3 groups work with CR:
1) Micro Rel: Microelectronics, terr.CR
2) Rad-Hard: Power electronics, primary CR
3) GIP CR: Power electronics, terr. CR

Disclaimer
Focus here on terrestrial Cosmic Radiation & Power Devices

Current capabilities and future requirements in radiation testing in Europe

Philipp Bender (GIP GEMS D P T CR)

12/06/2024

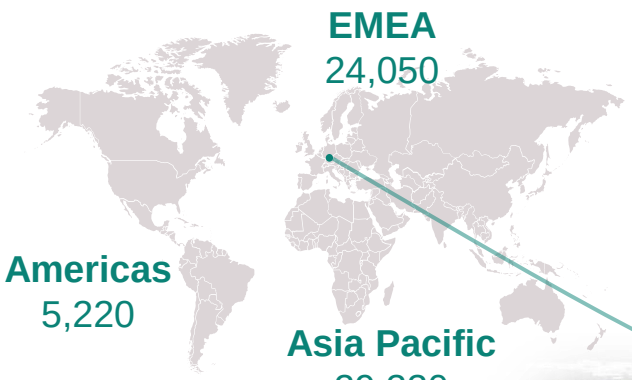
Infineon at a glance: *Driving decarbonization and digitalization*

Employees[1]

58,600
employees worldwide

69
R&D and

17
manufacturing locations



Headquarters in Neubiberg (Germany)

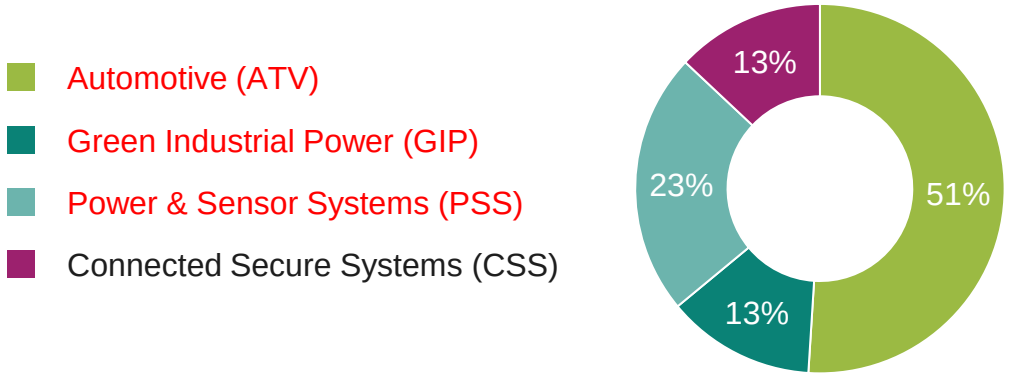
For further information: Infineon Annual Report.

[1] As of 30 September 2023

Infineon at a glance: *Driving decarbonization and digitalization*

– Our growth areas: Mobility, Energy & IoT

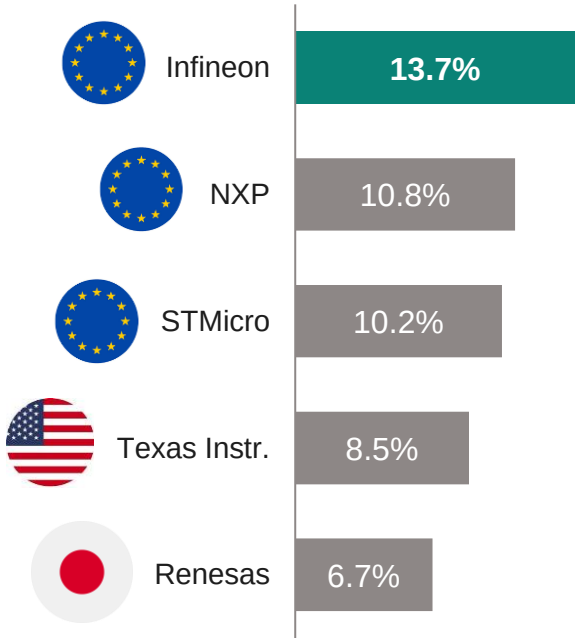
FY23 revenue by segment[1]



