

Dark Matter:

A Model Independent and Complementary study



Yann Mambrini

Laboratoire de Physique Théorique

Orsay, Université Paris XI

N. Bernal, A. Goudelis, C. Muñoz

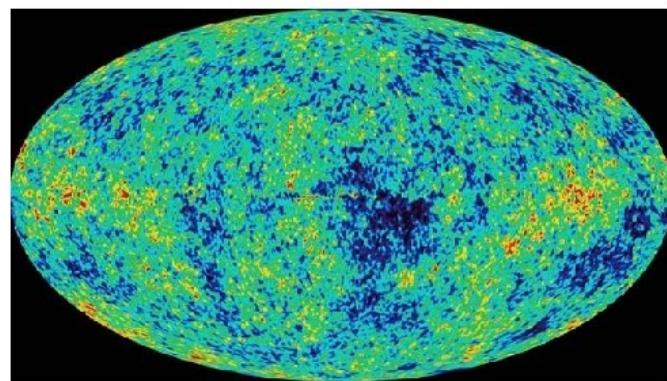
Warsawa, April 4th 2008

Overview

- I) The DM puzzle
- II) Direct Detection : principle, experiment and prediction
- III) Indirect detection : principle, experiment and prediction
- IV) A leptonic collider as a DM detector : the ILC example
- V) Complementarity, Conclusion and Outlooks

Dark Matter Evidences

CMB (WMAP)



Galactic Scale



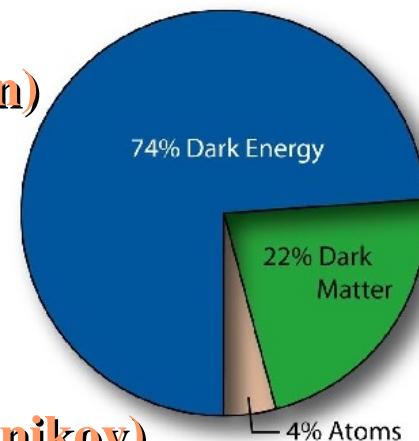
+

SUSY : neutralino, gravitino.. ([Jungman](#))

KK modes (Extra Dim.) ([Servant, Tait](#))

Light boson ([Boehm, Fayet](#))

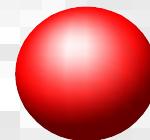
Sterile right handed neutrino ([Shaposhnikov](#))



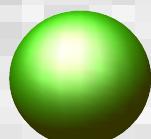
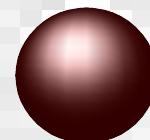
Astroparticle (part 0) : data....



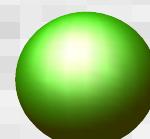
WMAP : $0.094 < \Omega < 0.129$



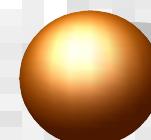
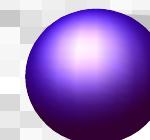
DAMA excess in direct detection



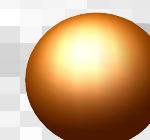
INTEGRAL : 511 keV line excess
(positronium)



HEAT : Positron excess,
100 GeV WIMP



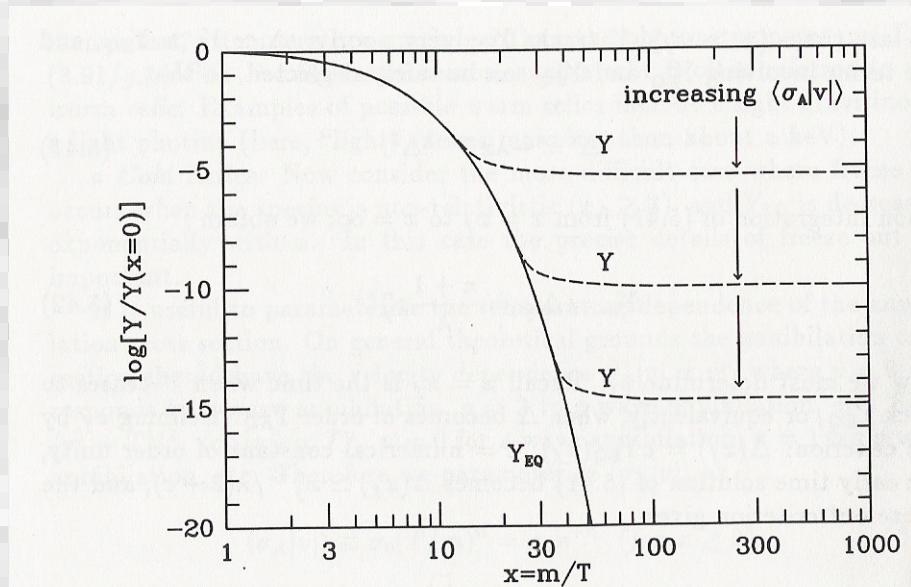
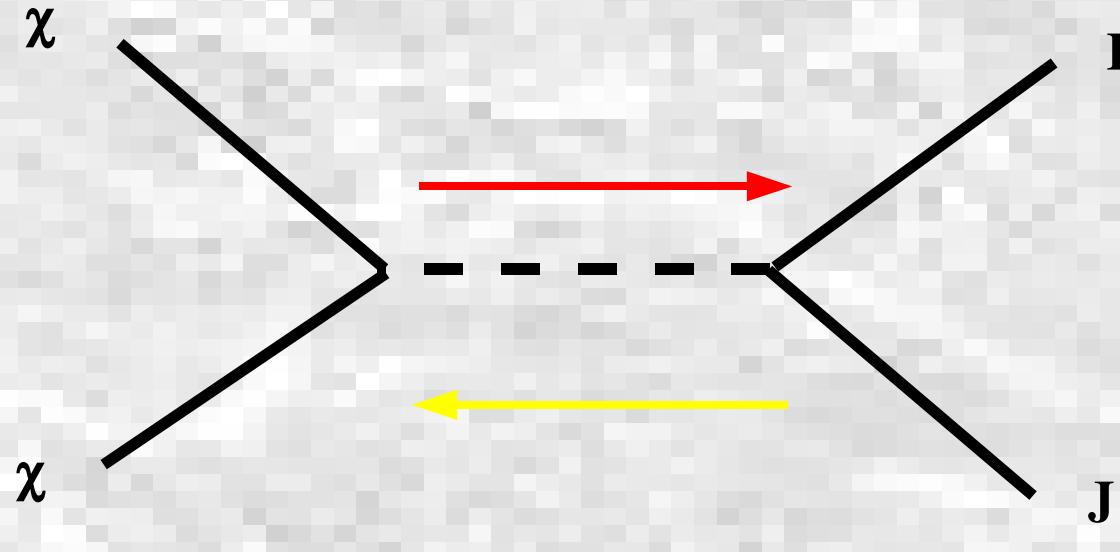
EGRET : gamma excess,
100 GeV WIMP



CANGAROO, HESS, gamma excess
1-10 TeV WIMP



Astroparticle (part I) : Relic Density (Ω)

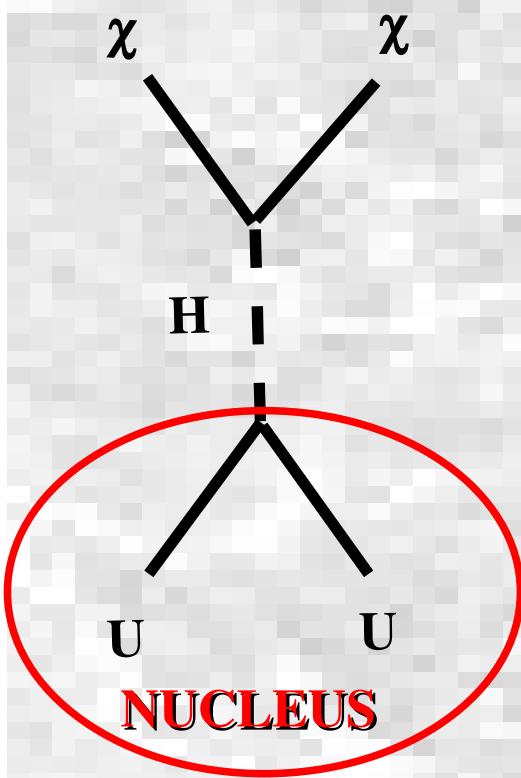


Boltzmann Equation

$$\frac{dn}{dt} = -3Hn - \langle \sigma v \rangle [n^2 - n_{eq}^2]$$

$$(H = \dot{R}/R)$$

Direct Detection : principle



XENON (1 evt per kg per year) : 10 kg – 100kg – 1T

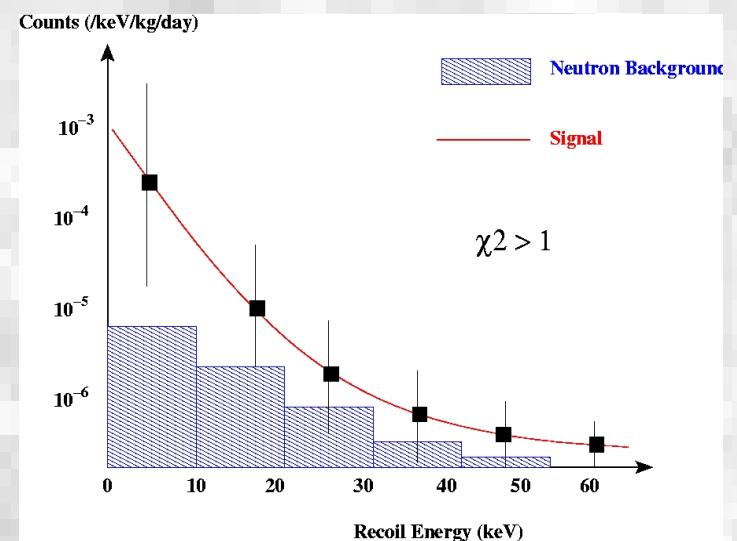


$$\frac{dN}{dE_r} = \frac{\sigma \rho}{2 m_\tau^2 m_\chi} F(E_r)^2 \int_{v_{min}(E_r)}^{\infty} \frac{f(v)}{v} dv,$$

