Direct Detection of Dark Matter and present status of ANAIS-112 experiment

MultiDark
Multimessenger Approach for Dark Matter Detection

Universidad Zaragoza

LSC
Laboratorio Subterráneo de Canfranc

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IX CPAN DAYS Santander, 23 - 25 October 2017

ANAIS

In Memoriam

- José Ángel Villar Rivacoba was ANAIS spokesperson and chair professor of Atomic, Molecular and Nuclear Physics at the Theoretical Physics Department of the University of Zaragoza
- He passed away last August and we are deeply in sorrow

ANAIS

In Memoriam

- He was Bachelor and Doctor in Physics (Thesis supervised by Julio Morales) by the University of Zaragoza
- He was always deeply involved in academic and research management activities in his University:
  - Dean of the Science Faculty at the University of Zaragoza (1992-2001)
  - Research Vice-Probost of the University of Zaragoza (2004-2008)
  - President of the Research Commission of the University of Zaragoza (2004-2008)

In Memoriam

- He was also strongly involved in scientific management at national and international level:
  - He was the coordinator of the national network of astroparticles (RENATA)
  - Member of the Executive Committee of the National Center for Physics of Astroparticles and Nuclear (CPAN)
  - Member of the general assembly and Joint Secretariat of the ApPEC Consortium
  - Organizer of numerous national and international congresses
  - Member of the Board and Science Assembly of ILIAS
  - Adviser to the successive Ministries responsible for Science and Technology, the Government of Aragon and Evaluation Agencies
  - ...

In Memoriam

- He incorporated to the Angel Morales's Group of Nuclear and Particle Physics and participated in the first efforts to build an underground facility in Spain, exploring different locations
- The Somport tunnel, in Canfranc, under the Pyrenees housed the first underground experiment devoted to the study of the Ge double beta decay around 1985-86 and it would become the Canfranc Underground Laboratory

In Memoriam

- With the group of the University of Zaragoza, he co-led with Julio Morales since 2003 and led since 2009, participated in relevant experiments in the international context in the rare events searches field:
  - Neutrino physics (IGEX, Kr-85)
  - Dark matter searches using Ge detectors (COSME, IGEX-DM), NaI (DM32, ANAIS) and bolometers (ROSEBUD)
  - Axion searches (CAST, IAXO)

- José Ángel was supervisor of 6 PhD Thesis
- He was the PI of more than 40 research projects
- He is co-author of more than 150 scientific publications

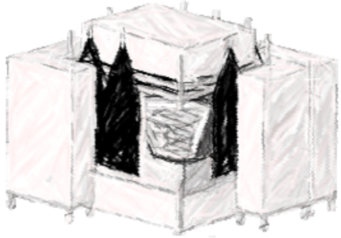
In Memoriam

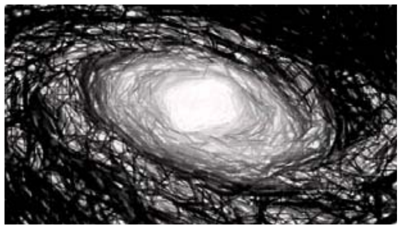
- He was strongly committed with the setting and commissioning of the new Canfranc Underground Laboratory Facilities
- Associate Director of the Canfranc Underground Laboratory (2007-2017)

In Memoriam

- Much more than numbers that are not able to measure the quality of a person, I would like to say that José Ángel was a nice and funny guy
- He always had a smile, a kind word
- It was very easy to work with him
- And we miss him

Outline

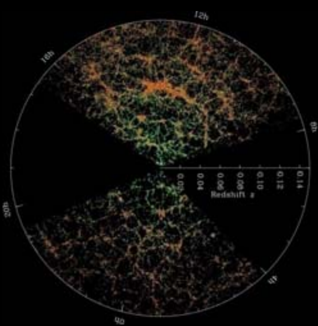


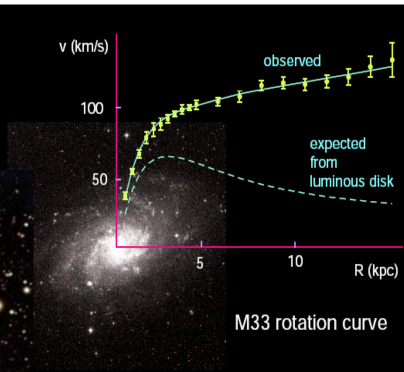


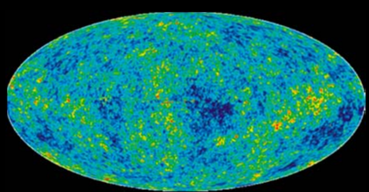
- The Dark Matter Paradigm and DM candidates
- DM Direct Search Strategy
- Present Experimental Status
- ANAIS experimental approach
- Commissioning ANAIS-112 at LSC
- ANAIS-112 general performance and prospects

The Dark Matter Problem

Evidences come from very different observational techniques at different scales and times of the Universe history

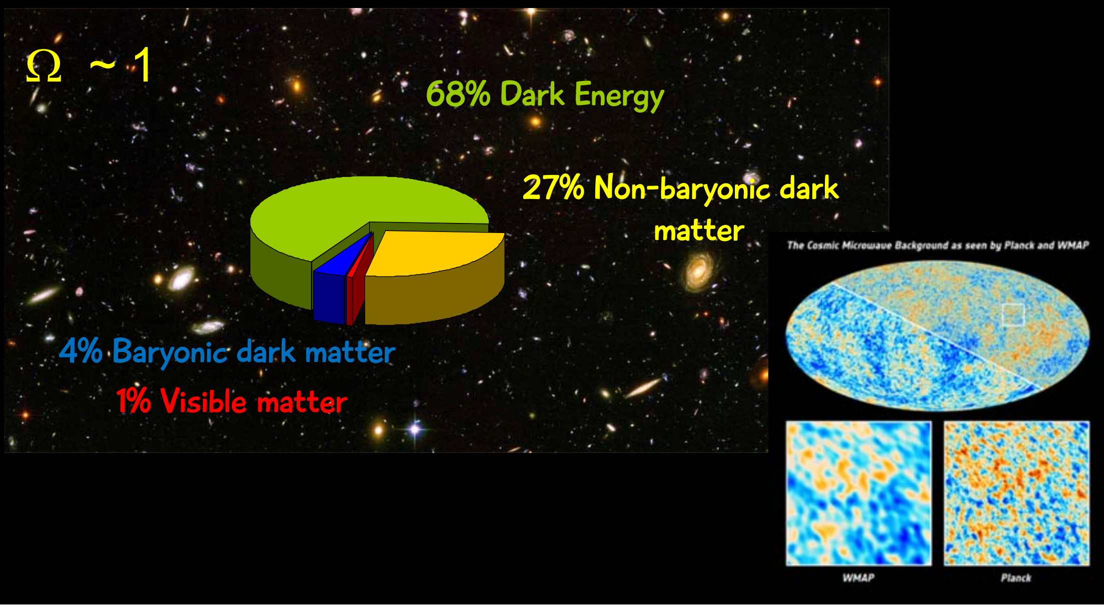




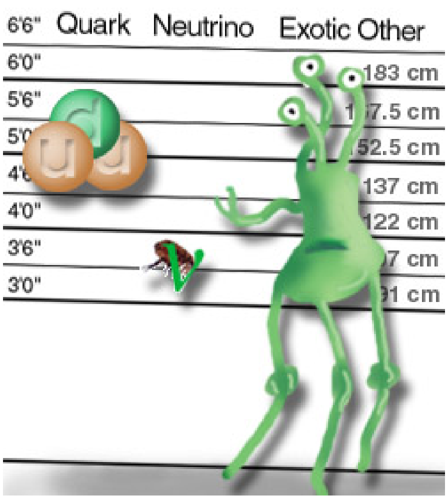


The Universe Recipe

After Planck …



The Dark Matter Nature



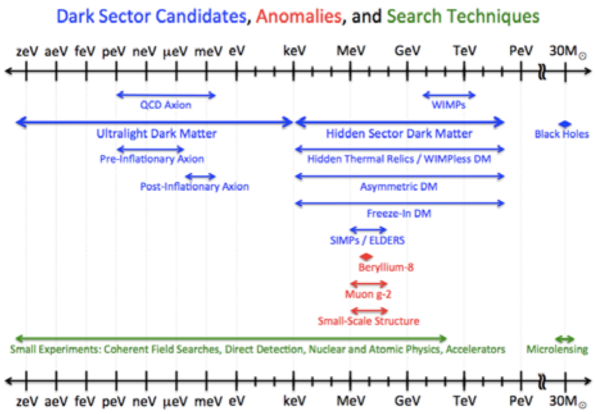
About 27% of the Universe consists of **unknown matter:**

- massive
- non-baryonic (*)
- neutral
- stable or very long lived
- non relativistic when structures formed (cold/warm)

Beyond the Standard Model of Particle Physics

The Dark Matter Nature

Many DM candidates are on scene



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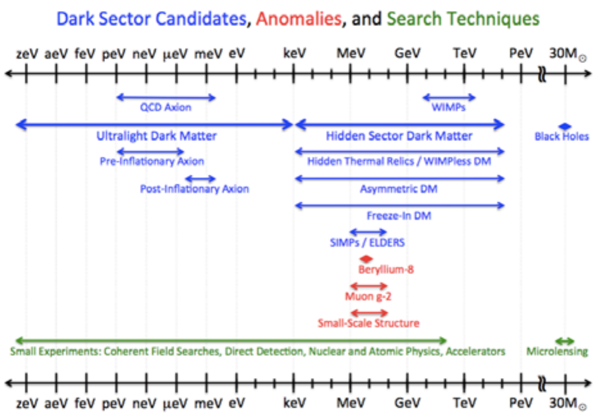


WIMPs
Axion - ALPs

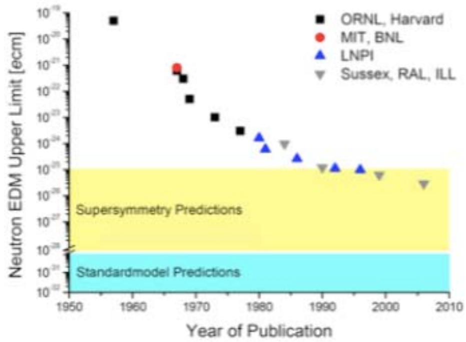
Well motivated !!!

