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| Dose assessment in the offices for zoning discussion |
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# Scope

The purpose of this report is to assess the current prediction of the dose in the offices in the public zones in the campus area and in E03 and E04, for the discussion on the zoning of this areas. This report is not intended as a shielding design report, and therefore shall not be used for shielding design.

# CONTRIBUTORS

Günter Muhrer

# Issuing organisation

*<<Text>>*

# Methodology

The dose in the offices was assessed in respect to the contributions from the accelerator, target and neutron scattering systems (NSS). This the case of the accelerator the data provided in [1] was used. In the case of the target the data provided in [2] was used and projected to the offices using hand book methods [3]. In the case of NSS, it is assumed that the instruments leak the maximum dose allowed, which is then projected to the offices using hand book methods. Furthermore, it shall be stated at this time, that the safety factors will be applied to the final result of the predictions, but not on the input parameters.

# Acceptance Criteria

This report only shows the current status. Therefore, there is no acceptance criteria.

# Open Items

Dose contribution from inhalation and immersion due to releases from the stack have not been estimated.

# Assumptions

**Radiation leakage from the instruments**:

It is assumed that the neutron scattering instruments leak the maximum allowable dose rate at all time and at any location. The instrument halls are defined as supervised zones [4,5]. In accordance with [6] the maximum allowable permanent dose rate at the outer surface of the shielding is 1.5 Sv/h.

It is further assumed that in the guide hall, after the bender, all instruments will only emit gammas, which are due to the capture of thermal neutrons, which are lost in the guide transport.

In case of the instrument caves it is assumed, that one half of the leaked radiation is from neutron and the other half issue to gammas.

The instruments are currently in the early phase of the design. Therefore, their exact layout is not known. For the purpose of calculating the dose in the E03 and E04 offices, it is assumed that the outside of the cave of the instruments in E03 and E04 have a radius of 3 m and that the scattering source is located at the origin of this sphere.

In the case of neutrons, it is assumed, that they are not attenuated in air.

In the case of gammas, the air attenuation factor as given in [3], is used, where the tenth layer is shown as about 300 m.

**Offices in E03 and E04**:

For the offices in E03 and E04 it is assumed that the closest instrument cave is 15 m from the closed offices. The next two closest instruments are assumed to be 30 m away and the third closest instruments are 45 m away.

In addition, it is assumed that the contribution of the other instrument caves can be neglected, as can the contribution of the beamlines in the guide hall.

**Offices in the campus area**:

Based on [7] it is assumed that the closed part of the B02 building is 50 m from the closest beamline inside the guide hall.

It is further assumed that the closed part of the B02 building is 50 m from the closest instrument cave in D03.

While these two locations are not the same, for the purpose of this evaluation, it is assumed that they are, which is a conservative assumption.

# Limitations

This report only deals with doses due to external radiation. It does not include contributions for inhalation or immersion.

# Computer Hardware and software

None.

# Calculation Inputs

N/A

# calculations

## Offices in E03 and E04

**Accelerator contribution**

The predicted dose contribution in these offices coming from the accelerator can be taken from figure 11 in [1]. In accordance with this figure, the predicted dose contribution from the accelerator is 3 nSv/h. At 2000 hours a year, for a worker on site, the annual dose rate DA amounts to about 6 Sv/year. Add the same time, one needs to point out, that this is a conservative estimate, because in the results shown in [1], the target building was not included in the simulations, which leads to an over prediction of the dose levels downstream of the accelerator tunnel.

**Target contribution**

Considering the geometry shown in [2], the target contribution can be considered as a spherical source with a Rm=6 m radius. The offices in question are at about Roff=150 m from the origin of the target coordinate system, the target contribution DT to these offices can be estimated as:

$$D\_{T}=\left(\frac{R\_{m}}{R\_{off}}\right)^{2}\left(D\_{n}+D\_{γ}e^{-λ\_{air}\left(R\_{off-}R\_{m}\right)}\right)$$

, with Dn and D are being the neutron and the gamma dose rates at the outer surface of the connection cell. For simplification reasons, it can be assumed that Dn=D=0.75 Sv/h for the prediction. As mentioned above the tenth layer for the gamma attenuation in air is given with 300 m. Therefore air = ln(10)/300m. This results in D=1.6 nSv/h = 3.2 Sv/year.

