LOW-DOSE NEUTRON MEASUREMENTS FOR RADIATION PROTECTION

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Environmental radiation monitoring at hadron accelerators

Beside the direct impact of radiation crossing shielding walls, radiation from an accelerator may extend out to large distances from the source by way of air scatter. This radiation is termed **skyshine** [1] (Fig. 1).

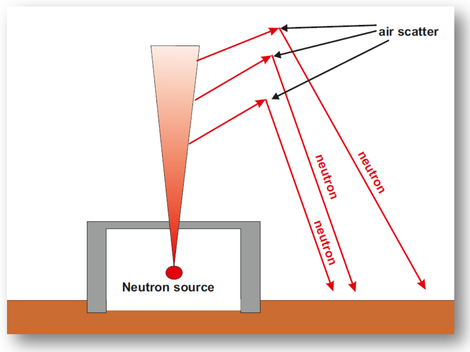

***Figure 1**. Skyshine.*

Neutron H*(10) monitoring at hadron accelerators is essential for the:
- radiation environment characterization;
- evaluation of the overall health risk;
- compliance with national laws;
- definition of the radiation protection measures to be implemented.

These measurements imply distinguishing between the neutron background (~15 nSv/h) and the accelerator induced neutron radiation. **Dose rates** with an accuracy **in the nSv/h range** have to be detected.

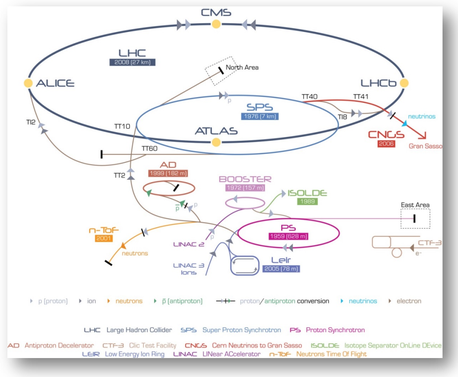

***Figure 2**. The CERN accelerator complex.*

How?

- Long measurements
- Detector reliable up to GeV range
- Beam intensity and H*(10) accurate correlation

The measurements: set-up and instrumentation

Neutron H*(10) measurements were performed in the vicinity of the Super Proton Synchrotron (SPS) to study a possible increase of the neutron background by stray radiation as function of the beam parameters in three critical positions [2].

Pos. 1 (Fig. 3): area dedicated to the new RP calibration facility → **is this location influenced by external neutron sources,** e.g. the SPS accelerator [3]?

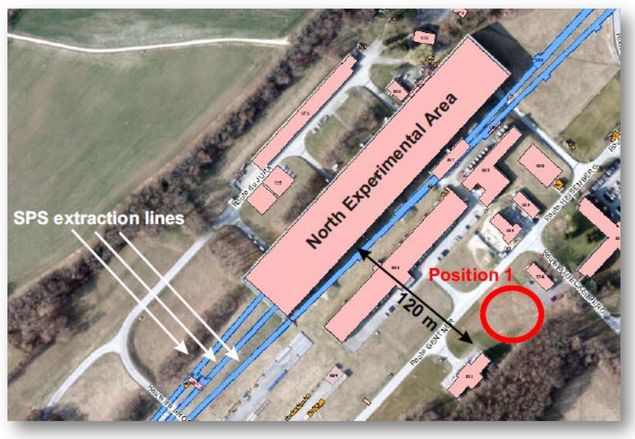

***Figure 3**. Position 1: the area of the new RP calibration facility at CERN.*

Pos. 2 (Fig. 4): in the proximity of an air shaft, located above the SPS extraction line and not top-shielded → **is the shaft a skyshine source?**

Pos. 3 (Fig. 4): location at a distance comparable to a public waste disposal area from the air shaft (~125 m) → **is the H*(10)** in a year **below** the CERN optimization limit (**10 µSv/year**)?

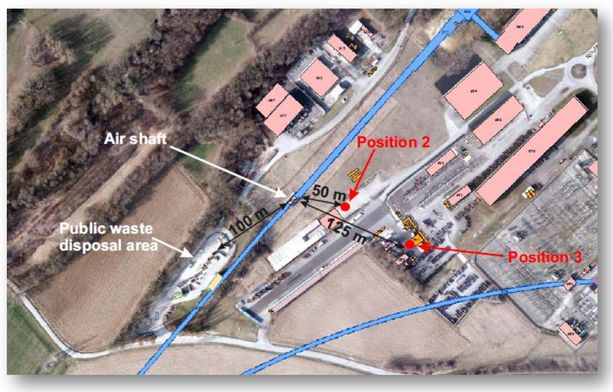

***Figure 4**. Position 2 and 3. The position of the waste disposal area is reported.*

The neutron H*(10) assessed during the following SPS beam conditions with the WENDI-II rem counter:
- SPS extracting **400 GeV/c protons** into a target cave;
- SPS accelerating **lead ions** with a momentum **< 200 GeV/c per nucleon**;
- **SPS beam off**, to assess the natural background.

