Measuring the neutron fields within Paarl Africa Underground Laboratory

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

DEPARTMENT OF PHYSICS UNIVERSITY OF CAPE TOWN

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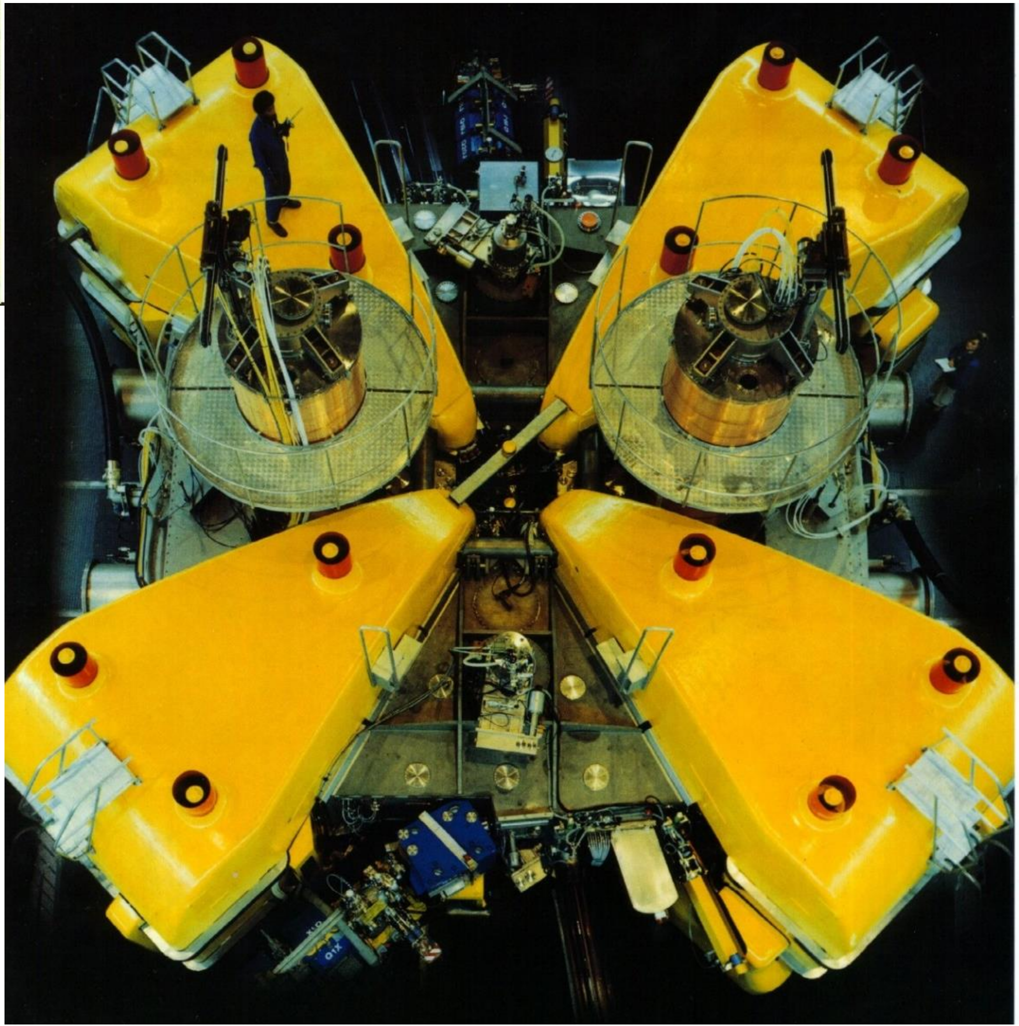
Existing facilities

1.



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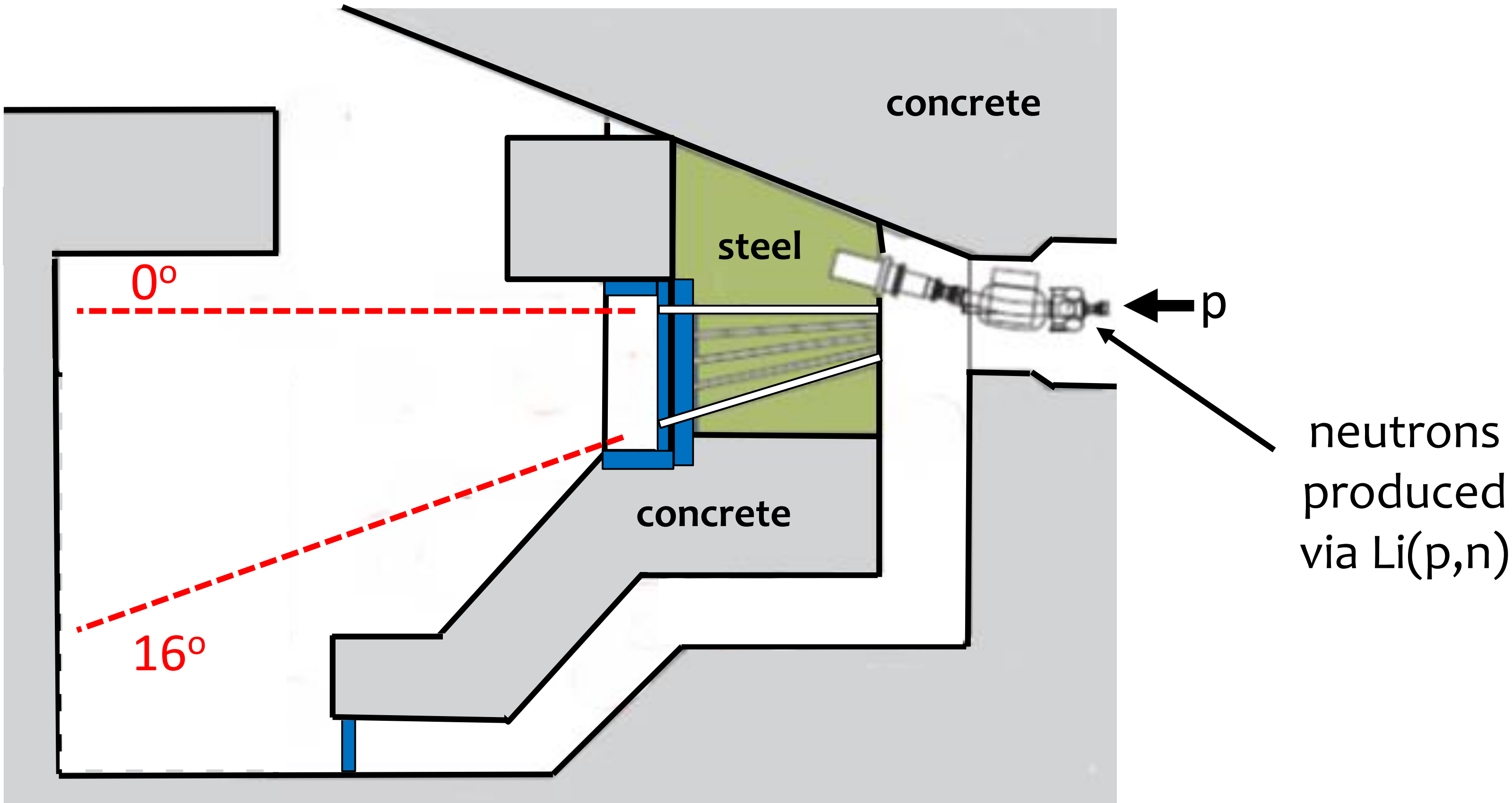
National Laboratory

