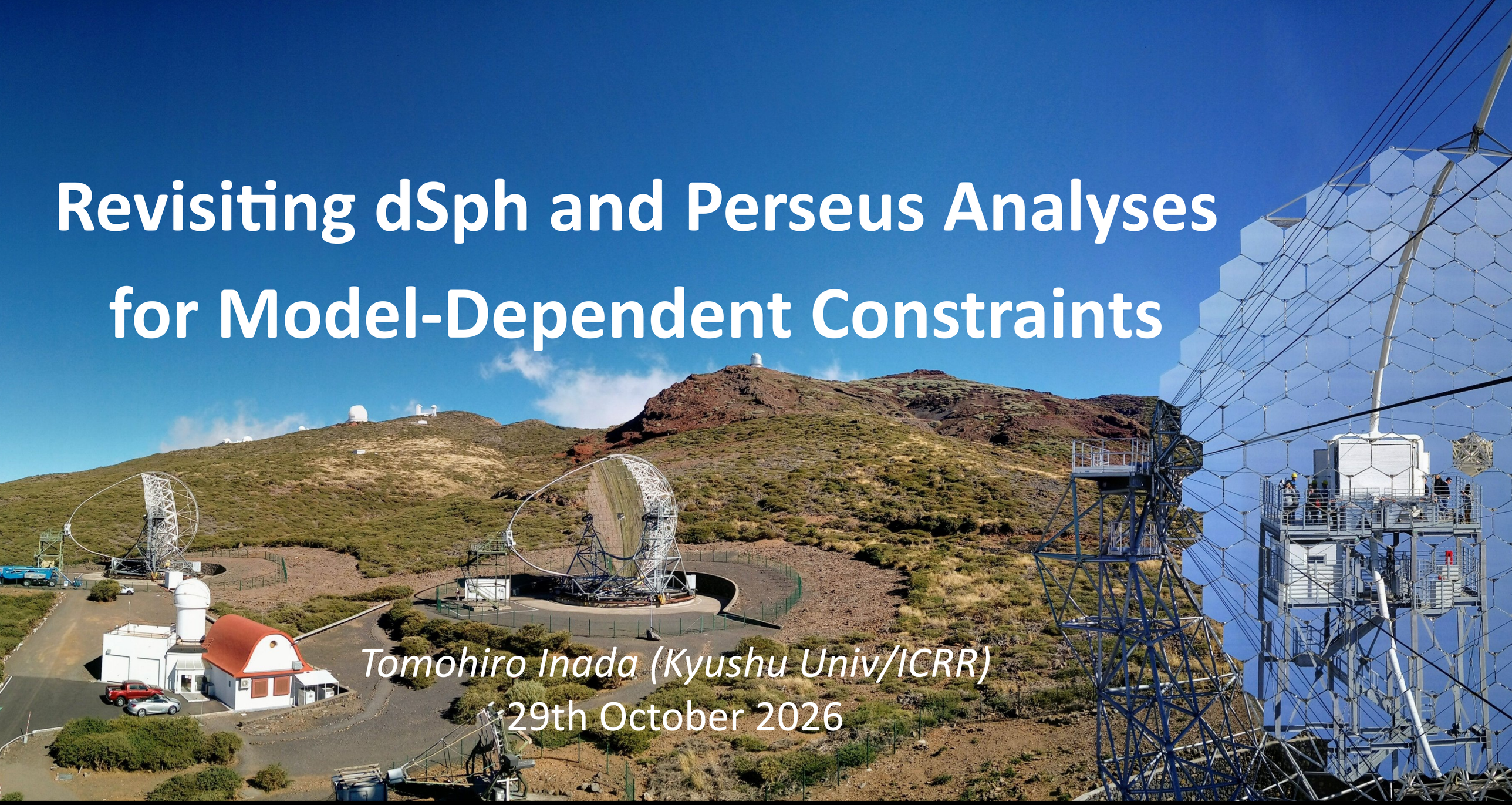
Revisiting dSph and Perseus Analyses for Model-Dependent Constraints



Tomohiro Inada (Kyushu Univ/ICRR)

29th October 2026

Motivation

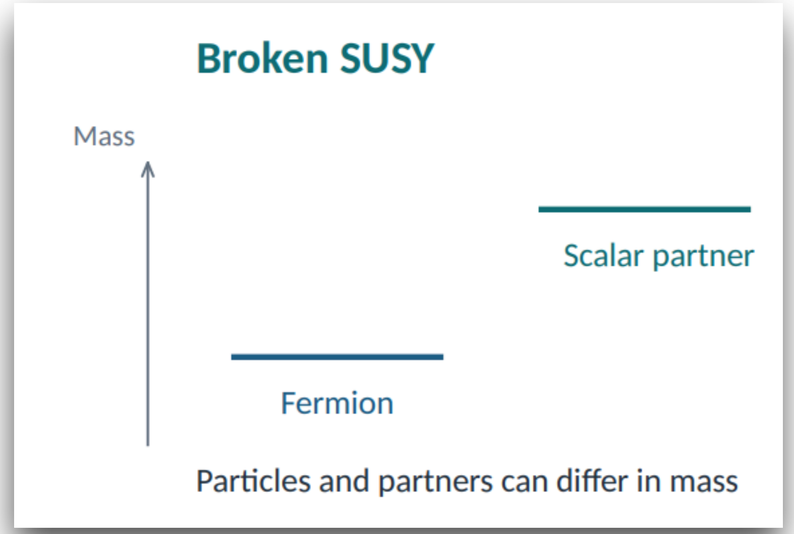
Plan to reuse or recast existing data for more interpretations

