LAr Detectors

(proposed by **Carlo Rubbia** in 1977)

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Detectors for Neutrino

- Neutrino telescopes
- Liquid scintillator detectors
- Liquid Argon detectors

Plan of Talk

- Detectors for Neutrino
- Why LAr Detector
- Merits of Ar over Xe & Ne
- Various LAr detectors
- Detector details
- Magnetized Liquid Argon TPC
- Future detectors

Why LAr

- Precise particle identification
- High background rejection (due to their very high spatial resolution)
- Fine grained 3D imaging
- Simultaneous detection of both ionisation and scintillation.
- Density (gm/cm^3) differences of WC (1.3), LS (0.8 to 1.0) & LAr(1.39) favors the LAr to have 40-50% more targets per unit volume.

Liquid Scintillators(LS), Water Cherenkov (WC) and Liquid Argon (LAr) detectors

Merits of Ar over Xe & Ne

- The event rate in argon is less sensitive to the energy threshold than in xenon, due to form factor effects
- Argon is cheaper than xenon
- Readily conceivable, safe and economically affordable.
- Ar has larger scattering cross section than Ne.

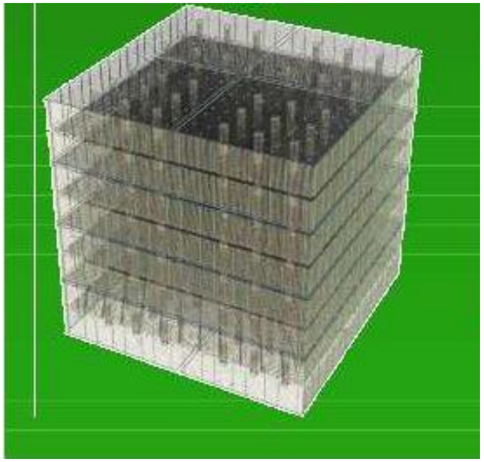
Various LAr detectors

GLACIER

ICARUS

WIMP

LANNDD

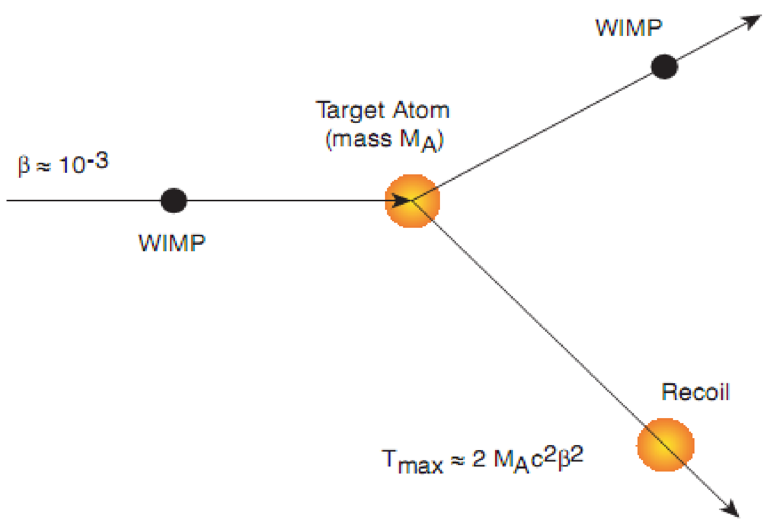


LANNDD (Liquid Argon Neutrino and Nuclear Decay Detector)

- Search for $p \to k^+ + \bar{\nu}_\mu$ to 10^{35} years lifetime
- Detection of large numbers of solar neutrino events and supernova events
- Study of atmospheric neutrinos
- Use as a Far Detector for a Neutrino Factory in the USA, Japan or Europe

