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Tune Measurements of the AGS

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Reported by J.P. Potier and W. van Asselt

Subject Tune measurements on the AGS

Observations and Conclusion

During May, tune measurements have been done with the aim to determine the chromaticity and the working points of the AGS along the acceleration cycle. The measurements have been done with and without activated chromaticity sextupoles.

The tune meter

The tunes are measured by inducing coherent oscillations with a fast kicker (~ 2.5 μsec kick length) and sending the low frequency part $(Q-8) \times f_{rev}$ of a difference P.U. signal to a counter.

The experiment with the tune meter show that the Q-values can be determined very reproducibly. The accuracy, however, strongly depends on the chromaticity (or more exactly on $\xi \times \Delta p/p$). This is because with increasing ξ the coherence time of the filtered difference signal decreases fast. An example is given in Fig. 1. The horizontal response is seen to decay in approx. 30 μsec ($\xi_H \approx -2$), which does not allow for an accurate frequency determination. Additionally the measured value for the frequency depends on the position of the gate for the counter relative to the kick time (we used: gate start ~ 20 μsec after kick and a length of 10 μsec). The vertical response time in fig. 1 is a few hundred μsec ($\xi_v < -.5$), allowing an accurate frequency determination, independent of the position and the length of the gate.

Fig. 2 shows some pictures illustrating the coupling of the two transverse motions. At the top (3 GeV/c) there is a strong beating between the two motions, which obstructs an accurate frequency determination. The other two pictures show coupling at 21 GeV/c and the influence of the high field skew quad string. Although frequency determination is well possible in these cases the measured tune values will depend on the coupling strength [E. Raka, IEEE NS-22(3) (1975)1938].

At high field and high intensity frequency determination can be difficult because spontaneous coherent signals are present and one has to use enough kicker strength to obtain a good signal to noise ratio of coherent/spontaneous signal. Typically we use kicks of 1 to 2 mm.

The measurements

We have done measurements on the AGS at normal operating intensity (~ 10^{13} ppp) and at a reduced intensity of ~ 3×10^{12} ppp. The trigger for all the equipment was derived from the Gauss clock; the range was 6000-54000 counts, from which the momentum range roughly is 3-27 GeV/c. The mean radius $\bar{R}$ has been obtained from "Equilibrium Orbit Acquisition". To work out the central tune and chromaticity a fit of a straight line to the experimental points was done using a linear regression program.

Fig. 3 shows the central tune and the chromaticity of the bare machine for both the transverse planes (Ip = 3 x 10^{12}). In fig. 4 the results of the measurement are plotted in the working diagram of the AGS. The range on $\bar{R}$ was roughly (-10mm, +5mm) at every point. It is seen that the central trajectory crosses the $3Q_x = 26 = 2Q_x + Q_y$ resonances and at low energies probably the $Q_H = Q_V$ resonance.

Figures 5 and 6 give the results with the chromaticity sextupoles on at normal operation settings (Ip = 3 x 10^{12}). The change in the chromaticity from 18 to 21 GeV/c roughly corresponds to the risetime of the power supplies. Note that the central tune values are also influenced through the sextupoles causing the working points to cross or to be very close to the coupling resonance.

Measurements with condition as in fig. 5 were also done at high intensity level (10^{13} ppp). Fig. 7 shows the results. Only minor differences with respect to the low intensity measurements were observed. In particular the coupling of the two transverse motions between 20 and 25 GeV/c was the same in the two cases.

<u>Quantitative influence of quads and sextupoles</u>

<u>Quads:</u>

In the following the influence of the high field quad will be compared with calculated values according to a transfer matrix taken from: Memo of Ahrens and Raka 2/19/85:

$$\begin{pmatrix} \Delta Q_x \\ \Delta Q_y \end{pmatrix} = \frac{\text{Pinj}}{p} \begin{pmatrix} .0436 & .0218 \\ -.0218 & -.0436 \end{pmatrix} \begin{pmatrix} I_x \\ I_y \end{pmatrix}$$ with p in GeV/c and I in Amps

I_x	I_y	ΔQ_x measured	ΔQ_x calc.	ΔQ_y measured	ΔQ_y calc.
45A	0	0.057	0.06	-0.024	-0.03
0	-50A	-0.024	-0.033	0.062	0.067

The measured values are systematically lower but in general the results seem to be consistent.

