Analysis of the CCOB–NB Run6 data

Camera Calibration Optical Bench – Narrow Beam

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CCOB–NB, what for?

- Commissioning of the integrated camera (LCA-283-F)
  - precise measurement of the **optical throughput**
  - determination of the **optics alignment/tilt**
  - mapping of the **baffle** between L1 and L2

- The Camera Calibration Optical Bench Narrow Beam (CCOB-NB) is a calibrated and (X,Y)+(Θ, Φ) positionable pencil beam monochromatic light source.
  - allows the illumination of the focal plane through the full optical system from a variety of incident angles in the 6 spectral bands
  - 2.5 mm wide monochromatic beam ($\delta\lambda \sim 1$ nm)
  - from 300 nm to 1100 nm

In–operation picture

Designed and built at LPSC, used at SLAC for Run 6 in 2023

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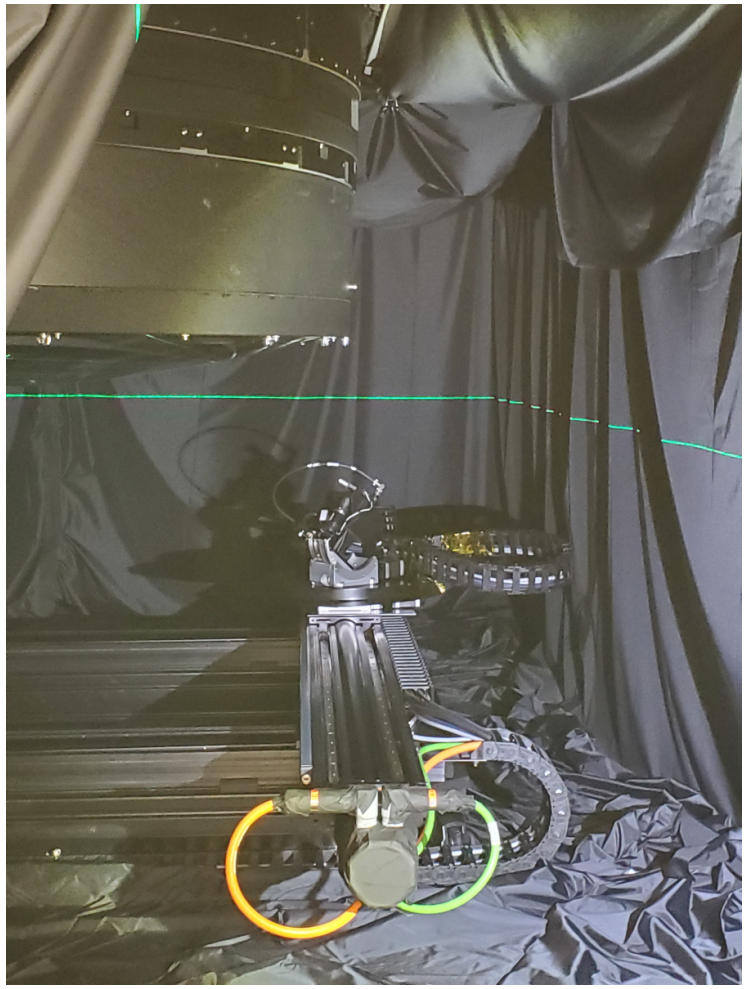
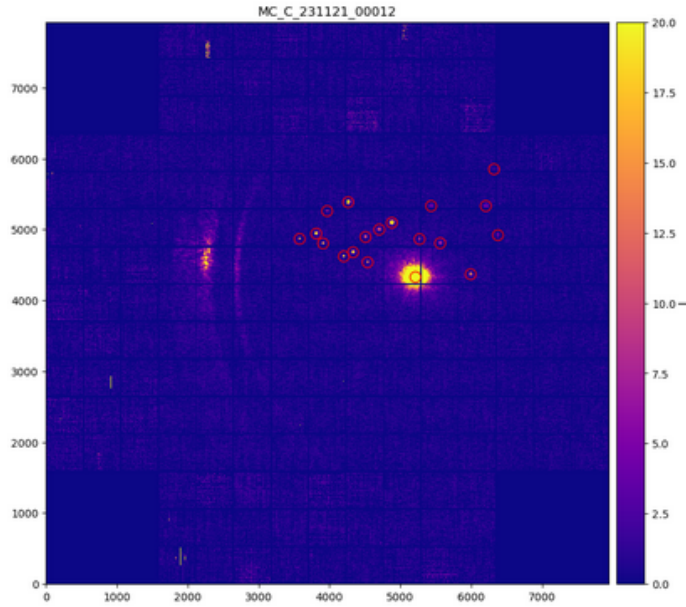
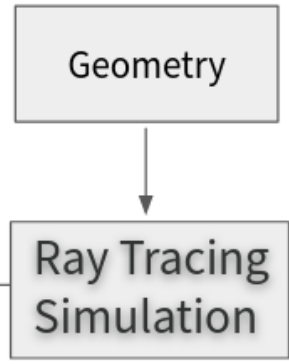
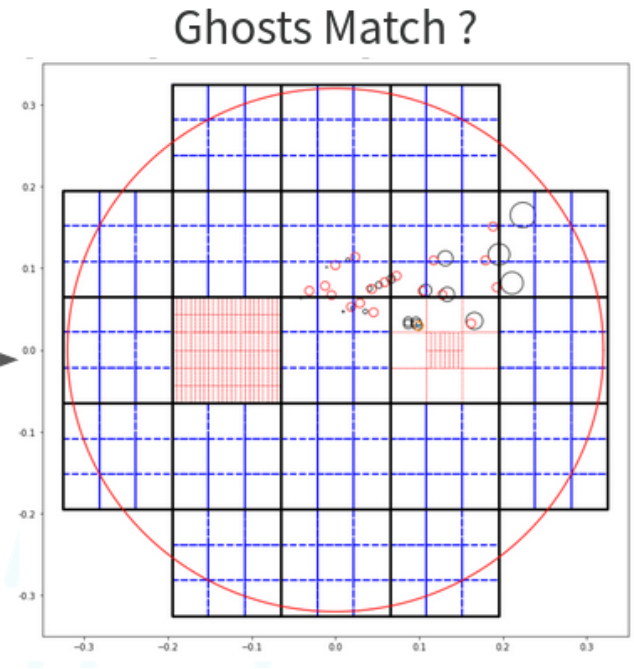


