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Electron beam loss assumptions for ELI-NPMEGa-ray radioprotection analysis

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TO: Chris Barty

FROM: Gary Deis

SUBJECT: Electron beam loss assumptions for ELI-NPMEGa-ray radioprotection analysis

As you know, the ELI-NP project is now working on the design of their conventional facility. Dr. Gheorghe Cata-Danil recently requested that I provide them with information on the location and amount of electron-beam loss in the MEGa-ray source we have proposed for ELI-NP. This memo is intended to document that information, for transmission to ELI-NP.

The ELI-NP MEGa-ray source, as presently proposed, consists of two x-band accelerator sections separated by a large chicane, as shown in Figure 1.

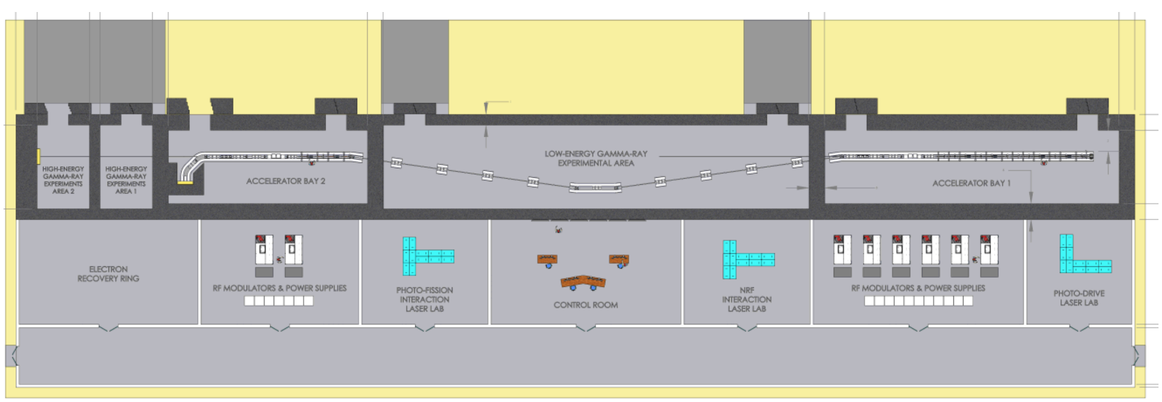

Figure 1 – Plan view of ELI-NP MEGa-ray source

The basic parameters of the machine that are pertinent for specifying the radiation source terms are shown in Table 1. These are the parameters of the intentionally-produced photobeam.

Table 1 – ELI-NP MEGa-ray electron beam (photobeam only) parameters

Parameter	Unit	Value
Maximum electron energy, low energy section	MeV	250
Maximum electron energy, high energy section	MeV	600
Microbunch charge, maximum	pC	250
Microbunches per pulse, maximum		100
Pulse rate, maximum	Hz	120
Average current, maximum	nA	3000
Maximum average beam power, low energy section	W	750
Maximum average beam power, high energy section	W	1800

In addition to the photobeam, the electron gun and accelerator will produce "dark current" that originates throughout the RF structures (that is, distributed along the accelerator axis) and therefore has a distribution of energy below the energy of the photobeam. Because it is emitted from surfaces inside the RF structures, much of it is not transported through the accelerator and is lost in the accelerator RF structures. A large fraction of the total dark current is produced in the photogun and lost at the entrance of the 1st accelerator RF structure.

Important sources of radiation during operation are beam alignment screens that are used for observing the image of the electron beam, during adjustment of beam steering and for general diagnostic purposes. Each screen consists of a 1mm thick Ce:YAG plate that is moved into the path of the beam when desired. This destroys the electron beam, spraying all beam current into the structures downstream of the screen. Only one screen is inserted at a time. These screens may be located after each accelerator RF structure, and after each set of bend magnets, as shown in Figure 3. The photobeam energy and currents at each location are listed in Table 2; for simplicity, the dark current energy is (conservatively) assumed to be the same as the photobeam energy.

