PS/LP Note 93-47 (Min)
07/07/93

SOME COMMENTS ON THE RESULTS OF THE CTF RUN NO.1 1993

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1. GENERAL

Start : 19th April

End: 4th June

The beamline is the same as used end last year. See PS/LP Note 93-17, fig. 2 and 3. The same gun - identified by gun 3a - was used as well.

Photocathode : CsI

Laser: 209 nm , energy per pulse at the output of the laser system 70 - 80 10^{-6} μJ at the beginning, energy jitter pulse to pulse ± 30% , pulse length 15 ±2 ps FWHH, after using another flashlamp 1 timing and voltage the energy jitter became ± 12% for 92 10^{-6} μJ, see logbook p. 150.

Vacuum in chamber downstream of gun: VGI04 9 10^{-10} / 1. 5 10^{-9} T without/with RF.

The following new facilities eased the experimental work:

- scope to measure the 30 GHz from the TRS in the control room (HCR),
- large tv monitor for streak camera signal in the HCR,
- programmed scan of laser phase with beam charge acquisition, data treatment and plot of results,
- programmed scan of phase between gun and LAS by keeping the laser phase constant.

2. OBJECTIVES OF THE RUN

- test the laser pulse train generator (PTG) based on 45°. splitting
- measurements on a single bunch to make comparisons with simulations
- find conditions for transmitting the highest possible charge in a single bunch, if time left,
- optimise performance of the PTG type 0° mirrors (used in Dec. '92) (as there was no time left, not done).

NOTE: we did not intend to go for maximum 30 GHz power.

3. GUN PERFORMANCE

A new CsI pc was put under vacuum in the gun. No bakeout. The multipactoring at low power could be crossed after a couple of hours and then the power was increased to the nominal PKI = 24 MW, 100 MV/m in the gun.

As observed last year, the power reflected by the gun increases after switch-on and then stabilizes.
By increasing the temperature of the water to the gun from 30 to 31. 8°C the reflection becomes as at low power (Fig. 1). However, the same water determines the temperature of the accelerating section, LAS. In the spectrometer line - BHZ430 - the momentum dropped from 58. 8 to 55. 3 MeV/c and we stayed at 30° C.

4. PHOTOCATHODE

The quantum efficiency - QE - remained constant during the run.
Page 73 of logbook, 29th april, with train of 8 bunches, QE = 3.4 %
P.153, 26th May, train of two times 8 bunches, QE = 3.6 %

P.199, 4th June, single bunch, QE = 3.3 % if 1.2 10-6 J on pc (at higher energies the current from the gun saturates, see chapter 6.2)

5.PULSE TRAIN GENERATOR (PTG)

PM. Devlin-Hill has made a description of the PTG and reported on the results obtained (Ref.: PS/LP Note 93-40, not yet published).

The train should consist of 8 equal pulses at 333.5 ps distance. The time jitter between a pulse and a given phase in the gun should be equal or less than 2 ps.

The PTG was tested with the e^- beam as follows:

- the phase of each laser pulse in the train in respect to the field in the gun was determined with the e^- bunch (the steep rise in gun current at low phases permits to extrapolate to zero current and find a reference phase; resolution 2-3 ps)
- if necessary a scan gun - LAS phase was made to assure optimum acceleration
- the position of each pulse was observed on the 'virtual cathode ' in the laser room and at one occasion on the entry window in the CTF, p. 87.
- at regular intervals the total energy out of the PTG was measured, the energy per pulse is at the bottom end of the instrument (total energy out of the PTG: 21 10^{-6} μJ, p.157, more often around 10 10^{-6} μJ.; 40% of the PTG output hits the pc).

The e^- bunch train measurements revealed a number of problems with setting the timings, position and energy. Directing the laser pulse train on the streak camera helped in unraveling the situation. Problably one of the best results - see p.136 - is shown on fig. 2.

By selecting two pulses separated by 4 ns from the output of the LEC-IR-laser and feeding them finally into the PTG a train of 2 times 8 pulses was obtained. Each of the two selected pulses had a satellite pulse with roughly 1/7 the energy and at 570 ps (p.148, 150). Thus we had in fact a ghost train of 2 times 8 bunches as well (see 7.2)..

6. BEAM PERFORMANCES

6. 1 Charge as function of the laser phase (LPh.)

The charge by UMA385 behind the gun,
UMA406 behind LAS,
UMA455 behind TRS.

LPh.: time the center of the laser pulse hits the pc minus the time the field is zero in the gun. Example: fig. 3 for a train of 8 bunches (25/05, p.138)

UMA385 sees practical all current leaving the gun. UMA406 is more selective as the transmission through LAS depends on the energy spread and the emittance. Fig. 4 compares the result with the PARMELA computation and the agreement is good. The phase span 'seen' by UMA406 is as expected smaller than by UMA385.

Fig. 5: phase scan for a single bunch, high charge (16.5 10^{-6} μJ,on pc).
Note that at all phases a charge is seen on UMA385. This is believed to be due to a pc (CsI) property: at high energy densities the charge in the pc remains and thus if created at a negative phase it gets out later. Fig. 6: scan for 1.8 10^{-6} J on the pc. Result rather similar to the train (ignore UMA455 as not optimised).

6.2 Beam transmission as function of the laser energy/charge

For a train of two times 8 bunches : fig.7 (p.167). We note: saturation not clearly setting-in on UMA385/406 up to highest charge - 1.9 nC average but the first bunch has about twice the charge. However, starting to saturate on UMA455 Saturation more rapid with a single bunch, fig.8 (p.199). The transmission was optimised for high charge, but 5 nC seems the limit on UMA455. This cannot be a beam loading effect as the train passed well! The bunch was stable on TCM455, in front of TRS. Thus we read on p.200: no sign of wakefield effects! The saturation is believed to be - at least partly - a CsI-pc effect. In fact, a Cs2Te-pc gave 4.2 nC on UMA385 and 3.7 nC on UMA455 or a transmission of 88%. (ref. PS/LP Note 93-17, fig. 10).

Some figures

two times 8 bunches:	UMA 385: 1468 10^8 e^-	23.5nC	100%
	UMA 406: 1361 10^8 e^-	21.8nC	93%
p.196	UMA 455: 1163 10^8 e^-	18.6nC	79%
laser:	total on the pc : 3.9 10^{-6} J		

With this beam we noted 10 MW.

two times 8 bunches:	UMA 385: 2141 10^8 e^-	34.3nC	100%
	UMA 406: 1982 10^8 e^-	31.7nC	92%
p.158	UMA 455: 1252 10^8 e^-	20.0nC	58%
laser:	total on the pc : 8.4 10^{-6} μJ,		

(comment in log.: laser train not perfect).

