ν probes of the Nature of light Dark Matter

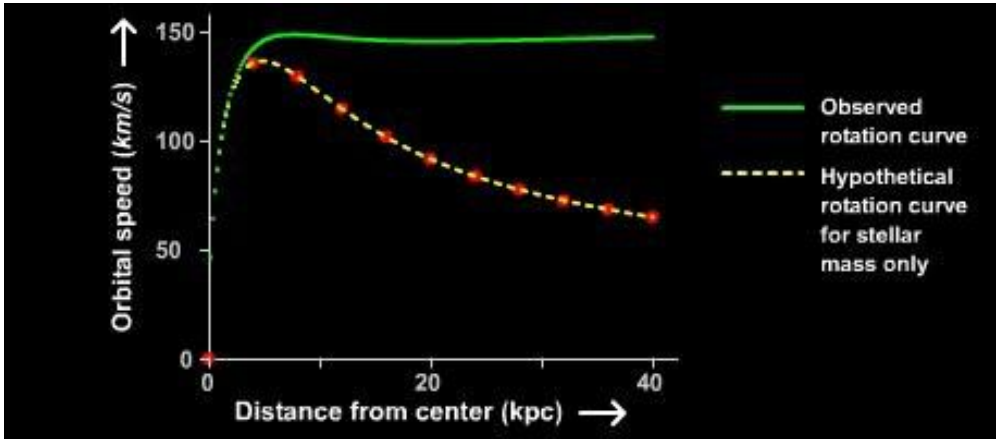
Enrique Fernández Martínez

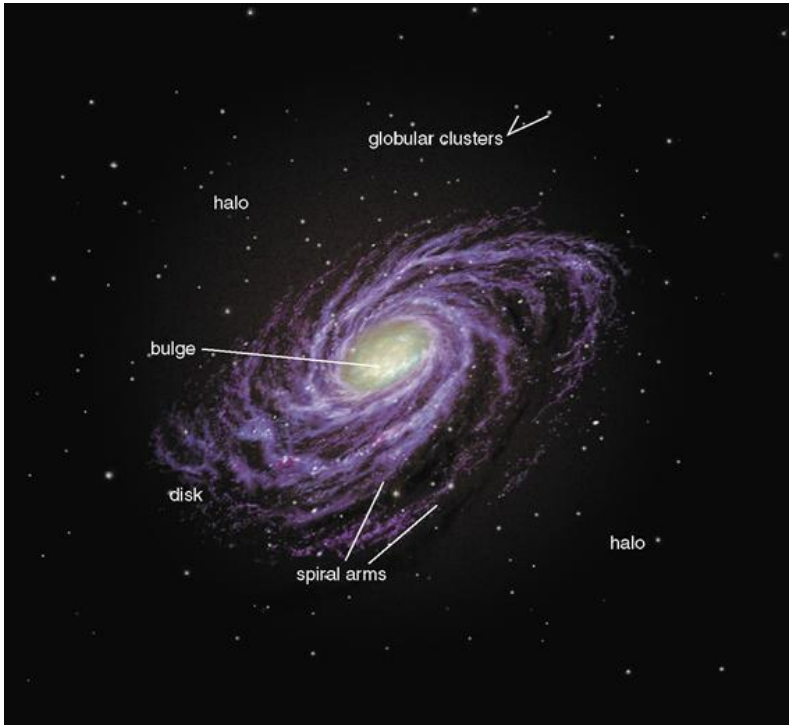
Work in collaboration with S. Agarwalla, M. Blennow and O. Mena arXiv:1105.4077

The DM puzzle

Extra invisible matter component constituting ~22% of the total energy density to account for:

Rotation curves of galaxies





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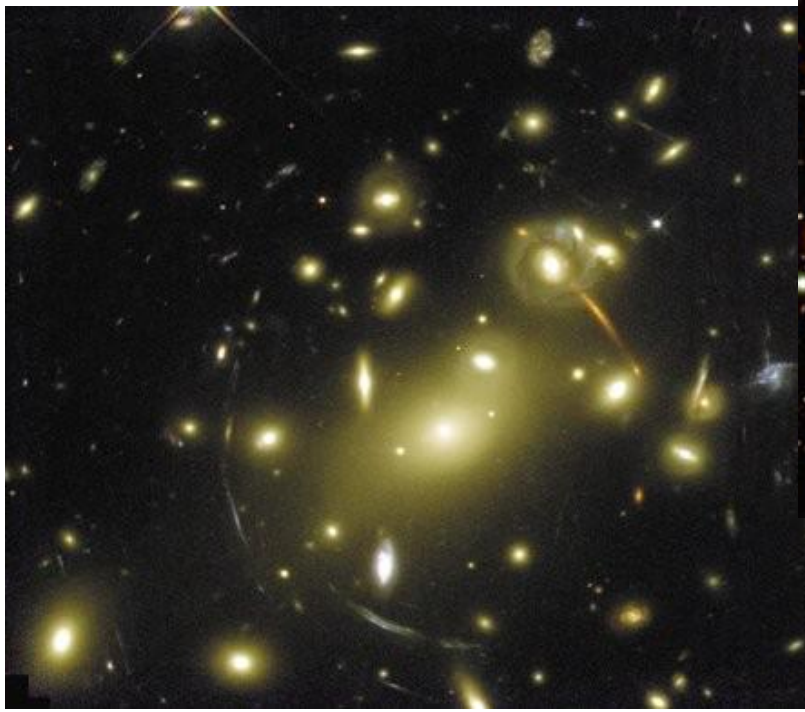

