Health physics calculations related to the target station radiation protection design

Zsófia Kókai
Supervisors: Luca Zanini, Péter Zagyvai, Szabina Török
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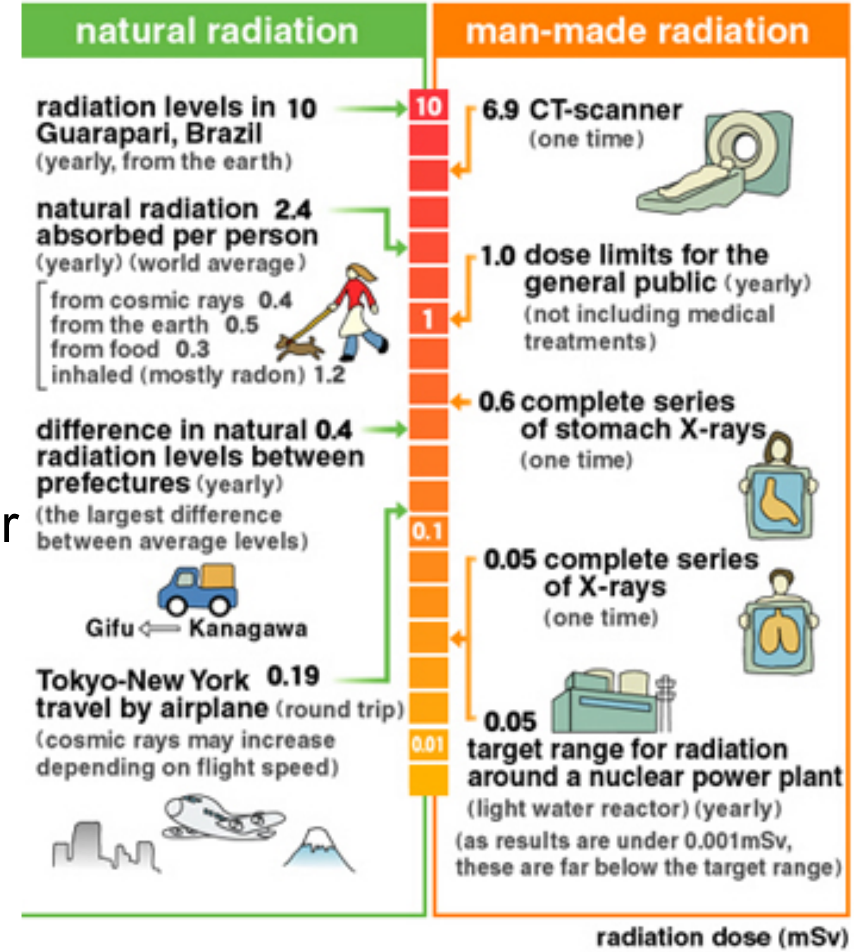
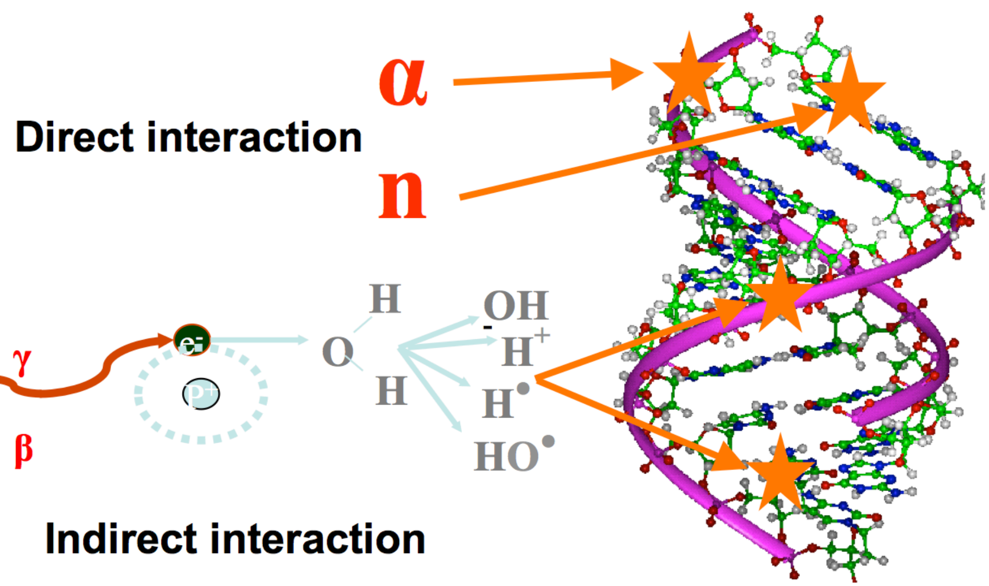
Outline

- Why do we need health physics calculations?
  - Radiation protection, input for shielding design
  - Safety, input for radiation safety calculations
  - Radioactive waste management, input for radioactive inventory
- Example: activation and dose rate calculation method
- Preliminary results of the neutron guide activation calculations

Radiation protection

- Dose limits for normal operation /SSMFS 2008:51, ESS-0000004/
  - Radiation workers: 10 mSv/year
  - Non-exposed workers: 0.05 mSv/year
  - Public: 0.05 mSv effective dose/year
  - ESS: 1 manSv collective dose/year

