



Summary about 2° year of PhD and *perspectives* on 3° year

Politecnico di Bari, Università di Padova

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PhD in *Technologies for Physics and Astrophysics*,
Curriculum *Detectors, optics and lasers*

Graduated in Physics (Astrophysics curriculum, 2023, Lecce)





General resume about activities of 1° year and 2° year

- Courses:

Particle detectors in space (S.Loporchio), **exam** given in April 2024

New technologies for Cherenkov telescopes (S.Loporchio), **exam** given in July 2024

Scintillators and Silicon photomultipliers (E.Bissaldi), **exam** given in July 2024

Simulations for scintillator-based detectors (D.Serini), **exam** given in November 2024

Evolution of active galaxies (F.Ricci, external course), **exam** given in March 2025





General resume about activities of 1° year and 2° year

- Schools:

ISAPP School (2 weeks), **Lecce** (ITA), June 2025

International school 'Francesco Romano' (1 week), **Monopoli** (ITA), September 2025

- Conferences with given talk:

2nd VHEGAM Meeting, **Bari** (ITA), May 2025

Astrophysics and Space Science in Marche II, **Camerino** (ITA), September 2025

Congress of Italian Society of Physics, **Palermo** (ITA), September 2025

- Publications:

S.Camposo: A new deepening of mass-radius empirical relation for main sequence stars,
EmSci vol.9 (2025), DOI: [10.1051/emsci/2025001](https://doi.org/10.1051/emsci/2025001)





General resume about activities of 2° year

- Main Research

- *Technological research*: Geant4 simulations ongoing about future **APT/ADAPT** detectors, running on local **High-Performance-Computing** system (provided by *INFN Bari*);
- *Physics research*: **indirect search for dark matter** through gamma-ray observation of **solar system objects** (currently, Jupiter).





General resume about activities of 2° year

- Other activities:

- Gravigamma workshop 5th edition, **Bari** (ITA), October 2024
- 2nd Kick-off Meeting of PhD students, **L'Aquila** (ITA), February 2025
- Attending course 'Cosmology' by prof. Amr Elzant, **Bari** (ITA), May 2025
- Outreach for *INFN Kids* program
- Parallel research ongoing regarding stellar and planetary science topics (continuation of my master degree thesis, with prof. V. Orofino, *INFN Lecce*).





Technological research

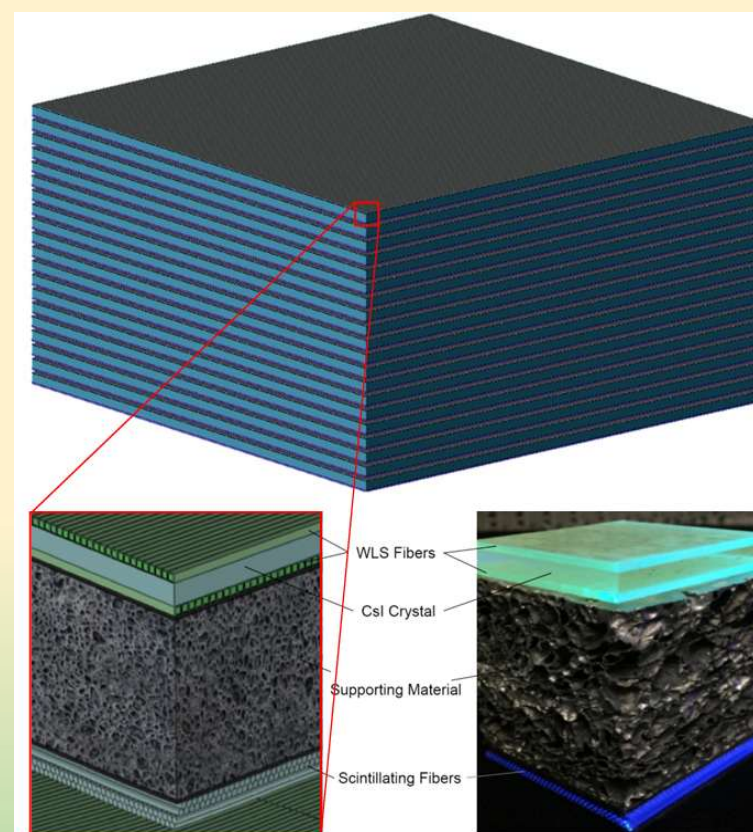
In order **to improve the indirect search for dark matter**, a new big space detector has been designed: its name is **APT** (Advanced Particle-astrophysics Telescope) and it will efficiently detect **photons from 0.3 MeV to few TeV**.

