



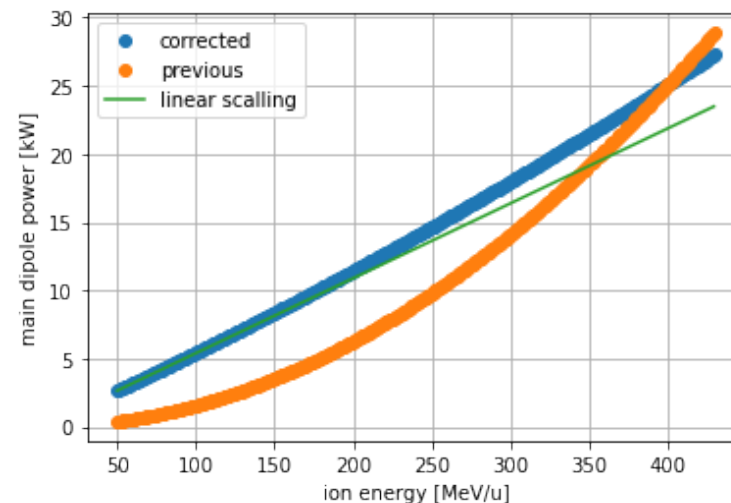
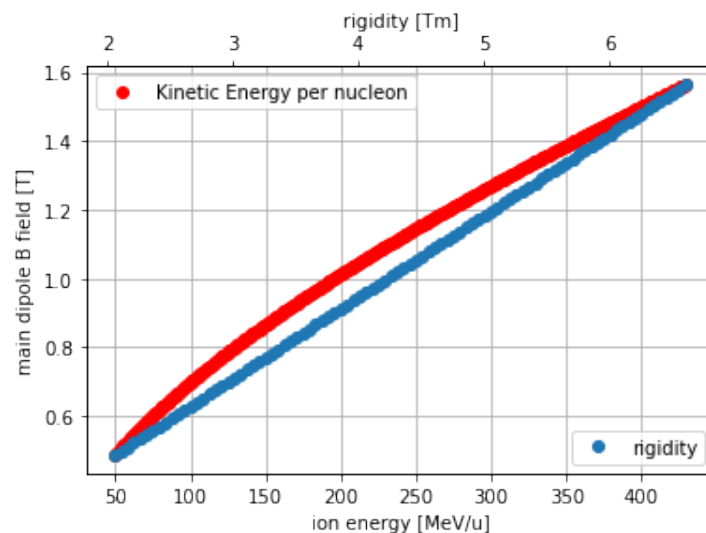
HEBT power consumption - update

Mariusz Sapinski, Feb 23, 2021
NIMMS green energy meeting

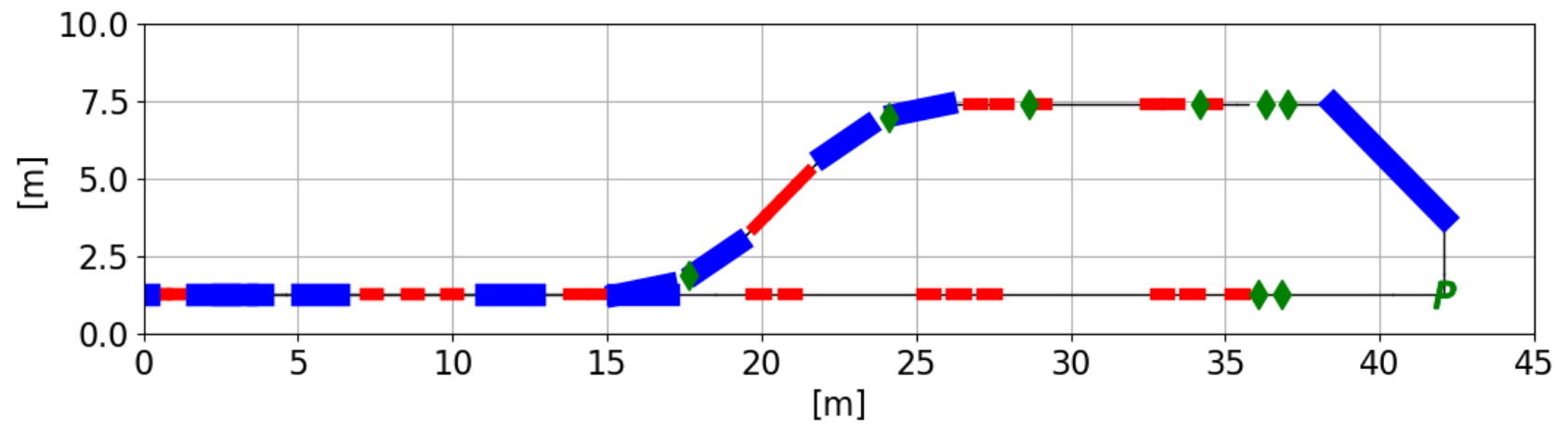
Remarks

Used the power consumption data presented on November 24th, 2020

- 25.1 kW – dipole at 400 MeV/u
- 1.17 kW – quadrupole at max current
- Quad power consumption scales with beam energy the same as dipoles (approximation)
- Corrections to the formula to compute power from beam energy – beam are not relativistic so $B \sim \sqrt{E_k^2 + 2E_k E_0}$, but $P \sim B^2$; The $2E_k E_0$ term dominates so the power scaling deviates not much from linear.



