MAGIC searches for Dark Matter

Adrian Biland, ETHZ
MAGIC-Collaboration

CTA/LINK, 12.11.10

The MAGIC Telescope(s)

- Roque de los Muchachos (La Palma, Canary Islands), 2200m asl
- 17m dish with active mirror control, f/d=1.0, 3.5deg FoV
- analog signals transferred to counting house (fibres)
- regular data taking:
  - first telescope since 2004
  - second telescope/stereo since Sept. 2009

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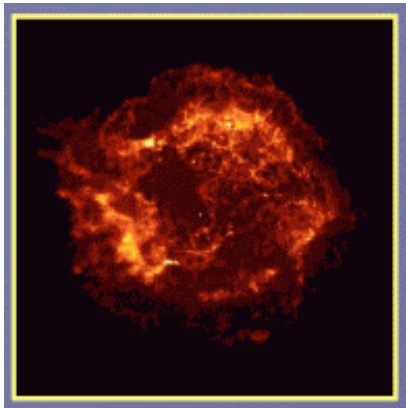
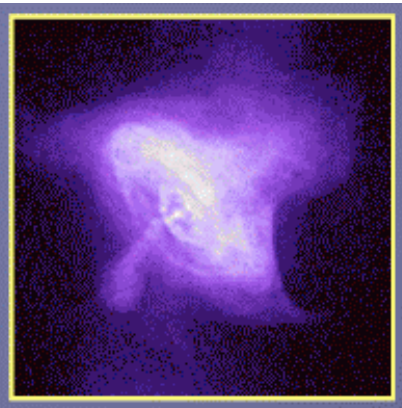
The MAGIC Telescope(s)

- Trigger threshold ~50 GeV (~25 GeV for Pulsars only)
- Analysis threshold >60 GeV (~50 GeV stereo)
- Energy resolution ~20% (~15% stereo)
- Integral sensitivity 50h: 1.6% Crab (1% Crab stereo)
- Fast repositioning: <20s

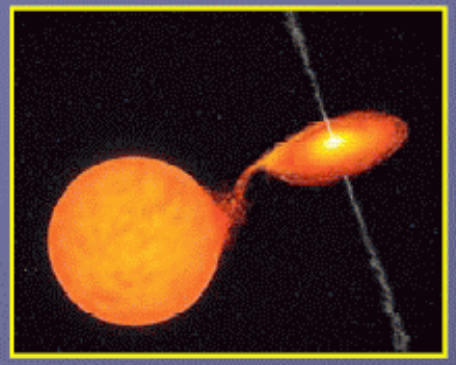
Some Physics Objectives



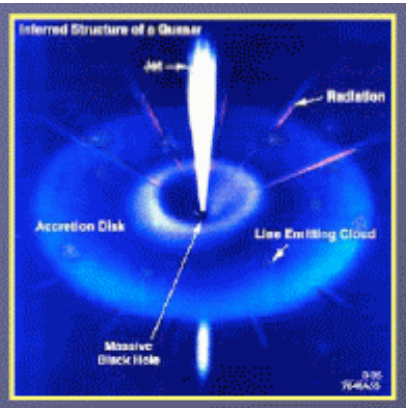
SNRs



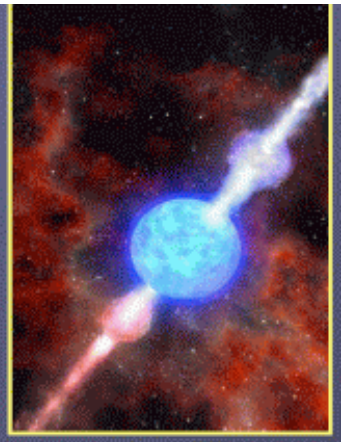
Pulsars and PWNe



Micro quasars X-ray binaries

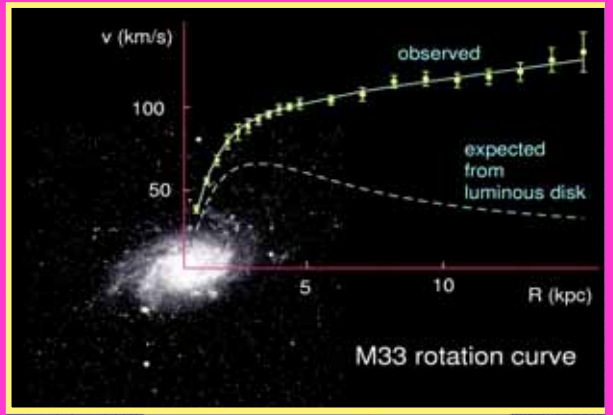


AGNs

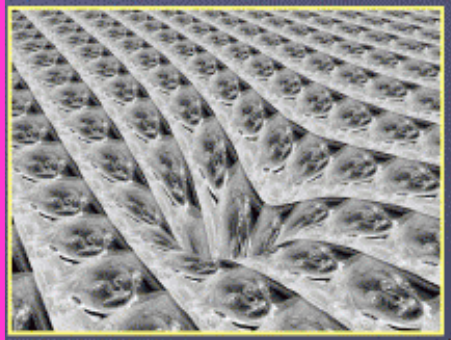


GRBs

Origin of cosmic rays

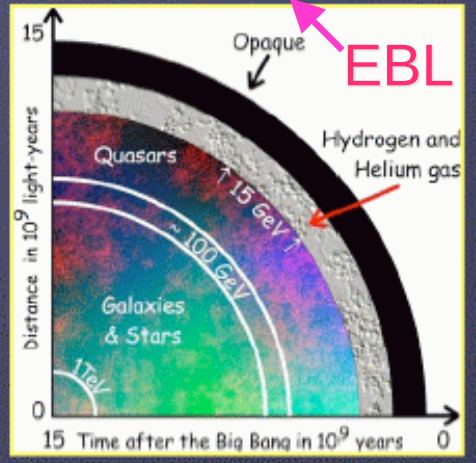


Dark matter



Space-time & relativity

Dark Stars ?

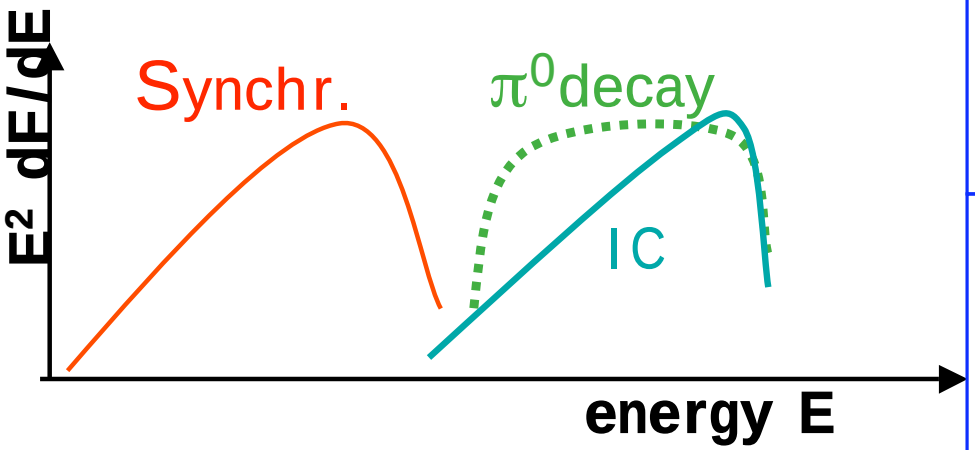


Cosmology

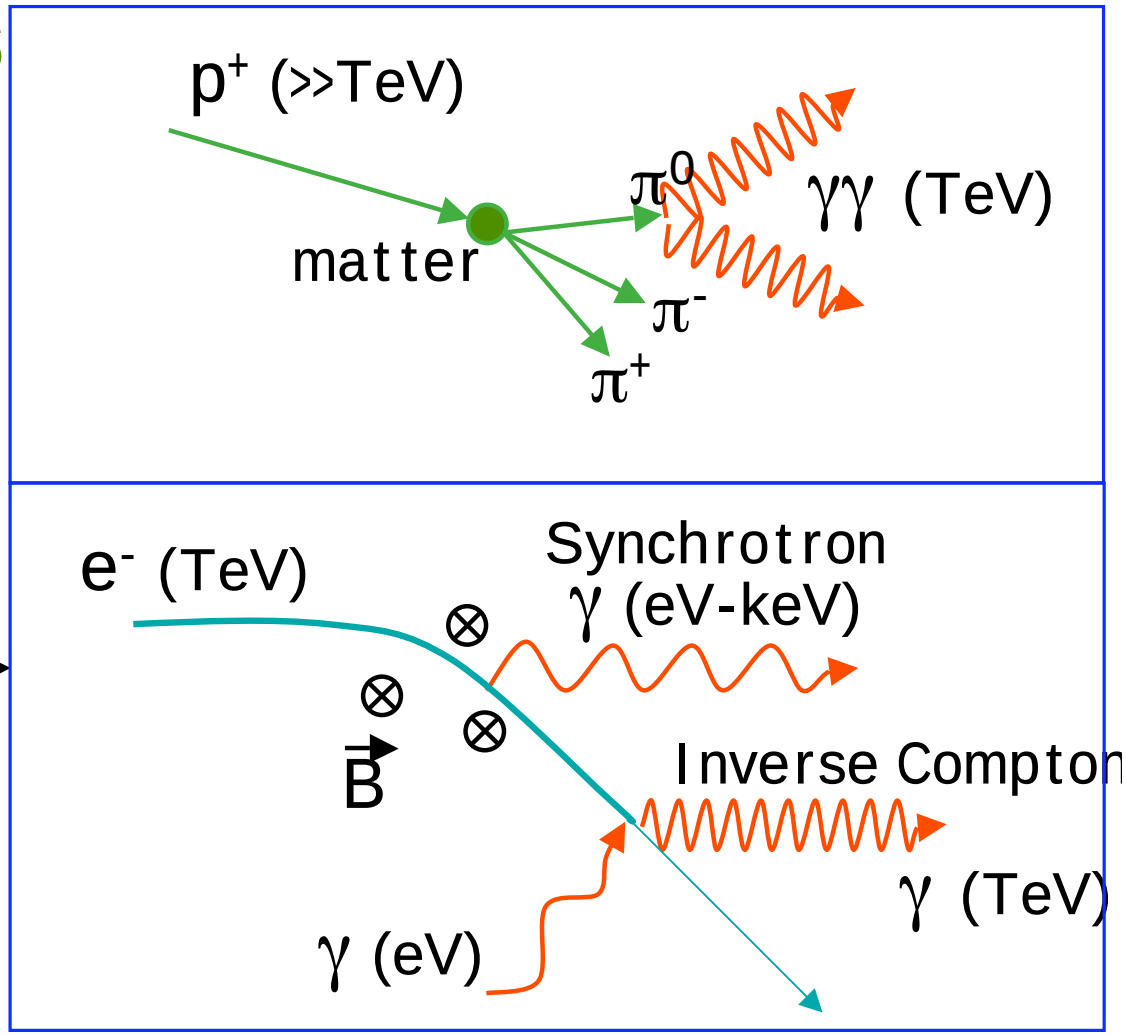
'Standard' Origins of VHE-γ

VHE photons do have non-thermal origin(s)

Do p or e^- act as seed particles?



