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Detailed investigation of a 4D phase-space distribution of an ion beam

H.R. Kremers, J.P.M. Beijers, S. Brandenburg
Kernfysisch Versneller Instituut,
Zernikelaan 25, 9747 AA, Groningen.

Content

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- Experimental setup/ simulation model
- Applications of the model:
  - Construct phase-space projections in the image plane of a dipole
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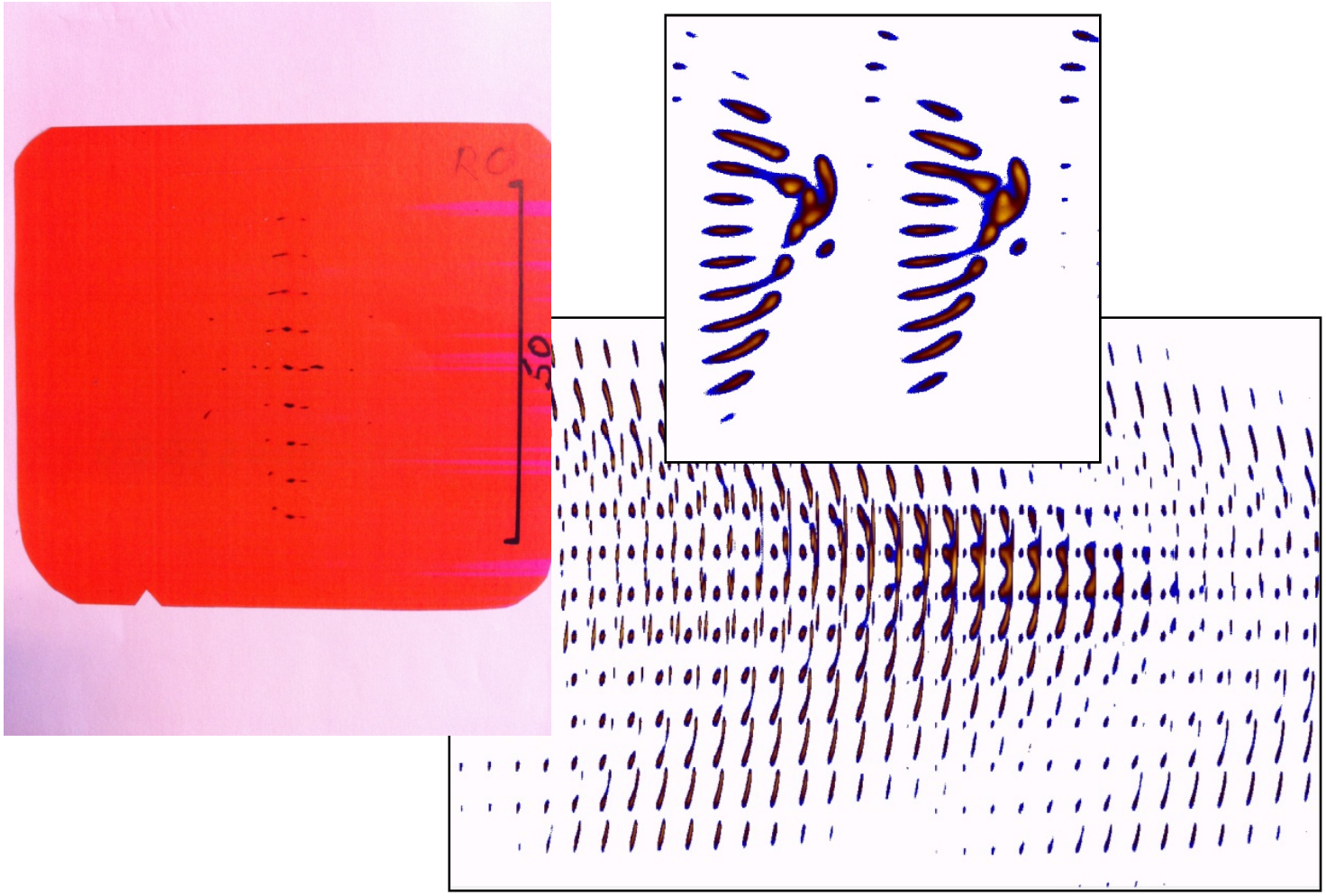
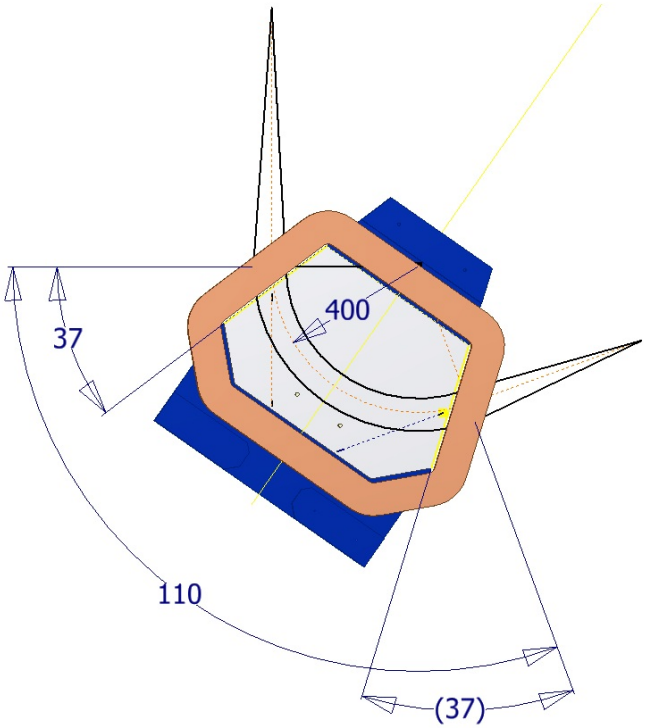
  - Derive an analytical expression to describe x'-y' distribution
  - Predict the response distribution of a slit on the MCP
  - Compare the simulation and measurement of a response distribution of an MCP
- Conclusions

Introduction



Experimental setup



Simulation model

$$\theta_1 = (\theta/x)x_0 + (\theta/x')x'_0 + (\theta/y)y_0 + (\theta/y')y'_0 + (\theta/xx)x_0^2$$
$$+ (\theta/xx')x_0x'_0 + (\theta/x'x')x'^2_0 + (\theta/xy)x_0y_0 + (\theta/x'y)x'_0\,y_0$$
$$+ (\theta/xy')x_0y'_0 + (\theta/x'y')x'_0\,y'_0 + (\theta/yy)y_0^2 + (\theta/yy')y_0y'_0 + (\theta/y'y')y'^2_0$$

x_1	%	x'_1	%	y_1	%	y'_1	%	$(x,x',y,y',\delta,l)_0$
0.82648	24	2.26816	5.8	0	0	0	0	100000
1.668E-06	0	1.20995	108	0	0	0	0	010000
0	0	0	0	-0.85078	9.2	-1.258137	3.8	001000
0	0	0	0	9.100E-02	35	-1.040819	110	000100
-1.3220	0	-0.84624	0	0	0	0	0	200000
-2.0211	-2	-1.6758	0.1	0	0	0	0	110000
-0.94047	33	-1.1015	3.4	0	0	0	0	020000
0	0	0	0	1.96766	0	-3.98394	0	101000
0	0	0	0	3.85987	1.5	-3.84397	0.4	011000
0	0	0	0	5.16242	2	5.65309	0.6	100100
0	0	0	0	5.34891	71	3.59906	13	010100
-3.35827	0	-5.66803	0	0	0	0	0	002000
-3.03125	3	-6.27946	0.6	0	0	0	0	001100
-2.43596	86	-3.12330	9.8	0	0	0	0	000200

Initial conditions

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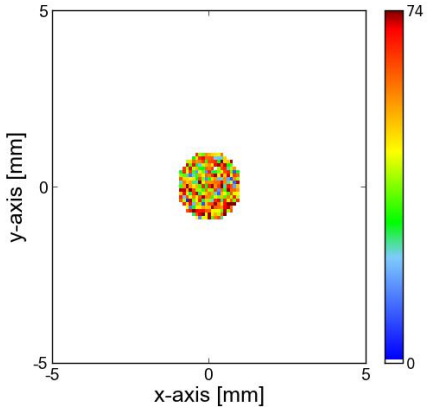
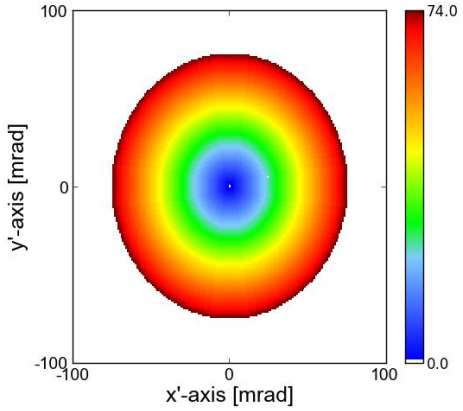
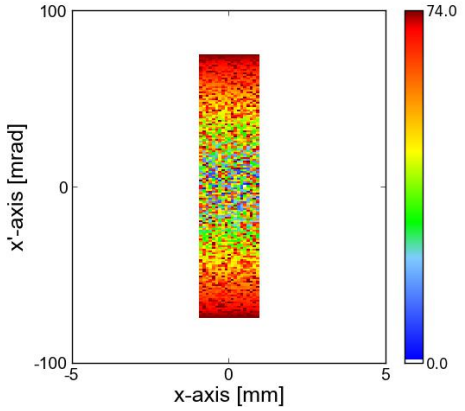
simulations







- Object in origin ϕ 2mm;
- Max angle = 74 mrad;
- $\Delta p/p = 0$;
- $\Delta l/l = 0$

ε = 296 mm.mrad

Result of the simulations versus measurements

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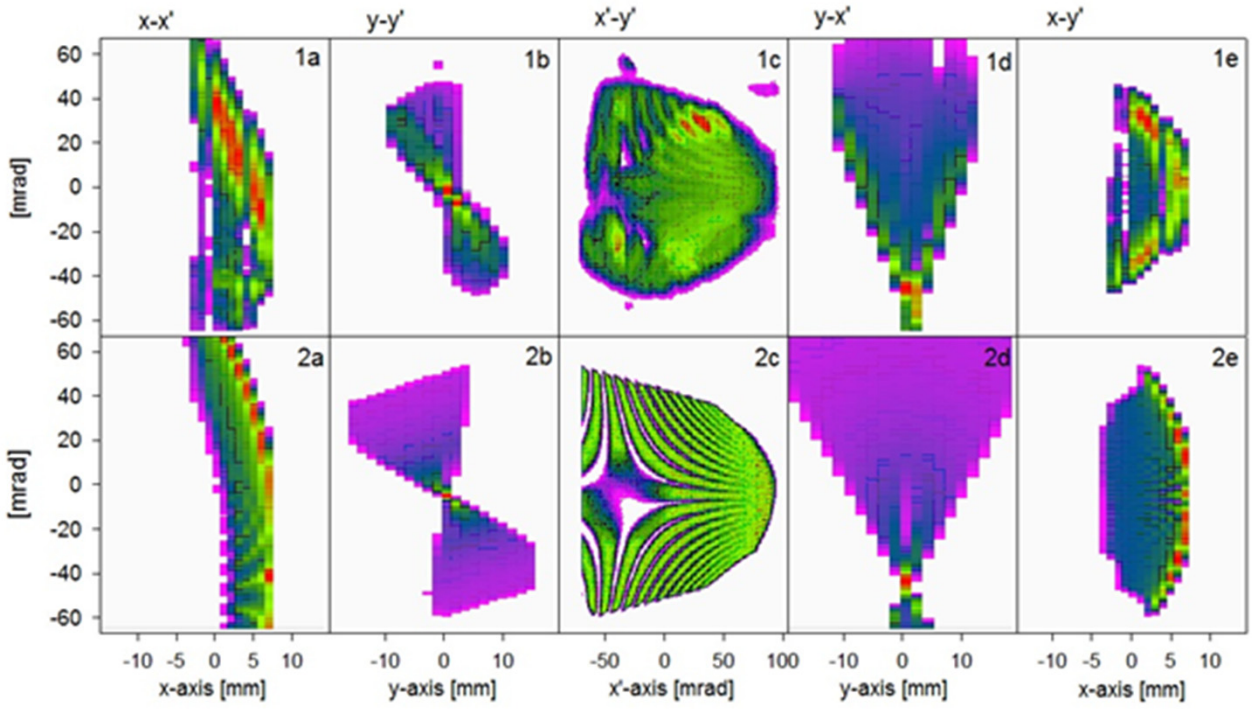

measurement

simulated

Six projections in the image plane of the dipole magnet

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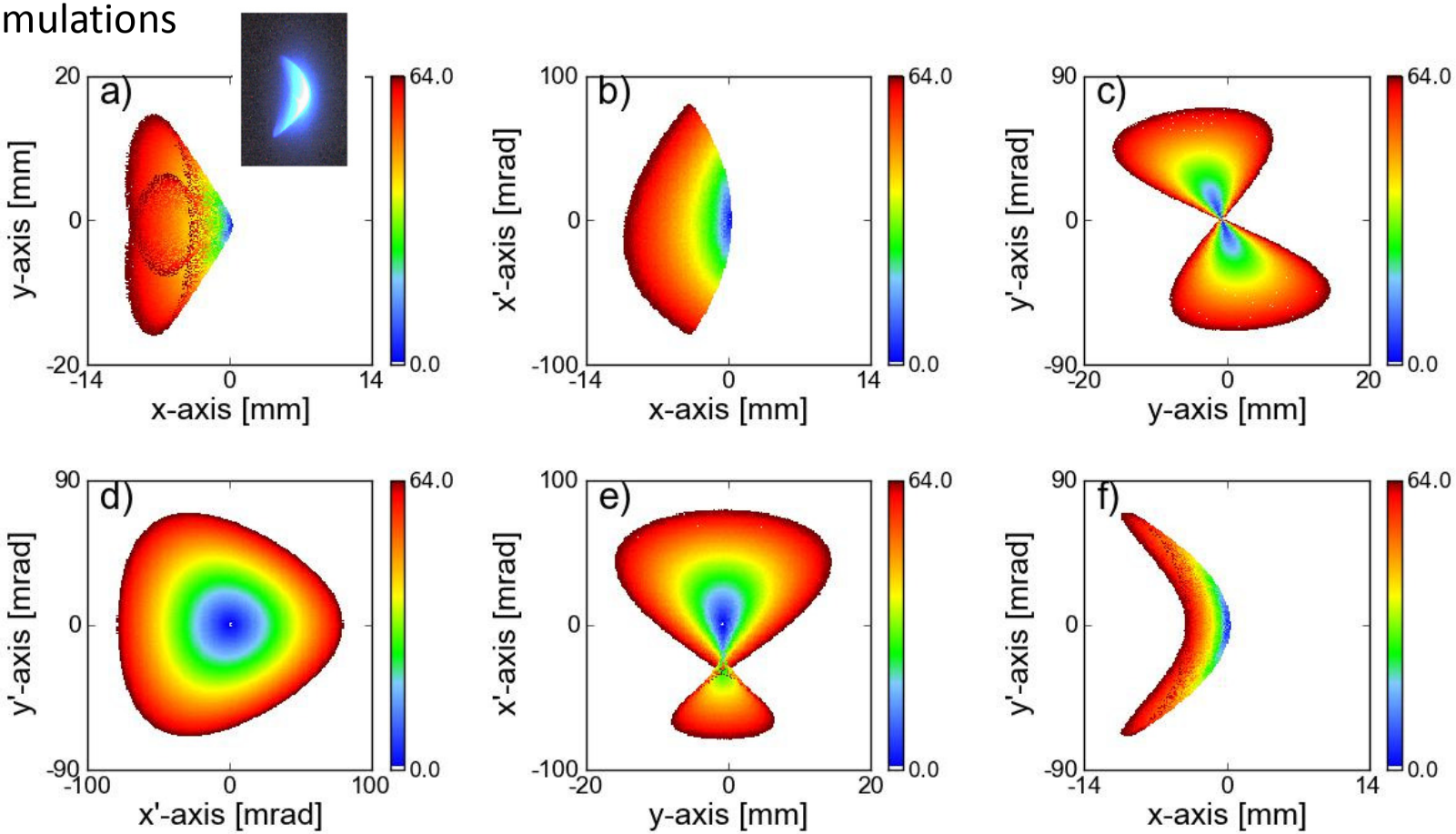
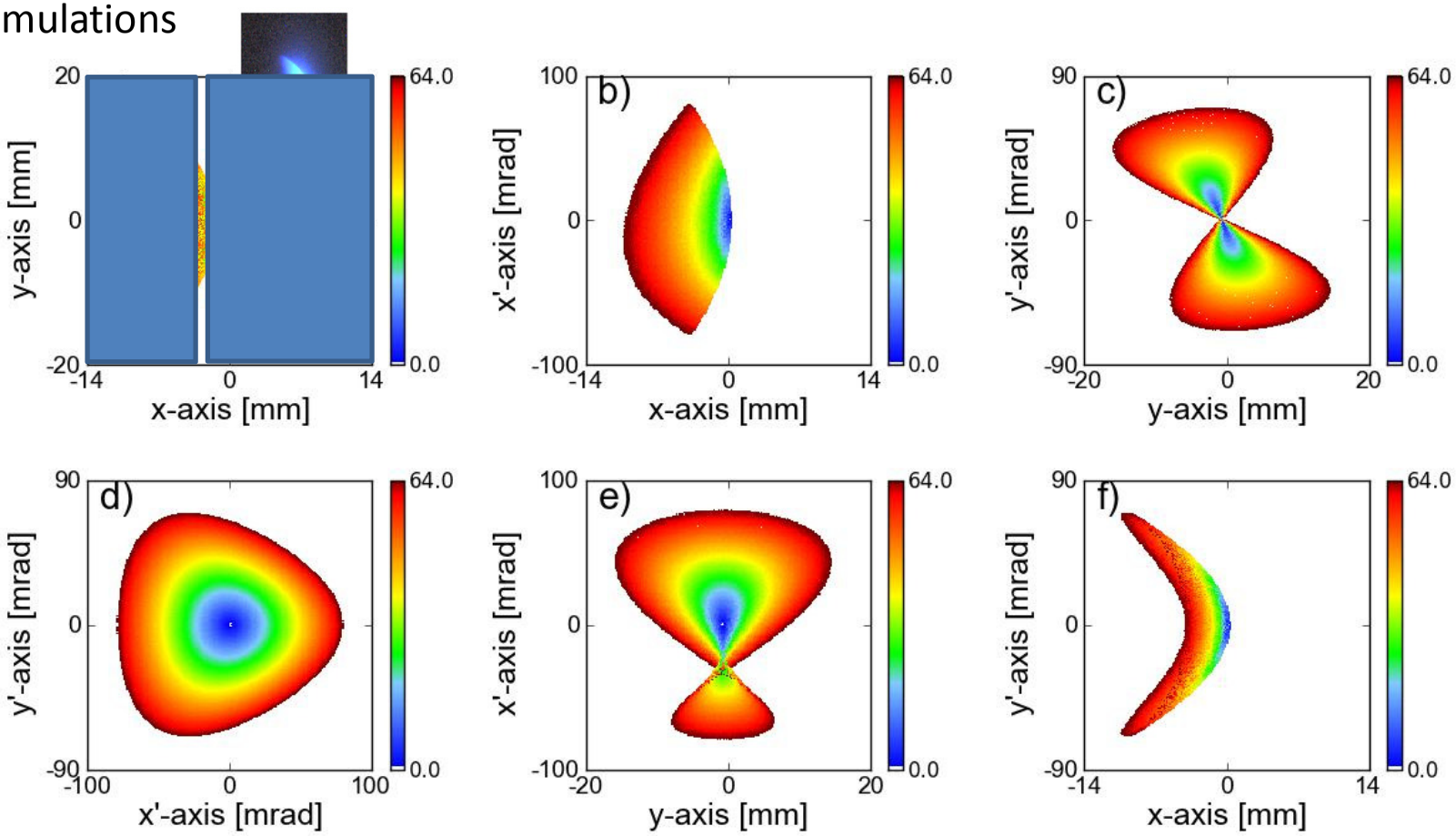
simulations