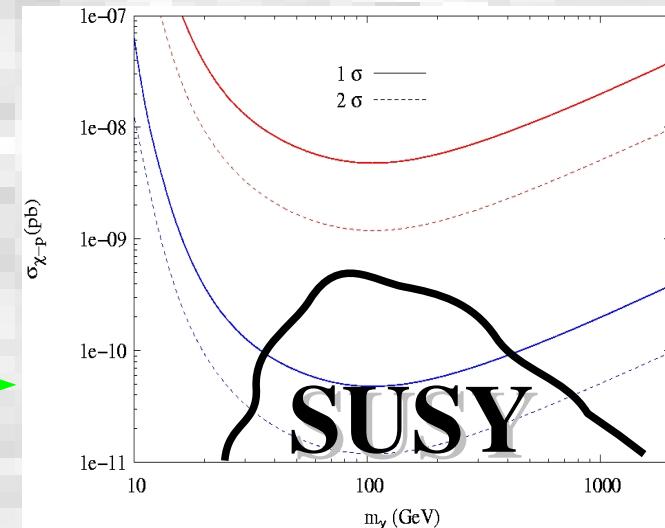
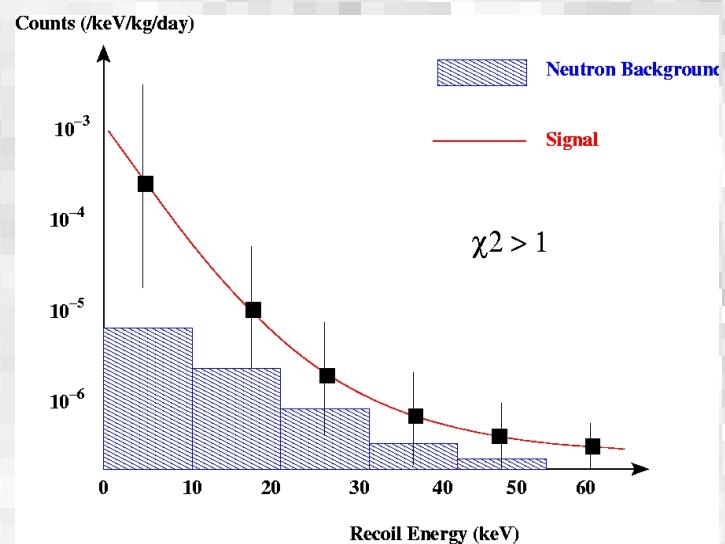
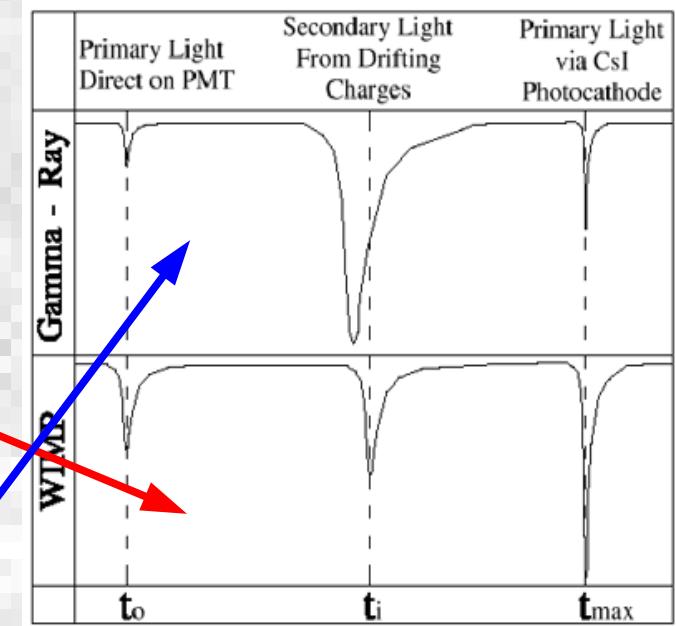
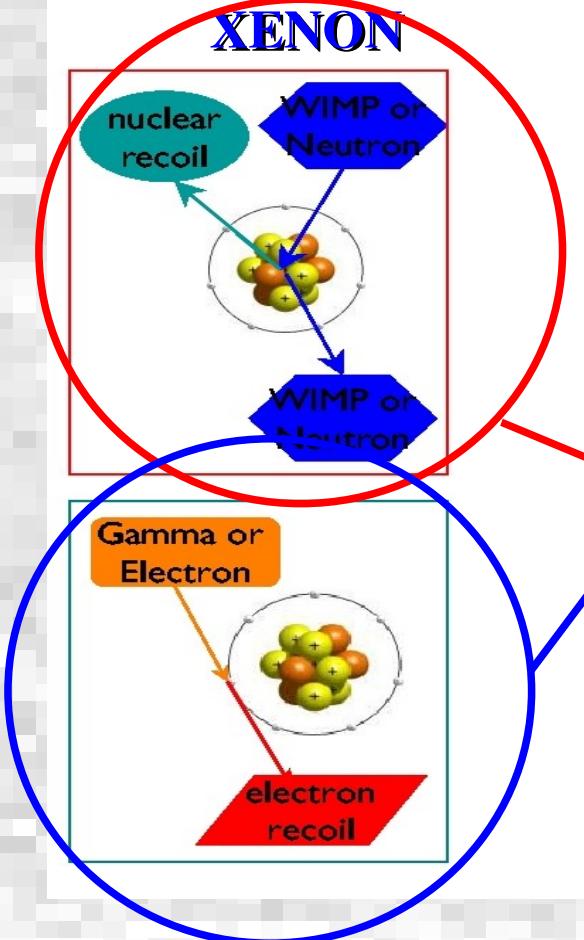
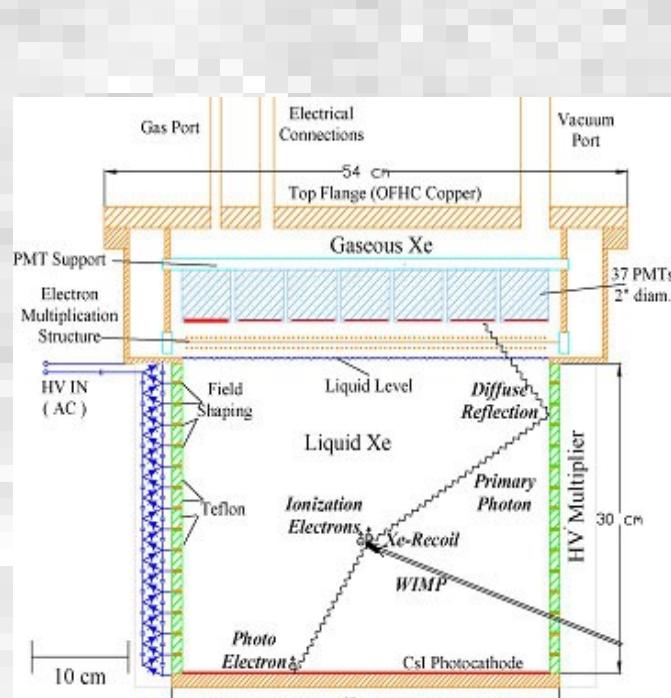
\downarrow

