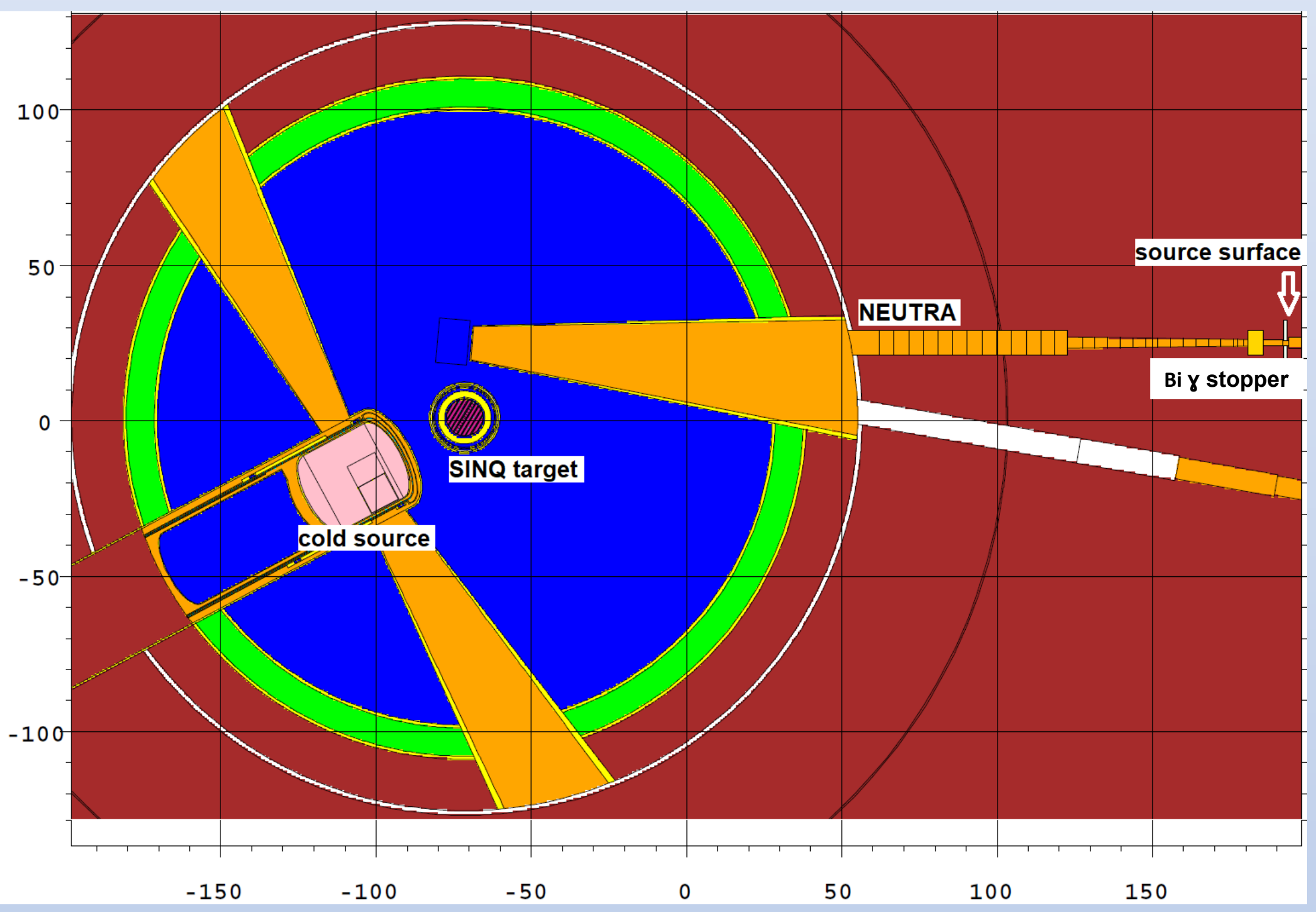
Neutron Transport Calculations in Support of the PSI-NEUTRA Instrument Upgrade

A. Ivanov, P. Trtik, U. Filges, A. Bollhalder, A. Kalt, S. Thürsam, M. Schild, P. Boillat, M. Busi, J. Hovind,
A. A. Kaestner, D. Mannes, E. Polatidis, J. Welte, M. Strobl
Paul Scherrer Institute, 5232 Villigen, Switzerland

