

Standardized Model for Air Activation at Electron Accelerator Facilities

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Contamination of air

- In large scale accelerator facilities there are two problems with the activation of air:
air inside the bunkers (access for personnel) and the dispersion of radioactive nuclides through exhaust (public).
- For proton accelerators bunkers and exhausts are usually monitored since high air activation is expected.
- For electron accelerators monitoring **might not be necessary**.



Swiss regulations

- Amount of radioactive nuclides dispersed through exhausts are regulated through a limiting dose for the public living in the surroundings (like for nuclear power plants).
- Through atmospheric dispersion calculations (ENSI Richtlinie G14) this dose limit is converted into an activity limit for the exhaust.
- Intervention thresholds for the exhaust monitoring can thus be defined.



Swiss regulations

- For air contaminations in working areas the StSV defines a reference value:

$$CA = \frac{20 \text{ mSv}}{e_{inh} \cdot 2400 \text{ m}^2/a} \text{ Bq/m}^3$$

i.e. breathing air with 1 CA for 40 hour per week during 50 weeks gives 20 mSv.

- Controlled areas in large scale research facilities in Switzerland are defined through the reference values of surface and air contamination.
- Zone type 0 can have max. 0.05 CA.



Our project

- Is there a simple way to decide if air monitoring at electron accelerators is necessary at all? How can we decide if a zone type 0 is justified?
- Our project aims to provide a simple and easy to use tool/fitting formula for a rough estimate of the air activation expected at electron accelerators.
- Of course there are simplifications/assumptions.
- NCRP report No. 144 (Rad. prot. for part. acc.) provides a similar tool for such estimates.
- In complex situations and/or for more accurate results dedicated simulations and/or measurements are necessary.



FLUKA model

- We take the model of Hohmann et al. 2014. They computed the neutron and photon dose rate generated at the SwissFEL accelerator at PSI for a given setup.
- Thereby we model the beam losses, i.e. electrons, hitting the elements around the beam line.
- The model: a 50 cm long Cu cylinder with 2.5 cm radius (Hohmann et al. 2014 considered more diameters).
- Cu is conservative due to higher n yield compared to Al or Fe.
- Simulations with electrons from 20 MeV to 10 GeV (15 different energies). We scored the neutron spectrum and the activation products in the air around the Cu target.

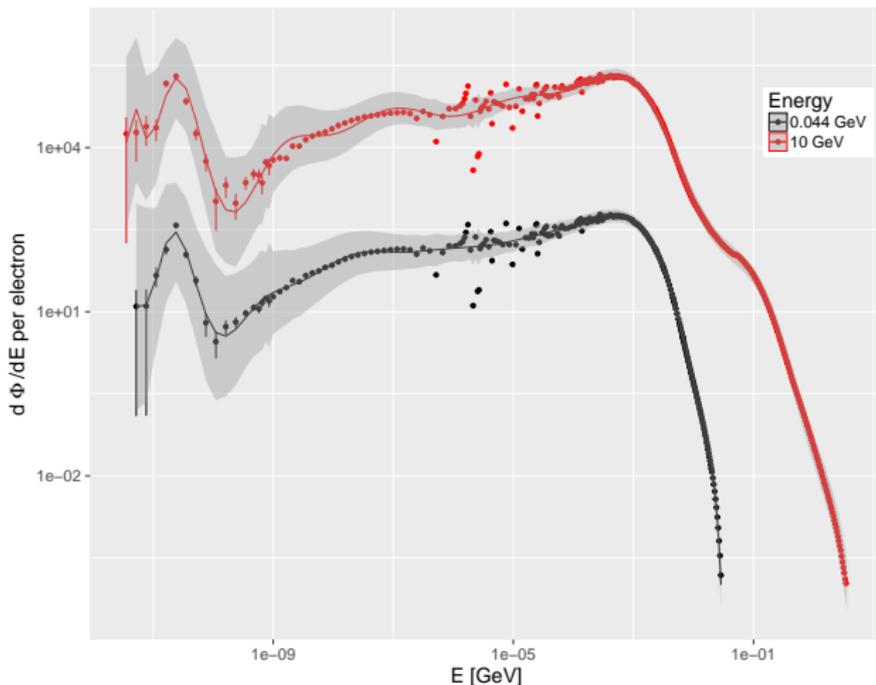


Neutron spectrum

- E.g. CERN and PSI have their own libraries of neutron spectra for their activation calculations (usually not public).
- We provide a fitting formula for the neutron spectrum.
- We project the simulated neutron spectrum onto Legendre polynomials (complete set of functions).
- The maximal degree of the Legendre polynomial depends on the desired accuracy of the fit (between 8 and 20).
- The energy dependence of the coefficients can be modeled.

