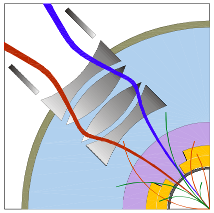
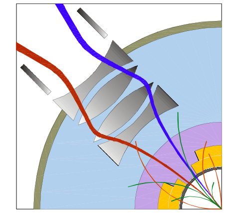


Reaction to Chamonix: APUL

Sandor Feher
Fermilab

LARP CM14, Fermilab April 26th, 2010

U.S. DEPARTMENT OF ENERGY | Office of Science



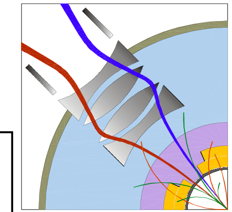
Outline

- APUL Status right before Chamonix
- APUL Status after Chamonix
- Possible avenues for APUL
- Lessons learned

What is APUL?

- Accelerator Project for the Upgrade of LHC
- Targeted the only well defined LHC upgrade => Phase I Upgrade
  - Interaction region at the high luminosity area (CMS & ATLAS) were planned to be replaced
- Collaboration with CERN => subproject of LHC phase I Upgrade
- LARP is a R&D Program; APUL is a construction project (minimal development work) with well defined deliverables and Cost & Schedule

APUL Scope



Fermilab will build: Cold Powering

DFX – Current lead box

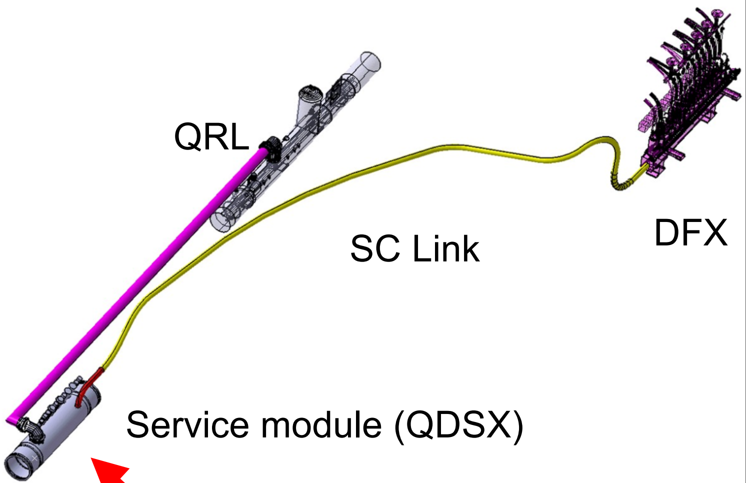
Superconducting Link – 30 -100m NbTi buses