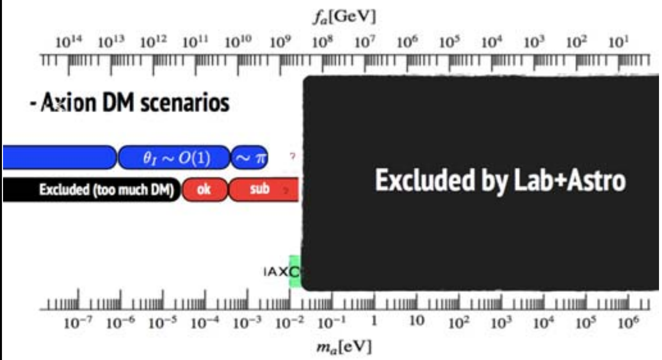
Axions (and ALPs)

Axions are well motivated DM candidates

They would solve the strong CP problem

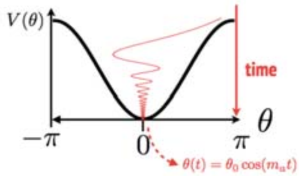
$$\mathcal{L}_\theta = \frac{1}{2}(\partial_\mu\theta)(\partial^\mu\theta)f_a^2 - \frac{\alpha_s}{8\pi}G_{\mu\nu a}\widetilde{G}^{\mu\nu}_a\theta$$





AXION DM

Axion DM is unavoidable if axions exist



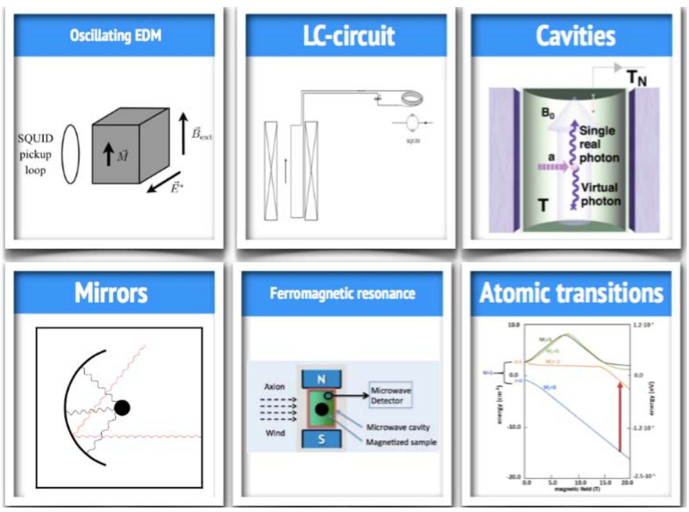
Axions (and ALPs)

Axions are very well motivated DM candidates

DM Axion DETECTION

Many R+D ideas on the field, until recently only one DM search: ADMX in Seattle

Moreover, experiments searching for solar axions, light shining through walls, long range forces, etc. are also very relevant



Th. Dafni talk, RENATA session

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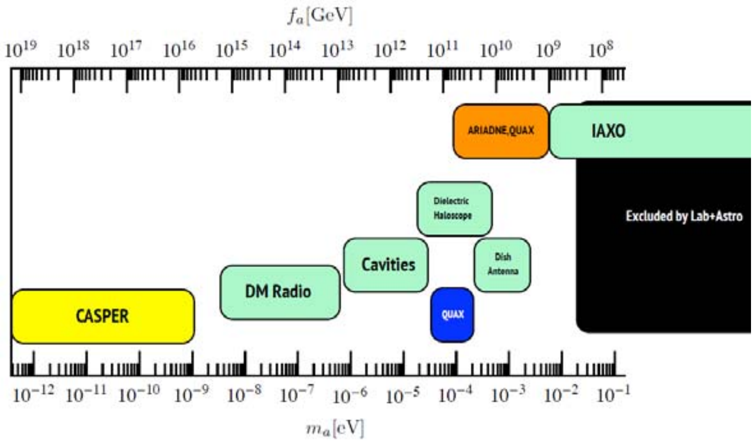


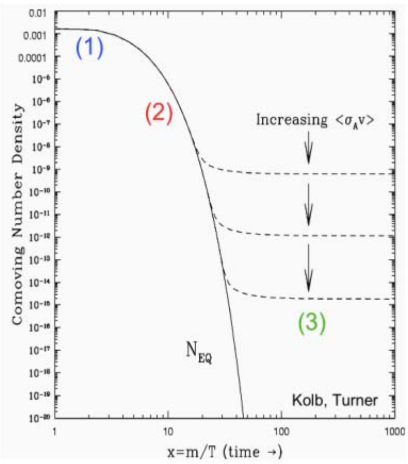
Weakly Interacting Massive Particles

WIMPs are well motivated DM candidates

If DM particle was in thermal equilibrium in the primordial soup, at freeze-out the annihilation cross-section determined the relic abundance

WIMP MIRACLE

electroweak scale cross-sections for a GeV particle produce the correct Ωm



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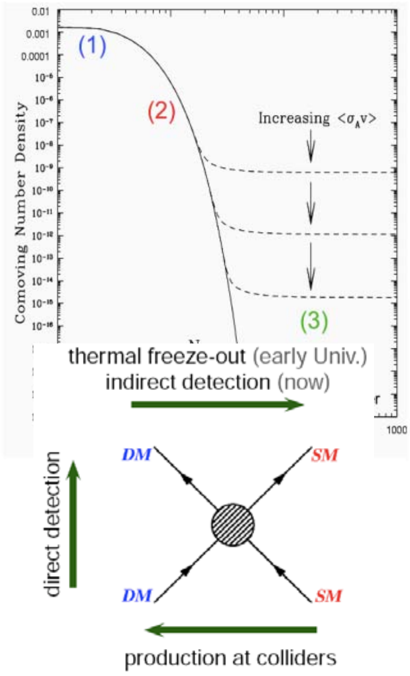
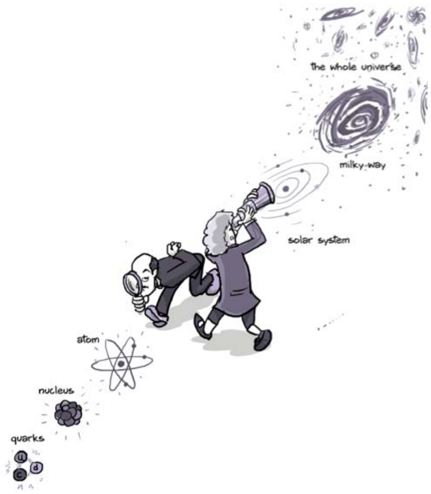
WIMP DETECTION
WIMP detection can be envisaged
-> Direct and Indirect Approach



The Challenge of DM Detection



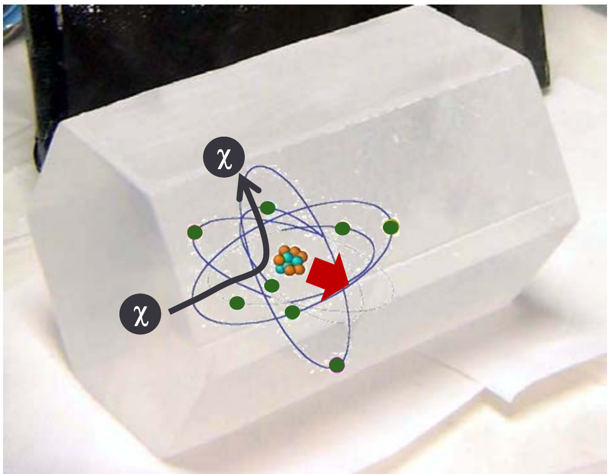
To decouple unknown and uncertainties in such a challenge for experimental detection

- Multimessenger approach (direct vs indirect vs accelerator searches)
- Multitarget and multi-technique strategy

WIMP DETECTION
It is challenge for: Astrophysics, Cosmology, Theoretical Physics, Particle Physics, Detector Technology, etc.

WIMP Direct Detection

Galactic WIMPs would produce NUCLEAR RECOILS by elastic scattering off nuclei



Extreme non-relativistic limit
Isotropic scattering in the CM reference frame

$$< p > \approx 6 - 70 MeV/c$$

$$10 GeV/c^2 < m_w < 1 TeV/c^2$$

WIMP Direct Detection

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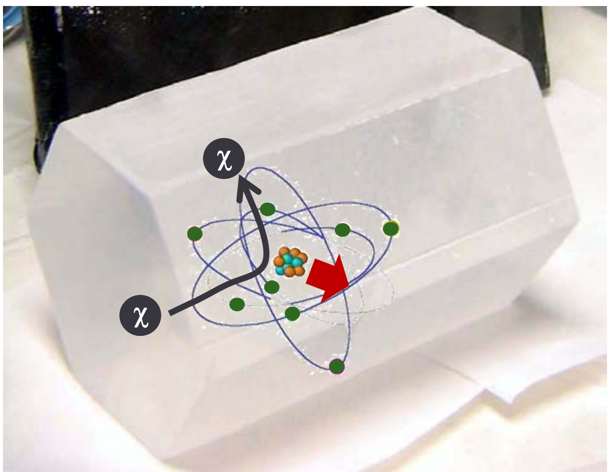
$$T_{recoil} = E_0 - E_{WIMP}^f = \frac{m_W{}^2 M_N}{(m_W + M_N)^2} v^2 (1 - \cos\theta)$$

$$T_{\max} = \frac{2 m_W{}^2 M_N}{(m_W + M_N)^2} v^2$$



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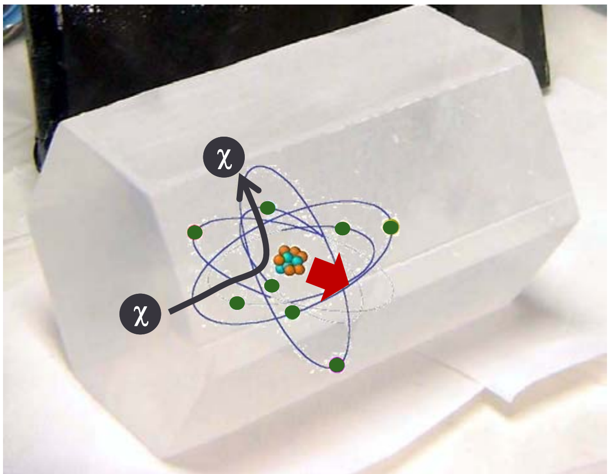
Detection Rate

$$\frac{dR}{dE_R} = n_{WIMPs}\, N_N \int f(v)\, v\, \frac{d\sigma_{WIMP-N}}{dE_R}\, dv$$

