IGORR Conference / TM on Research Reactor Ageing Management, Refurbishment and Modernization, May-June 2021

CODED APERTURE TECHNIQUE FOR CHARACTERIZATION AND LOCALIZATION OF RADIOACTIVE HOT-SPOTS
-
SIGNAL TO NOISE RATIO OPTIMIZATION FOR EXTENDED SOURCES

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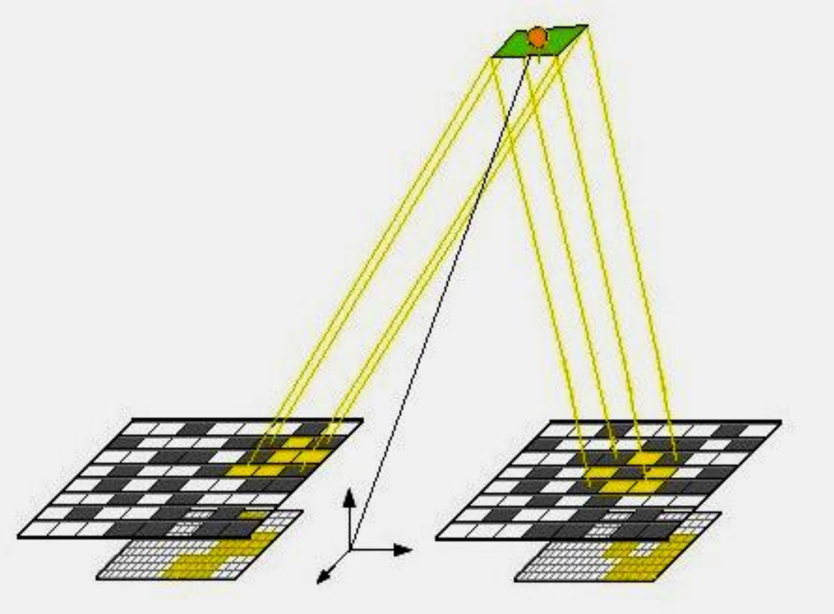
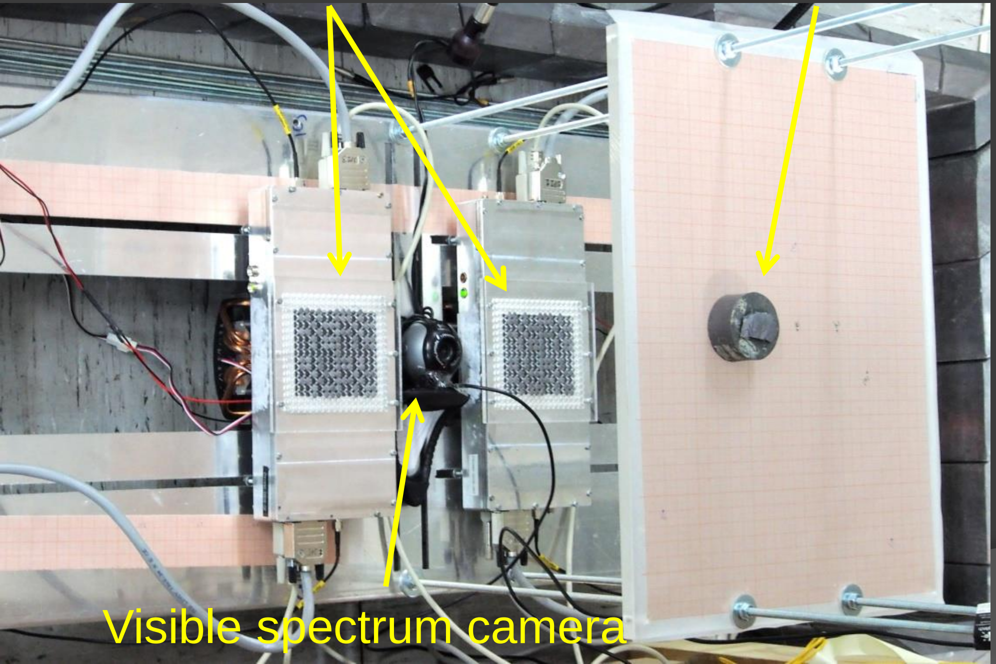
GREEK ATOMIC ENERGY COMMISSION

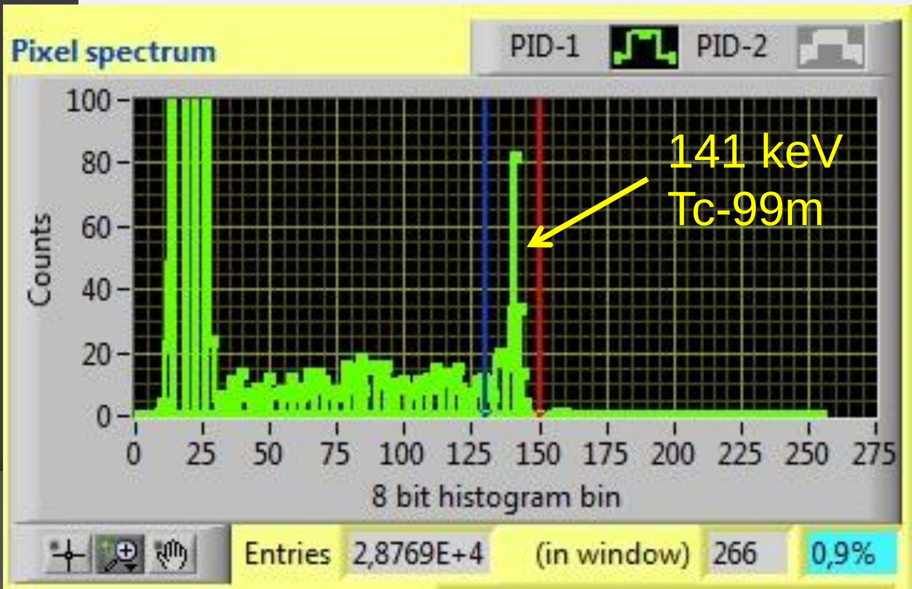
In short...: Exploit Parallax phenomenon of the shadowgrams of two γ-cameras with Coded Apertures

Capable for:

