

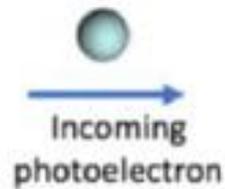
# MCPSIM-PY



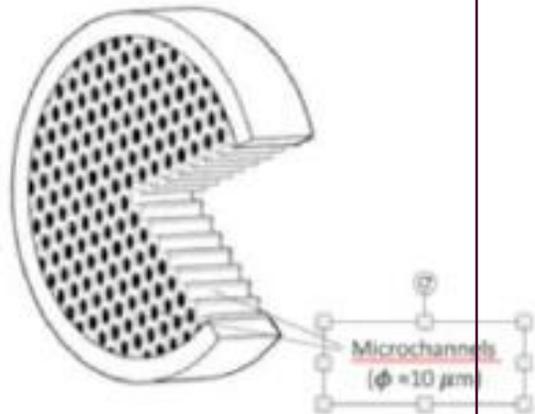
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Universidad Complutense de Madrid  
Space Astronomy Research Group

# COMPONENTS OF THE MCP DETECTOR



1. Data input



MCP, Gain  $\sim 1 \times 10^5 e^-$

2. MCP gain



Phosphor Converter  
 $e^- \rightarrow h\nu$   
 $\sim 40 \times 10^5$  photons

3. Phosphor gain



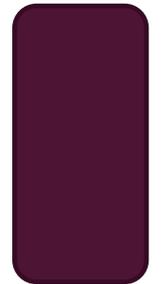
Fibers Taper  
(3.55:1 compression ratio)  
 $\sim 0.026 \times 40 \times 10^5$  photons

4. Fibers tape (compression)



CMOS Detector QE  
 $h\nu \rightarrow e^-$   
QE = 0.45 at 530 nm

5. CMOS



6. FPGA: Centroid detection

# THE SIMULATOR STEP BY STEP

INPUT WINDOW  
DATA  
PARAMETERS

The screenshot displays the MCPsim-Py software interface. The top-left panel, titled 'Simulation', contains input parameters: 'Center of coordinates (arcsec):' with values '0' and '0', 'Sky size (side of square, arcsec):' with a value of '10.05', 'Entry distribution sky:' set to 'Uniform', and 'UV-Photons number:' set to '10'. A yellow oval highlights this entire input section. Below it is a 'Simulate observation' button. The bottom-left panel, titled 'Centroiding Algorithms Control', includes 'Centroid algorithm:' set to '5-square', 'Subpixel algorithm:' set to '3 point center of gravity', 'Background threshold:' set to '40', and 'Hot pixel and cosmic ray threshold:' set to '0.2'. A blue oval highlights this section. The bottom-right panel, titled 'Results', features a plot area with axes ranging from 0.0 to 1.0. A large green oval encompasses the plot area and the 'Plot Options' sidebar on the right, which lists various plot types: 'Plot INPUT IMAGE', 'Plot DATA INPUT', 'Plot MCP', 'Plot PHOSPHOR', 'Plot FIBER TAPE', 'Plot CMOS', 'Plot CENTROIDING', and 'Plot DATA FIELD'. The 'Information' panel at the bottom right is currently empty.