- not only just limits but also converting limits to other words e.g. constraints on SUSY particle model itself, parameters to understand early universe…

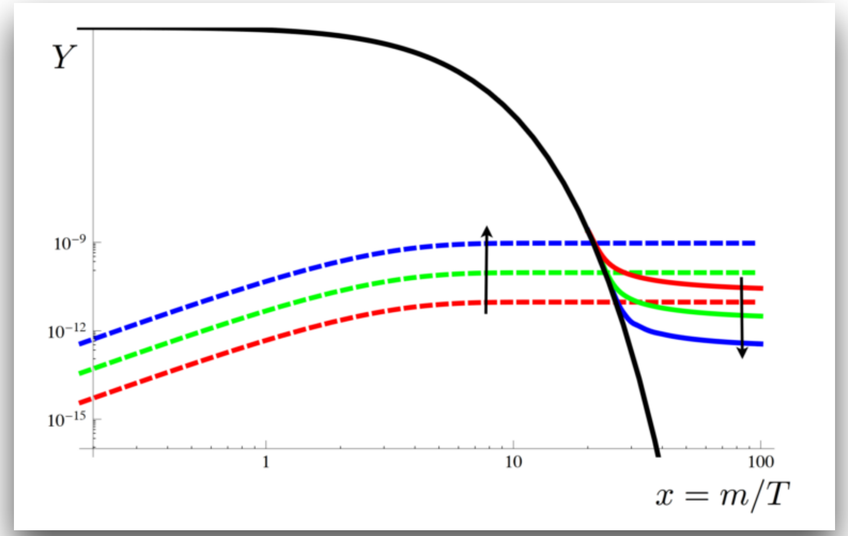
- trying to demonstrate (although some parts already done) gamma-ray astronomy is useful to help understanding with cosmology, particle physics etc

Focused on two datasets

- Perseus cluster data for dark matter decaying models
- dSphes models for dark matter annihilating models



SUSY-breaking scale?



Freeze-out or freeze-in?

Recasting the Perseus Cluster results

Used the published Perseus data set (202 h)

Phys.Dark Univ. 22 (2018) 38-47 [link]

shared from Daniel K. (Originally from Quim)


Physics of the Dark Universe 22 (2018) 38–47

Contents lists available at ScienceDirect

Physics of the Dark Universe

journal homepage: www.elsevier.com/locate/dark

Constraining dark matter lifetime with a deep gamma-ray survey of the Perseus galaxy cluster with MAGIC

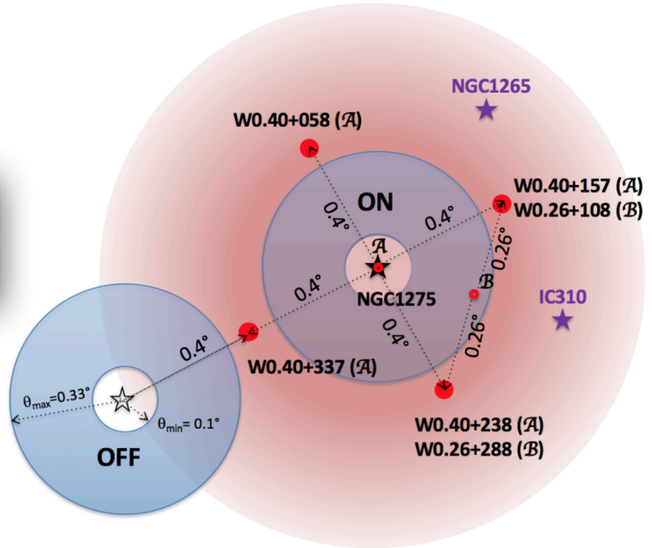
Perseus cluster contains huge dark matter but a extended source

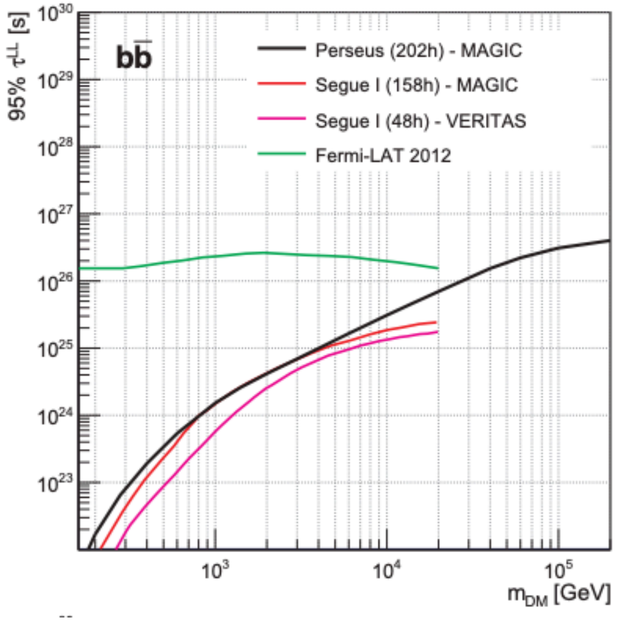
→ useful to study decaying dark matter

$$\frac{\mathrm{d}^2\Phi}{\mathrm{d}E\,\mathrm{d}\Omega} = \frac{1}{4\pi}\,\frac{1}{\tau_{\mathrm{DM}}\,m_{\mathrm{DM}}}\,\frac{\mathrm{d}N_\gamma}{\mathrm{d}E}\,\frac{\mathrm{d}J_{\mathrm{dec}}}{\mathrm{d}\Omega} \qquad \frac{\mathrm{d}J_{\mathrm{dec}}}{\mathrm{d}\Omega} = \int_{\mathrm{l.o.s.}} \mathrm{d}l\,\rho(l,\Omega)$$

Started from flute/gLike output.root files.

