PS/LP MD note 90-19

EPA ACCUMULATION TESTS

I-EPA Accumulation Rate and Maximum Current Versus Injected Beam Oscillations and Stored Beam Oscillations Experimental Results (Complements to PS-LP Note 89-25)

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1-Introduction

In [1] we described and analyzed measurements done late 88 on accumulation rate and maximum accumulated current of positrons in EPA. In December 88, complementary data were taken of the influence on these performances of the 2 injection kicker amplitude. In the present note, we give the results of the measurements and an analysis of these performances in terms of residual oscillations of injected and stored beam.

2-Experimental conditions preliminary results

The measurements were performed in one session on December 12,88 with a stable Linac providing 6.6 E08 e+/shot in HIP.UMA22 at 500MeV. The top accumulation efficiency recorded during this MD session was 50% in the best conditions. This value is not very high, but is typical of LEP production conditions. All performances values will be given relative to the peak performances of this session.

The injection slow bumpers were producing a bump of 12.6 mm, leaving a space between the septum and the stacked beam axis of 28.0 mm. The injection was done at a repetition rate of 80ms in each of the 8 buckets.

The first injection kicker, HR.KFI31, which affects only the stacked beam was varied from 11.0kV to 14.0kV by steps of 1.0kV, and the second one affecting both the incoming beam and the stacked beam, HR.KFI11 was varied from 19.0kV to 25.0kV. For each couple of kicker values, the EPA circulating current versus time was recorded with a camera. A fac-simile of these pictures can be seen on Fig.1 to 2. The settings used in operation are KFI31=12 kV and KFI11=24 kV as shown on Fig.1 On Fig.3, we have grouped all I=f(t) results to show what was the maximum maximorum accumulation rate which can be obtained , depending on the desired saturation intensity during this study session.

The experimental polaroids were analyzed in more details, to get the initial accumulation rate and the saturation current, for each injection kicker setting to have a more quantitative result.

3-Effect of stack oscillation on saturation intensity

Using the parameter Kcal=1.6 mm/kV given in [1] (all amplitude of oscillations refer to the beta value at the septum), we can work the residual amplitude of oscillation of the stack by:

$$Xstk = Kcal * (HR.KFI31 - HR.KFI11)$$

and injected beam amplitude of oscillation by

$$Xinj = Kcal * (HR.KFI11ax - HR.KFI11)$$

where HR.KFI11ax is the value for axial injection (31kV here).
Variation of saturation intensity versus Xstk at Xinj constant are shown on Fig.4.

4-Variation of initial accumulation rate with injected beam oscillation

On Fig.5 we show the variation of the initial accumulation rate versus Xinj, amplitude of oscillation of the injected beam, at constant stacked beam amplitude of oscillation. It can be seen that up to 10 mm of residual oscillation for the incoming beam , the initial accumulation rate increases. This is consistent with results of [1]: With a space between the distorted closed orbit and septum of 28 mm and a radius of the incoming beam at septum of 18 mm [1], it can oscillate of about 10mm only without losses affecting the initial accumulation rate.

Data were taken up to Xinj=20 mm only; for higher values of Xinj the accumulation rate drops very strongly [1].

5-Consequences on operation

For the regular operation with LEP, at its present requests , we can use the settings giving the maximum initial accumulation rate i.e. KFI11= 24 kV and KFI31= 12 kV providing Xstk= 20.9 mm and Xinj= 9.5 mm. The corresponding phase-space diagram is shown on Fig. 5.1. It will be only for study sessions, where we need the top current, that we will change the injection kicker settings, to reduce the residual oscillations of the stacked beam and go to higher stored current values.

II. EPA Accumulation Rate versus Injection Rate

1. Introduction

Electrons and positrons are ususally accumulated be adding the injected beam to the stored beam using betatron stacking; radiation damping merges then the injected beam with the stored beam. The question is always how the time Δ T elapsing between two consecutive injections into the same bucket is related to the stacking efficiency. This time intervall is logically measured in terms of the relevant damping time.

LPI offers the unique possibility to measure the stacking efficiency or stacking rate of EPA as a function of $\Delta T/\tau_x$ because Δ T can be varied by either changing the number of bunches k_b or by setting the linac repetition frequency appropriately. The damping time can be varied by choosing the operating energy of EPA.

The first measurement of this type was done by J.P.Delahaye and B.Frammery. Although the injection was certainly not very well optimized, the plot of the results is shown in Fig.6 for completeness. The value of η is defined as the ratio of the stacking rate to the injection rate averaged over the time in which the current rises linearly. The injection rate is nothing but the average current measured in the transfer line between LIL and EPA. It can be seen that waiting more than 2 damping times between 2 injections seems to be beneficial. By the way, the nominal stacking efficiency is 30% at 600 MeV.

In December 1988 part of the measurements were repeated. Although the results are not always coherent and they are even sometimes contradictory, they are written ~~y~~up for the record, in order to stimulate better measurements and also because so few measurements of this type are available from other machines. Especially, our measurements with electrons are rudimentary. Table 1 gives a synopsis of the parameters used.

Table 1, Synopsis of cases done

k / T(ms)		10		40		80		150	
MeV		500	600	500	600	500	600	500	600
1	e+	x	x	x	x	x	x	x	x
	e-	-	-	-	-	-	-	-	-
4	e+			x	x	x	x	-	x
	e-			x	-	x	-	-	-
8	e+					x	x	x	x
	e-					-	x	-	-

2. Positrons

2.1 500 MeV (measured on 17.11.88)

Only stacking rates per bunch were recorded and no injection rates. Fig. 7 gives relative stacking rates; the reference case is $k_b = 1$ and $\Delta T = 80$ ms $= 1.36\ \tau_x$. The dependence on $\Delta T/\tau_x$ seems to be very weak for a given k_b. The rate with $k_b = 8$ was considerable worse than the rate with $k_b = 1$; $k_b = 4$ yields the same rate as $k_b = 1$.

