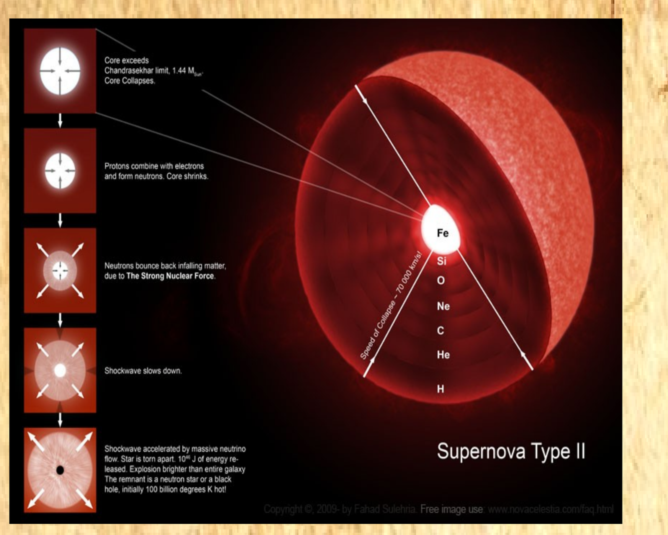
SUPERNOVA NEUTRINOS WITH NEWSdm DETECTOR

THEORY

The explosion of a Supernova is one of the most energetic observable phenomenon in the Universe



Neutrinos carry almost the total energy emitted by the source

⟶ They could directly explain the underlying processes inside the star leading to the explosion

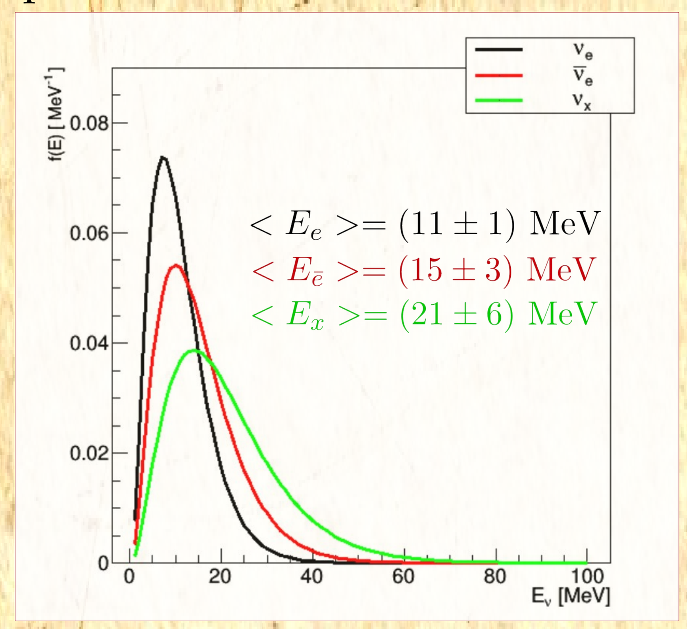
Total energy emitted by a Supernova

$$\mathcal{E}_B = (3 \pm 1) \cdot 10^{53}\ \mathrm{erg}$$

Number of emitted neutrinos

Energy equipartition $$N_i \simeq \frac{1}{6}\frac{\mathcal{E}_B}{\langle E_i \rangle} \quad (i = e, \bar{e}, x)$$

$$N_\nu \simeq N_e + N_{\bar{e}} + 4\,N_x \simeq (6 \pm 1) \cdot 10^{57}$$



Maxwell-Boltzmann energy spectrum assumed

$$f_i(E) = \frac{\beta_i^3}{2} E^2 e^{-\beta_i E} \quad \text{with} \quad \beta = \frac{3}{< E_i >}$$

