LUPIN, a novel REM counter for synchrotron facilities

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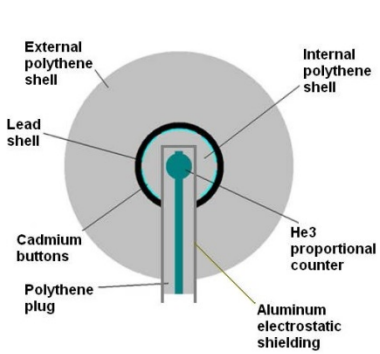
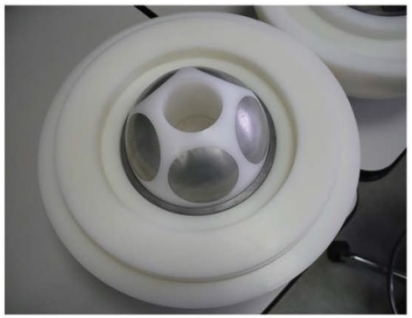
LUPIN



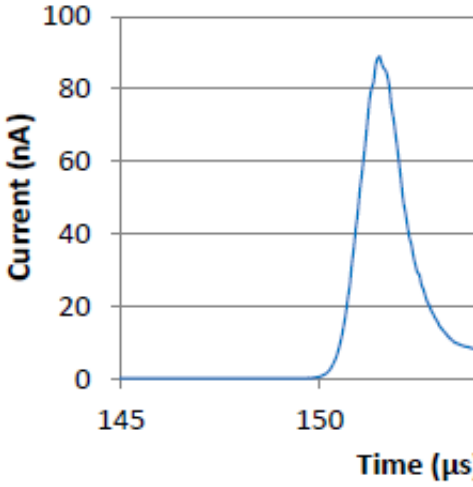


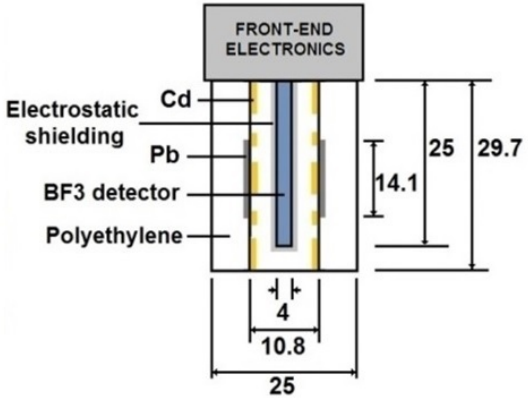
- Neutron REM counter developed in collaboration between ELSE Nuclear and Politecnico di Milano
- Uses a fast LOGAMP and unique acquisition method to allow it to cope with intense Pulsed Neutron Fields
- An ADC samples the current through the counter at 10MHz, then acquires for a user set time window (most commonly 2 or 4 ms) during a neutron burst
- The current is integrated over the time window to find the total charge of the window. This is then divided by a Charge Calibration Factor (CCF) to find the number of interacting neutrons. From this the dose is determined using an Ambient dose Equivalent (H*(10)) calibration factor.

$$H^*(10) = \frac{Total\ Integrated\ Charge}{CCF} \cdot C_{H^*(10)}$$

LUPIN

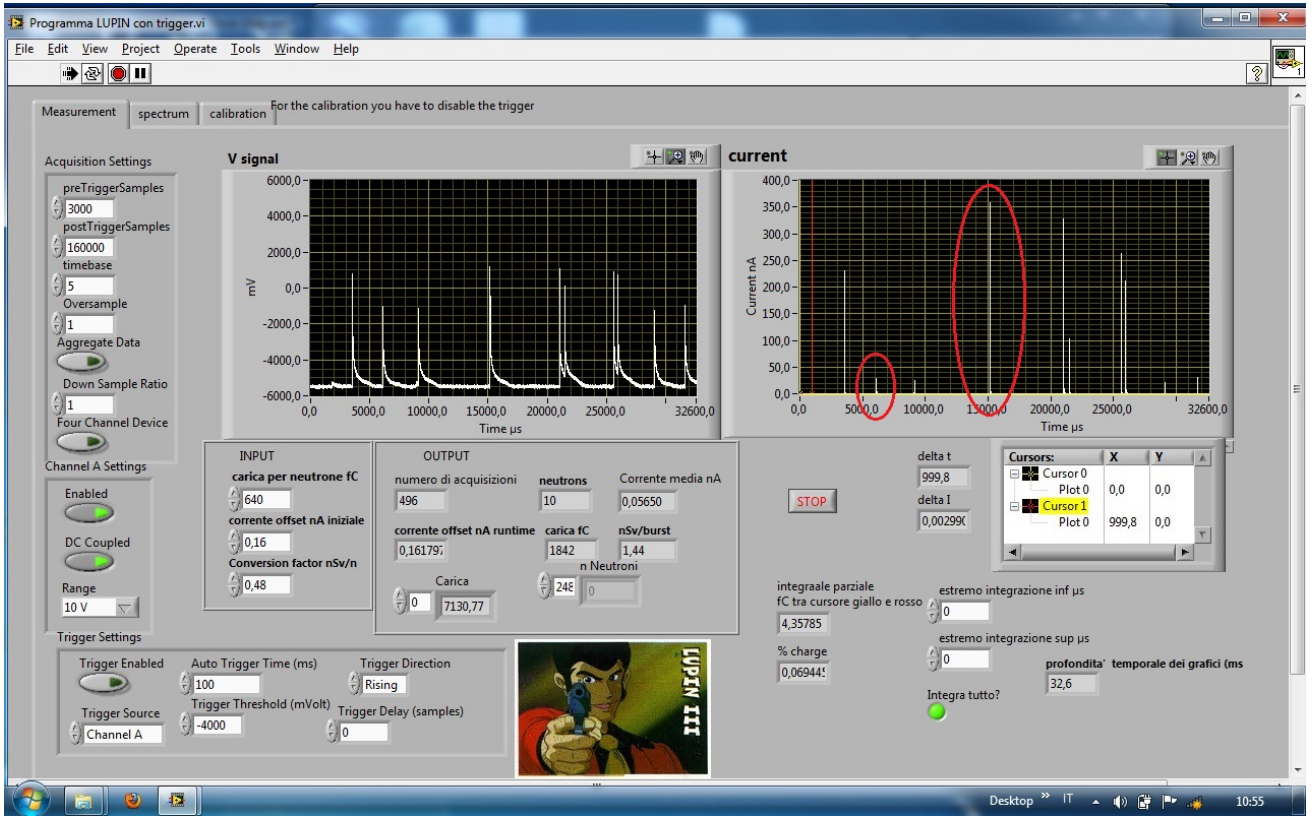
- The LUPIN-II replaces the ^{3}He counter with a BF_3 cylindrical counter and a cylindrical moderator
- BF_3 counter gives better discrimination between photons and neutrons (Q value of 2.31 MeV for BF_3 vs 0.76 MeV for ^{3}He)
- FPGA integrated into read-out electronics, automating calculations





