FD functional requirements

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.)

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.

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.

SLAC-PUB-13657
June 2009

Functional Requirements on the Design of the Detectors and the Interaction Region of an e^+e^- Linear Collider with a Push-Pull Arrangement of Detectors*

B.Parker (BNL), A.Mikhailichenko (Cornell Univ.), K.Buesser (DESY),
J.Hauptman (Iowa State Univ.), T.Tauchi (KEK), P.Burrows (Oxford),
T.Markiewicz, M.Oriunno, A.Seryi (SLAC)

Final Doublet

It is a fundamental assumption that a rapid exchange of detectors is possible only if the IP-side element of the magnetic doublet that provides the final focus for the beam, called QD0, moves with and is supported by the detector, while the partner magnet, QF1, remains stationary during a detector exchange. QF1 may reside in the beam tunnel or on a pier projecting into the IR Hall, but we assume, per the RDR, that its magnetic field focuses the beam between 9.5m and 11.5m from the IP. In the RDR design, QF1 is a compact superconducting (SC) magnet whose cryostat extends another 25cm toward the IP. As a pair of vacuum valves bracketing short bellows on both the incoming and outgoing beamlines will also be needed to isolate the detector and beamline vacuum systems when the detectors interchange, there will be approximately 18m of working length at the disposal of each detector concept when in its normal, data-taking state.

The QF1 to IP distance of 9.5m is the result of a study [3] that looked at luminosity as a function of energy and extraction line losses for QF1 L*=9.5m and QD0 L* and L^*_{ext} values of 3.51m/5.5m, 4.0m/5.95m and 4.5m/6.3m. This study sets the range of allowable QD0 L* to 3.5m < L* < 4.5m for the LOI. Each concept may choose an L* appropriate for their design within this range and the ILC BDS will construct a corresponding detector specific QD0 cryostat package and spool piece to mate to QF1. The spool piece will house the kicker required for beam-beam deflection based luminosity feedback.

The superconducting final doublets, consisting of the 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.[3.5]

QD0 support and alignment

Each concept must present a credible scheme to guarantee that the two detector-carried QD0 cryostats are adequately aligned and stable. There are two basic requirements. The first is that the detector brings the its axis, defined as a line connecting the centers of the two QD0 magnet cryostats, to a position close enough to the BDS beamline, as defined by a line through the center of the stationary QF1 magnet cryostats, that beam based alignment can begin. The second is that the detector provides a means to finely adjust the QD0 package using the beam to bring it within the capture range of the inter-bunch feedback system.

Given variations in floor height under load and with time it is assumed that each detector will have a large range but coarse means (shims, jacks, etc.) of bringing the QD0 cryostat to a position close enough to the QF1(e+) - QF1(e-) defined beamline that a finer resolution limited range alignment system can bring the cryostat to its final pre-beam position. Seemingly reasonable working values are

- Detector axis alignment accuracy: ± 1 mm and 100 µrad from a line determined by QF1s
- Detector height adjustment range: +/- several cm, to be determined after site selection and geologic study

A detector mounted alignment system for QD0 (functionally equivalent to the eccentric cam based mover system [7] developed for the FFTB and LCLS and used as well at ATF2) should fufill the following requirements:

- Number of degrees of freedom: 5 (horizontal x, vertical y, roll α, pitch ϕ, yaw ψ)
- Range per x,y degree of freedom: ± 2mm
- Range per α,ϕ,ψ degrees of freedom: ± 30 mrad (roll), ±1 mrad (pitch and yaw)
- Step size per degree of freedom of motion: 0.05 µm

Before low intensity beams are allowed to pass through QD0 for high precision beam-based alignment, the mechanical mover system will be required to bring QD0 into alignment with an

- Accuracy per x,y degree of freedom: ± 50 µm
- Accuracy per α,ϕ,ψ degree of freedom: ±20 mrad (roll), ± 20 µrad (pitch and yaw)

The QD0 mechanical alignment accuracy and stability after beam-based alignment and the QD0 vibration stability requirement are set by the capture range and response characteristics [8] of the inter-bunch feedback system.

- QD0 alignment accuracy: ± 200 nm and 0.1 µrad from a line determined by QF1s, stable over the 200ms time interval between bunch trains

QD0 vibration stability: Δ(QD0(e+)-QD0(e-)) < 50 nm within 1ms long bunch train We note that control of this mover system will remain under control of the BDS system during operation and that alignment of other parts of the detector with respect to the QD0 cryostats is an issue that may need careful consideration. The movers may be periodically adjusted during a run to keep luminosity at its maximum value. Operational examples of such positioning of SC FF quads exist [9]-[11].

Verification of Alignment before beam operations

It is assumed that each detector will provide a means of verifying the alignment of the QD0 cryostat to the stated accuracy before low current beam operations begin. While a frequency scanning interferometer system that would require the detector's flux return to accommodate four optical paths between each QD0 cryostat and the floor is being proposed [12] for such a purpose, it is also possible that a simpler less invasive verification scheme can be employed.