CHALLENGES AND CONCEPTS FOR DESIGN OF AN INTERACTION REGION WITH PUSH-PULL ARRANGEMENT OF DETECTORS – AN INTERFACE DOCUMENT*

B.Parker (BNL), A.Herve, J.Osborne (CERN), A.Mikhailichenko (Cornell Univ.), K.Buesser (DESY), B.Ashmanskas, V.Kuchler, N.Mokhov (Fermilab), A.Enomoto, Y.Sugimoto, T.Tauchi, K.Tsuchiya (KEK), J.Weisend (NSF), P.Burrows (Oxford Univ.), T.Markiewicz, M.Oriunno, A.Seryi, M.Sullivan (SLAC), D.Angal-Kalinin (STFC), T.Sanuki, H.Yamamoto (Tohoku Univ.)

Abstract

Two experimental detectors working in a push-pull mode has been considered for the Interaction Region of the International Linear Collider [1]. The push-pull mode of operation sets specific requirements and challenges for many systems of detector and machine, in particular for the IR magnets, for the cryogenics and alignment system, for beamline shielding, for detector design and overall integration, and so on. These challenges and the identified conceptual solutions discussed in the paper intend to form a draft of the Interface Document which will be developed further in the nearest future. The authors of the present paper include the organizers and conveners of working groups of the workshop on engineering design of interaction region IRENG07 [2], the leaders of the IR Integration within Global Design Effort Beam Delivery System, and the representatives from each detector concept submitting the Letters Of Intent.

INTRODUCTION

The process of finding an acceptable technical solution for the Interaction Region involves searching a balance between complex and often contradictory requirements coming from machine or detector. An Interface Document was thought as a way to keep track of the achieved agreements and assumption, and also as the way to highlight existing contradictions and focus the efforts for their resolution. The latter imposes the present Interface Document to be an evolving entity. The first attempt of creation of the Interface Document was undertaken at the IRENG07 workshop. The paper presented represents the next draft, which will be further developed as an integral part of LOI preparation.

FUNCTIONAL REQUIREMENTS

In this section, the minimal functional requirements, to which all detector concepts are bound, are summarized. These requirements are closely related to fundamental properties of design and less dependent on site location and similar specifics. In contrast, the next section will describe more detailed specification and outline the present working models and likely technical solutions.

The list of minimal functional requirement starts with the need to have two detectors in a single collider hall, able to work in turns, in push-pull mode.

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The speed of push-pull operation is the first defining assumption. We set as the goal that hardware design should allow the moving operation, reconnections and possible rearrangements of shielding to be performed in a few days, or less than a week.

The range of detector sizes considered in the design include detectors with half size of 6-7 meters, performing optimally if the IP to start of QD0 quadrupole (L^* parameter) would be in the range of 3.5-4.5 meters (different L^* is allowed for different detectors), while the distance from IP to the second quadrupole QF1 is 9.5 meters, which drives many parameters of the design, including the hall width.

The off-beamline detector is shifted in the transverse direction to a garage position, located 15m from the IP. The radiation and magnetic environment, suitable for personnel access to the off-beamline detector during beam collision, are to be guaranteed by the beamline detector using their chosen solution.

The IR and detector design is to satisfy the beam parameters defined in the RDR [1] including nominal, Low N, Large Y and Low P parameter sets.

INTERFACE SPECIFICATIONS

The superconducting final doublets, consisting from QD0 and QF1 quadrupoles and sextupoles SD0 and SF1 are grouped into two independent cryostats, with QD0 cryostat penetrating almost entirely into the detector. The QD0 cryostat is specific for the detector design and moves together with detector during push-pull operation, while the QF1 cryostat is common and rests in the tunnel.

