Gianluca Stringhini

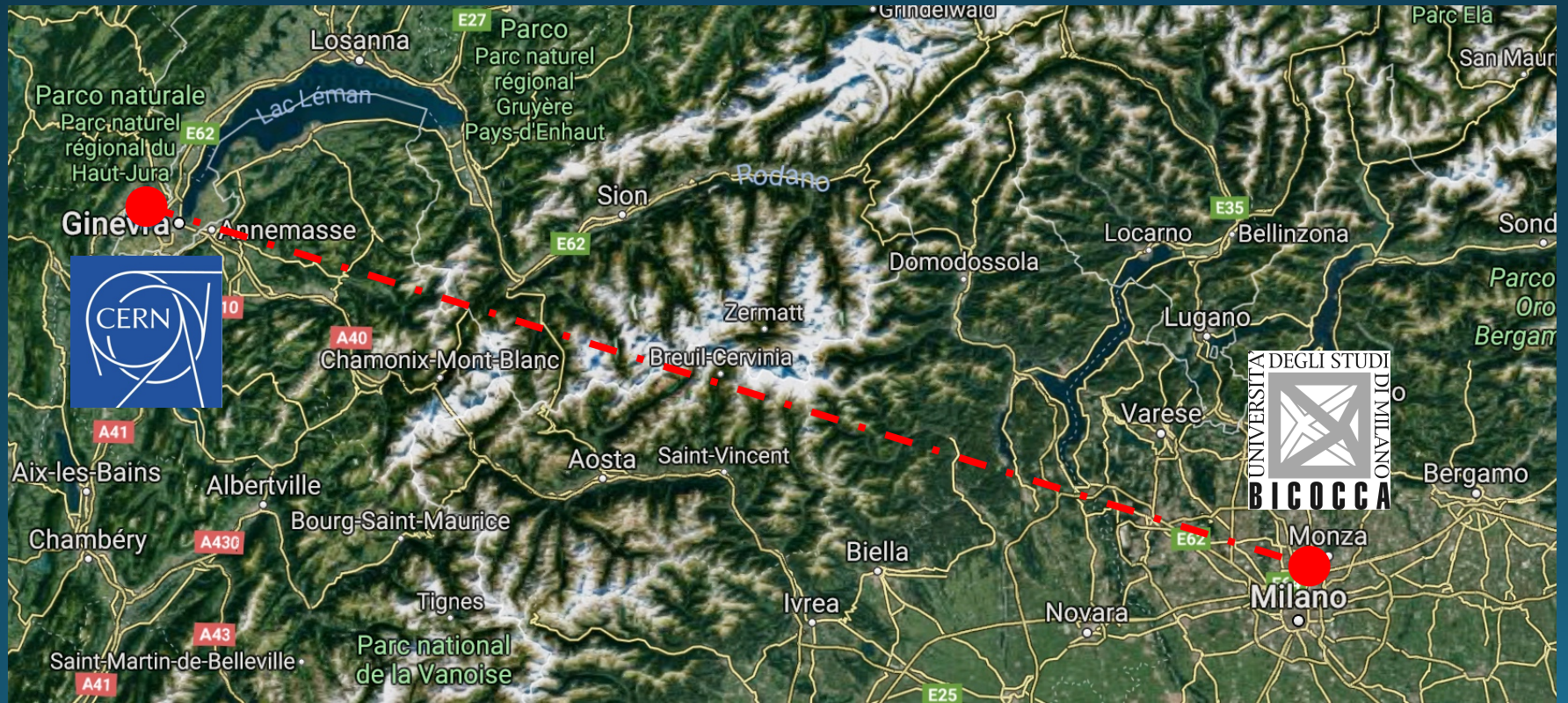
Image reconstruction algorithm applied to small PET systems

Prague, April, 14th 2018

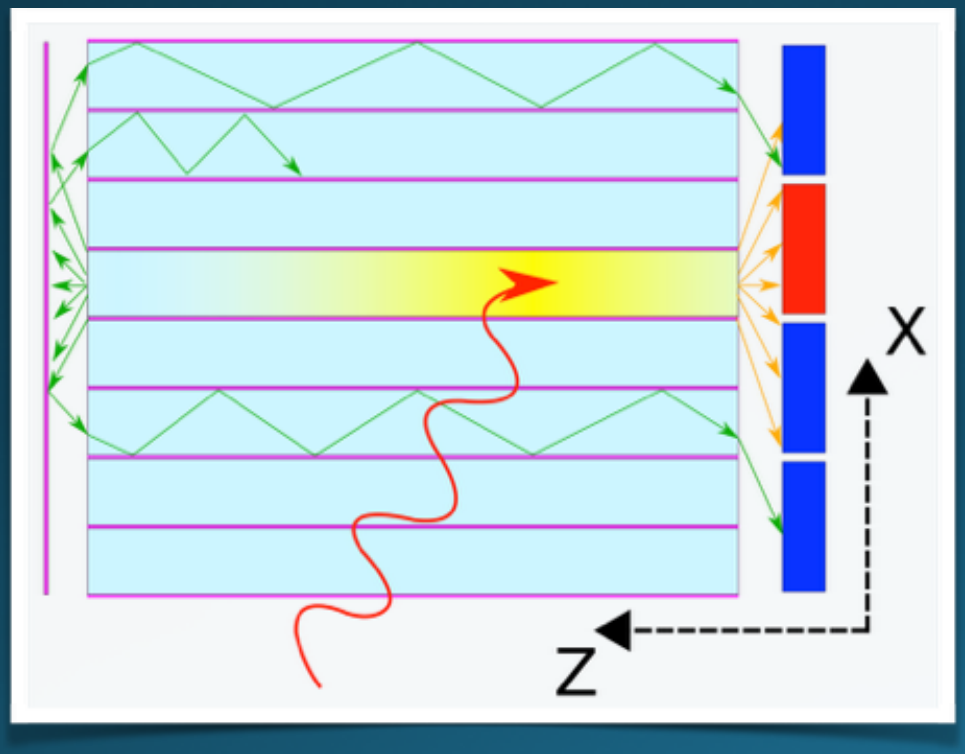
About me

- PhD at the University of Milano-Bicocca (Milan, IT)

- Doctoral Student at CERN (Geneva,CH)

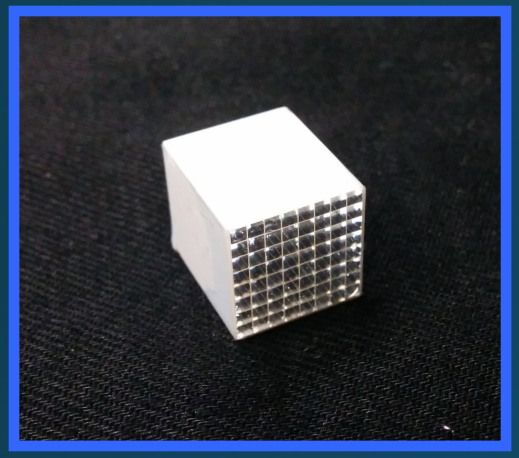


The innovative PET module



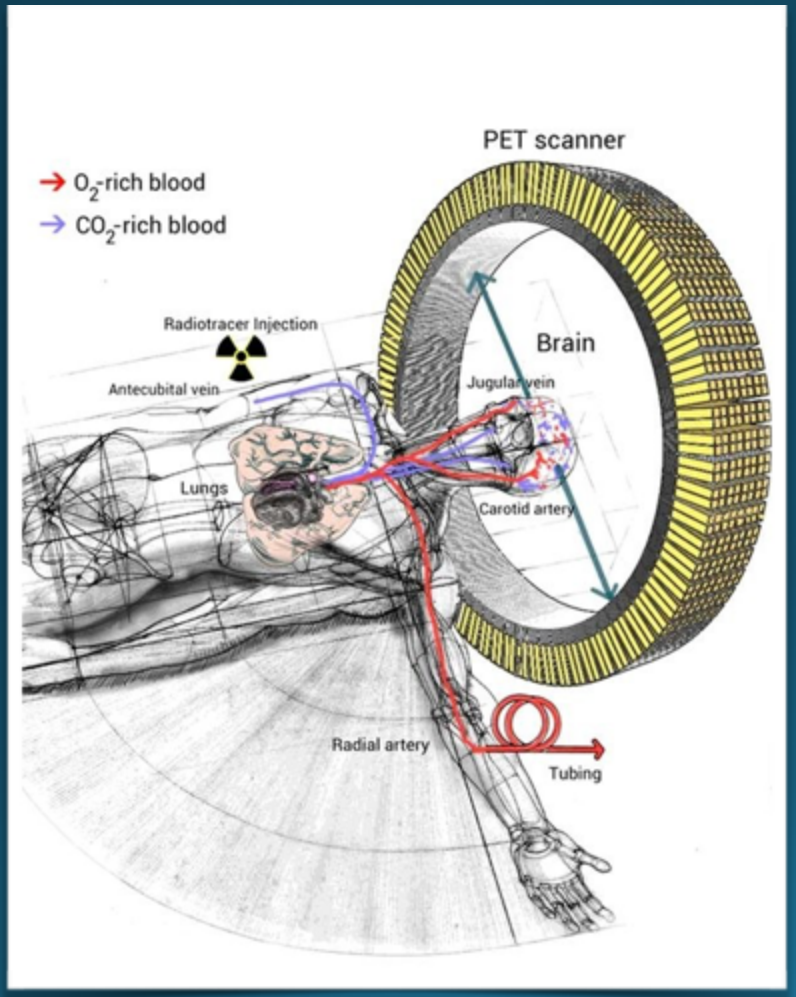
- 8x8 LYSO matrix (crystal dimension 1.5x1.5x15mm^3).
- 4 to one coupling between the scintillators and the detector (4x4 MPPC array).
- Recirculation of the light by using a reflector.
- Lateral surface of the crystals optically treated to be unpolished.
- Light sharing mechanism to obtain the depth of interaction (DOI) information.

The innovative PET module



- Excellent separation and identification of the single crystal energy spectrum.
- 10% FWHM energy resolution.
- 3 mm FWHM DOI resolution.
- Coincidence Time Resolution (CTR) less then 300 ps FWHM.
- Fast and precise method to obtain the DOI calibration.

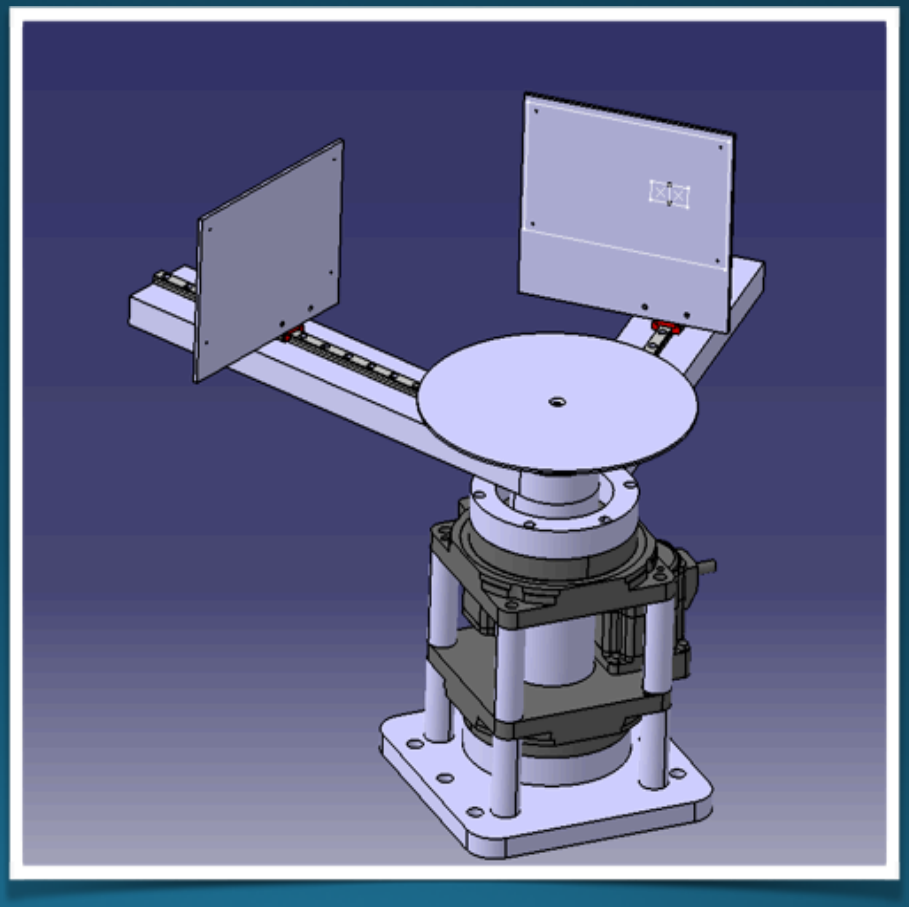
PET reconstruction



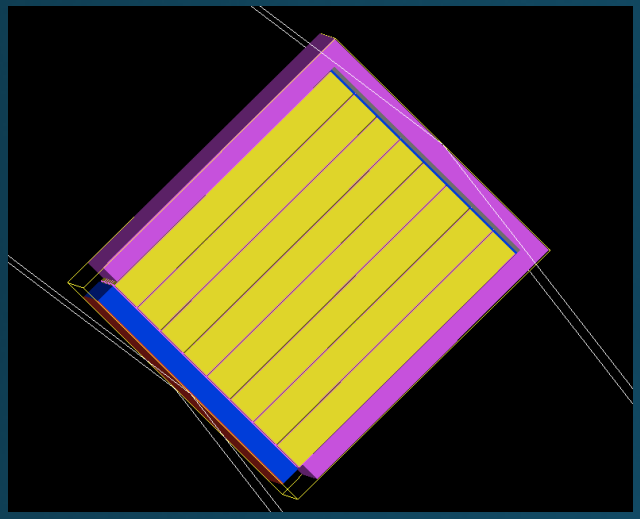
- Radiotracer labelled with a positron emmitter.
- Positron annihilation and production of two back-to-back gammas (511 KeV).
- Detection of the two gamma in coincidence.

