PAUL SCHERRER INSTITUT

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

Applied Particle Physics - Irradiation Facilities for Components Testing at PSI

LTP Monday Seminar 25.06.2018

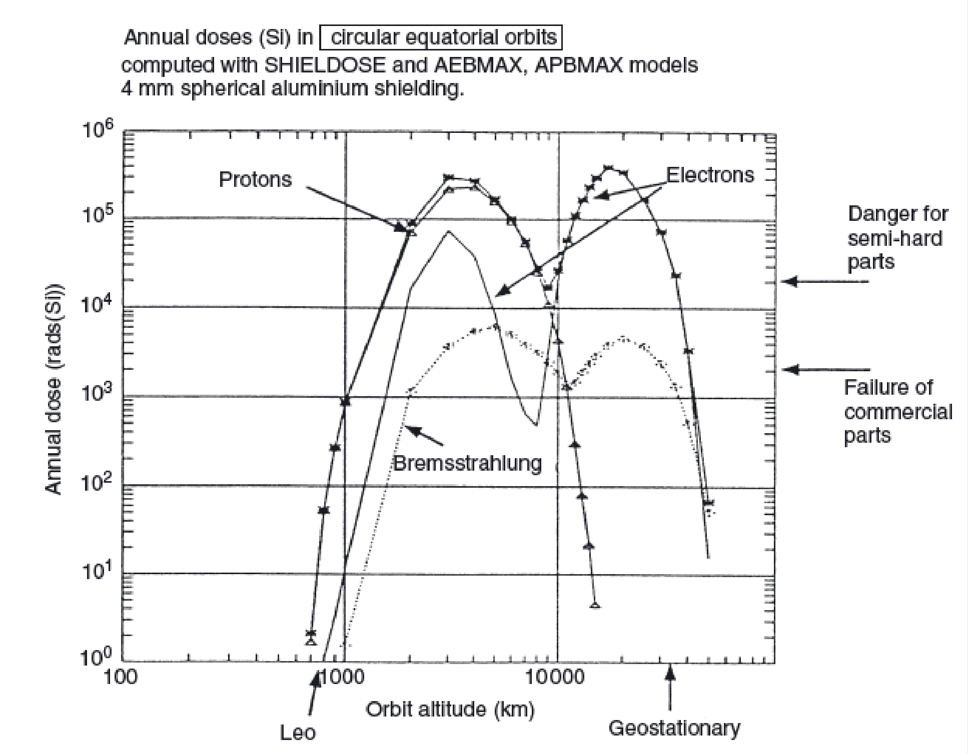
Outline

1. Spacecraft environments and radiation in space
    a. European Components Irradiation Facilities
    b. Why PSI and why protons? 1st latch-up in space
2. Radiation effects …general
3. Radiation hardness test definition
4. ESA test methods / radiation hardness characterization
5. Effects examples from two missions: Galileo and POLAR
6. Space radiation environment: solar, cosmic, trapped, Jovian
7. Models vs. reality / example from RHESSI
8. PSI exposure facilities for radiation effects
    a. Accelerators
    b. Protons PIF
    c. Electrons EMON
    d. Electrons piM1
9. Detection system and dosimetry
    a. Standard detector technology
    b. New developments / Propix II (m)
    c. PSI detectors for space RADEM (m)
10. Operation and users

Spacecraft environment

Spacecraft environment

- **Pre-operational and Operational**
- **Launch phase**
  - Vibration
  - Acoustics
  - Shock and acceleration
  - Thermal
  - Pressure
- **Operational**
  - **Solar radiation**
  - **Ionizing radiation**
  - **Charging**
  - Meteorites
  - Debris
  - Thermal
  - Earth orbit environment

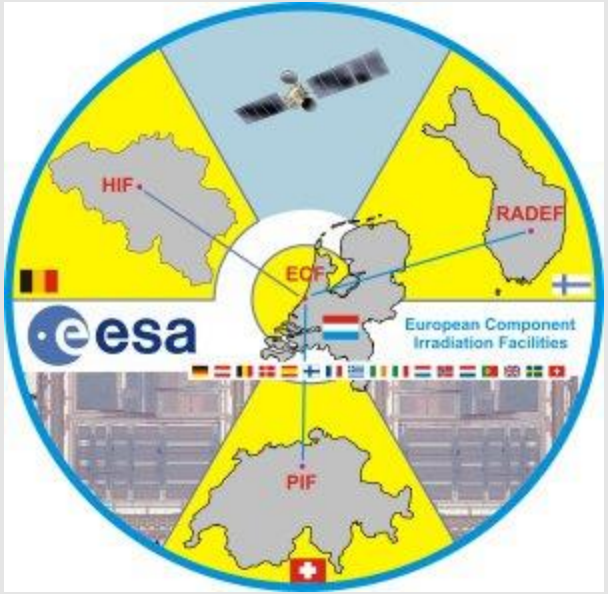


European Components Irradiation Facilities

ECIF for studies of radiation effects in lab

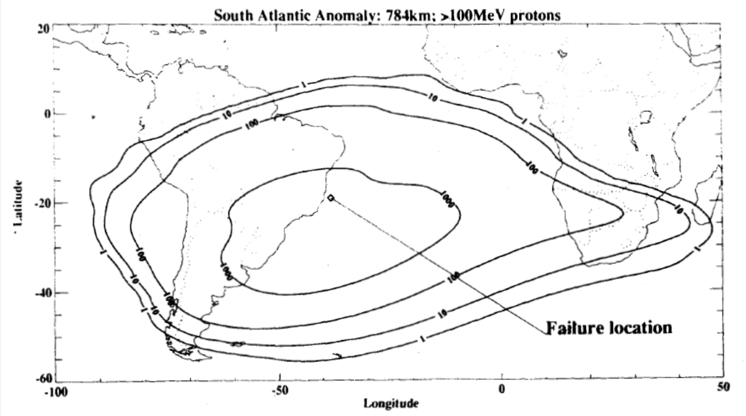
– HIF / Belgium
– RADEF / Finland
– PIF / Switzerland
– CASE / The Netherlands

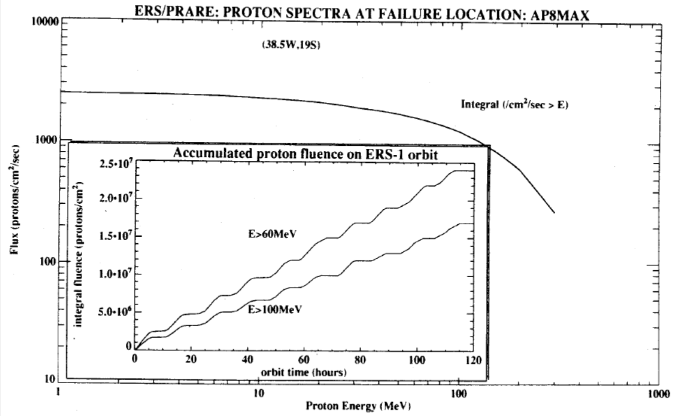
Other European Sites:
– *TSL / Uppsala / Sweden*
– *GANIL / France*
– *GSI, COSY / Germany*
– *AGOR / The Netherlands*
– *Catania*
– *…*



Why PSI, why protons? 1st Latch-up in space

- Earth Resource Satellite launched in July 1991 into 784 km orbit
- The Precision Range and Range Rate Equipment shuts down 5 days later
- Reason - 9W overcurrent lasting 32s; the instrument did not restart anymore
- Switch-off occurred at the South Atlantic Anomaly
- ESA, PSI (R. Henneck) and University of Stuttgart exposed PRARRE to protons at OPTIS
- System behavior confirmed and latch-up found in CMOS RAM (at F~$3\cdot10^7$ p/cm^2!)