200 MeV cyclotron

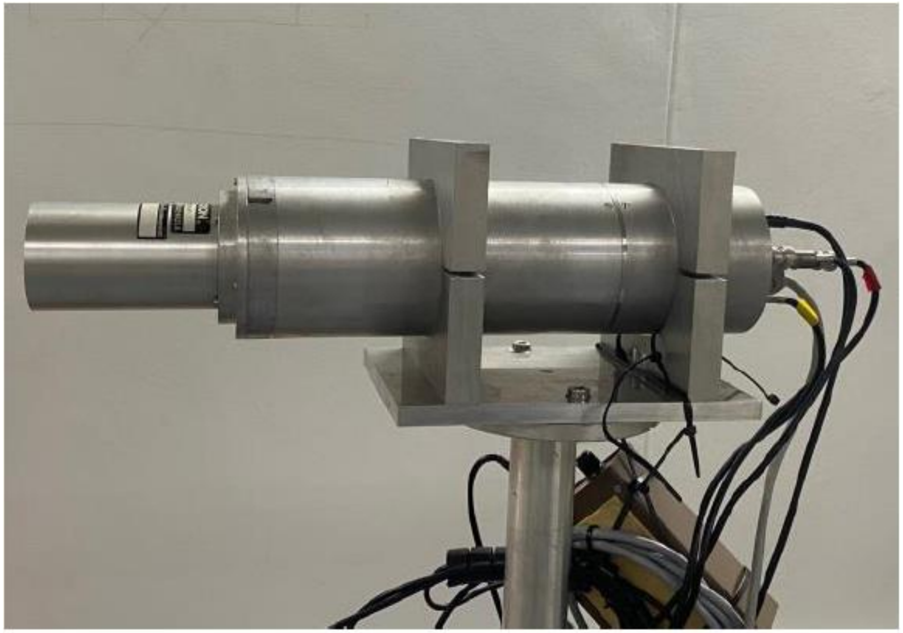
Fast neutron beam facility at iThemba LABS

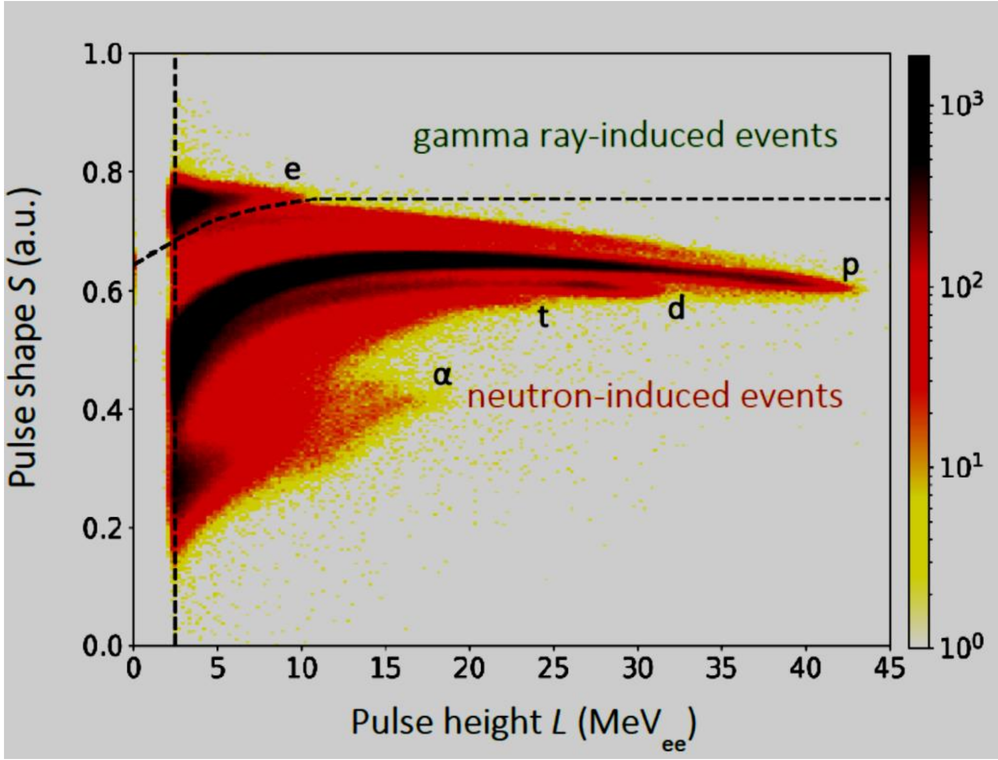
Development towards an ISO-accredited reference facility



