Towards a unified detector motion system for ILD and S

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Abstract

At a meeting of the CTG on July 6th, 2010 [1], it was agreed that a conceptual solution for the detector motion system for ILD and SiD needs to be prepared soon. It is hoped that a decision can be made by the time of the Oregon Linear Collider Workshop, which will take place in March 2011.

The starting point is the ILC-Note-2009-050 used as reference document [2]. However, this note tries to collect new facts and arguments coming from subsequent studies to prepare the decision process in an interactive way by introducing propositions, opened for separate e-mail discussion, trying to move from the most general arguments to the most detailed ones, so that the logical cascade of reasoning can be identified and followed.

As this document is in a permanent working state, the status of the proposals is identified by a color scheme.

- Modifications from the previous versions are shown in magenta.
- New propositions are shown in blue.
- Contentious propositions subject to separate e-mail discussion are shown in red.
- Agreed propositions are shown in black.

This is a working document in permanent evolution

1 Reasons and Role of the Push-Pull Scheme

For reasons of space and cost, e^+e^- high-energy linear colliders cannot efficiently separate the beams to offer two distinct IPs. It has been proposed for ILC to have only one IP, and to allow for two detectors to be exchanged quickly on the interaction point using the so-called Push-Pull scheme. It is essential that such an exchange be realized with a minimum of delay, say 4 days lost in data taking including the time needed for a precise realignment on the beam axis, that is:

1. one day heavy rigging to exchange experiments,
2. one day for the the fine realignment on beam, repumping vac pipe etc,
3. one day to restart machine and experiment including nominal magnetic field,
4. one day for beam calibration and alignment with beam to reach luminosity.

It is clear that the first operations may take longer, but it is hoped that if the push-pull system is correctly designed to minimize the number of operations, the time lost in data taking may be reduced to around three days.

[1] K. Büsser, Minutes of MDI Common Task Group Phone Meeting of July 6, 2010.

[2] B. Parker et al.,"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".

Clearly, in such a scheme, the luminosity has to be shared between two detectors in a predefined manner.

It may be noted that, even with two separate IPs, it may be necessary to move each detector to Garage Position every year for major maintenance, thus a major moving system is required anyway.

Proposition 1.1 An investment in time and money like ILC requires two experiments to mitigate the technical risks of having one experiment non functioning and requiring years of repair.

Proposition 1.2 The push-pull operation could be used around ten times per year over 15 years for a total of around 150 times during the life time of the experiments.

Proposition 1.3 The two movements, moving one detector out to Garage Position and moving the second detector to Beam Position on IP including its crude realignment on the beam (millimetric precision) must be performed in around 24 hours.

Proposition 1.4 , Although the present working estimates of the weight of ILD and SiD are 15 000 and 10 000 metric tons respectively, the movements must be smooth in all circumstances and not generate any vibration that may be detrimental to sub-detectors.

Proposition 1.5 The frequency of the push-pull operation on the two detectors, and its clear qualification as an heavy rigging operation, imposes that the movements of each detector be operated by a resident crew of mechanical riggers trained in the operation of the motion system of each detector.

Proposition 1.6 Even if partially financed through contributions of the experiments this resident crew of mechanical riggers will be employed on the long range by the host laboratory.

Proposition 1.7 Due to the cohabitation of the two systems in the same location and the fact that they will have to be operated by one unique crew in a reliable and safe way it will be advantageous that the motion systems of each detector be as similar as possible, and that the locomotion system be common.

2 Risks Associated with the Push-Pull Scheme

Proposition 2.1 There is no known system that satisfies all requirements of Chapter 1, and it is clear that an important risk is associated with delivering a system not meeting, in the end, the specification and thus not fulfilling its mission.

Proposition 2.2 However a more insidious risk is associated with the degradation with time of the conditions allowing a swift translation and rendering the system less an less performant and, even in the end, out of function.

Proposition 2.3 A bad functioning of the push-pull system would defeat the original purpose of the push-pull scheme and put in peril not only the concerned experiment but also the other one, as it may block access to IP, and in the end impedes the operation of the whole ILC accelerator complex.

Proposition 2.4 The sheer mass of the load and the difficulty of access render a repair of the cavern foundation very difficult if not impossible.

Proposition 2.5 The main risk is thus associated with the destruction of the supporting slab and/or the sliding surface that would render the system inoperative and very difficult to repair.

Proposition 2.6 The push-pull scheme is a demanding system. It is not unreasonable to assume that part of savings made by abandoning feeding two different IPs be used to design, construct and operate a reliable moving system .