Such we had a record charge and produced 9.2 MW.

single bunch:	UMA 385: 811 10^8 e^-	13.0nC	100%
	UMA 406: 618 10^8 e^-	9.9nC	76%
p.196	UMA 455: 306 10^8 e^-	4.9nC	38%
laser:	on the pc : 6.6 10^{-6} J		

single bunch:	UMA 385: 133 10^8 e^-	2.2 nC	100%
	UMA 406: 124 10^8 e^-	2.0nC	91%
p.196	UMA 455: 113 10^8 e^-	1.8nC	82%

6.3 Bunch length as function of LPh

See fig. 9. The bunch length varies much less than predicted by PARMELA. Bunch compression has never been observed and the bunch is always longer than the laser pulse.

6.4 Bunch position

The position of the laser spot on the pc is not the same for all pulses in the train. See p.87: at the window of the mirror box in the CTF the center of the spot varies from x=1.5 to 3.0 mm and y=3.0 to 4.5 mm. This is confirmed by the position red by the UMA's. p.162/3 and p.178/9. TCM445 shows the situation in front of TRS. Fig. 10, p.160. The position jitter limits of course the attainable transmission through TRS and may explain why it is difficult to reproduce good performance.

7. PUZZLING QUESTIONS

7.1 The 30 GHz power measured does not fit with the computed one.

On fig. 11 the measured power - 9.2 MW - is compared with the expected one and the resulting value for the form factor is 0.90 if we take for the contributing charge UMA 455. The corresponding bunch length is FWHH 1.5 - 8 ps. (depending on the time-charge profile assumed). This compares badly with the 20 ps measured. However, it may be that the contributing charge is between the values from UMA 406 and 455. If this is the case, then the comparison becomes better.

7.2 S. Schreiber estimated that the ghost train had about 1/7 of the train energy

The LPh - charge scan shows both trains, see fig.12, p. 170 . Why is the charge of the ghost that high ? Another pc effect ?

8. PEAK CURRENT (IP) AND PEAK CURRENT DENSITY (JP) FROM THE GUN

The time beam profile is assumed to be Gaussian.

$$I_p = \frac{Q}{\sigma_t} \bullet \frac{1}{\sqrt{2\pi}}$$

p.196: Q = 13.0 nC (UMA385)

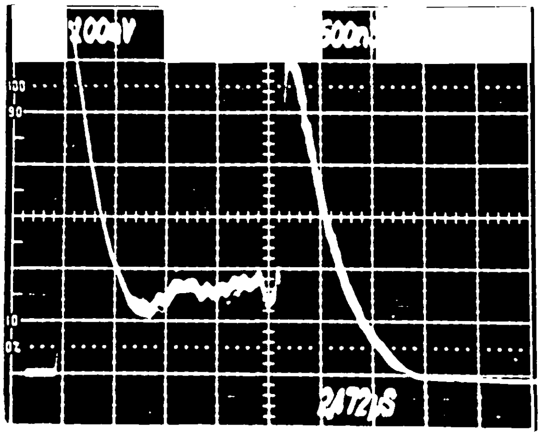
σ = 8.5 ps (TCM455)

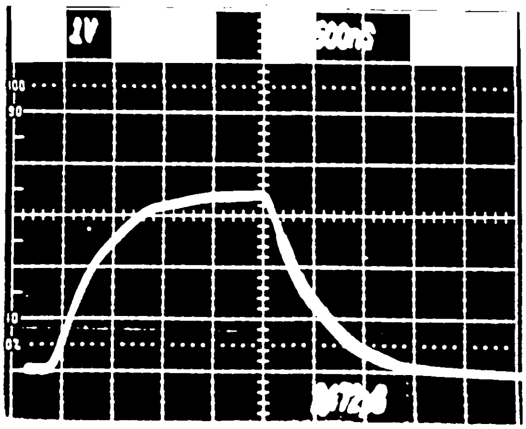
I_p= 610 A

Only 76% transmitted to UMA406.

Jp is a relevant figure if the transverse distribution is well defined. We have seen hot spots and an uneven energy distribution. But taking as illuminated surface 0.5 cm^2 then I_p = 1220 A/cm^2 This is below the space charge limit for the pc.

FOR PKI = 24.0 MW



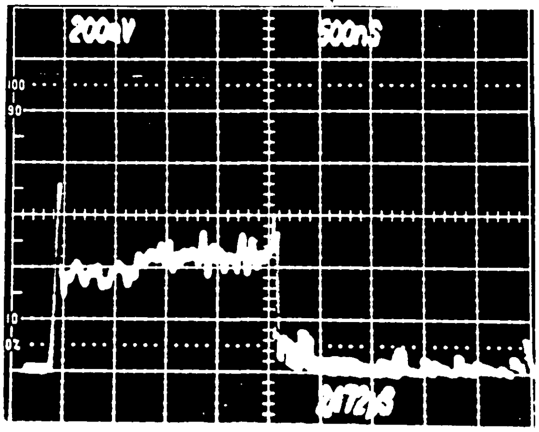


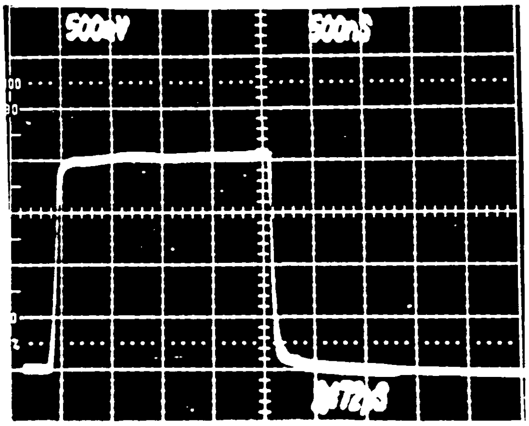
PGR (power reflected by gun)

PGL (signal from loop in gun)

