SLITS AND PHOTON SHUTTERS FOR THE NEW PETRA III UNDULATOR BEAMLINES

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Abstract

The design of a two slit system for the new PETRA III beamline frontend is presented. It is used for radiation safety and beam shaping. For radiation safety two vertical absorber slits are installed. They have to limit the neutron dose at the experimental hall originating from beam losses inside the undulator vacuum chamber. This feature is mandatory for the operation of PETRA III in a continuous filling mode. Additionally, the slit system will absorb off axis radiation of the undulator. The second slit also acts as a power absorber to shut off the photon beam. While the first slit only collimates in the vertical direction, the second slit also collimates in the horizontal direction. The total power in the white beam will be as high as 7.5kW and 250 W/mm² in 28m from the source in the case of the 5m long undulator at 100mA. Future upgrades to a beam current of 200mA will be accounted for in the design.

1. Introduction

Beginning in 2007 DESY will rebuild the 2304 m circumference storage ring PETRAII into the 3rd generation synchrotron radiation source PETRA III[1]. With the particle energy of 6GeV, a beam emittance of 1nmrad, and an initial current of 100mA, 13 independent undulators will deliver high quality beams for experiments.

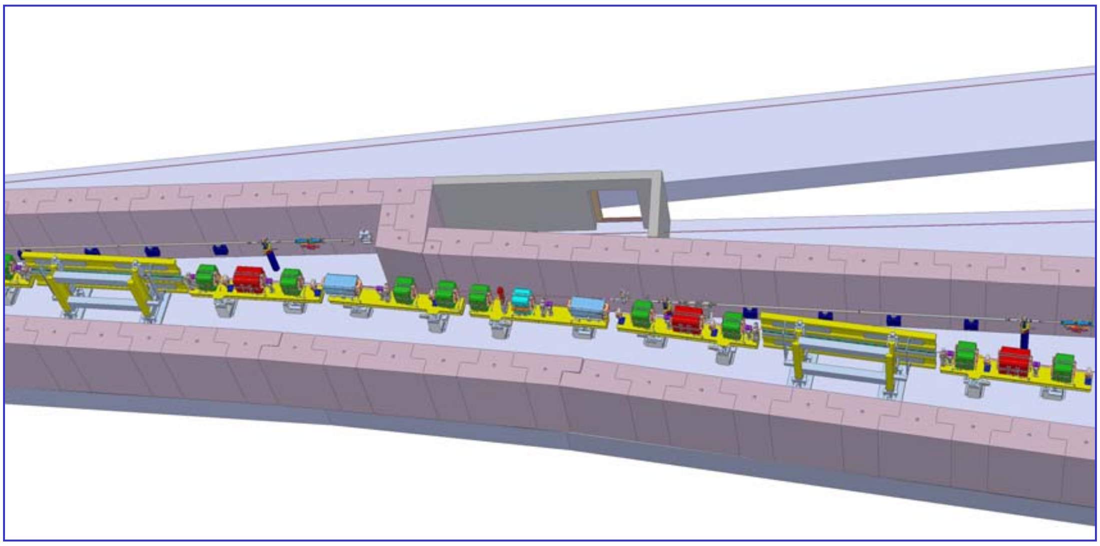

Figure 1: ***A look into the new PETRAIII tunnel section with two undulators and two beamline front ends***

A generic beamline setup is proposed for the beam transport between storage ring and experimental hall. The main tasks of the beamline front end in the storage ring tunnel are:
- Provide a hydrocarbon free vacuum system
- Photon beam transport conserving the unique beam properties

- Ensure radiation safety by collimation and suitable beamshutters
- Monitor the photon beam position
- Shape the beam with fixed and movable masks to reduce the power load on optical components

2. Front end layout

Inside the storage ring tunnel all components dealing with radiation safety, beam position and beam collimation, are placed as shown in the schematic overview. Main components are the two slit systems combined with beam position monitors and the beamshutter.