Detector Applications

- Originally designed to be used as a beam loss monitor
- Able to cope with extremely high H*(10) rates (as during a beam loss event), and can also be used to monitor H*(10) rate
- Sensitivity comparable to commercial devices: Calibration factor 0.6 nSv (LUPIN-II)



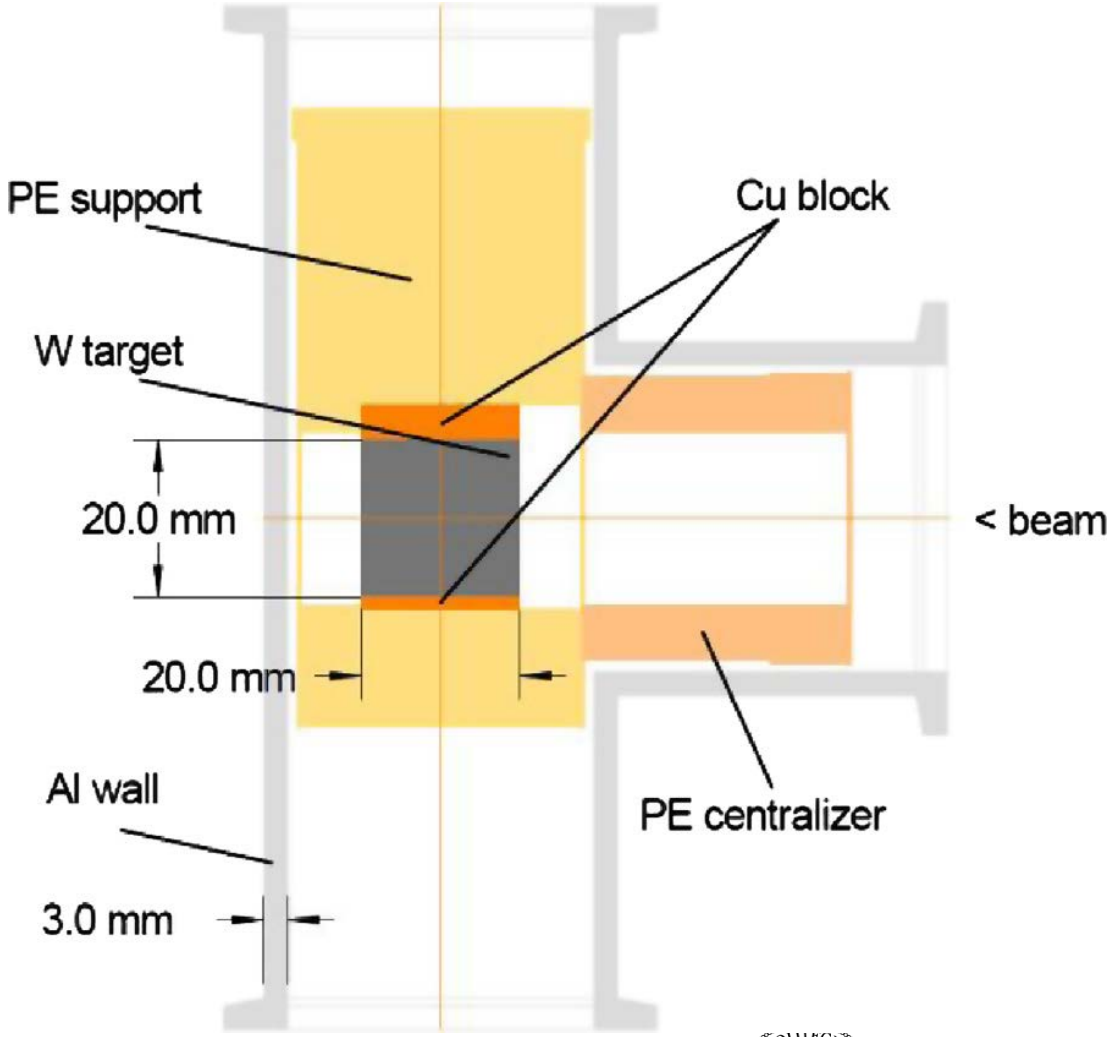
- Can be used to give simple Ambient dose equivalent rate (Sv/h), or to give more specific values like dose per burst (Sv) or simply number of detected neutrons using a PC
- Electronics can generate an alarm signal within 50 ms

