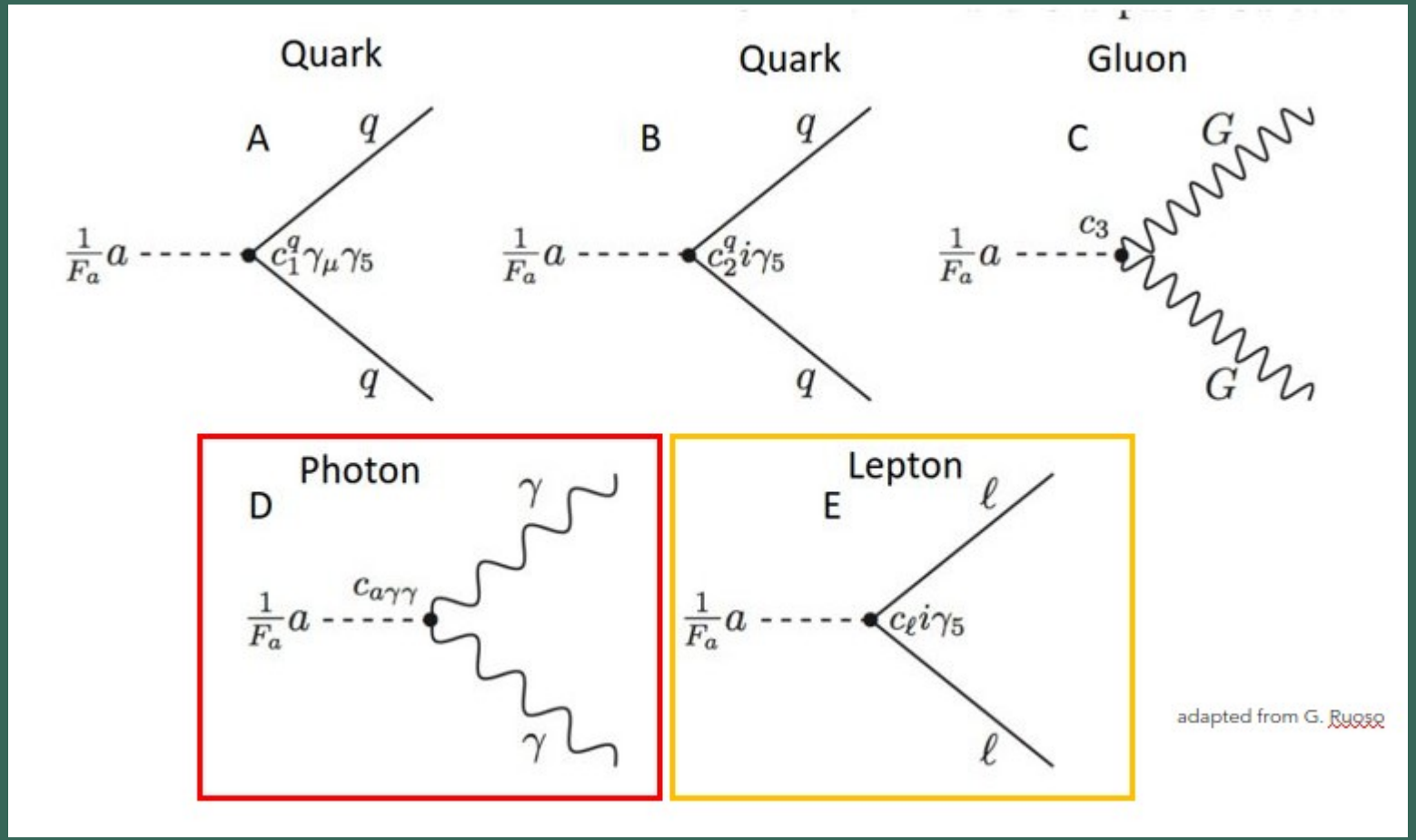
WG4 – DIRECT WISP SEARCHES

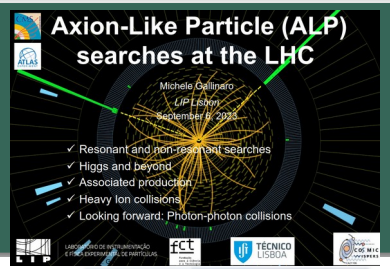
C GATTI - M KARUZA

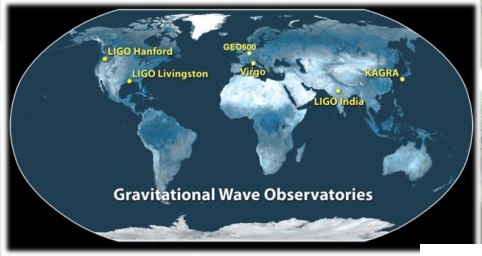
Discover the COSMIC WISPer

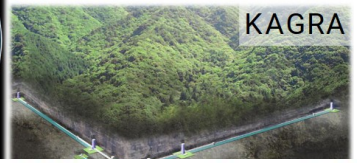


adapted from G. Ruoso

Discover the COSMIC WISPer

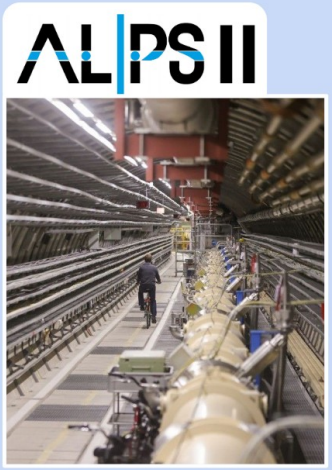






Todd Kozlowski
Cosmic WISPers
Bari, 08.09.2023

COSMIC WISPERS CA21106 · cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY



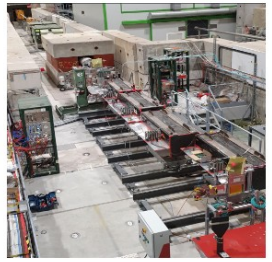
MADMAX

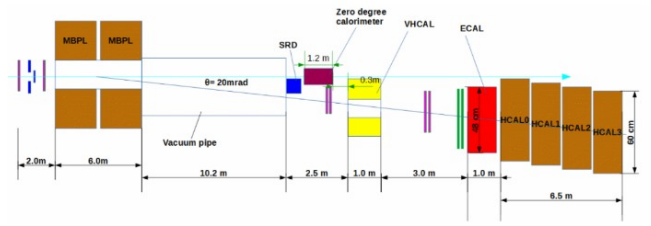
NA64 Experiment

Missing energy experiment at CERN North Area H4 line - 100 GeV e^- beam
H4 line: few 10^7 e^-/spill with energy resolution $< 1\%$ and hadron contamination $\sim 0.5\%$

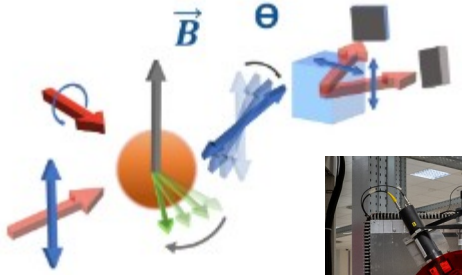
Experiment Setup

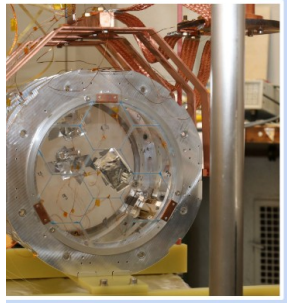
- Beam identification system: magnetic spectrometer and SRD tagging (MBPL magnets)
- EM-Calorimeter: $40X_0$, Pb/Sc Shashlik
- Plastic scintillator VETO
- Hadron calorimeter: 4 m, 30 λ_I

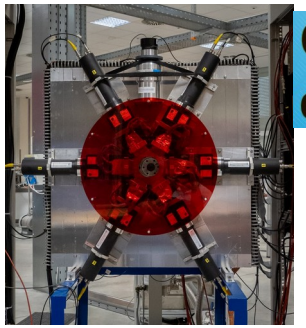




- Magnetometers as Dark Matter sensors



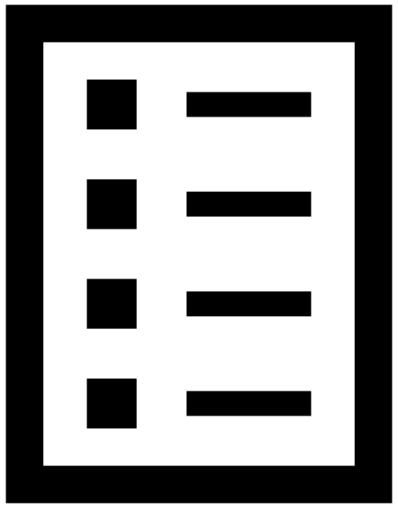




Axion Searches at DESY.

Observation of anomalies supporting the existence of the new particle X17

Tasks



T4.1: Review of present and future WISPs experiments (including DM ones) in order to assess their discovery potential.

- **Subtask 4.1.1**: Perform an update of summary plots of present limits for various WISPs models (axion, hidden photons, chameleons etc.). For the axion constraints on the coupling with photons, electrons, nucleons. For HP, bounds on the kinetic mixing angle. Reinterpretation of existing experimental limits with new WISPs models.
- **Subtask 4.1.2**: Combination of experimental results with astrophysical and cosmological limits to extract summary plots.
- **Subtask 4.1.3**: Highlight regions of the parameter space not yet covered by experiments and discuss feasibility of the experimental searches in these regions. Discuss the feasibility of testing all the couplings (to leptons, photons, baryons etc.) in all the parameter space.

T4.2: Identify progress need in the key technologies and techniques (data analysis, signal filtering) for present and future experiments needed to cover the theoretically motivated region in the parameter space.

- **Subtask 4.2.1**: perform a survey of technology (materials, detection, sources, cryogenics, magnets, high resolution detectors) needed in WISP experiments.
- **Subtask 4.2.2**: perform a survey of solutions available (in SME or academic research) and of the competences available.

