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SPS

Second Experiment to measure Resonance Driving Terms in the SPS

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Contents

1 Aim of the Experiment

It has been recently [1] shown that a refined Fourier analysis of tracking data can be used to obtain the resonance driving terms and even the non–linear one–turn map that represents the accelerator structure with all non–linearities arising from magnetic imperfections and correction elements. The same information should be obtainable from pick–up data of kicked beams. In case these resonance terms can be determined with high enough precision one can evaluate and compare different settings of non–linear elements and one will be able to correct resonances if the corresponding correctors are available in the accelerator at proper locations. This study is important in particular for the LHC, as the performance of this machine will depend on various non–linear correction systems, which will have to be adjusted using on–line measurements.

In 1998 the goal has been to establish the feasibility of the method. This year we are planning to study the driving terms in a systematic way by varying the strength of the sextupoles and changing the tunes. It is also planned to measure the resonances due to skew quadrupoles. Suppressing these resonances is equivalent to a linear coupling compensation.

Once properly tested, this tool will allow to provide simultaneously the following information:

1. Phase advance between pickups
2. β–beating
3. Linear coupling
4. Detuning versus amplitude
5. Driving terms of resonances
6. Full non–linear model of the accelerator

2 Preparation

The first experiment in June 1998 was hampered by various shortcomings [2]. The second session in September went very smoothly. This year we will make use of the largely improved closed orbit measuring sytem MOPOS which will make it possible to measure along the total length of the SPS. In 1998 the system had been available in $1/6$ of the machine only, data samples were limited to 170 turns and there had been some unavoidable electronic spikes. The planned upgrade of the MOPOS hardware should remove all those problems.

3 Experimental Set–up in 1998

- 120GeV
- Dampers and octupoles off
- 1×10^{12} protons
- Extraction sextupoles at 140A, with polarities: $+ + + + - - - -$
- Linear Coupling (closest tune approach): 1×10^{-3}
- Chromaticities: $\xi_x = -0.05$, $\xi_y = -0.09$
- Closed Orbit: $c.o._x(RMS) = 0.5$mm, $c.o._y(RMS) = 0.4$mm
- Tunes: $Q_x = 26.637$, $Q_y = 26.533$

4 Results of the Experiment in September 1998

We have analysed all data to determine the detuning as a function of the linear invariant $I_x = \epsilon_x/2$ and in search of the three first order horizontal driving terms which are due to sextupoles: i.e. the (3, 0) resonance or f_{3000} term and the two (1, 0) resonances f_{2100} and f_{1200} (see Ref. [1] for details).

The results are shown in Fig. 1. As expected from earlier experiments [3] the detuning as a function of linear invariant (part a. Fig. 1) is very well predicted by tracking (performed with SIXTRACK [4]). Very promising is the agreement between the tracking and experiment for the (3, 0) resonance (part b. Fig. 1), the experimental data are systematically lower by a few percent only. When studying the first (1, 0) resonance (part c. Fig. 1) the problem of the MOPOS system becomes apparent. This line is actually the (0, 0) line in the FFT spectrum. To determine this amplitude dependent offset one has to measure the offset before the kick with high precision which was not possible with MOPOS at that moment in time. Lastly, we present the other (1, 0) resonance in part d. Fig. 1, which should suffer less from the limitations of the measurement system. Indeed, we find less noisy signals in that case. However, there is a significant discrepancy with the tracking data which remains to be understood.

