PS/LP Note 92-13 5 June 1992

THE POSITRON PRODUCTION AT LIL

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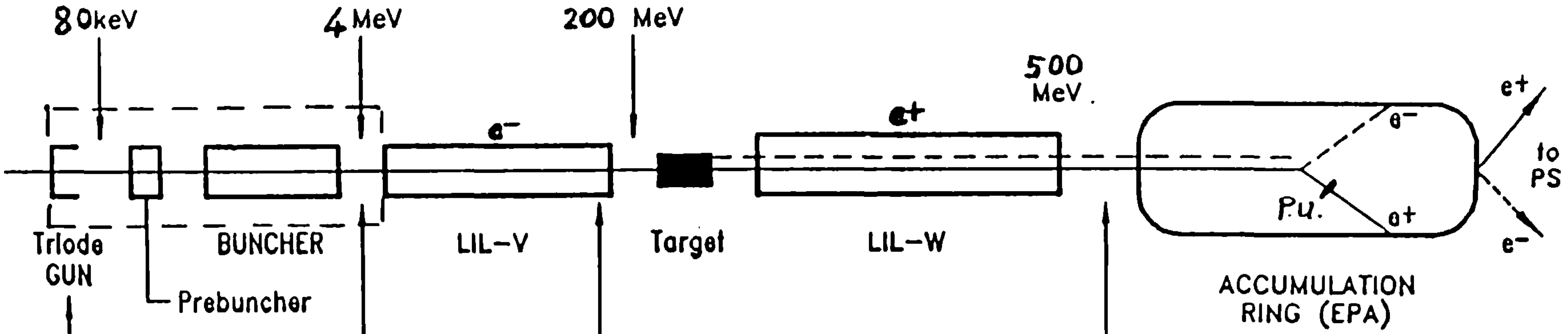
ESRF Workshop
Grenoble
4 June 1992.

Brief history

e^+ $\left(\frac{\Delta p}{p} = \pm 1\%\right)$

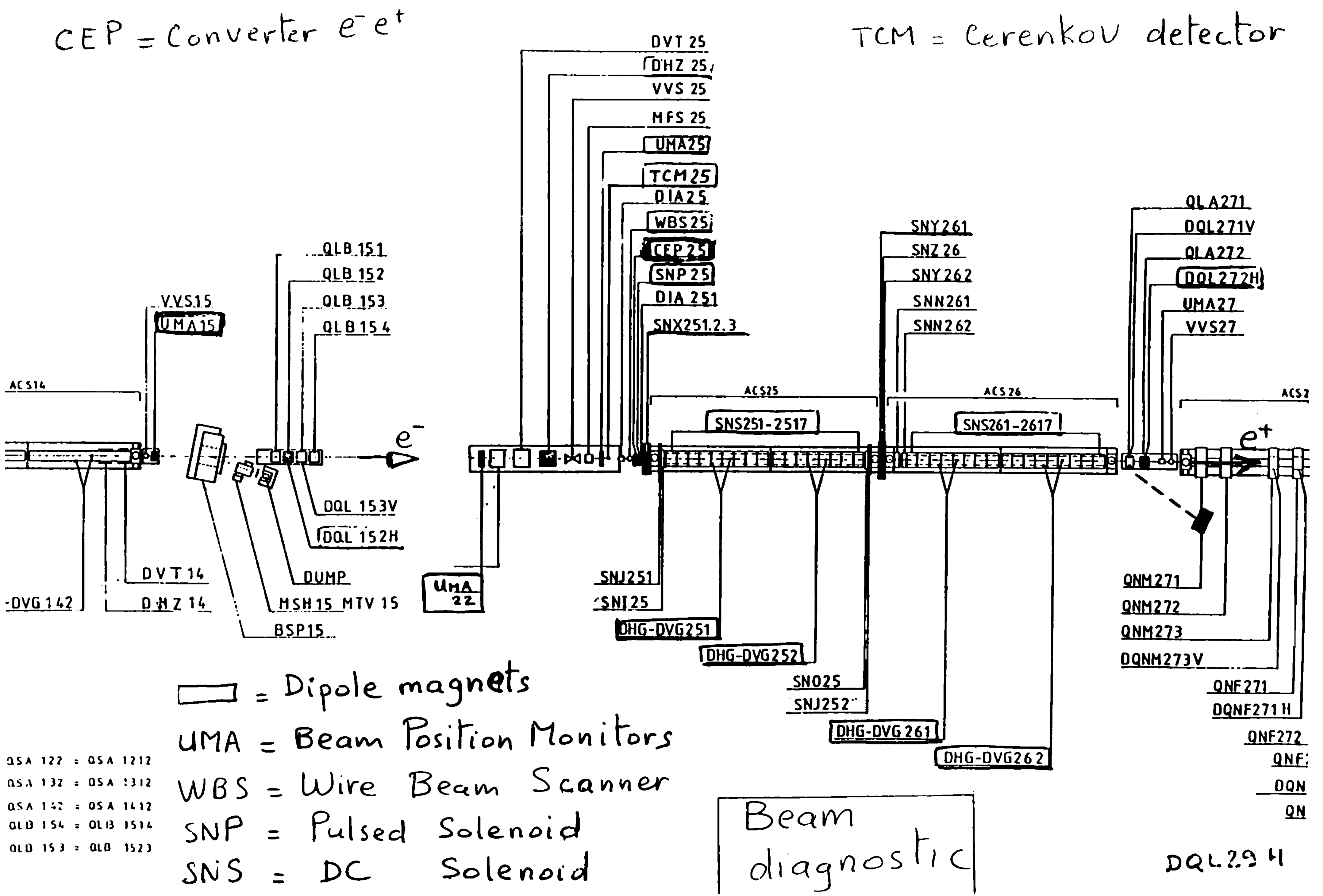
CERN – LAL Collaboration	March 1982	12 mA (Design)
First e^+ beam in LIL	March 1987	
First e^+ beam in LEP	July 1988	8 mA (Nominal)
Peak performances (old buncher)	December 1989	10 mA
New front-end in LIL	March 1991	12 mA

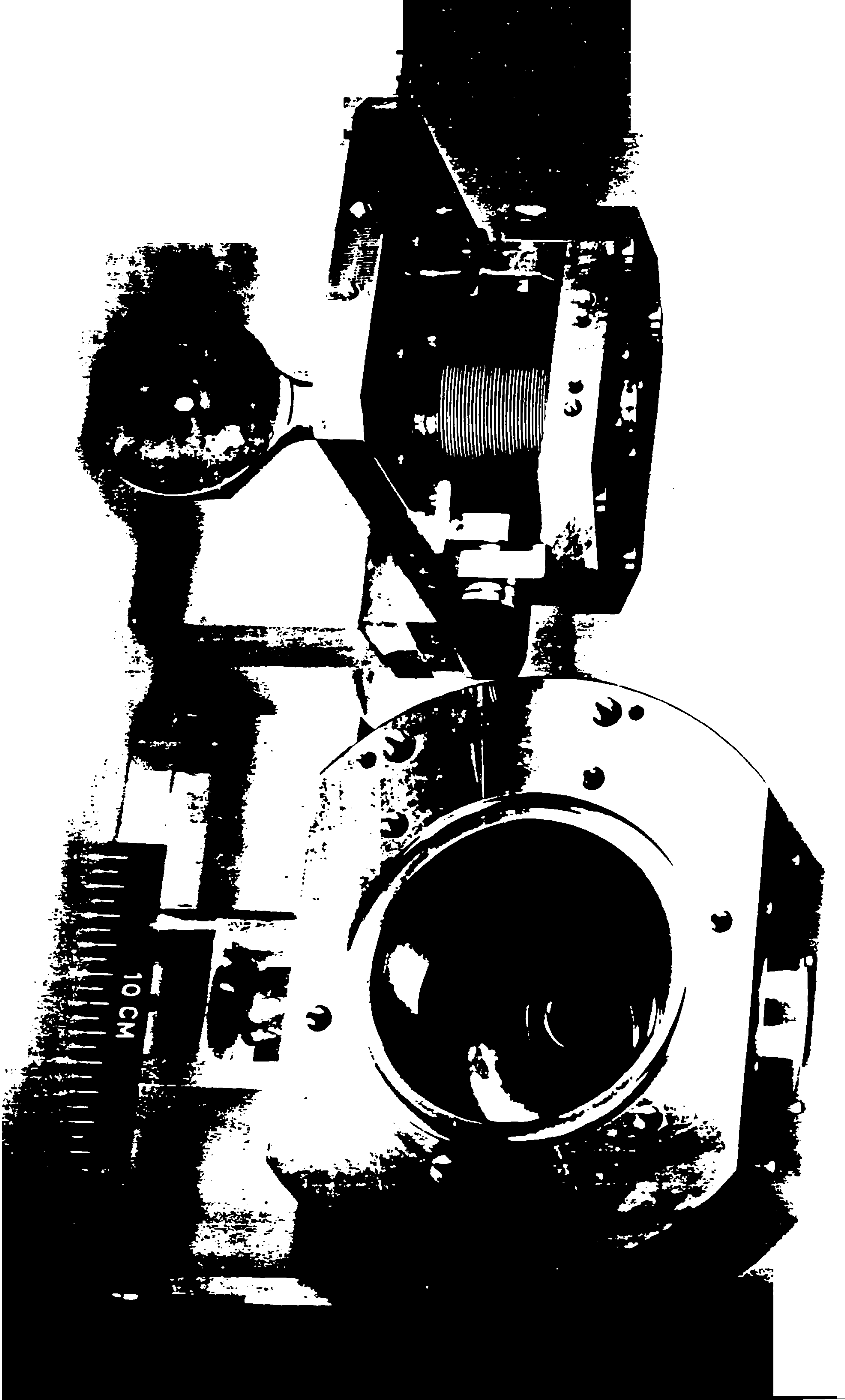
LIL Performance



53 nC	37 nC	30 nC	0.18 nC	Operation
2.6 A	1.85 A	1.5 A	9 mA	
$3.3\ 10^{11}$	$2.3\ 10^{11}$	$1.9\ 10^{11}$	$12\ 10^{8}$	
220 nC	130 nC	82 nC		Max values
$13.5\ 10^{11}$	$8.2\ 10^{11}$	$5.1\ 10^{11}$	$4\ 10^{8}$	