D-Line Standard Detector

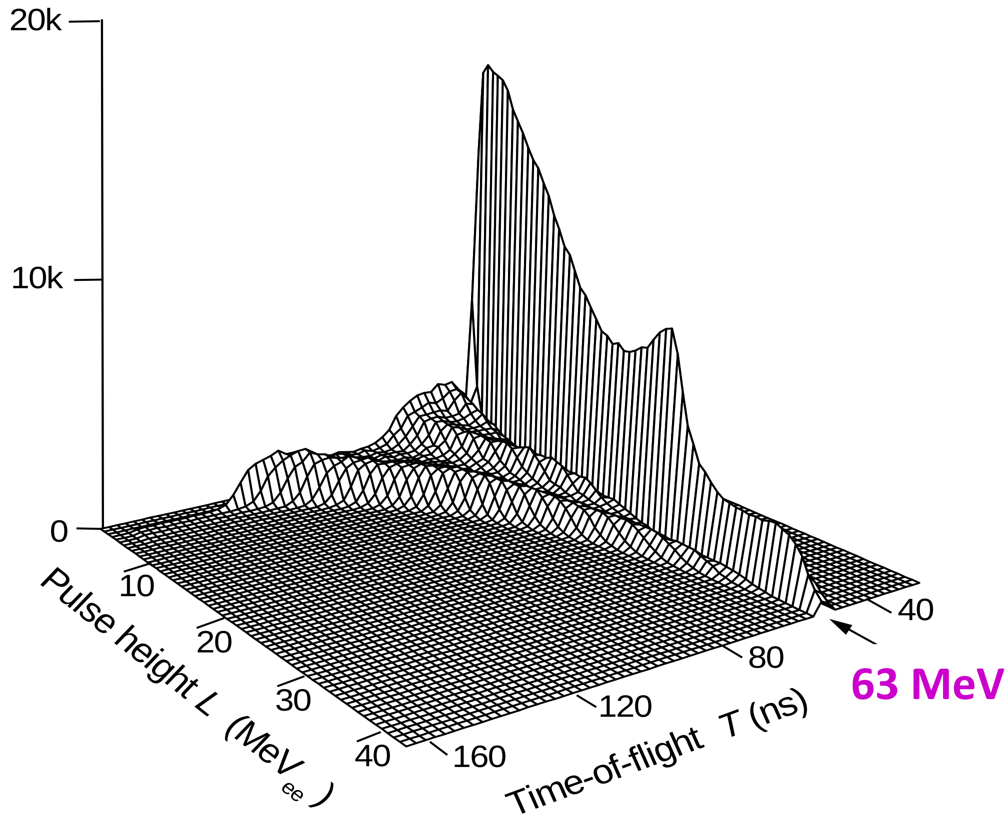
2″ × 2″ BC501A liquid scintillation detector

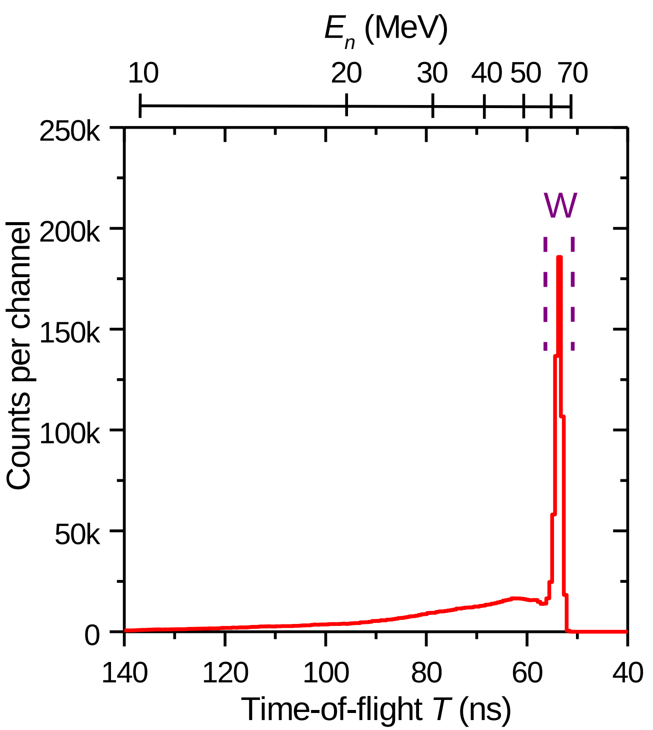




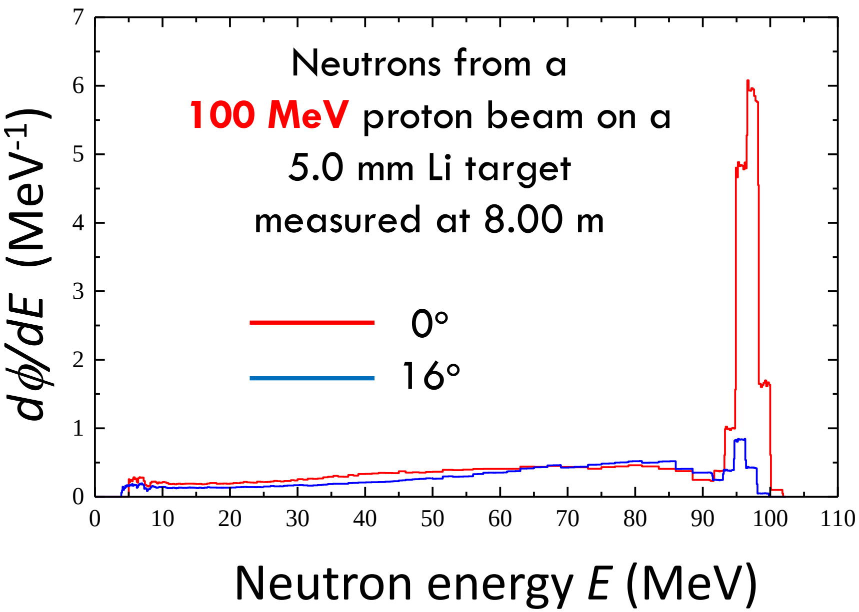
- Excellent pulse shape discrimination (PSD) properties.
- Fast timing performance.
- Well characterised.

