TRIUMF and ISIS test facilities

Radiation 2 Electronics (R2E) LHC Activities

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R2E tests at TRIUMF PIF facility

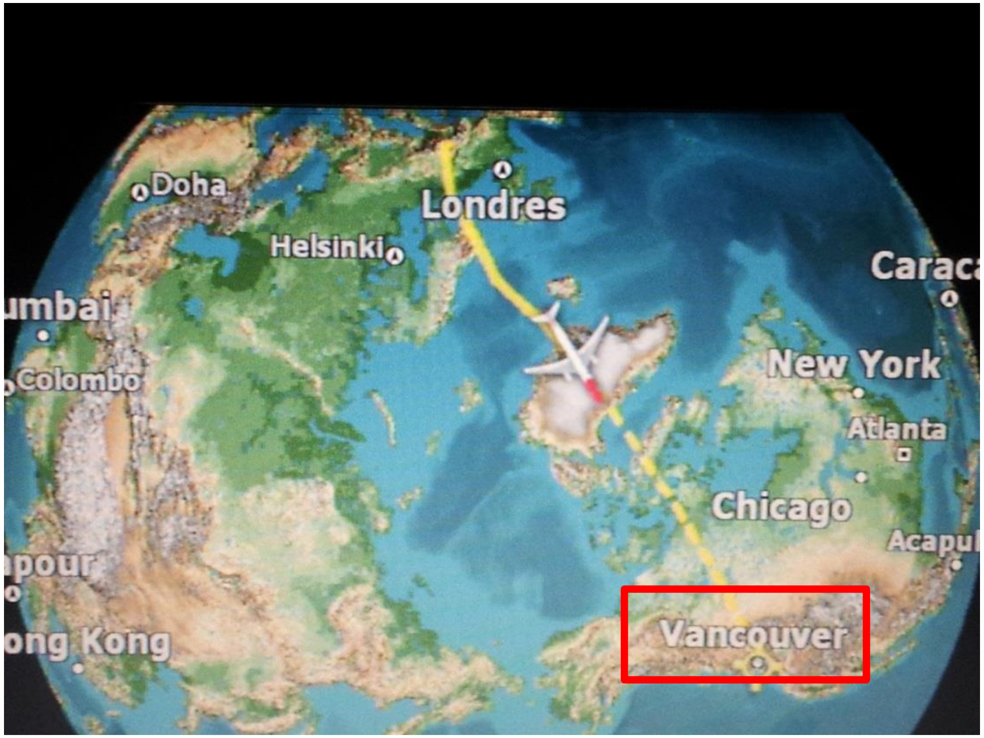
- **Scientific beam time** awarded to the R2E project for the study of the **SEE energy dependency** and impact on accelerator failure rate (**480 MeV** maximum energy, as opposed to 230 MeV at PSI)
- Test performed between Dec 12th and 16th 2013
- 9 different components tested:
  - **SEL test**:
    - ADS2171B (candidate for FGClite and QPS)
    - Commercial SRAM memories (ISSI x2, Samsung, Alliance, Cypress)
  - **SEU test**:
    - ESA SEU Monitor
    - Cypress SRAM (for RadMon v6)
    - Renesas SRAM (FGClite project)
- A big thanks to Mike Trinczek and Ewart Blackmore (huge help in terms of preparation, shipment, set-up, runs, analysis…)

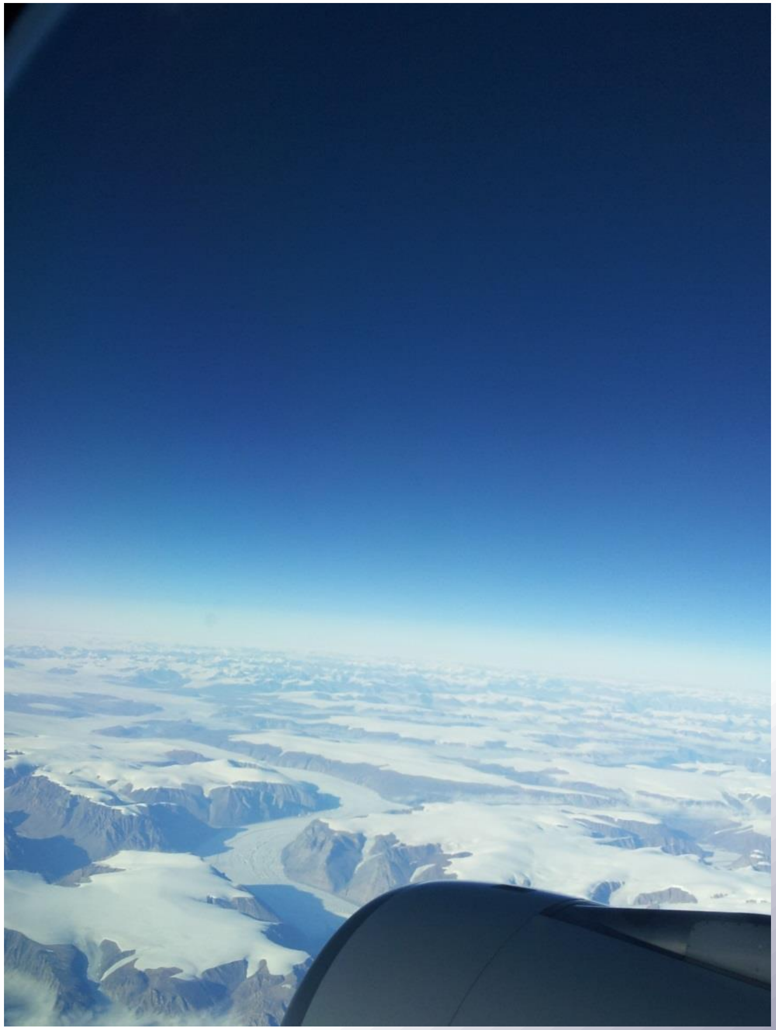
Intense preparation involved

- SRAM SEL and RadMon Cypress (Salvatore Danzeca + EN-STI-ECE)
- ADC and Renesas SRAM setup (Slawosz Uznanski, Karol Motala + TE-EPC-CCE)