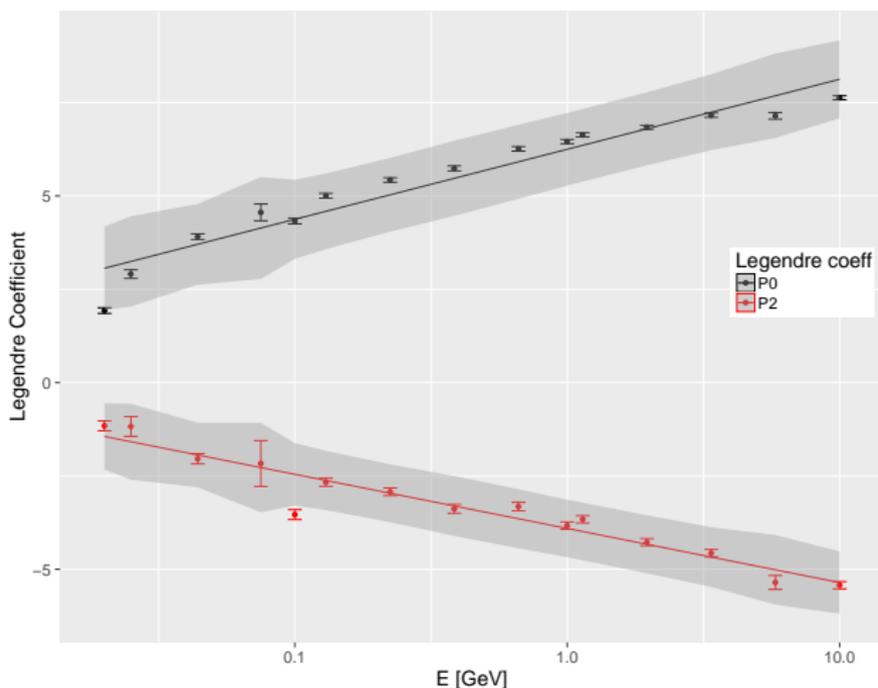


Neutron spectrum





Energy dependence of fitted Legendre coefficients



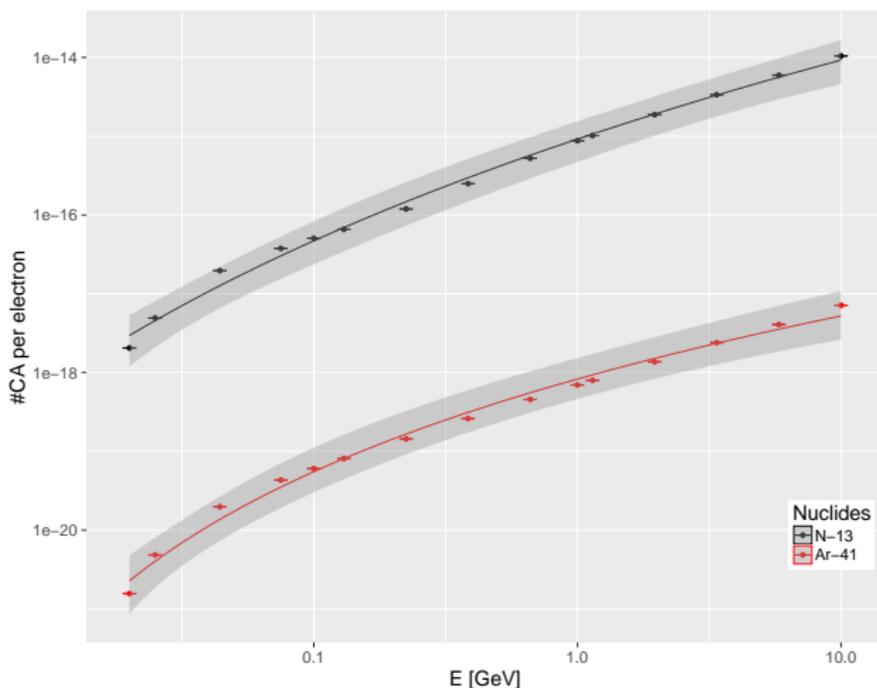


Air activation

- For the most common activation products (H-3, C-11, Cl-39, Ar-41, ...) we provide a fitting formula.
- Fitting formula: power law in log space
$$\log(A) = c_1(\log(E) - c_2)^{c_3}$$
- The user can easily estimate the air activation inside the accelerator bunker.
- Example from SwissFEL:
 $E = 5.8 \text{ GeV}$ with 200 pC per bunch at 100 Hz
 \implies full beam loss for 1 s produces $2.2 \cdot 10^{-9} \text{ CA/s}$ of Ar-41.



Air activation



Nuclides
■ N-13
■ Ar-41



Conclusions

- The determination of the activation of air at electron accelerators is important for regulatory purposes and facility design.
- We conclude that the activation of air is too low to require a permanent monitoring.
- We can provide a simple computational tool to estimate the air activation inside accelerator bunkers for electron energies between 20 MeV and 10 GeV.
- Outlook: finish the calculations, check variations of the model (different target diameters and target lengths).