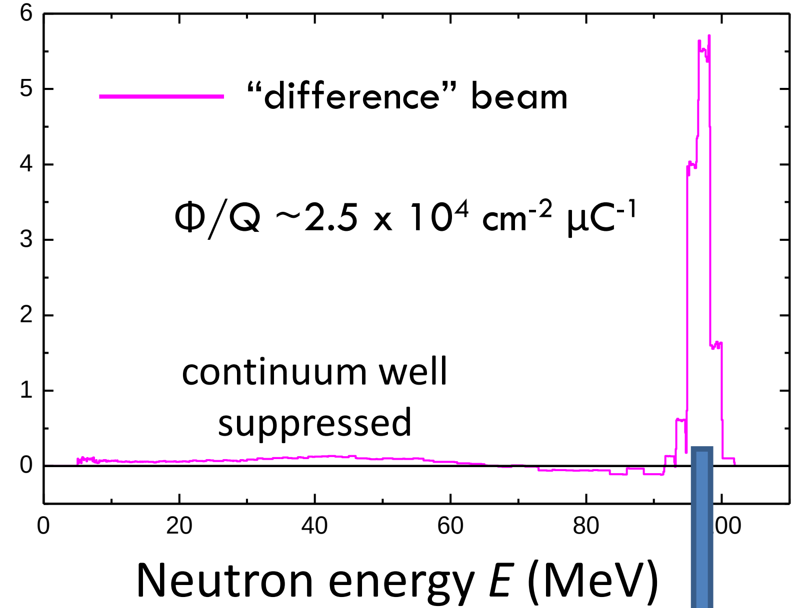
Time-of flight measurement of neutrons produced by a 66 MeV proton beam irradiating a 5.0 mm ^{nat}Li target. (Measurements at 6.00 m from the target at 0°).





Quasi-monoenergetic neutron beams at iThemba LABS





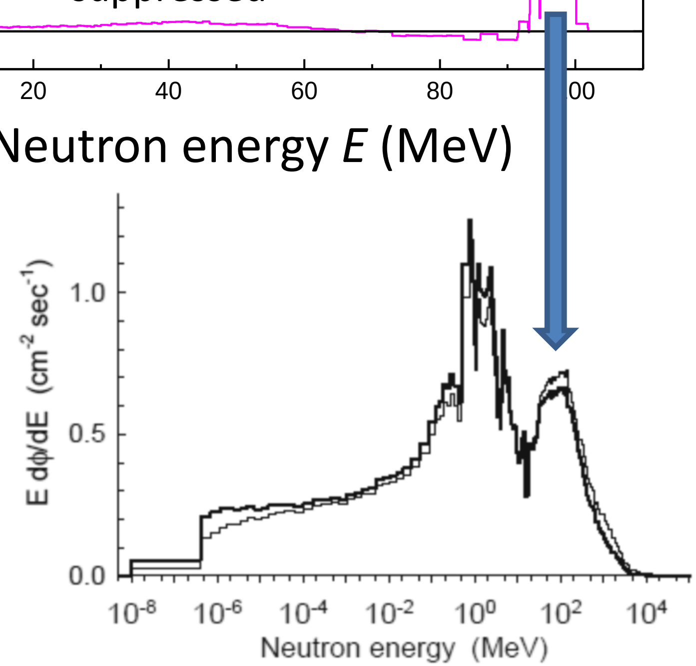
Cosmic-ray neutron spectrum: 20 km at 54° N, 117° W

Measured

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

Calculated

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



2.

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Fast neutron facility at UCT

