TITLE: Check and update of SPIRE straylight model (under BRO/ASAP, for use by ASED)

By: Marc Ferlet (RAL)

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CHANGE RECORD

ISSUE	DATE	SECTION	REASON FOR CHANGE
1.0	10/01/03	All	First issue of the document

CONTENTS

APPLICABLE AND REFERENCE DOCUMENTS

RD1 Email from A. Frey (ASED) to SPIRE, ESA & ALCATEL (11/12/2002), the file "***Spire_tel3.inr***" was sent with the email.
RD2 HP-2-ASED-TN0023 issue 2 (09/10/2002)
RD3 Email from A. Frey (ASED) to M. Ferlet (RAL), 19/12/2002

1. Introduction

ASED closed the action no 4 of HP-ASPI-MN-2298 (SPIRE IF meeting in November 2002) by sending RD1. RD1 contains a copy of the "***Spire_tel3.inr***", a BRO/ASAP script file with the implementation of the SPIRE model geometry as well as the Herschel telescope (including the geometry of M1, M2 and the supporting hexapod structure but excluding sunshield, CVV, other instruments, etc.), to be used for further straylight level evaluation by ASED. The ASAP file is attached to this note.
Verifications of the model were performed at RAL and conclusions/suggestions summarised in section 2 below. This paragraph was sent to ASED by email (17/12/2002). Comments and additional information from ASED were received (RD3, see Appendix A). From RD3 (see Appendix A), ESTEC received also the information via ASED.
An update on the implementation surface properties of some structural elements of the model was sent to ASED by emails (08/01/2003 and 09/01/2003) on and reproduced here in section 3 of this note.

2. Check and comments on the ASAP model (file "Spire_tel3.inr" from ASED)

The ASAP straylight model for SPIRE (from ASED, labelled "***Spire_tel3.inr***") has been run on ASAP 7.5b (beta version not officially released, test runs were also performed on 7.1.3 and 7.1.8). As explained in the model (side notes in the ASAP file), the straylight macros (i.e. surface definition and flux computations) are not included in the delivered file. The optional coarse centring of CM4 assembly wrt M1 hole was used. Elliptical bars for the telescope hexapod are chosen as assumed to be the chosen shape at telescope level, although for the check the impact is expected as minor.
Below are displayed the results in terms of 2D, 3D views of tel. and/or instrument model + ray-trace (backward and forward), chief ray only and full-field with spot diagrams on relevant surfaces in the optics chain.

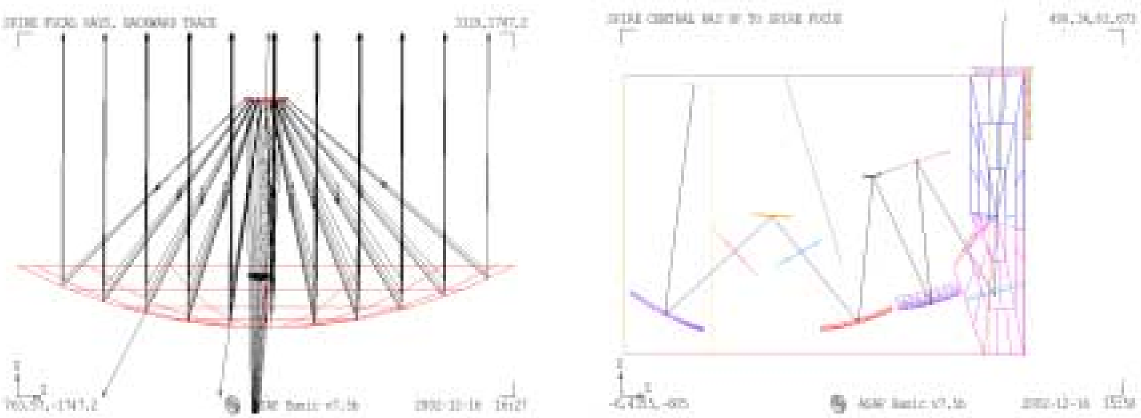


Figure 1: Backward ray-trace through from SPIRE position at TFP (left) and forward trace for chief (or gut) ray inside SPIRE instrument box as implemented in the model i.e. one photometer channel only (right).

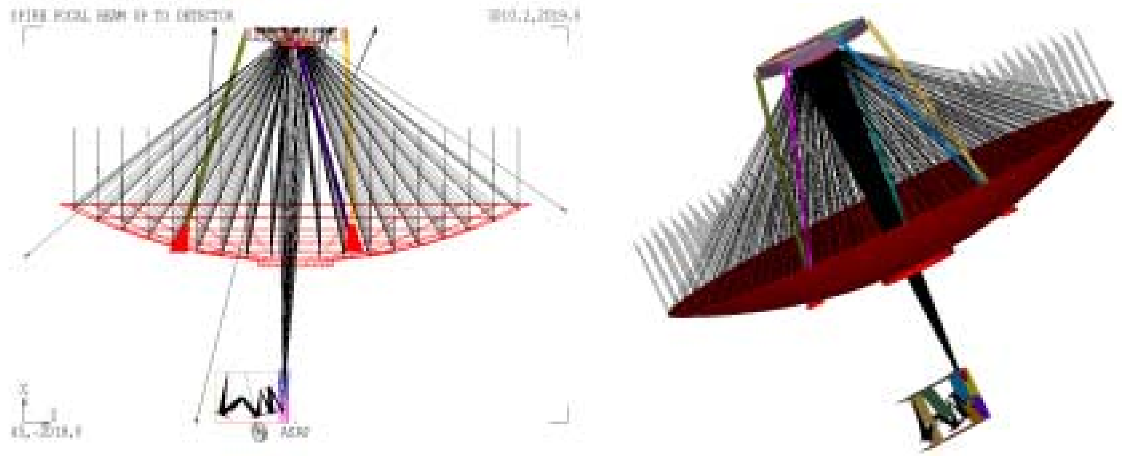


Figure 2: 2D (left) and 3D view (right) of forward ray-trace for full beam on-axis, i.e. centre of photometer FoV.