We noted that accumulation without early saturation is only possible with $\Delta T/\tau_x > 1$.

2.2 600 MeV (measured 21.12.88)

The stacking efficiency η is shown in Fig. 8 with k_b as parameter. In this case, a step from $\Delta T/\tau_x = 1.2$ to 2.4 improved η considerably, a further step to 4.4 brought little. Note that more bunches seem to have better individual stacking rates than a few, in clear contradiction to the 500 MeV measurement described above.

3. Electrons

3.1 500 MeV (measured 14.12.88)

Table 2 gives the results for $k_b = 4$. Although $\Delta T/\tau_x = 0.68$ at $\Delta T = 40$ ms, the stacking rate is twice the one at $\Delta T = 80$ ms. This means that the linac can very well run with 100 Hz to fill the usual 4 buckets of electrons yielding a doubling in the stacking rate. The average slope up to N_b^{max} was used to determine $\dot{N}$. No measurement of injection rate.

Some saturation effects at $N_b \approx 10^{11}$ for $\Delta T = 40$ ms, no saturation effects up to $N_b = 6.5 \times 10^{10}$ for $\Delta T = 80$ ms.

Table 2, Electron stacking at 500 MeV

k_b	ΔT ms	$\dot{N}/10^9$ s^{-1}	$N_b^{max}/10^{10}$
4	40	65	3.1
4	80	31	3.1

3.2 600 MeV (measured 18.11.88)

$k_b = 8$

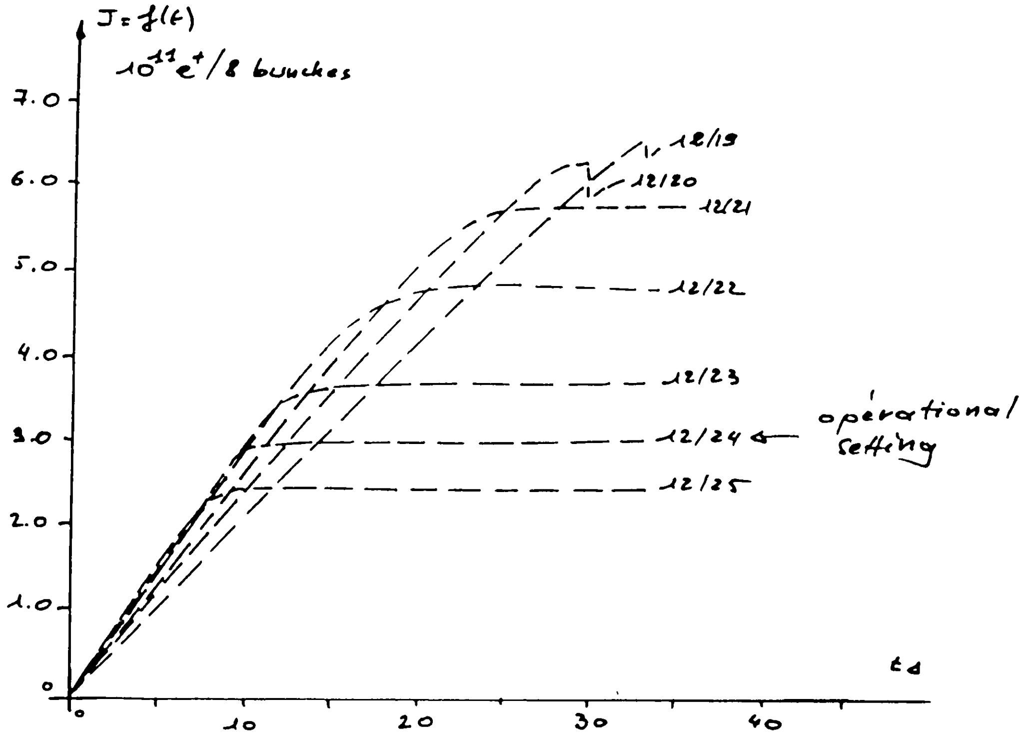
$\dot{N}_b = 2.3 \times 10^{10}\ s^{-1}$ up to $N_b = 2.3 \times 10^{10}$

$\eta = 83\ \%$

Distribution

LPS
Y.Baconnier
D.Brandt/SL
R.Cappi
J.P.Delahaye
A.Hofmann/SL
K.Hubner
J.H.B.Madsen
J.P.Riunaud
T.Risselada
A.Verdier/SL

[1] Injection and Accumulation Studies, K.Hubner, J.P.Potier, L.Rinolfi
PS-LP Note 89-25