Main idea

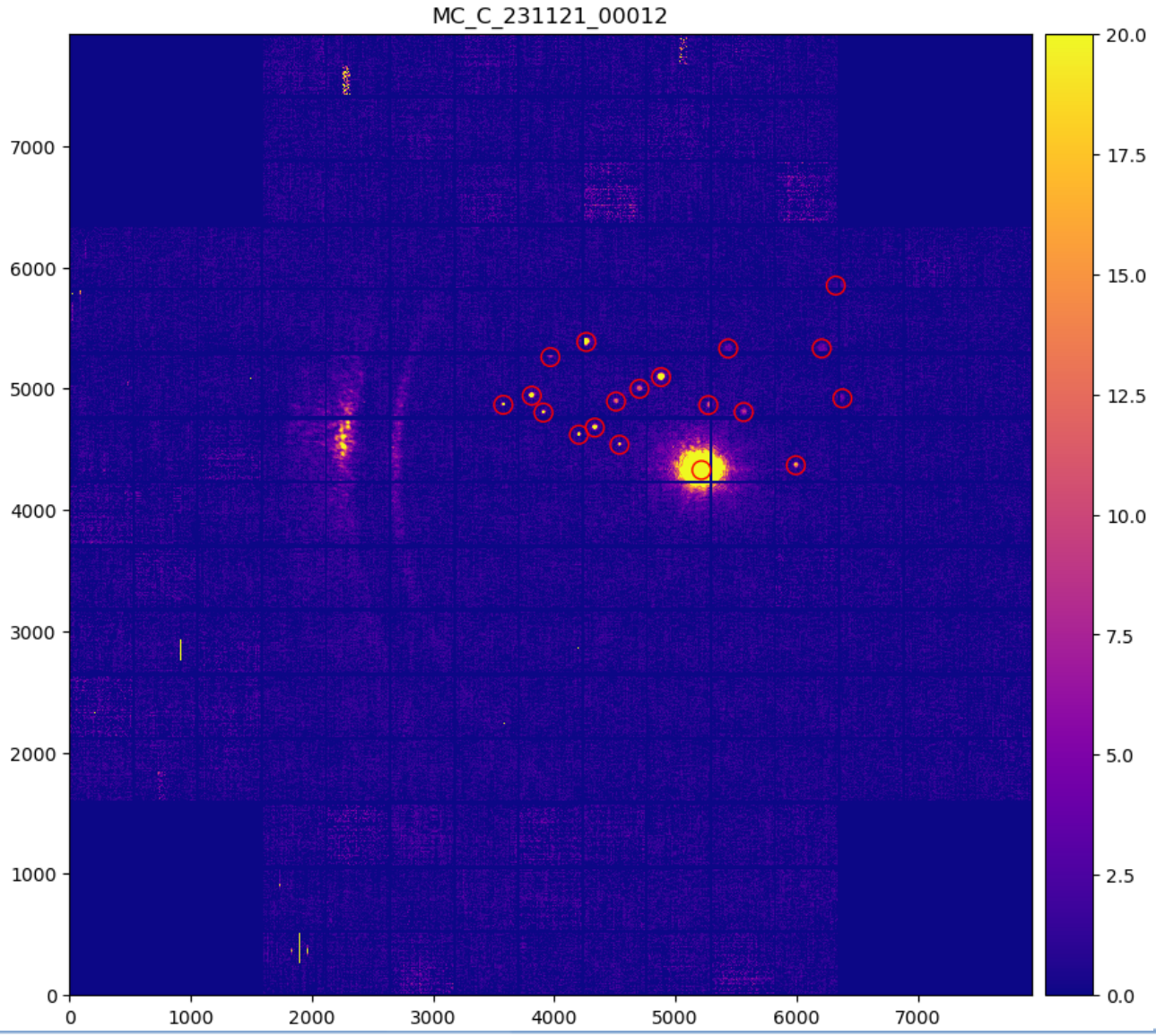
- Run6 data taken in november 2024 in 27 different configurations
- Ray tracing simulation package based on `batoid`