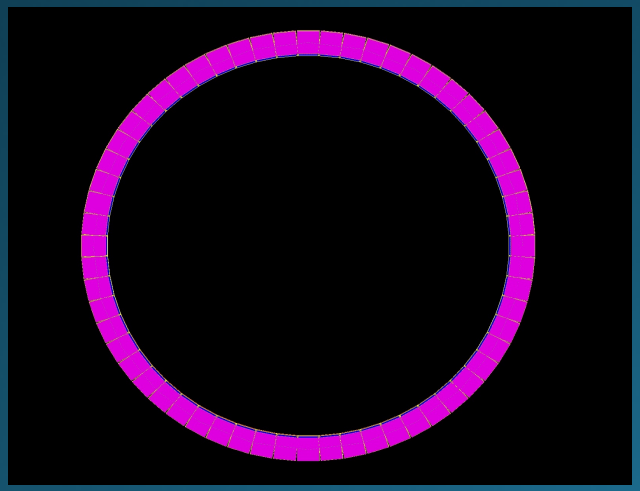
Small PET demonstrator

- Two arms that rotate indipendently.
- Variable distance between the modules
- Charge integration.
- Time stamp of each event.



Small PET demonstrator





Using GATE simulation software:

- 480 detectors per ring
- 60 sectors
- 8 rings
- 25 cm diameter
- vacuum

Simulated Na^{22} sources:

- Normalization cylinder (radius 10.5 cm)
- Cylinder for the reconstruction (radius 5.5 cm)
- Line of 1 mm diameter cylindrical source separate by 5 mm

Software for Tomographic Image Reconstruction

- Last version of STIR.
- Iterative algorithm to perform the reconstruction based on a sinogram approach.
- Help from Nikos Efthimiou from the Hull University.

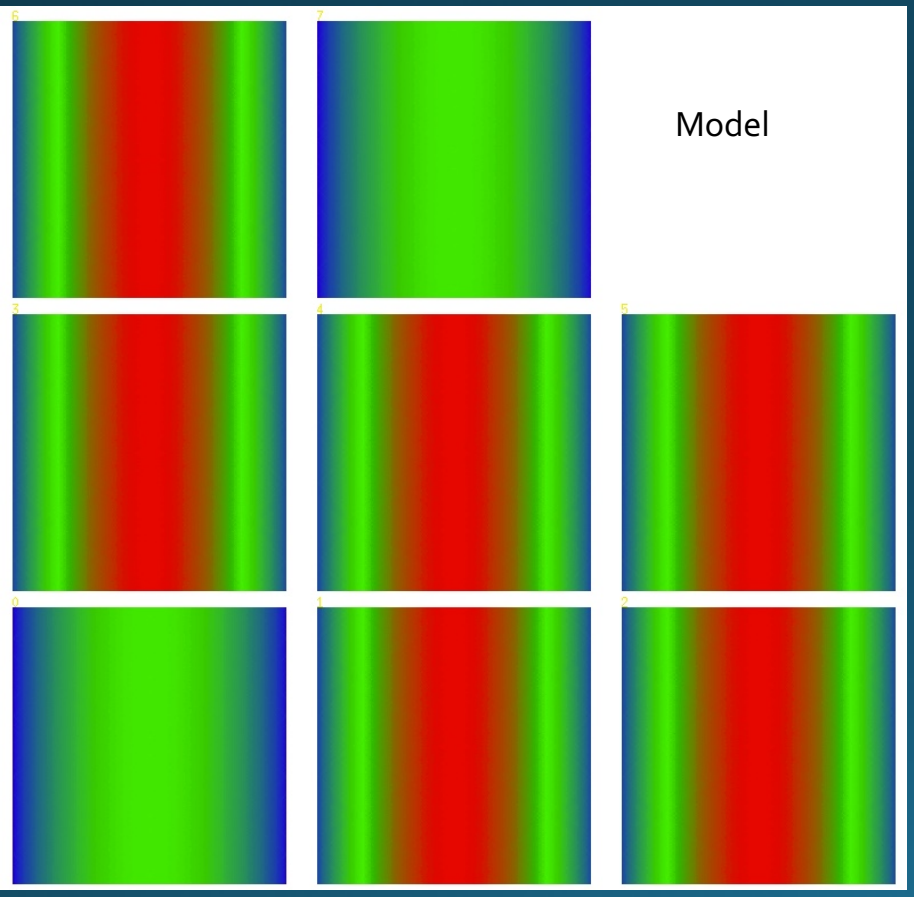
STIR

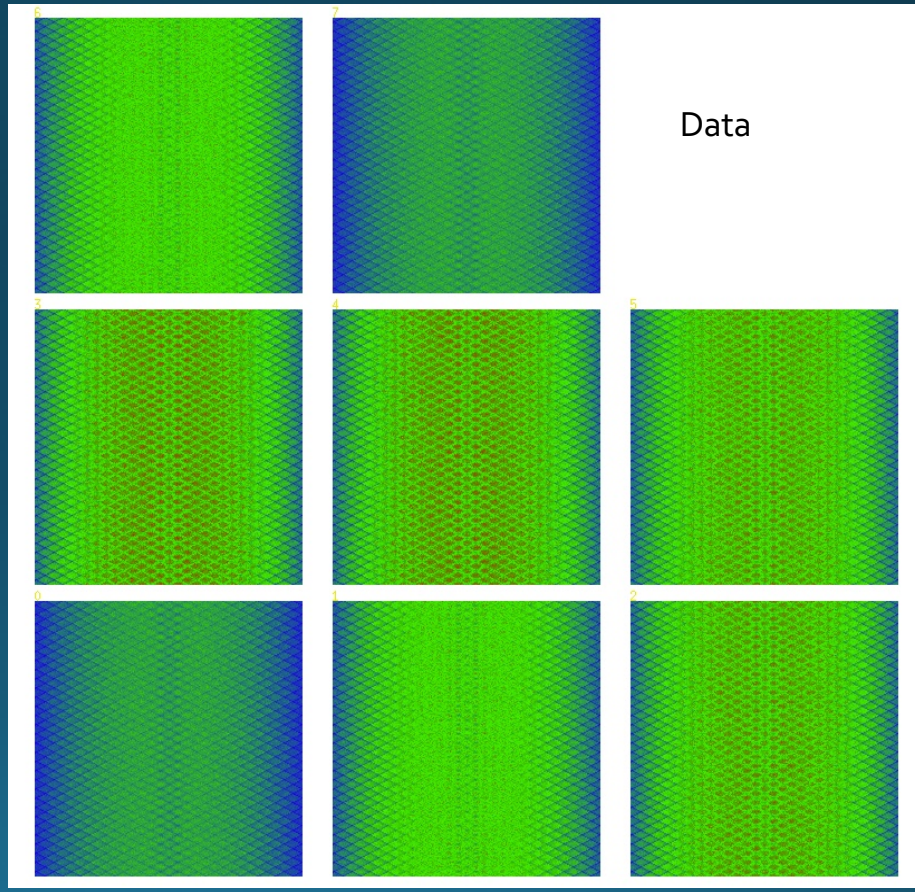
Software for Tomographic Image Reconstruction

STIR is Open Source software for use in tomographic imaging. Its aim is to provide a Multi-Platform Object-Oriented framework for all data manipulations in tomographic imaging. Currently, the emphasis is on (iterative) image reconstruction in PET and SPECT, but other application areas and imaging modalities can and might be added.

STIR is the successor of the PARAPET software library which was the result of a (European Union funded) collaboration between 6 different partners (see Credits).

Sinogram approach for the normalization





Normalization

$$n_{oivj} = b_o^{ax} \cdot b_v^{ax} \cdot g_{ov}^{ax} \cdot \varepsilon_{oi} \cdot \varepsilon_{vj} \cdot g_{x_r,(i,j)}^{tr} \cdot f_{x_r,(i,j)d}^{tr}$$

