ERL-based LHeC

BNL's version

I. Ben-Zvi, Y. Hao, D. Kayran, V.N. Litvinenko, V.Ptitsyn, D. Trbojevic, N. Tsoupas
Stony Brook University, Stony Brook, NY, USA
Brookhaven National Laboratory, Upton, NY, USA
Center for Accelerator Science and Education

F. Zimmerman, R.Thomas, O. Bruening
CERN

ERL-based LHeC

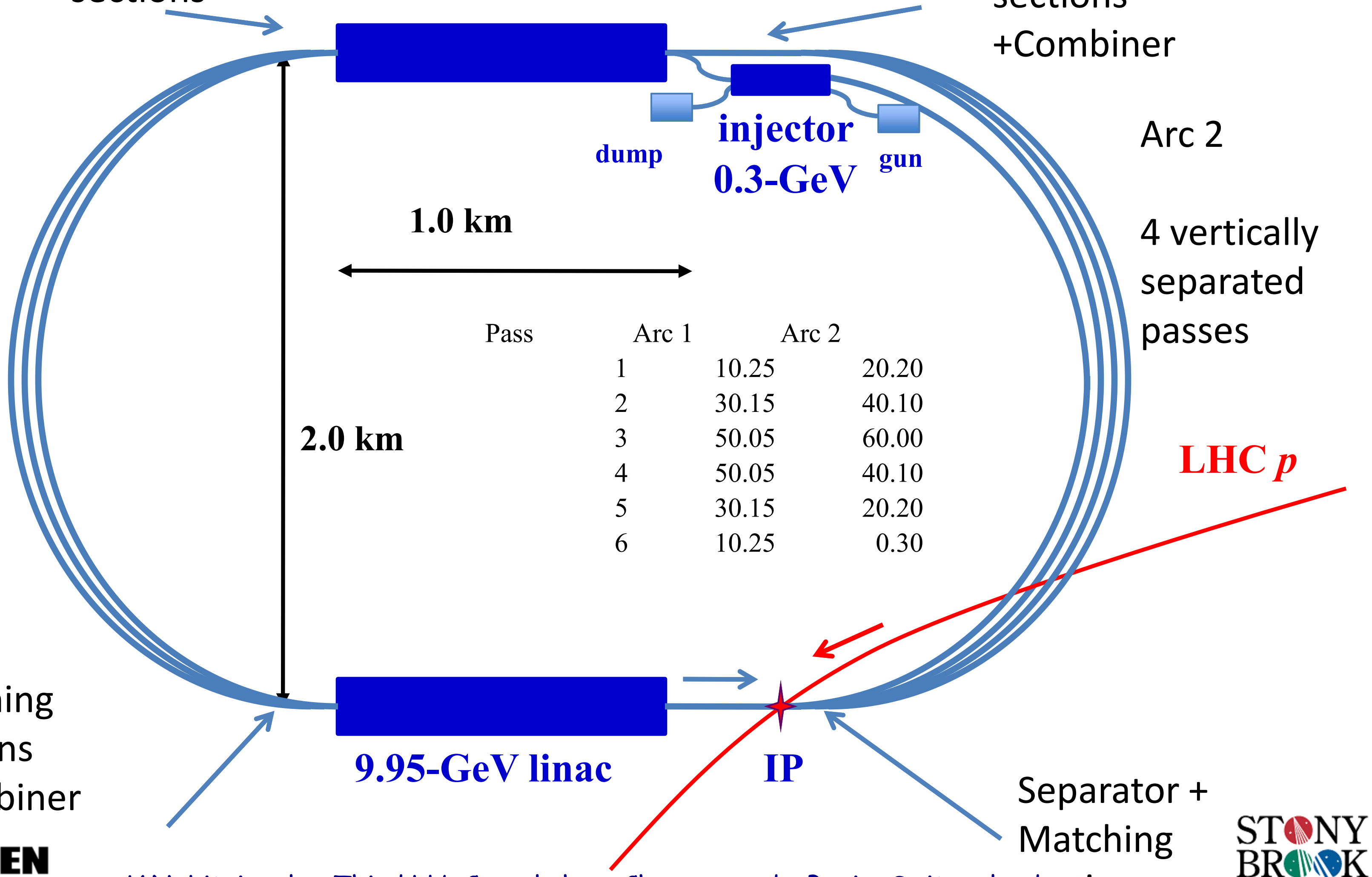
We use racetrack configuration for the system with the beam parameters specified in IPAC'10 paper: *Designs for a Linac-Ring LHeC, F. Zimmermann et al., Proceedings of First International Particle Accelerator Conference, IPAC'10, Kyoto, Japan from Sunday to Friday, May 23-28, 2010, pp. 1611-1613,* *http://accelconf.web.cern.ch/AccelConf/IPAC10/papers/tupeb039.pdf*

- Beam current is assumed to be 6.6 mA CW
- Radius of the arc's tunnel is 1 km, i.e. bending magnet field is > 0.2 T at 60 GeV arc
- Race-track with two 9.95 GeV linacs, 3 passes
- Injection energy – 0.3 GeV
- TBBU limitation are reasonable, but further improvements are possible

e− energy at IP [GeV]	60
Luminosity [10^{32} cm^{-2}s^{-1}]	10.1
Polarization (%)	90
Bunch population [10^{9}]	2.0
e− bunch length [μm]	300
Bunch interval [ns]	50
Transv. emit. $\gamma\varepsilon_{x,y}$ [μm]	50
Rms IP beam size [μm]	7
Hourglass reduction H_{hg}	0.91
Crossing angle θc	0
Repetition rate [Hz]	CW
Average current [mA]	6.6
ER efficiency η	94

Polarized electrons from the electron gun are accelerated to 300 MeV in the injector linacs and are injected into the racetrack ERL with two 9.95 GeV linacs. Electrons are accelerated to 60 GeV in 3 passes and then decelerated back to 300 MeV before being ejected into the injector. They are further decelerated in the injector and damped at energy ~ 10 MeV.

erl



Separator + Matching sections

9.95-GeV linac

Matching sections +Combiner

Arc 1

3 vertically separated passes

dump

injector 0.3-GeV

gun

Arc 2

4 vertically separated passes

1.0 km

2.0 km

LHC *p*

Matching sections +Combiner

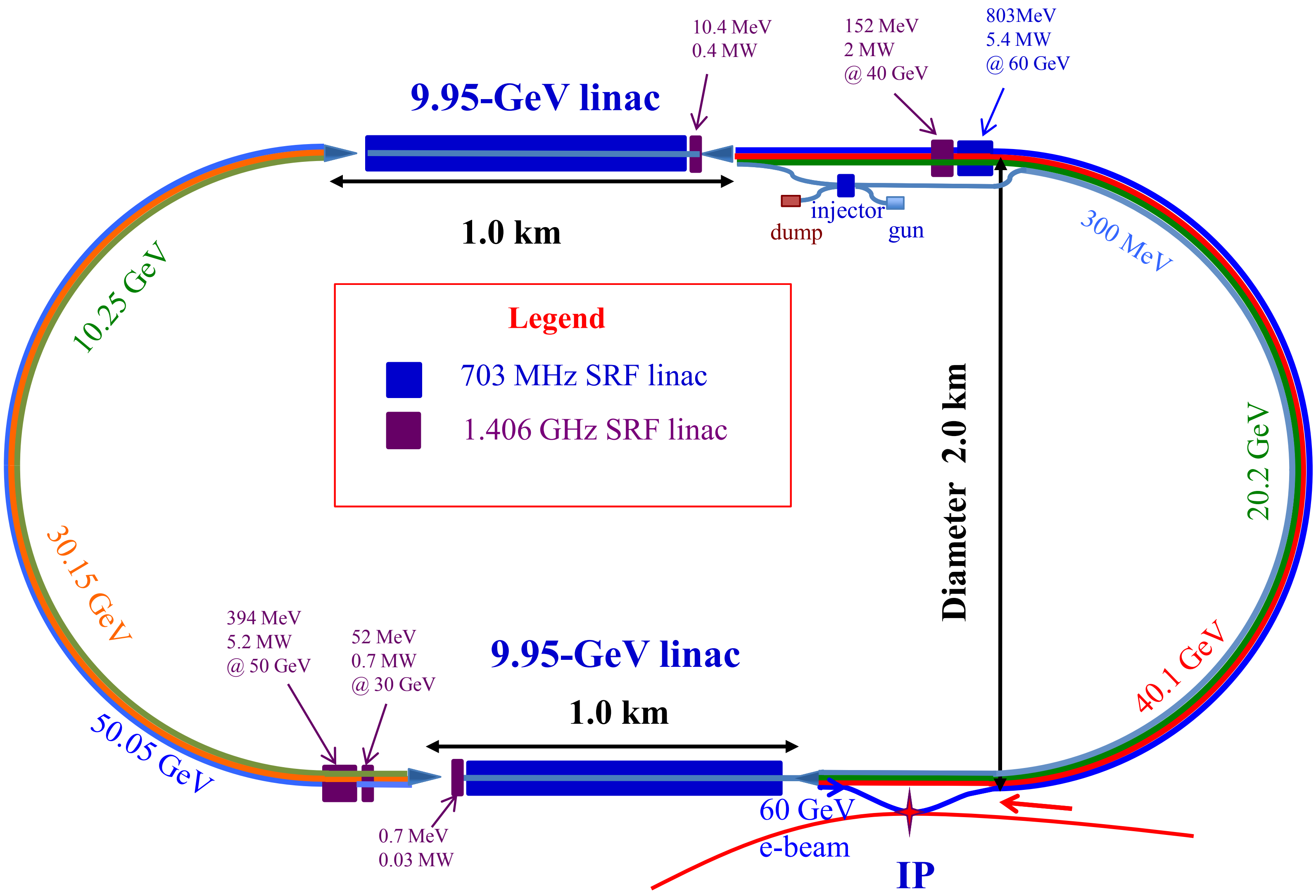
9.95-GeV linac

IP

Separator + Matching sections

Pass	Arc 1	Arc 2
1	10.25	20.20
2	30.15	40.10
3	50.05	60.00
4	50.05	40.10
5	30.15	20.20
6	10.25	0.30