Six projections in the image plane of the dipole magnet

rijksuniversiteit groningen

simulations



Sliced projection (slit in image plane on x = -2.75 mm)

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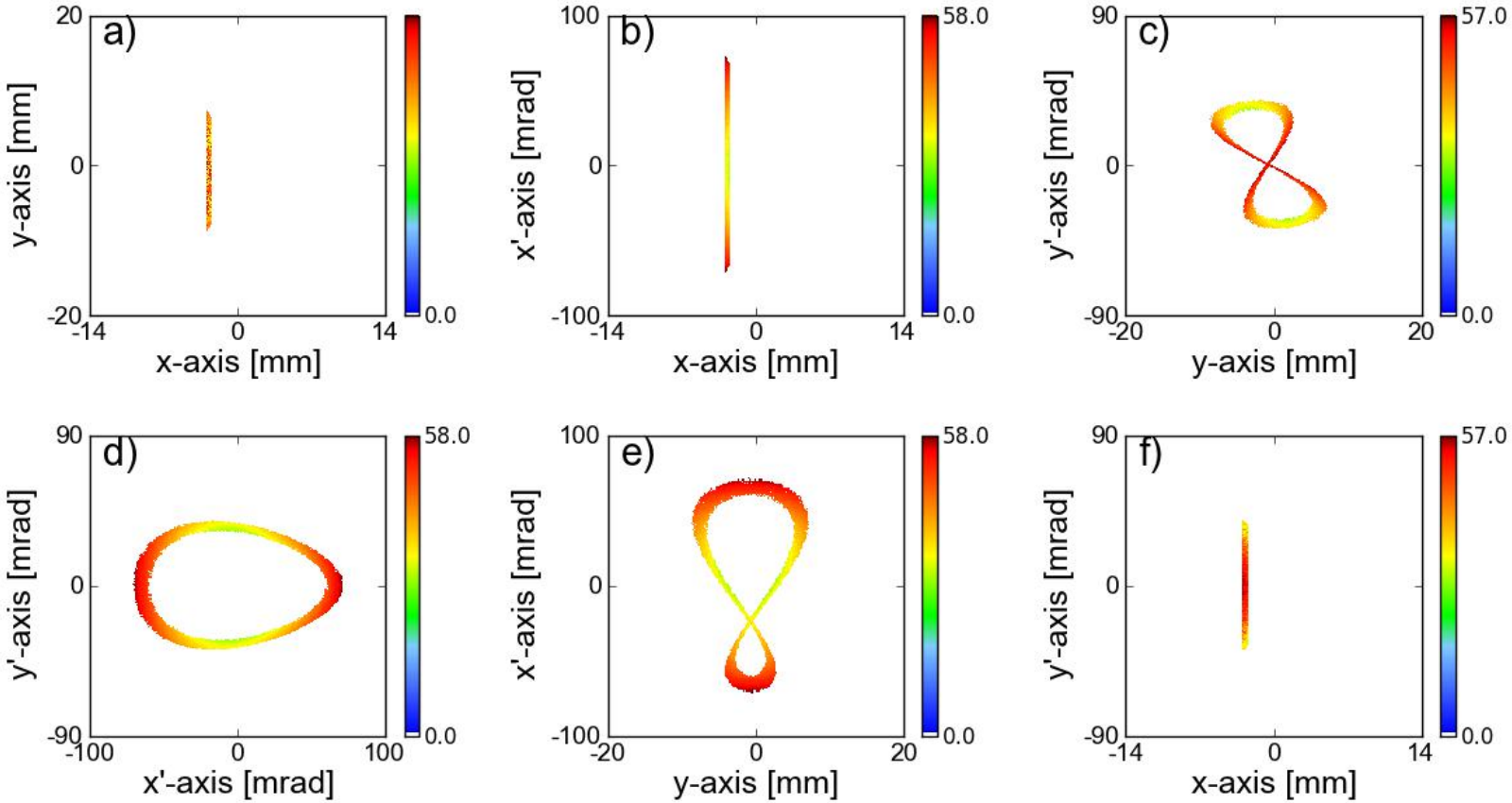
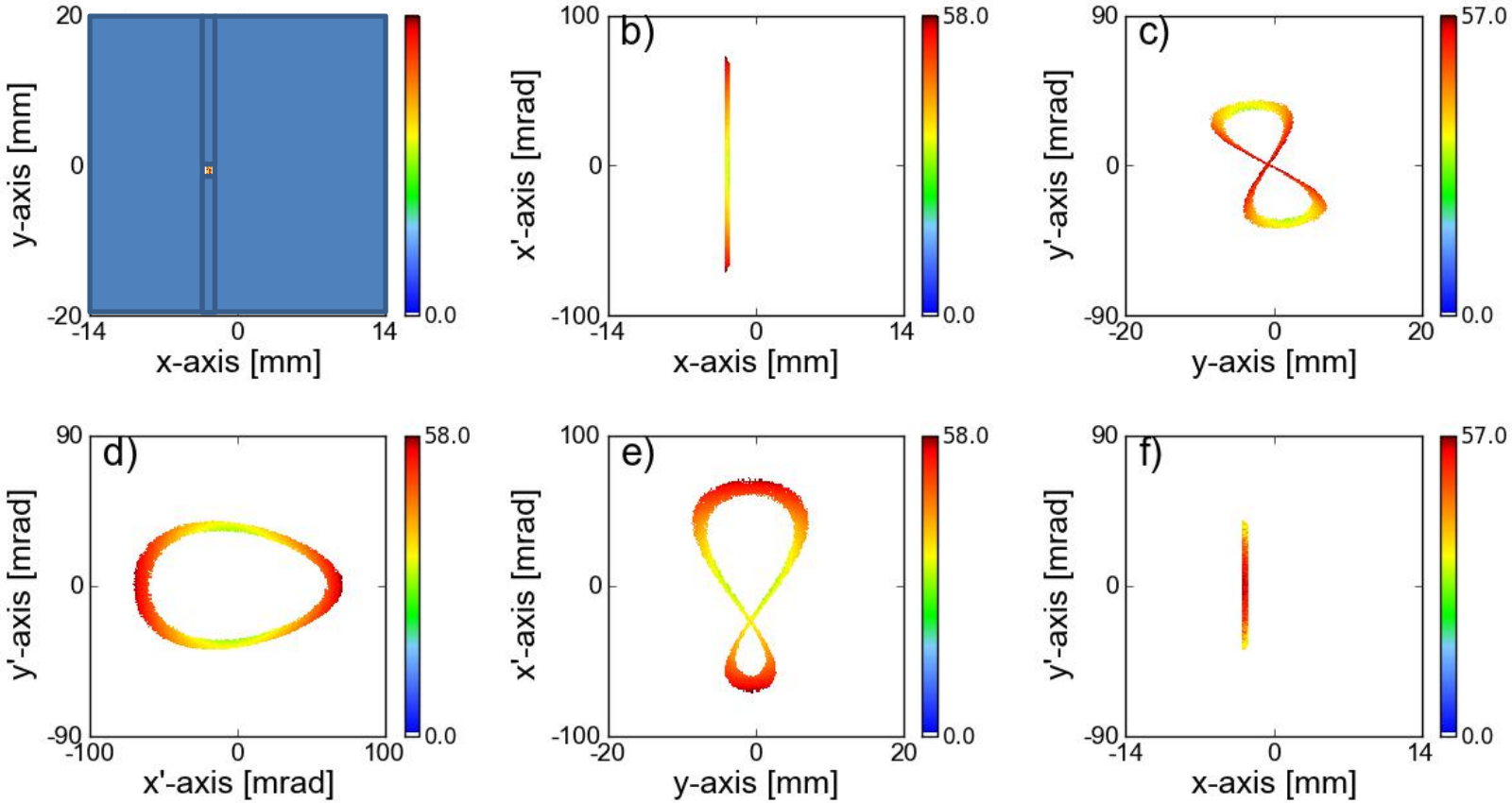
simulations



Sliced projection (slit in image plane on x = -2.75 mm)

rijksuniversiteit groningen

simulations



Sliced projection (one aperture x = -2.75 mm)

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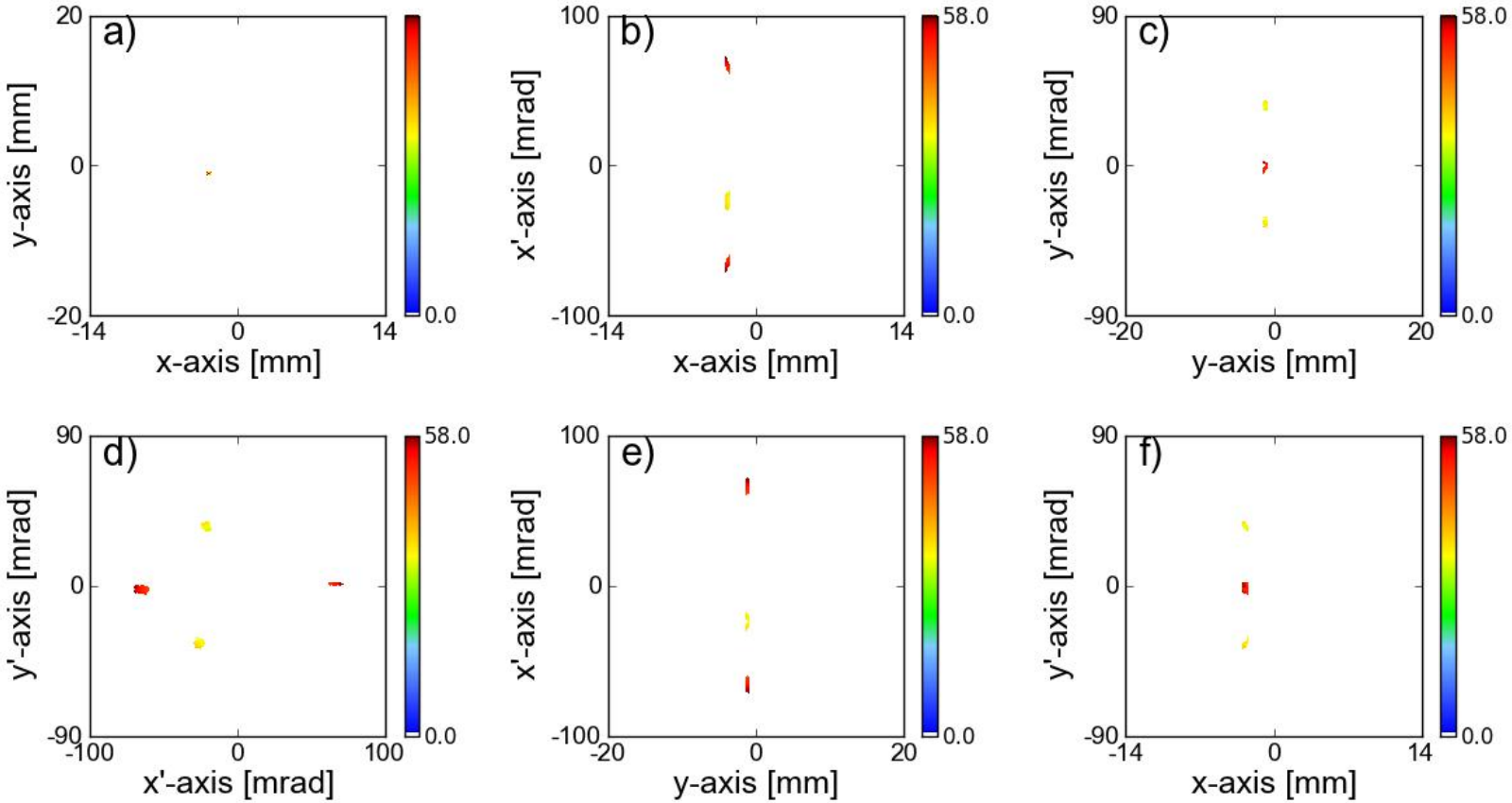
simulations



Sliced projection (array of 10 holes at x= -3.25 mm)

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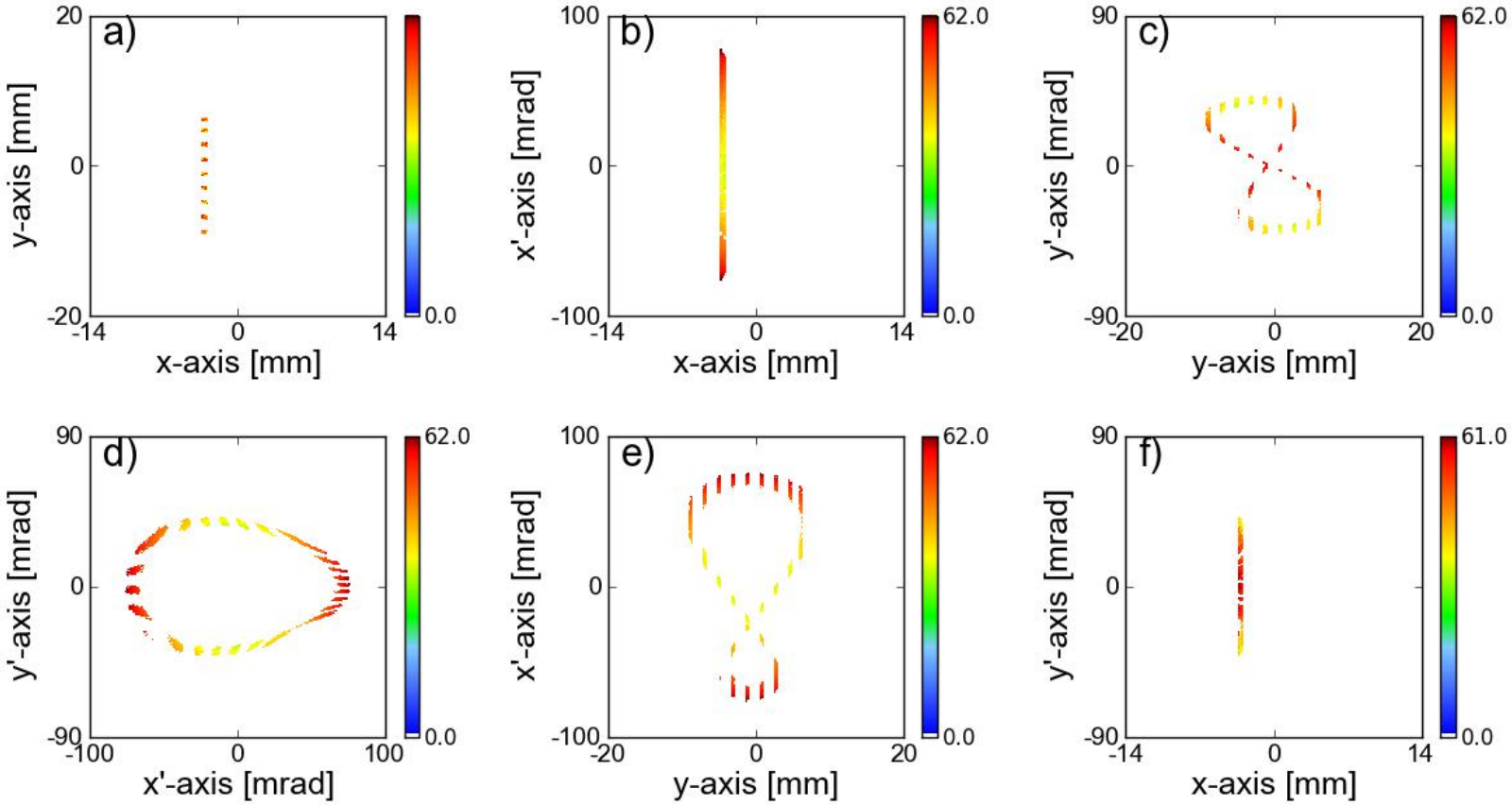
simulations