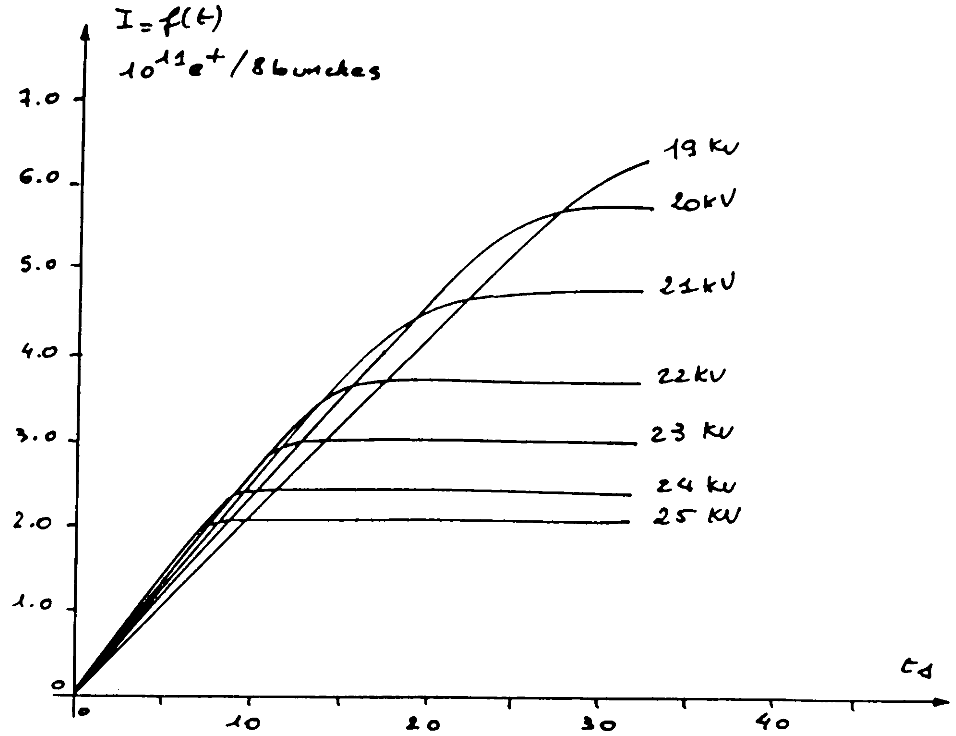


Intensity in EPA for 8 bunches of e^+

For KFI 31 = 12 kV
KFI 11 = 19 ... 25 kV

HR. BSW = - 1.7 A
HIP. UMA22 = $6.6\,10^8\, e^+$/shot

December 88 data



Intensity in EPA for 8 bunches of e^+

For KFI 31 = 11 kV
KFI 11 = 19 ... 25 kV

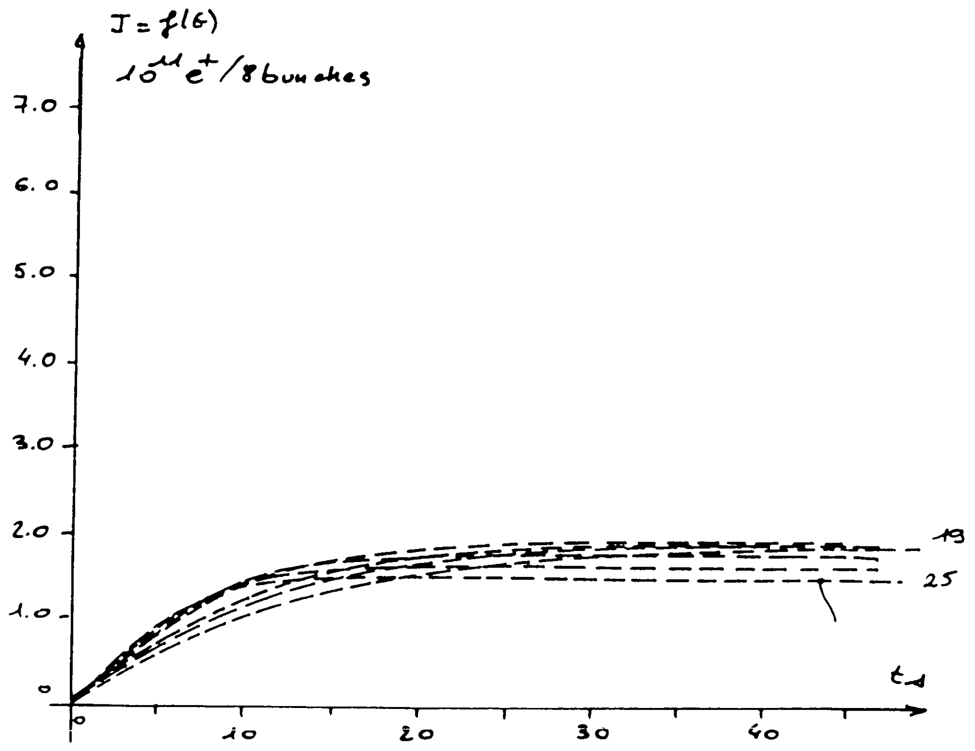
HR. BSW = - 1,7 A

HIP. UMA22 = $6.6\,10^8\, e^+$/shot

$\eta_{acc\,max}$ = 50%

December 88 data

Figure 1



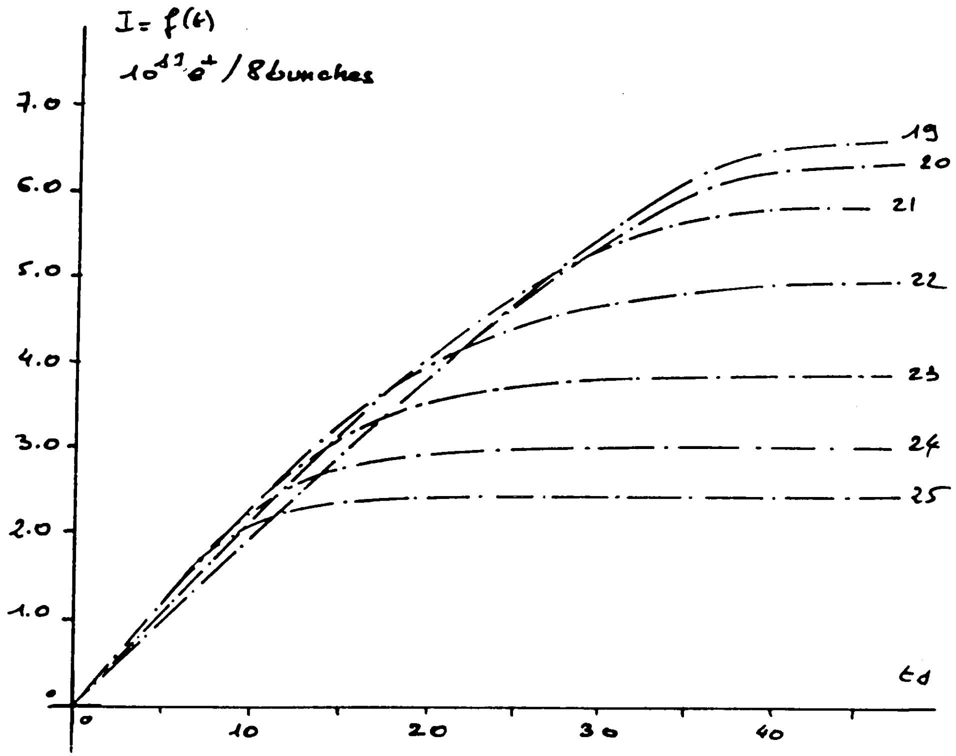
Intensity accumulated in EPA in 8 e^+ bunches