30°C

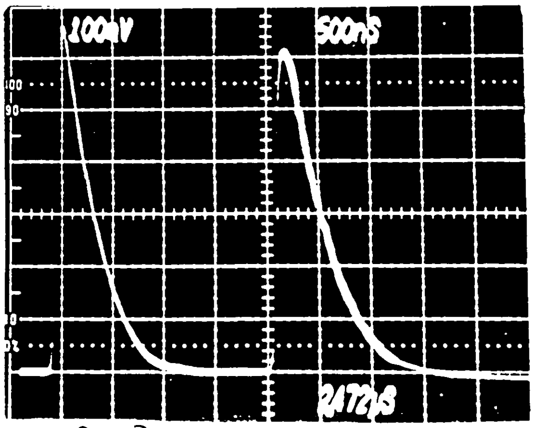
30°C

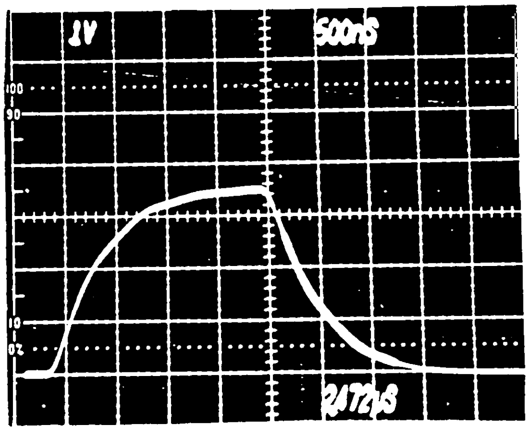




PSR (reflected of LAS)

PSI (into LAS)