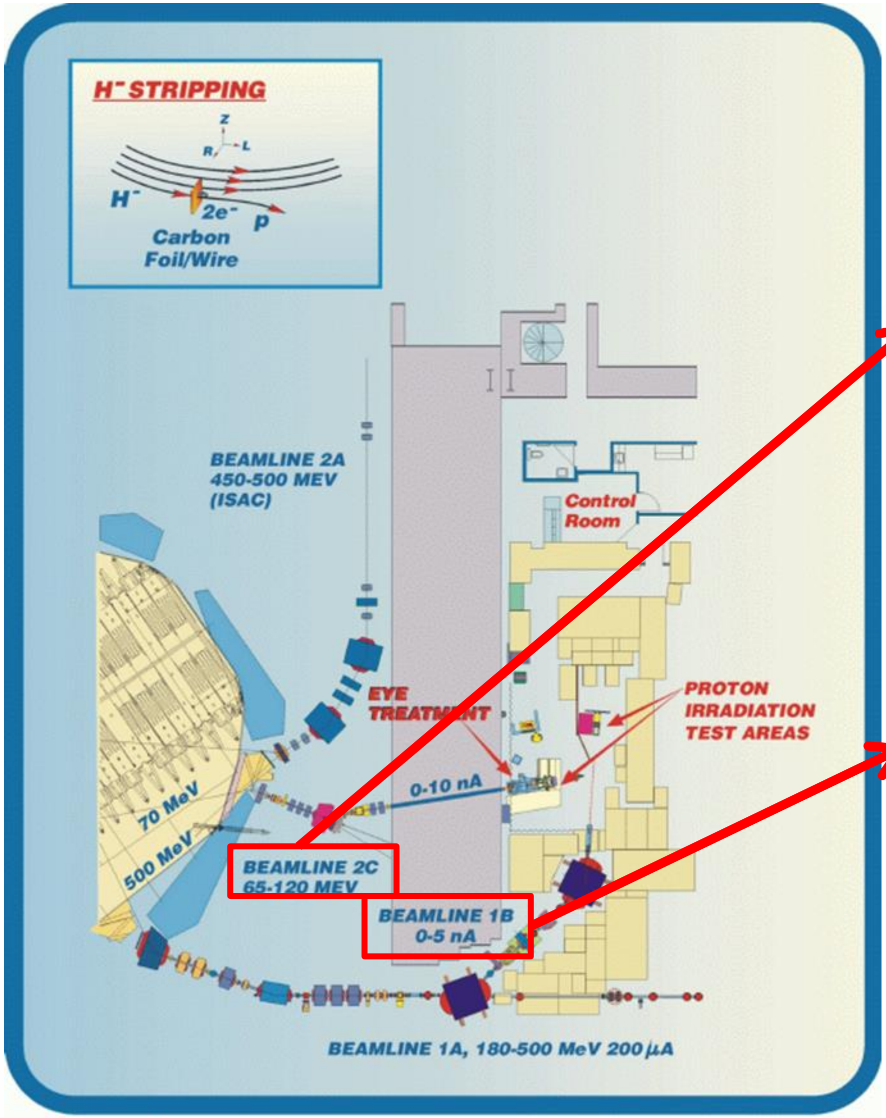
ADS1271B test set up: 4 DUTs per card, 4 cards per set up = 16 DUTs per set up in order to obtain good SEL count statistics (targeting >50 event for each cross section point)

Testing at the other side of the world





TRIUMF PIF beam lines



Layout *of the TRIUMF Cyclotron and proton beam lines*

BL2C Extraction energies:

- 65 to 120 MeV
- 5 to 65 MeV with a degrader *(interesting for direct proton ionization effects)*

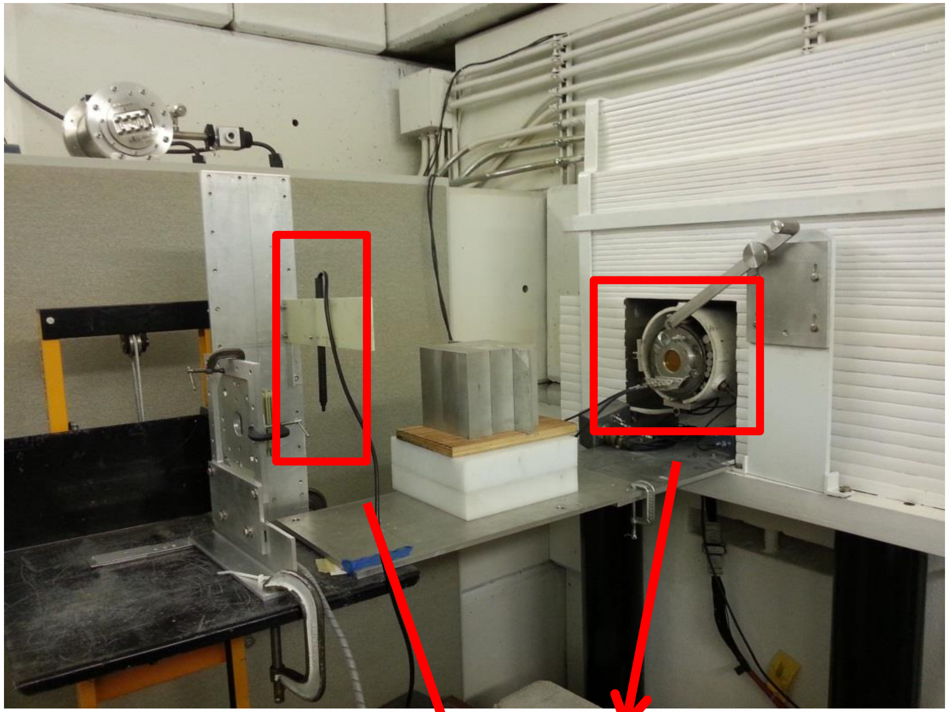
BL1B Extraction energies:

- 480 MeV
- 355 MeV
- 210 MeV (not available when we tested)
- Down to 120 MeV through degradation

TRIUMF beam specifications

	BL1B protons	BL2C protons
Energy	180 to 500 MeV (500 MeV preferred) 120 to 180 MeV with a Degrader	65 to 120 MeV 5 to 65 MeV with a Degrader
Initial Intensity	0.1 to 3 nA	0.1 to 7 nA
Flux (protons/cm^2/s)	Back location: 10^5 to $4x10^7$ (10^2 possible) Front location: $7x10^8$ max	Back location: 10^5 to $1x10^8$ (10^2 possible) Front location: $2x10^9$ max
Spot Size	Back location: 2x2 cm to 7.5x7.5 cm Front location: 1 to 2 cm diameter	Back location: 1 to 7.5 cm diameter Front location: 0.5 to 2 cm diameter
Spot Homogeneity	Back location: +/- 5% Front location: +/- 10%	Back location: +/- 5% Front location: +/- 10%
Dose Rate	Back location: 10 to 20 mGy/s (1 to 2 rads/s) Front location: up to 500 mGy/s (50 rads/s)	Back location: 50 to 100 mGy/s (5 to 10 rads/s) Front location: up to 1000 mGy/s (100 rads/s)
Beam Counting and Monitoring System	Ion Chamber or Scintillator	Ion Chamber, Scintillator, or Faraday Cup
Device-Positioning System	Remote-controlled X-Y platform with laser alignment	Remote-controlled X-Y platform with laser alignment
Access Conditions	20 m cable length to Control Area	20 m cable length to Control Area

