ESS Linac for ESSnuSB

Mamad Eshraqi
for Linac work-package

The ESSnuSB Workshop @ Hamburg University
2020 Oct 08

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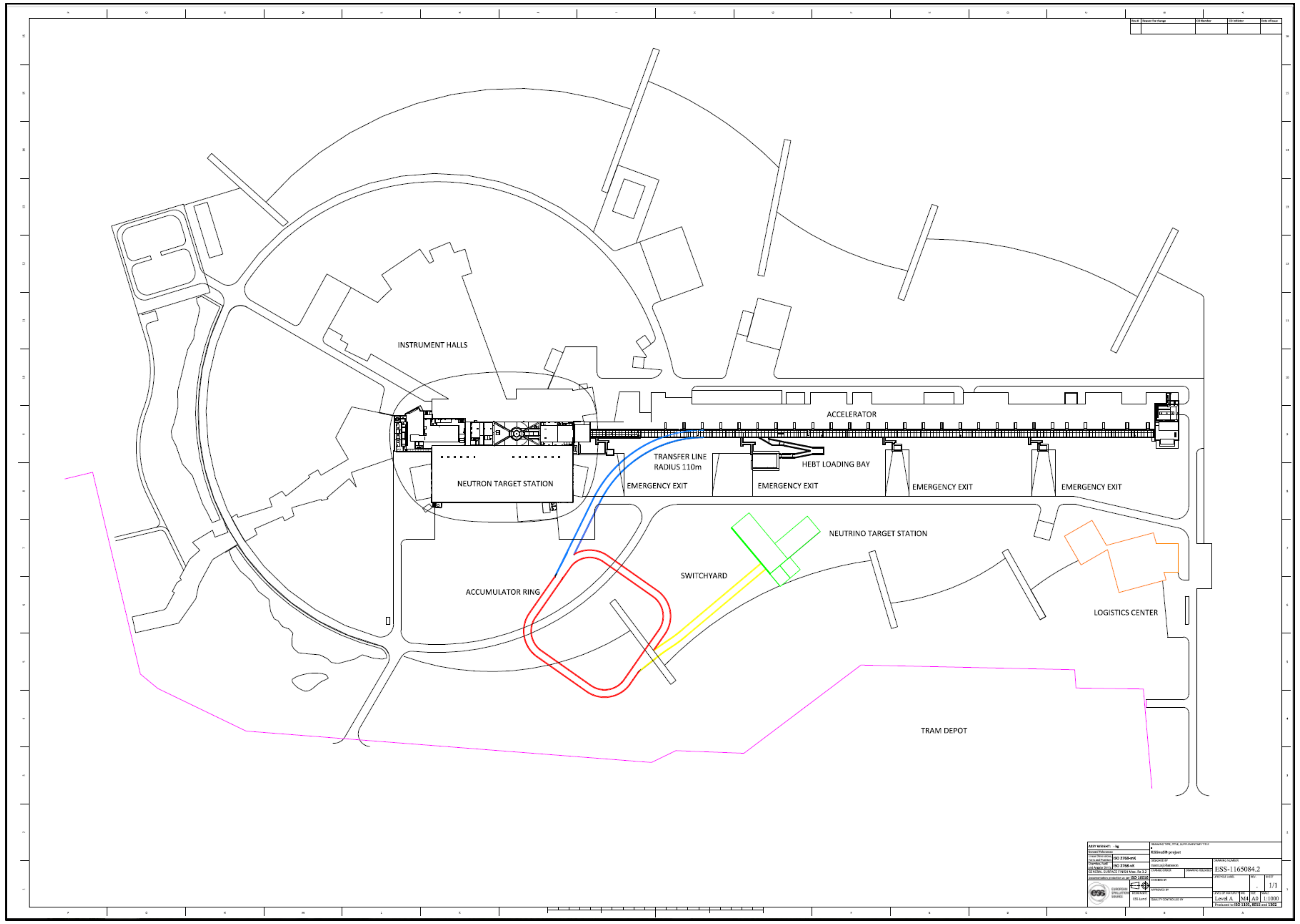
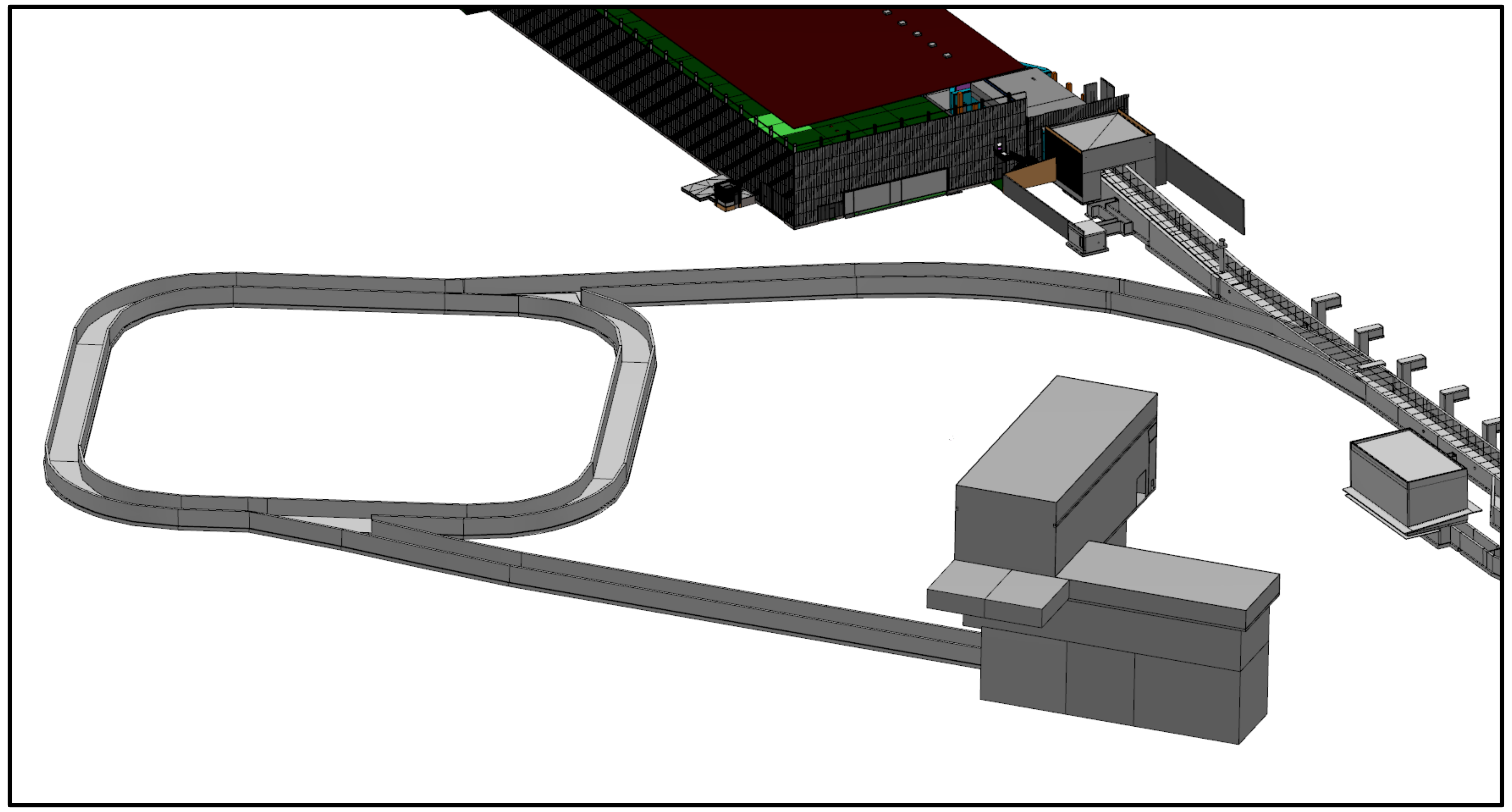
European Spallation Source (ESS) Site

ESSnuSB Layout

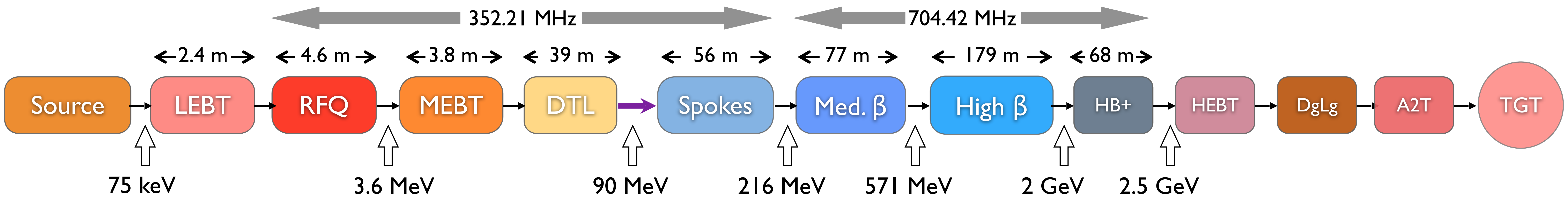




- Transfer line straight end.
- Longer possible switchyard length.
- Target station position flexibility increased.

Rasmus Johansson and Nick Gazis

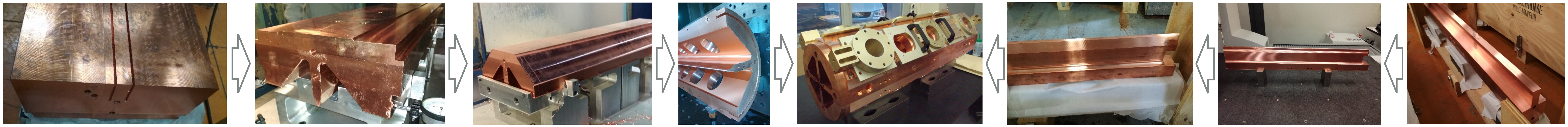
LINAC LAYOUT

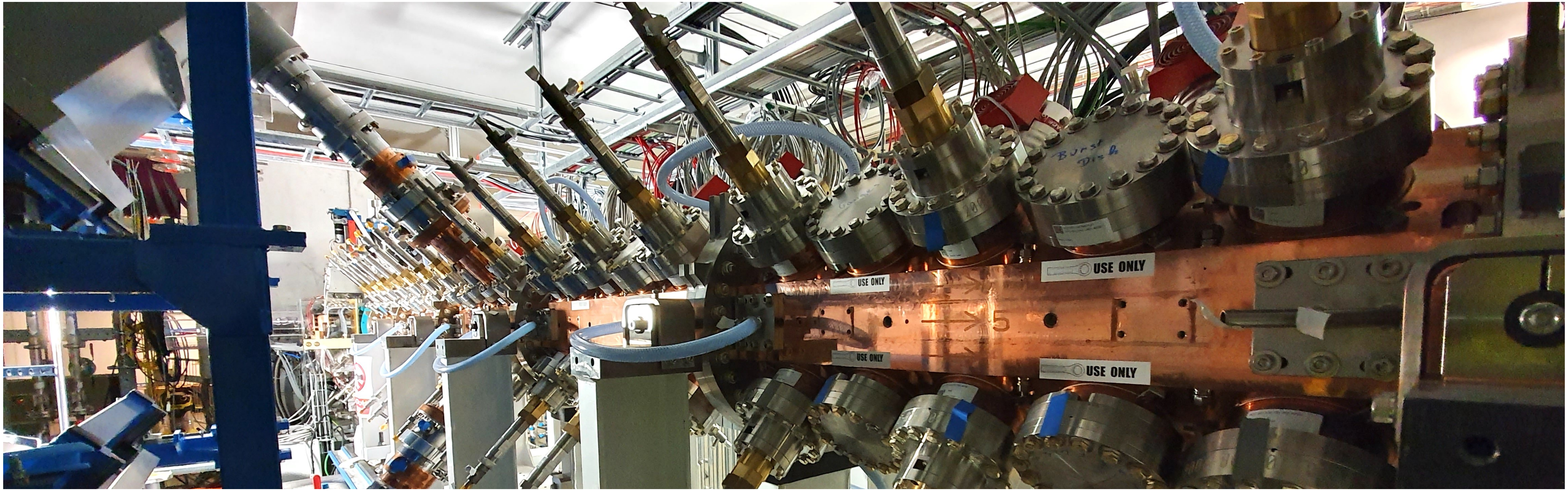


	Length (m)	W_out (MeV)	F (MHz)	β Geometric	No. Sections	T (K)
LEBT	2.38	0.075	—	—	1	~300
RFQ	4.6	3.62	352.21	—	1	~300
MEBT	3.83	3.62	352.21	—	1	~300
DTL	38.9	89.8	352.21	—	5	~300
LEDP + Spoke	55.9	216.3	352.21	0.50 (Opt)	13	~2
Medium Beta	76.7	571.5	704.42	0.67	9	~2
High Beta	178.9	2000	704.42	0.86	21	~2
HB+	68.2	2500	704.42	0.86	8	~2
HEBT	59.6	2500	—	—	7	~300
DogLeg	66.3	2500	—	—	6	~300
A2T	44.6	2500	—	—	1	~300