***Figure 5**. The WENDI-II neutron survey meter.*

Results and conclusions

Fig. 6 shows the correlation between the beam intensity and the neutron H*(10) as a function of the time: no correlation between the beam operation and the neutron dose can be seen. Such a correlation can be only observed by dose integration over long time periods containing exclusively beam on or beam off periods.

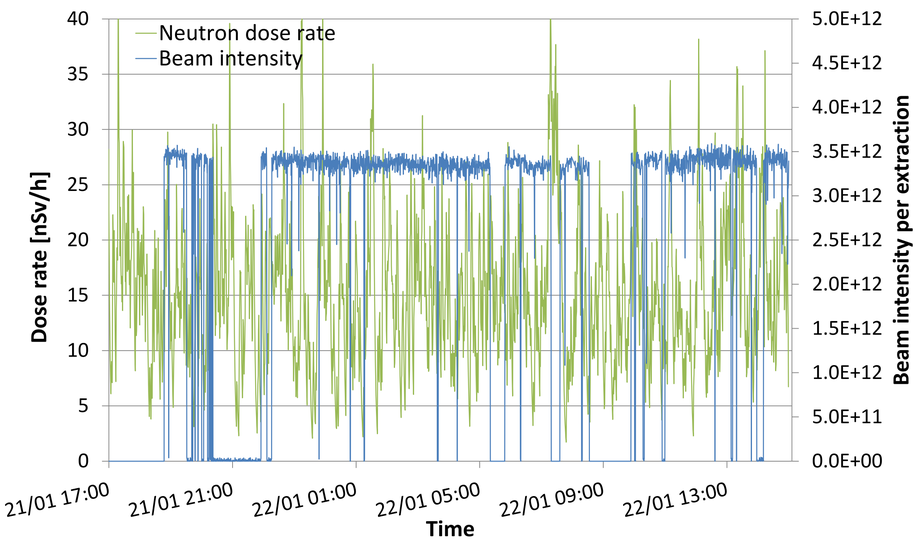

***Figure 6**. SPS beam intensity vs neutron H*(10) for the position 1.*

Table 1 and Fig. 7 show the H*(10) for each position and beam configuration.

***Table 1**. Neutron H*(10) and measuring time for each position and each beam configuration.*

	Natural background		Proton beam		Lead ion beam	
	H*(10) [nSv/h]	T_{meas} [days]	H*(10) [nSv/h]	T_{meas} [days]	H*(10) [nSv/h]	T_{meas} [days]
Pos 1.	14.5±1.7	3	15.9±1.7	1.7	15.6±1.8	0.7
Pos. 2.	14.5±1.7[a]	-[a]	20.9±2.0	1.1	16.6±1.6	2.0
Pos. 3.	14.5±1.7	3.5	18.3±1.9	1.4	16.3±1.8	0.8

[a]*The same value of pos.3 was assumed.*

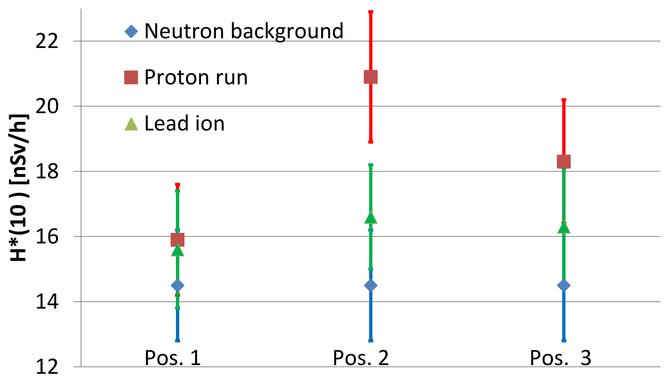

***Figure 7**. Summary of the neutron H*(10) for each position and each beam configuration.*

General considerations:
- no visible influence of neither proton nor ion beam operation in pos. 1
- indications of H*(10) increase during lead ion acceleration observed in pos. 2 and 3;
- evident H*(10) increase during proton acceleration for pos. 2 and 3;
- natural background in pos. 1 is equal to the one in pos. 3;
- verification of the CERN limit: the net SPS contribution to the H*(10) in pos. 3 is 3.8 nSv/h. If multiplied with 2000 hours (working time at the waste disposal area) = 7.6 µSv/year.

Conclusions:
- low-dose neutron measurements in the nSv/h range were performed;
- pos. 1: the area is not influenced by external neutron source;
- pos. 2: the air shaft is a skyshine source;
- pos. 3: the optimization limit is not exceeded; however it should be noted that the H*(10) is function of the beam intensity and SPS operation time;
- all measured dose rates are far below any legal radiation limits.

References

[1] A. H. Sullivan, A guide to radiation and radioactivity levels near high energy particle accelerators, Nuclear Technology Publushing (1992).
[2] P. Carbonez, F. Pozzi and H. Vincke, Neutron background measurements on the Prevessin site. CERN-RP-2014-038-REPORTS-TN (2014).
[3] M. Brugger, P. Carbonez, F. Pozzi, M. Silari and H. Vincke, New Radiation Protection calibration facility at CERN, Radiation Protection Dosimetry, doi: 10.1093/rpd/nct318 (2013).

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