SM/mh/afm

PS/AR Note 89-5
Rev. 1
21.7.1989

AAC PERFORMANCE: STATUS AND OUTLOOK

G. Adrian, B. Autin, X. Brunel, G. Carron, F. Caspers, N. Chohan,
T. Eriksson, R. Garoby, J. Kuczerowski, G. Le Dallic, S. Maury,
C. Metzger, D. Möhl, Y. Orlov, J. Ottaviani, F. Pedersen, A. Poncet,
Y. Renaud, J.-C. Schnuriger, R. Sherwood, L. Søby, C.S. Taylor,
L. Thorndahl, S. van der Meer, D.J. Williams

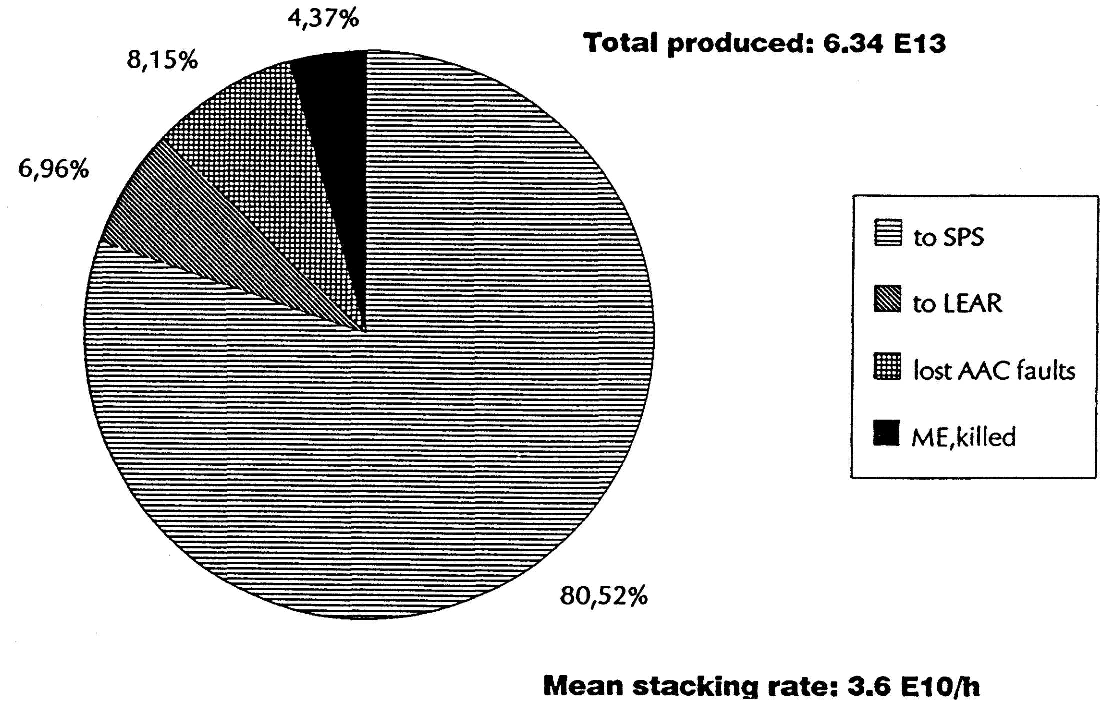
1. INTRODUCTION

Antiprotons are produced in the target area, debunched and stochastically precooled in the AC and then transferred to the AA for final cooling and accumulation into a stack from which bunches are finally extracted and transferred to the differents users.

During the summer of last year, $\bar{p}$ production was dedicated to LEAR. From September 1988 to June 1989, most of the daily production was sent to the SPS and only 7% to LEAR.

The stacking rate evolved steadily: in early 1988, it was 1.8×10^{10} $\bar{p}$/h and in June 1989 it reached 5.8×10^{10} $\bar{p}$/h (Figure 1).

Pbars distribution 1989 period 1



2. PRODUCTION BEAM AND COLLECTOR LENS

During this year we sent two kinds of production beam onto the target. The first one was recombined longitudinally in the Booster-PS transfer line, at 1 GeV, by means of an rf dipole. This beam had an intensity of 1×10^{13} protons per pulse with a bunch length of only 15 ns, very important for the $\bar{p}$ bunch rotation in AC. From November 1988 the second production beam was obtained by RF merging in the PS at 3.5 GeV/c followed by successive changes of harmonic numbers at 26 GeV/c; it had an intensity of 1.4×10^{13} ppp in 5 bunches with a bunch length of 30 ns.

The production beam is focused on the target with 2 pulsed quadrupoles. A target made of iridium embedded in graphite (L = 70 mm, 3 mm in diameter) was used for antiproton production, and no yield degradation was observed during this period. Antiprotons emerging from the target are focused and matched (6% in momentum bite and 200π mm·mrad in transverse emittances) into the injection transport line (known as Dogleg) by a collector lens.

