Update on Calibration Studies of the Canadian High-Energy Neutron Spectrometry System (CHENSS)

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14th Workshop for Radiation Monitoring for the International Space Station (WRMISS)
Dublin, Ireland, United Kingdom
September 8-10, 2009

Outline

- Introduction
  - CHENSS Design
- Calibration Studies at Accelerator Facilities
  - PTB and iThemba
- Future Development

Neutron Dosimetry in Space

- Complex particle and neutron field in space
  - Albedo neutrons from Earth's atmosphere and secondary production from spacecraft shielding contributes ~10-30% of total dose equivalent
    - TEPC reliable doses <20 MeV (response to higher energies?)
    - CR-39 passive dosimeters complement TEPC (and TLDs)

- Improve radiation dosimetry in space by accurately measuring neutron fluence and energy distribution

CHENSS

Canadian High-Energy Neutron Spectrometry System

- Three gain settings provide desired dynamic range (1 – 100 MeV scale)
- Internal ^{22}Na (200 Bq) γ-ray source and two green LED's provide energy calibration and gain stability checks
- Amplitude and shape signals, hit patterns, scalers and diagnostics recorded on two hard drives
- 50 W power from alkaline batteries
- Originally designed for autonomous operation in NASA Get-Away-Special (GAS) can on space shuttle

G. Jonkmans et. al., Acta Astronautica 56, 975 (2005) and M.B. Smith et. al., Proc. "International Workshop on Fast Neutron Detectors and Applications" PoS(FNDA2006)006

