RFQ3 beam dynamics design

Questions
Alessandra Lombardi
6/5/2021

Skip to slide 7 for update 15/7/2021
Skip to slide 13 for update 14/10/2021
Skip to slide 24 for update 4/11/2021
Some improvements that will try

• Smoother rms:
  • to ease the matching from the LEBT
  • to allow for more space between the last solenoid and the rfq

• Output rms:
  • to symmetrize the beam before exiting the RFQ
  • Entails readjustment of the MEBT

06/05/2021
Source

• Forget about the 80mA, let's fix 50mA peak current?

• Extraction energy: lower / higher: what is the acceptable range
Transverse acceptance

• Higher acceptance? Is this a good idea? We need to consider the next bottleneck in the linac/PSB transfer

• 95% transmission?
Maximum electric field on the vanetip

• This is an input to the beam dynamics design currently 33MV/m

• What shall we take?

• Constant along the vanes or concentrated in one point?

• Shall we avoid max efield in loss area? Is there a correlation?
Meeting 1 - 6/5/2021

• Summary:
  • Ok for 50 mA as limit
  • No particular feedback on input energy
  • No more than 35MV/m
RFQ3 beam dynamics design

Update and first draft
Alessandra Lombardi
15/7/2021

File in directory D:\352RFQreprise2021\designthecapturefirst
• Fixed parameters:
  • 35MV/m max field on vanetip
  • Current 60mA and emit=0.4 rms norm mm mrad
  • Energy from 35 to 55 kV
  • Rho/ro = 0.75 no room to further reduce Emax-what I quote in the next slides is already minimized

• Divide capture and acceleration-design capture choose together and then optimize acceleration that goes with it

• LINAC4 present RFQ:
  • Designed for 80mA, 0.25 mm mrad T=93%
  • Capture 45keV to 400KeV length =118cm + 182 cm acceleration
  • V=78KV, emax 35 MV/m
  • At the time of design we were not considering emittances bigger than 0.25 mm mrad, we had the acceptance =1.5 emittance that is 0.375 mm mrad

15/07/2021
Version 1- 35keV

• First design the capture (to about 0.4 MeV) then worry about acceleration to the final energy

• Start at 35keV to 400kV

<table>
<thead>
<tr>
<th>V (kV)</th>
<th>Emax (MV/m)</th>
<th>Min a // B</th>
<th>L (cm)</th>
<th>T (%) 60mA 0.4mmrad</th>
<th>T (%) 60mA 0.3 mm mard</th>
<th>Filename</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>75</td>
<td>1.9 // 6.11</td>
<td>76</td>
<td>84%</td>
<td>87%</td>
<td></td>
<td>RFQ1.in</td>
<td></td>
</tr>
<tr>
<td>75 //33MV/m</td>
<td>2.1 // 5.99</td>
<td>80</td>
<td>81%</td>
<td>85%</td>
<td></td>
<td>RFQ2.in</td>
<td>Parametric losses see phase ramps</td>
</tr>
<tr>
<td>70/29MV/m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Losses correspond to too fast phase ramp - smooth the phase from 30 to 40

15/07/2021
Version 2

• Increase the energy
• Start at 58keV
• Bunch and capture to 350keV

Higher long emittance but we have margin in the DTL
Version 3

• Stay at 45 kev
• Bunching to 350 keV

This is similar to the existing linac4 RFQ with a tradeoff between transverse acceptance and longitudinal emittance delivered to the DTL and a lower voltage.

<table>
<thead>
<tr>
<th>V</th>
<th>Emax</th>
<th>Min a // B</th>
<th>L</th>
<th>T 60mA 0.4mmrad</th>
<th>T 60 mA 0.3 mm mard</th>
<th>filename</th>
</tr>
</thead>
<tbody>
<tr>
<td>70//29</td>
<td>2.3 //5.7</td>
<td>171 cm</td>
<td>96%</td>
<td>97%</td>
<td>RFQ5.in</td>
<td></td>
</tr>
<tr>
<td>75//29??</td>
<td>// 5.1</td>
<td>120</td>
<td>88%</td>
<td>91.%</td>
<td>RFQ6.in</td>
<td></td>
</tr>
</tbody>
</table>
Next steps

• Accelerate to 3 MeV (forego exact length of 3 m for the moment)

• Track into and through the DTL

• Emittance measurement at the new source at 35 and 45 keV

• Track particles from measurements

• Check point with this group beginning September 2

• Switch to sinusoidal

• Track with higher than nominal voltage
RFQ3 beam dynamics design

Update
Alessandra Lombardi
14/10/2021
Bring to the final energy after efficient capture—continue what presented in July

• RFQ7.in
soft and safe but 5.5 m long (can be optimised but 5 m absolute minimum)