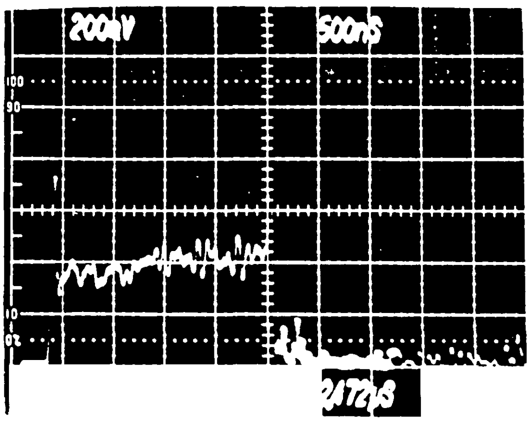


31.8°C

PGR

PGL

31.8°C



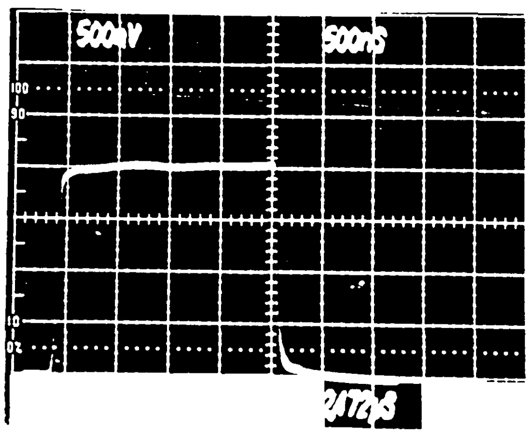


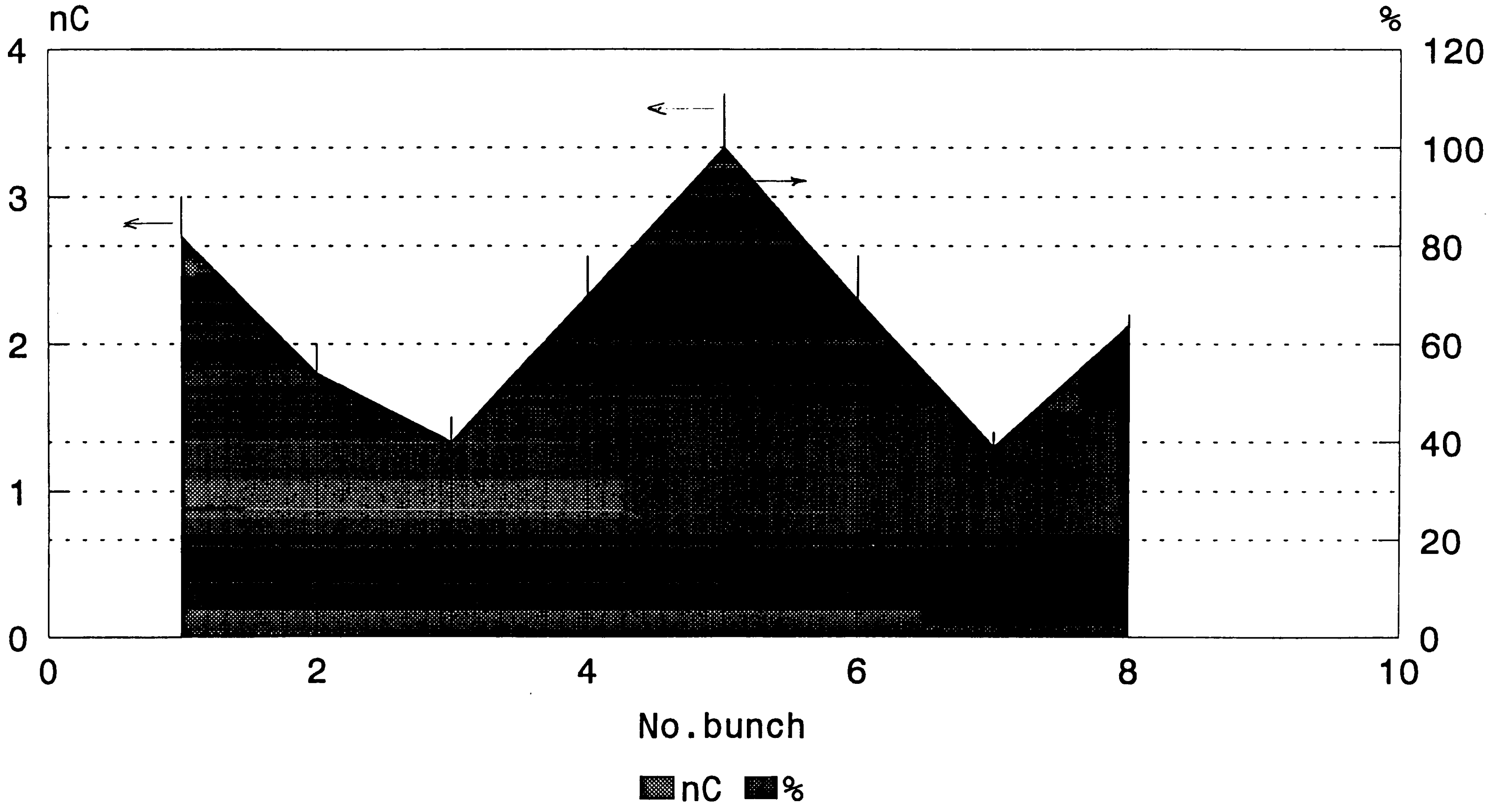
Fig 1

PSR

PSI

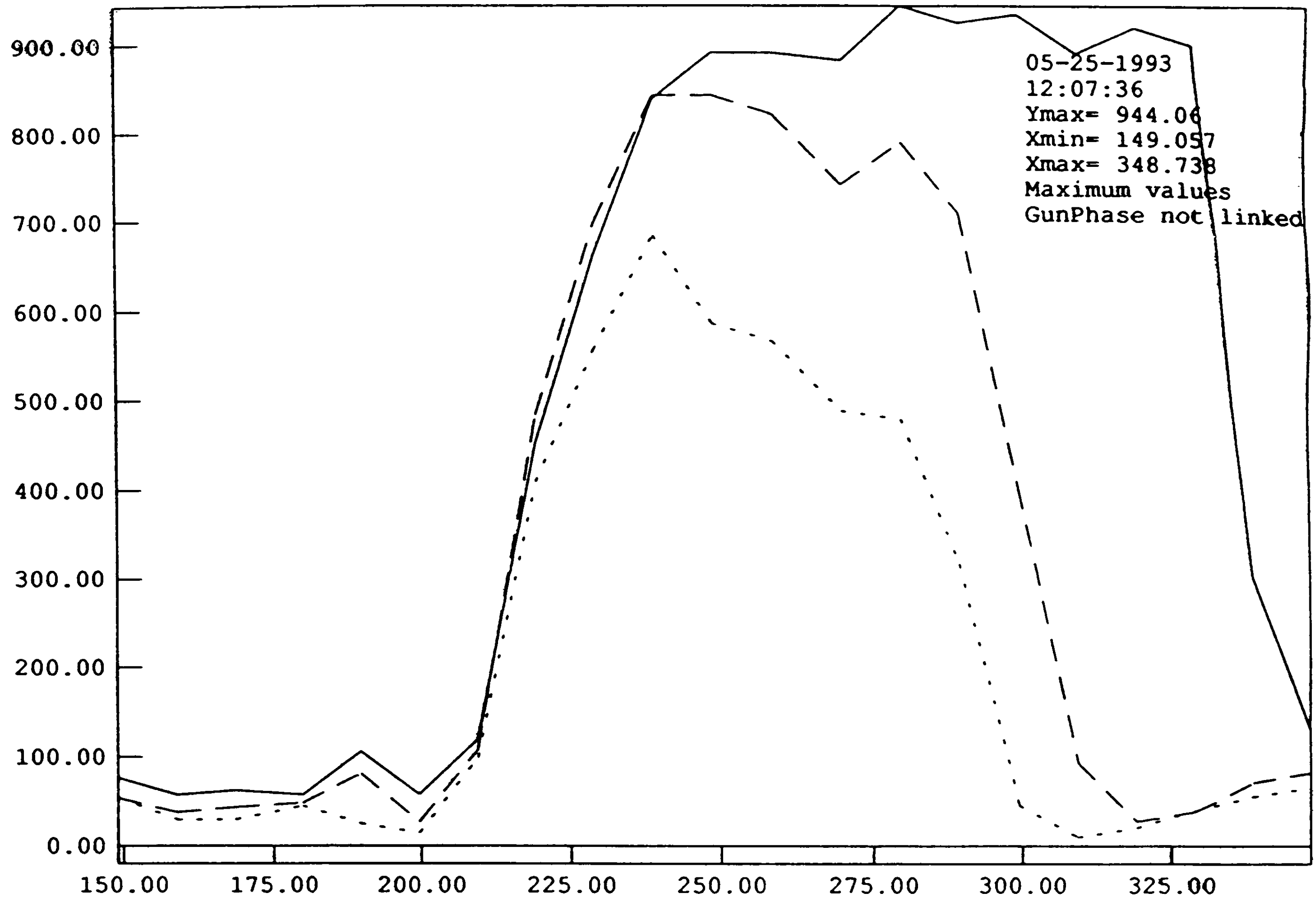
Each bunch of train alone

25/05/93, log p.137

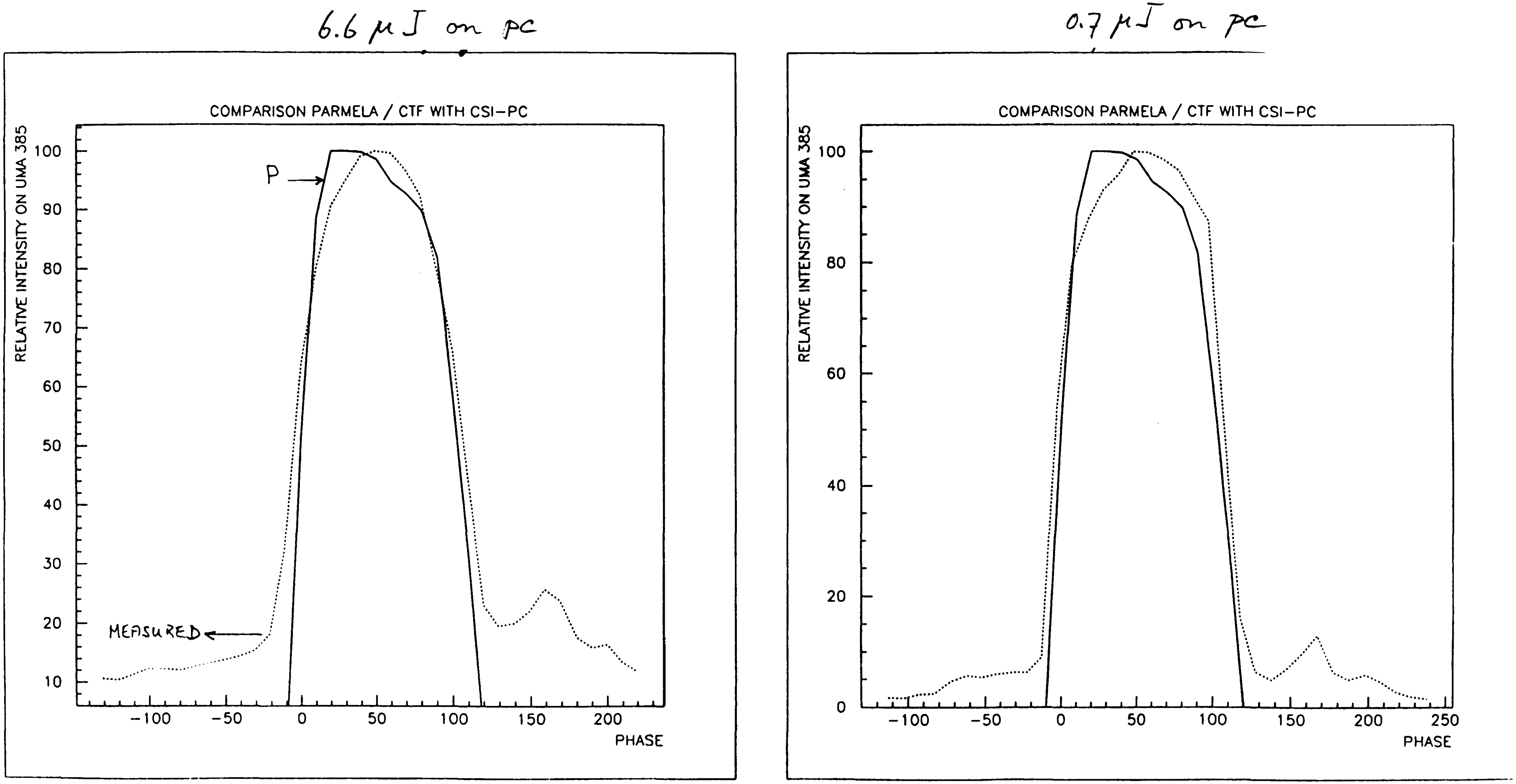


Charge of train : 13.5 nC or 70 %
