Laboratori Nazionali del GranSasso 21-03-2009

WARP

WIMP ARGON PROGRAMME

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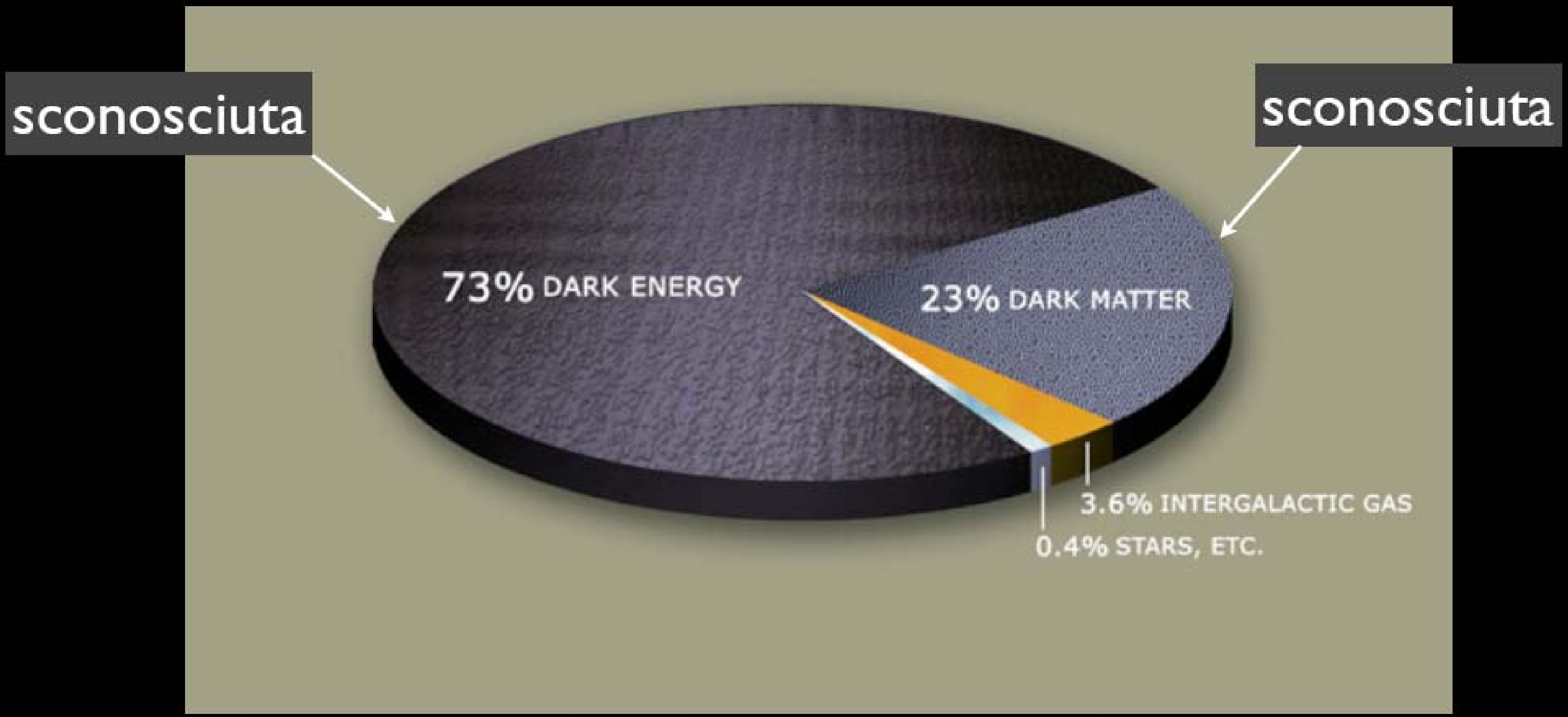
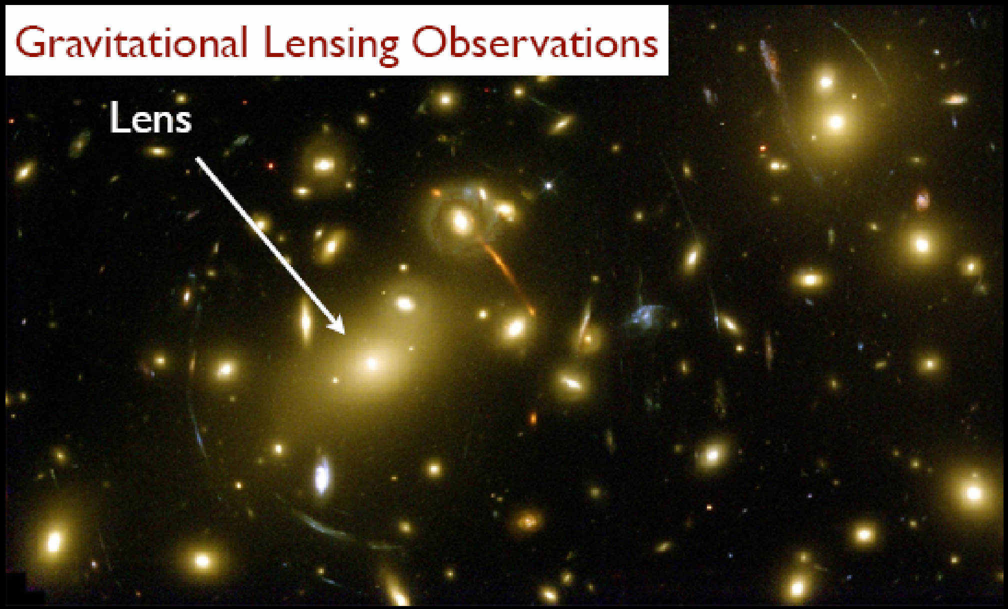
più del 95% dell`Universo ci è sconosciuto!!!