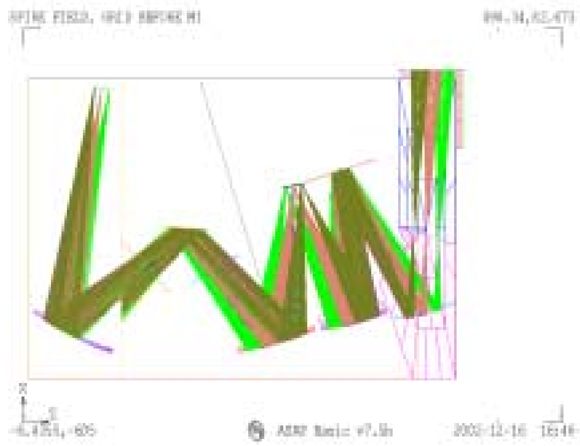
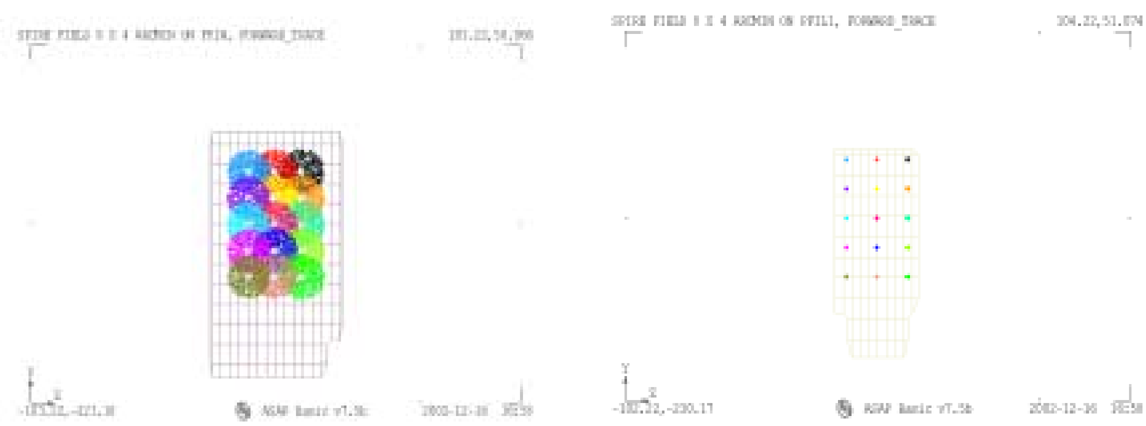
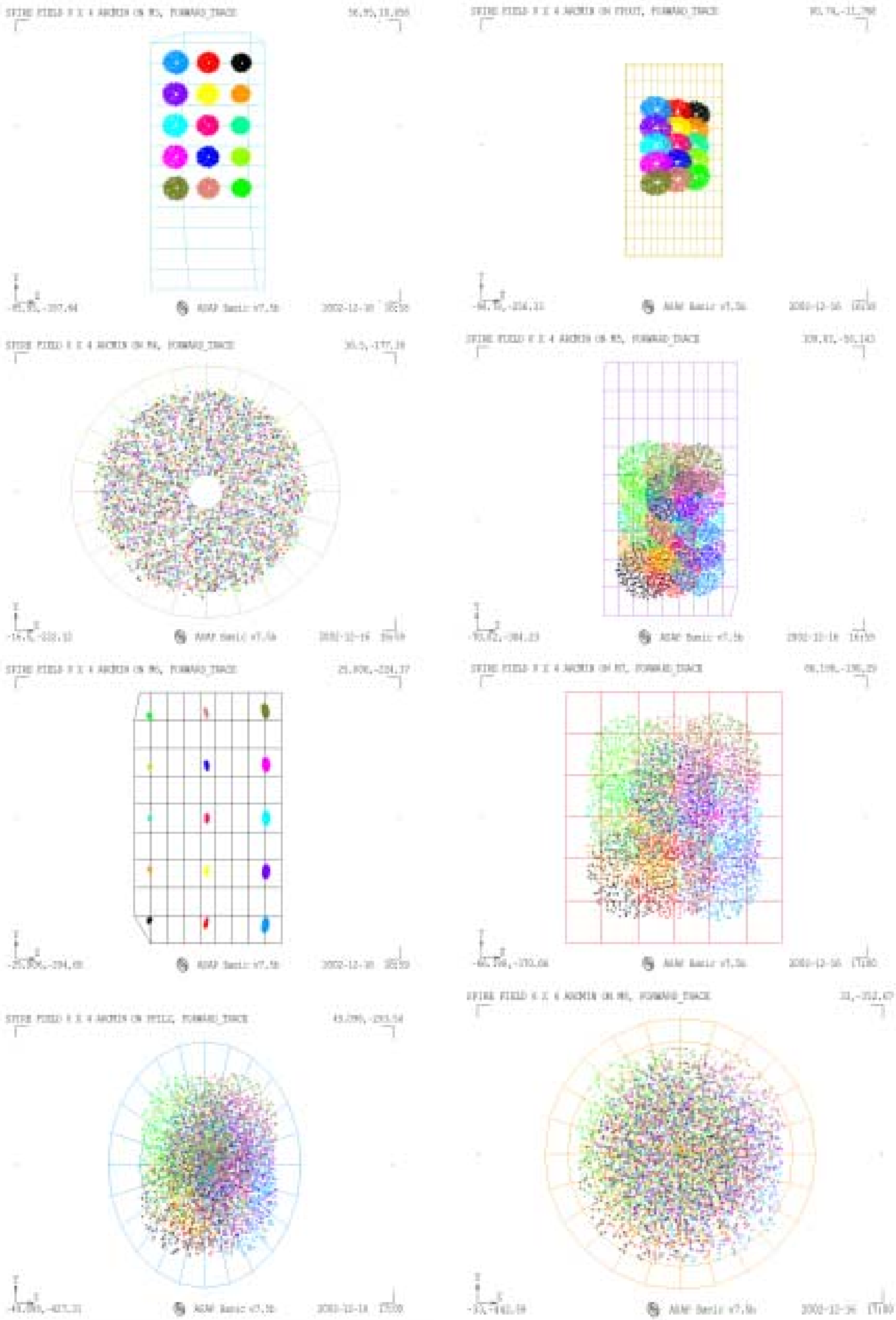
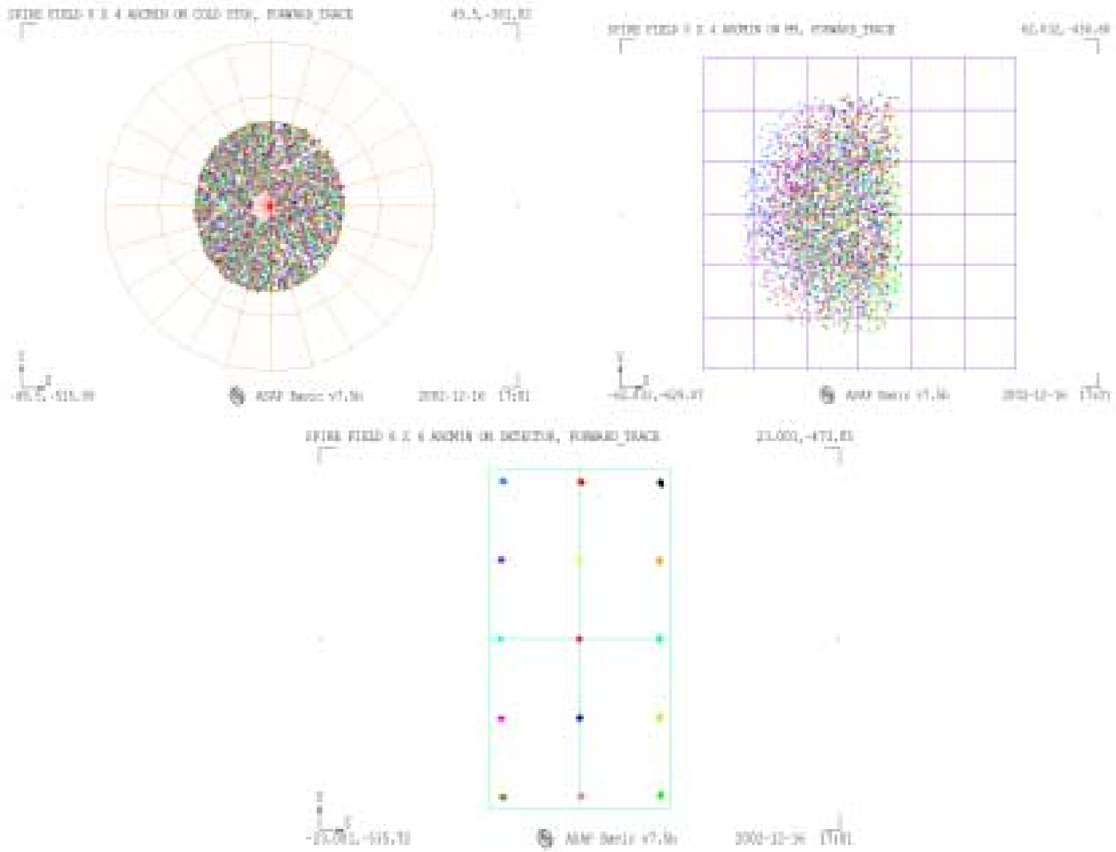


Figure 3: Forward trace, full-field from sky through instrument (right)