Sextupoles

The influence of the chromaticity sextupoles at 21 GeV/c are:

	Q_x	Q_v	ξ_x	ξ_v
Sext. OFF	8.698	8.752	-2.47	-0.05
Sext. ON	8.728	8.736	-1.10	-0.75

Besides the influence on the chromaticity the sextupoles clearly have an effect on the central tunes too, which cannot be explained by systematic distortion of the EO at the sextupole locations.

If we assume that there is a systematic difference between the central positions of the PUE and the sextupoles we find a value of -4mm, using the different sets of data available. This point is being checked (E. Bleser, private comm.).

Summary

- The tune meter, although manually controlled, is a powerful tool for AGS machine studies.

- There is evidence for coupling, which is especially strong at low energies (3 GeV), where it might cause troubles in comparing IPM and target measurements.

- The current settings for the chromaticity sextupoles drive the operating point towards the $Q_x = Q_y$ resonances between 20 and 25 GeV/c.

- The settings for the skew quads, high field quads and the chromaticity sextupoles vary from day to day, which might lead to an undesired drift from the wanted operating point.

- With the current operating conditions the dynamic aperture is quite small.

What to do with the working line

- Restore and improve decoupling, it will improve beam behavior and will allow more easy interpretation of Target/IPM comparison experiments.

- Prepare ramping of chromaticity sextupoles and high field quadrupole.

- The new working line should be tied up in a quiet area by controlling central tune and chromaticity. Care has to be taken about chromaticity driven instabilities.

- Once this is settled one can start studies on transverse emittances behavior along the cycle.

This will use a lot of studies time, but once the compatibility with slow extraction has been checked, most of the tests can be done in parallel with normal physics runs.

A few remarks on methods by Jean-Pierre.

During our machine studies, done in parallel with physics users, we have recorded that parameters were varying from day to day. This is at least the case for decoupling skew quadrupoles, chromaticity sextupoles, tune quadrupoles. This was done to improve temporarily the situation, but not always in a well understandable nor reproducible way.

In the near future, the AGS will have to cope with HITL, RHIC, Booster. To be more specific, it will become an injector, which is a fundamental difference with the present situation:

- As an injector one will have to provide a well known, predefined beam, in terms of its six dimensions area, as well as intensity.
- As a high intensity synchrotron, i.e., with the booster, it will not be possible to live with a few percent lower and with instabilities or beam blowup.

To prepare for this situation, people are investing a lot of time in machine studies for cleaning up and improving the understanding of the AGS. This can be accomplished only if we start to freeze systematically machine parameters in a well understood way and avoid to play with it without good physical reasons.

As the AGS is a production machine for physics experiments, sometimes it will not be possible to fix immediately problems and some fiddling with some parameters will be necessary. But as soon as possible one has to recover and to try to understand what was going on. As an end product a new procedure has to be provided to the operation crew and ultimately parameters will be frozen again. This will cost time but it is a necessary investment which will play in the future.

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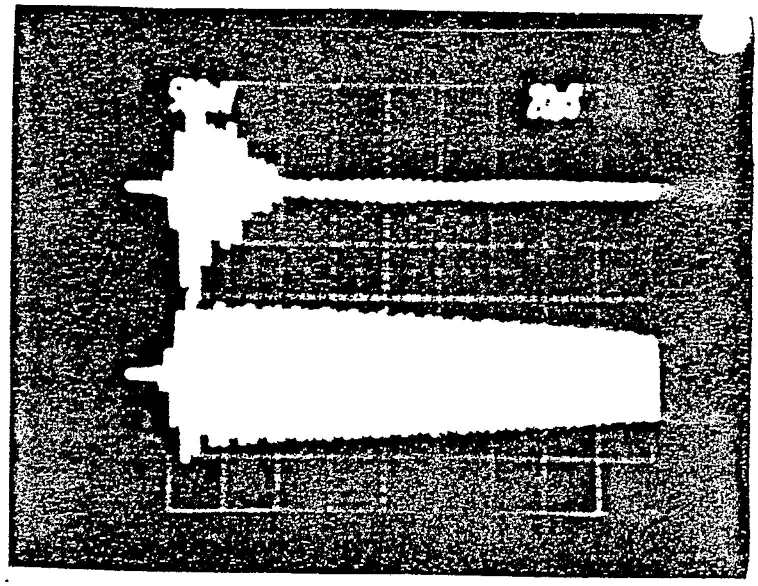
$I_0 = 10^{13}$ P