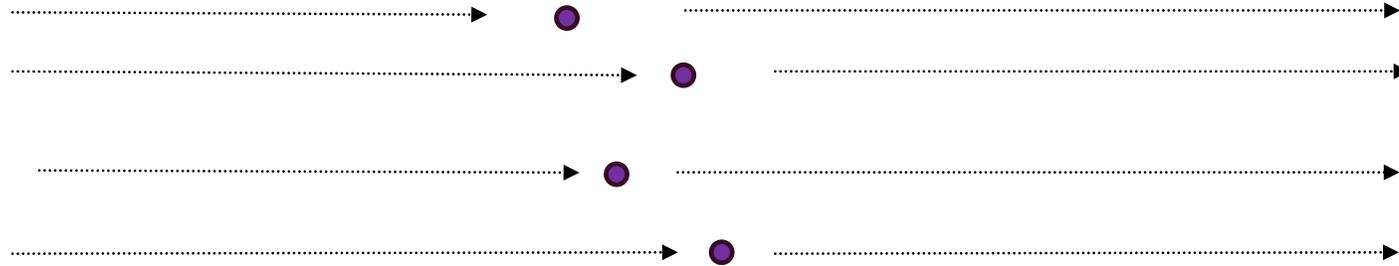
GRAPHIC  
OUTPUT

CENTROIDING  
ALGORITHMS  
CONTROL

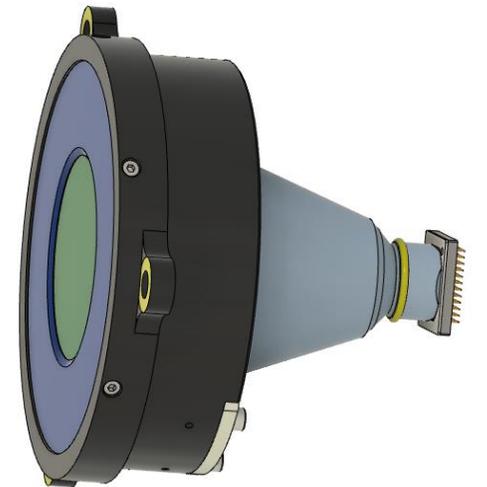
# I. DATA INPUT: GENERATION (THREE MODES AVAILABLE)



Image distribution



Uniform distribution



Two sources

THE LOCATION ON THE IMAGE AND THE TIMING OF THE SIMULATED PHOTONS IS DETERMINED STATISTICALLY

Center of coordinates (arcsec):

Sky size (side of square, arcsec):

Entry distribution sky:

UV-Photons number:

Center of coordinates (arcsec):

Sky size (side of square, arcsec):

Entry distribution sky:

Image path:

UV-Photons number:

Center of coordinates (arcsec):

Sky size (side of square, arcsec):

Entry distribution sky:

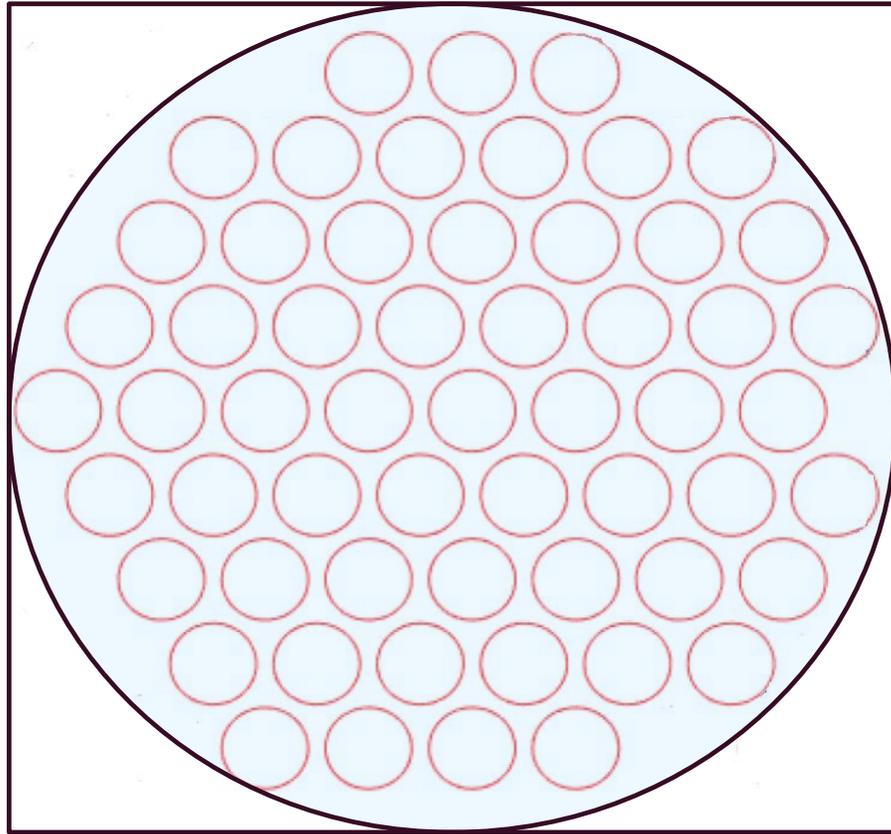
Source 1 (uv-photons/reading):