For KFI 31 = 14 KV
KFI 11 = 19 -- 25 KV

HR. BSW = - 1.7 A

HP. UMA22 = 6.6 10^9 e^+/shot

December 89 data



Intensity in EPA for 8 e^+ bunches

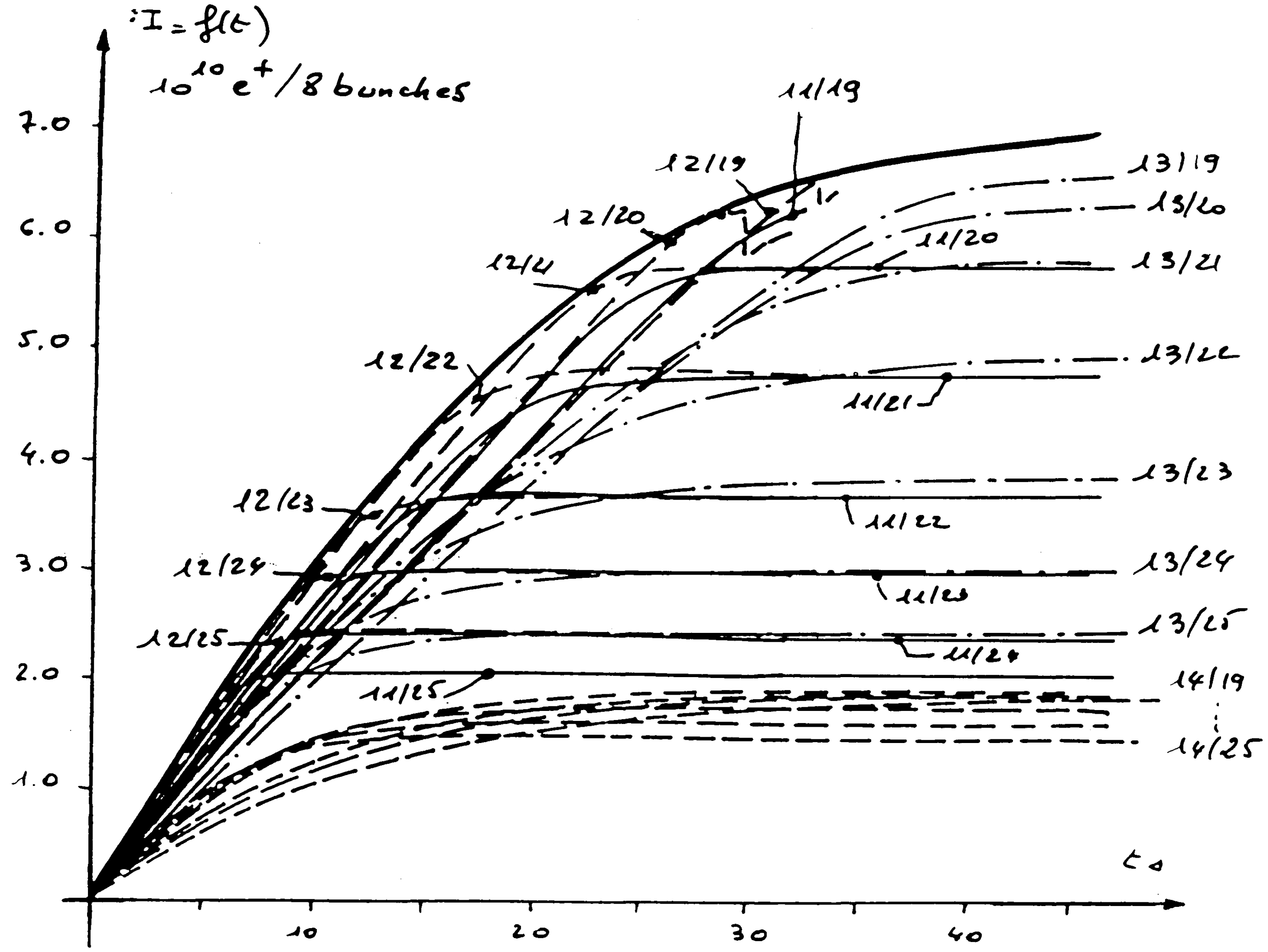
For KFI31 = 13 KV
KFI11 = 19 ... 25 KV

HR. BSW = - 1.7 A

HP. UMA22 = 6.6 10^9 e^+/shot

December 89 data

Figure 2



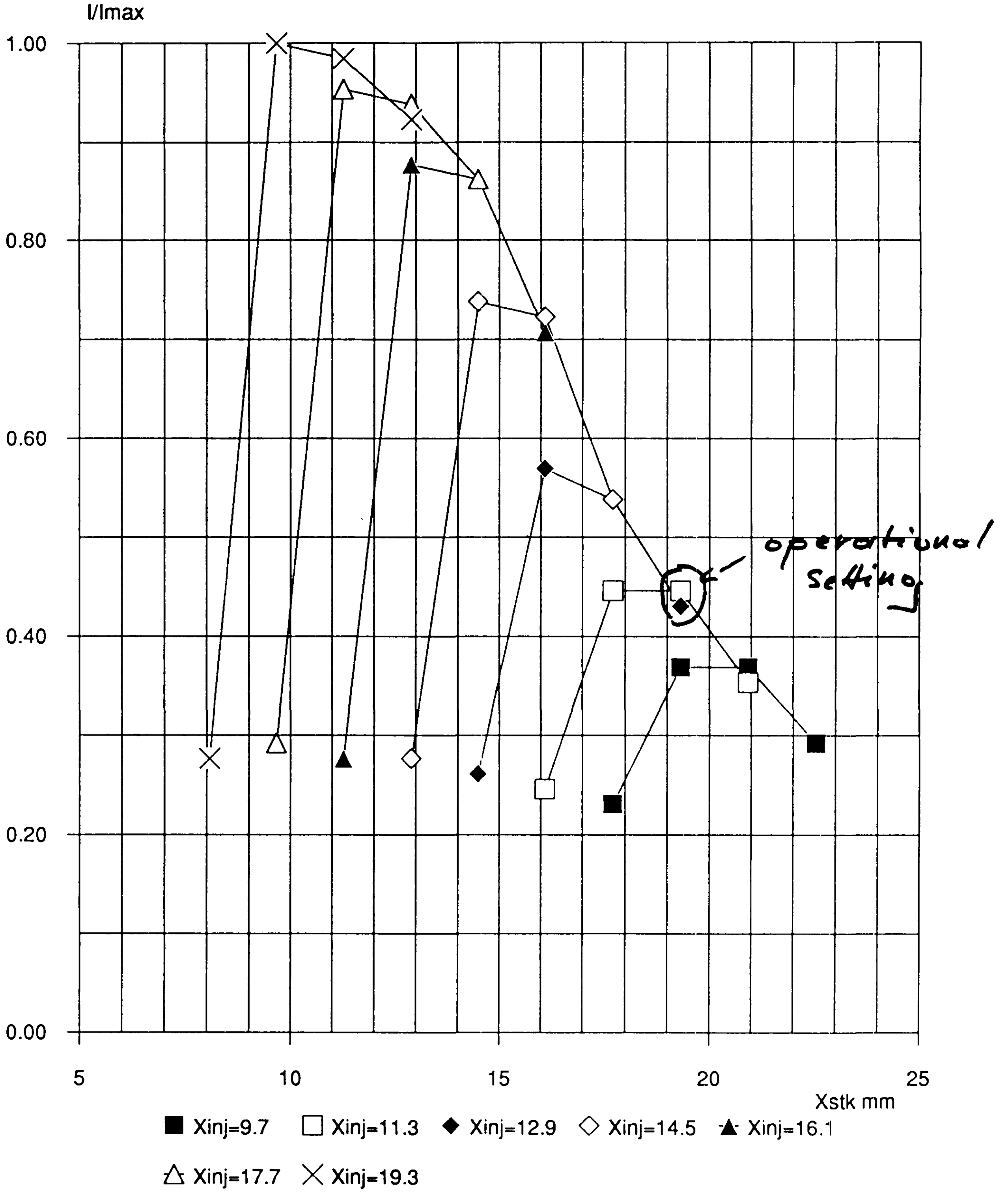
Intensity accumulated in EPA for
8 e+ bunches versus time
