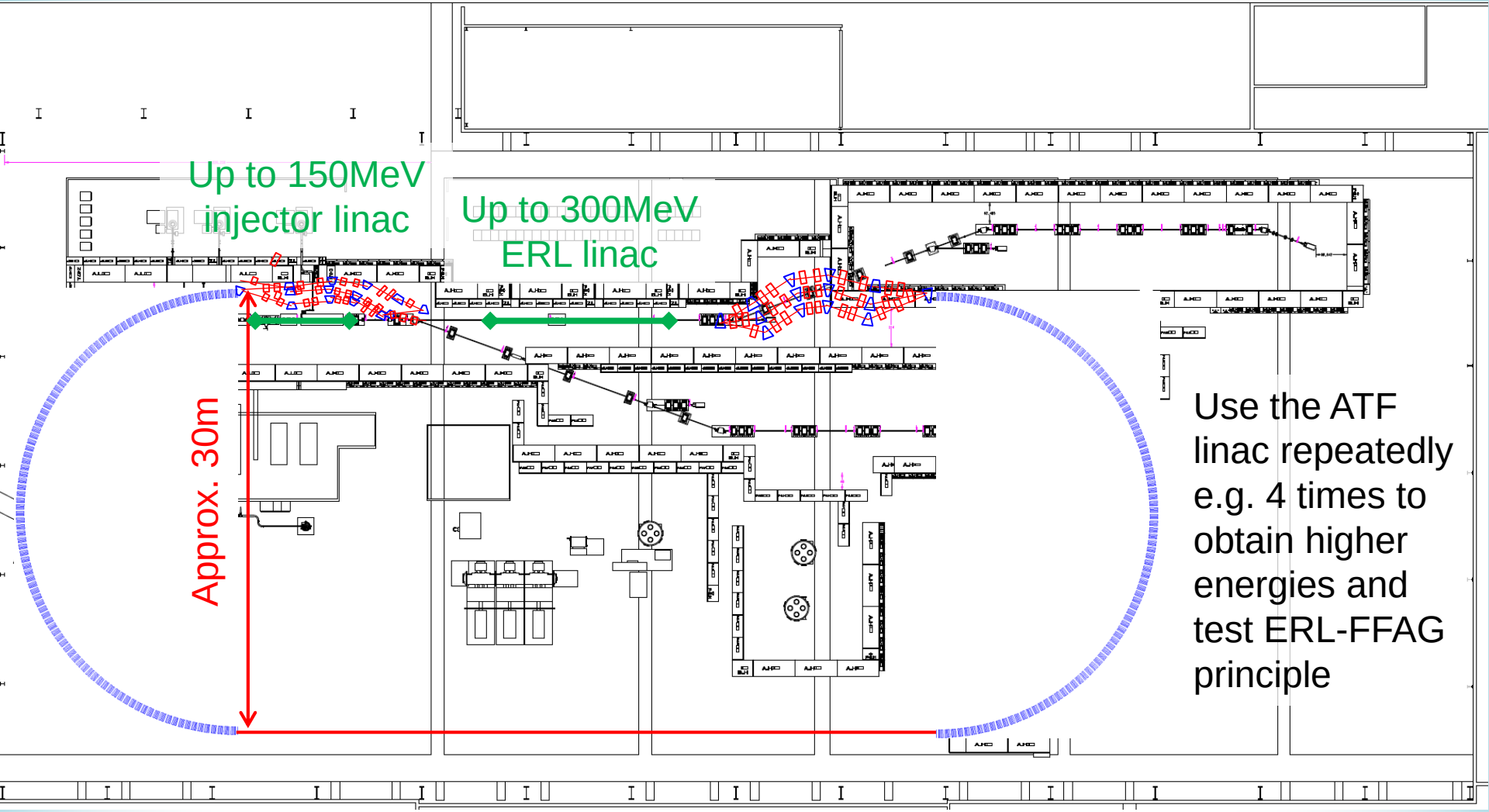
Making the ATF into an ERL-FFAG

In relation to eRHIC risks addressed

Approximate Site Layout (Dejan)



