Sparse Fibre Plane

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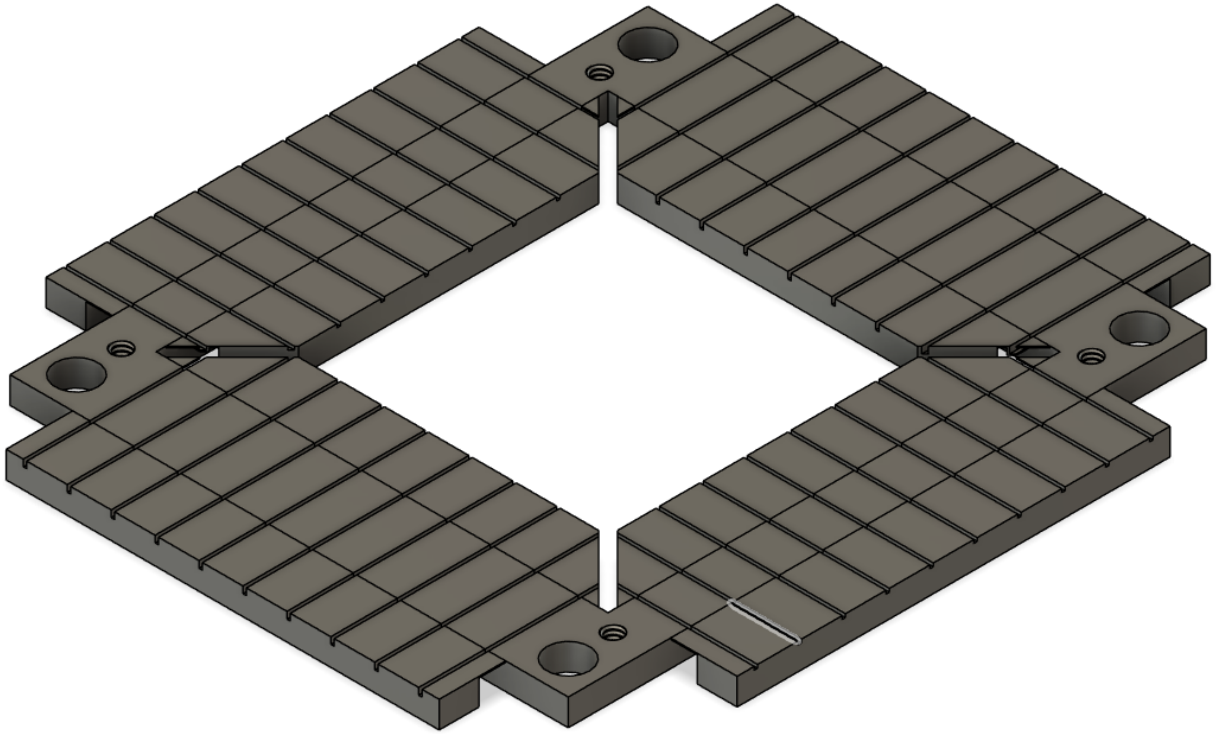
Simulation parameters

1. Starting to look at Ken's new sparse fibre plane for PoPLaR beam monitoring;
2. Non-sequential ray tracing is used;
3. Simulations use **Ansys ZEMAX OpticStudio Premium 2025R1.01** (PC is an i5 6/12 core @4.6 GHz peak with 32 Gbytes of 3200 MHz DDR4 memory);
4. Data shown for a wavelength of 491 nm (emission peak of scintillator);

3D Render of Sparse Fibre Plane Support



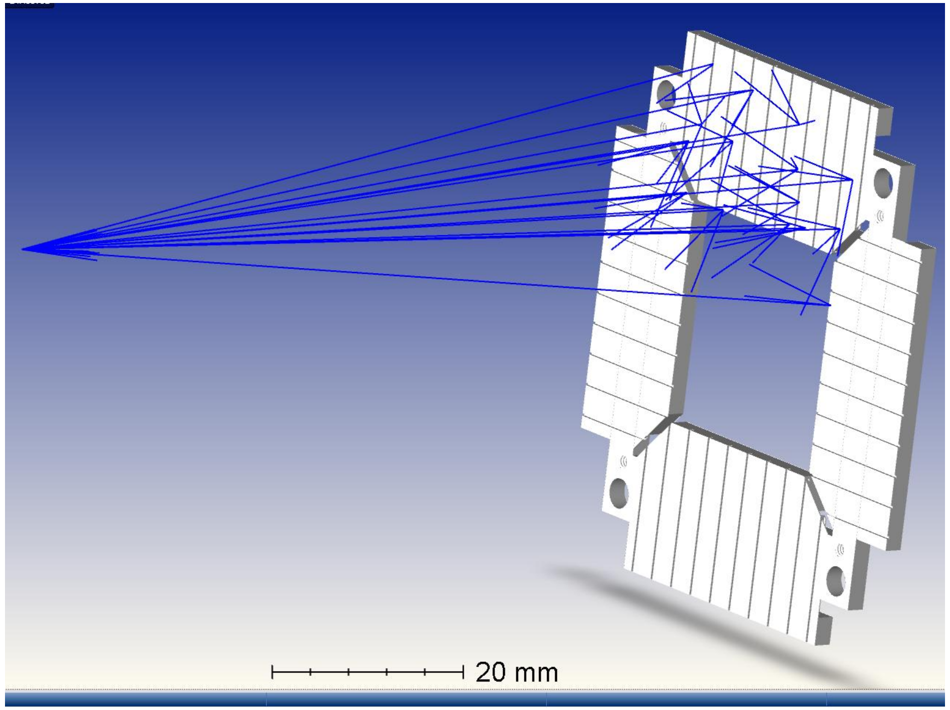
This is 48 × 42 mm in size and takes 250 μm diameter BCF-20 fibres. I now have the detailed drawings and a STEP file which has been imported into ZEMAX.

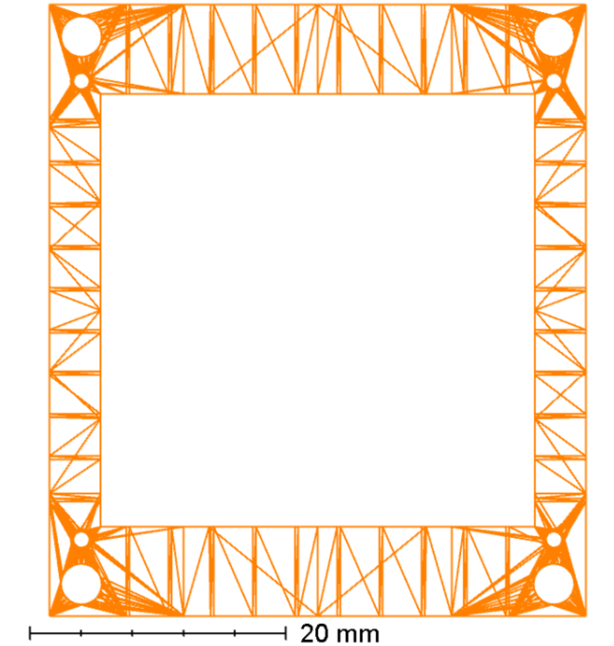
3D Render of Sparse Fibre Plane Support

48 × 42 mm in size and takes 250 μm diameter BCF-20 fibres.

