Queen Mary
University of London
Science and Engineering

# Optical Simulations for LhARA test stand (4)

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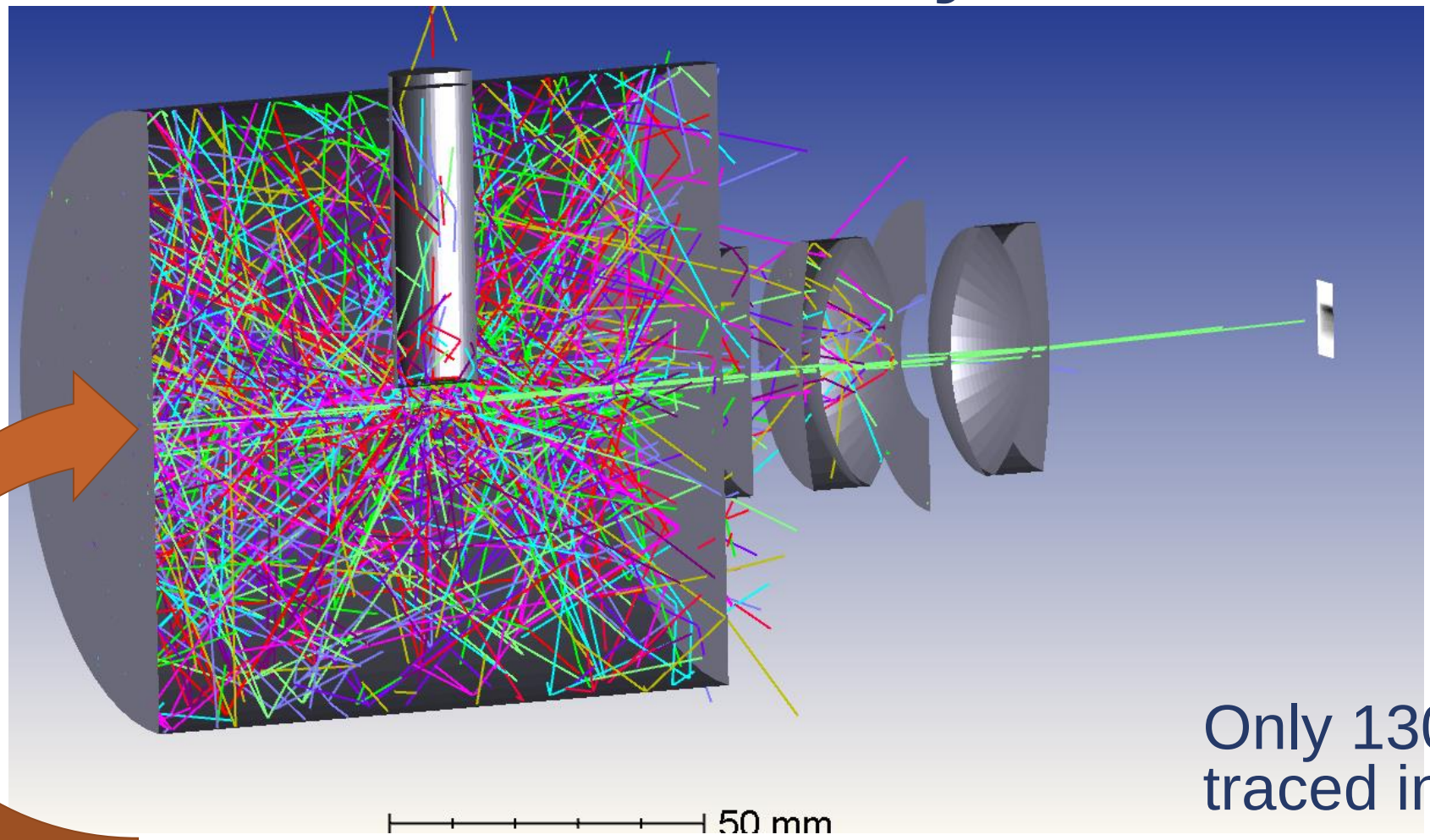
# Modelling of whole system

1. Using non-sequential ray tracing;
2. 200 million primary rays traced, rays split according to Fresnel equations;
3. 50 mm of water assumed before a glass window;
4. Glass window is BK7, 5 mm thick, followed by an air gap before the front surface of the imaging lens;
5. All rays have a single wavelength of 400 nm, **10000 photons per MeV** assumed;
6. “Black” surfaces are now 5% reflective (100% specular) or 5% reflective split 80% Lambertian scatter and 20% specular;
7. Simulations were carried out using ZEMAX OpticStudio Professional V22.2 on my home PC (Gen 11 i5 6/12 core @4.3 GHz sustained average, 32 Gbytes of 3200 MHz DDR4 memory).