Source 2 (uv-photons/reading):

FWHM (arcsec):

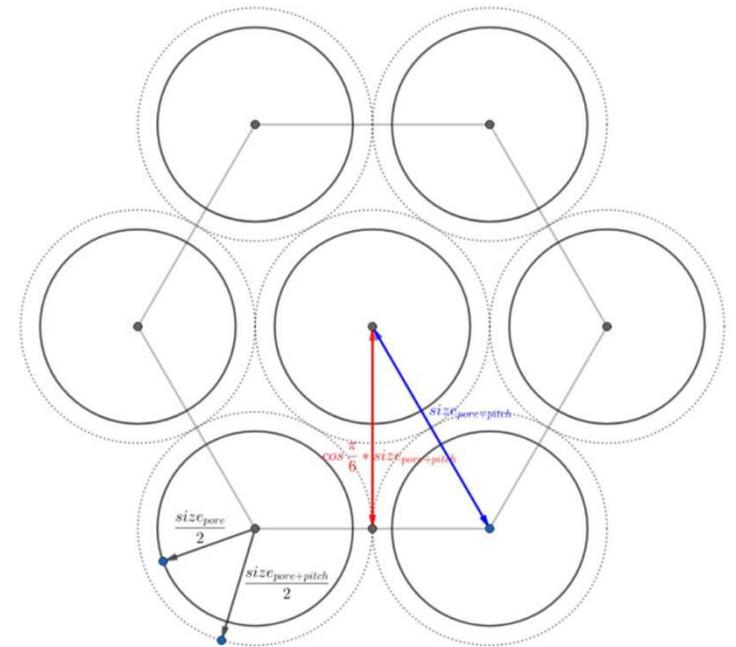
Distance between sources (arcsec):