Two types of collector lens were used, a magnetic horn of 60 mm in diameter, pulsed at 400 kA, which was commissioned and operated successfully, and a lithium lens of 20 mm in diameter, pulsed at 480 kA, which yielded 58×10^{-7} $\bar{p}$/proton after optimisation of the Dogleg optics.

The third collector lens, a lithium lens of 36 mm in diameter was tested in the laboratory, but after a flange failure at 1.2 MA the test in the beam was postponed to July 1989.

3. DEBUNCHING CAVITIES

Antiprotons were injected into the AC with the 5 bunch structure (same structure as the PS production beam) and then captured into 5 RF buckets at 9.55 MHz. The bunch rotation takes 60 μs and the subsequent debunching 10 ms. (The two debunching cavities were commissioned and put successfully into operation). The best ratio obtained of $\bar{p}$ in 1.5% momentum spread after bunch rotation divided by $\bar{p}$ in 6% momentum spread of the injected beam was 82% (debunching efficiency), it went down to about 70% when we put the second production beam with a longer bunch length into operation. In March 1989 the closed loop phase feedback was commissioned improving the isoadiabatic debunching and the efficiency went up again to 83%.

4. AC COOLING

For the AC cooling solid state amplifiers were developed to cover the 1 to 3 GHz band in three bands : 1 to 1.65 GHz, 1.65 to 2.4 GHz and 2.4 to 3.0 GHz. All these 3 bands were used in 3 planes (H,V,L) with cryogenic low noise preamplifiers. The dynamic phase compensation was developed to keep a good phase for cooling during the movement of the pick-ups. Betatronic filters were added in band I and band II on transverse planes to reduce the power due to the white noise. Additional cryogenic cooling of the combiner boards reduced the temperature from 100°K to 30°K and the noise by 4 dB. These improvements caused the $\bar{p}$ beam to be cooled and 110% of the beam within the 0.18% in momentum spread was obtained over a 4.8 s period. This efficiency is greater than 100 % because the system cools particules of a dp/p wider than 1.5% (design dp/p after the bunch rotation).

After the AC cooling in 4.8 seconds, the transverse emittances were measured and found to be 5 and 6π mm·mrad in H and V planes, respectively.

5. AC/AA TRANSFER LINE

Transfer efficiency is high when we are using the 4.8 s cycling because the p̄ emittances after the AC cooling are small, but the efficiency drops when we are using the 2.4 s cycling. The p̄ emittances are of course larger (about 17π mm·mrad in both planes) but the acceptance ought to be 25π mm·mrad. After the injection in AA the longitudinal blow-up may cause some trouble. At 4.8 s cycling, the beam is sufficiently cooled in the AC and even with a longitudinal blow-up at the injection in the AA, the pre-cooling can cool all the particles. However, at 2.4 s, it is not the case, the dp/p being too large such that the precooling cannot reduce it sufficiently.

6. AA COOLING

Lower-noise preamplifiers and the additional band II amplifiers, improved the precooling. It worked well at the present p̄ flux in 4.8 s.

The common mode of the 2-4 GHz system was suppressed by adding a longer delay for high-frequency particles. By reducing the hardware coupling in the 4-8 GHz system (the transverse HF cooling), a nice Beam Transfer Function (BTF) has been measured. But due to the high η in AA, we had problems to explore the full 4-8 GHz bandwidth. A cure would be to extend the cooling to lower frequencies.

7. STACK INTENSITY LIMITATIONS

The main problem during the summer of 1988 was the stack intensity limitation. During spring the limitation was due to the coherent ion-p̄ instabilities. To reduce the neutralization by ions the AA clearing was improved and combined with a tune change; the AA intensity could thus be increased but was then limited by ion induced non-linear resonances and by coherent transverse instabilities indentified as a quadrupolar instability. Then, in September, the AA intensity reached 8.53×10^{11} p̄ with a new technique, "SHAKING". It consists in exciting the p̄ stack transversally with a sinewave near the lowest frequency betatron mode to a coherent amplitude of a few microns. This was sufficient to modify the ion amplitude distribution and thus to reduce the excitation of high order resonances. But at stack intensities above 8×10^{11}, stack loss rate rose rapidly and consumed a large fraction of the stacking rate. Nevertheless, we reached the maximum stack intensity above 1.0×10^{12} still with a stacking rate of 3.0×10^{10} p̄/h.

8. AAC PERFORMANCE

After all these improvements the stacking rate at medium stack intensities was increased by a factor of 8 with respect to that of the old AA.

We show in Table 1 the peak performance and the operational values, compared to the design values. The daily stacking rate is an average during stacking periods, and takes into account the fluctuations of PSB, PS and AAC machines.

