Towards an ISO-accredited fast neutron beam facility at iThemba LABS

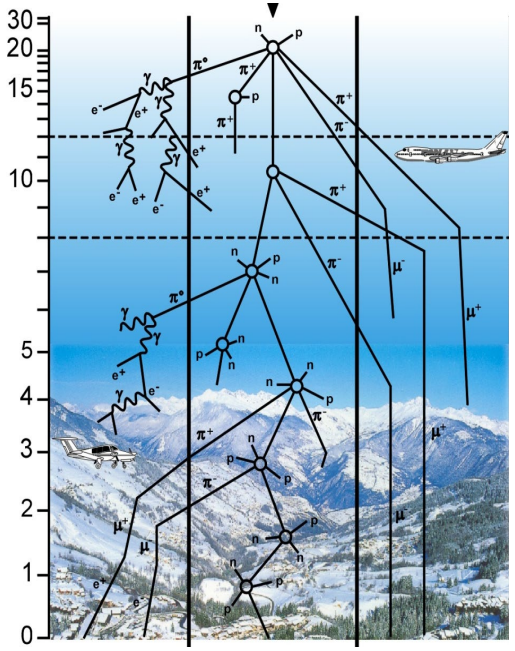
Zina Ndabeni

… on behalf of the …

Collaboration for the Upgrade of the Neutron Beam Facility at iThemba LABS

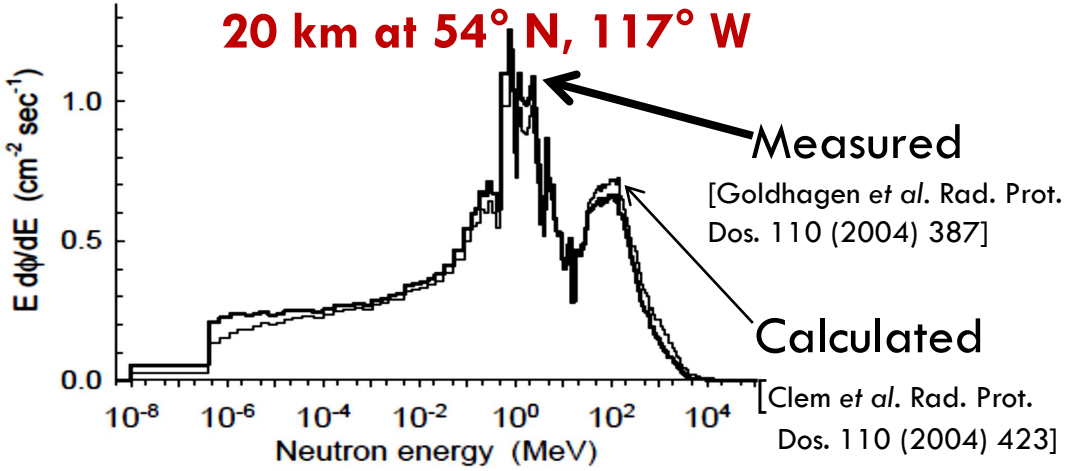
nBHEAM 2025: Neutron Beams at High Energy: Applications and Metrology IAEA Headquarters, Vienna, C-CR1, 7-8 July 2025

SCIENCE CASE



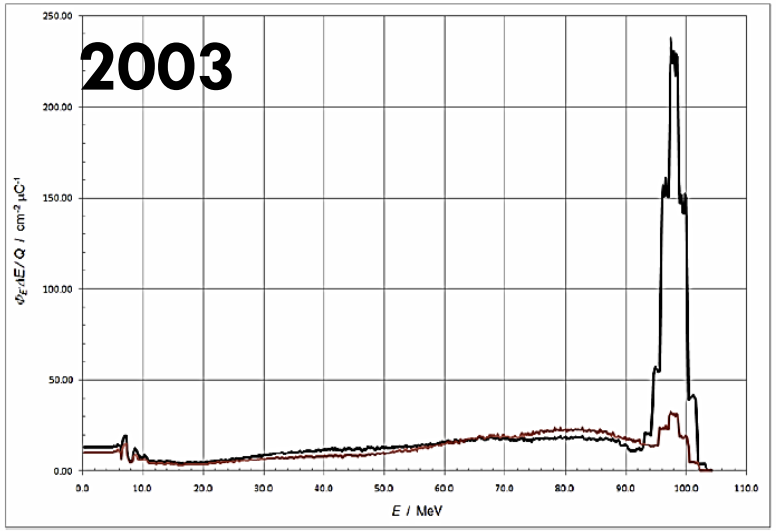
Quasi-monoenergetic neutron beam facilities important for applications associated with high energy workplace fields are scarce [Pomp *et al.* Rad. Prot. Dos. 161 (2014) 62]

Cosmic-ray neutron spectrum:
20 km at 54° N, 117° W



[Goldhagen *et al.* Rad. Prot. Dos. 110 (2004) 387]

[Clem *et al.* Rad. Prot. Dos. 110 (2004) 423]



Fast neutron users "phase space"

1. Production of (man-made) fields

Source development Reference fields Shielding

2. Development and testing of instrumentation

TLDs TEPCs Bonner spheres EPDs Si-based Scintillators

3. Use of instrumentation (measurement in different contexts)

Reactor/accelerator Medical Earth/Atmos/Space Reference fields Other

4. Numerical modelling (simulation / calculation)

Dosimetric calculations Nanodosimetry Detectors Reference fields Other

5. Effects

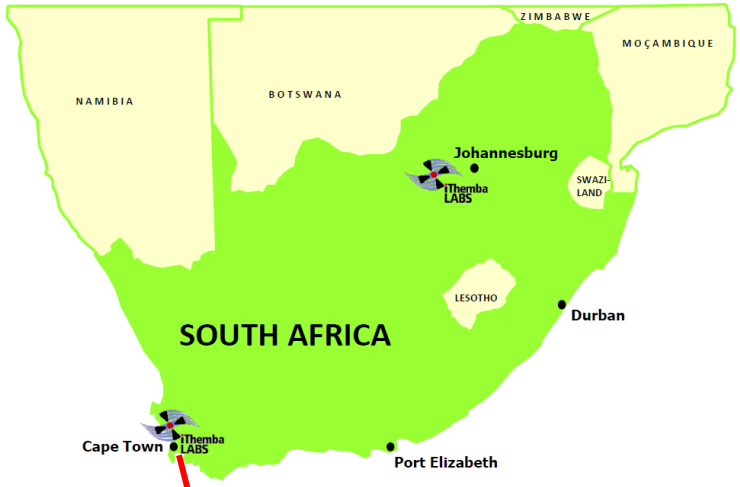
Biological / radiobiology Rad damage to electronics Other