3 Movement and Alignment of the Bulk Detectors

Proposition 3.1 The movement to be performed is a translation of around 25 meters. This distance may, in the end, depend of the level of stray field imposed by one detector to the other; the maximum tolerable level has been estimated to 50 Gauss at the boundary of the yoke of the unpowered detector.

Proposition 3.2 The pulling mechanism must be able to overcome friction and stick-slip and the working pulling force is estimated to be around 500 metric tons (see Proposition5.26), to be divided in two parallel pulling lines having a nominal capacity of 300 metric tons.

Proposition 3.3 To provide multiple anchoring points in a civil engineering structure, that can resist a 300 metric ton pulling force and thus be designed for 450 metric tons, is not simple.

Proposition 3.4 It is thus important to limit the number of anchoring points to the minimum (four, two at each extremity of the cavern to allow pulling in both directions). This disposition has the added advantage that the anchoring is permanent. In fact, a badly secured anchoring point may easily end up in the catastrophic pulling out of the entire anchoring point, and this risk is quite high for systems necessitating constant de-connection and re-connection of the anchoring points when moving along.

Proposition 3.5 Recent analyses [3] have concluded that a good candidate for a step by step locomotion system necessitating only two anchoring points at each extremity of the cavern is the strand jack system of which several candidates exist world wide.

Proposition 3.6 The movement must be smooth and thus the mean speed must be small. As the distance to travel is only 25 m, a safe speed of 20 cm/min (based on CMS experience) can be chosen for the load. Assuming a step by step system with fast returns and taking into account idle periods the mean speed can be estimated to half, i.e. 10 cm/min. The total travel time can thus be as fast as
4 hours.

Proposition 3.7 As ideally the two detectors will share the same locomotion system and the same anchoring points for reasons given above, one can imagine that four hours (see Proposition 3.6) will be needed to pull out one detector from IP to its garage position, four hours will be needed to disconnect and convert the locomotion system for pulling out the other detector (in the same direction) and four hour will be needed again to pull the second detector from its garage position to IP. Thus 12 hours will be needed for the heavy rigging operations proper, thus satisfying the requirements laid down in Proposition 1.3. Clearly for the first operations more time will be needed until all the procedures are fully validated.

Proposition 3.8 The movement must be linear by approximation such that the deviation of the center of the experiment from he ideal displacement line stays within ± 50 mm while at the same time the angular error is limited to ± 5 mrad. The trajectory must be corrected en route as needed to limit this deviation so that, at the end of the general movement, the center of the experiment lands in a circle of radius 20 mm centered on the IP and the angular error with respect to the theoretical beam axis is limited to ± 2.5 mrad.

Proposition 3.9 The final correction to be applied in-situ to the bulk of the detector is a three-axis movement (translation in x and z and rotation in the {x,z} plane) to arrive at a final positioning compatible with the range of the detector active alignment system. That is the center of the experiment falls in a circle of radius 2 mm centered on the IP and the angular error with respect to the theoretical beam axis is limited to 0.2 mrad.

[3] M. Oriunno et al., Progress on Push-Pull IR Studies, LCW Albuquerque, Sept. 2009.

Proposition 3.10 It is expected that the y position (altitude) with respect to the very nearby tunnel element will also be recovered within a precision of ± 2 mm by sitting on the predefined (and originally shimmed) reference support points. Nevertheless, to be on the safe side, an easy solution must be implemented in the supporting system to adapt this shimming as needed to recover unexpected vertical movements of the general cavern foundation.

Proposition 3.11 Although, as said above, it is expected that the y position (altitude) with respect to the very nearby tunnel element will be recovered within a precision of ± 2 mm, a general vertical movement of the entire zone will be induced by the exchange of large masses on the IP.

Proposition 3.12 This general perturbation having the shape of a downward oriented bell, will be smooth and limited to around 2 mm if the cavern and ends of tunnel foundations are sufficiently sturdy, but it may extend to ± 50 m and may take several weeks to fully stabilize.

Proposition 3.13 This continuous movement with respect to the rest of the collider must be taken care of by a slow active alignment system spanning ± 100 m around the IP, acting on the beam elements and on the jacks supporting the bulk experiment, to ensure a sufficient alignment of all these elements on the theoretical incoming beam lines so that the faster feed-back systems are always positioned inside their operative range.

4 Arguments for using or not a transport Platform to move SiD and ILD

4.1 Arguments for SiD

Proposition 4.1 SiD has been designed from the beginning with a large barrel yoke in one section and thus, in the closed configuration, it can be fully supported by its main frame.

