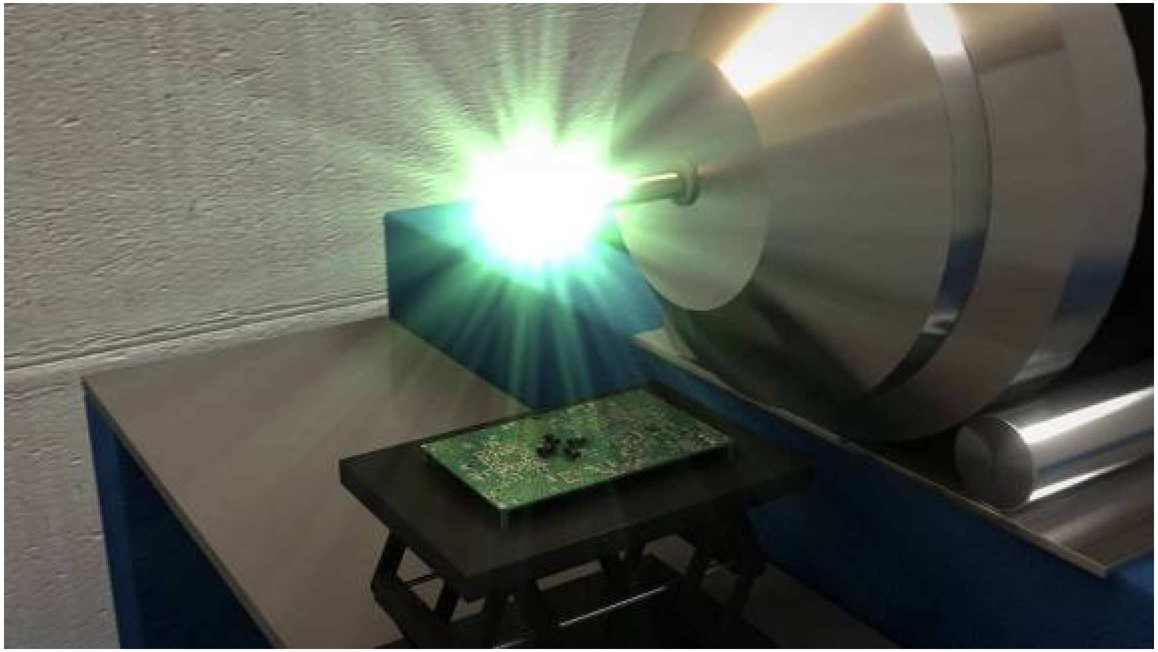
BUSINESS UNIT NEO

Business Unit “Nuclear Effects in Electronics and Optics (NEO)”
Fraunhofer Institute for Technical Trend Analysis (INT)



Fraunhofer INT
Overview

- **Employees:** about 100 (incl. about 50 scientists)
- **Budget:** approx. 7.5 million € (incl. approx. 1.5 million € contract research)

Fraunhofer INT
Business Units

Trends in Research and Technology

Planning, Programs and Structures
in Research and Technology

Nuclear Security Policy
and Detection Techniques

Electromagnetic Effects and Threats

Nuclear Effects in Electronics and Optics

Nuclear Effects in Electronics and Optics (NEO)
History

- Experience since 1965 in investigating the effects of nuclear detonations
- In 1999 the German Ministry of Defense (BMVg) discontinued funding
- Since then (2000):
  - Sustainable self funding of nuclear radiation effects group
  - > 300 projects with:
    > 40 companies
    > 10 research organizations
  - More than 200 papers, reports, publications, presentations
- 2009/10 Large expansion of irradiation capabilities due to funding by the German economic stimulus package
- Current members in nuclear radiations effects group:
  Scientists: 3, Engineers: 4,

Nuclear Effects in Electronics and Optics (NEO)
Main areas of activity

- Users of optical and electronic systems in radiation environments for
  - Space
  - Accelerators
  - Nuclear facilities
  - Others
- Qualification and optimization of electronic and optical components and systems
- Radiation sensing with optical fibers and semiconductors
- Consulting

