Detektory ciekłoargonowe a detekcja Ciemnej Materii

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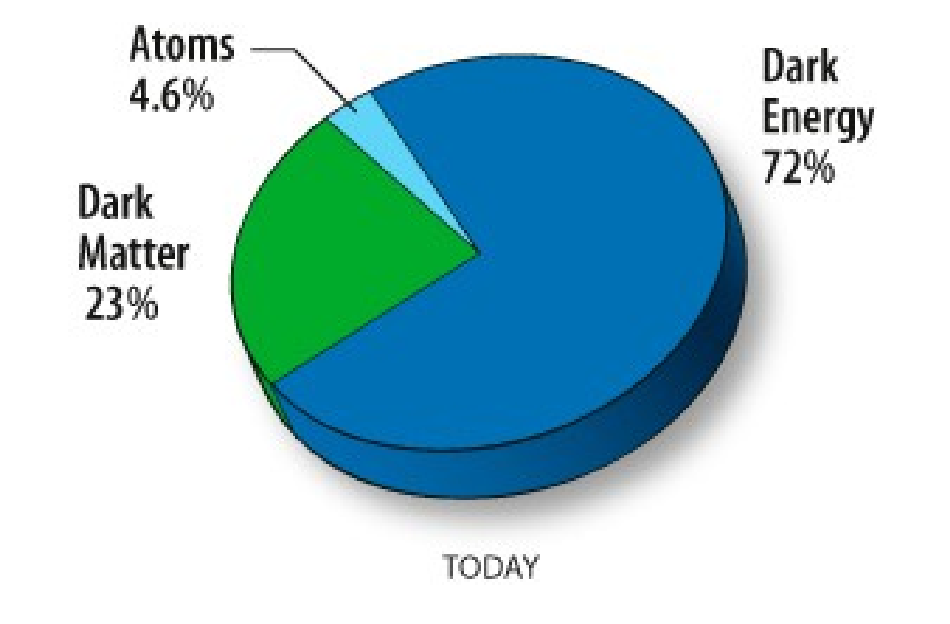
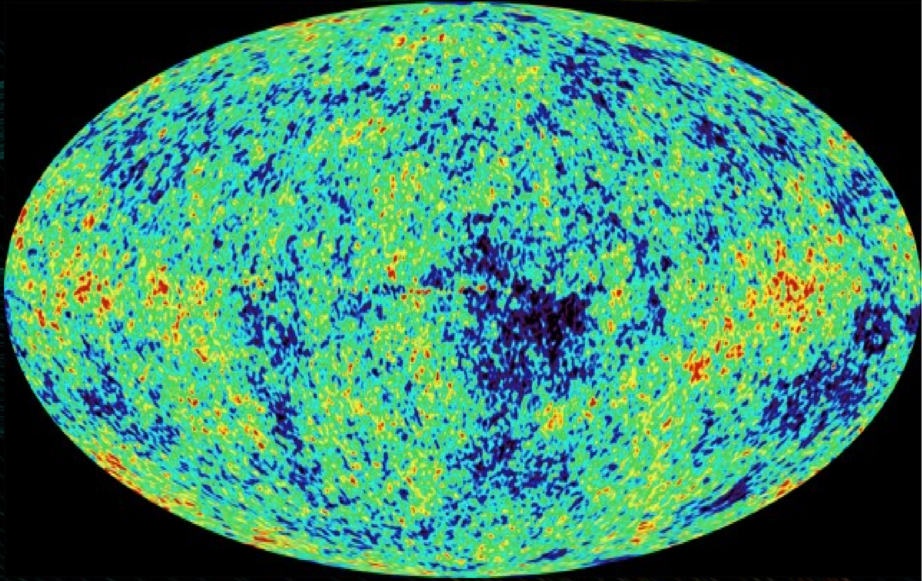
The Standard Cosmological Model (SCM)

The observations of astrophysical and cosmological experiments add up to a model of the Universe which we call the Standard Cosmological Model. According to this model, baryonic matter is at most ~5% of the mass-energy of the Universe.

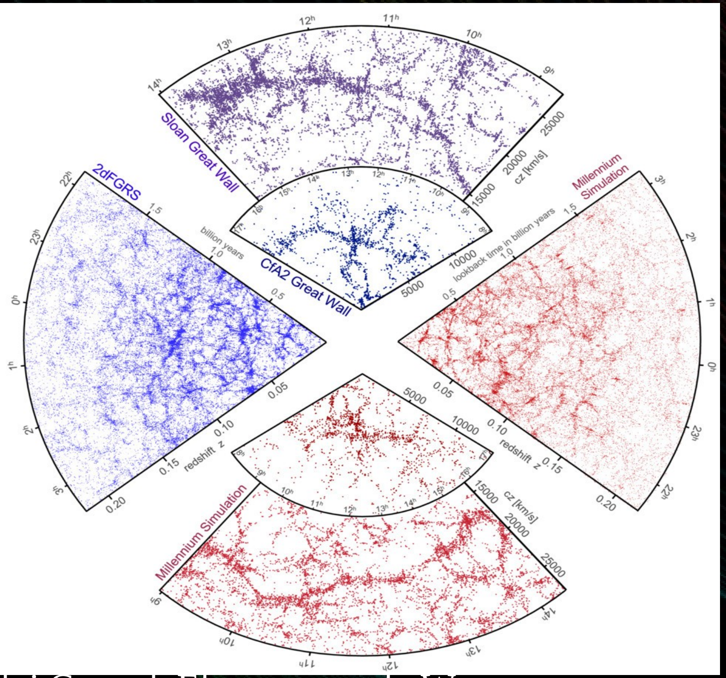


The missing mass-energy in this model is explained by Dark Matter and (even more so) Dark Energy. Finding the nature of Dark Matter is a riddle of the order of a quarter of the Universe.

Dark Matter is the missing element of the SCM



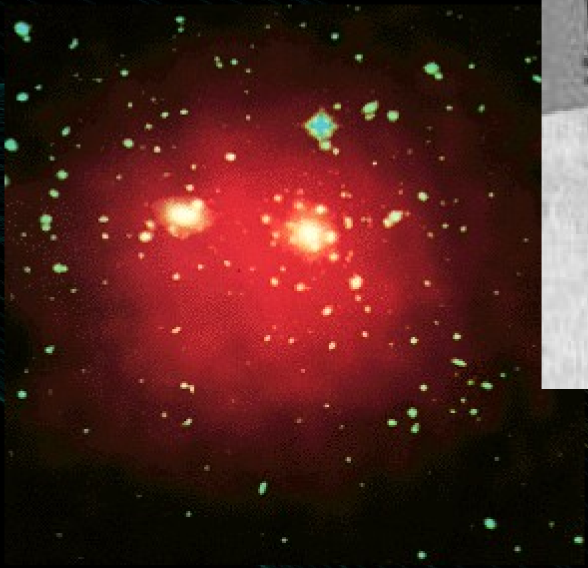
The Cosmological model is a result of many diverse observations, i.e. Cosmic Microwave Background, Type Ia Supernovae, matter distribution surveys (on various wavelengths) and the abundances of light elements.

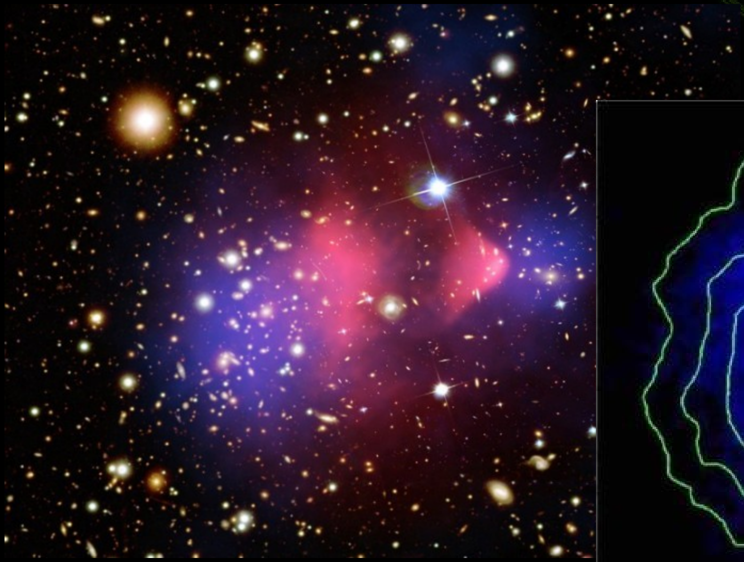


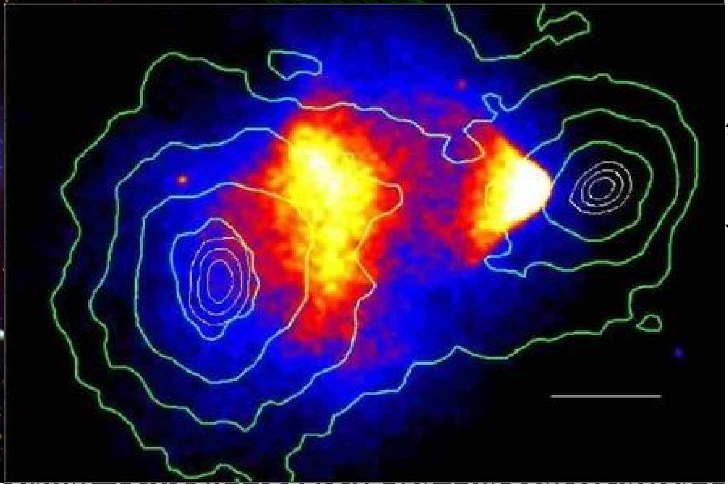
All of these results add up to form a puzzle in which Dark Matter plays an important part and hence they are also indirect proof of the existence of Dark Matter.

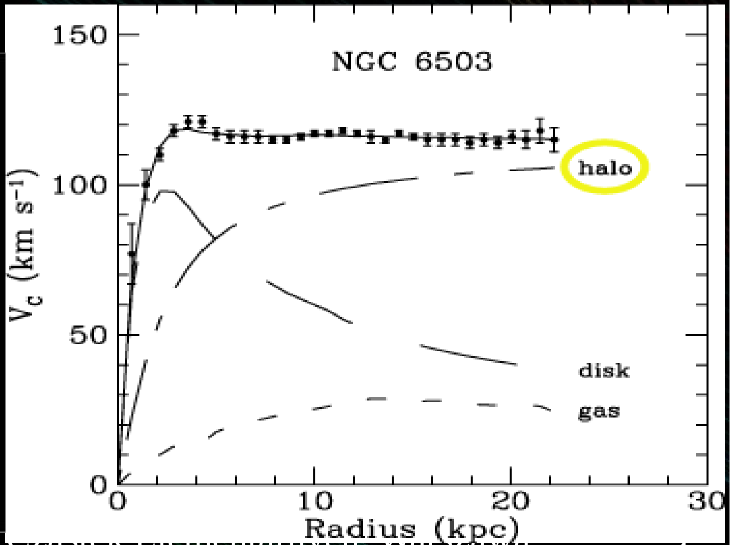
Astronomical evidence for Dark Matter

The idea of Dark Matter surfaced earlier than the cosmological model. The existence of invisible matter was postulated as early as the 1930s.

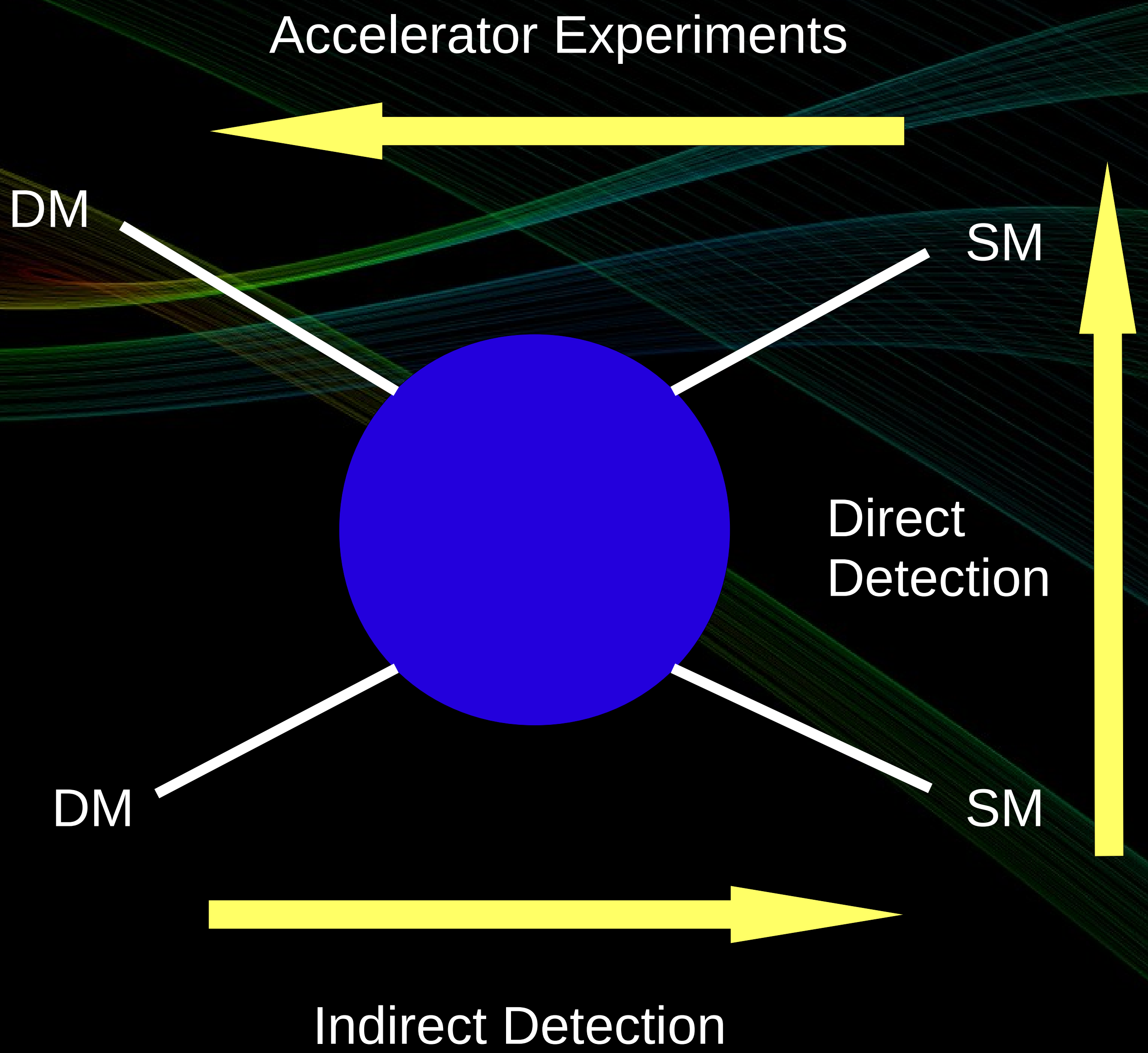








Dark Matter Detection



The most popular DM candidate is the WIMP or Weakly Interacting Massive Particle. Likely Candidates are the SUSY LSP and the lightest Kaluza Klein Particle.

Recently, theories where the DM particles have an excited state have become more popular (Inelastic DM)

We live(d) in interesting times (?)

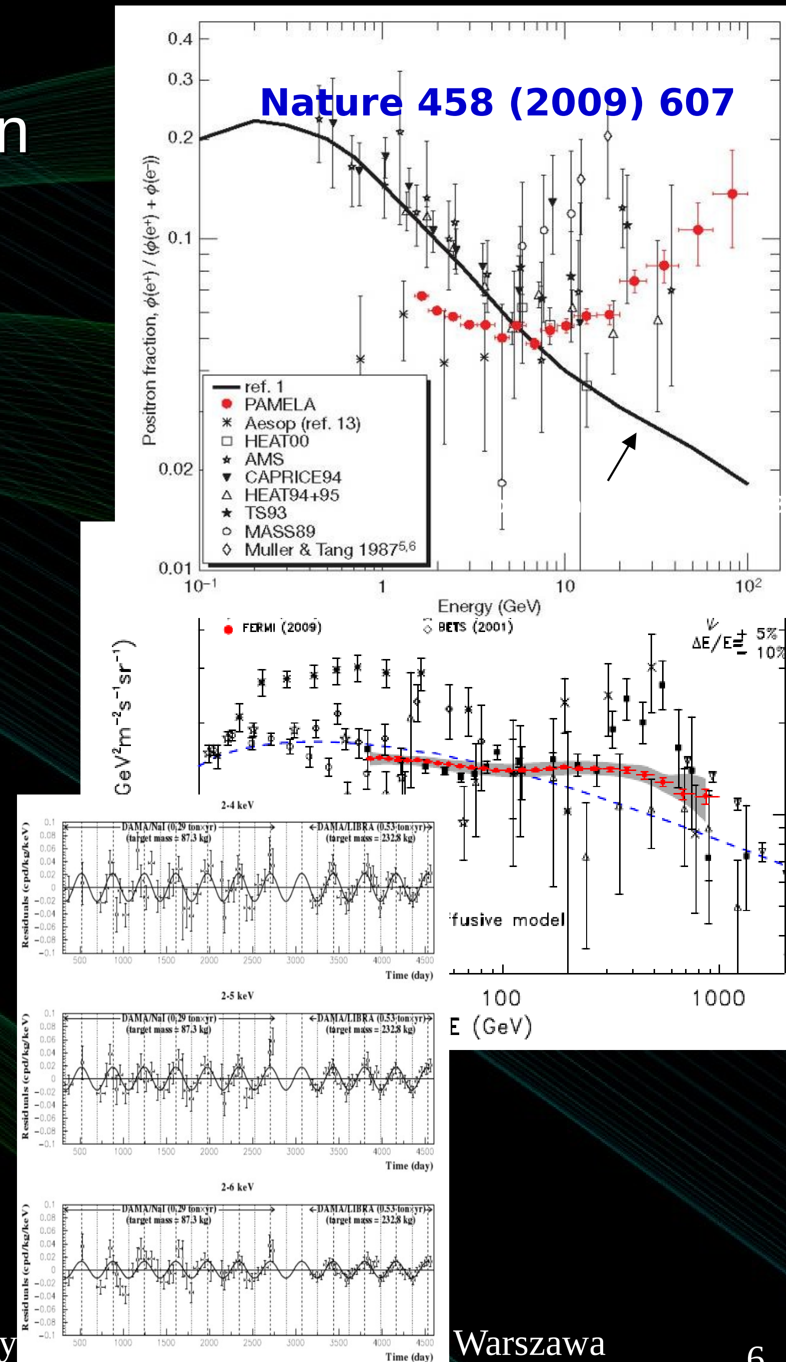
08.2008 - PAMELA observes a surplus of e^+ in the cosmic radiation.

11.2008 - ATIC reports a surplus of e^-.

05.2009 - FERMI does not see the EGRET γ excess. It does see an overabundance of $e^+ + e^-$.

12.2009 - Gossip spreads about a possible discovery of DM by CDMS II.

17.12.2009 - The gossip is not confirmed, however CDMS II does see 2 events,



Meanwhile. the DAMA results are still on the market.

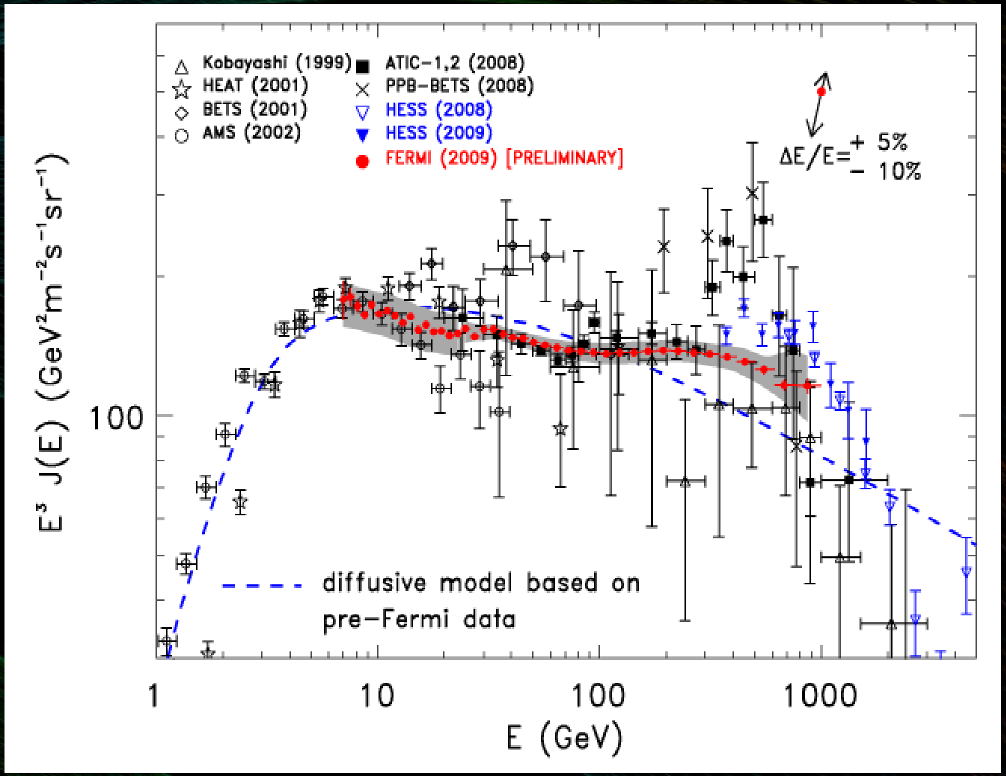
Current status and future prospects

The indirect experiments seem to see something above the predicted background. However their results are not fully consistent amongst themselves i.e. FERMI vs. EGRET, FERMI vs. ATIC.

They are also difficult to concile with the standard WIMP scenario DM.

Maybe, they could be explained by standard astrophysical phenomena, like pulsars?

More data is needed - fortunately FERMI and PAMELA are still in orbit. As is PLANCK, and AMS should be launched in the summer!

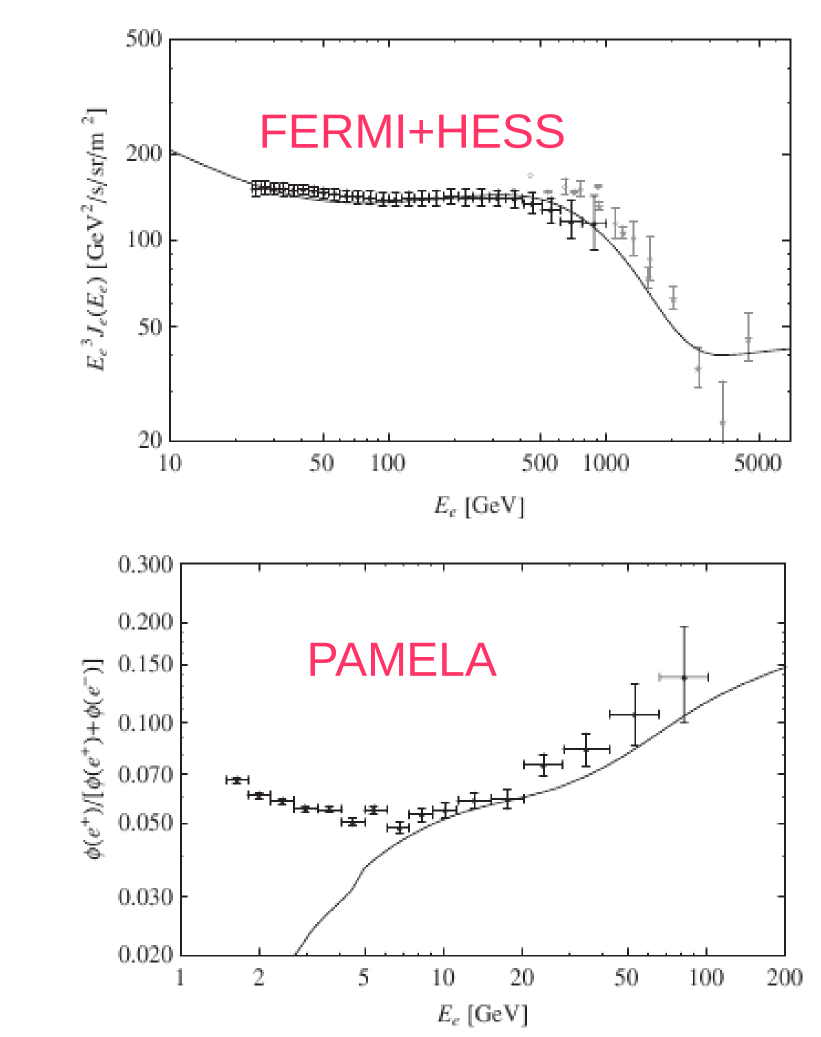


Wyniki poszukiwań pośrednich da się wyjaśnić bez DM?

- ON THE ENERGY SPECTRA OF GeV/TeV COSMIC RAY LEPTONS

  Łukasz Stawarz, Vah´ Petrosian and Roger D. Blandford

- Przy zastosowaniu ich modelu, w którym promienie kosmiczne oddziałują z fotonami światła gwiazd da się odtworzyć spektra zaobserwowane przez FERMI, PAMELA i HESS. Aby wyjaśnić wszystkie potrzebne jest lekki tuning parametrów modelu – możliwy do wyjaśnienia jeśli większośc oddziaływań jest blisko SNR.
- Model nie wyjaśnia sygnału ATIC.