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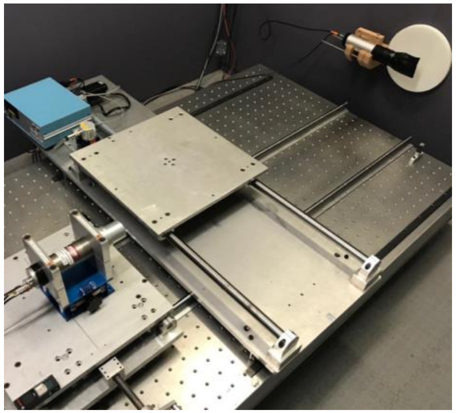
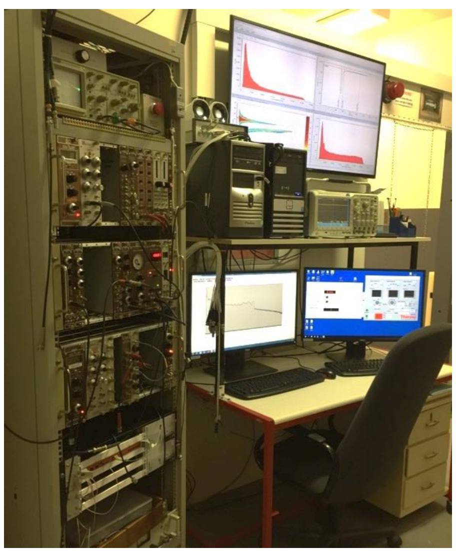
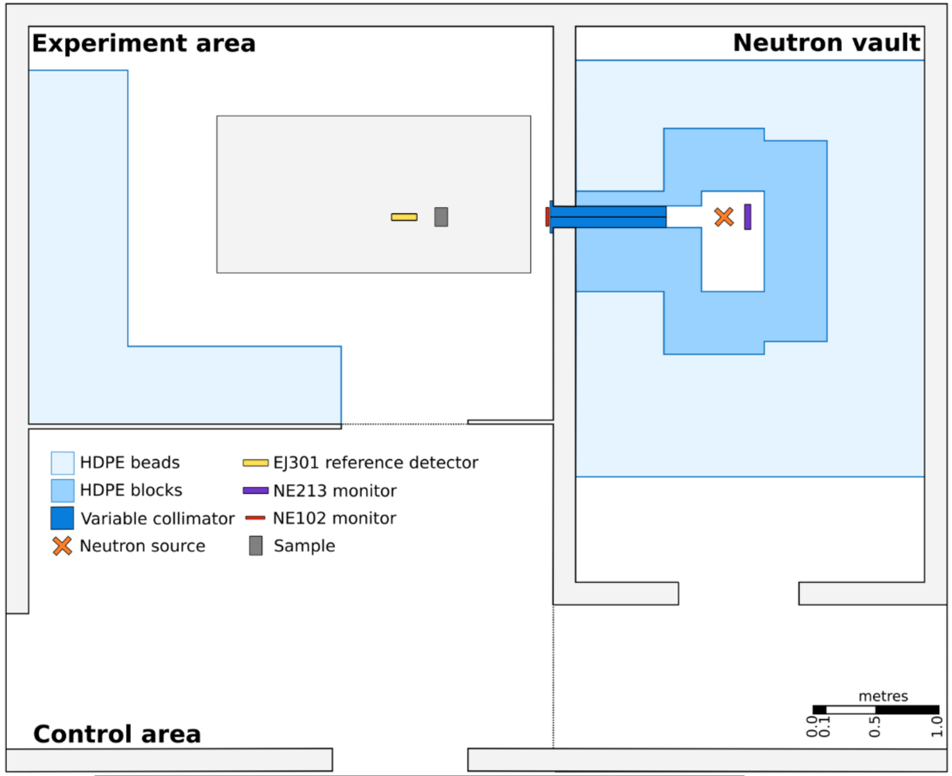
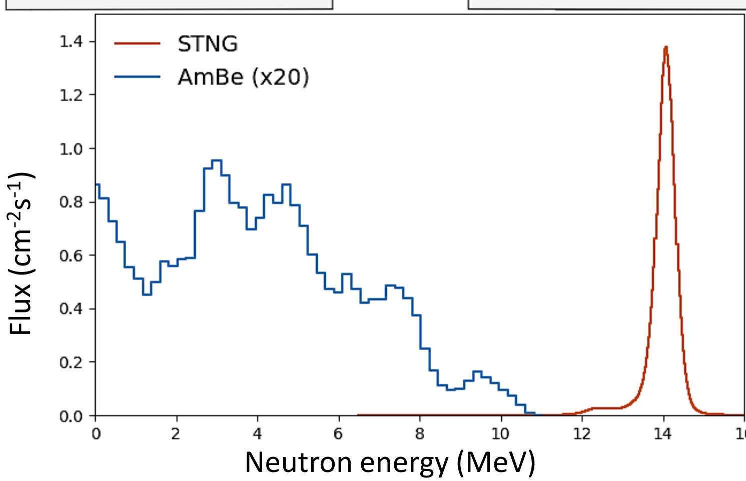
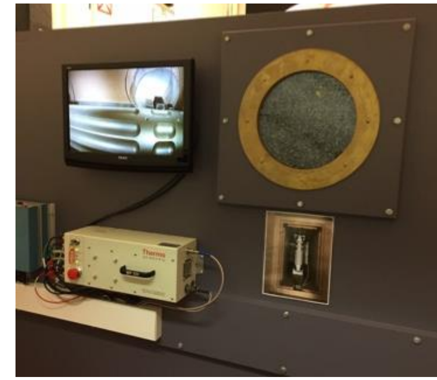






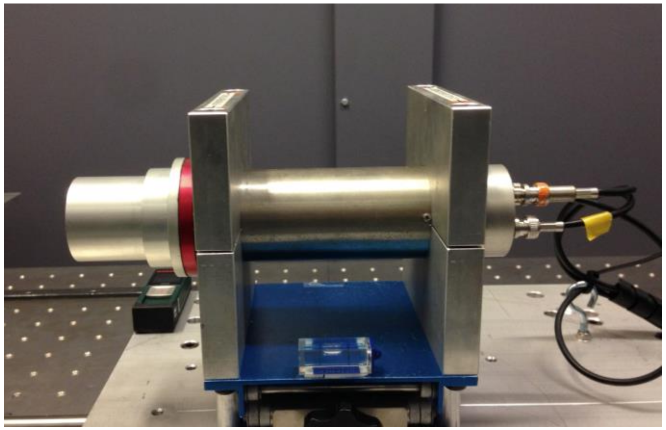




	STNG	AmBe
Type	Accelerator	Radioisotopic
Reaction	t(d, n)α	^{9}Be(α, n)^{12}C*
Energy	14.1 MeV	< 11 MeV
Yield	10^{8} s^{-1}	10^{7} s^{-1}

