I.Effects of the beam size at the target for the e+ production.

II.Trying to measure the beam energy spread with more accuracy with the LILV spectrometer.

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1. Abstract

Most of the experiments reported were performed in the machine developement of 15 – 11 – 88. The investigation about the effect of the e – beam size at target on the positron production was suggested by K. Huebner. We measured the positron production at end of LIL – W (HIPUMA22 in EPA transfer line).

Analysing our results,we are able to answer the following questions :

How much does the positron production depend on the geometry of the electron beam onto the target (angle, position of the center, dimension of the spot).

Are these quantities critical (any change would decrease the production of the positrons) or is some variation allowed (maintaining the production at its maximum level).

Is the maximum of e+ production defined by the geometry of the electron spot compared to the target geometry, or compared to the back – projection onto the target plane of the following LIL – W machine ′ acceptance ′. This would be the case if this ′ acceptance ′ contour would be smaller than the target.

In the second part,we compare the spectra obtained on the SEM – Grid SMH15 with spectrometer BSP15.

In the first experiment,we use the triplets with the currents necessary for transporting the beam to the target.

Then, we set the currents in the triplets such that the beam is focalised onto the SEM – Grid.

In parallel, we calculate the energy spread due to the beam loading.

The analysis is made for low current,for which it is suspected that the size of the beam profile as measured on MSH15, contains the energy spread,but also a non negligible part due to the emittance.

2. Effect of beam size at the target on the production of positrons.

2.1 Settings :

Mean energy : 215 MeV, δ E= (4 sigma) =8.5 MeV, Gun: 1.5 KV on cathode.

Charge per pulse : $-165\ 10^8$ e− at UMA 15.

Pre−buncher : attenuation 40, phase 60.

Klystron 13 modulator phase : 11°

The beam position and beam size are measured on WBS25, i.e. at less than 20 cm in front of the target.The beam divergence is small compared to this distance and the beam profiles measured on WBS 25 are also valid at the target.

2.2 Fig 1 shows the results of our observations :

We refer to quadrupole QLB1514 as the 2 quadrupoles in series with one at each end of the quadruplet, and to quadrupole QLB1523 as the pair in series at the center of the quadruplet.

Varying the currents in the quadruplet has an effect of defocalisation of the beam on the target.

This is because the initial values of the currents in the quadrupoles were ′ the best experimental settings ′ previously used for e+ production. We try to find if a small variation from the the ideal beam size and position on the target would change the e+ production in all circumstances, and if not, what would be the limits.

2.3 Summary of our measurements.

Variation of QLB 1514 or QLB 1523 has little influence on the horizontal beam size ($4\ \sigma_H$ = 1.5 mm) and on the position of the vertical beam center (δ_H = 1.3 mm).

Variation of QLB 1514, and more so of QLB 1523 induces important change in the vertical beam size($4\ \sigma_V$ from 1 to 5 mm).

The e+ production recorded at end of LIL−W (HIPUMA22) stays constant (30 mV recorded, i.e.: 1.9 mA), for rather large variations.

2.4 Calculation to verify the hypothesis of a beam displacement.

The horizontal position of the beam center varies from 0 to about 1.3 mm.

The variation of the horizontal position of the beam center with the currents shows that there is a misalignment of the beam at the quadruplet entry and/or a misalignment of the quadruplet. Calculating the transfer matrix of the quadruplet and following drift with program TRANSPORT provides the coefficients for the determination of the beam misalignment at the quadruplet entry, where the beam center may be displaced by dx_0 from the linac axis, and the derivative of this transverse horizontal displacement with the azimuthal position is the angle $d\theta_0$.

For finding dx_0, and $d\theta_0$, we measure dx_1 at the WBS, the displacement of the beam center compared to the geometrical axis, for 2 values of the current in one of the quadrupole family.

Varying the current in family QLB14, with 50.69 A in family QLB23 gives :

$dx_0 = 0.35$ cm ; $d\theta_0 = 0.15$ mrad.

Moreover, we repeat the operation , varying the current in family QLB23 when the current in QLB 14 stays at 53.9 A. In conditions similar as above, we obtain :

$dx_0 = 0.28$ cm ; $d\theta_0 = 0.16$ mrad.

The shift in x is therefore of the order of 0.3 cm. It can be a real shift of the beam at the quadruplet entrance or a displacement of the quadruplet, (but it is much more than the magnet alignement tolerances of about .2 mm), or the result of both errors.

