Changes to the Accelerator Design: Status and Outlook

Benno List

ILC@DESY Project Meeting 19.6.2015

LINEAR COLLIDER COLLABORATION

Designing the world's next great particle accelerator

Change Management

- **Formal Change Management in place since Sept 2014 for ILC (accelerator)**
- **Goals:**
  - Preserve an intact design baseline after TDR
  - Make sure all stakeholders are involved in design changes: ensure information flow, avoid frustration, avoid mistakes
- **Observation: Change Requests give structure to design activities**
  - Change Request review and implementation are often small projects, conducted by dedicated task forces
  - Change Request processing helps to prioritize tasks and have a common focus
- **In the current project phase:**

Managing Change = Managing the Project

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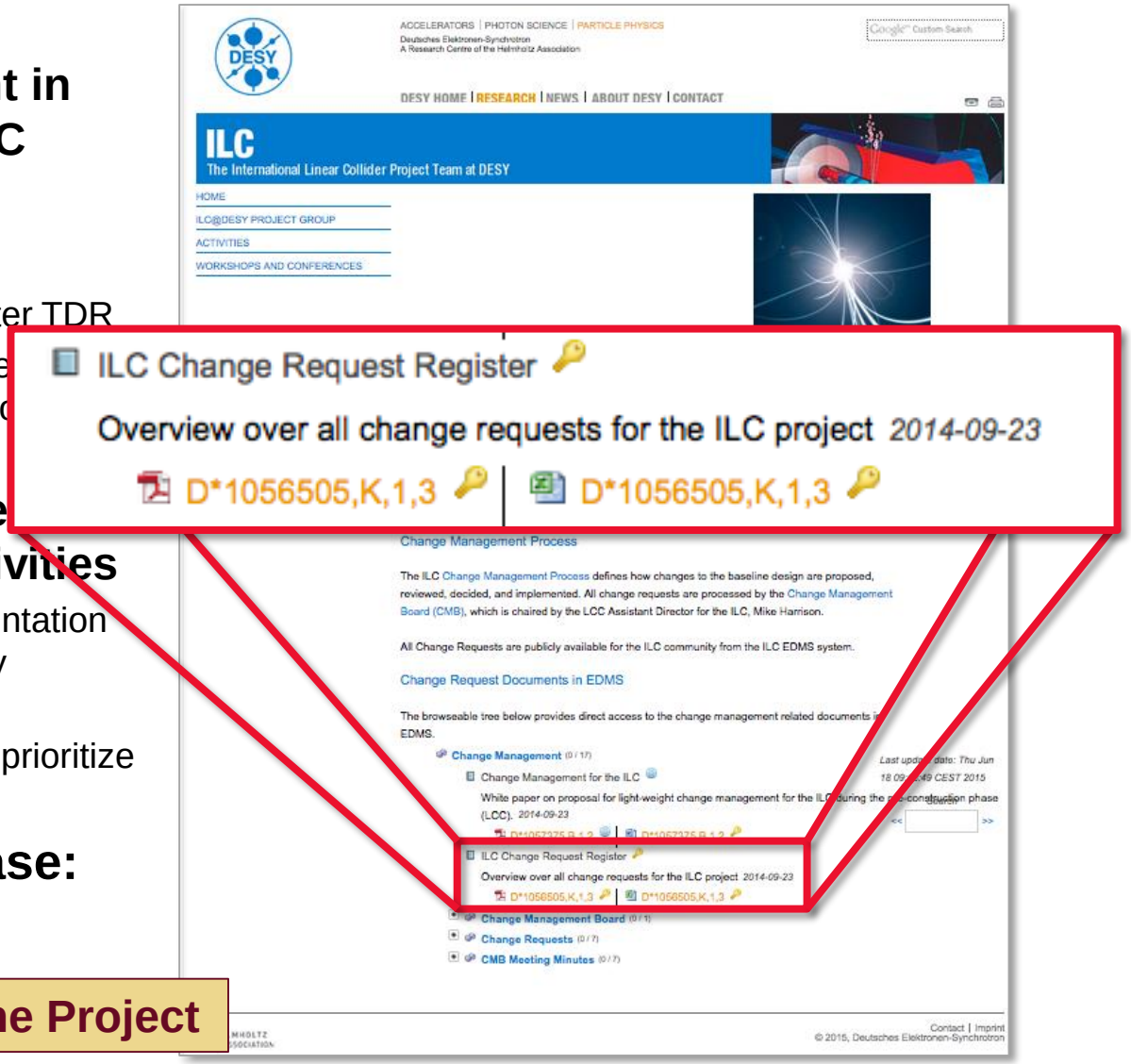

The Change Request Register (D*1056505)

- Overview over status of all official Change Requests
- Plus a longer list of possibly upcoming requests
- Updated regularly