**NSS contribution**

As stated in chapter 7 it can be assumed, that the closest instrument cave is R1=15 m from the closed offices. The next two closest instruments are assumed to be R2=30 m away and the third closest instruments are R3=45 m away. For simplification reasons, it can again be assumed that Dn=D=0.75 Sv/h. The dose contribution in these offices from NSS is then given as:

$$D\_{NSS}=\sum\_{i=1}^{3}N\_{i}\left(\frac{R\_{Cave}}{R\_{i}+R\_{Cave}}\right)^{2}\left(D\_{n}+D\_{γ}e^{-λ\_{air}R\_{i}}e^{-λ\_{wall}D\_{wall}}\right)$$

, with RCave=3 m being the instrument cave radius and N1=1, N2=2 and N3=2 being the counter for the number of instruments at the distance Ri. Furthermore, it is assumed that shell of the office building wall is built out 5mm sheet metal, which leads to Dwall=1cm. The tenth layer for steel given by [3] is 6cm, which leads to wall=ln(10)/6cm.

Based on these assumptions the contribution from the closest instrument is predicted to by about 33 nSv/h. The combined contribution from the two second closest instruments is predicted to be about 19 nSv/h, and the one from the 2 third closest instruments is about 10 nSv/h. This amount to 62 nSv/h. Based on the seen falloff of the contribution due to distance, and the fact that the instruments further way from the offices, will be at least partly shielded by the closer instruments, it can be assumed that the contribution of the remaining instruments will add less than 10%, and will be therefore be neglected at this point, because this is well within the uncertainty of this estimate. The annual dose contribution to these offices from NSS therefore amounts to 124 Sv/year.

**NSS skyshine**

In accordance with [9] figure 5 the total NSS skyshine contribution in the offices in E03 and E04 was estimated to be about 20 Sv/year. This result assumed a high energy neutron leakage rate on top of the bunker of 1 Sv/h, and 5400 hours of operation. However, the maximum occupancy of the offices in the campus area is 2000 hours per year. Adjusting for the hours spend, this leads to a contribution of about 7.5 Sv/year, which have of it coming from the instruments and half coming from the bunker roof. If the bunker roof were to reclassified and the allowed leakage rate increased by a factor of 10, this would increase the NSS skyshine contribution to about 41 Sv/year.

**ESS total**

Adding up the contributions from accelerator, target and NSS, the total amounts to about 140 Sv/year with the bunker roof being a supervised area, and about 174 Sv/year with the bunker roof being an unrestricted controlled area.

If one applies a safety factor of 2, this amounts to 280 Sv/year or 348 Sv/year respectively for a worker that spends 2000 hours per year in these offices. Considering the workers that will occupy these offices, it can be assumed, that their occupancy factor in these offices is about 10%. This means, that the dose they receive per year while working in these offices is about 28 Sv or 35 Sv respectively. If these offices were shielded to 50 Sv/year, their annual dose from working in these offices would be 5 Sv. This means, be not imposing the 50 Sv/year requirement on these offices the undissipated additional dose to the works per year is about 23 Sv or 30 Sv respectively depending on the zoning classification of the roof of the bunker.

## Offices in the campus area

**Accelerator and Target contribution**

Based on the layout shown in [7], it can be said that the closest offices in the campus area have about the same distance to the monolith and the A2T section as the offices in E03 and E04. Therefore, the results shown in chapter 11.1 for the accelerator and the target contribution, can also be applied in this case. This leads to a combined contribution from accelerator and target of about 9 Sv/year.

**NSS contribution**

Based on the layouts shown in [7] and [8] it can be concluded, that in case of the offices in the campus area the NMX beamline is the main contributor from the NSS side and that the other instruments are shielded by this beamline, and can therefore be neglected. Furthermore, it can be assumed that the contribution from NMX can be subdivide into the contribution from the cave and the contribution from the beamline in the guide hall.

