Combining Alanine Dosimeters and Monte Carlo Simulations: A method for demagnetization forecast by high dose exposure

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Motivation

- Sirius, the new Brazilian synchrotron, was designed to operate with 3 GeV, 350 mA in top-up mode and 0.25 nmrad of emittance, with photon flux per second of the order of 6.5×10^{16} for bending device.

- **Inevitable:** High-dose deposition by photons and neutron generation on magnetic lattice components.

Motivation

- Possible **long-term risk of demagnetization** of magnetic lattice components

- But …
  - What is the **effect of the radiation** responsible for the **demagnetization** of the magnets?
  - **How to measured?**

Motivation

There are theoretical models that have been proposed to explain this phenomenon, so

there is no single model that completely explains radiation-induced demagnetization

Proceedings of ERL2011, Tsukuba, Japan WG5005

BRIEF REVIEW OF THE APPROACHES TO ELUCIDATE THE MECHANISM OF THE RADIATION-INDUCED DEMAGNETIZATION

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ELSEVIER

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A review of radiation-induced demagnetization of permanent magnets

Adib J. Samin

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- Brief of theoretical information

Motivation

Definition of experimental values for comparison with simulations

research papers

Journal of Synchrotron Radiation

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Analyses of the factors for the demagnetization of permanent magnets caused by high-energy electron irradiation

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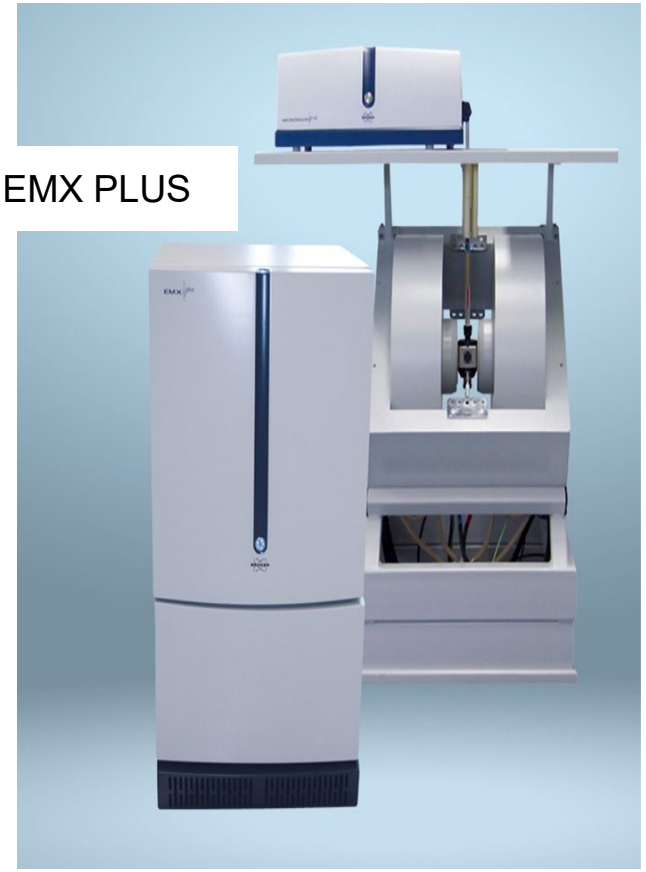
Objective

- **Preliminary results** of experiments carried out with **alanine/EPR dosimeters** and **Monte Carlo simulations with the FLUKA.CERN** code to investigate photon and neutron dosimetry at Sirius.

Materials and method

- Use of high-dose dosimeters composed of alanine and read by Electron Paramagnetic Resonance (EPR).

- FLUKA.CERN



Bruker EMX PLUS

Dosimeters

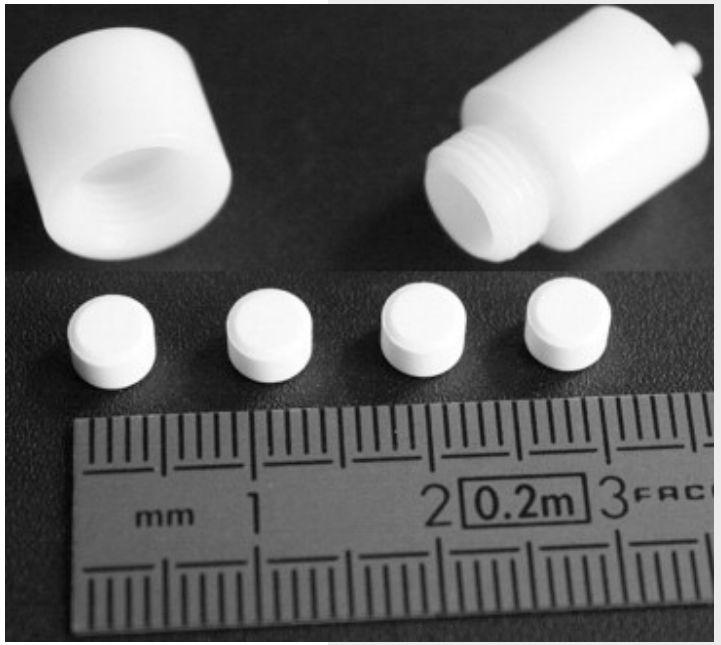
What is alanine dosimeter?

