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Wojtek Hajdas :: LTP/ DIAPP :: Paul Scherrer Institut

Summary Report - Proton Irradiation Facility at PSI

Detectors, Irradiations and Applied Particle Physics

28.06.2023

PSI and its accelerators

European Components Irradiation Facilities

PSI deliverables

Primary beam:

– Protons

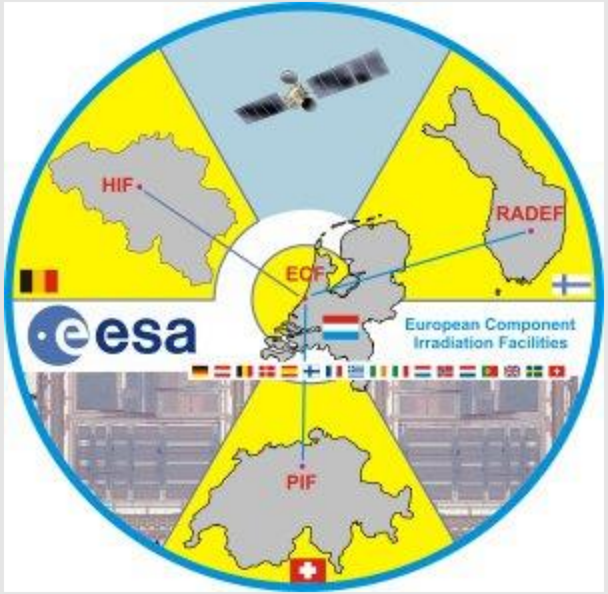
Other beams:

– Electrons

– Pions and muons

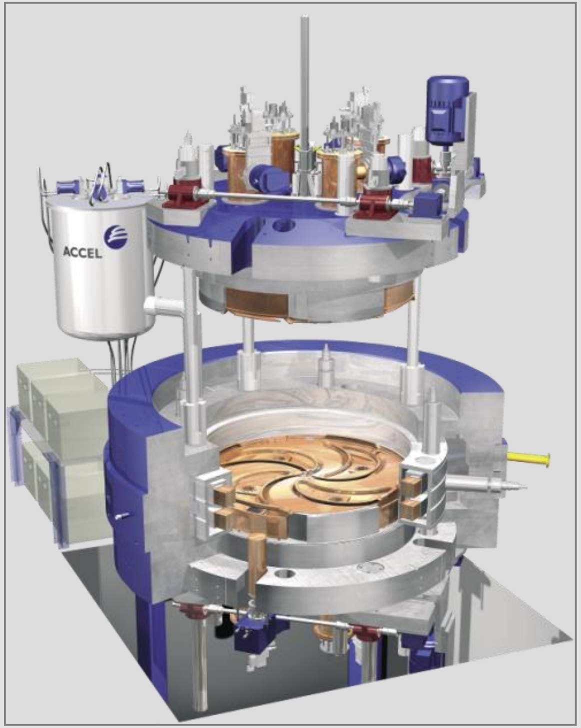
– Neutrons

– X-rays and gamma-rays



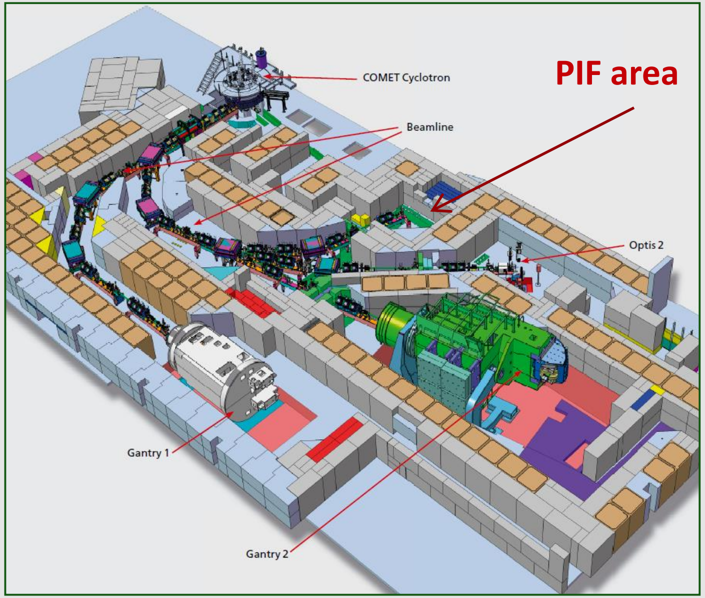
PSI exposure facilities for radiation effect studies