Implemented gamma-ray spectra from PNGB decaying dark matter





Goldstino dark matter: production and decay

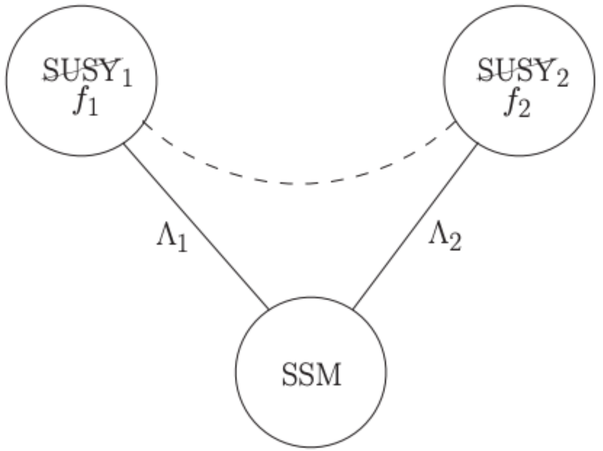
Pseudo-goldstino dark matter from SUSY breaking

- Motivation: SUSY can protect the Higgs mass from large quantum corrections.
- **A dark-matter candidate**:
  - Goldstinos are spin-(1/2) particles associated with spontaneous SUSY breaking. With two approximately independent SUSY-breaking sectors, two Goldstino modes arise.
  - In supergravity, one combination becomes part of the massive gravitino, the graviton's superpartner. The other remains as a physical particle: the pseudo-goldstino (ζ).
  - It can acquire a mass and, if sufficiently long-lived, be a dark-matter candidate.

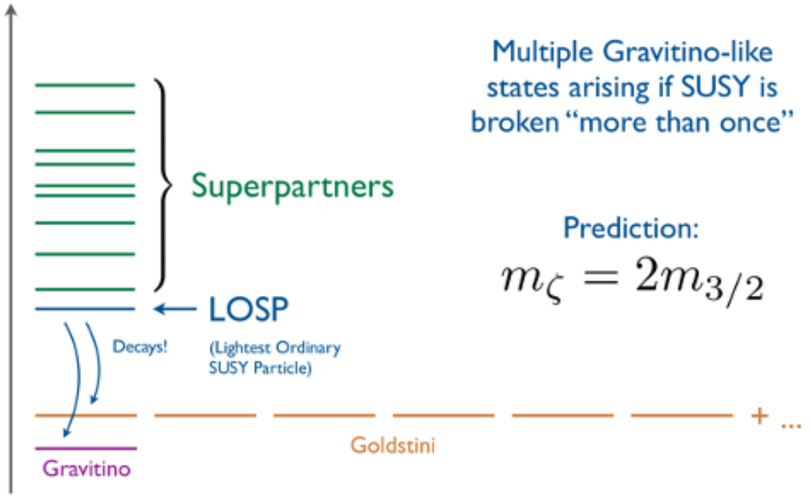
JHEP 03 (2010) 073

- **Production and decay**:
  - The SUSY-breaking scales ($\sqrt{F_1}$) and ($\sqrt{F_2}$), together with how these sectors interact with ordinary particles, govern both DM production and its possible decay today.
- **Assumed origin**: freeze-in. Starting from almost no DM, rare collisions in the hot early Universe produce pseudo-goldstino pairs: $f\bar{f} \to \zeta\zeta$.
  - The ordinary particles form a thermal bath, while the DM population remains out of chemical equilibrium.

1012.5300



[Link]