For KFI 11 = 19 ... 25 kV
KFI 31 = 11 ... 14 kV

———	KFI 31 = 11 kV
— —	KFI 31 = 12 kV
—·—·—	KFI 31 = 13 kV
- - - -	KFI 31 = 14 kV
━━━	maximum maximorum de I = f(t)

December 88 data

Figure 3

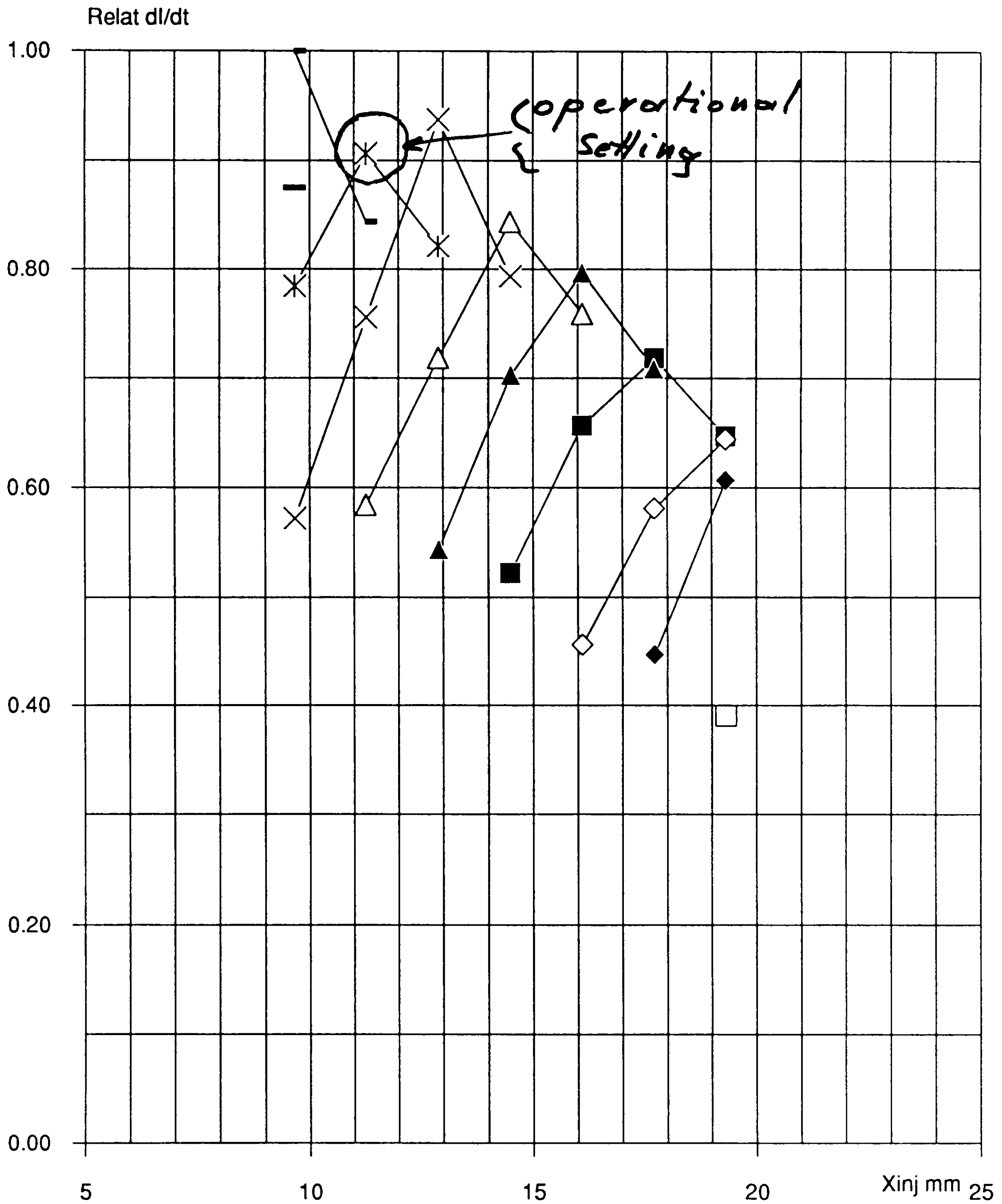
Relative Saturation of EPA Positron Intensity in 8 Bunches versus Stacked Beam Amplitude of Oscillation, at Constant Injected Beam Amplitude of Oscillation, December 88 data