What the future holds (a selection) – Styczeń 2010 vs. Marzec 2011

Year	Expected Mass	Expected sensitivity
2010	144kg LAr (WArP)	5 x 10^{-45} cm^2 (3 months) - problem HV
	50kg LXe (XENON)	2 x 10^{-45} cm^2 (200 days) - oczekiwanie
	15 kg Ge (CDMS II)	3 x 10^{-45} cm^2 - oczekiwanie
	60 kg BC (COUPP)	3 x 10^{-3} cm^2 SD! - przygotowania
	150 kg Lar CLEAN	9 x 10^{-46} cm^2 (2 years) - montaż
	100 kg LXe (LUX)	7 x 10^{-46} cm^2 (10 months) - na powierzchni
	100 kg Xe XMASS	3 x 10^{-45} cm^2 - commissioning
2011	1T LAr DEAP	
	1T LAr ArDM	
2013	3T Xe (LUX-ZEPLIN)	
	1T Xe (XENON)	

DARWIN - design study for a liquid noble gas detector (1t Lxe or 10t Lar)
MAX - Multition Argon Xenon
both aim to reach 10^{-47} cm^2
EURECA (1T cryogenic) i.e. Ge

A jednak ciekawe czasy?

Brak wyników wymienionych eksperymentów nie oznacza, że nic się nie dzieje!

- Obliczenia ograniczające efekt channeling dla eksp. DAMA
- Wyniki CoGENT, Cresst ->
- -> WIMP'y o niskich masach?
- CDMS II nie potwierdza wyników CoGent
- Wstępny wynik Xenon100 i zwiazana z nim dyskusja o Quenching

Direct Detection principles

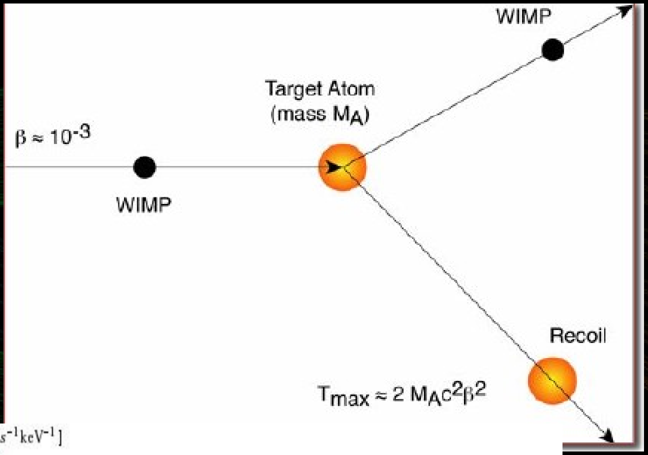
The WIMPs are usually assumed to inhabit the local galactic halo. The Standard Halo Model assumes a local density of 0.3 GeV/cm^3 in the solar neighborhood and a Maxwellian velocity distribution (~220km/s) with a cutoff at the galactic escape speed ~600km/s.

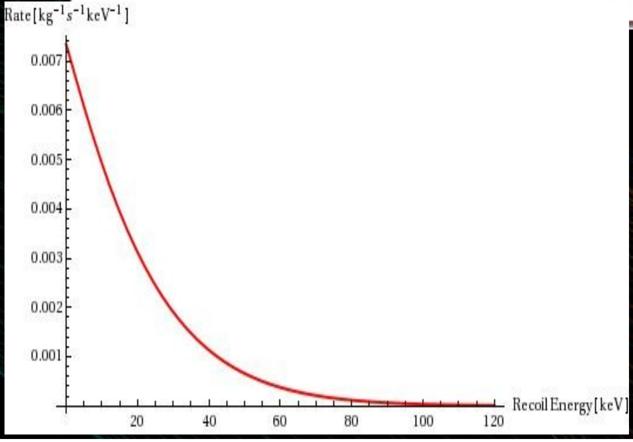
This would lead to a featureless exponential spectrum in a detector, with rates of the order less than 1 event/100kg/day (@ 10^{-43}cm^2)

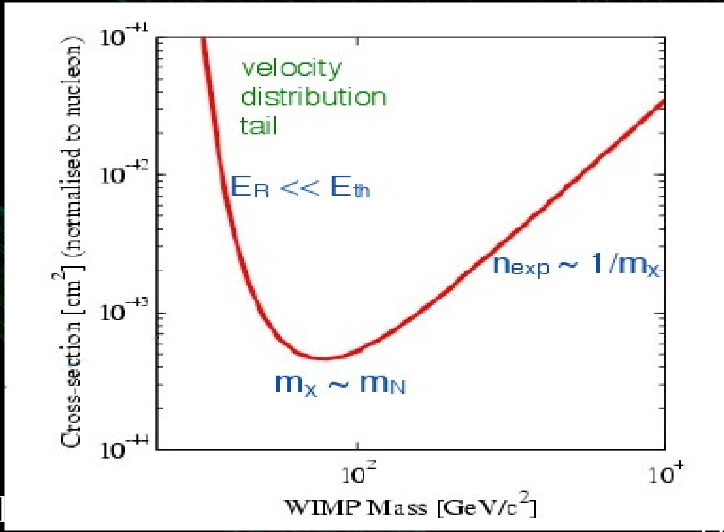
The interaction energies are of the order of tens of kev!

Hence, Direct Detection of DM requires:

- Large detector mass
- Low background
- Low energy threshold
- Patience!



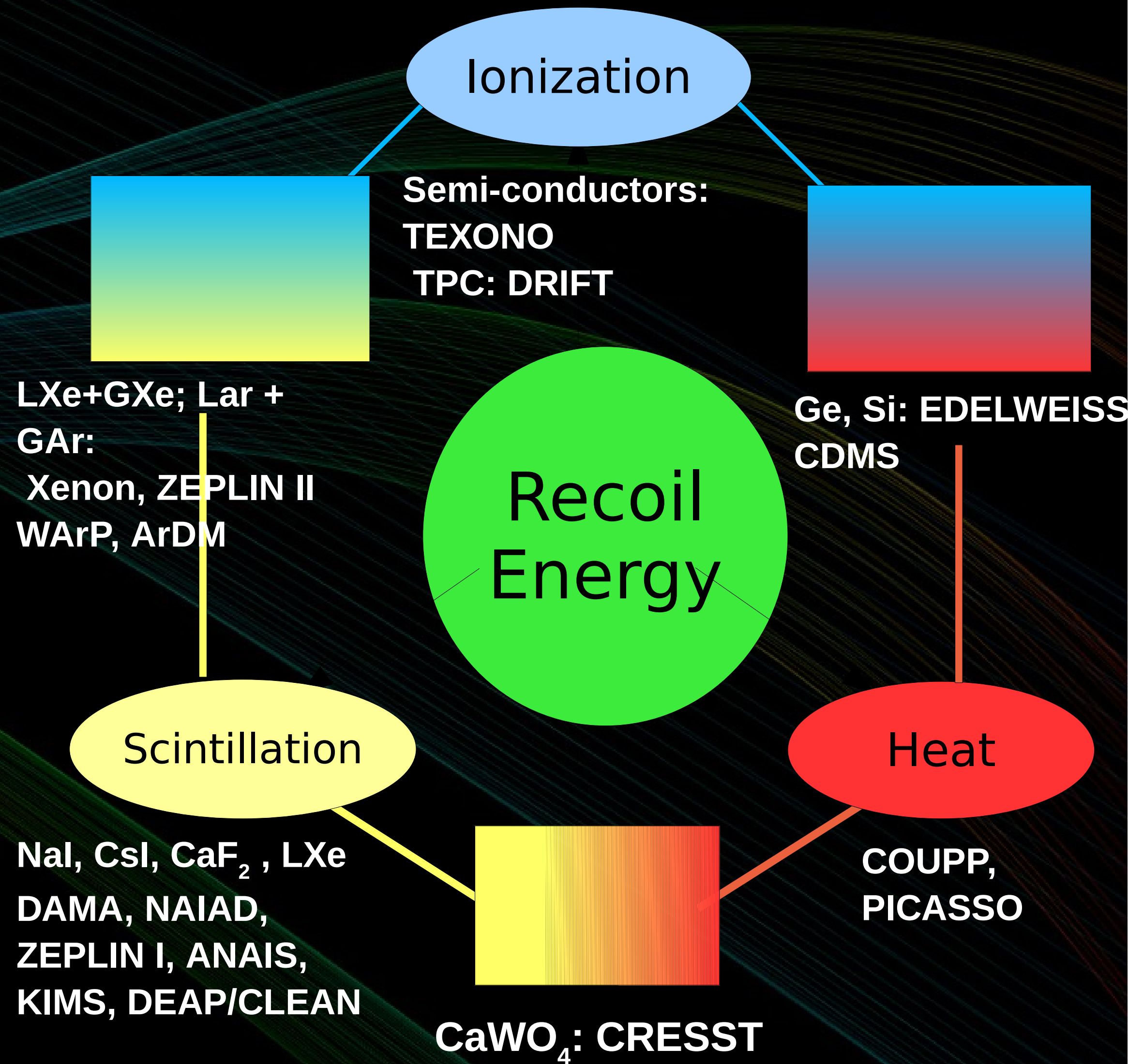


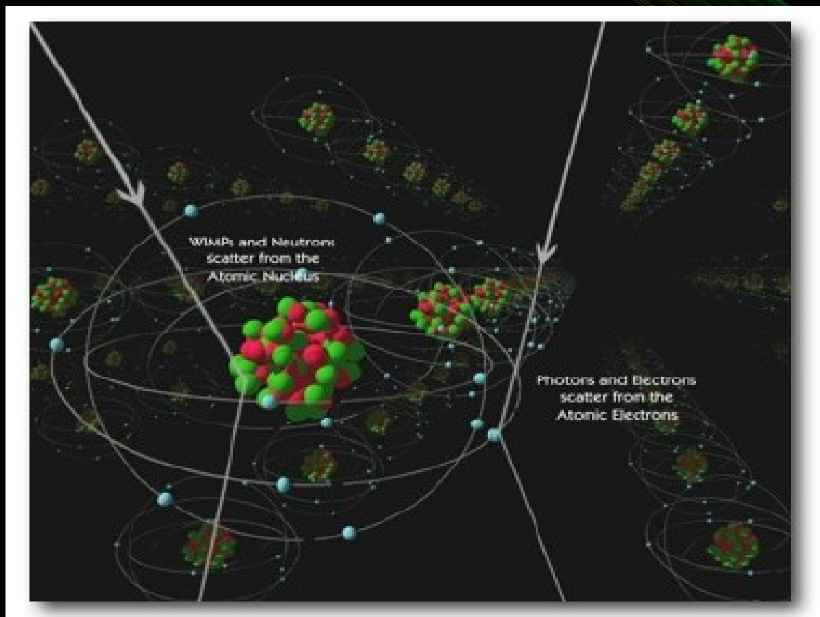


Direct Detection methods (I)

Event by event discrimination:

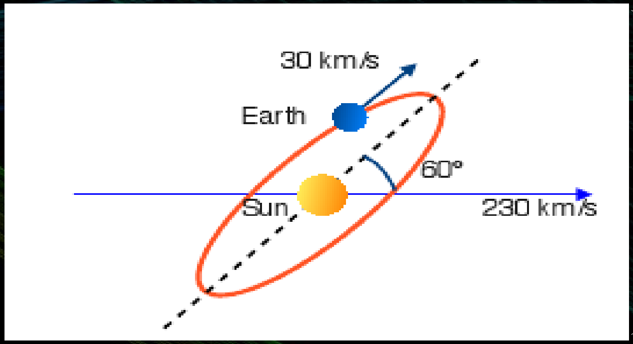
Nuclear and electron (γ,β) recoils have different energy deposition. Based on this It is possible to discriminate the background coming from electron recoils. Then, after eliminating the neutron background (via multiple scatters), what remains should be the WIMP signal.

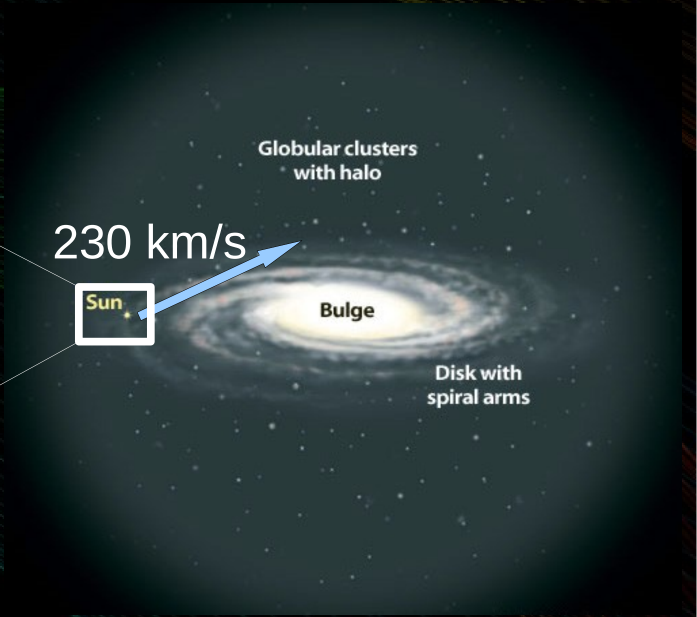




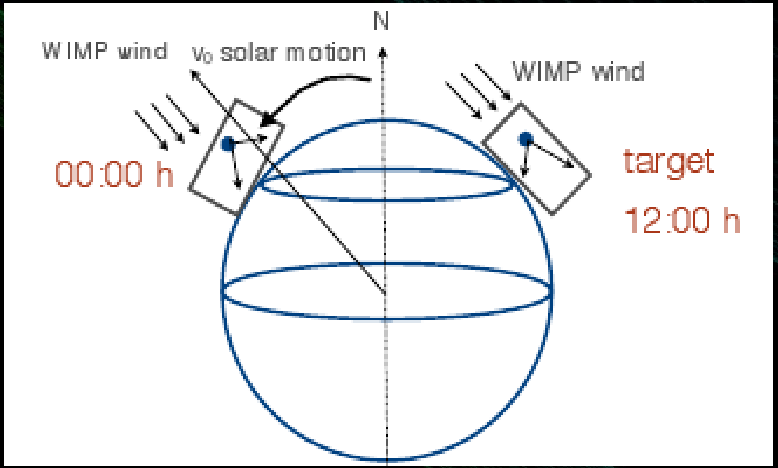
Direct Detection Methods (II)

- Two possible signatures of Dark Matter are the annual and diurnal modulations.
- The annual modulation should be an effect of ~5% (unless inelastic DM comes into play)





- The diurnal modulation effect is larger but requires a directional detector (gas TPCs)



Efekt „nuclear Quenching”

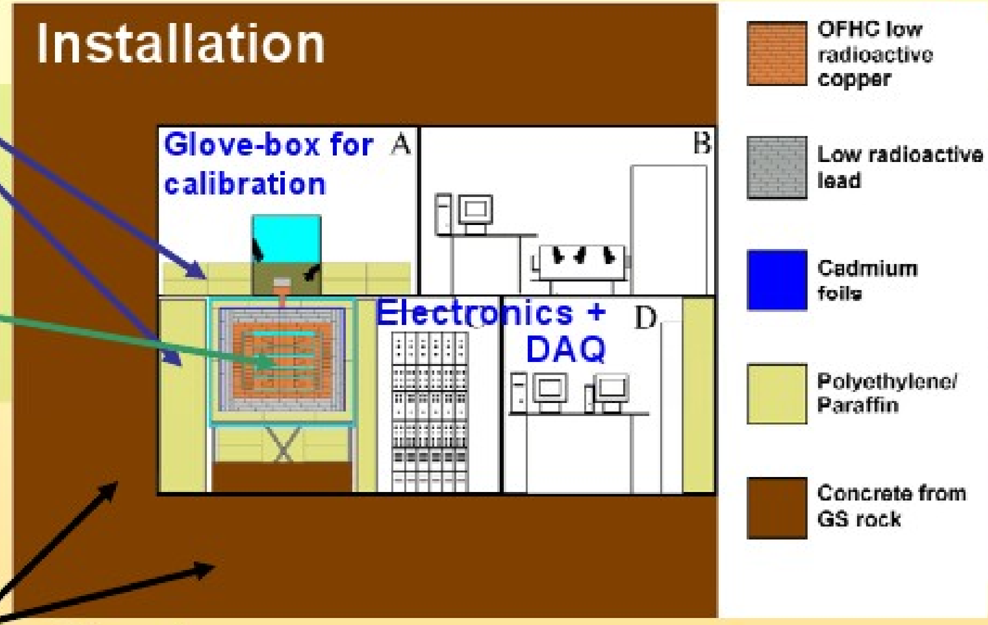
- Różnica w uzysku światła przy oddziaływaniach typu e-like i recoil-like (na niekorzyść tych drugich)
- Wystepuje w praktycznie wszystkich detektorach, ale skala jest różna.
- Dlatego często próg energetyczny podaje sie w keVee (electron equivalent)
- Efekt powoduje podniesienie progu energetycznego na zdarzenie recoil-like (WIMPy)

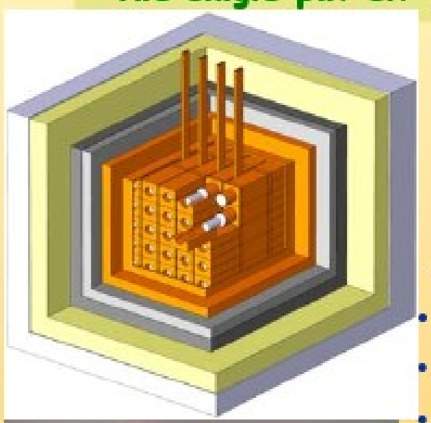
The DAMA/LIBRA set-up

For details, radiopurity, performances, procedures, etc.
NIMA592(2008)297

Polyethylene/ paraffin

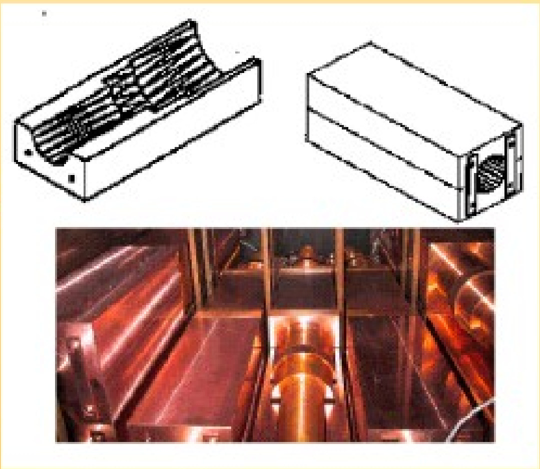
- 25 x 9.7 kg NaI(Tl) in a 5x5 matrix
- two Suprasil-B light guides directly coupled to each bare crystal
- two PMTs working in coincidence at the single ph. el. threshold





~ 1m concrete from GS rock

- Dismounting/Installing protocol (with "Scuba" system)
- All the materials selected for low radioactivity
- Multicomponent passive shield (>10 cm of Cu, 15 cm of Pb + Cd foils, 10/40 cm Polyethylene/paraffin, about 1 m concrete, mostly outside the installation)
- Three-level system to exclude Radon from the detectors
- Calibrations in the same running conditions as production runs
- Installation in air conditioning + huge heat capacity of shield
- Monitoring/alarm system; many parameters acquired with the production data
- Pulse shape recorded by Waweform Analyzer *TVS641A* (2chs per detector), 1 *Gsample/s*, 8 bit, bandwidth 250 MHz
- Data collected from low energy up to MeV region, despite the hardware optimization was done for the low energy

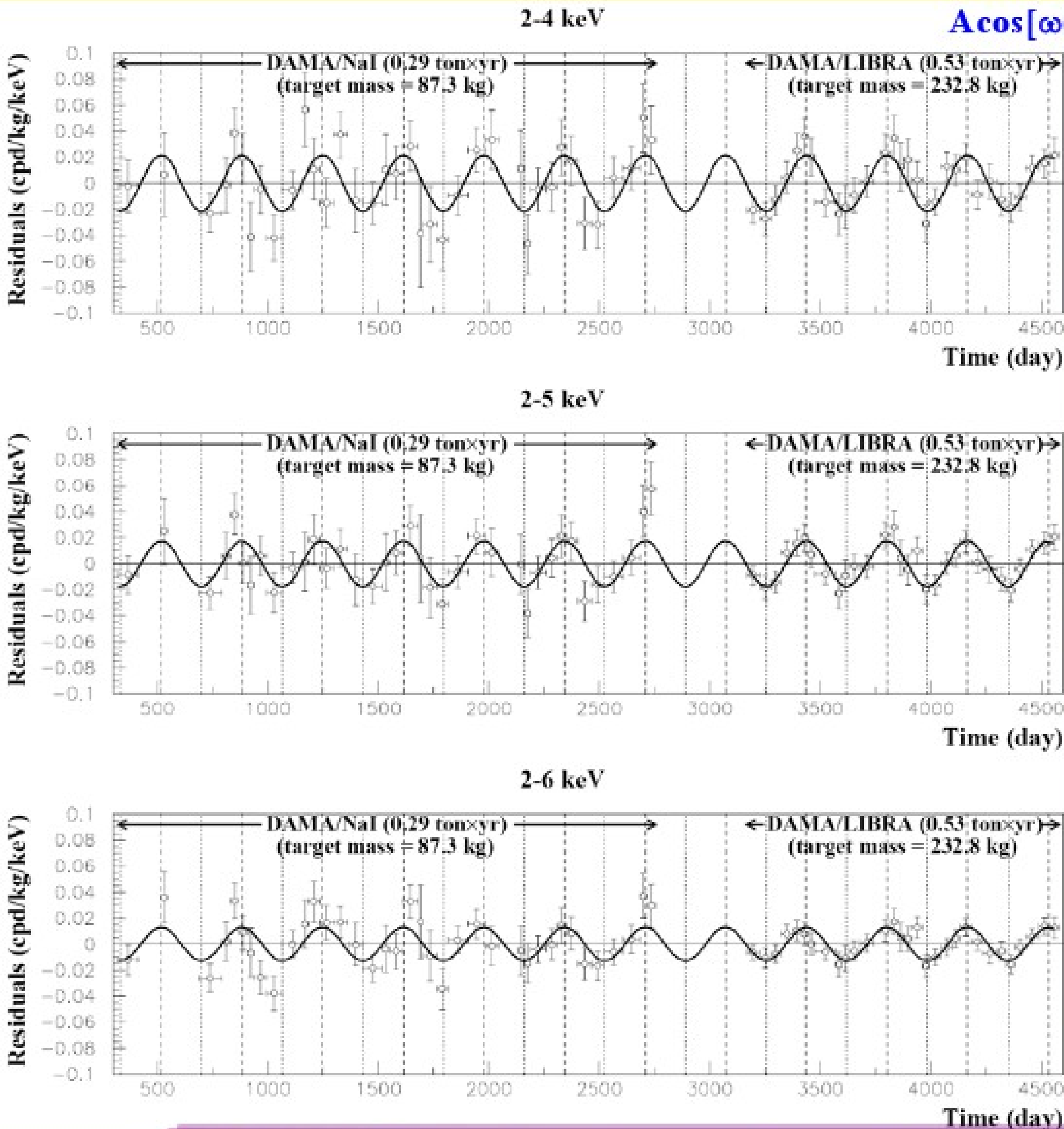


Model Independent Annual Modulation Result

DAMA/NaI (7 years) + DAMA/LIBRA (4 years)   Total exposure: 300555 kg×day = 0.82 ton×yr

EPJC56(2008)333

experimental single-hit residuals rate vs time and energy



$A\cos[\omega(t-t_0)]$; continuous lines: t_0 = 152.5 d, T = 1.00 y

2-4 keV

A=(0.0215±0.0026) cpd/kg/keV

χ^2/dof = 51.9/66   **8.3 σ C.L.**

Absence of modulation? No

χ^2/dof=117.7/67 ⇒ P(A=0) = 1.3×10^{-4}

2-5 keV

A=(0.0176±0.0020) cpd/kg/keV

χ^2/dof = 39.6/66   **8.8 σ C.L.**

Absence of modulation? No

χ^2/dof=116.1/67 ⇒ P(A=0) = 1.9×10^{-4}

2-6 keV

A=(0.0129±0.0016) cpd/kg/keV

χ^2/dof = 54.3/66 **8.2 σ C.L.**

Absence of modulation? No

χ^2/dof=116.4/67 ⇒ P(A=0) = 1.8×10^{-4}

P. Belli @ WIN 09

The data favor the presence of a modulated behavior with proper features at 8.2σ C.L.

DAMA

Dla standardowych wartości „quenching” rezultaty DAMA'y są dawno wykluczone (próg energetyczny ~20keV). Nadzieje na pogodzenie dawał tzw. efekt channeling – jeśli atom detektora uderzony przez WIMP'a leciałby wzdłuż osi sieci nie odczuwa efektu quenching -> efektywne obniżenie progu energetycznego.

