



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

K. Garrow¹, B.J. Lewis², L.G.I. Bennett², M.B. Smith,¹ H. Ing,¹
R. Nolte,³ S. Röttger,³ R. Smit⁴ and L. Tomi⁵

¹Bubble Technology Industries, Canada

²Royal Military College of Canada, Canada

³Physikalisch Technische Bundesanstalt, Germany

⁴iThemba LABS, South Africa

⁵Canadian Space Agency, Canada

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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**



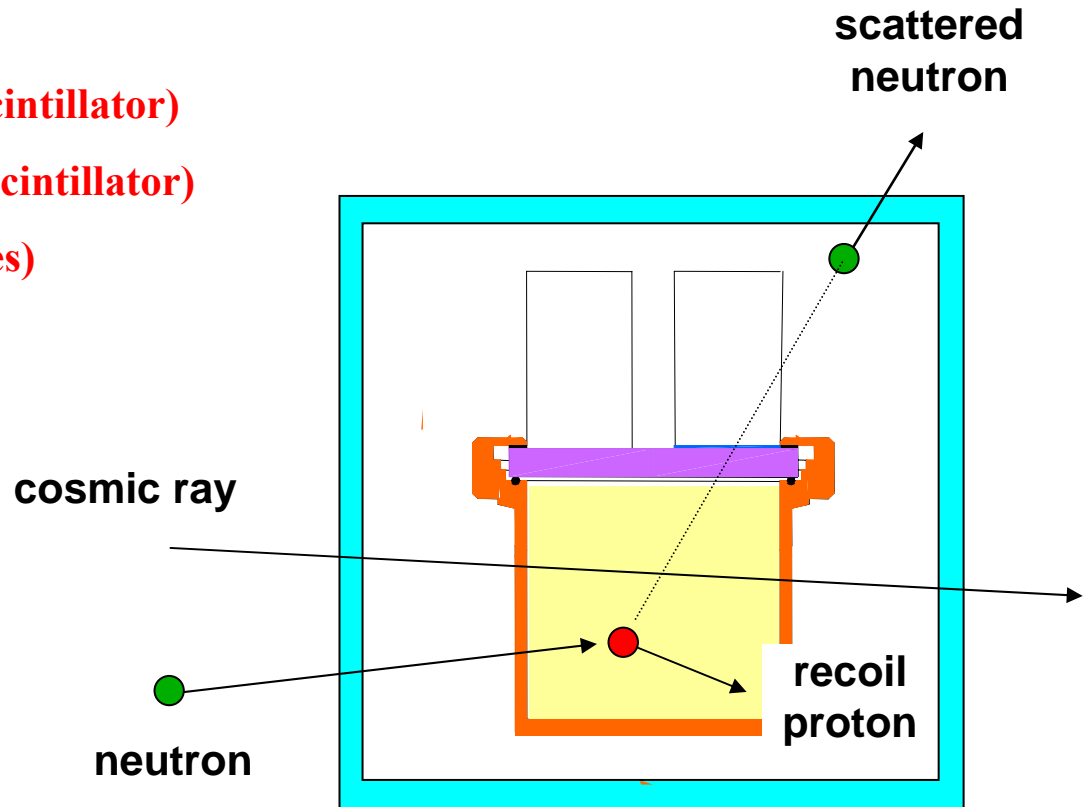
CHENSS: principle of operation

Types of space radiation

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

Visco-elastic scintillator

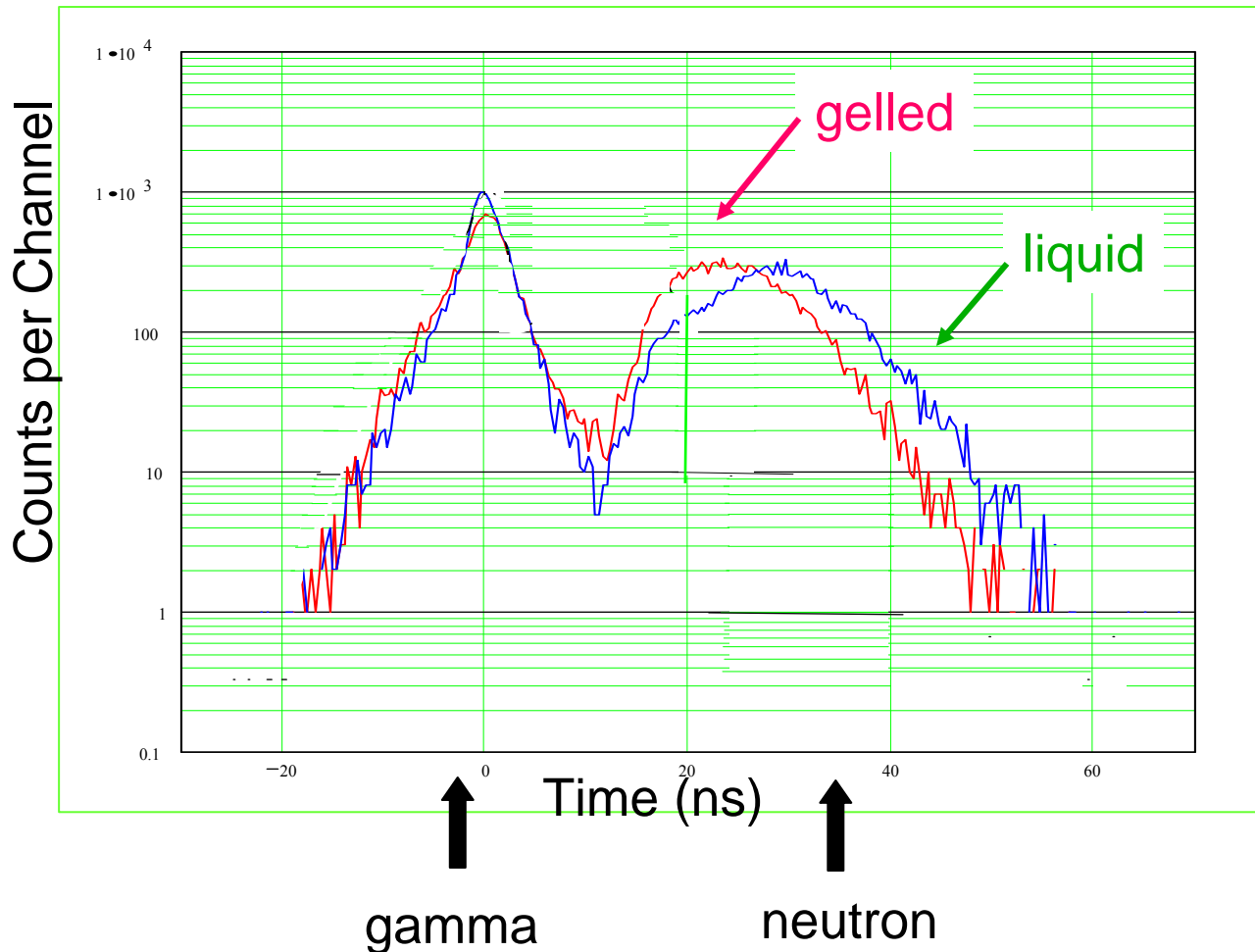
- xylene + naphthalene
- good n- γ discrimination
- isotropic response
- reliable cross-sections





