Transverse BBU Studies for eRHIC at Different Top Energy Settings

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ERL 2011, Oct 19, 2011

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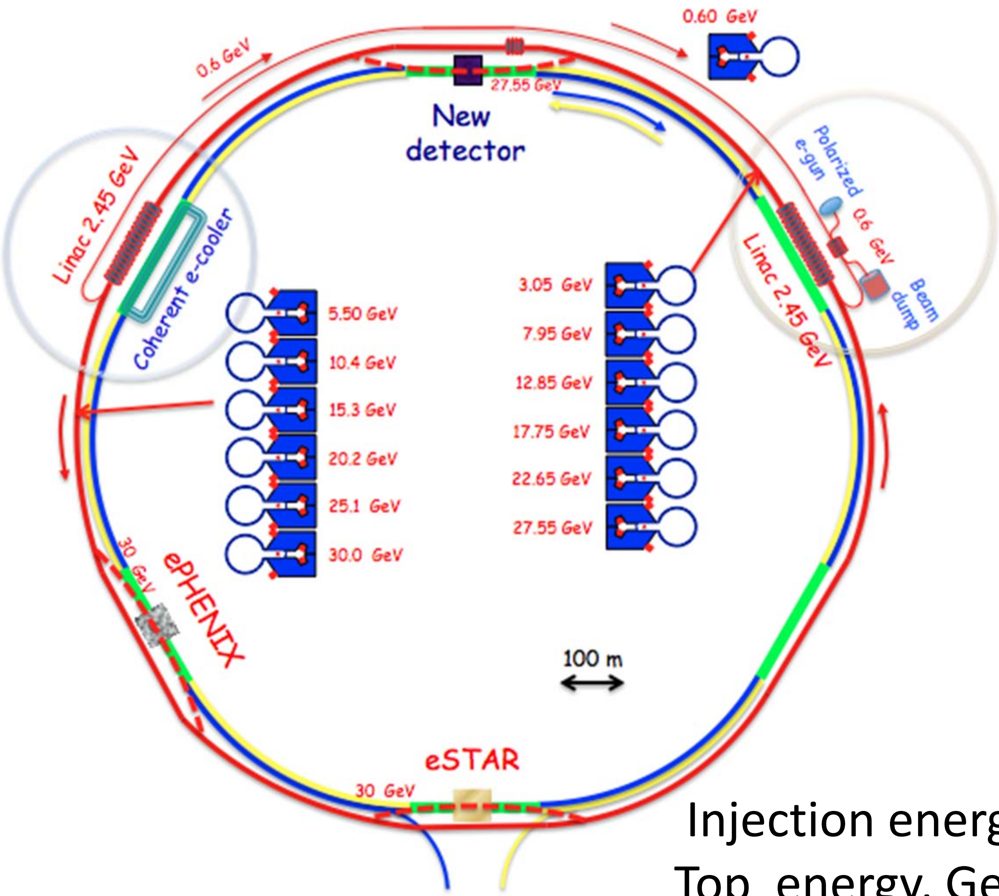
eRHIC Layout and important varables

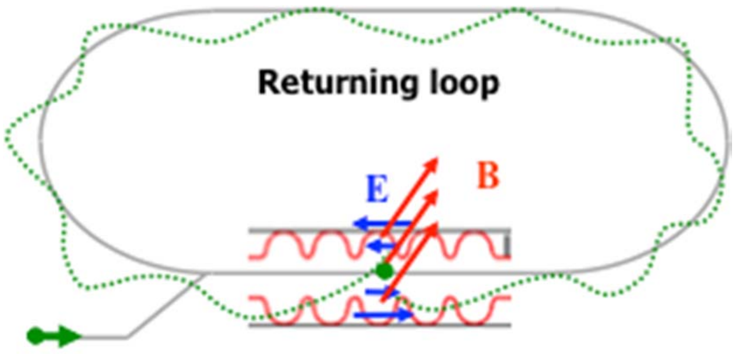


eRHIC:

ERL: 6 up passes up+ 6 passes down
Each pass ~ 3.8 km
2 linacs: 200 m

	1st stage		Max energy
Injection energy, MeV:	100	400	600
Top energy, GeV:	5	20	30
Energy gain per linac, GeV:	0.48	1.63	2.45
Average current, mA:	50	50	10
Numbers of cavities/ linac	24	120	120

Transverse beam break-up



1. Electrons is kicked by HOM transversely
2. Kick transferred into displacement due to transfer matrix
3. If phase is correct then displaced electron feed back the same HOM

Positive feed back and insufficient HOMs damping results of instability

In the simplest case of single mode and one pass system:

$$I_{th} = -\frac{2c}{e\omega\left(\frac{R}{Q}\right)Q_{ext}} \frac{1}{T12^{*}\sin(\omega t_r)}$$

$$T12^{*} = T12\cos^2\theta + \frac{T14+T32}{2}\sin 2\theta + T34\sin^2\theta$$

T12,T14,T32,T34 - transport matrix elements
R/Q, Q, ! - Cavity HOM parameters,
t_r – bunch return time

$$T12 = \sqrt{\frac{\beta\beta_0}{pp_0}}\sin(\Delta\mu)$$

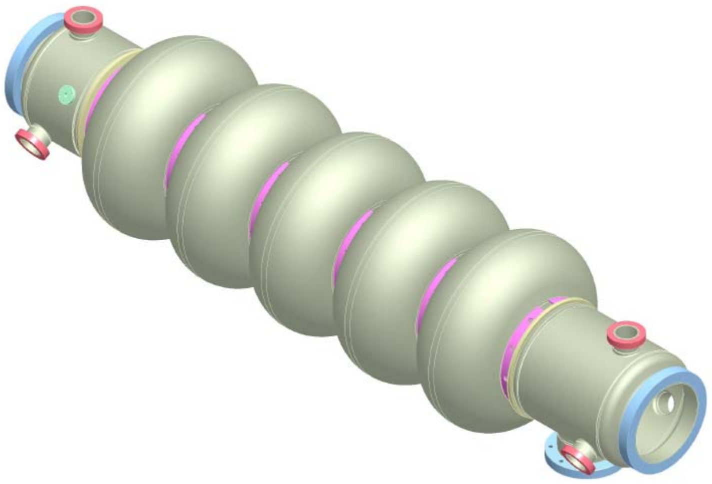
Low betas => large BBU threshold current
Especially it's important at low energy

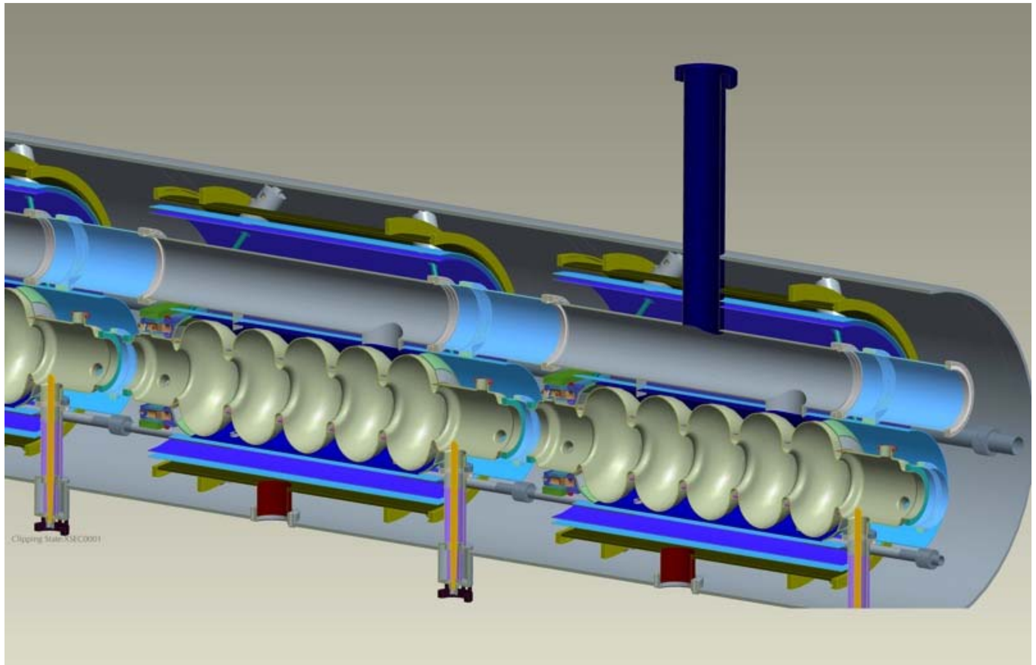
In case of multiple (N) passes ERL the BBU threshold current drops and can be estimated for similar frequencies and betas as:*)