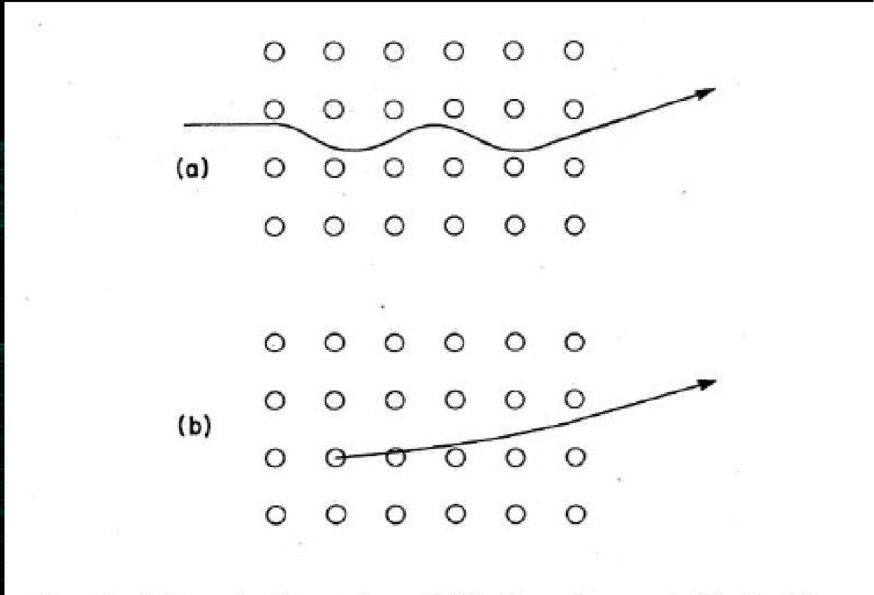
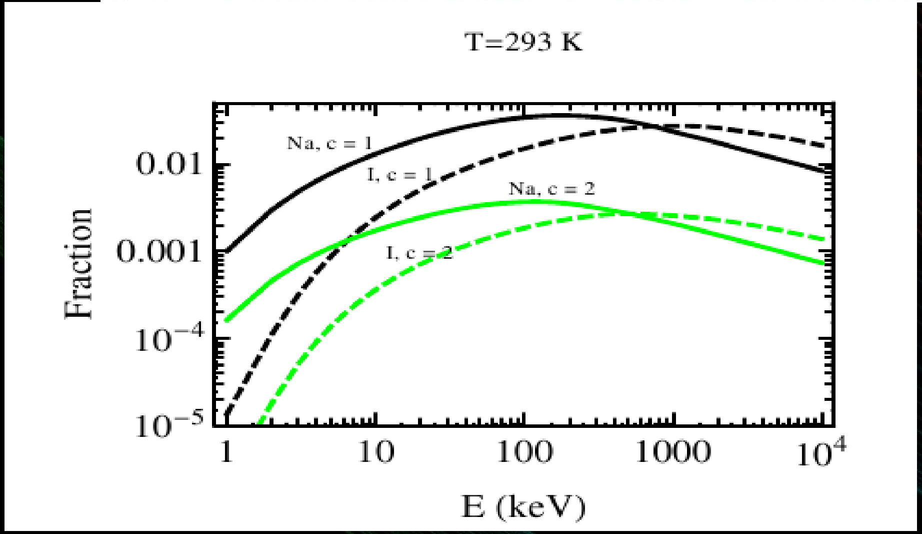


FIG. 1. Schematic illustration of (a) channeling and (b) blocking effects. The drawings are highly exaggerated. In reality, the oscillations of channeled trajectories occur with wavelengths typically several hundreds or thousands of lattice spacings.

(From D. Gemmell 1974, Rev. Mod. Phys. 46, 129)

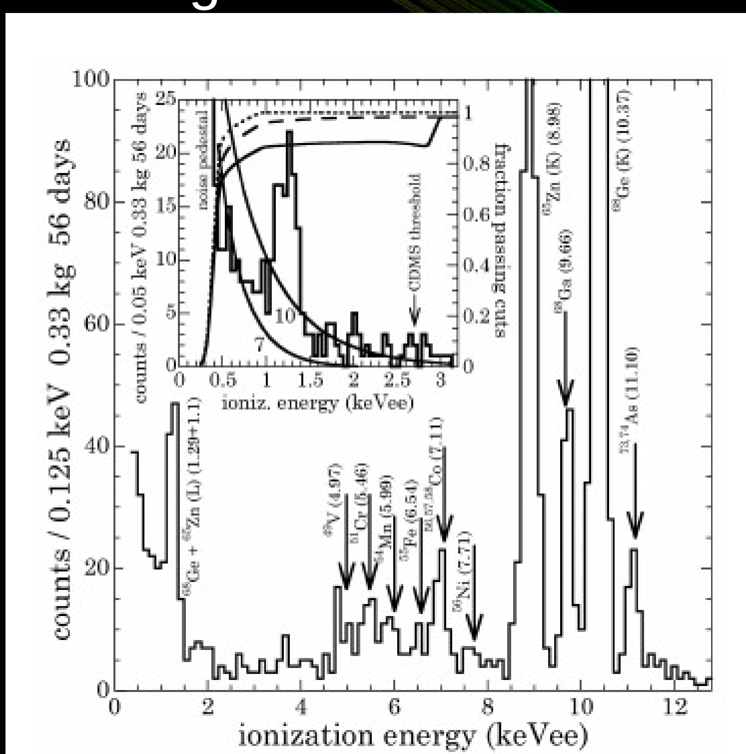
Ale: (Bozorgnia, Gelmini, Gondolo 1006.3110) :

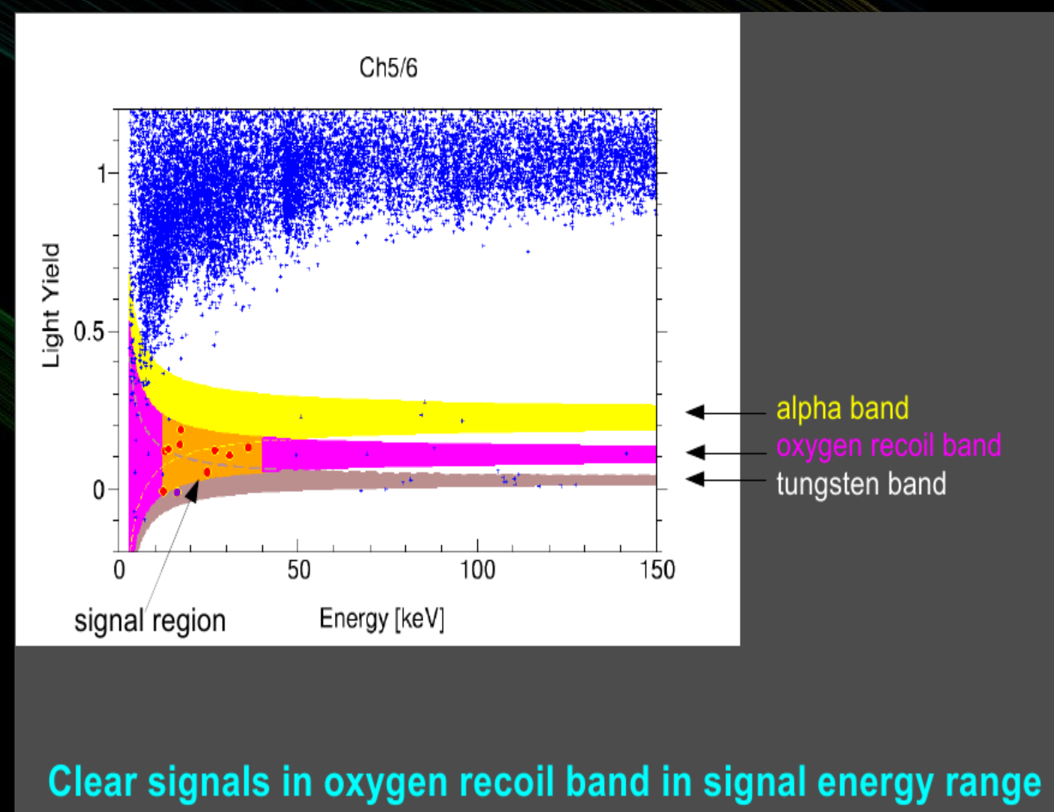
„When colliding with WIMPs ions are ejected from lattice sites, “blocking” is important and channeling fraction is reduced (in a perfect lattice would be zero)- A generous upper bound on the fraction (using analytic channeling models) is given by c = 1 curve”



CoGent + Cresst

- W 2010 roku 2 eksperymenty zaobserwowały nadmiar przypadków dla niskich energii, które – jeśli nie są manifestacją tła – sugerują WIMPy o niskich masach ~10GeV.
- CoGent – przypadki niskoenergetyczne – przypominające widmo WIMP'ów – under investigation.
- CRESST ok. 20 przypadków ponad spodziewane tło w obszarze, gdzie można się spodziewać rozproszeń na tlenie ($CaWO_4$) – być może alpha leakage?





Low mass WIMPs?

- DAMA+ CoGeNT excess (and may be also CRESST excess) generated a new bust of light WIMP models, most need light bosons with GeV massscale ...(e.g. Feldman et al. 1003.0437; Chang, Liu, Pierce, Weiner Yavin 10; Kufflic, Pierce Zurek, 1003.0682; Andreas et al 1003.2595; Essig, Schuster, Toro Wojtsekhowski, 1004.0691; Fitzpatrick, Hooper Zurek 1003.0014; Cline et al.1008.1796 Buckley Hooper Tait 1011.1499; Fitzpatrick Zurek 1007.5325; Kang et al 1008.5243; Buckley, Hooper Tait1011.1499)
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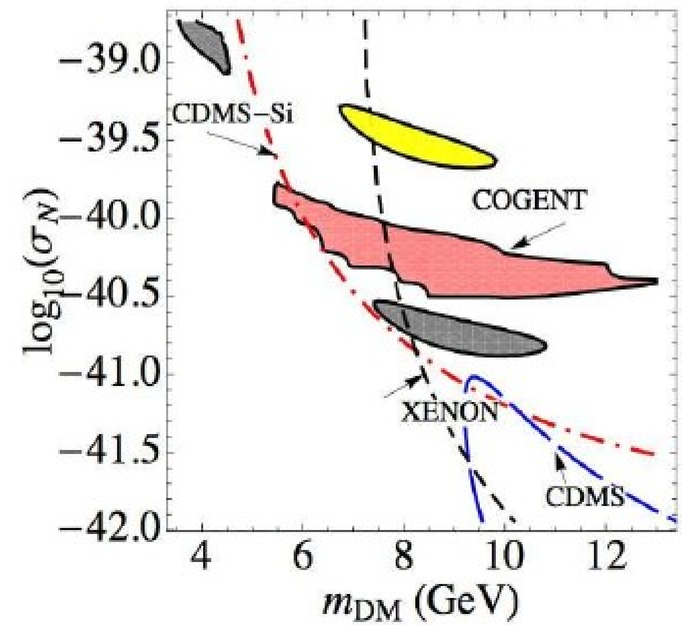


Fitzpatrick, Hooper, Zurek 1003.0014
“Constrained” exp. CoGeNT background

G. Gelmini @ Neutrino Telescopes.

CDMS II (1)

The CDMS II experiment was located in the SOUDAN underground laboratory.

30 detectors installed and operating in Soudan since June 2006.

- 4.75 kg of Ge, 1.1 kg of Si

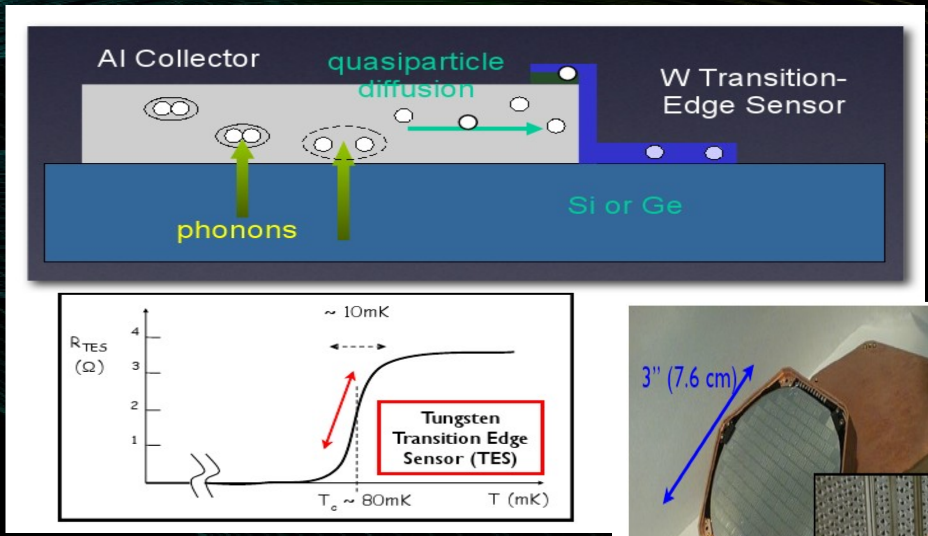
Combination of charge and heat readout allows very good background suppression.

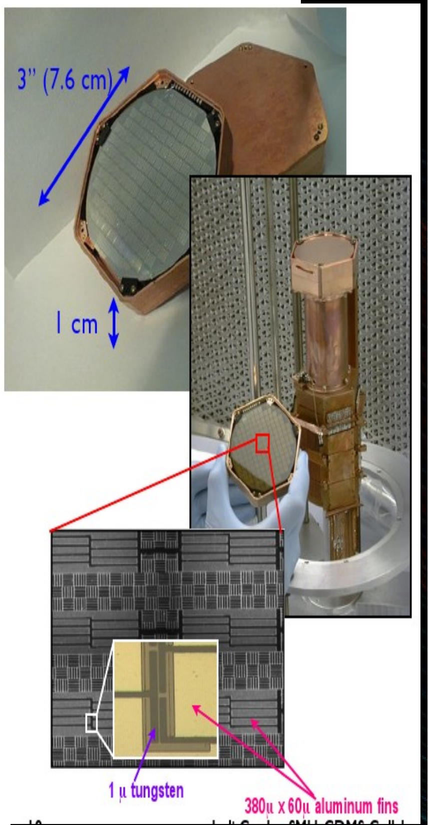
The most recent analysis (17.12.2009) is based on:

612 raw kg-days = 194.1 kg-d WIMP equiv. @ 60 GeV/c^2

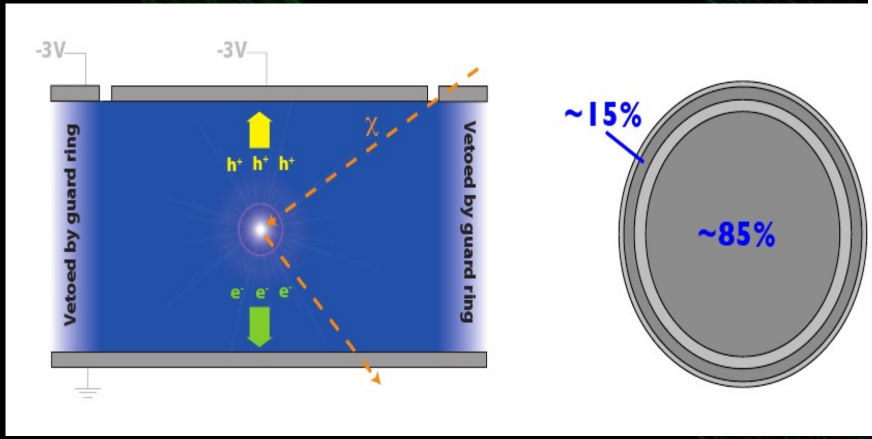
(10 -100 keV energy range)

Phonon readout





Charge readout

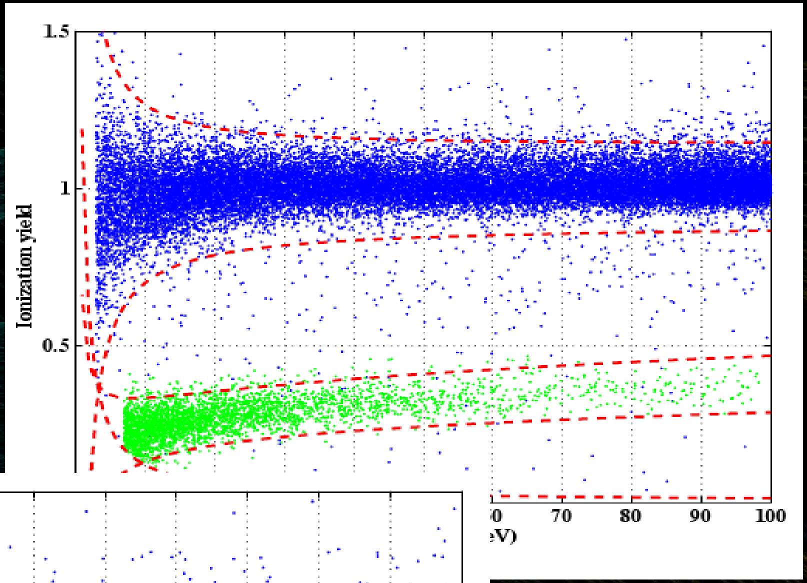


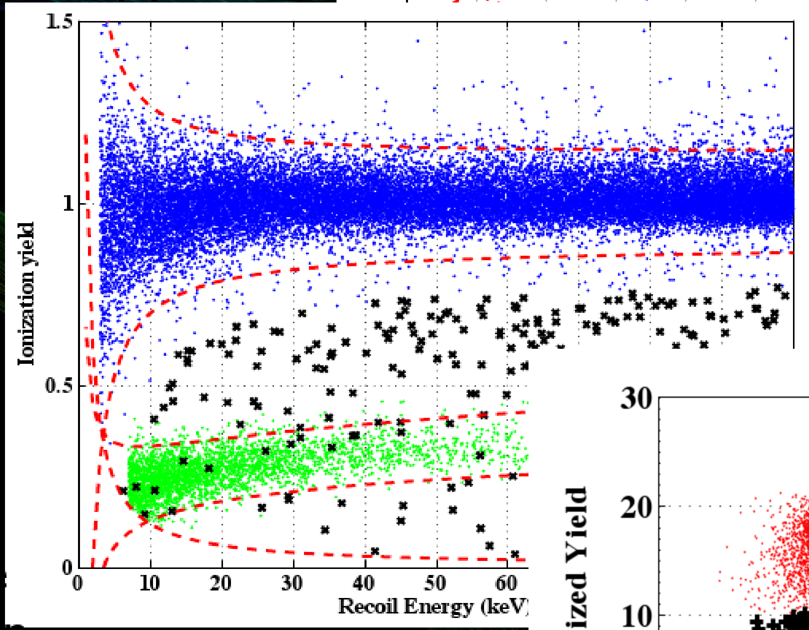
CDMS II (2)

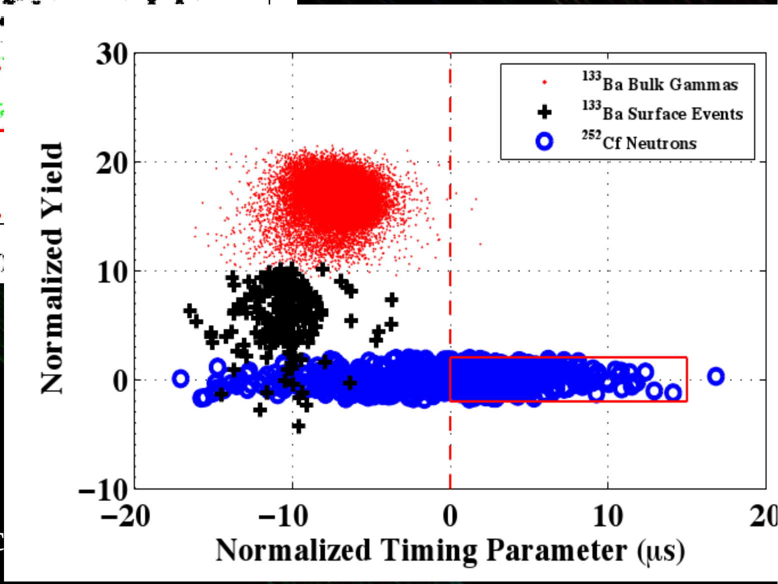
It has been found that even when using the heat/ionization ratio method some gamma events remain in the recoil region.

These were determined to be surface events, and a timing cut was applied to get rid of these events.

Combined methods allowed the reduction of the expected leakage background to **0.6 +/- 0.1 (stat) events.**







Opening the Box

Box opened November 5 , 2009 for 14 Ge ZIP detectors

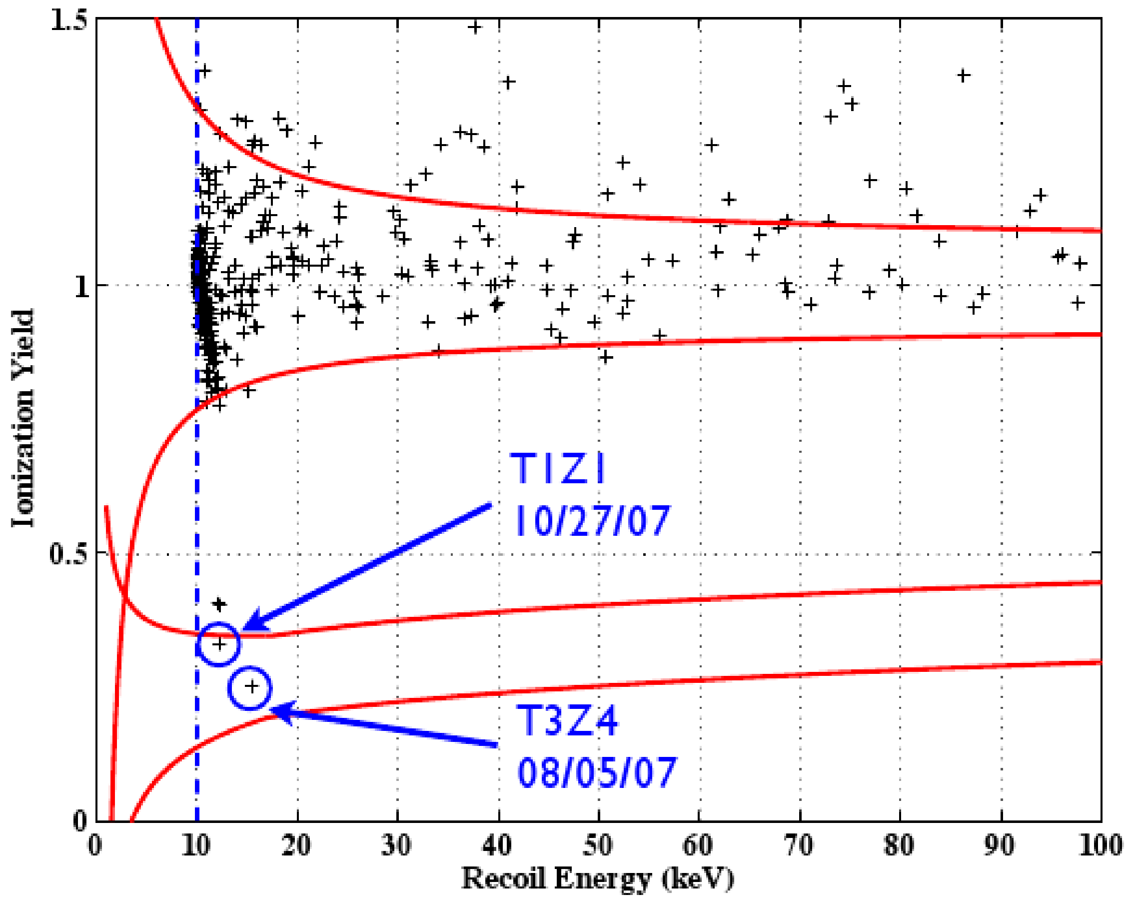
3σ region masked

☑ Hide unvetoed singles

Lift mask, see 150 singles failing timing cut

Apply the timing cut ...

