Instituto de Fisica Teórica, IFT-CSIC Madrid

Marco Taoso

Phenomenology of DM electroweak multiplets

Pascos 2016

Quy Nhon

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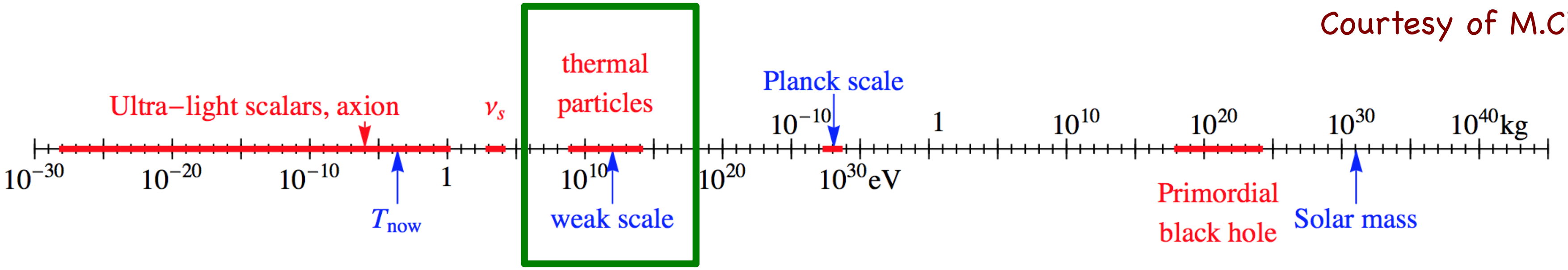
Instituto de Física Teórica UAM-CSIC

MultiDark
Multimessenger Approach for Dark Matter Detection

What do we know about DM?

Courtesy of M.Cirelli

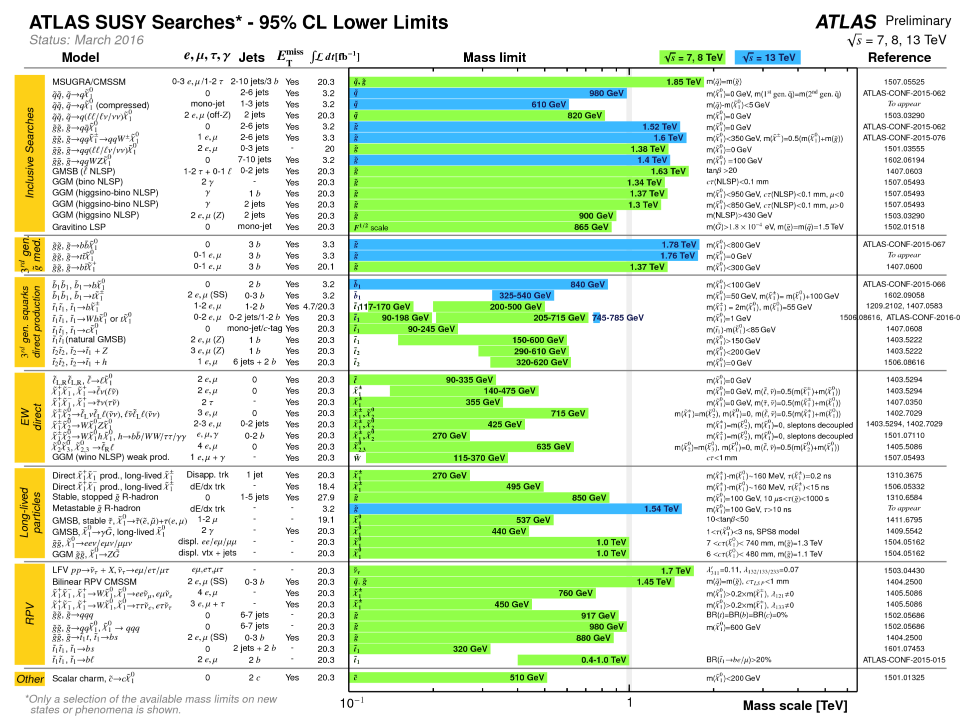


WIMPS often byproducts of Beyond SM theories at the Terascale...

but also independent motivations:

- abundance through thermal decoupling

- multiple way to test the scenario: collider, direct/indirect searches



An approach to WIMP DM

Minimalistic approach : add to SM an extra gauge multiplet and search for assignments giving a viable DM candidate
This means: stable, neutral and allowed by DM searches.

$$\mathscr{L}_{\rm SM} + c \begin{cases} \bar{\mathcal{X}}(i\not{D} + M)\mathcal{X} & \text{when } \mathcal{X} \text{ is a spin } 1/2 \text{ fermionic multiplet} \\ |D_\mu \mathcal{X}|^2 - M^2 |\mathcal{X}|^2 & \text{when } \mathcal{X} \text{ is a spin } 0 \text{ bosonic multiplet} \end{cases}$$

The winner is a **fermionic 5plet** (1,5,0).
- Accidental stability if NP scale is at Planck scale
- No Landau poles for the gauge couplings below the cut-off

Minimal Dark Matter

Cirelli, Fornengo, Strumia hep-ph/0512090

If B-L respected also fermionic **3plet** is stable

- capture low-energy pheno of SUSY models with Wino LSP and heavy scalars

- helps with gauge coupling unification in non-SUSY GUTS

Frigerio-Hambye 0912.1545

Relic abundance

Dominant annihilation channel is WW
Important to include:

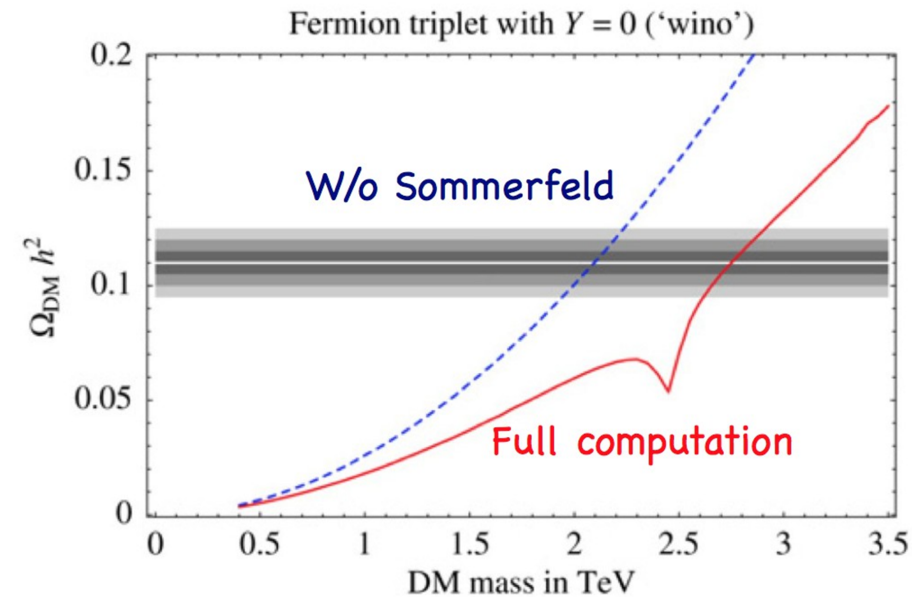
- Coannihilations
- Sommerfeld corrections

