nTOF SEE Benchmarks

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On behalf of the R2E Project

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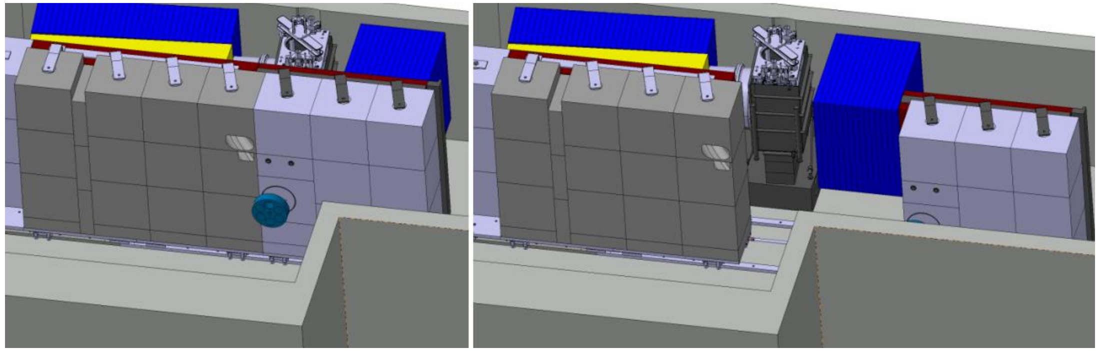
https://indico.cern.ch/event/1116677/

