Detection of X-ray sources with MXT telescope of SVOM satellite

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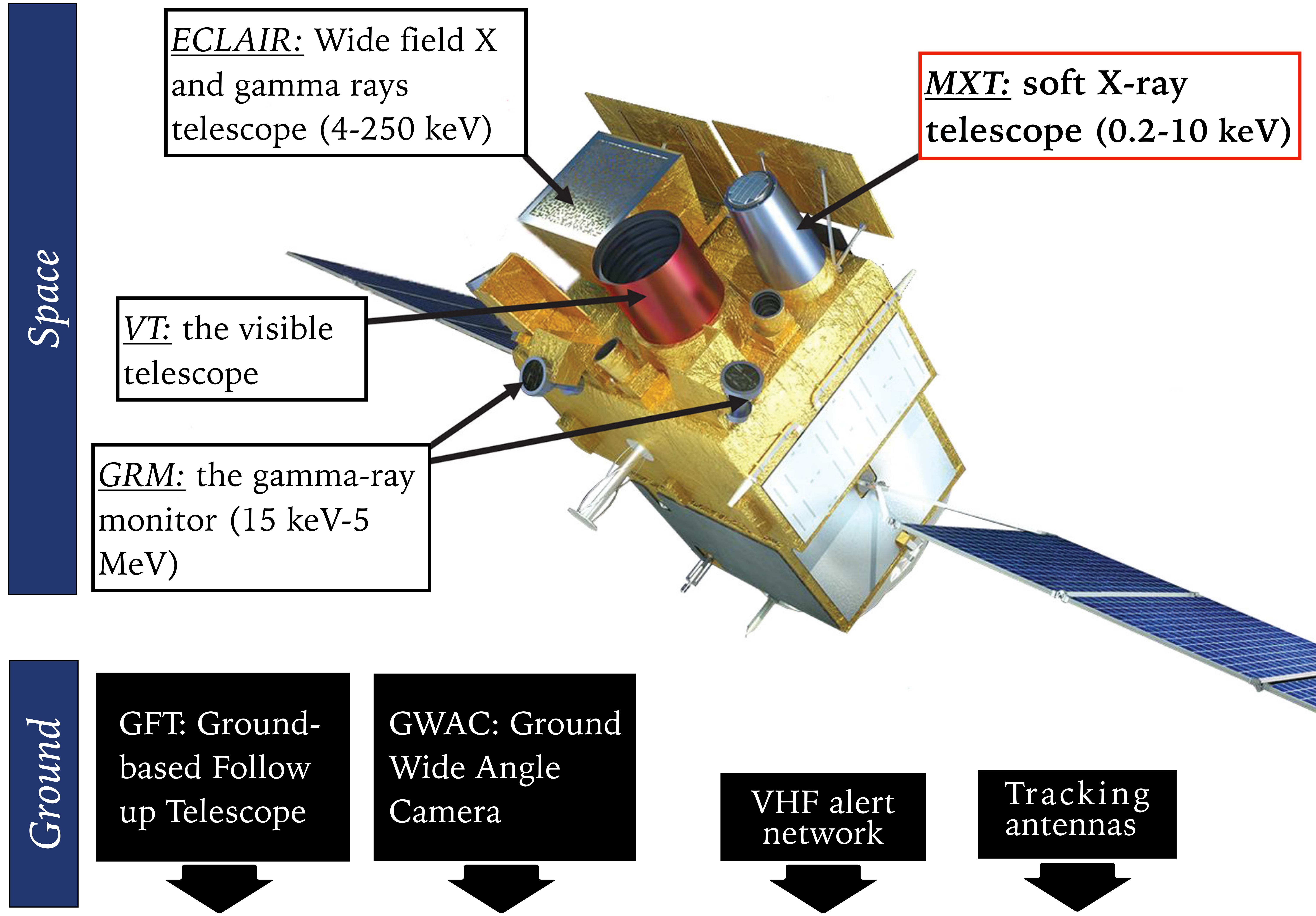
SVOM satellite

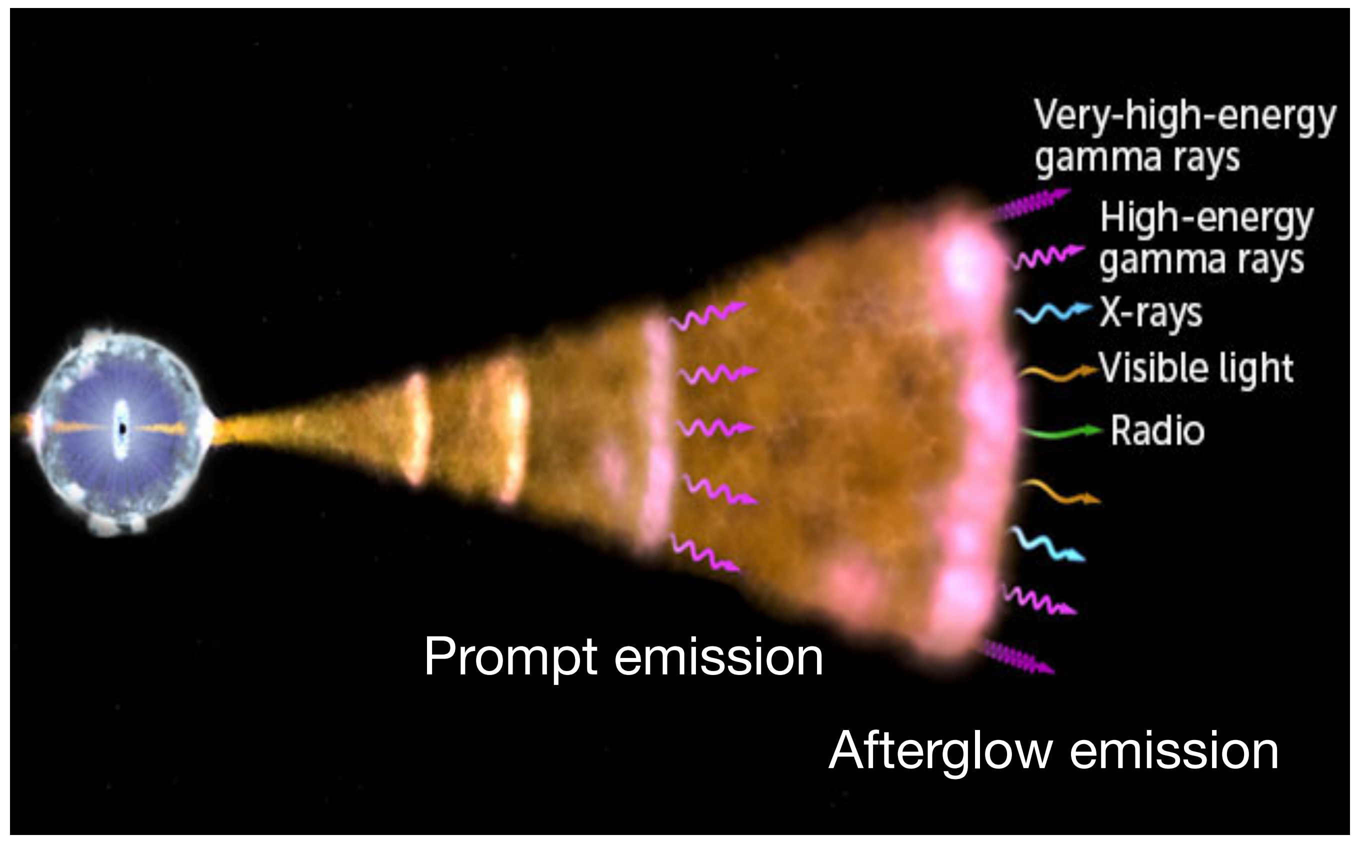
- **S**pace **V**ariable **O**bjects **M**onitor.
- A French-Chinese mission
- dedicated to GRBs and other high energy transient on the sky.
- SVOM has a complementary set of ground and space based instruments
- To be launched by the end of 2022.