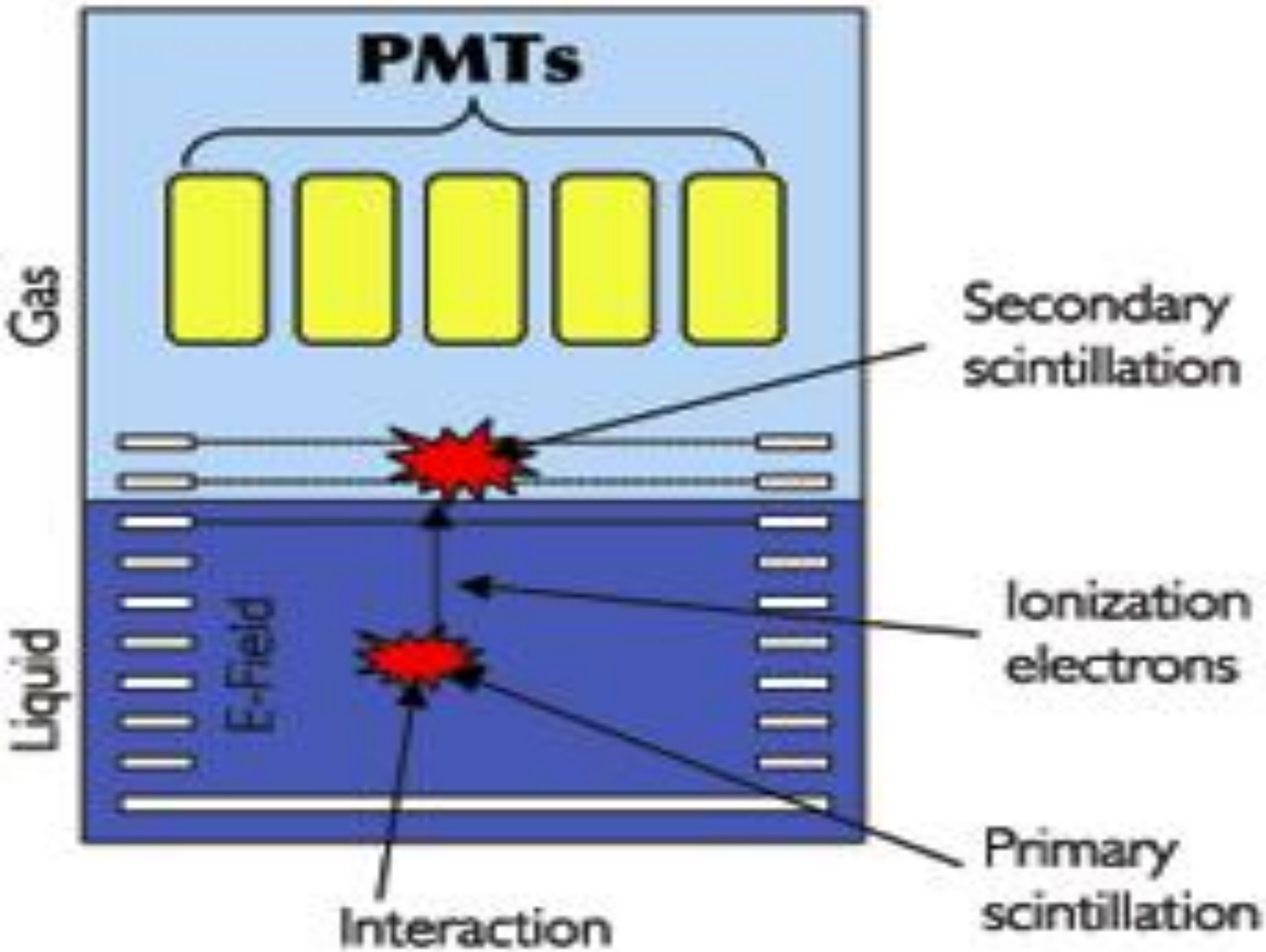
ArDM (Argon Dark Matter experiment)

• To **detect nuclear recoils and the spectrum induced by** Weakly Interacting Massive Particles(WIMP) interactions in the detector.