$$\frac{m_\chi m_N}{m_\chi + m_N}$$

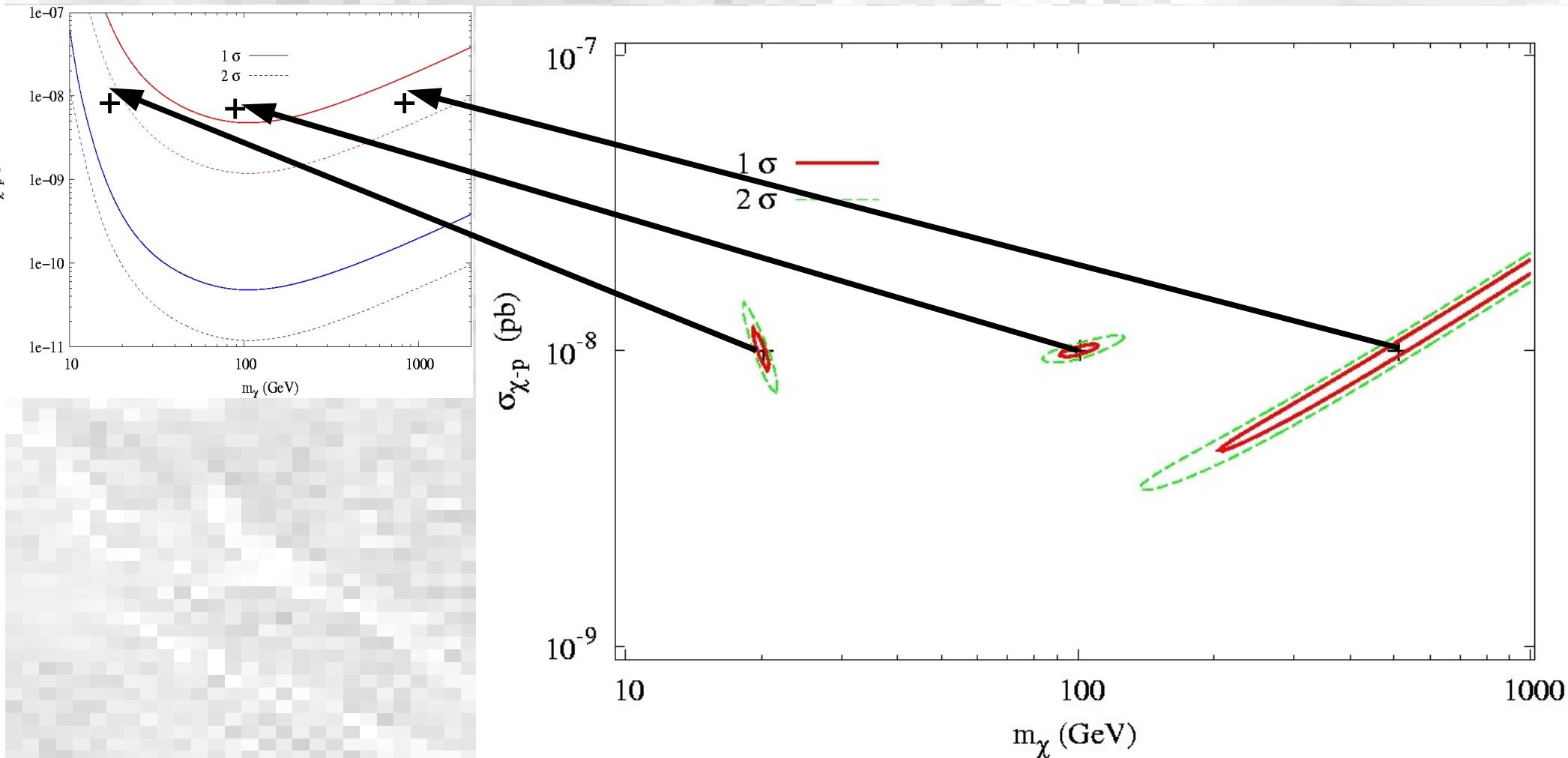
$$\chi^2 = \frac{1}{n} \sum_{i=1}^n \left(\frac{N_i^{tot} - N_i^{bkg}}{\sigma_i} \right)^2;$$



Direct Detection : the background



Direct Detection : Mass measurement

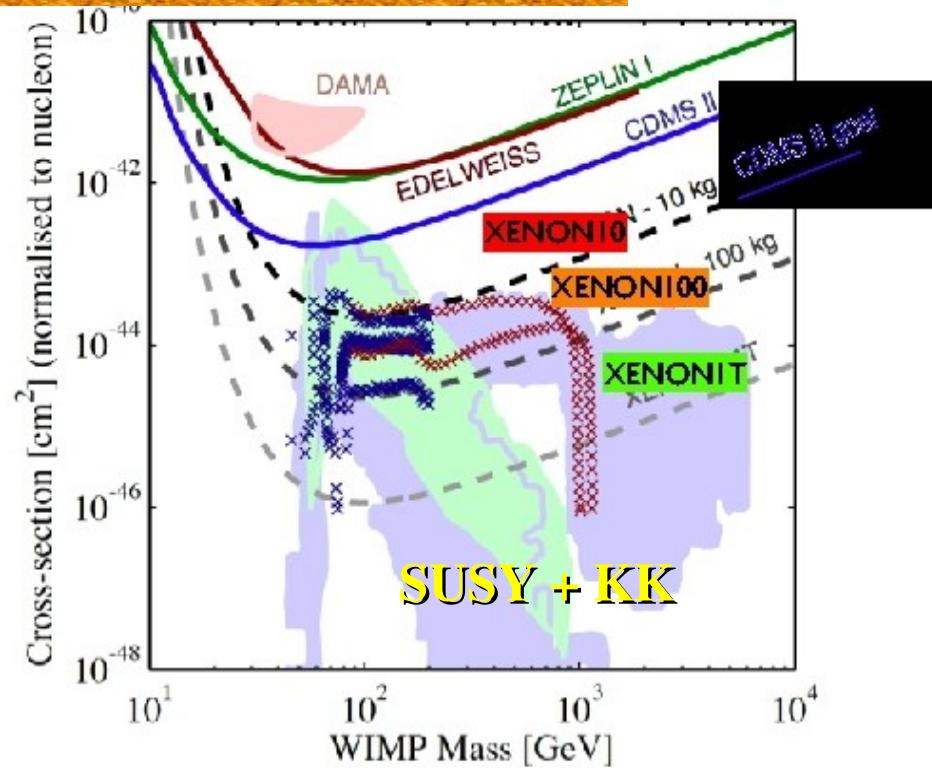


$$\frac{dN}{dE_\tau} = \frac{\sigma \rho}{2 m_\tau^2 m_\chi} F(E_\tau)^2 \int_{v_{min}(E_\tau)}^{\infty} \frac{f(v)}{v} dv,$$

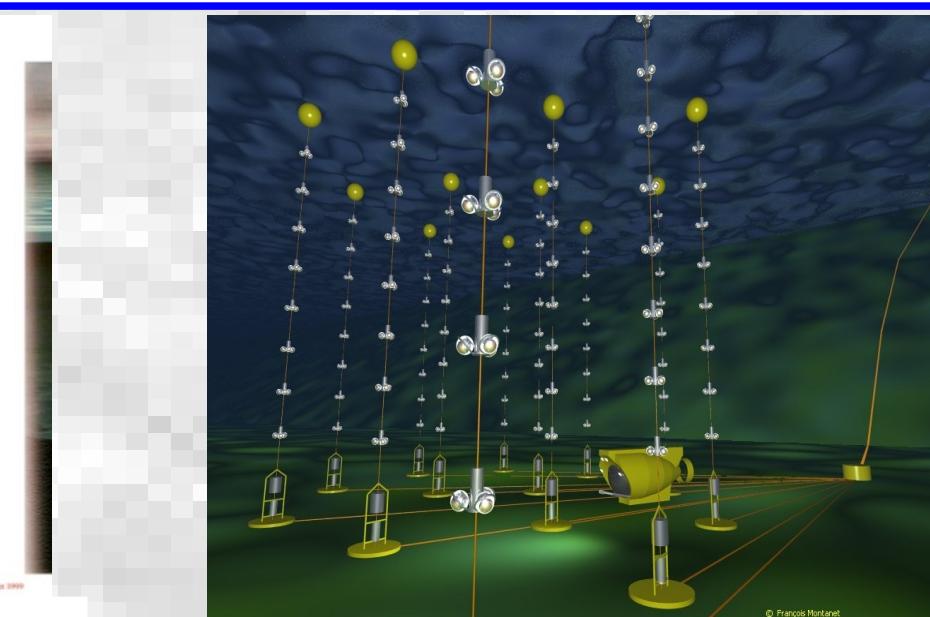
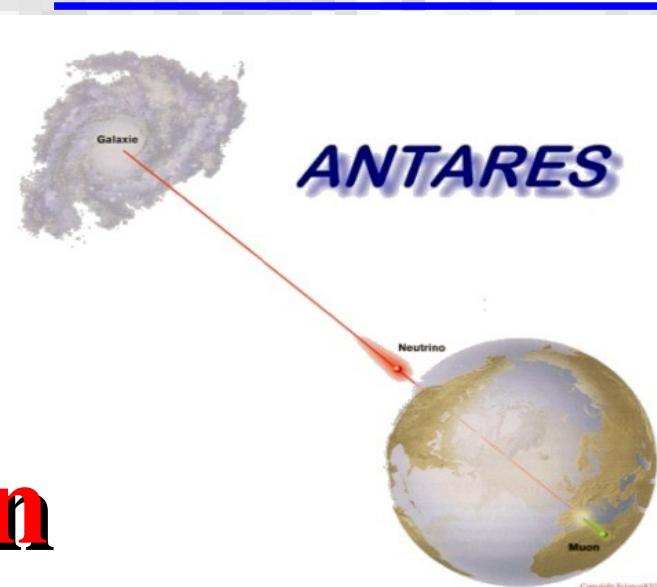
\downarrow
$$\frac{m_\chi m_N}{m_\chi + m_N}$$