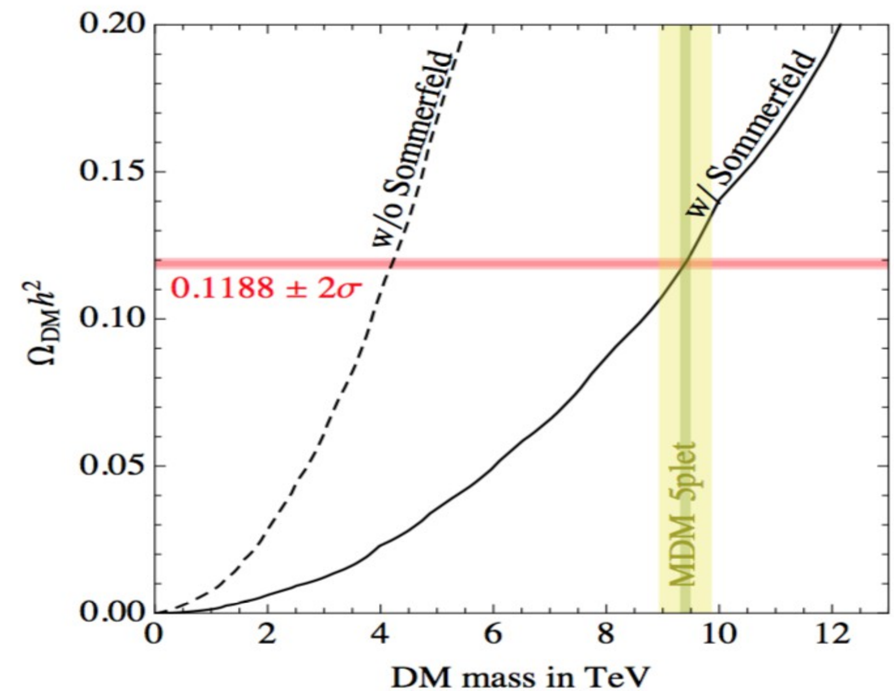
Thermal relic mass:

3 TeV 3plet
10 TeV 5plet

Under-abundant (over-abundant) for a larger (smaller) masses

Cirelli, Hambye, Panci, Sala, Taoso 1507.05519

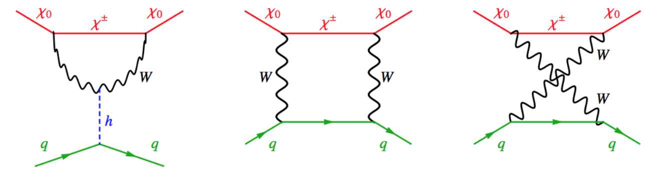




Direct detection

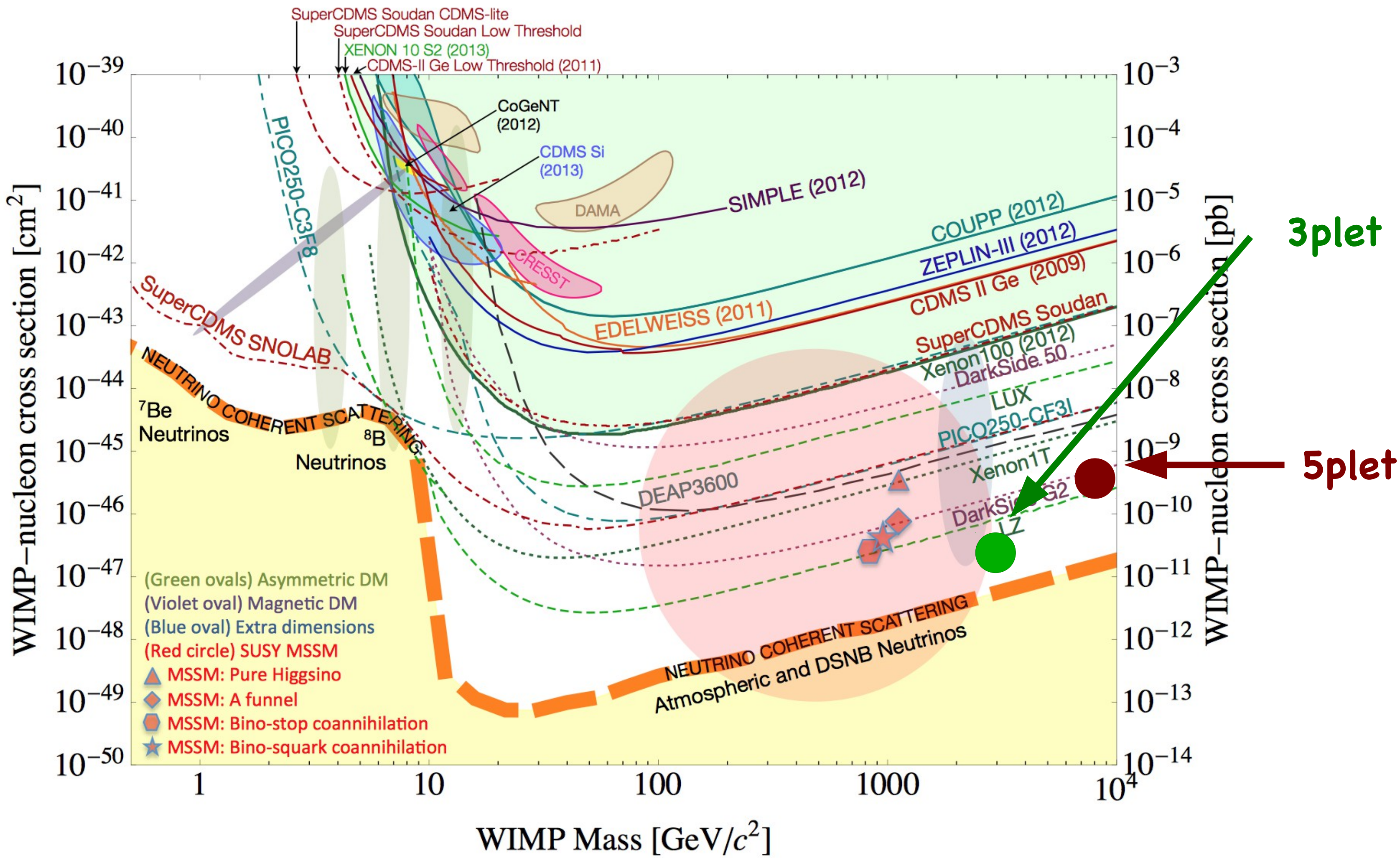
SI cross-section σ_{SI} = 2.3 10^{-47} cm^2 3plet

