Neutron detectors

TEAM OVERVIEW

Principal Investigator: Luís Margato

Researchers: Andrey Morozov, Alberto Blanco, Vladimir Solovov

PhD students: Giorgio Canezin (jointly hosted by LIP and ISIS (UK))

Master students: Jesús Villoria (finished), Carolina Felgueiras (NUC-RIA & nDet, finished) José Ferreira (ongoing), João Simões (ongoing)

Undergraduate students and Trainees: António Plácido, Ricardo Marques Emílio

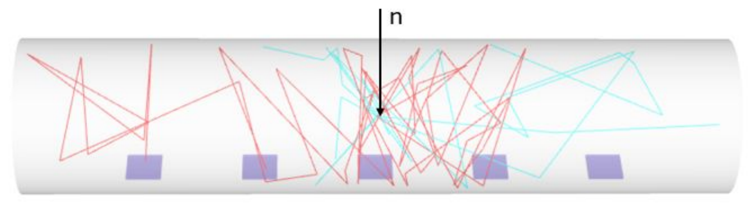
Funding
FCT 2024.00269.CERN | 25 582 € of 167.770 € | DRD1PT project
FCT 2023.15652.PEX | 50 000 € | UHRnD project
FCT PhD Studentship 2024.00754.BD (G. Canezin)

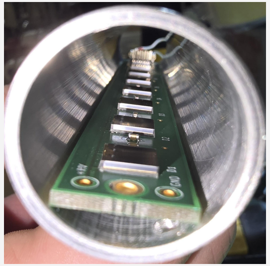
LIP

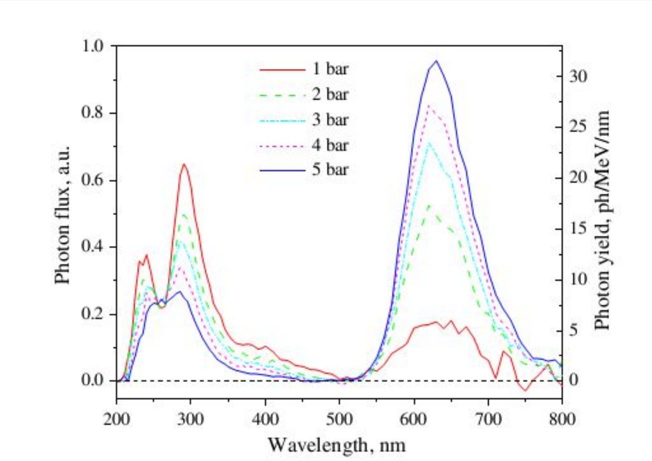
UHRnD-Ultra High Rate neutron Detector

MC Simulations (ANTS3 / Geant4)

- **Optimal configuration established:**
  - SiPM sensor type
  - SiPM positioning pattern
  - Light collection arrangement



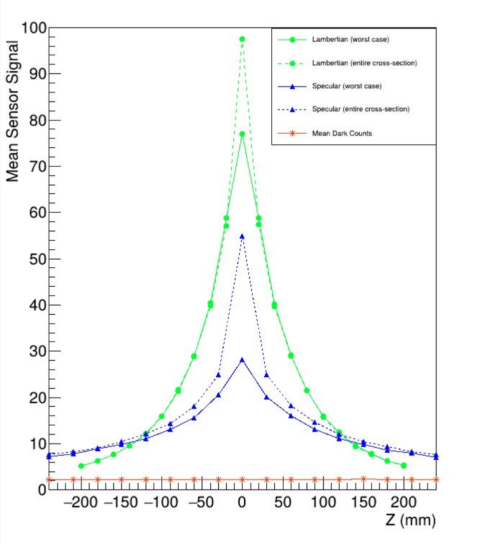




A. Morozov, M.M.F.R. Fraga, L. Pereira, L.M.S. Margato, S.T.G. Fetal, B. Guerard, G. Manzin, F.A.F. Fraga, **Photon yield for ultraviolet and visible emission from CF4 excited with α-particles** https://doi.org/10.1016/j.nimb.2010.01.012.