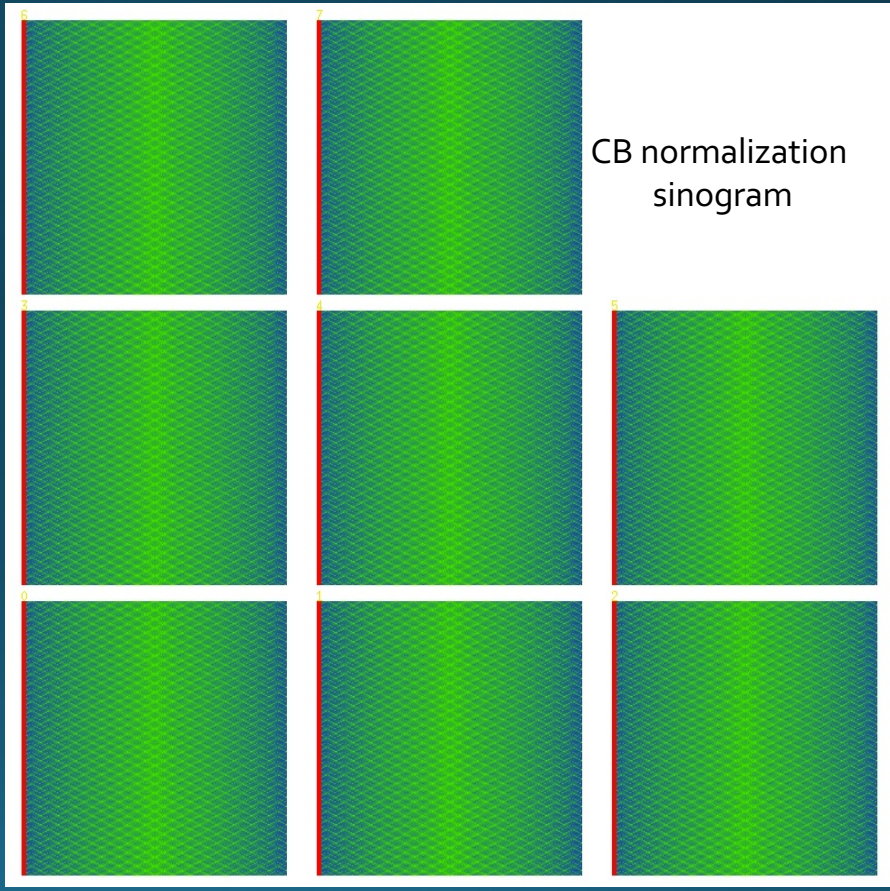
Axial block profile factor

Axial geometric factor

Intrinsic detector efficiency

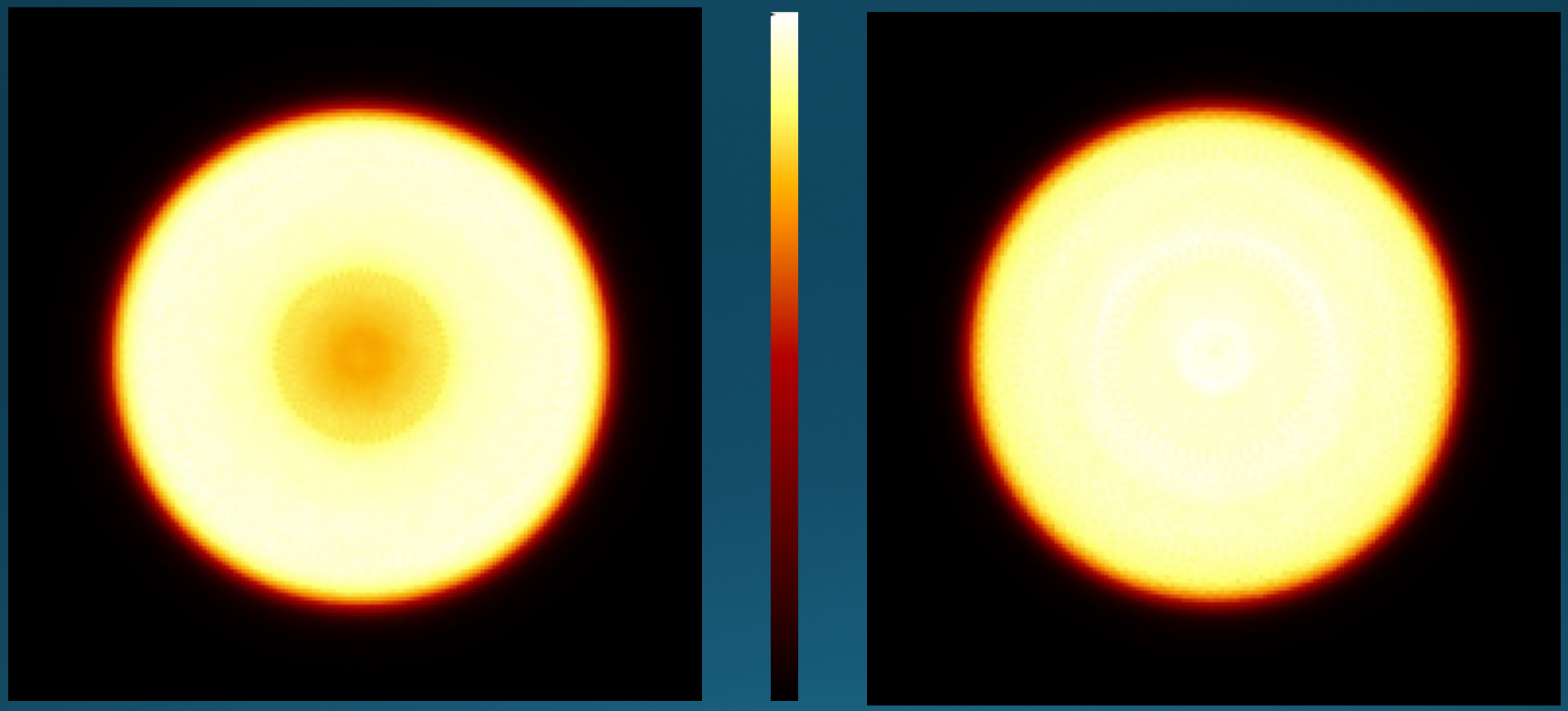
Transverse geometric factor

Modulated transverse geometric function



CB normalization sinogram

Graphic comparison



Raw data

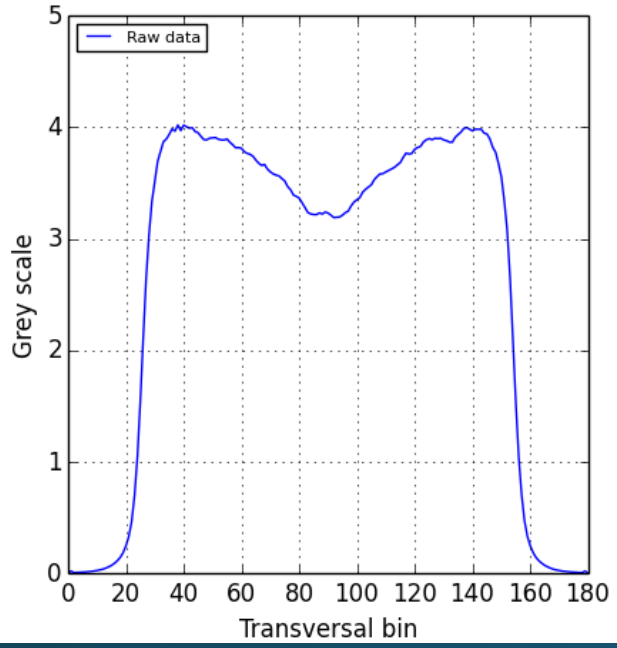
Normalized Data

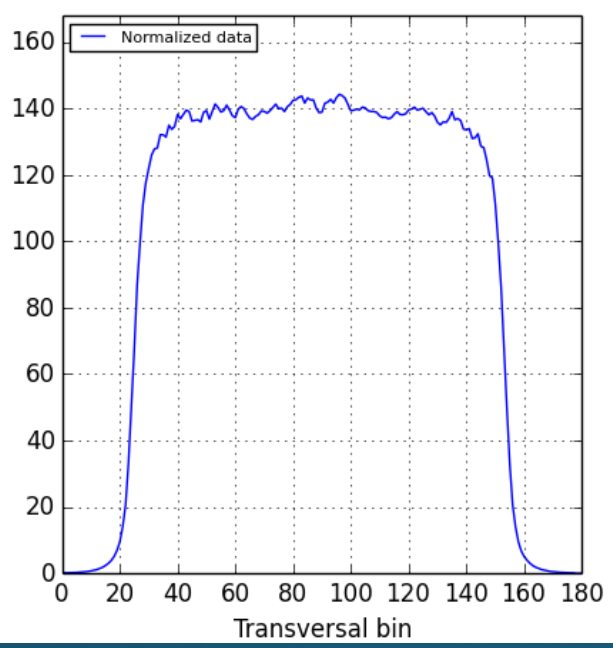
Graphic comparison

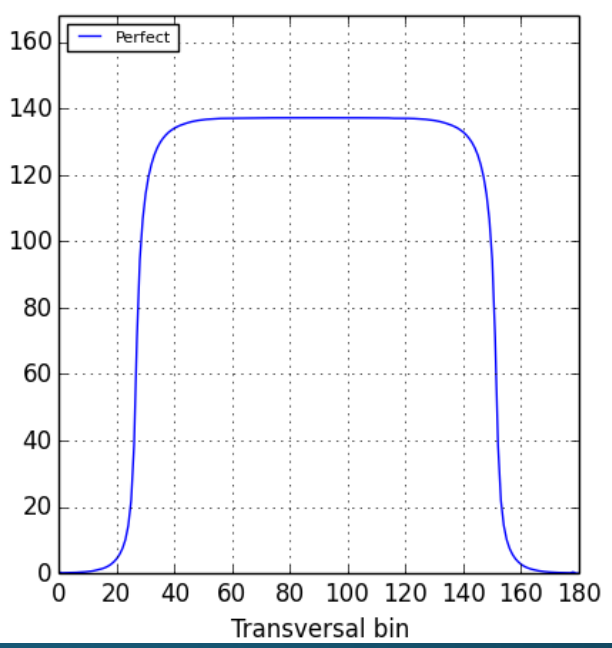
Raw data

Normalized Data

Profiles





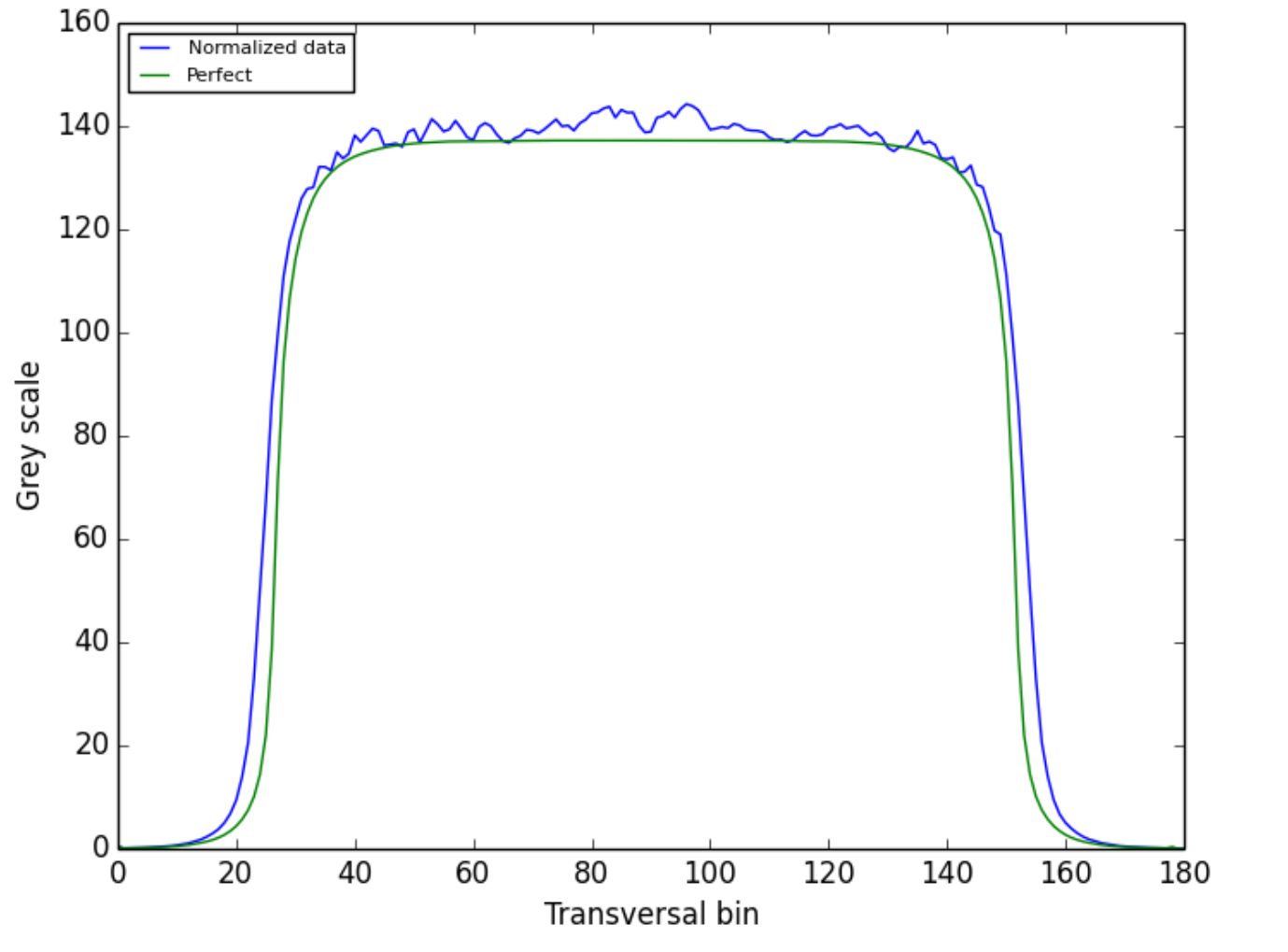


Raw data

Normalized data

Target reconstruction

Profiles


Normalized data
Perfect
Grey scale
Transversal bin
0
20
40
60
80
100
120
140
160
180

The DOI: the STIR game stopper

STIR advantages:

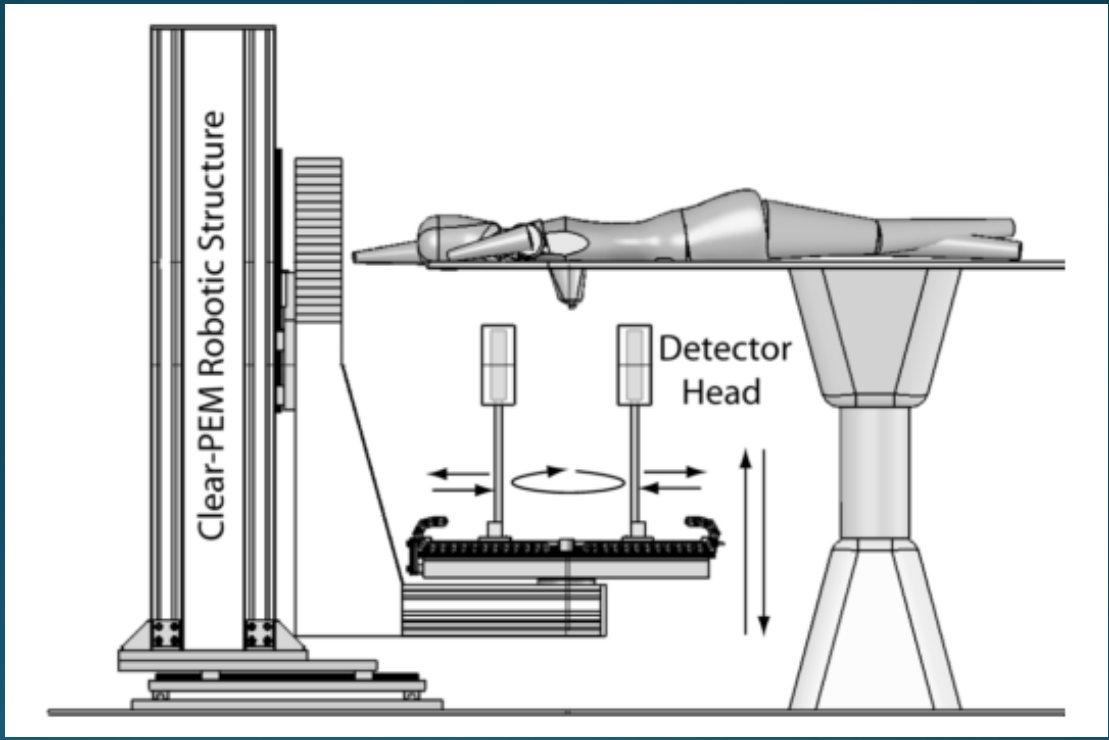
- Adaptable to different scanner geometry.
- Possibility to perform operation on sinograms.

STIR disadvantages:

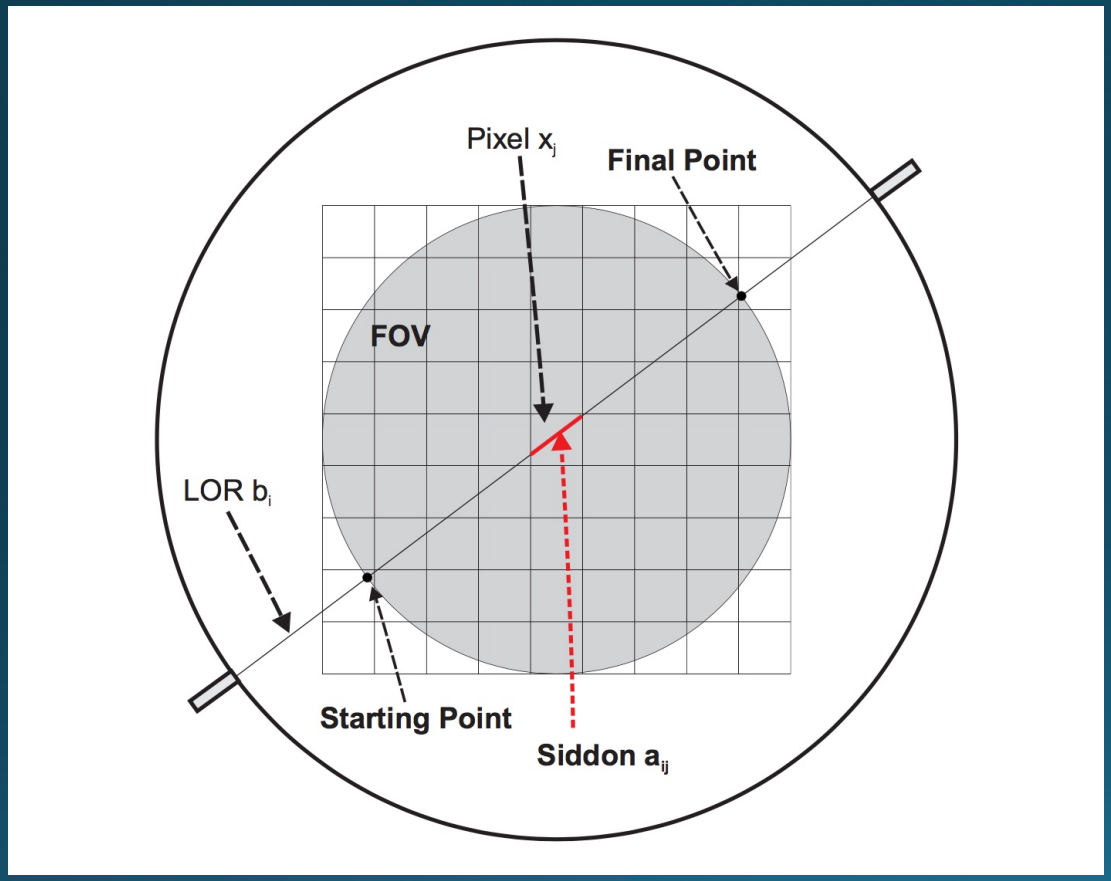
- Cylindrical geometry.
- No multilayer structure.

The ClearPEM algorithm

- List mode MLEM iterative reconstruction:
- Siddon ray-tracing algorithm.
- Metz filter.
- Dual plates geometry.