Dark Matter Halo model — Nuclear and Particle models



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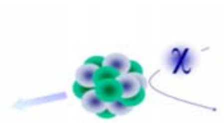

$$\frac{d\sigma_{WIMP-N}}{dE_R} = \frac{m_N}{2 m_r^2} v^2 \left[\sigma_{SI} F_{SI}^2(E_R) + \sigma_{SD} F_{SD}^2(E_R) \right]$$

$$\sigma_{SI} \propto \frac{m_{WN}^2}{m_{Wn}^2} A^2 \sigma_{SI}^{nucleón}$$

$$\sigma_{SD} \propto \frac{m_{WN}^2}{m_{Wn}^2} \sigma_{SD}^{nucleón} \frac{4}{3} \frac{(J+1)}{J} \frac{1}{a^2} \left(a_p \langle S_p \rangle + a_n \langle S_n \rangle \right)^2$$

Effective WIMP couplings to neutrons and protons can be calculated for every theoretical model from the effective Lagrangian, but experiments are sensitive to WIMP-nucleus coupling

COMPARISON OF EXPERIMENTS USING DIFFERENT TARGETS IS MODEL DEPENDENT

WIMP Direct Detection

Galactic WIMPs would produce NUCLEAR RECOILS by elastic scattering off nuclei

Milky Way Rotation Velocity Curve determines halo mass density but not particle number density

$n_W = \frac{\rho_0}{m_W}$

$\rho_0 \approx 0.2\text{-}0.4\ \text{GeV/cm}^3$

Detection Rate

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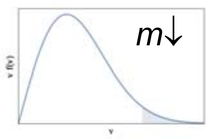
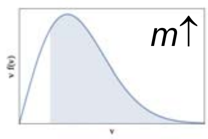
Dark Matter Halo model

Nuclear and Particle models





The most simple model isotropic and spherical thermal distribution of non relativistic WIMPs

$v_{rms} \approx 270\text{km/s}–300\text{km/s}$

$v_{esc} \approx 544\ \text{km/s}$

$$f(\vec{v}_{gal})d^3\vec{v}_{gal} = \frac{1}{v_0^3 \pi^{3/2}} e^{-\frac{|\vec{v}_{gal}|^2}{v_0^2}} d^3\vec{v}_{gal}$$

$$v_{min}^2 = \frac{(m_W + M_N)^2}{2 m_W^2 M_N} T_{threshold}$$

The whole WIMP phase space cannot be accesible → Energy threshold is very important for low mass WIMPs

WIMP Direct Detection

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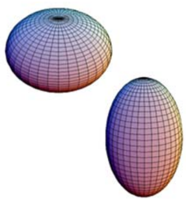
Haloes can be non-spherical



Haloes can have sub-structure:

-Sub-haloes

-Dark Disk

-Satellites producing directional fluxes

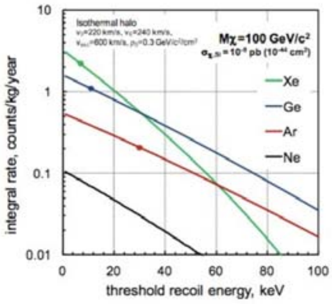
WIMP Direct Detection

Recoil energy conversion into visible energy is strongly dependent on the technique, target, and particle interaction

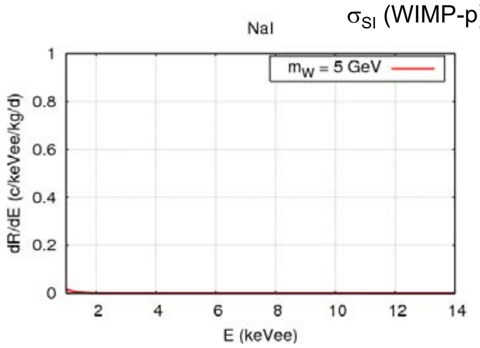
-> Calibration with nuclear recoils is not easy

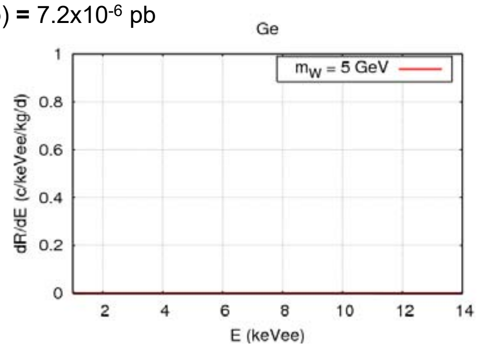
$E_R = Q\ Eee$

Still many uncertainties strongly dependent on target and technique

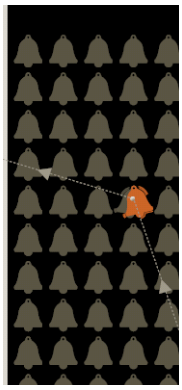


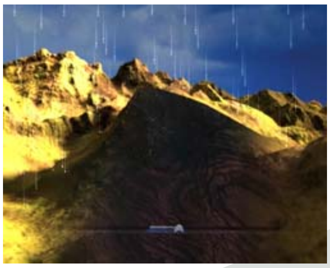
σ_{SI} (WIMP-p) = 7.2x10^{-6} pb

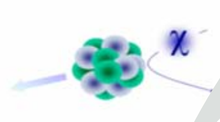




WIMP Direct Detection





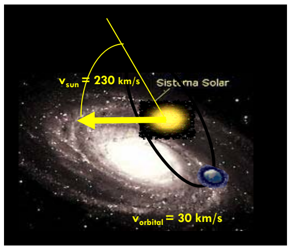


WIMPs interact (although weakly) with ordinary matter

Availability of very sensitive and radiopure particle detectors

Experiments have to be shielded against all possible backgrounds and profit from active background rejection techniques

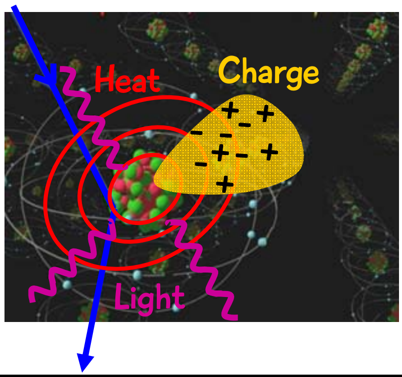
Signatures of a Dark Matter interaction are very convenient for a positive result



Particle Detection Techniques

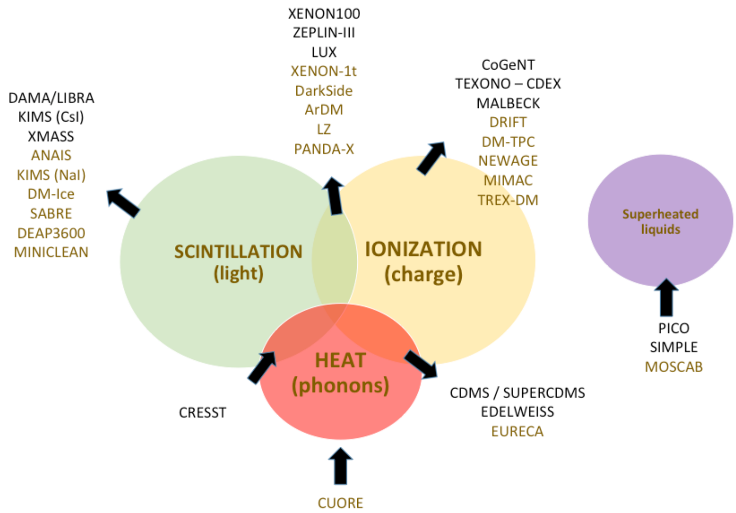
Detectors are those devices able to convert energy depositions of a particle passing through into a measurable signal

DM detectors requirements: high radiopurity material, high mass, low energy threshold, high response to nuclear recoils, wide absorber choice (light+heavy isotopes, spin content), modularity or spatial information on the interaction, particle discrimination capability



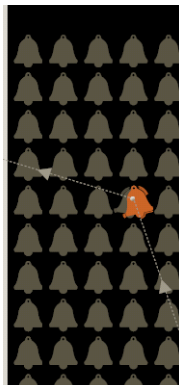
Energy conversion into VISIBLE signal is strongly dependent on the interaction mechanism, incident particle and target

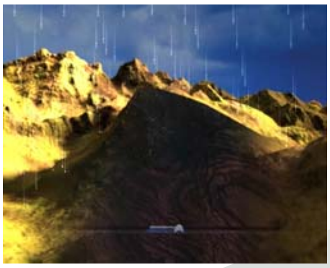
Particle Detection Techniques

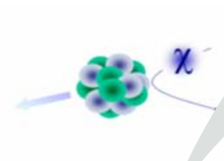


The most sensitive detectors are HYBRID Detectors profit from the simultaneous measurement of two energy conversion channels for particle discrimination

WIMP Direct Detection







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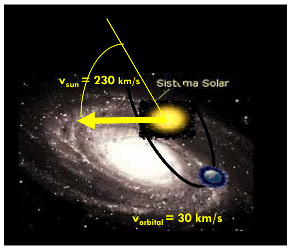
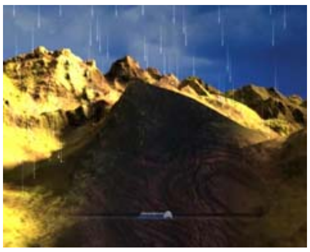
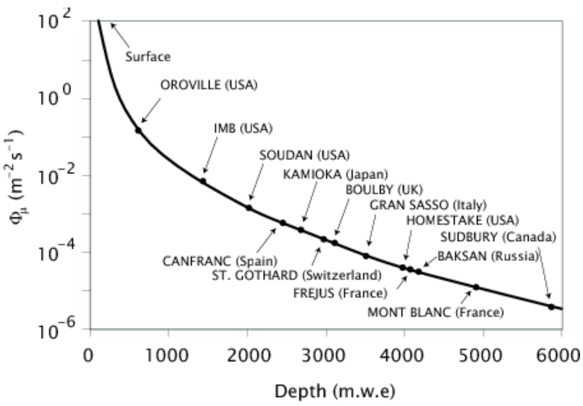


Shielding Strategy

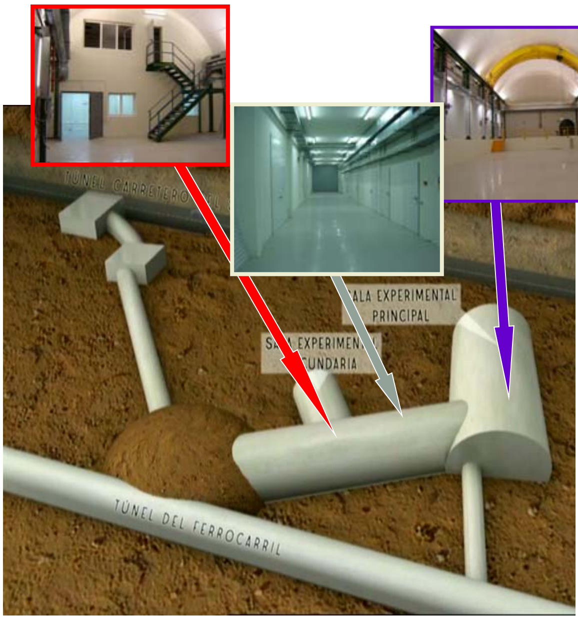
Background signals interferring with WIMP detection come from

- COSMIC Rays
- Environmental Radioactivity





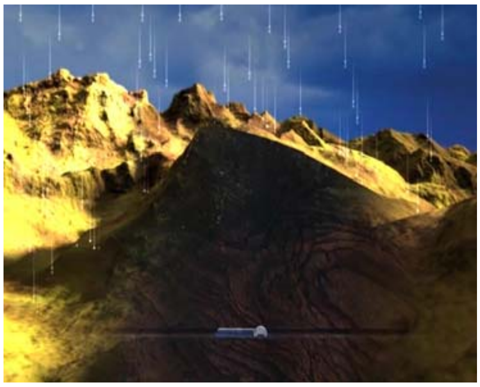
The Canfranc Underground Lab.