Total revenue FY23: 16 bn €

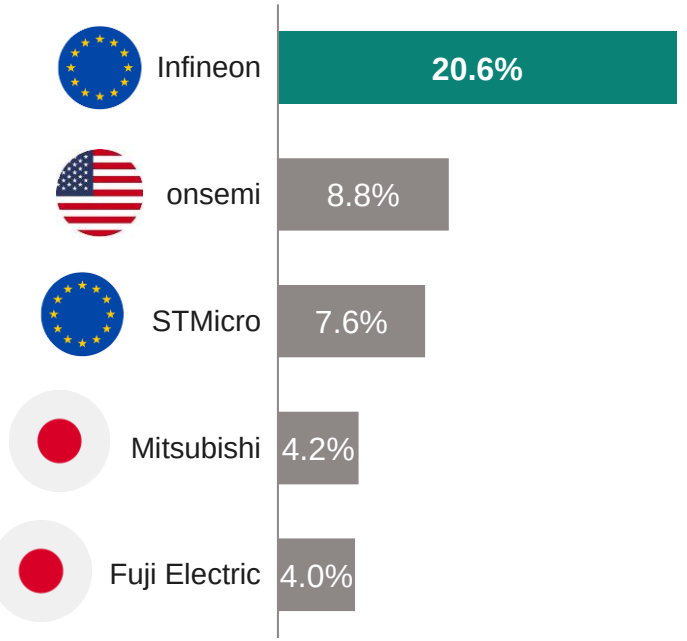
Automotive devices

2023 total global market: USD 69.2bn[2]



Power modules & disretes

2022 total global market: USD 30.9bn[3]



1 2023 Fiscal year (as of 30 September 2023) | **2** TechInsights: Automotive Semiconductor Vendor 2023 Market Shares. April 2024. | **3** Based on or includes research from Omdia: Power Semiconductor Market Share Database – 2022. September 2023. Results are not an endorsement of Infineon Technologies AG. Any reliance on these results is at the third party's own risk.

Reliability issues of Power Semiconductors – Cosmic Radiation (CR)

- Space applications: Heavy ions & high-energy protons of primary CR can provoke power device failure
- Ground-level applications: Terrestrial CR (TCR) can cause Single-Event Breakdown (SEB) of power devices

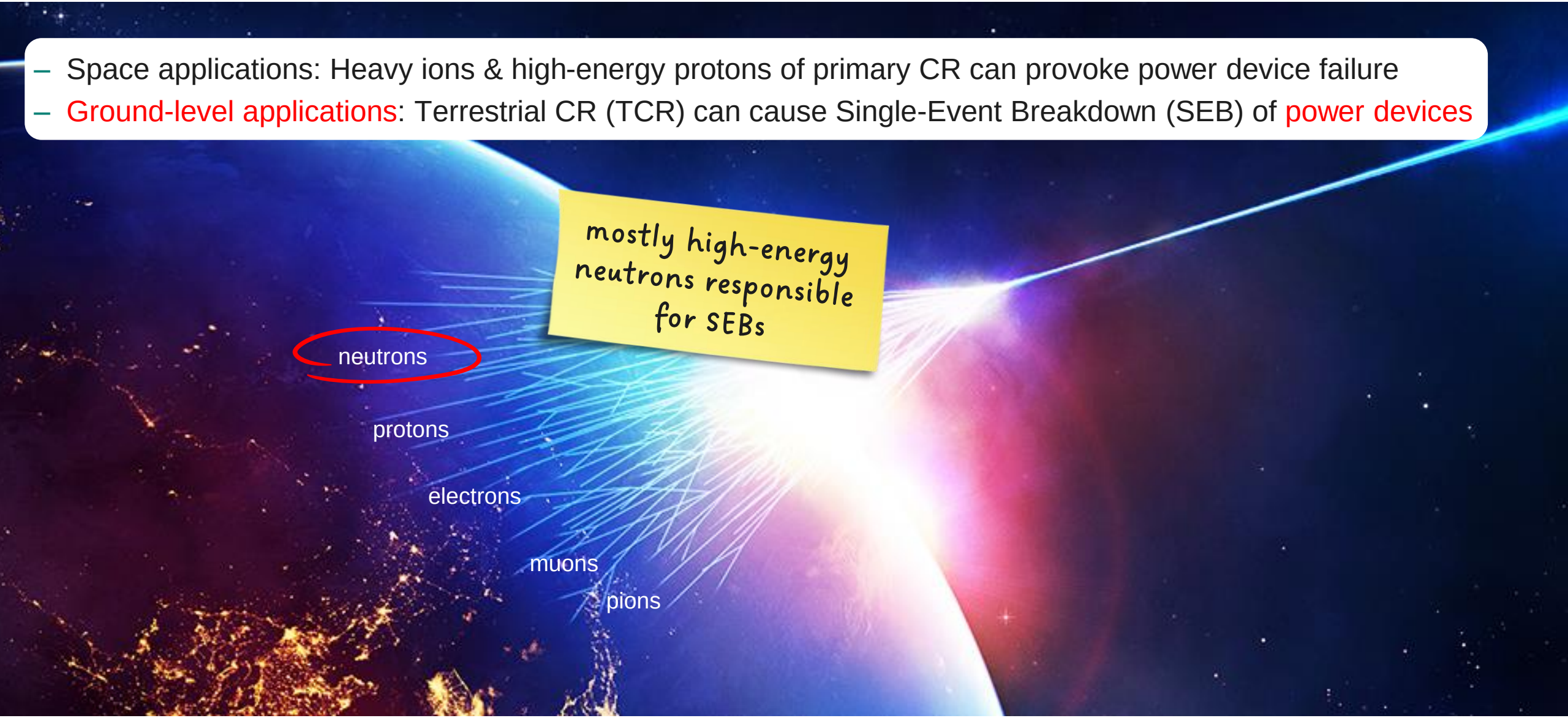
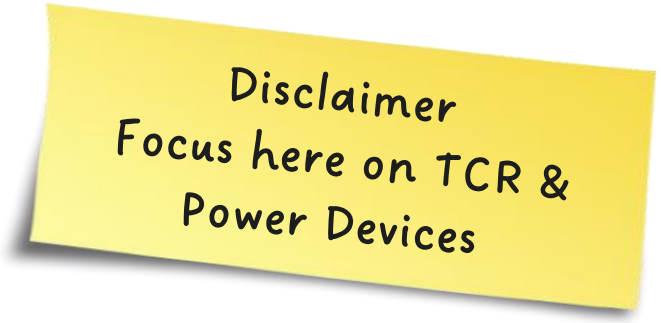