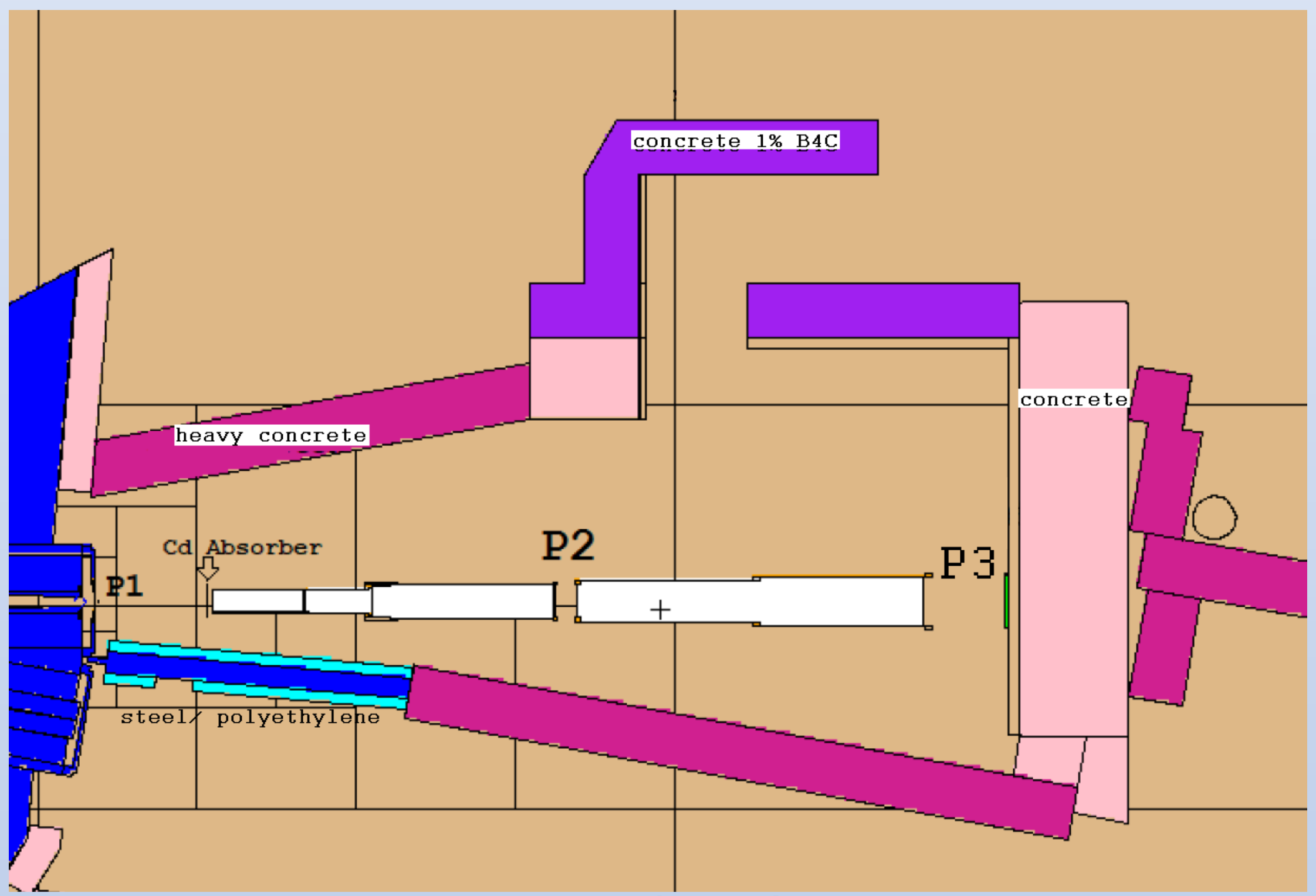
Abstract

- After more than 25 years of successful operation, the thermal neutron imaging instrument NEUTRA, the NEUTRA 2.0 upgrade project has been approved. The upgrade to NEUTRA 2.0 implies a complete reconstruction of the instrument including a redesign of the shielding bunker.
- The usable area of the bunker will be increased, creating ample space required in modern neutron imaging instruments for complex set-ups with bulk sample environments. Full access to an upstream measuring position, P1, of the beamline will allow utilizing about half an order and one order of magnitude higher flux than at the currently accessible measurement positions P2 and P3, respectively.
- Together with more available space the higher flexibility of the interior arrangement will enable accommodating components for advanced neutron imaging techniques such as in-situ simultaneous bimodal neutron/x-ray imaging, time-of-flight imaging and thermal neutron grating interferometry. While the upgrade will enable advanced neutron imaging capabilities at NEUTRA 2.0, the instrumentation and techniques that were pioneered at NEUTRA in the past, like the XTRA option for in-line bimodal neutron/X-ray imaging and the NEURAP insert for neutron imaging of highly radioactive samples will be retained in the suite of the available modalities at the beamline.
- To compute the resulting dose neutron and photon dose rates, the MC code MCNP 6.2 was used. Obtaining statistically reliable results was achieved by generating variance reduction parameters using the deterministic code system ADVANTG.