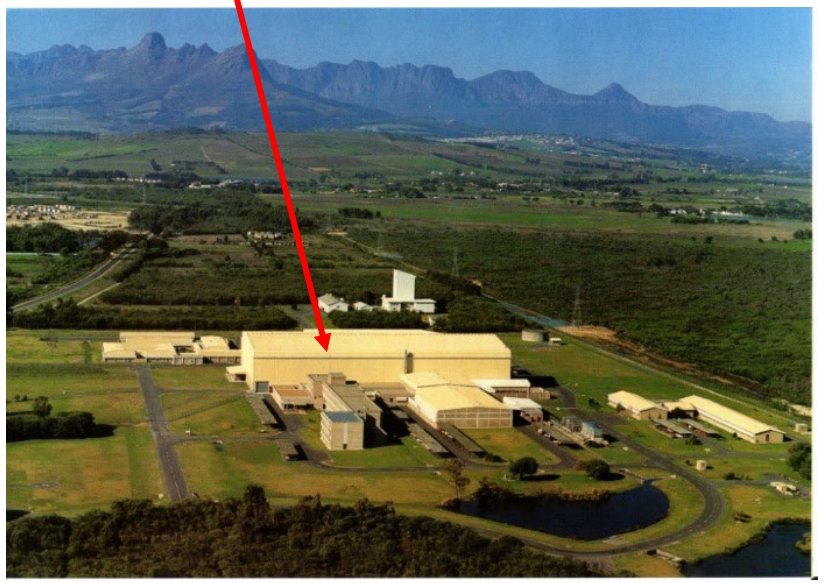
6. Physics

Cross sections Models Strong interaction: (n,p); (n,d); … Neutrino physics

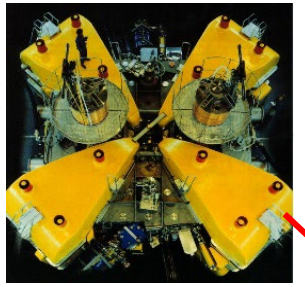
NRF-iThemba LABS (Laboratory for Accelerator-Based Science)

National Laboratory





C70 Cyclotron **(SAIF)**



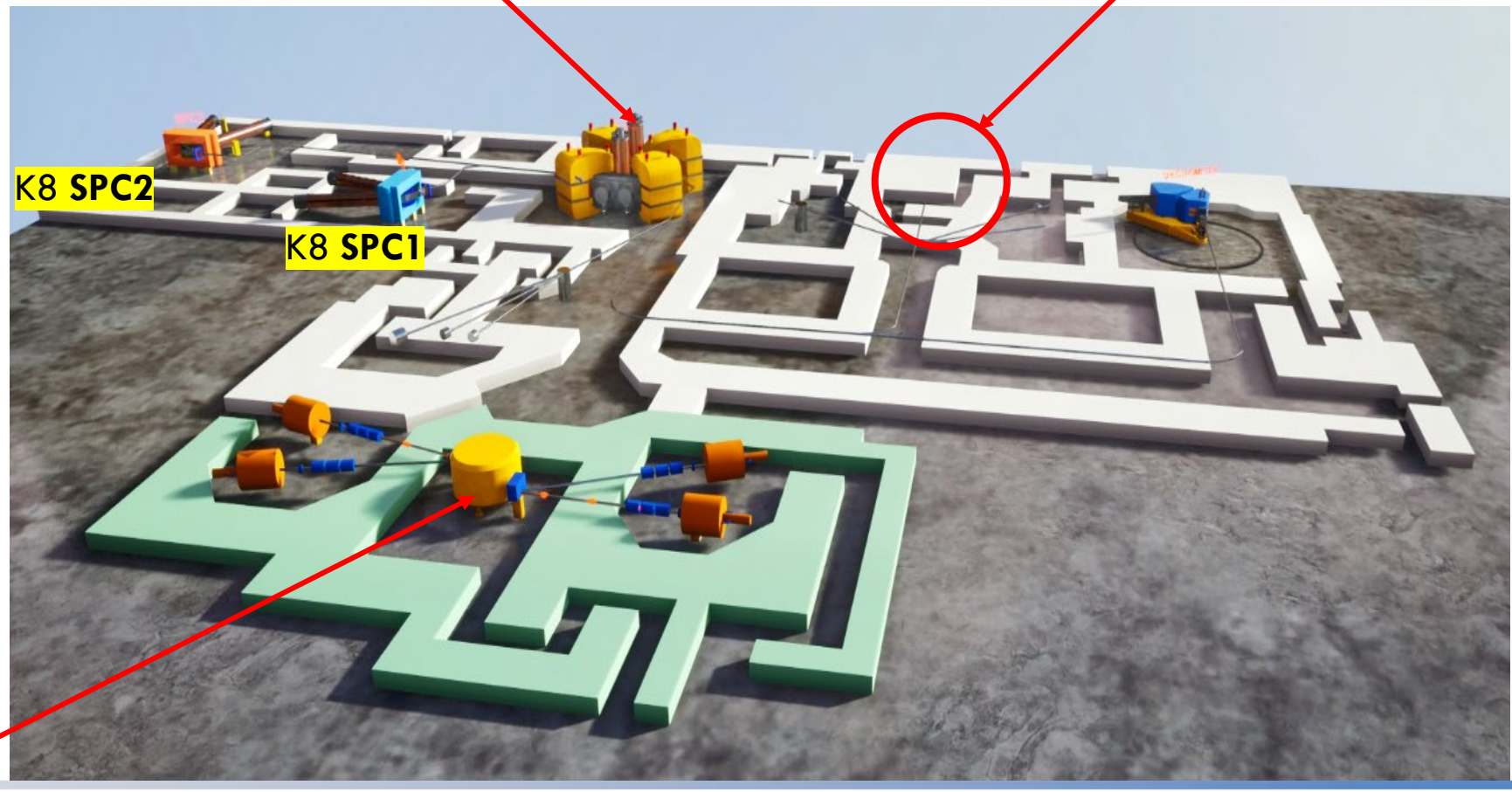
K=200 **Separated Sector Cyclotron (SSC)**