Table of contents

“Current capabilities and future requirements in radiation testing in Europe”



1. How do we test terrestrial CR reliability of power devices?
2. What are our future requirements?

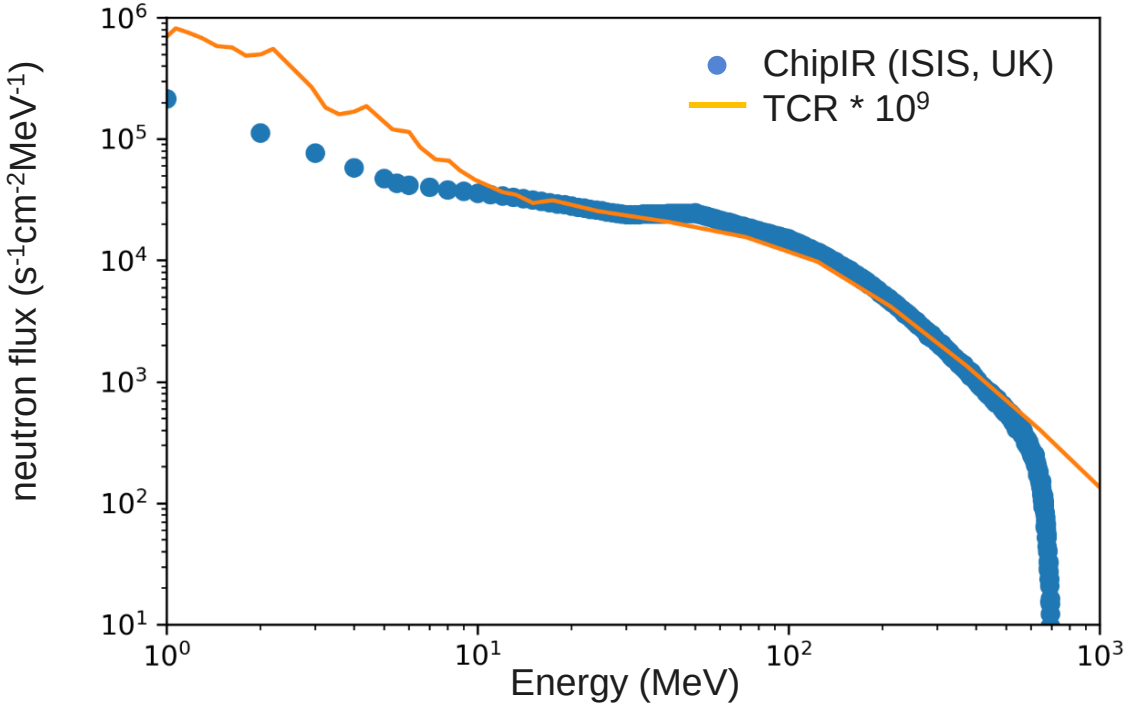
Table of contents

1. How do we test TCR reliability of power devices?

- We perform CR robustness tests using natural TCR (in lab or high altitudes)
- BUT: Standard tests are done using artificial high-flux nucleon beams (neutrons or protons)
- Following the JEDEC standard JEP151 "*Test Procedure for the Measurement of Terrestrial Cosmic Ray Induced Destructive Effects in Power Semiconductor Devices*":
  - beam: either monoenergetic protons or neutrons, or neutron beams with spallation energy spectrum (> 150 MeV)
  - devices: 30 – 50 devices must be simultaneously in beam path and tested in off-state with applied static voltage
  - failures: device fails must be unequivocally identified and recorded during irradiation
  - result: 3 – 5 data points *FIT* vs *V* (*FIT*: Failures in Time, 1 *FIT* = 1 fail in 10^9 hours)