•Energy range **10-100 keV.**

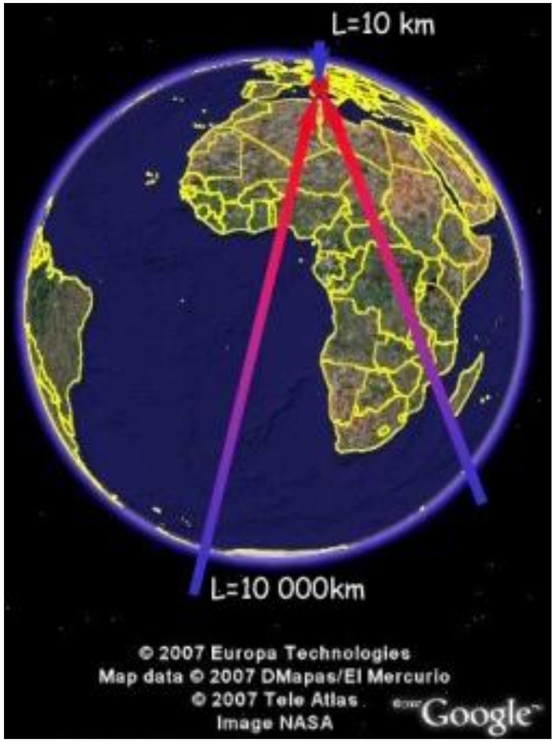
Working of the detector



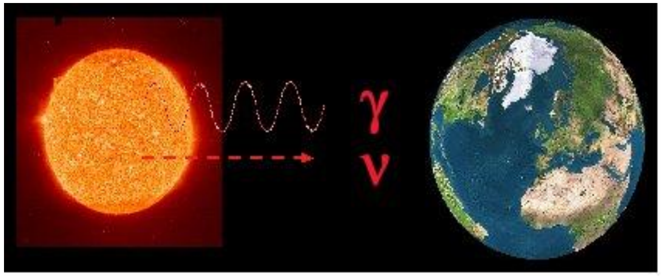
ICARUS
(Imaging Cosmic And Rare Underground Signals)

- Atmospheric neutrinos
- Solar neutrinos
- Supernovae neutrinos
- CNGS beam neutrinos
- Proton decay

Atmospheric neutrinos



The ICARUS detector will look for the oscillation of atmospheric neutrinos that are passing through the Earth



Solar neutrinos

Main nuclear interactions responsible for the neutrino production inside the sun are

- $^{1}H + {}^{1}H \rightarrow {}^{2}H + e^{+} + \nu$ (0.420 MeV)
- $^{7}Be + e^{-} \rightarrow {}^{7}Li + \nu$ (0.861 MeV, 90%)(0.383 MeV, 10%)
- $^{8}B \rightarrow {}^{8*}Be + e^{+} + \nu$ (14.060 MeV)
- Sensitive to the ^{8}B part of the solar spectrum.

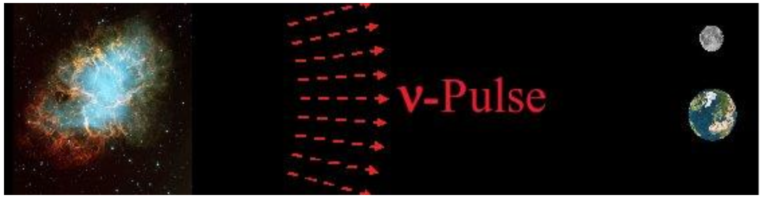
ICARUS can detect solar neutrino by observing e^{-}

- Elastic scattering by electrons: $\nu_{e,\mu,\tau} + e^{-} \rightarrow \nu_{e,\mu,\tau} + e^{-}$
- Absorption reactions on Argon nuclei: $\nu_{e} + {}^{40}Ar \rightarrow {}^{40}K^{*} + e^{-}$

Long baseline neutrinos

CERN Neutrinos to Gran Sasso (CNGS) :

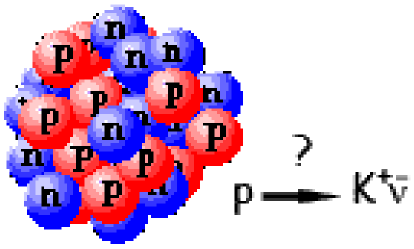
- Investigating the 'oscillation' of neutrinos.
- CERN SPS → (ν_μ) → 730km → (ν_τ) LNGS (Gran Sasso National Laboratory)



SuperNovae neutrinos:

- During explosion a short pulse of neutrinos is emitted.
- 99% of the energy is carried by the 10^{58} neutrinos
- Energy of 10MeV.
- Expect in our galaxy one Supernova explosion per 30 years

Proton decay:



•It's lifetimes beyond 10^{32} years.

