CYGNO additional physics

Working on it

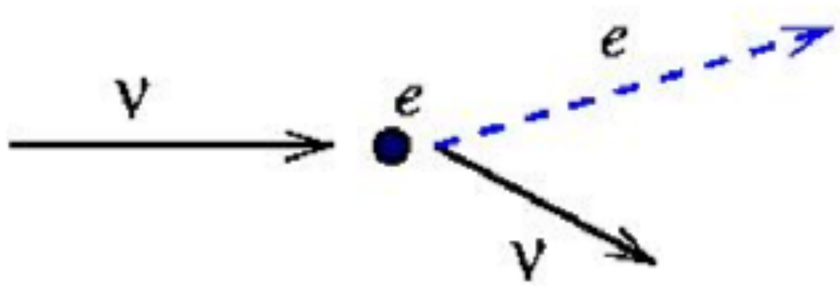
- Low energy solar neutrino via elastic scattering on electrons
- Dark Matter from Supernovae
- Sub-GeV DM via elastic scattering on electrons
- Migdal effect

To do (preliminary activity)

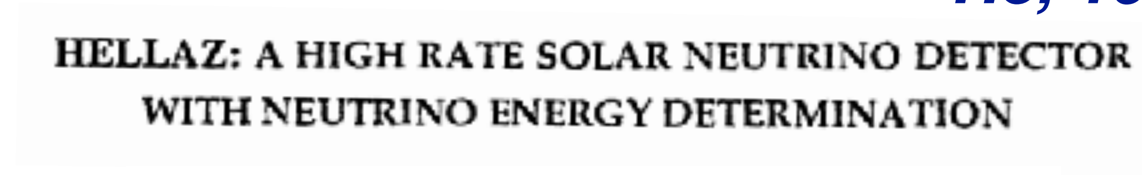
CYGNO potentialities for solar neutrino spectroscopy

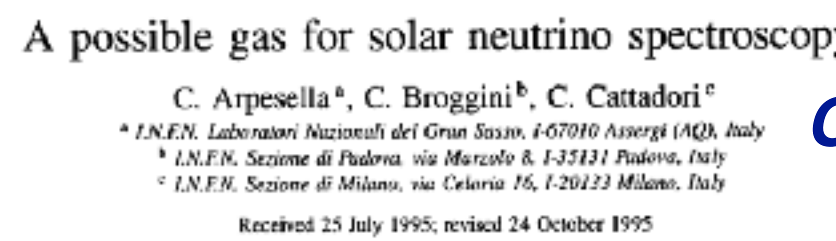
Low energy solar neutrino detection through elastic Neutrino-Electron scattering

with event by event precise neutrino energy determination



He, 1992


HELLAZ: A HIGH RATE SOLAR NEUTRINO DETECTOR WITH NEUTRINO ENERGY DETERMINATION


A possible gas for solar neutrino spectroscopy

C. Arpesella[a], C. Broggini[b], C. Cattadori[c]

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[b] I.N.F.N. Sezione di Padova, via Marzolo 8, I-35131 Padova, Italy
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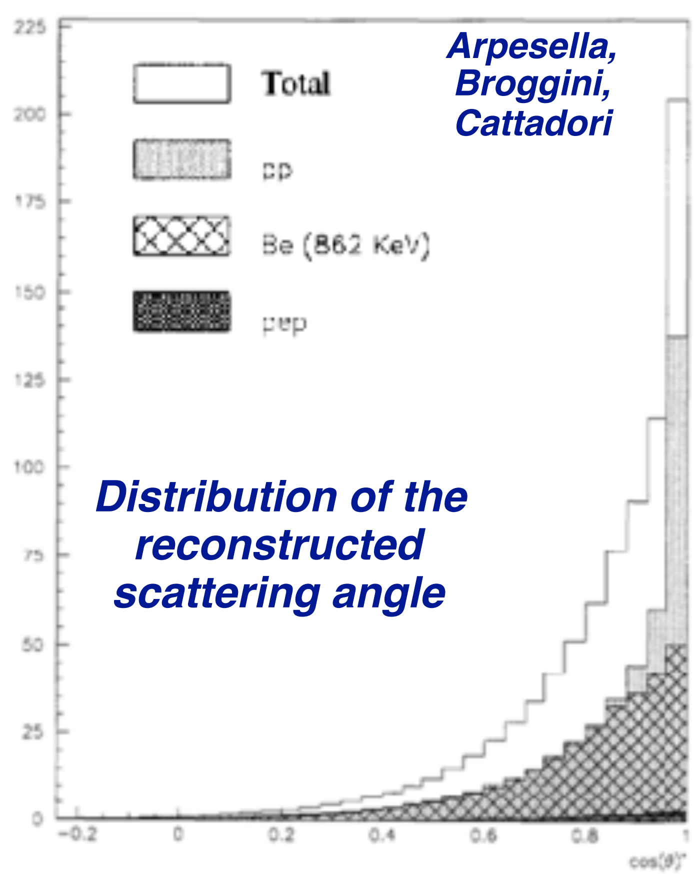
Received 25 July 1995; revised 24 October 1995