- Proton Irradiation Facility since 1992
  - Confirmation of the 1st latchup in space
- Connected to COMET cyclotron of the Proton Therapy Center
- Priorities given by patient exposure plan
- Other exposure sides and particles:
  - piM1 secondary beam area with electrons, pions and protons
  - Electron mono-chromator with mono-energetic electrons from beta sources



PSI exposure facilities for radiation effect studies

- Main functions:
  - User-lab for radiation effects studies in electronics
  - Realistic simulator of space radiation environment
  - Source of mono-energetic particles for rad-tests
  - Calibration station for monitors and detectors
  - Radiation qualification for space technologies



NA area with COMET cyclotron and exposure sites

COMET Compact Medical Therapy Cyclotron

- Facility of the PSI Proton Therapy Center
- Designer - H. Blosser, MSU/USA
- Delivered by VARIAN
- 250 MeV fixed energy
- Mass 90 tons
- Intensity range 0-1000 nA
- In operation since 2007

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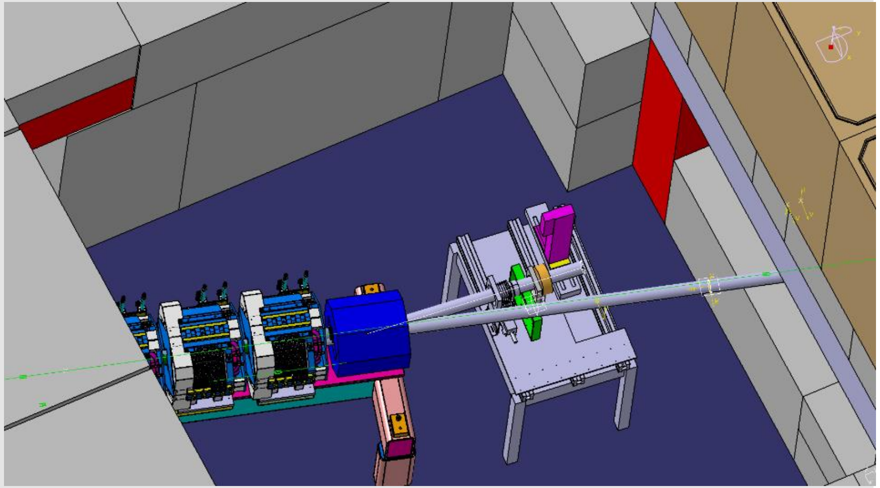
Proton Irradiation Facility I.

- Initial energies: 230, 200, 150, 100, 74 MeV
- Energies after degrader: 230 MeV to 6 MeV

- Max intensity: 2 nA (E>200) – 10 nA (E<100)
- Flux range $10^2 – 3 \cdot 10^8$ p/sec/cm^2

- Profiles Gaussian-like: FWHM 10 cm
- Max beam diameter of 98 mm
- Options: focused (6 mm ϕ) or flat beam

- User adapted dosimetry and test flow
- Standard calibrations runs and checks / fluxes, profiles, scaling



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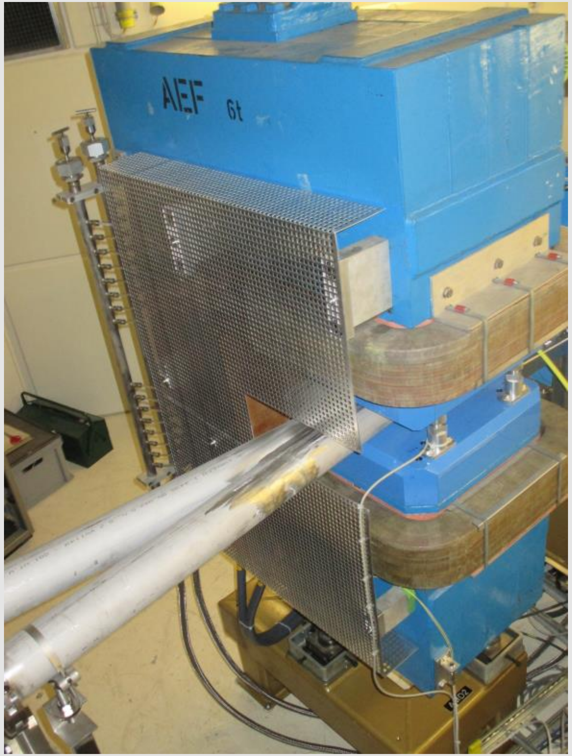
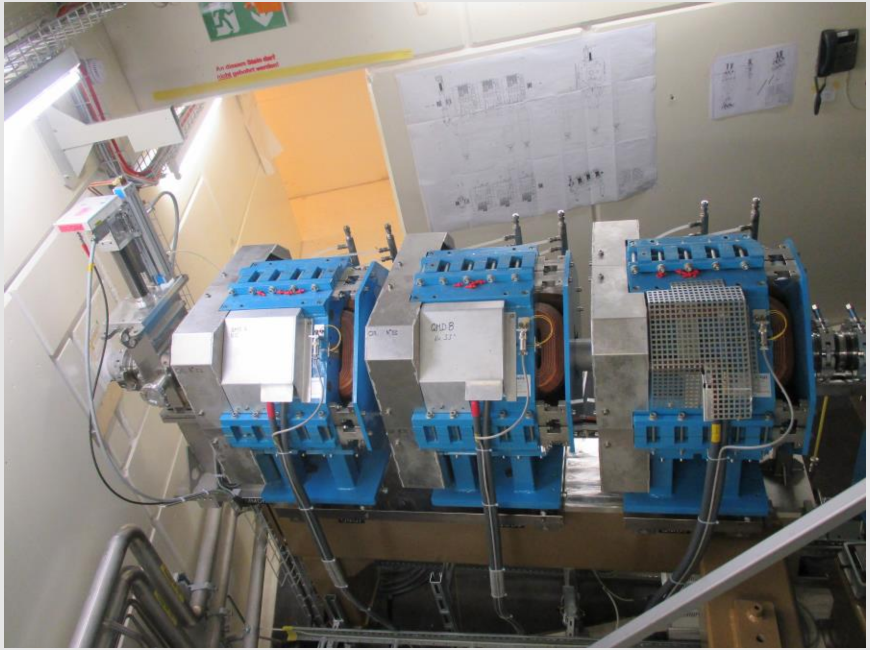