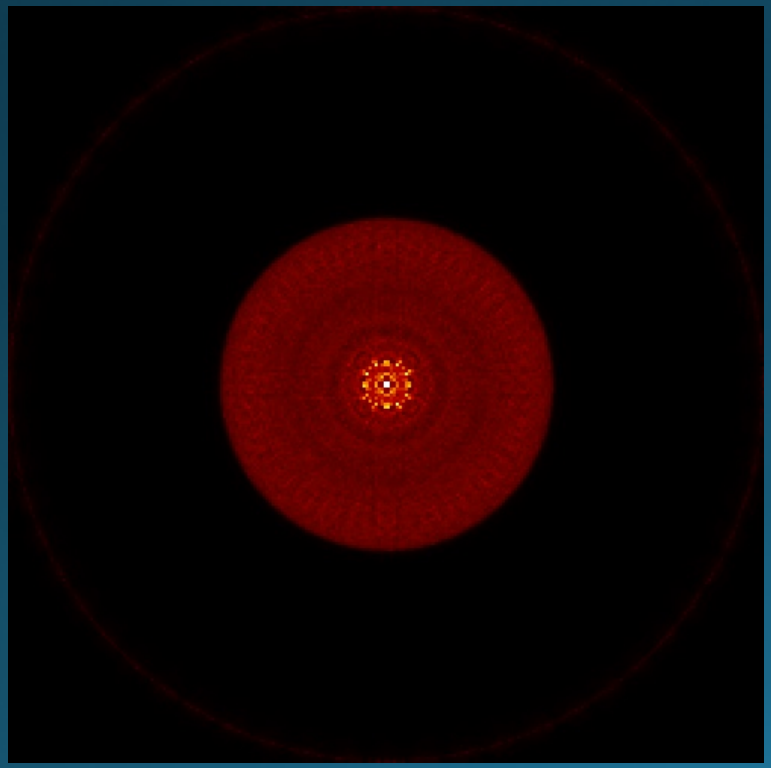
Siddon ray-tracing algorithm

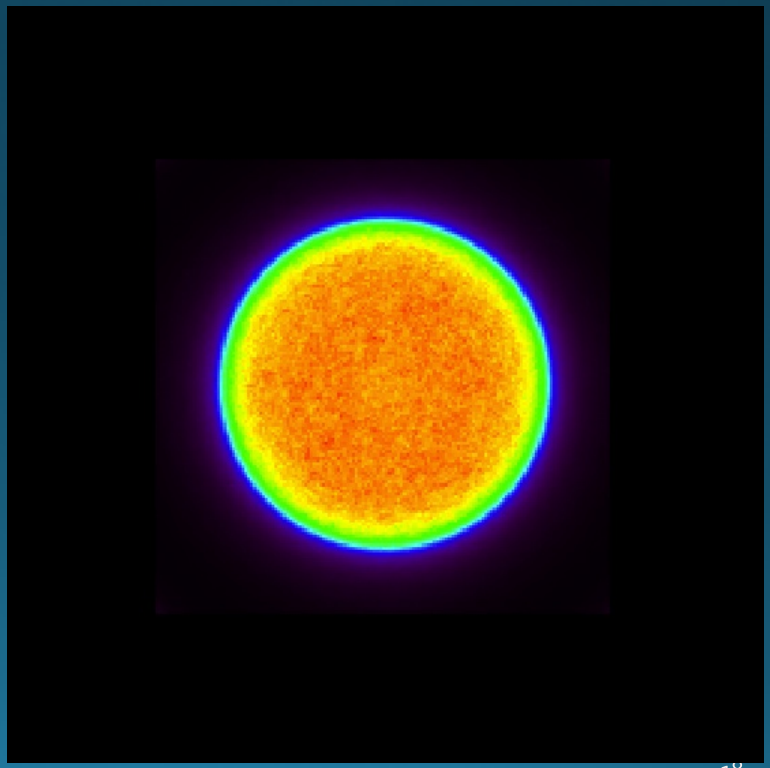


The LOR is fully described by using the coordinate of the interaction point of the gammas with the detectors. Easy to adapt this algorithm to a complete detectors ring.

Normalization

- Normalization is performed by dividing the images by the a sensitivity map obtained by an acquisition of a big cylindrical source (radius 105 mm)





Normalization

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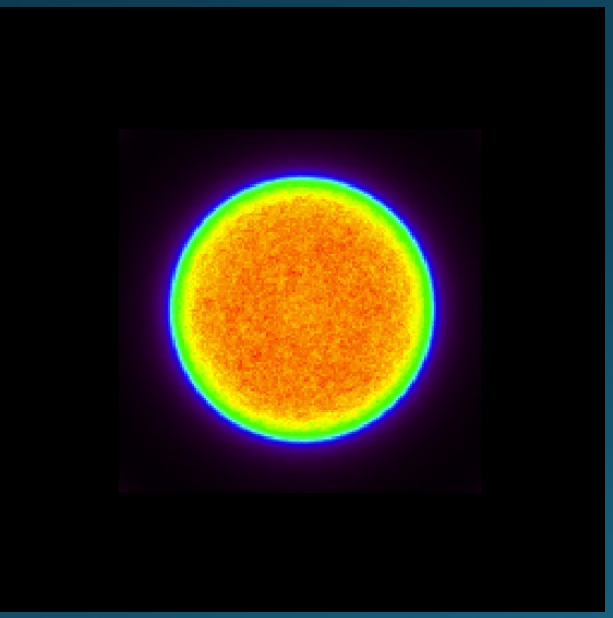
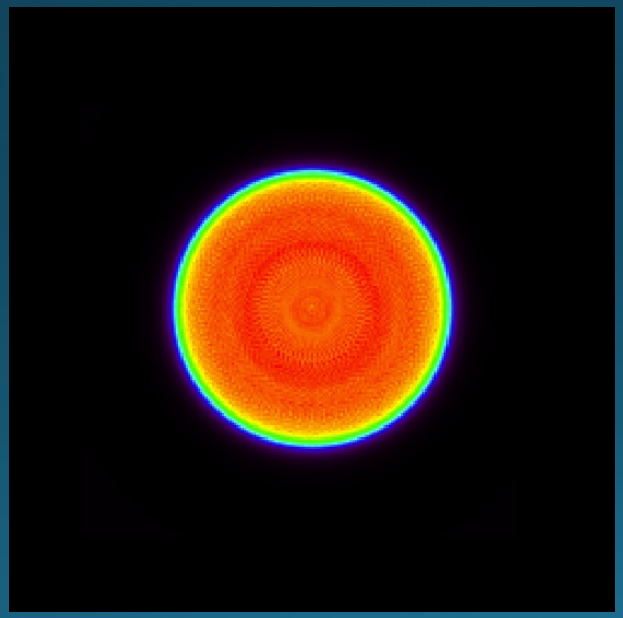
ClearPEM normalization