of the sum of bunches alone

Fig 2

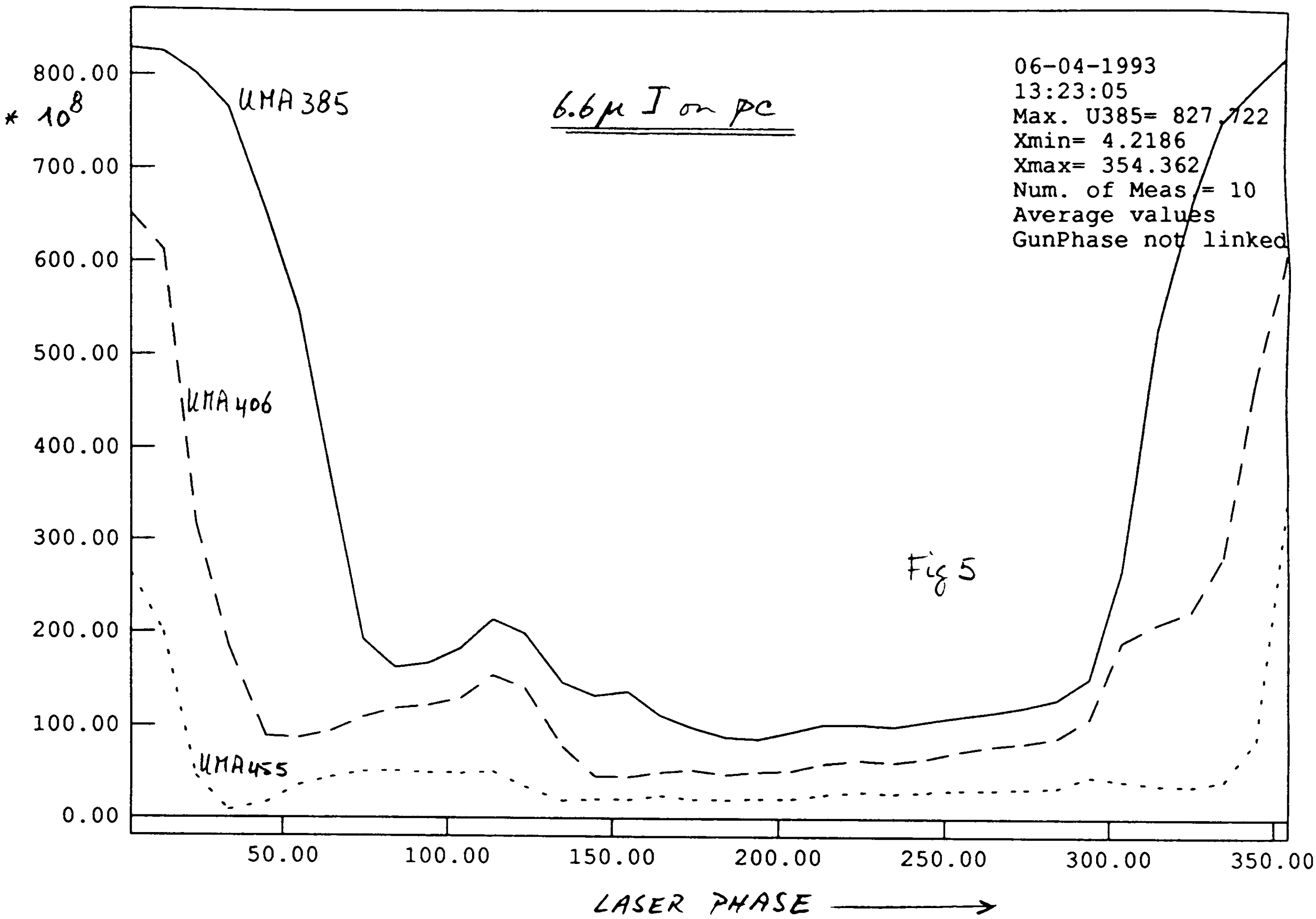


SP = 385 Train of 8 e⁻ bunches Fig 3



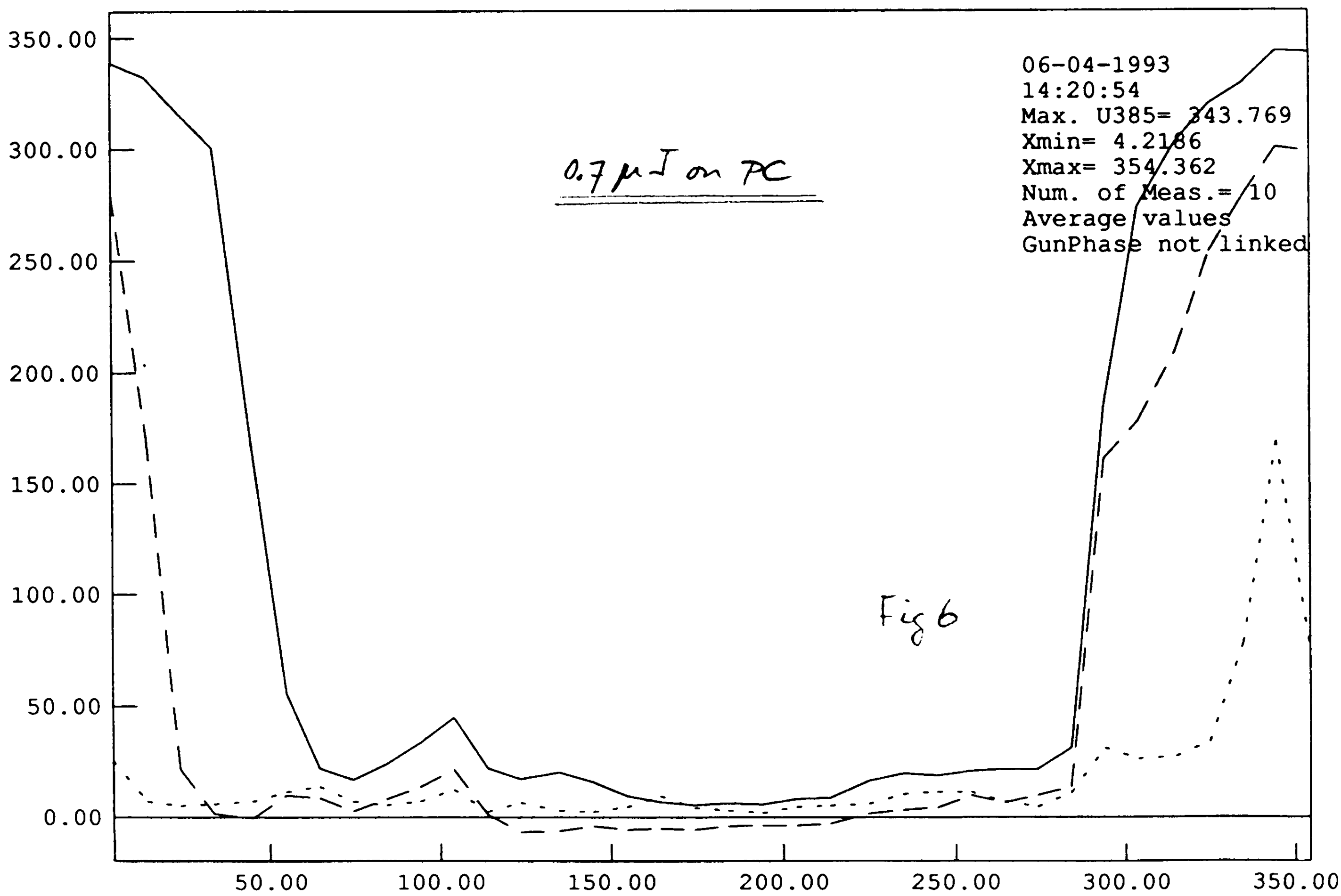
6.6 μJ on pc
COMPARISON PARMELA / CTF WITH CSI-PC
RELATIVE INTENSITY ON UMA 385
P
MEASURED
PHASE
0.7 μJ on pc
COMPARISON PARMELA / CTF WITH CSI-PC
RELATIVE INTENSITY ON UMA 385
