SUBJECT: **SPIRE instrument beam sections forwards of the focal plane aperture plate**

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KEYWORDS: **beams, cross-sections**

COMMENTS: **This document presents updated data on the expected size of the SPIRE instrument beams at various distances forwards of the newly-defined focal surface aperture plate, within the space presently occupied by the cryostat.**

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1. INTRODUCTION

This note updates some of the relevant data that is needed in order to size and design apertures that clear the beams that define the active views out of the FIRST focal plane instruments. The optical models used for the two instruments have been updated to the latest[1] ones, PH154B (photometer) and SP501E (spectrometer), and the effect of an inclined aperture plate[2], located near the telescope focal surface, has been included.

We present 2-D plots of beam cross-sections at several places between the aperture plate and the front of the space allotted to the cryostat. This graphical data can be supplemented on request with the original data that allows reconstruction of the beam boundaries at any plane in the beam path, after suitable manipulation. IGES-formatted files have also been produced that allow 3-D representations of the beam boundaries to be imported into CAD models. This data can also be supplied in any convenient co-ordinate reference frame, on request. Details are given in section 5.

2. OPTICAL GEOMETRY AND RAYTRACING

The CODEV models of the SPIRE instruments, which are presently in use at RAL, are versions identified as PH154B (photometer) and SP501E (spectrometer). These permit reverse ray tracing from the respective detectors (rectangular 19.1 mm x 38.2 mm for the photometer, circular 6.2 mm radius for the spectrometer) outwards to the telescope space. The latest so-called ‘thick’ telescope model places the pole of the primary mirror surface 1050.162 mm forwards of the telescope’s axial back focus and the pole of the secondary 1587.969 mm further forwards of the primary.

In order to be able to define each detector’s active view, several points uniformly spaced around the edge of each detector (24 photometer, 12 spectrometer), together with one point in the centre of each detector, were taken as sources of 37 rays. A chief ray from each source point, was traced through the centre of the chosen entrance pupil-defining aperture (pupil stop), the other 36 from each source point being traced through points uniformly distributed around the boundary of the pupil stop. The (x, y, z) intersections of each ray with all relevant surfaces was output in sequence and in a global co-ordinate system to an ASCII text file. The global co-ordinate system chosen was centred on a point 202 mm below the axial back focus of the telescope, with +Z pointing along this axis towards the telescope. The pole of the primary mirror in this system is therefore at Z= 202+1050.312 mm. The Y-direction is in the fold plane of the SPIRE photometer, pointing towards the SPIRE instruments.[3]

A two-axis steering mirror CM4 is located in the optical path common to both instruments. Tilts applied to this mirror are intended to displace the fields of view of both instruments by up to +- 2 arc minutes on the sky in a direction orthogonal to the fold plane (X direction) and by about +- 0.5 arc minutes on the sky parallel to the fold plane (Y direction). Rays were therefore traced through both instruments for several combinations of CM4 tilts that covered the extremes of each range, producing one data set for each combination of the two tilt angles.

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[1] Latest as of December 2000

[2] See SPIRE-RAL-NOT-000581 for full details of the shape of this aperture.

[3] This system is easily transformed to the standard FIRST-SPIRE system by cyclical transfer of co-ordinate labels X→Y, Y→Z, Z→X

An inclined aperture plate, located near to the telescope's focal surface, restricts the view that each instrument's detector has into the space forwards of the SPIRE instrument. This is included in determining the rays eventually traced forwards into the cryostat space and beyond.

Both instruments therefore have a range of active views that eventually must be combined into a composite instrument view through the aperture plate, cryostat apertures and into the telescope space. This combining was done using MATHCAD.