Radiation shielding is essential with two detectors occupying the same Interaction Region hall. The detector should either be self-shielded or need to assume responsibility for additional local fixed or movable shielding (walls) to provide an area accessible to people near the second detector when the first is running with beam. The radiation criteria to be satisfied are for normal operation and for an accident case. The radiation criteria will be developed in consultations with the project management. The criteria presently used for shielding design evaluation are those described in [3] and summarized below. In the normal operation, the dose anywhere near the non-operational second detector should be less than 0.5μSv/hour. In the accident case the dose should be less than 250mSv/h for maximum credible beam (simultaneous loss of both e+ and e- beams anywhere near the IP, at maximum beam power), and the integrated dose less than 1mSv per accident, implying the need of a robust emergency beam shut-off system. With such a criteria applied, the area near the second detector will be classified as supervisory access according to KEK and CERN rules, and GERT access according to SLAC and FNAL rules. It must be noted that regional differences of radiation rules [4] will be studied in detail and will be taken into account in selection of the final criteria. The radiation criteria are to be satisfied with consideration of all realistic gaps, cable and cryogenics openings in the detector or shielding. The outcome of these radiation requirements is understood to be the need for "Pacman" shielding of the IR beamlines, and additional shielding of detector and possibly a shielding wall for non-self shielding detector. The Pacman consists of two parts, with the one roughly overlapping with QF1 being machine responsibility, while the detector specific QD0 part being detector responsibility.

Proper design of cryogenic system for the FD is critical to ensure quick and reliable push-pull operation. There is a service cryostat connected to each QD0 cryostat. The service cryostat is placed outside of the Pacman. The cryo-line (with 1Bar He-II and current leads) connects QD0 cryostat to the service cryostat. This line is never disconnected except for major repairs. The line goes through Pacman in such a way that there is no direct view to the beamline from outside (thus, a knee may be needed) to satisfy radiation requirements. The service cryostat is connected to cryo-system via flexible line containing LHe single phase supply and low pressure He return. The QD0 cryo system and connections are sized from the assumption of maximum of 15 Watts (14 static + 1 dynamic) load at 1.9K.

Opening of the detector on the beamline must be allowed by design of all hardware (in particular supports, QD0 cryo-line, shielding, etc). Hardware design should allow opening or closing to be performed in half-a-day. At least 2m of opening should be provided. The corresponding detector collaboration is responsible for the operation.

Assembly of the detectors, for considered deep site configuration, is assumed to be done on surface, in a dedicated building, and only the final assembly is done in the collider hall underground, using a light crane with several tens of ton capacity and using air-pads for motion of larger weights underground. The assembled parts of detector are lowered from surface using a 2000-2500 ton gantry crane, which must be stationary when handling heavy loads (thus, a shaft cover is needed as handling ancillary), however, with no load, the gantry crane can be slid over one or the other shaft to service one detector or the other, as needed.

While the above described on-surface assembly is a baseline, the underground assembly will be evaluated as alternative approach, and may be found beneficial especially for the shallow location of the collider.

Segmentation of detector is entirely a choice of detector collaboration, provided that it does not contradict other agreed upon assumptions. The question whether the detector door is split vertically or not, seems to have most interference with machine design. The choice will involve evaluation of consequences for the vacuum chamber design, for support of FD and cryogenic line connection, for the magnetic forces acting on end caps, etc.

Alignment requirements are by far the most critical in determining the design of infrastructure in the Interaction Region. It is assumed that after the push-pull operation the detector elements would be placed within ±1mm from the ideal position and in that range the motion system should compensate for any elastic deformations or long term settlements. The QD0 cryostat would have its own alignment system of the ±2mm range for fine alignment. Before starting the beam, the FD apertures and Vertex apertures need to be aligned to better than ±0.2mm, and for that, the detector would provide to machine the means to know the vertex position and also provide four channels for an optical path to each of the QD0 cryostats, to perform interferometer triangulation from underneath of the detector. The responsibility to align the FD belongs to the machine.

For reference, the detector has its own internal alignment requirements, which typically involve measuring Vertex position with respect to tracker on a micron level, and measuring tracker to calorimeter on mm level. Such measurements and kinematic adjustments would likely have to be with magnetic field switched on, to take into account deformations under magnetic stress. The internal alignment of detector is entirely the responsibility of the detector groups, and mentioned here in as much as it is relevant for the following.

The design of detector motion system must be determined from the functional requirements of providing prompt push-pull operation and satisfying the alignment requirements. The working assumption for the motion system assumes the use of two platforms, with dimensions approximately 20x20x2m, on which the detectors and part of its services and shielding will reside. The motion system (thought to be a set of Hilman rollers) would be placed under the platform together with hydraulic jacks which would allow pushing the rollers to working height before the push-pull operation, or insertion of shims for fine adjustment of the height. The platform would be designed to limit deformation of its surface, where detector is placed, to be less than a millimeter during the entire push-pull operation. The responsibility for the motion of platform would belong to the machine group.