ESS Updates

- Radio Frequency Quadrupole (RFQ) installed in the tunnel

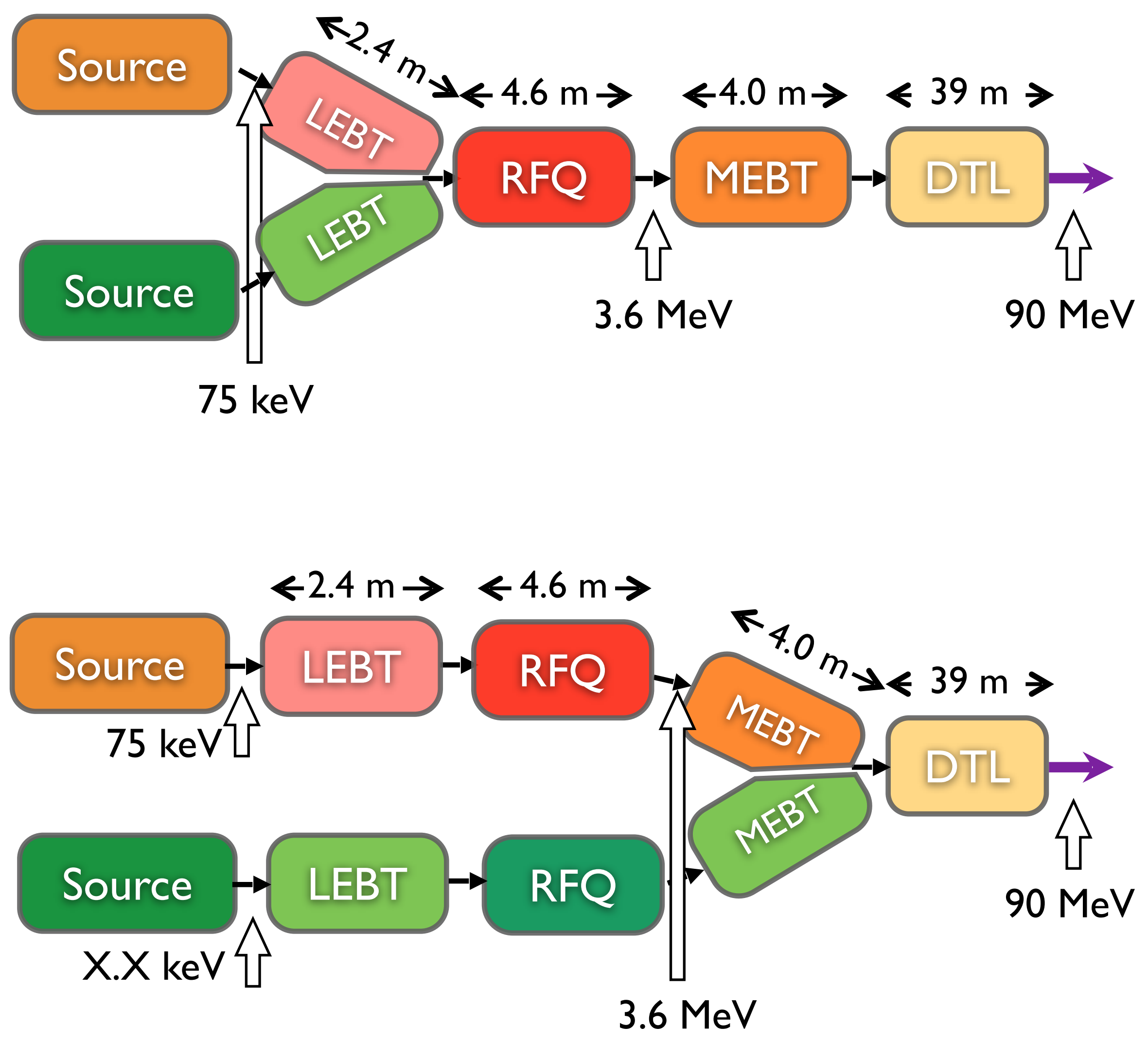


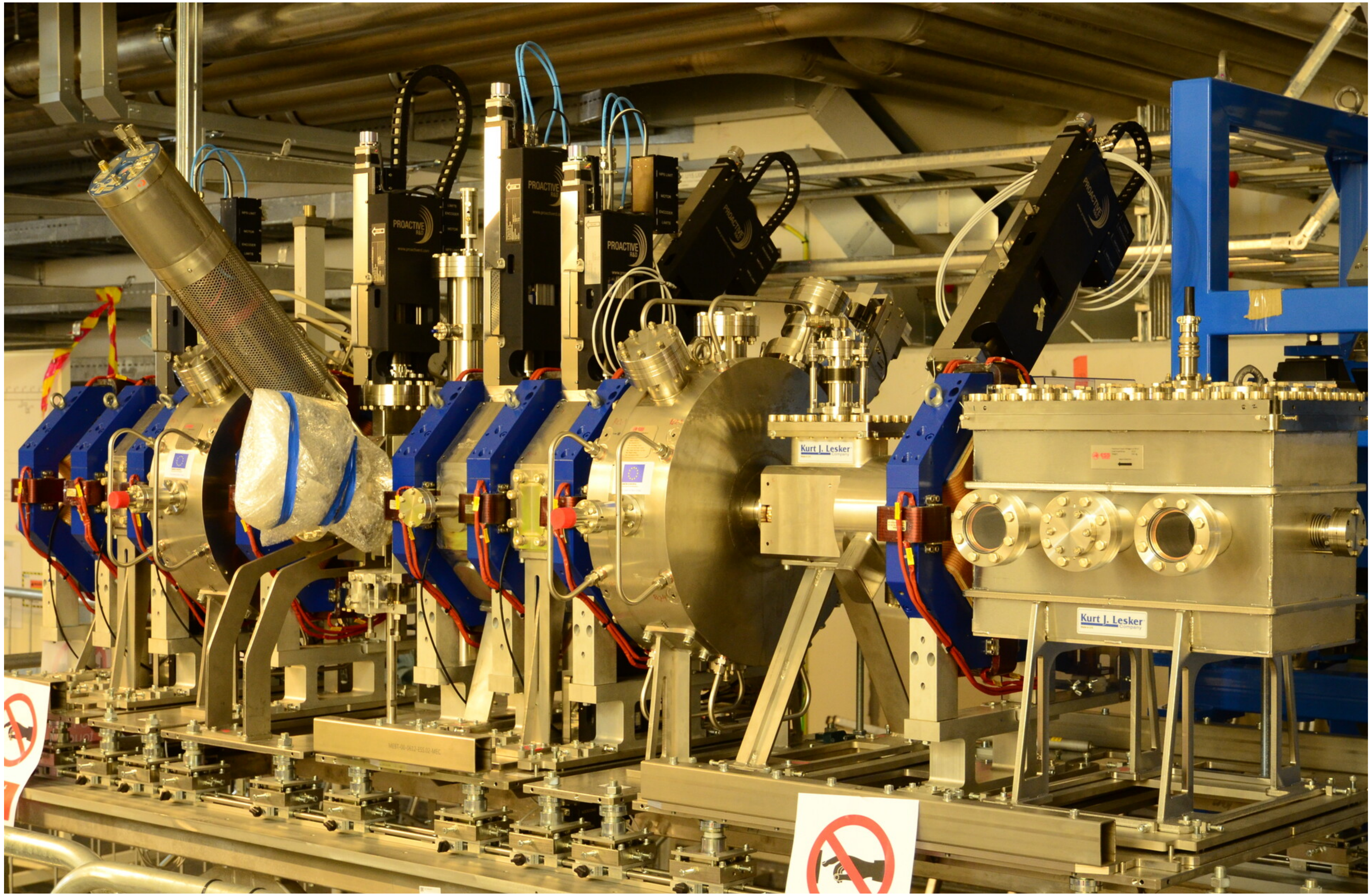


Anne-Catherine Chauveau

ESS Updates

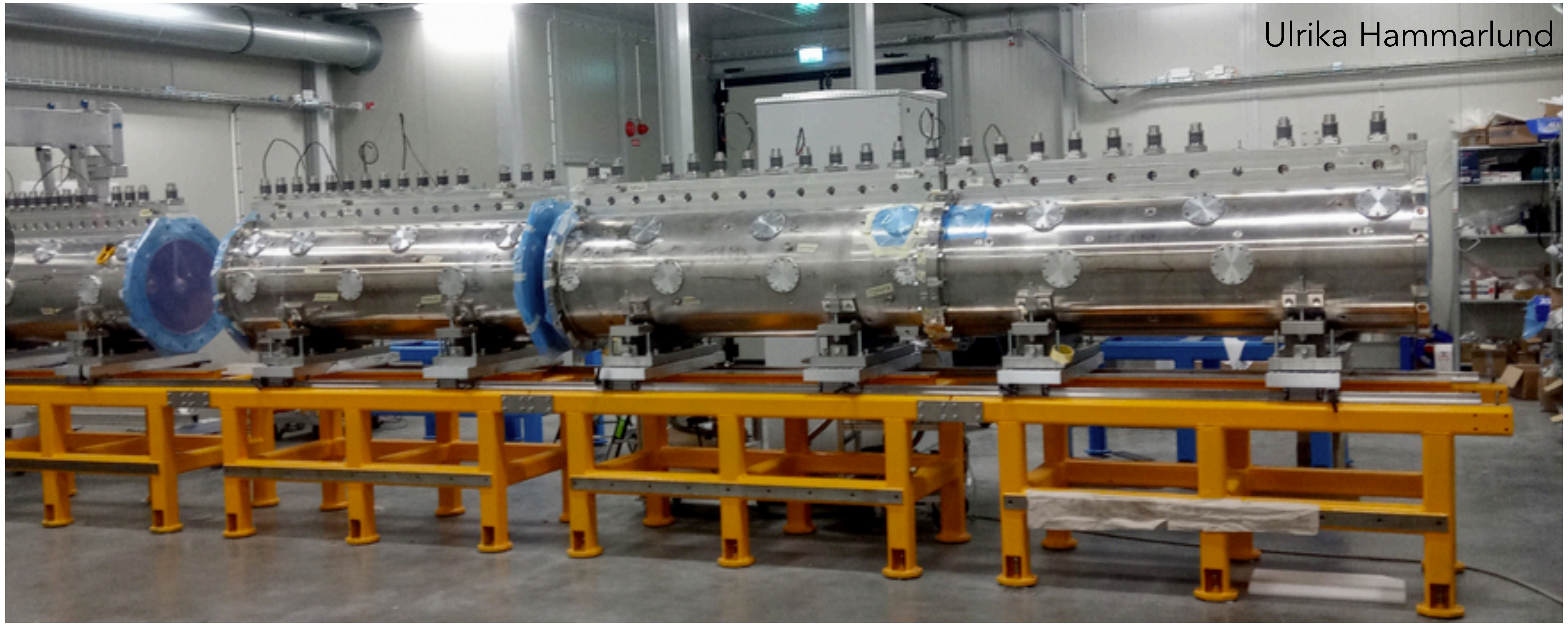
- Medium Energy Beam Transport (MEBT)
  - Installed in the tunnel

