Bubble Detector Characterization for Space Radiation

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Outline

- Introduction
  - Space Dosimetry
- Ground-Based Accelerator Study

Space Radiation Monitoring*

EV-CPDS: ***Extra-Vehicular Charged Particle Spectrometer***

IV-CPDS: ***Intra-Vehicular Charged Particle Spectrometer***

TEPC: ***Tissue Equivalent Proportional Counter***

RAM: ***Radiation Area Monitors*** **(TLDs)**

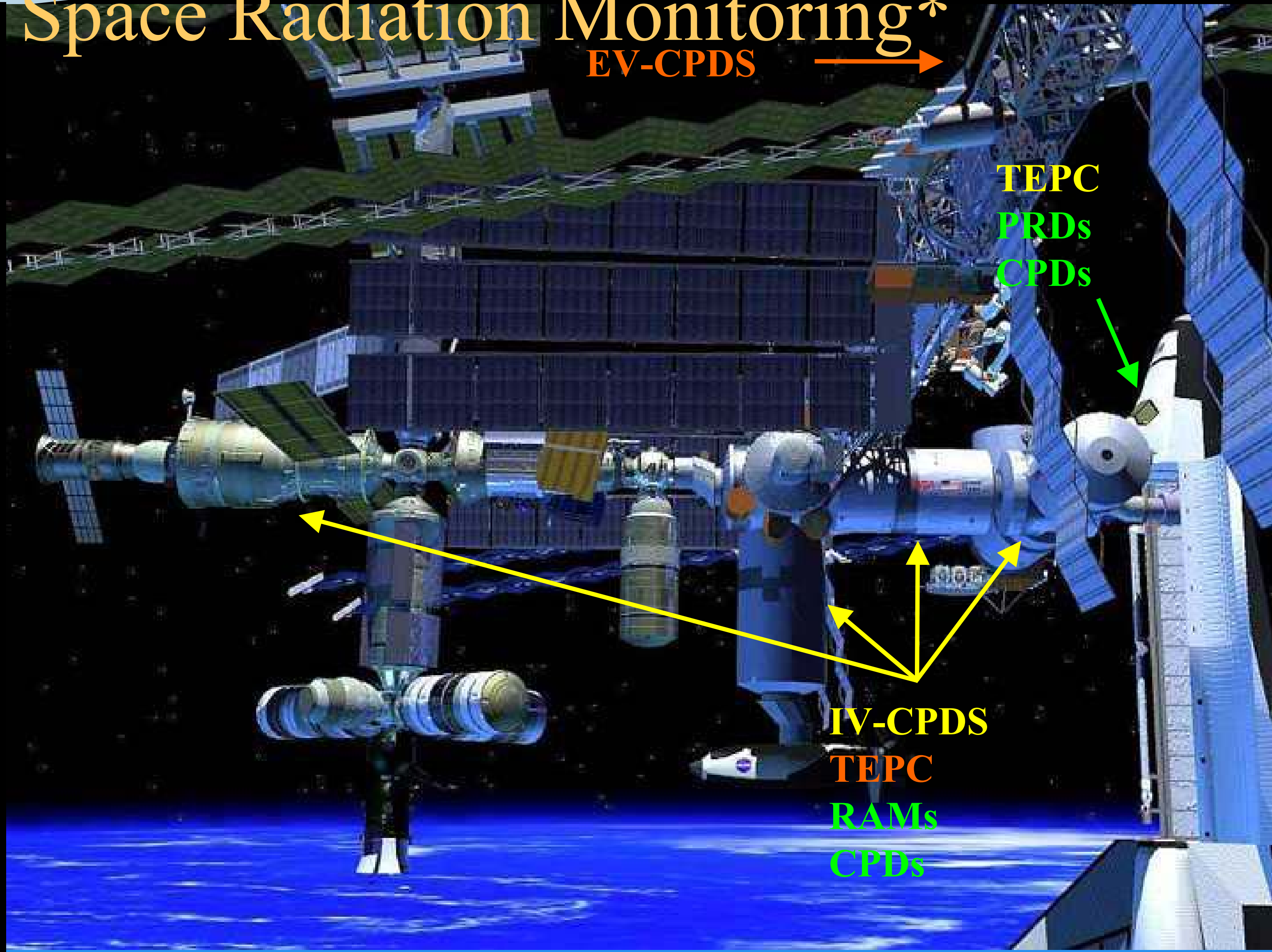
PRD: ***Passive Radiation Dosimeter*** **(TLDs)**

CPD: ***Crew Passive Dosimeter*** **(TLDs, PNTD)**

Active instrument real-time telemetry

Active instrument no real-time telemetry

Passive instrument



* Adapted from: M. Golightly, "Initial Briefing to Astronauts Radiation Exposure During Space Missions, 1998 Astronaut Candidate Class," NASA-JSC, June 10, 1999.

Space Dosimetry and Exposures*

Type	Program	Measurements
Crew Personnel Dosimetry:		
TLD-100	All Programs	Absorbed dose
TLD-300, 600, 700	STS, and ISS	Absorbed dose
CR-39 or other Nuclear plastic track detectors	Apollo, Skylab, STS, STS, Mir	Fluence vs. LET or Z
Fission Foils	Apollo, STS	Neutrons
Area dosimetry:		
TLD-100	STS, Mir, ISS	Absorbed dose
TLD-300, 600, 700	STS, ISS	Absorbed dose
CR-39 or other Nuclear plastic track detectors		Fluence vs. LET or Z
Fission Foils	Apollo, STS	Neutrons
Active Ionization Chambers	Apollo, Skylab	Absorbed dose
TEPC	STS, Mir, ISS	Lineal energy, dose, dose equivalent
Z,E Telescope	Mir, STS, ISS	Fluence vs. Z and E
Bonner Spheres	STS, ISS	Neutrons
Bubble detectors	STS	Neutrons?