Sliced projection (array of 10 holes at x= -4.25 mm)

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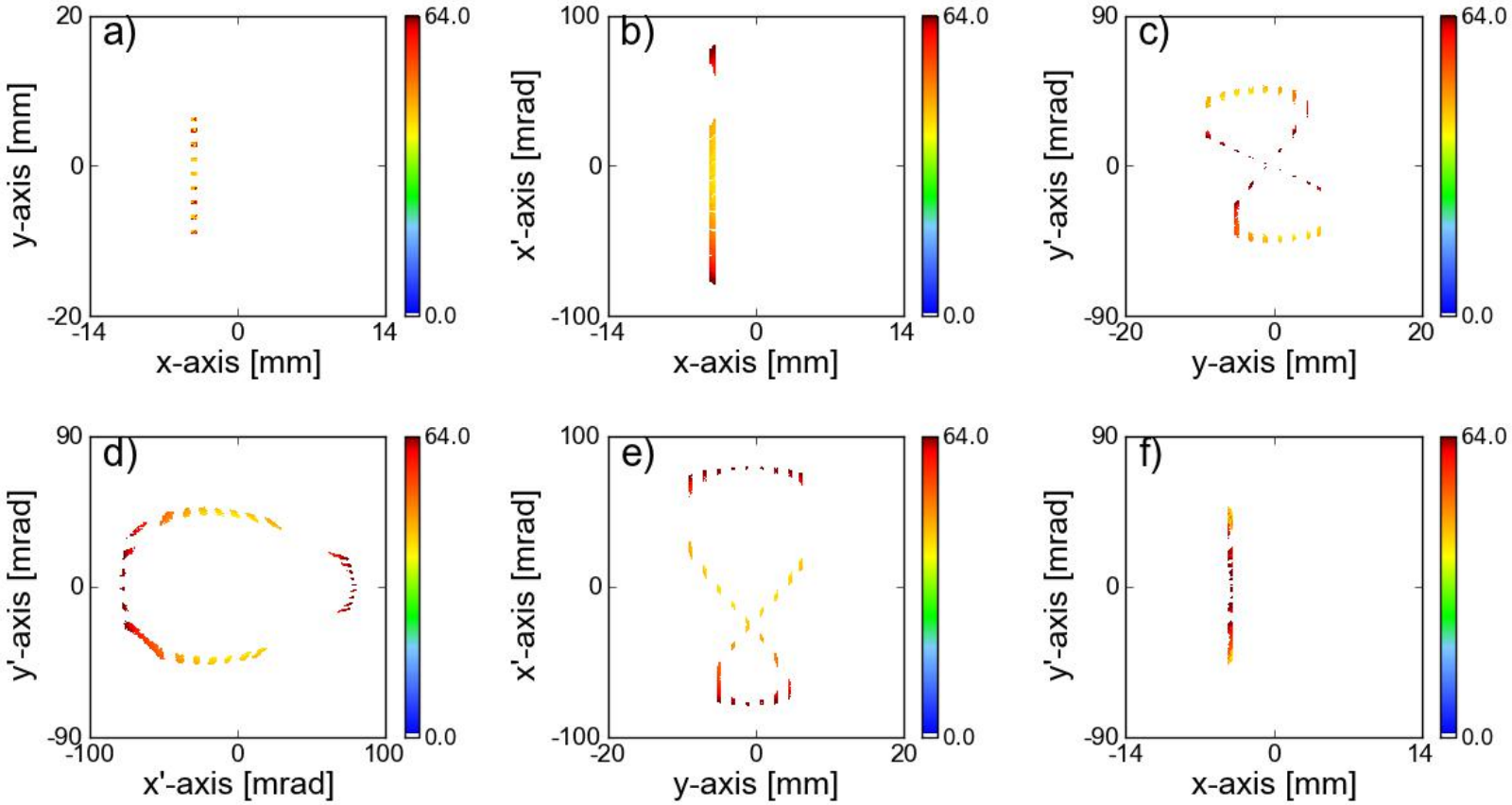
simulations



Sliced projection (array of 10 holes at x= -3.25 mm)

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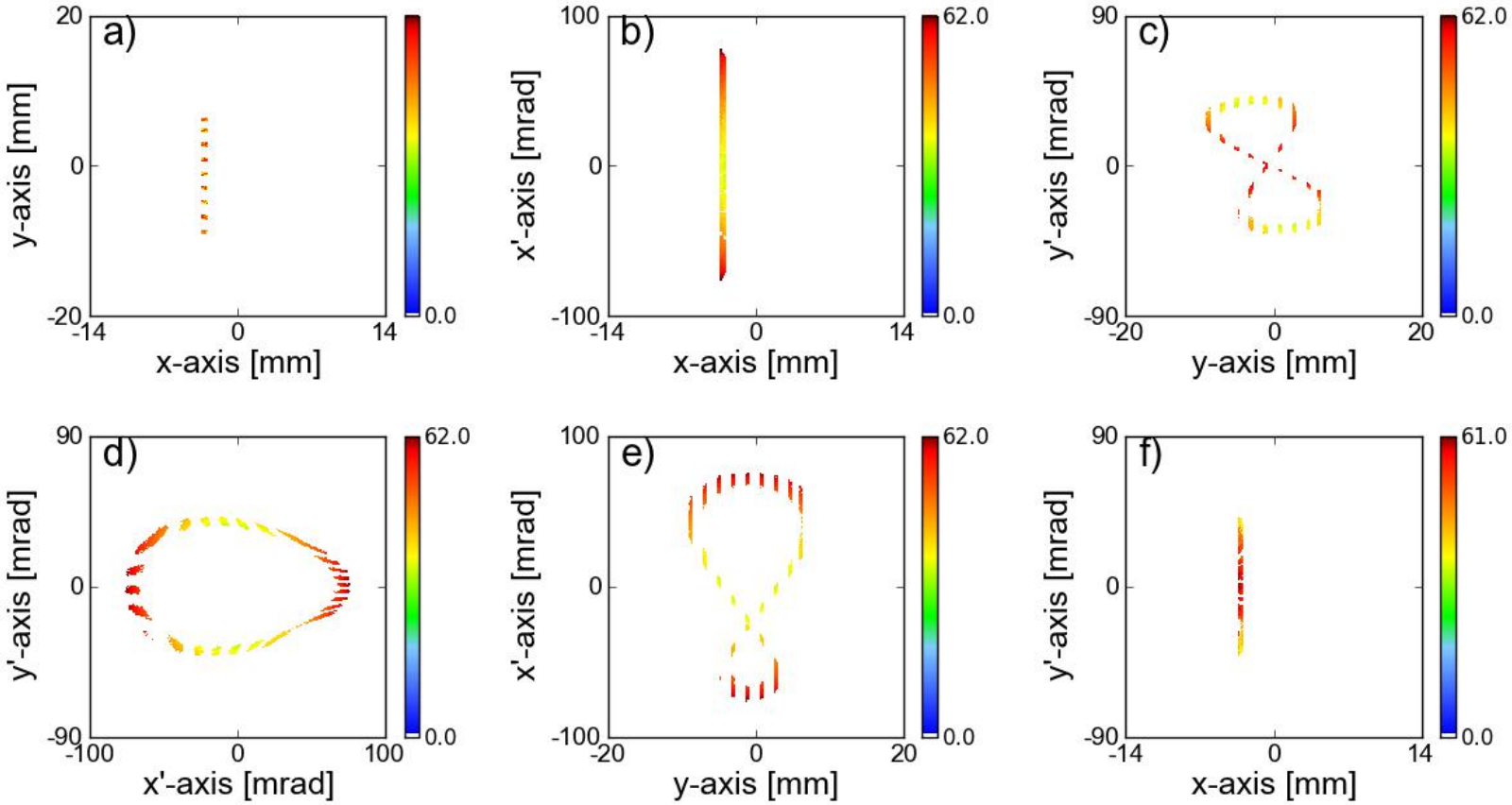
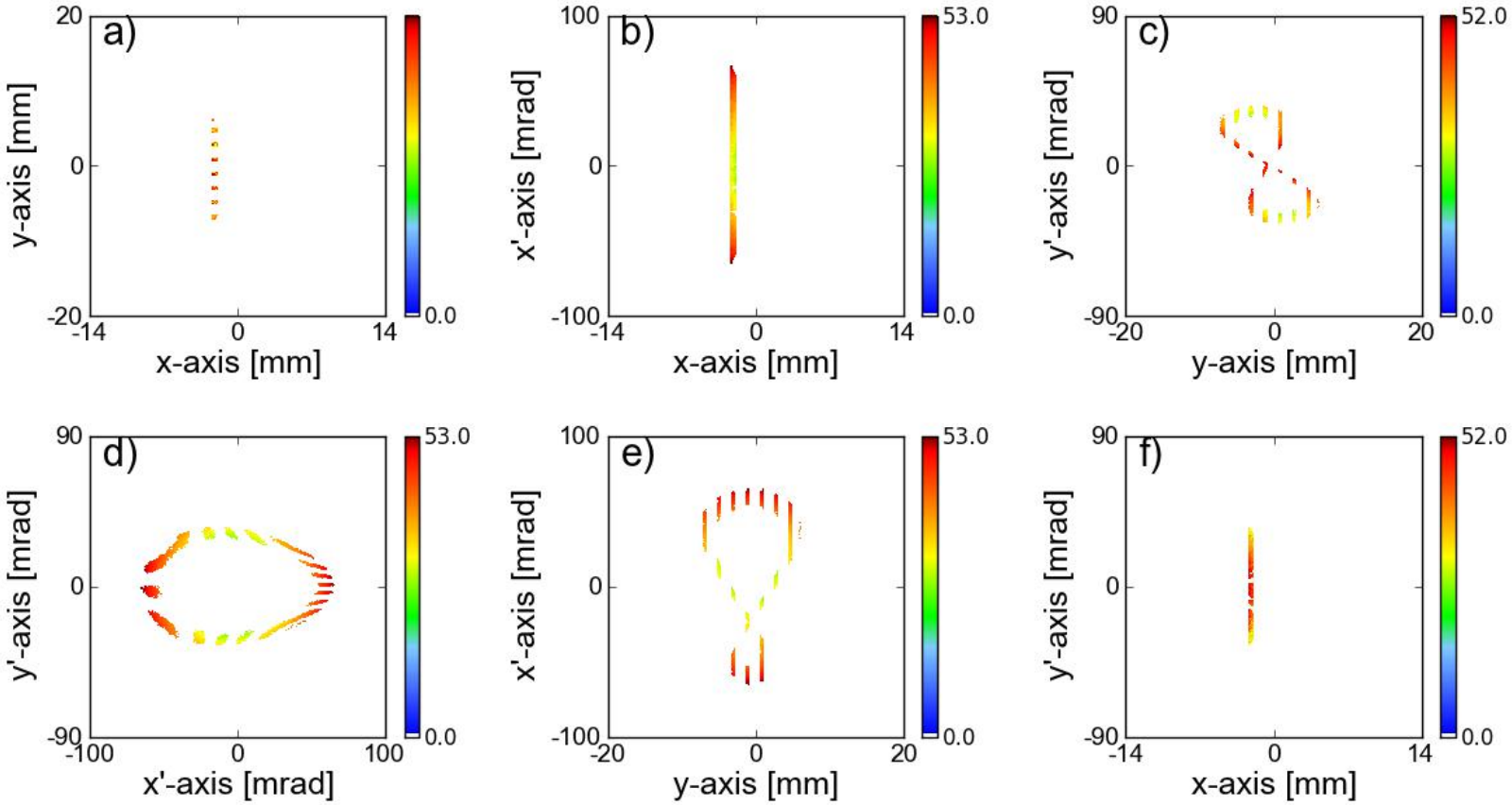
simulations



Sliced projection (array of 10 holes at x= -2.25 mm)

rijksuniversiteit groningen

simulations



Sliced projection (array of 10 holes at x= -1.25 mm)

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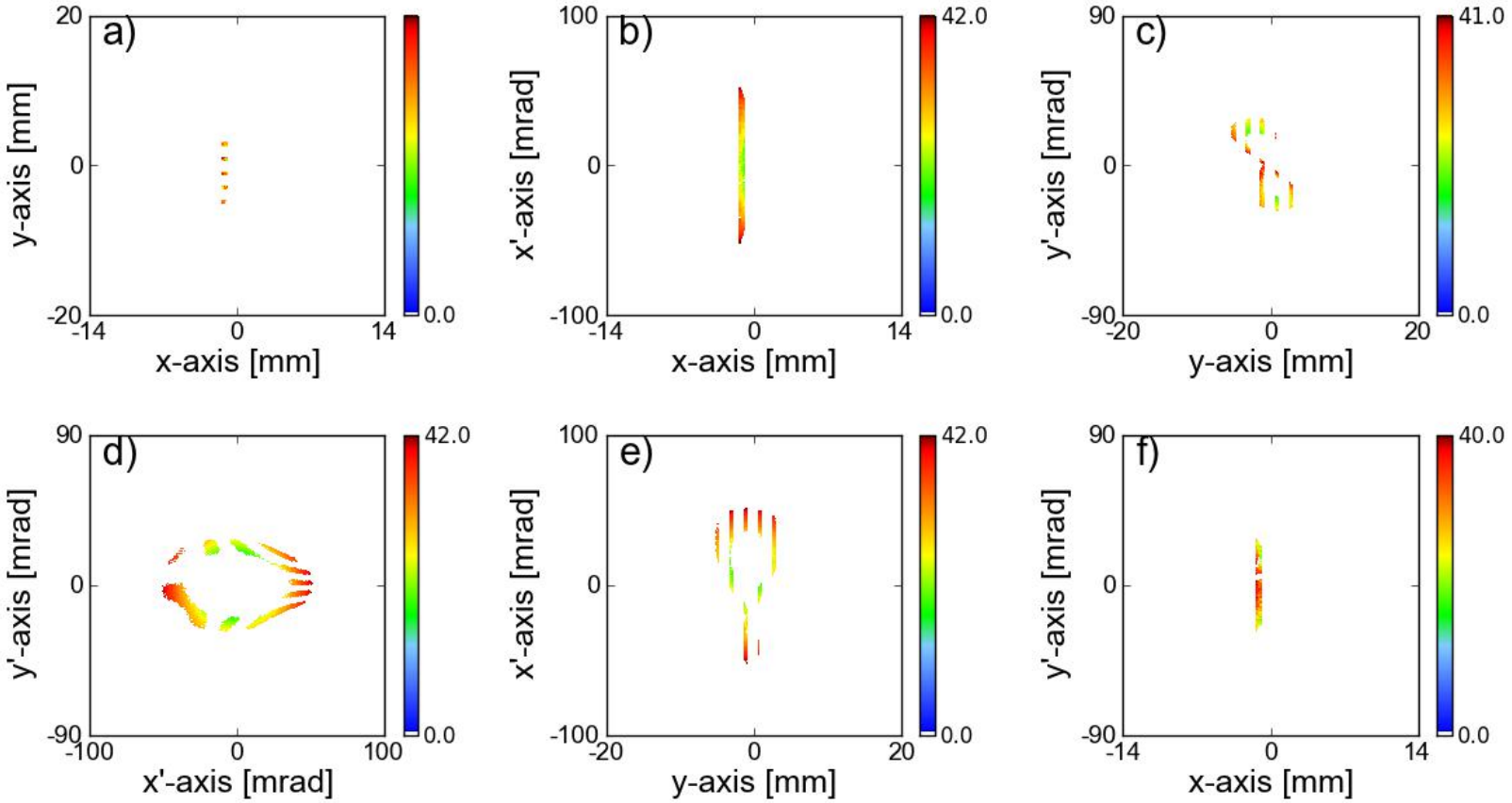
simulations



Sliced projection (array of 10 holes at x= -0.25 mm)