Performance of Gelled Xylene Scintillator

Neutron – Gamma Discrimination

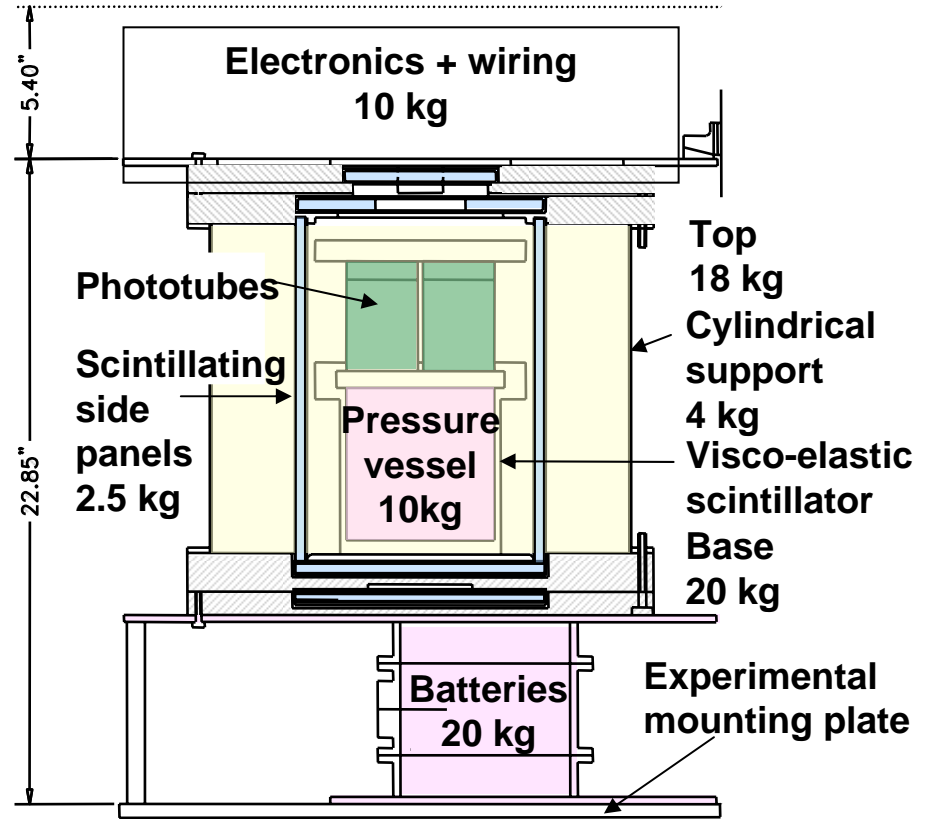


**Light output
~ 75% NE-213
liquid scintillator**

**Gelled scintillator
becomes opaque
below -10°C**



CHENSS Design



Total weight = 84.5 kg = 185 lbs



