100634-1001

DL/SCI/TM 27E

technical memorandum Daresbury Laboratory

DL/SCI/TM 27E

MACHINE ENERGY AND SPECTRAL INTENSITY OF SRS

by

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JUNE, 1981

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1. INTRODUCTION

By reducing the electron beam energy E for a given current I, the characteristic wavelength of the synchrotron radiation emitted, λ_c, will increase for the same bending radius with a corresponding drop in the total dissipated power. Within a certain working range, however, the synchrotron radiation power can be reinstated by increasing the current. This will amount to a nett gain in synchrotron radiation intensity at long wavelengths at the expense of the intensity at short wvelengths. The present note contains intensity calculations for the SRS over the range $1.6 < E\ (GeV) < 2.1$ and $0 < I\ (A) < 1$.

Operating the SRS with the wiggler or in single bunch mode will result in a lower maximum machine current being achieved at a given energy. The effects of these conditions on the spectral intensity are also examined in the same working range.

2. MACHINE CURRENT AND ENERGY

Figure 1 shows the relationship between machine current, I, and machine energy, E, predicted for the SRS running with a single klystron[1]. Curve (a) refers to the SRS operating without any wigglers. Above 2 GeV (curve (d)) the current will rapidly run to zero as the limitations set by a reasonable quantum lifetime and the r.f. power available are met. Below 1.6 GeV the maximum current attainable is uncertain and will only be clarified once the machine is properly understood. It is primarily dependent on the conditions under which the beam is stored at 600 MeV. It is set for the sake of argument at 1 A, but may in the end be larger. Curves (b) and (c) in fig.1 refer to the SRS running with one and two 5 tesla wigglers respectively. The progressive decrease in current for a fixed energy reflects the extra fraction of power each successive wiggler will take from the remaining magnets.

3. SYNCHROTRON RADIATION INTENSITY VERSUS MACHINE ENERGY

The computed synchrotron radiation intensity in photons/s/mrad

horiz./0.1% bandpass corresponding to the maximum machine current at a particular energy is plotted for salient wavelengths from x-rays to the far infra-red in figs.2 and 3. Figure 2 is for a field of 1.2 tesla and fig.3 for a field of 5 tesla - this being the maximum field in the wiggler magnet. Previous calculations for the wiggler magnet[2] indicate that the intensities in fig.3 should be increased by approximately × 2, depending on the observing angle, because in general two tangent points are always in view. All calculations have used the existing one electron synchrotron radiation programmes[3].

It is clear from figs.2 and 3 how the loss in the maximum intensity in the x-ray region resulting from lowering the machine energy through the working range from 2 to 1.7 GeV progressively worsens as the wavelength gets shorter. For instance at 1 Å the reduction can be as much as × $^1/_5$ at 1.2 tesla. In the soft x-ray region and at longer wavelengths it approaches an improvement of × 3. The turning point is approximately the characteristic wavelength λ_c at 2 GeV (i.e. 3.9 Å for 1.2 tesla and 0.9 Å for 5 tesla). At shorter wavelengths the maximum intensity drops for reduced machine energy; at longer wavelengths it improves; close to 3.9 Å (fig.2) or 0.9 Å (fig.3) the maximum intensity is independent of machine energy.

4. WIGGLER AND SINGLE BUNCH MODE OPERATION

The running of the wiggler magnet will reduce the maximum electron beam current attainable for a given energy (fig.1(b)) and the effect of this on the synchrotron radiation intensity at a standard 1.2 tesla dipole is shown in fig.4 (0.5 to 5 Å) and fig.5 (10 to 10^6 Å). The solid lines are the same as fig.2 for the SRS without the wiggler and the dashed line for the SRS with the wiggler. The reduction at all wavelengths is approximately 20 to 30%.

For single bunch mode operation the maximum machine current is not r.f. power limited and is therefore not expected to be dependent on machine energy except above 2.1 GeV. Its value is not known at this stage but a figure of 60 mA is likely. The synchrotron radiation intensities for single bunch operation are indicated in figs.4 and 5 by the dotted curves. The reduction in intensity is clearly greatest at low energies but improves as the energy increases towards 2 GeV. It is also feasible for the SRS to run in a mode intermediate between the single and multi-bunch extremes. In this case the maximum machine current would be higher than for single bunch mode operation and correspondingly r.f. power limited at higher energies.

