radiabeam SYSTEMS

MOPO077

Design of the High Gradient Negative Harmonic Structure for Compact Ion Therapy Linac*

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Oral poster at LINAC' 18 Conference

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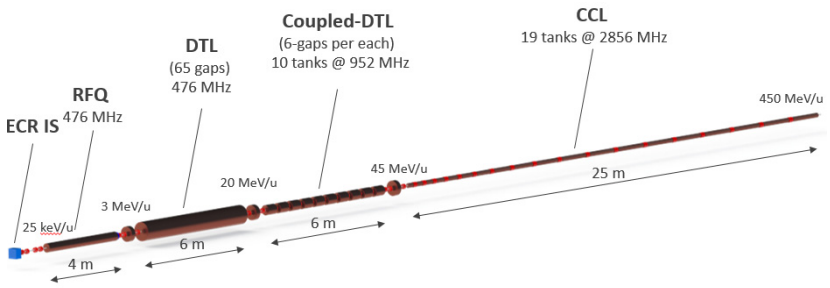
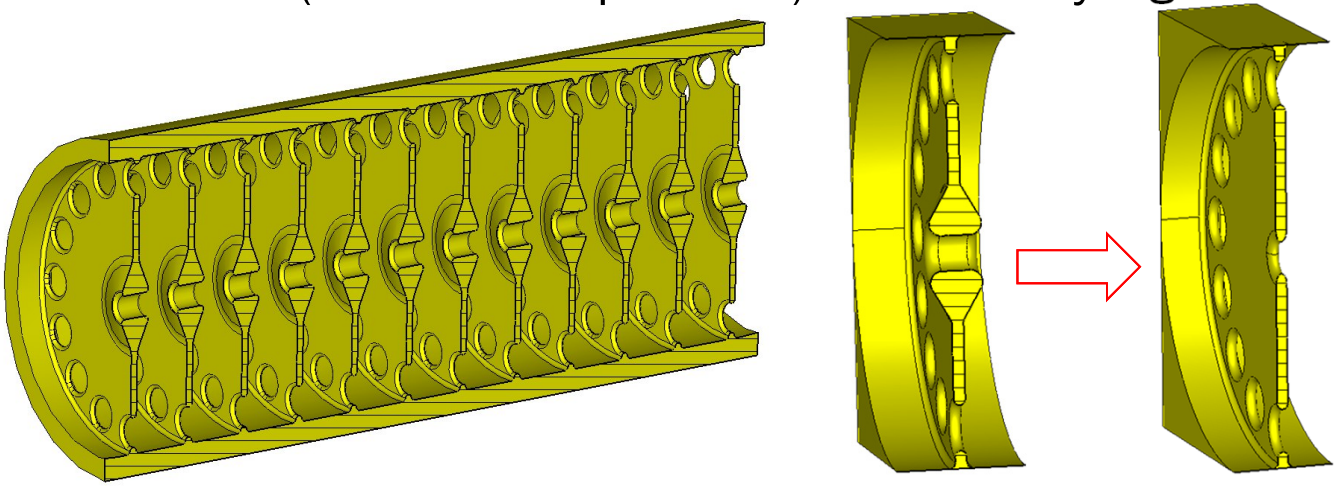
ACCIL: Hadron Therapy Linac

- An Advanced Compact Carbon high gradient Ion Linac (ACCIL) is being developed by collaboration of Argonne National Laboratory and RadiaBeam Systems



- 450 MeV/u ($^{12}C^{6+}$) and 250 MeV (p)
- 1 GV accelerating voltage in a 40m length
- 90% of energy gain in 60% of length!
- ~35 MV/m real-estate gradients and 50 MV/m accelerating gradients

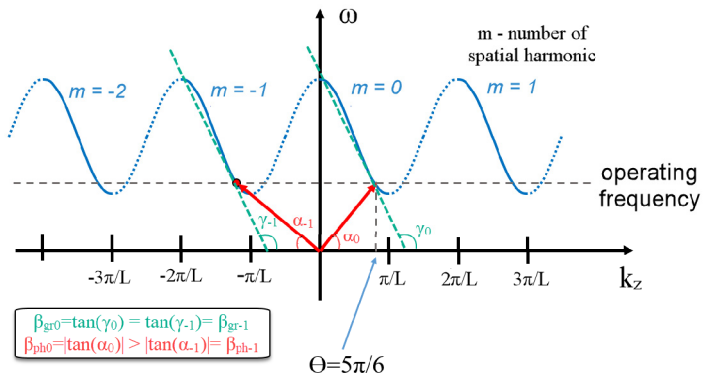
- High gradients structures must start from β=0.3
- Standard structures can't be adapted to such low velocities due to the lack of space for the noses (low shunt impedance) or extremely high fields (>250 MV/m)

