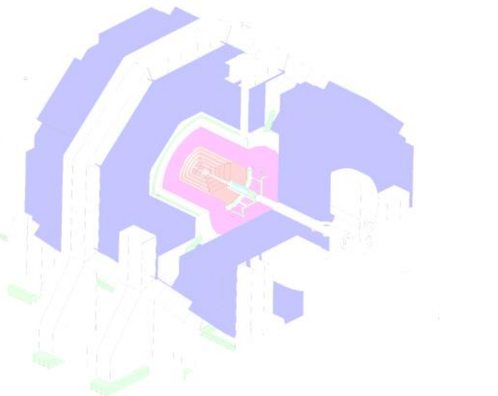
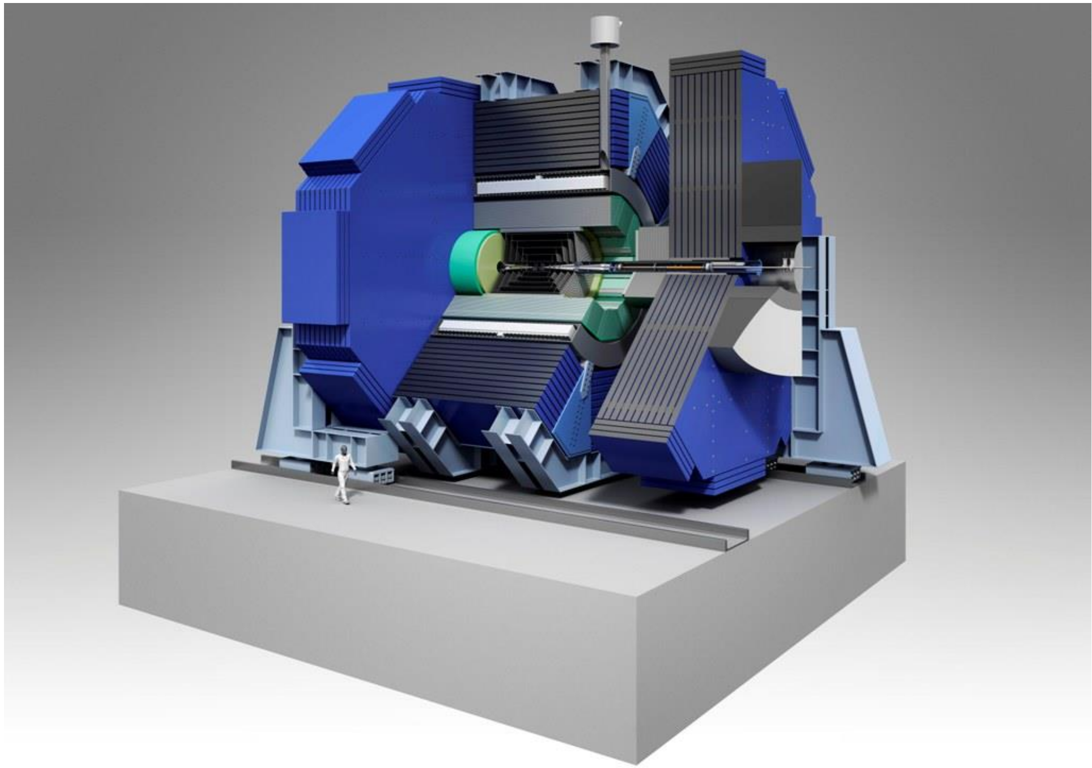