Use the ATF linac repeatedly e.g. 4 times to obtain higher energies and test ERL-FFAG principle

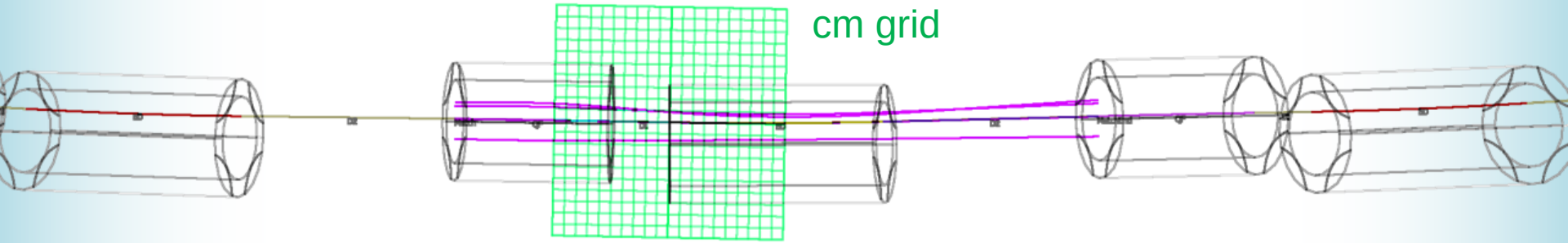
* not scaling FFAG laws

FFAG scaling* laws

Scaling type (by factor a)	Length	Angle	Dipole	Gradient	Quad offset (=dipole/grad) & orbit excursion
Momentum (~energy)	1	1	a	a	1
Machine radius	a	1	a^{-1}	a^{-2}	a
FFAG beta length (fixed bend radius, fixed cell tune)	a	a	1	a^{-2}	a^2
FFAG arc-to-straight (=row 3/row 2)	1	a	a	1	a
FFAG radius with fixed orbit excursion and field (row 2*row 1/sqrt(row 3))	$a^{1/2}$	$a^{-1/2}$	1	1	1

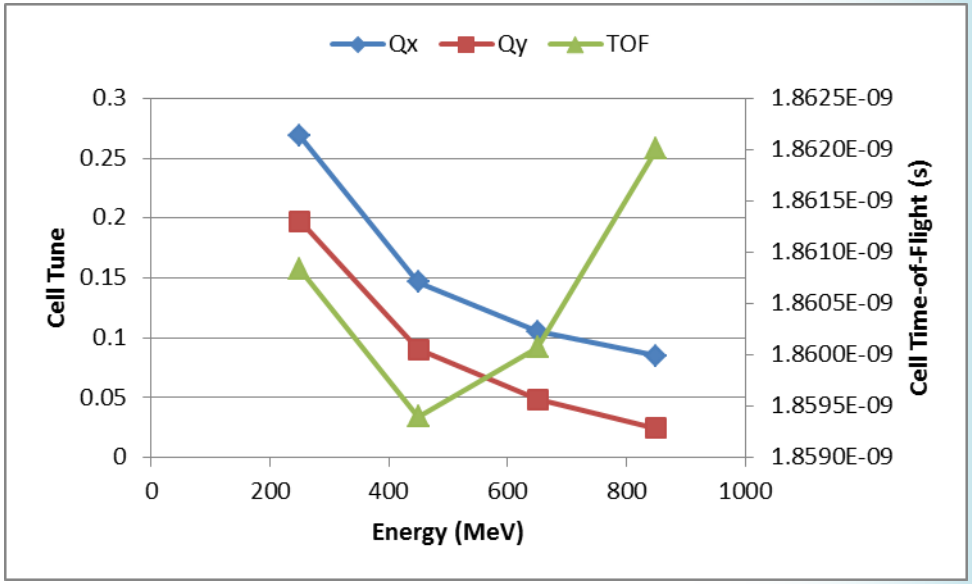
I'm going to use this one and the optimised 10.5m diameter Cβ cell as a start.