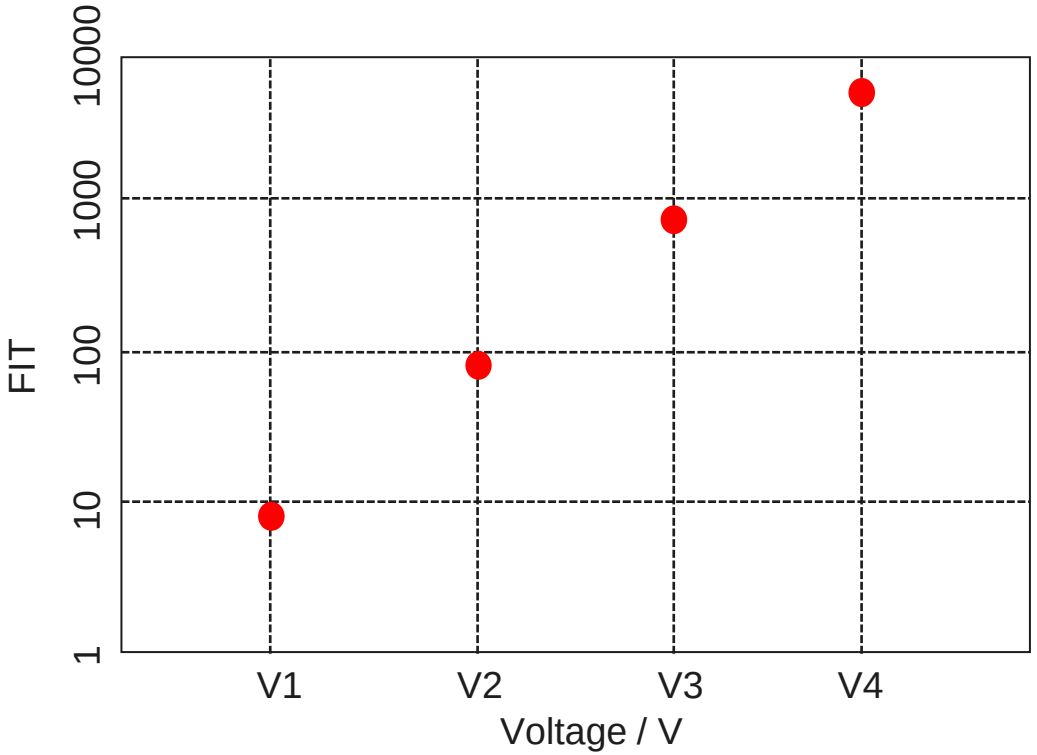
1. How do we test TCR reliability of power devices?

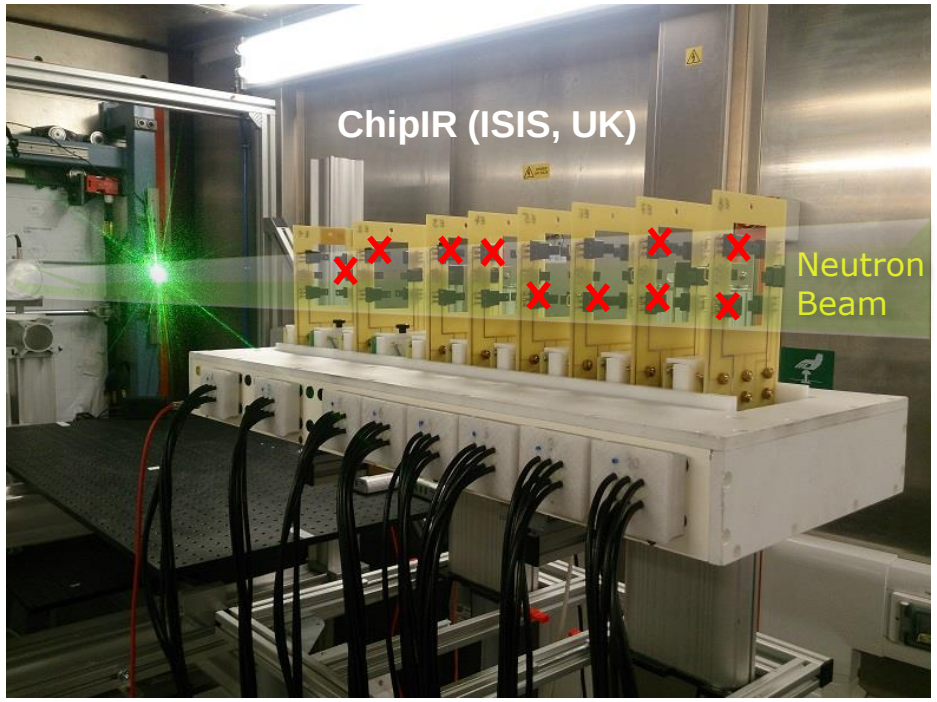
- We perform CR robustness tests using natural TCR (in lab or high altitudes)
- BUT: Standard tests are done using artificial high-flux nucleon beams (neutrons or protons)
- Following the JEDEC standard JEP151 "*Test Procedure for the Measurement of Terrestrial Cosmic Ray Induced Destructive Effects in Power Semiconductor Devices*":