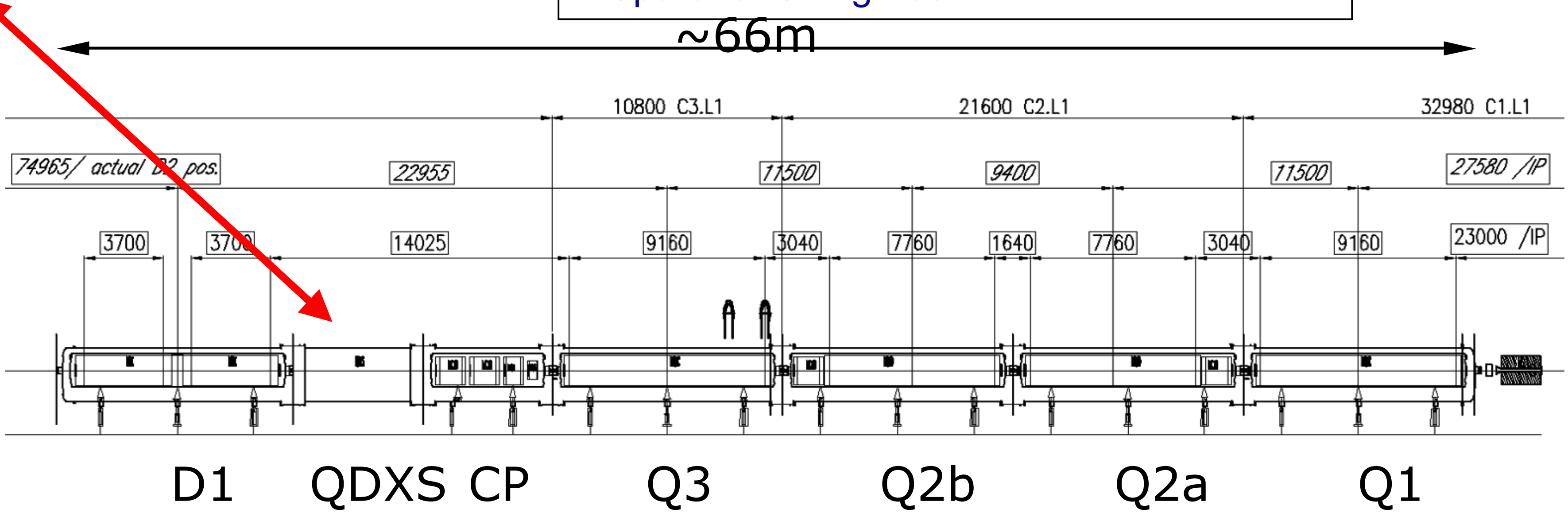
BNL will build: D1 cold masses

Two RHIC DX cold mass connected

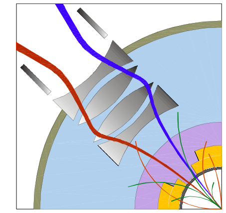
Four locations – ATLAS & CMS

1 Spare for String Test



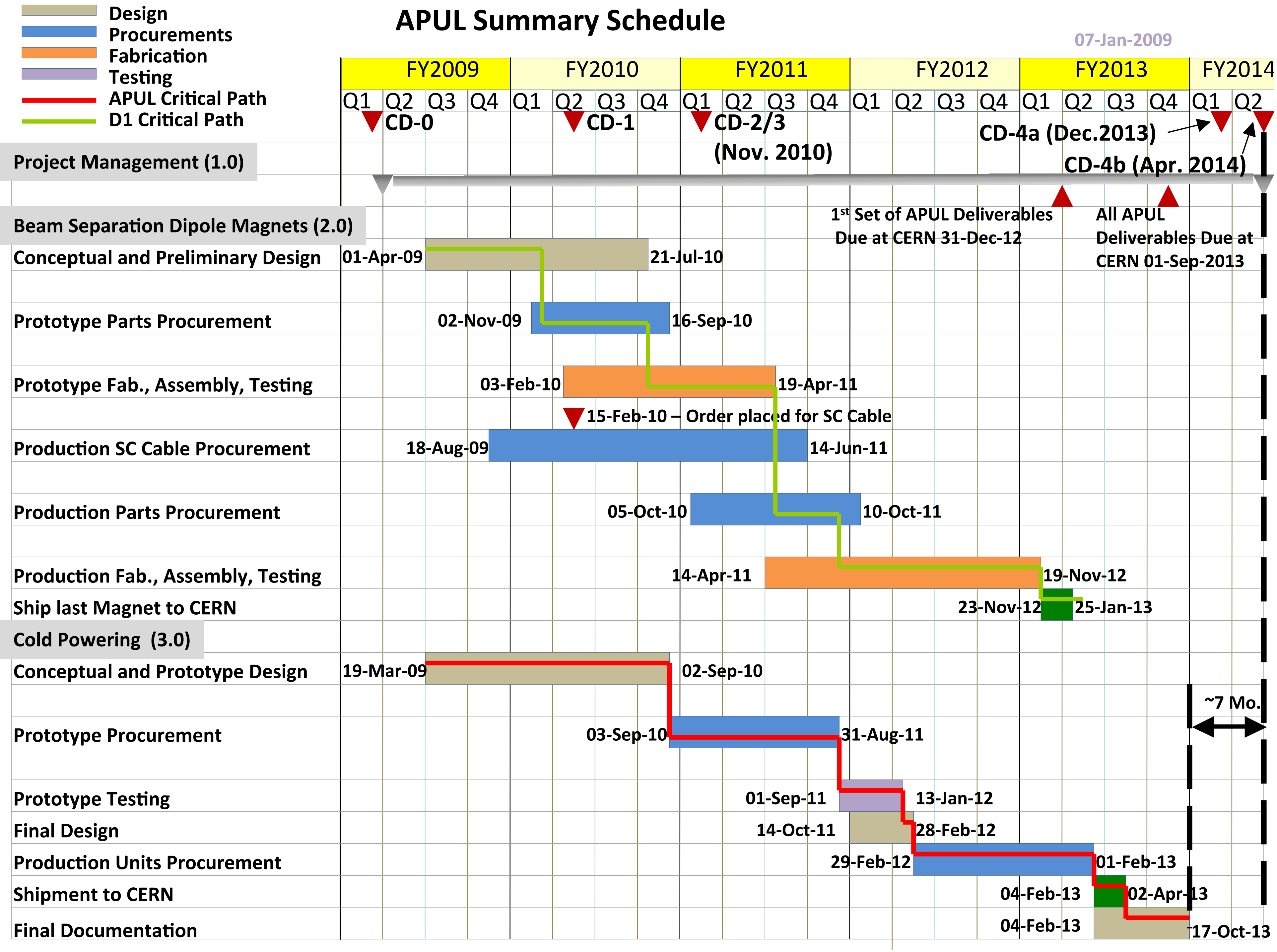


APUL Cost Summary



	WBS	Items	APUL's Cost Estimate AY $K: Estimated Cost (AY $k with indirects): M&S	Labor	Total	Contingency: Percent	Contingency: Total	Total Cost (AY $k)
TEC	1	Project Management	$ 349.3	$ 2,497.4	$ 2,846.7	31%	$ 878.4	$ 3,725.2
TEC	2	Beam Separation Dipole Magnets	$ 2,955.6	$ 2,896.2	$ 5,851.8	28%	$ 1,641.9	$ 7,493.7
TEC	3	Cold Powering System	$ 2,939.0	$ 1,163.9	$ 4,102.9	31%	$ 1,280.2	$ 5,383.2
		Total TEC:	**$ 6,244.0**	**$ 6,557.5**	**$ 12,801.4**	**30%**	**$ 3,800.6**	**$ 16,602.0**
OPC	1	Project Management	$ 243.6	$ 1,579.7	$ 1,823.3	30%	$ 547.0	$ 2,370.3
OPC	2	Beam Separation Dipole Magnets	$ 2,504.7	$ 2,294.6	$ 4,799.2	31%	$ 1,464.1	$ 6,263.4
OPC	3	Cold Powering System	$ 913.1	$ 2,273.8	$ 3,186.9	30%	$ 943.6	$ 4,130.4
		Total OPC:	**$ 3,661.4**	**$ 6,148.1**	**$ 9,809.5**	**30%**	**$ 2,954.7**	**$ 12,764.1**
		TPC:	**$ 9,905.3**	**$ 12,705.6**	**$ 22,610.9**	**30%**	**$ 6,755.3**	**$ 29,366.2**

APUL Summary Schedule



APUL Status Right Before Chamonix

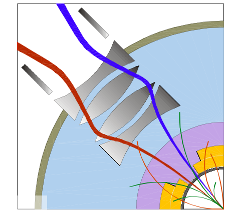
- DOE CD1 review was held in BNL on January 20-21
- It was a great success
- It was recommended that the TPC need to be increased to $31M
- The Implementing Arrangement was developed on and close to be ready for signatures
- There were no signs from CERN directorate that there could be any changes in the Phase I Upgrade deliverables:
  - The installation date could change however the due date of the deliverables would remain the same