compresa la natura della Materia Oscura

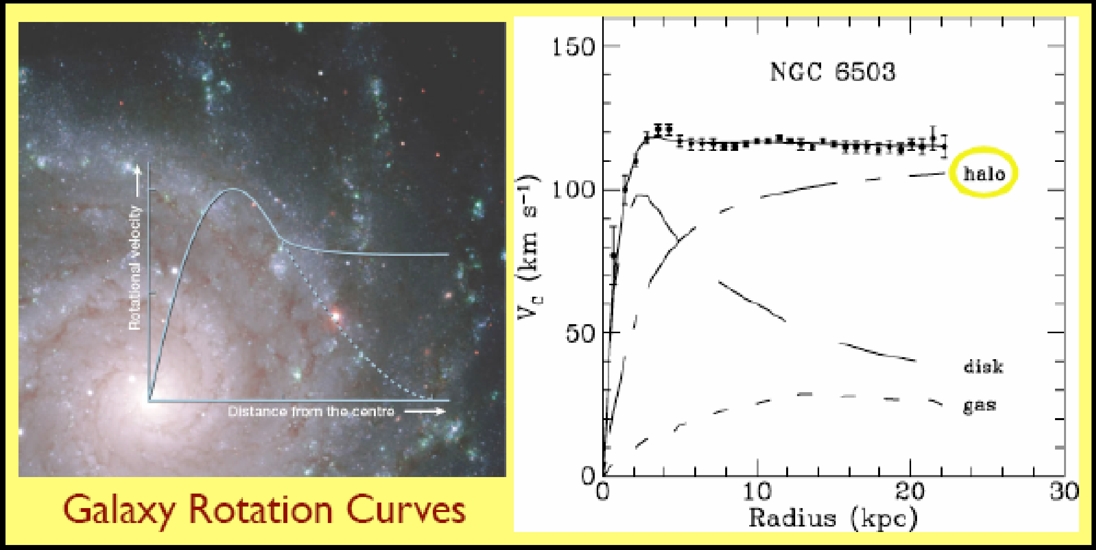
Dark Matter Puzzle

Dynamic of galaxies in Clusters



Gravitational Lensing Observations

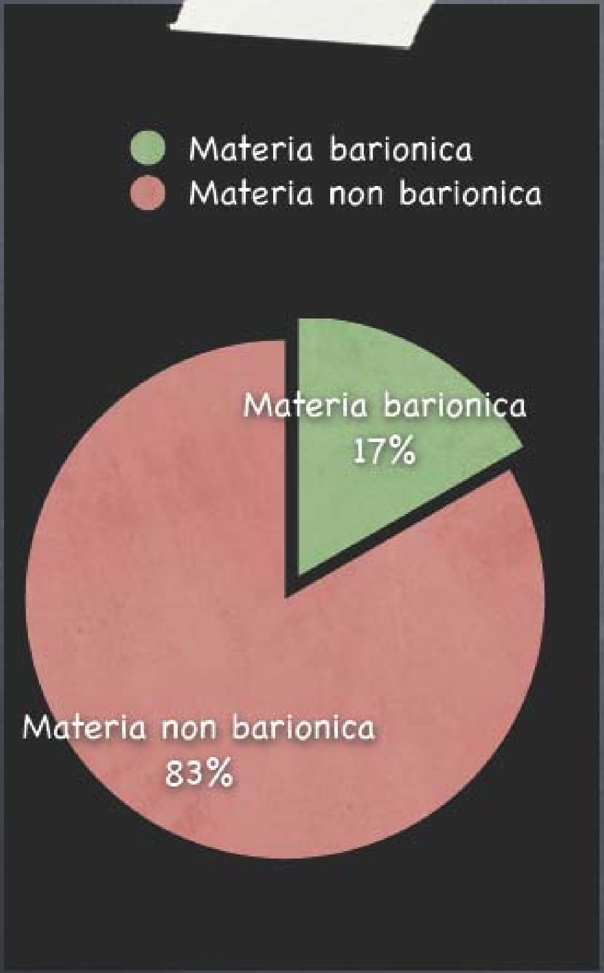
Merger Cluster



Galaxy Rotation Curves

Materia oscura

Esiste una teoria chiamata NUCLEOSINTESI molto accreditata e confortata dai risultati sperimentali che LIMITA la quantità di materia BARIONICA esistente nell'universo:



Al massimo il 17% della materia necessaria per giustificare $\Omega_m = 0.3$ può essere costituito da MATERIA ORDINARIA BARIONICA.

Se i MACHOs esistono possono giustificare solo una piccola porzione della materia oscura.

↓

CERCHIAMO LA MATERIA OSCURA SOTTOFORMA DI PARTICELLE ELEMENTARI!!!