•The exact nature of the decays is

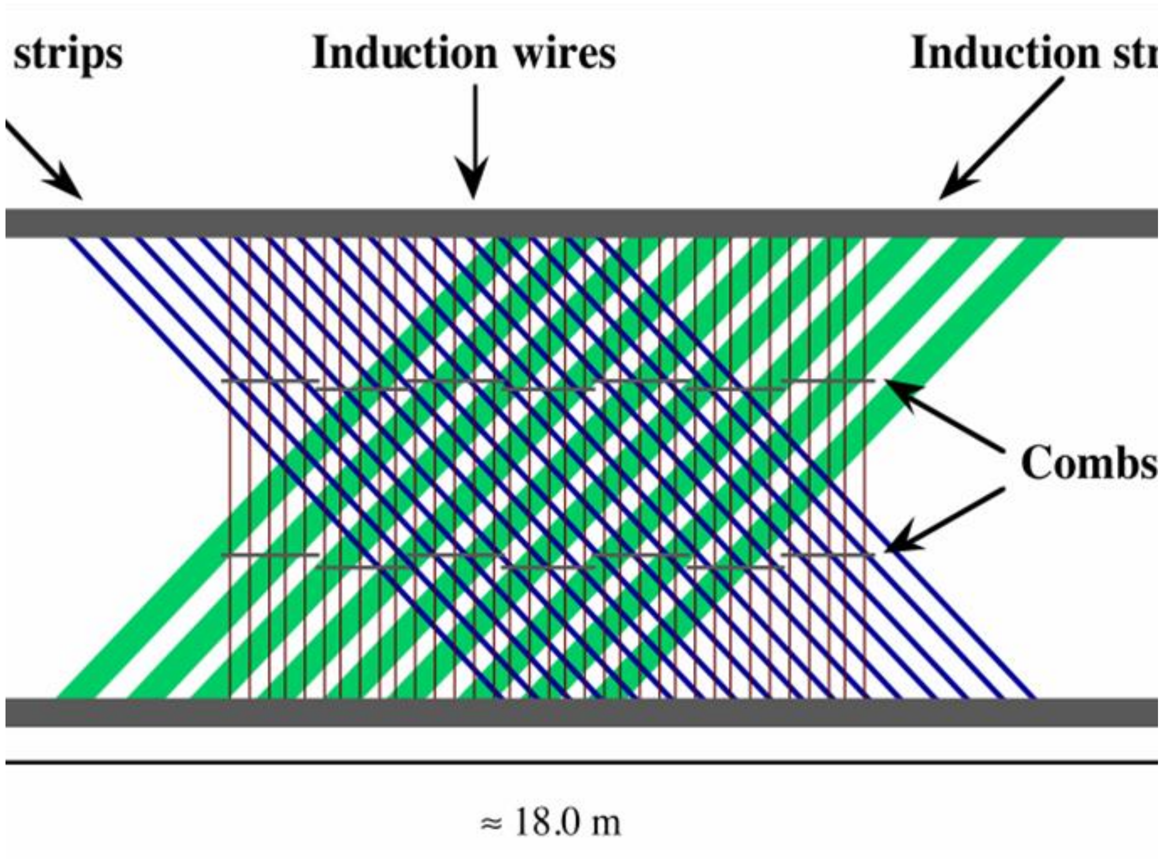
not known.

•Large sensitive mass and to its spatial and energy resolution capabilities.

•Bias-free, nucleon decay detection, open to all possible decay modes.

