DAΦNE TECHNICAL NOTE

INFN - LNF, Accelerator Division

Frascati, September 28, 1999

Note: **BM-4**

DAΦNE BEAM-BEAM MEASUREMENTS

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WHERE WE WERE BEFORE...

In the last luminosity runs for KLOE of 8 August the maximum single bunch luminosity was L_{SB} = 2 10^{29} cm^{-2} sec^{-1}, with e^-e^+ currents of 10 against 10 mA. Larger currents induced beam blow-up with no increase of luminosity. In the multibunch configuration (17 against 17 bunches) a luminosity L_{MAX} = 2.6 10^{30} cm^{-2} sec^{-1} with lifetimes larger than one hour and very low background level in KLOE was given to the experiment; the total integrated luminosity of a single run was ~ 4.4 nb^{-1}. Top-up injection of the positron beam was successfully tried. See Fig. 1.

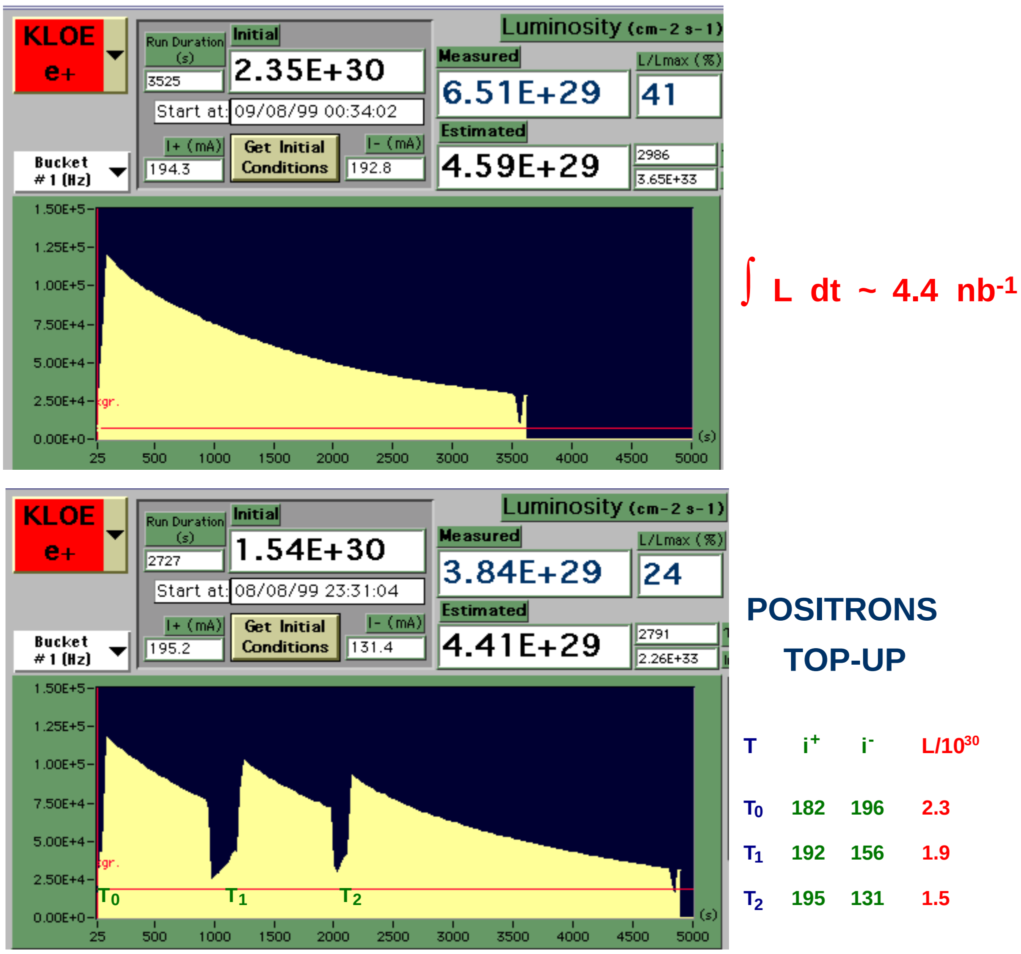

Figure 1: Luminosity Runs of August 8.

WHERE WE ARE NOW

In the last shift (16-18/9/99) the luminosity monitors were used to measure the effective cross section of the interacting beams. The measurements were performed scanning the position of one beam with respect to the other and measuring the luminosity value on the monitor relative to the other beam in order to avoid different gas target.
A summary of the measurements are here collected.

Calibration of the RF-phase versus Δs of the Interaction Point (IP).

The RF phase shifter calibration was performed in the laboratory with the Network Analyzer and on the bunch with the fast oscilloscope.
The bunches crossing time is observed with the combined button monitors placed at the IR ends close to the splitter magnets and measured with an oscilloscope with a bandwidth of 25 Ghz: the time difference is:

@ $V_{Rfphase}$ = 5.05, 29 ps toward the BPBI102 side

@ $V_{Rfphase}$ = 5.2, 23 ps toward the BPBI101 side

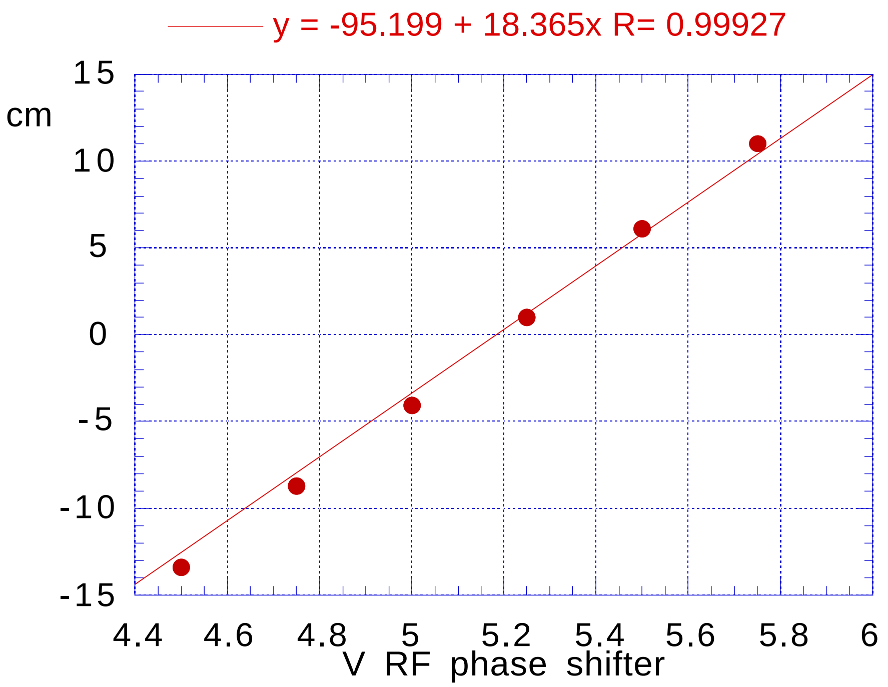

Figure 2: Phase shifter calibration

As a thumb rule: <u>0.1 V of the positron RF phase corresponds to 1 cm shift of the IP along the s direction</u>.