How do alanine dosimeters work?

Why we choose alanine dosimeter?

Dosimeters

What is alanine dosimeter?



The alanine dosimeter is primarily made of pure **alanine crystals**, which are highly sensitive to radiation and undergo structural changeswhen exposed. It may also include protective casingsand shielding materials to ensure accurate measurement of absorbed radiation dose.

- Calibration with Co-60 (1.3 MeV and 1.17 MeV)

Rodrigues Junior, Orlando, & Santos, Silas Cardoso dos (2019). Stability study of the Alanine EPR Dosimetry System at IPEN/CNEN SP. Brazil: ABEN.

Dosimeters

How do alanine dosimeters work?

When an alanine molecule is irradiated, it produces a stable free radical, CH3-CH-COOH.

The concentration of the stable free radicals can be measured as a signal (a dosimetric signal) using electron paramagnetic resonance (EPR) spectroscopy and is proportional to the absorbed dose.

It a valuable tool in various fields, including radiation therapy, nuclear industry, and occupational radiation monitoring .

Dosimeters

Why we choose alanine dosimeter?

1. The partnership between the Nuclear and Energy Research Institute (IPEN) and the Brazilian Synchrotron Light Laboratory (LNLS) began with the UVX, the first Brazilian synchrotron.

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2. The use of high-dose dosimeters composed of alanine and read by Electron Paramagnetic Resonance(EPR)**appears as a viable and robust dosimetric method** for monitoring throughout the useful life of the machine. The high-dose alanine EPR system is a secondary standard method for transfer dosimetry, radiotherapy dosimetry, and industrial applications, with dose **range of 10 Gy to 100 kGy, with low signal decay and a dose uncertainty of less than 3%**

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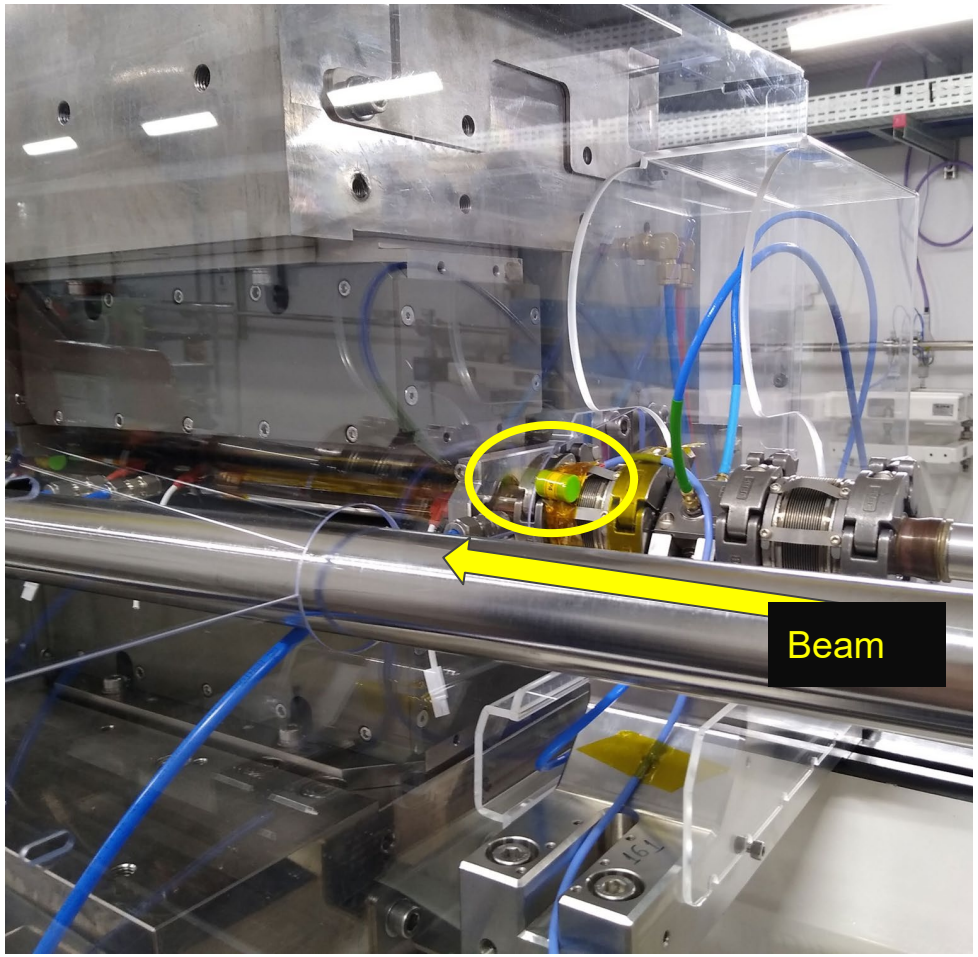
3. In this experiment, we used alanine dosimeters produced by Gamma Services (AGS)and **marketed** by Bruker BioSpin.
   The pellets are cylindrical in shape, 3mm high and 4.8 mm in diameter, mass of 64.5 mg, with approximately 62 mg of L-alanine, mixed with polyethylene as a binding agent. → **Possibility of comparative studies**