σ_{SI} = 1.9 10^{-46} cm^2 5plet



Hisano, Hishiwata, Nagata 1504.00915

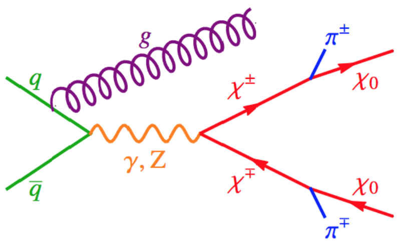
Full NLO in α_s



At colliders with disappearing tracks

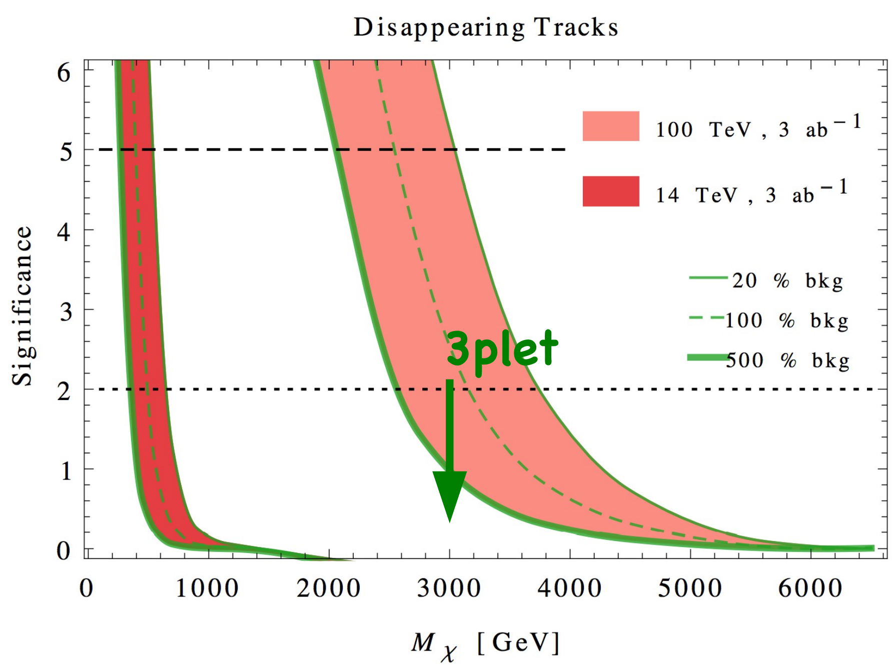
Mass splitting between charged and neutral components around 165 MeV
Charged state decays into DM + soft pions

Lifetime of charged particle around 0.2 ns
Charged tracks of ~ 10 cm

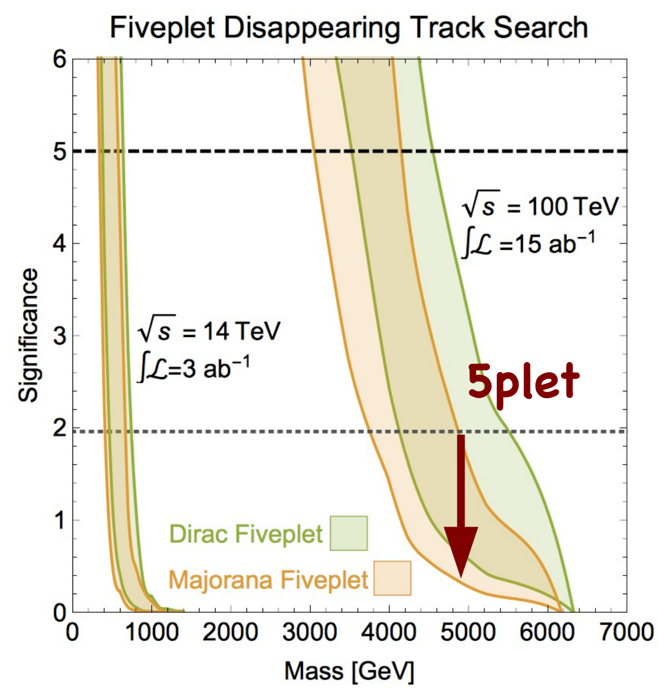


Current ATLAS bounds: M > 270 GeV

FCC-hh might probe thermal masses



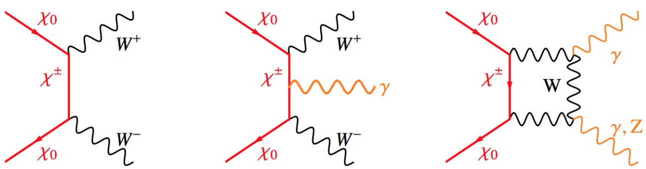
Cirelli, Sala, MT 1407.7058, Low Wang 1404.0682

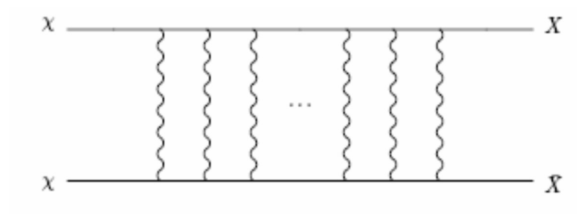


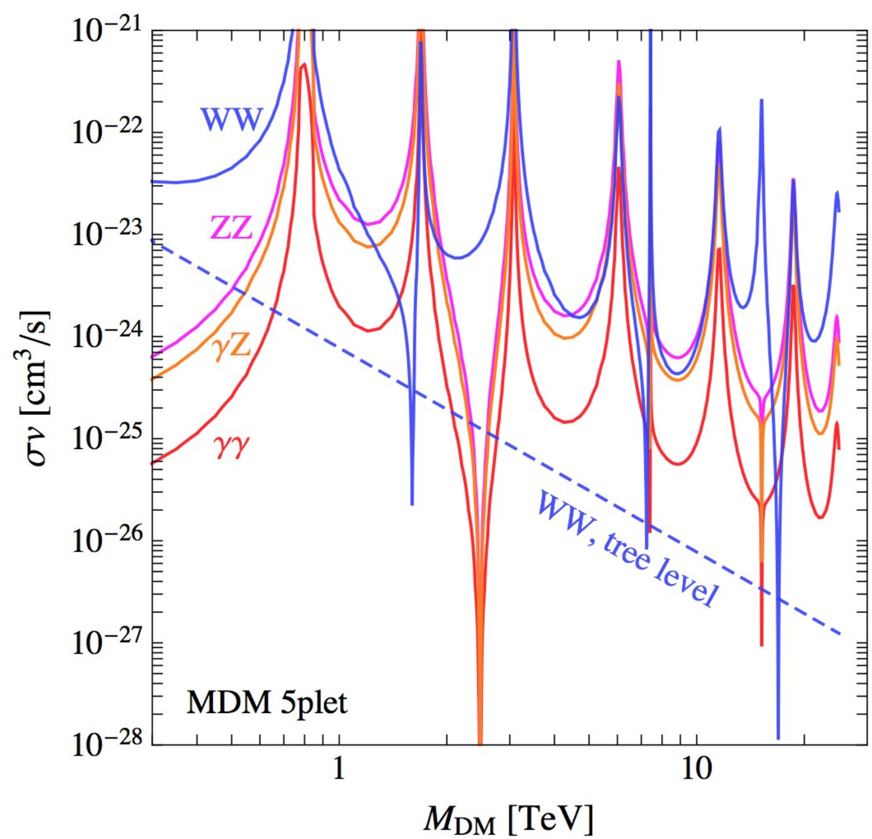
FCC hh report 1606.00947, Ostdiek 1506.03445

Sommerfeld corrections to annihilations

Non perturbative Sommerfeld corrections relevant at low velocities.
Gauge bosons mediate long range interactions.