5. SOURCE OPTICS

The photon opening angle for a single electron beam σ_v, increases with wavelength but decreases with characteristic wavelength. At a particular wavelength for a fixed bending radius, however, it is practically constant as a function of machine energy. This is borne out in fig.6 which includes the σ_v, versus E curves for wavelengths between 0.5 and 10^6 Å.

The electron beam source dimensions - the horizontal and vertical size and the bunch length - will increase slightly with machine energy. Figures for these parameters are speculative but for 1.7 GeV compared to 2 GeV operation it is unlikely they will amount to an improvement in brightness of more than about 30%.

6. CONCLUSIONS

The figures presented in this note are only intended as a guide to the possible operation of the SRS. They indicate the likely size of an improvement in intensity at longer wavelengths if the machine were run at lower energies and the likely size of the loss in intensity at shorter wavelengths. The effects of wiggler and single bunch mode operation are also estimates. The flux of photons at a particular experimental station however will depend on many other factors, not the least of which will be the alignment of the beam with respect to the beam lines for different machine operating conditions.

REFERENCES

1. G. Saxon, Daresbury Laboratory, SRUM 6/80 (1980).

2. G.N. Greaves, R. Bennett, P.J. Duke and R.S. Holt. To be published.

3. J. Poole, Daresbury Laboratory Internal Report DL/SRF/TM 1 (1975); DL/SRF/TM 4 (Revised) (1978).

FIGURE CAPTIONS

Fig.1 Predicted maximum SRS machine current versus energy for present operation (a) and for operation with one or two wigglers (b) and (c). (From ref.[1]).

Fig.2 Maximum SR intensity (photons/s/mrad horiz./0.1% bandpass) versus machine energy (GeV) predicted for a standard dipole (1.2 tesla) on SRS at various wavelengths.

Fig.3 Same as fig.2 but for the maximum field (5 tesla) on the wiggler.

Fig.4 Maximum SR intensity (photon/s/mrad horiz./0.1% pandpass) versus machine energy (GeV) predicted for a standard dipole (1.2 tesla) with no wiggler operating (solid line), and 5 tesla wiggler operating (dashed line) and in single bunch mode (dotted line) from 0.5 to 5 Å.

Fig.5 Same as fig.4 but from 10 to 10^6 Å.

Fig.6 Photon opening angle σ_v, FWHM (mrad) versus machine energy (GeV) from 0.5 Å to 10^6 Å.