Materia oscura

come particelle elementari

- Non Barionica (dalla nucleosintesi);
- Neutra (altrimenti interagirebbe elettromagneticamente);
- Fossile e Stabile (si deve essere disaccoppiata dall'equilibrio termico in modo tale da garantire una quantità di materia sufficiente per spiegare il problema della massa mancante); con questa richiesta sto imponendo implicitamente delle condizioni sulla sua MASSA e sulla probabilità di interazione con la materia ordinaria (sezione d'urto).
- Cold (non relativistica al momento del disaccoppiamento dipende dalla sezione d'urto, dalla massa e dal rate di espansione dell'universo);

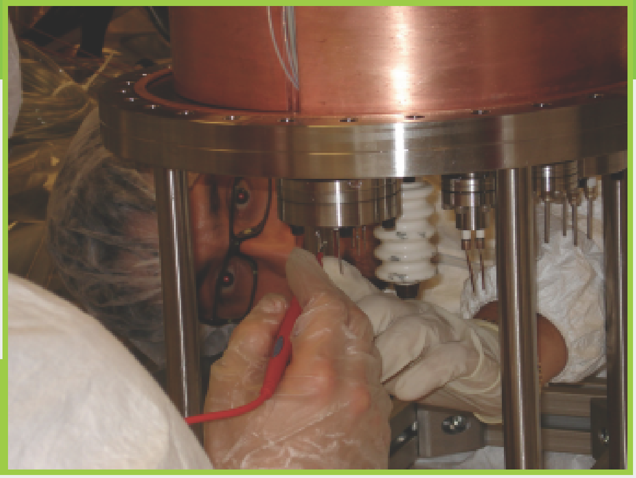
Una WIMP (Weak Interactive Massive Particle) avrebbe tutte le giuste caratteristiche.


World Wide Dark Matter Searches
Yangyang
KIMS
Homestake
LUX
SNOLAB
DEAP/CLEAN
PICASSO
Boulby
ZEPLIN
DRIFT
Kamioka
XMASS
Soudan
CDMS
Frejus/
Modane
EDELWEISS
Canfranc
ANAIS
NEXT
ArDM
Gran Sasso
CRESST
DAMA/LIBRA
WARP
XENON

Rivelazione di Materia Oscura al Gran Sasso

CRESST

WArP



Xenon

DAMA

La Collaborazione WARP

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Dark Matter & Liquid Argon

Direct detection of Dark Matter with noble gases liquified as target medium is one of the most promising line of development in experimental technology.

A particle interacting in noble liquid produce both atomic excitation and ionization inducing the emission of scintillation light.

Simultaneous measurements of free electron charge and light is at the basis of a strong discrimination power

Argon is an ideal medium for Dark Matter search and the feasibility of Ar-based detectors has been firmly proved by the WArP Collaboration [*Astropart. Phys. 28 (2008), 495*].

Why noble liquids?

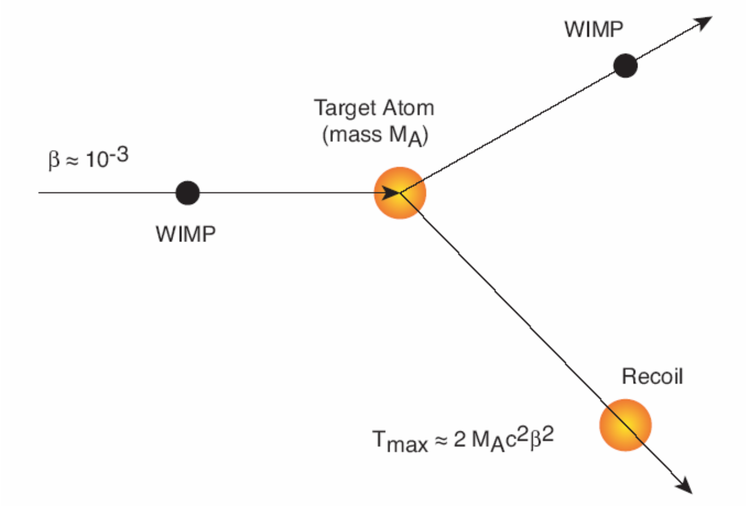
- High scintillation Yield
- Simultaneous measurement of scintillation and ionization (particle discrimination)
- Potentiality to be extended to multi-ton volumes

Scintillator	NaI(Tl)	Liquid Argon	Liquid Xenon
Photon Yield [ph/MeV]	4.3×10^4	4.0×10^4	4.2×10^4
Fast Decay Time [ns]	-	6	2.2
Slow Decay Time [ns]	250	1200-1500	27

Why liquid Argon?

- Scintillation decay times very different ($\tau_f \approx 6$ ns , $\tau_s \approx 1200\text{-}1500$ ns) → Two independent discrimination tech. very efficient background reduction!
- Argon Technology fully operational
- Easily available (1% of atmosphere) → low cost