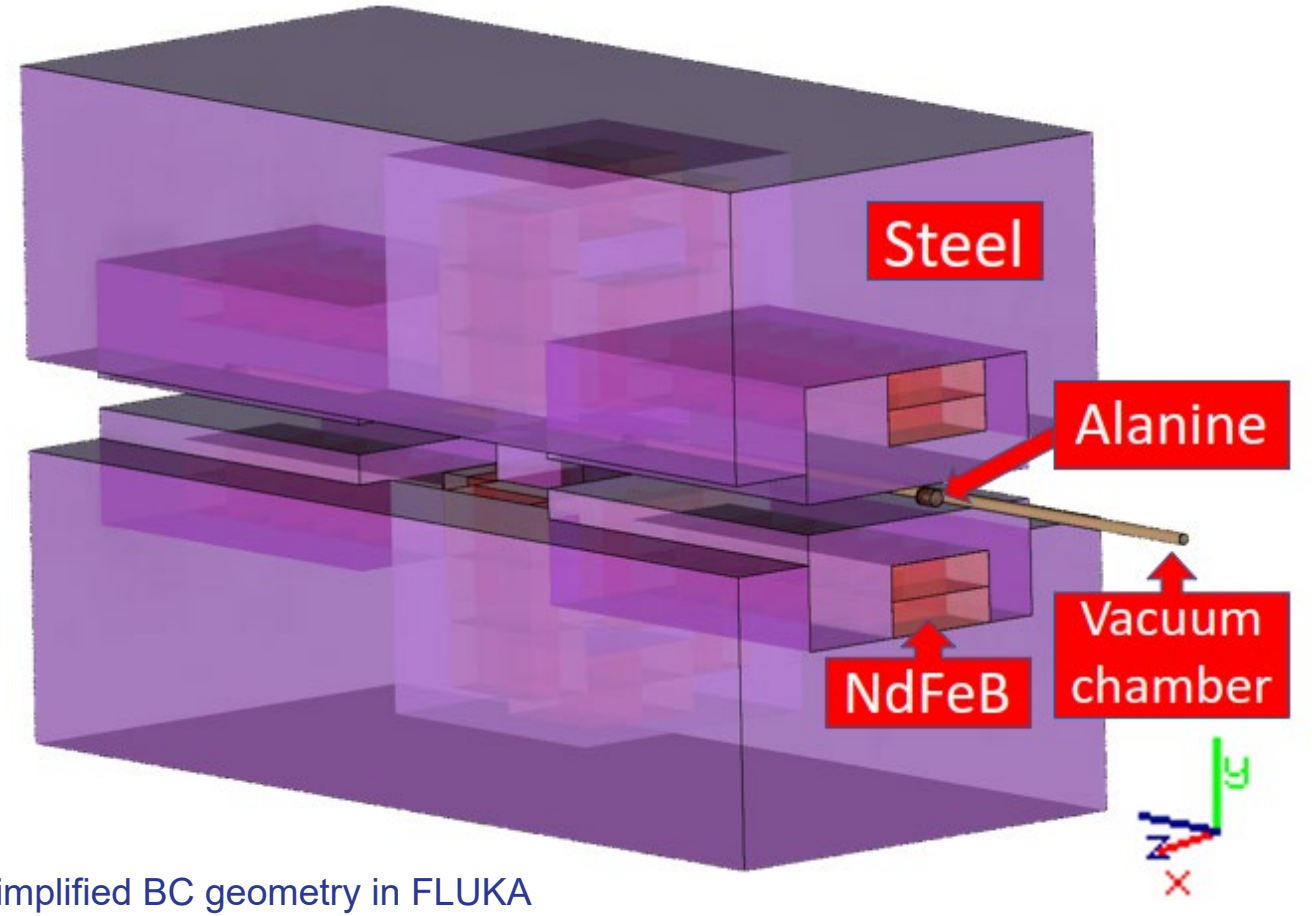
Materials and method

- Two long exposure time:
  - 12 months: 2020 to 2021 @ 5 to 40 mA
  - 06 months: June/21 to