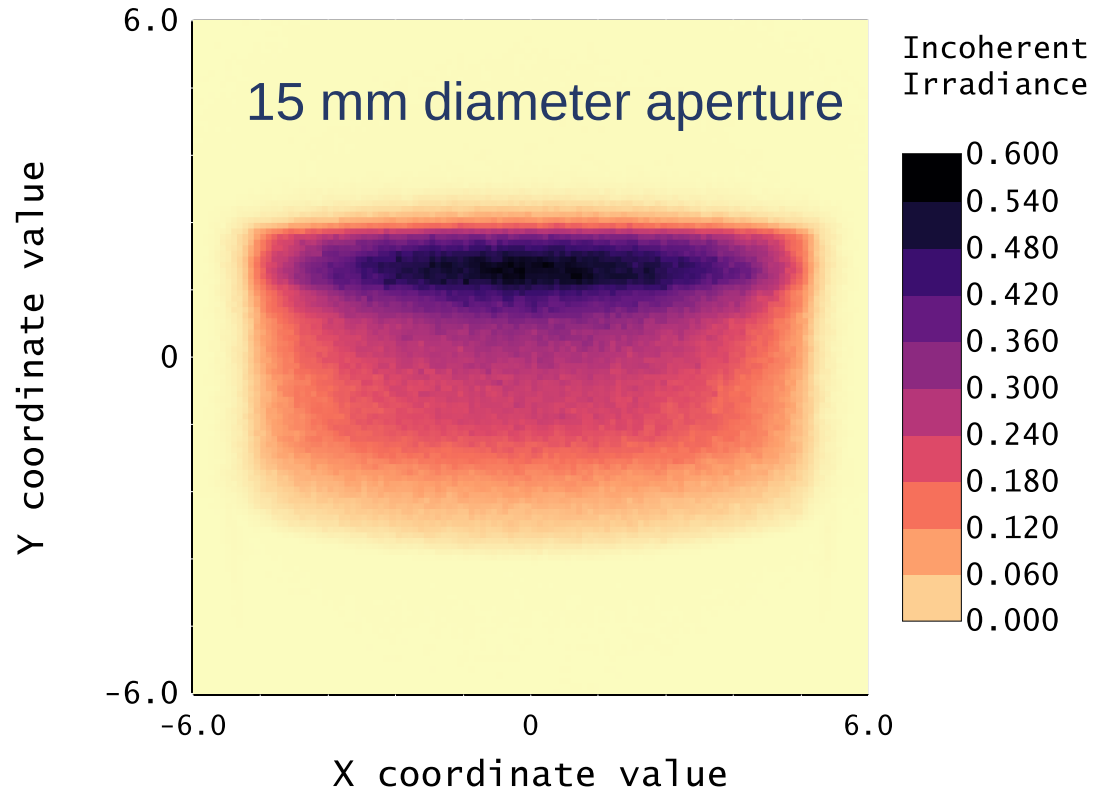
# Overall view of simulated system

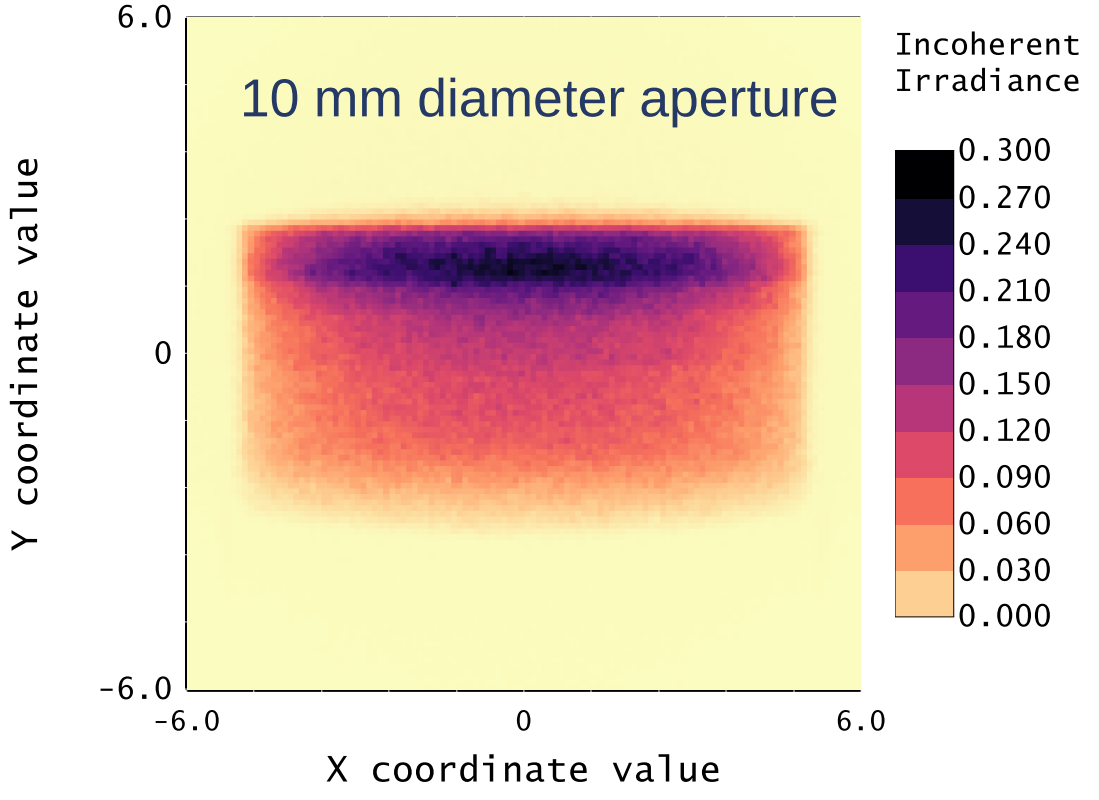



Only 130 primary rays traced in this plot

5% reflective: split 80% Lambertian scatter and 20% specular.

# Changing the F# of the imaging lens




Detector Image: Incoherent Irradiance

ARA Test 11
4/04/2023
Detector 21, NSCG Surface 1:
Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 3021585
Peak Irradiance : 5.8964E-01 Watts/cm^2