*** Forward ray-trace: full-field spot diagrams on the SPIRE (photometer) optics surfaces**







*** Pupil imaging (from telescope to SPIRE):**

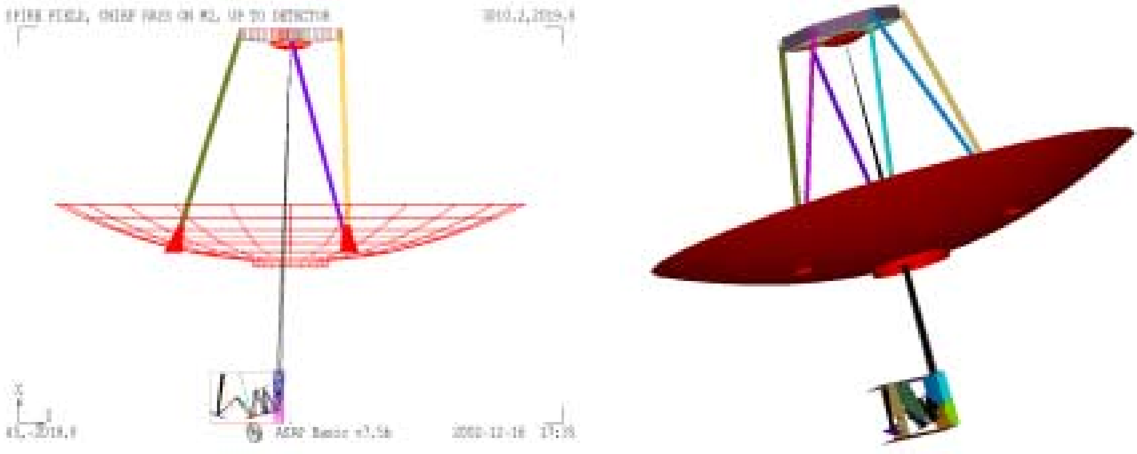


Figure 4: Chief ray at M2 centre traced towards SPIRE

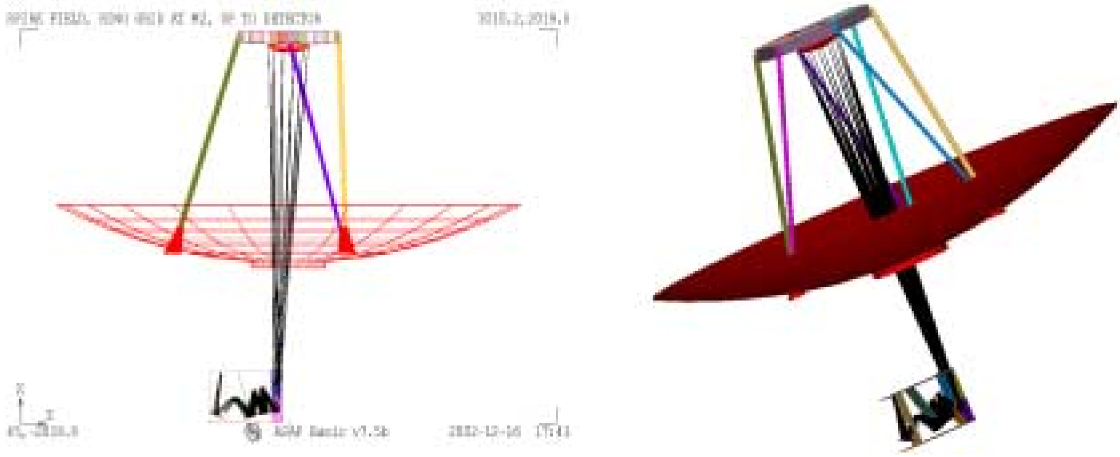


Figure 5: Edge of M2 being traced towards and inside SPIRE

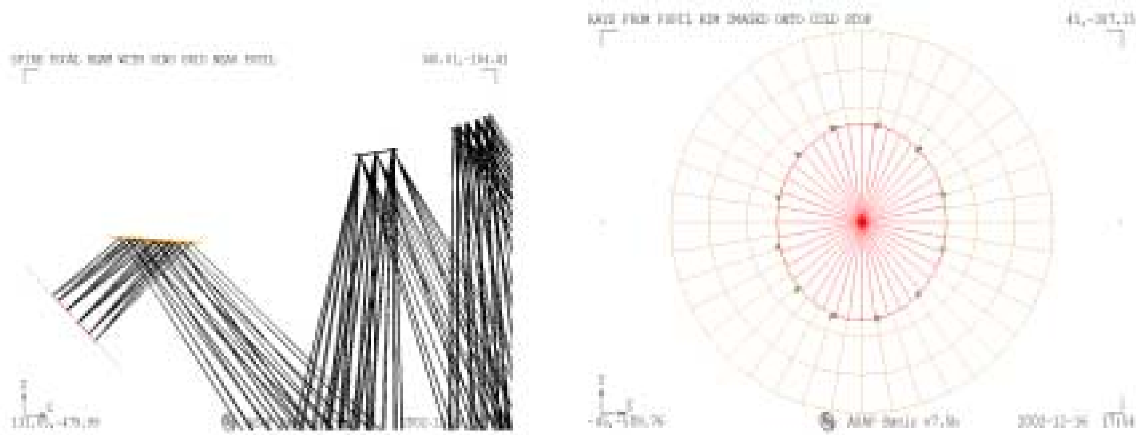


Figure 6: imaging the edge of M2 up to SPIRE cold stop via tracing of beams with sources at M2 edges

*** Direct illumination through M1 hole:**

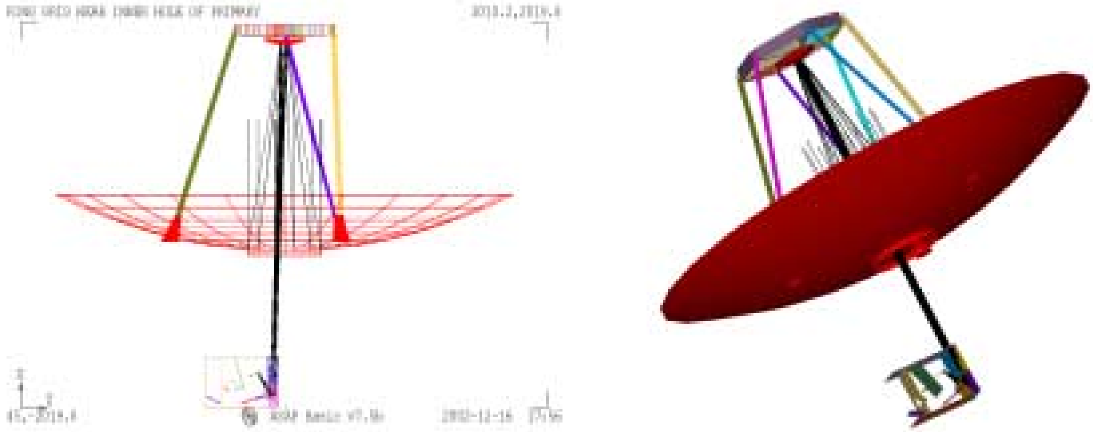
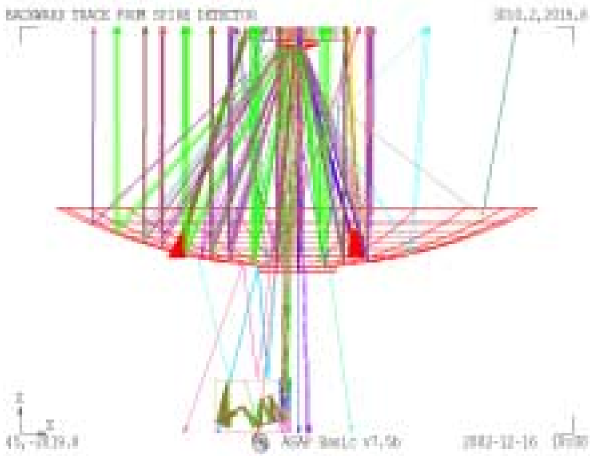
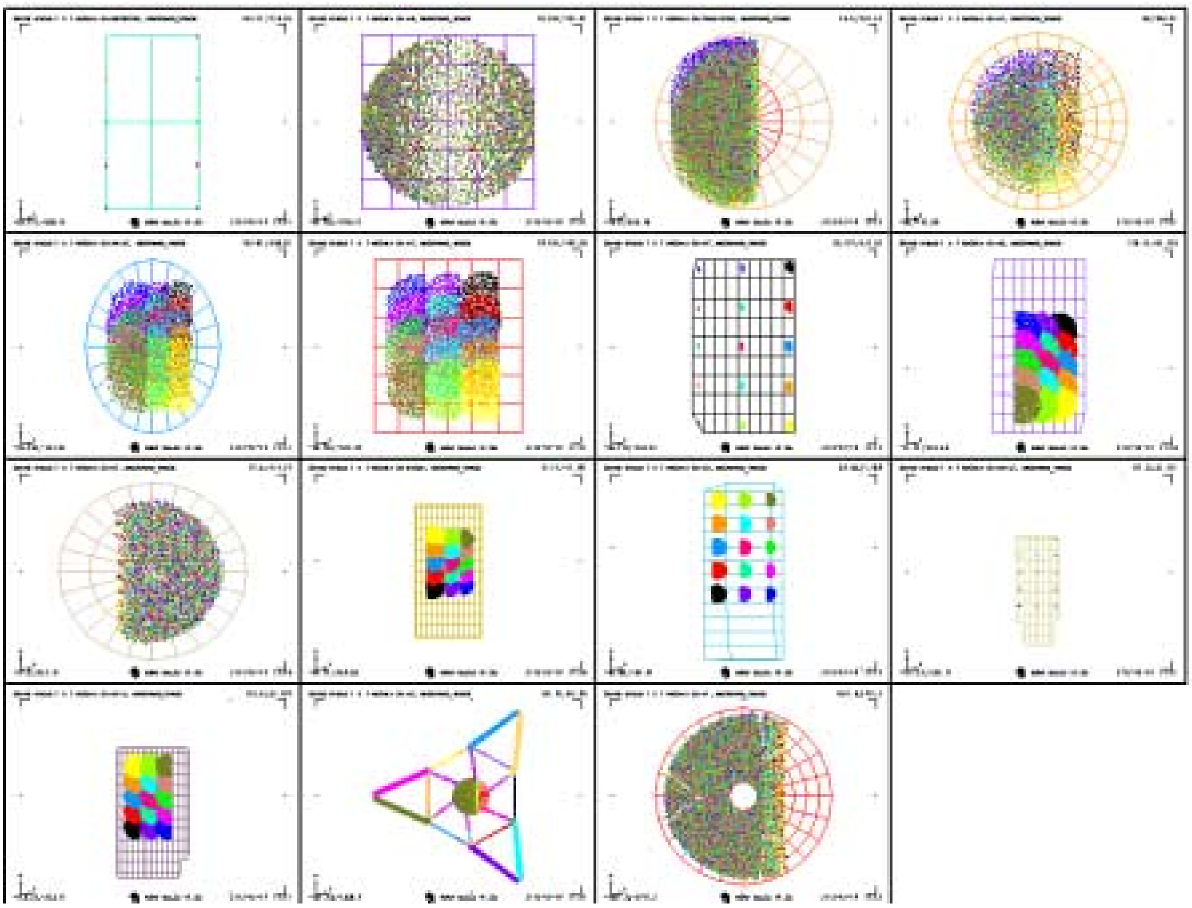


Figure 7: Trace of rays directly through hole in M1 towards SPIRE up to M4

*** Backward ray-tracing (from detector plane):**





Analysis of the different results above lead to the following preliminary conclusions regarding the model:
- surfaces (optics) definition looks OK,
- interface (optical, no CVV, radiation shield present between back of M1 and instrument) with telescope look OK,
- direct imaging (focal plane) and pupil imaging looks OK,

Quick comparison of some parameters (geometric mostly) for surface and rays with the *SPIREconfig42.xls* file data seems in global agreement.
- backward trace looks ok but complete assessment difficult because one geometrical element (labelled SPIRE.HOUSING.WALLM8), defined as last baffle (i.e. inner enclosure of detector box) is providing extra undesired clipping of the beam for nearly all field positions (well noticeable on the above plots of spot diagrams on the different optics surfaces). This is thought to come from the implementation of the hole (beam cut-out) in this structural element.

3D views below can help understanding the issue.