No.	Creation Date	Last Modified	Creator	Primary WGs	Title	Description	State
ILC-CR-0003	07/10/14	31/03/14	K. Buesser	MDI / CFS	Detector hall with vertical shaft access	Consolidated solution for IR hall / layout which supports surface construction of the detectors.	Accepted / Implementing
ILC-CR-0002	02/09/14	09/10/14	G. White	BDS / MDI	Adopt equal L* for both detectors	Find solution for single L* value for BDS and both detectors.	Accepted / Implementing
ILC-CR-0004	18/12/14	31/03/14	N. Walker	ADI	Extension of the electron and positron Main Linac tunnels by about 1.5km	Lengthen Main Linac tunnels by about 1.5km, to (i) fulfill the Global Timing constraint and (ii) add margin for total beam energy as risk mitigation to ensure 500GeV CME.	De
ILC-CR-0007	11/06/15	11/06/15	M. Harrison	ML	Adoption of the Asian design as sole baseline	Only the Asian version of the TDR designs will be the basis for further developmen; the baseline HLRF distribution scheme will be DKS, the CFS planning will be based on the mountainous topography design.	Su
			N. Walker	RTML / ML	Move Bunch Compressor to Main Linac	The Bunch Compressor formally becomes a part of the Main Linac instead of the RTML.	In
ILC-CR-0005	22/04/15	15/06/15	N. Walker	ADI	Update top-level parameters	Correct errors in reported luminosity for 500 GeV baseline and 1 TeV (b) parameters.	Co
ILC-CR-0001	01/09/14	09/10/14	K. Yokoya	PS / BDS / RTML	Add return dogleg to target by-pass	Add additional lattice to bring BDS beamline on axis with main linac, to accommodate future >1 TeV beam energies.	Re
ILC-CR-0006	12/05/15	12/05/15	G. White	BDS / MDI	Add BPM downstream of QD0	Add a BPMs immediately downstream of the QD0s to facilitate beam capture and construction of a "virtual IP BPM".	Ac
ILC-CR-0008			M. Woodley	Machine-wide	Formal release TDR-2015a lattice	Complete set of matched lattices reflecting TDR design	In

No.	Creation Date	Last Modified	Creator	Primary WGs	Title	Description	Impact	Remark
			A. Yamamoto	CRYO / ML	Relocate cryo components to surface	Move compressors and helium storage to surface sites (requires long transfer line).	1 High	Currently under discussion. Should review status.
		27/04/15	M. Harrison	CFS	Reduce the width of the ML tunnel shield wall by adopting no access during beam-on operation.	Reduce the width of the ML, tunnel shield wall by adopting no access during beam-on operation.	1 High	Major shift in availability policy.
				BDS	Adopt Kamaboko-style solution for BDS / central region	Replace separate service tunnel with Kamaboko-style solution	1 High	Major scope. Will likely drive many smaller CRs.
		27/04/15	G. White	BDS / CFS	Updates to BDS lattice	Release of new lattice after review and subsequent development.	2 Medium	Many changes expected towards new release of baseline lattice, in particular implementation of CR-003 as well as central region consolidation.
		27/04/15	G. White	BDS / CFS	Include beta matching section	Add a dedicated beta matching lattice section to aid tuning (similar to ATF2)	2 Medium	Part of the above request?
			N. Walker	ML	Increase bandwidth of extraction lines in BC	Review operational requirements of fast extraction lines and dumps and re-design appropriately.	2 Medium	Current design bandwidths driven by nominal beam energy spread. Being re-evaluated as part of Solyak's Failure Mode appraisal.
		27/04/15	Wei Gai	ES / PHYS	Increase e- polarisation at IP to 95% (?)	Adopt strained cathode with higher polarisation.	2 Medium	Discussed at ALCW2015.
		27/04/15	B. Parker	BDS / MDI / CFS	Reduce IR crossing angle	Develop highly-compact SC FD to allow for smaller crossing angle.	1 High	Change status back to under consideration after ILC feedback via K. Buesser.
			N. Walker	BDS / MDI	Alternative FF scheme removing strong sextupoles from FD	Consider alternative FF schemes which would remove the strong sextupole magnets from the FD.	1 High	
			N. Walker	MDI	Integrate laser wire(s) into IR region (detectors)	Incorporate one or more laser wire system in into the detectors ± some distance from the IP to facilitate accelerator tuning.	1 High	
			N. Solyak	SRF / ML	Implement cost-effective PDS	Update current PDS design to a cheaper simpler alternative	1 High	Requires R&D. Left over from TDR, since PDS is very expensive. Resource limited!
		27/04/15	M. Kuriki	PS / CFS / PHYS	300-Hz e-driven source	Add 300-Hz e-driven positron source to baseline	1 High	Place holder for very high-lever CR. Text modified after discussions at ALCW2015
		12/01/15	LCB	ML / CFS	Implement design for energy staging	Effectively develop lattice / CFS design for first-stage 250 GeV cm operations.	1 High	250 GeV first stage dropped by LCC decree.
		12/01/15	G. White	BDS / MDI	Move FFBK kicker downstream of QD0	Locate intra-beam FFBK downstream of QD0 (inside detector), to effectively increase FD vibration tolerance correction range.	1 High	Initial studies showed no benefits.
		03/02/15	H. Hayano	SRF	Adopt LCLS-2 tuner and associated helium tank and flange solution.	Adopt LCLS-2 tuner and associated helium tank and flange solution.	2 Medium	Impact changed to Medium (from Low) at A. Yamamoto's request following TB meeting on 27/01/15
			E. Paterson	PS	Add timing adjustment chicane system	Implement a timing adjustment chicane in the positron injection system to allow for fine path-length adjustment.	2 Medium	Part of global-timing task force review
		12/01/15	E. Paterson	DR	Modify circumference of DR	Adjust circumference of damping ring to accommodate global timing constraint	2 Medium	This will be made redundant by an acceptance of CR-0004.
			N. Walker	DR	Add RF and wiggler for high current 10Hz operation	Configure DR designs to accommodate 100ms damping time with 2625 bunches to allow for 10-Hz collisions after the luminosity upgrade.	2 Medium	Make sure baseline design can be upgraded
		12/01/15	N. Walker	ML / CFS	Change in average gradient specification in ML	Adjustment of baseline average accelerating gradient in the main linacs.	2 Medium	Linked to CR-0004. Additional tunnel gives us margin to add more linac if necessary. Hence reduced impact status.
		12/01/15	N. Walker	ML	Modify lattice for staged implementation	Lattice design for the first-stage 250 GeV machine.	2 Medium	250 GeV first stage dropped by LCC decree.
		12/01/15	H. Yamamoto	ML / CFS	Extend max. energy reach	Extend maximum energy range of the machine to 550 GeV centre of mass.	2 Medium	Linked to CR-0004. (Note achievable gradient and tunnel length all link to this).
			Wei Gai	PS	Extend undulator length to 230m as baseline	Remove need for 10-Hz production mode at 250 GeV centre-of-mass energy	2 Medium	
			Wei Gai	PS	Alternative target design	Adopt alternative photon target design	2 Medium	Place holder for whatever is decided with the target. R&D needed.
		03/02/15	H. Hayano	SRF	Magnetic shield inside helium tank	Place magnetic shielding inside helium tank to simplify string / cryomodule assembly.	3 Low	Removed following TB meeting 27/01/15. Technically mag. shield inside tank is already TDR baseline (although this still requires development work).