Current HEBT layout - TR1V

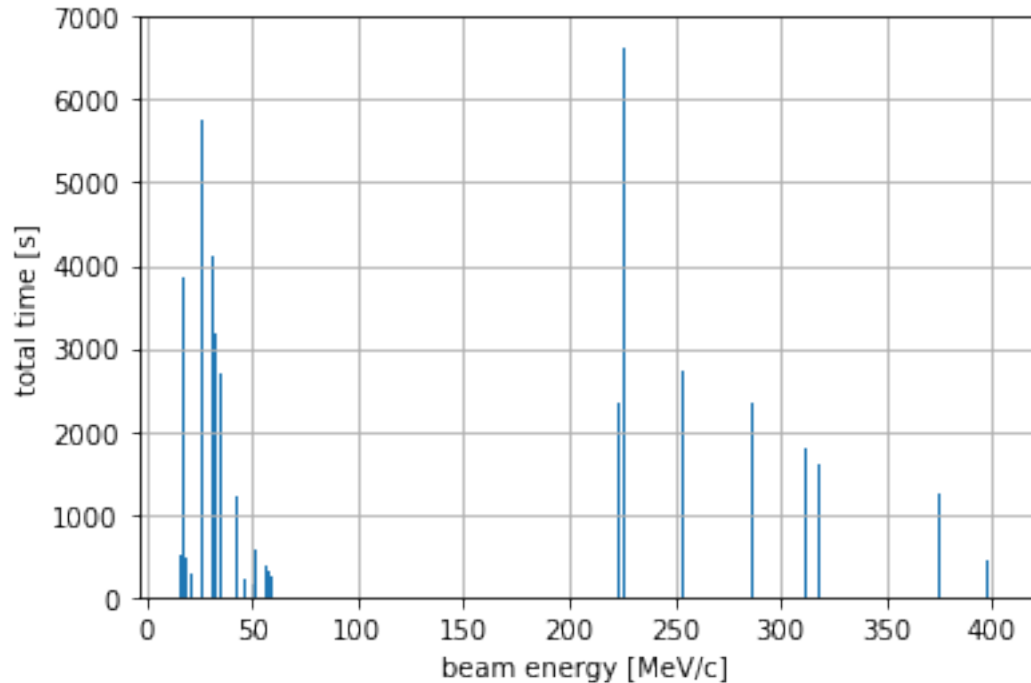


Main magnets (I)

- Regular Dipoles:
 - Angle: 22.5 deg, Field 1.5 T
 - Dissipated DC power at I_{\max} is **25.1 kW**
 - Resistance at 20°C 14.83 mΩ (cables not included)
- Big 90 deg vertical dipole (based on info from Giovanni):
 - Current at max beam energy: 2044 A
 - Resistance: 126 mΩ (cables included)
 - Therefore, power at 400 MeV/u: **526.4 kW**
 - 20x more than 22.5 deg magnets, seems quite a lot

Beam energy distribution

Based on the big CNAO file, using April 2020:



- Average beam energy: 123 MeV/u
- Average beam energy weighted by total duration: 134 MeV/u
- Average E_k^2 weighted by duration: 184 MeV/u
- For March: 197.6 MeV/u
- For May: 195.4 MeV/u
- For October: 182.3 MeV/u

To get HEBT energy consumption the total duration of the beam-on state should be taken into account, and this is about 170-180 hours/month.

Power consumption at 400 MeV/u

Beam line	#dipoles	#quads	P dipoles [kW]	P quads [kW]	• P total [kW]
TR1H	3	17	75.3	5.6	80.9
TR1V	7 (+1)	17	175.7 (+ 526.4)	6.8	708.9
TR2 (H)	3	17	75.3	12.1	87.4
TR3 (without gantry)	3	20	75.3	14.5	89.8
EX1	3	16	75.3	12.8	88.1
EX2	3	18	75.3	13.0	88.3

Power consumption at 184 MeV/u

Beam line	#dipoles	#quads	P dipoles [kW]	P quads [kW]	P total [kW]
TR1H	3	17	34.3	2.34	36.7
TR1V	7 (+1)	17	319.9	2.82	322.73
TR2 (H)	3	17	34.30	5.04	39.35
TR3 (without gantry)	3	20	34.30	6.02	40.33
EX1	3	16	34.31	5.31	39.62
EX2	3	18	34.31	5.31	39.62

Conclusions

- 1) All horizontal beam lines have similar power consumption of ~ 90 kW at 400 MeV/u and ~ 40 kW at 184 MeV/u.
- 2) Vertical beam line power consumption dominated by vertical dipole (700 kW at maximum energy).
- 3) The power is driven by dipoles (85-95%, at lower energy quadrupole contribution is larger).
- 4) For all horizontal lines there are 3 active dipoles in a given moment, so the power consumption is almost the same for all of them.
- 5) The energy consumed by active magnets per month is about 7.5 MWh (without vertical line contribution), it corresponds to cost of about 750 euros (Croatia: 0.1 euro/kWh)