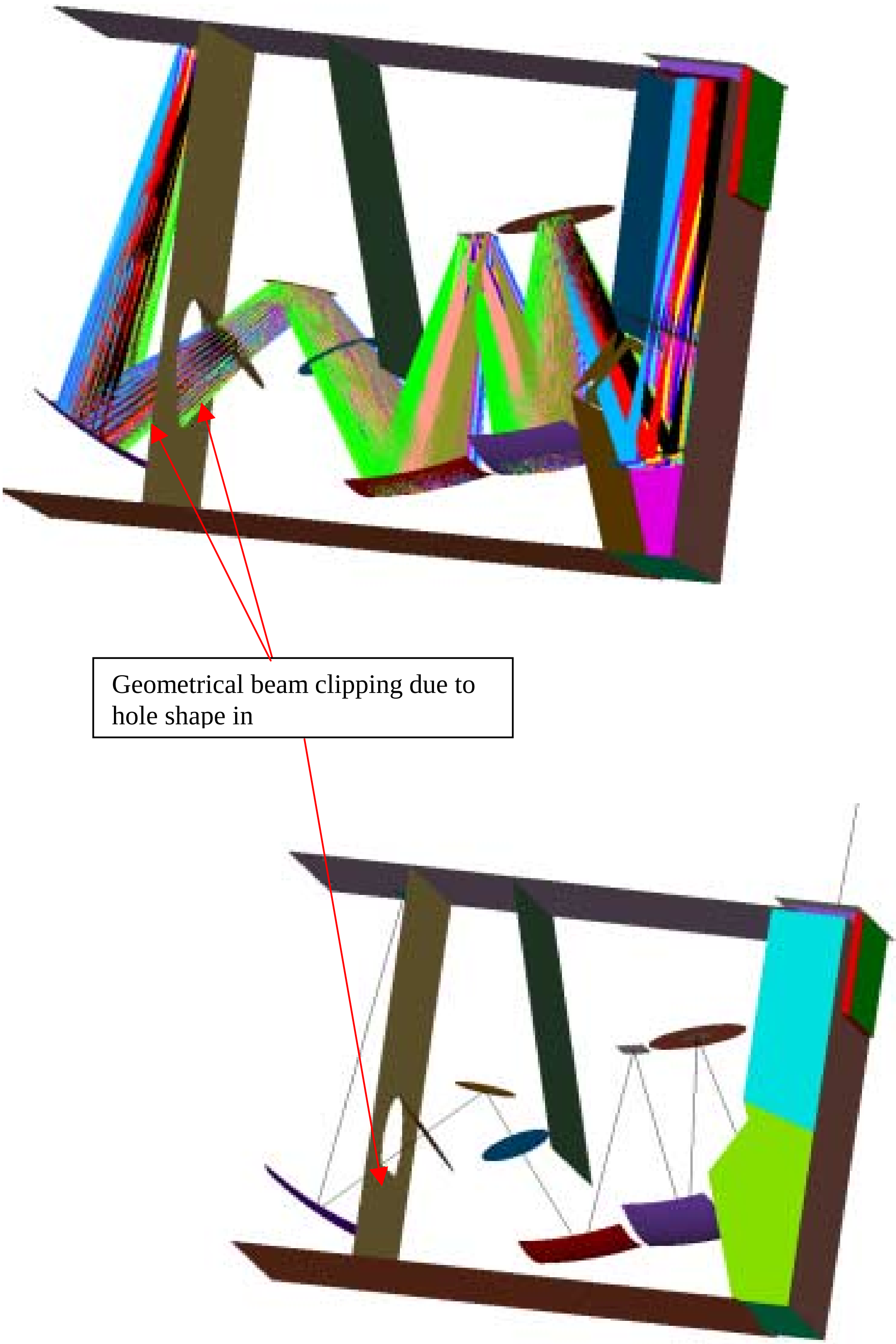


Figure 8: 3D views of the modelled SPIRE structure with the vignetting issue highlighted

Different versions of ASAP and facets values were used for the graphical displays to check that the effect is not coming from approximation/interpolation of surface shape during graphical representation.

In ASAP script language, the hole in WALLM8 is defined by BOUNDS with a TUBE of limited extent. The hole shape seen above is the results of the intersection of a conical surface (tube, potentially not long enough) with a flat plain wall surface. It is therefore suggested to replace, in the ASAP model:

```
SURFACE
 TUBE Z -50 2@45 50 2@45      !! used for bounds, see COLD_STOP_RING
  ROTATE Y ASIN[0.679971]    !! according to e-mail 29.04.02
  SHIFT 192.327 0 -448.460   !! according to e-mail 29.04.02
SURFACE
 PLANE Z -480 RECT (433.5-50)/2 105
  SHIFT X (433.5+50)/2
 OBJECT; 0.1 'WALLM8'
  BOUNDS 0.2
```

By (extending the limit of the cutting tube):

```
SURFACE
 TUBE Z -100 2@45 100 2@45      !! used for bounds, see COLD_STOP_RING
  ROTATE Y ASIN[0.679971]     !! according to e-mail 29.04.02
  SHIFT 192.327 0 -448.460   !! according to e-mail 29.04.02
SURFACE
 PLANE Z -480 RECT (433.5-50)/2 105
  SHIFT X (433.5+50)/2
 OBJECT; 0.1 'WALLM8'
  BOUNDS 0.2
```

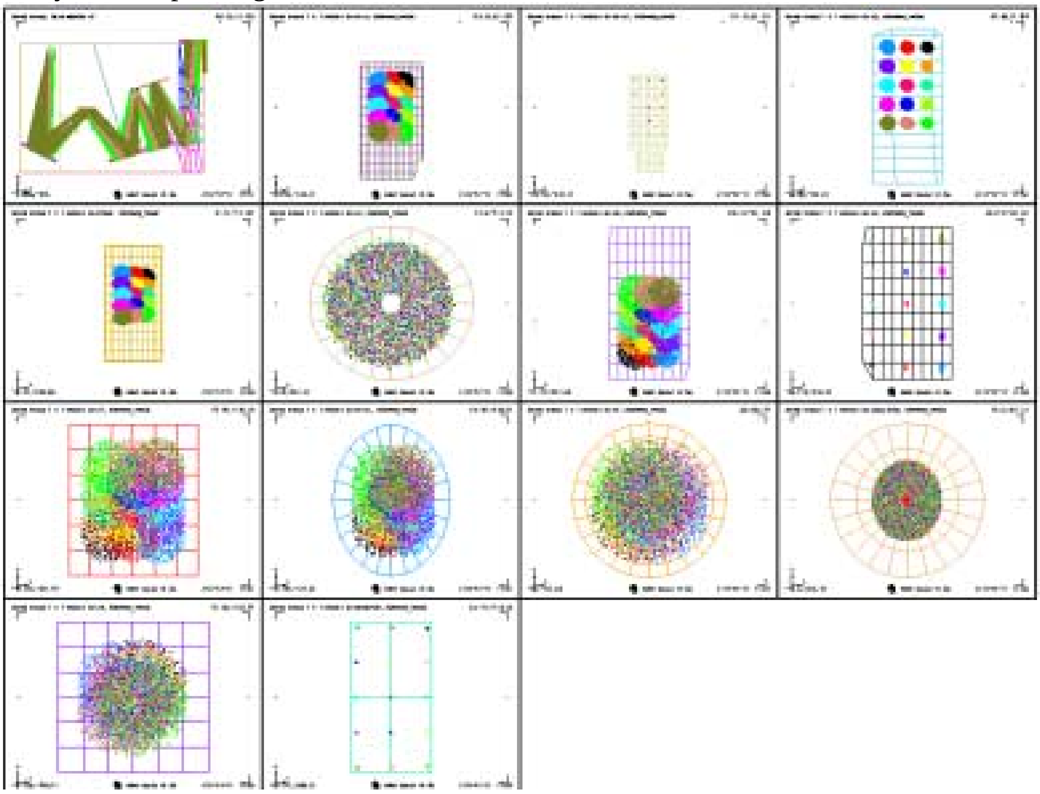
Or equivalently by the following (using EDGE which extends infinitely by default in the perpendicular plane):

```
EDGES
 ELLIPSE Z 0 2@45               !! used for bounds
 ROTATE Y ASIN[0.679971]   !! according to e-mail 29.04.02
 SHIFT 192.327 0 -448.460   !! according to e-mail 29.04.02

SURFACE
 PLANE Z -480 RECT (433.5-50)/2 105
  SHIFT X (433.5+50)/2
 OBJECT; 0.1 'WALLM8'
  BOUNDS 0.2
```

