SWGO
The Southern Wide-field Gamma-ray Observatory

The Galactic Center as seen by SWGO

MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

γ 2024
8th Heidelberg International Symposium on
High Energy Gamma Ray Astronomy
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Helena Ren on behalf of the SWGO Collaboration

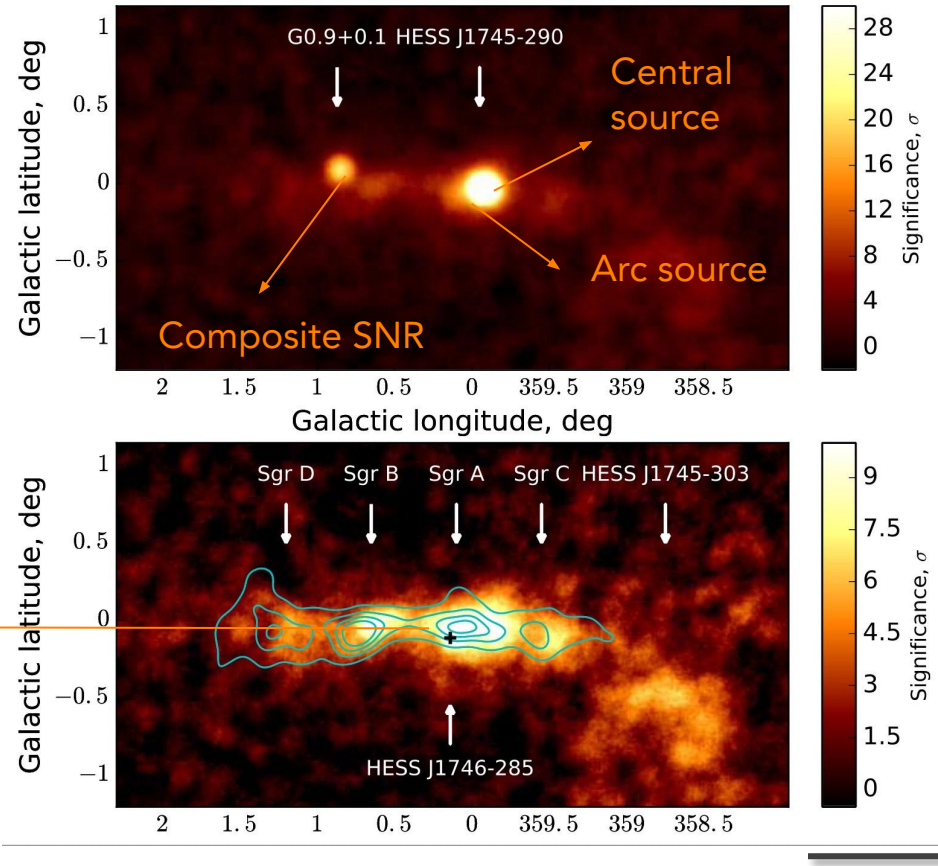
2th September, 2024

Outline

- Introduction to the Galactic Centre
- SWGO: the future VHE and UHE observatory
- Galactic Centre Model
- Dark Matter Sensitivity
- Conclusions

Introduction

- The Galactic Centre (GC) is one of the most interesting and complex regions in our own Galaxy.
- Candidate PeVatron (H.E.S.S. Coll. 2016).
- Central ~200 pc of the Galaxy



Central Molecular Zone (CMZ)

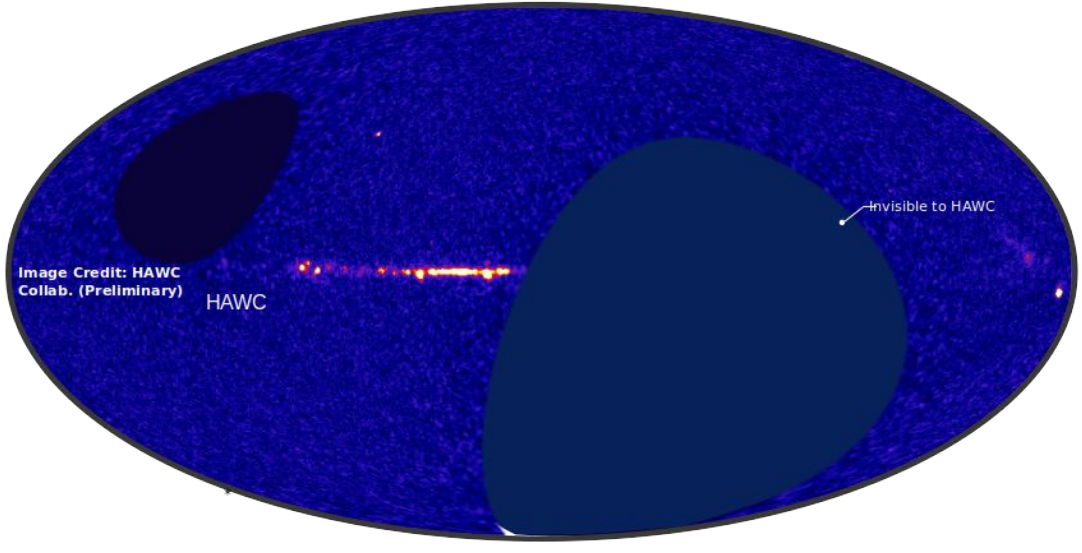
H.E.S.S. Coll., Abdalla et al. 2017

Southern Wide-field Gamma-ray Observatory

→ SEE FRIDAY PLENARY TALK by ULISSES BARRES DE ALMEIDA

Why in the South?

- The Southern sky at this energy range is missing.
- GC is at the edge of current instruments (high zenith angles) like HAWC and LHAASO.



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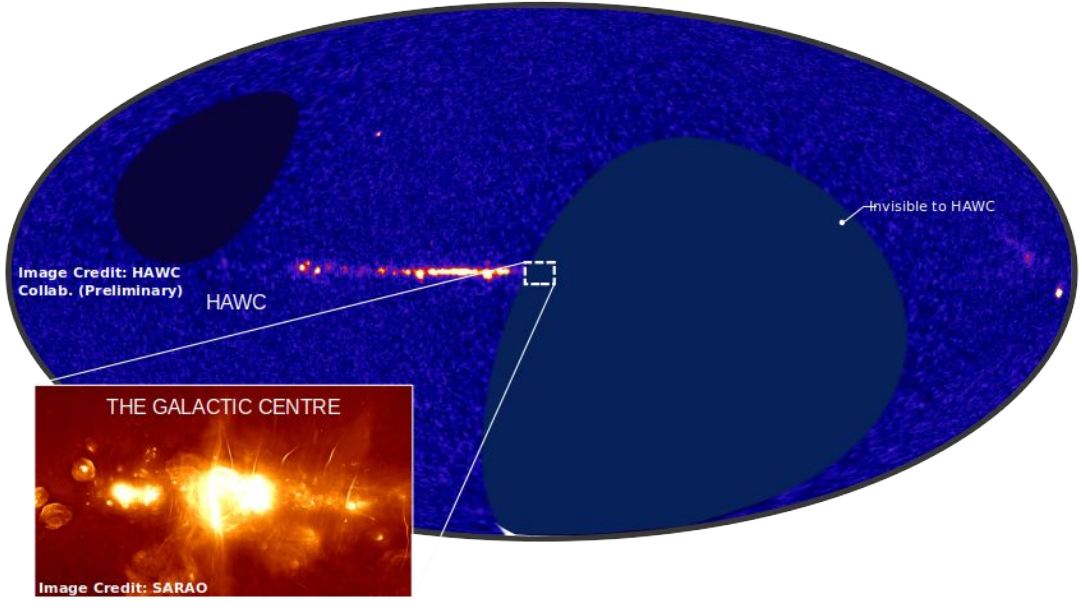