Bullet cluster

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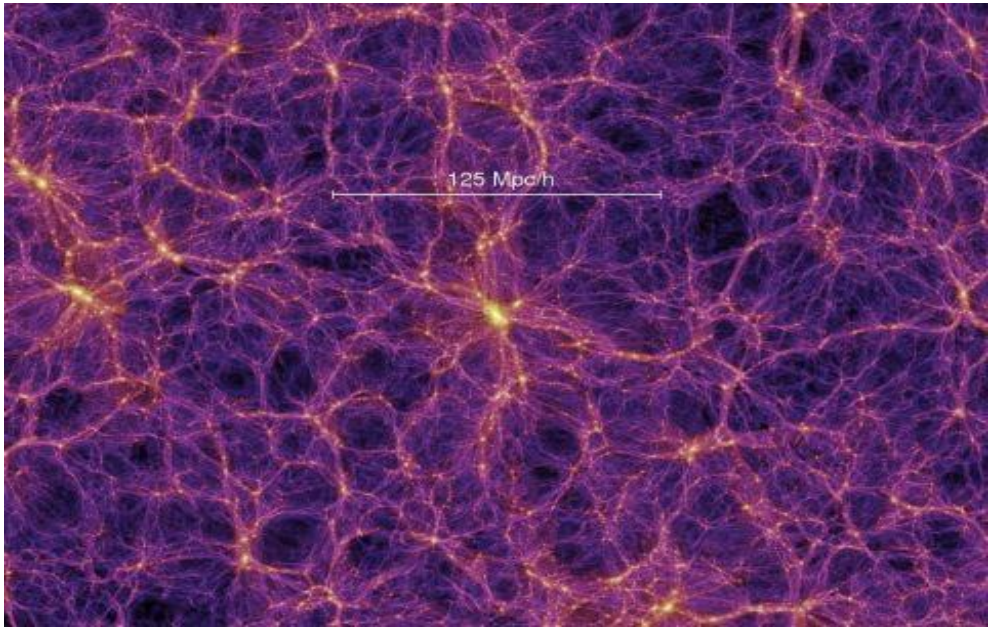
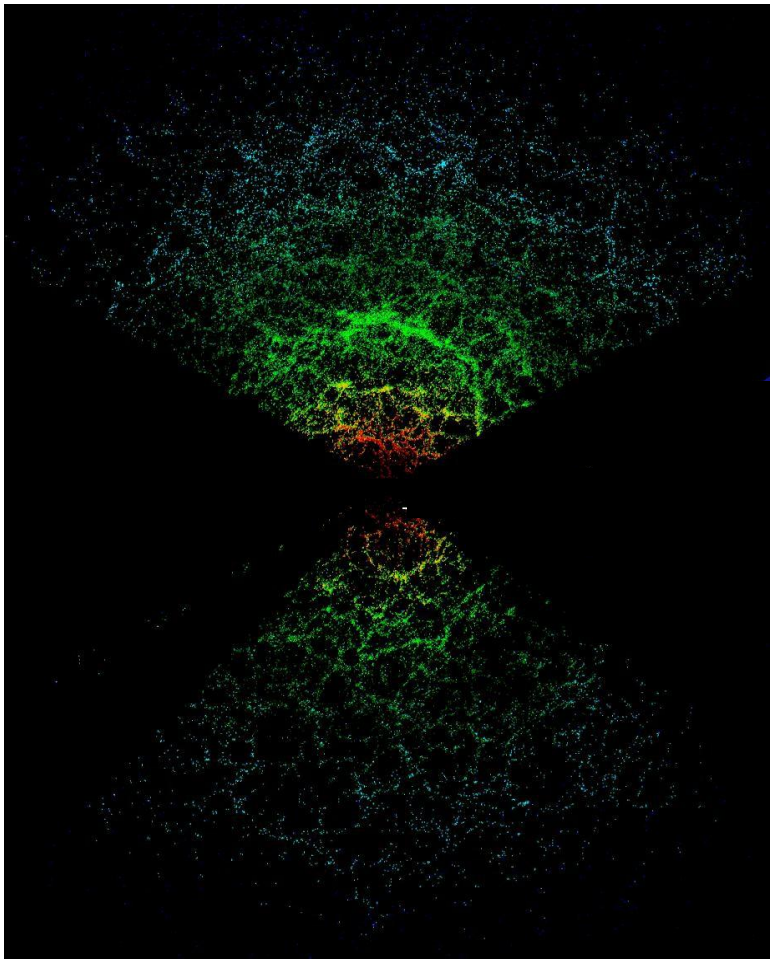
Structure Formation



Millenium simulation



SDSS

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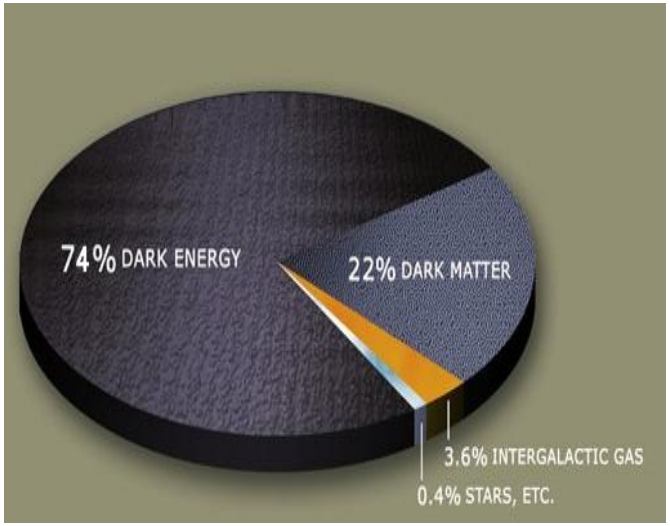