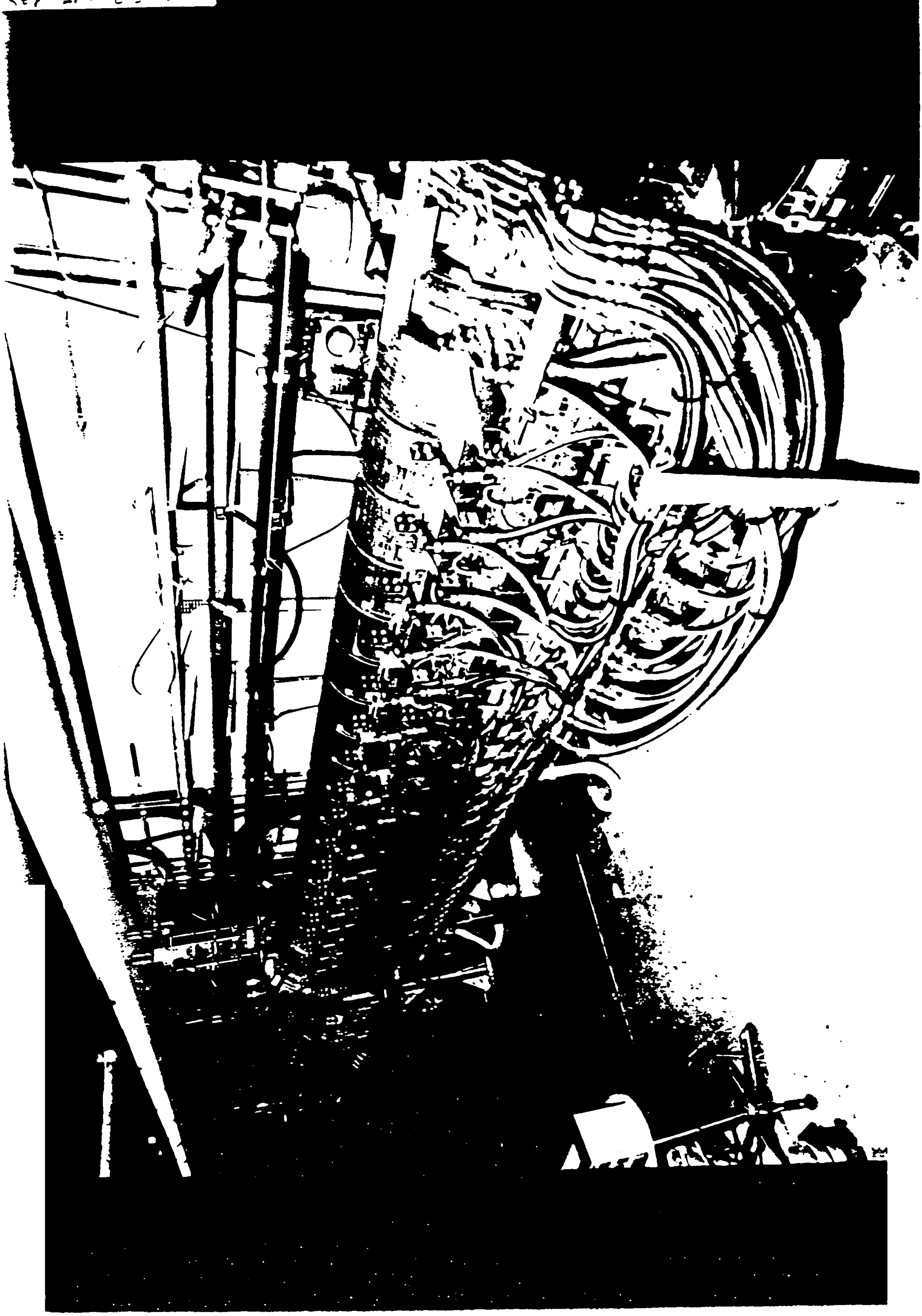
PU for e^+ (HiPUMA??)


CEP = Converter e⁻e⁺
TCM = Cerenkov detector
DVT 25
DHZ 25
VVS 25
MFS 25
UMA25
TCM25
DIA25
WBS25
CEP25
SNP25
DIA 251
SNX251.2.3
SNY261
SNZ 26
SNY262
SNN261
SNN262
QLA271
DQL271V
QLA272
DQL272H
UMA27
VVS27
ACS14
VVS15
UMA15
QLB 151
QLB 152
QLB 153
QLB 154
ACS25
ACS26
ACS2
SNS251-2517
SNS261-2617
e⁻
e⁺
DQL 153V
DQL 152H
DUMP
MSH15 MTV 15
BSP15
DVT 14
DHZ 14
-DVG 142
UMA 22
SNJ251
SNJ25
DHG-DVG251
DHG-DVG252
SNO25
SNJ252
DHG-DVG261
DHG-DVG262
QNM271
QNM272
QNM273
DQNM273V
QNF271
DQNF271H
QNF272
QNF
DQN
QN
= Dipole magnets
UMA = Beam Position Monitors
WBS = Wire Beam Scanner
SNP = Pulsed Solenoid
SNS = DC Solenoid
QSA 122 = QSA 1212
QSA 132 = QSA 1312
QSA 142 = QSA 1412
QLB 154 = QLB 1514
QLB 153 = QLB 1523
Beam diagnostic
DQL294

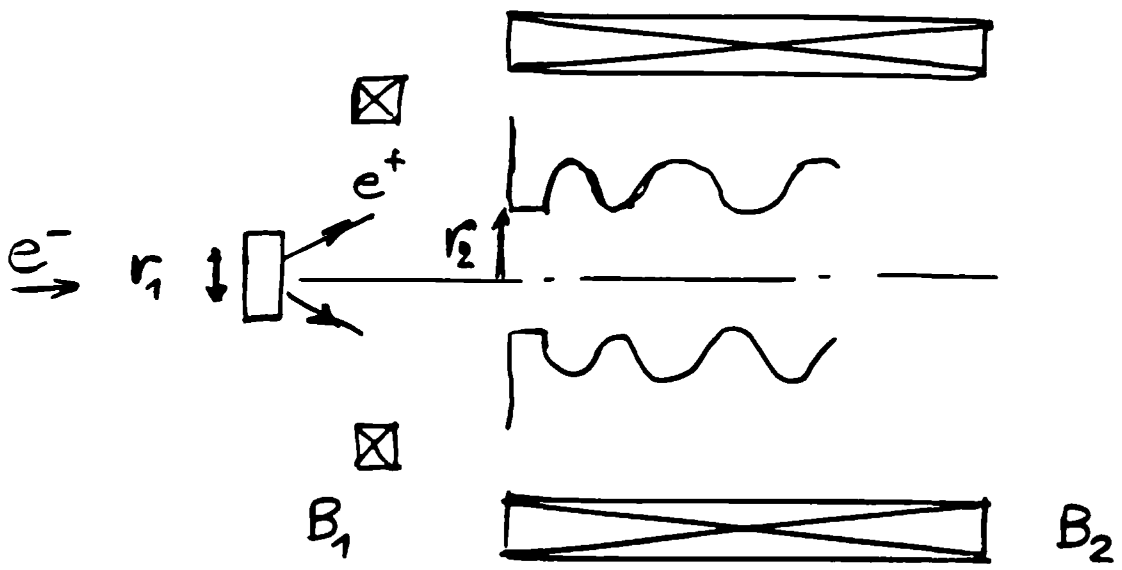


x558.1.84

Réf. LP: 0041



Theory



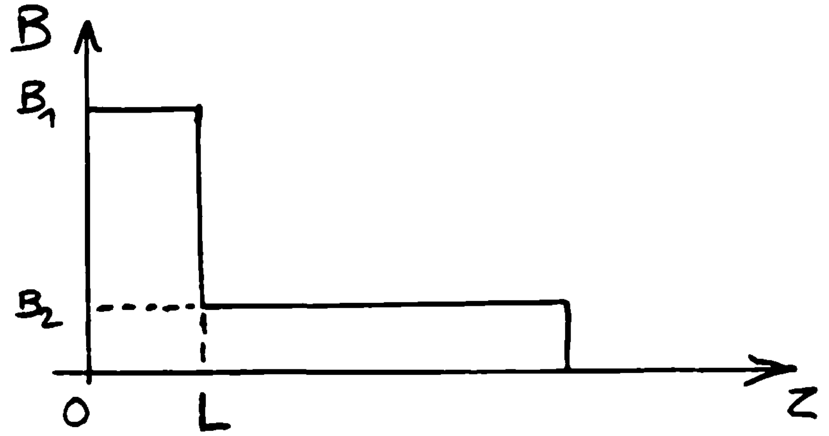
Acceptance $\quad A = \frac{c}{2} (r_2)^2 B_2$

Maximum transverse momentum

$$P_r = \frac{A}{r_1}$$

Matching condition

$$B_1 r_1 = B_2 r_2$$



Total momentum of e^+

$$P \approx \frac{r_2}{r_1} B_2 L$$

Momentum bandwidth

$$\Delta P \approx \frac{r_1}{r_2} P$$

Phase difference $(0 - P_r)$

$$\Delta \varphi \approx \frac{r_2}{r_1} \frac{A}{P}$$

Length L to match the beam for a total momentum P

$$L \approx \frac{P}{B_2} \frac{r_1}{r_2}$$

Simulations for LIL
e^+ capture

Mode	Case	RF-phase [deg.]	P [MeV/c]	r_1 [mm]	$I \cdot N$ [kA]	L [mm]	unres. yield $\cdot 10^2$	res. y ield $\cdot 10^2$
Accelerating	1	-17.5	5.3	3.4	35.0	44.0	1.22	0.48 *
	2	-17.5	9	2.0	70.0	44.0	1.56	0.54
	3	-17.5	5	1.6	137.3	0.3	2.33	0.88
	4	-17.5	5	1.8	83.4	7.4	2.11	0.81
	5	-17.5	5	2.0	66.6	12.4	1.91	0.70
	6	-17.5	6	1.6	78.7	14.7	2.06	0.79
	7	-17.5	6	1.8	67.6	20.0	1.89	0.78
	8	-17.5	6	2.0	60.3	24.9	1.72	0.66
	9	-17.5	7	1.6	80.3	21.0	2.09	0.86
	10	-17.5	7	1.8	71.6	26.5	1.89	0.78
	11	-17.5	7	2.0	65.6	31.7	1.80	0.76
Decelerating	12	182.5	5.3	3.4	35.0	44.0	1.20	0.66
	13	182.5	9	2.0	70.0	44.0	1.52	0.66
	14	182.5	5	1.6	137.3	0.3	2.23	1.18
	15	182.5	5	1.8	83.4	7.4	2.03	1.19
	16	182.5	5	2.0	66.6	12.4	1.86	0.98
	17	182.5	6	1.6	78.7	14.7	1.98	1.04
	18	182.5	6	1.8	67.6	20.0	1.80	0.99
	19	182.5	6	2.0	60.3	24.9	1.66	0.87
	20	182.5	7	1.6	80.3	21.0	1.90	1.00
	21	182.5	7	1.8	71.6	26.5	1.80	0.94
	22	182.5	7	2.0	65.6	31.7	1.71	0.91