The crossing time changes by ~ 30 ps changing the RF voltage from 100 to 200 kV.

All the measurements have been done at fixed electron RF phase reference : ψ = 1.81

IP PARAMETERS

The emittance of the ring is estimated to be 5 10^{-7} m rad.
The values of the betatron functions estimated from the last fit are:

	e+	e-
β_x* (m)	4.1	4.2
β_y* (cm)	4.9	4.4

We assume σ_x*= 1.5 mm, corresponding to β_x* = 4.5 m.

The roundness r measured at the synchrotron light monitor (slm) gives us an estimate of the coupling factor, assuming a factor 2 between the betatron functions at that position: σ_y* is proportional to the roundness: σ_y* = r sqrt (β_y* ε /2).

Another thumb rule: for β_y* = 4 cm, σ_y* (μ) = 100 r. The following figure represents the linear variation of σ_y* as the roundness change for three different values of β_y*.

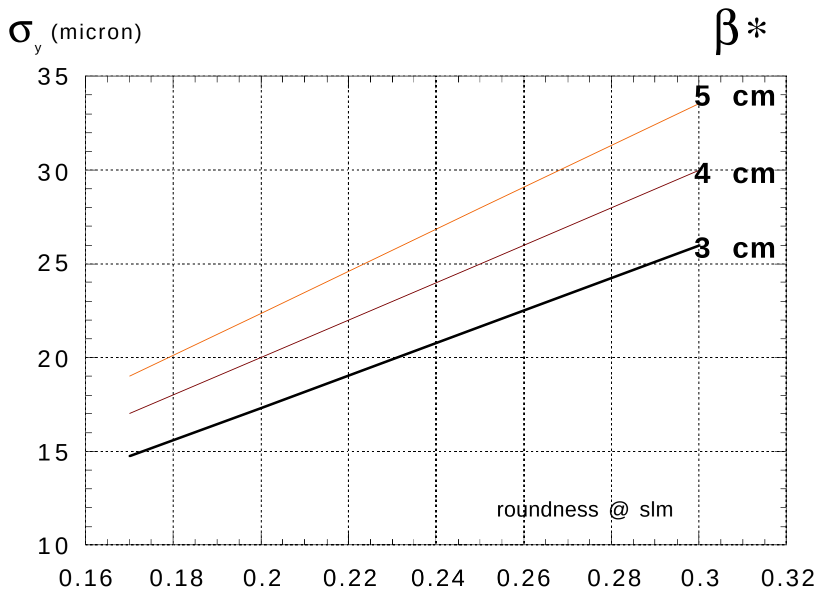

Figure 3: σ_y* as a function of the roundness

SET-UP A

The ring optics were the same as those used in the last KLOE luminosity runs (8-august). The main objective was to measure the longitudinal behaviour of the effective vertical interacting beam size, σ_{yeff}, in order to check the betatron functions and waists at the IP.

A summary of the beam parameters is given in the Table I.

Table I

	electrons	positrons
Current (mA)	3.8	3.5
Roundness	.218	.209
Coupling (%)	2.4	2.2
Tilt (°) @ slm	4	1
V_{RF} (kV)	100	100

The runs effective height σ_{yeff} was measured along five different phase values, corresponding to a total Δs excursion of about 9 cm (see Fig. 4). Each scan was done after centering the horizontal crossing on the new longitudinal position. The maximum luminosity measured for every scan is plotted in Fig. 5. Since the geometrical crossing of the trajectories is optimized for every phase point, the luminosity versus phase is the maximum corresponding to each point.

In two points (5.05, 5.20) the horizontal σ_{xeff} was also measured, showing an asymmetric behaviour (see Fig. 6).

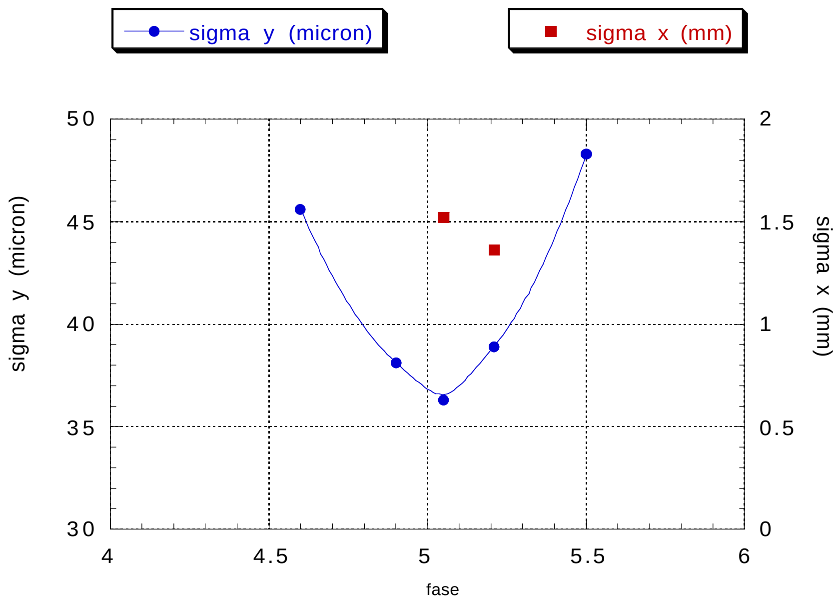

Figure 4: Vertical σ_{yeff} and horizontal σ_{xeff} along s.