Change Management

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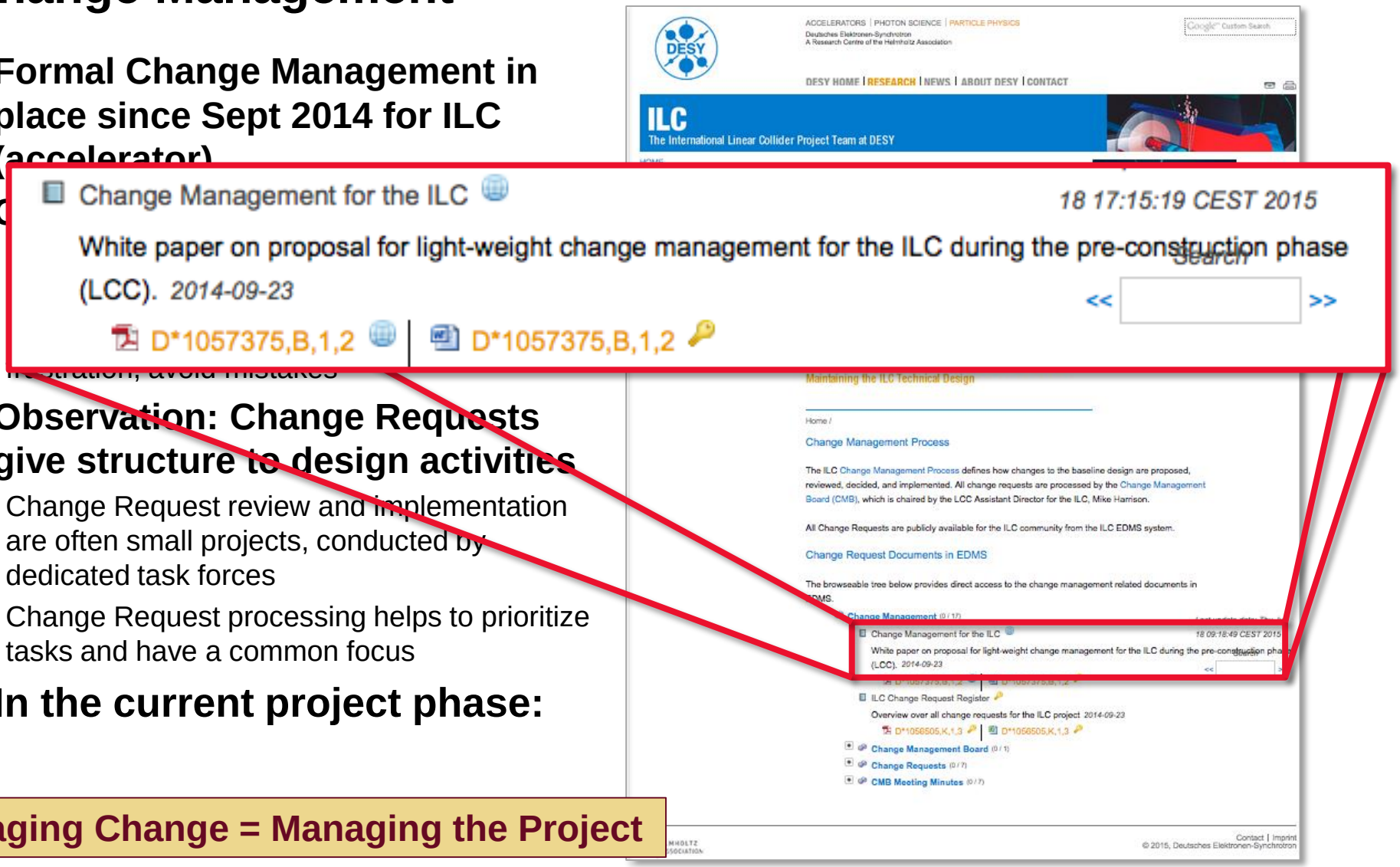
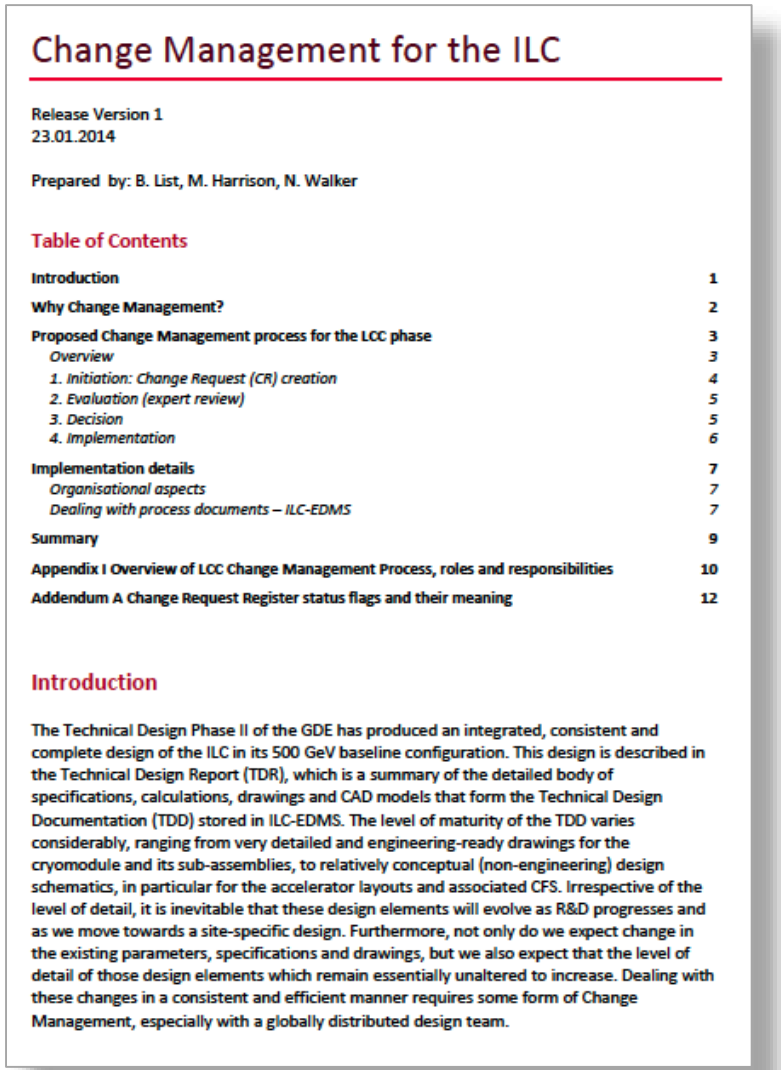