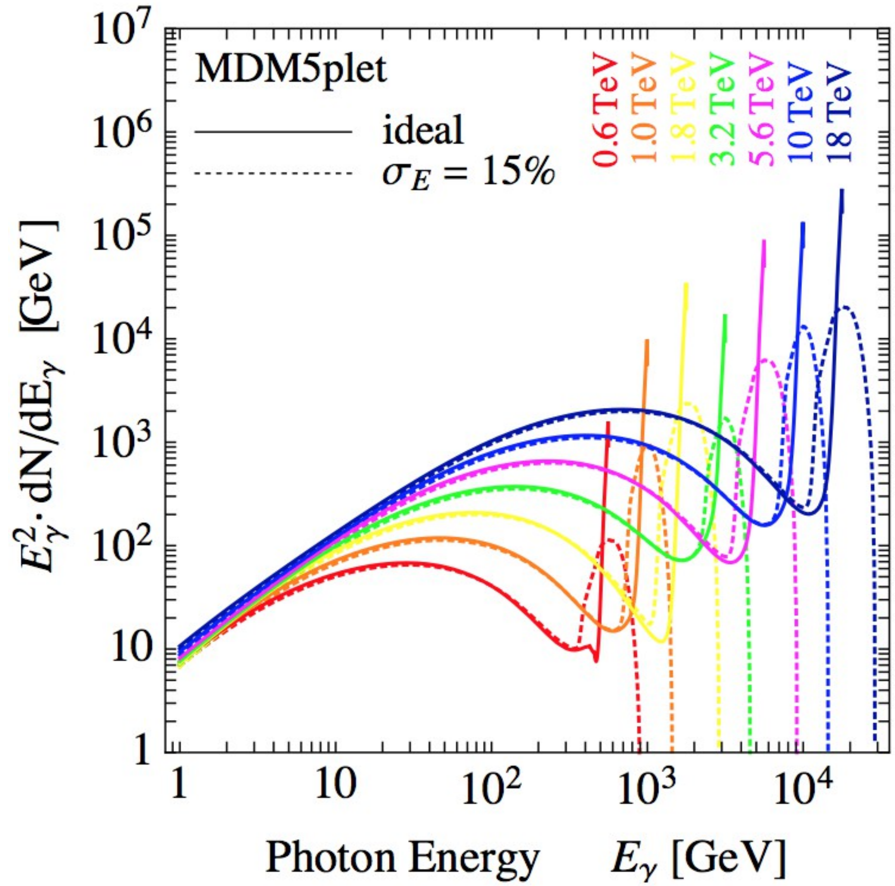






Sommerfeld corrections to annihilations

Look for continuum photon emission or feature in energy spectrum (line)



Fermi LAT

ACT: Hess, Magic,...

Bounds from gamma-ray observations

Use full-sky Fermi-LAT observations.

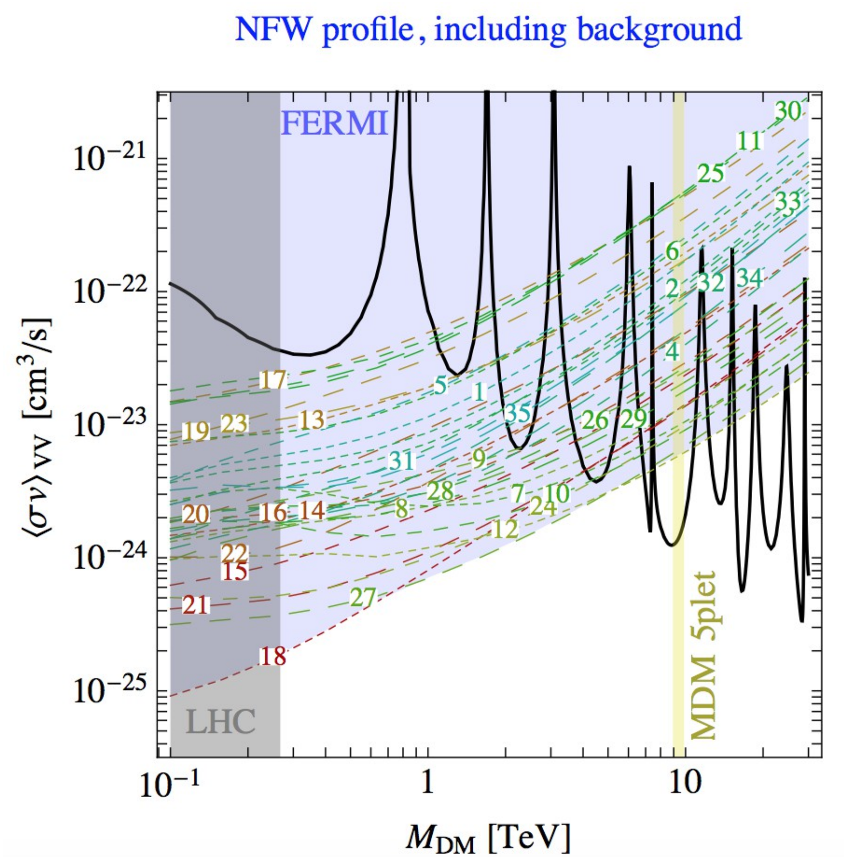
Divide sky in non-overlapping ROI and include templates for astro emission:

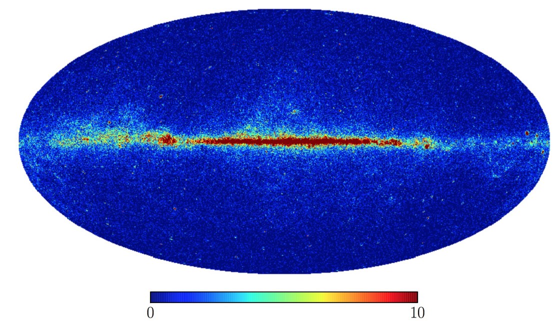
-diffuse emission from CRs

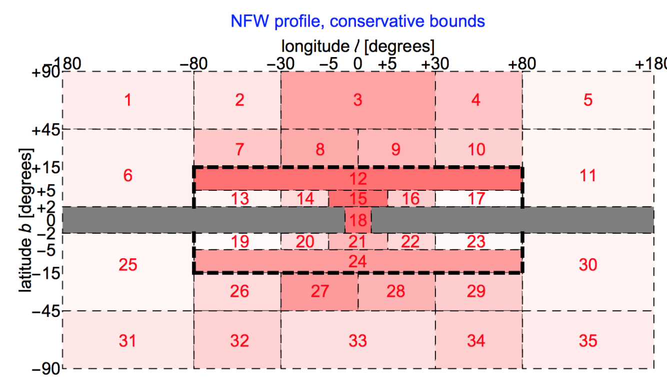
-Fermi bubbles

-Isotropic emission

-Point sources



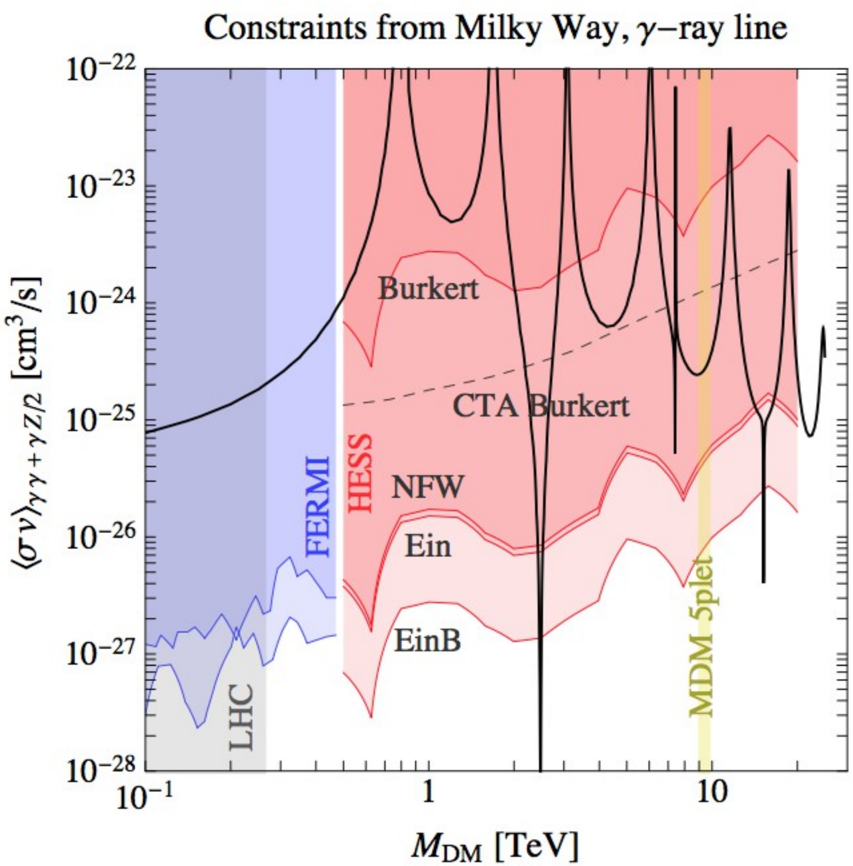


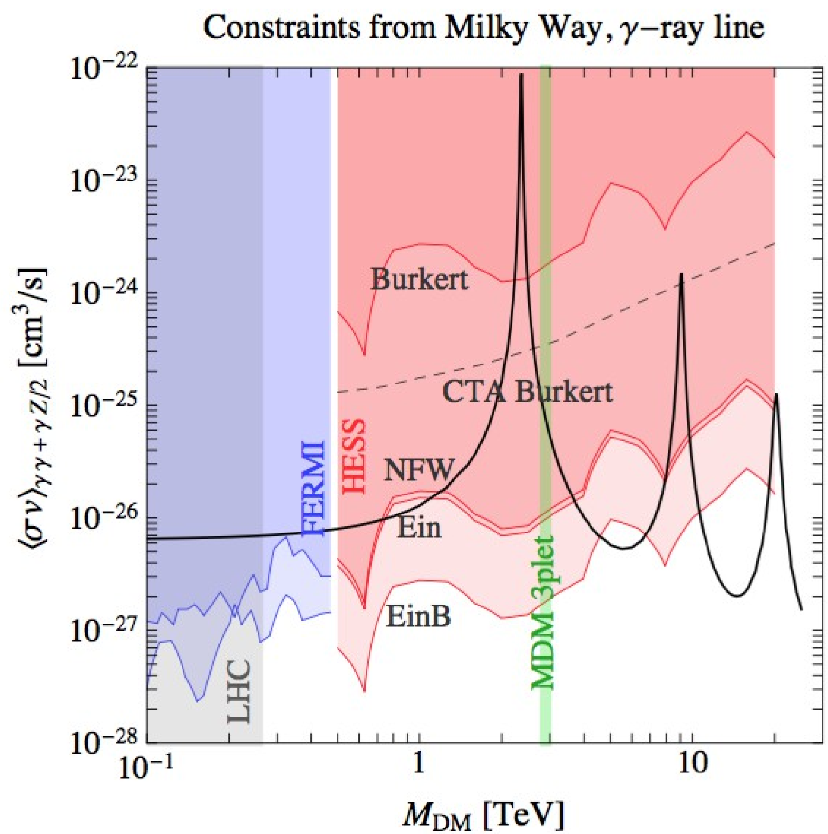


Cirelli, Hambye, Panci, Sala, Taoso 1507.05519

Gamma-ray lines

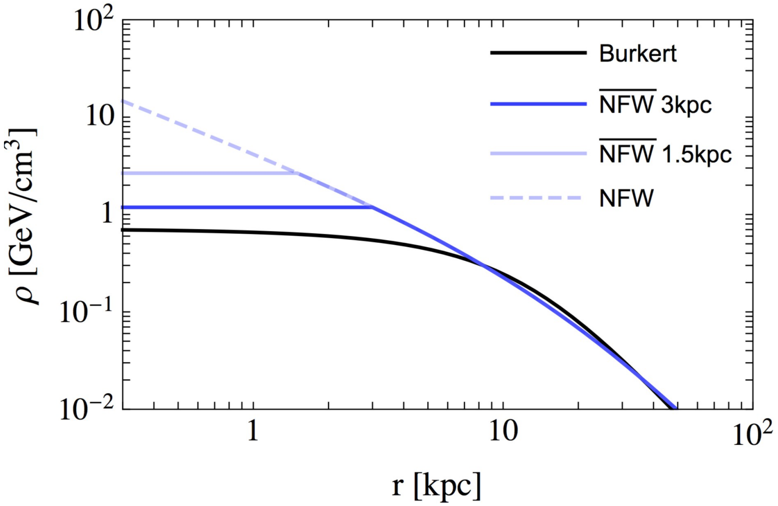
HESS: small region of observations around GC (1 degree). Huge dependence of bounds on DM density profile