This is obtained with 2 of any set of values which are given on the figure, where δ_H is linear with the current. It is worthwhile to notice the consistency of these results.

We observe that there is a systematic shift in the vertical position of the beam center on the target, constant with the currents in the quadrupoles, and measured as 1.3 mm. We believe that it is due to a systematic shift of the values recorded(perhaps a shift in the vertical position of the WBS). The same systematic vertical shift is reported in [1] and [2].

2.5 *Final interpretation*

When we look at the variation of the beam size with the current,we note that the vertical beam size varies much more than the horizontal one. This may be due to the particular choice of the current which is fixed. We note that the e+ production is stable for the following currents (see Fig.1) :

QLB 23 = 50.7 A , QLB 14 = 53.5 A + − 3.7 A

QLB 14 = 53.9 A , QLB 23 = 52.0 A + − 2.5 A

The radius of the tungsten target is 2.5 mm. The decrease of the e− production when the currents go beyond the preceding limits are the combined results of the horizontal displacement of the beam center, the extent of the H and V beam sizes , and the variation of the V beam size with the currents.

By adding the horizontal beam displacement to the quadratic sum of the horizontal and vertical beam half sizes, $\delta_H + \sqrt{\sigma_H^2 + \sigma_V^2}$, we should obtain for each of the preceding limits a position of the edge of the spot just touching the target circle, of 2.5 mm radius. If that was true, the e+ production would depend mainly on the fact the target circle contains all the primary beam , or not,as, in the first event, the production is unchanged as long as the primary beam is inside the target circle. This is nearly verified for each pair of the 2 currents at the limit of the maximum production range we have found (Fig. 1) . Applying the above formula, we find :

2.7 mm, 2.3 mm (for QLB23 fixed at 50.7 A) and

2.9 mm, 2.2 mm (for QLB14 fixed at 53.9 A).

Our approximations give us about the 2.5 mm radius of the target, as expected.

Horizontal displacements measured on the WBS can be taken as the measure of the real beam center horizontal displacement on the target, in order to interpret the limitations of the e+ production. This indicates that the target and WBS alignment are correct in the H plane.

At the contrary, the vertical displacement is not sensitive to the variation of the strength of none of the pair of quadrupoles of the quadruplet. We interpret this as a vertical shift of the WBS. This shift is of the order of 1.3 mm.

2.6 *Conclusion.*

We conclude that the beam spot must lay all on the target, the spot position and size resulting from the steering and the focusing. But there is apparently no other limitation: the maximum is flat and there is no effect of small beam displacements or variations of sizes ,as long as the spot stays within the target perimeter.

The vertical position of the WBS and of the target should be verified ,and, if necessary, corrected.

2.7 *Limit of validity of this conclusion : High currents.*

The chromatic effects of the beam we use are small, because of the low charge of the electron pulse (2.6 nC at UMA 15).

We have no time to repeat with high charge. However, a previous calculation [3], in which the beam size on the target was optimized (beam waist) gave us the expected beam sizes for a charge per pulse of 37 nC, with beam loading evaluated by K. Huebner [4].The results were :

	energy (MeV)			energy (MeV)	
mean	head	tail	mean	head	tail
190	207	174	242	259	226
beam 1/2 size(mm)			beam 1/2 size (mm)		
(H) 0.62	1.2	1,2	0.5	0.9	1.0
(V) 0.70	1.5	1.6	0.5	1.2	1.2

Note that the beam size for head or tail is about twice the value obtained for the mean energy. To take into account this factor 2, due to the beam loading, we have just to replace in our preceding calculation of the position of the edge of the electron spot σ by 2 σ, for H and V.

Then for QLB 1523 at 50.69 A, the lowest value achieved for $\delta_H + \sqrt{4\sigma_H^2 + 4\sigma_V^2}$ is 2.83 mm at a current of 52.5 A in QLB 1414, while the equivalent value is 2.64 mm with 53.9 A in QLB1514 and 53 A in QLB1523.

These values are greater than the target radius of 2.5 mm. The beam spot is not anymore within the target circle. While increasing the beam charge, the spot size increases up and finally crosses the target circle. Then, we can get a critical optimum solution by centering the primary electron beam on the target.

2.8 Precision of the measurement.

The consistencies we found in this interpretation are bound to the precision of the measurements. We think that our precision is sufficient ,because we are able to derive from the measurements a calculation of the beam emittance which is not far from the results obtained on special experimental session, devoted to this measurement.

emittances should be multiplied by $\pi 10^{-6}$ m.rad.

