Simulations of radiation from a 3-pole wiggler. Comparisonn between the ESRF and the APS upgrade projects.

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Abstract

Spectral and geometrical characteristics of the emission of 3 pole-wigglers are discussed in the context of the upgrade of present 3rd generation storage rings. The spectrum and, more important, the intensity distribution versus the horizontal divergence depend on the shape of the 3PW magnetic field. The cases of the ESRF and APS are compared. It is shown that the horizontal distribution shows a hole on-axis and sharp interferences at the edges. Some ideas for possible optimization are given. Spectral calculations are done with XOP [1], and angular characteristics are simulating using a recent upgrade of SHADOW [2] and a recent code from APS [3].

Introduction

The largest existing SR facilities, like ESRF and APS are undertaking important upgrades aiming to fully replace their storage rings with new low-emittance ones that will increase the coherence and brightness of the emitted radiation by at least two orders of magnitude. The existing bending magnets (BM) will be replaced by a set of less intense magnets with will emit less radiation than present bending magnets. An envisaged solution is to include short wigglers in the lattice that will boost the radiation. Here I calculate and compare the radiation from two 3-pole wiggler devices, those projected for ESRF and APS.

Magnetic field, electron trajectory and spectrum

Magnetic field of the 3PW devices planned for the ESRF and APS are represented in Fig. 1. These design are not definitive and may change. In particular, the maximum magnetic field can be changed, or even made variable. For the calculations and discussions here I use these values taken from the respective upgrade project reports.

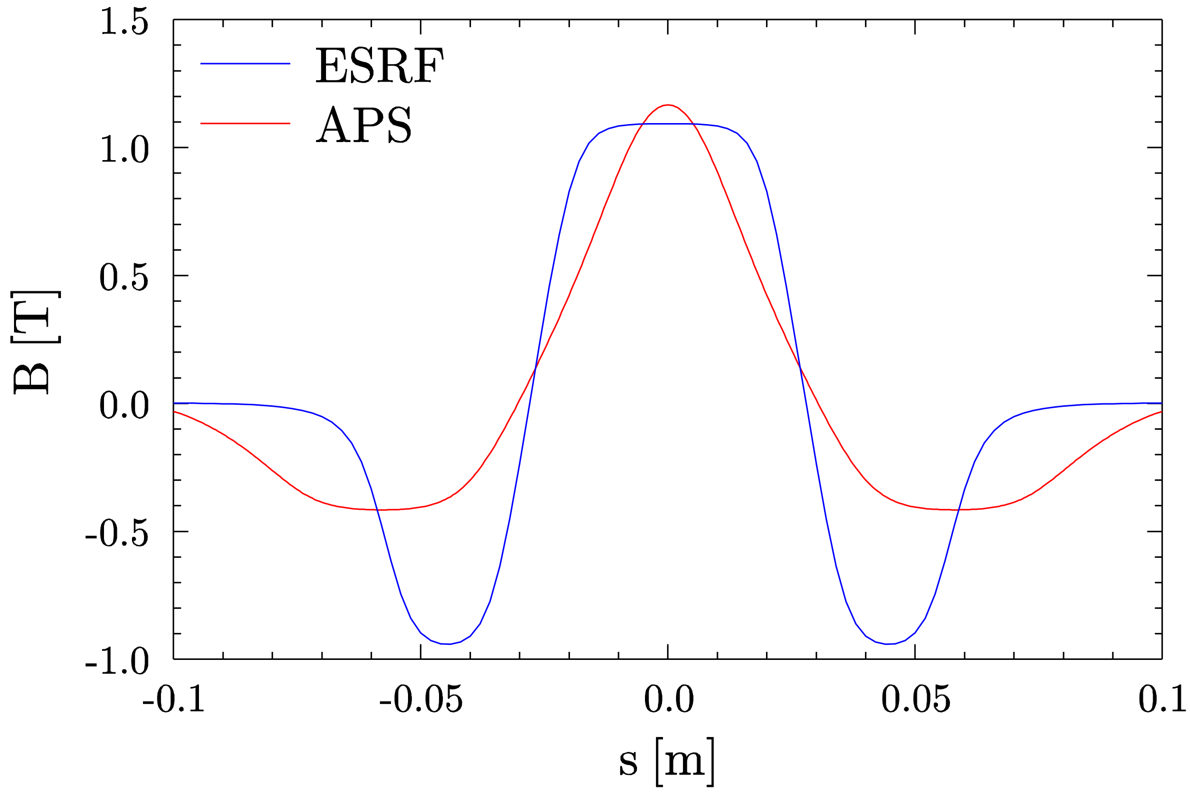

Fig 1 Magnetic field for the ESRF-II 3PW (blue) and for the APS (red).