$$I(N) \sim \frac{I_{th}}{N(2N-1)}$$

*) G.H. Hoffstaetter, I.V. Bazarov, Phys. Rev. ST Accel. Beams, V7, 054401,2004

eRHIC Linac design





Based on BNL3 5cell 703.75 MHz SRF cavity
Total linac length -> 200 m plus
two warm-to-cold transition only at the ends
Maximum energy gain per pass –> 2.45 GeV
Accelerating gradient – 19.2 MV/m

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Simulation setup

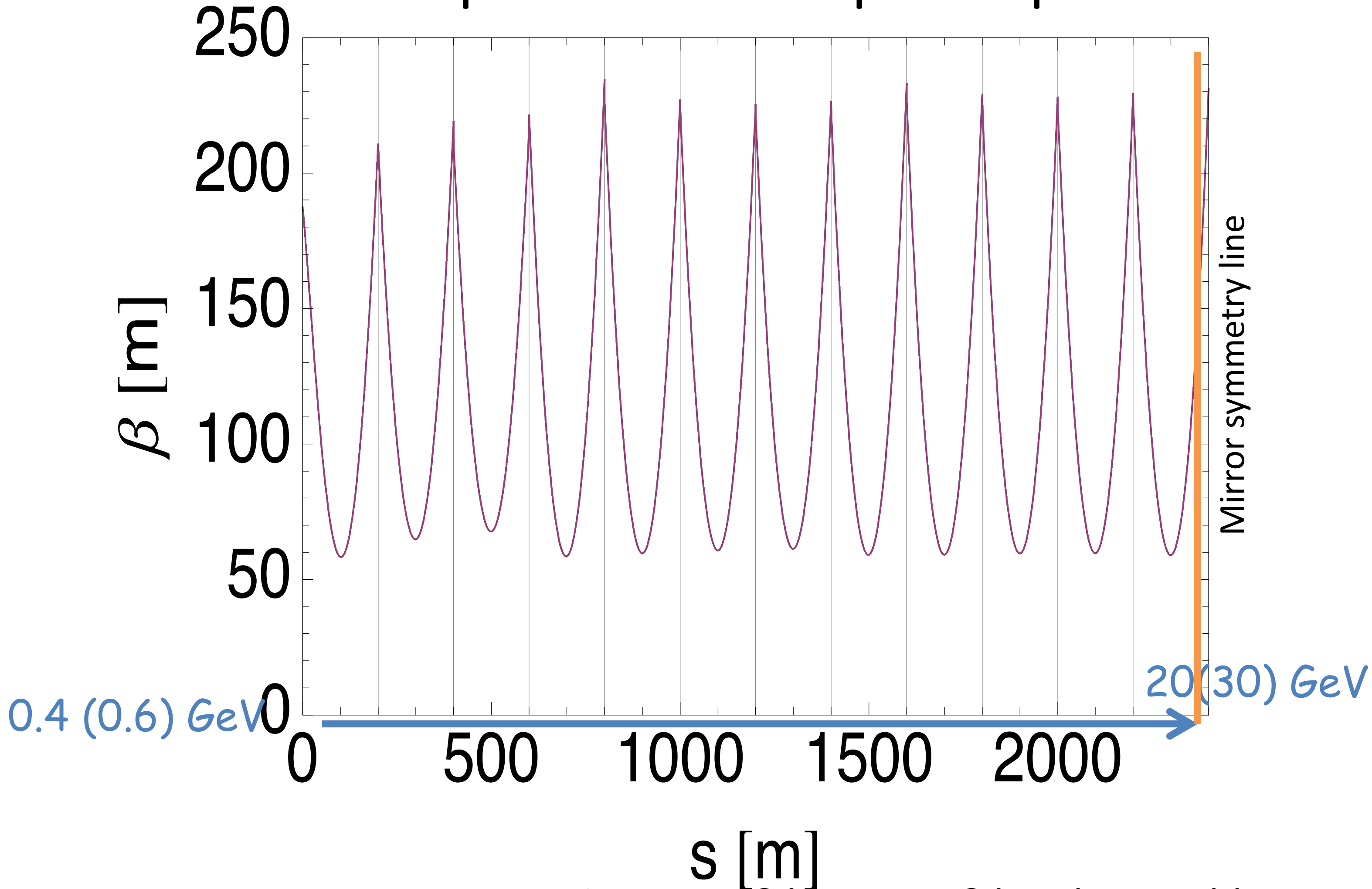
- (Einj)
- 1st pass Linac1-Arc1-Linac2-Arc2
- 2nd pass Linac1-Arc3-Linac2-Arc4
- ……..
- 6th pass Linac1-Arc11-Linac2-Arc12
- 7th pass Linac1-Arc11-Linac2-Arc10
- 8th pass Linac1-Arc9-Linac2-Arc8
- ….
- 12th pass Linac1-Arc1-Linac2 (Einj)