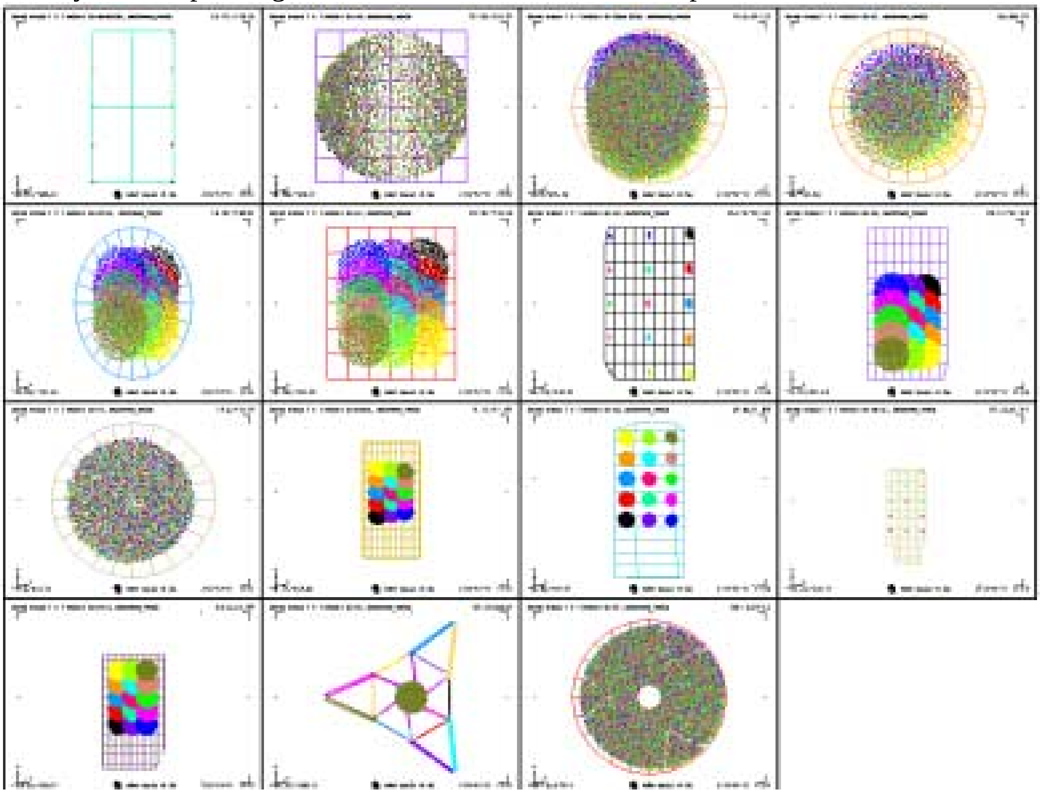
Any of the above would give a correction to the wrong clipping while remaining a low impact modification on the model i.e. the straylight level estimations from such as small change should not be affected much quantitatively (no such effect appeared in the tech. note HP-2-ASED-TN-0023 issue 2). It is suggested that the source ASAP model is checked for this effect before running straylight computations.

After applying the above modification in the model, one can get the following results:

-Forward ray-trace +spot diagrams in the instrument:

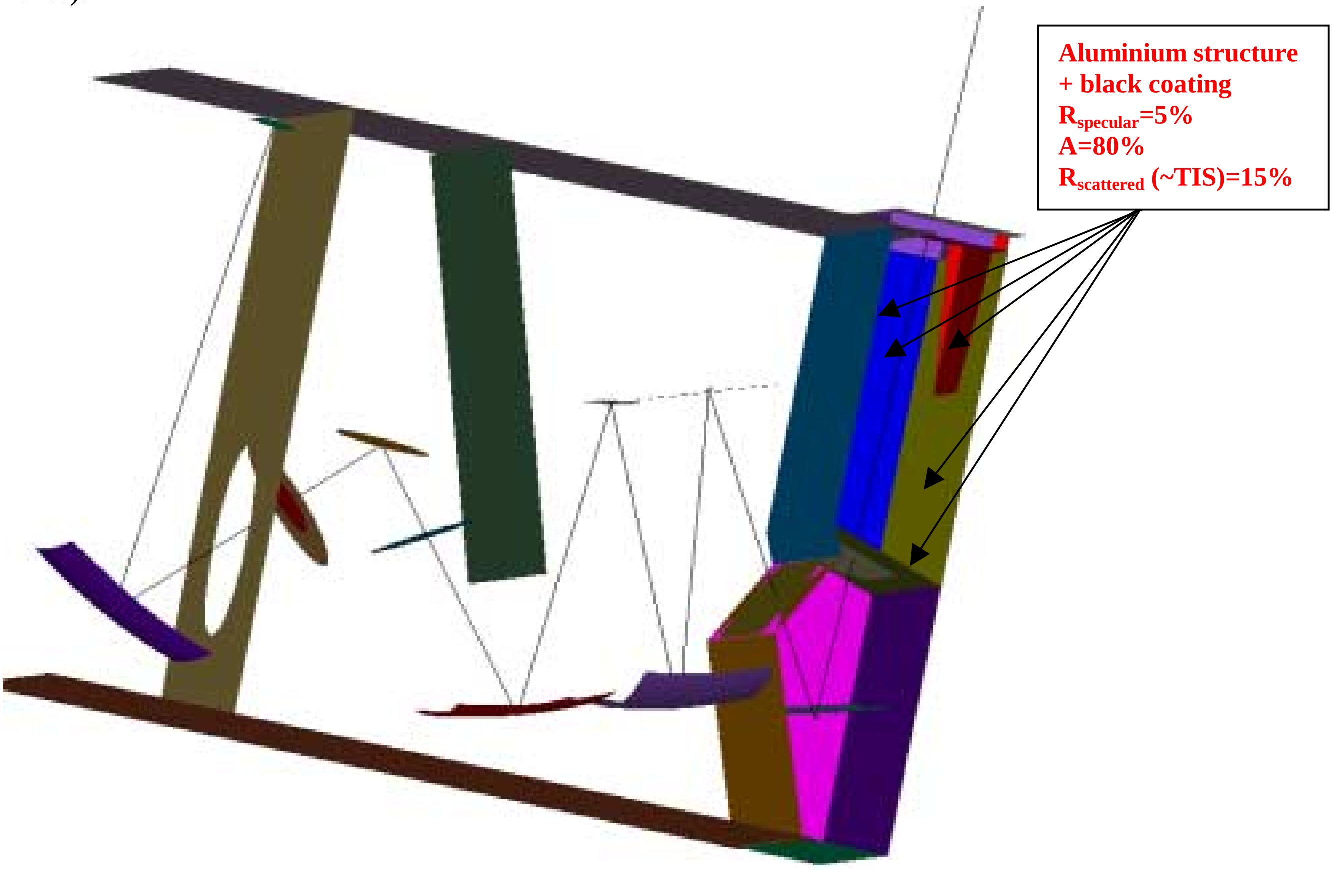


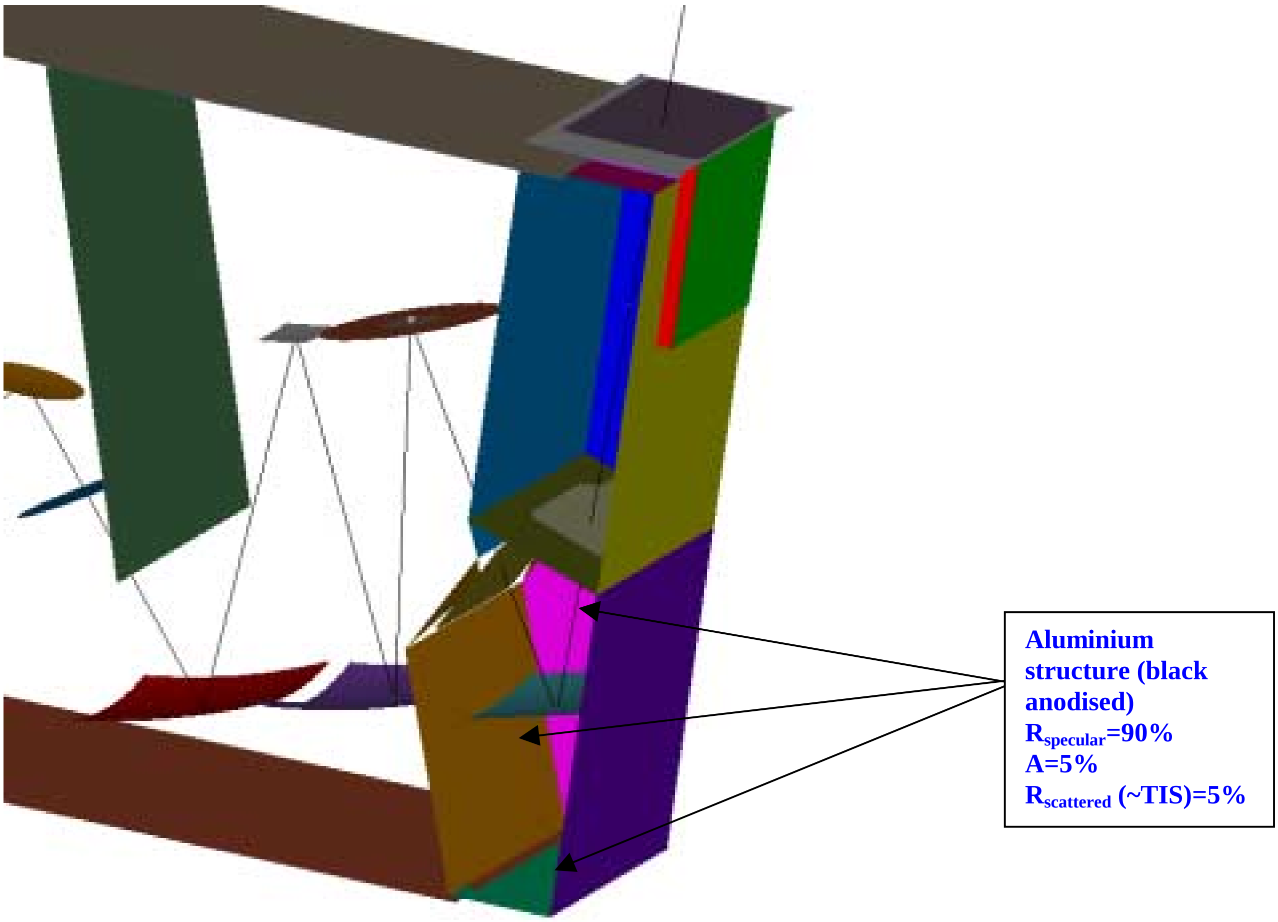
-Backward ray-trace +spot diagrams in the instrument and telescope:



3. Update on the surface properties for the FP_UNIT structural parts

This short note is aimed at providing updated information on the surface properties of structural part around the SPIRE FP_UNIT region to be used in the instrument and overall ASAP straylight models maintained by ASED. The figures below show 3D display of the ASAP SPIRE model (from "***spire_tel3.inr***"with gut-ray traced from telescope, some walls removed for visualisation of inside zones).





