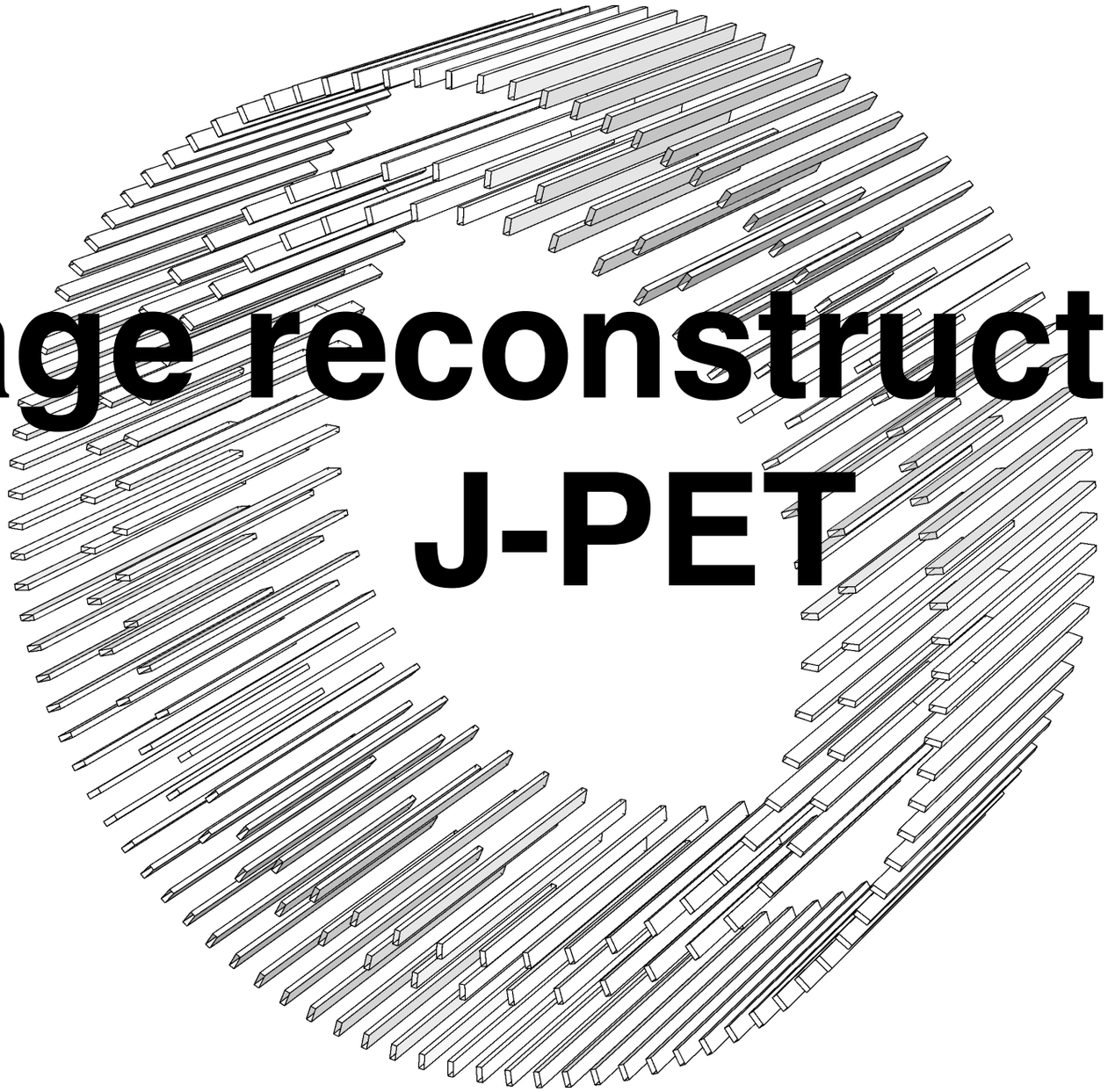
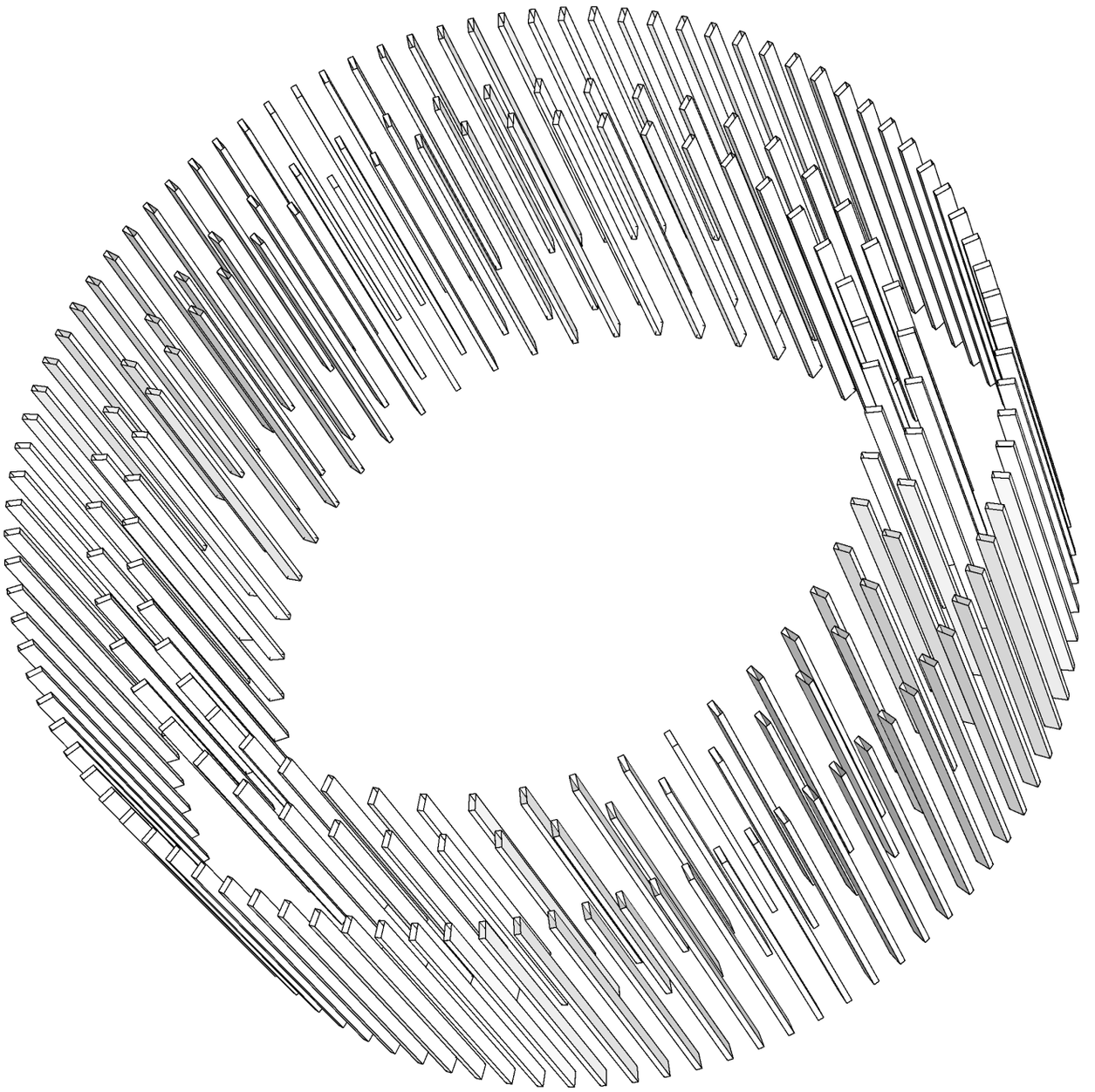
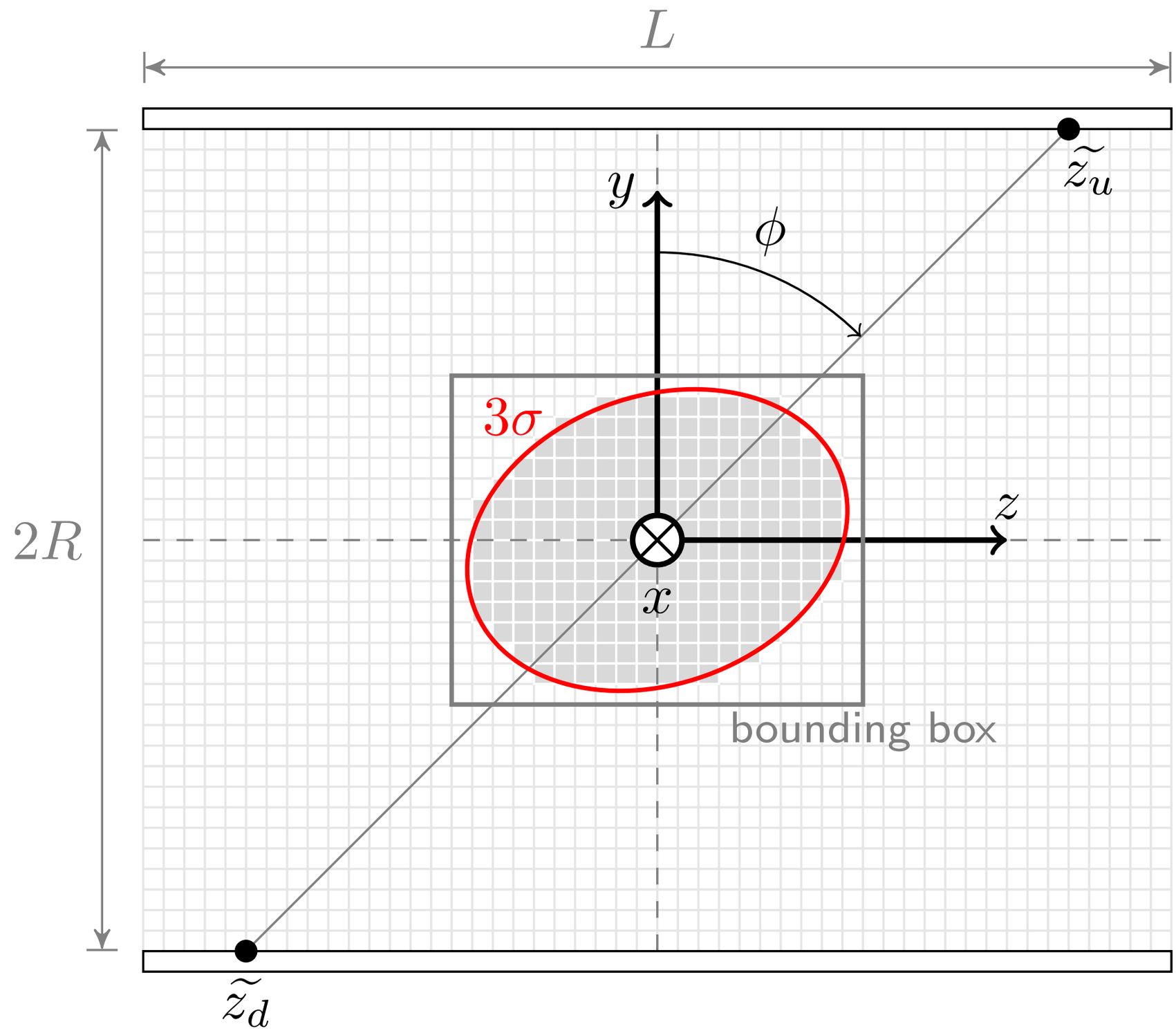