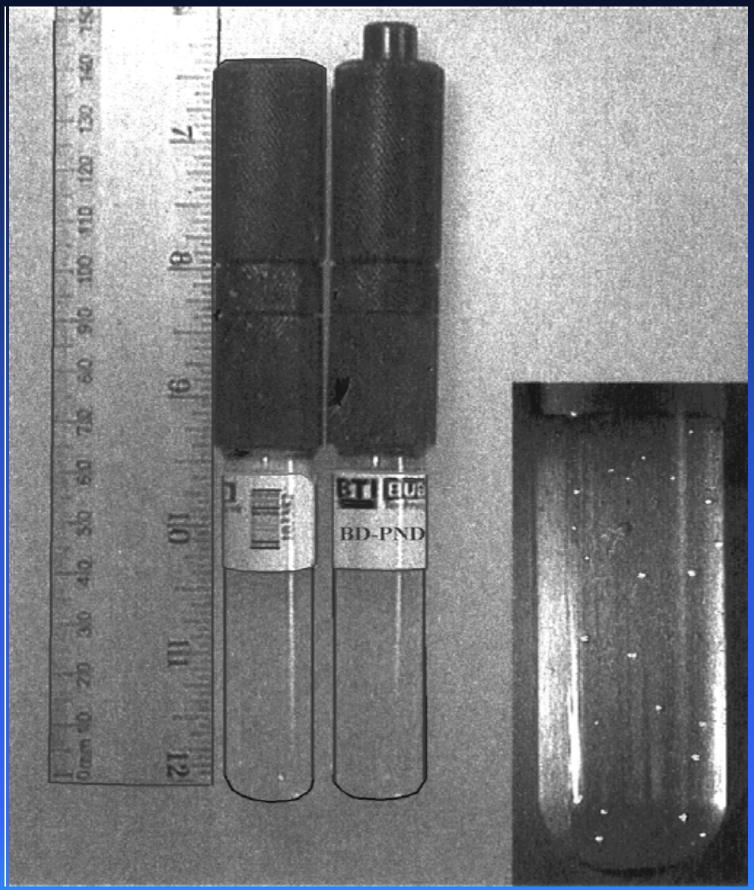
- 150 – 200 μGy/d (currently @ solar max) (~2 x greater during solar min)
- ~ 60 mSv for 140 days (CNSC terrestrial limits are 20 mSv/y)

*Adapted from: F. Cucinotta, “Organ Dose Estimates for Astronauts,” CSA Training with SRAG, NASA-JSC, January 27-31, 2003.

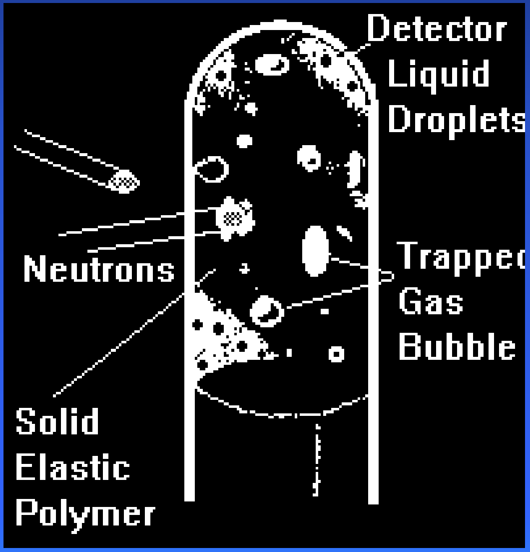
Experimental

- Equipment Tested
  - Extended Range (“Space Pack”) Bubble Detector Spectrometer (BDS)
    - Normal BDS + high threshold detectors (20 and 100 MeV), Bi Loaded: $^{209}Bi(n,f)$
  - Temperature-Compensated Bubble Detectors (BD-PND)
  - Nuclear Fragmentation Separation Experiment (NFSE)
- Ground-Based Accelerator Measurements
  - CERF (Integral neutron field – simulant space spectrum)
  - HIMAC (180 MeV/u N & 500 MeV/u Ar ions)
  - TRIUMF (81.7 MeV p)