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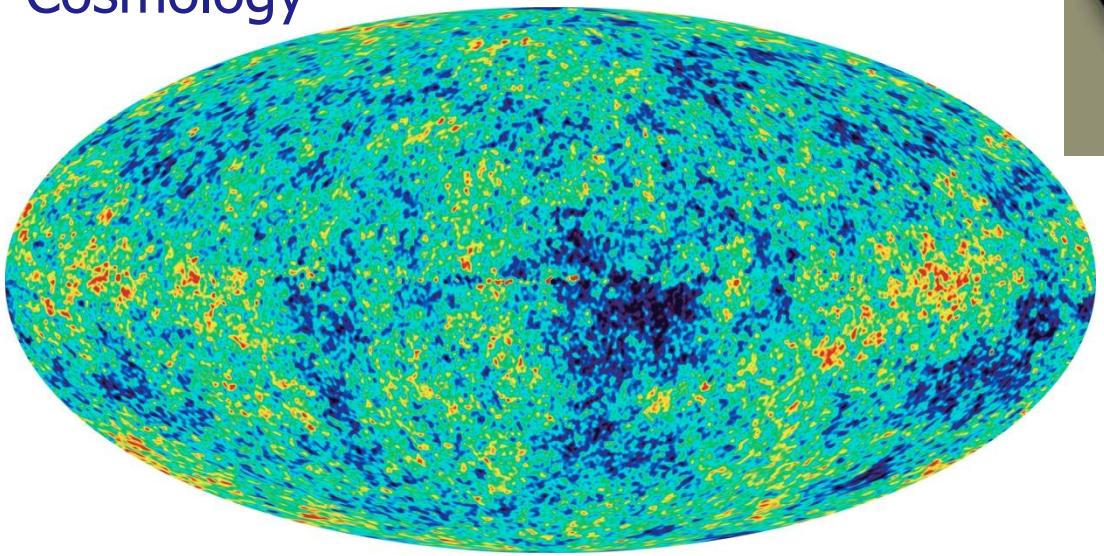

CMB as seen by WMAP

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What are the DM proporties?
Mass?
Interactions with the SM?

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We need DM probes to measure them

Direct probes of DM

Direct detection: Measure the nuclear recoil produced by the scatering of DM with the detector