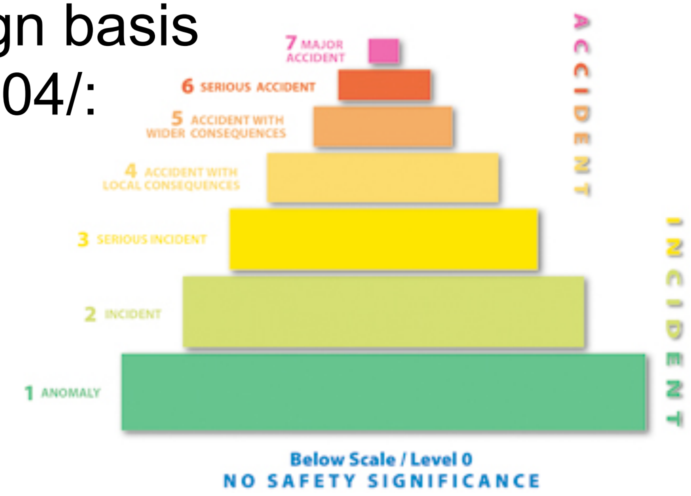


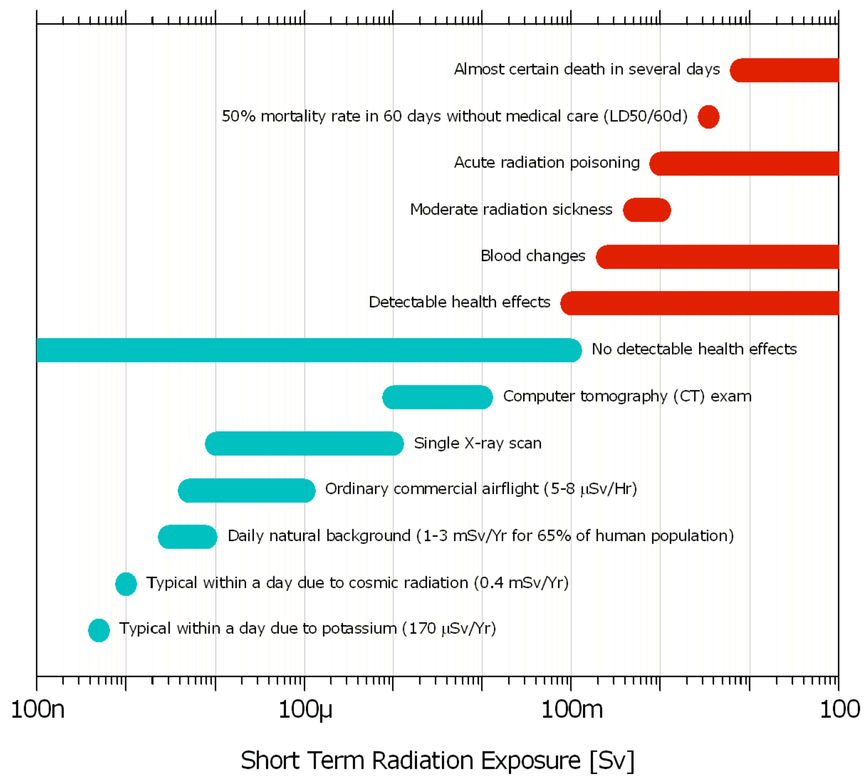


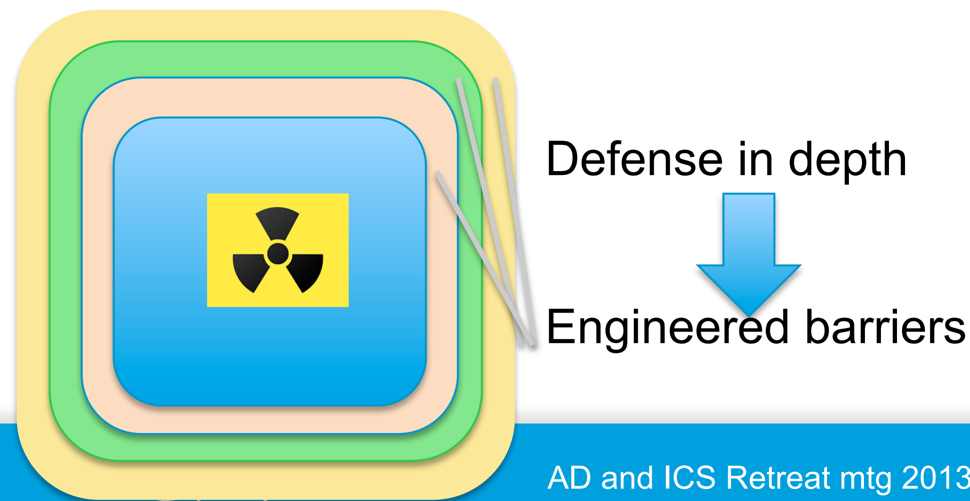
- ALARA principle
- Shielding design

Radiation safety

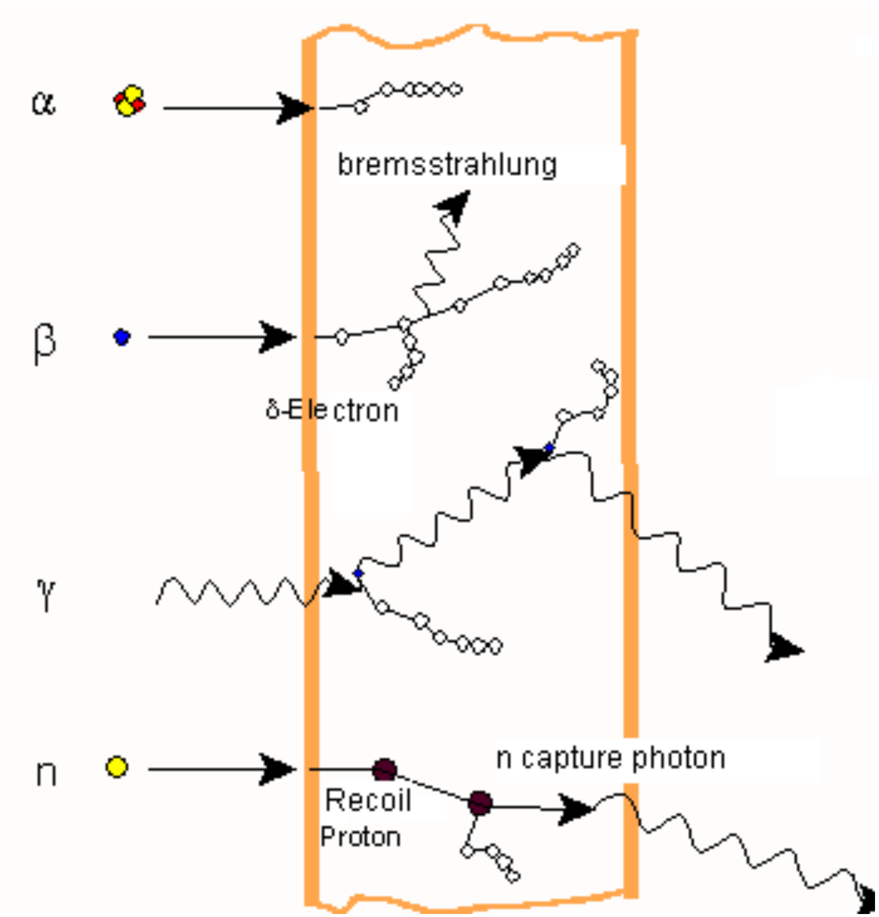
- Different dose limits for events with different probability of occurrence, e. g. for design basis accident /SSMFS 2008:51, ESS-0000004/:
  - Radiation workers: 50 mSv/event
  - Non-exposed workers: 20 mSv/event
  - Public: 20 mSv/ event