Proton Irradiation Facility II.

- Operation: weekends and nights;
- Flexible, user-specific test arrangement
- Fast, uncomplicated set-up and operation
- Automated irradiations
- Standard ESA sample frame

  Irradiation usually in air
- Typical laboratory apparatus available

  (also vacuum chambers)



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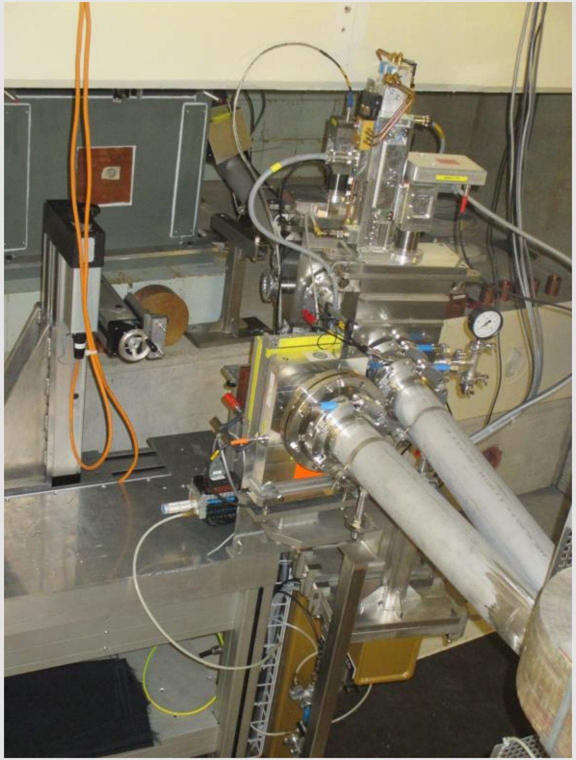
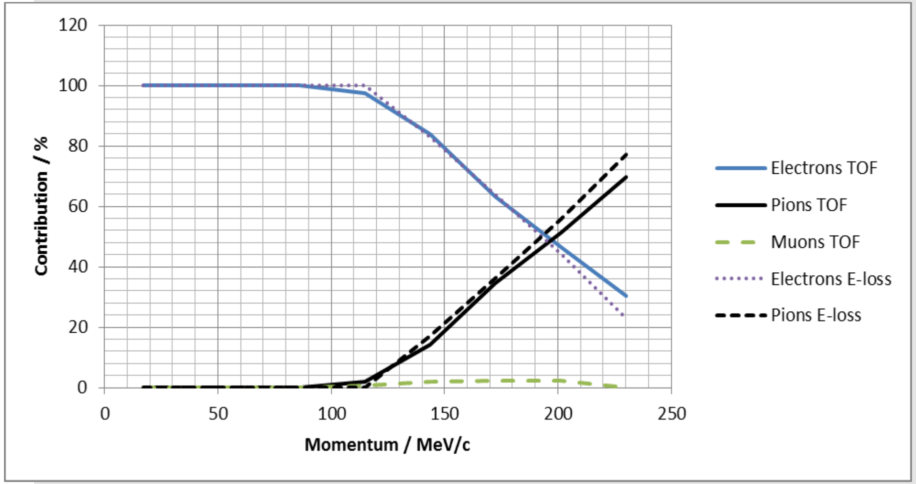