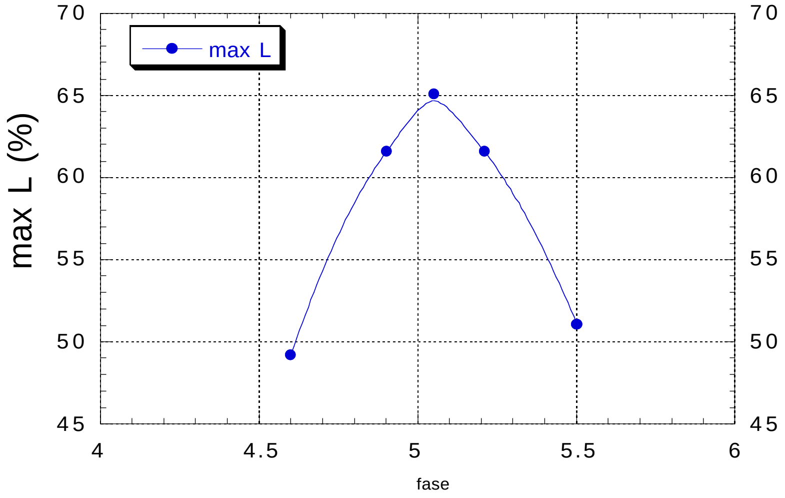

Figure 5: Luminosity versus the RF phase.

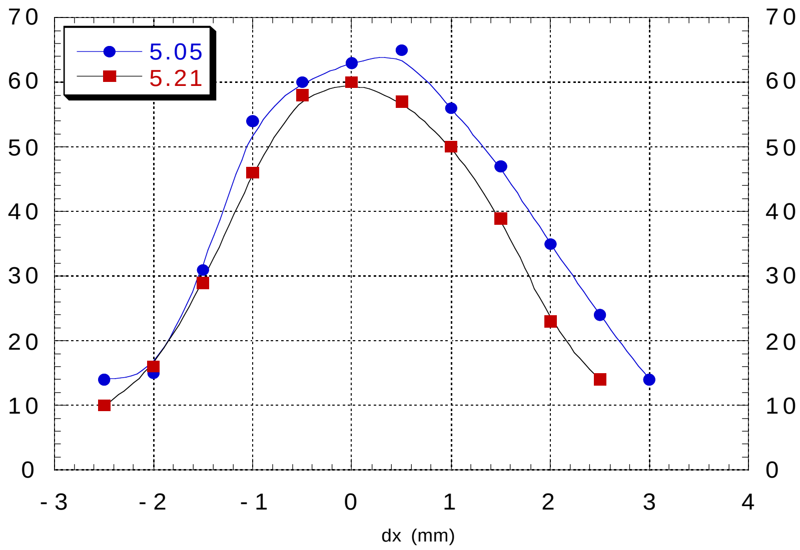

Figure 6: Horizontal scan at two different RF phase value; the plot shows different sizes and similar asymmetry

SET-UP B

The positron beam was tilted at the slm by -4° and the roundness slightly diminished. The objective was to check the dependence of both the minimum σ_{yeff} and of its position on the relative transverse tilt of the two beams.

Table II

	electrons	positrons
Current (mA)	2/3	2/3
Roundness	.218	.18
Coupling (%)	2.4	1.6
Tilt (°) @ slm	4	-4
V_{RF} (kV)	100, 200	100, 200

The measurements have been done at two different values of RF voltage. At 200 kV any hour-glass effect was negligible. Since the RF phase is slightly different, the measurements were repeated at 100 kV to be comparable with previous ones.

Measurements can be compared to case A: The minimum σ_{yeff} corresponds to a phase reference shifted by 0.15 (equivalent to Δz = 1.5 cm) with respect to A. The minimum is slightly smaller in case B (33 μ angainst 37 μ) (see Fig. 10).

Measurements were done with very low currents to avoid any beam-beam blow-up; in fact two different scans made at e+ currents of 1.3 mA and 3 mA gave different values of σ_{yeff} (see Fig. 9).

The RF scan was done at constant trajectories, with the superposition optimized in the RF phase point corresponding to the minimum σ_{yeff} (see Fig. 11). This scan shows an asymmetric behaviour.

The luminosity expected with the nominal values of betatron functions and measured roundness is L = 1.18 10^{28} cm^{-2} sec^{-1}; the luminosity measured at the optimum σ_{yeff} is L = 0.9 10^{28} cm^{-2} sec^{-1}; we are therefore close to the nominal values.

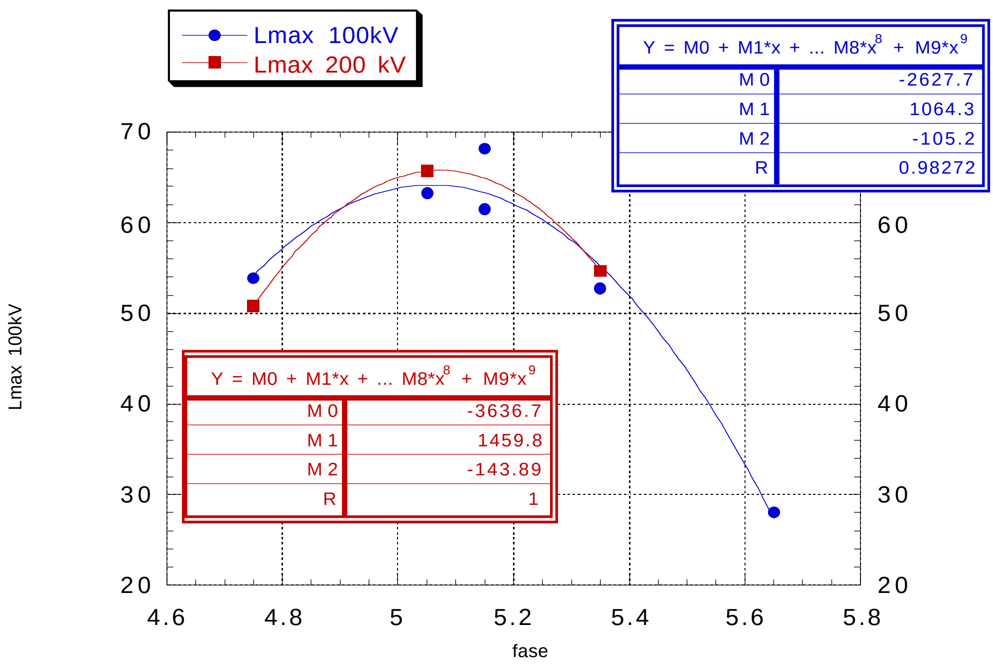

Figure 7: Maximum luminosity along phase.

