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DAΦNE GENERAL CONSOLIDATION AND UPGRADE

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Abstract

In the first six months of 2013 the KLOE detector has been upgraded inserting new layers in the inner part of the apparatus, around the interaction region. The long shutdown has been used to implement a general consolidation program aimed at improving the Φ-Factory operation stability and reliability and, in turn, the collider uptime. In this context several systems have been revised and upgraded, new diagnostic elements have been installed, some critical components have been modified and the interaction region mechanical support structure has been redesigned to improve its mechanical stability and to deal with the weight added by the new detector layers.

INTRODUCTION

DAΦNE 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 infrastructure has been working for more than 17 years. In recent years frequent faults have affected the collider operations reducing drastically the uptime. Several sub-systems relying on obsolete technologies suffered from spare part shortage. The mechanical structure of the interaction region (IR) had shown to be inadequate to steadily support the heavy defocusing quadrupoles cantilevered inside the detector. As a consequence the two beams were oscillating in phase at 10 Hz in the vertical plane. Some components got seriously damaged. It is the case of some bellows in the IR, which had lost electrical continuity causing anomalous beam induced heating of one of the two defocusing quadrupoles, resulting in a harmful random vertical tune-shift. The shut-down scheduled in 2013, mainly intended to install new detector layers inside the KLOE-2 experiment, offered a convenient opportunity to revise the IR mechanical design as well as to undertake a wide consolidation program involving several subsystems.

MECHANICAL UPGRADE

A major effort has been done to upgrade the Interaction Region (IR) mechanical structure.

Interaction Point

The vacuum chamber around the Interaction Point (IP) has been replaced. The new one has tapered transition between the thin ALBEMET sphere and the Al beam pipes, and includes reshaped bellows with new designed RF contacts, see Fig. 1. Replacing the bellows solved the low-β defocusing quadrupole heating problems, recovering working point stability in operations.

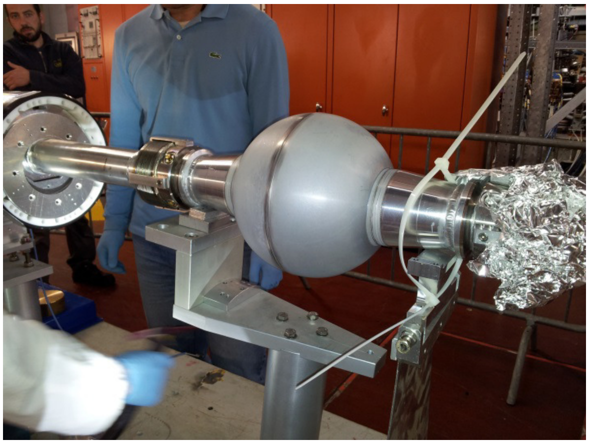

Figure 1: IP spherical vacuum chamber.

Two cooling pipes have been added on the tapers and new semi-cylindrical thin (35 μm) beryllium shields have been placed inside the sphere. Two additional Beam Position Monitors (BPM) have been installed on both sides of the IP, for a more accurate beams overlap and to perform transverse betatron coupling studies.

Structural Improvements

The IP chamber and the low-β defocusing quadrupoles are suspended at the two sides of the detector. The whole support structure is critical for the stability of the assembly.

Figure 2: The DAΦNE IR with the new detector layers ready to be inserted in KLOE-2.

The design of supports of the vacuum chambers and equipment, as well as for the magnetic and diagnostic elements have been revised to host the new detector components and the hugely increased number of cables and pipes for gas and coolant, as well as to stand additional weight, see Fig. 2, and improve alignment precision. In particular, a pair of carbon fiber composite additional legs has been designed and superimposed to the existing ones, and some rubber pads previously inserted below the cradle support have been removed, thus strengthening the structure and increasing its rigidity. As a result the spectrum of the vertical beam oscillation has been modified. The main harmonic has been shifted toward higher frequencies, ~15 HZ, and its amplitude reduced by a factor three, see Fig. 3.

About the steelwork structure around the IR, some reinforcing plates have been added to the H-shaped girders, including new grounding anchorage with adjustable bolts for the tail of the girders itself.