30 – 200 MeV

proton beam

from cyclotron

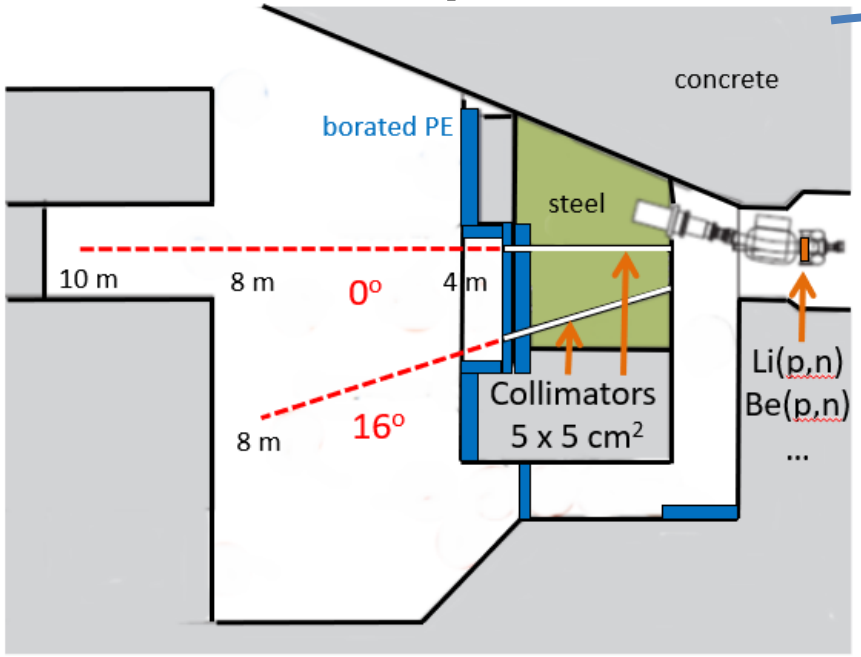
neutron vault (D-line)



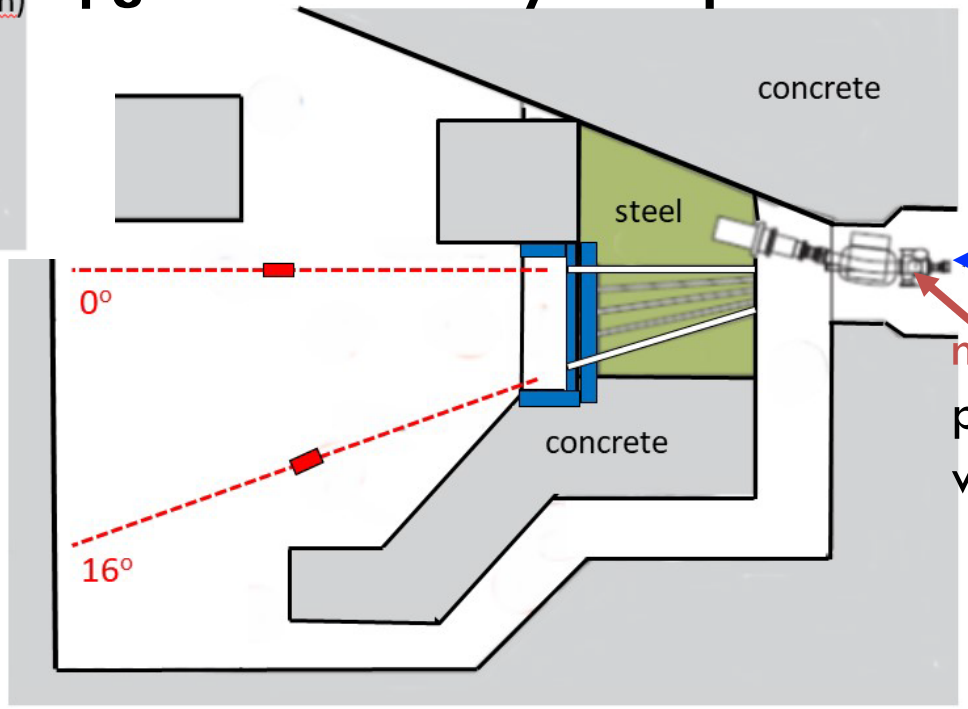
Fast neutron beam facility at iThemba LABS