TUNE METER OUTPUT



ΔH

ΔV

Same kick

18 GeV/c 360 ms/inj

COHERENCE

Figure 1

TUNE-METER OUTPUT

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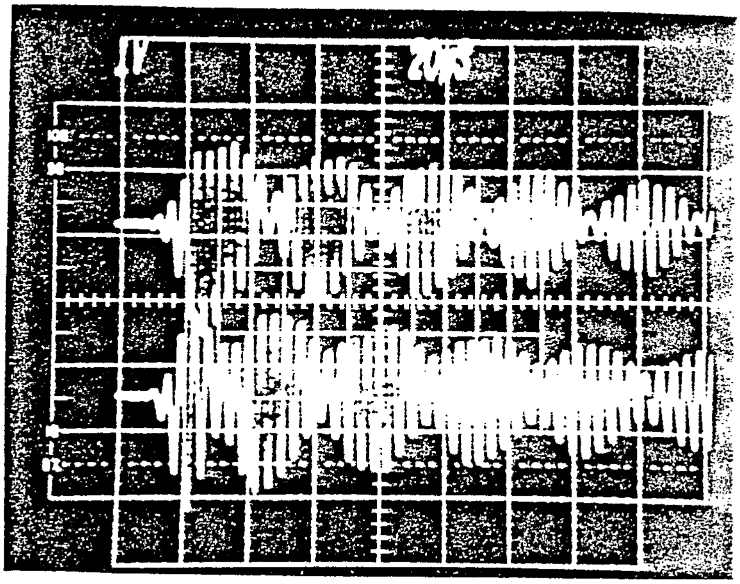
I_B = 3 10^{12} ?