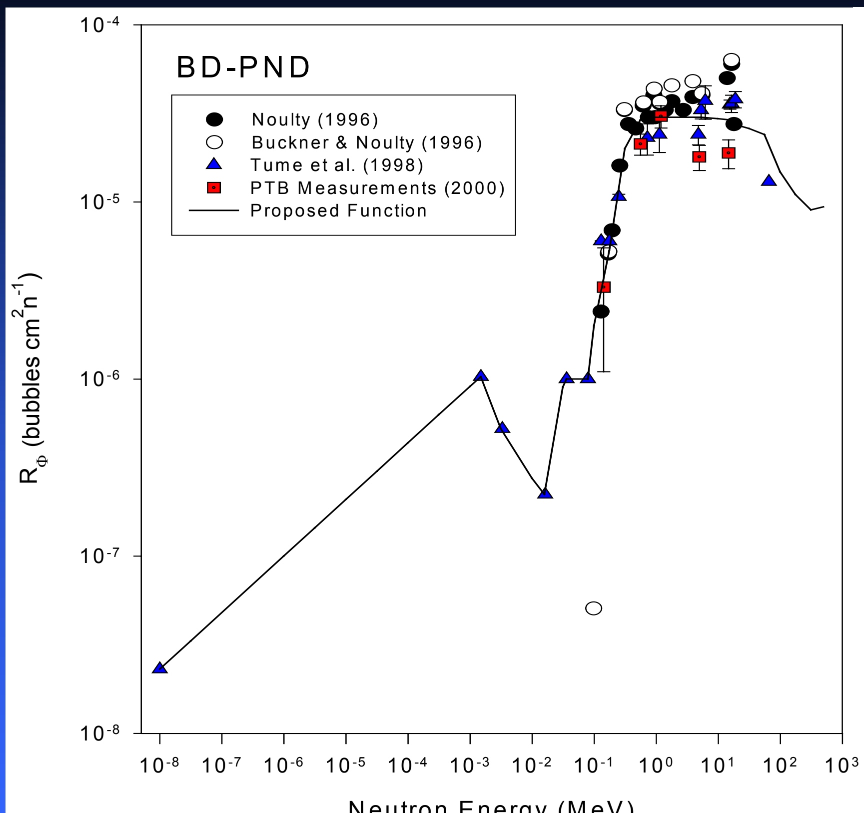
Neutron-Sensitive Bubble Detector

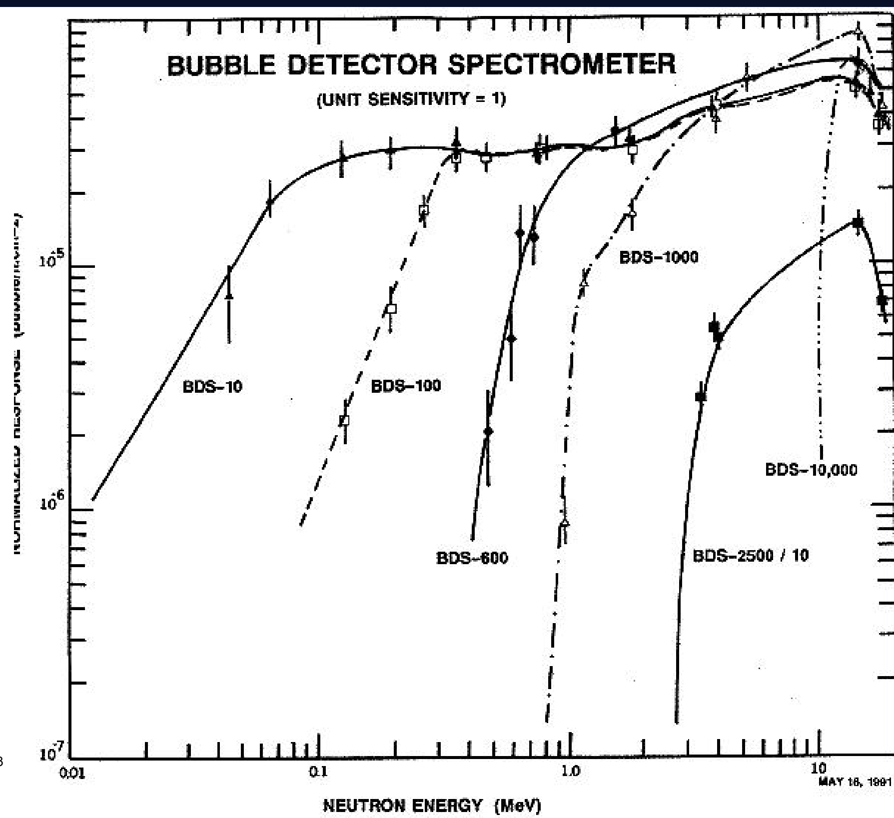


$$\frac{M}{H} = R_H = \frac{\int R_\phi \phi_E dE}{\int h_\phi \phi_E dE}$$

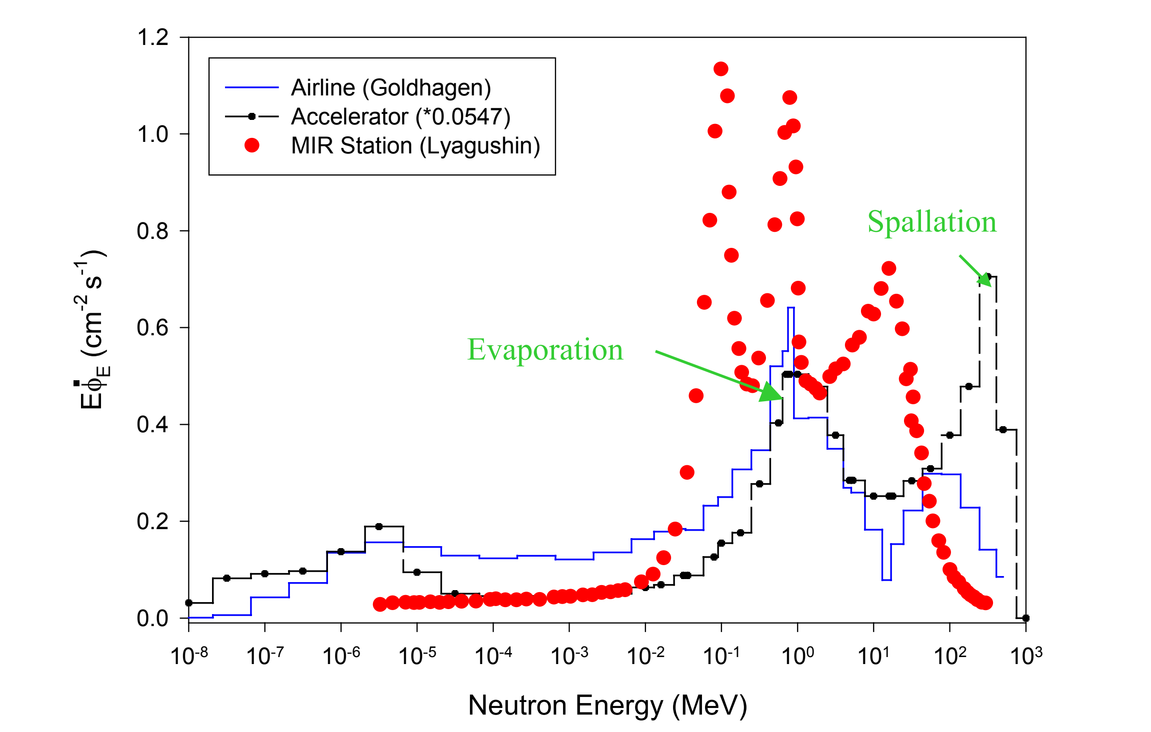


Response-to-Fluence Functions R_ϕ for BD-PND and BDS





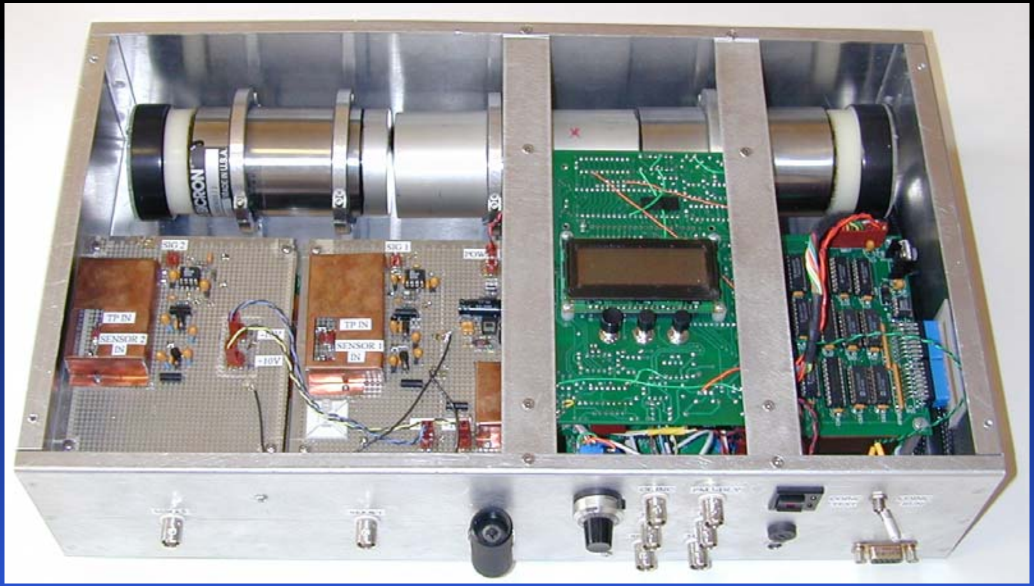