Indeed this telescope will exploit **both Compton scattering and Pair production** to detect incoming photons.

Moreover a light version of APT has been designed: its name is **ADAPT (Antarctic Demonstrator for APT)** and it will fly over Antarctic lands in 2026.

ADAPT has roughly 1% of APT materials and will be operative for several weeks, giving a demonstration of validity of APT design

[W.Chen et al., DOI:10.22323/1.444.0841].





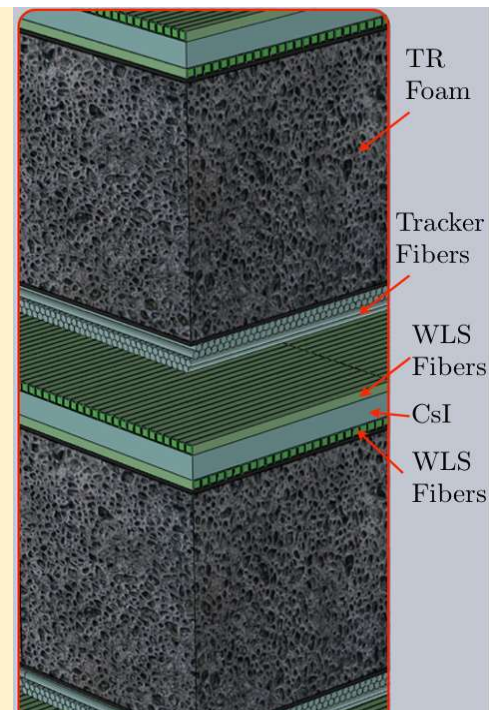
Technological research

ADAPT is made of 4 modules, each containing **three layers** (Imaging Calorimeter + Supporting material + Tracking fibers). Each module is partitioned into **9 tiles**.

Both imaging calorimeter and tracking layer exploit **scintillation** in order to measure energy or position of the **charged particles** (which are the **triggers of scintillation**).

Charged particles are 1) **scattered electrons** or 2) high-energy electrons/positrons generated by **pair production**. In **both cases**, trigger of charged particles is the primary **gamma-ray photon**.

On **Geant 4** toolkit (running on the **HPC system** provided by INFN), I am currently performing simulations regarding scintillation **optical photons** generated inside the **imaging calorimeter**.