6 passes up (1st to 6th pass)

6 passes down (7th to 12th pass)

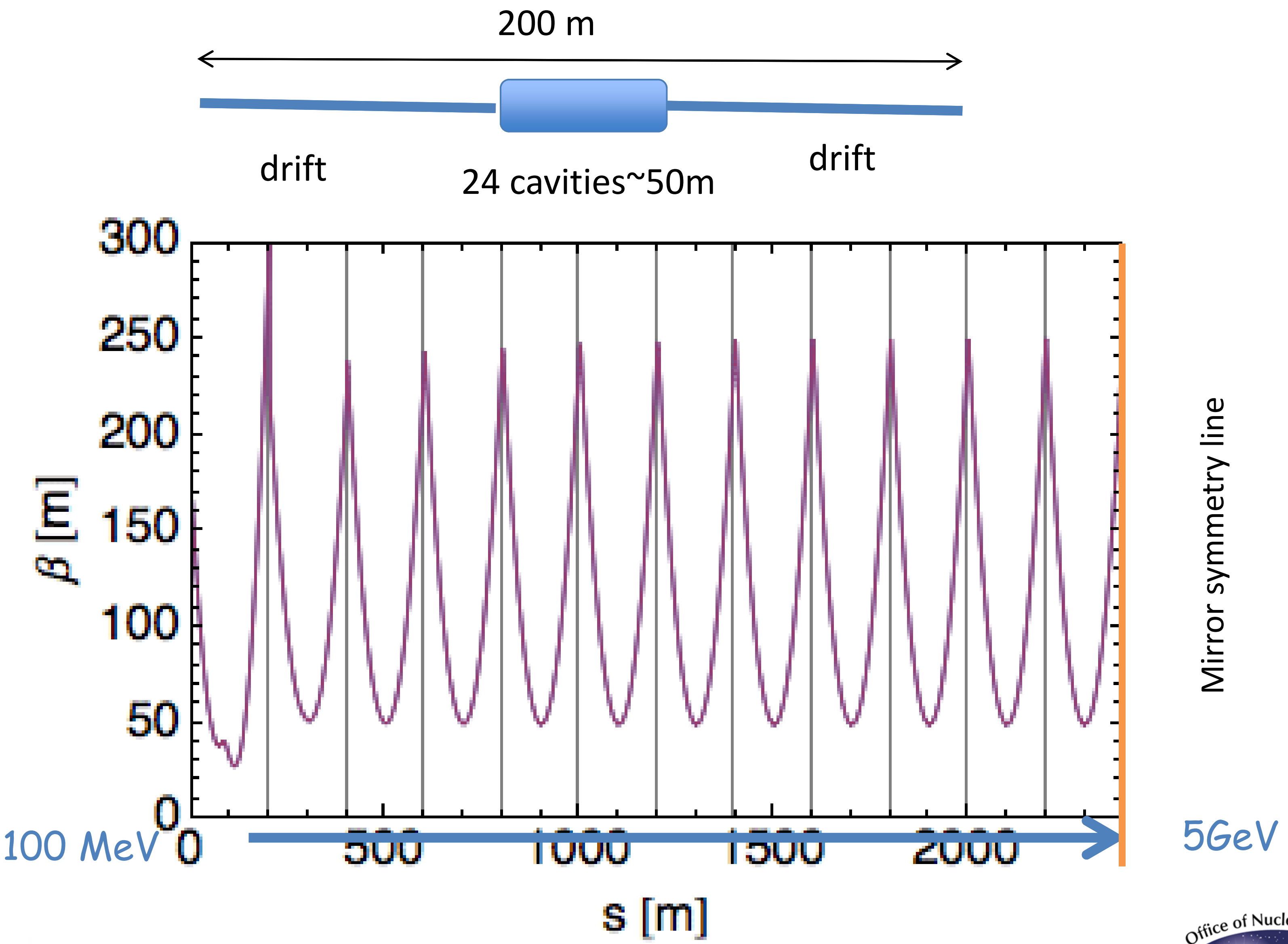
Each arc represented by 4x4 transport matrix
Linac1 and Linac2 200 m each consist of 120 (or 24) individual cavities each with individual HOMs characteristics

