COMPACT NEUTRON GENERATORS FOR THE CALIBRATION OF LOW BACKGROUND EXPERIMENTS

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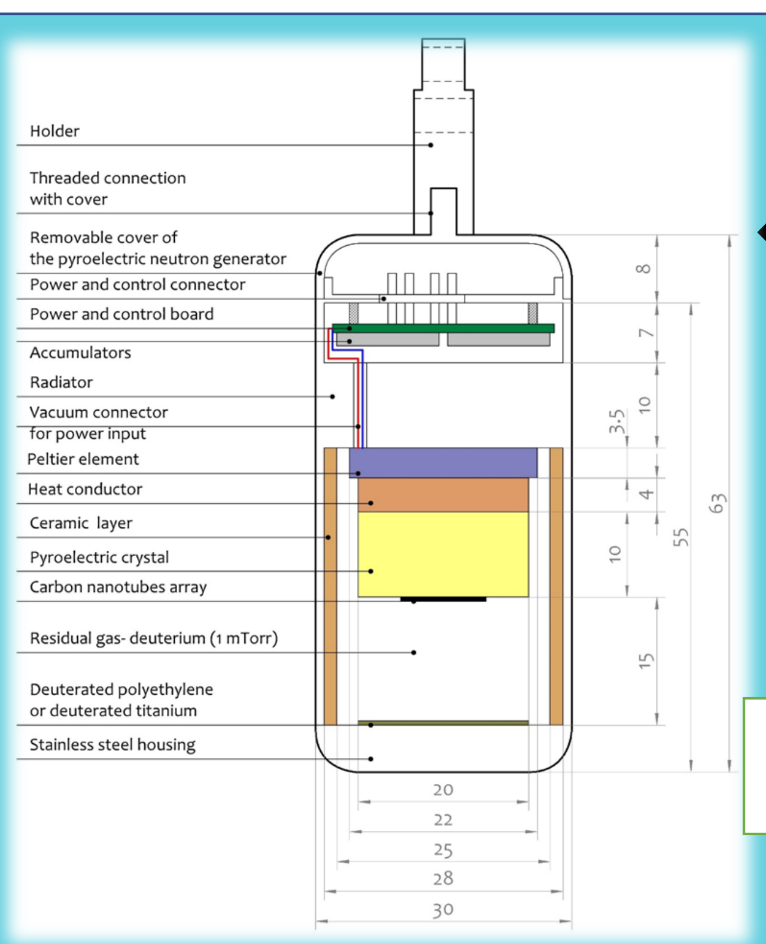
ABSTRACT

In the coming years, the compact monoenergetic neutron generators (CNG) producing up to 10^4 n/s may become an alternative to the standard neutron sources based on radioactive isotopes for the calibrations of neutrino and dark matter detectors. Such neutron generators have a typical size of about several centimetres, they may be manufactured using low-background materials and require only low voltage power supply for operation. We discuss the advantages and disadvantages of two types of the compact neutron generators, namely a pyroelectric neutron source and a source based on the carbon nanotubes. Also the results of the technical analysis of the possibilities to apply such sources for the calibration of low-background experiments are given, the variants of the internal device design are shown and the full-size compact neutron generator prototype are presented.