3. OUTPUT DATA AND PROCESSING

The files containing traced ray intercept data were input to MATHCAD. Two parallel planes are selected in a relevant space between two of the surfaces at which intercepts are evaluated and listed. In each plane, the boundaries of the beams from all object points are displayed so that a single boundary curve can be estimated and parameterised. Figure 3-1 is an example. This shows the boundaries of the 'views' from all 25 object points on the photometer detector for one combination of M4 tilts, together with an outer dashed line boundary, flagged with diamond symbols. This composite boundary has been sized to match the outer extremes of the overlapping boundaries, or to clear them by a small positive margin. It has been found possible to parameterise the beam between any two suitably chosen analysis planes by generating just two sets of composite boundary points, one in each of the planes, and just interpolating between ordered pairs of points (one from each plane) to any intervening plane. Thus the boundary for the photometer beam at any plane located between axial locations approximately 100 and 1050 mm from the focal surface can be accurately determined using two suitably chosen sets of 41 points in each of these planes. This Z-range covers the space occupied by the cryostat and centre of the primary mirror.

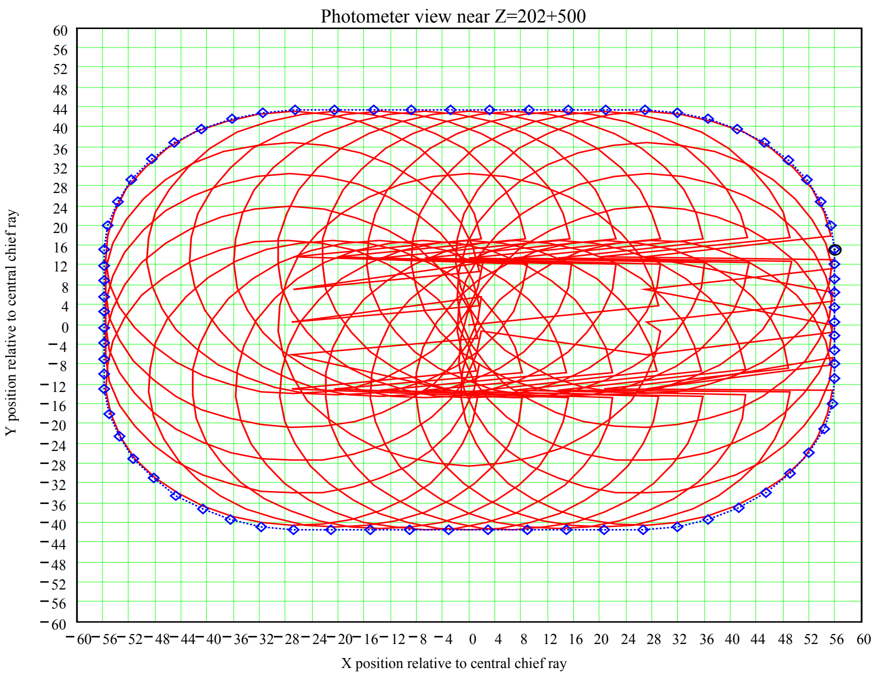

Figure 3-1 Photometer beam envelope 500 mm forwards of telescope focal surface

As well as the two sets of 41 points used to define beam boundaries in two parallel planes, the MATHCAD analysis uses them to generate beam boundaries at intervening planes by interpolation.

The beam boundary data is converted to a convenient co-ordinate reference frame and then output to an ASCII text file. The data is also used to create a wire-frame model that is also output in a suitable format to 3-D vector plot files. These plot files enable the beam to be visualised. Figure 3-2 shows such a visualisation of the beam, a section of which is represented by the dashed line in figure 3-1.