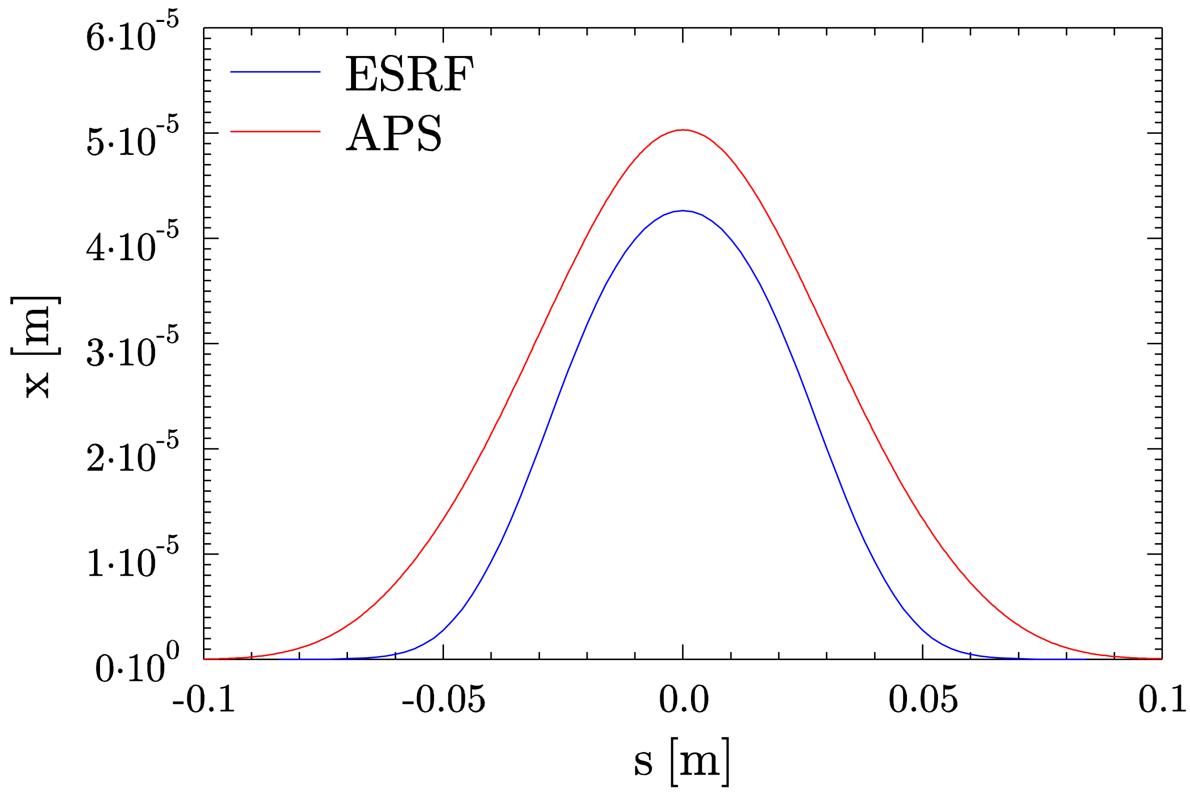

Fig 2 Electron trajectory for the ESRF-II 3PW (blue) and for the APS (red).