Review of present and future WISPs experiments

3.1. Pure lab (LSW, collider etc.)

Has set a limit

- ALPS
- BMV
- CROWS
- NA64
- OSQAR
- PVLAS
- QUAX-gp gs

In progress/planned

- ALPS-II
- VMB@CERN

Concept

- STAX
- ALPS-III
- STE-QUEST

3.2. Helioscope

Has set a limit

- CAST
- SHIPS

In progress/planned

- BabyIAXO
- IAXO

Planned/concept

- IAXO+
- TASTE (Russian)

3.3. Haloscope

Has set a limit

- BRASS
- CASPEr-gradient
- CASPEr-ZULF
- CAST-CAPP
- FUNK
- GrAHal
- JEDI
- MADMAX
- NASDUCK (Israel)
- QUAX
- RADES
- SHUKET
- WISPDMX
- SUPAX

In progress/planned

- AION
- FLASH
- WISPFI
- WISPLC

Concept

- AEDGE
- DALI
- STE-QUEST
- TOORAD

3.4. beam dump (M<1 GeV)

- PADME

3.5. Non-WISP focused experiments with ability to detect WISPs

Has set a limit

- ATLAS (collider -> heavy ALP/dark photon)
- AURIGA (GW detector -> scalar DM detection)
- CMS (collider -> heavy ALP/dark photon)
- BASE (antiproton trap -> lumped element axion haloscope)
- DAMIC (underground detector -> ALP/dark photon absorption)
- DarkSide (underground detector -> ALP/dark photon absorption)
- EDELWEISS (underground DM detector -> ALP/dark photon absorption)
- GERDA (Neutrinoless double beta decay -> ALP/dark photon absorption)
- GEO600 (GW detector -> scalar/vector DM)
- LOFAR (Radio telescope -> dark photon DM)
- NOMAD (Neutrino detector -> light shining through wall)
- XENON (Undeground DM detector -> solar axion/dark photon, DM absorption)

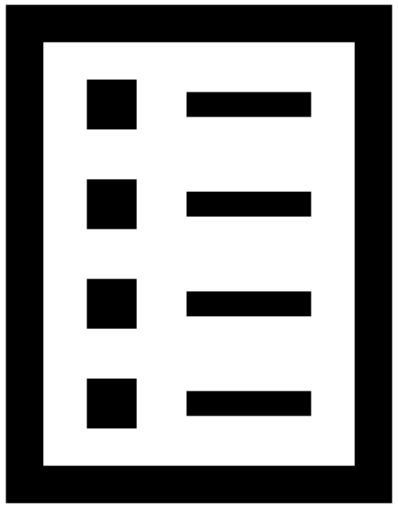
- Helioscopes
- Haloscopes
- LSW
- polarization
- AMO
- Magnetometers

- 5^{th} Force exp.
- Casimir
- Torsion balance
- Atomic tests
- Levitated microspheres
- Micro resonators
- GW Interferometer
- Atom Interferometer
- Neutron interferometry
- Cold neutrons
- Variation of fundamental constants

- Colliders
- Beam dump/on target
- Underground

...

Subtasks



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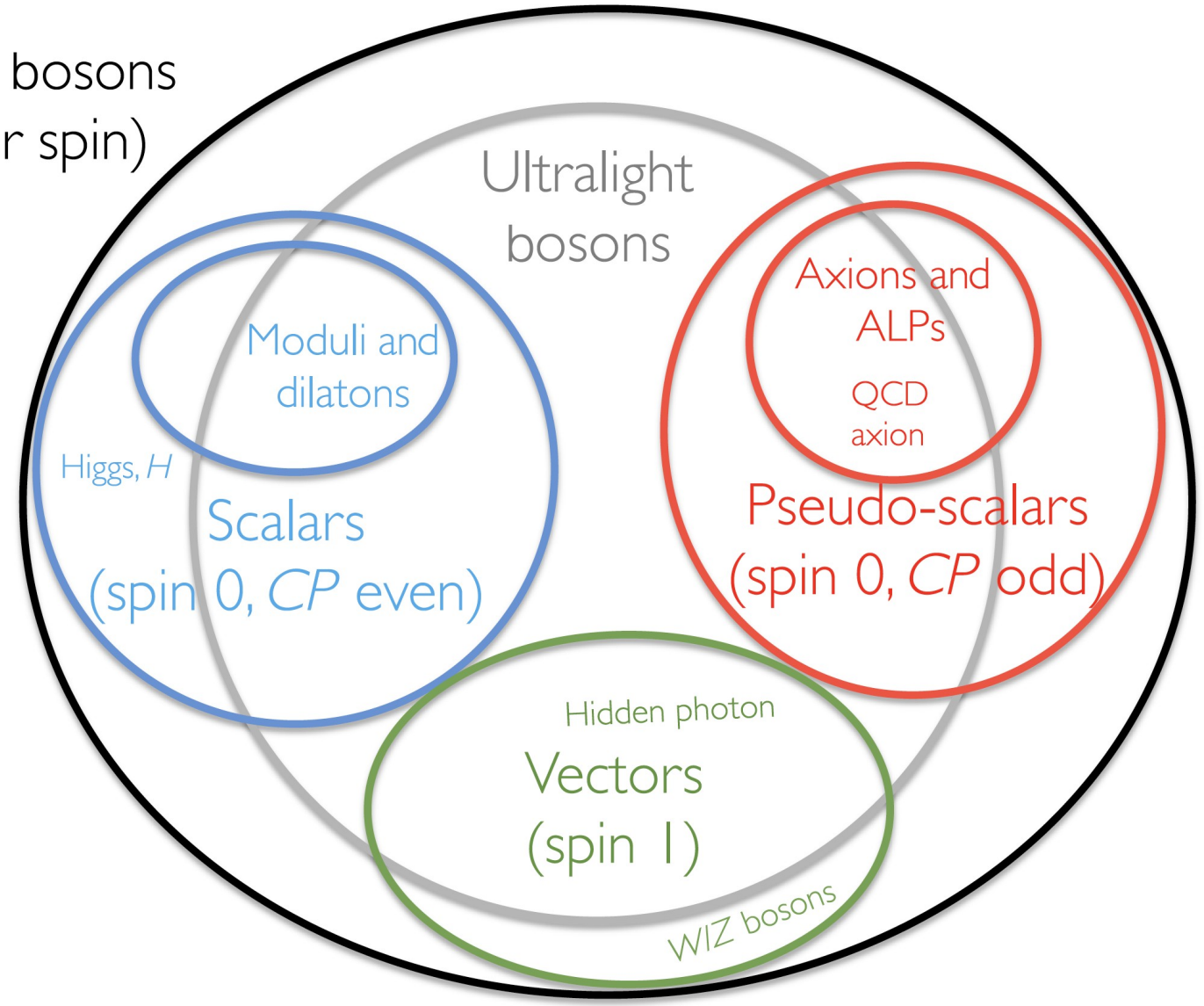
Inputs from WG1