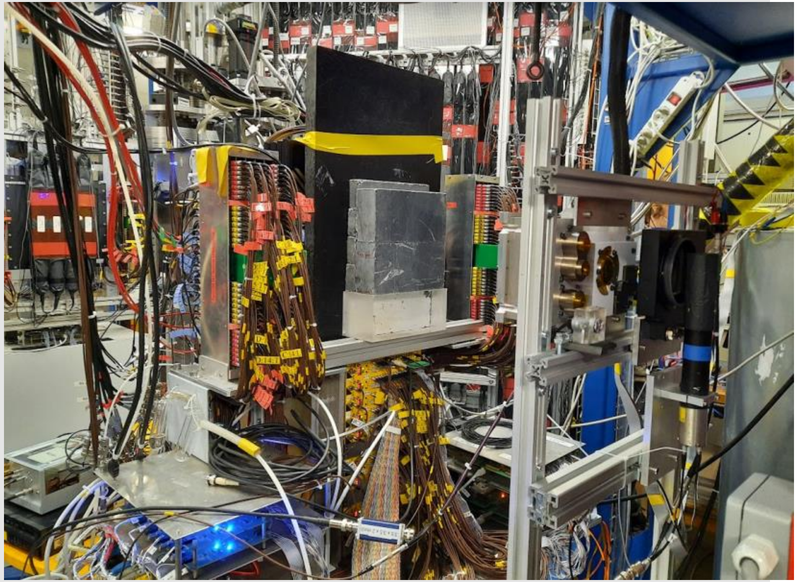
Electron monochromator – lower energies

- Simple bending magnet
- Strong electron source
- Large vacuum chamber
- Control system constructed
  - *Si-detector, Vacuum, Dedicated DAQ*
  - *XY-table*
  - *Centering Llaser*
  - *TV cameras*
  - *Illumination*

High energy electrons in piM1

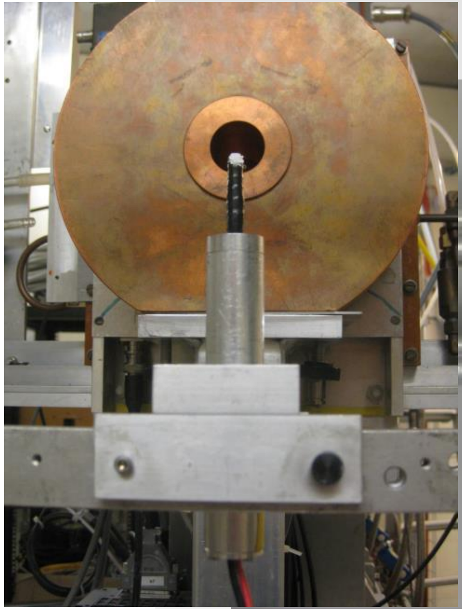
- Secondary beam area piM1 of PSI large cyclotron
- Positive and negative particles possible
- Clean electrons beams from about 10 MeV up to 100 MeV
- *Protons available up to 70 MeV*
- *Pions and muons from 100 MeV/c to 350 MeV/c*