We also show in Figs. 3 and 4 the evolution in the AA of the p̄ emittances versus p̄ intensity and on Fig. 5 the p̄ stack-width versus p̄ intensity.

TABLE 1

		1988	1989	
	DESIGN	OPERATION	OPERATION	PEAK
Production beam (ppp)	1.0×10^{13}	1.35×10^{13}	1.45×10^{13}	
Repetition period	2.4s(1500/h)	4.8s(750/h)	4.8s(750/h)	
Yield ($\bar{p}$/p)	10.0×10^{-6}	5.7×10^{-6}	5.4×10^{-6}	5.8×10^{-6}
$\bar{p}$ injected in AC	10.0×10^{7}	7.7×10^{7}	7.7×10^{7}	8.3×10^{7}
$\bar{p}$ after bunch rot.	9.0×10^{7}	5.6×10^{7}	6.2×10^{7}	6.8×10^{7}
$\bar{p}$ after AC cooling		5.7×10^{7}	7.2×10^{7}	7.6×10^{7}
p after transf. to AA		5.4×10^{7}	6.3×10^{7}	7.0×10^{7}
H emit. after AC cool.		10.π	5.π	
V emit. after AC cool.		10.π	6.π	
$\bar{p}$ after AA precool.		5.3×10^{7} (4eVs)	7.5×10^{7}	7.9×10^{7}
		3.8×10^{7} (1eVs)	6.2×10^{7}	6.2×10^{7}
$\bar{p}$/pulse	5.0×10^{7}	4.9×10^{7}	7.0×10^{7}	7.7×10^{7}
Stacking rate (10^{10}/h)	7.5	3.6	5.3	5.8
Daily production (10^{11})	10	6.0	8.5	11.5
Daily stack.rate(10^{11}/h)		3.3	4.4	5.16
Stack intensity max.	1×10^{12}	0.85×10^{12}	1.03×10^{12}	
Transverse emittances	1-2 π	2-3 π	2-3 π	
Total efficiency	50 %	63 %	91 %	93 %

For comparison, we show in Table 2 the 2.4 s repetition-time test (not operational).

TABLE 2

	UNDER STUDY
Production beam (ppp)	1.24×10^{13}
Repetition rate	2.4 s (1500/h)
Yield ($\bar{p}$/p)	5.0×10^{-6}
$\bar{p}$ injected in AC	6.1×10^{7}
$\bar{p}$ after bunch rotation	4.6×10^{7}
p after AC cooling	4.0×10^{7}
H emittance after AC cooling	18 π
V emittance after AC cooling	17 π
$\bar{p}$ after transfer to AA	2.8×10^{7}
p after AA precooling	2.9×10^{7} (4 eVs)
	2.1×10^{7} (1 eVs)
$\bar{p}$/shot	1.5×10^{7}
Stacking rate	2.3×10^{10}/h
Daily production	
Daily stacking rate	
Stack intensity max.	
Emittances	
Total efficiency	25 %

Due to its poor efficiency, this mode was used only to assess the stacking rate. Even if the efficiency were the same as with 4.8 s repetition time, the daily production rate would not increase by a factor of 2. There are always cycles in the supercycle devoted to other users (LEAR, SPS, East Hall, LPI) and the daily $\bar{p}$ production could increase by a factor of 1.6 at best. We can thus see from the tables that the daily production will never be better at 2.4 s than at 4.8 s.

9. RELIABILITY

In general the AAC reliability was rather good. However 3 spikes can be observed on Figure 2, during Easter the BHZ2611S transformer, (bending magnet in the TTL2 transfer line between AA and PS) has been changed, and then the AA septum circuit cooling water, since, apart from these 2 main faults, the AAC machine worked quite well. The reliability improved gave us the opportunity to stack almost 9.0×10^{11} $\bar{p}$ every day. At several occasions, more than 1×10^{12} $\bar{p}$ were obtained in operation.