Science observation programs

Core program:

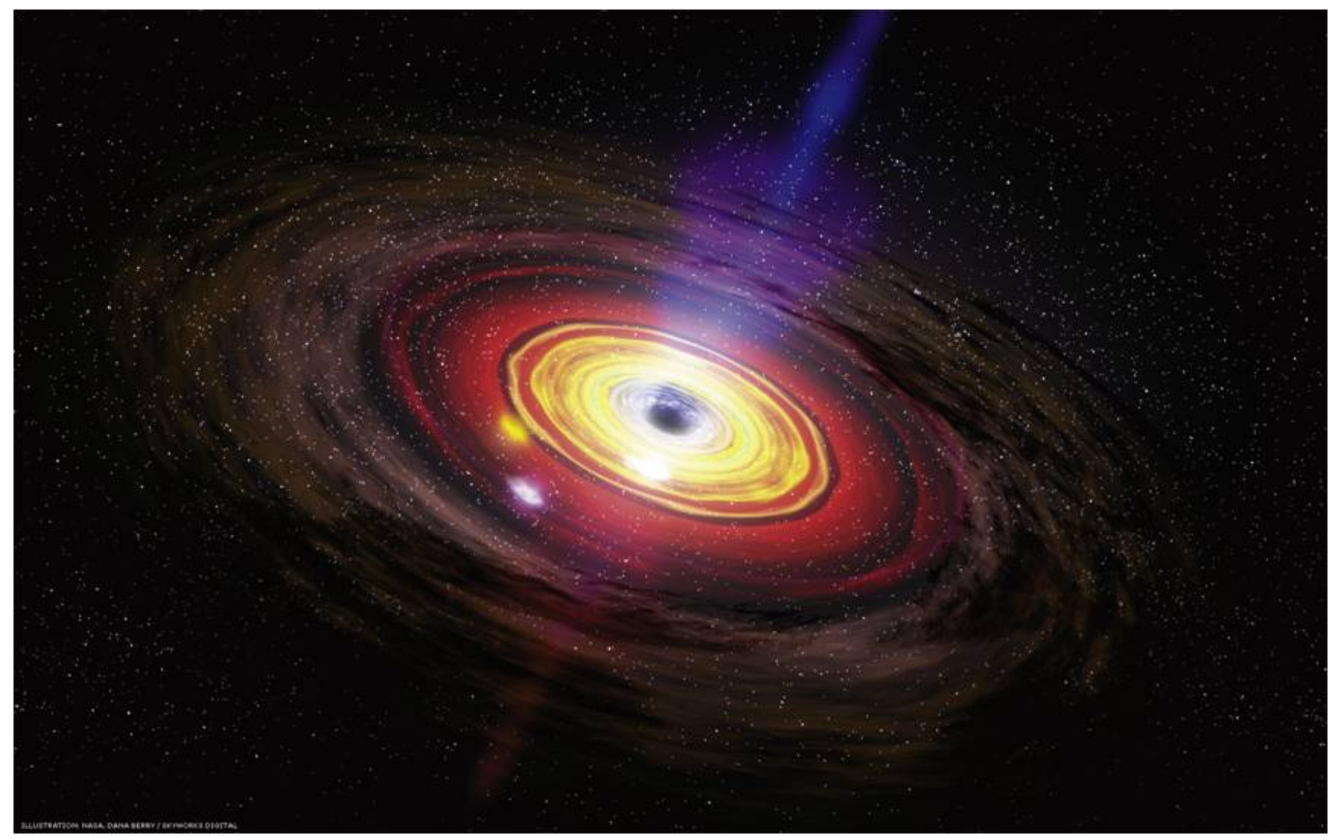
- Observe all types of gamma ray bursts



- MXT will observe X-ray afterglows

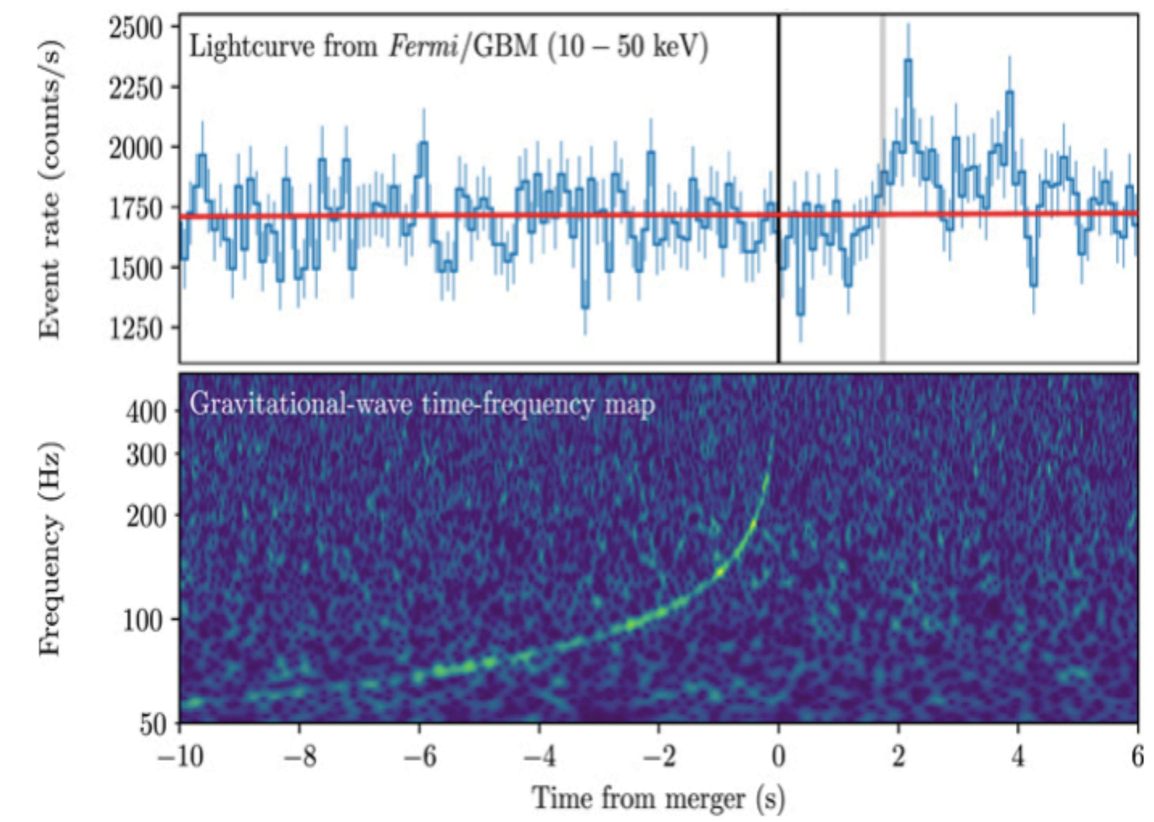
General program

- Active Galactic Nuclei, Accreting objects, Flaring objects



Target of opportunity program

- Unplanned observations of transient and variable sources, ex: follow-up of multi-messenger alerts from experiments like LIGO-VIRGO, the IceCube, the Cherenkov Telescope Array .. etc.



MXT will observe these sources in X-ray range to achieve 2 requirements:

- **Localize the source down to 2′ within few minutes —> better understanding of the source, ex: measure the redshift, host galaxy .. etc.**
- **Provide a good photometry and spectroscopy of the source —> determine the astrophysical origin of the source**

➡ MXT needs a specific design + onboard scientific software.

MXT telescope

Main features:

- *~35 kg & ~1.2 m.*
- *FoV: 1.1° x 1.1°.*

MXT optics:

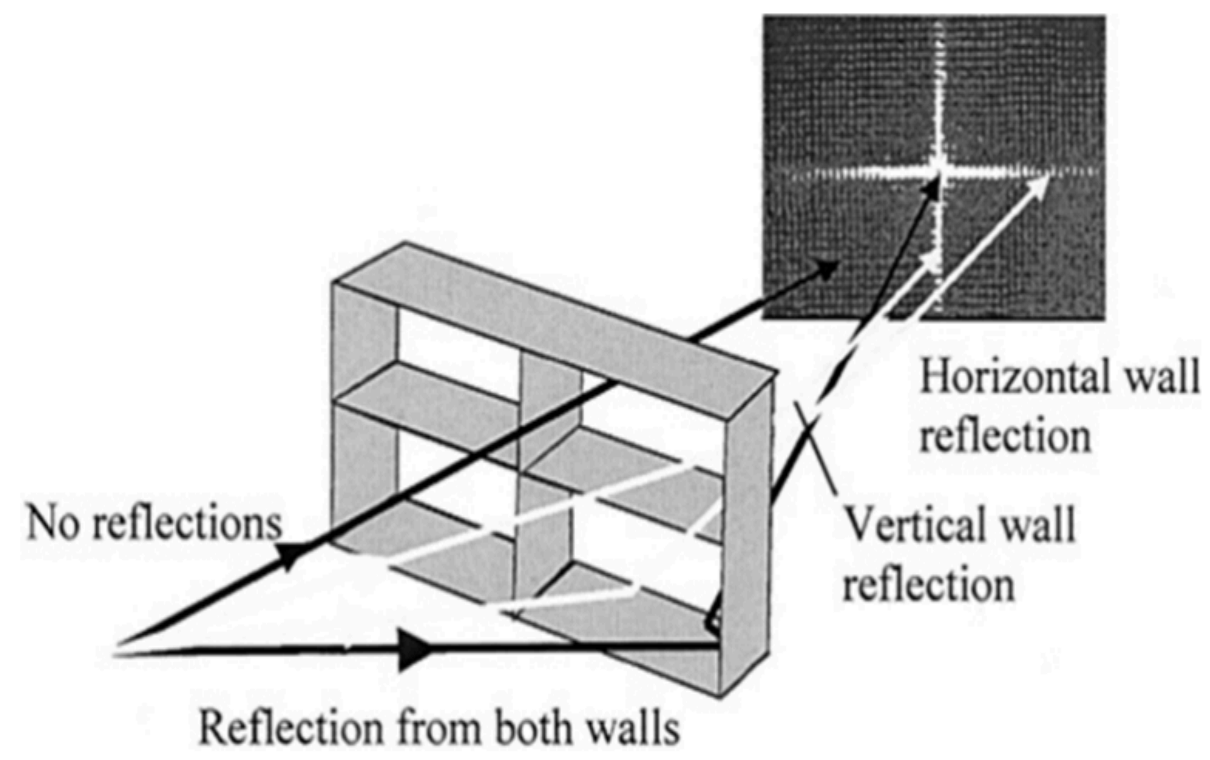
- *Micropore optics arranged in a lobster-eye configuration*
- *Point spread function composed of a central spot and cross arms*