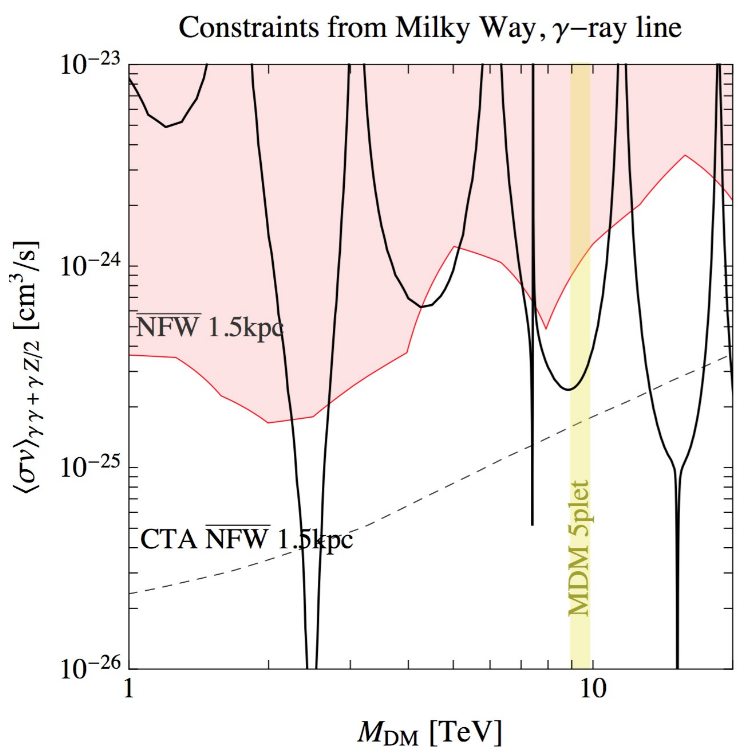


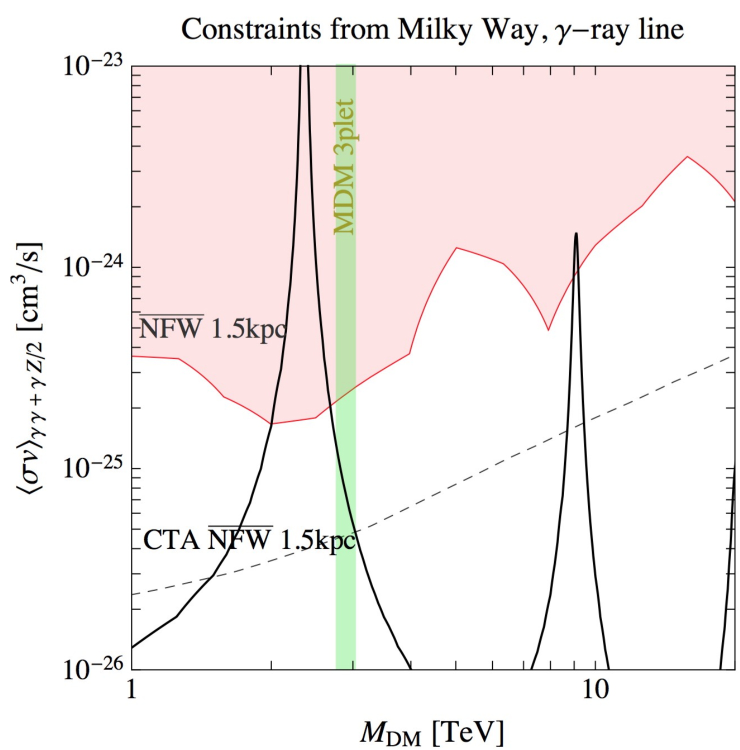


From measurements:
Density profile unknown in inner few kpc region

Pato, Iocco, Bertone 1504.06324





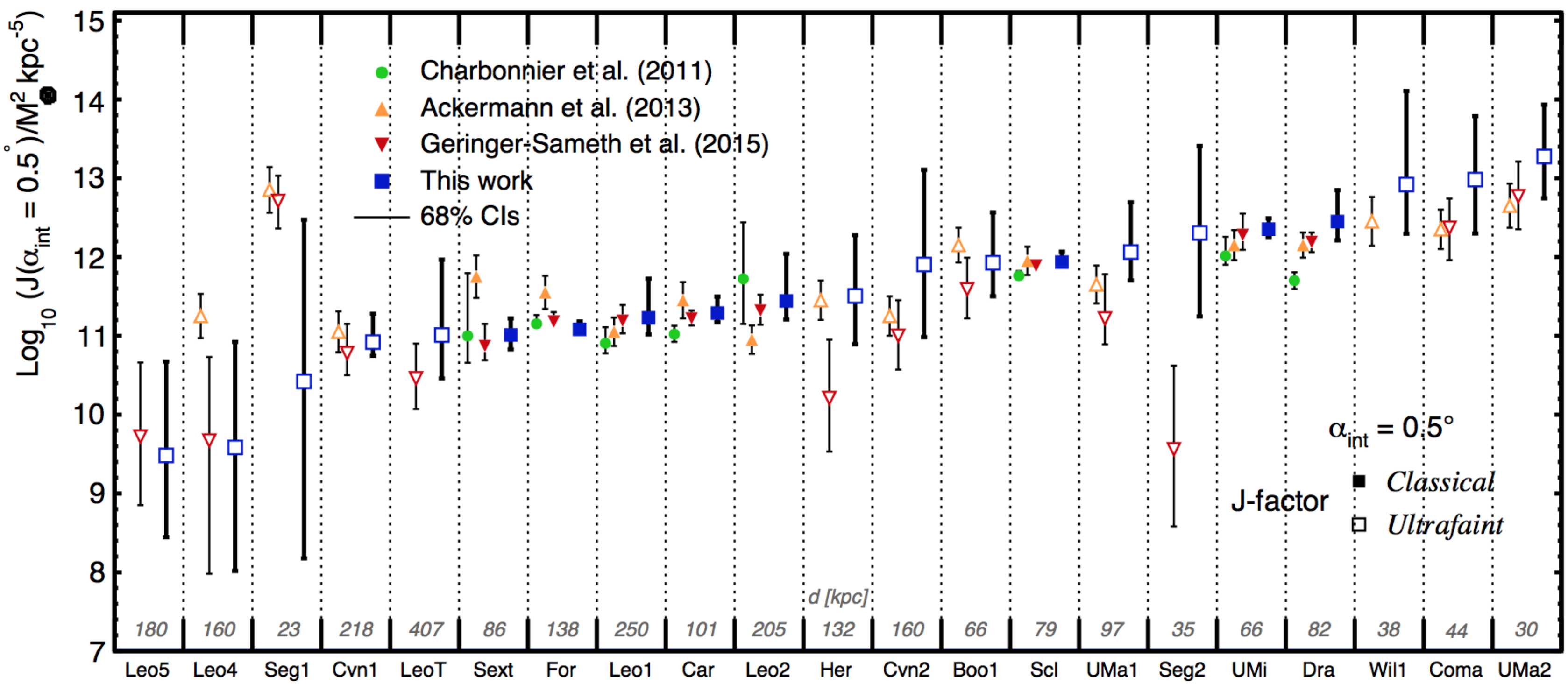


Dwarf galaxies

Close to us, gravitationally dominated by DM, DM density profile reconstructed from star kinematics.