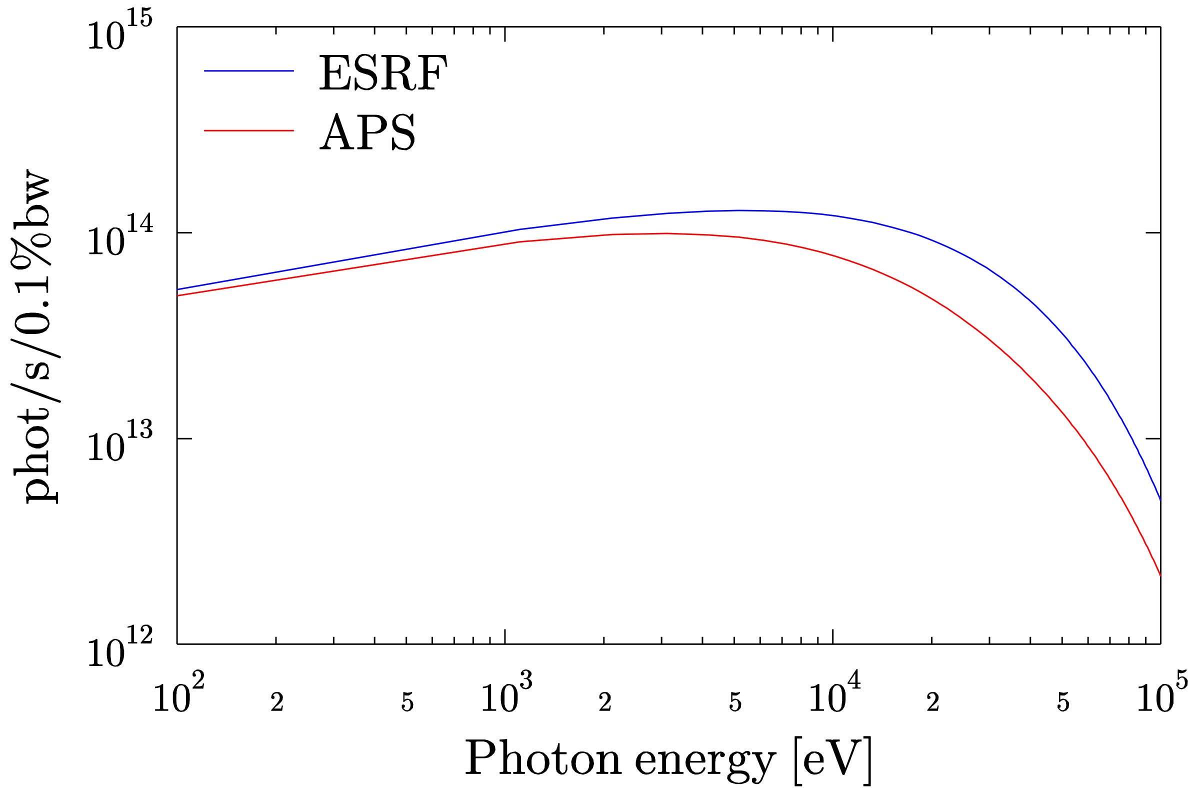

Fig 3 Emission spectrum for the ESRF-II 3PW (blue) and for the APS (black) calculated by XOP[1].

Fig 1 shows the magnetic field of the 3PW for ESRF and APS. The ESRF magnet design gives a uniform magnetic field at the center and quite strong side poles to compensate (the integral must be zero). The APS design includes am intense but less flat central field and less intense side poles. Fig2 shows electron trajectory under the magnetic field. The ESRF design shows a magnetic field that approximates better in the center the bending magnet field thus producing a spectrum closer to the BM for high energies (Fig. 3). However, the peak magnetic field of the side poles is quite strong and contributes substantially to the radiation even for high energies. This is illustrated in Fig. 4 where it can be seen that for 3 keV all poles strongly contribute to the radiation, but for high energies (100 keV) the side poles still contribute to the full emission for the ESRF but not for the APS. On one hand there is high flux especially at high energies, but it affects the angular photon distributions.