ε_H	ε_V	
0.6	0.76	
while we found		
0.41	0.61	[5]
all values at 215 MeV.		

The last values are more precise because we had a better alignment of the beam along the axis and much better statistics as well.

3. Trying to measure beam energy spread with more accuracy on MSH 15.

3.1 Special settings of the triplets for use of the spectrometer.

The contribution of the beam emittance to the beam width recorded on MSH15 is not negligible. It is possible to set the focusing in the last 2 triplets (the last one will not suffice,because of power supply limitations) to values minimizing the part of the beam size due to the emittance . Thus a beam of 10 mm width reduces to less than 5 mm, corresponding to the relative 2% energy spread (5E−3/.24).The accuracy of the energy spread measurement depends very much on these settings. Calculations of the quadrupoles optimum currents were previously made for 180 and 240 MeV only, and the settings for other energies were obtained by linear interpolation.

Fig.2 represents the beam spectrum with triplets set at their nominal values for transporting the beam towards the converter.

Fig.3 represents the spectrum with triplets values set for a minimum waist on MSH 15, using the spectrometer for a 212 MeV beam. The triplets are set by the linear interpolation (fig4).

This interpolation on 2 points is inadequate. The calculation at 215 MeV has been made as for 180 MeV and 240 MeV, and the curves of Fig. 5 ,based on 3 points should be used for any energy between 180 MeV and 240 MeV .

Figure 7 shows a spectrum obtained with these last curves,at a lower intensity (25 E8 e− per pulse) Compared to Fig.3, the reduction in spectrum spread is due to the combined effects of a smaller intensity (less beam loading) and a good setting of the quadruplets to achieve a beam waist on the SEM grid.

3.2 Results with and without these special settings. Evaluation of the beam loading.

We shall compare two spectra corresponding to the same beam current, one with the standard setting in the triplets(Fig.7a),from [6], obtained in August 88, and the other one with the special setting of the triplets one should use for observing beam energy,(Fig.6).

As these 2 spectra were not obtained the same day, we shall first compare the spectrum Fig.7c. from [6],August 88, to the spectrum of Fig.2, both spectra were obtained with the standard settings of the triplets, at the same beam current, but on 2 different days. If these last spectra are the same, we will eliminate all doubt on the comparison we want to make.

The spreads of the profiles we have measured are given in MeV, although they result from beam profile spreads, given by the emittance of a monoenergetic beam,that are quadratically added to energy spreads.

3.2.1 Verification from comparing 2 spectra at the same current, taken in August 88 and at present.

setting of triplets	Fig 2 beam transport	Fig.7c beam transport
Nb e- per pulse : 10^8 *	320	342
max. energy (MeV)	222.4	233.4
spread of profile(MeV) (4 σ)	10.2	13.2
calculated total DE (beam loading only) MeV	6.2	

3.2.2 2 spectra, taken in August 88 and at present, with and without special currents in triplets.

setting of triplets	Fig 6 spectrometer	Fig.7a beam transport
Nb e- per pulse : 10^8 *	25	29.7
max. energy (MeV)	216.0	233.4
spread of profile(MeV) (4 σ)	5.0	10.0
calculated total DE (beam loading only) MeV	0.4	

The effect of the beam loading is calculated according to [4]

3.2.3 Discussion.

On the first comparison, a simple verification,we obtain the same results.

The second comparison shows that, for low beam currents, setting the triplets for foccusing the beam onto MSH15 with the triplets is a necessity when one uses the spectrometer.

The remaining 5 MeV on Fig.7a accounts for the size of the beam waist and a dispersion in energy which is bigger than that calculated from the beam loading effect. At buncher exit, the dispersion in energy is of the order of 2 MeV,[7]. With a beam loading effect of the order of .5 MeV, we are left with 2.5 MeV, i.e. 3 mm, to account for the beam waist size, which is about what we expect.

3.3 Need of console software implementation.

To set the correct currents in the triplets according to the situations:

1. normal e− production in LIL V.

2. use of the spectrometer, with minimum contribution of the size due to the emittance. It is unrealistic to set all the values of the currents by hand, at operation time. A very simple program could do it, according to beam energy.

This is only intersesting for the e− production. The nominal beam charge is low ,and the beam loading effect (the real energy spread) is not too large compared to the effect of the emittance.