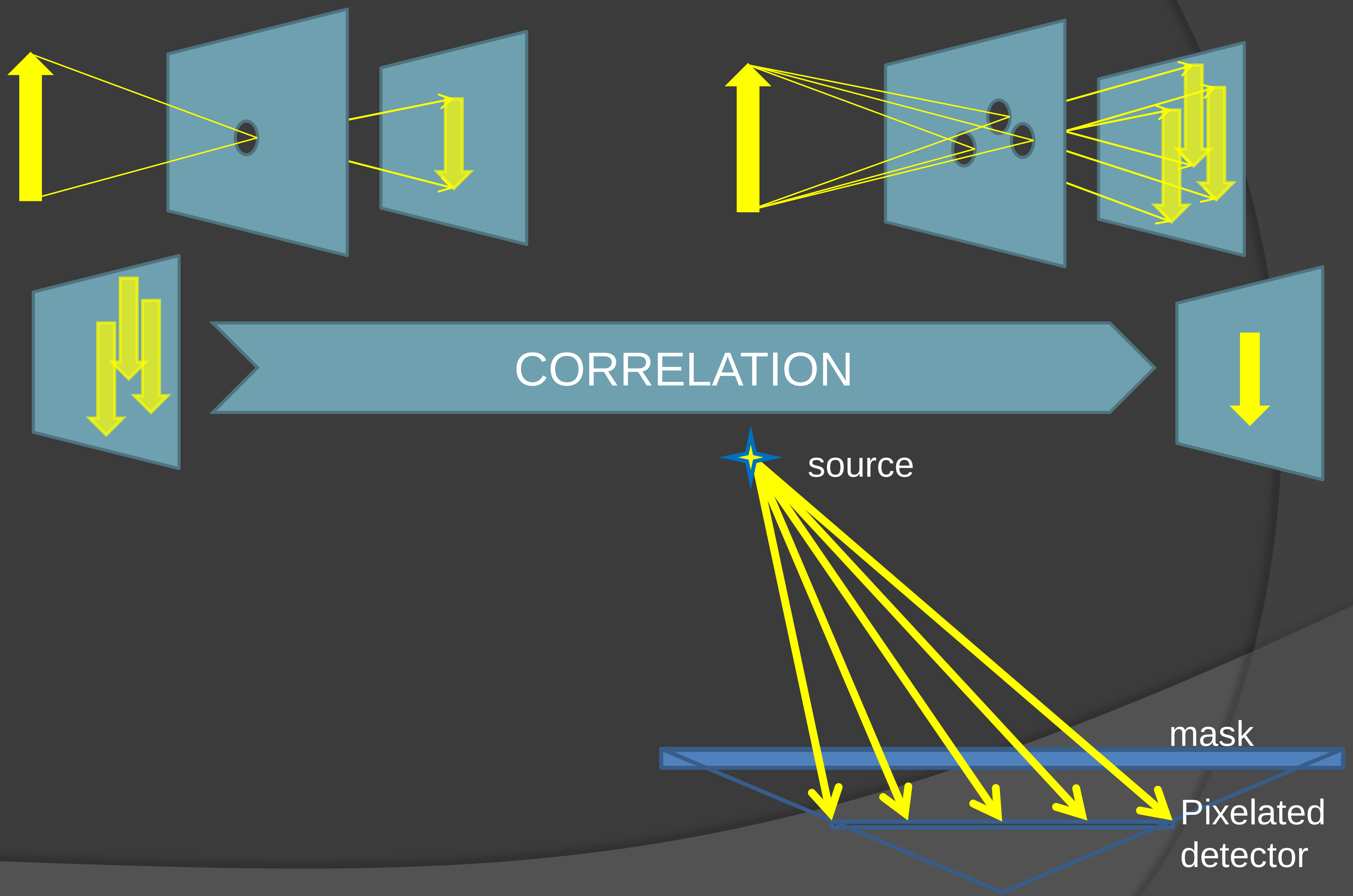
- 3D localization
- Resolving two radioactive spots in 3D
- Resolving photon energy





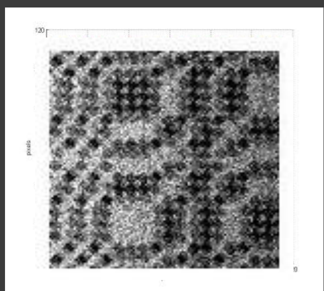


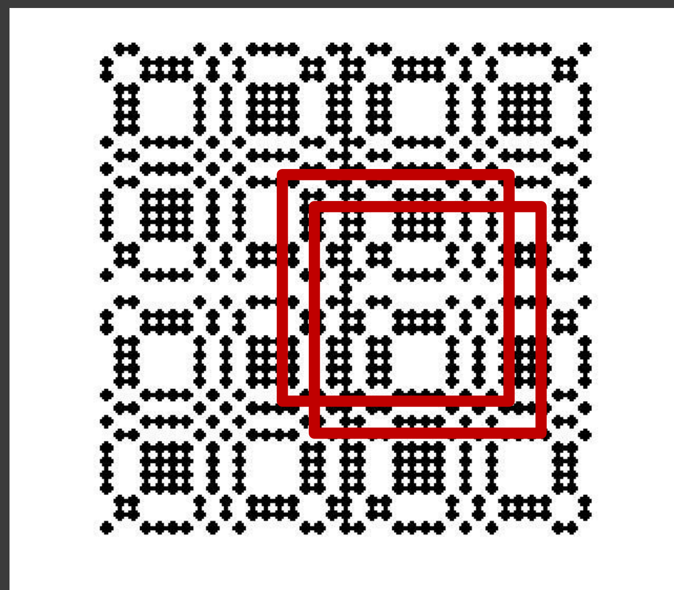
From Pinhole Aperture to Coded Aperture

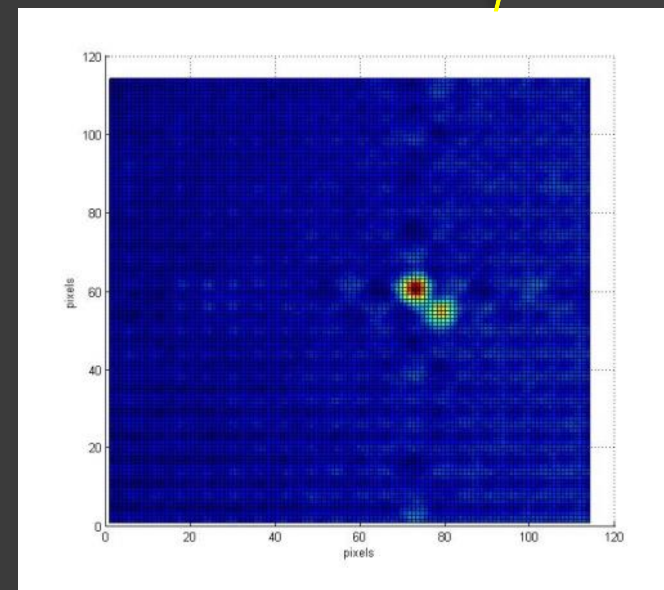


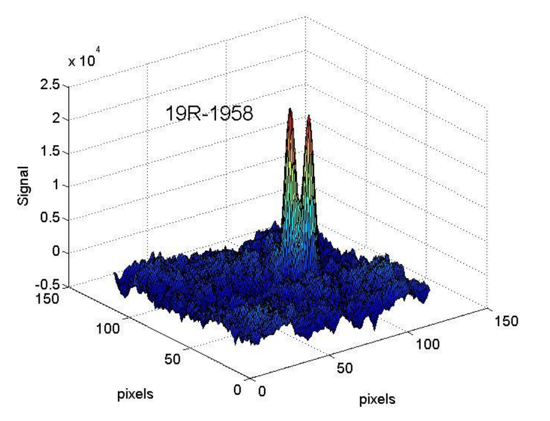
From Shadowgram to Point Spread Function (PSF)