Managing Change = Managing the Project

The Process in a Nutshell

- Change Request (CR) is written and submitted to Change Administrator (CA)
- CA puts CR into EDMS, sends it to Change Management Board (CMB)
- CMB Chair: Mike Harrison
- Members:
  - ILC Technical Board members,
  - J. List and T. Markiewicz for ILD and SiD
  - V. Kuchler for CFS
- CMB has ~monthly Fuze meetings
- CMB asks Change Review Panel to appraise CR and give recommendation
- CMB deliberates, CMB Chair decides
- Change Implementation Team is asked to implement the CR



Change Management for the ILC

Release Version 1
23.01.2014

Prepared by: B. List, M. Harrison, N. Walker

Table of Contents

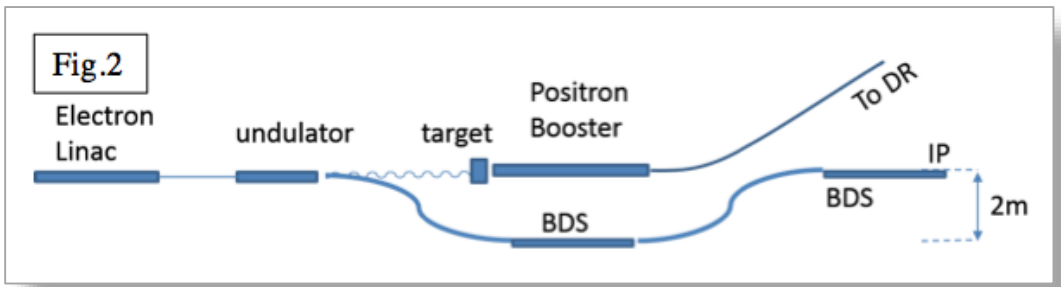
Introduction

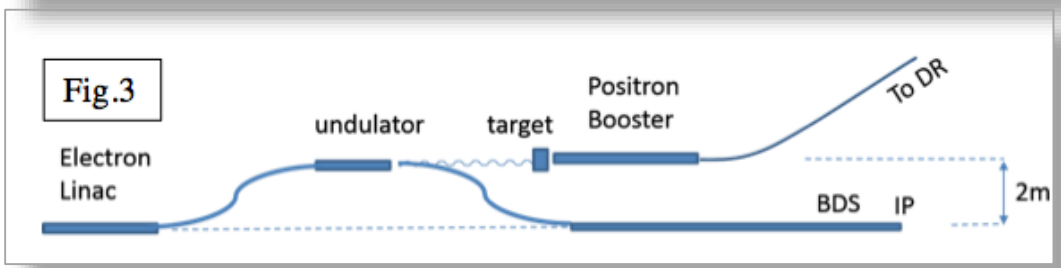
The Technical Design Phase II of the GDE has produced an integrated, consistent and complete design of the ILC in its 500 GeV baseline configuration. This design is described in the Technical Design Report (TDR), which is a summary of the detailed body of specifications, calculations, drawings and CAD models that form the Technical Design Documentation (TDD) stored in ILC-EDMS. The level of maturity of the TDD varies considerably, ranging from very detailed and engineering-ready drawings for the cryomodule and its sub-assemblies, to relatively conceptual (non-engineering) design schematics, in particular for the accelerator layouts and associated CFS. Irrespective of the level of detail, it is inevitable that these design elements will evolve as R&D progresses and as we move towards a site-specific design. Furthermore, not only do we expect change in the existing parameters, specifications and drawings, but we also expect that the level of detail of those design elements which remain essentially unaltered to increase. Dealing with these changes in a consistent and efficient manner requires some form of Change Management, especially with a globally distributed design team.