Total Power : 1.3472E-01 Watts

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Detector Image: Incoherent Irradiance

ARA Test 11
4/04/2023
Detector 21, NSCG Surface 1:
Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 1519687
Peak Irradiance : 2.9121E-01 Watts/cm^2
Total Power : 6.0554E-02 Watts

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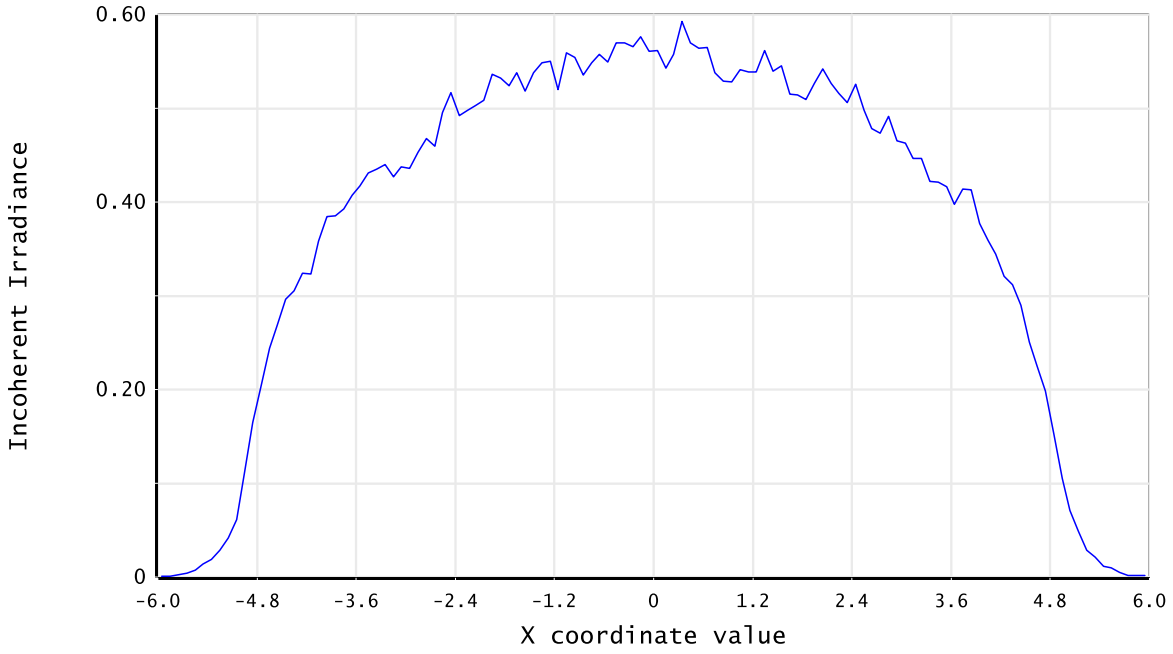
Black surfaces are 5% specular reflecting

