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Design and Numerical Investigations of Scintillation Beam Loss Monitor for PolFEL.

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INTRODUCTION

The Beam Loss Monitor (BLM) system is used mainly for machine protection and is particularly important in the case of high energy density of accelerated beam, when such a beam could lead to serious damages in the case of uncontrolled loss. The BLM concept for PolFEL is based on several scintillation probes placed along the linear accelerator. The paper reports on numerical investigation of radiation induced during fast electron losses. We also present design of BLM detectors and results of first tests of a prototype on the linear electron accelerator at SOLARIS research centre.

Types of beam losses in accelerator

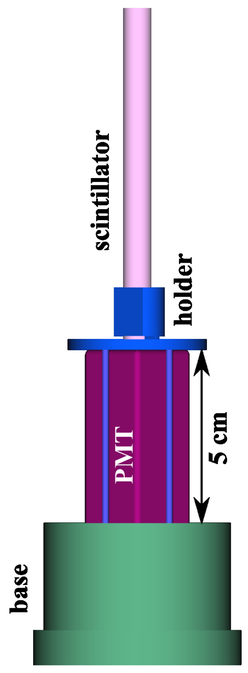
Beam loss type	characteristics	caused by
Regular (controlled, slow)	localized on collimator, aperture limits, magnets;	aperture changes, scattering on residual gas, lifetime limitation
Irregular (uncontrolled, fast)	distributed along the machine, fast and intense source of radiation	misaligned beam, faults in magnetics/RF cavities, vacuum leaks

Important factors for BLM detector selection for PolFEL

- **wide gain regulation**
- **total pulse length < 20 µs**
- **no HV cables outside**
- **good radiation resistance**
- **time for emergency shutdown decision: ~µs**
- **affordable (about 20-30 detectors needed)**

Considering the mentioned factors and taking into account the experience of various NCBJ groups we have decided to use plastic scintillation detector coupled with photomultiplier. Such a system provides:

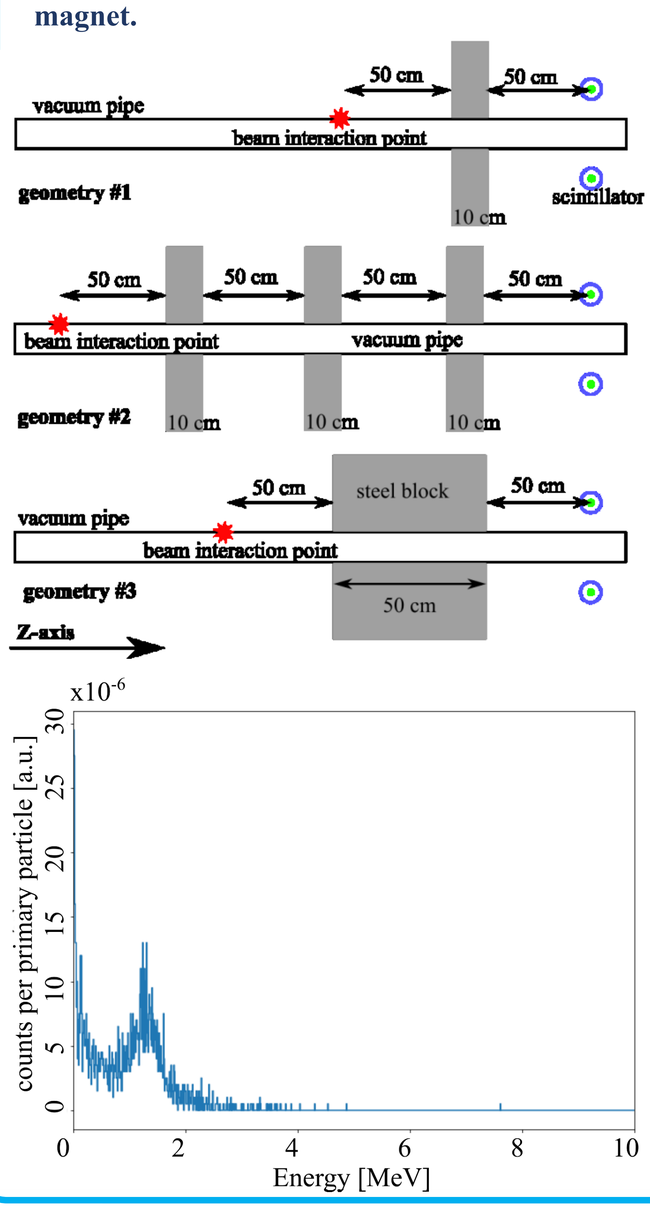
- **high detection efficiency compared to other detector types**
- **high dynamic range and possibility to change it voltage**
- **possibility of calibration using standard radiation sources**
- **availability in custom size and shape**
- **relatively low price**
- **additional failsafe checks using built-in LED**