January/22 @ 60 to 80 mA

- Now: Jan/23 until 2024 @ 100 mA topup



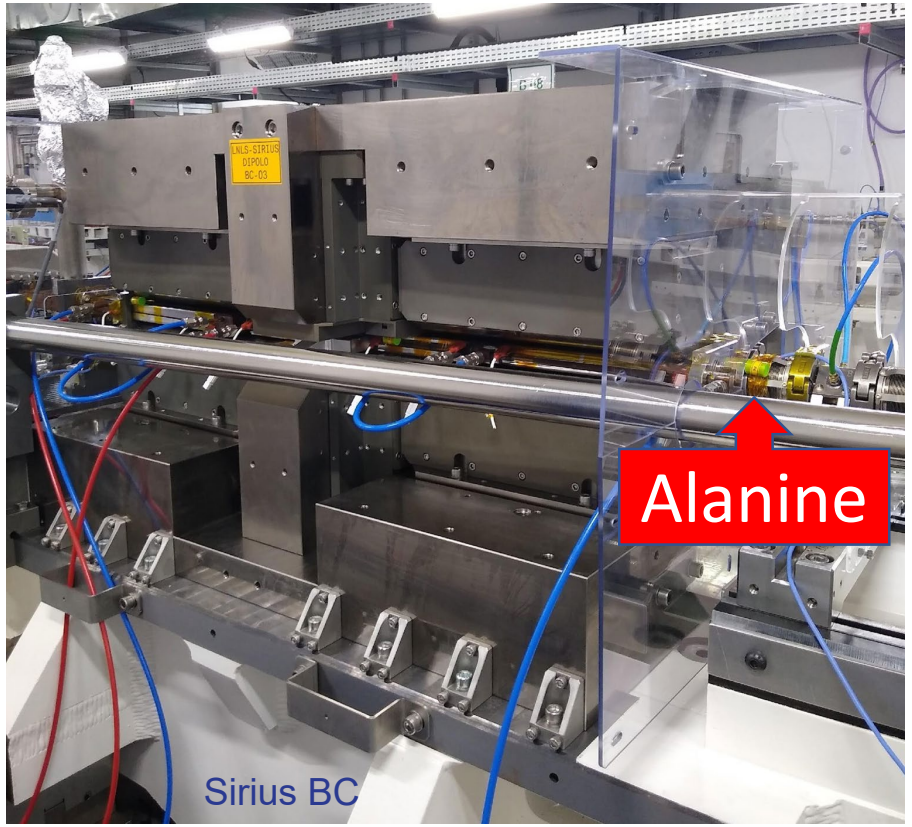
BC Central permanent magnetic dipoles | NdFeB