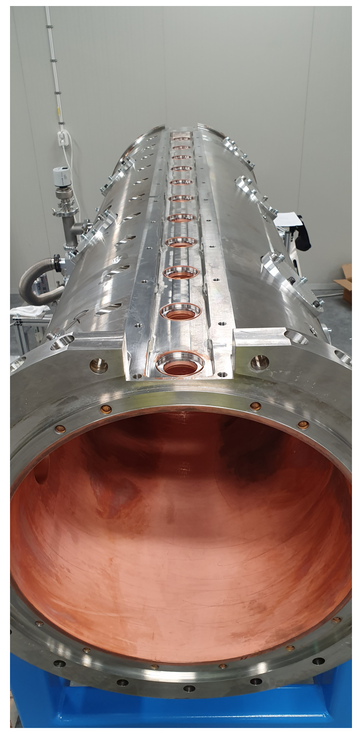


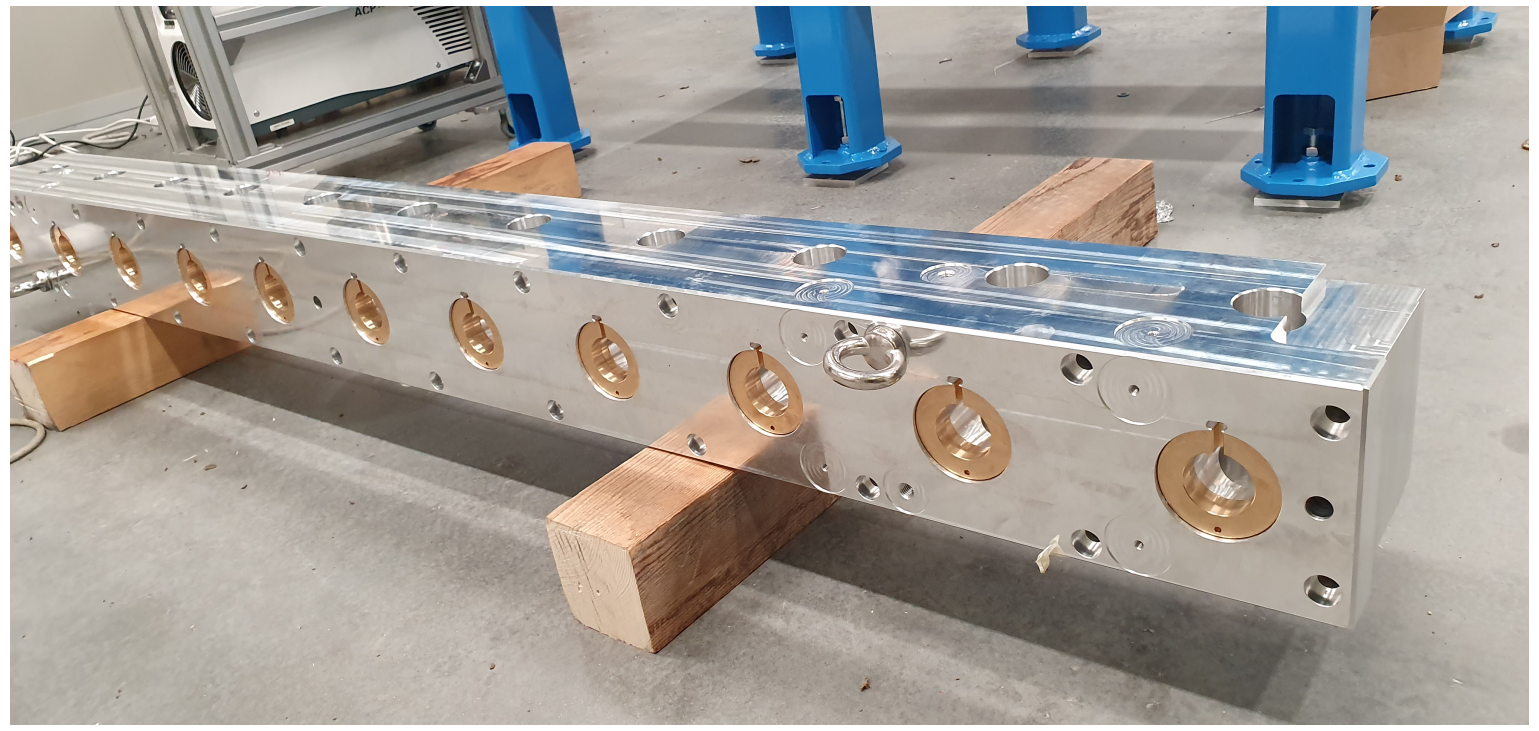


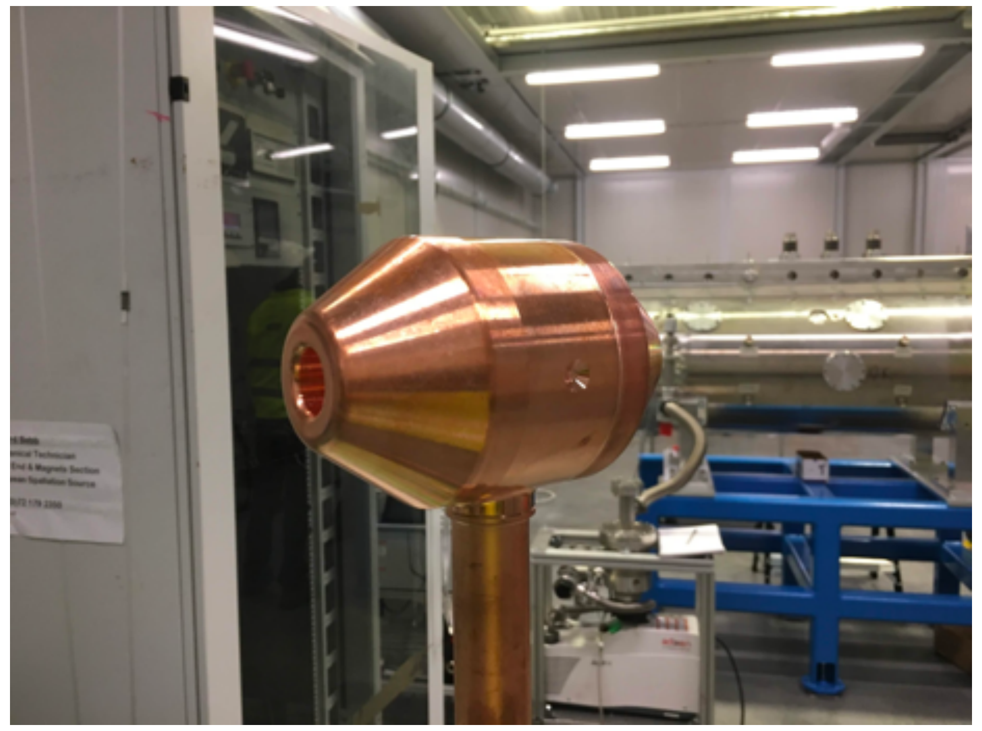
ESS Updates

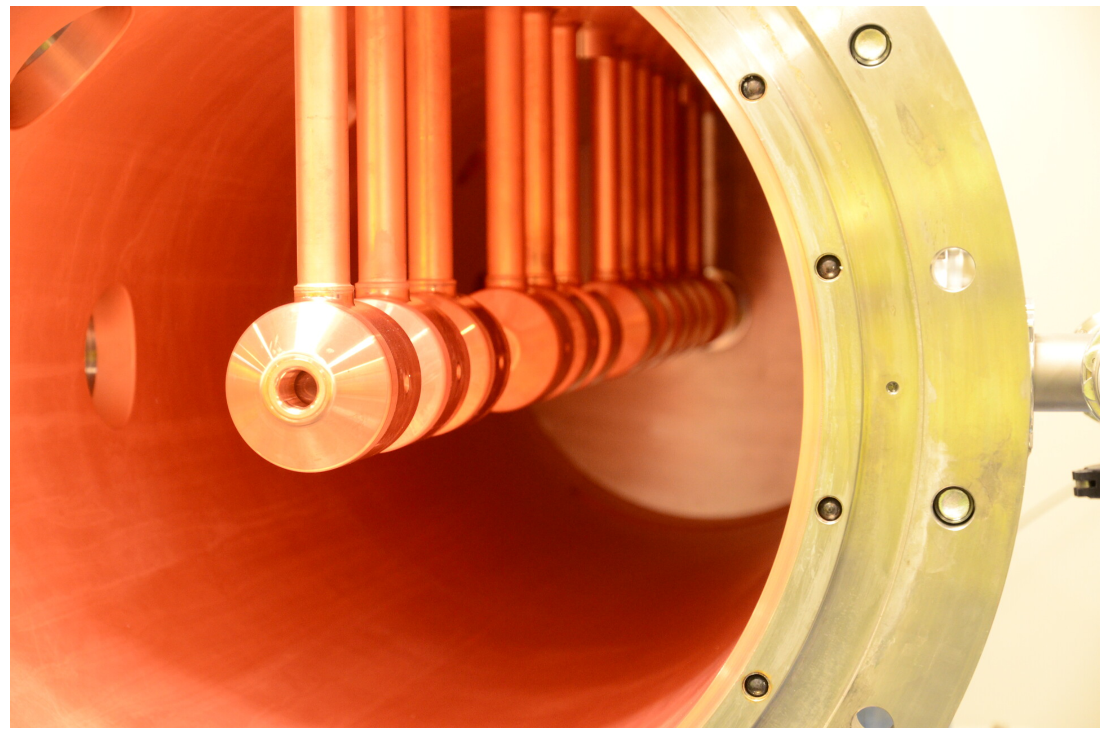
- Drift Tube Linac (DTL), assembled on site