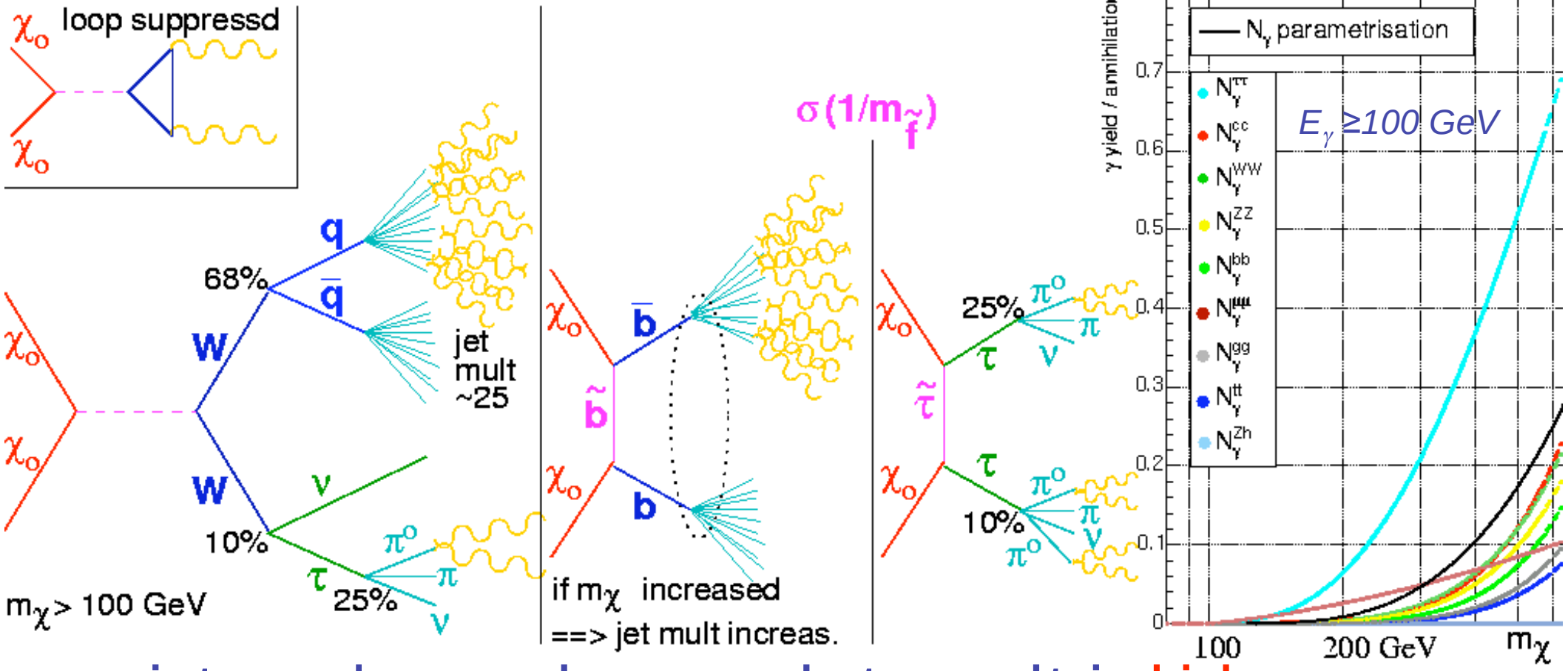
distinguish hadronic vs. leptonic 'acceleration':
=> shape of spectrum;
Multi-wavelength



VHE-γ from e.g. χ_0-annihilation

X_0 does not directly couple to γ (else not 'dark') ==>

Some important processes to produce VHE γ:



q-jets produce much more γ, but τ result in higher energy γ

==> VHE γ rare or (rather) low energy

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Where to look for DM ?

Flux calculation:

$$\Phi = \frac{N(\sigma v)}{2\,\pi\, m_\chi^2} \times \frac{1}{\Delta\Omega} \int d\Omega \int \rho^2 ds$$

uncertainties $O(10^x)$

Particle physics

CDM density distribution

Particle Physics:
in this talk concentrate on 'mSUGRA' (subset of SUSY parameter space)

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- Galactic Center

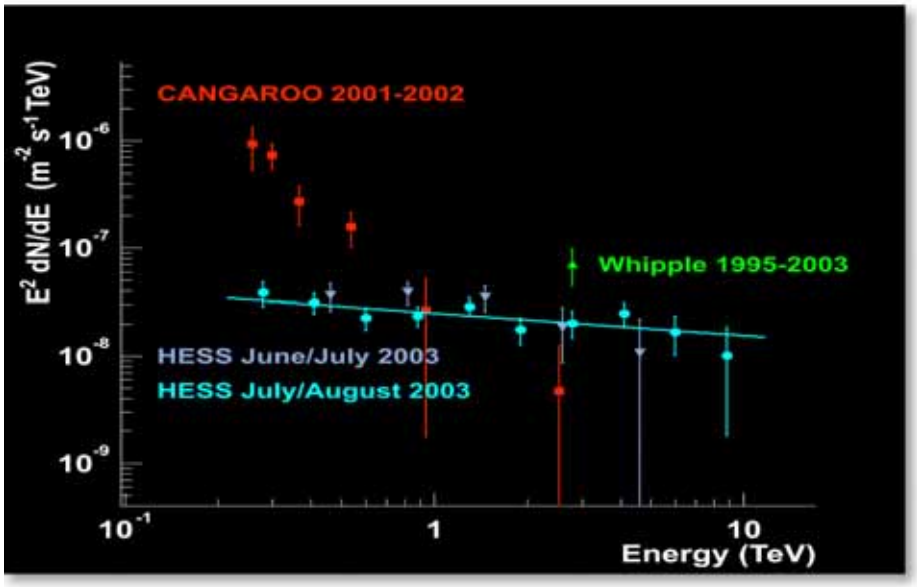
- Spheroidal Dwarf Galaxies

- MiniHalos, Intermediate Mass Black Holes...

- Galaxy Clusters

Galactic Center

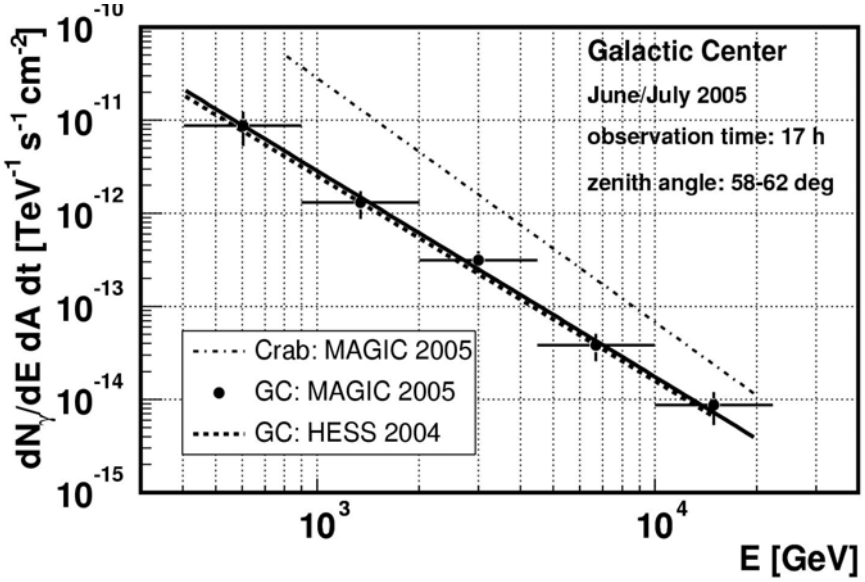
MAGIC: ApJ 638, L101 (2006)



existed contradicting measurements

CANGAROO vs. H.E.S.S.