CNG TYPES: PNG AND HVNG

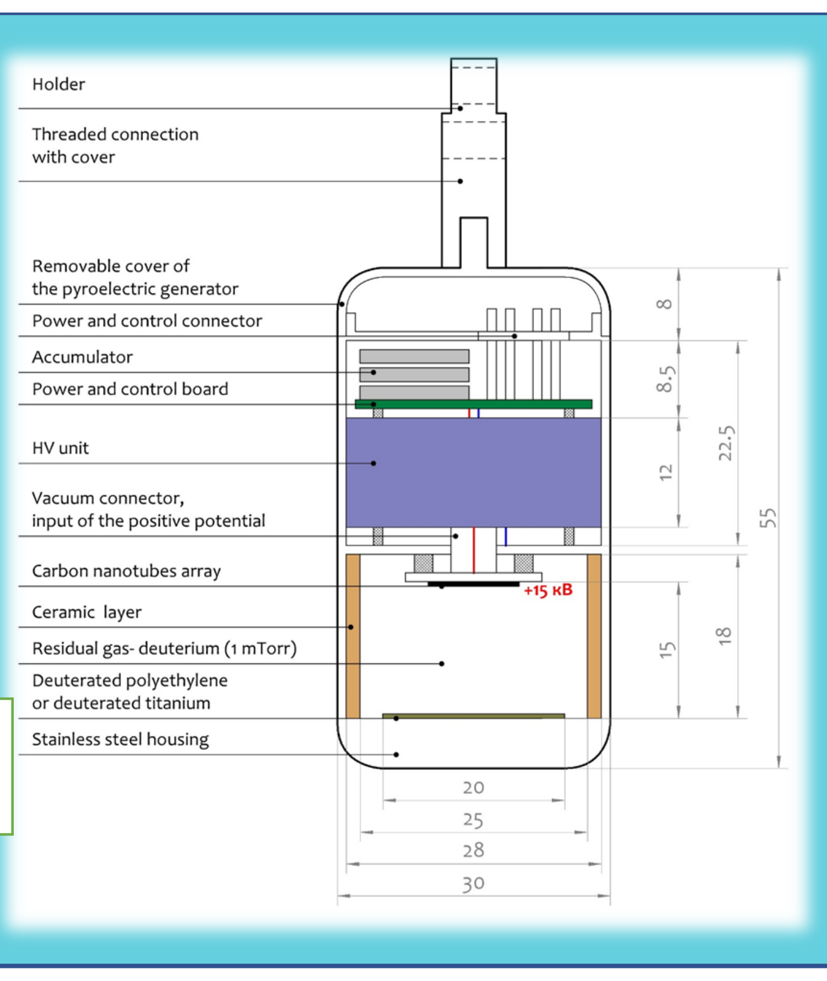


Conceptual designs

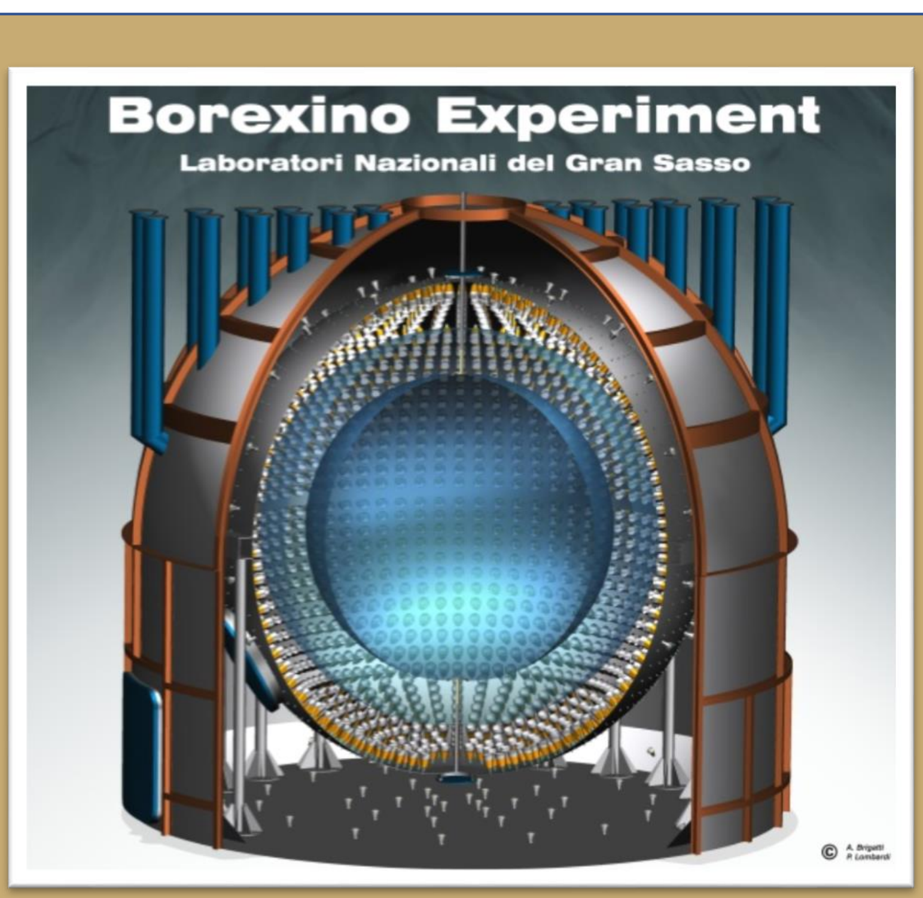
Main difference:

PNG
pulse mode

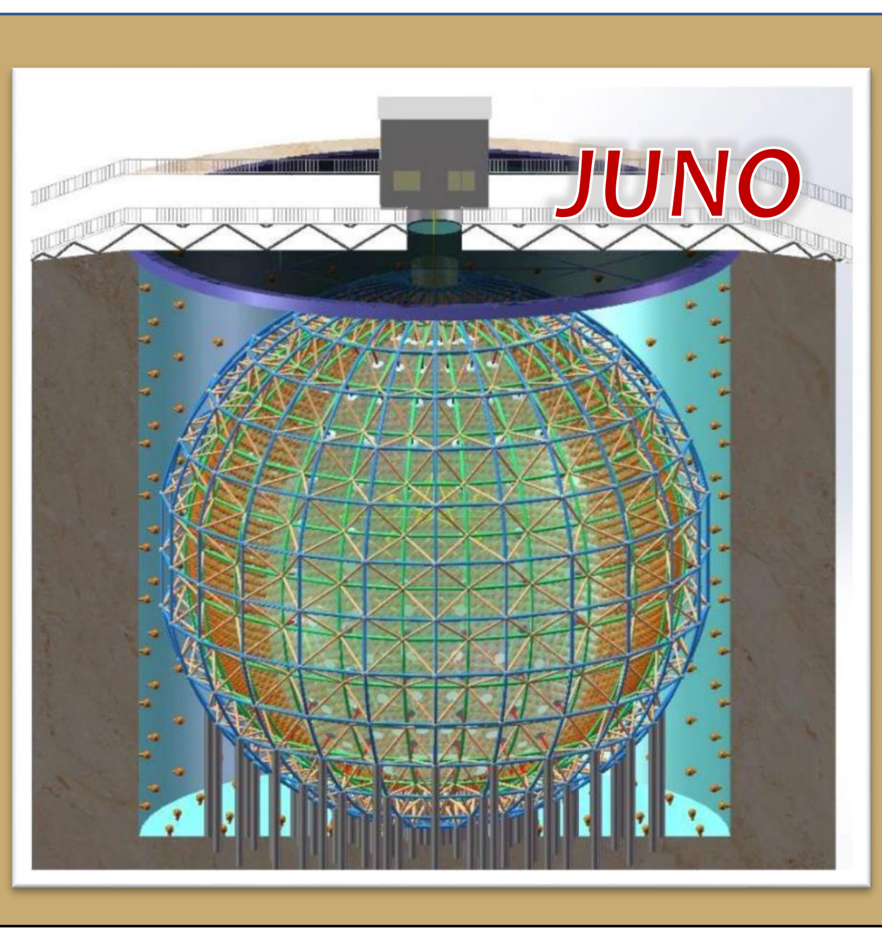
HVNG
almost continuous mode



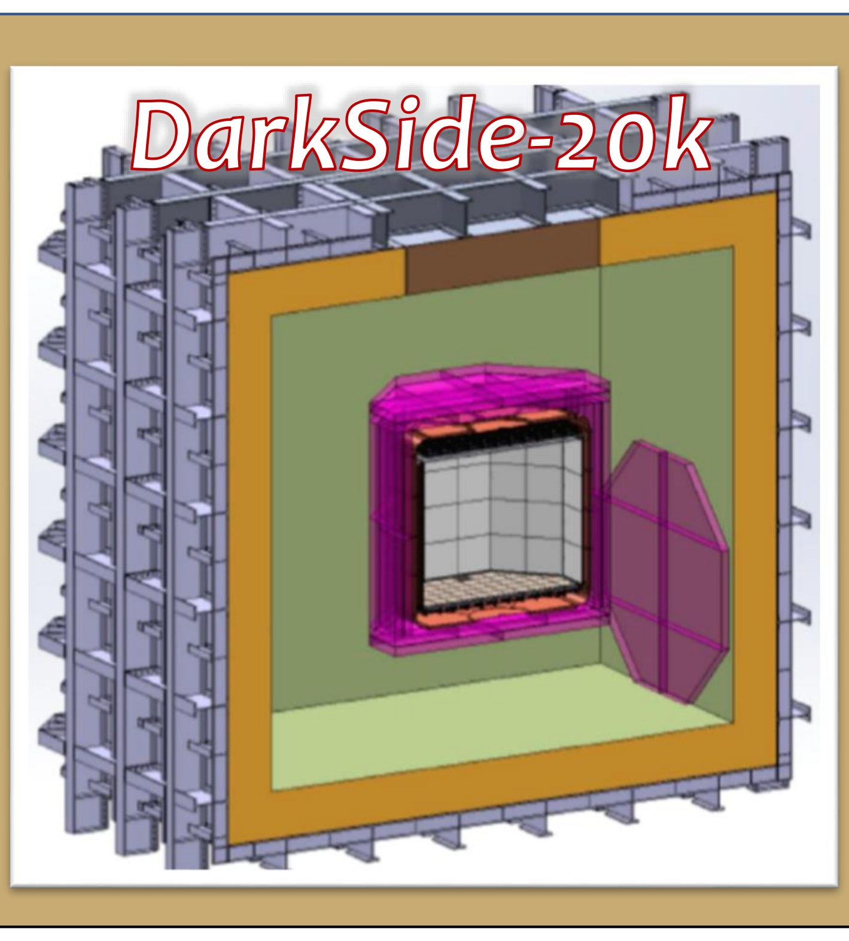
ULTRA LOW-BACKGROUND EXPERIMENTS IN NEUTRINO AND DARK MATTER PHYSICS



Solar neutrino physics
Target: Liquid scintillator, 278 t



Neutrino mass hierarchy
Target: Liquid scintillator, 20 kt



Search for dark matter particles
Target: Underground LAr, 20 kt

CNG SPECIFICATION

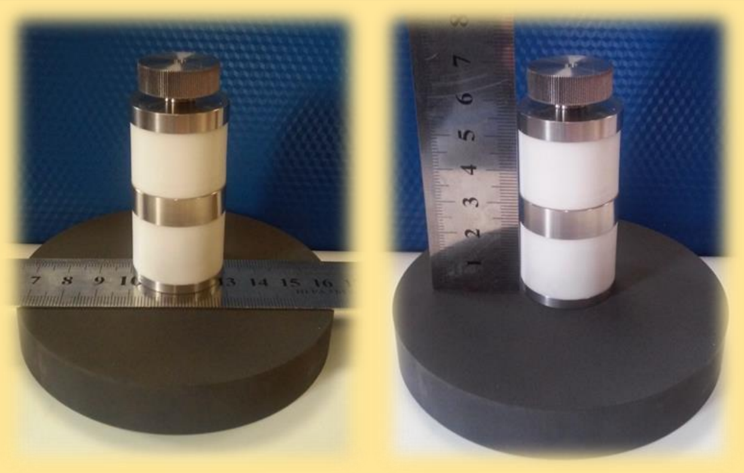
based on features of the low-background detectors and their calibration systems

Characteristic size ➢ Height ➢ Diameter	< 70 mm (max 100 mm) 30-40 mm (max 50 mm)