CHENSS Calibration at PTB





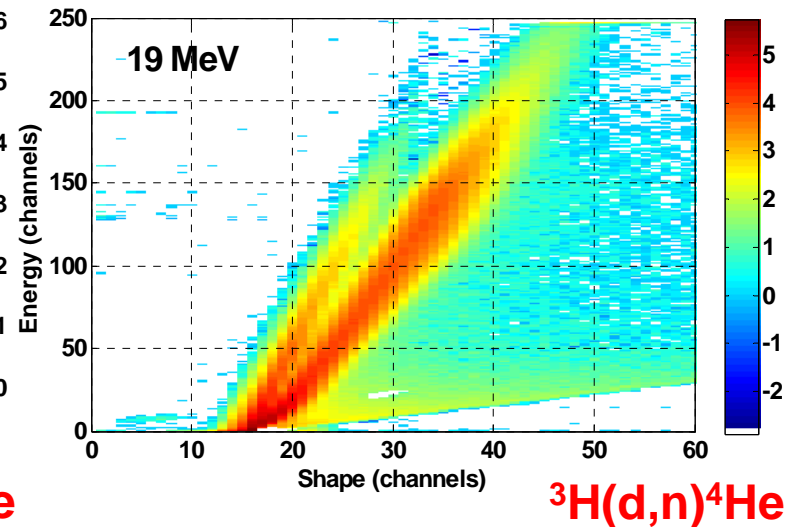
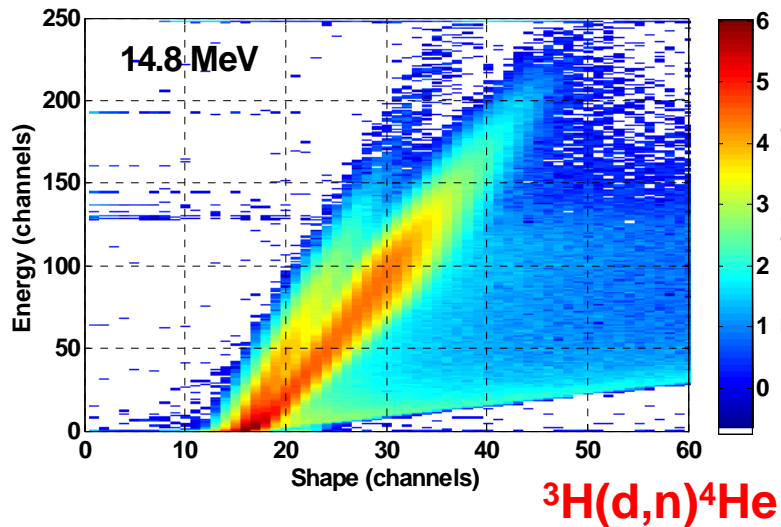
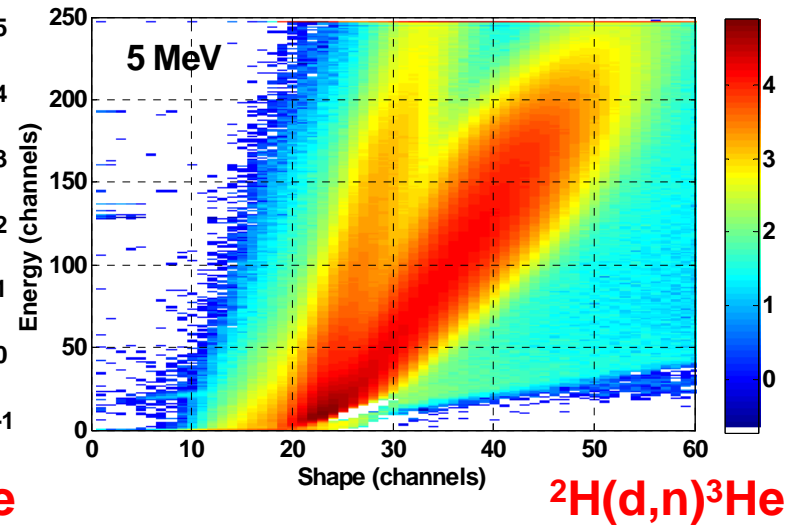
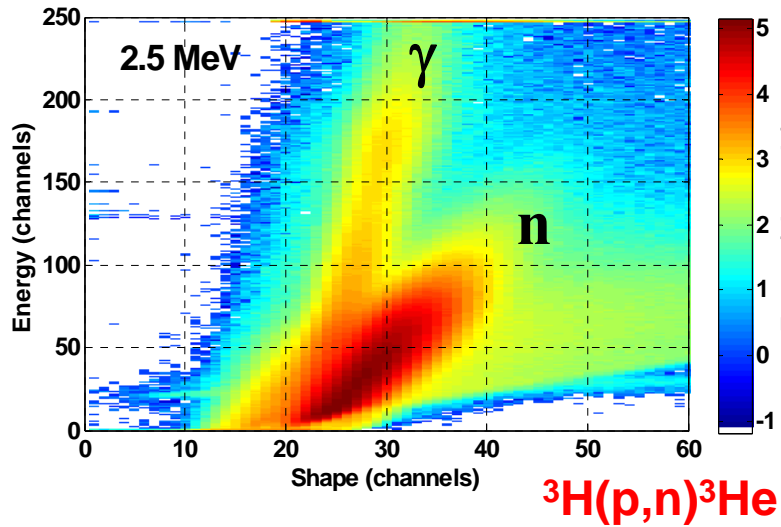
CHENSS Calibration at PTB

- 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)