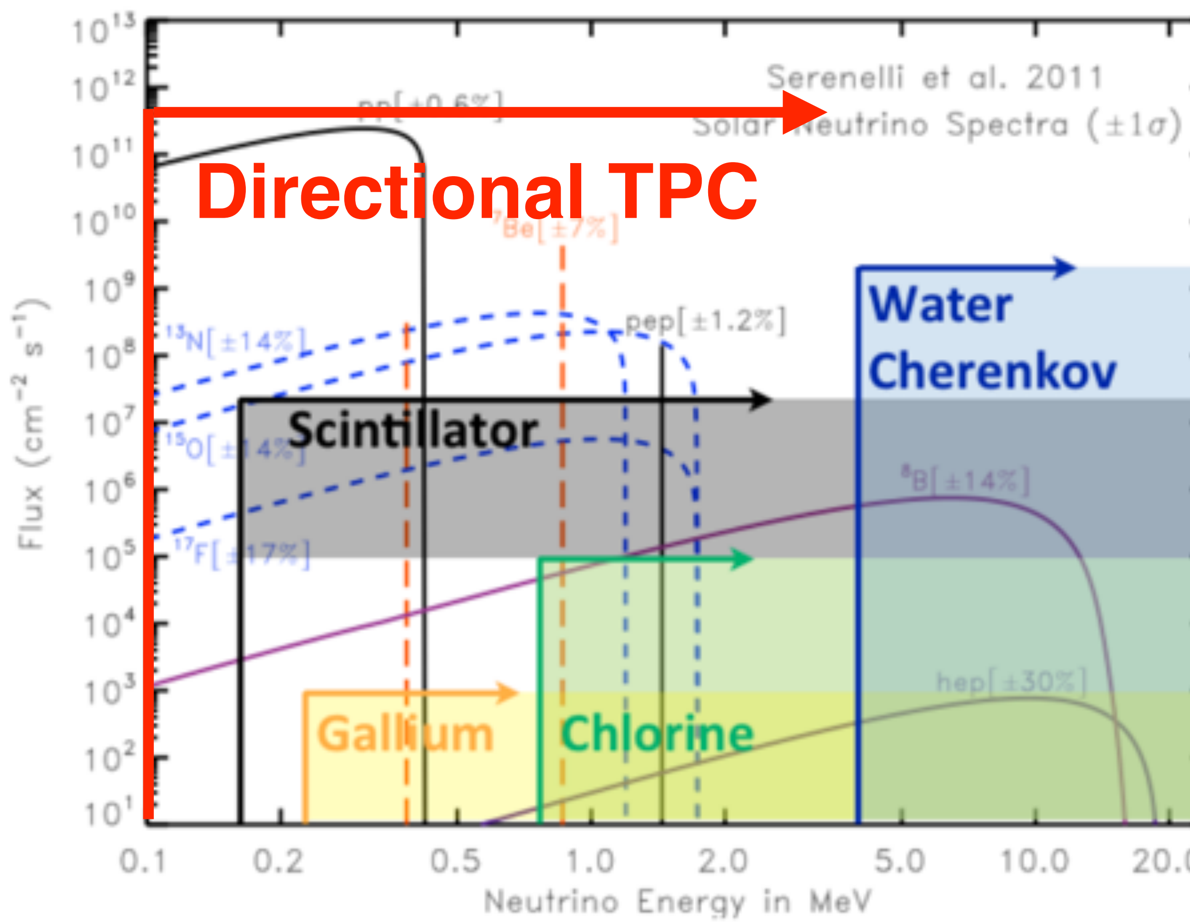
CF_4, 1996

Performances strongly dominated by diffusion and multiple scattering in gas, rather than readout performances

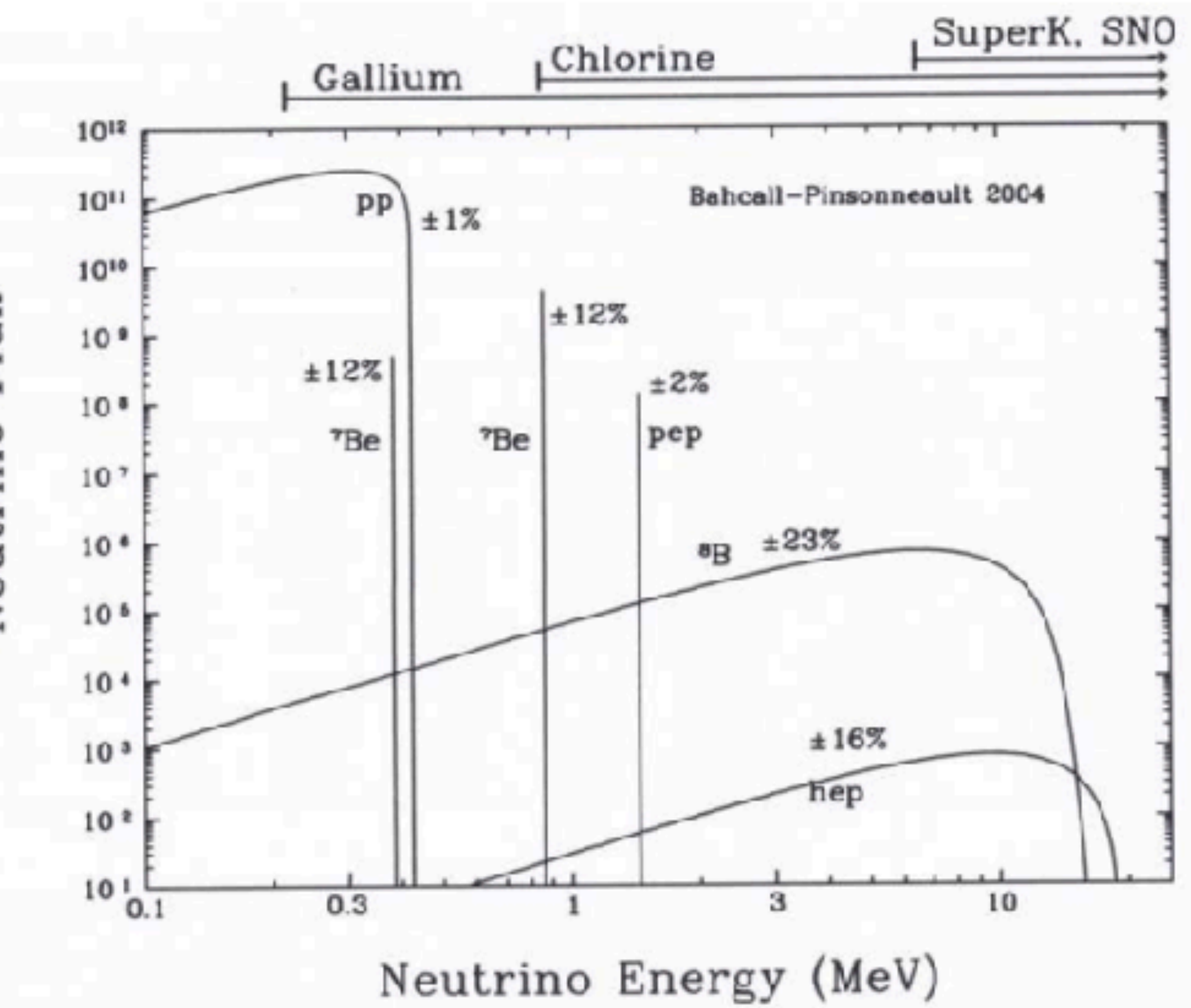


Arpesella, Broggini, Cattadori

Distribution of the reconstructed scattering angle



Expected neutrino yield



$$\sigma_{\nu_e e^- \to \nu_e e^-} = \frac{G_F^2 s}{\pi}\left[\left(\frac{1}{2}+\xi\right)^2+\frac{1}{3}\xi^2\right] \approx 9.5\cdot 10^{-49}\ \mathrm{m}^2\left(\frac{E_\nu}{1\ \mathrm{MeV}}\right)$$

CF_4 electron density = 1.05×10^{21} cm^{-3}

1 m^3 of He:CF_4 @ 60:40 = 6×10^{26} electron (from CF_4 alone

1 year = 3.15×10^7 s

Flux x cross section x target @ 100 keV neutrino energy

10^{11} cm^{-2} s^{-1} x 10^{-45} cm^2 x 6 x 10^{26} m^{-3} =6 x 10^{-8} m^{-3} s^{-1} = 2 m^{-3} y^{-1}