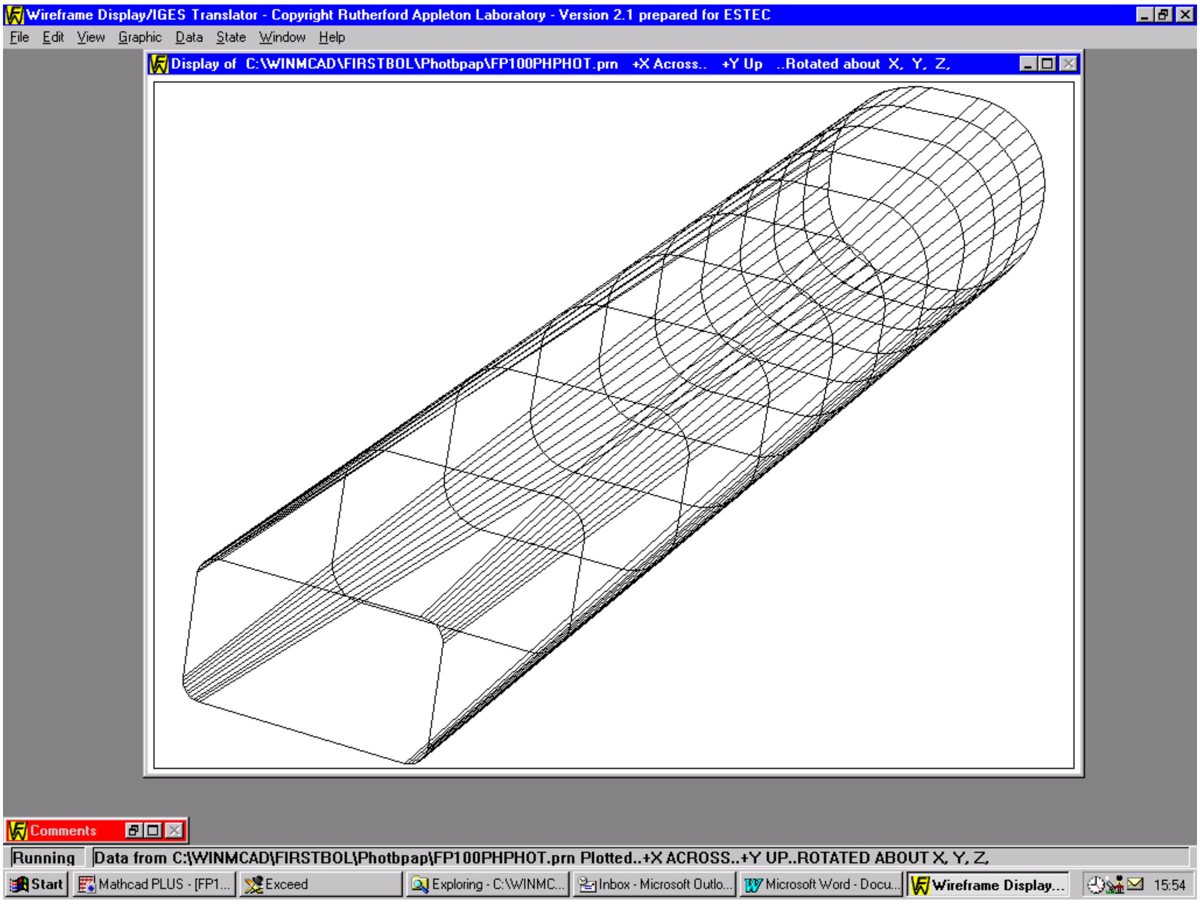

Figure 3-2 Wire-frame representation of a composite photometer beam boundary

4. COMBINED BEAM SECTIONS

Figures 4-1, 4-2, 4-3 and 4-4 show sections through the combined boundaries of beams from both SPIRE instruments. The spectrometer beam is the roughly circular one to the left. Several overlapping boundaries are shown for beams from each instrument, one for each of the four extreme pairs of tilt angles applied to CM4. For the case where CM4 tilts the photometer view away from the spectrometer FOV (X tilt), the beam representing the rightmost 1+1/2 arc minutes of the detector has been 'cut off' by the aperture plate located at the telescope focal surface. This reflects the fact that CM3 and the aperture plate will not be extended by more than ½ arc minutes beyond the edge of the central detector FOV in that direction. On each plot, sections of three circular boundaries, each centred on the telescope axis, with radii 130, 135 and 140 mm, have been drawn as a guide to the radius required by apertures at various points in order to allow transmission of the beam without vignetting.