Neutron Spectra ϕ



- Airline and Accelerator Shielding: Multisphere spectrometer
- MIR: nuclear photoemulsion, fission foils, recoil protons in organic scintillator and reaction products from CsI(Tl) scintillation crystal

Ground-Based Calibration at CERF

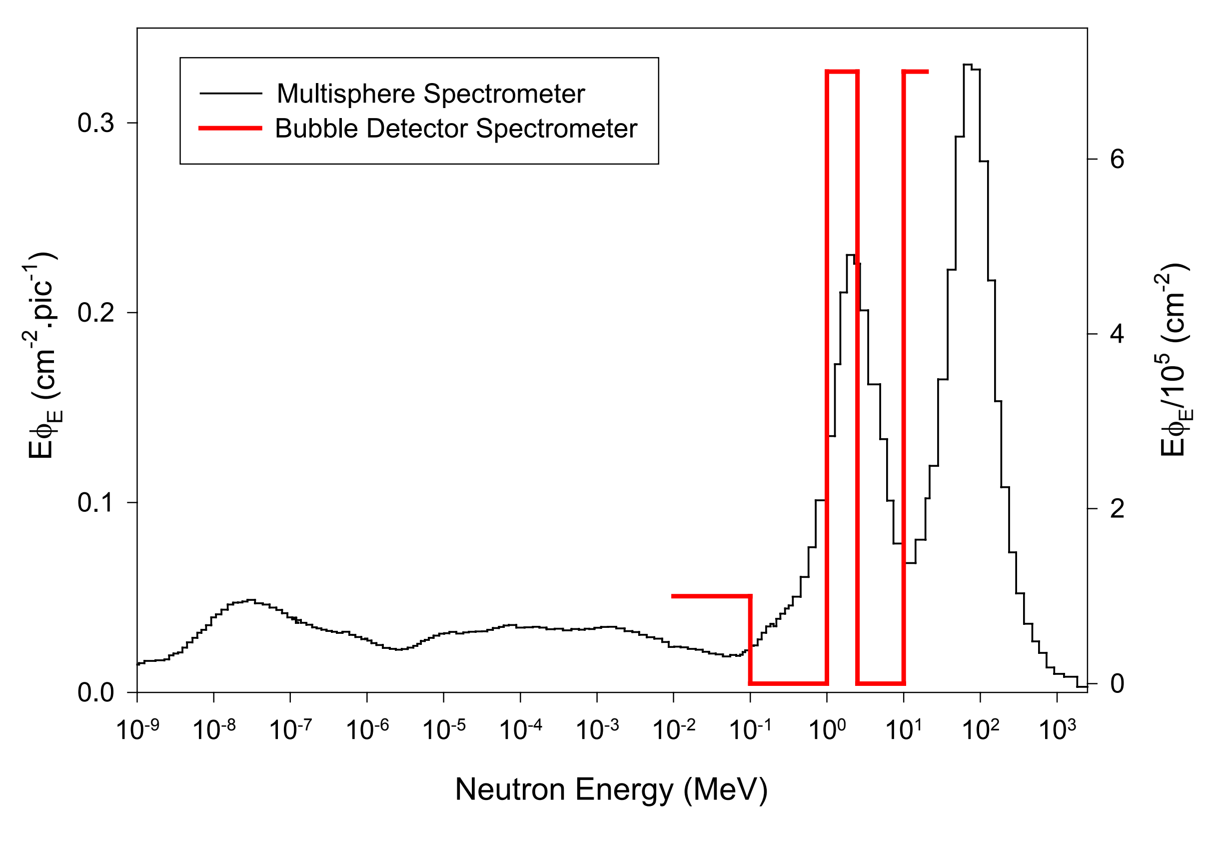
Nuclear Fragmentation Separation Experiment (NFSE)