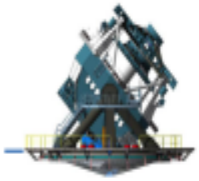






Full focal plane image with ghosts





Data processing steps

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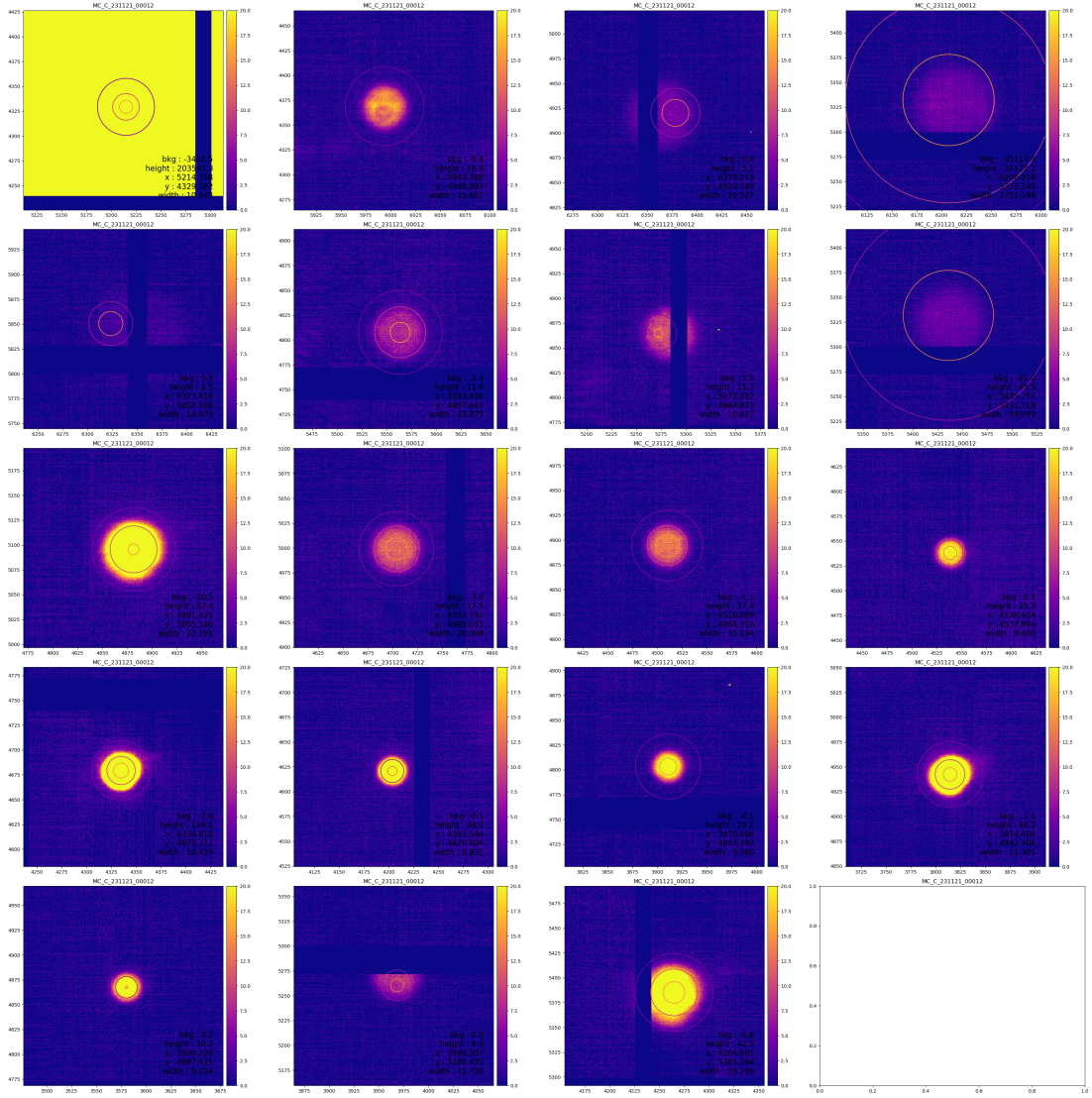
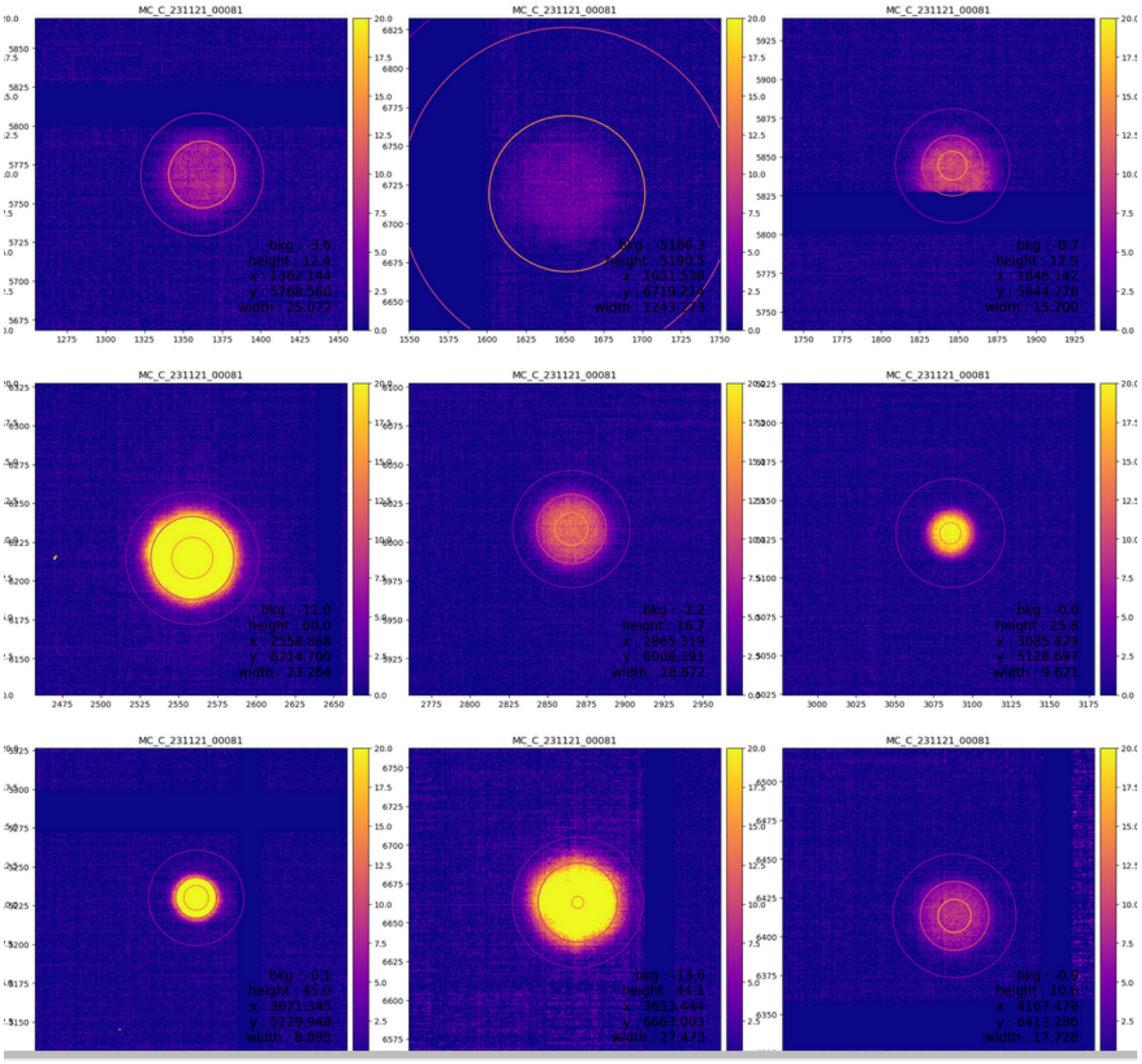
- Run the ISR on each CCD, relying on `eo_pipe`
- Make a mosaic image : assembling CCDs into one focal plane image
- Point and click on each ghosts
- Fit each ghost position with a 2D gaussian to get a precise position (and a rough flux estimation)
- Coordinate transform to get the CCD in which each ghost is
- Fit each ghost position again on the post–ISR CCD images: to get a correct coordinate transform to absolute focal plane position (a.k.a `DVCS`)