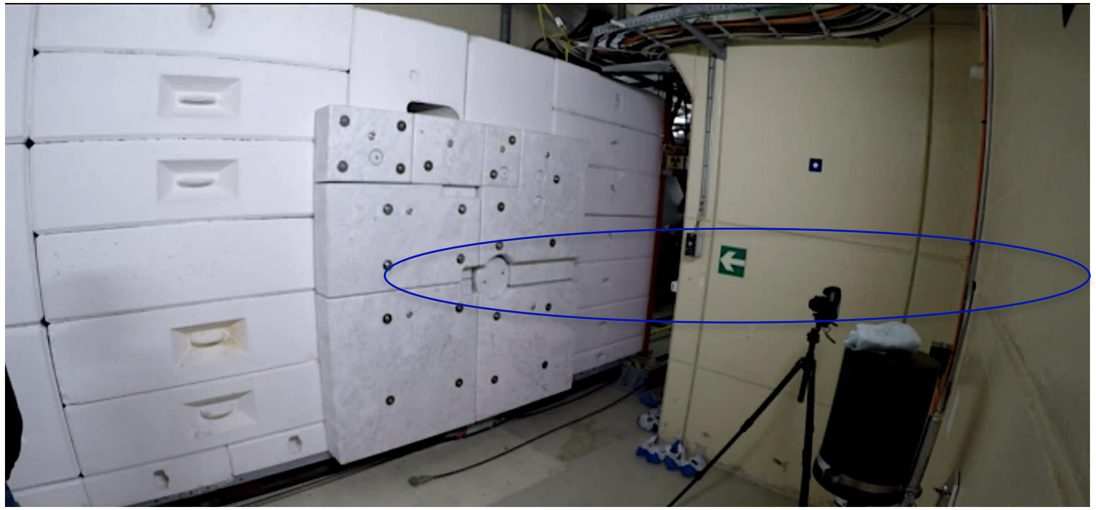
Agenda

1. Facility and objectives
2. Test setup and strategy
3. Beam properties
4. Experimental results
5. Spectral hardness

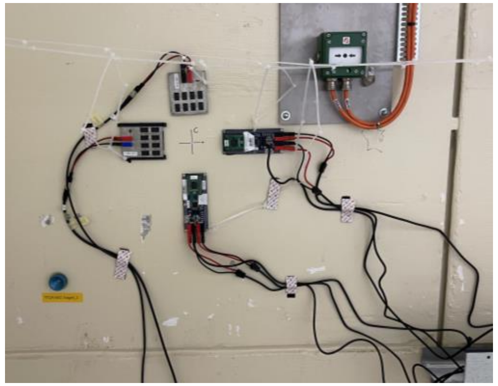
Facility and objectives

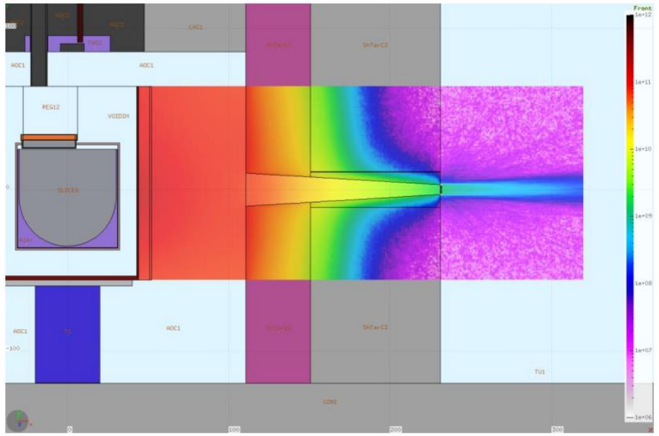
- New **NEAR nTOF** experimental station providing pulsed neutron beam directly from nTOF target.
- Interesting flux for future **SEE and Displacement Damage testing** in electronics.
- Sole **beam** intensity **data from PS** monitoring system.
- Preliminary **FLUKA calculations** suggest **$5 \cdot 10^6$ HEH/cm^2/pulse for $7 \cdot 10^{12}$ protons/pulse** in the collimator output.
- By means of SRAM memories → Determine the **High Energy Hadron flux** at NEAR.





Test setup and strategy





SEL Board

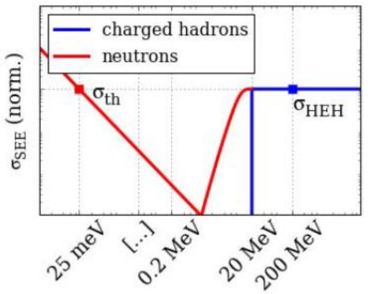
SEU Board

- **SRAM memories characterised** in a number of neutron environments (mixed fields, pseudo-monoenergetic and thermal neutron sources).
- Set of 4 SRAMs used:
  - **x2 SEU sensitive**: Cypress 65 nm and ISSI 40 nm (calibration in Ref. 1,2,3). Better thermal and intermediate energy neutron resolution.
  - **x2 SEL sensitive**: Samsungx8 and Alliancex8 (calibration in Ref 4). Better high energy neutron resolution.
- DUTs placed **2 m far from collimator** (Z axis).
- 10 cm from projection centre (XY plane).
- 80m patch panel to the control area. USB read-out converted to Ethernet.

Test setup and strategy

- **No direct neutron measurement** but protons on nTOF target from TIMBER.
- **SRAMs** provide an **aggregated value of the fluence** (High Energy Hadron equivalent, Thermal Neutron equivalent).
- Combination of data from:
  - **TIMBER** Protons on Target: Time dependence and total number of protons.
  - **FLUKA** simulations: Neutron yield per pulse (standard unit, 7e12 protons per pulse).
  - **SRAMs Weibull calibration fit**: SEE cross-section as a function of energy [Refs 1-4].
- **Matching** of **expected SEEs** from TIMBER+FLUKA+FIT and **experimentally measured SEEs** helps validating other variables/energy ranges from FLUKA.