PHASE

Fig 4



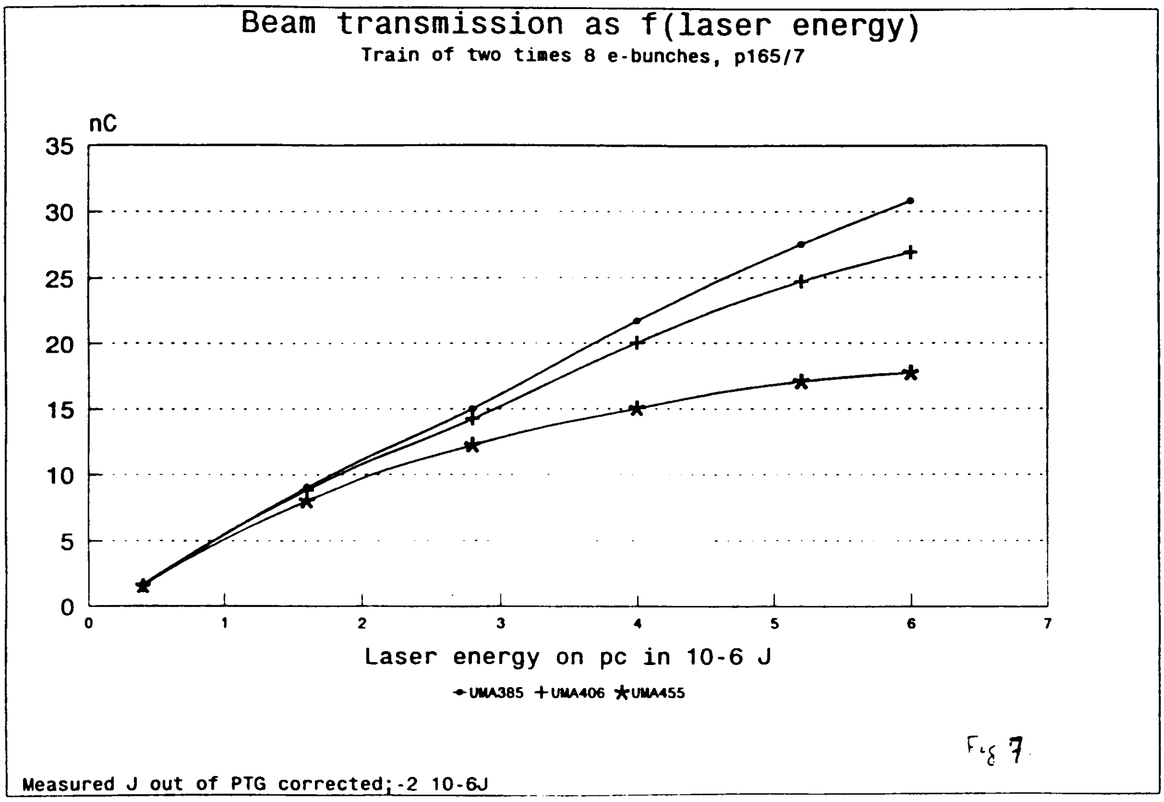
800.00
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
* 10^8
UMA385
UMA406
UMA455
6.6μJ on pc
06-04-1993
13:23:05
Max. U385= 827.722
Xmin= 4.2186
Xmax= 354.362
Num. of Meas.= 10
Average values
GunPhase not linked
50.00
100.00
150.00
200.00
250.00
300.00
350.00
LASER PHASE →