Radiation effects … broad view

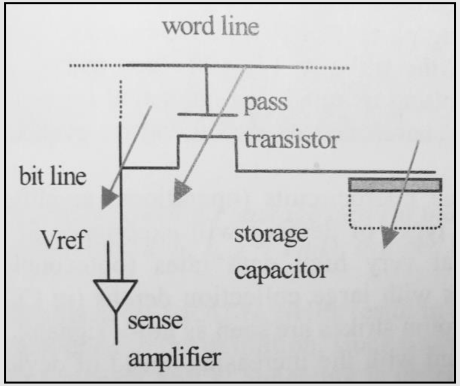
Relevant for tests at PSI

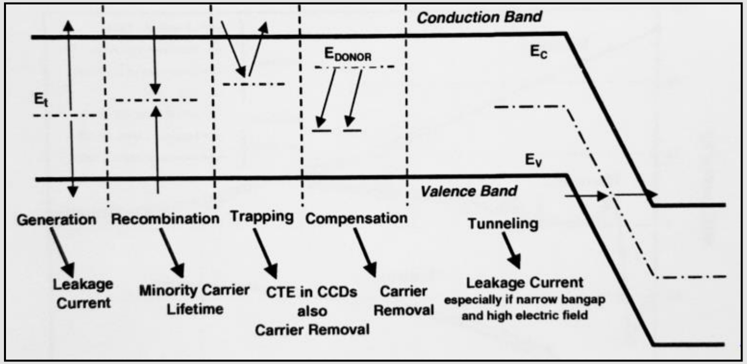
Single Event Effects **SEE**

- Mostly in nuclear processes
- Critical charge
- Sensitive volume

Displacement Damage **DD**

- Lifetime damage
- Carrier removal
- Mobility





PAUL SCHERRER INSTITUT PSI

Radiation hardness test definition

Radiation effect	Parameter	Test means
Electronic component degradation	Total ionising dose	Radioactive sources (e.g. ^{60}Co), particle beams: electron, proton
Material degradation	Total ionising dose	Radioactive sources (e.g. ^{60}Co), particle beams: electron, proton
Material degradation (bulk damage)	Non-ionising dose (NIEL)	Proton beams
CCD and sensor degradation	Non-ionising dose (NIEL)	Proton beams
Solar cell degradation	Non-ionising dose (NIEL) & *equivalent fluence*.	Proton beams (~ low energy)
Single Event Effects SEE SEU, MEU, SEL, SEFI, SET, SEB, SEGR, etc. .	LET spectra (ions), proton energy spectra, explicit SEU/L rate.	Heavy ion particle beams Proton particle beams
Sensor interference - background signals	Flux above energy threshold, explicit background rate.	Radioactive sources, particle (e.g. proton) beams
Internal Electrostatic Charging	Electron flux, fluence dielectric E-field.	Electron beams Discharge characterisation

ESA test methods

ESTEC - EUROPEAN SPACE RESEARCH AND TECHNOLOGY CENTRE

ECSS - EUROPEAN COOPERATION FOR SPACE STANDARDAZATION

- Standard documents
  - Radiation test specifications and procedures
    - **ECSS-Q-ST-70-06C Annex B**
  - Radiation test report
    - **ECSS-Q-ST-70-06C Annex C**
  - Request for radiation test
    - **ECSS-Q-ST-70-06C Annex A**
- Applicable documents
  - Single Event Effects Test Method and Guidelines
  - Total Dose Steady-state Irradiation Test Method
  - Radiation Design Handbook

Example-1 of effects in space – Galileo

Galileo - NASA mission to Jupiter

Launch 1989, operation 1995 – 2003

Most instruments affected by radiation

Displacement Damage:

- *Dark current*
- *Response uniformity*
- *Electronic chain degradation*
- *Sensor current consumption etc.*

Single Event Effects:

- *Upsets*
- *Transients*
- *Latch-ups*
- *Stacked bits etc.*

In the meantime things just … evaluated

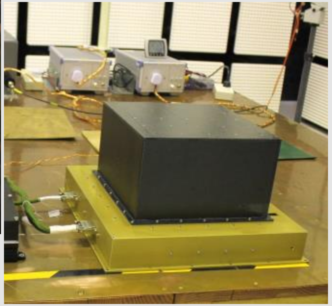
SYMPTOM	CAUSE	FIX
Spurious signals at slip rings.	+++,1A	Reprogram software to ignore signals
Camera returns white images.	+++,1A	Drop signal input to sensitive FET.
Infrared spectrometer (NIMS) memory resets.	+++,1B	Scheduled software reloads in radiation.
Instrument (EPD) memory resets.	+++,1C, 4C	Scheduled software reloads in radiation.
Quartz oscillator frequency changes.	+++,2A,3A	Receivers widen bandwidths.
Spin detector signal noise increase.	+++,2A	Reprogrammed to output a constant spin rate determined by other means.
Gyro electronics suffer signal bias.	+++,2B	Frequent characterization tests. Less use of gyros.
Star Scanner sees false stars, blinded.	+++,3A	Use bright stars.
Visible camera (SSI) image noise.	+++,3A	Adjacent pixel averaging.
Polarimeter (PPR) signal noise.	+++,3A,1C	Strip out "impossible" values from data set.
Infrared spectrometer (NIMS) signal noise.	+++,3A,1C	Hand removal of noise from data set.
Dust detector (DDS) signal noise.	+++,3A,1B	Instrument design allows noise/data discrimination.
Voltage controlled oscillator frequency jump.	++,1C, 2C	Pulse current to neutralize ion drift in electronic device.
Particle detector (EPD) sensitivity loss.	++,2B	Park detector behind nearby mass to provide shielding. Loss of channel in one case.
Spectrometer (UVS) grating failure.	++,2B	None - loss of instrument.
Photomultiplier tube (Star Scanner) gain loss.	++,2B	Use bright stars, adjust predicted intensities.
Camera (SSI) image compression failure.	++,2B	None - some forms of on-CCD compression lost.
S-band fr degradation in Io torus.	++,3B	De-weight data for navigation
Magnetometer processor lock-up.	+,1C, 4C	Scheduled power-cycles & memory reloads.
Voltage controlled oscillator frequency drift.	+,2C	Input frequency adjusted to VCO's new base frequency.
Dust detector sensitivity decrease.	+,2C	None
Analog to digital converter shift.	+,2C	None
CMOS Memory cell failures.	+,4C	Reprogram around failed cells.

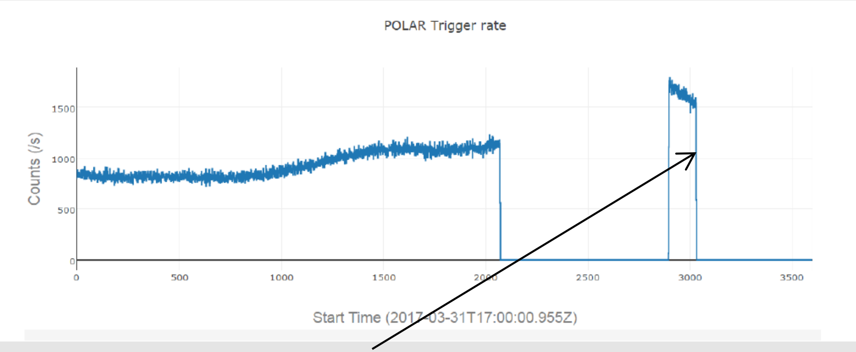
Example-2 of effects in space – POLAR

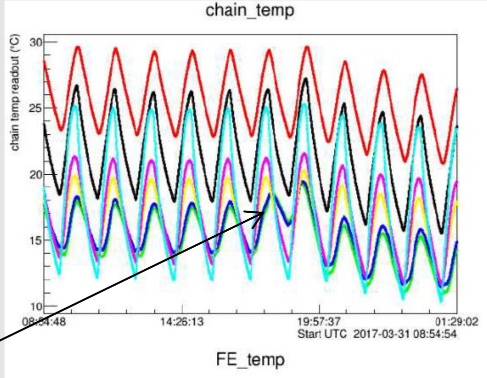
POLAR – novel hard X-ray polarimeter (CH-CN)

- Launched in Sep 2016 on Chinese TG2
- Goal - polarimetry of Gamma Ray Bursts (linked to GW)
- PSI electronics onboard: Frontends and Central Unit
- High Voltage unit lost on 31.03.2017 – catastrophic failure
- Location at SAA boarder
- Reasons unclear: charging, protons …

(see polar.psi.ch , POLAR PSI Data Center by Hualin Xiao)