TRIUMF beam calibration

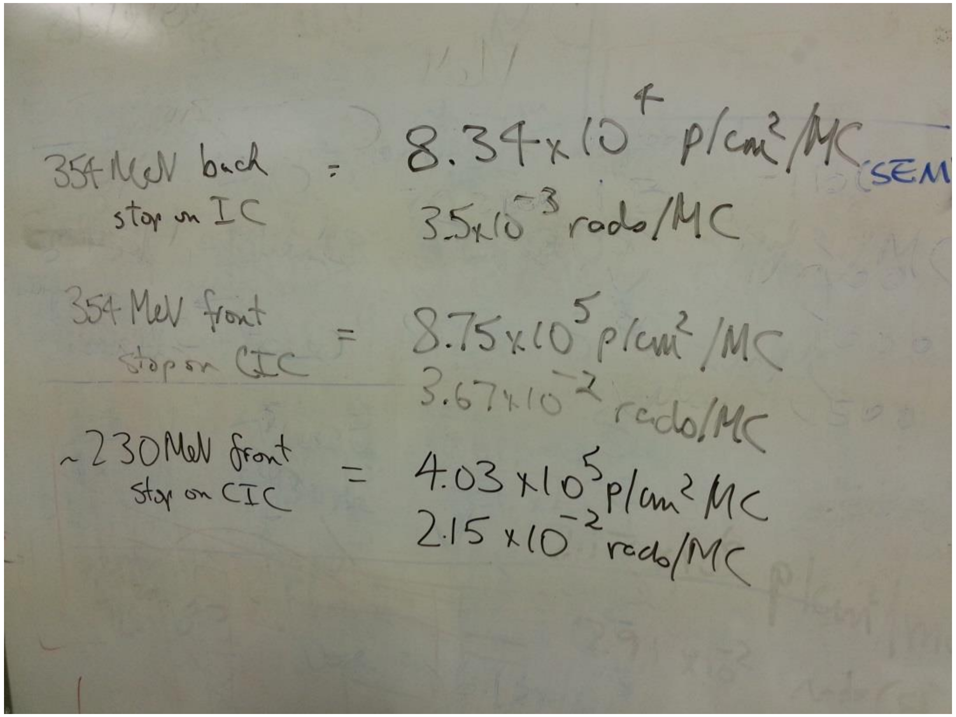


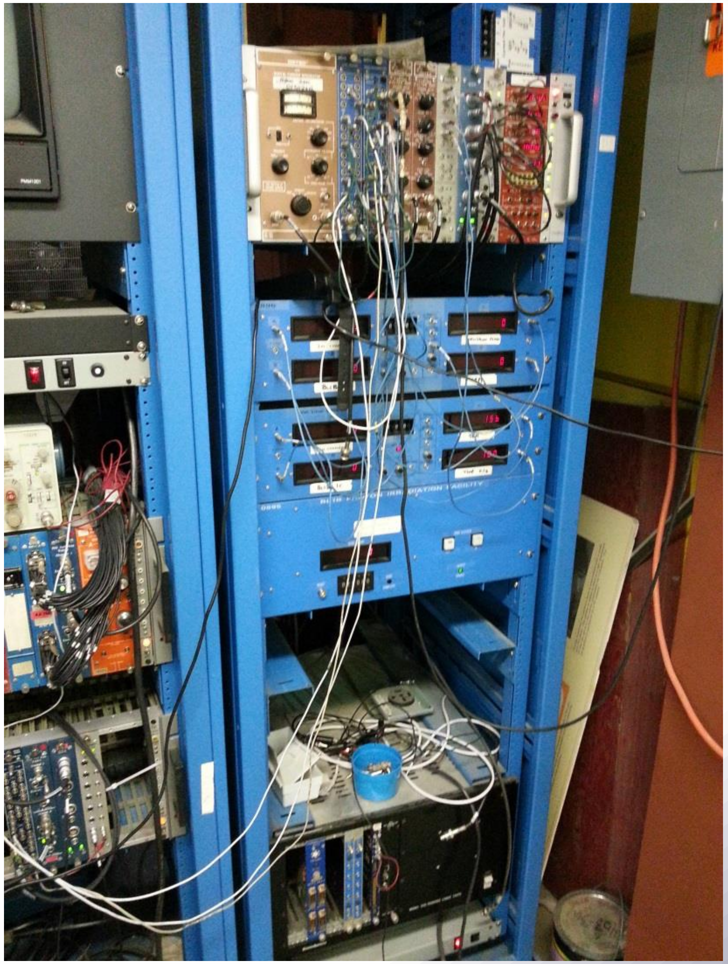
Each test configuration requires a **beam calibration** at the beginning of the run:

- Cyclotron status
- Test location
- Extraction energy
- Scatterer size
- Use of degrader
- …

Portable ionization chamber (medical applications) used to calibrate each configuration + permanent ionization chamber

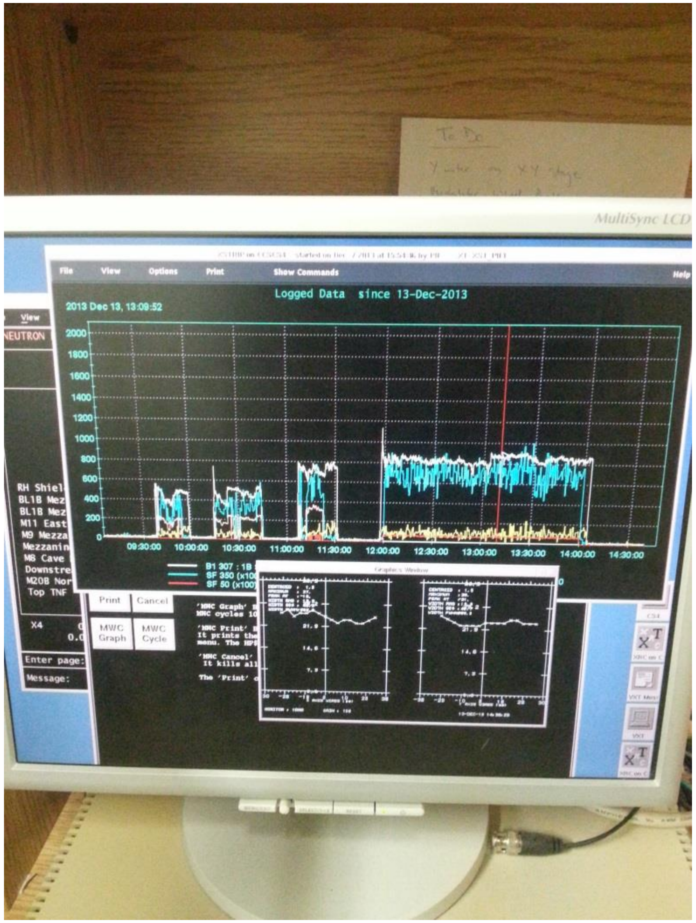
TRIUMF beam monitoring and steering

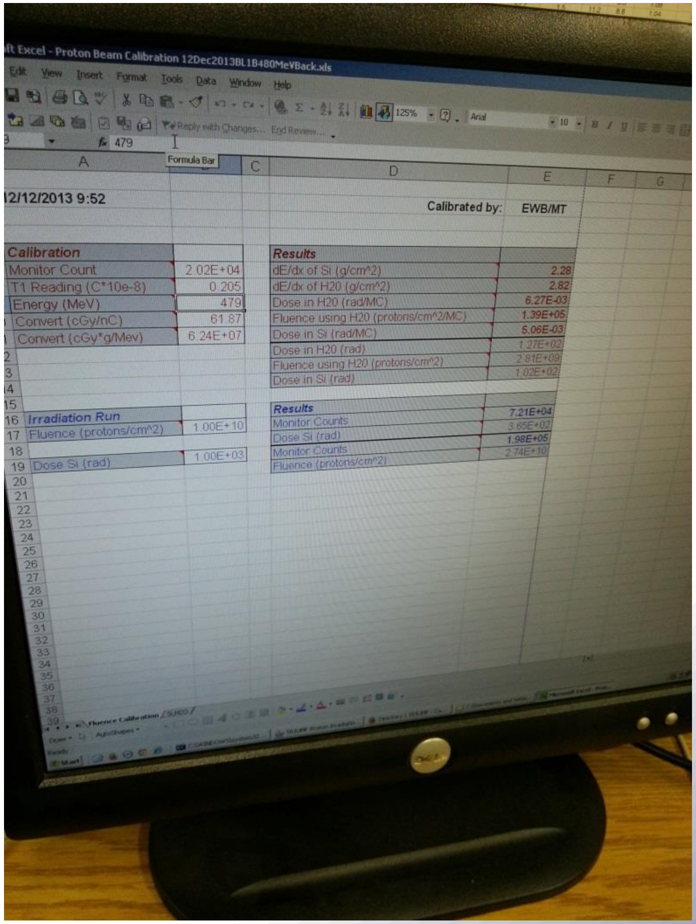




- **MC counter** proportional to **fluence**
- **SEM counter** proportional to **flux** (units communicated to the operators to alter the flux)