Expected neutrino energy resolution

HELLAZ: He @ 5 bar, 10 m drift, 1 mm x,y,z strips

Electron energy threshold: 100 keV

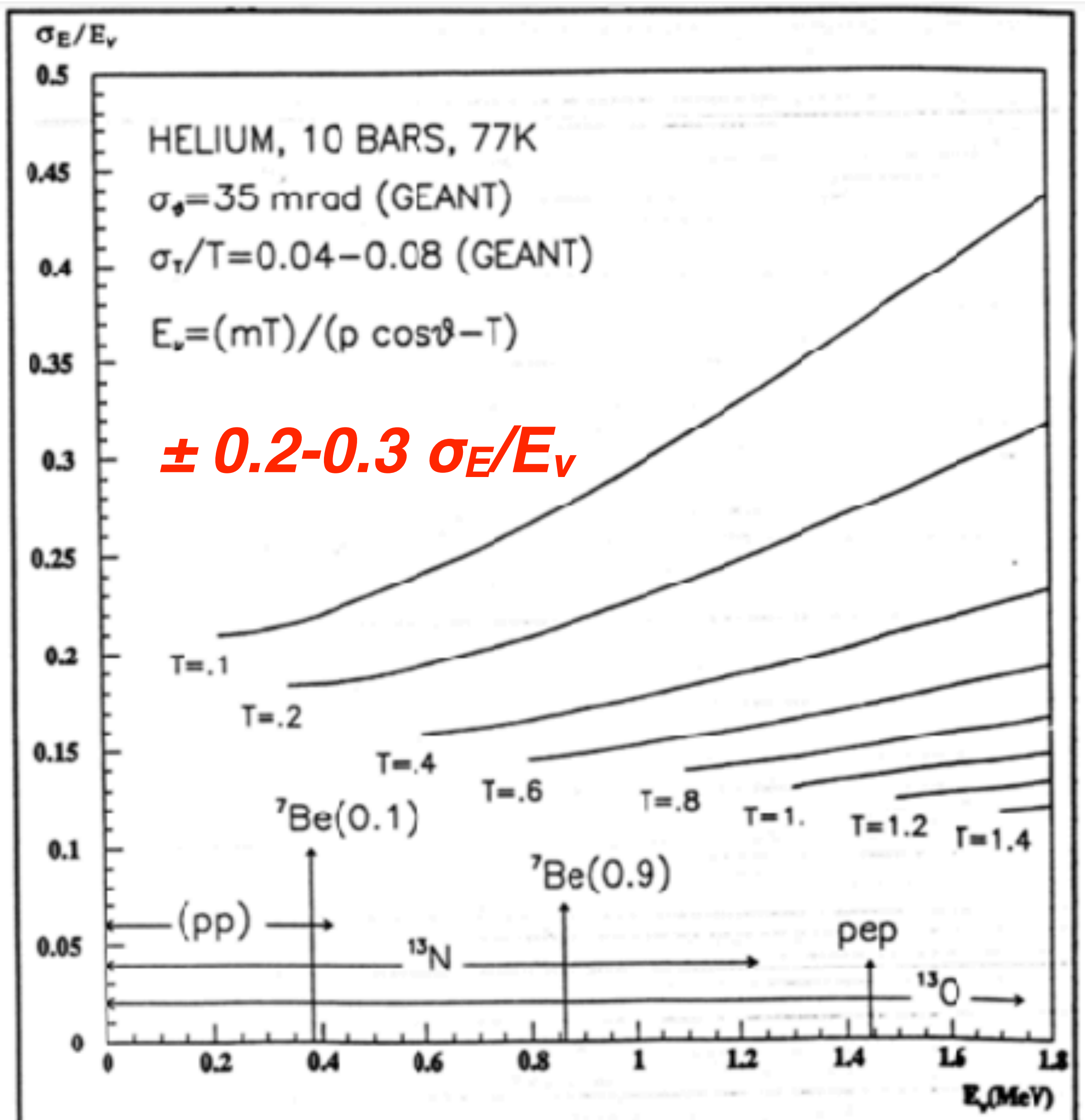
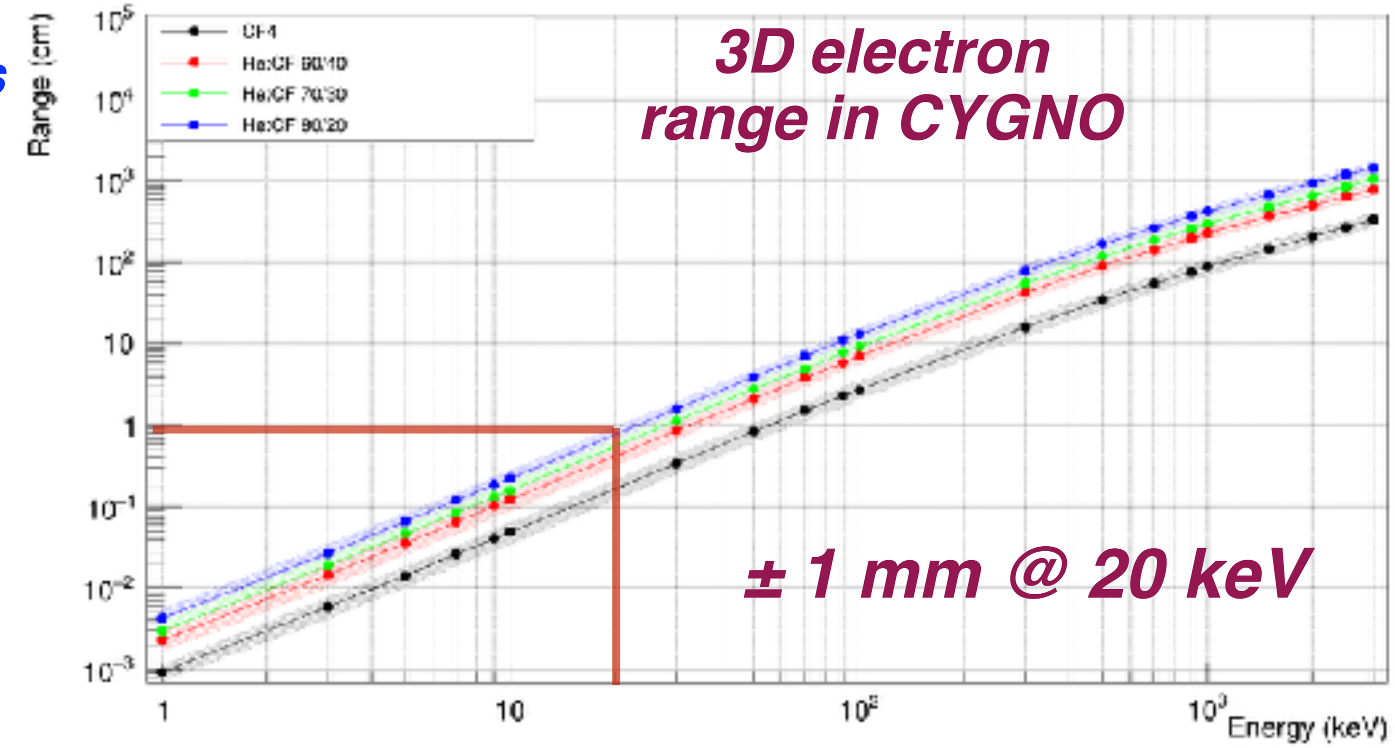


Fig. 12. The neutrino fractional energy error σ_E/E_ν vs neutrino energy E_ν for various fixed values of the electron energy T (MeV).