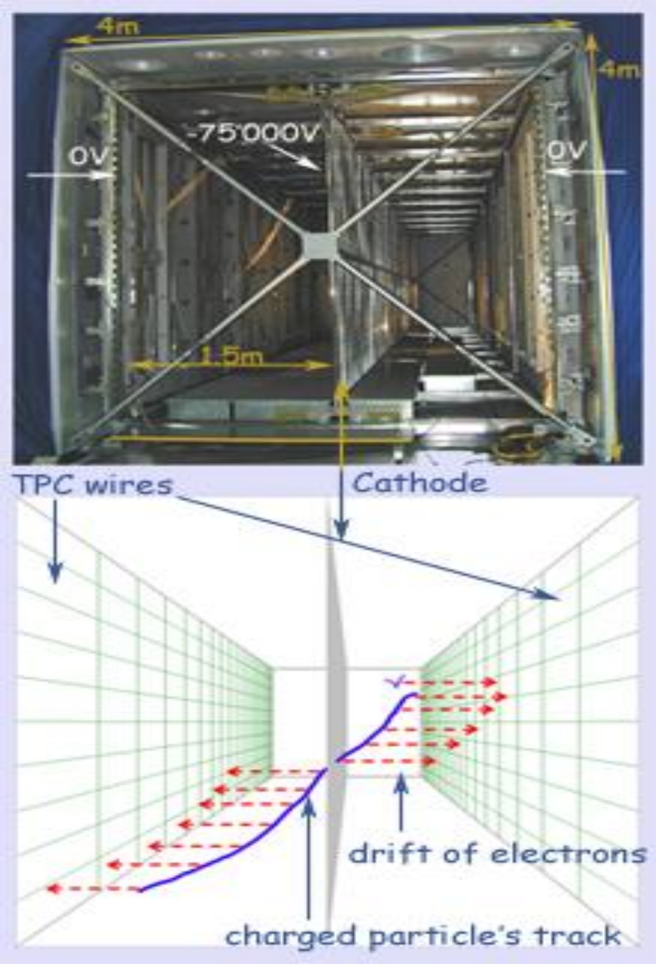
Detector details

- The LAr cryostats (The Aluminium LAr containers, the thermal insulation and the cooling system(LN_2))
- LAr purification (no. of ionization e^- will $\downarrow$ due to electro –ve impurities & hence impurity level 0.1ppb)
- Wire chamber (Induction -1 & 2 (non-destructive 0^o and $+60^o$) plane and Collection plane -60^o)
- Photomultipliers (To detect scintillation light)
- Read-out electronics
- Data Aquisition System (DAQ)
- Event Reconstruction

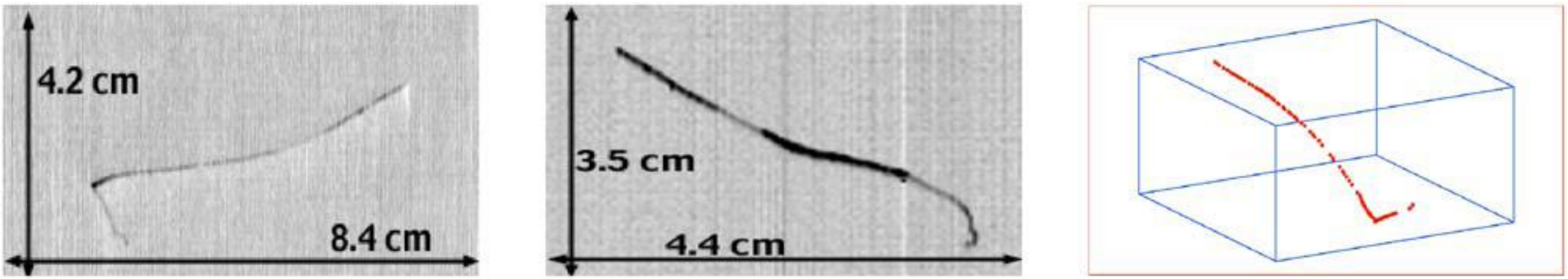


Schematic layout of the “multi-layer + wires” read-out chamber

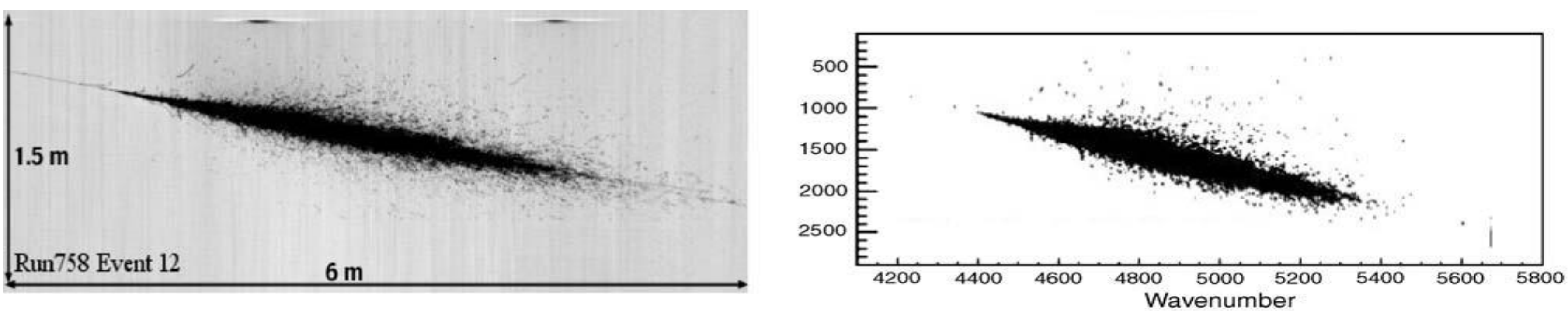
Schematic representation of a single module of the ICARUS detector and its functionality



A muon decay, seen (from left to right) by the induction-2, collection wire planes, and by the 3D reconstruction



An electromagnetic shower, seen by the collection wire plane (left) and reconstructed in 2D (right) by the hit-finding algorithm



Magnetized Liquid Argon TPC

- Charge discrimination
- Momentum measurement of particles escaping the detector (e.g. high energy muons)
- Very precise kinematics, since the measurements are multiple scattering dominated (e.g. $\Delta p/p \simeq 4\%$ for a track length of $L = 12$ m and a field of $B = 1T$).