- Calibration values (right) and beam monitor (left) showing SEM counts and neutron counter limited to 10 for RP reasons, and beam profile (with wire number, each is 3 mm)



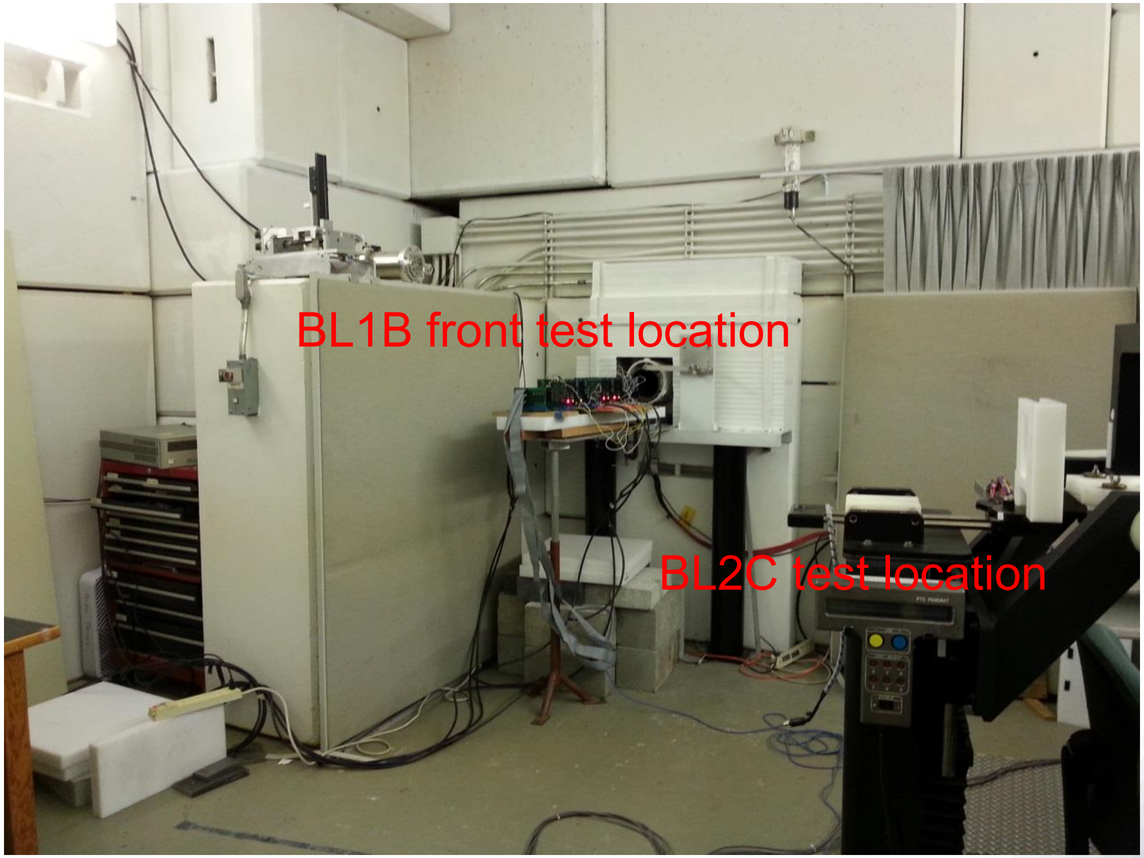


Back location

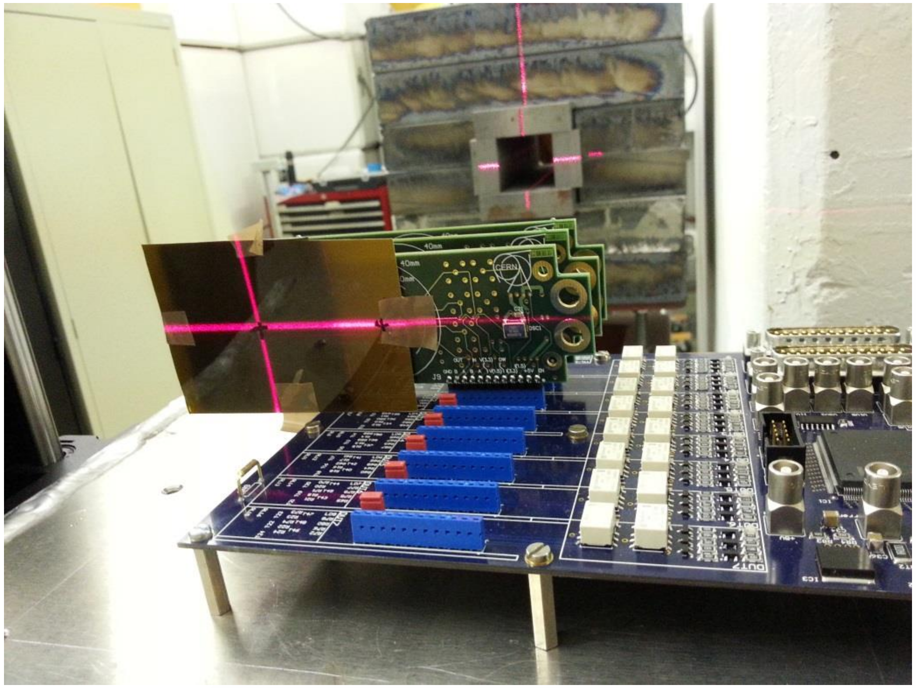
- Larger beam size (good for homogeneity and position uncertainly)
- Lower flux:
  - ~ **6·10^{7}** p/cm^{2}/s @480 MeV
  - ~ **2.5·10^{7}** p/cm^{2}/s @355 MeV
  - ~ **6·10^{6}** p/cm^{2}/s @230 MeV