Direct Detection : other experiments

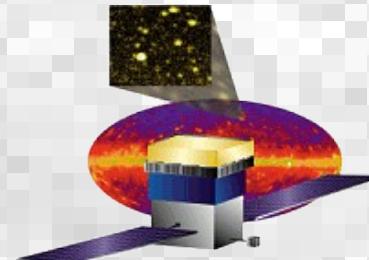
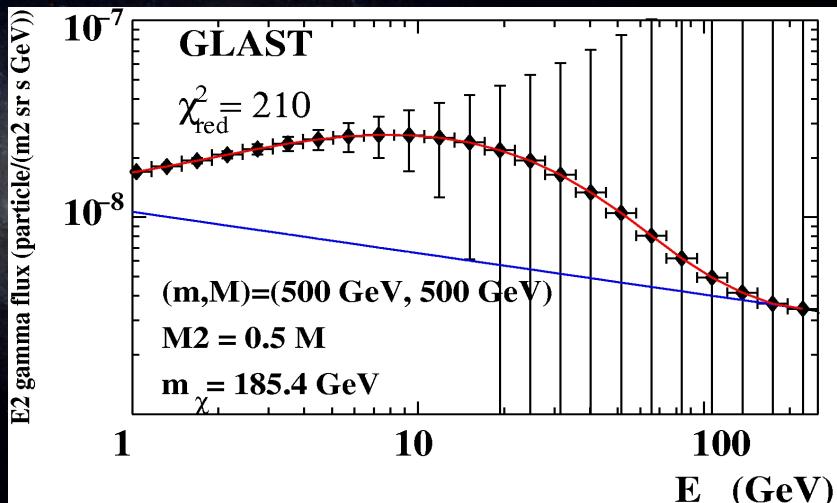
Spin dependant/spin independent : COUPP
[Fermilab]
Edelweiss [UE]
CDMS [US]
KIM [Korea]



Local
Detection



Indirect detection from GC



GLAST (2007)

HESS (Namibie, 2004)

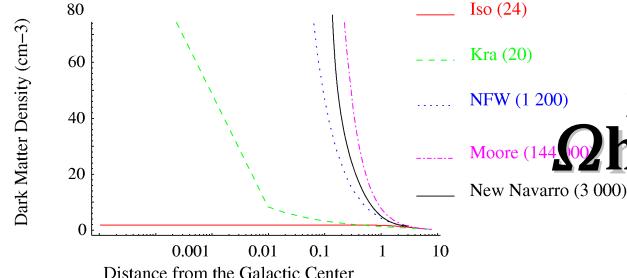


	a (kpc)	α	β	γ	$J(4 \cdot 10^{-3} \text{sr})$
NFW	20	1	3	1	$5.859 \cdot 10^2$
NFW _e	20	0.8	2.7	1.45	$3.254 \cdot 10^4$
Moore et al.	28	1.5	3	1.5	$2.574 \cdot 10^4$
Moore _e	28	0.8	2.7	1.65	$3.075 \cdot 10^5$

$$\frac{1}{2} \frac{dN_\gamma}{dE_\gamma} \frac{\langle \sigma v \rangle}{4\pi M^2} \int \rho dl^2$$

$$\frac{v}{(100 \text{ GeV})^2} \frac{J \Delta \Omega}{M^2 [1 + (r/a)]^{\alpha(\beta-\gamma)/\alpha}}$$

$$10^{-27} \text{ cm}^3 \text{ s}^{-1} \sim 0.1 \rightarrow \Phi_\gamma \sim 10^{-11} J \Delta \Omega$$



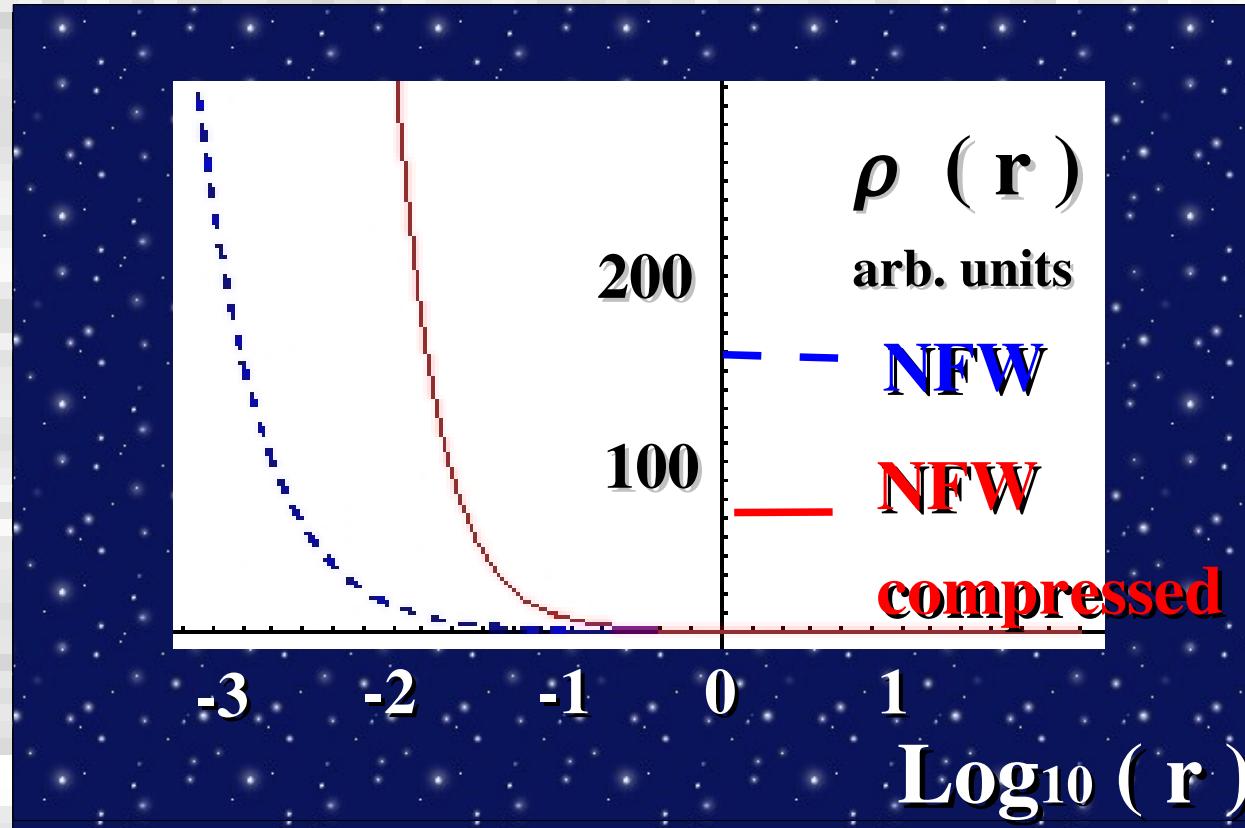
$$\Omega h^2 \sim 3.10^{-27} \text{ cm}^3 \text{ s}^{-1} \sim 0.1 \rightarrow \Phi_\gamma \sim 10^{-11} J \Delta \Omega$$

$$< \sigma v >$$

Adiabatique Compression

● Baryons

● Neutralinos



$$\rho(r) \sim 1/r$$



$$\rho(r) \sim 1/r^{1.5}$$

(NFW
compressed)