Helmholtz Zentrum Berlin

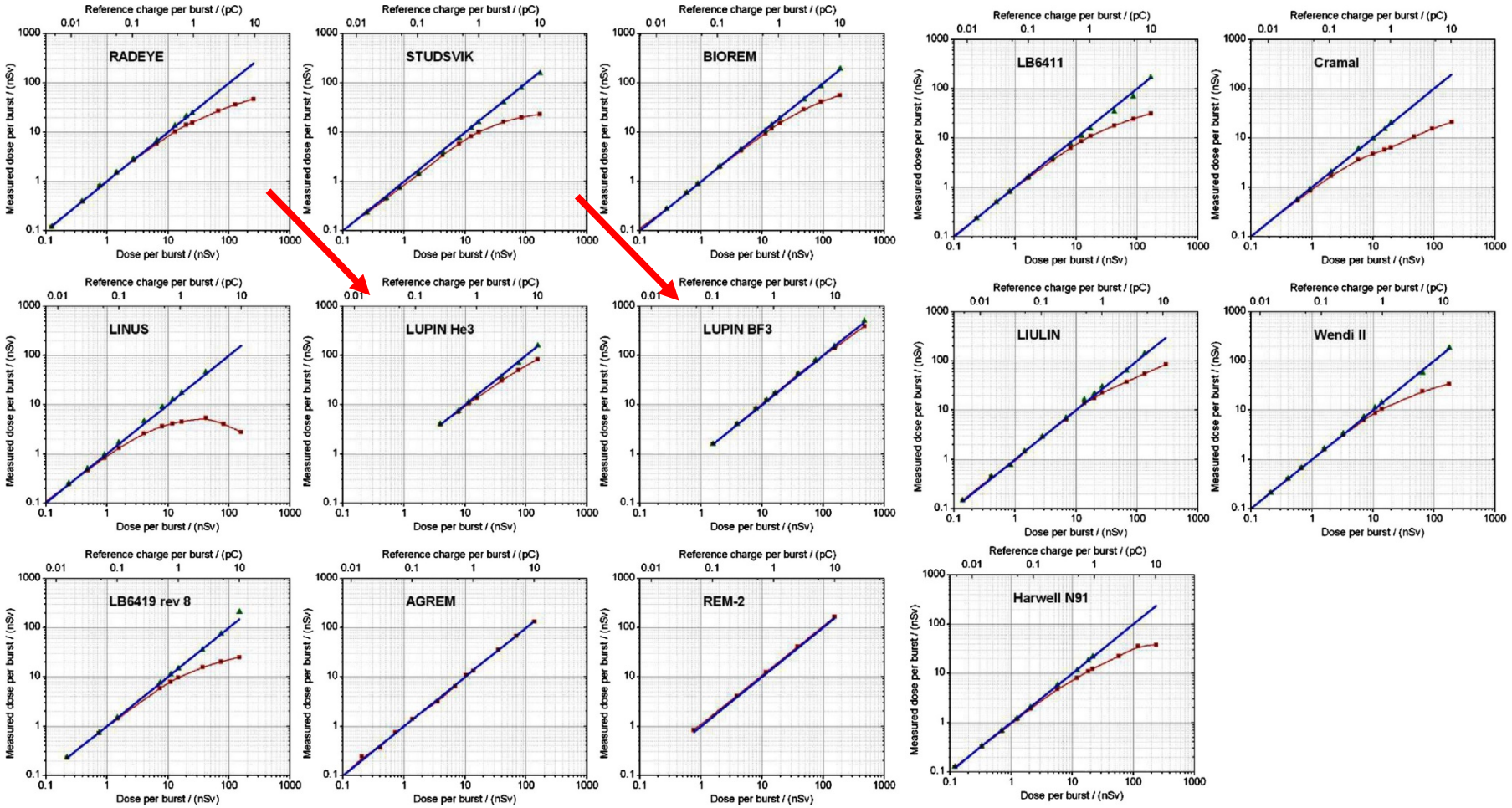
- Helmholtz-Zentrum Berlin (HZB) is a proton therapy centre designed for the treatment of ocular tumors
- Delivers 68 MeV protons with beam current from 0.5 pA to 300 nA
- the use of a burst suppressor allows delivery of proton bursts with a duration of 50 ns to 1 ms with a 100 kHz repetition rate
- The burst current and duration was varied to obtain total burst charges ranging from 5 fC to 32000 fC (reference neutron burst yield 10 pSv – 500 µSv per burst)

Helmholtz Zentrum Berlin

- Beam was directed onto Tungsten target
- Measurements were undertaken to evaluate different active neutron survey metres within the framework of Eurados WG11
- A full description of the campaign is included in [3]