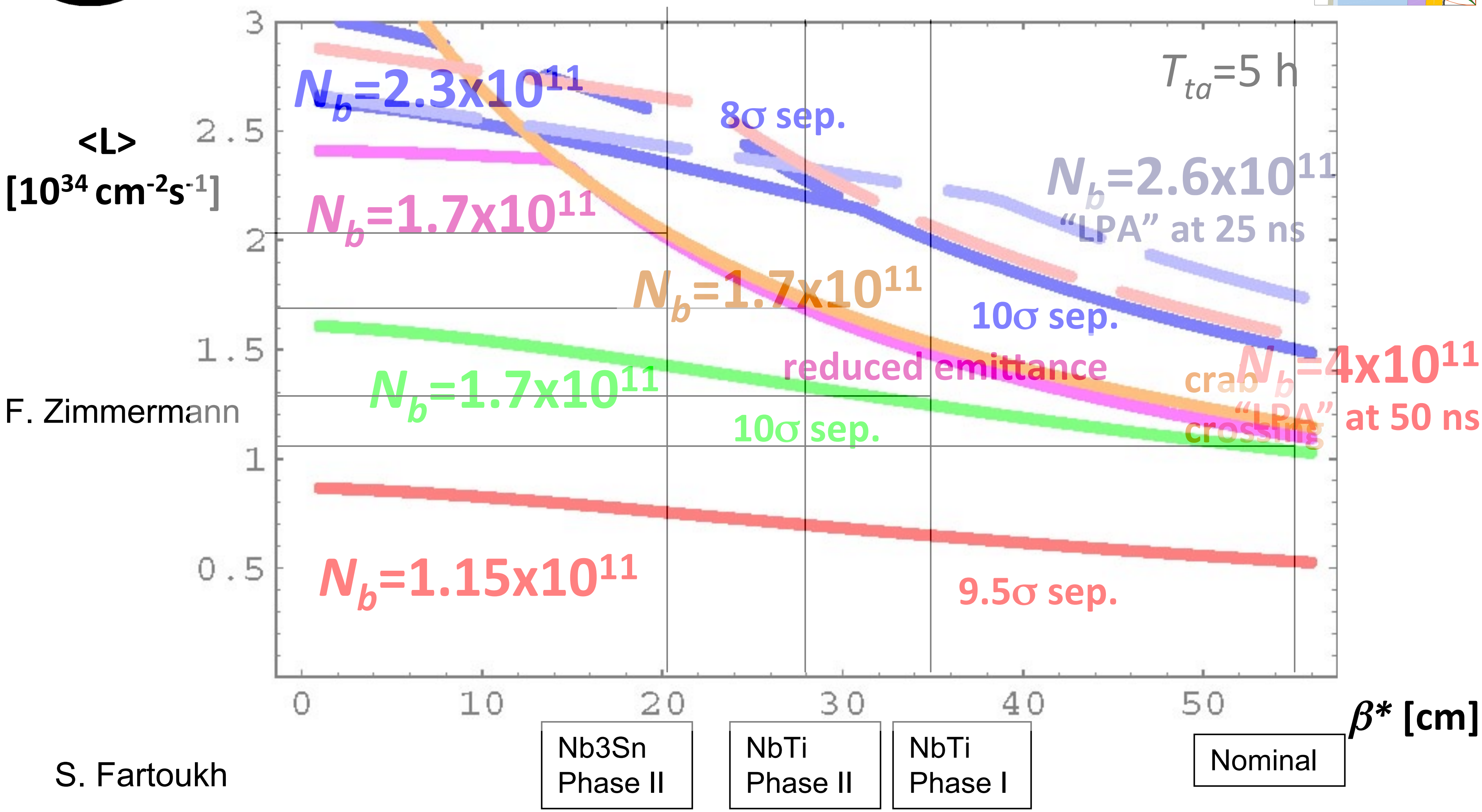
Chamonix with respect to the Phase I and Phase II Upgrade

- Phase I went through strong criticism
- Two “tough” questions were formulated by S. Myers:
  - Will the Phase I upgrade produce an increase in useful integrated luminosity?
    - Installation time and re-commissioning a new machine afterwards
  - Do we have the resources to complete on a time scale which is reasonable with respect to Phase II?
- A special Task Force by Lucio Rossi was assembled to answer these questions
- Comments:
  - At Chamonix there was no clear definition of Phase II other than higher luminosity is required than Phase I
  - Besides resource issues, there was a clear emphasis on a signifcant increase in luminosity to decide whether one should consider an upgrade

APUL

beam intensity is much more important than β^*, reducing β^* only helps with crab cavities or with smaller emittance

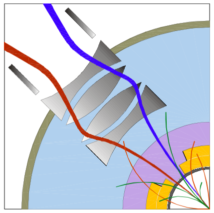




APUL after Chamonix

- The "wind" from Chamonix reached DOE
  - US participants informed their officials
- CD1 approval was delayed indefinitely
- APUL was put into "Hibernation"

Hibernation Plan



- Costs associated with hibernation: The cost of going into hibernation is $604k. Essentially all of this effort is already included in the TEC. The burn rate in hibernation is $2.2 k per month. The cost of the restart, which would add to the TEC, is $554 k.
- Cost to complete: Relative to the cost presented at the CD-1 review, the cost will be increased by the Restart cost (given above), inflation factors due to the schedule delay, and costs associated with implementing the Recommendations of the CD-1 review committee for D1 production.
- Schedule: Hibernation will be reached by the end of May. The restart time is the time between the end of hibernation and a CD-1 mini-review. The time is estimated at five months. The times required to obtain the long-lead components (e.g., NbTi superconductor) will not increase the completion time. Implementing the Recommendations of the CD-1 review committee for D1 would not affect the completion date of the D1 work.
- TEC with hibernation work included (without restart of the project): $2679k