Nuclear Effects in Electronics and Optics (NEO)
Research

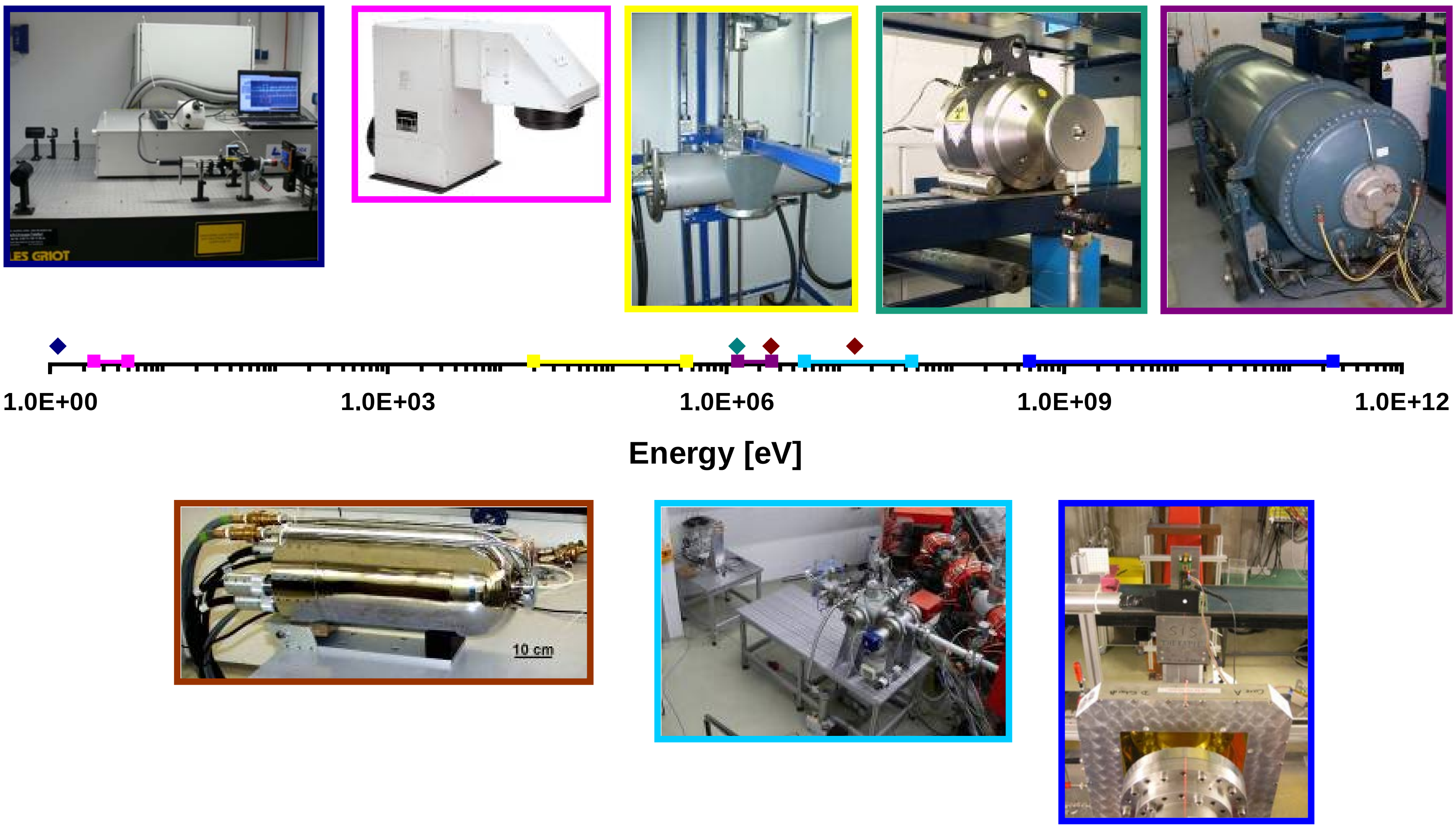
- Influence of particle energy on Single-Event Effects
- Advancements in radiation test facilities and procedures
- Development of radiation sensors
  - Fiber optic radiation sensing
    - Large scale implementation of fiber optic dosimetry systems based on radiation induced loss
    - Enhancements for fiber optic Cherenkov detectors
    - Radiation dosimetry with Fiber-Bragg-Gratings
  - For space applications based on memory devices