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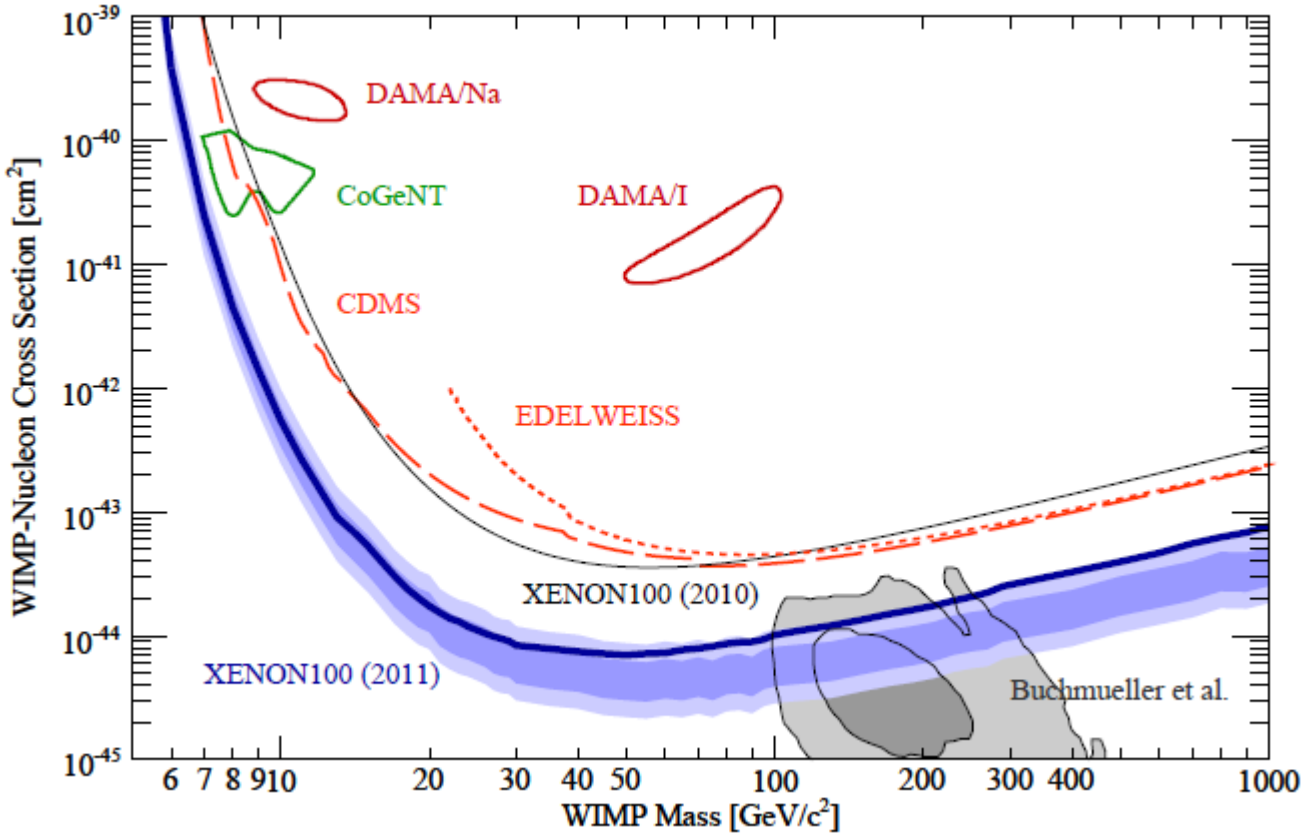
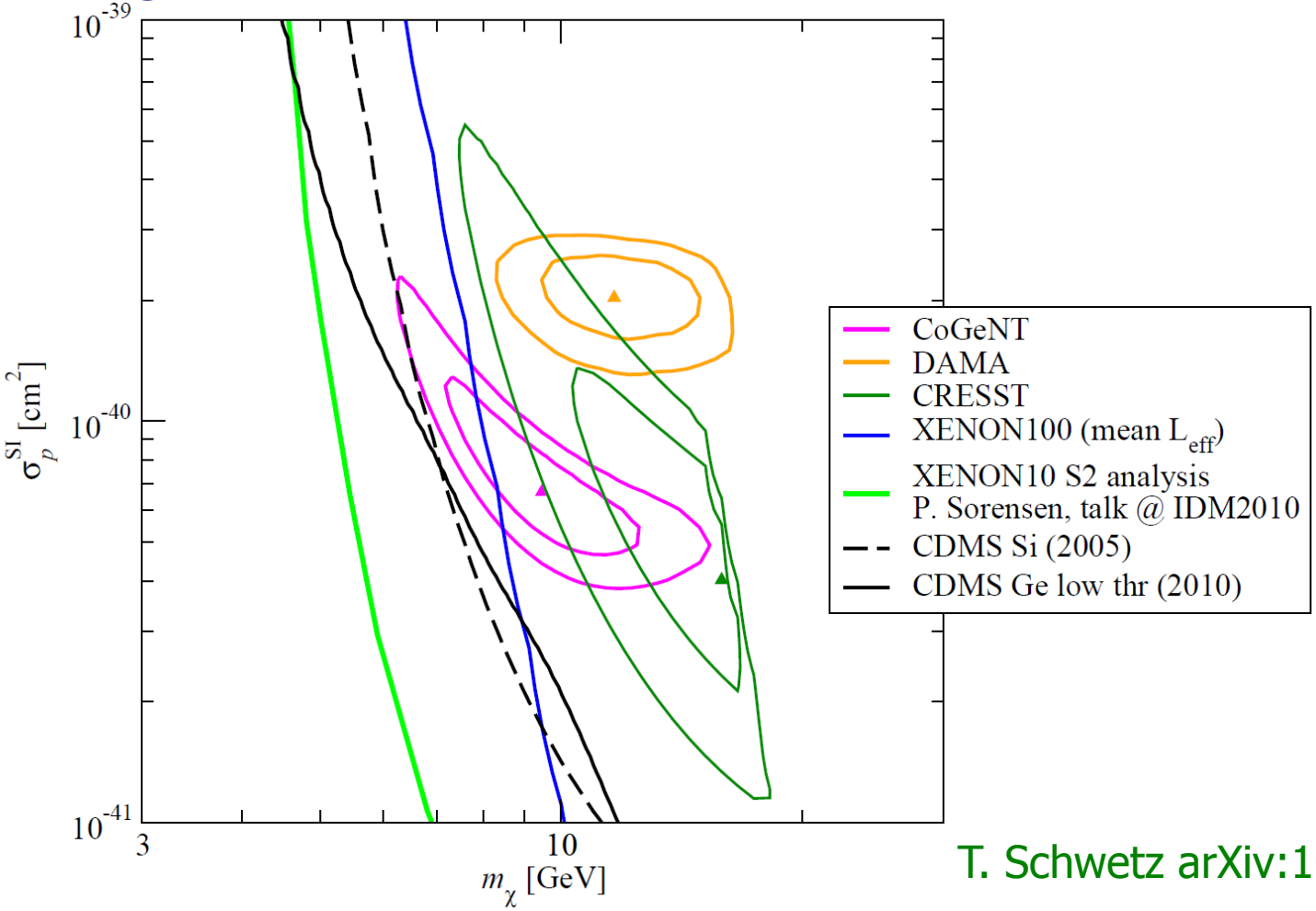


from E. Aprile *et al.* arXiv:1104.2549

Direct probes of DM

Direct detection: Measure the nuclear recoil produced by the scatering of DM with the detector



T. Schwetz arXiv:1011.5432

Indirect probes of DM

Indirect detection: Search for the producs of DM annihilations or decays

gamma rays: MAGIC, CANGAROO-III, HESS, VERITAS, EGRET, Fermi...

positrons & antiprotons: HEAT, BESS, PAMELA, AMS…

neutrinos: IceCUBE, Super-Kamiokande

Neutrino fluxes are challenging to measure.
Stronger flux from the regions with larger DM density: near the galactic centre or from Sun and Earth

DM from celestial bodies

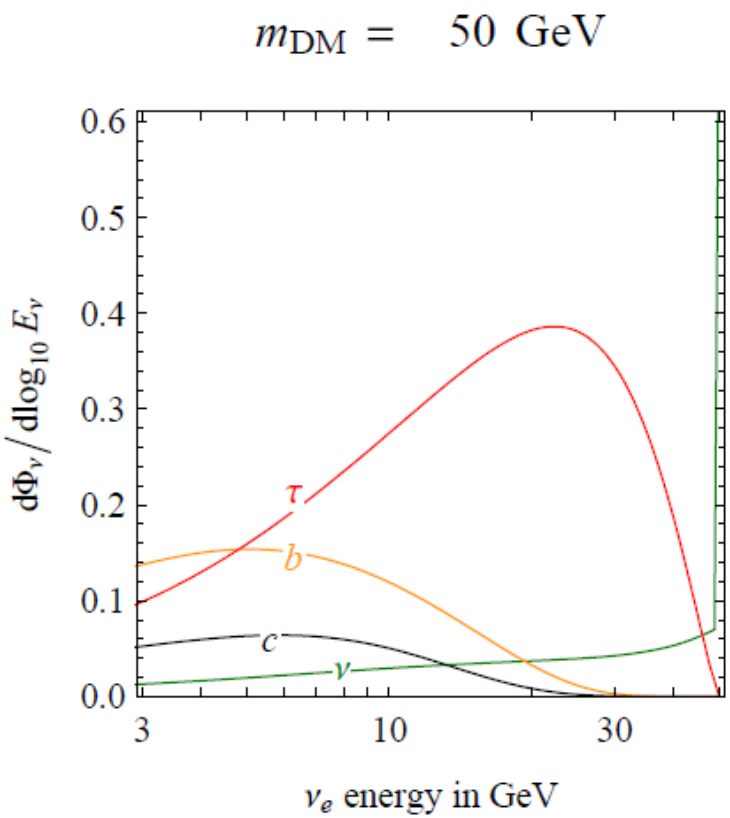
As the Sun passes through the DM halo, scatterings between DM and nuclei in the Sun can lower the DM velocity and trap it.