1. How do we test TCR reliability of power devices?

- We perform CR robustness tests using natural TCR (in lab or high altitudes)
- BUT: Standard tests are done using artificial high-flux nucleon beams (neutrons or protons)
- Following the JEDEC standard JEP151 "*Test Procedure for the Measurement of Terrestrial Cosmic Ray Induced Destructive Effects in Power Semiconductor Devices*":

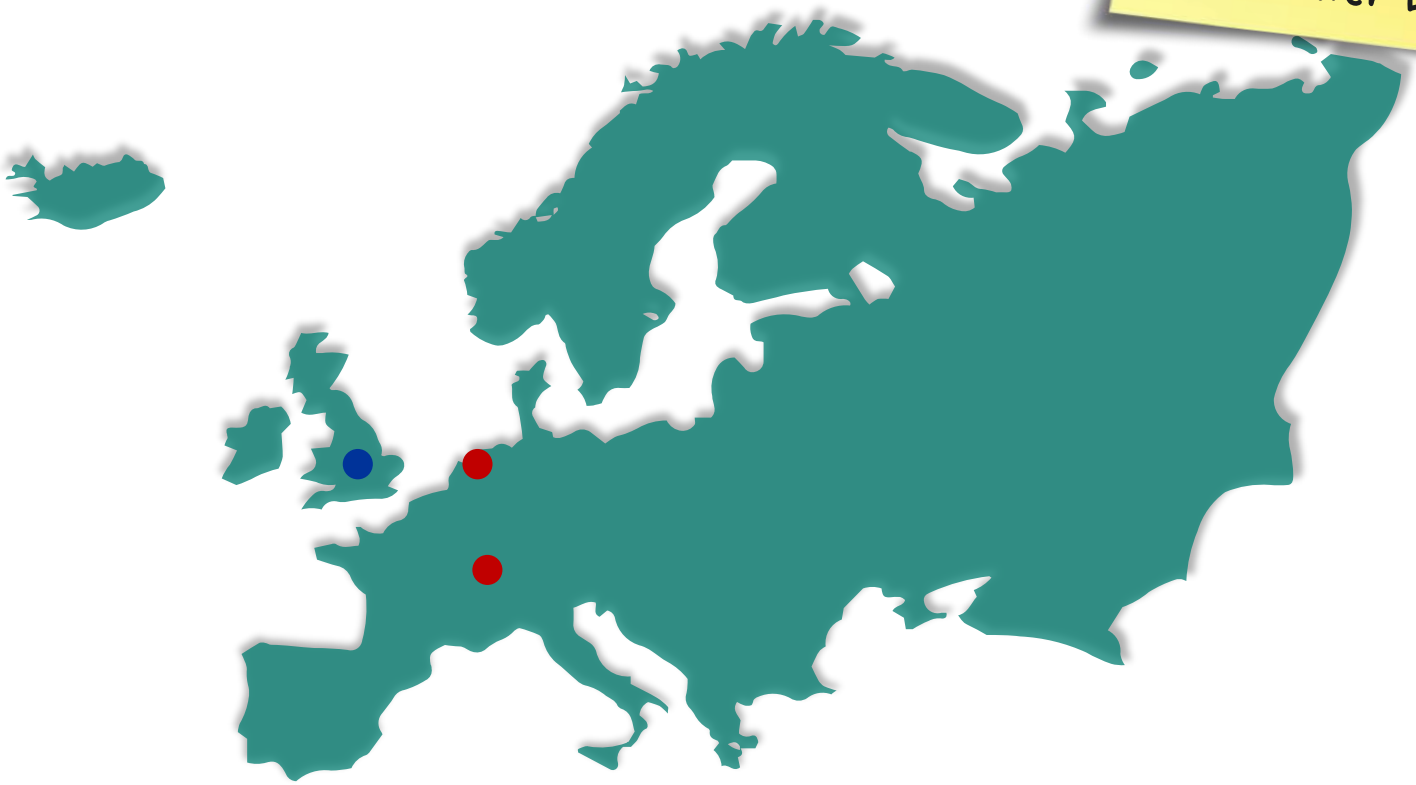




1. How do we test TCR reliability of power devices?

"Current capabilities in radiation testing in Europe"

Disclaimer
Focus here on TCR & Power Devices



Neutrons (spectrum)

- STFC-ISIS

Protons (monoenergetic)

