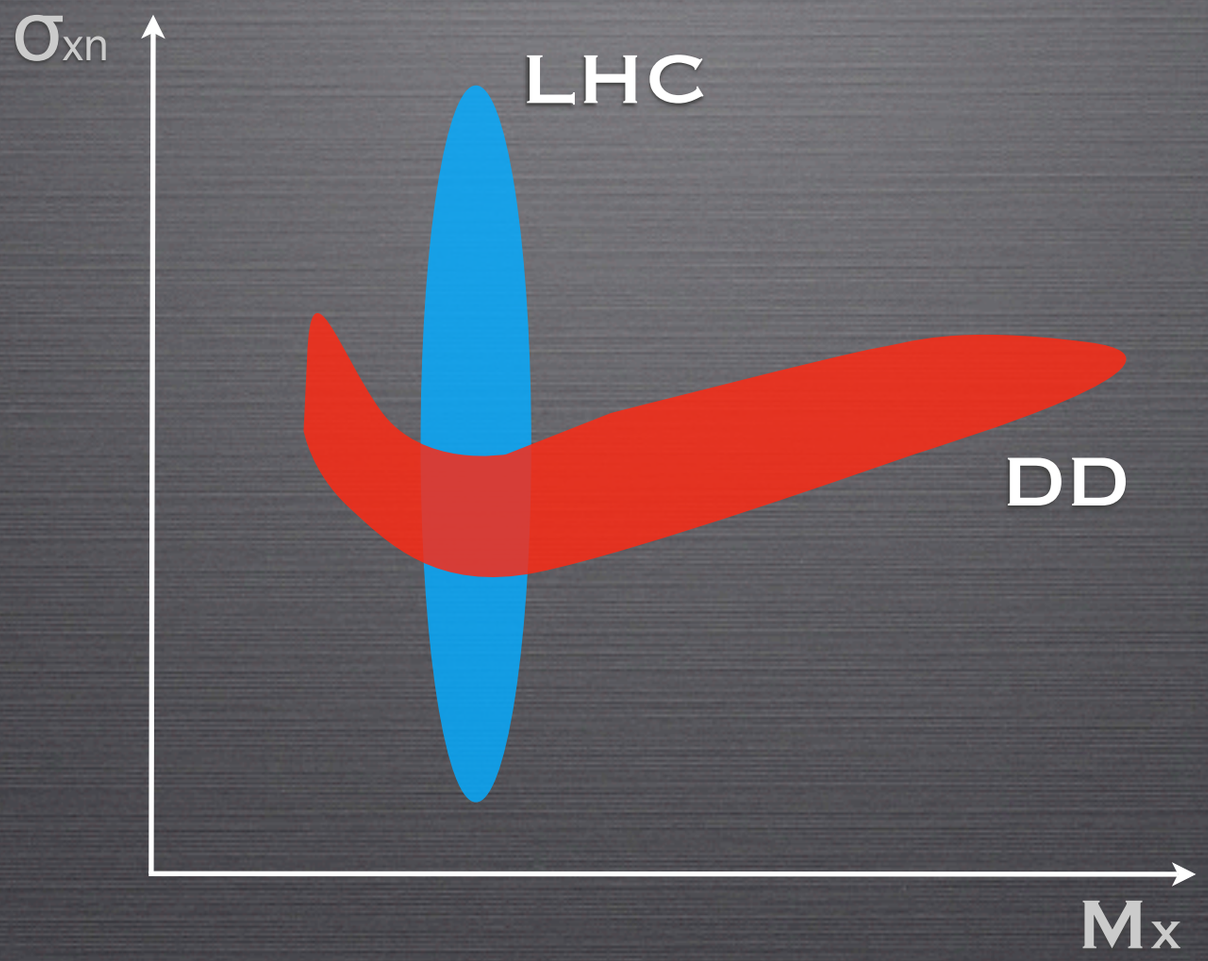


$$\rho_\chi < \rho_{dm}$$

LHC+DD