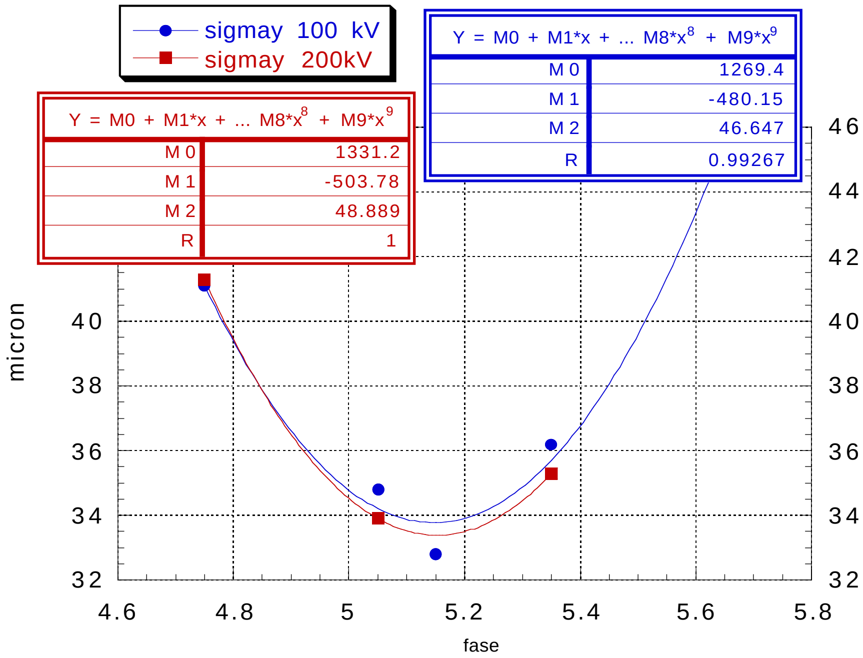

Figure 8: Vertical size measurements at RF voltage 200 kV and 100 kV.

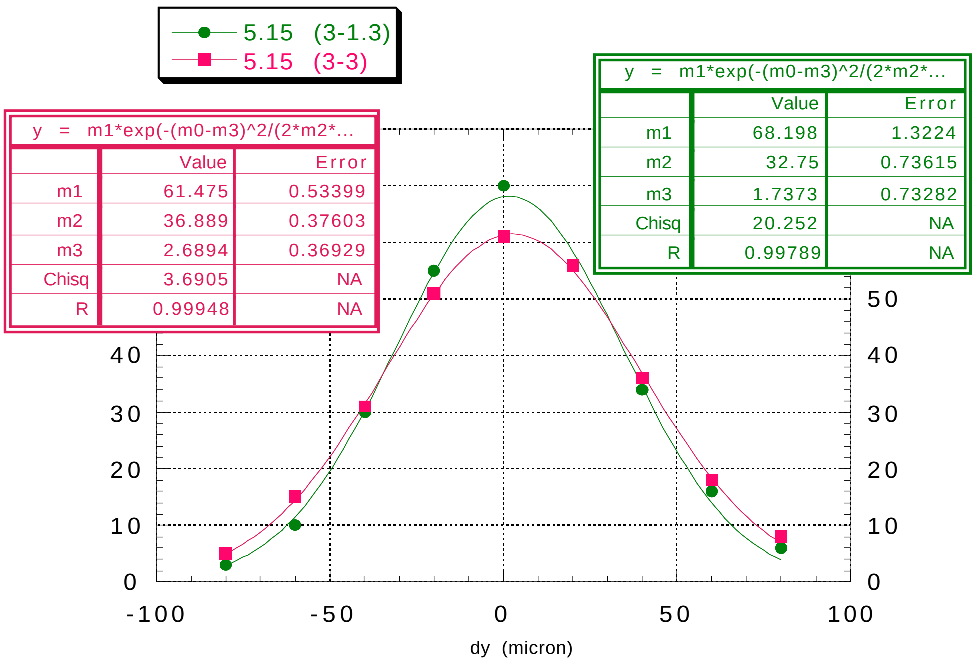

Figure 9: Vertical distributions at two different current of the positron beam.
(I + = 3 mA and 1.3 mA)

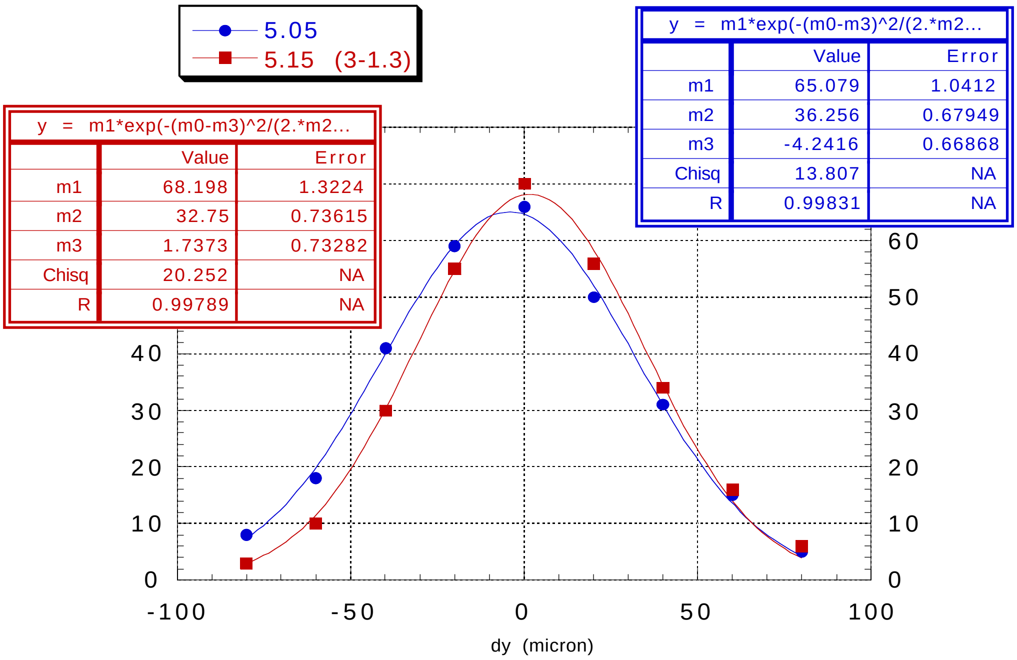

Figure 10: Comparison between the two optimum vertical distribution of case A (dots) and case B (squares).