Compensation scheme for 2.05 GeV SR losses with additional RF system

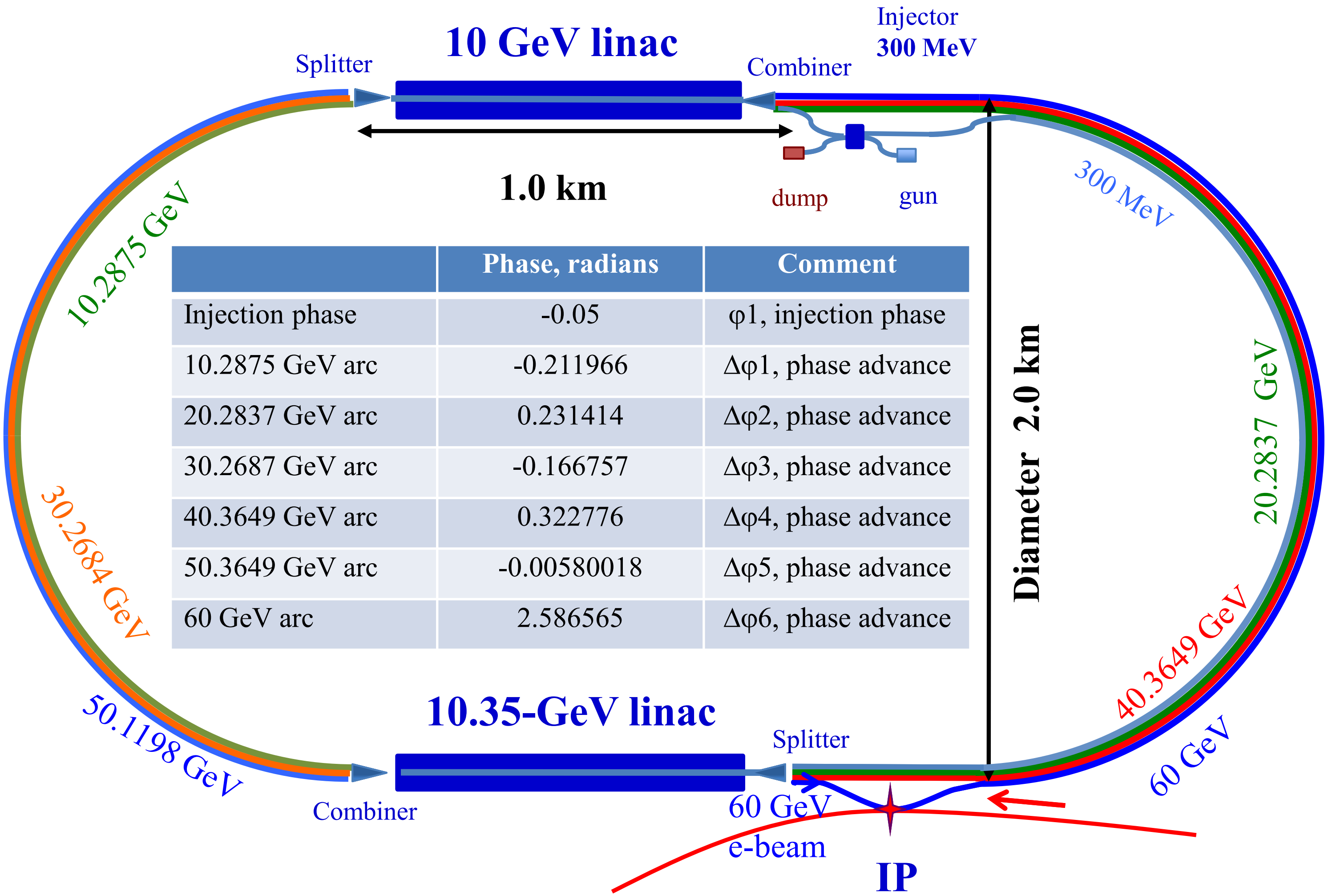


Additional 1.412 GeV RF linacs, need to by-pass these linacs

Using second harmonic RF is the key

New compensation scheme for SR losses with main linacs (VL)

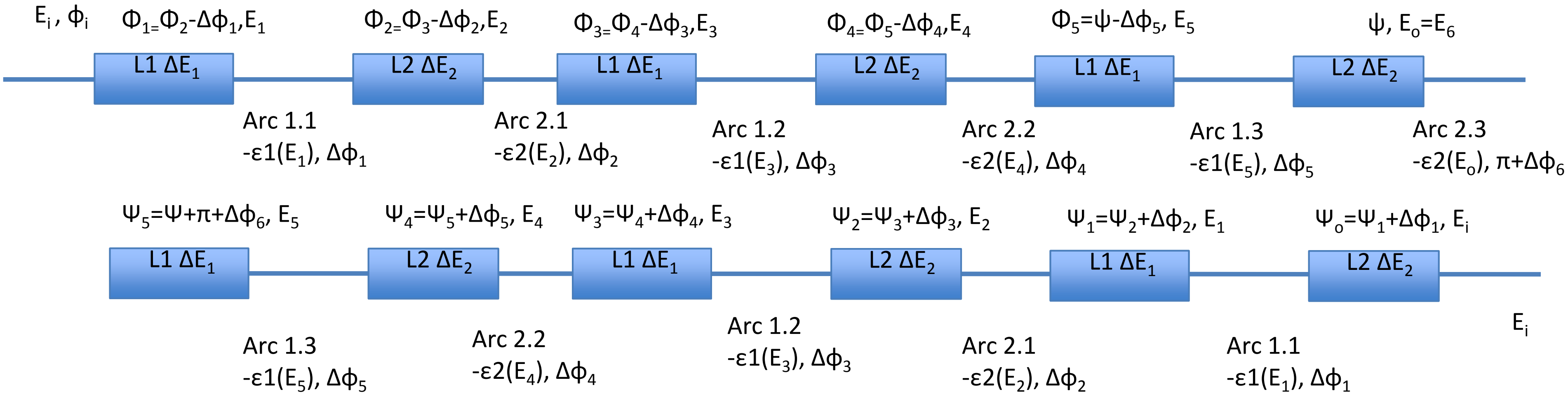
Additional 0.4 GeV of the main RF linac (i.e. ~20 m)



	Phase, radians	Comment
Injection phase	-0.05	φ1, injection phase
10.2875 GeV arc	-0.211966	Δφ1, phase advance
20.2837 GeV arc	0.231414	Δφ2, phase advance
30.2687 GeV arc	-0.166757	Δφ3, phase advance
40.3649 GeV arc	0.322776	Δφ4, phase advance
50.3649 GeV arc	-0.00580018	Δφ5, phase advance
60 GeV arc	2.586565	Δφ6, phase advance

The electron bunch passes through the main linacs twelve times in the following sequence of phases: -0.05, -0.261966, -0.0305519, -0.197309, 0.125467, 0.119667, 3.08786, 2.85644, 3.0232, 2.70042, 2.70622, 2.87589. Finally, linac 1 will compensate for 0.922 GeV of the energy loss, while the linac 2 will compensate for the remaining 1.144 GeV.

There are enough variables and even two parameters can vary
Mathematica was used to find some reasonable solutions