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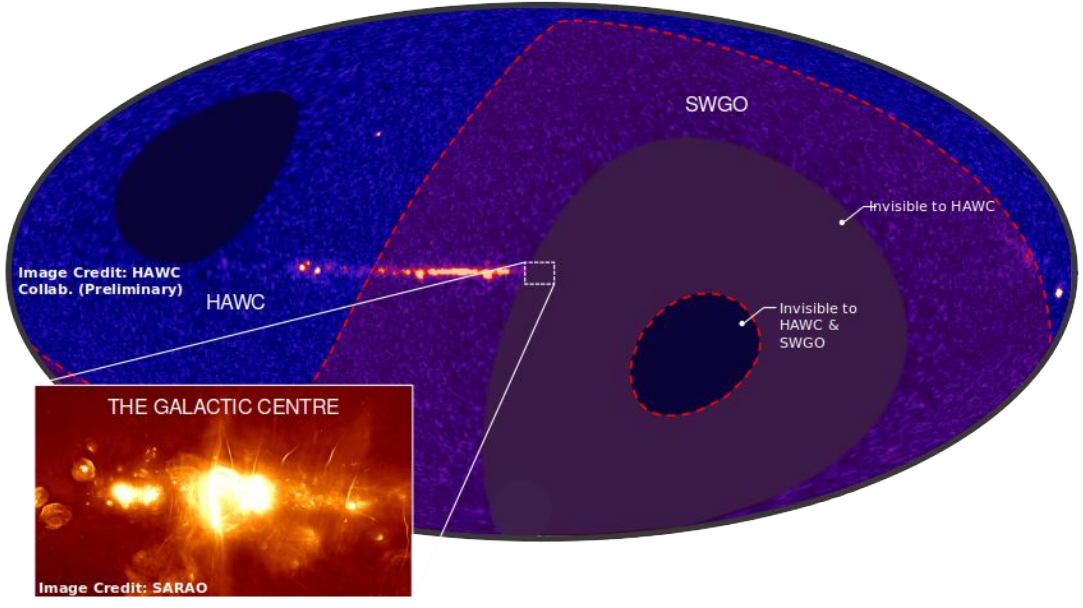
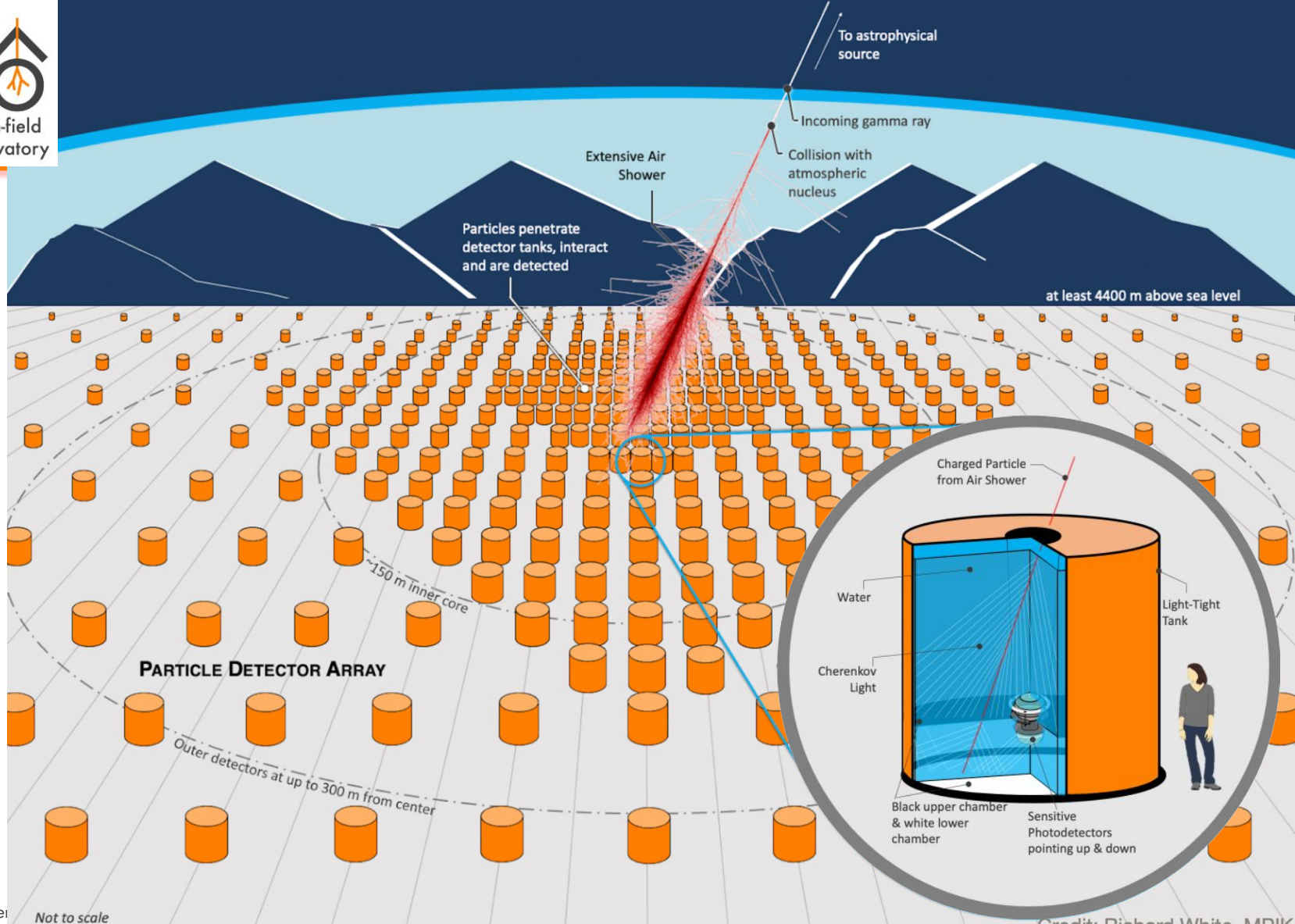
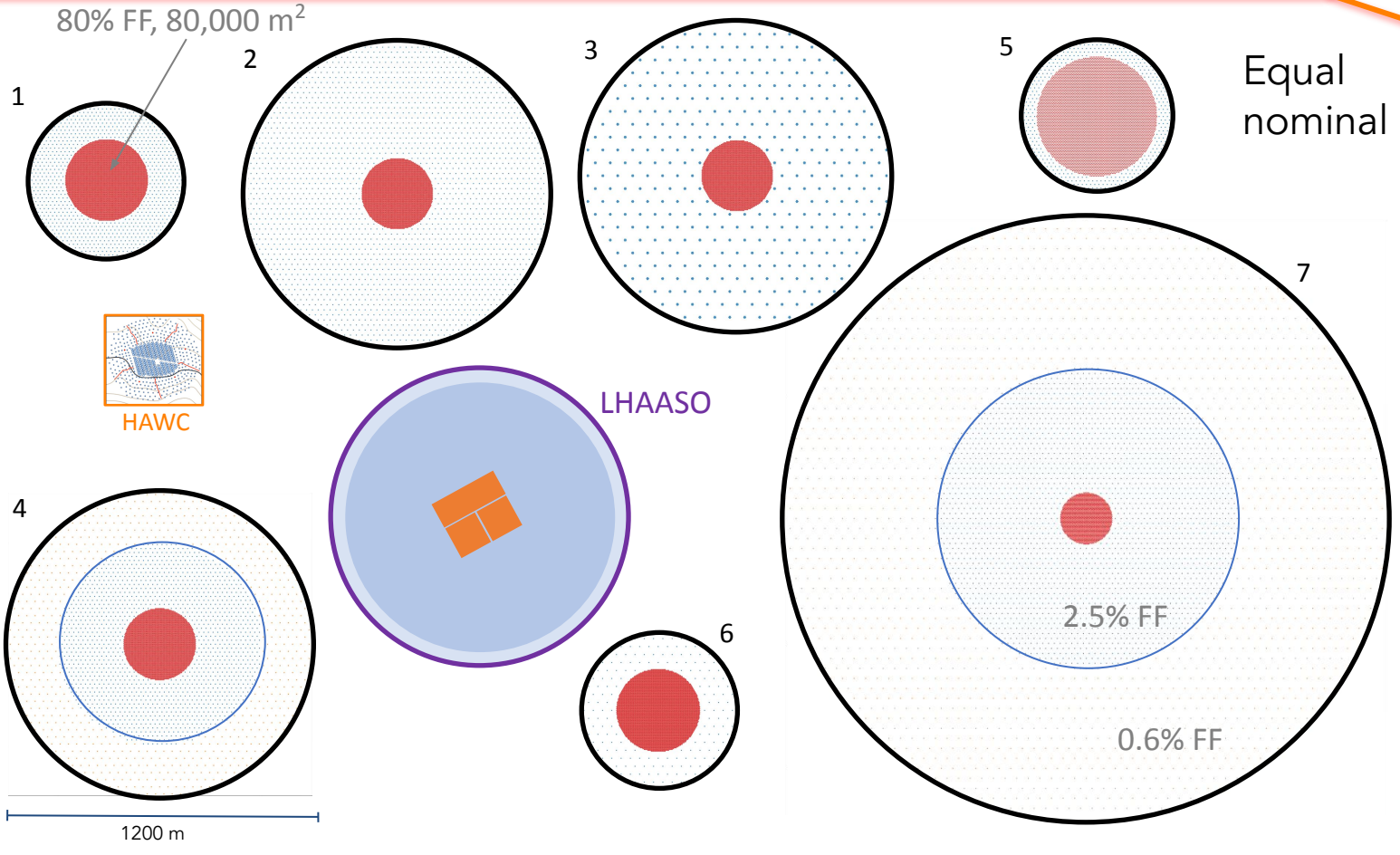


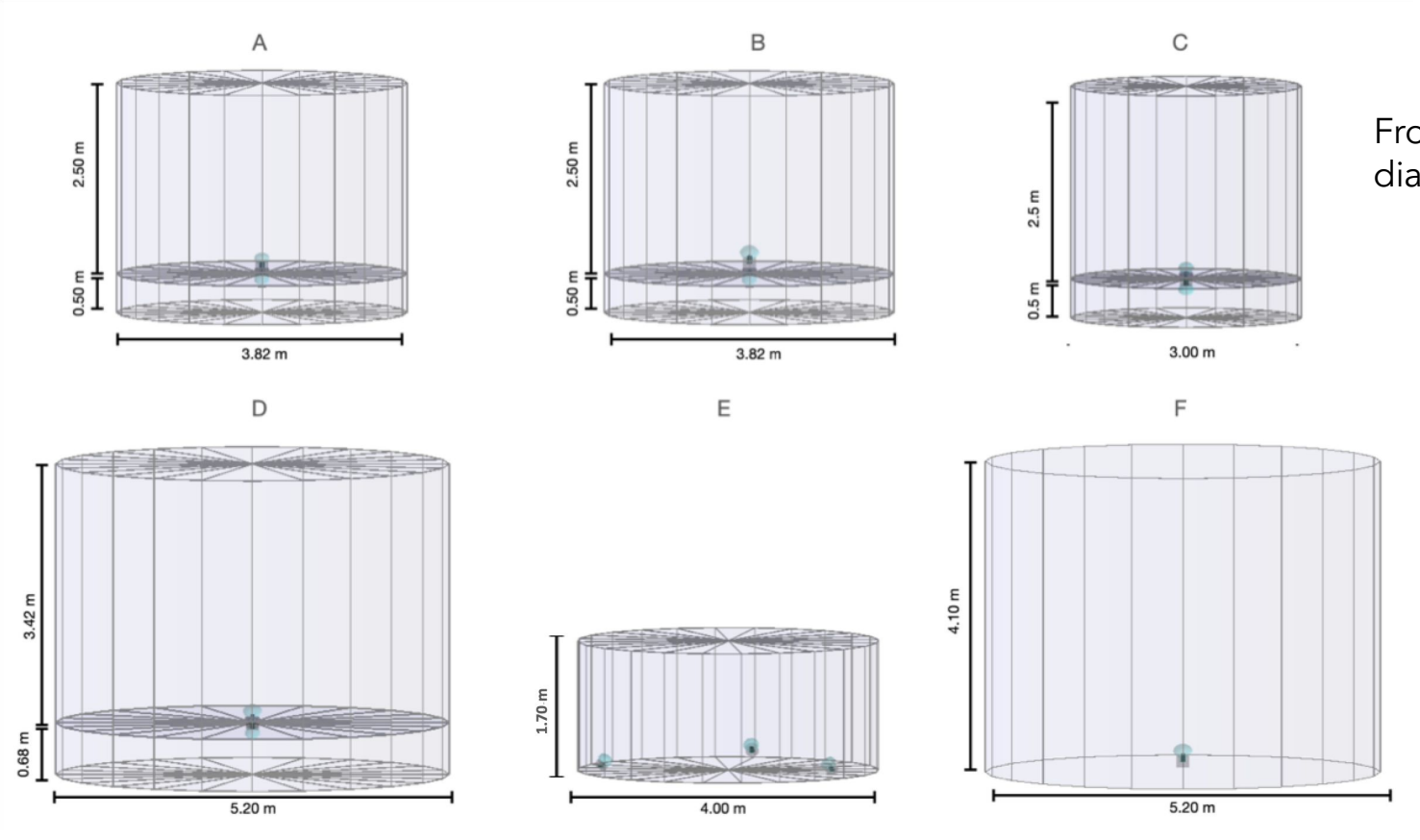
SWGO
The Southern Wide-field Gamma-ray Observatory



Candidate Array Configurations



Candidate Detector Unit Designs



From 3 to 5.2 m diameter tanks

Simulations in the Design Phase

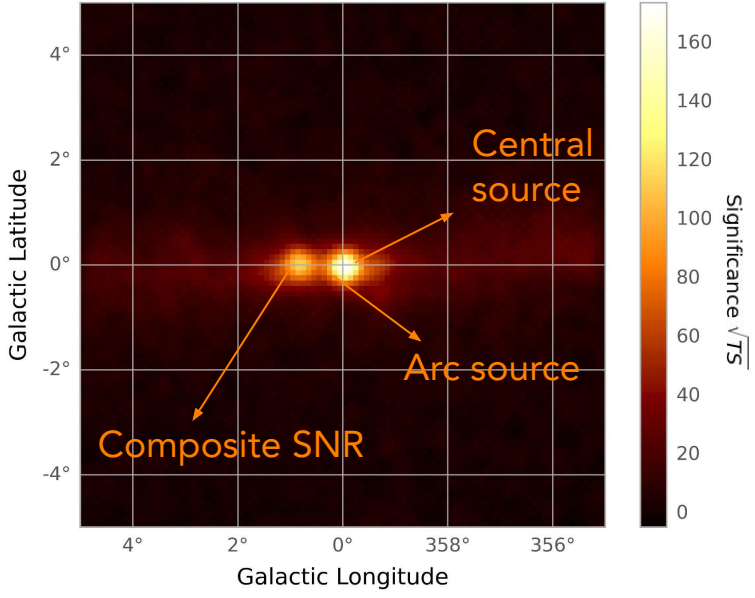
Simulations of gamma-ray sources for the different array and detector designs help us to identify the best configuration.

