First MD on BBLR 20/08/2002

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1 Aims

The aims of this first MD was mostly to commission the hardware components and get experience with the instrumentation necessary to evaluate the beam situation. We aimed as well at a first non-systematic sampling of the parameter space.

2 Planning and Efficiency

The MD was scheduled on Tuesday 20/08/2002 from 8:00 to 14:00. The PS set-up took some 15 minutes. Due to a problem in a transfer line affecting the P1 cycle, the machine was effectively available about 5 hours out of 6 scheduled.

3 Commissioning of the Hardware without Beam

3.1 Remote Control of Wire Power Converter

The name of the power converter is BBLR5176M. It is connected to the MuGeV which allows its control from the control room. It was loaded in the database on Monday but we found that it had not been propagated to the operations database. The refresh is indeed at 11:45 and not at 24:00!

The transfer of information was forced by xxx. Later JW modified the specification of the calibration to allow more than 55 A. At this stage, the power converter was operational.

3.2 Dynamic Range for the Power Converter Current

It had already been identified on Monday by MR that the inductive load almost disappears at 130 A. This causes the Power Converter to oscillate. We reproduced this observation and limited the current to 120 A maximum. The inductive coil needs to be modified or changed to reach the nominal current of 267 A.

3.3 Efficiency of the Water Cooling

During these tests, the water temperature was monitored by JC. The outlet temperature increased only by 1 degree, from 24 to 25 degrees. This is consistent with the water pressure drop of 7 bars, a water flow of 0.9 l/mn and a nominal temperature increase of 20 degrees at 300 A. The cooling capacity is therefore on the safe side. We checked later with beam if losses change this conclusion.

4 Machine and Beam Set-Up

The MD is carried out on the P2 cycle. The beam current was minimized to allow approaching the wire without risk with a good safety margin according to J.B. Jeanneret: we took only 12 bunches of the LHC type, representing a total charge of 2.3 10^{11} protons.

The closed orbit was corrected to .... (JW). The interpolation of the beam position at the BBLR (JW) gave 0 mm both planes (?).

The tunes were left at Qx=.1781 and Qy= .1508

The beam size was found reproducible from cycle to cycle with a very good accuracy. Without excitation, the measured emittances were: $\gamma\epsilon_x \approx 1.9$ μm, and $\gamma\epsilon_x \approx 1.1$ μm, which correspond to beam sizes of $\sigma_x \approx 1.85$ mm, and $\sigma_x \approx 1.41$ mm at the BBLR ($\beta \approx 50$ m).

5 Commissioning with Beam

5.1 Bumping the beam at the BBLR

Jorg

5.2 Calibration of the BBLR BPM

The BBLR is made of two tanks recuparated (old BCPL's). In each tank, the antennas of the BCPL's were kept to measure the beam position in one plane. This capability should provide an easy and accurate means of measuring the beam-wire separation.

It had been found before this MD that, while the BPM reacts well to calibration signal, it seemed to sho a very large offset with beam (about -15.5 mm!). Analysis of the perturbations in each plane seemed to show that the beam field is perturbed by the metallic support of the wire. A calibration of the offset and of the transfer function in the vertical plane was therefore carried out. The beam was moved in steps of 2 mm from the interpolated 0 to - 14 mm.

Step	Interpolated BBLR position (mm)	BBLR position from BBLR BPM
reference position	-0.06	
m2 (minus 2 mm)	-1.51	
m4	-2.99	
m6	-4.45	
m8	-5.86	
m10	-7.32	
m12	-8.76	
m14	-10.18	

5.3 Calibration of the Beam Losses

The BBLR is equipped with a local detection of beam losses with an ionization chamber and a photo-multiplier for increased sensitivity.

Initially, the gain of the ion chamber was increased as no losses could be detected with the beam at 19 mm from the wire. When this distance was decreased, the ion chamber saturated and the gain was readjusted to ....(GF F)

The photomultiplier signal is very sensitive. Under nominal conditions (wire off, no beam displacement at the BBLR), the counting rate increases to 4 KHz at injection and decreases exponentially to reach 0.5 KHz at the end of the cycle. The integrated rate amounts to about 1000 per cycle.

When the beam-wire distance was reduced to a minimum during the calibration of the BPM, the integrated rate went up to about 6 10^5.

5.4 Waveform for the Wire Power Supply

After exciting the wire for the whole cycle, we found that a wave form where the wire is off at the beginning of the cycle provides a better understanding. The programme is as follows:

- 0 to 1s: wire off
- 1 to 1.5s: wire ramping to its set value
- 1.5 to 4s: wire stable at set value
- end of the cycle: wire ramped down with all other power converters.

6 Experimental Results

6.1 Closed orbit perturbation and tune shift due to the wire

The closed orbit was recorded for the following wire excitation levels: 0, 20, 50, 80, 100 and 120 A. It will be analysed. The perturbations are small enough not to cause any problem and do not require correction in this first experiment.

The tune shift due to the wire (120A) at the ‘nominal” -10 mm position was recorded: $dQx = -0.0059$; $dQy = +0.0061$: this is consistent with Annex1 and Annex2. The tune shift is consistent with a beam wire separation of about 14.5 mm. This is slightly larger than the value of 12.95 mm expected from the bump ($= (19.0 - 7.32 + 1.27$ mm)). We took the length of the wire to be 1.2 m.

6.2 Losses and Water Temperature versus Beam-Wire Separation

The aim of this step was to verify that the beam losses do not heat the wire and to get experience in the signal provided by the photomultiplier PMT. The wire excitation was kept constant at 120 A. The separation was varied in steps of 2 mm from 0 to -10mm (at betamaxx), i.e. from 0 to -7.3mm at the BBLR.