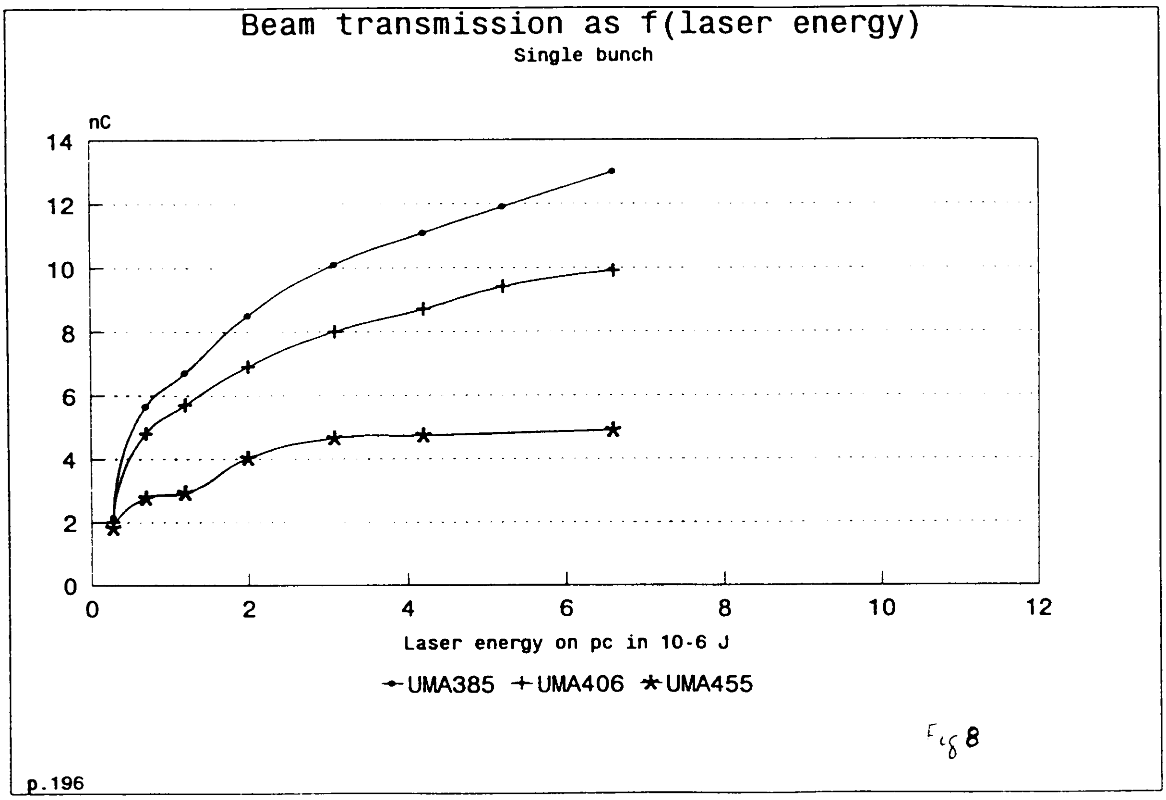
Fig 5

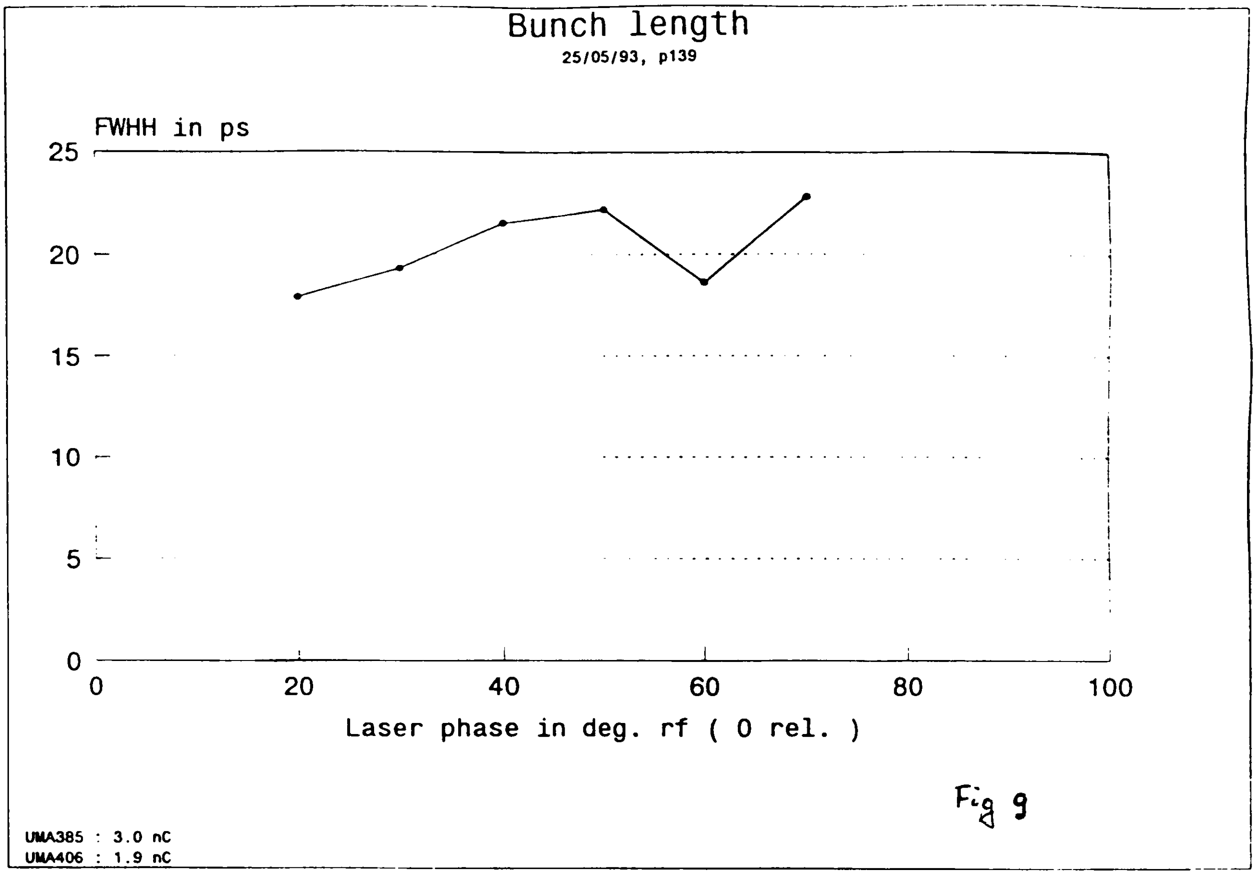


350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
0.7 μJ on PC
06-04-1993
14:20:54
Max. U385= 343.769
Xmin= 4.2186
Xmax= 354.362
Num. of Meas.= 10
Average values
GunPhase not linked
50.00
100.00
150.00
200.00
250.00
300.00
350.00

Fig 6


Beam transmission as f(laser energy)
Train of two times 8 e-bunches, p165/7
nC
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
Laser energy on pc in 10-6 J
UMA385 UMA406 UMA455
Fig 7
Measured J out of PTG corrected;-2 10-6J


Beam transmission as f(laser energy)
Single bunch
nC
14
12
10
8
6
4
2
0
0
2
4
6
8
10
12
Laser energy on pc in 10-6 J
UMA385 UMA406 UMA455
Fig 8
p.196