Cβ-like Cell (can use iron)



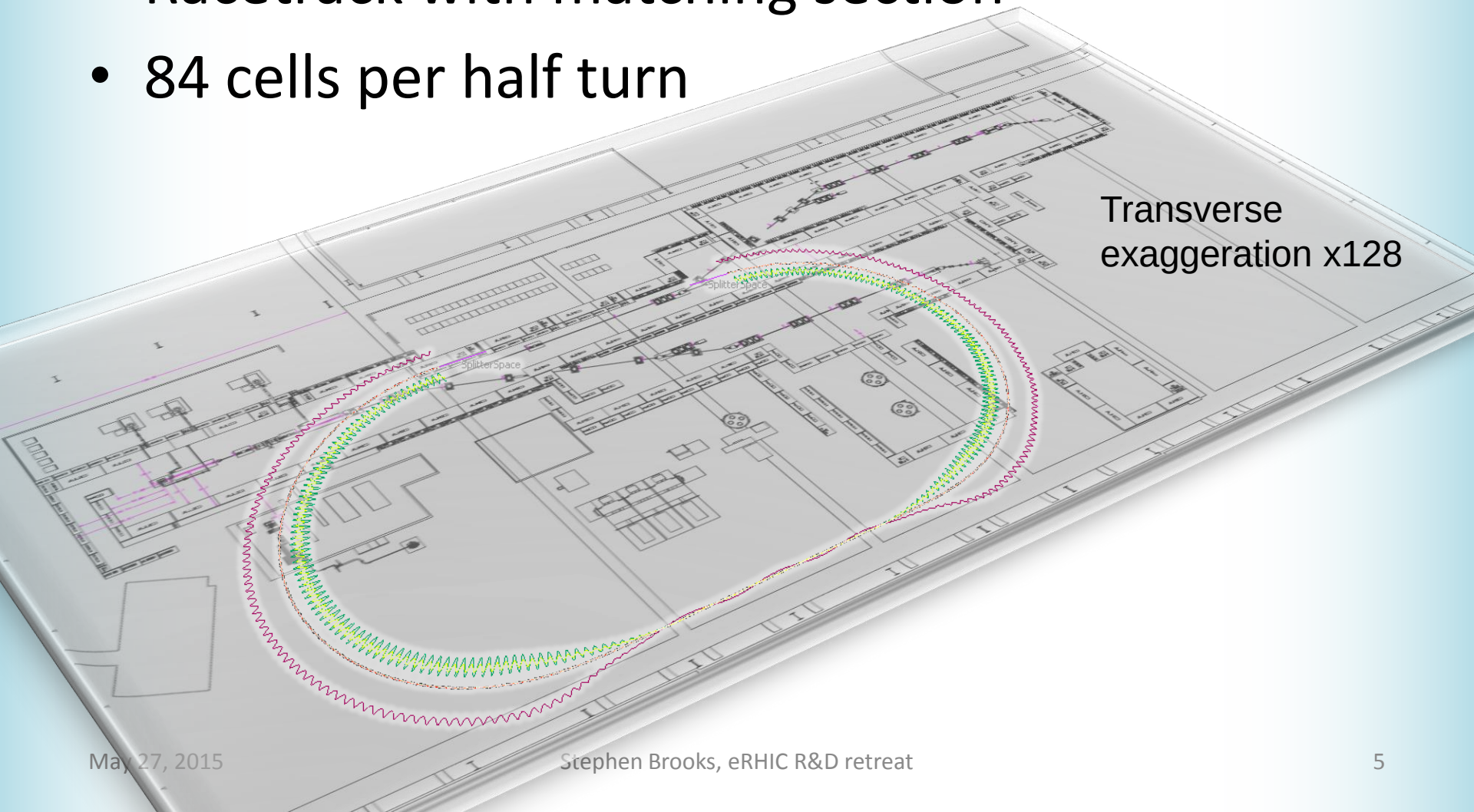
50 MeV injector	200 MeV linac
Energies (MeV)	250, 450, 650, 850
Bending diameter	30 m
Orbit max range	32.8 mm
Max field on orbit	0.732 T
Quad gradients	QF: -42.54 T/m BD: 27.493 T/m
Cell length	55.76 cm
TOF range (rel.)	1.402×10^{-3}