The SINQ tank and the NEUTRA neutron channel



SINQ target



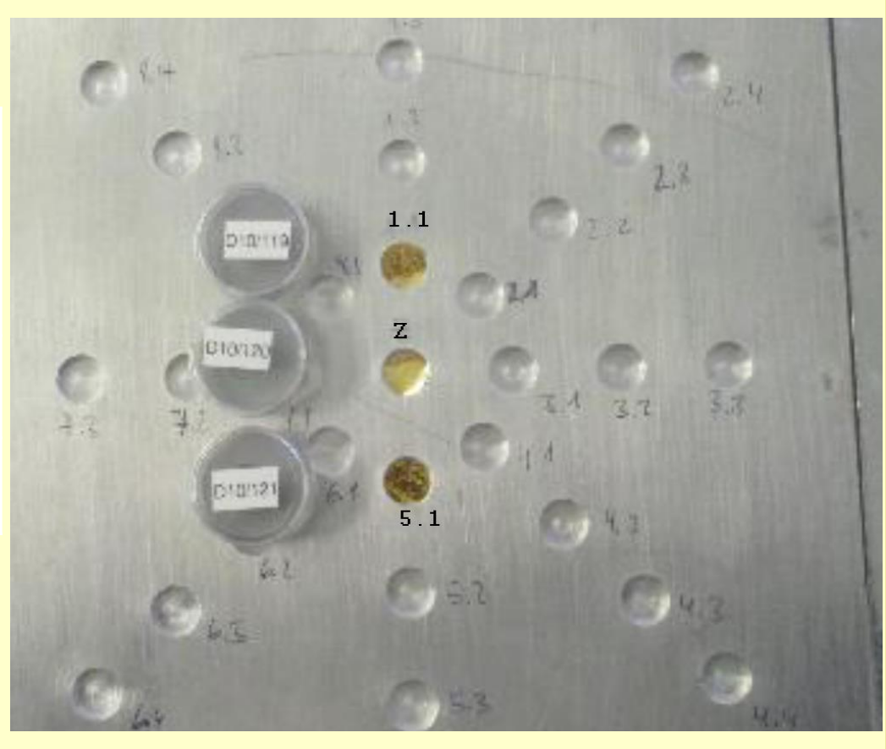
NEUTRA bunker

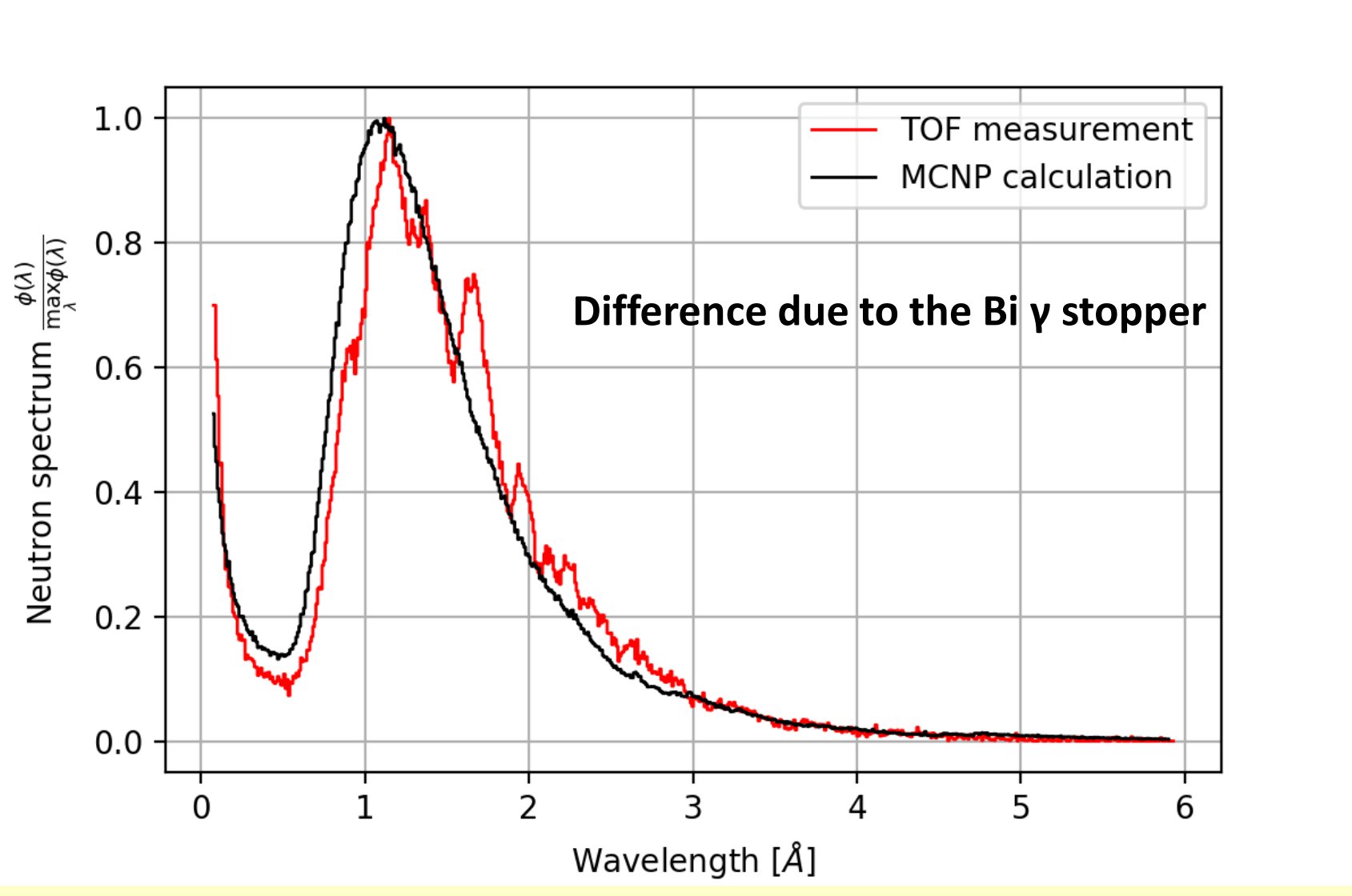
- The NEUTRA measurement station uses the neutrons emanating from the SINQ source
- Within the NEUTRA bunker 3 measurement positions, labeled P1-3 are available.
- The goal of the calculation was to prove, that the neutron/gamma DR outside the redesigned bunker satisfy the Swiss regulatory limits.