CANGAROO looked more DM-like, but (unfortunately) MAGIC showed H.E.S.S. to be correct …



Observed for 17h Jul/Aug.05; ZA:58°-63°

- 6σ signal
- α = -2.2±0.2
- 600-15000 GeV
- Excellent agreement with H.E.S.S. ; incompatible with CANGAROO

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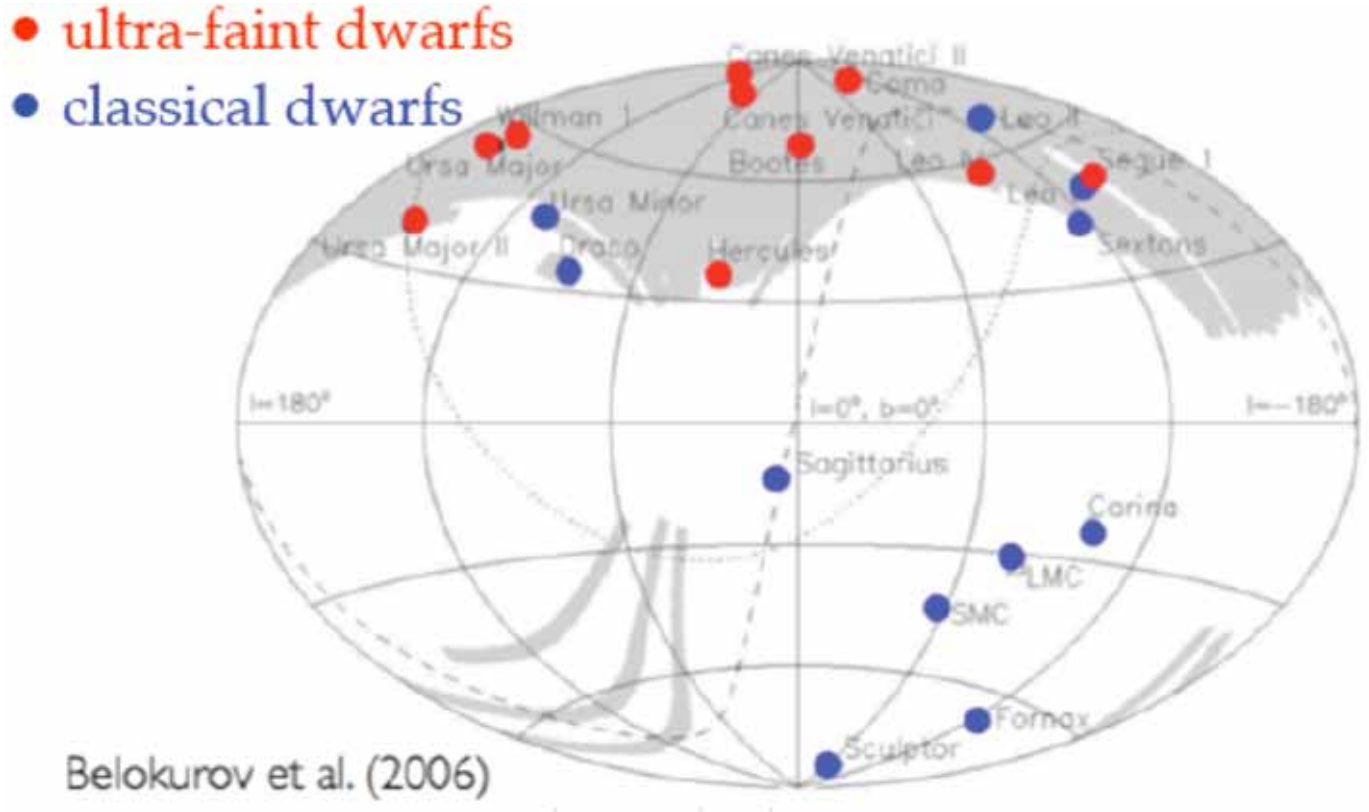
Spheroidal Dwarf Galaxies

-small companion galaxies of Milky Way
==> rather nearby

-usually have very large M/L ratio
==> high ρ_{DM}^2



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e.g. DRACO ('classical Dwarf')

MAGIC: ApJ 679, 428 (2008)

7.8h good observation data in 2007
large zenith angle (37^o) ==>high $E_{threshold}$=140GeV
u.l. ~$10^{-11}\gamma cm^{-2}s^{-1}$ (assuming spectral index -1.5)

But upper limit depends on expected spectra (spectral index and cutoff energy)
==> different for each mSUGRA model
==> not very useful to give a global u.l. value

Better: u.l. for predefined benchmark points

[Battaglia et al., Eur.Phys.J., C33, 273]

e.g. DRACO ('classical Dwarf')

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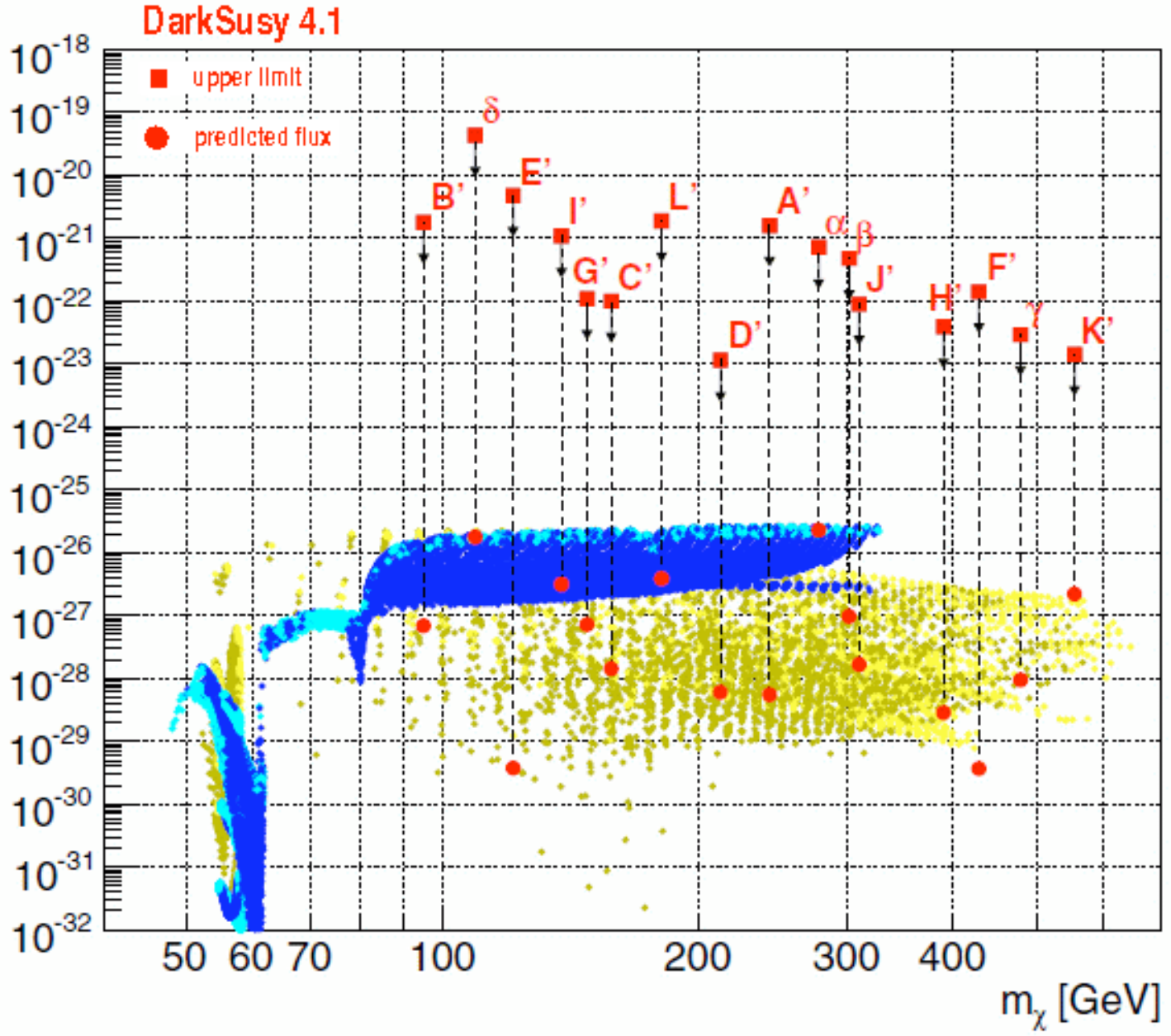
u.l. far from expected flux if assume conservative ρ^2

[Sanchez-Conde at al., Phys Rev D76]

and no boost

(can exclude boosts >>1000)



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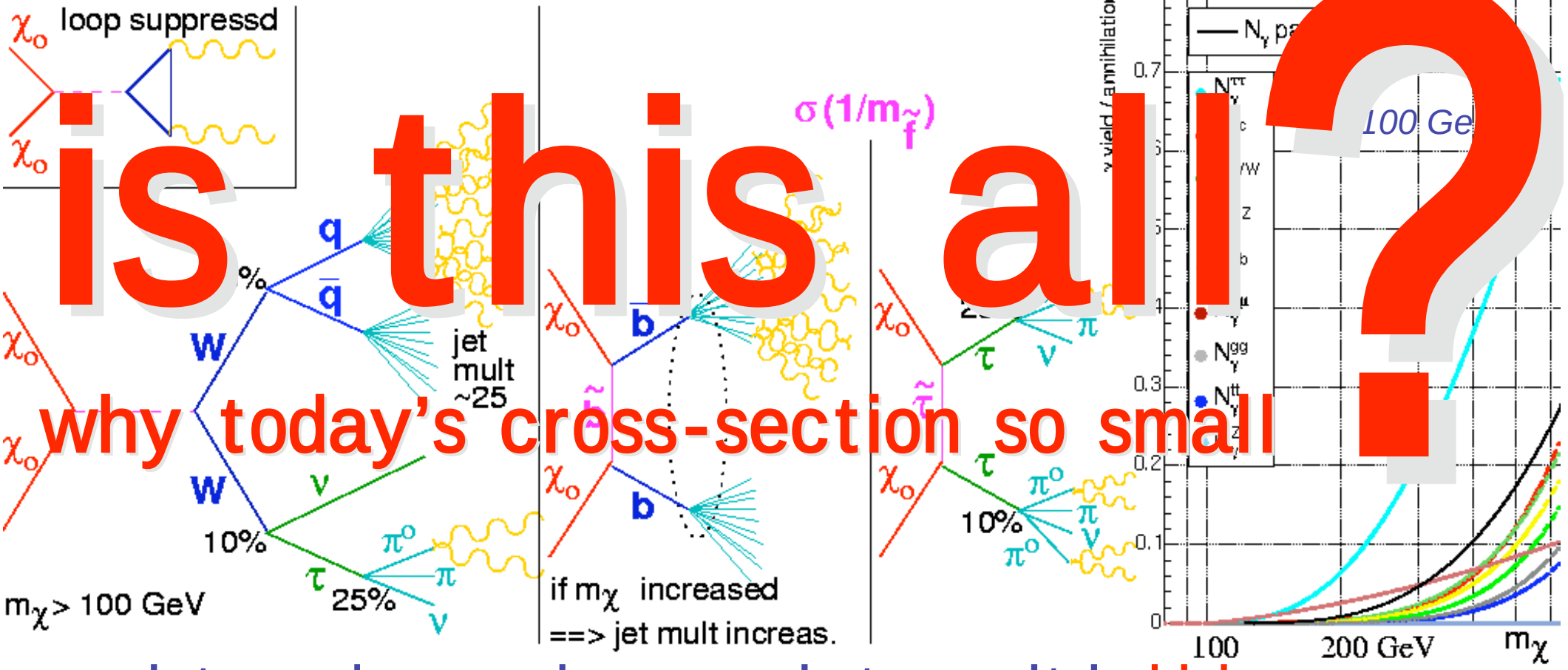

is this all?