E_i, ϕ_i

$\Phi_1=\Phi_2-\Delta\phi_1, E_1$

$\Phi_2=\Phi_3-\Delta\phi_2, E_2$

$\Phi_3=\Phi_4-\Delta\phi_3, E_3$

$\Phi_4=\Phi_5-\Delta\phi_4, E_4$

$\Phi_5=\psi-\Delta\phi_5$, E_5

ψ, $E_o=E_6$

L1 ΔE_1 | L2 ΔE_2 | L1 ΔE_1 | L2 ΔE_2 | L1 ΔE_1 | L2 ΔE_2

Arc 1.1
$-\varepsilon 1(E_1)$, $\Delta\phi_1$

Arc 2.1
$-\varepsilon 2(E_2)$, $\Delta\phi_2$

Arc 1.2
$-\varepsilon 1(E_3)$, $\Delta\phi_3$

Arc 2.2
$-\varepsilon 2(E_4)$, $\Delta\phi_4$

Arc 1.3
$-\varepsilon 1(E_5)$, $\Delta\phi_5$

Arc 2.3
$-\varepsilon 2(E_o)$, $\pi+\Delta\phi_6$

$\Psi_5=\Psi+\pi+\Delta\phi_6$, E_5

$\Psi_4=\Psi_5+\Delta\phi_5$, E_4

$\Psi_3=\Psi_4+\Delta\phi_4$, E_3

$\Psi_2=\Psi_3+\Delta\phi_3$, E_2

$\Psi_1=\Psi_2+\Delta\phi_2$, E_1

$\Psi_o=\Psi_1+\Delta\phi_1$, E_i

L1 ΔE_1 | L2 ΔE_2 | L1 ΔE_1 | L2 ΔE_2 | L1 ΔE_1 | L2 ΔE_2

Arc 1.3
$-\varepsilon 1(E_5)$, $\Delta\phi_5$

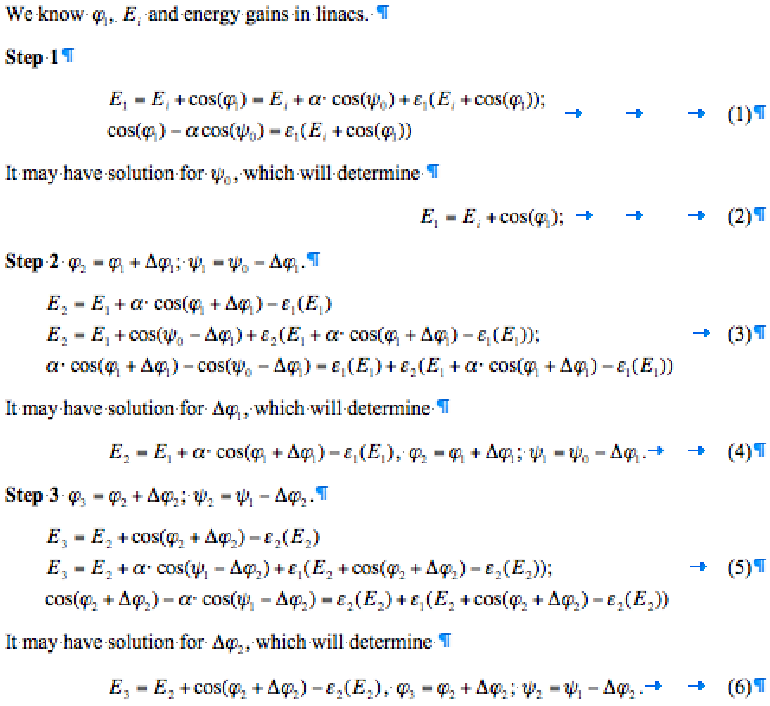
Arc 2.2
$-\varepsilon 2(E_4)$, $\Delta\phi_4$

Arc 1.2
$-\varepsilon 1(E_3)$, $\Delta\phi_3$

Arc 2.1
$-\varepsilon 2(E_2)$, $\Delta\phi_2$

Arc 1.1
$-\varepsilon 1(E_1)$, $\Delta\phi_1$

E_i



We know φ_1, E_i and energy gains in linacs.

Step 1

$$E_1 = E_i + \cos(\varphi_1) = E_i + \alpha\cdot\cos(\psi_0) + \varepsilon_1(E_i + \cos(\varphi_1));$$
$$\cos(\varphi_1) - \alpha\cos(\psi_0) = \varepsilon_1(E_i + \cos(\varphi_1)) \qquad (1)$$

It may have solution for ψ_0, which will determine

$$E_1 = E_i + \cos(\varphi_1); \qquad (2)$$

Step 2 $\varphi_2 = \varphi_1 + \Delta\varphi_1$; $\psi_1 = \psi_0 - \Delta\varphi_1$.

$$E_2 = E_1 + \alpha\cdot\cos(\varphi_1 + \Delta\varphi_1) - \varepsilon_1(E_1)$$
$$E_2 = E_1 + \cos(\psi_0 - \Delta\varphi_1) + \varepsilon_2(E_1 + \alpha\cdot\cos(\varphi_1 + \Delta\varphi_1) - \varepsilon_1(E_1)); \qquad (3)$$
$$\alpha\cdot\cos(\varphi_1 + \Delta\varphi_1) - \cos(\psi_0 - \Delta\varphi_1) = \varepsilon_1(E_1) + \varepsilon_2(E_1 + \alpha\cdot\cos(\varphi_1 + \Delta\varphi_1) - \varepsilon_1(E_1))$$

It may have solution for $\Delta\varphi_1$, which will determine

$$E_2 = E_1 + \alpha\cdot\cos(\varphi_1 + \Delta\varphi_1) - \varepsilon_1(E_1),\ \varphi_2 = \varphi_1 + \Delta\varphi_1;\ \psi_1 = \psi_0 - \Delta\varphi_1. \qquad (4)$$

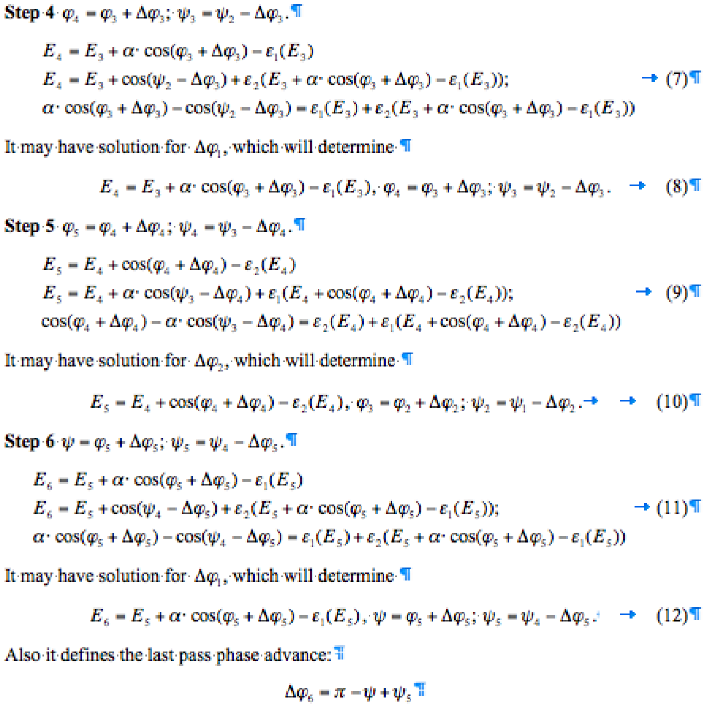
Step 3 $\varphi_3 = \varphi_2 + \Delta\varphi_2$; $\psi_2 = \psi_1 - \Delta\varphi_2$.

$$E_3 = E_2 + \cos(\varphi_2 + \Delta\varphi_2) - \varepsilon_2(E_2)$$
$$E_3 = E_2 + \alpha\cdot\cos(\psi_1 - \Delta\varphi_2) + \varepsilon_1(E_2 + \cos(\varphi_2 + \Delta\varphi_2) - \varepsilon_2(E_2)); \qquad (5)$$
$$\cos(\varphi_2 + \Delta\varphi_2) - \alpha\cdot\cos(\psi_1 - \Delta\varphi_2) = \varepsilon_2(E_2) + \varepsilon_1(E_2 + \cos(\varphi_2 + \Delta\varphi_2) - \varepsilon_2(E_2))$$

It may have solution for $\Delta\varphi_2$, which will determine

$$E_3 = E_2 + \cos(\varphi_2 + \Delta\varphi_2) - \varepsilon_2(E_2),\ \varphi_3 = \varphi_2 + \Delta\varphi_2;\ \psi_2 = \psi_1 - \Delta\varphi_2. \qquad (6)$$

© VL



Step 4 $\varphi_4 = \varphi_3 + \Delta\varphi_3$; $\psi_3 = \psi_2 - \Delta\varphi_3$.

$$E_4 = E_3 + \alpha\cdot\cos(\varphi_3 + \Delta\varphi_3) - \varepsilon_1(E_3)$$
$$E_4 = E_3 + \cos(\psi_2 - \Delta\varphi_3) + \varepsilon_2(E_3 + \alpha\cdot\cos(\varphi_3 + \Delta\varphi_3) - \varepsilon_1(E_3)); \qquad (7)$$
$$\alpha\cdot\cos(\varphi_3 + \Delta\varphi_3) - \cos(\psi_2 - \Delta\varphi_3) = \varepsilon_1(E_3) + \varepsilon_2(E_3 + \alpha\cdot\cos(\varphi_3 + \Delta\varphi_3) - \varepsilon_1(E_3))$$

It may have solution for $\Delta\varphi_1$, which will determine

$$E_4 = E_3 + \alpha\cdot\cos(\varphi_3 + \Delta\varphi_3) - \varepsilon_1(E_3),\ \varphi_4 = \varphi_3 + \Delta\varphi_3;\ \psi_3 = \psi_2 - \Delta\varphi_3. \qquad (8)$$

Step 5 $\varphi_5 = \varphi_4 + \Delta\varphi_4$; $\psi_4 = \psi_3 - \Delta\varphi_4$.

$$E_5 = E_4 + \cos(\varphi_4 + \Delta\varphi_4) - \varepsilon_2(E_4)$$
$$E_5 = E_4 + \alpha\cdot\cos(\psi_3 - \Delta\varphi_4) + \varepsilon_1(E_4 + \cos(\varphi_4 + \Delta\varphi_4) - \varepsilon_2(E_4)); \qquad (9)$$
$$\cos(\varphi_4 + \Delta\varphi_4) - \alpha\cdot\cos(\psi_3 - \Delta\varphi_4) = \varepsilon_2(E_4) + \varepsilon_1(E_4 + \cos(\varphi_4 + \Delta\varphi_4) - \varepsilon_2(E_4))$$

It may have solution for $\Delta\varphi_2$, which will determine

$$E_5 = E_4 + \cos(\varphi_4 + \Delta\varphi_4) - \varepsilon_2(E_4),\ \varphi_3 = \varphi_2 + \Delta\varphi_2;\ \psi_2 = \psi_1 - \Delta\varphi_2. \qquad (10)$$