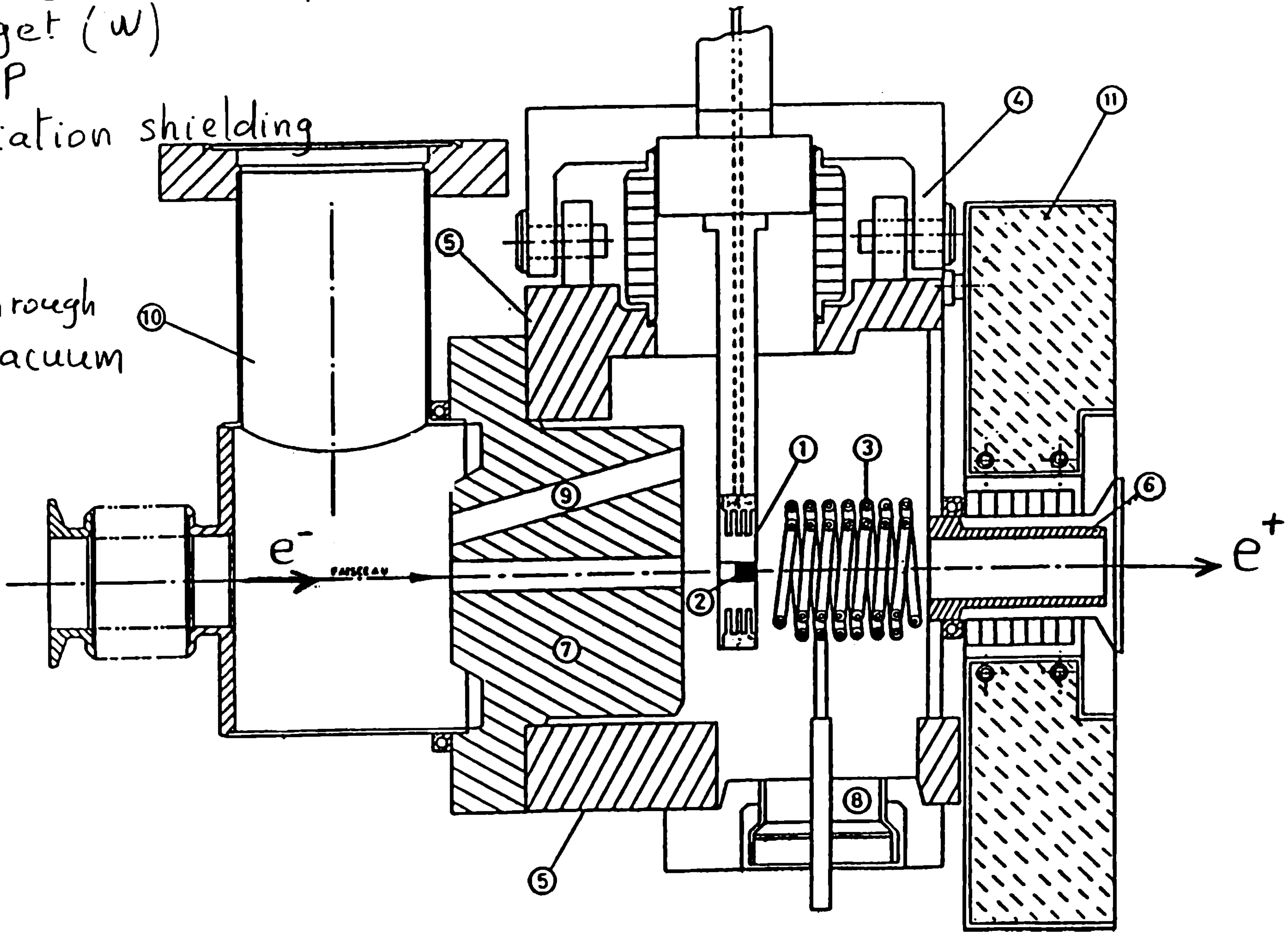
Table 1: Tracking results from H. Braun

- ☐ Present situation
- ☐ Design values
- ☐ New design

* Measured experimentaly 0.49

Convertisseur $e^- \longrightarrow e^+$

(1) Cooling in the copper
(2) Target (W)
(3) SNP
(6) (7) (11) Radiation shielding
(8) Feedthrough
(9) For vacuum
(10) WBS



Target	CEP 25
Material	Tungsten
χ_0 (mm)	3.5
Length (mm)	7
Diameter (mm)	5

97% W 2% Cu
1% Ni

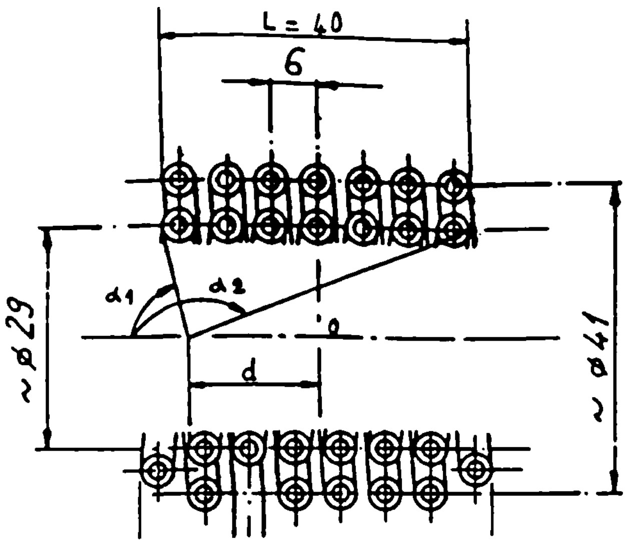
Pulsed solenoid	SNP 25
B_1 (T)	0.825
I (kA)	2.5
Length (mm)	44
Inner diameter (mm)	25
Number of turns	14

DC solenoid	SNL 25
B_2 (T)	0.36
I (A)	650
Length (m)	4
Inner diameter (mm)	180
Number of turns	95X17

Bridge coil	SNX 25
B_2' (T)	0.16
I (A)	650
Length (mm)	38
Inner diameter (mm)	360
Number of turns	14X4

Accelerating section	ACS 25
Iris radius r_2 (mm)	9
Electric field (MV/m)	9.5
Wave length λ_{RF} (cm)	10
Energy gain (MeV)	43
Klystron power (MW)	20