why today's cross-section so small

q-jets produce much more γ, but τ result in higher energy γ

==> VHE γ rare or (rather) low energy

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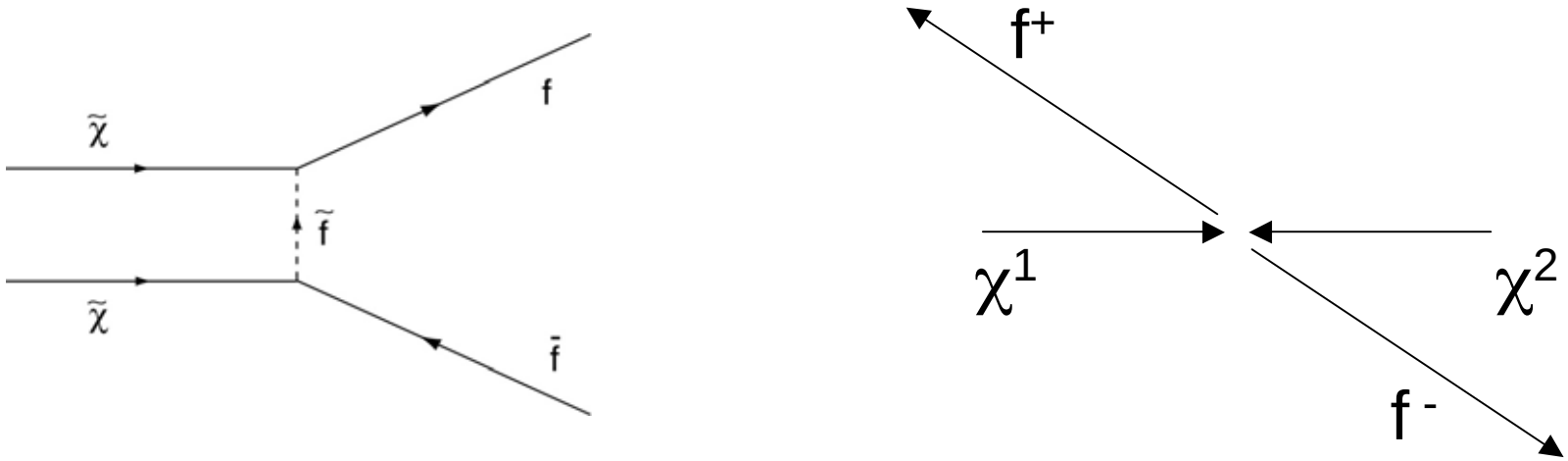


In center of mass system:

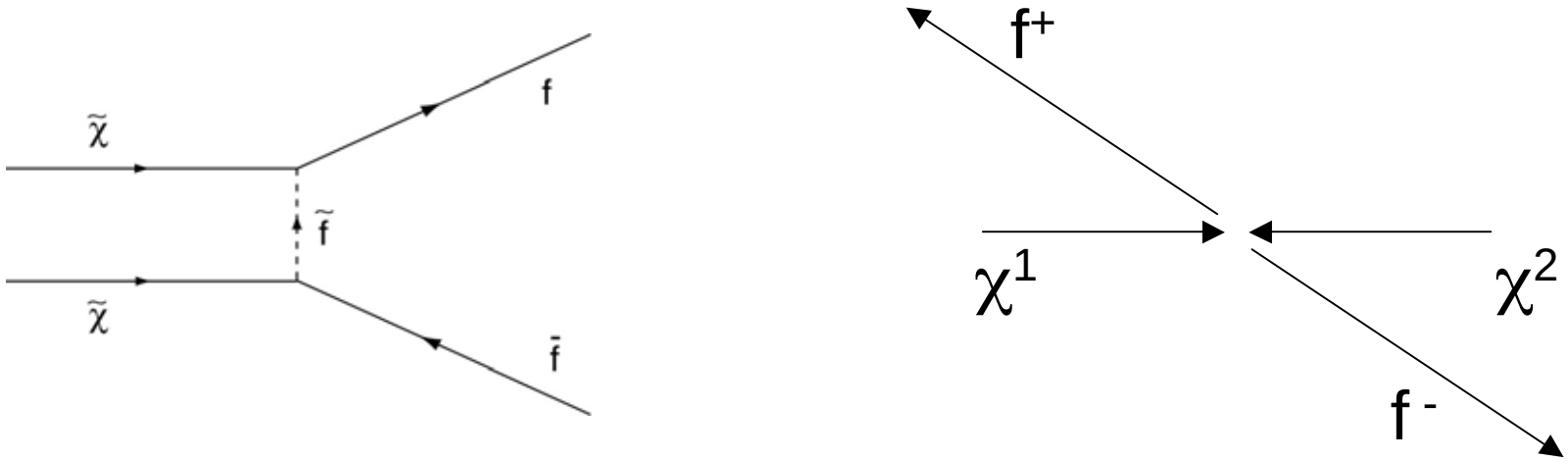
$p_{tot}=0 \Rightarrow p_{f+}= -p_{f-}$; $p_{\chi 1}= -p_{\chi 2}$

$\Rightarrow$ **helicity:** $s_{f+}= +s_{f-} \Rightarrow s_{\chi 1}= s_{\chi 2}$

Annihilation: $x_{\chi 1}= x_{\chi 2}$

Early Universe (=>relic density): no problem

VHE-γ from e.g. χ_0-annihilation



In center of mass system: today

$p_{tot}=0 \Rightarrow p_{f+}= -p_{f-}$; $p_{\chi 1}= -p_{\chi 2} = 0$

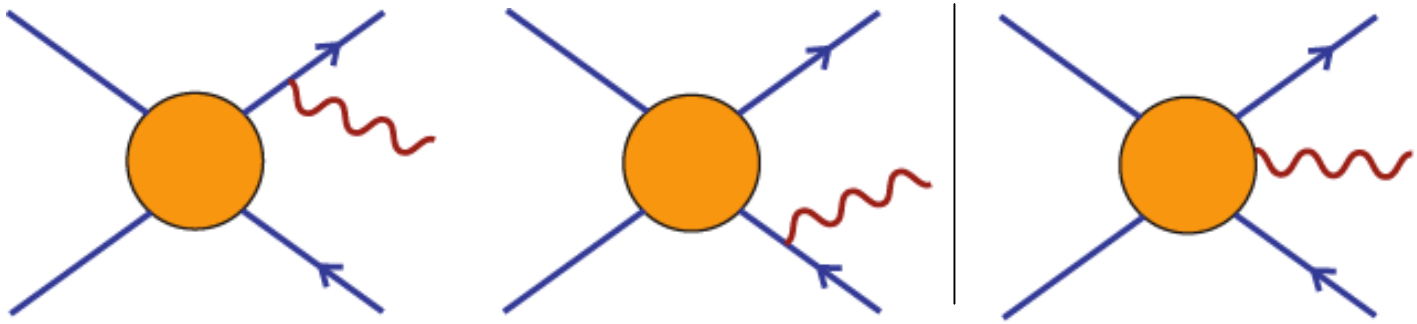
$\Rightarrow$ **helicity:** $s_{f+}= +s_{f-} \Rightarrow s_{\chi 1}= s_{\chi 2}$

Annihilation: $x_{\chi 1}= x_{\chi 2}$

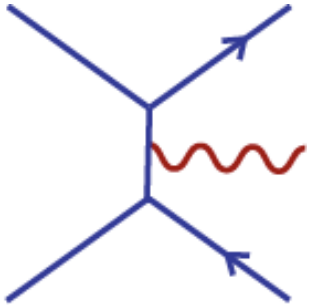
identical quantum state ⇒ annihilation suppressed by Pauli-Principle

VHE-γ from e.g. χ_0-annihilation

Bringmann, Bergstrom, Edsjo; JHEP 0801,049 (2008)



Bremsstrahlung: does not help YES !!!



photon has s_γ=1 => $s_{\chi 1}$=-$s_{\chi 2}$ => allowed
==> much higher cross-section
QED correction O(10^6) instead O(10^{-2})

Additionally: typical E_γ > 0.5 m_χ
(perfect for Cherenkov Telescopes)

e.g. DRACO ('classical Dwarf')