Step 6 $\psi = \varphi_5 + \Delta\varphi_5$; $\psi_5 = \psi_4 - \Delta\varphi_5$.

$$E_6 = E_5 + \alpha\cdot\cos(\varphi_5 + \Delta\varphi_5) - \varepsilon_1(E_5)$$
$$E_6 = E_5 + \cos(\psi_4 - \Delta\varphi_5) + \varepsilon_2(E_5 + \alpha\cdot\cos(\varphi_5 + \Delta\varphi_5) - \varepsilon_1(E_5)); \qquad (11)$$
$$\alpha\cdot\cos(\varphi_5 + \Delta\varphi_5) - \cos(\psi_4 - \Delta\varphi_5) = \varepsilon_1(E_5) + \varepsilon_2(E_5 + \alpha\cdot\cos(\varphi_5 + \Delta\varphi_5) - \varepsilon_1(E_5))$$

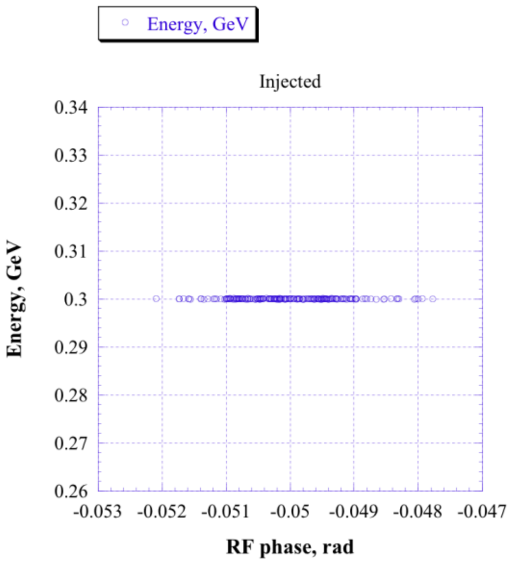
It may have solution for $\Delta\varphi_1$, which will determine

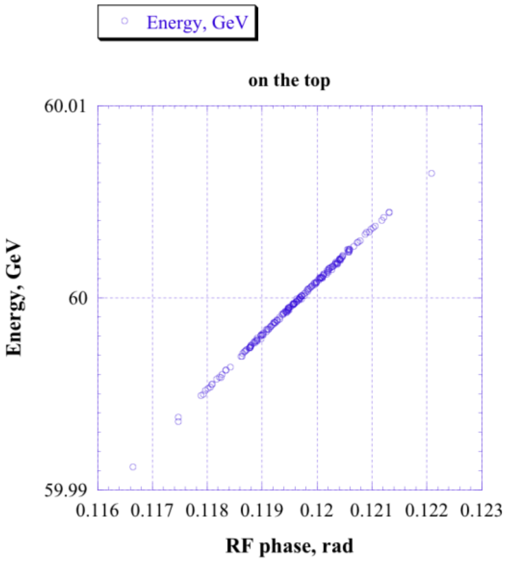
$$E_6 = E_5 + \alpha\cdot\cos(\varphi_5 + \Delta\varphi_5) - \varepsilon_1(E_5),\ \psi = \varphi_5 + \Delta\varphi_5;\ \psi_5 = \psi_4 - \Delta\varphi_5. \qquad (12)$$

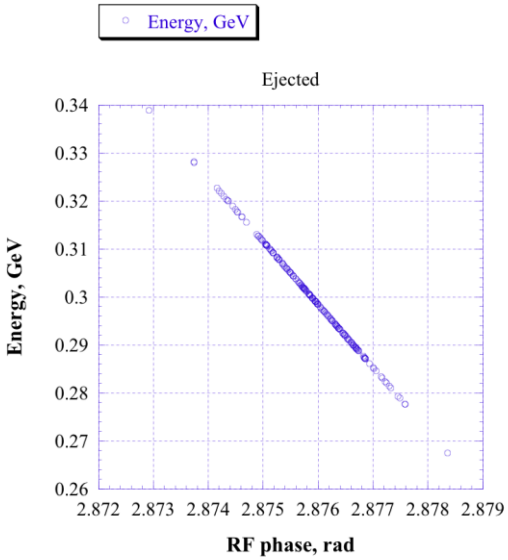
Also it defines the last pass phase advance:

$$\Delta\varphi_6 = \pi - \psi + \psi_5$$

Longitudinal beam dynamics







Nothing pathological

Linac without and with quads

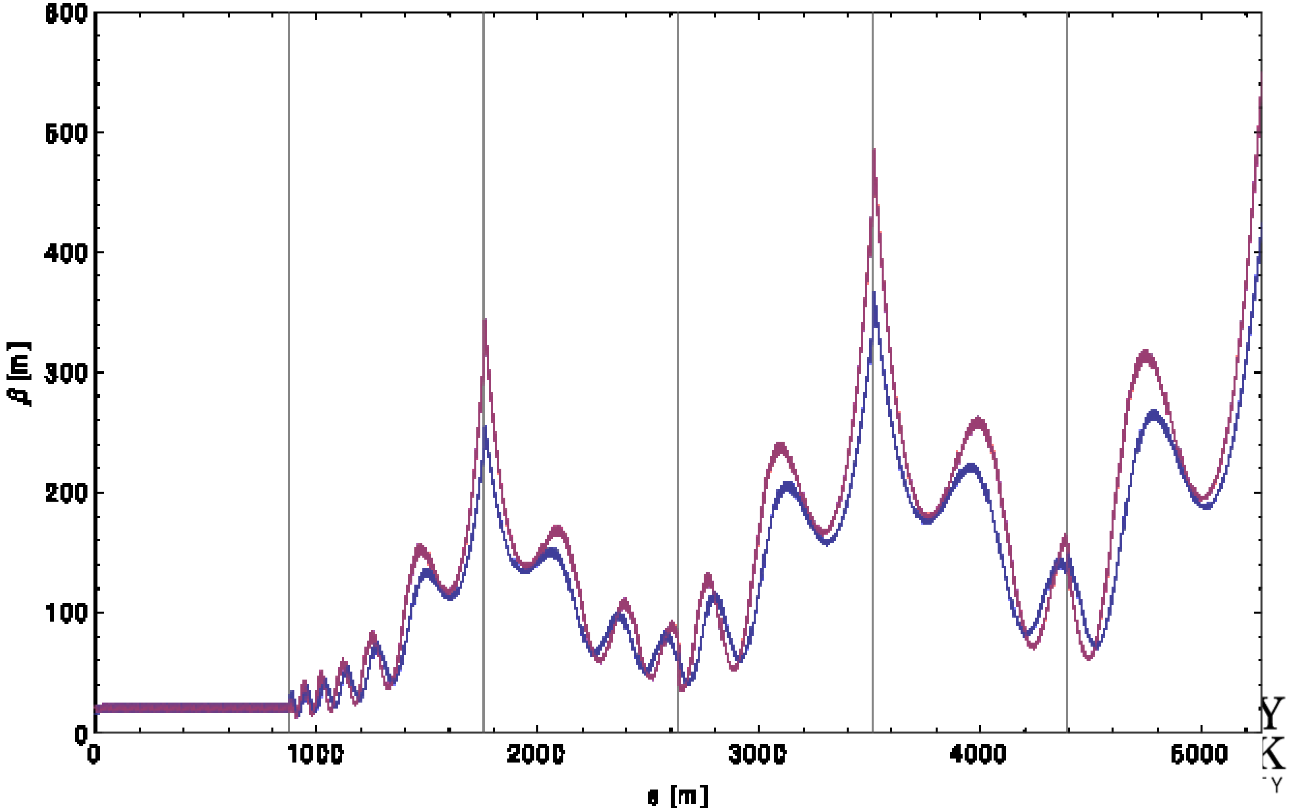
# of pass in linac	β (entr.)	α (entr.)	β (exit)	α (exit)
1	294.6	-1.14	769.3	-1.18
2	898.1	1.89	905.3	-1.53
3	915.4	1.84	916.7	-1.61
4	919.7	1.81	920.0	-1.65
5	921.4	1.79	921.6	-1.67
6	922.3	1.78	922.2	-1.68

- On the way down the exit value becomes entrance and vice versa
- No quadrupoles inside linac

$$\frac{dx}{dt} =\approx \frac{p_x}{mc(\gamma_o + \gamma' z)};$$

© Y.Hao

For high energy, the average beta function is beta*+L^2/3/beta* (L is the half length of linac), therefore the best case is beta*=L/1.