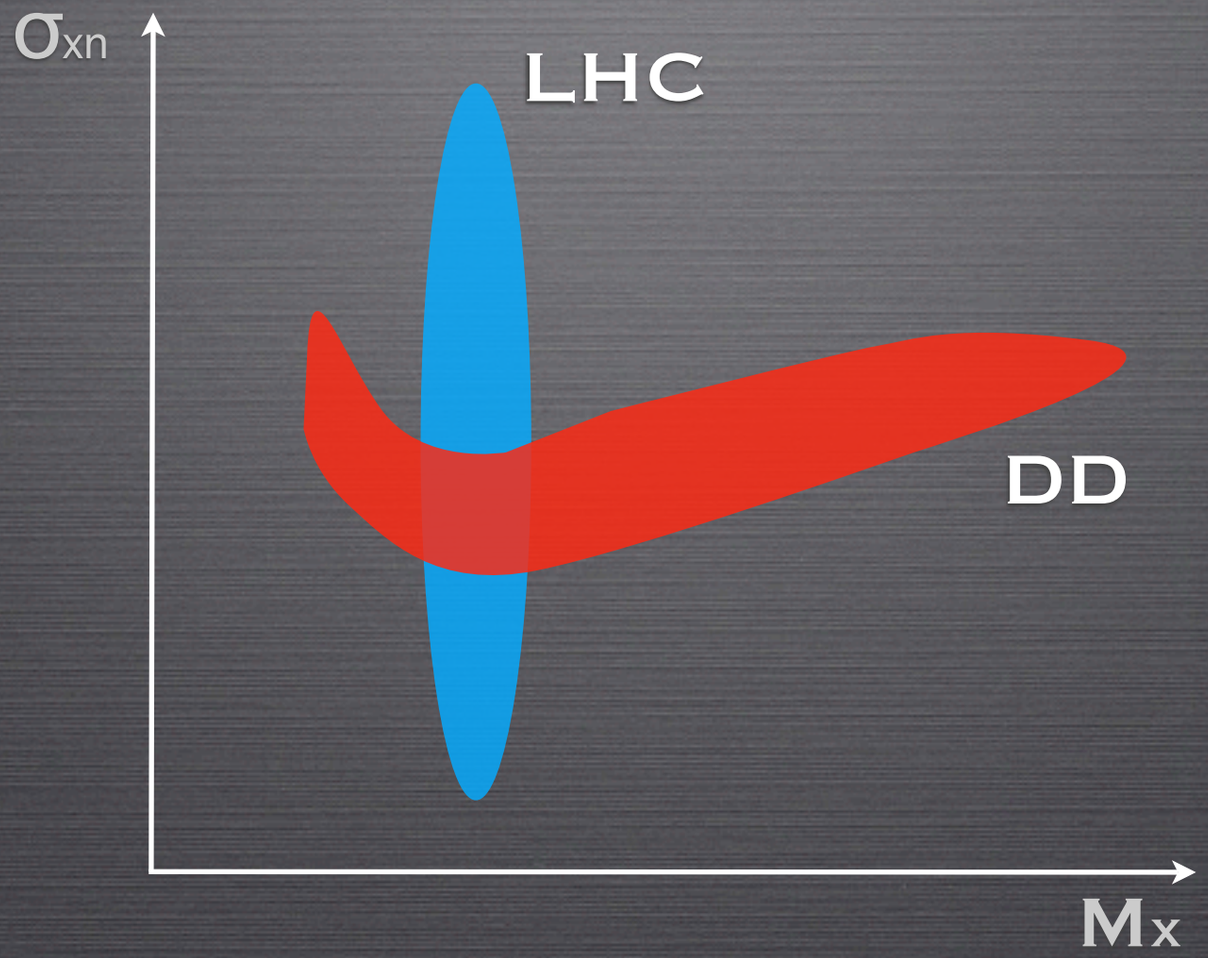
LHC+DD



$$\rho_\chi < \rho_{dm}$$

$$f(v)$$

LHC+DD