TIMBER POT + FLUKA +



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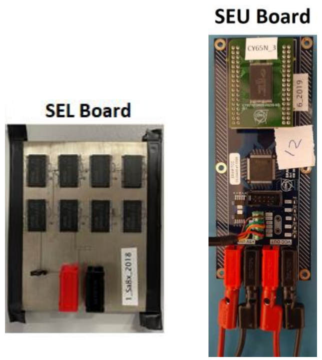
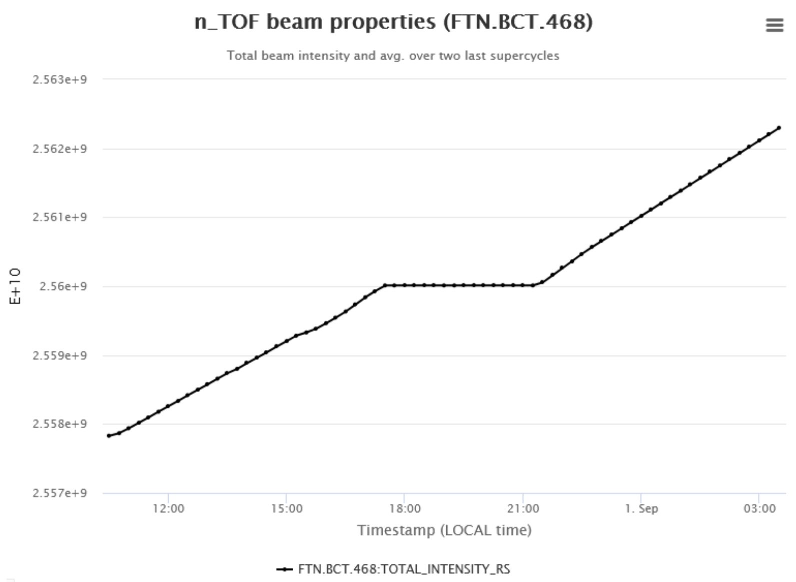
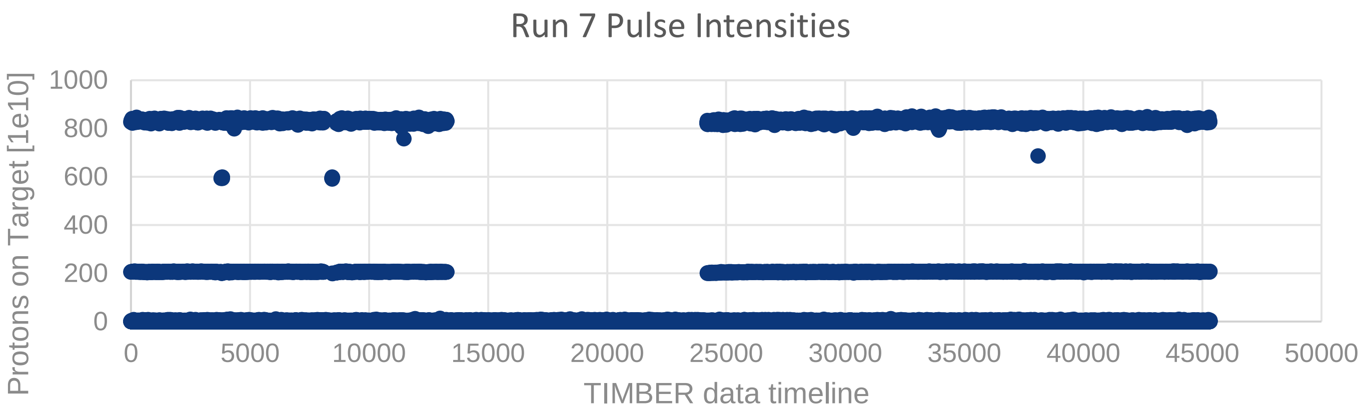
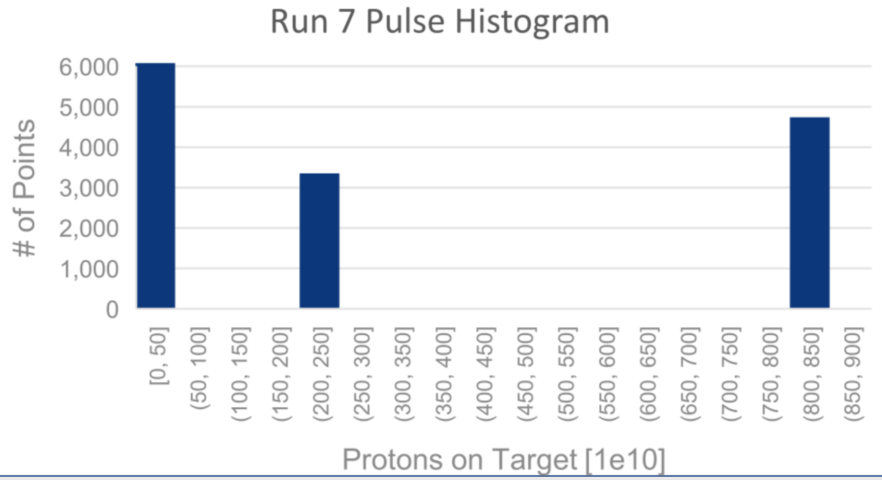