$$M_i(r_i) r_i = [M_{\text{CDM}}(r_f) + M_b(r_f)] r_f$$



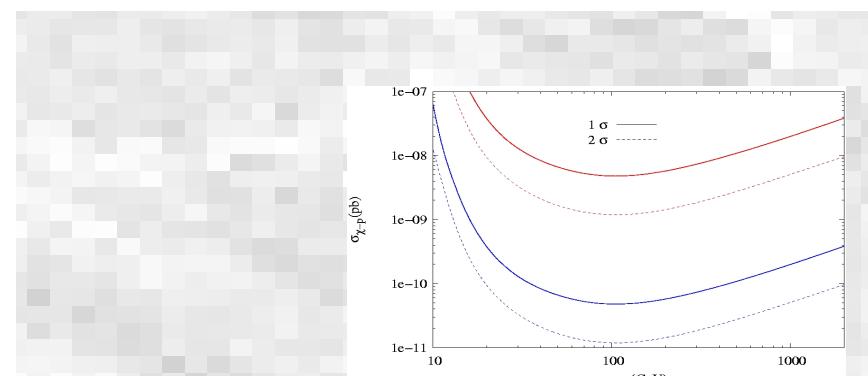
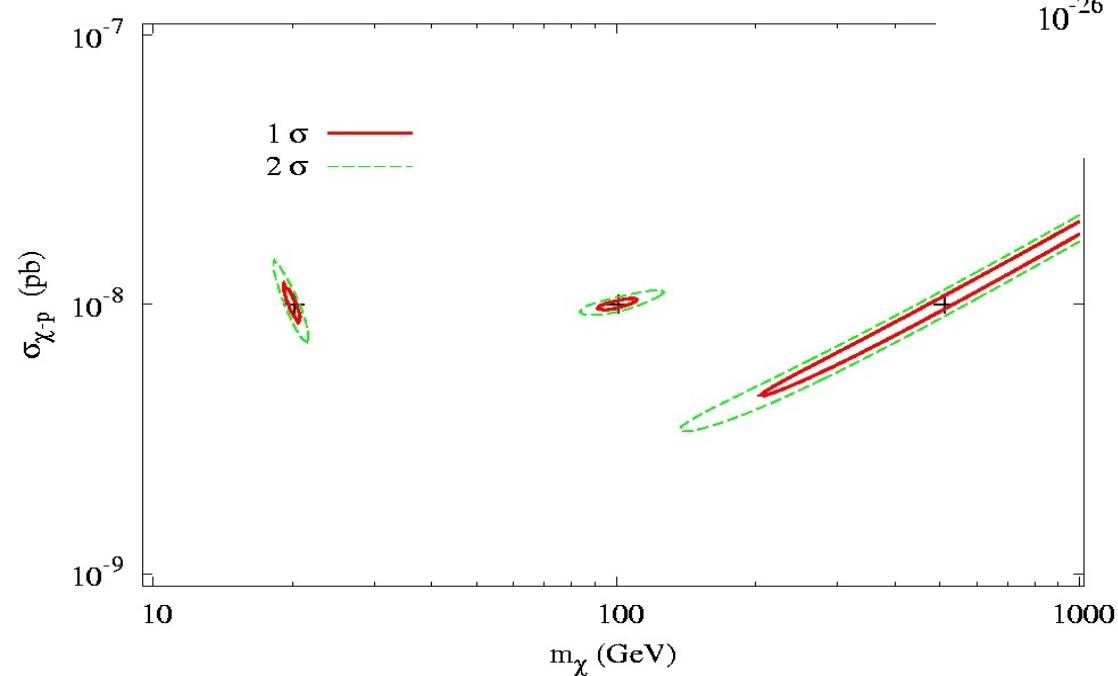
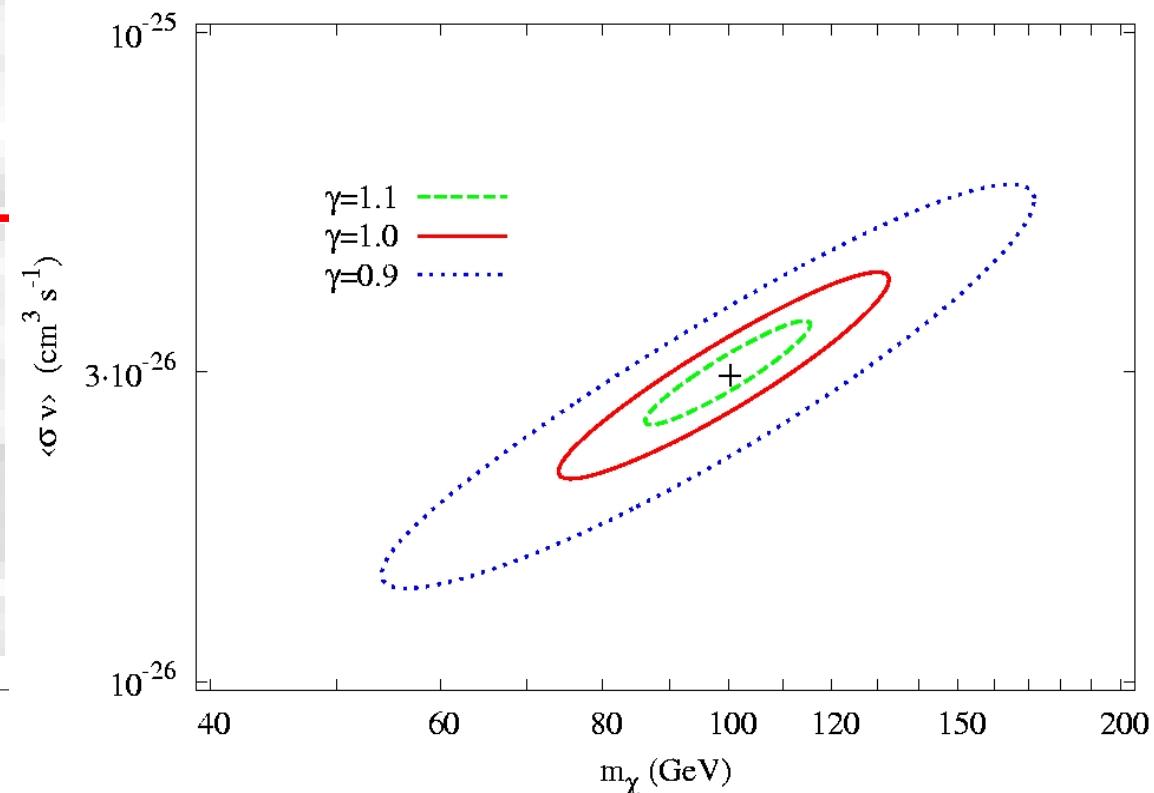
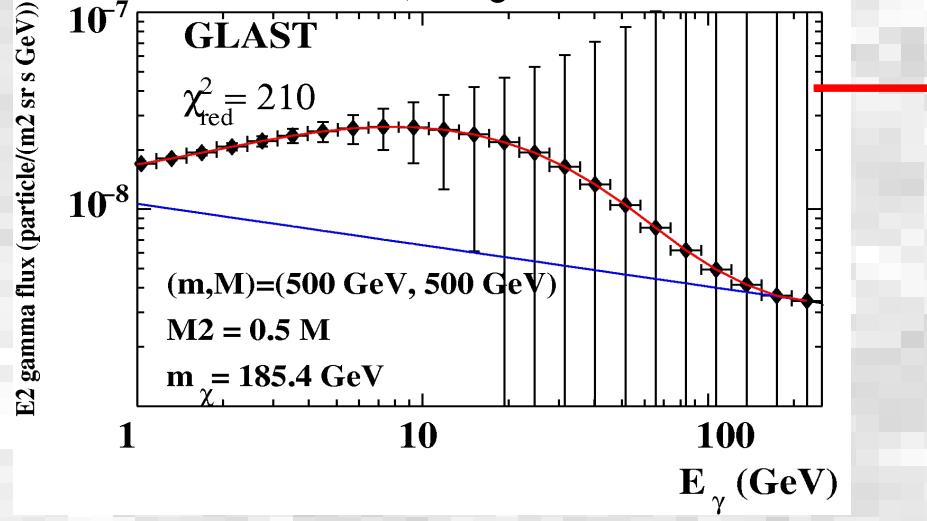
N-Body simulation
(NFW, Moore)

???