BROOKHAVEN
NATIONAL LABORATORY

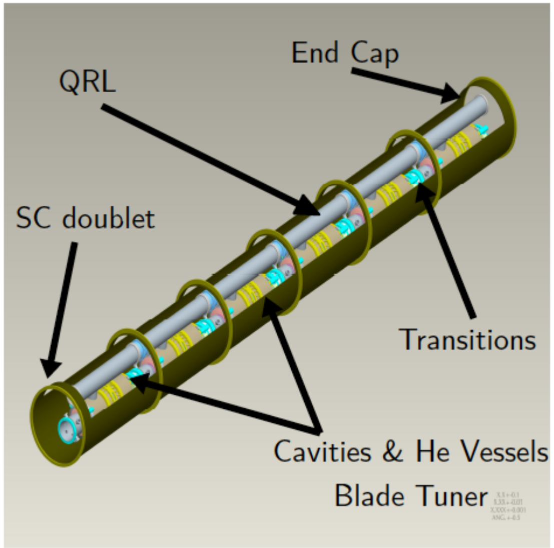
Linac: case #1

injection energy - 0.3GeV , top energy - 60GeV, energy gain per linac - 9.95GeV. Each linac contains 80 eRHIC Cryomodules, each with 6 Cavities and 0.2m overhead length. Length of the linac is 800m with 20.73 MeV per cavity. More realistic is 83 modules (830 m) with 20 MeV per cavity.
Additional 1.4 GeV (90 m) of RF linacs at 700 MHz and 1.4 GHz to compensate for SRF

Linac: case #2

injection energy - 0.3GeV , top energy - 60GeV, max energy gain:
linac1 – 10 GeV, 84 modules, 840 m, 19.84 MeV per linac
linac2 – 10.35 GeV, 87 modules, 870 m, 19.83 MeV per linac

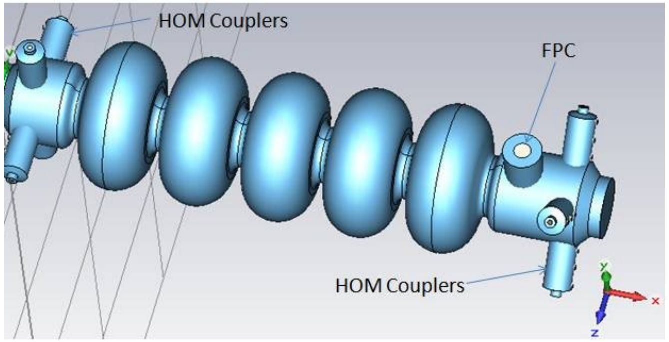
PRELIMINARY CRYOMODULE



String assembly of multiple cavities. Heat shielding and top covers removed for clarity.

Breakdown of the eRHIC Cryomodule
N cavities = 6 (but can 4-8)
Module length = 9.6 m
L period = 10.6 m
E_{acc} = 18.0 MV/m
dE/ds = 10.2 MeV/m

New design of 704 MHz cavity (BNL III):
-reduced peak surface magnet field
-reduced cryogenic load

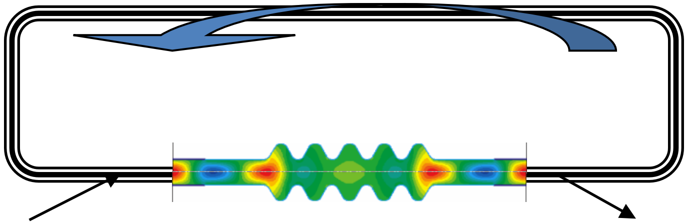


Expected cryogenic load

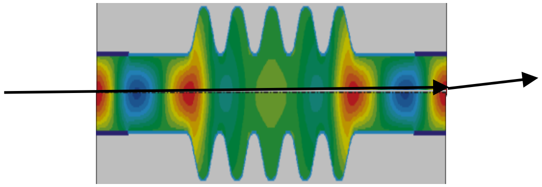
- Assume Q vs. E as measured for BNL I.
- Assume 18 MV/m operation.
- Assume losses scale with surface magnetic field.
- For comparison with measured results, scale field by the magnetic field ratio of BNL III to BNL I, giving 13.3 MV/m.
- The measured Q for BNL I at this field is 4E10.
- Assume losses scale down by the geometry factor, that leads to a Q of 5E10.
- With this Q at 18 MV/m the cryogenic load is 13 W/cavity.
- For 280 cavities the dynamic load is 3.6 kW: Less than MeRHIC estimate (which was based on older cavities).
-

TBBU - Preliminary (©D. Kayran)

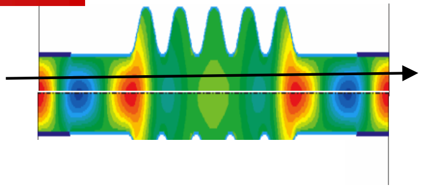
- HOMs based on R. Calaga's simulations/measurements
- 70 dipole HOM's to 2.7 GHz in each cavity
- No focusing in the linac



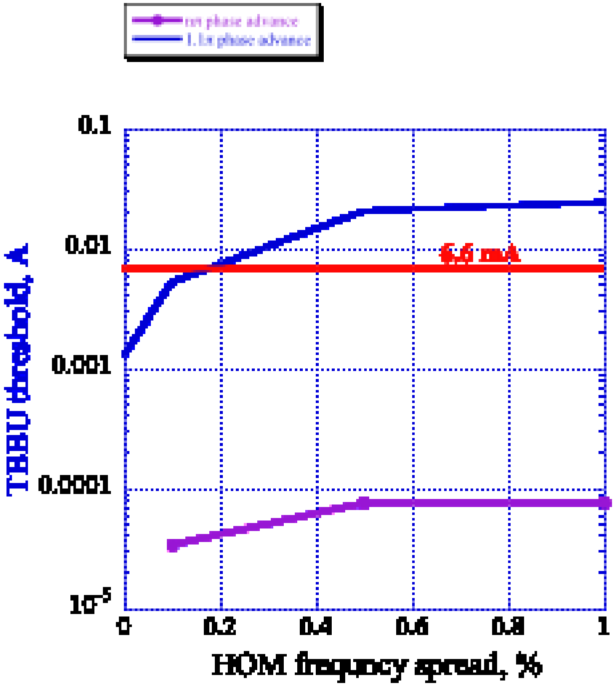
Excitation process of transverse HOM



$$\begin{bmatrix} x \\ x' \end{bmatrix}_{return} = \begin{bmatrix} m11 & \boldsymbol{m12} \\ m21 & m22 \end{bmatrix} \cdot \begin{bmatrix} 0 \\ x' \end{bmatrix}_{comming}$$



F (GHz)	R/Q (Ω)	Q	(R/Q)Q
0.8892	57.2	600	3.4e4
0.8916	57.2	750	4.3e4
1.7773	3.4	7084	2.4e4
1.7774	3.4	7167	2.4e4
1.7827	1.7	9899	1.7e4
1.7828	1.7	8967	1.5e4
1.7847	5.1	4200	2.1e4
1.7848	5.1	4200	2.1e4



hreshold
HOM
read.

Threshold exceeds the required beam current,
Potential for increasing TBBU threshold further exists

LHeC Isochronous arc cell

Each 180-degree arc is comprised of 113 cells

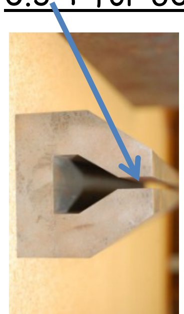
Note that arcs must be isochronous to avoid using 3rd harmonic cavities

Name	Length (m)	Gradient (T/m)
QF0	0.665	84.975
QD0	0.600	-88.970
QF3	1.200	107.75
QD3	0.800	-103/89
QF3S	1.200	107.220
QD3S	0.800	-101.095

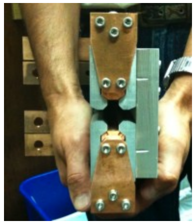
© D.Trbojevic

H function ~7E-5 m this arc
Filling factor 60%
Dipole field is ~ 0.28 T
@ 60 GeV pass