Since 1985 an underground laboratory under the Pyrenees

2450 m.w.e. rock overburden

@ Somport railway tunnel



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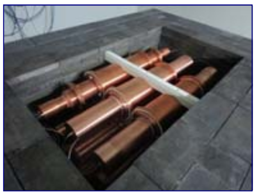
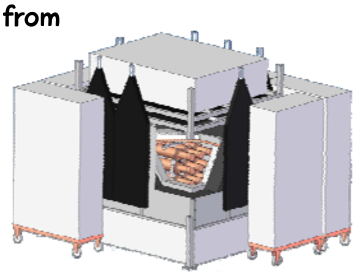
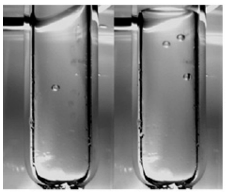
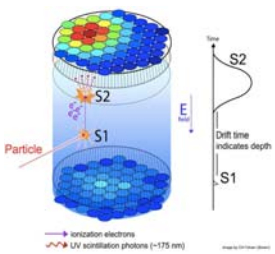
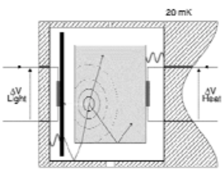


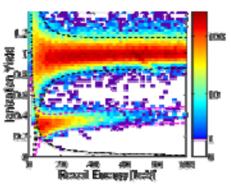






Convenient shieldings against:
Gammas, Neutrons, Muons, Radon intrusion





Active Background Rejection

Nuclear recoils vs electron events

Neutron backgrounds under control considering multiple scattering and combination of different targets

Shielding Strategy

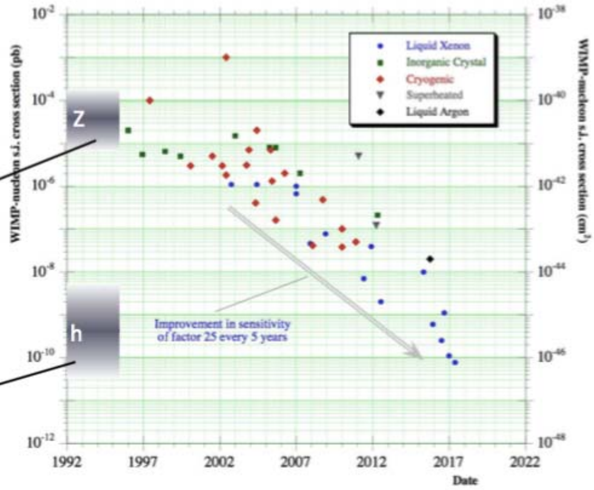
Background signals interfering with WIMP detection come from

-COSMIC Rays

-Environmental Radioactivity

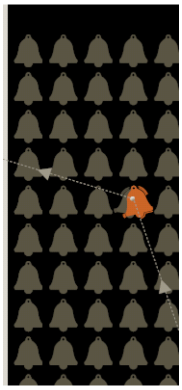
Sensitivity Evolution

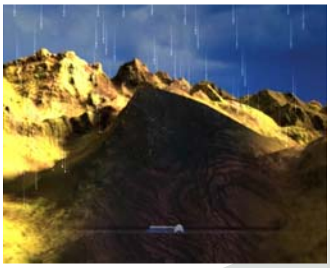
- Already (1990's) excluded Z-mediated exchanges (e.g. heavy neutrinos)
- Now into higgs-mediated cross sections



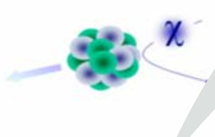
From R. Gaitskell & N.J. Smith

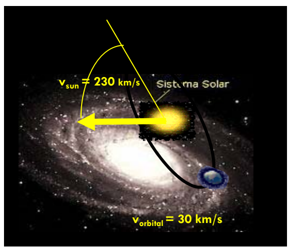
WIMP Direct Detection





- WIMPs interact (although weakly) with ordinary matter
- Availability of very sensitive and radiopure particle detectors
- Experiments have to be shielded against all possible backgrounds and profit from active background rejection techniques
- Signatures of a Dark Matter interaction are very convenient for a positive result

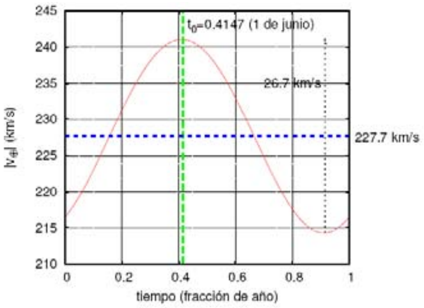




Dark Matter Signatures

Positive identification of WIMP against backgrounds

- Annual modulation
- Directionality of recoils



$$\eta(t) = v_\oplus(t)/v_0 = \eta_0 + \Delta\eta cos\omega(t - t_0)$$

$$S_k(t) = S_{0,k} + S_{m,k} cos\omega(t - t_0)$$

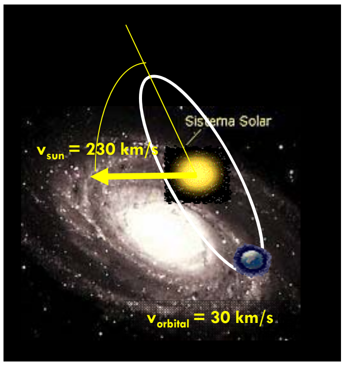
$\omega = 2\pi/365\ d^{-1}$

t_0 ~1st June

Small effect (<7% of S_0)

Inverse modulation at very low energies

It depends strongly on the halo model



Experimental Situation

One single experiment has reported evidence of a signal compatible with Dark Matter observing a model independent annual modulation

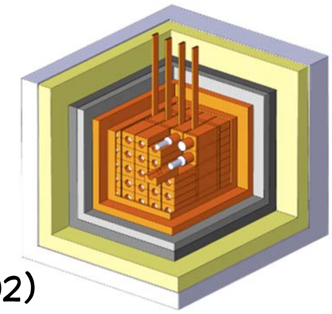
Other much sensitive experiments do not have any hint, and in fact they are reaching the NEUTRINO FLOOR

CONTROVERSIAL issue for more than a decade
Is possible a model independent confirmation or refutation?

Many WIMP scenarios considering halo and particle models have been considered and reconciling all results seems very difficult

DAMA/LIBRA experiment

~250kg NaI(Tl) scintillators @ LNGS



Total exposure:
DAMA/NaI (100 kg NaI, 7 years, completed in 2002)
+ DAMA/LIBRA (250 kg NaI, 7 cycles, + ongoing)
→ total exposure: 1.33 ton x year

Data taking ongoing after upgrading PMTs …

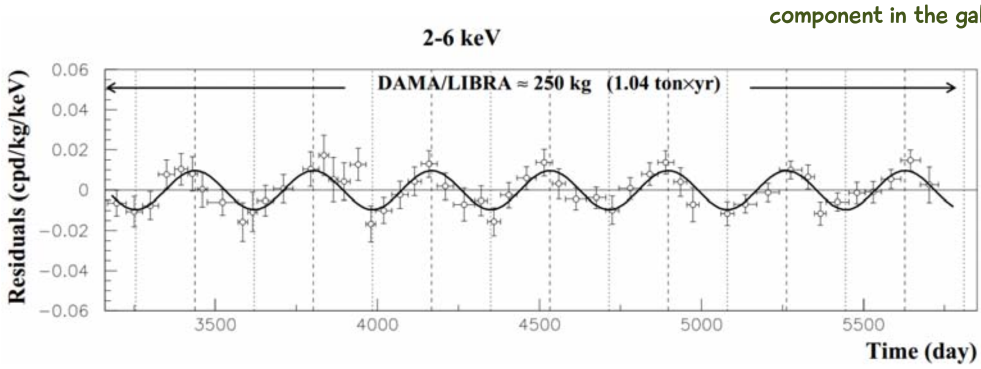
Experimental Situation

DAMA/LIBRA experiment

Model Independent Result

A_m = 0.0112 ±0.0012 cpd/kg/keVee
T = (0.998 ±0.002) y
T_0 = (144 ±7) d (2nd June=153)
No modulation above 6 keV

Evidence (9.3 σ C.L.) of an annual modulation of the *single-hit* events in the (2–6) keVee energy region satisfying all the requests of a DM component in the galactic halo