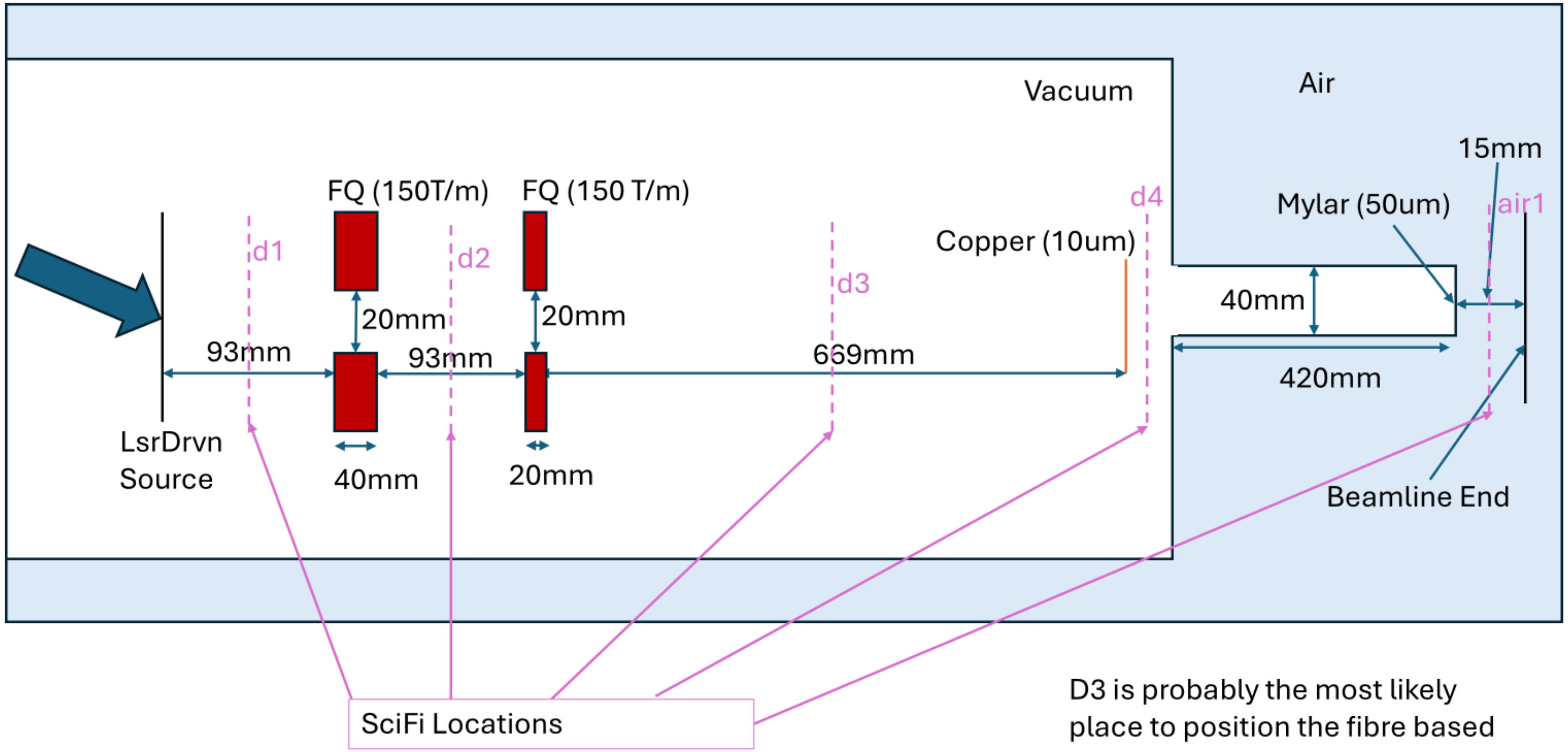
This is coated with "Black Aluminium": Lambertian scattering but no specular reflections.

With the manufacturing "tabs" (shown in the ZEMAX scattering render) removed, the fibre support plane looks like this →





Potential locations of Fibre Planes

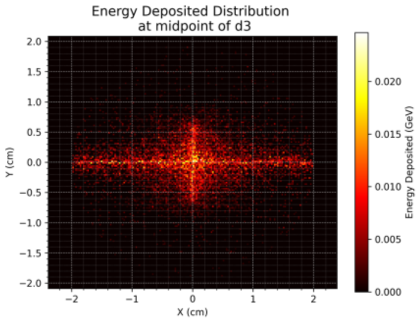


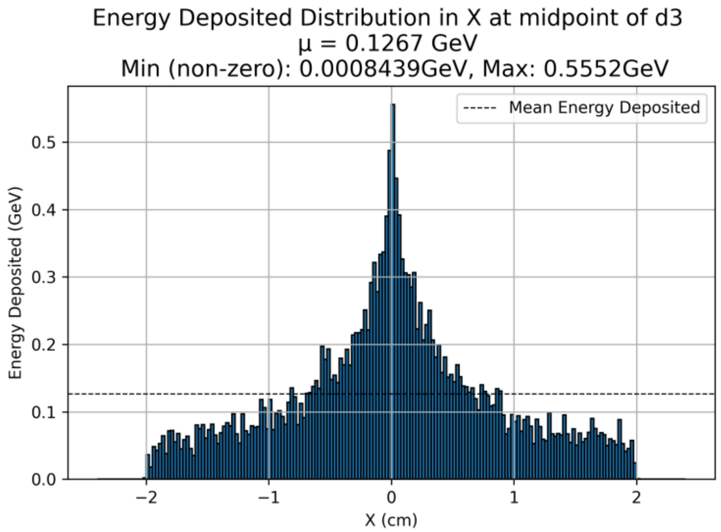
D3 is probably the most likely place to position the fibre based on ease of implementation