Irradiation facilities
Overview

- Co-60 gamma sources
  - MDS Nordion GammaMat TK1000 A/B
  - MDS Nordion GammaMat TK100
- X-ray sources
  - Febetron 705 (pulsed)
  - Comet MXR-451 (continuous)
- Neutron generators
  - Thermo Electron D-711
  - EADS Sodern Genie 16C
- Pulsed laser SEE test system
  - Lumera STACCATO
  - CryLas DSS1064-Q1
- Sun simulator
  - Oriel LS0911
- External facilities
  - Proton-irradiation at FZ Jülich
  - Relativistic heavy ions at GSI Darmstadt (currently limited availability)
  - External Co-60 sources

Irradiation facilities

Energies

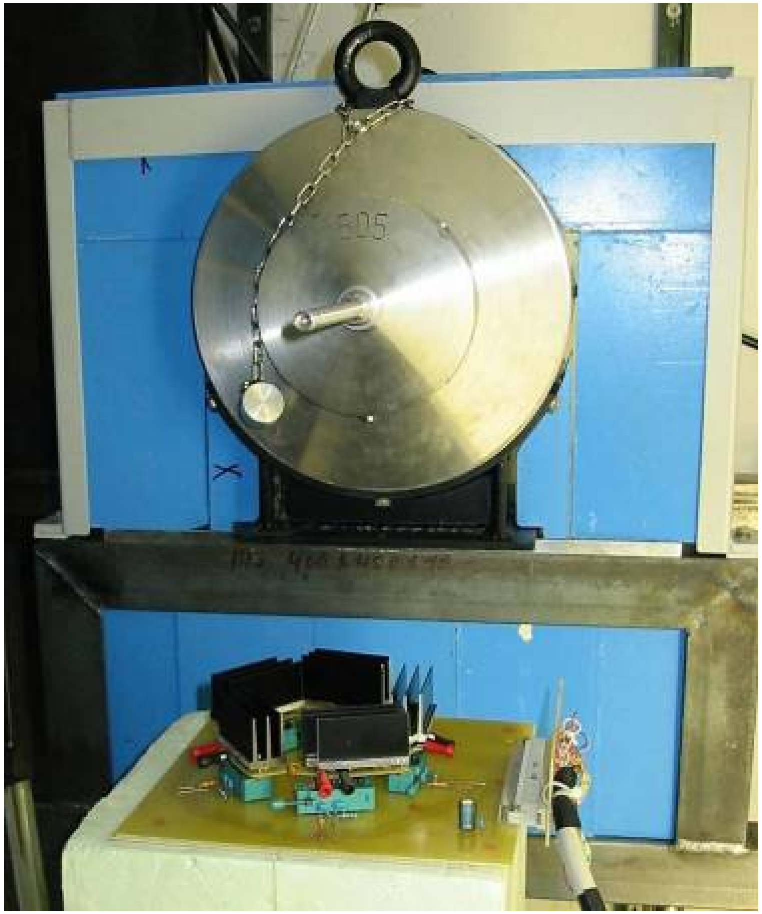


Irradiation facilities
"Large" Co-60 source: TK1000

- Typical activity:
  - 2×10^{13} Bq (500 Ci)
- Maximum dose rate:
  - ~3 Gy/s (300 rad/s)
- Maximum dose (small samples):
  - 1 MGy (100 Mrad) in 4-6 days
- Temperature range:
  - -55°C to +150°C
- Dosimetry:
  - Calibrated ionisation chambers and TLDs (LiF)
- Large test volume (~1 m³)