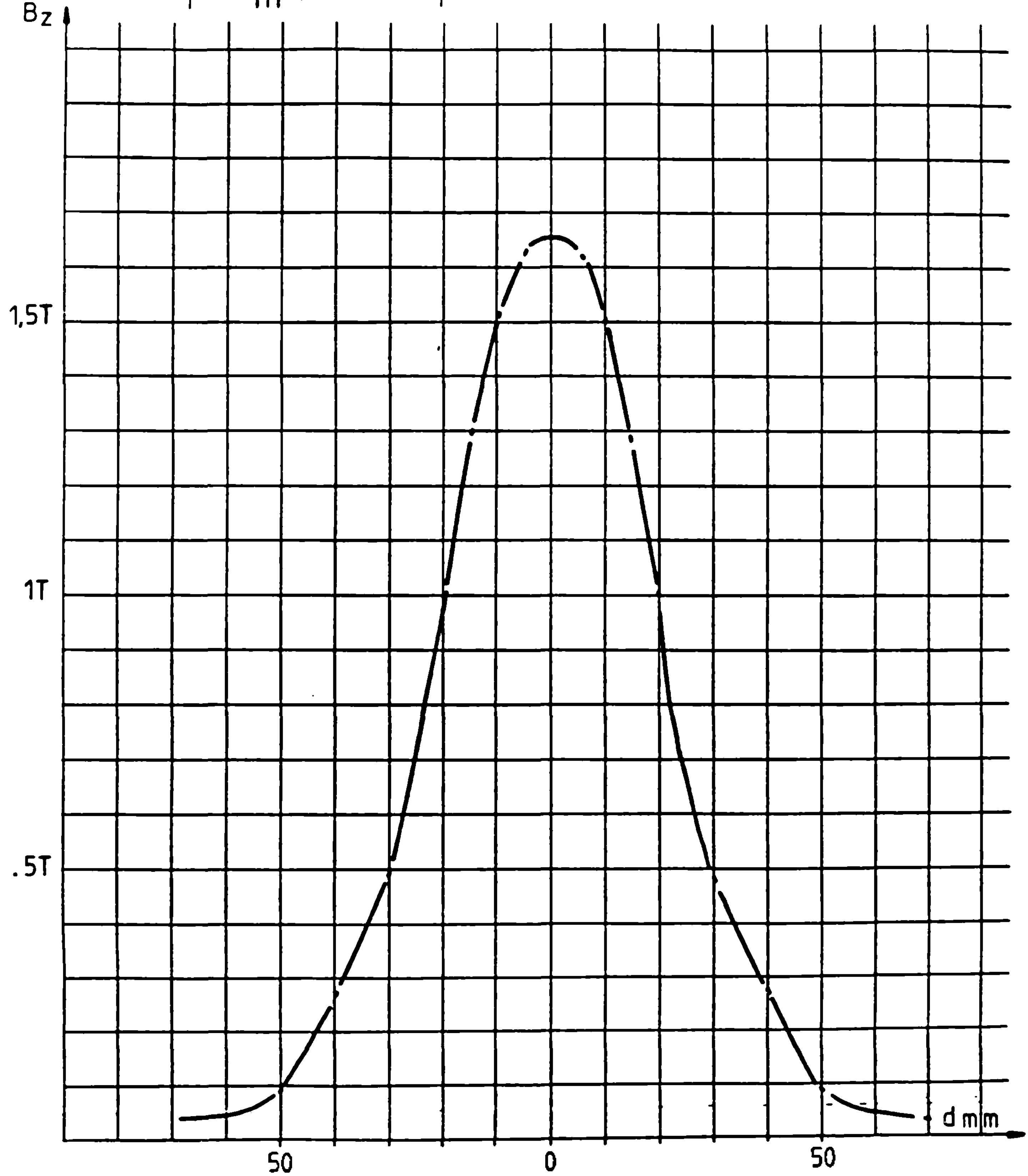
LIL positron production characteristics

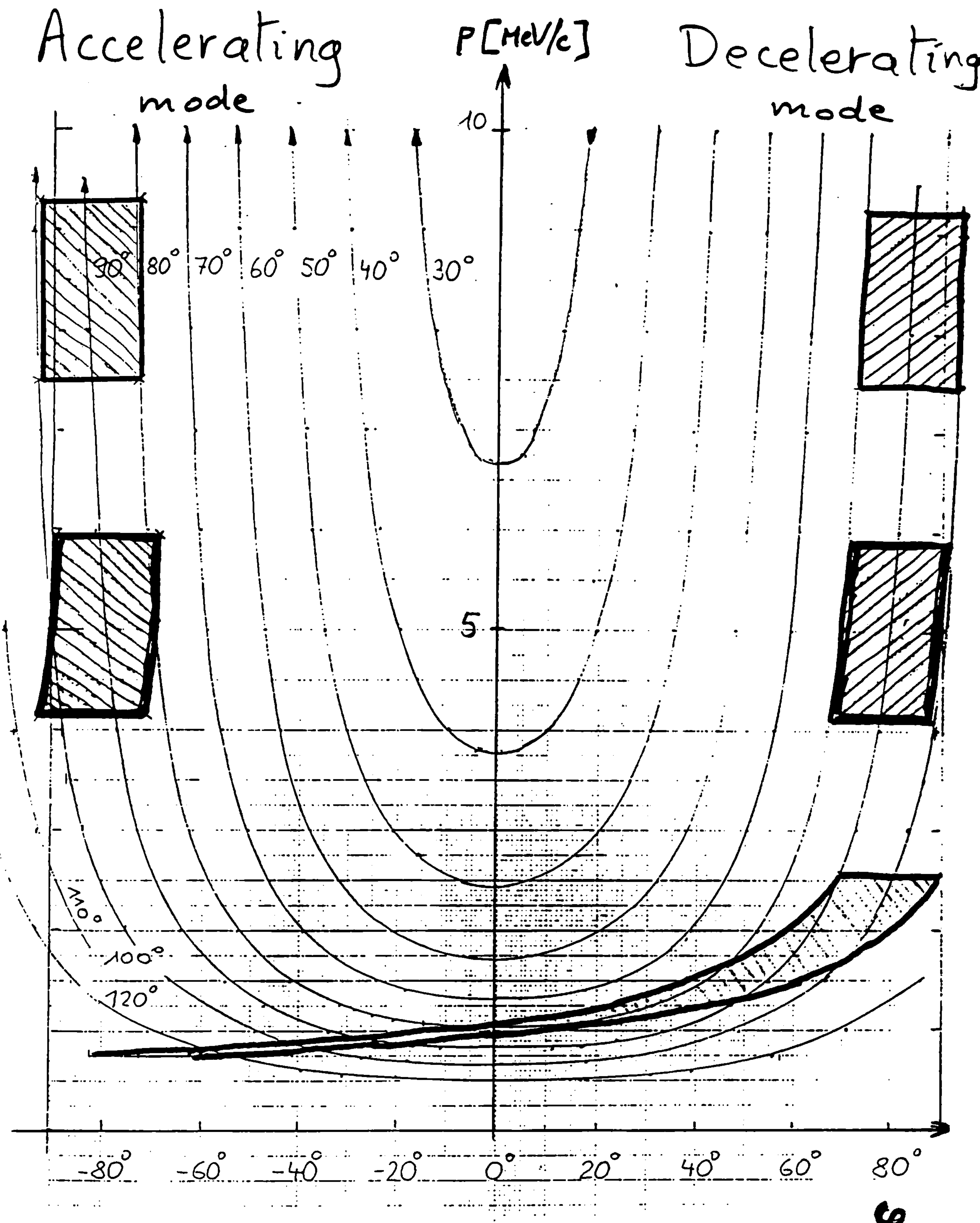


Calculations

$$H_z = \frac{NI}{2L}\,(\cos\alpha_1 - \cos\alpha_2)$$

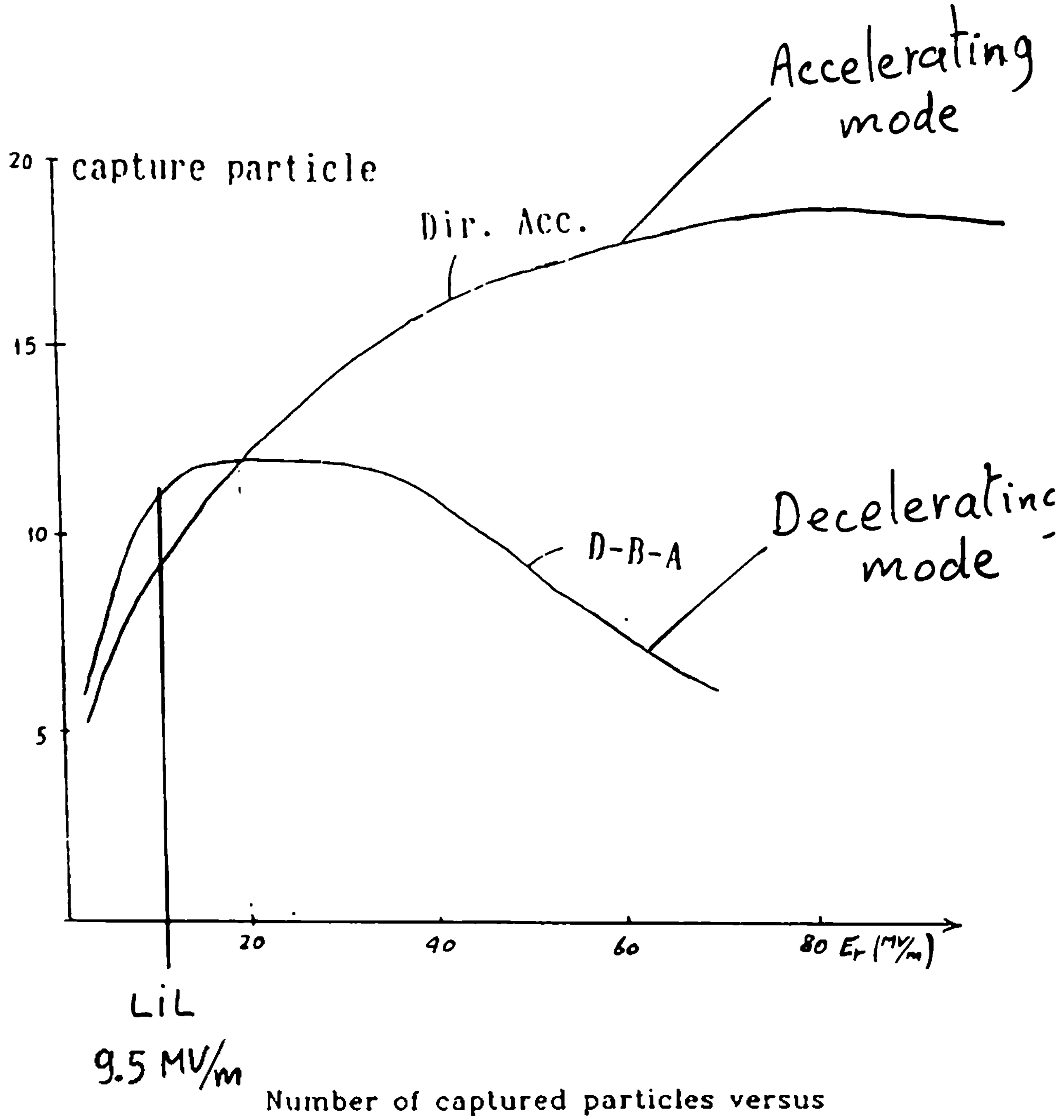
I=5000 Amp





Trajectories in long. phase space for E_z = 9.3 MeV/m and p_r = 0. Shaded areas correspond to input beam at I_1 = 5kA, **3kA**, 1kA from K. Hübn

(B_1 field)



Number of captured particles versus the field gradient. (A total of 30 probe particles)

Simulations (China)