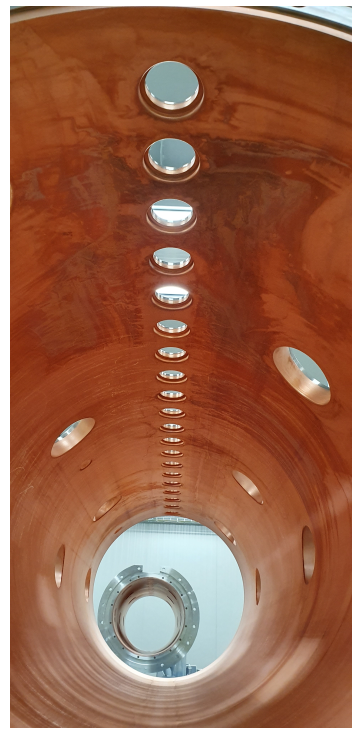




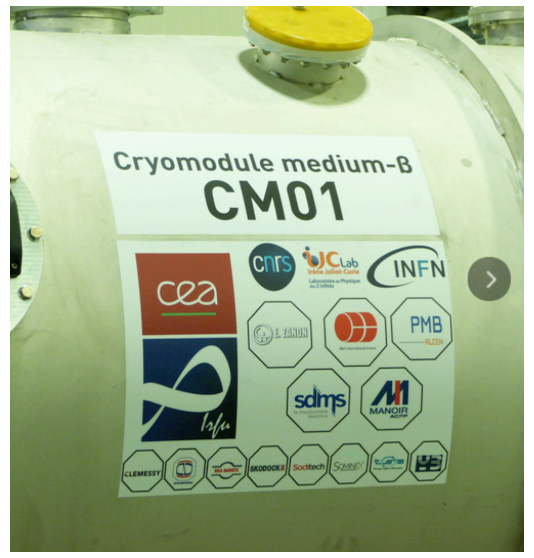


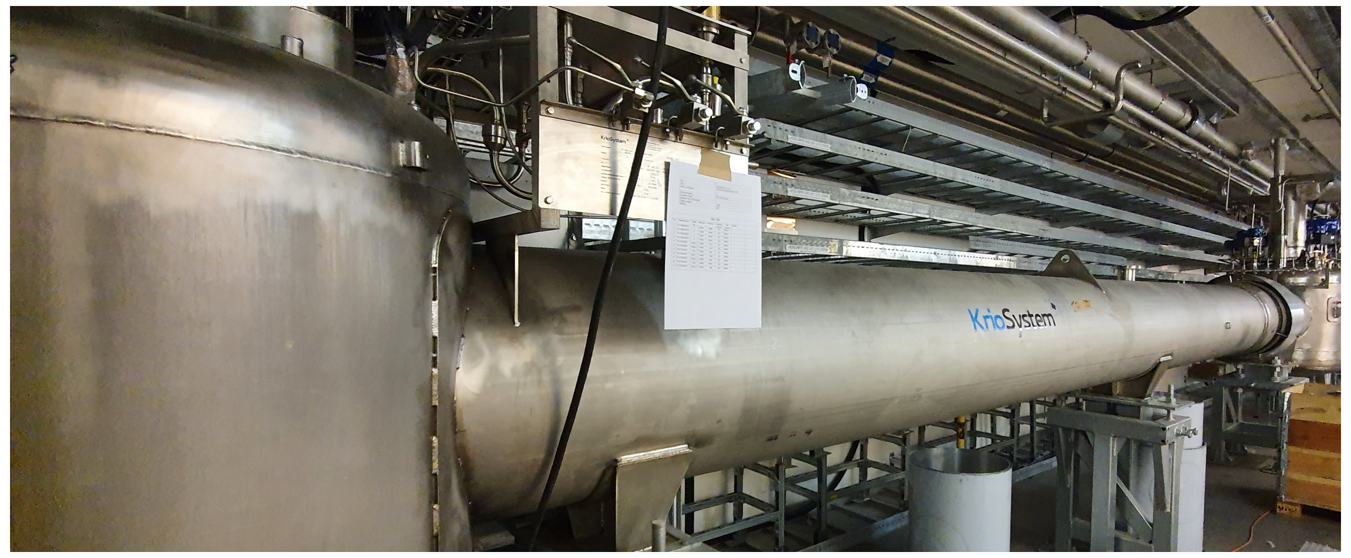


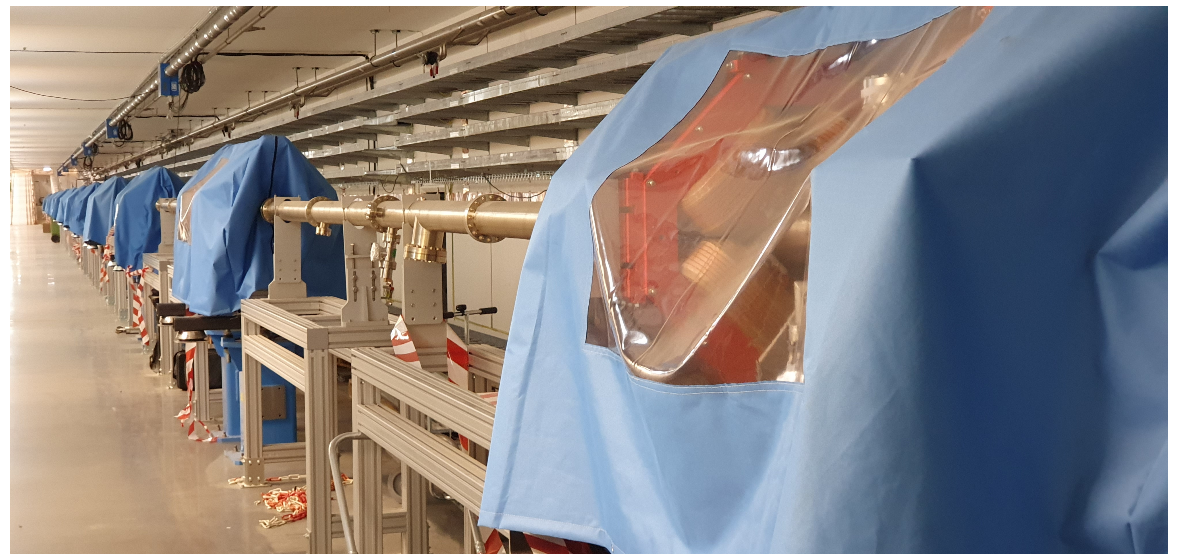


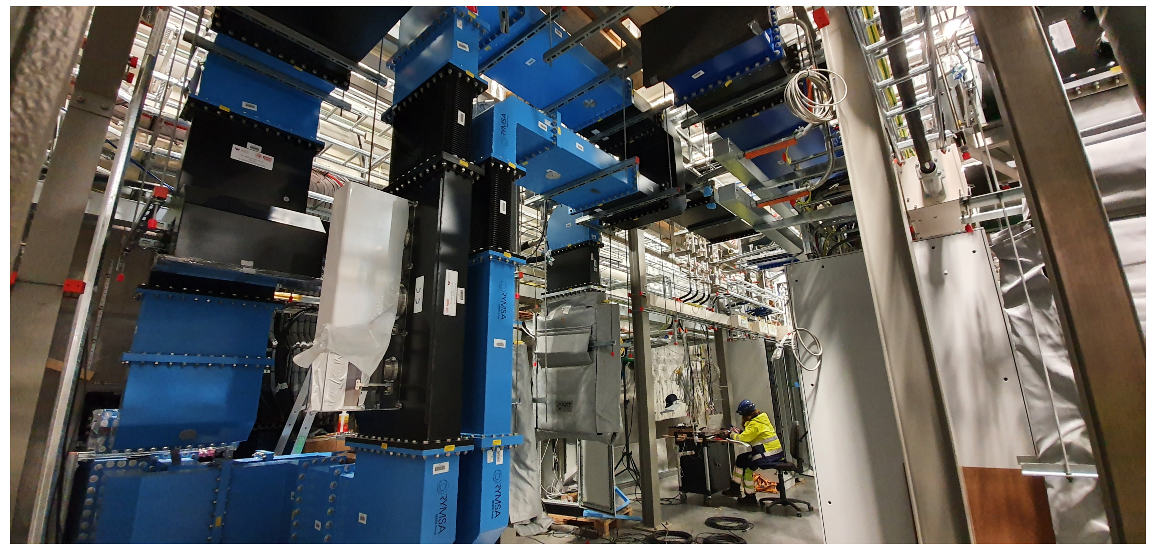


ESS Updates

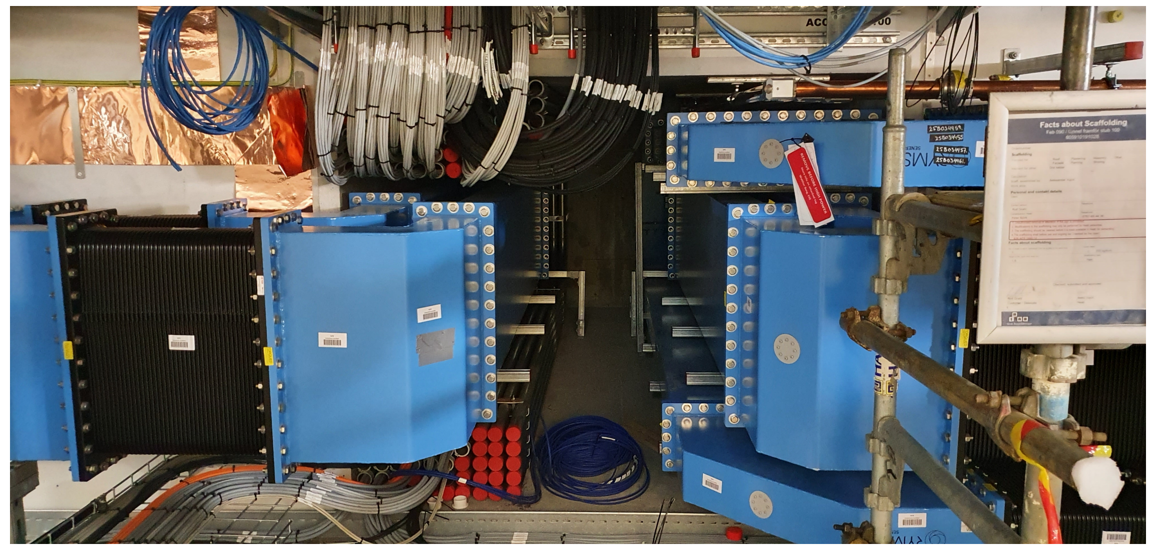







NCL RFDS, Gallery


SCL RFDS, Gallery


NCL RFDS, Tunnel


SCL RFDS, Tunnel

Radio Frequency Distribution system

LUND TO GARPENBERG VIA ZINKGRUVAN

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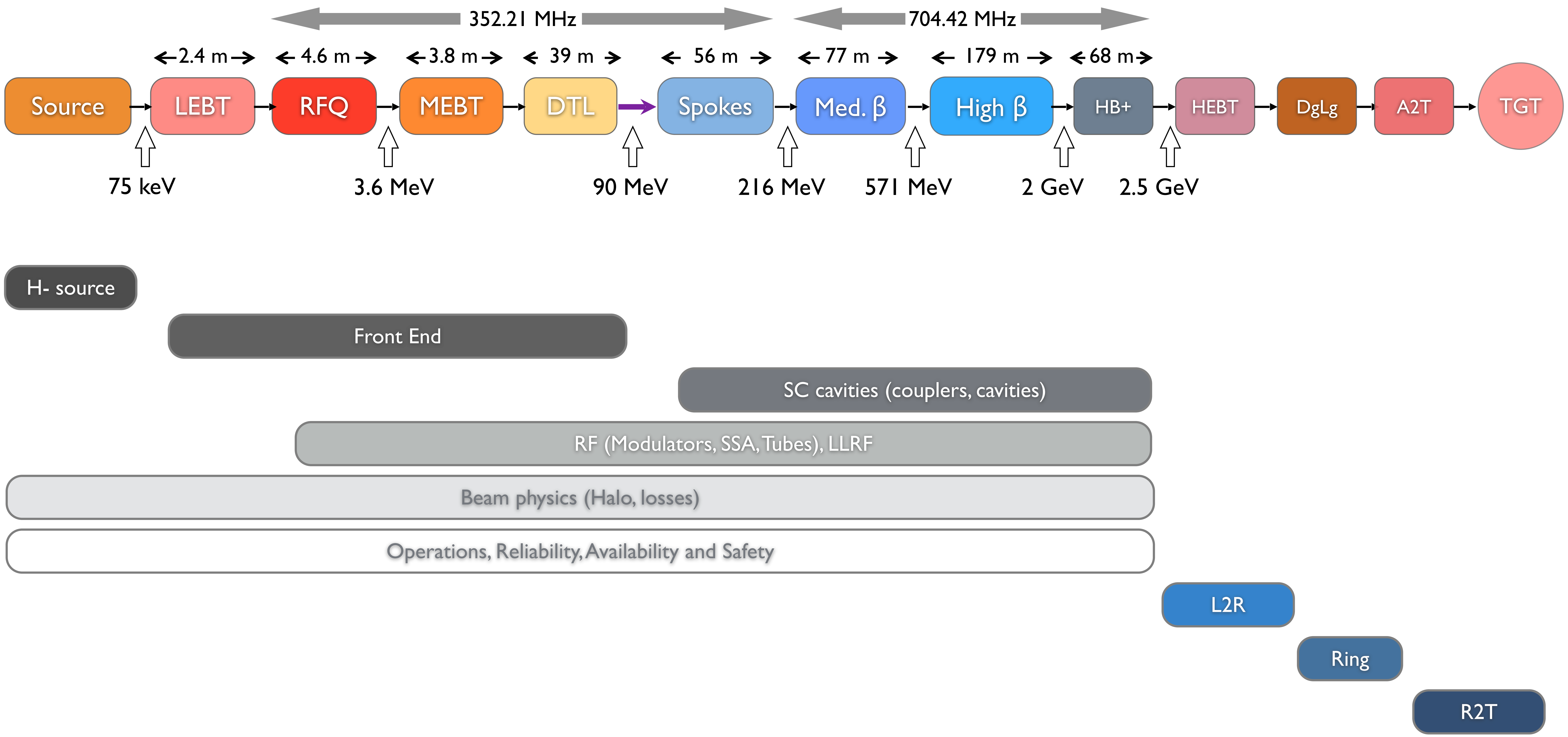
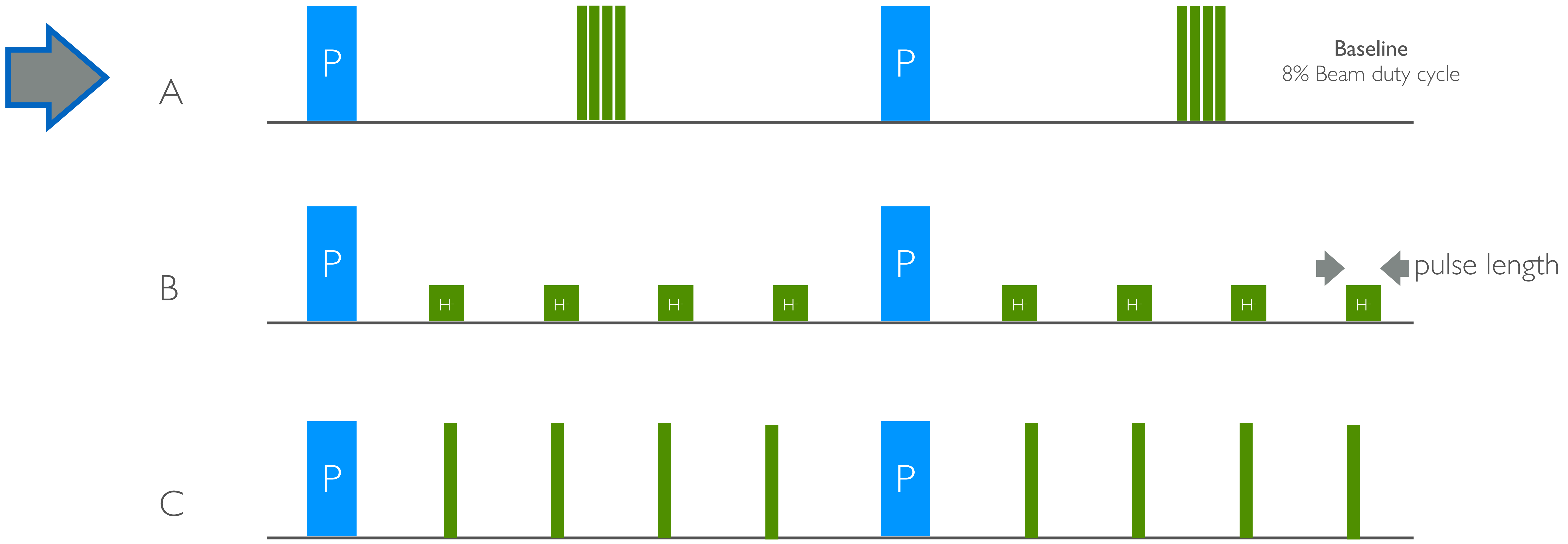
AREAS OF CHANGE

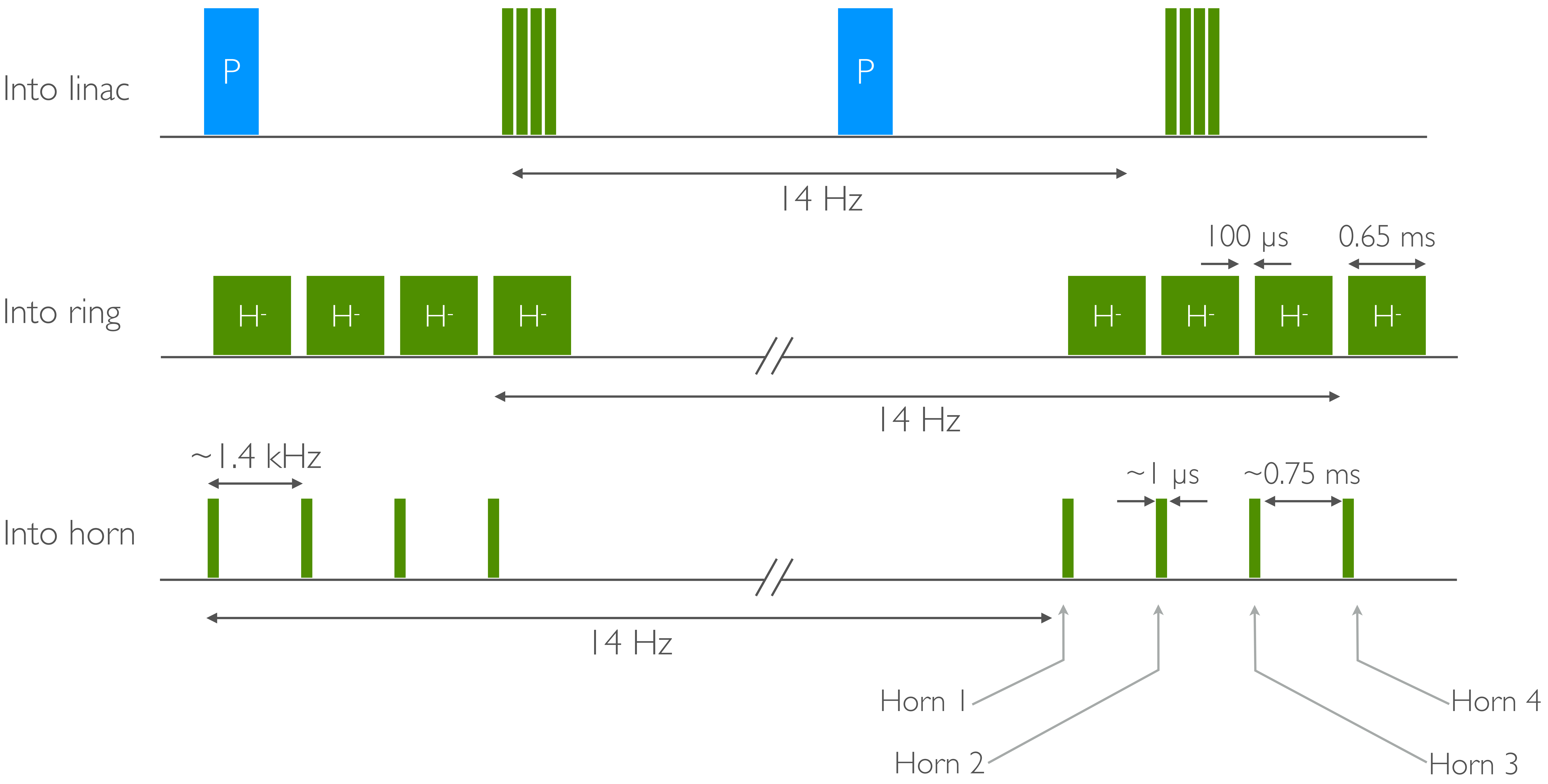


PULSING



Scenario	A	B	C
(Sub)-pulse length (ms)	0.65	~1.3*	0.77
Beam current# (mA)	60	~30	50
Frequency (Hz)	14	70	70
Time between pulses (ms)	72 (0.75)	14	14
Particles per batch	$2.23 \cdot 10^{14}$	$2.23 \cdot 10^{14}$	$2.23 \cdot 10^{14}$
Batches per macro pulse	4	4	4
Particles per macro pulse (72 ms / 14 Hz)	$8.93 \cdot 10^{14}$	$8.93 \cdot 10^{14}$	$8.93 \cdot 10^{14}$