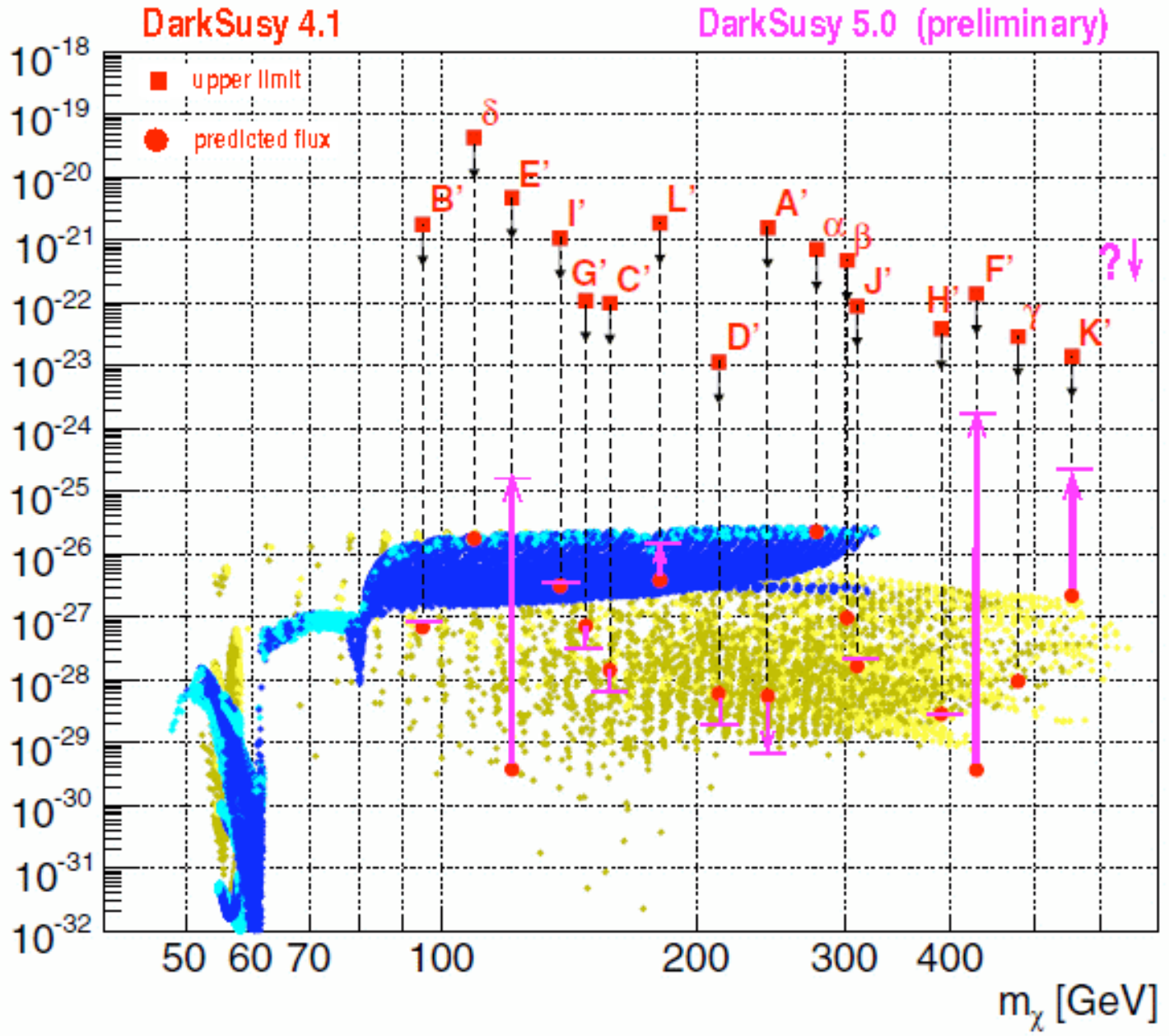
MAGIC: ApJ 679, 428 (2008)

u.l. far from expected flux if assume conservative ρ^2

[Sanchez-Conde at al., Phys Rev D76]

and no boost

expected flux can change drastically with DS 5.0



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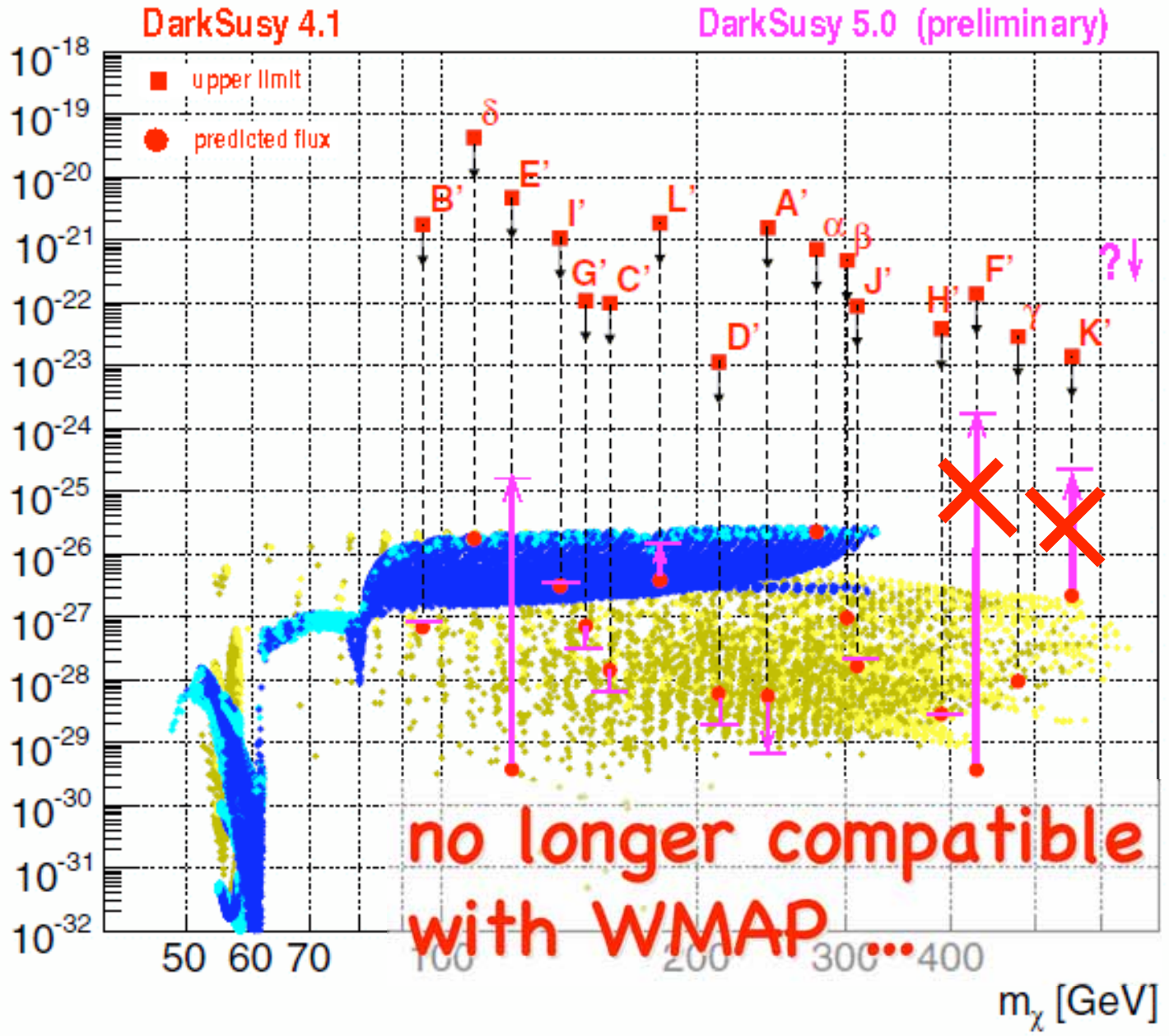

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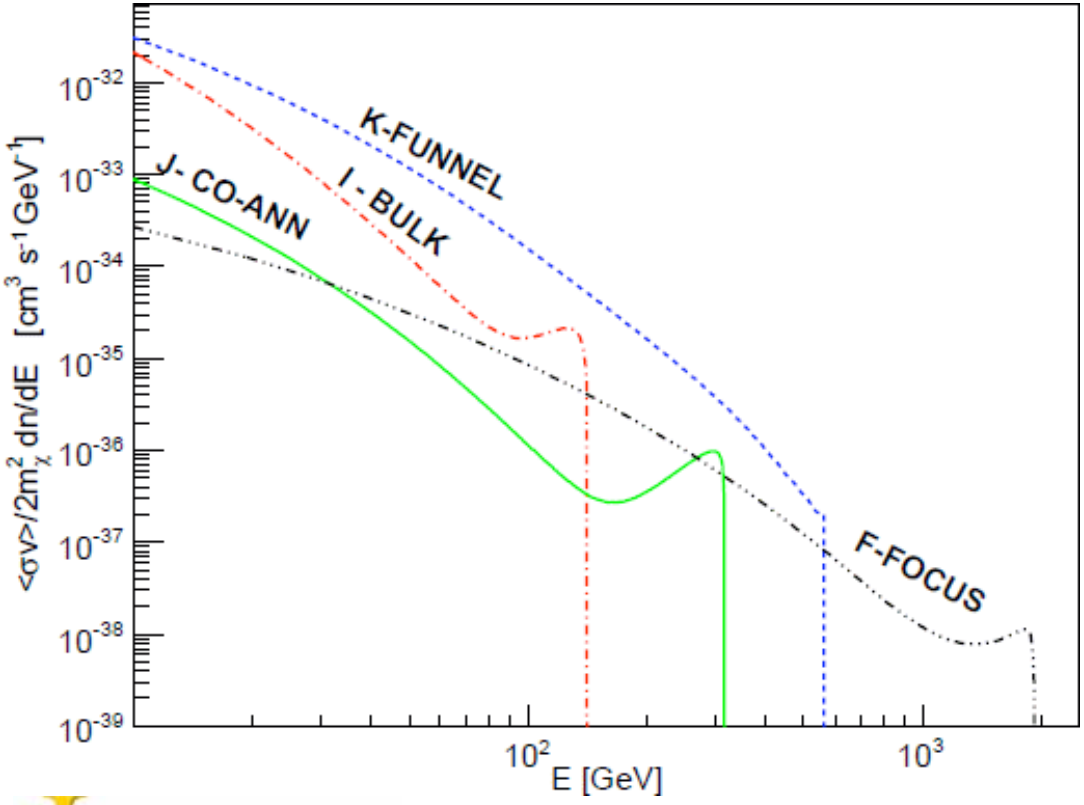
Other Benchmark Points ...

