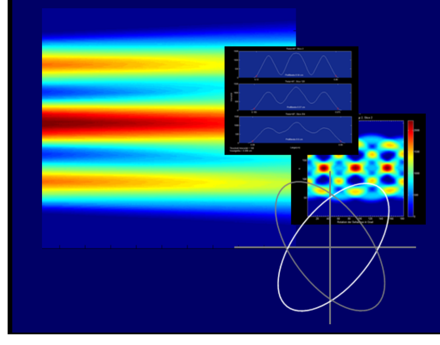

Optical Diagnostics for Frankfurt Neutron Source

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A non-interceptive optical diagnostic system on the basis of beam tomography, was developed for the planned Frankfurt Neutron Source (FRANZ). The proton driver linac of FRANZ will provide energies up to 2.0 MeV. The measurement device will non-interceptively derive required beam parameters at the end of the LEBT at beam energies of 120 keV and a current of 200 mA. On a narrow space of 351.2 mm length a rotatable tomography tank will perform a multi-turn tomography with a high and stable vacuum pressure. The tank allows to plug different measurement equipment additionally to the CCD Camera installed, to perform optical beam tomography. A collection of developed algorithms provides information about the density distribution, shape, size, location and emittance on the basis of CCD images. Simulated, as well as measured data have been applied to the evaluation algorithms to test the reliability of the beam. The actual contribution gives an overview on the current diagnostic possibilities of this diagnostic system.

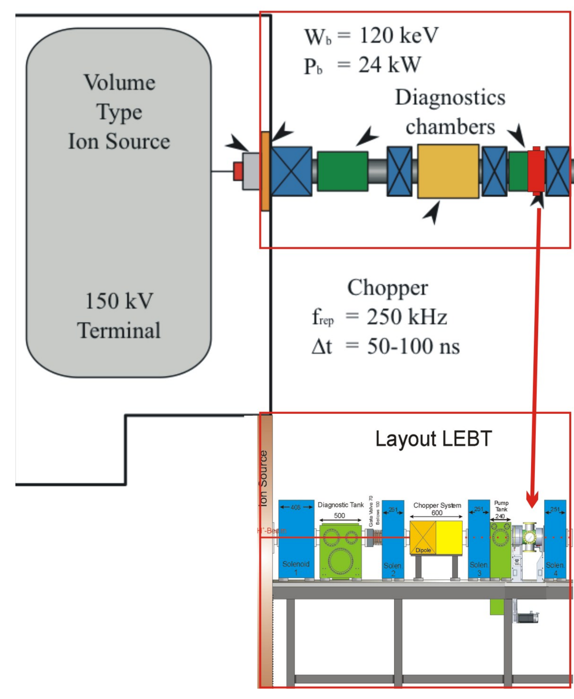


Figure1: Schematic construction of the Frankfurt Neutron Source including the position of the rotatable vacuum chamber in the back end of the LEBT.