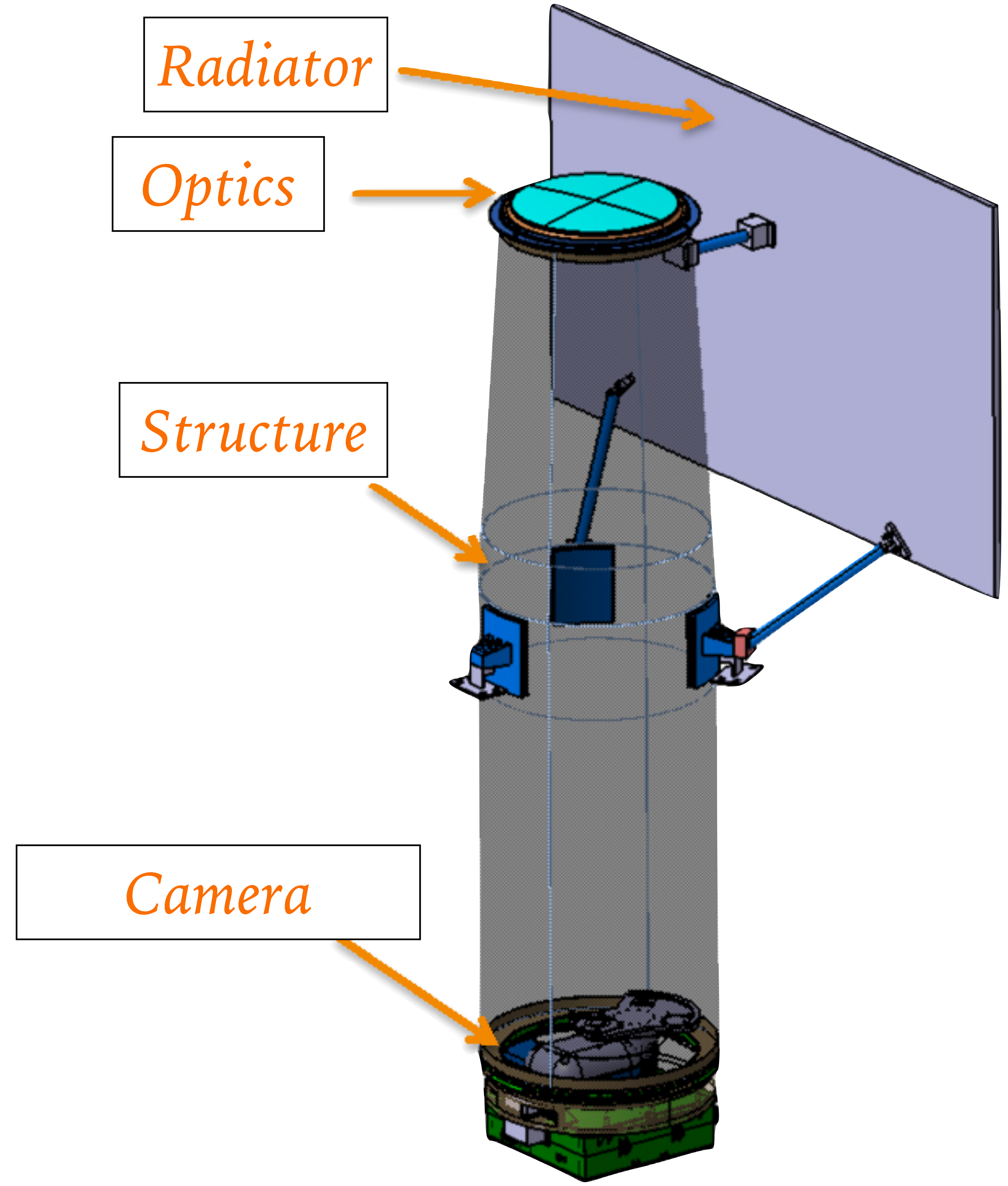
MXT camera:

- *PnCCD detector, 256x256 pixels*

MXT data processing unit:

- *handle the instrument power distribution.*
- *telemetry and telecommand management.*
- ***the scientific data processing***





MXT subsystem

Science software onboard of MXT

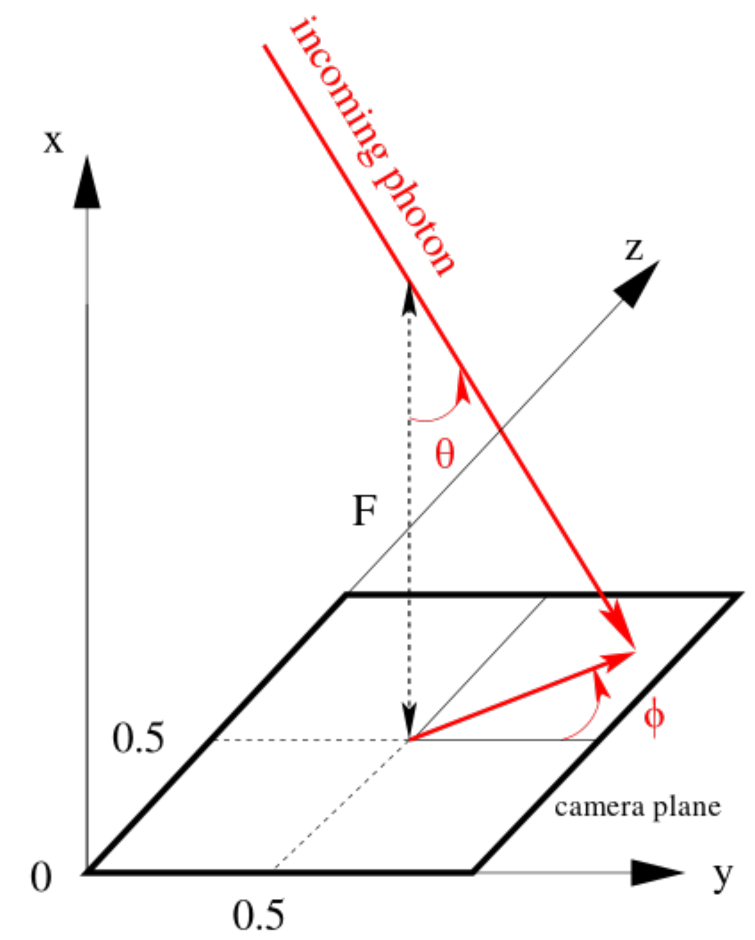
IJCLab in collaboration with CEA and CNES teams took the responsibility of developing and implementing the **onboard** scientific software of MXT:

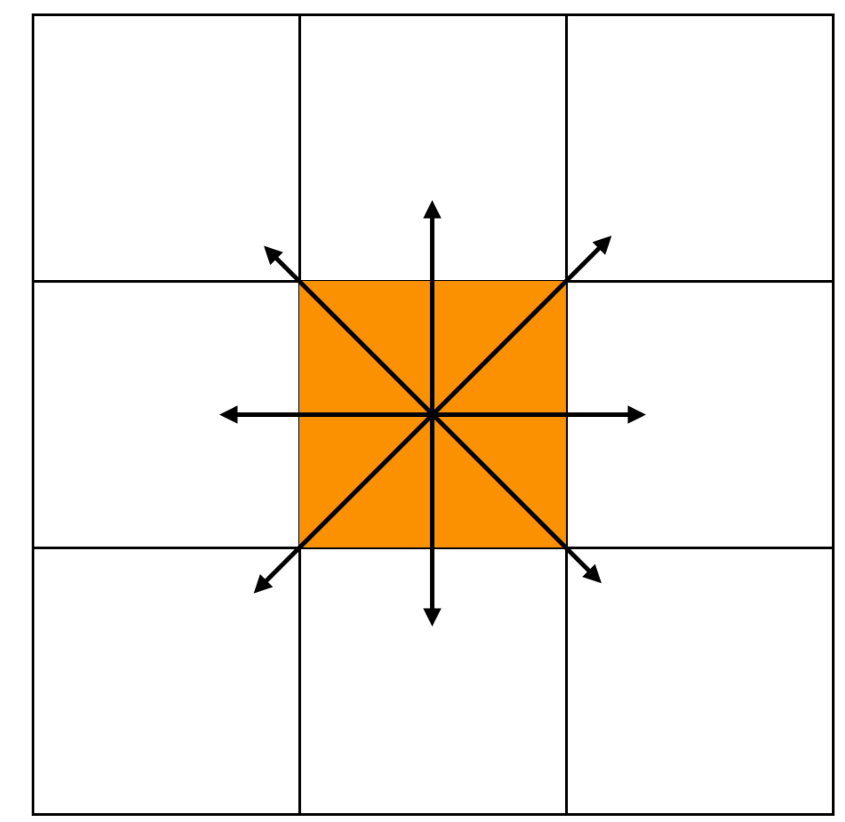
- Camera noise characterization
- **Photon reconstruction and source localization**
- Data monitoring
- Science telemetry packets (VHF and X-band)