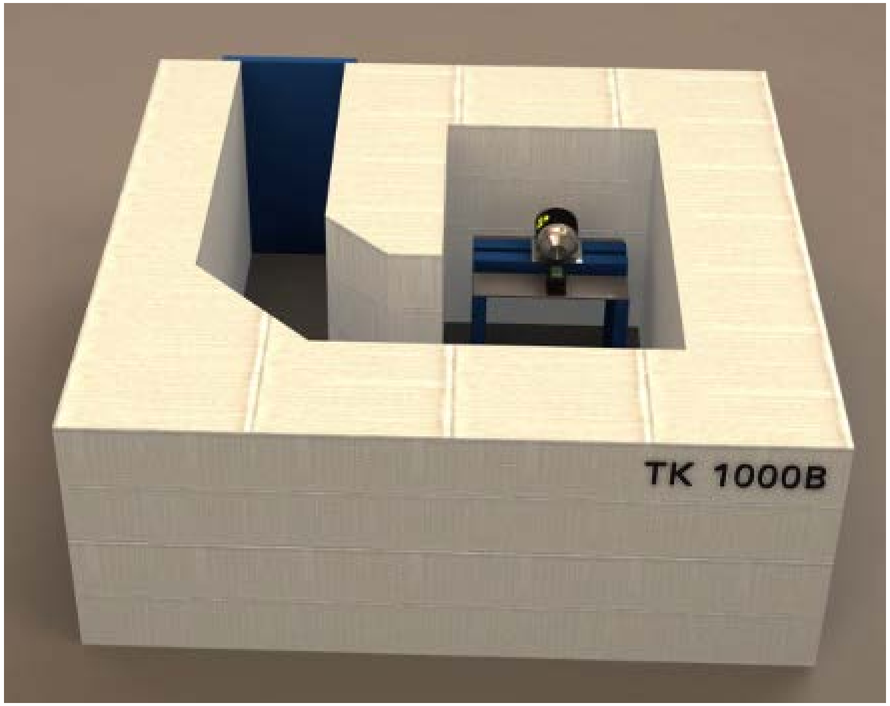
Irradiation facilities
"Small" Co-60 source: TK100

- Maximum activity:
  - 7.4×10^{11} Bq (20 Ci)
- Maximum dose rate:
  - ~300 Gy/h (30 krad/h)
- Mrad irradiations possible during weeks and even months (low dose rate irradiation)
- Temperature range:
  - -55°C to +150°C
- Dosimetry:
  - Calibrated ionisation chambers and TLDs (LiF)



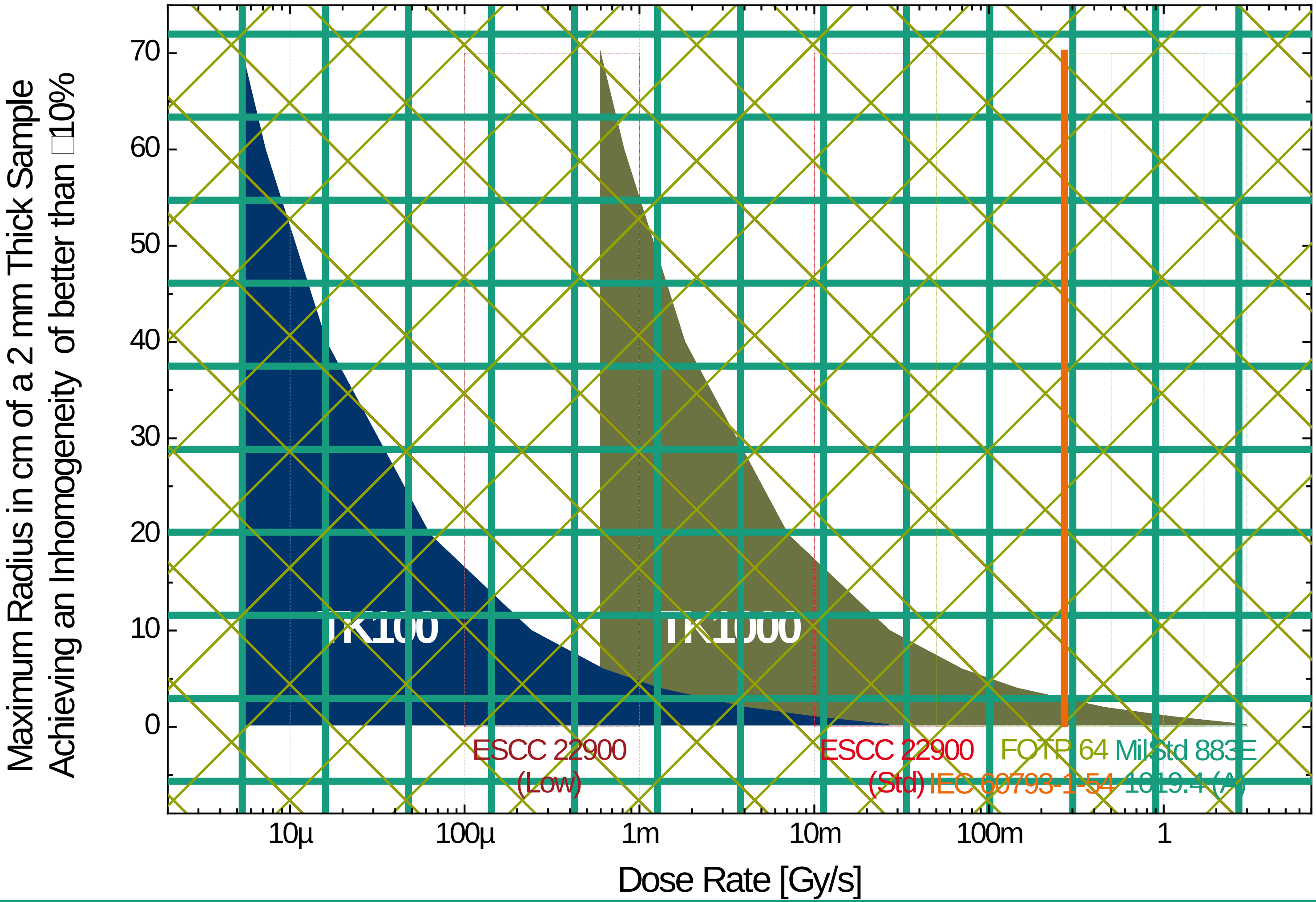
Irradiation facilities
New TK 1000B Co-60 irradiation facility