V=70kV
Emax= 29 MV/m
L=5.6 m
I =70mA
Emit=0.4 mm mrad

redo
Take another approach

• LINAC4 RFQ
  • 78 kV nominal Voltage / 35MV/m maximum field
  • Bfactor=5.585 , min aperture = 1.77
  • Transmission
    • 93% 70mA emit=0.25 mm mrad
    • 80% 70mA emit=0.5 mm mrad

• Higher voltage : V=85 kV but keep Emax=35MV/m
• Lets aim at increasing min aperture but keep B factor
• Lets design for I=70mA and emit=0.5 pi mm mrad aiming at T>90%
Iteration 1 – keep length and max field

<table>
<thead>
<tr>
<th>V (kV)</th>
<th>E_max</th>
<th>L cm</th>
<th>B</th>
<th>Min a (mm)</th>
<th>T (70mA , E=0.25)</th>
<th>T (70mA , E=0.5)</th>
<th>Filename</th>
</tr>
</thead>
<tbody>
<tr>
<td>81</td>
<td>34</td>
<td>300</td>
<td></td>
<td>1.85</td>
<td>94%</td>
<td>83%</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>35</td>
<td>300</td>
<td>5.4</td>
<td>1.92</td>
<td>95%</td>
<td>85%</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>35</td>
<td>300</td>
<td>5.7</td>
<td>1.94</td>
<td></td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>35</td>
<td>300</td>
<td>5.8</td>
<td>1.89</td>
<td></td>
<td>87%</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>35</td>
<td>300</td>
<td>5.9</td>
<td>1.87</td>
<td></td>
<td>88.5%</td>
<td></td>
</tr>
<tr>
<td>85</td>
<td>35</td>
<td>300</td>
<td>6.0</td>
<td>1.86</td>
<td>95.4%</td>
<td>89%</td>
<td>RFQ9.IN</td>
</tr>
</tbody>
</table>

Remnant losses are due to the fact that we keep the length and the modulation in the final part is too high.
Iteration 2 – reduce final modulation and allow length above 3 m

<table>
<thead>
<tr>
<th>B</th>
<th>Final m</th>
<th>L</th>
<th>T (70mA, E=0.25)</th>
<th>T (70mA, E=0.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2.1</td>
<td>301</td>
<td></td>
<td>90%</td>
</tr>
<tr>
<td>6</td>
<td>1.9</td>
<td>310</td>
<td></td>
<td>90.4%</td>
</tr>
<tr>
<td>6</td>
<td>1.82</td>
<td>325</td>
<td>96.7%</td>
<td>91.6%</td>
</tr>
<tr>
<td>6</td>
<td>1.72</td>
<td>342</td>
<td>96.9%</td>
<td>92.3%</td>
</tr>
<tr>
<td>6</td>
<td>1.72</td>
<td>343</td>
<td>96.9</td>
<td>93.6</td>
</tr>
</tbody>
</table>

We are left with 3% longitudinal losses and 3% transverse losses
Evolution from iteration 1 to iteration 2

Comparison RFQ9 and RFQ13

Emittance RMS mm mrad vs length in cm
Evolution from iteration 1 to iteration 2

Comparison rfq9 and rfq13
Transmitted current vs z (cm)
Details of the last iteration

- $R_o = 0.3306$ cm

- For $\rho/\rho_o = 0.75$, $\rho = 0.2479$ cm $E_{\max} = 34.25$ MV/m

- For $\rho/\rho_o = 0.85$, $\rho = 0.2810$ cm $E_{\max} = 35$ MV/m

LINAC4 $R_O = 0.3256$; $\rho = 0.2768$ cm
## Summary

<table>
<thead>
<tr>
<th></th>
<th>V (kV)</th>
<th>L (cm)</th>
<th>Emax (MV/m)</th>
<th>T (70mA, 0.5mm mrad)</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>LINAC4</td>
<td>78</td>
<td>300</td>
<td>35</td>
<td>80%</td>
<td></td>
</tr>
<tr>
<td>Redesign 1</td>
<td>70</td>
<td>550</td>
<td>29</td>
<td>94</td>
<td>+34%</td>
</tr>
<tr>
<td>(conservative field)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redesign 2</td>
<td>85</td>
<td>343</td>
<td>35</td>
<td>94</td>
<td>+20%</td>
</tr>
</tbody>
</table>

**Next steps:**
- concentrate on redesign 2 for further optimisation (1month)
- Start RF design by end of October (fix Ro, rho and length)
- try more radical approach (2 RFQs ....)
Fix parameters for RF design

R0=0.33 cm
Rho=0.28 cm
L=352 cm
V=85 kV

Questions:
One or 2 rf tanks?