	Diffusion	Target density	Electron energy threshold	Expected yield from pp
HELLAZ	0.2 sqrt(cm)	3 kg/m^3	100	0.5-1 m^{-3} y^{-1}
CYGNO	0.01 sqrt(cm)	1-1.5 kg/m^3	10-20	1-2 m^{-3} y^{-1}

CYGNO versus HELLAZ:

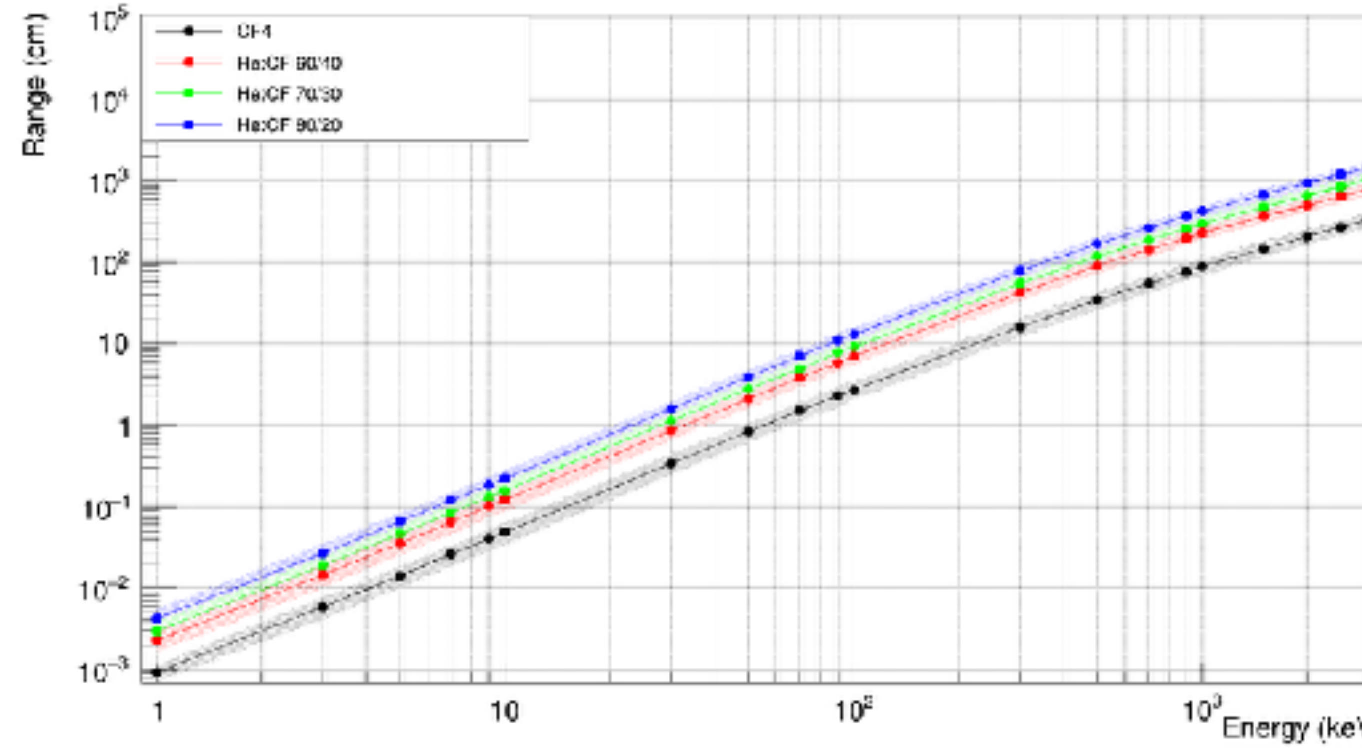
- Lower diffusion
- Lower multiple scattering
- Lower threshold
- Improved tracking
- Sensitivity to single ionisation cluster (improved electron energy resolution)

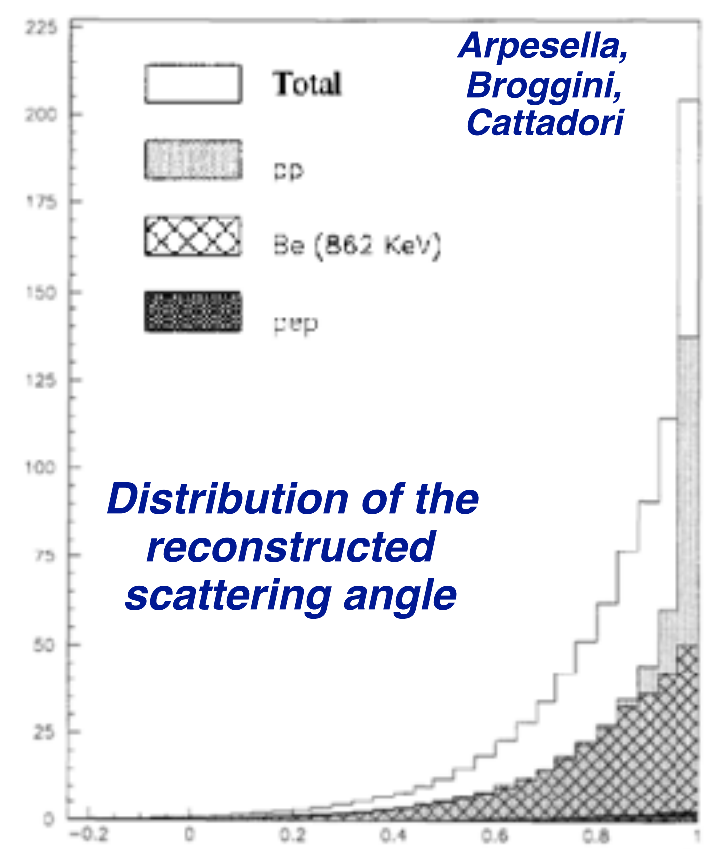
PHASE-2 can detect about 50 events/year

Activity on neutrino physics case:

G. Dho, D. Marques

- Simulation of electron recoils in geant4
- Add ionisation, diffusion, gas gain, light yield and digitisation to estimate angular resolution on MC
- Energy resolution from MC or data?
- Determine lower and higher energy threshold
- Determine neutrino energy resolution as a function of energy
- Study all the physics we can do with this





DM from supernovae

NOTE: only a directional DM detector can distinguish this from usual WIMPs!