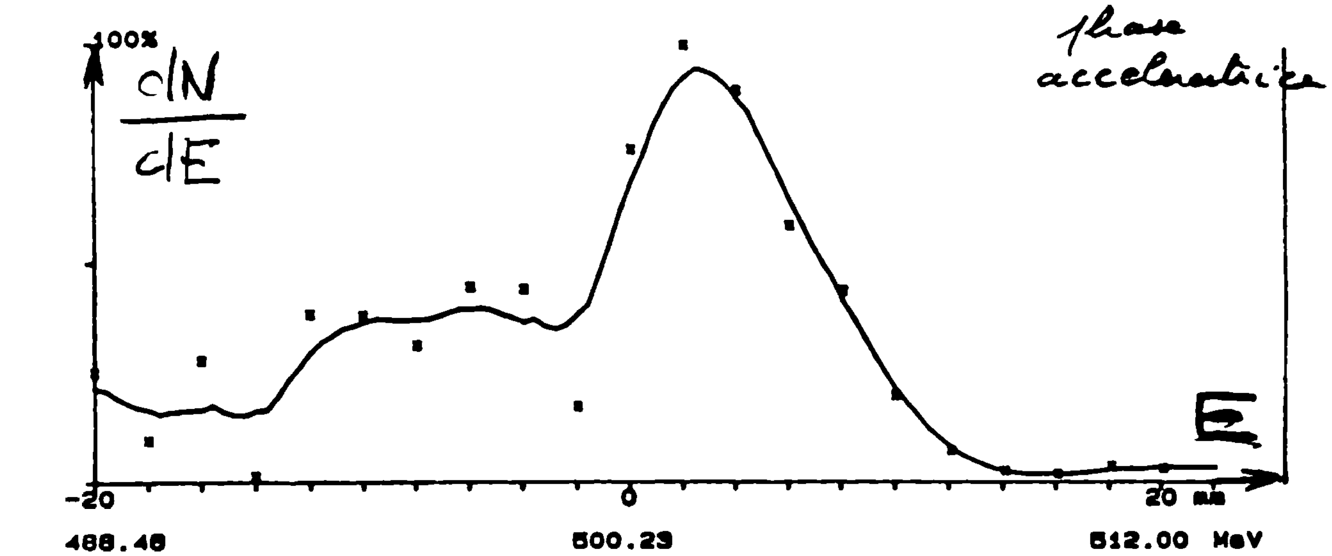
[Crude analytical model]

⑥ Mesure de l'énergie de capture des e^+

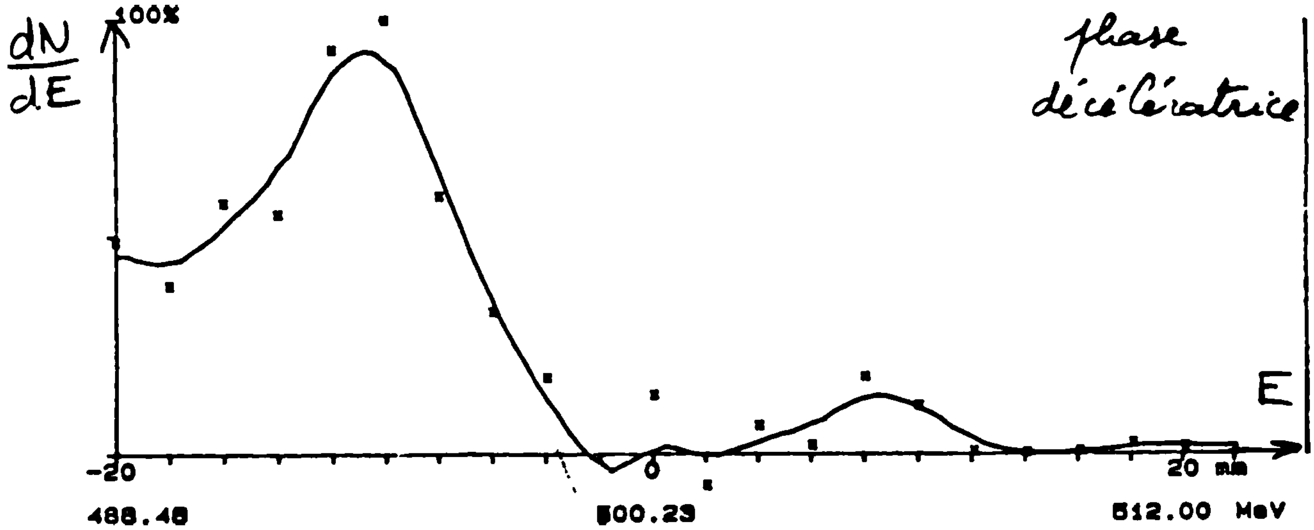
Spectre d'énergie en phase accélératrice
$E_{max} = 507$ MeV
Spectre d'énergie en phase décélératrice
$E_{max} = 498$ MeV

$\Delta E = \frac{9 \text{ MeV}}{2}$ = énergie de capture des e^+ = 4,5 MeV

BEAM PROFILE MEASUREMENT - HIP.MSH20



BEAM PROFILE MEASUREMENT - HIP.MSH20

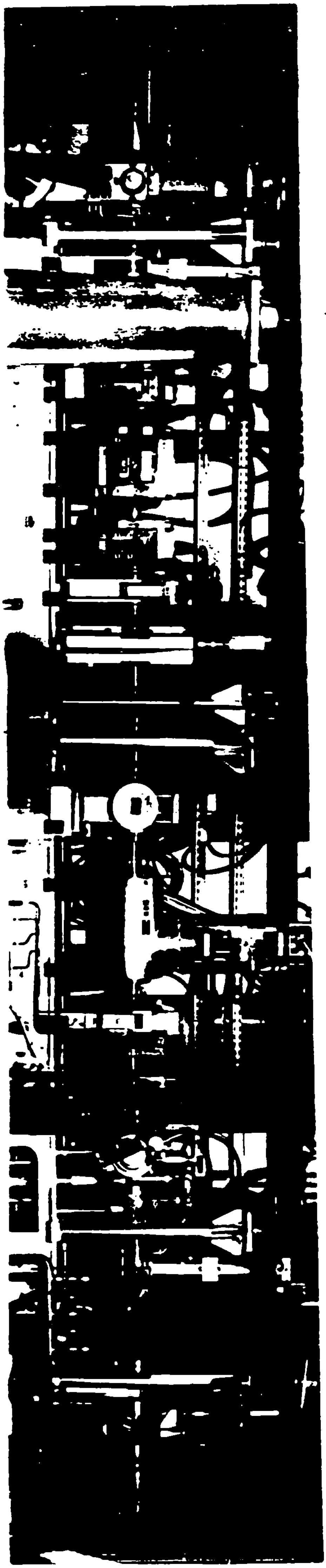


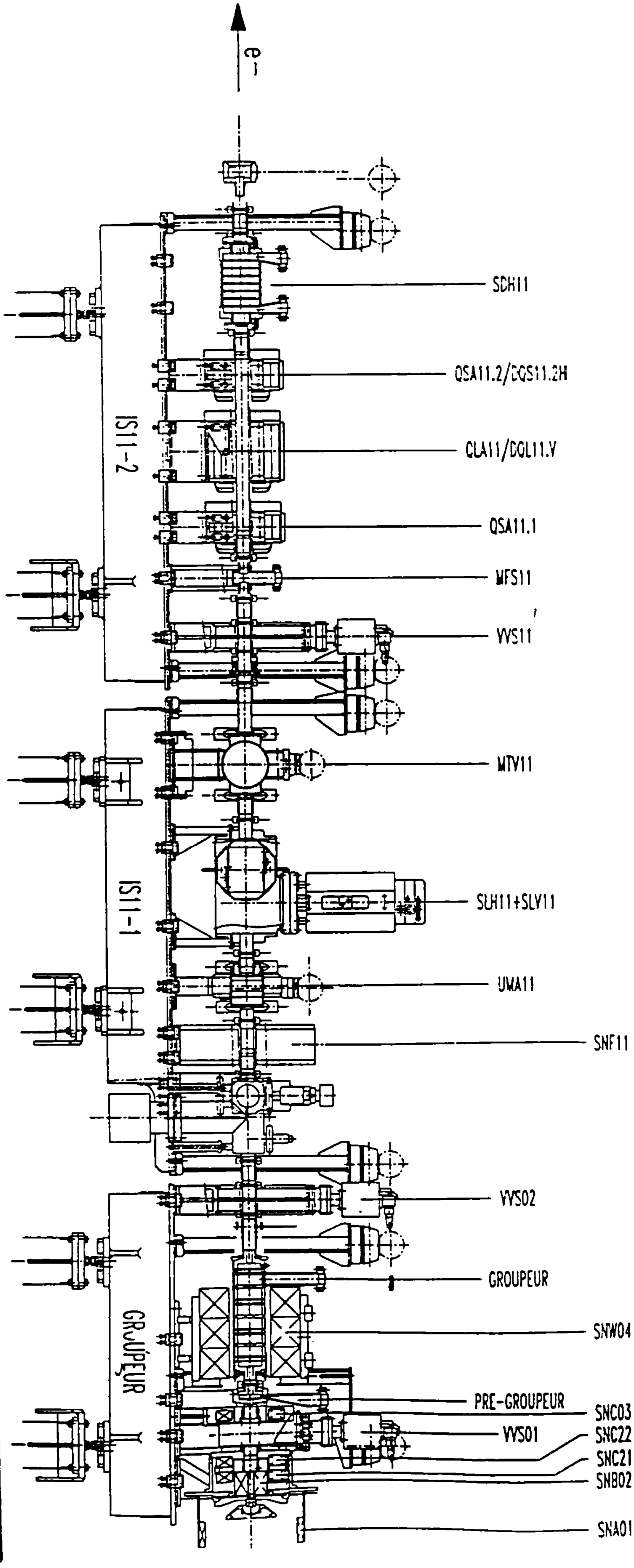
Central Energy 500.23 MeV

Digital Value at 100%   1388 (sat. 2047)

INTENSITY (UMA meas.)   8.78 1E8 part.