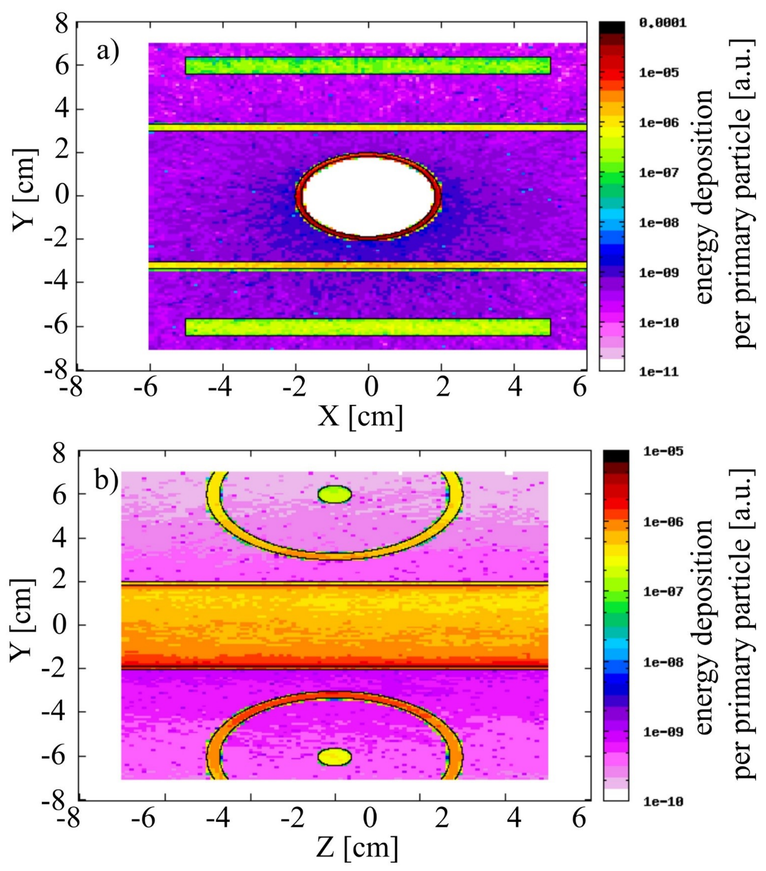


Design of BLM detector for PolFEL accelerator

NUMERICAL INVESTIGATION

In order to assess the amount of radiation which could be expected during PolFEL operation and beam loss event, we have performed numerical studies of chosen design of BLM detector, using FLUKA (version 2021.2.1) Monte Carlo code. We have tested three geometry configurations of the detector vicinity. The detectors (cylinders made of Polyvinyl toluene, 8mm in diameter and 10 cm in length), parallel to X-axis, were positioned at Z = 0 coordinates and placed in Aluminum housing, with 6cm in diameter and 20 cm in length. The steel beam (vacuum) pipe, with inner and outer diameters equal to 3.68 and 4.0 cm respectively, was parallel to Z-axis. Solid cylindrical blocks of steel, (magnet mock-up), were placed at chosen position along the beam pipe. The beam interaction point was put 50 cm in front of the magnet.





Geometry used during MC simulations (upper left, not to scale) and results of calculations: Energy deposition spectrum (lower left), Energy deposition in Cartesian grid: XY plane (upper right), YZ plane (lower right), as calculated for one of the geometry and chosen detector.