Towards a Physical SiD

Steps towards a project completing in the 2020's



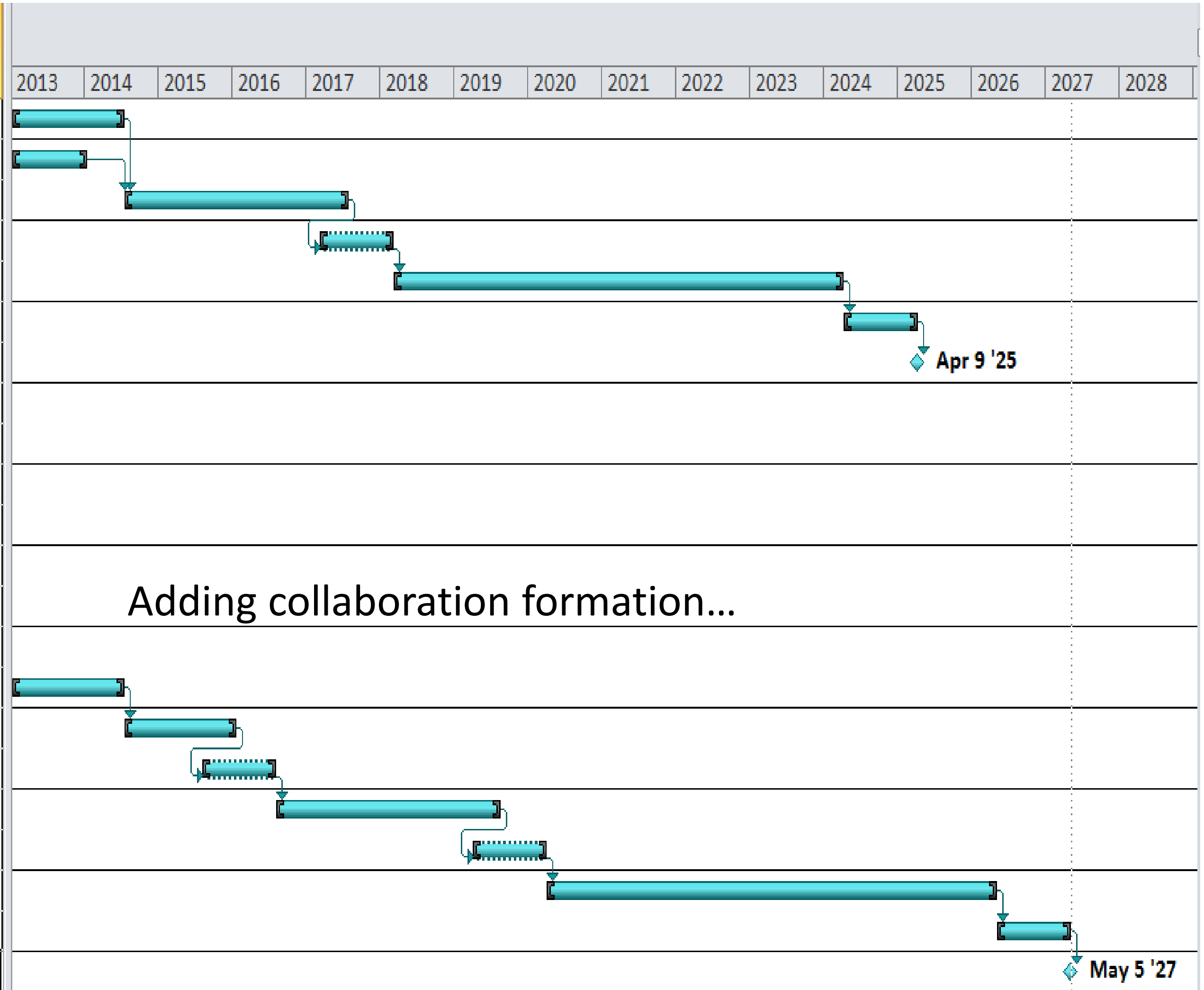
Steps toward SiD

- Some national body (ies) (Japan and collaborators) commits to linear collider 2015-16
- Optimize SiD (Only crude optimization for LOI; ~0 for DBD!) Can we lower costs and preserve performance?
- Prepare serious TDR with technical prototypes and serious cost estimate. 3 years: 2018
- Requires a fully reviewed TDR. Assume the review process, with minor iterations, takes 1 year. 2019
- Procurement, fabrication, and assembly: 6 years 2025
- Begin Commissioning

- But SiD is still a concept, not a collaboration.
- We will need technically a collaboration of ~500 people.
- They will have to develop an understanding of all the issues, optimize SiD, and buy into a design.
- This will also take time.

Technically Limited Timeline – Just Add your Δt

	Task Name	Duration
1	ILC Political Decision	18 mons
2	Optimize SiD	12 mons
3	Technical Design	36 mons
4	Agency Reviews	12 mons
5	Construction	72 mons
6	Commission	12 mons
7	Data	0 mons
8		
9		
10		
11		
12		
13		
14		
15	ILC Political Decision	18 mons
16	Collaboration Formation	18 mons
17	Optimize SiD	12 mons
18	Technical Design	36 mons
19	Agency Reviews	12 mons
20	Construction	72 mons
21	Commission	12 mons
22	Data	0 mons

