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DESIGN OF THE ROOM TEMPERATURE FRONT END FOR A MULTI-ION LINAC INJECTOR

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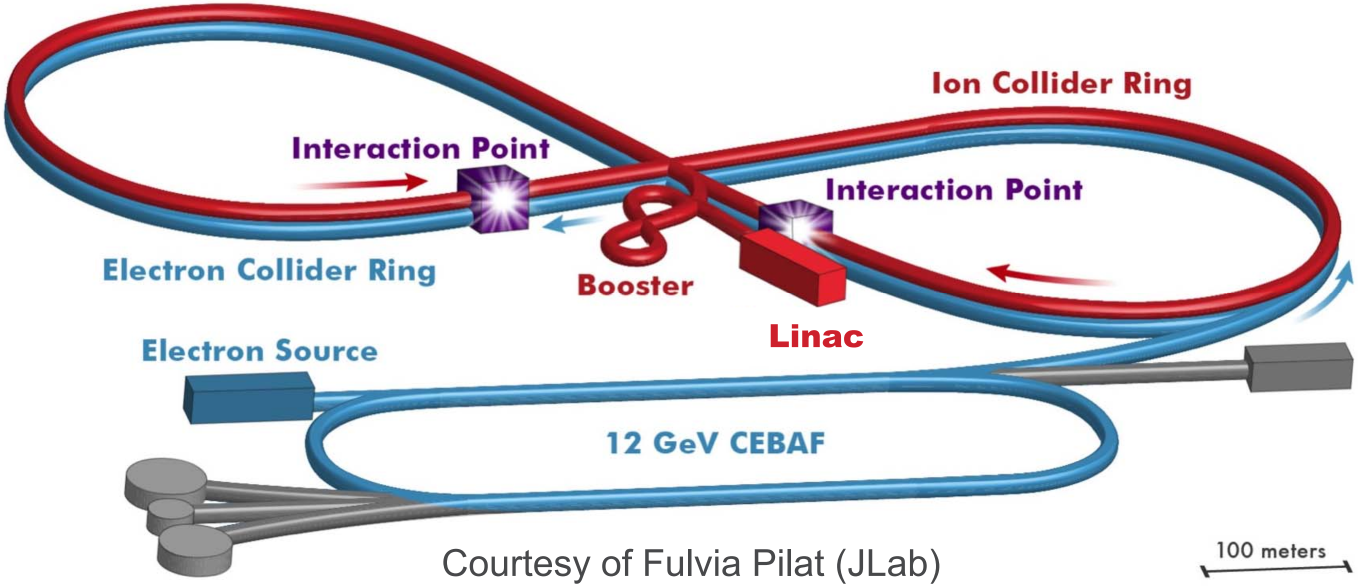
JLAB ELECTRON-ION COLLIDER*

- Polarized electrons + Polarized Light Ions
- Polarized electrons + Non-polarized Light to Heavy Ions



Courtesy of Fulvia Pilat (JLab)

* “Overview of Jefferson Lab EIC Design and R&D”, Vasiliy Morozov (JLab), MOB2IO02

BEAM PARAMETERS FROM ION SOURCES

Ions	A / Z	Source	Current, mA	Polarization	Emittance, π·mm·mrad
$^{1}H^{-}$	1	ABPIS / OPPIS	2	> 90%	1.0
$^{2}D^{-}$	2	ABPIS / OPPIS	2	> 90%	2.0
$^{3}He^{2+}$	1.5	EBIS	1	70%	< 1
$^{6}Li^{3+}$	2	ABPIS	0.1	70%	< 1
$^{208}Pb^{30+}$	~ 7	ECR	0.5	0	0.5

Atomic Beam Polarized Ion Source (ABPIS), Optically-Pumped Polarized Ion Source (OPPIS), Electron Beam Ion Source (EBIS), Electron Cyclotron Resonance ion source (ECR)

“MEIC Design Summary”, arXiv:1504.07961

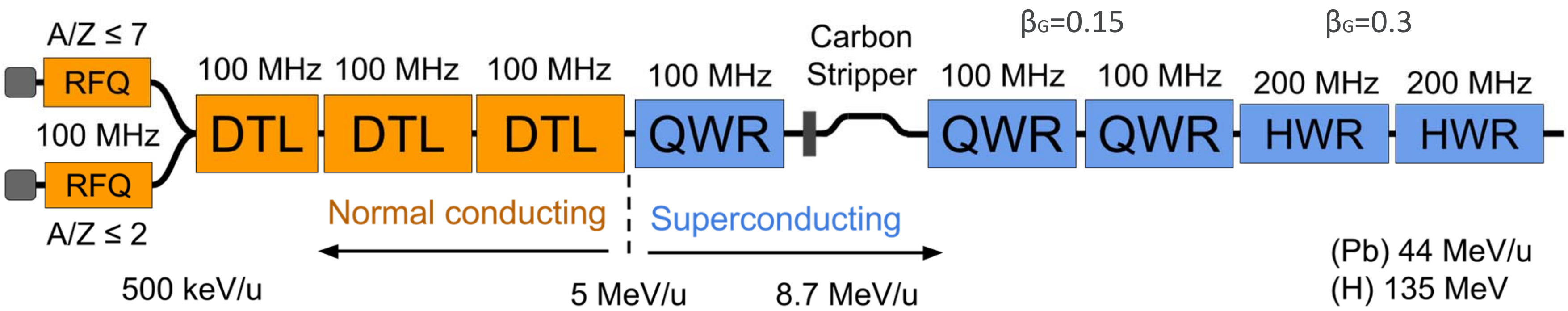
TWO RFQs

- **HEAVY IONS**
  - The heaviest ions (A/Z ~ 7) define the RFQ acceptance,
    Not enough for polarized light ions