Can produce 30–200 MeV quasi-monoenergetic neutron beams

Original vault layout – till 2019

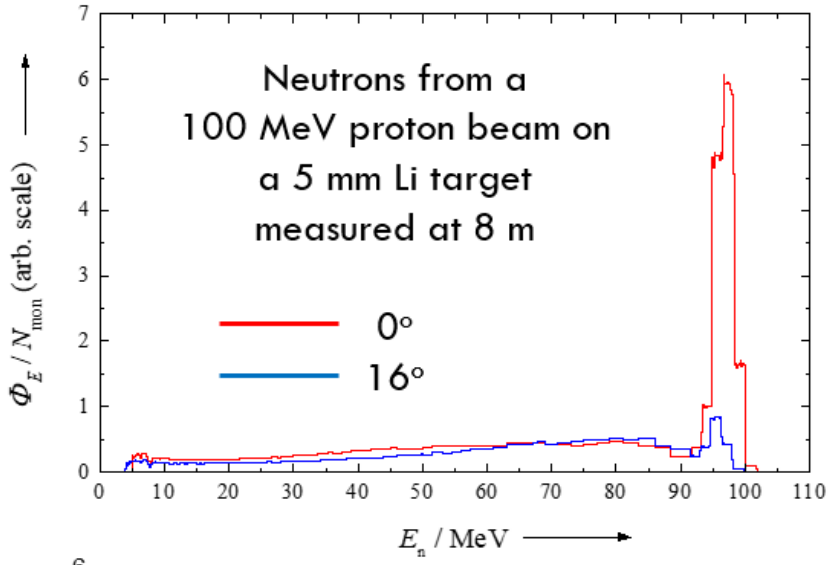


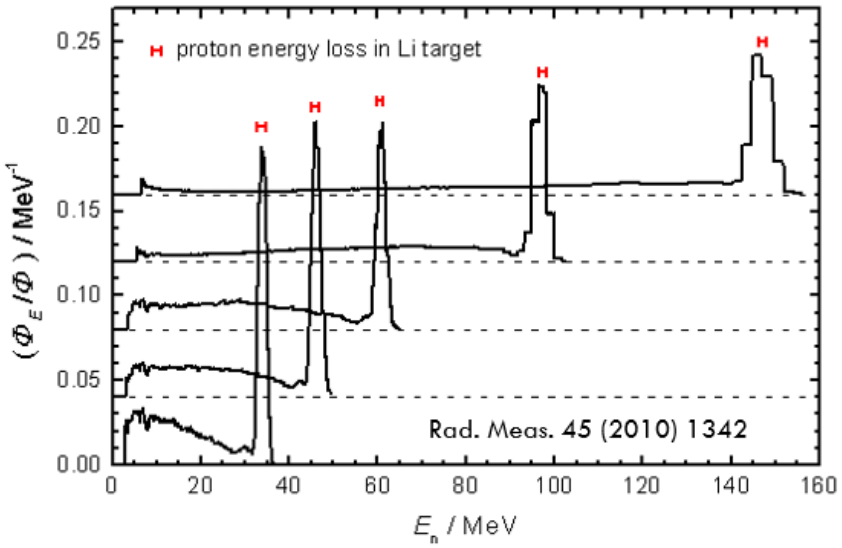
Upgraded vault layout – post 2019

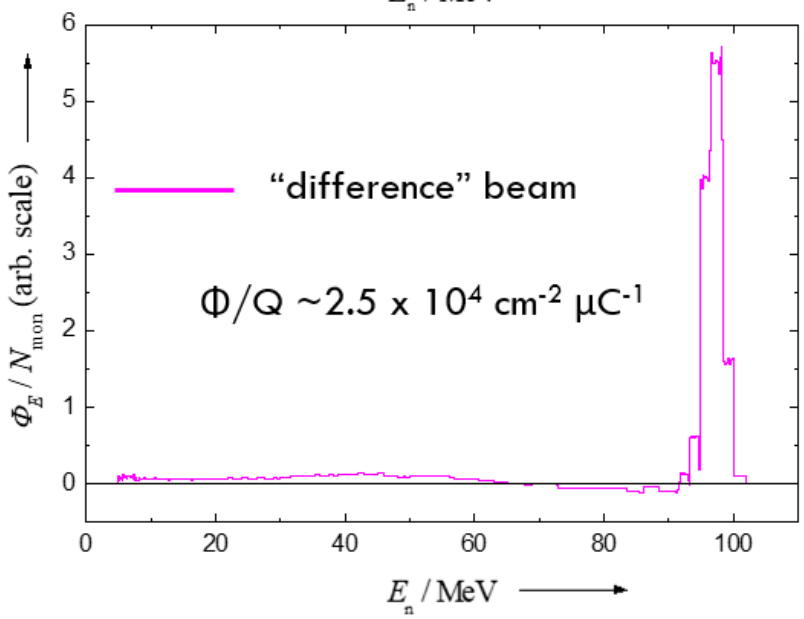


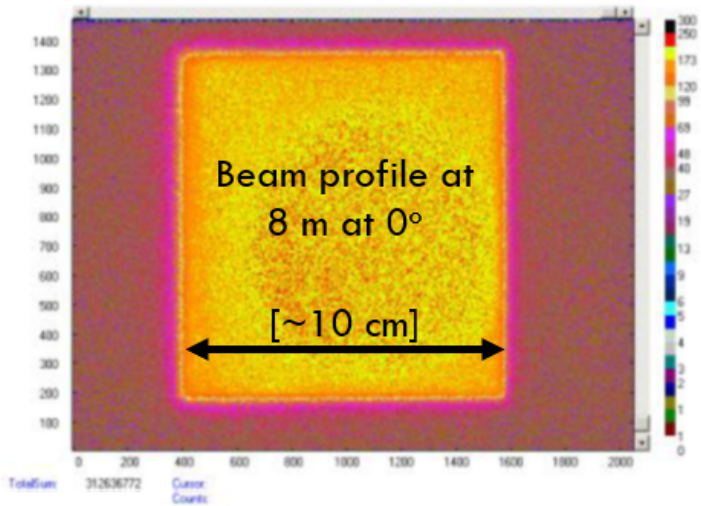
neutrons produced via Li (p, n)

Quasi-monoenergetic neutron beams at iThemba LABS





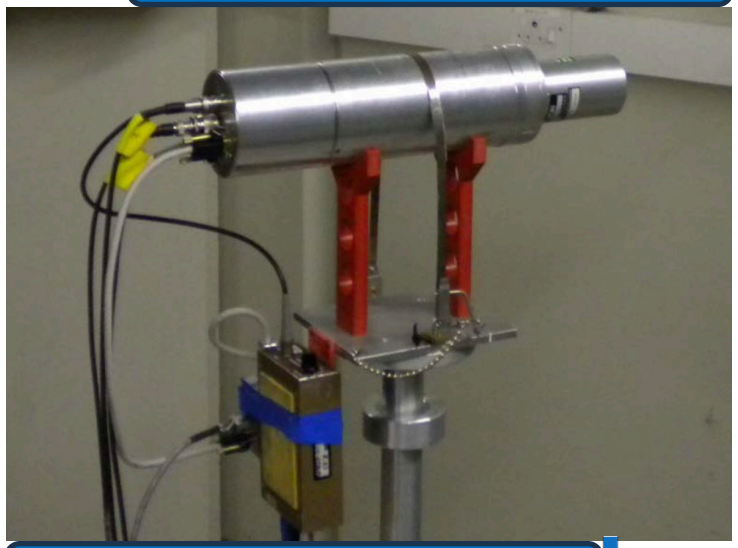




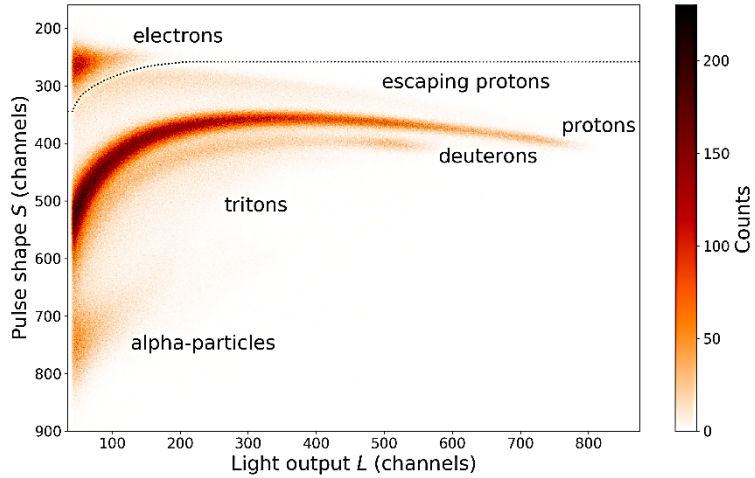
Beam characterisation (traceable to PTB Physikalisch Technische Bundesanstalt standards) [Mosconi *et al.* Radiat. Meas. 45 (2010) 1342]

Measurements with **BC501-A liquid scintillator** at low beam currents.