- Charged particle signature accompanies ~ 10% of events registered in BD
  - Agreement with FLUKA: charged hadron (p, π) fluence rate one order of magnitude less than neutrons
- BD-PND (260±50 pSv/PIC) vs CERF reference value (265±5 pSv/PIC)
  - Supports BD-PND calibration factor R_H
- NFSE needs space qualification

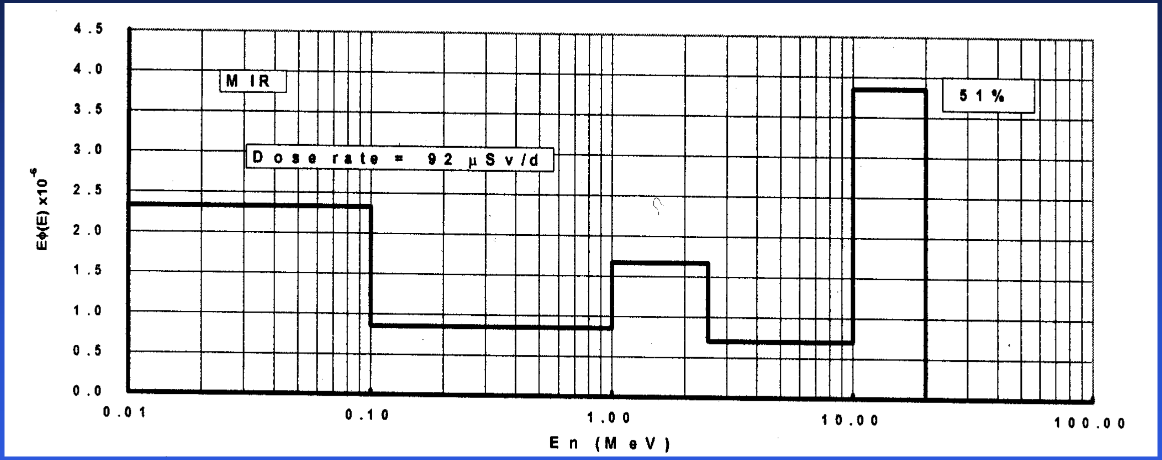
CERF Neutron Spectrum

Comparison of BDS with Multisphere Spectrometer



MIR Neutron Exposure (Nov 92-Jan 93)

- BDS: 150 μSv/d (with CERF calibration factor)



- TLD Measurements (Badhwar)
  - 260 μGy/d x 2.5 (average TEPC quality factor) x 20% (neutron fraction of charged particle dose equivalent) = 130 μSv/d

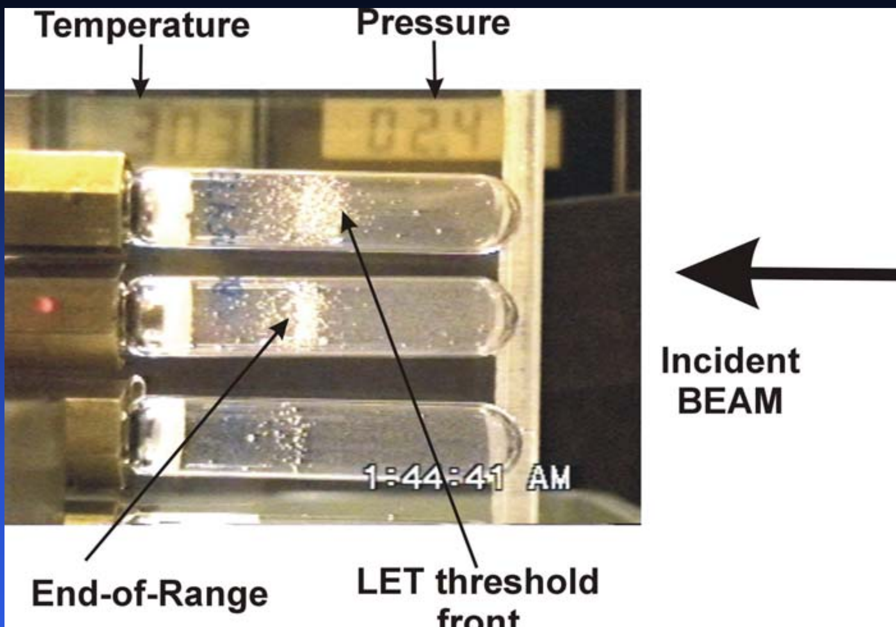
BD Testing at HIMAC (Ar and N ions)