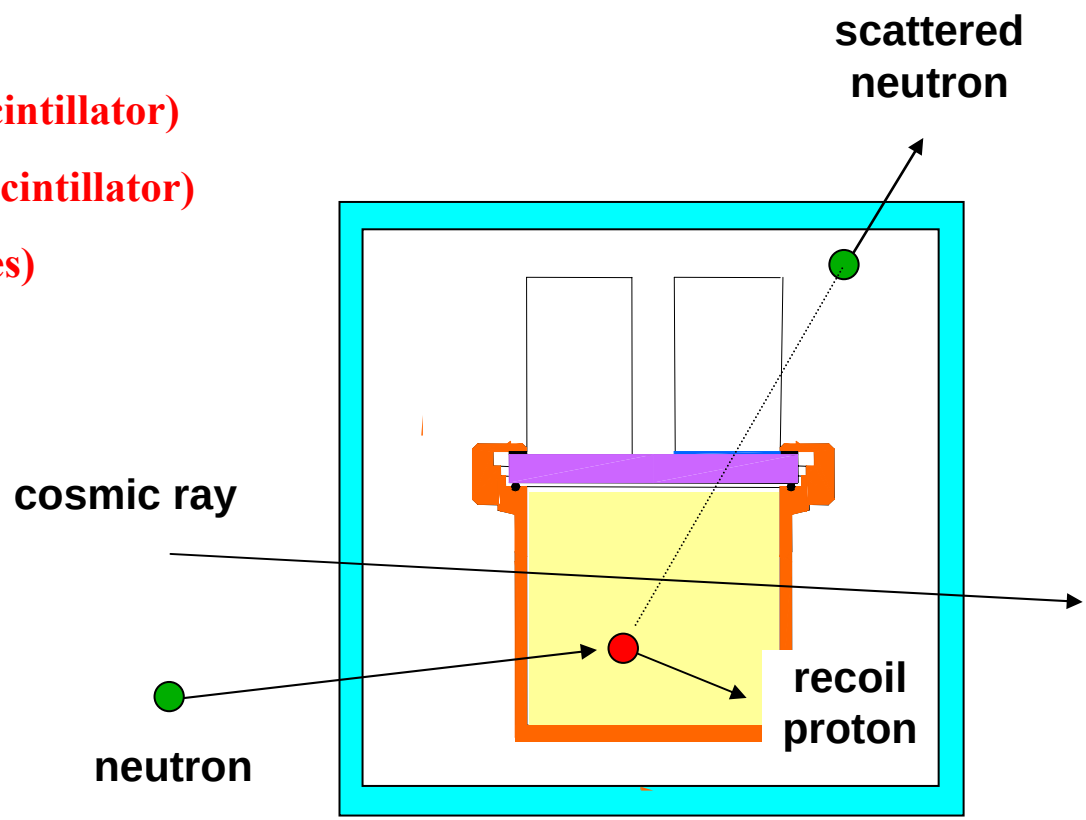
CHENSS: principle of operation

Types of space radiation

- cosmic rays (vetoed by plastic scintillator)
- neutrons (detected by primary scintillator)
- electrons and γ rays (short pulses)

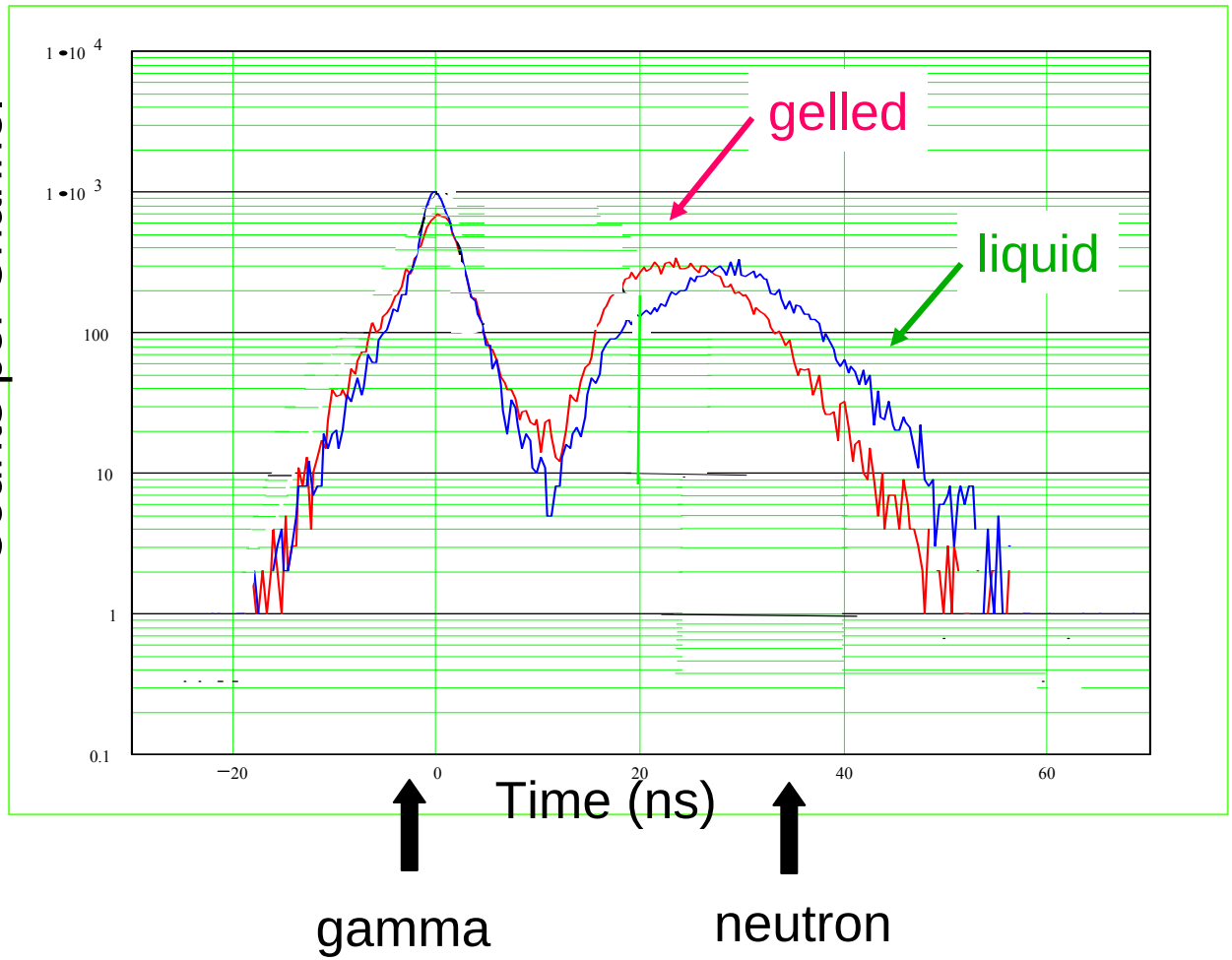
Visco-elastic scintillator

- xylene + naphthalene
- good n-γ discrimination
- isotropic response
- reliable cross-sections



