Radiation Levels Expected in Electronic Devices for Mirror Control at Sirius

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Summary

Radiation Effects on Electronics

Electronics in synchrotrons are exposed to radiation, which may cause:

Total Ionizing Dose (TID)

Gradual degradation by cummulative

Displacement Damage (DD)

Damage to the crystal lattice

Single-Event Effects (SEE)

Sudden failures from single particles

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Radiation Damage Thresholds Reference

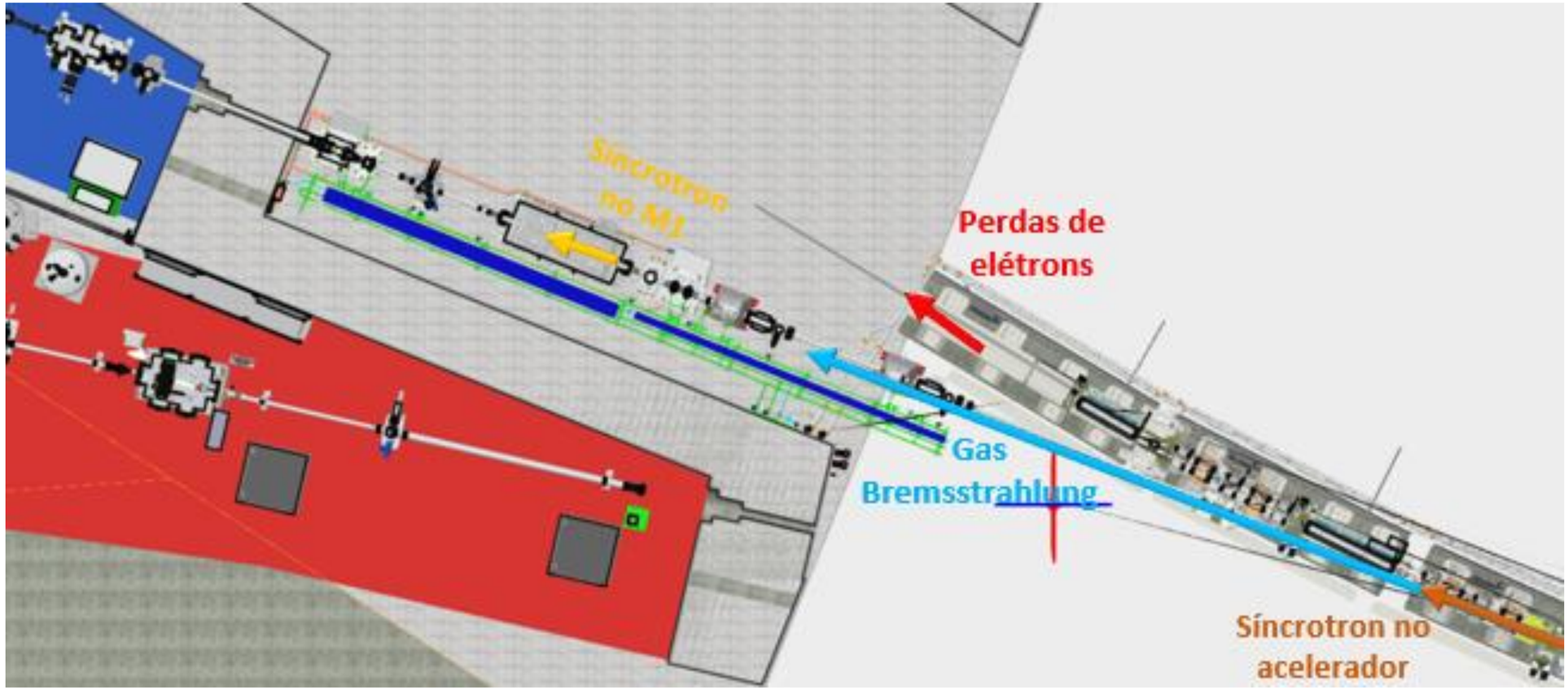
TID:

- Sensitive electronics → Issues from ~1 krad;
- Encoders failed between 16–300 krad (literature).