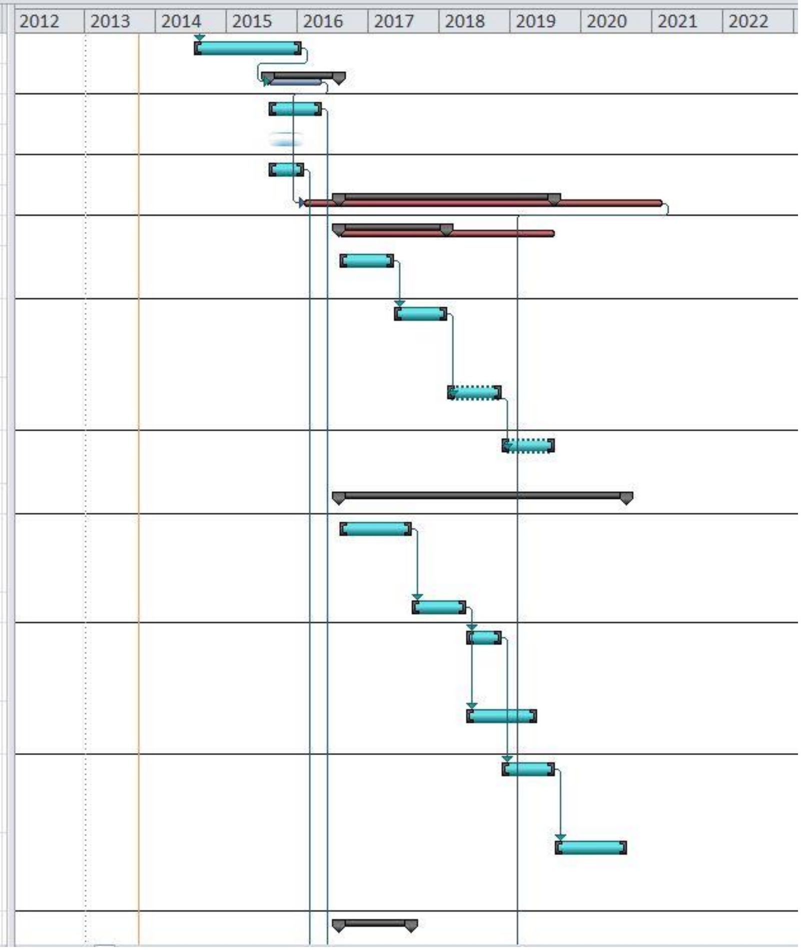


Adding collaboration formation…

Some overlap of major tasks possible…

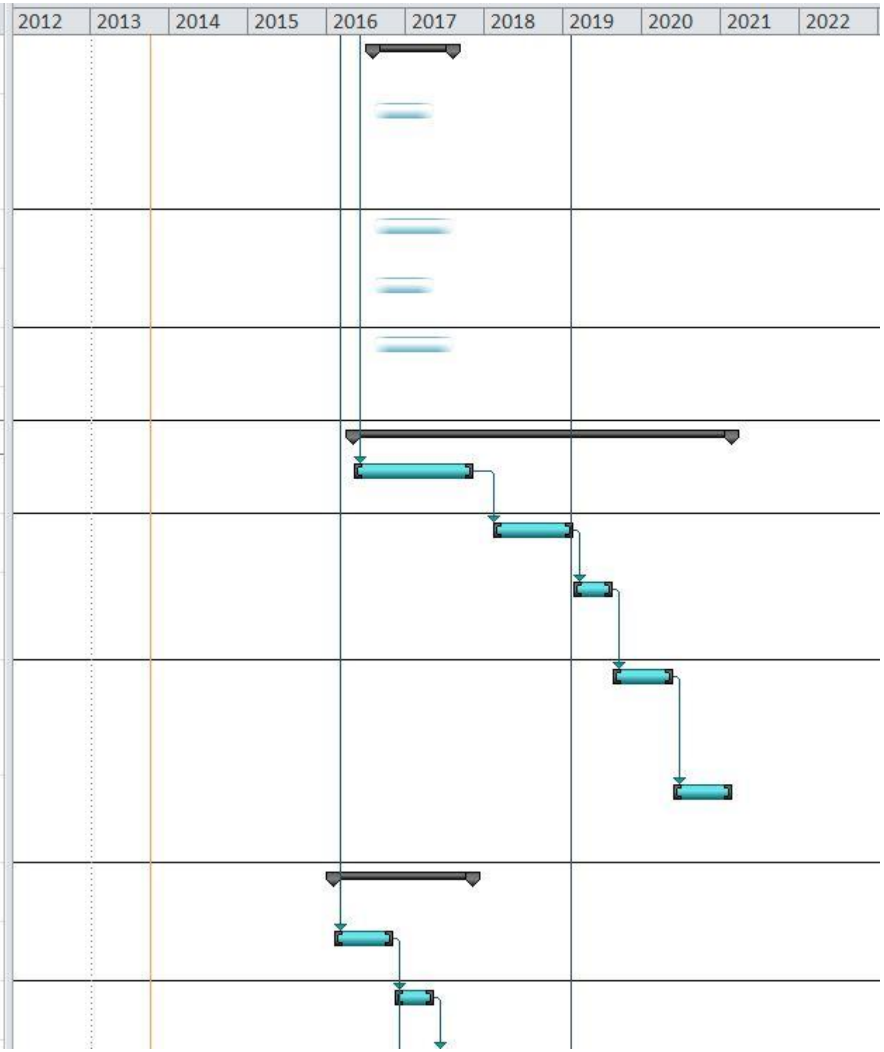
Background to Schedule

	Task Name	Duration	Start	Finish	Predecessors
16	Collaboration Formation	18 mons	Thu 7/17/14	Thu 1/21/16	15
17	**Optimize SiD**	**12 mons**	**Mon 8/3/15**	**Thu 8/4/16**	**16**
18	Optimize Hcal	9 mons	Mon 8/3/15	Wed 5/4/16	
19	Optimize EMCal	6 mons			
20	Optimize Tracker	6 mons	Mon 8/3/15	Tue 2/2/16	
21	**Technical Design**	**36 mons**	**Fri 8/5/16**	**Mon 8/19/1**	**17**
22	**Optimize Iron Design**	**18 mons**	**Fri 8/5/16**	**Fri 2/9/18**	
23	Optimize Exoskeleton; seismic design	9 mons	Fri 8/5/16	Tue 5/9/17	
24	Optimize iron segmentation for transport & Assembly	9 mons	Wed 5/10/17	Fri 2/9/18	23
25	Design Door Motion System	9 mons	Mon 2/12/18	Wed 11/14/18	24
26	Develop Assembly & Tooling Plan	9 mons	Thu 11/15/18	Mon 8/19/19	25
27	**Complete Coil Design**	**48 mons**	**Fri 8/5/16**	**Fri 8/21/20**	
28	Complete Solenoid cold mass design, including supports	12 mons	Fri 8/5/16	Wed 8/9/17	
29	Complete DID Design	9 mons	Thu 8/10/17	Mon 5/14/18	28
30	Complete Current Leads & Monitoring System	6 mons	Tue 5/15/18	Wed 11/14/18	29
31	Develop Transport & Assembly Plan	12 mons	Tue 5/15/18	Fri 5/17/19	29
32	Complete Cryogenics Design, specify treaty points	9 mons	Thu 11/15/18	Mon 8/19/19	30
33	Complete Power, Monitoring, & Quench Protection Design	12 mons	Tue 8/20/19	Fri 8/21/20	32
34	**Complete EMCal Design**	**12 mons**	**Fri 8/5/16**	**Wed 8/9/17**	