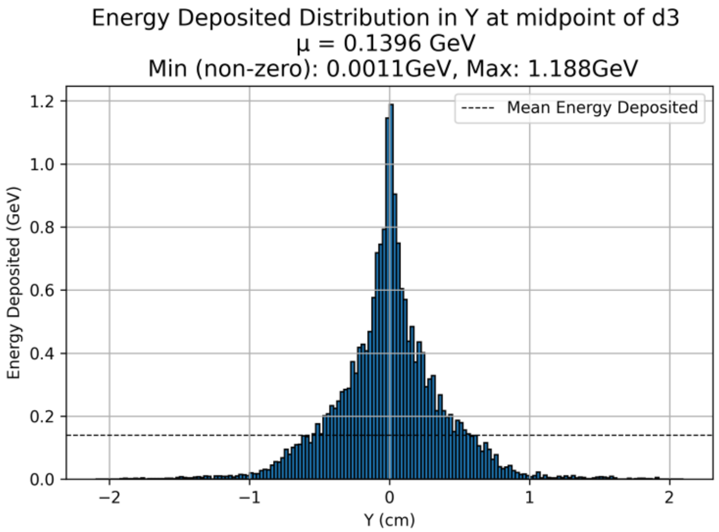
This figure is provided by Calvin Dyson, IC

Simulated Protons per Fibre Plane

D3 (Energy Deposited)



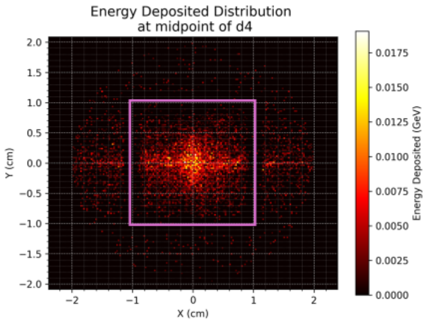


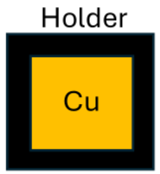


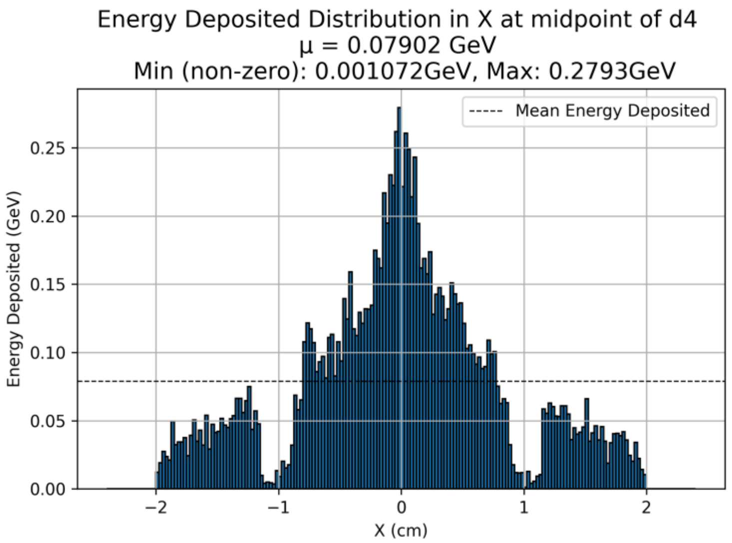
This data is from a simulation by Calvin Dyson. The mean quoted is the average number of protons per fibre but only counting the fibres that received at least one proton. The source was assumed to produce 100 k protons per pulse.

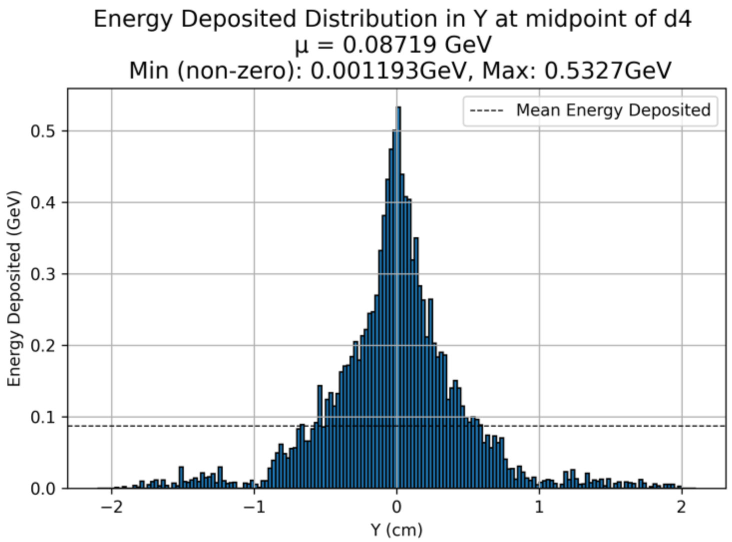
Simulated Protons per Fibre Plane

D4 (Energy Deposited)







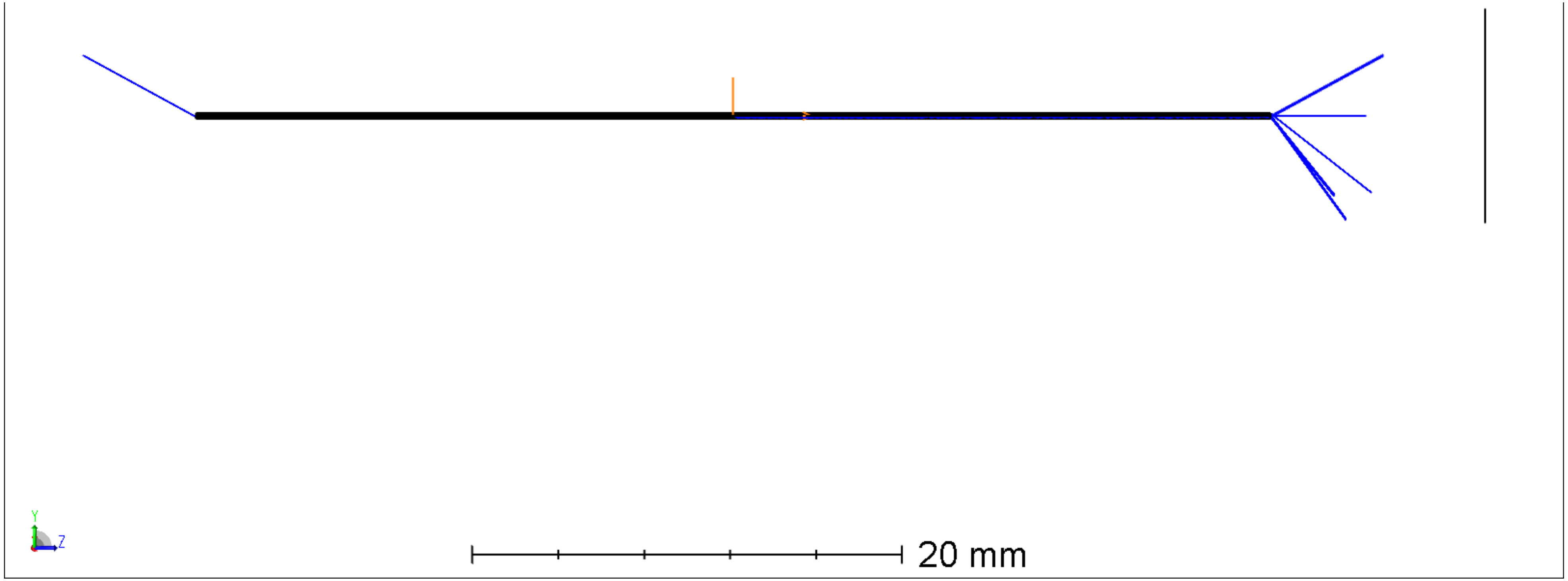


This data is from a simulation by Calvin Dyson. The mean quoted is the average number of protons per fibre but only counting the fibres that received at least one proton. The source was assumed to produce 100 k protons per pulse.

