Solenoid

2nd Costing Meeting,
May 16th

CLD note: 50 MCHF

Dear Mogens,

I have happy to try, but please keep in mind that this involves a lot guess work, and should not be taken too literally. Unfortunately, it is also clear that my estimates are more pessimistic than those of Herman.

I have done the following calculations:

In the superconducting solenoid version presented by Nikkie earlier this year (see attachment), the stored magnetic energies were as follows:

- CLD: 600 MJ
- IDEA: 130 MJ
- LCalo: 250 MJ

For generic superconducting detector magnets, historically a strong correlation was found between stored magnetic energy and overall magnet cost (see attachment) **excluding cryogenic** . Note that this means that for cryogenics you will have to contact the colleagues you have been in contact with to get some estimates and this comes on top of the estimates given here.

With cost scaling for superconducting detector magnets (equation 9 in attached paper), I get to the following numbers:

- CLD: 48 MUSD (2007)
- IDEA: 17 MUSD (2007)
- LCALO: 26 MUSD (2007)

I estimate the conversion factor from USD to CHF in 2007 at 1.2 CHF/USD. Then I assume that you will place the order in 2035, i.e. 28 years after the reference date of 2007, and I assume an annual average inflation rate of 1% for the Swiss Franc (where obviously I am guessing here and there may be more qualified people than me to weigh in on this).

With that I get to the following numbers:

- CLD: 76 MCHF (2035)
- IDEA: 26 MCHF (2035)
- LCalo: 42 MCHF (2035)

Important caveats here is that I am treating these magnets as generic detector magnets. For example, the IDEA solenoid is aimed to be as transparent as possible, which comes at an extra cost, and I don't know how to cost that. All these magnets require aluminum-stabilized conductor technology which is presently not commercially available. While we are investigating this issue, presently we do not have a solution and eventually this matter will become important for FCC-ee as well. And, as already mentioned, cryogenics is not included in the above-mentioned prices.

For general scaling, I would suggest to study the attached paper, where they indicate a power of 0.69 to get from stored magnetic energy to cost. The stored magnetic energy scales with magnetic field magnitude squared (but keep in mind that for detector magnets, Nb-Ti is practically limited to a bore field of about 4 T), radius squared, and the length.

I hope that this answers your questions. Please let me know if anything is unclear about my reasoning, the above-mentioned calculations, and the results.

Have a nice day!

Best regards,

Matthias

The Cost of Superconducting Magnets as a Function of Stored Energy and Design Magnetic Induction Times the Field Volume

Michael A. Green and Bruce P. Strauss

The cost equations for detector magnets in Fig. 4, Fig. 5, and Fig. 6 take the following form;

$$\mathrm{C(M\$)} = 0.58\,[\mathrm{E(MJ)}]^{0.69}, \tag{9}$$

$$\mathrm{C(M\$)} = 0.55\,\left[\Omega(\mathrm{T\text{-}m^{-3}})\right]^{0.65}, \tag{10}$$

and

$$\mathrm{C(M\$)} = 0.75\,[\mathrm{M(tons)}]^{0.80}, \tag{11}$$

where C is the magnet cost; E is the design magnet stored energy Ω is the design magnetic field volume times the average magnetic induction; and M is the magnet cold mass and cryostat mass given in metric tons.

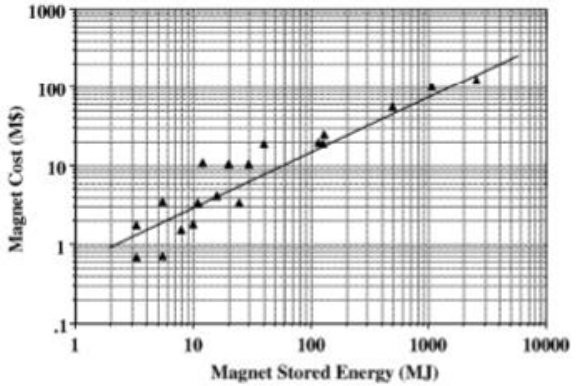


Fig. 4. The Cost of Detector Magnets as a Function of Magnet Stored Energy.

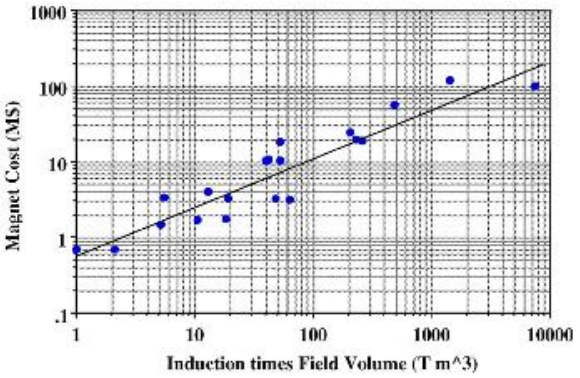


Fig. 5. Detector Magnet Cost as a Function of Induction times Field Volume.