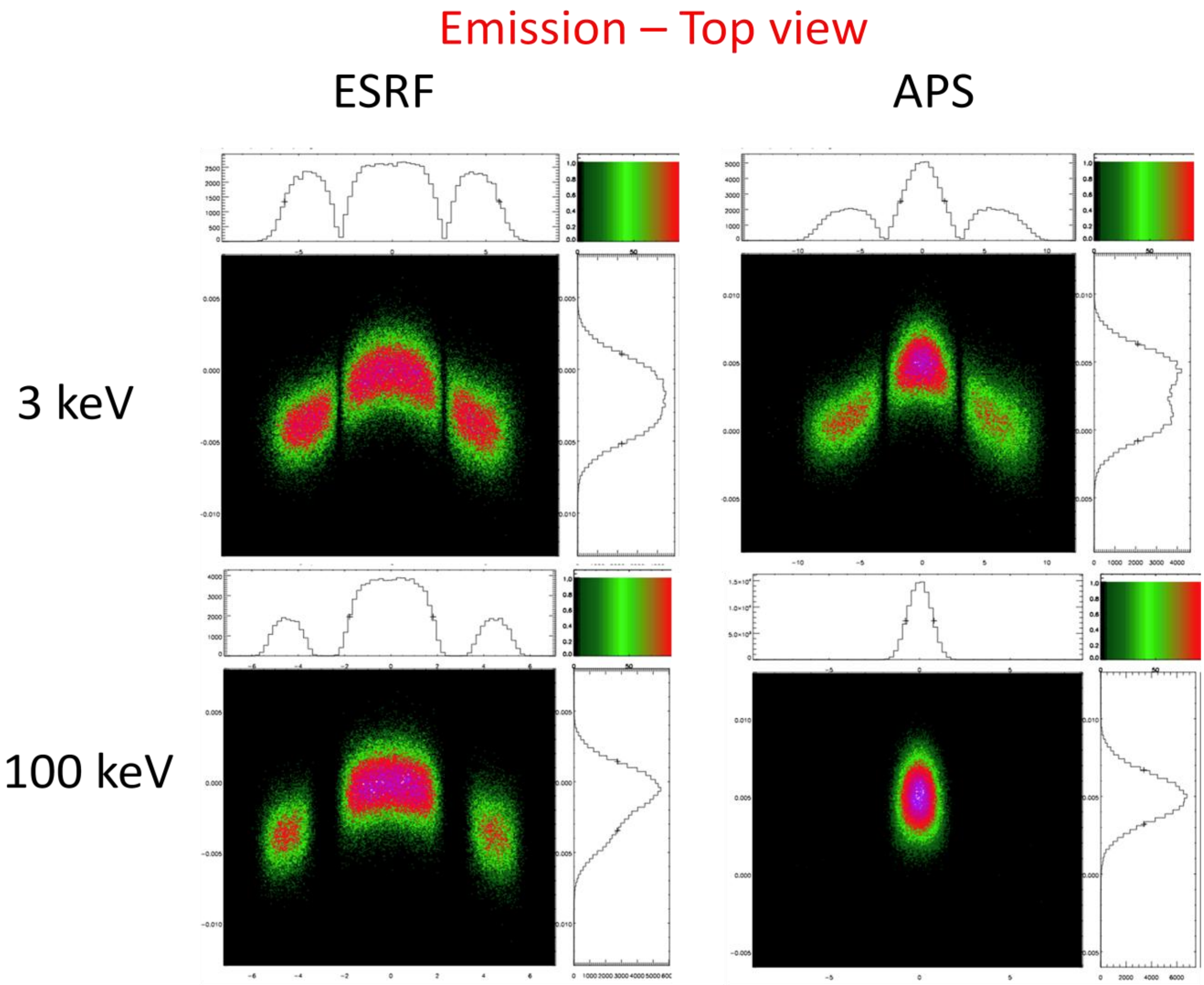

Fig 4 Emission intensity (color scale) as a function of the electron trajectory (s[cm] in horizontal, y[cm] in vertical). It can be appreciated that at low energy all wiggler poles contribute to the emission, but at high energy the influence of the side poles is small for the ESRF and practically zero for the APS.

The angular distribution is illustrated in Fig. 5. It is plotted here the full radiation fan emitted at different photon energies. In vertical it shows the effect of higher collimation for higher energies. The interesting part is the horizontal distribution, which basically depends on the shape of the magnetic field. When all poles contribute to the radiation it can be seen a pronounced hole in the middle of the radiation distribution. This hole is present when all poles contribute to the emission. The hole disappears when the side poles are not contributing to the radiation, as in the case of the APS design at 100 keV.