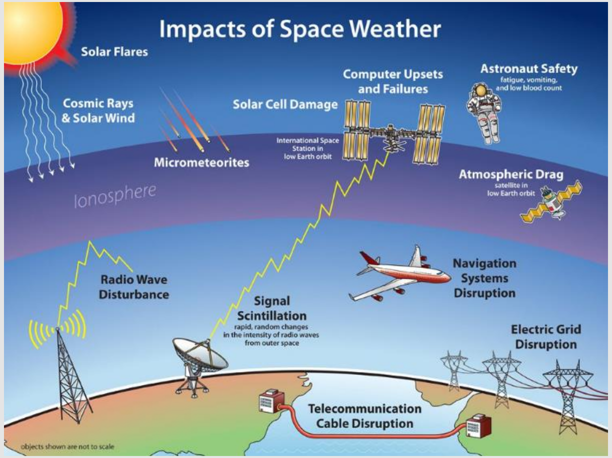




Sudden rate break with HV loss and temperature rise

Space radiation environment

Real, dynamic, wide-ranging and costly



Solar Events

- Solar energetic particles
- Geo-storms; particle injections

Trapped Radiation

- Proton belt
- Electron belts
- South Atlantic Anomaly
- Human made

Cosmic Rays

- Galactic
- Anomalous

Jupiter Radiation Environment

Hot Plasma

Testing on ground is indispensable

Solar events

Solar flares

Electron rich

Lasting hours

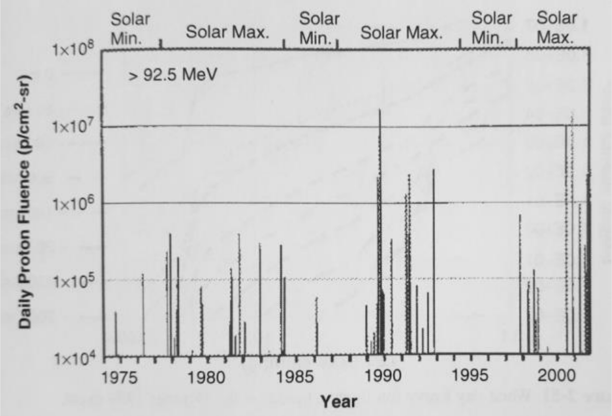
Coronal mass ejections

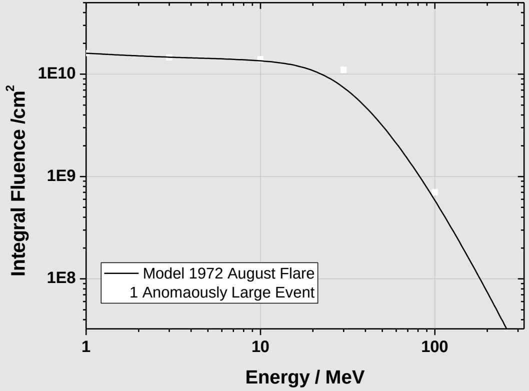
Proton rich

Lasting days

Solar energetic particles can cause doses of even ~10 krad

See e.g. srem.web.psi.ch for observations of PSI designed ESA Standard Radiation Environment Monitor SREM





Cosmic rays

Galactic Cosmic Rays GCR

Low intensities

High penetration

High energies > GeV/n

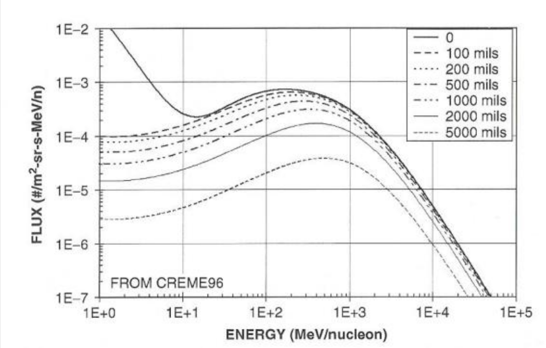
High LET > 10^4 MeV/g/cm^2

Anomalous Cosmic Rays ACR

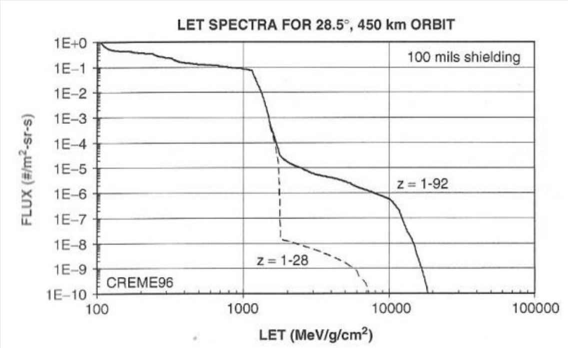
Reaching tens MeV/n

Weakly ionized

- GCR mainly responsible for Single Events Effects
- In longer missions also for Displacement Damage and Total Ionizing Dose effects
- ACR effects often negligible



GRC iron spectra behind Al-shielding

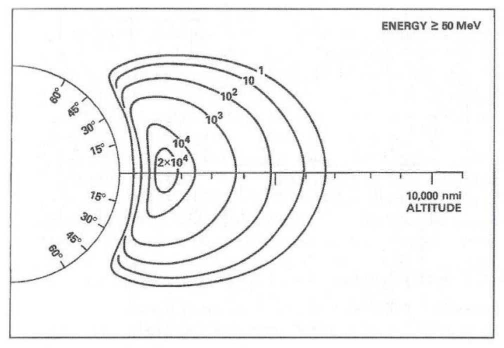


GRC LET spectra with two different ranges of elements

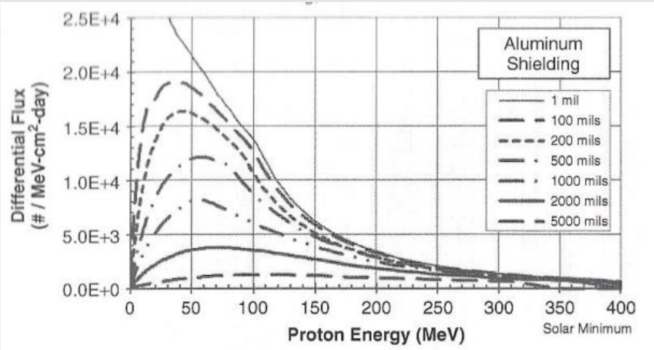
Trapped protons I.

Proton Radiation Belt and South Atlantic Anomaly SAA

- Partially responsible for Single Event Effects
- Major agent for Displacement Damage
- Energies above hundred MeV
- Shielding partly effective
- Typical doses ~ 10 rad/day
- Peak energies after shielding ~50-60 MeV
- Proton belt is relatively stable



AP8MIN omnidirectional proton flux (p/cm²/s)

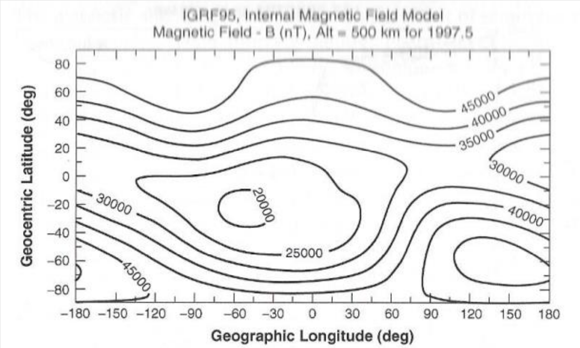


Proton spectra behind Al-shielding (97° inc., 500 km)

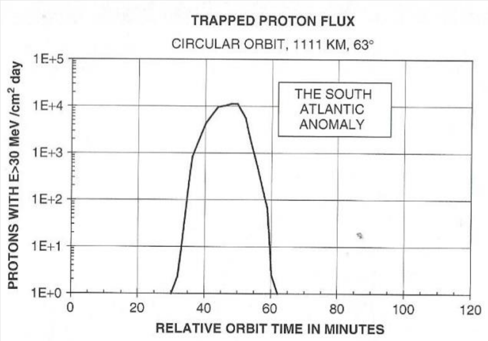
Trapped protons II.

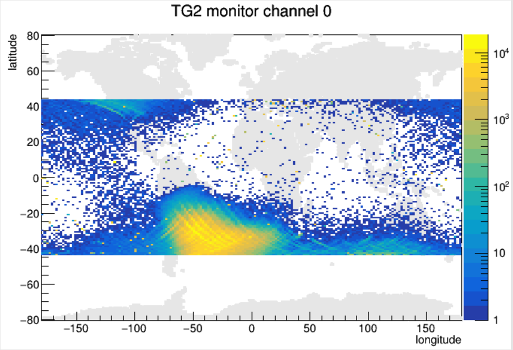
Proton Radiation Belt and South Atlantic Anomaly SAA

- SAA dominates at low altitudes and inclinations
- Caused by offset and tilt between geo-magnetic axis and Earth rotation axis
- The belt is intruding to lower altitudes
- Both protons and electrons are present
- *ISS also crosses SAA (fast passage ~20%)*



Magnetic field contours for 500 km altitude





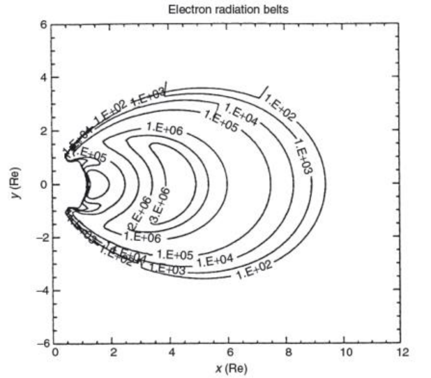
TG2 Radiation monitor rate map with SAA (6.3.2017)