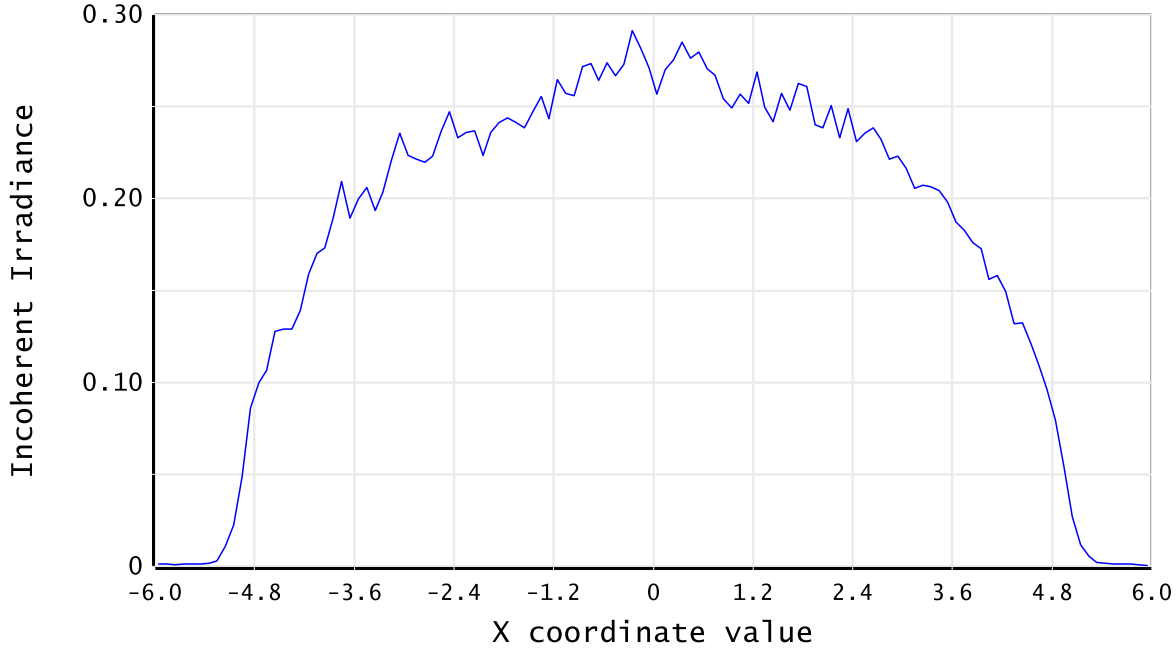
# Changing the F# of the imaging lens

## 15 mm diameter lens aperture
## Row 75 of 120 (y = 1.45 mm)




| Incoherent Irradiance | |
|---|---|
| LARA Test 11<br>14/04/2023<br>Detector 21, NSCG Surface 1: Row 75, Y = 1.4500E+00<br>Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 3026238<br>Peak Irradiance : 5.9265E-01 Watts/cm^2<br>Total Power : 1.3470E-01 Watts | Queen Mary University of London<br>School of Physical and Chemical Sciences<br>London, E1 4NS UK<br><br>Test11_reallens_cylinderVol_3_KaptonAir_imperfectAbs.zmx<br>Configuration 1 of 1 |