Xinj = Betatronic amplitude of injected beam   Xstk = Betatronic amplitude of stacked beam

Figure 4

Relative Maximum Rate of EPA Positrons Accumulation versus Injected Beam Oscillations at Stack Oscillations Constant, data of December 88



■ Xstk=12.9 □ Xstk=8.1 ◆ Xstk=9.7 ◇ Xstk=11.3 ▲ Xstk=14.5

△ Xstk=16.1 × Xstk=17.7 ✳ Xstk=19.3 — Xstk=20.9 — Xstk=22.5

Xinj = injected beam oscillation amplitude Xstk = stacked beam oscillation amplitude

Figure 5

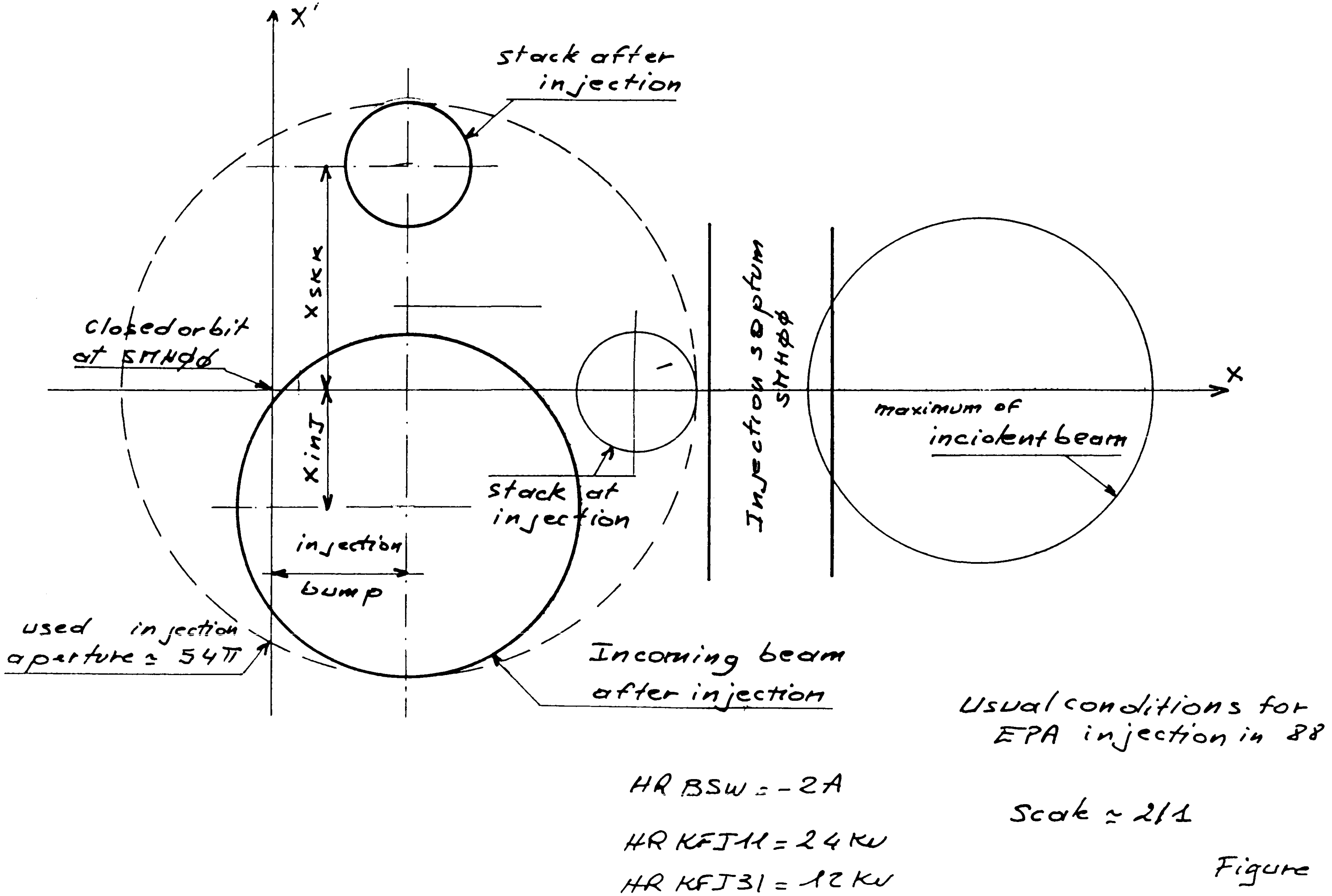
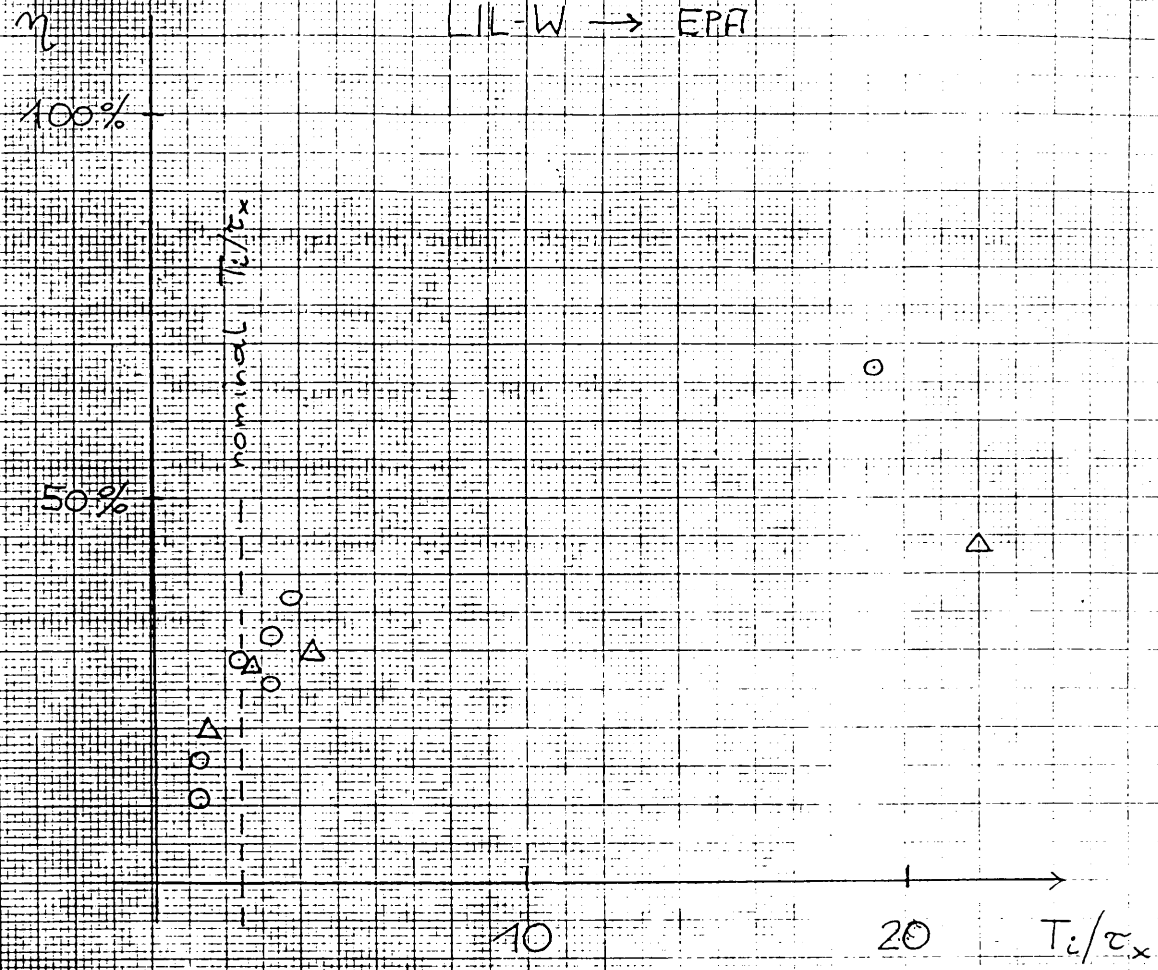