- PARTREC
- PSI

Table of contents

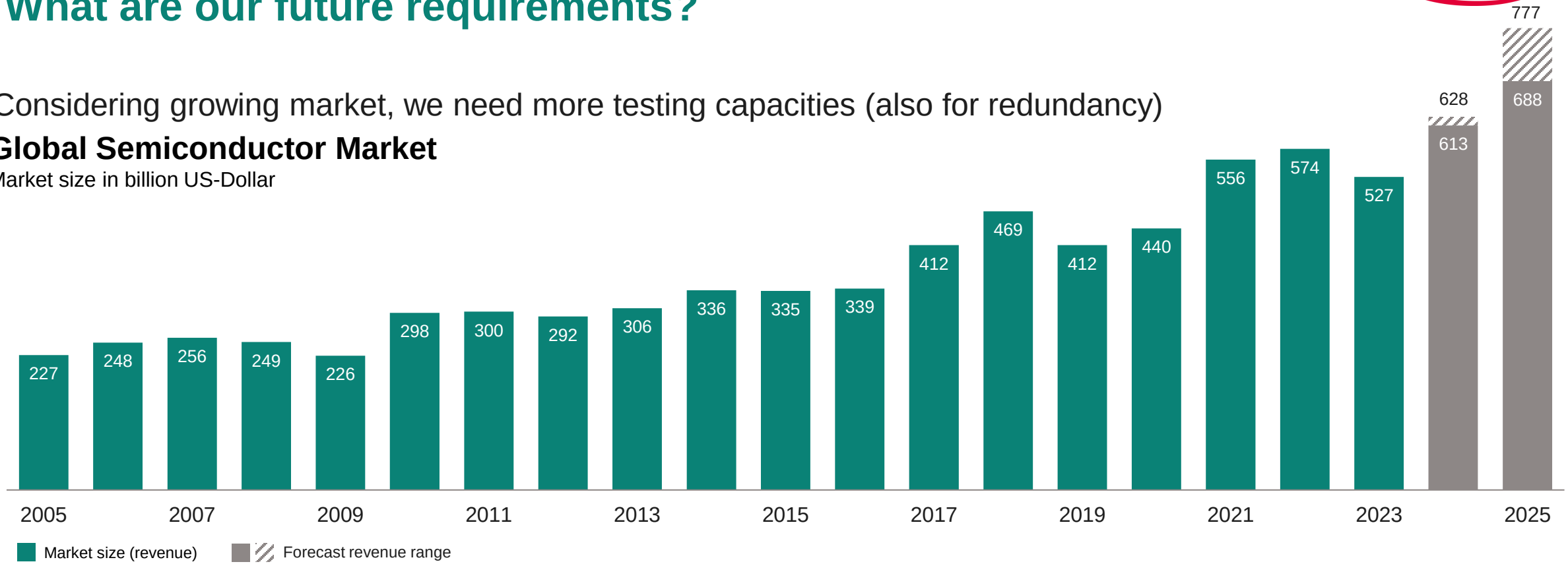
Table of contents

2. What are our future requirements?

– Considering growing market, we need more testing capacities (also for redundancy)

Global Semiconductor Market

Market size in billion US-Dollar



Source: WSTS for historical data.| **Forecast:** of WSTS, Omdia, Gartner, TechInsights; last update 2 May 2024.

→ We need second instrument with neutron spallation energy spectrum in Europe

→ Currently, only spallation source where ChipIR-like instrument could be built is ESS

2. What are our future requirements?

We go every 2 – 3 months to a testing campaign, 1 campaign are 2 – 3 days of beamtime
One test takes 20 – 60 min → usually 20 – 60 tests per campaign

- Requirements for standard tests:
  - Either monoenergetic beams or neutron beams with spallation energy spectrum (> 150 MeV, ideally up to 1 GeV)
  - Flux densities 1e6 n/cm²/sec – 1e8 n/cm²/sec (ideally tunable)
  - Beam with *constant* flux, high spatial uniformity and low divergence
  - Diameter > 10 cm but < 20 cm to reduce irradiation of electronics
  - Precise value for flux must be provided to obtain correct *FIT* values
  - Enough room to position setup and surrounding electronics
  - Easy access to setup to change devices fast (time = money)

  - Fast access to get beamtime (regular visits necessary)
  - Low travel costs & organizational effort → Europe

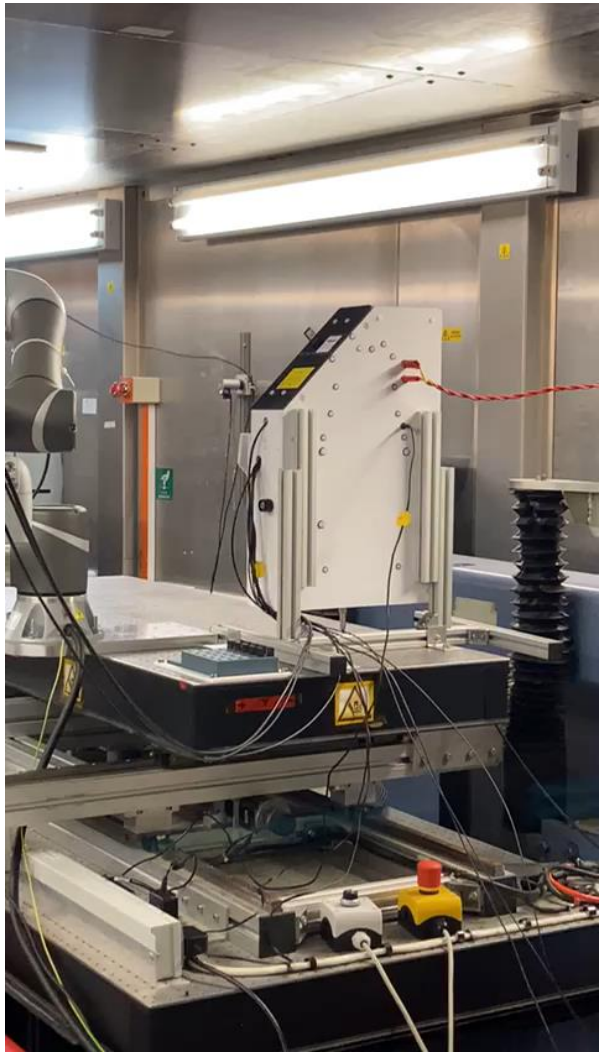
2. What are our future requirements?