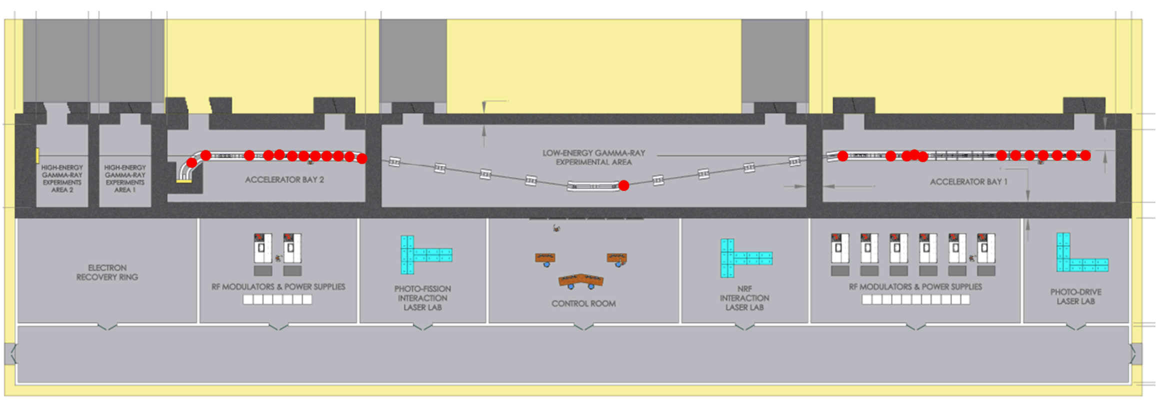

Figure 3 – Locations of potential beam alignment screens

Table 2 – Beam characteristics at each beam alignment screens

No.	Location	Photobeam energy (MeV)	Photobeam current (nA)	Dark Current (nA)
1	After photogun	10	3000	118
2	After RF section 1	50	3000	30
3	After RF section 2	90	3000	30
4	After RF section 3	130	3000	30
5	After RF section 4	170	3000	30
6	After RF section 5	210	3000	30
7	After RF section 6	250	3000	30
8	Before small chicane dipole #1	250	3000	30
9	Before small chicane dipole #2	250	3000	0
10	Before small chicane dipole #4	250	3000	0
11	Beam transport section	250	3000	0
12	Before large chicane dipole #1	250	3000	0
13	Before large chicane dipole #2	250	3000	0
14	Before large chicane dipole #4	250	3000	0
15	Before RF section 7	250	3000	0
16	After RF section 7	308	3000	30
17	After RF section 8	367	3000	30
18	After RF section 9	425	3000	30
19	After RF section 10	483	3000	30
20	After RF section 11	542	3000	30
21	After RF section 12	600	3000	30
22	Before small chicane dipole #1	600	3000	30
23	Before small chicane dipole #2	600	3000	0
24	Before small chicane dipole #4	600	3000	0
25	Beam transport section	600	3000	0
26	Before dump dipole #1	600	3000	0
27	Before dump dipole #2	600	3000	0

In normal operation, the locations of other beam losses and the estimated current and energy of the lost beam are listed in Table 3

Table 3 – ELI-NP MEGa-ray normal electron beam loss assumptions

No.	Beam Loss Location	Type of current	Current loss (nA)	Electron Energy (MeV)
1	Entrance of accelerator structure #1, after photogun	Gun dark current	118	0 to 7
2	Distributed in 1st accelerator (T-53) section	Gun dark current	2.4	0 to 52
3	Distributed in each accelerator (T-53) section	Accelerator dark current	2.4 per section	0 to 25
4	Beam alignment screens	Photocurrent and dark current	See table 2	See table 2
5	Between 1st and 2nd dipole in small chicane, first accelerator section	Dark current	30	0 to 250
6	Between 1st and 2nd dipole in small chicane, second accelerator section	Dark current	30	0 to 350
7	Beam dump	Photocurrent	3000	600 MeV

In addition to these "normal" beam losses, it is assumed that the beam may be accidentally mis-steered by up to 1 degree at every steering magnet, so that it hits the surrounding beam tube and other structures. This loss can be modeled as occurring at the locations listed in Table 2, numbers 1-7 and 16-21.

Similarly, it is assumed that any of the dipole magnets, in chicanes or at the beam dump, may fail, resulting in total beam loss straight ahead. These locations can be assumed to be the same as listed in Table 2, numbers 8-10, 12-14, 22-24, 26, and 27.

The data provided above are estimates of the beam loss, for the purpose of calculating radiation source terms. Dark current estimates are conservative, until we acquire actual operational data. Neither the estimated currents nor the estimated energies listed above contain any intentional margin. When we have performed similar calculations for our own purposes, we have typically added approximately 10% to the beam energy to provide some overall margin in the analysis.