Can extract 1.05 GeV in non-ERL mode



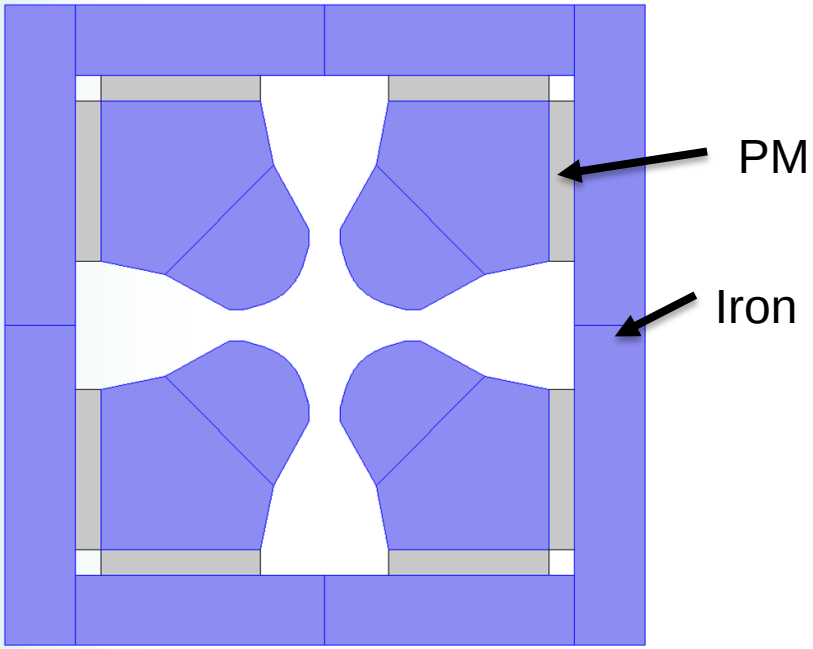
Superimposed on ATF area

- Racetrack with matching section
- 84 cells per half turn

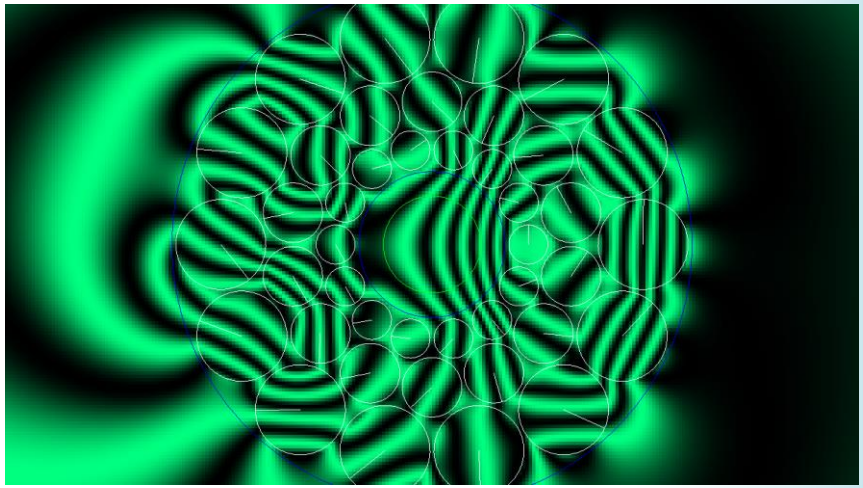


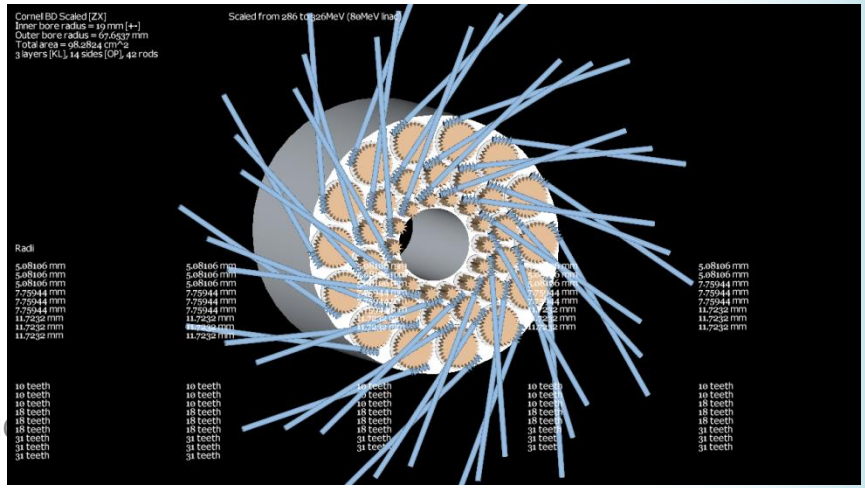
Magnet Options

Holger Witte's quadrupole using iron poles

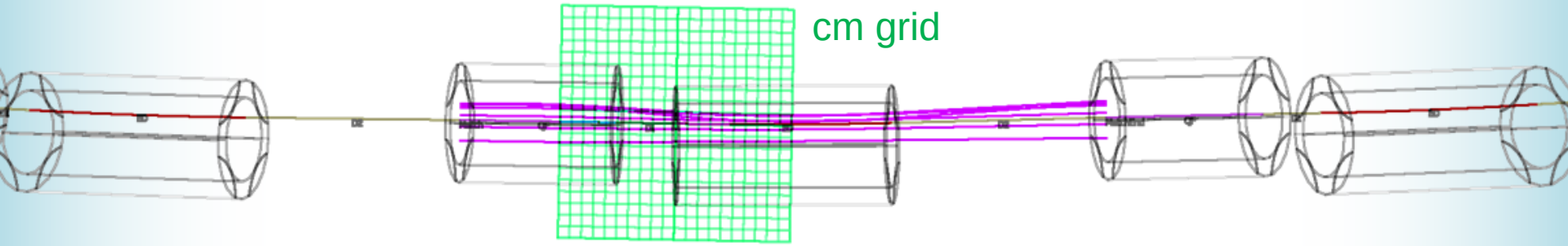


Pure permanent magnet with rotatable rods (BD shown), or Halbach quad



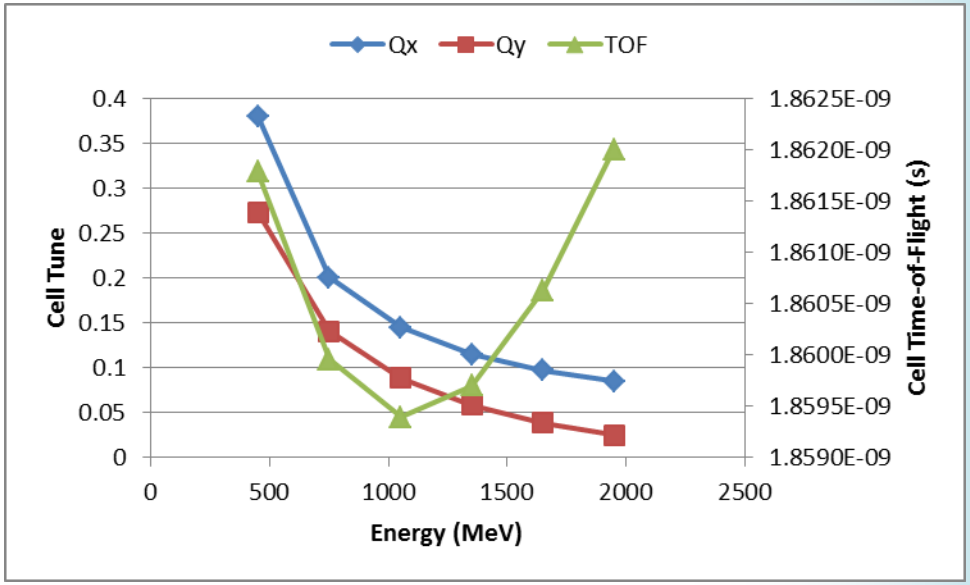


High-field Cell Option



150 MeV injector	300 MeV linac
Energies (MeV)	450, 750 … 1950
Bending diameter	30 m
Orbit max range	32.7 mm
Max field on orbit	1.673 T
Quad gradients	QF: -97.59 T/m BD: 63.07 T/m
Cell length	55.76 cm
TOF range (rel.)	1.403×10^{-3}

Can extract 2.25 GeV in non-ERL mode



Achievable with Halbach Magnets?

- No
- The $B=B_r \ln(R_{out}/R_{inner})$ law is only for dipoles!
  - It was tempting to think we could get arbitrarily high-field quads using the log term
- As our FFAG magnets are predominantly quadrupoles, the ~1.6T pole tip fields do not look achievable using permanent magnets
  - Or at least that is what my code is telling me

