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OPTICS MODEL AND MEASUREMENTS OF THE DAFNE TRANSFER LINES

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Abstract

The different components of the DAFNE accelerator complex: LINAC, Damping Ring and two colliding rings are connected by a composite system of Transfer Lines which, thanks to adaptive configurations, are able to transport electron and positron beams at 510 MeV. Recently, thanks to the introduction of new diagnostics tools, the optics model of the DAFNE Transfer Lines has been improved and successfully used to make the collider operations more efficient.

The measurements done by using the new tools and their impact on the optics model optimization process are presented and discussed.

INTRODUCTION

DAΦNE [1] is an e^+e^- collider working at the center of mass of 1 GeV, about 0.5 GeV/beam and ~100 m long main rings, which successfully delivered data to the KLOE-2 experiment [2, 3] from 2014 to March, 2018, and it is foreseen to continue its collider operation during 2019 delivering data to the SIDDHARTA-2 [4, 5] experiment.

At the DAΦNE facility, the LINAC accelerates particles of both charges up to 510 MeV with repetition rate of 50 Hz. Beam bunches are transported to the damping ring to be accumulated and subsequently extracted at 2 Hz repetition rate. The procedure to change the magnets polarities and set points from the injection of one particle species to the other is called "*switch*".

MOTIVATION AND SCOPE

During the past years of operation of DAΦNE there has been a continuous effort to optimize the multiple sectors of the machine [6]. In particular, it was clear that the short beam life in the main rings at high current during collision, typically 900 s$\leq \tau \leq$1200 s, was the main issue to address in order to achieve higher peak and average luminosities.

An update of the transfer lines operation was required aiming at faster and more frequent injections in both rings.

We present the update of the control procedure to switch the magnet polarities between injections in the accumulator and transfer lines. We also present measurements on the positron transfer line (TLp) from the accumulator ring to the main positron ring using several existing/reviewed diagnostic tools.

TOOLS FOR TRANSFER LINES DIAGNOSIS

The TLp is 65.9 m long. Eleven stripline beam position monitors (see Fig. 4) are distributed along this section with an estimated resolution of 0.1~0.2 mm [7]. There are also eleven beam profile monitors (see Fig. 4) consisting on targets of Beryllium Oxide with grids of either 2 or 3 mm [8].

Many of the already existent tools have been revised and upgraded to optimize operations:

- The communication protocol between the control system and the power supplies has been reviewed to reduce the communication errors
- Parallel control switching has been implemented
- The pulse by pulse acquisition of the transverse beam position has been implemented to analyze the injection history
- Hit maps of the transverse beam position are visualized in order to gain live information of the injection stability
- Maintenance and improvement of the beam profile monitors.

MEASUREMENTS

Transverse Position Stability

The pulse by pulse acquisition of the beam XY-position along the line allowed to identify the pulsed dipole DHPTT001 as a source of fluctuations, typically below 1 mm of amplitude. Figure 1 shows the correlation of the horizontal fluctuations measured at the last stripline with another upstream, just after the dipole. Such correlation is not visible in any of the striplines before the dipole.

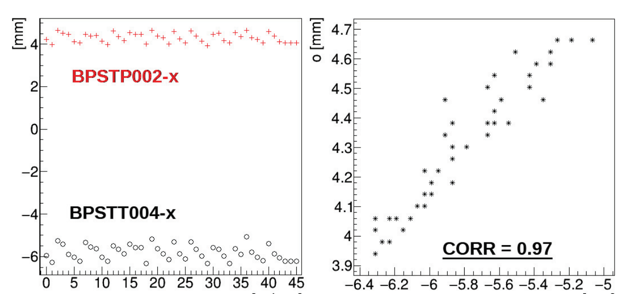

Figure 1: (Color online) LEFT: Pulse by pulse horizontal position measured at two different striplines. RIGHT: Correlation of the horizontal fluctuations.

Effect of the Switch

Figure 2–top shows the hit map of two positron injections separated by one electron injection, therefore, after

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two switches of the transfer lines. There are two spots visible, showing the limits of the repeatability of the magnet configuration. In general, differences on the order of one millimeter have been observed along the transfer lines between switchings, although, they do not compromise the effective injection in the positron ring.

The hit map profile available in the control room during the machine operation allowed to see the spread of the transverse position due to the multiple switchings executed (Fig. 2–bottom).