Models



Plots for Exclusion Limits

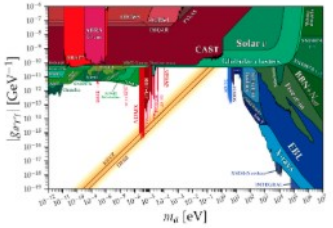
We will use the software from Ciaran O'Hare

https://cajohare.github.io/AxionLimits/

Ciaran's project already rich of data on limits for several couplings of WISPS. We can help to extend the physics case, collect data and create new summary plots. Will organize a subworking group on this.

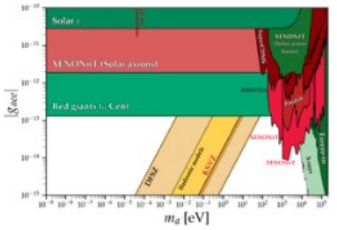
Axion-photon coupling

Data files
Plot (pdf, png)
Plot with projections (pdf, png)
Plot of dimensionless coupling (pdf, png)
Plot of dimensionless coupling with projections (pdf, png)



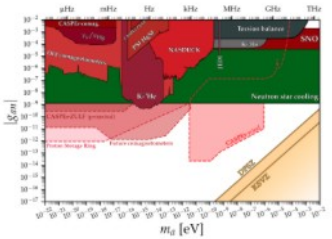
Axion-electron coupling

Data files
Plot (pdf, png)
Plot with projections (pdf, png)



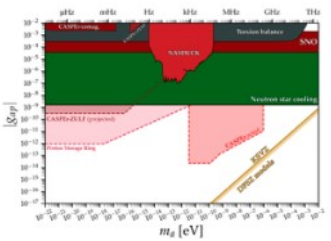
Axion-neutron coupling

Data files
Plot (pdf, png)
Plot with projections (pdf, png)