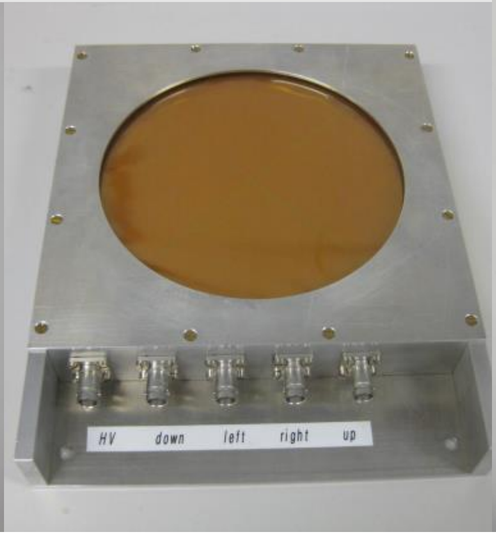


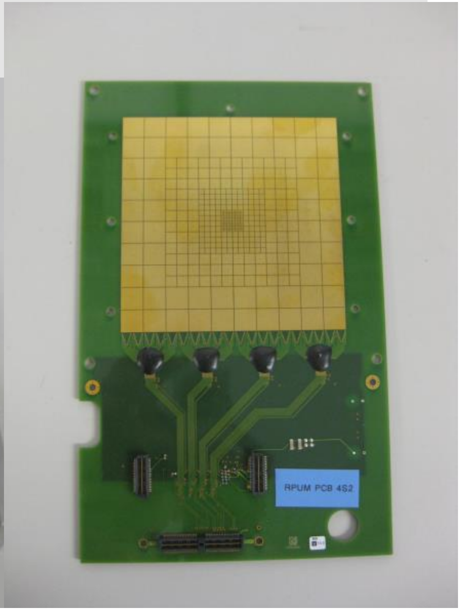


Detectors and dosimetry

- Scintillation or semiconductor detectors to calibrate the beam
- Real time dosimetry uses ionization chambers IC (nominal flux) or detectors (low fluxes)
- Profiles are measured with pixelated IC or detector scans (or luminescence foils)

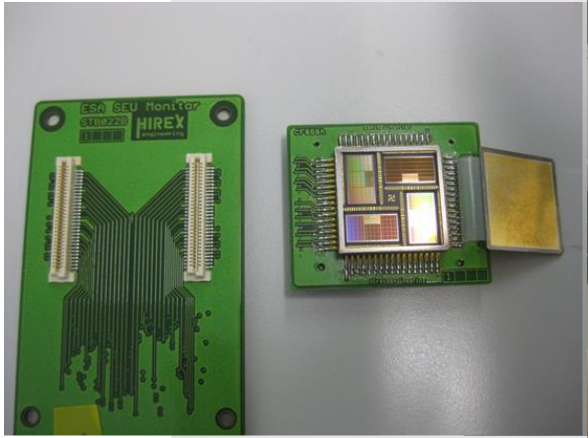


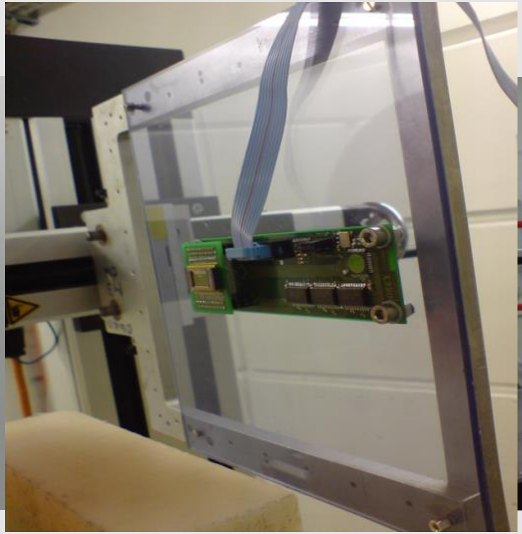


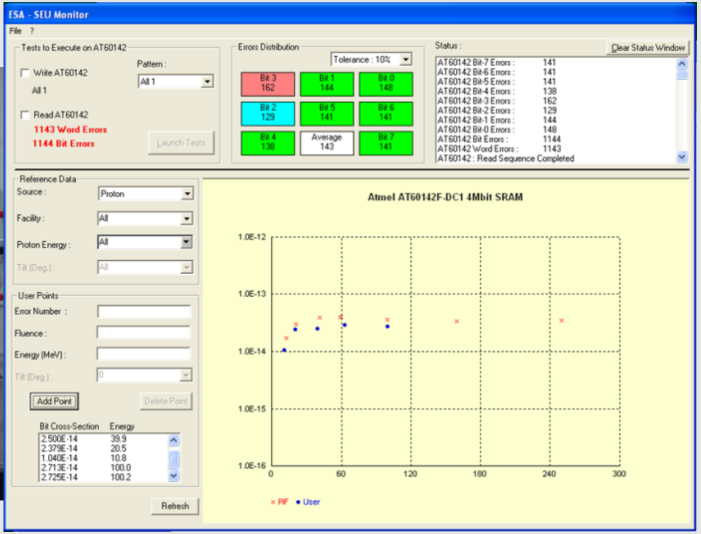


Verifications: ESA SEU Monitor

- Developed in 2005 by R.H. Sorensen (ESA-ESTEC) and HIREX
- Based on ATMEL AT60166F 16Mbit SRAM, version 2009
- PIF validation by CERN users once per month; many monitors used at different sides
- Easy comparison of measured and expected flux values