Housing material	acrylic, stainless steel, teflon, ceramics (Al_2O_3), quartz
Fixing method	hang on a tether (s) or rod (s)
Power supply method	wired or autonomous (battery)
Neutron yield, n/s	1-10^4 (adjustable)
Wireless switching system	preferable

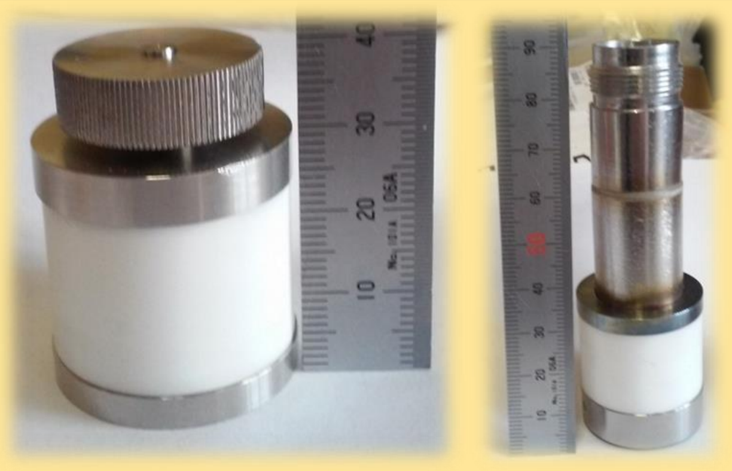
CALIBRATION WITH CNG: ADVANTAGES

1. Non-radioactive source in off mode:
   - Safety for experimenters and technical staff
   - Safety for low background environment
   - No papers
   - Easy logistics
2. Cheap source
3. Adjustable neutron yield
4. Reusable
5. Stable neutron rate (doesn't decay)