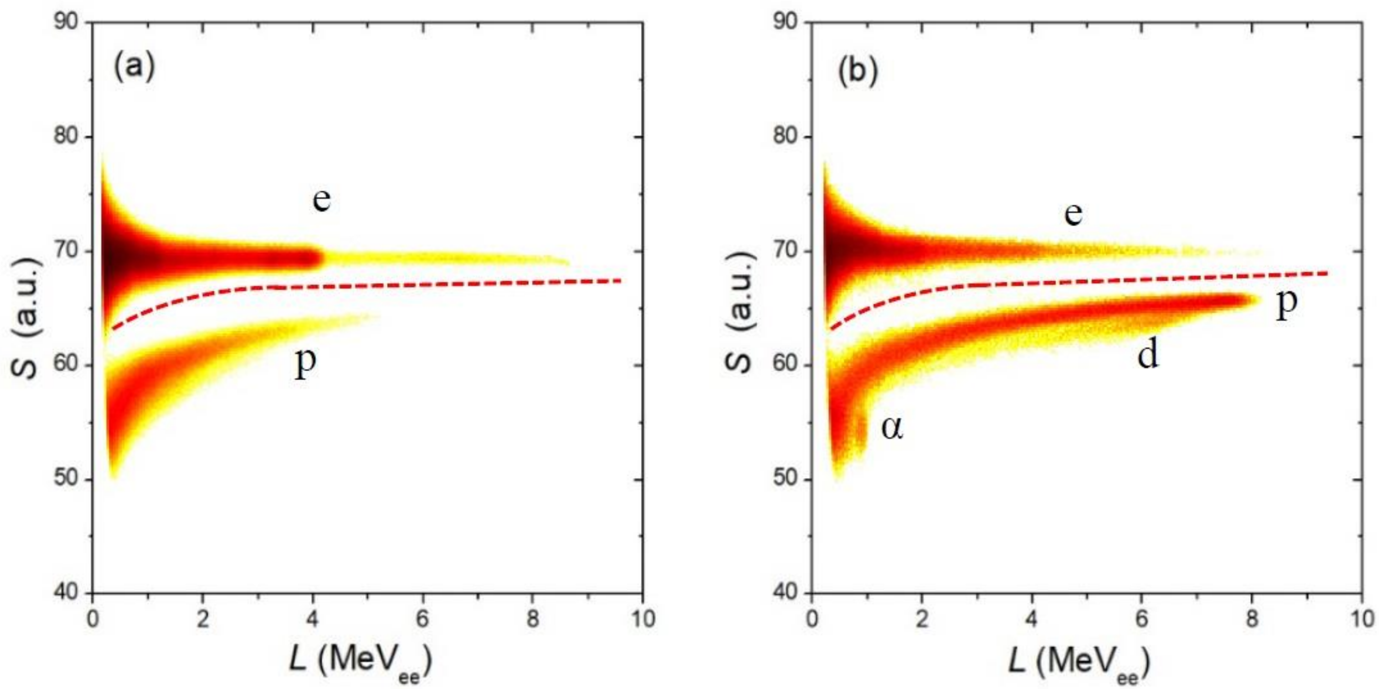
n-lab Reference Detector

50 mm x 50 mm cylindrical EJ-301 Liquid Scintillator



- PSD properties to exclude gamma rays
- Well characterised

AmBe



STNG

dDAQ for measurements

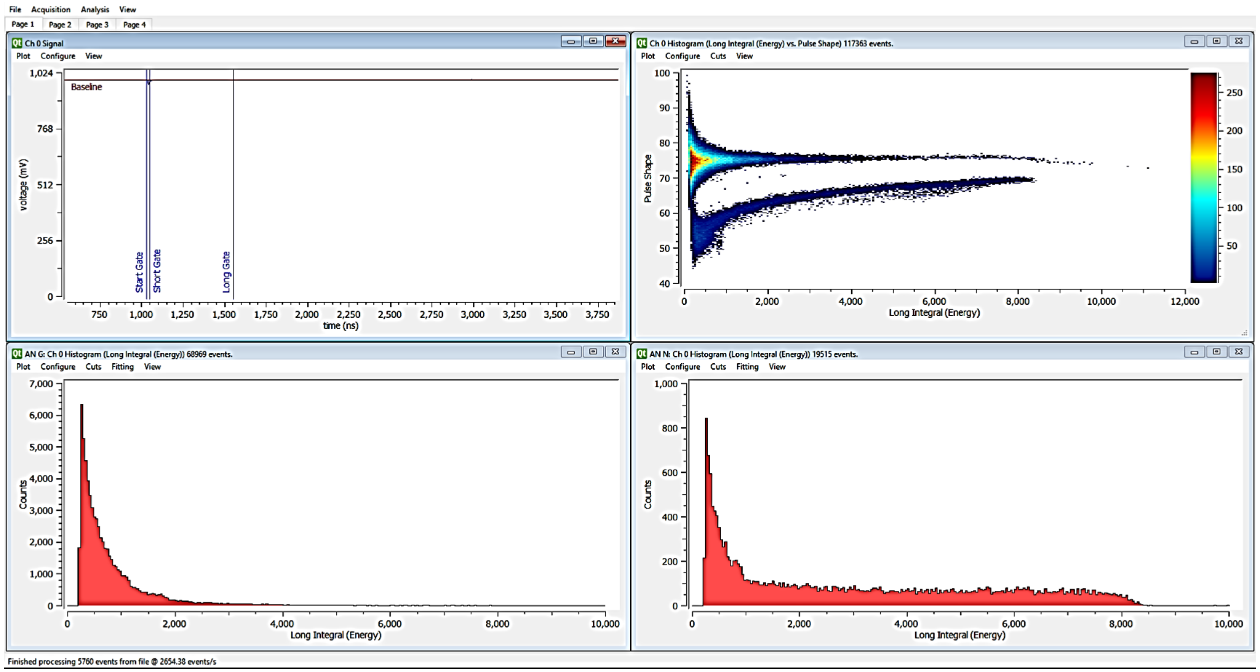
CAEN Vx1761
10 bit, 4.0 GS/s
1.0 V_{pp}

or

CAEN DT5730
14 bit, 0.5 GS/s
0.5-2.0 V_{pp}

CAEN
Tools for Discovery

- QtDAQ software (designed and developed at UCT)
- Data written in list mode for off-line processing



Typical Neutron Background Measurements in the ULs: (Possibility for PAUL...?)