Tube inner walls:

Specular or Lambertian reflection



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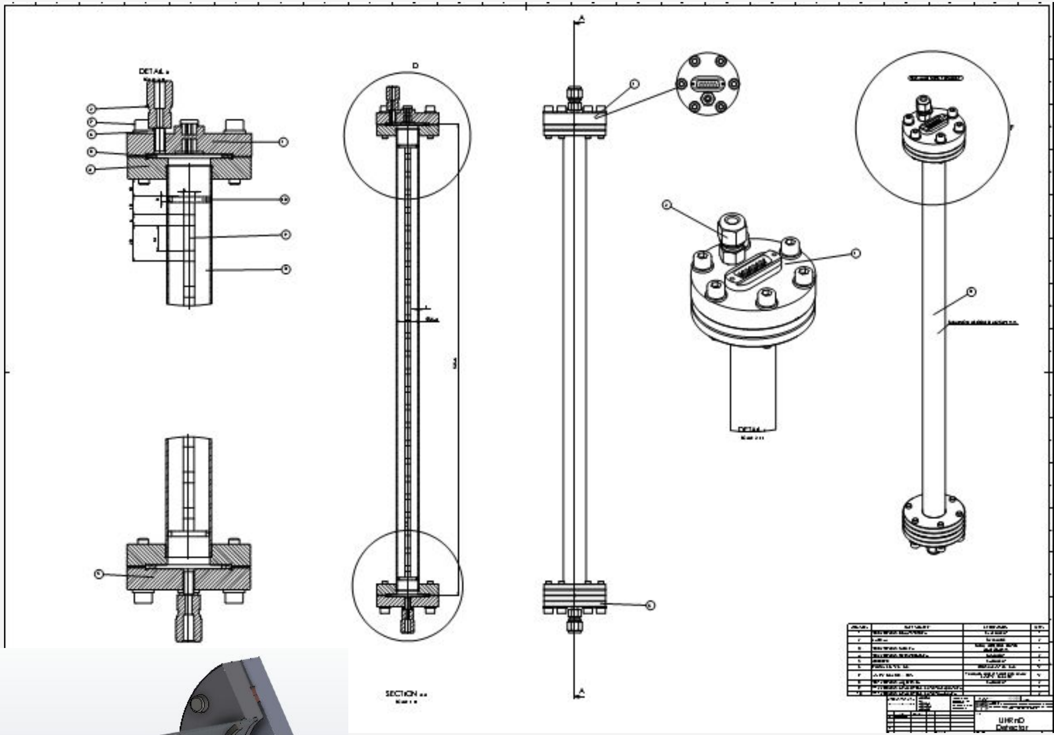