Experimental Situation

DAMA/LIBRA experiment

Experimental Situation

Model Independent Result

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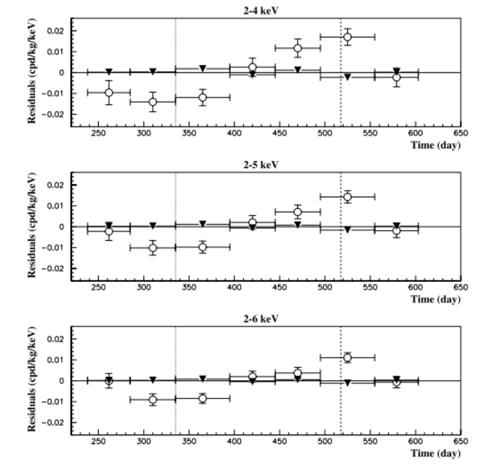
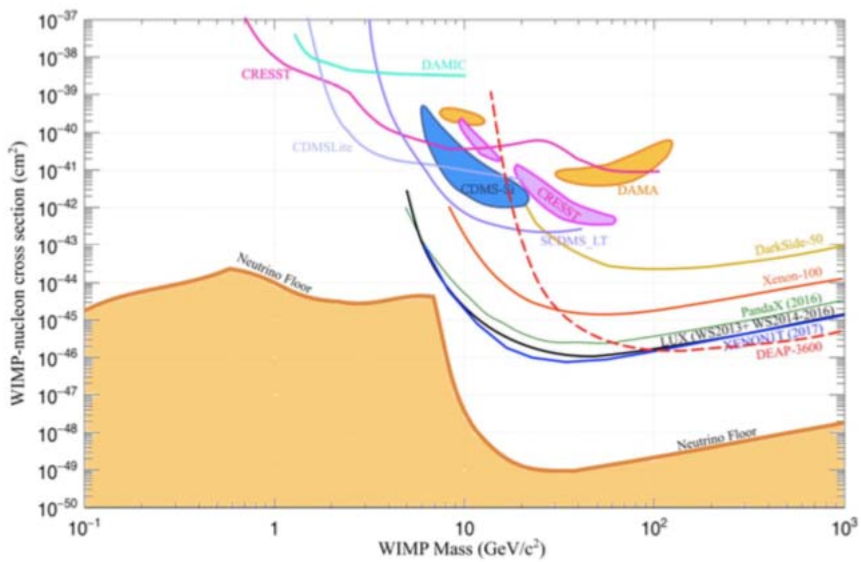


Evidence (9.3 σ C.L.) of an annual modulation of the *single-hit* events in the (2–6) keVee energy region satisfying all the requests of a DM component in the galactic halo

Modulation disappears when looking at multiple hit events due to background and it is not compatible neither with muons, nor other radioactive backgrounds

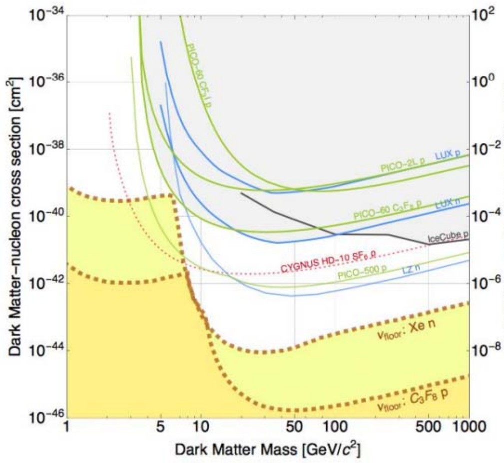
Experimental Situation



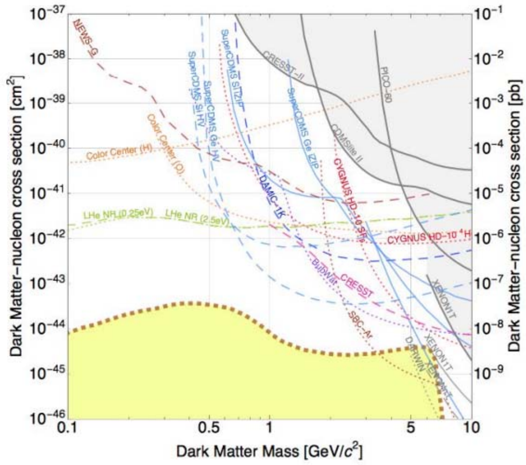
SI interactions

From N.J. Smith at TAUP 2017, Sudbury

Experimental Situation



Spin-dependent
WIMP-nucleon (p or n) cross section



Spin-independent, low mass,
WIMP-nucleon cross section

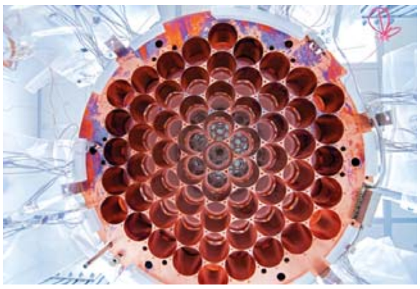
From N.J. Smith at TAUP 2017, Sudbury

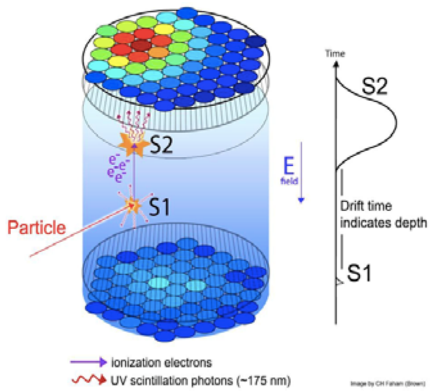
Experimental Situation

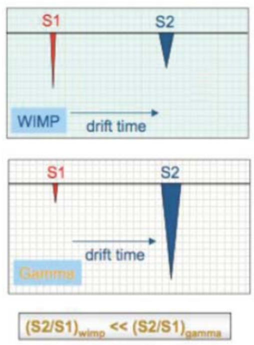
Most sensitive experiments

Xe double phase TPC

LUX @ Sanford Laboratory (350 kg)







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Most sensitive experiments

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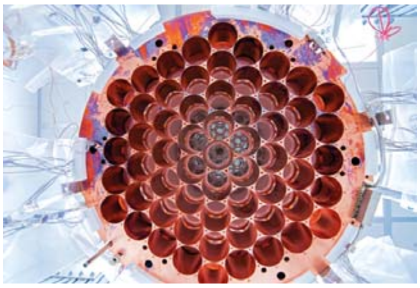
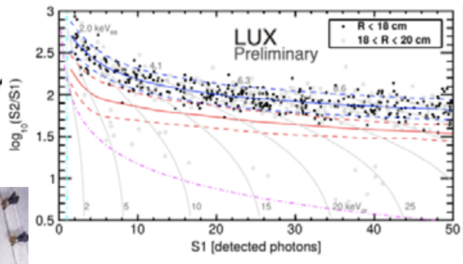
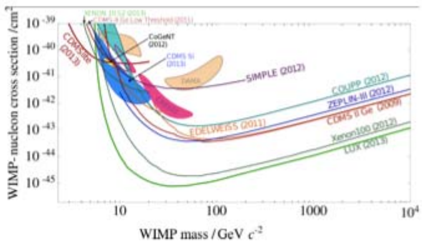






95 days net (previously 85 d)

145 kg fiducial (118 kg)

- conservative **1.2 keV** signal cutoff →**3.3 GeV** m_{min} (3.0 keV, 5.2 GeV)

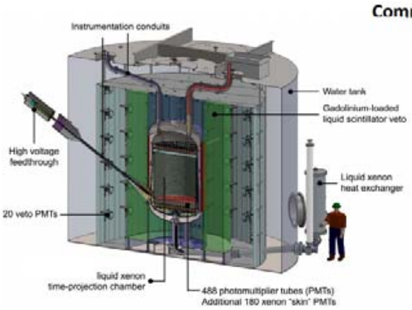
LZ Detector - 10 tonnes Xe

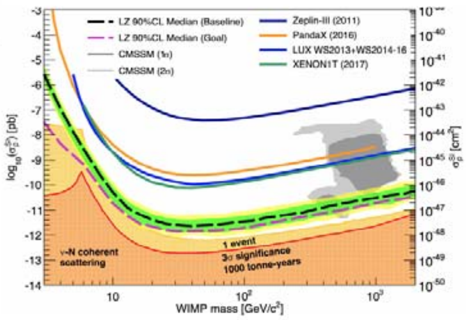
Replacing LUX at the Sanford Underground Research Facility (SURF)

Technical Design Report arXiv:1703.09144 260 Authors, 400 Pages

DOE Project, Construction Fully Underway > CD4
Commissioning April 2020, Physics in 2021, Goal 1000 days

Baseline WIMP sensitivity @ 40 GeV is 2.3 x 10^{-48} cm²
Other promising science targets:
ββ0n, pp & 8B solar neutrinos,
coherent neutrino scattering

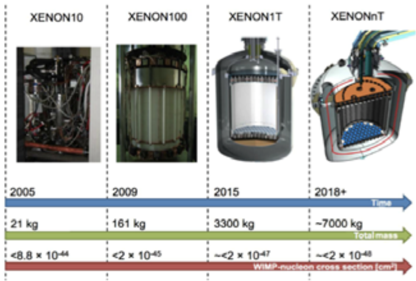


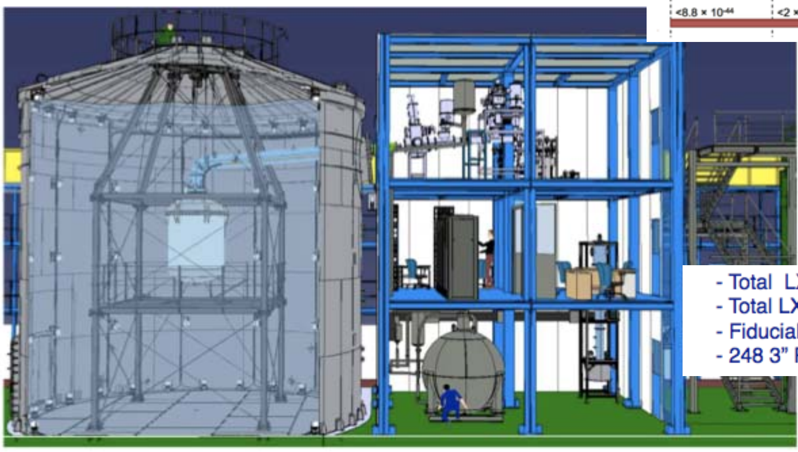


Most sensitive experiments

Xe double phase TPC

XENON100 & XENON1T @ LNGS





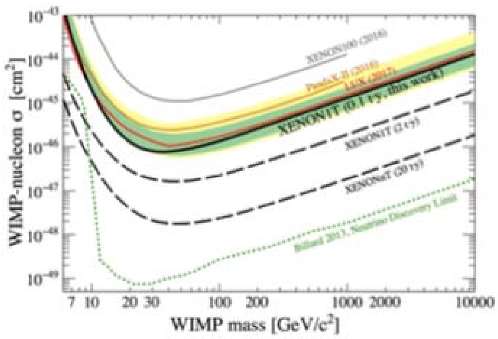
- Total LXe mass: ~3.3 tonnes
- Total LXe active volume: ~ 2 tonnes
- Fiducial volume: ~1 tonne
- 248 3" PMTs Hamamatsu R11410-21