Functional Improvements

Several other actions have been undertaken:

- More and better placed CCR holes for alignment have been added.
- Newly designed mechanics (cams and kinematics) now allows a better control of the angular rotation of the low-β focusing quadrupoles from outside the detector.
- Temperature probes have been added on the Interaction Region vacuum chamber.
- Toroidal shields have been added around the IP to reduce the background hitting the detector.
- New Beam Position Monitors have been placed along the rings.

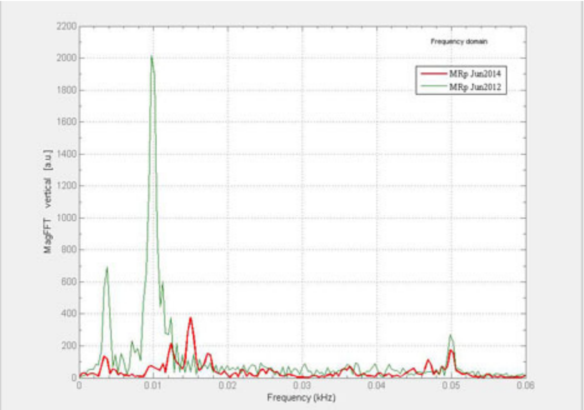

Figure 3: Spectrum of the e^+ beam vertical oscillation as measured before (green line) and after (red line) the IR mechanical consolidation.

ANCILLARY PLANTS' CONTROL SYSTEM REVAMPING

The control system of several utility plants serving the accelerator has been revised. The systems involved have been the Fluids plants (cooling and HVAC, compressed air), the RF plants, the Vacuum plants and the safety system of the magnets over-temperature control subsystem. 15 PLC substations have been replaced. The control system of the Fluids plants has been re-engineered, substituting the whole PLC system.

The control logic of the new system has been modified to take into account the huge power demand reduction of the largest magnets (Wigglers, Septa), and aiming at saving energy for the cooling plants. Replacement of obsolete items drove the change of the PLCs controlling the Vacuum plants (valves and gauges) and the RF plants (klystrons, cavities, circulators and loads), but in this case the dismissed equipment has been kept to be used as spare parts for the magnets over temperature control subsystem.

In this refurbishment also the SCADA has been renewed allowing the remote control of all the subsystems to facilitate and speed up faults diagnosis during the current machine operation. The Supervisor was developed with Movicon SCADA and customised upon specific requests.

CONTROL SYSTEM UPGRADE

The DCS (DAΦNE Control System) has been deeply modified in order to dismiss most of the VME bus platforms.

In its original design, the system central shared memory - where all the live data reside - relied on VME RAMs and the communication channels were based on point-to-point optical links, realized with VME boards. This architecture required the use of VME embedded processors for any purpose.

The new design of the DCS hinges on the redirection of the whole data flow to the network and the adoption of an *Object Caching* service (*Memcached*) for hosting the live data.

Most of the front-end boards (serial communication boards, DAQs, ADCs, etc.) have been replaced by network devices, which allowed for the porting of many control programs to remote Linux virtual machines. In particular, the adoption of *serial device servers* instead of serial communication boards, permitted to increment the number of daisy chain lines (RS-422) employed in connecting the magnets' power supplies and consequently to speed up the commutation of the machine from the positrons to the electrons operating modes (and vice-versa).

The DCS upgrade also aimed at the replacement of the original distributed front-end VME processors (forty-five 68030 custom boards, running MacOS 7) with Intel boards, running Linux. At the present time, only 11 of the original VME processors are left.

New Linux servers have been setup for the core services (NFS, DHCP, diskless boot, MySQL, memcached) and for the SunRay™ thin-clients employed as consoles. The virtualization system hosting the virtual machines has been set-up with Red Hat Cluster Suite and XEN 3.2014. The upgrade has also concerned both the *hardware* and the *software* of many front-end systems, in order to take advantage of the new DCS structure. The systems that have gone through major changes are: RF Slow Control, Main Ring Scrapers, Programmable

Delays, Power Supplies, Main Rings and Damping Ring Kickers, Beam Charge Monitors, Spectrometer, Vacuometers, Vacuum Pumps and Clearing Electrodes.