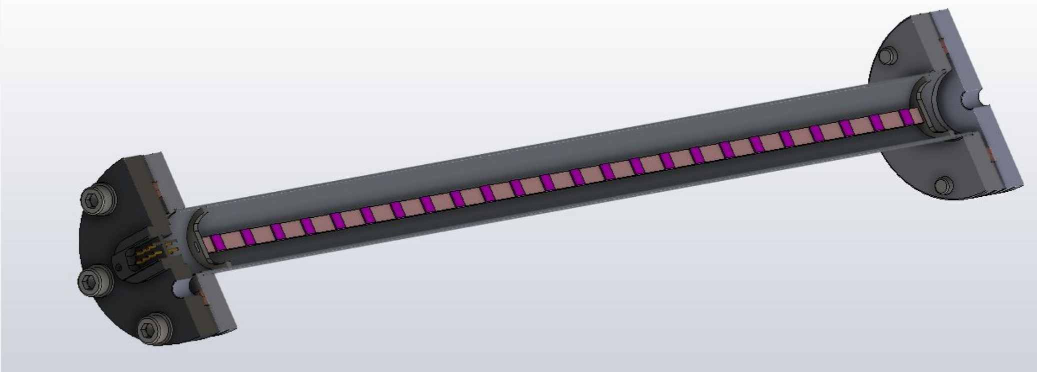

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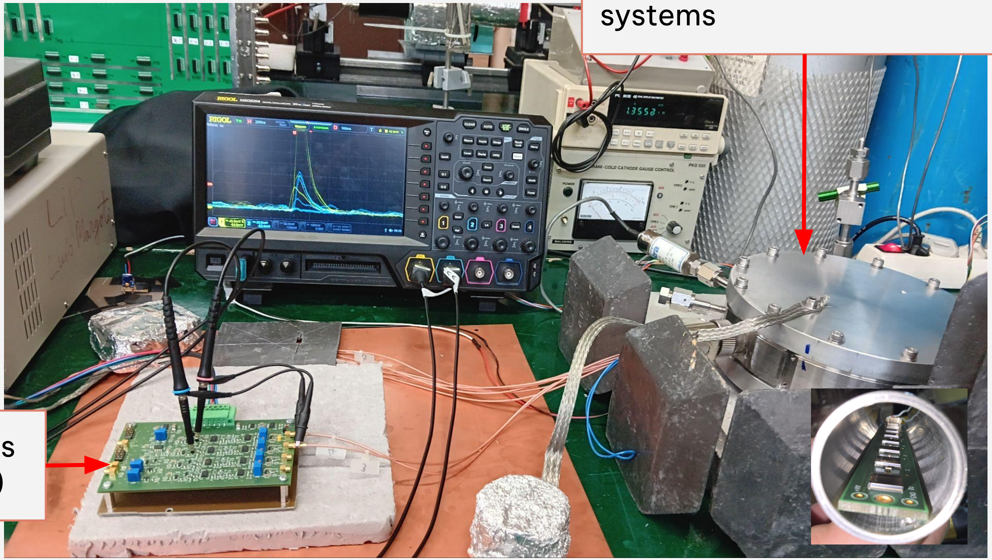
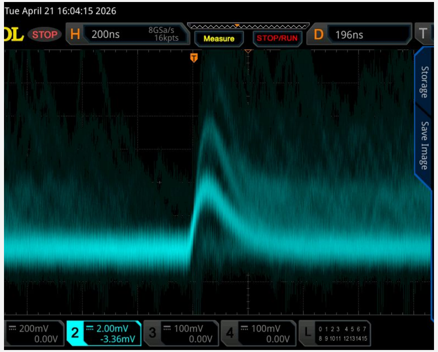
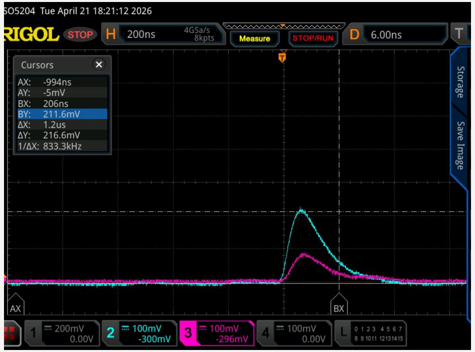
- **High pressure test chamber + 1st FEEs version manufactured**

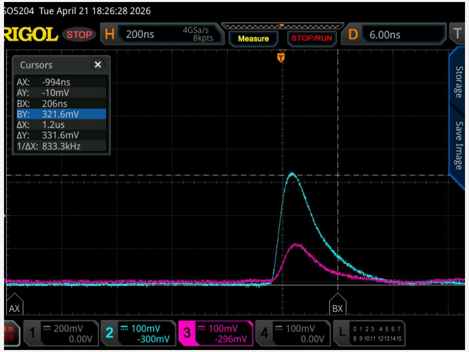
Test Chamber connected to the gas and high vacuum systems



Custom FEEs (V. Solovov)





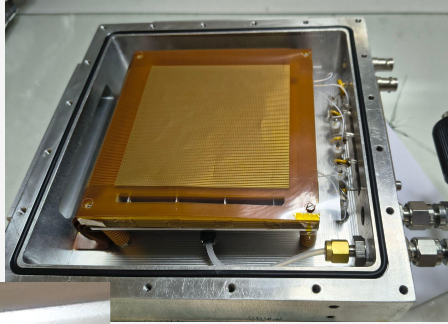


Signals from two adjacent SiPMs

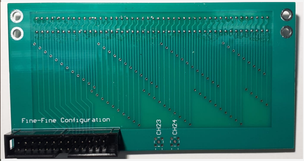
CF4 @ 1 atm excited with alpha particles (241Am)

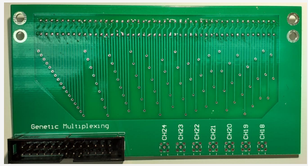
High-Precision nRPC-4D Detector

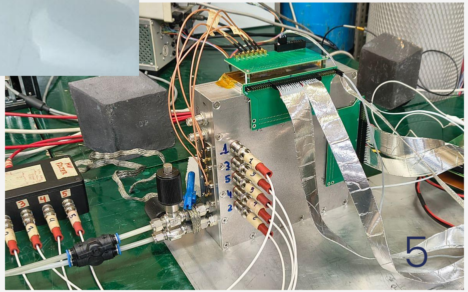
- **Equiped with 5 nRPC units made with low-resistivity glass** (Crispin Williams)
- **Targeting >10x improvement in count rate capability over float-glass RPCs**
- **Custom front-end electronics** designed to reduce EM noise and provide fast timing for nTOF and DAQ triggering (Vladimir Solovov)
- **PCB-implemented multiplexing schemes** to address limited electronic channels
- **Deployed to ISIS** for testing on a pulsed neutron beam by our PhD student and ISIS detector's group.



