Discussion on eRHIC FFAG Design for 20GeV

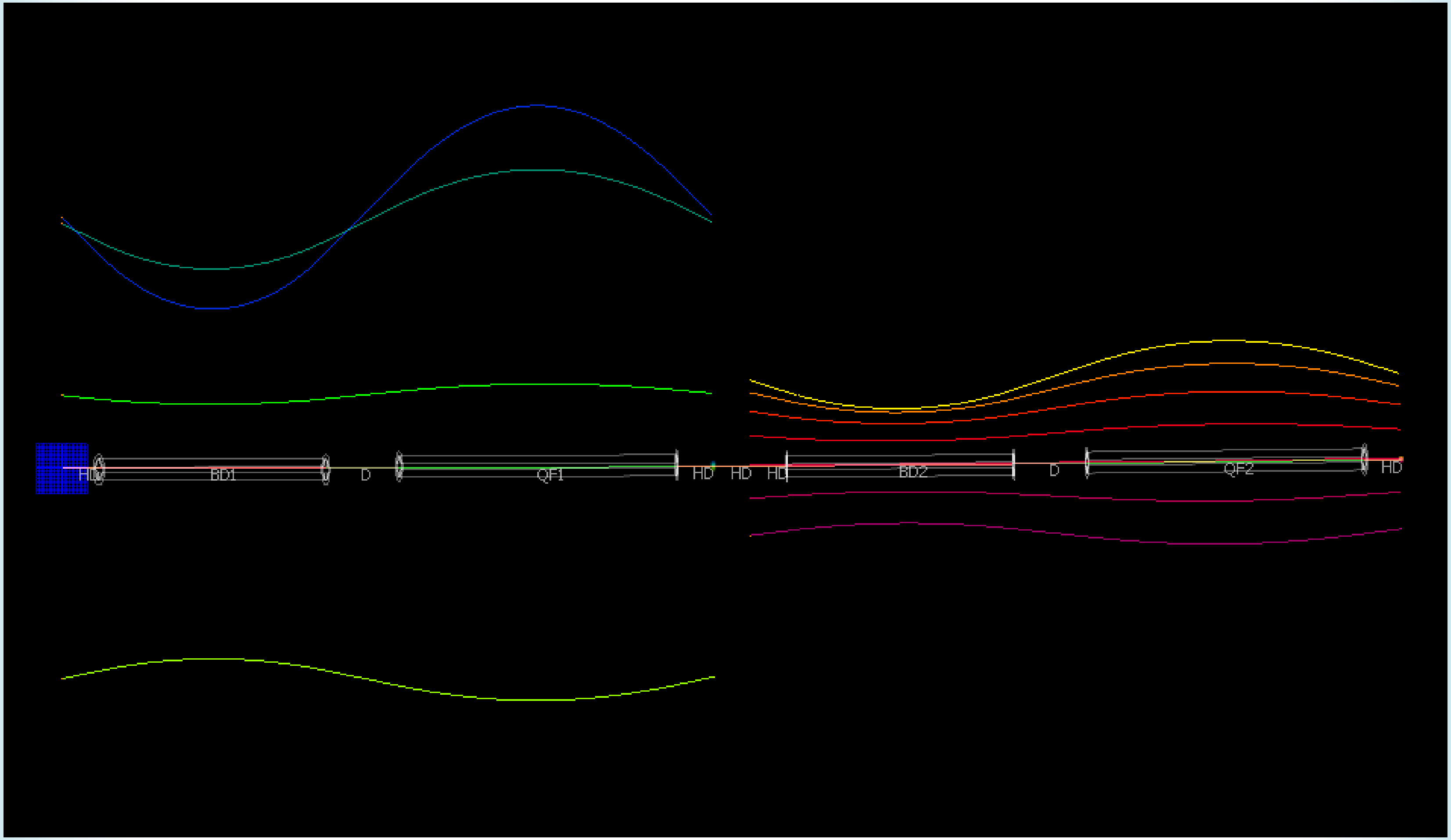
I. Muon1 Verification of Vadim's Lattice
II. Permanent Magnet Upgrade Issues
III. Scaling of Quadrupole Size

I. Muon1 Verification of Vadim's Lattice

Introduction

- Vadim found different splits of 11 turns between the two FFAGs reduces the synchrotron radiation
- I will show the 4+7 split case scaled up to 20GeV
- FFAG 1: 1840 – 7288MeV (3.96×)
- FFAG 2: 9104MeV – 20GeV (2.20×)
- Linac energy: 1816MeV; 24MeV injector