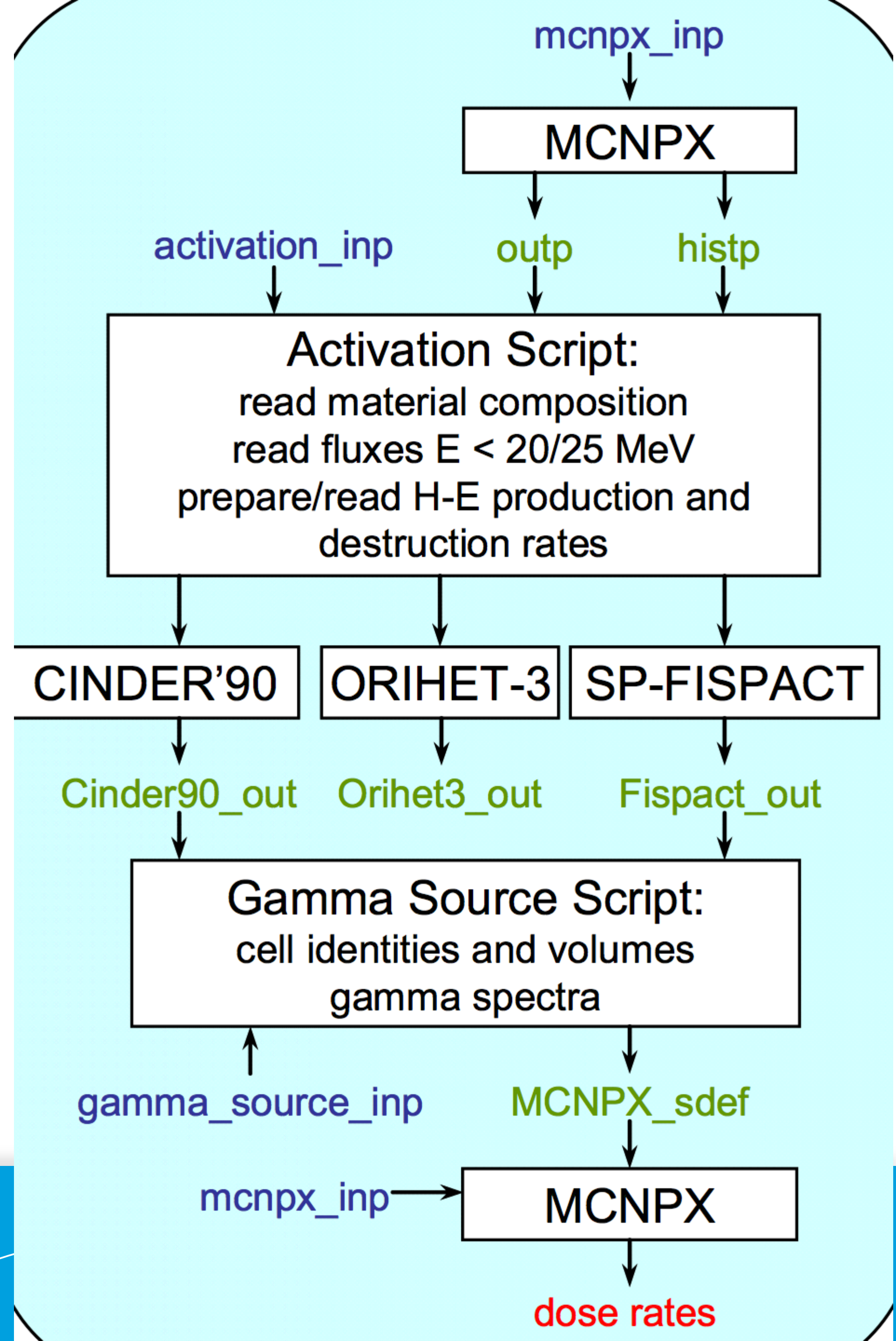




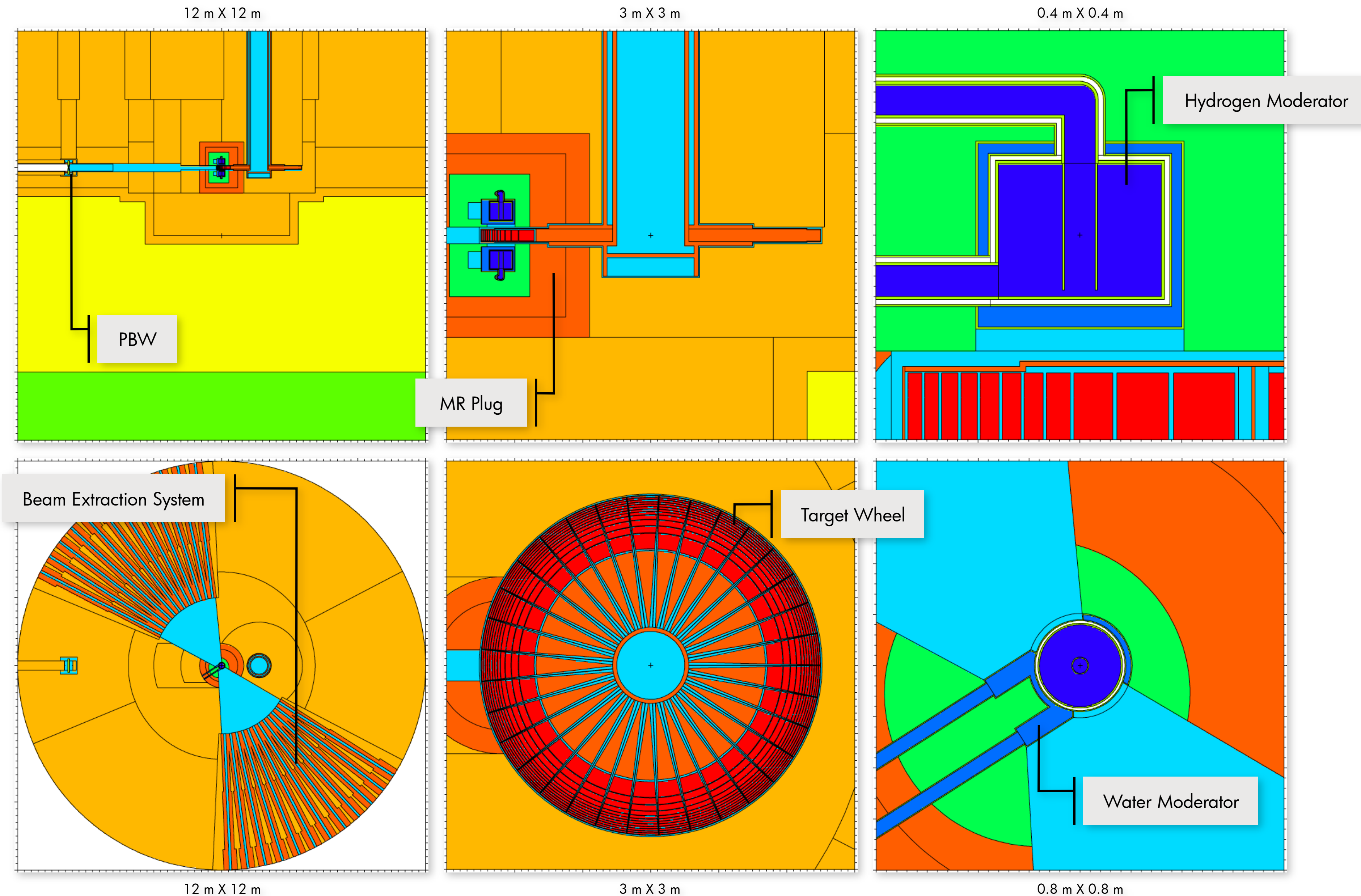
Method for radioactive inventory and dose rate calculation



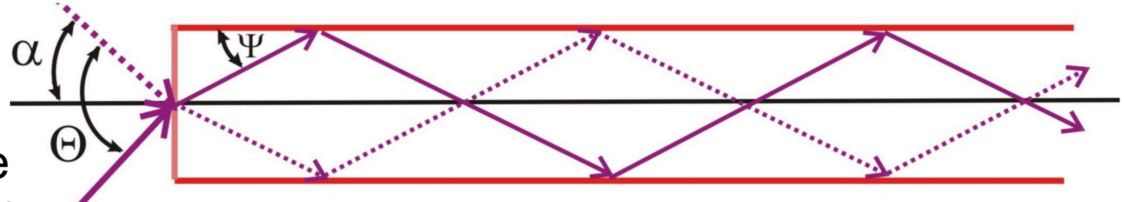
$$\frac{dN_i}{dt} = -(\sigma_i^a \Phi + \lambda_i) N_i + \sigma_j^c \Phi N_j + \lambda_k N_k$$



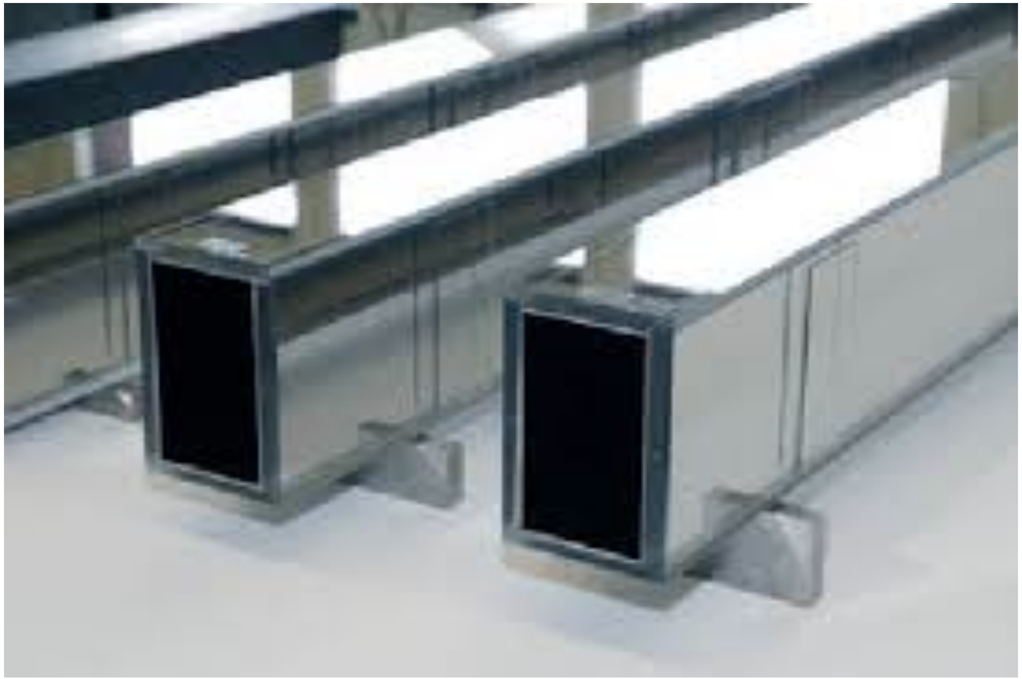
Target station monolith design (Alan Takibayev)