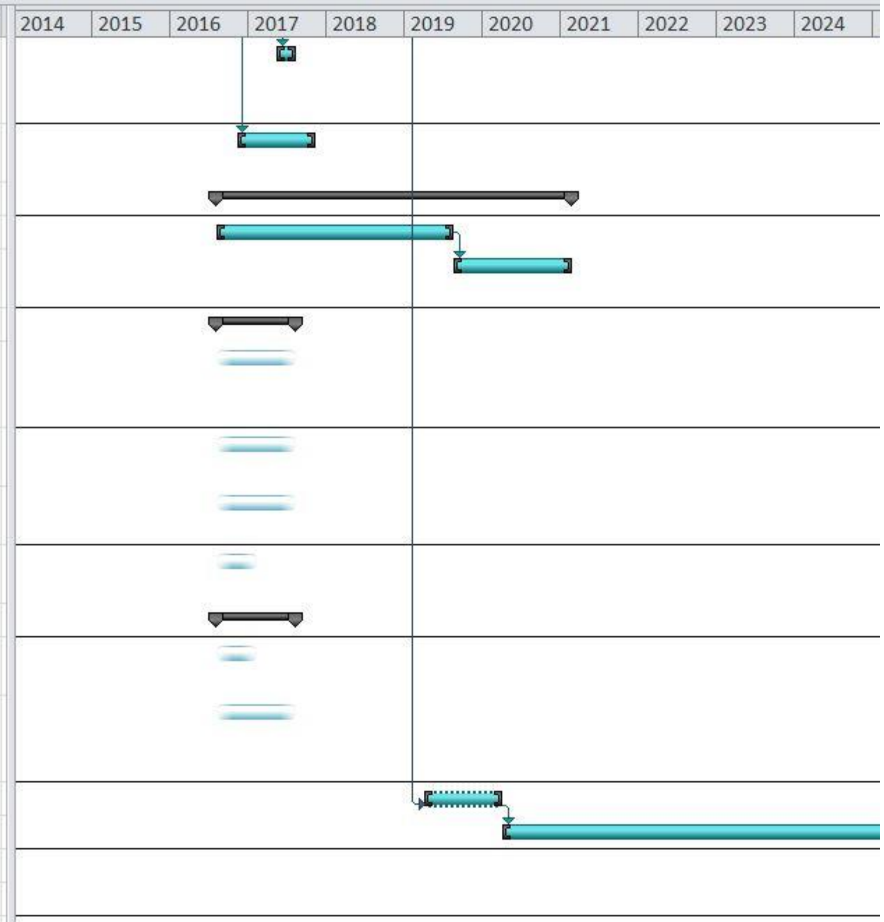
And more

	Task Name	Duration	Start	Finish	Predecessors
34	**Complete EMCal Design**	**12 mons**	**Fri 8/5/16**	**Wed 8/9/17**	
35	Design radiator structure, including supports & cooling; barrel & EC's	9 mons			
36	Design, prototype & test cables	12 mons			
37	Design complete sensor suite	9 mons			
38	Design assembly tooling & procedures	12 mons			
39					
40	**Complete Hcal Design**	**57 mons**	**Thu 5/5/16**	**Tue 2/23/21**	
41	Select detector technology	18 mons	Thu 5/5/16	Thu 11/9/17	18
42	Select electronics readout	12 mons	Mon 2/12/18	Thu 2/14/19	41
43	Complete detailed design of radiator system	6 mons	Fri 2/15/19	Mon 8/19/19	42
44	Complete detailed layout of detectors, specifying quantities and sizes.	9 mons	Tue 8/20/19	Thu 5/21/20	43
45	Develop procurement, production,assembly, test plan.	9 mons	Fri 5/22/20	Tue 2/23/21	44
46	**Complete Tracker Design**	**21 mons**	**Wed 2/3/16**	**Thu 11/9/17**	
47	Design Support tubes & tooling	9 mons	Wed 2/3/16	Fri 11/4/16	20
48	Design Sensor Bracket & Clips	6 mons	Mon 11/7/16	Tue 5/9/17	47



But this is it.

	Task Name	Duration	Start	Finish	Predecessc
49	Develop Clip Attachment & Alignment Strategy	3 mons	Wed 5/10/17	Wed 8/9/17	48
50	Develop FSI Alignment System	12 mons	Mon 11/7/16	Thu 11/9/17	47
51	**VXD Design**	**54 mons**	**Fri 8/5/16**	**Tue 2/23/21**	
52	Select sensor	36 mons	Fri 8/5/16	Mon 8/19/19	
53	Complete conceptual design	18 mons	Tue 8/20/19	Tue 2/23/21	52
54	**MDI Design**	**12 mons**	**Fri 8/5/16**	**Wed 8/9/17**	
55	Design Beampipe & Supports, including vacuum components	12 mons			
56	Design LumiCal Mechanics	12 mons			
57	Design BeamCal Mechanics	12 mons			
58	Design QD0 Support & Interfaces	6 mons			
59	**Front End Systems**	**12 mons**	**Fri 8/5/16**	**Wed 8/9/17**	
60	Review Status of Conceptual Design	6 mons			
61	Develop Power & Distribution Requirements	12 mons			
62	Agency Reviews	12 mons	Mon 4/1/19	Thu 4/2/20	21
63	Construction	72 mons	Fri 4/3/20	Wed 4/29/26	62
64	Commission	12 mons	Thu 4/30/26	Tue 5/4/27	63
65	Data	0 mons	Wed 5/5/27	Wed 5/5/27	64



From here to Commitment

- The DBD does not demonstrate significant technical progress since the LOI except for Benchmarking. Much of our mechanical engineering has faded away – except for the beam test.
- SiD needs an optimization based on current simulation and analysis…
- A Technical Design Report should include:
  - Clear baseline choices for all subsystems
  - Final subsystem dimensions & clearances
  - Reasonably complete mechanical designs including tooling
  - Prototypes and beamtests
  - Serious cost estimate
- We presently have < 0.5 Mechanical Engineers total in SiD. This would have to go to 2 FTE's to begin to make mechanical progress.
- In the intensive TDR stage, this should be ~10 FTE's + similar number of designers.
- The Electronic Engineering is in somewhat better shape.
- System Engineering (Interfaces) needs serious effort, particularly cryogenics interfaces . Japanese codes (e.g. radiation, B fields, seismic, transport, etc) need to be studied. Need to encourage US-Japan collaboration proposal.