- Exactly the same irradiation source as previous Co-60 TK 1000A
- Lots of improvements
  - Whole irradiation chamber thermally stabilized ±0.2°C
  - Larger test volume resulting in large variation of dose rate
  - Exclusive concrete bunker without interference with other irradiations
  - Measurement equipment close in precision climate chamber



Irradiation facilities

Dose rate ranges at the Co-60 facilities (November 2010)



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Irradiation facilities
Flash X-ray Febetron 705

- Pulsed Electrons or X-rays
- E_{max}= 2.2 MeV, t~30 ns
- Dose per pulse:
  - 5-8000 Gy (Electrons)
  - 0.1-5 Gy (X-ray)
- Applications:
  - Fusion research
  - Effects of nuclear detonations
  - Accelerators
- Dosimetry:
  - Calorimeters, TLDs

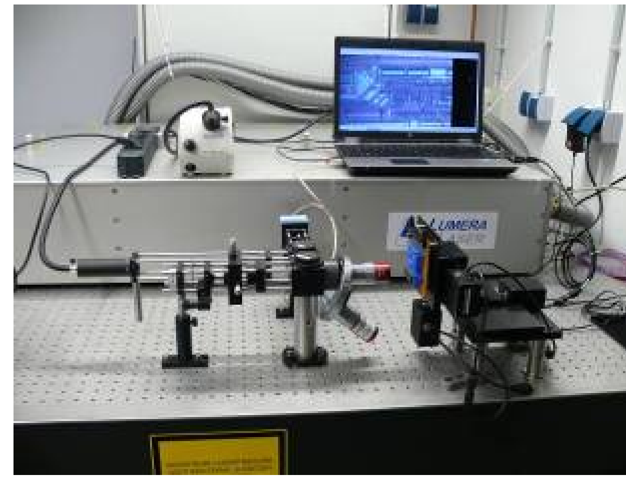
Irradiation facilities
Continuous X-Ray Source

- COMET 450 kV commercial x-ray facility
- Energy between 20 and 450 keV
- Power: 4500 W
- Laser assisted positioning
- X-ray tube electrically moveable