- **LIGHT IONS**
  - Large emittance of polarized beams requires **larger acceptance**
  - **Minimum losses** for $^{2}D^{-}$ beam to avoid activation

→ **Two separate RFQs** are required: one for light (A/Z ≤ 2) ions,
another for heavy (A/Z ≤ 7) ions

MULTI-ION SRF-BASED INJECTOR



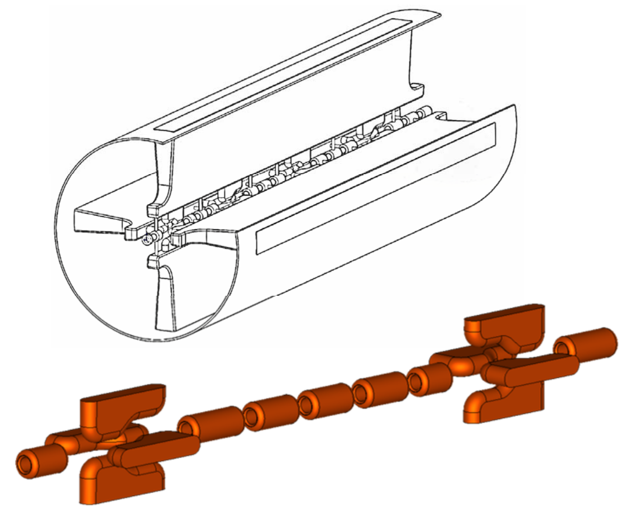
Repetition Rate: 10 Hz
Beam Pulse Width: heavy ions 0.25 ms
light ions 0.5 ms

P.N. Ostroumov et al., "Pulsed SC ion linac as injector to booster of electron ion collider", SRF'15
P.N. Ostroumov et al., "Design and Beam Dynamics Studies of a Multi-Ion Linac Injector for the JLEIC Ion Complex", HB'16

OPTIONS FOR THE DTL

BNL EBIS Injector 100 MHz IH Structure
(Courtesy of J. Alessi)

+ Highest efficiency
- Limited acceptance for polarized ions

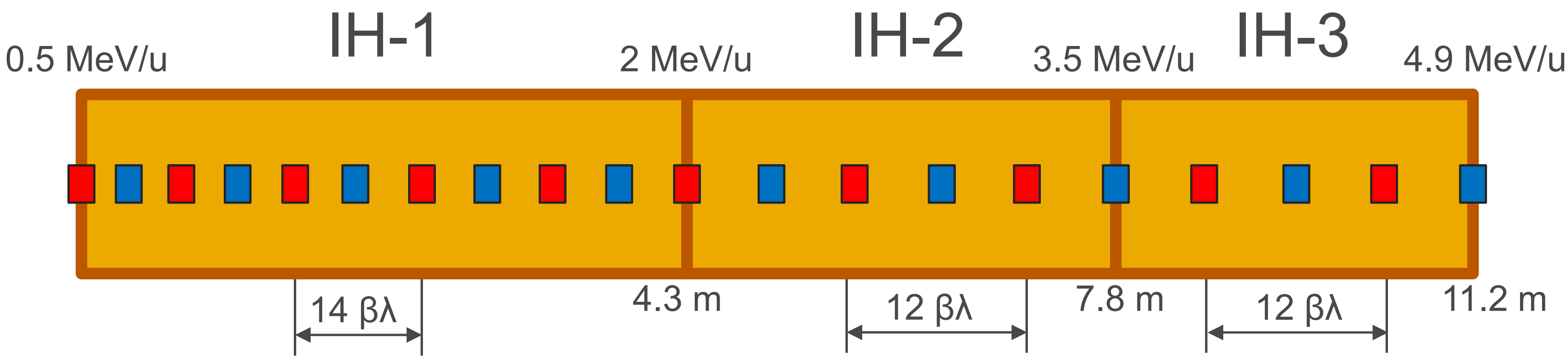


RF Quadrupole Focusing 4-vane DTL

+ Large acceptance
- Low Shunt Impedance

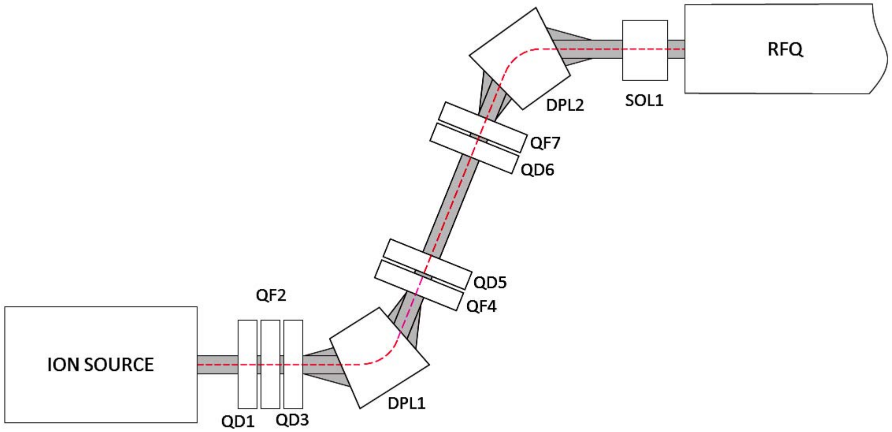
→ Better solution is IH-DTL with **FODO** lattice