## 10 mm diameter lens aperture
## Row 75 of 120 (y = 1.45 mm)



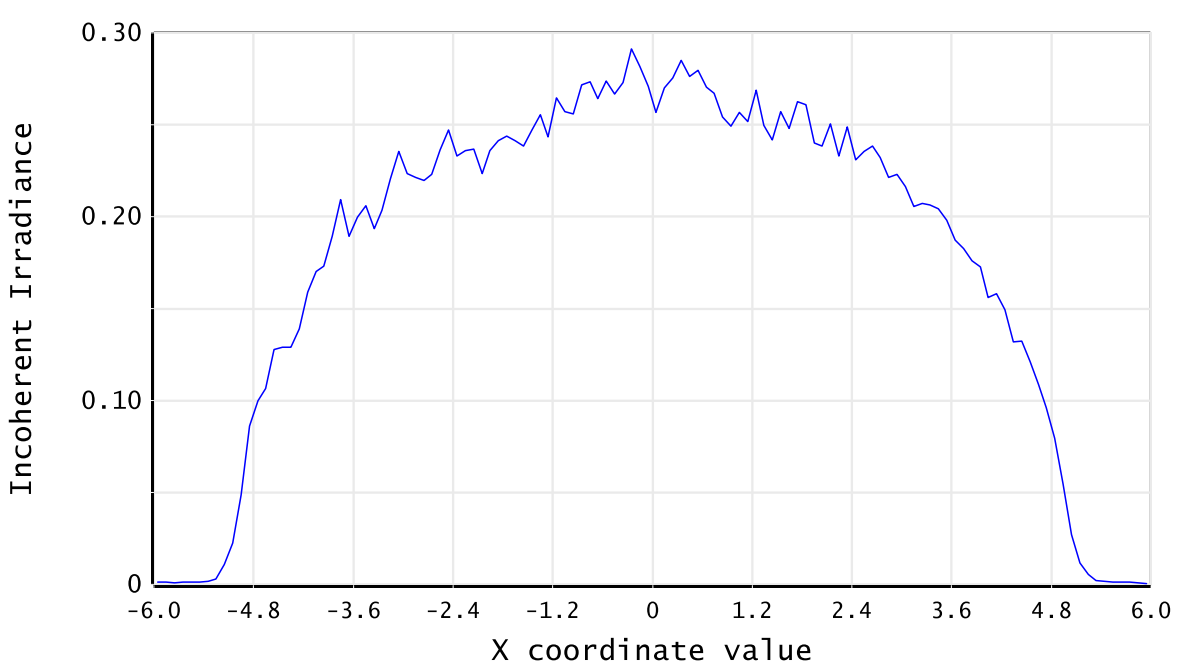

| Incoherent Irradiance | |
|---|---|
| LARA Test 11<br>14/04/2023<br>Detector 21, NSCG Surface 1: Row 75, Y = 1.4500E+00<br>Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 1519687<br>Peak Irradiance : 2.9121E-01 Watts/cm^2<br>Total Power : 6.0554E-02 Watts | Queen Mary University of London<br>School of Physical and Chemical Sciences<br>London, E1 4NS UK<br><br>Test11_reallens_cylinderVol_3_KaptonAir_imperfectAbs.zmx<br>Configuration 1 of 1 |



Black surfaces are 5% specular reflecting

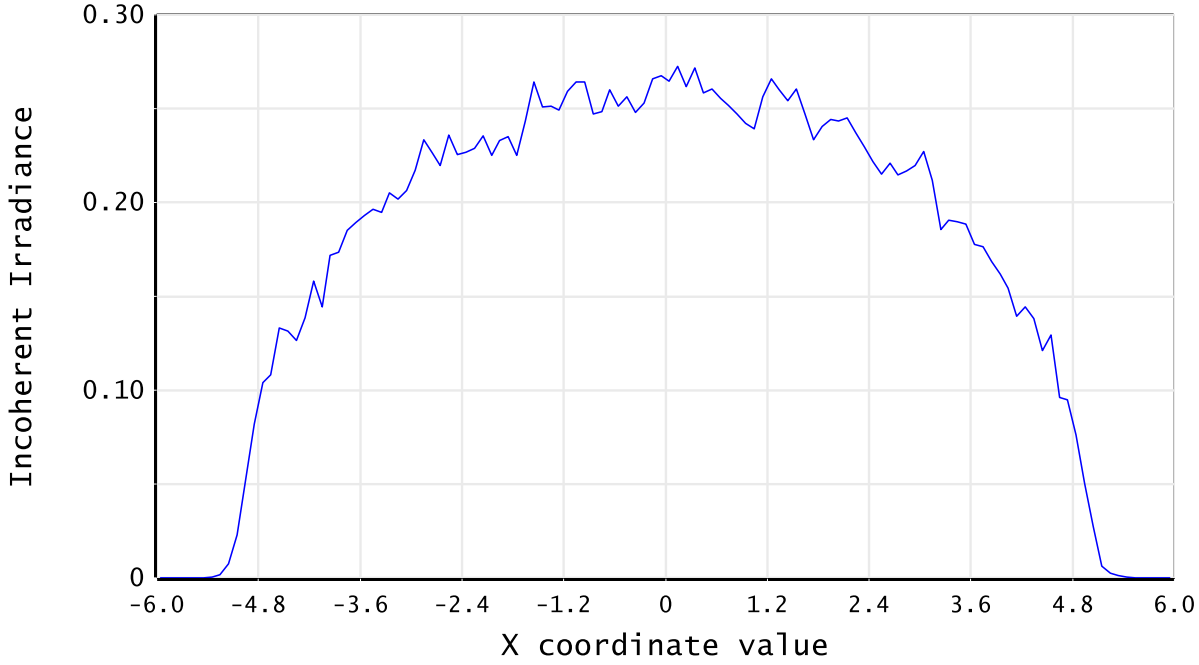
# Changing the scatter function of “Black” surfaces

10 mm diameter lens aperture
5% specular reflection




| Incoherent Irradiance | |
|---|---|
| LARA Test 11<br>14/04/2023<br>Detector 21, NSCG Surface 1: Row 75, Y = 1.4500E+00<br>Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 1519687<br>Peak Irradiance : 2.9121E-01 Watts/cm^2<br>Total Power : 6.0554E-02 Watts | Queen Mary University of London<br>School of Physical and Chemical Sciences<br>London, E1 4NS UK<br><br>Test11_reallens_cylinderVol_3_KaptonAir_imperfectAbs.zmx<br>Configuration 1 of 1 |