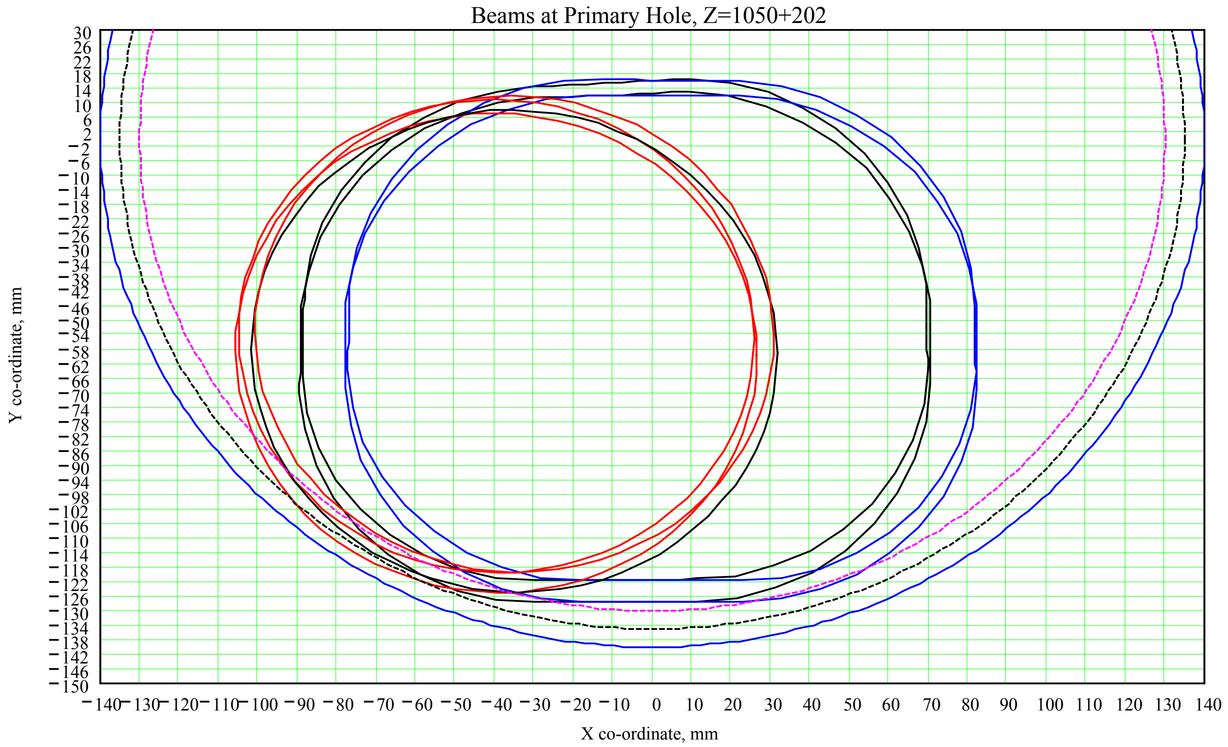

Figure 4-1 Composite beam boundaries at 1050 mm forwards of the telescope axial focus