4. Acknowledgments.

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5. Bibliography.

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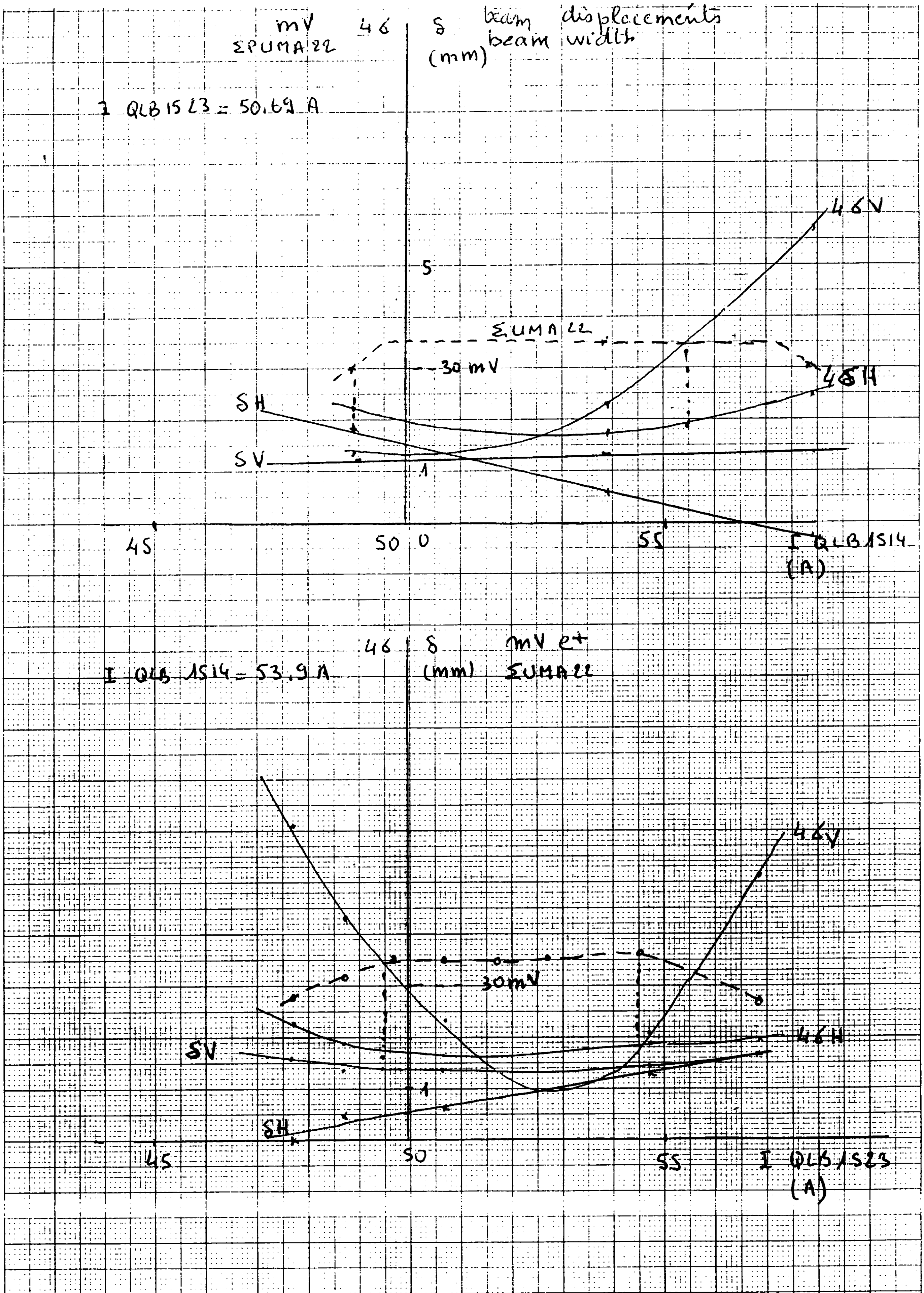
Fig. 1: Variation of beam width, beam center on WBS 25 related to the variation of e+ production as recorded as linac end.