Front location

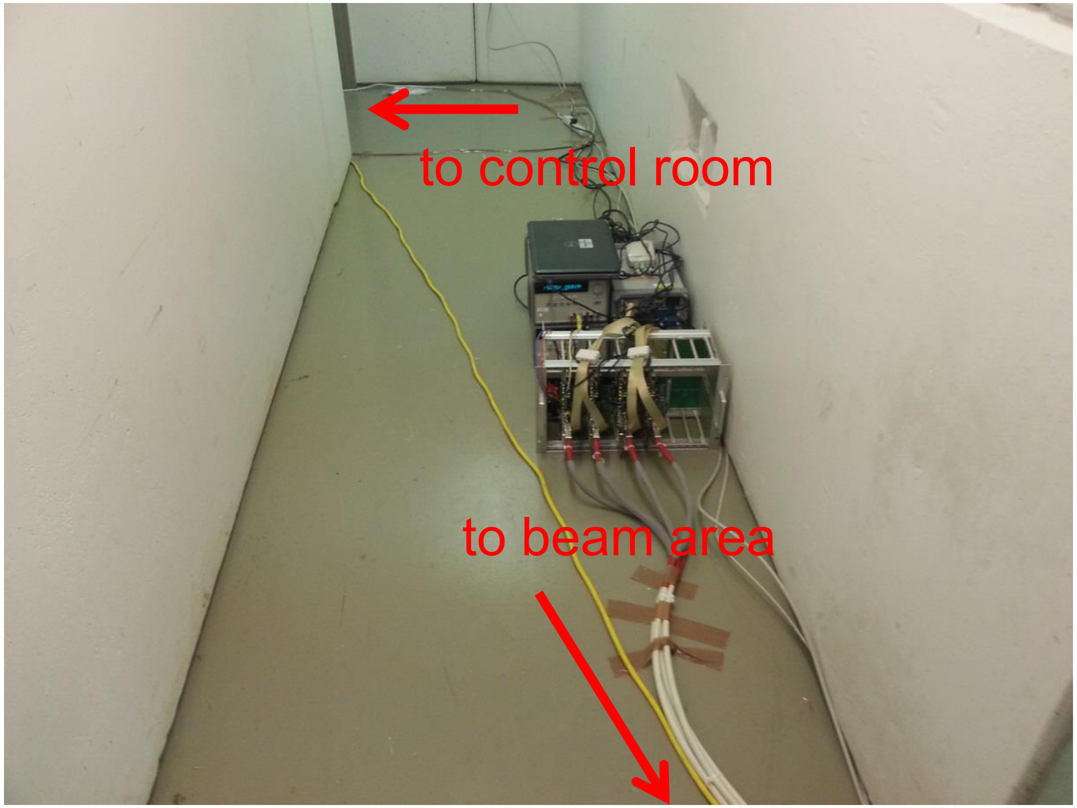
- Larger flux: up to ~$3\cdot10^8$ p/cm^2/s by @480 MeV using thin (1.3 mm) degrader
- Smaller beam size (flux uncertainly related to position increases)



Laser alignment system

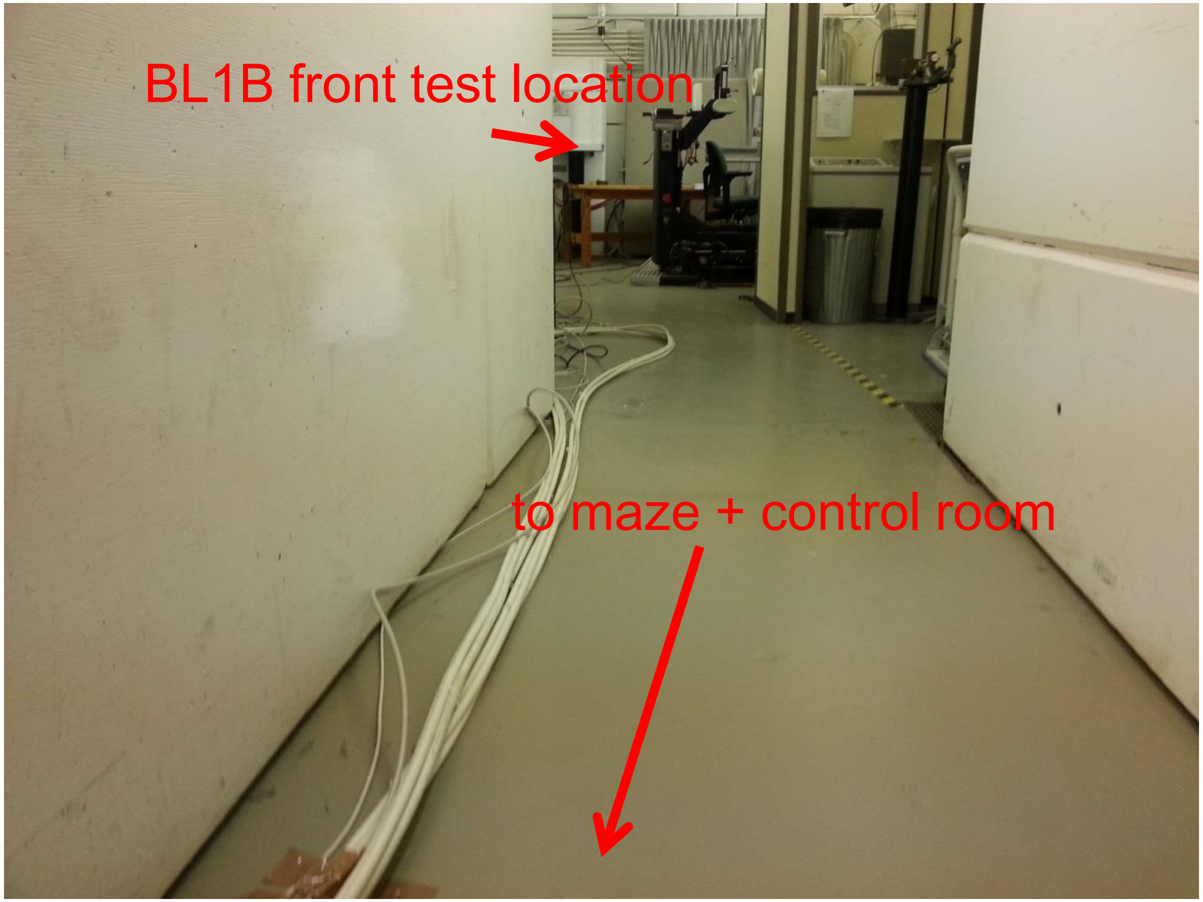


Cable length



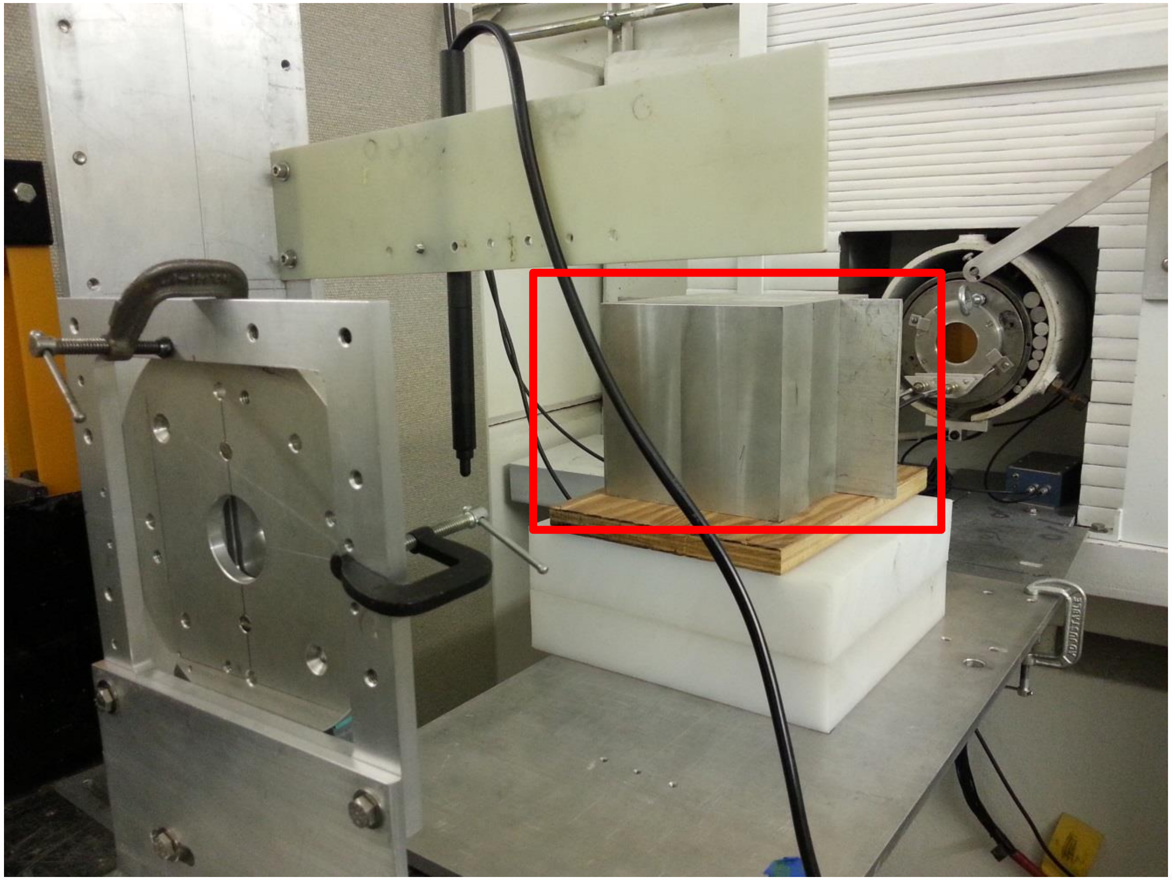
- Cables need to be pulled (no patch panels available)
- ~20 m from control room to front location
- ~15 m from control room to back location
- ~10 m from control room to maze area (internal but low radiation level)

