# Development of pyroelectric neutron source for calibration of neutrino and dark matter detectors


A. Chepurnov[a], M. Gromov[a], V. Ionidi[a], M. Kirsanov[b]
A. Klyuyev[c], A. Kubankin[c,d], A. Oleinik[c,*], A. Shchagin[c,e], K. Vokhmyanina[c],

[a]*Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Moscow, Russia*
[b]*National Nuclear Research University "MEPhI", Moscow, Russia*
[c]*Laboratory of Radiation Physics, Belgorod National Research University, Russia*
[d]*Lebedev Physical Institute, Moscow, Russia*
[e]*Kharkov Institute of Physics and Technology, Kharkov, Ukraine*
[*]*andreyoleynik92@mail.ru*

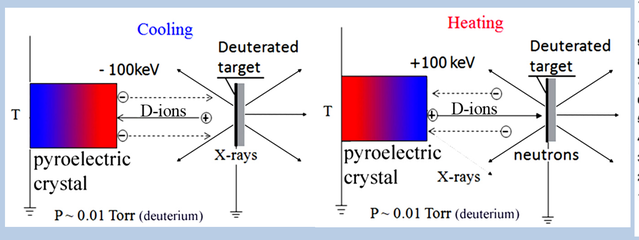

## Pyroelectric neutron source

Pyroelectric neutron generator advantages:
- compact size;
- NO radioactive components;
- NO HV power supply;
- can be remotely controlled.

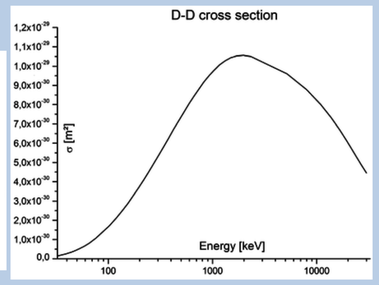
disadvantages:
- cyclical intensity, period about 1 min;
- low neutron yield ~ $10^4$ neutrons per cycle.

$$^2D + {}^2D \rightarrow \begin{cases} {}^3He\ (0.82\ MeV) + {}^1n\ (2.45\ MeV) \\ {}^3T\ (1.01\ MeV) + {}^1H\ (3.02\ MeV) \end{cases}$$

**Scheme of pyroelectric neutron source**




**Dependence of D-D reaction cross-section on ion energy**



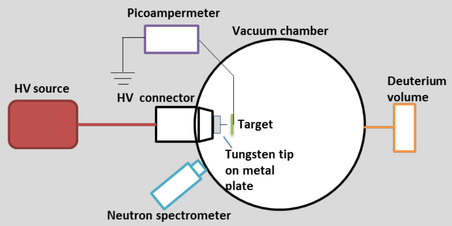

## Experiments with HV source

### *Main task*

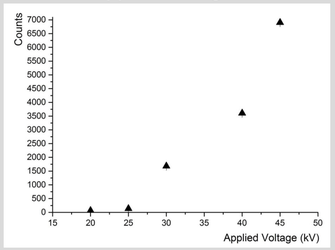
**Estimation of neutron yield in pyroelectric source geometry at low electric potential source**

- **Target – steel with deuterated coating**
- **Distance between target and tip – 10 mm**
- **Length of tip – 8 mm**
- **Initial diameter of tip – about 800 nm**
- **Pressure – about 1 mTorr**

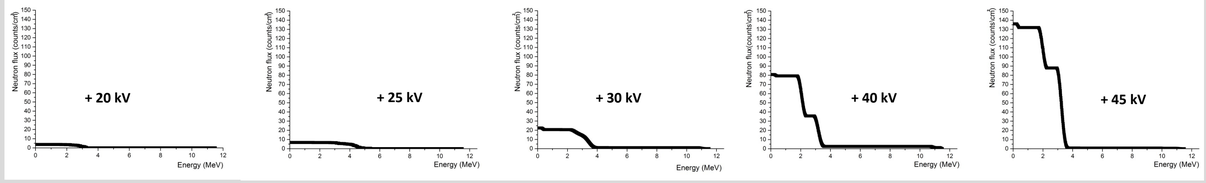
**Scheme of experimental setup for neutron generation by HV source**