Bump	Int. losses
-2mm	600
-4mm	700
-6mm	10^4
-8mm	$5\ 10^5$
-10mm	$2\ 10^6$

Table 1: Integrated losses at the BBLR PMT versus separation

The first observation is that the PMT turns out to be a very sensitive device which seems very informative. We need to work on this signal to understand it well.

For a separation of nominal -4 mm, the losses increase suddenly. This seems consistent with the BBLR becoming the primary apperture limit. One can therefore wonder whether the losses are simply due to the beam grazing the aperture at 6 or more sigma’s or if particles are pushed by the wire excitation.

For the a nominal bump of -10 mm, we switched off the wire excitation and observed a decrease of the losses by one order of magnitude: $2\ 10^6$ to $3\ 10^5$.

Therefore the wire has an action on the tails. The most stricking difference is in the loss pattern: while the losses decrease along the cycle when the wire is off, they are stable at a higher level when the wire is on. In the next step, we study how this pattern changes with wire excitation.

6.3 Losses versus wire excitation

This step was carried out with a constant separation (bump of ‘-10mm’).

There is a gradual increase of the losses from 10A to 30A. At 30A we considered the losses to be already high. The pattern in the cycle is the same as when the wire is off, but at a higher level. At 90A, there seems to be a transition in the pattern: the losses do not decrease anymore in the cycle but are in general very stable, a kind of saturation effect. The same pattern with only a small increase of the losses is observed at 120A.

We probably need to subtract the losses with wire off from the losses with wire on to disentangle the effect of the wire excitation alone.

6.4 Transverse distribution versus wire excitation

The transverse distribution was blown up by a factor of two by kicking the beam,... (Frank + Jorg).

The data collected seem compatible with the wire excitation cutting the tails, say beyond 3 sigma’s. Such a cut is not observed when the wire is off at the same position, i.e. it is not a physical aperture issue.

6.5 Beam Lifetime

The current being very low, the BCT signal was very small and noisy. We did not attempt to exercise the program prepared by Lars to record the beam loss in each cycle, but this will become an important observable.

7 Conclusion

The hardware commissioning shows that the set-up works overall very well. The weak point is the inductive coil which is much too weak and need to be replaced for the next experiment. M. Royer offers to lend us a coil of either 10 or 25 mH. In both cases, we could reach the nominal current. The largest inductance would yield a ripple of the order of 0.1% which is satisfactory.

The large safety margin implemented in the water cooling is confirmed.

No losses could be detected in the BBLR under SPS physics conditions. A bump of 4 mm at the BBLR (about 6mm at the BPM's) is required to lose the beam tails on the BBLR without any temperature increase nor any apprciable signal on the ion chambers. We need to perform more experiment and establish the level of losses allowed, with a criterion of a few degrees of temperature increase. This would probably allow experimenting with more bunches and a higher current (good for instrumentation). It would be convenient to include the BBLR ion chamber in the standard machine BLM's.

The BBLR BPM reading is biased by the presence of the metallic support of the wire. The correction to the offset and to the vertical transfer function were measured and will be included in the BPM software.

The experimental part was a rough sampling of the parameter space, complicated by the limit in wire excitation. We compensated this situation by moving the beam closer to the wire.

The perturbation of the closed orbits and tunes are consistent with the expectations (to be verified indeed!!). We found them small enough not to justify correction in a first experiment. With this caveat, it appears that both the losses on the BBLR as measured by the PMT and the transverse profile measurement indicate enhanced losses leading to a cut of the transverse tails. The losses show a threshold in behaviour when increasing the wire current which is not really understood but is qualitatively consistent with the threshold in diffusion observed in the simulation studies. The very small inductance of the coil creates a ripple of the order of 1% which might contribute to this phenomenology. It is however not expected to modify the main lines of the dynamics (do you agree?). Before quantitative experiments are done, we need the higher inductance coil to reproduce the LHC conditions. We need as well to exercise the measurement of the diffusion by scraping with collimators. We need to develop a proper control of the physical aperture to measure at what amplitude the particles are cut and to loose preferably on the TIDV. However, the measurement of the losses at the BBLR with the PMT seems interesting and may modify our initial aperture strategy. We need to correct for orbit or tune shifts to completely exclude a possible influence of these parameters.

Annex 1: Field expansion of the SPS Wire corrector

$$B_y + iB_x = \frac{\mu_0 I_b}{2\pi r_0} \sum_{n=1}^{\infty} (-\cos n\frac{\pi}{2} + i \sin n\frac{\pi}{2})\ (\frac{x+iy}{r_0})^{n-1} \tag{1}$$

- $n = 1$: $B_y = 0$, $B_x = \frac{\mu_0 I_b}{2\pi r_0}$. One expects a closed orbit perturbation only in the vertical plane.
- $n = 2$: $\frac{\partial B_y}{\partial x} = \frac{\mu_0 I_b}{2\pi r_0^2}$, $\frac{\partial B_x}{\partial x} = 0$. One expects a tune shift and no change of coupling. The tune shift shall behave like any other lens, i.e. opposite in the two planes.

Annex 2: Beam-Wire Distance and Tune Shift

The distance between the beam and the center of the wire is related to the tune shifts $\Delta Q_{x,y}$ induced by a wire current I_b via

$$d = \left(\frac{r_p I_w l_w \beta_{x,y}}{2\pi\gamma ec(\Delta Q_{x,y})} \right)^{1/2}, \tag{2}$$

where l_w denotes the effective length of the wire. The radius of the wire is 1.27 mm.