Number of measurements 100

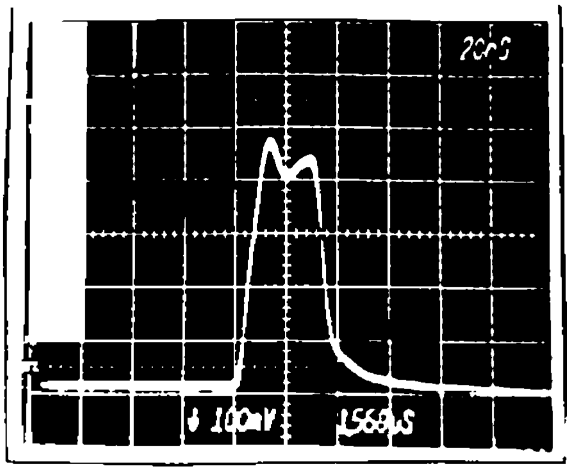




e−
SCH11
QSA11.2/DQS11.2H
QLA11/DQL11.V
QSA11.1
MFS11
VVS11
MTV11
SLH11+SLV11
UMA11
SNF11
VVS02
GROUPEUR
SNW04
PRE-GROUPEUR
SNC03
VVS01
SNC22
SNC21
SNB02
SNA01
IS11-2
IS11-1
GROUPEUR

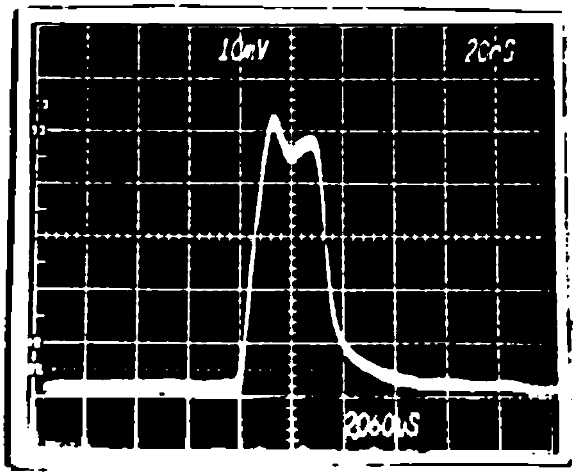
		LIL Front-End	
		1991 (New)	1989 (Peak Performance)
Gun energy	keV	80	70
Buncher output energy	MeV	4	28
No-load energy at the target	MeV	204	228
$\Delta E/E$ (full width at the base)	%	±6.6	±8
Transmission efficiency:			
- Bunching system 50 nC	%	67	66
- Bunching system 30 nC	%	72	61
- Bunching system 2 nC	%	77	56
- LIL primary beam 50 nC	%	75	76
- LIL primary beam 30 nC	%	83	83
- LIL primary beam 2 nC	%	90	90
Maximum charge at the target (e^-)	nC	83	48
For figures below, charge = 32 nC			
Beam sizes at FWHH			
- Horizontal	mm	1.0	1.0
- Vertical	mm	1.0	2.5
Unresolved yield (e^+ / e^-)	10^{-3}	6.4	5.7
Resolved yield $\frac{(e^+)}{(e^-)}$, $for \frac{\Delta E}{E} = \pm 1\%$	10^{-3}	4.9	4.3
Normalized yield $\frac{(e^+)}{(e^- \times GeV)}$, $for \frac{\Delta E}{E} = \pm 1\%$	10^{-2}	2.40	1.95

Analog signal e^+ ≡ Analog signal e^-



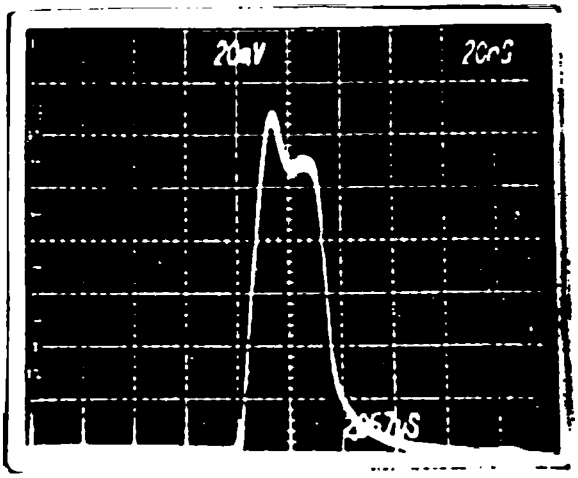
e^- at the Buncher output

VL. UMA 11



e^+ at the end of linac

HiP. UMA 22



Same signal after optimization

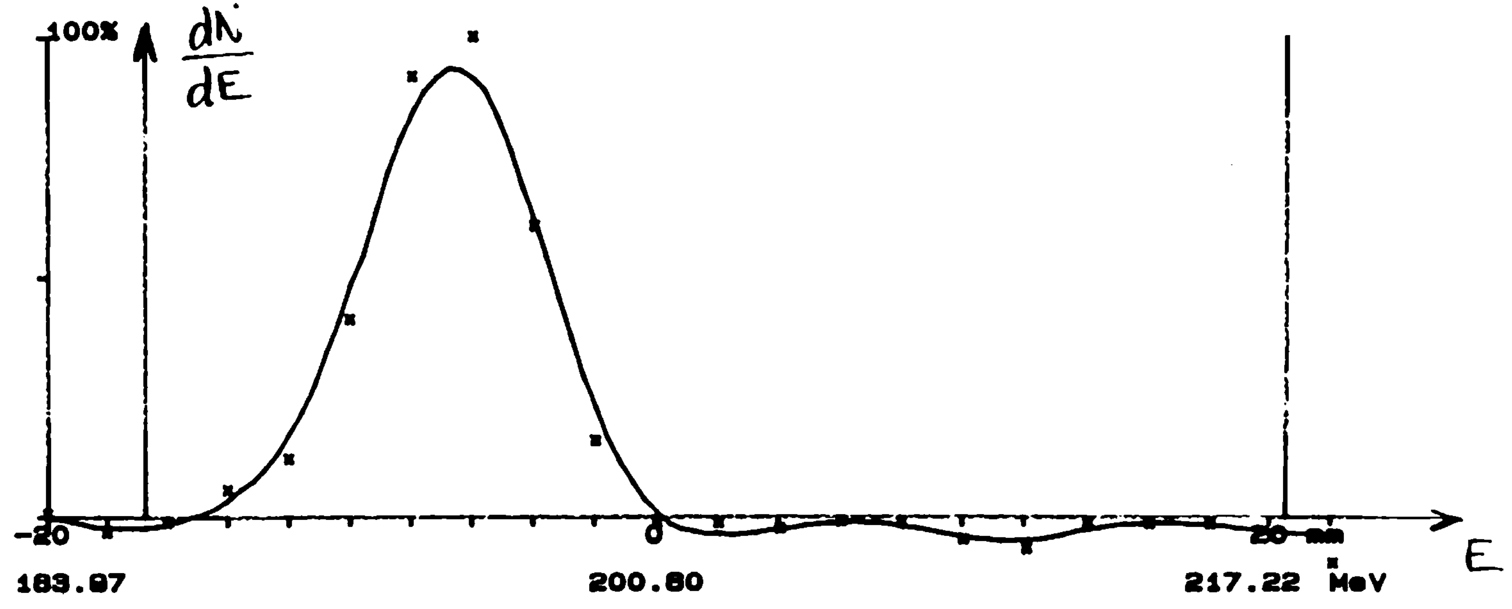
$\Sigma = 11.10^8 \ e^+$

$\Delta H = 0.7$ mm

CONSOLE - GRAPHIC SYSTEM HARD-COPY

20/MAR/1991-23:16:13
YVETTE (LPI)

BEAM PROFILE MEASUREMENT - VL.MSH15



Energy spectrum of primary beam

Low charge

($1.2 \cdot 10^{10}$ e^-)

Central Energy 200.80 MeV

Digital Value at 100% 481 (sat. 2047)

INTENSITY (UMA mess.) -10.32 1E8 part.

Number of measurements 51

DE: 10.26MeV DE/E: 5.118%

Gain is .01

Scraper VL.SLV11 (Top) : -18.7(-18.5) mm

(Bottom) : 18.4(18.4) mm

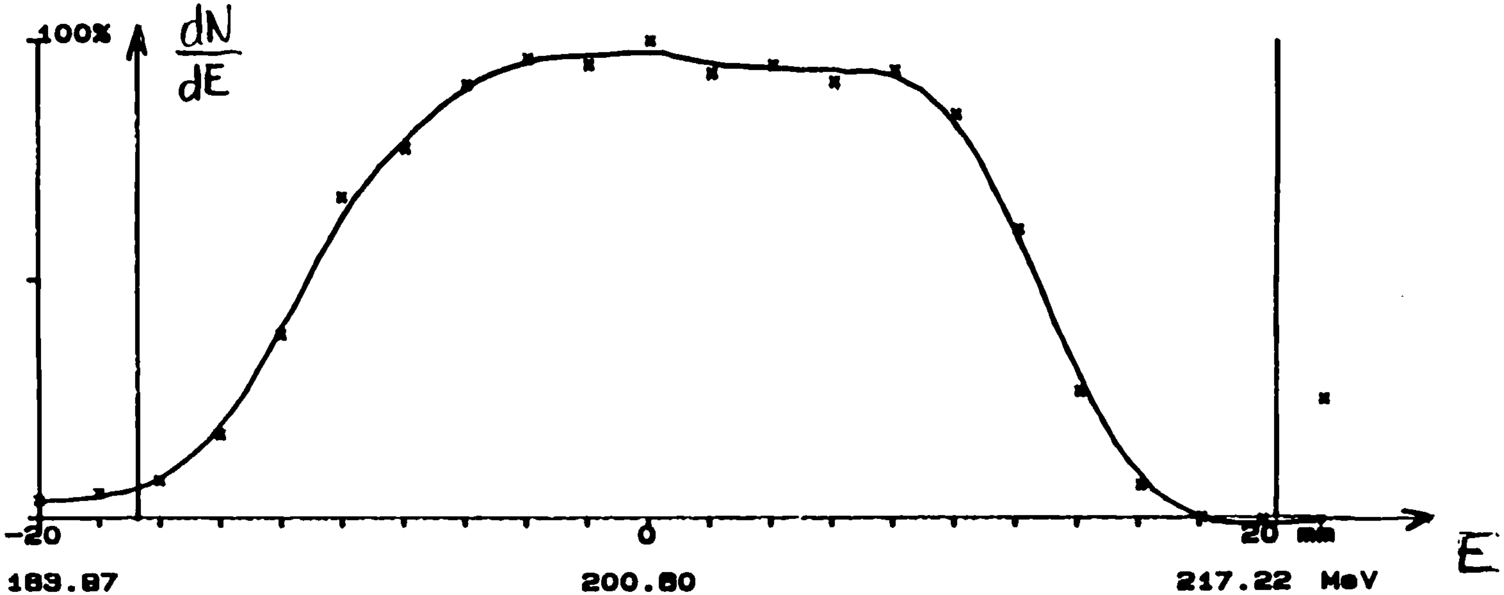
$\frac{\Delta E}{E} = \pm 1.1\%$

(at the base)

CONSOLE - GRAPHIC SYSTEM HARD-COPY

20/MAR/1981-10:40:40
YVETTE (LPI)

BEAM PROFILE MEASUREMENT - VL.MSH15



Central Energy 200.80 MeV

Digital Value at 100% 1343 (sat. 2047)

INTENSITY (UMA meas.) -113.92 1E8 part.