6	7	8
3	4	5
0	1	2





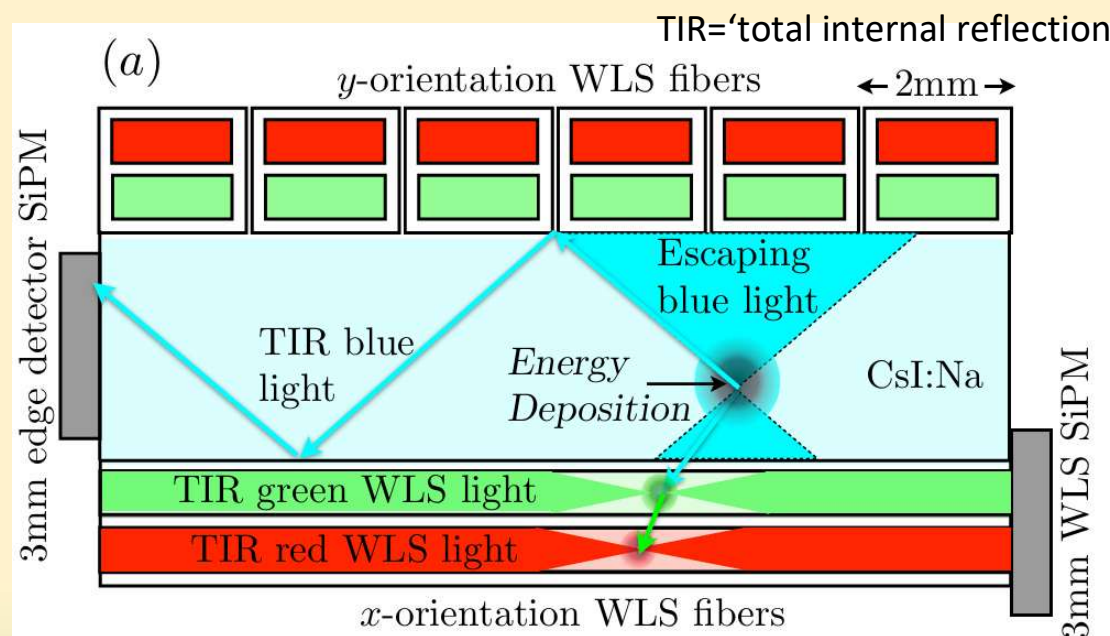
Technological research

Imaging calorimeter is itself partitioned in three layers:

CsI crystal +
x-oriented WLS fibers +
y-oriented WLS fibers.

Until now I have simulated only a **single module**.
In particular, I have focused on scintillation light collection on SiPMs placed at **WLS' bottoms**.

Scintillation happens inside the CsI calorimeter but part of generated photons are then «trapped» inside WLS fibers (where their wavelength is also **stretched**).



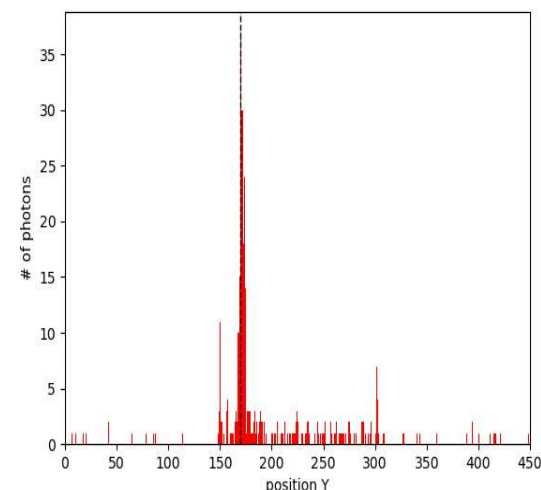
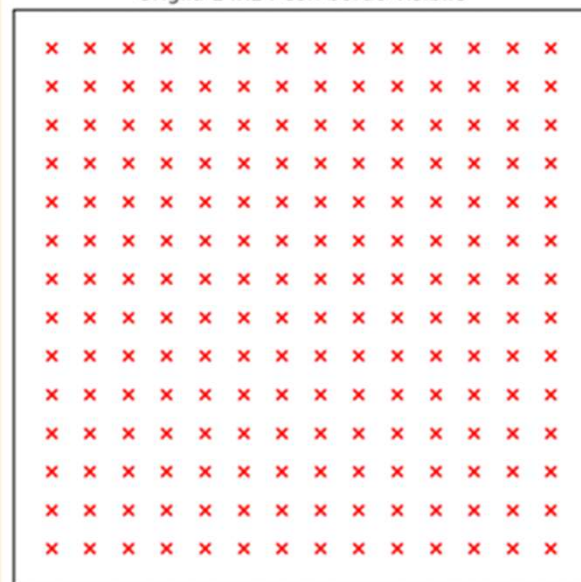


Simulation aim is to study **the distribution of photons** between all WLS' SiPMs (both x-oriented and y-oriented).