Performance of Gelled Xylene Scintillator

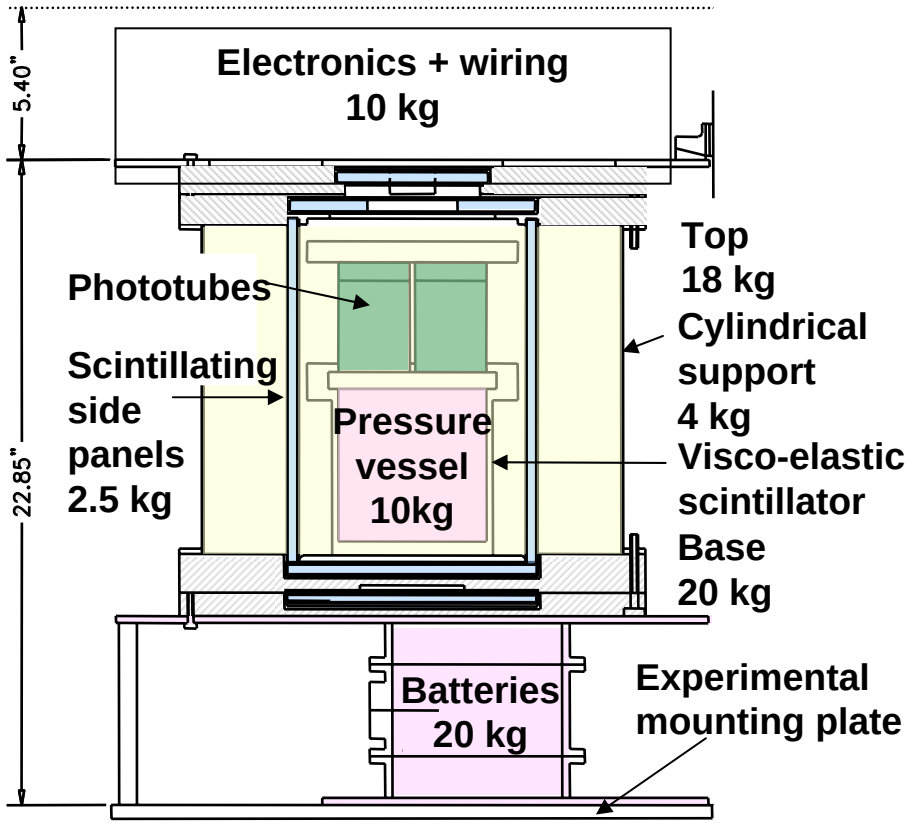
Neutron – Gamma Discrimination



Light output ~ 75% NE-213 liquid scintillator

Gelled scintillator becomes opaque below -10°C

CHENSS Design



Total weight = 84.5 kg = 185 lbs

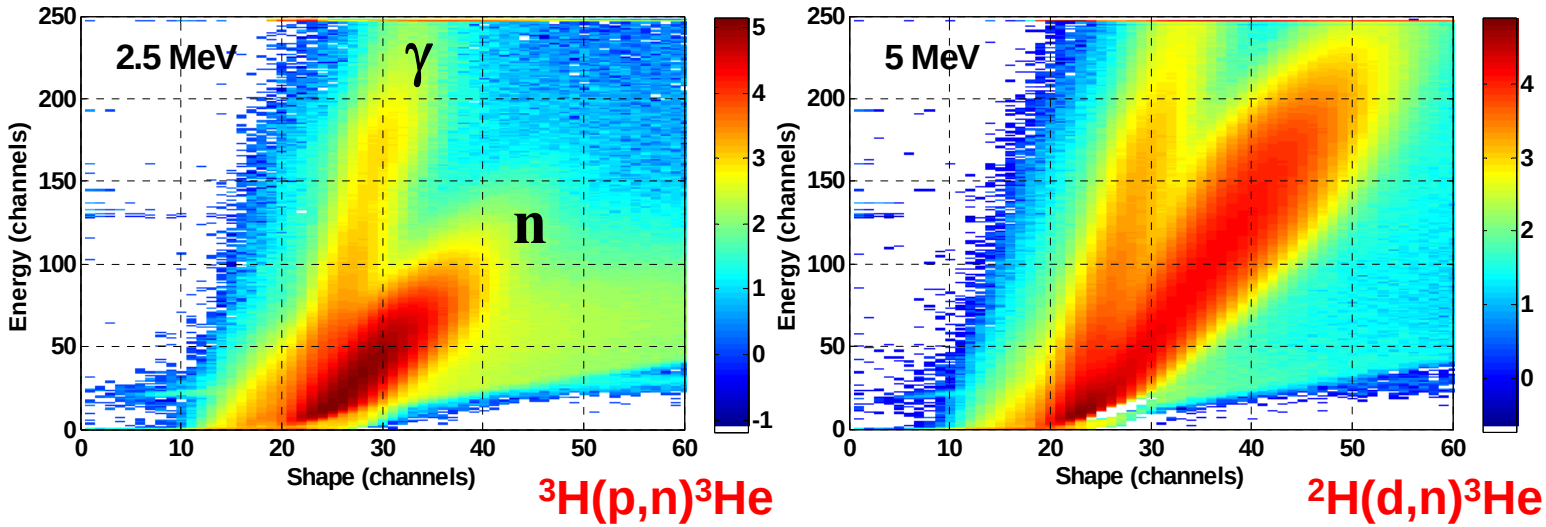
CHENSS Calibration at PTB