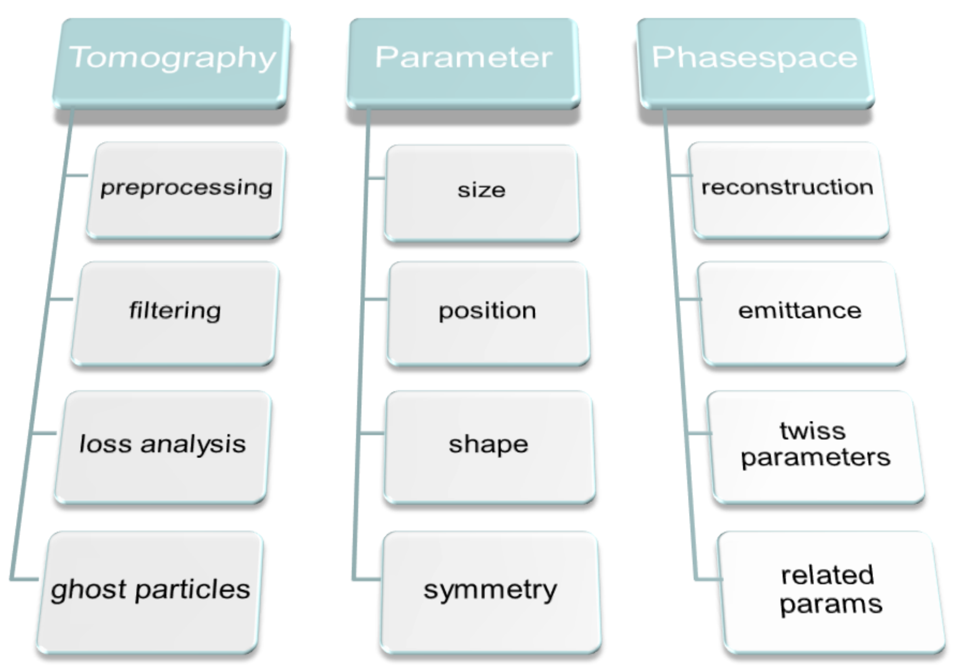


Figure 2:
A collection of performed and implemented investigations on beam tomography

Beam Shape

The beam shape directly is given by the backprojected intensity distribution in the transversal (x,y)-plane of every longitudinal z position of the volume. To compare different degrees of symmetry a symmetry factor was used to compare different beams and to analyze the symmetry evolution in time.

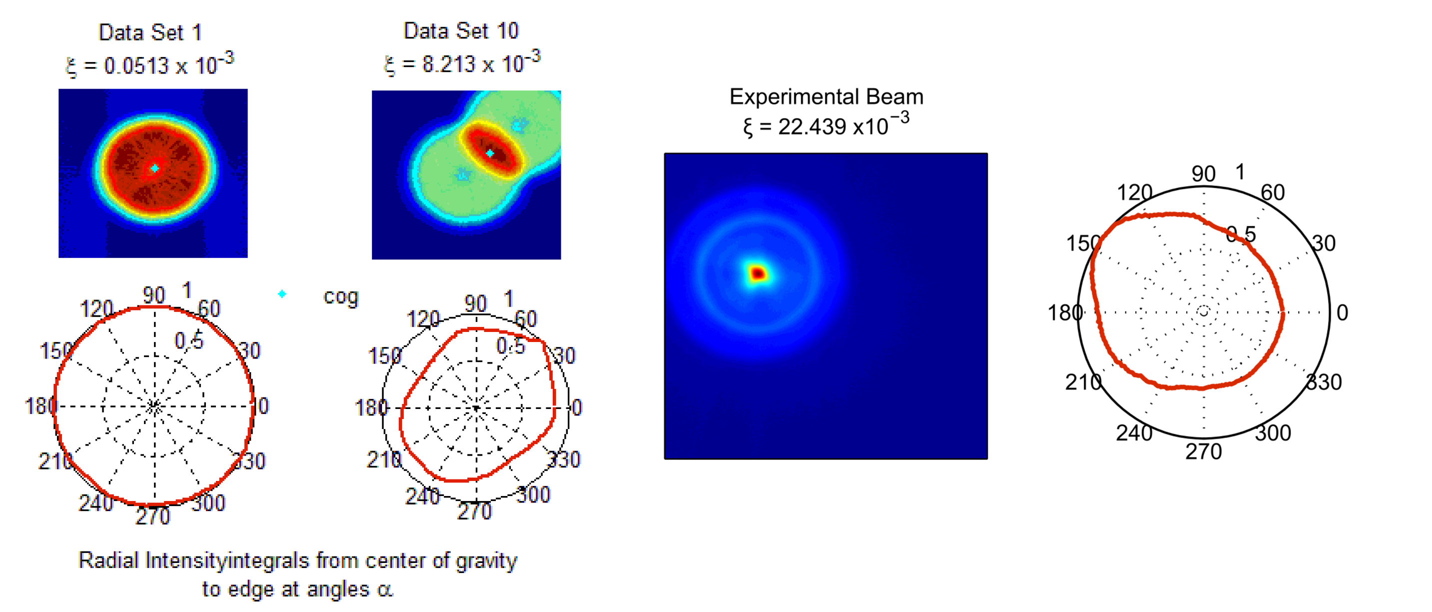


Figure 3:
The symmetry analysis used to compare different beams. On the left, two examples of the 10 data sets are compared. The left one is nearly radial symmetric, the right one is axis symmetric. On the right hand side a mesured beam is analyzed.