Signal Multiplexing PCBs

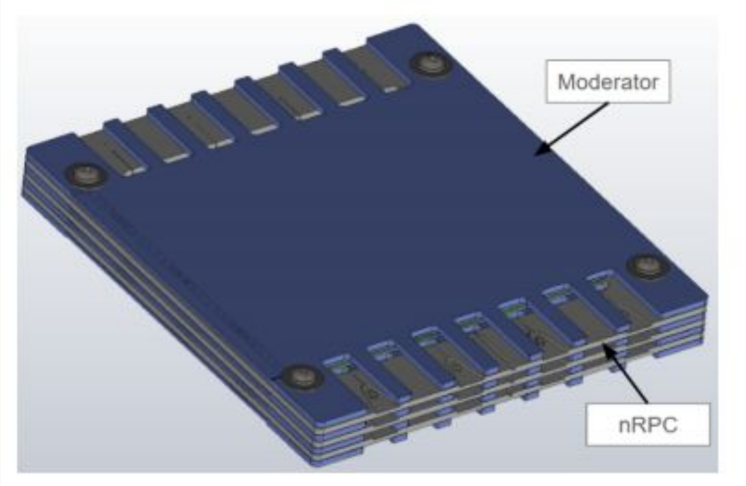






Epithermal and Fast Neutron nRPC Detectors

- **HISPAnOS Dataset Analysis:** Results demonstrate the feasibility of extending nRPCs to epithermal and fast neutron detection.



nRPCs interspersed with HDPE sheets

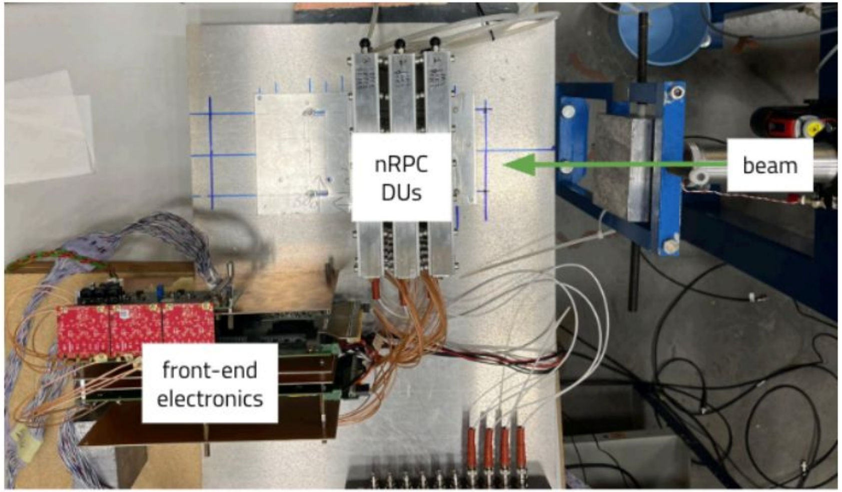
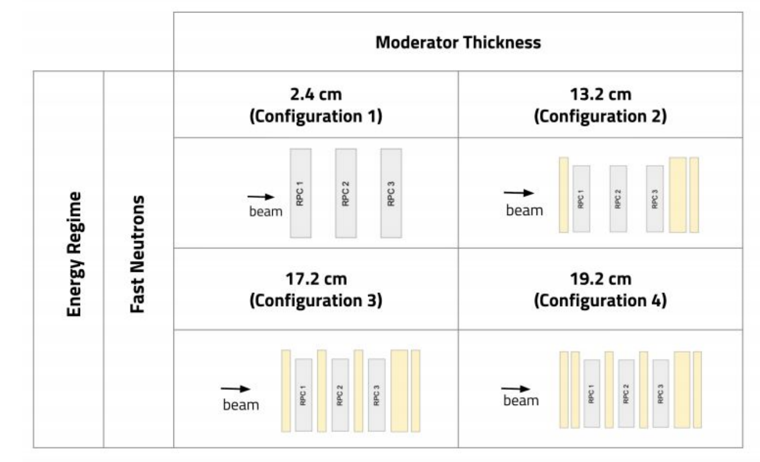


Figure 4.5: Photo from the top of the Experimental Setup at HiSPANoS beamline.