Trapped electrons

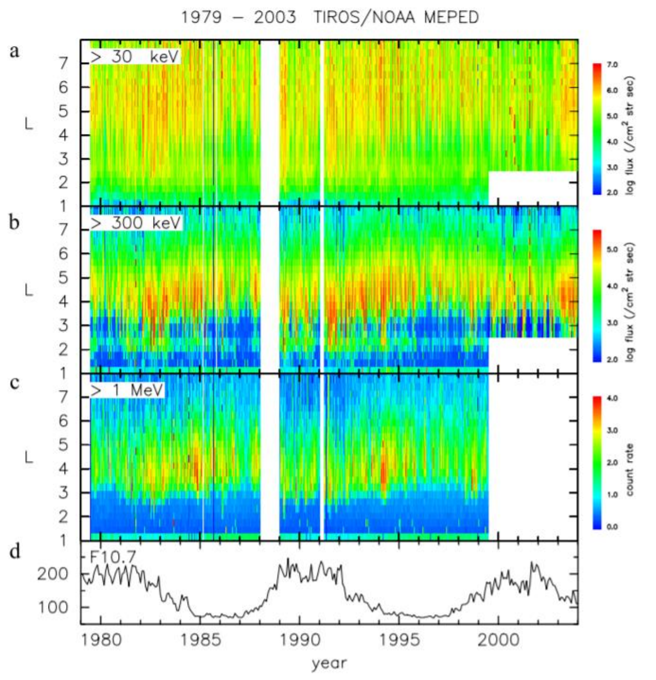
Radiation Belts:

inner, outer and SAA

- Major agent for total ionizing dose
- Energies up to few MeV
- Highly dynamic, sensitive to storms
- Extends behind GEO orbit
- Shielding effective (local, thin plates)
- Typical doses ~ 10 rad/day
- Causes bremsstrahlung



AE8 model omnidirectional electron flux (e/cm^2/s)

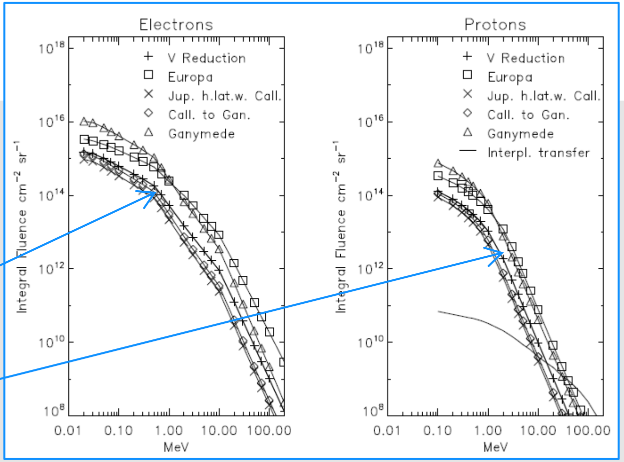


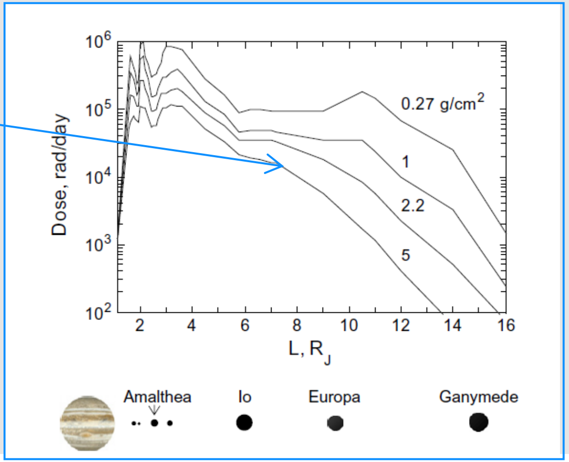
Electrons flux data from NOAA satellites (E>1MeV)

Jupiter radiation environment

Challenge for satellites and subsystems

- Intense radiation belts
- Highly variable environment
- Very high fluxes / doses
- Examples for ESA JUICE mission (GIRE model)
  - F_e ~ 10^{14}-10^{15}/cm^2/sr (E>300 keV)
  - F_p ~ 10^{11}-10^{12}/cm^2/sr (E>5 MeV)
  - Dose rate ~ 10^4 – 10^5 rad/day
- High energy tails (> 100 MeV)
- Presence of heavier elements
- Strong magnetic fields
- *Not well studied yet*
- *PSI participates in JUICE radiation monitor*





Models vs. reality / example from RHESSI

ECSS Standard models

- AE8 trapped electrons
- AP8 trapped proton

- Static, isotropic models based on limited dataset for solar minimum and maximum

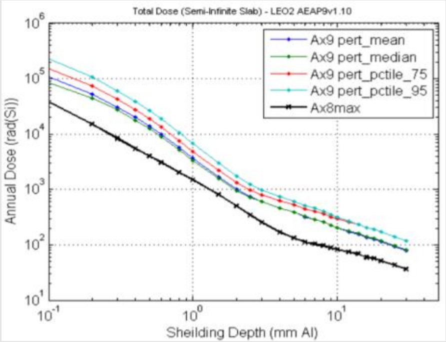
- Not suited for low altitude and inclination

ESA estimated accuracy at factor of 2-3

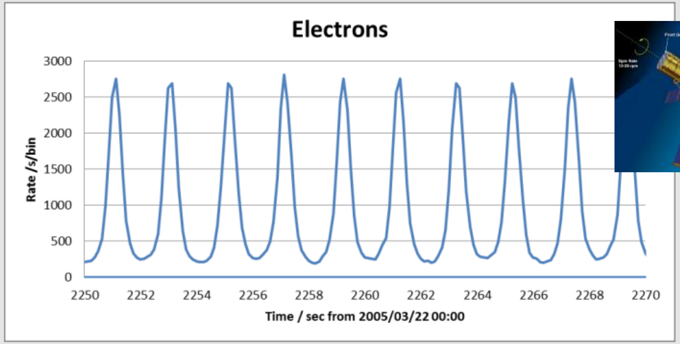
New development – AE9 and AP9

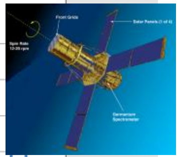
- with uncertainties and errors in data
- based on probabilities with Monte Carlo

Tend to predict higher fluxes than AP8/AE8



Comparison of AX8 and AX9 models for LEO orbit



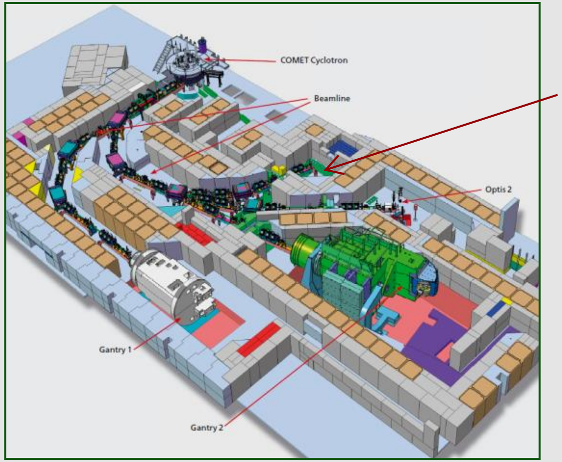


Electron rate in RHESSI monitor vs. rotation angle

PSI exposure facilities for radiation effect studies

- Proton Irradiation Facility operates continuously since 1992
- Connected to COMET cyclotron of the Proton Therapy Center
- Priorities given by patient exposure plan
- Other exposure sides and particles are also utilized:
  - piM1 secondary beam area with electrons, pions and protons
  - Electron mono-chromator with mono-energetic electrons from beta sources

