HEBT power consumption

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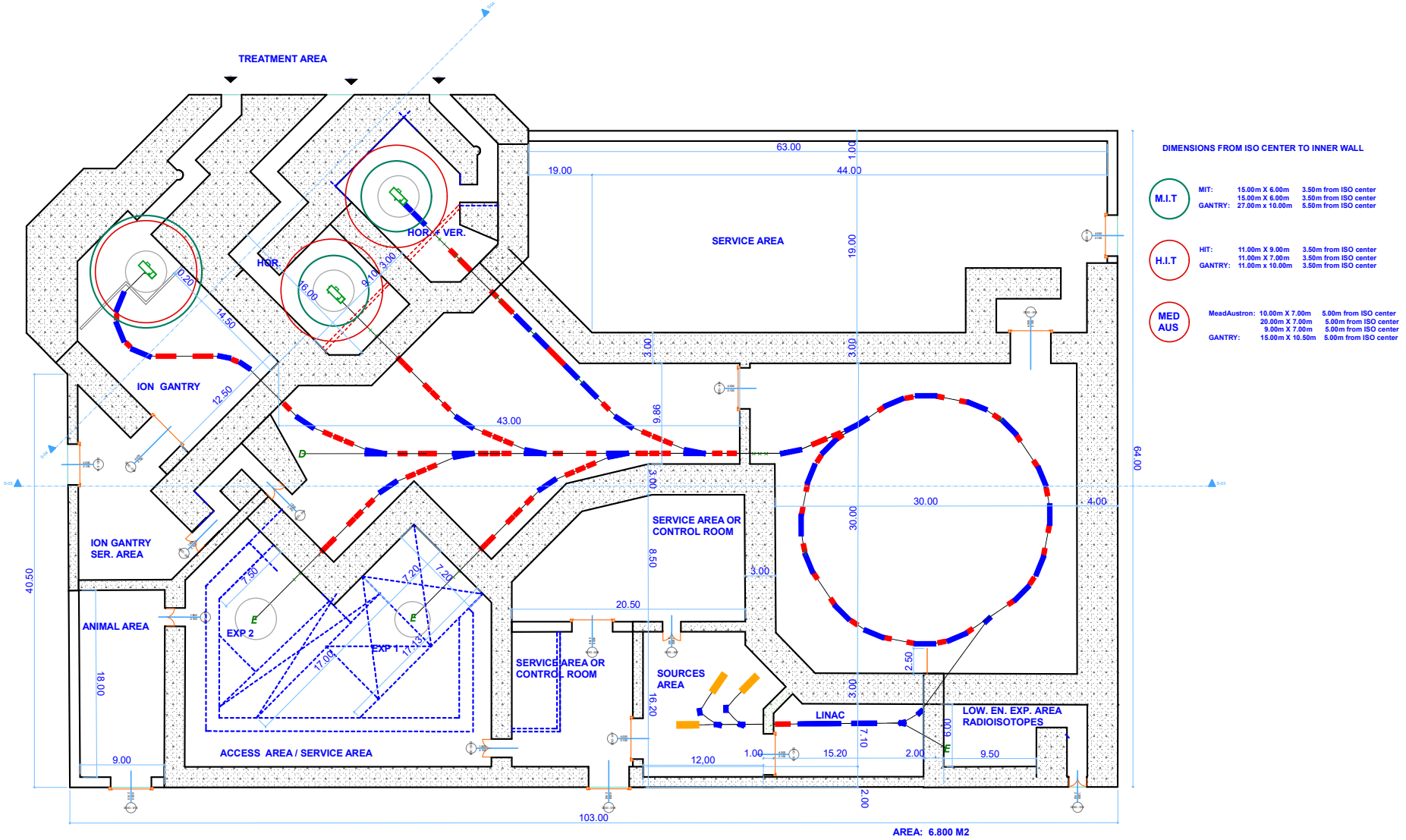
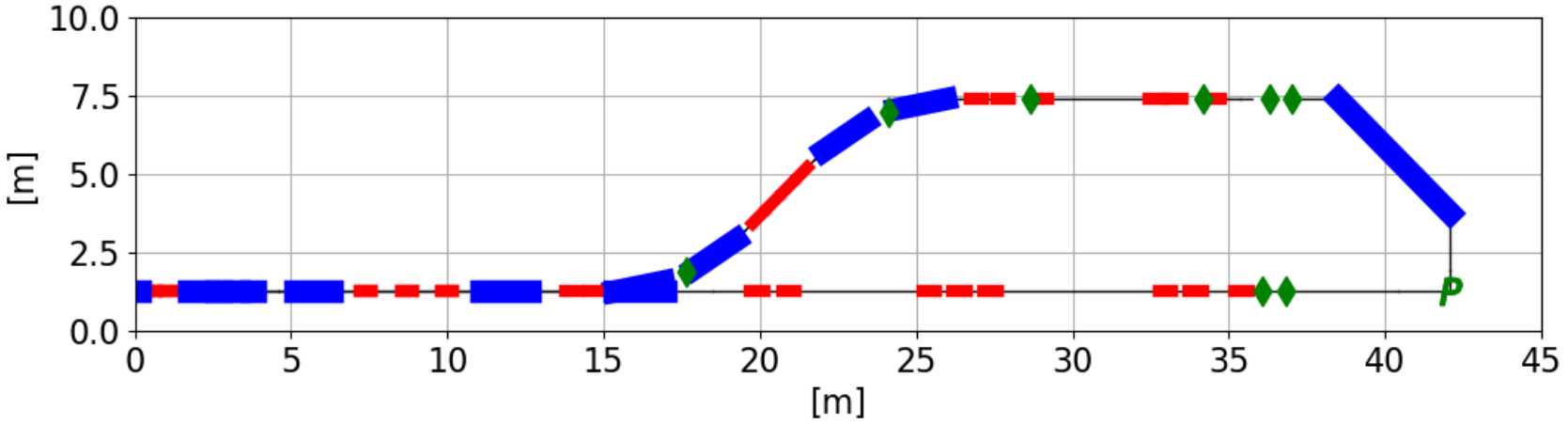
Remarks