Epithermal and Fast Neutron nRPC Detectors

- **HISPAnOS Dataset Analysis:** Results demonstrate the feasibility of extending nRPCs to epithermal and fast neutron detection.
- **Moderator Configuration:** Analysis reveals the critical role of moderator geometry in detection efficiency.
- **Study detailed in the Master's thesis of Carolina Felgueiras** "Benchmarking nRPC neutron detectors with fast neutrons"
- **Ongoing R&D in the frame of the OFFERR** (Horizon Europe/Euratom) funded project: **NUC-RIA**, **nDET** and CNA (Seville, SP)



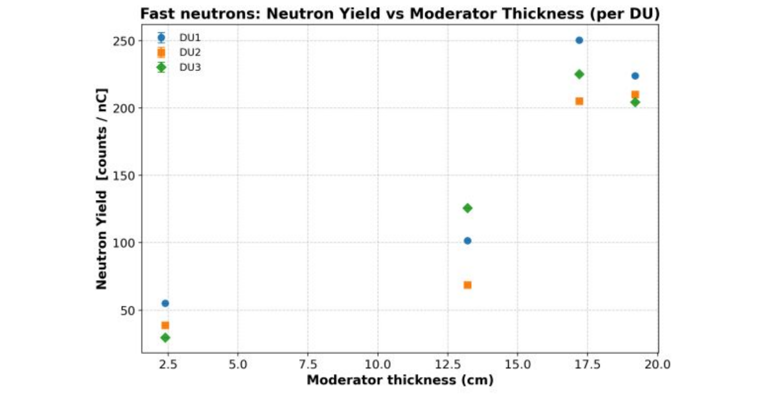
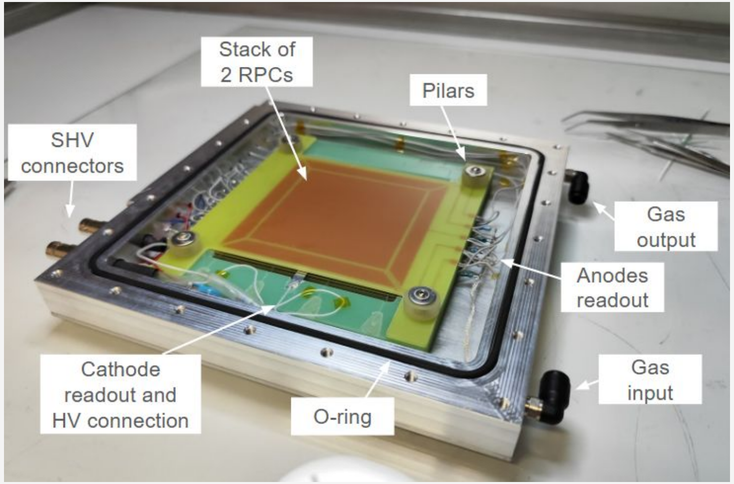
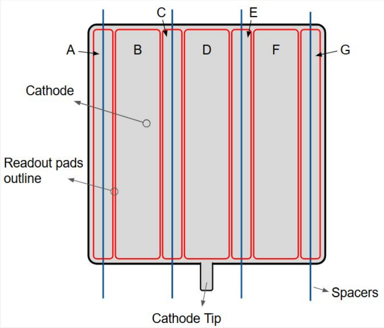


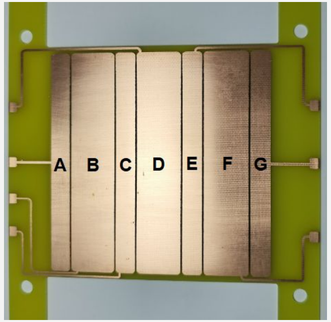
Figure 5.13: Neutron yield per RPC as a function of moderator thickness for fast neutrons, for three characteristic neutron energies ($E \approx 3.76$ MeV, $E \approx 4.13$ MeV, and $E \approx 4.8$ MeV).