Image reconstruction in J-PET

P.B, J. Kowal, A. Strzelecki




L
$2R$
y
ϕ
$\widetilde{z}_u$
3σ
z
x
bounding box
$\widetilde{z}_d$

List mode MLEM

$$\rho_l^{(t+1)} = \sum_{j=1}^{N} \frac{P(\widetilde{\mathbf{e}}_j|l)\rho_l^t}{\sum_{i=1}^{M} P(\widetilde{\mathbf{e}}_j|i)s_i\rho_i^t}.$$

$$\widetilde{\mathbf{e}} = (d_1, d_2, \tilde{z}_1, \tilde{z}_2, \Delta l)$$

List mode MLEM

$$s_l \rho_l^{(t+1)} = \sum_{j=1}^{N} \frac{P(\widetilde{\mathbf{e}}_j|l) s_l \rho_l^t}{\sum_{i=1}^{M} P(\widetilde{\mathbf{e}}_j|i) s_i \rho_i^t}.$$

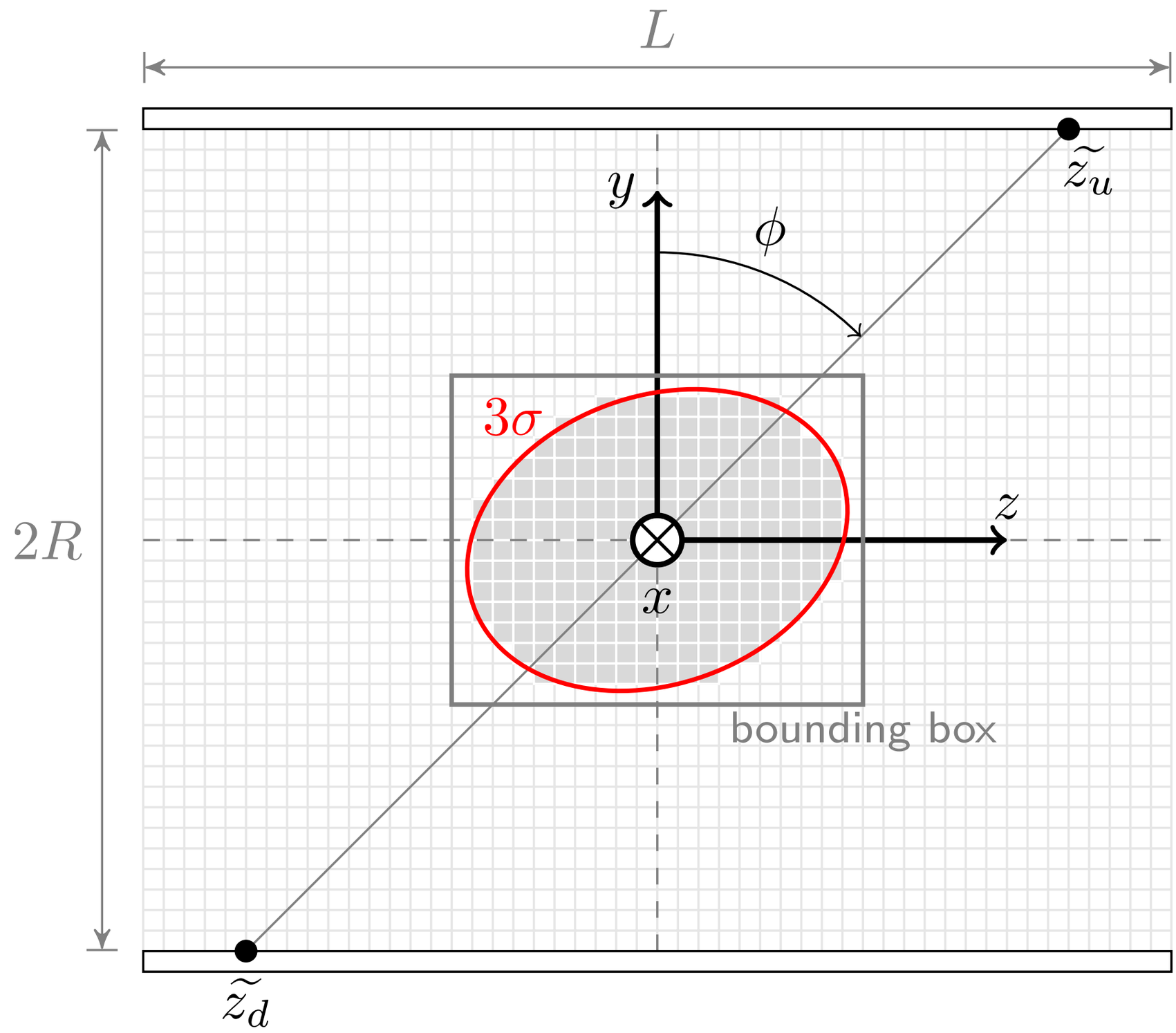
List mode MLEM

$$\rho_l^{'(t+1)} = \sum_{j=1}^{N} \frac{P(\widetilde{\mathbf{e}}_j|l)\rho_l^{'t}}{\sum_{i=1}^{M} P(\widetilde{\mathbf{e}}_j|i)\rho_i^{'t}}.$$

$$\rho_l' \equiv s_l \rho_l$$

2D reconstruction

2D Kernel



2D Kernel

$$P(\widetilde{\mathbf{e}}|i) \approx \frac{\det{}^{\frac{1}{2}} C}{2\pi} \exp\left(-\frac{1}{2}\vec{b}C^{-1}\vec{b}\right)$$

$$\vec{b} = \begin{pmatrix} \Delta z - \Delta y \tan\widetilde{\theta} \\ \Delta z - \Delta y \tan\widetilde{\theta} \\ -2\Delta y \cos^{-1}\widetilde{\theta} \end{pmatrix},$$

Corelation matrix

$$\begin{pmatrix} \sigma_z^2 & 0 & cov \\ 0 & \sigma_z^2 & -cov \\ cov & -cov & \sigma_{dl}^2 \end{pmatrix} = \sigma_z \sigma_{dl} \begin{pmatrix} q & 0 & cor \\ 0 & q & -cor \\ cor & -cor & 1/q \end{pmatrix}$$

Corelation matrix

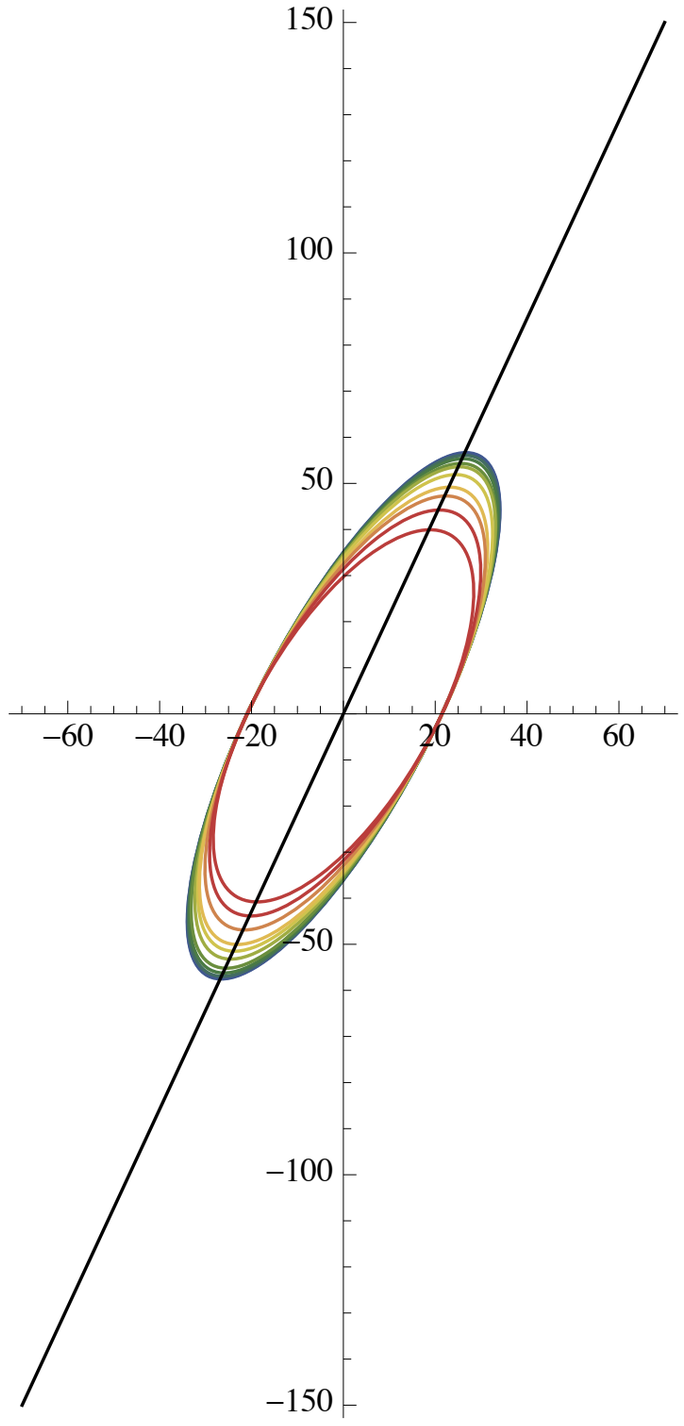
$$\begin{pmatrix} \sigma_z^2 & 0 & cov \\ 0 & \sigma_z^2 & -cov \\ cov & -cov & \sigma_{dl}^2 \end{pmatrix} = \sigma_z \sigma_{dl} \begin{pmatrix} q & 0 & cor \\ 0 & q & -cor \\ cor & -cor & 1/q \end{pmatrix}$$