EDMS: D*1057375

CR-0001: Insertion of a dogleg in the electron side

- Insertion of a 400m long dogleg to compensate target bypass dogleg of undulator source
- Motivation: allow straight beamline for > 1TeV
- Rejected by LCC directorate: ILC scope limited to 1TeV





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CHANGE REQUEST NO. ILC-CR-0001	EDMS No: D*6168 2365	Created: 27-08-2014
		Last modified: 27-08-2014

INSERTION OF A DOGLEG IN THE ELECTRON SIDE

Insert a dogleg of ~400m long between the end of electron linac and the BDS. This should place the BDS on the extension of the electron linac line.

RATIONALE

Provide an option for removing the undulator source bypass to support a beamline geometry for possible energy upgrades beyond 500 GeV beam energy, at which energies the existing target bypass dogleg would produce severe horizontal emittance degradation due to synchrotron radiation.

SCOPE: POSITRON SOURCE, RTML, BDS, CENTRAL REGION

Adds an additional estimate 400 m of tunnel to the electron side of the machine. Adds an additional 400 m to the positron source and electron RTML lattice. Displaces the existing BDS axis transversely by ~2m.

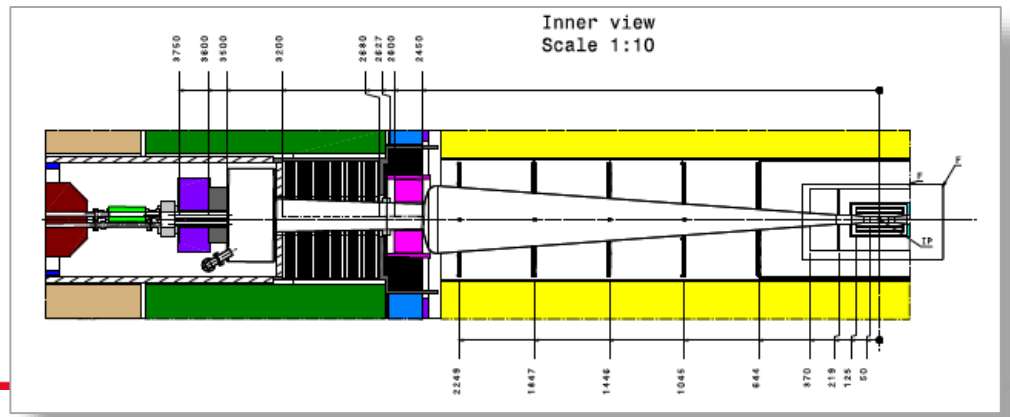
COST IMPACT: EST. 30 MILCU

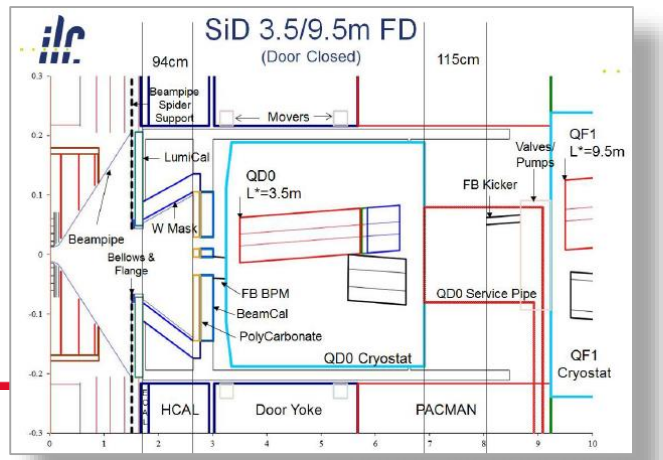
Initial estimate by requestor based on cost of existing target bypass dogleg (beamline + tunnel).

Requested and prepared by:	Kaoru Yokoya (KEK)

CR-0002: “Single L*”

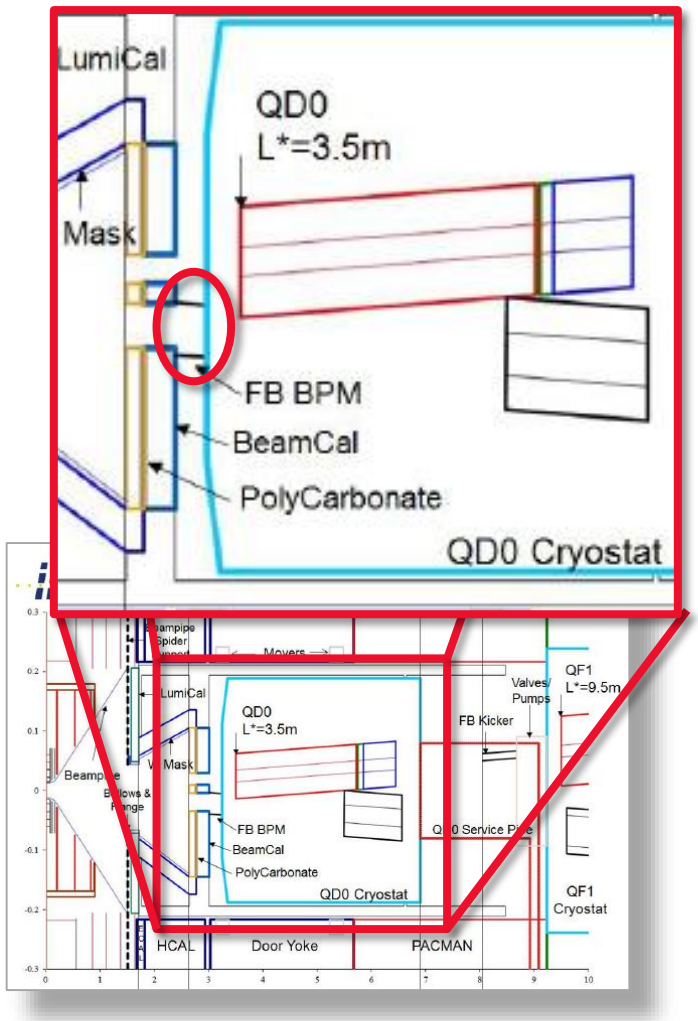
- L*: Distance between interaction point and edge of closest final focus magnet (called “QD0”)
- ILD and SiD had different L* of 4.5 and 3.5m
- Makes re-tuning after push-pull operation difficult for machine, leads to non-optimal optics for both experiments
- CR submitted on 1st CMB meeting 25.9.2014
- Review process took 8 months, with 2 workshops and a special session at AWLC2015, and lots of dedicated studies
- Accepted at 7th CMB meeting 12.5.2015
- Now in the implementation phase
- By-product: CR-0006: Beam Position Monitor close to IP