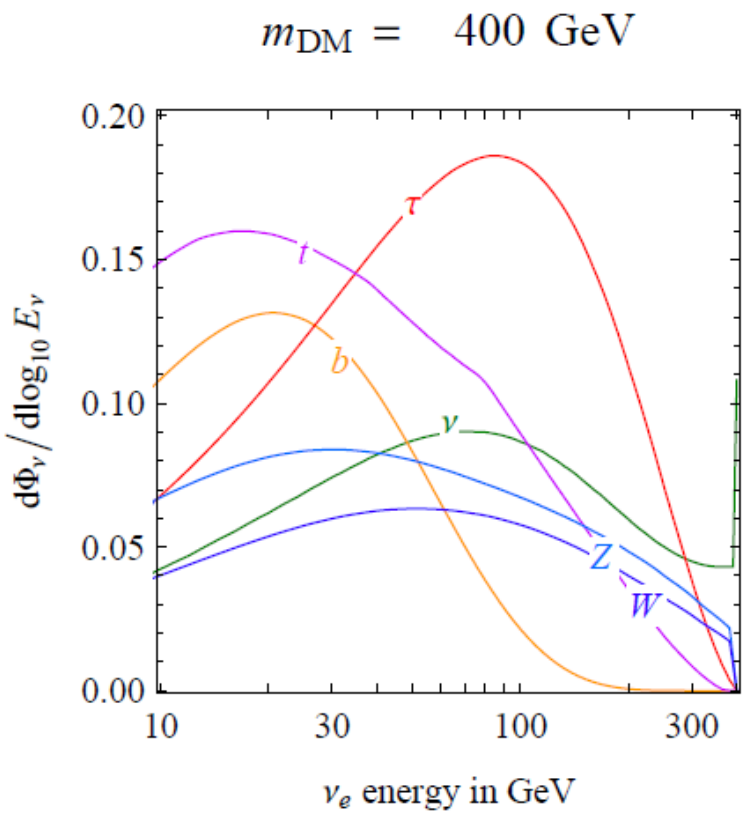
DM accumulates in the Sun and the higher density provides enhanced annihilation rates. In equilibrium $\Gamma_{capture} = 2\Gamma_{annihilation}$

$$\Gamma_{capture} \cong 9 \times 10^{24} s^{-1} \left(\frac{\rho_{local}}{0.3\,\mathrm{GeV/cm}^3} \right) \left(\frac{270\,\mathrm{km/s}}{\bar{v}_{local}} \right)^3 \left(\frac{\sigma}{10^{-2}\,\mathrm{pb}} \right) \left(\frac{50\,\mathrm{GeV}}{m_{DM}} \right)^2$$

Most annihilation products are lost in the Sun interior but neutrinos can shine through and be observed at Earth

nu fluxes from DM anihilations



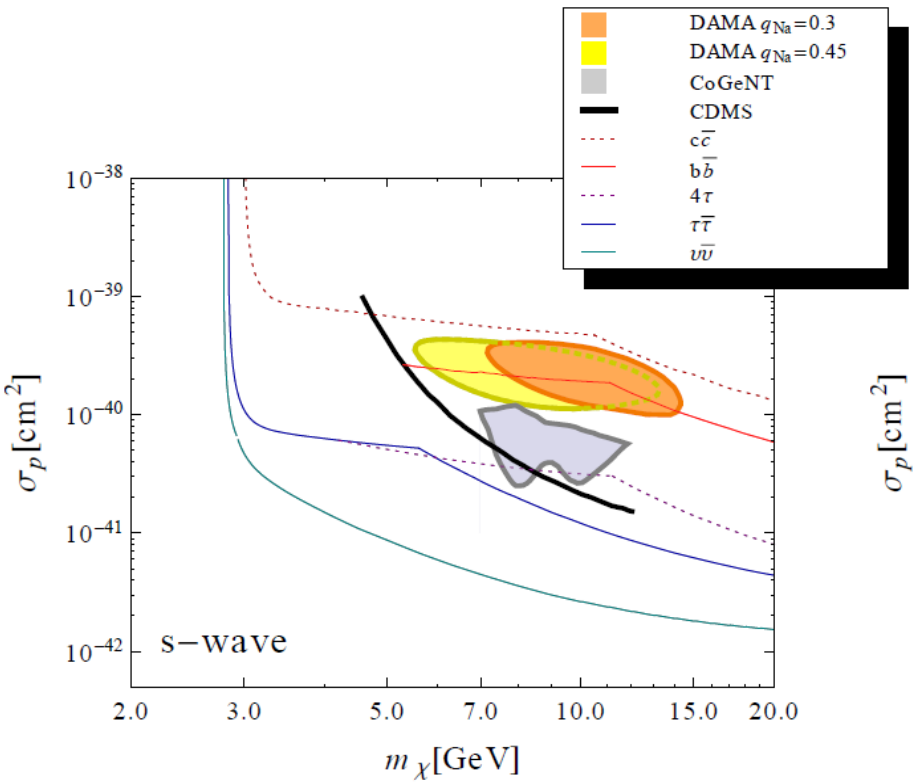


Oscillations and absorption in the Sun important!