2 EVENTS OBSERVED !



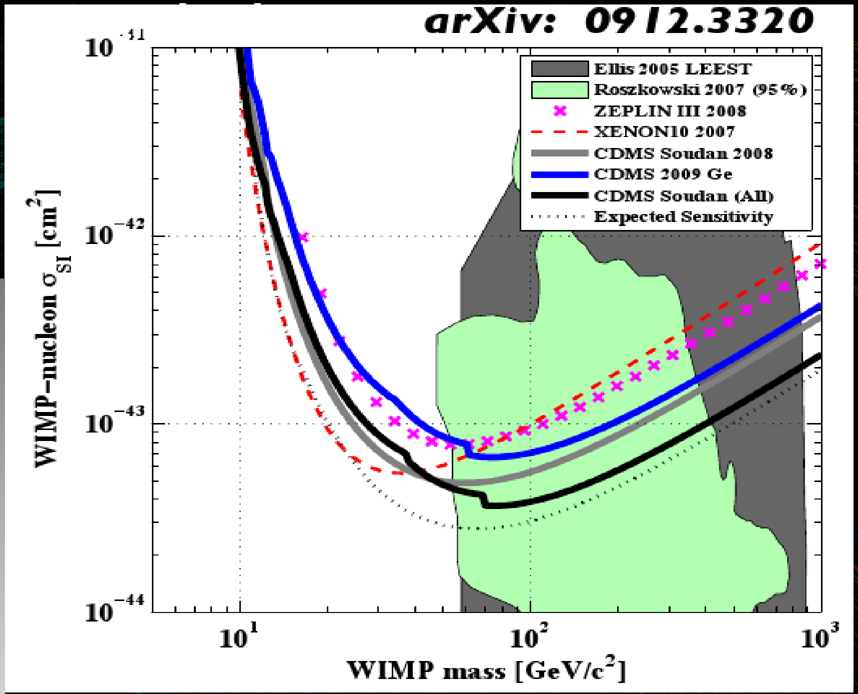
What the CDMS II result means

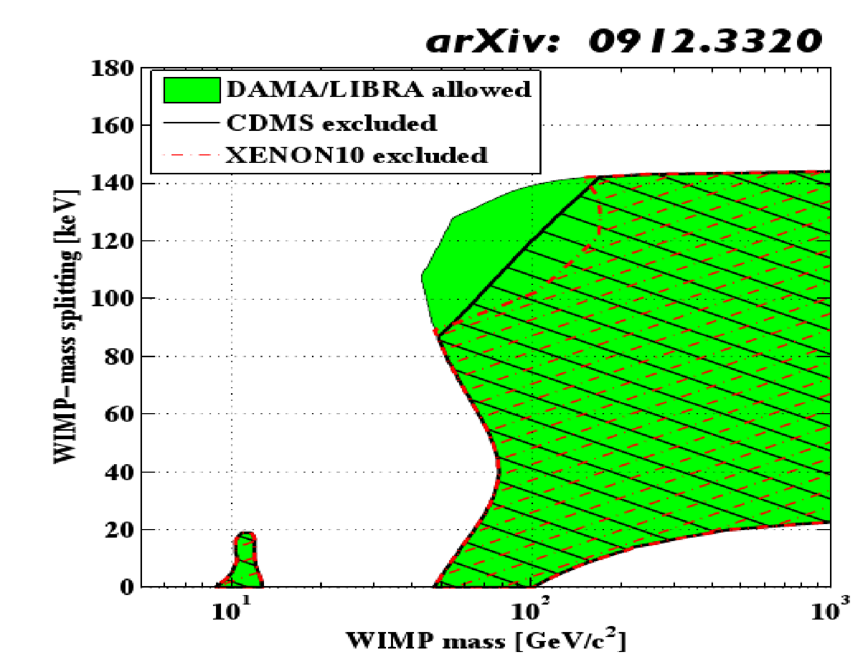
After unblinding the analysis, the background expectation was raised to:

0.8 +/- 0.1 (stat) +/- 0.2 (syst)

The probability to observe 2 or more surface events based on the estimated background is
20%

After including the neutron background, the probability to observe 2 or more events is
23%

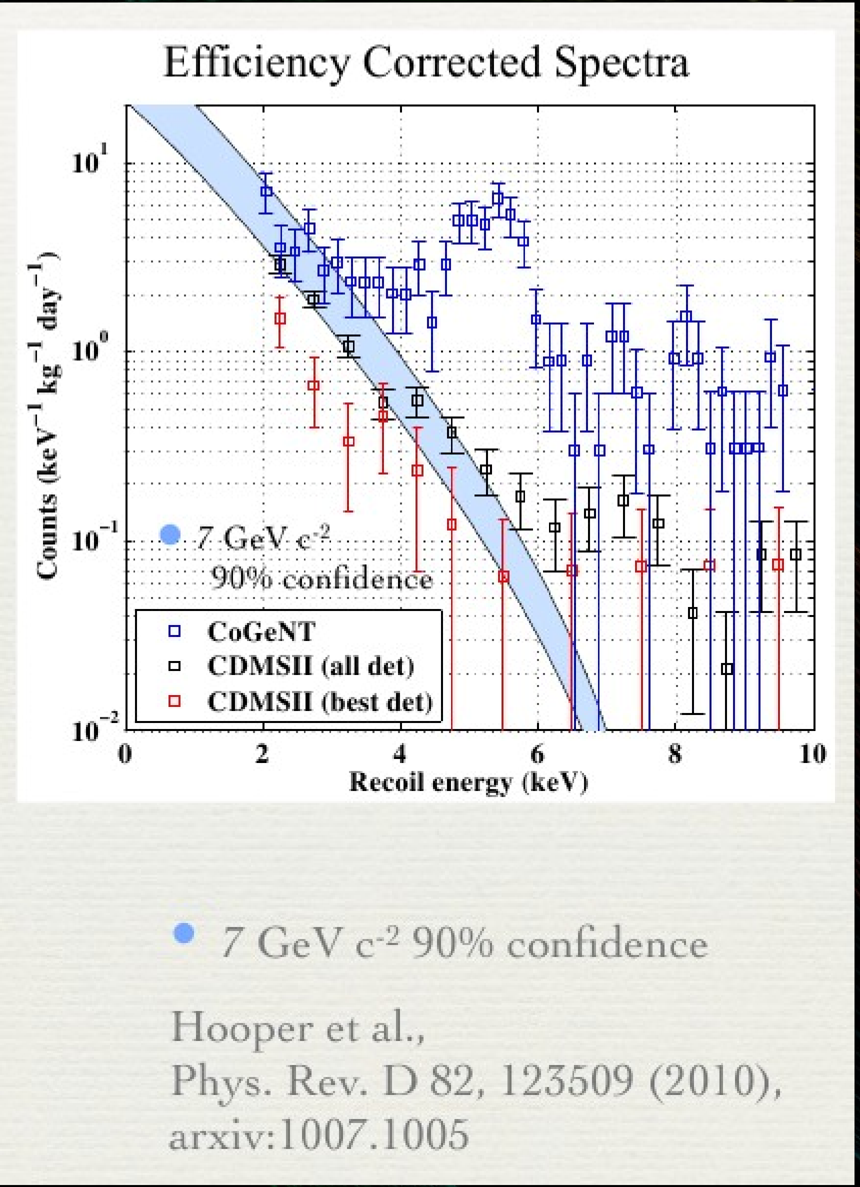




2 events can either be background or a sign that a signal is just around the corner.

CDMS low energy

- Powtórna analiza danych z obniżonym progiem energetycznym nie obserwuje sygnału CoGent.
- Ahmed et al, PRL (accepted), arXiv:1011.2482



The Noble Liquid Revolution

Noble liquids are relatively inexpensive, easy to obtain, and dense.

Easily purified

- low reactivity
- impurities freeze out
- low surface binding
- purification easiest for lighter noble liquids

Ionization electrons may be drifted through the heavier noble liquids

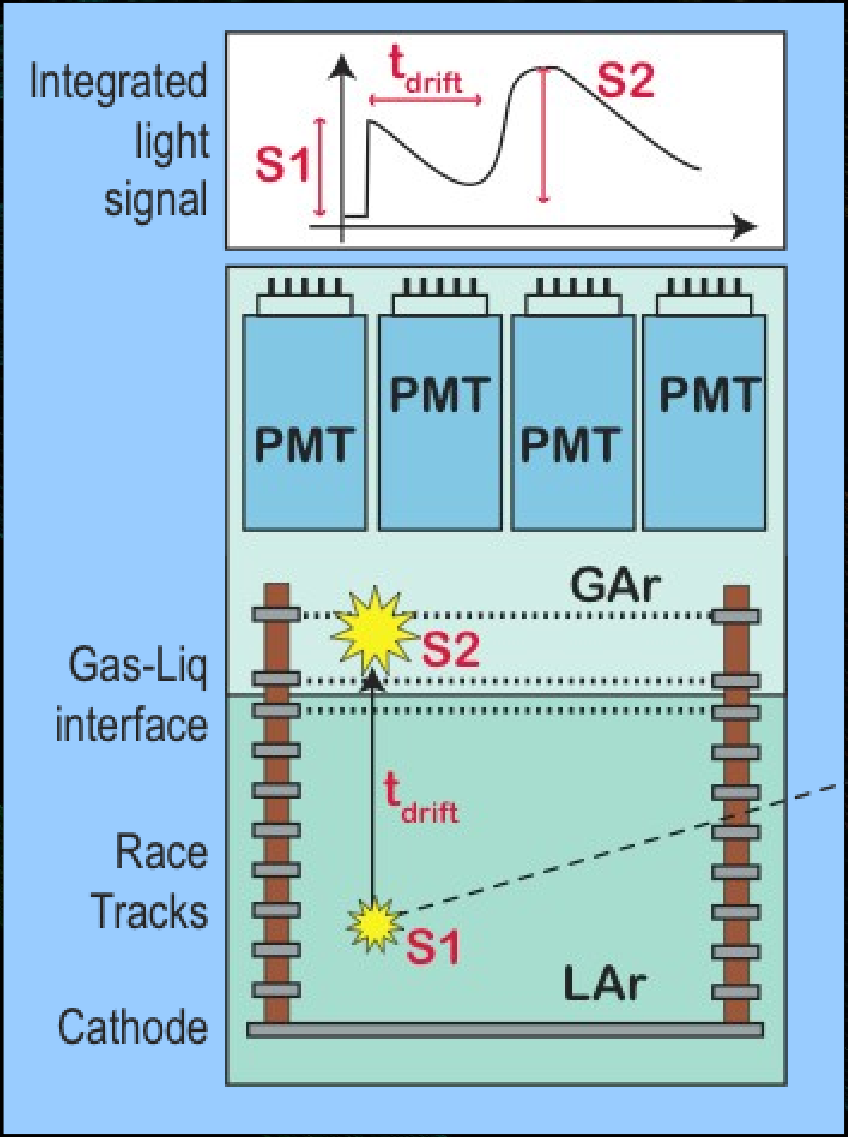
Very high scintillation yields

- noble liquids do not absorb their own scintillation
- 30,000 to 40,000 photons/MeV
- modest quenching factors for nuclear recoils

Easy construction of large, homogeneous detectors

Double - phase detection technique

- The detection method is based on registering the primary scintillation pulses (S1) coming from the light emitted during the interaction and the secondary pulses (S2) emitted by ionization electrons accelerated in the gaseous phase.
- This method allows for very good background elimination.

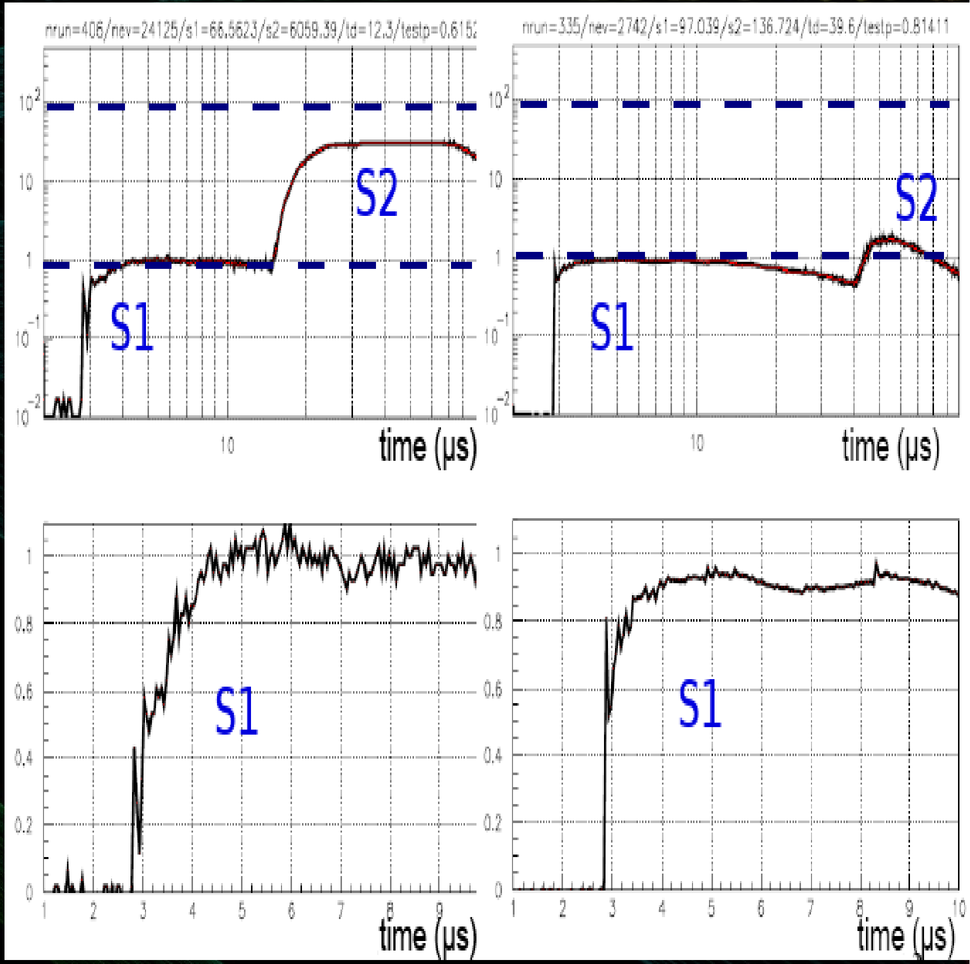


Double-phase detection technique

In liquid noble gases the discrimination between γ/β particles and particles interacting with the nucleon i.e. WIMP and neutrons can be conducted by comparing their S2/S1 (Xe, Ar, Ne) ratio and the S1 pulse shape (only Ar and Ne).

This eliminates the more abundant γ/β background.

To eliminate the more dangerous neutron background a veto or large enough detector is needed.

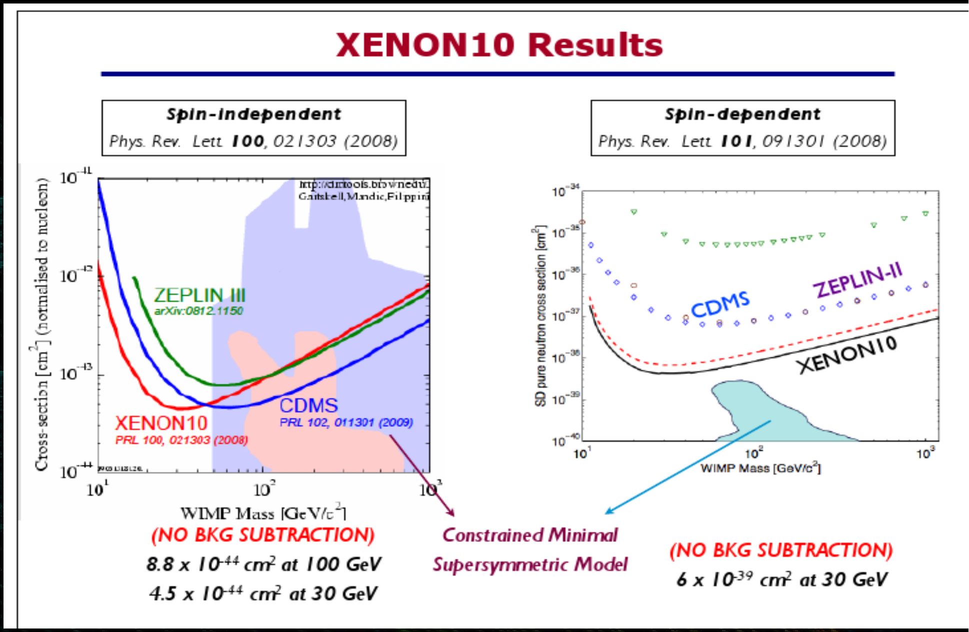


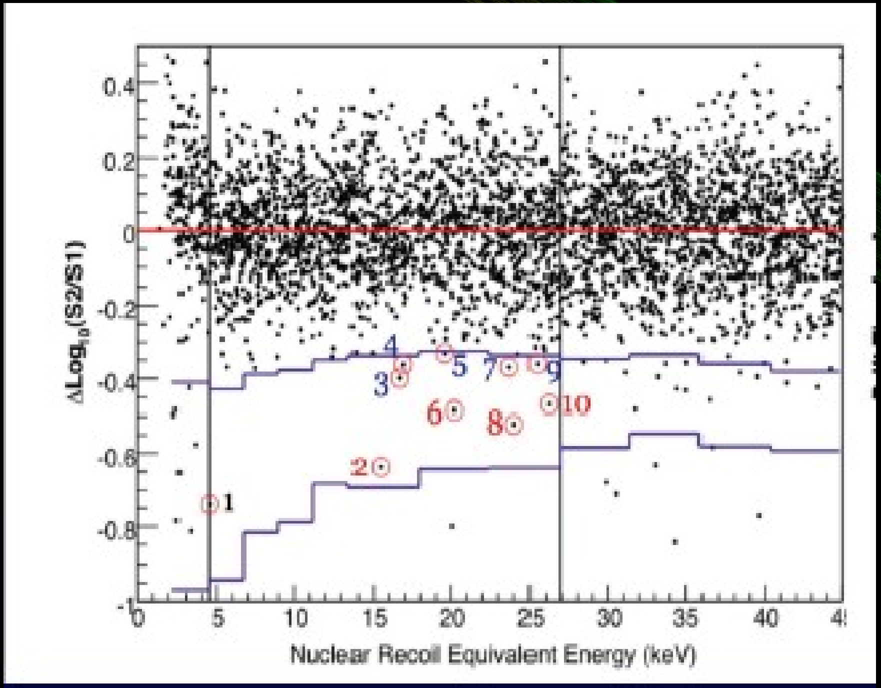
The S1 pulse shape discrimination methods depend on the amount of light seen in the detector.

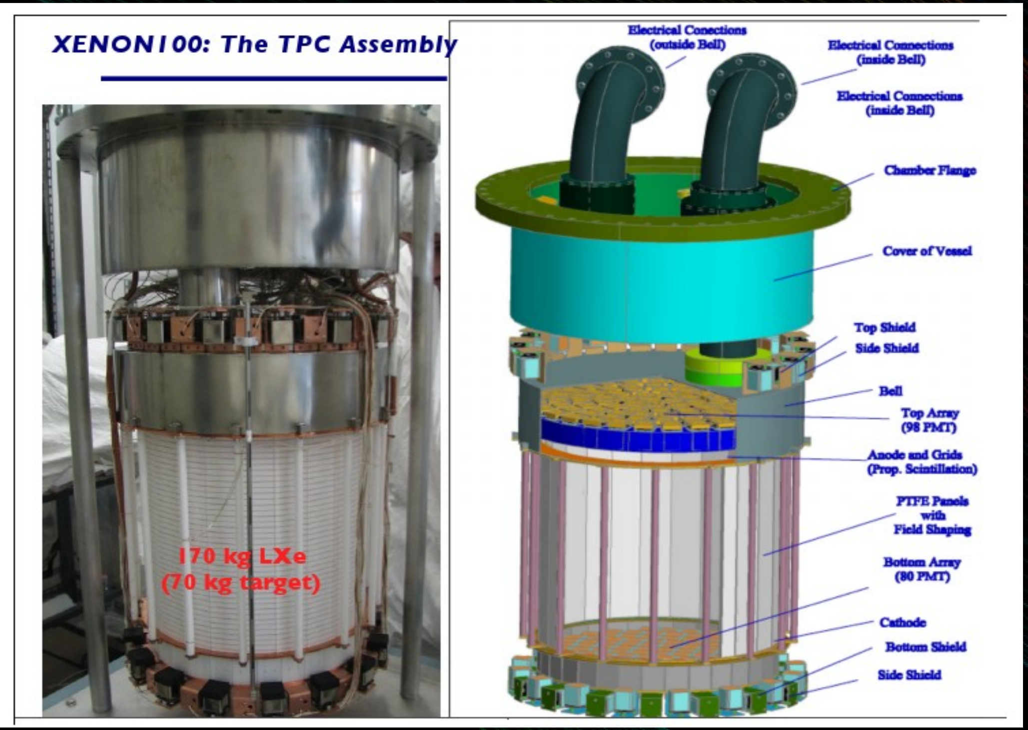
XENON 10

The XENON Experiment is being operated at the Gran Sasso laboratory. The first detector, XENON 10, published DM search results in 2008 and it continues to be one of the leading limits.

10 events were observed, with 6.8 expected from γ leakage.







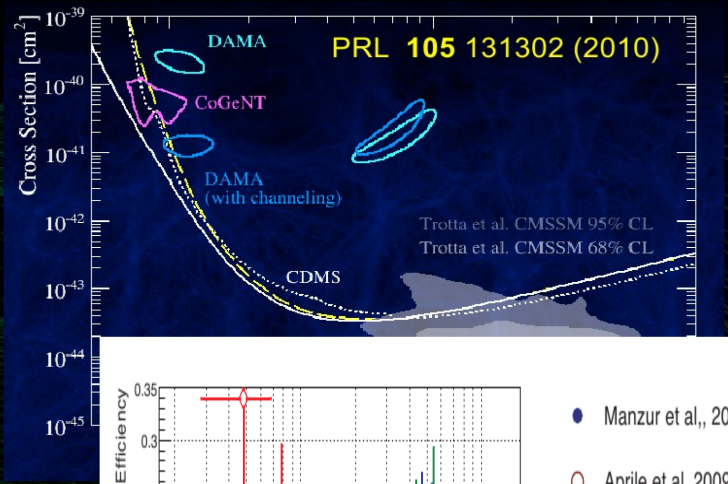
Xenon 100 – pierwszy rezultat

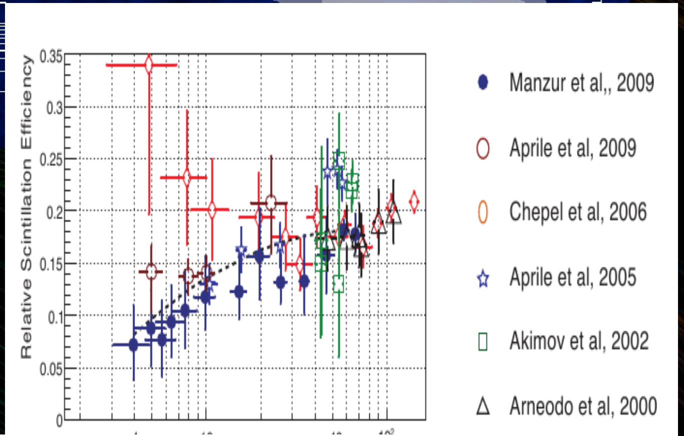
W kwietniu 2010 XENON opublikował dane z krótkich pomiarów testowych, które dają czułość porównywalną z XENON10

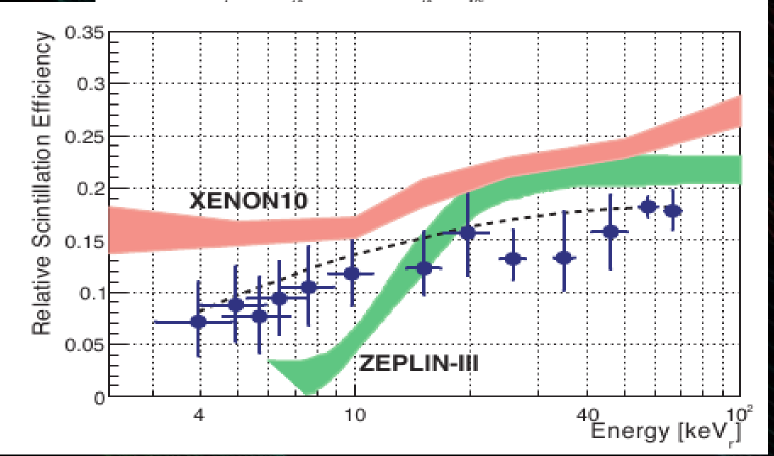
Publikacja wywołała gorącą dyskusję, głównie z powodu sposobów ekstrapolacji czynnika „quenching”

Obie strony chcą ponownie go zmierzyć – od mocno zależą wyniki dla niskich energii.

W najbliższych tygodniach powinno nastąpić otwarcie danych z długiego pomiaru – spodziewany duży skok jakościowy.



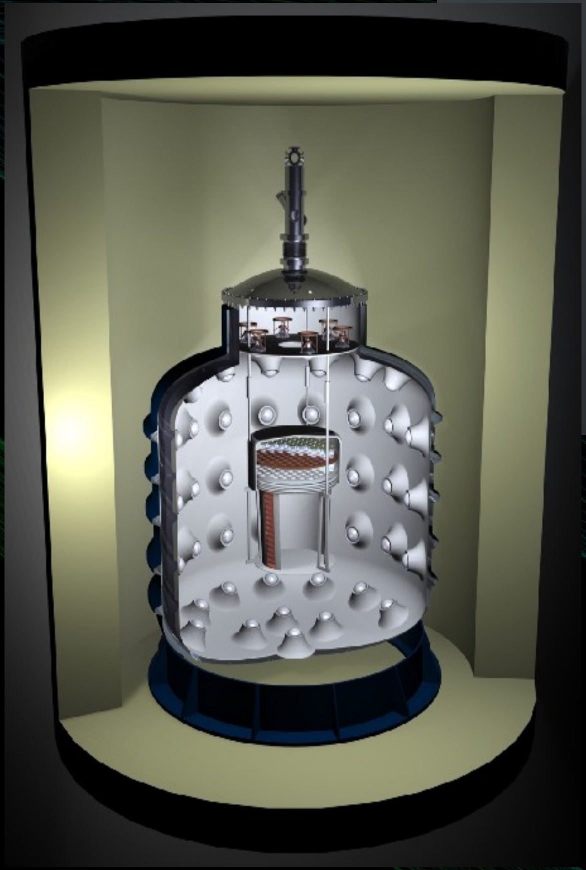




E. Aprile

The WArP Experiment (1)

- The WArP experiment is a two-phase (liquid-gaseous) argon detector .
- Two apparatus are being used by the WArP collaboration - the 2.3 l prototype detector and the 100 l main WArP detector, surrounded by 8 tons of LAr as a veto detector.
- Both detectors are placed in the underground laboratory in Gran Sasso.