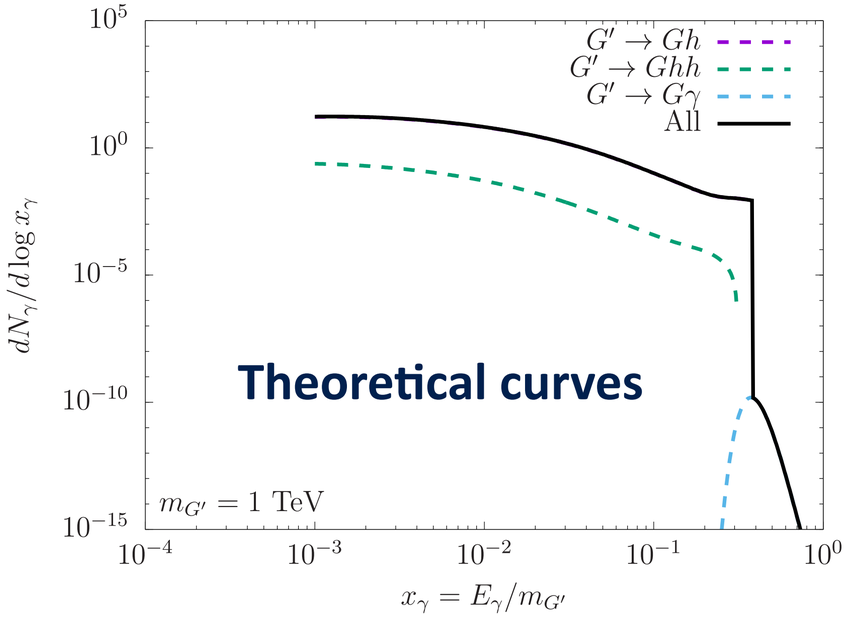


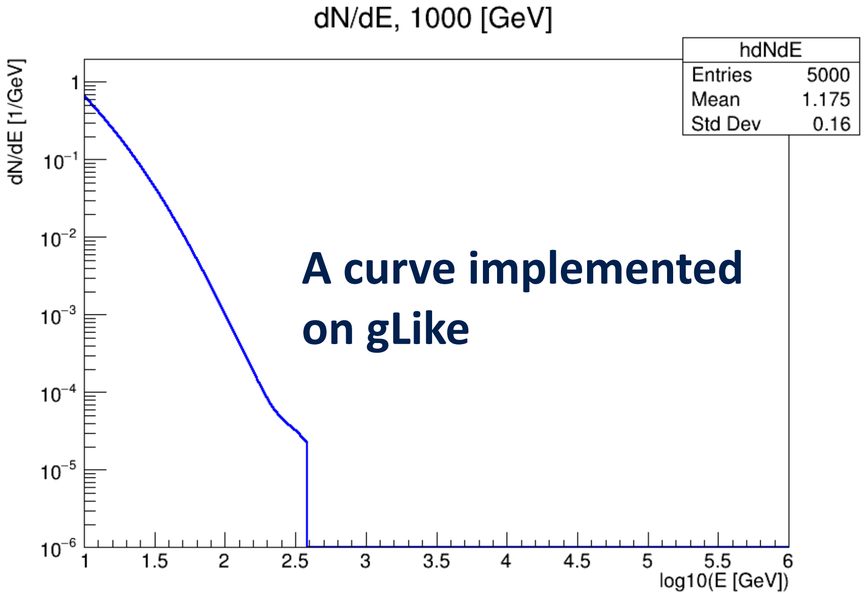
Example gamma-ray spectra from PNGB decay

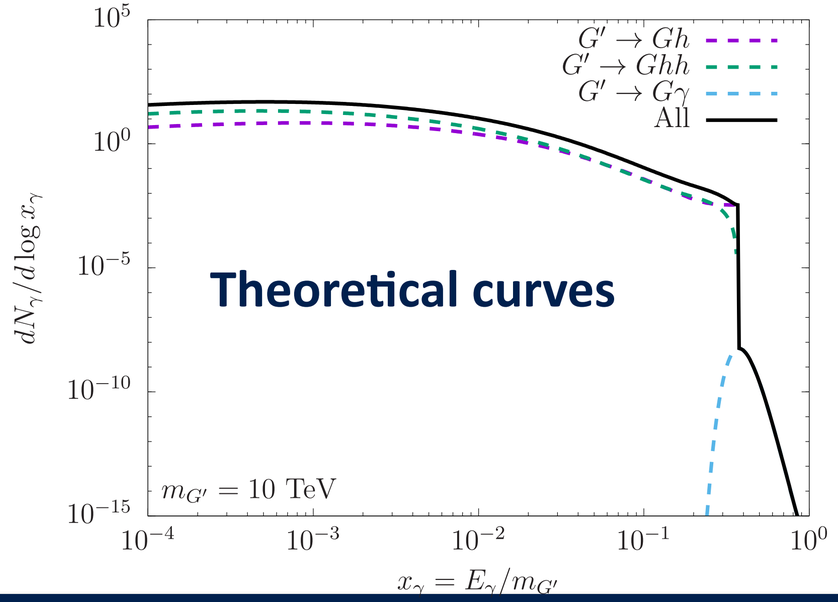
Assuming contributions from all channels

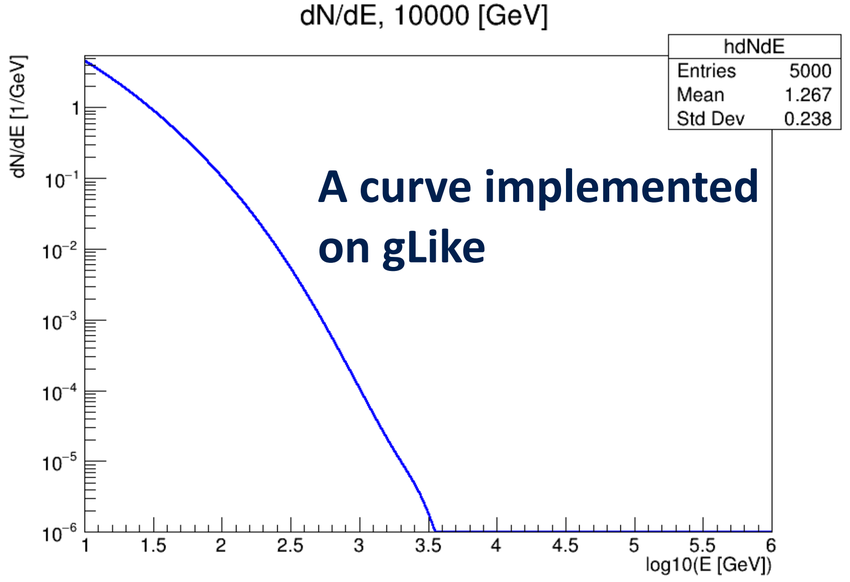
Three decay modes considered:

- G’ → G + h
- G’ → G + h + h
- G’ → G + gamma (line)