Neutron Background UL

- In the ULs, neutrons are from muon induced secondary particles, spontaneous fission and (α, n) reactions

Underground lab	Depth (m.w.e)	Thermal neutron flux ($cm^{-2}s^{-1}$)	Fast neutron flux ($cm^{-2}s^{-1}$)	References
CPL	1000	No data	$(3.00\pm0.02\pm0.05)\times10^{-5}$	Kim H J et al[14]
YangYang	2000	$(2.42\pm0.22)\times10^{-5}$	8×10^{-7}	Park H et al. [15];Lee H S et al.[16]
Soudan	2090	$(0.7\pm0.08\pm0.08)\times10^{-6}$	No data	Best A et al [17]
Canfranc	2450	$(1.13\pm0.02)\times10^{-6}$	$(0.66\pm0.01)\times10^{-6}$	Jordan D et al.[13]
Boulby	2800	No data	$(1.72\pm0.61\pm0.38)\times10^{-6}$	Tziaferi E et al. [18]
Gran Sasso	3600	$(1.08\pm0.02)\times10^{-6}$	$(0.23\pm0.07)\times10^{-6}$	Belli P et al. [19]
Modane	4800	$(1.6\pm0.1)\times10^{-6}$	$(4.0\pm1.0)\times10^{-6}$	Chazal V et al. [20]
CJPL	6720	$(4.00\pm0.08)\times10^{-6}$	No data	Zeng Z M et al.[9]
CJPL	6720	$(7.03\pm1.81)\times10^{-6}$	$(3.63\pm2.77)\times10^{-6}$	This study

PAUL: ~ 800 m of rock overburden

Table adopted from (Q. Hu, et al., Nucl. Instrum. Meth. A 859 (2017) 37)

Popular neutron detectors/instruments

For ULs…, the neutron spectra (+flux) needs to be known and continuously monitored!

1. **A gaseous ^{3}He proportional ionization chamber** enables determination of *thermal neutron flux*.

2. **Gadolinium doped plastic scintillators / Gadolinium-loaded liquid scintillator (Gd-LS)** allow for detection of the *fast neutron background* via delayed coincidence of proton recoils followed by thermal neutron capture.

3. **A multiple Bonner sphere neutron spectrometer**, with ^{3}He ionization chambers enclosed in polyethylene shielding of varying thickness, for neutrons up to 20 MeV energy (i.e. *useful for both thermal and fast neutrons*).

J. Cheng et al., ***Annual Review of Nuclear and Particle Science,*** *67:1, pp. 231-251, 2017.*

Relevance of iTL + UCT… to PAUL

- ONGOING PROJECT: Upgrade of iTL fast neutron beam facility towards neutron metrology compliance (iTL, UCT, NMISA; IRSN; NPL; PTB)

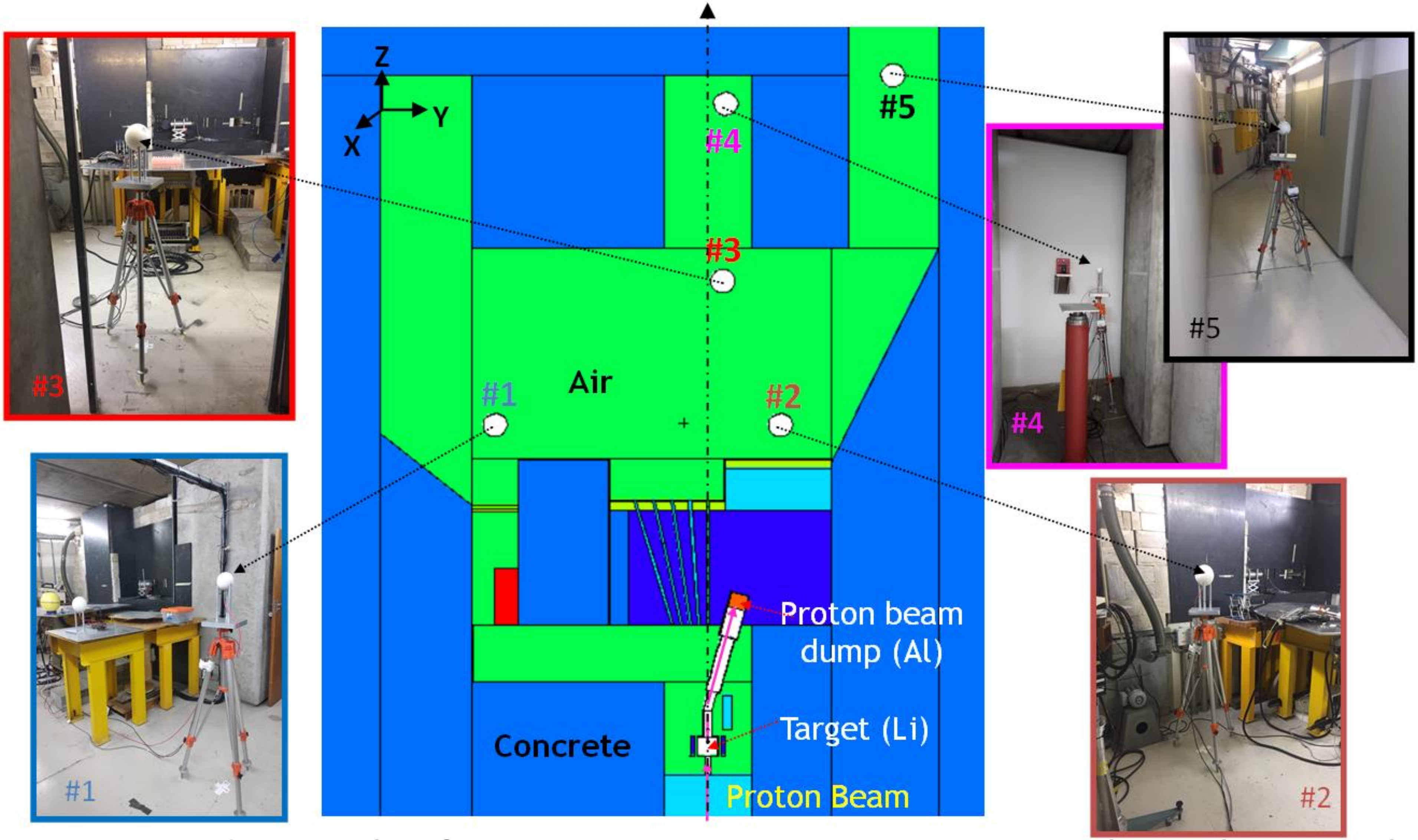
  ……. iTL fast neutron beam facility with reliable neutron beam monitoring and neutron beam characterisation traceable to PTB standards (Mosconi et al., 2010).