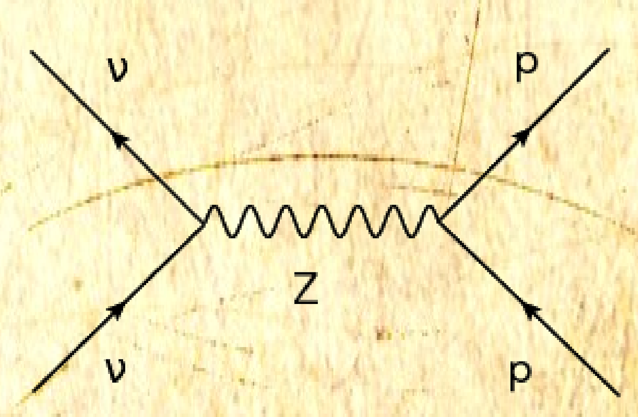
Neutrinos interacting in the detector

$$N(E) = \frac{dN}{dE} = \frac{M_{riv}}{A m_{uma}} \sigma(E) \mathcal{F}(E)$$

Differential fluence of incoming neutrinos (D = 10 kpc used for calculations)

$$\mathcal{F}(E) \equiv \frac{d\mathcal{F}}{dE} = \sum_{i=e,\bar{e},x} \frac{N_i}{4\pi D^2} f_i(E)$$

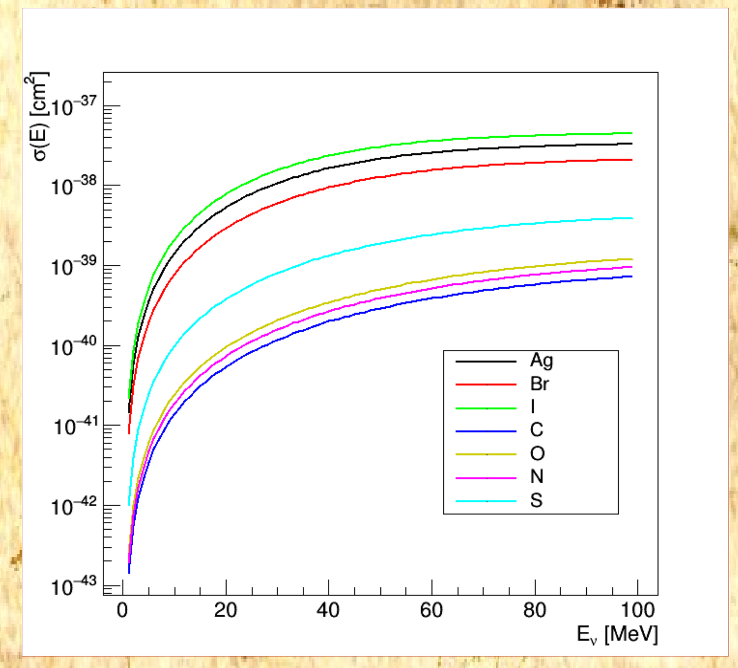
Neutral Current interaction



Neutrino nucleus cross-section

Fermi's constant — Weak charge — Helm's form factor

$$\frac{d\sigma}{d\Omega} = \frac{G_F^2}{(2\pi)^2} \frac{Q_W^2}{4} E_\nu^2 (1 + \cos\theta) F^2(q)$$