2. **Supernova signals of light dark matter**
William DeRocco, Peter W. Graham (Stanford U.,
pp.
Published in **Phys.Rev. D100 (2019) 075018**

MeV DM travelling at relativistic speed induce a keV nuclear recoil just as a WIMP travelling not relativistically!!!

Dark fermions generated during SN explosions

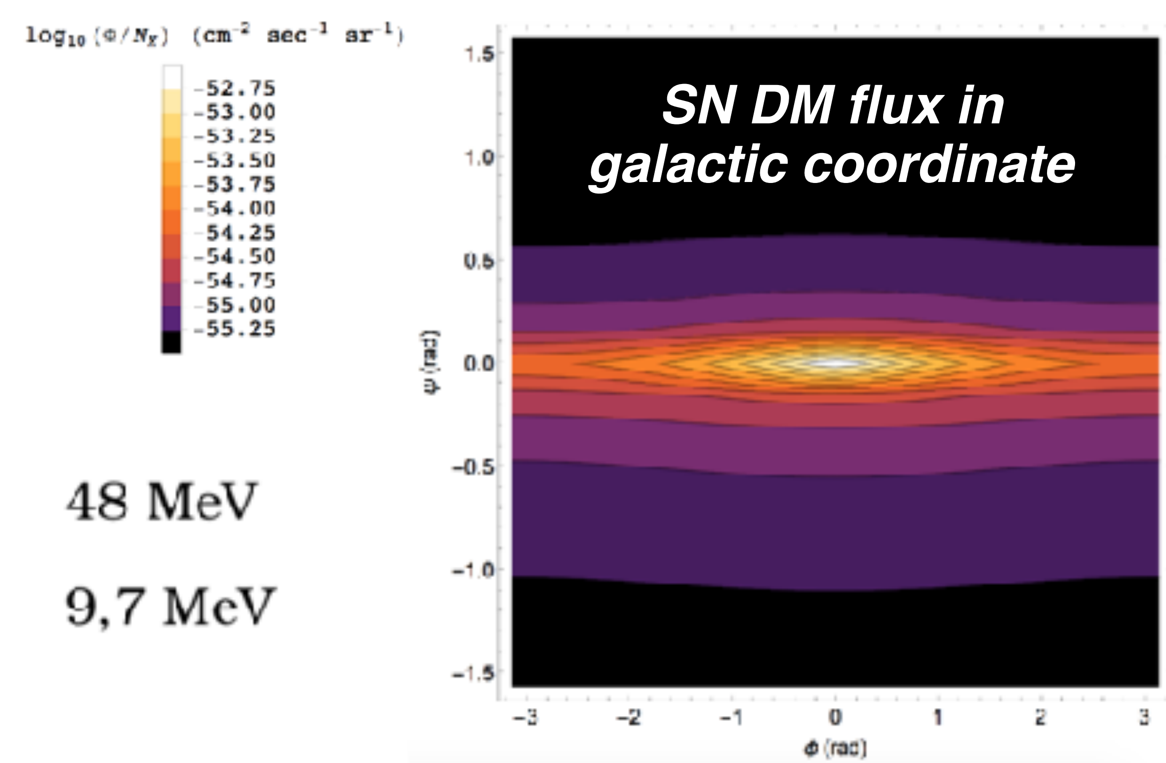
Momenta distribution due to thermal coupling with the SN plasma

$$f(p)=\frac{A}{e^{\frac{\sqrt{p^2+m^2}}{T}}+1}$$ Fermi-Dirac distribution

A diffuse stream of these particles in the Galaxy, peaked in the direction of the Galactic centre

- Two extreme model parameters considered

Mass of the Dark fermion (M)	11 MeV	48 MeV
Temperature of decoupling (T)	4,3 MeV	9,7 MeV



From G. Dho

Working with W. De Rocco

DM from supernovae: activity

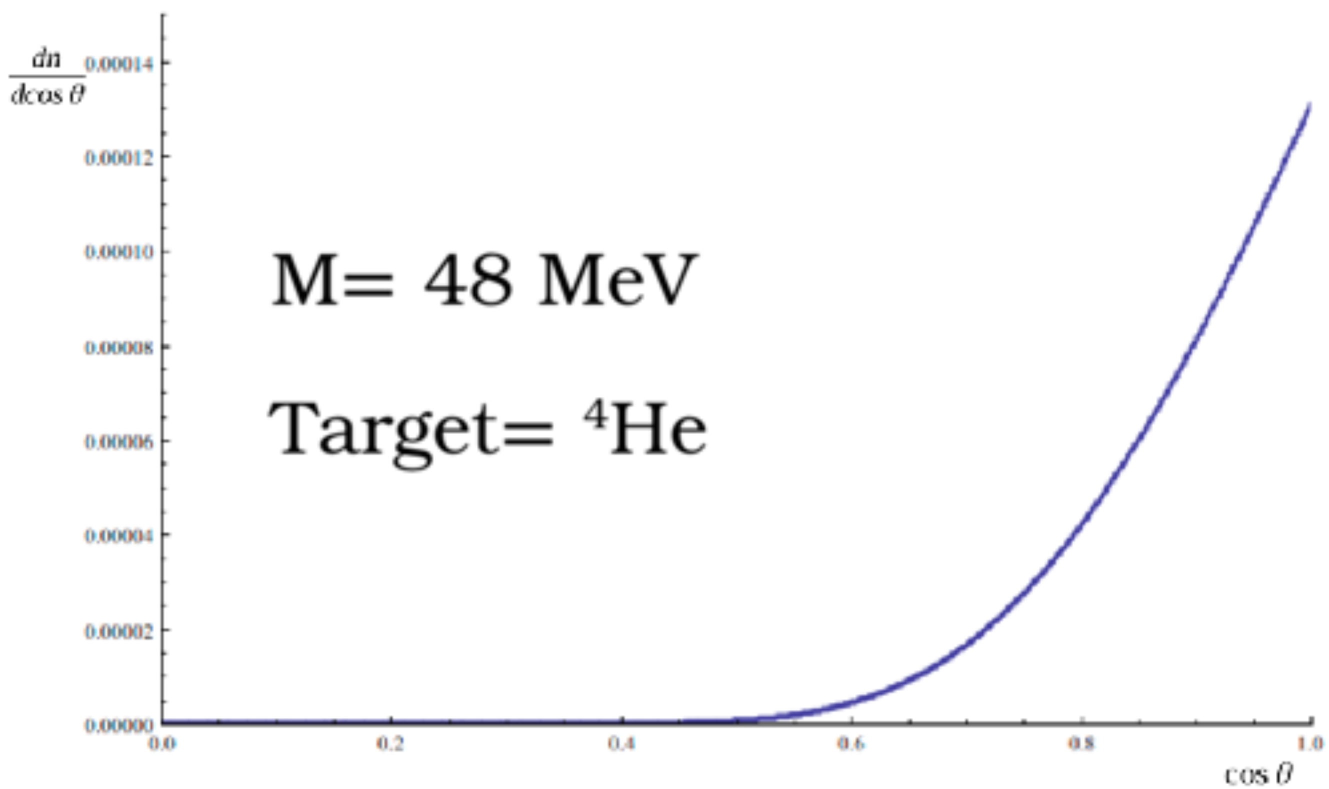
Calculation of the expected recoil distribution from DeRocco model