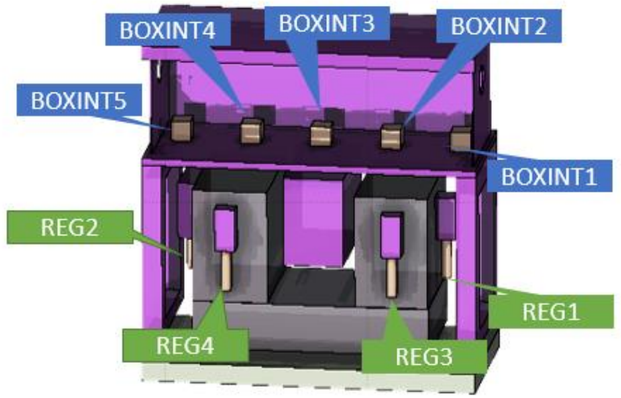
DD:

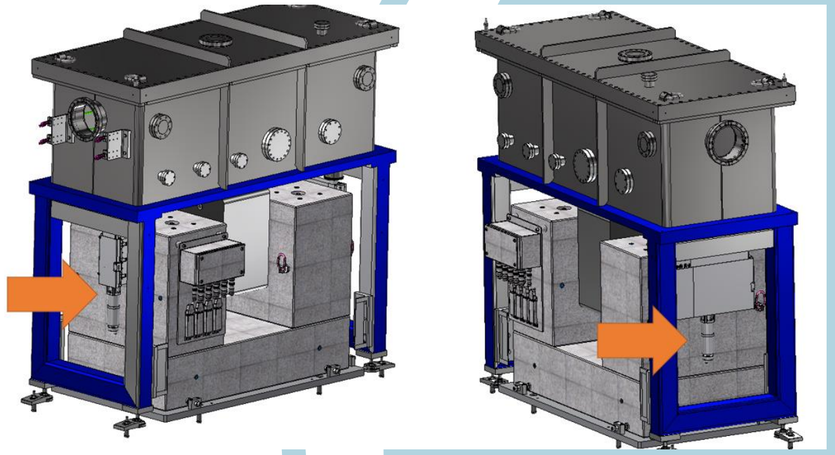
- Fluence > 3×10^{10} n/cm^2 can cause displacement damage.