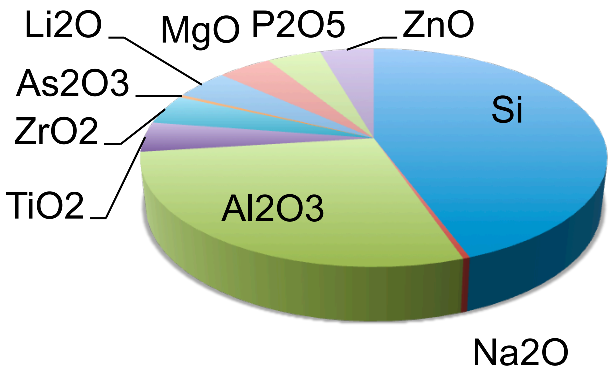
Neutron guides in the target station



- Neutron transport
- Planned systematic replace
  (radiation damage, mechanical failure, progress in guide technologies)

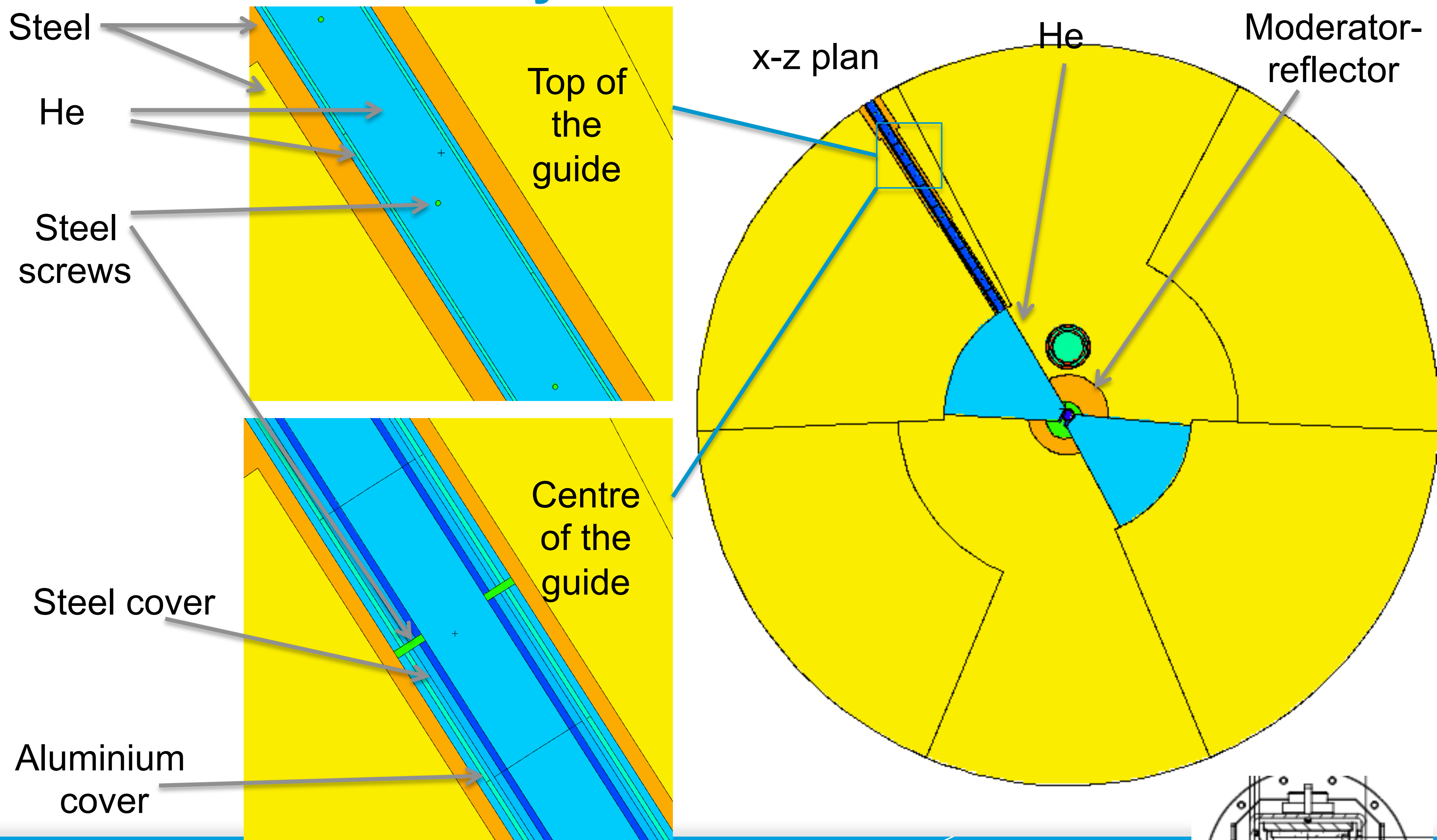


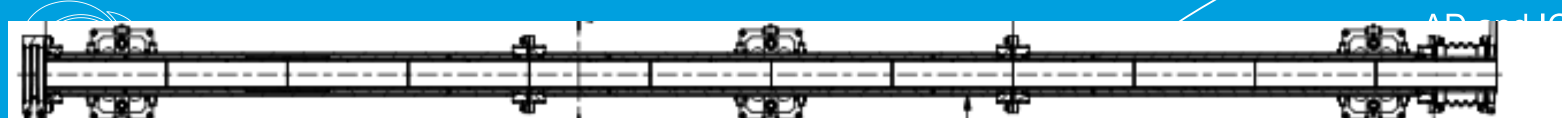
Extremely low expansion ZERODOUR® glass

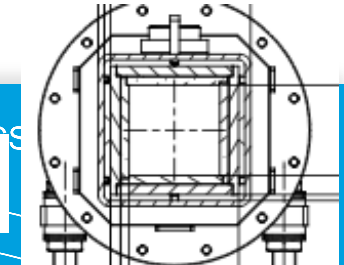


- Other parts: aluminium and stainless steel cover, screws

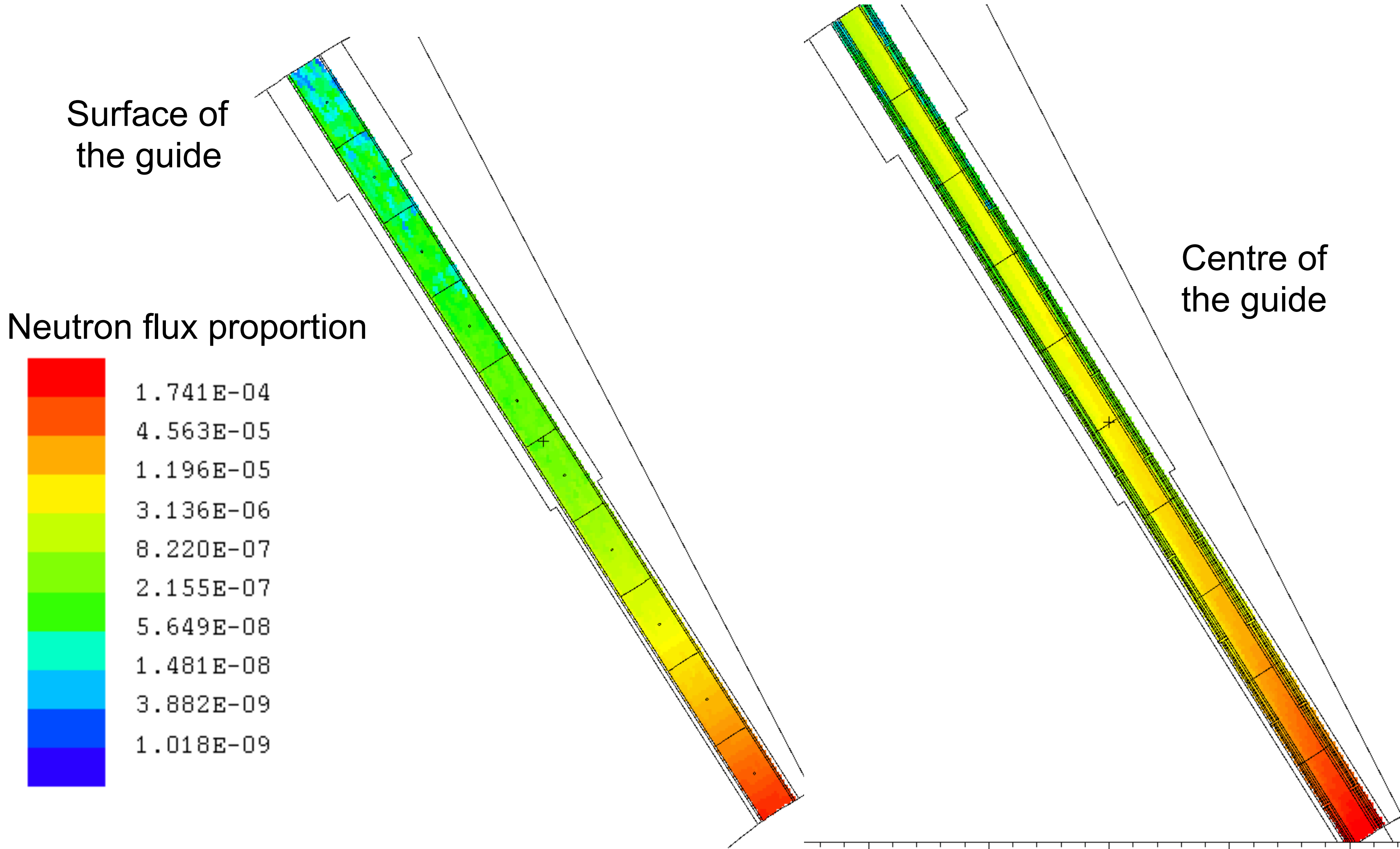