$$\sigma_z \approx 15mm$$

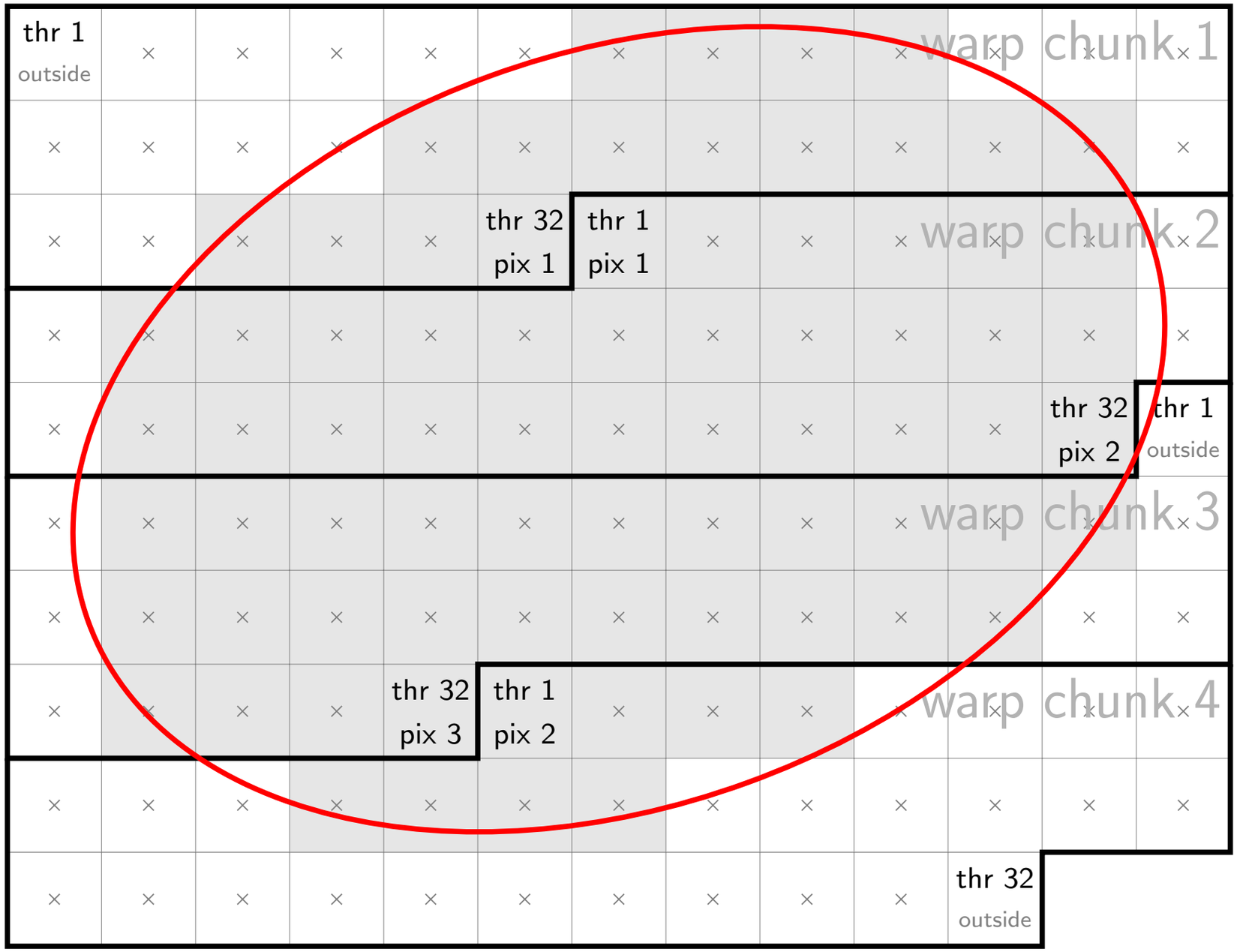
$$\sigma_{dl} \approx 60mm$$

$$cov \approx 0$$

Kernel dependence on correlations



GPU implementation - CUDA



GPU implementation - CUDA

30 X speedup

Kepler GTX 670 GPU

Results - data from (almost) point sources

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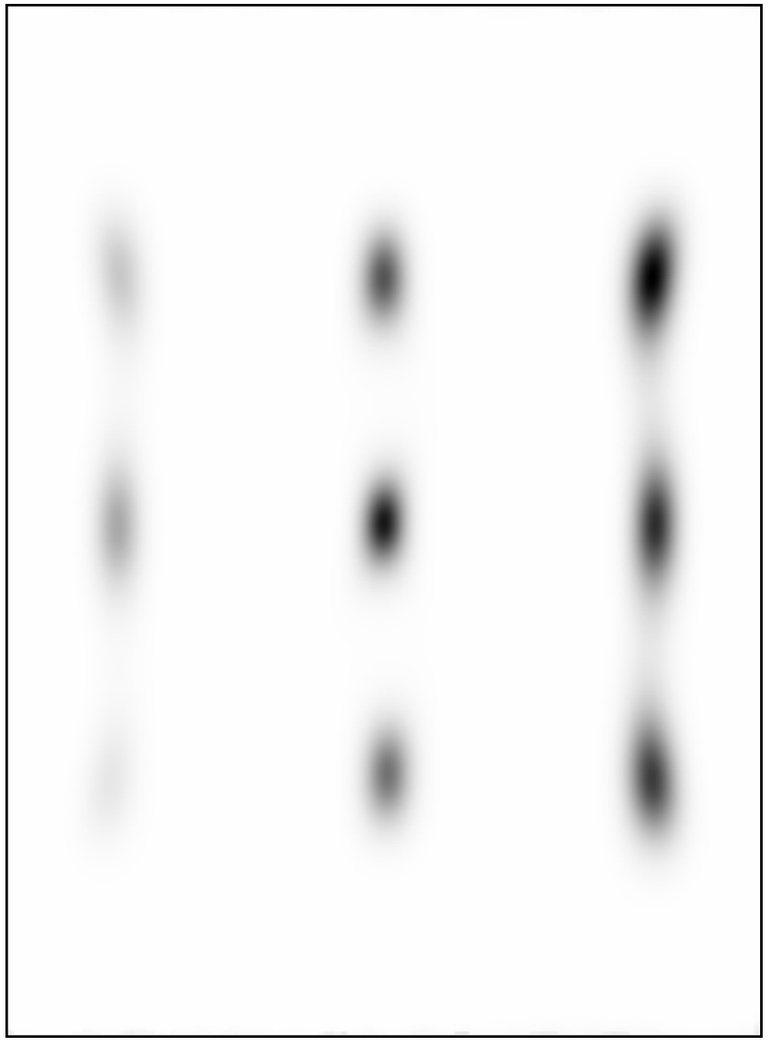
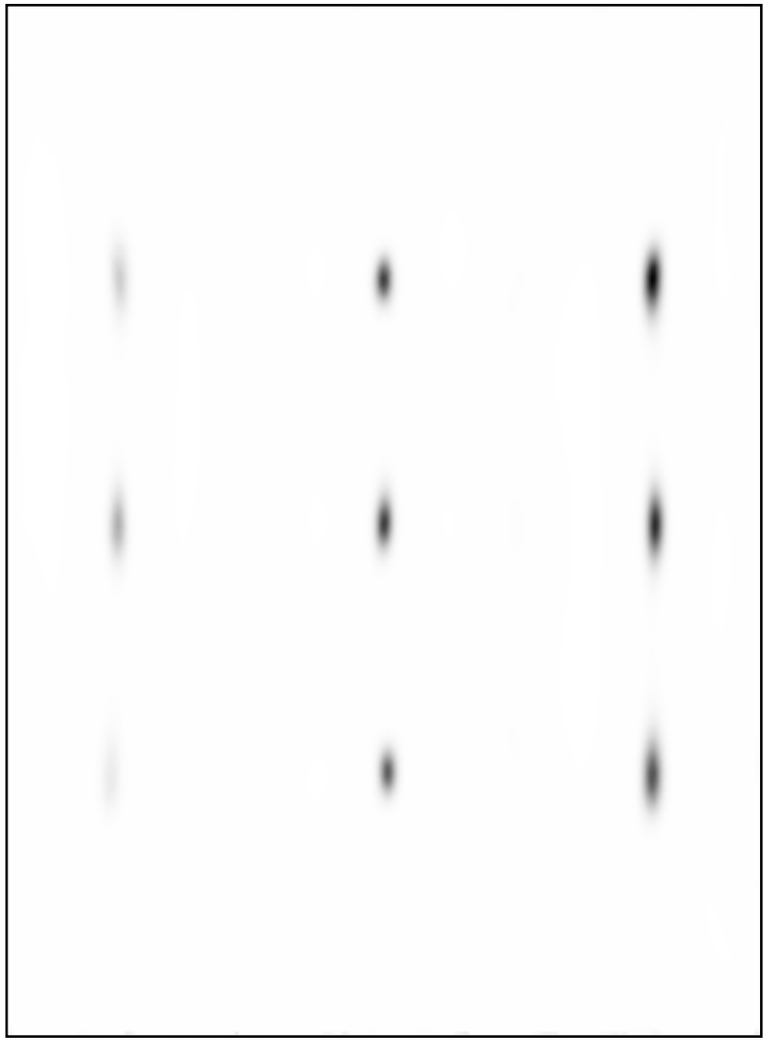
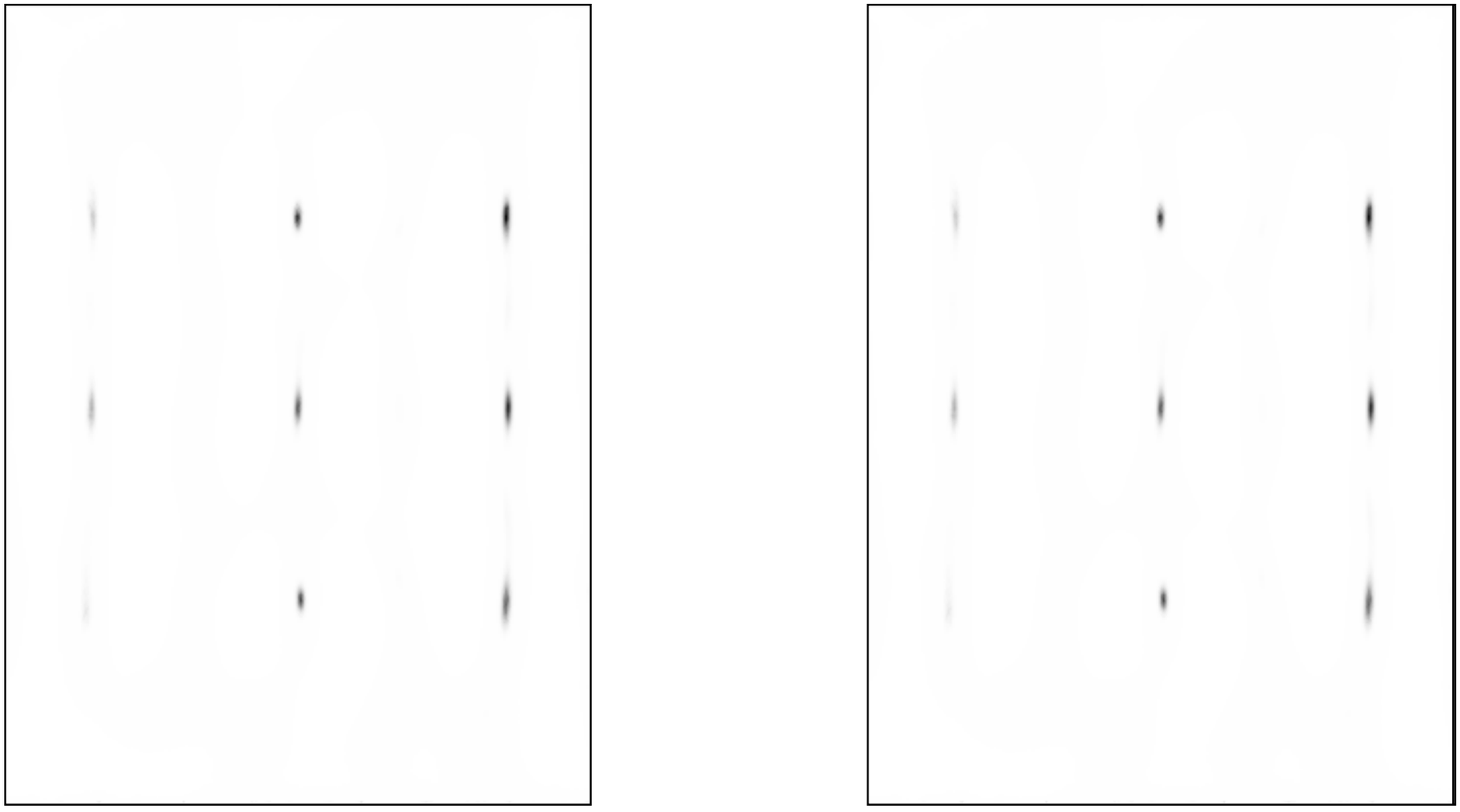
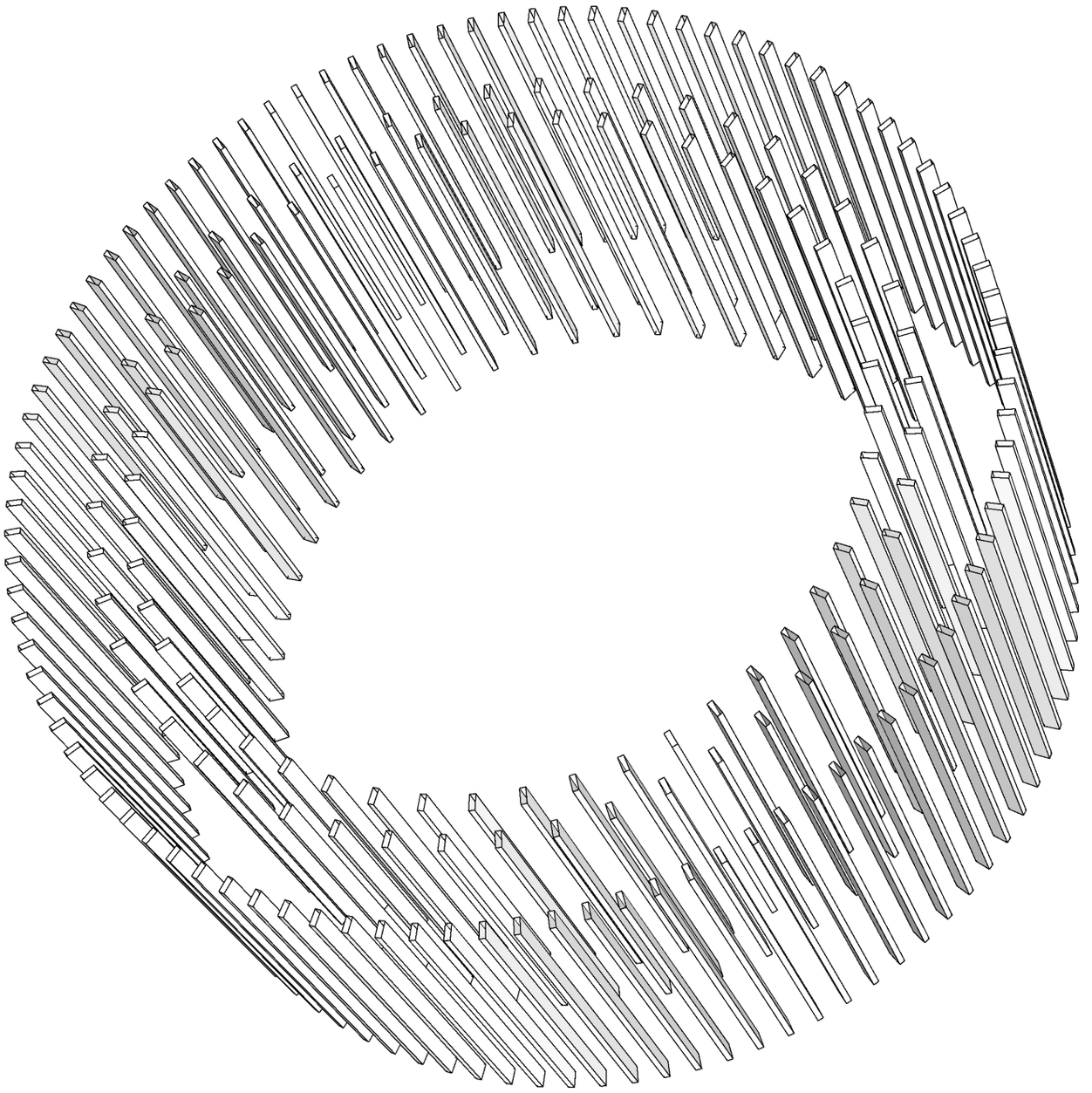