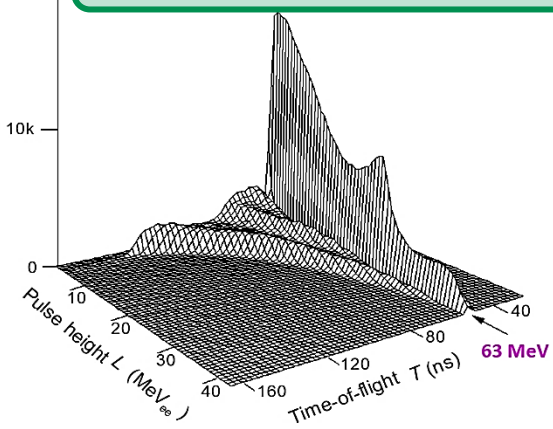
Pulse shape discrimination

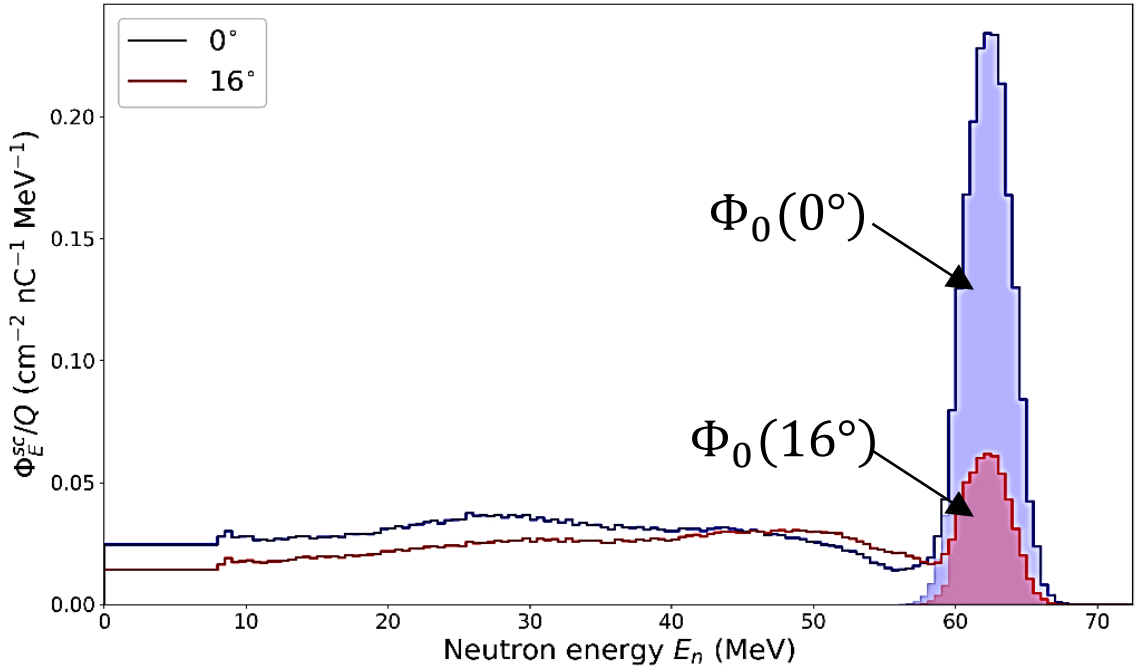


Time-of-flight



Neutron metrology





Fluence measurements

Measurements with **^{238}U fission chamber** at high beam currents

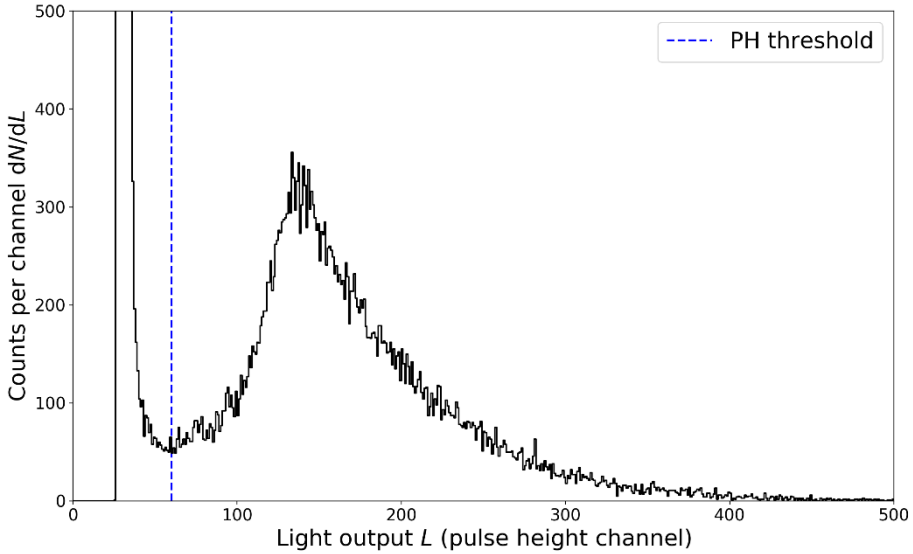
Correction factors

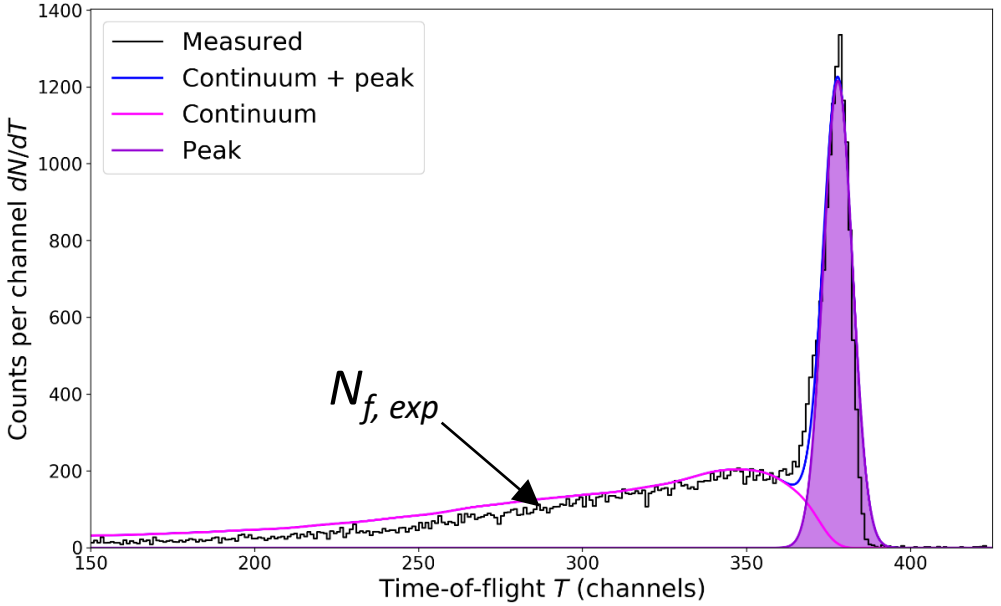
Measured fission counts