Orbits Exaggerated 100x

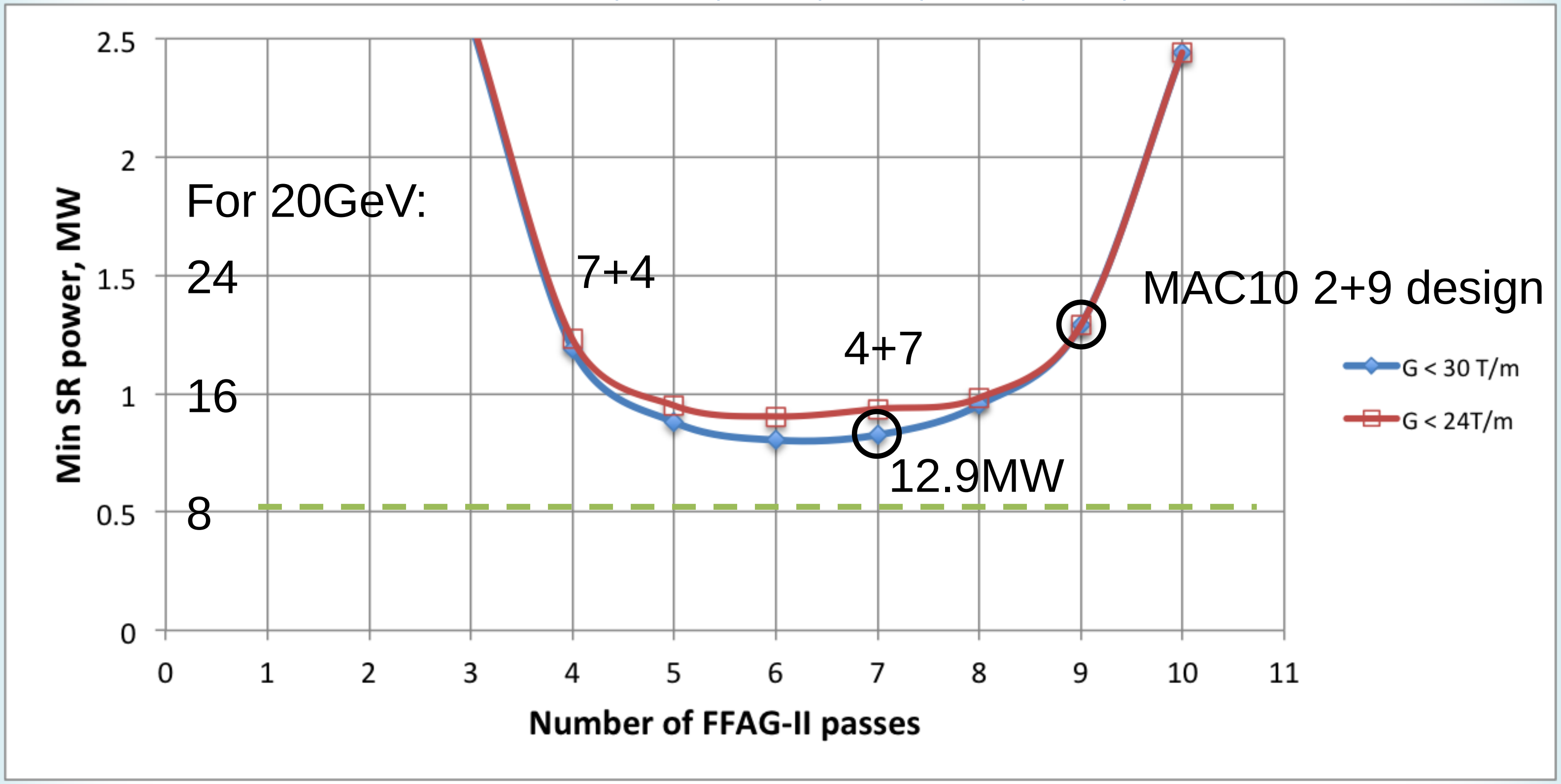


Comparison

Parameters	FFAG 1	FFAG 2	MAC10 FFAG 2
Energy range	1840 – 7288MeV	9104MeV – **20GeV**	2736MeV – 10GeV
Energy ratio	3.96×	2.20×	3.65×
Max |**B**| on orbit	0.1809 T	0.3870 T	0.2570 T
Synchrotron power	0.277MW	12.638MW	1.221MW
TOF range	43.4ppm	14.5ppm	35.6ppm
Tune range	0.036-0.395	0.036-0.395	0.038-0.406
Orbit range (quads)	23.6mm	8.1mm	19.6mm