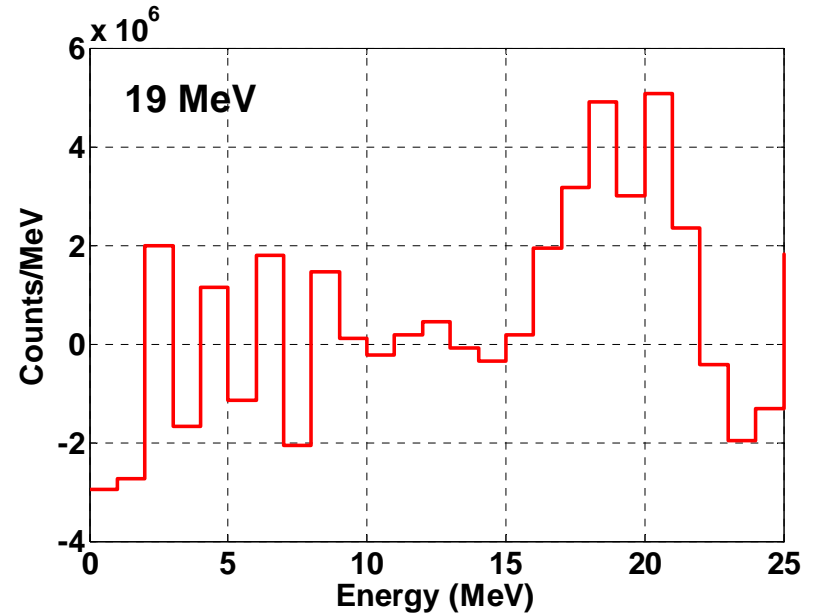
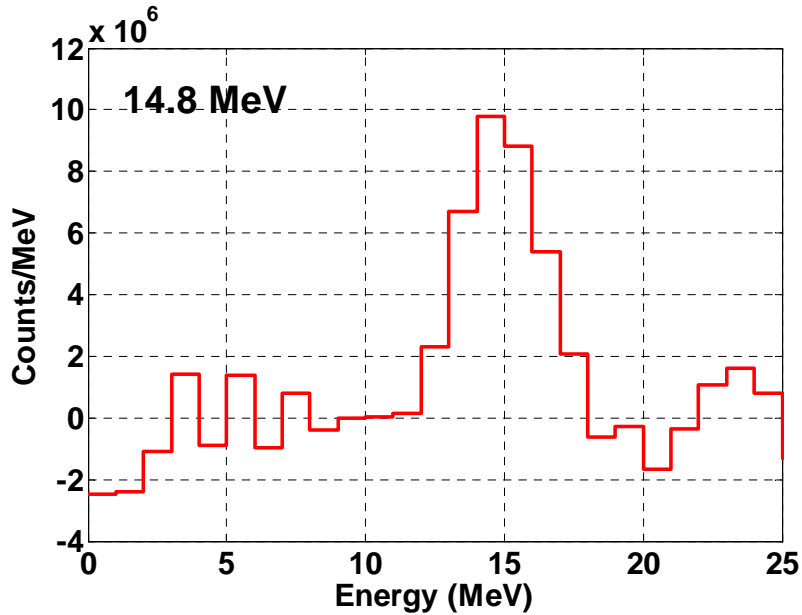