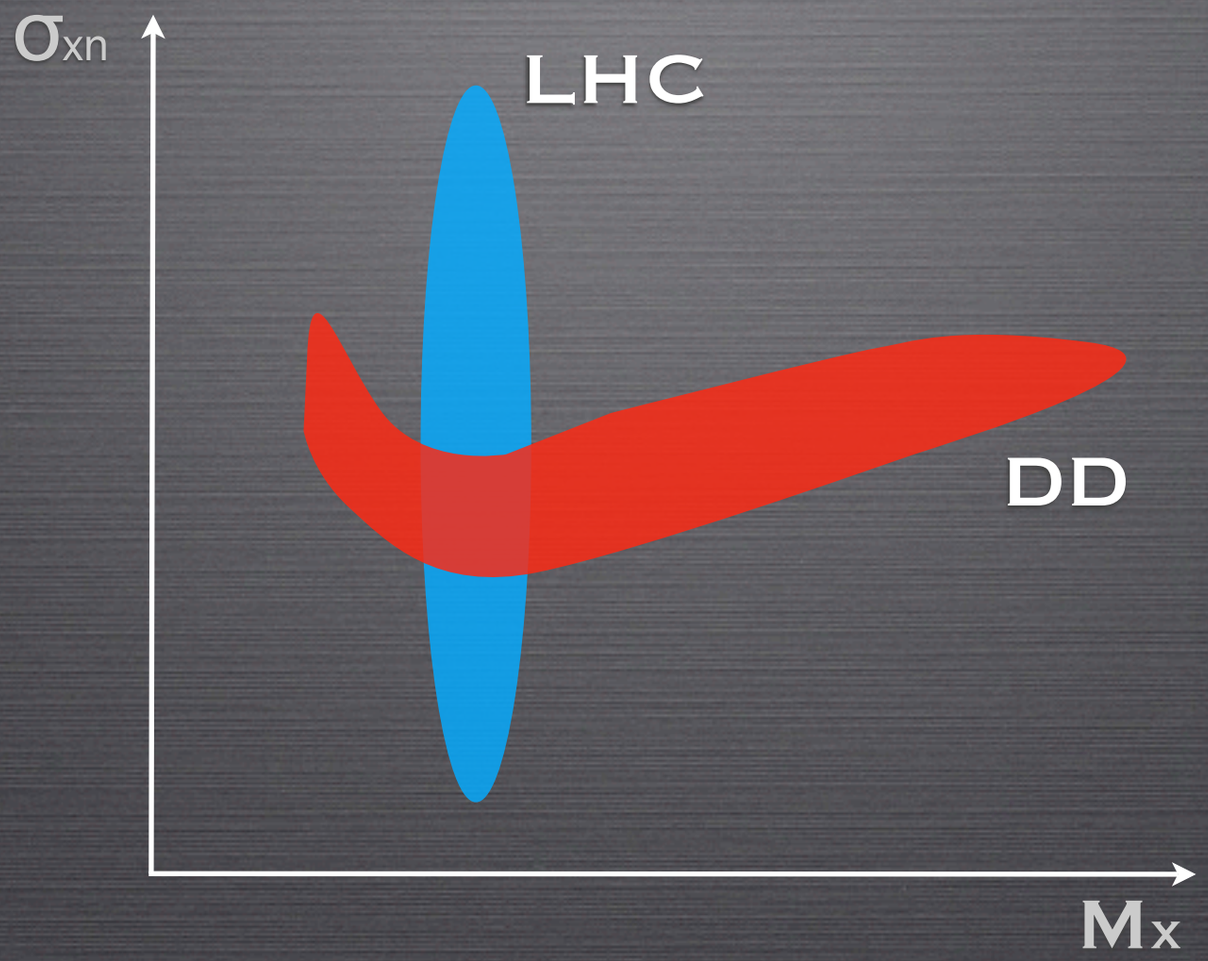
$$\rho_\chi < \rho_{dm}$$

$$f(v)$$

Ansatz:

$$\frac{\rho_\chi}{\rho_{dm}} = \frac{\Omega_\chi}{\Omega_{dm}}$$

LHC+DD



$$\rho_\chi < \rho_{dm}$$

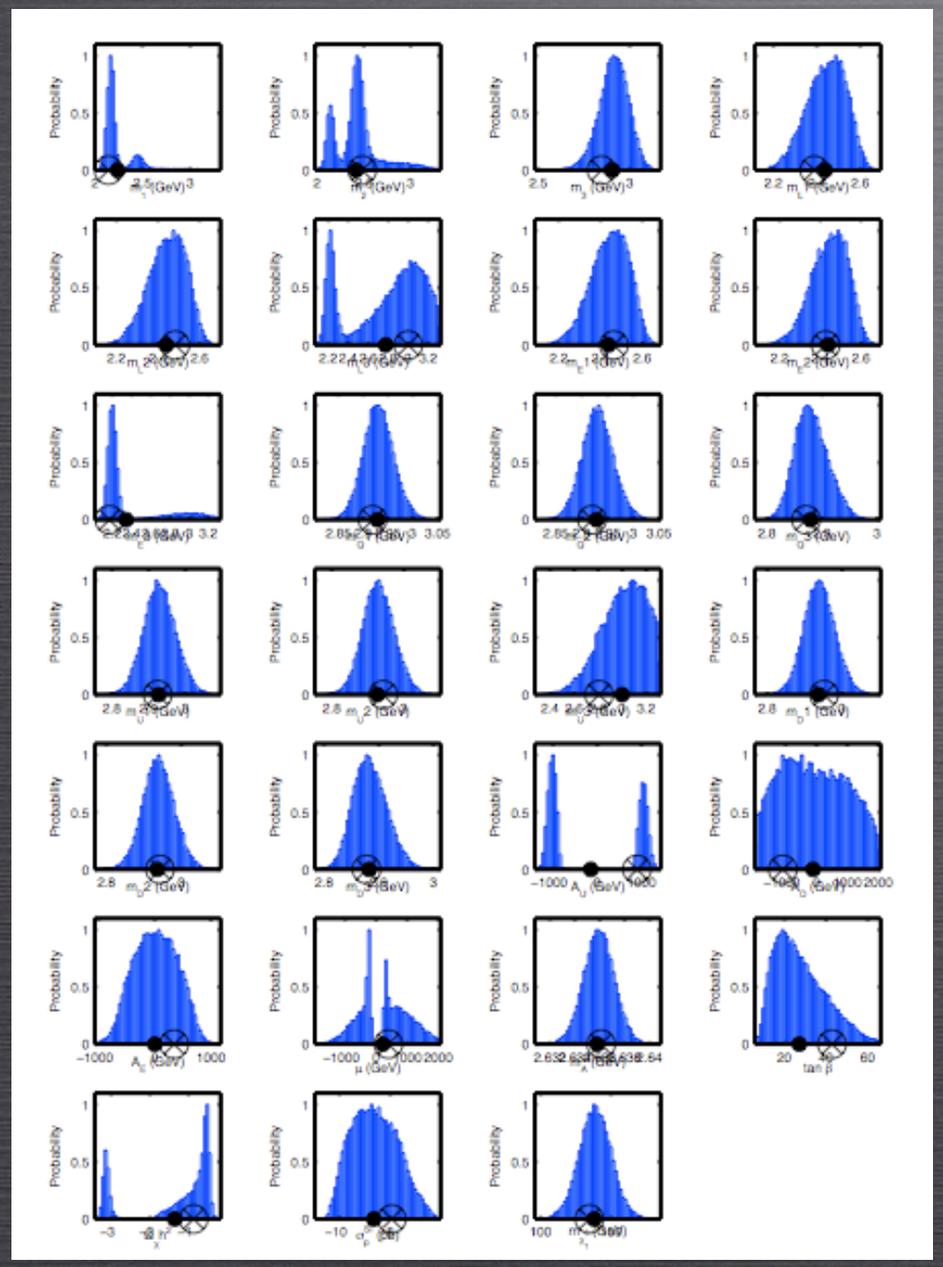
$$f(v)$$

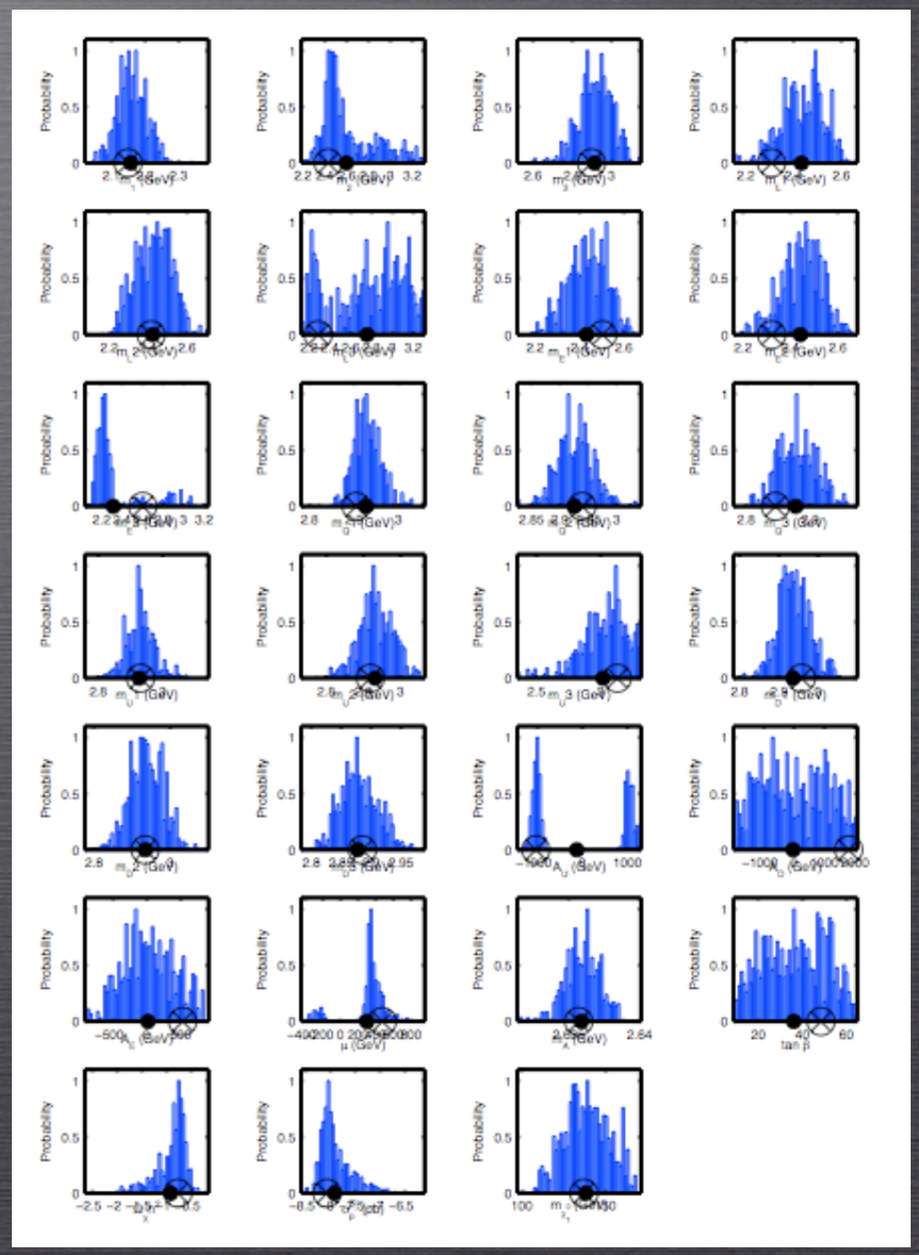
Ansatz:

$$\frac{\rho_\chi}{\rho_{dm}} = \frac{\Omega_\chi}{\Omega_{dm}}$$

$$\sigma \propto \varrho_x^{-1} \propto \Omega_x^{-1}$$

LHC+DD

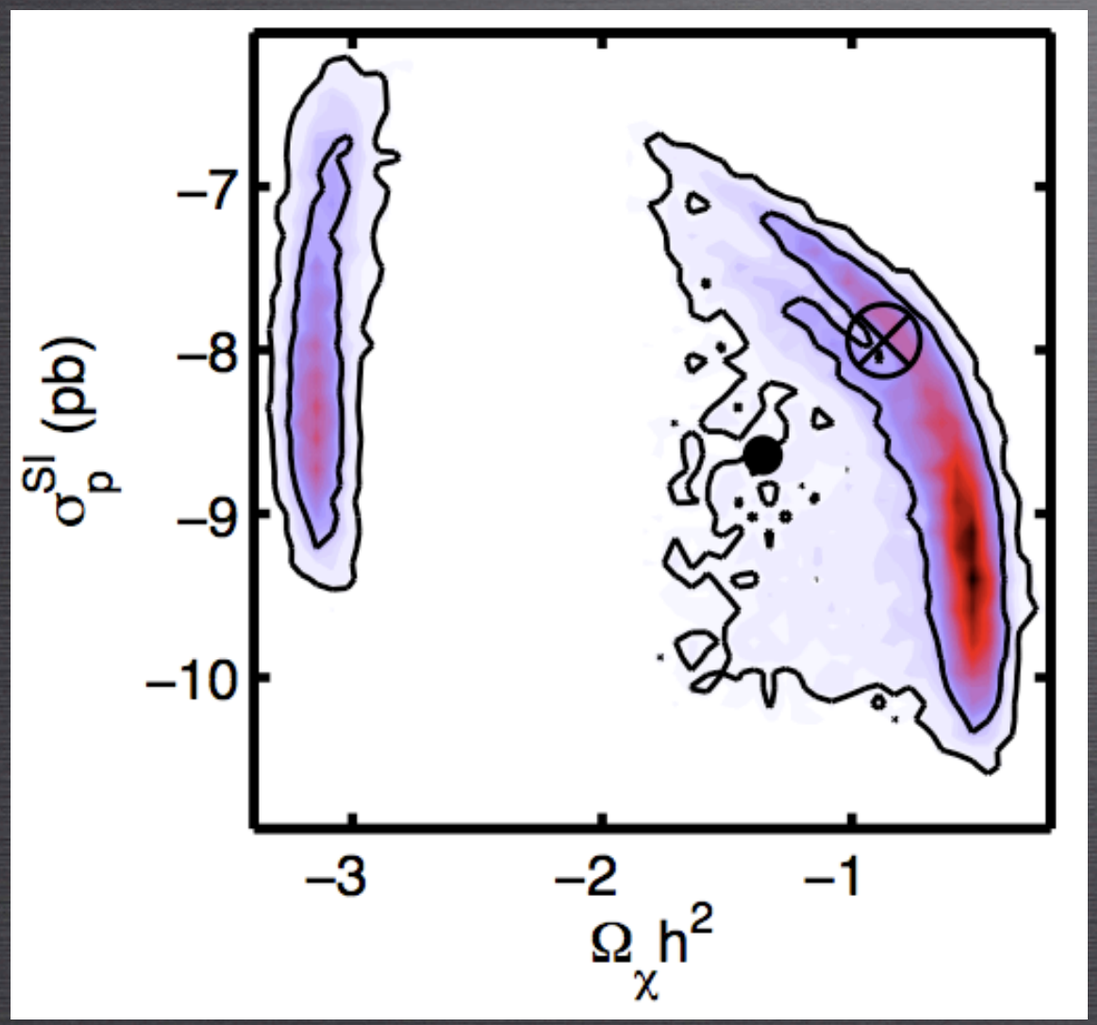




GB, Cerdeno, Fornasa, Ruiz de Austri & Trotta (2010)

Example in the co-annihilation region (24 params. MSSM)

LHC



Example in the co-annihilation region (24 params. MSSM)

