- Project: **nEDM**
- Work Package 10: **UCN detectors**
- Subtask 10a: **Development of ^{6}Li doped glass scintillators**
- Subtask manager: **O. Naviliat-Cuncic (LPC-Caen)**
- Status: **January 2004**

1 Context and objectives

The main goal of this subtask is to study the performances of ^{6}Li doped glass scintillators (GS) for the detection of UCN. The results of this study are aimed to provide informations relevant to the task 10 for the choice of the detection system. Glass scintillators are known as a robust and efficient detection tool for thermal neutrons. Their use for UCN had not be proved experimentally prior to the tests described below.

2 Specifications

We recall that the UCN counters should fulfill a number of criteria associated with the running conditions of the EDM experiment:

a) The detectors must have a high detection efficiency over the UCN velocity range between 4 to 8 m/s. The efficiency figure should take into account the losses on dead layers and those due to electronic conditions or cuts.

b) The time response must be sufficiently fast to cope with counting rates up to 10^5 n/s/cm^2.

c) The gain of the system has to be stable under varying rates like those associated with the counting of UCN during emptying the spectrometer chambers.

d) The isotopes used for the neutron absorption have to be well packed to avoid the contamination of the neutron guides and chambers.

e) The system must have a low sensitivity to gamma radiation or be able to discriminate between neutrons and gammas.

f) The detectors must be radiation hard to avoid gain losses under moderate neutrons doses of about 10^8 n/cm^2/year.

g) It is suitable that the system, including the associated electronics, be simple to operate and to maintain and that the cost be adapted.

3 Progress Report

3.1 Test measurements with UCN

A short (3 days) test run has been performed in November 2003 with UCN at the PF2 source of ILL.

Setup

Four types of glass scintillators (from Applied Scintillator Technologies) have been tested. They were mounted in three pieces: one of GS1, another of GS10 and the third consisting of two scintillators GS20/GS3 glued together. The calculated critical velocities of these scintillators are listed in table 1 along with the ^{6}Li density and the thicknesses. The surface of the scintillators were 60×20 mm^2. The scintillators were coupled to a Photonis PM1911 tube through a Plexiglas light guide. For the GS1 and GS10 pieces, a 200 nm Al reflector layer was evaporated on the opposite face to the Plexiglas. This is the only dead layer traversed by the UCN before entering the scintillators. Each scintillator was located at about 1 m from a beam chopper mounted on the beam line. Under typical running conditions the chopper duty cycle was about 6%.

Table 1: Data of glass scintillators. GS3 and GS20 were glued in a single piece.

scintillator type	critical velocity (m/s)	^{6}Li density (cm^{-3})	thickness (μm)
GS3	4.4	6.4×10^{17}	250
GS1	4.4	5.1×10^{20}	500
GS10	4.0	1.8×10^{21}	250
GS20	4.5	2.2×10^{22}	250

Signals and data

The signals from the PMs were amplified and integrated in a standard way. Three informations have been recorded for each event: the total charge of the signal from the PM, the charge of a fast component of the signal and the TOF relative to the chopper. The charge of the fast component was recorded for eventual discrimination of the gamma background. The TOF measurement relative to a signal from the chopper was used to study the detector response as a function of the UCN velocity. It also allows to estimate the uncorrelated background which is not discriminated by the pulse height.

Results

The main result of this test is the demonstration that glass scintillators are adapted to detect UCN. Due to the different ^{6}Li densities the losses due to edge effects are not expected to be the same, a fact which has also been observed. Such effects are large for GS20 but do not appear to be important for GS1 and GS10. No attempt has been made so far to quantify this effect and compare the measured results with simulations.

The relative efficiency of the scintillators as a function of the velocity have been compared assuming that for the upper part (above 16 m/s) of the velocity spectrum they are all identical. The results indicate that GS10 presents the highest efficiency toward lower velocities.

Future improvements

During the short test at ILL a technical problem with the electronics of the PM signals affected the shape of the measured distributions. This worsened the effective width of the distributions which had not been optimized at this stage in terms of the light collection geometry. Earlier measurements with VCN at ILL using other preamplifiers and geometries and tests performed in the laboratory with moderated neutrons from radioactive sources showed typical energy resolutions in the range 25-30% FWHM. The optimization of the geometry should improve the resolution to 20-25% which is sufficient for an efficient gamma/neutron separation.

The thicknesses of the scintillators have been chosen to ensure that all incident UCN will be captured. The higher ^{6}Li density of GS10 scintillators allows to consider the use of thinner pieces which are then less sensitive to gamma background.