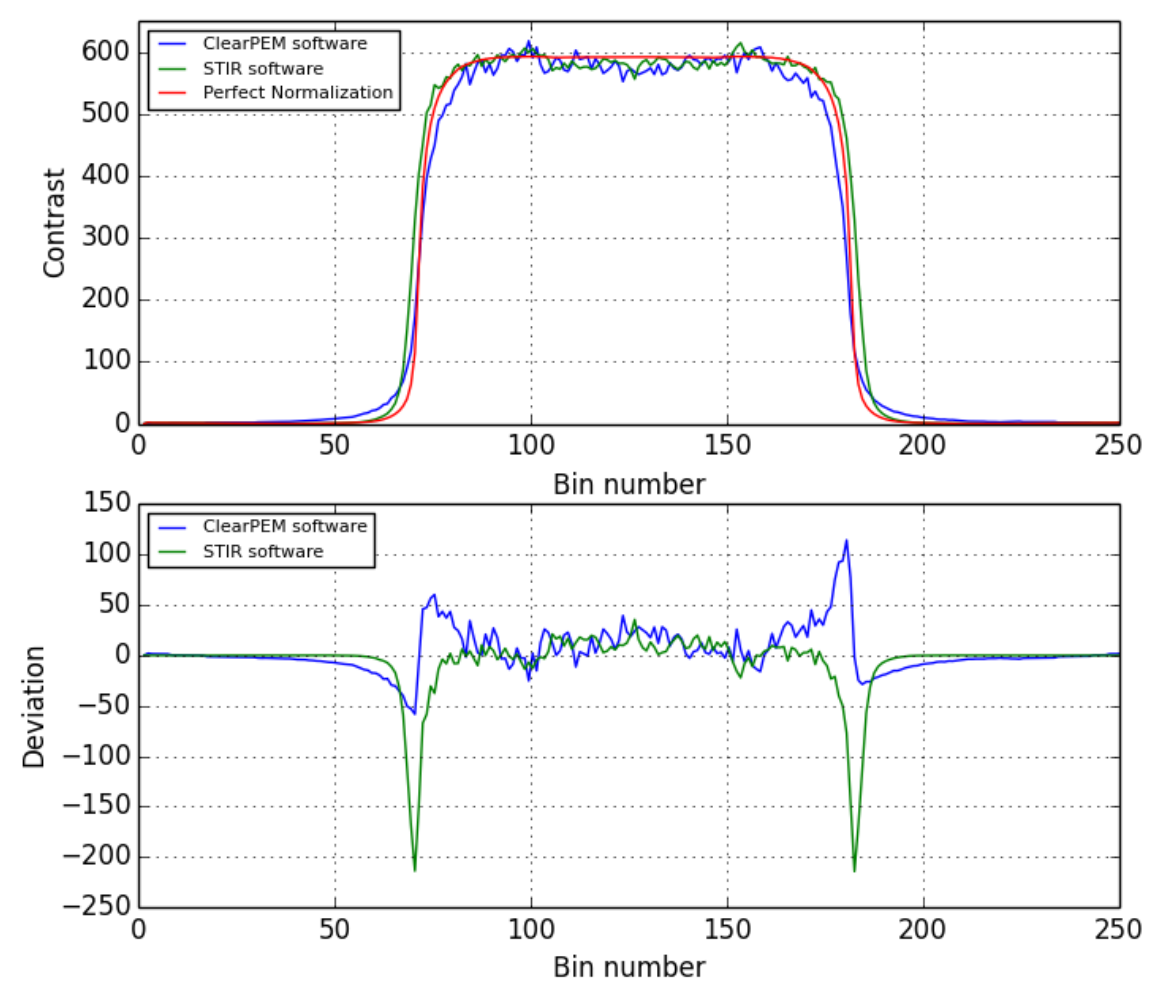


STIR normalization

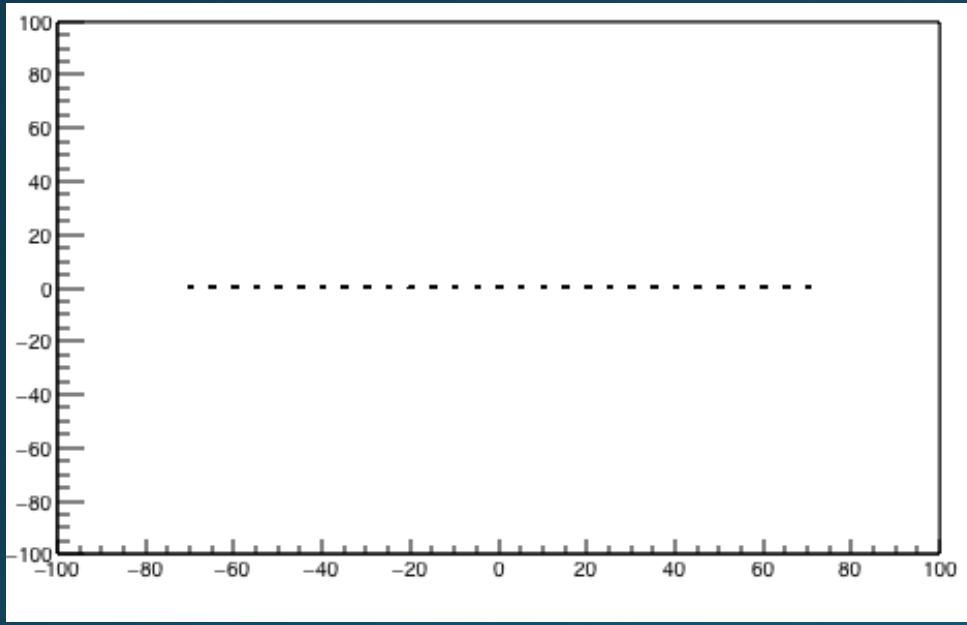


Perfect normalization

Normalization



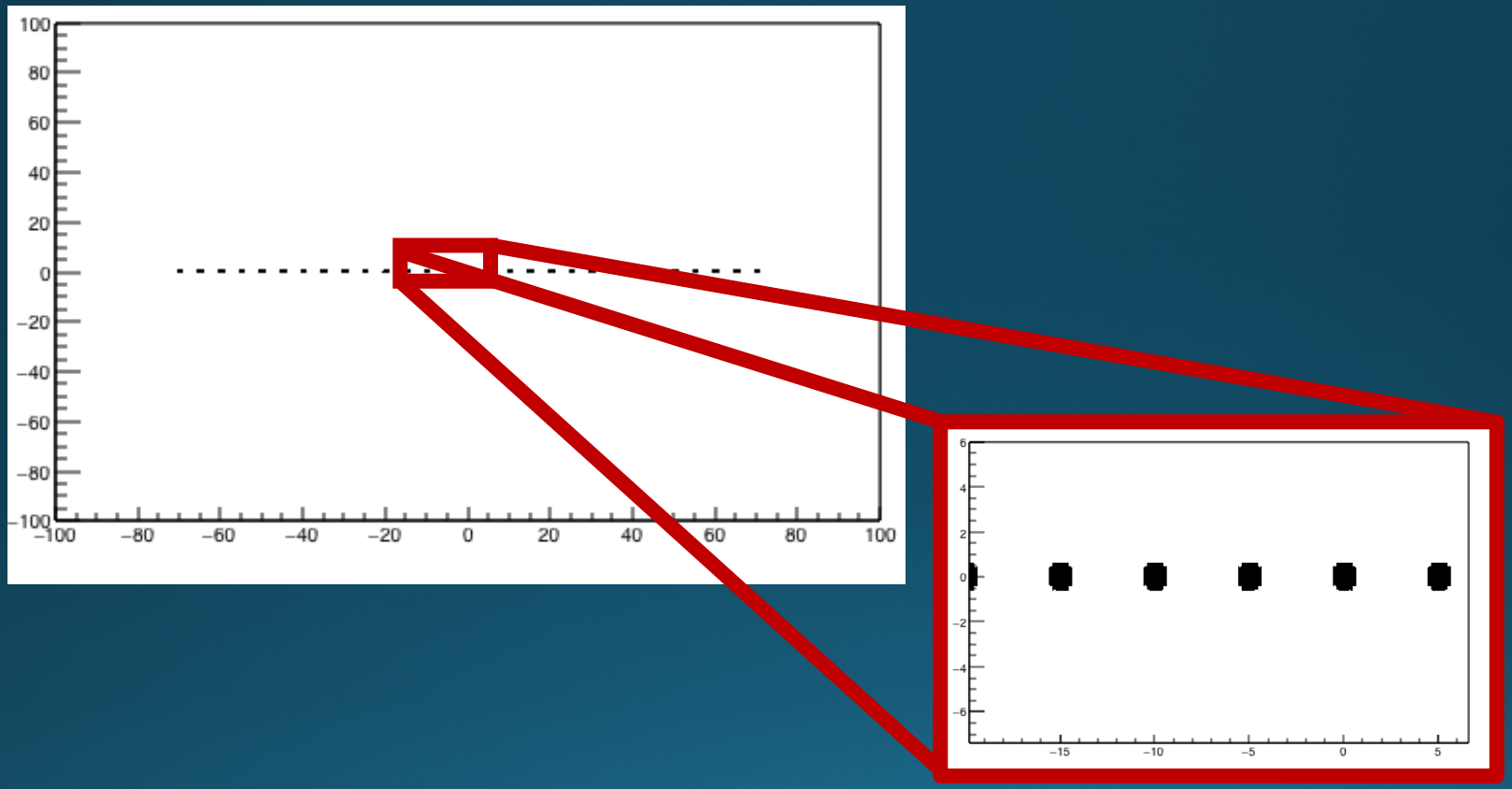
Line of sources



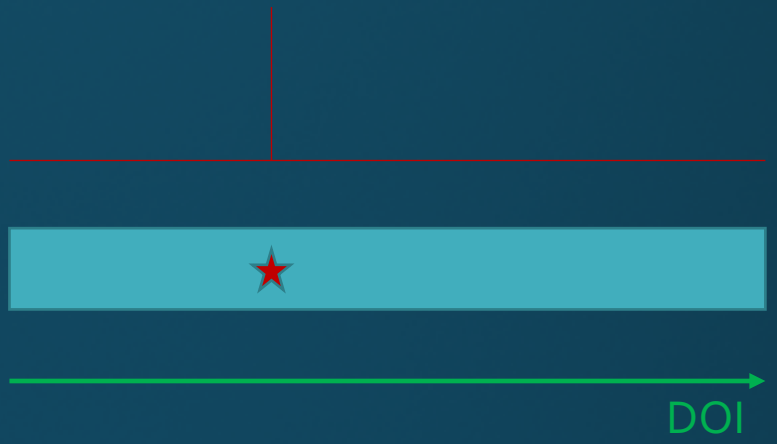
Simulations of cylindrical sources.

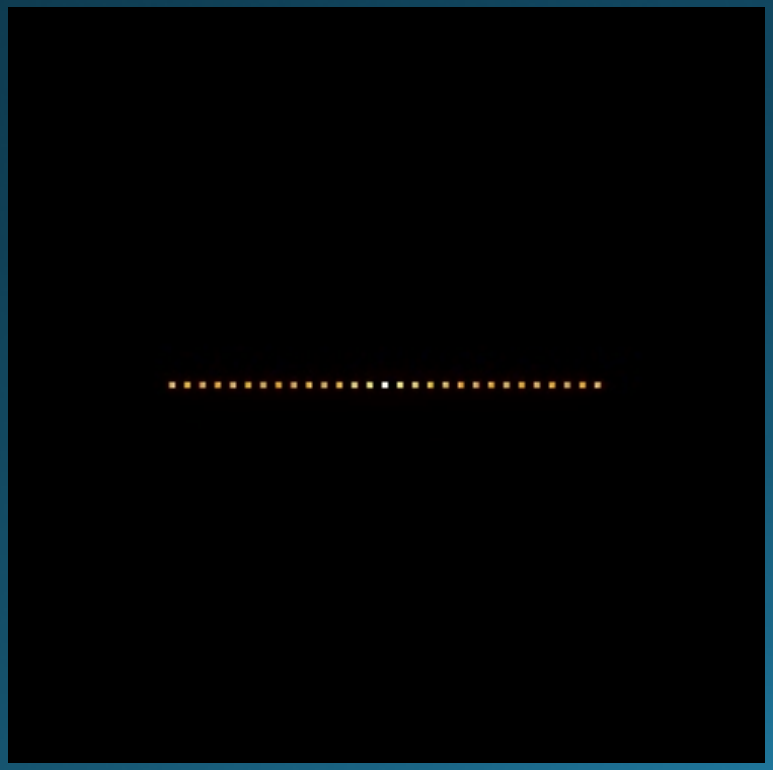
- 1 mm diameter.
- 5 mm distance between the sources.
- Cylinder height 10 mm.

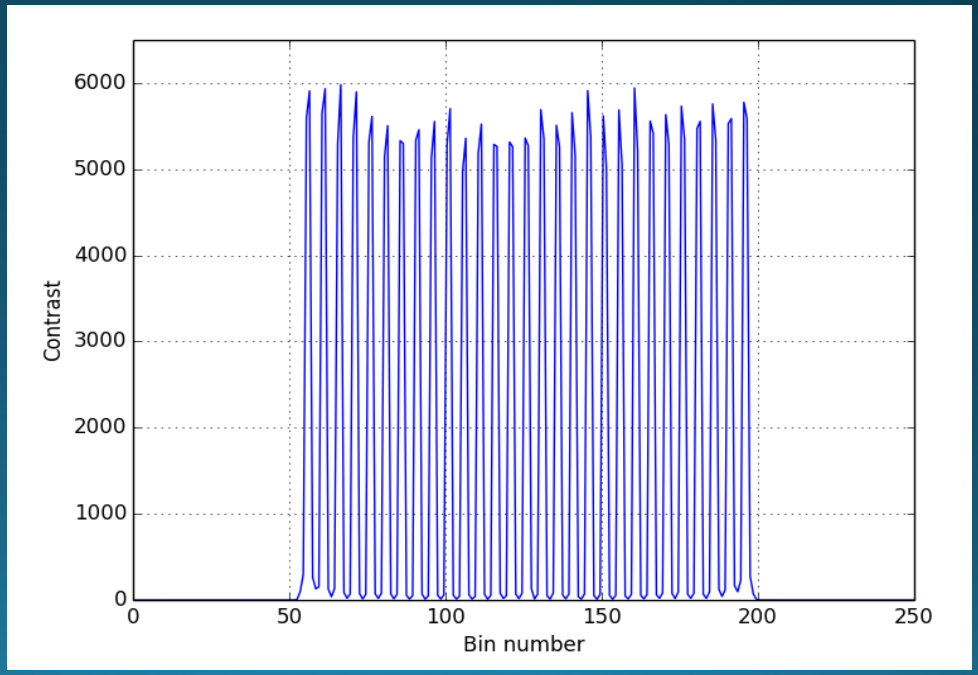
Line of sources



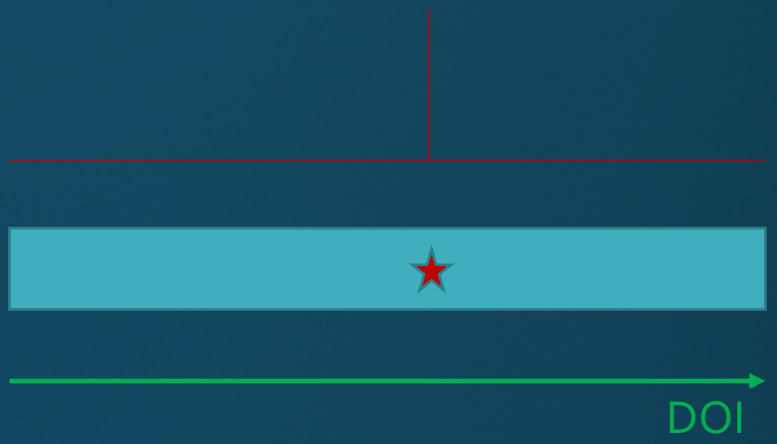
Reconstruction with infinite FWHM DOI resolution

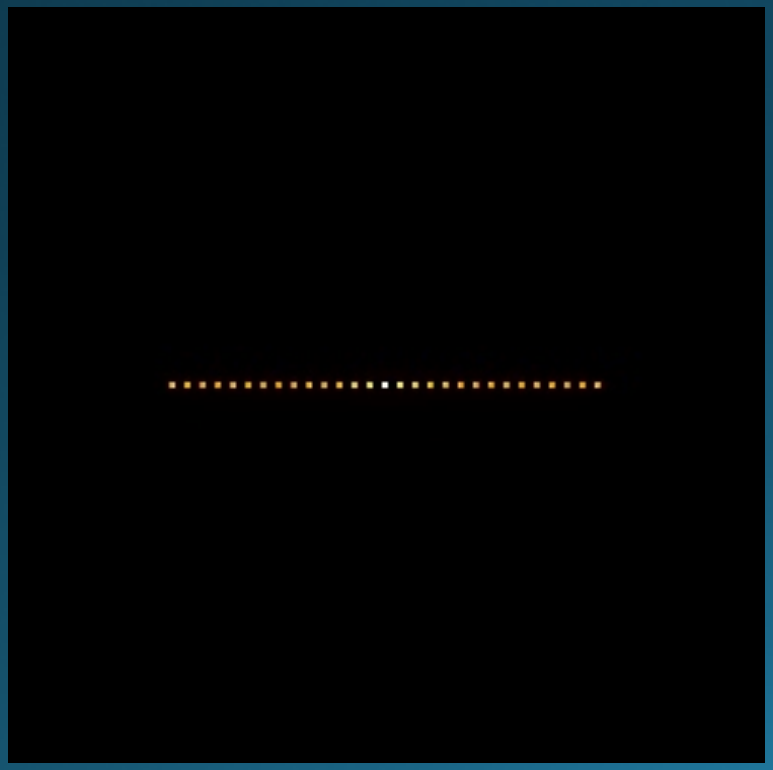


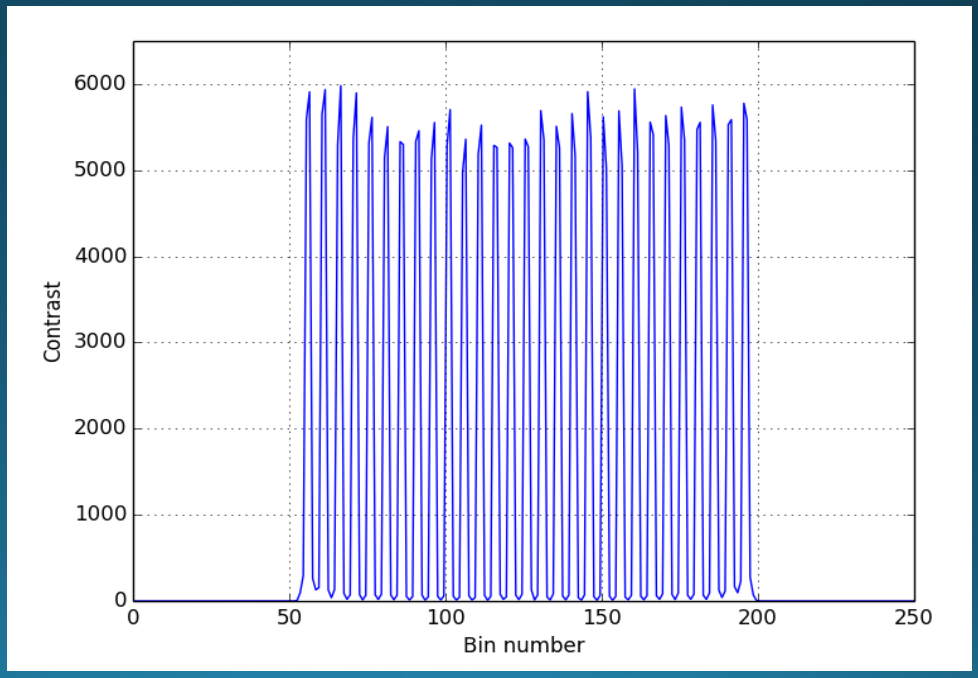




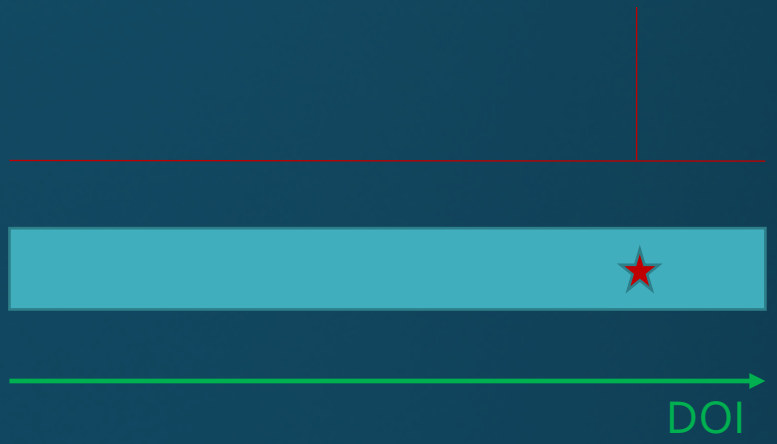
Reconstruction with infinite FWHM DOI resolution