10 mm diameter lens aperture
1% specular plus 4% Lambertian scatter

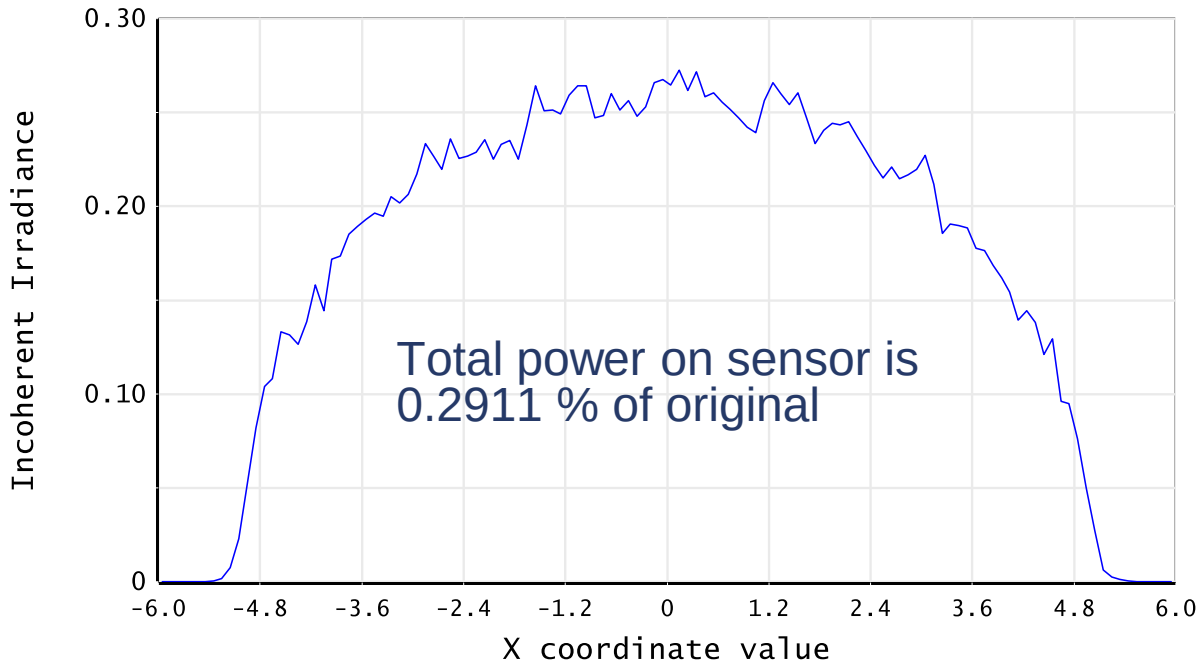



| Incoherent Irradiance | |
|---|---|
| LARA Test 11<br>14/04/2023<br>Detector 21, NSCG Surface 1: Row 75, Y = 1.4500E+00<br>Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 1004710<br>Peak Irradiance : 2.8656E-01 Watts/cm^2<br>Total Power : 5.8216E-02 Watts | Queen Mary University of London<br>School of Physical and Chemical Sciences<br>London, E1 4NS UK<br><br>Test11_reallens_cylinderVol_3_KaptonAir_imperfectAbs.zmx<br>Configuration 1 of 1 |

Row 75 (y = 1.45 mm) shown here

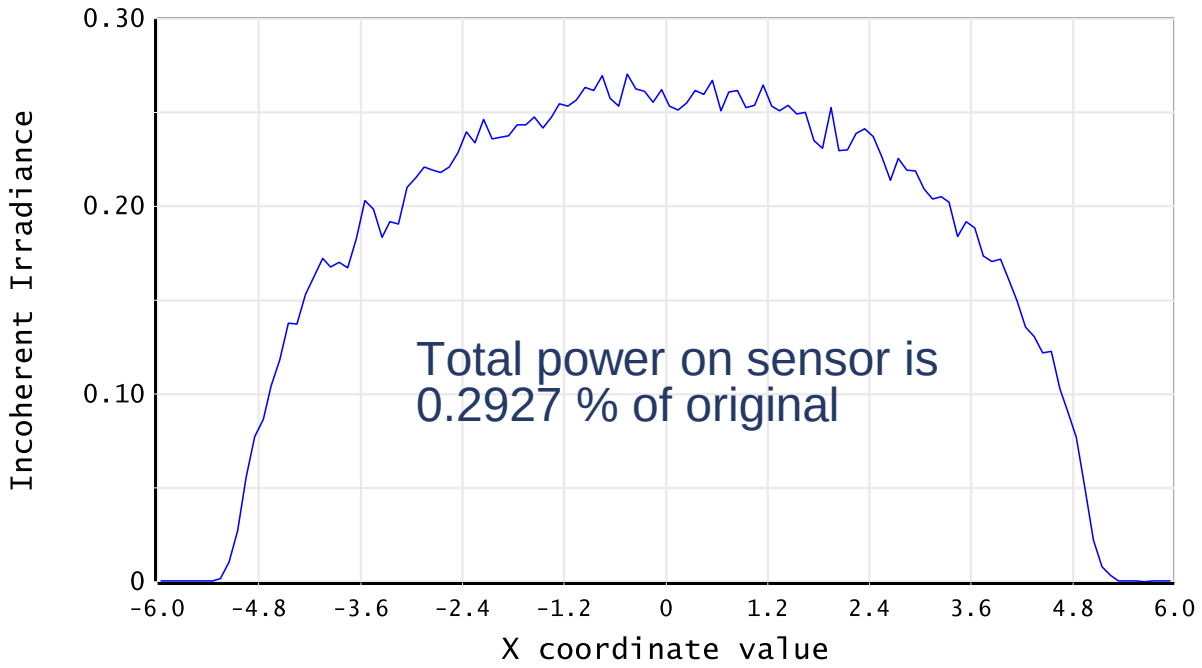
# Changing the minimum relative ray intensity (1)