Indeed this distribution gives information about the **position** at which the charged particle has **hit the instrument**. This position will **roughly** correspond to the coordinates given by **most illuminated** x-oriented fiber and most illuminated y-oriented fiber.

In the simulations, we know both this **distribution** and the **true interaction-position** (which is an input data), so we can develop a **reconstruction-algorithm** which can be used in the «real world» where we measure and know the first information **but not the second one**.

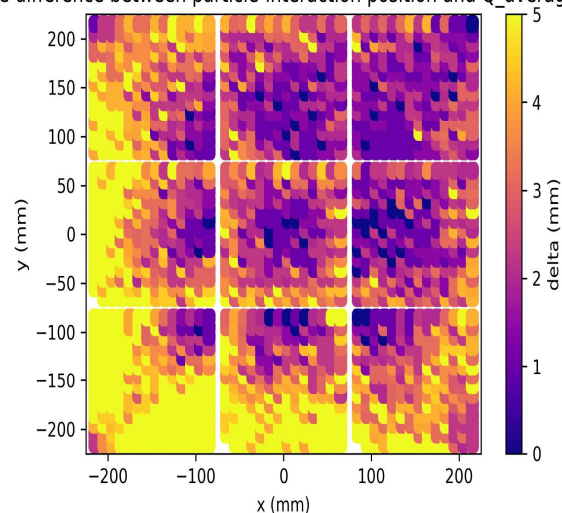
Griglia 14x14 con bordo visibile



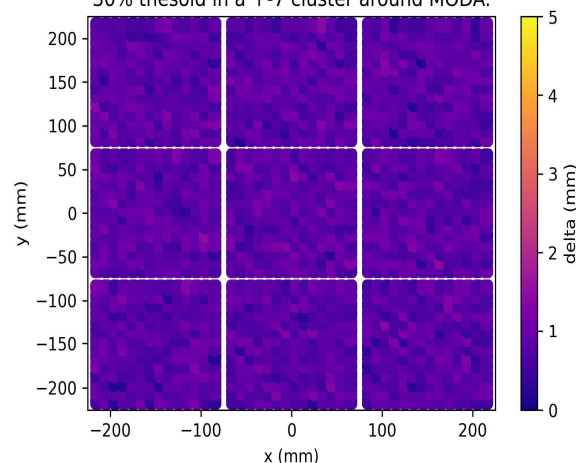
Technological research



$\text{delta} = \sqrt{[\text{deltax}]^2 + [\text{deltay}]^2}$
 No data collected on tile edges (glue).
 delta is simply the difference between particle-interaction position and Q_averaged fiber (MediaQ).



$\text{delta} = \sqrt{[\text{deltax}]^2 + [\text{deltay}]^2}$
 No data collected on tile edges (glue).
 delta is simply the difference between particle-interaction position and mediaQ computed with 30% threshold in a +/-7 cluster around MODA.



Simulations have been performed with 500 KeV electrons until now.

All tiles have been scanned with 1 cm steps.

Difference (called 'delta') between true interaction position AND reconstructed one has been computed for each scan.

Reconstructed position depends on the **specific algorithm** which has been exploited.

For example, on the left, we see a very inefficient reconstruction algorithm (top) and a **very efficient one (bottom)**.

The **unefficient** algorithm whose results are showed in the top figure is one of the simplest, i.e. the **weighted arithmetic mean**.

It means that the reconstructed position is estimated as mean of positions of all WLS fibers weighted on the fiber-specific number of collected photons (in the fiber SiPM).