Proposition 4.2 Assuming that satisfying supporting and sliding points can be designed, a platform is not necessary to transport SiD as one rigid body, however, the design of SiD is technically fully compatible with the use of a transport platform.

Proposition 4.3 The use of a transport platform must not jeopardize the general stability of the experiment, especially with respect to microseisms (see Chapter 6), because SiD is planning to support the extremities of the QD0 quadrupoles directly from the endcap yokes.

4.2 Arguments for ILD

Proposition 4.4 Due to its size and weight ILD has been designed from the beginning with the barrel yoke in three sections, thus, including the endcaps, it comprises five large sections.

Proposition 4.5 This configuration is very similar to CMS, and based on the CMS design and con- struction experience it can be said that ILD cannot be easily rigidified to be safely transportable as one unit and satisfy the requirements laid down in Chapter 1.

4.3 Remarks

Proposition 4.6 The Push-Pull project requires having SiD and ILD to co-habitate on the same IP and this imposes that compatible solutions be adopted by each concept.

Proposition 4.7 An extensive effort has been conducted at SLAC [4] in 2009 to explore possible com- patible solutions between the respective designs presented in the two LoIs, and in particular have either:

1. ILD with a platform and SiD without one,
2. ILD and SiD both without a platform,
3. ILD and SiD both with a platform.

No fully satisfying solution has been found.

Proposition 4.8 The fact that ILD requires a platform, and that SiD does not need one, prevents the design of a common experimental area and its detailed study.

Proposition 4.9 At this stage, technically, the only compatible solution seems to be that both experiments use a platform. However, as said in Proposition 4.3 it must be shown that the use of a platform would not weaken the stability of SiD with respect to microseisms.

Proposition 4.10 Once a transport platform is shown necessary and not harmful to any experiment, all effort should be made to exploit this investment to the maximum advantage of both experimental concepts, in particular by allowing:

1. A full decoupling of the experiments from the moving system easing the operation by a common crew (see Proposition 1.6),
2. A full protection against vibration during transport,
3. The use of a common locomotion system,
4. An easy pre-alignment on IP after a push-pull movement (see Proposition 3.9),
5. An easy maintenance and repair of the moving system to mitigate the risk of any prolonged blocking of access to IP (see Proposition 2.5).

5 Supporting systems, Rollers and Airpads

5.1 Rollers

Proposition 5.1 The use of a roller system is the simplest, and potentially the less expensive, solution that can be envisaged.

Proposition 5.2 The heavy duty rollers originally produced by Börkey and presently produced by both Börkey and Hilman are highly precise mechanical objets that must sit on a track of high mechanical and geometrical properties. Applications are mainly fully mechanical for loads up to 300 metric tons.

Proposition 5.3 The requirements for ILC exceed what has been safely achieved as far as load and number of operations are concerned; 500 ton rollers exist and have been used for few movements, but 1000 ton or even more 2000 ton roller exist only on paper.

[4] M. Oriunno, A. Hervé, T. Markiewicz, A. Seryi

Proposition 5.4 In any case the track must be of high grade steel (700 MPa yield strength), hardened in surface (HBC 55 to 58) and ground, and this preclude any subsequent welding; and the track must be flat, even under loading, on the full surface of the roller.

Proposition 5.5 To allow a correct distribution of the load on each individual roll, and this is the key of the success, the deformation of the rail must not exceed 0.2 mm on the full surface of the roller[5].

Proposition 5.6 The rail has thus to be considered in its full interaction with the cavern foundation so that the total rigidity (rail + foundation) guarantees the above specification even after several years when the cavern floor has been degraded and may have moved.

Proposition 5.7 The rail sections cannot be welded and cannot present steps that are not accepted by individual rolls. The risk of blocking when crossing from one section to the next is important.

Proposition 5.8 The above requirements on the quality and alignment of the track render a repair very difficult if not impossible.

Proposition 5.9 A heavy loaded roller has a tendency to go straight along the line defined by its individual rolls. Thus the direction followed by a given roller is completely dependent of the local geometry and flatness of the track. If the geometry is not perfect each roller follows its own built-in direction and large hyper-static internal lateral forces are generated.

Proposition 5.10 Using the same argument one sees that once the load starts going off axis, it is practically impossible to bring it back on track without unloading the roller and redirecting it in a modified direction.

Proposition 5.11 Thus to land the load after a travel of 25 meters with the precision defined in Proposition 3.8 in a short time seems challenging.

Proposition 5.12 If landing on IP is already difficult, obtaining the final precision on IP as defined in Proposition 3.9 using a roller system is very difficult and necessarily time consuming as it may involve numerous smaller onward and backward corrective movements that are not compatible with a strand jack system that requires lengthy operations to reverse the pulling direction.