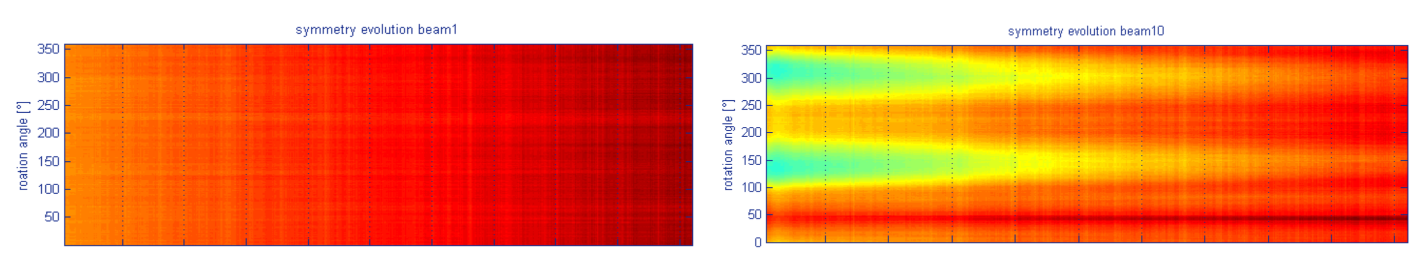
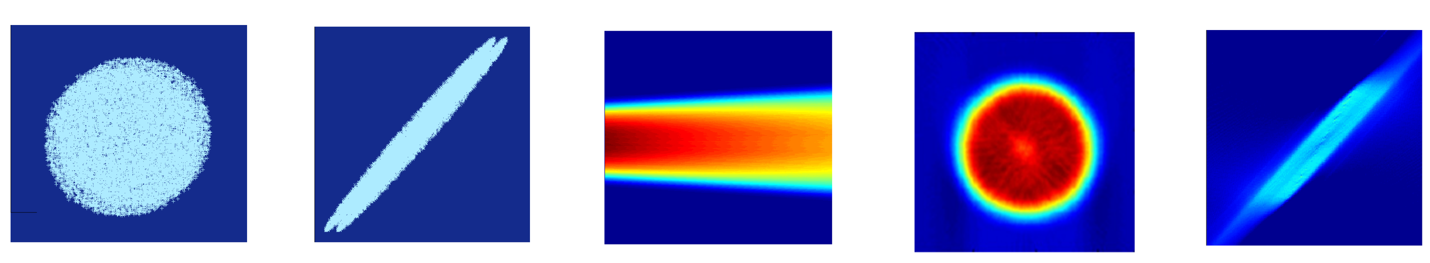


Figure 4:

Symmetry evolution in one beam.



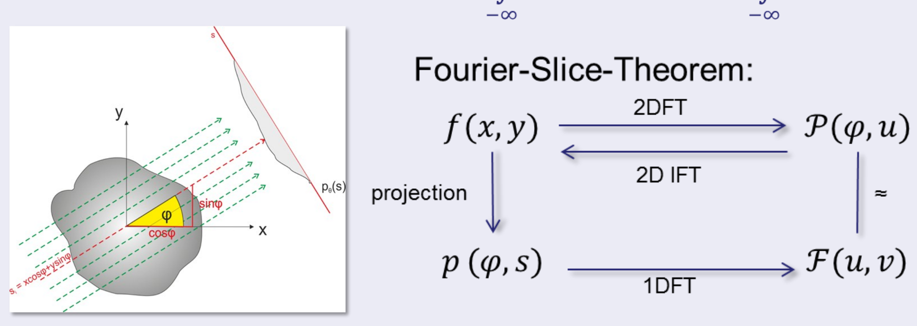
a) b) c) d) e)

Figure 5:
position space and phase space tomography

a) position space of the start distribution b) phase space of the start distribution c) side projection of the raw data d) obtained position space distribution e) obtained phase space distribution

tomography in position space

Radontransformation $\Re(f)(m,b) := \int_{-\infty}^{\infty} f(x, mx+b)dx = \int_{-\infty}^{\infty} f(x,y)dx$



$$f(x,y) \xrightarrow{2DFT} \mathcal{P}(\varphi,u)$$
$$p(\varphi,s) \xrightarrow{1DFT} \mathcal{F}(u,v)$$