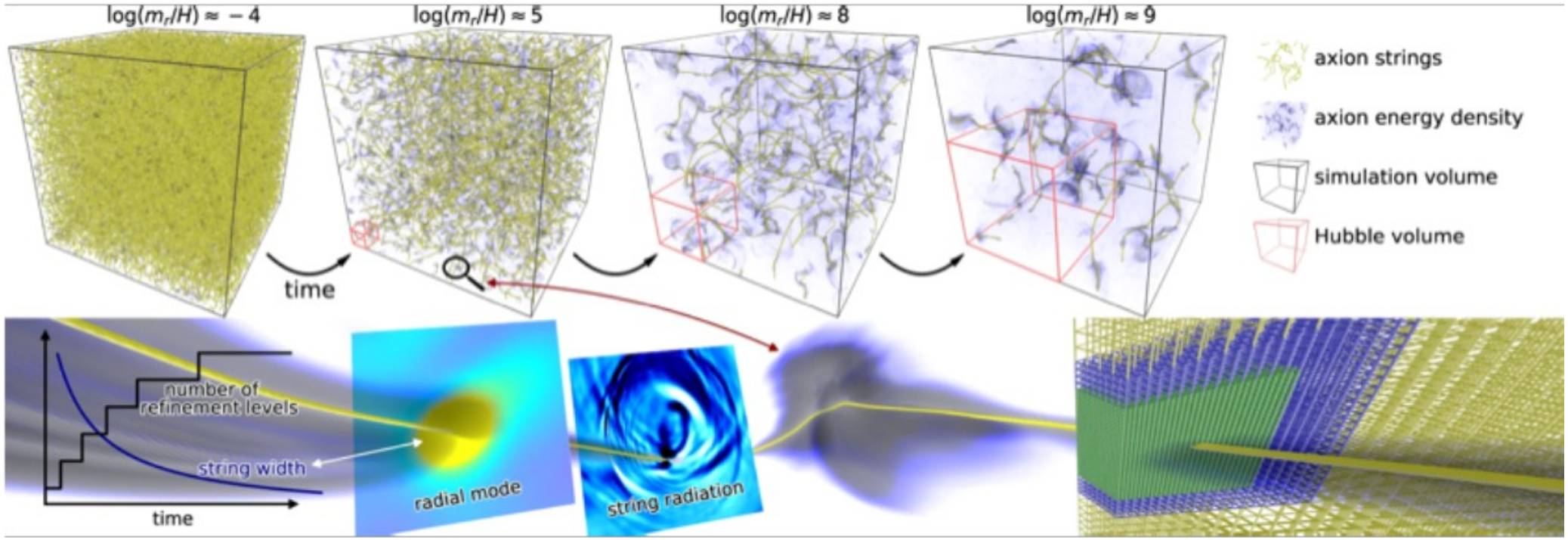
Axion-proton coupling

Data files
Plot (pdf, png)
Plot with projections (pdf, png)