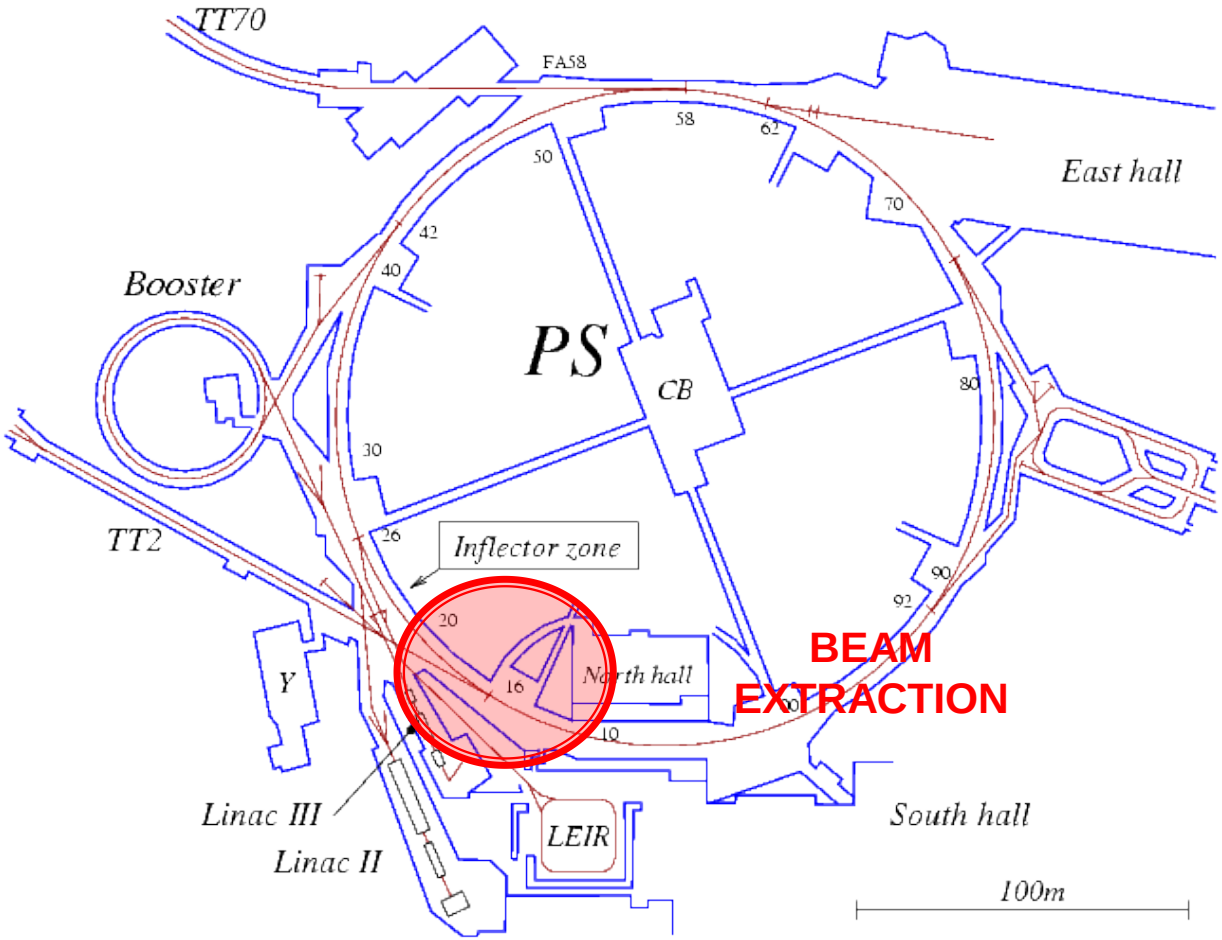


HZB


RADEYE
STUDSVIK
BIOREM
LB6411
Cramal
LINUS
LUPIN He3
LUPIN BF3
LIULIN
Wendi II
LB6419 rev 8
AGREM
REM-2
Harwell N91
Reference charge per burst / (pC)
Measured dose per burst / (nSv)
Dose per burst / (nSv)

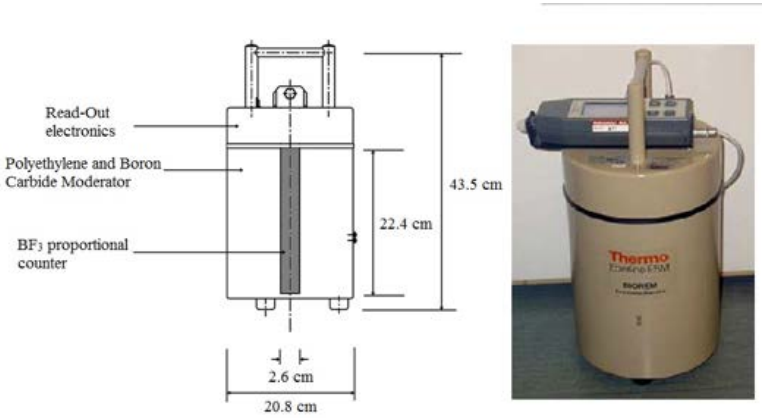
CERN Proton Synchrotron

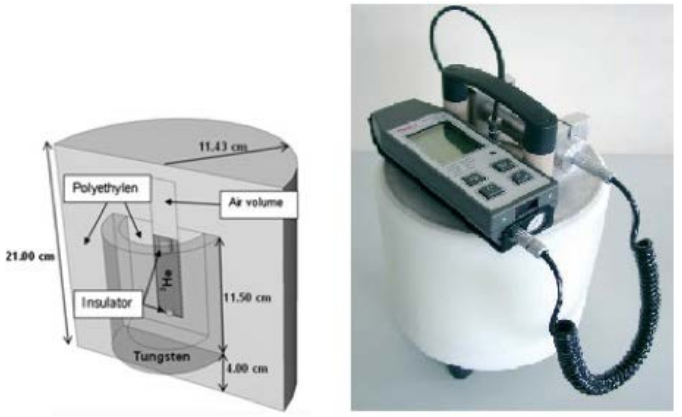
- Field around Septum 16 measured
  - Extraction point for protons to the Super Proton Synchrotron
  - Beam losses of 1% due to electrostatic septum



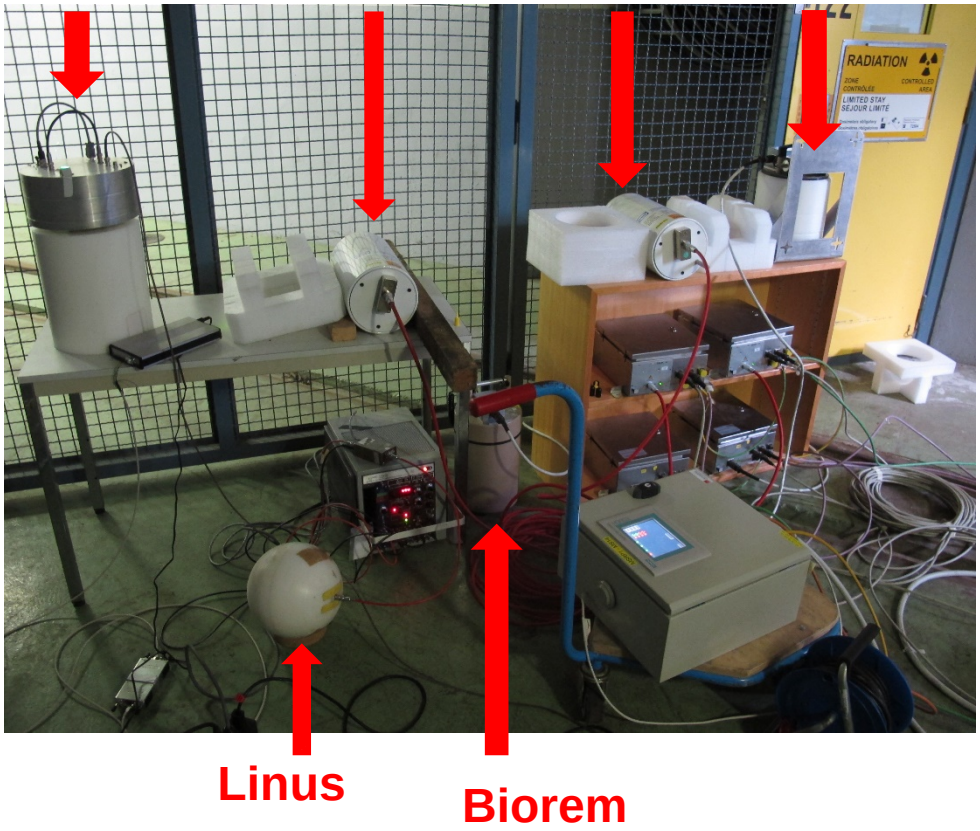
CERN Proton Synchrotron

- An intercomparison measurement between 3 commercial rem counters, the LUPIN-II and 2 ionisation chambers
- Commercial rem counters: Thermo Wendi-2, Biorem and the CERN LINUS
- Ionisation chambers were custom Centronics IG5 filled with H and Ar
- Beam was extracted using Continuous Transfer technique
  - Beam extracted in 5 turns of 2.2 μs gives neutron pulse length of 11 μs