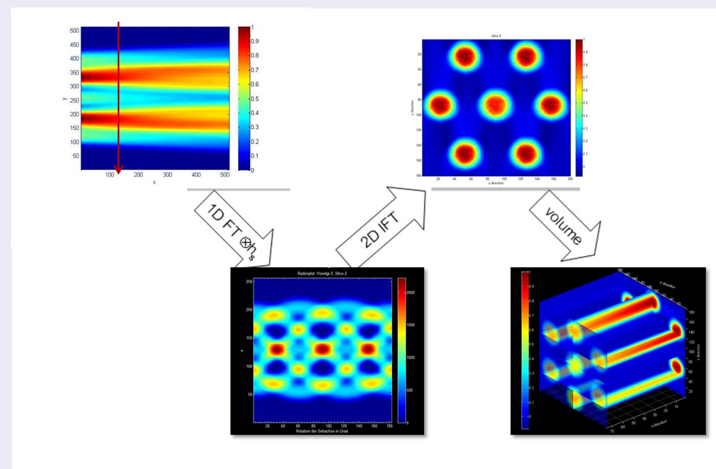
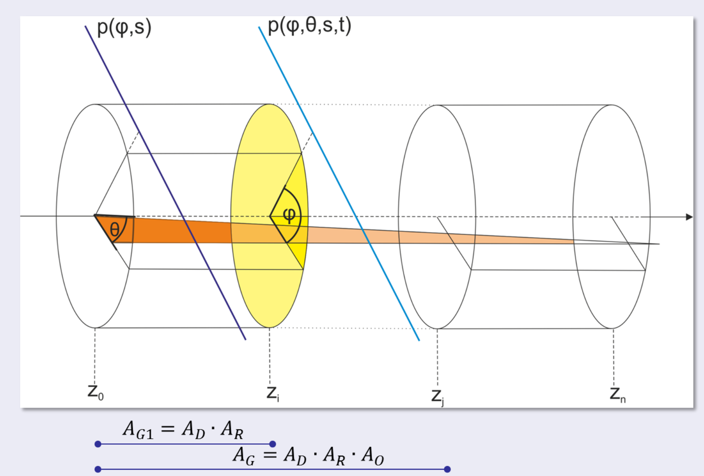


Figure 6:
example of position space tomography on a simulated 7-beamlet beam

tomography in phasespace



transfer matrix $\begin{pmatrix} x_1 \\ x'_1 \end{pmatrix} = \mathcal{A} \begin{pmatrix} x_0 \\ x'_0 \end{pmatrix}$

scaling factor $t = \sqrt{\mathcal{A}_{11}{}^2 + \mathcal{A}_{12}{}^2}$

phase space rotation angle $\tan\theta = \frac{\mathcal{A}_{12}}{\mathcal{A}_{11}}$

filtered projection for phase space:

$$\tilde{f}\left(\frac{x}{t}, \theta\right) = t \cdot p_\varphi{}^{s,t}(x,\theta)$$

Determination of Beam position

For the determination of the beam position and direction, first the center of gravity is computed with usual method, from the three dimensional backprojected volume:

$$P_x = \sum_{i=1}^{n} i \cdot \frac{I_{x_i}}{\sum_i x_i}; P_y = \sum_{j=1}^{m} j \cdot \frac{I_{x_j}}{\sum_j x_j}; P_z = \sum_{k=1}^{l} k \cdot \frac{I_{x_k}}{\sum_k x_k}$$

In the next step the direction of the beam through the center of gravity in longitudinal direction will be determined. First the volume has to be whitend by substracting the center of gravity from all coordinates. Then the eigenvalues and eigenvectors of the inertia tensor have to be determined. The beam direction then is given by the scalar product of the eigenvector with the smalest eigenvalue and the direction vector of the longitudinal z-direction.

Given the inertia tensor T, the eigenvalues λ_i and the corresponding eigenvectors v_i could be determined by:

$$T = \sum_{i=1}^{n} \lambda_i v_i v_i^T$$

The eigenvector $\vec{e}_1 = (e_{1,1}, e_{1,2} e_{1,3})$ with the smalest eigenvalue and the direction vector of the longitudinal axis $\vec{z} = (0,0,P_z)$ give the angle of abberation by the scalar product:

$$\cos\phi = \frac{\vec{z} \cdot \vec{e_1}}{P_z \cdot \sqrt{e_{1,1}{}^2 + e_{1,2}{}^2 + e_{1,3}{}^2}}$$