10. CONCLUSION AND OUTLOOK

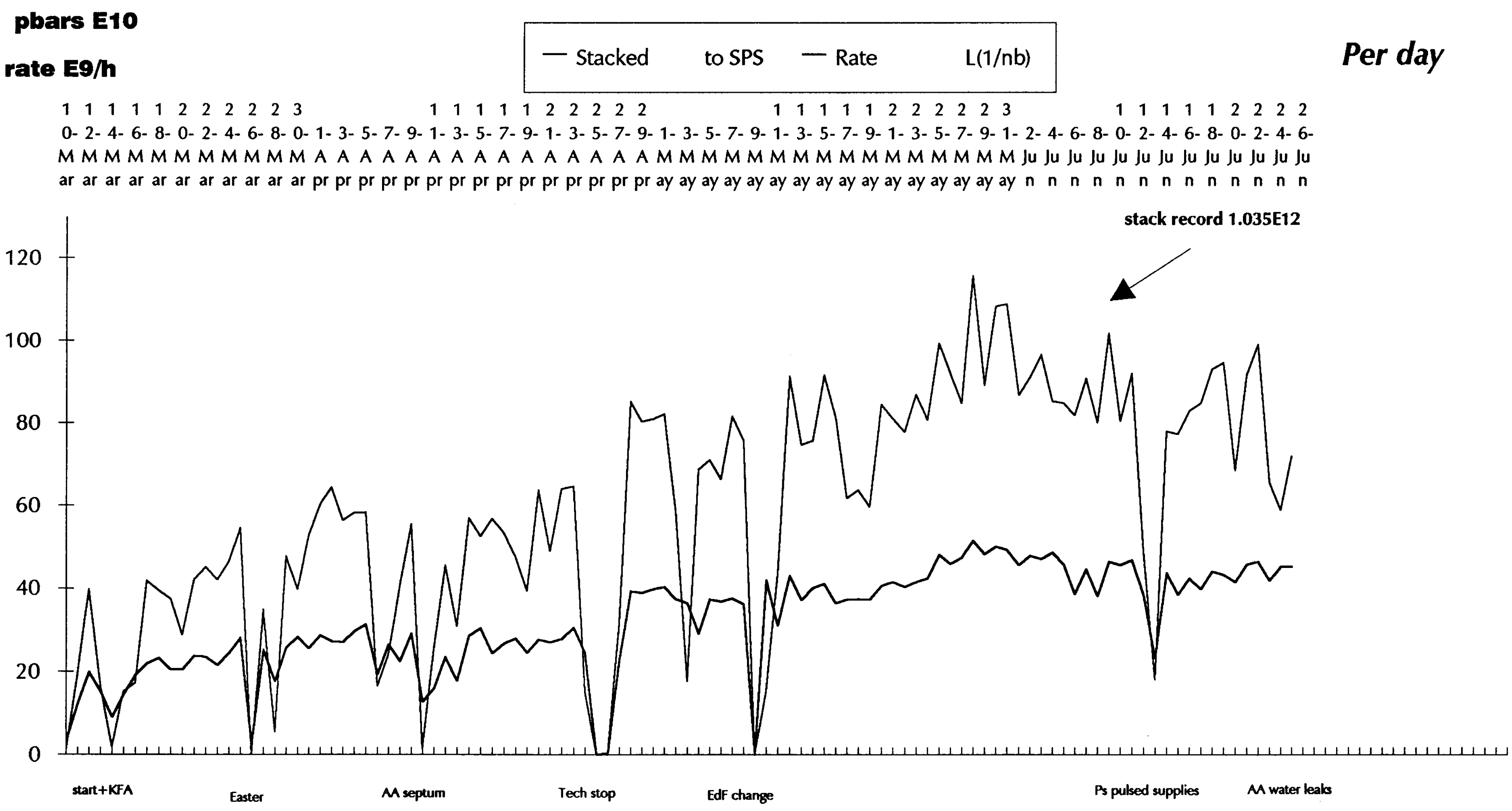
In the second half of this year it is planned to supply all the $\bar{p}$ production to LEAR. ME sessions will be devoted to study the high stack intensities and efficiencies of the 2.4 s cycle. To increase the stacking rate, the high intensity production beam obtained with 4 Booster rings and PS merging will be tried and should reach about 2×10^{17} ppp. The 36 mm lithium lens, which should capture about 40% more antiprotons, will be tested in July.

REFERENCES

- *Statisques AAC, Run 1, PS/OP/Note 89-25, J. Kuczerowski, Y. Renaud.*
- *$\bar{p}$ transfer statistics from PS PC Network, M. Bouthéon.*