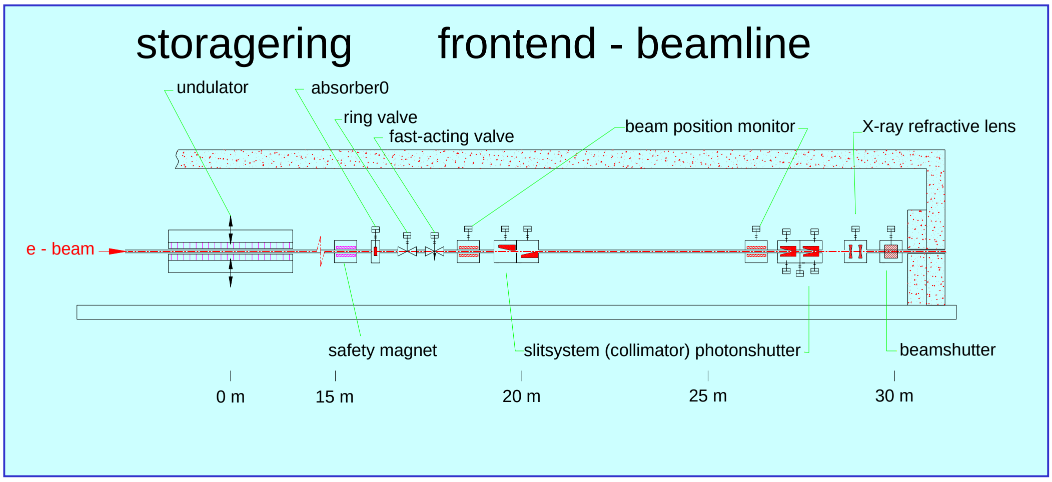

Figure 2: ***Schematic layout of the generic beamline components located inside the storage ring tunnel***

3. Two variable slits for radiation safety

The radiation safety system allows a safe access to the beamline devices in the optics hutch and the experiment without interruption of the storage ring operation. PETRAIII will run in a continuous filling mode which requires a special arrangement of radiation safety components. For a fail safe particle injection, each beam outlet has to be equipped with a permanent magnet which extracts misguided particles out of the photon beamline. To limit the neutron dose caused by the Bremsstrahlung originating from electron beam losses at the undulator chamber wall, two vertical absorber slits are installed in the front end at 18m and 28m from the source. During normal operation of the storage ring an aperture size of ~1mm prevents a direct line of sight towards the undulator vacuum chamber (Figure 3). During the set up of storage ring and beamlines the apertures are wide open and continuous filling is prohibited. A special slit drive allows a fast change to narrow slits allowing continuous filling mode again.

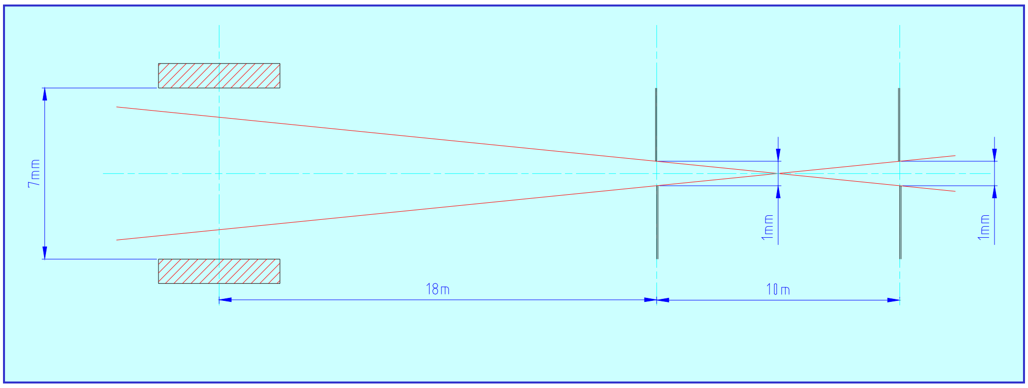

Figure 3: ***Sketch of the slit positions placed in the beamline front end relative to the undulators chamber***