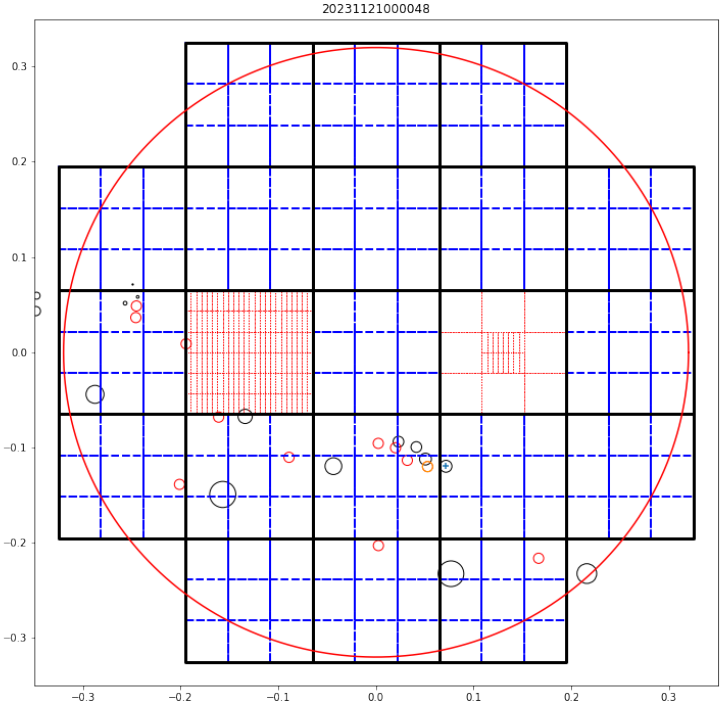
Ghosts fits

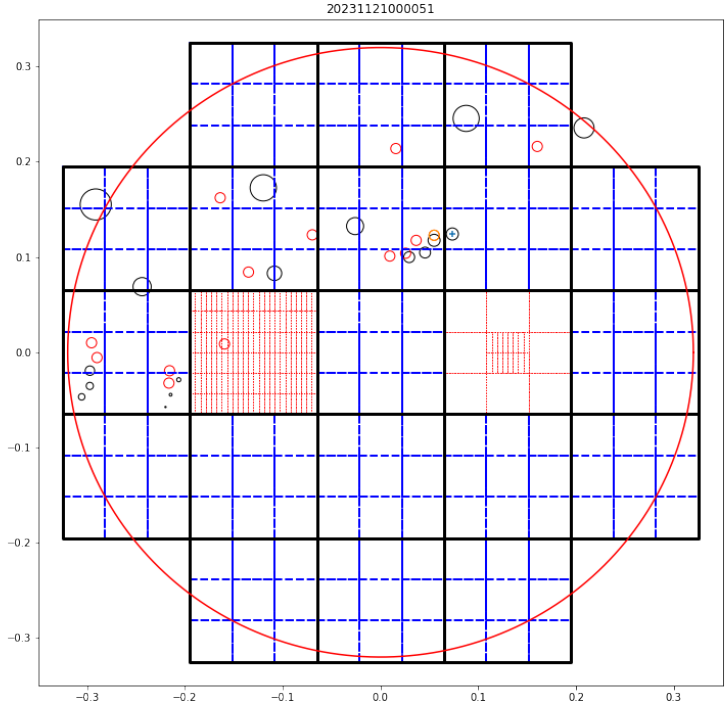

MC_C_231121_00012
bkg : -0.3
height : 2.5
x : 6323.418
y : 5850.508
width : 14.073
bkg : -0.1
height : 78.1
x : 5093.785
y : 4388.897
width : 15.801
bkg : 0.9
height : 55.1
x : 6378.219
y : 4920.180
width : 24.327
bkg : -10.5
height : 67.4
x : 4881.431
y : 5091.546
width : 22.191
bkg : -3.0
height : 17.5
x : 4703.731
y : 4979.035
width : 20.099
bkg : -4.1
height : 17.4
x : 4510.099
y : 4894.516
width : 15.104
bkg : 0.3
height : 25.3
x : 4538.654
y : 4527.804
width : 9.400
bkg : -2.6
height : 139.1
x : 4174.818
y : 4678.012
width : 10.429
bkg : -0.1
height : 46.0
x : 4200.546
y : 4620.804
width : 8.931
bkg : -0.1
height : 29.2
x : 3916.898
y : 4883.592
width : 9.560
bkg : -1.3
height : 58.2
x : 3814.406
y : 4942.406
width : 11.305
bkg : -0.2
height : 30.2
x : 3580.206
y : 4867.425
width : 9.304
bkg : 0.0
height : 9.4
x : 3946.247
y : 5200.470
width : 13.750
bkg : -6.6
height : 42.3
x : 4264.901
y : 5385.284
width : 20.296