Realistic Fibre

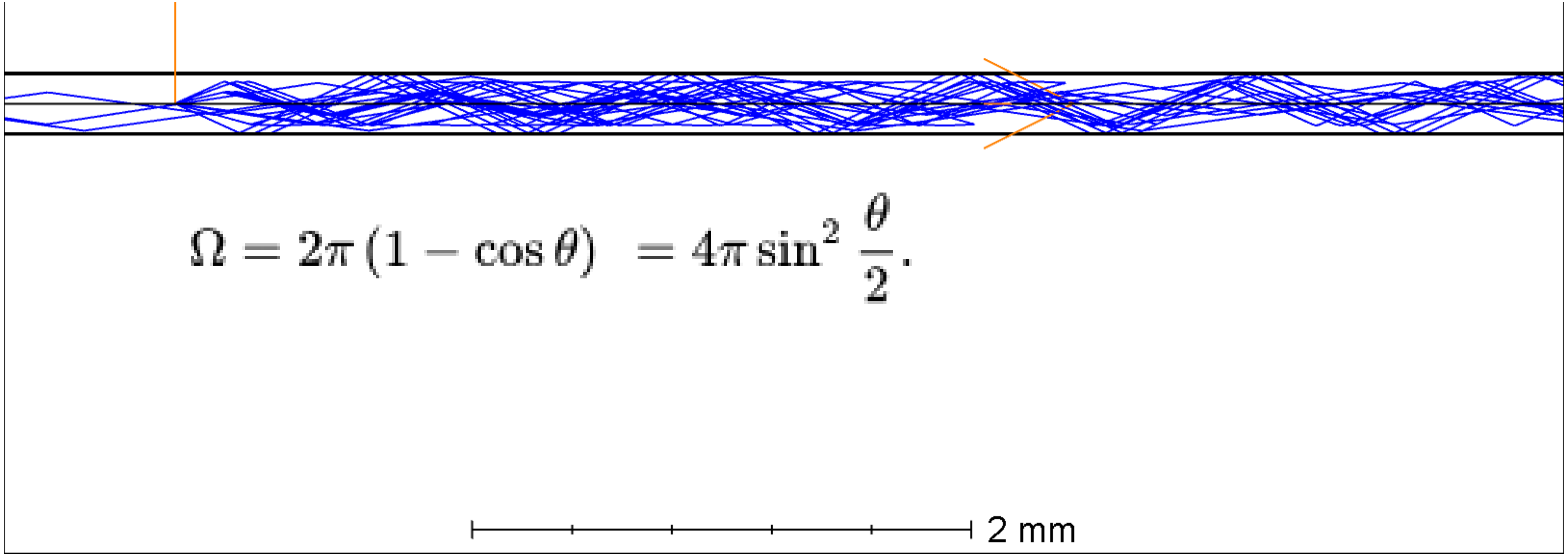
Simulated at Polystyrene (Core) and PMMA (cladding) as per BCF20. NA = 0.58

50 mm long fibre



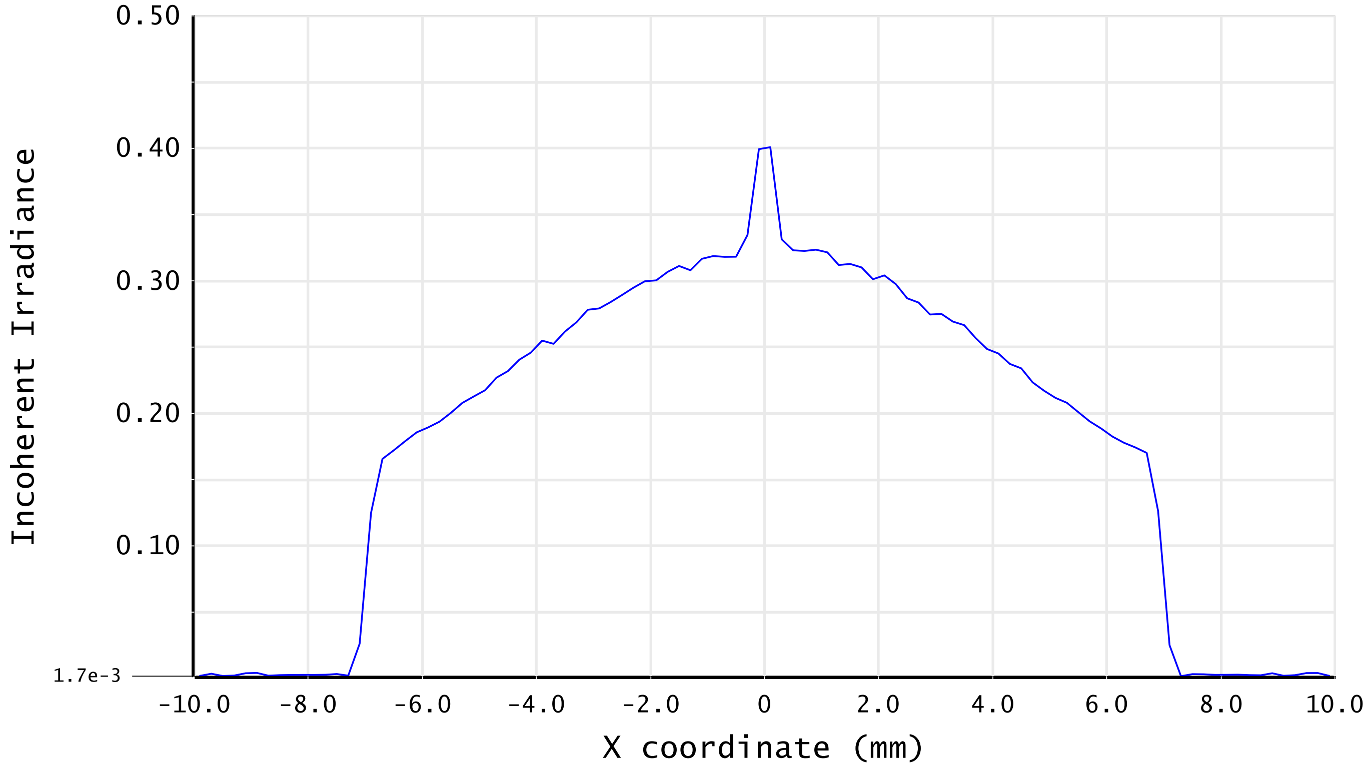
Realistic Fibre

Here you can see core and cladding modes from a point source with a 70 degree cone apex angle 2θ emitting to the right. Remember we get Fresnel reflection at the ends of the fibre. The actual scintillation light is produced in 4π sr, here we generate rays into only 1.1 sr.