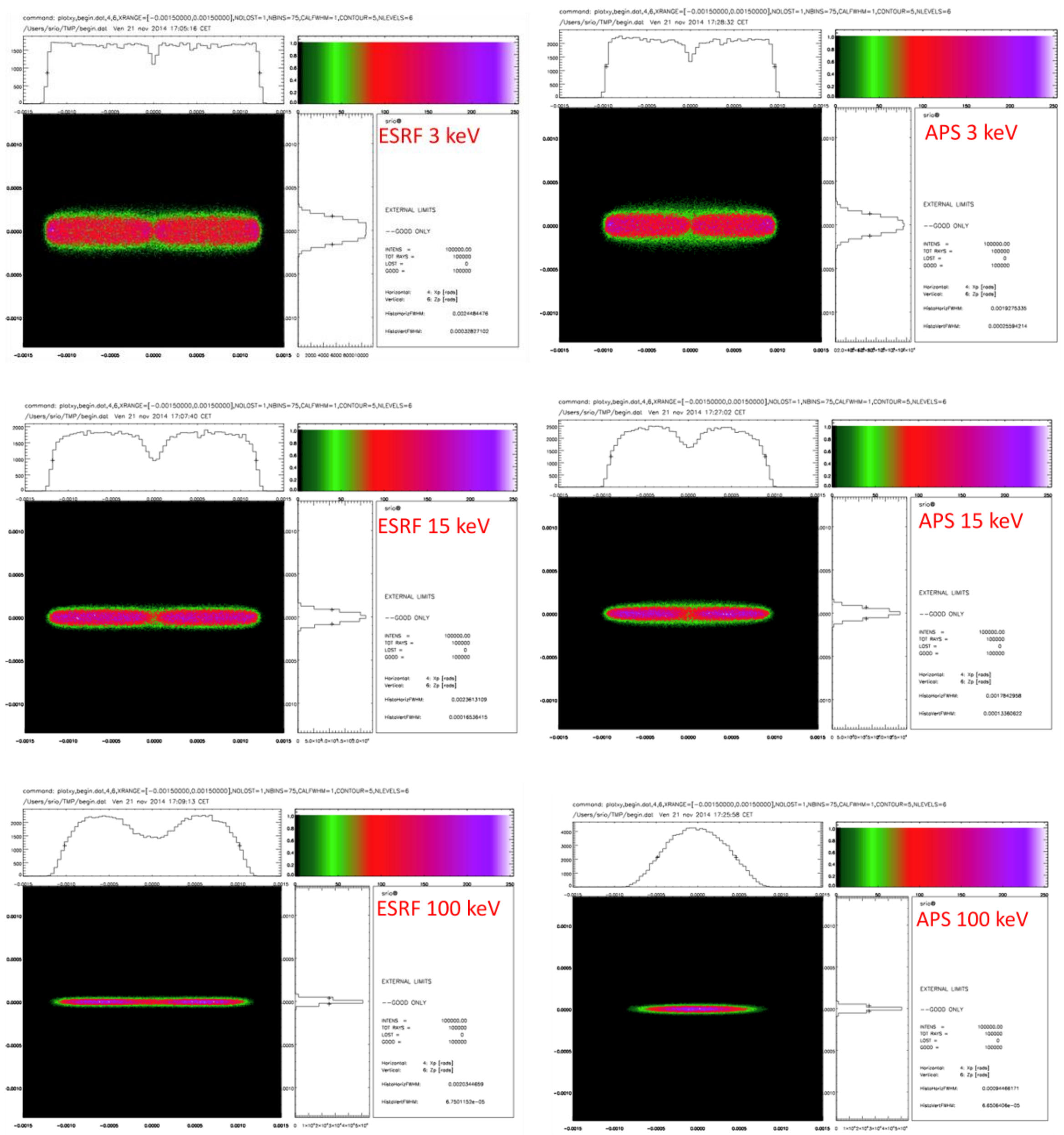

Fig 5 Emission intensity (color scale) as a function of horizontal and vertical emission angle (in rads).

Effect of interferences

The model implemented in SHADOW [2] simulates the wiggler adding incoherently BM-like radiation emitted along the electron path and does not take into account possible "undulator-like" interference that would introduce ripples in the horizontal divergence. This effect has been studied at APS [3]. They made calculations using the SPECTRA code [5] and then developed an ad-hoc code from basic principles [3]. Both codes give the same results. I have used this code to simulate the radiation pattern at a screen at 30 m from the wiggler. Results are in Fig. 6. They show the same on-axis hole except for the APS case at 100 keV, as shown before. Moreover, there is an interference effect at the edges. This is more pronounced at APS because the σ'_x value is smaller.