- Possibility of neutron detector/instruments testing and/or calibrations.

- Available neutron fields: ***Thermal - fast neutrons*** (UCT n-Lab)
  Fast (iTL D-line)

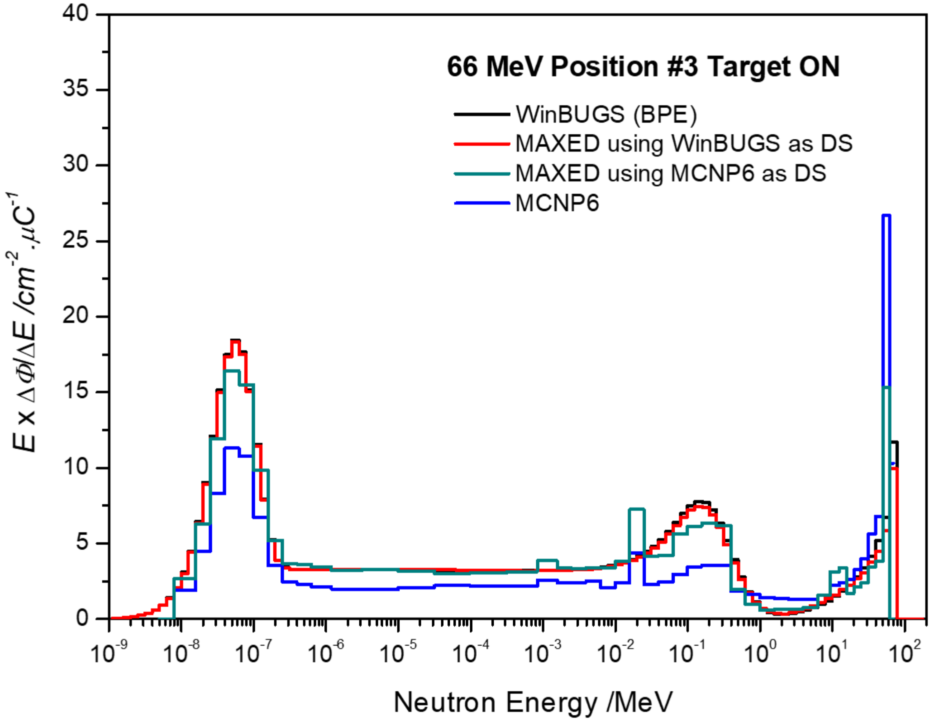
- Neutron spectra unfolding (response functions)
- Monte Carlo simulations

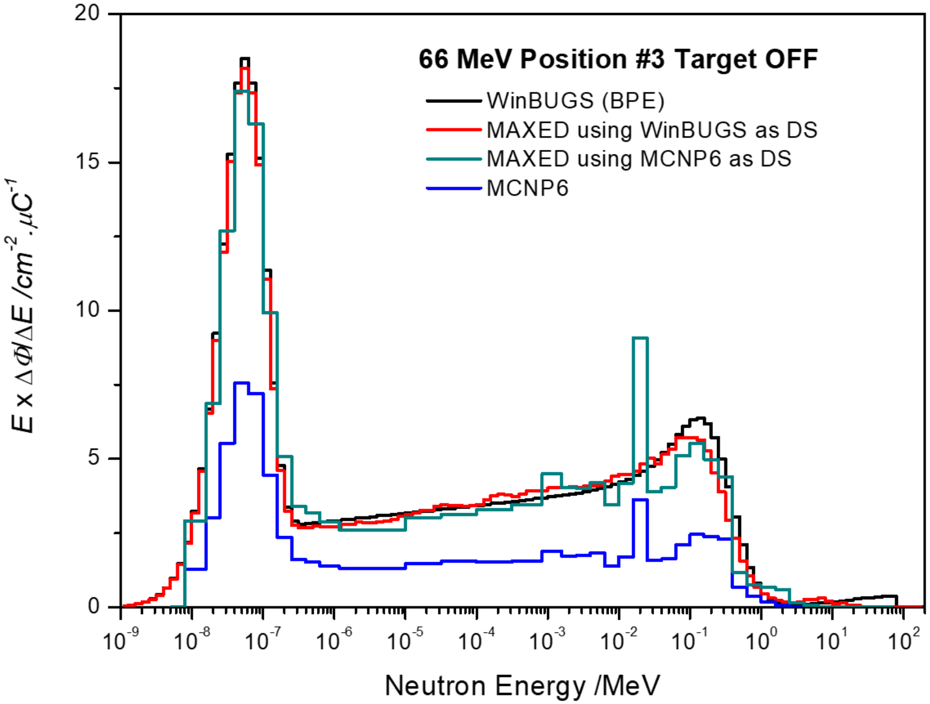
Measurement Campaign at iThemba LABS using HERMEIS Bonner Sphere Spectrometer system



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

Bonner Sphere Spectrometer system: HERMEIS





Summary

- Facilities at iTL and UCT are available to contribute to the development of instruments required for PAUL.

- There is ongoing detector development and instrumentation dedicated to neutron physics.

- Human capacity development on neutron science at iTL is also necessary.

Thank you

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