PROTOTYPES UNDER TEST



The vacuum-sealed metal ceramic bodies for PNG and NNG generators



The smallest version (left) and the assembly with a vacuum gauge (right)

ANISOTROPY OF THE PNG RADIATION

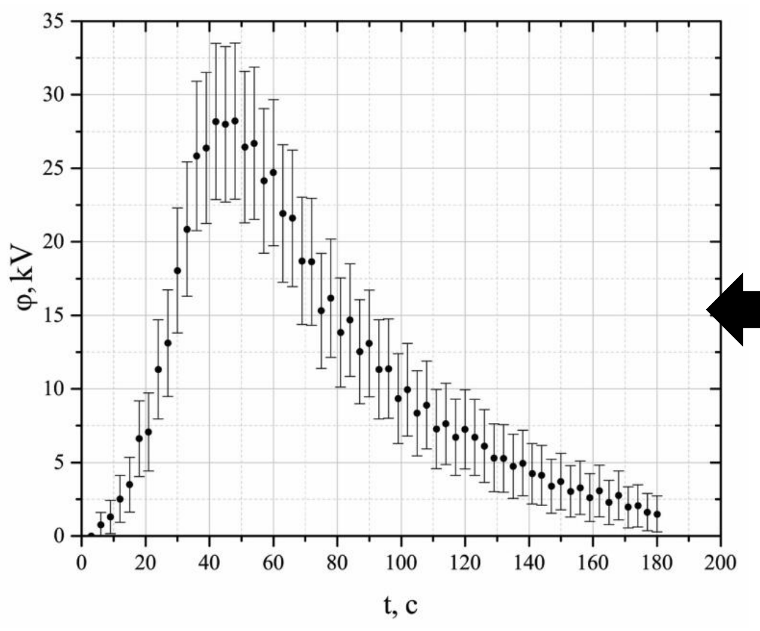
$$\widetilde{\frac{dN}{d\Omega}}(\theta) \equiv \frac{\frac{dN}{d\Omega}(\theta)}{\frac{dN}{d\Omega}(90^\circ)} = \frac{\frac{d\sigma}{d\Omega}(\theta)}{\frac{d\sigma}{d\Omega}(90^\circ)}$$

$$\frac{d\sigma}{d\Omega}(\theta, E_d) = \text{const} \cdot (1 + a_2(E_d)P_2(\cos\theta) + a_4(E_d)P_4(\cos\theta)),$$

where $P_2(\cos\theta)$, $P_4(\cos\theta)$ – Legendre polynomials.

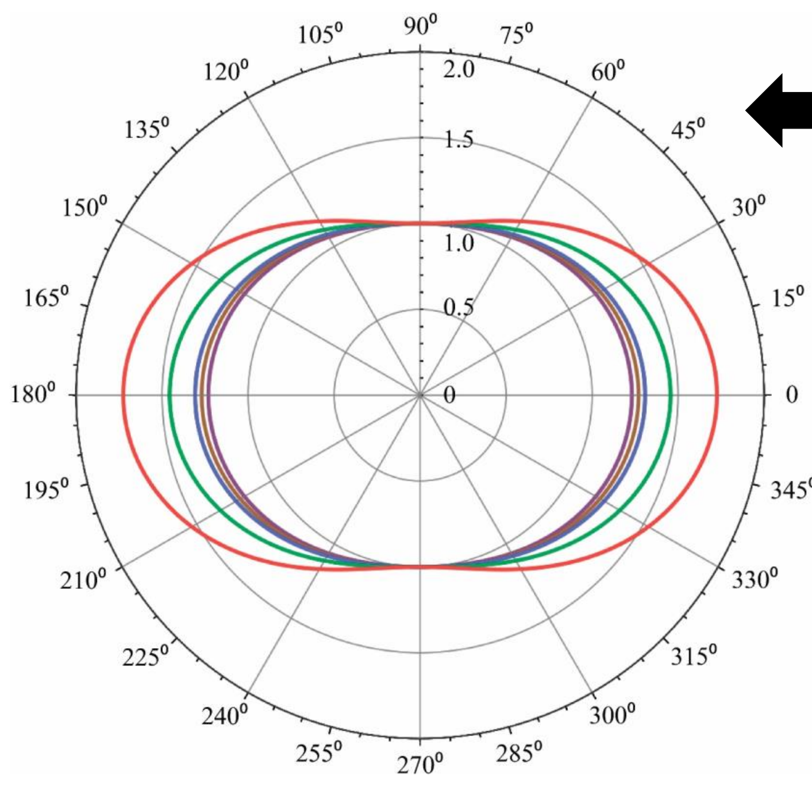
$a_2(E_d) = k_1(1 - e^{-k_2 E_d})$, where
$k_1 = 0.77564,\ k_2 = 0.01384;$
$a_4(E_d) = k_3 + k_4 E_d$, where
$k_3 = -0.01495,\ k_4 = 0.00053.$