CHENSS Calibration at PTB

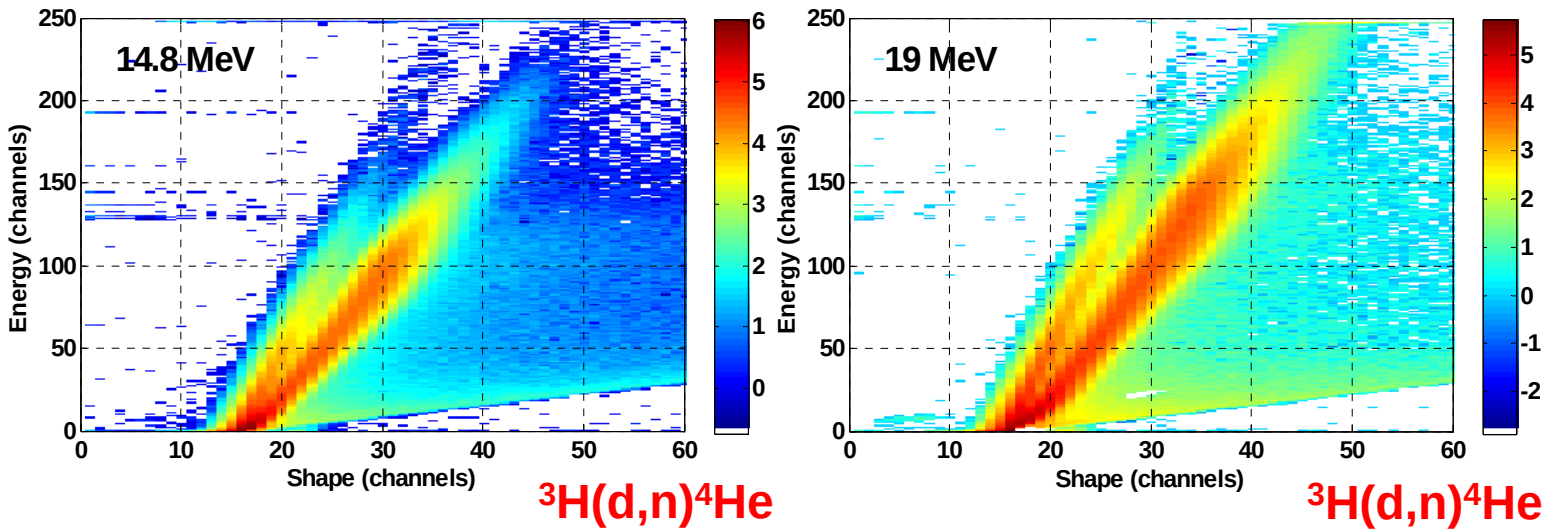
- CHENSS irradiated by 2.5-, 5-, 14.8- and 19-MeV neutrons
- Shadow-cone and blank-target backgrounds subtracted
- γ-ray events removed using pulse-shape analysis
- Spectra unfolded using (5-inch cylindrical) BC-501A response matrix*
- Fluence compared to independent PTB measurements