# I. MCP ENTRANCE WINDOW



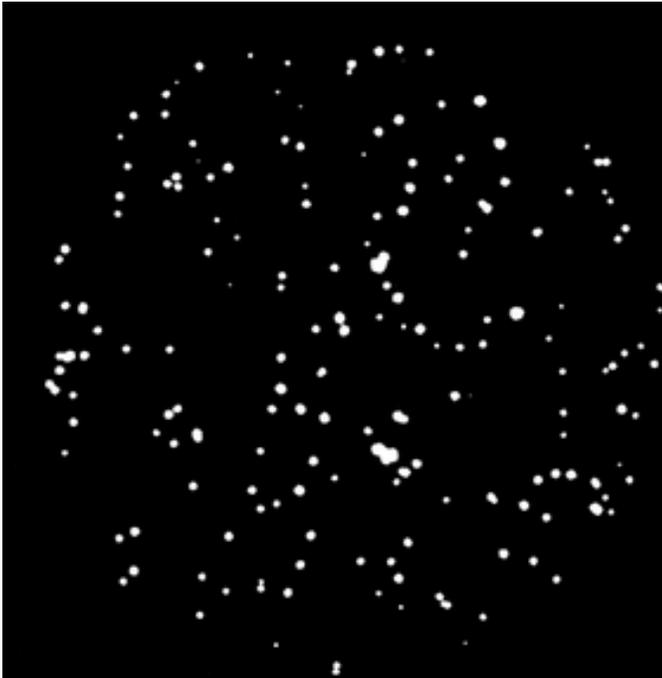
## MICRO TUBES CHARACTERIZATION

- PORE DIAMETER
- PITCH
- GEOMETRY



## 2. MCP GAIN TRANSFER FUNCTION

SAMPLE IMAGE OF THE DETECTOR PERFORMANCE



**IMPORTANT:**

DUE TO THE STATISTICAL NATURE OF THE DETECTION PROCESS  
SIMILAR EVENTS PRODUCE DIFFERENT SHOWERS



THIS STATISTICAL NATURE IS MODELLED  
AND IMPLEMENTED IN THE SIMULATOR

# STEPS TO CHARACTERIZE THIS BEHAVIOR

Image  
binarization

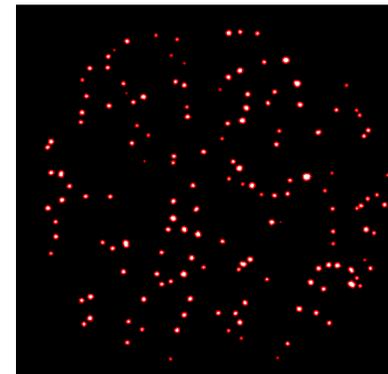
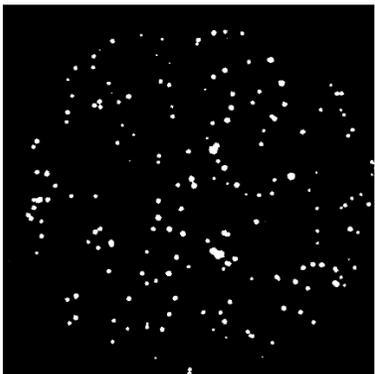
Elimination of  
all the showers  
with little size

Connected  
regions  
detection

Elimination of  
showers with  
eccentricities  
that are bigger  
than a threshold  
value

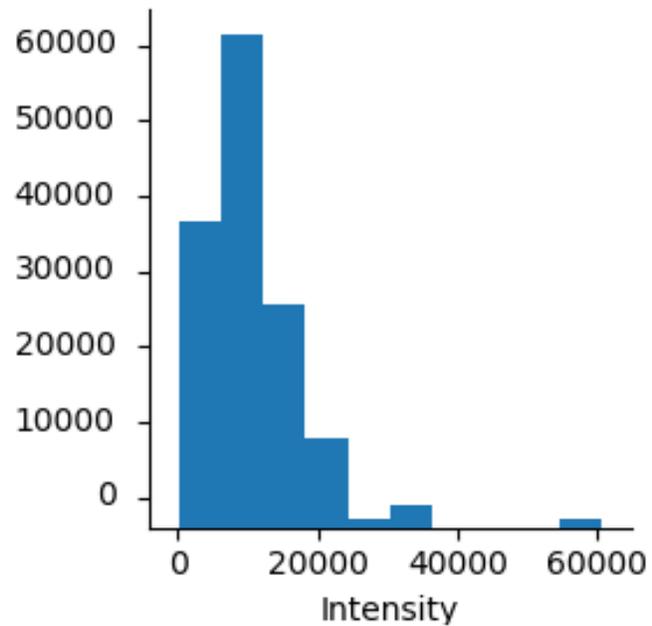
Remove  
background  
noise  
(minor than 4  
electrons)

Calculate the  
mayor axis (a),  
minor axis (b)  
and the peak of  
each resultant  
shower