Pressure Control

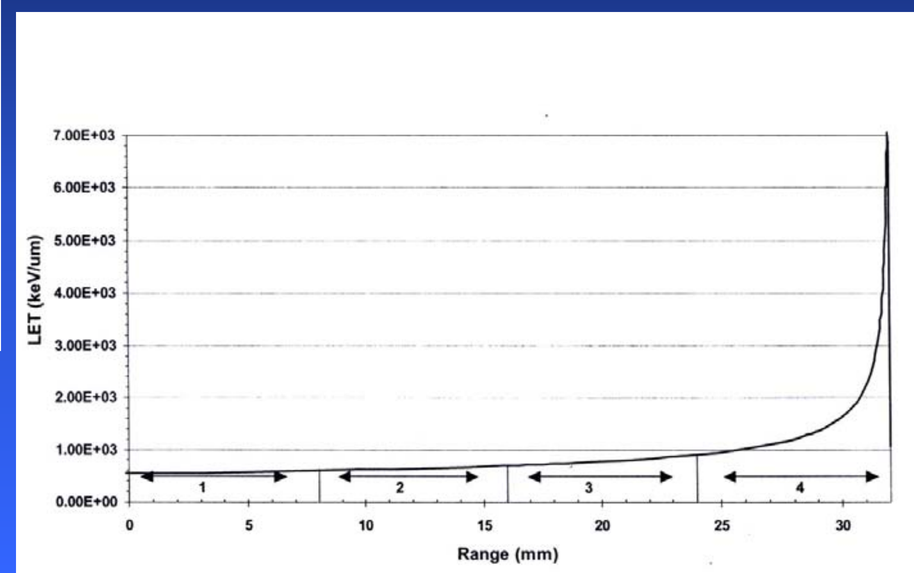
Temp. Control

Bubble Detectors

BD Testing at HIMAC (Ion Beams)