- 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
- Idle power consumption and ramping losses not included
- Dipole nonlinearity above 1.5 T (400 MeV/u) – not considered
- 6 beam lines
- Results are preliminary, verifying the analysis script

Current HEBT layout



Current HEBT layout - TR1V



Main magnets (I)

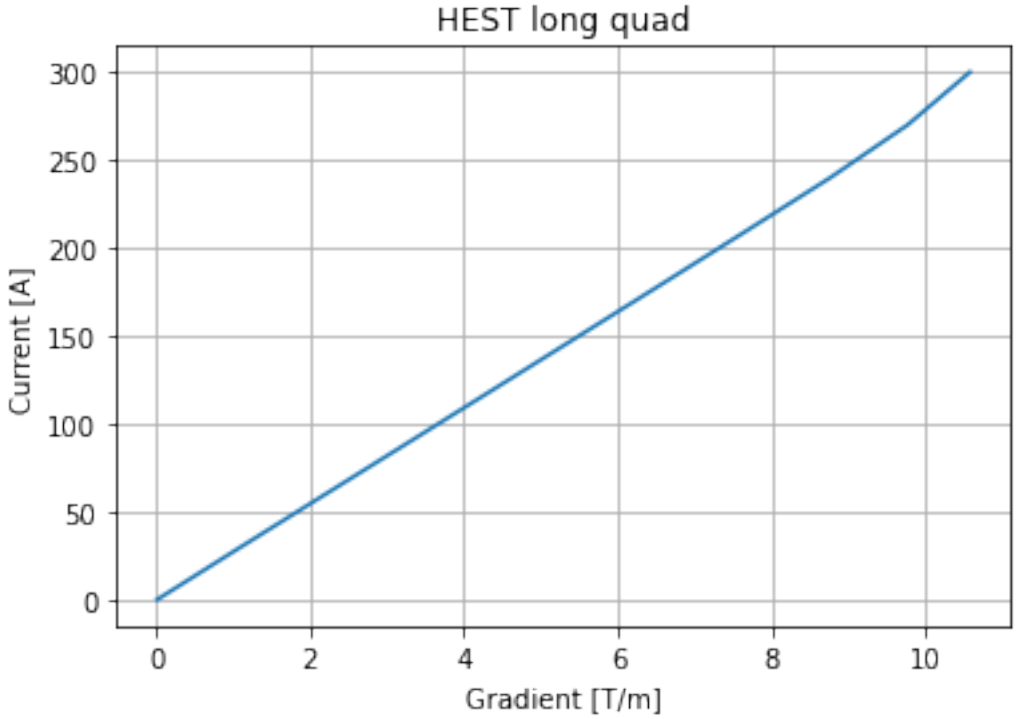
- Dipoles:
  - Angle: 22.5 deg, Field 1.5 T
  - I_{max}=1300 A (1500 A with saturation)
  - Dissipated DC power at I_{max} is **25.1 kW**
  - Resistance at 20°C 14.83 mΩ
  - Inductance L=11.33 mH
  - Ramping loss $E_{ramp}=LI^2/2$ = 10 kJ
    – no energy saving if ramp every second! So just correct for rigidity
  - Number of dipoles: 6 switching + 6 bending = 12 total
  - Currently we have 90 degree huge dipole for vertical line, I have no data for this magnet
  - At a given moment there are 3 to 7(+big 90deg) dipoles powered

