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PREPARATION ACTIVITY FOR THE SIDDHARTA-2 RUN AT DAΦNE

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Abstract

DAΦNE, the Frascati lepton collider working at the c.m. energy of the Φ resonance, continues to be a prominent infrastructure to realise experiments aimed at studying elementary particles and nuclear physics. The motivations of this long lasting interest are related to the DAΦNE ability to increase its performances in terms of luminosity thanks to the innovative Crab-Waist collision scheme developed and implemented for the first time by the Frascati Team.

In this framework, a new run for the SIDDHARTA-2 experiment has been planned in the year 2019. The detector presently installed in the interaction region, KLOE-2, will be removed and a new low-β section equipped with new permanent magnets quadrupoles, will be installed. Diagnostics tools will be improved especially the ones used to keep under control the beam-beam interaction. The horizontal feedback in the positron ring will be potentiated in order to achieve a higher positron current.

The design and development work done in view of the SIDDHARTA-2 run is presented and discussed.

INTRODUCTION

DAΦNE [1] is an accelerator complex consisting of a double ring lepton collider working at the c.m. energy of the Φ-resonance (1.02 GeV) and an injection system. The collider includes two independent rings, each ~97 m long. The two rings share a purpose built interaction region (IR), where the detector on duty is installed. A full energy injection system, including an S-band linac, 180 m long transfer lines and an accumulator/damping ring, provides fast and high efficiency electron–positron injection also in topping-up mode while delivering luminosity.

DAΦNE attained its maximum luminosity during the test of the new Crab-Waist collision scheme [2-4] with the SIDDHARTA apparatus achieving a peak luminosity of $L = 4.5 \cdot 10^{32}$ cm^{-2}s^{-1}.

Presently DAΦNE, after having successfully completed the KLOE-2 run [5], is facing the preparatory phase propaedeutical to a new operation period aimed at delivering data to the SIDDHARTA-2 detector, an upgraded version of the old one. The new experimental apparatus aims at performing the first kaonic deuterium measurement by improving its measurement resolution, which, in turn, requires to considerably reduce the signal background ratio and increase the signal rate [6]. The SIDDHARTA-2 experiment aims at integrating a sample of data of the order of 1.0 fb^{-1}. This target should be achieved in one year operations.

REVAMPING PROGRAM

In view of the SIDDHARTA-2 physics run many subsystems and machine components are going to be revamped.

Mechanical structures supporting and giving access to the Interaction Region (IR) must be reviewed in order to be compliant with the new experimental apparatus and with the present safety standards.

Several vacuum components will be replaced. New sputter ion pumps will substitute for faulty devices and for the NEG ones previously installed in the IR.

A general check up of more than 500 power supplies has already started. Each power supply will be tested in all its components with special attention to the cooling units and to the DCCT calibration. The capacitor banks of the power supplies powering the two pulsed dipoles, the more sophisticated magnets of the Transfer Lines, will be replaced with new components. Each capacitor bank is composed by 50 capacitors and the total capacity amount is about 7 mF. The possibility to substitute all the correctors power supplies (short and long) both in the positrons and in the electrons rings is also under evaluation as well. The accuracy and resolution of the new power converter would be improved by more than a factor 10 with respect to the old devices. This last aspect is of extreme importance in order to guarantee reliable and stable performances during collisions.

The two dump kickers, one in each ring, previously installed in the section opposite to the IR will be replaced by a straight beam pipe in the e^- ring, and by a new feedback kicker in the e^+ one in order to implement an additional horizontal feedback system.

SIDDHARTA-2 INTERACTION REGION

Several well founded considerations led us to install the SIDDHARTA-2 apparatus in place of KLOE-2 one that, as a consequence, must be moved back into its hangar.

Regardless, the IR hosting the SIDDHARTA-2 detector is based on the Crab-Waist collision scheme too, it is deeply different from the one used to deliver data to the KLOE-2 experiment. The only components that could be reused are the Permanent Magnet Quadrupoles, PMQ, of the low-β which, however, should be extracted from the

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inner side of the apparatus requiring considerable time and manpower. The decision to build new PMQ gave us a useful opportunity to speed up the installation procedure and to improve design aspects of the low-β quadrupoles as well.

Low-β Quadrupoles

The low-β insertion of the SIDDHARTA-2 IR requires 6 magnets: 2 defocusing quadrupoles, PMQD, common for the two beams, and 4 focusing magnets, PMQF, one for each branch of the IR.