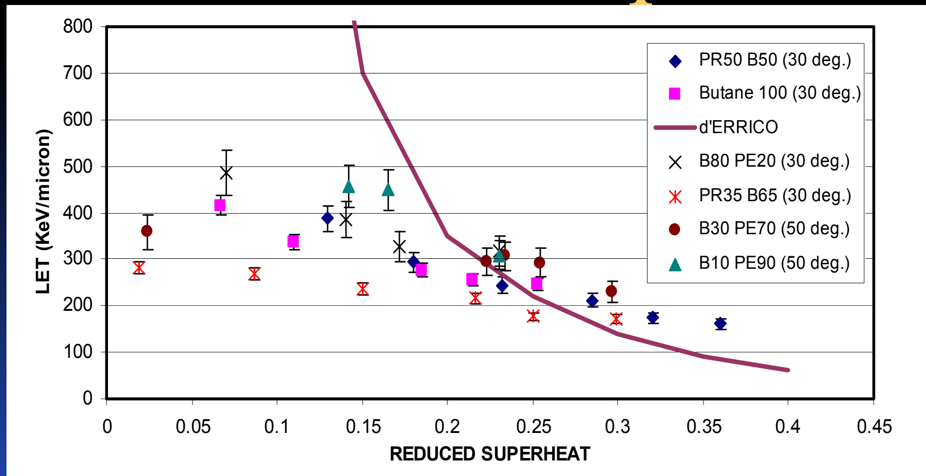


- Response of BD: LET vs S
- Compare with d'Errico theory

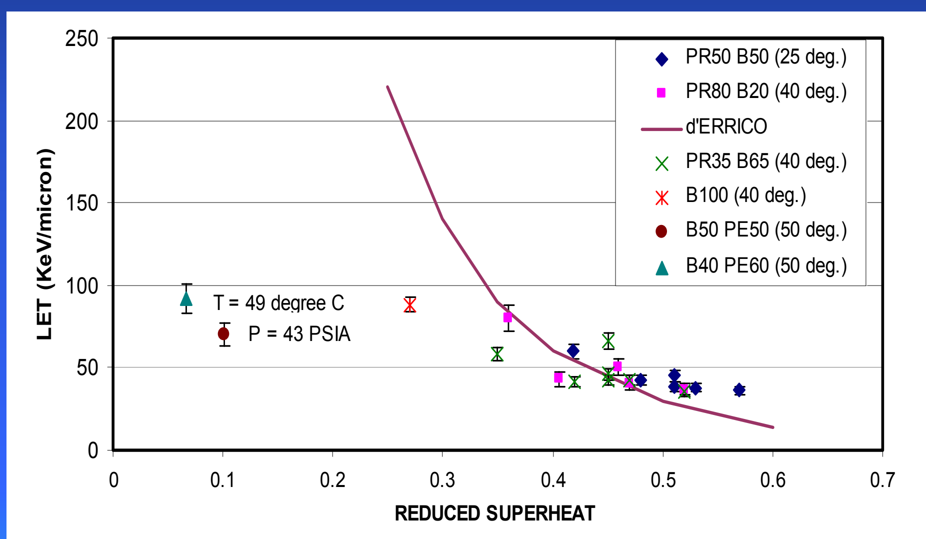


Super Heat: $S = \dfrac{T - T_b}{T_c - T_b}$

BD LET Vs Super Heat Response

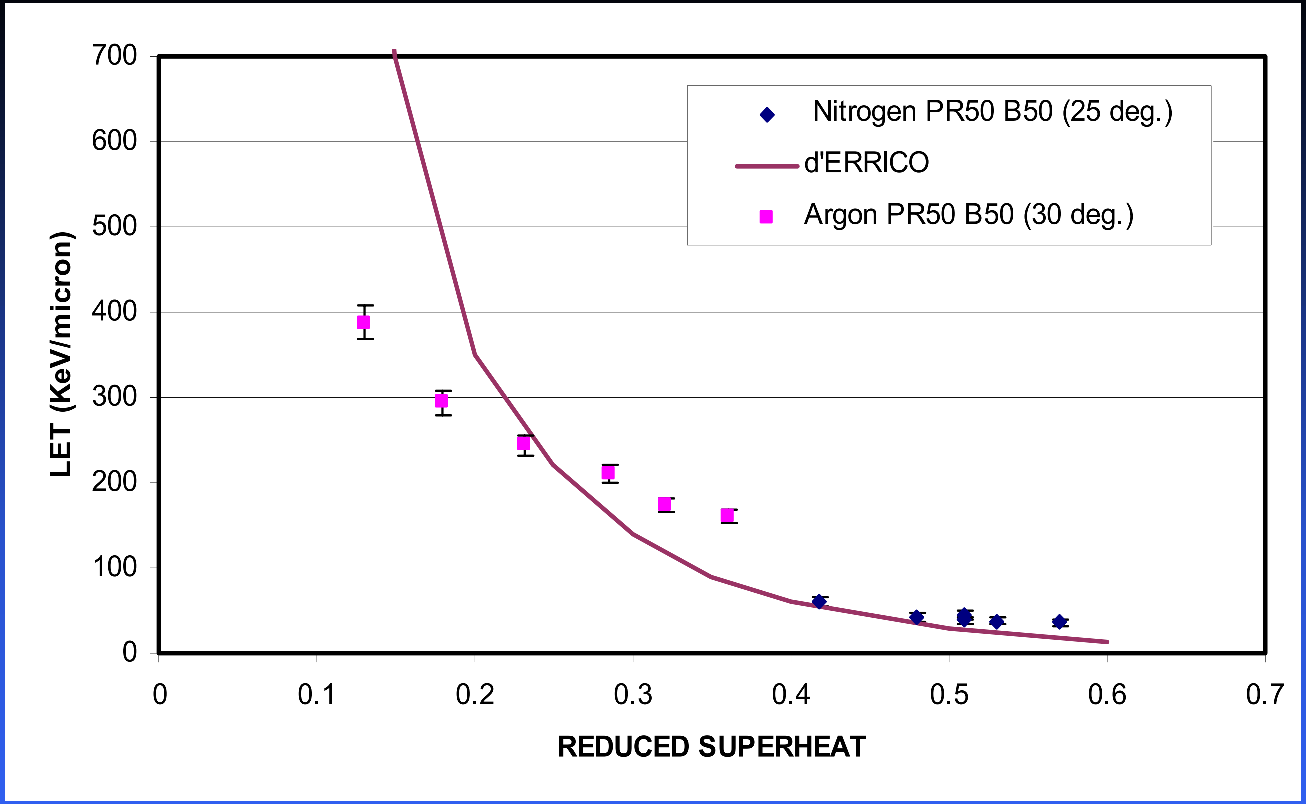


Argon Beam



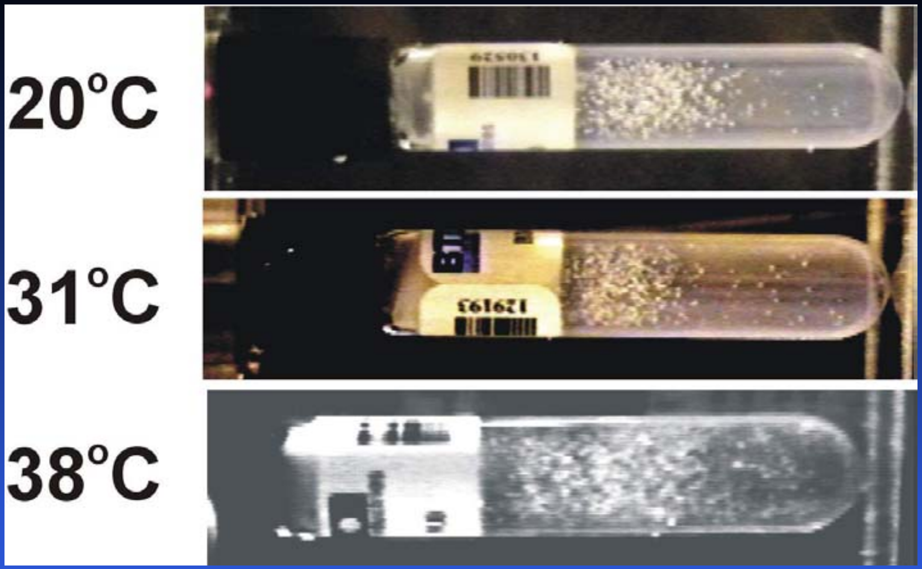
Nitrogen Beam

Comparison Among Nuclei



⇒ Effect of track structure?