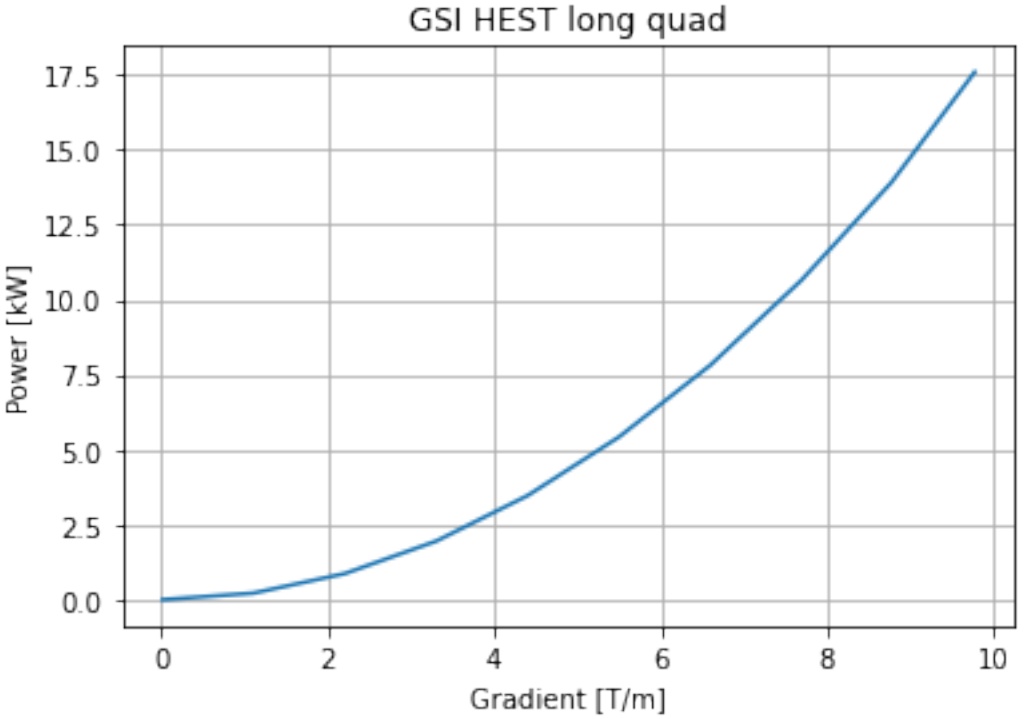
Main magnets (II)

- Quadrupoles:
  - Imax=135 A
  - Dissipated DC power at Imax **1.17 kW**
  - Resistance at 20°C 64.1 mΩ (long quads) or 41.1 mΩ (short)
  - Inductance 36.42 mH/18.84 mH
  - Ramping loss $E_{ramp}=LI^2/2$ = 330 J
    – rather small gain when ramping down between shots

Example: GSI HEST quadrupole

- Imax=270 A (up to 300 A with iron saturation)
- Dissipated DC power at Imax: **17.6 kW**
- Resistance at 20°C: 241.3 mΩ





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 (+ ?)	6.8	182.5+?
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 140 MeV/u

Beam line	#dipoles	#quads	P dipoles [kW]	P quads [kW]	P total [kW]
TR1H	3	17	9.2	1.8	11.0
TR1V	7 (+1)	17	21.5 (+ ?)	2.1	23.6 +?
TR2 (H)	3	17	9.2	3.8	13.0
TR3 (without gantry)	3	20	9.2	4.5	13.7
EX1	3	16	9.2	4.0	13.2
EX2	3	18	9.2	4.1	13.3

Conclusions

1) All horizontal beam lines have similar power consumption of ~90 kW at 400 MeV/u and ~13 kW at 140 MeV/u
2) The power is driven by dipoles (85-95%, at lower energy quadrupole contribution is larger)
3) 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
4) Vertical beam line consumes ~3 times more power because it has 7 dipoles instead of 3 plus one 90 deg dipole which dominates the power consumption (but I have no data for it).