The WARP Experiment: detection of WIMP-Ar elastic scattering

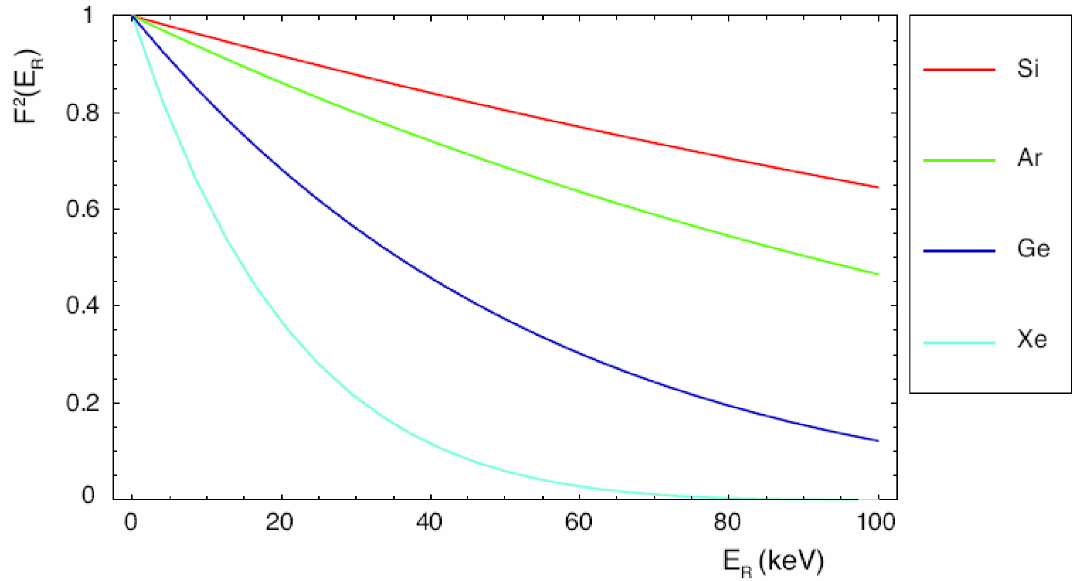


$$R(E_1, E_2) = \int_{E_1}^{E_2} c_1 \frac{R_0}{E_0 r} e^{-c_2 \frac{E_R}{E_0 r}} F_A^2(E_R)\, dE_R$$

Argon recoil energy is in the range $E_R \sim 10 \div 100$ keV

Coherent cross section behave as A^2 (A=40 for Argon)

Spin-independent form factor since natural Argon is composed by spinless isotopes



Liquid Argon scintillation light emission

An interaction in argon produces Atomic

✓ excitation
✓ ionization

→ emission of 128 nm luminescence through 2 processes

self trapped exciton luminescence

1)

$$Ar^* :$$

$$Ar^* + Ar \rightarrow Ar_2^*$$

$$Ar_2^* \rightarrow 2Ar + h\nu$$

recombination luminescence

2)

$$Ar^+ :$$

$$Ar^+ + Ar \rightarrow Ar_2^+$$

$$Ar_2^+ + e^- \rightarrow Ar^{**} + Ar$$

$$Ar^{**} \rightarrow Ar^* + heat$$

$$Ar^* + Ar \rightarrow Ar_2^*$$

$$Ar_2^* \rightarrow 2Ar + h\nu$$

both processes

- ✓ ending up with the same radiative reaction
- ✓ inducing the emission of a 128 nm UV photon

The WARP detection technique

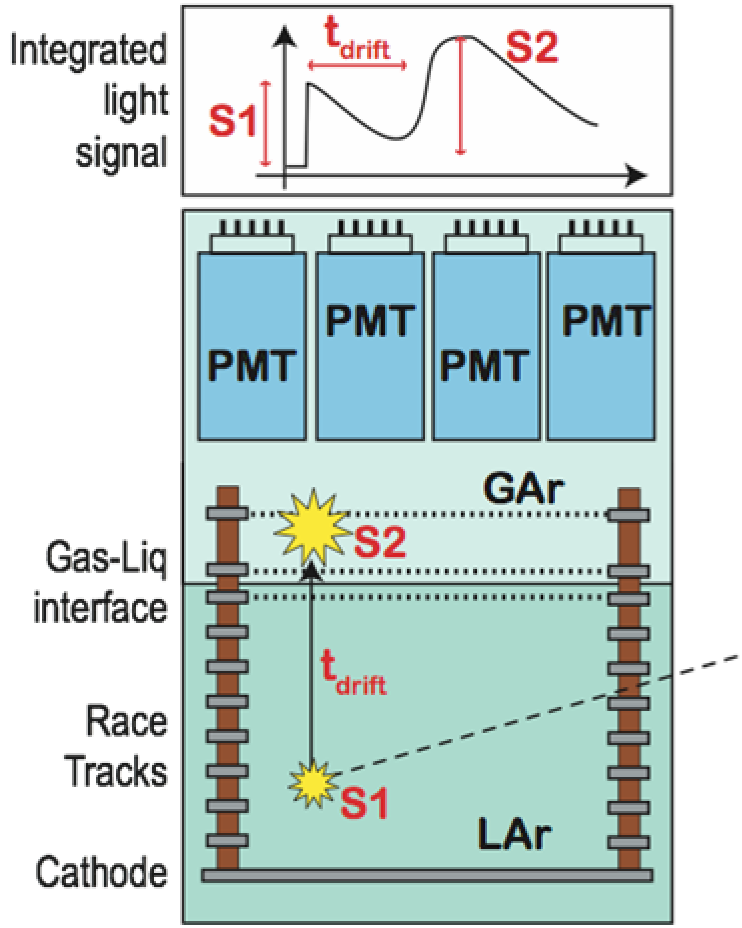
"Identification of the nature of a particle interacting within a double phase Argon detector by means of the simultaneous measurement of the produced scintillation and ionization" **(WARP Letter of Intent 1999)**

In liquid Argon for energy depositions in the range of interest for Dark Matter searches (20-100 keV) we have that

- the amplitude of the first signal (S1)
- the pulse shape of the first signal (S1)
- the amount of free electrons that drift toward the multiplication grids (S2)

strongly depend on the nature of the ionizing particle (Ar recoil, electron, heavy ion, etc)