As shown in the top figure, we recommend the black coated inner surfaces of the top (entrance) cavity (i.e. above the thermal filter CFIL1) in the FP_UNIT to have the following properties:

Table 1	**Values recommended**	**Comments**
Reflectivity (specular)	**5%**	May be wavelength and incidence dependent but expected average value used here.
Absorption	**80%**	Absorption by black coating is expected in the range of 90-95% or better but the potential high incidence here may reduce its effectiveness.
Total scattered (in reflection, TIS)	**15%**	Addition of a wide-angle diffuse scattering component expected worst-case.

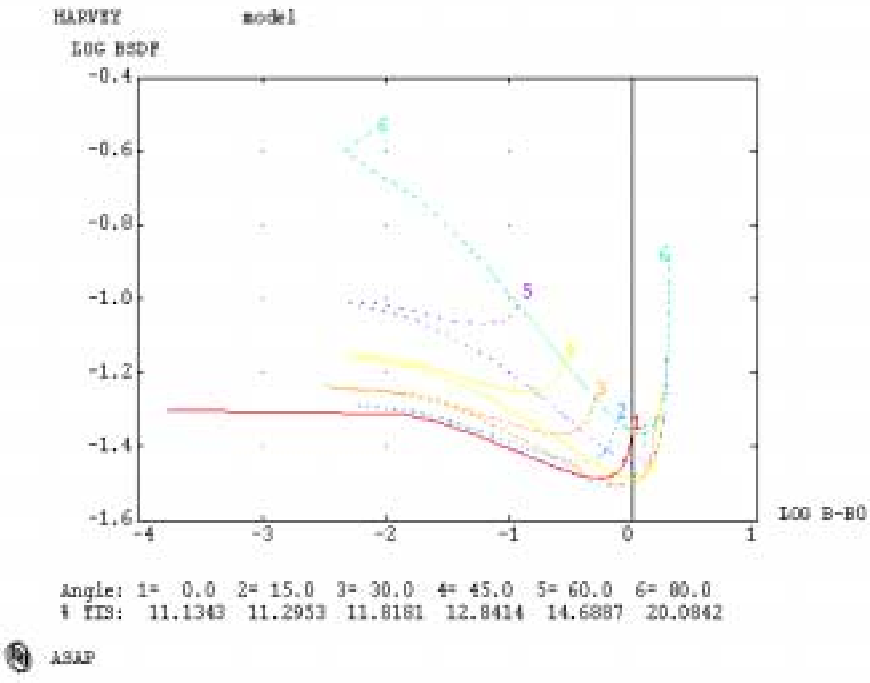
The surfaces concerned by the above are (labelling from “spire_tel3.inr”):

SPIRE.HOUSING.FP_UNIT.BAFFLE
SPIRE.HOUSING.FP_UNIT.POCKET
SPIRE.HOUSING.FP_UNIT.SIDE1MZ_UPPER
SPIRE.HOUSING.FP_UNIT.SIDE2PZ_UPPER
SPIRE.HOUSING.FP_UNIT.SIDE5PY_UPPER
SPIRE.HOUSING.FP_UNIT.SIDE6MY_UPPER

A possible ASAP implementation of the diffuse scattering would be:

MODEL
HARVEY 0.05 -0.15 0.02 1 1
RETURN

And illustrated by the following, for different angles of incidence:



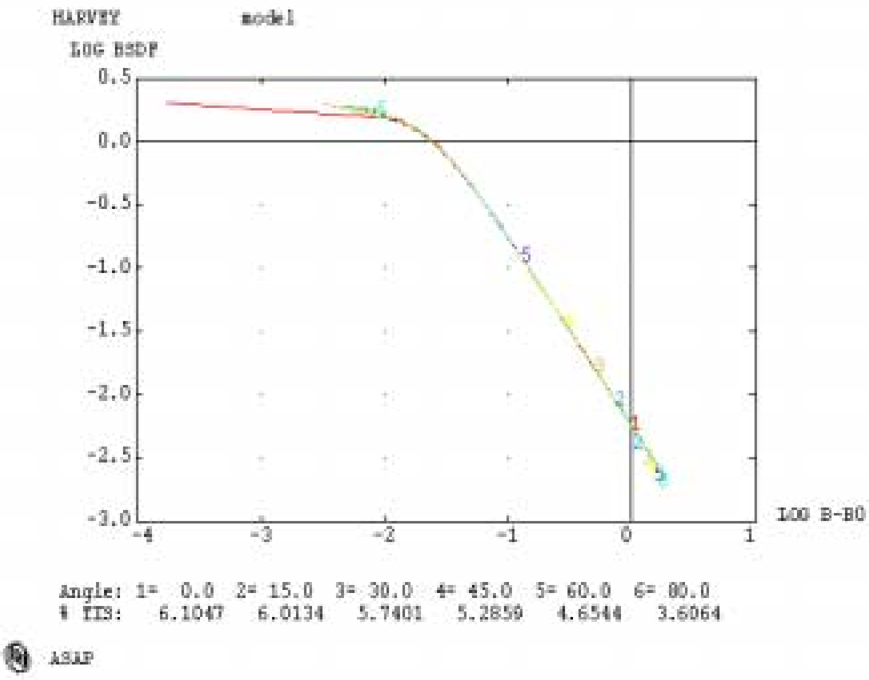
The rest of the structure is made of aluminium (eventually all or locally black anodised) and can be modelled with the values suggested in Table 2 below. This applies also to the inner surface of the bottom cavity of the FP_UNIT (i.e. after CFIL1 along the path, around M3) as shown in the lower figures on previous page.

Table 2	**Values recommended**	**Comments**
Reflectivity (specular)	**90%**	Even with black anodised treatment, the reflectivity is expected to be very high across the SPIRE spectral range.
Absorption	**5%**	Due to surface defects of surface treatment, should be a worst-case
Total scattered (in reflection, TIS)	**5%**	Addition of a surface scattering component expected worst-case.

A possible ASAP implementation of the scattering for these structural parts would be:

MODEL
HARVEY 2 -1.5 0.02
RETURN

And illustrated with the plots below for different incidences:



It is expected that these new values are representative (better than the previous single absorption/reflection/scattering model, see Appendix A section 2 and 3) of the surface characteristics for structural elements in the FP_UNIT (and the rest of the structure) of SPIRE. It should be noticed that they go in the same direction as one of the previous suggestions (see RD2, paragraph 10, page 70) regarding a more absorbing FP_UNIT, and therefore straylight level from next run of simulations should be affected.

Appendix A: "Answers to Comments of Marc Ferlet" by A. Frey (ASED), from RD3

1.) Vignetting by WALLM8

The RAL ASAP 2D-plots were a great surprise, because the vignetting does not appear on the Astrium computers (with the identical file spire_tel3.inr as sent to RAL), see next pictures.

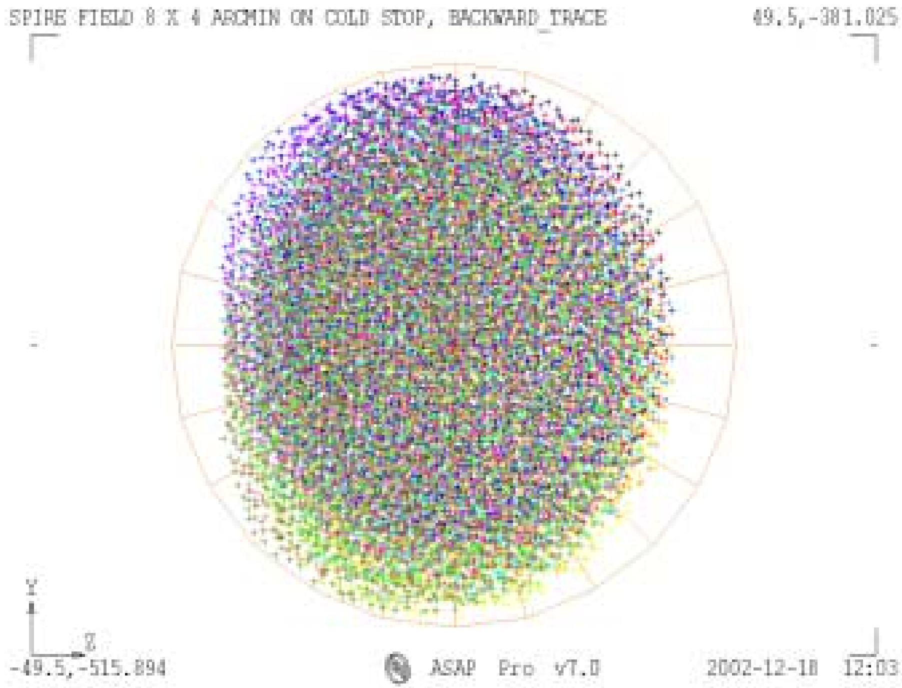


Fig. 1-1: Spots on cold stop (stop surface and open hole) from backward trace.