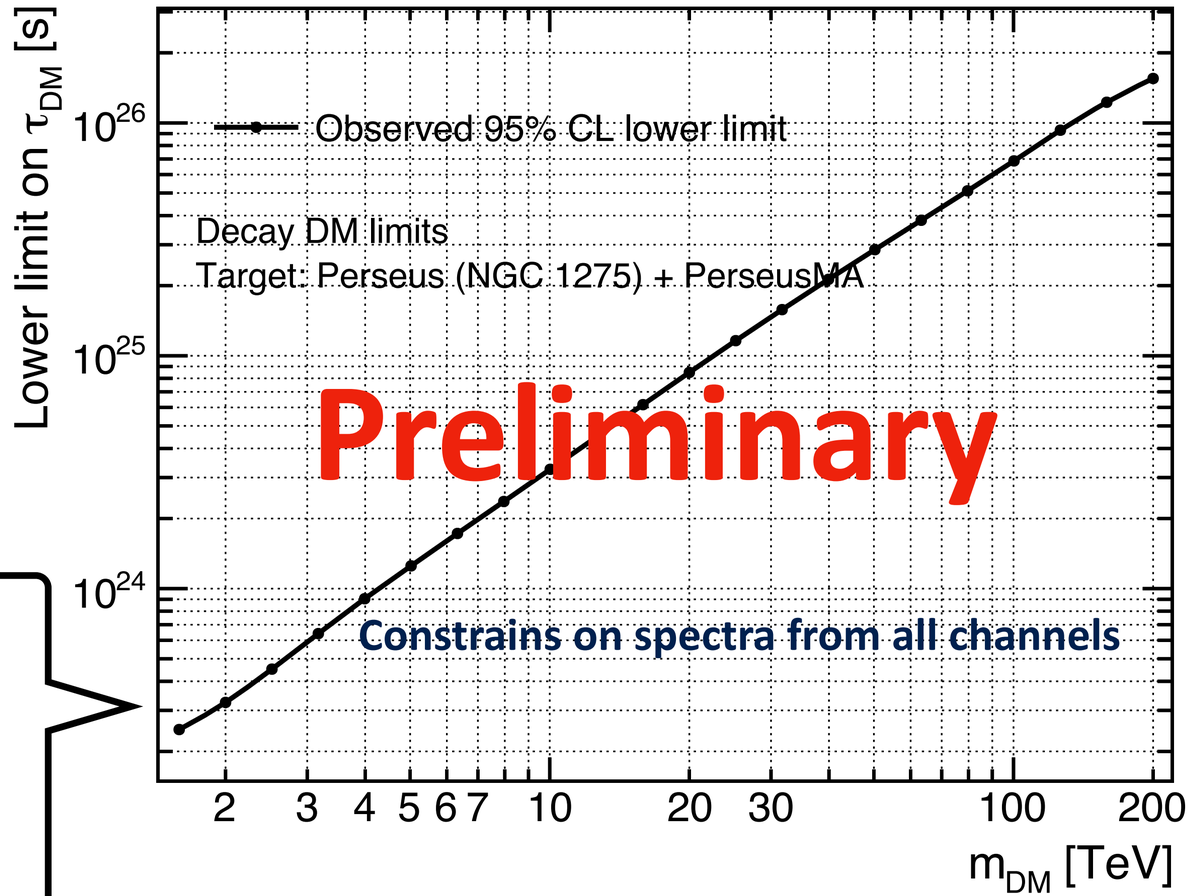


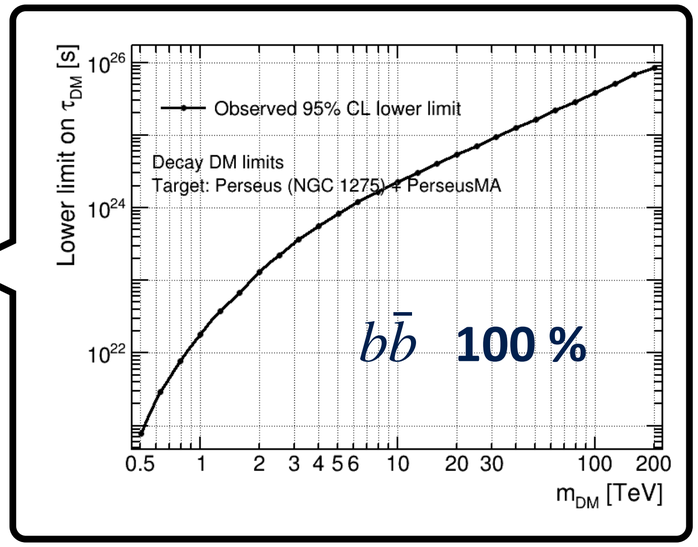


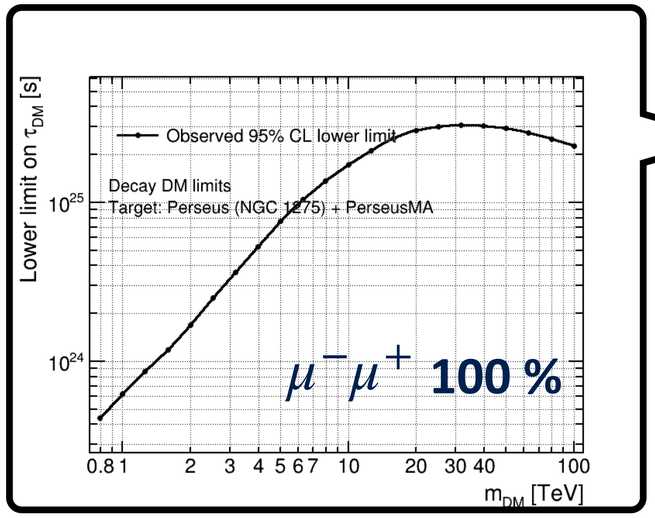




Limits on lifetime







High energies:
dominated by quark channels

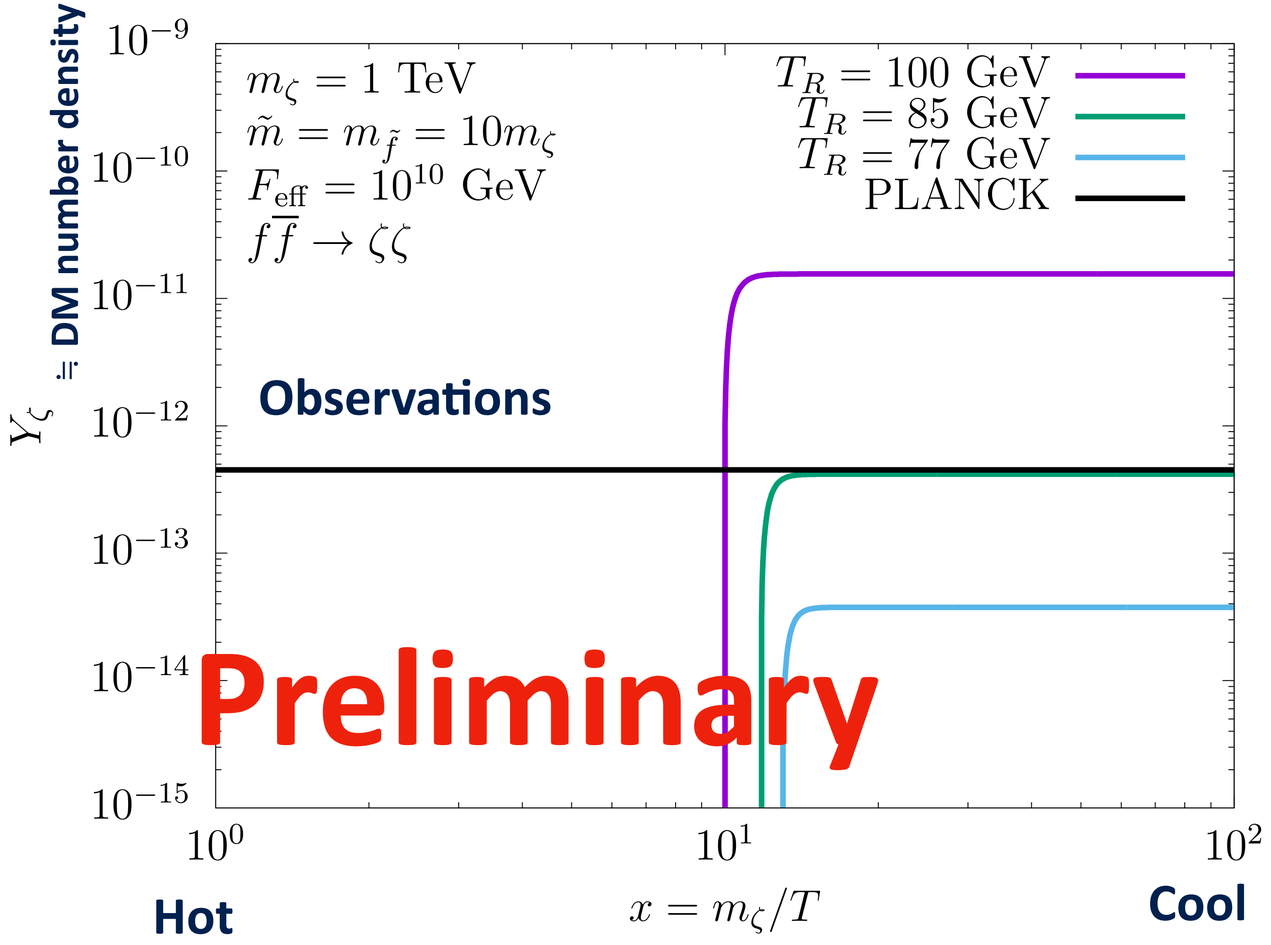
Low energies:
dominated by lepton channels

Interpretation: constrains on reheating temperature

- **Constraints on Freeze-in production of PGDM**
  - Converting limits into theoretical interpretation
- **Reheating**: energy from inflation heats the plasma. (T_R) characterizes its temperature when radiation domination begins.
- **Freeze-in:** rare scatterings ($f\bar{f} \to \zeta\zeta$) produce dark matter without bringing it into thermal equilibrium.
- For ($T_R < m_\zeta$), only the high-energy tail of the thermal distribution can produce DM pairs. Production rapidly stops as the Universe cools.

Most production occurs near (T_R) in this scenario. A small change in (T_R) strongly changes the final abundance.