- Several scenarios, by placing absorbers and scatterers in the neutron beam, were computed to test the adequacy of the shielding design.

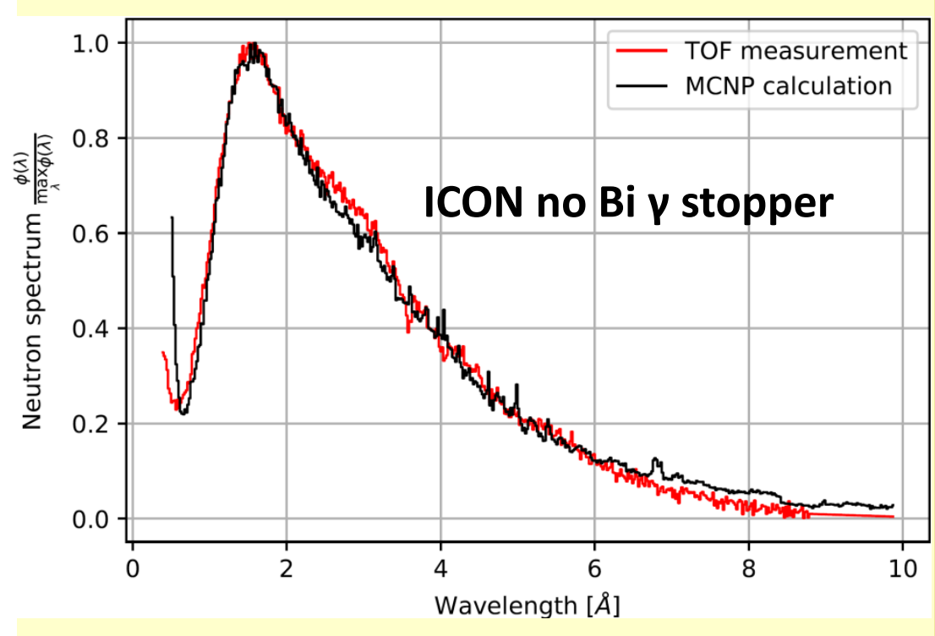
Validation of the neutron source

- The discretized neutron source was validated using gold foil measurements and TOF data, carried at P1.
- The Bateman equation system was solved with SP-FISPACT