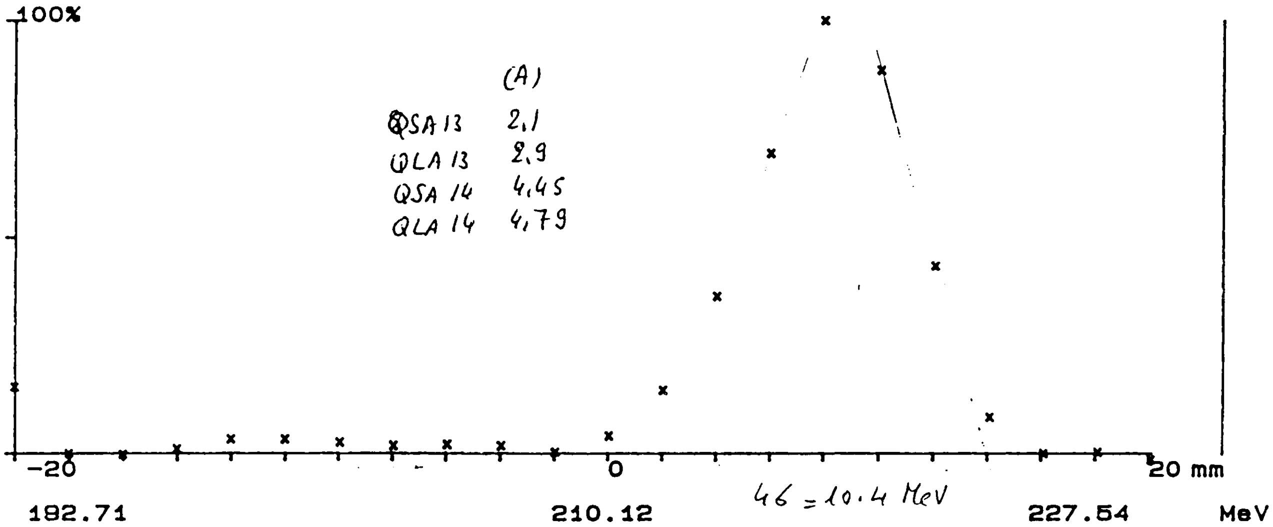
E = 215.3 ΔE (46) = 8.5 MeV gun 1.5 kV UMA 15 - 165 10^8 p.

attenuation 40 phase 65 MDK13 phase 11

Fig.2 and 3 Trying to reduce the beam size at MSH 15 for accurate beam spread measurements: First Figure with triplets current unchanged Second Figure with Triplets currents interpolated from 2 calculated points corresponding to 180 & 240 MeV. This linear interpolation is inadequate.

normal currents (A) in QS13, QL14, QS14, QL14	2.1	2.9	4.5	4.8
special currents (215 MeV interpol. on 2 points)	7.7	8.6	8.3	8.9
for spectrometer calculated	7.7	8.6	8.4	9.8

BEAM PROFILE MEASUREMENT - VL.MSH15

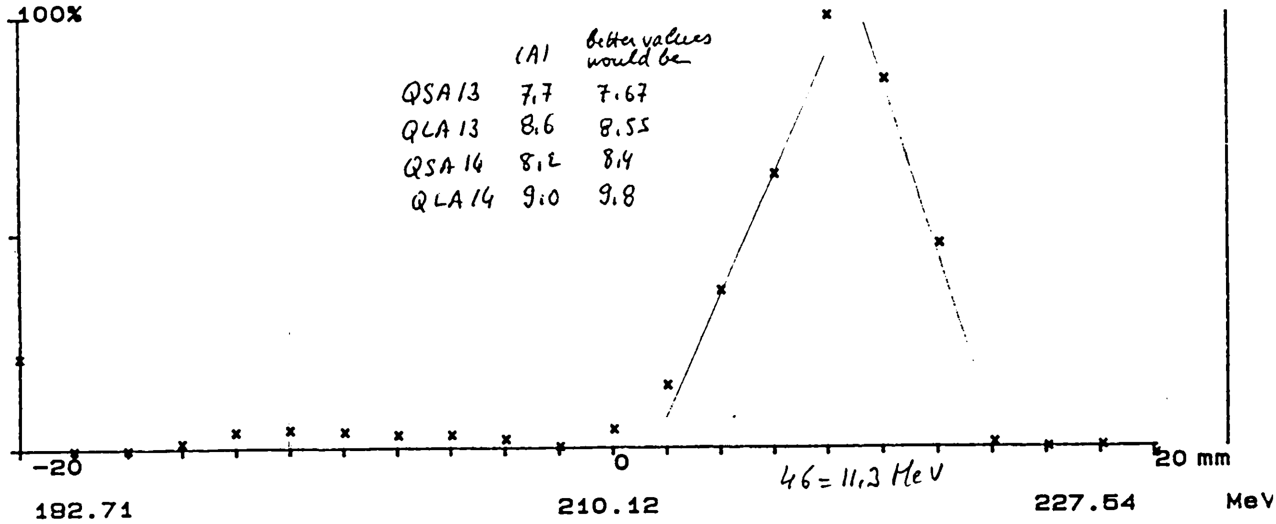


Central Energy 210.12 MeV

Digital Value at 100% 1002 (sat. 2047)

Intensity (UMA meas.) -320.507 1E8 part.