*N. Nakao et. al., Nucl. Instrum. Meth. Phys. Res. Sect. A 362, 454 (1995)

PTB Irradiation Spectra

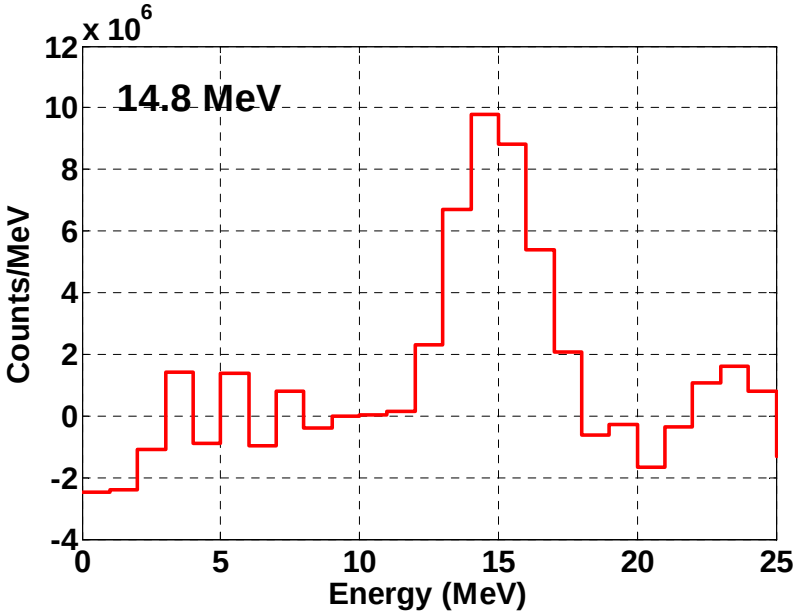


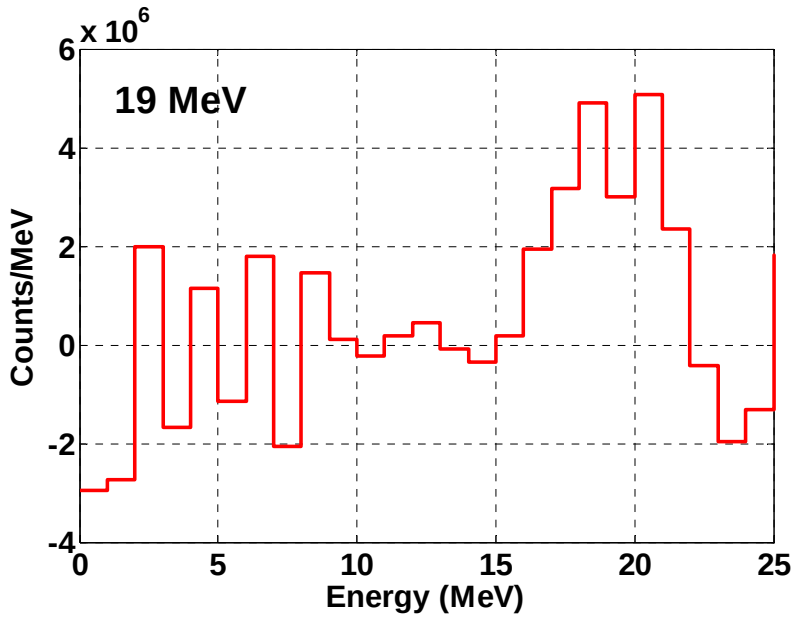
$^{3}H(p,n)^{3}He$ $^{2}H(d,n)^{3}He$



$^{3}H(d,n)^{4}He$ $^{3}H(d,n)^{4}He$

Spectral Unfolding and Fluence Analysis





Neutron energy (MeV)	Φ_{PTB} (10^5 neutrons/cm^2)	Φ_{CHENSS} (10^5 neutrons/cm^2)
2.5	3.3(3)	2.0(4)
5.0	2.2(2)	1.9(4)
14.8	2.2(3)	2.2(2)
19.0	1.4(2)	1.3(2)

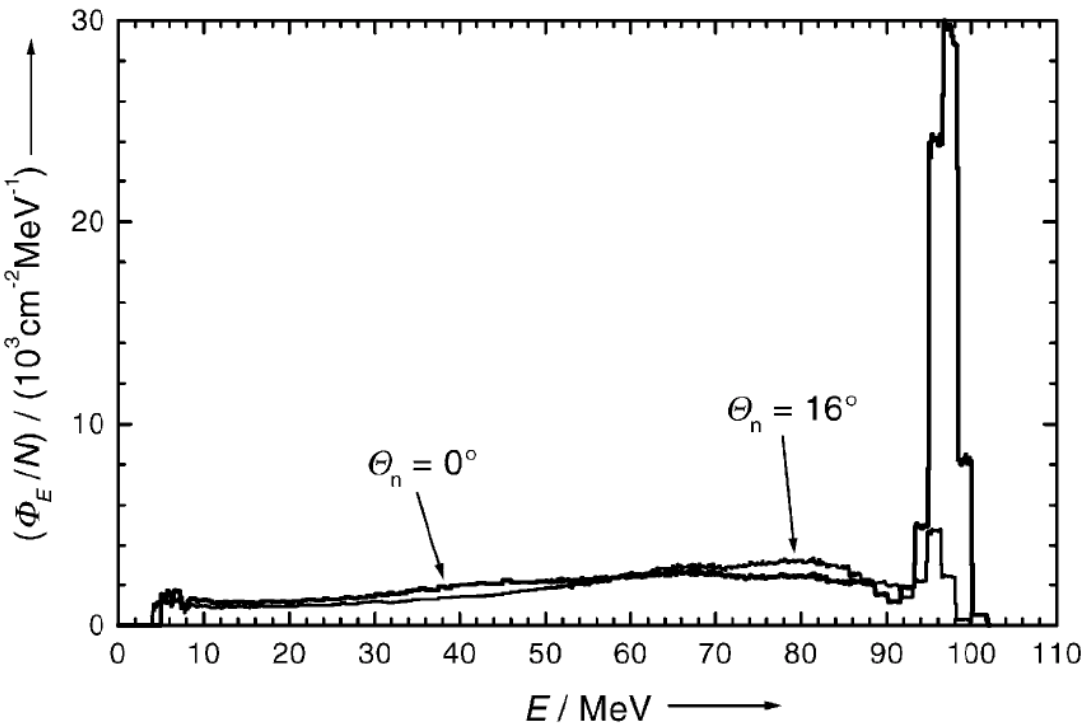
PTB and CHENSS fluences normalized to CHENSS live-time

CHENSS Calibration at iThemba

- Higher-energy tests conducted at iThemba Laboratory Facility (June 14-25, 2007)
  - 100 and 200 MeV p(^{7}Li,n)^{7}Be and p(^{7}Li,n)^{7}Be* quasi-monoenergetic neutron reference beams

iThemba Fluence Measurements

- Time-of-flight measurements for 100 MeV protons incident on ^{7}Li target at 0 and 16 degrees
  - Neutron continuum shapes are similar at 0 and 16 degrees
    - Background continuum can be subtracted off ⇒ quasi-monoenergetic neutron fluence