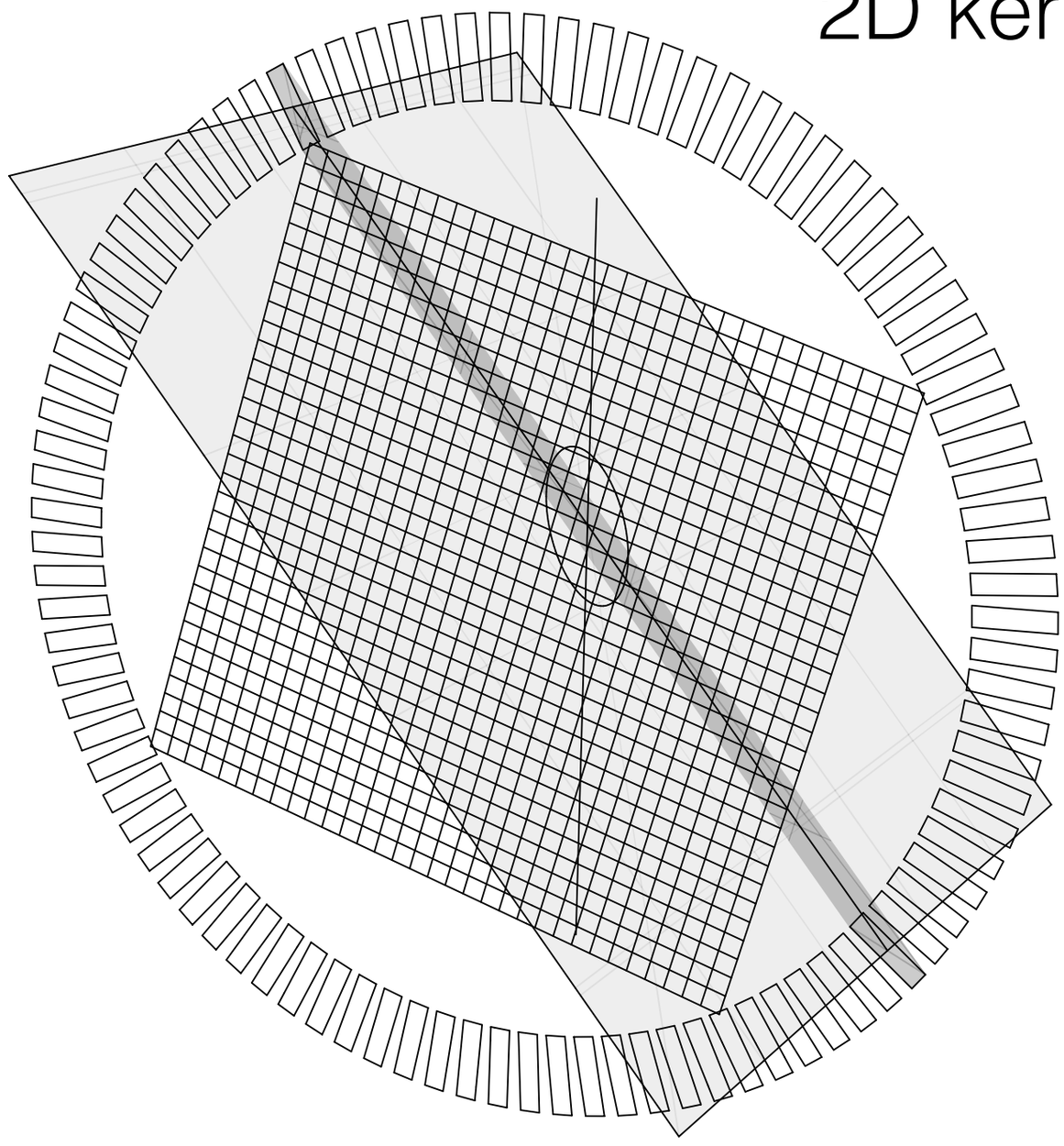
Results - data from (almost) point sources

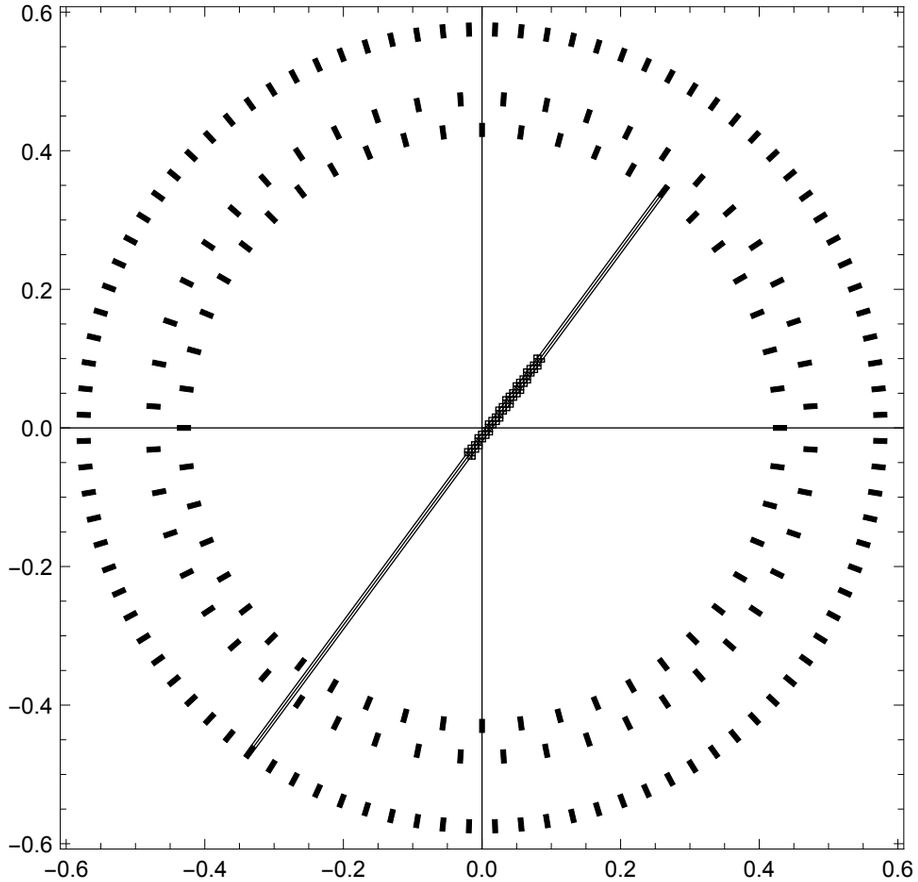


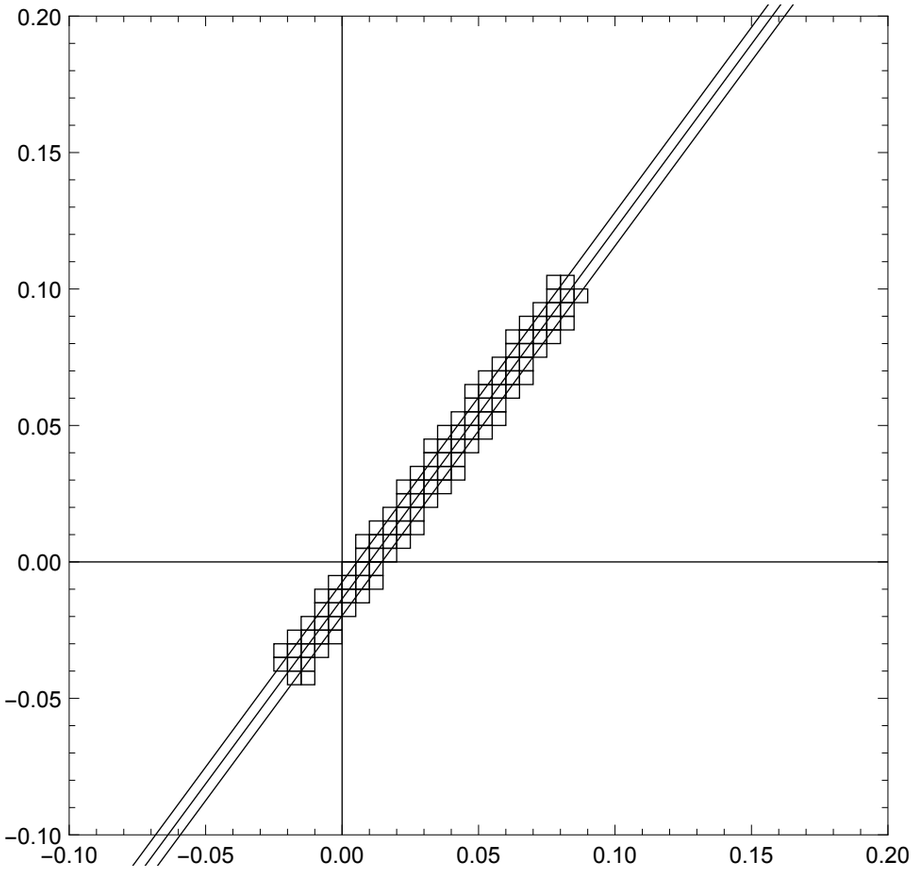
3D reconstruction



2D kernel in LOR plane







$$\frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{1}{2}\frac{l^2}{2\sigma^2}}$$