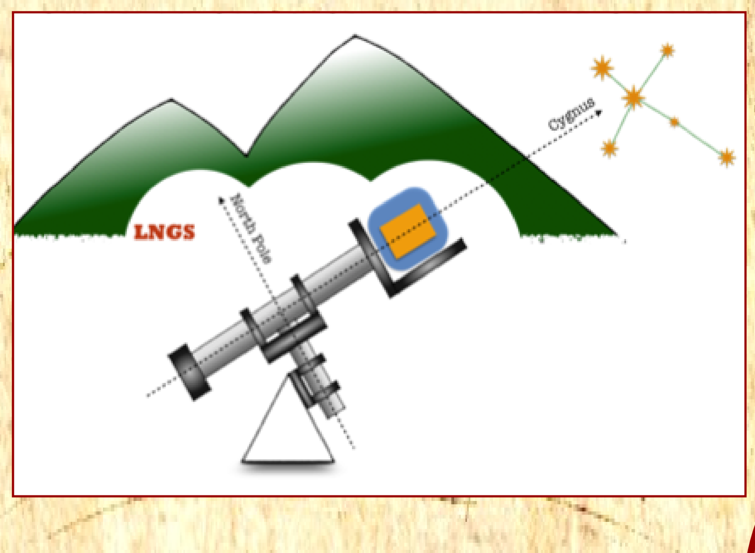


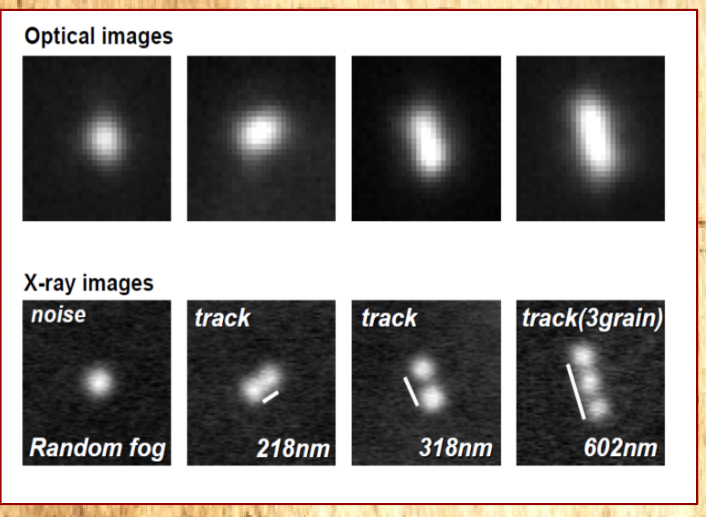
Cross section vs neutrino energy for different target in NEWSdm detector

DETECTOR

Aim: Directional detection of nuclear recoils induced by WIMP scattering with the target

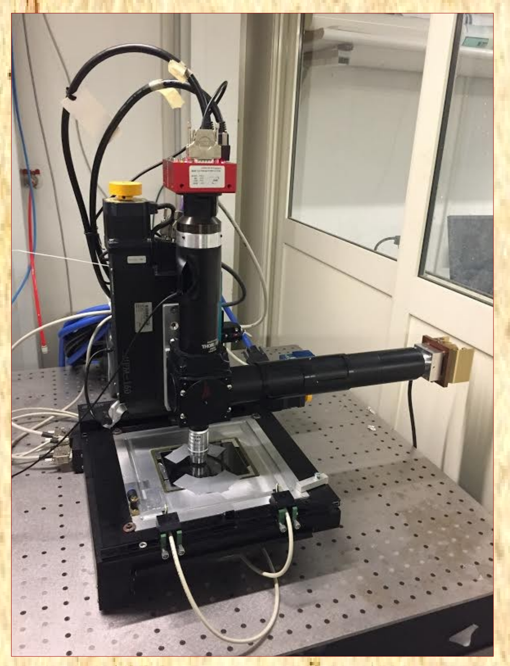
- Principle: Nuclear emulsions both as target and tracking detector
- Orientation: Towards Cygnus constellation with equatorial telescope
- Location: Gran Sasso Underground Laboratories
- Detector mass = 1 ton
- Shield: Environmental and cosmogenic background source suppression





- Nuclear emulsion: AgBr crystal (40nm) and organic gelatine
- Readout system: Optical Microscope
- Threshold: 100 nm track length

Analysis strategy to detect tracks shorter than the optical resolution:

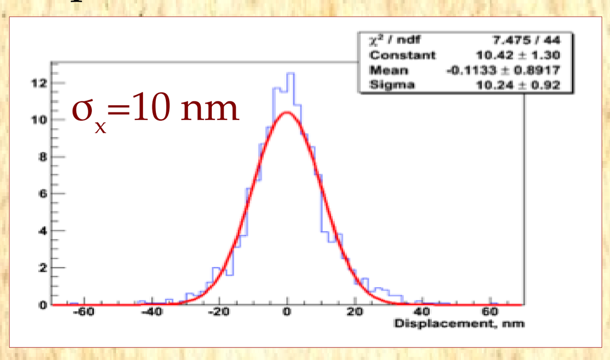


1) Elliptical fit of clusters (first selection)