ΔV

ΔH kick = H

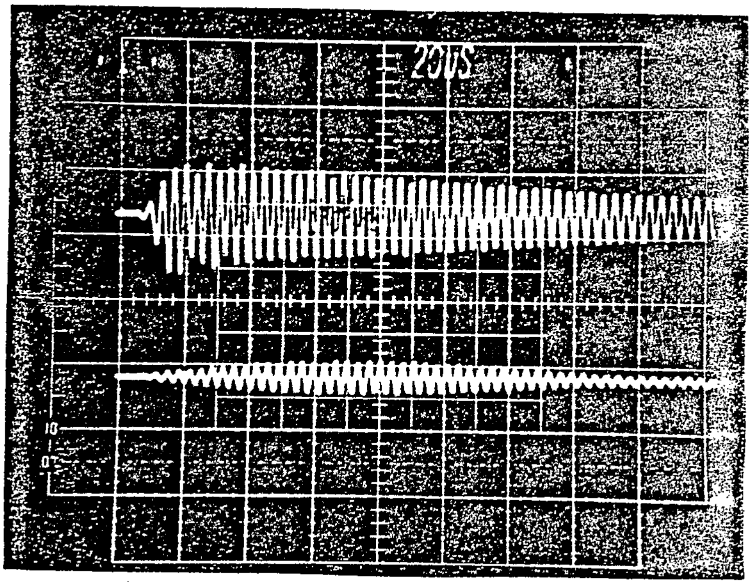
~3 GeV/c 100 ms/inj



ΔV kick = V

ΔH

~21 GeV/c 430 ms/inj

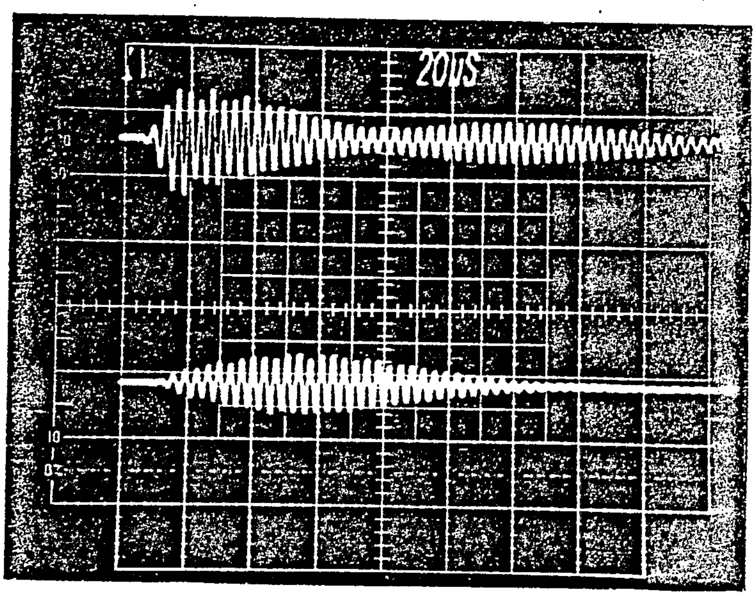


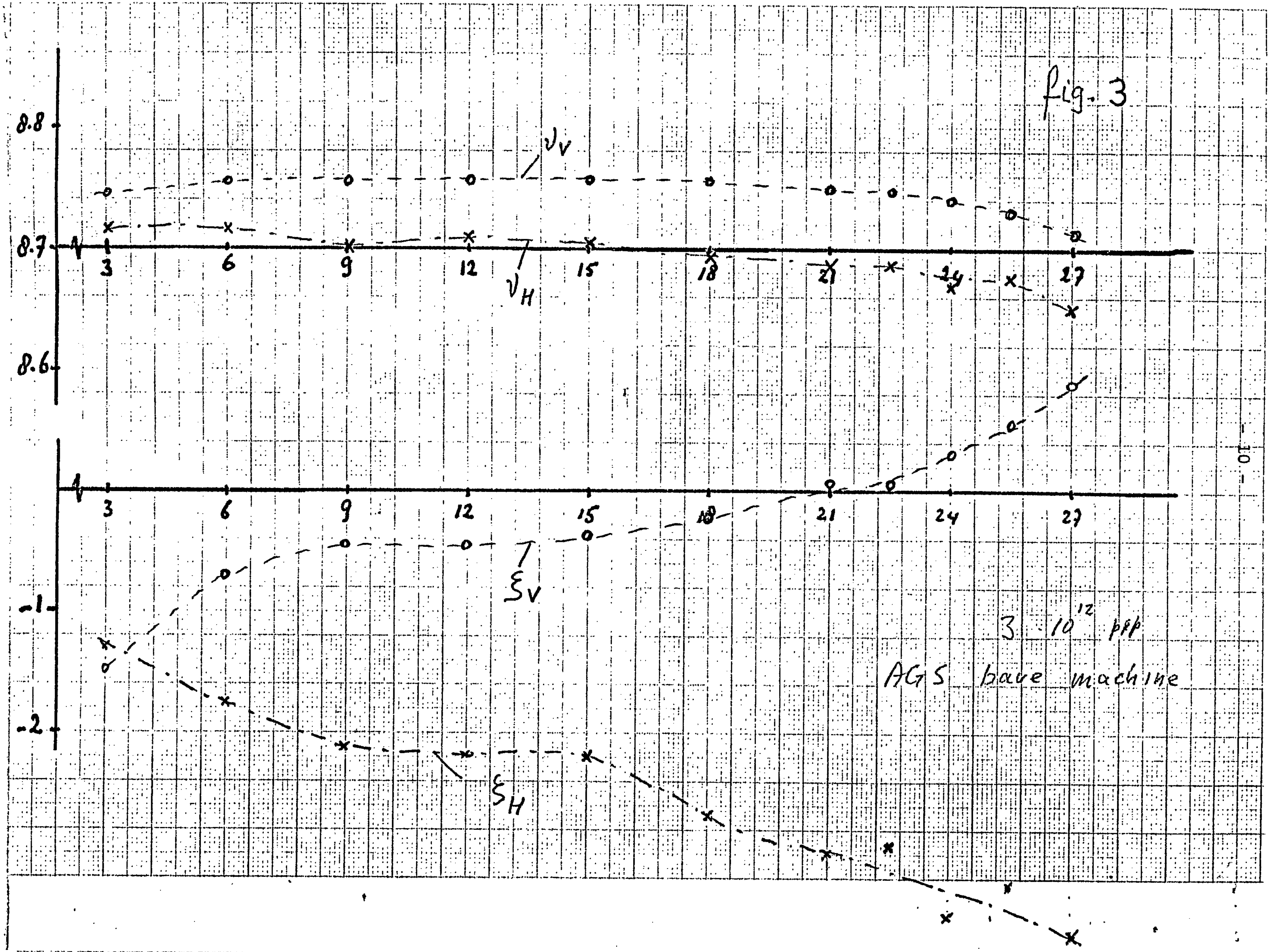
ΔV kick = V

ΔH

~21 GeV/c 430 ms/inj

High field Skew Quad OFF

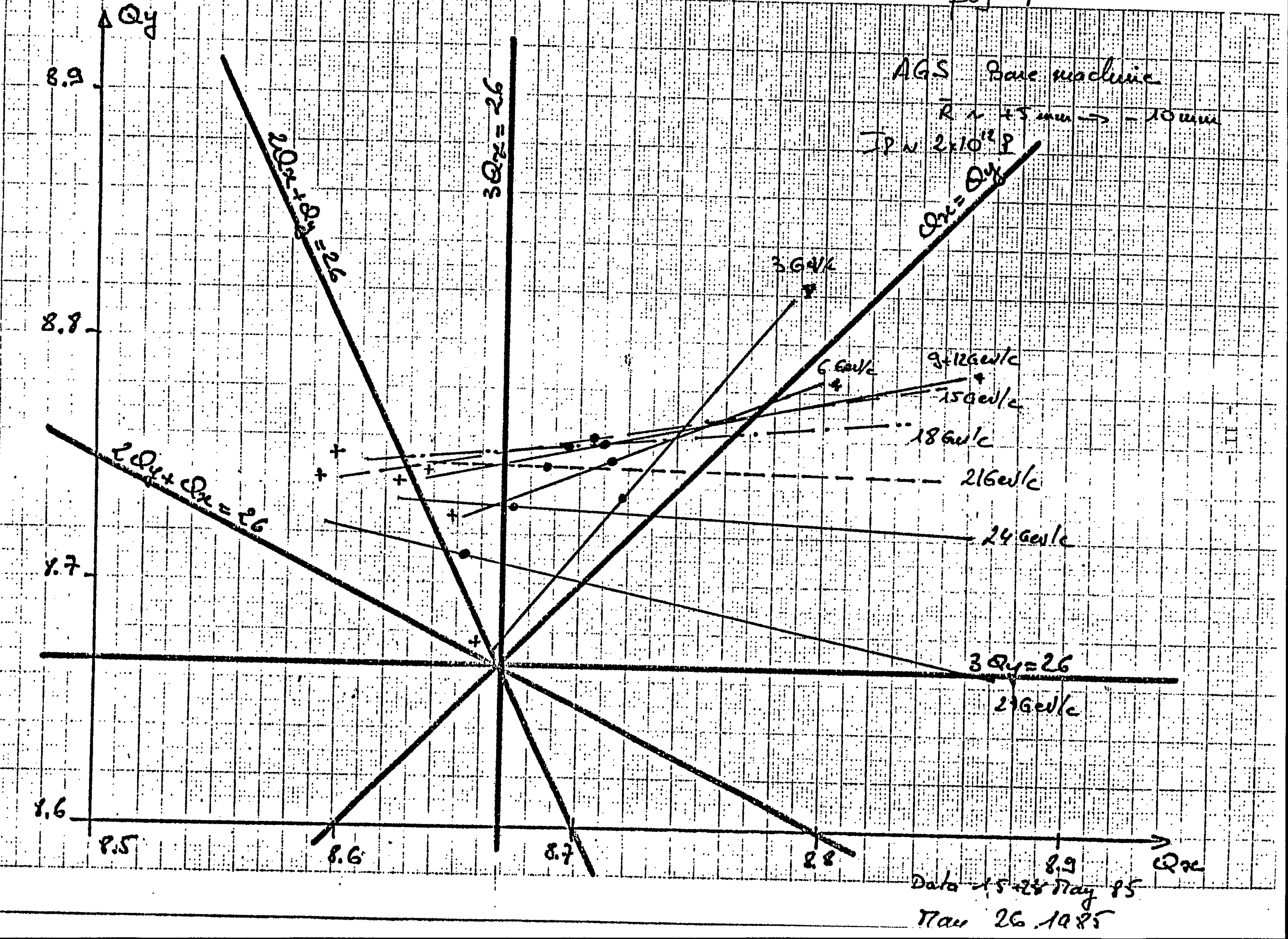




8.8
8.7
8.6
ν_V
ν_H
3
6
9
12
15
18
21
24
27
ξ_V
ξ_H
-1
-2
$3 \cdot 10^{12}$ ppp
AGS bare machine

fig. 3

fig. 4


Qy
8.9
8.8
8.7
8.6
8.5
8.6
8.7
8.8
8.9
Qx
3Qx = 26
2Qx+Qy=26
Qx=Qy
2Qy+Qx=26
3Qy=26
AGS Bare machine
3 GeV/c
6 GeV/c
9+12 GeV/c
15 GeV/c
18 GeV/c
21 GeV/c
24 GeV/c
27 GeV/c
Data 15+28 May 85
May 26. 1985