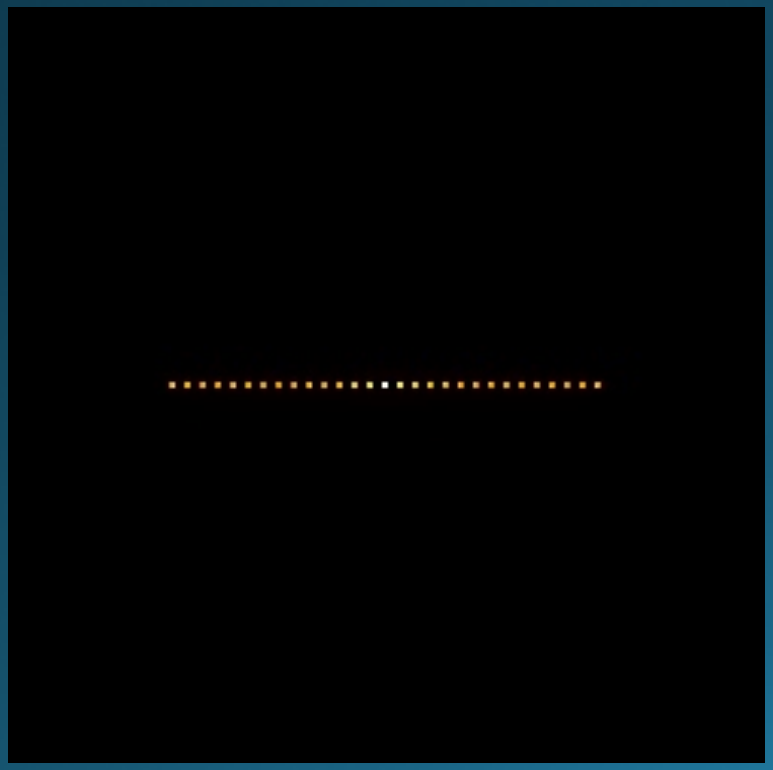


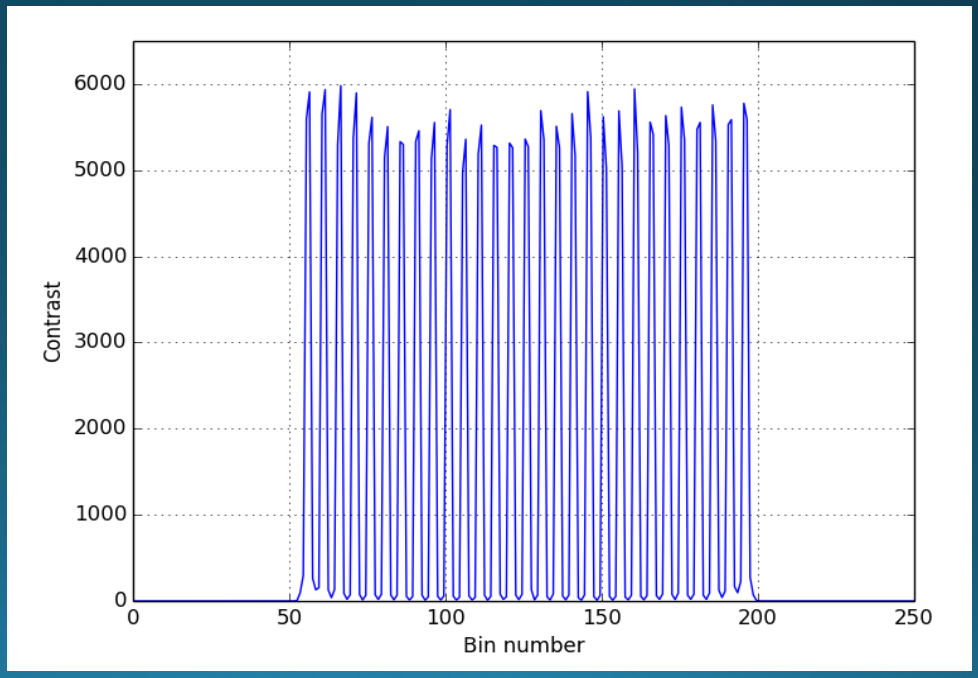




Reconstruction with infinite FWHM DOI resolution







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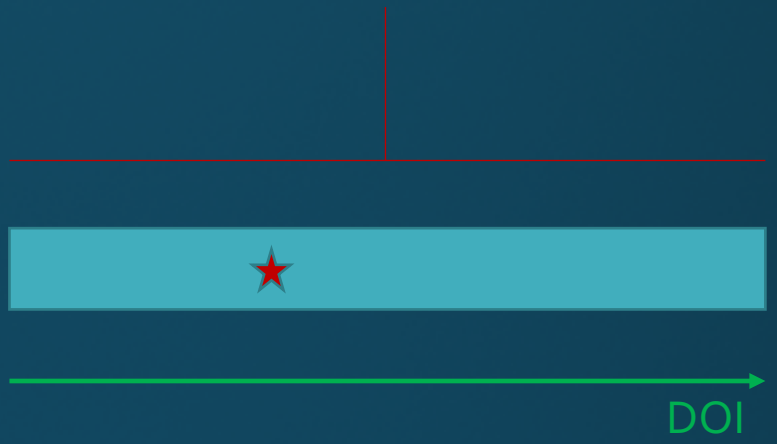
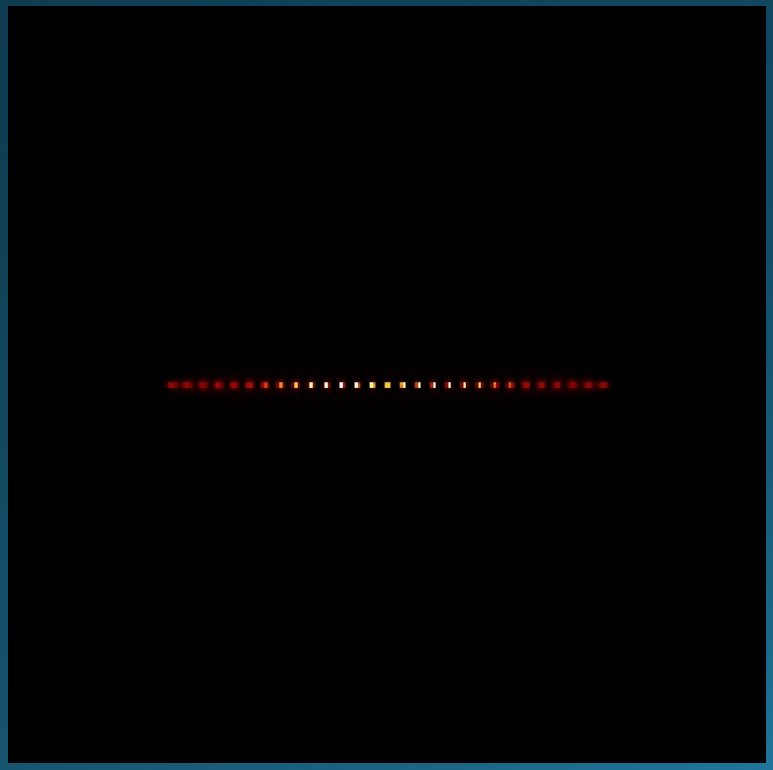
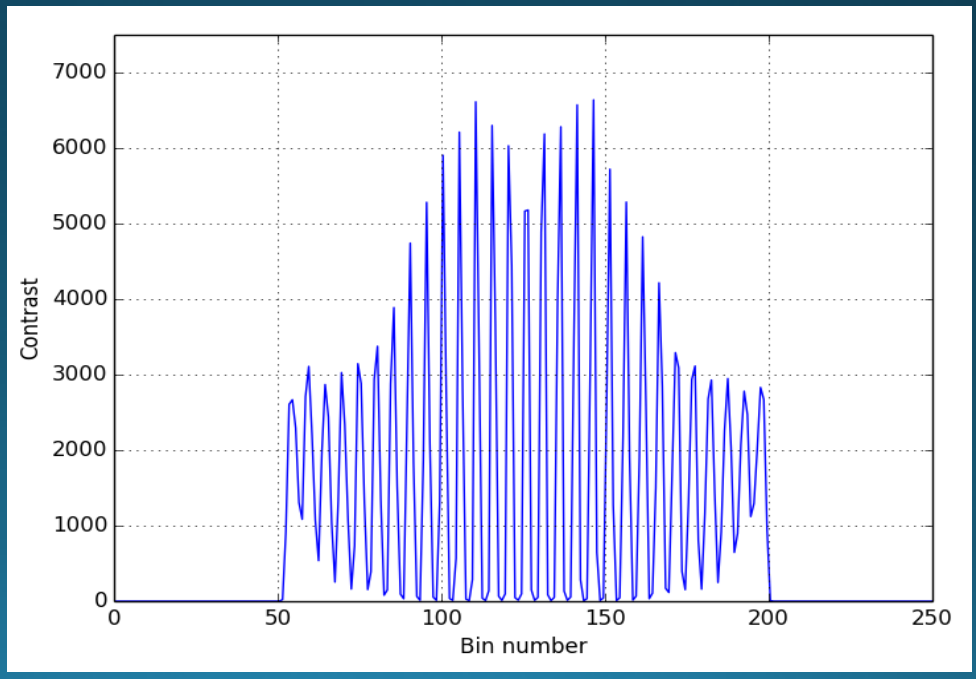
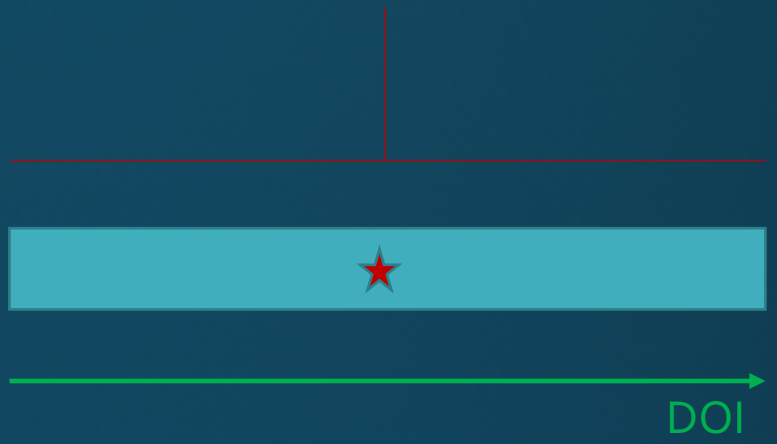
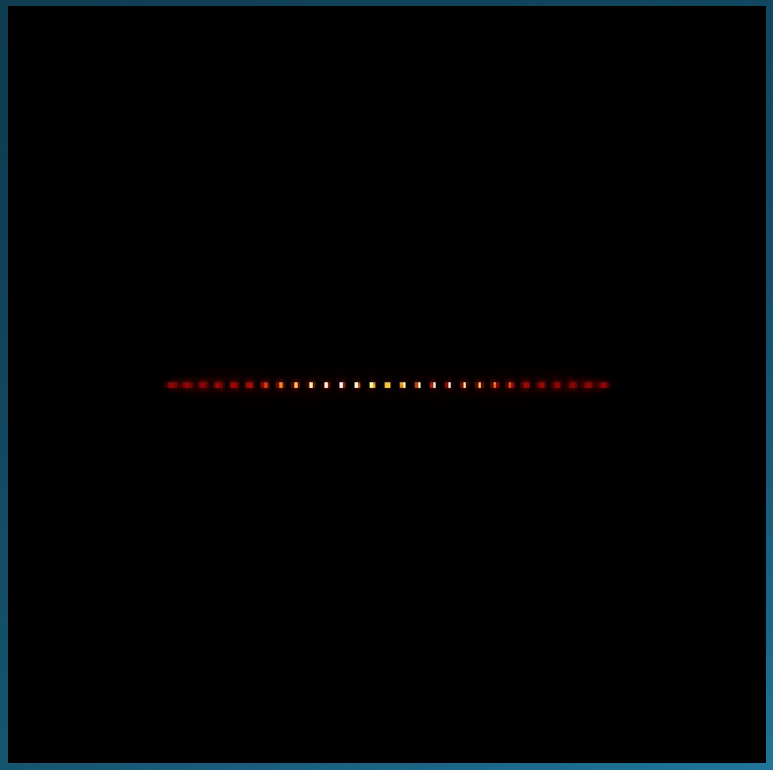