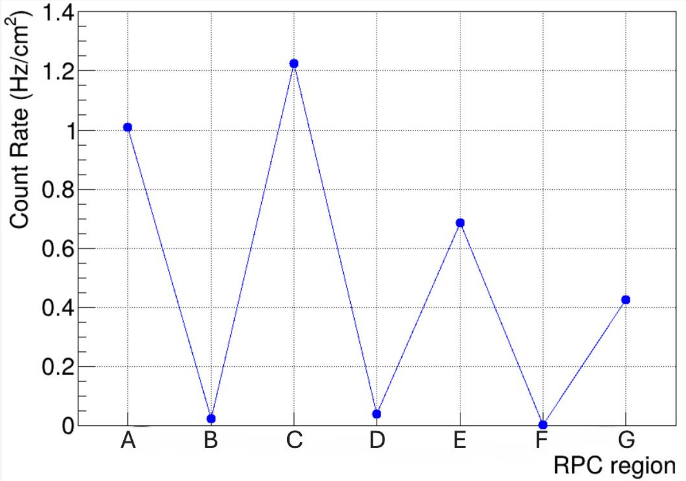
Background sources in RPCs

- **Nylon spacers identified as a dominant source of spurious counts**







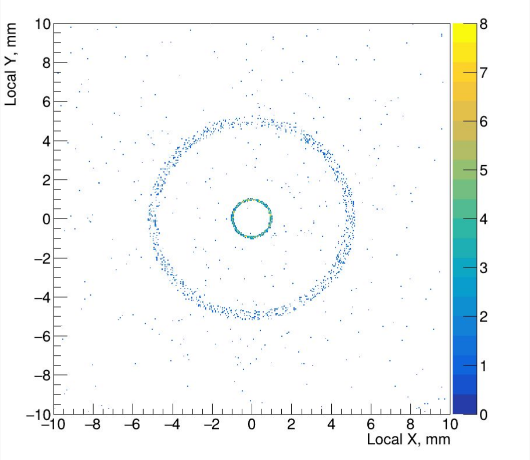


nRPCs operated at -2200 V
Error bars are smaller than the symbols

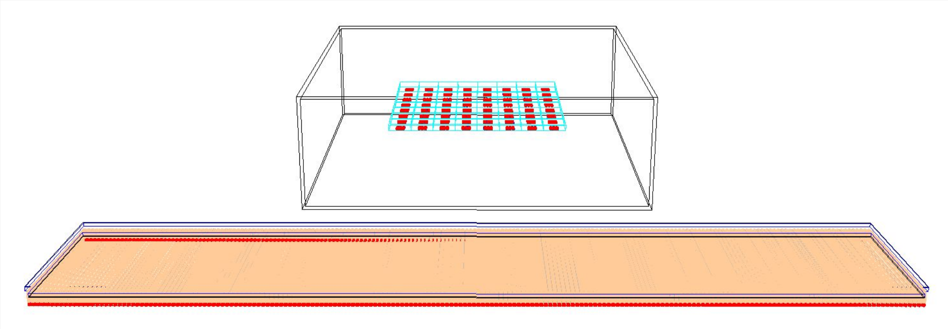
Simulation tools: Ants3 toolkit

- **Public Release:** Source code and documentation are available on **GitHub**
- **Feature Update:** Successfully integrated the **NCrystal library** for neutron scattering simulations addressing limitations of Geant4
- **Publication:** Paper describing Ants3 is published in a high-impact computational physics journal:

A. Morozov, L.M.S. Margato, G. Canezin, J. Gonzalez, Ants3 toolkit: Front-end for Geant4 with interactive GUI and Python scripting, Comput. Phys. Commun. 318 (**2026**) 109869.
https://doi.org/10.1016/j.cpc.2025.109869



Back-scattering of thermal neutrons in a pencil beam from Al plate: rings are due to coherent scattering



WSF detector (200 optical fibers)

2026 Lines of Work & Objectives

- **UHRnD Project**
  - Manufacturing of the components, assembling of the prototype
  - Production of the full-scale FEE and DAQ system
  - Full system validation at LIP-Coimbra
  - In-beam characterisation at ILL

- **High-Precision nRPC-4D Detectors**
  - Perform tests on pulsed neutron beamline at ISIS
  - Comprehensive evaluation of the detector performance
  - Continue work towards the design and construction of a fully instrumented large-scale demonstrator