Vadim's Graph

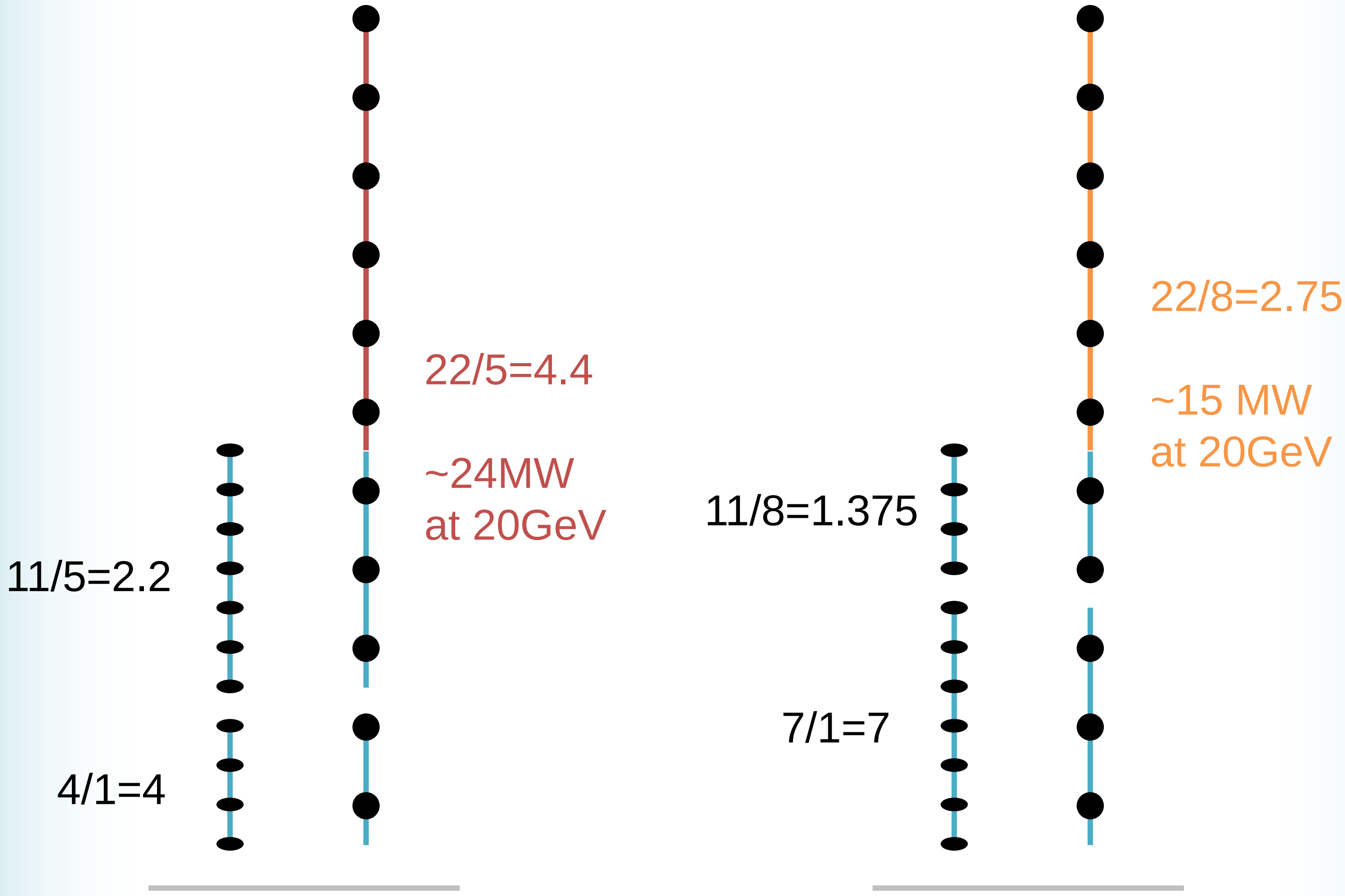
Ratio of FFAG 2: **1.37**, **1.57**, **1.83**, **2.20**, **2.74**, **3.65**, **5.47**



Ideal case: uniform field, 11 turns, 20GeV = **8.26MW** (using R=382.13m)

II. Permanent Magnet Upgrade Issues

Trying to extend range upwards



Extra Costs of Upgrading

- Compromises performance
  - FFAG energy ranges will be non-optimal in at least one of the stages
- If we use permanent magnets in the splitters, they have to be entirely rebuilt
  - Also septums, line to detector
- Avoid some of this by using EM quads in splitter and detector lines
  - But should compare with cost of just using EM quads everywhere (allows optimal upgrade)

Scope of February Design Report

- Still seems to be undecided
- I'd recommend a single lattice nominally for 20GeV, no upgrade scheme, but could be optionally implemented in EM quads
- Discuss…

III. Scaling of Quadrupole Size

Gradient/Cell Length Scaling

- There is another way to "scale" FFAG lattices besides energy and B-field
- Orbit offsets $\propto$ 1/Gradient
- B fields constant
- Cell length $\propto$ 1/sqrt(Gradient)
  - Also element lengths and angle per element
  - Beta functions (focal lengths) scale as cell length to keep cell optically the same to first order

Result of Gradient Scaling

- Max quadrupole field in good field region stays the same, but aperture is free to vary
  - E.g. 20GeV FFAG 2 requres $|\mathbf{B}|_{max}$ = 0.387 T
- Finding aperture for minimum cost per metre is now an engineering problem not a beam optics problem
- Warning: I haven't worked out how the TOF variation scales with this yet

Possible Parametrisation of Costing

- Cost/length =
  - Per-length costs +
  - Per-magnet costs * G^0.5 +
  - Material volumetric costs * G^-2 +   [is this right?]
  - Corrector copper costs * G^{2?}
- Correctors get harder with increasing G since B_error = G * x_error
  - And there is less room, proportional to 1/G

One Final Thing

- According to Brett Parker, the vertical gap size required for the synchrotron radiation fan to get out is a critical dimension for all the engineering (vacuum pipe, magnet poles etc.) that go around it. I haven't seen anyone calculate this, we should figure out a value.