$$\sigma = 0.3w$$

Timings

~ 500 000 events, 0.5 cm voxel

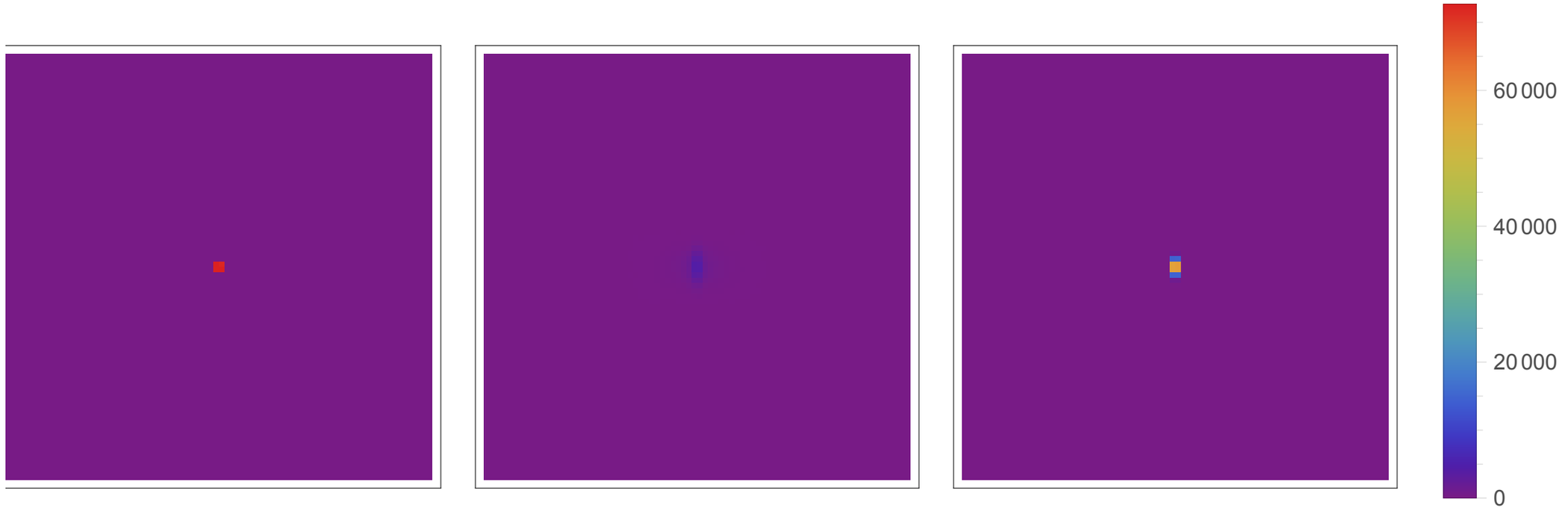
~ 20 sec for one iteration on 4 core MacBook

Not optimized :)

