RF Design of a High-Frequency RFQ Linac for PIXE Analysis

H. W. Pommerenke$^{1,2}$, A. Bilton$^1$, A. Grudiev$^1$, A. M. Lombardi$^1$, S. Mathot$^1$, E. Montesinos$^1$, M. Timmins$^1$, M. Vretenar$^1$, U. van Rienen$^2$
The PIXE RFQ

**PIXE** = particle/proton-induced X-ray emission
- low energy ion beam excites X-ray in specimen atoms
- spectrum allows for non-destructive analysis of artefacts, cultural heritage (among others)

**PIXE RFQ**
- 750 MHz RFQ provides 2 MeV protons over only one meter
- goal: first transportable system for *in situ* ion beam analysis

![RFQ Diagram](image)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input energy</td>
<td>20 keV</td>
</tr>
<tr>
<td>Output energy</td>
<td>2 MeV</td>
</tr>
<tr>
<td>RF frequency</td>
<td>749.48 MHz</td>
</tr>
<tr>
<td>RFQ length</td>
<td>1072.938 mm</td>
</tr>
<tr>
<td>Vane voltage</td>
<td>35 kV</td>
</tr>
<tr>
<td>Min. aperture</td>
<td>0.7 mm</td>
</tr>
</tbody>
</table>
RF Design

- optimisation for 749.48 MHz and maximum Q factor
- end plates with bead pull holes and dipole stabilisation rods

- maximum surface electric field: 39.1 MV/m at module gap

- 16 copper slug tuners with conical tip
- 7 vacuum ports with crossbar
RF Design

- power loss can be calculated from decomposition into segments

\[ P_0 = \frac{\omega_0 V^2}{2} \sum_s \frac{1}{Q_{0,s}} \int_{\text{Seg. } s} C'(z) dz \]

without simulating full model

- one input power coupler (coaxial magnetic loop antenna) mounted on rotatable flange

<table>
<thead>
<tr>
<th>Loss factor</th>
<th>6000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacitance</td>
<td>125  pF/m</td>
</tr>
<tr>
<td>Stored energy</td>
<td>82   mJ</td>
</tr>
<tr>
<td>RF power loss</td>
<td>64.5 kW</td>
</tr>
<tr>
<td>Max. surface field</td>
<td>39.1 MV/m</td>
</tr>
</tbody>
</table>
Thermal Simulation

- RF power loss raises RFQ temperature, thermal expansion results in deformation and frequency shift
- study frequency shift in dependence of duty cycle and water cooling properties
1D Particle Tracking

- validate RF design by tracking particles through RF field
- so far: longitudinal tracking only
  - 0..2π start phases
  - 20 keV → 2 MeV
  - \( x = y = 0 \)

- Frequency shift due to RF heating acceptable for transmission
Conclusion

- RF design done for cavity, tuners, pumping ports, power coupler
- Thermal simulation conducted to obtain requirements on cooling circuit
- First tracking results: deformation due to RF heating acceptable
- Current state: machining, first brazing expected Oct 2018
Thank you!

www.cern.ch

This work has been sponsored by the Wolfgang Gentner Programme of the German Federal Ministry of Education and Research (grant no. 05E12CHA)