Foil number	MCNP[Bq]	Measurement [Bq]
P 1.1	306	312
PZ	317	329
P 5.1	307	326

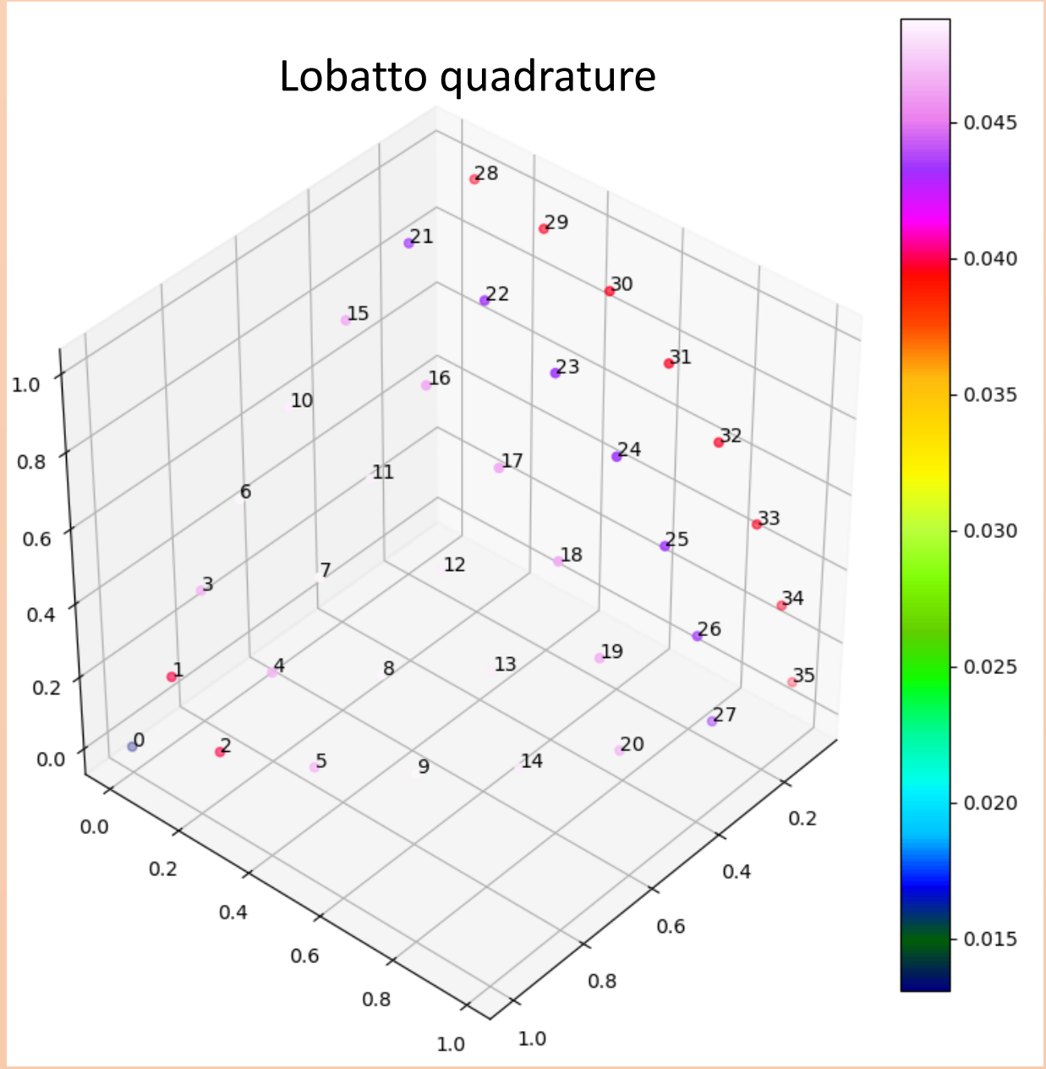


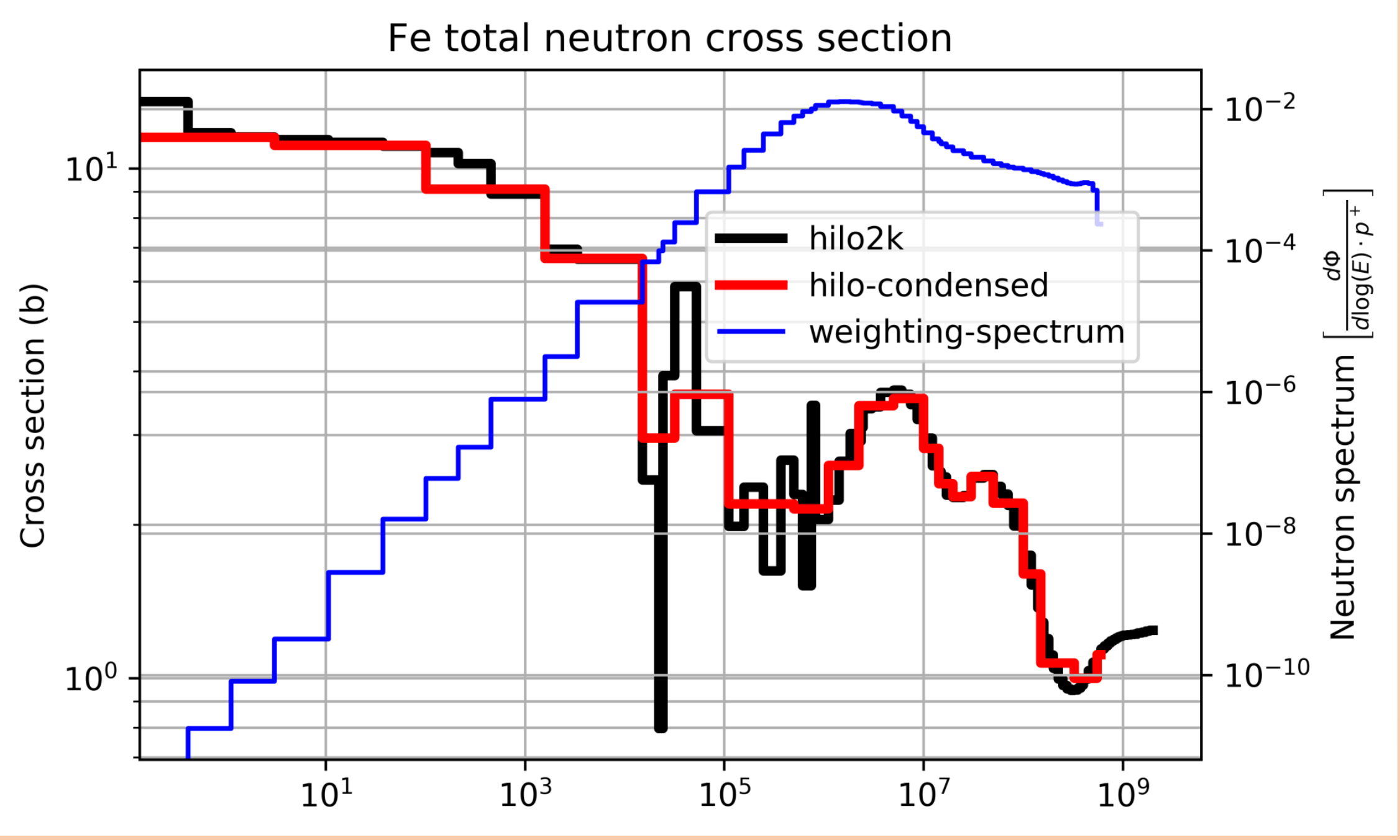




Calculation methodology

- The calculation was carried out in two steps:
  1. Starting with the SINQ proton source, energy-angular dependent MC source was tallied downstream the NEUTRA channel.
  2. This discretized source was used for the subsequent determinsitic/MC calculations
- To generate phase space biasing parameters the fw-cadis methodology, as implemented in the ADVANTG code system, was used.
- fw-cadis uses a forward and adjoint deterministic calculations to generate MCNP energy-dependent weight window maps.
- fw-cadis biases the initial source distribution, via the adjoint flux. Therefore, starting with a neutron source allows for a more efficient calculation.
- To properly resolve the streaming in the neutron channel, the Lobatto quadrature with an ordinate along the x-axis was used. Doing otherwise, would result in the "smearing" of the neutron streaming path with the bulk shielding. This causes exponential weight attenuation along the streaming path and oversplitting.
- The hilo2k library provided with the ADVANTG distribution contains 83 neutron and 22 photon groups. This level of detail is not necessary for generating weight windows. Therefore, hilo2k was condensed, using a custom code and then neutron spectrum at SINQ, to 18 neutron groups.
- The idea to condense the hilo2k library was introduced by Dr. T. M. Miller at ORNL and applied to the shielding of the SNS.
- CAD -> MCNP conversion with GEOUNED (J. P. Catalan, P. Suauvan et.al.)