These quantities can be used to characterize WIMP induced Argon recoils



Background rejection using Pulse Shape Discrimination on S1

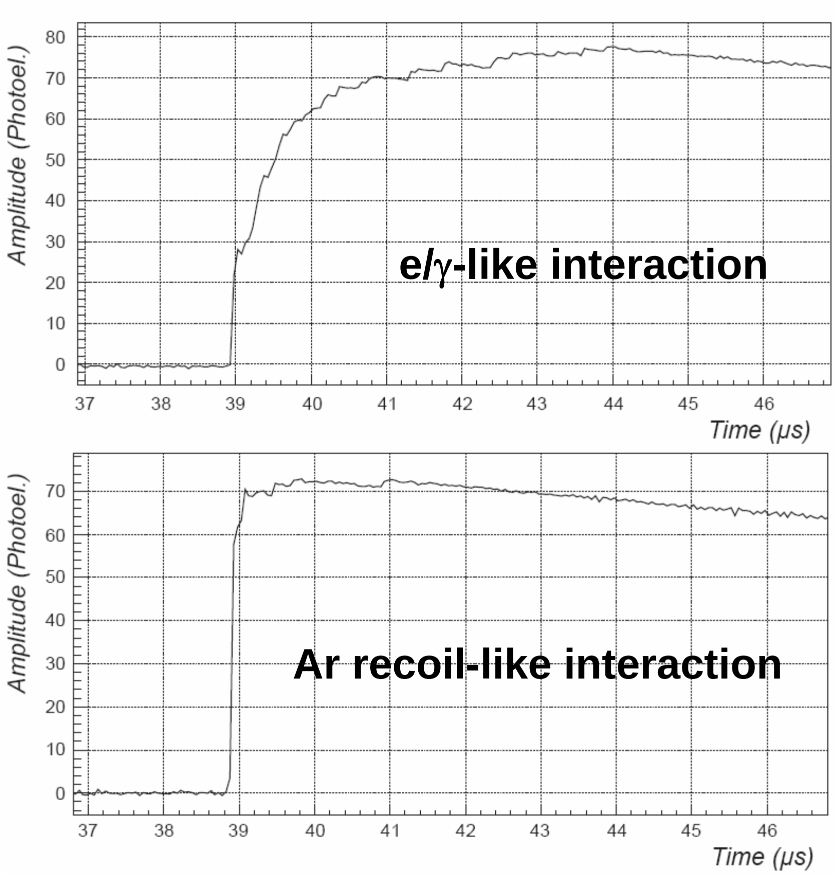
Time structure of scintillation light in noble gases is characterized mainly by de-excitation of $^1\Sigma$ (singlet) and $^3\Sigma$ (triplet) molecular states

These states, almost degenerate in energy, are characterized by very different decay times:

- singlet (fast component) ~ 7 ns
- triplet (slow component) ~ 1.4 μs

Fast and slow components are very differently populated by different ionizing particles (depend on the ionization density)

A. Hitachi et al., Phys. Rev. B 27 (1983)



The wide difference between fast and slow decay times is a unique feature of Argon

A parameter F has been adopted to characterize the S1 rising time

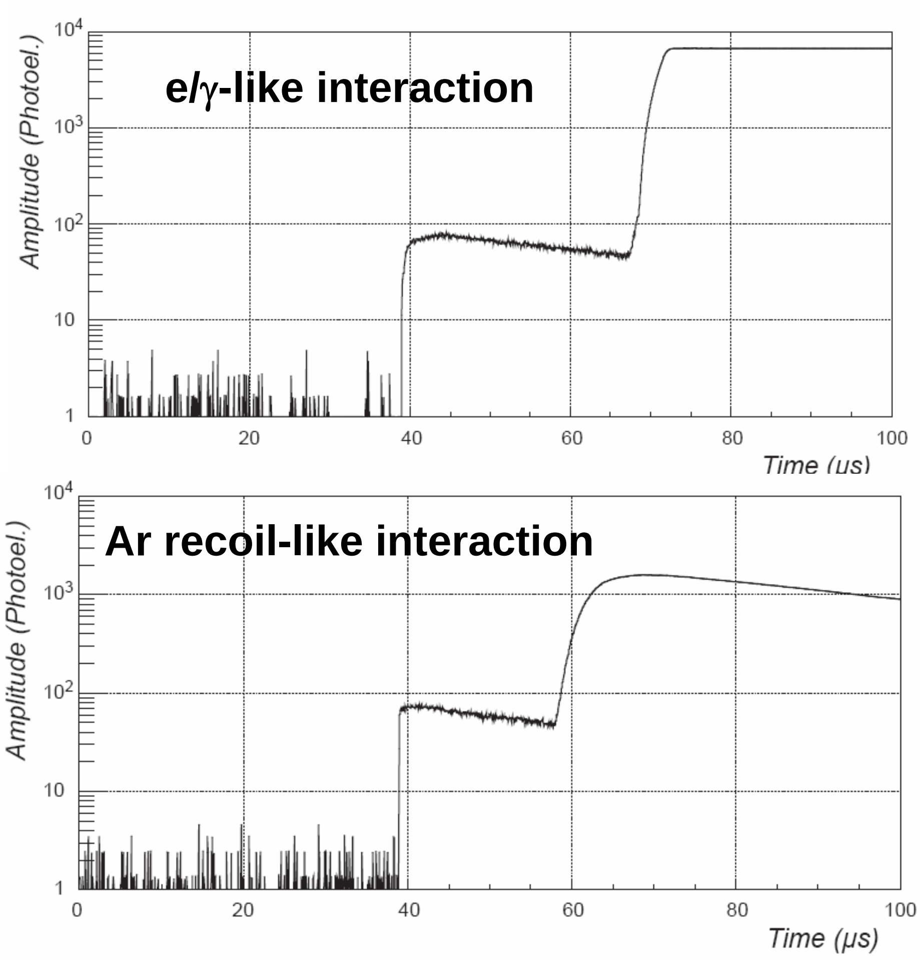
Background rejection using S2/S1

The amount of primary scintillation light (S1) depends on the ionizing particle and on the deposited energy
T. Doke et al., NIM A 269 (1988)