Number of measurements 100

DE: 12.58MeV DE/E: 6.279%

Gain is .01

Scraper VL.SLV11 (Top) : -18.7(-18.5) mm

(Bottom) : 18.4(18.4) mm

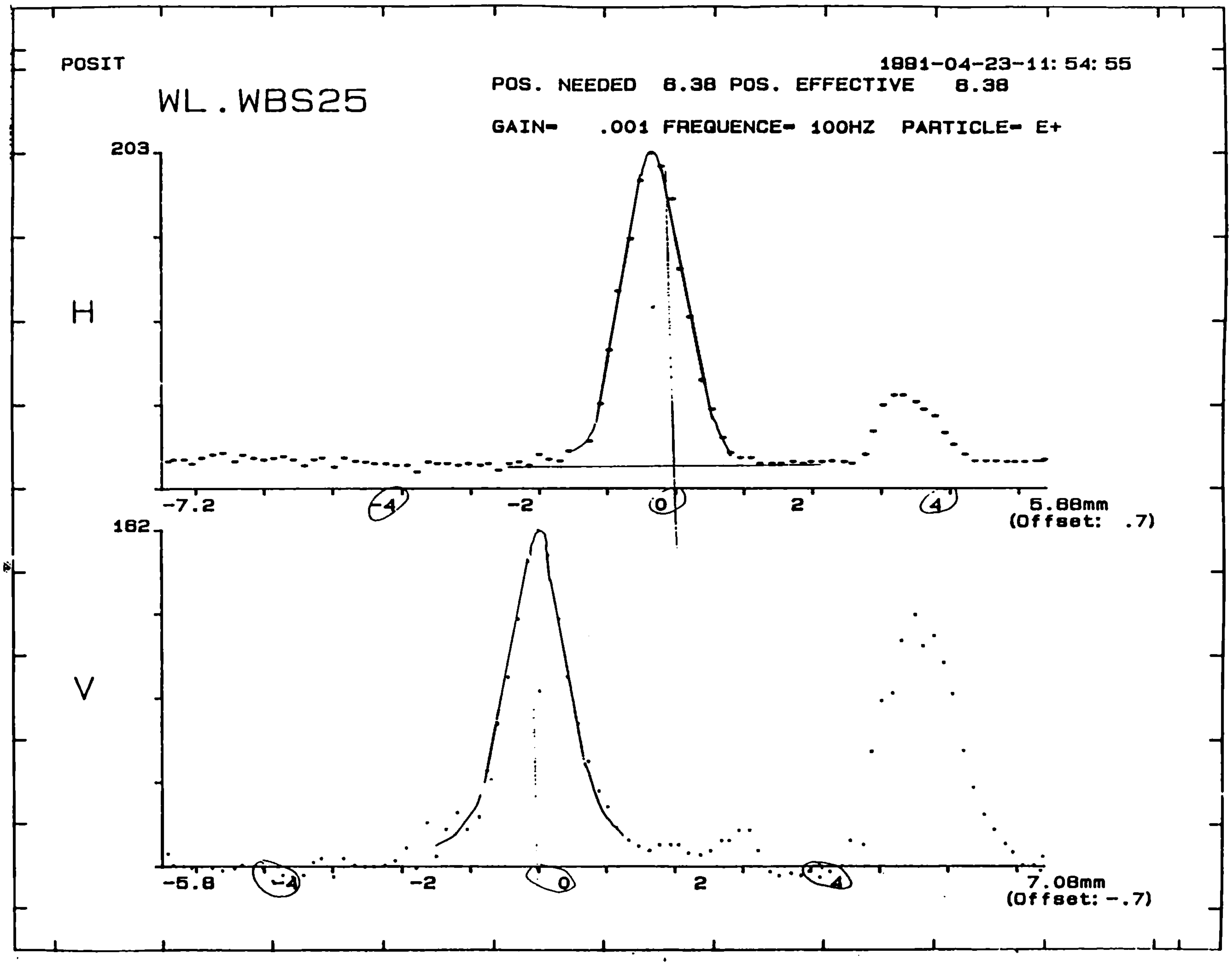
Energy spectrum of primary beam

High charge ($1.8 \; 10^{11} \; e^-$)

$\frac{\Delta E}{E} = \pm 6.6\%$ (at the base)

CONSOLE - GRAPHIC SYSTEM HARD-COPY

YVETTE (LPI)



Horizontal

H = 1.04 mm
(FWHM)

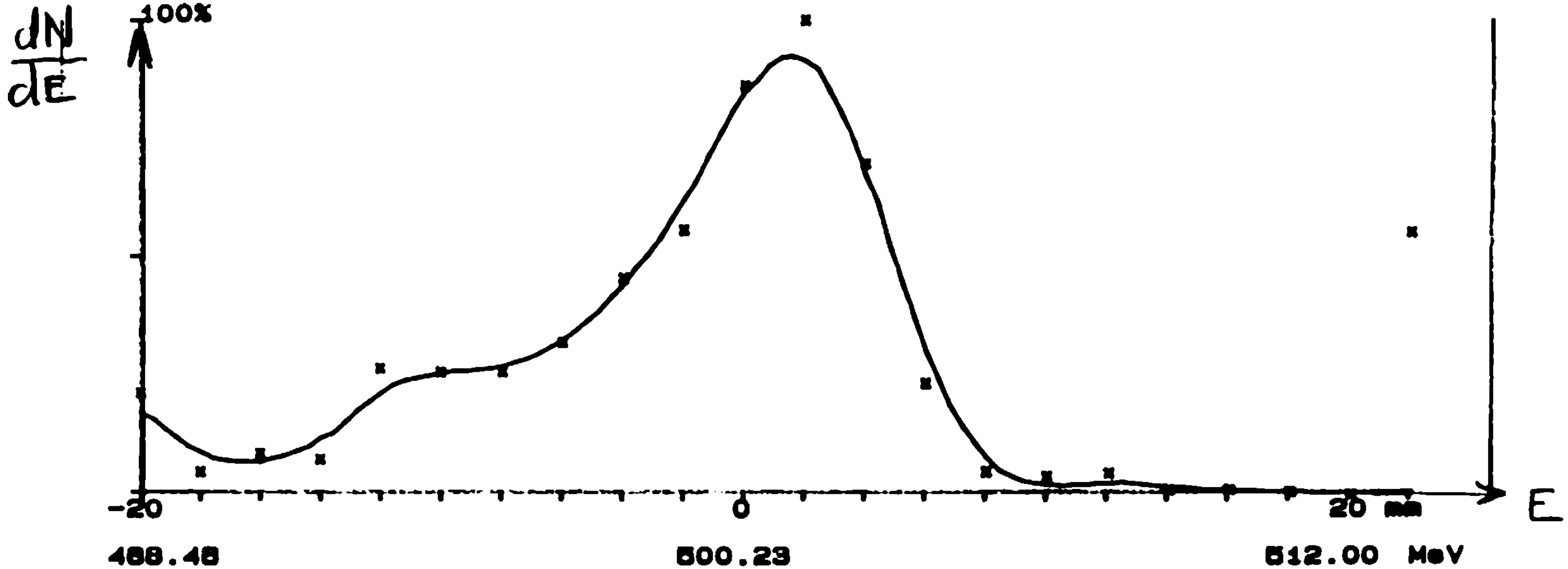
Vertical

V = 1.04 mm
(FWHM)

CONSOLE - GRAPHIC SYSTEM HARD-COPY

22/MAR/1991-18:14:44
YVETTE (LPI)

BEAM PROFILE MEASUREMENT - HIP.MSH20



Energy spectrum of e^+ beam

$(10.5\ 10^8\ e^+)$

Central Energy 500.23 MeV

Digital Value at 100% 256 (sat. 2047)

INTENSITY (UMA meas.) 13.50 1E8 part.