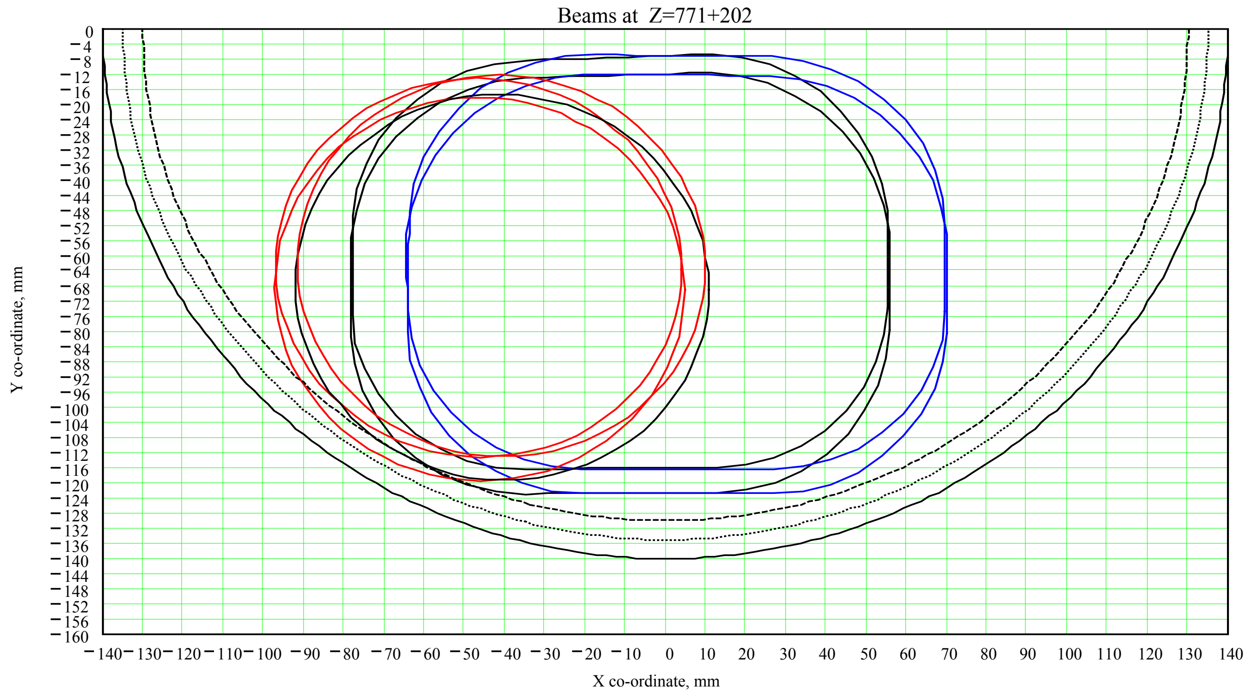

Figure 4-2 Composite beam boundaries at 771 mm forwards of the telescope axial focus