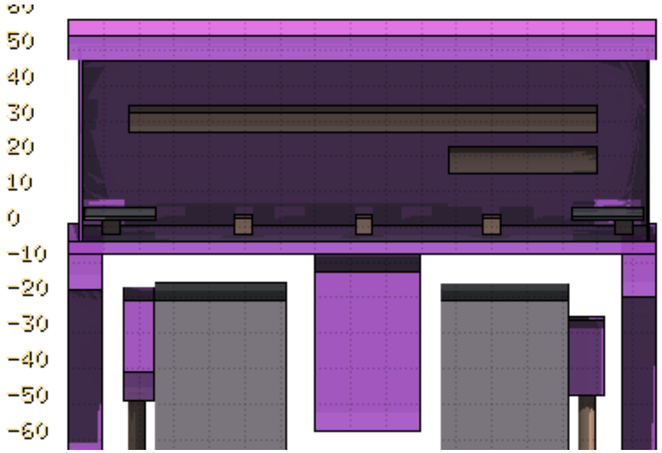
QUATI Front-End Challenge

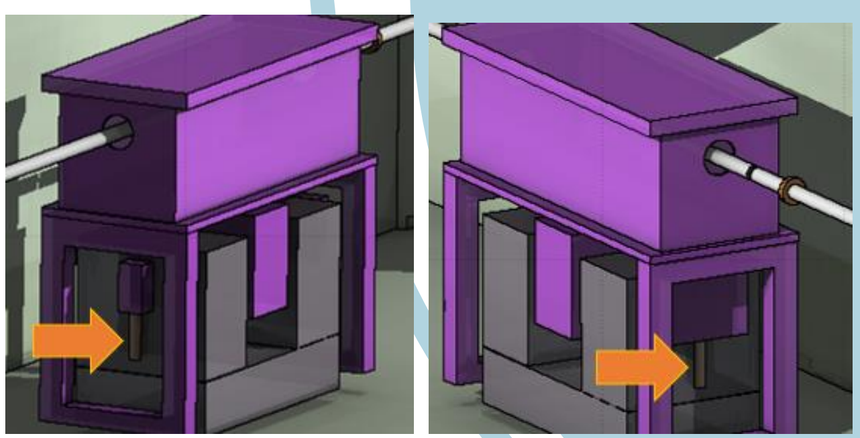


Geometry


BOXINT4
BOXINT3
BOXINT2
BOXINT5
BOXINT1
REG2
REG1
REG4
REG3

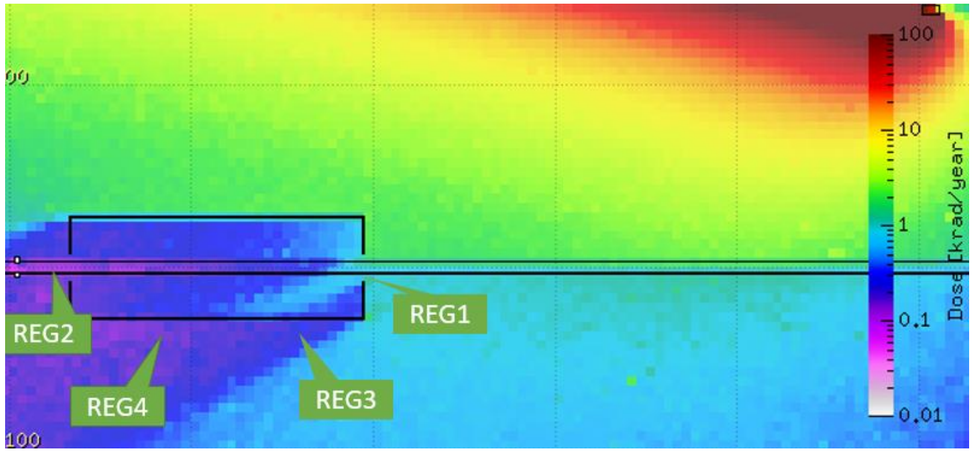



50
40
30
20
10
0
-10
-20
-30
-40
-50
-60

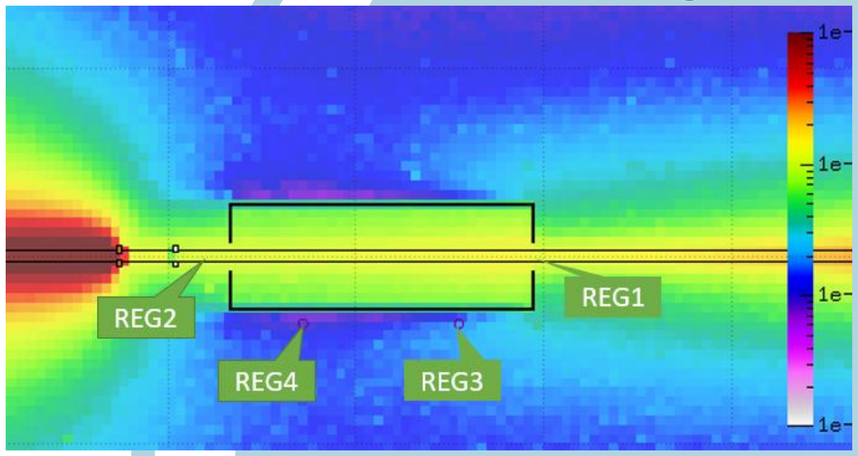