1. GC sensitivity (simulated observation time: 1 year)
2. Dark matter sensitivity (simulated observation time: 5 year)

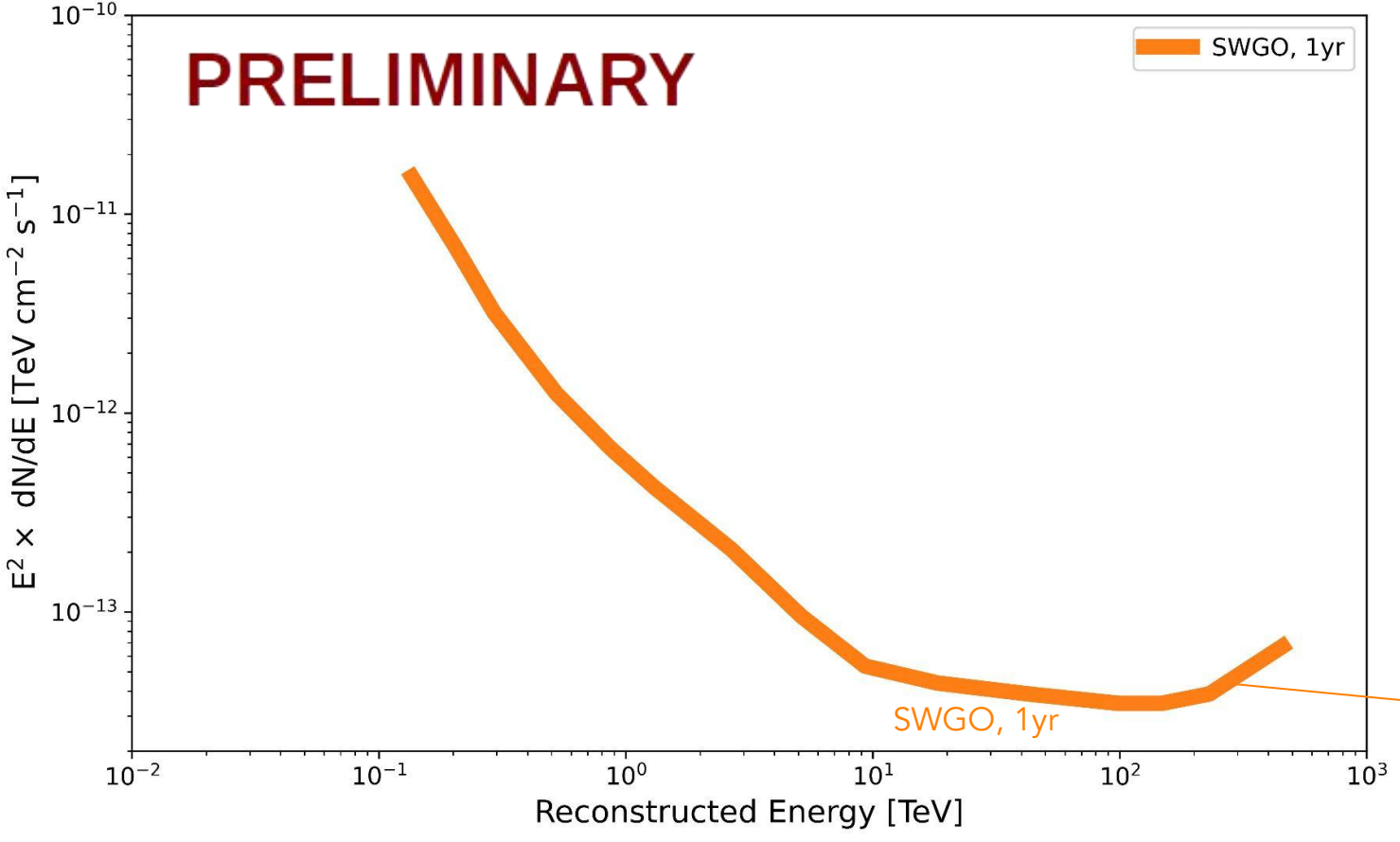
Simulating the GC region

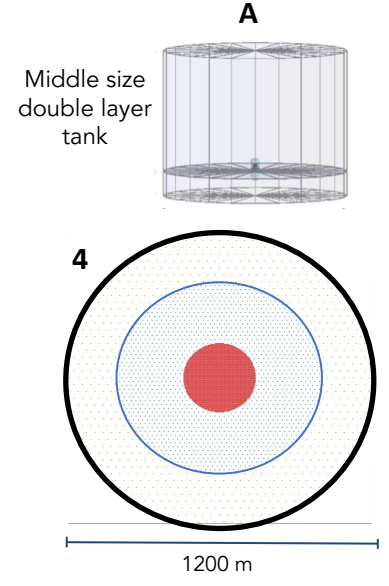
- Latest Instrument response functions (IRFs)
- Map region: 10° x 10° centered on the GC.
- Spatial and spectral model: CTA GPS models (publicly available)
- 1 year of observation time

Simplified model
5 components:
- Central source
- SNR G0.9+0.1
- Arc source
- GC ridge (CMZ)
- Diffuse background (IEM)



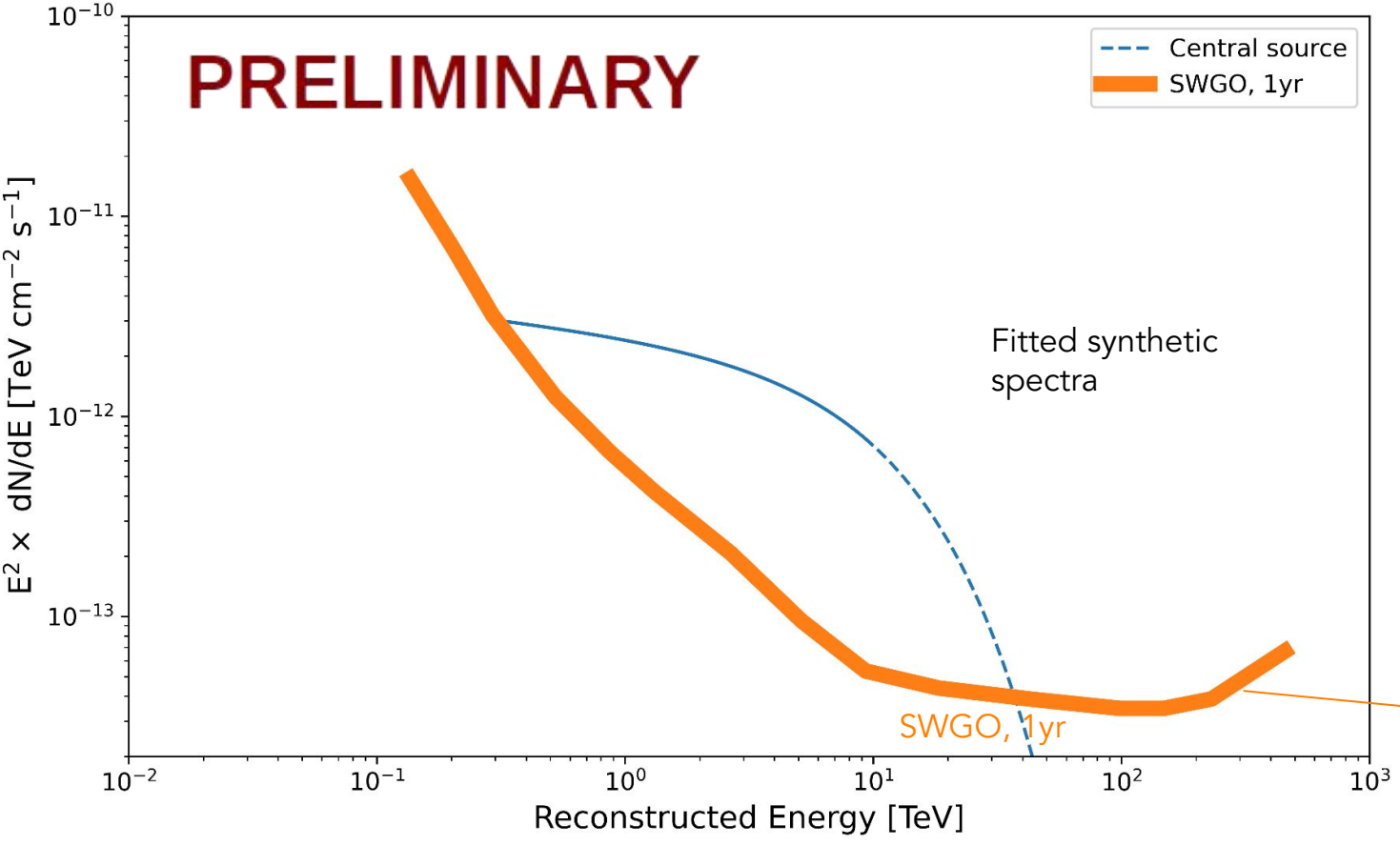
Predicted Spectra vs SWGO's sensitivity curve

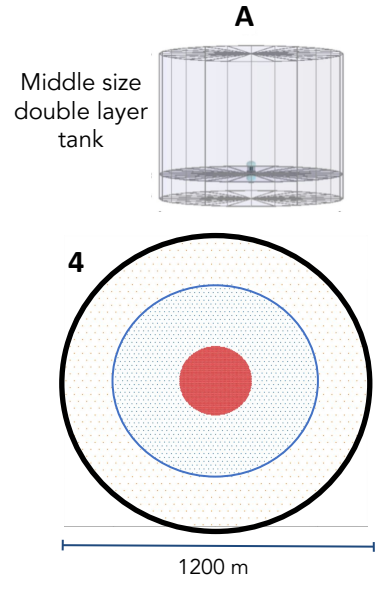




Configuration A4

Predicted Spectra vs SWGO's sensitivity curve





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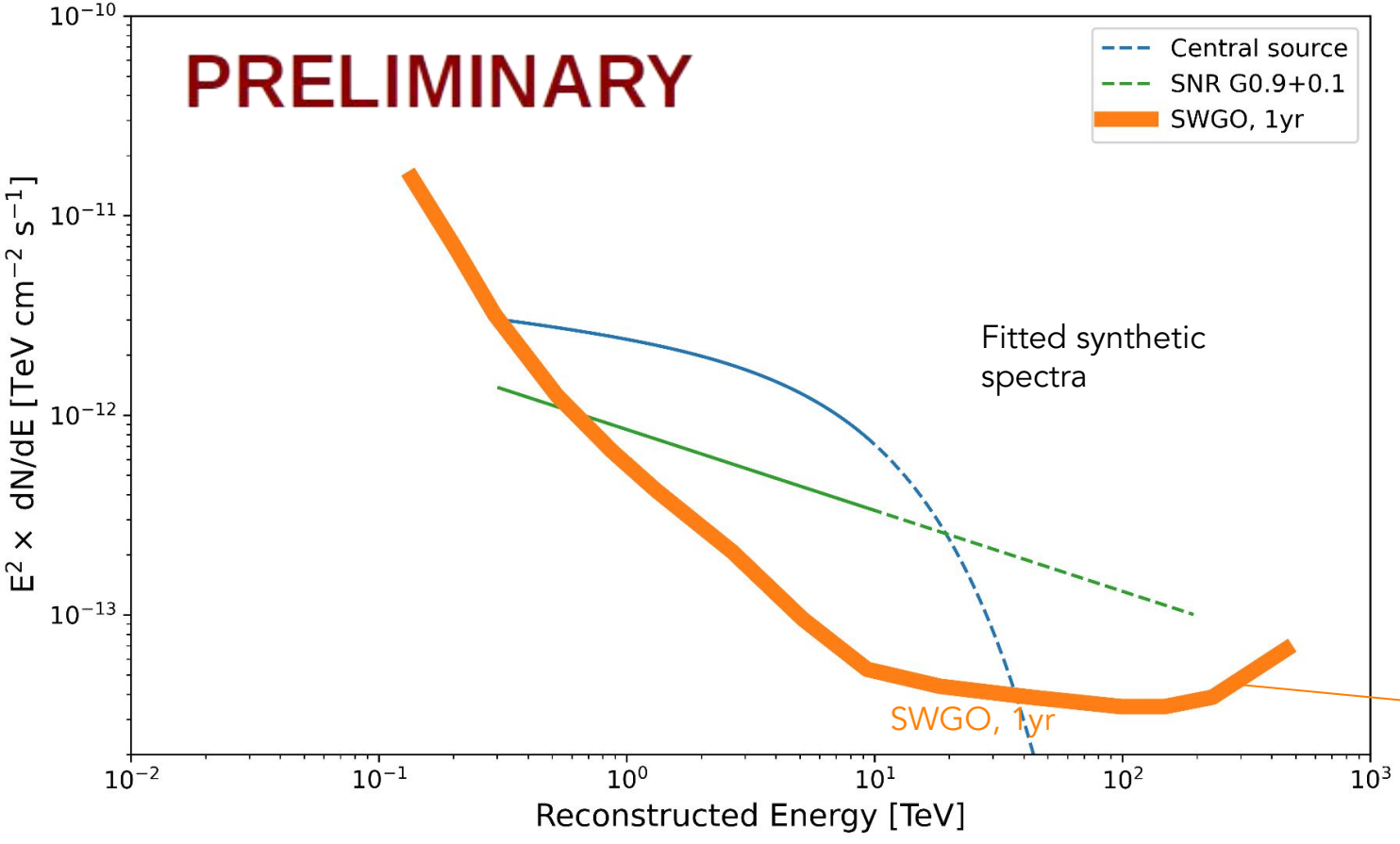