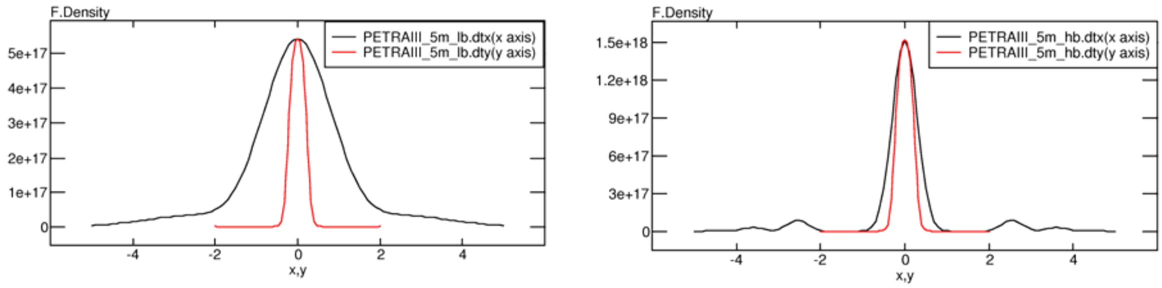

Figure 4: ***This figure shows the vertical and horizontal flux density of the third harmonic at 28m. The red curve shows that a 1mm vertical slit causes no losses of usable photons in the central cone of the undulator beam generated in a low beta(left) or high beta (right) section. The calculations were performed with SPECTRA [2]***

The beam shutter will be placed directly in front of the storage ring wall. The second slit acts simultaneously as a photon shutter to absorb the full beam power.

4. The technical concept

The slit systems will absorb off axis radiation of the undulator. This shows the comparison between the vertical power density in Figure 5 and the vertical flux in Figure 4. The total power in the white beam of the 5m undulator will be 7.5 kW with a maximum power density of 250W/mm^2 in 28m from the source at a beam current of 100mA.

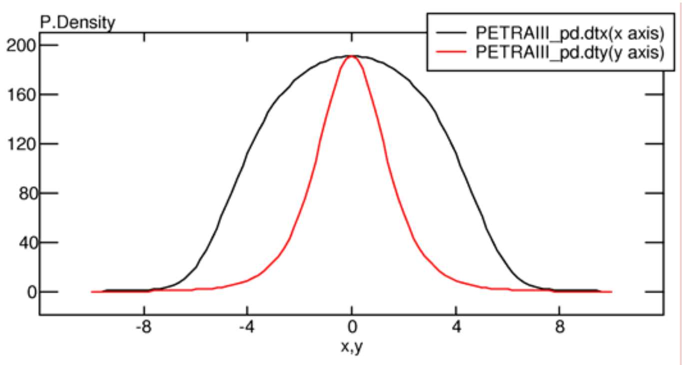

Figure 5: ***Power density (kW/mrad^2) of the undulator beam at 28 m distance from the source.***

Figure 6 shows the cross-section and the principle of the operation of the vertical slit system [3]. The upper and lower jaw of the slit consist of an inclined (~1 to 4 degree) water cooled copper absorber. The copper accepts the power and is combined with a tungsten blade to stop high energetic radiation. The slit jaws are linked to control the slit width by one vertical motion, while the vertical slit position is adjusted moving the whole set up. This allows introducing a vertical shutter function of the slit by superimposing the linear motion of a pneumatic cylinder.

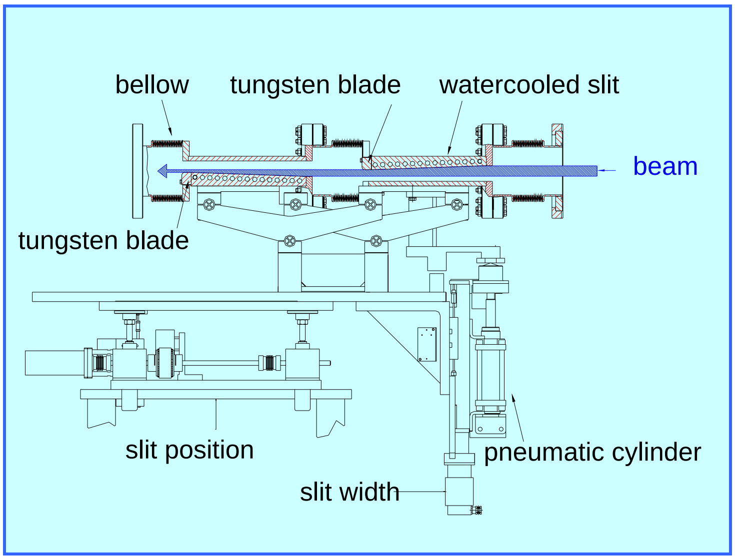

*Figure 6: **Cross-section of the slit system showing the principal components of the set up***