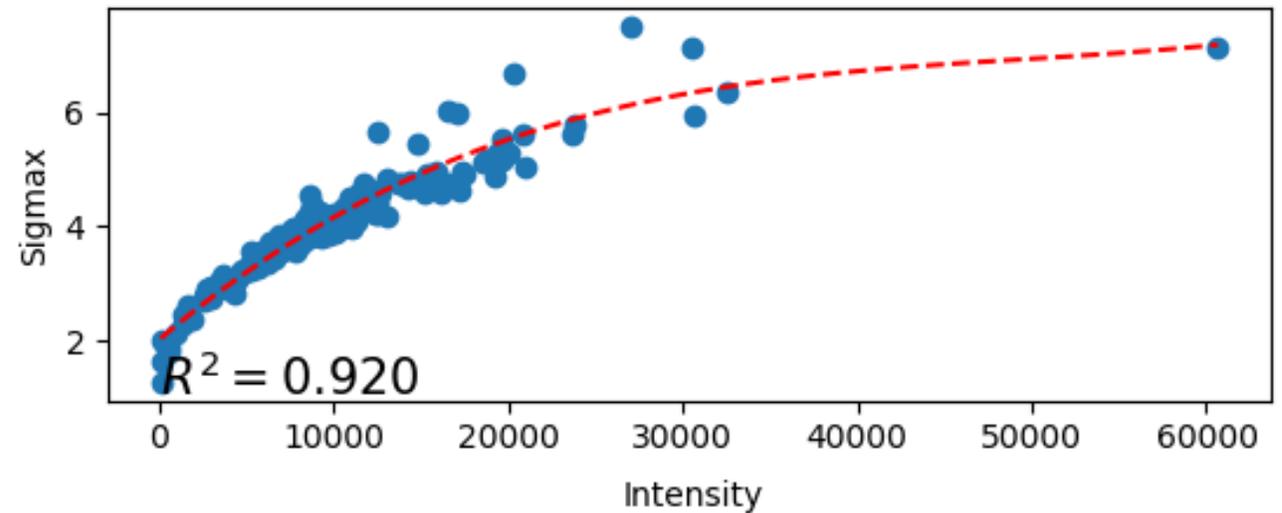


# SHOWER PARAMETERS (TRANSFER FUNCTION)

Statistical distribution by intensity



Statistical distribution by width



MCP Gain:

100000

Simple transfer function (normal deviate of the showers):

0.106

MCP-specific transfer function:

../img/mcp/

Search

Eccentricity filter:

0.7

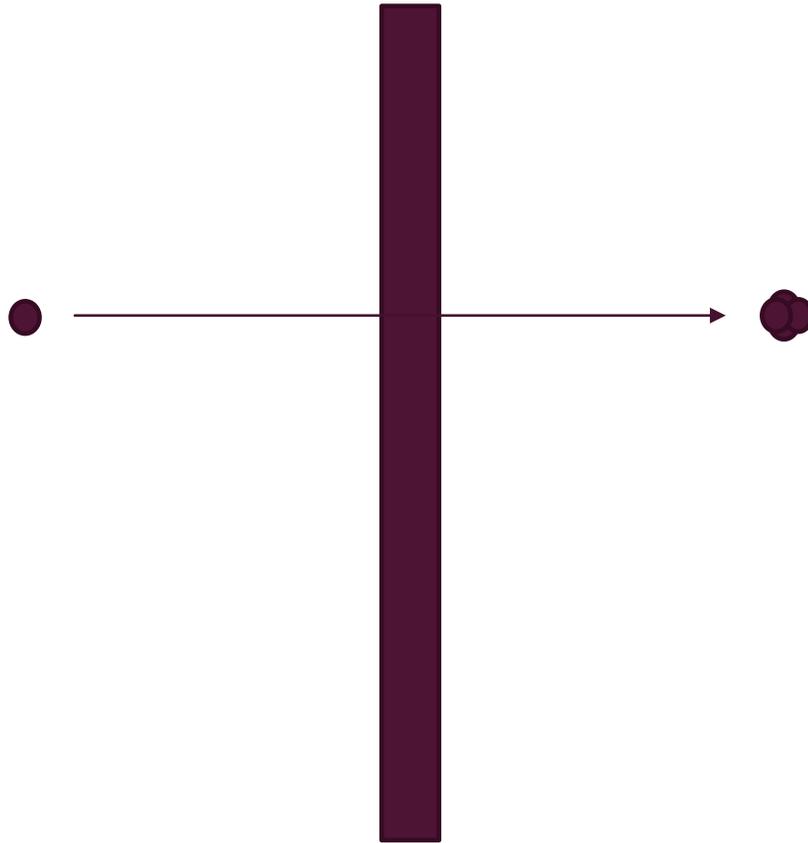
Pore diameter on MCP (microns):

10

Pore pitch on MCP (microns):

12

### 3.PHOSPHOR GAIN

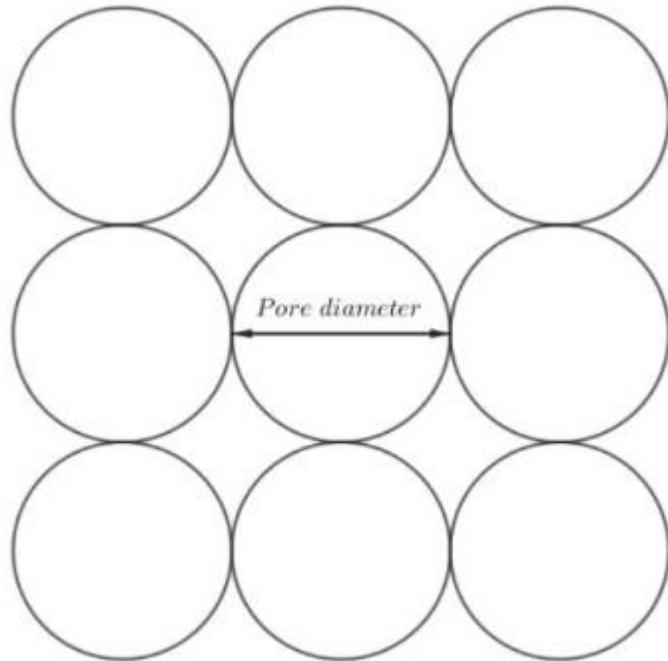


Example: x4 phosphor gain

Phosphor Gain:

40

## 4.FIBERS TAPER



Steps:

- Filter photons that do not go through the fibers.
- Apply a spatial uniform distribution inside each tube

$$\text{Loss factor} = \frac{\text{Circle area}}{\text{Square area}} = \frac{\pi * R^2}{4 * R^2} = \frac{\pi}{4}$$

Pore diameter on fiber inlet (microns):

10

Factor (demagnification factor):

3.55

Fiber transmittance:

0.0331

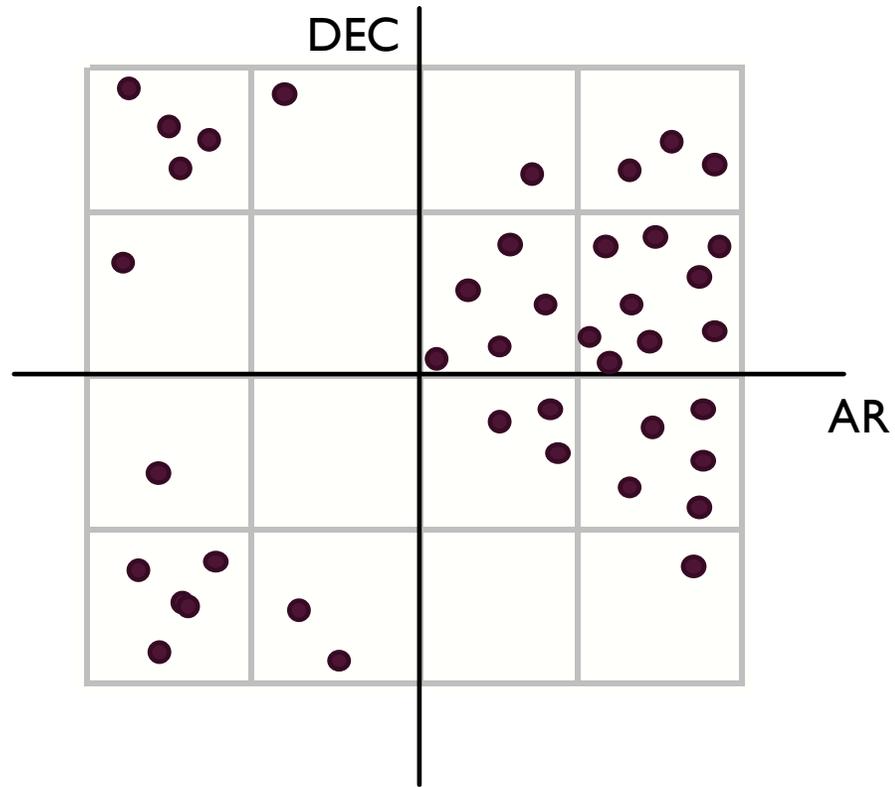
*Flux loss factor (geometry):*

*0.7854*

*Flux decrease in the fiber tape (geometry factor \* fiber transmittance):*

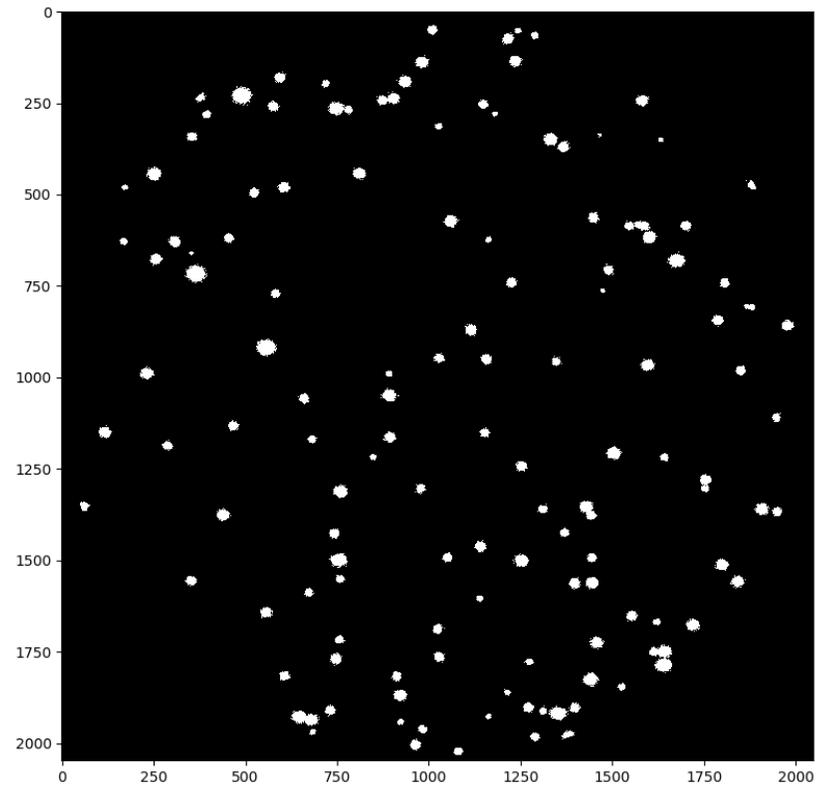
*0.026*

# 5. GENERATION OF THE CMOS IMAGE



4	1	1	3
1	0	5	9
1	0	3	5
5	2	0	1

# OUTPUT EXAMPLE



Pixel size (microns):

5.5