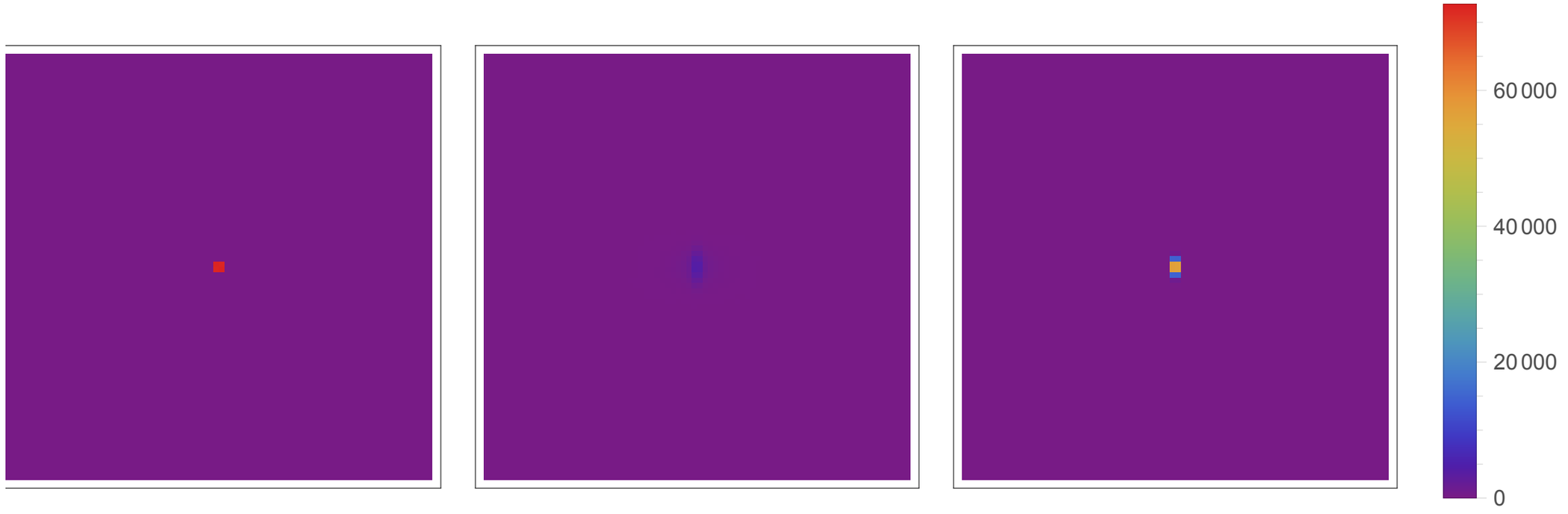
3D point source

Results - simulated data - iteration 32

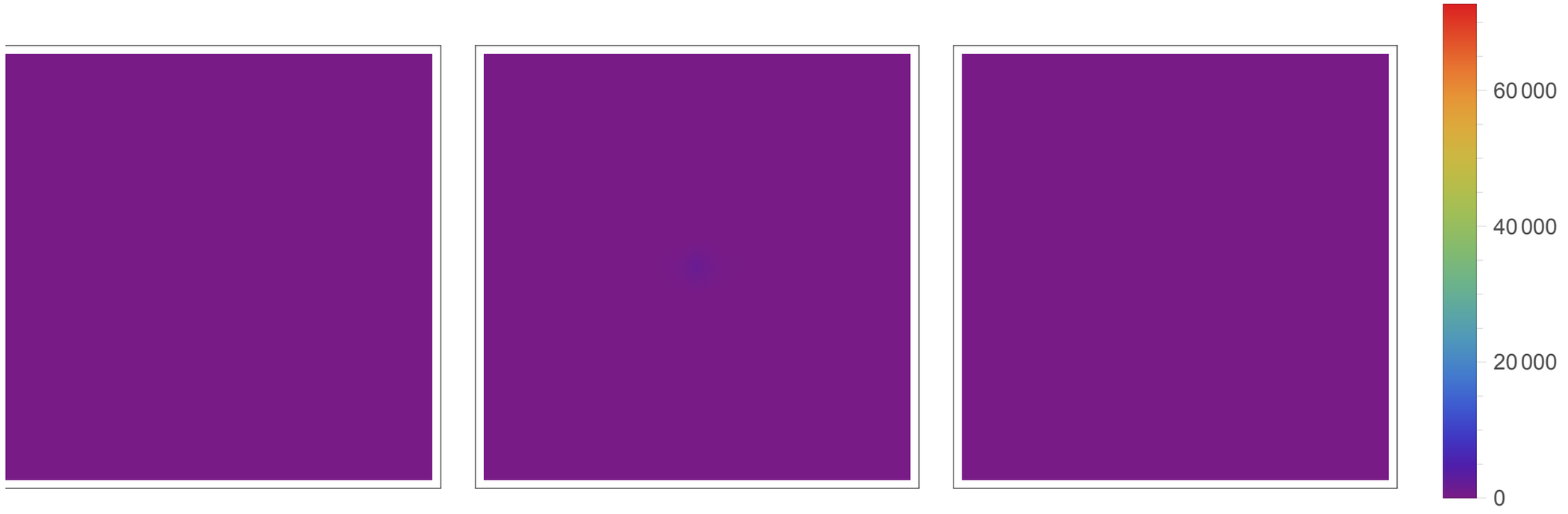
Results - simulated data



Results - simulated data



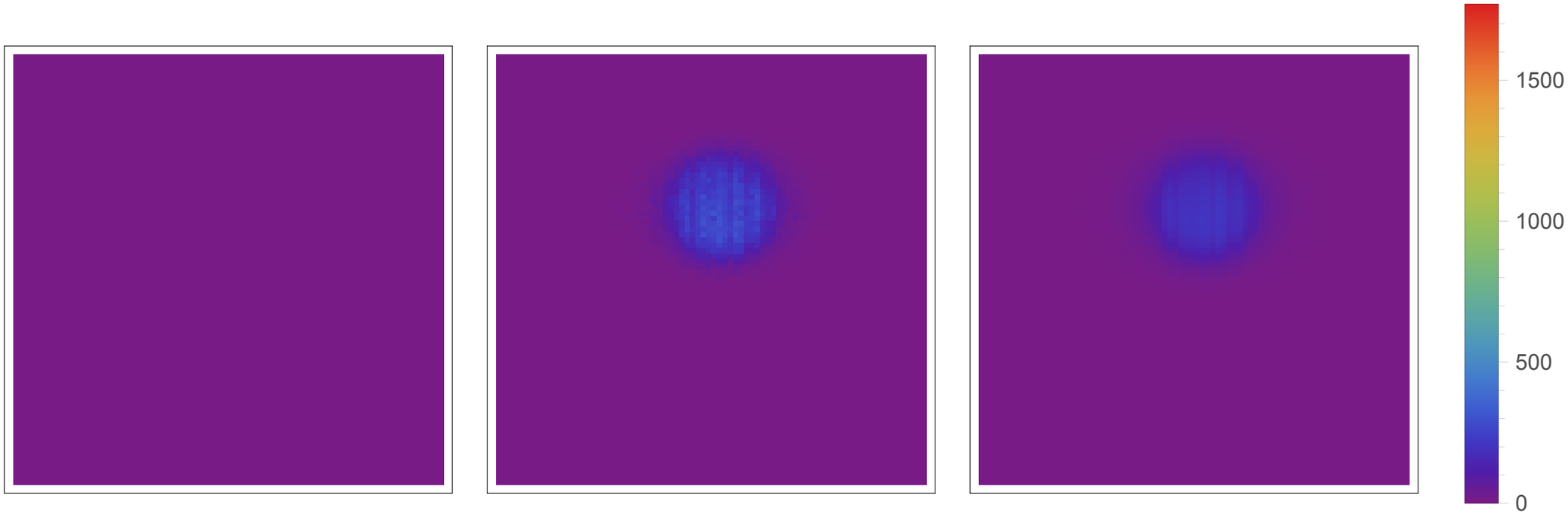
Results - simulated data



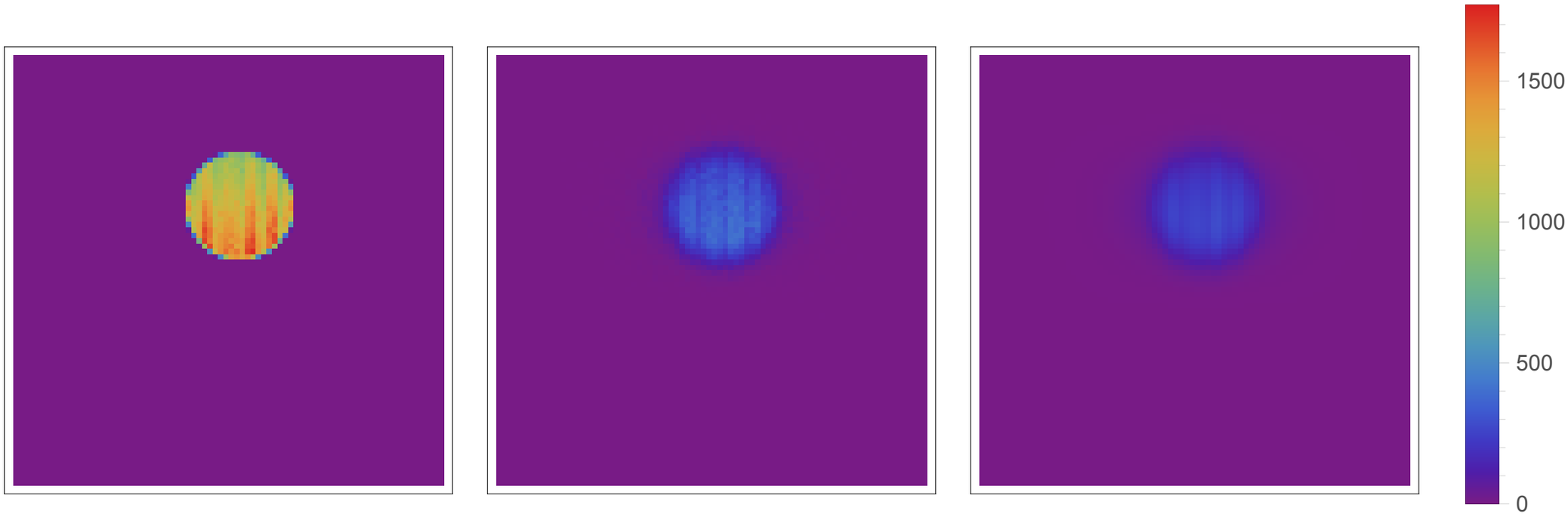
3D extended source

1 iteration

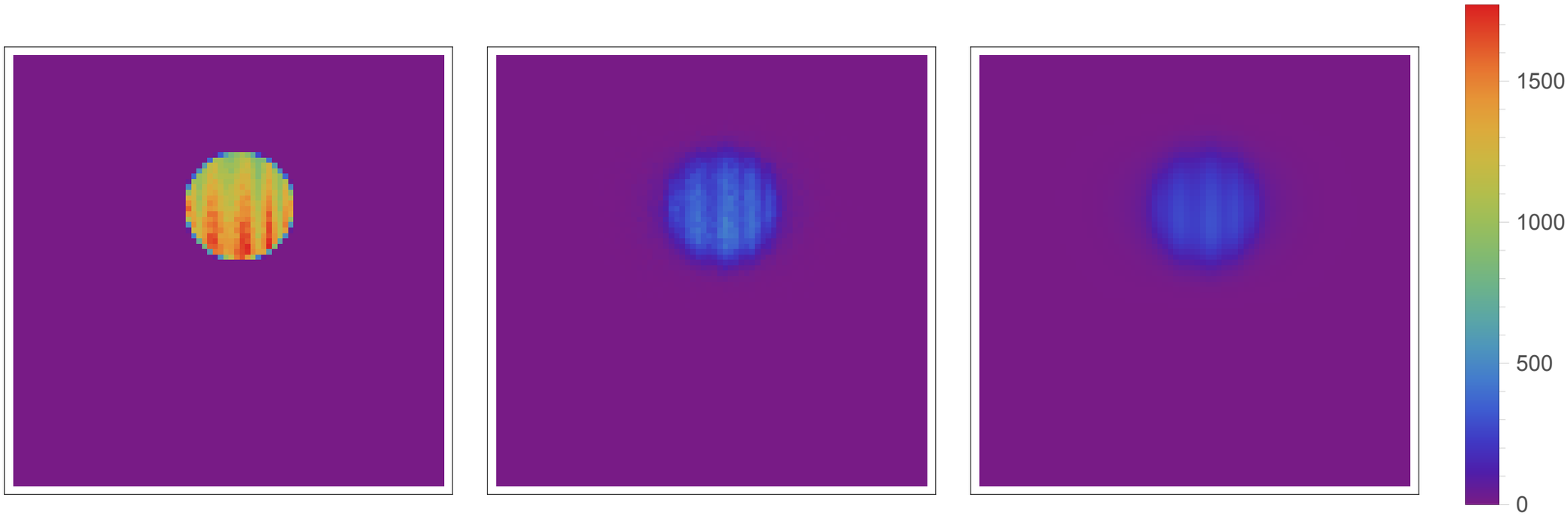
Results - simulated data



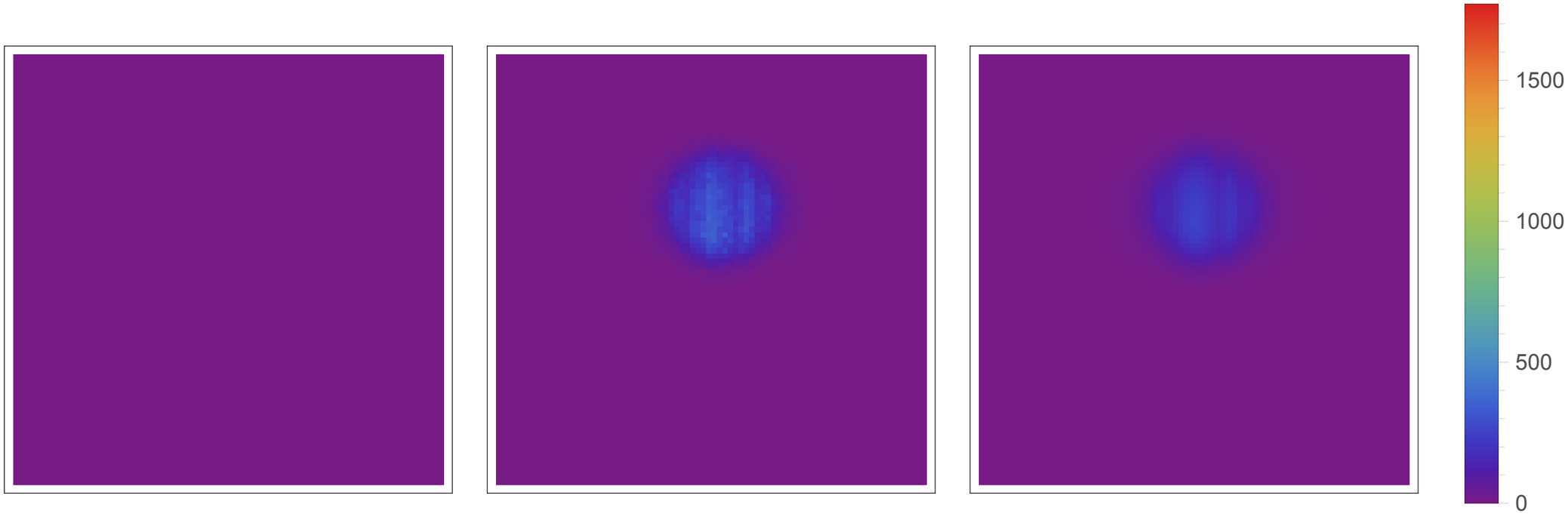