Cable length



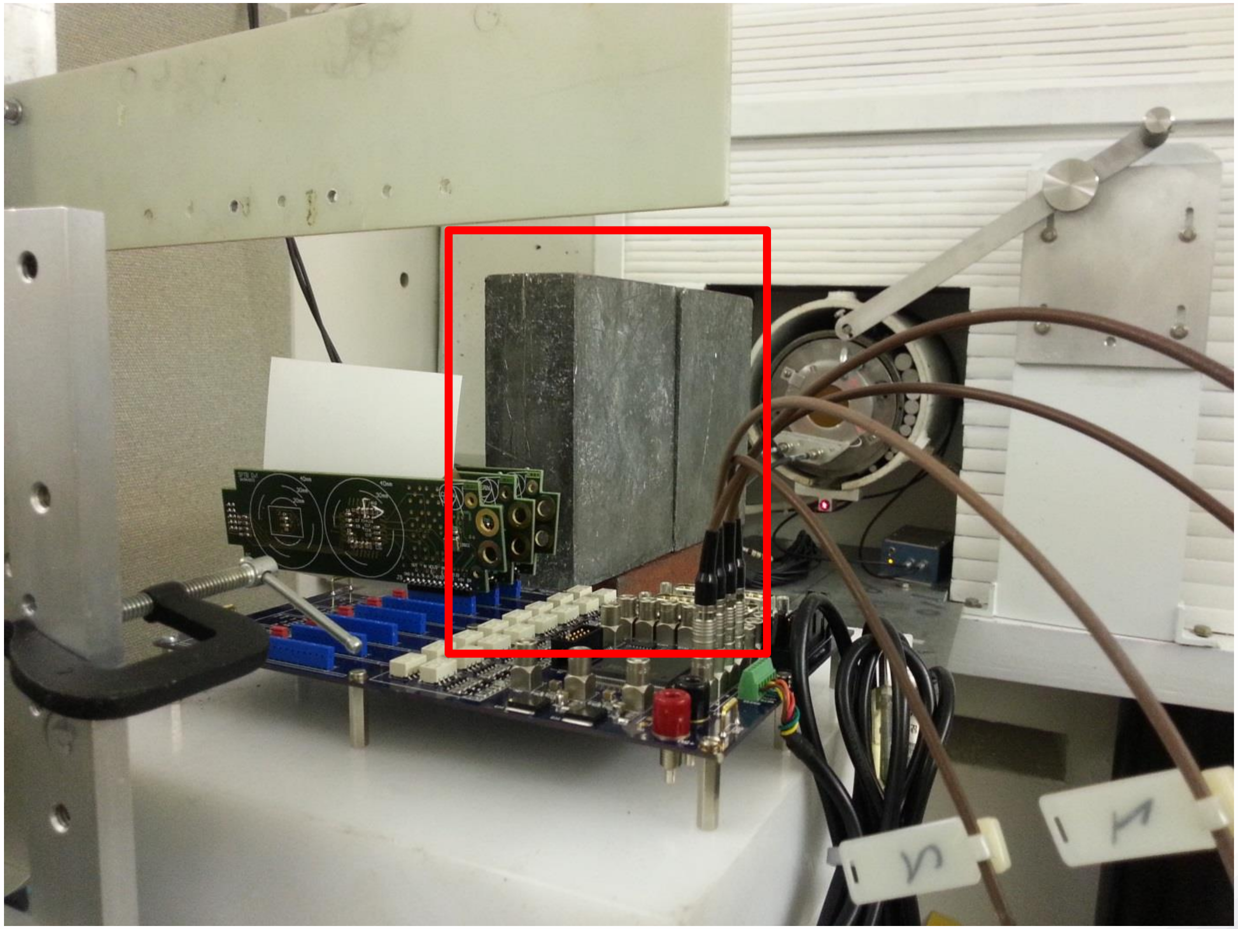
Manual degrader

15.9 cm aluminum degrader (SRIM calculation from 480 to 230 MeV)

