ISR-RF/LT/ps

23rd August 1974

ISR PERFORMANCE REPORT

Run 505, R2, 26 GeV/c, 0.835A, 9 hours

26.7.74

Cooling Test

The ratio of closed loop vertical Schottky signal to open loop vertical signal is plotted against frequency in Graph 1. Cooling is obtained for almost all frequencies except in small intervals between 0.6 and 0.7 GHz.

The overall gain between pick-up and kicker has been increased from ∿90 dB to ∿95 dB, as can be seen from annex 1. Special phase correcting filters are inserted in the network to correct phase distortions at the low frequency roll off of the power amplifier. Compare the curve measured on 22nd June 1974 with the curve measured during run 505.

The estimated cooling rate for our system with its band from 0.75 to 1.5 GHz is obtained as the difference between the cooling rates of two systems, one system working between zero frequency and 1.5 GHz and another system working between 0 and 0.75 GHz. The details of this estimation are given in annex 1. This indicates a cooling rate of about 3-4% per hour. For most of this estimation the standard method of S. Van der Meer has been applied (ISR-PO/72-31).

Vertical increase in effective beam height calculated by K. Hübner is given in annex 2. It is about 0.5% per hour.

The vertical beam blow-up due to white noise of the amplifier chain is calculated to be 0.81% per hour in annex 3.

Conclusions

The net cooling rate should therefore be ∿2.2% per hour. A change of 20% in vertical height should be visible with the vertical Vosicki monitor. Vosicki scans at the beginning and at the end of the run are, however, identical. Vosicki believes that the monitor might not see changes in beam heights when h_{eff} <2.8 mm, due to lack of resolution. This was unfortunately not known to us before the experiment. The low h_{eff} was chosen to obtain a low loss rate, the aperture of our pick-up and kicker being only ±5 mm. Out of 0.835 mA stacked only 70 μA were lost during the 9 hours.

Longitudinal beam density variations are not perfectly suppressed in the pick-up, due to asymmetries in the chamber. These signals may cause a blow-up of the beam (S. Van der Meer). The signals appear as revolution harmonics but do not overlap on the frequency axis with the vertical Schottky signals. An especially narrow beam in momentum was chosen to avoid this overlapping.

To increase the effect of the damping compared with that of the white noise and the intra-beam scattering, and also to obtain workable conditions for the Vosicki monitor, it seems reasonable to experiment with beams having effective heights of about 4 mm.