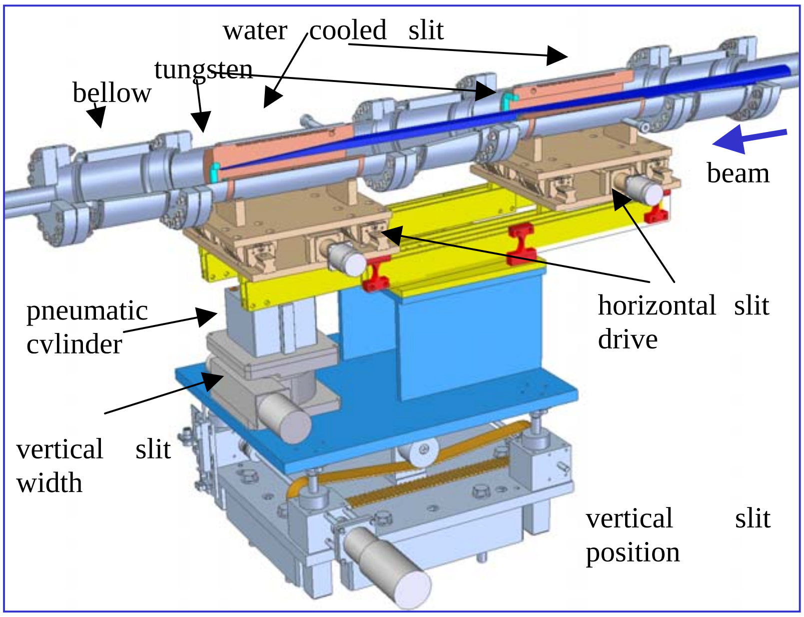

Figure 7: The design of the vertical – horizontal slit system with integrated vertical shutter function

Figure 7 shows the realization of the proposed shutter slit system with a total length of about 1 m. The beam enters the set up from the right. The two water cooled slit jaws are mounted on slides, which allow a horizontal slit adjustment [4]. These slides are mounted on a balance system with slip stick free solid state bearings, which link the vertical motions of the slit jaws. The vertical slit width is controlled either by the air cylinder for fast switching or the z–table for the fine adjustment of the slit width. The vertical slit position is adjusted using another z–table. Bellows decouple the relative movement between slit jaws and beamline vacuum system.