WArP (3)

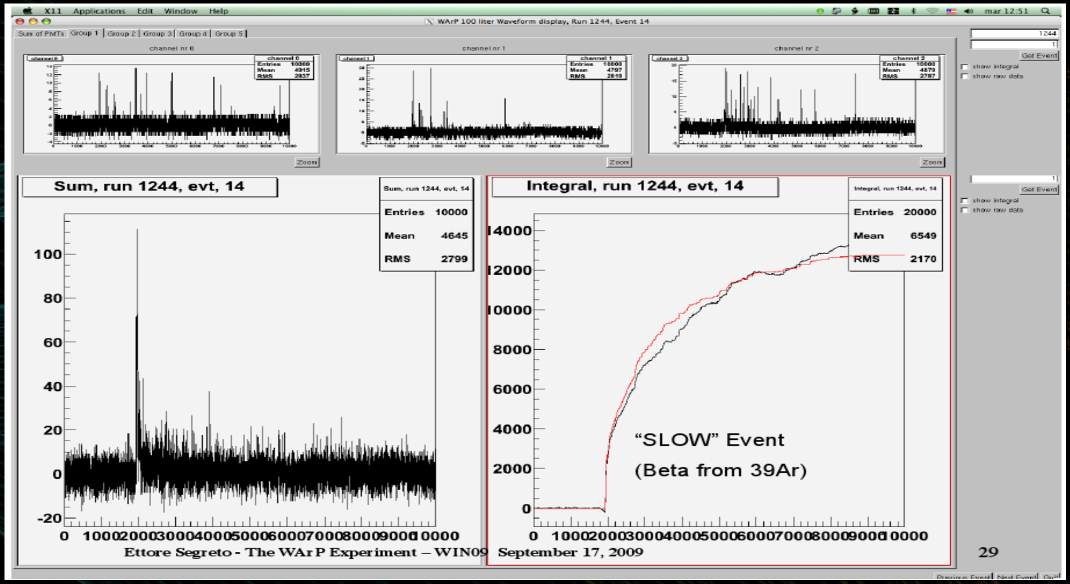
The WArP 100l detector has been commisioned at LNGS starting May 2009.

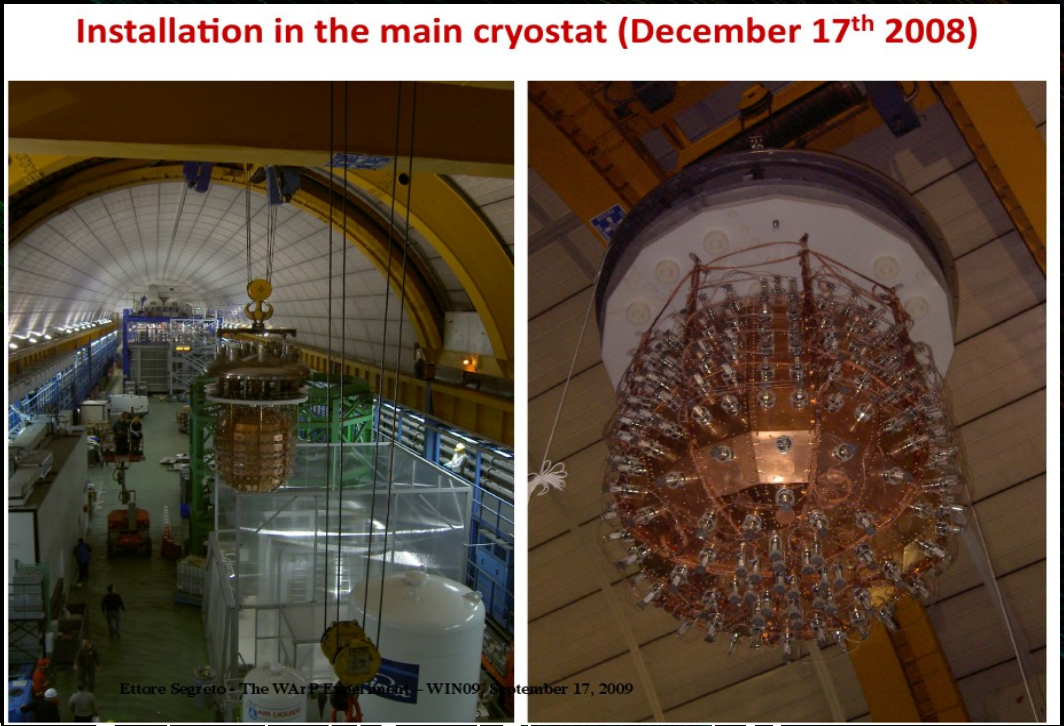
Due to problems with the HV cable, the detector was opened in August.

During the operation of the chamber in single phase the DAQ and reconstruction algorithms were tested.

Second HV failure.

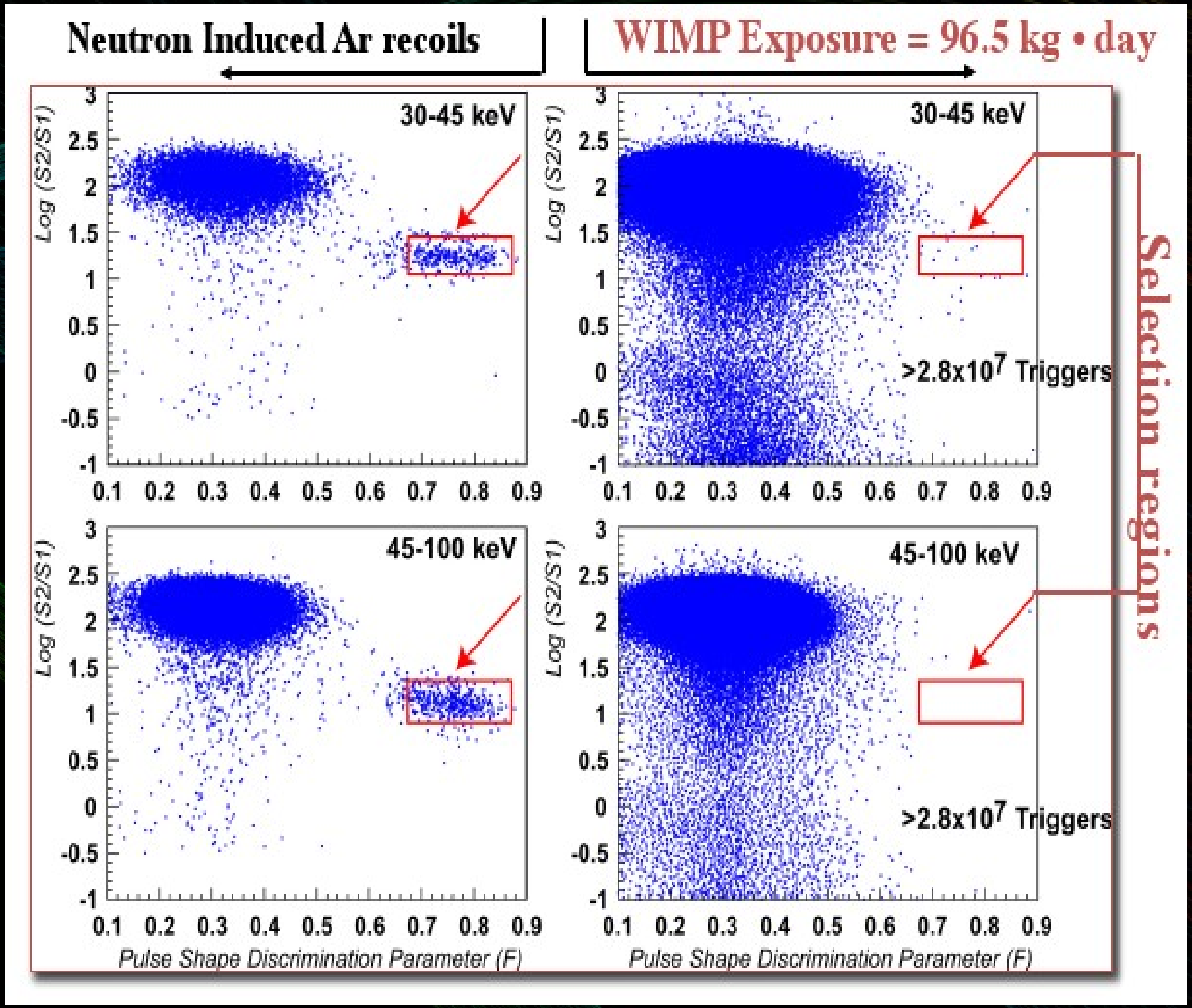
The detector should begin a technical run in the spring.





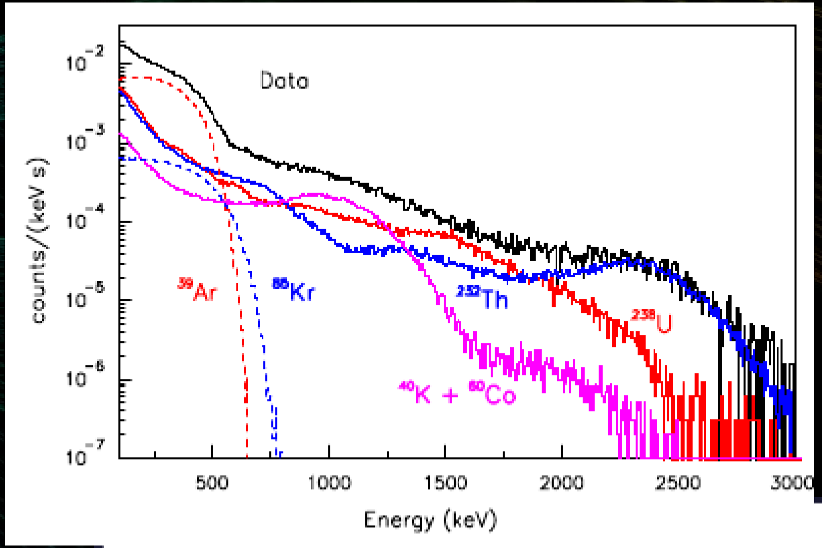
WArP (2)

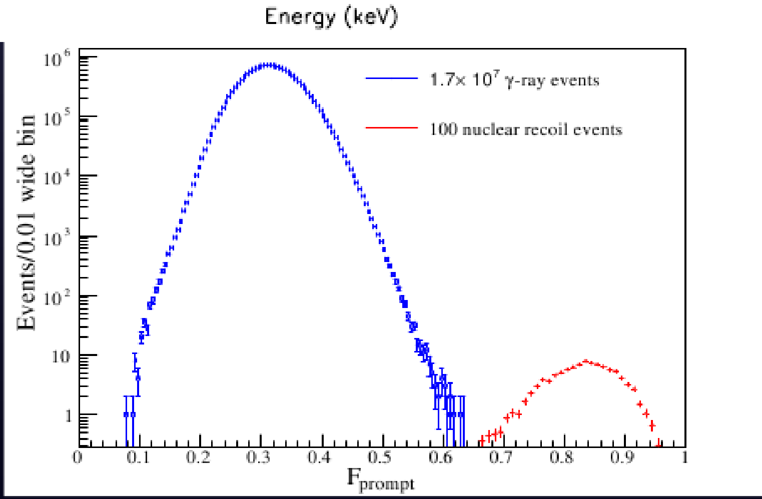
- The largest background in argon detectors is the cosmogenic ^{39}Ar. To operate in a Dark Matter search the background suppression must be good enough to exclude this background.
- Another option is to use isotopically depleted argon (centrifugues or underground reservoirs)



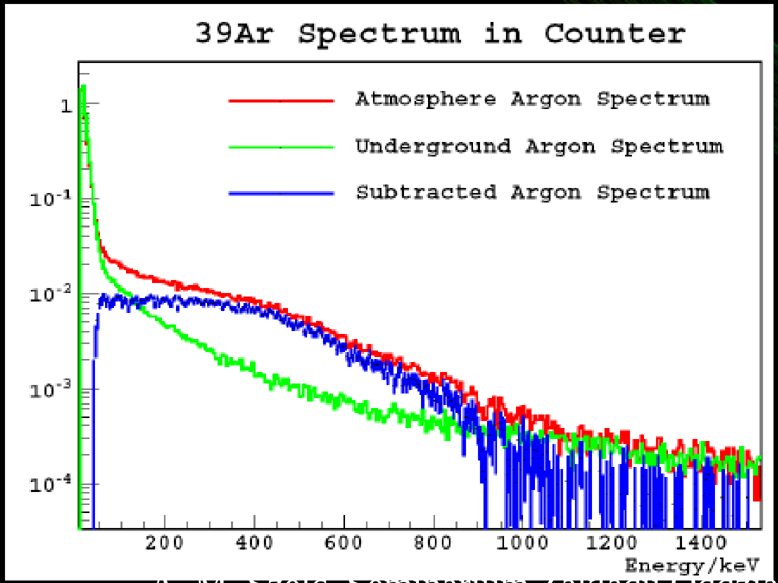
Argon 39 – problemy dla większych detektorów

- Tło „wyciek” gamm to interesujacegoobszaru ~ 1Bq/kg
- Pile up – szczególnie dla eksperymentów dwufazowych.
- Prowadzone są pierwsze pomiary ze zubożonym argonem uzyskanym w U.S.A. (obniżenie zawartości o czynnik 25)



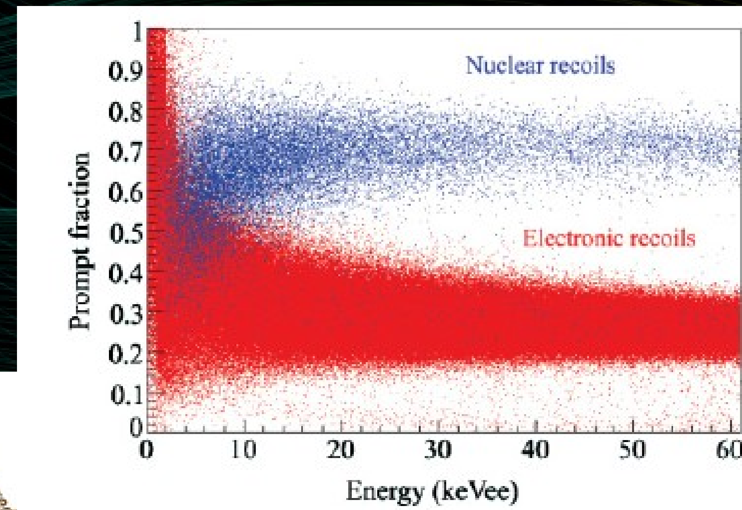


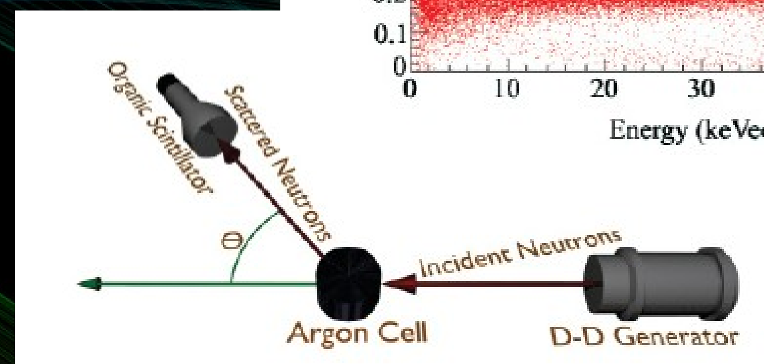
Electron/Nuclear Recoil Data from DEAP-1

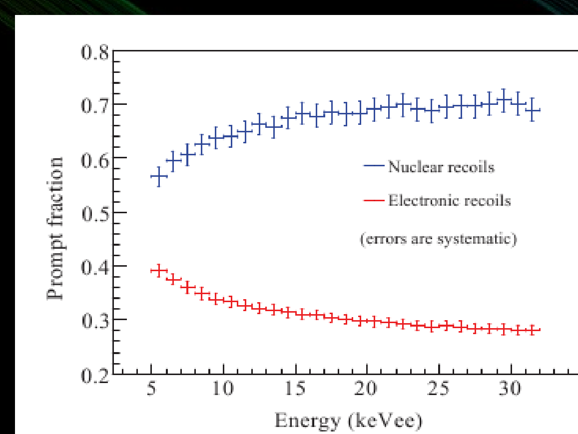


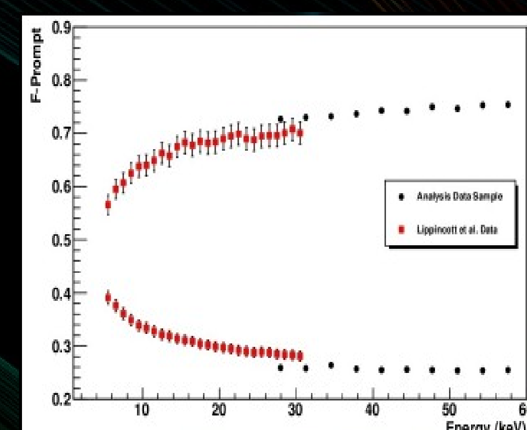
Jak oddzielić tło od Ar 39

- Separacja na podstawie S1 potężniejsza.
- Pierwszy pomiar Lippincott – tagowanie przypadków dodatkowym detektorem.
- Wynik daje możliwą separacje pomiędzy neutronami i elektronami.
- Pierwsze pomiary w GS nie dochodziły do tak niskich energii ale wydawały sie poprawiać ten wynik.



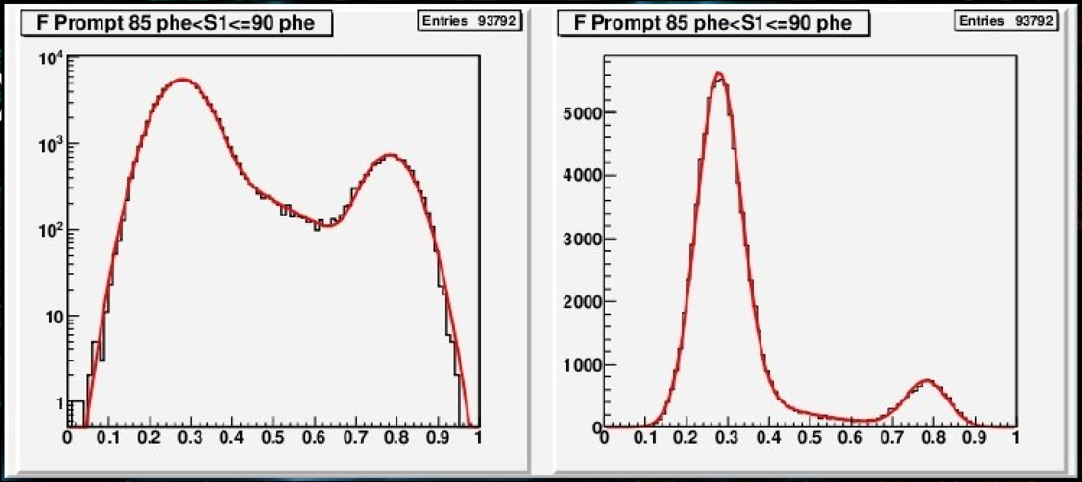




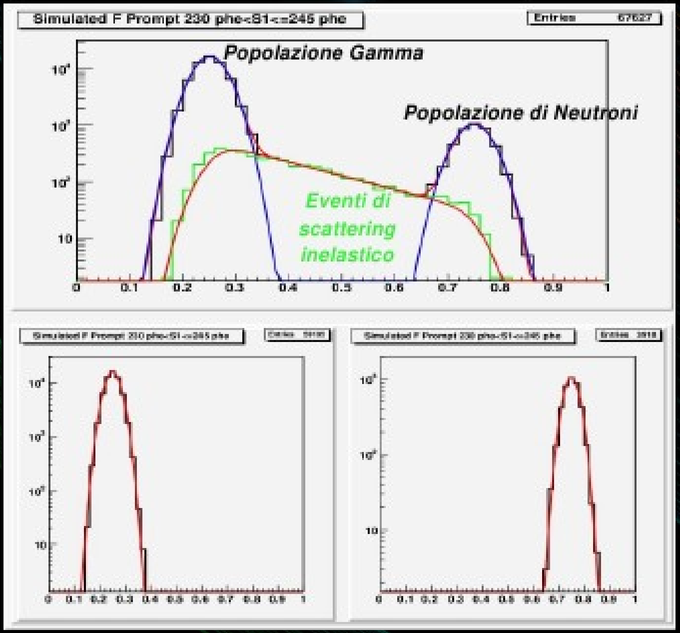


Populacja pośrednia

- Przy naświetlaniu detektora źródłem AmBe (neutrony + gamma) zaobserwowano przypadki znajdujące się pomiędzy populacjami neutronów i gamm, które nie pasowały do hipotezy „wycieku” gamm.



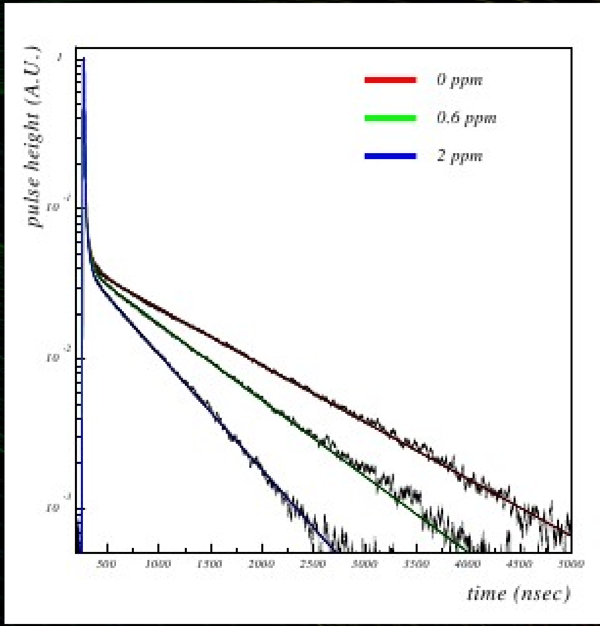
- Przypadki te odpowiadają nieelastycznym oddziaływaniom neutronów – potwierdzone przez Monte Carlo.

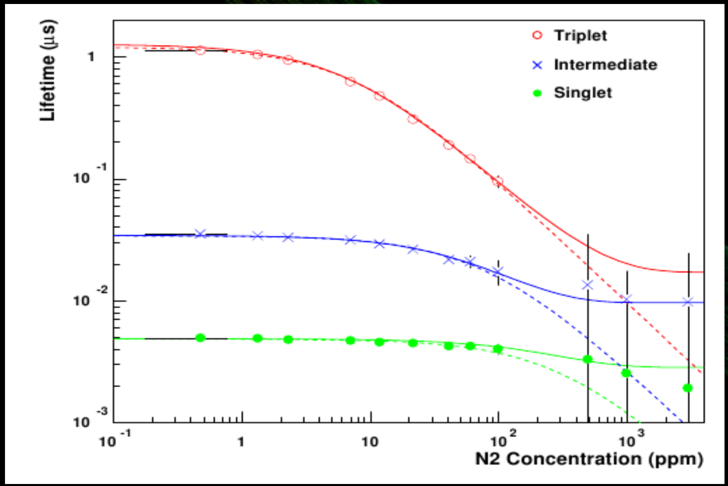


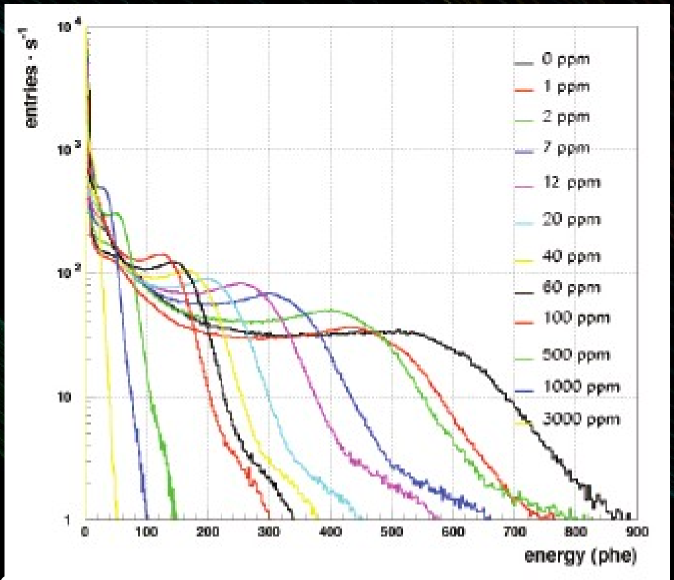
- Praca dokt. R. Acciarri'ego polegała na analizie tych danych uwzględniajac dodatkową populację przypadków.

Uzysk światła

- Potrzebny wysoki, zeby obnizyc próg energetyczny
- Bardzo delikatny parametr
- Zanieczyszczenia tlenem i azotem powoduja tłumienie scyntylacji w argonie.
- Ważna jakosc wavelengthshiftera – TPB
- Sa przeslanki, ze woda moze obnizac jakosc TPB
- Fotopowielacze.

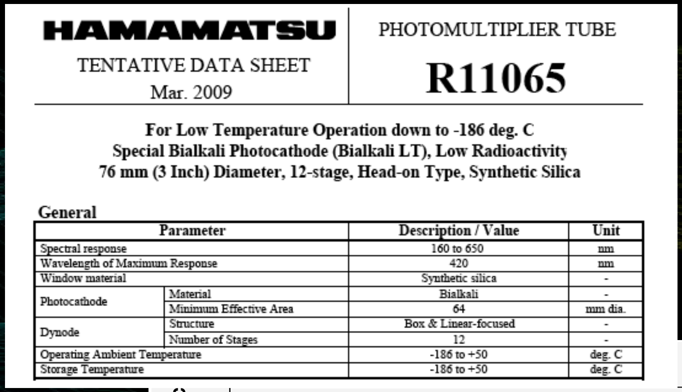






R & D argonowe w LNGS

- Nowe fotopowielacze Hamamatsu Q.E. ~35%
- Oprócz wyższej wydajności kwantowej lepsze parametry szumu.
- Juz w jednym z pierwszych pomiarów udało sie osiągnać 7phel/keV.
- Porówanienie z jednym z dotychczas używanych fotopowielaczy. Są stabilniejsze i lepszy uzysk światła.