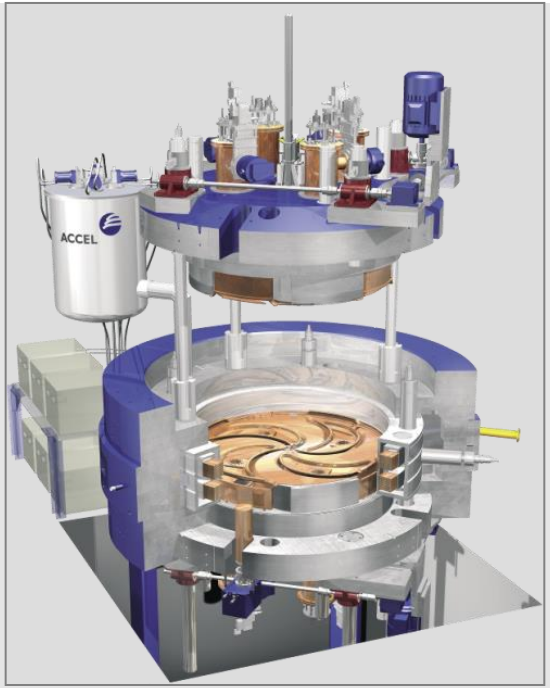
- Main functions:
  - User-lab for radiation effects studies in electronics
  - Realistic simulator of space radiation environment
  - Source of mono-energetic particles for rad-tests
  - Calibration station for monitors and detectors
  - Radiation qualification for space technologies



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



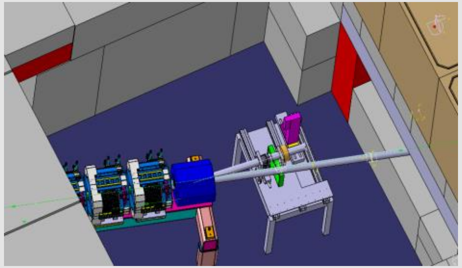
Proton Irradiation Facility

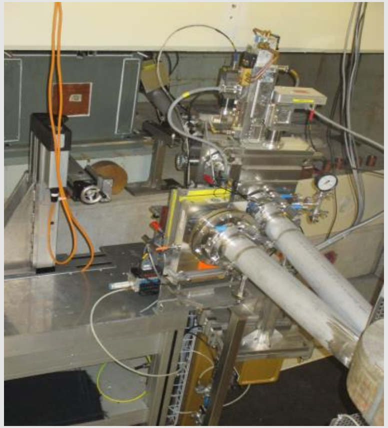
- Initial energies: 230, 200, 150, 100, 74 MeV
- Energies after degrader: 230 MeV to 6 MeV

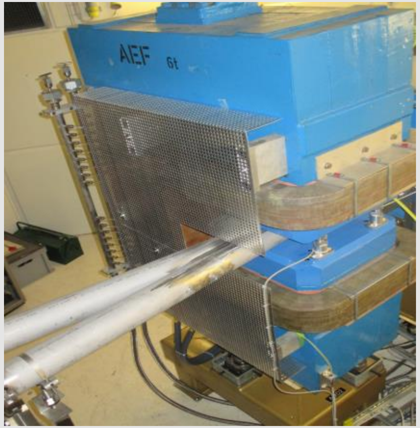
- Max intensity: 2 nA (E>200) – 10 nA (E<100)
- Flux range $10^2 – 2 \cdot 10^8$ p/sec/cm^2

- Profiles Gaussian-like: FWHM 9 cm
- Max beam diameter of 90 mm
- Options: focused (6 mm ϕ) or flat beam

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



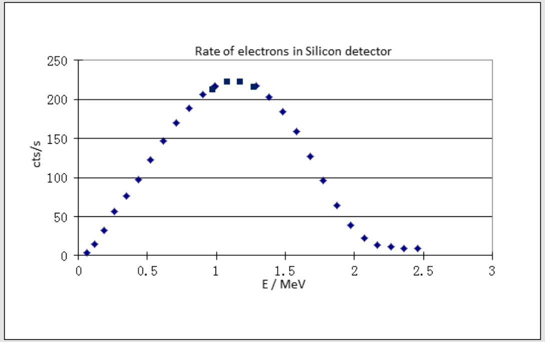




Electron monochromator

- Simple bending magnet and strong electron source in large vacuum chamber
- Flux control system constructed; Si-detector with dedicated DAQ
- XY-table with remote sample control; support with TV cameras and illumination
- Two units:
  - PSI
  - ESTEC

Si-sensor and DAQ system (left)
Monochromator chamber (right)

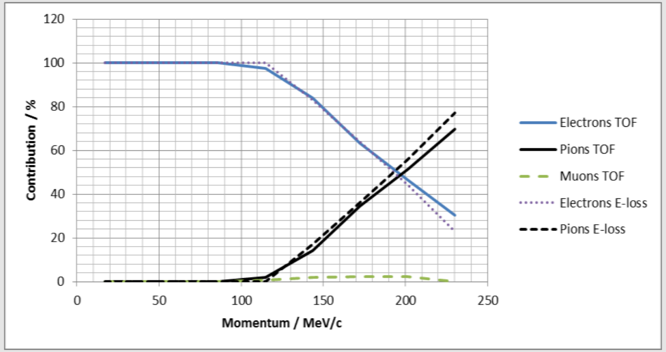


Intensity curve for ^{90}Sr source; Si-detector 2 cm from beam exit

High energy electrons in piM1 I.

- Adapting 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

piM1 Test area: beam exit and PIP-JUICE setup



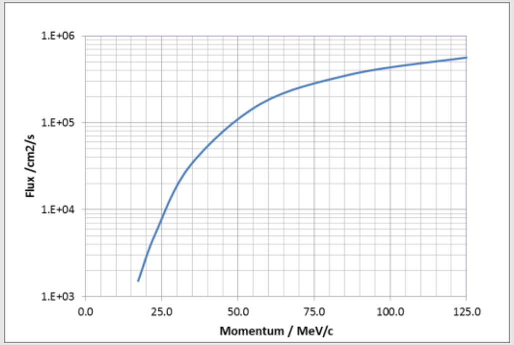
Beam contamination level as function of momentum

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.

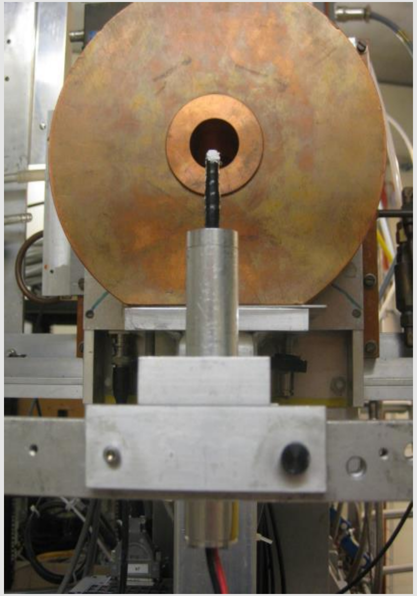
Momentum MeV/c	Intensity s/mA	Flux cm2/s/mA	FWHMx cm	FWHMy cm
17.3	1.16E+05	7.21E+02	10.4	13.2
23.0	3.28E+05	2.57E+03	9.0	12.9
34.5	1.16E+06	1.56E+04	6.6	9.6
57.5	3.08E+06	7.88E+04	5.2	6.6
86.3	5.13E+06	1.69E+05	4.2	5.1
115.0	5.18E+06	2.42E+05	4.4	4.3

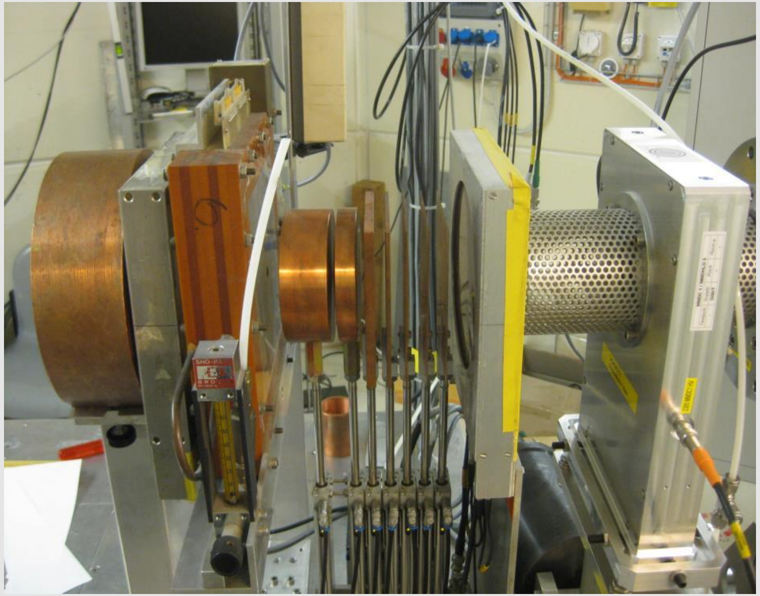


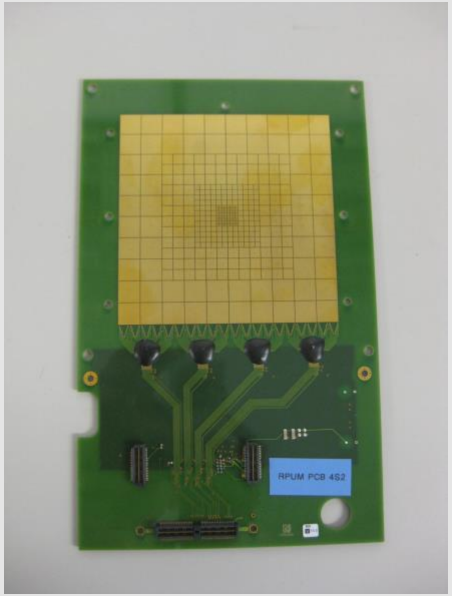
Electron flux vs. momentum

Detector technology and dosimetry

- Plastic or Silicon detector to calibrate the beam
- Real time dosimetry uses two ionization chambers IC
- Profiles are measured with pixelated IC, plastic scans or luminescence foils