This holds also for the amount of free electrons surviving Ar^+ e^- recombination (S2)

In the 2.3 litre prototype the S2/S1 ratio is found to be:

~ 150 for electron-like interactions
~ 3 for α interactions



WARP 2.3 litre results

neutron induced Ar recoils

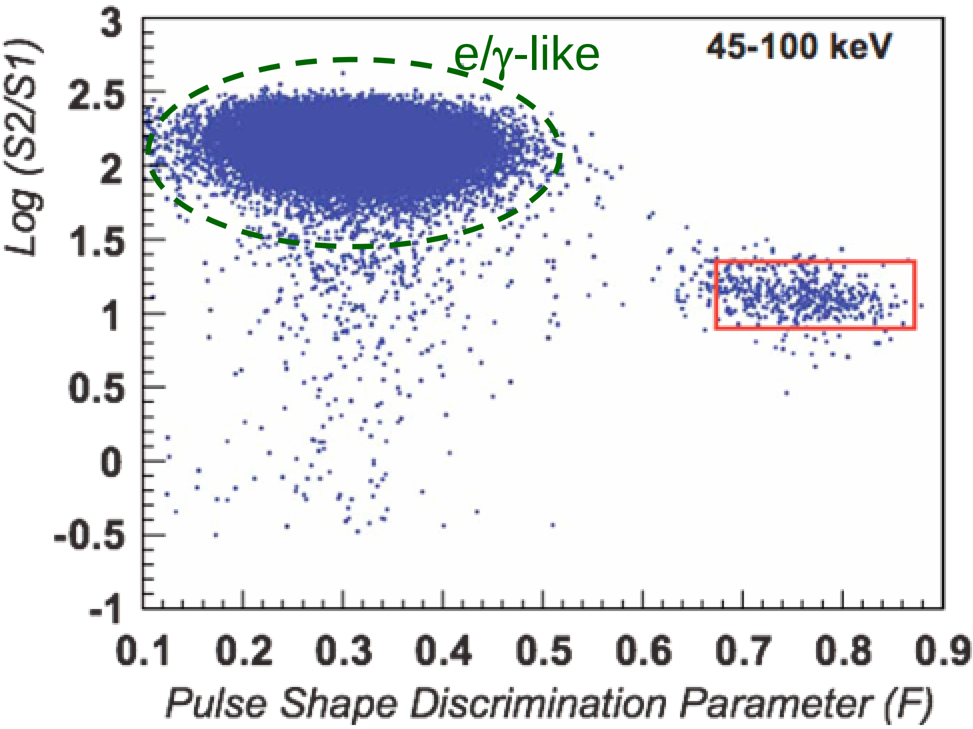
(Am-Be calibration source)

Calibration neutrons are characterized by

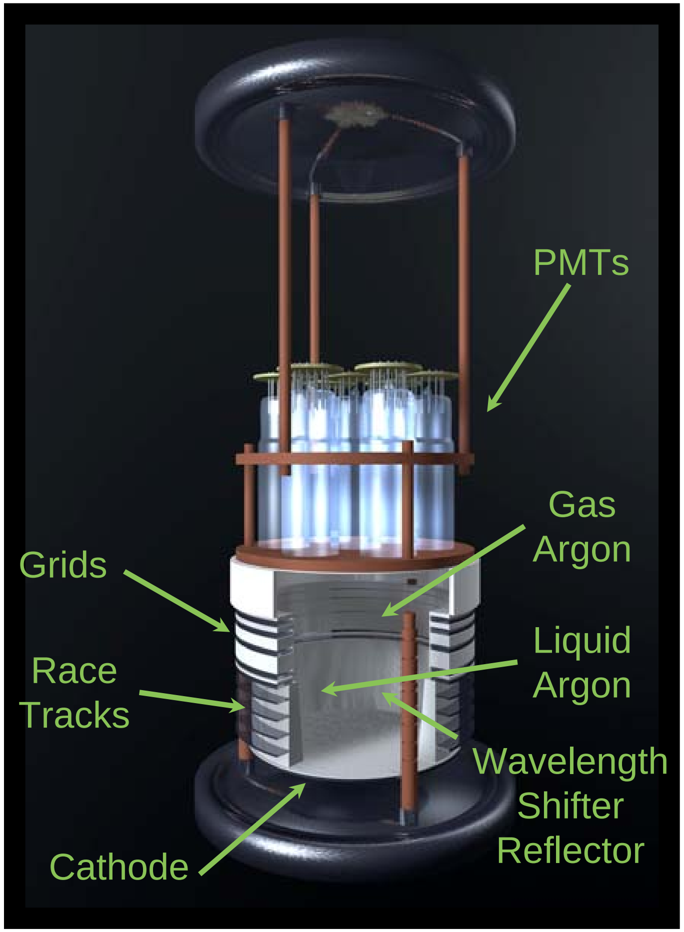
$0.68 \leq F \leq 0.87$

$8 \leq S2/S1 \leq 30$ (energy dependent)

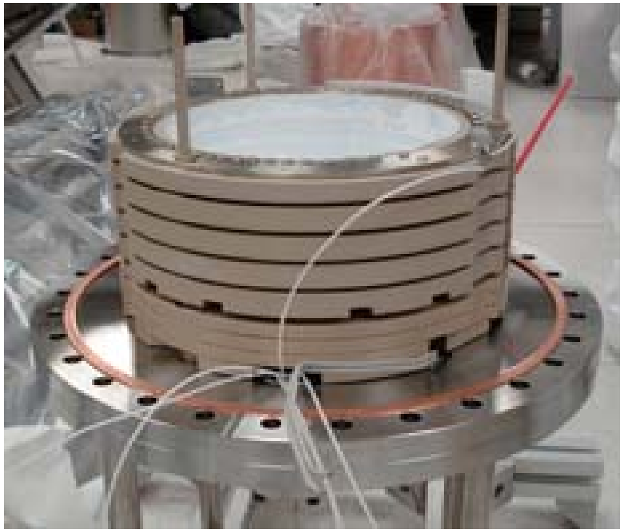
The simultaneous application of both identification techniques allows highly efficient discrimination of neutron induced Argon recoils from electron/gamma-like interactions.