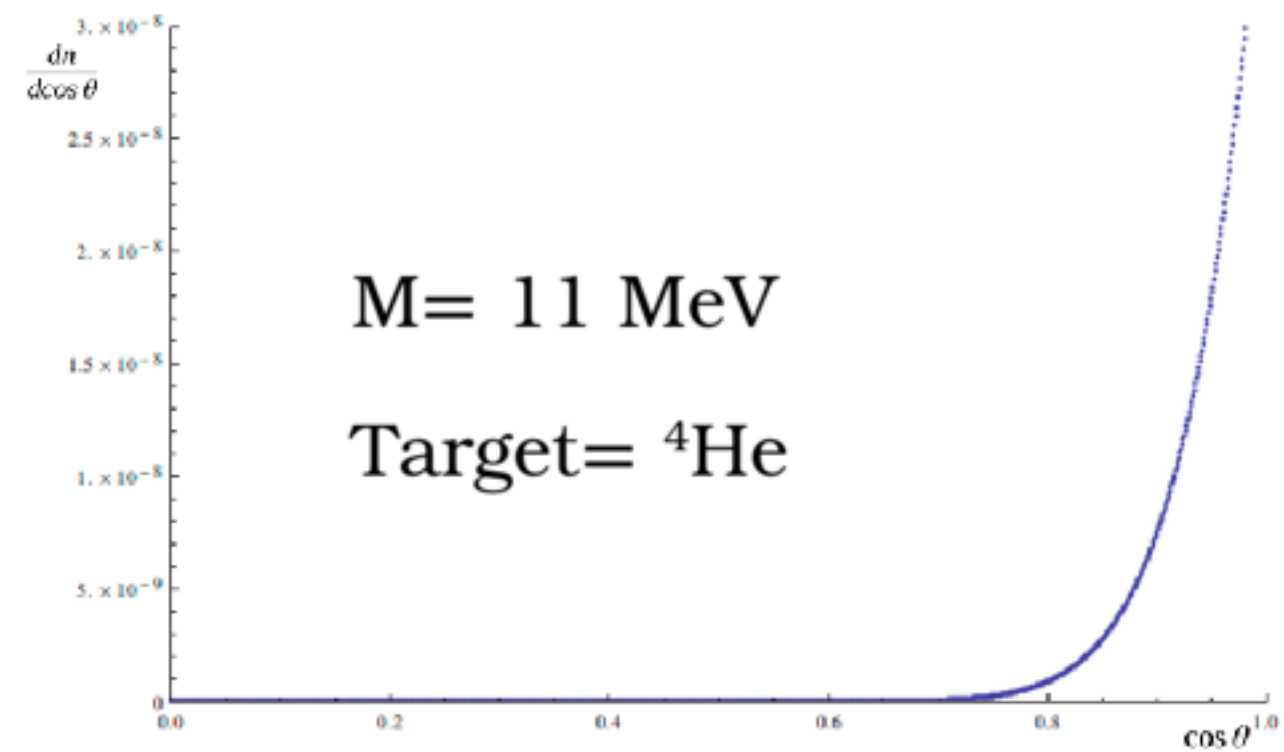
$$\frac{dR}{dq^2\, d\Omega} = \frac{1}{M_n} \int \frac{d\sigma}{dq^2\, d\Omega} \cdot n \cdot v \cdot f(v)\, d^3 v$$

$$\frac{dR}{dE_r\, d\cos\theta} = A' \int \delta\left(\cos\theta - \frac{q}{2p}\right) \cdot \frac{p}{M} \cdot \frac{1}{\sqrt{1+\frac{p^2}{M^2}}} \cdot f(p)\, dp$$