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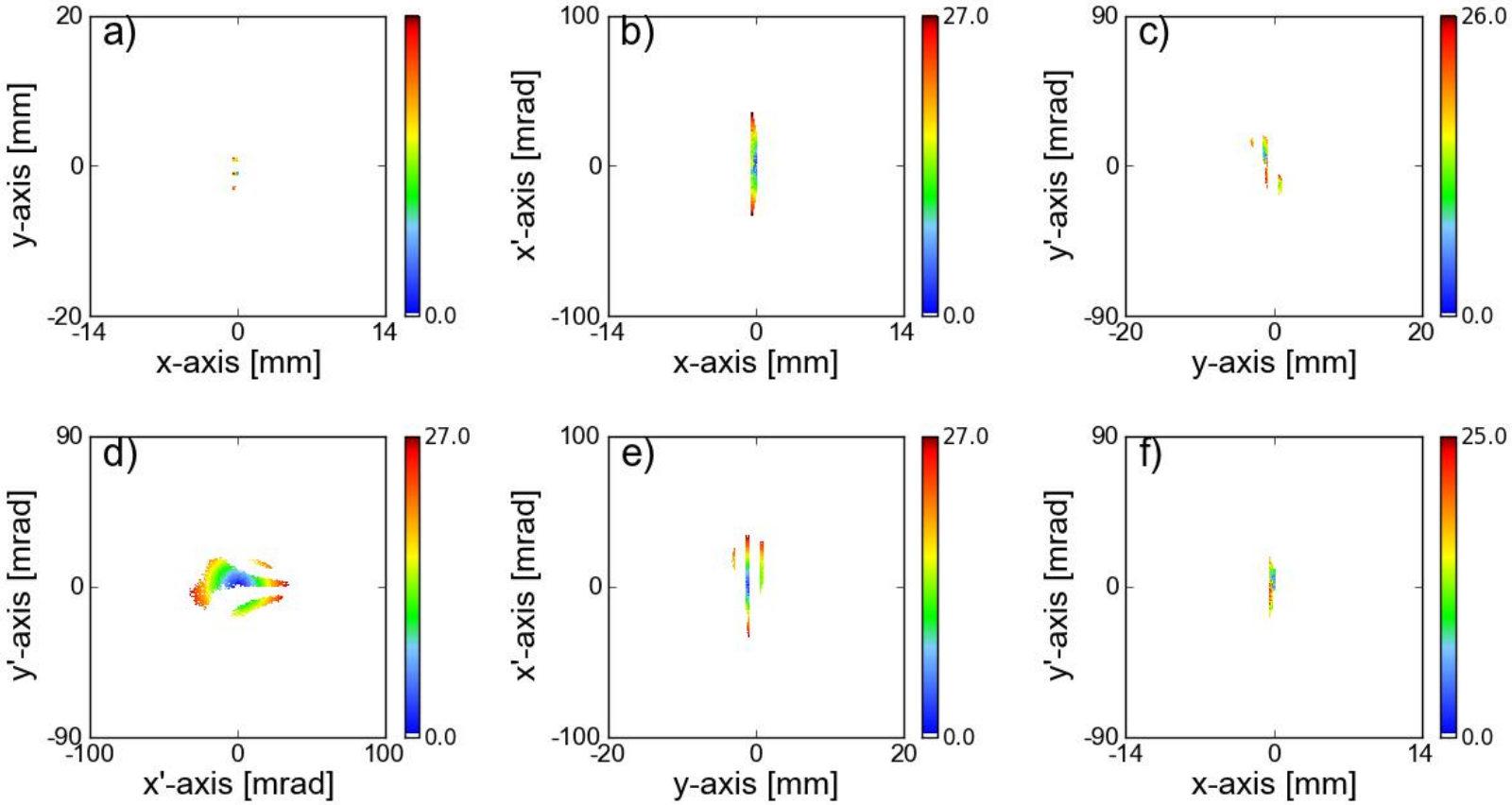
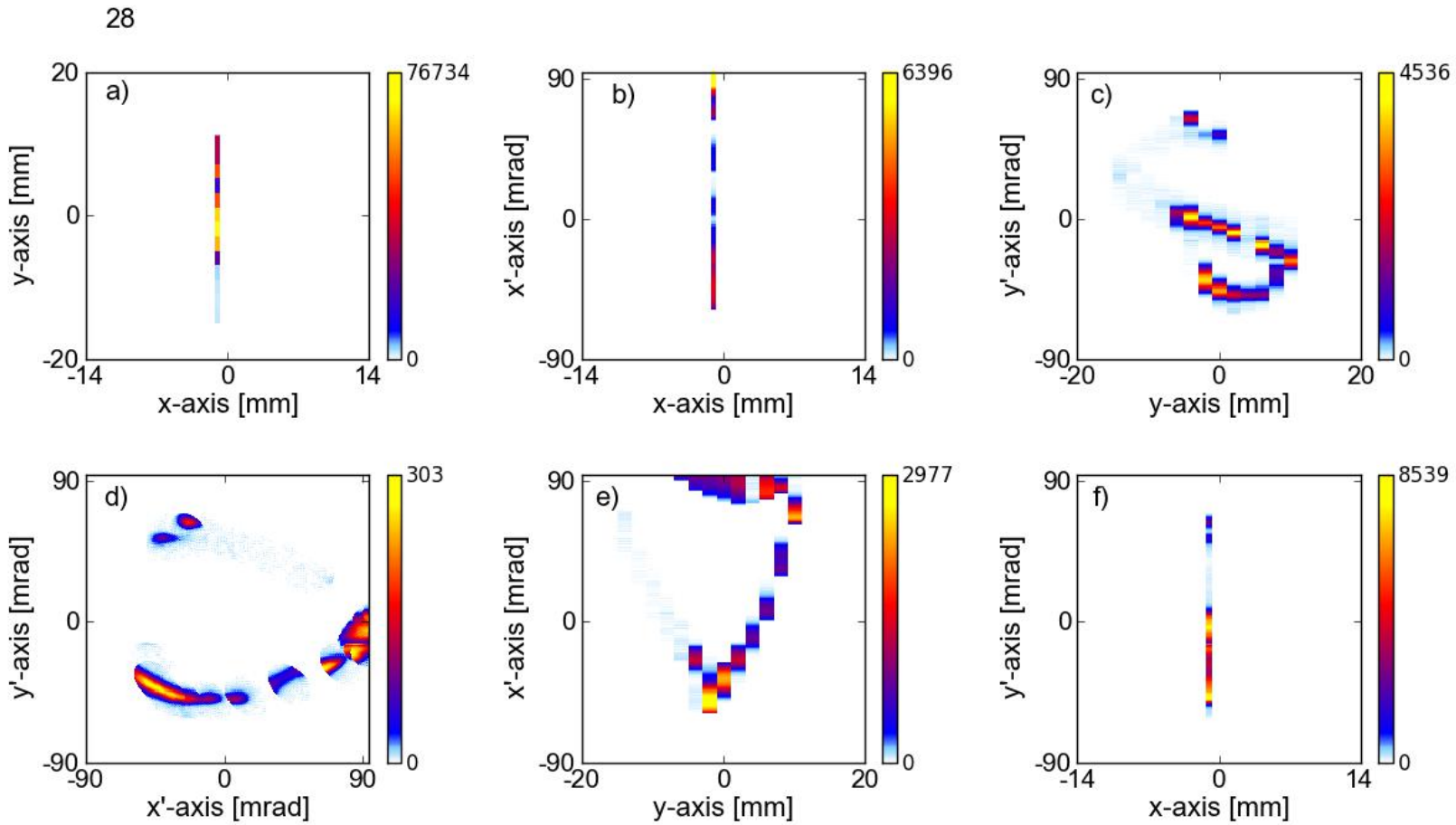
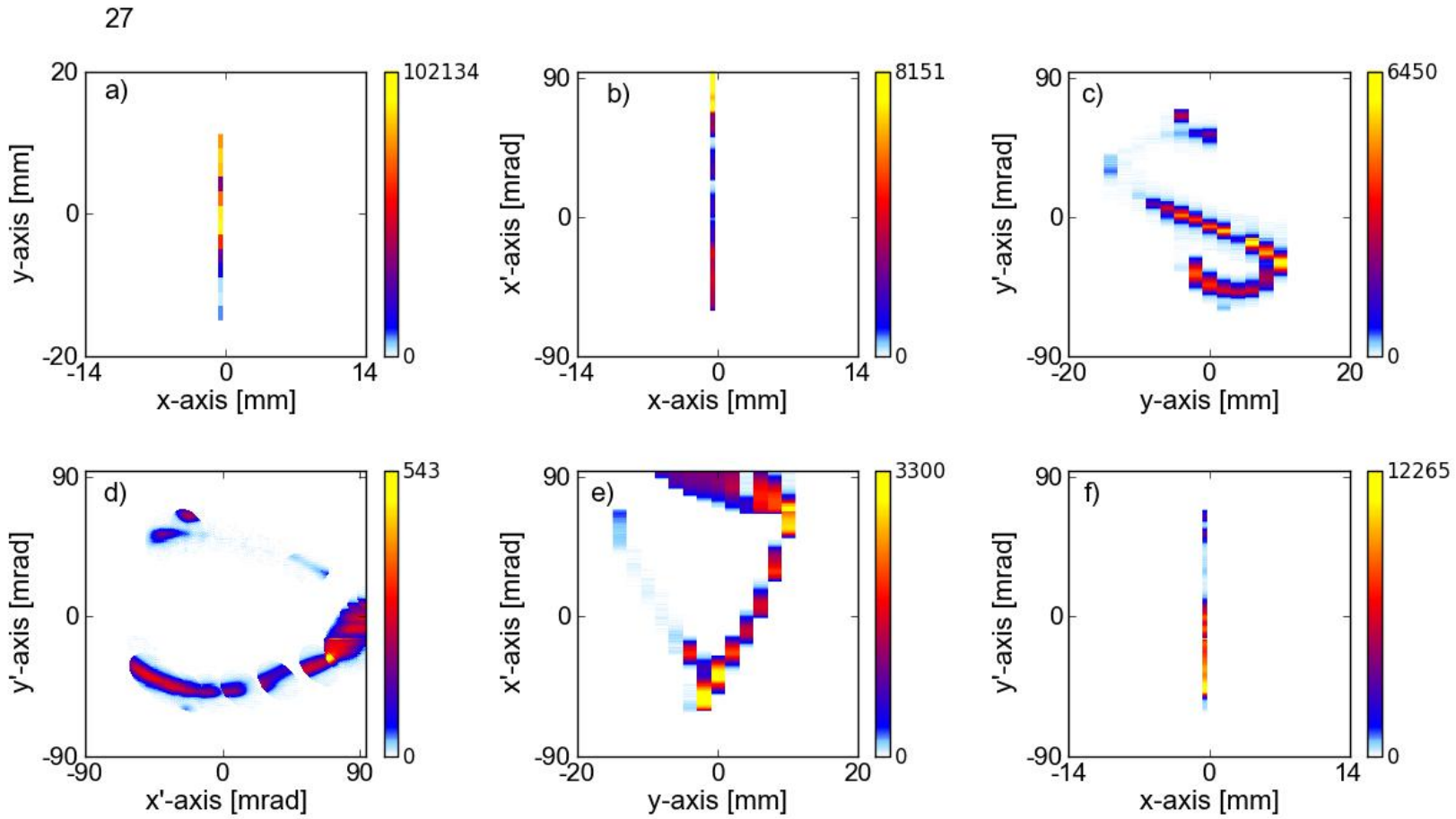
simulations