Ghosts fits

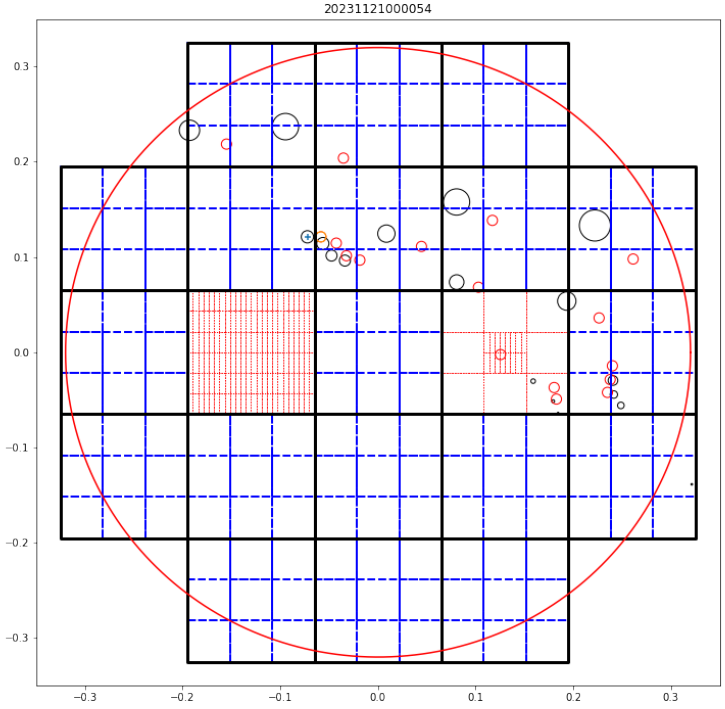

MC_C_231121_00081
bkg : -3.6
height : 12.4
x : 1362.144
y : 5768.560
width : 25.072
MC_C_231121_00081
bkg : -5186.3
height : 5190.5
x : 1651.538
y : 6719.217
width : 1243.273
MC_C_231121_00081
bkg : -0.7
height : 12.9
x : 1846.142
y : 5844.276
width : 15.200
MC_C_231121_00081
bkg : -11.0
height : 60.0
x : 2558.868
y : 6214.700
width : 23.264
MC_C_231121_00081
bkg : -2.2
height : 16.7
x : 2865.319
y : 6008.391
width : 18.872
MC_C_231121_00081
bkg : -0.0
height : 25.8
x : 3085.829
y : 5128.697
width : 9.621
MC_C_231121_00081
bkg : -0.1
height : 45.0
x : 3671.345
y : 5229.948
width : 8.895
MC_C_231121_00081
bkg : -13.6
height : 44.1
x : 3653.444
y : 6663.003
width : 27.473
MC_C_231121_00081
bkg : -0.9
height : 10.6
x : 4167.478
y : 6413.286
width : 17.728