**NMX cave**

As shown in chapter 11.1, the contribution from the cave can be approximated as a spherical source. If one considers further, as mentioned above, that NMX will be the only instrument contributing, the contribution DNMX Cave can be expressed as:

$$D\_{NMX Cave}=\left(\frac{R\_{Cave}}{R\_{cc}+R\_{Cave}}\right)^{2}\left(D\_{n}+D\_{γ}e^{-λ\_{air}R\_{cc}}e^{-λ\_{wall}D\_{wallc}}\right)$$

, with Rcc=50m being the distance from the instrument cave to the nearest office in the campus area, and Dwallc = 2 cm, accounting for 2 walls with 5mm of sheet metal on the outside. The leads to DNMX Cave=12,6 nSv/h, which is about 25 Sv/year.

NMX beamline in the guide hall

The NMX beamline part in the guide hall can be seen as a line source. In case of a uniform line source the radiation dose levels drop proportionally to the inverse of the distance from the source. In addition, due to the fact that NMX has already curved out of line of site by the end of the bunker, it can be assumed that the dose contribution predominately come from (n,) reactions due to losses of thermal neutrons in the instrument optics. Based on these assumptions the contribution DNMX GH from the beamline in the guide hall can be expressed as:

$$D\_{NMX GH}=\frac{R\_{GH}}{R\_{gc}+R\_{GH}}D\_{γGH}e^{-λ\_{air}R\_{gc}}e^{-λ\_{wall}D\_{wallc}}$$

, with Rgc=50m being the shortest distance from the guide hall to the closest offices in the campus area. Furthermore RGH=0.6m is the distance of the outer shielding surface to the centre of the guide system and DGH=1.5 Sv/h. This yields to DNMX GH=5.6 nSv/h which is about 11 Sv/year.

**NSS skyshine**

In accordance with [9] figure 5 the total NSS skyshine contribution in the offices in the campus area was estimated to be about 20 Sv/year. This result assumed a high energy neutron leakage rate on top of the bunker of 1 Sv/h, and 5400 hours of operation. However, the maximum occupancy of the offices in the campus area is 2000 hours per year. Adjusting for the hours spend, this leads to a contribution of about 7.5 Sv/year, which have of it coming from the instruments and half coming from the bunker roof. If the bunker roof were to reclassified and the allowed leakage rate increased by a factor of 10, this would increase the NSS skyshine contribution to about 41 Sv/year.

**NSS total**

As mentioned above, even though the closest offices in the campus area from the NMX cave and the guide hall are not necessarily the same, it is conservatively assumed that they are. Therefore, the total contribution from NSS to these offices results to about 44 Sv/year, assuming the bunker roof is classified as supervised area [4]. This contribution will increase to about 77 Sv/year, if the top of the bunker roof will be classified as unrestricted controlled area.

**ESS total**

Adding the contribution from accelerator, target and NSS, the predicted dose in the closest office in the campus area results to about 53 Sv/year in case the roof of the bunker is classified as supervised area and 86 Sv/year if the top of the bunker roof is classified as unrestricted controlled.

If a safety factor of 2 is applied to the estimates that expected dose in the campus offices is about 106 Sv/year with the current baseline, and about 172 Sv/year with the bunker roof being reclassified as unrestricted controlled area.

# CONCLUSIONS AND RECOMMENDATIONS

Including a safety factor of 2 the dose in the offices in E03 and E04 was estimated as to be 280 Sv/year or 348 Sv/year respectively depending the zoning classification of the top of the roof. Assuming a 10% occupancy factor in these offices, the additional dose per worker per year is estimated to be about 28 Sv or 35 Sv depending on the classification of the top of the roof.

Considering the same safety factor of 2, the dose in the offices in the campus area was estimated to be 106 Sv/year if the top of the roof is classified as supervised area. If the top of the roof is reclassified to an unrestricted controlled area, the estimated dose will increase to 172 Sv/year.

# Glossary

| Term | Definition |
| --- | --- |
| <<Sample term>>  | <<Sample explanation >> |
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Document Revision history

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