(This has to be done for **both x- and y-oriented** fibers, since we need both coordinates!). 10



Physics research

Important document for this research is the following paper:

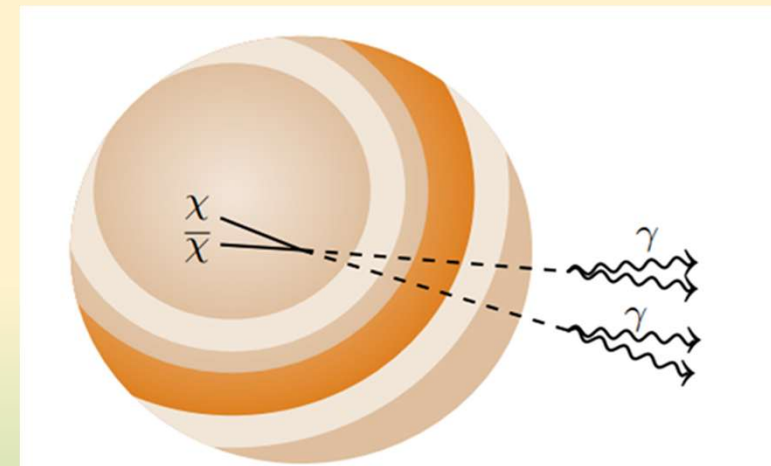
First Analysis of Jupiter in Gamma Rays and a New Search for Dark Matter

[Rebecca K. Leane and Tim Linden, DOI:10.48550/arXiv.2104.02068].

Besides typical mechanisms (**inverse Compton scattering** or **neutral pion decay**), also “exotic” mechanisms of gamma-ray **production** should be considered.

In particular, annihilation between two DM particles (if they are Majorana particles $X=\bar{X}$) could yield two **scalar** mediators ϕ (with spin 0) and each mediator should fastly decay producing two gamma rays:

$$X \bar{X} \rightarrow \phi \phi \rightarrow 4\gamma.$$



Schematic of DM annihilation to long-lived particles in Jupiter. The long-lived particles can decay outside the Jovian surface, producing a new source of γ -rays.





Physics research

Since Jupiter is a **moving** object in the sky, 15-year FERMI-LAT data has been collected in 1200 distinguished **steps** (each one corresponding to a **0.5 deg path** of the planet in the sky). All steps have been stacked through the maximization of total likelihood.

Upper limits on gamma ray flux by Jupiter can be translated into **upper limits on X -nucleon cross section** by exploiting the following equation [*S.Profumo, ISBN:978-1786340016*]:

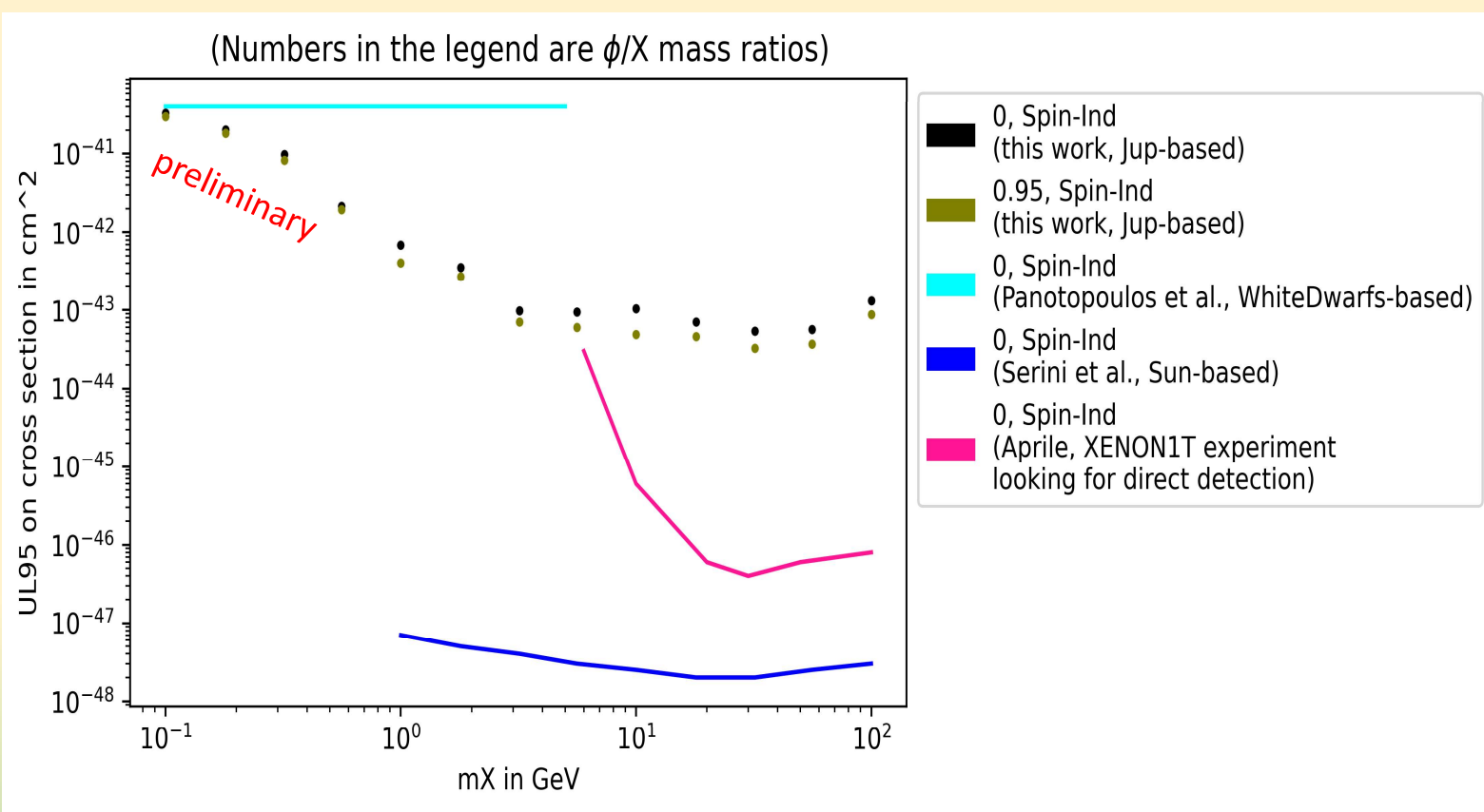
$$\sigma_{X-Nucleon} = \frac{2\pi}{a_{(m_X)}} \cdot (Flux \cdot d^2)$$

where $a_{(m_X)}$ is related to the dark matter capture rate and is computed with 'Darksusy' Fortran Package.