Bringmann, Doro, Fornasa; JCAP01, 016 (2009)

BM	$m_{1/2}$	m_0	$\tan\beta$	A_0	$sign(\mu)$	m_χ	$\langle\sigma v_{\chi\chi}\rangle$	$\Phi^{PP}(>100)$
I'	350	181	35	0	+	141	3.62×10^{-27}	7.55×10^{-34}
J'	750	299	35	0	+	316	3.19×10^{-28}	1.23×10^{-34}
K'	1300	1001	46	0	−	565	2.59×10^{-26}	6.33×10^{-33}
F^*	7792	22100	24.1	17.7	+	1926	2.57×10^{-27}	5.98×10^{-34}

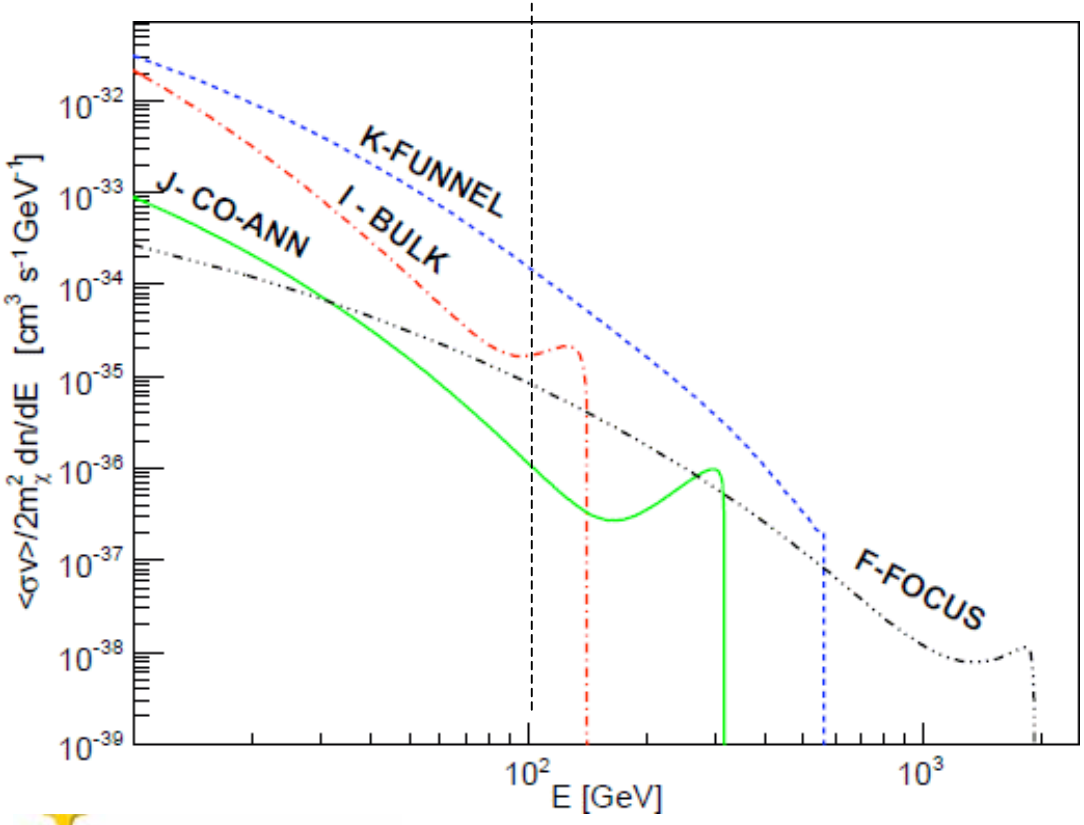


taking into account 'internal Bremstrahlung'

Willman-I ('ultra-faint Dwarf')

MAGIC: ApJ 697,1299 (2009)

Observed for 15.5h in 2008
==> upper limit 10^{-12} ph $cm^{-2}s^{-1}$ above 100 GeV



$\Phi^{model}(>100$ GeV)	$\Phi^{u.l.}(>100$ GeV)	$B^{u.l.}$
2.64×10^{-16}	9.87×10^{-12}	3.7×10^{4}
4.29×10^{-17}	5.69×10^{-12}	1.3×10^{5}
2.32×10^{-15}	6.83×10^{-12}	2.9×10^{3}
2.09×10^{-16}	7.13×10^{-12}	3.4×10^{4}

again, can only exclude boosts >1000 ...

The Usual Suspects

- Galactic Center
  - southern source (==> better suited for H.E.S.S.)
  - strong VHE source obscuring hypot. DM signal
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  - too faint to be detectable within reasonable observation time (at least for mSUGRA models)
- MiniHalos, Intermediate Mass Black Holes...
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UFOs Unidentified Fermi Objects

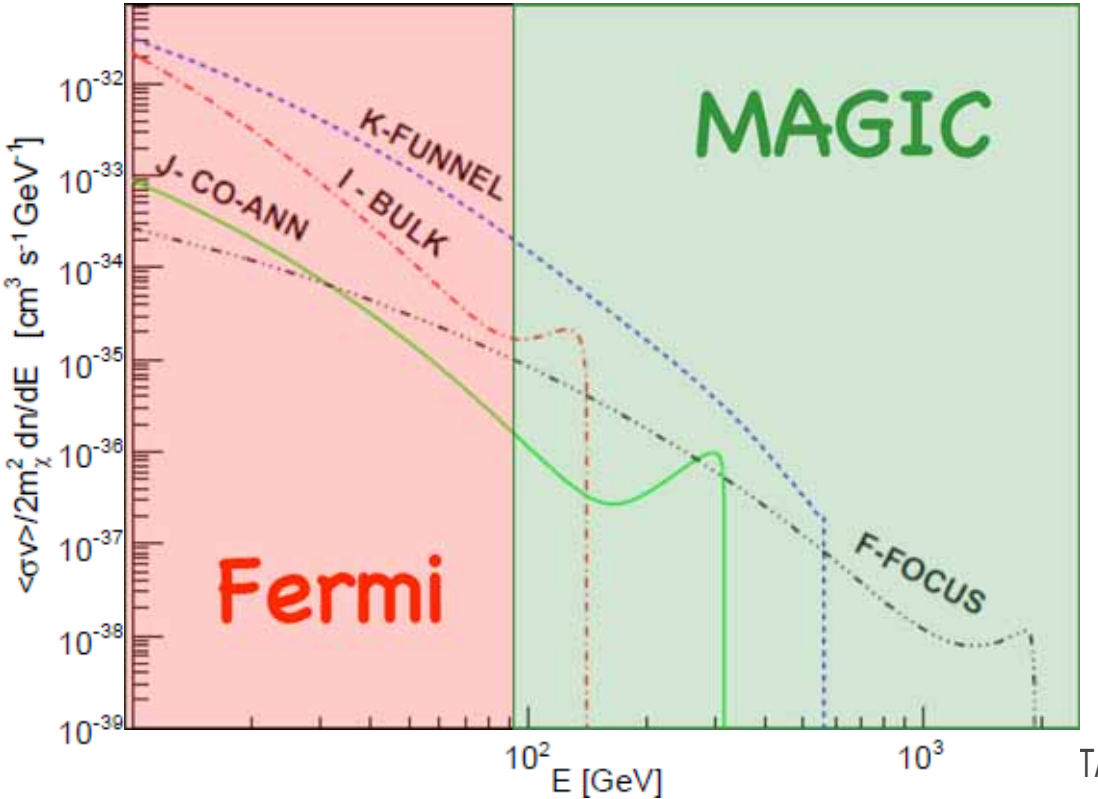
- Predicted existance of DM-clumps within our galaxy (smaller version of Dwarf Gal.)
- Hypothetical Intermediate Mass Black Holes within our galaxy could have accreated large amount of DM

==> could be very nearby ==> very bright

But only significant emission from DM
==> invisible to 'ordinary Astronomers'
but bright(?) for Fermi or AGILE

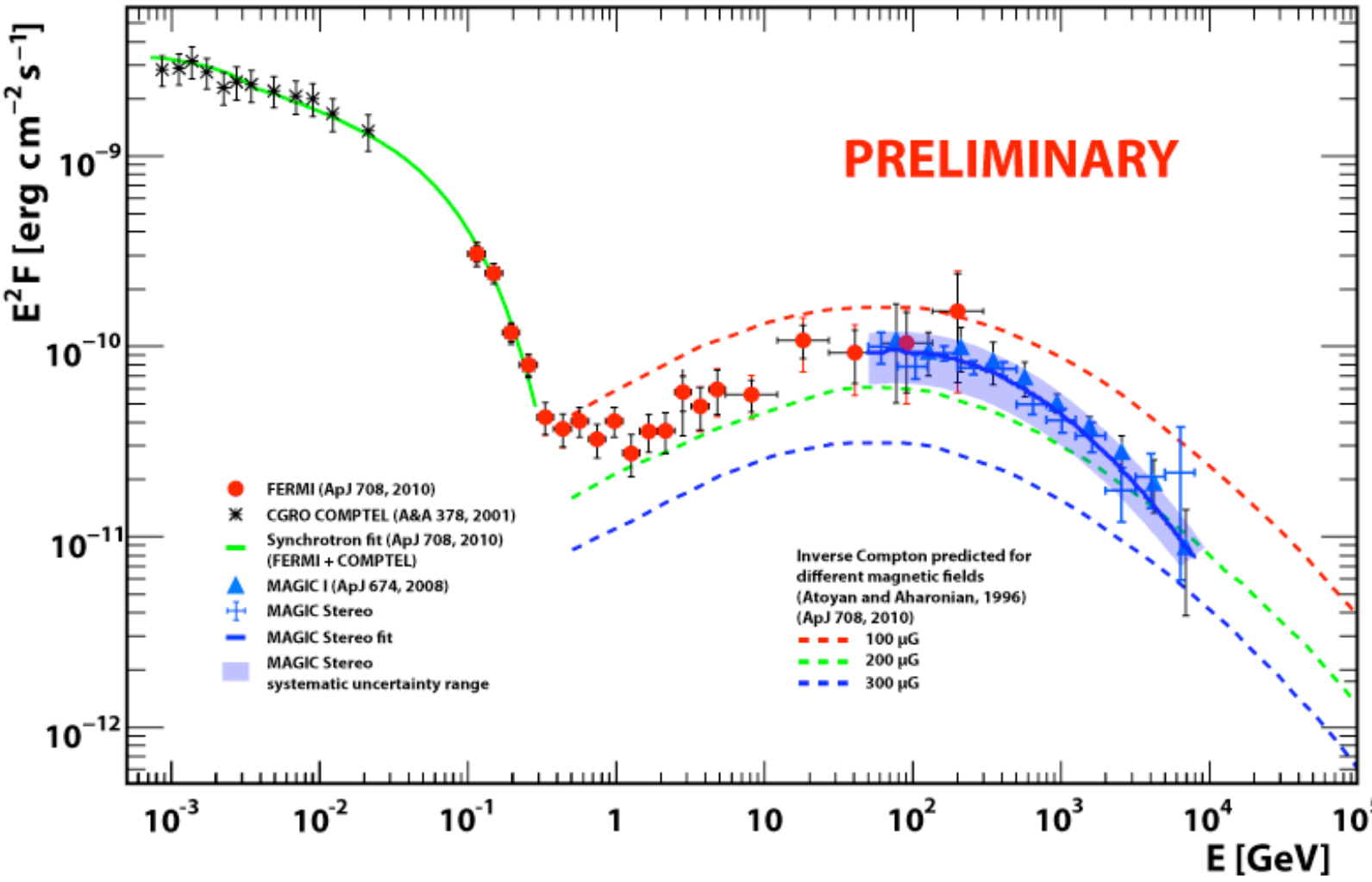
UFOs Unidentified Fermi Objects

smoking gun: Fermi finds several objects
- without counterpart in other wavelengths
- all having same spectrum
(spectrum compatible with a DM model ?)