Proposition 5.13 Thus a roller system must be supplemented by another system that allows a 3-axis movement on IP. A good candidate would be a grease-pad system on top of the roller supporting platform.

5.2 Airpads

Proposition 5.14 Airpad systems have been developed for unconventional demanding applications like moving submarines on port docks or moving bridges over rail tracks for final assembly. They comprise a labyrinth gasket sliding on the ground, so that the air consumption is low but the friction is not zero.

[5] Börkey private communication.

Proposition 5.15 The main advantage of airpads is that they can follow by nature a 3-axis movement and in fact they must be firmly guided to define the moving direction. This renders the alignments as defined in Propositions 3.8 and 3.9 easily feasible.

Proposition 5.16 Airpads accept tracks of low surface quality and do not require any hardness at all. In fact the pressure to the ground is less than 1000 N/cm^2 and it is not uncommon to move directly over a concrete surface. Thus a common steel plate on a concrete foundation is amply sufficient.

Proposition 5.17 Airpads accept tracks not only of low surface quality but also not flat or even locally inclined, up to 20 mm over 1 m. They do not accept steps but welding and grinding may be used to get rid of them.

Proposition 5.18 From the above description one can conclude that to repair locally part of the foundation or part of the track is possible, even directly under one airpad (once removed).

Proposition 5.19 Airpad systems require a 100 bar pressurized air distribution, the needed flow depending on the surface quality of the sliding surface.

Proposition 5.20 Standard airpad systems have the disadvantage of requiring a slight lift of the load of around 5 mm. However as the landing is obtained by leaking air through orifices this landing is very smooth as it had been verified by installing accelerometers on CMS elements.

5.3 Remarks and alternative systems

Proposition 5.21 The adoption of a platform system has the advantage of completely decoupling the detector transport system from the detector proper, and thus the two projects would proceed in parallel.

Proposition 5.22 The space available under the platform is compatible with the use of multiple lower capacity rollers equipped with a sliding surface, conventional air pads, or another system to be identified and developed.

Proposition 5.23 Another important advantage of this configuration is that it would be possible to completely revamp or even replace the platform supporting system, if needed during the lifetime of the ILC, independently of the experiments.

5.4 Pulling force required

Proposition 5.24 The friction coefficient of a roller system on a good track is 3%, however an increment must be added for the stick-slip effect plus a safety coefficient. Manufacturers of rollers advise to assume a friction value of 5% [6] to take everything into account. The corresponding values for an airpad system are 1% and 1.5%.

Proposition 5.25 The locomotion system must be specified for exerting a pulling force of 750 metric tons if both SiD and ILD are moved on rollers.

Proposition 5.26 The locomotion system must be specified for exerting a pulling force of 500 metric tons if SiD is moved on rollers. This would have to be increased to 750 metric tons if ILD with its platform are moved on rollers.

Proposition 5.27 The locomotion system must be specified for exerting a pulling force of 300 metric tons if ILD with its platform are moved on airpads.

[6] Hilman private communication

6 Microseisms considerations if QD0 is supported from the yoke

Proposition 6.1 Selecting a site free of microseisms induced by cultural noise and not degraded by nearby technical equipment is a key parameter for ensuring a maximum luminosity of the ILC.

Proposition 6.2 If the QD0s are supported from the experiment itself, as in SiD, one must ensure that the way the experiment is supported from the cavern floor does not magnify the level of microseisms applied to the yoke and seen by the QDO supports.

Proposition 6.3 In particular, if a platform is used for the push-pull operation, one must ensure that the stacking of: support of platform / platform / support of experiment / yoke is not substantially less stable than the simpler stacking of: support of experiment / yoke.

Proposition 6.4 Due to the large scale of the structures, it is difficult to carry on experimental studies on meaningful prototypes. FEA is used instead but there is a need of meaningful benchmarks to validate the model and correctly interprets the results.

Proposition 6.5 The CMS concrete slab on the of the PX56 shaft at the LHC Point 5 has dimensions very close to a possible push-pull platform, although it has been designed to work under static loads and to provide radiation shielding.

Proposition 6.6 The experimental characterization of the vibration and dynamic performances of this structure represents a unique full-scale benchmark of the numerical model used in the FEA of the Linear Collider Platform, and ascertain the Transfer Function.

Proposition 6.7 A request to CERN to perform such in-situ measurements is being prepared [7]

7 Civil Engineering issues

Proposition 7.1 The sheer weight of the experiments imposes that the sliding surface cannot be considered as a rigid rail. In fact the system has to be considered as a sliding rail supported by a semi-elastic foundation with non negligible hysteresis.