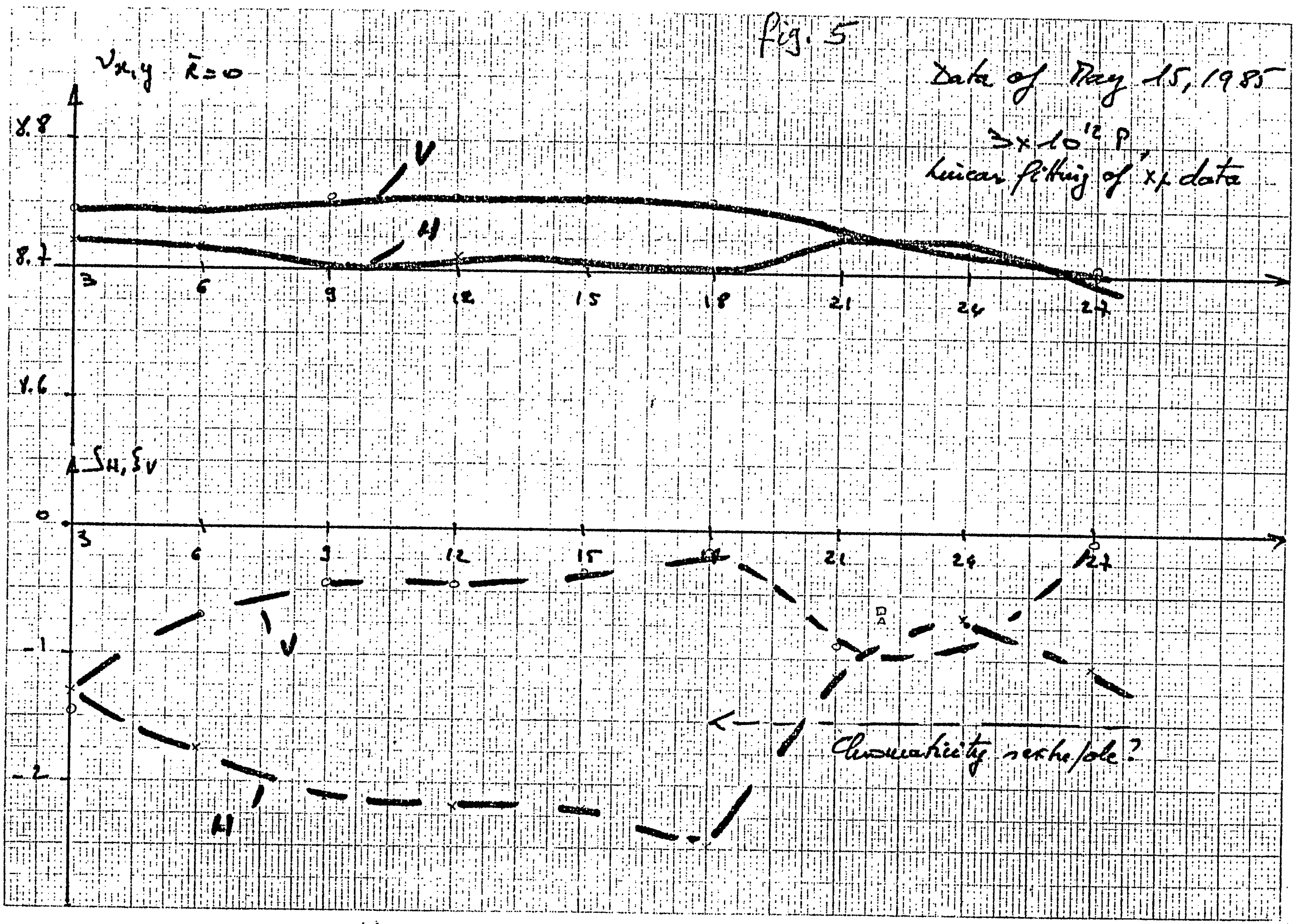