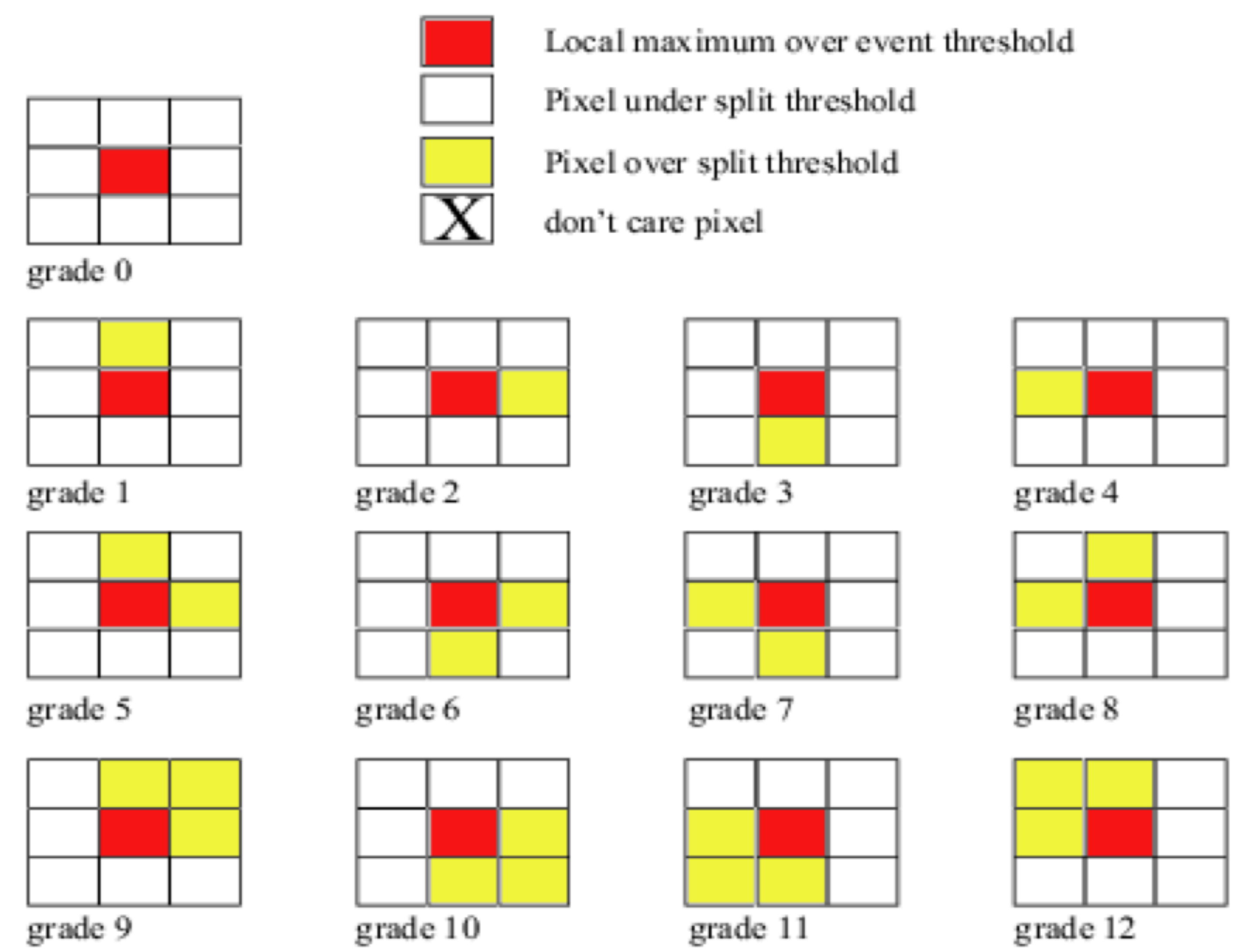
* *As this algorithm is implement onboard, it is highly constrained, and to achieve the scientific requirements; the algorithm must be fast, optimised and robust against all space conditions.*

Photon reconstruction

- X-ray photons interact with the camera by depositing energies in one or few adjacent pixels forming a pattern depending on it is energy
- Contiguous pixels are clustered together
- Photons are identified using the XRT photon patterns
- Photons are accumulated in a table “photon map” with a **128x128** grid resolution