Small magnets for eRHIC should be fine for LHeC ERL © VL



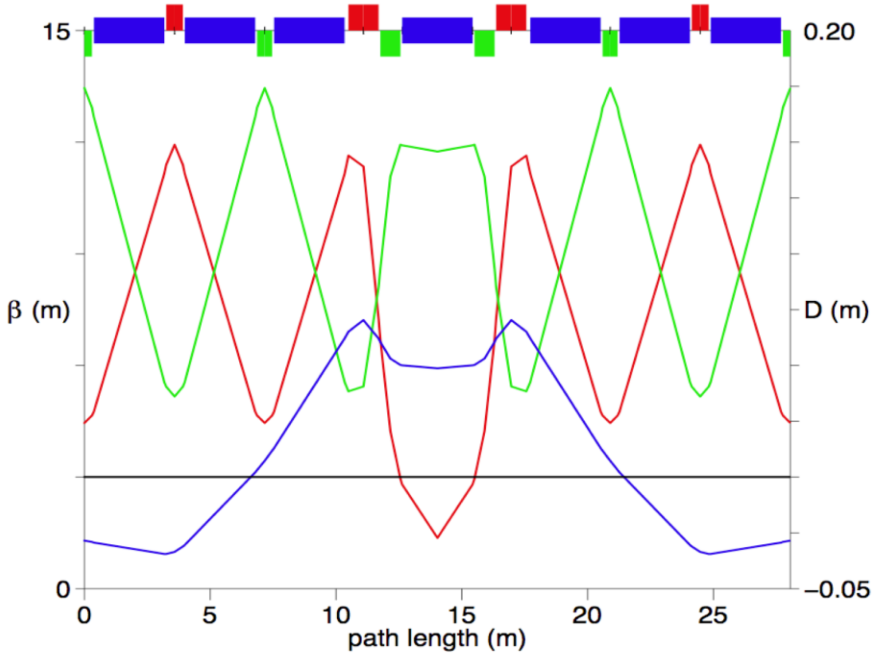
Gap 5 mm total
0.3 T for 60 GeV



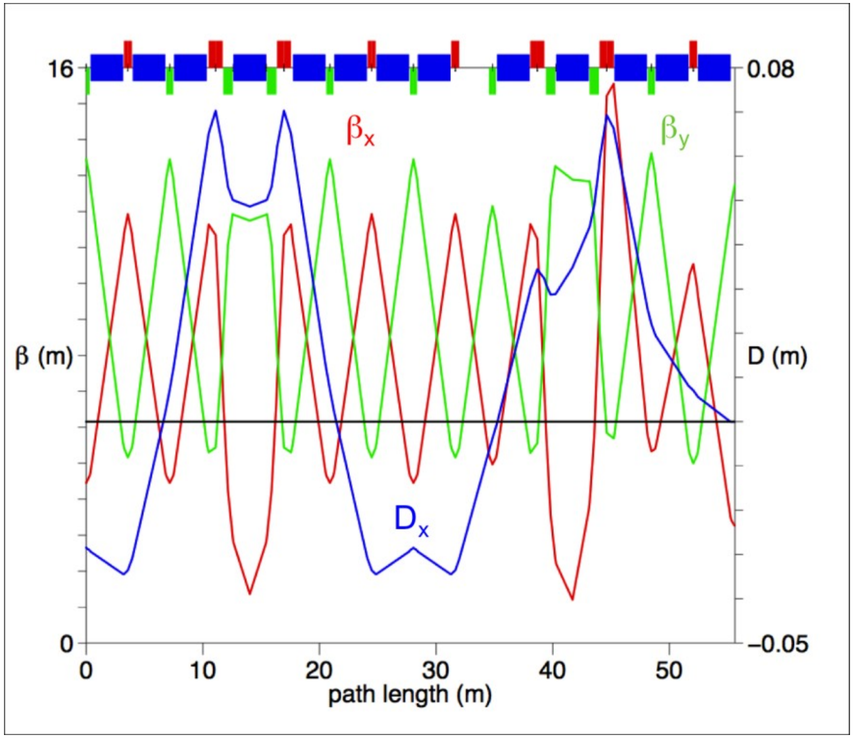
Arc's lattice

© D.Trbojevic

- Regular isochronous lattice of ERL's arcs. Length of cell is 27.8017 m. Red line – horizontal β-function, green - vertical β-function, blue – dispersion.



- The regular and the end of the arc cell lattice.



ERL-based LHeC with achromatic arcs

Up to the collision point			
	$\delta\varepsilon_{norm}$	8.59	mm mrad
	σ_γ	31.27	
	σ_E	15.98	MeV
Accumulted			
	$\delta\varepsilon_{norm}$	36.53	mm mrad
	σ_γ	68.96	
	σ_E	35.24	MeV

Formulae can be derived from equations (5.16) and (5.6) in Kolomensky/Lebedev book

© VL 28/09/10

$$\varepsilon_n = \varepsilon_{no} + \frac{55}{24\sqrt{3}} \Lambda_c r_e \int \gamma^6(s) K^3(s) H(s) ds$$

$$\langle\delta\gamma^2\rangle = \langle\delta\gamma^2\rangle_o + \frac{55}{24\sqrt{3}} \Lambda_c r_e \int \gamma^7(s) K^3(s) ds$$

Normalized emittance growth **per 180° arc!**

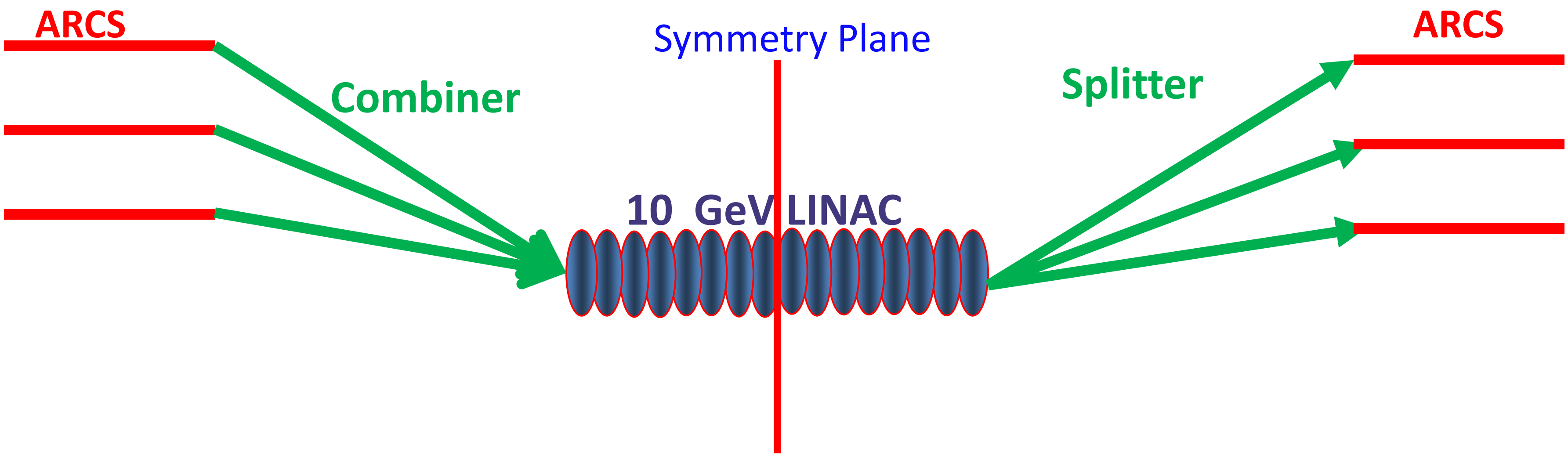
Arc	E, GeV	γ	δE, SR, GeV	δεn, m rad	$\delta\gamma^2$	*total*	*σγ/γ*
1	10.25	2.01E+04	6.93E-04	4.811615E-10	1.19E-02	*1.19E-02*	*5.44E-06*
2	20.2	3.95E+04	1.04E-02	2.818746E-08	1.37E+00	*1.38E+00*	*2.98E-05*
3	30.15	5.90E+04	5.18E-02	3.116532E-07	2.27E+01	*2.40E+01*	*8.31E-05*
4	40.1	7.85E+04	1.62E-01	1.725099E-06	1.67E+02	*1.91E+02*	*1.76E-04*
5	50.05	9.79E+04	3.94E-01	6.521871E-06	7.87E+02	*9.78E+02*	*3.19E-04*
6	60	1.17E+05	8.13E-01	1.935776E-05	2.80E+03	*3.78E+03*	*5.23E-04*
5	50.05	9.79E+04	3.94E-01	6.521871E-06	7.87E+02	*4.56E+03*	*6.90E-04*
4	40.1	7.85E+04	1.62E-01	1.725099E-06	1.67E+02	*4.73E+03*	*8.77E-04*
3	30.15	5.90E+04	5.18E-02	3.116532E-07	2.27E+01	*4.75E+03*	*1.17E-03*
2	20.2	3.95E+04	1.04E-02	2.818746E-08	1.37E+00	*4.76E+03*	*1.74E-03*
1	10.25	2.01E+04	6.93E-04	4.811615E-10	1.19E-02	*4.76E+03*	*3.44E-03*
Total			**2.05E+00**	**3.65E-05**	**4.76E+03**		

The bottom line – the quality of the beam is not spoiled neither in the collision point nor on the way back to the injection energy

Classical radius of electron	r_e	cm	2.817938E-13	m	2.81794E-15
Compton wavelength of electron	Λ_e	cm	3.861591E-11	m	3.86159E-13