After the upgrade, the DCS proved to be performable and reliable and its overall uptime - in real operating condition - significantly increased. The remaining legacy front-end processors will be replaced by the end of 2014.

CRYOGENIC PLANT

The cryogenic plant, serving the superconducting solenoid of the experimental apparatus and the four anti-solenoids installed on the collider rings, has been completely overhauled and some specific parts have been mended or replaced. Some o-rings sealing in the helium transfer lines have been replaced with soldered connections. Two partially damaged Joule-Thomson needle valves have been reworked. A remotely controlled pneumatic valve has been added in the liquid nitrogen line. PT100 thermometers were installed in the nitrogen line of the anti-solenoids transfer lines, close to the gas flow controllers. The obsolete remote PC for the plant control has been replaced as well as the operator interface panel. The listed activities were aimed at preventing accidental freezing at the controller level, and at ensuring remote procedures for refilling the anti-solenoids.

LINAC

All the LINAC components have been overhauled paying special attention to the four RF power plants. In this context several exhausted components such as filter capacitors, thyratrons and high power pulse discrete elements have been replaced, and a new designed RF driver system has been installed aiming at achieving a better stability in terms of delivered power.

New vacuum pumps and ancillaries have been added on the four main waveguides downstream the SLEDs, in order to reduce discharge occurrences.

Concerning the RF-vacuum devices in the LINAC accelerating sections, the residual pressure considerably improved by replacing all the RF loads. The vacuum safety system gating valves and some in-vacuum diagnostic elements such as flags and BPMs have been also replaced.

All the ceramic windows, placed downstream the klystron ones to decouple the LINAC vacuum, were almost at the end of their operating-life and have been preventively substituted.

As a special case, the RF power plant ‘D’, driving the last four accelerating sections, required an extraordinary mending effort, even beyond the 2013 shut-down. Several parts had to be replaced such as: the klystron, the waveguide elbow interfacing the klystron, the SLED and many ancillary components.

Some bugs in the Helmholtz Coil power supplies have been detected and fixed. The PLC control system has been upgraded, and its parts underwent an accurate revision involving: water ducts, flux-meters and water pumping system, leading to replacement of many components. The LINAC control system has been revised and upgraded in order to be compliant with the renewed Ethernet architecture (new routers and VLAN relying on fiber connections) and to profit from new network features. In this context a new control application, based on dedicated multiplexed DAQ, has been designed and implemented for the 14 LINAC BPMs.

OTHER ACTIVITIES

Many other remarkable activities have been done.

The magnetic field of the IR defocusing quadrupoles has been measured detecting discrepancies of the order of few % only with respect to *ab initio* characterization. The 32 power supplies powering a family of corrector magnets have been replaced with updated devices.

The HV power supplies polarising the e-cloud clearing electrodes have been exchanged with devices providing twice the original voltage and having negative polarity. This to achieve a complete neutralization of the e-cloud generated by a positron current of the order of ~1. A, and to reduce the generator delivered current.

More robust feedthroughs have taken the place of the ones originally used for the electrodes installed inside the wiggler magnets of the e^+ ring.

The screw holes in the jaw of four scrapers, installed two in the e^- and two in the e^+ ring, have been filled by adding shielding copper extensions, to avoid HOM trapping. Moreover the limit switches have been extended to increase the collimator stroke, to better suppressing the background hitting the experimental detector.

Two new vacuum chambers have been built and installed near the injection sections of both rings. Each new beam pipe is carrying eight button BPMs to be used for orbit measurements and as feedback pickup.

Concerning the bunch-by-bunch feedback systems, a new horizontal kicker with a doubled stripline length has replaced the original one on the electron ring, providing larger shunt impedance at the low frequencies typical of the unstable modes. This allows doubling the feedback damping rate for the same setup (gain, power amplifier, etc.). A dedicated virtual LAN for all feedback units provides a faster real-time data processing. Hardware has been upgraded and Linux software updated to be compliant with the most recent netware and software releases.

CONCLUSION

The DAΦNE consolidation plan has been completed almost on schedule. Since then a clear positive trend has been observed in terms of machine up-time and operation stability. Some criticalities remain mainly concerning the LINAC and cryoplant systems, which will require further consolidation efforts to be planned in the near future.

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