Neutron guide MCNPX geometry based on draws by Mirrotron co.







MCNPX results: Neutron flux map



Fluence

- The 2 mA current means $1.248 \cdot 10^{16}$ proton/sec intensity (I_{proton})

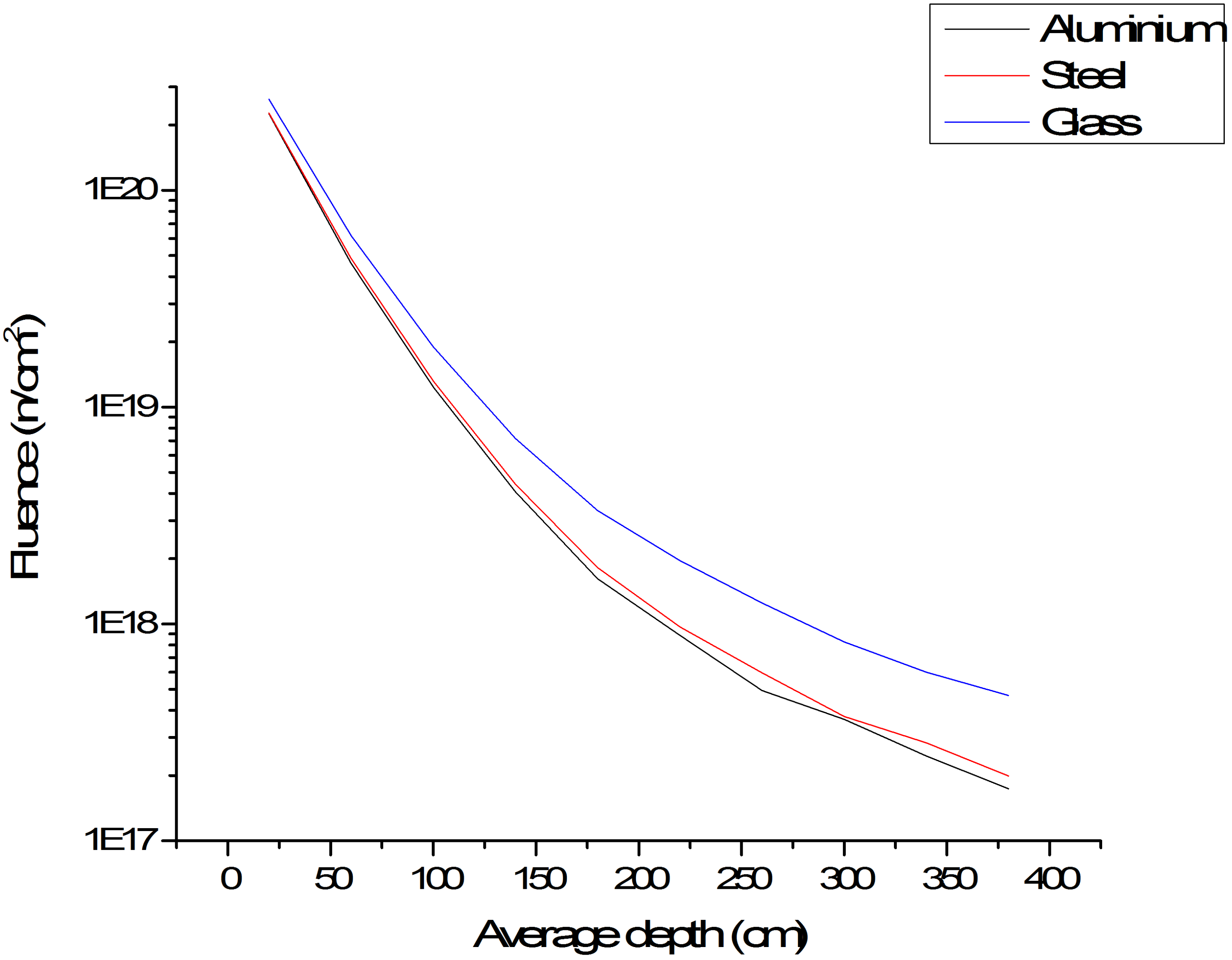
- In this calculation 200 days per year operation time has been assumed at full power. It corresponds to an average current of $6.841 \cdot 10^{15}$ proton/sec.
  The total neutron flux is proportional to this intensity:

$$\Phi := \Phi_{tot} = I_{proton} \cdot \int_0^{E\max} \Phi(E)\,dE$$

- The fluence has been calculated assuming irradiation time of 10 years

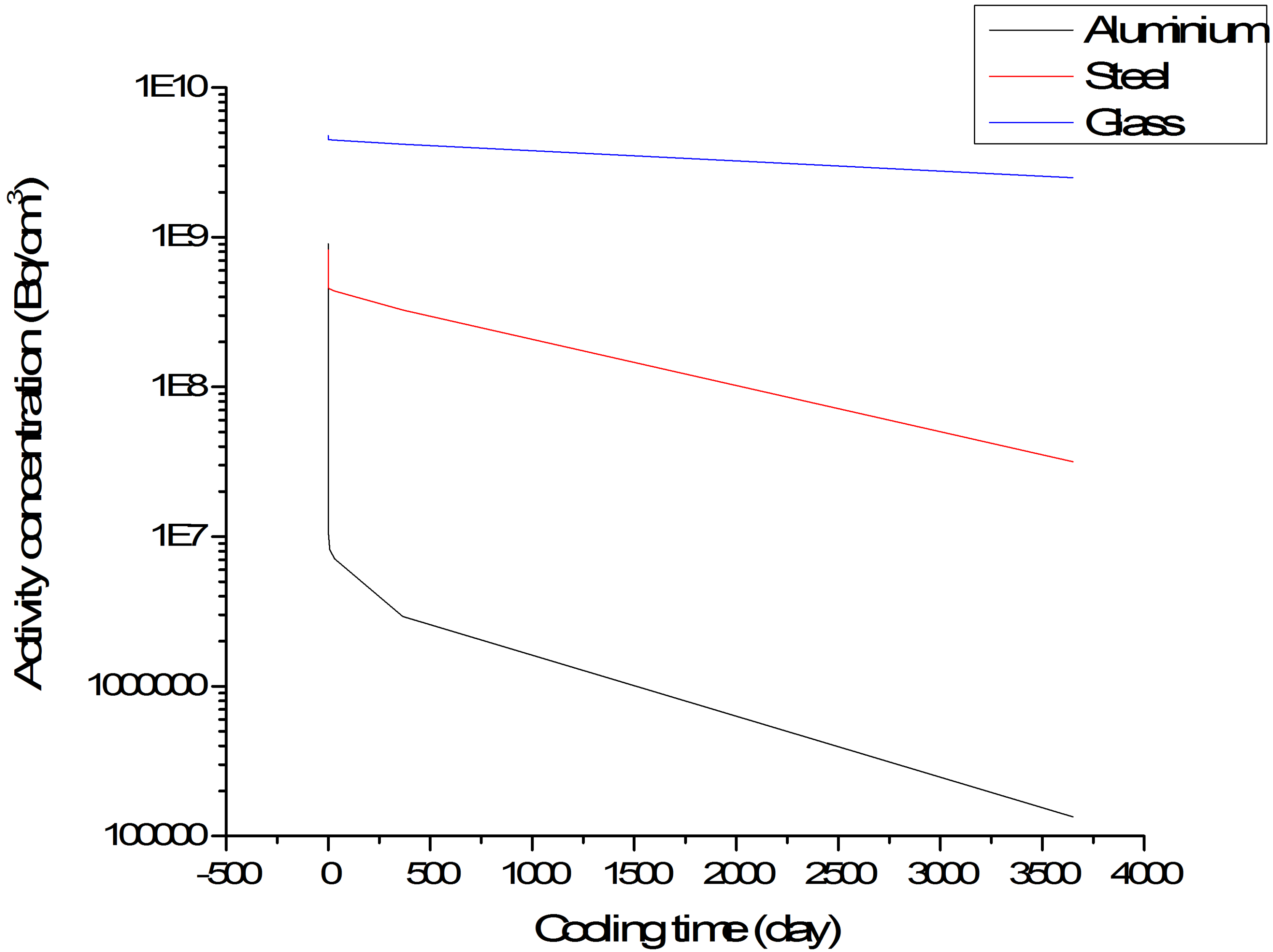
$$F = \int_0^{10\,years} \Phi_{tot}(t)\,dt$$

Fluence



Aluminium
Steel
Glass
1E20
1E19
1E18
1E17
Fluence (n/cm^2)
0
50
100
150
200
250
300
350
400
Average depth (cm)

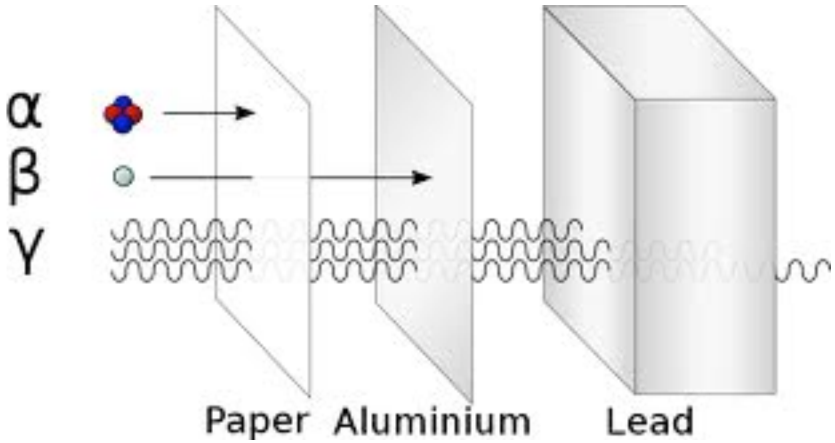
CINDER'90 activation script results: Activity concentration

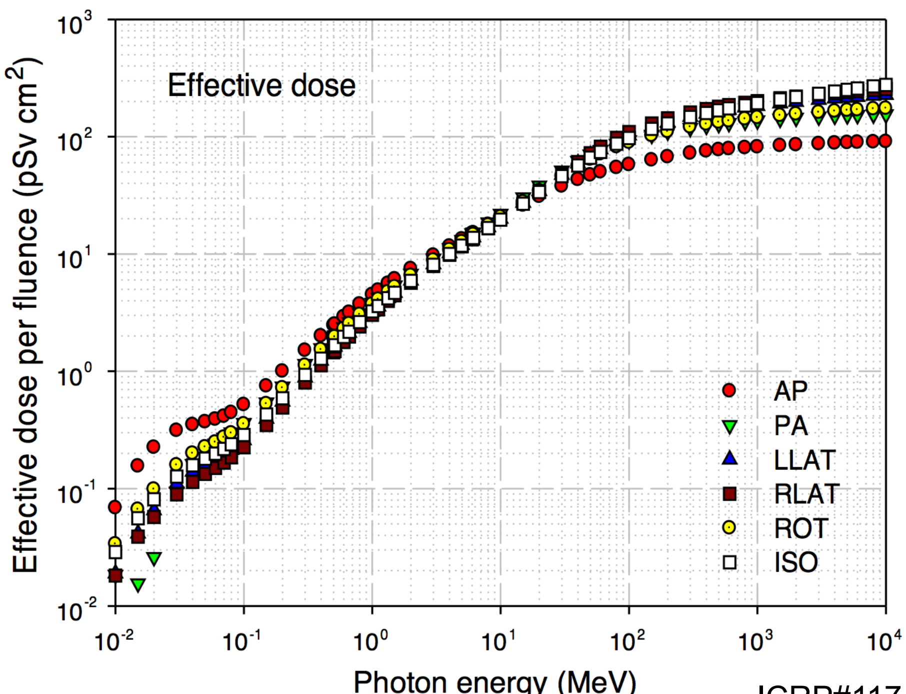


CINDER'90 activation script results

Most active isotopes in the glass after 1 day cooling

Isotope	Activity concentration (Bq/g)	E_{gamma}(MeV)
H-3	1.73E+009	-
Zn-65	3.51E+007	1.11 (50%)
P-32	2.96E+006	-
Na-24	9.54E+005	2.75 (100%)
		1.37(100%)
Zn-69	8.17E+005	-
Nb-95	7.63E+005	0.77 (100%)
Zn-69m	7.61E+005	0.44 (95%)
Zr-95	7.56E+005	0.72 (44%)
		0.76 (54%)
Nb-97	5.61E+005	0.66 (98%)
		1.02 (1%)
Zr-97	5.21E+005	0.74 (93%)
		0.51 (5%)
		1.15 (3%)
Nb-97m	4.94E+005	0.74 (100%)