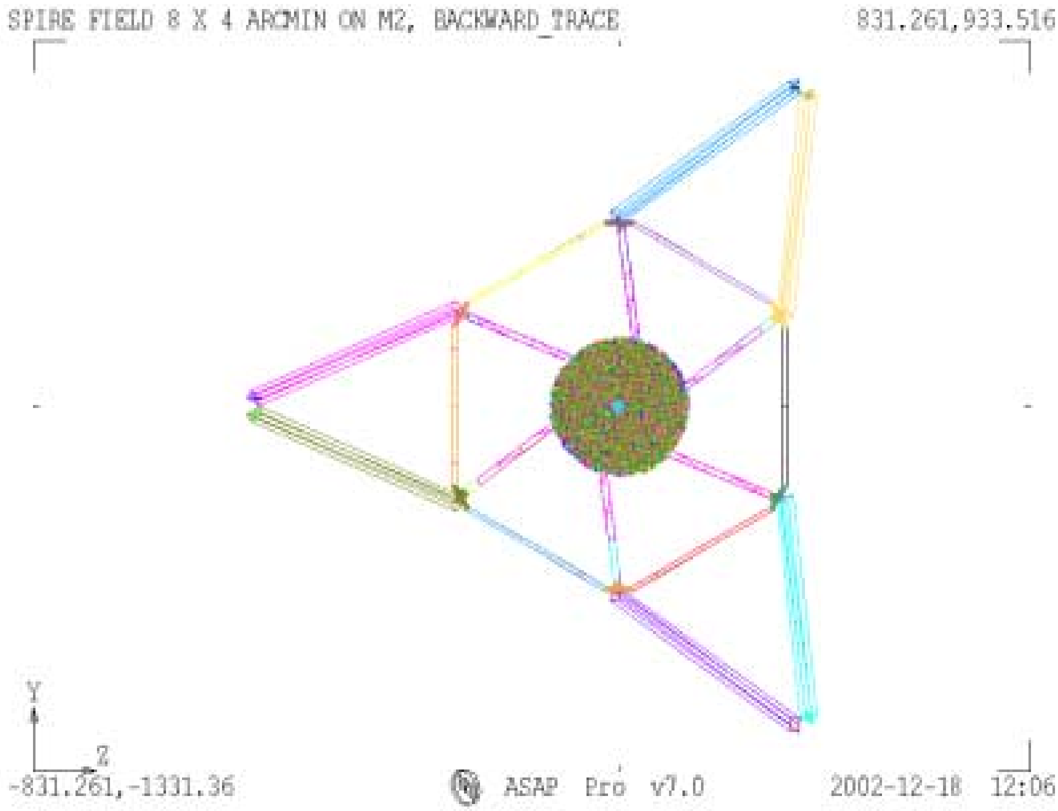


Fig. 1-2: Spots on M2 from backward trace.

So what happened? Very probably the solution to this mystery is the combination of

- the RAL pictures were calculated with ASAP 7.1 and ASAP 7.5
- the Astrium pictures (and all other calculations of Astrium Germany) were made with ASAP 7.0
- Volker Kirschner (ESTEC) once mentioned a change in the function of BOUNDS with SURFACES when switching from ASAP 7.0 to ASAP 7.1.

We would like to emphasize that the pictures shown above demonstrate that all straylight calculations (made up to now with ASAP 7.0) do not suffer from the vignetting present in the RAL pictures with ASAP 7.1 or later.

We welcome (and will include) your suggestion of enlarging the TUBE for BOUNDS, so that no vignetting will appear even when we switch to a later version of ASAP. Your discovery is very helpful, because now the change of function of BOUNDS will not cause any error when we change the ASAP version in the future.

I have addressed Volker Kirschner for a more detailed explanation of the change in ASAP behaviour, however I can investigate that subject only after installation of a later version of ASAP.

2.) FP_UNIT

The inner sides of the FP_UNIT (up to now) have an INTERFACE COATING with reflectivity=0.3 according to a telephone call in early summer 2002. That value could be changed in future calculations, if desired by SPIRE.

During the meeting in november, Bruce suggested to make these inner surfaces scattering (in addition to the residual reflectivity used up to now). The last calculations on ground testing submitted in the e-mail of 11. december 02 already contained this additional scattering. The earlier calculations

- on ground testing (e-mail from 22. november 2002)
- on the orbit situation (HP-2-ASED-TN-0023 issue 2)

did not contain that scattering. All future calculations will include that scattering.

3.) Scatter models

For convenience we add the scattering models used within SPIRE. These models were delivered to Astrium by ESTEC (Volker Kirschner) with the original SPIRE ASAP code based on SPIRE data.

```
!! models and media for SPIRE

MEDIA  !! from SPIRE file
  2.1`0.15 'PARTICLE_INDEX'

!! A WAVELENGTH MUST BE SET

$FCN MIL_STD S=(_2-_1)*_+(_2+_1),
           N=10^(0.926*(LOG[_3]^2-LOG[S]^2)),
           N*2*.926*LOG[S]/S
SMIN=1; SMAX=500 !! particle radii to be set in wavelength units
CLEANLEVEL=350; FRAC=3E-3
MODEL (MSMIR=1) !! for SPIRE mirrors
  PARTICLE MIE PARTICLE_INDEX SMIN/2 SMAX/2 FRAC. MIL_STD 250 SMIN. SMAX.
CLEANLEVEL. PLOT 0 30 60

MSSTRB=0.2; MSSTRM=-0.2
MODEL (MSSTR=MSMIR+1) !! for SPIRE structure
  HARVEY (MSSTRB) (MSSTRM) !! PLOT
```

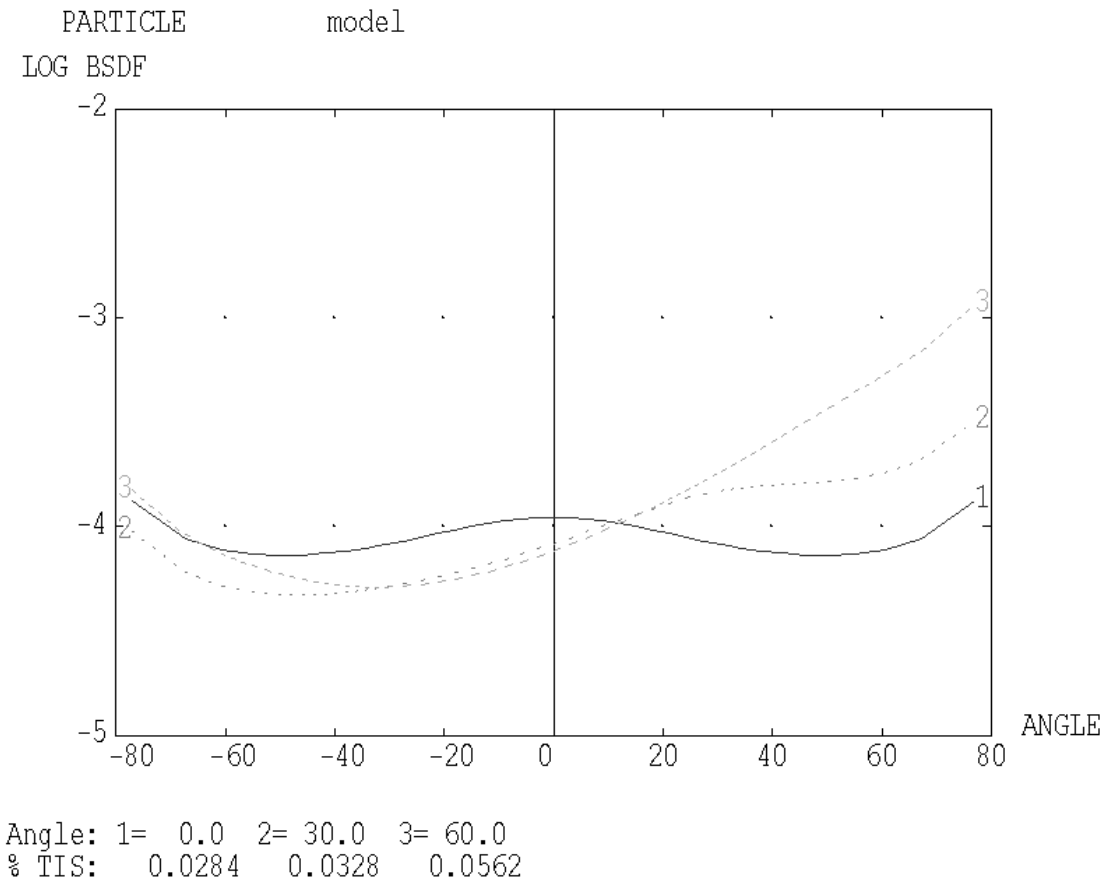


Fig. 2-1: Particle scattering function delivered to Astrium with the SPIRE model for mirrors.

The particle model (applied to mirrors) yielded insignificant straylight contributions.

No scattering functions were delivered to Astrium for thermal filter 1. This object is likely to be the most important scatterer within SPIRE, since

- it is directly visible to the detector
- it can be irradiated considerably by oblique rays.

As a worst case, we inserted a tentative lambertian scatterer with TIS=0.1 for thermal filter 1. Clearly this pessimistic scattering function should be replaced by a real one, once the real one is known.

Thus the summary for

- the ground testing (e-mail from 22. november 2002)
- the orbit situation (HP-2-ASED-TN-0023 issue 2):

is:

- ♦ the scattering function of fig. 2-1 was applied to M3 of SPIRE
- ♦ the tentative lambertian scattering with TIS=0.1 was applied to the thermal filter 1 of SPIRE.