Today baryon
distribution

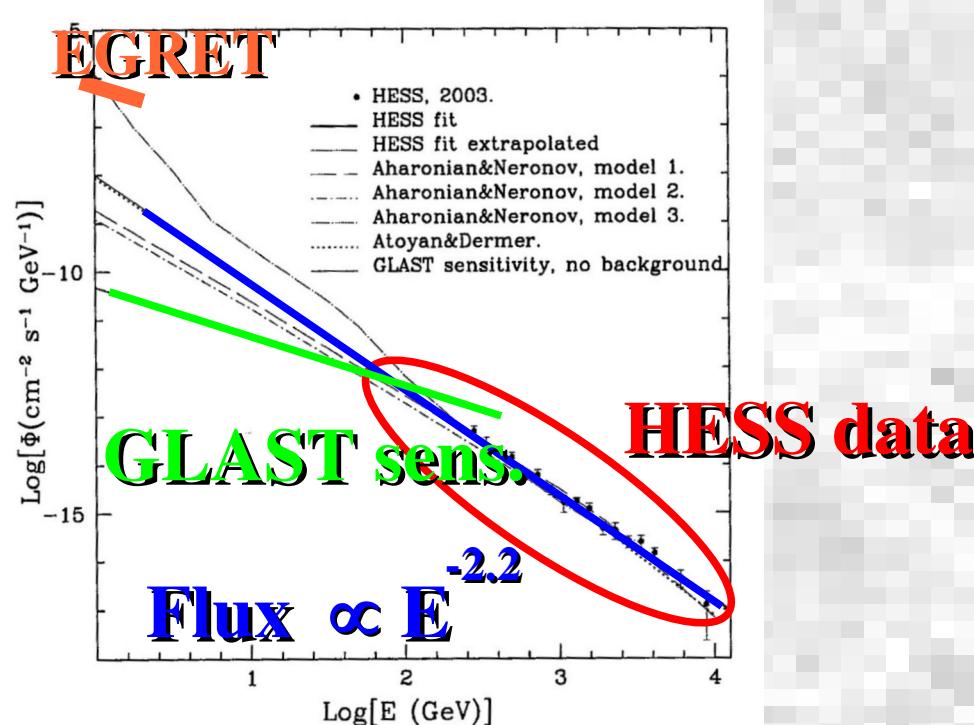
Indirect detection : Mass measurement

GLAST, 3yrs

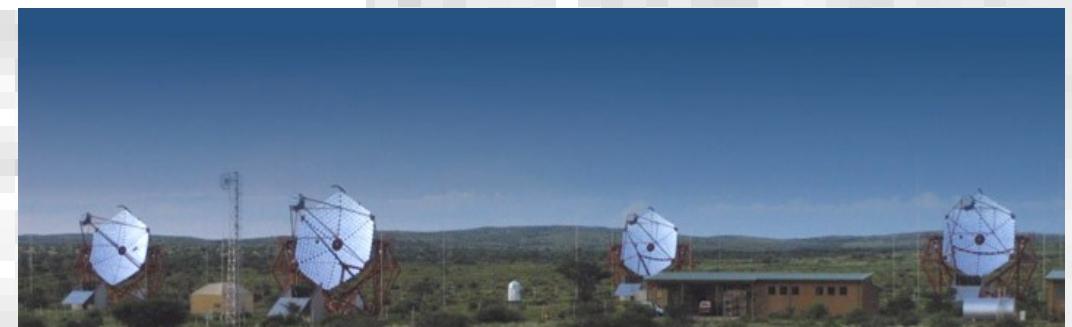


XENON, 3 yrs

Others Experiments

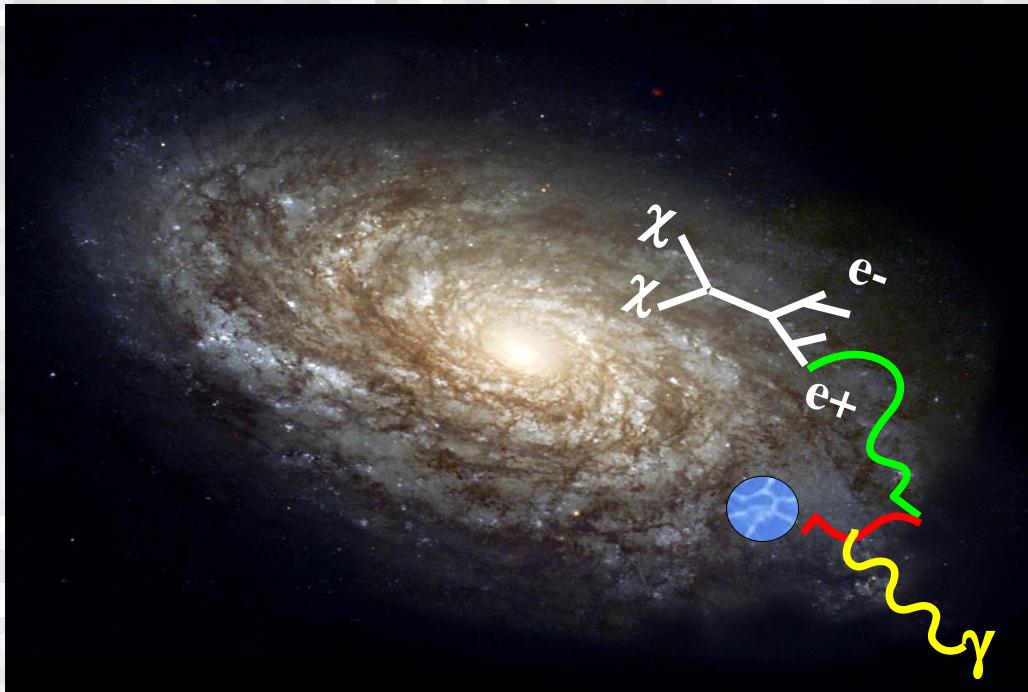


MAGIC
VERITAS

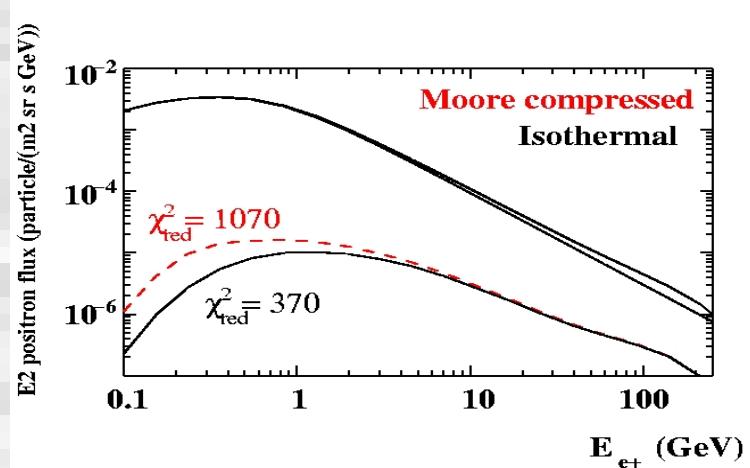


Positrons flux

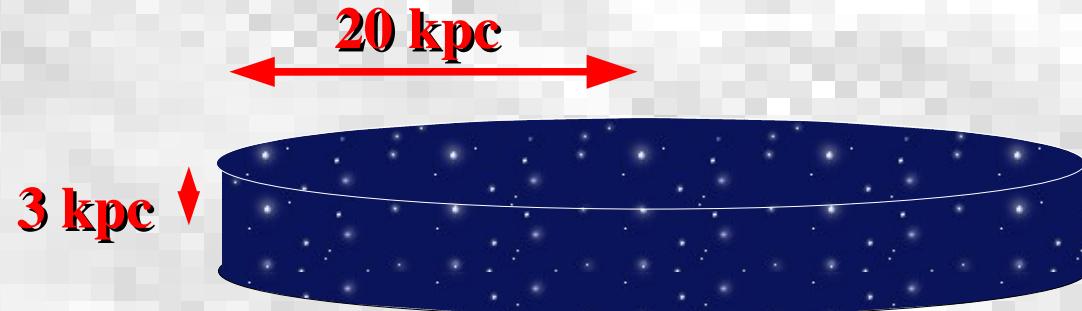
[Julien Lavalle]



$$Q_{\text{source}} = \frac{1}{2} \frac{dN_{e+}}{dE_{e+}} \langle \sigma v \rangle \left(\frac{\rho}{M} \right)^2$$

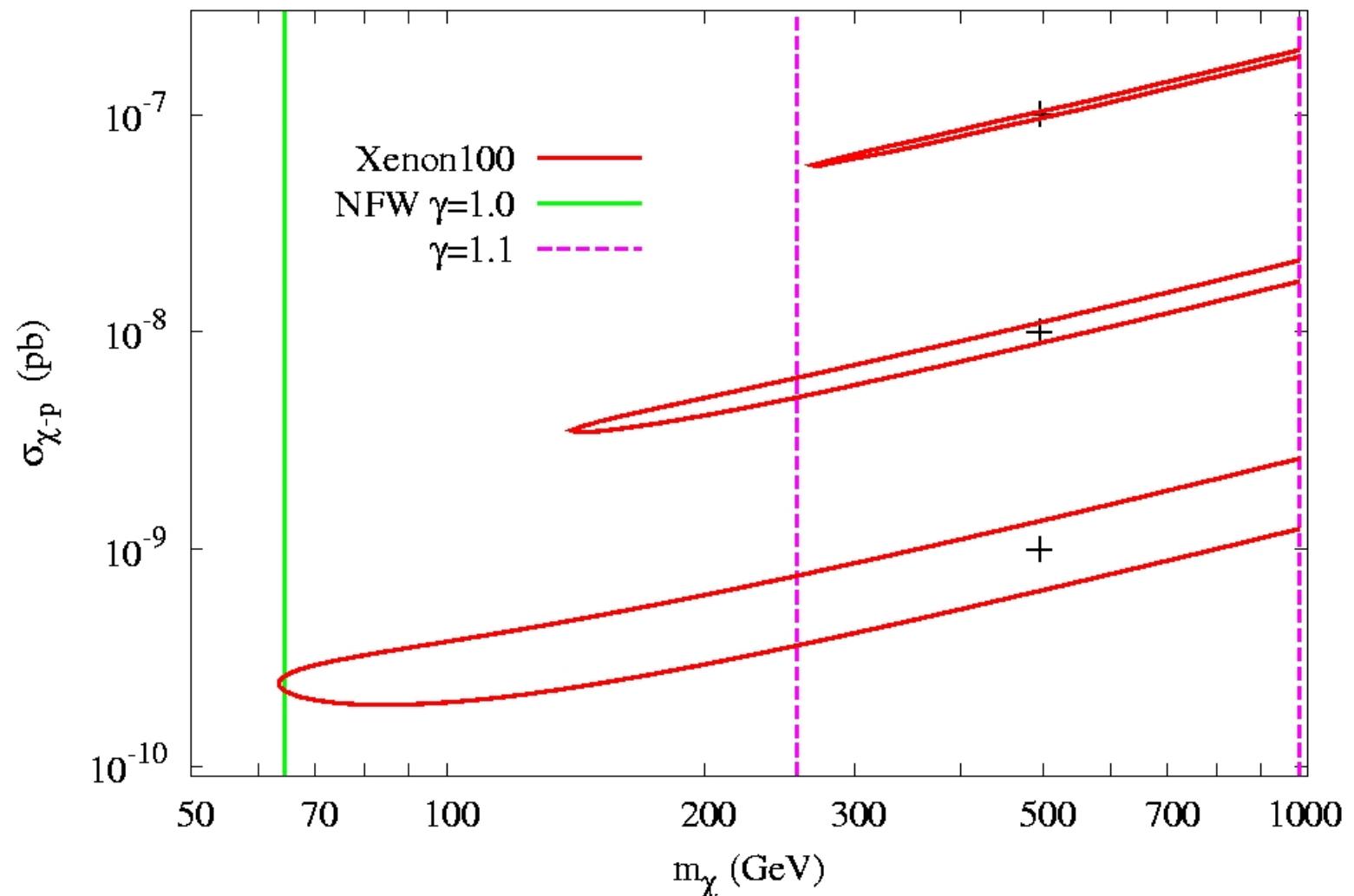


$$[\text{particle/cm}^3] \quad \frac{df(E,r)}{dt} = \frac{db(E)}{dE} * f(E,r) + K(E) * \Delta f(E,r) + Q_{\text{source}}$$

