

UCN DETECTION WITH ⁶Li DOPED GLASS SCINTILLATORS

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Properties of the ⁶Li-doped glass GSx scintillators

Scintillators	⁶ Li enriched (95 %)*	⁶ Li natural (7.5 %)*	⁶ Li depleted (0.01 %)*			
GS2	GS20	GS1	GS10	GS3	GS30	
Li ₂ O weight (%)	6	18	6	18	6	18
Critical velocity (m/s)	4.6	4.5	4.4	4.0	4.4	4.0
Fermi potential (neV)	109	107	102	85	103	83

* Percentage of ⁶Li among the Li present within the scintillator

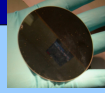
- o Composition: SiO₂, MgO, Al₂O₃, Li₂O, Ce₂O₃ ...
- o Density ~ 2.5 g/cm³
- o Scintillating atom: Ce³⁺
- o Maximum emission wavelength: 395 nm
- o Fast pulse: ~ 300 ns
- o Produced photons / neutron capture: ~ 7000

NEUTRON CAPTURE



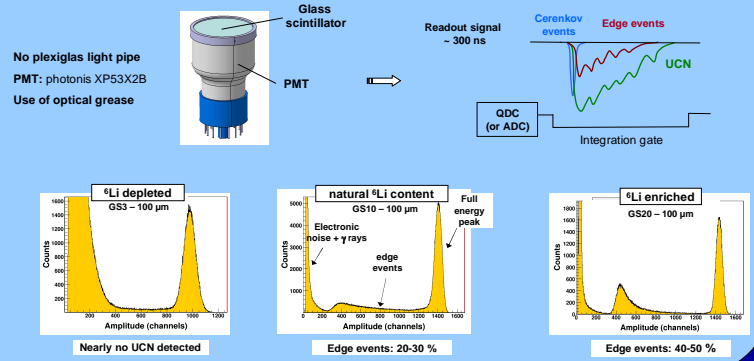
$$\sigma_{\text{absorption}}({}^6\text{Li}) = 940 \text{ barns}$$

Rate capability : up to a few 10⁶ UCN/s



Charge distributions of the single ⁶Li-doped scintillators

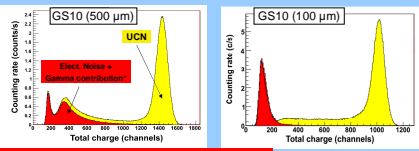
[Measured at PF2@ TEST beam line]



Gamma sensitivity of GS10 scintillator

[Measured at ILL PF2@ TEST beam line]

Scintillators directly coupled to PMT without any optical interface



* Measured with a full disk of Polyethylene in front of the detector

→ better neutron gamma discrimination with thin scintillators

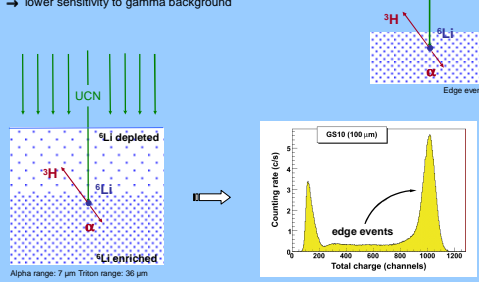
GS10 scintillator (100 μm thick): 10 times more sensitive to background than gas detectors BUT at the full energy peak location, the background sensitivity is similar [G. Ban et al., NIM A 611 (2009), 280-283]

Stack of two scintillators

Idea: get back the energy of the escaping particles from the edge events

Motivation:

- better discrimination between the gamma and the neutrons
- lower sensitivity to gamma background



Development of a new system: ⁶Li depleted scintillator in front of a ⁶Li enriched scintillator

Search for the best combination of scintillators

[Measured at ILL PF2@ TEST beam line]

High efficiency of detection:

- transmission of the first stage as high as possible
- two possibilities: lower its thickness, vary its composition

Stack composition	GS3-GS3-GS10 (100-100-100 μm)	GS3-GS10 (100-100 μm)	GS30-GS10 (100-100 μm)
Efficiency of detection / single GS10	54 %	72 %	80 %
Stack composition	GS3-GS20 (100-100 μm)	GS30-GS20 (100-100 μm)	GS30-GS20 (60-120 μm)
Efficiency of detection / single GS20	81 %	88 %	95 %

- ⁶Li depleted scintillator with the best transmission: GS30 (60 μm)
- Same efficiency of detection for single: GS10 (100 μm) and GS20 (100 μm)