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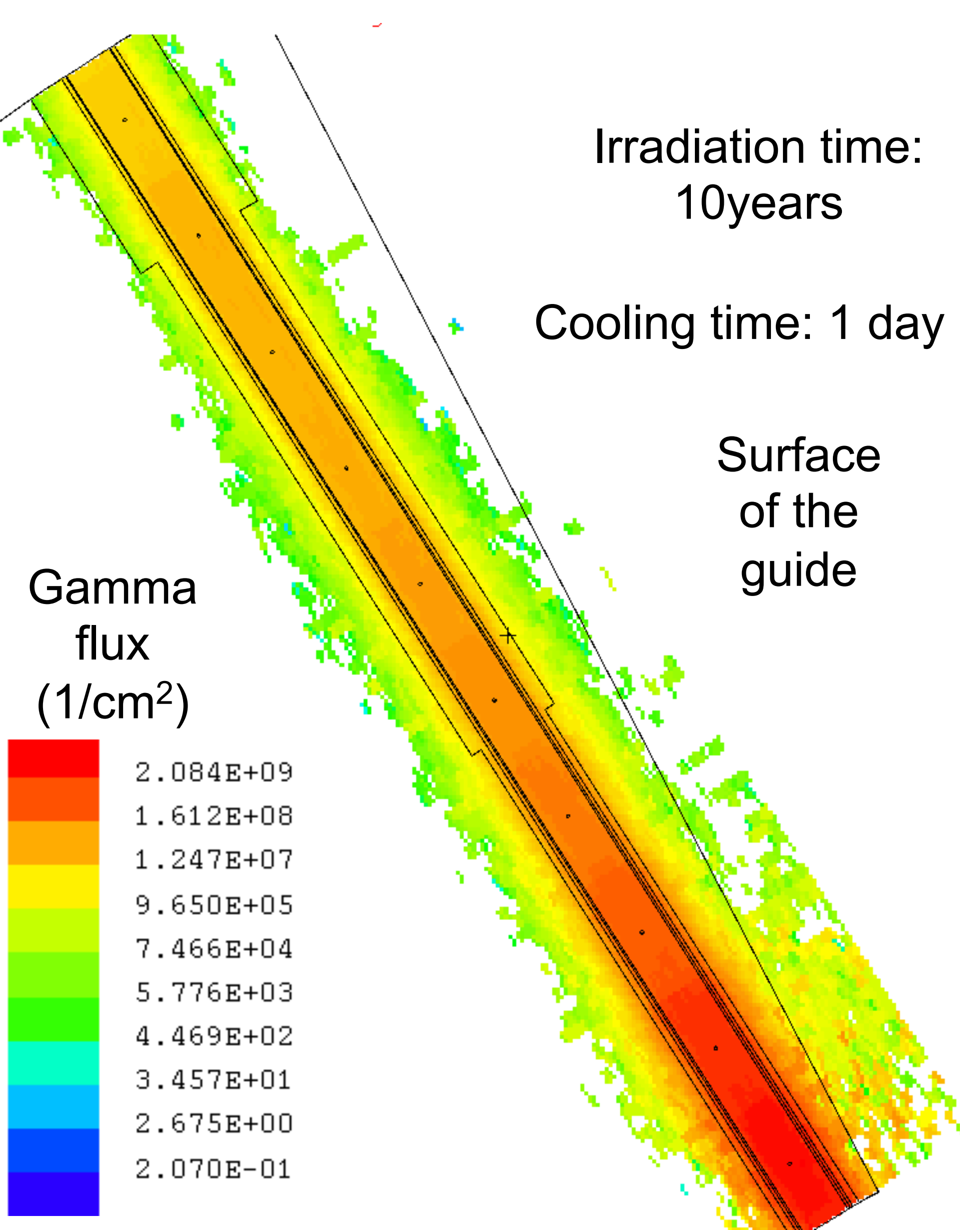
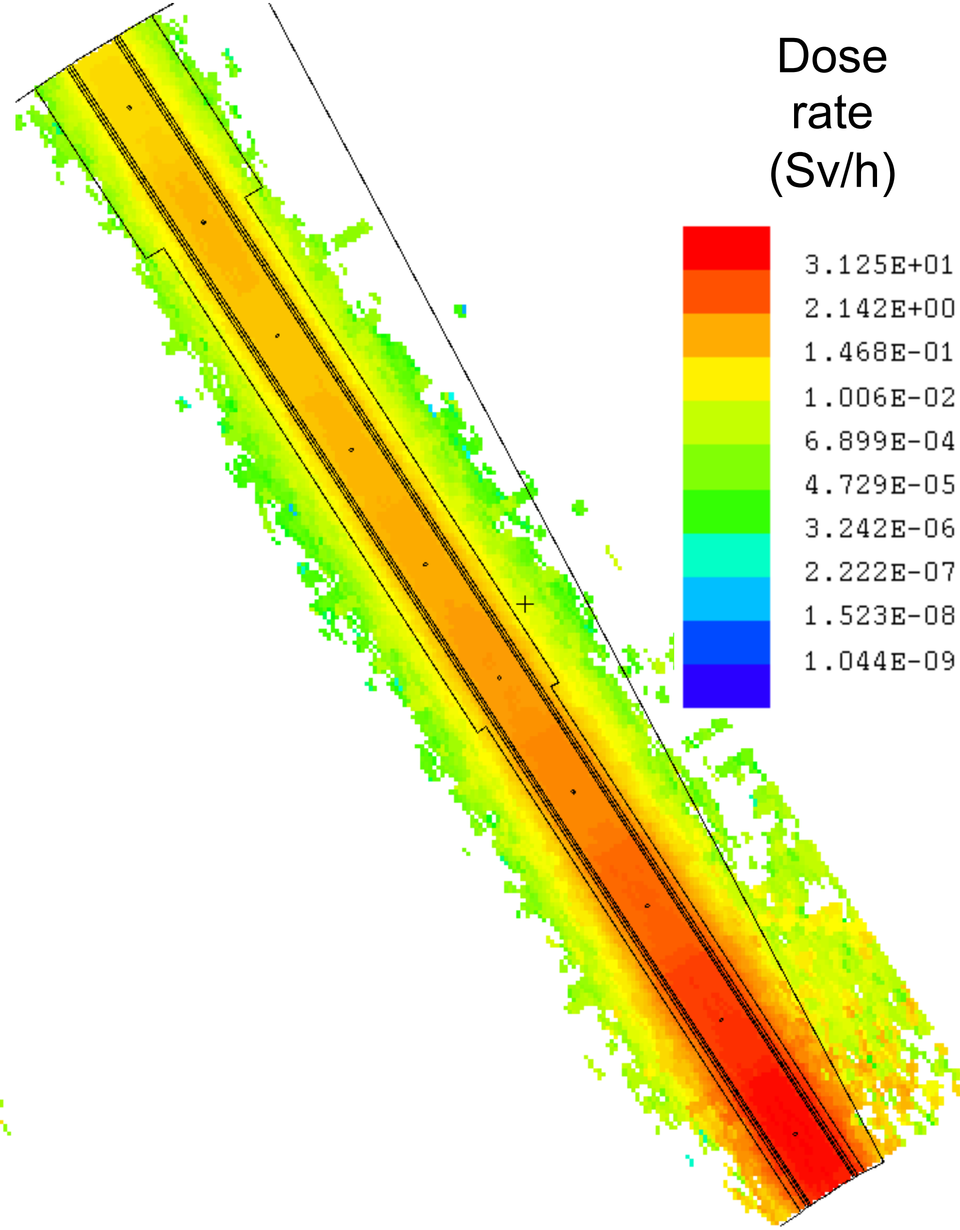
CINDER'90 gamma script and MCNPX results: Gamma flux and gamma-ray dose rate maps