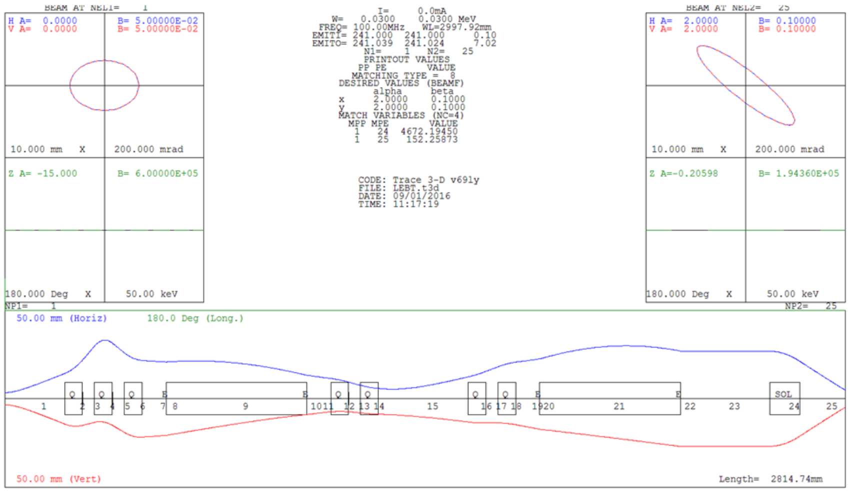
IH-DTL WITH FODO FOCUSING



POLARIZED LIGHT ION BEAMS

LIGHT ION LEBT





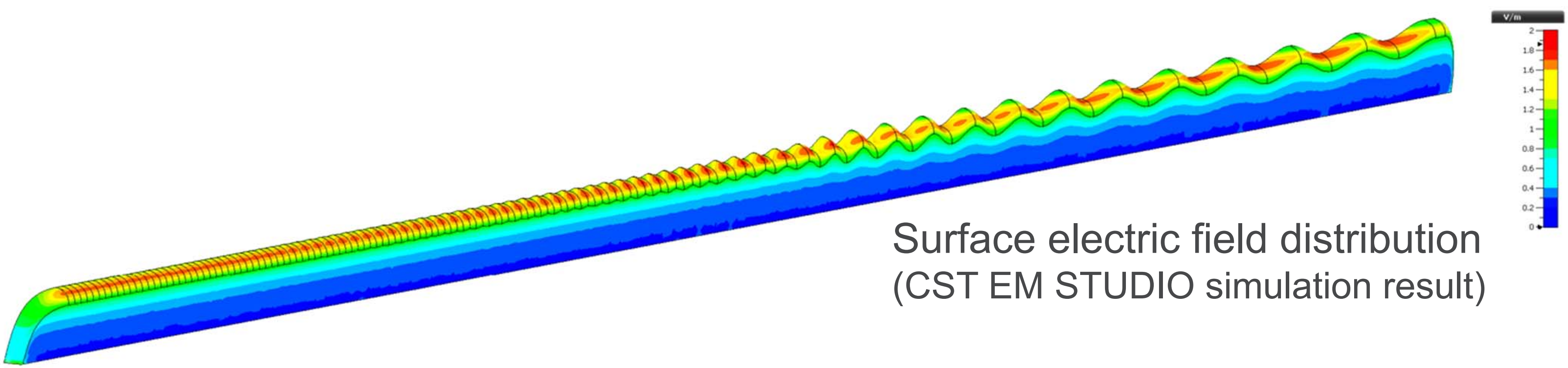
Based on BNL OPPIS LEBT* design

Designed with TRACE3D**

* J. Alessi et al., “Design of a 35 keV LEBT for the new High Intensity OPPIS at BNL”, in Proc. PAC’99, NewYork, pp. 1964-1966.
** K.R. Crandall, “TRACE3D manual,” LANL publication, LA-UR-97-886, 1997.