10 mm diameter lens aperture
1% minimum relative ray intensity




| Incoherent Irradiance | |
|---|---|
| LARA Test 11<br>14/04/2023<br>Detector 21, NSCG Surface 1: Row 75, Y = 1.4500E+00<br>Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 1004710<br>Peak Irradiance : 2.8656E-01 Watts/cm^2<br>Total Power : 5.8216E-02 Watts | Queen Mary University of London<br>School of Physical and Chemical Sciences<br>London, E1 4NS UK<br><br>Test11_reallens_cylinderVol_3_KaptonAir_imperfectAbs.zmx<br>Configuration 1 of 1 |

10 mm diameter lens aperture
0.1% minimum relative ray intensity



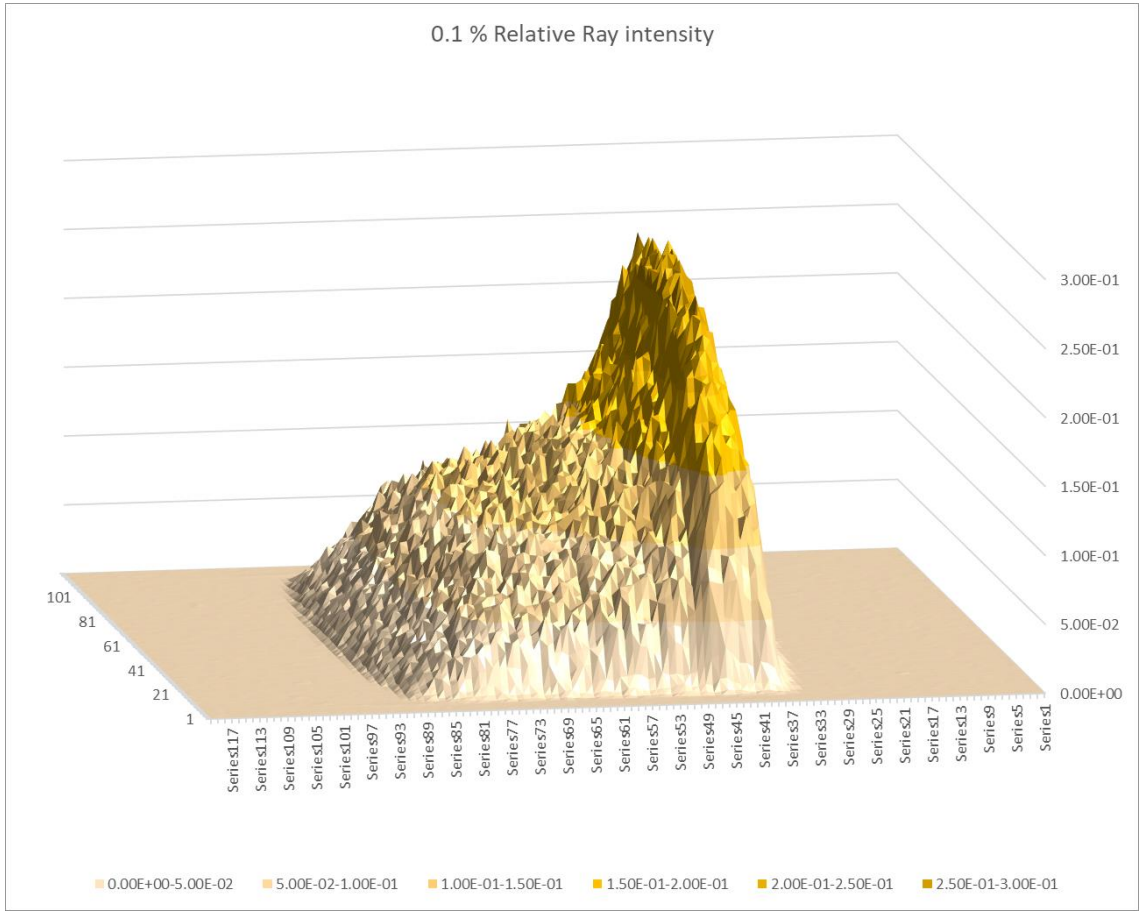

| Incoherent Irradiance | |
|---|---|
| LARA Test 11<br>14/04/2023<br>Detector 21, NSCG Surface 1: Row 75, Y = 1.4500E+00<br>Size 12.000 W X 12.000 H Millimeters, Pixels 120 W X 120 H, Total Hits = 2275921<br>Peak Irradiance : 2.8169E-01 Watts/cm^2<br>Total Power : 5.8576E-02 Watts | Queen Mary University of London<br>School