Linac optics without quadrupoles



For mirror symmetrized betas: (β(i)out = β(i+1)in , α(i)out=- α(i+1)in the phase advance per arc can be adjustable without changing optics in the linacs

Linac Lattice for 5GeV



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D. Kayran, ERL2011, Oct. 16-20, 2011

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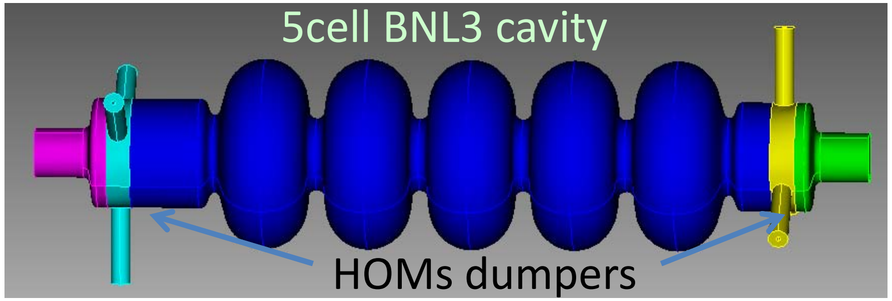
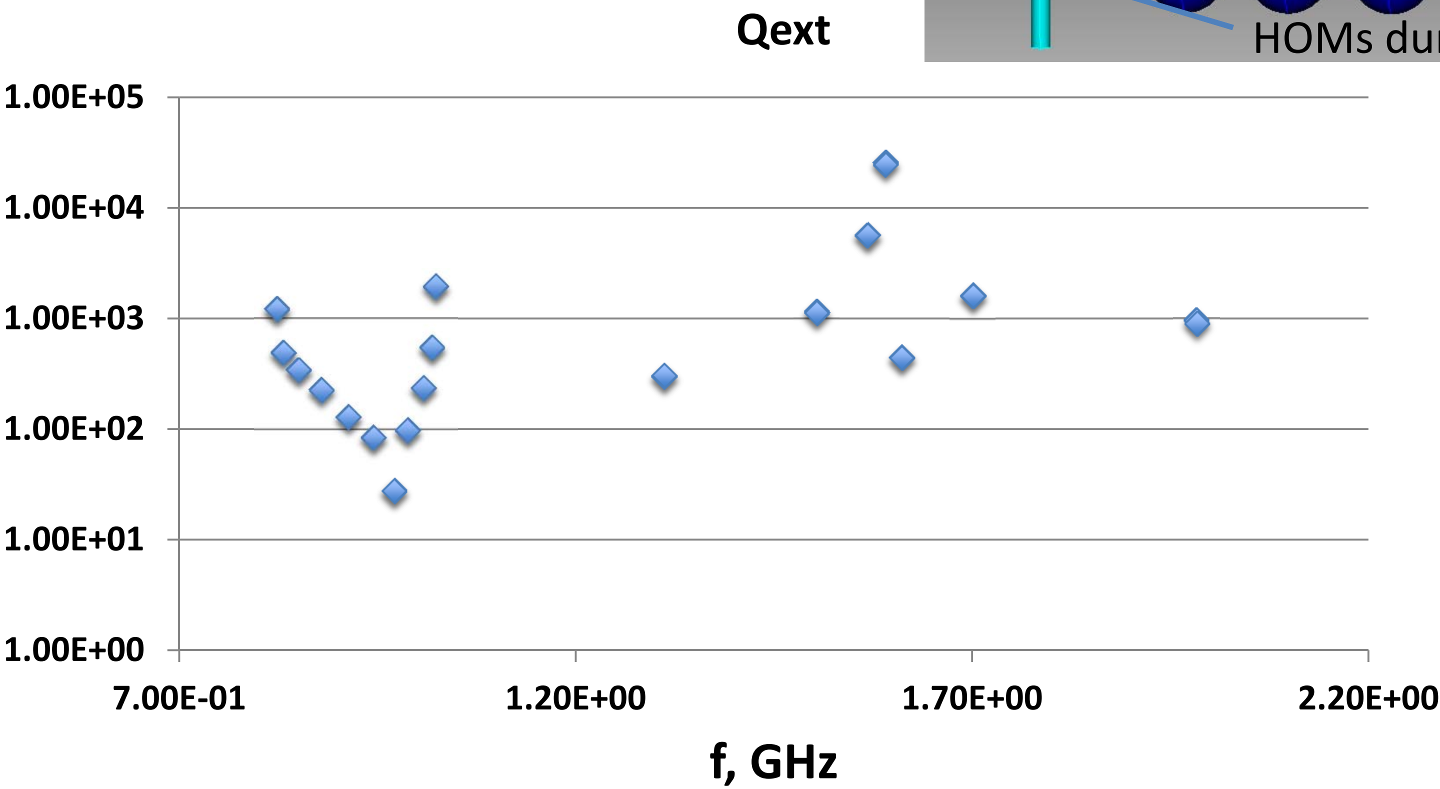
HOMs used for TBBU simulation





Frequency(G	Qext
8.23E+08	1.22E+03
8.24E+08	1.21E+03
8.31E+08	4.94E+02
8.32E+08	4.90E+02
8.50E+08	3.45E+02
8.51E+08	3.43E+02
8.79E+08	2.28E+02
8.80E+08	2.26E+02
9.13E+08	1.30E+02
9.13E+08	1.29E+02
9.45E+08	8.50E+01
9.45E+08	8.45E+01
9.71E+08	2.77E+01
9.71E+08	2.77E+01
9.88E+08	9.77E+01