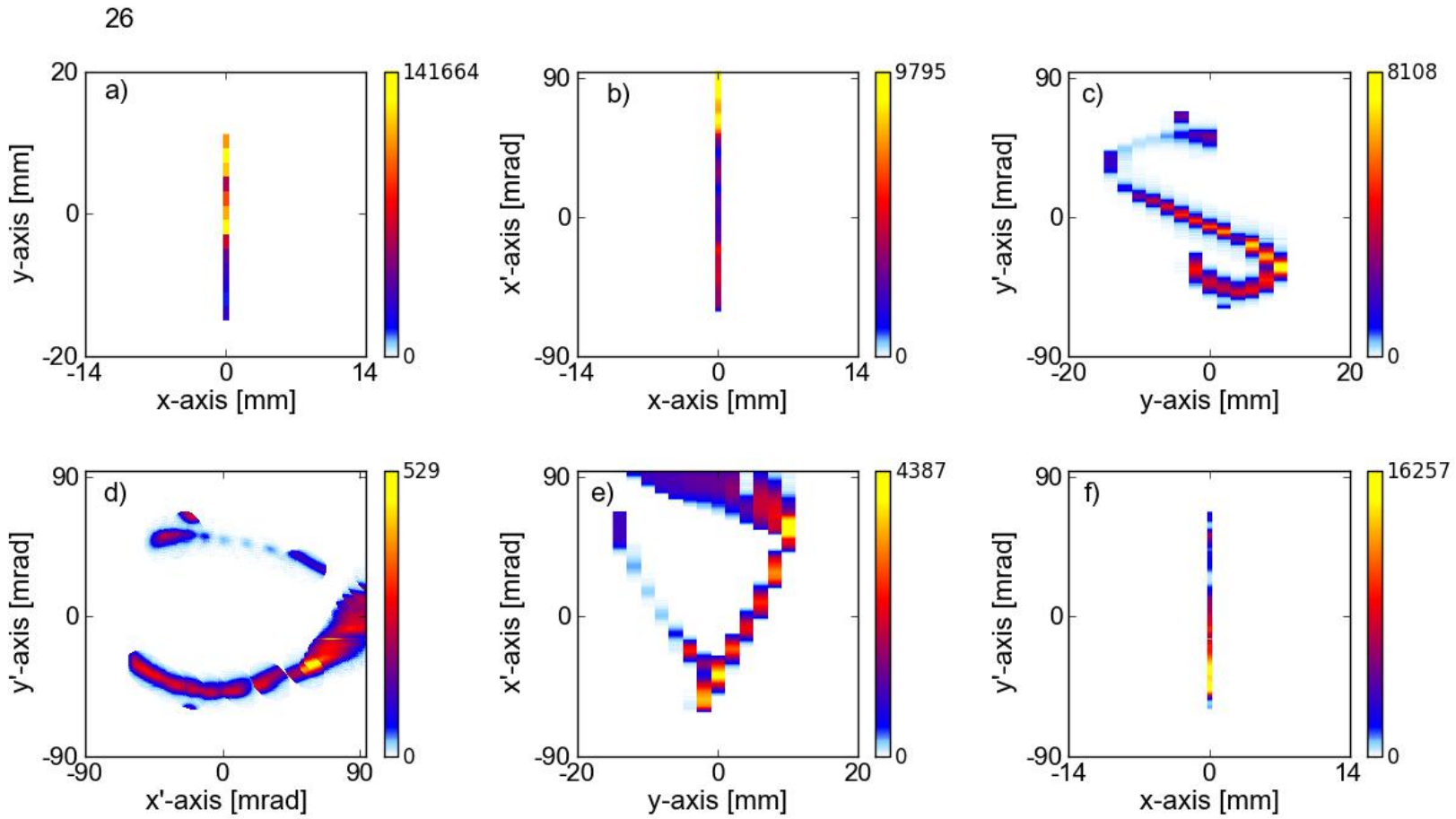
Sliced projection: measurements



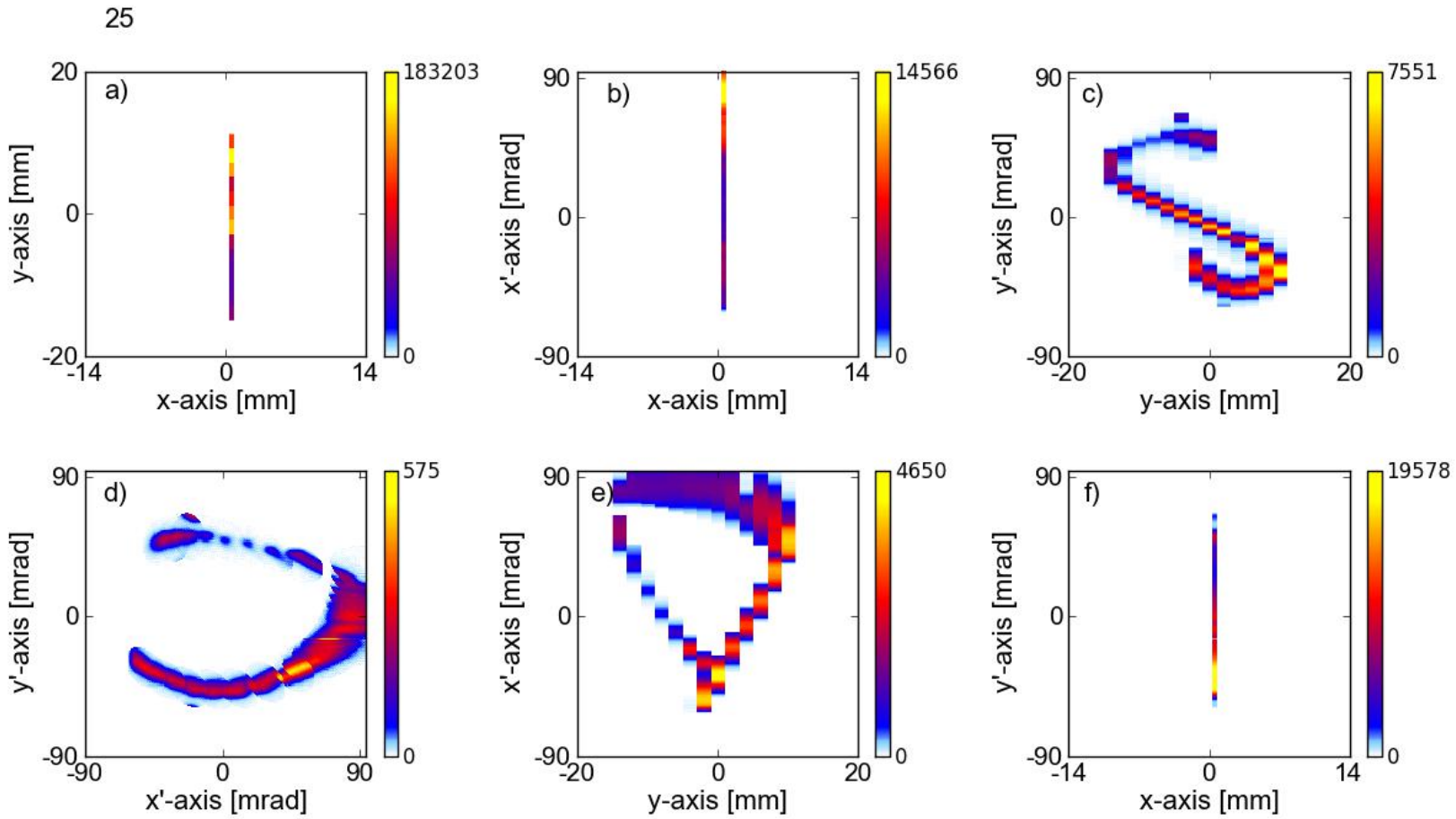
Sliced projection: measurements



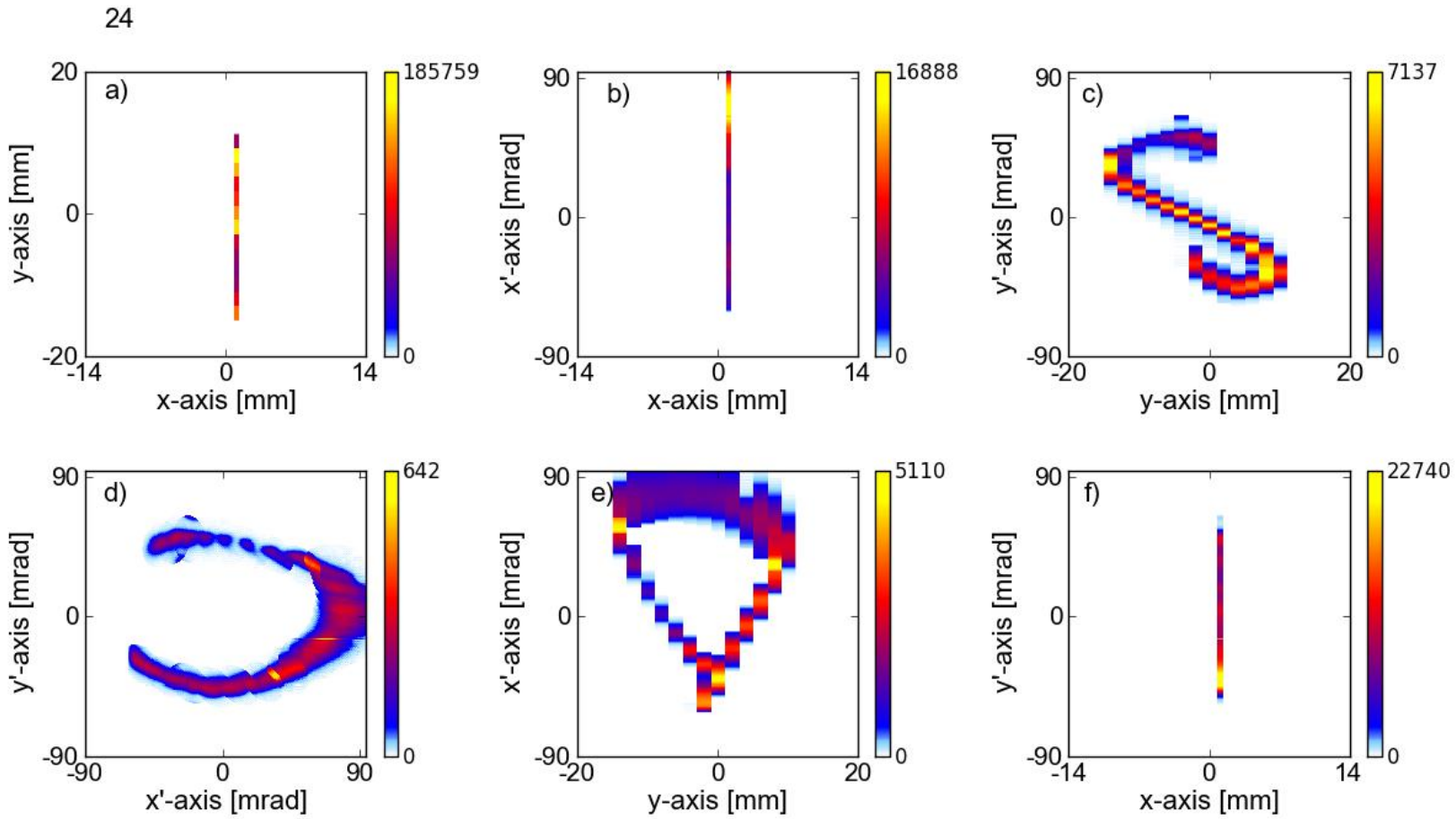
Sliced projection: measurements



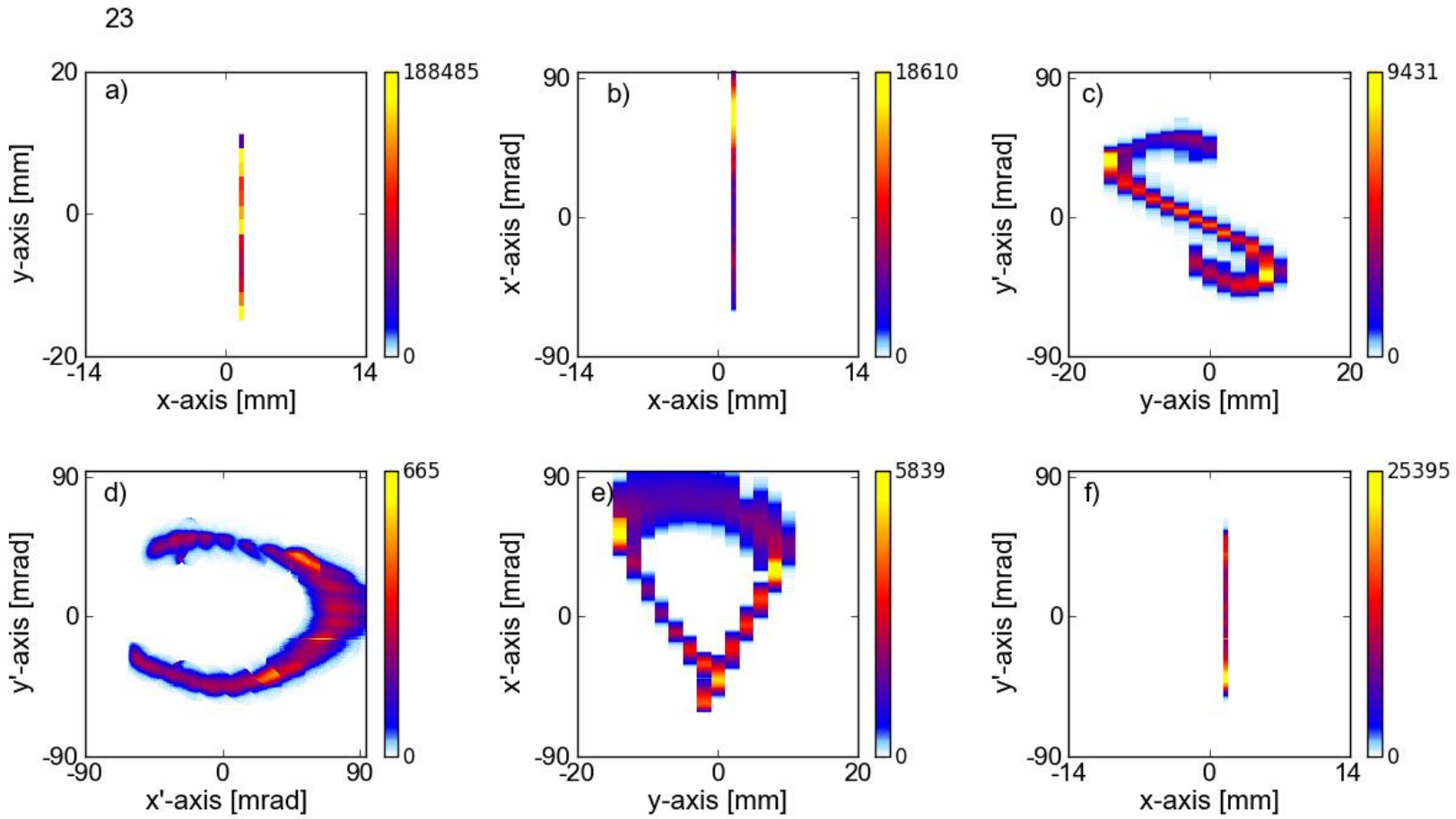
Sliced projection: measurements



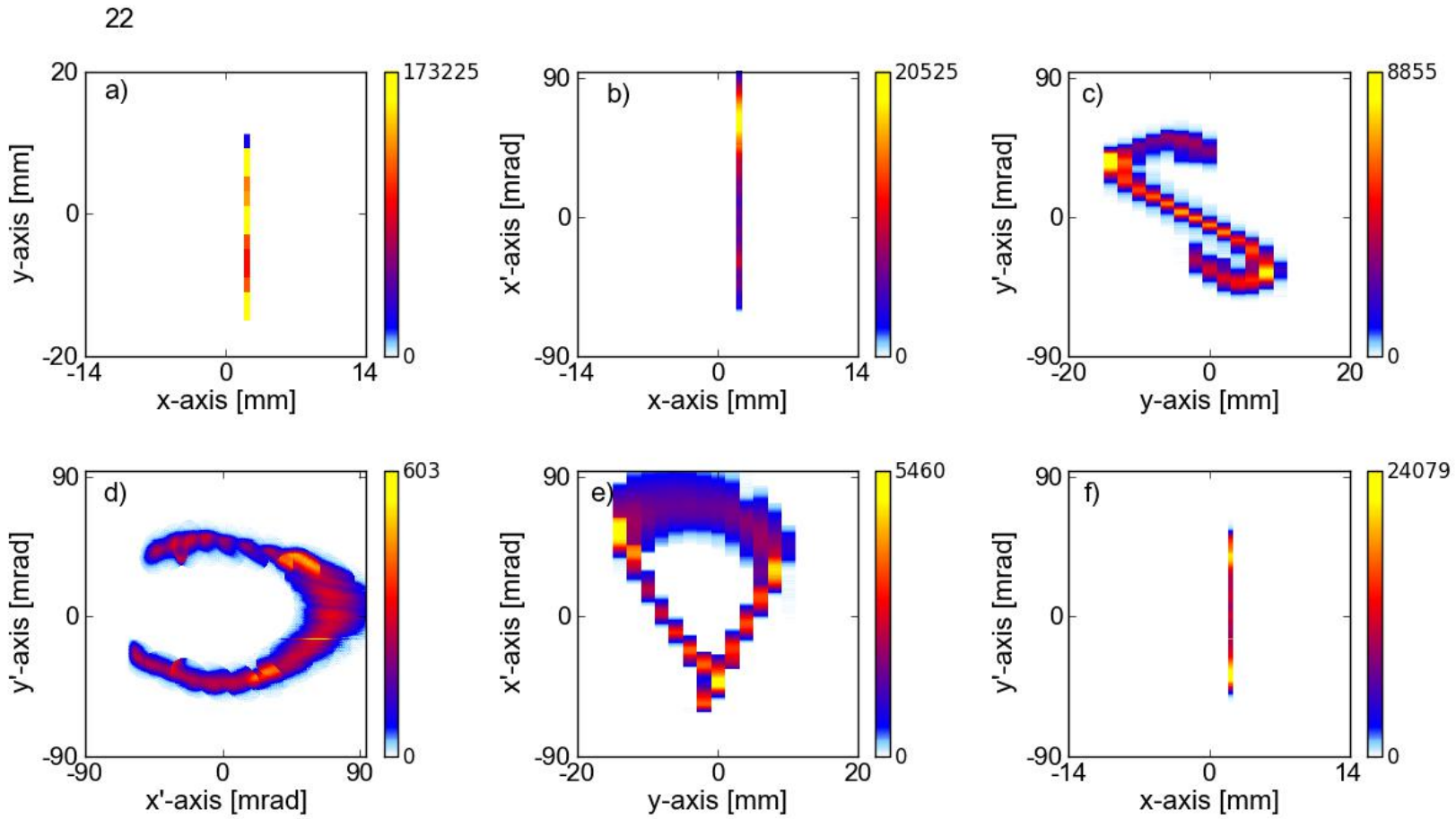
Sliced projection: measurements



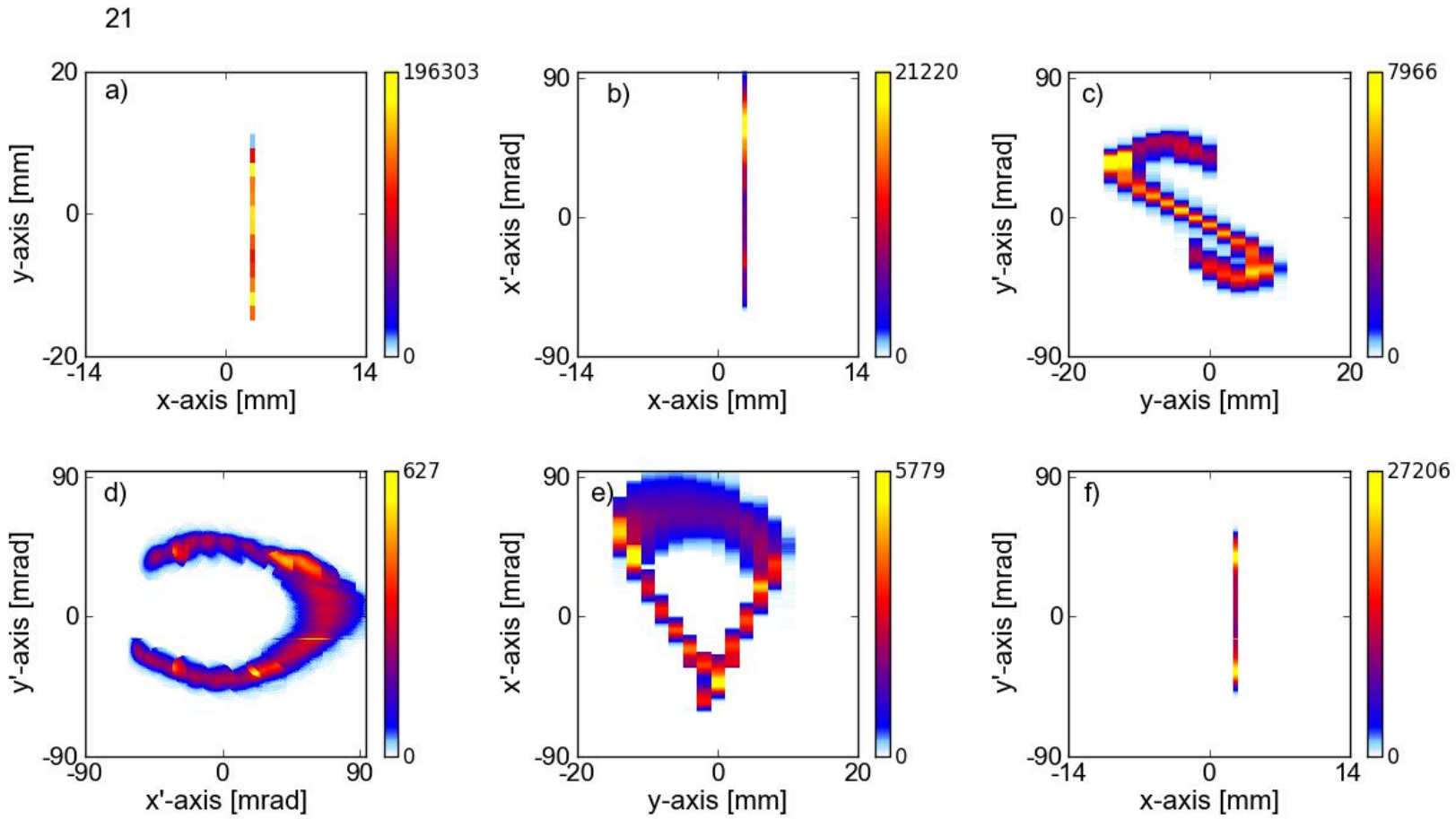
Sliced projection: measurements



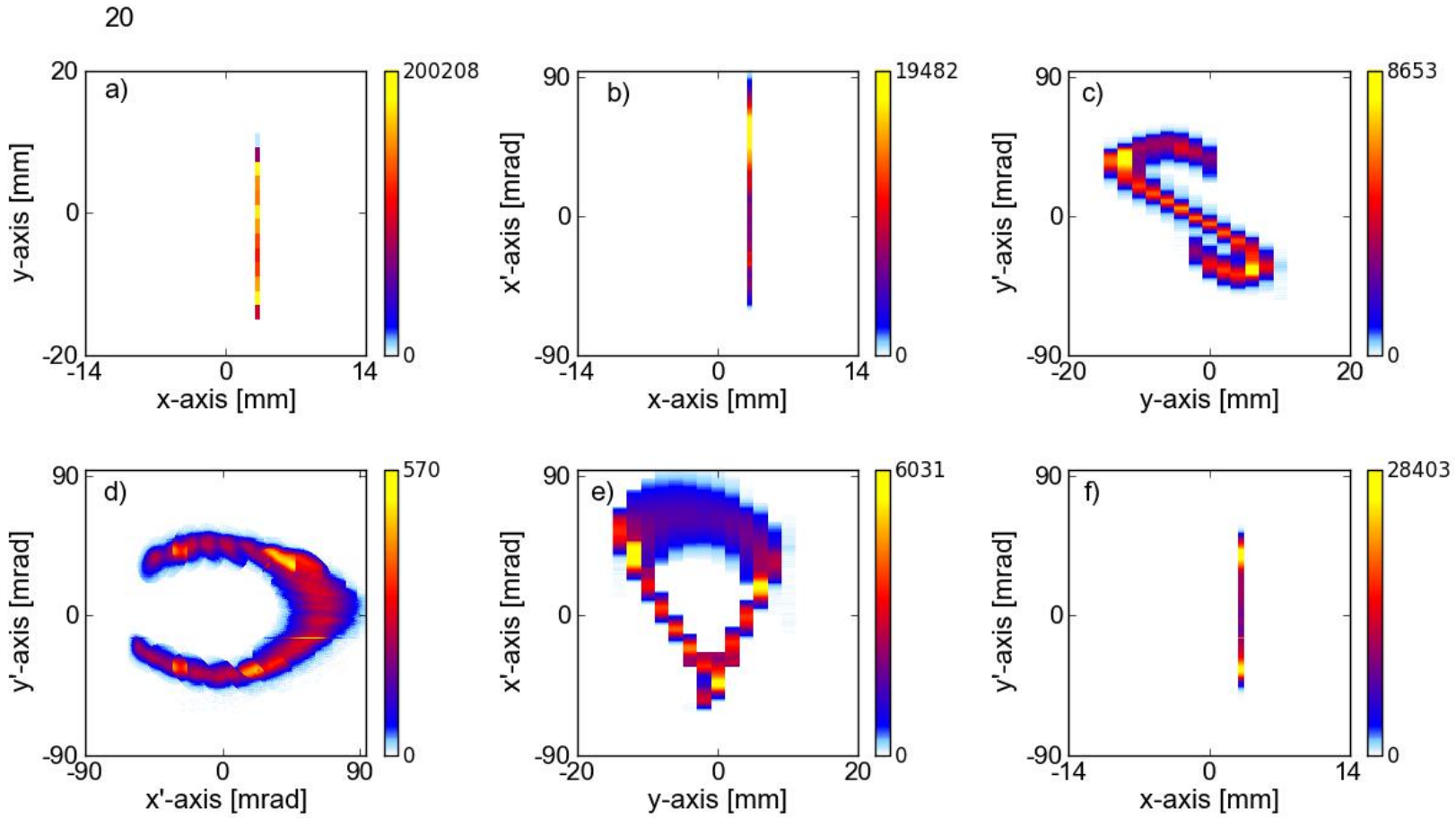
Sliced projection: measurements



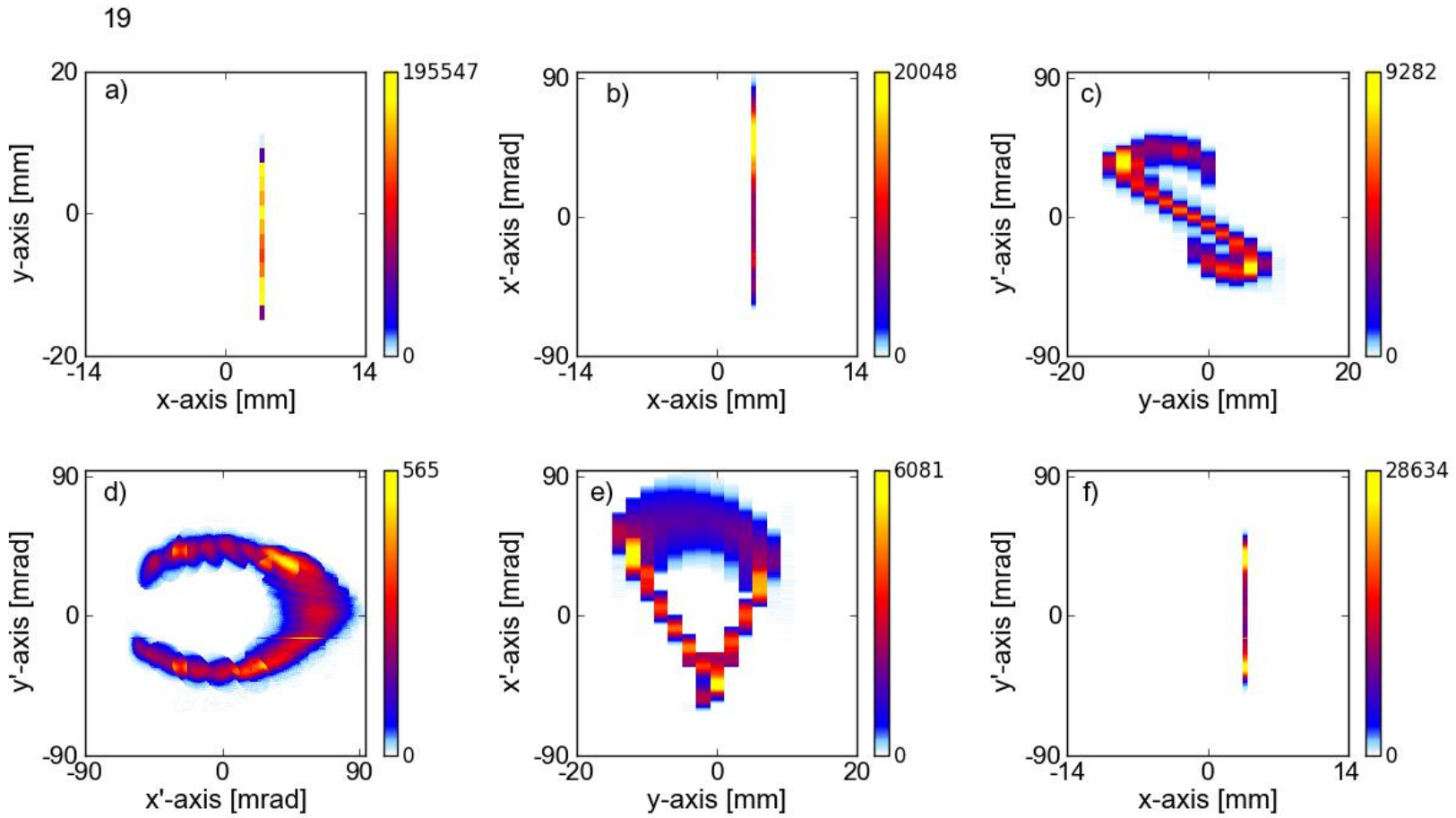
Sliced projection: measurements



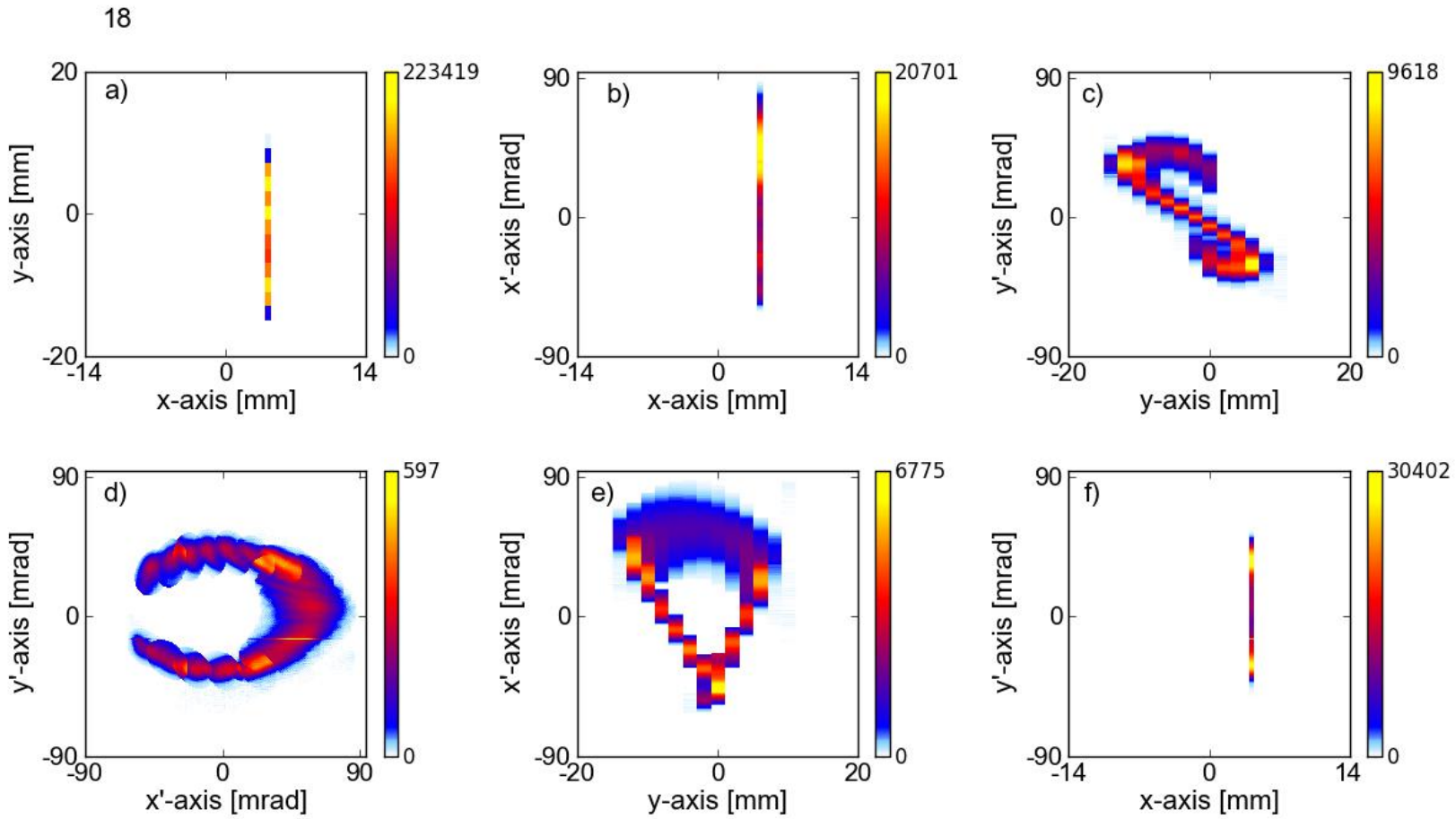
Sliced projection: measurements



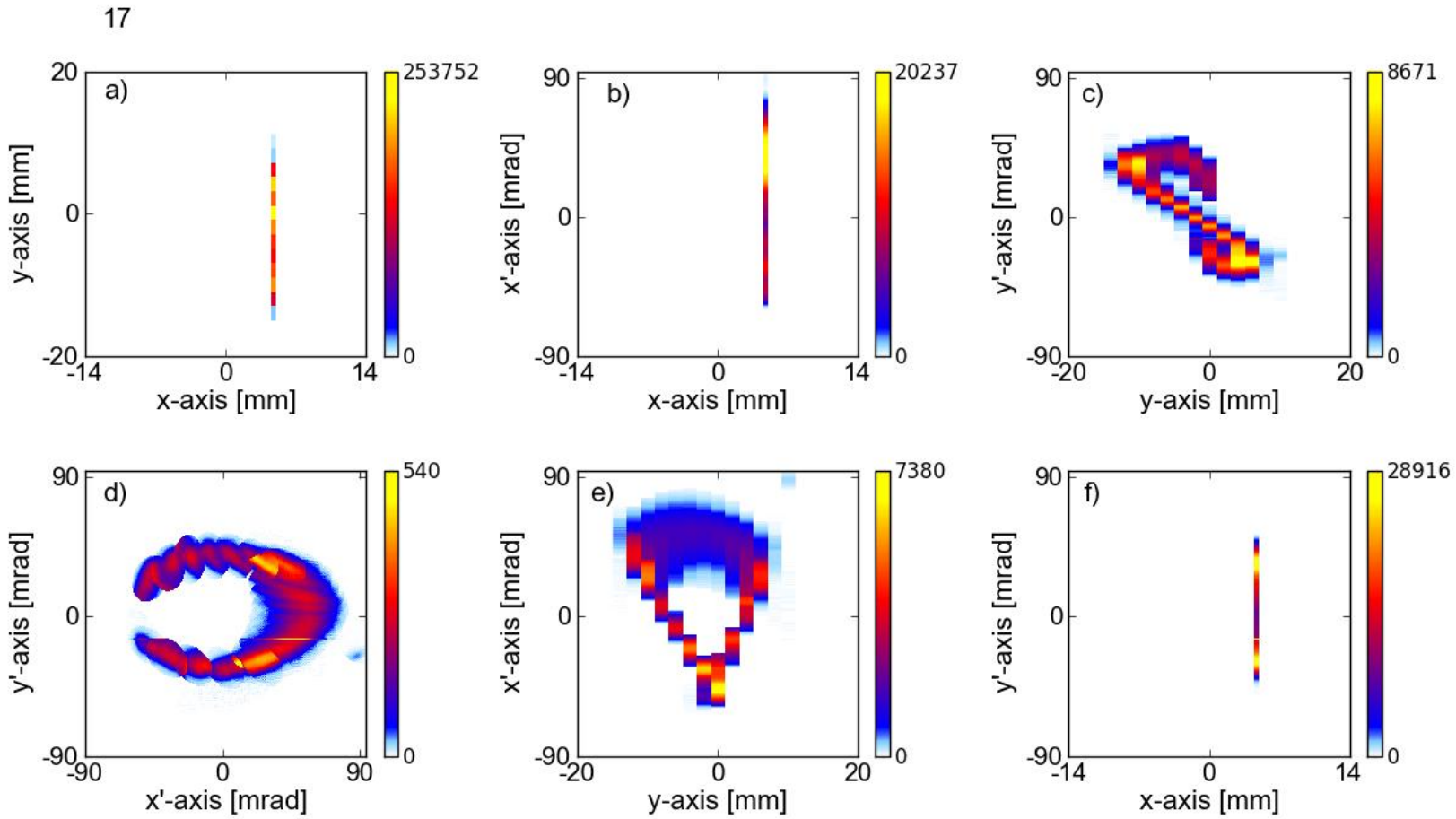
Sliced projection: measurements



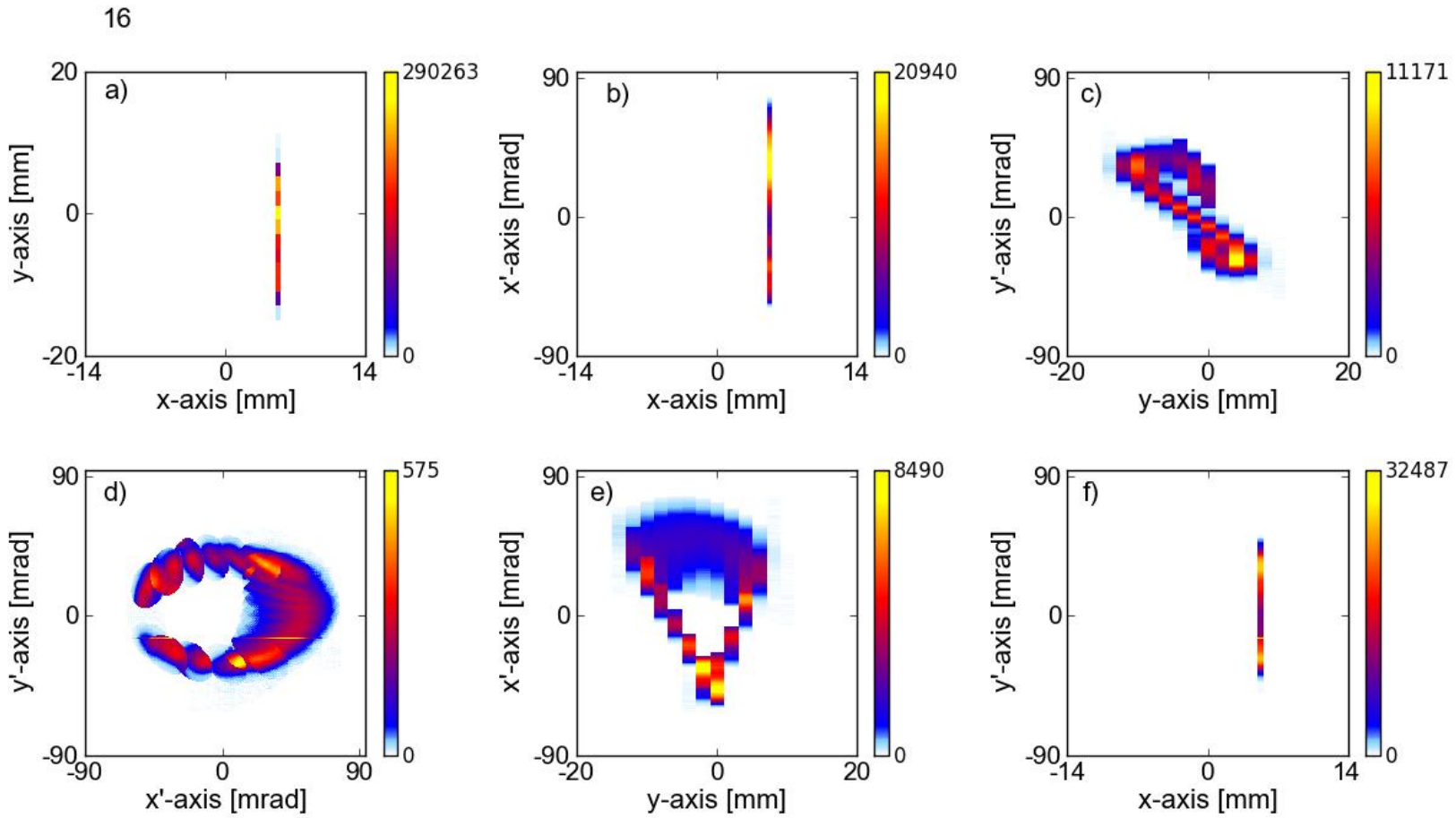
Sliced projection: measurements