LIGHT ION RFQ

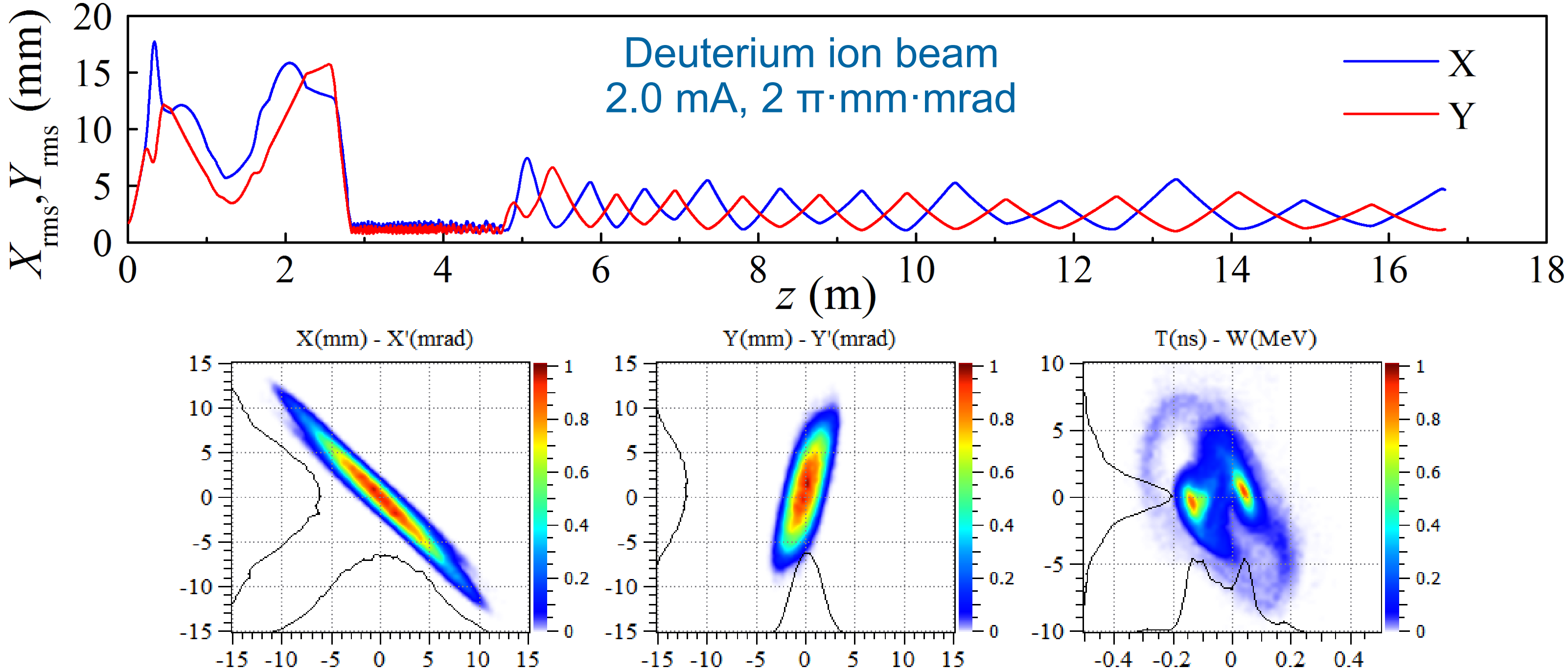
U = 103.4 kV
R_0 = 7 mm
E_{smax} = 1.84 Kilpatrick units
L = 2.0 m (tips only)



Surface electric field distribution
(CST EM STUDIO simulation result)

LIGHT ION BEAM DYNAMICS SIMULATION

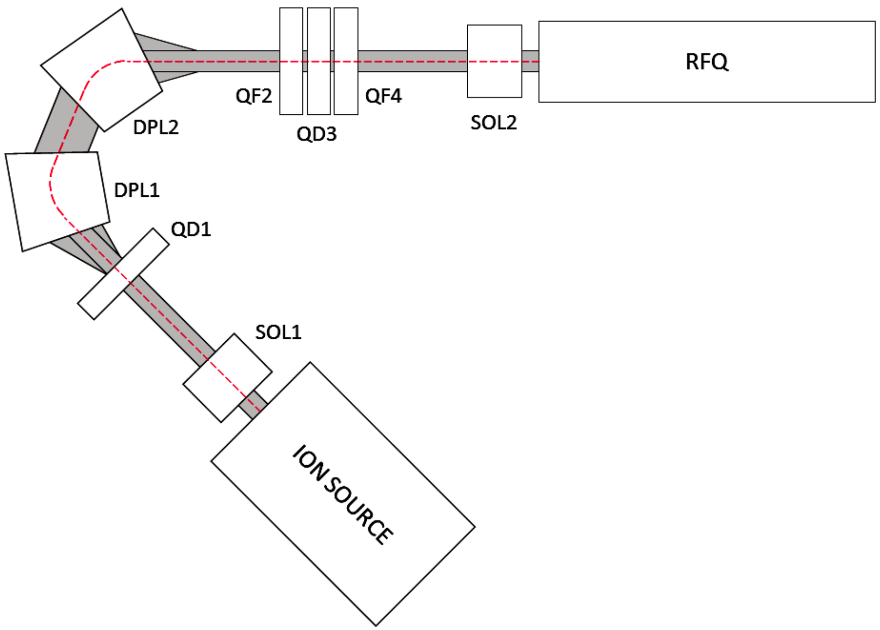
with TRACK code

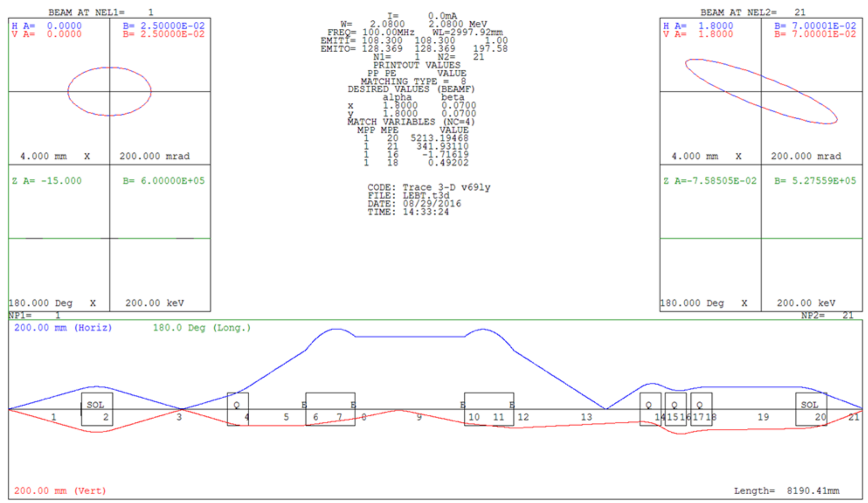


Emittance growth: 13% 13% 0%

HEAVY ION BEAMS

HEAVY ION LEBT





Based on CERN Linac3 LEBT* design

Designed with TRACE3D**

* “CERN heavy-ion facility design report”, CERN, Geneva, 1993
** K.R. Crandall, “TRACE3D manual,” LANL publication, LA-UR-97-886, 1997.