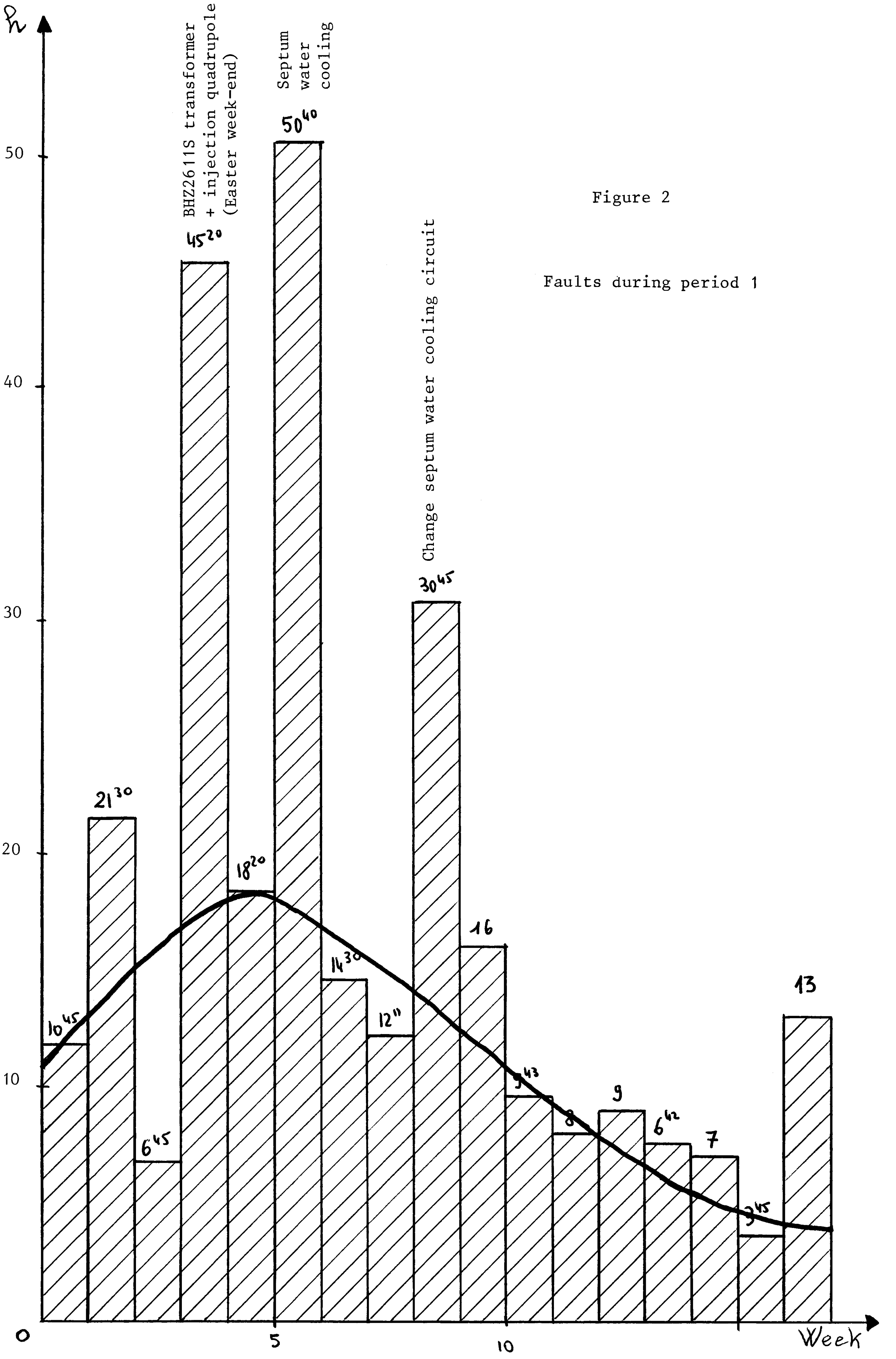
Distribution :

G. Adrian	R. Maccaferri		Y. Baconnier
E. Asséo	E. Malandain		R. Billinge
B. Autin	M. Martini		E. Jones
S. Baird	S. Maury		
D. Boimond	C. Mazeline		
J. Bosser	G. McMonagle	BS:	R. Rasmussen
M. Bouthéon	C. Metzger		H. Schönauer
E. Brouzet/SPS	D. Möhl		
R. Brown	G. Molinari		
X. Brunel	F. Ollenhauer	LEAS:	D. Manglunki
R. Cappi	Y. Orlov		G. Tranquille
G. Carron	J. Ottaviani		
F. Caspers	A. Pace		
M. Chanel	F. Pedersen	SM Linac:	L. Bernard
J. Chevallier	J.C. Perrier		H. Charmot
V. Chohan	T. Pettersson		C. Dutriat
M. Conte	B. Pincott		E. Tanke
A. Dainelli	A. Poncet		J.L. Vallet
T. Eriksson	J.-P. Potier		
M. Frauchiger	Y. Renaud		
R. Galiana	H. Riege	Gp Lds:	B.W. Allardyce
R. Garoby	J.-P. Riunaud		J. Boillot
R. Giannini	C. Scheffre		J.-P. Delahaye
J. Guillaume	J.-C. Schnuriger		J. Gruber
M. Guillon	R. Sherwood		F. Pedersen
H. Gundel	L. Søby		F. Perriollat
S. Hancock	Ch. Steinbach		P.L. Riboni
L. Henny	M. Stetter		K. Schindl
G. Himbury	C.S. Taylor		D.J. Simon
C.D. Johnson	L. Thorndahl		
J. Kewell	S. van der Meer	Associates:	D. Blechschmidt
J. Kuczerowski	C. Vasseur		D. Dekkers
G. Le Dallic	B. Williams		H. Haseroth
R. Ley	D.J. Williams		H. Koziol
M. Lubrano di S.	G. Yvon		P. Lefèvre
J.E. Lundmark	K. Zioutas		E.J.N. Wilson