$$\Omega = 2\pi\,(1-\cos\theta) \;= 4\pi\sin^2\frac{\theta}{2}.$$

Light Distribution 10 mm after Fibre (no lens)



Incoherent Irradiance

Fibre Test for PoPLaR
12/12/2025
Detector 4, NSCG Surface 1: Row Center, Y = 0.0000E+00
Size 20.000 W X 20.000 H Millimeters, Pixels 100 W X 100 H, Total Hits = 465598
Peak Irradiance : 4.0100E-01 Watts/cm^2
Total Power : 3.5433E-01 Watts

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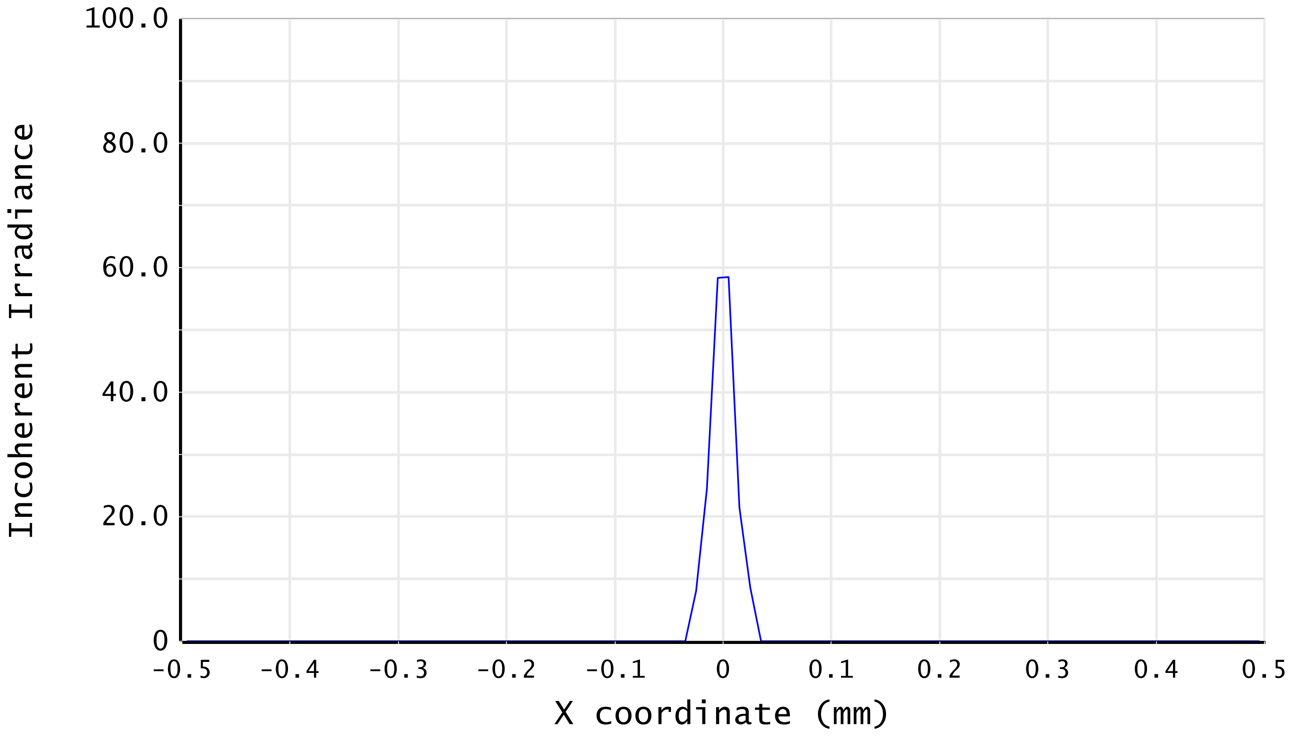
Fibre_TestBCF20.zmx
Configuration 1 of 1

Nominal source of power 1W, 1 million primary rays traced.

Light Distribution Imaged to Camera



Incoherent Irradiance

Fibre Test for PoPLaR 12/12/2025 Detector 5, NSCG Surface 1: Row Center, Y = 0.0000E+00 Size 1.000 W X 1.000 H Millimeters, Pixels 100 W X 100 H, Total Hits = 6324 Peak Irradiance : 5.8817E+01 Watts/cm^2 Total Power : 6.2057E-04 Watts	School of Physical & Chemical Sciences Queen Mary University of London Fibre_TestBCF20.zmx Configuration 1 of 1

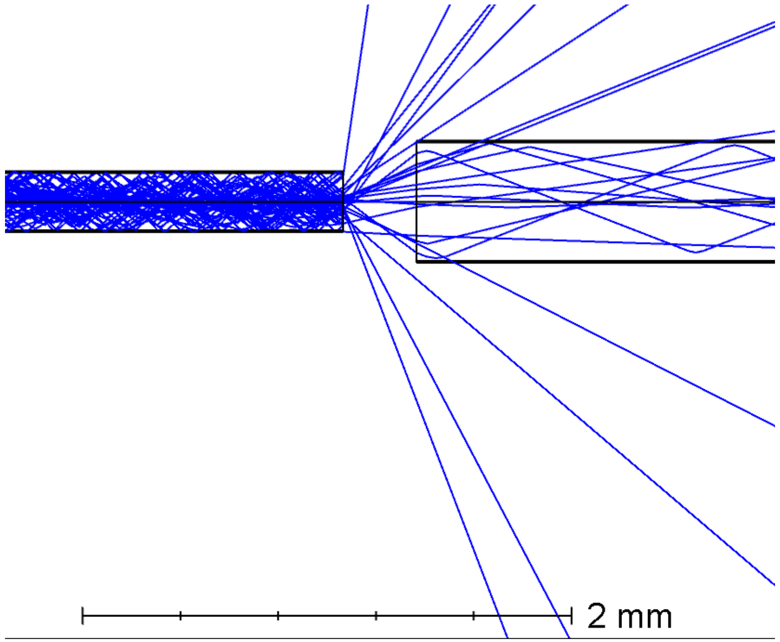
F = 25 mm, 6 mm aperture paraxial lens located at 150 mm from fibre end. Paraxial image plane shown.