Irradiation facilities
Neutron generator Thermo Electron D-711

- Neutron generation via fusion reaction
  - $T(d,n)^4He$ $E_n \cong 14$ MeV
  - $D(d,n)^3He$ $E_n \cong 2.6$ MeV
- 14 MeV: Source particles $< 4 \times 10^{10}$ n/s in 4π
  Fluence of 10^{13} n/cm^2 after several hours
- 2.5 MeV: About a factor of 100 less
- 14 MeV–n in Si are twice effective as 1 MeV–n
- Fluence and dose measured with activation foils and fission chambers

Irradiation facilities
Laser SEE Test Facility at INT



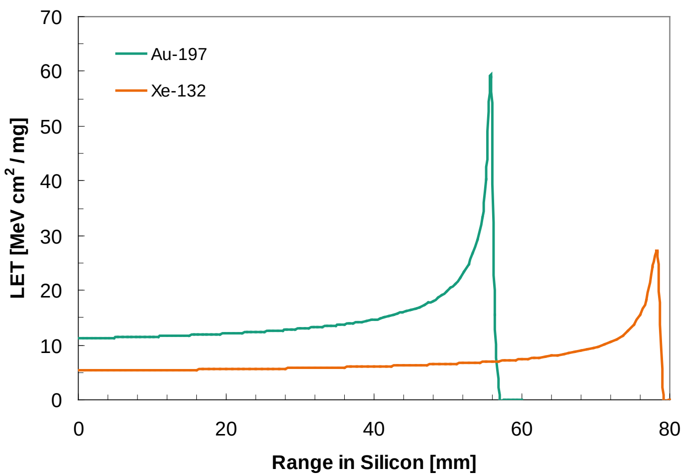
- Lumera STACCATO
  - Wavelength: 1064 nm
  - Pulse width: 9 ps (FWHM)
  - Max. pulse energy: ~ 180 µJ
  - Repetition rate: Single shot up to 80 kHz
- CryLas DSS1064-Q1
  - Wavelength: 1064 nm
  - Pulse width: 1.3 ns (FWHM)
  - Max. pulse energy: ~ 16 µJ
  - Repetition rate: Single shot up to 15 kHz
- Focusing optics: Mitutoyo M Plan Apo NIR series microscope optics (10x and 100x)

Irradiation facilities
Proton irradiation facility at JULIC (FZ Jülich)

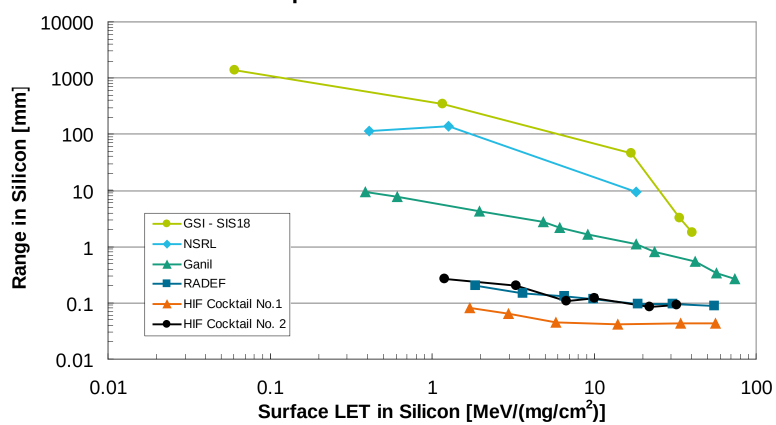
- Dedicated beam line for irradiation tests
- Maximum proton energies:
  - 45 MeV (in vacuum)
  - up to 39 MeV (in air)
- Homogenous fluence distribution
  - e.g. in 200 cm distance:
    10% variation over area of ~20 cm diameter
- Typical fluences of 10^{12} p/cm^2 after ~1000 seconds
- Measurement of fluence and dose:
  - Calibrated ionisation chamber, activation analysis
- Availability: Every ~6 weeks for 1-2 days