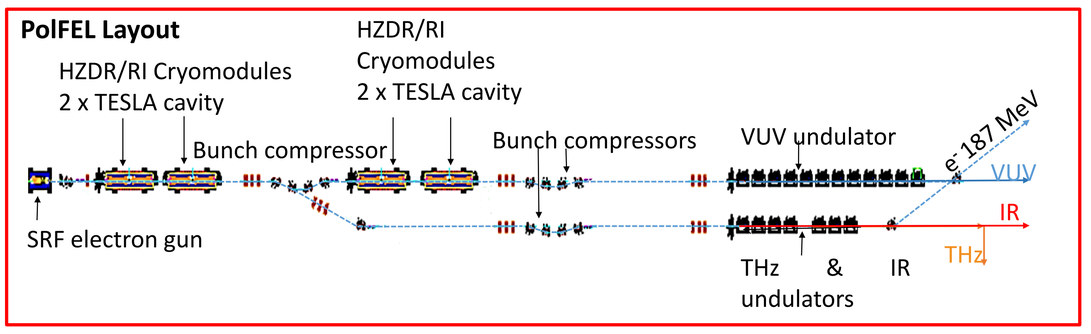
PolFEL FACILITY

The Polish Free Electron Laser, PolFEL is a project currently in the preparatory phase, and is planned to be built at the end of 2023. It will be equipped with linear superconducting accelerator operating in continuous wave regime. The maximum energies of electrons will be equal to about 180 MeV, or 270 MeV for 2nd phase of operation. The beam charge, pulse width and repetition rate will be in the range of 100-250 pC, 0.1-10 ps and 50 kHz respectfully.

Parameters of PolFEL accelerator

	Unit	Gun	VUV/electron line	THz line
Bunch charge	pC	20-250	max 100	250
Bunch repetition rate	kHz	50	50	50
Bunch duration at the electron line exit	ps	2-10	0.4	up to 10
Beam energy* at the line exit, cw mode	MeV	4	90-154	79
Maximal beam current	µA	12.5	5	12.5
Beam power at dump, cw mode	W	-	650	813

PolFEL Layout

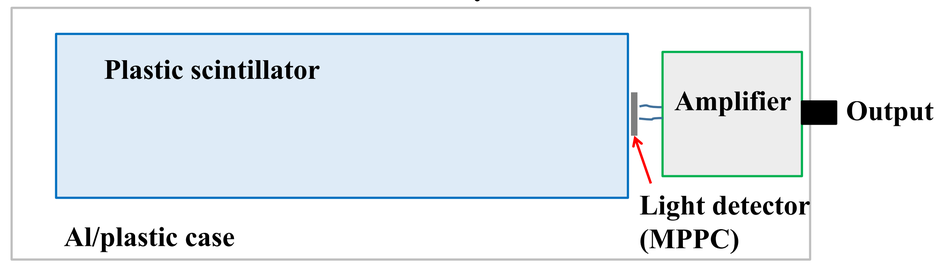


PRELIMINARY EXPERIMENTAL TESTS

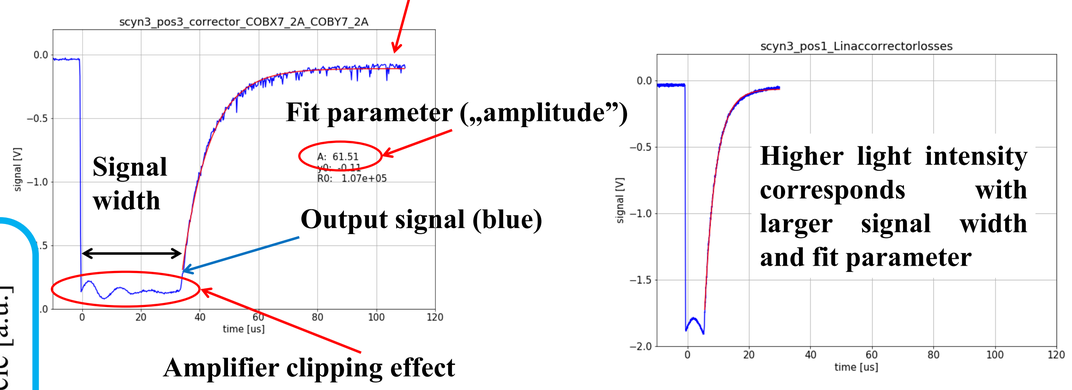
The first device, a so-called concept-prototype, was built to check the principles and operation of plastic scintillation detector at linear accelerator. Due to the built-in amplifier and fixed operational voltage of the detector, the registered signal was severely clipped. Nevertheless, it was possible to observe changes in the signal width, which could be interpreted as an effect of increase in amplitude.

Concept-prototype tests @ SOLARIS

Probe layout



Exponential fit (red)



CONCLUSIONS

The working parameters of PolFEL electron accelerator induce need to install and operate the BLM system. On the basis of numerical (Monte Carlo) calculations and experimental test, we have designed a prototype BLM detector for PolFEL, which uses fast plastic scintillator (EJ-232 type) coupled with miniature photomultiplier (H11901 type). The further investigation, both experimental and numerical, of designed prototype is the next step of BLM system development for PolFEL facility.

ACKNOWLEDGEMENTS

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