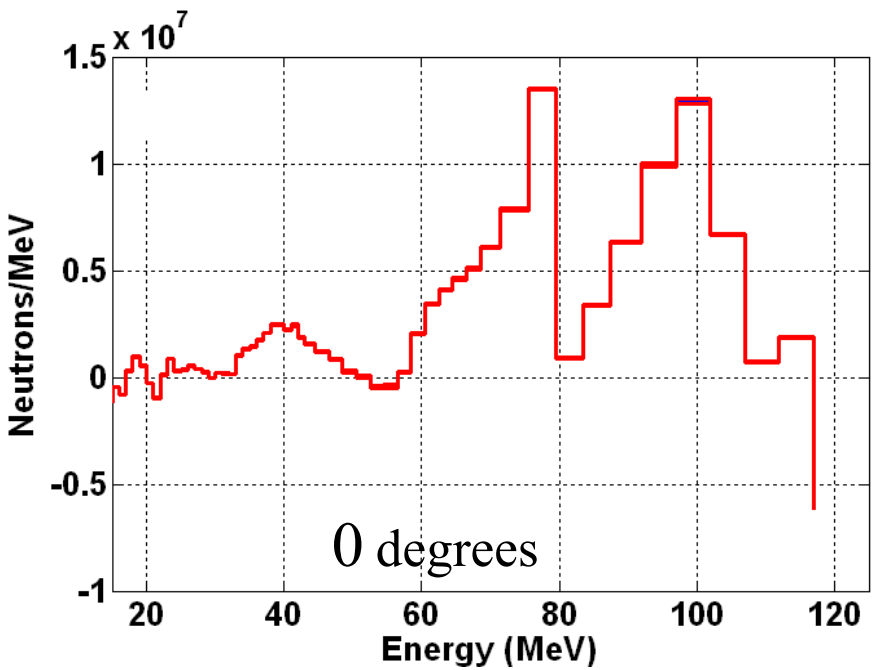


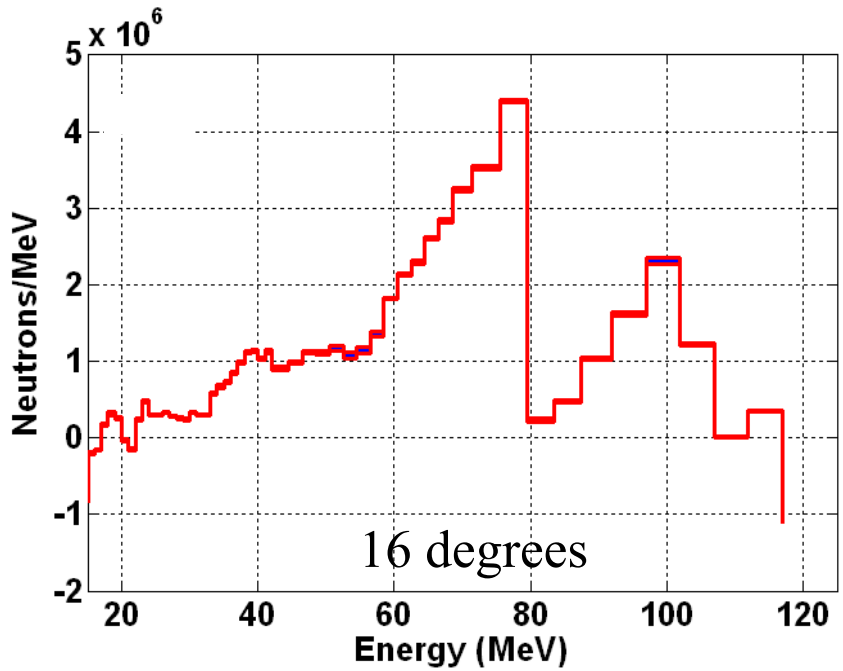
iThemba Fluence Measurements

- Experimental data provided by PTB
  - ^{238}U fission chambers measure neutron fluence at 0° degrees and scintillation spectrometer measures fluence at 16° (spectral tail correction)
  - Bonner sphere spectrometer for fluence measurement below fission chamber threshold (few MeV)