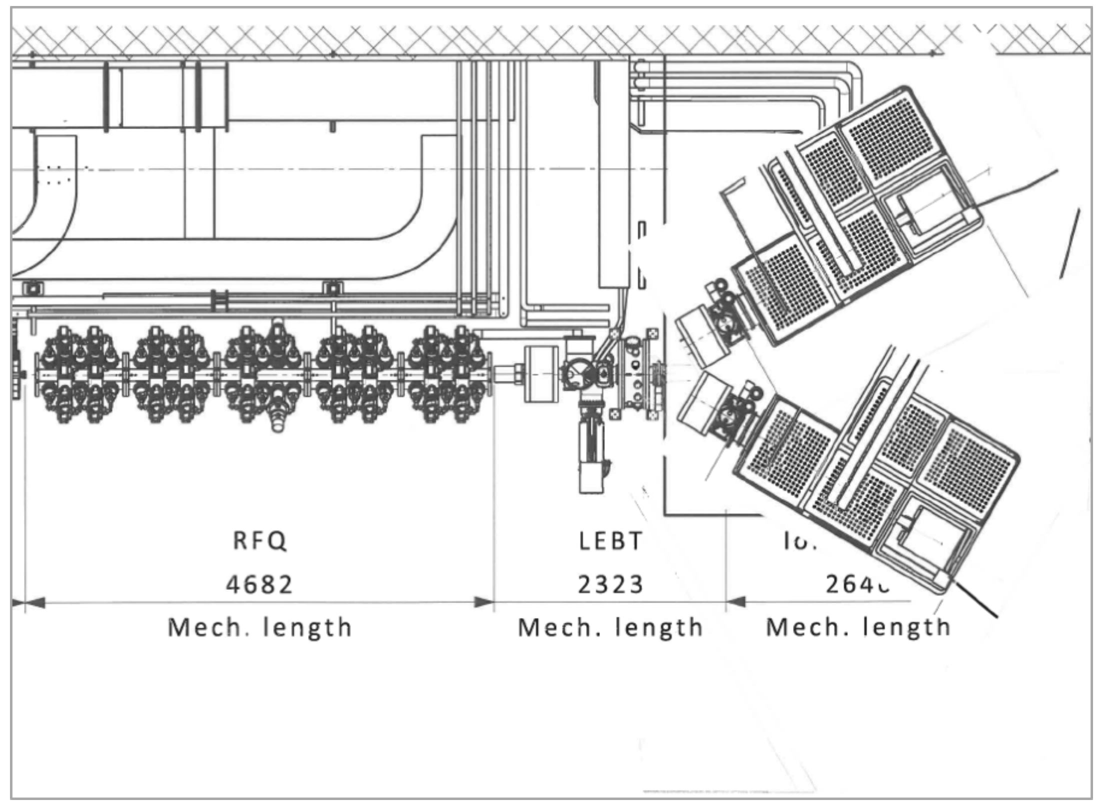
Pulsing II

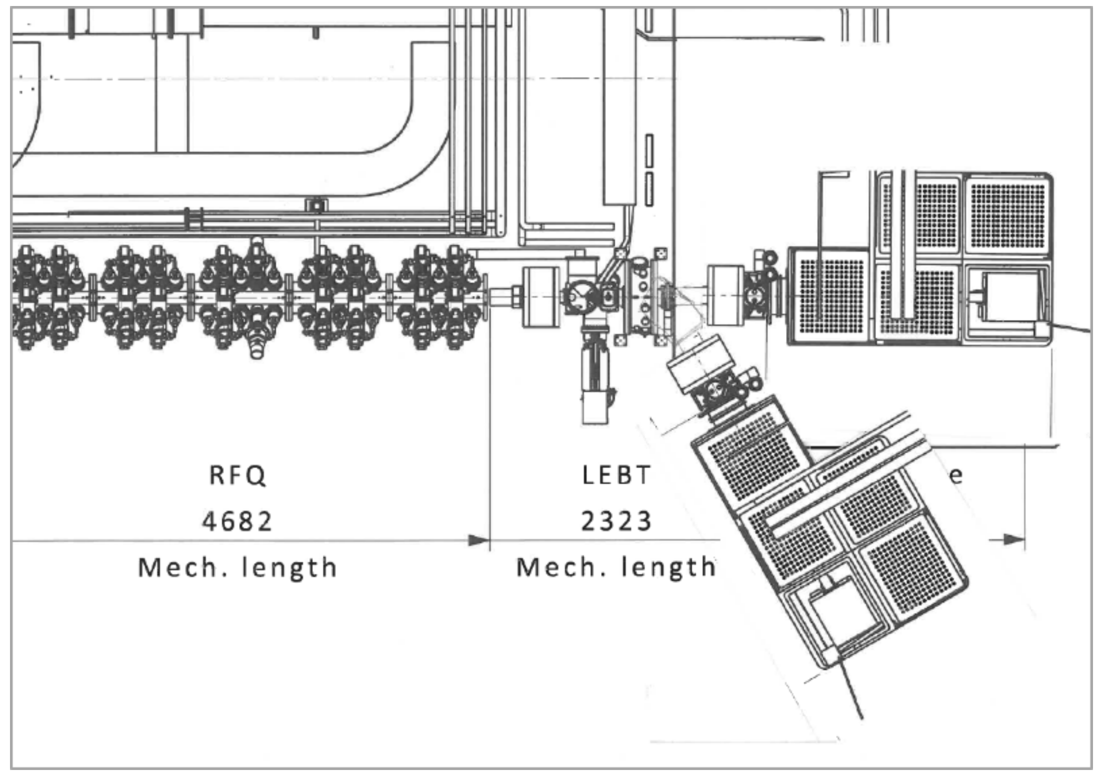


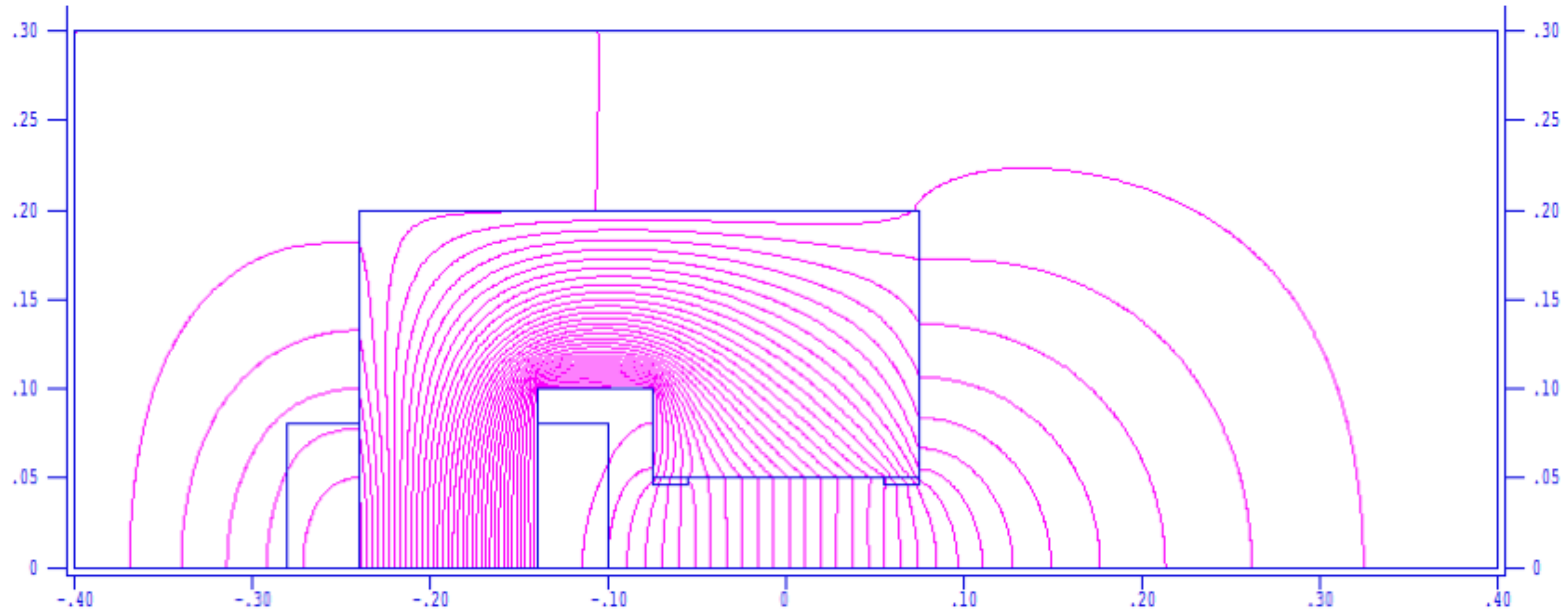
Into linac
P
P
14 Hz
100 μs
0.65 ms
Into ring
H-
H-
H-
H-
H-
H-
H-
H-
14 Hz
~1.4 kHz
~1 μs
~0.75 ms
Into horn
14 Hz
Horn 1
Horn 2
Horn 3
Horn 4

RAL AND SNS SOURCES

Parameter	RAL Penning 1X ISIS	RAL Penning 2X FETS	SNS, Oak Ridge, RF surface enhanced volume source
Beam pulse length (ms)	0.25 ms	2 ms	1 ms
Repetition frequency	50 Hz	50 Hz	60 Hz
Beam current	55 mA	100 mA	60 mA
Duty cycle	1.25 %	10 %	6 %
Lifetime	5 weeks	2 weeks	14 weeks
Cs consumption	~0.7 g/week	~3.5 g/week	~2 mg/week
Emittance rms norm	0.25 mm mrad	0.3 mm mrad	0.25 mm mrad
LEBT	Sector magnet 90 degrees bend plus Cs cold trap Magnetic LEBT	Einzel lens, carbon Cs trap Magnetic LEBT	Electrostatic LEBT
RMS emittance after initial beam transport stage	0.7 mm mrad	0.3 mm mrad	N/A
Extraction voltage	18 (35) kV	18 (65) kV	65 kV



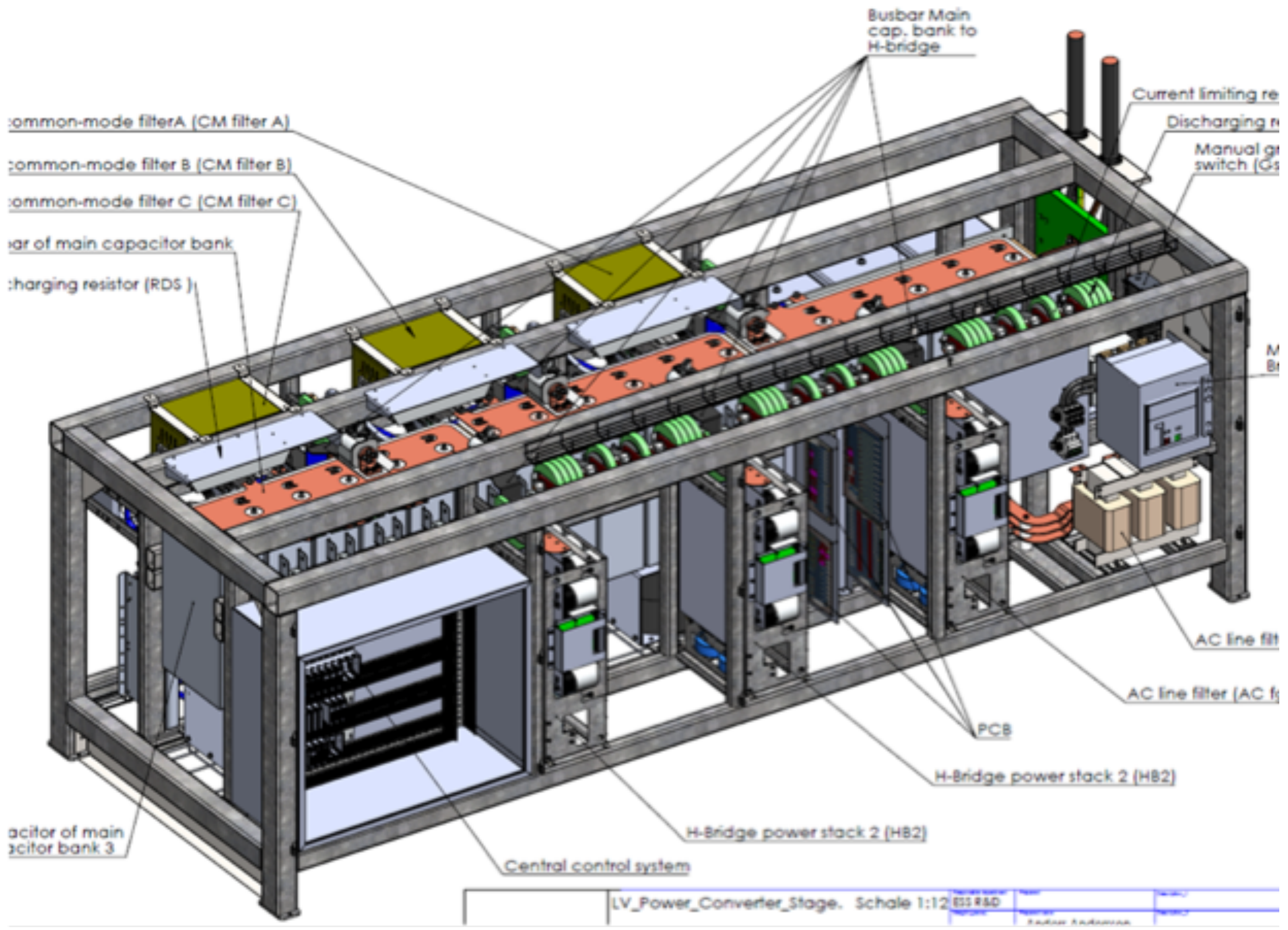


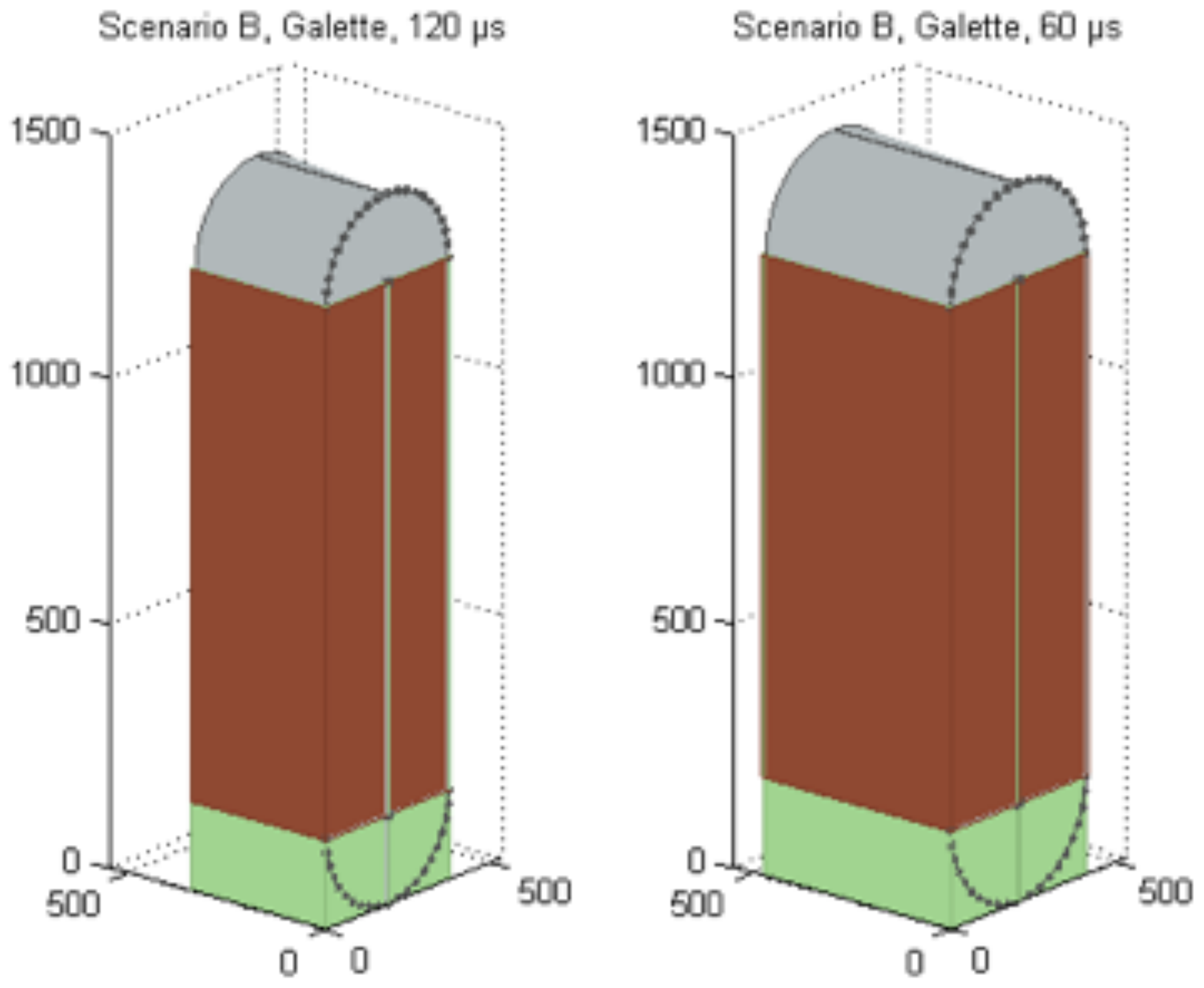


Björn Gålnander, Håkan Danared

Modulator

- Two different power upgrades for the modulators have been studied:
  - Using the SML modulators of ESS and upgrading the capacitor chargers
  - Using the SML modulators of ESS and adding pulse transformers for the H- beam