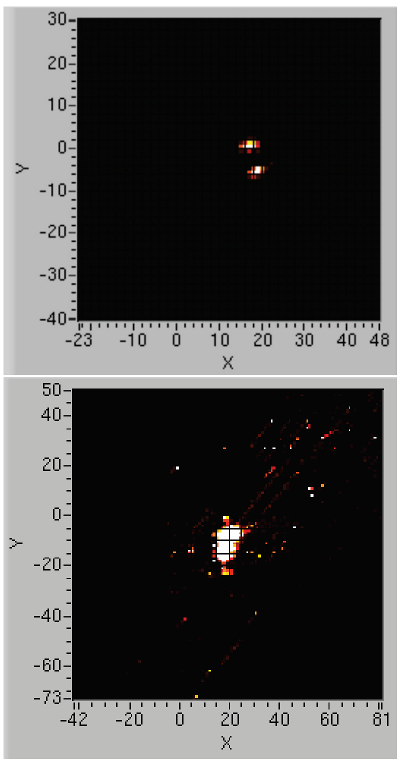

Figure 2: (Color online) Hit map of the transverse position seen at the last stripline in the TLp: (TOP) in two injections separated by one electron injection, (BOTTOM) and multiple injections. Five a.u are equivalent to 1 mm.

Dispersion

The trajectory of the injected beam has been also acquired for three different energy configurations of the accumulator ring using the dipoles current set-point : the nominal 610.5 A, a change of -0.5 A and a change of -1 A. It is worth to mention that a change of 1 A in the dipoles of the accumulator corresponds to 0.07% of change in energy.

Figure 3 shows the effect on the transverse position measured at the last stripline (BPSTP002). The mean transverse position of the injected particles for two different accumulator configurations has been used to calculate the dispersion from the trajectory. Figure 4 shows the results.

RESULTS

The reduction in the transfer lines switching time allows to achieve up to 42 injections (21 for positrons and 21 for electrons) in the main rings in two hours of operation. This corresponds an injection every 3 min, reducing the impact on luminosity because of the short beam life time mentioned before. Such top-up injection performance also helps to optimize the collisions at high current in the main rings, further increasing the luminosity and allowing to collect more than 630 nb/hour.

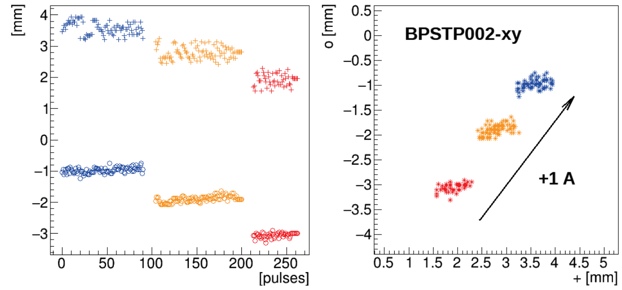

Figure 3: (Color online) LEFT: Pulse by pulse record of the XY-position of the injected beam for three different accumulator setting : in blue the nominal value, yellow is -0.5 A in accumulator dipole, and red is -1 A. RIGHT : XY-position.

Dispersion measurements and beam transverse position along the transfer line has been used to match the linear optics of the model. Figure 5 shows the latest result of the optics model. Table 1 list the matched values in percentage with respect to the nominal gradient $K1$ or the angle with respect to the magnet in the MAD-X convention [9].

Table 1: Matched Elements in the TLp to Obtain the Beam Profiles and Dispersion Measured

Element	Parameter	Value	Match condition
SPTA1002	ANGLE	90%	η at BPSTL002
QUATT003	K1	115%	β_{max}<100 m, η at BPSTT003
QUATT005	K1	80%	β_{max}<100 m, η at BPSTT003
DHSTT001	E1	30 mrad	η at BPSTT005
DVRTT001	E1	-8 mrad	β at FL1TT003
QUATT010	K1	75%	η at BPSTP002
QUATT011	K1	78%	η at BPSTP002
QUATP004	K1	120%	β at FL1PL101

CONCLUSIONS

The performance of the transfer lines of the DAΦNE facility has a sizable impact on the beams intensity in the collider rings. The latest update on the switching control increased the injection repetition rate and simplified the operation, successfully improving the overall machine conditions.

Diagnostic tools have been revisited to achieve an improved control of the transfer lines. The measurements done along the positron transfer line from the DAΦNE accumulator to the main rings have been used in combination with beam profile monitors to update the optics model.