Total power imaged < 0.1% of what was produced into an artifically restricted cone.

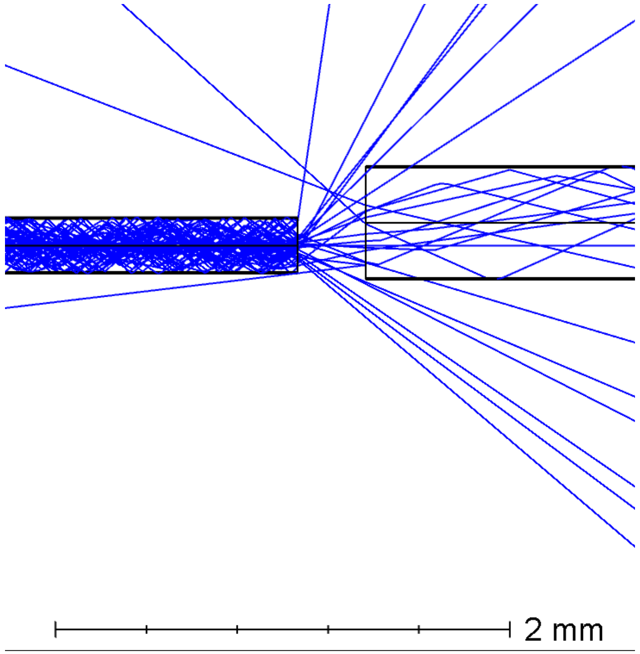
Nominal source of power 1W, 1 million primary rays traced.

Light Coupling to transparent fibre (0.5 mm Ø, BCF98XL)

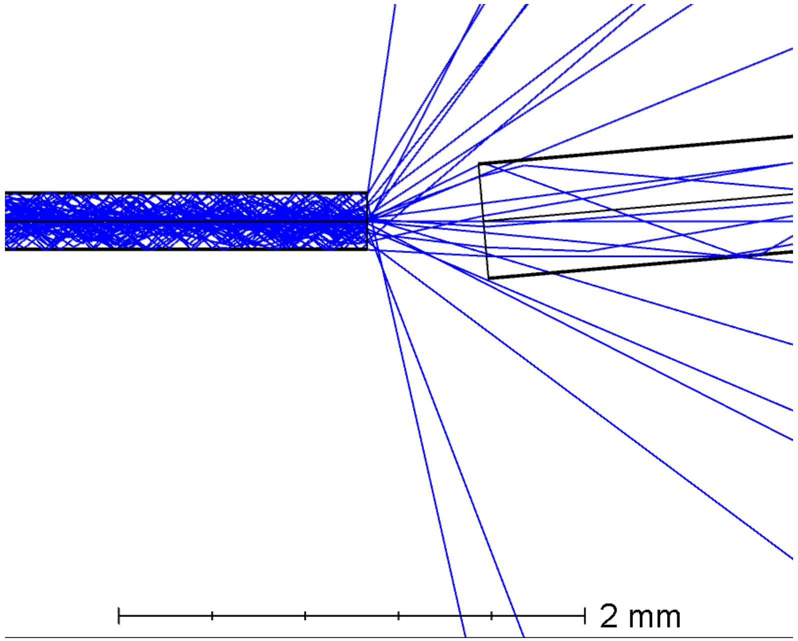
Effect of tolerances on fibre-to-fibre alignment, cone angle in BCF-20 scintillator was 55 °. Source power 1W, 1 million primary rays traced per simulation.



Longitudinal only



Lateral only



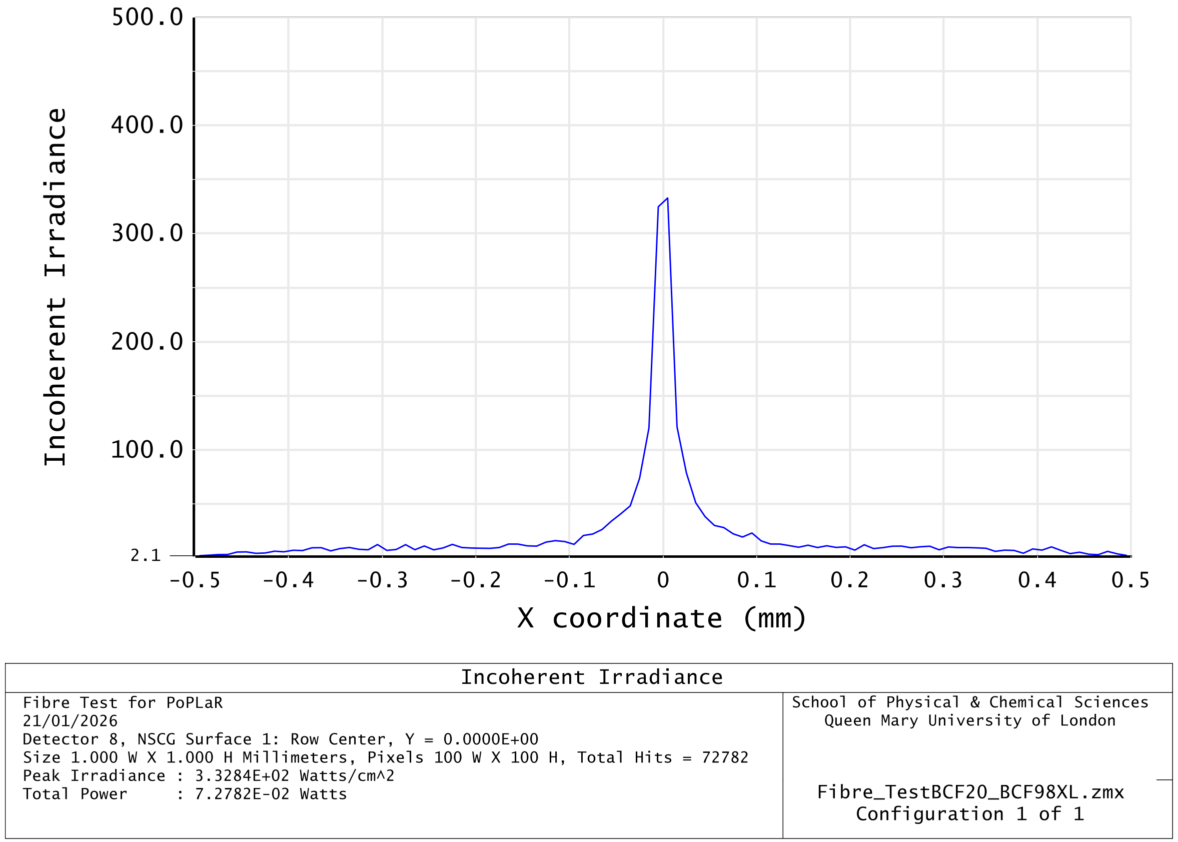
Angular only

Light Coupling to transparent fibre

Effect of tolerances on fibre-to-fibre alignment, cone angle in BCF-20 scintillator was 55 °. Source power 1W, 1 million primary rays traced per simulation.