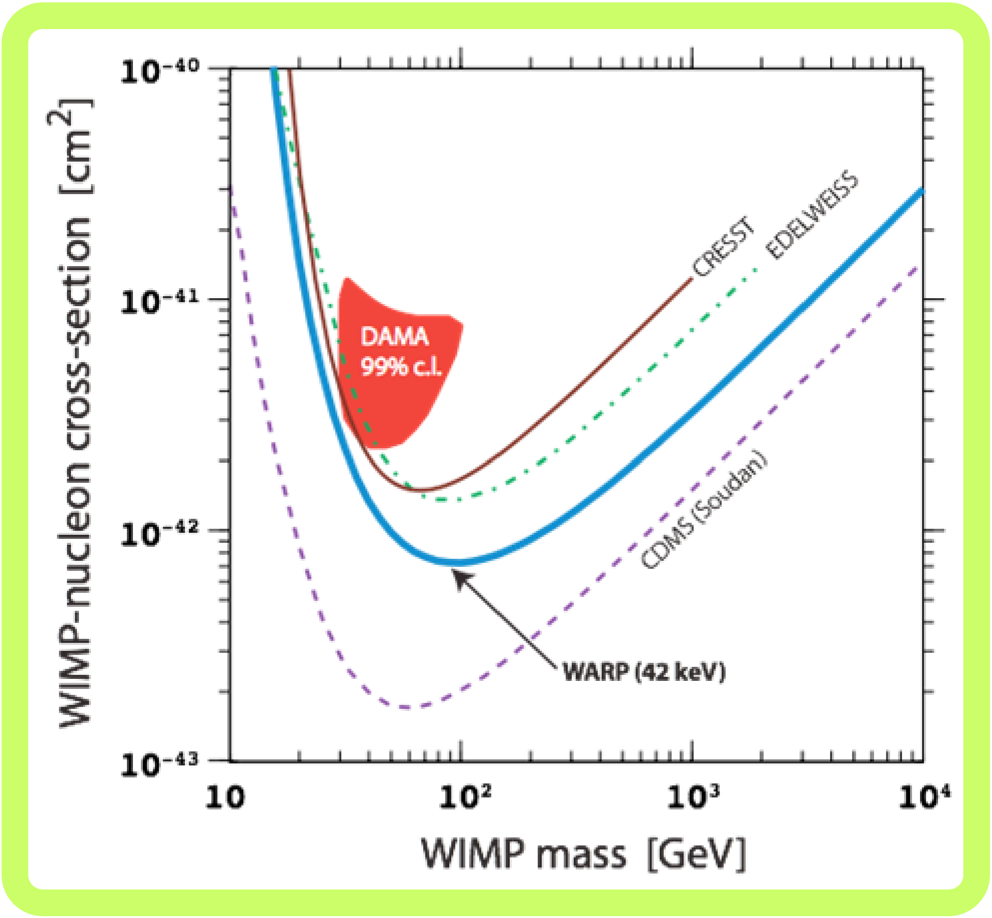
Prototipo da 2.3 litri al LNGS



- **PMTs: 7×2” (designed by EMI to work at 87 K)**
- **7.5 cm depth (40 μs max drift time with 1kV/cm)**
- **stable Argon purity (<1 ppb O_2 equiv.)**
- **Passive shield (10 cm Pb + 60 cm Polyethylene)**
- **Trigger threshold of about 5 keV (6 Hz rate)**