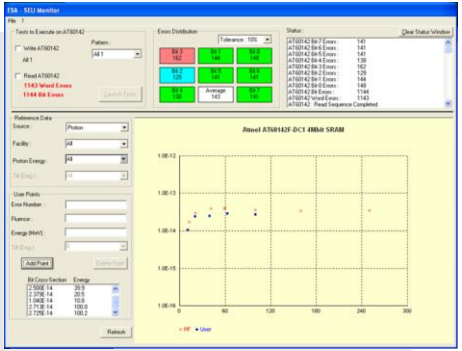


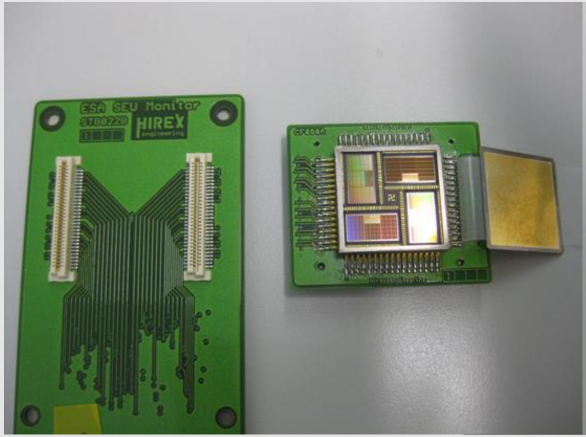




Dosimetry I. ESA SEU Monitor

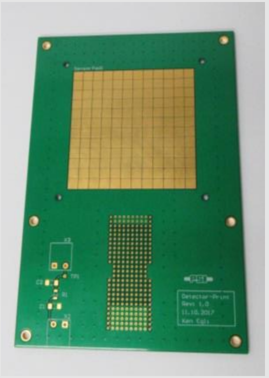
- Developed in 2005 by R.H. Sorensen (ESA-ESTEC) and HIREX
- Based on ATMEL AT60166F 16Mbit SRAM, version 2009
- Carefully calibrated at ESA facilities; tens of units at different test sites
- Easy comparison of measured and expected flux values

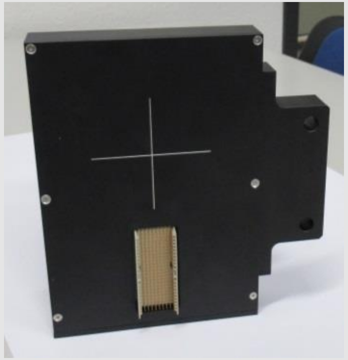


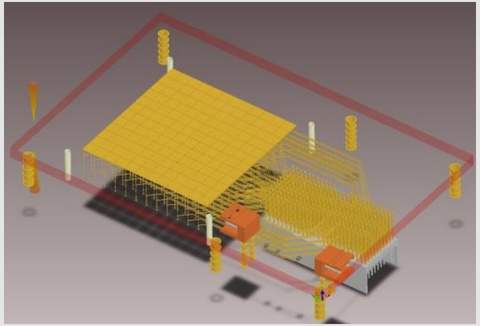


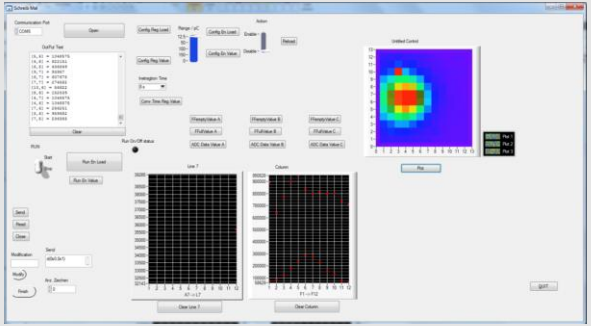
Dosimetry II. new PIF pixel ionization chamber

- Standard ionization chamber components
- Sensitive, improved readout electronics
- Easy data acquisition system
- Easy setup and operation
- Fast beam profiling
- Very wide dynamic range

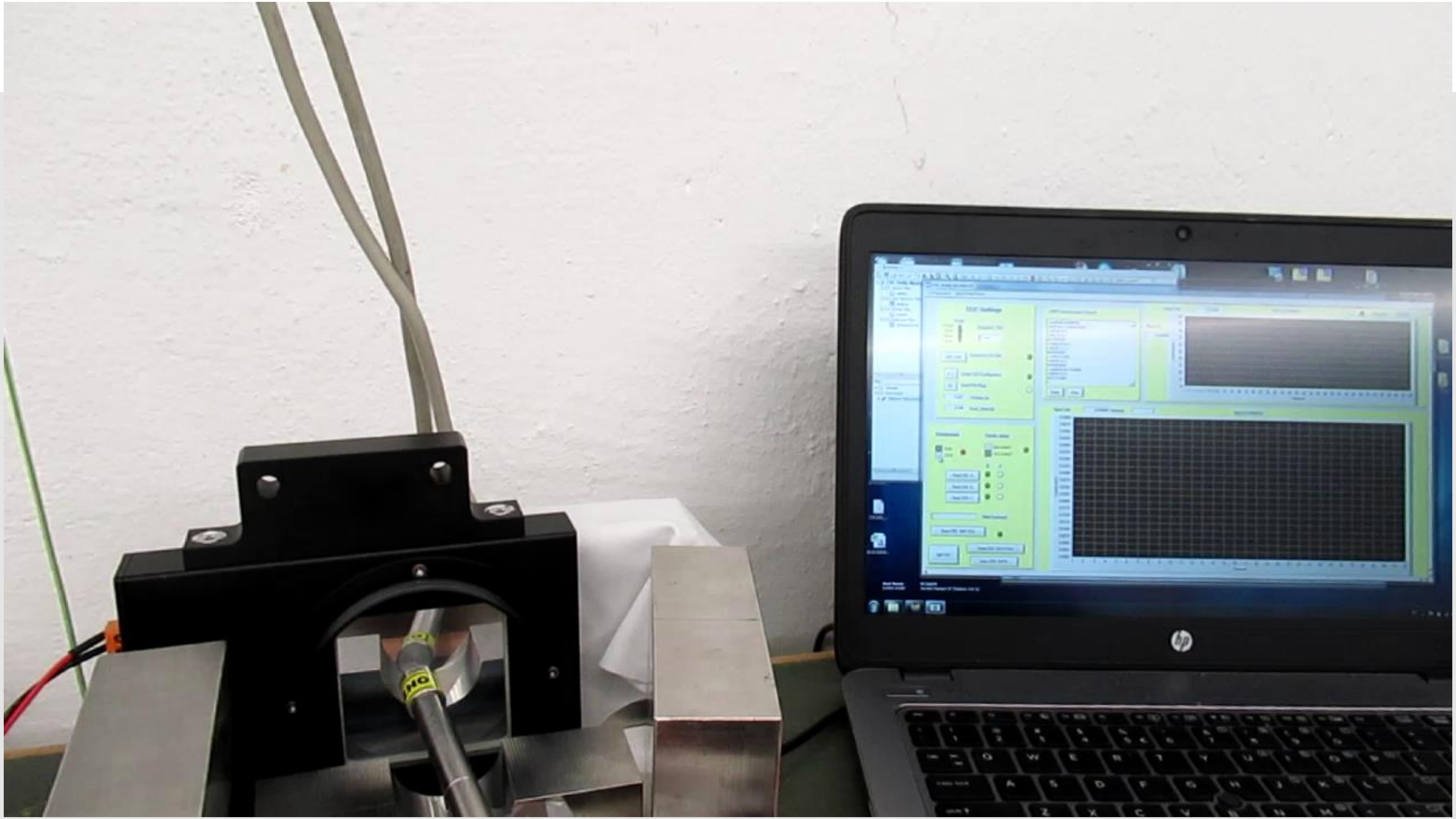








Dosimetry III. new PIF pixel ionization chamber



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Dosimetry II. new PIF pixel ionization chamber