CR-0006: BPM downstream of QD0

- Corollary of CR-0002:
  Once ILD redesigns its entire forward region, might as well make room for a 10cm Beam Position Monitor
- Our “smallest” CR so far
- CR document is just 2 pages
- Was submitted in 6th CMB meeting and accepted in 7th meeting
- Implementation will be lumped together with CR-0002
- application of “lightweight” decision procedure for simple CRs
- We do not want to create more bureaucracy than necessary

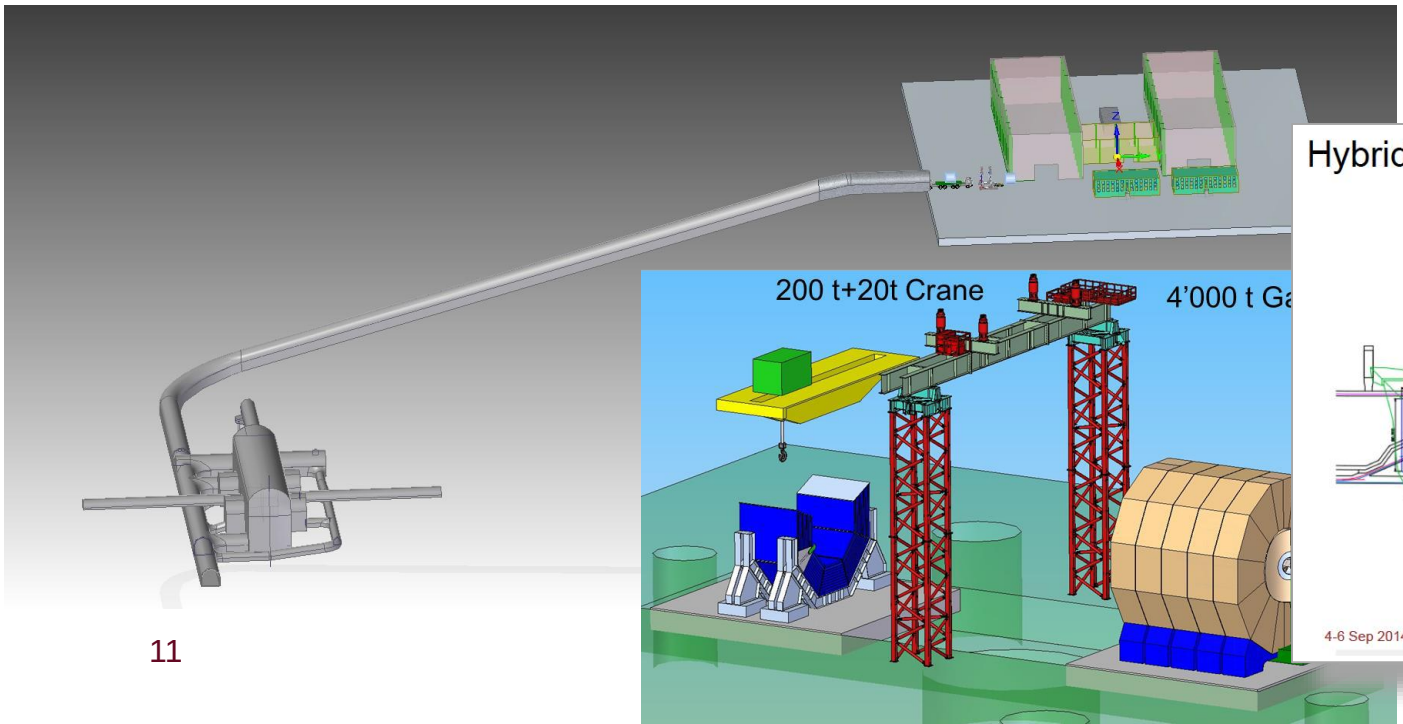


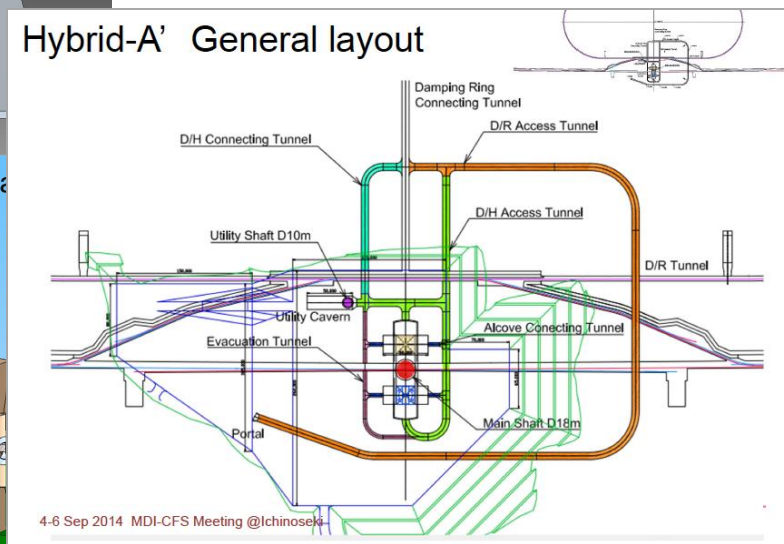
Interlude: What is “Implementation”