**Dependence of neutron yield on applied voltage**




**Neutron spectrum at different applied voltages** (The duration of each measurement is 120 s)



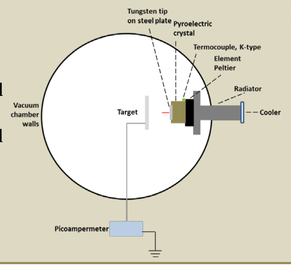

## Experiments with pyroelectric source

### *Main task*

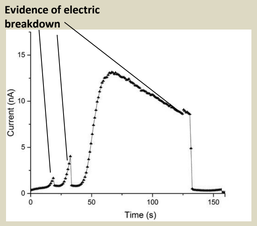
**Obtaining of necessary neutron flux by pyroelectric neutron source**

- **Target – steel with deuterated coating**
- **Distance between the target and the tip – 13 mm**
- **Length of the tip – 6 mm**
- **The initial tip diameter – 800 nm**
- **Pressure is about 1 mTorr**

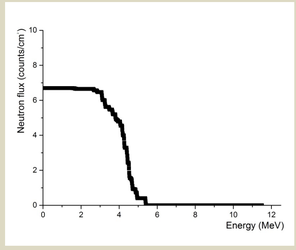
**Scheme of experimental setup for neutron generation by pyroelectric crystal**




**Typical ion current during thermal phase**




**Typical neutron spectrum during thermal phase** (Each spectrum gathered within 120 second)




## Conclusion

- **Pyroelectric neutron source can be used for calibration of low background neutrino and dark matter detectors. In general, it satisfies desirable parameters for calibration neutron sources. But some characteristics of the device must be improved, namely thermal heat exchange with environment and X-ray background can be reduced. The optimal way to do that is to decrease the electric potential, obtained with pyroelectric crystal.**
- **Experiments with HV source in geometry of pyroelectric source with tungsten tip allow to determine the lowest boundary of electric potential at tungsten tip for required level of neutron generation in calibration source. This boundary is slightly lower 30 kV. Keeping this value potential on tungsten tip with pyroelectric crystal is a sufficient condition for required level of neutron generation .**
- **Measurements of ion current from target show a presence of the electric breakdown during working process in a pyroelectric source. That process doesn't allow to keep the electric potential on the tungsten tip at required constant level, and as a consequence, it leads to unstable neutron generation with the pyroelectric source. The way of eliminating of the electric breakdown is a selection of optimal mode of temperature changes on the crystal.**
- **For the moment the development of pyroelectric neutron source for calibration of low background neutrino and dark matter detectors is at the laboratory stage. The decision of the problem with electric breakdown will allow to create a new compact device – the pyroelectric neutron source.**