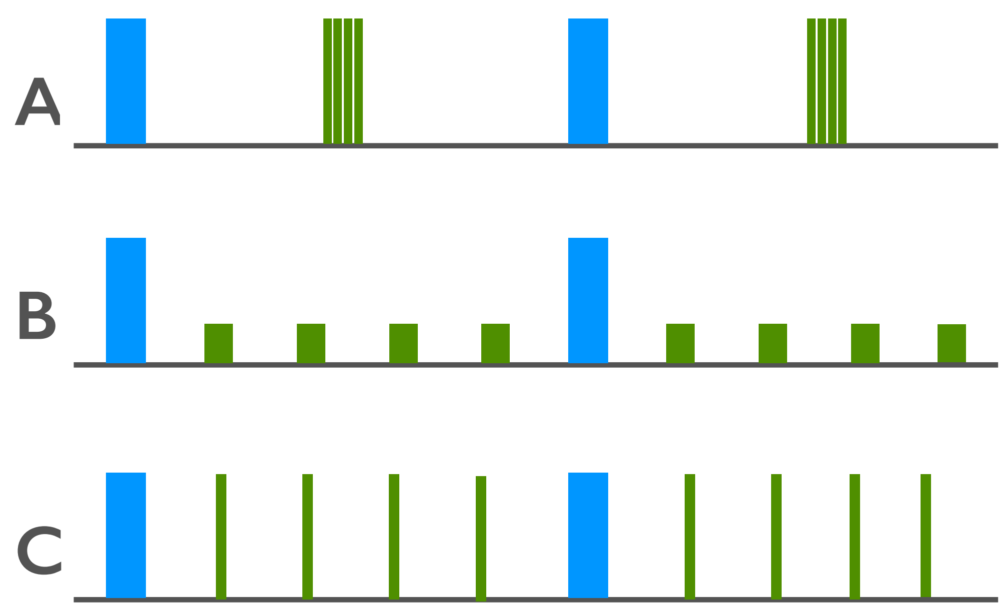




Max Collins and Carlos Martins

Modulator

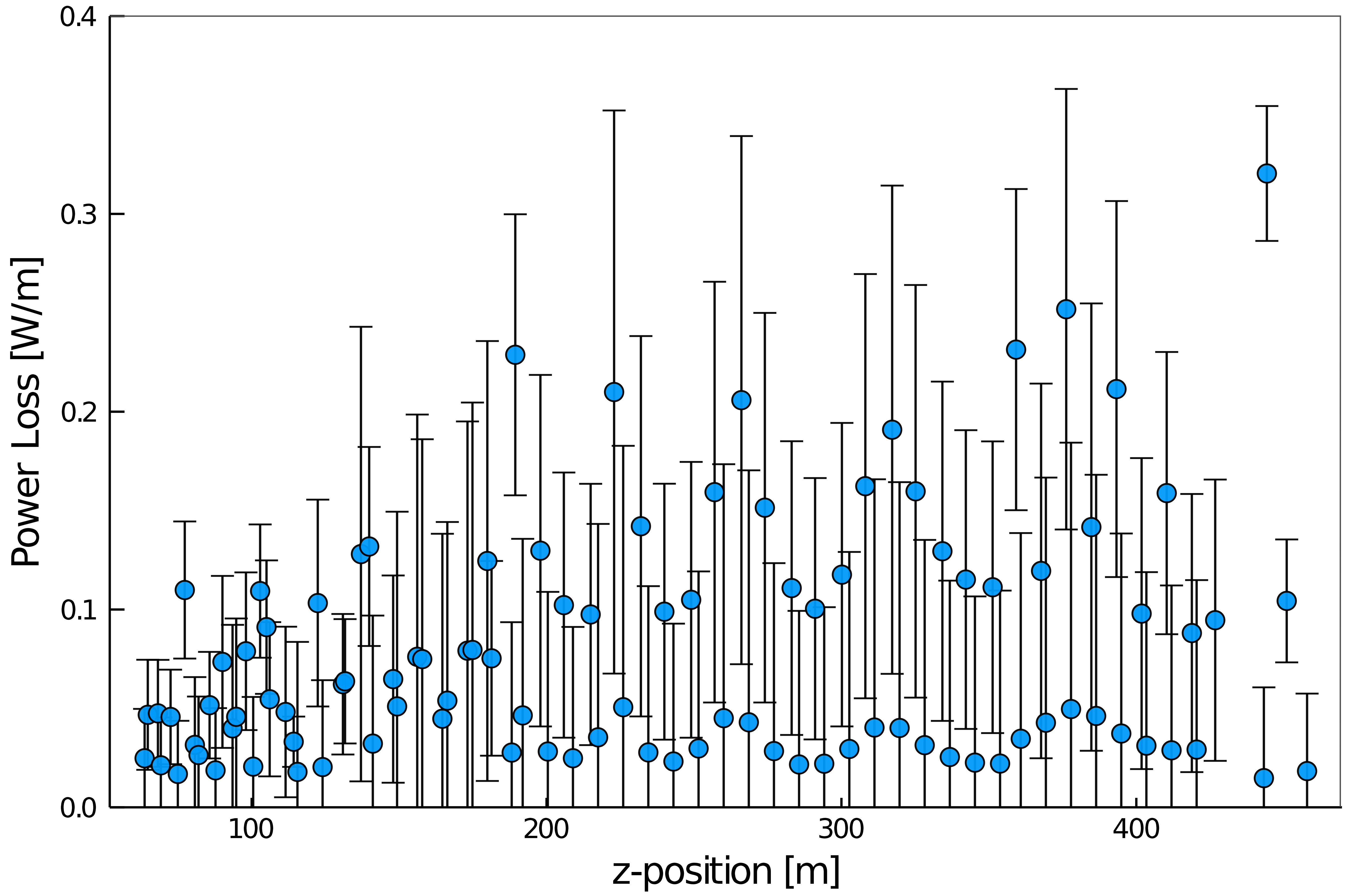
Scenario	Solution	Eta	Investment cost [M€]	Electricity cost per year [M€/y]	Increased system footprint [m²]	Total system height [m]	H^- pulse rise time [μs]
A	SML upgr.	0.82	13.4	14.6	0	3.1	< 120
B	SML upgr.	> 0.80	13.4	14.8	0	3.1	< 80
	SML + PT	> 0.80	26.3	14.8	< 2.5 x 1.5	2.4	60-120
C	SML upgr.	> 0.71	13.4	16.7	0	3.1	< 170
	SML + PT	> 0.72	26.6	16.5	< 2.5 x 1.5	2.4	50-120
Baseline	SML	0.82	N/A	7.30	N/A	2.6	N/A

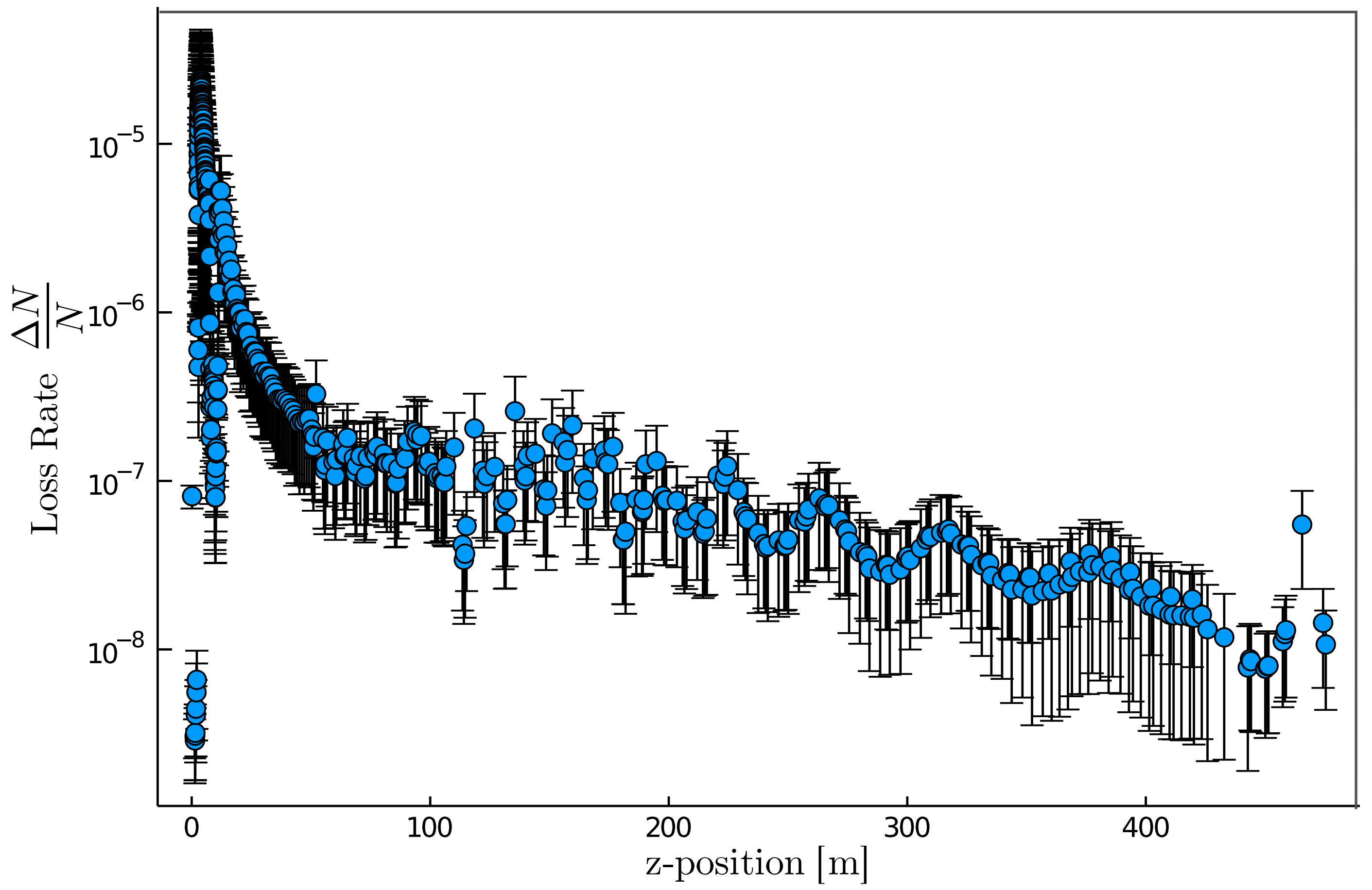


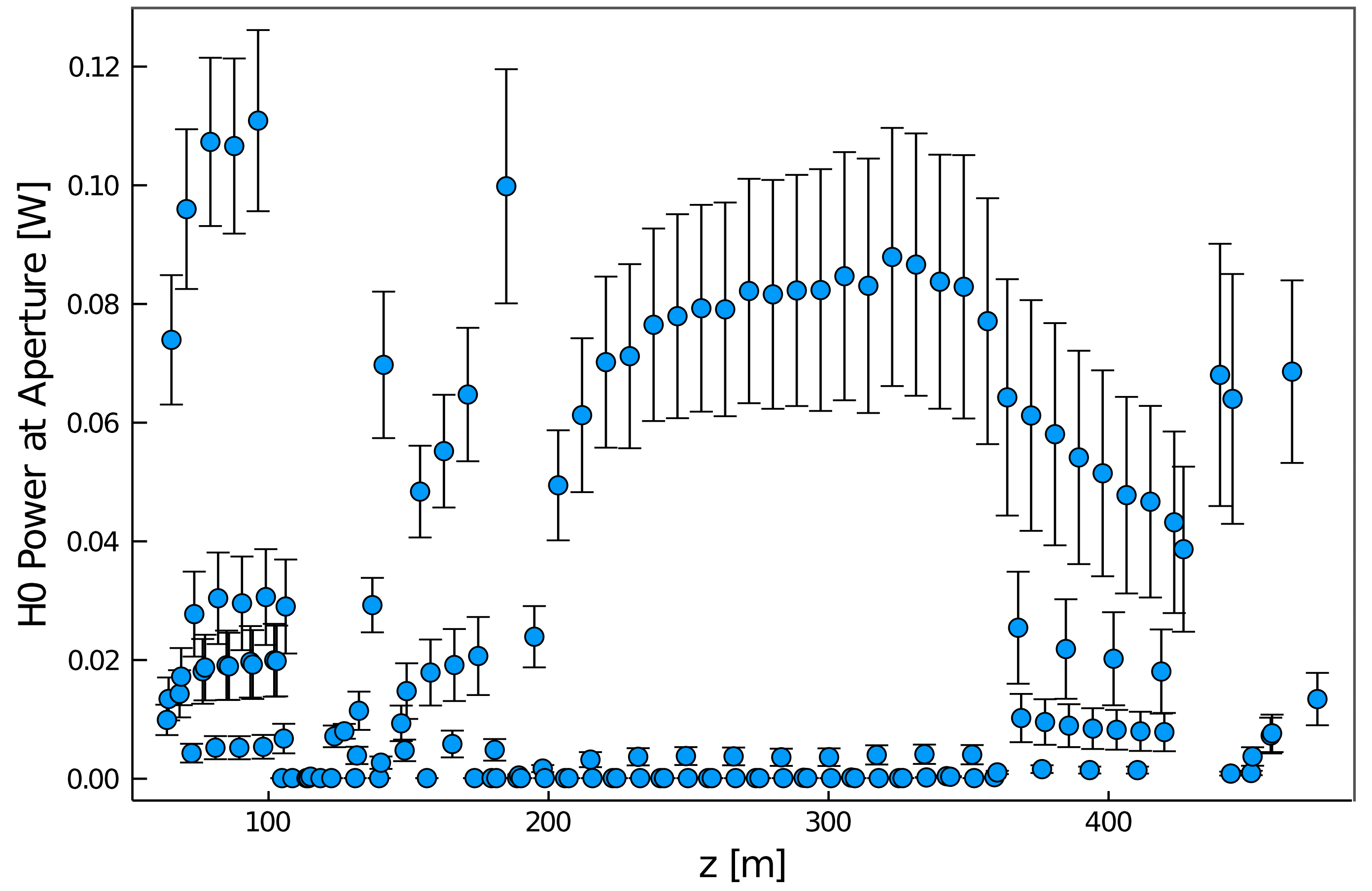
Max Collins and Carlos Martins

INTRA BEAM STRIPPING

$$\frac{1}{N}\frac{dN}{dS} = \frac{N\sigma_t\sqrt{\gamma^2\theta_x^2 + \gamma^2\theta_y^2 + \theta_z}}{8\pi^2\gamma^2\sigma_x\sigma_y\sigma_z} F\left(\gamma\theta_x, \gamma\theta_y, \theta_z\right)$$