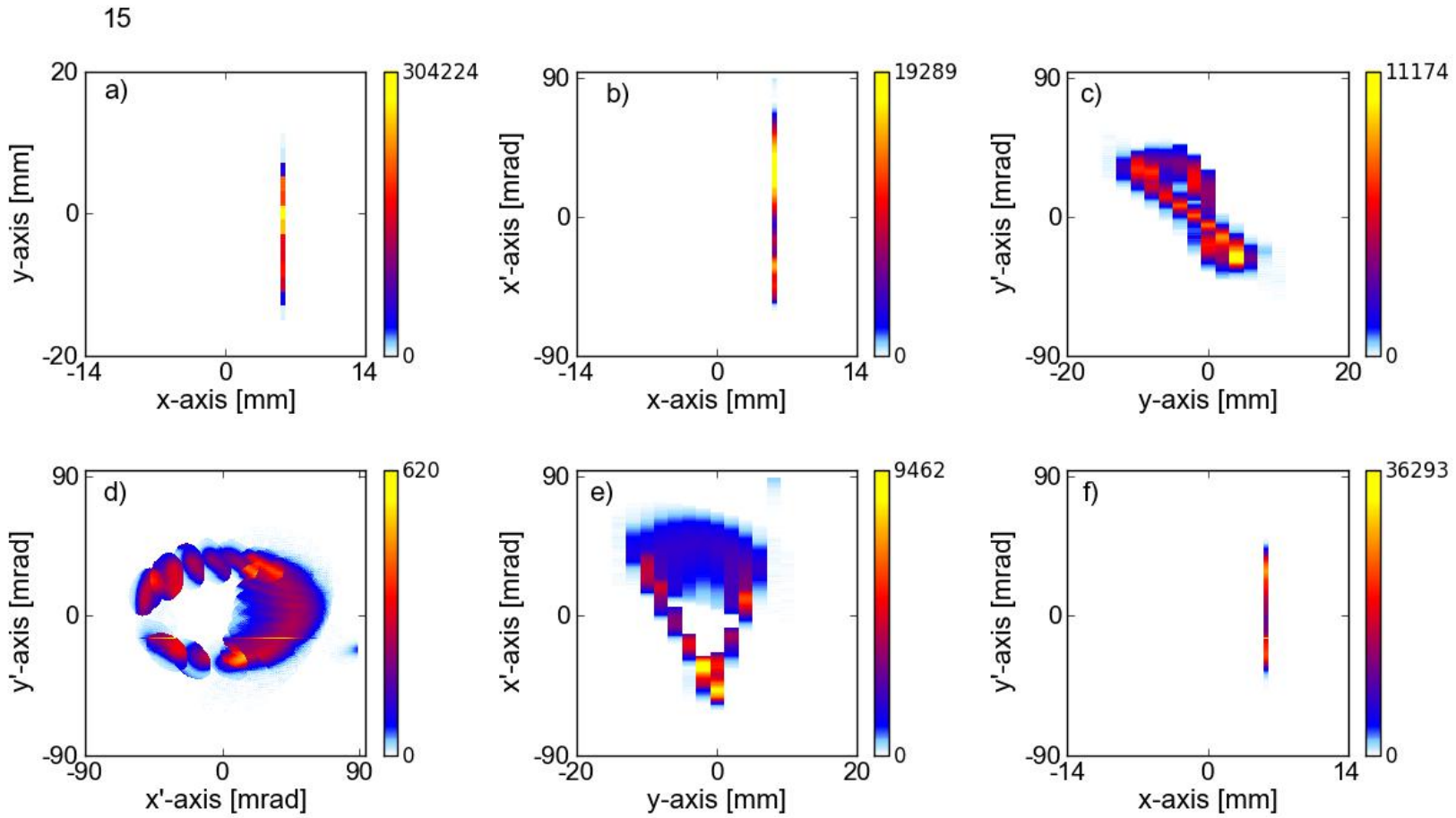
Sliced projection: measurements



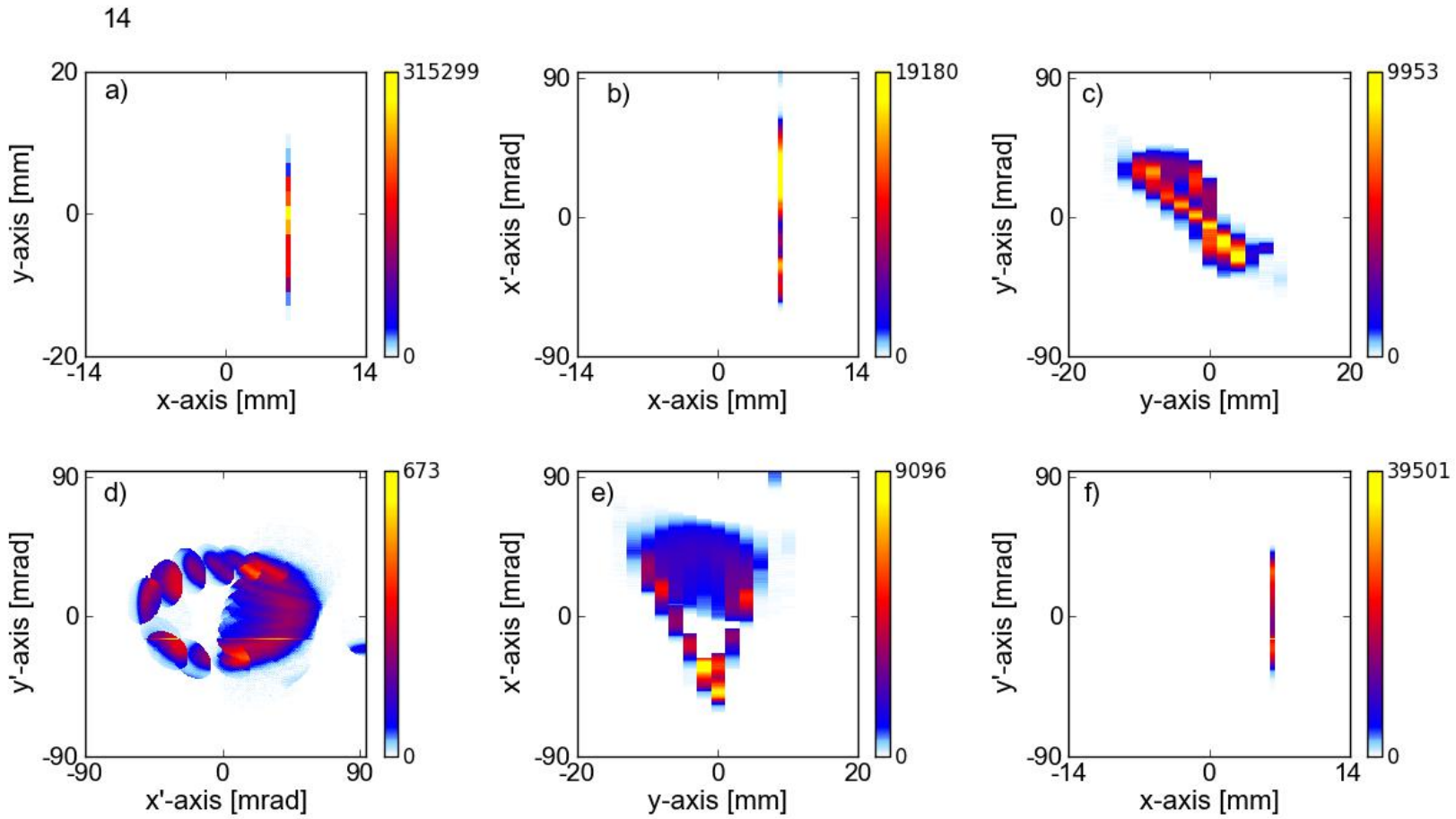
Sliced projection: measurements



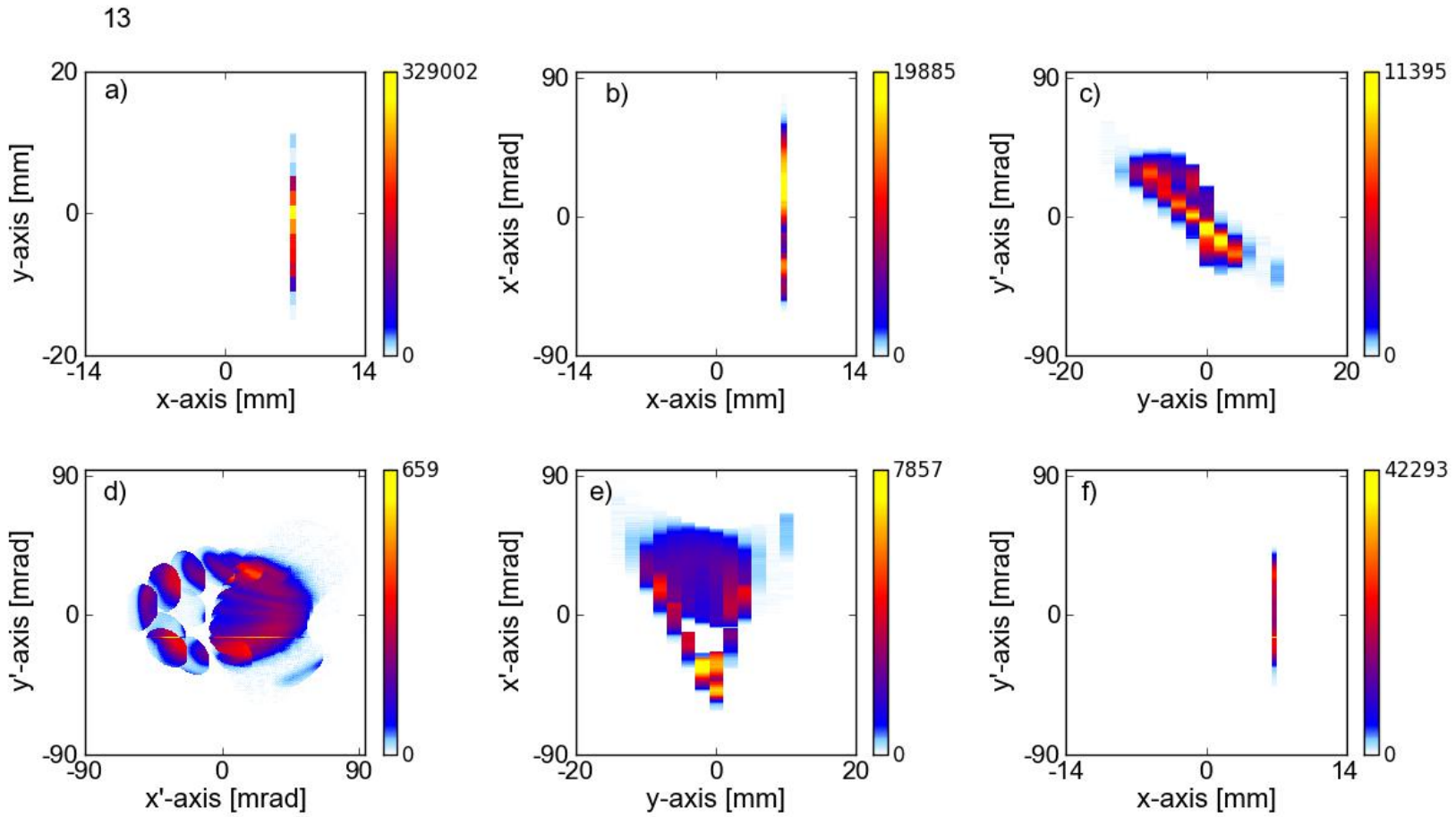
Sliced projection: measurements



Sliced projection: measurements



Sliced projection: measurements



Analytical description of the x'-y' distribution

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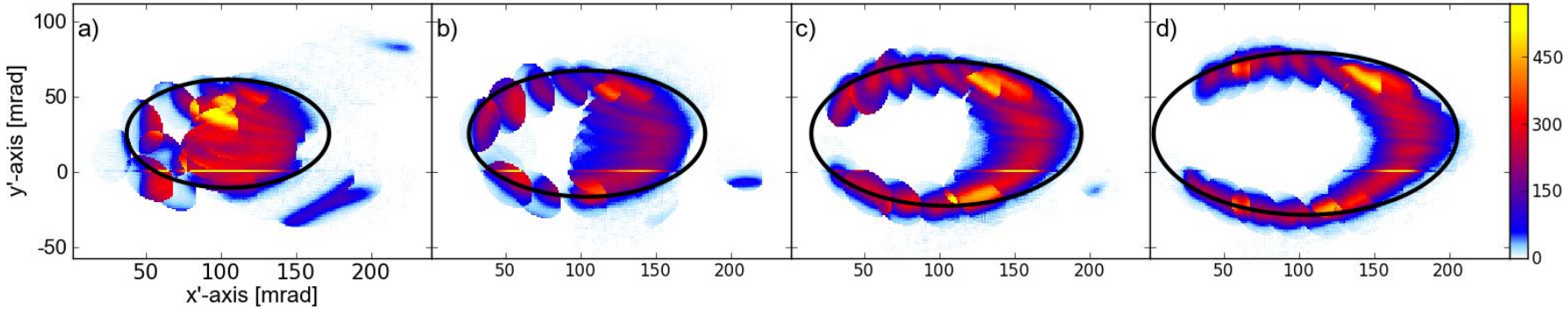

Expansion coefficients of the 2nd order transfer matrix

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COSY Infinity 9.1: Michigan State university

x_1	%	x'_1	%	y_1	%	y'_1	%	$(x,x',y,y',\delta,l)_0$
0	24	0	5.8	0	0	0	0	100000
0	0	1.20995	108	0	0	0	0	010000
0	0	0	0	0	9.2	0	3.8	001000
0	0	0	0	9.100E-02	35	-1.040819	110	000100
0	0	0	0	0	0	0	0	200000
0	-2	0	0.1	0	0	0	0	110000