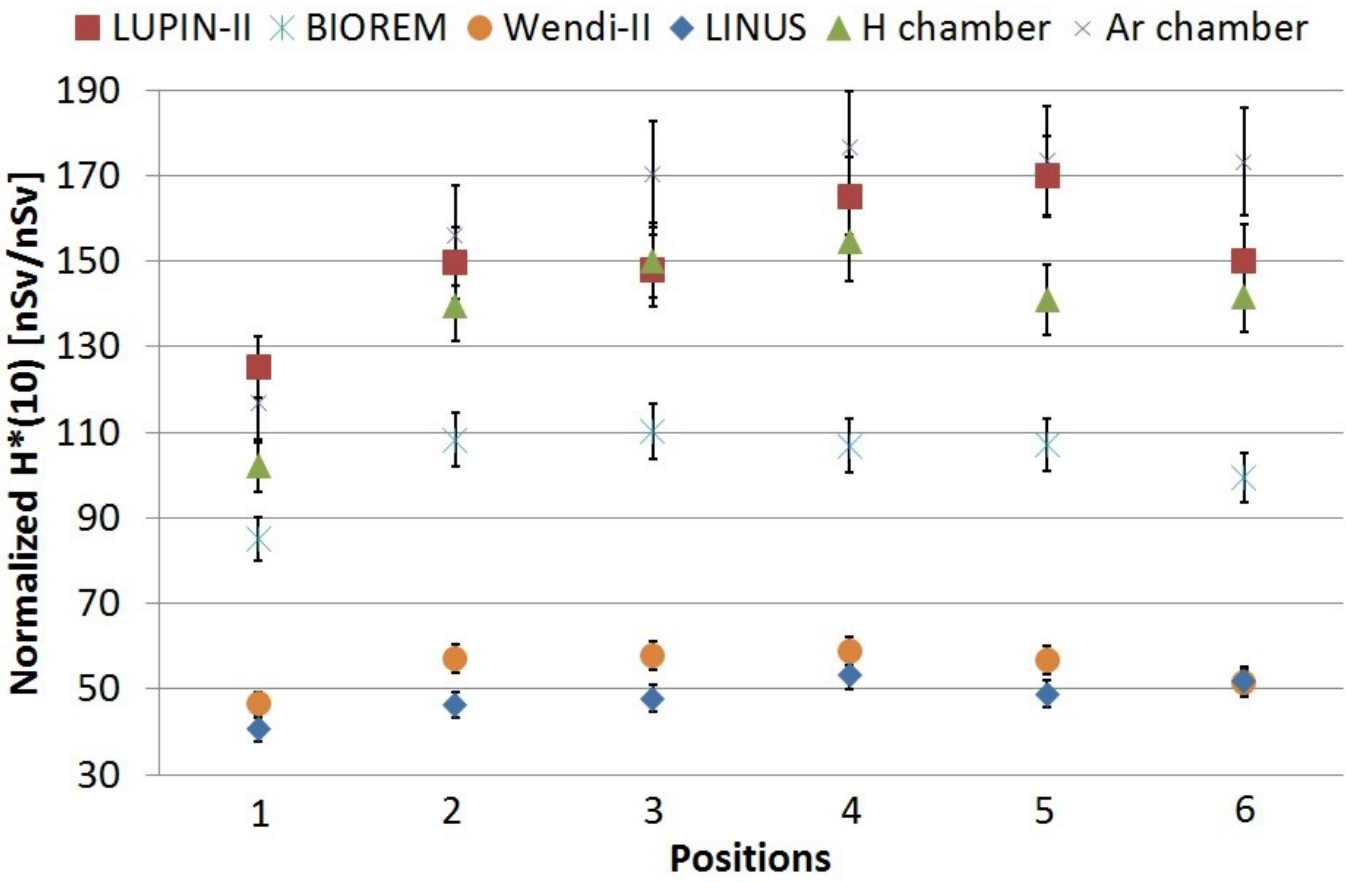


CERN Proton Synchrotron

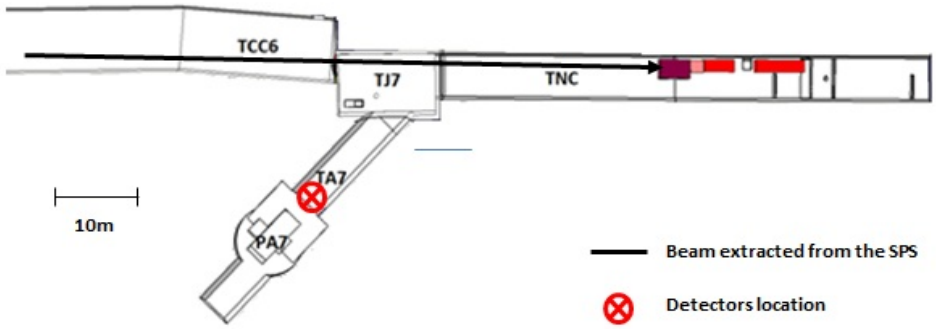


- Each detector placed in one of 6 positions within Septum 16 access tunnel
- Detectors interchanged and measurement repeated to obtain a measurement with each detector in each position