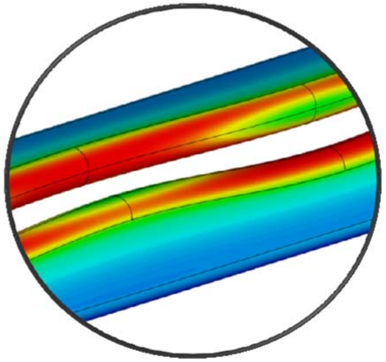
HEAVY ION RFQ

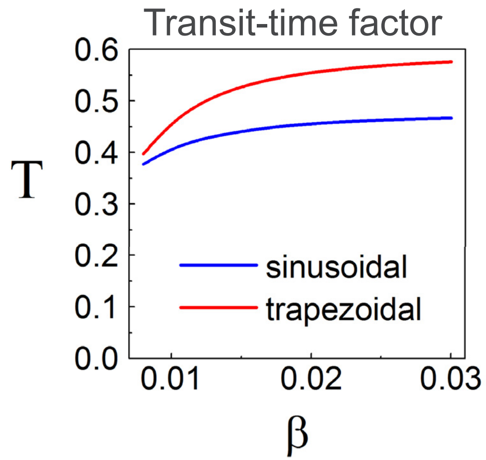
U = 70 kV
E_{smax} = 2.05 Kilpatrick units

R_0 = 3.7 mm
L = 5.6 m (tips only)

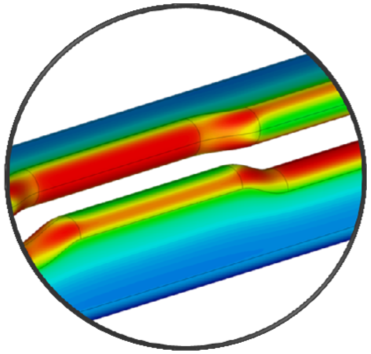
75% of the RFQ – acceleration on the bunched beam to 500 keV/u.