The correlation of Shadowgram with G matrix produces the Correlation Matrix









PSF: Point Spread Function

ACF: Auto Correlation Function

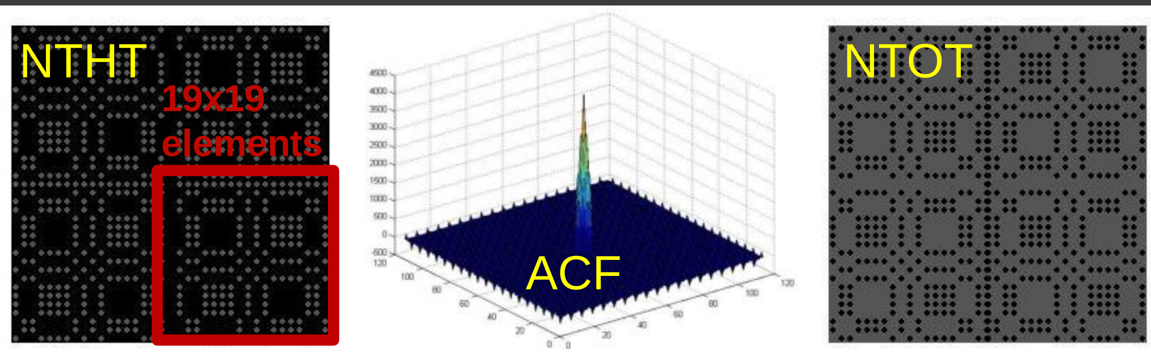
PSLA: Point Source Location Accuracy

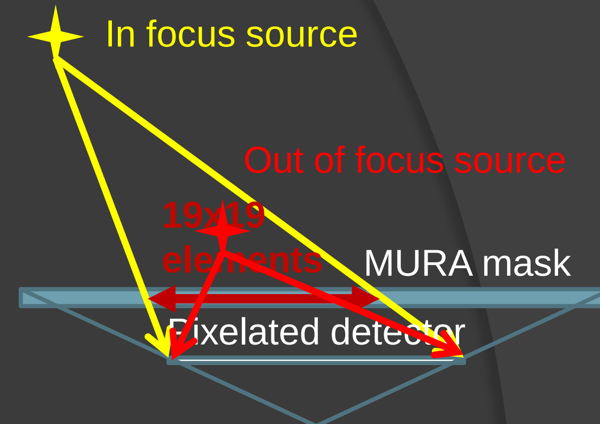
SNR: Signal to Noise Ratio

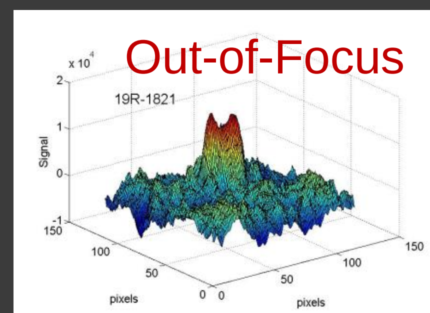
AR: Angular Resolution =

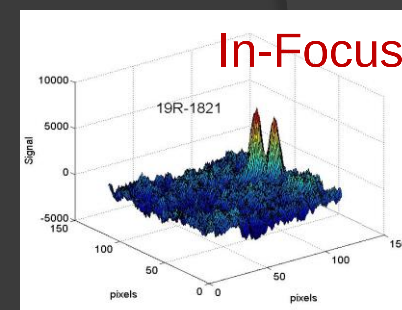
=FWHM of PSF

Modified Uniformly Redundant Arrays (MURA) – No Two Holes Touching - No Two Obscures Touching







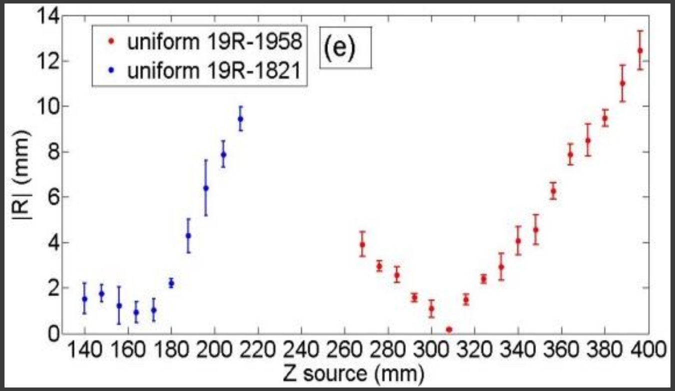


Mask Type	7R-5600	19R-2000	19R-1958	19R-1821
Mask Rank – Basic Pattern	7x7	19x19	19x19	19x19
# of elements	13x13	37x37	37x37	37x37
Shape of elements	Cylinder 2mm	Sphere	Sphere	Sphere
Diameter of elements (mm)	5,6	2,0	1,7	1,7
Pitch of elements (mm)	5,6	2,0	1,958	1,821
Active Area (mm^2)	72,8x72,8	74,0x74,0	72,19x72,19	67,23x67,23
Ideal Source Distance (mm)	~4000	~500	308	160

Image Quality Indices vs Z source

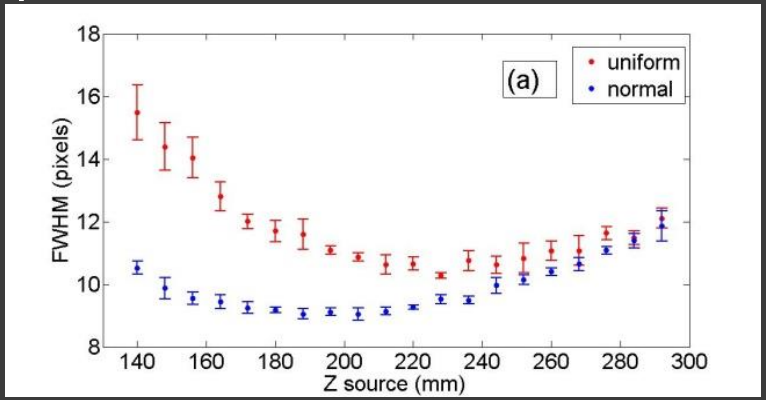
For the 2 γ-cameras system:

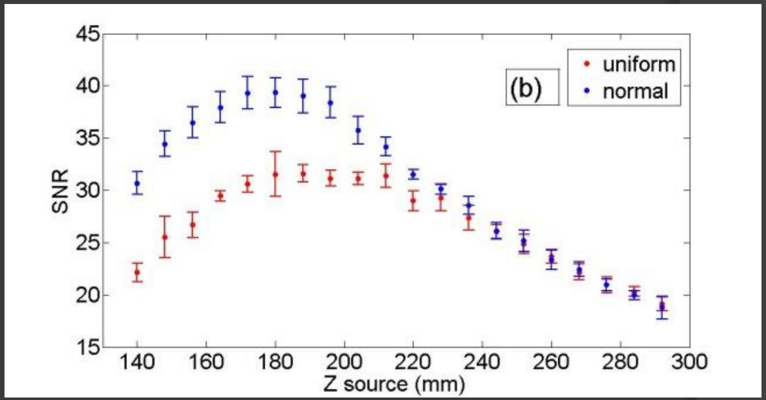
- SLA



For a single γ-camera 19R-1821:

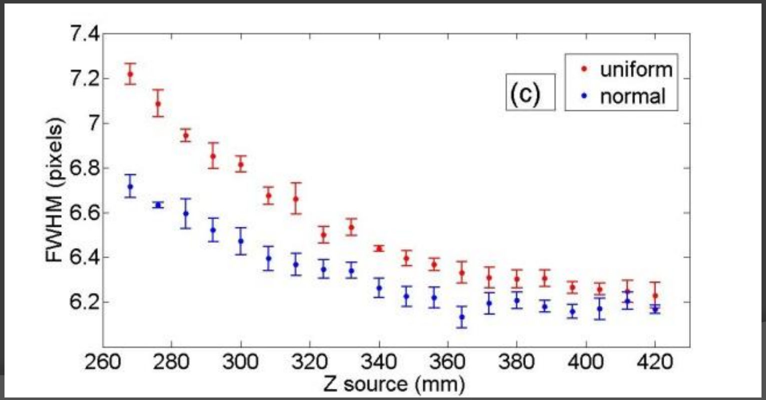
- FWHM
- SNR





For a single γ-camera 19R-1958:

- FWHM
- SNR



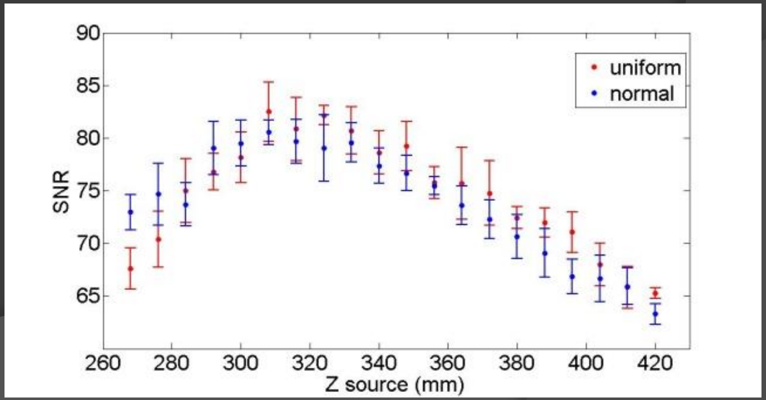
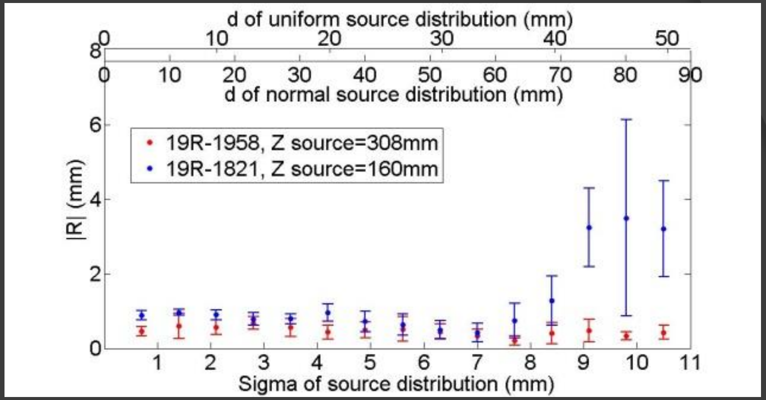


Image Quality Indices vs Extension of Hot-Spots

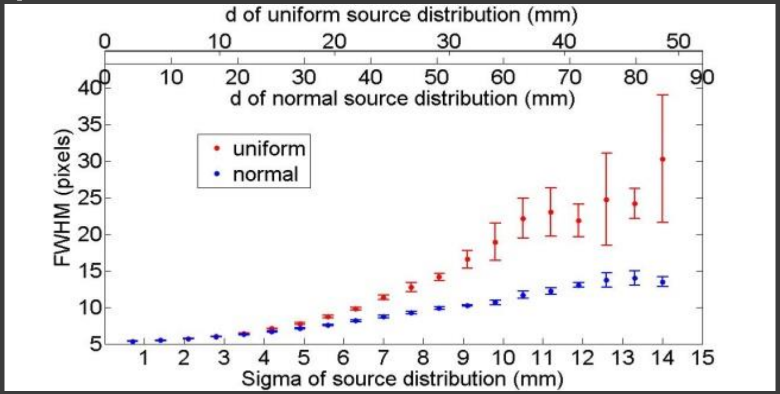
For the 2 γ-cameras system:

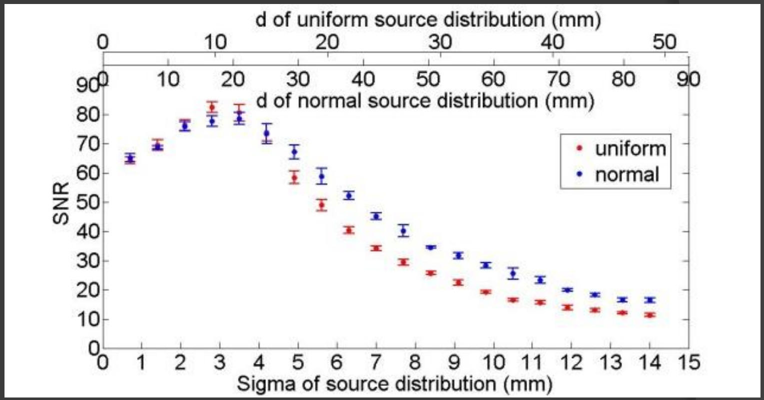
- SLA



For a single γ-camera 19R-1821:

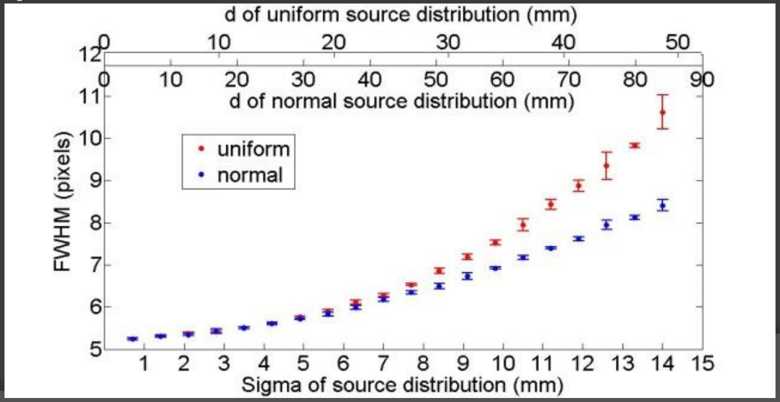
- FWHM
- SNR

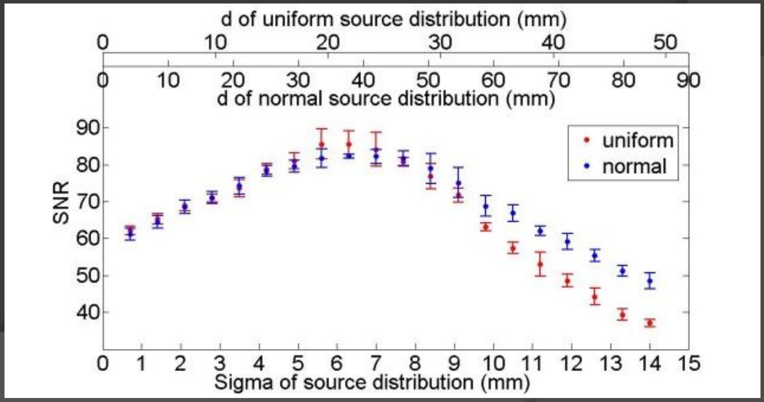




For a single γ-camera 19R-1958:

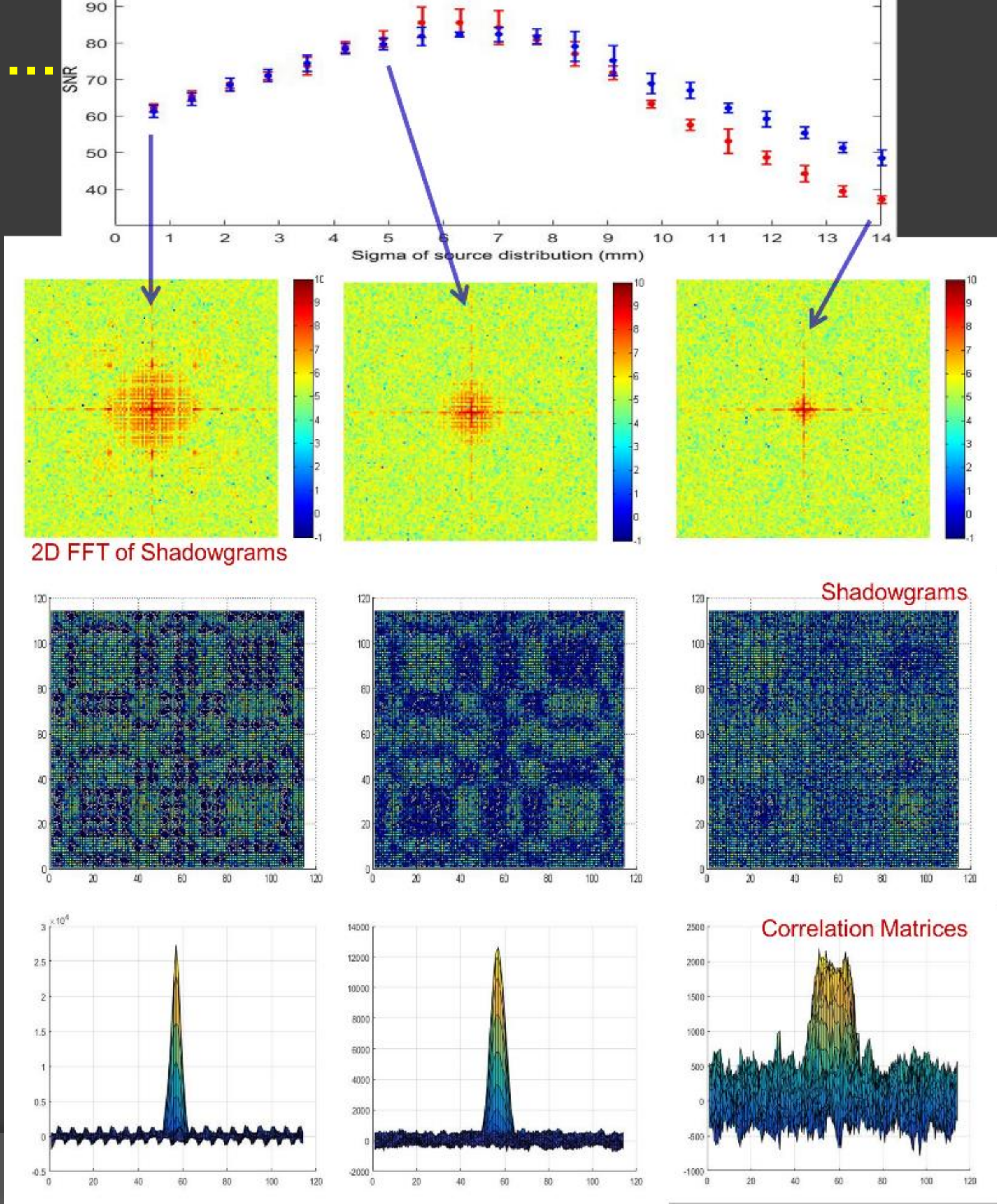
- FWHM
- SNR

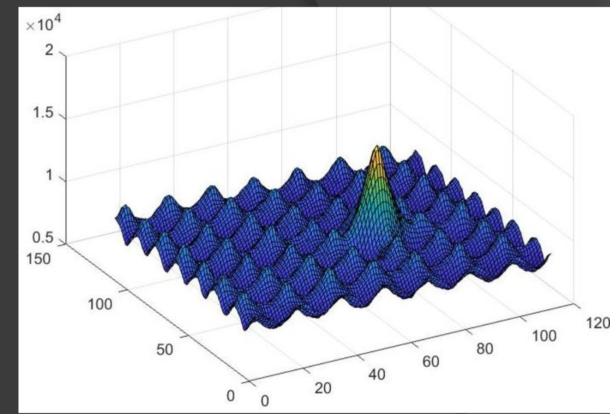


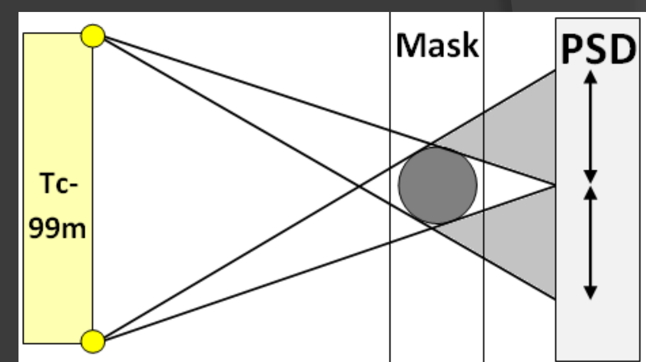


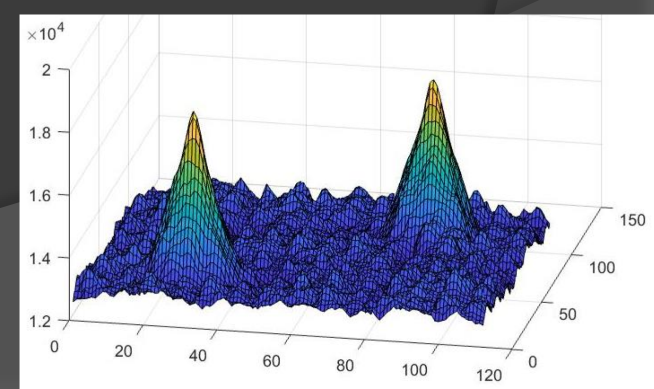
...

SIM


SNR
Sigma of source distribution (mm)
2D FFT of Shadowgrams
Shadowgrams
Correlation Matrices

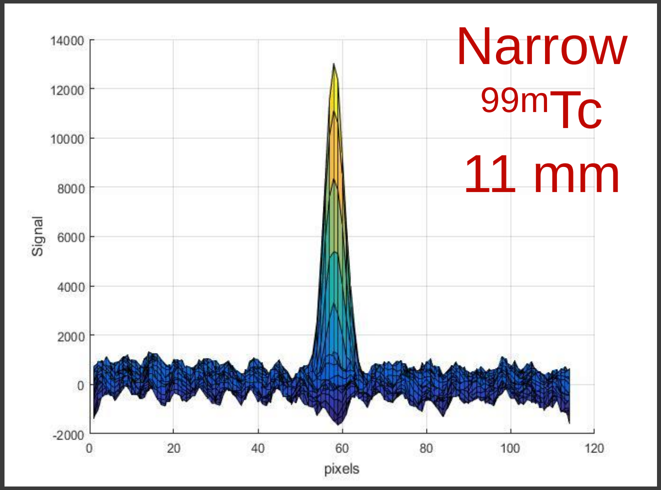


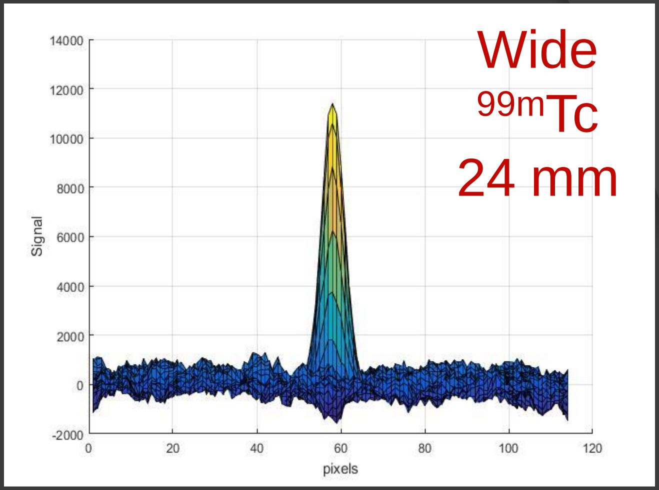

Mask
PSD
Tc-
99m



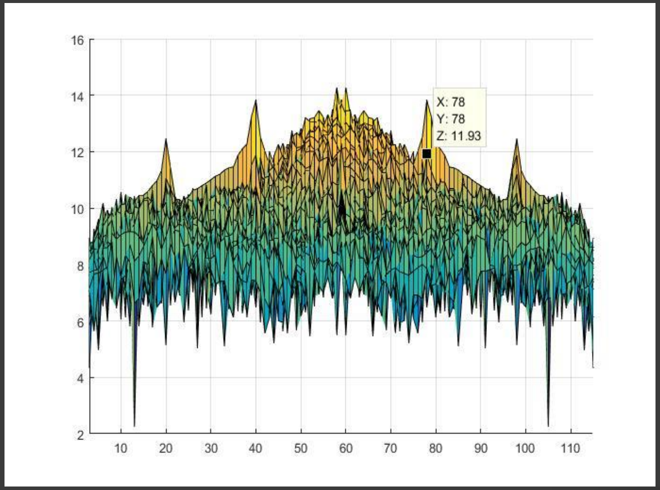
Signal to Noise Ratio vs Extension of Hot-Spots