Beam properties

- Beam monitoring via PS proton **TIMBER variables**.
- Amount of **protons** reaching the **NTOF target** every 1.2 seconds.
- Alternating pulse intensities: $\mathbf{2 \cdot 10^{12}}$ and $\mathbf{8 \cdot 10^{12}}$ protons/pulse in a comparable rate.
- **Constant** average **flux** in time.

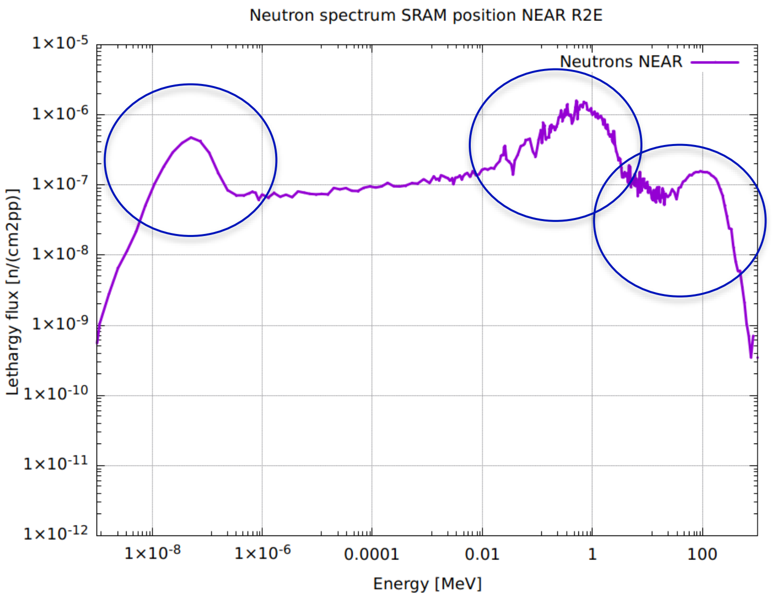






Results: SRAM behaviour

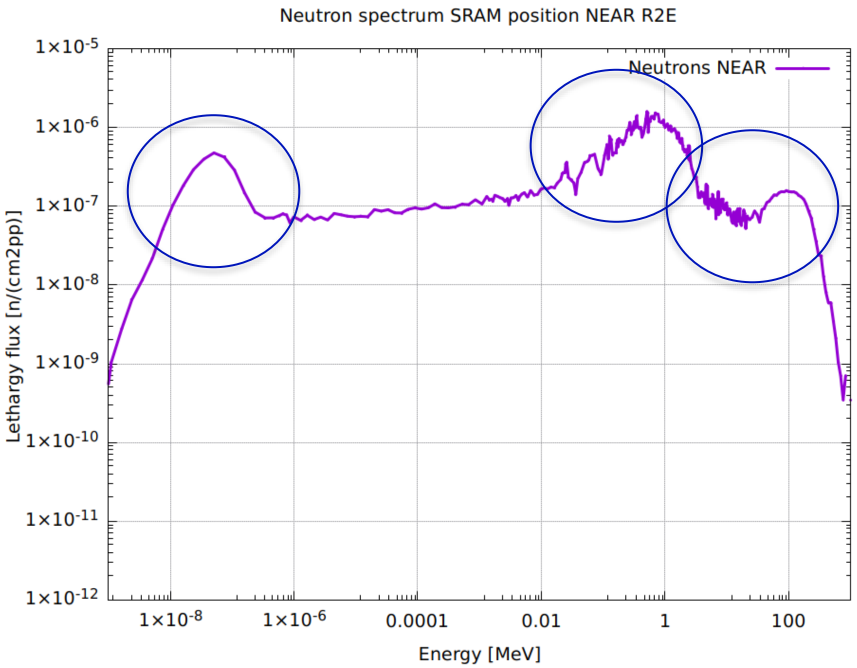
- **Complementary sensitivity** thanks to the differences in technology and composition.
- **SEL** memories, Alliance and Samsung, sensitive to **energies larger than 25 and 40 MeV** respectively.
- **SEU** memories, together with **high energy** neutrons, show sensitivity to **intermediate energies 0.01-10 MeV**.
- Also, **ISSI** memory is particularly sensitive to **thermal neutrons**, completing the spectrum to three important ranges.