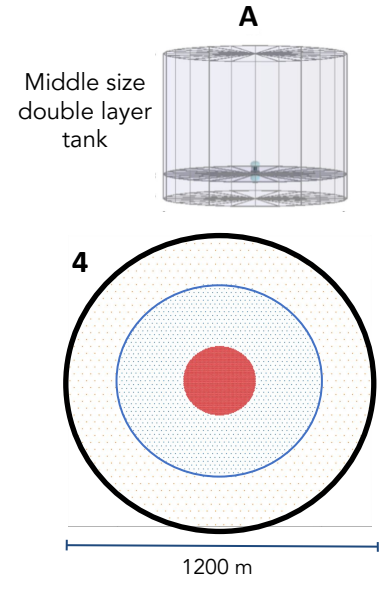

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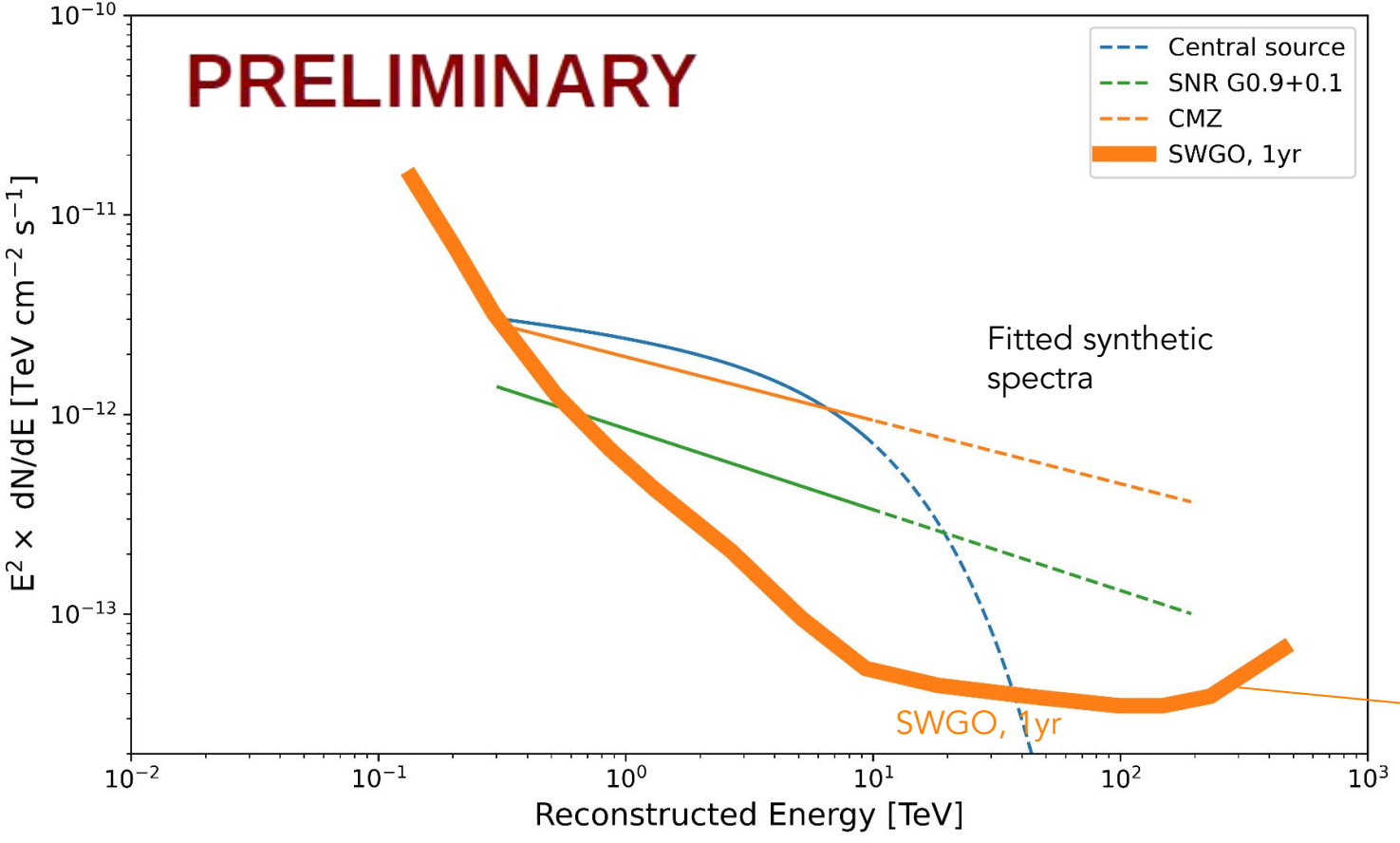

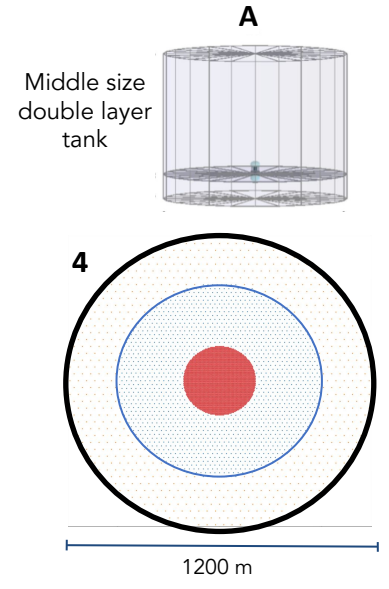

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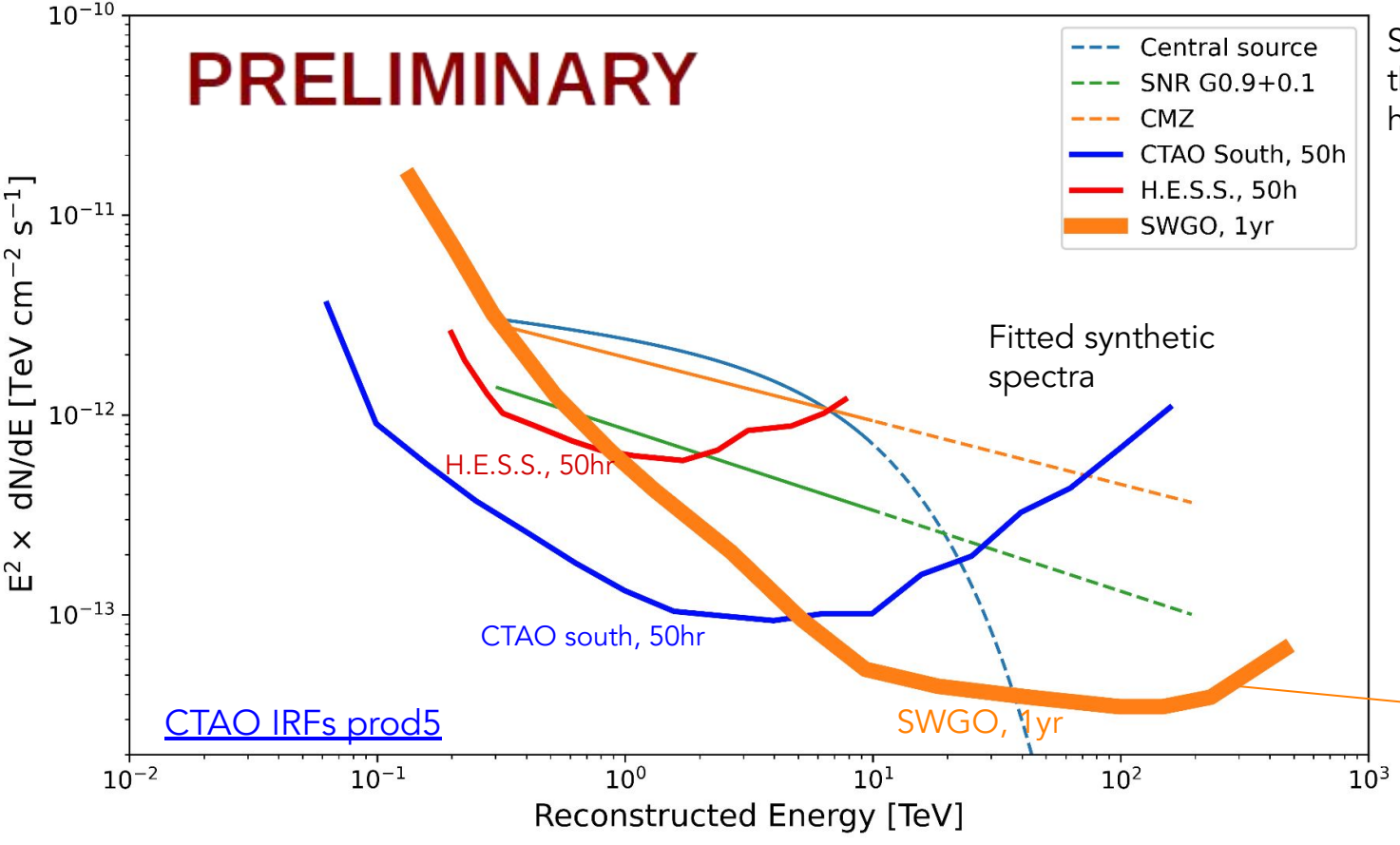
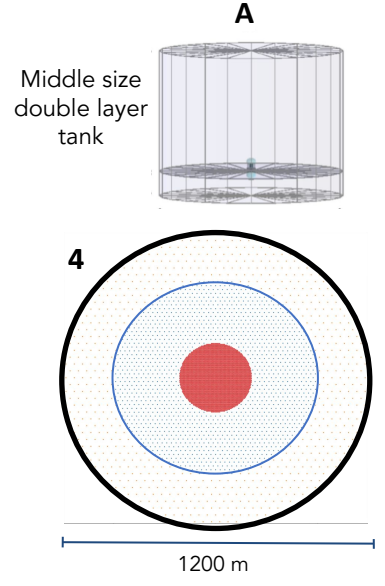


SWGO will extend the spectra to hundreds of TeV



Configuration A4

DM sensitivity

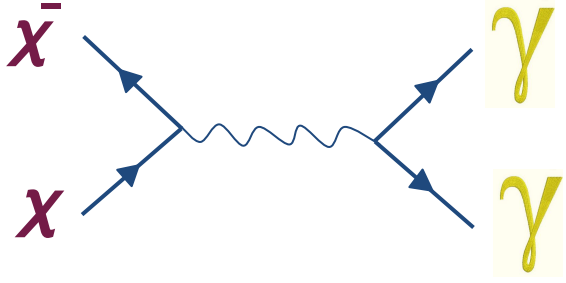
(5 years)

SWGO benchmarks

Science Case	Benchmark Description
Transient Sources: Gamma-ray Bursts	Minimum flux (>100 GeV) for 5σ detection using a PWL index = -2., F(t) $\propto t^{-1.2}$ two redshift values (z = 0.3, z = 0.8)
Galactic Accelerators: PeVatron Sources	Detection significance $>$ 100 TeV in 5 yr, ensuring 5σ cutoff detection, for: ECPL Index = -2.0, Cutoff = 200 TeV
Galactic Accelerators: PWNe and TeV Halos	Maximum source angular extension detectable at 5σ in 5-yr integration for: F(>1TeV) = 5×10^{-13} TeV/cm^{-2}.s
Galactic Accelerators: Source Confusion	Minimum angular separation detectable between two sources at 5σ level in 5-yr integration at low energies (3 TeV) and high energies (50 TeV.)
Diffuse Emission: Fermi Bubbles	Achievable background rejection power at 10 TeV whilst keeping 80% of gamma-rays that remain after quality cuts.
Fundamental Physics: Dark Matter from Galactic Halo	100 TeV $b\bar{b}$ thermal-relic cross-section limit at 95% CL in 5-years, for Einasto profile.
Cosmic-rays: Mass-resolved dipole/multipole anisotropy	Log-mass species reconstruction accuracy for A={1, 4, 14, 56}; Maximum dipole energy at 10^{-3} level; Maximum multipole scale > 0.1 PeV

Dark Matter self-annihilation in the GC region

- Weakly interacting massive particles (WIMP) are promising candidates of DM.
  - → Can eventually self-annihilate or decay and produce gamma-rays → indirect detection.