-0.94047	33	0	3.4	0	0	0	0	020000
0	0	0	0	0	0	0	0	101000
0	0	0	0	0	1.5	0	0.4	011000
0	0	0	0	0	2	0	0.6	100100
0	0	0	0	5.34891	71	0	13	010100
0	0	0	0	0	0	0	0	002000
0	3	0	0.6	0	0	0	0	001100
-2.43596	86	0	9.8	0	0	0	0	000200

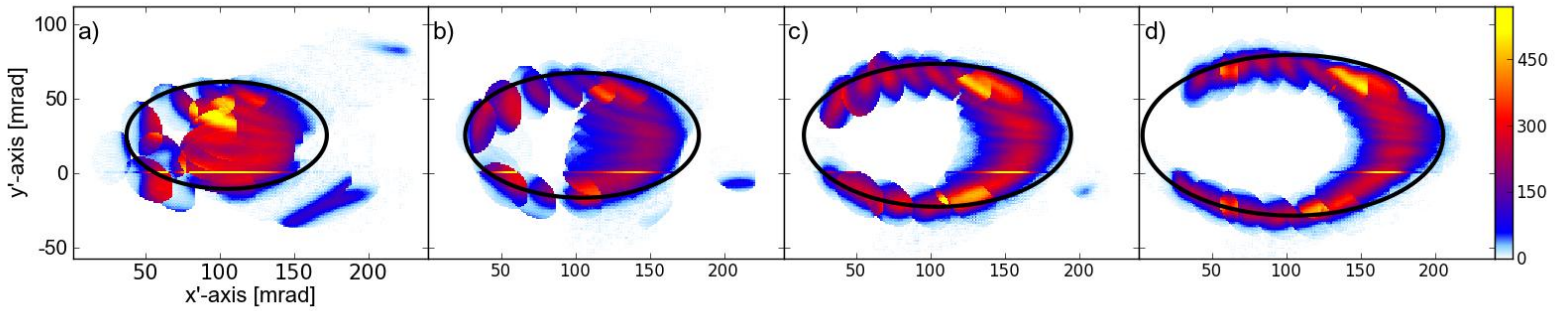
$$x_1 = (x/x'x')x'^2_0 + (x/y'y')y'^2_0 \; (x/xx')x_0x'_0 + (x/x'x')x'^2_0$$

$$x'_1 = (x'/x')x'_0 \; yy')y_0y'_0 + (x/y'y')y'_0\,y'_0$$

$$y_1 = (y/y')y'_0 + (y/x'y')x'_0\,y'_0$$

$$y'_1 = (y'/y')y'_0$$

Analytical description of the x'-y' distribution



$$x_1 = \left(\frac{x'_1}{(x'/x')/\sqrt{(x/x'x')}} \right)^2 + \left(\frac{y'_1}{(y'/y')/\sqrt{(x/y'y')}} \right)^2$$

$$x_1 = (x'/x')x'$$

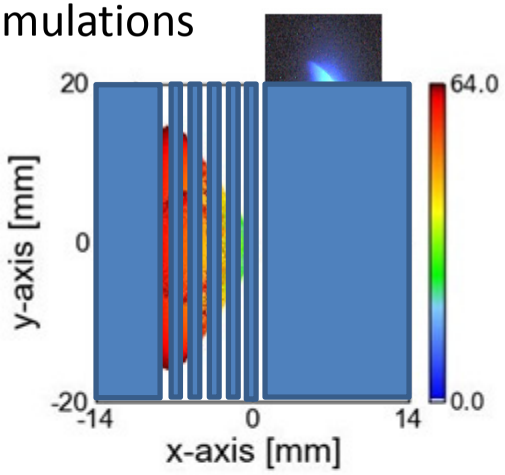
$$y'_1 = (y'/y')y'$$

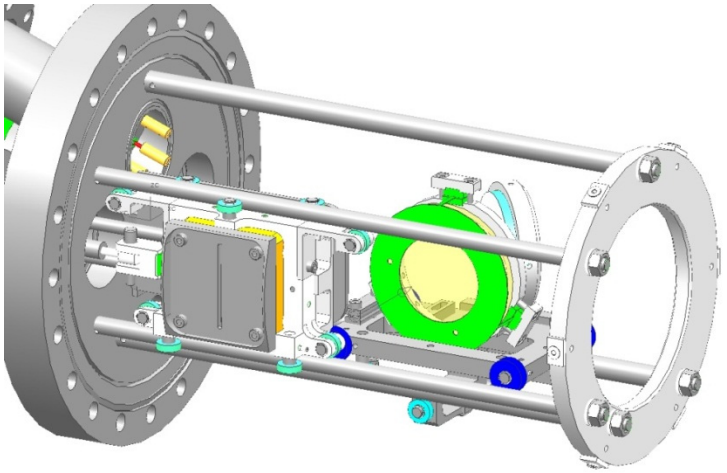
$$a = (x'/x')/\sqrt{(x/x'x')} = 1.21/\sqrt{0.94047} = 1.24$$