CERN Proton Synchrotron

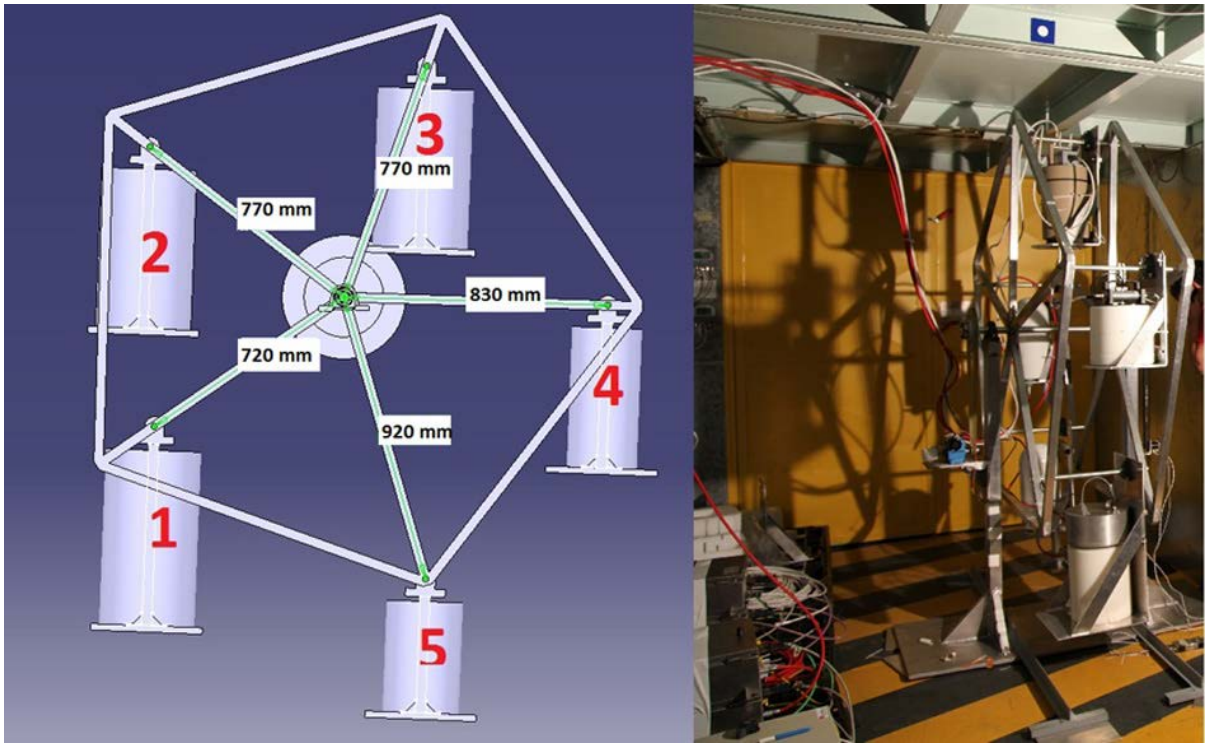


CERN HiRadMat



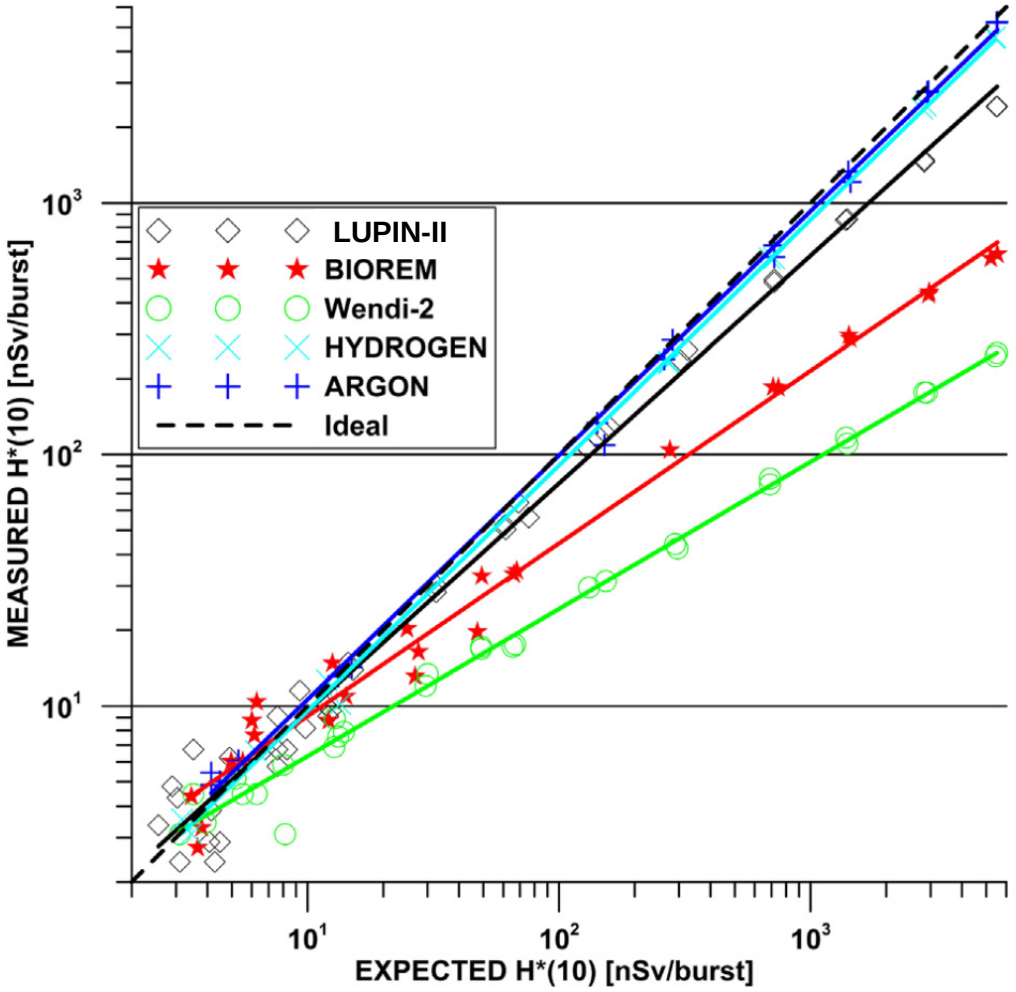
- HiRadMat (High Radiation to Materials) is a facility at CERN using the beam from the Super Proton Synchrotron (SPS) to test radiation hardness of materials
- The facility delivers 440 GeV/c momentum proton pulses into a target area
- Each pulse contains 1 – 288 bunches with a spacing of 25 – 100 ns and intensity 10^9 – $1.7 \cdot 10^{11}$ protons (giving maximum bunch intensity of $5 \cdot 10^{13}$ protons)
- For this experiment, 50 ns spacing was selected and pulse intensity was varied from $5 \cdot 10^9$ up to $7.5 \cdot 10^{12}$ protons
- The beam impinged directly on the beam dump and the detector was placed just inside the access door to the experimental area, allowing the stray neutron field to be measured