3.2 Radiation hardness tests with cold neutrons

A test measurement has been carried at the SINQ source at PSI with the aim to observe eventual modifications of the optical properties of the scintillators under large neutron doses.

Two pieces of 1 mm thick GS20 glass scintillator with a surface of 20×20 mm^2 have been irradiated under the high flux of the FUNSPIN beam line. The estimated absorbed dose were respectively 3×10^8 and 1×10^{12} neutrons/cm^2. The neutron flux has also been monitored by activation of Au foils.

For each piece the amplitudes of the signals before and after irradiation have been compared. No measurable effect has been observed within the level of reproducibility of the detector test bench. This confirms that glass scintillators provide a robust solution with respect to aging effects due to irradiation.

4 Plans and Schedule

The results of this first series of tests look promising despite of the problem with the electronics. No serious drawback of the glass scintillators has been identified so far which would motivate abandoning this solution.

We consider as next step to build a prototype module for the UCN polarization analysis. The module will include several detectors using GS10 scintillators around a magnetized foil. This prototype will also orient the choice of the PM tubes to work in such an environment. These can either be compact to operate under high magnetic fields or standard with an appropriate shielding.

5 Requested Resources

The LPC-Caen group obtained from IN2P3 a "Young Team Grant" in 2003 to carry the tests described above. The total cost (equipment, travel and subsistence) was 12 kEuro. The cost of the tests to be performed in 2004 is estimated to about 10-13 kEuro and will be funded directly by LPC-Caen.

6 Related work packages

The activities in this subtask have connections with the following tasks and work packages:

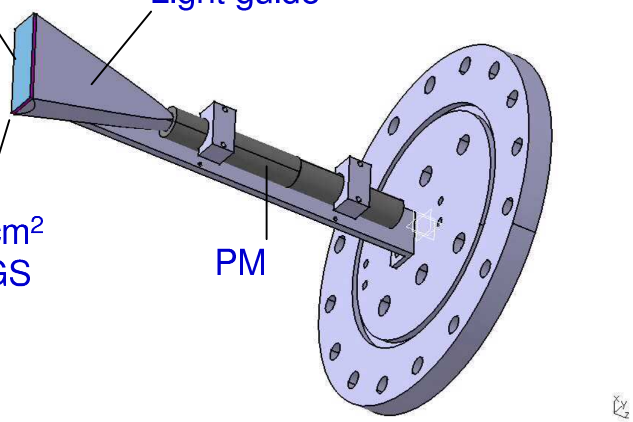
- Mechanical of the vertical UCN guides and their housings.
- Electronics for detection system.
- Data acquisition.

7 People

This subtask is being carried by the LPC-Caen group. The persons involved in these developments are:

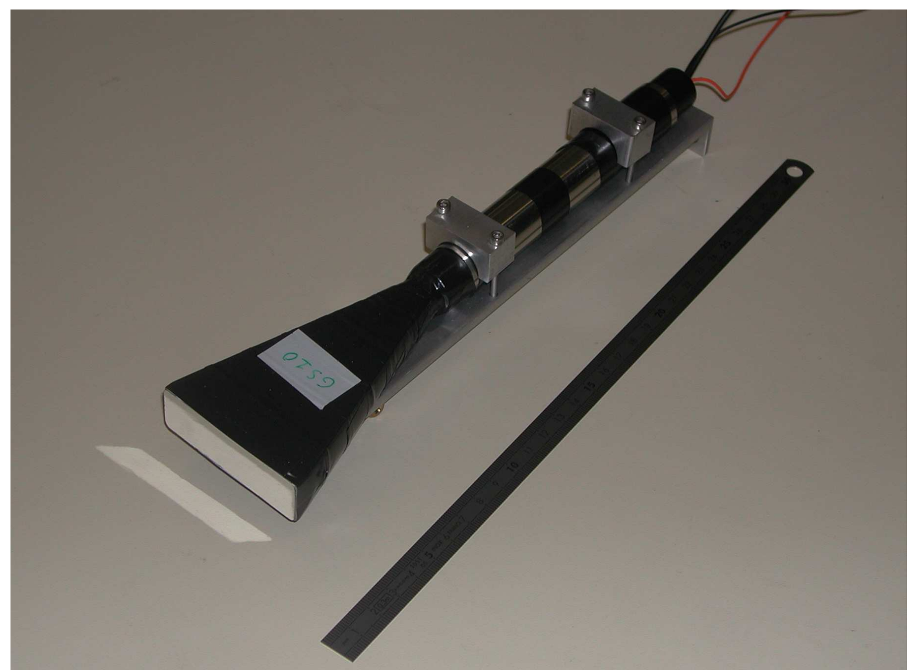
G. Ban, X. Fléchard, M. Labalme, T. Lefort, E. Liénard, O. Naviliat-Cuncic