BEAM PROFILE MEASUREMENT - VL.MSH15



Central Energy 210.12 MeV

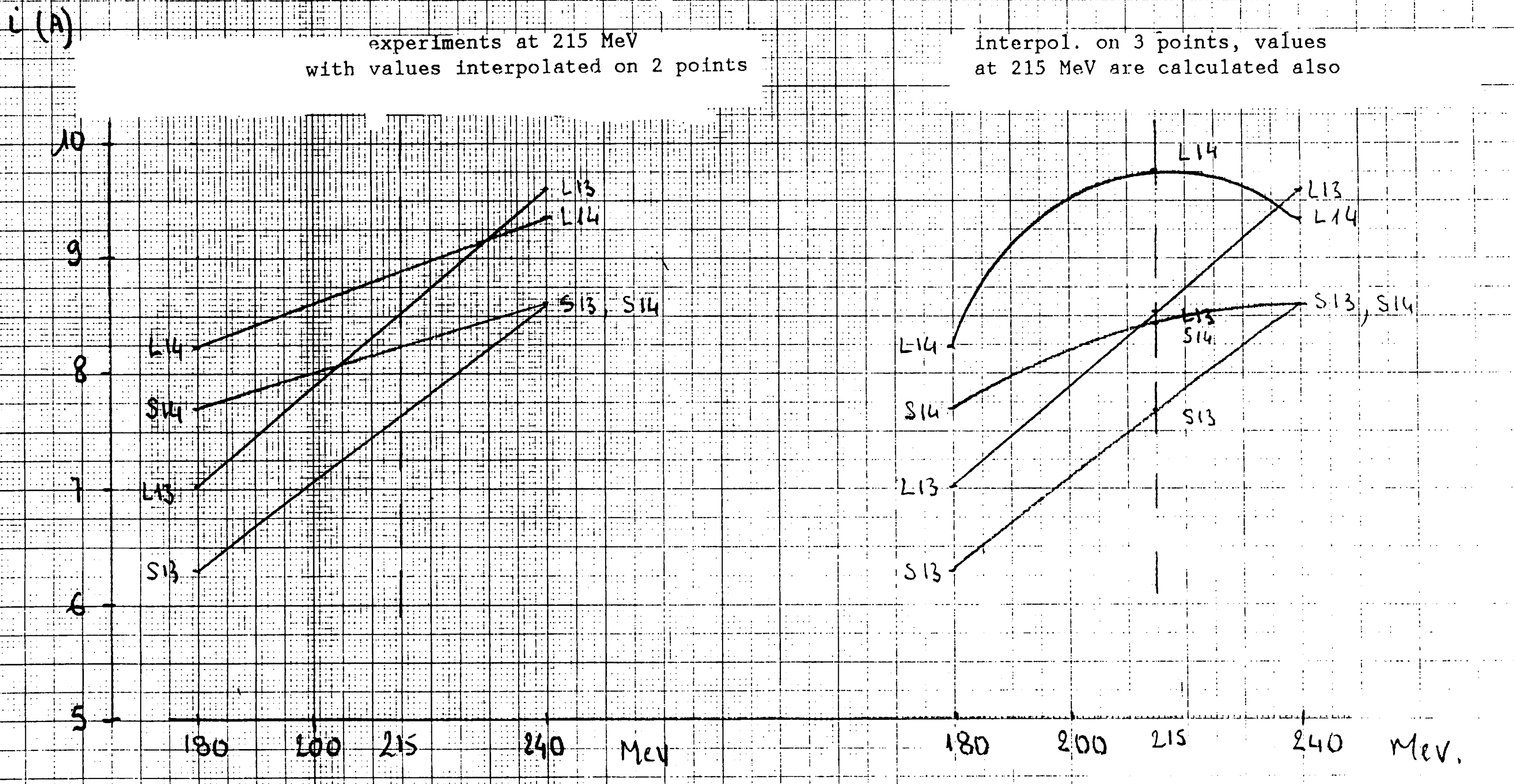
Digital Value at 100% 875 (sat. 2047)

Intensity (UMA meas.) -347.38 1E8 part.