Experimental Situation

Most sensitive experiments

Xe double phase TPC

XENON100 & XENON1T @ LNGS



First science run: 34.2 live-days
- Largest ever Xe fiducial mass: 1042 kg
- Lowest ever low-E ER bg.: (0.193 ± 0.025) mDRU
- Most stringent SI-WIMP limit

Still running, >100 live-days taken

XENONnT upgrade planned for 2019

Experimental Situation

R. Santorelli Talk, RENATA session

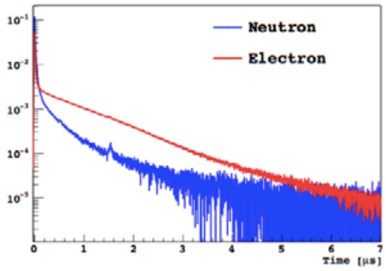
Most sensitive experiments

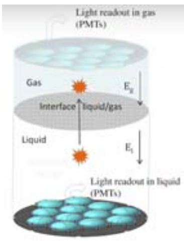
Ar double phase TPC

ArDM @ LSC

The ArDM-1t detector is the largest two-phase liquid argon detector for Dark Matter Searches in the world

Pulse shape discrimination





Experimental Situation

R. Santorelli Talk, RENATA session

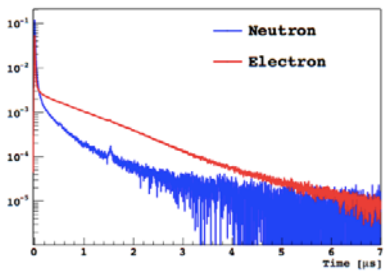
Most sensitive experiments

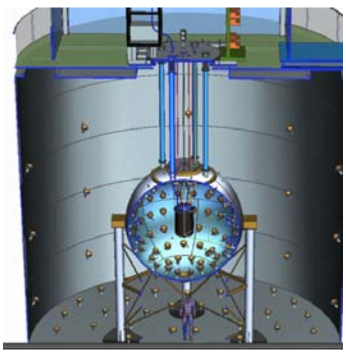
Ar double phase TPC

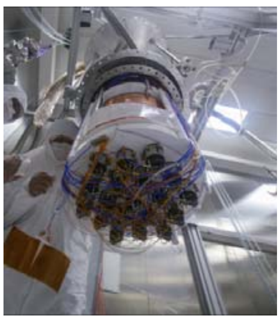
DarkSide @ LNGS

46 kg active 153 kg total -> going to 20 ktons

Pulse shape discrimination







Liquid Scintillator for n

Water tank for muons

Free from ^{39}Ar

Moving towards ARGO -> Most Sensitive DM exp. (1000 t yr) above 10 GeV

Experimental Situation

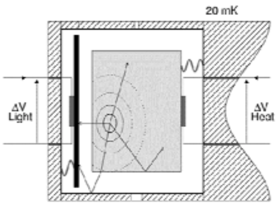
Experimental Situation

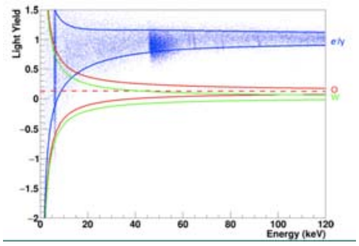
Most sensitive experiments

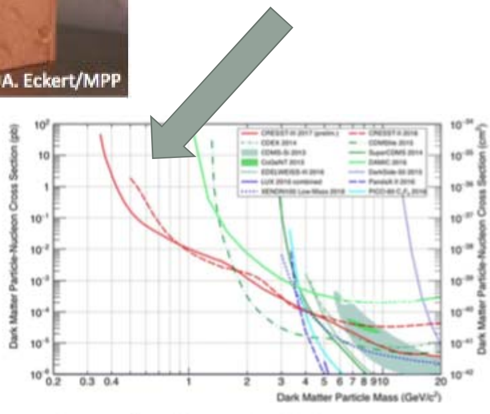
CRESST-III @ LNGS

$CaWO_4$ bolometers

100 eV threshold
24g absorber mass
2.21 kg days







Experimental Situation

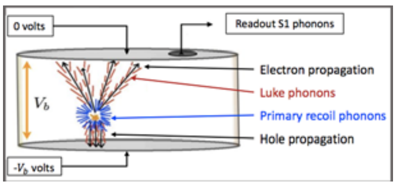
Most sensitive experiments

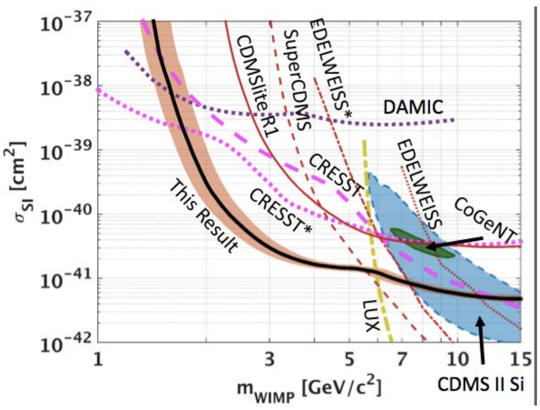
Heat Ionization Bolometers

CDMS Lite @ SOUDAN

<100 eV Ionization Trigger
70 kg day exposure

Further improvement expected
after moving into SNOLAB



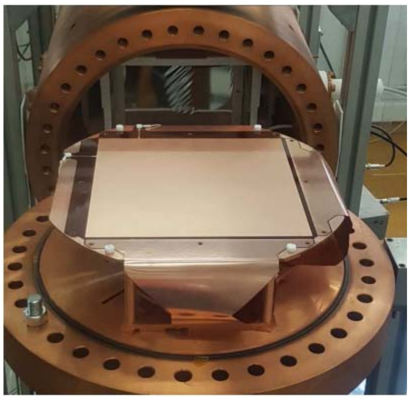


Experimental Situation

Most sensitive experiments

Ionization Gaseous Detectors

TREX-DM @ LSC



Different target gas can be used (Ne, 160g)
Microbulk Micromegas readout
Very low threshold as goal (100 eVee)
In preparation

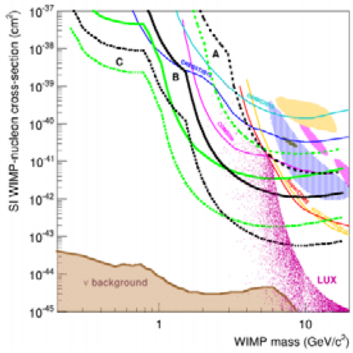


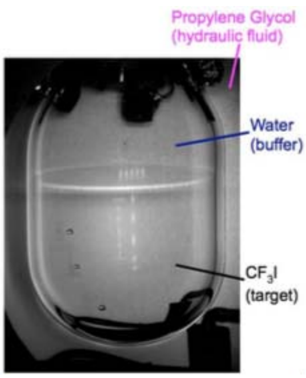
Figure 4. 90% C.L. sensitivity of TREX-DM under different conditions (see table 3) for Ar+1%iC_4H_{10} (black lines) and Ne+2%iC_4H_{10} (green lines).

Experimental Situation

Most sensitive experiments

Bubble chamber

PICO Program @ SNOLAB



Very good background rejection ability

Still improving sensitivities

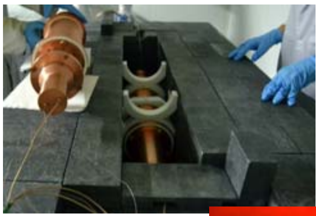
Interesting targets to explore SD interacting candidates-> competitive

PICO-60
52 kg of C3F8

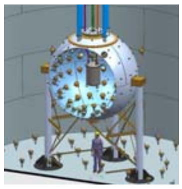
Experiments trying to reproduce DAMA LIBRA signal

NaI scintillators (same target and technique)

ANAIS @ LSC (2000 - ...)

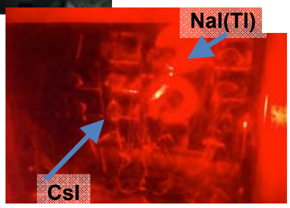


DM-ICE @ South Pole (2011 - ...)

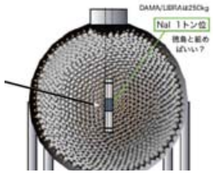


SABRE project

Joint in COSINE - 100 project

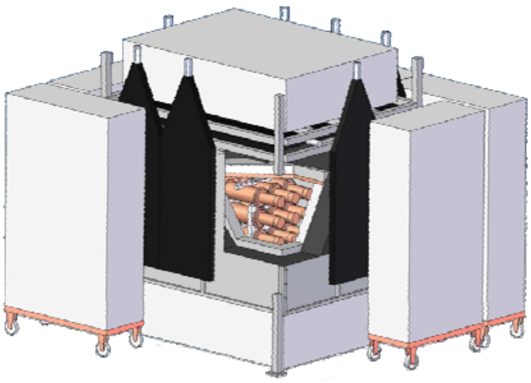


KIMS @ Y2L (2013 - ...)

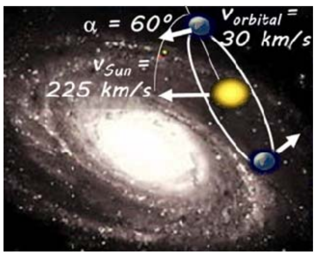


KAMLAND-PICO @ KAMIOKA (2014 - ...)