Best combination: GS30 (60 μm) – GS20 (120 μm)

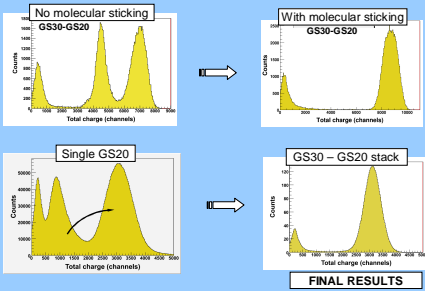
Light collection issue: molecular sticking technique

The charge distribution of the scintillators stack shows two peaks

Origin: full light collection at the scintillators interface is not achieved

Solution: perform a molecular sticking between the two scintillators

Technique: highly polishing of the glasses surfaces, press the two pieces together then the Van Der Waals forces act and stick the two scintillators



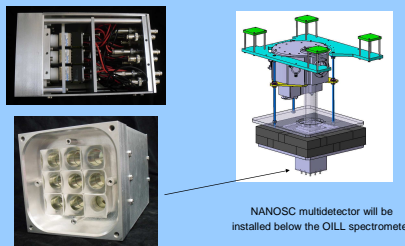
Development of a UCN multidetector with a high rate capability for the nEDM experiment at PSI

Maximum expected rate at PSI below the nEDM spectrometer: few 10⁶ UCN/s

- Rate capability of the glass scintillators: about a few 10⁶ neutrons/s
- But light readout is performed with PMT limited to a few 10⁵ pulses/s

Development of a square mosaic of 9 glass scintillators (NANOSC)

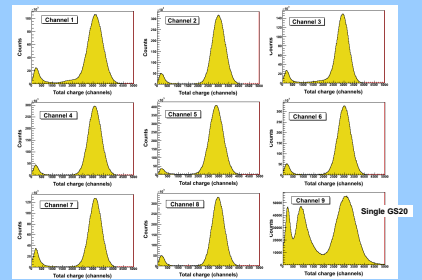
- each channel is made of: GS30-GS30 stack + light pipe + PMT



NANOSC multidetector will be installed below the OILL spectrometer

NANOSC multidetector tested at ILL

Charge distribution of the 9 channels measured at PF2/TEST beam line - clear separation between the neutron and gamma contributions is achieved



³He gas detector

[Strelkov type], Daria-10

o Composition: mixed gas

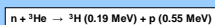
Ar (1.1 bar), ³He (15 mbar), CO₂ (15 mbar)...

o Slow pulse: 2 μs

o Entrance window: Al (100 μm)

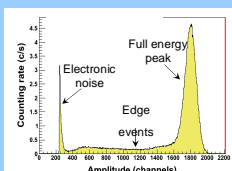
o Critical velocity: 3.2 m/s (V_{Fermi}=55 neV)

NEUTRON CAPTURE



$$\sigma_{\text{absorption}}({}^3\text{He}) = 5330 \text{ barns}$$

Rate capability: up to few 10⁴ UCN/s



Scintillators vs. ³He gas detector

[Measured at PF2@ TEST beam line]

Glass scintillator with natural ⁶Li content: GS10

Turbine → UCN → Detector

Thickness of the GS10	100 μm	250 μm	500 μm
Relative efficiency / ³ He	85 %	98 %	115 %

→ highly efficient with a large enough thickness

⁶Li depleted + ⁶Li enriched scintillators: GS30 (60 μm) - GS20 (120 μm)

Depending on the UCN velocity distribution (preliminary results !)

- relative efficiency / ³He gas detector: 93% - 115 %

NANOSC multidetector made of nine GS30 (60 μm) - GS20 (120 μm)

Depending on the UCN velocity distribution (preliminary results !)

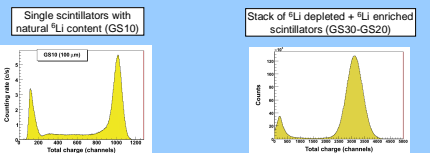
- relative efficiency / ³He gas detector: 87% - 110 %

Conclusions

UCN detector based on ⁶Li doped glass scintillators

- maximum rate capability: up to few 10⁶ c/s
- highly efficient above UCN velocity: 4 - 4.5 m/s
- low background sensitivity
- radiation-robust : successful test at 10¹² n/cm²

Two type of glass scintillators can be used for UCN detection



Easy to use but worst neutron gamma discrimination

Nice neutron gamma discrimination but fragile

Special thanks to Peter Gellenbort