$$\boxed{\widetilde{\frac{dN}{d\Omega}}(\theta) = \frac{\sum_i \widetilde{\frac{dN}{d\Omega}}(\theta, E_d^i)E_d^i}{\sum_i E_d^i}}$$



The dependence of the maximum value of the formed potential on the measurement time averaged over the surface of the pyroelectric crystal

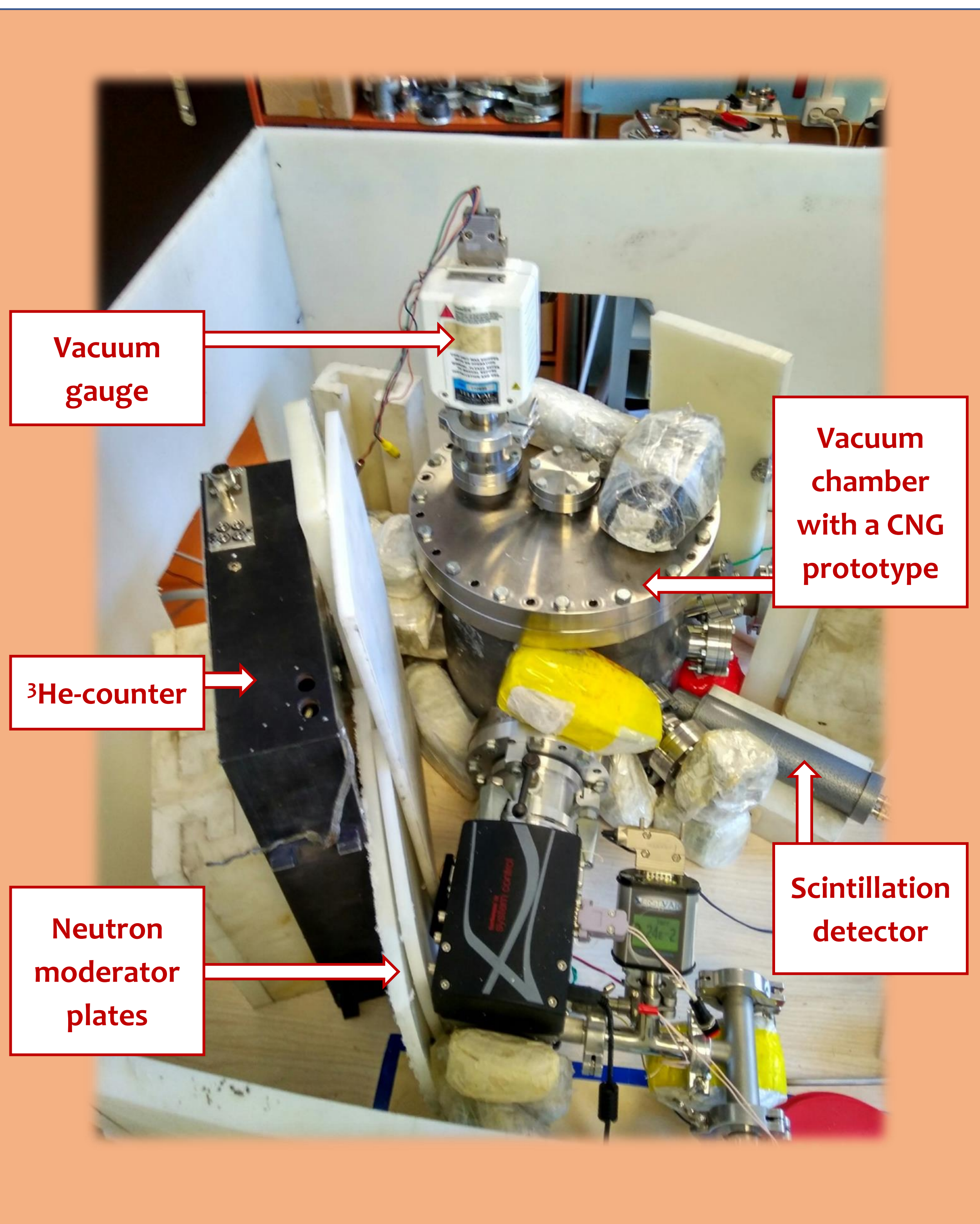
See more details: [1], [2], [3]