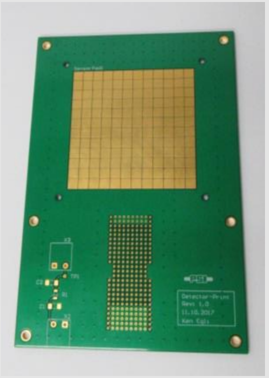


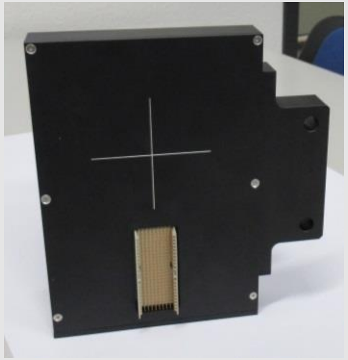


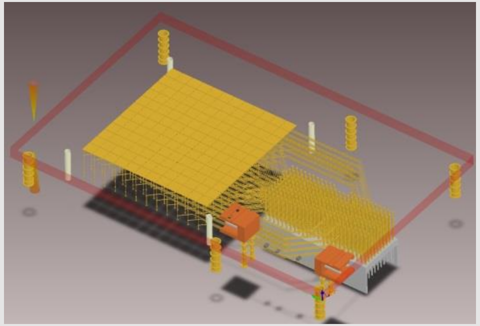


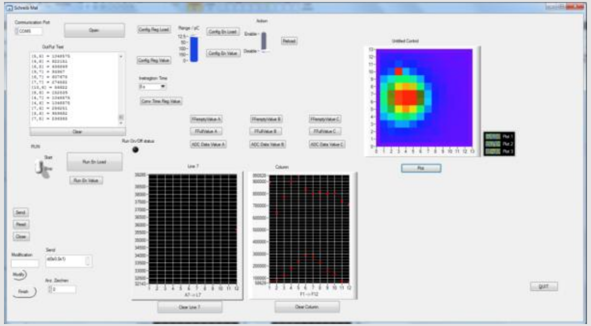
PIXCHA pixelated ionization chamber

- Standard ionization chamber components
- Easy data acquisition system
- Easy setup and operation
- Fast beam profiling – real time
- Very wide dynamic range
- New version this year









Example: cryogenic tests of SiGe transistors

SiGe technology:

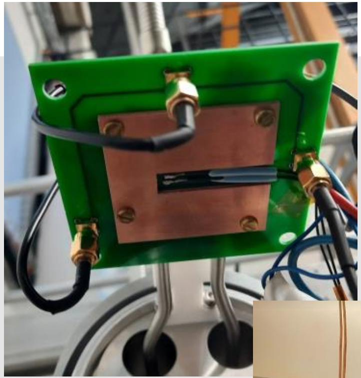
- Good radiation hardness (TID)
- Relatively simple production
- Relatively fast
- Wide operation temperature range
- No need for room temperatures at S/C

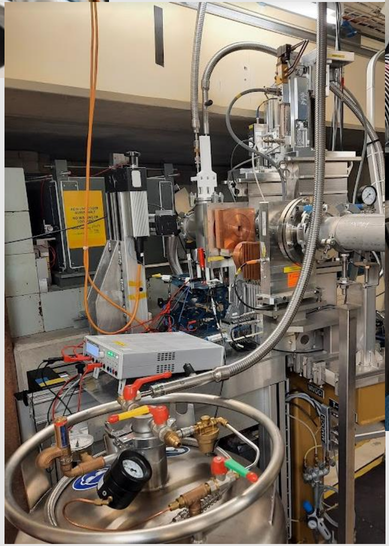
Test of transient events (SEU)

Comparison of cross section at room and LN2

Dedicated cryogenic setup

Active measurements





Operation and users 2022 I.

Shifts	**- 162**
Experiments	**- 84**
ESA related shifts	**~ 118**
ESA pool shifts	**~ 33**

Facility	Shifts	%
PROSCAN	148	91
EMON/PiM1/γ,e-	14	9
TOTAL	**162**	**100**

- More than 150 test days per year
- More than 150 visitors annually
- Users: EU, Switzerland, China and USA
- About 42 different institutions and companies
- Test teams from both industry and academia
- Biggest users are **ESA** and **CERN**