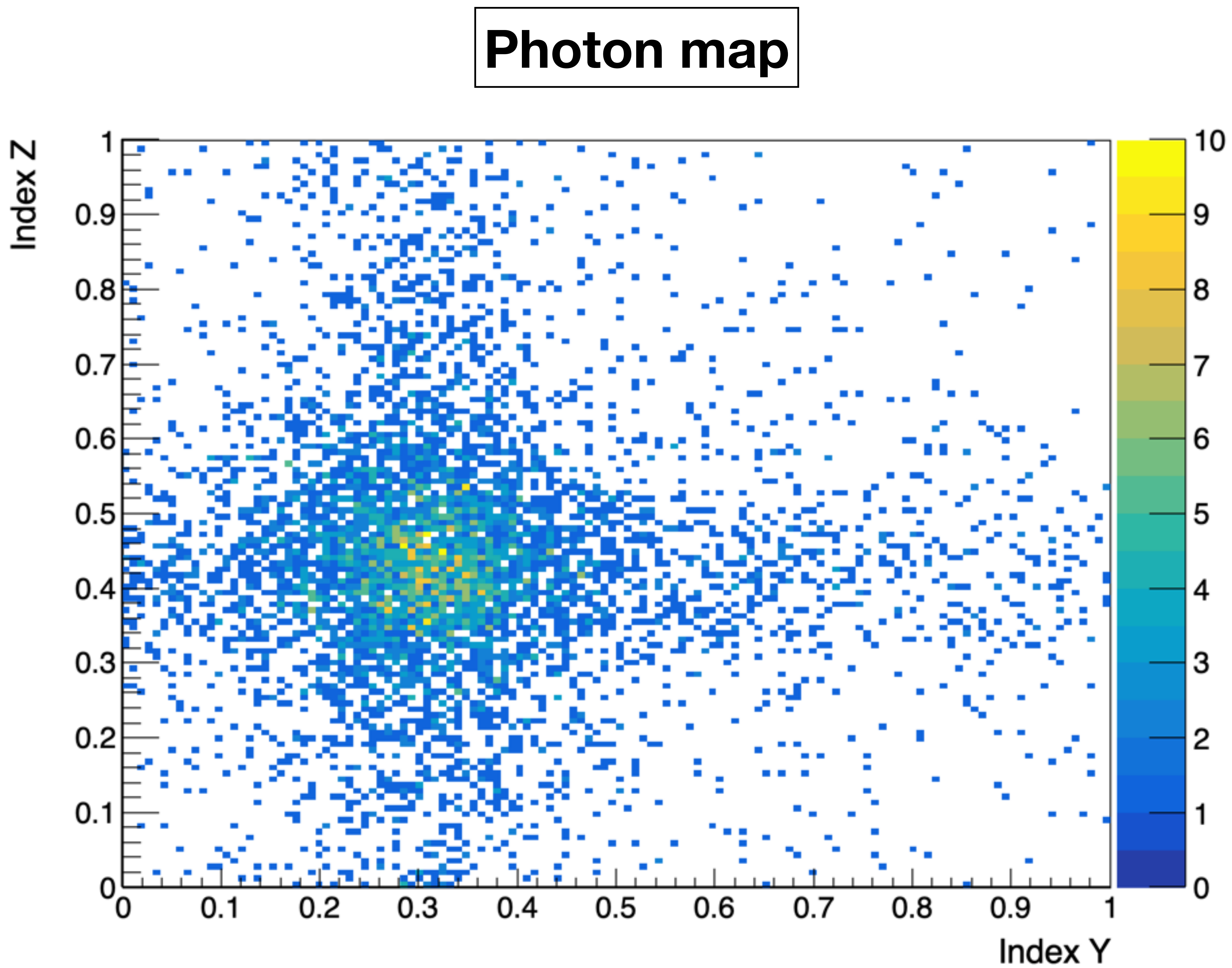


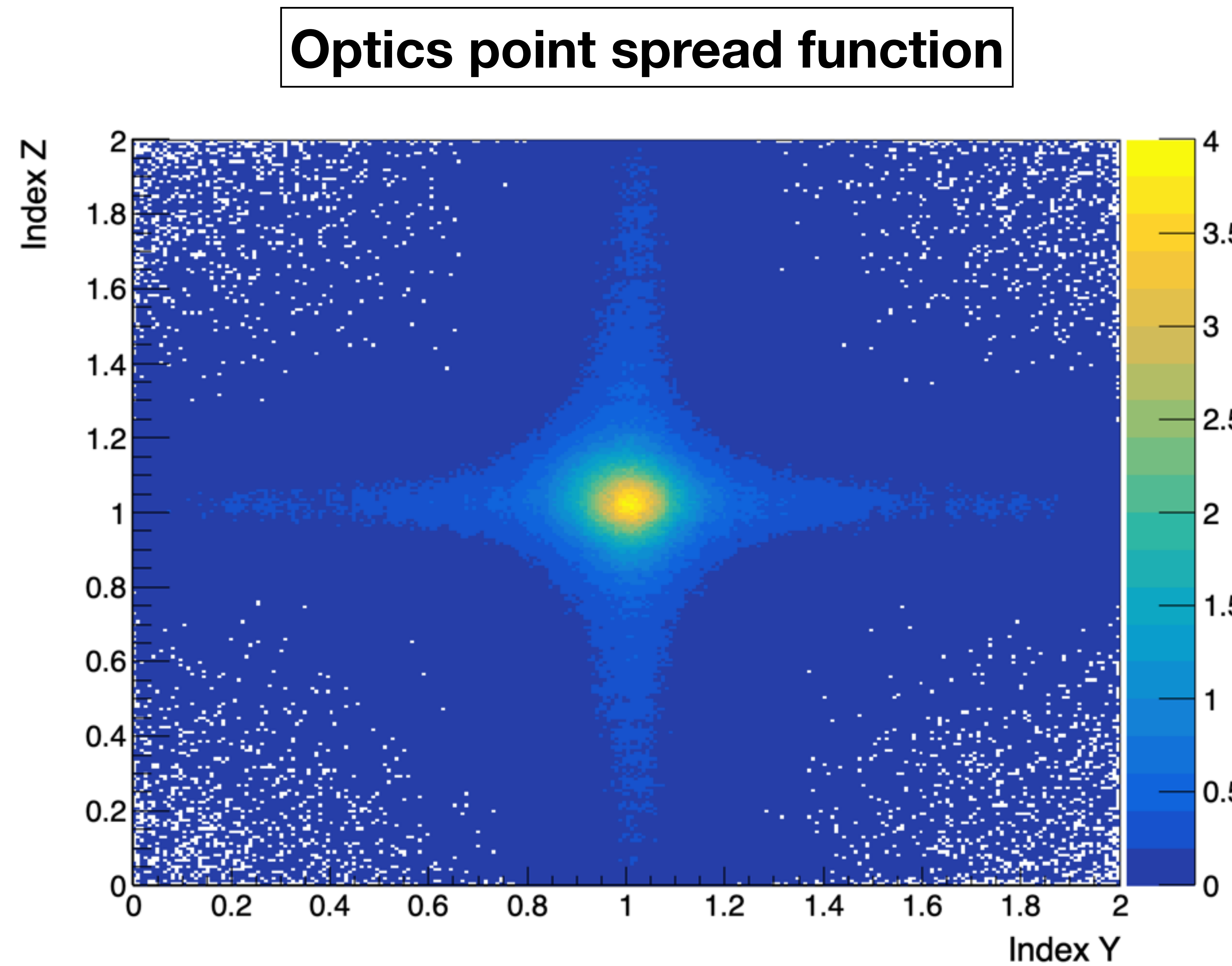




Photon reconstruction

Photon map and the point spread function PSF are the inputs of the onboard localization algorithm





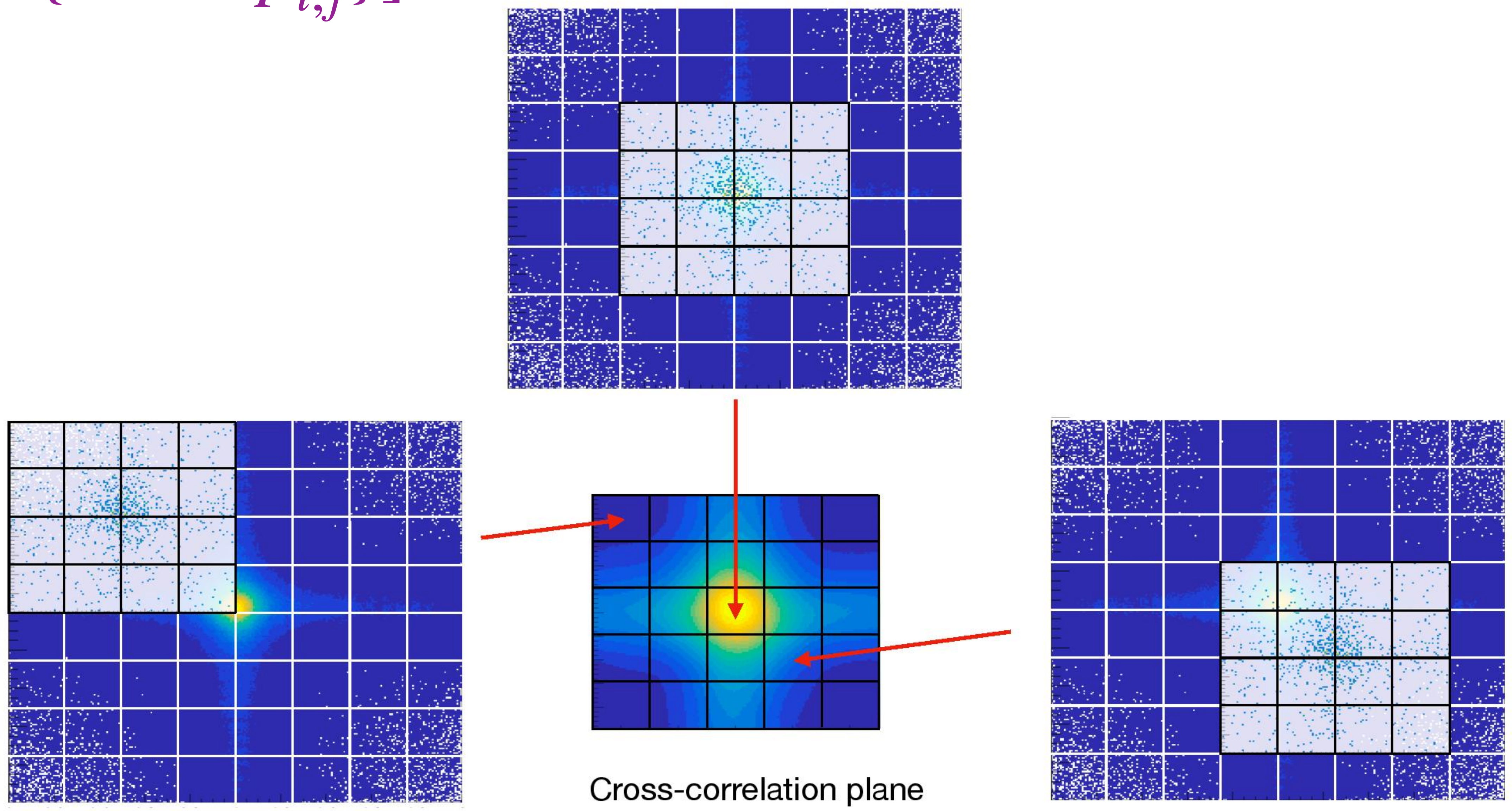
* MXT PSF is energy independent.
* It is twice the camera plane size to cover all incoming directions.

Source Localization

* First the source peak position is computed in the photon map then it is transformed to the sky location in spherical coordinates
* To find the peak position, the centroid method (as used for XRT\swift) is simple, but it's limited in low photons intensity.
* A method based in cross correlation between the PSF and the photon map, and the 2D barycentre is implemented onboard

- ***Cross-correlation***
  - Cross correlate the photon map with the PSF in the Fourier domain.