HAMAMATSU

PHOTOMULTIPLIER TUBE

TENTATIVE DATA SHEET

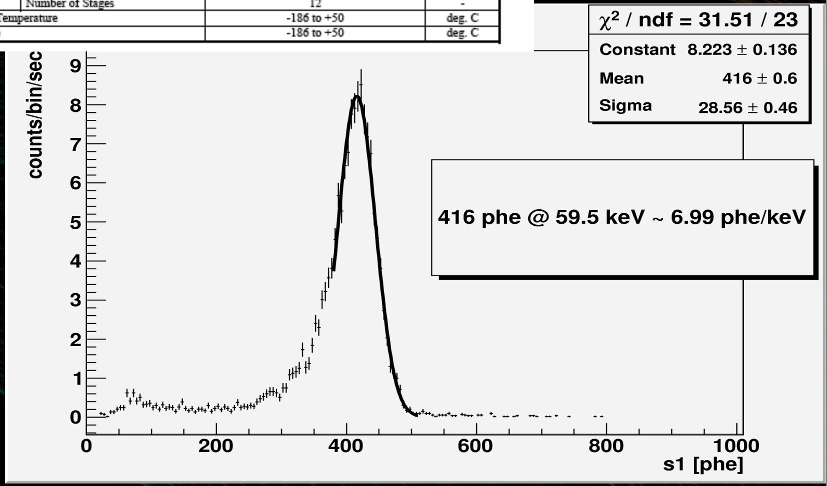
Mar. 2009

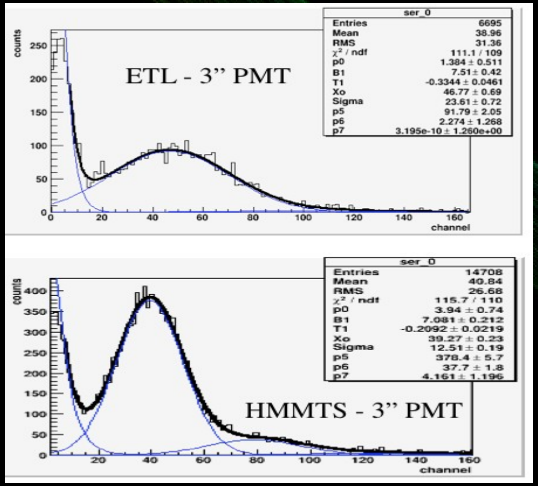
R11065

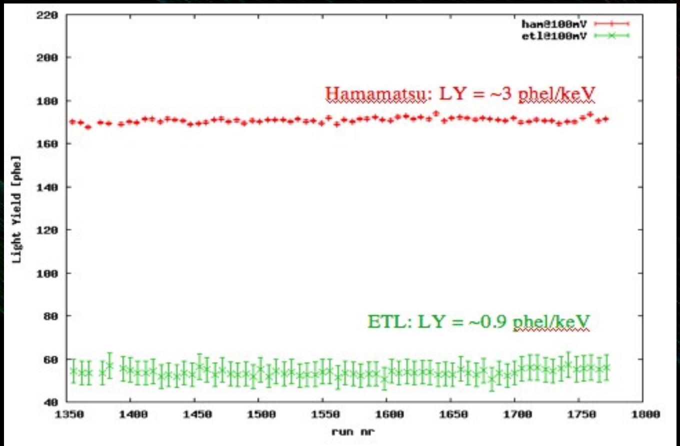
For Low Temperature Operation down to -186 deg. C
Special Bialkali Photocathode (Bialkali LT), Low Radioactivity
76 mm (3 Inch) Diameter, 12-stage, Head-on Type, Synthetic Silica

General

Parameter		Description / Value	Unit
Spectral response		160 to 650	nm
Wavelength of Maximum Response		420	nm
Window material		Synthetic silica	-
Photocathode	Material	Bialkali	-
	Minimum Effective Area	64	mm dia.
Dynode	Structure	Box & Linear-focused	-
	Number of Stages	12	-
Operating Ambient Temperature		-186 to +50	deg. C
Storage Temperature		-186 to +50	deg. C

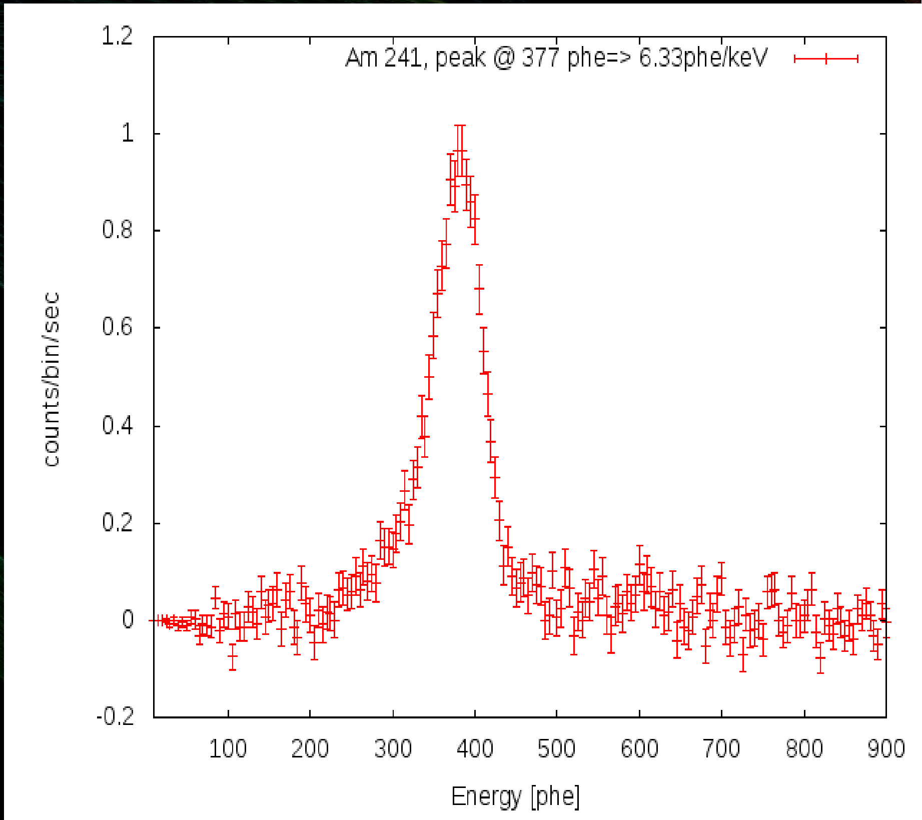






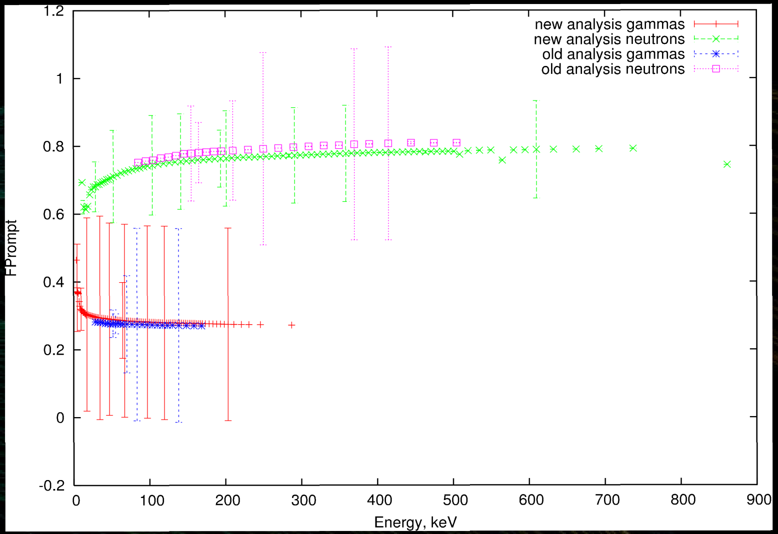
Skalowanie do wiekszej masy

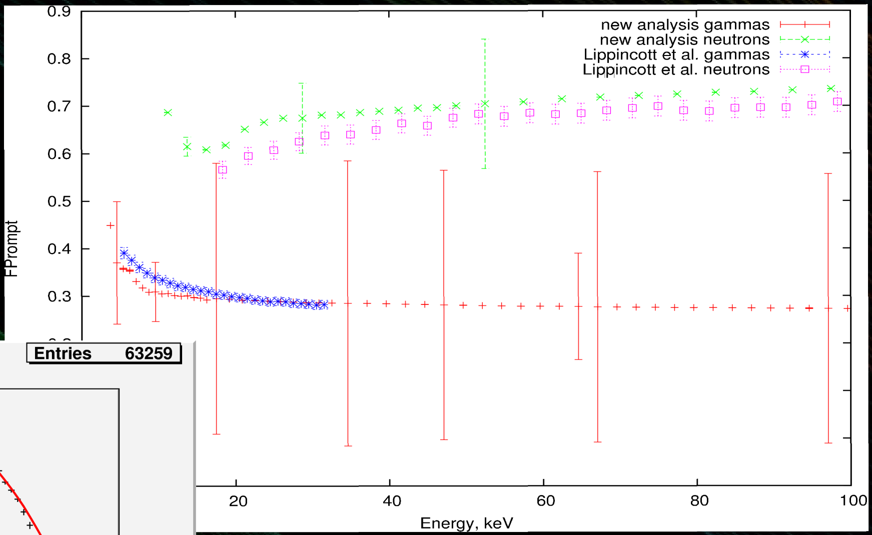
- Nie takie proste jak by sie moglo wydawac.
- Po kilku probach udało sie dojsc do wyniku 6.3 phe/keV dla detektora 2.3 litra.
- W detektorze obecne zanieczyszczenie ~5ppm azotu oraz jeden fotopowielacz systematycznie słabszy od pozostałych ekstrapolujac -> LY > 7 phe/keV (obecnie najlepszy wynik na Świecie)
- Teoretycznie można myśleć o progach energetycznych rzędu kilku keVee

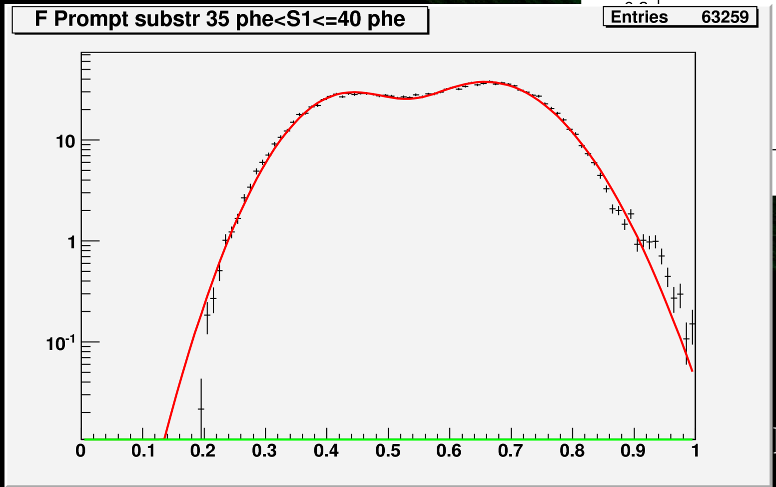


Pomiar separacji neutronów

- Detektor wykorzystany do dalszych prac nad oddzielaniem tła na podstawie sygnałów pierwotnych – praca magisterska P. Kryczyńskiego.
- Separacja neutrony – gamma przy uzysku światła ~6.1phe/keV – kontynuacja pracy R. Acciarriego.
- Bardzo wstępne wyniki!

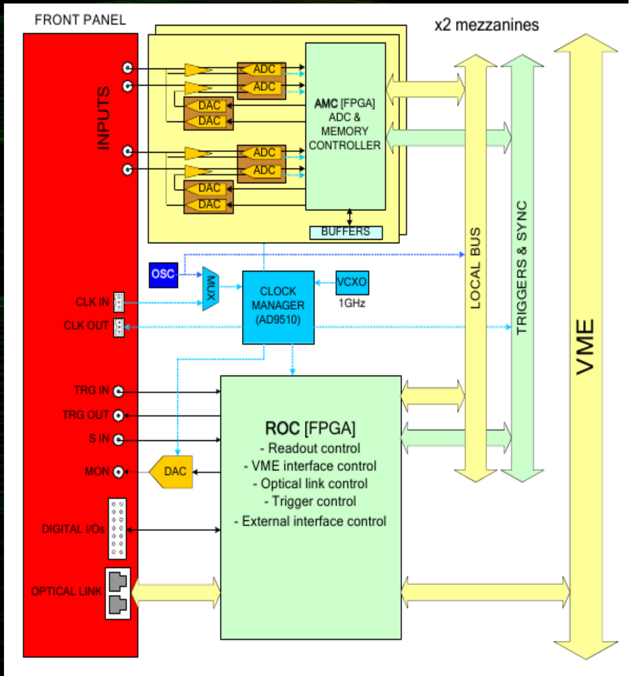


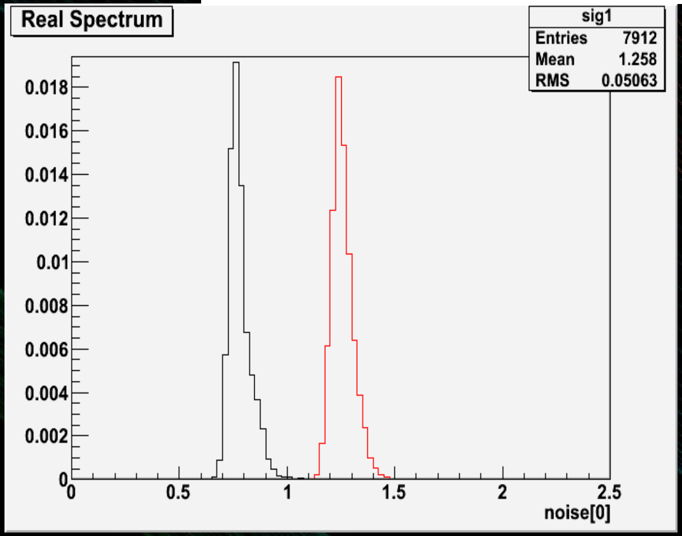


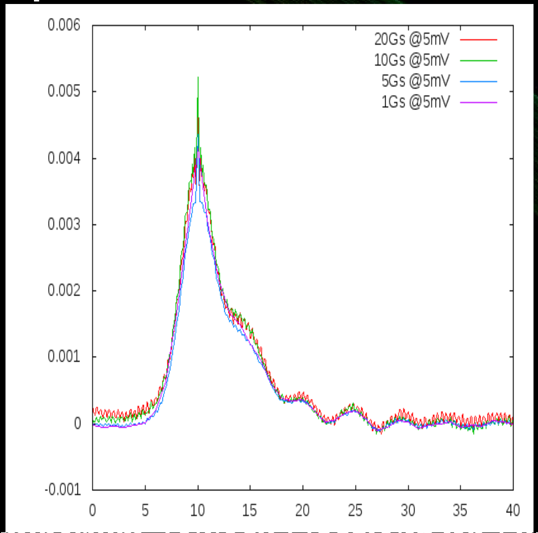


Testy nowej elektroniki

- WArP używa elektroniki o próbkowaniu 1GS/s.
- Pytanie brzmi, czy to wystarczy a jeśli nie to czy jest to sensowny kompromis?
- Porównanie kart CAEN V1751, Acqiris z Oscyloskopem LeCroy (do 20GS/s – próbkowanie co 50ps)
- Nowa karta CAEN ma zdecydowanie niższy szum, co bardzo ułatwia rekonstrukcje.
- Praca w toku – wstepnie widać pewną utratę ładunku dla niższych próbkowań.







Podsumowania

Przewidywania z początku 2010 roku okazały sie zbyt optymistyczne.

Sytuacja na polu poszukiwań Ciemnej Materii nadal jest ciekawa, ale ciężar przesunął się troche w kierunku bezpośrednich poszukiwań.

Na pewno można się spodziewać czegoś ciekawego po spodziewanych wynikach eksperymentu XENON100

Ciekły argon został troche z tyłu, ale jeśli zostaną zbudowane detektory o skali tonowej o wysokim uzysku światła i z wykorzystaniem zubożonego izotopowo argonu ma szansę dogonić stawkę ew. Przeskoczyć do następnego etapu – ArDM, DEAP/CLEAN.

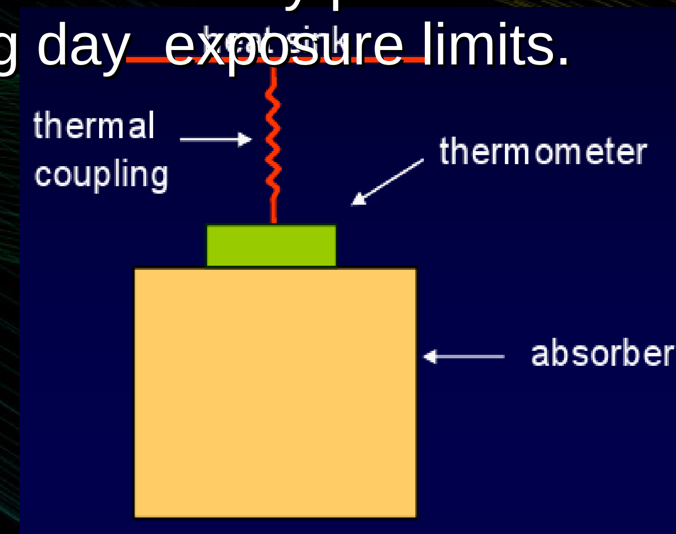
Acknowledgements

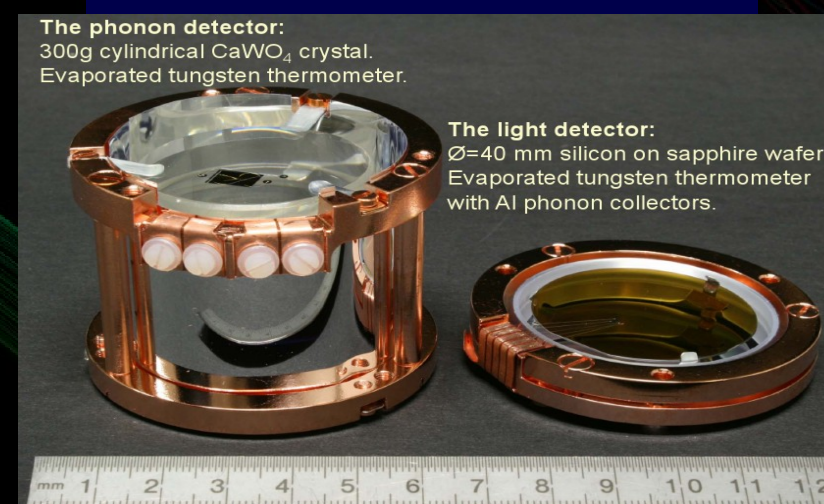
Slides and images from presentations by: O. Adriani, C. Galbiati, D. McKinsey, F. Giuliani, E. Segreto, V. Langlard, L. Baudis, F. Petrucci, J. Cooley, L.J. Rosenberg, B. Serfass, L. Latronico, W. Rau, E. Aprile, C. Lazzaro, K. Martens, J. Nikkel,A. Sonenschein, C. Pobes, P. Belli, J. McEnery, A. Strong, J. Isbert,G. Gelmini, F.Probst

CRESST

CRESST, $CaWO_4$ crystals.

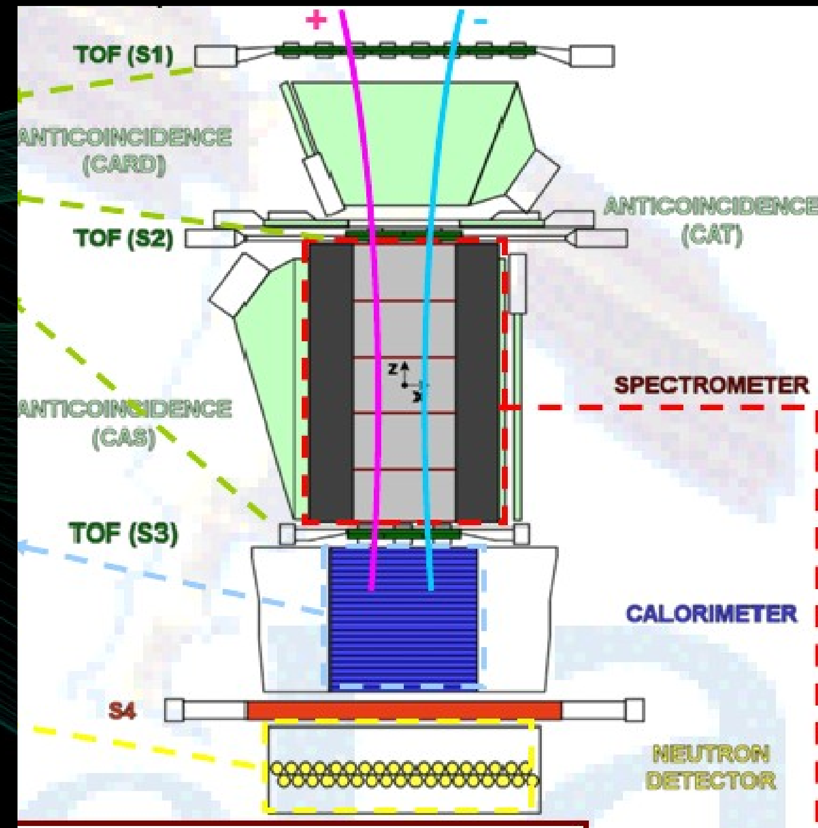
Scintillation + phonons. Based at LNGS. Recently published 60kg day exposure limits.

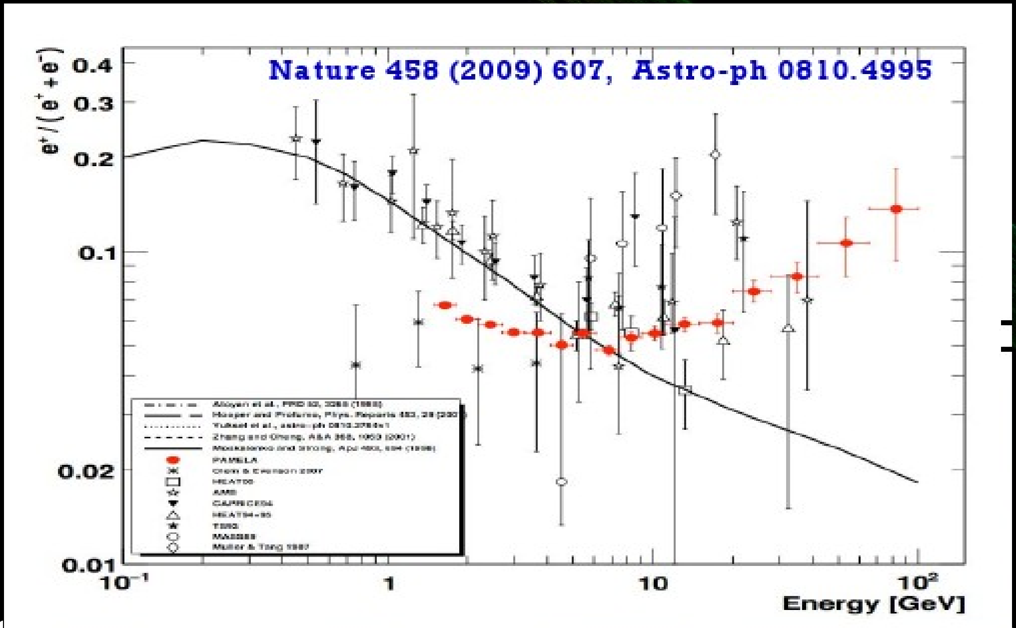




PAMELA

- Satellite observatory equipped with TOF, Calorimeter, Neutron-detector and spectrometer.
- The detector observed a surplus of e^+, which caused a large stir in the scientific community. As of now, the article has been cited more than 400 times.