- **Epithermal and Fast Neutron nRPCs (nDET + NUC-RIA groups)**
  - Develop nRPC with geometries replicating the form factor of ^{3}He counters, aiming for their replacement
  - Perform prototype testing at the HISPANOS neutron facility at Spain

Outlook (3–5 yrs) & SWOT

Strategic Goals (3–5 Years)

- Advance nRPCs for cold and thermal neutron applications to the full scale demonstrator level
- Develop low background, high-efficiency nRPC detectors for epithermal and fast neutrons
- Establish proof-of-concept for high-rate technology via the UHRnD concept
- Collaborate with ILL on a proposal for full-scale prototype development

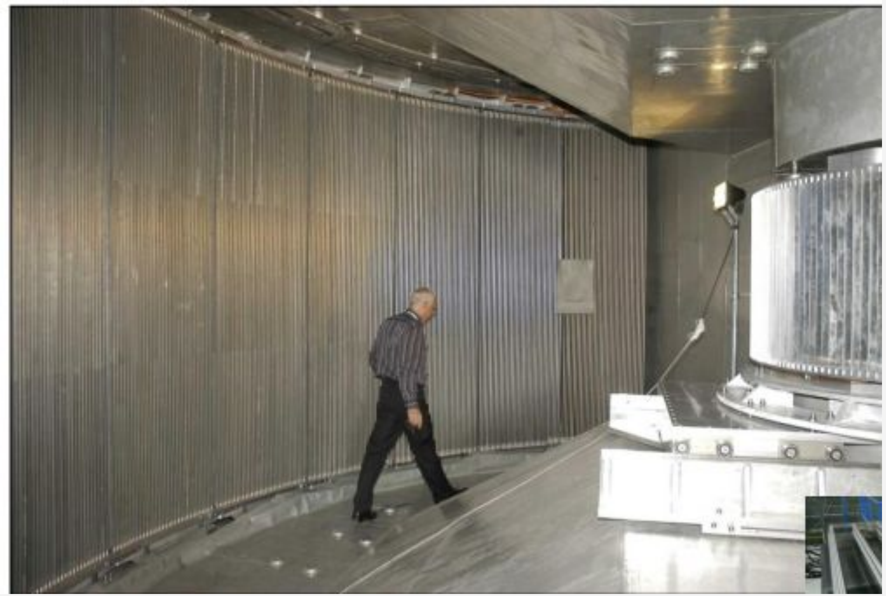
S - Strong expertise in detector R&D and simulation; Demonstrated innovation; Established partnerships with detector groups of world-leading neutron facilities: Access to neutron beamlines and international funding opportunities.

W- Limited human resources; The lack of an in-house neutron source requires external facilities for detector testing.

O- Leading position in innovation via the UHRnD concept; High global demand for next-generation detectors at ESS and in applied science; Validation of nRPC-4D on pulsed beamlines supported by ISIS collaboration and PhD student.

T- Funding instability; Ongoing uncertainty issues following the PI contract expiration in October 2025; These circumstances threaten research activities, FCT project coordination, student supervision continuity and jeopardize long-term planning.

BKup slide

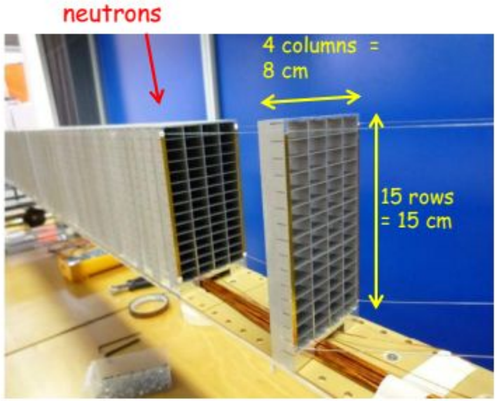


IN5 inelastic spectrometer at ILL

! ESS and ILL have finalized an agreement for the delivery of Multitube detectors by the end of 2027.

These Helium-3 detectors are scaled versions of the ILL IN5 and PANTHER models

Multigrid ($^{10}B_4C$)



Stacking of 96 grids of 2 cm height electrically insulated from each other
60 anode wires (gold plated W 20 μm)

Recently developed large-area detectors without ^{3}He fail to meet current performance requirements.

Standard ^{3}He-tube detectors **lack the counting rate needed** for next generation instruments and high-brightness facilities like ESS, Such as the large are nTOF spectrometers.