SOFT RANKING OF LHC UPGRADE POSSIBILITIES

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Abstract

An attempt to introduce objective approach to the upgrade scenario ranking… and initiate discussions.

THINGS TO CONSIDER

When it comes to the LHC Upgrade proposal ranking one should definitely pay attention to: a) whether technology available (if not – when); b) cost of the upgrade (<few M$ of EU,<few 10's M$, <few 100'sM$); c) time needed to construct and install d) luminosity gain; e) assurance=physics risk to not get the gain (e.g. energy deposition, BB, optics).

Big Table below tries do summarise personal vision of various project ranking. For each of the criteria a) - e) mentioned above, a number from 1 to 3 is assigned depending on how the project ranks (1 is considered to be less attractive, 3 is most attractive, e.g., luminosity gain of 1-10% has ranking 1 and is less attractive than luminosity gain of 30-100% which ranks as high as 3). The Table does not rank injector complex upgrades or detector upgrade projects, and considers only the LHC machine upgrades discussed at the Workhsop: a) IR upgrades (Nb3Sn quad 1st, NbTi quad 1st, dipole 1st, small angle crab crossing); b) bunch length reduction to 3.5 cm by using more RF; c) intensity upgrades (wire long-range compensation, electron lens head-on compensation, 12.5 ns or 75 ns bunch spacing to suppress e-cloud, rotating collimators, hollow electron beam collimators, bent crystal collimators, instability suppression by octupoles, dampers or electron lenses). Corresponding presentations can be found in Proceedings of this Workshop.

The second line from the bottom shows the sum of all rankings. On that basis, one can separate two groups of projects: a) Group A (ranking above ~10, projects definitely explore)

all collimator and instability projects

both quad first paths

b-b compensation schemes: wires, e-lenses

LHC UPGRADES

Injector Complex Upgrades (Support operations + allow intensity upgrade) — Linac, PS+, SPS+, LER

Machine upgrades — Detector upgrades (>300 fb⁻¹)

IR upgrade: Quad 1st, D. 1st

Intensity upgrade: σ_s; Beam-beam; e-cloud; collimation; instabilities

	Nb3Sn	NbTi	Dipole 1st	Crab X-ing	more RF $\sigma_s \to 3.5$ cm	wire LRBB	LHC e-lens	12.5 ns 75 ns	RC	e-lens	crystal	octupoles	damper	e-lens
Technology available	2009	Now	N/A	N/A	Now	2008	Now	Now	2009	Now	'09	Now	Now	Now
	2	3	1	1	3	2	3	3	2	3	2	3	3	3
Cost S(<few M$), M(<10's M$), L(100's M$)	L	L	L	M	M	S	S	S-M	M	S	S	M	S	S
	1	1	1	2	2	3	3	2.5	2	3	3	2	3	3
Time to des/build/install S(<2yr), M(2-4yr), L(>4yr)	L	L	L	M-L	M-L	S	S-M	S	M	M	S-M	M	S	M
	1	1	1	1.5	1.5	3	2.5	3	2	2	2.5	2	3	2
Physics/optics/BB/ED assurance S-showstoppers M-problems, L-easy	L	M-L	S-M	S	S	M-L	M	S-M	M	M	M	M-L	L	M-L
	3	2.5	1.5	1	1	2.5	2	1.5	2	2	2	2.5	3	2.5
Luminosity Gain S 1-10% M 10-30% L 30-100%	M-L	M-L	M-L	S-M	S-M	M-L	M-L	M-L	L	M-L	M-L	M-L	L	L
	2.5	2.5	2.5	1.5	1.5	2.5	2.5	2.5	3	2.5	2.5	2.5	3	3
Total score, Σ	9.5	10	7	8	9	13	13	12.5	11	12.5	12	11.5	14	12.5
Manager's Score Σ × (Assurance)	28.5	25	10.5	8	9	32.5	26	19	22	25	24	18	42	31

and b) Group B (lower ranking, to look carefully into)

Short bunch and 12.5-75 ns

Dipole first

Crab crossing

If one to concentrate on the cost aspect only, then with respect of the Tevatron (RHIC?) project efficiency "rule of thumb" - 1M$ upgrade to give 2-4% in luminosity gain – the projects can be divided in 2 groups :

Group A ("worth the buck") -

feedback

b-b compensation schemes: wires, e-lenses

new collimation schemes

both quad first paths

new 12.5-75ns schemes

Group B (to look carefully into)

Short bunch

All IR upgrades

Of course, when it comes to decision, it should be made by a manager. So, if we assume an "intelligent manager" model which includes the desire to minimize the risk, assure at least *some* improvement, and idea of starting long lead projects ASAP , then the ranking will somewhat change – see the bottom line in the Table above. Now, the projects can be grouped as following

- Group A (really attractive, start acting now)
  - both quad first paths (need magnet R&D)
- Group B (high gain, support now, be prepared to do later)
  - feedback projects
  - collimator schemes (RC, LEL, Crystals)
  - beam-beam compensation schemes
- Group C (make sure assumptions/ estimates right, before rule out):
  - dipole first
  - short bunches
  - crab crossing

CONCLUSIONS

Although IR upgrade projects look as a sure way to improve LHC luminosity, it seems necessary to work actively and support high-gain high-risk low or moderate cost projects focused on compensation of beam-beam effects, beam collimation and instability suppression. Such multi-tasking surely requires more resources but seems to be necessary – operation of all hadron colliders shows that typically there is no "silver bullet" which fixes or improves machine, and many various type improvement steps/projects are needed [1].

Closer collaboration of CERN with other accelerator centers should be helpful for looking in detail into items promising a lot of return for small investment. Such a collaboration will take some load off CERN scientists which will be busy with machine commissioning for years ahead. Other labs may also arrange beam demonstrations of promising techniques – that always is the most convincing way of proposing upgrades. Collaborations will also allow to attract and keep younger scientists interested in doing accelerator research.

REFERENCES

[1] V.Shiltsev, *"CPT Theorem for Accelerators"*, FNAL-Conf-04-126 (2004).