## Introduction

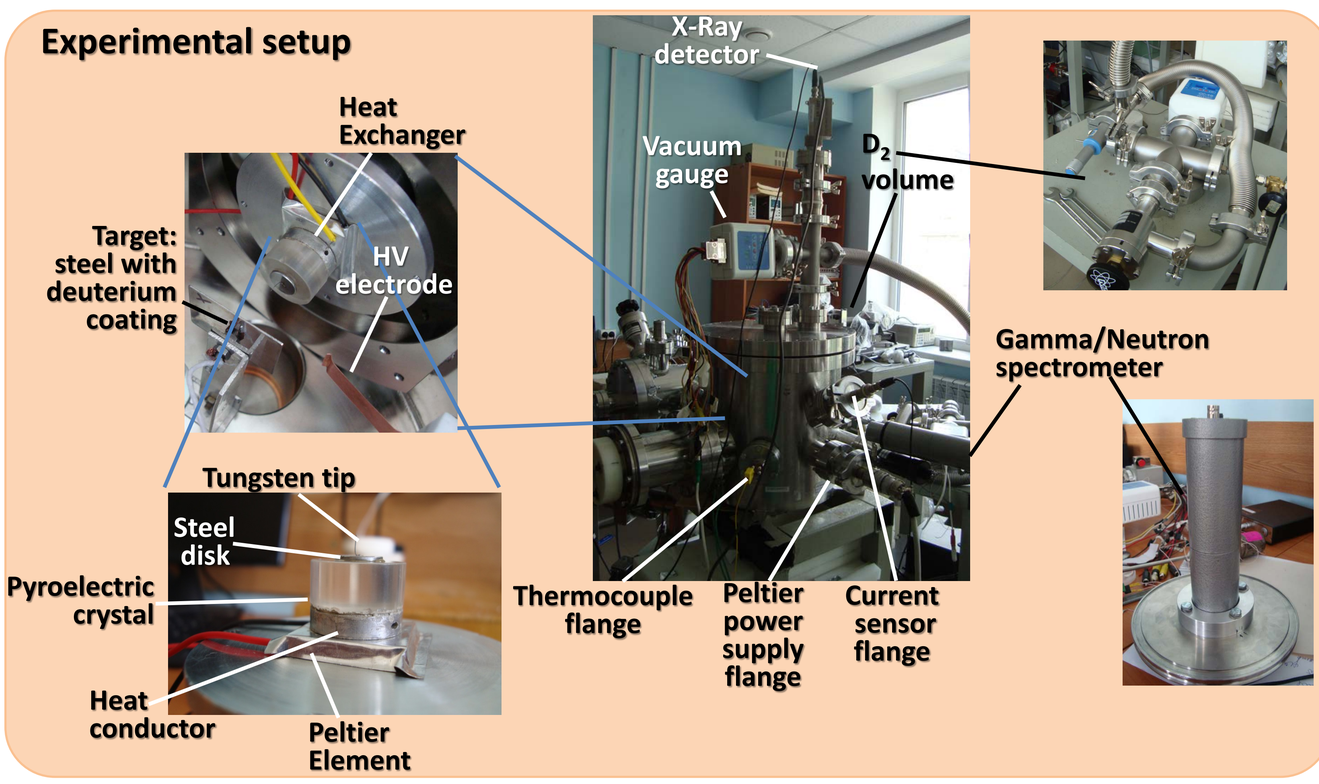
**Pyroelectric crystal ($LiTaO_3$) is used to produce fast neutrons with 2.45 MeV energy [1,2]. It is possible due to the pyroelectric effect, which creates strong electric field (about $10^6$ V/cm) near the pyroelectric surface, while temperature of pyroelectric is changed. The necessary conditions for generation of neutrons are presence of D2 and target from deuterated matter.**

**Pyroelectric source is considered as a promising and convenient instrument for neutron calibration of neutrino and dark matter detectors [3,4]. Such calibration tool will have a typical size of several cubic centimeters. The device doesn't contain any radioactive materials and can be manufactured low background. An external high voltage power supply isn't required. It is also important that the output neutron intensity can be controlled.**

**But there are also some problems :**

- **The presence of X-Ray background in parallel with neutron flux**
- **Instability of neutron flux**
- **Absence of data on durability of the source**
- **Risk of tungsten tip degradation**

## Experimental setup





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## References


[1] Naranjo B, Gimzewski J and Putterman S, *Nature* **434** (2005) 1115
[2] Geuther J, Danon Y and Saglime F *Phys. Rev. Lett.* **96** (2006) 054803
[3] Chepurnov A S, Ionidi V Y, Ivashchuk O O, Kubankin A S, Oleinik A N and Shchagin A V *J. Phys.: Conf. Series* **675** (2016) 032031
[4] Friske E, Deuter G and Jochum J *Eur. Phys. J.* A **51**, 42, 2015