Full well capacity (e-/pixel):

13500

Gain (e-/ADU):

1.6

Quantum Efficiency:

0.6

Hot pixels

Percentage (%):

0.001

Hot pixel  
value:

13500

Flat field

Image path:

../../img/flatfield/flat\_field\_1.jpg

Search

Readout noise

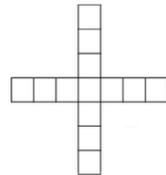
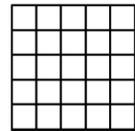
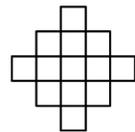
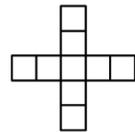
Value  
(e-/pixel):

6

# 6.FPGA: CENTROID DETECTION

## Centroid algorithms

- 3-cross
- 3-square
- 5-cross
- 5-circle
- 5-square
- 7-cross

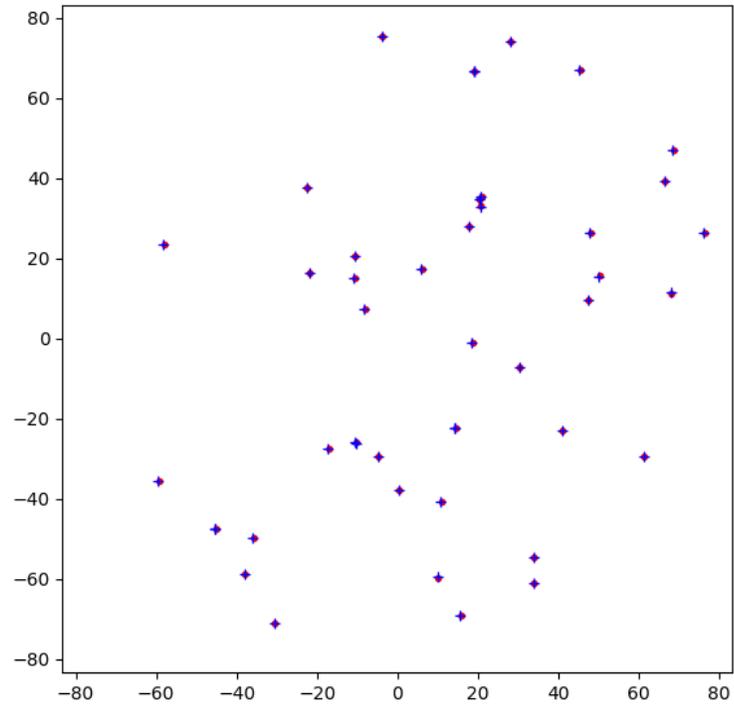


## Subpixel algorithms

- 3-point center of gravity
- Gaussian
- Lorentzian
- Parabola
- 5-point center of gravity
- 7-point center of gravity