Results - simulated data



Results - simulated data

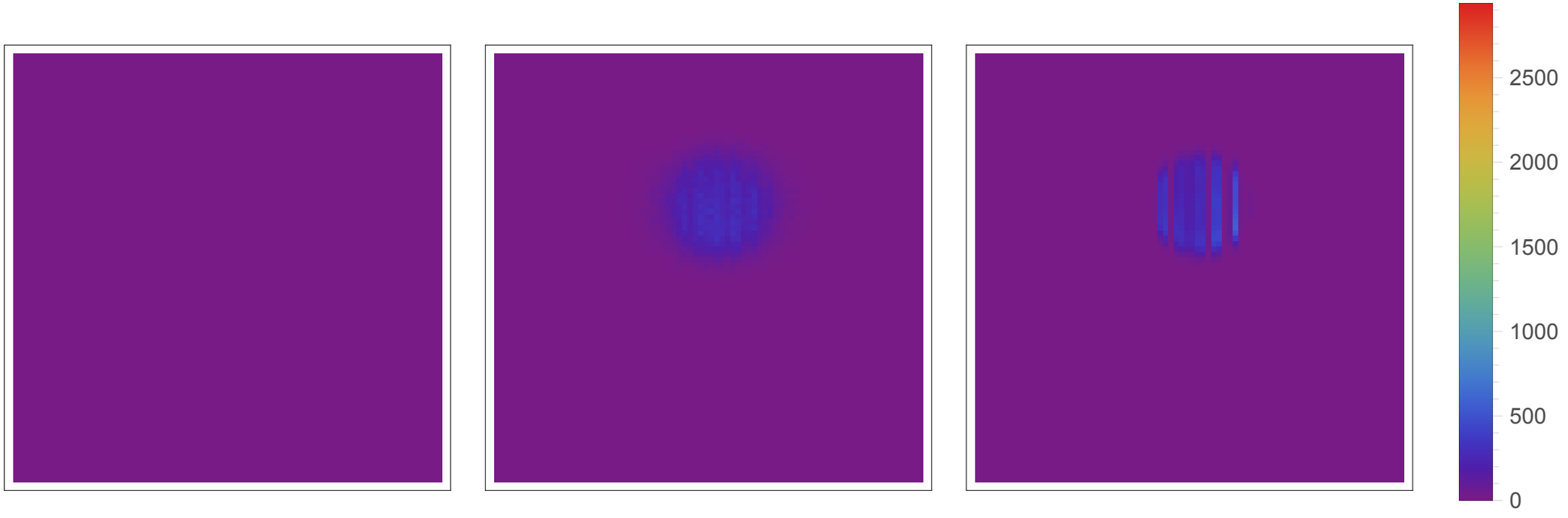


Results - simulated data

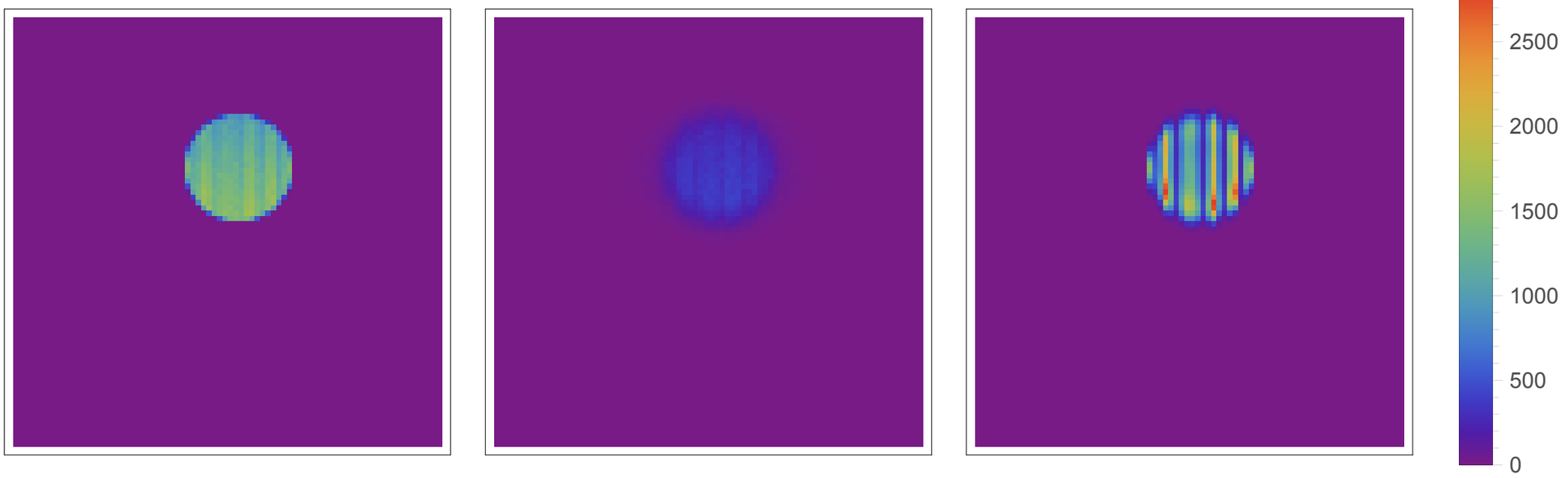


16 iterations

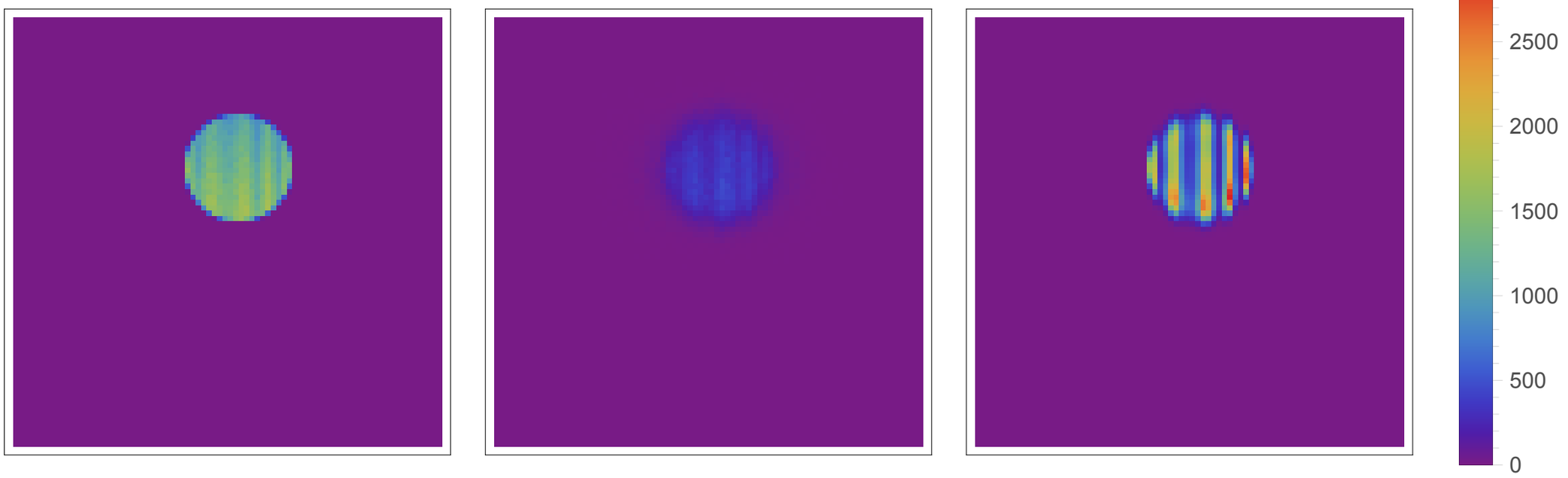
Results - simulated data



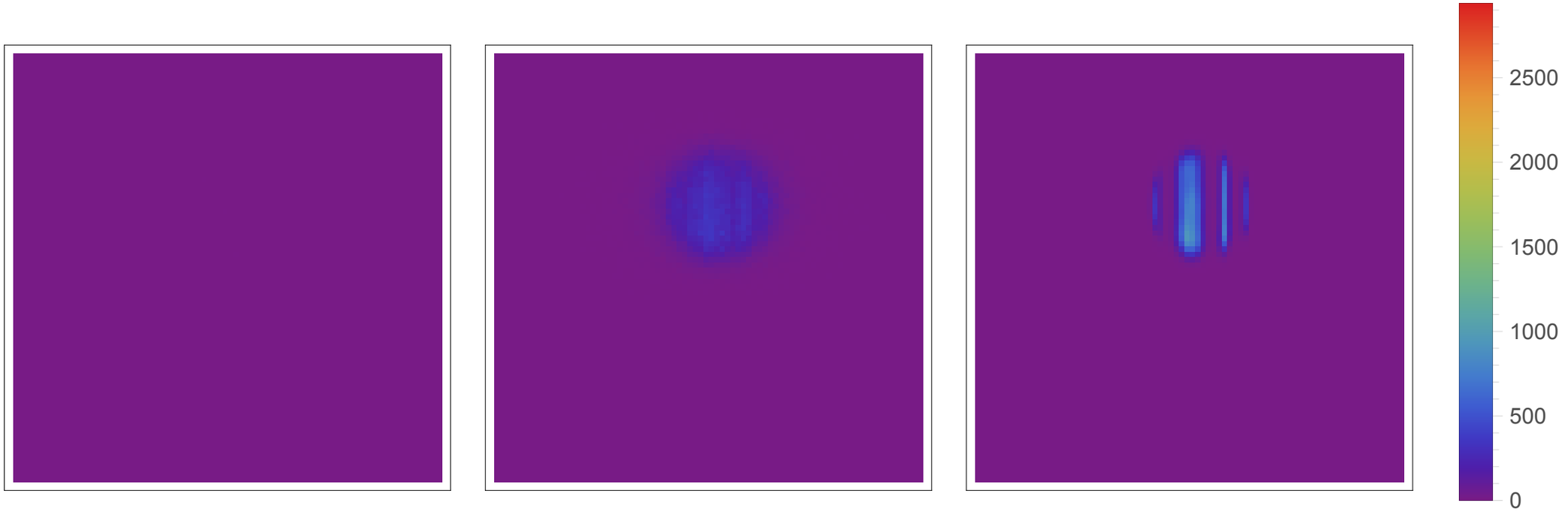
Results - simulated data



Results - simulated data

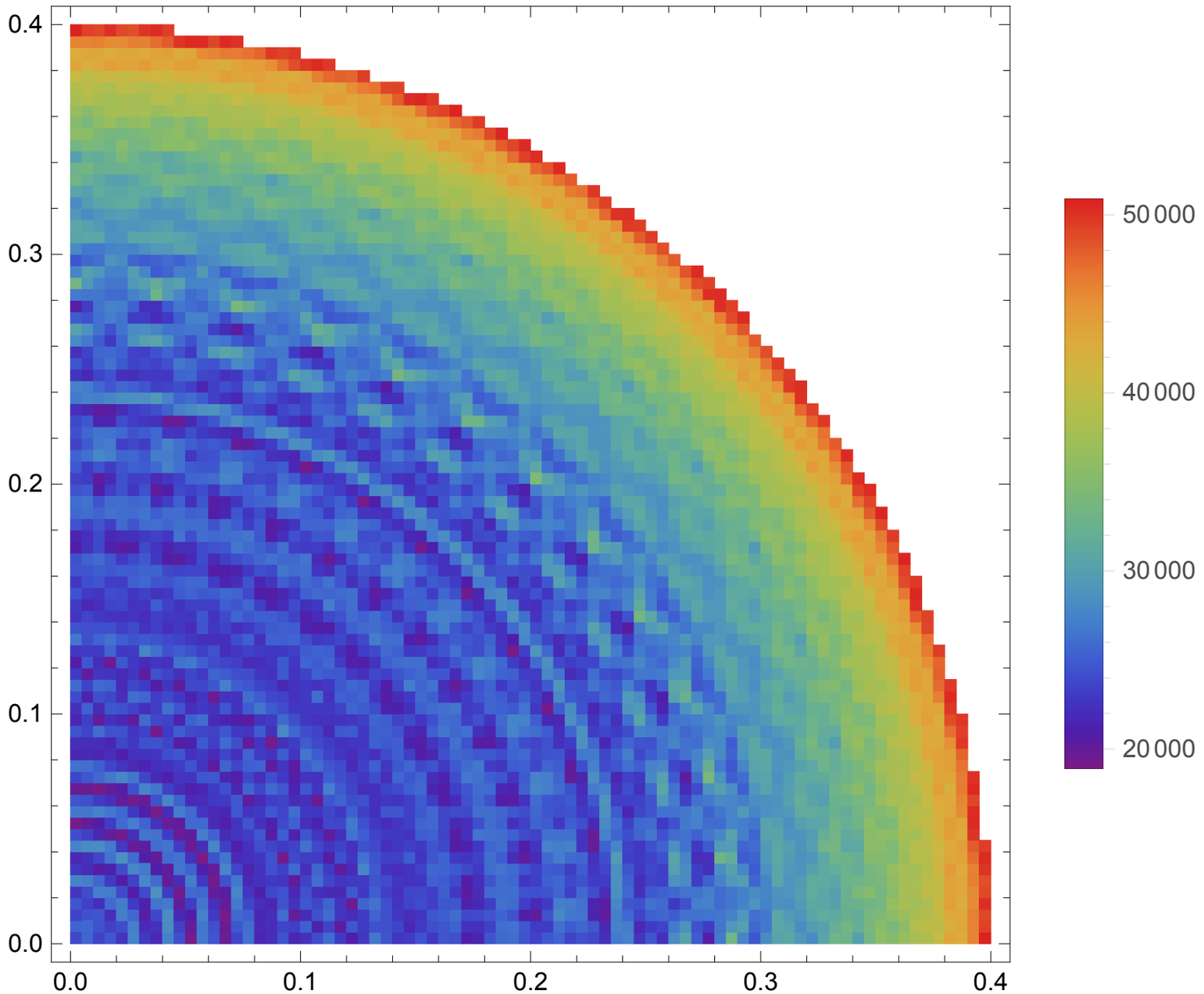


Results - simulated data

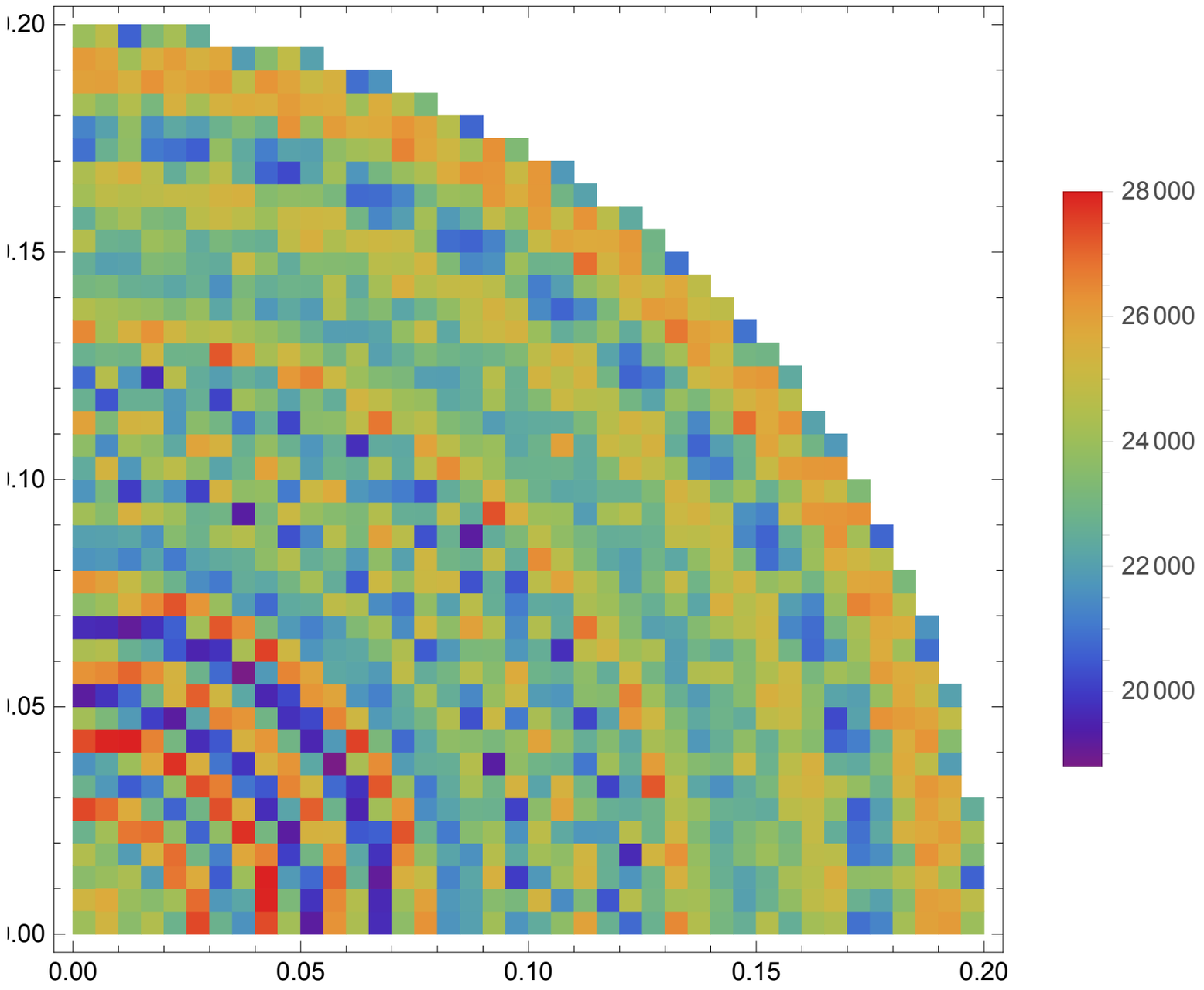


