RF structures for Linac4

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Since last week Linac4 is an approved project!
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Now it is time to deliver!
Linac4 will enable the CERN proton injector chain to reach the “ultimate” LHC luminosity,
Linac4 will inject at 160 MeV into the PS Booster (PSB) ➔ increase $\beta Y^2$ by a factor of 2 ➔ double the number of particles per cycle (TUPAN109, TUPAN093)
as PSB injector Linac4 will operate at low duty cycle (<0.1%),
Linac4 is also designed to become the front end of the SPL, a multi-GeV, multi-MW H⁻ linac, which will operate at a duty cycle of ≈5%,
while the accelerating structures and klystrons are designed for 5% duty cycle the Linac4 infrastructure (klystron modulators, cooling water, electrical station, etc) is only designed for 0.1% and will then be upgraded.
Linac4 machine layout

Linac4 as PSB injector (0.1% duty cycle)

\[ \begin{align*}
\text{H}^+ \text{source} & \quad \text{RFQ} & \quad \text{chopper} & \quad \text{DTL} & \quad \text{CCDTL} & \quad \text{PIMS} \\
3 \text{ MeV} & \quad 50 \text{ MeV} & \quad 102 \text{ MeV} & \quad 160 \text{ MeV}
\end{align*} \]

352.2 MHz
Linac4 machine layout

Linac4 as PSB injector (0.1% duty cycle)

Linac4 as SPL injector (5% duty cycle)
Site layout SPL
Linac4 layout

klystron hall (above ground)

accelerating tunnel

H⁻ source & RFQ
Accelerating structures

Final round of optimisations is now finished → design frozen!

All structures have been re-assessed and the overall approach was revised.

Latest optimisation:
- decrease safety margin on LEP klystron operation (0.8 MW → 1.0 MW, max. power: 1.3 MW, CW), maintaining 80% of Superfish $ZT^2$,
- shift in transition energies:
  - DTL/CCDTL: 40 to 50 MeV,
  - CCDTL: 90 to 102 MeV,
- exchanged the SCL (90-160 MeV) with a π-mode structure (102 - 160 MeV)
- one single frequency (352 MHz).
Shunt impedance

DTL with PMQs:
\( \rightarrow \text{high } ZT^2 \text{ but not flexible,} \)
Shunt impedance

DTL with PMQs:
- high $ZT^2$ but not flexible,

CCDTL with ext. EMQs:
- high $ZT^2$ and flexible,
- cannot be used < 40 MeV,
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90/100 MeV to 160 MeV:

SCL: $\pi/2$ mode structure at 704 MHz: 4 modules with 5 coupled cavities (21 cells each!): 468 cells!
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90/100 MeV to 160 MeV:

**SCL**: $\pi/2$ mode structure at 704 MHz: 4 modules with 5 coupled cavities (21 cells each!): 468 cells!

**PIMS**: $\pi$ mode structure at 352 MHz: 12 cavities with 7 cells each: 84 cells (+3 CCDTL tanks)
RFQ:
- nominal solution: IPHI RFQ (CW, 100 mA, $P_{av}=300$ kW), under development at CEA,
- a scaled down version ($P_{av}=10$ kW) is under study at CERN,
- 3 m instead of 6 m, simplified cooling, simplified construction,
3 tanks, 3 - 50 MeV, ITEP, VNIIIEF, Russia: PMQs, drift tubes, revised hot prototype under development at CERN, cold model under construction (KASCT, Saudi Arabia).
Drift tube prototype (VNIIEF)

Evacuation channel

Bellow

Cooling channel

Permanent magnet

Laser weldings
PMQ ITEP prototype

PMQ made of SmCo5, constructed to specifications, measured at CERN
Accelerating structures: CCDTL

CCDTL prototyping:
- under development at CERN since ~5 years,
- CERN hot model with 2 half cavities and one coupling cell was high-power tested,
- BINP/VNIITF hot model with 2 full cavities and 1 coupling cell is high-power tested this week,
CCDTL module: 3 cavities
CERN prototype: 2 half-cavities
BINP/VNIITF prototype: 2 full cavities

- field flatness error < 1%,
- surface roughness: 1.3 μm,
- 90% of theoretical Q value (36200),
- vacuum quality depends on Helicoflex joints,
Comparison of the field profile measurements done at CERN and at BINP (green)
**PI-mode structure (PIMS):**
- 7-cell pi-mode cavities at 352 MHz,
- scaled (β) version of the LEP NC accelerating structure,
- in operation at CERN until 2000,
- cold and hot prototype under development.
Accelerating structures: PIMS

7-cell structure

different coupling slot geometries
## Structure parameters

<table>
<thead>
<tr>
<th></th>
<th>DTL</th>
<th>CCDTL</th>
<th>PIMS</th>
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<tbody>
<tr>
<td>output energy [MeV]</td>
<td>50</td>
<td>102</td>
<td>160</td>
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<tr>
<td>cavities</td>
<td>3</td>
<td>7 x 3</td>
<td>12</td>
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<td>peak power [MW]</td>
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<td>movable tuners</td>
<td>8</td>
<td>9</td>
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<tr>
<td>length [m]</td>
<td>18.7</td>
<td>25</td>
<td>22</td>
</tr>
</tbody>
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![Diagram of structure parameters](image-url)
Linac4 is approved!
The final round of structure optimisations is completed.
Prototyping for all structures is in progress.
Civil engineering plans ready by August.
Next year we will start to dig!!