The concept of using the moving platform is an approach where an additional device is employed at the machine side to ease the alignment of detectors. One can also imagine another approach, where the problem and responsibility are pushed to the detector side entirely. While at this moment it is not clear if detectors can solve the alignment problem without the use of platform, study of such an approach is planned and the eventual configuration will be determined from consideration of both the technical feasibility and cost effectiveness.

Vacuum requirements in the Interaction Region may determine the background condition in IR via beam gas interaction. We assume that vacuum should be less than 1nTorr within 200m of the IP, with the exception of the drift inside of detector, where 10nTorr are allowed (pressure specified at room temperature and for composition of 62% H_2, 22% CO, 16% CO_2). It will be investigated further if higher pressure is allowable in the QD0-QD0 drift. It is assumed that detector concepts responsible for providing space for needed pumps near the IP side of QD0, and that the cold bore of the QD0 cryostat is not considered as a free cryo-pump.

Requirement for the magnetic field outside of detector is an important factor which defines the amount of iron in the detector (or degree of compensation for iron-free design). We assume that effects of any static field outside of detectors on the beam can be corrected, and the requirements should come only from human safety factor and from the limit of field map distortion due to off-beamline detector. Assuming that access to the IR hall will be restricted for people with pacemakers, we require that the field on any external surface of on-beamline detector to be less than 2kGs, while its field in non-restricted area (including near the off-beamline detector) to be less than 100Gs. The magnetic field effect from the off-beamline detector onto the on-beamline detector must limit distortion of magnetic field map of the latter to less than 0.01% anywhere inside its tracking volume.

Fire safety imposes an absolute restriction for use of flammable gas mixtures underground. Only halogen free cables are allowed. Smoke detectors with sufficient granularity are mandatory inside sub-detectors. The inner enclosed volumes of detector to be maintained at low oxygen content. Outside of detector the fire fighting systems must be foreseen, which may use suppression gases and sprinkler or foam. Fire safety also imposes the use of safety evacuation passages (small tunnels) around collider hall, and affects location of shafts and cross-galleries, to avoid corners with single escape route.

Elements for machine commissioning include an additional temporary shielding, FD supports and special instrumentation that will be used when detectors are not yet on the beamline. The FD for commissioning would be one of those not yet installed in a detector.

Vibration stability requirements define construction of the inner parts of detector and location of its services. We assume that the needed stability of detector surface on which the FD rests, is about 50nm (rms relative displacement of two FDs between any of 5Hz pulses), and that detector concepts are responsible for providing this stability. This also assumes that final stability of the Final Doublet would be about 100nm and the difference constitutes the machine vibration budget.

Definition of the push-pull operation – we assume that it includes time from the switch-off the beam until the moment when luminosity is restored to 70% level and at the same energy, after the detector exchange. Any possible calibration of the detector, at nominal or lower energy, is not included in the time of push-pull operation and is entirely up to the detector collaboration.

The procedures foreseen to be done on beamline and in garage position are essential for determining space allocation and IR design. Such procedures are under development. The design and responsibility for use of machine components built-in into detector, such as Detector Integrated Dipole, are to be spelled out. Design and development efforts for physics options, in particular gamma-gamma collider and its enabling laser hardware, are expected to rise up, and corresponding efforts in the IR and Detector designs would be needed – the exact plans will be worked out and described in the final version of the Interface Document.

Configuration of the collider hall and surface buildings must encompass all the requirements for detector and services, and must also be extremely carefully scrutinized, being one of the cost drivers of the design. The layouts, sizes, location of shafts, allocation of space to detector and machine, air, power, heat removal, temperature stability, humidity, grounding, as well as specifics of near-surface collider hall configuration and other issues will be discussed in the future issues of this Interface Document.

DISCUSSION AND OUTLOOK

The present document represents a step towards creating a final IR Interface Document. It is expected that specifications, assumptions and responsibilities will be further adjusted and optimized. The process of optimization is expected to take approximately one year, which will be followed by the period of detailed design of the Interaction Region and Detectors according to agreed upon specifications.

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