Calculation Results

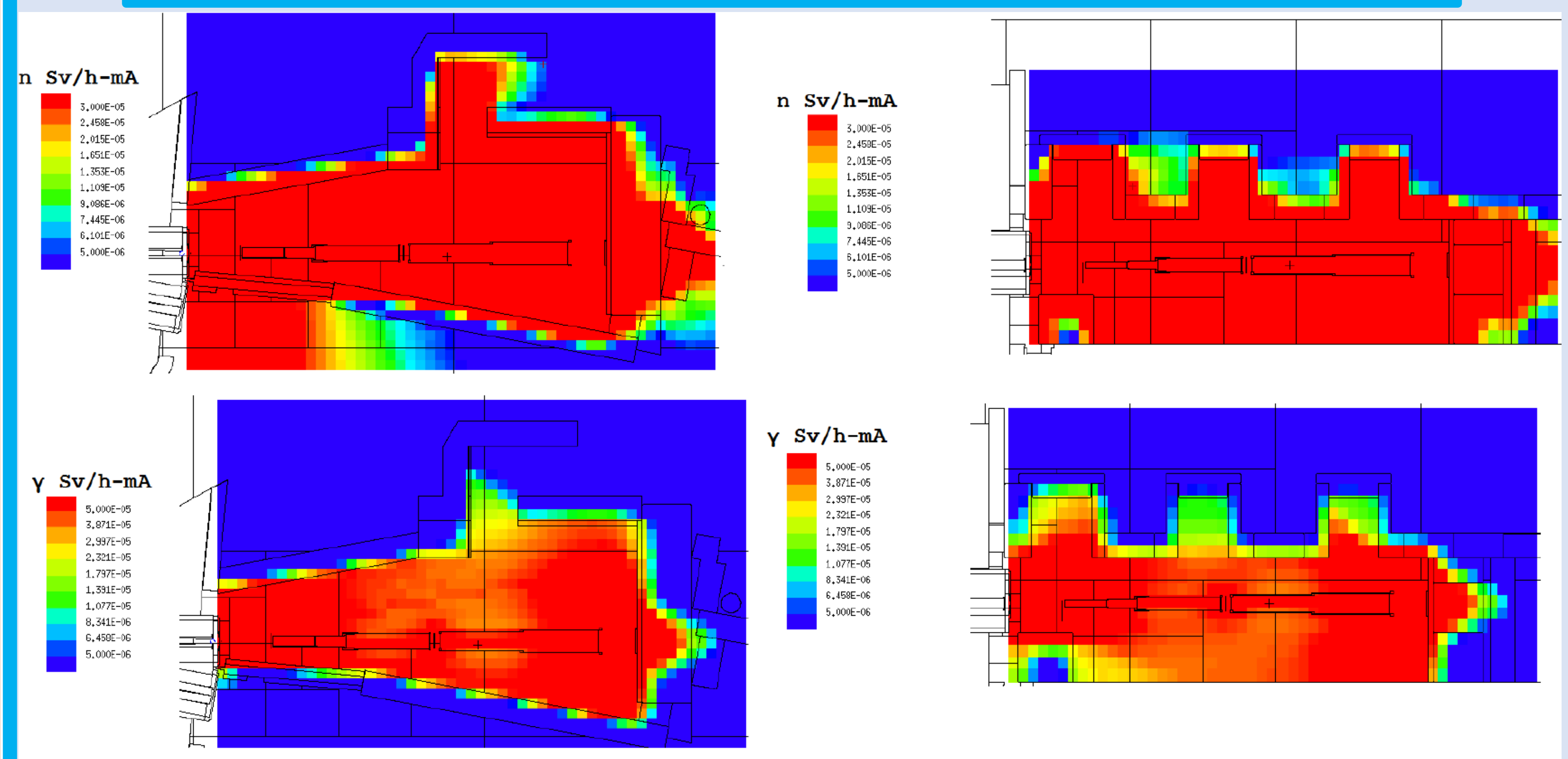


Figure 3: Top and sideways views of the neutron and the gamma dose rate $\left[\frac{Sv}{h-mA}\right]$ distributions, without the Cd absorber and **with** a H_2O scatterer at P2. On the top the neutron dose and on on the bottom the gamma dose are shown $\left[\frac{Sv}{h-mA}\right]$. Theresults are normalized to 1 mA proton current on the SINQ target.