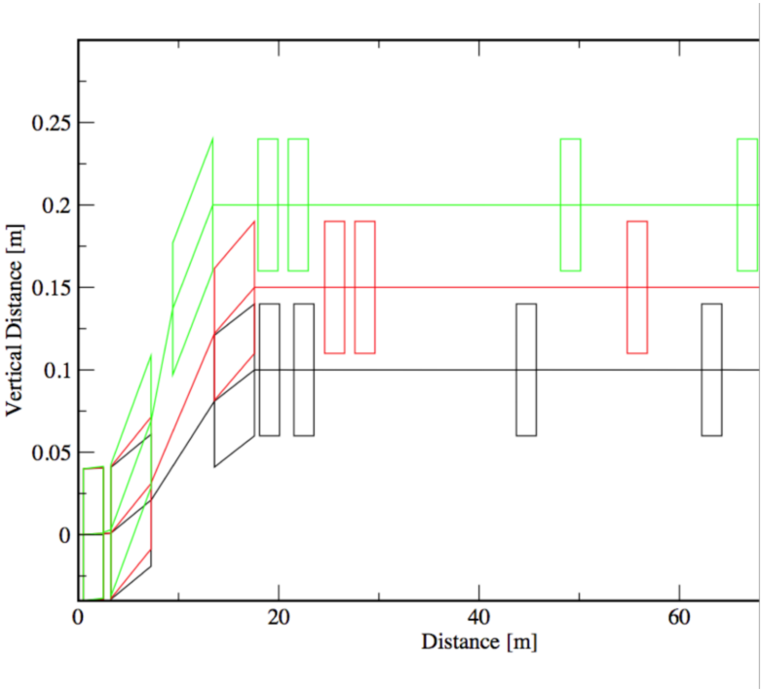
Splitters/combiners

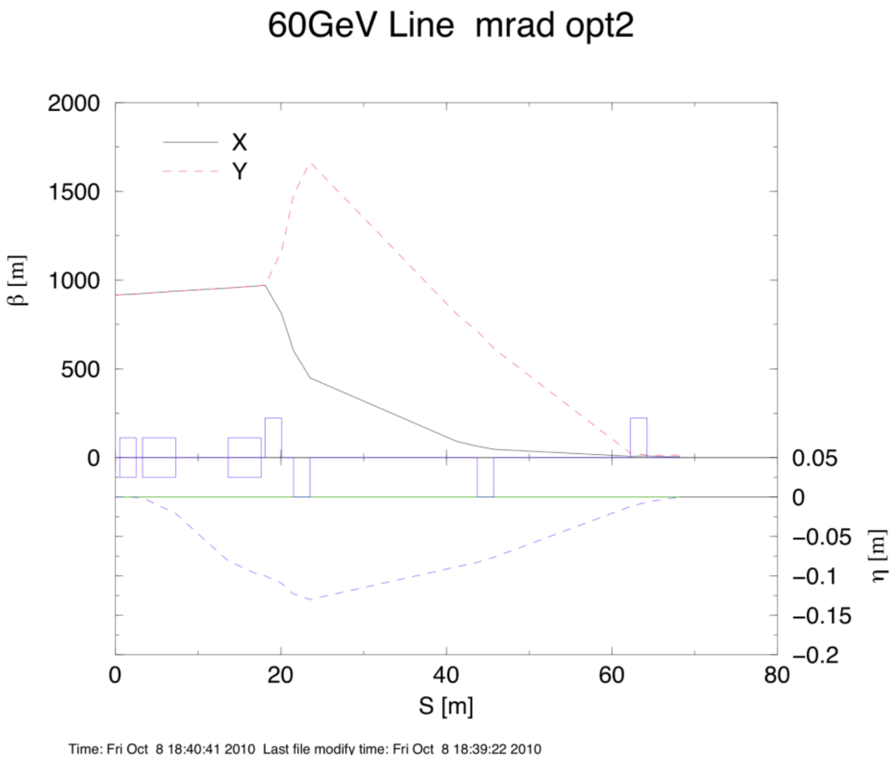
"Beam" is nearly mirror symmetric with respect to a plane passing by the center of LINAC, Therefore
"Beam Optics" of **Combiner** is the near mirror image of that of the **Splitter**



© N.Tsoupas

Splitters/combiners + matching





Optics functions of splitter for 20, 40 and 60 GeV beams and matching with the arc.

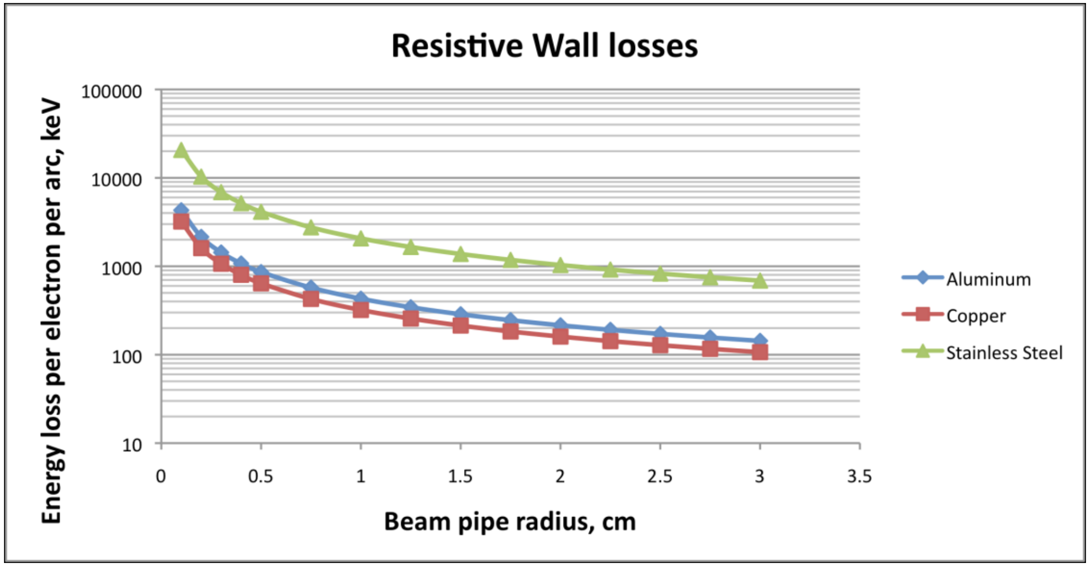
- 13.54 MW of the SR losses radiated power with 6.6 mA CW current
- Max power density ~ 2 kW/m, which is well within the demonstrated 8kW/m in B-factories

Other losses

- HOM loss
- CSR power loss
- **Resistive wall losses**
- …….

(©V.Ptitsyn)

Bunch length	0.3mm
Number of electrons per bunch	$2\ 10^9$
Average arc radius	1000 m
Bending radius	697 m



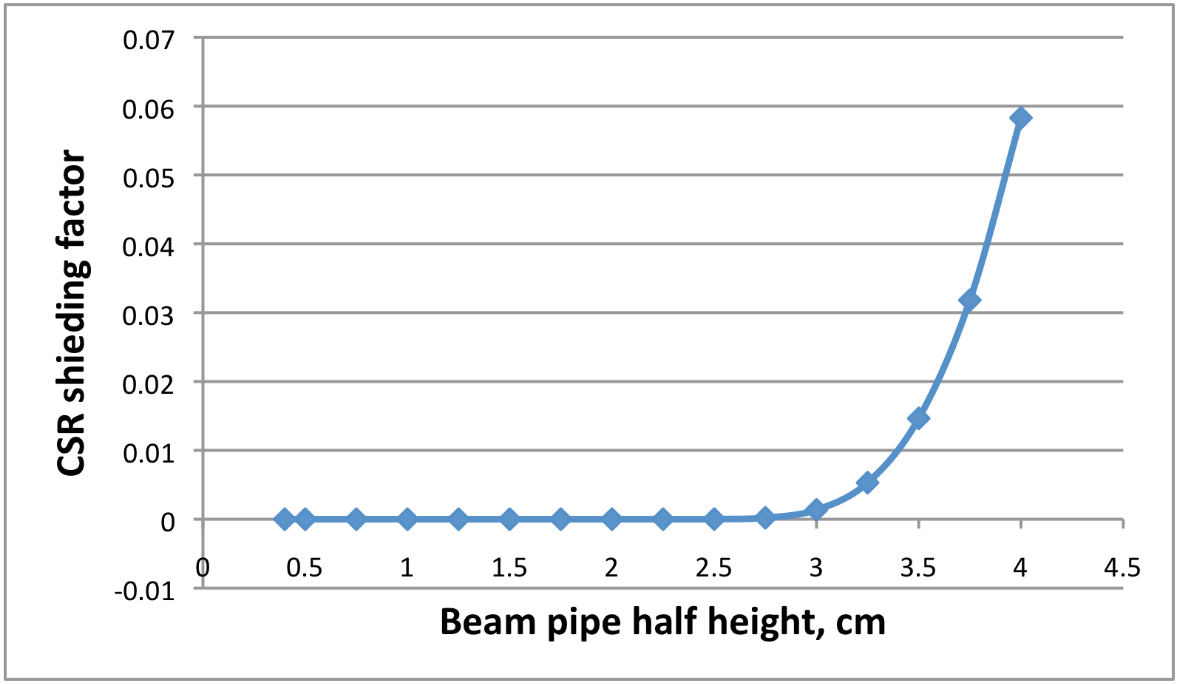
With the effective Al pipe radius ~ 2 mm there will be additional 24 MeV energy loss and similar level of the energy spread due to the resistive wall. While 24 MeV energy loss is very small compared with 2.05 GeV SR loss, the induced correlated energy spread is comparable with the 35 MeV RMS uncorrelated spread induced by SR

CSR power loss

Bunch length	0.3mm
Number of electrons per bunch	2 10^9
Average arc radius	1000 m
Bending radius	697 m

Without shielding, the beam will loose 1.4 MeV per arc due to Coherent Synchrotron Radiation (CSR). Again, it is dwarfed by the incoherent SR losses. The total induced correlated energy spread will be about 12 MeV. In any case, the CSR will be strongly suppressed by the walls of the vacuum chamber

(©V.Ptitsyn)