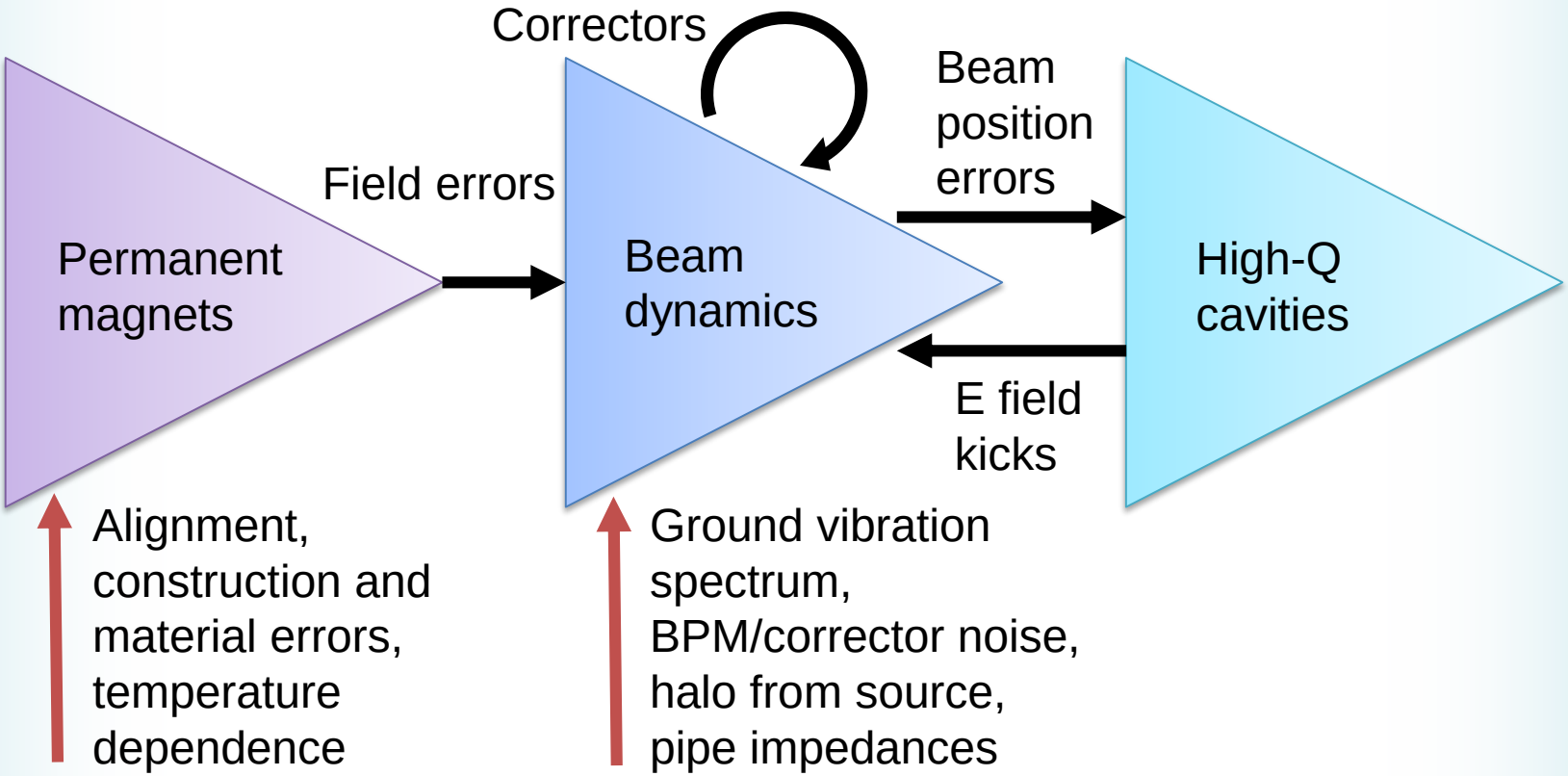
Cost/Components Scaling

- The 850MeV 4-turn ATF design uses exactly the same magnet cross-sections as Cβ
  - Beamline length increased by 30/10.5 = 2.86x
  - Also applies to PM volume, as packing factor same
- Rough cost scaling: Cβ is $5-10M/10m diam. FFAG, eRHIC is $50-100M/1km, so sqrt law
  - Expect $8-17M for ATF FFAG loop
- Cheaper “just a line of magnets” expt possible

ATF Normal-Conducting Linac

- ATF linac cannot run CW
  - Maximum bunch train length so far: 3us (~6 turns)
  - 10us might be possible (~20 turns)
  - Limited by RF modulators (Marcus Babzien)
  - Need 8+ turns to establish multi-turn ERL pattern!
- Can have up to 100 bunches in train period
- Bunch length 100fs – 6ps (0.03–1.8mm)
  - No problems with charge, size etc.

My View of eRHIC Risk



- 3 chained amplifiers for errors and noise
- Messy, real-world inputs (surprise potential)