Experimental Situation



Annual modulation with NAI Scintillators

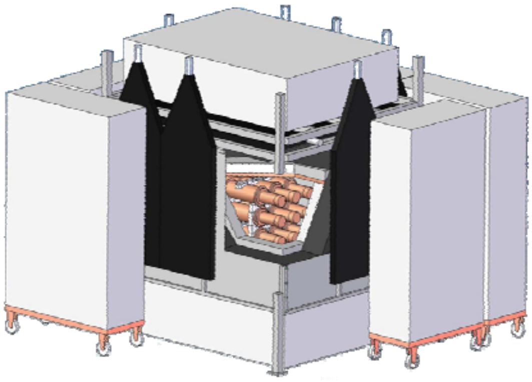


- Confirmation of DAMA-LIBRA modulation signal -> **same target and technique** / **different** experimental approach / **different** environmental conditions affecting **systematics**
- At Canfranc Underground Laboratory, @ **SPAIN** (under **2450** m.w.e.)
- 3x3 matrix of 12.5 kg cylindrical modules = 112.5 kg of active mass

ANAIS experiment at LSC

ANAIS experiment at LSC

Annual modulation with NAI Scintillators

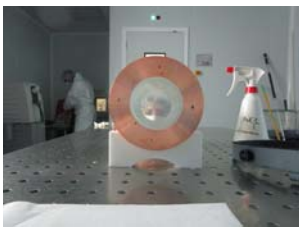


- Energy threshold at or below 2 keVee
  - High light collection per energy unit
  - Effective filtering protocols for non-bulk scintillation / robust estimates of acceptance efficiencies
- Background as low as possible below 10 keVee (at or below a few cpd/kg/keV level)
- Stability of operation and monitoring of possible systematics

ANAIS Detectors

- 12.5 kg cylindrical NaI(Tl) detectors built @ AS, Co (US) from NaI selected powder & developing specific radiopurity protocols
- housed in OFE copper @ AS
- Mylar windows allow for LE calibration

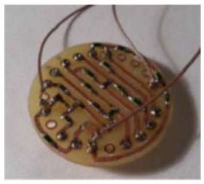
Last three modules received at LSC in March 2017

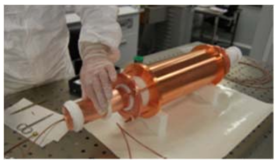


ANAIS Detectors

2xHE PMT Ham12669SEL2 model coupled to each module at LSC clean room

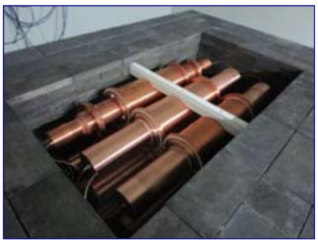
- High Quantum Efficiency / Low dark current
- Electroformed copper housing made at LSC facility
- Voltage dividers made of Cuflon PCB
- PMT Radioactivity screening at LSC

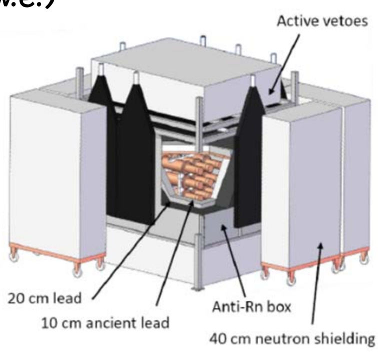



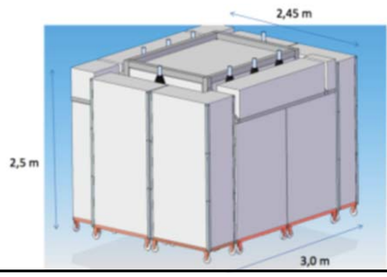
ANAIS-112 Shielding

Since January'2017 decommissioning of previous set-up and conditioning of ANAIS-112 shielding at LSC Hall B (under 2450 m.w.e.)
In March'17 modules were installed for testing
Neutron shielding was finished on July'17





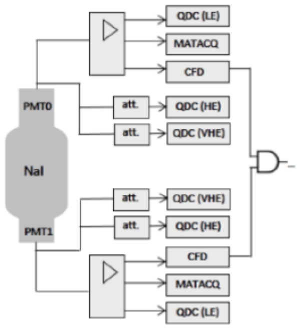


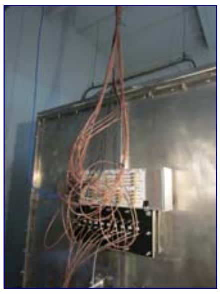


ANAIS Data acquisition

- DAQ hardware and software designed and tested with previous set-ups
  -> ROBUST &> SCALABLE
  - Individual PMT signals digitized and fully processed
  - Trigger at phe level for each PMT
  - Logical AND coincidence in 200ns window for each module triggering
  - Redundant energy conversion

  - Preamplifiers designed at UZ
  - Electronics at air-conditioned-room to decouple from fluctuations in Hall B





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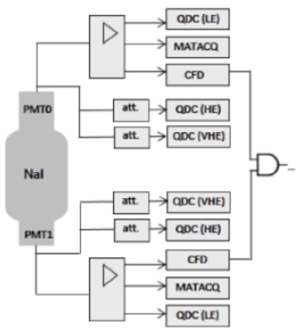
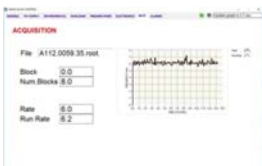
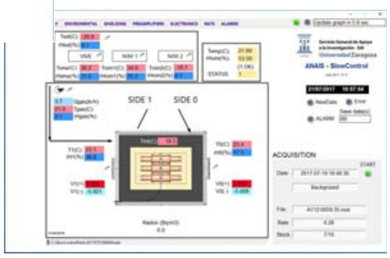
  -> ROBUST &> SCALABLE
  - Individual PMT signals digitized and fully processed
  - Trigger at phe level for each PMT
  - Logical AND coincidence in 200ns window for each module triggering
  - Redundant energy conversion

- Muon detection system implemented to:
  - tag muon related events
  - monitor onsite muon flux

- Slow control operative:
  - Monitoring: external Rn, humidity, P, T, N2 flux, PMT HV
  - Stability checks: gain, trigger rate, ...

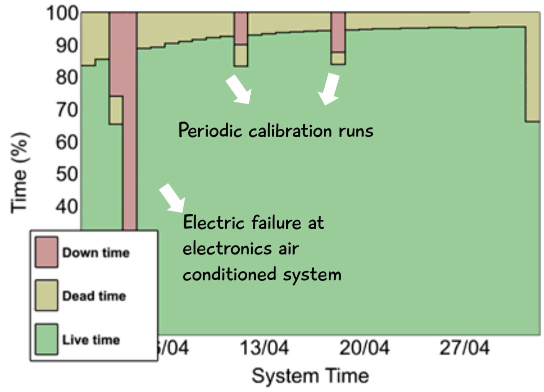




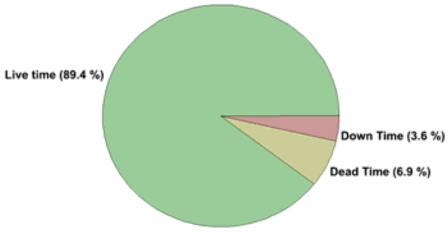


ANAIS-112 Performance

ANAIS-112 Excellent Duty Cycle -> Very important for annual modulation analysis



Live Time: 29.24 days



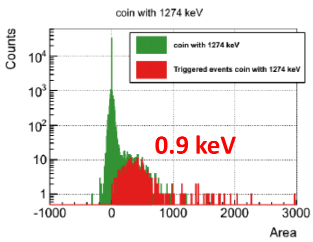
Detector	PMT/set-up	Total Light Collection (phe/keV)
D0	Ham R12669 /ANAIS-112	15.3 ± 1.1
D1	Ham R12669 / ANAIS37	14.4 ± 0.1
D2	Ham R12669 /ANAIS-112	15.3 ± 1.4
D3	Ham R12669 /ANAIS-112	14.6 ± 0.8
D4	Ham R12669 /ANAIS-112	14.0 ± 0.8
D5	Ham R12669 /ANAIS-112	14.0 ± 0.8
D6	Ham R12669 /ANAIS-112	12.6 ± 0.8
D7	Ham R12669 /ANAIS-112	17.0 ± 2.0
D8	Ham R12669 /ANAIS-112	14.6 ± 0.9

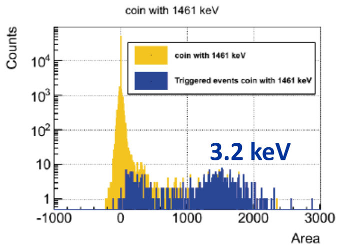
Excellent light collection

A factor of 2 larger than the published light collection for DAMA/LIBRA detectors

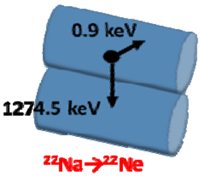
ANAIS-112 Performance

Triggering below 1 keVee:
checked with coincidences from contaminants in the bulk

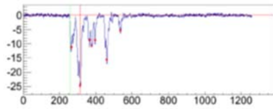


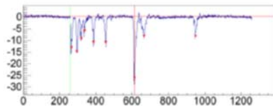


C. Cuesta et al., EPJ C 74 (2014) 3150



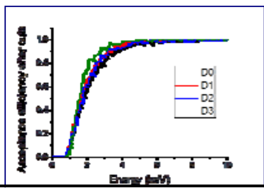
PMT noise filtering:





Multiparametric cuts on:
- Number of peaks in the pulse (n>2 in each PMT)
- Temporal parameters of the pulse
- Asymmetry in light sharing

Acceptance efficiency curves from external calibration data

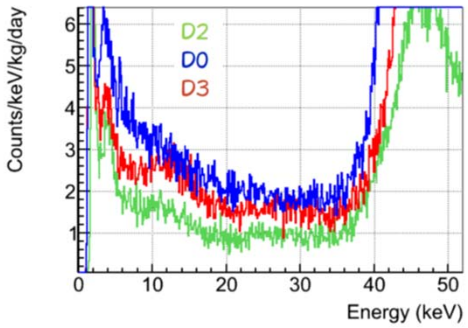


ANAIS-112 Background

- **Summary of crystal activity** (from last 30.1 days in ANAIS-112)

Detector	^{40}K (mBq/kg)	^{210}Pb (mBq/kg)
D0	1.1	3.15
D1	1.4	3.15
D2	0.9	0.70
D3	0.7	1.8
D4	1.0	1.8
D5	1.0	0.75
D6	1.1	0.76
D7	1.0	0.75
D8	0.6	0.72
average	1.0	1.5

^{210}Pb contribution at ~**50 keV** region, consistent with the measured alpha specific activity



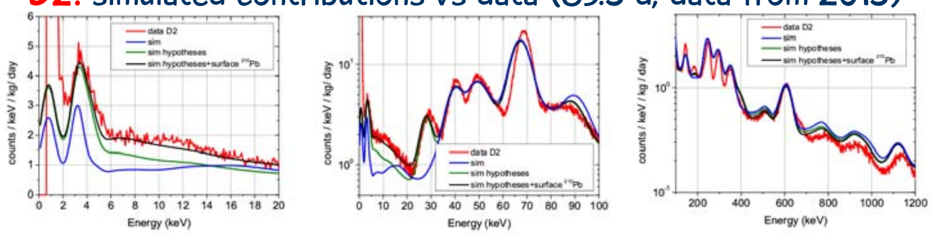
ANAIS-112 Background

Detailed **background models** for first modules operated in Canfranc, based on Geant4 Monte Carlo simulation and accurate quantification of **background sources**