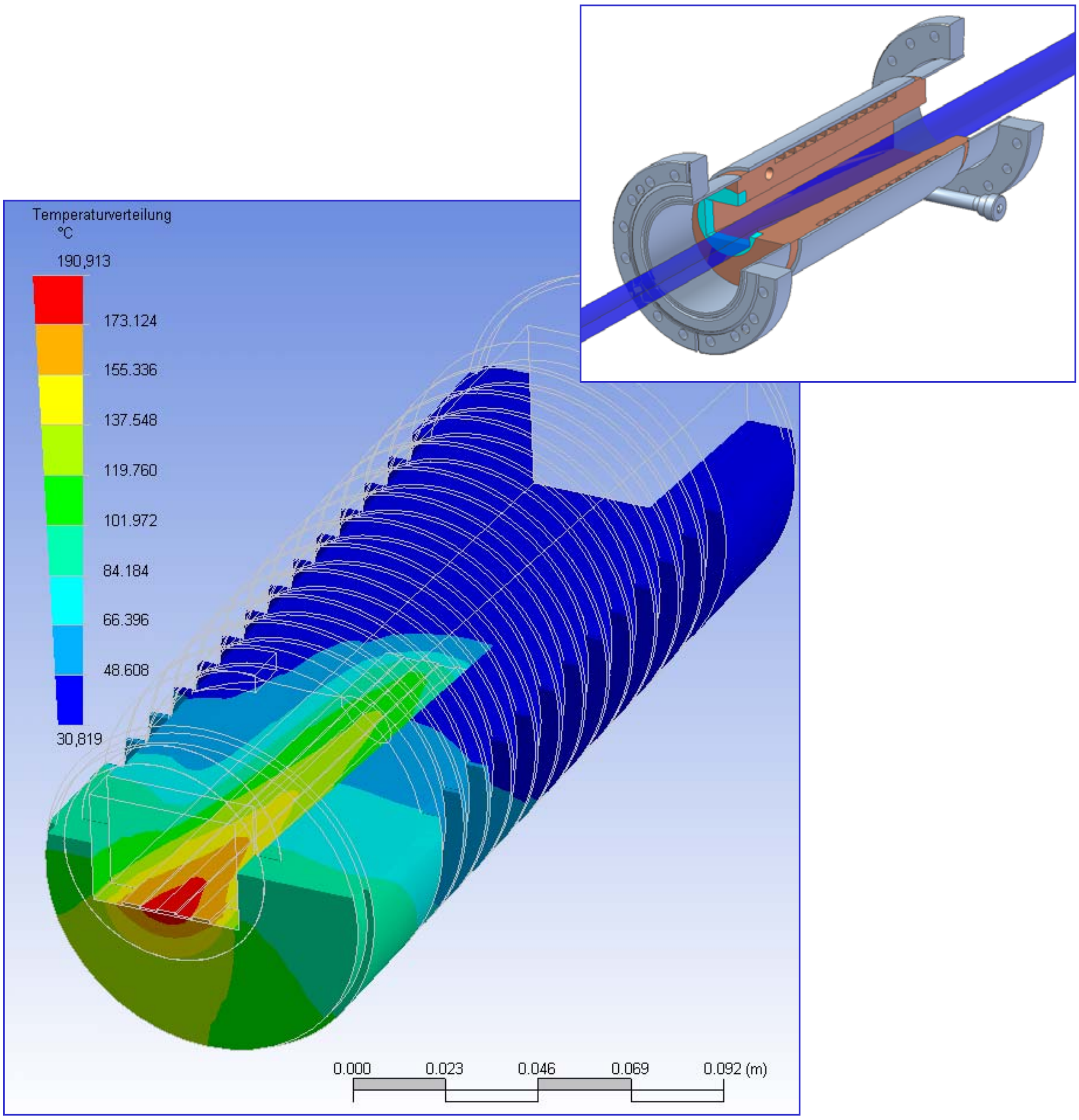

Figure 8: ***First FEM model calculations of a slit jaw. The insert on top shows the intersection of the jaw with the beam.***

Figure 8 shows a single slit jaw shaping the beam vertically. Horizontally the slit jaw is centred. First basic FEM model calculations [5] of the power load have been performed for a slit jaw with an inclination angle of 4º. In this case the jaw absorbs 75% of the total power at 28 m distance from the source. The calculations for a current of 100mA show, that the beam shaping, resp. shutting off the beam with the slit system will cause no serious technical problems. For the final design more detailed FEM calculations especially for the first slit will be performed.

5. Conclusion

We have shown the design of the standard slit system for the new PETRA III beamline front ends. The mechanical layout enables us to combine shutter and slit functions in one device. The first FEM calculations show that the handling of the thermal loads of the PETRAIII undulator beams is feasible.

6. References

[1] PETRA III, A Low Emittance Synchrotron Radiation Source, Technical Design Report, DESY 2004 - 035

[2] SPECTRA 7.1., T. Tanaka and H. Kitamura, J. Synchrotron Rad. 8(2001)1221.

[3] German Patent DE 101 35 307 C2

[4] P. Marion and L. Zhang, New high power primary slit for the ESRF beamlines, AIP Conference Proceedings SRI 2003, (2003) 705, 320 - 323

[5] ANSYS 8.0 - designspace