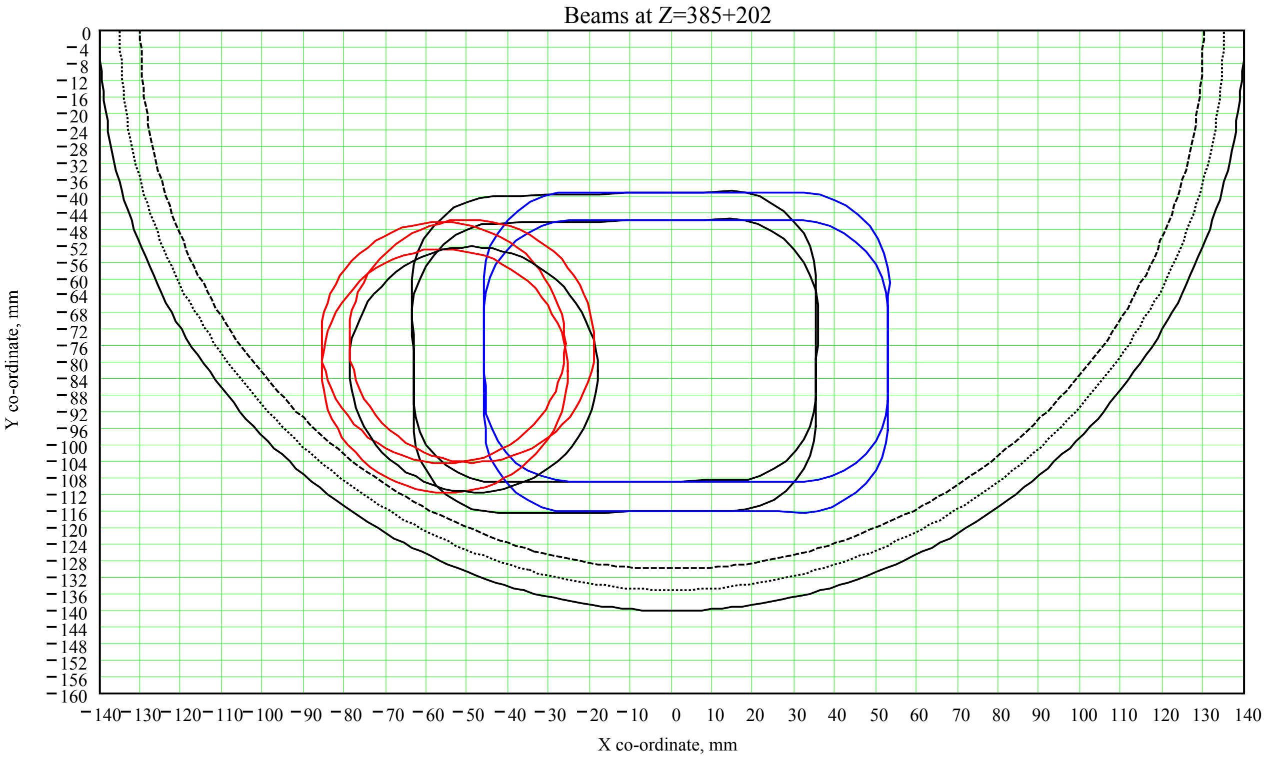

Figure 4-3 Composite beam boundaries at 385 mm forwards of the telescope axial focus

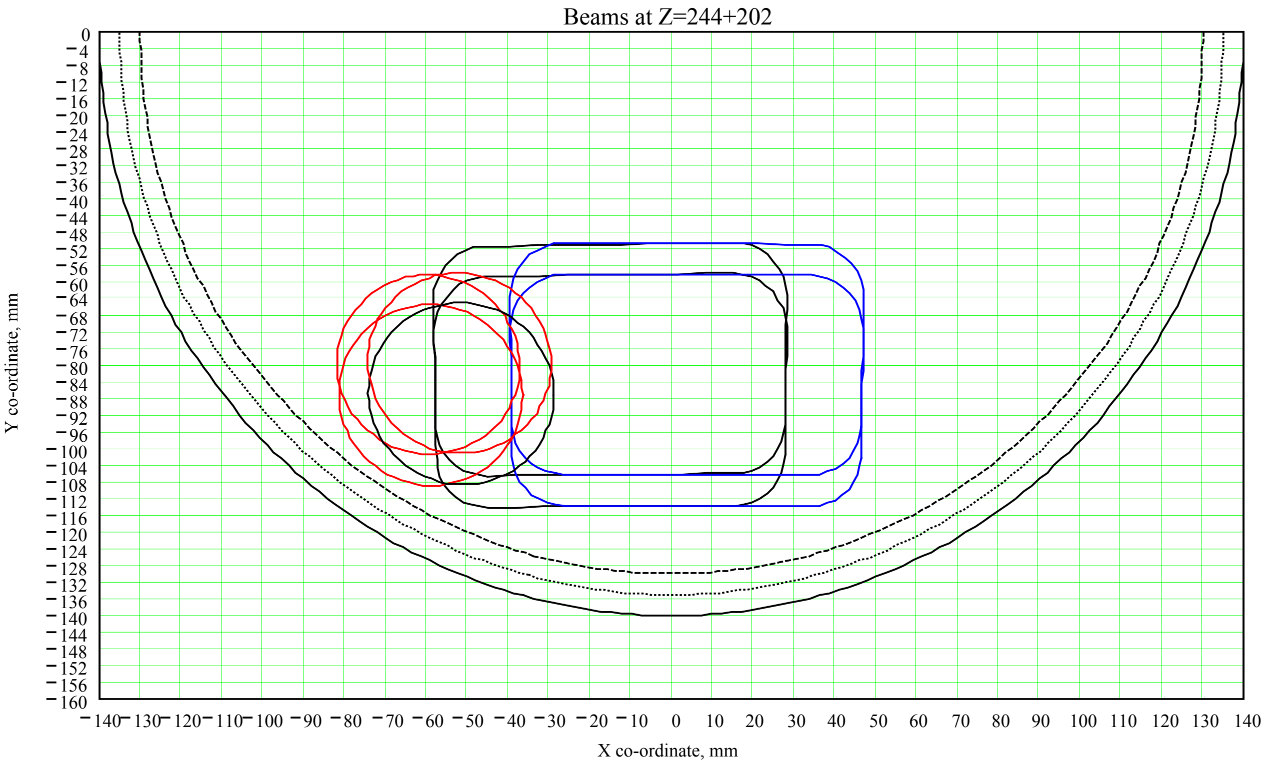

Figure 4-4 Composite beam boundaries at 244 mm forwards of the telescope axial focus

