HL-LHC
Options for the HL-LHC Baseline

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HL-LHC Hardware Options: 2nd C&S Review 10/16

2 Categories: Hardware and Parameter / Operation Scenarios

-Costs are only implied for hardware but certain parameter options can imply certain hardware options ➔ implicit cost implications

Hardware Options:

-Required readiness for installation
-Required readiness for taking a decision
-Assigned budget for development
-Required Budget for implementation
-Integration aspects

Parameter / Operation Scenarios:

-No explicit budget implications but risk mitigation
-Backup option (with reduced performance) for baseline hardware
-Summary of hardware implications for HL-LHC

HL-LHC Hardware Options: 2nd C&S Review 10/16

Five Categories:

1) Considered for machine protection and Risk mitigation
(as auxiliary system for other HL-LHC baseline components)

2) Options for facilitating required HL-LHC interventions

3) Options for additional diagnostics

4) Mitigation against unforeseen performance limitations

5) Additional performance improvement

➔ **Goal is to review the option list in view of the upcoming C&S Review**

HL-LHC Hardware Options

H1) Considered for machine protection and risk mitigation:

WP14

-**<u>MKB or TDE upgrade</u>**

(Dump protection in case temperature of TDE can reach 3000°).

Still Valid!!!

d) Modification of the dump windows

- ➔ Technical solution needs to be ready for LS3
- ➔ Decision required during RunIII
- ➔ Studies and development included in WP14
- ➔ ~~Ca. 3.6 MCHF for dump upgrade implementation~~
- ➔ Integration should not be an issue

➔ 6.4 + 1 MCHF for full upgrade

HL-LHC Hardware Options

H1) Considered for machine protection and risk mitigation:

WP14

-**MKI upgrade**

(new series ...
sustain hig...
a) ...
b) Screen conductors
c) Coating (e-cloud)

In Baseline Now!!!

Could be covered due to lower cost for the prototype development

➔ Chamber installation in LS2 and installation of full system upgrade in LS3

➔ Technical solution needs to be ready for LS2

➔ Decision required during RunII

➔ Preparation studies and tests in SPS in 2017 included in WP14

➔ ~~Ca. 3.5 MCHF for full MKI upgrade~~ ➔ 1.8MCHF for Ferrite rings

➔ Integration should not be an issue

HL-LHC Hardware Options

H1) Considered for machine protection and risk mitigation:

New Option!!!

WP14

-**TCDQ and BETS**

a) TCDQ mechanics upgrade
b) BETS upgrade
c) New absorber

➔ Technical solution can be ready for LS3
➔ Decision required by 2020
➔ Ca. 0.75 MCHF for full upgrade
➔ Integration should not be an issue

HL-LHC Hardware Options

H1) Considered for machine protection and risk mitigation:

WP3

-**Cold Diodes**

New Option!!!

R&D included in HL-LHC baseline

a)

- ➔ Technical solution can be ready for LS3
- ➔ Radiation hardness of cold diodes is the open issue
- ➔ Full upgrade should approximately cost neutral after R&D spending
- ➔ Integration should be simplified

HL-LHC Hardware Options

H1) Considered for machine protection and risk mitigation:

WP5

-**Beam halo depletion devices** (MP for coping with CC failure and loss spikes)

Options

, LHC)

IC)

Would like to bring the hollow e-lens to the HL-LHC Baseline with installation in LS3!

In discussion with UK and Russia for in-kind contributions

Still discussions on Test Stand needs (0.5MCHF)

➔ Include as Option at this stage?

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cryogenic infrastructure ✔ ➔ conflict / exclusion with other options!

HL-LHC Hardware Options

H1) Considered for machine protection and risk mitigation:

WP5

-**Rotatable Collimators** (might be required for MP in case of higher than expected rate of asynchronous beam dumps)

➔ In-s

No longer pursued!!!
But tests and validation in SPS and LHC have been completed

➔

➔

➔ RP money)

➔

➔ Integration assumed as replacement of already existing HL-LHC collimators

HL-LHC Hardware Options

H1) Considered for machine protection and risk mitigation:

WP11

-**Additional 11T dipole magnets and DS collimation units**

Was introduced as an option after the project re-baselining in 2016

a) Additional 11T dipole magnets

7

1/IR5

3

No longer pursued!!!

➔ Technical solution exists

➔ Decision required for intime production by end of Run2

➔ 10s MCHF for full upgrade

➔ Integration will be affected

HL-LHC Hardware Options

H2) Considered for facilitating interventions for HL-LHC

WP12

-**Laser Engineered Surface Structures [LESS]** → interesting as alternative for a-C coating for in-situ surface treatment of vacuum components in IR2 and IR8 and ot

→

→ years)

→ ithin WP12)

→

→

Still Valid!!!

Collaboration with Uni Dundee and STFC

→ Investigate possibility of coating all matching section quadrupoles as an additional Option!