CERN HiRadMat



- Another intercomparison, this time with only 5 detectors: LUPIN-II, Wendi-II, Biorem, and IG5 H and Ar Ionisation chambers
- Detectors placed on a rotating support to minimise access when interchanging detector position

CERN HiRadMat



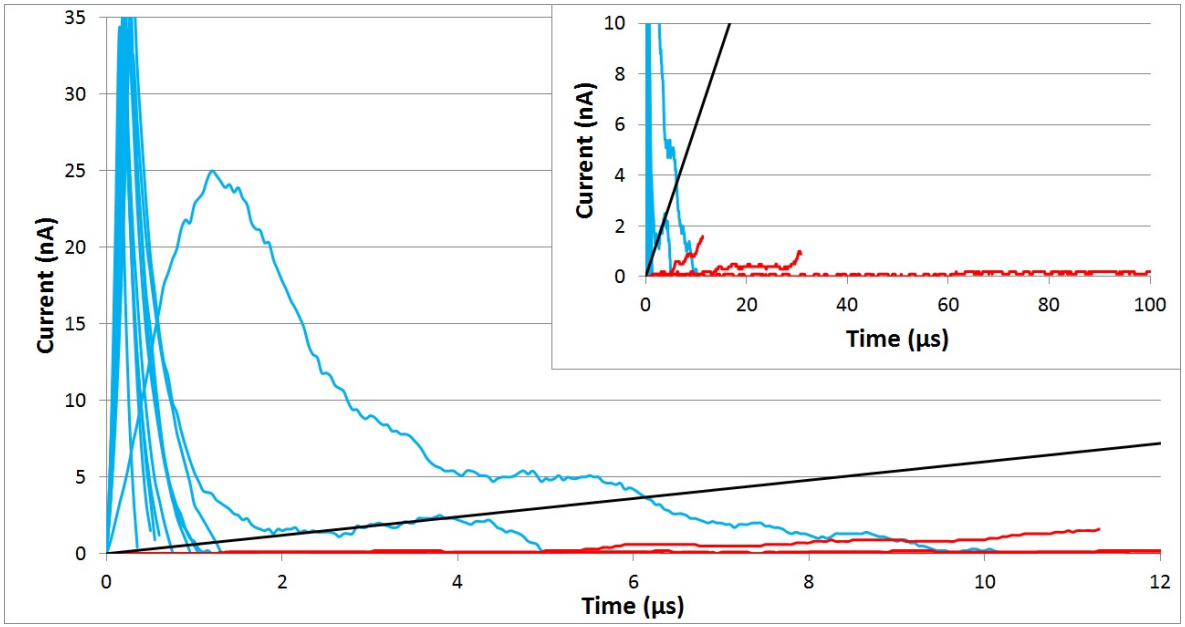
Ongoing: Photon discrimination

- In order to discriminate between neutron and a steady photon signal, a second operational mode was introduced
- LUPIN-II reverts to a counting mode, but uses a trigger threshold on the pseudo-derivative of the signal
- For sample number N:

$$D = \frac{X_{N+1} - X_{N-1}}{2}$$

where X_N is the current sample N

- Works due to the large difference in the rate of change of the signal comparing a neutron burst to a photon background



LUPIN-II signals from neutron bursts (blue) and steady photon field (red), with proposed derivative threshold in black

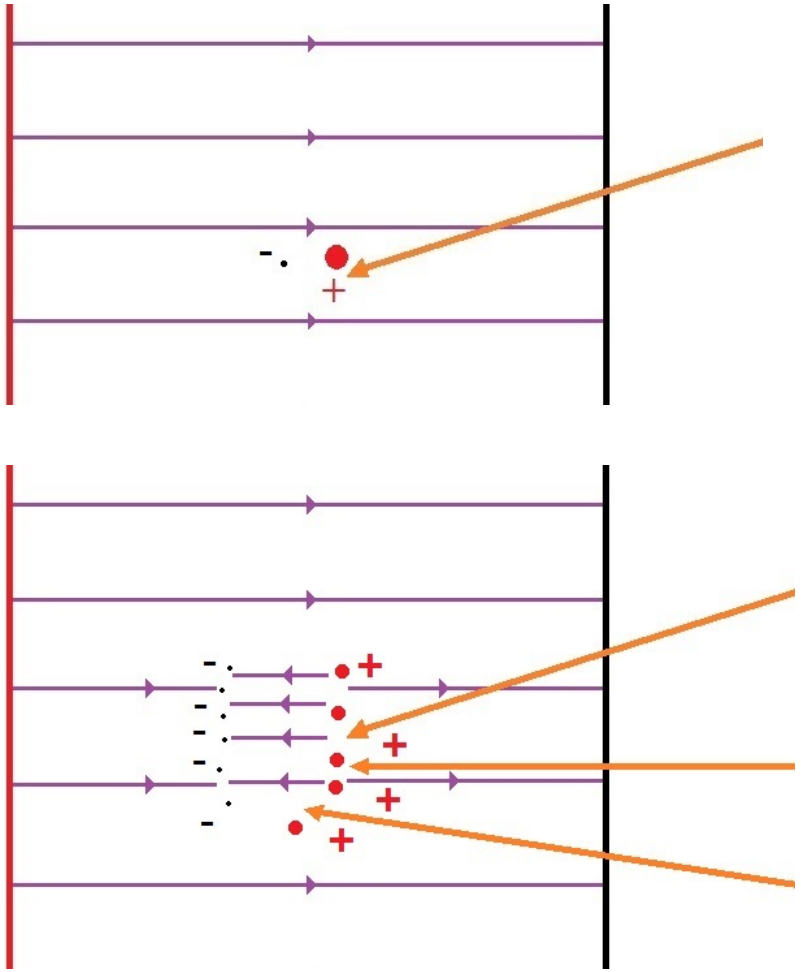
Ongoing: Photon discrimination

- Tests conducted at the Secondary Standards calibration lab at PoliMi
- The neutron count rate was measured with a Am-Be source alone, and with the Am-Be source and a gamma source together
- Both acquisition modes used
- Gamma source was set to give a 40 mSv/h H*(10) rate, neutron source placed so that only single neutrons detected per window
- While Current Integration mode showed overestimation due to gamma signal, Derivative mode did not