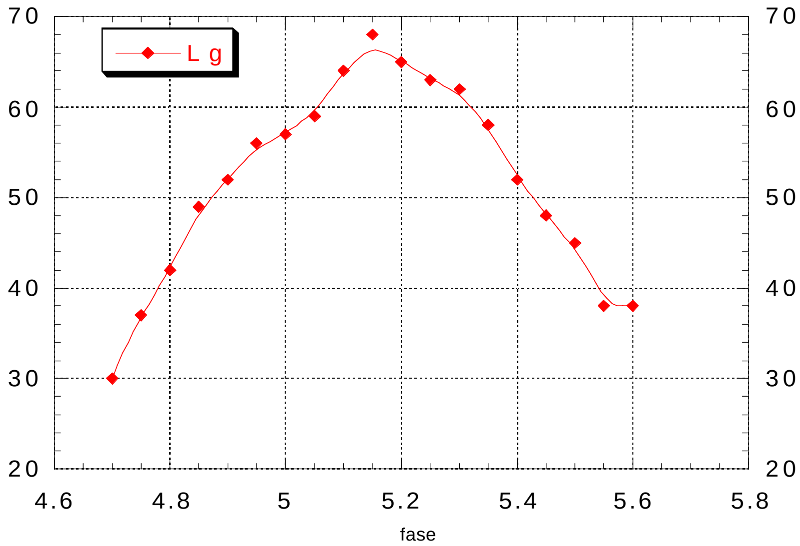

Figure 11: The luminosity versus RF phase at constant trajectories.

SET-UP C

The electron beam was squeezed to r - ~ .175, which gave a larger luminosity at low current with respect to previous set-ups.

The measurements were done similarly to case A and B. The maximum luminosity is larger and the σ_{yeff} smaller (28 μ). The horizontal scan done at the optimum phase is in this case symmetric (see Fig. 14), and well fitted by a gaussian with σ_x = 1.2 mm.

The expected luminosity is L = 3.7 10^{28}; and the luminosity measured at the optimum value is L = 3. 10^{28};

Table III

	electrons	positrons
Current (mA)	2/3	2/3
Roundness	.18	.18
Coupling (%)	1.6	1.6
Tilt (°) @ slm	4	-4
V_{RF} (kV)	100	100

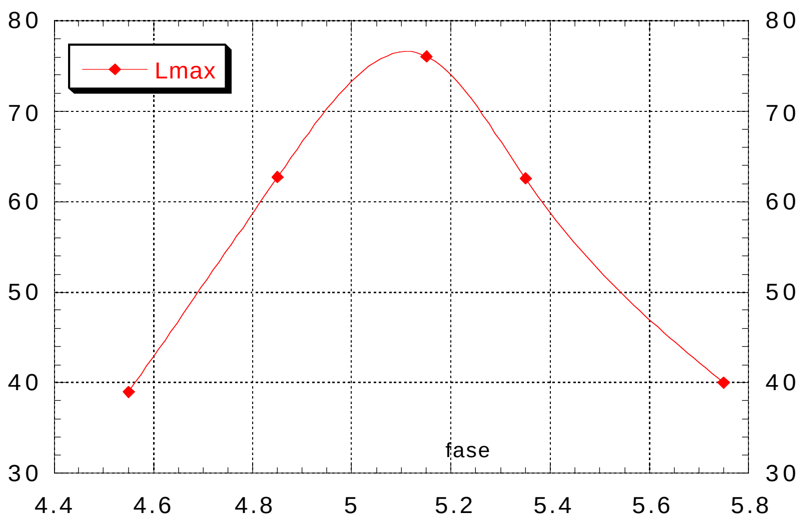

Figure 12: Maximum luminosity versus phase.

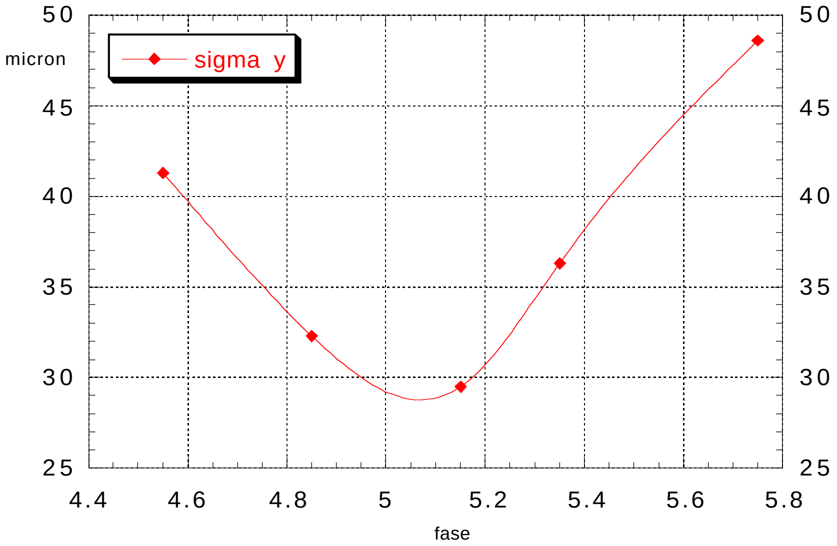

Figure 13: vertical effective size (lower) versus the RF phase.

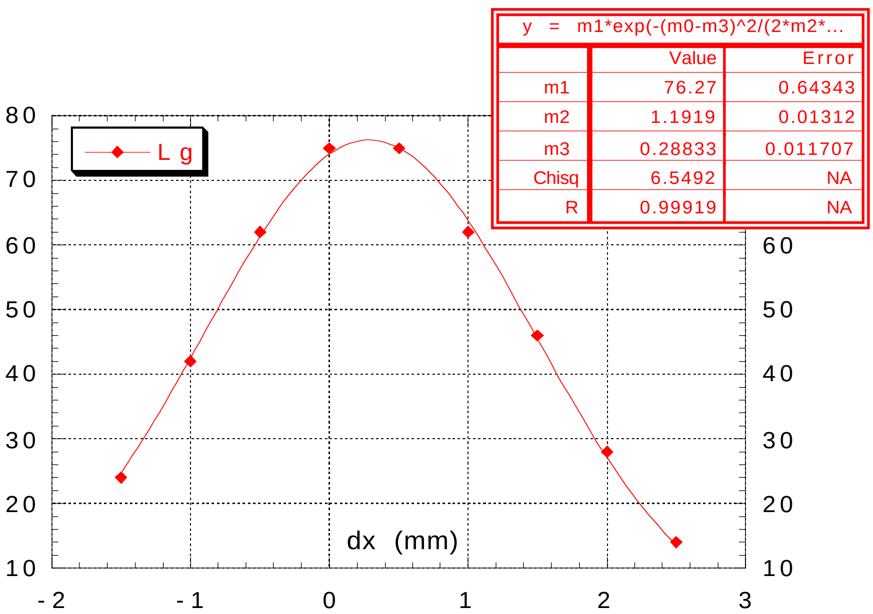

Figure 14: Horizontal scan in this point is symmetric!