Optimization

- Optimization – Demonstrate through simulation the dependence of selected physics measurement errors (or other capabilities) on fundamental SiD parameters.
  - Tracker Radius and aspect ratio.
  - EMCal thickness total and distribution. (Nice work by CLIC should be studied)
  - HCal thickness and number of layers. Scintillator vs gas detectors.
- Expect to be able to see “knees” as performance degrades.
- Where is the current design with respect to the knees?
- We don’t necessarily need to be near each knee, but we should understand where they are. This process will lead to final dimensions for all sub-systems, except for clearances.
- Interesting way for new people to learn about SiD and its simulation/analysis tools, and to suggest improvements.

Critical Issues for Mechanical Engineering

Critical Issues for Mechanical Engineering

Mechanical Engineering is in short supply

- Fermilab has reduced its commitment to SiD. (Will this change now?)
- SLAC is down to <<1 FTE

- It is believed – within the engineering group – that while there are *plenty* of other difficult problems to work on, they do not have the impact or logjam effect of optimization, which will set the major subsystem dimensions.
- There was an enhanced effort on MDI issues at SLAC, which tried to focus on support of the detector, quads, and vibrations and costs. This has largely decayed.

Engineering – Detector Subsystems

- Beamline:
  - Adequate conceptual design.
  - Impedance issues that can generate wakefields and heating have been checked.
  - Synchrotron radiation issues seem ok.
  - Vacuum design seems ok.
- Vertex Detector:
  - Minimal conceptual design for modeling.
  - Little ongoing work on support structures, power and cooling, which may make the modeling of multiple scattering and dead regions somewhat optimistic.

Detector Subsystems

- Tracker:
  - High priority – evaluation of Tracker Sensors and KPiX!
  - Adequate conceptual design for modeling, but need to move towards prototypes.
  - Conceptual design for support mechanics.
  - Need to understand Lorentz force issues from pulsed power and cable design.

Detector Subsystems

- EMCal:
  - Decide on possible 2nd generation sensor design with shielding between traces and pixels; solve problems smoked out in beamtest!
  - Develop 2nd sensor source.
  - There are significant problems bump bonding to the sensors. Expect new sensors to have Au plated pads from vendor.
  - Adequate conceptual design for modeling. (But may not be optimized; CLIC work suggests 20 layers adequate for PFA)
  - Mechanical prototyping of structure using relatively small tungsten sheets has stalled. This needs serious FEA.
  - Need work on assembly strategy. Current estimate is extremely labor intensive. Robotics?

Detector Subsystems

- HCal:
  - No settled conceptual design.
  - Active efforts in PFA work.
  - Critically need outer dimensions of barrel and endcap for solenoid and iron engineering.
  - Radial cracks between modules are apparently accepted, documentation may be weak.
  - The actual detector choice is secondary to the mechanical engineering issues as long as it fits in the allocated space, but a process to move towards decisions is needed.

Detector Subsystems

- Solenoid:

- In principle CMS approach is ok.

- Iron structure and supercoil – have a pre-conceptual design. R&D is ~stalled on interesting aspects such as better superconductors and stabilizers. Might be significant cost improvements with advanced conductor R&D.

- Japanese mountain sites require iron engineering & optimization study of segmentation for:
  - Transport
  - Assembly including handling fixtures
  - Integration of muon system on surface

- The integrated dipole seems difficult. A "bent" solenoid seems effective at reducing backgrounds, but cannot be tuned. Another possibility is double helix coils on the solenoid (C. Goodzeit et al) which appear technically safer than the DID.
- The design cannot progress beyond this until the inner radius and length of the solenoid is settled.
  - This requires optimization of the solenoid.
  - This is not an engineering choice, but a physics and cost issue.
- The Exoskeleton should be revisited. Is it needed?

Detector Subsystems

- Muon System:
  - SiD has changed baseline to scintillator.
  - Detector layout concepts probably stalled waiting iron segmentation design.
  - Need conceptual design for SiPM readout.
- BeamCal:
  - Minor mechanical engineering issues.
  - Needs sensor development! Work happening at UCSC.