Irradiation facilities
Heavy Ion irradiations at GSI

- Light and medium ions from ca. 100 up to 2000 MeV/nucl. and heavy ions, e.g. Uranium, up to 1000 MeV/nucl. (max. 18 Tm beam rigidity)
- Available ions: Uranium, Nickel, Carbon, (Gold, Xenon, Iron)
- Intensity modulated raster scanner (field 20 x 20 cm^2, step width > 1 mm)
- Particle fluence: $1 < \Phi < 10^{12}$ cm^{-2}
- Pencil beam (∅ > 2 mm)
- Slow extraction: Typ. 2 - 4 s
- Exit window: 0.1 mm Al
- Distance in air: ca. 85 cm



Comparison of Accelerators

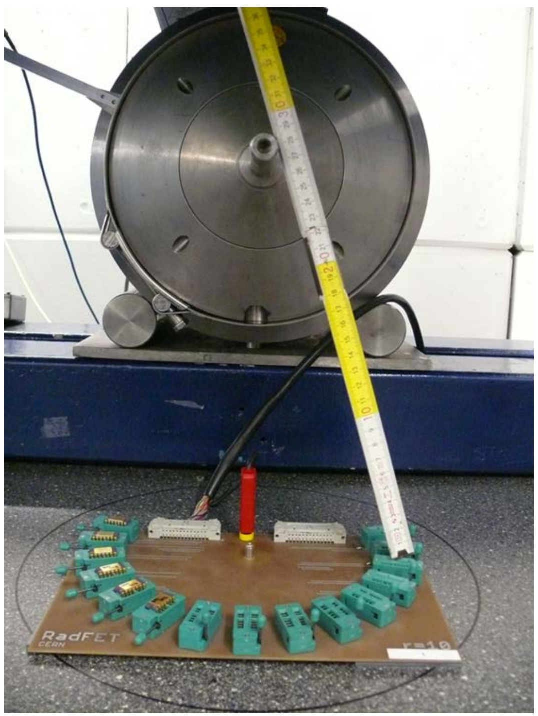


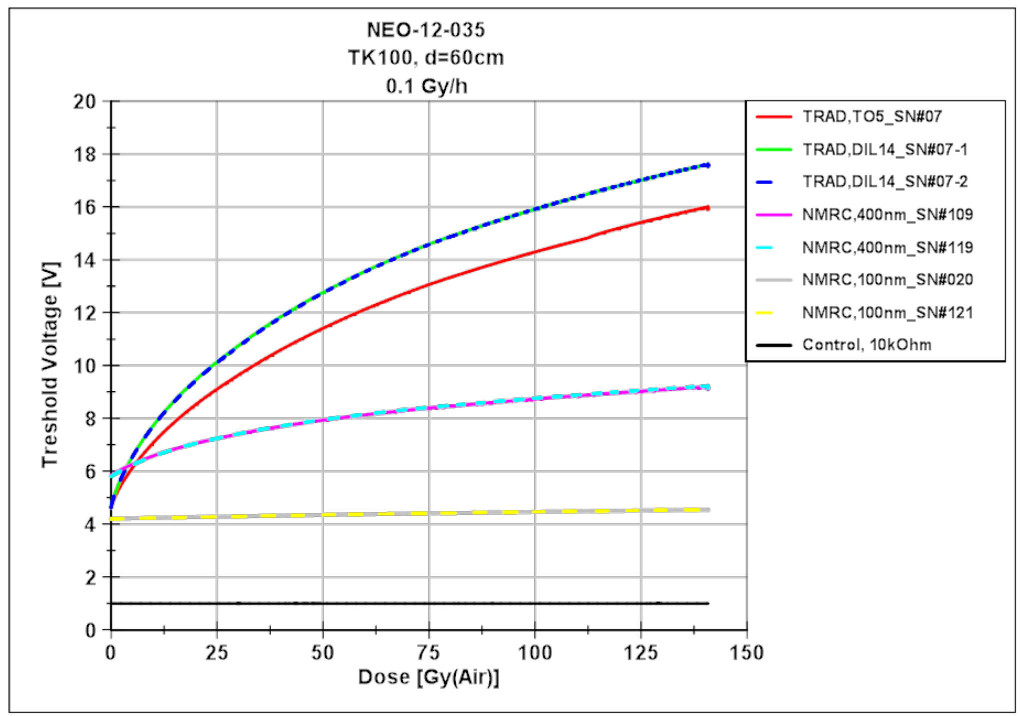
Special installations
Low-temperature-irradiation tests