Fig. 4 & 5 : Settings for the triplets when using the spectrometer Fig. 4 . This linear interpolation between 180 MeV and 240 MeV (15 − 11 − 88) is not adequate Fig. 5 . Adequate curves for interpolating triplets currents

QSA 13
QLA 13
QSA 14
QLA 14
→ MSH/S

monocinetic beam at MSH 15 ,natural size , 4 sigmas>= 10 mm reduction, by adjusting 4 quadruplets, to 5mm.



15-11-88 A. Rich

Fig. 6 : Energy spread fo 25 E8 e − per pulse, at 212 MeV, and the right settings of the triplets.

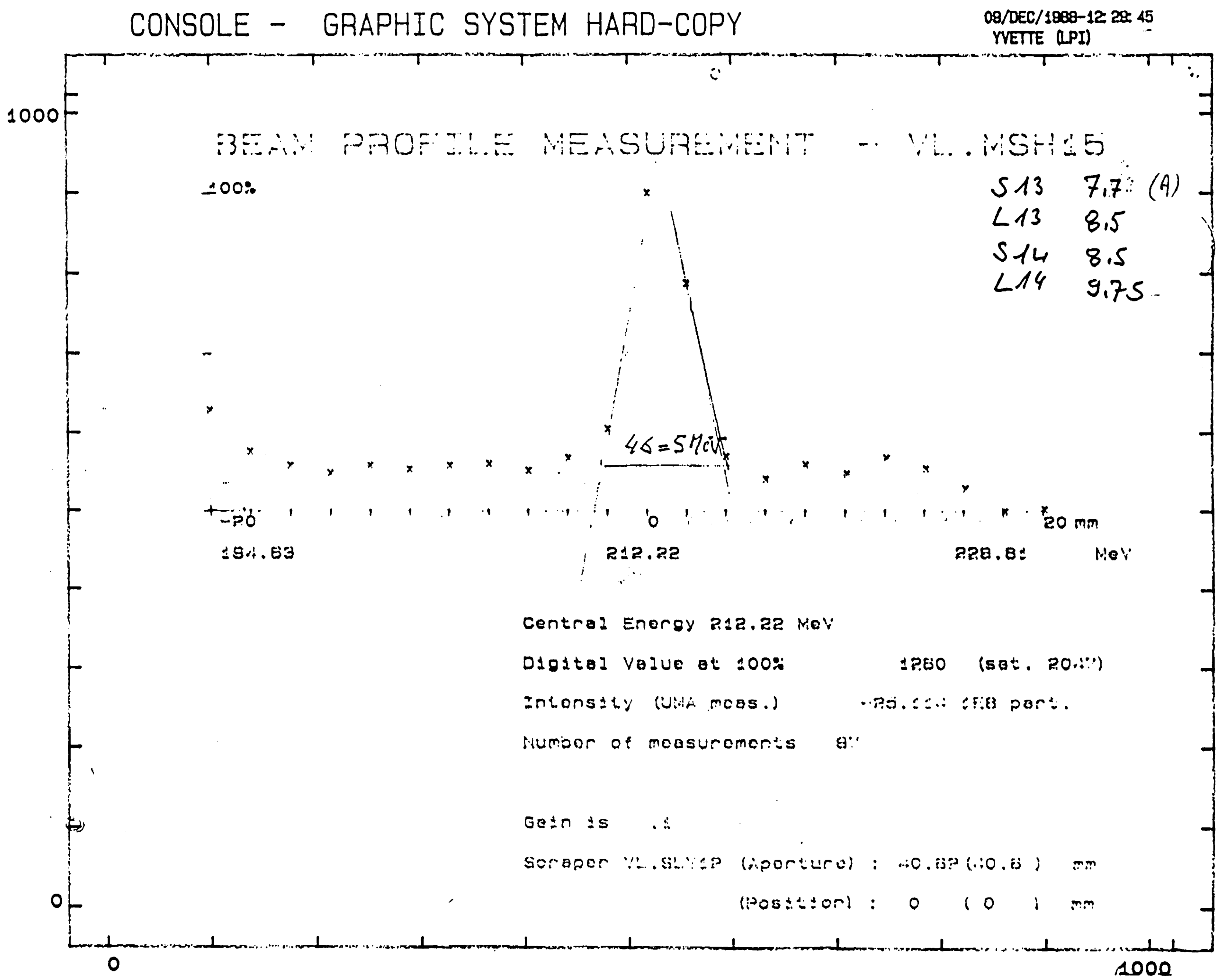
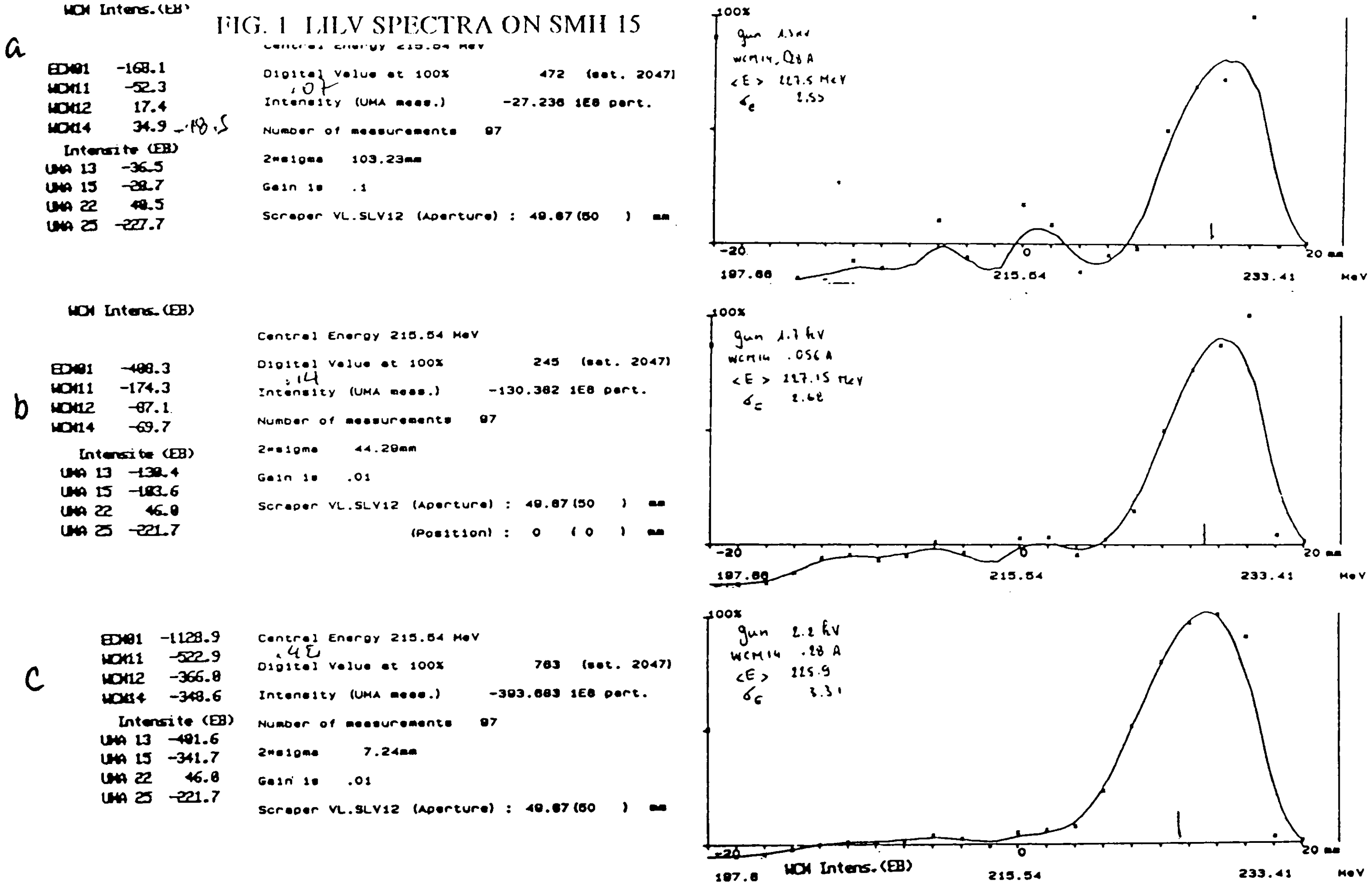


Fig.7 : LILV SPECTRA ON SMH 15, As measured in August 88 (LP Note 88 – 65)



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