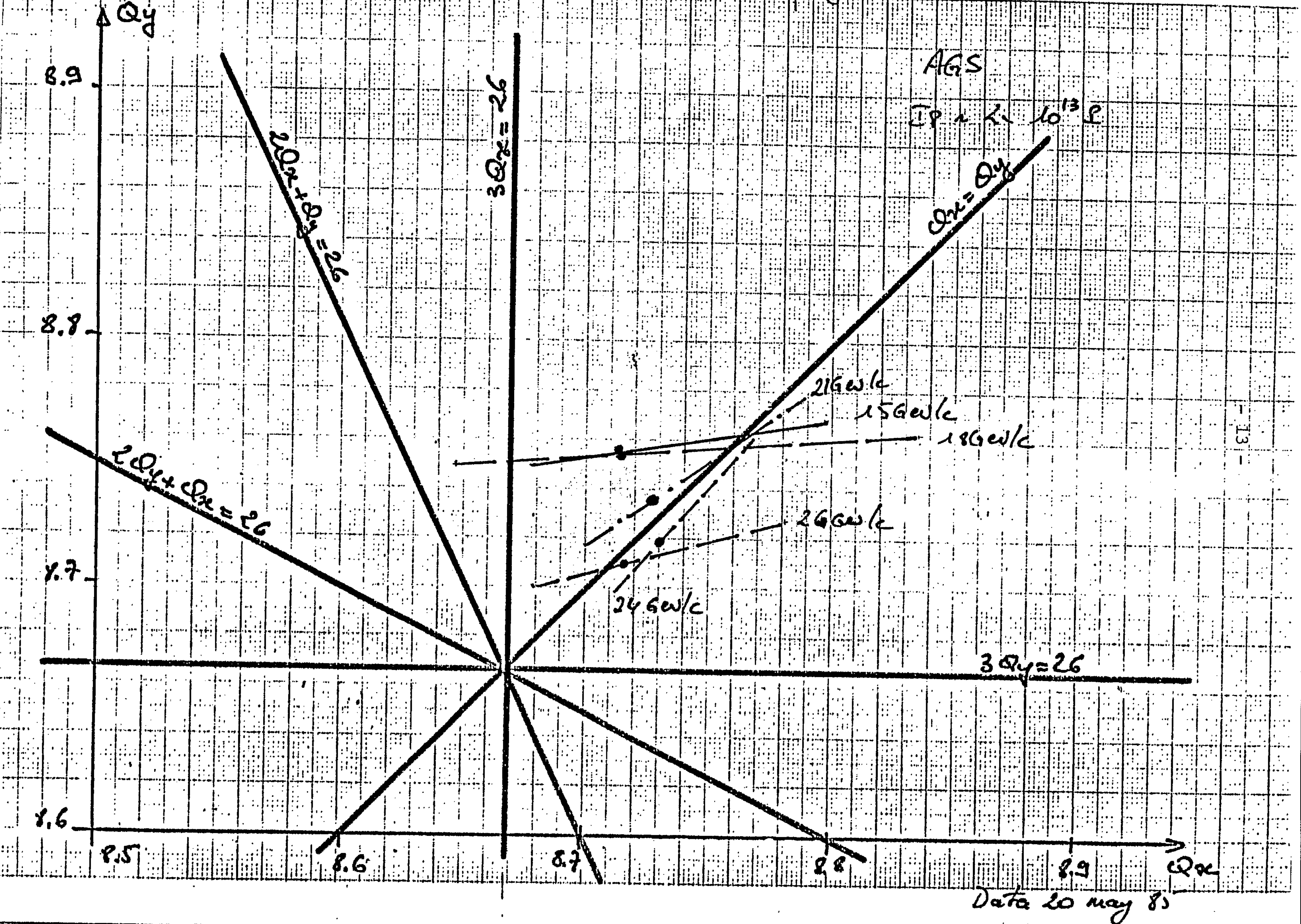