	ISSI 40nm	Cypress 65 nm	Alliance	Samsung
Eth [MeV]	0.01	0.01	25	40
$\sigma_{HEH,sat}$ [cm^2/device]	4.70E-07	1.30E-06	7.50E-9	7.50E-9
σ_{Th} [cm^2/device]	1.07E-07	8.05E-09	N/A	N/A

Results: Comparison

- FLUKA energy spectrum is weighted with every Weibull SRAM model and compared to the experimental equivalent fluence.



	ISSI 40nm	Cypress 65 nm	Alliance	Samsung
Experimental HEHeq flux [n/cm2/pulse]	(5.82 ± 0.73) E+06	(4.08 ± 0.41) E+06	(1.39 ± 0.37) E+04	(3.77 ± 0.82) E+04
FLUKA HEHeq flux [n/cm2/pulse]	(4.26 ± 0.51) E+06	(4.73 ± 0.56) E+06	(2.30 ± 0.31) E+04	(3.32 ± 0.44) E+04
Exp HEHeq / FLUKA HEHeq	1.37 ± 0.18	0.86 ± 0.16	0.60 ± 0.30	1.14 ± 0.26

- The **good agreement in experimental measurements and FLUKA** simulations let us conclude the flux in front of the collimator as:

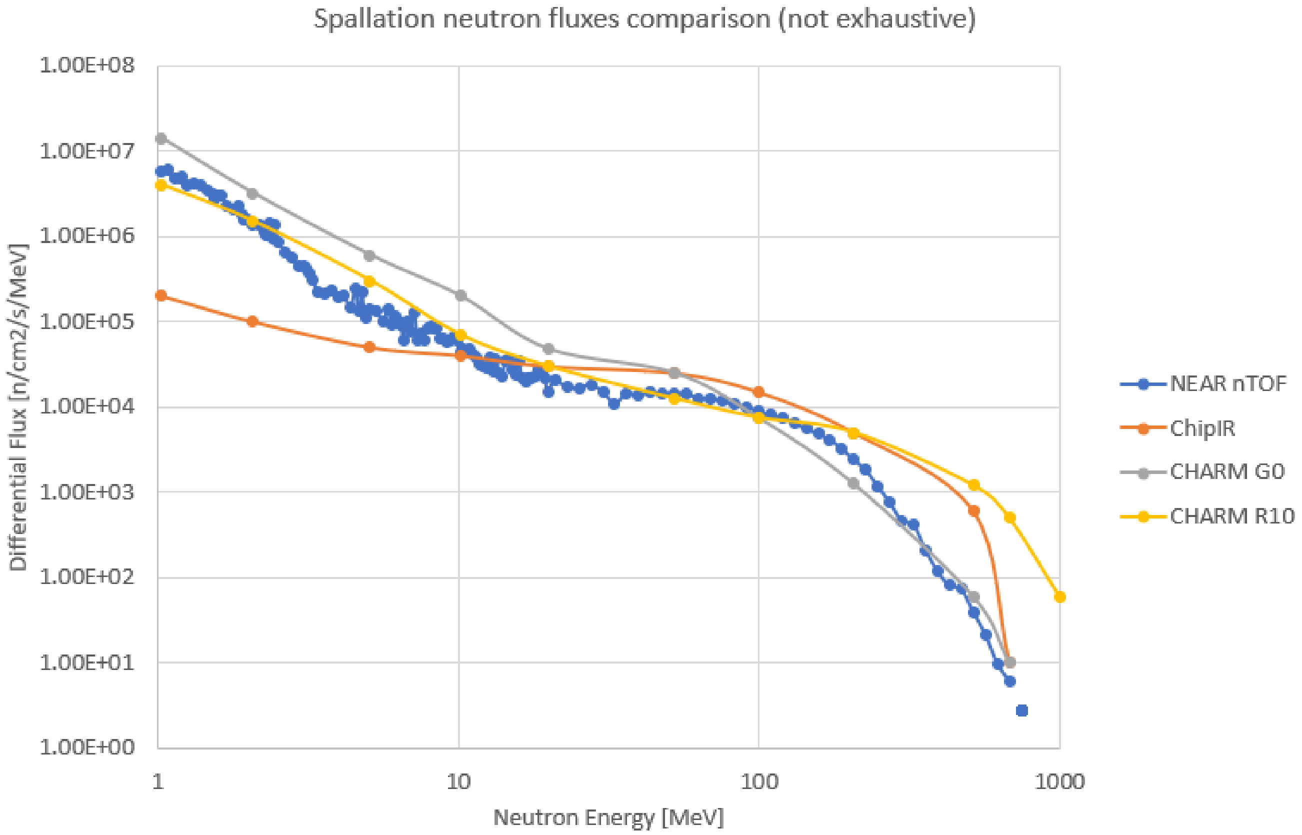
HEH (>20 MeV) [n/cm2/pulse]	HEH_{eq} Toshiba [n/cm2/pulse]	Th_{eq} [n/cm2/s]	$Si1MeVn_{eq}$ [n/cm2/pulse]
$2.09 \cdot 10^6$	**$2.66 \cdot 10^6$**	**$5.67 \cdot 10^6$**	**$2.25 \cdot 10^7$**

Spectral hardness

- NEAR nTOF spectral hardness comparable to other spallation facilities.
- Lower $H_{10\%}$ balanced by larger flux in the intermediate energy range 1-10 MeV.

Facility	NEAR nTOF	ChipIR	CHARM G0	CHARM R10
