STATUS AND EXPERIENCE WITH THE ALIGNMENT OF LINAC$_4$

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Introduction

• The goal of the Linac4 is to build a **160 MeV H− linear accelerator** replacing Linac2 [50 MeV, commissioned in 1978] as injector to the PS Booster (PSB).

• LINAC4 is part of the **LIU program**: consolidation and upgrade of LHC injectors,

• The new linac is expected to increase the beam brightness out of the PSB by a factor of 2 and increase the LHC luminosity.

• LINAC4 connection to the PS booster will take place during the Long Shutdown 2 (LS2) in 2019-2020 or earlier if any major failure of the LINAC2
LINAC 4
L4 & L4T ARCHITECTURE

PS Booster

Vertical bending magnet

Horizontal bending magnet

DUMP

PIMS

CCDTL

DTL

Corso le 28.05.2012

~76m
LINAC 4

LINAC 4: CCDTL CAVITIES

LINAC 4 & LINAC 4T
# Alignment Precision

<table>
<thead>
<tr>
<th>L4 Element</th>
<th>Alignment Precision</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chopper line quadrupoles, bumpers, inline dump and chopper plates.</td>
<td>X,Y (Radial) ±0.1 mm, Z (Long.) ±1 mrad</td>
<td>2 mrad (probably even more) Chopper plates are very critical the rest is more forgiving.</td>
</tr>
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<td>Linac quadrupoles (DTL, CCDTL, PIMS)</td>
<td>±0.1 mm X,Y, ±1 mrad Z</td>
<td>2 mrad (probably even more) Critical for beam quality. We have 1 corrector / 40</td>
</tr>
<tr>
<td>Transfer lines quadrupoles</td>
<td>±0.2 mm X,Y, ±2 mrad Z</td>
<td>2 mrad (probably even more)</td>
</tr>
<tr>
<td>Steeres and dipoles</td>
<td>±0.5 mm X,Y, ±2 mrad Z</td>
<td>2 mrad (probably even more)</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>±0.5 mm X,Y, Not relevant Z &amp; Roll</td>
<td>Not relevant For any passive element it is important to know the position but not necessarily to align, provided of course it doesn't influence the acceptance of the lines.</td>
</tr>
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<tr>
<th>Position Determination</th>
<th>X,Y (Radial) ±0.1 mm, Z (Long.) ±1 mrad, Roll ±2 mrad</th>
<th>Pitch and yaw ±3-5 degrees</th>
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SURVEY NETWORK

CERN survey fiducials used for 3D, direct levelling and offset measurements (pillars and components)
• All the 3D coordinates are known in the CERN Coordinate System (CCS)
• Measurements were linked to others beam components of PS, PS BOOSTER and LINAC2
• Periodical controls:
  • maintain the accuracy of the network,
  • monitor the possible deformations of the floor of the tunnel.
BUILDING STABILIZATION

• Linac4 tunnel “cut and cover” excavation with civil engineering works from 2008 to the end of 2010.
• Linear vertical displacement towards the top direction following the L4 tunnel up to +1.5 mm / year
• RFQ used as the main reference for the vertical position at +3.4 mm (2015)
FIDUCIALISATION

• All the components that need to be aligned on the L4 beam have been measured before installation in surface using a laser tracker for metrology and/or fiducialisation operations,

• Laser tracker measurements are needed in order to determine the position of the new “fiducials” with respect to the roll surface and beam axis of the component
ALIGNMENT PROCESS

• Marking out of the beam line on the floor, beam components (“entry” and “exit” points), the support and jack positions,
• Pre-alignment of the jacks before sealing (+/- 3 mm),
• Alignment of the head of jack after sealing ( +/- 1 mm)

All the elements were installed in the tunnel without any more survey support.
ALIGNMENT PROCESS

• The components were aligned before the vacuum connection.

• The initial positioning of the elements has been carried out from the geodetic reference network (GGPSO, pillars) using an AT40x (angles and distances), direct levelling and offsets measurements.
ALIGNMENT PROCESS

• A final smoothing to achieve the desired relative alignment of the components along the L4 and L4T line has been carried out before each beam commission steps at 12MeV, 50 MeV, 100 MeV and 160 MeV by using AT40x, wire offset measurements and direct levelling

• Vacuum and mechanical constraints
VERTIVAL SMOOTHING (160 MeV)

Floor movement towards top direction (+ 0.8 mm since 2015)

+3.4 mm : vertical reference ("RFQ", 2015)

+- 0.2mm
RADIAL SMOOTHING (160 MeV)

DR - Radial Offset [mm] (beam points)

\[ y = -8E-07x^3 + 3E-05x^2 + 0.0168x - 0.6572 \]

+/- 0.2mm
OUTLOOK

• The **vertical and radial smoothing** before the **160 MeV commissioning** is finished,

• The Linac4 starts a new phase during which its performances and reliability will be improved to meet the LIU requirements.

• The **connection is scheduled during the LS2 in 2019** : Linac4 will become the new injector for the CERN proton accelerator complex.

• Since 2008, more than 6 topographical colleagues have been involved in the L4 project for the geodetic studies, database management, scanning acquisition and computing, metrology and alignment operations, ....... **Thank you!**
THANKS FOR YOUR ATTENTION
LINAC 4 building

- Linac4 tunnel
- Low-energy injector
- Linac4 transfer line
- Vertical step (2.5 m) for compatibility with SPL
FEEDBACK (1) : L4T SUPPORTS
FEEDBACK (2) : RFQ