Sensitivity

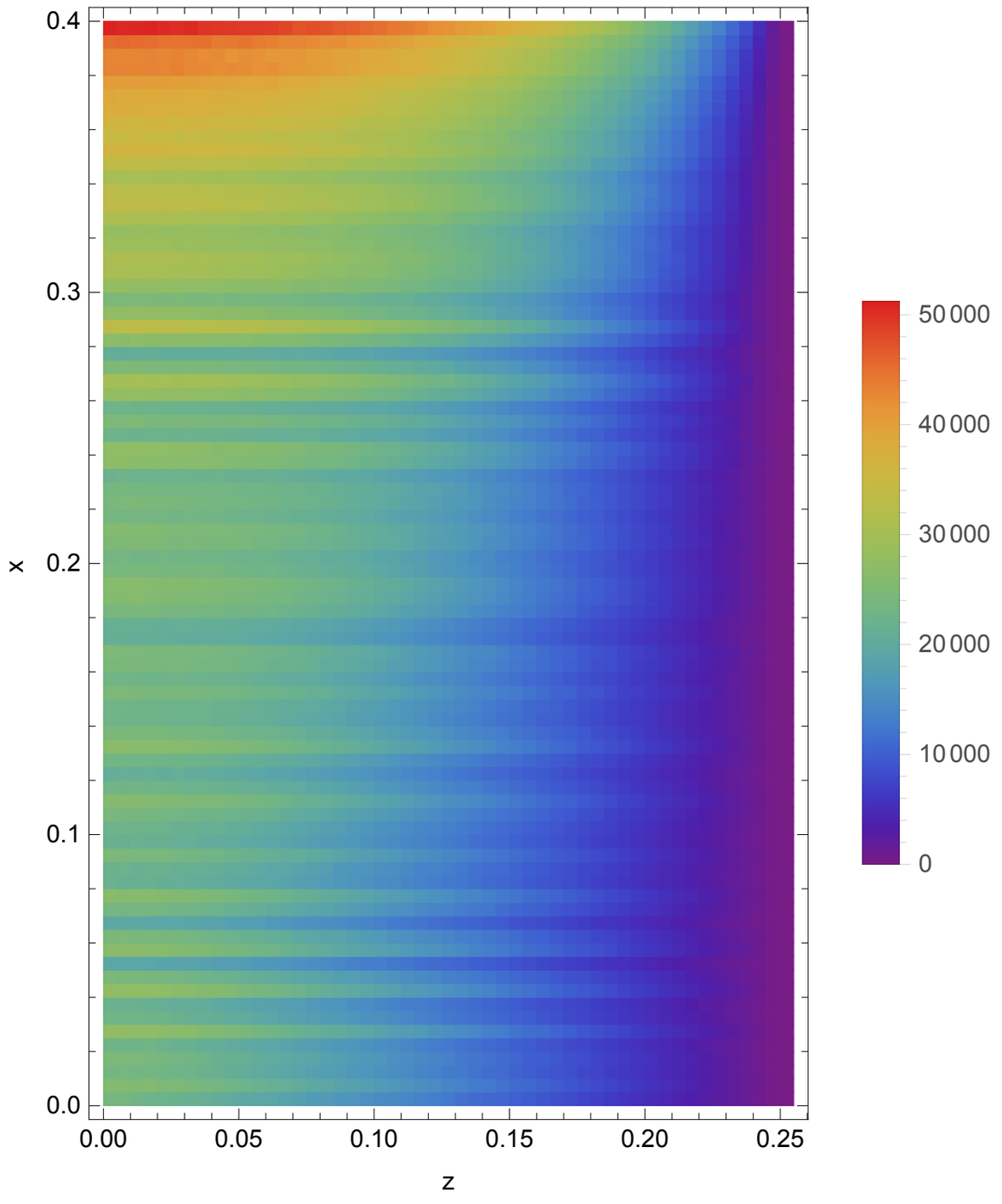
Sensitivity - central z-plane



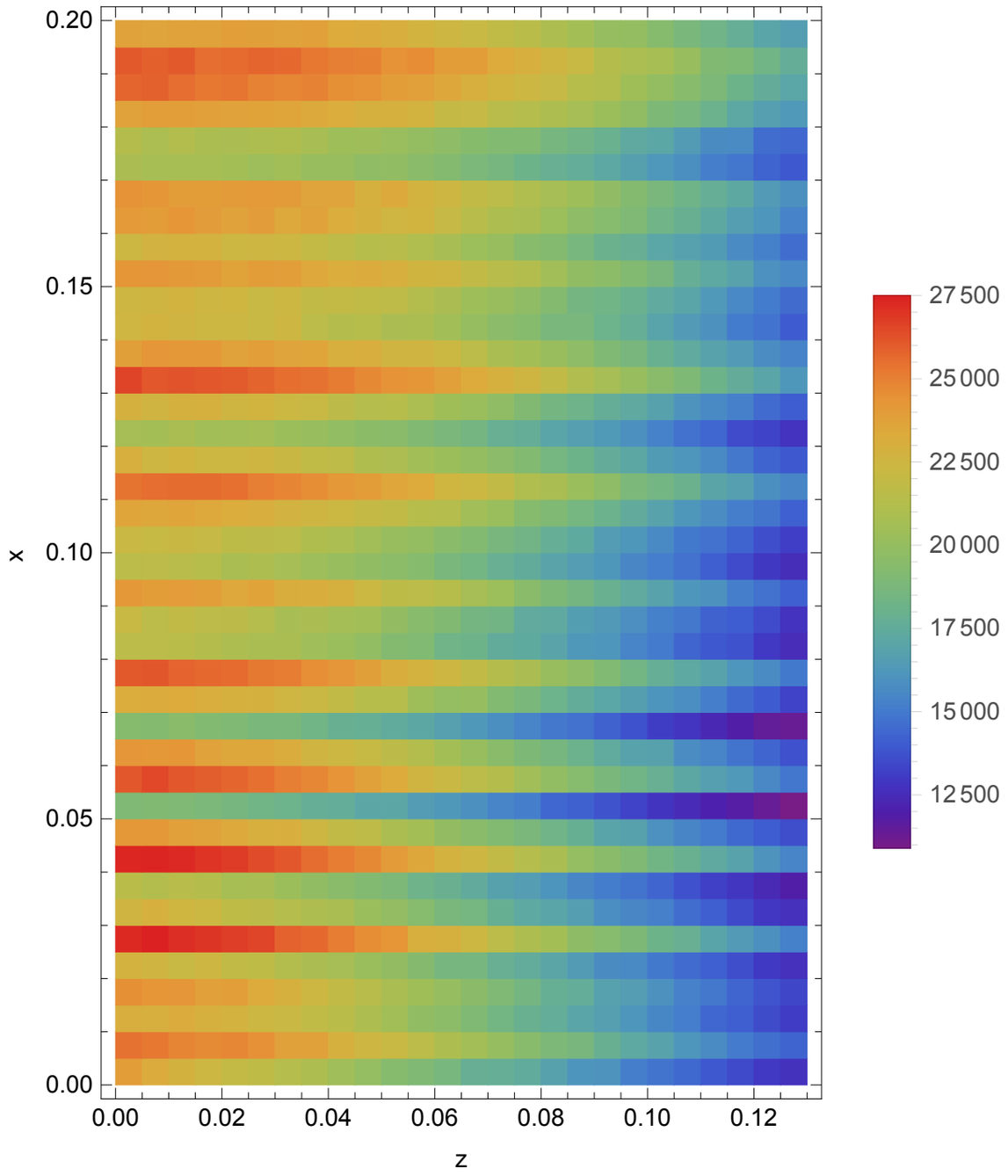
Sensitivity - central z-plane



Sensitivity - central y-plane



Sensitivity - central y-plane



Sumary

- In 2D we can achieve ~1cm resolution or better.
  - Better input data comming soon.
- 3D reconstruction looks promising but needs more work.
  - A good sensitivity map needed.
    - Several days of Monte-Carlo.