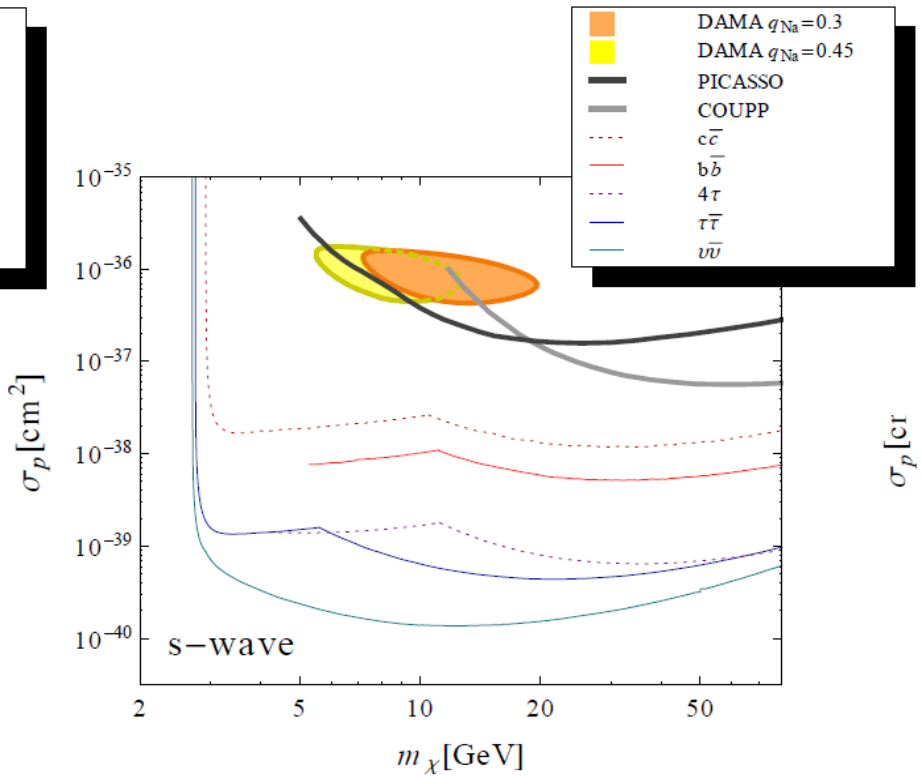
M. Cirelli et al. NPB06
hep-ph/0512090

$$\frac{dN_\nu}{d\Omega dt dE_\nu} = \frac{\Gamma_{ann}}{4\pi R^2} \sum_i BR_i \frac{dN_i}{dE_\nu}$$

Probing light DM at SK



Spin independent



Spin dependent

R. Kappl and M. W. Winkler 1104.0679

Future neutrino detectors

Large, precise neutrino detectors are being considered for the next generation of neutrino experiments:

GLACIER: Giant Liquid Argon Charge Imaging ExpeRiment
100 kt Liquid Ar neutrino detector proposed to study SuperNovae, atmospheric and astrophysical neutrino sources as well as neutrino oscillations from an accelerator beam

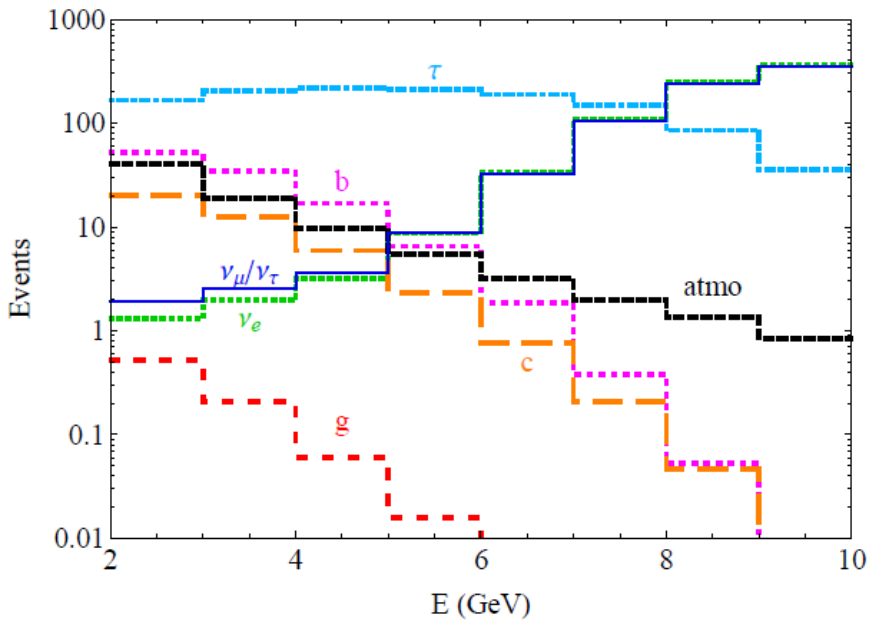
MIND: Magnetized Iron Neutrino Detector
100 kt iron detector proposed in combination with the "Neutrino factory" neutrino beam from muon decay to explore leptonic CP violation