The additional scattering function for the FP_UNIT (in the results of e-mail of 11. december 02 and in future calculations) is taken from the ASAP code listed above (the Harvey function labeled 'for SPIRE structure'). Fig. 2-2 shows the graphical representation.

All these scattering functions can be modified for future calculations, if there are demands from SPIRE. The next calculations for the orbit case are expected for January 2003 (we are waiting for some informations from PACS).

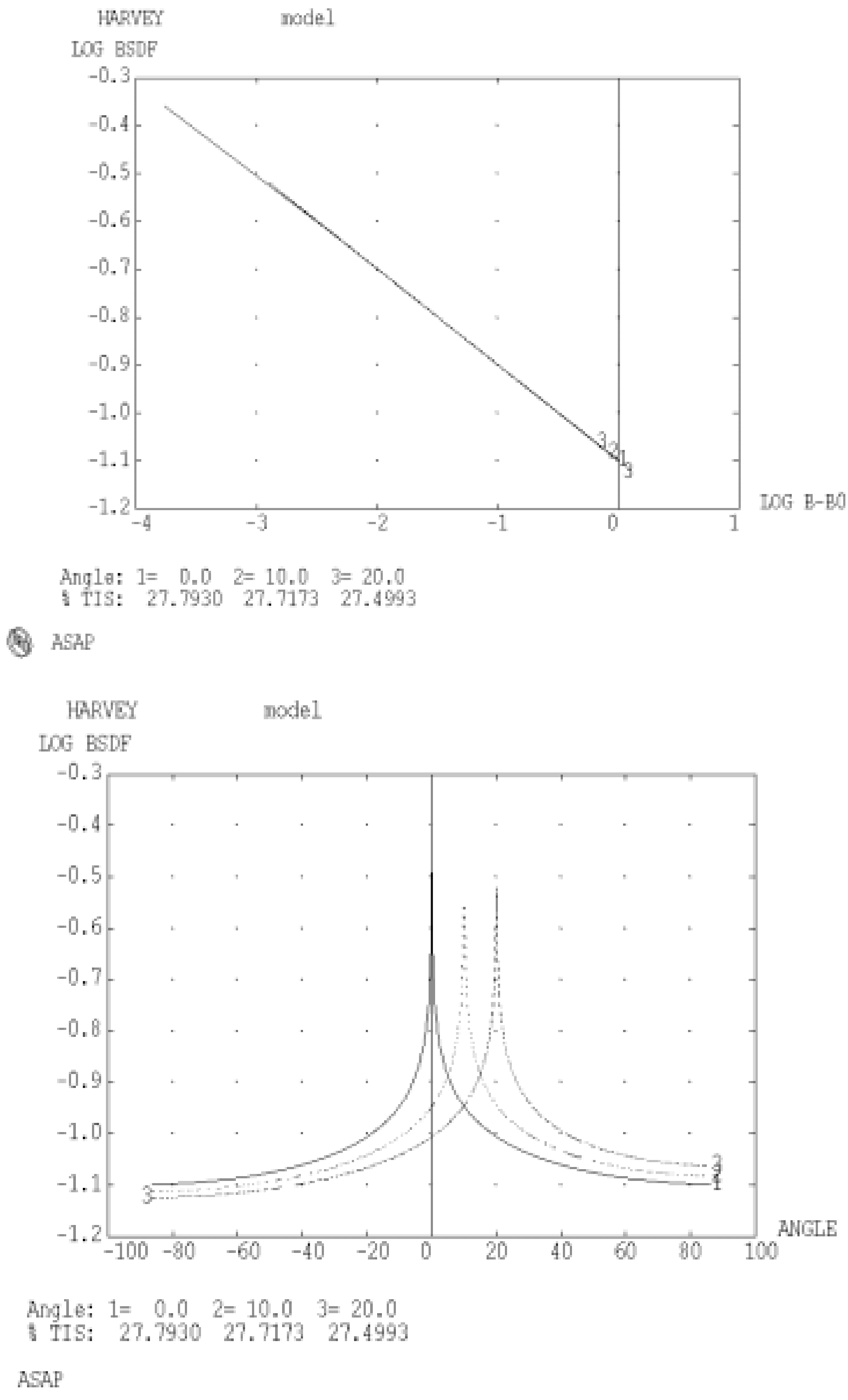


Fig. 2-2: Harvey scattering function delivered to Astrium with the SPIRE model for SPIRE structure (will be applied to the FP_UNIT).

4.) Telescope model

We had tried hard to have the same telescope model both

- for the overall straylight calculations (HP-2-ASED-TN-0023 issue 2)
- for some specialized telescope calculations (HER.NT.0017.T.ASTR issue 3).

The ASAP model for the second TN does not contain the experiment models, but a simplified experiment path. The results of the second TN are valid for those cases where there is direct view from the telescope to the experiment detectors. The first TN includes all experiments, the CVV, the heat shields, the sunshade, etc.., thus should give the total straylight.

The only exception (known to us) for a difference of the telescope model used in both technical notes is the scattering function for the telescope mirrors. This function has been increased in the French analysis but did not made it across the Rhine river (in time for our own analysis). We will use the new increased scattering function in the future analysis. The scattercone was analysed in both analyses both with the large and the small option.

One of the reasons for the future analysis is the desire of HIFI for avoiding standing waves. That desire induced a recent change in the tilts of the hexapod bars, this change is not included in any of the analyses up to now. The future analysis (ASED) will be done with

- the tilted hexapod bars (modeled by Volker Kirschner)
- the small scattercone
- whatever hexapod legs the scientists will prefer
- any change in the experiment models communicated to us.

5.) Apodisation

The apodisation was applied to the rays impinging onto the SPIRE ASAP(!)detector, i.e. before the horns (which are not modeled). Thus it was applied after the raytrace. Before apodisation, the beam (as a whole) was shifted to 0/0/0, then aligned with the command

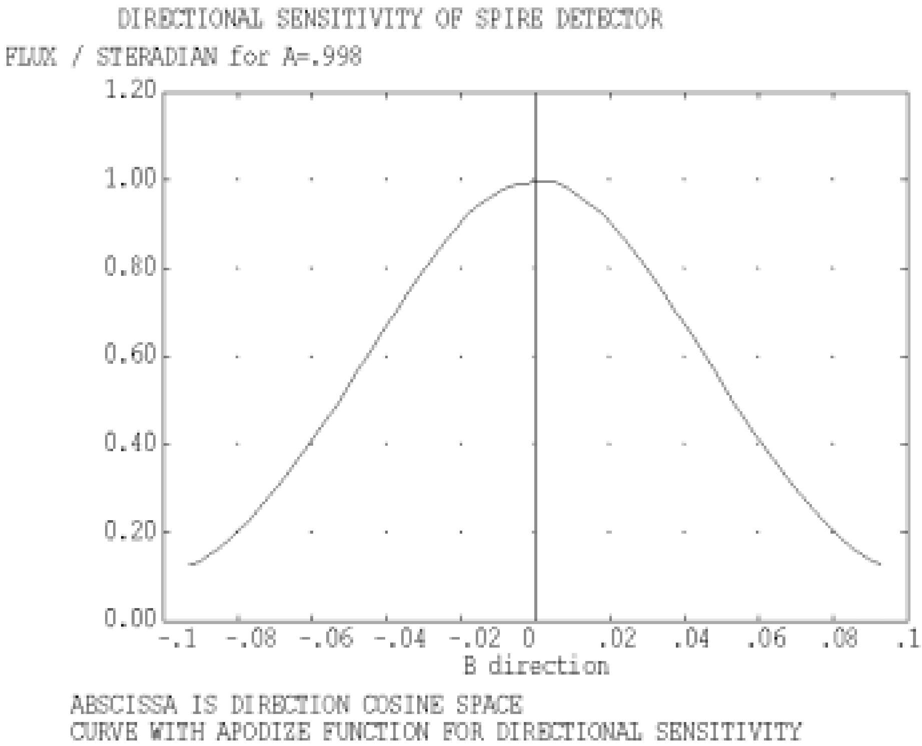
ALIGN + (BSDET) (CSDET) 1 0 0 0 0 0

where + (BSDET) (CSDET) are the direction cosines of the ASAP detector normal.

Then a directional apodisation is programmed with the aim of having an edge taper of -8dB at the rim of the angular cone of each beam towards the detector, this rim was found to be at 4.9 degrees from the normal of the detector centre. The ASAP commands shown below were derived for a beam towards the detector centre, this angular apodisation was assumed to be accurate enough also for beams to other positions on the detector area.

```
!! for SPIRE apodization

$FCN APDZ EXP(-2*(_1^2+_2^2)/_3^2)

MRA=4.928 !! angle of cone towards ASAP detector centre (before horn)

SEDGT=8 !! edge taper (dB) for SPIRE

W=SIN[MRA]*SQRT(20/(SEDGT*LOG(10)))

APODIZE DIR APDZ (W).
```

It is somewhat time consuming to go through the commands in detail. Instead, a graph is shown below with the result of the apodisation gained with a beam (from the telescope) impinging on the detector centre with the apodisation active as programmed above, i.e. an ASAP raytrace result.


DIRECTIONAL SENSITIVITY OF SPIRE DETECTOR
FLUX / STERADIAN for A=.998
1.20
1.00
0.80
0.60
0.40
0.20
0.00
-.1 -.08 -.06 -.04 -.02 0 .02 .04 .06 .08 .1
B direction
ABSCISSA IS DIRECTION COSINE SPACE
CURVE WITH APODIZE FUNCTION FOR DIRECTIONAL SENSITIVITY