$$\Phi_0 = \frac{(\Pi_i k_i) N_{f,exp}}{\sigma N_u}$$

^{238}U fission cross section

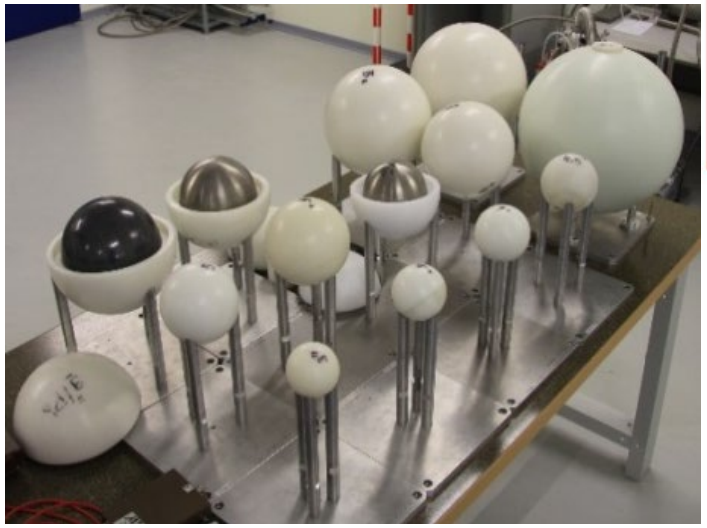
number of fissile ^{238}U atoms



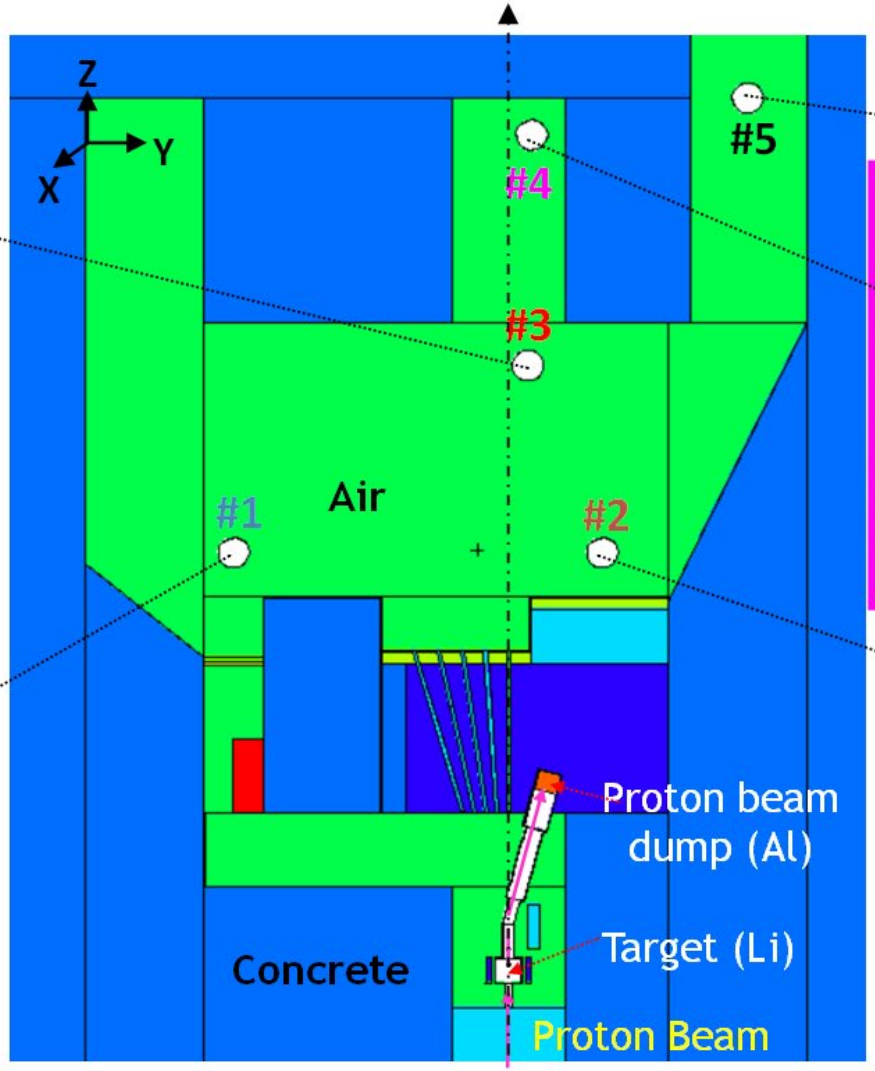


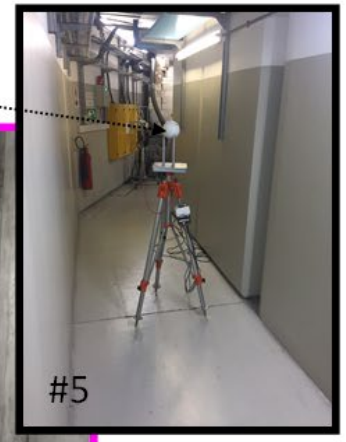
Measurement Campaign at iThemba LABS: 2019

Neutron Background Measurements Using HERMEIS Bonner Sphere system



HERMEIS Bonner Sphere system (IRSN)