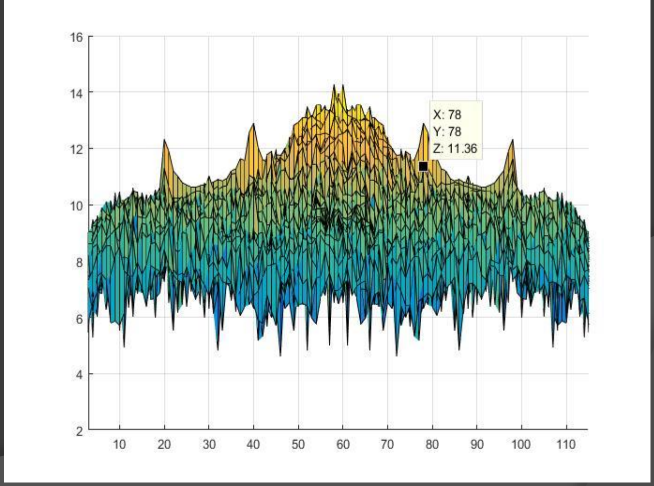
EXP



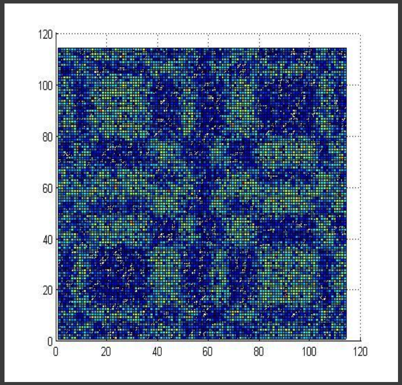


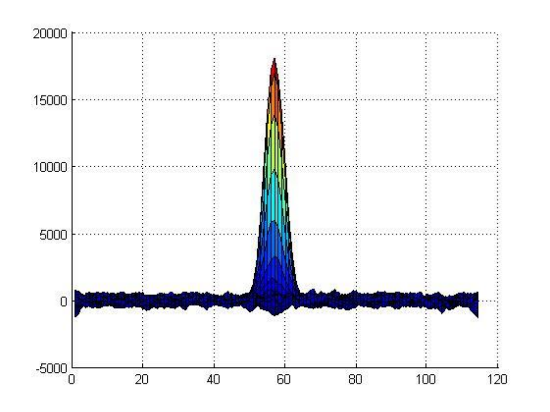
Fast Fourier Transform 2D



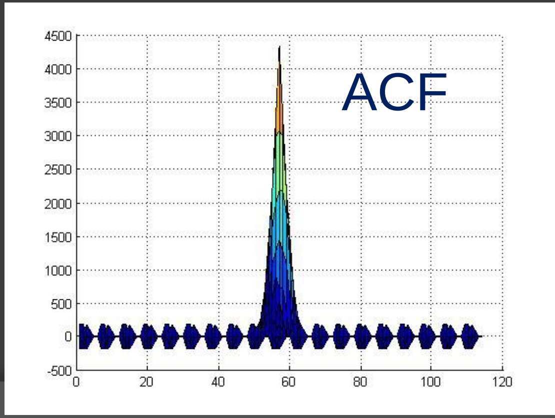


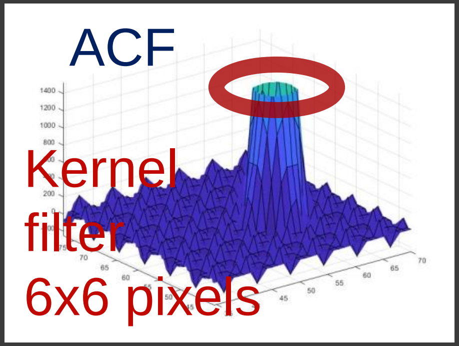
Reduction of intrinsic noise with Kernel filter





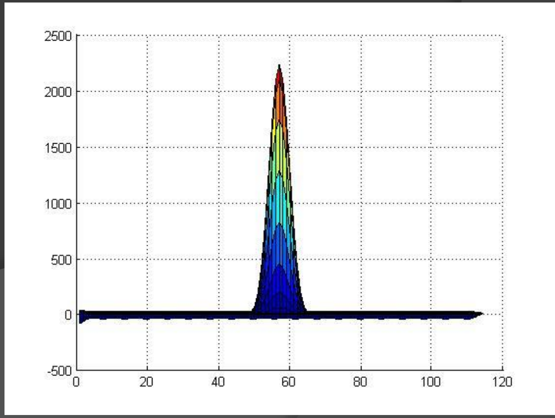
Correlation matrix with intrinsic, element-wise noise