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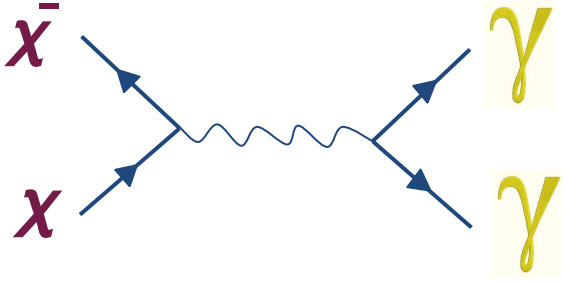
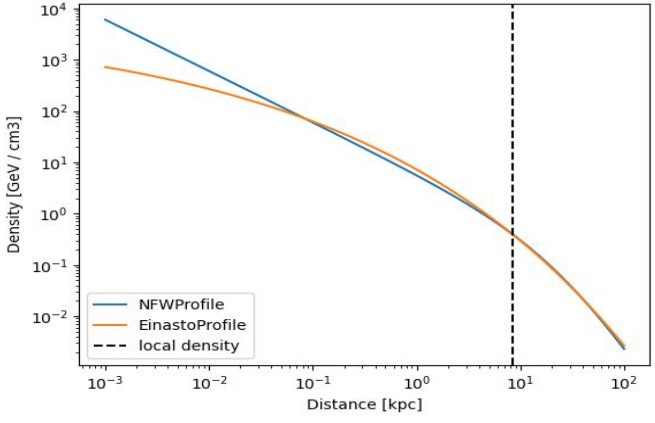


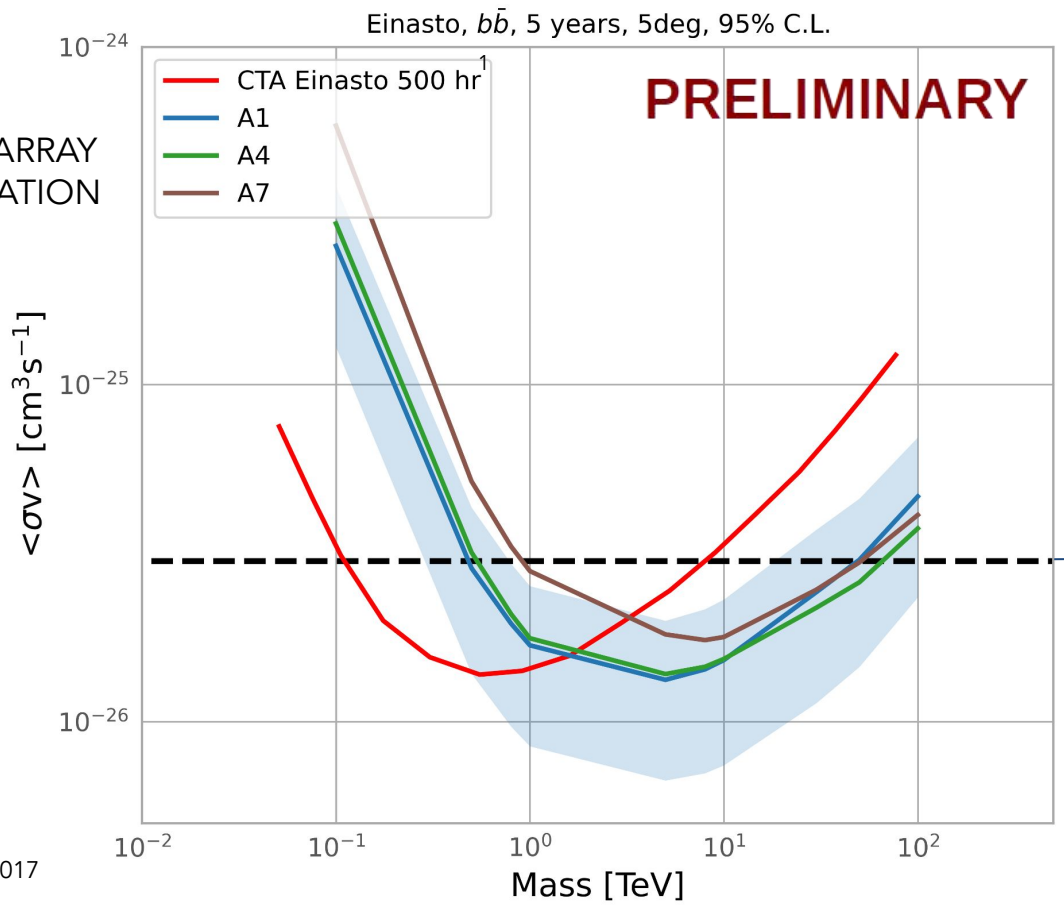
- GC region is a prominent regions of DM detection.
  - → Increase of DM density toward the center (Einasto, NFW profiles)
  - → So far, DM analysis only masking the Galactic Plane (A. Viana, et al. 2019; A. Acharyya, et al. 2020)

  - ✔ Include the plane and GC in our analysis.