Recent activity to quantity uncertainty on J-factors

e.g. Ullio, Valli 1603.07721, Evans et al. 1604.05599, Genina Fairbairn 1604.00838



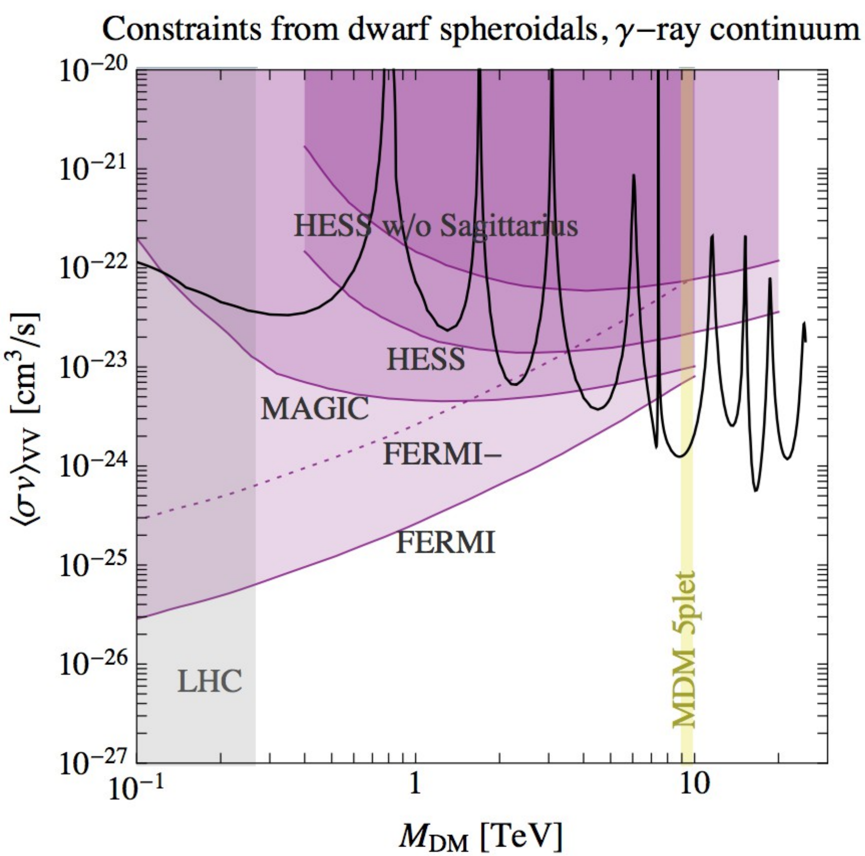
Bonnivard et al. 1504.02048

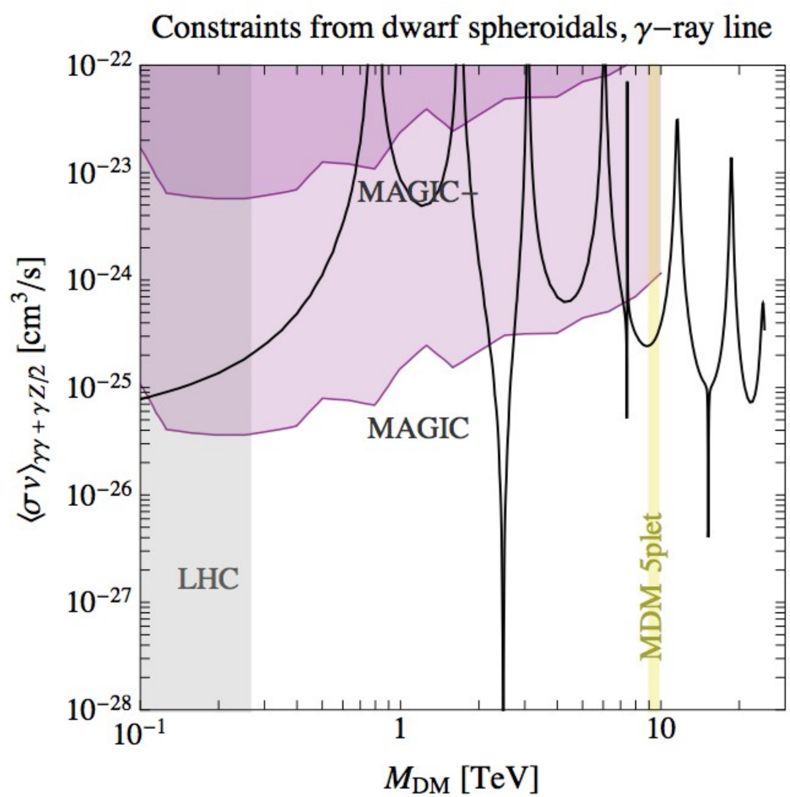
Dwarf galaxies

Fermi-LAT: stacked analysis of 15 dwarves
HESS: 4 dwarves
MAGIC: only Segue 1. Current uncertainty on J-factor is large for this dwarf

HESS obs of dwarfs could be used also for lines!

Ongoing analysis:
Hess collaboration + Cirelli, Panci, Sala, Silk, MT



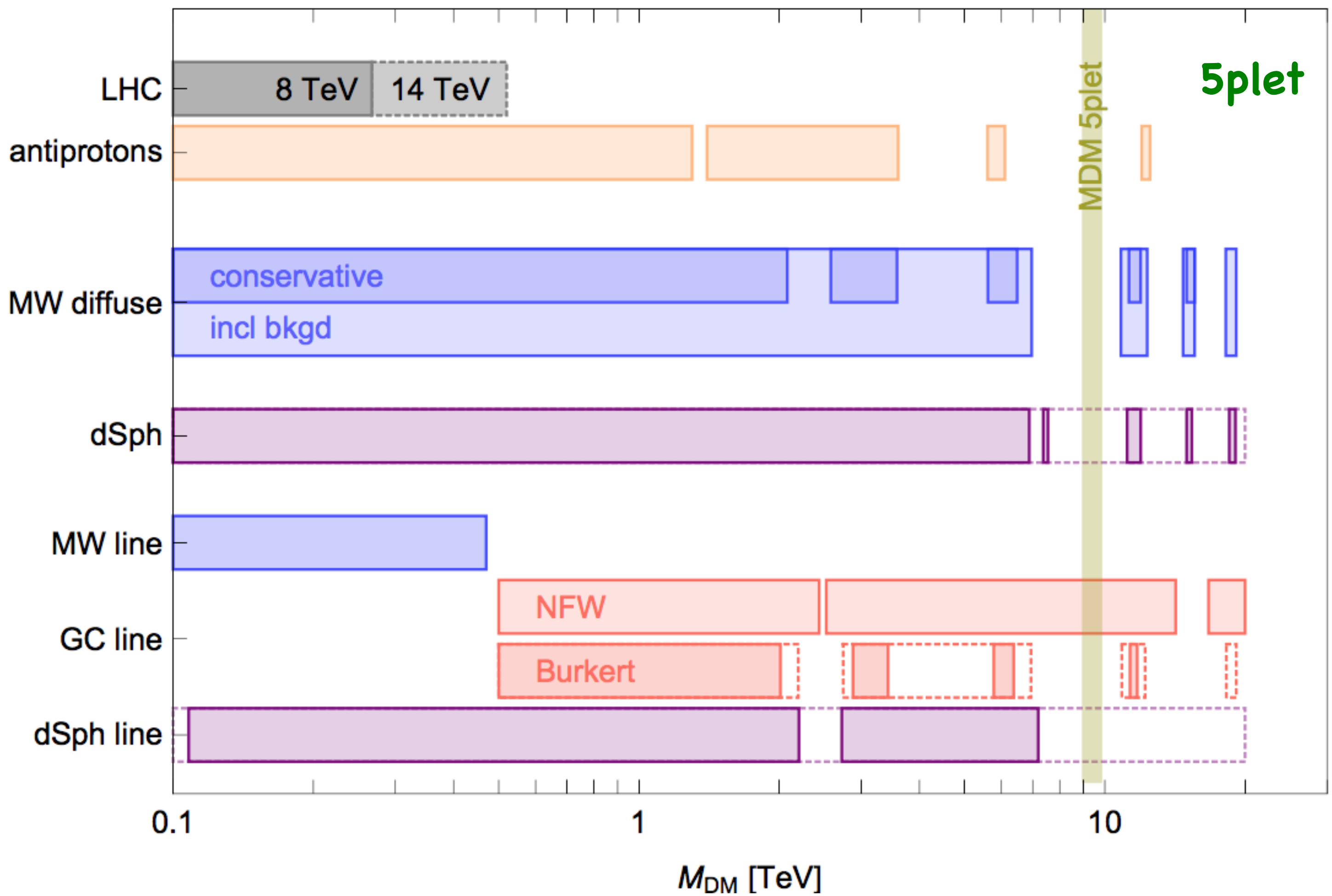


Summary

Lines from inner galaxies good probe of 3-plet and 5-plet but large uncertainties.