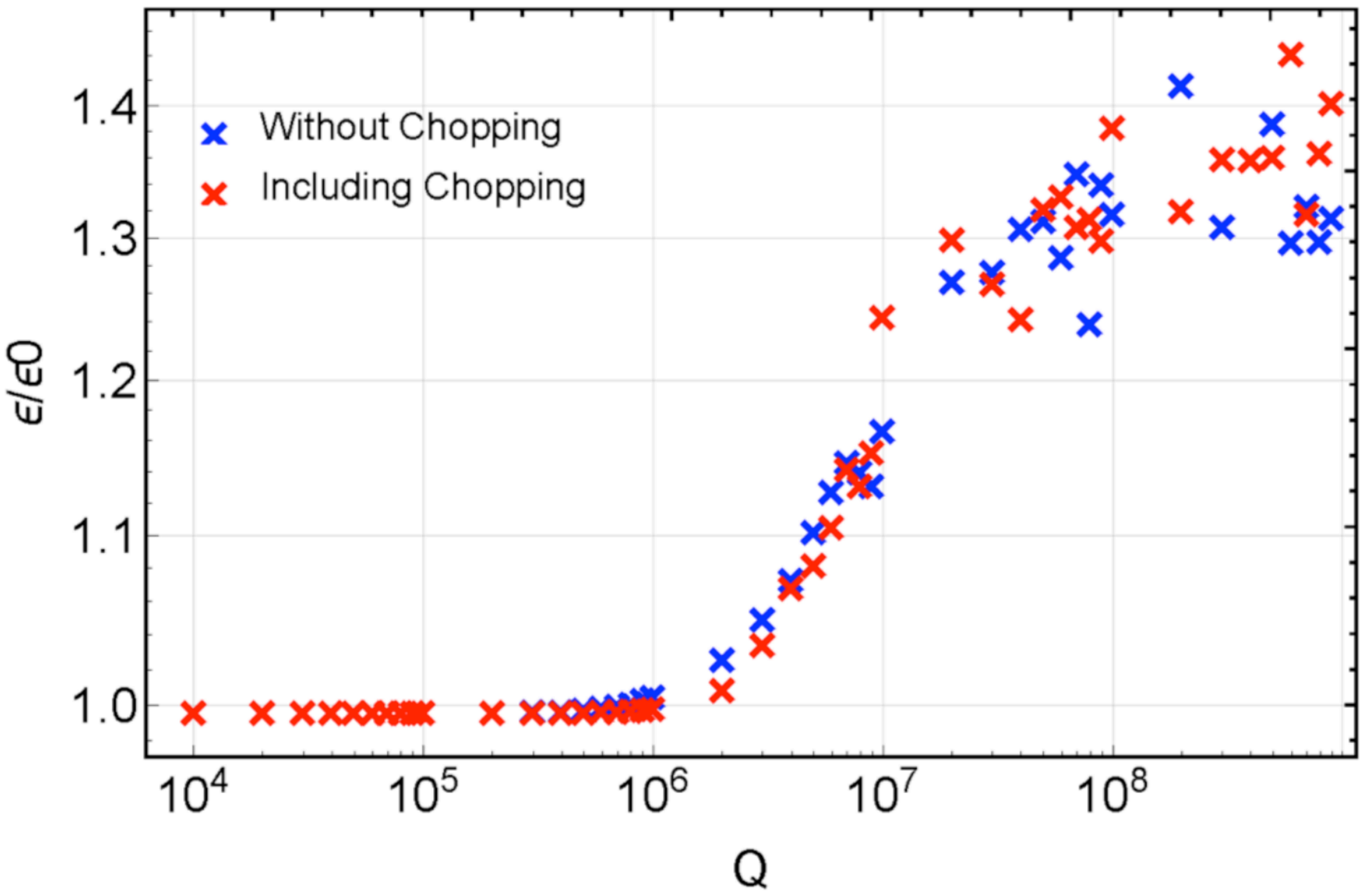


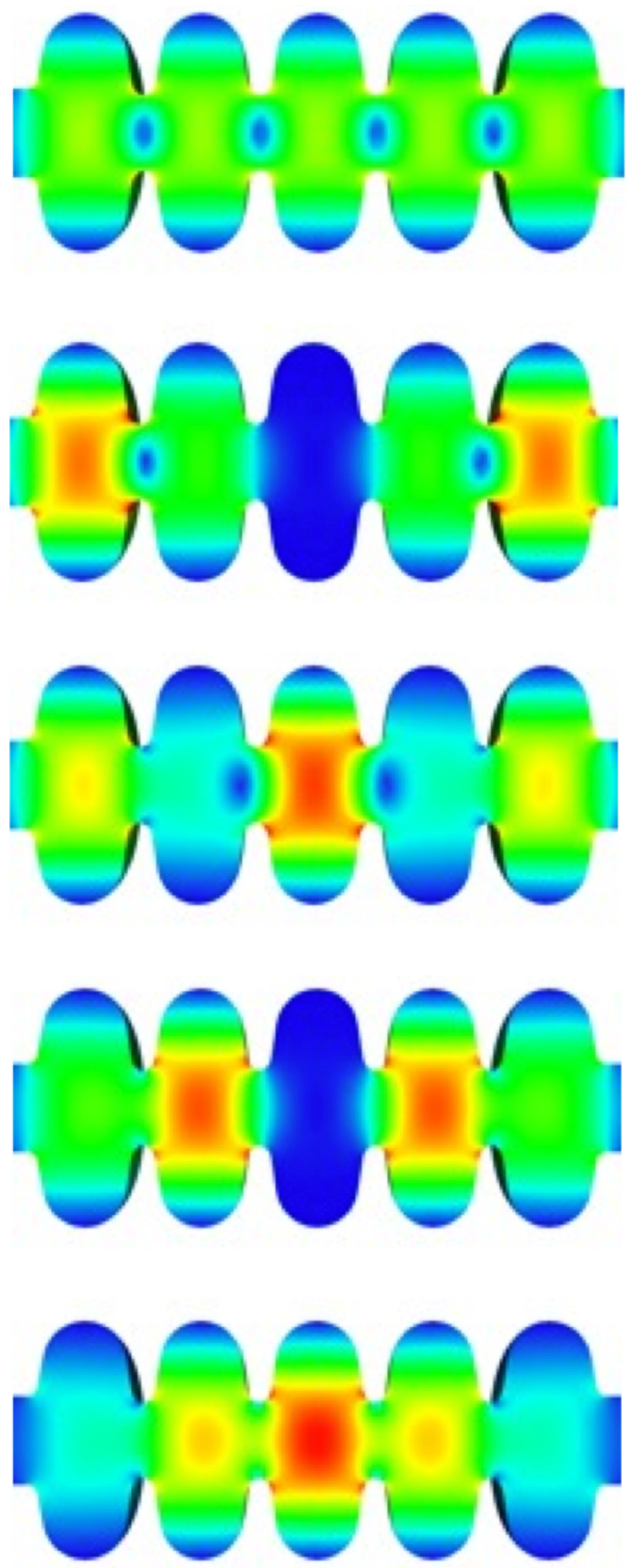




Ben Folsom

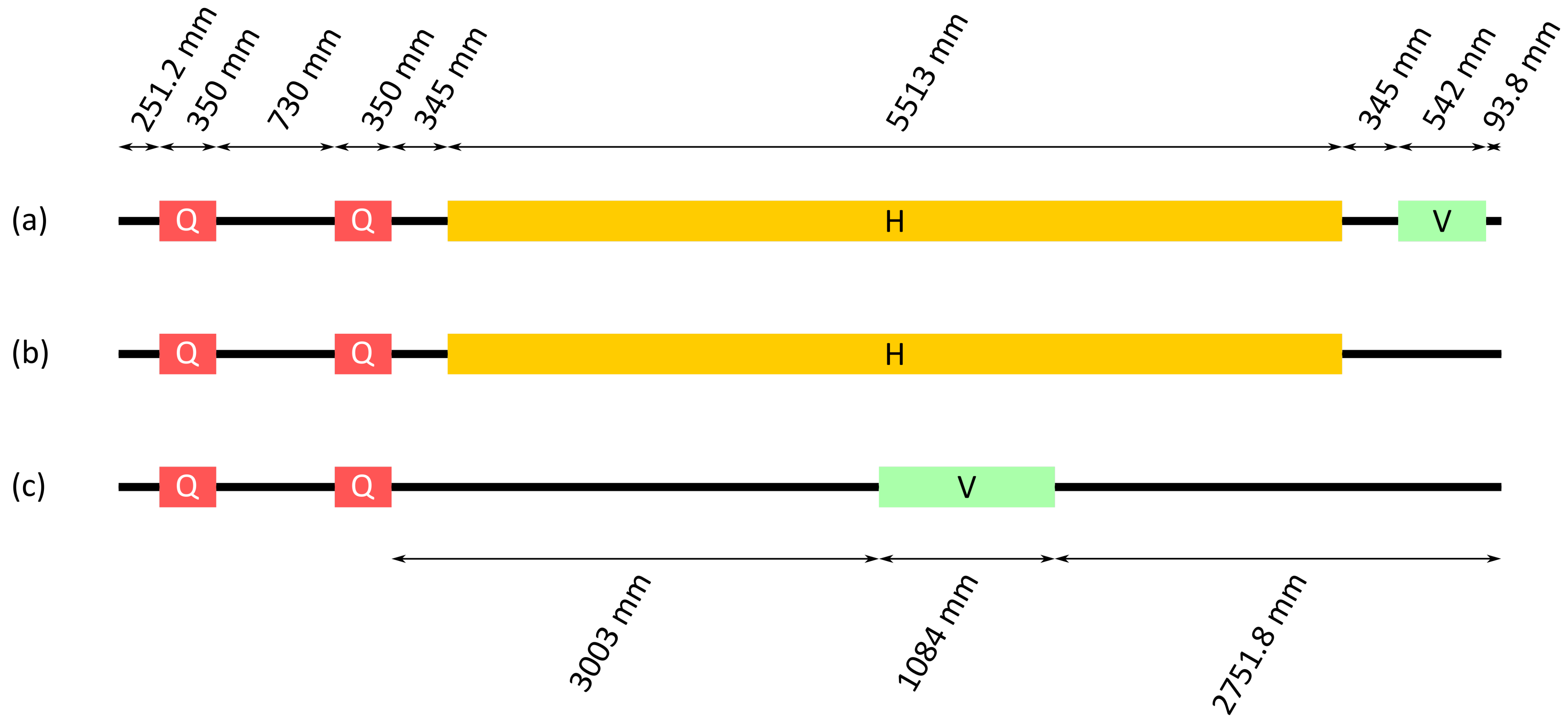
Impact of Higher Order Modes in SC Cavities