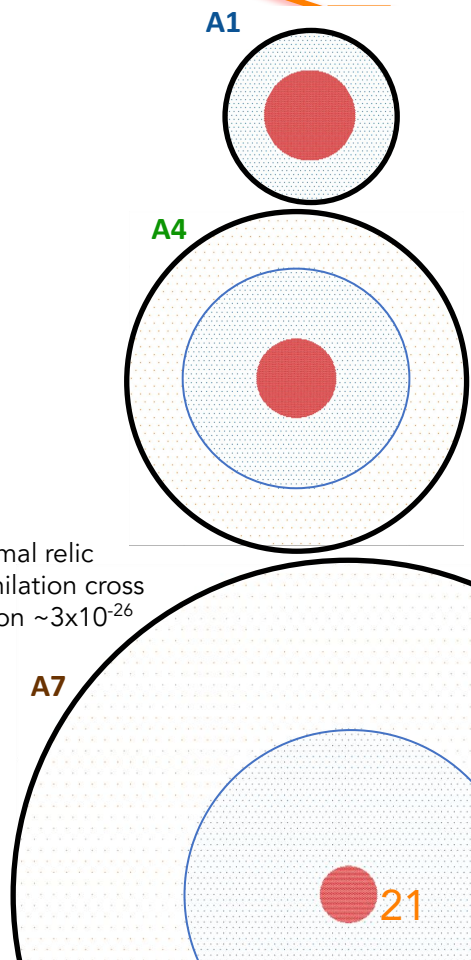


Cross section: compare array layout

COMPARE ARRAY CONFIGURATION
BEST: A4



Thermal relic annihilation cross section ~3×10^{-26}

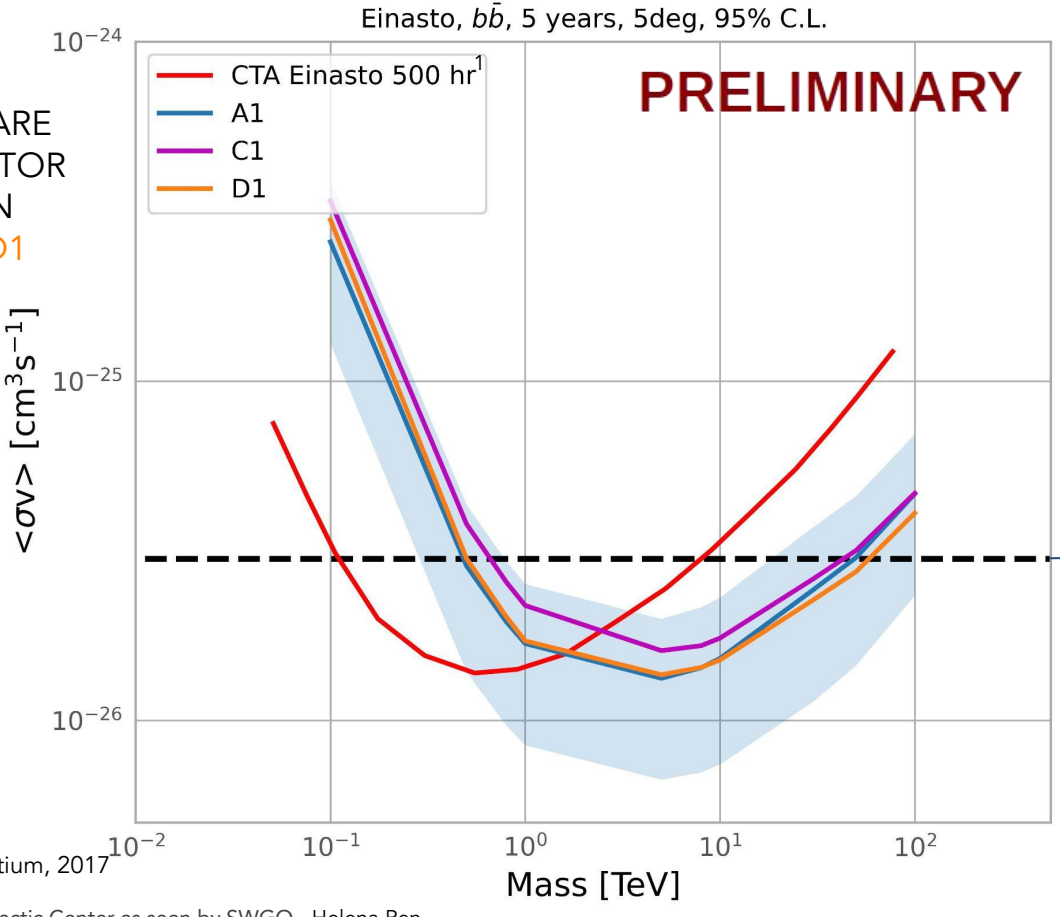


[1] CTA consortium, 2017

Cross section: compare detector unit

COMPARE DETECTOR DESIGN

BEST: D1



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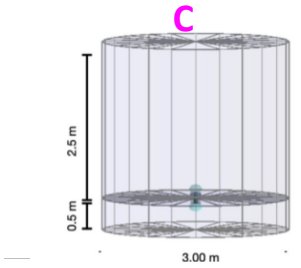
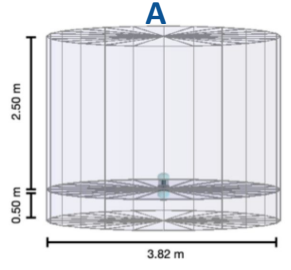
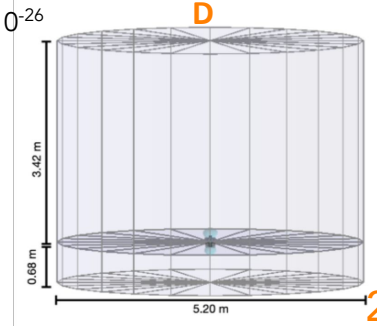
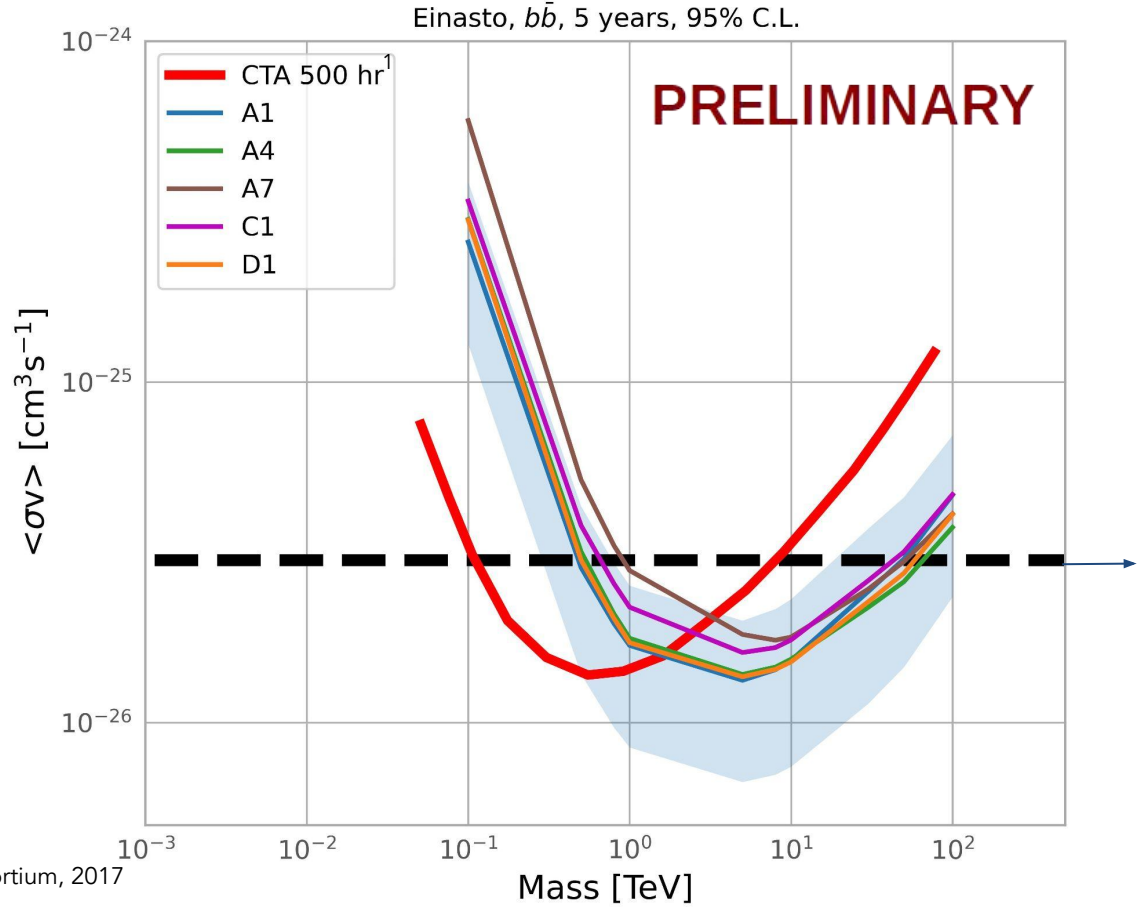






[1] CTA consortium, 2017

Cross section: compare arrays & detectors



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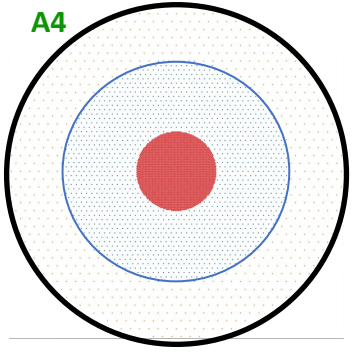
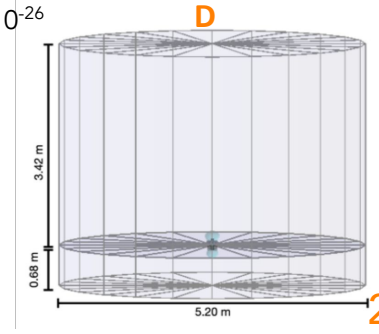




[1] CTA consortium, 2017

Conclusions

- Simulation of gamma-ray sources and estimate the expected significance, spectrum and sensitivity for different configurations during the design phase of SWGO is crucial.

- Result for the latest version IRFs:
  - → Spectrum of GC components can be expanded to hundreds of TeV.
  - → The array layout 4 and detector design D seems to be the best candidate when exploring the DM sensitivity.

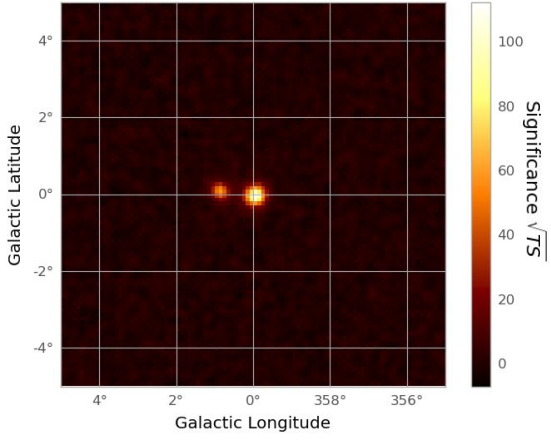
Thank you for listening
and Stay Tuned!

Back-ups

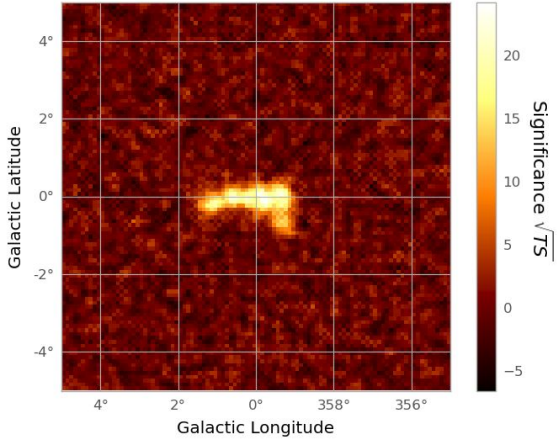
Simulation

Significance map, correlation radius 0.2 deg.

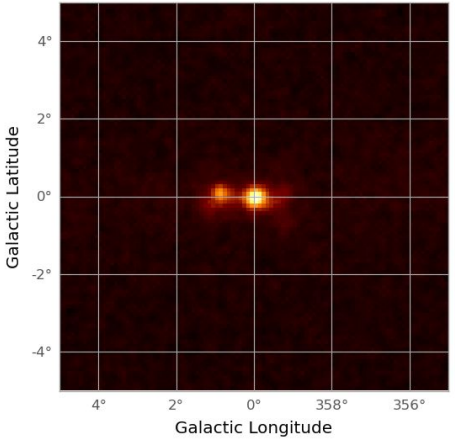
PRELIMINARY



Point like sources



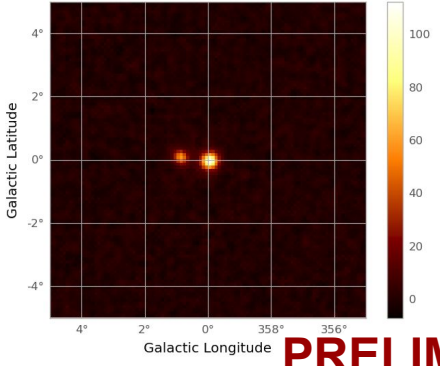
GC ridge (CMZ)



All components (+IEM)

Simulation

Significance map, correlation radius 0.2 deg.



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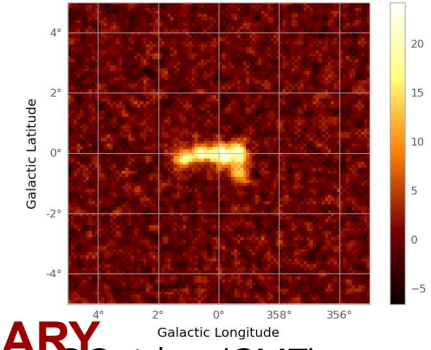

GC ridge (CMZ)

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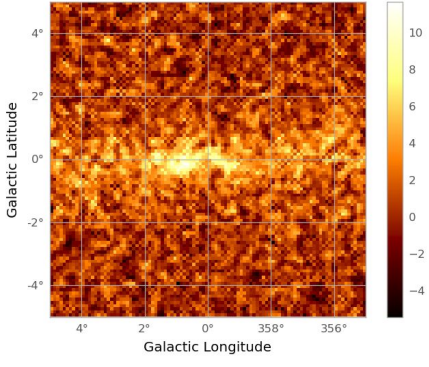
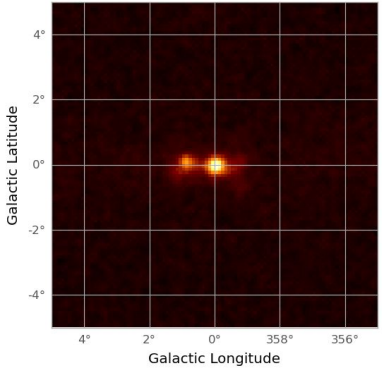
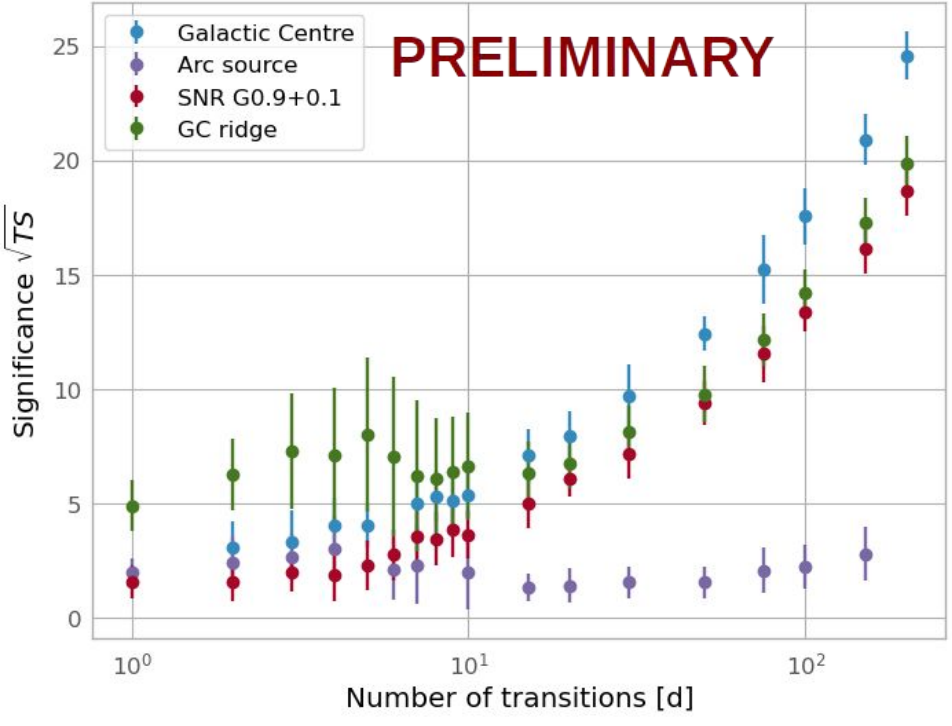