Sinusoidal modulation



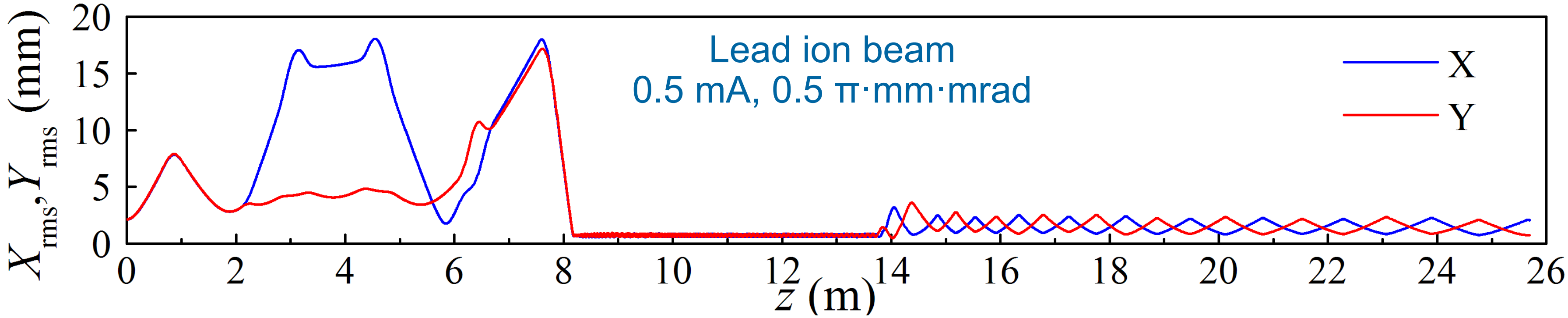


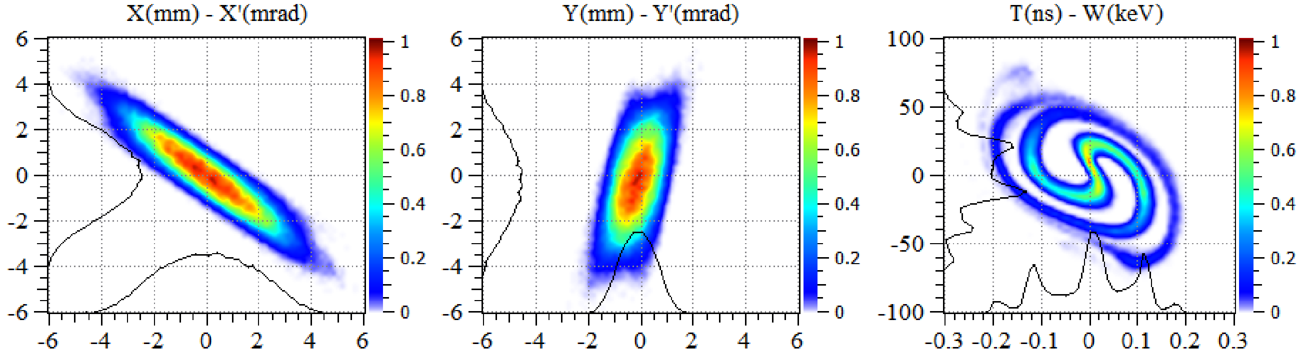
Trapezoidal modulation



5.6 m → **4.6 m**
180 kW → **150 kW**

BEAM DYNAMICS SIMULATION with TRACK code



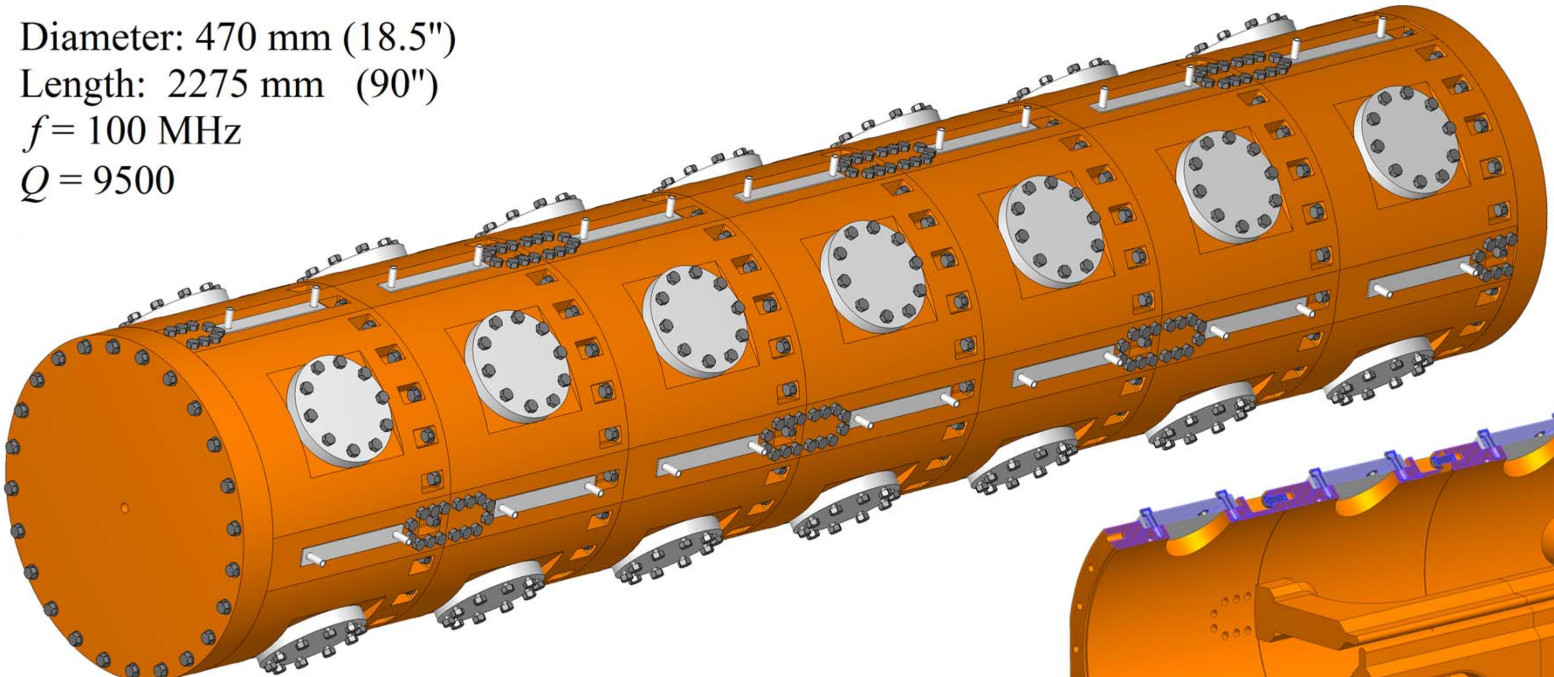


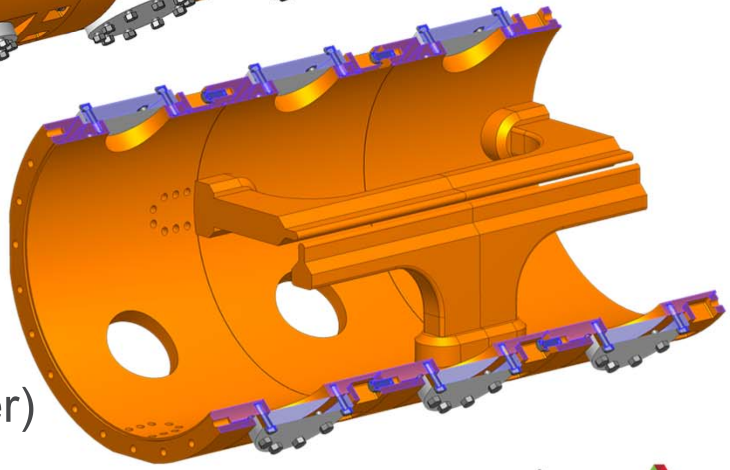
Emittance growth: 17% 17% 0%

RESONATORS' DESIGN

LIGHT ION RFQ

Diameter: 470 mm (18.5")
Length: 2275 mm (90")
f = 100 MHz
Q = 9500





No brazed or welded joints
Tank-only water cooling (700 W of dissipated power)