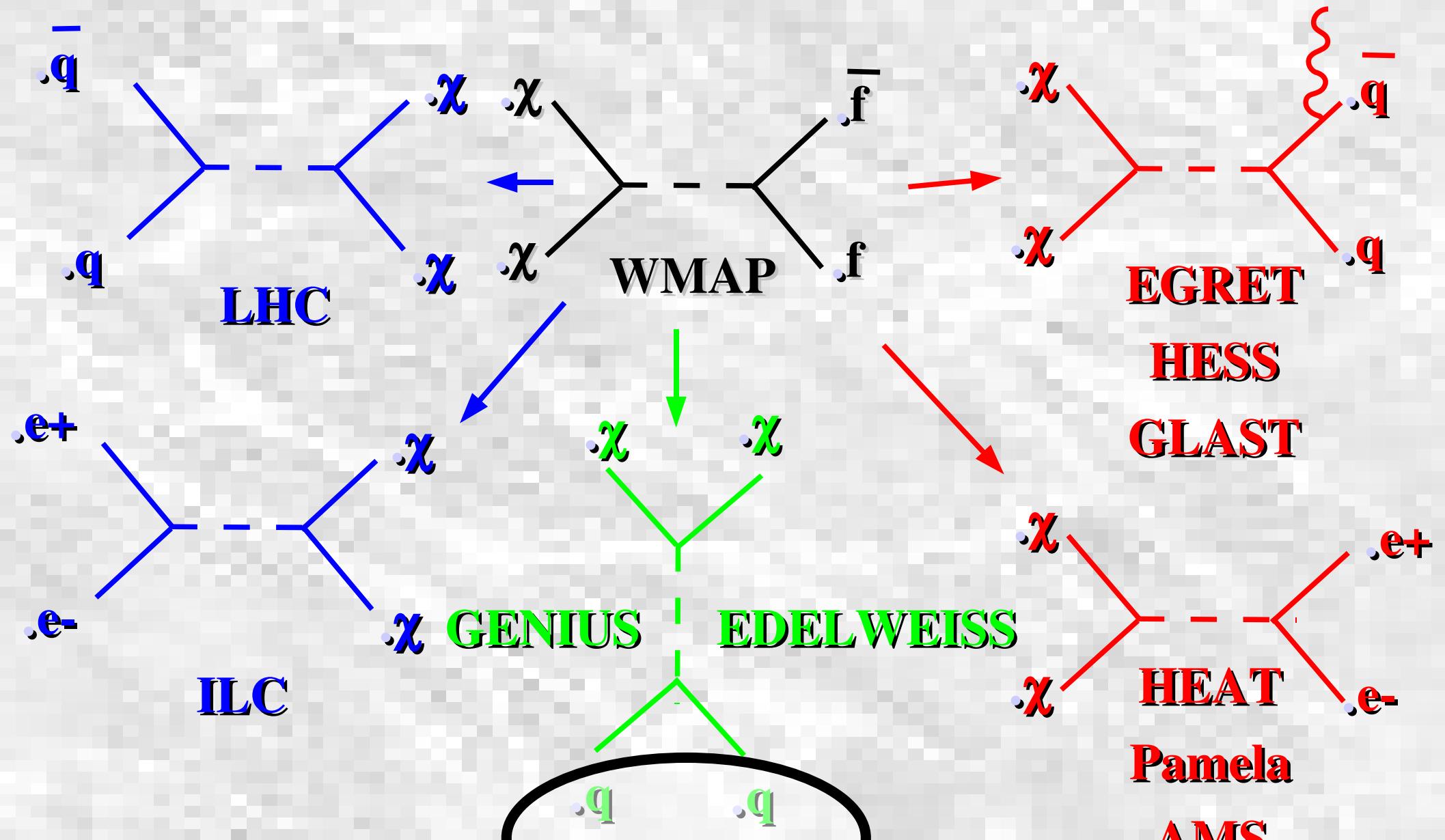


$$D_{\text{source}}(E) \sim \sqrt{\frac{E * K(E)}{b(E)}} \sim 1.8 (E/1\text{GeV})^{-0.2}$$

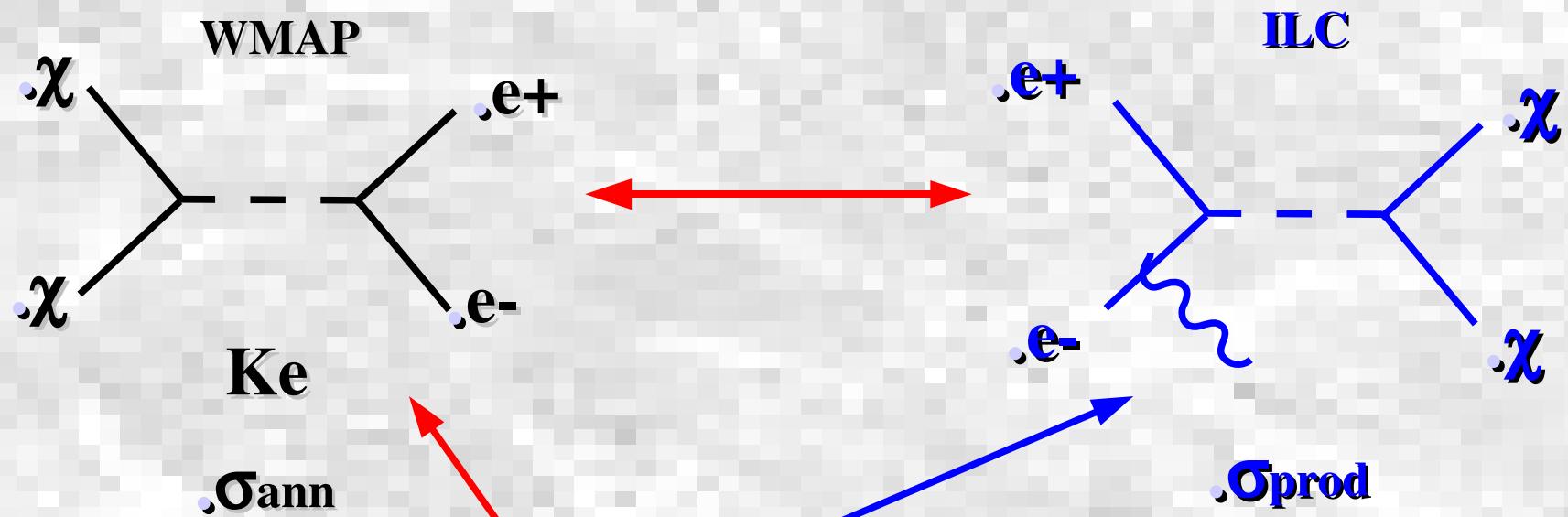
Complementarity between Direct and Indirect detection



Complementarity between different detection modes



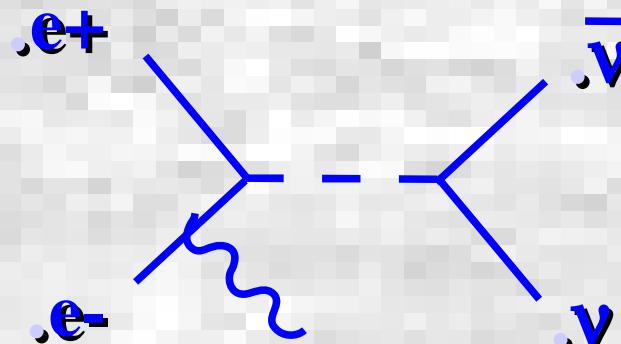
A leptonic collider as a Dark Matter detector