fig. 5
$\nu_{x,y}$ $\xi = 0$
Data of May 15, 1985
3×10^{12} p,
Linear fitting of x,y data
8.8
8.7
8.6
V
H
3
6
9
12
15
18
21
24
27
ξ_H, ξ_V
0
-1
-2
Chromaticity sextupole?

Fig. 6


Qy
8.9
8.8
8.7
8.6
8.5
8.6
8.7
8.8
8.9
Qx
3Qx = 26
2Qx + Qy = 26
2Qy + Qx = 26
3Qy = 26
Qx = Qy
AGS
21GeV/c
15GeV/c
18GeV/c
26GeV/c
24GeV/c
Data 20 may 85

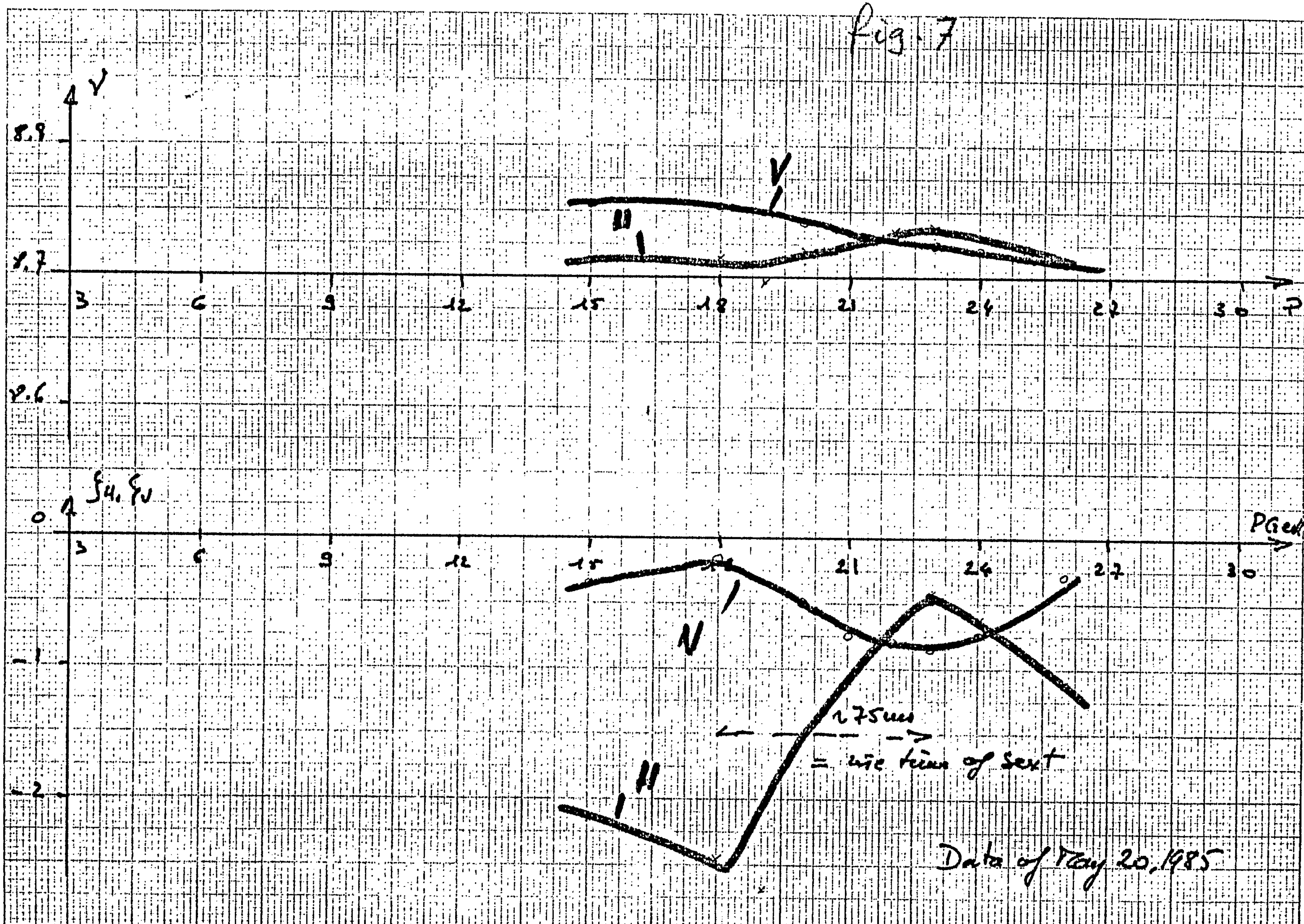


fig. 7
ν
8.8
8.7
8.6
3
6
9
12
15
18
21
24
27
30
PG
V
II
I
ξ_u, ξ_v
0.
-1
-2
PG cm/c
N
I
II
175 ns
= rise time of sext
Data of May 20, 1985