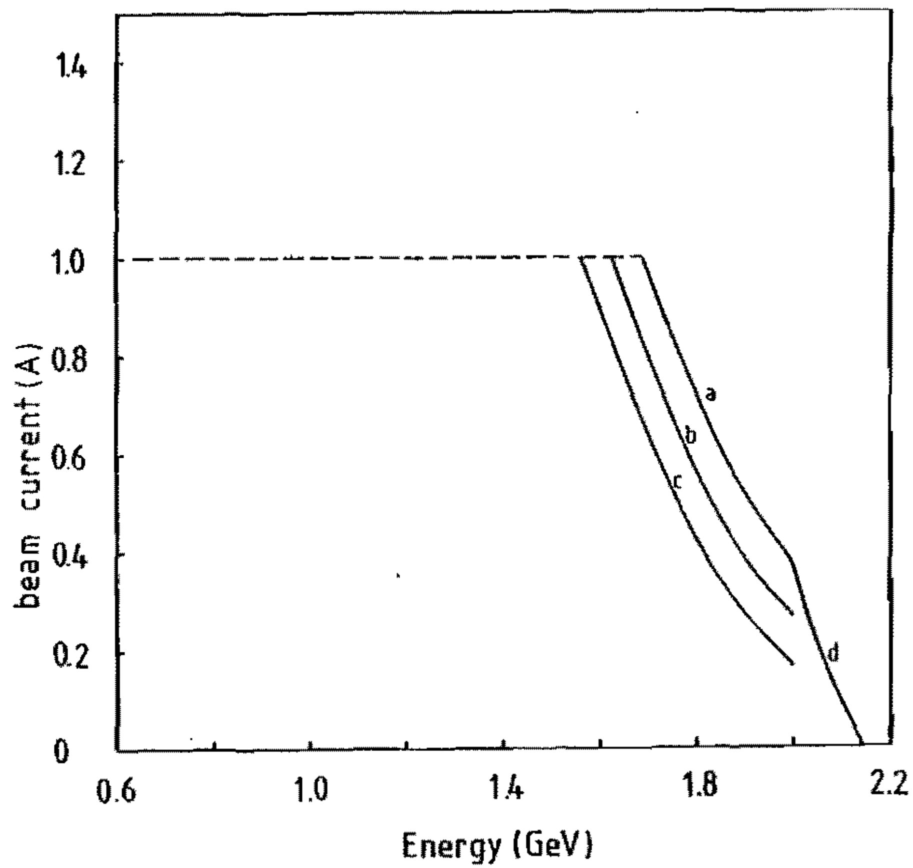
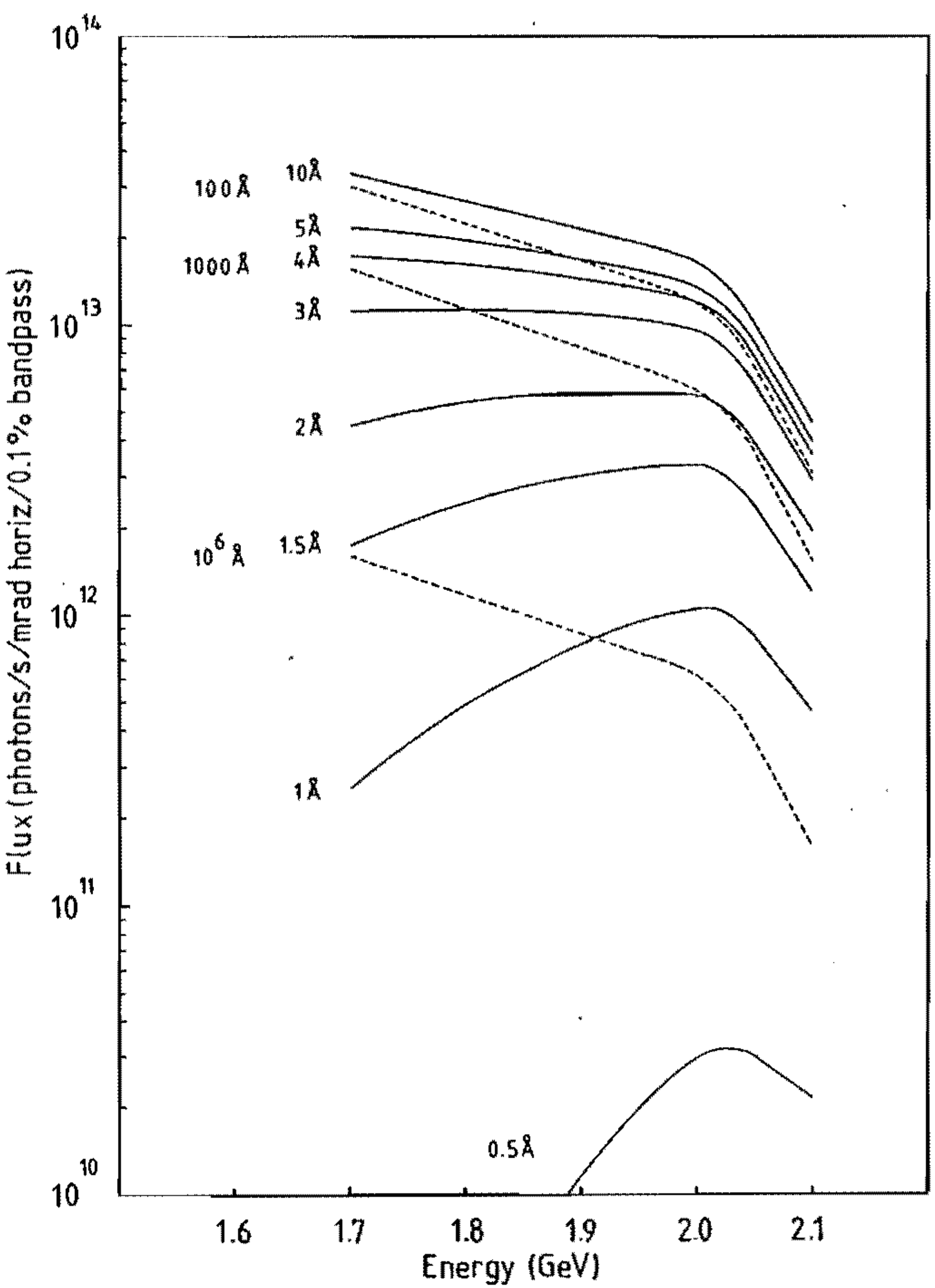