New HL-LHC Hardware Options

H2) Considered for facilitating interventions for HL-LHC

WP2; WP3; WP5; WP7; WP9; WP10; WP12; WP13; WP15

-**Remote controlled alignment** ➔ interesting alternative for swapping Q4 & Q5 retrofitting Q5 and Q4 with new corrector magnets and requiring new sector valves

- ➔ Technical solution being developed at CERN
- ➔ Decision planned for second half of 2018 (in time for annual meeting)
- ➔ Full cost still to be assessed!!!
- ➔ Beneficial also for ALARA
- ➔ Impact on integration

New Hardware Option!!!

HL-LHC Hardware Options

H3) Considered for additional diagnostics:

WP13

-**Full implementation of the Beam Gas Vertex Detector**

Real-tin ... ccuracy

Still Valid and is now in the Baseline!!!

- ➔ Technical solution being demonstrated by 1st prototype installed in LHC
- ➔ Decision required in time for full implementation in LS3 (4 years) ➔ LS2
- ➔ Two prototypes are being developed for LHC (1.5MCHF)
- ➔ ~~Ca. 2MCHF for 2 system upgrade implementation~~
- ➔ No impact on integration

➔ Ca 0.75MCHF for full system implementation

HL-LHC Hardware Options

H3) Considered for additional diagnostics:

WP13

-**<u>Second Undulator per beam for Synchrotron Light monitor:</u>**

Bas … l diagnostics
… energy for
additional diagnostics (Streak camera and Coronograph)

→ second undulator

→ **<u>Halo monitor operation during full cycle NOT possible without it!!!</u>**

→ Technical design based on existing undulators

→ Decision required in time for implementation in LS3 (4 years) → LS2

→ No R&D cost implied

→ Ca. 1.1MCHF per undulator → 2.2MCHF for both beams

→ Ir…

Still Valid!!!

→ Currently evaluating also option of warm / fixed field undulator
→ Could also be installed at a later stage

HL-LHC Hardware Options

H3) Considered for additional diagnostics:

-**Inclinometer for vibration measurements** (e.g. for civil engineering construction during LHC operation and earth quakes during HL-LHC operation)
➔ interesting for HL-LHC civil engineering work

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➔ k) ➔ 2017
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➔

Only pursued as a study
Without full implementation!!!

Collaboration with Dubna

HL-LHC Hardware Options

H4) Considered as mitigation against unforeseen performance limitations or measures for parameter variations and re-optimization in the HL-LHC:

WP4

-**Wide Band Feedback System** for stabilizing intra-bunch instabilities driven by the e-cloud (potentially enhancing the possibility of beam scrubbing) or impedance driven instabilities

No longer pursued!!!

➔ … r SPS

➔ … Sept.'16)

➔ Ca. 3.7M$ already invested for studies and development (LARP)

➔ Assume ca. 7M$ for implementation in HL-LHC

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Jo… system

➔ But would like designs for the pickup and kicker to estimate the impedance impact!

➔ Impact on integration need to be clarified (upgrade / replacement of existing system & additional equipment)

HL-LHC Hardware Options

H4) Considered as mitigation against unforeseen performance limitations or measures for parameter variations and re-optimization in the HL-LHC:

WP4

➔ **Eliminated 800MHz @ Chamonix 2017**

-**Addit**

ating)

b) 800 MHz (Landau damping, full DT)

➔ Technical solution developed by CERN

➔ Decision required end of RunII (in time production ➔ Chamonix 2016)

➔ Studies and development done within R&D of RF group and WP4

s

➔Not yet strong evidence of need for 200MHz

➔In-time production for Run4 unlikely

➔No longer supported as option for LS3

em

HiLumi HL-LHC PROJECT

HL-LHC Hardware Options

H4) Considered as mitigation against unforeseen performance limit… re-optin…

WP13…

-**Long**…

a)…

…pected.

… LS2.

Decision required by end of RunII (budget integration)

… (RunII)

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…served

for 2nd CC system?

Installed test infrastructure [wire in collimator] in the LHC for MD tests!

Very encouraging results in MDs!
➔ Wire in Collimators [or bare wires] could be an interesting option as mitigation in case of CC failure

➔ Compensator based on electron beam no longer pursued!

HL-LHC Hardware Options

H4) Considered as mitigation against unforeseen performance limitations or measures for parameter variations and re-optimization in the HL-LHC:

WP5

Mod
Mag

No longer pursued!!!