- Requirements for instruments regarding standard tests:
  - Either monoenergetic beams or neutron beams with spallation energy spectrum
  - Flux densities 1e6 n/cm²/sec – 1e8 n/cm²/sec (ideally tunable)
  - Beam with *constant* flux, high spatial uniformity and low divergence
  - Diameter > 10 cm but < 20 cm to reduce irradiation of electronics
  - Precise value for flux must be provided to obtain correct *FIT* values
  - Enough room to position setup and surrounding electronics
  - Easy access to setup to change devices fast (time = money)
  - Fast access to get beamtime (regular visits necessary)

- In case of new instrument, we would like to be involved during design stage

- Additional options:
  - Thermo-streamer for low-temperature measurements
  - Collaboration regarding automation of measurements

  → longterm ideally completely remote experiments

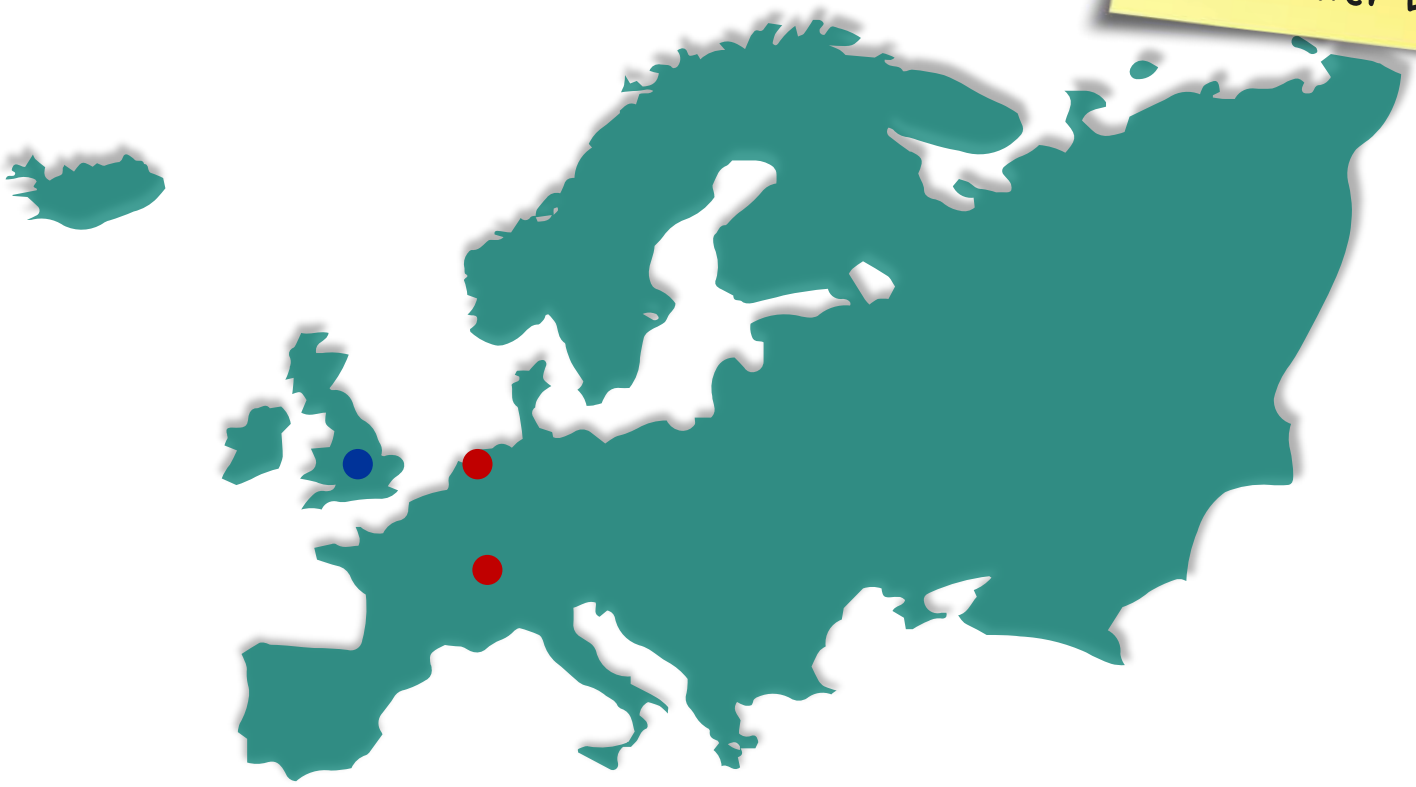


https://www.isis.stfc.ac.uk/Pages/SH24_InfineonRobot.aspx

2. What are our future requirements?

"Current capabilities in radiation testing in Europe"

Disclaimer
Focus here on TCR & Power Devices



Neutrons (spectrum)

- STFC-ISIS

Protons (monoenergetic)

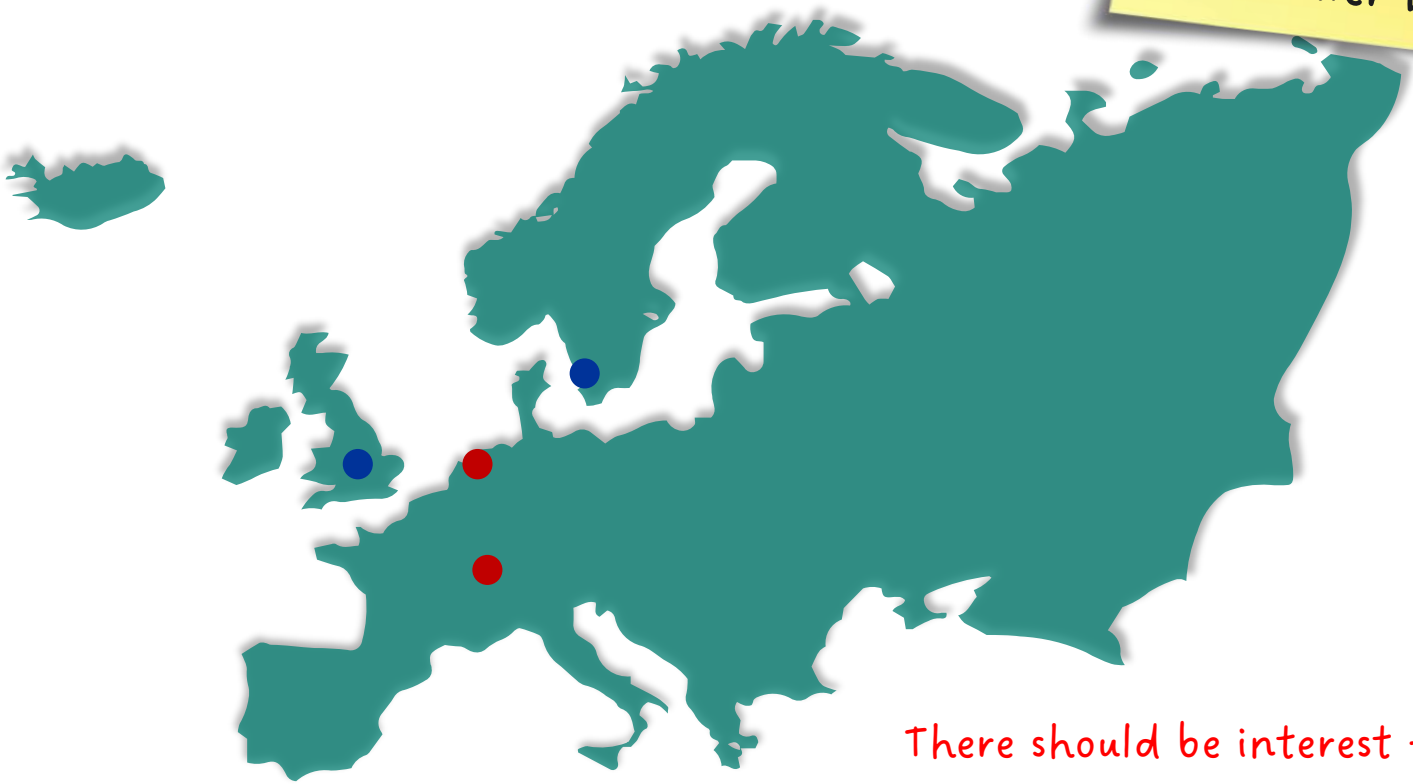
- PARTREC
- PSI

2. What are our future requirements?

"Current capabilities and future requirements in radiation testing in Europe"

Micro Rel colleagues would also use new instrument provided certain requirements are met

Disclaimer
Focus here on TCR & Power Devices



Neutrons (spectrum)

- STFC-ISIS
- ESS

Protons (monoenergetic)

- PARTREC
- PSI

There should be interest from several European companies to build instrument
→ business case


Infineon