Angular distributions of neutron emission in polar coordinates for the reaction D(d,n)³He (numerical simulation)

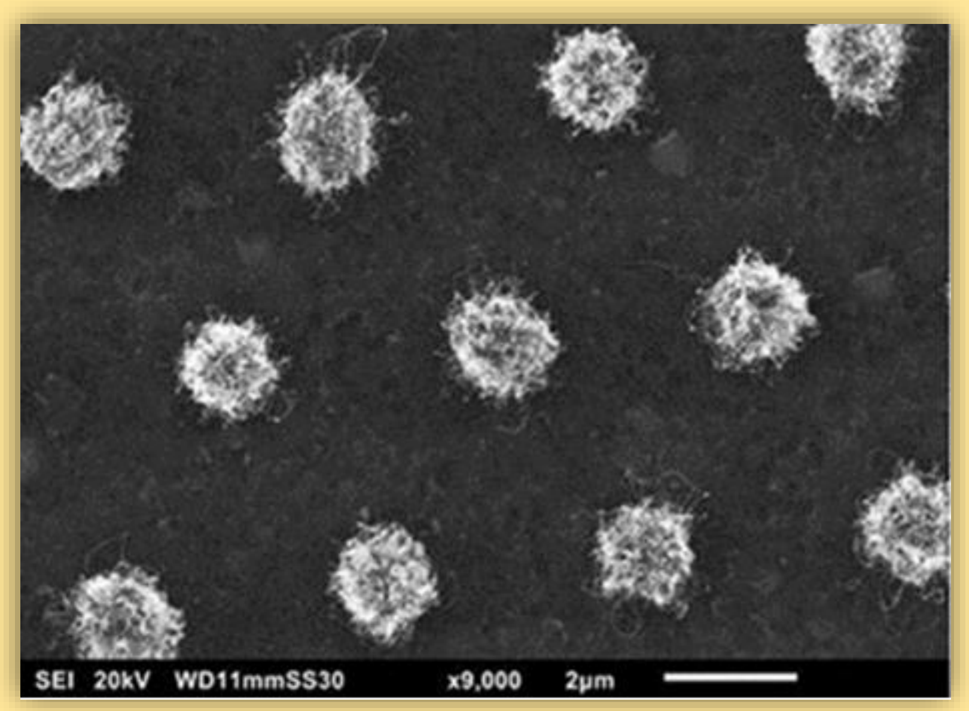
Deuterium incident energy
- 50 keV
- 30 keV
- 20 keV
- 0 - 30 keV (PNG)
- 15 keV

EXPERIMENTAL SETUP



NANOTUBE ION SOURCE

The array of carbon nanotubes as an ion source



Measuring of neutron yield (in seconds, 4π solid angle) in dependence from gas pressure and applied voltage

Applied voltage, kV	Scintillation detector			³He-counter		
	Deuterium pressure, mTorr			Deuterium pressure, mTorr		
	1.5±0.7	3±1	5±1	1.5±0.7	3±1	5±1
10	16±4	24±8	26±6	12±4	17±6	18±5
15	20±6	32±10	42±8	16±4	22±3	29±5
20	24±4	38±8	46±10	22±5	26±4	32±4
25	39±8	47±10	53±12	27±5	33±8	40±7
30	45±6	51±10	55±6	31±6	37±5	45±6
40	69±12	87±10	109±10	42±6	55±3	65±6

🟥 > 80
🟧 60-70
🟨 50-60
🟩 40-50
🟦 30-40
🟦 20-30
🟪 < 20

See more details: [4]

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