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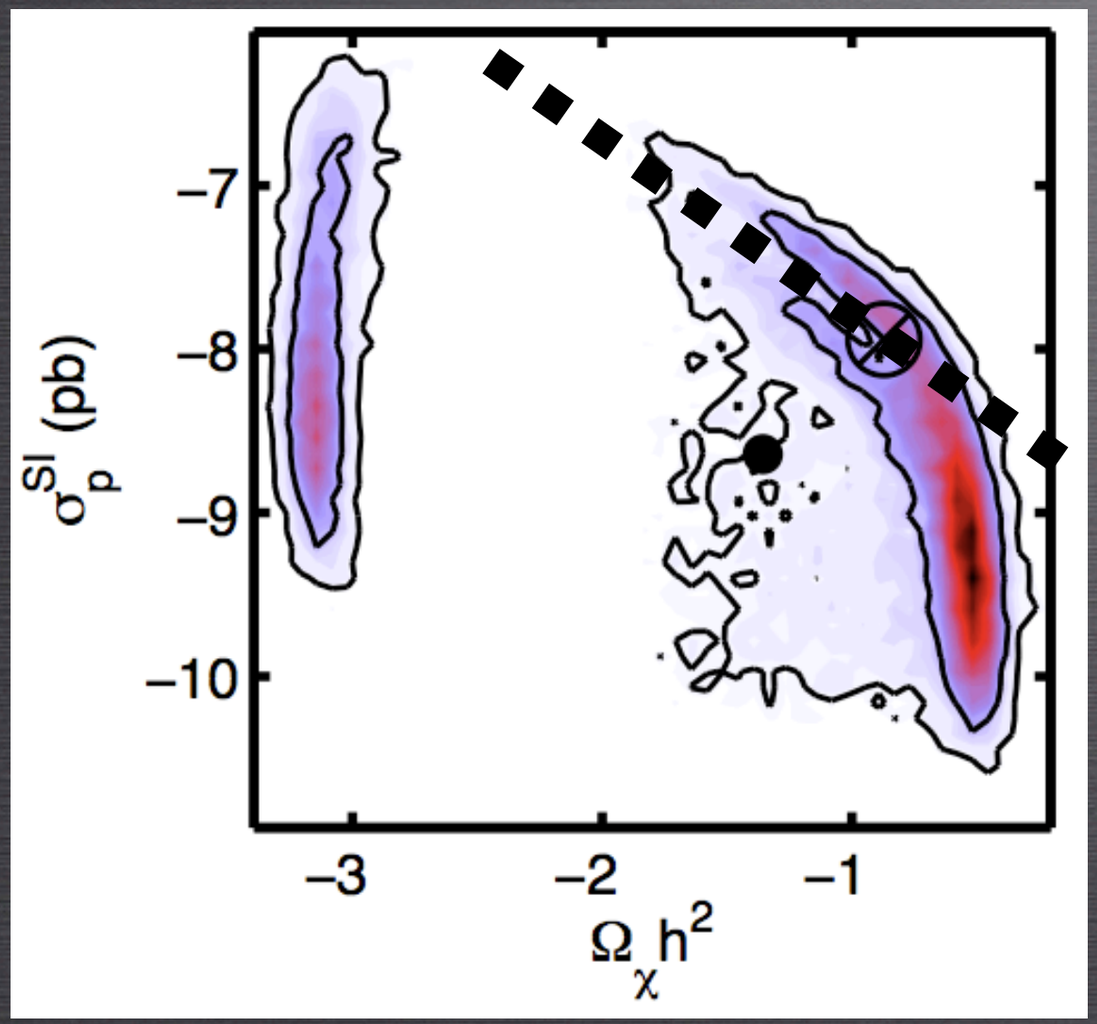
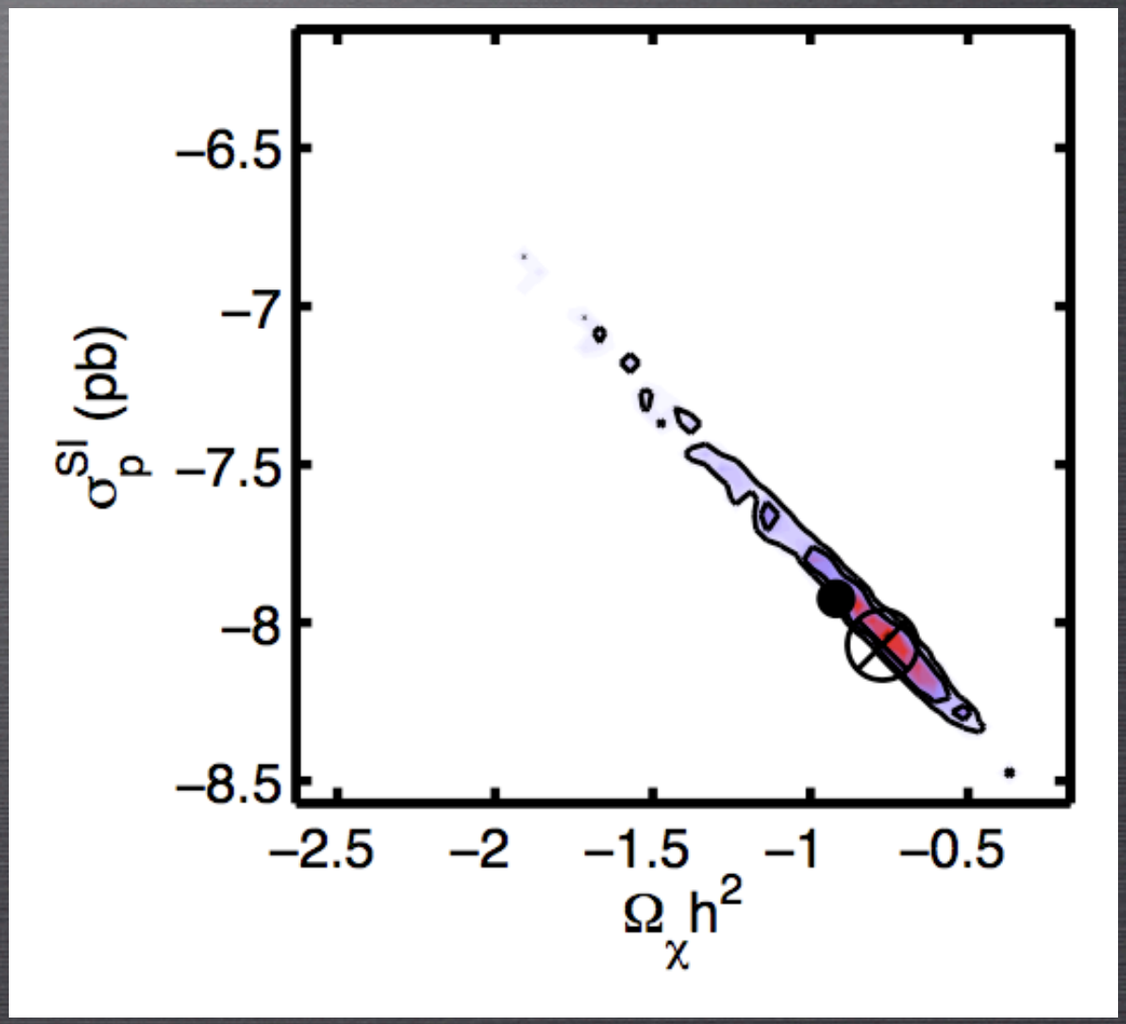


LHC + DD



Bertone, Cerdeno, Fornasa, Trotta, Ruiz de Austri 2010

Conclusions

- As we prepare for discoveries, it is crucial to quantify uncertainties and systematic effects

- Direct detection is affected by uncertainties of different kinds, including a ~50% systematic uncertainty on ϱ_x

- LHC is running! Exciting times ahead, but direct and indirect searches likely necessary to identify DM

- Combining LHC and DD is possible: consistency checks or joint constraints under the (reasonable) assumption that ϱ_x scales with Ω_x

TeV Particle Astrophysics 2010

19-23 July

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