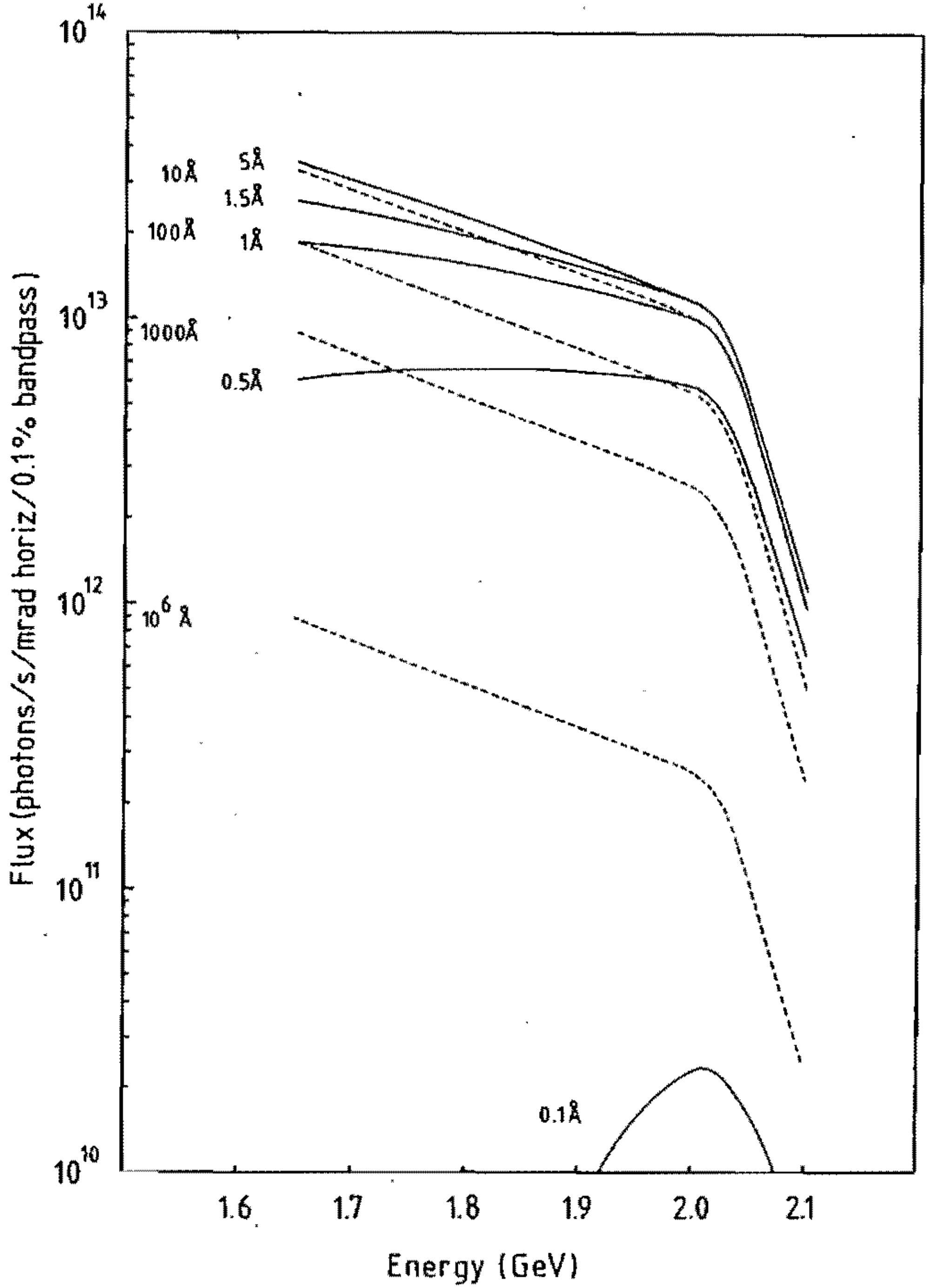