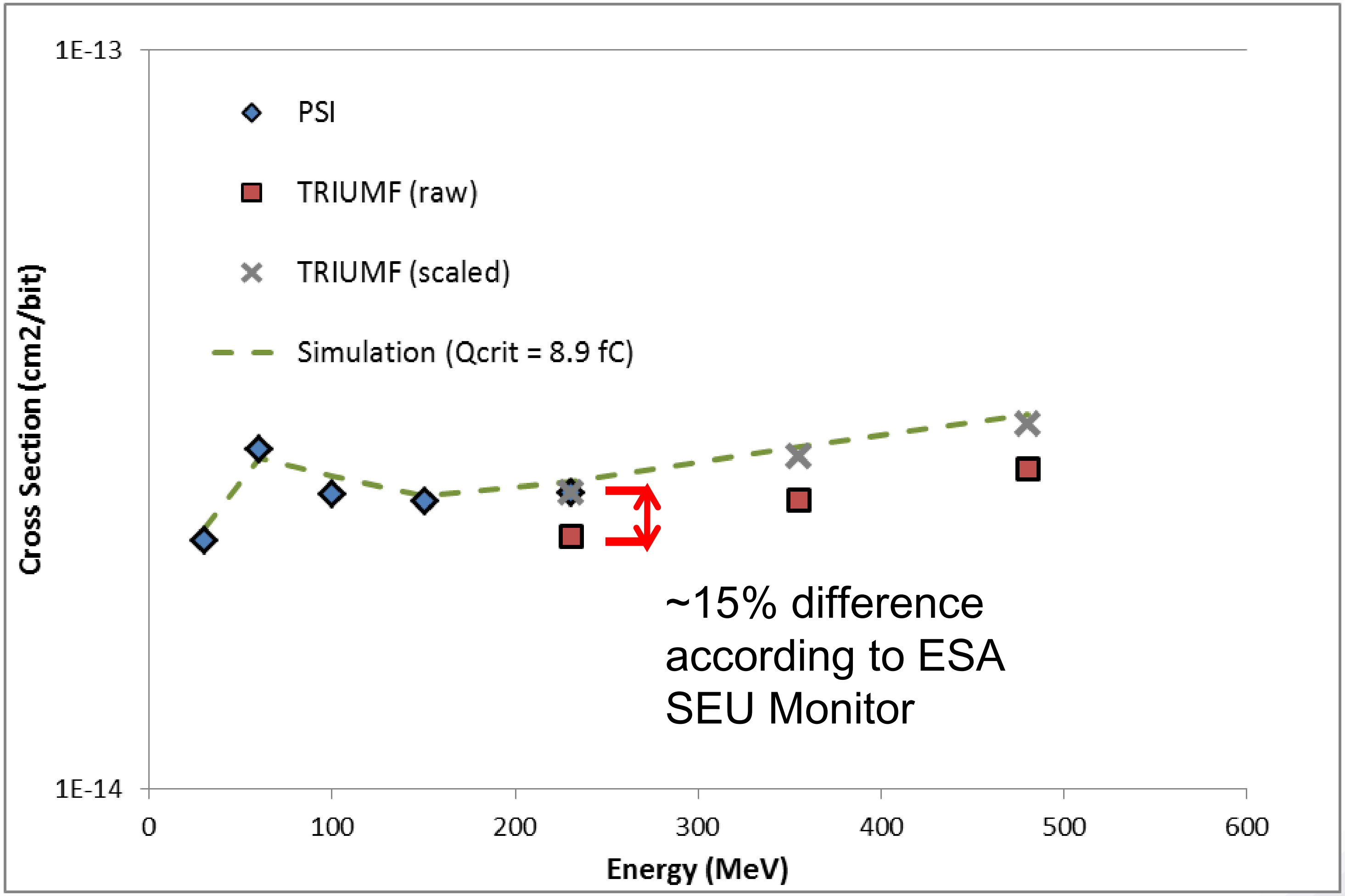


Manual collimator

Renesas SRAM memory: protection of FPGA on test board



Cross-calibration with PSI



R2E test campaign at ISIS

- **Scientific beam time** awarded to the R2E project for SEE testing in an atmospheric-like neutron environment
- Goals were to study the SEU error rate for SRAM based detectors (ESA Monitor, RadMon v6) and SEL failure rate in order to compare with different **CHARM** locations
- Test performed between Mar 11th and 13th 2014
- When compared with other neutron facilities, **low flux** (and not very energetic):

Table 1 Accelerator based neutron facilities for atmosphere neutron radiation test

FACILITY	NEUTRON FLUX (>10 MeV)	PROTON ENERGY
TRIUMF	2.6×10^5 n/cm^2/s	500 MeV
TSL (ANITA)	$3.7\times10^4/3.6\times10^5/9.5\times10^4$ n/cm^2/s	22/109/174 MeV
ISIS TS1 (Vesusio)	>5.8x10^4 n/cm^2/s	800 MeV
ISIS TS2 (ChipIR)	>1x10^6 n/cm^2/s	800 MeV
LANSCE (ICE I& II)	4.6x10^5 n/cm^2/s	800 MeV
CSNS (FuNIS)	2.3×10^6 n/cm^2/s	1600 MeV

Testing in the UK

ISIS-VESUVIO neutron spectrum

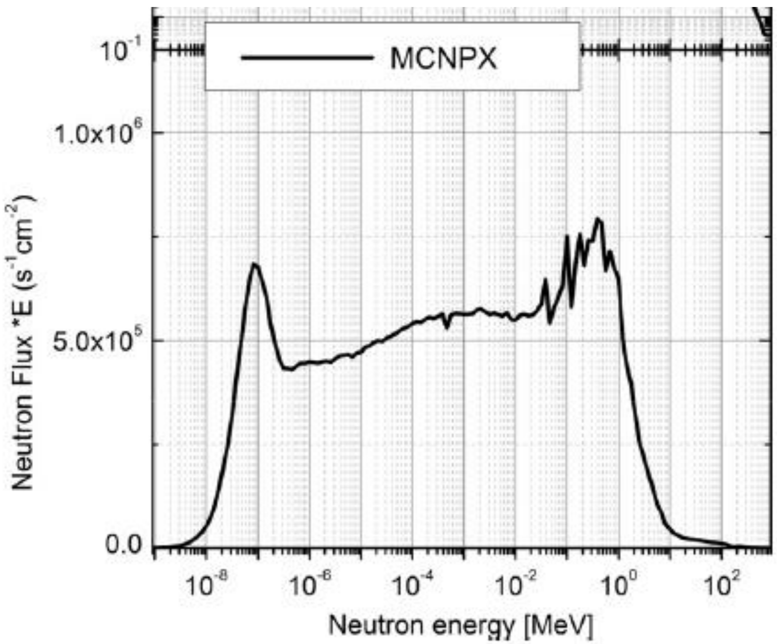
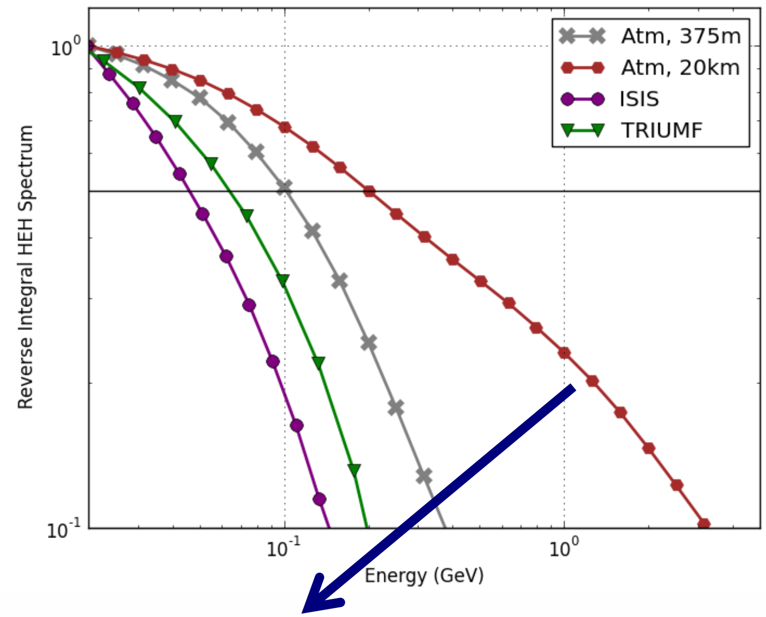


Fig. 1. Spectral neutron flux at the VESUVIO instrument at the ISIS neutron source, calculated with the MCNPX code [6]. The data relate to the reference position (1105.5 cm from the frontal surface of the moderator) and to the primary proton beam current of 180 μA.