Luminosity Upgrade Task Force with respect to APUL

- Lucio presented 6 pages of conclusions - I only picked a handful of them which I felt relevant for APUL:
  - The Upgrade will be delayed until 2018 - 2020 but not later:
    - Delayed: incident/consolidation/manpower, no radiation limitation of the IR until 2020 - 2022, Performance compare to nominal is not significantly increased, optimizing number of shut downs, Global optics layout optimization
    - No later: Detectors (ATLAS, CMS) needs an upgrade (skill set and funding), Present IR magnets aperture limitation ~ factor of 2-4 (emittance blowup, collimator impedance compensation)
  - Luminosity goal is **$\sim 5 \times 10^{34}\ L_{peak}$ AND $\int_{year} Ldt \geq 150\ fb^{-1}$** sd
  - Delay opens new possibilities to pursue new ideas:
    - Investigate new optics layout, which must take into account the limitation of the LHC arcs
    - Investigate the advantages of new technology (Crab Cavity, Nb3Sn magnets, MgB2)
    - Investigate better use of existing technology (NbTi magnets)

Future of APUL

- The four years of delay means that the project need to be re-defined
  - The likelihood that the scope will change is quite high
  - It is questionable whether US labs interest still there or they are busy with other projects
- Possible scope for New-APUL:
  - APUL D1 magnets - quite likely to be usable for any upgrade scenario
  - Cold Powering Transfer System - new scope: number of elements, technology choice if above ground, might change
  - IT magnets using Nb3sn technology. APUL as a construction project can utilize the Nb3Sn development from LARP assuming LARP solves the outstanding R&D issues and produces the first long prototype magnet. The R&D issues are:
    - R&D work to procure a prototype magnet: 120mm aperture, long magnets (length similar to the present triplet, 10-13m and/or 6.5-8m prototype quadrupoles)
    - Cooling scheme of the quadrupole to take out the heat utilizing superfluid helium or supercritical forced flow helium.

Future of APUL continued

- Quench limit due to radiation is adequate for Nb3Sn magnets. No surprises due to coupled effects of instability and local radiation induced heating along the path of particle showers.
- Radiation hardness of the insulator and conductor itself
- Demonstration that stringent Field Quality requirements can be met and flux jumps will not influence Field Quality in terms of machine operation.

– QPS electronics. Energy dump system needs further development. The US is in excellent position to contribute to this effort since the most advanced high current semiconductor electrical components are built by US companies

Lessons Learned

- From CD0 to CD4 => five years minimum

  If D1 cold masses work will continue or Nb3Sn cold masses will be built and assuming that there will be a string test prior to installation

  - Proposal for CD0 no later than 2011 - 2012 (to get approval it takes time)
  - CD0 to be granted no later than 2012
  - CD1 approval by 2013
  - Requirements - sufficient to finalize the R&D work - ASAP
  - Requirements and specifications by 2012
  - Prototype concluding any R&D by 2012 - 2013
  - Pre-production prototype by 2013 -2014
- Cost:
  - D1 magnet will be more costly due to inflation ~$12M (4 + 1 spare)
  - For Nb3Sn IT cold masses if tooling is mainly available (similar way than for D1):
    - Assuming that the cost of the Nb3Sn cold masses will increase relative to D1 cold masses by ~25% one would expect the cost to be ~$62M including a set of spare magnets
    - Management cost is ~$6M
    - Assuming 35% contingency TPC = ~ $92M (APUL was $30M; LARP + base funds for five years is ~$50M)

Lessons learned continued

- Well before CD0 long range commitment from CERN is needed
- CERN is not necessarily keen on using new technology unless it is completely proven to be safe - minimal technical risk is acceptable - and it gives great advantages (e.g. factor of 10 luminosity improvement) or it is absolutely necessary (like dealing with heat loads)
- The improvement from Nb3Sn magnets will not alone provide the complete luminosity increase that is required:
  - Bunch intensity need to be increased from 1.2×10^{11} to 1.7×10^{11}
  - Even under the most optimistic scenario the maximum average Luminosity improvement using Nb3Sn technology (β^* = 15 cm) and including Crab Cavities (CC) is no more than ~40% relative to NbTi (also using CC). If accepting the current optics limitations this goes down to ~18%.
  - Without CC the Nb3Sn advantage in luminosity increase is negligible
  - Using NbTi magnets (if the heat load can be managed) one can reach the new luminosity goal (if CC is used) => CERN continues with the NbTi development work and planning to put effort into CC, however CERN can't afford to deal with Nb3Sn development as well since consolidation work eats up all the resources until 2015