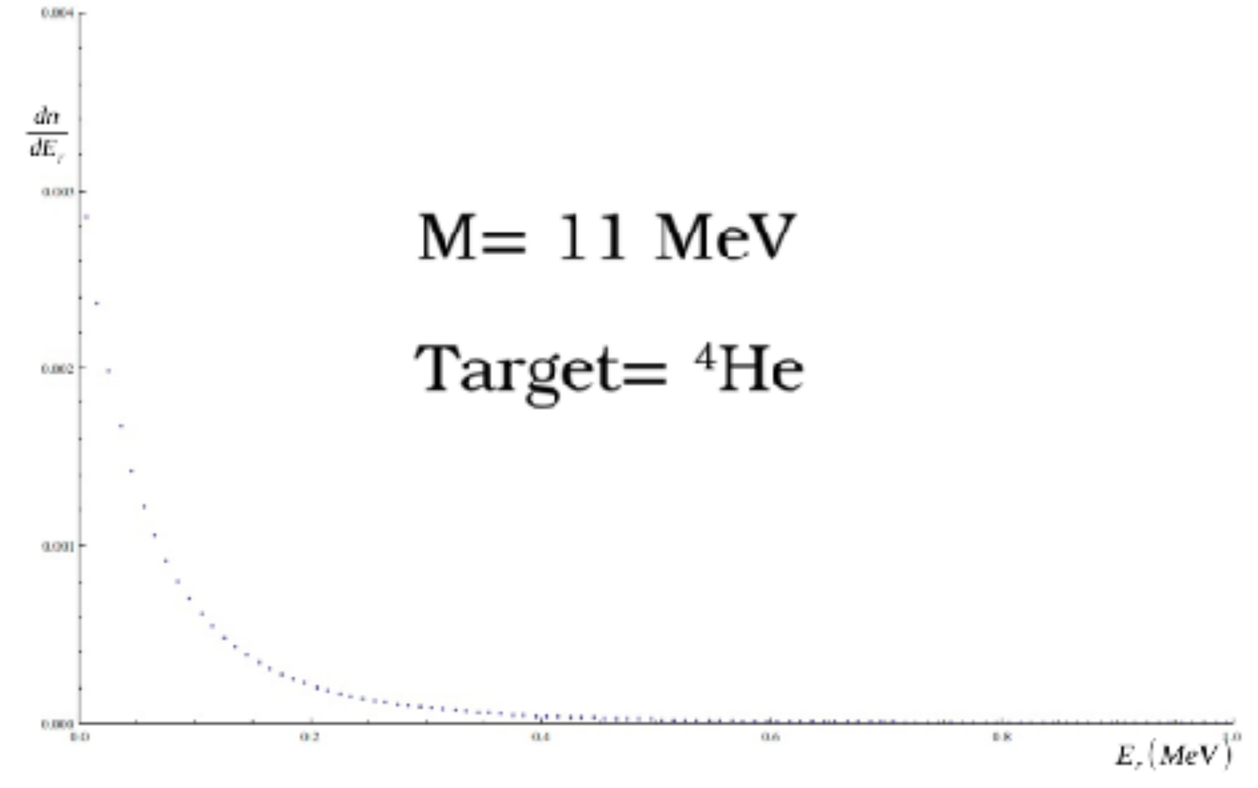
q recoil momentum

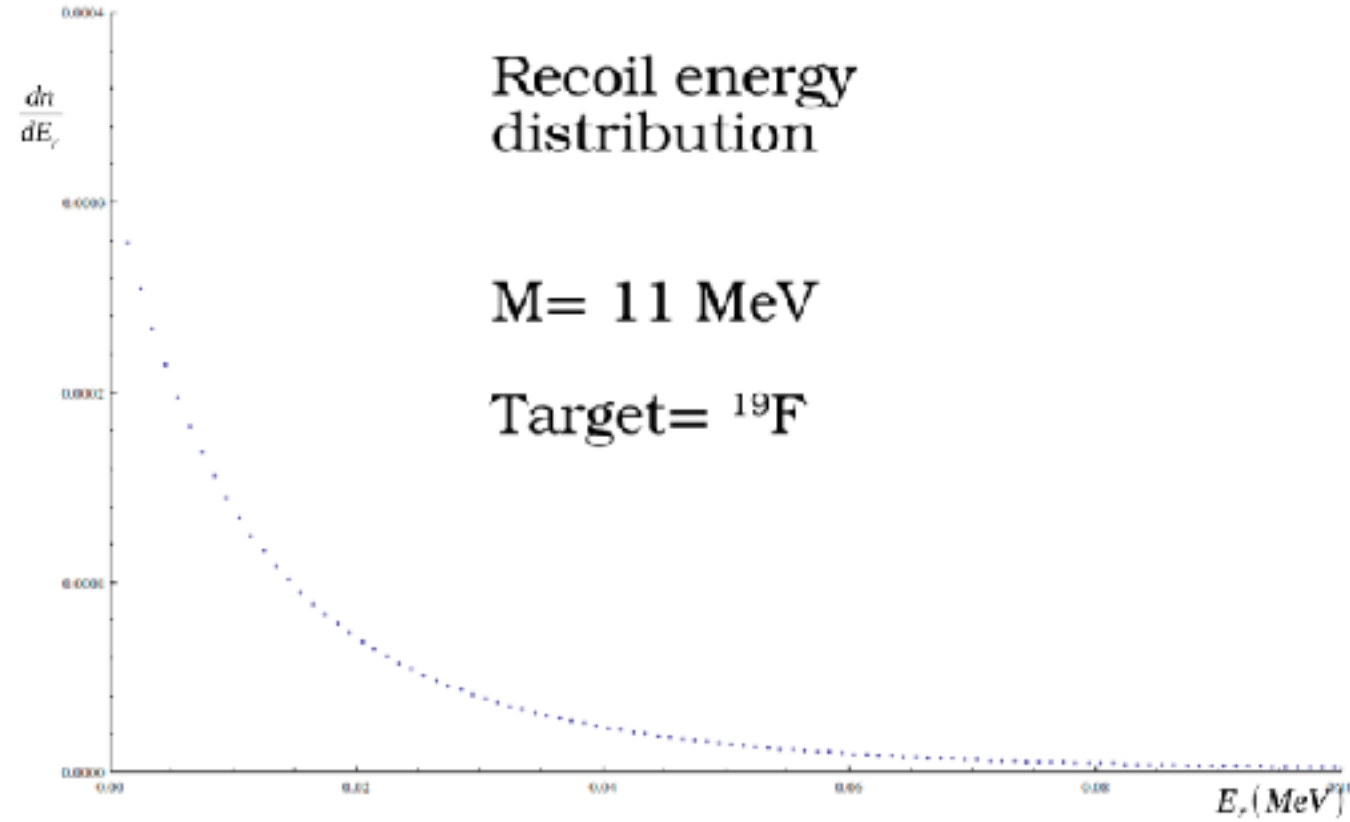
M mass of Dark fermion

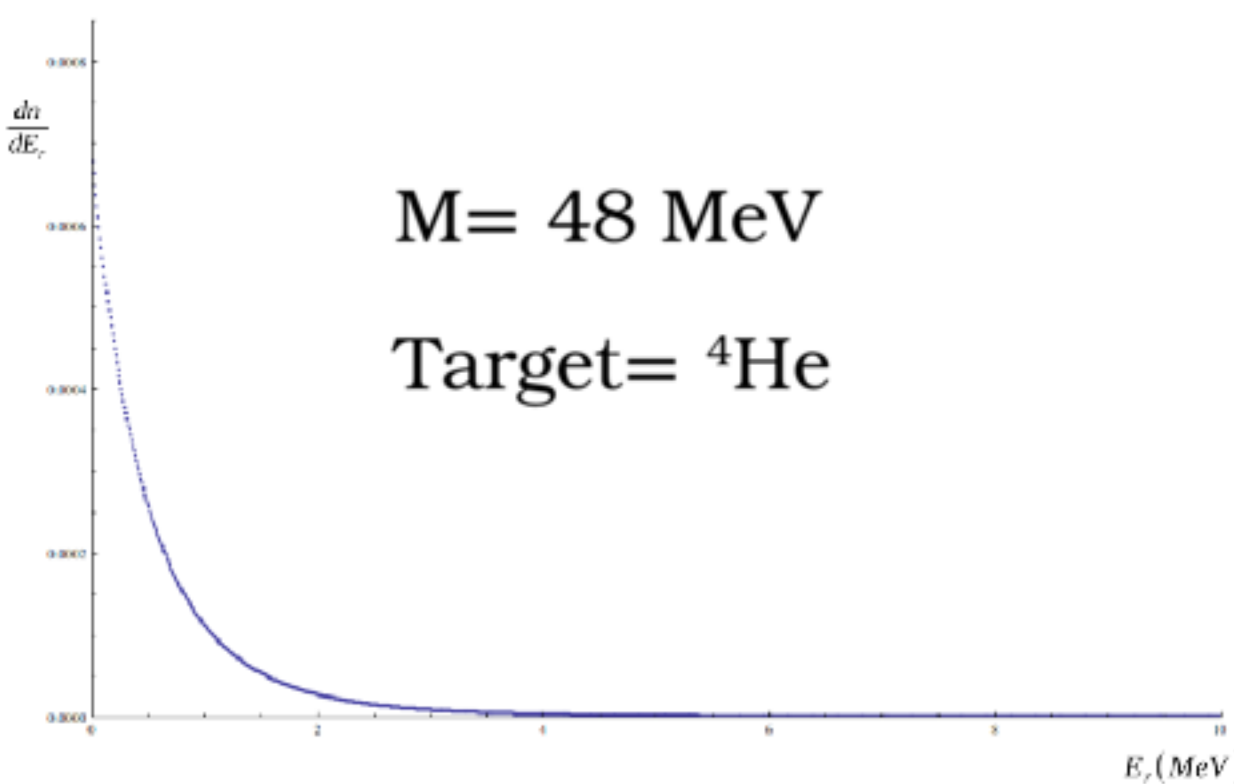


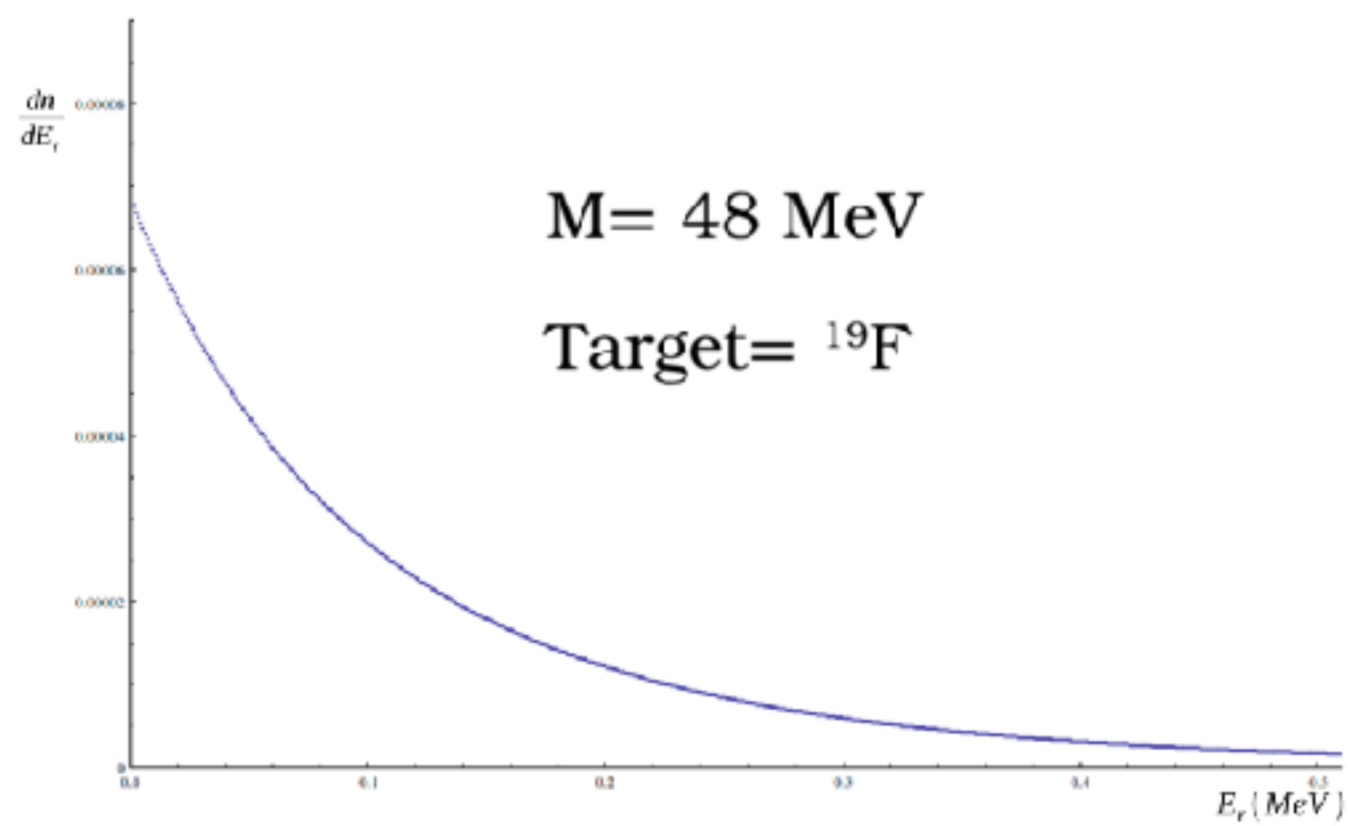


From G. Dho


dn/dE_r
M= 11 MeV
Target= ^{4}He
E_r (MeV)


dn/dE_r
Recoil energy distribution
M= 11 MeV
Target= ^{19}F
E_r (MeV)


dn/dE_r
M= 48 MeV
Target= ^{4}He
E_r (MeV)


dn/dE_r
M= 48 MeV
Target= ^{19}F
E_r (MeV)

From G. Dho

Activity on DM from Supernova:

- Calculation of the expected energy and angular recoil distribution for DM from Supernovae
- Calculation of the expected energy and angular recoil distribution of WIMP <u>in galactic coordinates</u>
- Determine how many events are needed to discriminate one model from the other with:
- Energy only (conventional DM detectors)
- Angle only
- Angle + energy (directional DM detectors)
- Write the paper (already started…)

International relationships

S. Pauling offered himself at TAUP 2019 to contribute to CYGNO

BOULBY UNDERGROUND LABORATORY

Sean Pauling (Boulby Director):
material screening & background minimisation

The University Of Sheffield.

Neil Spooner:
gas purification & background minimisation

THE UNIVERSITY OF NEW MEXICO

Dinesh Loomba:
gas studies, cathode and field cage

I am currently drafting a tentative collaboration agreement between us and these 3 subjects

Ministero degli Affari Esteri
e della Cooperazione Internazionale

Collaboration with Japan (K. Miuchi) for development of optical readout

CALL FOR PROPOSALS
OF JOINT RESEARCH PROJECTS WITHIN THE EXECUTIVE PROGRAMME OF
COOPERATION IN THE FIELD OF SCIENCE AND TECHNOLOGY
BETWEEN ITALY – JAPAN FOR THE YEARS 2020-2022
CLOSING DATE: 31 October 2019 h. 13.00 C.E.T.

50 kEUROs grant submitted by Davide