^{6}Li doped GS-UCN detectors



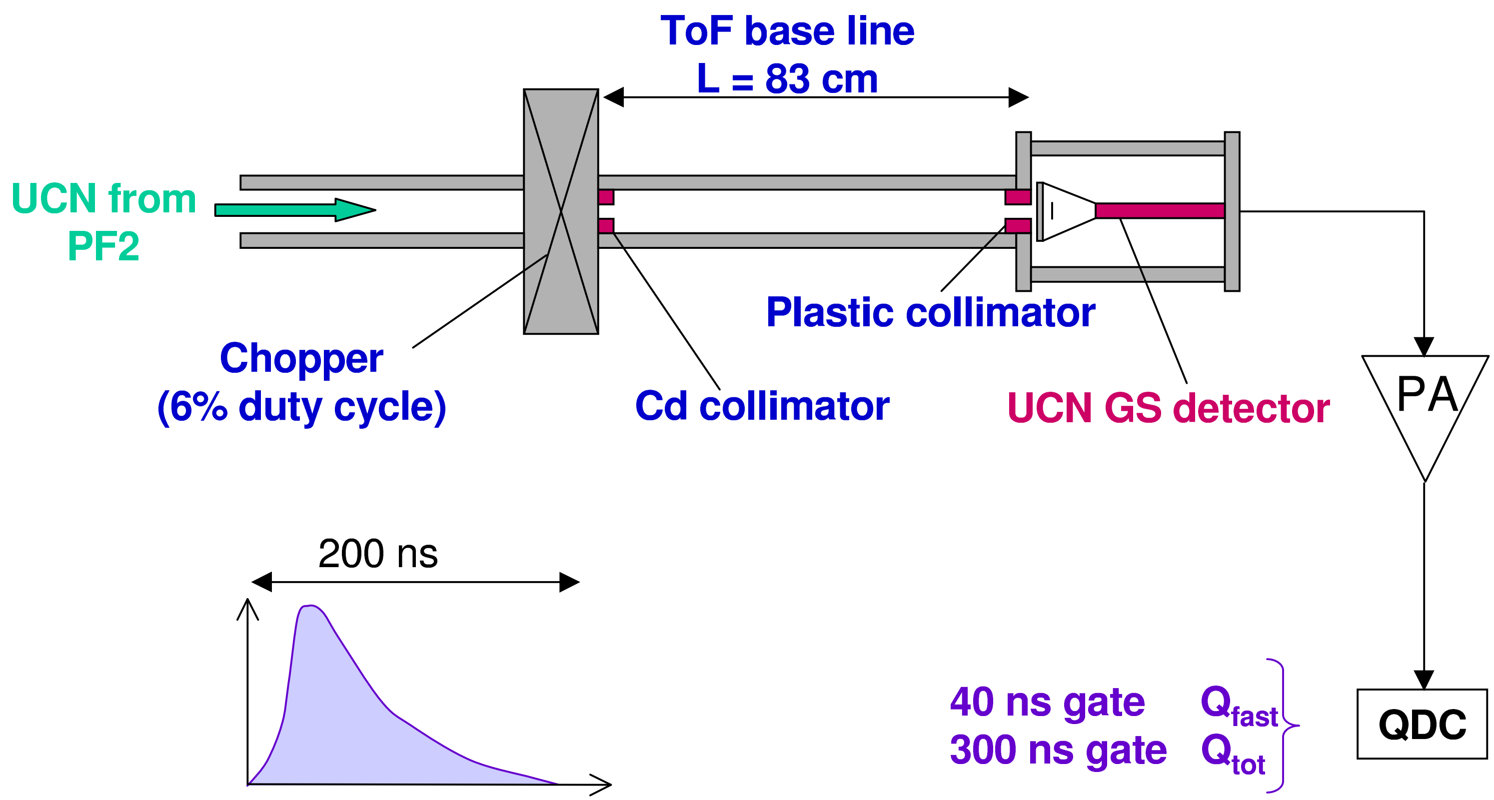
GS type	Thickness (μm)	^{6}Li Oxide weight (%)
GS1	500	0.45
GS10	250	1.35
GS20 / GS3	250 / 250	17 / ≈ 0