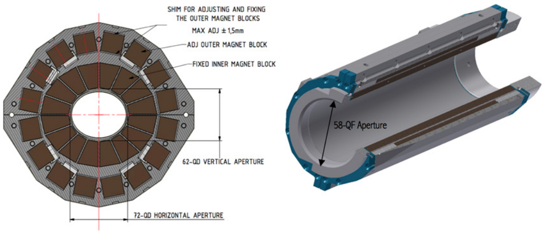

Figure 1: PMQD mechanical cross section (left), and PMQF 3-quarter section (right).

The new PMQ, shown in Fig. 1, have been designed in collaboration with the ESRF magnet group with the intent to improve: good field region, gradient uniformity, aperture, and mechanical assembly. The last aspect has special relevance for the PMQF which are installed very close to each other, see Fig. 2. Bore radius is the main issue in order to provide a proper stay clear aperture for the beams and reduce background on the detector. A larger horizontal aperture is very relevant mainly for the PMQD, in which colliding beams trajectories passes of axis.

The new PMQ are Halbach type magnets made of SmCo2:17, some of their more relevant parameters are shown in Table 1 along the corresponding beam pipe aperture. PMQD consist of 2 rings of permanent magnet wedges, as in Fig. 1, the inner blocks are arranged according a fixed elliptical symmetry, while the outermost ones are disposed with circular symmetry and can be moved radially to shim the gradient strength and its inhomogeneity. PMQF are based on 2 concentric cylinders of PM wedges having different lengths, see Fig. 1, also in this configuration the PM blocks of the outer cylinder can be moved radially for shimming purpose.

Table 1: PMQ and Beam Pipe Parameters

	PMQD	PMQF
Beam Pipe Aperture H-V (mm) at IP (I row) and at Y (II row) side	57 69 - 55	54
Inner Apert. With Case H-V (mm)	72 - 62	58
Outer Diameter H-V (mm)	238 - 220	95.6
Mech. Length Inner-Outer (mm)	220	168 - 240
Nominal Gradient (T/m)	29.2	12.6
Integrated Gradient (T)	6.7	3.0
Good Field Region (mm)	±20	±20
Integrated Field Quality |dB/B|	5.00E-4	5.00E-4
Magnet Assembly	2 halves	2 halves

Aluminium casing has been designed relying on a comprehensive analysis of the magnetic forces among the different PM wedges and paying attention to installation requirements as well. The new PMQD vacuum chamber has a tapered design allowing to match the elliptical quadrupole aperture, on the side of the Y-shape beam pipe, and the IR circular one at the entrance of the common vacuum chamber, as shown in Fig. 2.

IR Vacuum Chamber

The vacuum chamber of the low-β section have been designed in order to fit with the new quadrupole apertures, paying great attention to the impedance budget of the new structure.

In a collider composed of two separate rings having a common IR it is unavoidable to create electromagnetic higher order modes (HOM) in the area where the vacuum beam pipes of the two rings merge in the common beam pipe (Y-shape chamber) [7, 8].

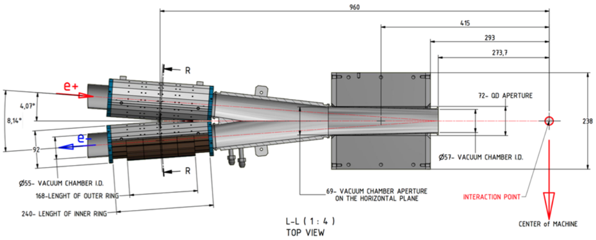

Figure 2: Half IR mechanical assembly, top view.

The numerical simulations with HFSS [9] have revealed the existence of two HOMs trapped in the Y-chamber of the new SIDDHARTA-2 IR at frequencies of 1.863 MHz and 2.299 MHz respectively. These modes are rather weak to create any dangerous multi-bunch instability that can be always controlled by the power feedback systems of DAΦNE. However, despite these are the TE-like modes, there are non-negligible longitudinal fields along the beam trajectory contributing into the longitudinal beam coupling impedance. Since the mode frequencies are rather close to the beam power spectrum lines there is a high probability of power loss enhancement in multi-bunch operations. For example, the first mode frequency is very close to the 5th harmonic of the RF frequency at 1.843 MHz. In the worst scenario of the full coupling of the spectrum line with the mode frequency the released power is estimated to be of the order of 0.5 kW. In order to avoid excessive overheating of the Y-chamber, and a resulting vacuum pressure rise in the vicinity of IR, it has been decided to apply cooling pipes on the top of the chamber. The simulations with ANSYS [10] have confirmed that the chamber temperature is kept under control in that case. Moreover, the temperature variation can also help in shifting the mode frequency with respect to the spectrum line thus providing another safety knob.