- **From Change Management document:**
  “Once the CR receives a positive decision from the CMB (formally from the chair or his delegate), the affected technical design documentation (TDD) in ILC-EDMS must be updated and a new ILC Baseline released.”
- We considered this to be obvious, apparently it is not ☹
- “Implementation” means that all relevant documents (in EDMS) that define the design of the accelerator are updated to reflect the change stated in the Change Request
- The general idea:
  - Start with a correct, consistent and complete set of documents (a “baseline”)
  - Process a Change Request (submit, review, accept, implement)
  - End with a correct, consistent and complete set of documents (new baseline)
- Reality:
  - Our baseline mostly consistent and correct, but not complete
    -> also new or more detailed, improved designs must be reviewed -> a CR
  - Several CRs will be processed and thus implemented concurrently
  - In some cases, implementation has to be deferred due to ressource limits

CR-0003: Detector hall with vertical shaft access

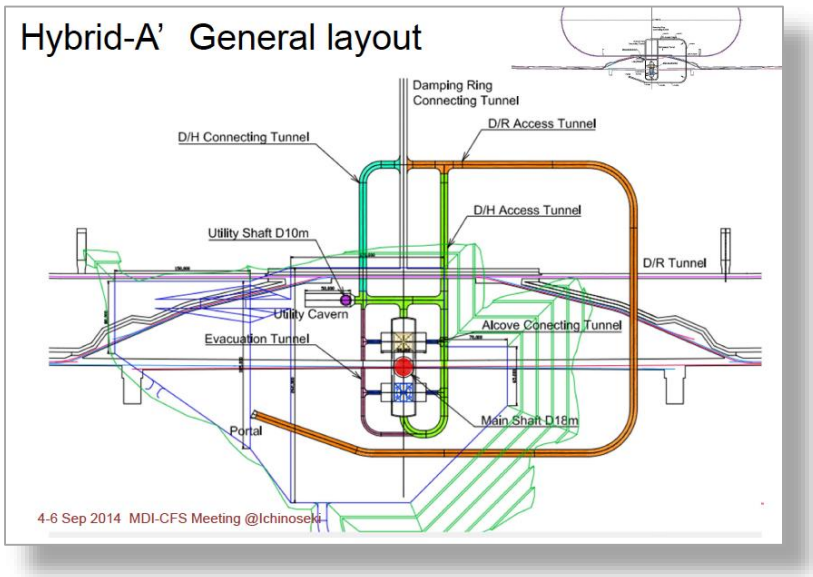
- Change Request with the longest preparation time so far: ~1 year
- Discussion started in CFS&MDI session at LCWS13 (Nov 13) after Japanese recommendation of Kitakami site:
  Kitakami has hills, not mountains -> vertical shaft might be possible
- Very thorough preparation with lots of studies by CFS and MDI group before submission of the Change Request in Oct. 14
  by a joint group of CFS, MDI groups and both detectors
  -> most of the work was already done





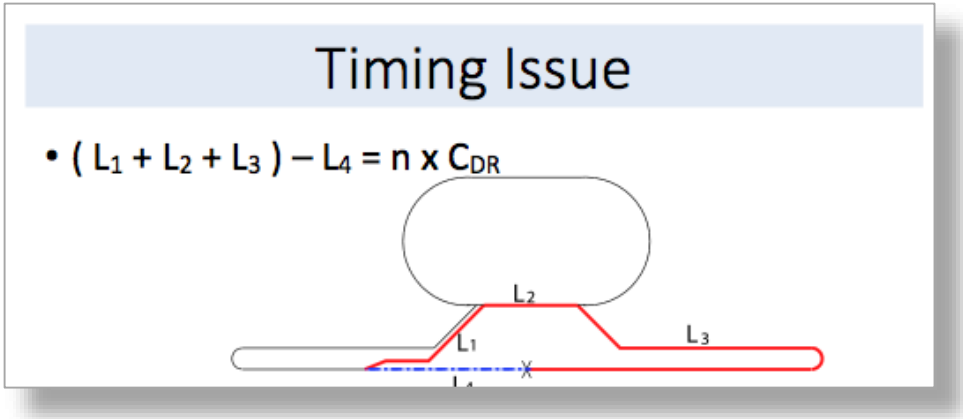
CR-0003: Status now

- CR-0003 submitted at 2nd CMB meeting 9.10.14
- Approved at 3rd CMB meeting 20.11.14
- Change Implementation Team (CIT) formed at 4th CMB meeting
- Implementation is close to complete, final implementation document is being prepared



- A very complex Change Request:
  - Interaction point had to move by ~800m
  - Needs new/more Geologic study
  - Completely new Experimental hall design
  - Completely different way to build / assemble / install detectors
- A large and important decision to take
- Needed all stakeholders (detectors, CFS, site experts) on board

CR-0004: Extension of the Main Linac tunnels



- Another CR with a long history
- Undulator positron source constrains round-trip length around accelerator to be an integer multiple of the Damping Ring circumference
- TDR layout is 150m too long, or 1500m too short, for current DR
- There are several ways out, but:
  1.5 km more Main Linac tunnel would make it easier to react _**if**_ cavity gradient of 31.5MV/m would be below design value of 31.5 MV/m, and one still wants to reach 500GeV
- This “reaction” would still require building more cavities, cryomodules, klystrons etc -> would be costly, but possible
- Why is 500GeV important?
  Before Higgs discovery, 500 was an arbitrary, round number.
  Now, 500 GeV is just high enough above the tth threshold!