- **Internal activity** directly assessed (mainly ^{40}K, ^{210}Pb)
- **Cosmogenic activity** in crystals quantified from ANAIS-25 data
- **Activity from external components** measured with HPGe detectors at Canfranc

J. Amaré et al, Eur. Phys. J. C 76 (2016) 429; JCAP 02 (2015) 046

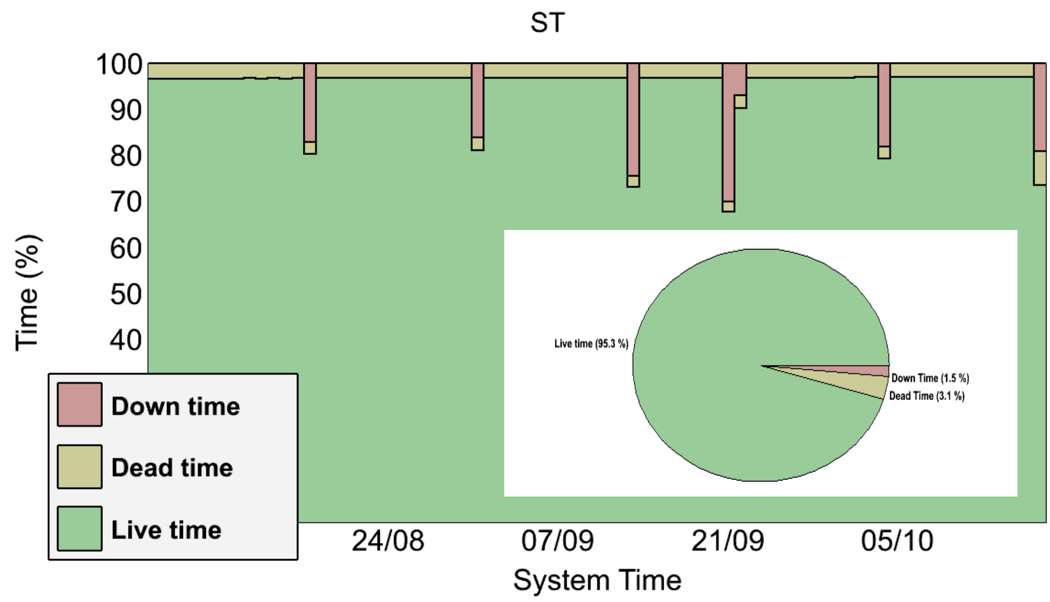
D2: simulated contributions vs data (89.5 d, data from 2015)



^{40}K and **^{22}Na** peaks and **^{210}Pb** (bulk+surface) and **^{3}H** continua are the most significant contributions in the very low energy region

ANAIS-112DM Status

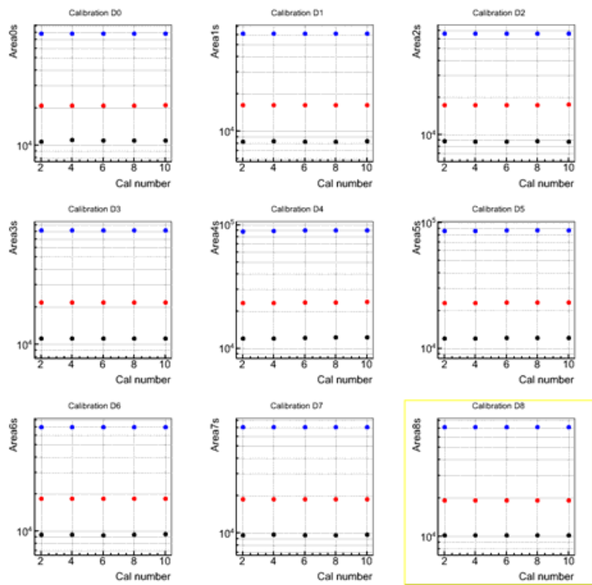
Data Taking since August the 3rd



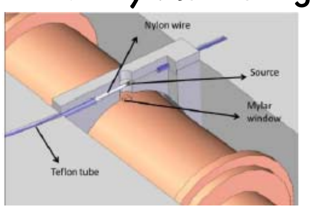
ANAIS-112DM Status

Data Taking since August the 3rd

Calibrations every 2 weeks at low energy -> energies 11.87 keV, 22.2 keV and 88 keV



Stability Monitoring



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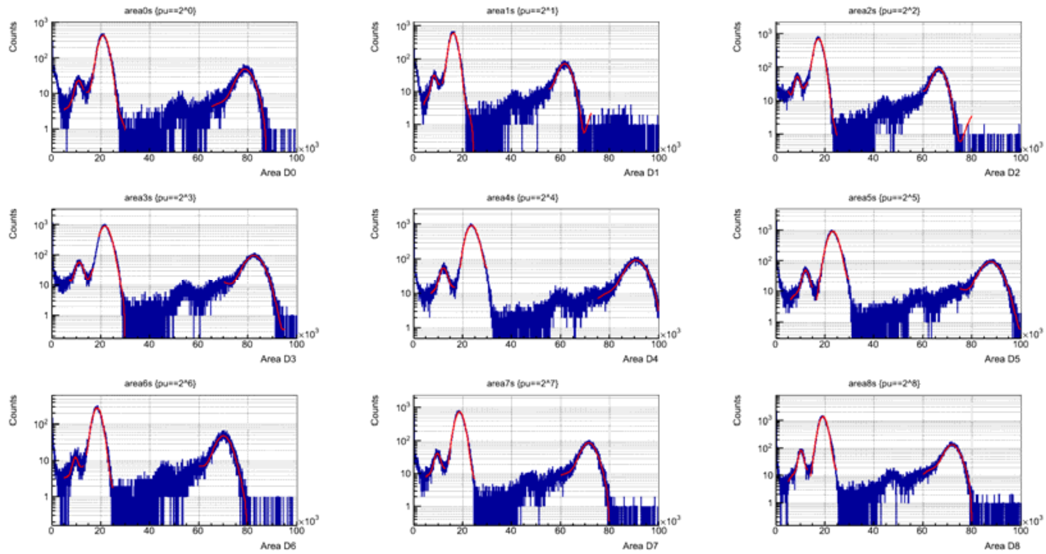
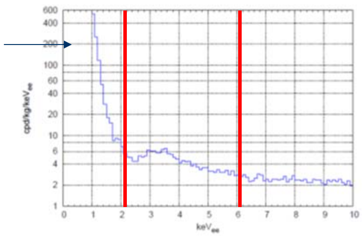


ANAIS-112 Sensitivity

https://arxiv.org/pdf/1704.06861.pdf / I. Coarasa Talk



Annual modulation of dark matter: The ANAIS-112 case

I. Coarasa[a,b], J. Amaré[a,b], S. Cebrián[a,b], C. Cuesta[a,b,c], E. García[a,b], M. Martínez[a,b,d], M.A. Oliván[a,b], Y. Ortigoza[a,b], A. Ortiz de Solórzano[a,b], J. Puimedón[a,b,1], M.L. Sarsa[a,b], J.A. Villar[a,b], P. Villar[a,b]

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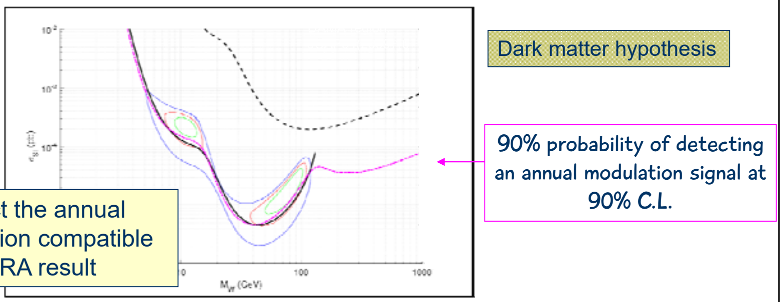
[b] Laboratorio Subterráneo de Canfranc, Paseo de los Ayerbe s/n, 22880 Canfranc Estación, Huesca, Spain
[c] Present Address: Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas, CIEMAT, 28040, Madrid, SPAIN
[d] Present Address: Università di Roma La Sapienza, Piazzale Aldo Moro 5, 00185 Roma, Italy

Detection limit at 90% C.L. for a critical limit at 90% C.L. for **ANAIS-112**

- Estimated **average background** from **D0-D5 measured levels** (corrected for cut efficiency)
- 2-6 keV_{ee} region
- 5 years



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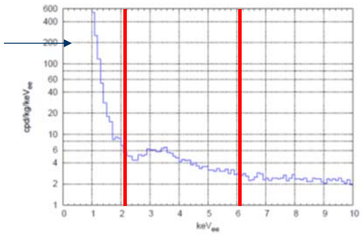

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- 2-6 keV_{ee} region
- 5 years

ANAIS-112 has a detection limit for annual modulation lower than the measured amplitude by DAMA/LIBRA: 0.0112 ± 0.0012 $cpd/kg/keV_{ee}$

Model-independent annual modulation

Factor of Merit: from the variance of the estimator of the modulated amplitude

$$FOM = \left(\frac{2 \cdot B}{\Delta E \cdot M \cdot T_M \cdot \varepsilon}\right)^{\frac{1}{2}}$$

Detection Limit for annual modulation amplitude: for ANAIS-112 parameters

$$L_D = (8.40 \pm 0.25) \cdot 10^{-3}\ \mathrm{cpd/kg/keV_{ee}} \quad (90\%\ \mathrm{C.L.})$$

SUMMARY AND OUTLOOK

ANAIS-112 has been installed successfully at LSC:
112.5 kg (3x3 crystals matrix) of NaI(Tl) built at AS
 -outstanding light collection
 -good background understanding
Electronics/Acquisition has been fine-tuned
Dark matter run started data taking by August, 3rd (funded only until Dec17)
Data taking expected to go on in these conditions during the next two years
 Control populations (muon-related events, blank module…) available
 Blind annual modulation analysis foreseen
Plan to make ANAIS data public after use to allow independent analysis
Good sensitivity prospects for exploring the DAMA/LIBRA signal:
2-5 years data taking needed (requiring funding)
LSV/additional detection mass could be faced as second phase (requiring funding)
Neutron calibrations and REF measurements pending (requiring funding)

ACKNOWLEDGMENTS

ANAIS

MultiDark
Multimessenger Approach
for Dark Matter Detection

LSC
Laboratorio Subterráneo de Canfranc

Universidad
Zaragoza