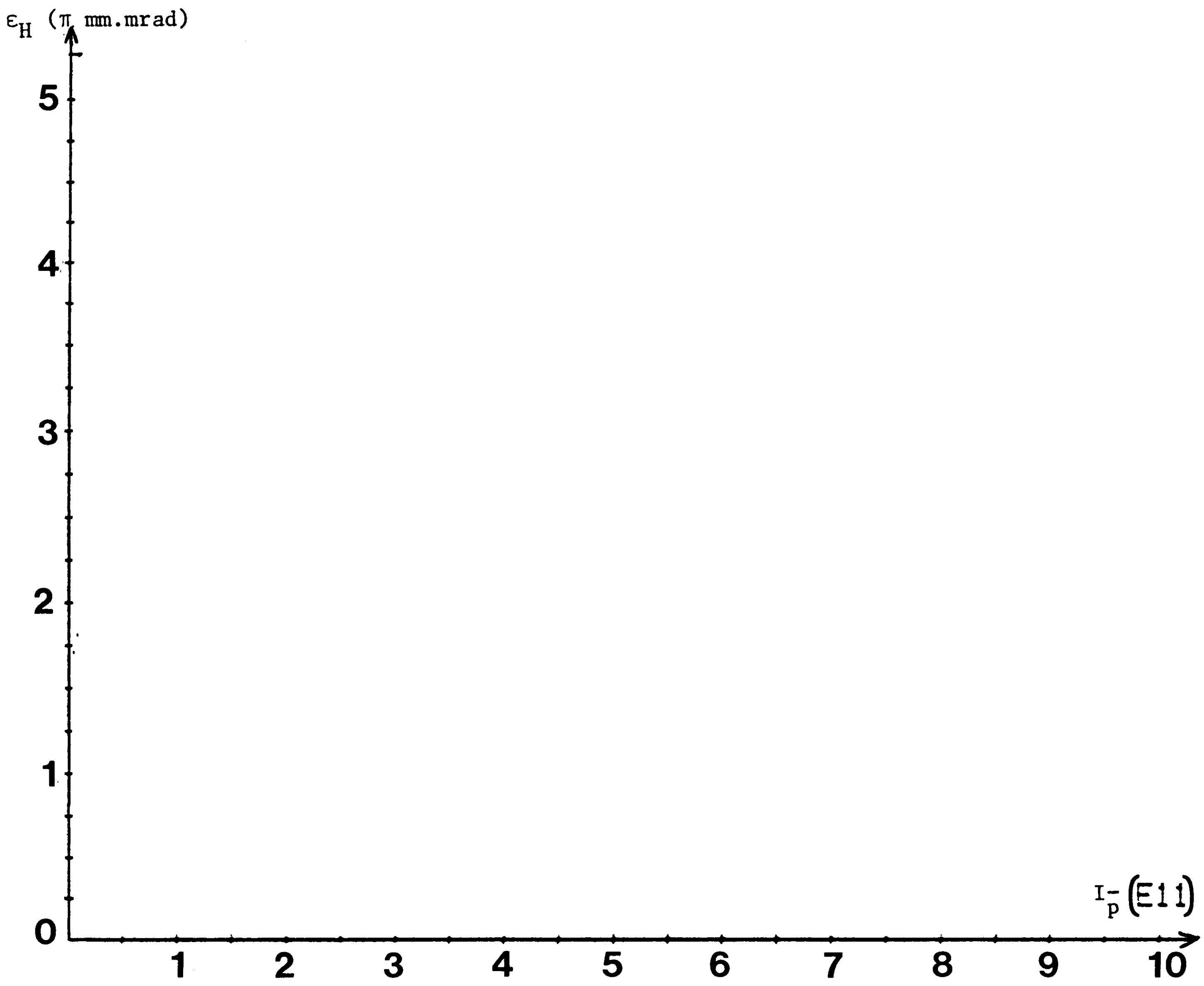


pbars E10
rate E9/h
Stacked
to SPS
Rate
L(1/nb)
Per day
stack record 1.035E12
120
100
80
60
40
20
0
start+KFA
Easter
AA septum
Tech stop
EdF change
Ps pulsed supplies
AA water leaks