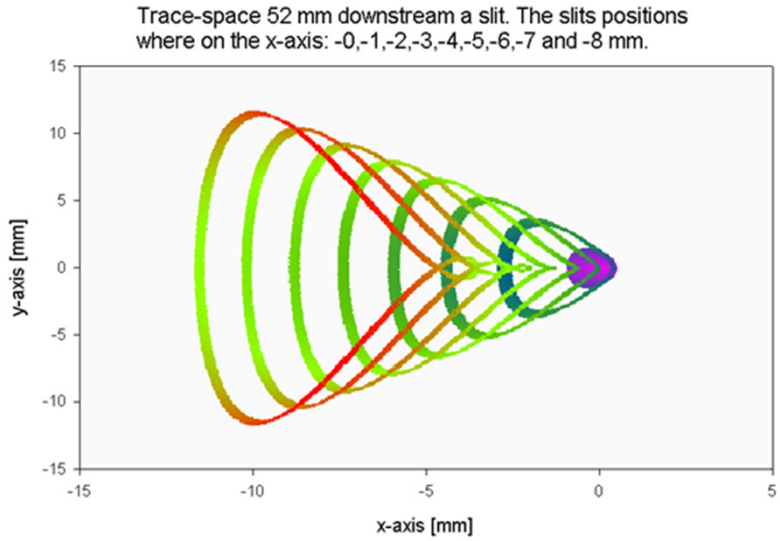
$$b = (y'/y')/\sqrt{(x/y'y')} = 1.041/\sqrt{2.435} = 0.66$$

Response distribution of the MCP

simulations







Simulation and measurements of a full response distribution from a 24.6 keV He^{1+} beam.

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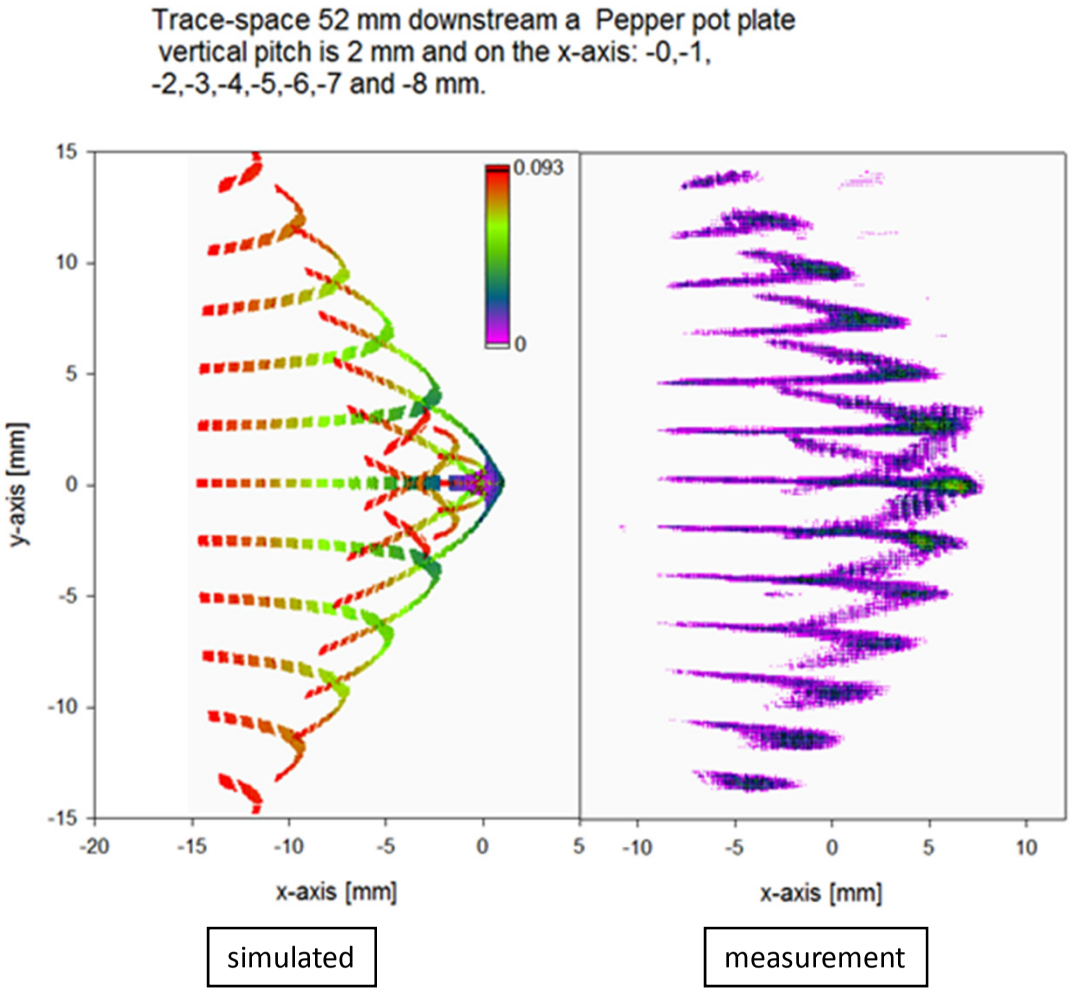
Simulations versus measurements



Conclusions

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- These 2nd order matrix simulations show that the response distributions measured are dominated by second order aberrations of the dipole magnet.
- The similarity between the simulated and measured projections in the image plane validates the assumption that ions originate from a point source.
- A route is shown to retrieve the expansion coefficients from the overall transfer matrix from a measured x'-y' distributions.

Thank you for your attention

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Simulated influence of the pepper pot design on the projection at the location of the pepper pot plate.

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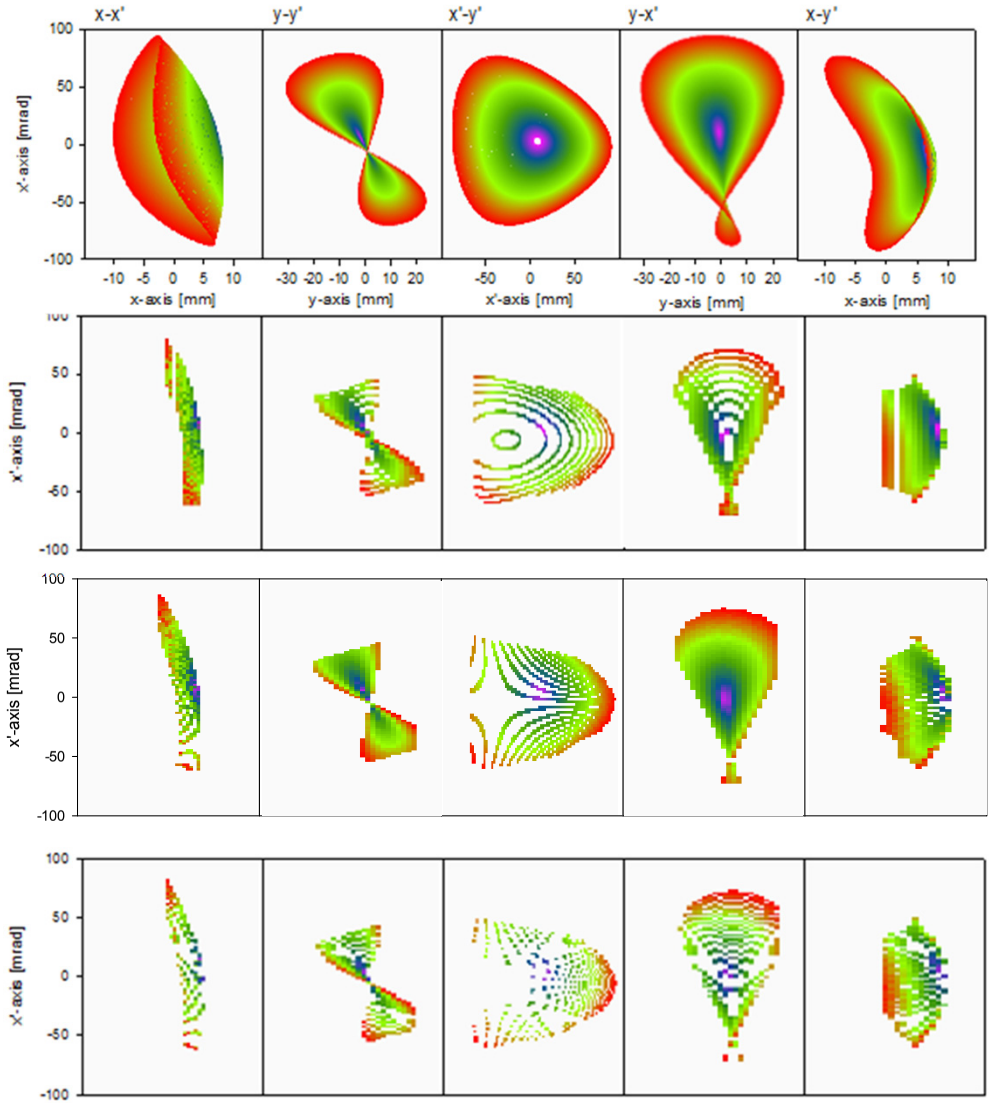

Complete beam

Vertical slits

Horizontal slits

Apertures

Measurements versus simulations

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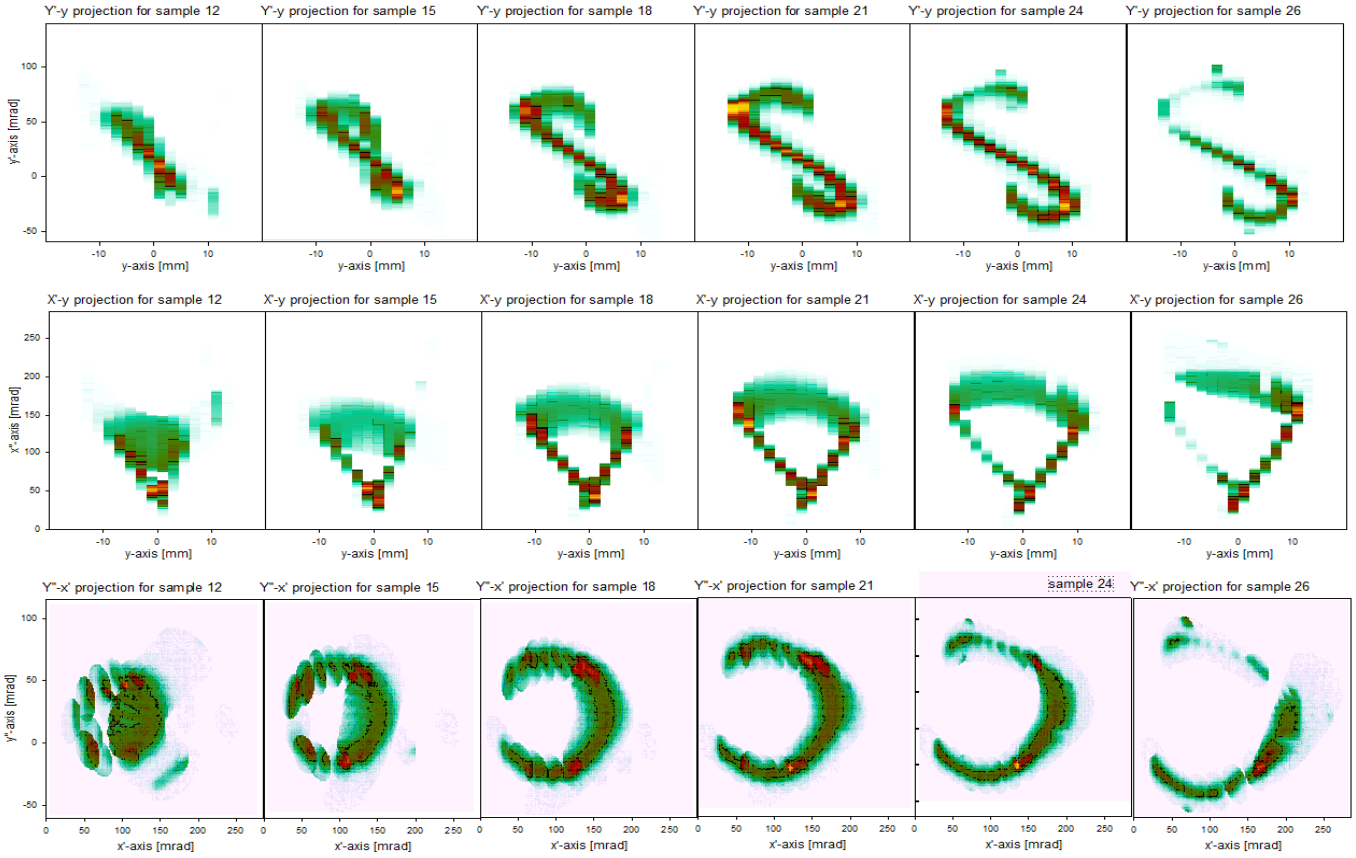
Measurements

X = 0 mm

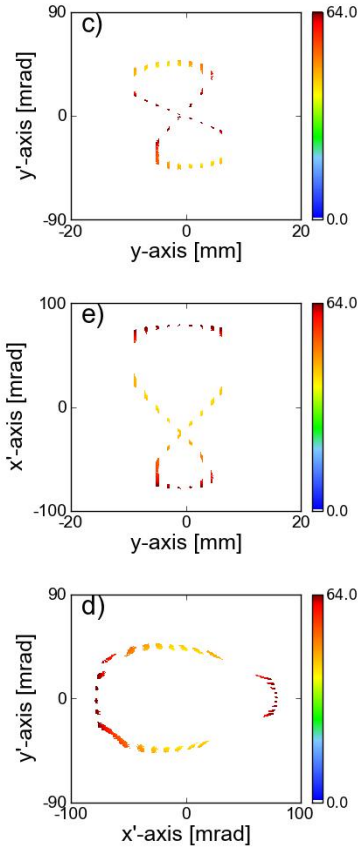
X = -3 mm

X = -6 mm



Simulated

X = -4.25 mm



Simulated response downstream slits on the location of a pepper pot plate

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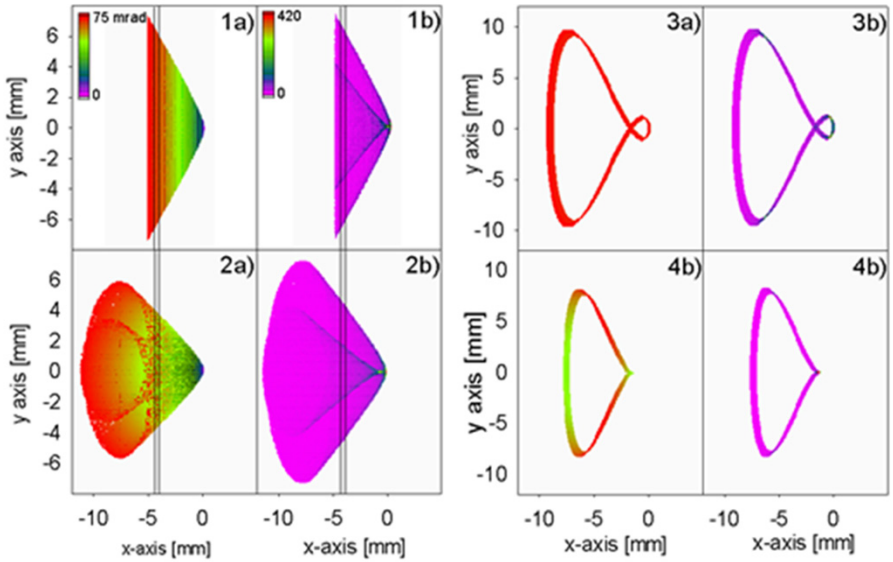
simulations

Measured beam profile on a viewing screen



Fringe field model 1

Fringe field model 2