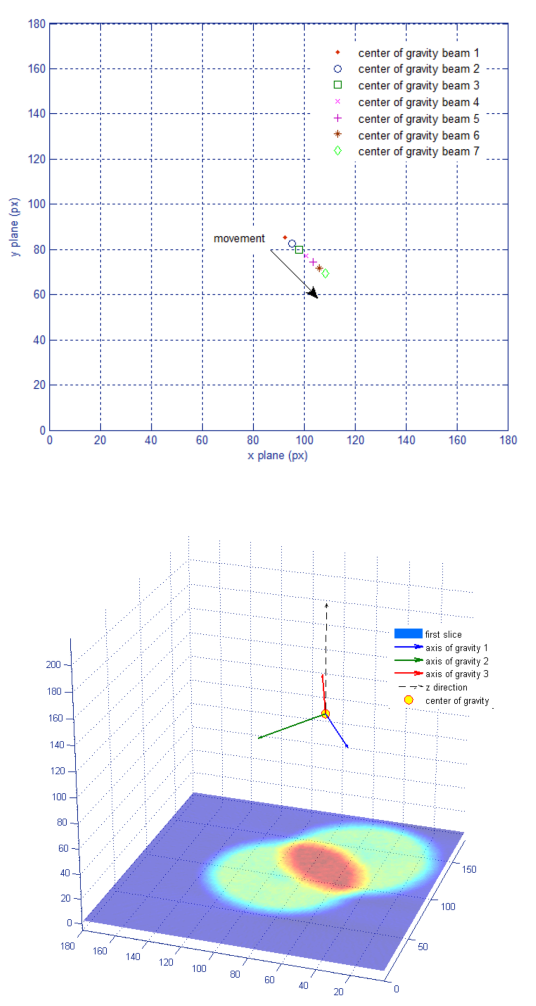
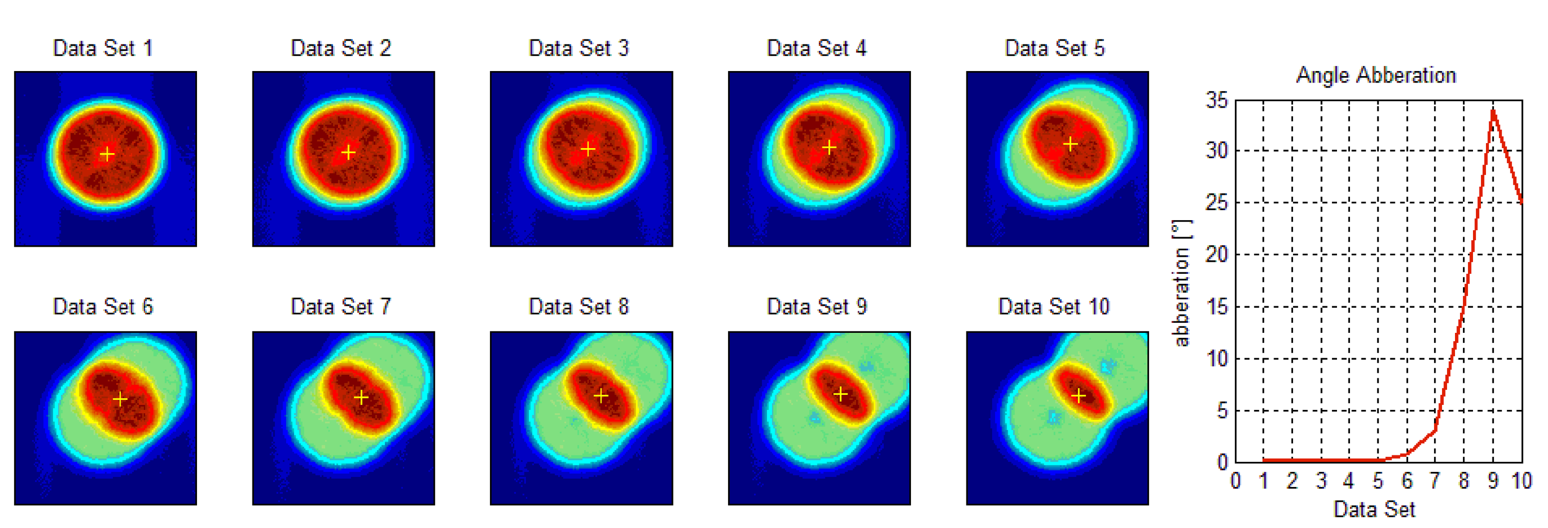


Figure 7:
experiment series on beam direction



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