P. Bramham

W. Schnell

L. Thorndahl

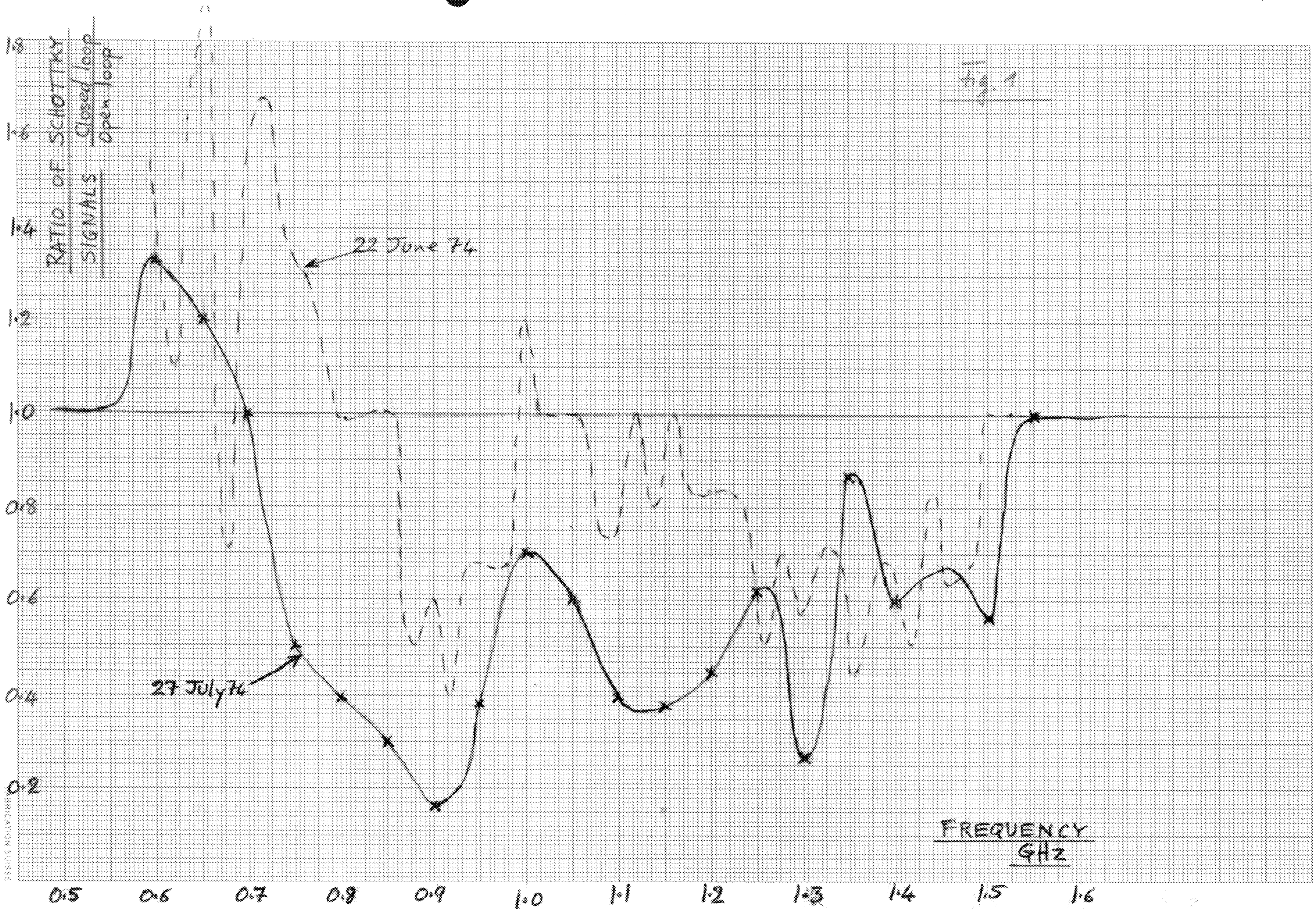


Fig. 1
RATIO OF SCHOTTKY SIGNALS
Closed loop / Open loop
22 June 74
27 July 74
FREQUENCY GHz
1·8
1·6
1·4
1·2
1·0
0·8
0·6
0·4
0·2
0·5
0·6
0·7
0·8
0·9
1·0
1·1
1·2
1·3
1·4
1·5
1·6

ANNEX 1

Estimate of cooling time 26.5 GeV/c

Band 0.75-1.5 GHz

Upper freq. sample length $\tau = \frac{1}{2\pi 1.5\cdot 10^9} = 106$ ps 3.18 cm

Lower freq. sample length $= \frac{1}{2\pi 1.5\cdot 10^9} = 212$ ps 6.36 cm

current 0.835 A . $0.167\cdot 10^{14}$ protons

protons in upper sample $0.531\cdot 10^9$

protons in lower sample $1.062\cdot 10^9$

Average momentum spread 0.2% , 4 mm average over run half height

difference in revolution time

slip in length between extreme momenta $2\pi 4$ mm = 25 mm

Upper freq. mixing factor = 2.5/3.18 = 0.79

Lower freq. mixing factor = 2.5/6.36 = 0.39

Relative increase in damping time
for upper frequency mixing factor 2.2 Van der Meer ISR-PO/72-31 Fig. 2

Relative increase in damping time
for lower frequency mixing factor 3.7 "

Upper frequency damping rate for
ideal phase and gain per turn $\frac{1}{2\times 2.2\times 0.531}\ 10^{-9} = 0.428\cdot 10^{-9}$

Lower frequency damping rate for
ideal phase and gain per turn $\frac{1}{2\times 3.7\cdot 1.062\cdot 10^9} = 0.127\cdot 10^{-9}$

Net damping rate per turn

$$(0.428-0.127)\cdot 10^{-9} = 0.301\cdot 10^{-9}$$

Our system acts only on detected position and not angle, therefore damping rate is reduced by factor 2