COLLIDER UPGRADES

Feedback Systems

In a low energy machine as DAΦNE high current performances depend greatly on bunch by bunch feedback systems. DAΦNE works routinely thanks to the 3 bunch by bunch feedbacks installed in each ring, one dedicated to stabilize longitudinal motion, and the other two intended to dampen transverse horizontal and vertical oscillations. The total power available for each apparatus is of the order of 500 W and 750 W for transverse and longitudinal feedbacks respectively. In view of the SIDDHARTA-2 run these systems will be upgraded in order to assure the highest possible stable beam intensities.

The longitudinal feedbacks will be upgraded adopting the back end timing remote control module based on the QPSK modulator, in order to achieve a more effective tradeoff between dipole and quadrupole longitudinal motion control at the same time [11].

As far as the vertical feedback systems are concerned the low noise front end module will be upgraded in terms of user interface, and by providing the phase shifter with remote control to achieve an easier and cleaner response. Moreover the environmental RF and DC noise coming from pickups, which can lead to anomalous vertical beam size growth, will be mitigated by adopting a low noise front end; the one that has been designed, in the past years, in collaboration with SuperKEKB feedback Team.

High intensity e^+ current deserves special attention since it is dominated by the e-cloud induced instabilities. This effect, at DAΦNE, is counteracted by means of powerful bunch-by-bunch transverse feedback systems, by solenoids wound all around the straight sections and by appositely designed electrodes [12] installed inside dipole and wiggler vacuum chambers. Such electrodes proved to be very effective in mitigating the e-cloud formation, and they have had a primary role in achieving high intensity e^+ currents during the first half of the KLOE-2 run. However, after 40 months of operations, two electrodes only were working properly, and none of them was in the wiggler magnets were the e-cloud formation is more harmful. Moreover, due to the lack of conditioning with the beam, it is reasonable to expect a higher secondary emission yield from the new Al beam pipe in the IR. In this context, it has been decided to add a second transverse horizontal feedback in the e^+ ring, thus doubling the total power available to keep under control the e-cloud detrimental effects.

Luminosity Measurement

In order to ensure fast absolute luminosity measurement the IR will be equipped with two independent diagnostic tools.

The main luminosity measurement will rely on the small angle Crystal CALorimeters with Time measurement, CCALT [13], that was part of the KLOE-2 detector, in order to measure the Bhabha scattering events at small angle. The CCALT consists of two identical crystal calorimeters installed in front of each PMQD. This detector has been efficiently used, while providing data to the KLOE-2 experiment, to implement an absolute instantaneous luminosity measurement with an accuracy of the order of 5÷10% depending on repetition rate and threshold settings [14].

The CCALT luminosity measurement has been successfully cross-checked with the more accurate one provided by KLOE-2 apparatus. Moreover the diagnostics time resolution has proven to be suitable to implement bunch by bunch luminosity measurement.

A second diagnostics based on Bhabha GEM tracker and a gamma bremsstrahlung proportional counter [15] will be installed as well. These detectors, thanks to the very high rates, can be efficiently used as real time tool during machine luminosity optimization. However they cannot provide a reliable absolute luminosity measurement since they are heavily affected by beam losses due to interaction with the residual gas, Touschek effect, and low angle scattered particles generated along the IR.

Machine-experiment Data Exchange

Dynamic Data exchange between machine and experimental staffs is a key feature. Having data reporting machine operating conditions and experiment meaningful parameters helps both staffs to run in the most effective way. A typical example is the continuous machine tune up needed to grant the highest luminosity rate while lessening the background level on the experiment apparatus.

Data exchange requires a proper network interconnection between the computers handling the experiment and the machine Control System. Those systems are often independentent from each other because experimental groups are used to managing their systems with hardware and software tools specifically targeted. In the DAΦNE-SIDDHARTA collaboration the network set up has been kept as simple as possible, using a dedicated vLAN for the computers dedicated to the front-end acquisition and the experiment slow control. Such vLAN is then routed on the laboratories LAN which the users' consoles are connected to.

Two data records have been defined; one being sourced from the machine Control System and the other from the experiment. The records are then continuously written in plain text format by the two counterparts to files mutually shared with NFS. Besides this conservative approach, it has also been decided to stream the same information in JSON packets sent through http REST queries to a !CHAOS [16] installation, in order to make them available also in this new control framework, recently implemented at LNF.

CONCLUSION

An extensive program has been defined, and is under way to prepare the run for the SIDDHARTA-2 experiment at DAΦNE.

Several aspects of the collider and many subsystems have been upgraded in order to grant the highest performances in terms of luminosity and the lowest background contamination on the acquired data.

The run for SIDDHARTA-2 will be the very last physics run of DAΦNE as a collider; thereafter the accelerator complex will most likely be converted to a test facility.

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