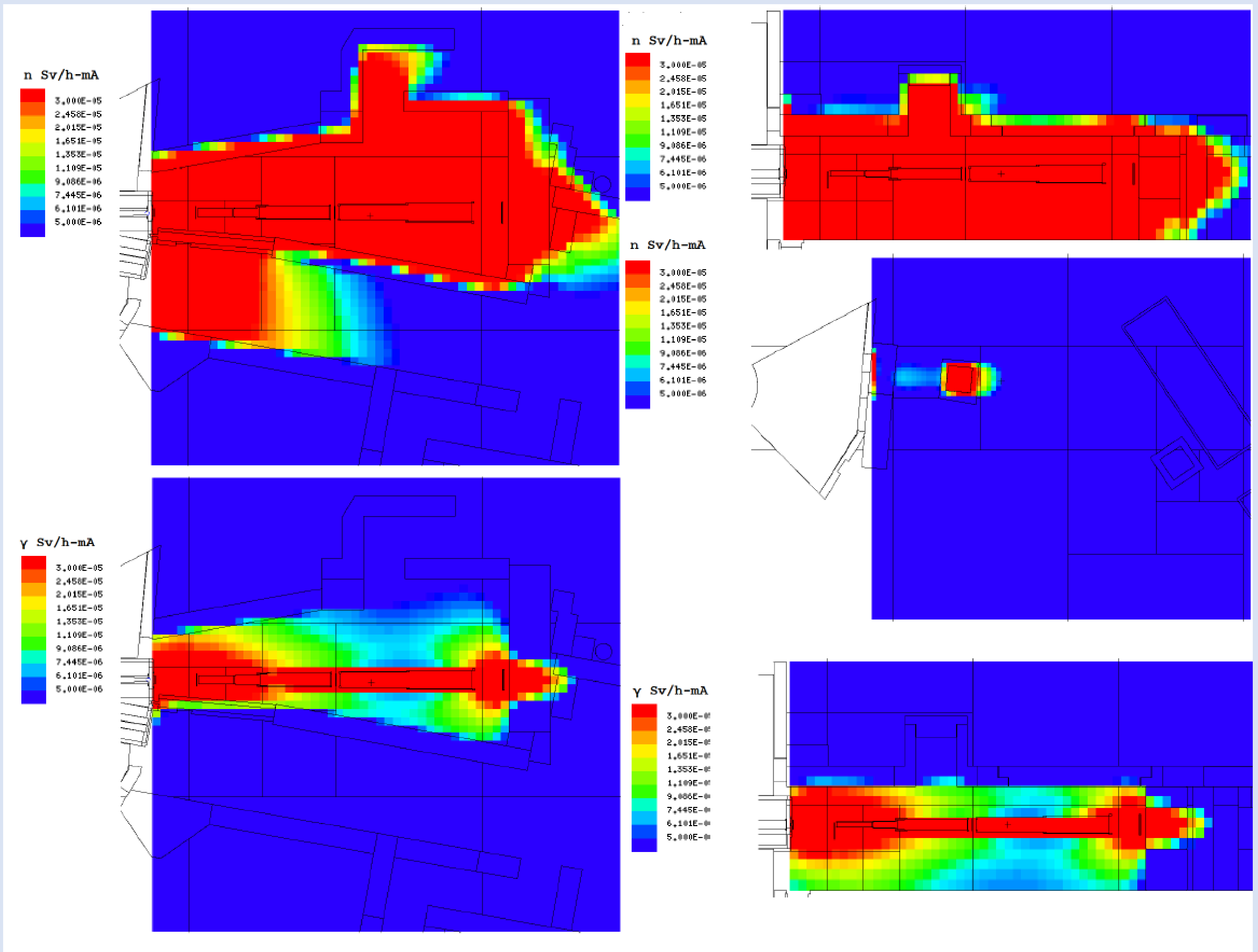


Figure 9: Neutron and gamma dose rates $\left[\frac{Sv}{h-mA}\right]$ of the new shielding configuration, with the Cd absorber inserted and without scattering object at P2.