$0.15\cdot 10^{-9}$ per turn

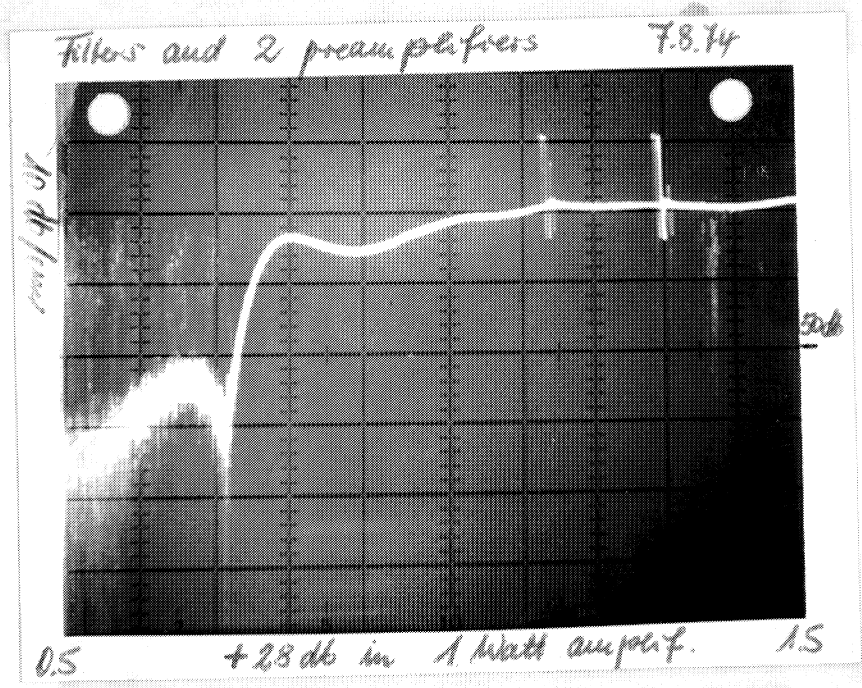
15% per hour with ideal gain and phase

The ideal gain for 0.835A and our electrode configuration is estimated to be 100 db. (W. Schnell, ISR-RF/72-46). Our gain, however, is 95 dB (max. gain available with our present amplifiers).

ANNEX 1 (continued)

Furthermore, the phase response, as can be seen from Fig. 1, is not perfect and we assume therefore the damping rate reduced by a factor 2 due to the gain being too low and by another factor 2 due to the phase errors. We therefore estimate a damping rate of

<u>3-4% per hour</u>



ANNEX 2

```
***************************************************************
*                                                             *
*  INTRABEAM SCATTERING ACC. TO PIWINSKI (STANFORD 74)        *
*                                                             *
*  FOR 1A UNBUNCHED IN UNITS OF M,S,A    CUTOFF B=2*SZ        *
***************************************************************
```

SXB	H	SN	GAM	A	X^2./TAUE	X^2./TAUXP
.200E-02	.277E-02	.109E-02	28.36	.2354E-07	.1809E-04	.8796E-05
.260E-02	.277E-02	.109E-02	28.36	.1393E-07	.1355E-04	.3811E-05
.340E-02	.277E-02	.109E-02	28.36	.8147E-08	.9968E-05	.1612E-05

ERROR SUMMARY
ERROR TIMES

Intrabeam scattering in the beam used for cooling.

$\gamma = 28,36$

$h = 2,77$ mm

$d = 7,5$ mm $\qquad \sigma_\eta = \frac{d}{2\sqrt{F}} \frac{1}{\alpha_p} = 1,09.10^{-3}$

$I = 0,835$ A

We assume three values for →

$\sigma_{x\beta}$ [mm]	2,0	2,6	3,4
E_x [rad m.10^{-6}]	0,23	0,39	0,66
$\frac{1}{\tau_z} = \frac{1}{h}\frac{dh}{dt}$ [sec^{-1}]	$0,125.10^{-5}$	$0,141.10^{-5}$	$0,129.10^{-5}$
$\frac{1}{\tau_z} = \frac{1}{h}\frac{dh}{dt}$ [h^{-1}]	$0,46.10^{-2}$	$0,51.10^{-2}$	$0,46.10^{-2}$

ANNEX 3

Beam blow-up due to white noise from amplifiers

Noise figure is 6 dB → ×4 in power

1 GHz noise power at input

$= 4 \cdot 4 \cdot 10^{-21} \cdot 10^{9}$ Watts

$= 16 \cdot 10^{-12}$ Watts

Gain of amplifier chain 95 dB

$\sim 4 \cdot 10^{9}$

Output noise power is therefore

$64 \cdot 10^{-3}$ Watts

2.53 V rms on 100Ω

13 Volts give a displacement of 2.3×10^{-8} metres (ISR-RF/72-46)

Electrode length 3 cm, spacing 1 cm, $\beta_V = 15$ m

ε = rms kick p. turn $= 2.53/13 \cdot 2.3 \cdot 10^{-8} = 0.45 \cdot 10^{-8}$ m

9 hours → $0.9 \cdot 10^{10}$ turns

$$\Delta \langle z^2 \rangle_{amplitude} = 0.2\ 10^{-16}\ 0.9\ 10^{10}$$
$$= 0.18 \cdot 10^{-6}$$

The initial $\sqrt{\langle z^2 \rangle} = \frac{2.77}{2\sqrt{\pi}} = 0.78$ mm

$$\sqrt{\langle z^2 \rangle}_{amplitude} = 0.78 \cdot \sqrt{2} = 1.10 \text{ mm}$$

$$\sqrt{(1.21 + 0.18) 10^{-6} \text{m}} = 1.18 \text{ mm}$$

7.3% increase in rms z value over 9 hours

0.81% per hour