SET-UP D - Measurements changing the positron tilt @ slm

The set-up of the rings is the same as in case C.

D1) weak (e^-) weak (e^+)

Measurements with two weak beams where done to check the dependence of luminosity on the relative transverse tilt (in the plane x-y) of the two beams.

Since the ‘pretunes’ used to change the tilt at the SLM changed also the e+ roundness, the larger effect on the luminosity is due to the e+ roundness change. No blow-up in the electron beam was expected nor detected.

Two different ‘pretune files’ to tilt the e+ beam were used.

In Fig. 16, together with the measured luminosity on both monitors, there is a curve named expected luminosity: it corresponds to the luminosity calculated taking into account only the change of the coupling as measured on the slm. The difference between the measured and expected value can be interpreted as due to the different tilt between bunches.

Table IV

	electrons	positrons
Current (mA)	~2.5	~2.5
Roundness	.18	varying
Coupling (%)	1.6	varying
Tilt (°) @ slm	4	varying
V_{RF} (kV)	100	100

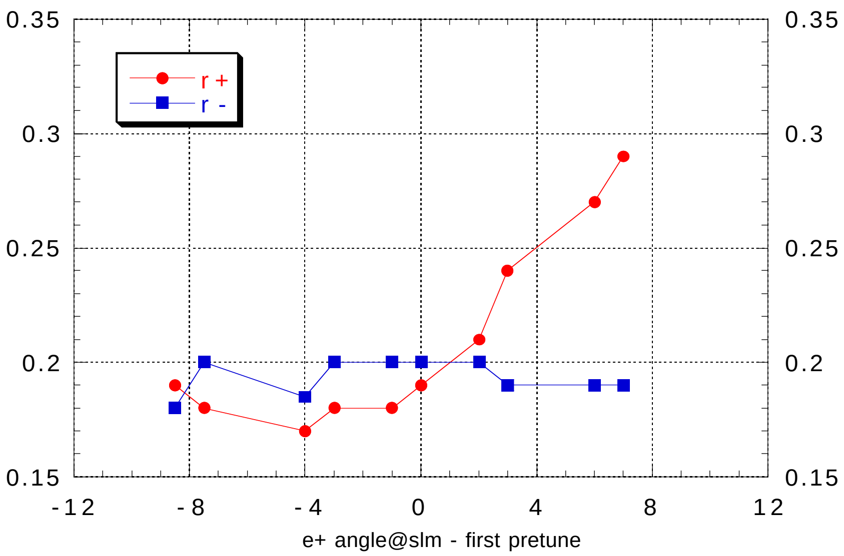

Figure 15: Roundness of the electron and positron beam vs the positron rotation angle made using the first pretune file.

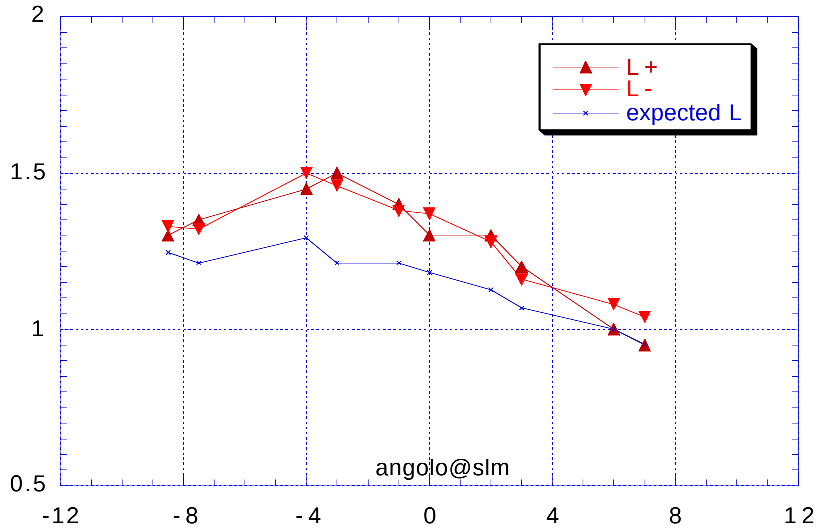

Figure 16: Luminosity measured and expected with the electron and positron luminometers vs the positron rotation angle made using the first pretune file.

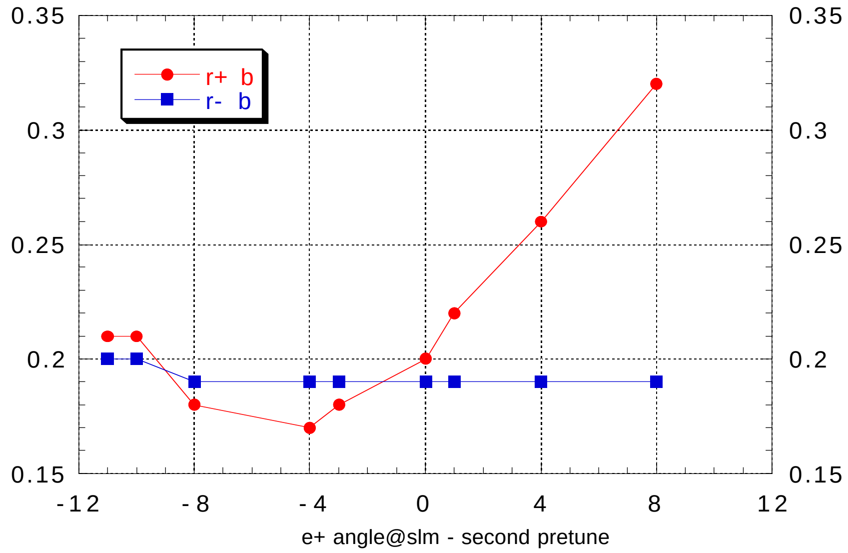

Figure 17: Roundness of the electron and positron beam vs the positron rotation angle made using the second pretune file