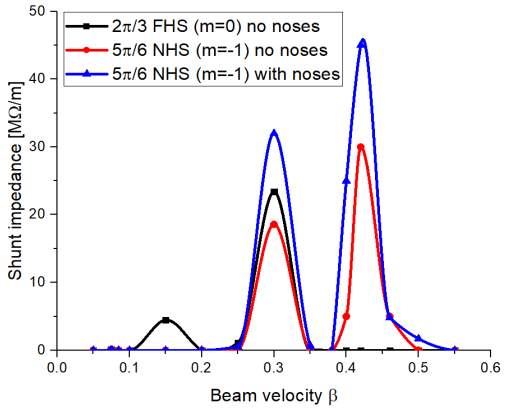


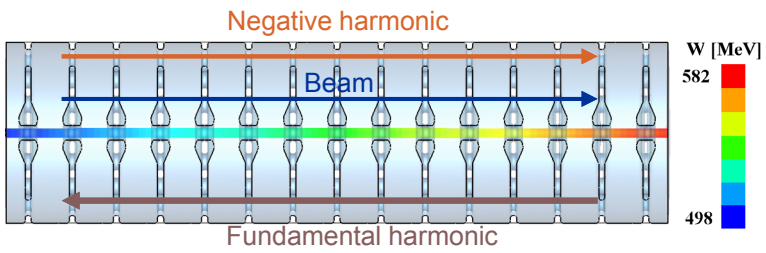
P. Ostroumov et al., "Compact Carbon Ion Linac", NAPAC'16, Chicago, IL, 2016, MOA4CO04

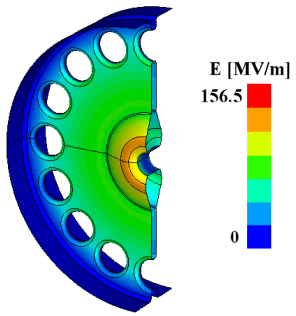
Negative Harmonic Structure

- For the same beta, the cell period is larger for higher harmonics
  - $D = \beta\lambda(1 + n\theta/2\pi)$
- Higher harmonic amplitudes are lower but the cells have larger distance between irises and thus allow noses
- Nose shape has elliptical features to reduce peak fields







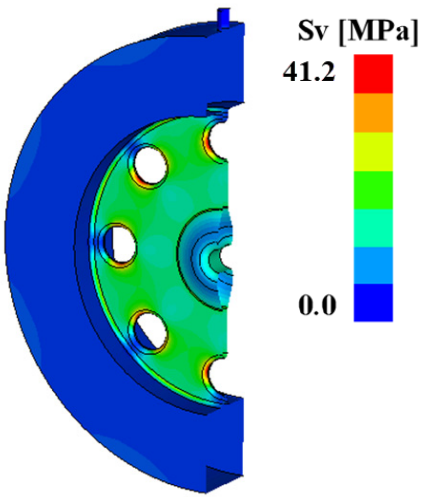


Harmonic	-1
Mode of operation	5π/6
Number of cells	15
Shunt impedance, MΩ/m	31.7
Q-factor	8065
Group velocity (out), % of c	0.26
Fundamental harmonic velocity β	0.42
Particle velocity β	0.3
Accelerating gradient, MV/m	50
Peak E-field, MV/m	156.5
Modified Poynting vector, MW/mm²	1.3
Pulsed heating @ 1μs, K	28.2
Temperature gradient, °C	15.6
Peak mechanical stresses, MPa	59.6

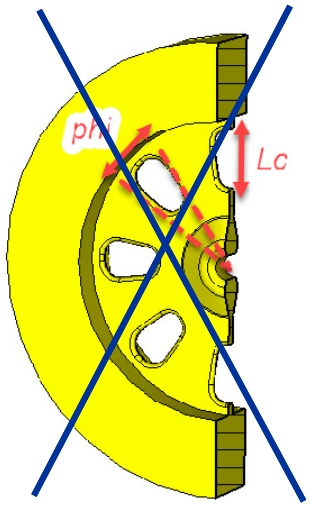
S. Kutsaev , "Compact High Gradient Ion Accelerating Structure", International Patent Application PCT/US2018/030980, 2018