Fig. 1



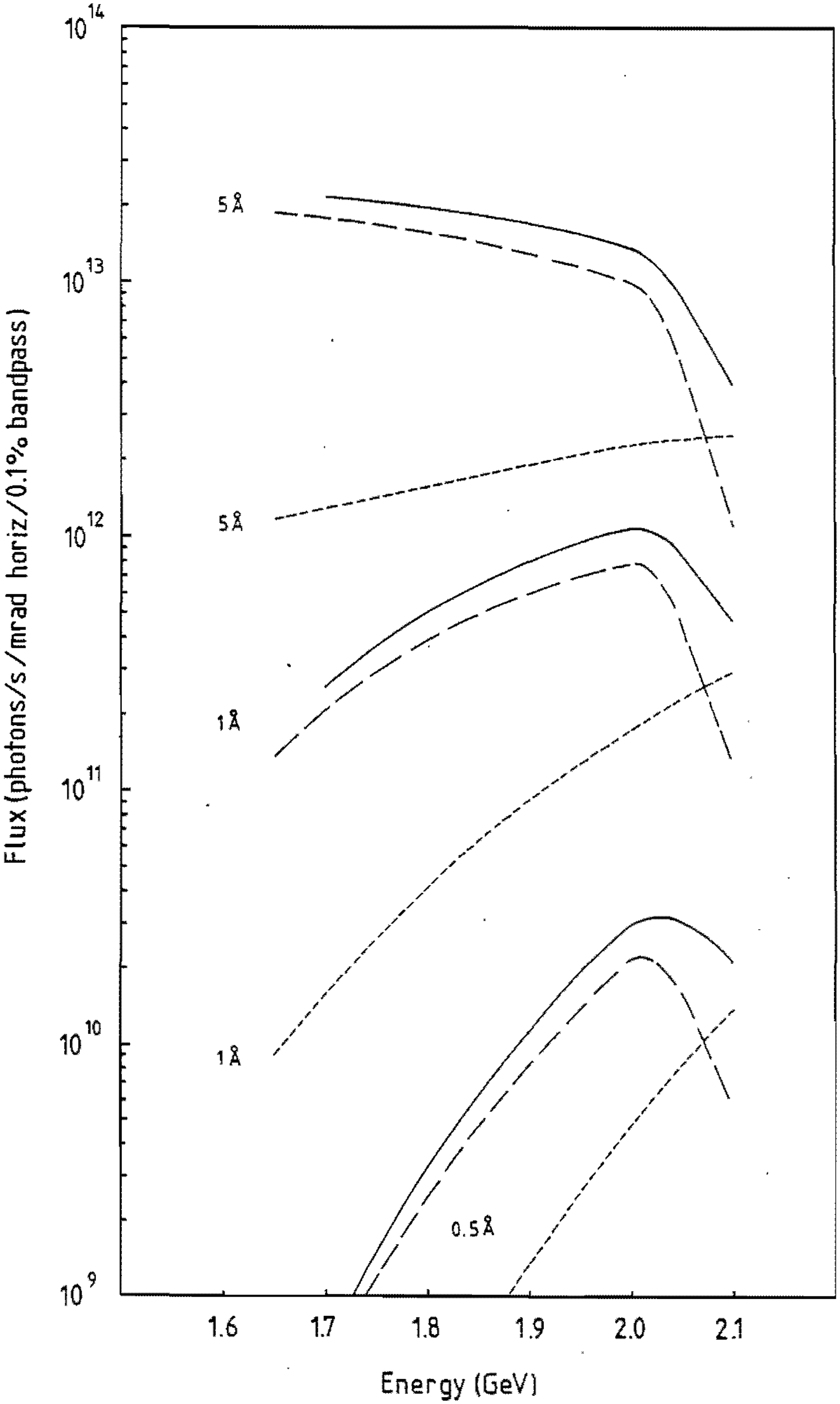
Flux (photons/s/mrad horiz/0.1% bandpass)
10^14
10^13
10^12
10^11
10^10
100 Å
1000 Å
10^6 Å
10Å
5Å
4Å
3Å
2Å
1.5Å
1Å
0.5Å
1.6
1.7
1.8
1.9
2.0
2.1
Energy (GeV)

Fig. 2



Flux (photons/s/mrad horiz/0.1% bandpass)
10^14
10^13
10^12
10^11
10^10
10Å
100Å
1000Å
10^6 Å
5Å
1.5Å
1Å
0.5Å
0.1Å
1.6
1.7
1.8
1.9
2.0
2.1
Energy (GeV)