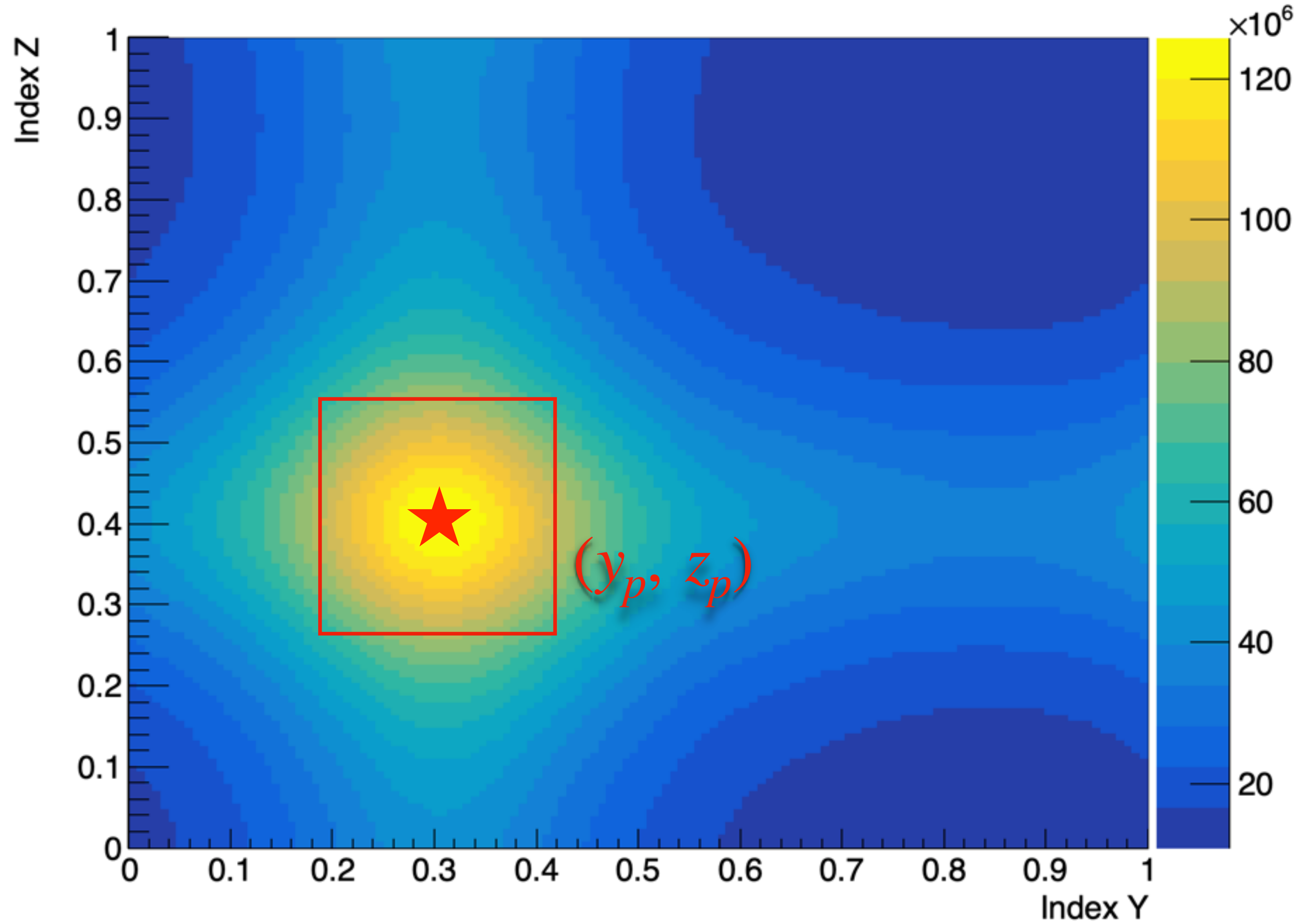
$$C_{i,j} = \mathscr{F}^{-1}[\overline{\mathscr{F}\{PSF_{i,j}\}} \cdot \mathscr{F}\{PhMap_{i,j}\}]$$



Cross-correlation plane

Source Localization

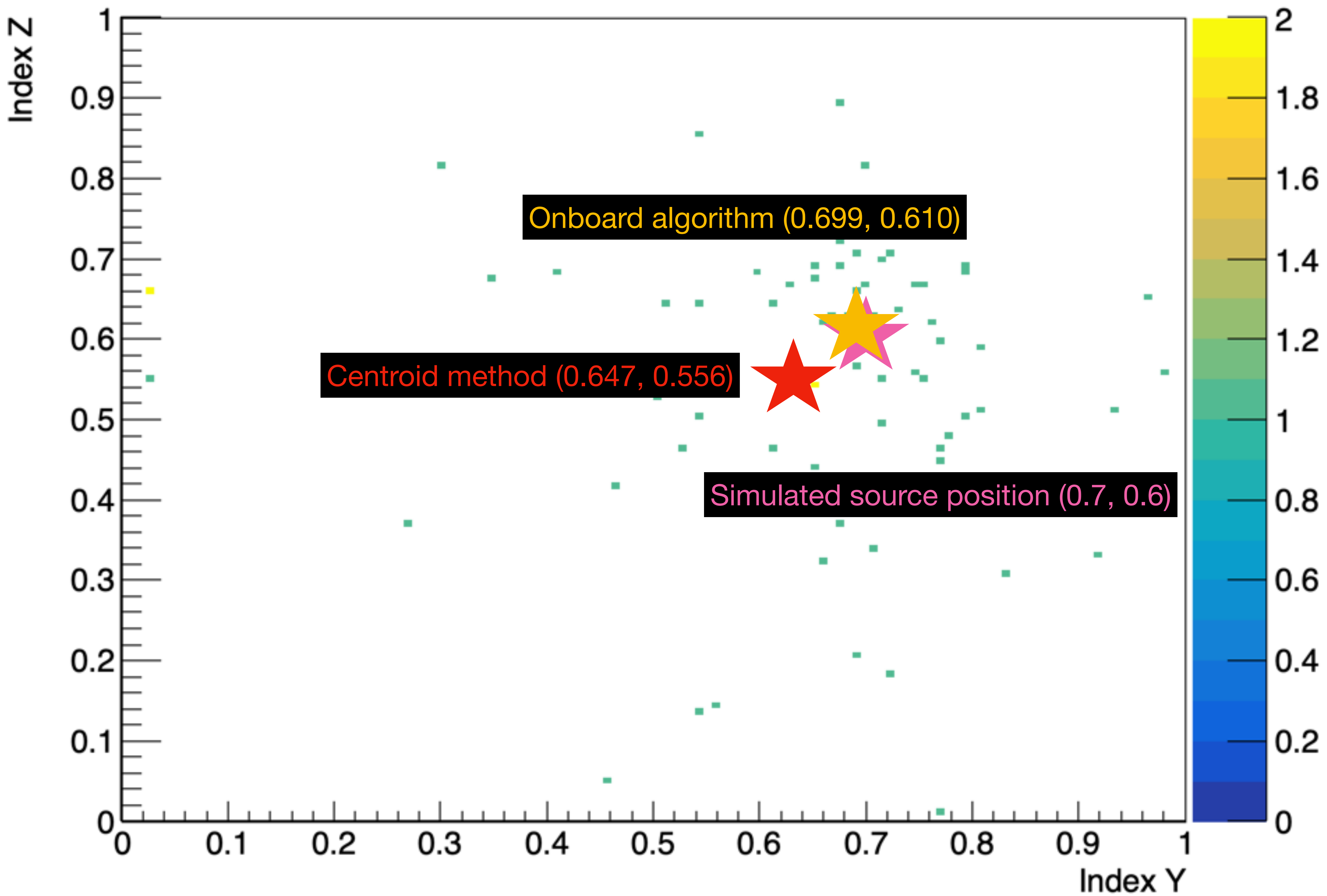
- ***2-D barycentre:***
  - The peak position is given by the 2D barycentre within a window centred on the max value at the correlation map



  - The peak position (y_p, z_p) is then transformed to polar and azimuthal angle (θ, ϕ).
  - This coordinate is transferred to ground centre for the follow up.