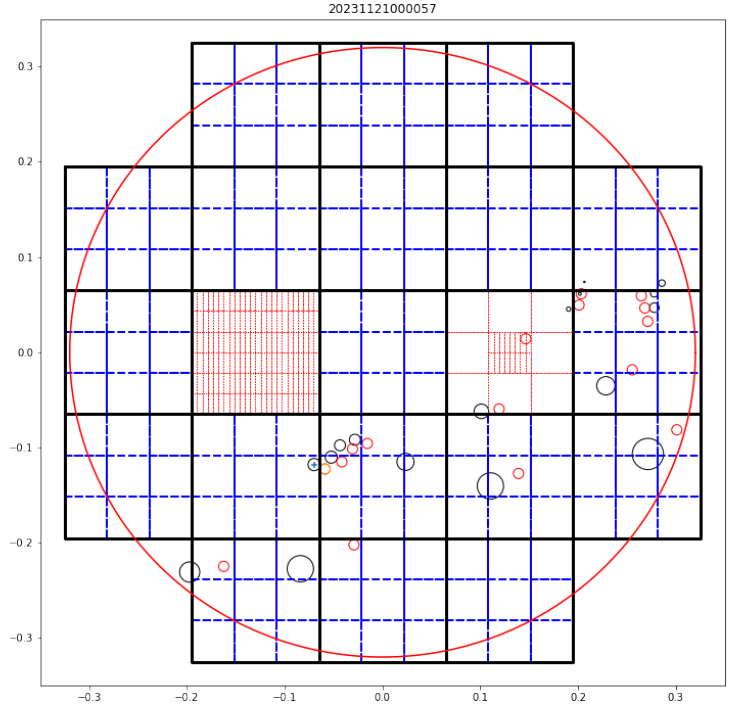
Match data and simulations



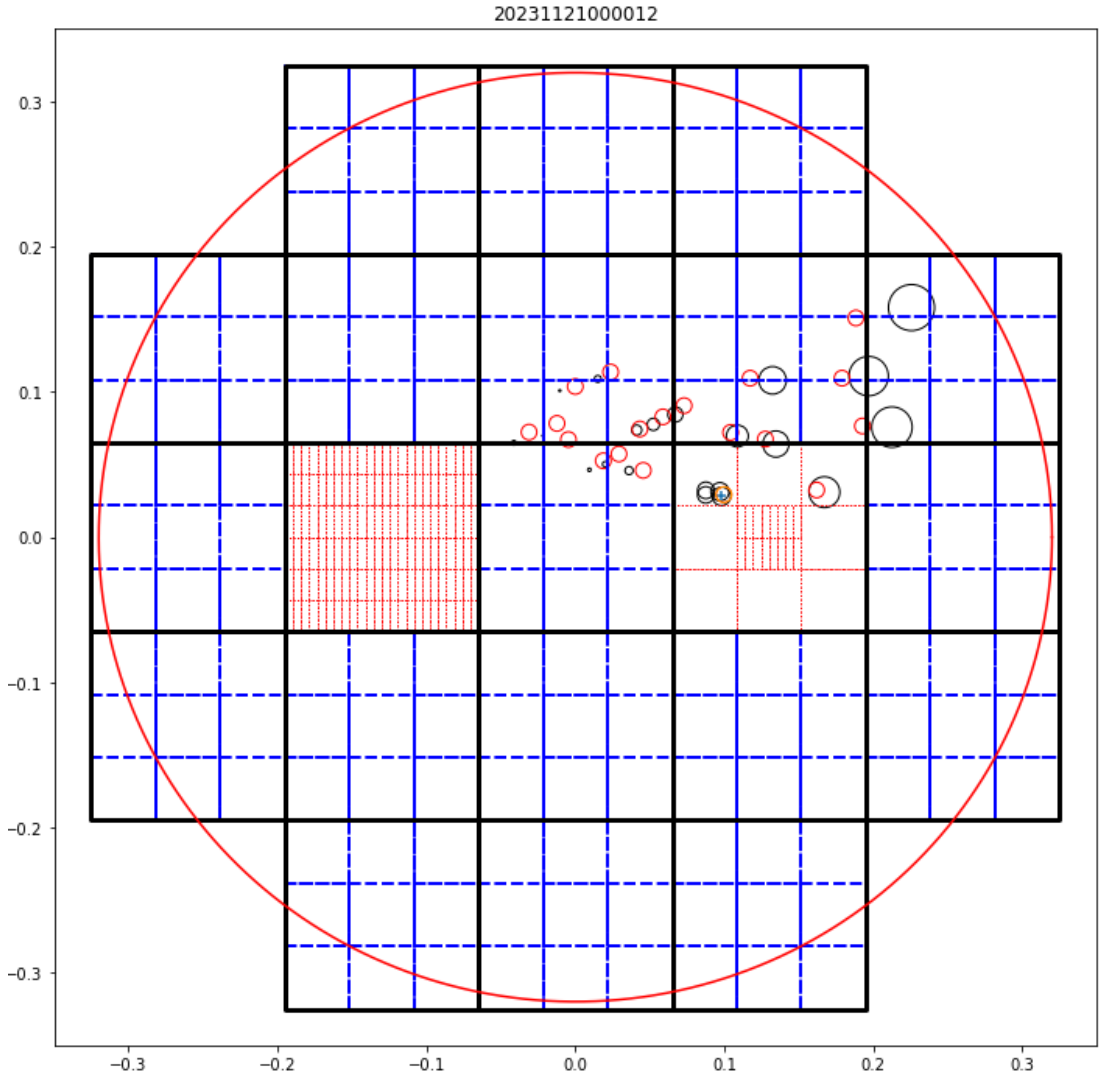


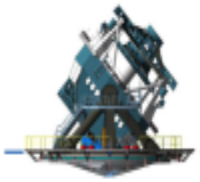
Match data and simulations





Match data and simulations





Distance between ghosts catalogs

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ghost spot $g_{r,i}$ has parameters $[x_{r,i}, dx_{r,i}, y_{r,i}, dy_{r,i}, rad_{r,i}, drad_{r,i}, p_{r,i}]$ for position in x and y with uncertainties dx and dy, radius rad and uncertainty $drad$ and intensity.

the 2D Euclidean distance between 2 ghosts spots is defined as:

$$d(g_{r,j}, g_{s,i}) = \sqrt{(x_{s,i} - x_{r,j})^2 + (y_{s,j} - y_{r,j})^2}$$

and the associated error is:

$$\sigma_d(g_{r,j}, g_{s,i}) = \sqrt{(dx_{s,i}^2 + dy_{s,i}^2) + (dx_{r,j}^2 + dy_{r,j}^2)}$$

with the distances spot to spot between the 2 lists $(g_{r,j1..m}, g_{s,i1..n})$, one can them associate each spot in the S_s set with the closest spot in the S_r set.