Simplified BC geometry in FLUKA

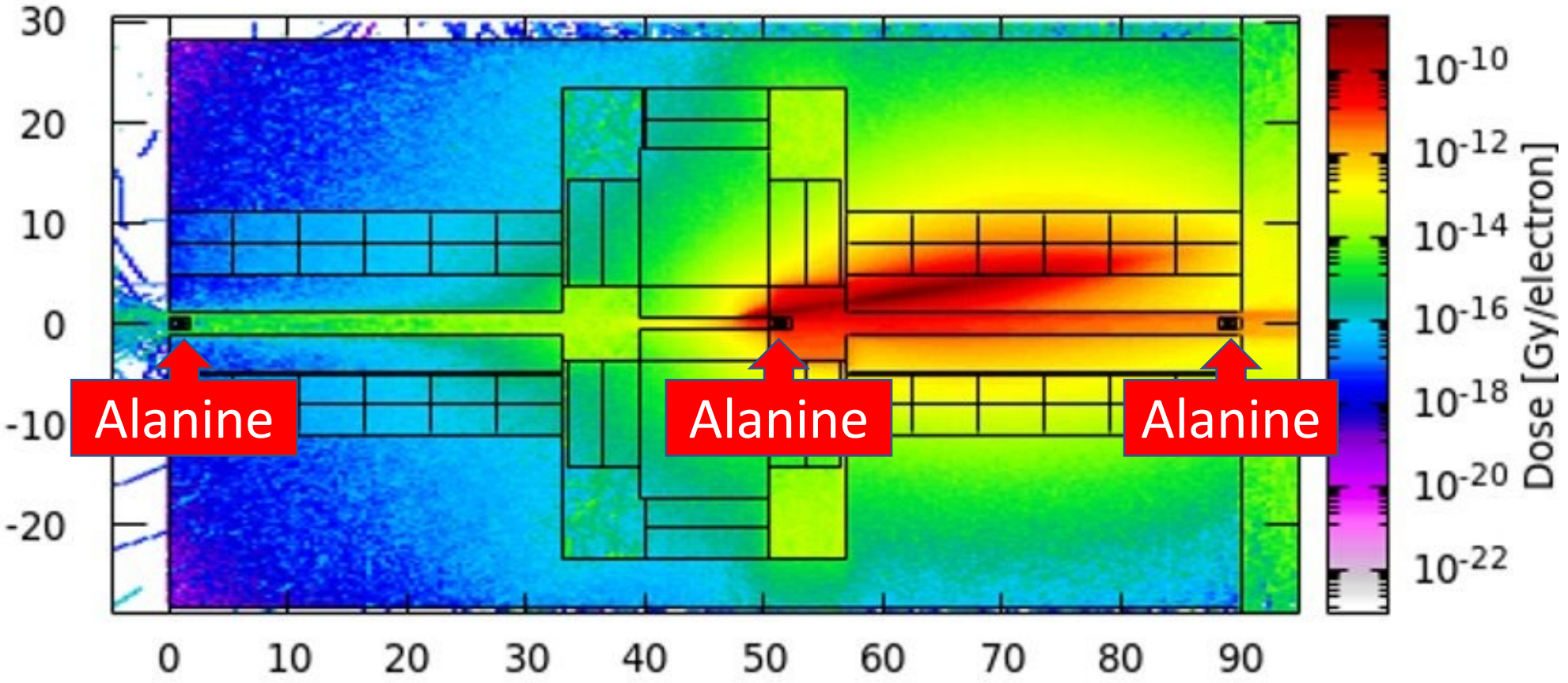
Conservative considerations:

- Beam loss: 2. 10 ^{12} e/hr in center of BC.
- 1 year of operation: 24/7
- Spectrum: 1 MeV - 3GeV



Sirius BC

Simulation



Estimated dose:
1.3 10^{4} Gy/year

Neutron dose:
3.1 10^{11} n/cm²

Values below the literature reference

Demagnetization is not a problem at Sirius..(?)

Preliminary results

- Zero means less than 1.5 Gy

1st experiment: 12 months (20/jan - 21/jan)		
Point	Dose (Gy)	Uncertainty (%)
BC01-I	17,8	2,3
BC01-M	386,6	2,9
BC-01-F	32,4	0,5
BC03-I	0	0
BC03-M	0	0
BC03-F	16,8	0,5
BC05-I	0	0
BC05-M	0	0
BC05-F	2,5	1,1
BC09-I	0	0
BC09-M	0	0
BC13-I	0	0
BC13-M	3,3	0,8

2nd exp.: 6 months (21/jun- 22/jan)		
Point	Dose (Gy)	Uncertainty (%)
BC01-M	3,29	0,7
BC01-F	2,17	1
BC03-F	2,69	1,1
BC04-M	0	0
BC04-F	1,98	0,7
BC08-M	0	0
BC08-F	1,95	0,7
BC11-M	2,2	0,7
BC11-F	0	0
BC12-M	0	0
BC12-F	3,45	1,5
BC16-M	1,53	1,1
BC16-F	9,02	1,1
BC20-M	0	0
BC20-F	3,02	0,5

Perspectives

Promising validation methodology

Comparative between dosimetry
with low cost and simulation.

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New scenarios

New beamlines (IDs), beam current and top-up operation.

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Understand the contribution of neutron dose

Studies with CR-39 and measurements with neutron spectrometer is coming.
Alanine dosimeters with filters **for neutrons**

↱ We hope to publish the results with longer exposure time soon.

Thank you

Merci

Obrigada

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