- 200 nm dead layer
- Fast (fall times < 150 ns)
- Low critical velocity
- Low γ sensitivity
- Radiation hard
- Simple and cheap



Test experiment at ILL

- **Experimental setup**

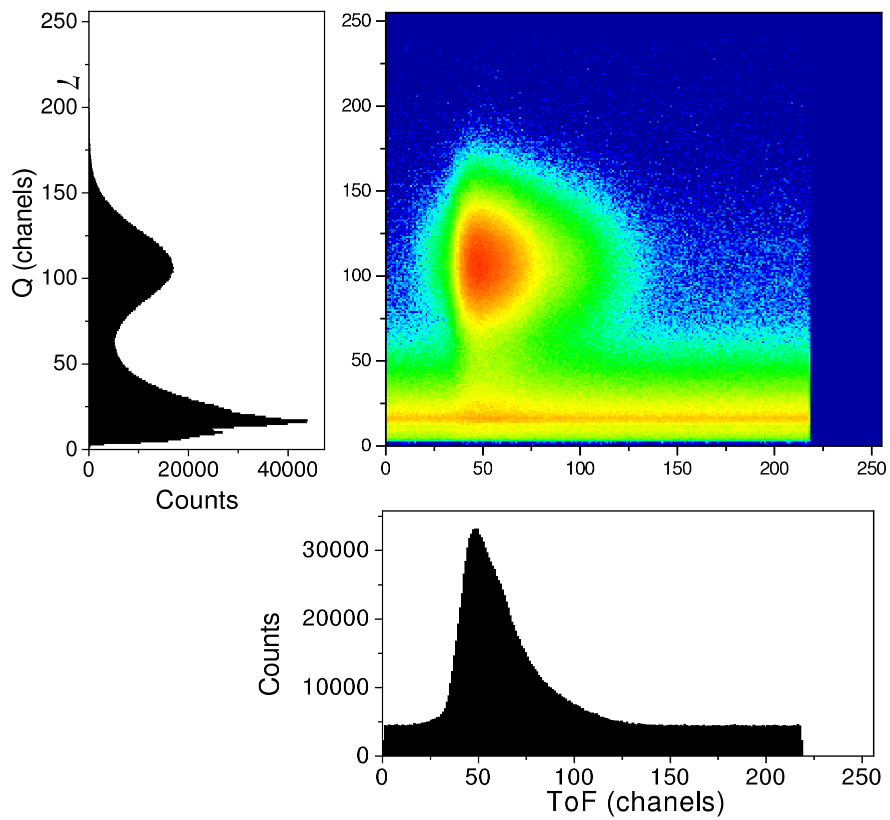


•Typical charge signal from UCN

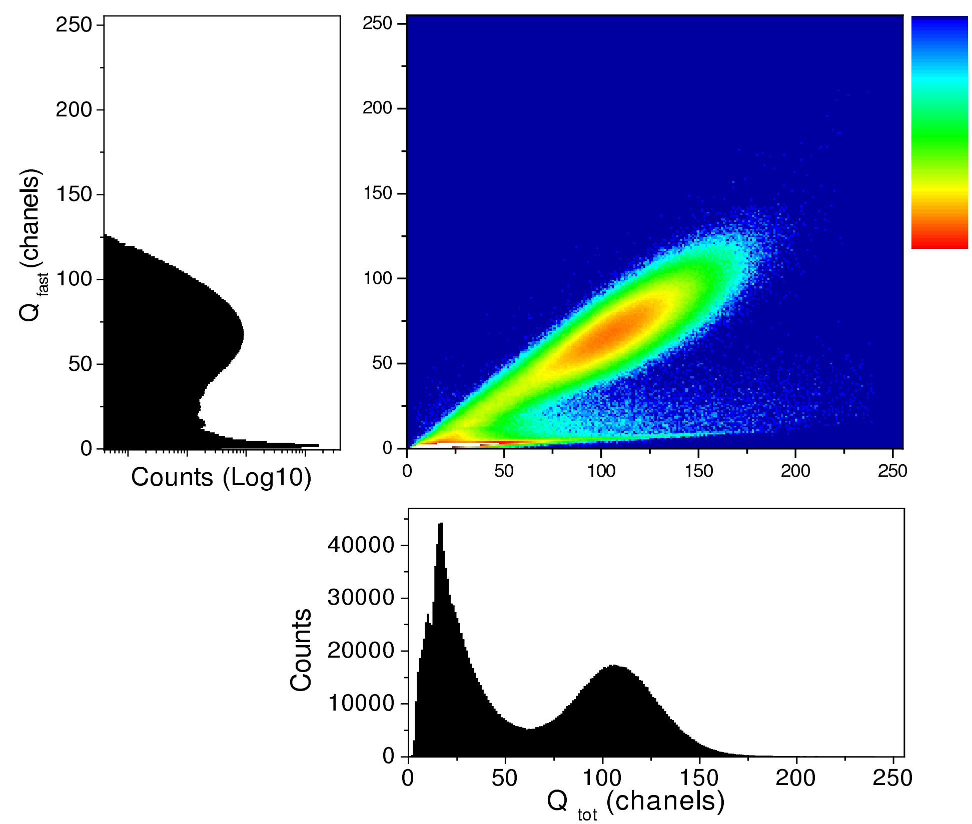
Raw data

- **GS10 raw spectra**

Q_{tot} vs Tof

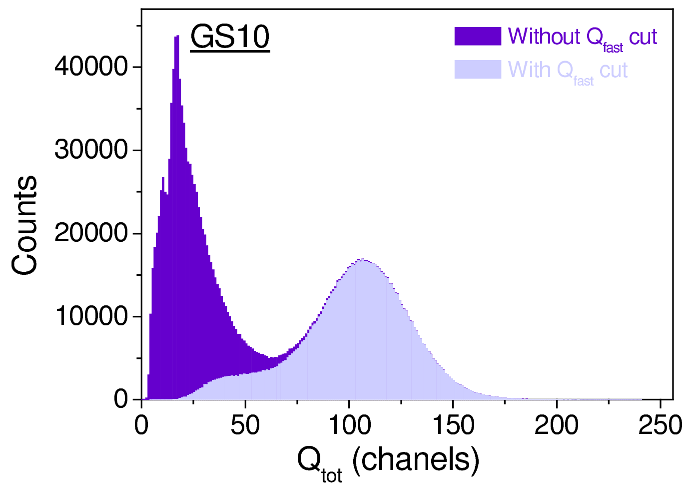


Q_{fast} vs Q_{tot}

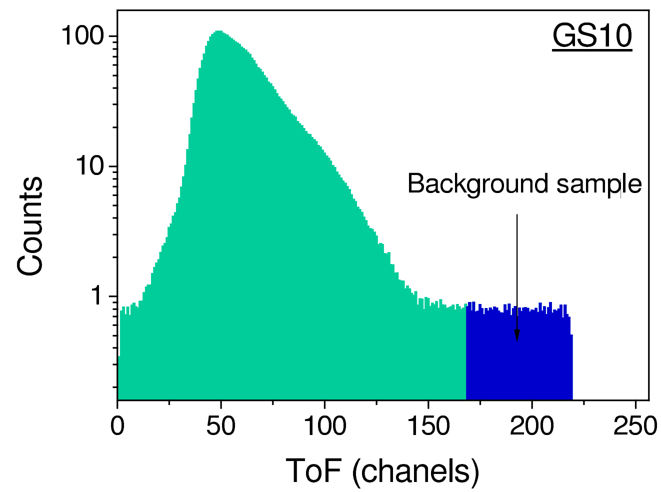


