Status of Linac4 Construction at CERN

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1. Motivations
2. Civil engineering
3. Status of machine components
4. Linac4 Virtual Tour
The LHC Luminosity Upgrade

<table>
<thead>
<tr>
<th></th>
<th>Luminosity (cm(^{-2})s(^{-1}))</th>
<th>Beam intensity @ injection (*)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present (August 2010)</td>
<td>10(^{31})</td>
<td></td>
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<tr>
<td>Nominal</td>
<td>10(^{34})</td>
<td>1.1 x 10(^{11})</td>
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<tr>
<td>Upgraded</td>
<td>~5 x 10(^{34})</td>
<td>~2.4 x 10(^{11})</td>
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</tbody>
</table>

(* protons per bunch, in 3 \(\mu\)m emittance

At the moment, the injectors can provide only the intensity required for the nominal luminosity (10\(^{34}\))

↓

Upgrade program to reach ~5 x 10\(^{34}\), to be completed by 2020

foreseen in near future

requires upgrade of both LHC and injectors, to be achieved by 2020
Three bottlenecks identified for higher intensity from the LHC injectors:

1. Space charge tune shift at PSB injection (50 MeV).
2. Space charge tune shift at PS injection (1.4 GeV).
3. Electron cloud and other instabilities in SPS.

Low injection energy into the PSB is the first and most important bottleneck → Decision (2007) to build a new linac (Linac4) to increase from 50 to 160 MeV (no space for energy upgrade of Linac2).

Additional steps: a) upgrade of PSB final energy to 2 GeV; b) upgrade (coating, new RF) of SPS.

Reduced program w.r.t. SPL & PS2 construction, but less expensive and achievable in a shorter time.
Main motivations (summary):

1. Higher intensity in PSB for the LHC upgrade.
3. Implement techniques for flexible operation with reduced losses (chopping, H- injection).
4. Increase intensity for non-LHC users.
5. Prepare for a possible high-intensity upgrade (neutrino facility).

- **Energy of 160 MeV** → factor 2 in $\beta\gamma^2$ with respect to Linac2 → double intensity in PSB with same tune shift ($\Delta Q \sim N/\beta\gamma^2$).
- Use LEP RF frequency of $352$ MHz → recuperate some klystrons and RF equipment.
- Repetition frequency $2$ Hz (1.1 Hz present PSB limit), upgradable to 50 Hz with new power supplies and additional cooling installed.
- Beam current $40$ mA in $400$ ms: >2 present PSB maximum.
Linac4 description

• Conventional (normal-conducting) layout:
  1. Pre-injector (source, magnetic LEBT, 3 MeV RFQ, chopper line)
  2. Three types of accelerating structures, all at 352 MHz.
  3. Beam dump at linac end, switching magnet towards transfer line – PSB.
  4. Beam measurements at linac end and at PSB entrance.

<table>
<thead>
<tr>
<th>Energy [MeV]</th>
<th>Length [m]</th>
<th>RF power [MW]</th>
<th>Focusing</th>
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<tbody>
<tr>
<td>RFQ</td>
<td>0.045 – 3</td>
<td>3</td>
<td>0.6 RF focusing</td>
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<tr>
<td>DTL</td>
<td>3 – 50</td>
<td>19</td>
<td>5 112 perm. quads</td>
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<tr>
<td>CCDTL</td>
<td>50 – 102</td>
<td>25</td>
<td>7 21 EM quads</td>
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<tr>
<td>PIMS</td>
<td>102 – 160</td>
<td>22</td>
<td>6 12 EM quads</td>
</tr>
</tbody>
</table>
- Overall floor surface of Linac4 installations = 3’305 m² (over 4 levels)
Status of building construction

Status end of August 2010
Linac4 – Equipment building

Status Friday September 10th

Delivery foreseen 15th October 2010 (2 year construction time)
# Linac4 – schedule

<table>
<thead>
<tr>
<th>Task Name</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tbody>
<tr>
<td><strong>Linac systems</strong></td>
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<td>Source and LEBT construction, test</td>
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<td>Test stand operation (3 MeV)</td>
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## 2011: Infrastructure installation

## 2012/13: Cabling, accelerator installation

## 2013/14: Commissioning

- Front end (3 MeV)
- DTL tank1 (10 MeV)
- DTL t2/t3 (50 MeV)
- CCDTL (100 MeV)
- PIMS (160 MeV)

## 2014: Reliability run

## From 2015: Linac4 ready for connection to PSB
Linac4 – Low energy

- Ion source (RF volume, Cs free) assembled, under test.
- Magnetic LEBT ready.
- RFQ being built at CERN, to be delivered in early 2011.
- 1st RFQ module successfully brazed in May 2010.
- Chopping line built and tested (w/o beam).
- LEP klystron (+ modulator) installed, tested in pulsed op.
Linac4 – Drift Tube Linac

- 3-50 MeV, 3 tanks.
- Design Completed and tested on a prototype (1m, 12 drift tubes) at full RF power (10% duty cycle).
- Main features: DTs rigidly mounted on a girder, with special mounting mechanism, only metallic joints and no adjustment. Tank in Cu-plated Stainless steel. PMQs in vacuum.
- Construction started (DTs with ESS-Bilbao).
- Tank1 ready for test in 2011.
Linac4 – Cell-coupled DTL

- 50-100 MeV, 7 modules of 3 tanks each.
- Design completed and tested on a prototype (2 tanks, 4 drift tubes) at full RF power (10% duty cycle).
- Main features: Focusing by PMQs (2/3) and EMQs (1/3) external to DTs. Tanks with 2 DTs connected by coupling cells.
- Construction started at VNIITF (Snezinsk) and BINP (Novosibirsk) in January 2010.
- Module#1 to be delivered to CERN for testing in January 2011.
Linac4 – Pi-Mode Structure

- 100-160 MeV, 12 tanks of 7 cells each.
- Design completed, tank #1 completed and tuned, to be tested (end 2010) at full RF power.
- Main features: Focusing by external EMQs, tanks of 7 cells in pi-mode. Full-Cu elements, EB-welded.
- Construction will start at beginning 2011 in collaboration with Soltan Institute (Warsaw) and FZ Julich.
Construction of the Linac4 accelerating structure – an European enterprise (and beyond…)

- Drift Tube Linac (DTL): prototype from INFN/LNL (Italy), drift tubes from ESS-Bilbao (Spain), tanks and assembly at CERN
- Cell-Coupled DTL: tanks from VNIIEF (Snezinsk), drift tubes and assembling from BINP (Novosibirsk)
- PI-Mode Structure (PIMS): tanks from Soltan Institute (Poland), EB welding from FZ Juelich (Germany), assembly and final EB welding at CERN.
Progress being made on the main Linac4 components:

- RF system: layout defined (mixing LEP and new klystrons), 8 new klystrons (2.8 MW, pulsed) ordered, other components being procured.
- LLRF defined, prototype modules being built.
- Modulator prototype model1 (LEP klystrons) tested, model2 (new klystrons) being assembled.
- Magnets being designed and procured.
- Design of dumps, measurement lines, transfer line completed.
- Beam diagnostics defined (based on LHC and existing linac components), starting procurement.
Conclusions

- Linac4, to be completed by the end of 2014, will pave the way to the increase of the LHC luminosity.

- At the same time, it will replace Linac2 with a more modern and powerful machine, with reliability as a prime objective.

- Civil engineering is now completed, as well as the 3D full integration of the new facility. Construction of the main components has started.

- New designs and technologies have been developed for the main accelerating structures, aiming at efficiency, reliability, maintainability and low cost.

- Operation at high duty cycle for other applications is possible.