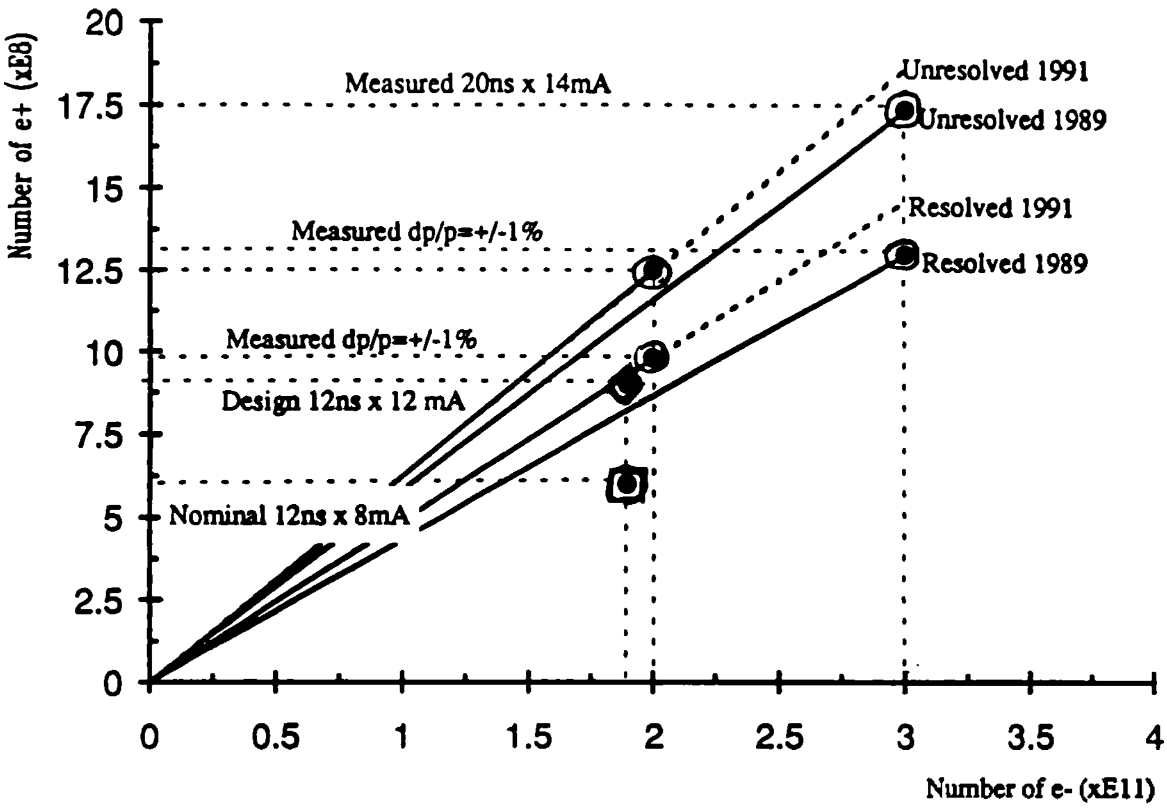
Number of measurements 100

DE: 7.73MeV DE/E: 1.545%

Gain is .1

Scraper HIP.SLH20 (Aperture) : 49.8 (50) mm

(Position) : 0 (0) mm



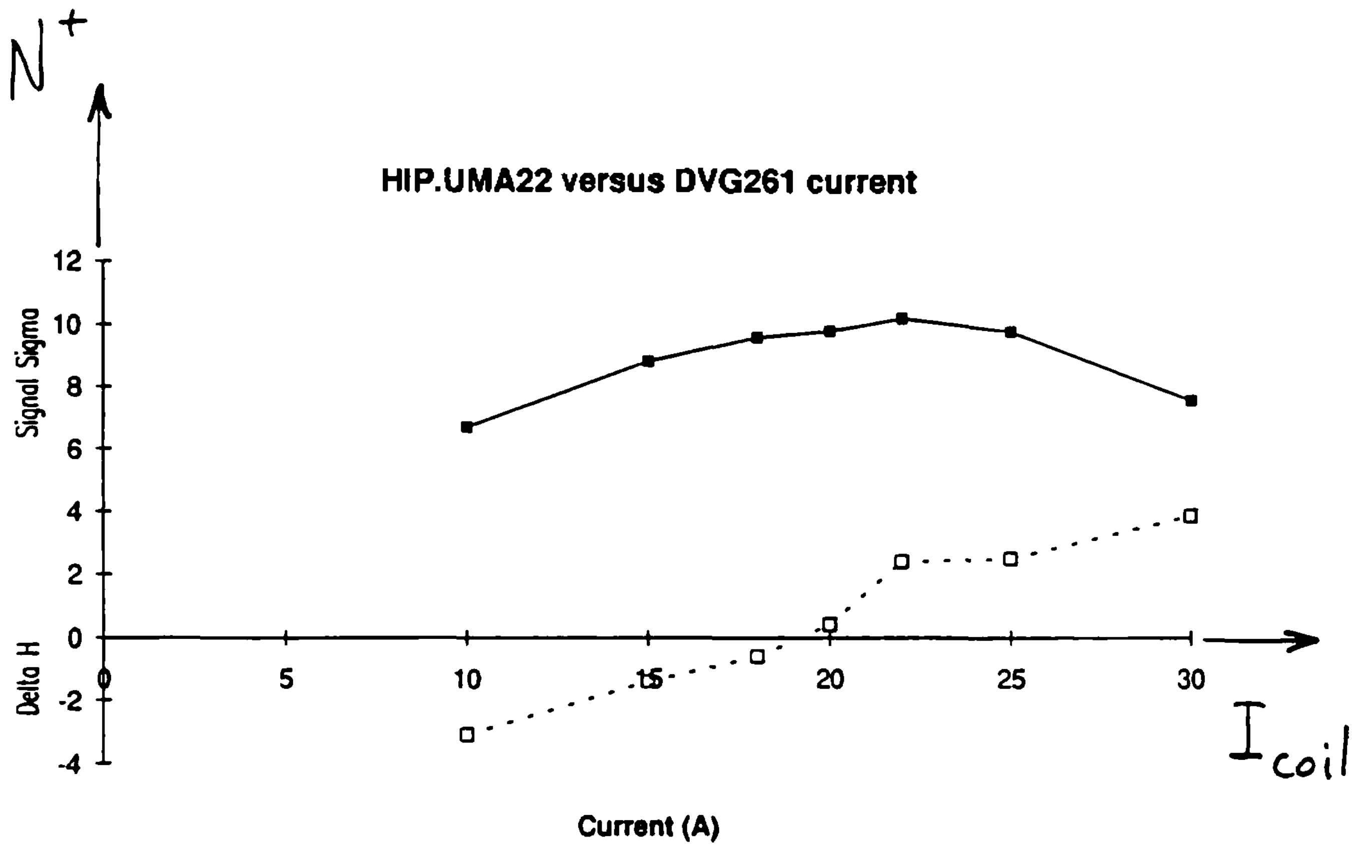
○ Measured

◇ Design

□ Nominal

Future improvements

- Pulse solenoid rigid (6 kA) (100 Hz)
- Short solenoid (increase P_r)
- Correction coils (along B_z field)
- Distance target - pulsed solenoid



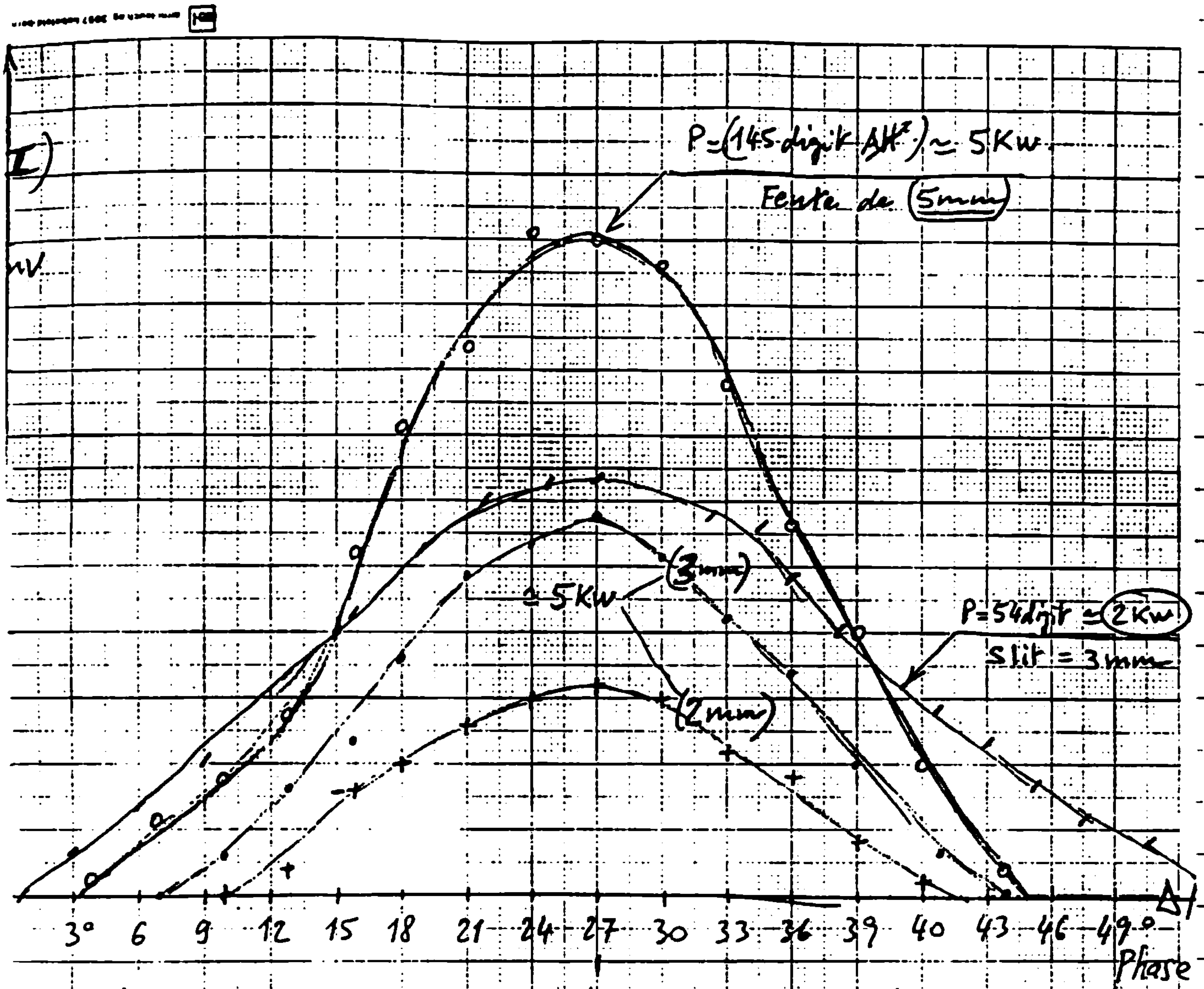
3 correcting coils adjusted provides 10% more e^+!

New developments

- Microbunch measurements
  - 4 MeV (RF deflecting structure)
  - 200 MeV (Cerenkov radiations)
- Test stand
  - Power supply with thyristors
    6 kA 40 µs 100 Hz
- Spectrometer line for e^+
  - 10 m downstream converter
    80 MeV
- Chicane
  - only e^+ along the linac
- Independant phasing on the 1st e^+ accelerating section

(microbunch)

Mesure de la longueur du bunch



L'échelle du scope étant de 5 mV/div (mini), il était difficile d'être précis dans les faibles valeurs de courant.

Avec la fente ouverte à 5 mm et une puissance de 5 kW, on mesure

$\Delta\varphi \simeq 34°$ à la base

Proposition pour le prochain MD

- Diminuer la ε_y du faisceau (optique 4 Mel)
- Augmenter la transmission
- Augmenter la sensibilité du WCM 12
- Augmenter la puissance dans SDV 11

Positron Working Group at CERN

C. Bourat (CGR_MeV)

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R. Pitthan (SLAC)

L. Rinolfi (CERN) (Convener)

M.A. Tordeux (LURE)

Conclusion

1) Improve the reliability for LEP physics

2) Increase the e^+ production at low cost

3) Preparation of a project to get a factor 2 on the positron accumulation

4) Positron Working Group at CERN