Future neutrino detectors

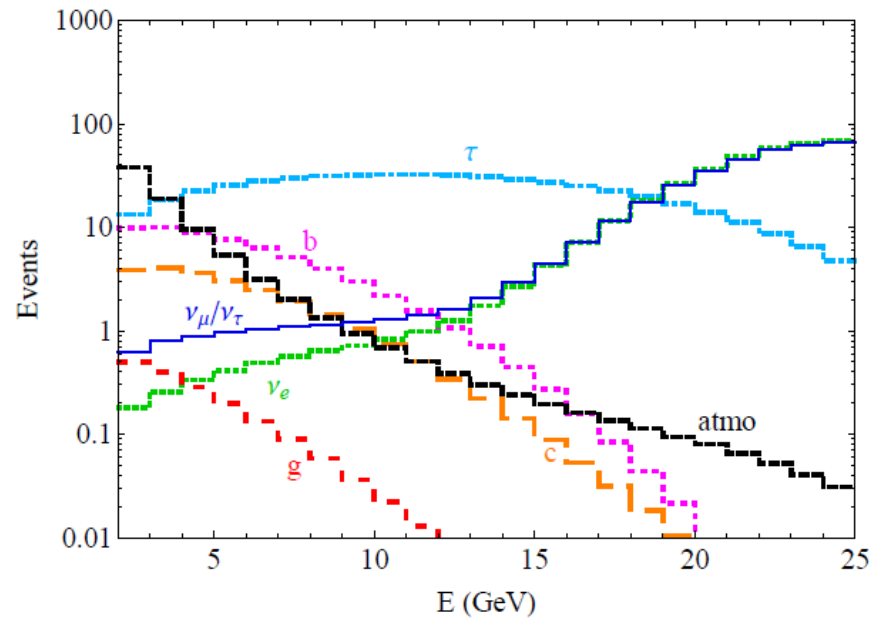
Detector characteristics	IRON (Only $\mu^{\pm}$)	LAr (Both $\mu^{\pm}$ & $e^{\pm}$)
Fiducial mass	100 kt	34/100 kt
ν energy threshold	2 GeV	2 GeV
Detection efficiency (ϵ)	60-70%	100 % for $\mu^{\pm}$ 80 % for $e^{\pm}$
ν energy resolution (δE)	$0.15E$	$0.15\sqrt{E/1\ \mathrm{GeV}}$ GeV
ν angular resolution ($\delta\theta$)	15º-3º	8º-2º
Bin size	1 GeV	1 GeV

Event rates at detectors

M = 10 GeV



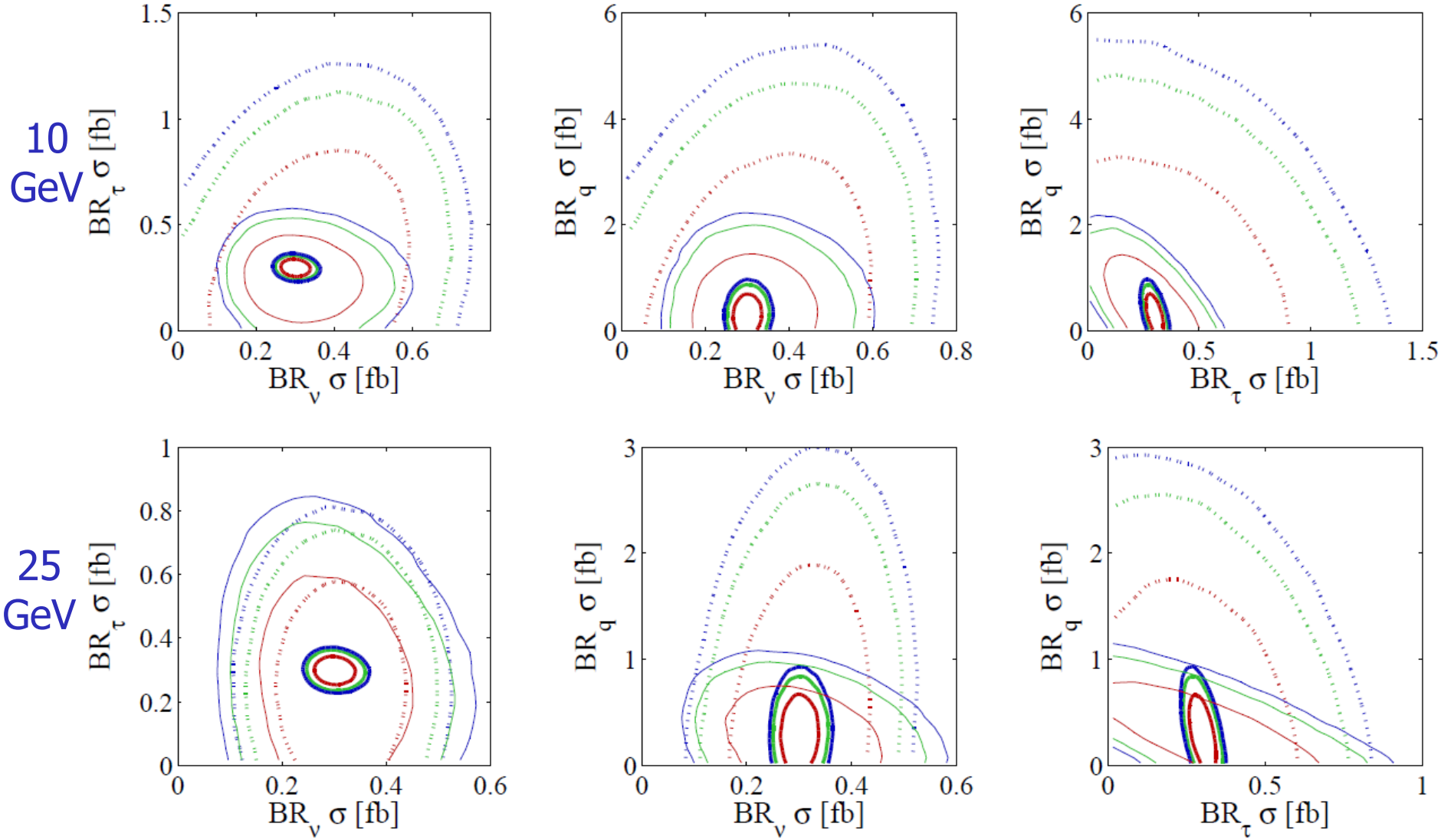
M = 25 GeV



Muon event rates at the GLACIER detector after 10 years data taking with a DM spin dependent interaction of 1 fb