Source Localization

- **<u>Advantage of this method appears when a faint source is detected</u>**

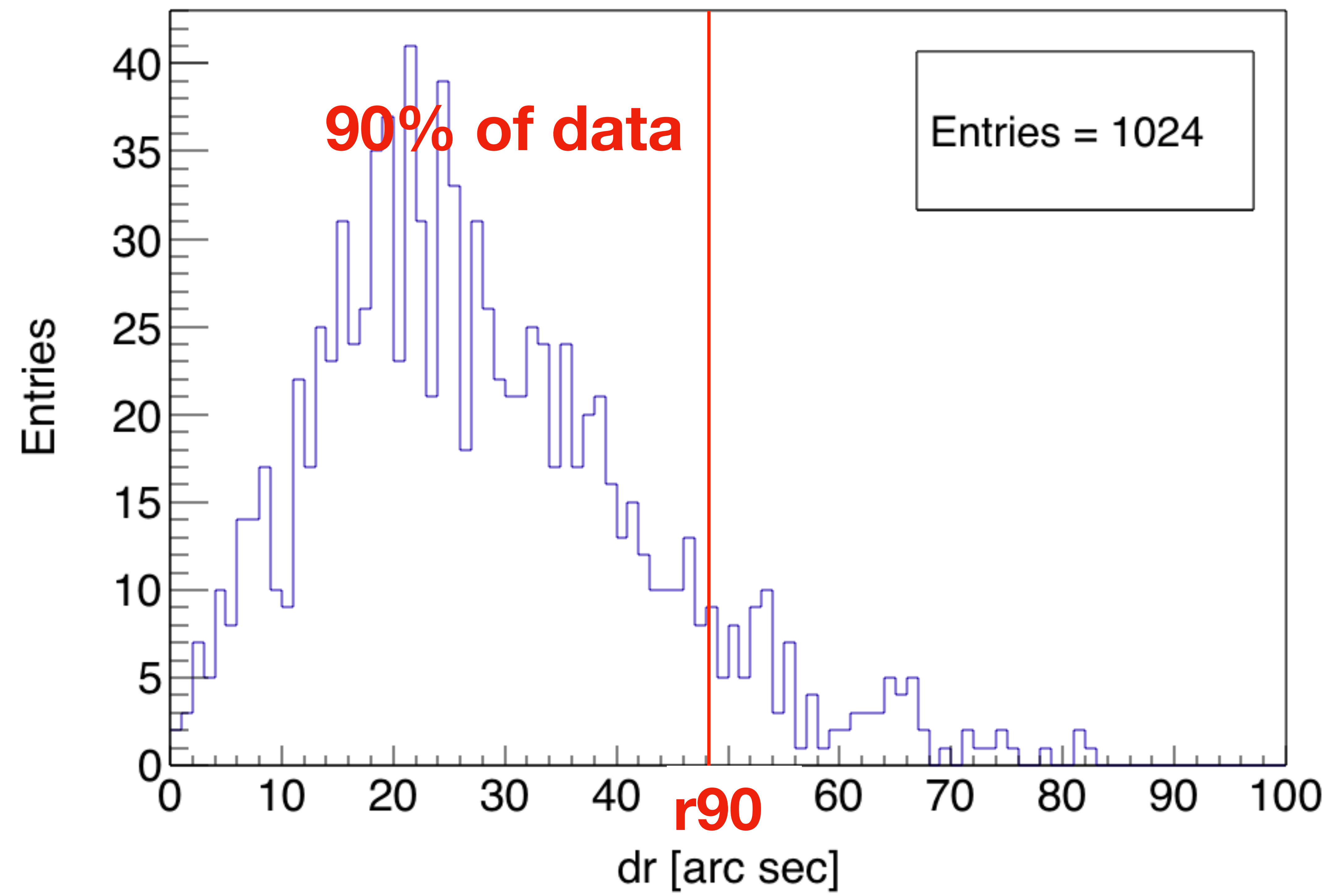


Localization performance

** The performance of the localization algorithm is determined by computing r_{90} value.*

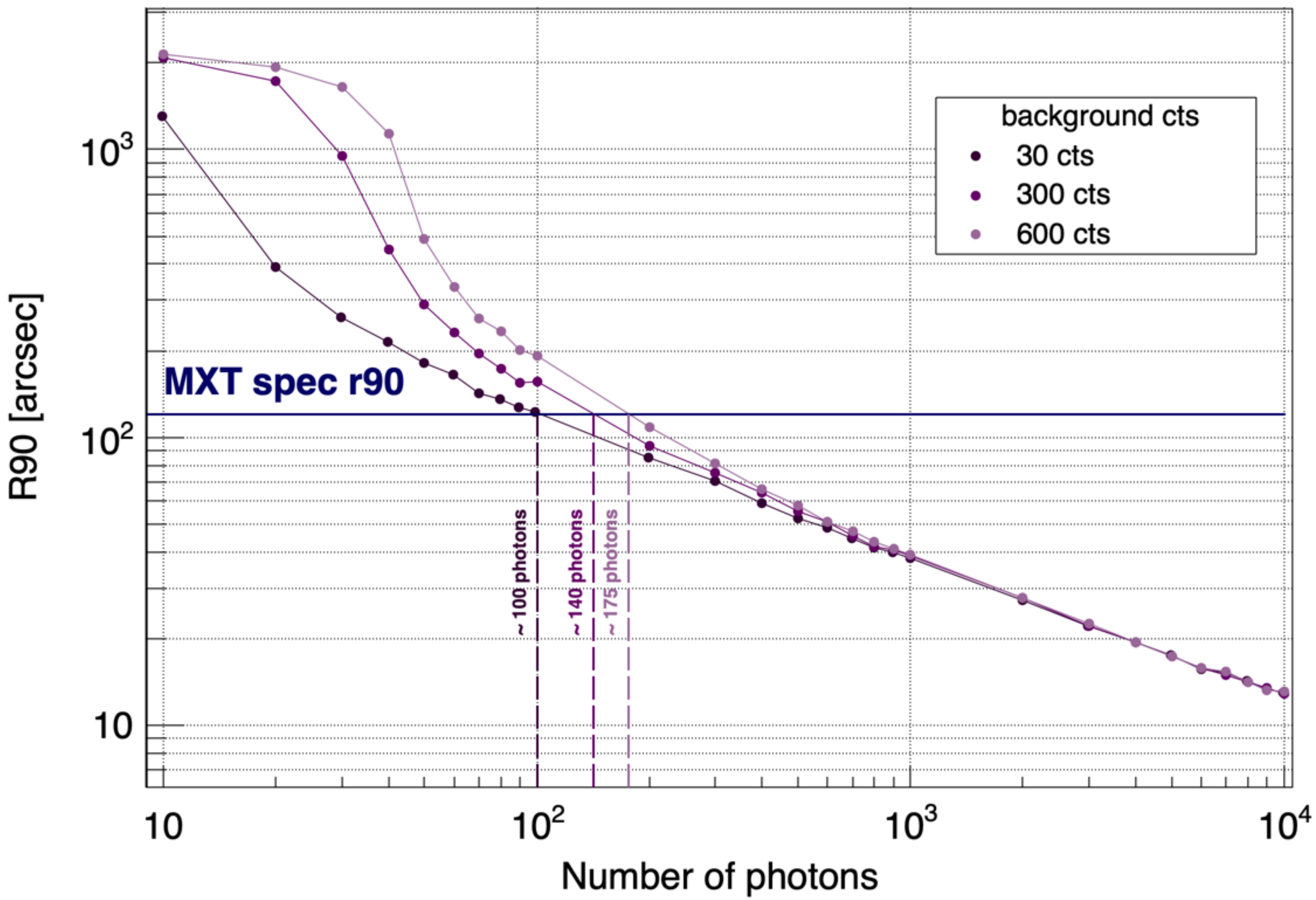
For a given source flux and background counts :

- Generate ~1000 simulations with random source positions within MXT FoV.
- For each simulation run loc algorithm.
- Compute difference between measured and true source positions dr.
- r_{90} is given by the the 90th percentile .