The section at Z=1050+202 is located at the front of the hole in the primary mirror. The Z co-ordinates chosen for the other sectional planes (771, 385 and 244 mm above the telescope's axial focal point) represent the approximate locations of respectively the front opening to the cryo-vessel, the cryostat vent closure plate and the rearmost heat shield, inside the cryostat, nearest the focal plane instruments. The last three dimensions reflect the cryostat design that existed at the time of the original FIRST payload module study. The 130 mm radius semicircular boundary drawn on each figure represents the size of the openings in all the cryostat shields that were included in that cryostat model. All dimensions shown in the figures are in millimetres.

The plots show that whereas 130 mm radius suffices for the apertures in the shields inside the cryostat, the radius must be increased to at least 135 mm at the top-most level of the cryo-vessel. Also, if the edge of the tilted spectrometer field of view is to clear the inside of the hole in the primary, the primary hole radius must exceed 137 mm.

5. DATA FILES

5.1 File names

Each beam data file and its associated IGES file has a 3-part name which reflects

a) Its start and end location, e.g. APAP100 denotes a beam from the aperture plate (AP) plane to a plane located at about 100 mm from it (AP100) along the principal ray. AP100PH denotes a beam from the latter plane to a plane located at the Primary Hole (hence the 'PH')

b) The instrument concerned, either PHOT (photometer) or SP (spectrometer)

c) The combination of chop (CH) and jiggle (JIG) angle extreme values used for CM4. These extreme values are denoted 'P' (Plus or positive extreme) and 'M' (Minus or negative extreme). Since two extreme values were used for each tilt angle, there are 4 combinations, namely

CHP_JIGP

CHP_JIGM

CHM_JIGP

CHM_JIGM

This prescription generates filenames such as APAP100PHOT_CHM_JIGP.DAT, for beam-generating ray co-ordinate data, and APAP100PHOT_CHM_JIGP.IGS, for the same data transformed to splines and presented in IGES format. A list of filenames for beam envelopes in the cryostat space is given in table 1.

Table 1 Files containing data describing Photometer and Spectrometer beam envelopes in the cryostat space

Beam co-ordinate data files	IGES-formatted files
AP100PHPHOT_CHM_JIGM.DAT	AP100PHPHOT_CHM_JIGM.IGS
AP100PHPHOT_CHM_JIGP.DAT	AP100PHPHOT_CHM_JIGP.IGS
AP100PHPHOT_CHP_JIGM.DAT	AP100PHPHOT_CHP_JIGM.IGS
AP100PHPHOT_CHP_JIGP.DAT	AP100PHPHOT_CHP_JIGP.IGS
AP100PHSP_CHM_JIGM.DAT	AP100PHSP_CHM_JIGM.IGS
AP100PHSP_CHM_JIGP.DAT	AP100PHSP_CHM_JIGP.IGS
AP100PHSP_CHP_JIGM.DAT	AP100PHSP_CHP_JIGM.IGS
AP100PHSP_CHP_JIGP.DAT	AP100PHSP_CHP_JIGP.IGS
APAP100PHOT_CHM_JIGM.DAT	APAP100PHOT_CHM_JIGM.IGS
APAP100PHOT_CHM_JIGP.DAT	APAP100PHOT_CHM_JIGP.IGS
APAP100PHOT_CHP_JIGM.DAT	APAP100PHOT_CHP_JIGM.IGS
APAP100PHOT_CHP_JIGP.DAT	APAP100PHOT_CHP_JIGP.IGS
APAP100SP_CHM_JIGM.DAT	APAP100SP_CHM_JIGM.IGS
APAP100SP_CHM_JIGP.DAT	APAP100SP_CHM_JIGP.IGS
APAP100SP_CHP_JIGM.DAT	APAP100SP_CHP_JIGM.IGS
APAP100SP_CHP_JIGP.DAT	APAP100SP_CHP_JIGP.IGS

5.2 File contents

5.2.1 Beam data files

All these files are given a file extension .DAT (see table 1). They contain fixed-format records containing 7 numbers as ASCII text:

N x1 y1 z1 x2 y2 z2

Where

N = integer ordinal number/record number

x1, y1, z1 = floating point co-ordinates of one end of a ray on the beam envelope

x2, y2, z2 = floating point co-ordinates of the other end of the same ray

The Photometer and spectrometer beam data files contain different numbers of records.