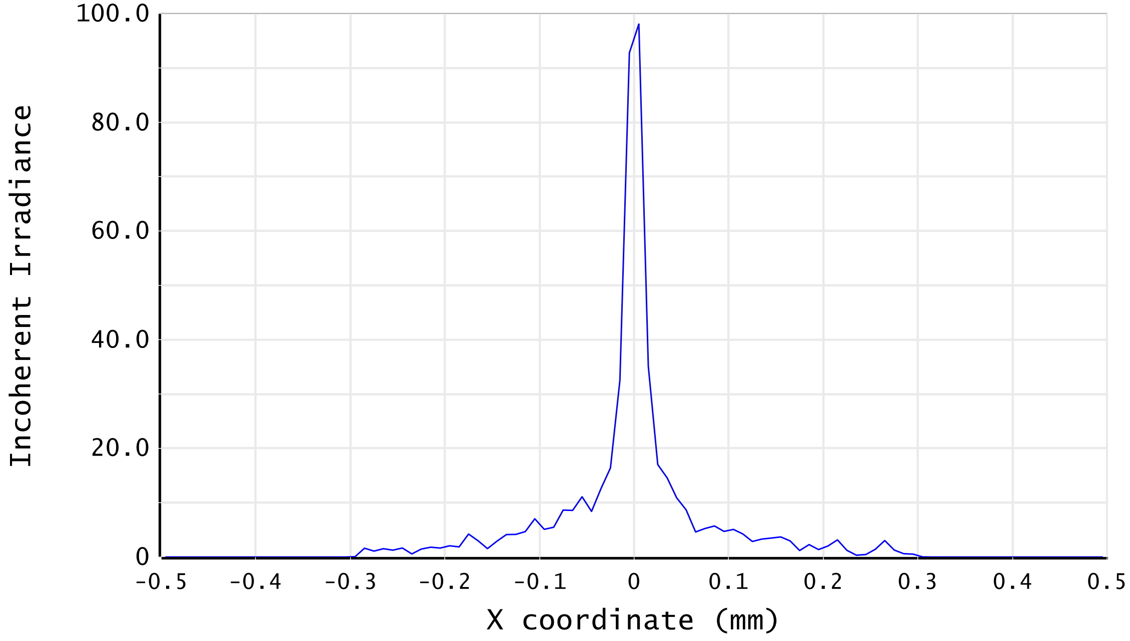
Longitudinal Offset (mm)	Lateral Offset (mm)	Power inside BCF98-XL fibre (W)	Compared to 1W launched in BCF-20 fibre
0.1	0.0	3.733E-01	37.3%
0.3	0.0		
0.5	0.0	9.730E-02	9.7%
0.7	0.0		
1.0	0.0	3.133E-02	3.1%
0.1	0.05	3.678E-01	36.8%
0.3	0.05		
0.5	0.05	9.692E-02	9.7%
0.1	0.10	3.500E-01	35.0%
0.3	0.10	1.714E-01	17.1%
0.5	0.10	9.268E-02	9.3%
	Angular Offset (degrees)		
0.5 mm for all	0.0	9.730E-02	9.7%
	1.0	9.723E-02	9.7%
	3.0	9.737E-02	9.7%
	5.0	9.725E-02	9.7%

Light Distribution 1 mm after 100 mm of BCF98XL Fibre (no lens), 0.5 mm gap



Nominal source of power 1W, 1 million primary rays traced. 7% of power reaches the detector plane.

Light Distribution after 100 mm of BCF98XL Fibre imaged with f = 12.5 mm paraxial lens.



Incoherent Irradiance

Fibre Test for PoPLaR
21/01/2026
Detector 8, NSCG Surface 1: Row Center, Y = 0.0000E+00
Size 1.000 W X 1.000 H Millimeters, Pixels 100 W X 100 H, Total Hits = 9937
Peak Irradiance : 1.0660E+02 Watts/cm^2
Total Power : 9.9370E-03 Watts

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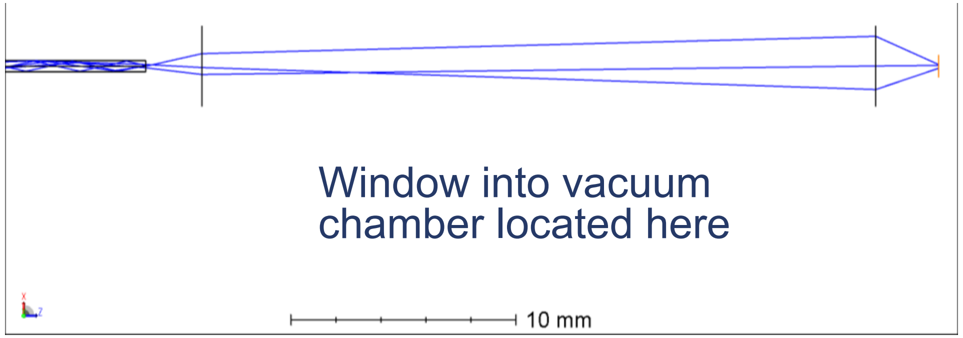
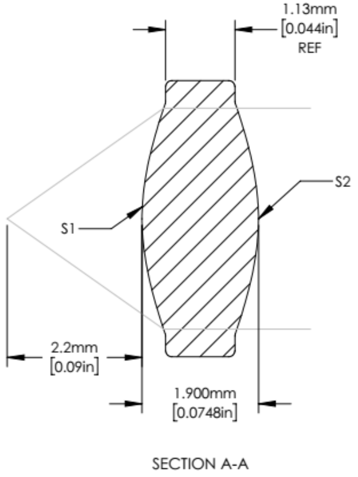
Fibre_TestBCF20_BCF98XL.zmx
Configuration 1 of 1