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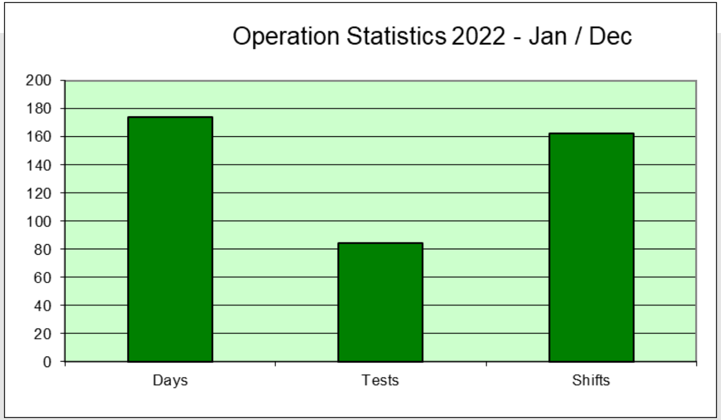
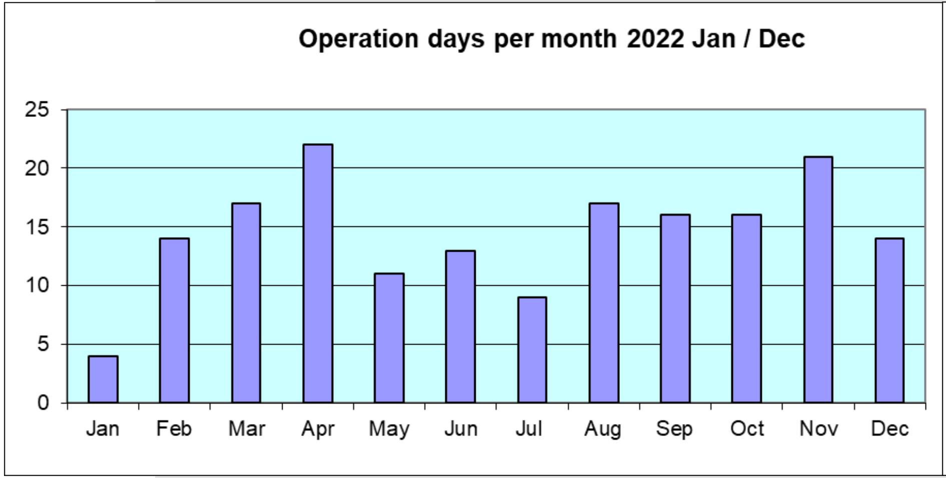
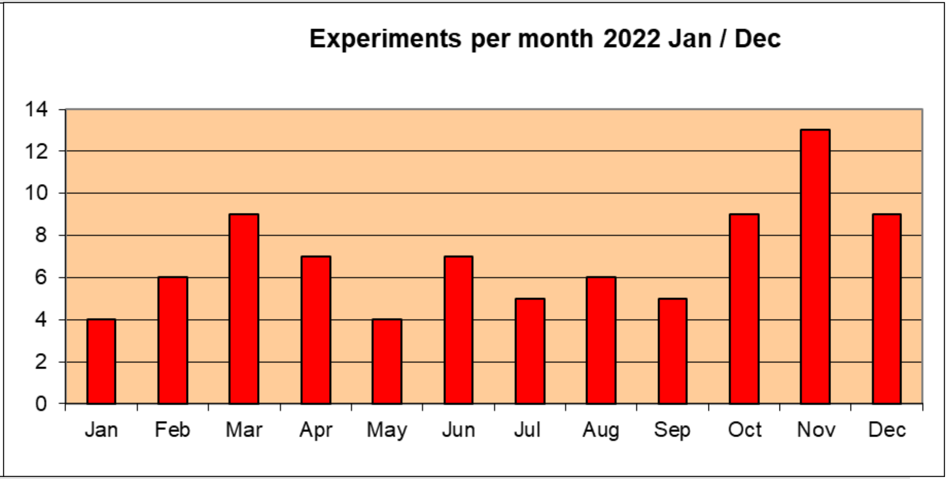
Operation and users 2022 II.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31		Days	Tests	Shifts
Jan																																Jan	4	4	5
Feb																																Feb	14	6	14
Mar																																Mar	17	9	17
Apr																																Apr	22	7	18.5
May																																May	11	4	10
Jun																																Jun	13	7	13
Jul																																Jul	9	5	8
Aug																																Aug	17	6	13
Sep																																Sep	16	5	14.5
Oct																																Oct	16	9	14
Nov																																Nov	21	13	23.5
Dec																																Dec	14	9	11.5
																																	174	**84**	**162**