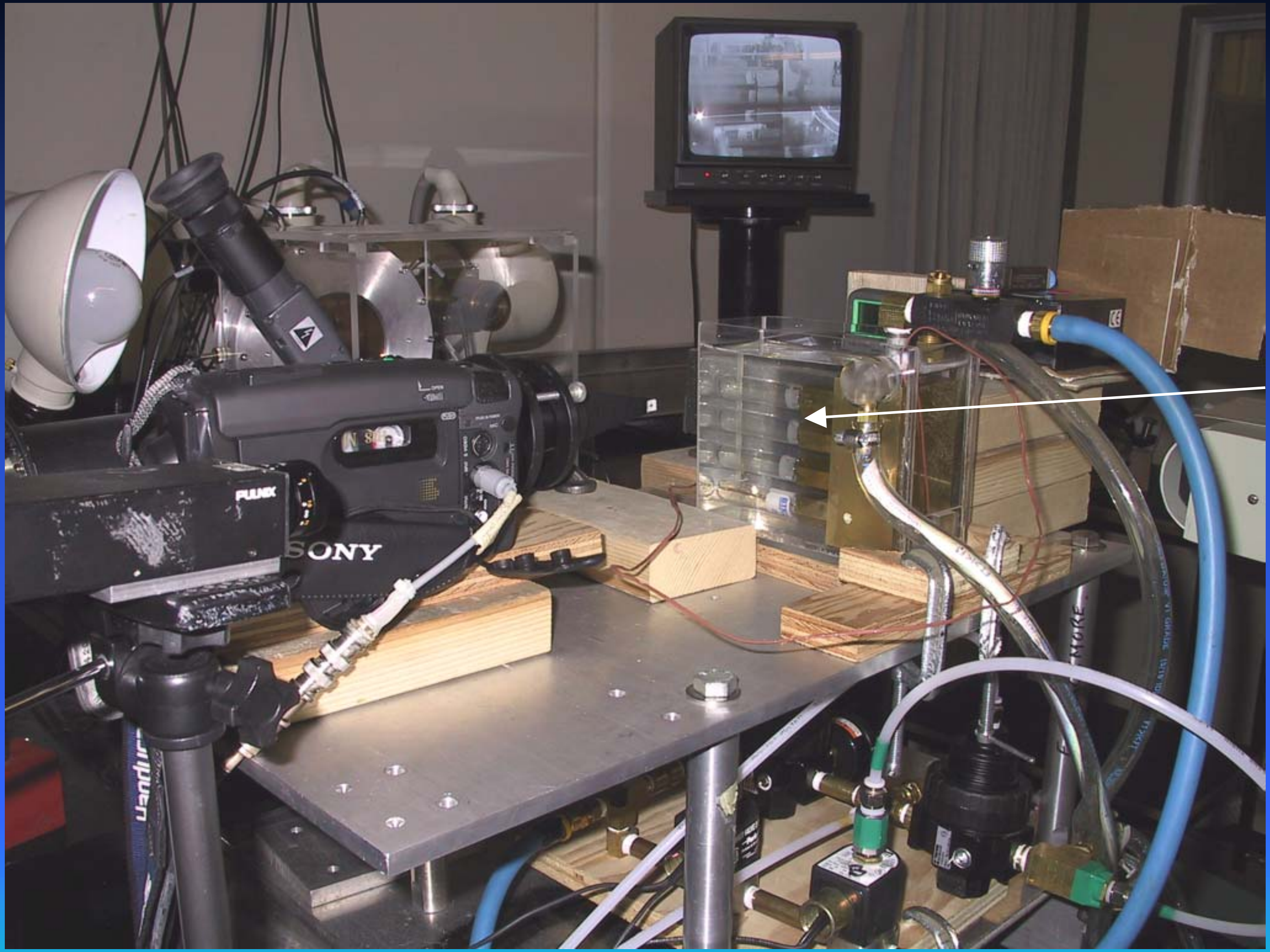
Temperature Compensated BD-PND (S = 0.3)



- BD-PND exposed to Ar beam

- BD-PND show constant response over broad range of temperature
- Response of BD-PND
  - -$LET_{Ar} = 201 \pm 40$ keV/µm
  - -$LET_{N} = 116 \pm 40$ keV/µm

BD Testing at TRIUMF (Protons)



Bubble Detectors

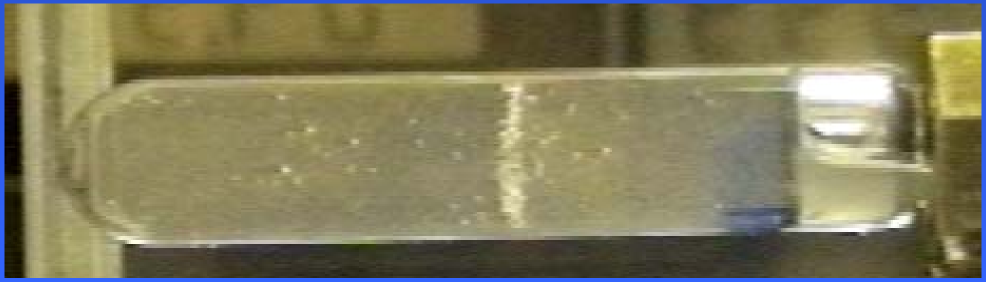
BD Response to Protons

- 81.7 MeV protons
- 90 keV/micron
- Straggling 2 mm

Comparison Among Nuclei

Proton

Nitrogen



Argon

Conclusion

- Better understanding of BD response to charged particles
  - Modulate response of BD to desired LET
  - Super heat alone insufficient to describe LET response (d'Errico curve)
  - BD-PND response constant over wide temperature range
- NFSE successfully tested for charged particle discrimination
- BDS can be used for (high-energy) neutron spectral measurements
  - Further testing required with Bi-loaded detectors

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