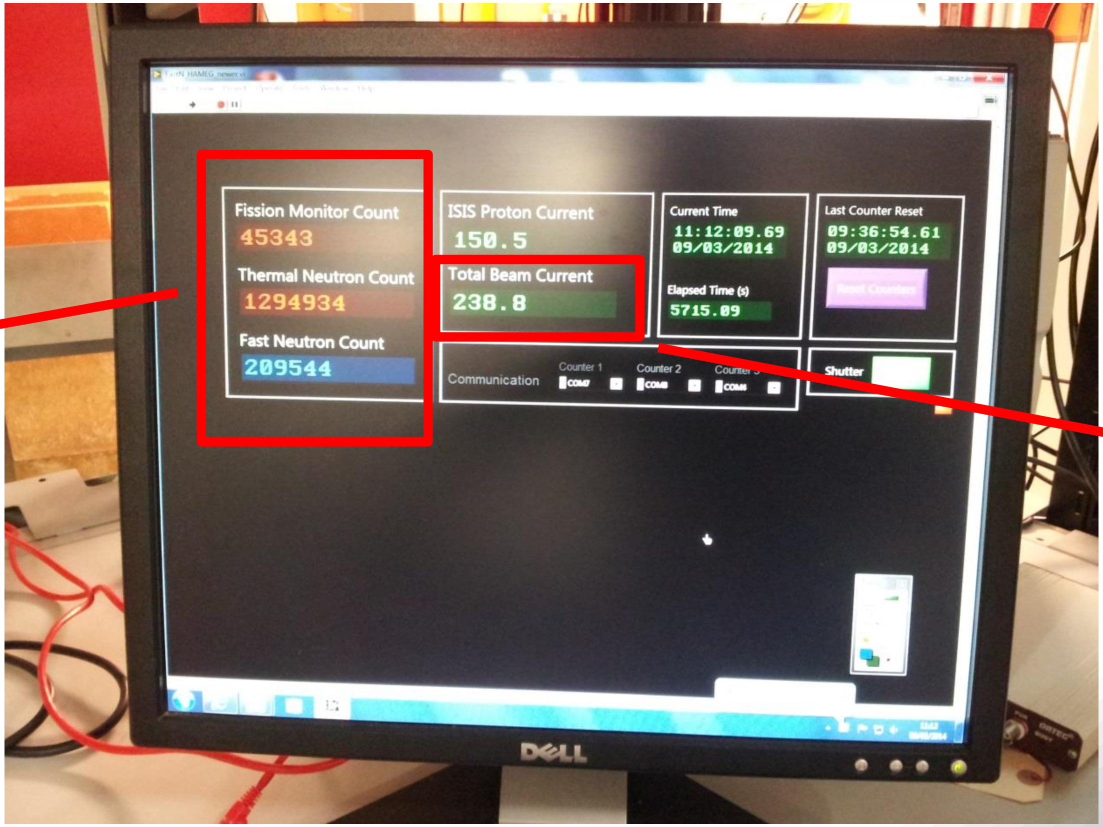
Atmospheric 20 km very similar to LHC -> CHARM will cover the full range

800 MeV proton synchrotron + tungsten target + 60° neutron beam line -> low HEH flux (several intermediate elements) and low energy distribution

Beam monitoring and dosimetry

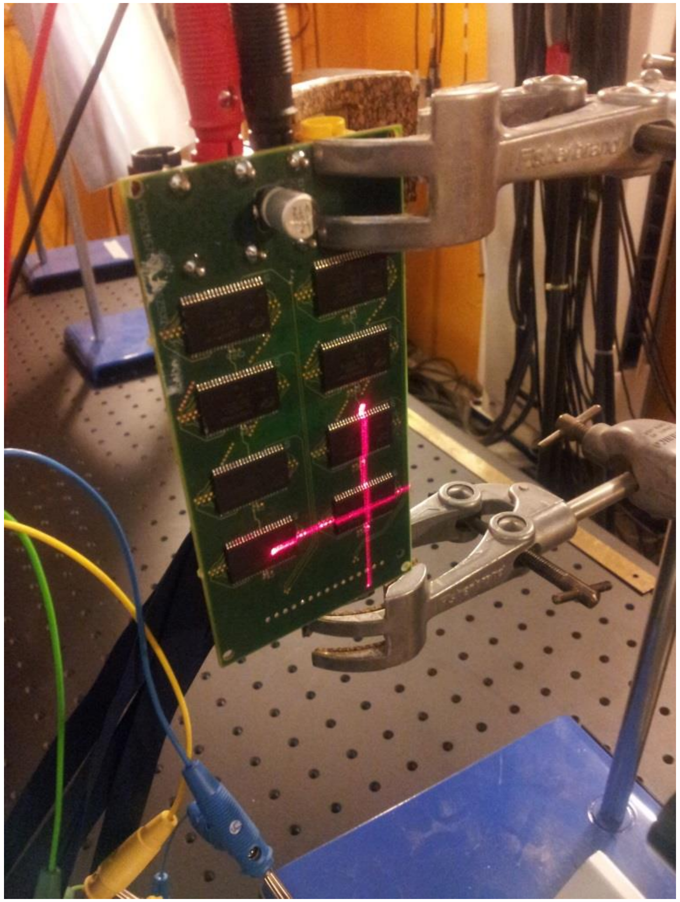
- **Fluence** extracted though (calibrated) **MC calculations** + current normalization + position normalization
- HEH flux (neutron flux above 20 MeV) equal to **$2.4 \cdot 10^4$ n/cm^2/s** (future **Chipir** facility will have a factor ~30 more)

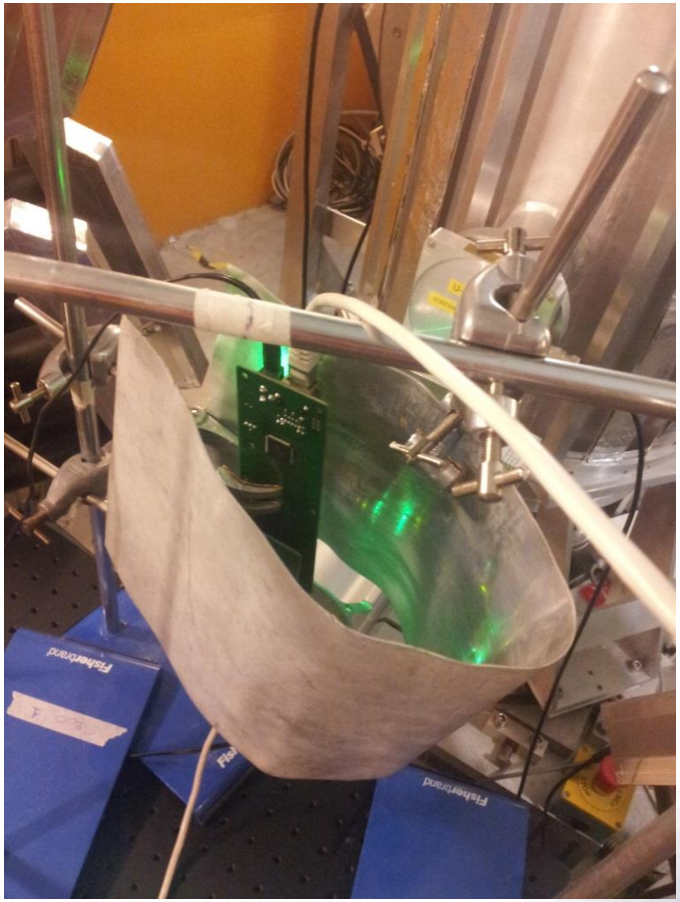
U238 detector (fission), LiF detector (thermal), diamond detector (fast neutrons)



Fluence related to total beam current (still runs when shutter is closed!)

Alignment and Cadmium absorber





ESA SEU Monitor results

Full neutron spectrum	Thermal	Equivalent HEH
Cross Section (cm^2)	$3.3\cdot10^{-15}$	$2.6\cdot10^{-14}$
Fluence (cm^{-2})	$3.0\cdot10^{9}$	$2.0\cdot10^{8}$
Expected Number of Events	160	80
Measured Number of Events	220	

Cadmium absorber	Thermal	Equivalent HEH
Cross Section (cm^2)	$3.3\cdot10^{-15}$	$2.6\cdot10^{-14}$
Fluence (cm^{-2})	-	$2.5\cdot10^{8}$
Expected Number of Events	-	104
Measured Number of Events	99	