Preliminary iThemba Results

- 100 MeV data unfolded from CHENSS
  - Peak observed at ~97 MeV (as expected)
- Quantitative fluence verification (in progress)
  - PTB measurements and Monte Carlo simulations





Aircraft Measurements

- Neutron measurements in aircraft performed by RMC
- New RF enclosure for the CHENSS designed and built
- Several hours of data collected at altitudes up to 38,000 feet
- Data analysis in progress

Aircraft Measurements

CC 150 Polaris of 437 Transport Squadron

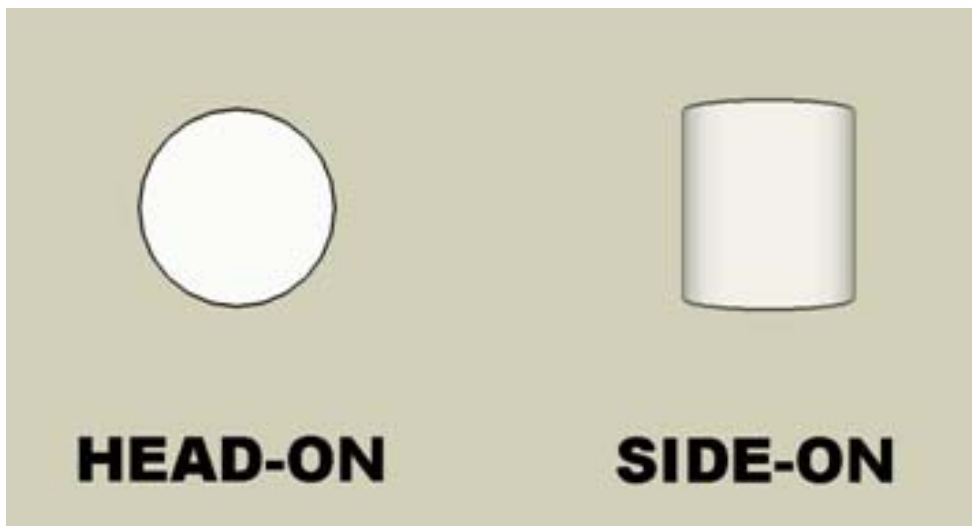
photo credit: Bryce Bennett

CHENSS in the cargo hold of CC15004

photo credit: Bryce Bennett

Second iThemba Measurement

- iThemba Labs calibration experiments (August 21-28, 2009)
- 66 and 100 MeV neutron beams
- Two different orientations of the CHENSS
  - Head on and side on
  - Aim is to understand possible differences in the response function with orientation
- Analysis in progress



Conclusions

- CHENSS can be used for high-energy neutron spectral measurement
  - Calibration at accelerator facilities
    - Excellent agreement with fluence data of PTB (2.5 to 19 MeV)
    - Unfolded spectra for 100 MeV data at 0 and 16 degrees shows quasi-monoenergetic neutron peaks (at expected neutron energies of 96.7 and 95.6 MeV with continuum neutron distribution)
    - Data analysis continuing:
      - o Fluence measurements from PTB
      - o GEANT version 3.21 Monte Carlo simulations of CHENSS response function (matrix elements from Nakao et al. derived for head-on configuration vs front face irradiation at iThemba)

Future Plans

- Recent iThemba data completes ground-based data collection
- Re-design of the CHENSS is being discussed with the CSA and NASA
- Aim is to reduce size and weight, so that CHENSS could become a permanent monitoring device on the ISS

Acknowledgements

- Funding support from the Life and Physical Sciences Directorate of the Canadian Space Agency (CSA)
- H.R. Andrews, E.T.H. Clifford, V.T. Koslowsky, R. Noulty, M. Zhang (BTI), M. Boudreau (RMC)