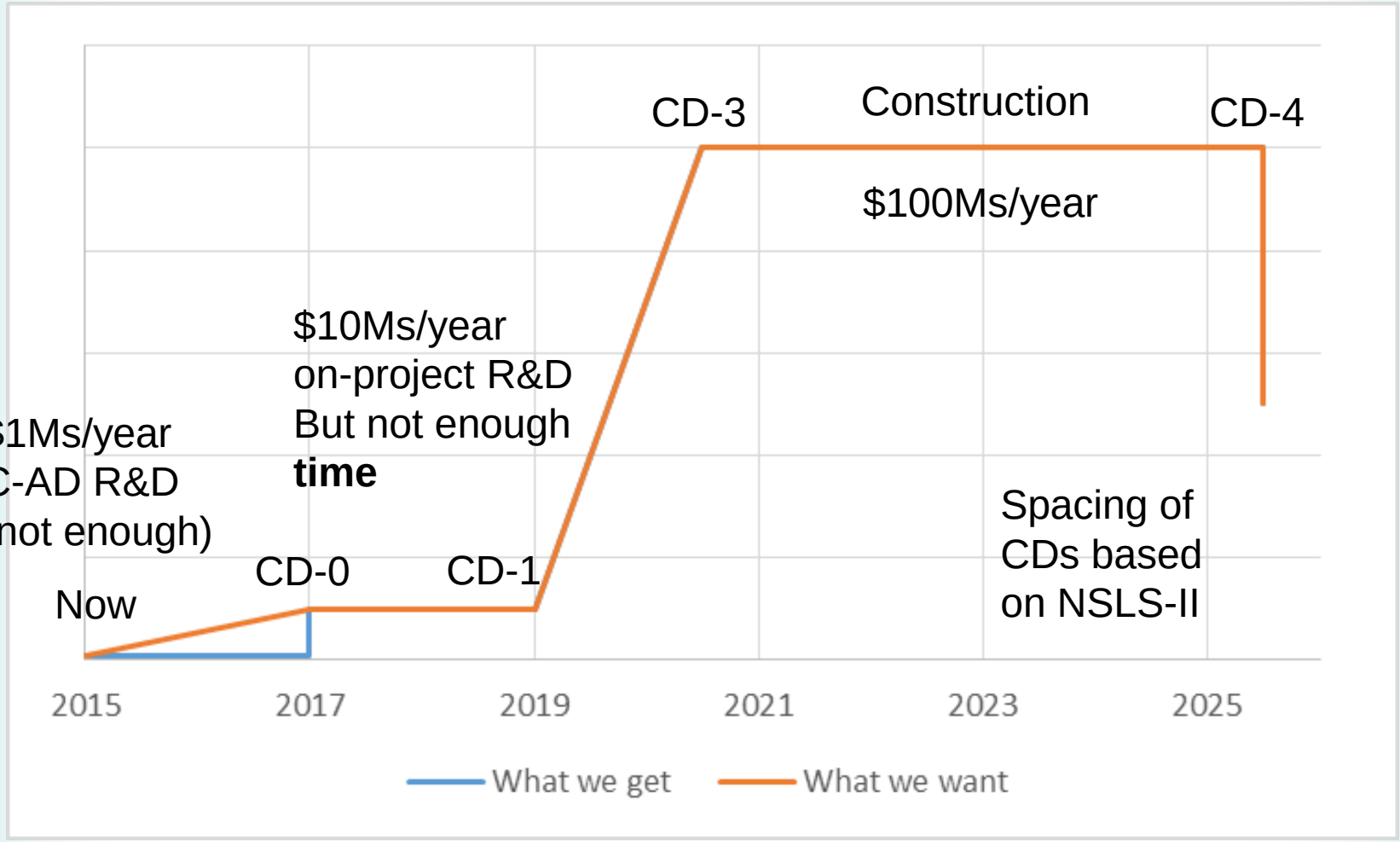
Commonality of ATF-FFAG with Cβ

- The linac and RF are already available
  - Major cost advantage over “green field” machine
- First ever ERL-FFAG
- First ever PM-based FFAG (of this size anyway)
- Record NS-FFAG energy range of ~4x
  - Similar to eRHIC FFAG1, similar tune range, similar orbit excursion, similar chromaticity per cell
- Real, complete tests of single particle optics

Differences of ATF-FFAG with Cβ

- Main: ATF is not a CW superconducting linac
  - No high-Q cavity coupled to the system
    - Can't study BBU or any other modes coupled via cavity
  - Energy recovery unlikely to reach equilibrium state
- ATF-FFAG energy is higher (850 vs. 286MeV)
  - Might be able to measure synchrotron emission
- ATF FFAG cells are longer by 1.69x
  - Helps with engineering, less magnet interference

Funding Profile Risk



Conclusion(?)

- This is really for group to decide
- ERL-FFAGs are a **new class of accelerator**
  - C=3.8km is quite large for the prototype
  - Building a small one first seems a sane approach
- Cβ addresses more issues for eRHIC only
- ATF-FFAG has a great deal of synergy with eRHIC and might choose it if desire for ATF upgrade explicitly weighted into consideration