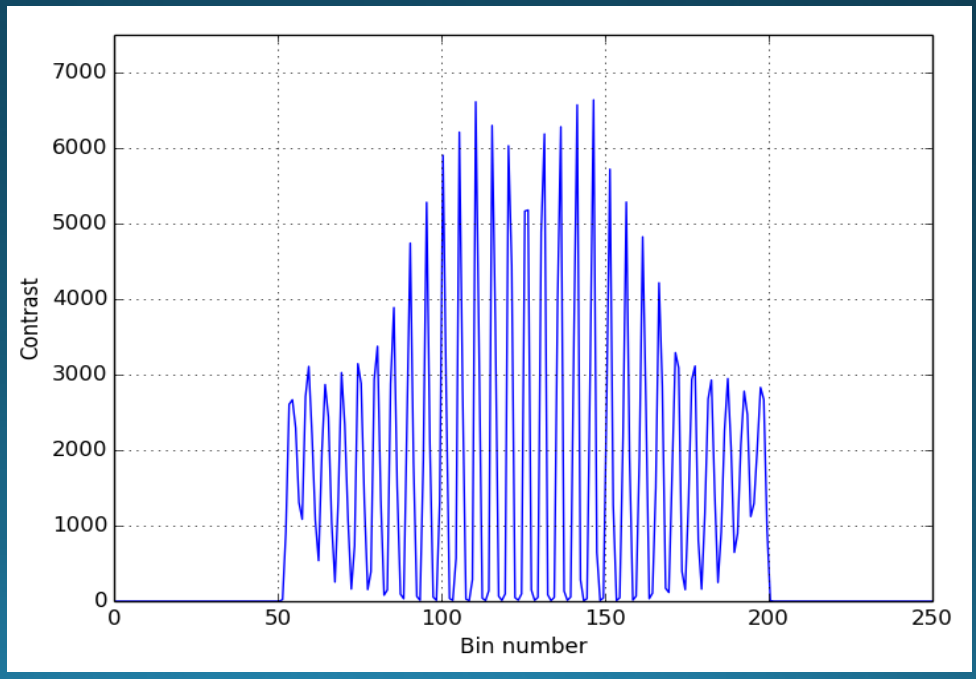




Reconstruction with no DOI







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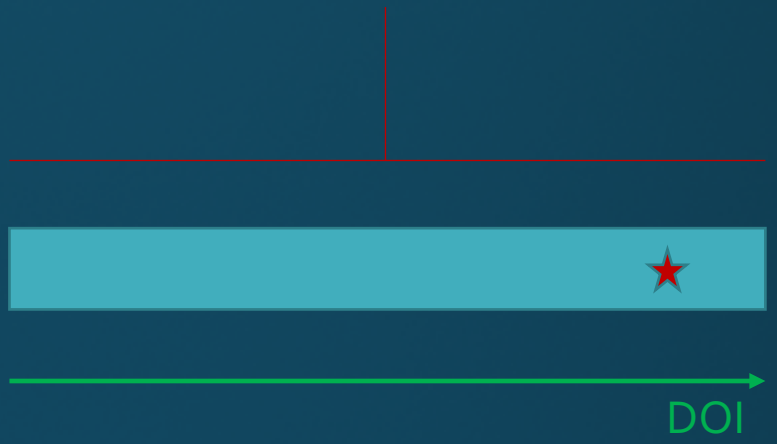
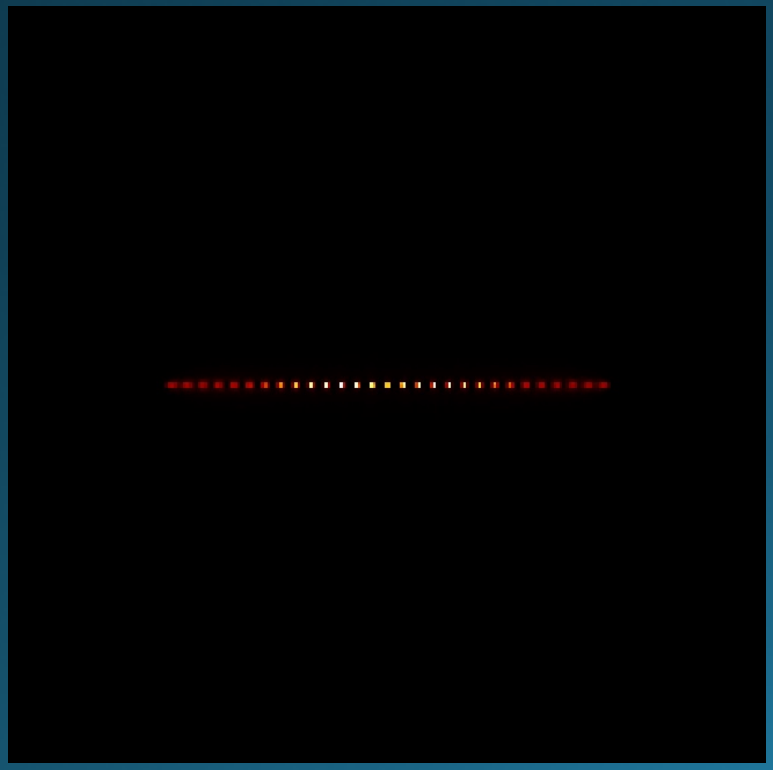
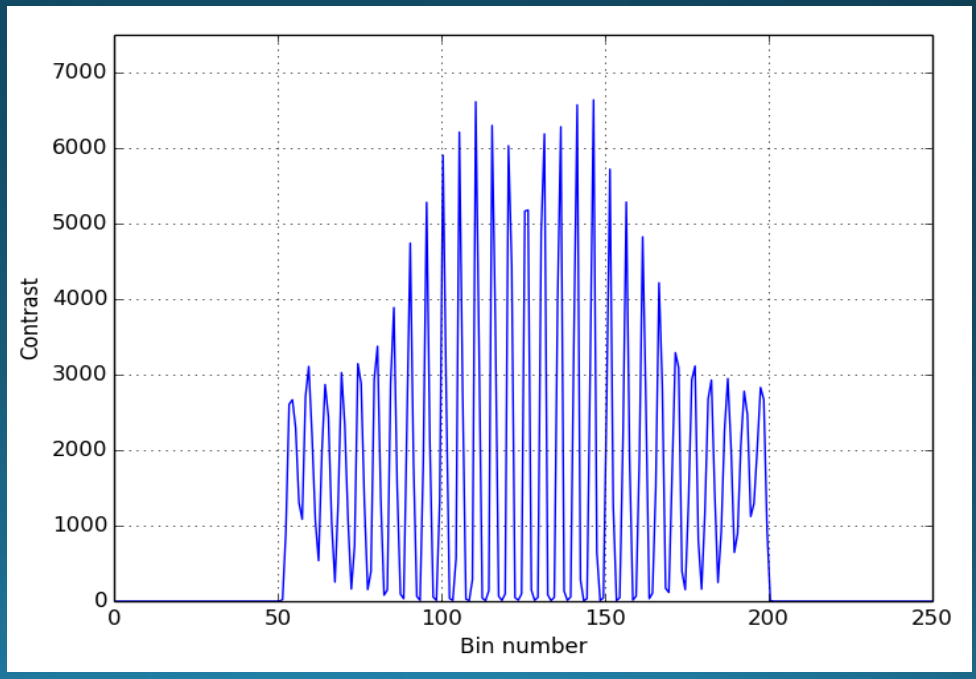
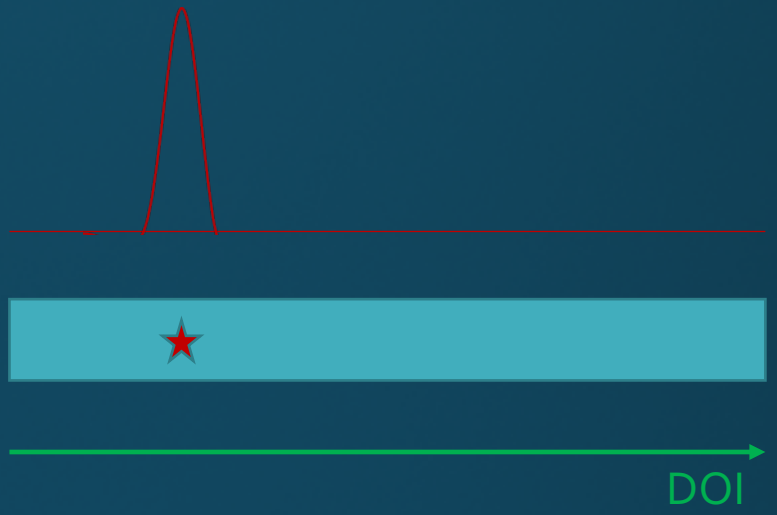
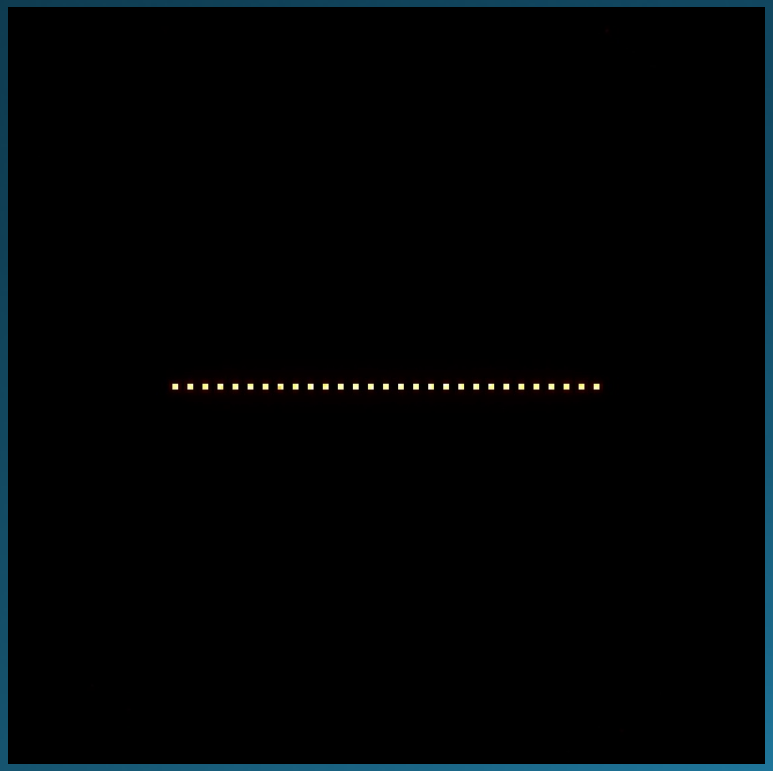


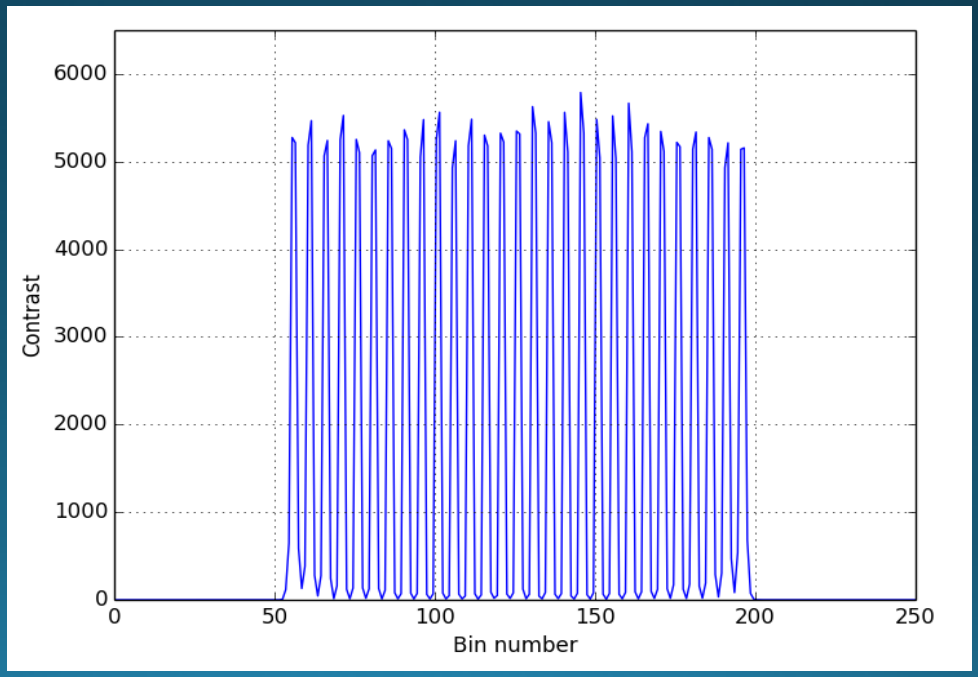




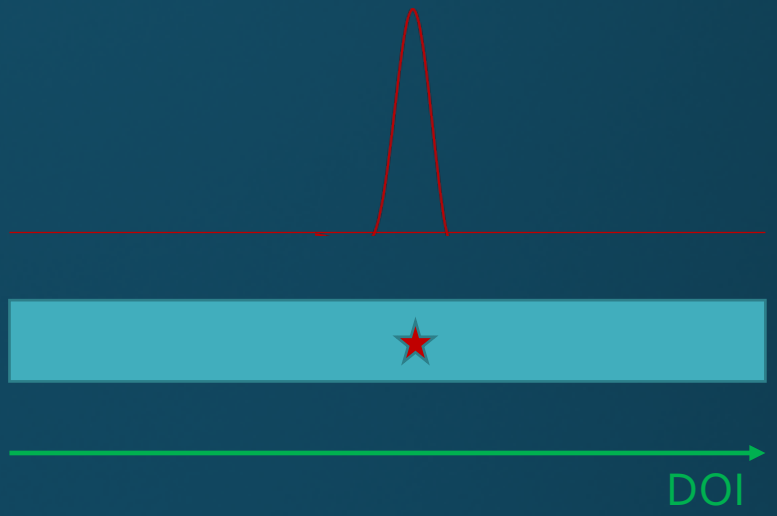
Reconstruction with 3 mm FWHM resolution

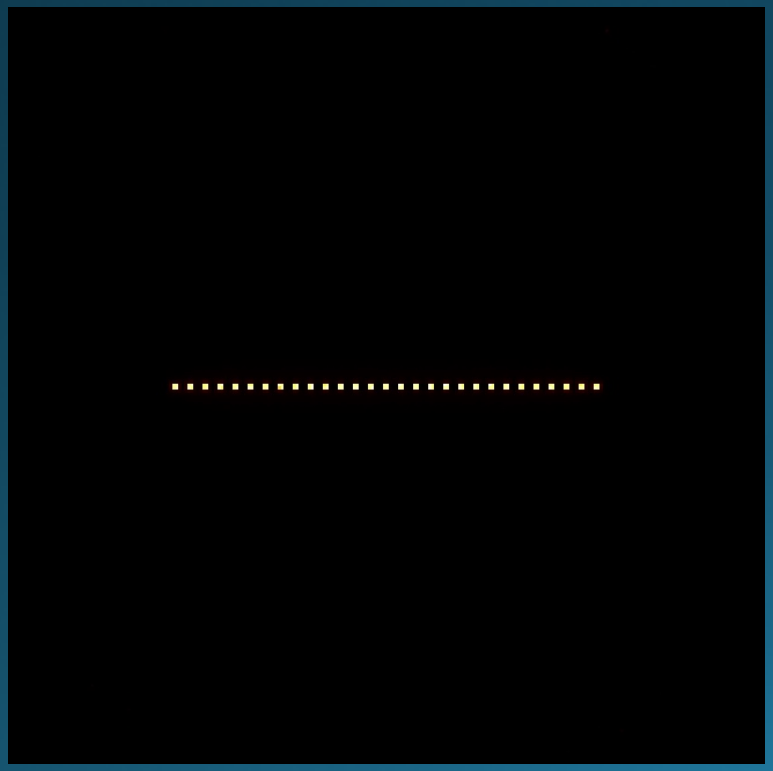


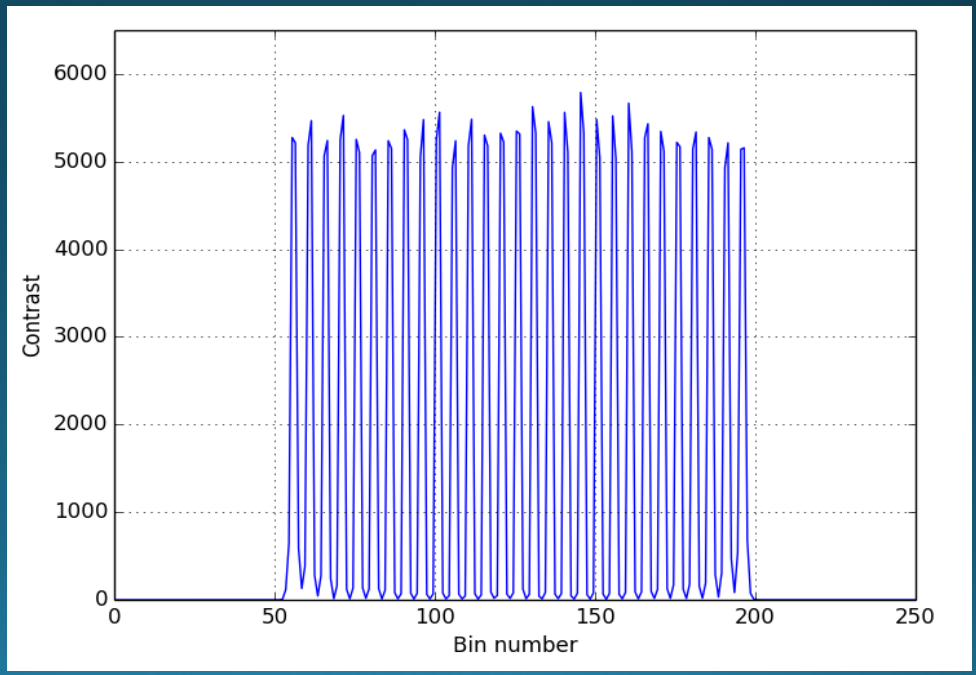




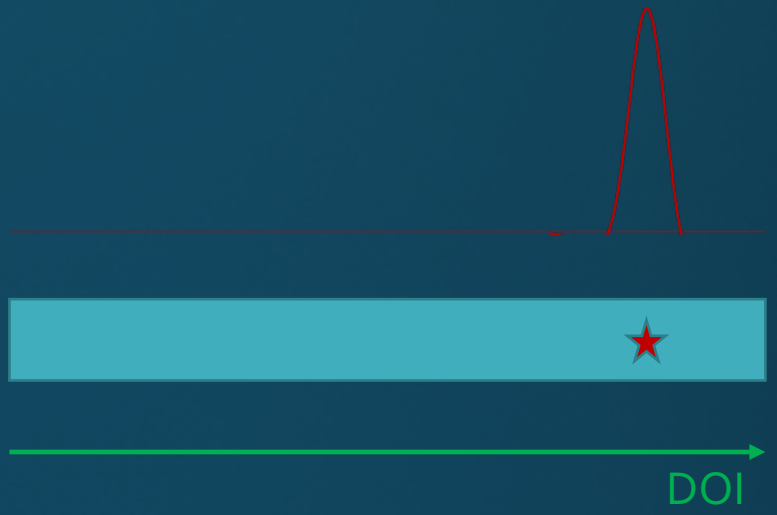
Reconstruction with 3 mm FWHM resolution