Proposition 7.2 The semi-elastic foundation encompasses the steel rail itself the reinforced concrete slab of the floor, the caver invert or its equivalent, the interface to the surrounding rock and the neighboring rock itself.

Proposition 7.3 To maintain a stable flat sliding surface under load, it is most likely necessary to install deep piling or deep anchoring in the surrounding bottom rock under the invert.

Proposition 7.4 The amount and depth of the anchoring piles will depend on the acceptable tolerance load density, and thus of the number of supporting points (under the experiment if no platform is used, or under the platform is one is used).

[7] Request of Experimental Vibrations studies of the reinforced concrete slab on the PX56 shaft at the LHC, Point 5., M. Oriunno et al.

Proposition 7.5 The amount and depth of the anchoring piles will in addition depend on the accept- able flatness tolerance of the sliding surface under load, which is imposed by the sliding system itself, see Propositions 5.5 and 5.17.

Proposition 7.6 The use of heavy-duty rollers requires a very flat rail surface, horizontal, without bumps, even under load, and this geometry has to be maintained for the full life-time of the ILC complex.

Proposition 7.7 Heavy-duty air pads are very tolerant on the flatness, bumpiness and horizontality of the sliding surface, and thus they will tolerate settling of the foundations easily up to 20 mm. If ground movements are locally too important in time, the sliding surface can be re-adjusted at the proper position by normal masonry work then patching the sliding rail by welding.

Proposition 7.8 The use of a platform requires a non negligible space below the floor level, first to house the platform itself (roughly 2 m) and an array of trenches (also 2 m) below the platform to access and maintain the transport system.

Proposition 7.9 If the site is situated in CERN type geology (molasse rock) this space is naturally available because the cavern section has to be roughly cylindrical for stability reasons. The space for the platform and trenches can be obtained by forming when casting concrete to obtain the floor.

Proposition 7.10 If the site is situated in harder rock (like proposed for the Japanese site) this space must be obtained by extra excavation, the extra volume to be excavated representing less than 5 % of the cavern volume.

8 Cost

8.1 Cost considerations

Proposition 8.1 The cost comparison between a solution using heavy-duty rollers or air pads has to take into account the important difference in deep piling required by each solution.

Proposition 8.2 The required deep piling is site dependent and its sizing and costing requires detailed civil engineering studies that can be carried out only by specialized consultants. Nevertheless a ball park figure of 2.5 M$ can be estimated (based on the piling done under the SX5 or the reinforcement of the Atlas cavern at CERN) for reinforcing 50 m of slab in a future underground cavern.

Proposition 8.3 One available experience is the example of CMS in its cavern that shows that the present invert cavern structure is sufficient to maintain the sliding surface tolerance required by an airpad system without any deep piling system into the surrounding clay.

Proposition 8.4 For a heavy-roller solution the sliding surface of the rail must be made of hardened steel with a perfectly adjusted geometry, without any welding, see Proposition5.4. For the airpad solution the sliding surface can be made from standard 40 mm thick steel plates welded together, see Proposition5.16 . It is considered that the increased quantity needed for the second solution will be compensated by the superior quality required by the first solution.

Proposition 8.5 In a molasse type geology the over-cost for preparing the volume to house the platform and the associated trenches is assumed to be covered by the concrete not used for preparing a solid floor, see Proposition 7.9.

Proposition 8.6 For a hard rock site the over-cost for preparing the volume to house the platform and the associated trenches is assumed to be, for the present cavern reference design, 5% of the cavern excavation cost proper, see Proposition 7.10.

Proposition 8.7 The cost of a platform can be estimated from the CMS example, remembering that the platform construction has been negotiated as an addition to the main civil engineering contract. Clearly, if platforms were to be adopted for the ILC, their construction should be part of the main civil engineering contract, and they should be cast in-situ directly in the cavern.

Proposition 8.8 The cost of each platform for ILC, to move either SiD or ILD, constructed in the conditions defined above, is estimated to 1 M$ at current exchange rates.

Proposition 8.9 The cost of an airpad system is estimated to be 100 $/ton to be moved, inclusive of associated hydraulic jacks and static supports in-between airpads. The necessary ancillaries like redundant compresses air distribution and controls, that can be in common for the two experiments, is estimated to 0.5 M$.

8.2 Cost Tables

(to come)

Summary cost Tables for 2 solutions:

- One experiment on heavy duty rollers and hard rails without a platform
- One experiment on a platform supported by airpads.

9 Conclusions

(to come)