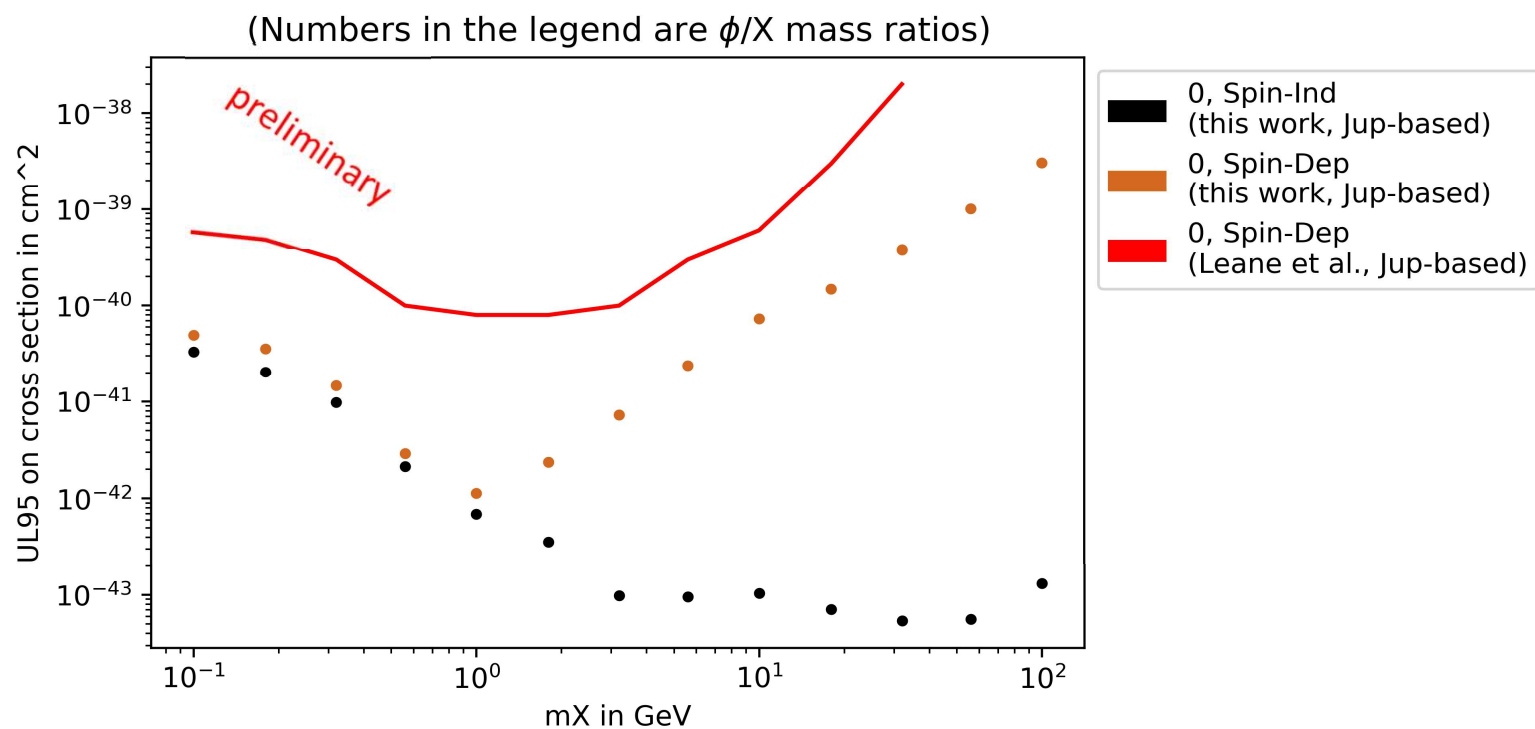


Physics research





Physics research





Perspectives on next year (3° Year)

Since all training activities (courses, schools etc.) have been **completed**, next 12 months will focus on **continuation** of current research work.

In particular, there are **two short-term goals**:

- I will perform **more general** simulations on ADAPT instrument going from current 1-module configuration to the «realistic» **4-modules** configuration;
- Submission of **a paper** describing our indirect search for dark matter.



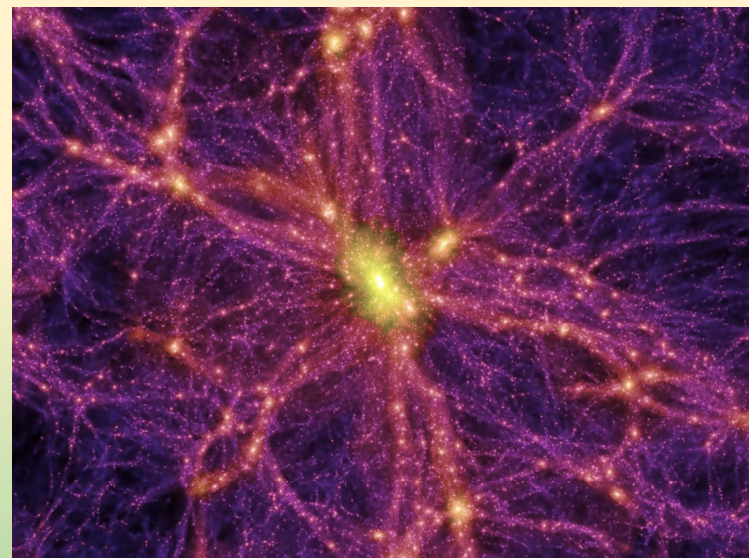


Perspectives on next year (3° Year)

In January 2026 I will start writing my PhD thesis.

Title will probably be:

«*Current and **future** perspectives of **indirect search for dark matter** through low-energy astrophysical gamma-rays*».





End