ν fluxes computed with WimpSim M. Blennow, J. Esdjö and T. Ohlsson 0709.3898

Results



From a MCMC using MonteCUBES M. Blennow and EFM 0903.3985; input 0.3 fb into ν, τ and q

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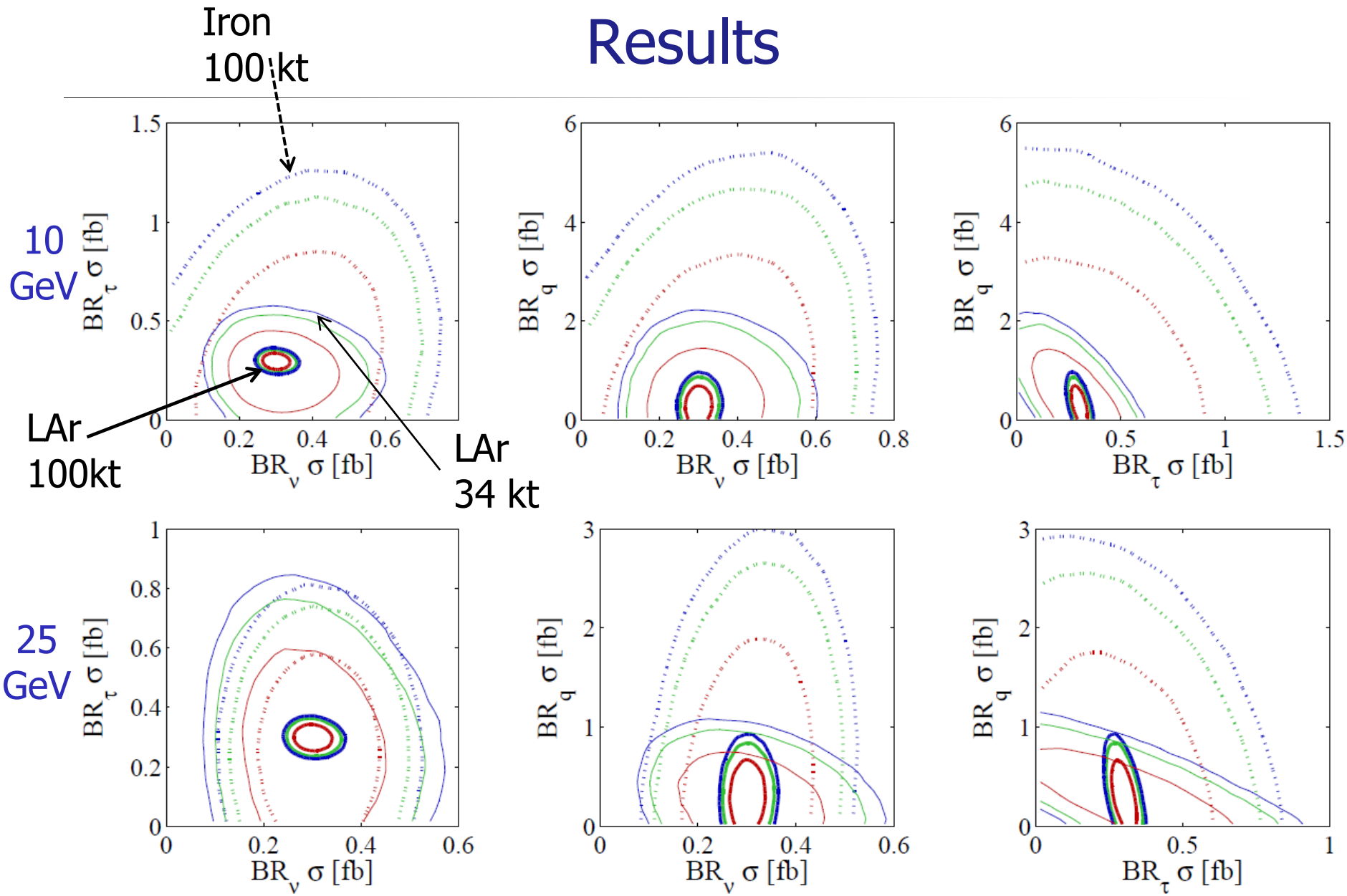

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Sensitivities

Experiment	DM mass	$BR_\tau \sigma$ [fb]	$BR_\nu \sigma$ [fb]	$BR_q \sigma$ [fb]
MIND	10 GeV	0.70	0.35	3.4
	25 GeV	0.34	0.15	1.7
LArTPC (34 kt)	10 GeV	0.15	0.11	0.73
	25 GeV	0.16	0.10	0.21
GLACIER	10 GeV	$1.5 \cdot 10^{-2}$	$6.4 \cdot 10^{-3}$	0.25
	25 GeV	$1.0 \cdot 10^{-2}$	$5.2 \cdot 10^{-3}$	0.19
Super-K	10 GeV	0.65	0.12	10
1104.0679	25 GeV	0.45	0.19	5.0

Conclusions and Outlook

- Next generation neutrino detectors will have enough precision to discern the different annihilation channels of DM
- Very complementary probe to direct detection or collider searches and to indirect searches with γ rays, e^+ and p^-
- Particularly sensitive to light DM mass, test of the DAMA and CoGeNT favoured region
- Extend the analysis to higher energies adding all the new channels that become available and the sensitivity on the dependence on the DM mass
- Explore different next generation neutrino detectors