Charge selection and velocity distribution

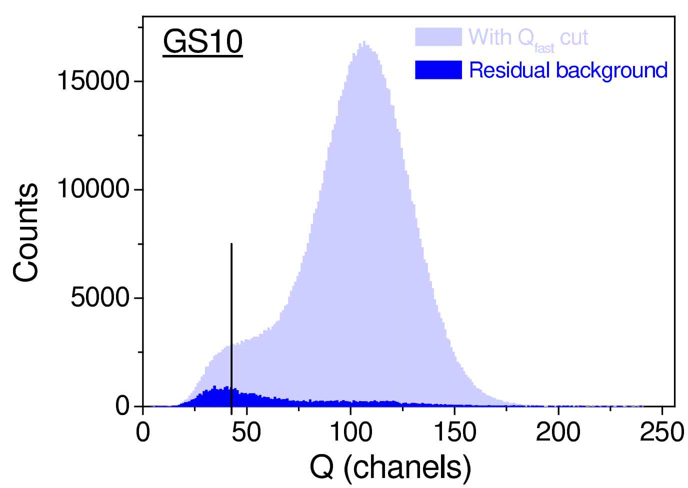
- Charge selection



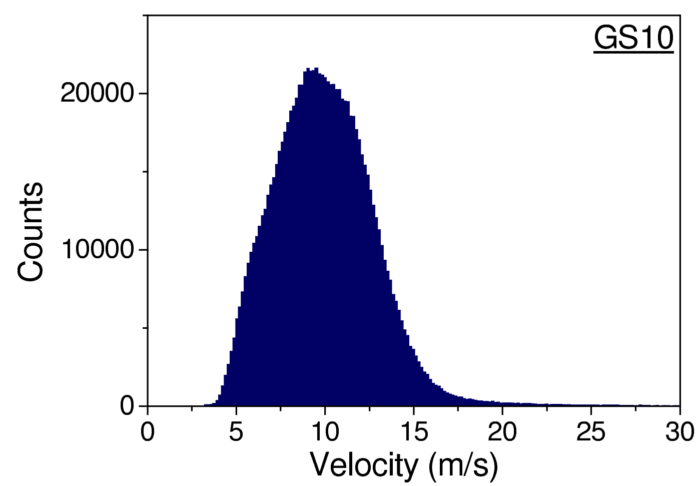
- ToF measurement



- Background measurement



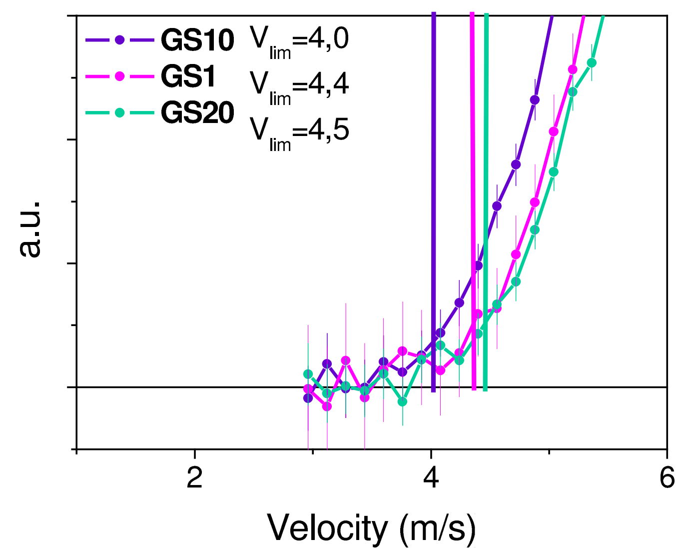
- Velocity distribution



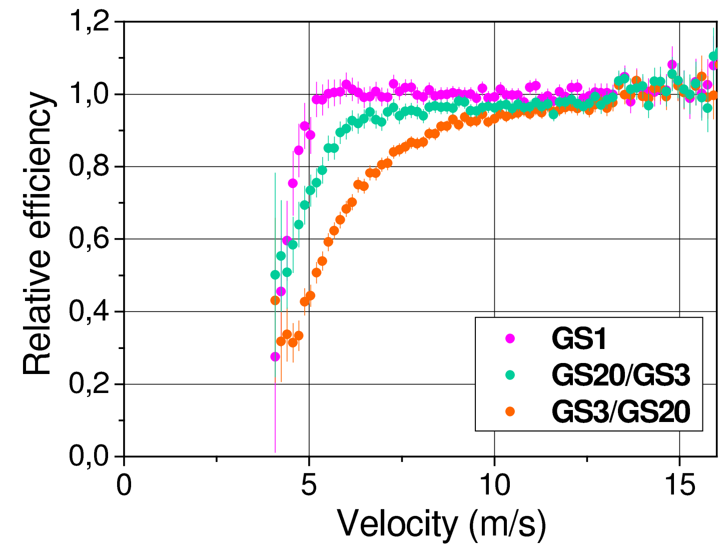
- Cut at 3 σ ⟶ 95 % of UCN, background < 1.5 counts / s

GS ^{6}Li doping comparison

- Behavior at low velocity



- Efficiency relative to GS10



Radiation hardness

- Tests with cold neutrons at SINQ

Estimated absorbed doses: 3×10^8, 1×10^{12} — No measurable effect !

Conclusions

- **Criteria for UCN detectors**
  - Efficiency (including dead layers and electronics)
  - Time response
  - Gain stability vs rate
  - Packaging of ^{6}Li
  - Sensitivity to γ radiation
  - Radiation hardness
  - Simplicity of operation and cost

- **GS detectors appear competitive for all requirements**
- **Further improvements and tests under way**