- Standard ionization chamber components
- Sensitive, improved readout electronics
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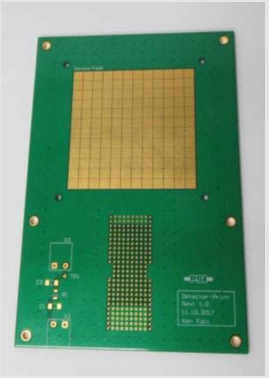
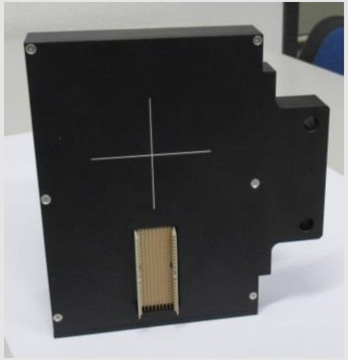
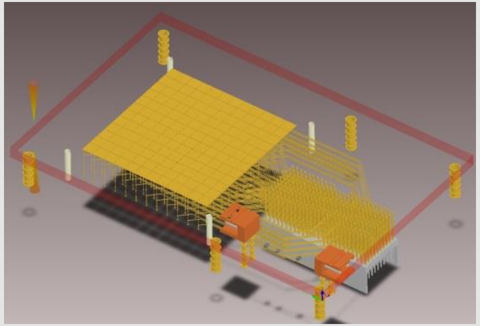
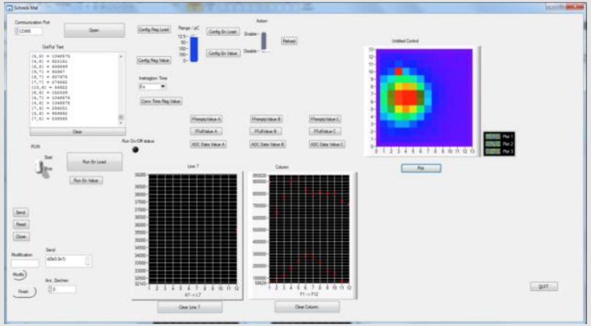








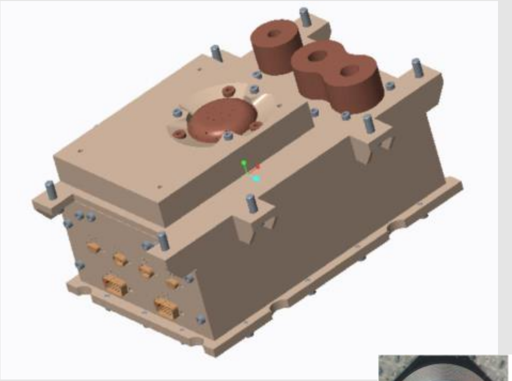
Detector technology I. RADEM for ESA JUICE

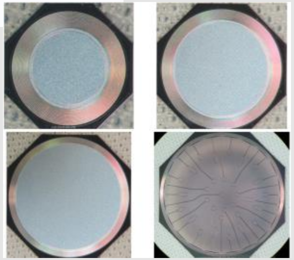
Radiation Hard Electron Monitor RADEM

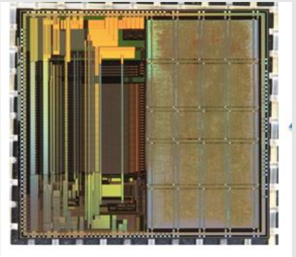
Electron energy range	0.3 - 40 MeV
Proton energy range	5 - 250 MeV
Energy resolution	8 log bins for e and p
Peak flux	10^9 /cm^{2}s^1
Ion sensitivity	LET 0.1-10 MeV/(mg/cm^2)
Directionality	31 directions; $\Delta\Theta=\pm75°$
Mass; Volume	~ 4 kg; 1000 cm^3
Power; Temperature	~ 4 W; -30/+50 ° C
Lifetime	11 years
Dedicated readout ASIC	VATA466

RADEM EM currently at PSI for particle tests

Final delivery – December 2019







Detector technology II. RADEM for ESA JUICE

Detector technology II. RADEM for ESA JUICE

efacec PAUL SCHERRER INSTITUT PSI LIP ideas Integrated Detector Electronics AS

- Structure integration
- Propulsion integration
- Harness integration
- MAG off-line pre-assembly
- Optical bench off-line pre-assembly
- Hardware units mechanical and electrical integration
- Walls mounting
- External units mounting
- Optical bench coupling
- MAG boom coupling
- HGA integration
- MLI installation
- Solar generator integration

RIME antenna
PEP/NU
PEP/JENI
RADEM
RIME/Matching network
SAS +Z

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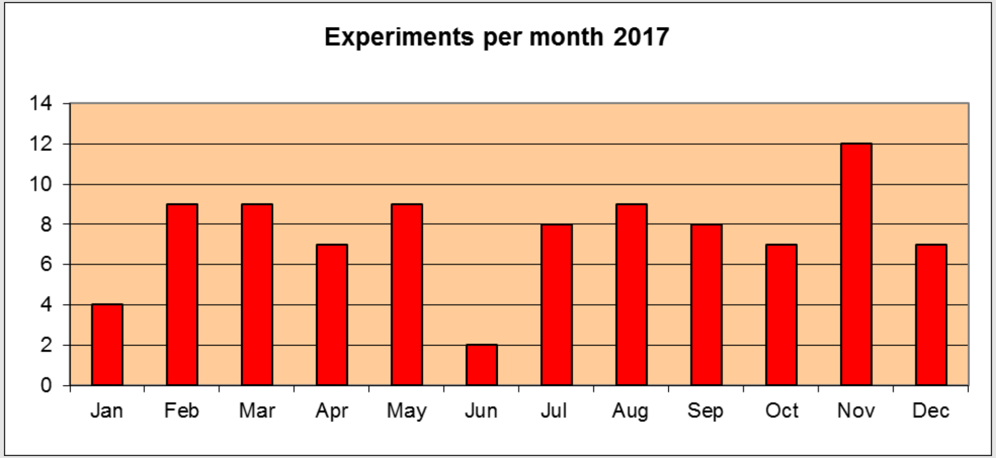
Operation and users I.

- Operation: weekends and nights; usually 2-3weekends/month
- Flexible, user-specific test arrangement
- Fast, uncomplicated set-up and operation
- Automated irradiations
- Standard sample frame
  (as at HIF, RADEF and Brookhaven)
- Irradiation usually in air
- Typical laboratory apparatus available
  (also vacuum chambers)

Statistics for 2017

Shifts	> 200
Number of tests	- 91
Institutions	- 29
Users	- 160
ESA related shifts	- 142
ESA pool shift	- 30

Operation and users II.