Machine – Detector Interface

– There is ~1.5 m radial difference between SiD and ILD. The SiD platform is 3.8 m thick. The platforms appear to add a year to the construction schedule. Revisit platforms??
– SiD L* = 3.5 m; ILD L* = 4.5 m. BNL design dimensions for the SiD QD0 are needed.
– Support and vibration issues need continued work.
– SiD needs seismic analysis and mitigation design.

Critical Issues for Electronic Engineering

- KPiX operation with sensors with large parasitic capacitance. See KPiX and EMCal Beam test talks.
- EMCal: Demonstrate ~10 sensors on same cable.
- Issues for Electrical Engineering (excluding sensors):
  - Fix problems discovered in beam test. Continue evolution of KPiX, including possible consideration of time structure of warm machines.
  - Continue evolution of Beam Calorimeter readout chip.
  - Support prototype work, including readout planes for gas detectors.
  - Evaluate concepts for front end powering, e.g. DC-DC conversion.
- Defer:
  - Continued design of DAQ. Existing ATCA – RCE conceptual design is adequate, will profit by delay. This assumes uniform architectures of the front end systems (except for the vertex detector).
  - Note that SiD will not have a hardware trigger. (A warm machine may need consideration of a trigger)

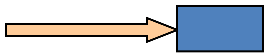
Integration Issues

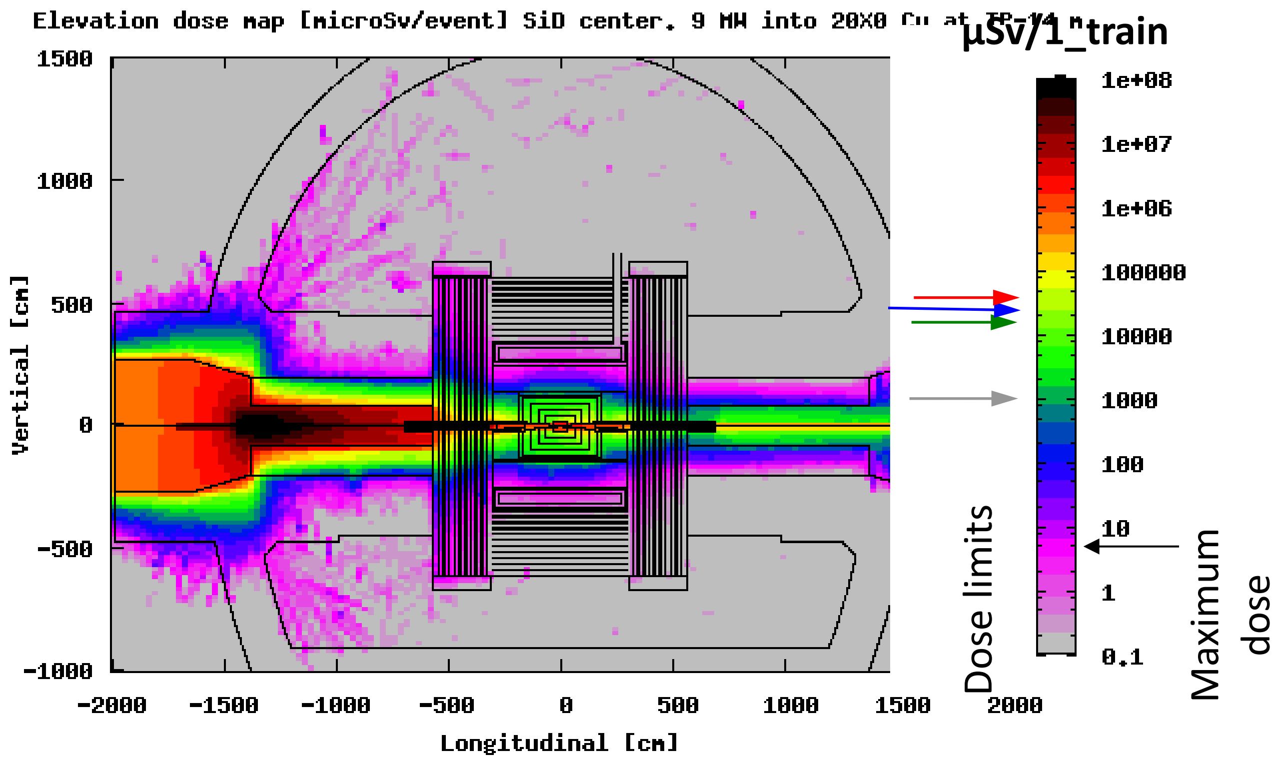
- MDI issues are real, but are believed workable.
- The Self Shielding concept has had another round of Fluka testing, and appears to be conservative. There are schemes for hinged Pacmen to work with both detectors.
- The vertex detector is being treated as a moderate integration issue. The beampipe conceptual design accommodates the SiD vertex detector design, and appropriate space within the tracker volume is allocated. Details can be worked out once a sensor strategy is selected. This could be quite late.