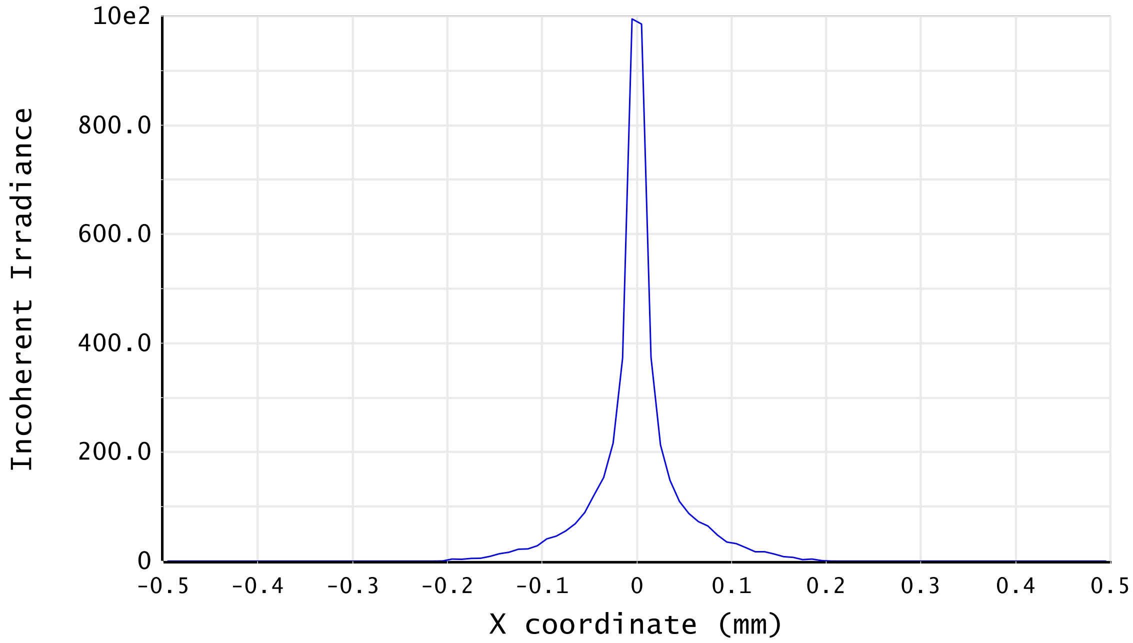
Nominal source of power 1W, 1 million primary rays traced. 1% of power reaches the detector plane.

Light Distribution after 100 mm of BCF98XL fibre imaged with two f = 2.8 mm paraxial lenses.





THORLABS www.thorlabs.com	
0.55 NA ASPHERIC LENS, f=2.8 mm, DW=830 nm, A COATED	
MATERIAL SEE NOTES	REV E
ITEM # 355390-A	APPROX WEIGHT 0.1 g

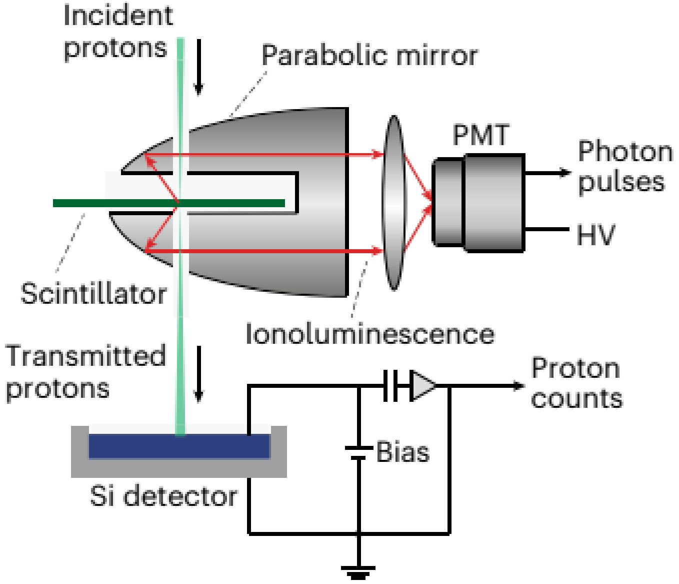


Incoherent Irradiance	
Fibre Test for PoPLaR 21/01/2026 Detector 10, NSCG Surface 1: Row Center, Y = 0.0000E+00 Size 1.000 W X 1.000 H Millimeters, Pixels 100 W X 100 H, Total Hits = 45761 Peak Irradiance : 9.9634E+02 Watts/cm^2 Total Power : 4.5761E-02 Watts	School of Physical & Chemical Sciences Queen Mary University of London Fibre_TestBCF20_BCF98XL_Lenses.zmx Configuration 1 of 1

Nominal source of power 1W, 1 million primary rays traced.
4.6% of power reaches the detector plane.

Other approaches?

Detecting/imaging using parabolic or elliptical electroformed optics



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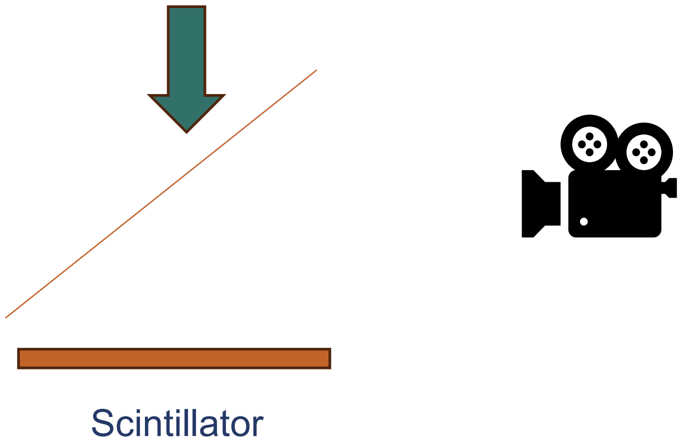
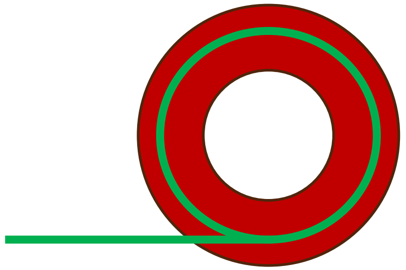
Detecting/imaging using pellicle beamsplitter (hydrocarbon typically 2 μm thick)



Use the area just outside the cell plate which is highly correlated in dose (see Calvin). Readout annular scintillator with WLS fibre and PMT to ≥ 10-bit scope



What next?

Include the frame, minus the production “tabs”, as CAD object in the simulation with some coating derived from measurements on the actual frame;

Calvin has simulated the typical light produced in a sparse fibre per laser pulse, now need to determine what coupling efficiency to detector is acceptable;

Look at how we can get the scintillation light efficiently out of the vacuum chamber so that active components (camera) are not outgassing nor subject to so much EMP risk;

Determine how to image efficiently onto standard “C” mount CMOS camera with collimated beam via vacuum feedthrough (simple version shown on previous won’t work for multiple fibres);

Are any cameras/lenses I bought with STFC LhARA funds now useful ? ☺