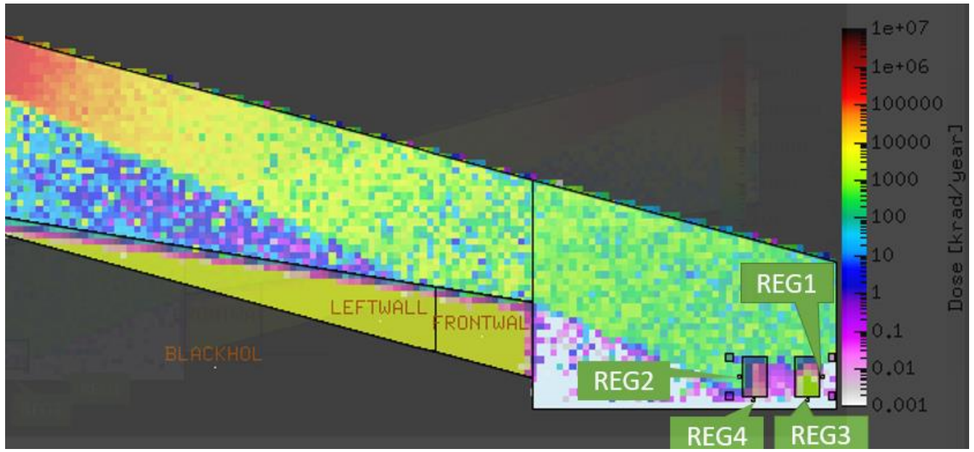
Dose maps

Electron losses

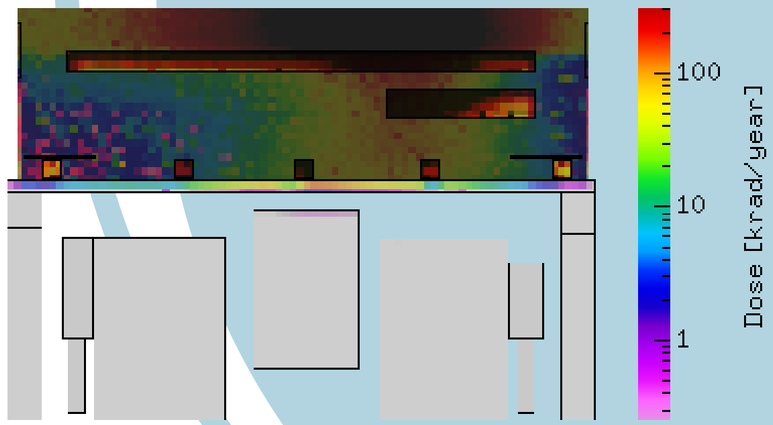


Gas Bremsstrahlung





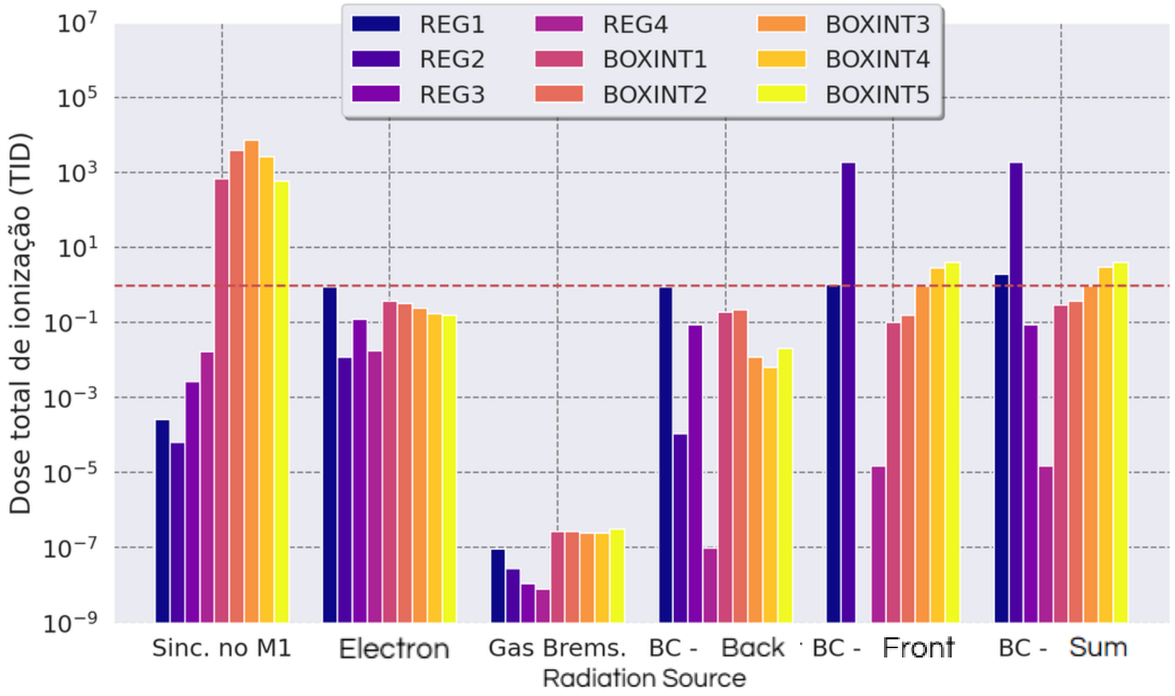
Synchrotron from bending



Synchrotron at the mirror

Total Ionizing Dose (TID)

Radiation sources



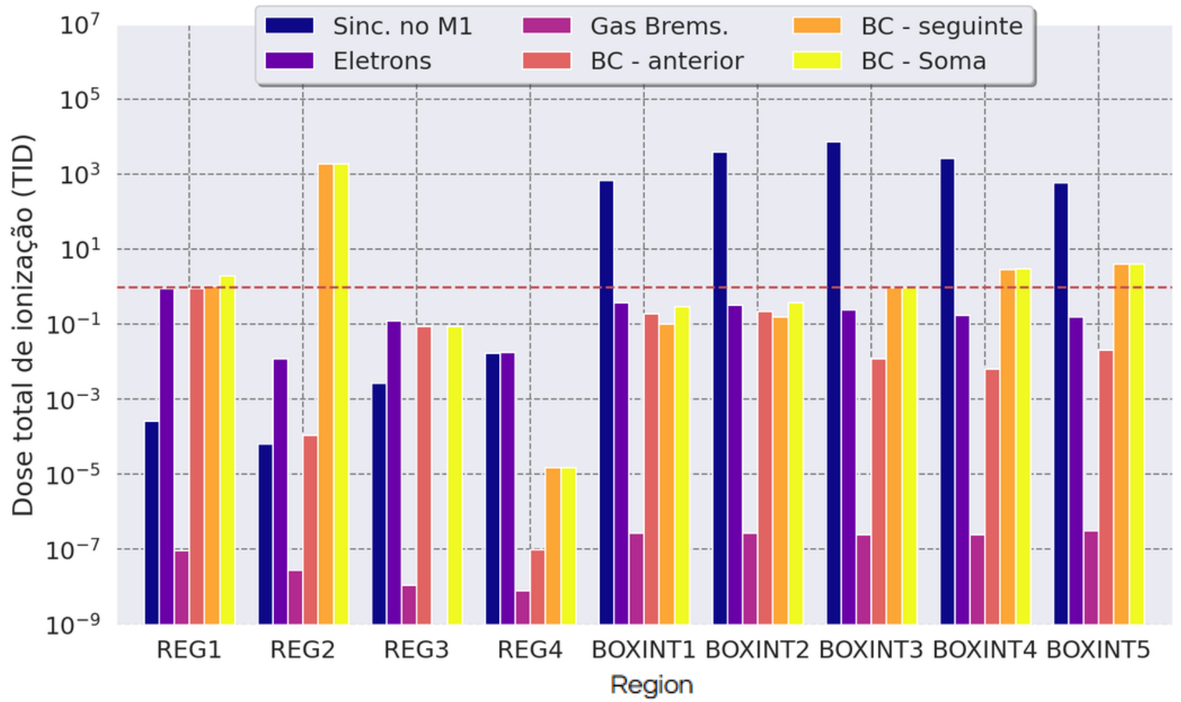
- Gas Bremsstrahlung:
  - Contribution is several orders of magnitude below the 1 krad threshold.
  - No specific evaluation needed.
- Electron loss radiation:
  - All evaluated points show doses at or below 1 krad, the limit for sensitive electronics.
- Sincrotron:
  - Need to evaluate with more atention.