Risultati della presa dati del prototipo da 2.3 litri in Hall B

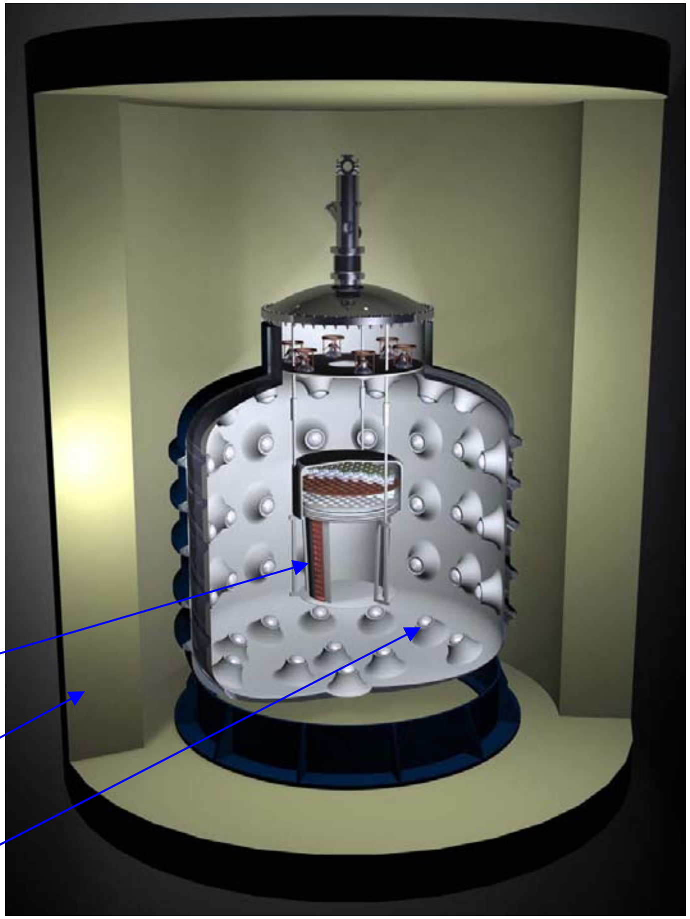


Astroparticle Physics 28 (2008) 495

WARP: the detector

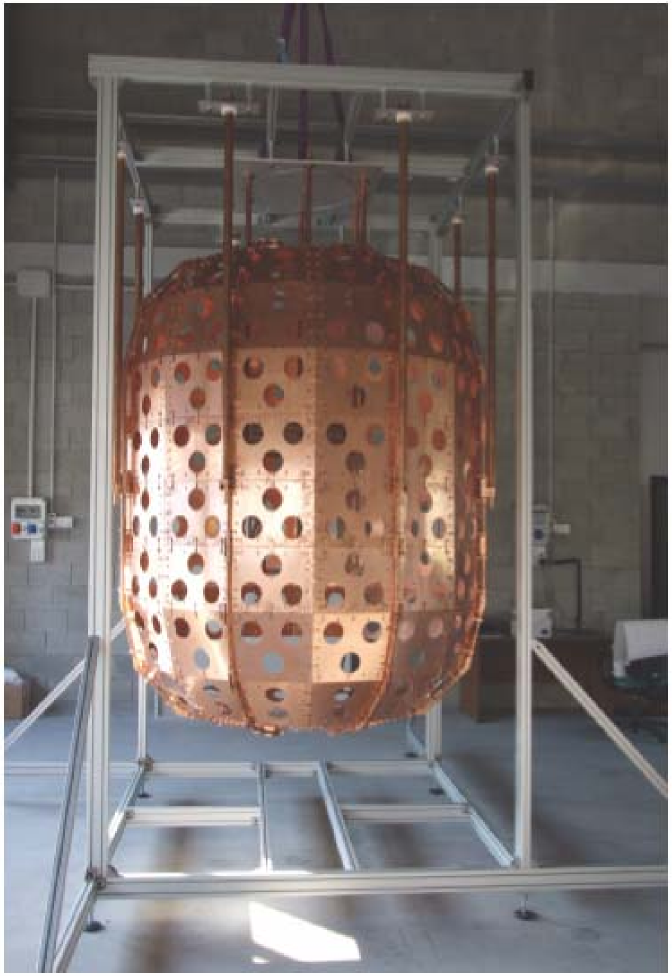
Under construction at Gran Sasso underground Laboratories

- High sensitive mass
  (140 kg scalable to 1 Ton)
- Detector threshold ≤ 20 keV
- Active shielding
  (8000 kg Liquid Argon and 300 3” PMTs)
- Gamma shield (Pb)
- Neutron shield (Polyethylene)
- Low activity materials



WARP Detector mechanics

WIMP ARGON PROGRAMME



Active VETO

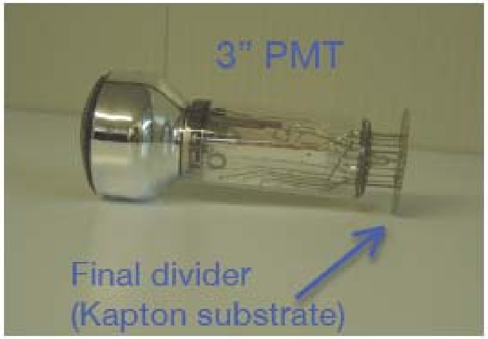
Polyethylene shield

Inner Detector

WARP Pre-assembly operations

WIMP ARGON PROGRAMME

- The inside of the detector is covered with a highly reflective foil, covered by a wavelength shifter (TPB)
- All detector components are pre-assembled in a clean area of the external facilities of LNGS
- The wavelength shifter is evaporated on the plastic reflective layer (and on PMTs)

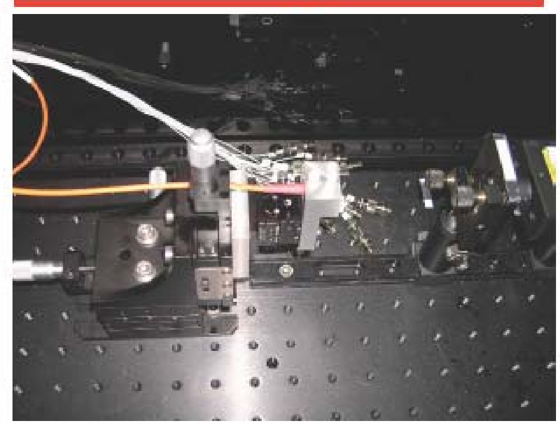


WARP Photomultipliers

WIMP ARGON PROGRAMME

- 3” and 2” Bialkali Photomultipliers developed in co-operation with **Electron Tubes EMI** to work at **LAr temperature (ETL D750UKFLA, D757UKFLA)**
- **7% coverage** in the active veto
- **10% coverage** in the inner detector
- Low activity (0.2 Bq/PMT) and high QE (19% on average)

More than 400 PMTs verified to work at cryogenic temperature (77 K) in Napoli INFN laboratories and delivered to LNGS



WARP 140 kg status and expected performances

- **Detector construction is (almost) complete**

- **Liquid Argon filling procedure will start at the end of March...**