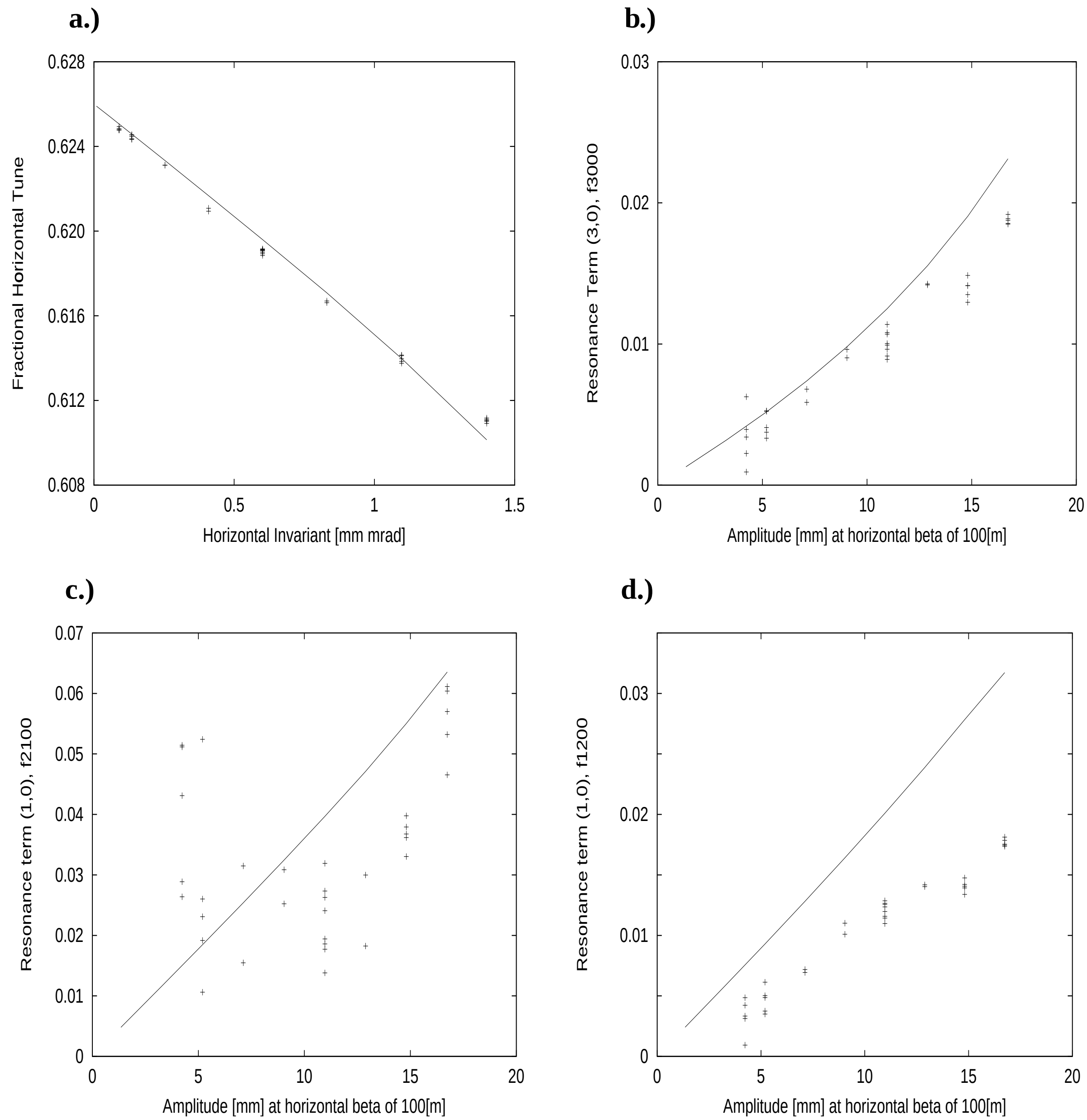

Figure 1: *Detuning and First Order Sextupole Driving Terms*
Part **a.)** Detuning versus linear Invariant I_x
Part **b.)** (3, 0) Resonance versus Amplitude
Part **c.)** (1, 0) Resonance (f_{2100}) versus Amplitude
Part **d.)** (1, 0) Resonance (f_{1200}) versus Amplitude
–Lines are from tracking
–Symbols are experimental data

5 MD plans for 1999

To really show the usefulness of the method we need more systematic studies by varying the sextupole strength and the tunes. To establish a baseline we need to measure without the strong sextupoles for all pickups available and with the improved set–up of the MOPOS system. To find the three resonances with better precision the 8 extraction sextupoles should be turned on and powered as in the previous experiment [2].

Tracking studies have shown that a change of the polarity allows to increase the (3, 0) resonance by a factor of five while reducing both (1, 0) resonances by a factor of two. This second powering scheme of the sextupoles gives us therefore a sufficiently different alternative. It goes without saying that in all three cases the closed orbit, the coupling, the tunes and, in particular, the chromaticity have to be adjusted to their desired values. For the first setting of strong extraction sextupoles it is foreseen to explore another working point and also to approach the third order resonance. The latter case (the traditional approach) will provide a benchmark to test the proposed measurement via FFT spectra.

Lastly, we will explore the possibility to measure the (1, –1) and the (1, 1) resonance, i.e. the linear sum and difference resonances due to skew quadrupoles. It has been shown recently [5] that our analysis tool "SUSSIX" [6] can be used to measure these resonances from beam data. Further tracking studies have demonstrated that the method should work even in case of large linear coupling.

The measurement requirements are:

- Two sessions needed, 8h each
- 120GeV
- Dampers and octupoles off
- 1×10^{12} protons
- Sextupole Settings:
  - strong 8 extraction sextupoles switched off
  - extraction sextupoles at 140A, with polarities: $++++----$
  - extraction sextupoles at 140A, with polarities: $++++++++$
- Linear Coupling
  - (closest tune approach): 1×10^{-3}
  - measuring the two linear resonances f_{1001} and f_{1010} and minimising them to decouple the machine
- Chromaticities: $\xi_x = -0.05$, $\xi_y = -0.09$
- Closed Orbit: $c.o._x(RMS) = 0.5$mm, $c.o._y(RMS) = 0.4$mm
  It would be desirable to have the closed orbit readings at the 8 locations of the extraction sextupoles.
- Tunes (including extraction sextupoles):
  - $Q_x = 26.637$, $Q_y = 26.533$
  - $Q_x = 26.605$, $Q_y = 26.538$
  - close to $1/3$ resonance

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