Collaboration with T. Toma

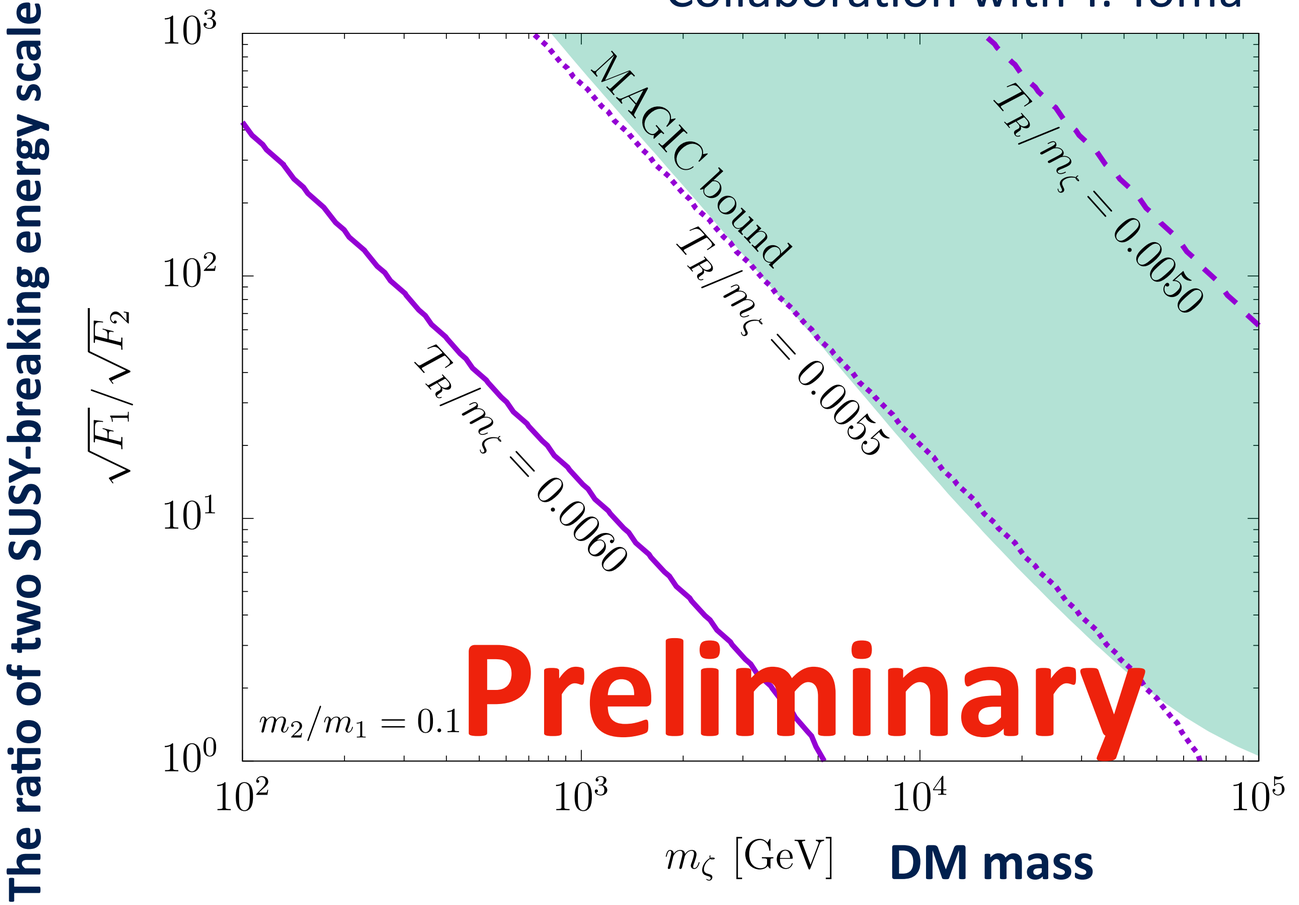


Interpretation: constrains on SUSY-breaking scale

- **Relic abundance and MAGIC constraints**
  - SUSY breaking produces mass differences between particles and their superpartners.
  - (F_i) measures the breaking strength in sector (i), with units of energy squared. ($\sqrt{F_i}$) is the corresponding energy scale.
  - These parameters control both Goldstino production and decay in this model.

Combining the relic abundance with MAGIC constrains (T_R/m_ζ), for the assumed model and production history.

Collaboration with T. Toma



Purple contours: ($\Omega_\zeta h^2 = 0.12$) at fixed (T_R/m_ζ).

Shaded region: excluded by MAGIC gamma-ray limits on DM decay.

Recast dSphes dataset for SUSY-Wino constraints

Plan to use the published dSphes data set (354.3 h)

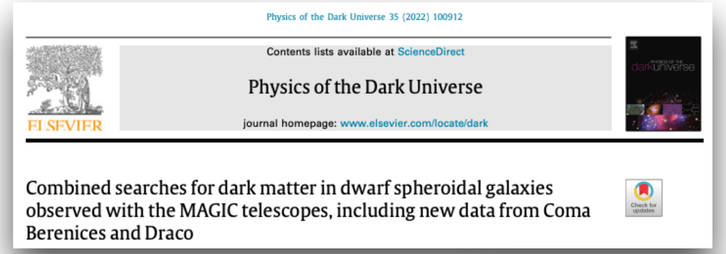
Phys.Dark Univ. 35 (2022) 100912 [link] and Glory duck [link] shared from Daniel K.

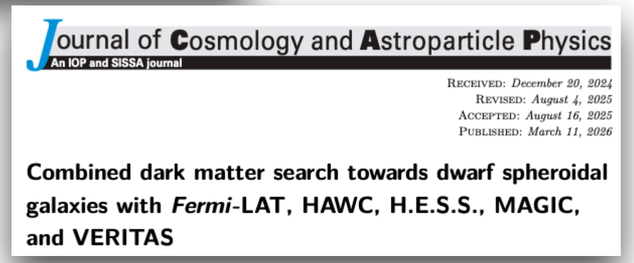
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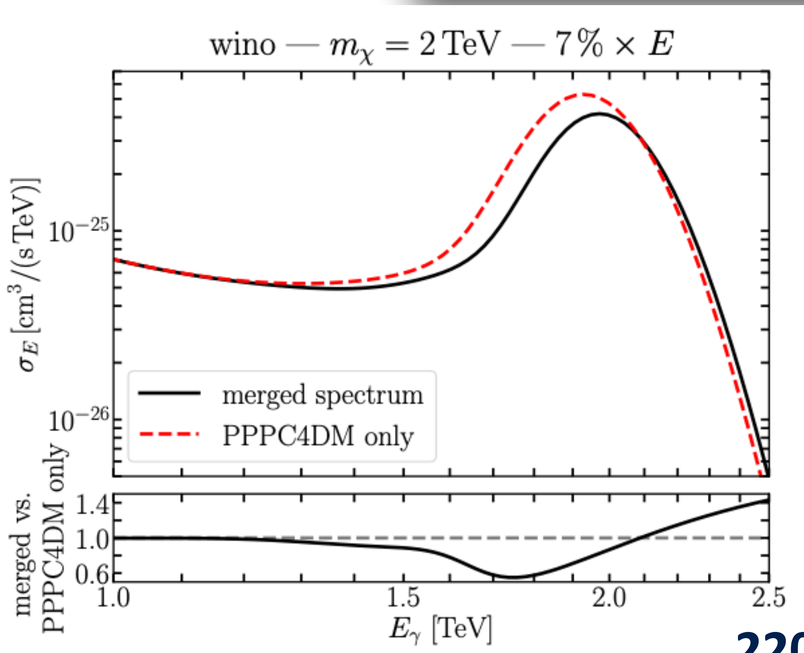
Implement gamma-ray spectra from SUSY-Wino annihilation

Original discussion started together with David Paneque and theoreticians.