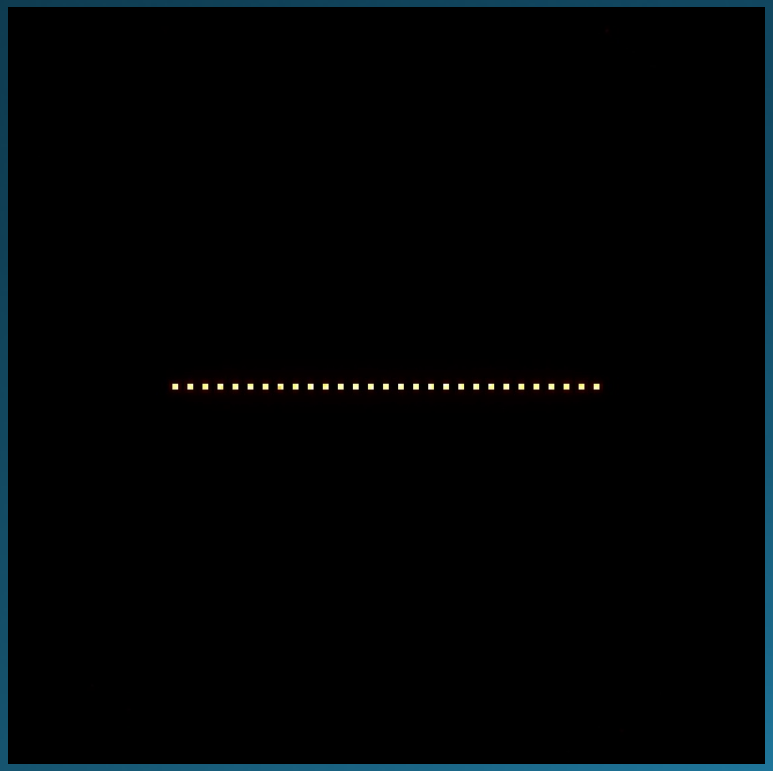


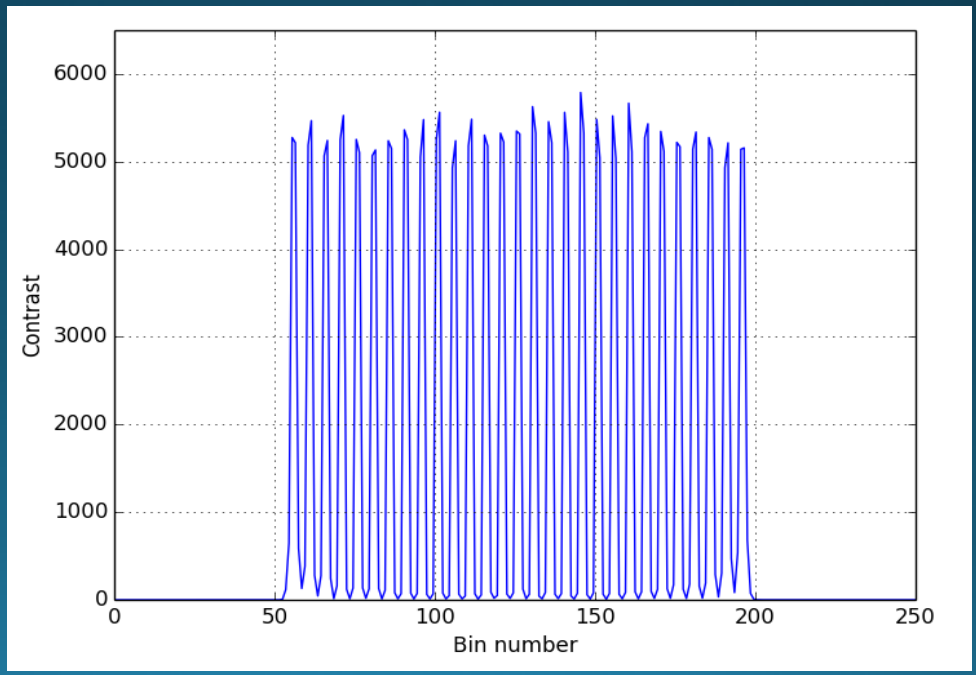




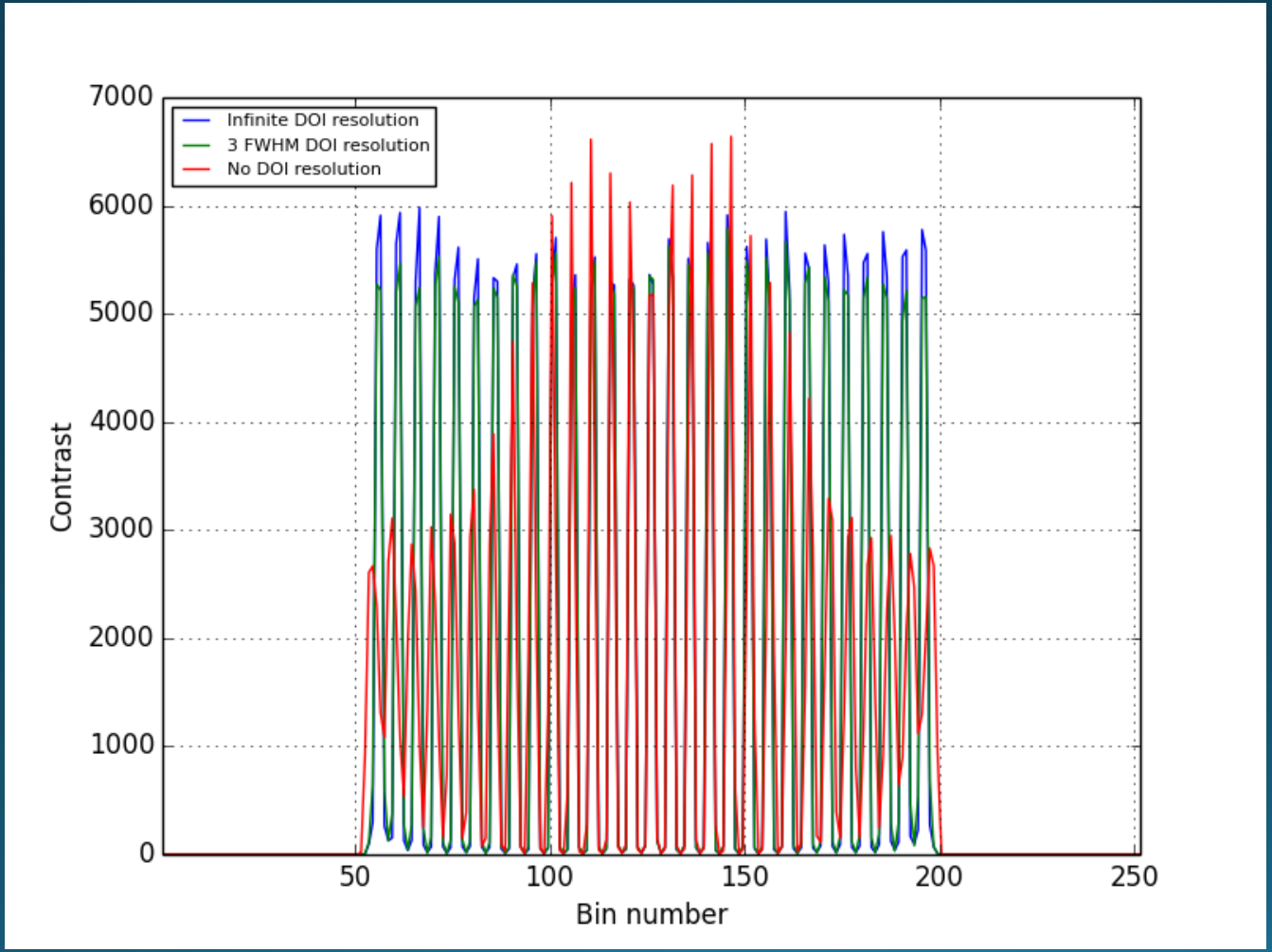
Reconstruction with 3 mm FWHM resolution



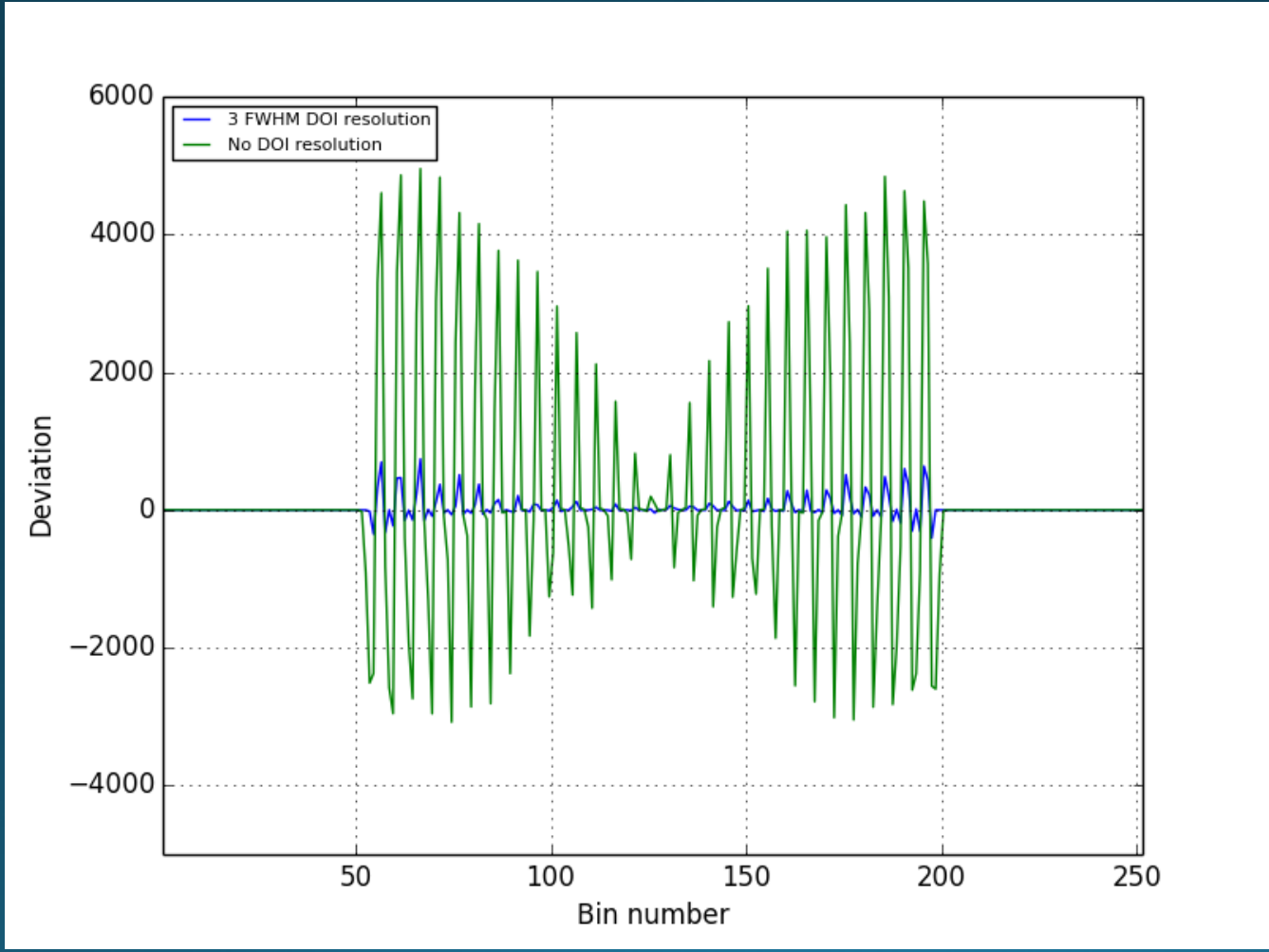




Comparison


Infinite DOI resolution
3 FWHM DOI resolution
No DOI resolution
Contrast
Bin number
0
1000
2000
3000
4000
5000
6000
7000
50
100
150
200
250

Comparison


3 FWHM DOI resolution
No DOI resolution
6000
4000
2000
0
−2000
−4000
Deviation
50
100
150
200
250
Bin number

Conclusions

Software:

- STIR is not the best solution in a geometry dominated by parallax effect.
- The ClearPEM reconstruction software can deal with the DOI.

DOI performances:

- In our setup, having 3 mm FWHM DOI resolution improves the spatial resolution.

To do:

- Optimization of the reconstruction parameter.
- Reconstruction using real data.