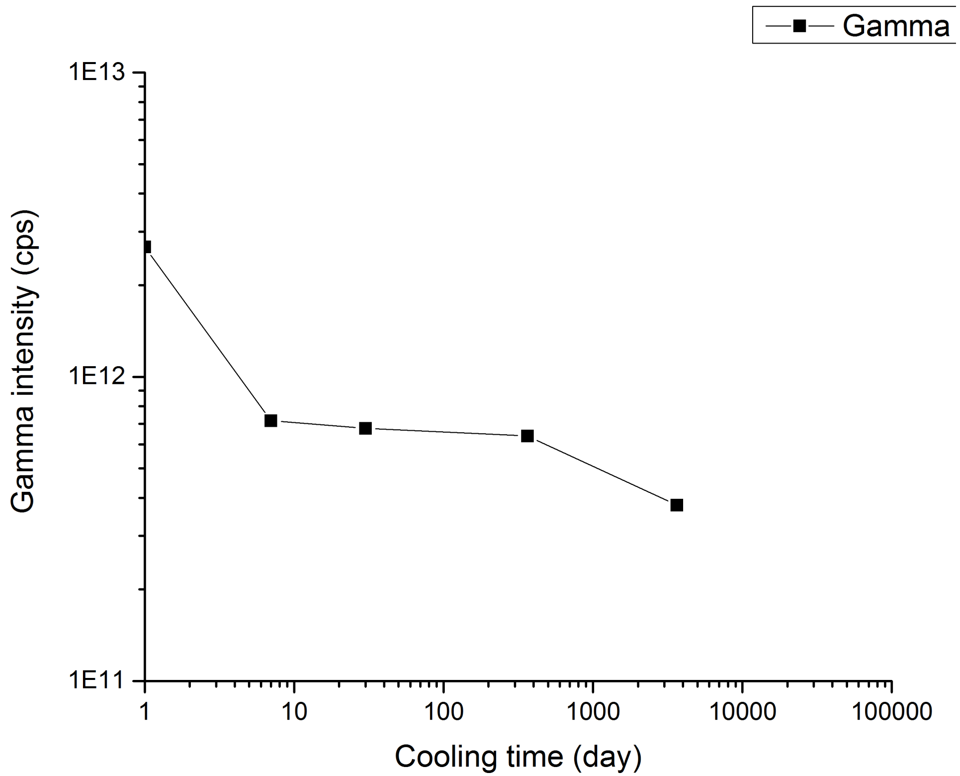
Irradiation time: 10years

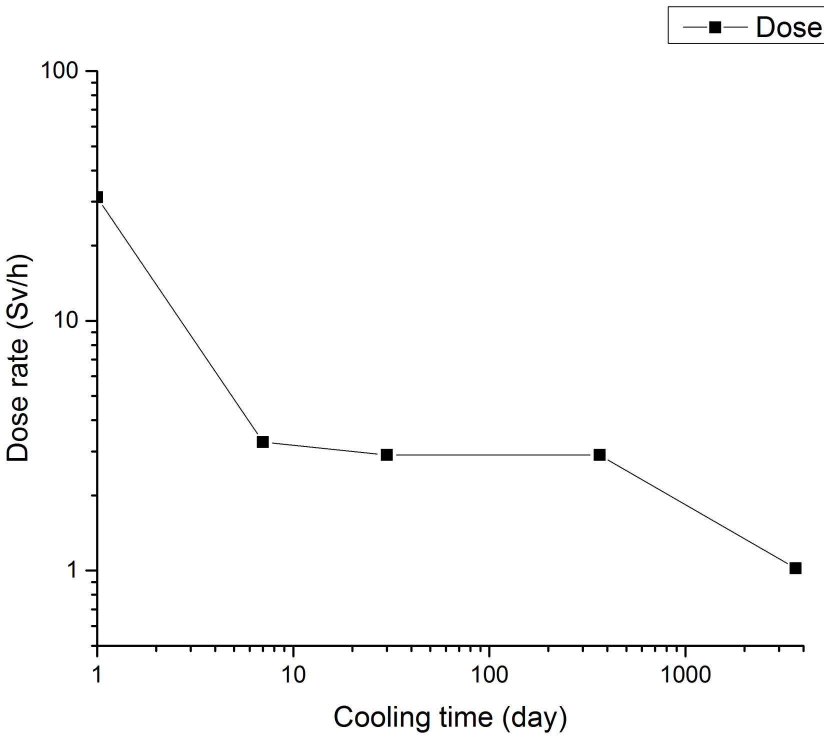
Cooling time: 1 day

Surface of the guide



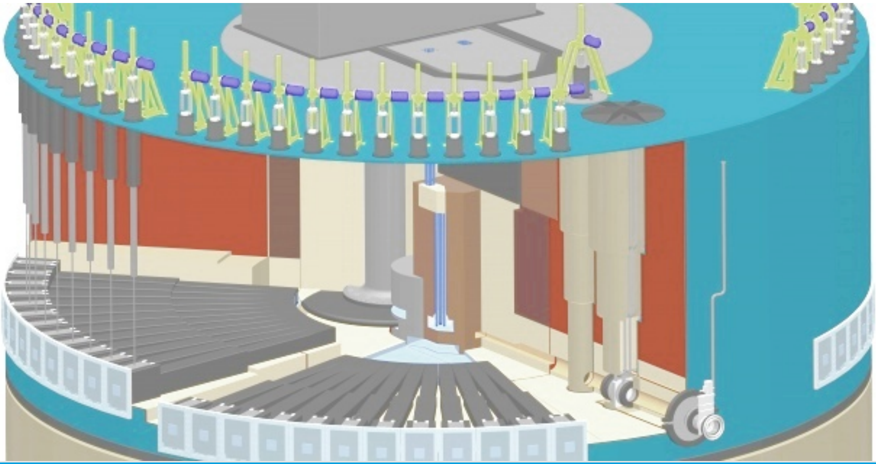
CINDER’90 gamma script and MCNPX results: gamma intensity and gamma-ray dose rate maximum

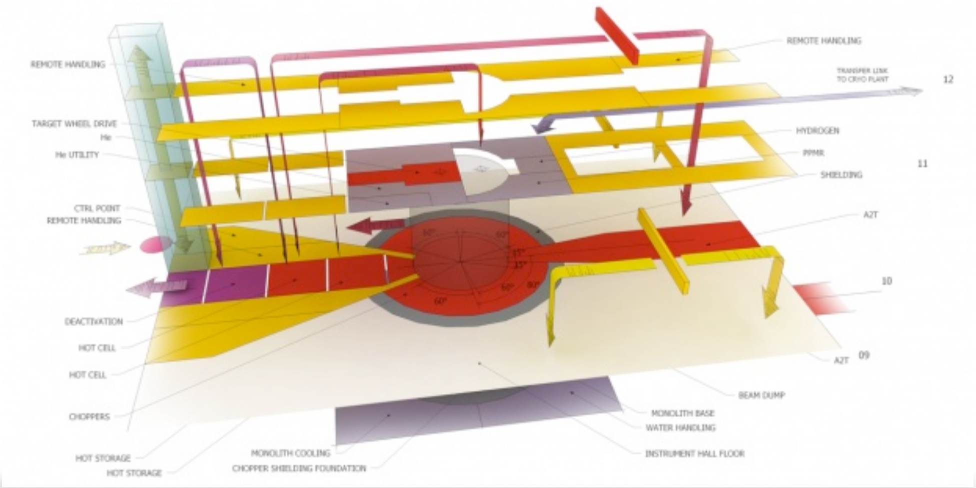




Future tasks

- Additional activation studies of target station elements in terms of radiation protection
- Define different scenarios to estimate the effective doses of workers and the public
- Based on the results optimize the shielding and material concept





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Thank you for your attention

Guarapari, Brasil

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