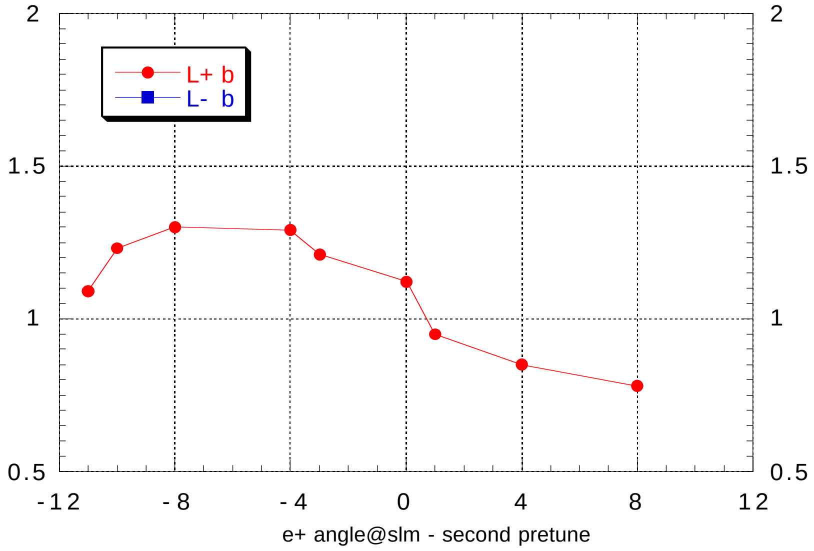

Figure 18: Luminosity measured with the positron luminometer vs the positron rotation angle made using the first pretune file

D2: weak (e^-) strong (e^+)

Once checked the basic beam-beam parameters the actual problem is the blowup at large currents.

We have measured the blowup of the weak electron beam against the tilt of the e^+ beam and corresponding change of the e+ roundness. The change in the luminosity is therefore due essentially to the change in both sizes. From these measurements the best condition seems to be the one with the e+ beam tilted ~-10° at the SLM.

Table V

	electrons	positrons
Current (mA)	~4.5	~9
Roundness	varying	varying
Coupling (%)	varying	varying
Tilt (°) @ slm	4	varying
V_{RF} (kV)	100	100

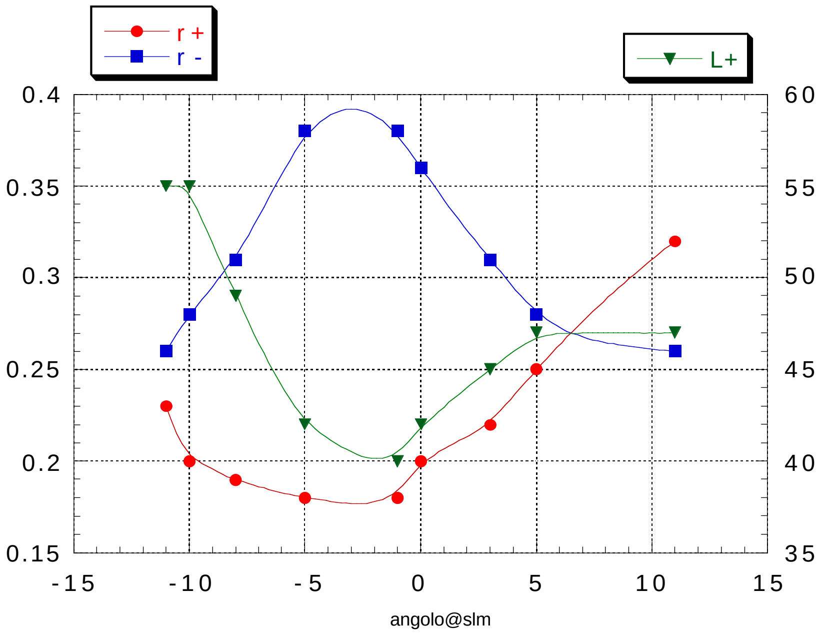

Figure 19: Luminosity vs positron rotation angle together with the electron and positron roundnesses simultaneously measured.

From this point on we left the positron beam with tilt = -10° which gave the minimum blowup on the electron beam.

The maximum single bunch luminosity reached in this lifetimes configuration was **L_{SB} = 3.3 10^{29} cm^{-2} sec^{-1}** obtained with I- = 18mA and I+ = 12 mA and τ- ~ τ+ ~2000sec. Different sets of current were used to increase this value, but the blow-up in the beams gave no increase in the maximum luminosity. We obtained repeteadly values between 2.5 and 3 10^{29} with good beam lifetimes.

SET-UP E - Measurements done with multibunches

Measurements done with 20 bunches I + ~ I- ~30 mA showed a better signal/background ratio.

Table VI

	electrons	positrons
Current (mA)	~35	27
Roundness	.17	.17
Coupling (%)	1.5	1.5
Tilt (°) @ slm	4	-10
V_{RF} (kV)	100	100
#bunches	20	20

In this case the horizontal trajectory was not moved. Only the vertical bump was used. Therefore the luminosity value is not optimized at every point.

A very useful information comes from the shift of the center of the vertical distribution along s: it is a measure of the relative angle of the trajectories in the normal plane which outside the IR corresponds to the vertical. For trajectories with no relative angle this shift should be zero. In the configuration of these measurements the angle was ~ 0.7 mrad.

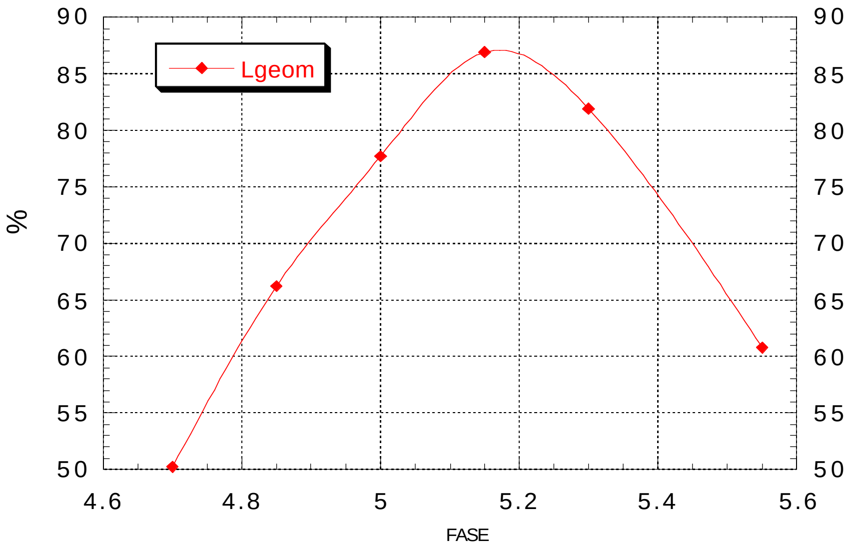

Figure 20: Luminosity versus RF phase.