Electron losses

Total Ionizing Dose (TID)

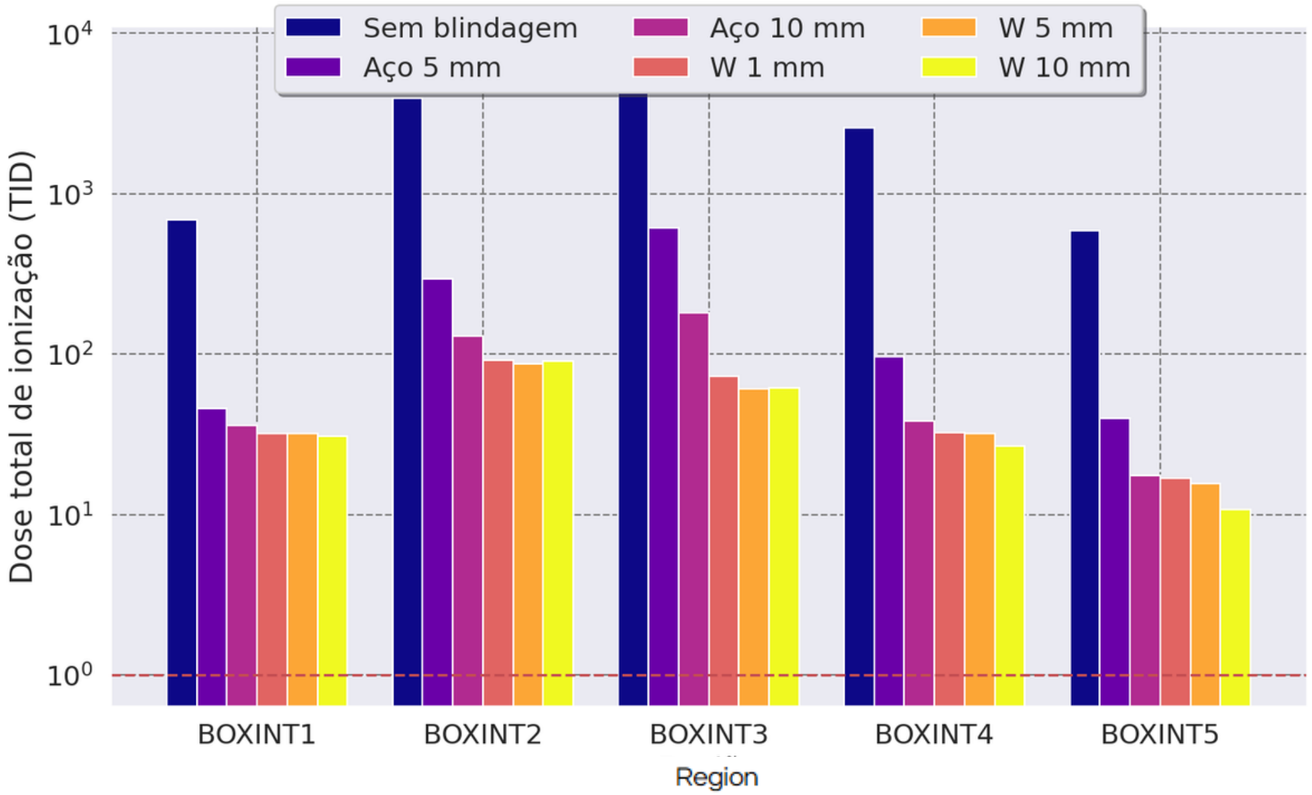
Region

- Synchrotron radiation:
  - REG2 exceeds standard thresholds, but remains within limits for more robust electronics → should be avoided if possible.
- Recommendation:
  - Relocate electronics to areas farther from the ring, avoiding REG1 and REG2.
- In REG3 and REG4 regions, dose levels are about 10× lower than the critical threshold.