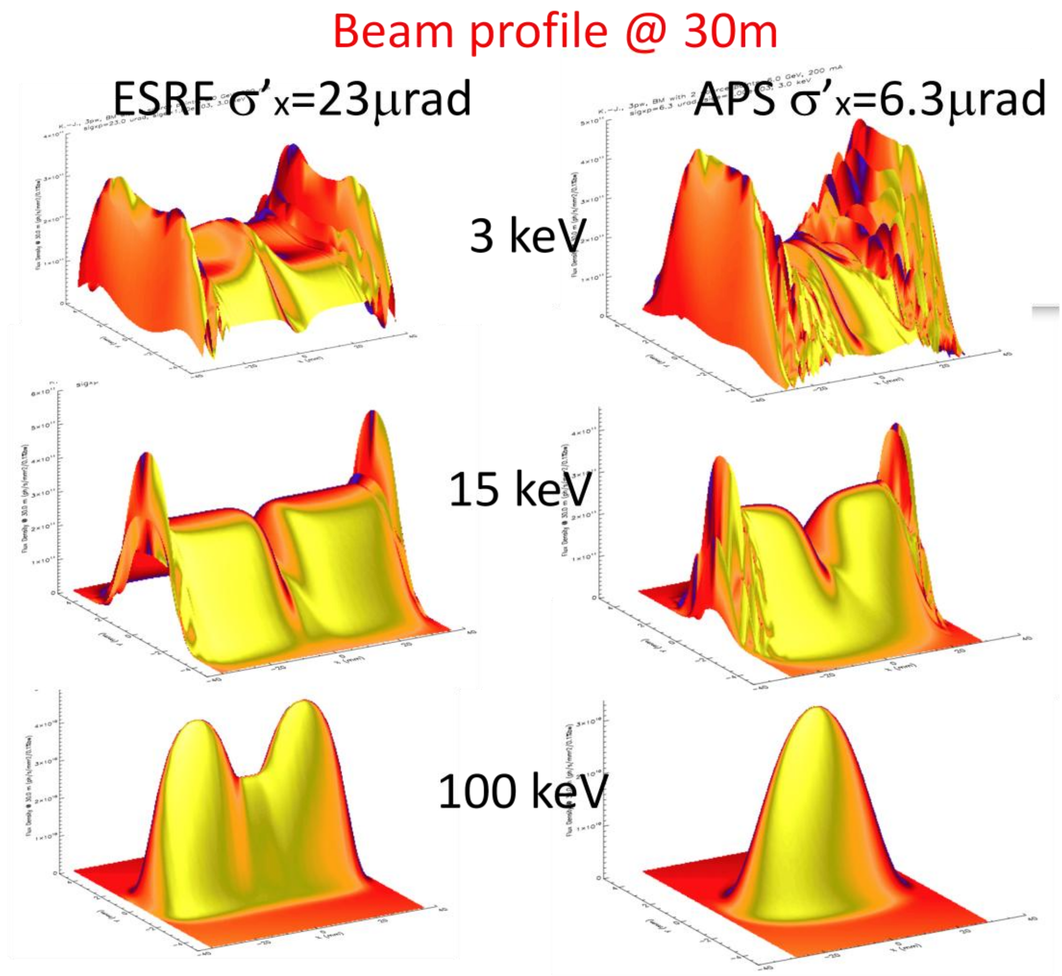

Fig 6 Emission intensity at a screen at 30 m Note that H and V scales are different.

Final remarks

It has been shown that the horizontal divergence of the 3PW is not flat, with a hole in the middle and ripples at the edges. The hole can be reduced for high energies of the side poles are made weaker. It will not be possible to eliminate the hole at low energies. For practical purposes, it may be interesting to use the radiation from one of the two side lobes, thus off-axis radiation in horizontal. Respect to the ripples, they are smeared by the σ'_x which I do not know if can be changed. The distribution of the magnetic field can be optimized to get flatter distribution at working energies around 15-35 keV. The SHADOW code complemented with the APS code could be used to evaluate and optimize the emission. SRW can also be used, however, similar calculations presented by O. Chubar [5] do not show edge effects, which seems not very realistic. It may depend of which model of radiation emission has been used in SRW.

References

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[4] Spectra version 9: http://radiant.harima.riken.go.jp/spectra/

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