X'
stack after injection
Closedorbit at SMHØØ
XSKK
XINJ
stack at injection
Injection septum SMHØØ
X
maximum of incident beam
injection bump
used injection aperture ≃ 54π
Incoming beam after injection
Usual conditions for EPA injection in 88
HR BSW ≃ -2A
HR KFI11 = 24 KV
HR KFI31 = 12 KV
Scale ≃ 2/1

Figure 5.1

21.8.86

Transfer efficiency × Injection efficiency = η

LIL-W → EPA



normalized period between two injections

○ 400 MeV run 7.8.86 $k_b = 8$ electrons

△ 500 MeV run 14.8.86 $k_b = 8$

Fig. 6

Results by J.P. Delahaye and B. Frammery

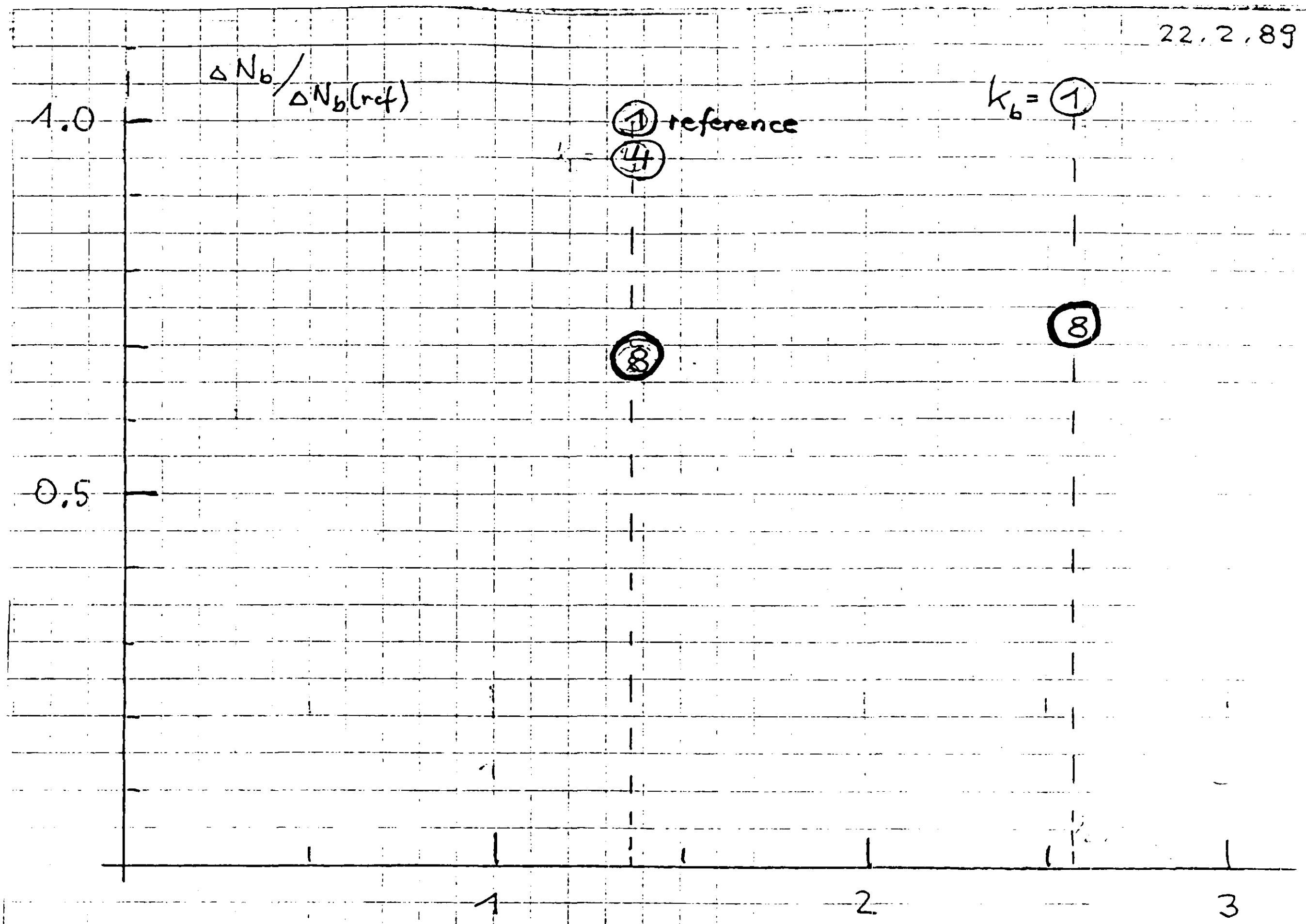


Fig. 7 Relative stacking rate ; Positrons 500 MeV

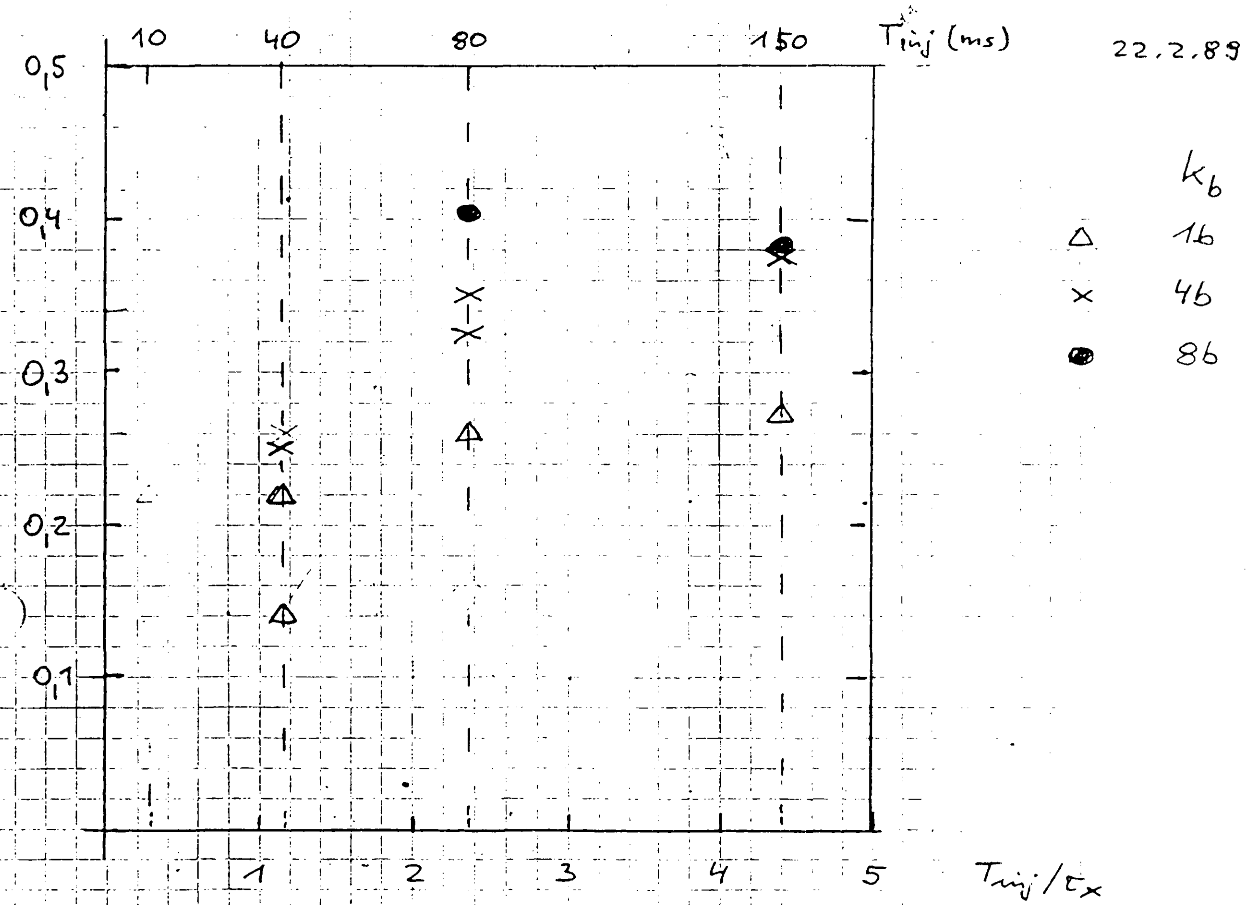


Fig. 8 Accumulation efficiency versus injection period
Positrons 600 MeV