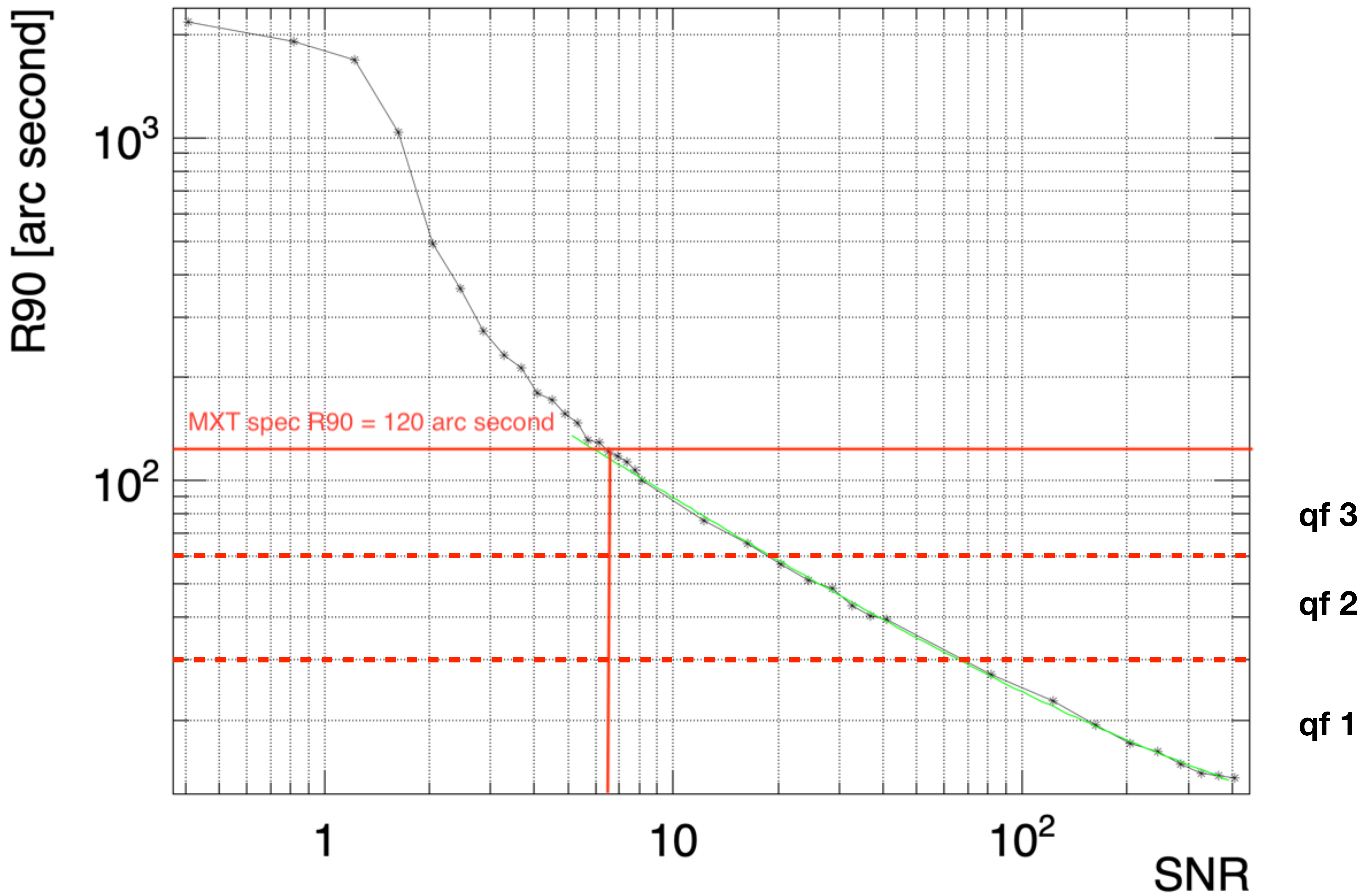
Localization performance

PSF : 2020 at 1 kev



SNR Vs. R90

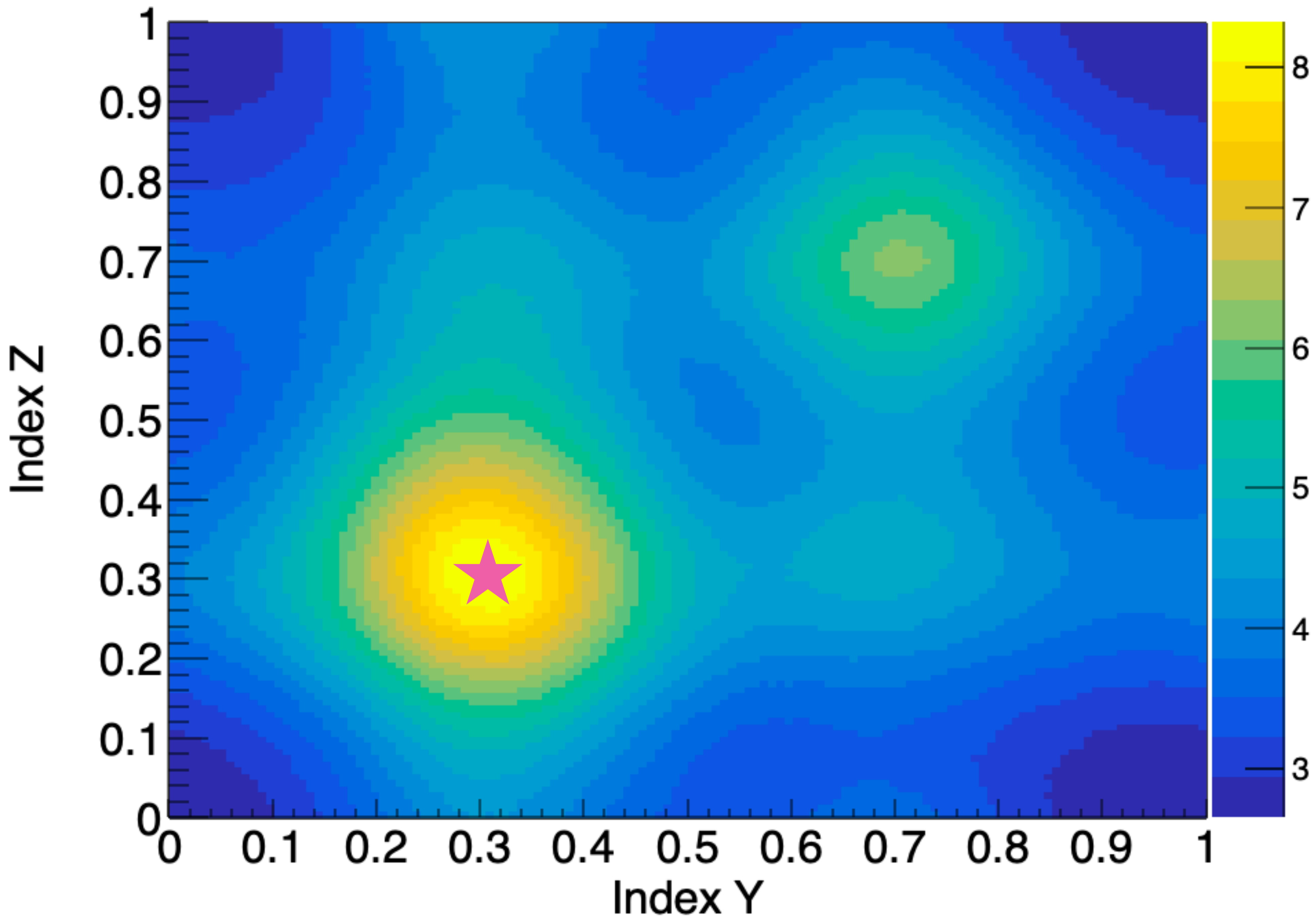
- To compute r_{90} onboard -> SNR is computed.
- Use transfer function to convert SNR to r_{90} : $r_{90} = a \times SNR^b + c$.
- A quality factor is given for sub ranges of r_{90} values.
- This quality factor is transferred to the ground, and the follow up is planed depending on this factor



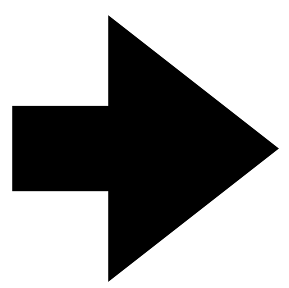
Multiple sources in the FoV

It is possible to have > 1 source in the FoV —> extend the algorithm to localize multiple sources.

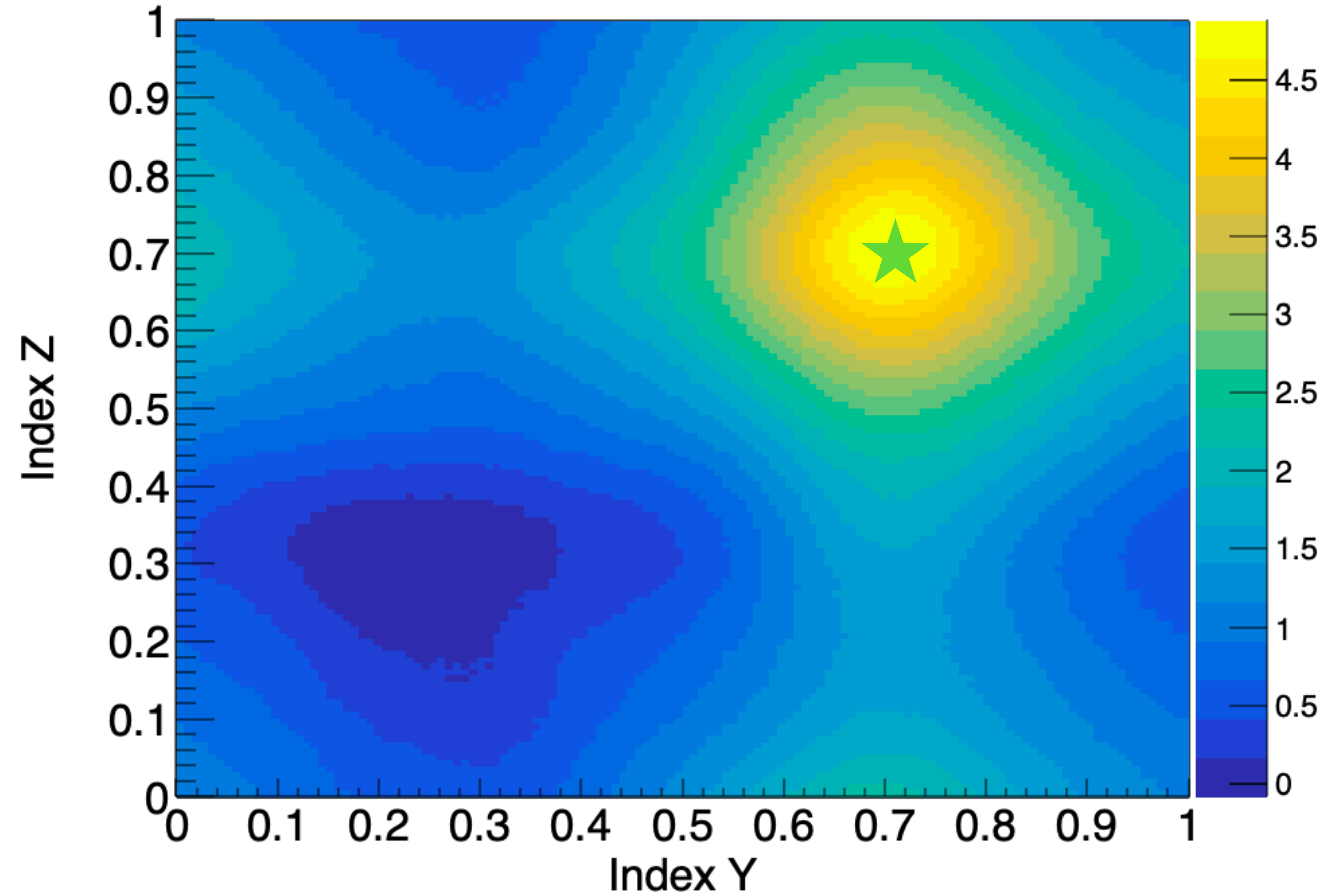
- **<u>Method:</u>** Iterative subtraction of the previous peak:



Detect Brightest peak



Peak subtraction



Detect the next peak

Conclusion

- The main requirement of MXT is to localize the source rapidly down to 2’
- Localization algorithm are now fully implemented and tested using data from X-ray source test facility at Munich.
- I have characterized the algorithm in different cases: having different source intensities, having source in the edge of the telescope, having corrupted pixels in the camera .. etc.
- In the next year of my PhD I will work in characterizing the onboard scientific algorithm with realistic gamma ray bursts observation scenarios.
- Use data from previous similar mission like xrt\swift and convert it to MXT observation.
- What we can learn about GRBs with MXT?

Back up slides