-**Additional Dispersion Suppressor collimators:**
Second set in IR7 (2); up to 8 (2 / side / beam) in IR1 and IR5,

- ➔ Technical solution developed by CERN
- ➔ Decision required after LS2 (Run3 + production of 11T dipole magnets)
- ➔ no extra budget required for studies and development (already baseline)
- ➔ Assume ca 7MCHF per unit ➔ 28MCHF for IR7
- ➔ Integration in beam line straight forward as already done in IR7 but infrastructure integration still needs to be finalized (PC trim, QPS)

HL-LHC Hardware Options

H4) Considered as mitigation against unforeseen performance limitations or measures for parameter variations and re-optim

No longer actively pursued

WP5

-**Low impedance collimators** Up to 8 secondary collimators in IR3

- ➔ Technical solution already developed by CERN
- ➔ Decision required by start LS3 (production of collimators)
- ➔ no extra budget required for studies and development (already baseline)
- ➔ Would allow to further tighten the collimator hierarchy for radiation sharing between IR3 and IR7
- ➔ Assume ca 4.3MCHF for implementation (rely on consolidation for this)
- ➔ Integration: Replacement of existing equipment in LHC

HL-LHC Hardware Options

H4) Considered as mitigation against unforeseen performance limitations or measures for parameter variations and re-optimization in the HL-LHC:

WP5

-**New tertiary collimators in IR2 and IR8** ➔ Up to 8

➔ ...s baseline)

➔

➔ ...y baseline)

➔

➔ ...nt in LHC

No longer Pursued by HL-LHC

Will be covered by CONS

Proposed to Russia as in-kind contribution

HL-LHC Hardware Options

H4) Considered as mitigation against unforeseen performance limitations or measures for parameter variations and re-optimization in the HL-LHC:

New Option!!!

WP6b

-**<u>Higher precision Current Control for Power Converters for the S12, S45, S56, and S81main dipole circuits</u>**

a) Mitigation against increased tune fluctuation due to ATS optics
b) New current controller electronics for PC

➔ Technical solution can be ready for LS3
➔ Might help in improving the tune and β^* control with ATS optics
➔ Ca. 0.6 MCHF for full upgrade
➔ Integration should NOT be affected

HL-LHC Hardware Options

H5) Considered as measures for additional performance upgrades:

WP4

-Installation of the **<u>second half of Crab Cavities</u>**

➔ full anti-crabbing and the possibility of Crab Kissing scheme for a minimization of the pileup density inside the detectors and possibility of changing the crossing angle plane in IR1 and IR5 [peak radiation dose].

➔

➔

No longer pursued!!!

➔ No additional studies and development required;
Ca. 2MCHF for preparation of infrastructure included in HL-LHC

➔ Assume ca. 23.6MCHF for implementation (16 cavities including power and overhead for relaunching production)

➔ Integration assumed for IR1 and IR5 ➔ space reservation and infrastructure preparation ✔ (LRBB)

HL-LHC Hardware Options

H5) Considered as measures for additional performance upgrades:

-**Crystal collimation** for enhanced cleaning efficiency (Pb ion beam operation!)

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Still a Valid Option for Pb Operation

Active support from UA9 collaboration and

Proposed to Russia as in-kind contribution

HL-LHC Hardware Options

H5) Considered as measures for additional performance upgrades:

-**MQ4 MQYY** large aperture (90mm) insertion quadrupole:

➔ Would allow smaller β* values for flat beam option.

No longer pursued!!!

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➔ … ead time)

[1 year tender, 1 year preparation and tooling, 2 years production]

➔ 4.5 (3.1)MCHF assigned for studies and development (already spent)

➔ Ca 8.3MCHF for implementation (saving from Q4 and correctors)

➔ Integration already foreseen in HL-LHC planning

HL-LHC Hardware Options

H5) Considered as measures for additional performance upgrades:

-**RF Quadrupole** for generation of additional Landau damping

No longer pursued!!!

ties;

installation not before LS4

- ➔ No HL-LHC funds assigned yet
- ➔ No cost estimate existing yet for implementation
- ➔ Not studies for integration yet

HL-LHC Hardware Options

H5) Considered as measures for additional performance upgrades:

-**Stochastic cooling** (a la RHIC) for Pb ion beam operation

➔

➔ **No longer pursued!!!** LS2)

already

➔ No HL-LHC funds assigned for studies

➔ No cost estimate existing yet

➔ Integration challenging

HL-LHC Options: Parameters, Configurations

P1) Considered for machine protection and risk mitigation measures:

-Operation with **crossing angle plane exchange** between IR1 and IR5
➔ reduction of the peak radiation in certain hotspots of the triplet

IR5
lf and
4 orbit corrector magnets next to Q4

No longer pursued!!!

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plet

Assumed as a Valid Operation Option

➔ no hardware implications

HL-LHC Options: Parameters, Configurations

P4) Considered as mitigation against unforeseen performance limitations or measures for parameter variations and re-optimization in the HL-LHC:

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Assumed as a Valid Operation Option

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Assumed as a Valid Operation Option

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No longer pursued!!!

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Only pursued with 200MHz RF System?

2018

HL-LHC Options: Parameters, Configurations

P5) Additional performance improvement:

Assumed as a Valid Operation Option

-**BCMS filling scheme** ➔ smaller than nominal emittances in case

ers

Assumed as a Valid Operation Option

HL-LHC Hardware Options

Summary

8 Hardware Options still maintained

➔ 2 actively being integrated into baseline

5 Hardware Options added

14 Hardware Options no longer pursued

5 Operation Options still maintained

3 Operation Options no longer pursued