Total Ionizing Dose (TID)

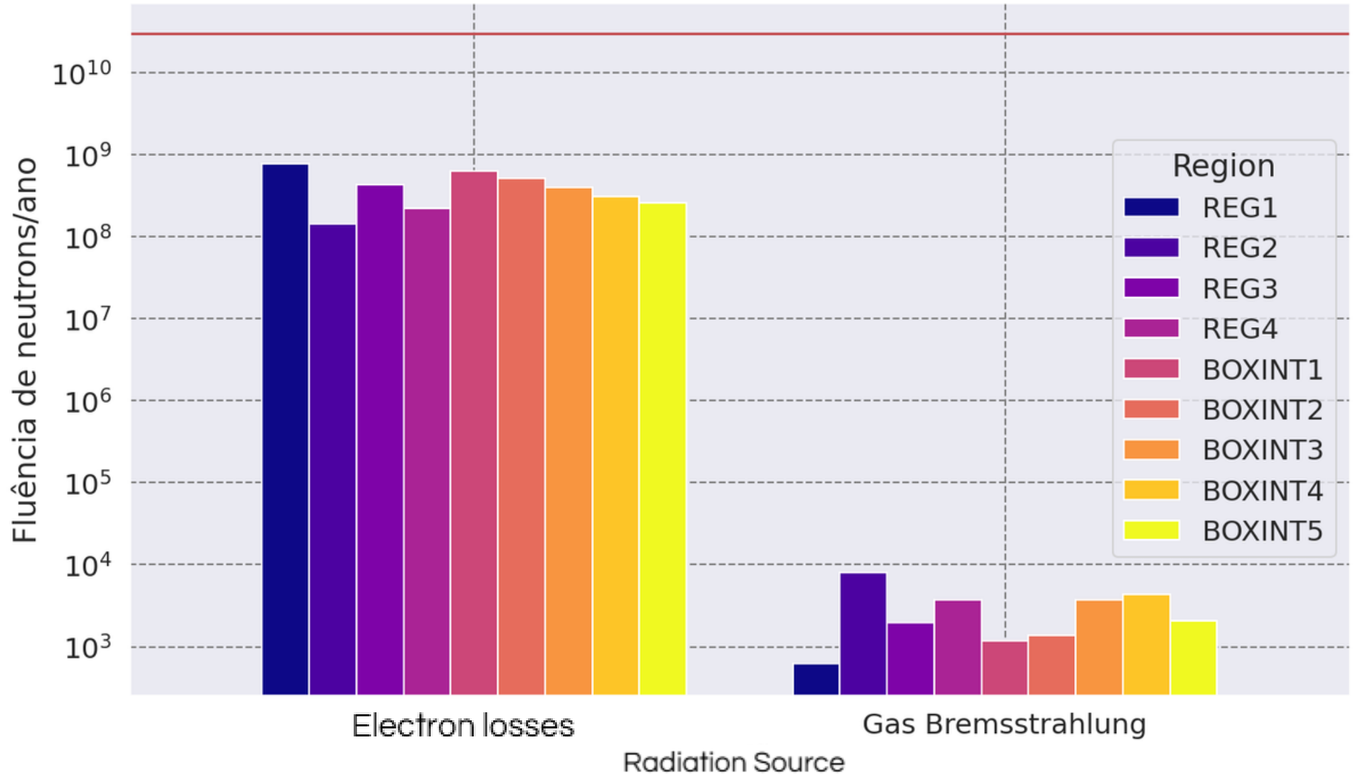
Shielding solution - Sincrotron inside M1



- The impact of adding attenuating materials such as steel and tungsten was evaluated.
- For synchrotron scattering inside the mirror chamber, a shielding geometry was designed with a plate of variable thickness positioned over the electronics region.
- Applying such shielding could be an effective option to reduce the risk of equipment damage.

Displacement Damage (DD)