Most probably, Fermi energy range not sufficient to measure spectrum (especially cutoff)

UFOs Unidentified Fermi Objects



The low energy threshold makes MAGIC ideal partner...

UFOs Unidentified Fermi Objects

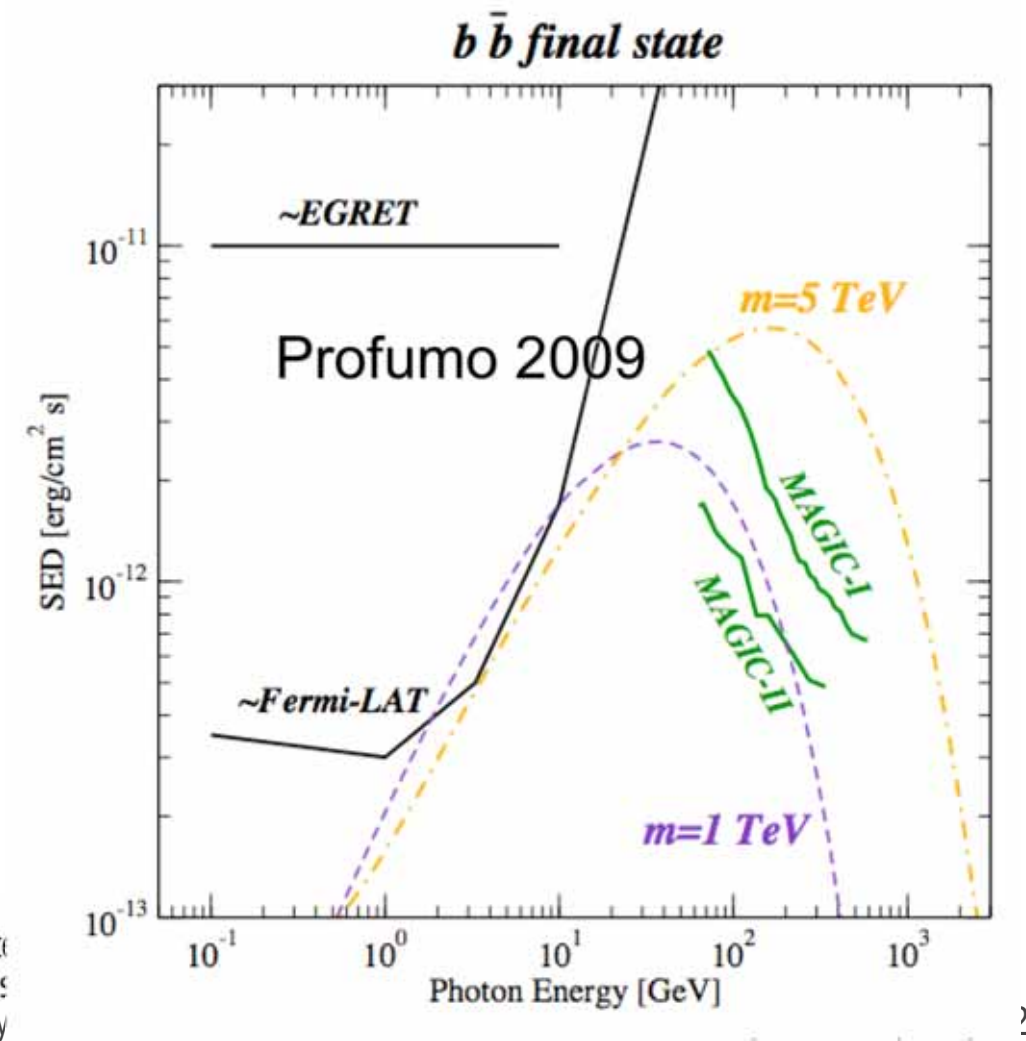
Some potentially interesting(?) Fermi sources

[see talk R.Wagner]

UFOs Unidentified Fermi Objects

Some potentially interesting(?) Fermi sources
[see talk R.Wagner]

but:



Maybe we have to wait for CTA all-sky scan ???

UFO -> UCO

(or serendipity detections...)

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Galaxy Clusters

(Zwicky 'invented' DM in 1933 because Coma Cluster has *not enough mass to be bound* ...)

Some clusters do not have a bright AGN in the center ==> expect less BG

but difficult to get obs. time ?

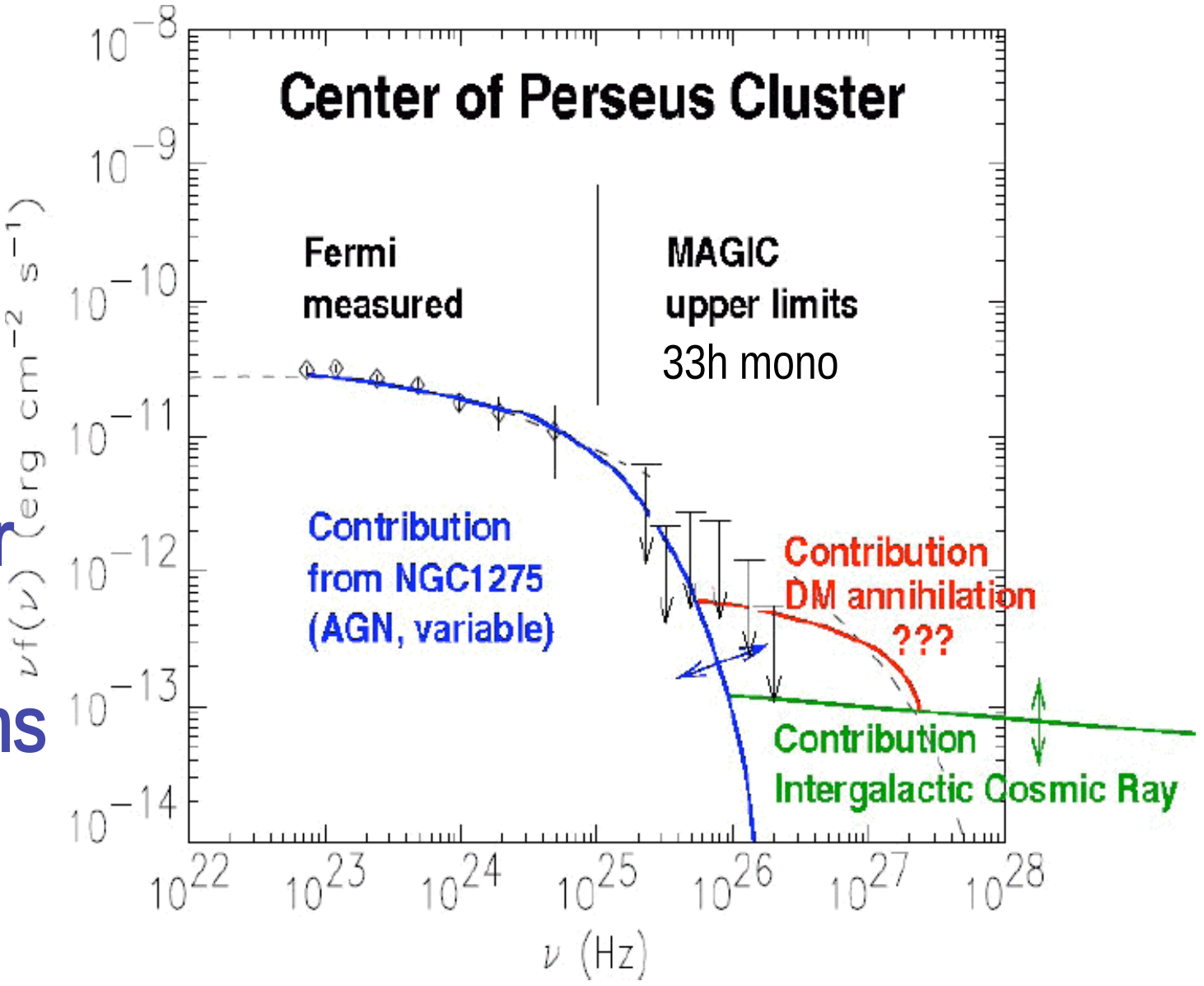
Cluster	RA	Dec.	z
Fornax	54.6686	-35.3103	0.0046
Ophiuchus	258.1115	-23.3634	0.0280
Coma	194.9468	27.9388	0.0231
Centaurus (A3526)	192.1995	-41.3087	0.0114
Norma (A3627)	243.5546	-60.8430	0.0157
M49	187.4437	7.9956	0.0033
A1060	159.1784	-27.5212	0.0126
NGC 4636	190.7084	2.6880	0.0031
AWM 7	43.6229	41.5781	0.0172

Perseus Cluster / NGC1275

MAGIC: ApJ 710,634 (2010)

Or try to disentangle signal from
- AGN
- Cosmic Rays
- Dark Matter

NGC1275 seems to have soft spectrum ...