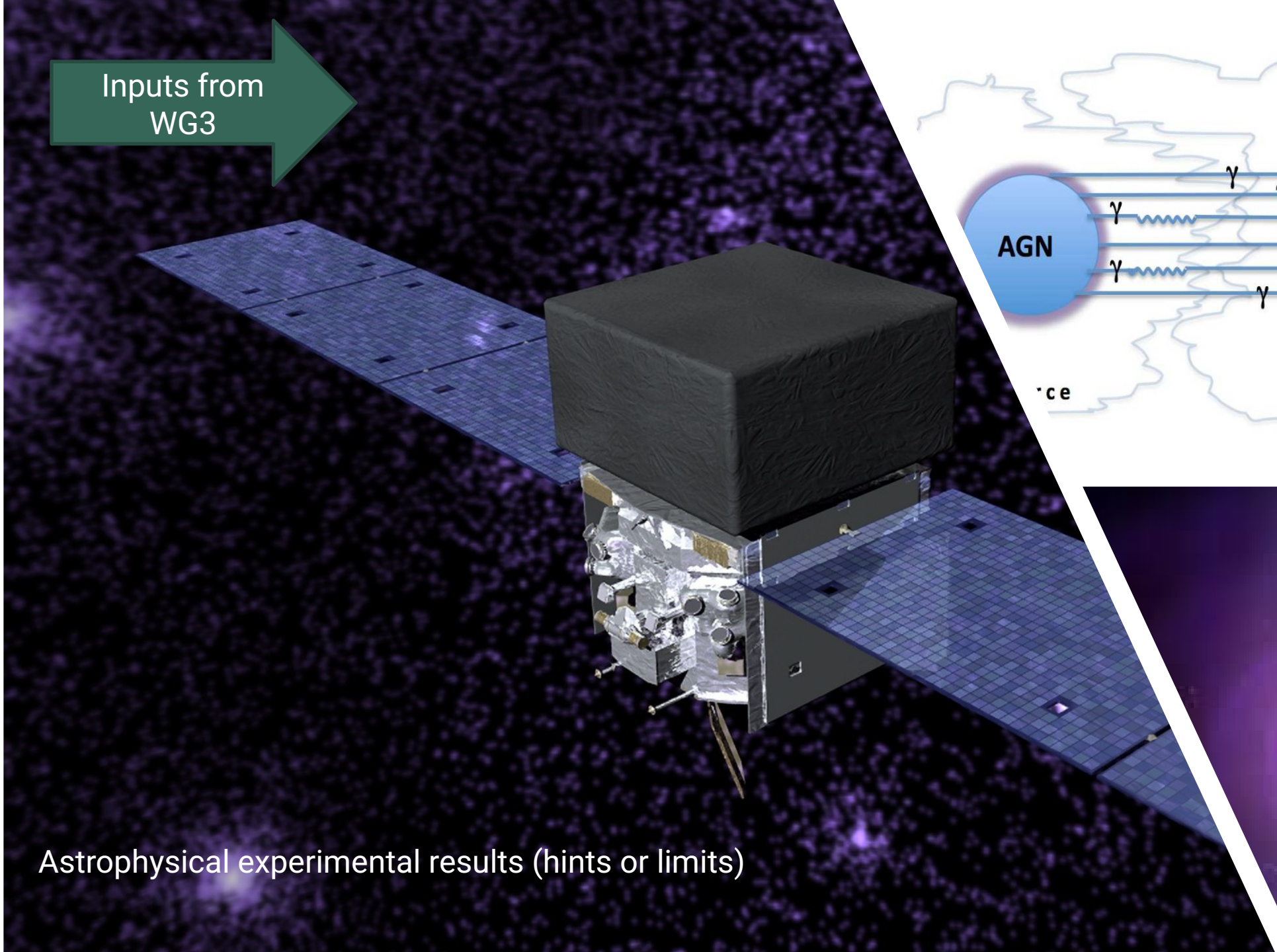


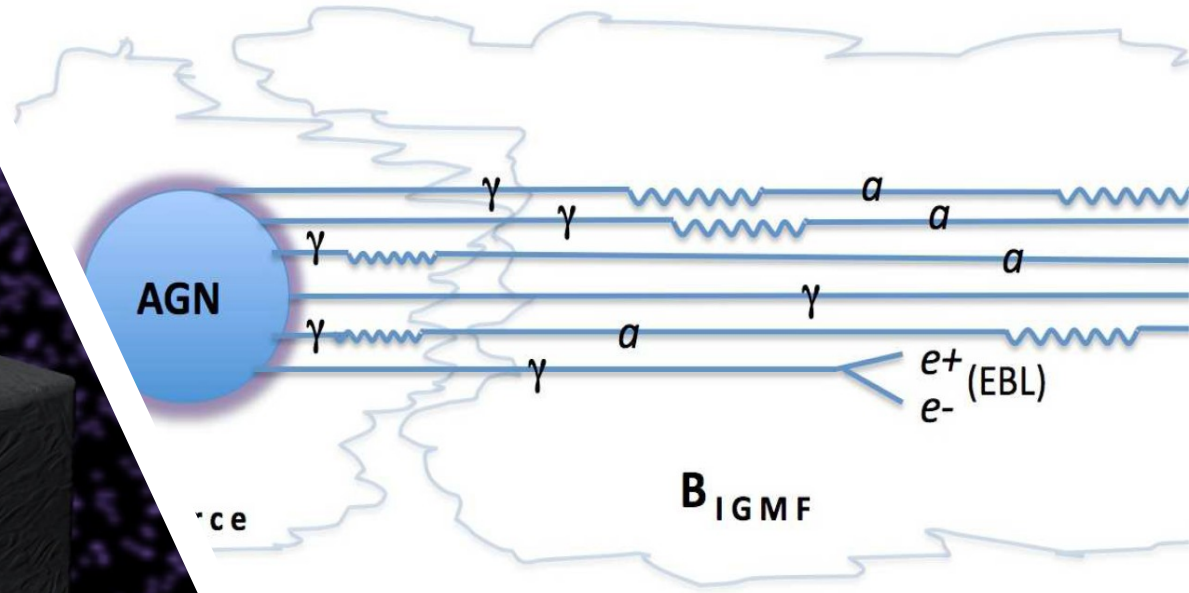
Inputs from WG2

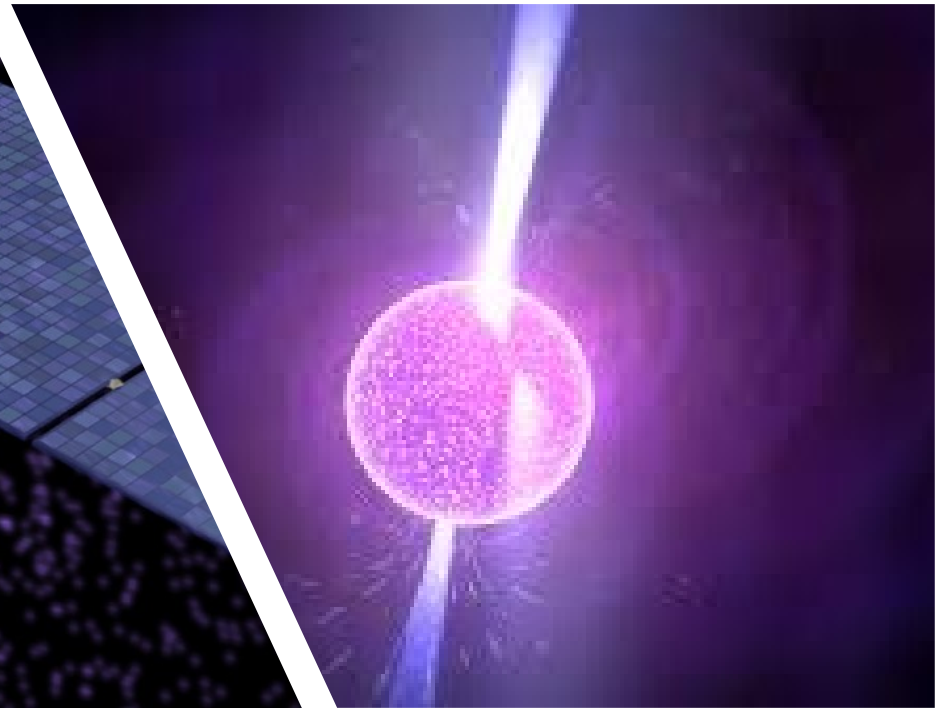
Preferred parameter space for WISP dark matter candidates



Inputs from WG3







Astrophysical experimental results (hints or limits)