- Interesting to test well-motivated particle models







2203.01692

Current situation and Prospects

VERITAS has recently showed this wino-dedicated searches with full spectra from wino annihilation

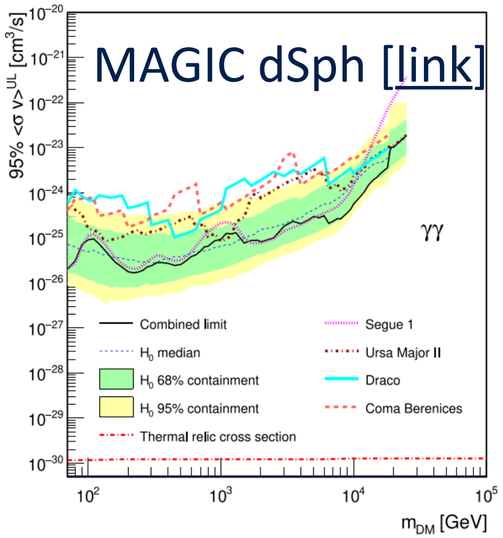
Comparable VERITAS (full spectra) vs MAGIC (only γγ)

MAGIC can also try to conduct with full spectra search

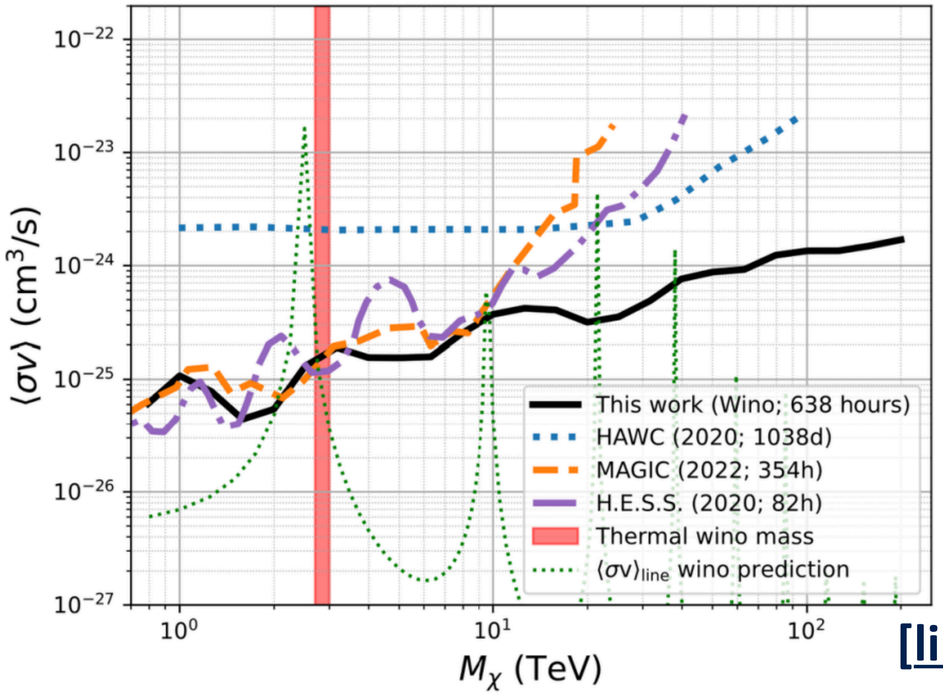
- chances to improve sensitivity more than VERITAS

Future combination established by glory duck would have a chance to exclude SUSY-Wino DM marginally (some people are contacting us, including Tjark and Daniel K)

Also, good motivation to prepare future common analysis format with gamma-py (dm-module)



VERITAS submitted Awaiting PRD publication



[link]

Photon Spectra Equation

Differential photon count per photon energy

Final states with multiplicity 3 or greater

$$\frac{dN_\gamma(E)}{dE} = 2\delta(E - M_\chi) + \frac{dN_\gamma(E)}{dE}^{\text{endpoint}} + \frac{dN_\gamma(E)}{dE}^{\text{continuum}}$$

χχ→γγ
2 photon final state

W and Z decay processes to photons

Summary and prospects

Pseudo-goldstino dark matter searches

- Could be the first time to constrain this model with SUSY-breaking scales
  - As well as reheating energy scale
  - Combination of gamma-ray astronomy, astroparticle, particle physics and cosmology
- Publication planning
  - Main plot with MAGIC data is the constraint to spectra from all channels
    - Recast data which has published (Perseus)
  - Then, theory interpretation plots with a few theoreticians
  - Possibly, short-listed author paper (like branon?) (link)

Wino constraints with dSph

- Plan to recast dSphes data used for publication in the past
- Could be competitive with VERITAS or even beyond
- Plan to prepare pipeline with gamma py for the future joint analysis, validating gLike results
  - DL3 conversion is necessary (working on it).
  - Some students are interested in it (good students project)
- Possibly, we will make an observational proposal with LST-1
- If you are interested, please let me know