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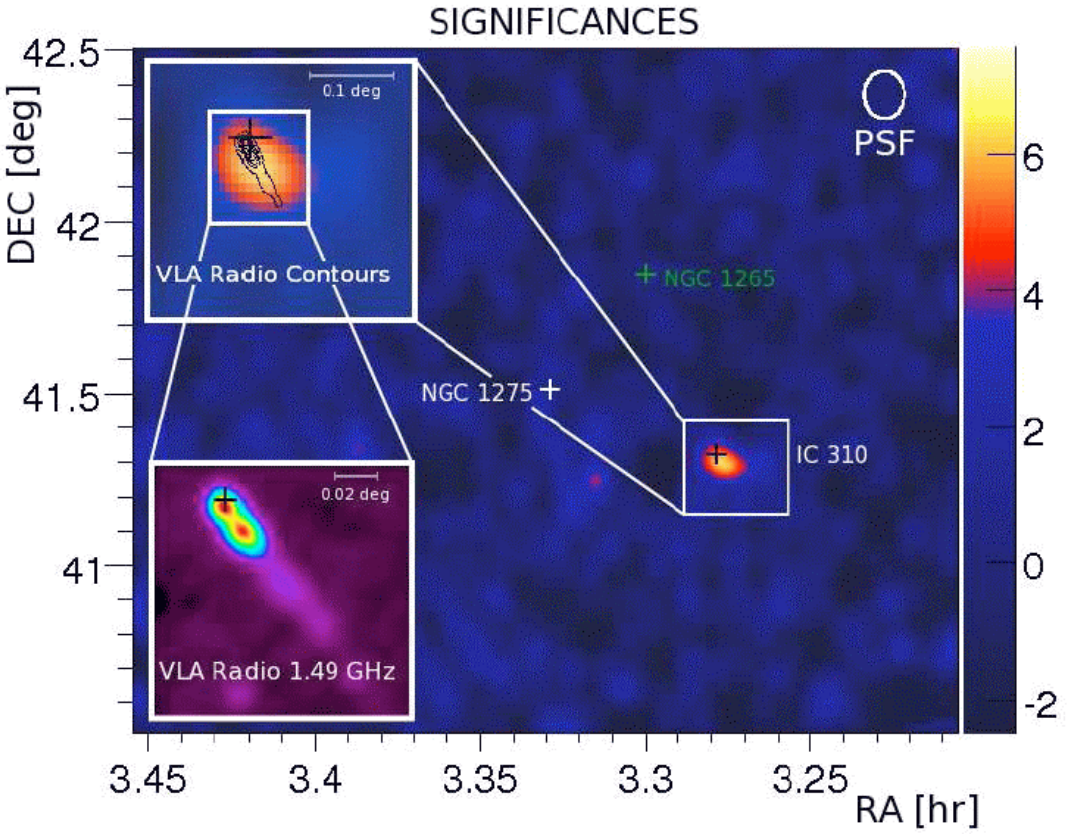
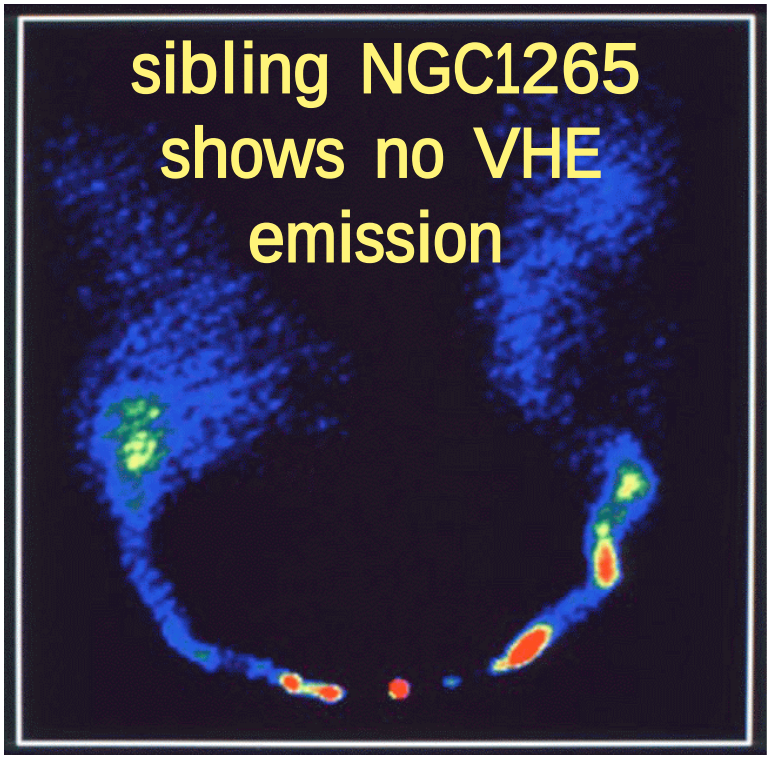
Perseus Cluster / IC310

MAGIC: ApJ 723, L207 (2010)

2010 Stereo Observation:





serendipity detection of first head-tail galaxy

(VHE emission from shock-waves or AGN ?)

Perseus Cluster / NGC1275

Discovery of Very High Energy Gamma-Ray Emission from NGC1275 by MAGIC

ATel #2916; *Mose Mariotti (INFN and Univ. of Padova) on behalf of the MAGIC Collaboration*
*on **10 Oct 2010; 15:00 UT***
Distributed as an Instant Email Notice (Request for Observations)
Password Certification: Mosè Mariotti (mariotti@pd.infn.it)

Subjects: Gamma Ray, >GeV, TeV, VHE, AGN, Blazars, Cosmic Rays

The MAGIC Collaboration reports the detection of Very High Energy (VHE) gamma-ray emission from a position consistent with NGC 1275, the central radio galaxy of the Perseus cluster of galaxies.

The MAGIC observations were carried out in stereoscopic mode starting from August 2010, accumulating 14 h of good quality data. Preliminary analysis using the standard analysis chain with a energy threshold of 100 GeV, shows an excess of 280 gamma-rays, corresponding to a statistical significance of 5.2 standard deviations. The observed flux is estimated to be ~3% of the Crab nebula flux above 100 GeV, and it decreases rapidly with energy. No signal is detected above 400 GeV.

The MAGIC VHE detection happened during a period of increased high gamma-ray activity of NGC 1275, as reported in July 2010 by the Fermi/LAT collaboration, ATel#2737, and continuing until October, according to an analysis of public Fermi/LAT data.
MAGIC will continue observations of NGC1275. Observations at other wavelengths are encouraged.

==> will 'soon' know spectrum of NGC1275

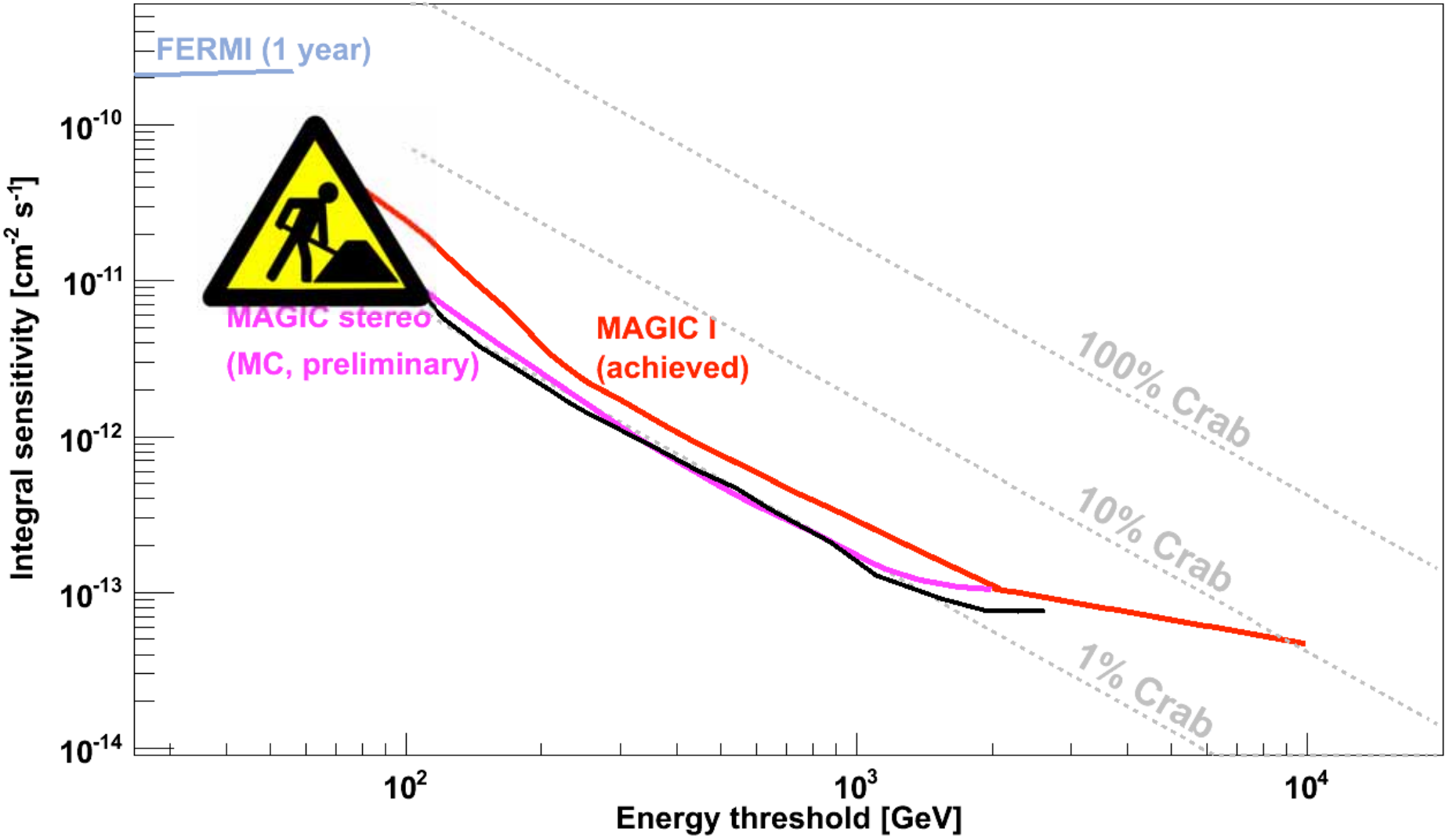
Summary

-MAGIC has not yet found any indication of a Dark-Matter signal

-Since one year significantly improved sensitivity by stereo observations

We will not give up !!!

backup


FERMI (1 year)
MAGIC stereo
(MC, preliminary)
MAGIC I
(achieved)
100% Crab
10% Crab
1% Crab
Integral sensitivity [cm^{-2} s^{-1}]
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{2}
10^{3}
10^{4}
Energy threshold [GeV]