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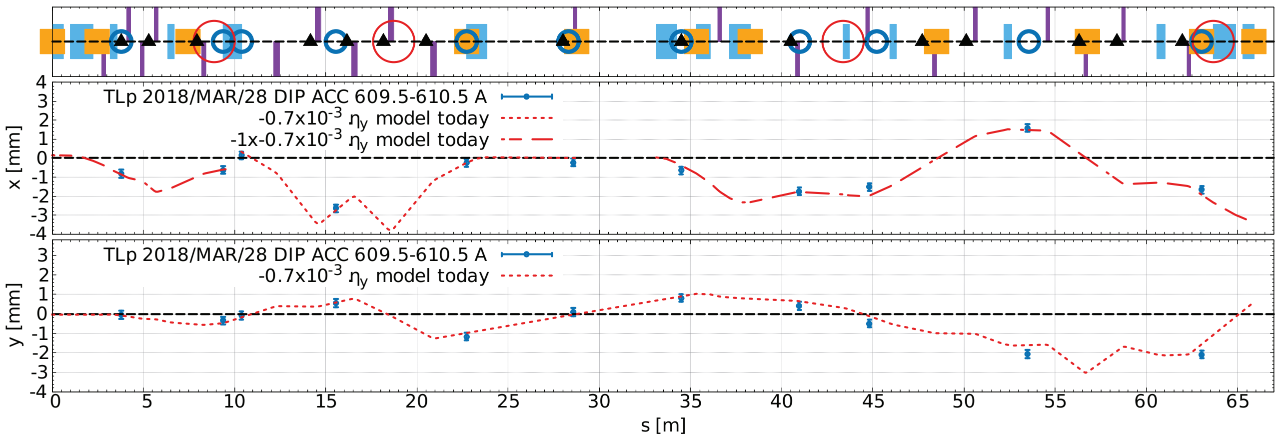

Figure 4: (Color online) TOP: Magnetic elements (dipoles in light–blue, correctors in black and quads in violet) along the TLp including diagnostics (blue circles are stripline BPMs, yellow squares are beam profile monitors, red circles are wall current monitors). BOTTOM: Measured (dots with error bars) and matched (dashed line) dispersion.

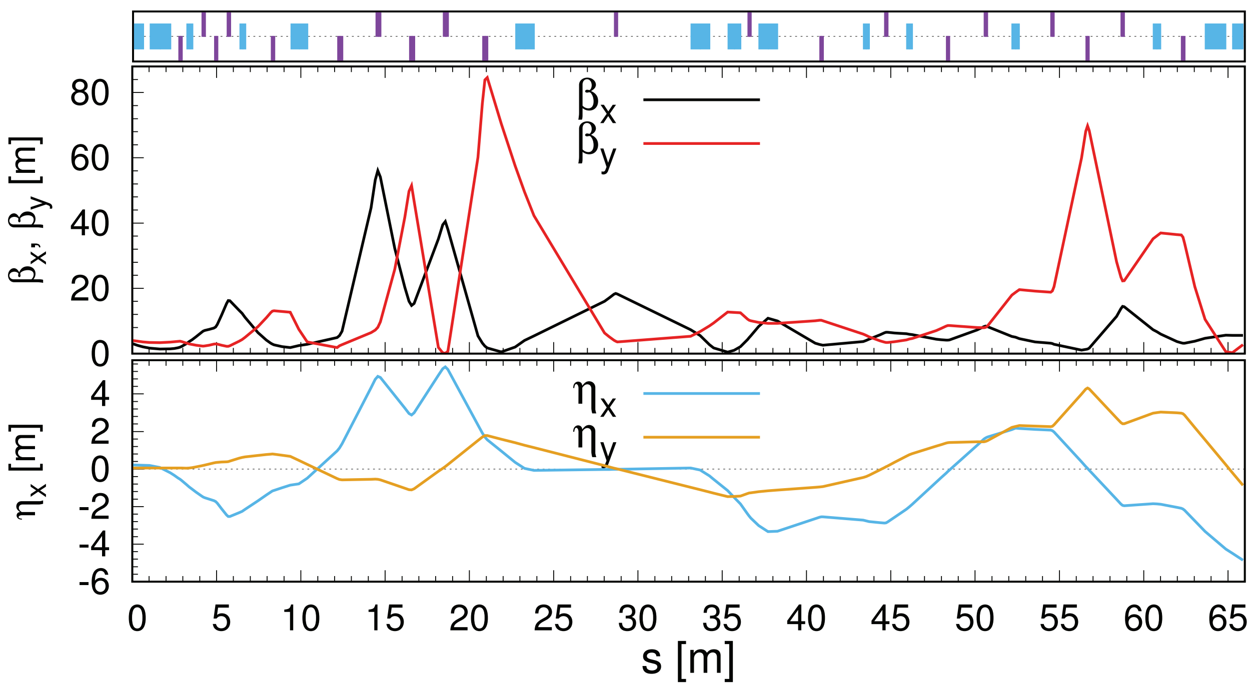

Figure 5: (Color online) Optics β functions and dispersion along the TLp.

The work here presented also contributes to the understanding of the electron transfer line, as several critical sections pointed out here are common to both injections.

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