CR-0004: Current status

- Everybody wants the longer tunnel,
  because it reduces risk, or adds possibilities for higher energy upgrade
- Problem: The cost!
  Rough estimate: 100M ILCU for 2x1.5km tunnel with transfer lines
- Finding ways to save this cost elsewhere is not part of the review, but there is a consensus that it has to be counter financed somehow
- CR-0004 was submitted before 4th CMB meeting on 19.12.14
- CRP was formed in February, will present report soon
- Formal decision will probably be at LCC directorate / LCB level

- Decision on CR-0004 is absolutely essential for further site studies!
- At LCWS13 in Tokyo, the plan was to fix the length of the machine by early 2015. Budget limitations reduced the urgency somewhat…
- Again, an important, and costly, decision to take
  -> Change Management provides a robust framework for the decision making process, with all stakeholders on board

CR-0005: Update of luminosity parameters

- Harmless start: discovery of an error in the luminosity calculation for one 1TeV upgrade scenario: lumi was 17% too high
- Triggered re-evaluation of all luminosity values, which were confirmed within a few %; luckily, all other values were higher than TDR calculation
- Naïve idea: “Just fix the table”
- But: Energy and luminosity are the two most basic performance numbers of the machine! They define the scope of the whole project. -> changing them is **always** a big issue!

CR-0006: The numbers

- Decision taken: Update only the wrong 1TeV A1 number, for other energies stay with the numbers of the TDR to avoid confusion
- CR-0006: Our first “administrative” CR:
  does not really change the design as such, but affects the documentation

	TDR	Update	Rel. diff.
200 GeV	0.56	0.59	6%
230 GeV	0.67	0.73	8%
250 GeV	0.75	0.82	10%
350 GeV	0.99	1.03	4%
500 GeV	1.79	1.79	0%
Lumi Up. 500 GeV	3.58	3.60	1%
1 TeV A1	3.65	3.02	-17%
1 TeV B1b	4.90	5.11	4%

CR-0007: Asian design as sole baseline

- The next “administrative” CR
- Background: TDR design was for “generic” site, with sample sites in America, Asia, Europe
- Sample sites had different topography (flat vs. mountainous), with
  - different tunnel technologies and different tunnel cross sections (round vs. Kamaboko),
  - different RF distribution schemes (klystrons in clusters on top: KCS for America/Europe, klystrons in tunnel: DKS for Asia)
  - Different cryogenic layouts
  - Different ML lattices with (slightly) different lengths
  - Different costs
- CR-0007 states that the KCS design is no longer maintained, because we concentrate on the Japanese site
- TDR cost was average of America/Europe/Asia cost estimates, Asian cost estimate is 2% higher than average: 7.982 vs. 7.780MILCU
- Decision will be taken next CMB meeting

CRs in the Pipeline: Administrative Stuff

- **CR-0008: ILC 2015a Lattice**
  - Consolidated lattice, fully matched, by Mark Woodley
  - A BIG step forward
  - Does not change the TDR design as such (geometry, magnet count, costs stay) -> administrative CR
  - Will serve as basis for implementation of CR-0002 (single L*)/CR-0006 (BPM) and CR-0004 (Extended ML tunnel)
  - Will be submitted soon
  - In future, lattice releases as such will not require a Change Request, but all changes that go into the new release need a CR!
- **CR-000x: Move Bunch Compressor to Main Linac**
  - Another administrative CR: Bunch Compressors (at end of RTML) are now under purview of ML group -> groups together all standard cold linac sections
  - Requires quite some work on document side to have a consistent set of documents again

What may come: reading the tea leaves

- **Change Request Register lists 26 possible requests**
- **Some important ones:**
- **Relocate cryo components to surface**
  - A purely technical issue, but with significant impact on CFS planning, risk, costs, schedule
- **Reduce width of Kamaboko shield wall**
  - Could be the big cost saver to finance the tunnel extension
  - Reopens all the old discussions about need to access, availability – a big déjà vu for the old hands ☺
- **Adopt Kamaboko-style tunnel for BDS/central region**
  - A consolidation of the central region design for Asia is urgently needed, but requires significant engineering resources
  - Some activities are ongoing
  - What about the electron driven positron source?

The Big Gorilla in the Room – a very personal view

- Japan pushes for electron driven source "in addition" to undulator source
- This is a BIG thing: all together 11 GeV worth of normal conducting linac, plus new target (radioactivity! Dirty!), requires larger tunnel, more electricity, more cooling -> essentially a full new linac
- All this would be expensive: >100MILCU
- Current statement from Japan: Study how much space would be needed for such a source
- A TDR-style design promised before LCWS15 in November
- Envisage a 1st Change Request to reserve space for such a source
- How much would that cost? Will be an interesting discussion
- CR-0004 (tunnel extension) may set a precedent here

A personal conclusion

- **ILC is in a difficult phase:**
  - The team is distributed (scattered) around the globe
  - Resources are scarce
  - No clear mandate (yet) to do the next step: engineering design -> little “top-down” initiation of activities
    -> not so much to do for “classical” project management
- **Keeping a reliable design intact is difficult at the best of times, much more now**
- **Any design activity results in design changes**
  -> managing those changes is the way to keep the project together
- **Our observation: Works much better than expected**