$H_{10\%}$ [MeV]	207	283	194	790
$H_{50\%}$ [MeV]	87	96	62	190

Facility	NEAR nTOF*	ChipIR	CHARM** (Average)
HEHeq (>10 MeV) [n/cm2/s]	**$2.04 \cdot 10^6$**	**$3.57 \cdot 10^6$**	**$2.7 \cdot 10^6$**



*NEAR is a pulsed source -> assuming 1 pulse each 1.2s
**CHARM has a number of locations with different flux and spectral hardness.

Summary

- Neutron flux at NEAR nTOF has been measured by means of SEU and SEL-sensitive SRAM memories.
- **FLUKA simulations merged with SRAM Weibull fits** to confront the experimental values.
- **Complementary sensibilities of the SRAM** to cover high energy (> 20 MeV), intermediate energies (0.01-20 MeV) and thermal neutrons (~25 meV).
- Energy distribution shows a comparable spectral hardness to that of other spallation facilities, having a larger flux in the range (1-10 MeV).
- NEAR provides an **interesting neutron beam for neutron induced SEE and Displacement Damage testing** in electronics thanks to both the neutron energy distribution and flux.

HEH (>20 MeV) [n/cm2/pulse]	HEH_{eq} Toshiba [n/cm2/pulse]	Th_{eq} [n/cm2/s]	$Si1MeVn_{eq}$ [n/cm2/pulse]
$2.09 \cdot 10^6$	$2.66 \cdot 10^6$	$5.67 \cdot 10^6$	$2.25 \cdot 10^7$

References

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Thank you for
your attention!