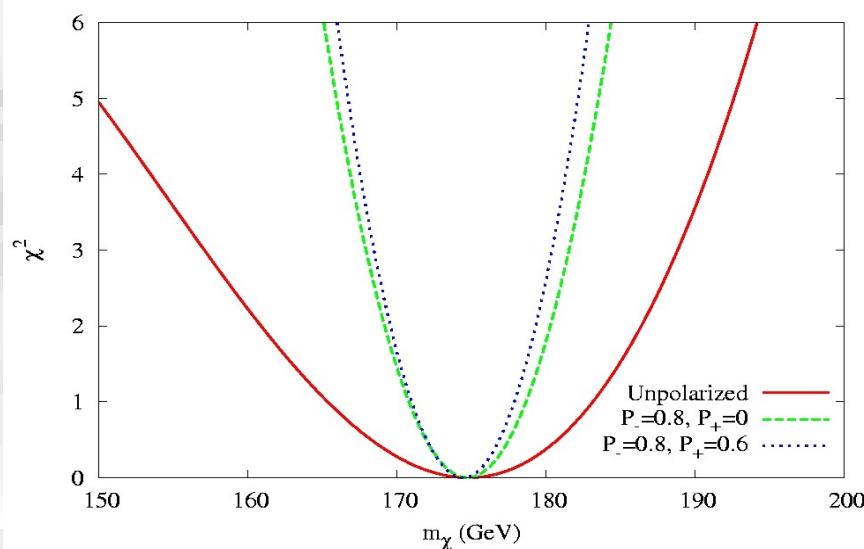
$$\frac{d\sigma}{dx d\cos\theta} (e^+ e^- \rightarrow 2\chi + \gamma) \approx \frac{\alpha \kappa_e \sigma_{ann}}{16\pi} \frac{1 + (1-x)^2}{x} \frac{1}{\sin^2\theta} 2^{2J_0} (2S_\chi + 1)^2 \left(1 - \frac{4M_\chi^2}{(1-x)s}\right)^{1/2+J_0}. \quad (5.20)$$

Colinear or soft-gamma approximation

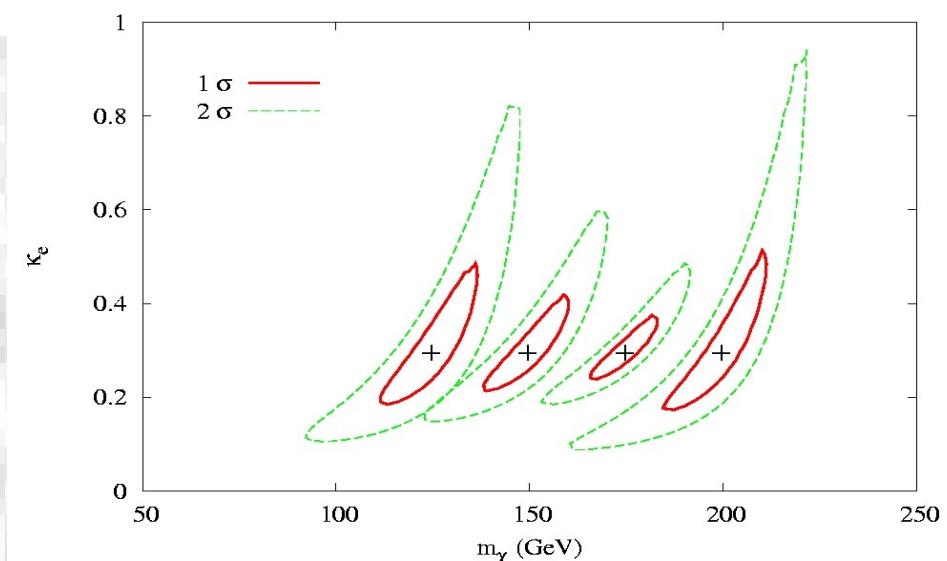
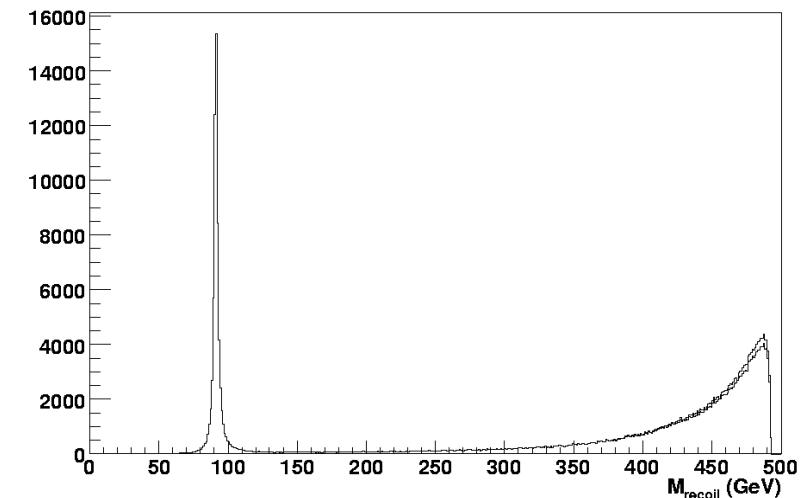
The background



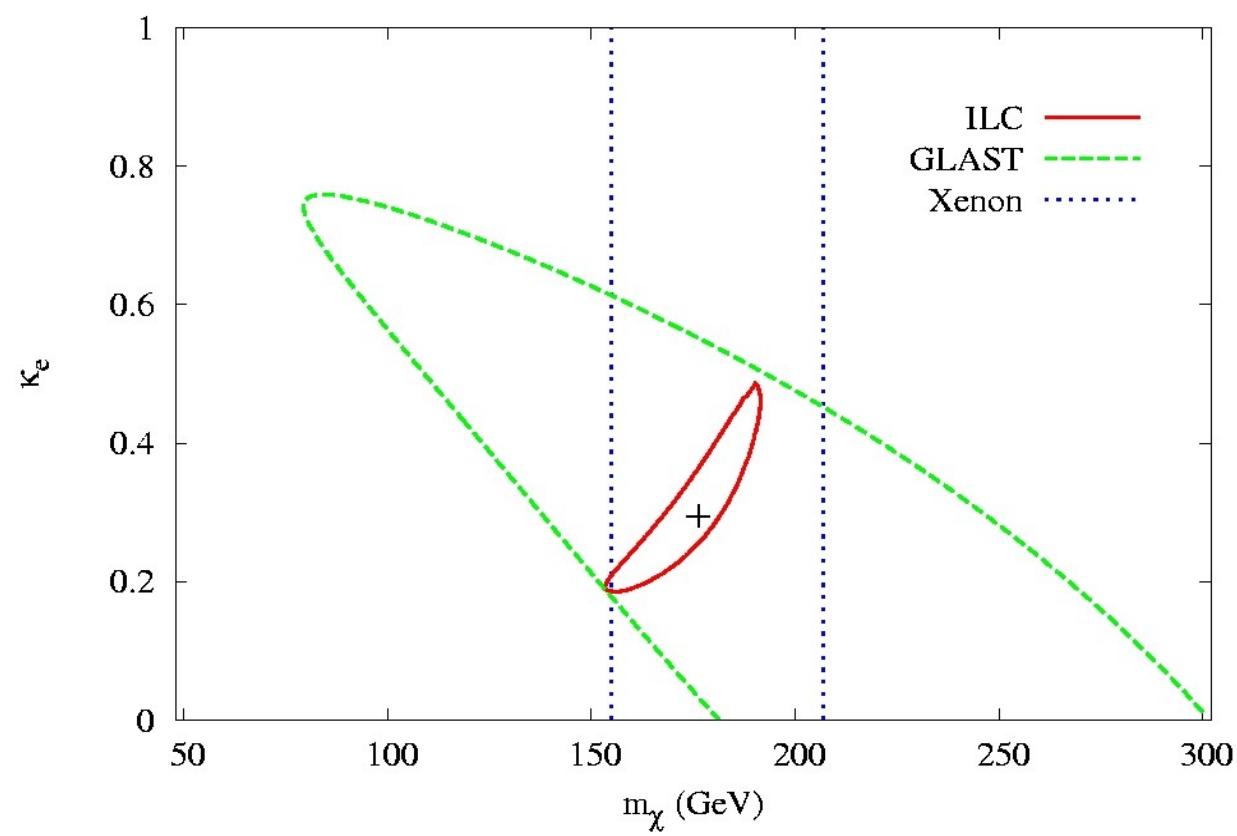
Background



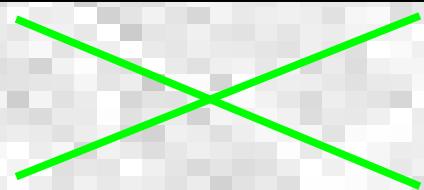
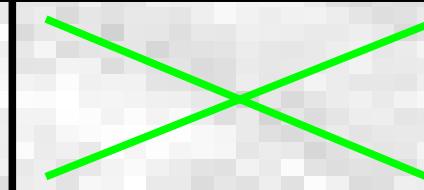
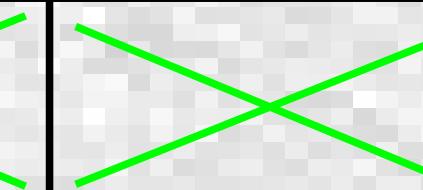
N_{bi}



Complementarity Direct, Indirect and ILC



Summary

Mass	Direct detection	Indirect detection	Leptonic collider
50 GeV	+/- 5 GeV	+/- 10 GeV	
100 GeV	+/- 10 GeV	+/- 20 GeV	+/- 40 GeV
175 GeV	+/- 60 GeV	+/- 90 GeV	+/- 25 GeV
500 GeV			

Conclusions

Possible Model Independent Studies

Surprising how similar are the precisions reached

Strong correlation/complementarity

More precise spectrum : 50-200 GeV

Testable within the 5 next years

(possibilities of seeing nothing at LHC)