	NEUTRONS ONLY	NEUTRONS AND PHOTONS
	Count rate (Hz)	Count rate (Hz)
Current Integration mode	3.27	604.05
Derivative mode	3.28	3.42

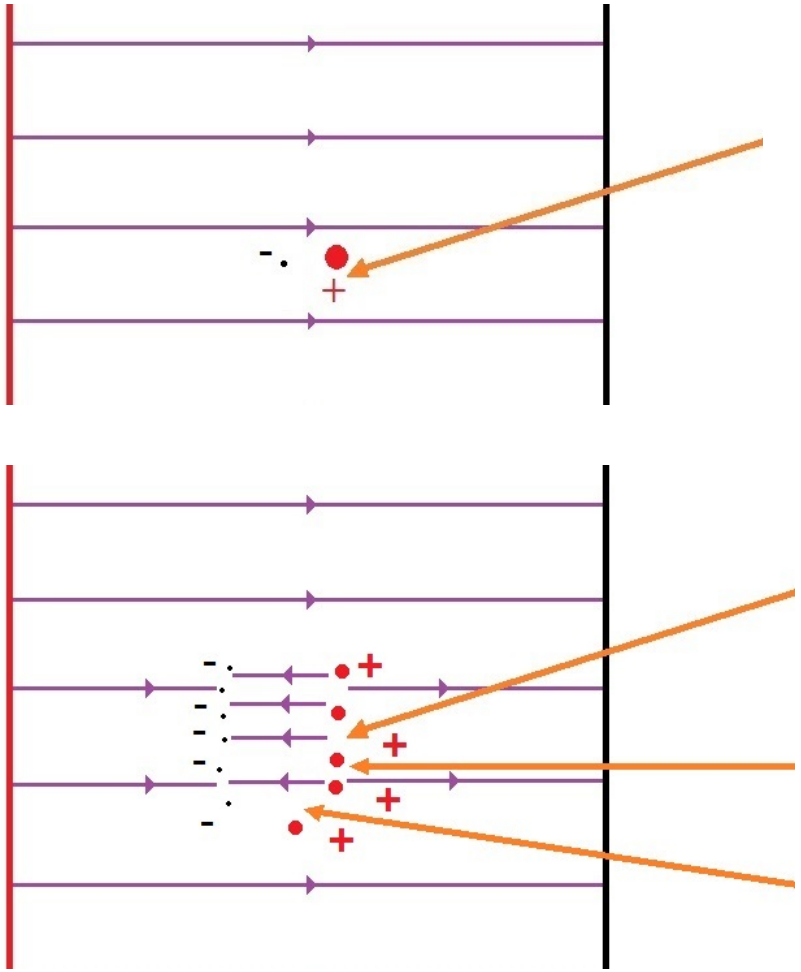
Ongoing: Space Charge Effect

- When measuring a high-intensity burst of radiation, large amounts of localised charge is generated inside the proportional counter within a REM counter
- The charge generated may cause subsequent interacting particles to be partially shielded from the electric field, reducing the multiplication factor



Ongoing: Space Charge Effect

- It is possible to assess this effect by modelling the electric field inside the detector during a neutron burst
- By quantifying this in terms of the Multiplication factor of the device, it is possible to correct it
- This is the subject of an article under review



Conclusions

- LUPIN is an extended range rem counter developed to be used in High Intensity fields
- Exists in versions using ^{3}He and BF_3
- Can be used as a beam loss monitor or radiation protection device
- Capable of coping with fields of up to the order of μSv/burst with only a 20% underestimation, with possibility of improvement
- Shows excellent discrimination between gamma and neutron fields

Thank you!

References

[1] Aza, E., Caresana, M., Cassell, C., Charitonidis, N., Harrouch, E., Manessi, G.P., Pangallo, M., Perrin, D., Samara, E., and Silari, M., "Instrument intercomparison in the pulsed neutron fields at the CERN HiRadMat facility," Radiation Measurements 61C (2014), pp. 25-32, DOI: 10.1016/j.radmeas.2013.12.009

[2] Rios, I., González, J., Mayer, R.E., "Total Fluence Influence on the Detected Magnitude of Neutron Burst using Proportional Detectors", Radiation Measurements (2013), doi: 10.1016/j.radmeas.2013.01.007.

[3] Caresana, M. Denker, A. Esposito, A. Ferrarini, M. Golnik, N. Hohmann, E. Leuschner, A. Luszik-Bhadra, M. Manessi, G. Mayer, S. Ott, K. Röhrich, J. Silari, M. Trompier, F. Volnhals, M. Wielunski, M. "Intercomparison of radiation protection instrumentation in a pulsed neutron field", Nucl Instrum Meth A. Volume 737, 11 February 2014, Pages 203–213

[4] Caresana, M. Cassell, C. Ferrarini, M. Hohmann, E. Manessi, G. P. Mayer, S. Silari, M. Varoli, V. "A new version of the LUPIN detector: improvements and latest experimental verification", Review of Scientific Instruments 85, 065102 (2014); doi: 10.1063/1.4879936

[5] Aza, E. Caresana, M. Cassell, C. Colombo, V. Damjanovic, S. Gilardoin, S. Manessi, G. P. Pangallo, M. Perrin, D. Silari, M. "Comparison of the performance of different instruments in the stray neutron field around the CERN proton synchrotron", Radiat. Prot. Dosim. 161 (2014), No. 1 – 4, Pg. 190–195

[6] Caresana, M. Farrarini, M. Manessi, G. P. Silari, M. Varoli, V. "LUPIN, a new instrument for pulsed fields", Nucl Instrum Meth A. 712 (2013), Pg. 15–26

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