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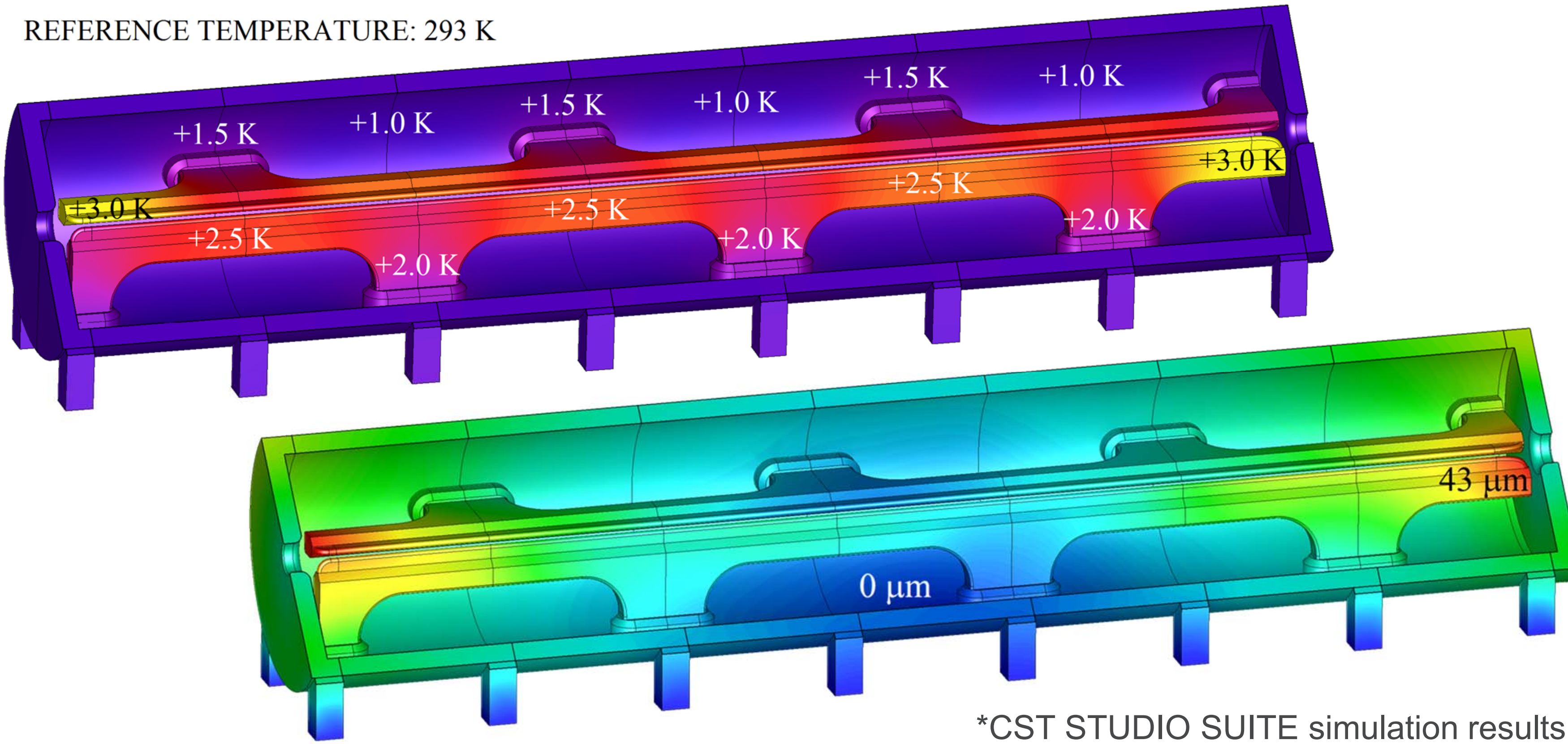
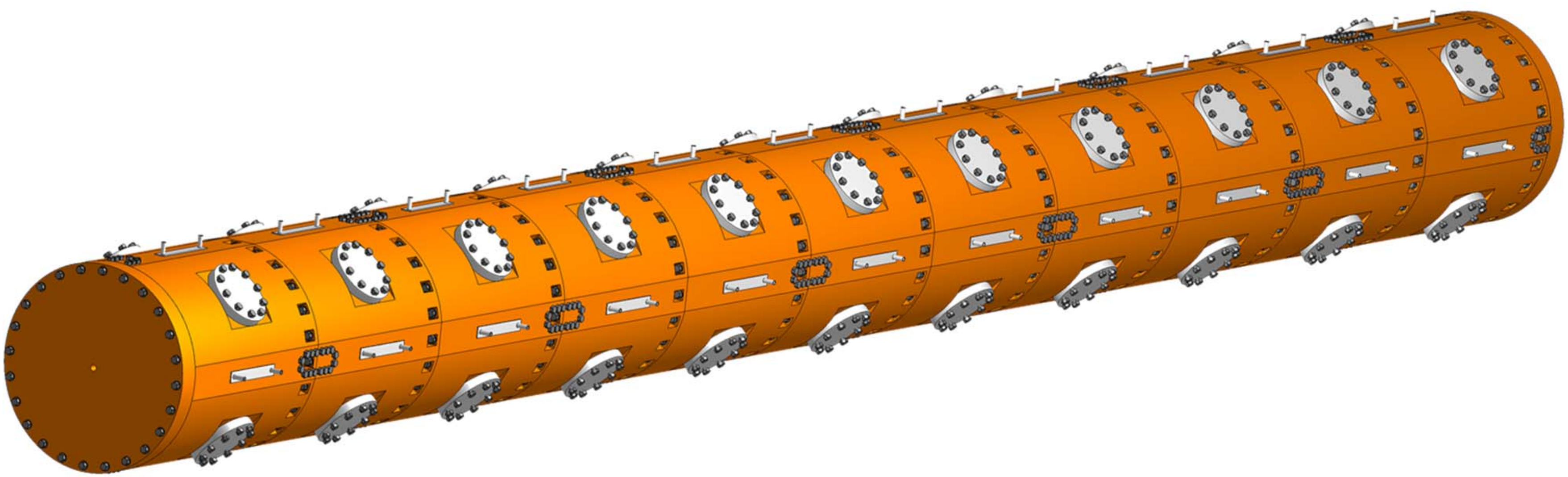
TEMPERATURE DISTRIBUTION & DEFORMATIONS*



*CST STUDIO SUITE simulation results

HEAVY ION RFQ

- …has the **same RF and mechanical design** as the Light Ion RFQ, except the number of resonator segments and their dimensions.
- The length of the heavy ion **RFQ is 5.6 m**.
- **Lower power density** than of the Light Ion RFQ.