Obs. Of dwarf galaxies look promising and significant progress may come in near future.

Summary of constraints (solid edge) and reaches (dashed edge)



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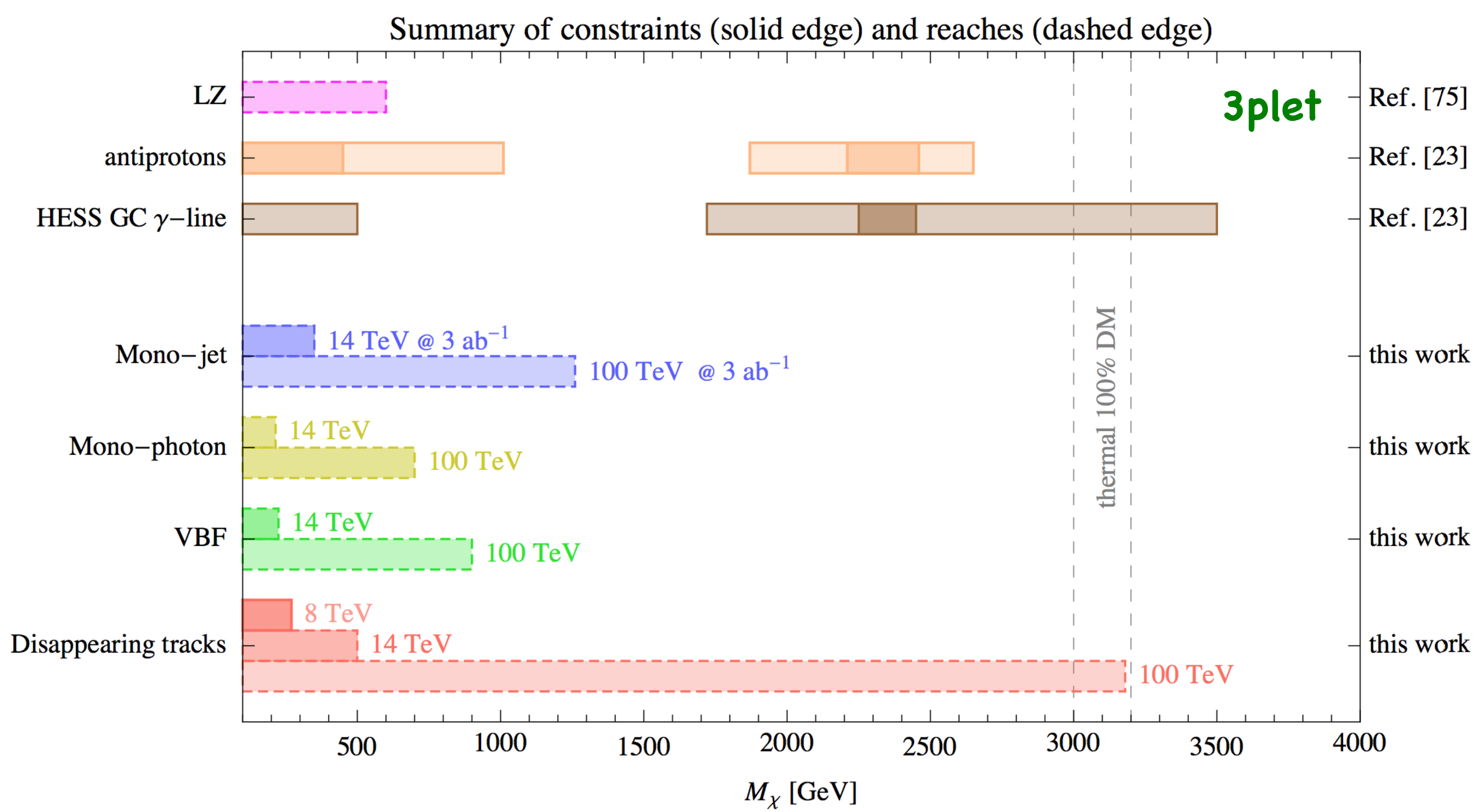


Thanks!

THANKS

Minimal Dark Matter

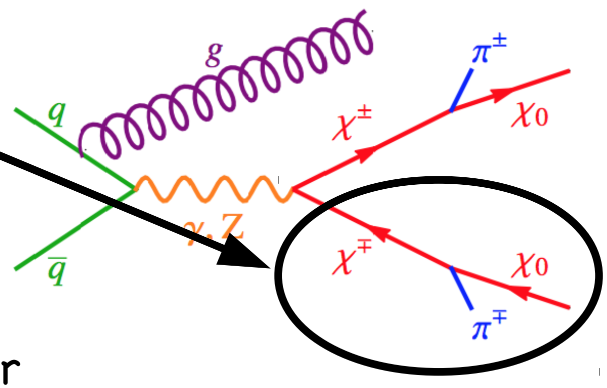
From Cirelli, Strumia 0903.3381

Quantum numbers			DM can	DD	Stable?
$SU(2)_L$	$U(1)_Y$	Spin	decay into	bound?	
2	1/2	S	EL	×	×
2	1/2	F	EH	×	×
3	0	S	HH^*	√	×
3	0	F	LH	√	×
3	1	S	HH, LL	×	×
3	1	F	LH	×	×
4	1/2	S	HHH^*	×	×
4	1/2	F	(LHH^*)	×	×
4	3/2	S	HHH	×	×
4	3/2	F	(LHH)	×	×
5	0	S	(HHH^*H^*)	√	×
5	0	F	–	√	√
5	1	S	$(HH^*H^*H^*)$	×	×
5	1	F	–	×	√
5	2	S	$(H^*H^*H^*H^*)$	×	×
5	2	F	–	×	√
6	1/2, 3/2, 5/2	S	–	×	√
7	0	S	–	√	√
8	1/2, 3/2 ...	S	–	×	√

7-plet not stable Di Luzio et al. 1504.00359

Disappearing tracks

Lifetime of charged particle around 0.2 ns
Charged tracks of ~ 10 cm



Backgrounds:

- interactions of charged hadrons in the detector

- unidentified leptons

- pT mis-measured tracks
  (dominant at large pT)

ATLAS 8 TEV with 20 fb^{-1}

Bound M>270 GeV (95% CL)