of Physical and Chemical Sciences<br>London, E1 4NS UK<br><br>Test11_reallens_cylinderVol_3_KaptonAir_imperfectAbs.zmx<br>Configuration 1 of 1 |

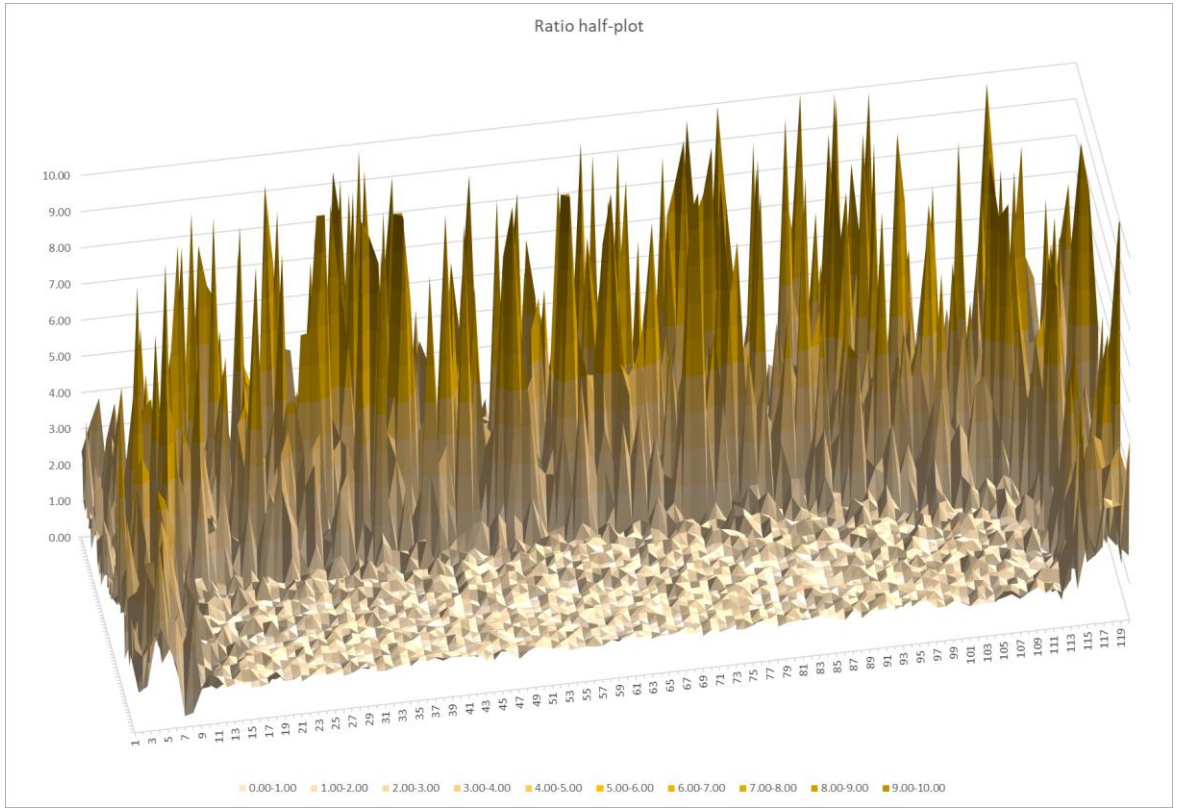


1% specular plus 4% Lambertian scatter. Row 75 (y = 1.45 mm)

# Changing the minimum relative ray intensity (2)

10 mm diameter lens aperture
0.1% minimum relative ray intensity




Half-plot (cut at row 60) showing the ratio between a 0.1% and 1% relative-ray intensity cut.

1% specular plus 4% Lambertian scatter.

# To do list!

1. Add dark/readout noise from a real camera to the images;
2. Use actual wavelength(s) and yield of WbLS (~ 1000 photons per MeV)*
3. Determine if it matters if the water volume is a cuboid;
4. Add the self-absorption of the scintillation light in the water*.
5. You need to add to this list (in priority order)!

*See for example:

*NIMA* **660** (2011) 51–56; *NIMA* **967** (2020) 163860; *NIMA* **969** (2020) 163931