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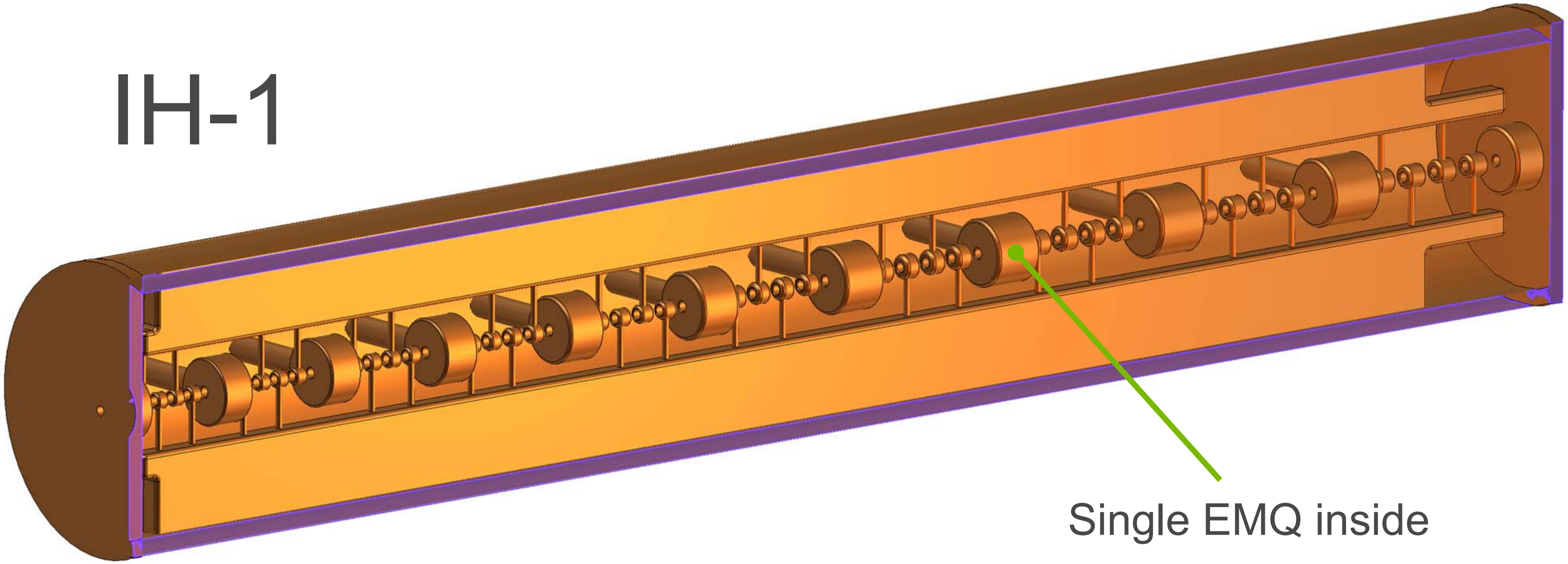
IH-DTL WITH FODO FOCUSING



FRONT-END FOR MULTI-ION INJECTOR

Parameter	Units	Light Ion RFQ	Heavy Ion RFQ	IH-1	IH-2	IH-3	Total
Energy range	MeV/u	0.015 – 0.5	0.010 – 0.5	0.5 – 2.0	2.0 – 3.5	3.5 – 4.9	0.01 - 4.9
Length	m	2.0	5.6	4.3	3.5	3.4	
Diameter	m	0.47	0.44	0.7	0.7	0.7	
Number of cells / gaps		136	264	50	30	24	
Number of quads				11	5	4	20
Voltage	kV	103.4	70.0	200 - 500	500	570	
Aperture (R_0)	mm	7.0	3.7	12.5	12.5	12.5	
Quality factor		9500	9200	18000	18000	18000	
RF power losses	kW	110	180	280	400	620	1480 (max)
Peak surface electric field	Kilpat. units	1.84	2.05	2.0	2.0	2.0	
Norm. transverse emittance (90%)*	π·mm·mrad	1.47	0.35	1.62 / 0.40	1.66 / 0.41	1.66 / 0.41	+13% / +17%
Norm. longitudinal emittance (90%)*	π·ns·keV/u	4.9	4.5	4.9 / 4.5	4.9 / 4.5	4.9 / 4.5	+ 0%
Transmission*		99.9%	99.7%	99.8%	100%	100%	99.7%
Beam current*	mA	2.0	0.5	2.0 / 0.5	2.0 / 0.5	2.0 / 0.5	2.0 / 0.5

* Deuterium ion beam / Lead ion beam

SUMMARY

- Two RFQs
- IH-DTL with FODO lattice
- Cost-efficient RF and Mechanical design

THANK YOU !

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