Detector Strategic Work

- Review and document:
  - Radiation shielding properties of SiD.
  - Magnetic field leakage
    - Identify any orientation issues for power transformers, motors, etc.
- Seismic – Japan has very significant seismic activity. Understand interplay of platform, detector, and beamline. Japanese codes?
- Detector Alignment procedures:
  - How will initial assembly alignment be done?
  - Conceptual design of FSI networks.
- Internal detector services
  - Space assignments for electronics, power conversion
  - Preliminary cable routing
- Develop better understanding of interfaces and Treaty points with ILC.

20 R.L. Cu target in IP-14 m. Large pacman.

9 MW 



- The maximum **integrated dose** per event is ~8 µSv << 30 mSv

- The corresponding peak **dose rate** is ~140 mSv/h < 250 mSv/h

Integration Issues

- The tracker and EMCal baseline approach is to use KPiX chips with local connections to Primary Concentrators which will transition to optical signal transmission and handle low voltage power distribution.
- There is no genuinely accepted solution for the HCal sensor and readout scheme. This is a cost and DAQ – event building/filtering issue.
- The service penetration requirements for SiD have had a first look, and seem quite modest. Another study will be needed when the magnet end door concept settles down.

Cost

- There has been a heroic effort by ILC over the past few years to reduce costs, resulting nominally in “SB2009”.
- There has been no corresponding effort by SiD.
- Historically there was a strong effort to keep a cost cap, but that evaporated in the push for the LO I. There was an explicit effort to optimize the detector using Mark Thompson’s parameterization of PFA performance vs R_{trkr}, B, and Hcal λ against the SiD parametric cost model. However, there was no cost cap. This was crude! There has been no subsequent optimization.
- In ILC costing, the answer is:

	LOI	DBD (August 2012)
– M&S Base	$238M	$315M
– M&S Contingency	$88M	$127M
– Engineering Labor	206 MY	186 MY
– Technical Labor	613 MY	532MY
– Administrative Labor	25 MY	30 MY

Costs – Is this Reasonable?

- In US accounting, assuming we start construction in 2016; 3.5% inflation; and DOE National Laboratory labor rates, this corresponds to $857M.
- Is this reasonable and rational going forward – particularly in view of the cost consciousness of ILC? (Not to mention that this is probably huge compared to DOE expectations…)
- Will there be (more) pressure to move to a single detector?
- If so, are we better off being a bit more modest?
- We need a mechanism to make some rational decisions…
- Will this be a LCO issue?

Costs – Are they right?

- To a reasonable extent, there are two semi-disjoint exercises in generating the SiD cost estimate:
  - Calculating quantities of a material or service – e.g. how many tonnes of iron.
  - Estimating unit costs – e.g. how much does a tonne of machined, painted, QC'ed, delivered iron cost.
- The quantity calculations have been done largely by one person. They need to be checked. Each review has found errors. There is no rational reason to believe all have been found!
- The unit costs have been studied and agreed upon between SiD and ILD. *This does not make them correct*!! The sensitivities to unit costs for the major items are indicated in the following by showing the effect of doubling the assumed unit cost:

Unit Cost Sensitivity

Item	Nominal Unit Cost	ΔSiD Base M&S Cost (M$)
Magnet Iron (finished and delivered)	$6/Kg	48
Tungsten (powder alloy) plate	$180/Kg	14
Si Detector	$\$6/cm^2$	79
Hcal Detector (sensor)	$\$12000/m^2$	42

There may be little basis to adjusting these numbers to be “correct” – but there seems to real value in both detectors using the same values. There is some indication ILD is using $\$3/cm^2$ for Si.

Conclusions

- There are "technical" and "philosophical" issues that must be resolved before significant forward progress on SiD:
  - Detector (but particularly calorimeter) optimization
  - HCal sensor & readout decisions
  - What do we do (if anything) about the SiD cost?