LAGUNA

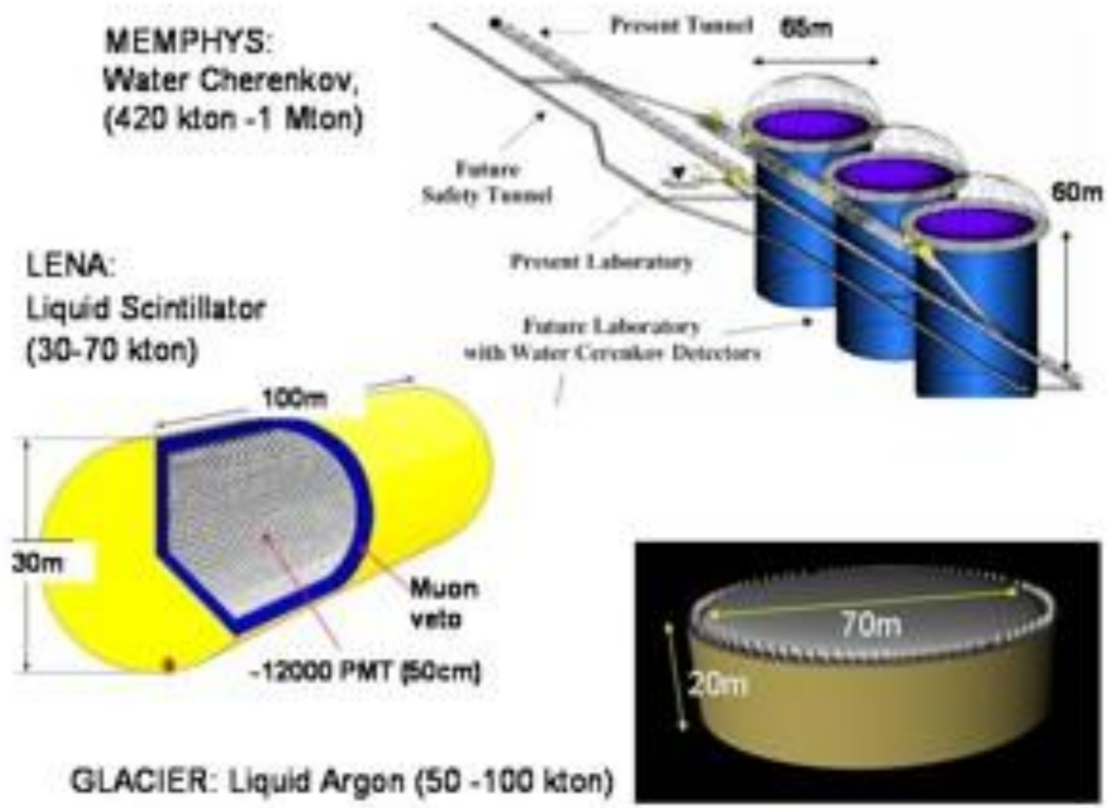
(Large Apparatus studying Grand Unification and Neutrino Astrophysics)

DUSEL

(Deep Underground Science and Engineering Laboratory)

They use all three technologies:

- Water Cerenkov Imaging.
- Liquid scintillator.
- Liquid Argon Time Projection Chambers (LAr TPC).



Possible next generation very large volume underground detectors: MEMPHYS(MEgaton class PHYSics), LENA(Low Energy Neutrino Astronomy) and GLACIER(Giant Liquid Argon Charge Imaging Experiment)

Conclusion

- Seen merits of LAr detectors compared to other detectors, discussed about various LAr detectors.
- Then we discussed about detector details, what can we obatin by applying magnetic field.
- Then finally discussed about the future detectors

Reference:

- http://icarus.lngs.infn.it
- http://warp.lngs.infn.it
- The ICARUS Liquid Argon TPC a complete imaging device for particle physics.
- LANNDD-- A Massive Liquid Argon Detector for Proton Decay, Supernova and Solar Neutrino Studies, and a Neutrino Factory Detector.
- The liquid argon time projection chamber of ICARUS
- ArDM: a ton-scale liquid Argon experiment for direct detection of Dark Matter in the Universe