WG4 - General organization

- WG4 meetings one per month

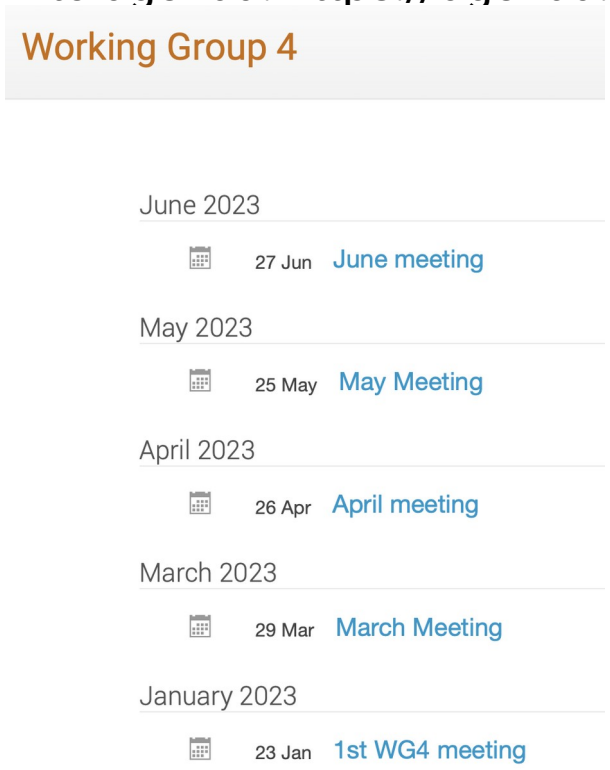
- Report on direct detection and Tech. Forums: Overleaf LATEX

- WG4 documents on Drive/Dropbox

- Mailing List cosmicwisperwg4@lists.infn.it
- INDICO meetings https://agenda.infn.it/category/1831/

MONTHLY MEETINGS

Link to agenda: https://agenda.infn.it/category/1835/



Experiments

Axion limits package and data combination - C Ohare
BRASS Experiment - LH Nguyen
WISPFI Experiment - M Maroudas
Haloscopes - A Rettaroli
Helioscopes - J Vogel
Gnome - G Zoran

Experimental techniques

Microcalorimeters at Heidelberg - L Gastaldo

Theory Models

Spin 2 ULDM - F Urban

Experimental Schemes

Axions in plasma - H Tercas
Directly Deflecting Particle Dark Matter - S Ellis

Contact Persons

- WG contact persons:
  - WG1 Mario Reig
  - WG2 Jose Cembranos
  - WG3 Maurizio Giannotti, Federico Urban
  - WG5 Loredana Gastaldo, Serkant Ali Cetin

- Contact person with CERN-PBC Technology working group: Giovanni Cantatore, Pierre Pugnat

- Contact person with ECFA Quantum Sensing WG (tbd)

WG4 REPORT DRAFT

Link to Report: https://www.overleaf.com/4678842289cfhfndnmvtyr

CosmicWispers WG4 Report: WISPs direct searches

Claudio Gatti[1], Alessio Rettaroli[1], Marin Karuza[2], and Name[3]

[1]INFN, Laboratori Nazionali di Frascati, via Enrico Fermi 54, Roma, 00044 Italy
[2]Rijeka University
[3]Institution name

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Abstract.

Version September 4, 2023

Contents

REPORT CONTENT

3.6. TEMPLATE Experiment

- 5-10 lines of description (1 or 2 pictures of experimental site)
- Experimental site
- goal of experiment
- Collaboration
- Status: Proposal, R&D, Construction, Running, Finished
- (expected) Period of operation
- R&D and technologies
- Bibliography

Plots of results and projections will be shown in the summary plots by Ciaran in a separate section and are not needed here.

Additional information useful for the summary plots are:

- Definition of coupling (i.e. what lagrangian interaction term)
- Assumed dark matter density
- Definition of the projection (i.e. is it an estimated sensitivity, projected 90% CL limit, order-of-magnitude estimate etc.)
- Location (required for the dark photon case and for experiments sensitive to a daily modulation)

Template experiment uses the following Lagrangian definition:

$$\mathcal{L} = \frac{1}{2}(\partial^\mu a)(\partial_\mu a) + \frac{\alpha_s}{8\pi}\frac{a}{f_a}\tilde{G}^{\mu\nu}G_{\mu\nu} + \frac{1}{4}g^0_{a\gamma\gamma}a\tilde{F}^{\mu\nu}F_{\mu\nu} + \frac{1}{2f_a}(\partial_\mu a)j^\mu_{a,0}\,, \qquad (1)$$

Experiment position and orientation are listed in Tab. 1.

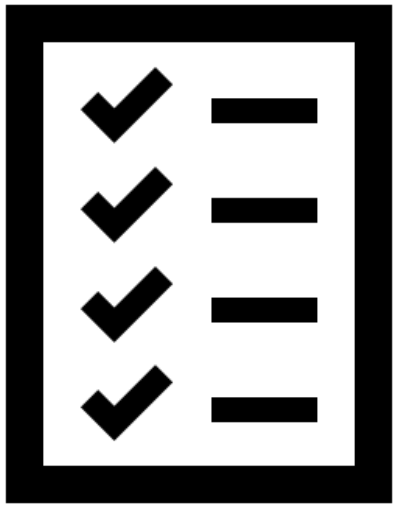
Table 1. Position and magnetic-field direction of template experiment

Latitude	41° 49′ 26″
Longitude	12° 40′ 13″
Elevation	100 m
B field direction	East−northeast

LATEX TEMPLATE FOR EXPERIMENTS

REPORT CONTENT

WHAT ARE WE DOING?