Design Optimization

- Reduced number of holes from 16 to 8
- Increased iris thickness from 2.5 mm to 3.0 mm
- Reduced peak power requirement from 42 to 37 MW
  - Increased filling time from 350 ns to 500 ns
- Improved thermal conductivity
- Reduced peak stresses by 40%



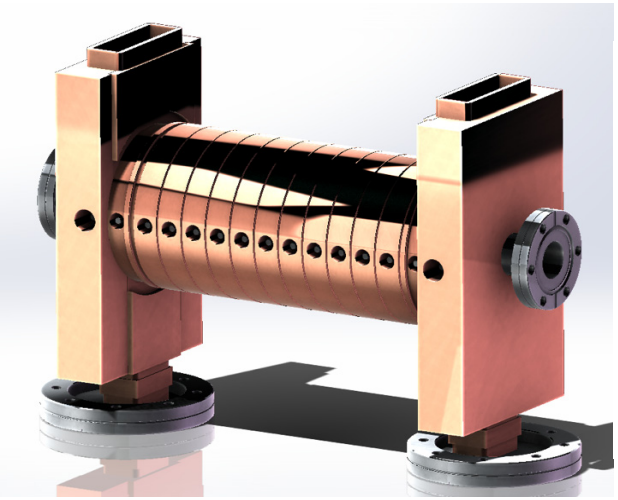
Number of holes	16	12	8	4
Peak E-field, MV/m	155.5	156.0	155.4	155.7
Pulsed heating, K	19.78	20.51	22.48	27.8
Shunt impedance, MΩ/m	33.08	33.64	34.35	35.34
Modified Poytning, MW/mm^2	1.08	1.17	1.38	1.90
Temperature gradient, K	14.8	13.34	12.37	11.06
Mechanical stresses, MPa	62.4	49.27	41.21	34.58

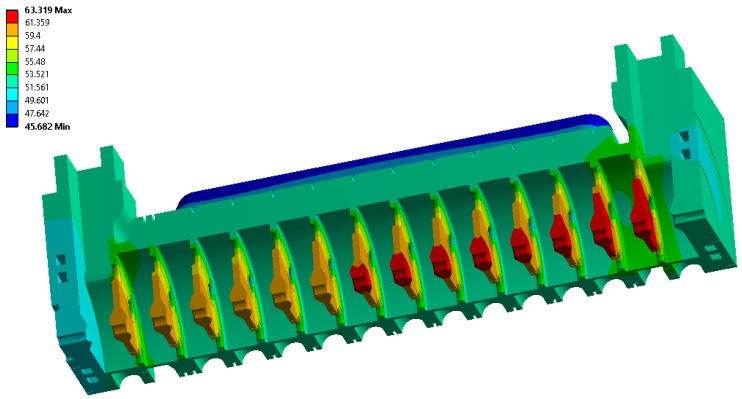


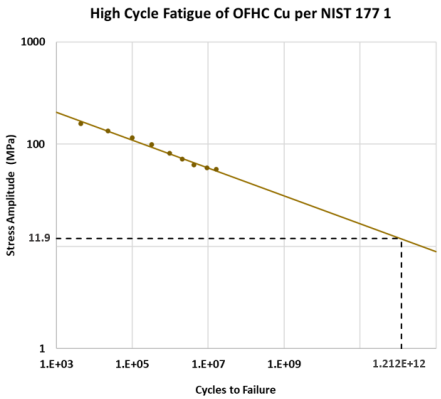
S.V. Kutsaev et al., “High-gradient low-β accelerating structure using the first negative spatial harmonic of the fundamental mode”, Phys. Rev. Accel. Beams 20, 120401 (2017).

Engineering Design

- Average RF power losses are 2.5 kW
- The structure is cooled with four cooling blocks
- Maximum average temperature rise is 18.2°C
- Maximum pulsed temperature rise is 19.8°C
- Pulsed von Mises stresses (45.8 MPa) are less than yield stresses of OFHC copper (54 MPa)
- Fatigue stress is 11.9 MPa
- Projected life is 10^{12} cycles (life expectance is 320 years)







Thank You!

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  - Alexander Plastun.

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