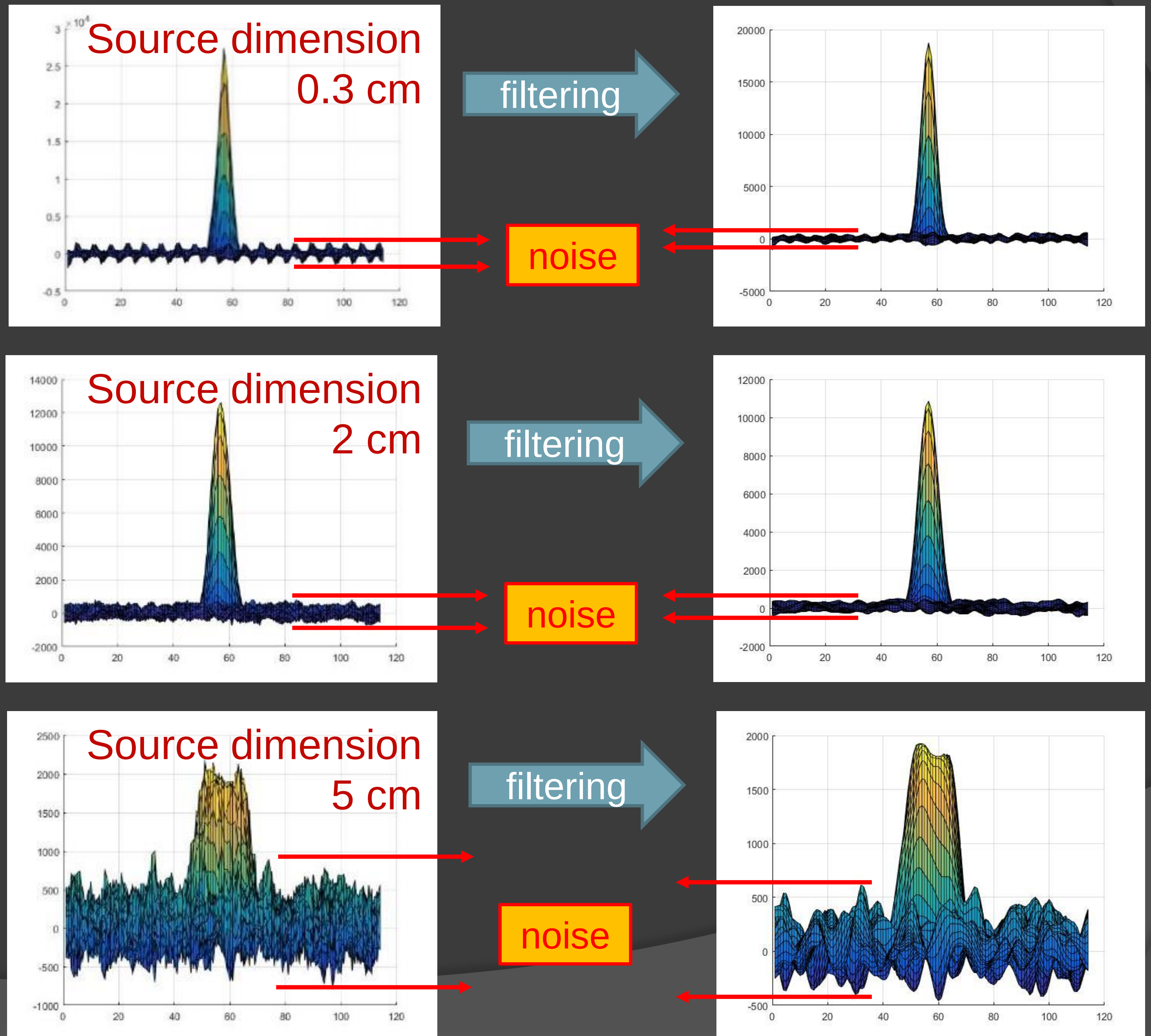
filtering

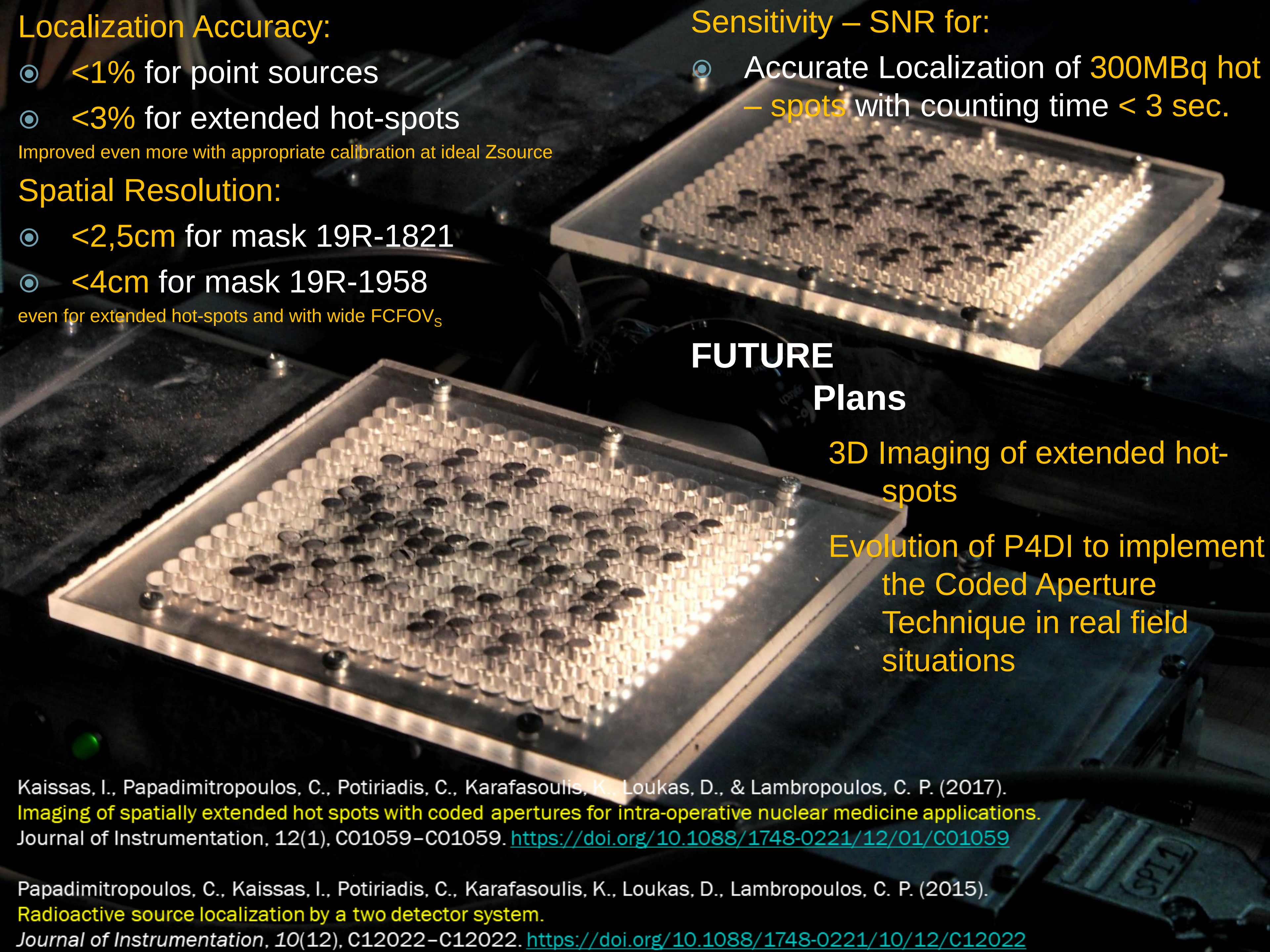
Correlation matrix with reduced intrinsic, element-wise noise



Reduction of intrinsic noise with Kernel filter

SIM





Localization Accuracy:

- <1% for point sources
- <3% for extended hot-spots

Improved even more with appropriate calibration at ideal Zsource

Spatial Resolution:

- <2,5cm for mask 19R-1821
- <4cm for mask 19R-1958

even for extended hot-spots and with wide $FCFOV_s$

Sensitivity – SNR for:

- Accurate Localization of 300MBq hot – spots with counting time < 3 sec.

FUTURE Plans

- 3D Imaging of extended hot-spots
- Evolution of P4DI to implement the Coded Aperture Technique in real field situations

Kaissas, I., Papadimitropoulos, C., Potiriadis, C., Karafasoulis, K., Loukas, D., & Lambropoulos, C. P. (2017). Imaging of spatially extended hot spots with coded apertures for intra-operative nuclear medicine applications. Journal of Instrumentation, 12(1), C01059–C01059. https://doi.org/10.1088/1748-0221/12/01/C01059

Papadimitropoulos, C., Kaissas, I., Potiriadis, C., Karafasoulis, K., Loukas, D., Lambropoulos, C. P. (2015). Radioactive source localization by a two detector system. *Journal of Instrumentation*, *10*(12), C12022–C12022. https://doi.org/10.1088/1748-0221/10/12/C12022