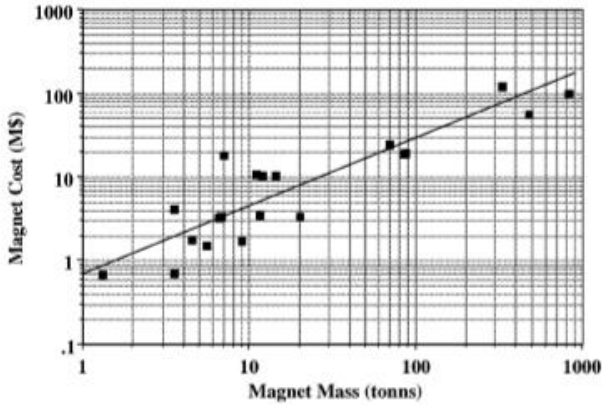


Fig. 6. The Cost of Detector Magnets as a Function of Overall Magnet Mass.

Price escalation,
Inflation,
Reference year?

Dear Matthias,
Thank you very much for carrying through this exercise.
It is clearly not a simple thing to do and hence it will have quite
a bit of uncertainty, as you write.

Let me point to something which may indeed bring you in better agreement with Herman's numbers for CLD.
I see that you have a 2007 estimate of 57.5 CHF. Now, I have no idea of whether Herman has used the
concept of price escalation, which the estimate in LCD-Note-2018-006 uses. In this note you will find
the attached graph.

If I read this graph correctly it says that industrial production in Switzerland has indeed
become cheaper from 2007 (index 107) to 2017 (index 100). Would I take your 57.5 CHF number from
2007 and escalate this to 2017 (or 2018, which is the basis of the note) I would have to
divide by 1.07 and end up at 53.7 MCHF. Pretty close to Herman's 50 MCHF number.

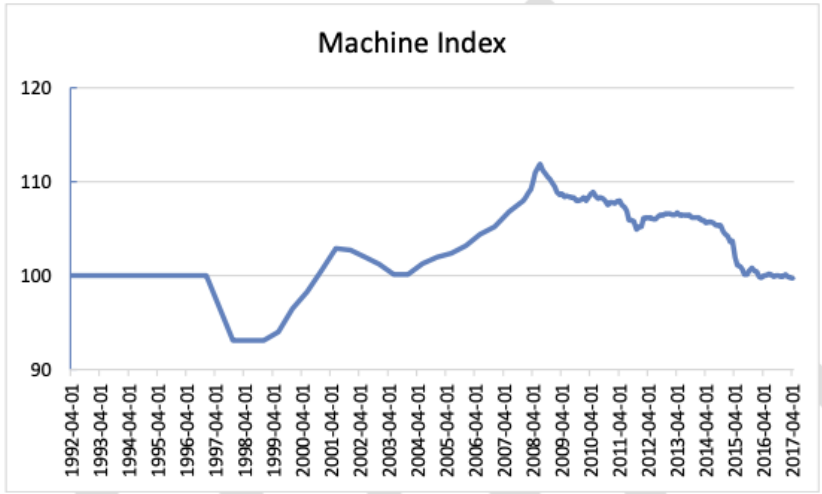
Immediately, I was surprised to see the escalation index falling in the period 2008 to 2017,
but it may have to do with he rising the CHF(?).

I will have to undesstand from Anders Unnervik which year we should take as basis and how
he wants us to treat inflation/escalation. But you have provided details so I believe I have
what we need.

All the best and thank you again,
-Mogens

Annex A:
The Swiss escalation index, as used in the costing tool

The escalation factors used in the costing tool are shown in the Figure. Here, machine index 100 is defined as the average of the period 1990-1996. Note that the majority of the cost estimates used in this note date from 2007 to 2011 – a few estimates, stemming from CMS, are from earlier dates.



TPC

Found in Sent - dam@nbi.dk Mailbox

MD

Mogens Dam

Re: FCC-ee detector costing exercise

To: Behnke, Ties

Dear Ties,

For our meeting in the Costing Panel, would you have any input on the ILD TPC costing.

I find the attached text snippet in the ILC TDR, which is perhaps what we should stick to(?).
Except possibly for some inflation correction to a year which I am not sure what should be yet.

Best wishes,
-Mogens

7.3.3 Time Projection Chamber

The estimate of the TPC price comes largely from the prices found in the construction of the STAR and ALICE TPCs. It has been updated for inflation but does not contain any added contingency. The cost of the field cage includes the experience from the construction of the large prototype, which was built in industry, using technology similar to the one to be used for a full scale field cage. A significant part of the TPC cost will be in the readout electronics, estimated to be around 30% of the total cost. The field cage - the iner cylinder, the outer cylinder, and the endplates, will account for around 20% of the cost, the rest being in tooling, anciliary systems and control systems. The total cost of the detector is estimated to be 35.9 MILCU.