Figure 1

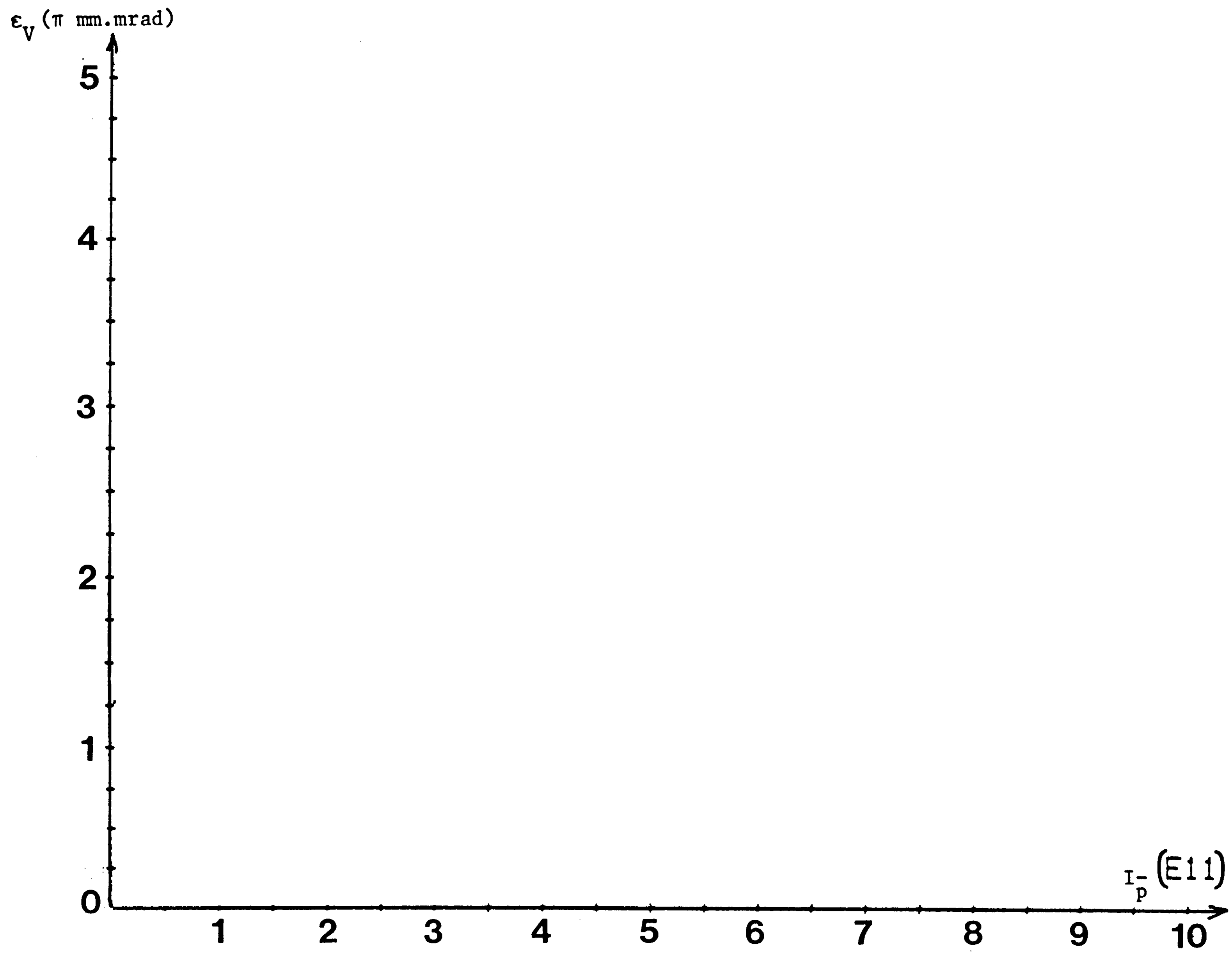


h
Week
BHZ2611S transformer + injection quadrupole (Easter week-end)
Septum water cooling
Change septum water cooling circuit
Figure 2
Faults during period 1