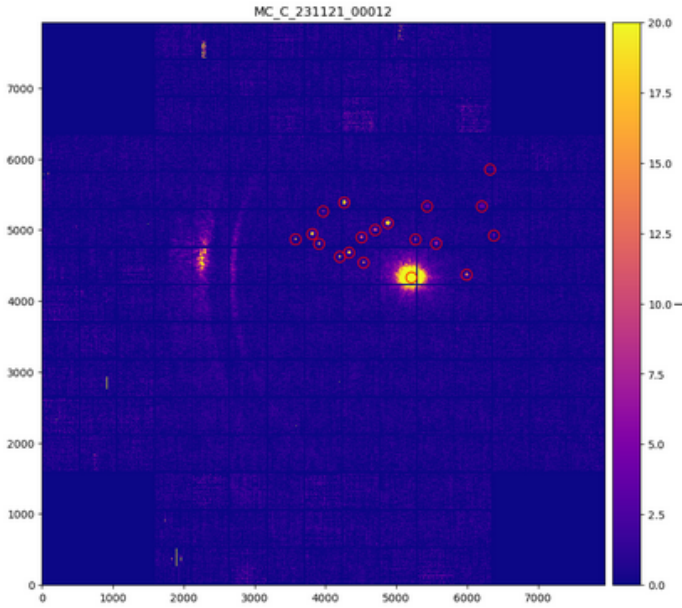
we note g_{r,k_i} the closest ghost spot in S_r to the ghost spot $g_{s,i}$ in S_s.

the reduced distance between 2 sets of ghosts spots may then be defined as follow:

$$L = \frac{\sqrt{\sum_{i=1}^{n} \frac{d(g_{s,i}, g_{r,k_i})^2}{\sigma_d(g_{s,i}, g_{r,k_i})^2}}}{n}$$

if 2 sets of beam spots are the same $L = 0$, and if they are really close then L should be small.

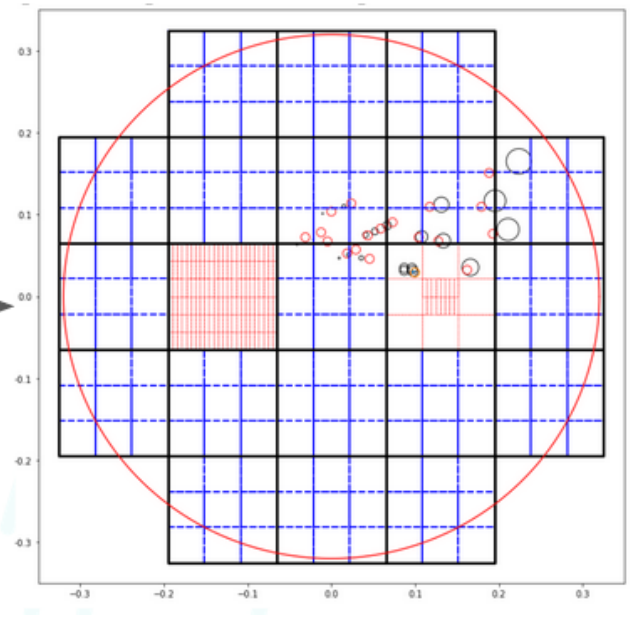
Fit principle

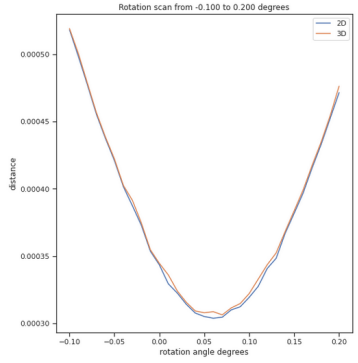


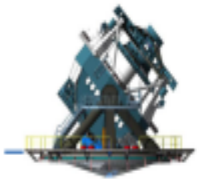
Geometry

Ray Tracing Simulation

Ghosts Match ?







Fit strategy

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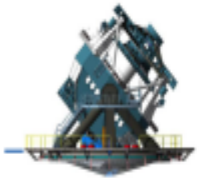
- Some complexities
  - 5 parameters $\times$ (3 lenses + focal plane)
  - the beam position is not well known: need to fit it as well (not implemented yet)
  - ghosts sometimes fall in between CCDs (error on position)
  - some ghosts are really dim
  - running one simulation for one geometry configuration is quite fast O(1) s. . . but that's atually slow when you need to run O(10^5) for 27 configurations
- Fit strategy
  - fit iteratively one parameter for each lens
  - fit iteratively one lens at a time
  - fit all lenses together
  - fit using multiple configurations at a time

$\Rightarrow$ No results yet. . .



Conclusions

- CCOB–NB designed and built at LPSC, sent and received at SLAC in Summer 2021 (after a long journey)
- Used at SLAC on the LSST Camera for Run6 in 2023: lots of high quality data
- Data analysis for optical alignment underway!
  - `[github:lsst-camera-dh/ghosts]`
  - `[github:lsst-camera-dh/ghosts_nb_analysis/]`
- New data taking will occur on the summit this summer both for transmission and alignment purposes