PTB Irradiation Spectra





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

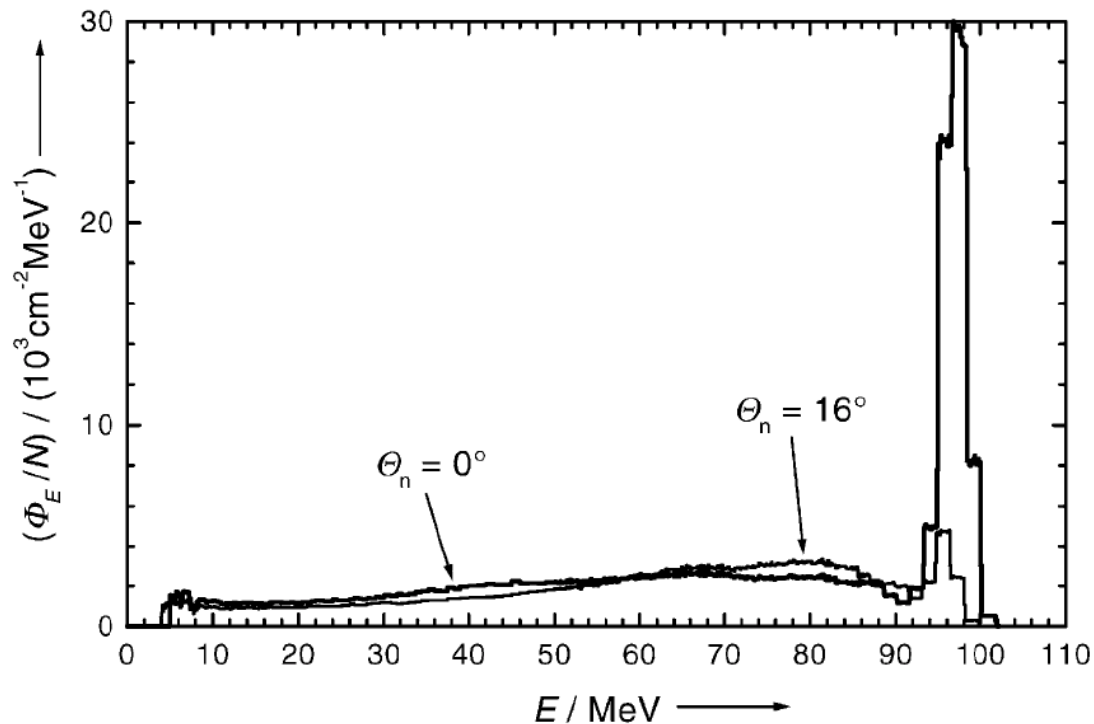
- Higher-energy tests conducted at iThemba Laboratory Facility (June 14-25, 2007)
 - 100 and 200 MeV $p(^7\text{Li},n)^7\text{Be}$ and $p(^7\text{Li},n)^7\text{Be}^*$ quasi-monoenergetic neutron reference beams