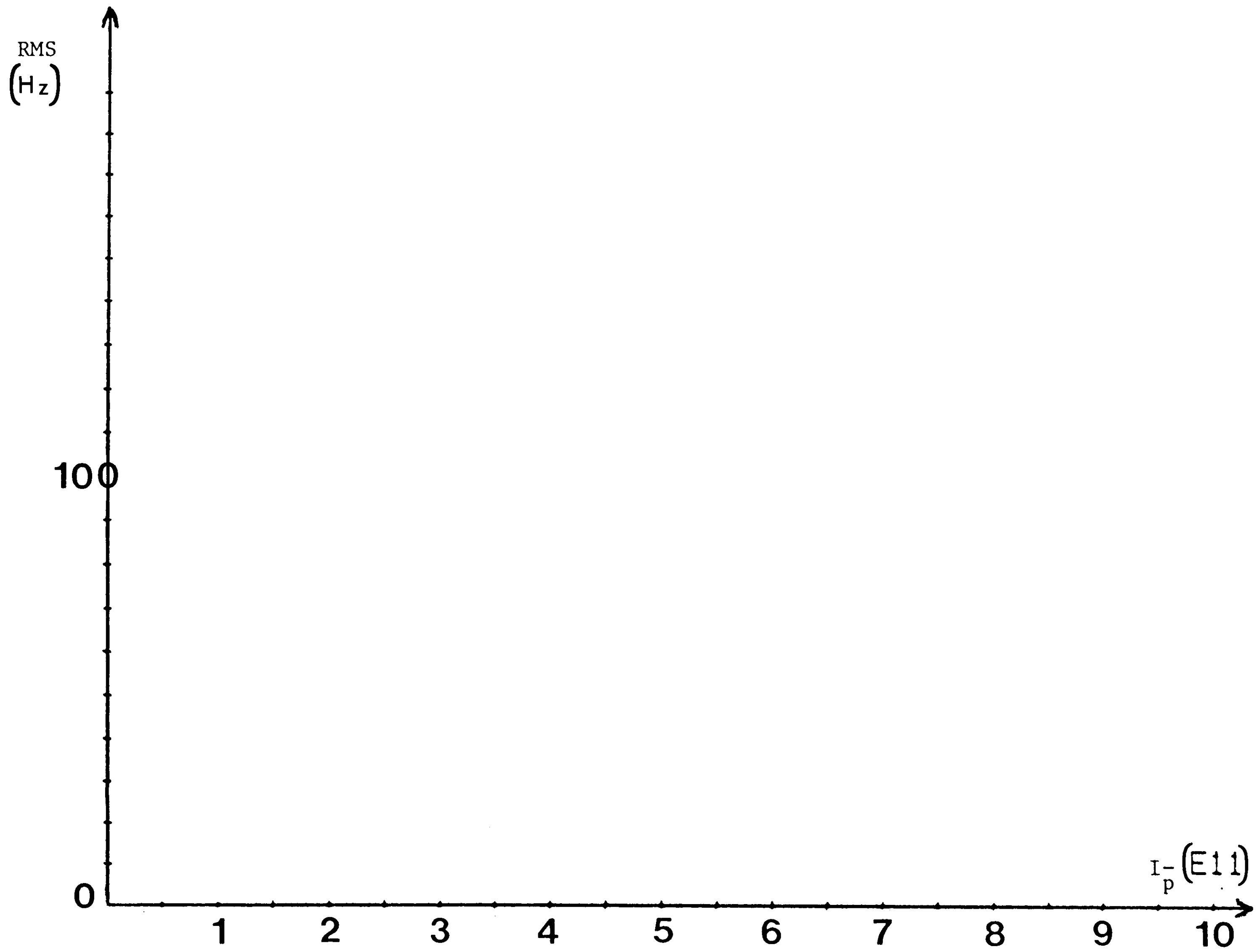
Horizontal emittance versus $\bar{p}$ intensity in AA

Figure 3



Vertical emittance versus $\bar{p}$ intensity in AA

Figure 4



Stack width (RMS) versus $\bar{p}$ intensity in AA

Figure 5

Distribution :

G. Adrian
E. Asséo
B. Autin
S. Baird
D. Boimond
J. Bosser
M. Bouthéon
E. Brouzet/SPS
R. Brown
X. Brunel
R. Cappi
G. Carron
F. Caspers
M. Chanel
J. Chevallier
V. Chohan
M. Conte
A. Dainelli
T. Eriksson
M. Frauchiger
R. Galiana
R. Garoby
R. Giannini
J. Guillaume
M. Guillon
H. Gundel
S. Hancock
L. Henny
G. Himbury
C.D. Johnson
J. Kewell
J. Kuczerowski
G. Le Dallic
R. Ley
M. Lubrano di S.
J.E. Lundmark

R. Maccaferri
E. Malandain
M. Martini
S. Maury
C. Mazeline
G. McMonagle
C. Metzger
D. Möhl
G. Molinari
F. Ollenhauer
Y. Orlov
J. Ottaviani
A. Pace
F. Pedersen
J.C. Perrier
T. Pettersson
B. Pincott
A. Poncet
J.-P. Potier
Y. Renaud
H. Riege
J.-P. Riunaud
C. Scheffre
J.-C. Schnuriger
R. Sherwood
L. Søby
Ch. Steinbach
M. Stetter
C.S. Taylor
L. Thorndahl
S. van der Meer
C. Vasseur
B. Williams
D.J. Williams
G. Yvon
K. Zioutas

Y. Baconnier
R. Billinge
E. Jones

BS: R. Rasmussen
H. Schönauer

LEAS: D. Manglunki
G. Tranquille

SM Linac: L. Bernard
H. Charmot
C. Dutriat
E. Tanke
J.L. Vallet

Gp Lds: B.W. Allardyce
J. Boillot
J.-P. Delahaye
J. Gruber
F. Pedersen
F. Perriollat
P.L. Riboni
K. Schindl
D.J. Simon

Associates: D. Blechschmidt
D. Dekkers
H. Haseroth
H. Koziol
P. Lefèvre
E.J.N. Wilson