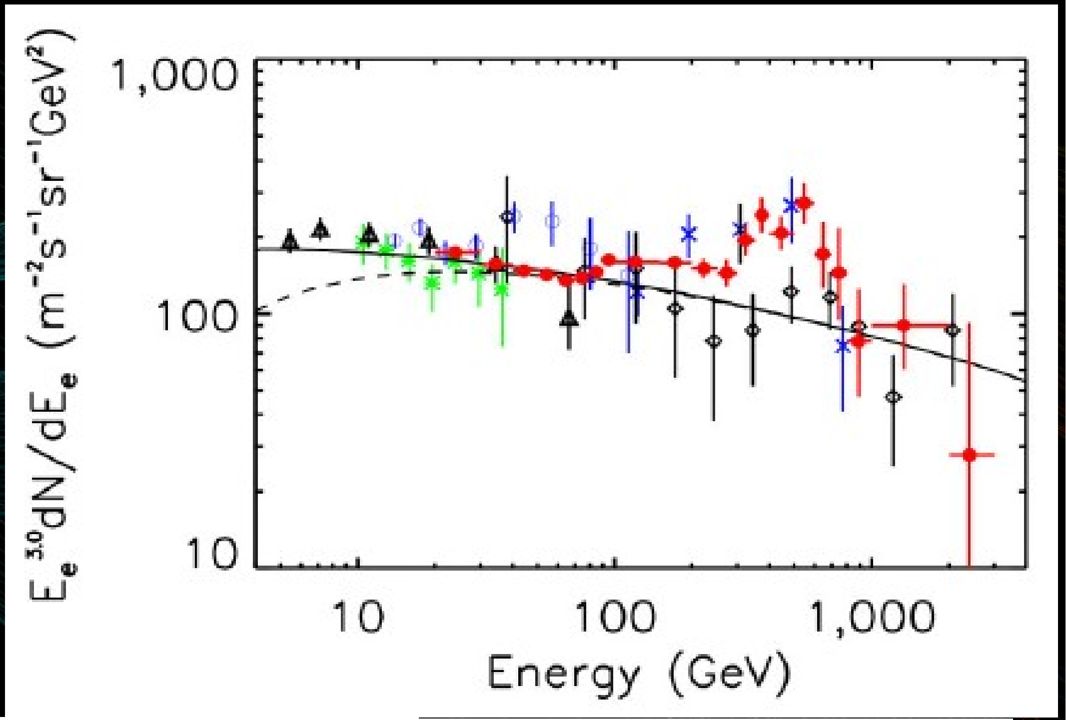


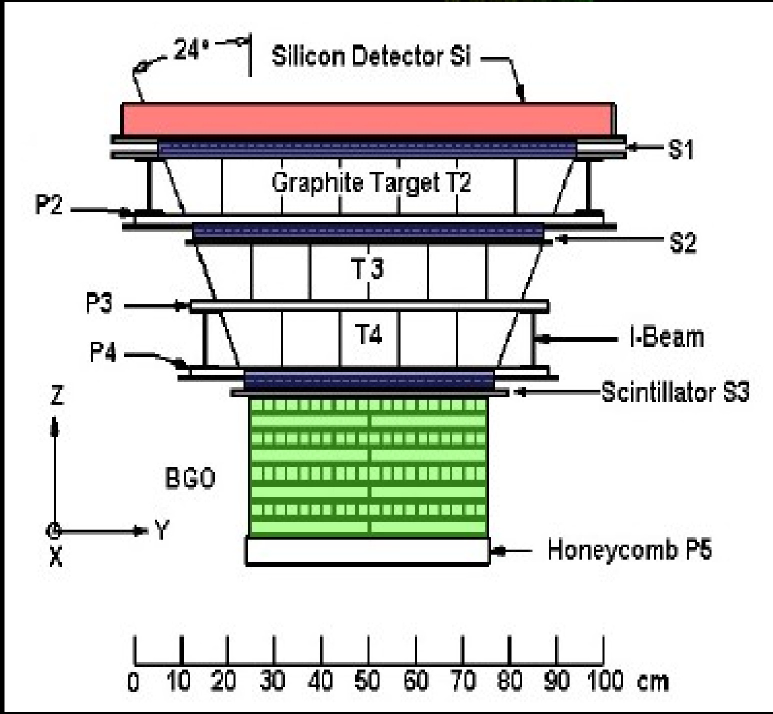
• Antiprotons	80 MeV - 190 GeV
• Positrons	50 MeV – 300 GeV
• Electrons	up to 500 GeV
• Protons	up to 1000 GeV
• Electrons+positrons	up to 2 TeV (from calorimeter)

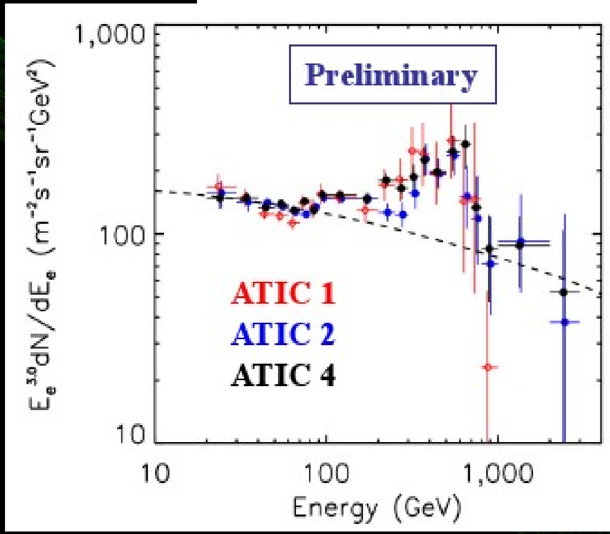
ATIC Baloon Experiment

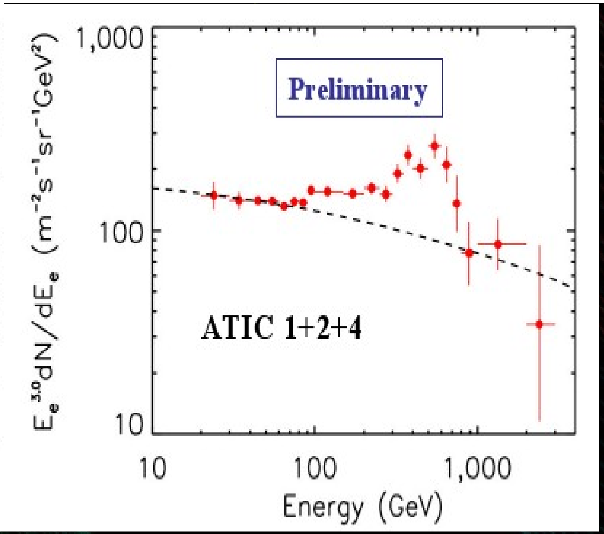
ATIC has observed a surplus of e^- with a peculiar structure @ ~(300-700GeV). (published in Nature)

The unpublished data from the last flight seem to confirm this result.

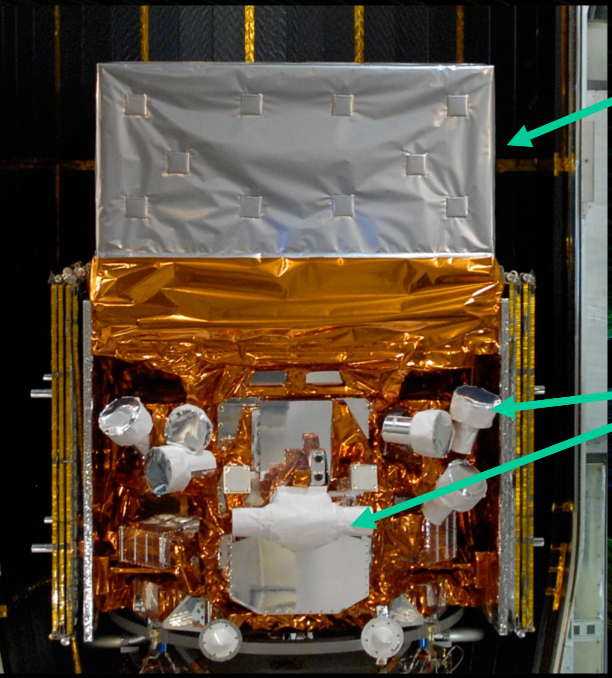








FERMI-LAT



Large Area Telescope (LAT):

20 MeV - >300 GeV (including unexplored region 10-100 GeV)

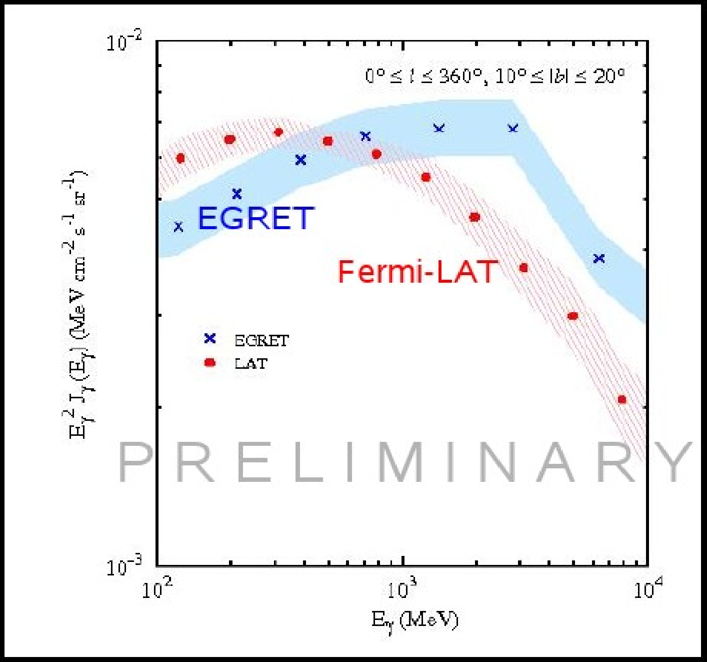
2.4 sr FoV (scans entire sky every ~3hrs)

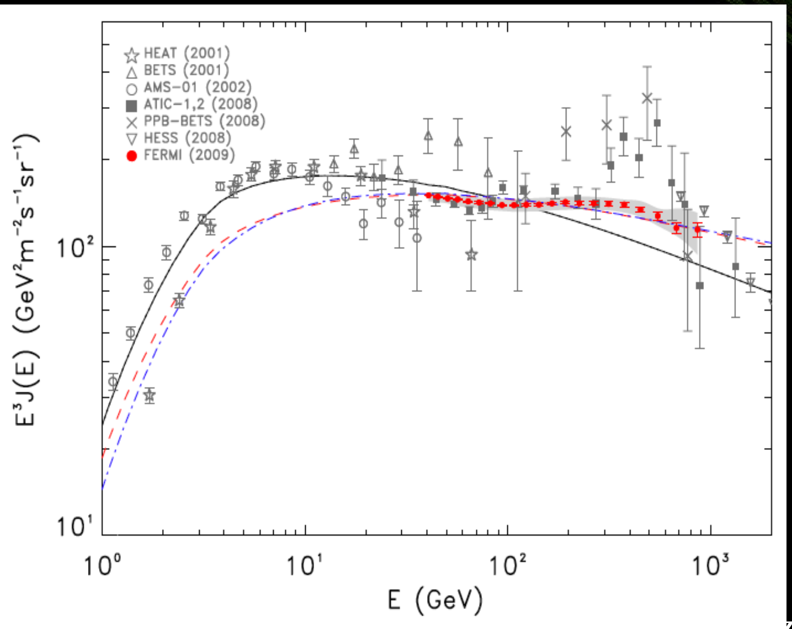
Gamma-ray Burst Monitor (GBM)

8 keV - 40 MeV

views entire unocculted sky

Launched June 2008!





<u>Total statistics</u> collected for 6 months of Fermi LAT observations

- **~4.5 million candidate electrons above 20 GeV**

544 candidate electrons in last energy bin (770-1000 GeV)

FERMI does not confirm the γ excess seen by EGRET. However, it does see an excess of e^-+e^+

Testing DAMA

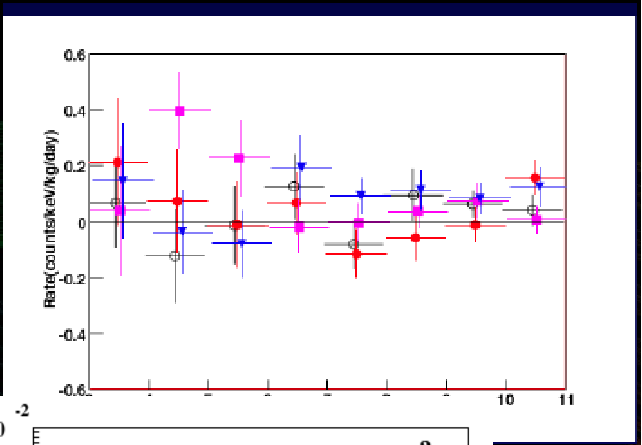
The DAMA result has not yet been fully excluded by a by a pure scintillation NaI experiment. Some attempts have been made, some are on their way:

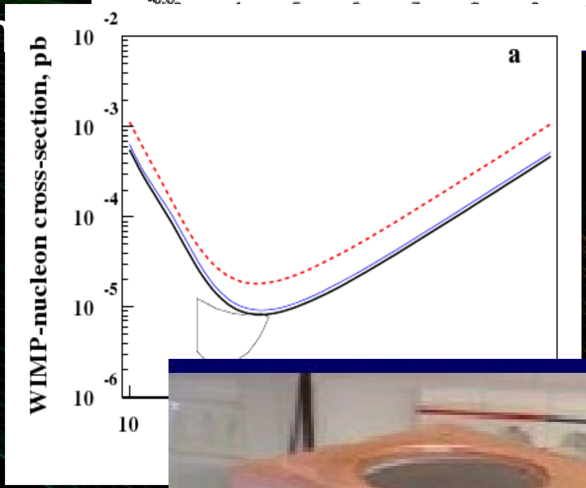
KIMS - Located in Korea (Yangyang) taking data with 12 CsI detectors (104.4 kg), 3409 kg-days consistent with null result (PRL 99, 091301)

NAIAD - NaI detectors, ran from 2000 to 2003. Used pulse shape discrimination, 44.9 kg x years exposure. Limit above „DAMA region".

ANAIS - NaI crystals, first 9.7 kg module in testing at Canfranc.

Princeton NaI Effort - R&D program on development of radioclean (^{40}K) NaI crystals. Inclusion of 4p liquid scintillator veto would reduce ^{40}K by many orders of magnitude.





COUPP - the reneissance of the bubble chamber

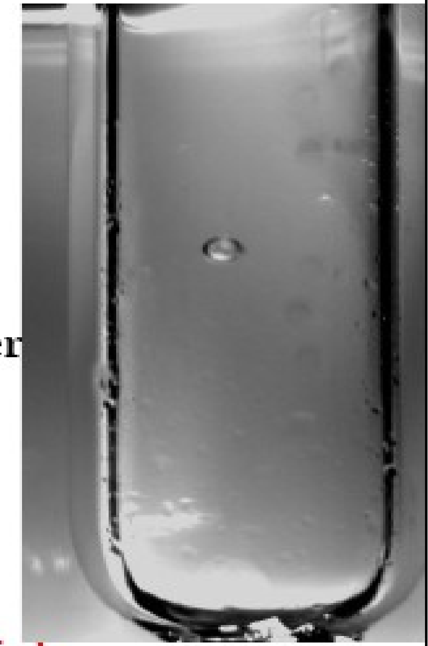
Why Bubble Chambers?

Large target masses would be possible.

- Multi ton chambers were built in the 50's- 80's.

An exciting menu of available target nuclei.

***No liquid that has been tested seriously has failed to work as a bubble chamber liquid* (Glaser, 1960).**

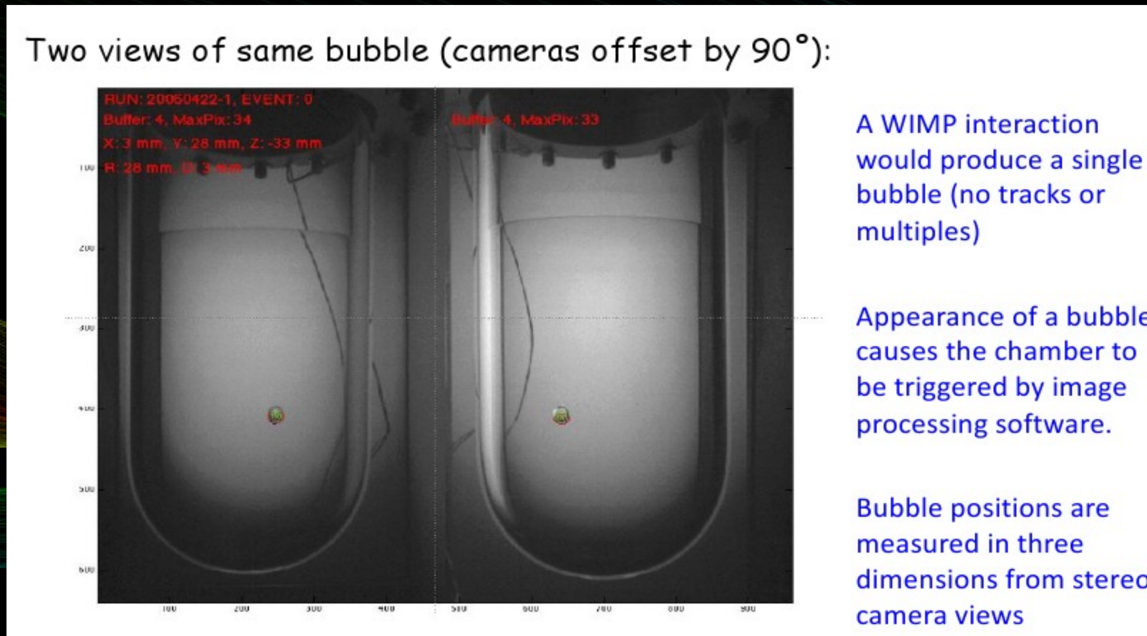


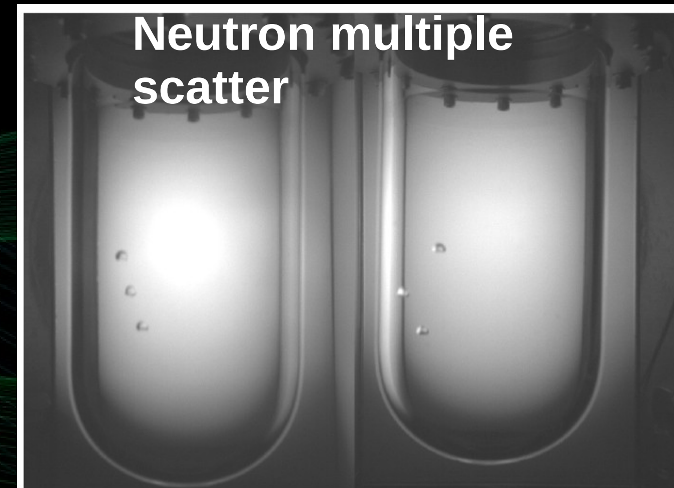
- Most common: Hydrogen, Propane
- But also "Heavy Liquids": Xe, Ne, CF_3Br, CH_3I, and CCl_2F_2.
- Good targets for both spin- dependent and spin-independent scatter
- Possible to "swap" liquids to check suspicious signals.

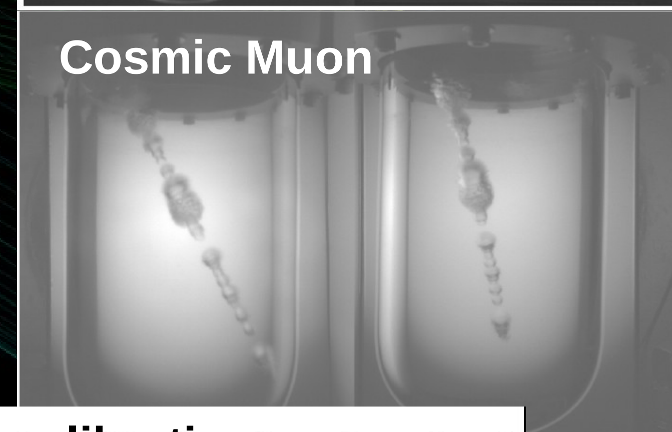
Backgrounds due to environmental gamma and beta activity can be suppressed by running at low pressure.

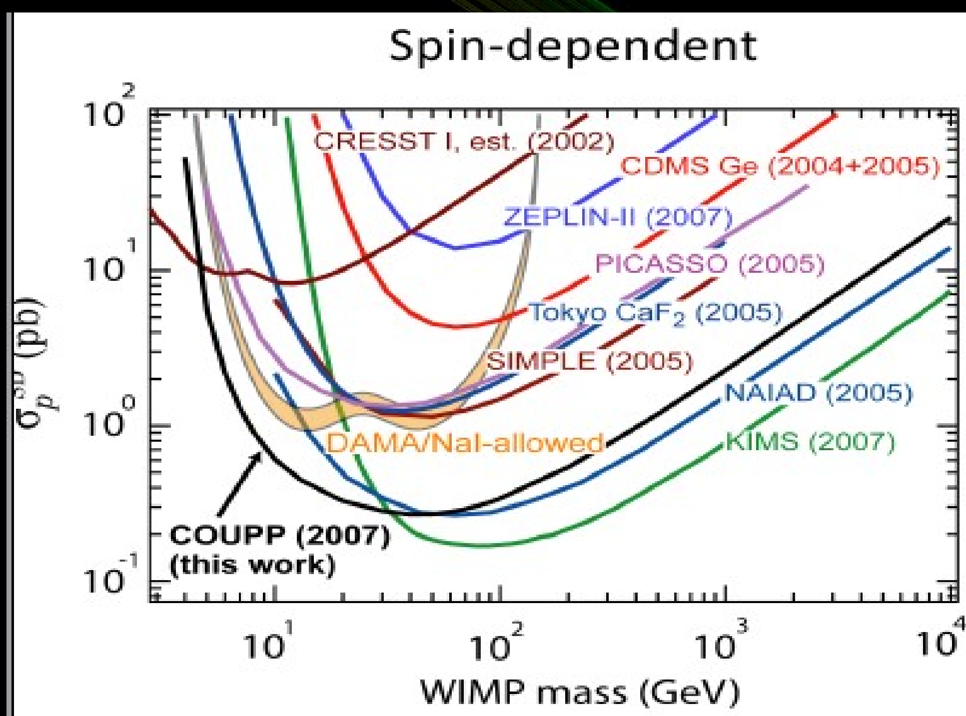
- Bubble nucleation depends on dE/dx, which is low for electrons, high for nuclear recoils

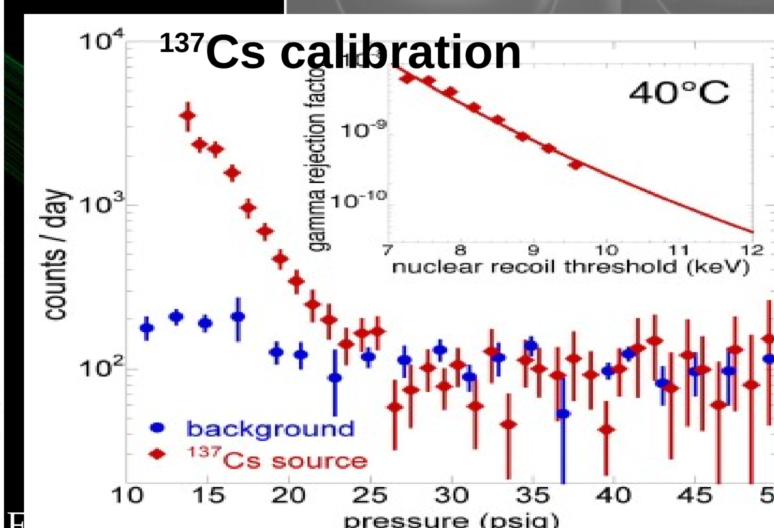
COUPP results











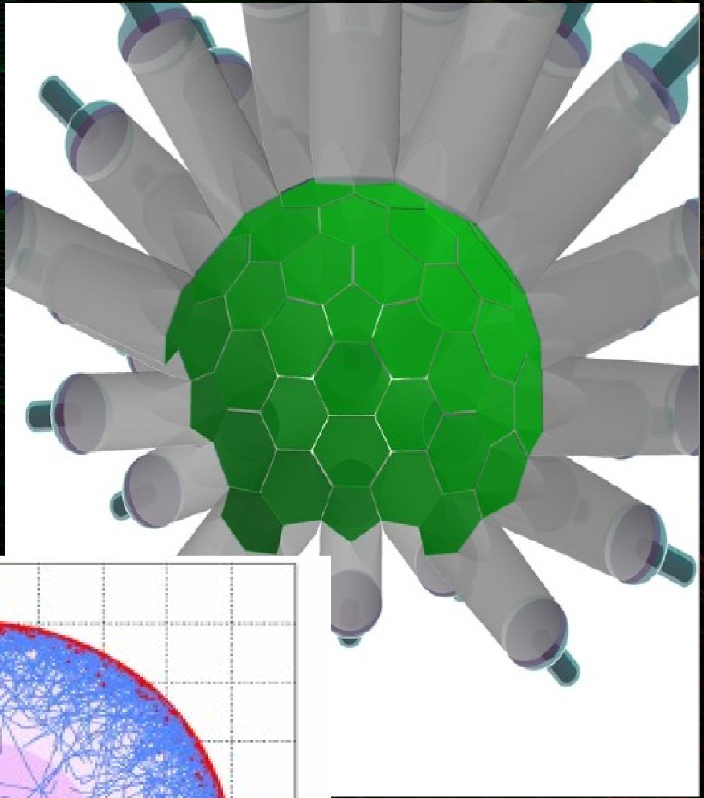
COUPP new results

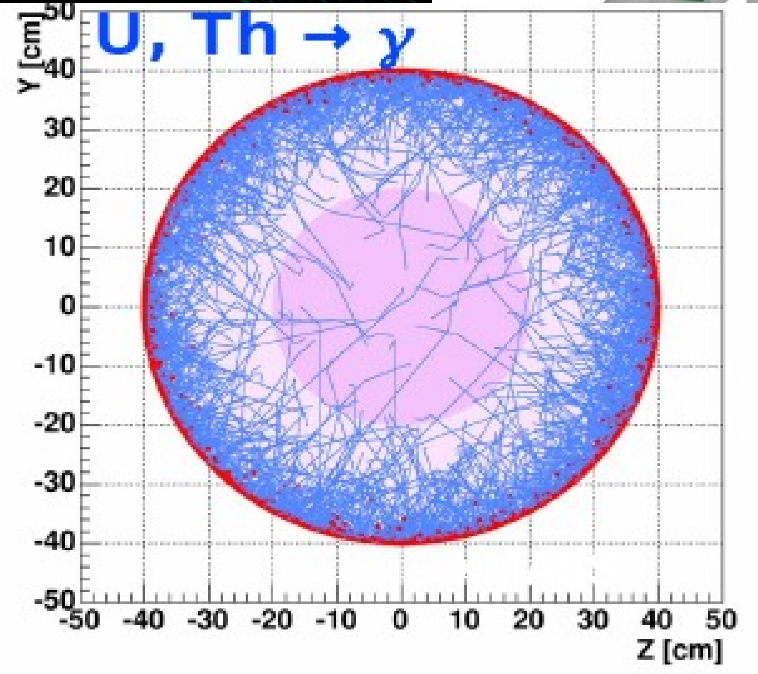
Single-phase detection technique

Usually 4π PMT coverage. This allows for event localization and detector fiducialization.