N.Pixels	NAME OF ALGORITHM	1-axis (X-axis) centroid	GRAPHIC LAYOUT
3	3-point center of gravity	$x_c = \frac{c - a}{a + b + c}$	
	Gaussian	$x_c = \frac{\ln(c) - \ln(a)}{2(2\ln(b) - \ln(a) - \ln(c))}$	
	Lorentzian	$x_c = \frac{c - a}{2\left(c + a - \frac{2ac}{b}\right)}$	
	Parabola	$x_c = \frac{c - a}{2(2b - a - c)}$	
	Hyperbolic cosine	$x_c = \frac{\ln\left(\frac{2\sqrt{\frac{b}{a}} + \sqrt{\left(\sqrt{\frac{b}{a}} + \sqrt{\frac{b}{c}}\right)^2 - 4}}{2\sqrt{\frac{b}{c}} + \sqrt{\left(\sqrt{\frac{b}{a}} + \sqrt{\frac{b}{c}}\right)^2 - 4}}\right)}{2\ln\left(\frac{1}{2}\left(\sqrt{\frac{b}{a}} + \sqrt{\frac{b}{c}} + \sqrt{\left(\sqrt{\frac{b}{a}} + \sqrt{\frac{b}{c}}\right)^2 - 4}\right)\right)}$	
5	5-point center of gravity	$x_c = \frac{2e + d - b - 2a}{a + b + c + d + e}$	
7	7-point center of gravity	$x_c = \frac{3g + 2f + e - c - 2b - 3a}{a + b + c + d + e + f + g}$	

Results



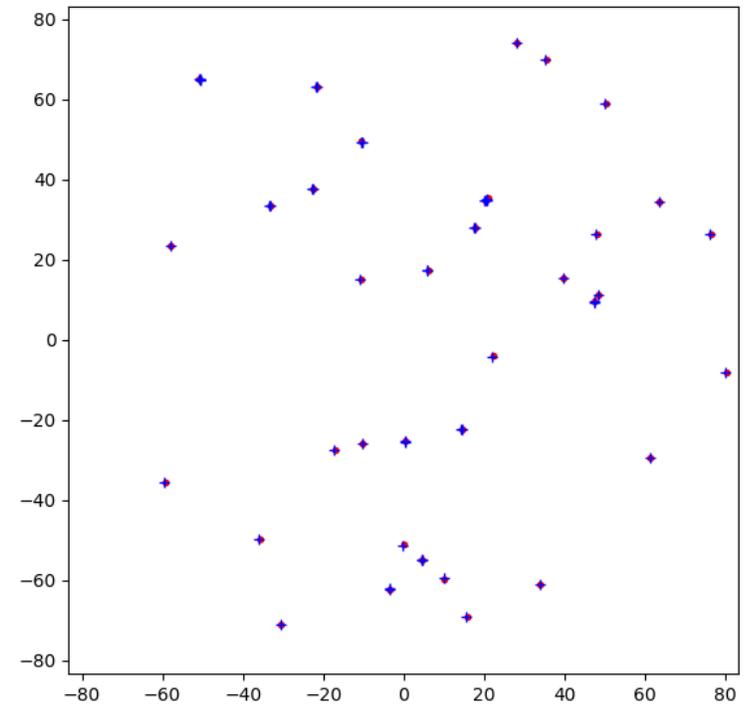
Information

Data\_input (uv-photons): 100  
MCP-in (uv-photons): 41  
MCP out (electrons): 1079577  
Phosphor (photons): 43183080  
Fiber Tape (photons): 1086953

Centroids info:

Real events: 41  
Detected events: 45

Results



Information

Data\_input (uv-photons): 100  
MCP-in (uv-photons): 36  
MCP out (electrons): 934908  
Phosphor (photons): 37396320  
Fiber Tape (photons): 949437

Centroids info:

Real events: 36  
Detected events: 52