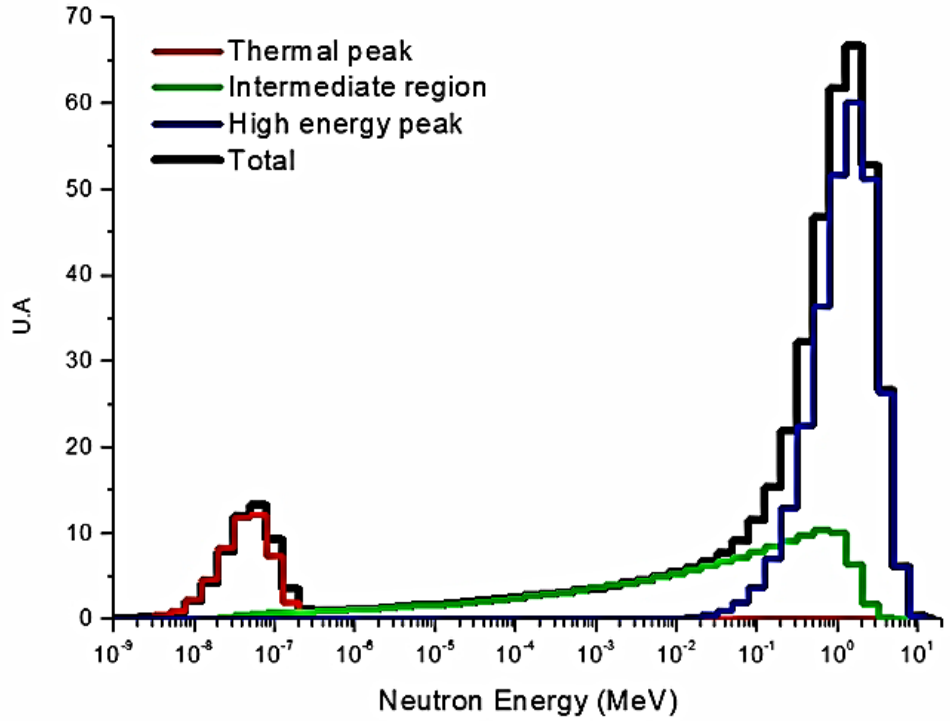


#1 - #5 indicate the five measurement positions in the D-line vault

Examples of Unfolded Spectra: WinBUGS and MAXED

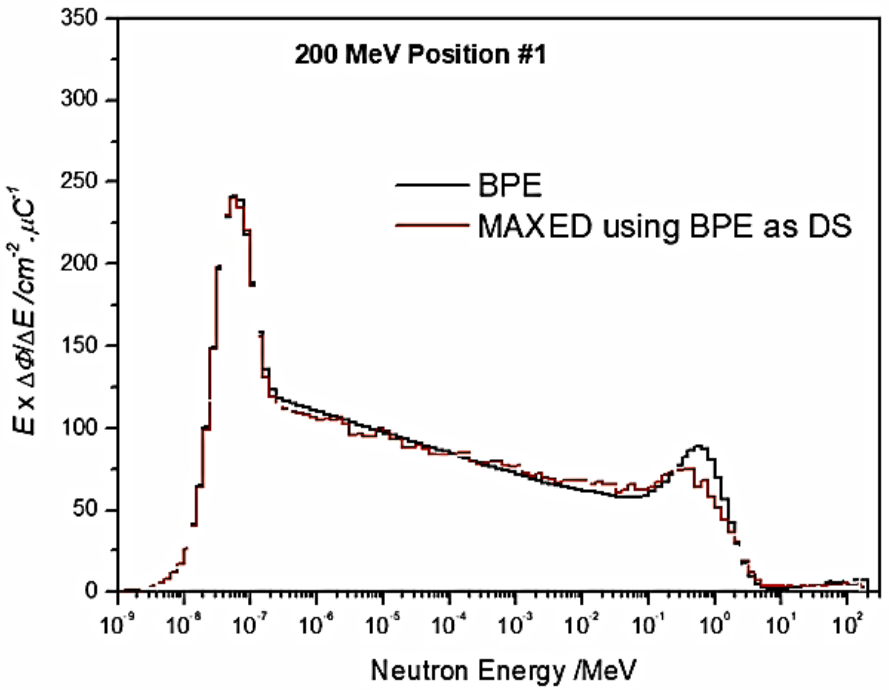
WinBUGS

Bayesian parameter estimation (BPE) applied to a parametrized model of the neutron spectrum

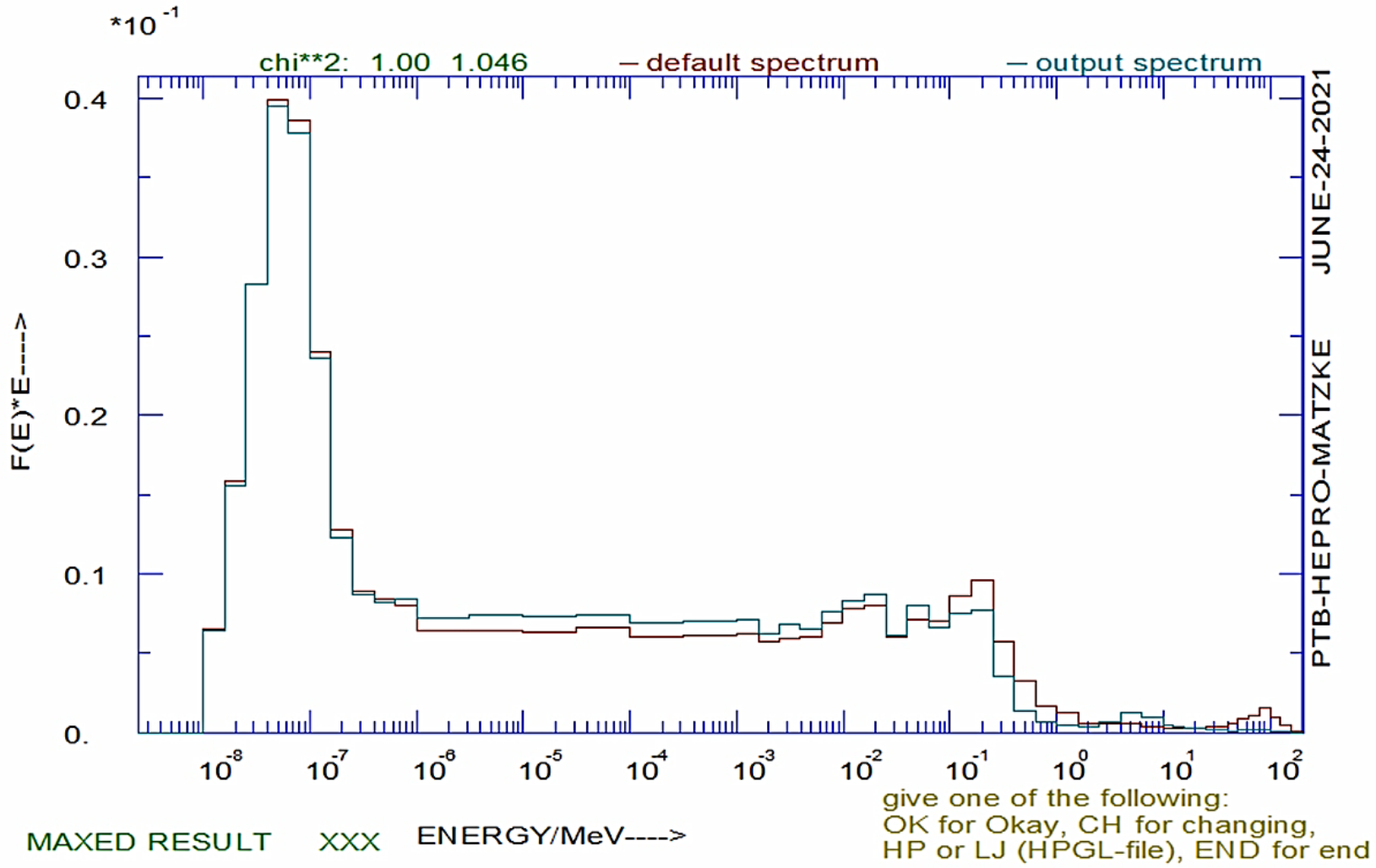


MAXED

Maximum entropy approach : maximizing the relative entropy of the solution spectrum with respect to a default spectrum