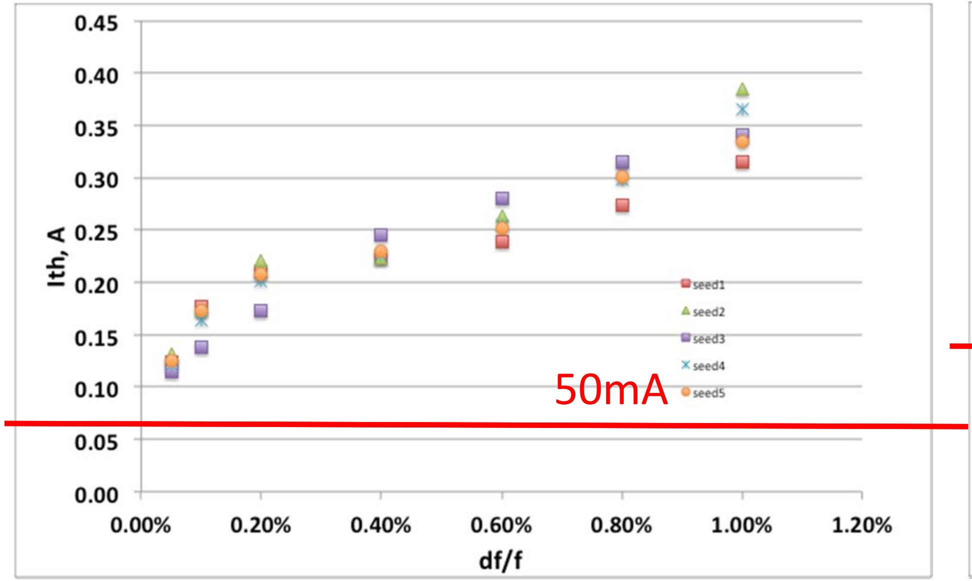
New design antenna type HOM dumper for BNL 3 cavity reduces HOMs Qs below to 10^5

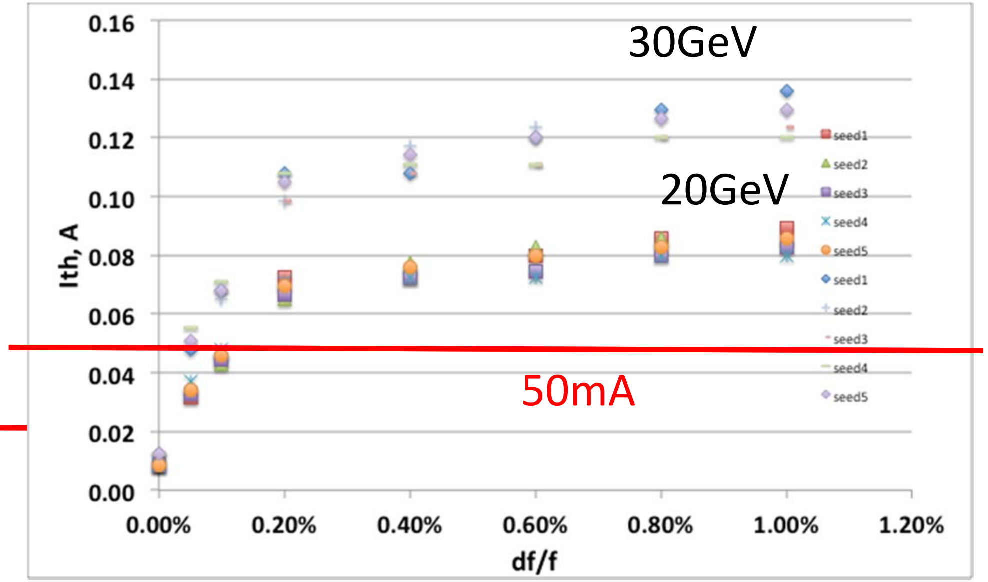
BBU simulation results

For simulation:

- 36 dipole HOMs a
- HOM Frequency spread varied 0-1%
- 5 different initial seeds are shown

Simulated BBU threshold (GBBU*) vs. HOM frequency spread.





5 GeV top energy

20 Gev and 30 GeV top energy

*) E.Pozdeyev, Phys.Rev. ST Accel. Beams Vol 8, 054401 (2005)

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Conclusion

- The current design of BNL3 cavity with new HOMs dumpers relaxes requirements for the linac lattices (removes quadrupoles).
- TBBU simulations demonstrate BBU threshold current ~250 mA for 5 GeV which is sufficient for 1st stage operation.
- For 30 GeV the BBU threshold current (120 mA) is well above required 10 mA operation current too
- The most chelenge case is 20 GeV and 50 mA current. The BBU threshold current ~80 mA. Linac optics and/or returning loop phase advance should be optimized as a next step.
- Things to include in simulations:
  - The injection to eRHIC (due to only one pass ERL the injector should not introduce much difference) .
  - Measured HOMs for new designed dumpers

Thank you!