- Fraunhofer INT installed a cryostat for ultra-cold irradiation tests at Co-60 facilities
  - Any temperature
    between 5.5 K and 420 K (~ 150°C)
  - Precession temperature control system
  - Test volume in a NW100 flange

Example (I): RadFET Calibration

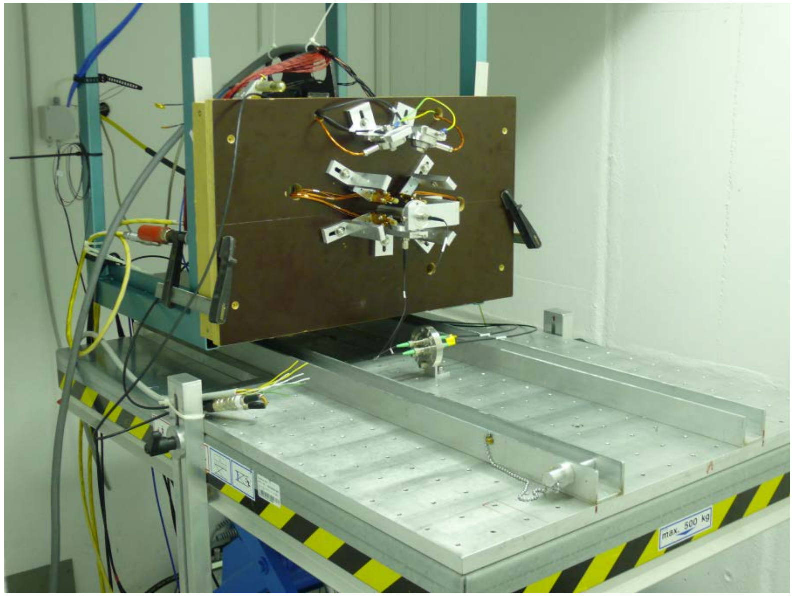
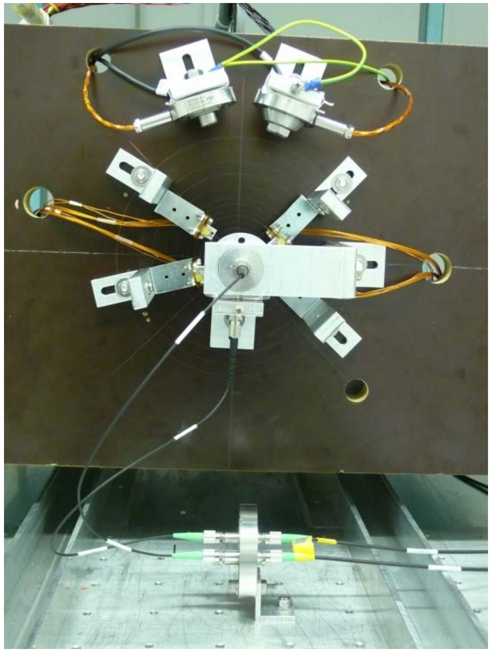
- Dose-rates between 0.1 and 50 Gy(Air)/h
- Dose-rate uncertainty lower than 5 %
- Measurement (here voltage) stability better 99.95 %
- Temperature stability better than +/- 0.2 °C over several weeks





Example (II): Active Tests of Load Sensors, Piezo Actuators and Optical Sensorheads

- Dose-rates: 6.6, 92.3 and 100.8 kGy(Air)/day
- Dose inhomogeneity up to 40 % inside DUT
- Irradiation time of 60 days
- Temperature stability better than +/- 0.2 °C over a few weeks (at the beginning)

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Radiation testing at Fraunhofer INT

- Fraunhofer INT is a neutral, highly specialized governmental lab
- Independent operation of irradiation facilities with instant access, optimized and exclusively used for irradiation of specialized components
- Team of nuclear physicists and electronic engineers with long experience in the field of radiation effects testing
- Autonomous operation of the facilities allows the undisturbed conduction of several tests at the same time
- Irradiation takes place in air in a large open space, no container is used, no risk because of water or other source related difficulties
- No data or details have to be published, no information will be given to third parties

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