Diffuse background



4 components

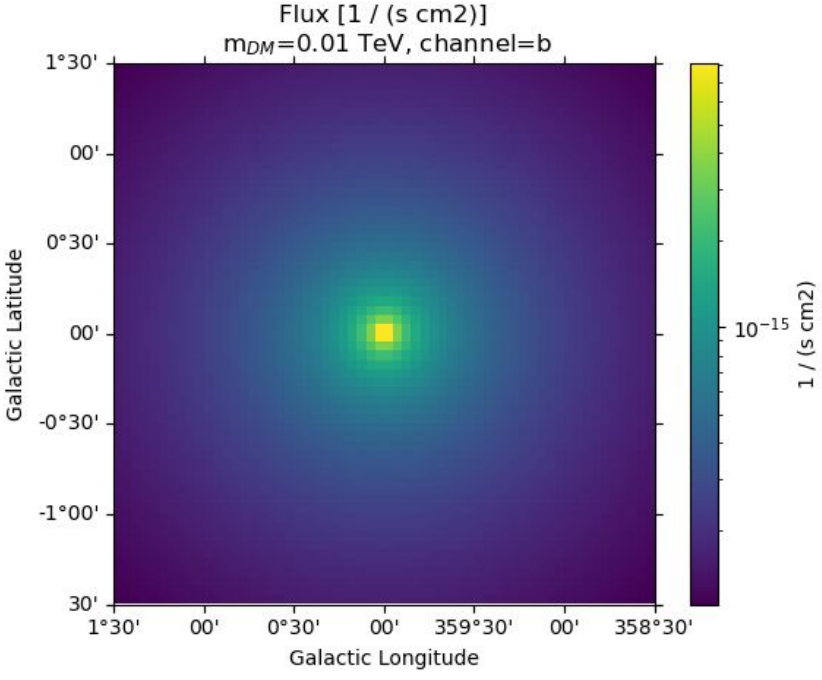
Significance over time

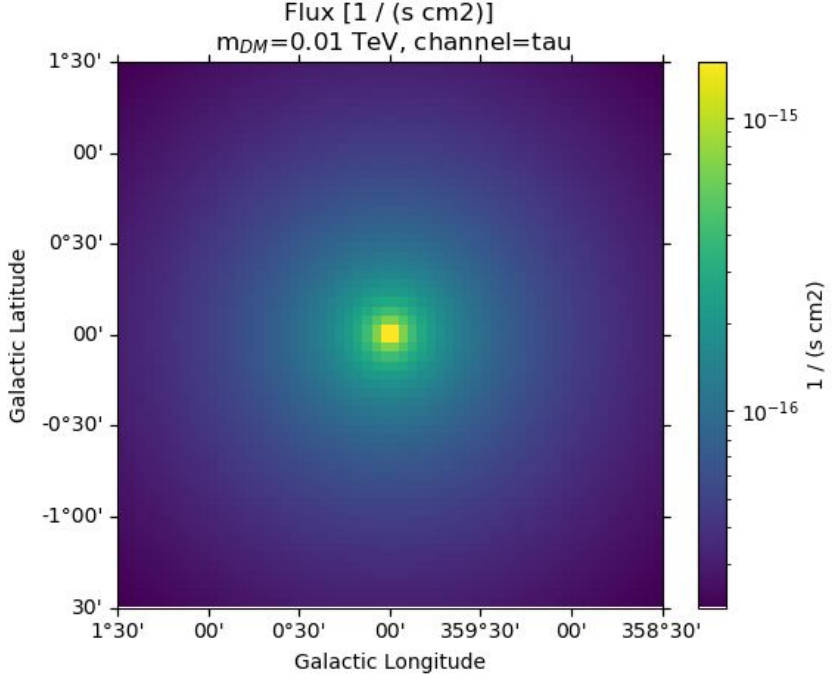


2nd simulation - DM sensitivity

- Settings:
  - Longer observation time needed → 5 years.
  - 2 profiles: Einasto and NFW.
  - 2 DM self-annihilation channels: $b\bar{b}$, $\tau^+\tau^-$
  - DM mass considered: 100 GeV to 100 TeV.
  - Statistical study: 300 simulations for each configuration and model.
  - Keep the 95% C.L. for each simulation → Get the average value.