Neutron Fluence

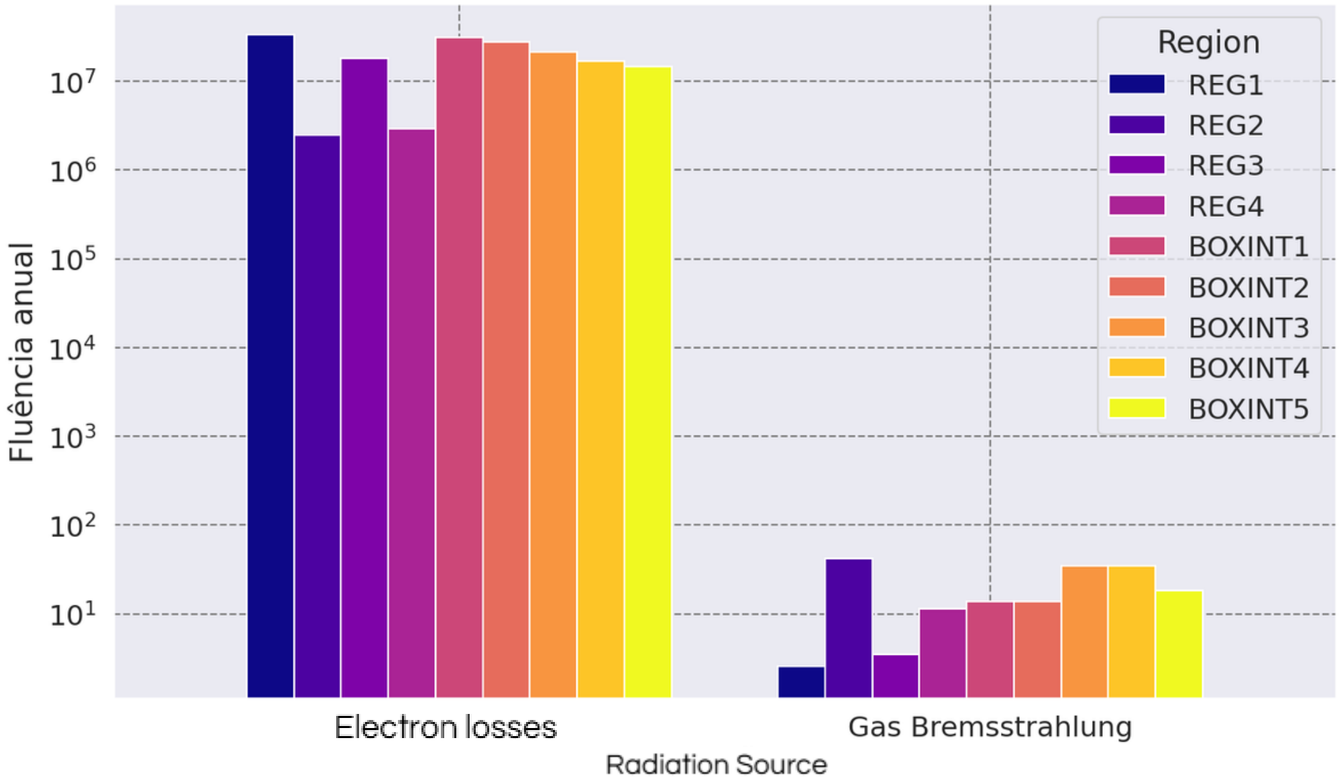


- Evaluated based on neutron fluence.
- Fluences above 3×10^{10} particles/cm^2 are typically required to cause notable degradation in components.
- DD is only relevant for electron losses and Gas Bremsstrahlung.
- Values below the damage threshold, indicating that DD is not expected to be a concern for the installed equipment.

Single-Event Effects (SEE)

Hadron Fluence

- Fluence of all hadrons with E ≥ 20 MeV, neutrons in the 0.2–20 MeV range (energy-weighted), and the thermal neutron fluence (weighted by inverse velocity)
- Fluence values are even lower than those found for Displacement Damage (DD), indicating a low likelihood of SEE occurrence.
- However, due to the presence of energetic particles, SEE-related failures cannot be entirely ruled out, although the expected failure rate is low.



Conclusions & Recommendations

Component location relative to the accelerator is a major factor in exposure levels:

- Electronics inside the mirror chamber are subject to significantly higher doses, mainly from synchrotron radiation scattered by the mirror itself.
- External components, located farther from the beamline, receive lower synchrotron doses, but are more affected by radiation from the accelerator. Components positioned closer to the ring remain more exposed.

Targeted shielding is recommended for exposed electronics:

- Enclose components in attenuating materials (steel or tungsten) based on the type and origin of radiation.
- This report includes dose reduction percentages for different thicknesses and shielding positions, which can be used as a reference to reduce the risk of equipment degradation or failure.

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Obrigada!

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