Nr	Institution	Project	Days	Start	Stop	Shifts	ESA Project	ESA Pool
1	PSI	Maintenance services of the proton and electron facility	3	18.1	20.1	3	Y	N
2	PSI	Test of beam setup and beams after winter shutdown	2	22.1	23.1	1.5	Y	Y
3	PSI	Maintenance services of the electron facility	1	22.1	22.1	1.5	Y	N
4	E2V	DD and TID tests of new CCDS	2	29.1	30.1	1	Y	N
5	Spacetech	Tests of components for MERLIN mission / TID and DD	2	3.2	4.2	2	Y	N
6	PSI	Test and operation of new camera	2	2.2	3.2	1	Y	Y
7	ESA	Test of OpAmps and transients	2	4.2	5.2	3	Y	Y
8	E2V	Various optical sensors exposures	2	10.2	11.2	1.5	Y	N
9	PSI-EFACEC-LIP	Measurements of active area of the RADEM Directionality Sensor	1	11.2	11.2	2	Y	N
10	Open University	Exposure and tests of optical sensors from E2V	1	12.2	12.2	2	Y	N
11	CERN	Beamline dosimetry electronics	3	16.2	18.2	5	N	N
12	E2V	Irradiations of CCDs	2	24.2	25.2	2	Y	N
13	Haute-Ecole Arc	Irradiations of CubeSat components	2	25.2	26.2	2	Y	N
14	ESA, TRAD	Tests of various SEE components	2	3.3	4.3	3	Y	Y
15	Thales-Alenia	Test and calibration of NGRM EM / noise, thresholds, responses	3	1.3	4.3	3	Y	N
16	Thales-Alenia	Test and calibration of NGRM EM/ angles, area and deadtime	2	5.3	6.3	2	Y	N
17	ETHZ	testing of NEO-M8T GNSS receiver	1	15.3	15.3	2	Y	N
18	E2V	Exposure and tests of optical sensors from E2V	1	18.3	18.3	2	Y	N
19	CERN	Beamline dosimetry electronics	2	25.3	26.3	4	N	N
20	EFACEC-PSI-LIP	Characterization of RADE/JUICE diodes / area, sensitivity	2	1.3	2.3	2	Y	N
21	PSI-EFACEC-LIP	Tests of active area of DD sensor (signal line contribution) / RADEM	1	22.3	22.3	2	Y	N
22	Thales-Alenia	Test and calibration of NGRM EM /with electrons	1	23.3	23.3	2	Y	N
23	EASII	Tests of various Radio Frequency components SEE/SET sensitivity	2	1.4	2.4	2	N	N
24	Tsinghue University, PSI	TID/ DD characterization of CASCA ASIC	2	6.4	7.4	1.5	N	N
25	Thales-Alenia	Calibration of NGRM EM/ accurate deadtime tests	2	7.4	8.4	2	Y	N
26	CERN	Beamline dosimetry electronics	2	22.4	23.4	4	N	N
27	ESA, Uni Montpellier, ESCC, JPL	Tests of various CubeSat components	1	28.4	28.4	3	Y	Y
28	E2V	Optical devices for Flex project	1	30.4	30.4	1	Y	N
29	PSI, ESCC and Uni Montpellier	Characterization of beam / retest of beam settings	1	30.4	30.4	1	Y	N
30	PSI	Test of proton beams at 350 and 372 MeV/c at PiM1 area	1	10.5	10.5	1	Y	Y
31	Tsinghue University, PSI	Beam optimization for CASCA ASIC SEE tests at piM1	1	21.5	21.5	1	N	N
32	E2V	Tests of optical sensors at PiM1	2	22.5	23.5	3	Y	N
33	Tsinghue University, PSI	SEE tests of the CASCA ASIC at PiM1	2	23.5	24.5	3	N	N
34	PSI	Test of electron beams between 20 and 350 MeV/c at PiM1	1	24.5	24.5	2	Y	Y
35	PSI-EFACEC-LIP	Proton tests of RADEM BB DD with ASIC VATA466 at PiM1	2	25.5	26.5	2	Y	N
36	PSI-EFACEC-LIP	Electron test of RADEM BB DD with ASIC VATA466 at PiM1	1	27.5	27.5	1.5	Y	N
37	PSI-EFACEC-LIP	RADEM BB DD ASIC and detector test with electrons from EMON	2	28.5	31.5	3	Y	N
38	Thales-Alenia	NGRM EQM, test of electron discrimination in EDSS and SDSS	2	29.5	30.5	3	Y	N
39	PSI-EFACEC-LIP	RADEM BB DD ASIC and detector test with electrons from EMON	2	1.6	2.6	2	Y	N
40	PSI	Beam tests and verification of system after upgrade	2	28.6	30.6	2	Y	Y
41	Tshinghua University / PSI	Test of cAScA ASIc	2	1.7	2.7	2	N	N
42	ESA ESTEC	Tests of optical transceivers	3	7.7	9.7	4.5	Y	Y
43	CERN	Various dosimetry electronics tests	3	14.7	16.7	5	N	N
44	EASII	Test of various IC	2	21.7	22.7	2	N	N
45	PSI/ PIF	Software and hardware optyimization fo rdosimetry	1	22.7	22.7	1	Y	Y
46	EASII	Test of various IC	1	23.7	23.7	2	N	N
47	PSI/ PIF	Optimization of beam dosimetry and camera installation	1	28.7	28.7	1	Y	Y
48	PSI / LIP / EFACEC	RADEM EM tests of SI-diodes energy resolution	3	10.7	12.7	3	Y	N
49	PSI	piM1 tests of electron beams	2	25.8	28.8	3	N	N
50	Xinjiang Institute of CAS	Xinjiang Institute of CAS	3	26.8	28.8	1.5	N	N
51	Tsinghua Universit / PSI	Further tests of CASCA ASIC sensitivity to neutrons	1	27.8	27.8	1.5	N	N
52	Xinjiang Institute of CAS	Xinjiang Institute of CAS / continuation	1	28.8	28.8	1.5	N	N
53	PSI / LIP / EFACEC	RADEM FM diodes electronic resolution tests	1	2.8	2.8	1.5	Y	N
54	PSI / LIP / EFACEC	RADEM FM diodes electronic resolution tests	1	4.8	4.8	1.5	Y	N
55	PSI / LIP / EFACEC	RADEM FM diodes electronic resolution tests	2	17.8	18.8	2.5	Y	N
56	PSI / LIP / EFACEC	RADEM FM diodes electronic resolution tests	1	28.8	28.8	1.5	Y	N
57	PSI	Replacement of IC chamber and new Plastic detector tests	1	23.8	23.8	1	Y	Y
58	INTA	Tests of microcontrollers	2	1.9	2.9	2	Y	N
59	PSI	Electron beam tests at PiM1	2	1.9	5.9	2	N	N
60	PSI	Test of various optical sensors	4	13.9	16.9	4	N	N
61	SkyLab	Test of ProASIC3 FPGA	1	16.9	16.9	2	Y	N
62	AIRBUS	Test of transient events in flash memories	1	30.9	30.9	2	Y	N
63	PSI / LIP / EFACEC	RADEM FM diodes electronic resolution re-tests	2	6.9	8.9	2	Y	N
64	PSI / LIP / EFACEC	RADEM FM diodes electronic resolution re-tests (3 mm diam)	1	11.9	11.9	1.5	Y	N
65	PSI / LIP / EFACEC	RADEM FM Si-diodees recheck and retest of electronic resolution	2	28.9	29.9	2	Y	N
66	AIRBUS	Radiation characterization of flash memories	2	1.10	2.10	2	Y	N
67	EASII	Test of various components	3	6.10	8.10	4	Y	N
68	E2V-Teledyne	DD and TID tests of new CCDS	2	8.10	9.10	2	Y	N
69	TRAD	Radiation characterization of flash memories	3	14.10	16.10	6	Y	N
70	PSI	Tests of SI-PMTs	1	28.10	28.10	1	N	N
71	PSI	Beam optimization and calibration for RADEM / JUICE	1	29.10	29.10	1	Y	N
72	EFACEC-PSI-LIP	First calibration of RADEM EM	2	30.10	31.10	3	Y	N
73	Seibersdorf Lab	TPC and absorbers tests	2	3.11	4.11	2.5	Y	Y
74	HIREX	Test of various components for ESA projects	3	4.11	6.11	4.5	Y	Y
75	E2V-Teledyne	Test of various optical sensors	2	9.11	10.11	2	Y	N
76	CERN	Test of various parts for beam line dosimetry	2	10.11	11.11	4	N	N
77	PSI	Test of new SW and Plastic deetector automated beam scanner	2	17.11	18.11	2	Y	N
78	PSI	Beam pre-calibration for EASII	1	18.11	18.11	0.5	Y	N
79	ESA / NANOEXPLORE	Test of BRAVE FPGA	2	18.10	19.10	4	Y	Y
80	PSI / LIP / EFACEC	Test of focused beams for acceerated DD tests	1	20.11	20.11	1	Y	N
81	EASII / ST	Test of new memory types and test structures	2	22.11	23.11	3	Y	N
82	ESA / SITAEL	OBM, TMTC PCBs for spacecraft platforms	2	25.11	26.11	4.5	Y	Y
83	E2V-Teledyne	Test of optical sensors for PLATO mission	2	26.11	27.11	1	Y	N
84	Surrey Satellite Technologies	Test of various integrated circuits	1	30.11	30.11	2	Y	N
85	CERN	Test of various components for LHC accelerator	3	1.12	3.12	4	N	N
86	Surrey Satellite Technologies	Test of various integrated circuits for TID and SEL effects	1	3.12	3.12	1	N	N
87	E2V-Teledyne	Test of optical parts for Euclid mission	2	3.12	4.12	2	Y	N
88	PSI / CERN and E2V-Teledyne	Pre-calibartions of beam (tests congestions)	1	14.12	14.12	1	N	0
89	CERN	Test of various parts for beam line dosimetry	3	15.12	17.12	4	N	0
90	E2V-Teledyne	Test of optical sensors for MTG and Flex	2	17.12	18.12	1	Y	N
91	PSI	test of new pixelated ionization chamber (PROPIX upgrade)	1	19.1	19.1	1	Y	Y

My thanks go to you