Flux maps for bb and tau channels

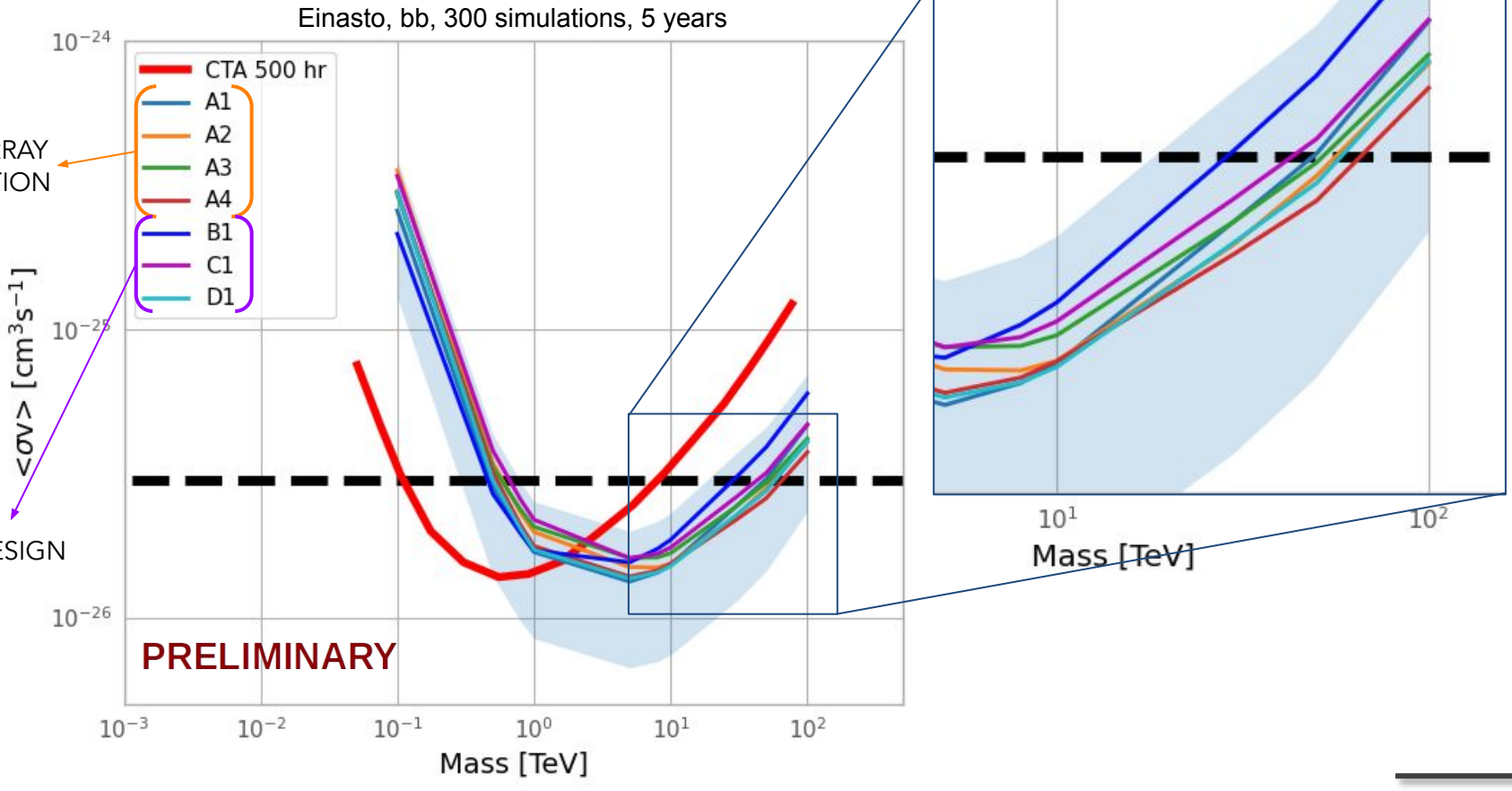




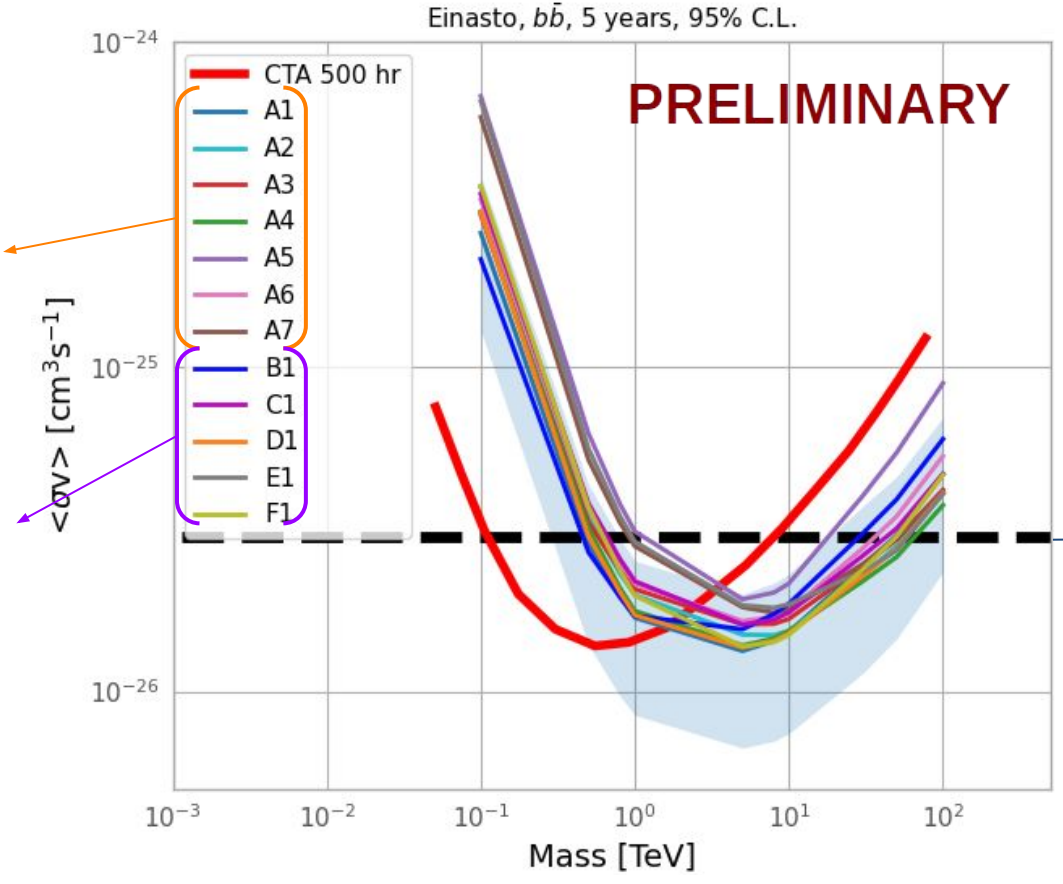
Einasto bb

COMPARE ARRAY CONFIGURATION
BEST: A4

COMPARE DETECTOR DESIGN
BEST: D1



Einasto bb, all

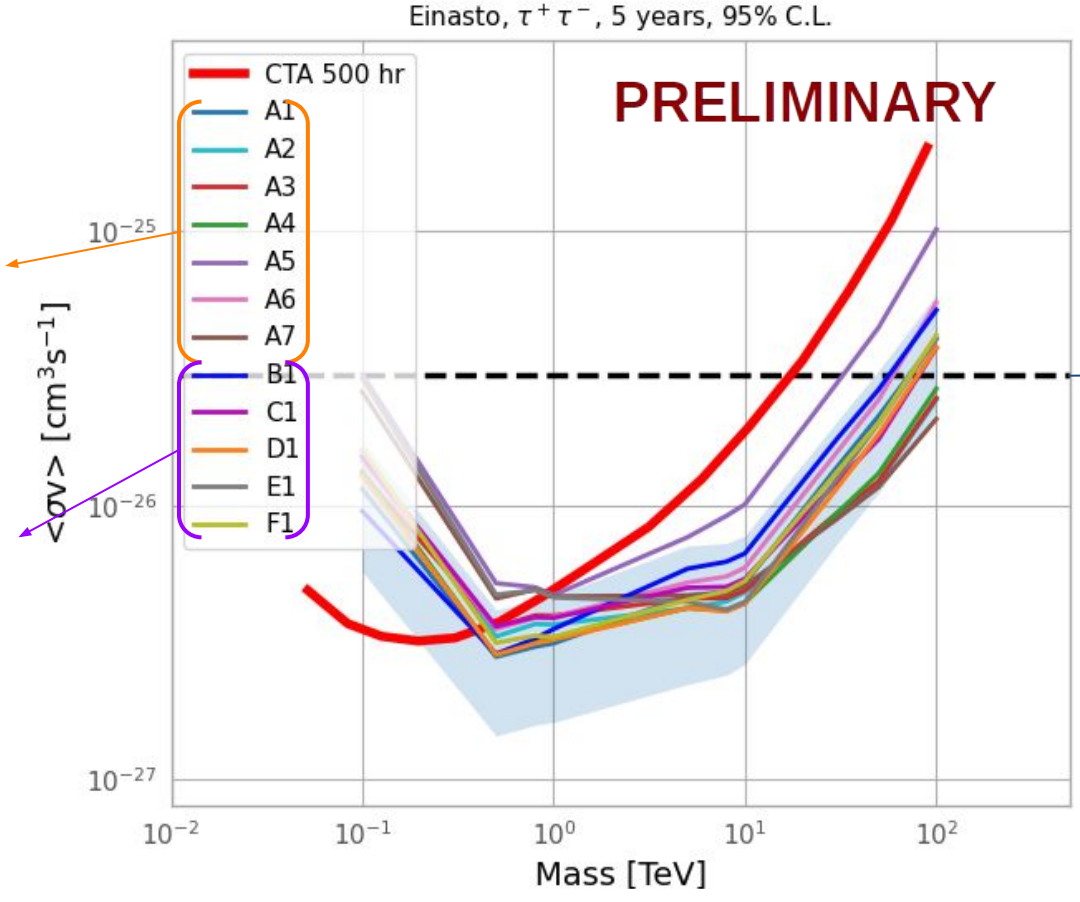


COMPARE ARRAY CONFIGURATION

COMPARE DETECTOR DESIGN

Thermal relic annihilation cross section ~3×10^{-26}

Einasto tau, all

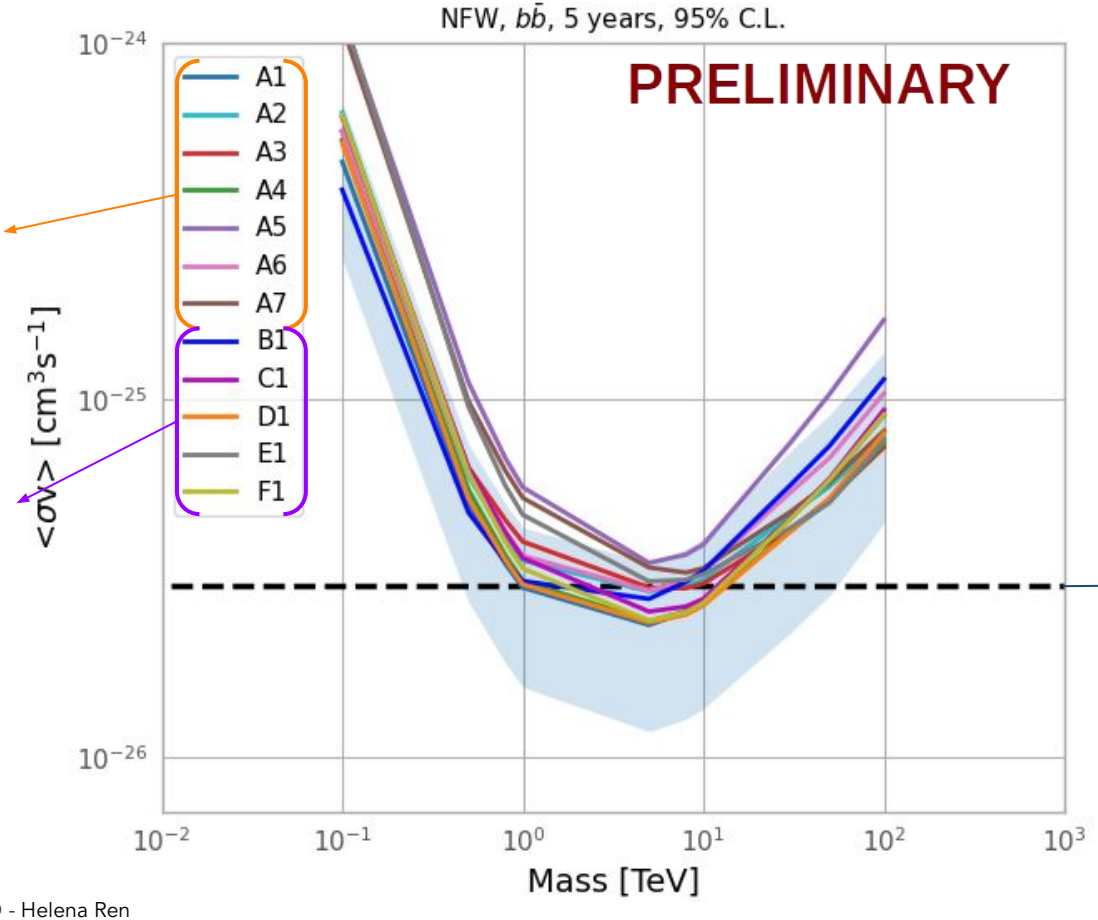


COMPARE ARRAY CONFIGURATION

COMPARE DETECTOR DESIGN

Thermal relic annihilation cross section ~3x10^{-26}

NFW bb, all



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Thermal relic annihilation cross section ~3×10^{-26}

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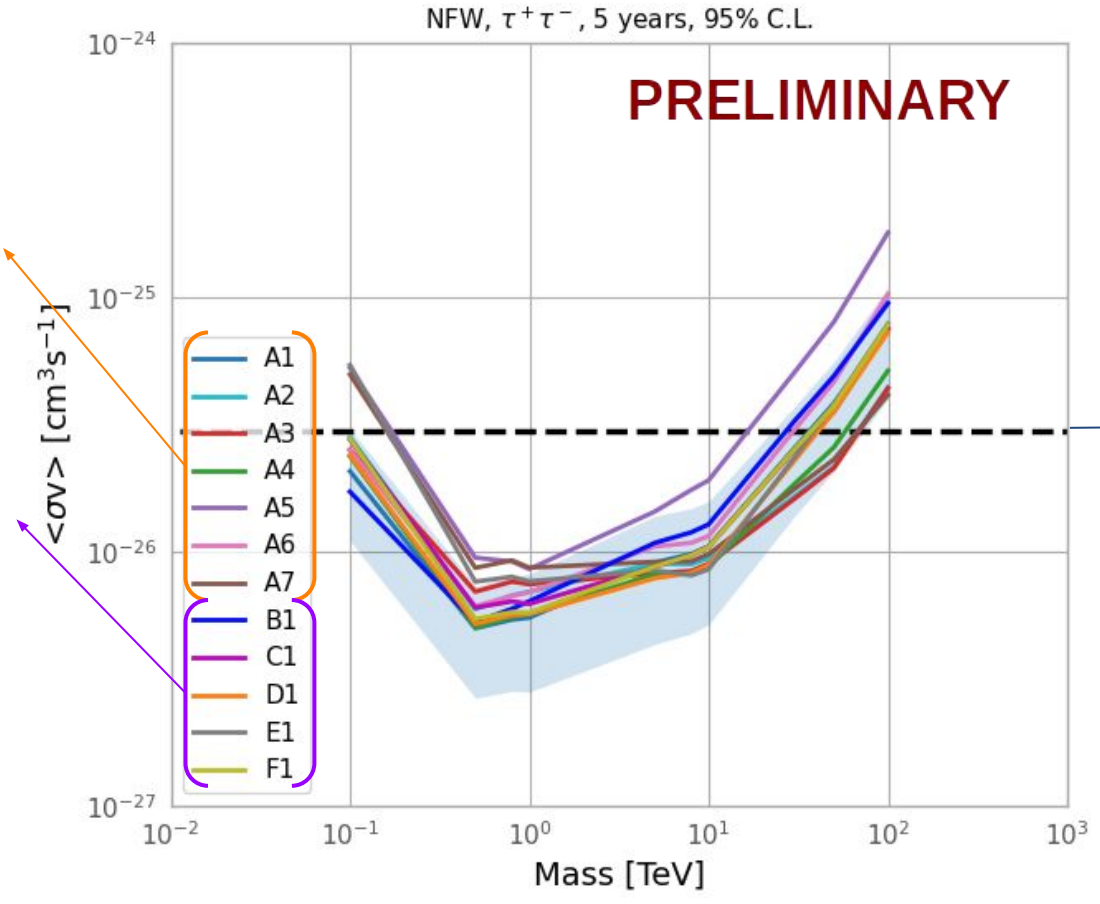
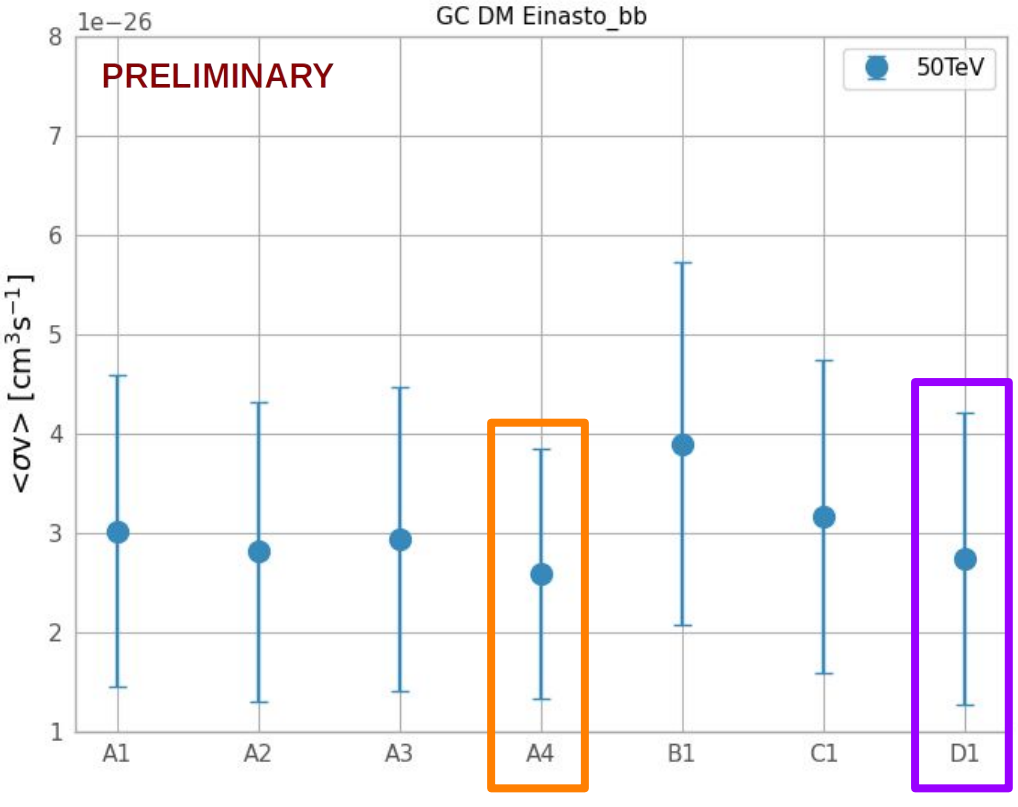


COMPARE ARRAY CONFIGURATION

COMPARE DETECTOR DESIGN

Thermal relic annihilation cross section ~3×10^{-26}

Results


GC DM Einasto_bb
1e−26
PRELIMINARY
50TeV
<σv> [cm³s⁻¹]
8
7
6
5
4
3
2
1
A1
A2
A3
A4
B1
C1
D1