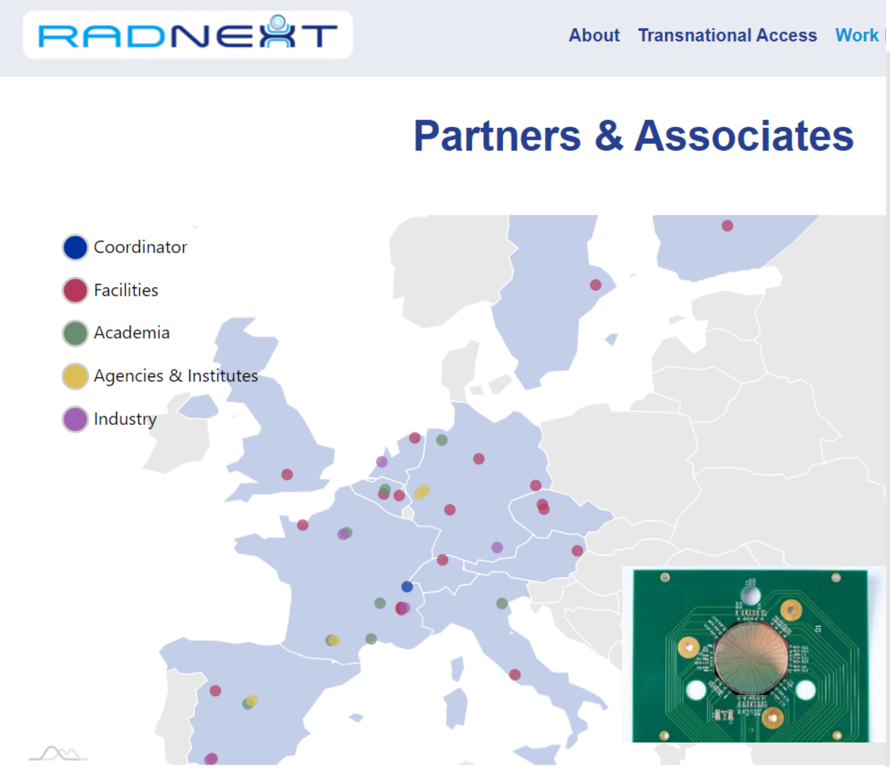
Operation and users 2022 III.





PIF team … operators …

Collaboration programs, future



- Long term contracts and collaborations:
  – ESA
  – CERN
- Collaborations with industry:
  – Thales Alenia CH: Radiation monitors RMUs
  – EFACEC/AIRBUS: Radiation monitor for JUICE
  – SE2S - PSI Spin-off
- Collaboration with Academia:
  – ETHZ: new semiconductors
  – CERN: RADNEXT transnational access
  – HSLU, NCBRS: space biology

Upcoming: European Space Deep Innovation Center at PiA by PSI

- **Cube and Nano-sat sub-systems**
- **Novel semiconductors**
- **Commercials off the shelf - COTS**
- **Radiation monitors, Space Weather**

Wir schaffen Wissen – heute für morgen

My thanks go to you

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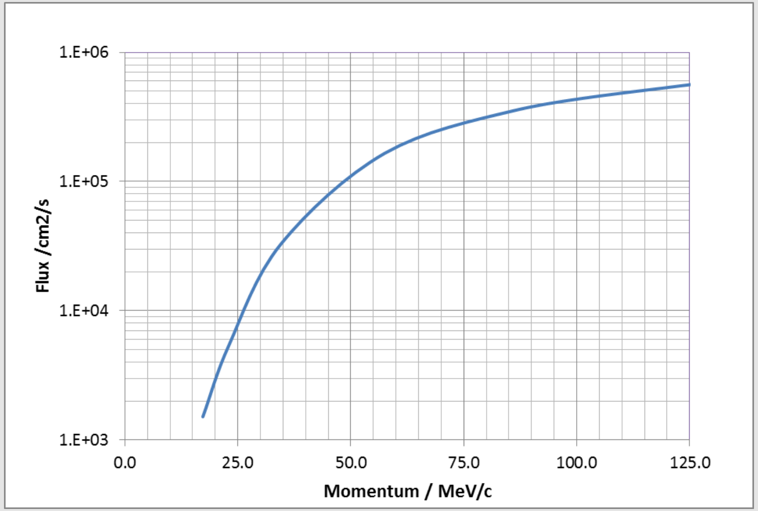
High energy electrons in piM1 II.

- Typical intensities: $2 \cdot 10^5 - 1 \cdot 10^7$ /s and fluxes: $2 \cdot 10^3 - 5 \cdot 10^5$ /cm²/s
- FWHM between 4 cm and 10 cm
- Well suited for studies of instrument shielding and calibration
- Too low fluxes for TID tests; other test areas studied

Electron beam parameters in piM1 area.

Momentum MeV/c	Intensity s/mA	Flux cm2/s/mA	FWHMx cm	FWHMy cm
17.3	1.16E+05	7.21E+02	10.4	13.2
23.0	3.28E+05	2.57E+03	9.0	12.9
34.5	1.16E+06	1.56E+04	6.6	9.6
57.5	3.08E+06	7.88E+04	5.2	6.6
86.3	5.13E+06	1.69E+05	4.2	5.1
115.0	5.18E+06	2.42E+05	4.4	4.3



Electron flux vs. momentum