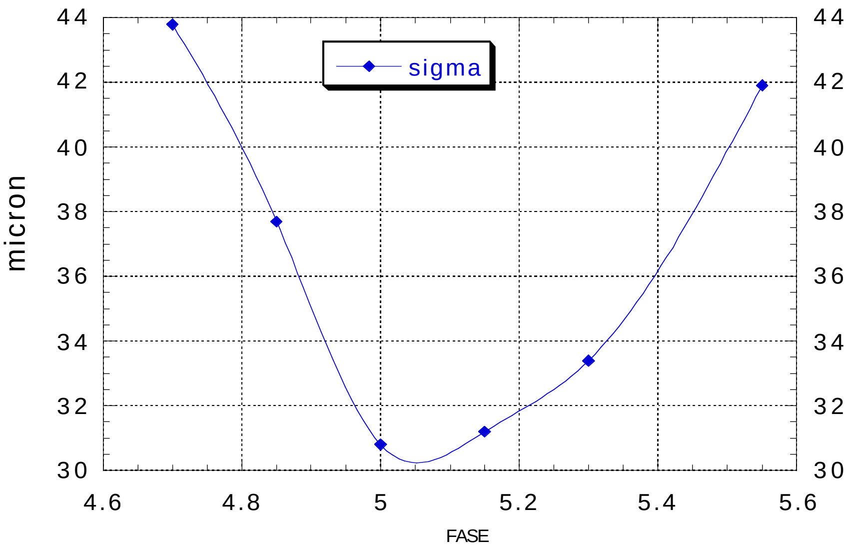

Figure 21: Vertical effective size versus RF phase.

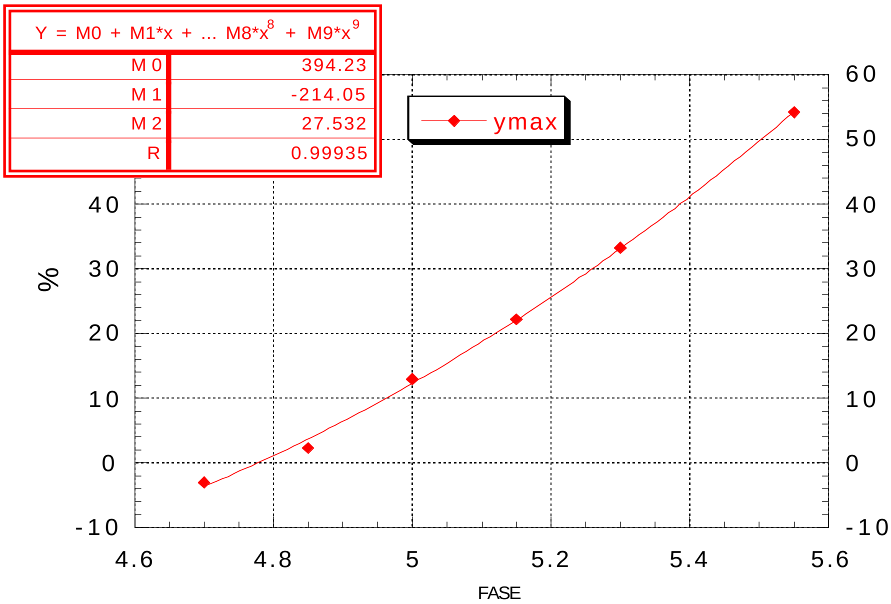

Figure 22: Shift of the center of the vertical scan measured at different RF phase.

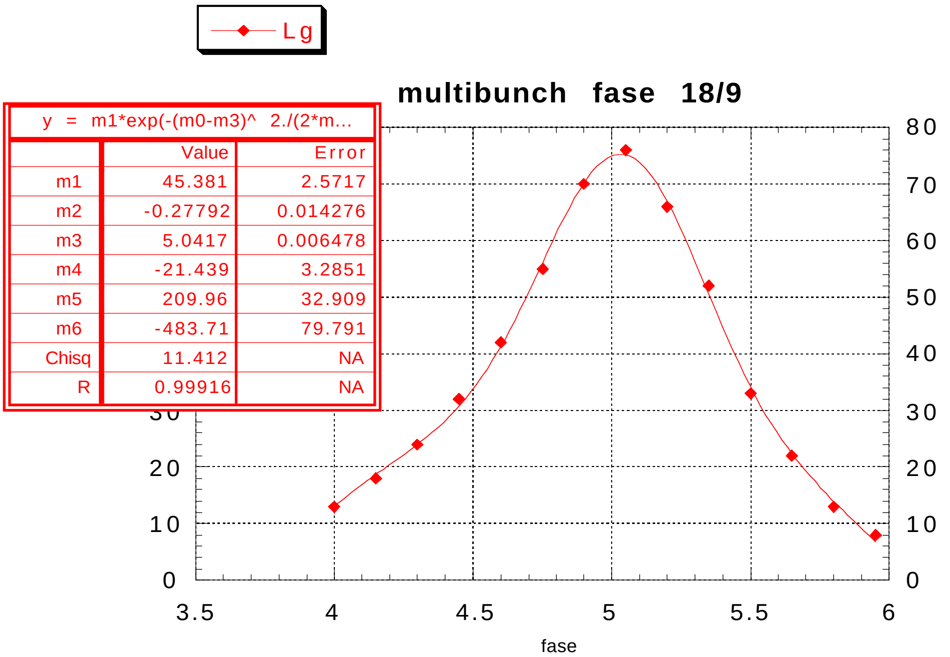

Figure 23: Luminosity versus RF phase.

CONCLUSIONS

The beam-beam scans are a very useful tool as IR diagnostics.

The optics parameters at the IP are near to the nominal ones. In the different set-ups used during these measurements the minimum of σ_{yeff} moved along Δz ~ 1.5 cm. Our present interpretation is that the waists of the two betatron functions, which have not been changed during the measurements, are inside that interval. The relative transverse tilt of the beams or the vertical angle of the trajectories could be the responsible ot the shift.

The single bunch luminosity has been increased by ~50% with respect to the values of August.