- Grains closer than 200nm appear as single cluster
- Spherical shape: single grain in a cluster (background-like)
- Elliptical shape: ≥ 2 grains in a cluster (signal-like)
- Elliptical fit: major axis gives the direction of the recoiled nucleus

2) Validation of the selected tracks with polarized light analysis

- Use of resonance effects for nanometric metallic grains in dielectric medium (*Applied Phys. Lett. 80 (2002) 1826*)
- Elliptical shape: different resonance response according to the polarization of the incident light

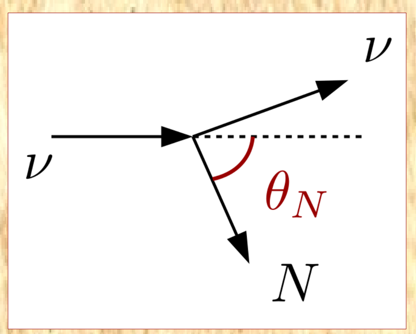


BREAKTHROUGH
Accuracy of about 10 nm in both coordinates achieved

SIMULATION AND RESULTS

Neutrino-nucleus neutral current simulation

- track length distribution
- θ angle distribution
- φ angle distribution



Kinematic relations

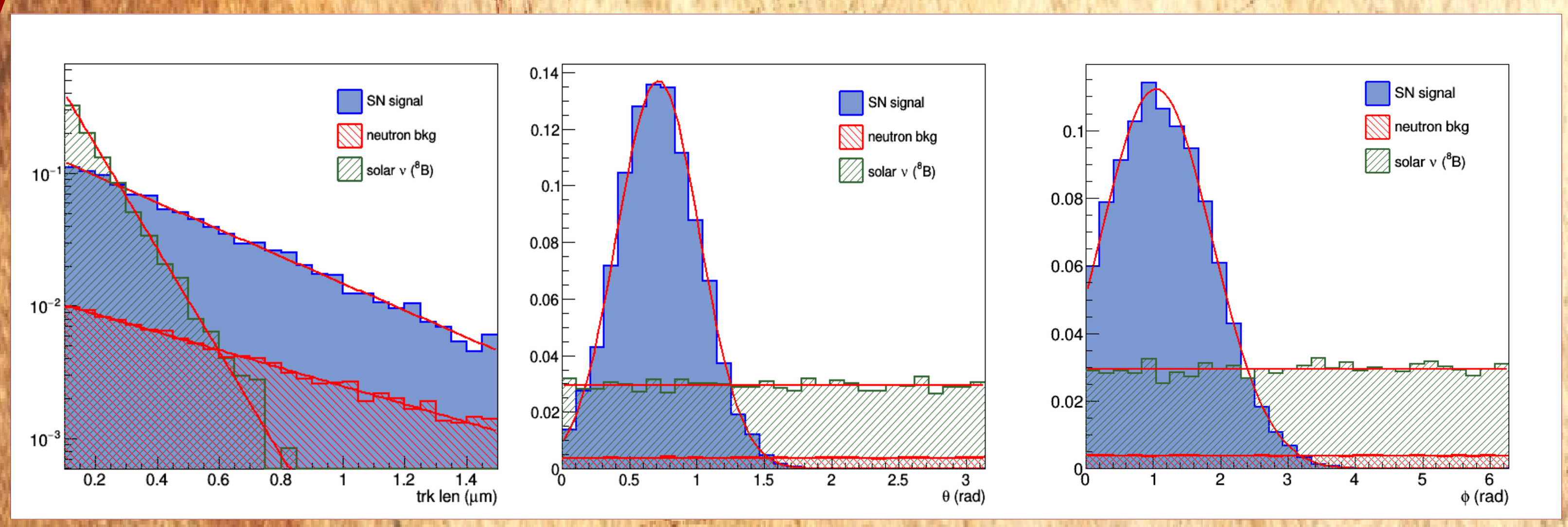
$$T = \frac{E_\nu^2(1-\cos\theta)}{E_\nu(1-\cos\theta)+M}$$

$$\cos\theta_N = \frac{(E_\nu + M)}{E_\nu}\sqrt{\frac{T}{2M}}$$

Main background sources:

- radiogenic neutrons (~1 n ton^{-1} y^{-1})
- solar neutrino from ^{8}B

Directional reconstruction of recoiled nuclei provides an unambiguous proof of the SN neutrino interaction



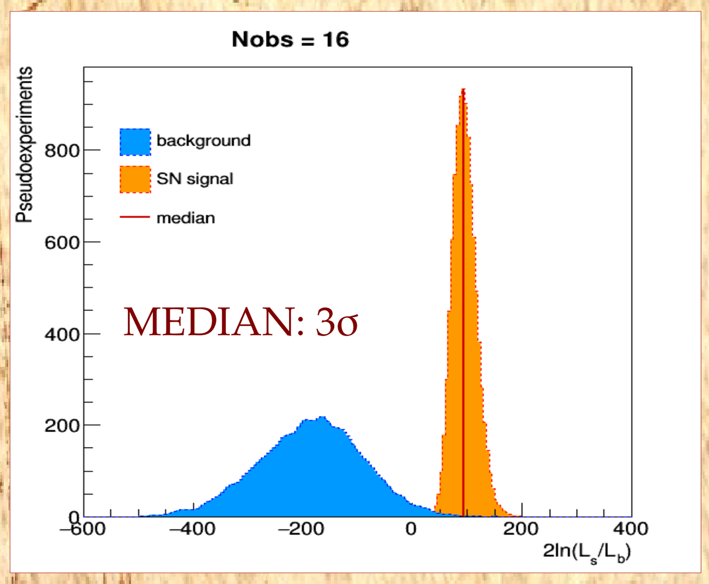
Likelihood ratio test used to estimate the separation between the signal (S) and background (B) hypotheses

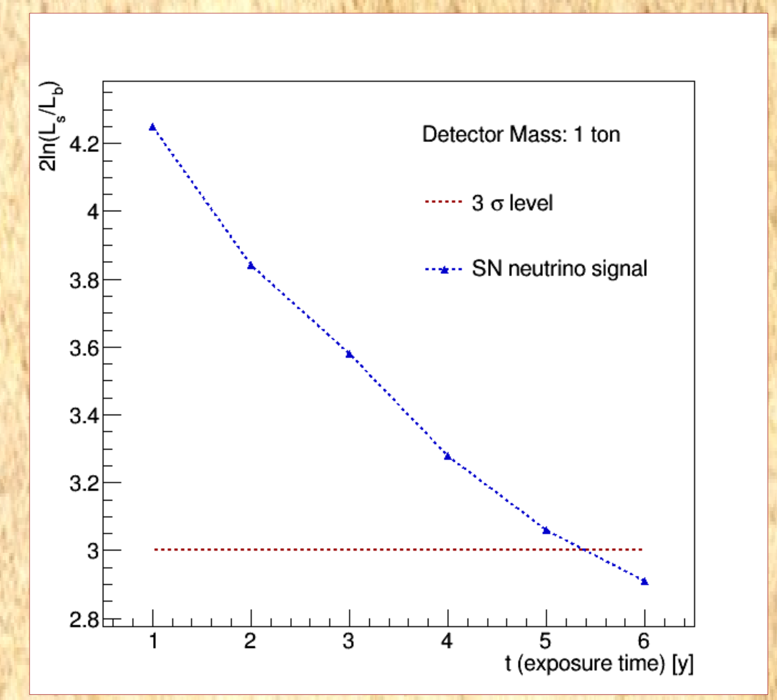
$$\mathscr{L}_b \equiv \mathscr{L}(x_1, ..., x_n \mid H_0) = \prod_{i=1}^{N} f(x_i \mid H_0)$$

$$\mathscr{L}_s \equiv \mathscr{L}(x_1, ..., x_n \mid H_1) = \prod_{i=1}^{N} f(x_i \mid H_1)$$

Test statistics: $q = 2\ln(\mathscr{L}_s/\mathscr{L}_b)$

Test statistics q for the signal hypothesis tested against the background only hypothesis, assuming 16 observed events





Test statistics as a function of the exposure time t for the S + B hypothesis (B proportional to t)

(* see poster 130317)

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