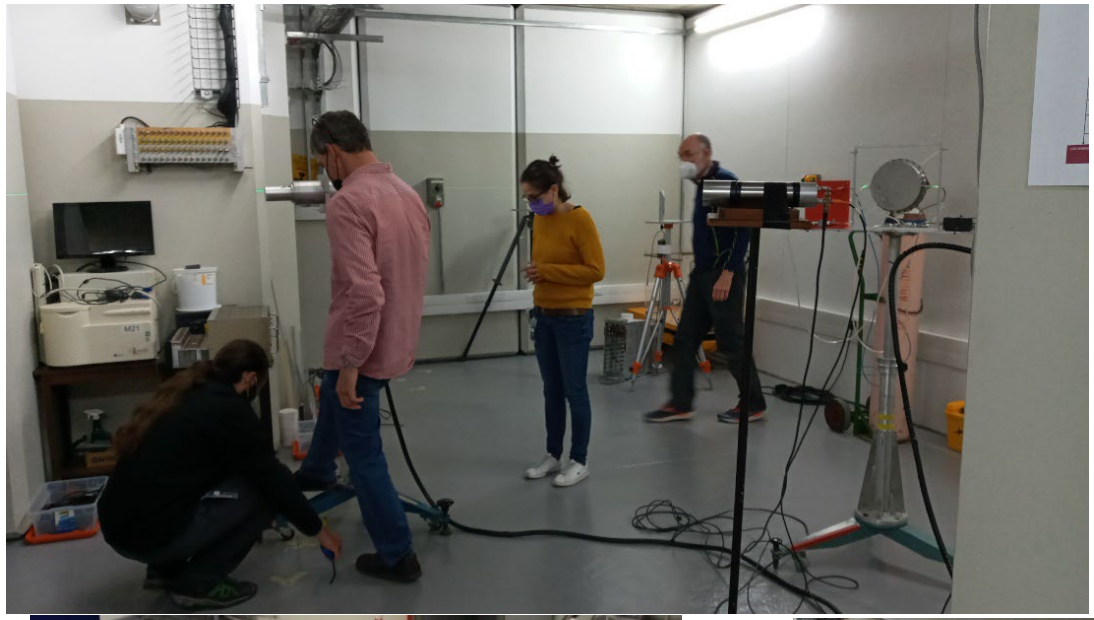
HERMEIS Experimental Data / MCNP6



Example:

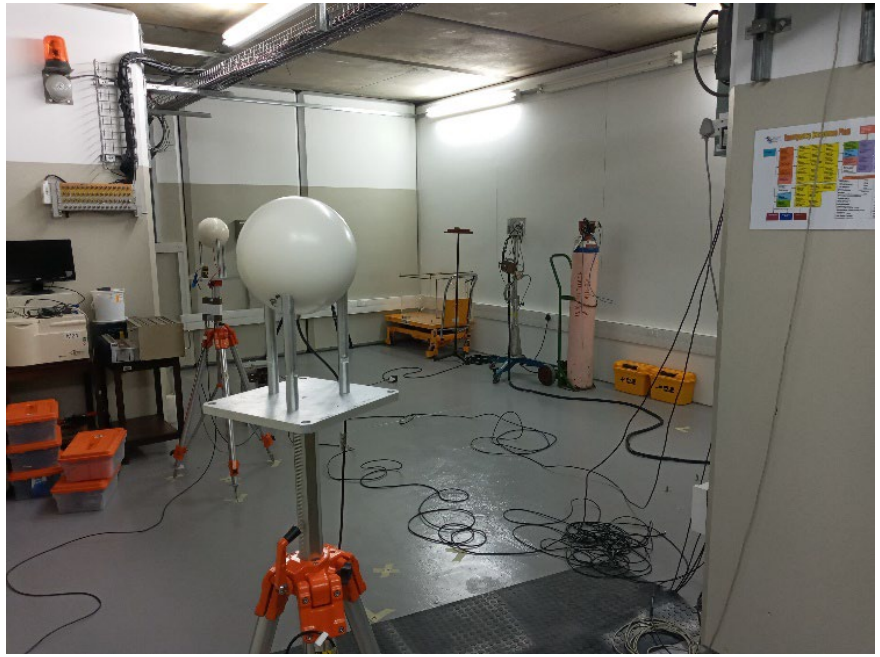
- Unfolding with MAXED of the 200 MeV data (pos #5 – in the chicane)
- Default Spectrum from MCNP6
- Good agreement !

Measurement Campaign at iThemba LABS: 2022



- Verification tests in the new D-line vault settings; May-June 2022 using 66 MeV proton beam.
- Further tests with proton beam of 200 MeV (or much higher energy than 66 MeV) still outstanding to complete these tests.

HERMEIS Bonner Sphere system (IRSN)



Ongoing Project

Plan of Action (Overview)

1. Improvements to physical infrastructure – Complete
2. Improvements to instrumentation – Ongoing
3. Towards a metrology facility – Still to be done

1. Setting up a primary standard for neutron measurements in the energy range from 30 MeV to 200 MeV.

2. Participating in international key-comparison studies in the area of neutron metrology for medium to high-energy neutrons.

3. Performing cross-section measurements of neutron-induced reactions and calibrating neutron detectors and radiation protection dosimeters.

Vision for fast neutron facility

To be an ISO-designated fast neutron facility at iThemba LABS spanning the range 30 to 200 MeV, recognized and supported by the international neutron physics and metrology communities!

Beam Time Allocation at iThemba LABS

- Beam is currently shared between Isotope Production and the Research groups.

- Beam time for the Research;

1. SSC at iThemba LABS is capable of accelerating protons; E_p = 30 MeV - 200 MeV; of interest to this community, means quasi-monoenergetic neutrons E_n = 30 MeV - 200 MeV are possible.
2. Project Advisory Committee (PAC) members gather to review submitted proposals and advise on approval for beam allocation.
3. At the discretion of the Director, beamtime can also be allocated on special request. This requires an additional motivation to the science case on why proper channels (via PAC) could not be followed
4. Once the submission is approved and beam time is allocated, the spokesperson can discuss the scheduling plan of the experiment, currently from Wednesday to Monday.

Enkosi; Thank you; Danke!

Acknowledgements

- DSI – NRF - iThemba LABS

- Upgrade Collaboration team :

NRF National Research Foundation | iThemba LABS Laboratory for Accelerator Based Sciences

DEPARTMENT OF PHYSICS UNIVERSITY OF CAPE TOWN

MeASURe Metrological and Applied Sciences University Research Unit

IRSN INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

nmisa National Metrology Institute of South Africa

PTB Physikalisch Technische Bundesanstalt

NPL National Physical Laboratory