Activities [WG1-4]:

- Organization of workshops on specific topics of the WGs.
- Organization of Short Term Scientific Missions (STSM).
- Organization of Technology Forums (WG4).
- Publication of report on the scientific results in the webpage (in cooperation with WG5). Participation in outreach activities (in cooperation with WG5).
- Preparation of the final White Paper and of the Training School Lecture Notes.

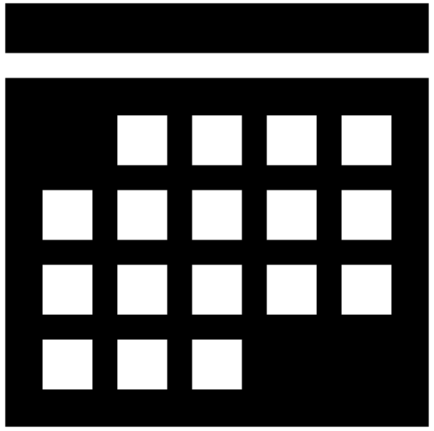
Milestones [WG1-4]:

- WG meetings to track the progress of each WG and to take corrective measures in case of problems.

Deliverables:

- D4.1 Draft Report on direct detection (month 12)
- D4.2 Interim Report on direct detection (month 24)
- D4.3 Final Report on direct detection
- D4.4 Report on Technologies Forums

First year plan



- Make a list of WISPs models
- Make a list of WISPs experiments
- Preliminary Summary Plots
- Contact experts in specific experiments and techniques within and outside the COST. Invite them to join the COST.
- Make a list of technology needed by WISP experiments
- Draft of Direct Search Report

WG4 PROGRAM

- Distribute Latex template for experiment and complete the overview on experiments by end of November
- Started working on R&D, facility and experimental schemes sections will be completed in 2024
- Keep inviting speakers to monthly meeting and involve them in report preparation
- Organization of second Technology Forum on (quantum) sensors.

REQUEST FOR HELP

Conclusions

- Anomalous internal pairing was first observed from the excitation of an M1 multipolarity transition of ^{8}Be at 18.15 MeV. A peak-like deviation was found in the $e^{+}e^{-}$ angular correlation at large angles (140 degrees). The anomaly was later confirmed in an experiment with our upgraded spectrometer at a new accelerator and also very recently by a Vietnamise group.
- For ^{4}He, at an excitation energy of 20 MeV, the anomaly appeared at smaller angles (115 degrees), but could be explained by the formation and decomposition of a particle of the same mass (17 MeV). This provided kinematic evidence for the formation of the X17 particle. It was also found that the anomaly may have occurred in the direct capture of the proton and was not related to the excited states of 0^{+} or 0^{-} in ^{4}He.
- An anomaly was also observed in the ^{12}C 17.2 MeV E1 transition. It is a broad resonance and we investigated it at 4 different bombarding proton bombarding energies, and the angle of the anomaly was slightly changed according to the decay kinematics of the X17 particle.
- Very recently, the X17 anomaly was also observed in the decay of the Giant Dipole Resonance of ^{8}Be. The spectra measured show a peak like anomaly at 120 degree and a broader anomaly also above 150 degree. Both anomalies could consistently be described by assuming that the same hypothetical X17 particle was created both in the ground-state transition and in the transition going to the broad (Γ=1.5 MeV), first excited state in ^{8}Be. The invariant mass of the particle, which was derived to be $m_X c^2$ = 16.95±0.48(stat.) MeV, agrees well with our previously published values.
- We are planning to study the decay of the very broad GDR (Γ~7 MeV) with different proton bombarding energies in order to stretch the kinematic evidence for the decay of the X17 particle.
- I would like to ask you, theorists, to help us understanding the nature of X17 and my be its role connected to the dark matter.

D4.1 DRAFT REPORT ON DIRECT DETECTION (MONTH 12)

Tentative agenda

- February: List of editors; Latex/Word template
- March-June: Meeting to define Report index/sections. Identify Editors for each section. Collect bibliography. Collect list of particles/models/experiments. Updated results for plots/limits. Combine experiment results. Inputs from other WGs.
- September-October: First draft; Identify missing models/experiments. Invite experts to join COST.
- December: Draft Report on direct detection (State of Art)

Experiments and Techniques

- Helioscopes
- Haloscopes
- LSW
- polarization
- AMO
- Magnetometers

- 5th Force exp.
- Casimir
- Torsion balance
- Atomic tests
- Levitated microspheres
- Micro resonators
- GW Interferometer
- Atom Interferometer
- Neutron interferometry
- Cold neutrons
- Variation of fundamental constants

- Colliders
- Beam dump/on target
- Underground

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