iThemba Fluence Measurements

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





iThemba Fluence Measurements

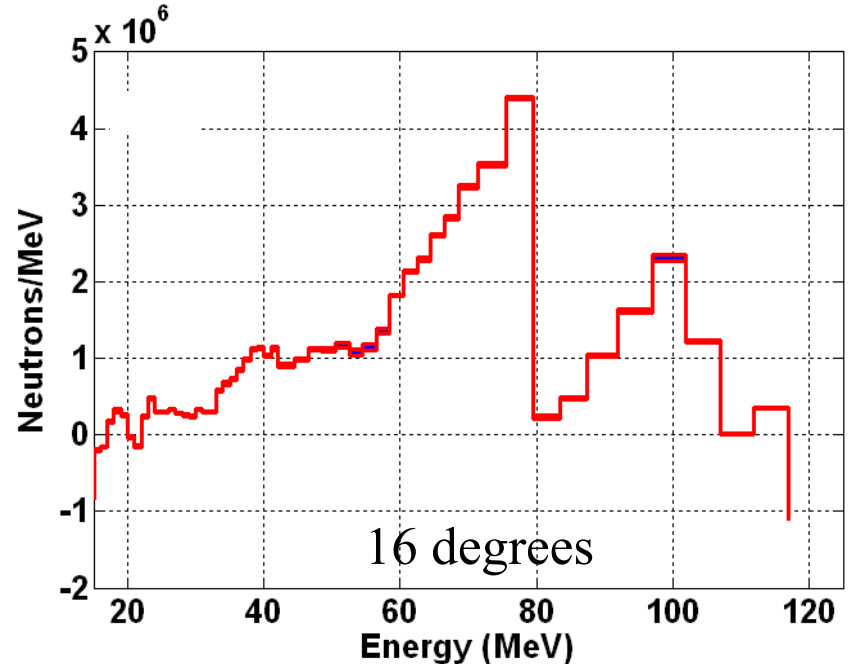
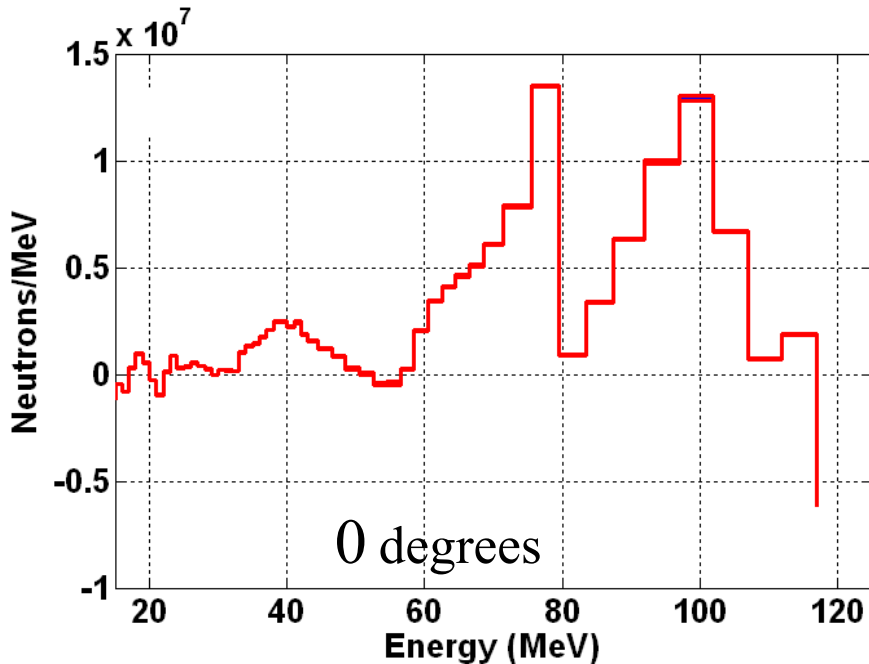
- Experimental data provided by PTB
 - ^{238}U fission chambers measure neutron fluence at 0° degrees and scintillation spectrometer measures fluence at 16° (spectral tail correction)
 - Bonner sphere spectrometer for fluence measurement below fission chamber threshold (few MeV)





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



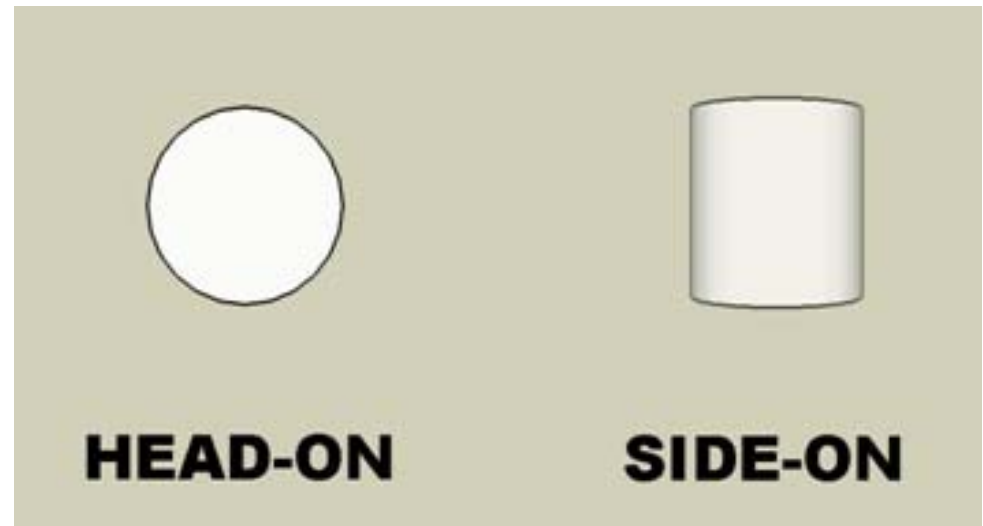
CHENSS in the cargo hold of CC15004

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



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