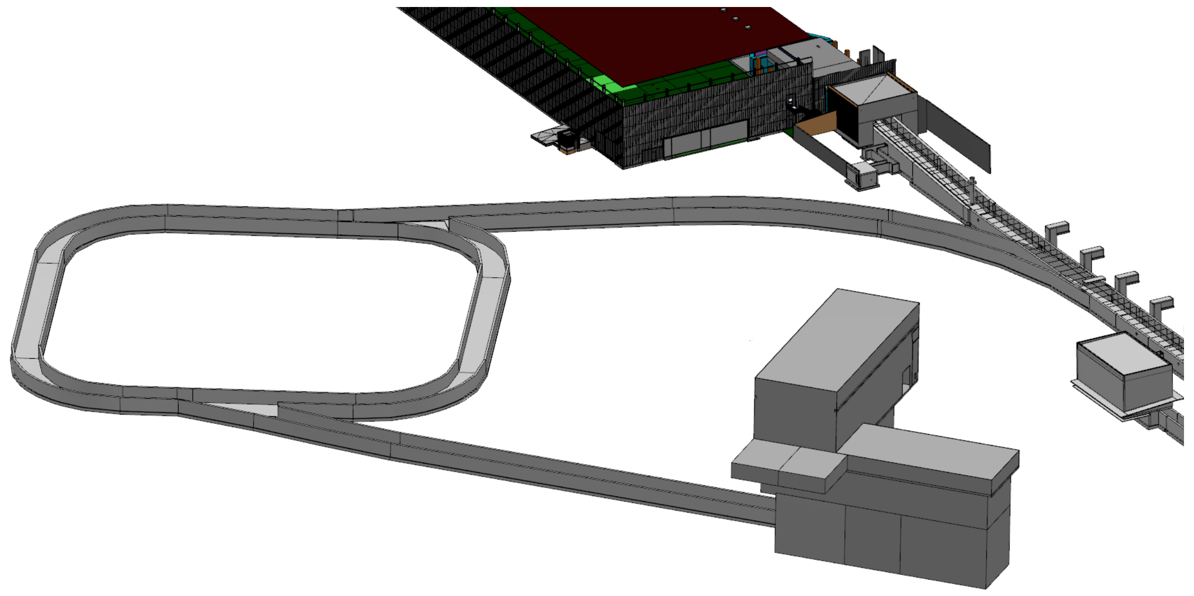




Aaron Farricker

Linac to Ring (L2R) Transfer line



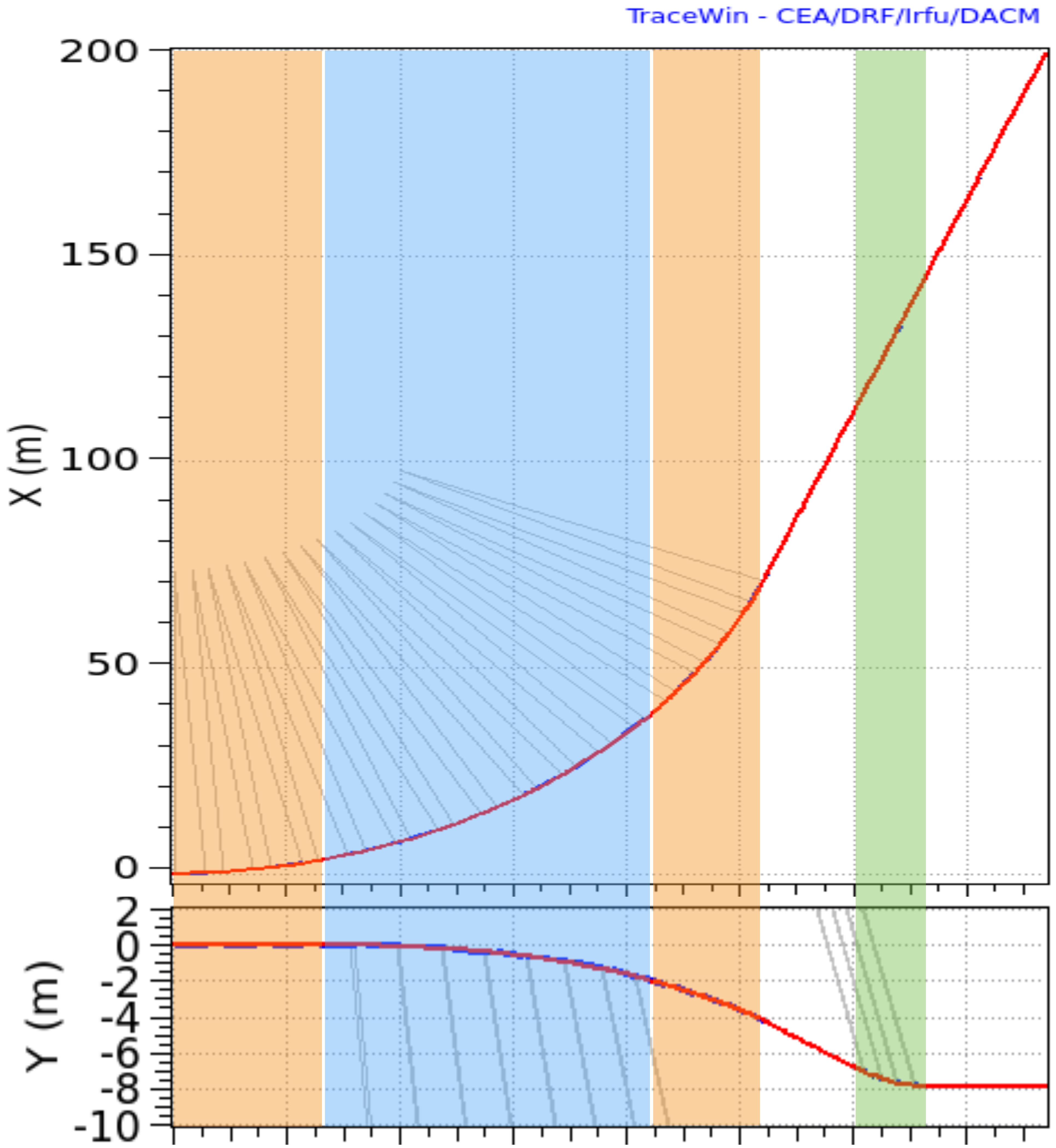


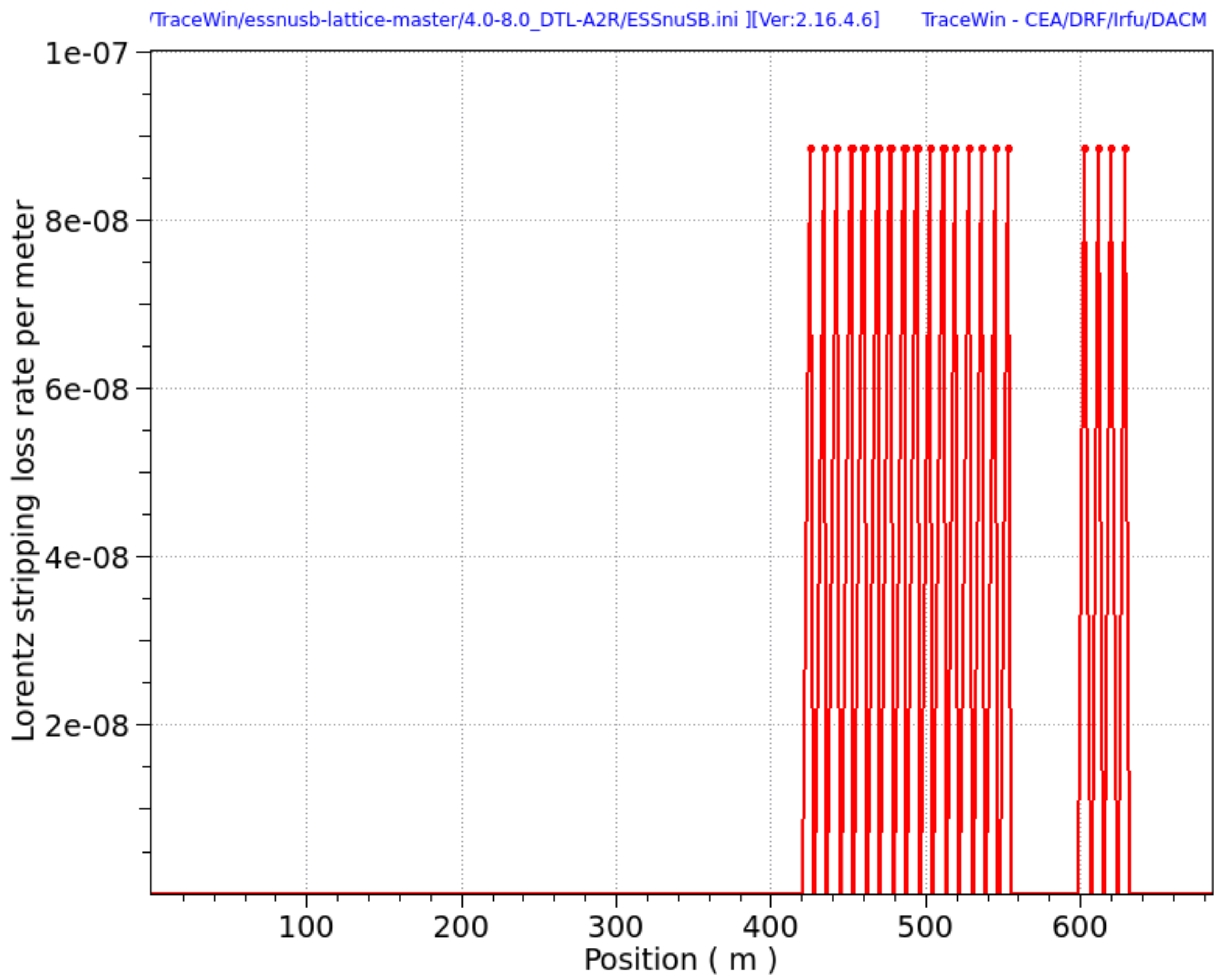
b a b c

AR depth (m)	Lattice cells																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
7.864																																
8.887																																
9.514																																

Neven Blaskovic

Lorentz Force Stripping in the L2R

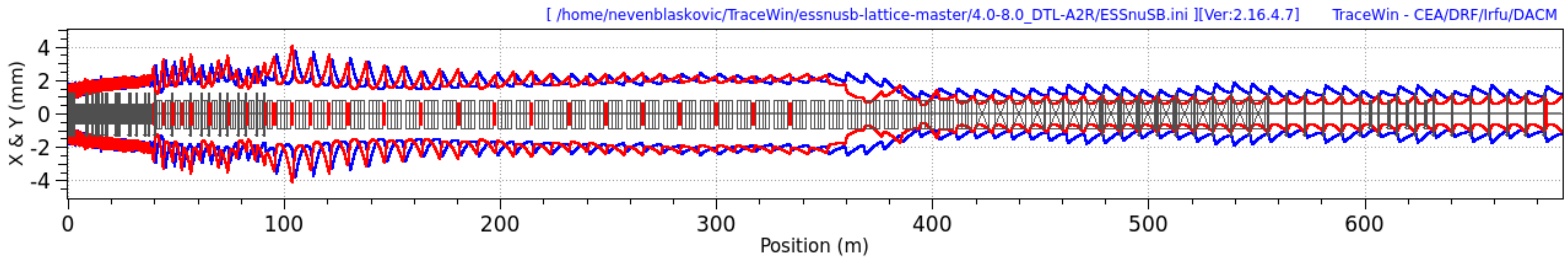


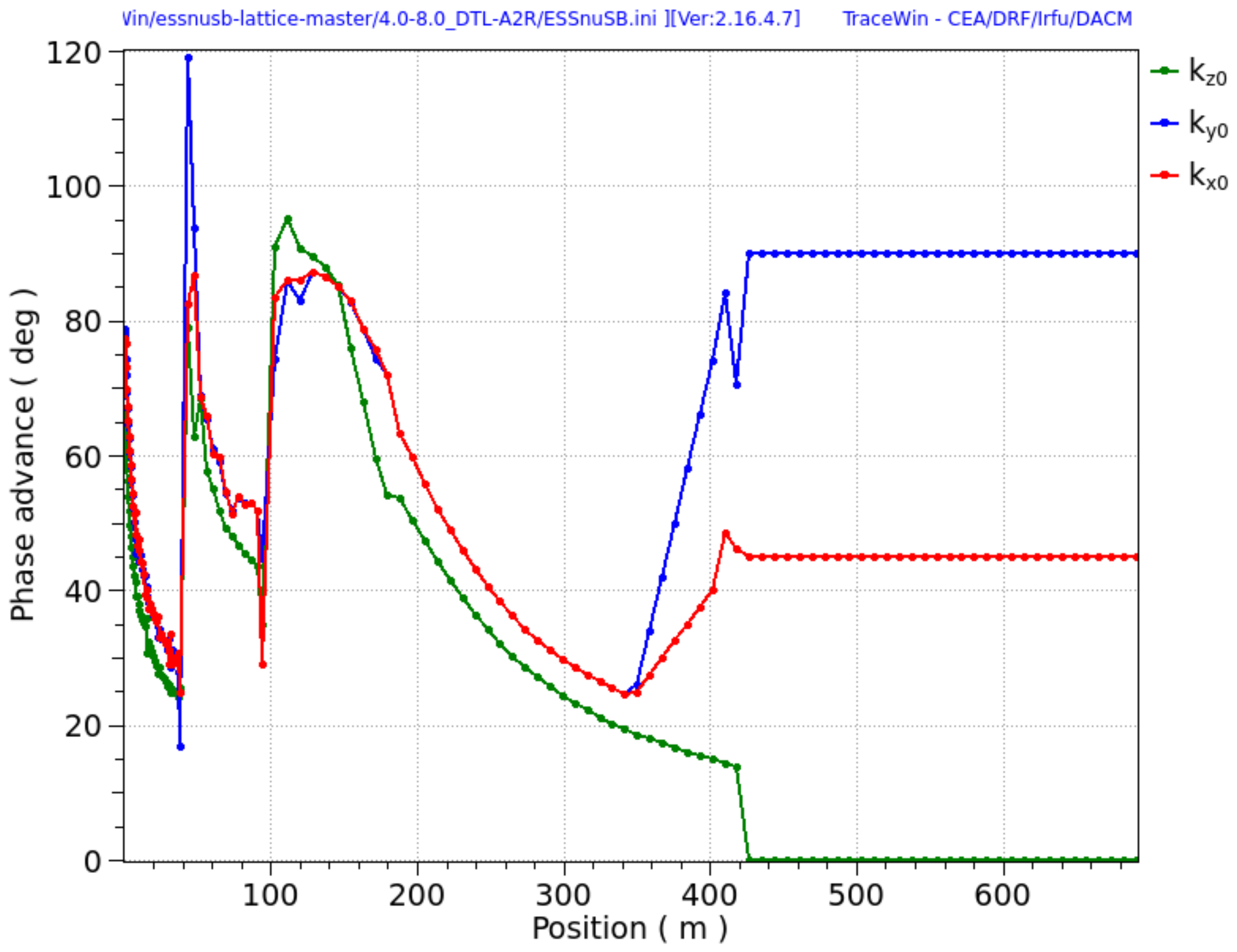


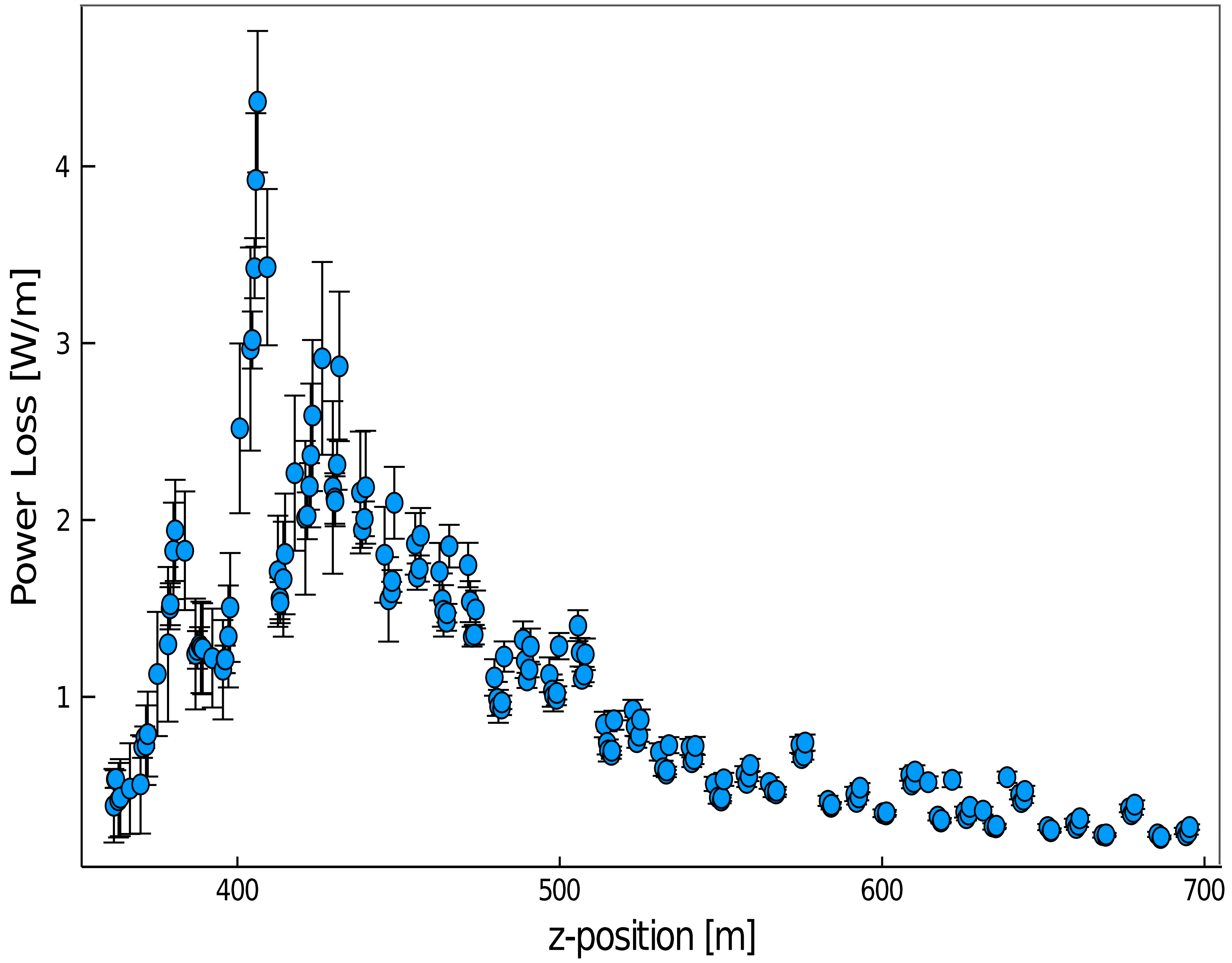
- Tunnel arc bending radius: 110 m
- Dipole bending radius: 73.5 m (corresponding to 0.15 T @ 2.5 GeV)
- Accumulator ring depth: 7.864 m

Neven Blaskovic

INTRABEAM STRIPPING IN THE L2R







Neven Blaskovic, Ben Folsom

SUMMARY

- Feasibility studies so far have not found any show-stoppers on the possibility of using the ESS linac for ESSnuSB
  - Developments in H- ion sources demonstrate a trend which would fit the needs of ESSnuSB
  - Only a couple of structures in the NCL of ESS may need an upgrade
  - RF sources are consumables and could be replaced with adequate ones for ESS+ESSnuSB
    - Existing modulators could be upgraded
  - Losses, which are the main concern in H- beams, are controlled in the linac
    - L2R is being redesigned

Thank you!