Self-shielding best in Xe detectors (3g/cm^3 density).

In Ar and Ne detectors pulse shape discrimination will also be used



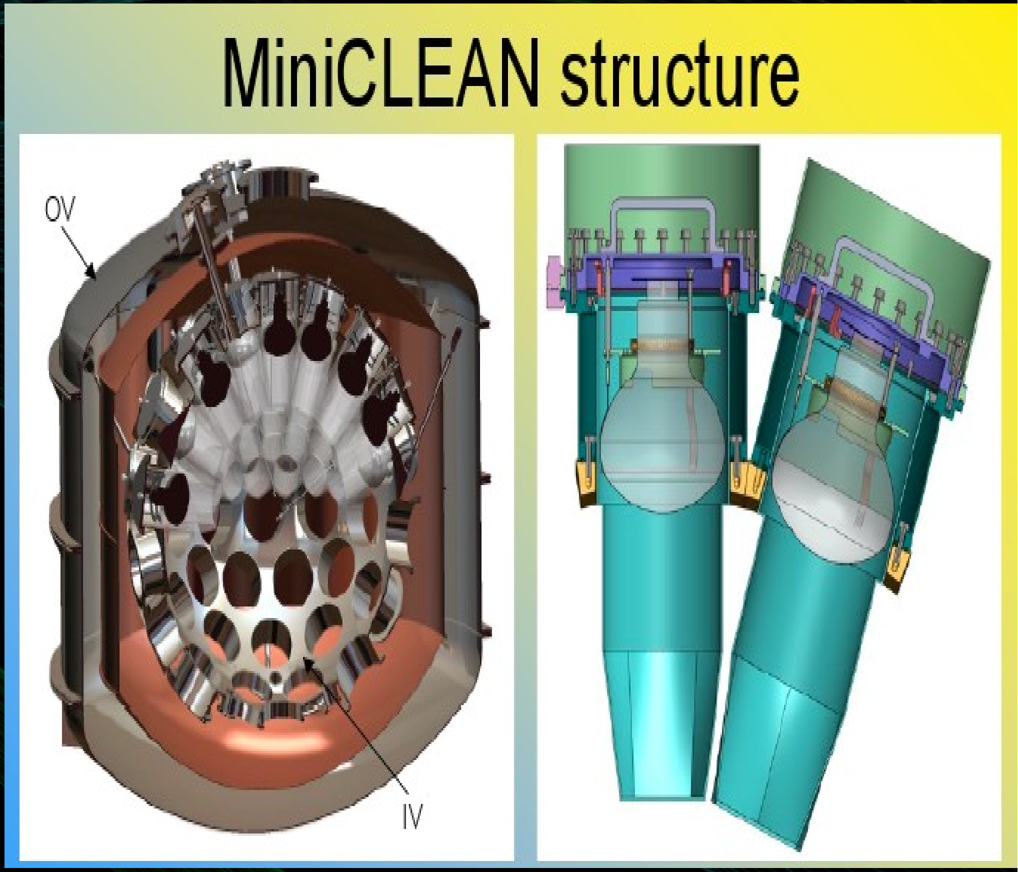


DEAP/CLEAN

The DEAP/CLEAN collaboration is planning to operate single phase argon and neon detectors, using only the pulse shape discrimination capabilities of these detectors.

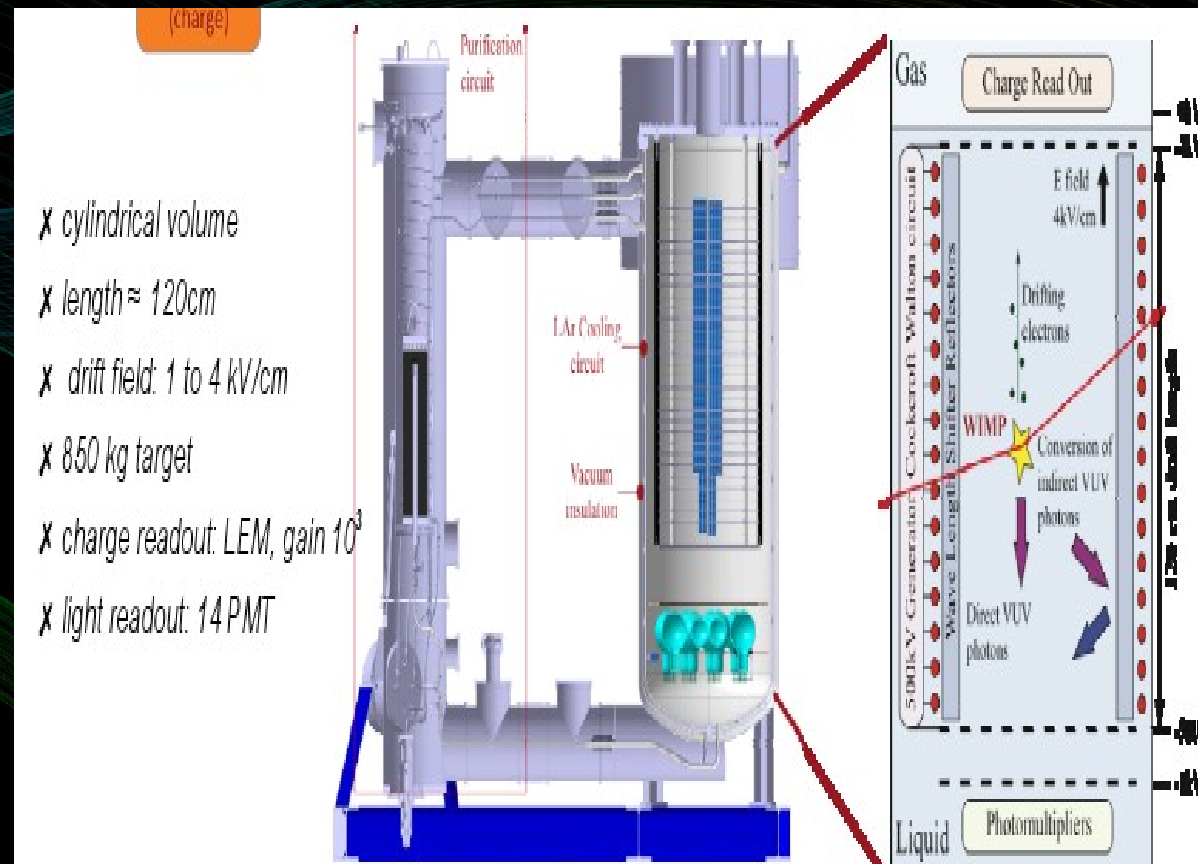
The MiniCLEAN detector with 150 kg of Fiducial mass is planned to be commisioned at SNOLAB in mide 2010.

In 2011 the DEAP-3600 detector with a fiducial mass of 1t is planned to be commissioned. Currently in design phase.



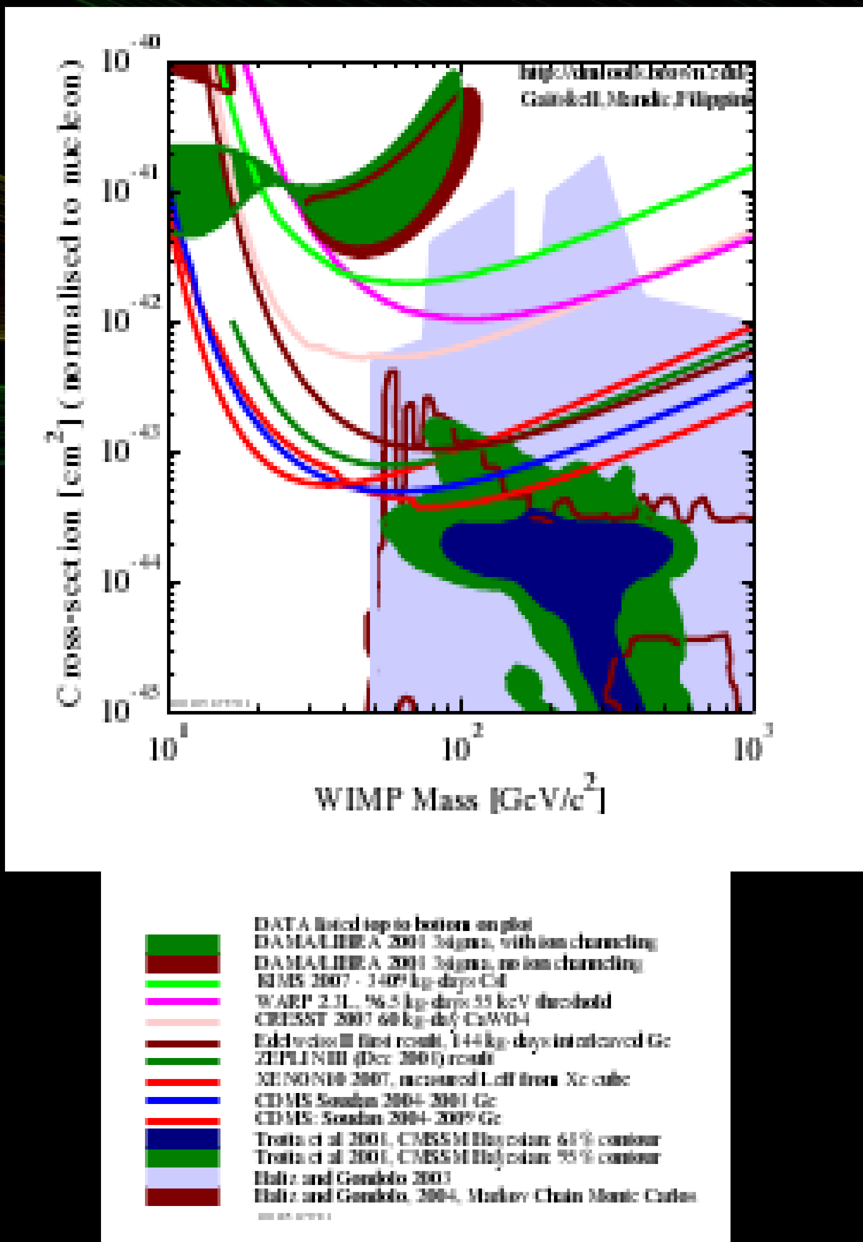
ArDM

- 1 ton double phase argon detector. Charge collected directly using LEM detectors.
- Chamber already operated at ground level with half ot the PMTs - obtained light yield of 0.5 phe/keV.
- Possible locations: **SUNLAB (Poland),** Canfranc (Spain), Slanic (Romania)
- Details in M. Haranczyk's talk.

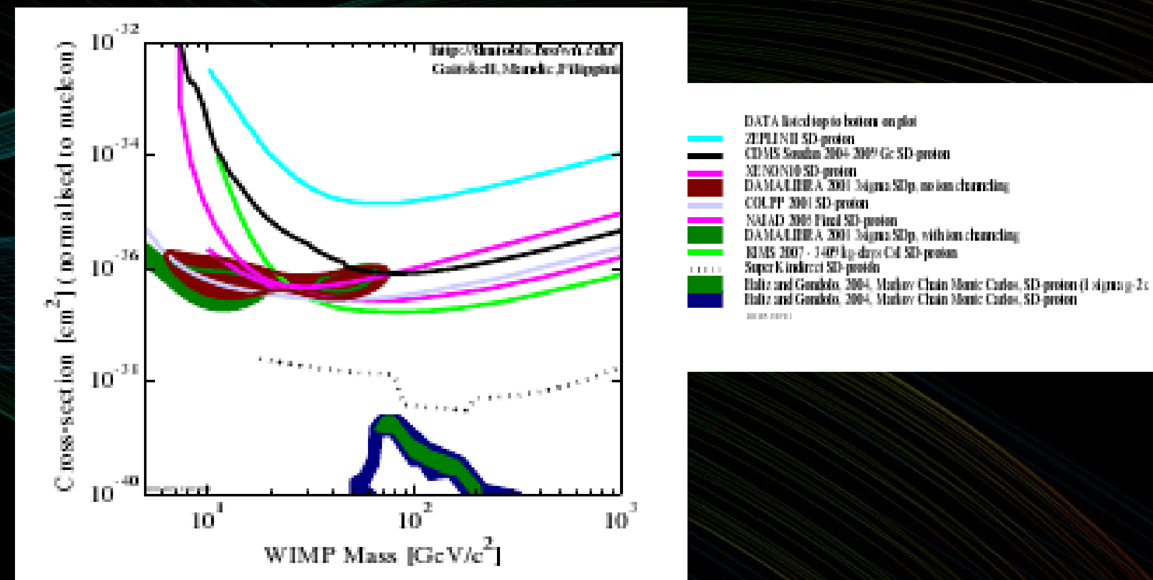


Current Experimental Status

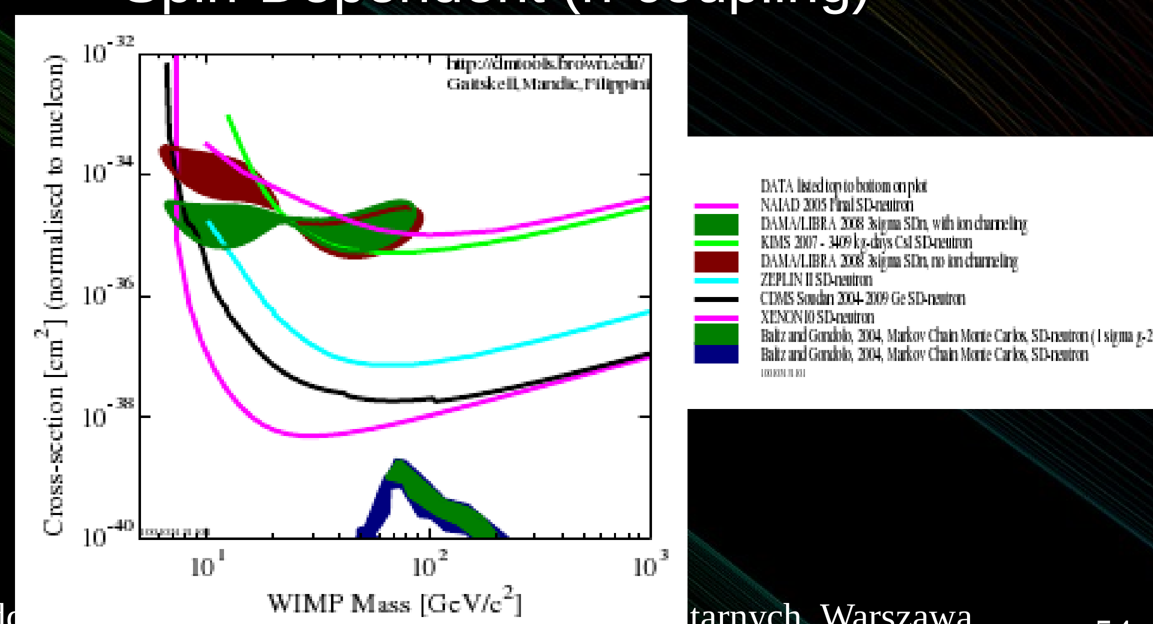
Spin - Independent



Spin-Dependent (p-coupling)



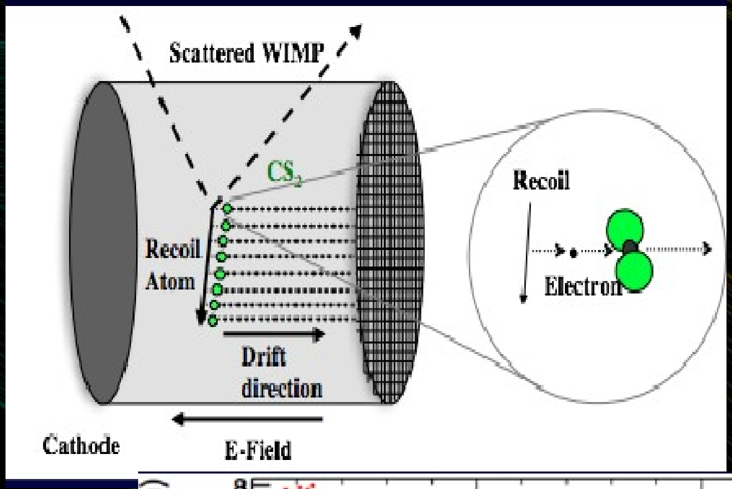
Spin-Dependent (n-coupling)



Directional detectors

The diurnal modulation could probide a powerful signal of DM, very hard to mimic by background. Need to measure nuclear recoil track directions.

Use TPC with low pressure gas and a large volume:



DRIFT at Boulby

- 1 m3 gas TPC (CS_2, possibly with CF_4 fraction)

NEWAGE at Kamioka

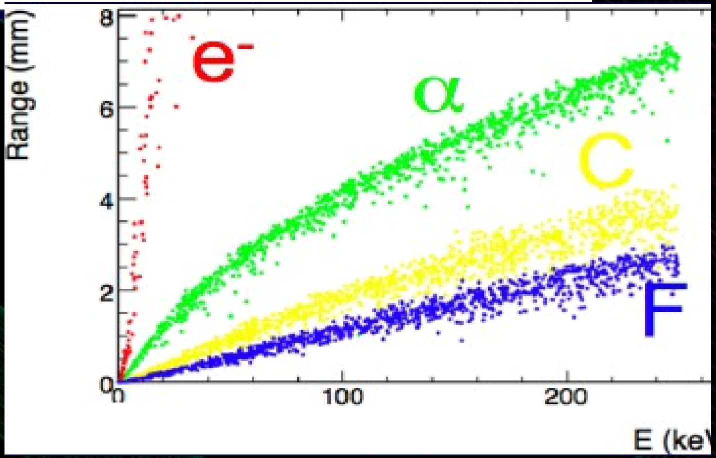
- 0.03 m3 gas TPC (CF_4), Low pressure (152 Torr), ~11 g

DMTPC

- 10 L gas TPC (CF_4), Low pressure (75 Torr), 3 g

MIMAC

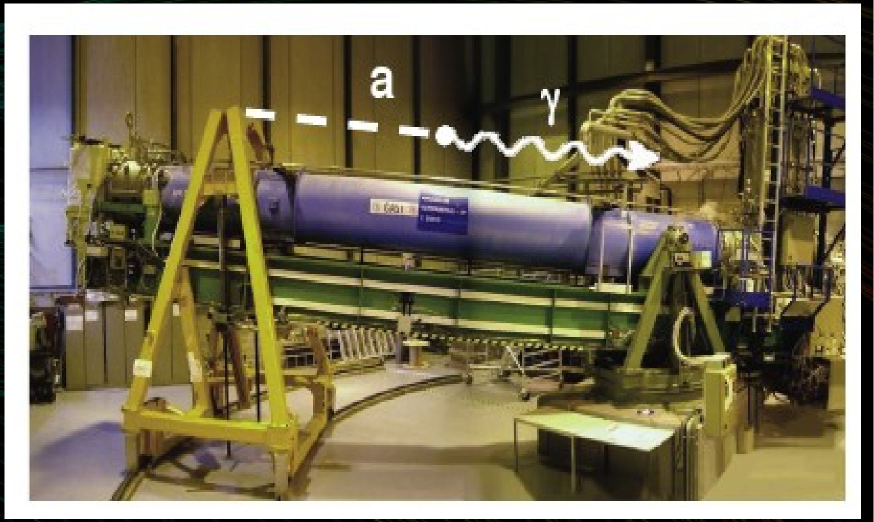
- (15 cm)3 gas TPC (3He or CF_4), Medium pressure (350 Torr)



Axion searches

The axion is a light pseudoscalar particle introduced to conserve CP in strong interactions.

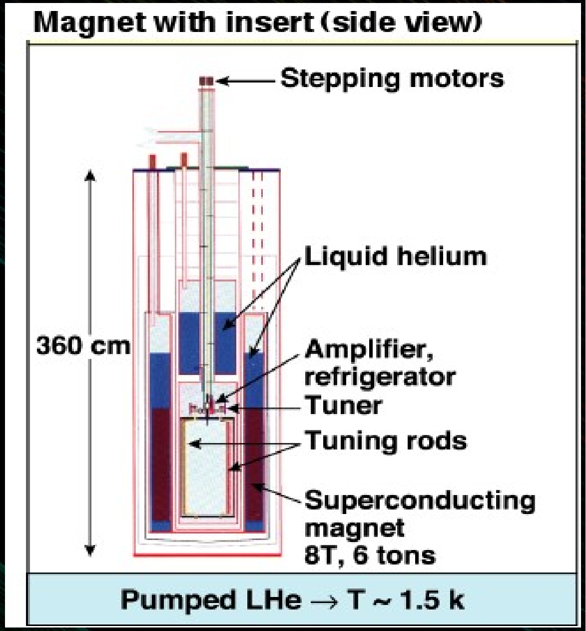
It couples weakly, has a low mass but is created non-thermally (can be Cold Dark Matter)



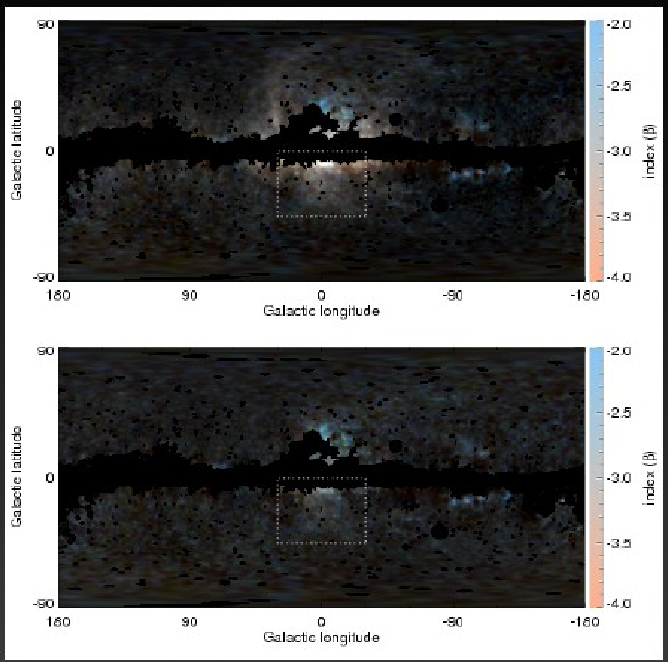
Can be detected mainly via the Primakoff Effect, i.e. Axion coupling to photons in a strong magnetic field:

CAST - conversion of axions from the Sun in a LHC magnet

ADMX - detection of halo axions in a RF cavity.



Other results

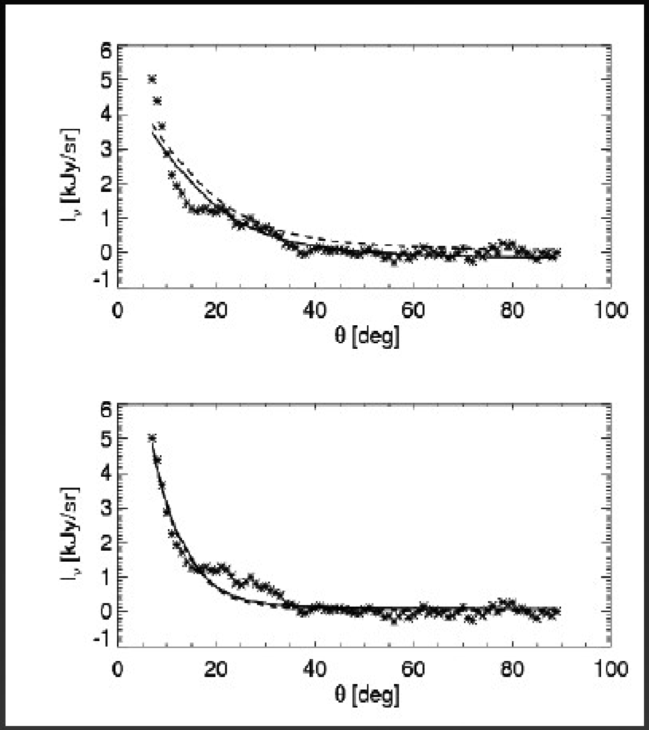


- Looks like synchrotron with, $E^2 dN/dE \propto E^{\alpha}$ $-0.1 \leq \alpha \leq 0.2$

Can be confirmed by **ICS** signa[...] *Fermi*!

Dobler & Finkbeiner (200[...]

dark matter and the haze



Galactic/baryon params:

$B \sim 10\ \mu G$

$K(E) \sim 10^{28}\ cm^2/s$

Dark matter params:

$\rho = \rho(r)$

$M \sim 100$ GeV

$<\sigma v> \sim$ few $x10^{-26}\ cm^3/s$

the haze is **consistent** with a WIMP annihilation scenario