5.2.2 IGES-formatted files

Each file contains an IGES-representation of a single section of a beam envelope. Each file contains data defining a set of 3-d cubic spline curve entities, which represent the joined-up points that make up the ends of the beam envelope, and 3-d ruled surface entities derived from these spline curves, which make up the surface of the beam envelope between the ends. The IGES 5.2 standard was used as a guide when writing the code used to generate these files.

5.3 Co-ordinate systems

5.3.1 Beam data files

The beam data files use a co-ordinate system centred on the telescope axis, 202 mm below the telescope axial focus. +Z is along the telescope axis towards the secondary mirror. -Y is towards the SPIRE instrument and is in the fold plane of the photometer. +X completes a Right-hand orthogonal system.

5.3.2 IGES-formatted files

The IGES data is presented with X-Y-Z in the standard FIRST orientation, but still centred at the point on the telescope axis 202 mm below the axial focus. To transform the beam data to the FIRST orientation, just cyclically swap the co-ordinate labels e.g. the+X co-ordinate becomes +Y, the +Y co-ordinate becomes +Z, and the +Z co-ordinate becomes +X.

5.4 File retrieval

The beam data and IGES files are available via anonymous FTP from JACKAL.BNSC.RL.AC.UK. When logging-on use 'anonymous' as the username and the files can be found in the sub-folders (see figure 5-1)

…/pub/spire/CRYOBEAMS/DATA
…/pub/spire/CRYOBEAMS/IGES

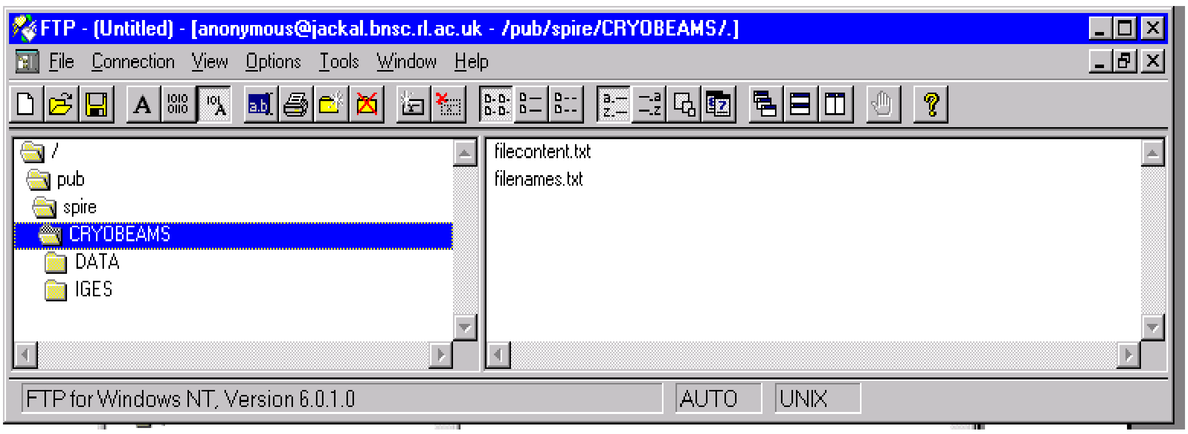

Figure 5-1 Where to find the data at the 'JACKAL' anonymous FTP site

6. REQUESTS FOR FURTHER DATA

If for any reason the text data files referred to above cannot be obtained, please e-mail me at A.G.Richards@RL.AC.UK and I will endeavour to satisfy your requirements.