Bunch length
25/05/93, p139
FWHH in ps
25
20
15
10
5
0
0
20
40
60
80
100
Laser phase in deg. rf (0 rel.)
UMA385 : 3.0 nC
UMA406 : 1.9 nC

Fig 9

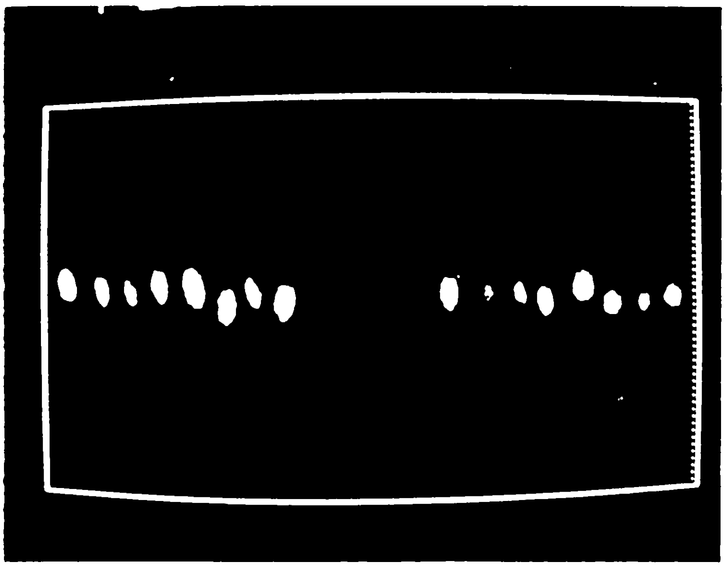


Fig 10

* trying to improve transmission through TRS → difficult

|Average: ( )			
nmeas 10	HOR(mm)	VER(mm)	Ch. (EB)
K_UMA170	27.6	0.5	25.4
K_UMA235	111.1	111.1	0.0
K_UMA385	-1.8	1.2	-1950.1
K_UMA406	-1.0	0.1	-1745.9
K_UMA455	-1.0	-0.7	-1025.4

Thu May 27 21:42:08

Thu May 27 22:00:31

|Average: ( )			
nmeas 10	HOR(mm)	VER(mm)	Ch. (EB)
K_UMA170	28.8	0.5	25.4
K_UMA235	111.1	111.1	0.0
K_UMA385	-2.0	0.7	-2093.1
K_UMA406	-0.6	0.6	-1837.2
K_UMA455	-0.7	-0.2	-1178.3

|Average: ( )			
nmeas 10	HOR(mm)	VER(mm)	Ch. (EB)
K_UMA170	28.8	0.5	25.4
K_UMA235	111.1	111.1	0.0
K_UMA385	-1.8	1.1	-2140.8
K_UMA406	-1.0	0.2	-1901.7
K_UMA455	-0.9	-0.[illegible]	-1252.2

30,6 nC upstream TRS

not better than R-L

20,1 nC downstream TRS

$$\hat{P} \simeq 30{,}74 \cdot q^2 \cdot F^2 \cdot 0.92$$

← Reduction due to splitting in 2 trains

$30{,}6\,nC \rightarrow F = 0{,}59$

$20{,}1\,nC \rightarrow F = 0{,}90$

USA 602A DIGITIZING SIGNAL ANALYZER
date: 27-MAY-93 time: 21:48:40

30 GHz Signal (downconverted)

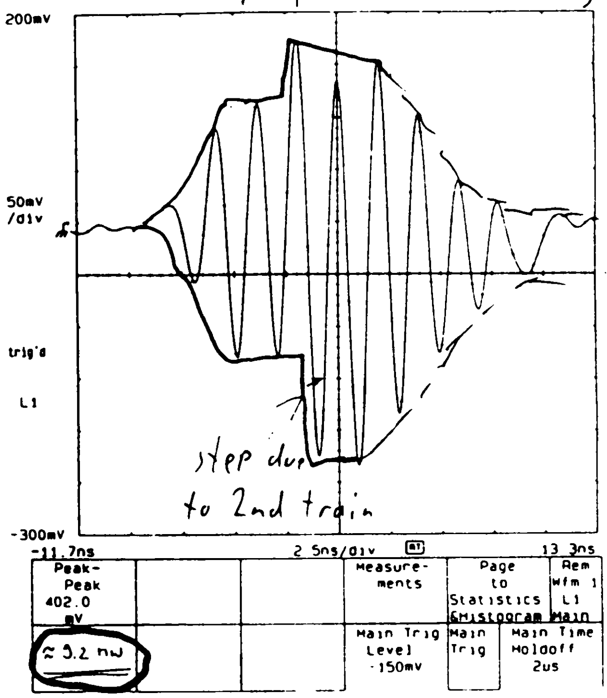
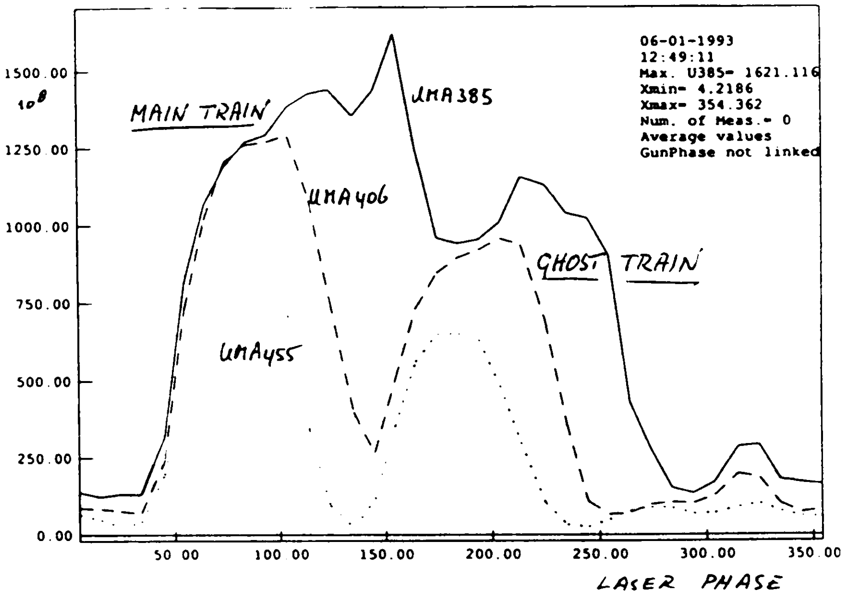


Fig 11



Train 2 x 8 e⁻ bunches with ghost. Fig 12