Fig. 3



10^{14}
10^{13}
10^{12}
10^{11}
10^{10}
10^{9}
Flux (photons/s /mrad horiz/0.1% bandpass)
5 Å
5 Å
1 Å
1 Å
0.5 Å
1.6
1.7
1.8
1.9
2.0
2.1
Energy (GeV)

Fig. 4

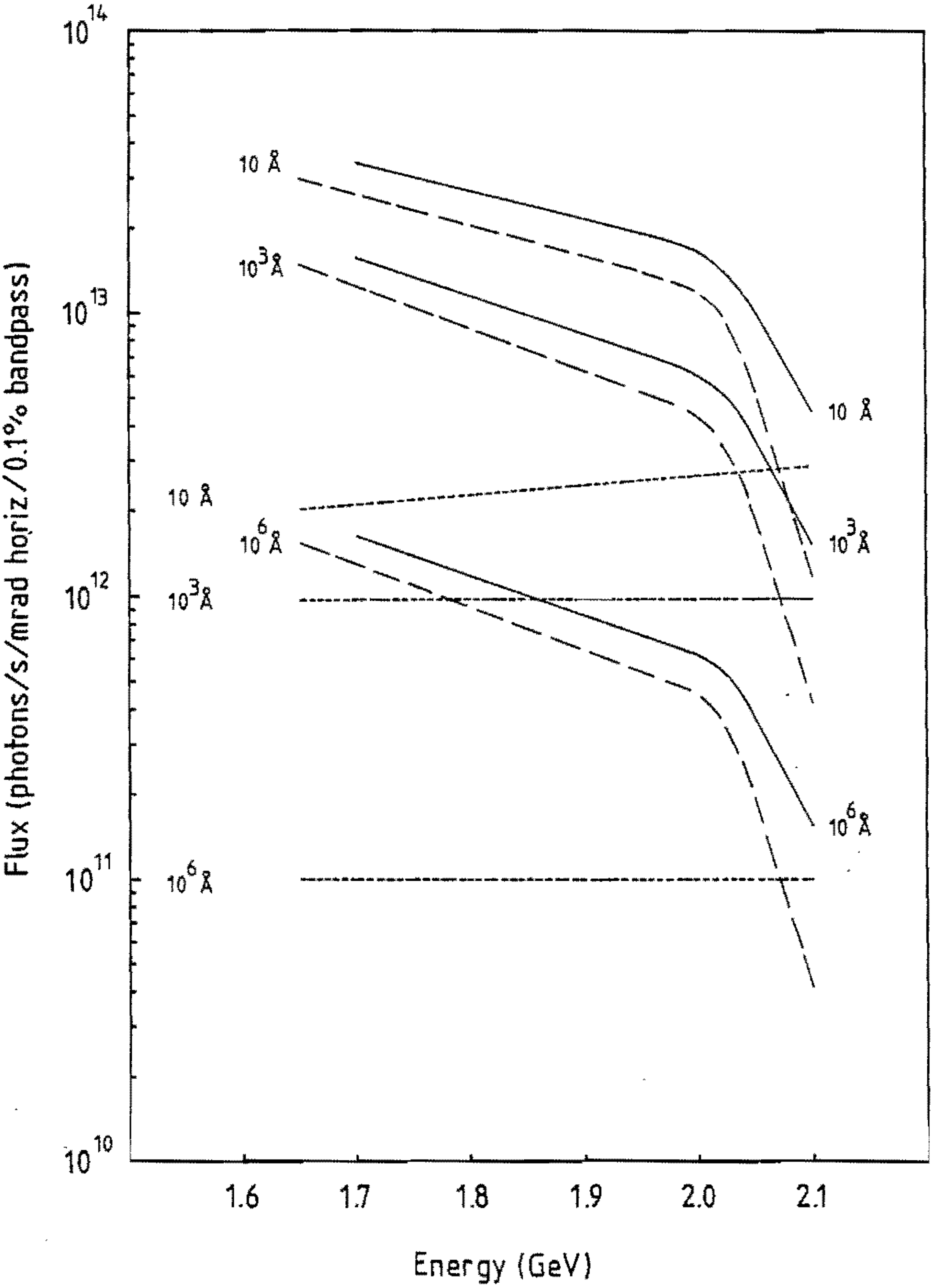
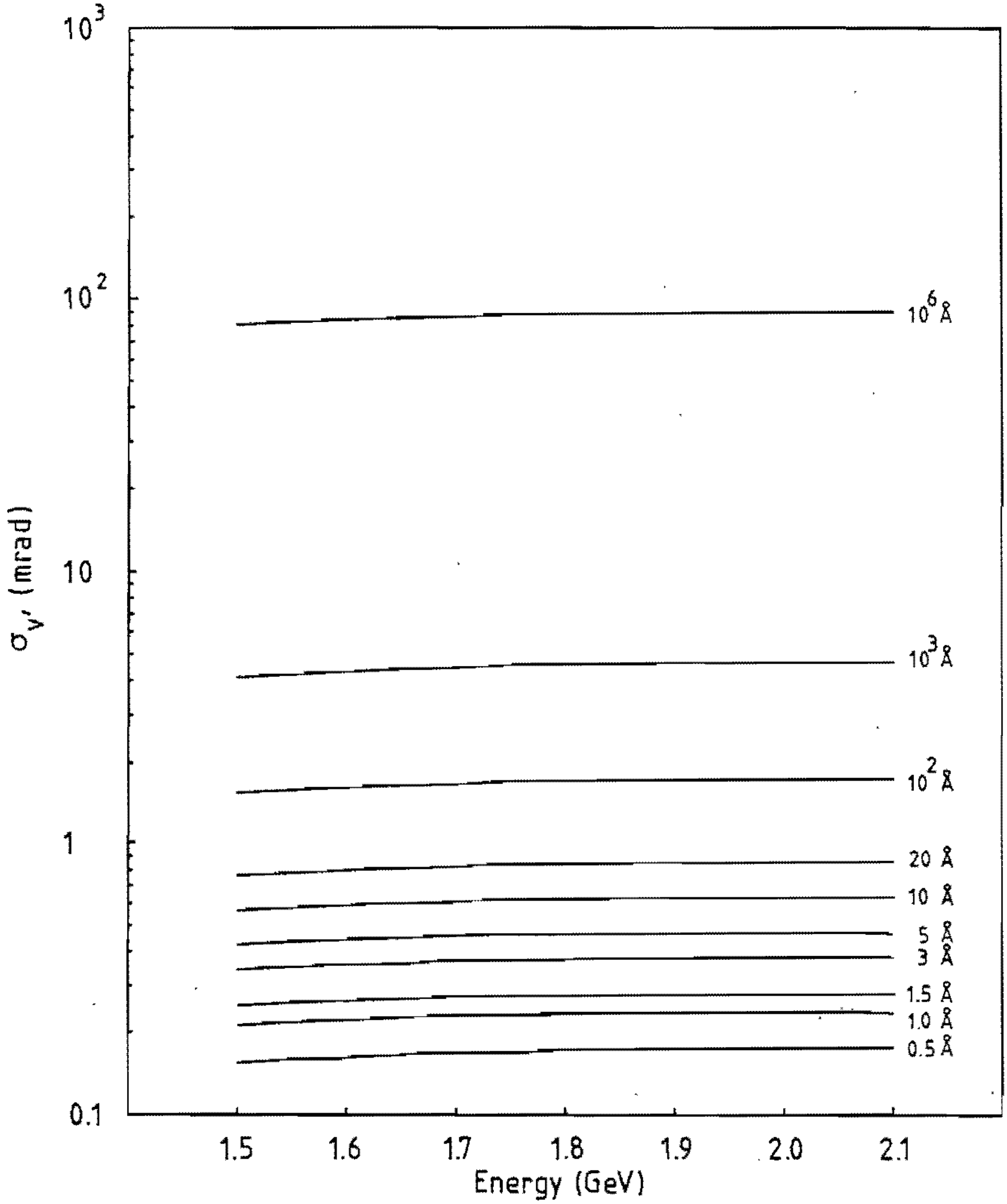

Flux (photons/s/mrad horiz/0.1% bandpass)
10^14
10^13
10^12
10^11
10^10
10 Å
10^3 Å
10 Å
10^6 Å
10^3 Å
10^6 Å
10 Å
10^3 Å
10^6 Å
1.6
1.7
1.8
1.9
2.0
2.1
Energy (GeV)

Fig.5



10^3
10^2
10
1
0.1
$\sigma_{y'}$ (mrad)
10^6 Å
10^3 Å
10^2 Å
20 Å
10 Å
5 Å
3 Å
1.5 Å
1.0 Å
0.5 Å
1.5
1.6
1.7
1.8
1.9
2.0
2.1
Energy (GeV)

Fig. 6

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