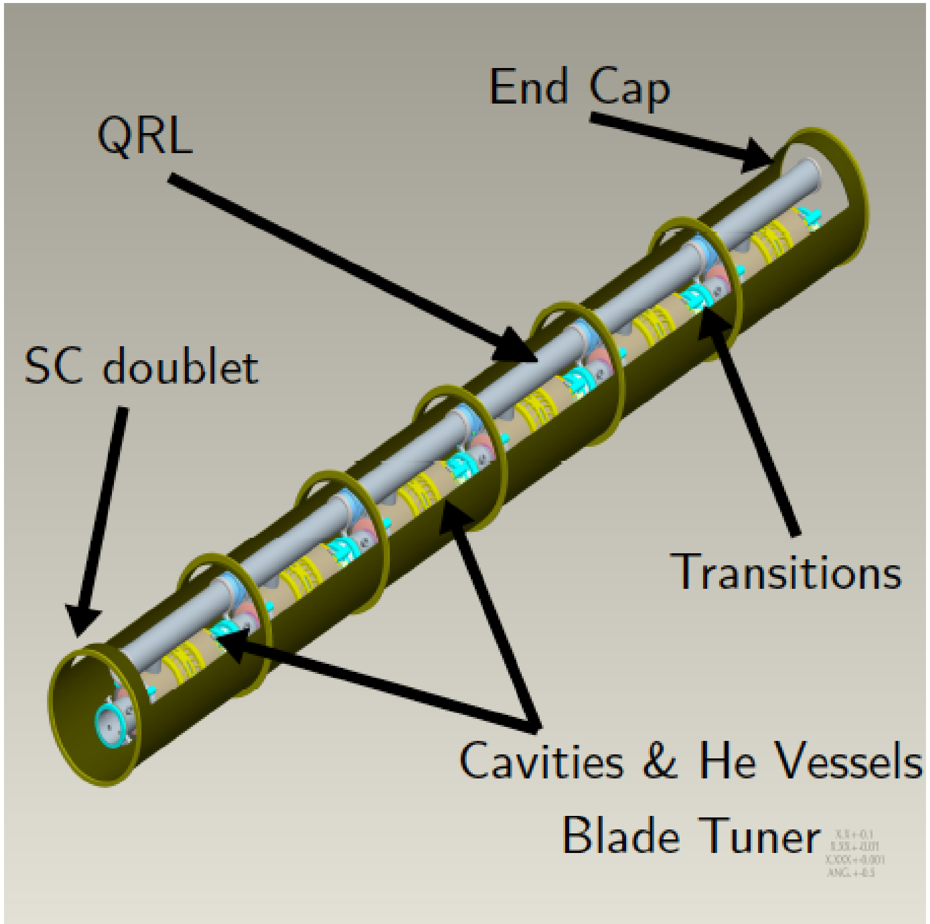


Conclusions

- High luminosity ERL-based LHeC looks feasible
- Linacs with and without focusing elements can be used
- Important feature is full (100%) spin transparency from the gun to the IP
- Design has no obvious showstoppers
- Beam-beam effects weaker that we had simulated for eRHIC, i.e. no unexpected surprises here
- Details should be studied further
- The BBU threshold should be further increased 3-4 fold by optimizing the arcs and linac lattice

Back up

Preliminary Cryomodule



String assembly of multiple cavities.

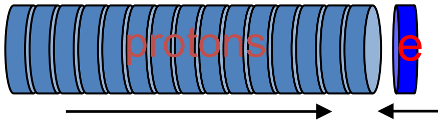
Heat shielding and top covers removed for clarity.

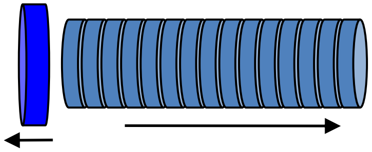
Breakdown of the eRHIC Cryomodule

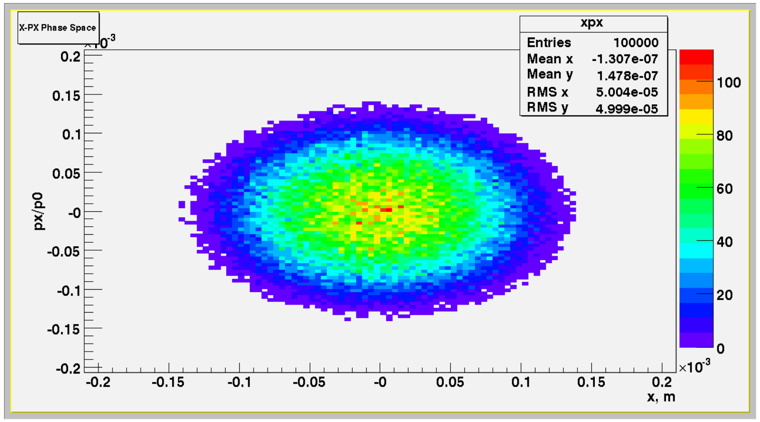
- N cavities = 6 (but can 4-8)
- Module length = 9.6 m
- L period = 10.6 m
- E_{acc} = 18.0 MV/m
- dE/ds = 10.2 MeV/m

New design of 704 MHz cavity (BNL III) with reduced peak surface magnet field should have similar cryogenic losses at 20 MeV per cavity

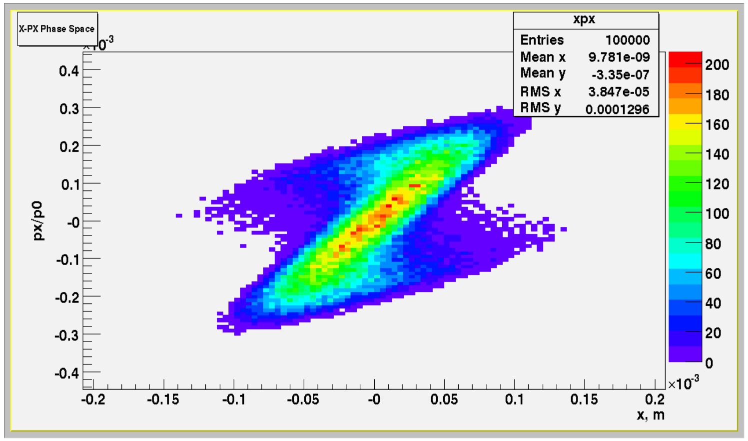
Beam Disruption



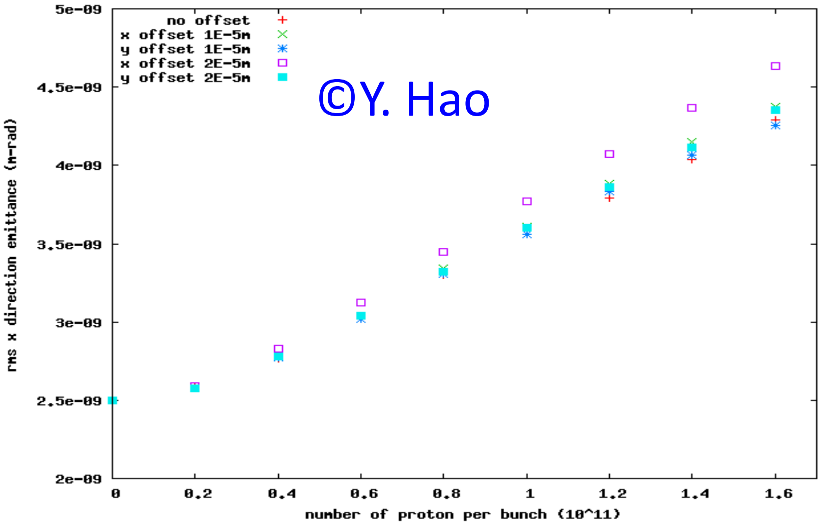




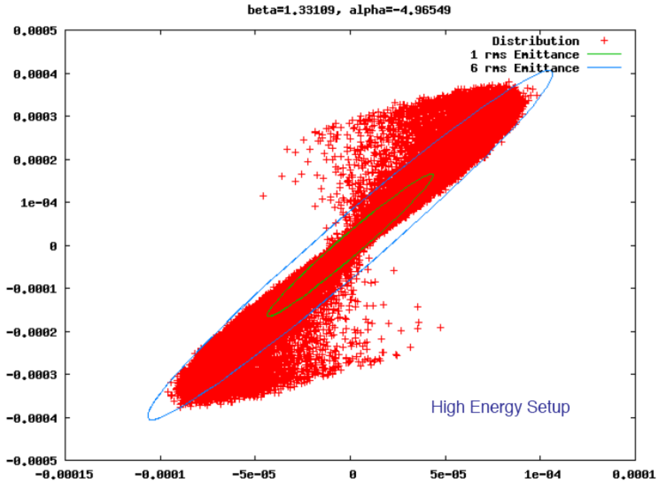
Interaction



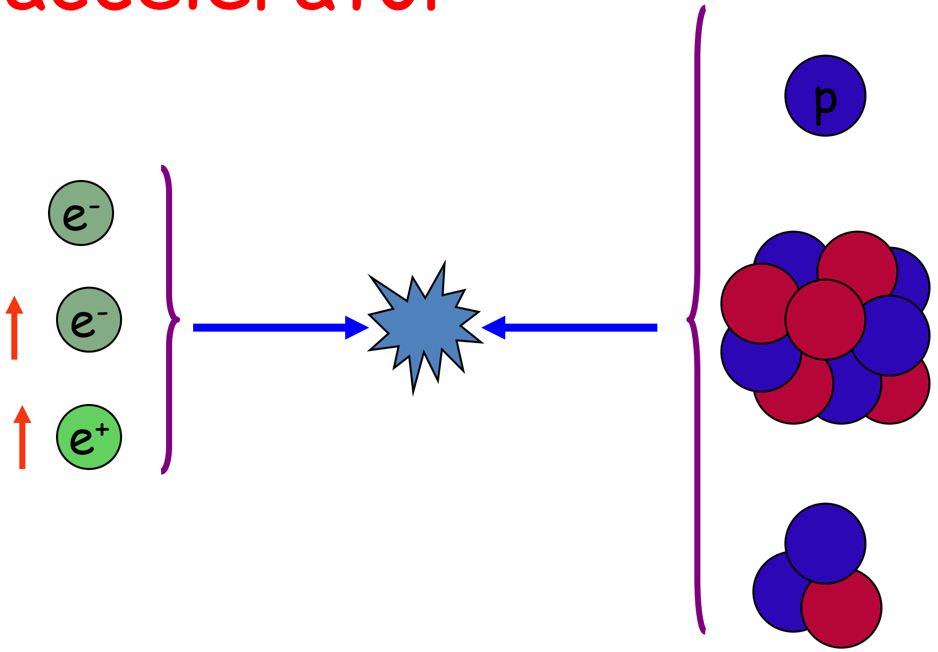
Optimized



©Y. Hao



LHeC Scope



Electron accelerator

Unpolarized and
polarized leptons
60-140 GeV

LHC

Protons up to 7 TeV

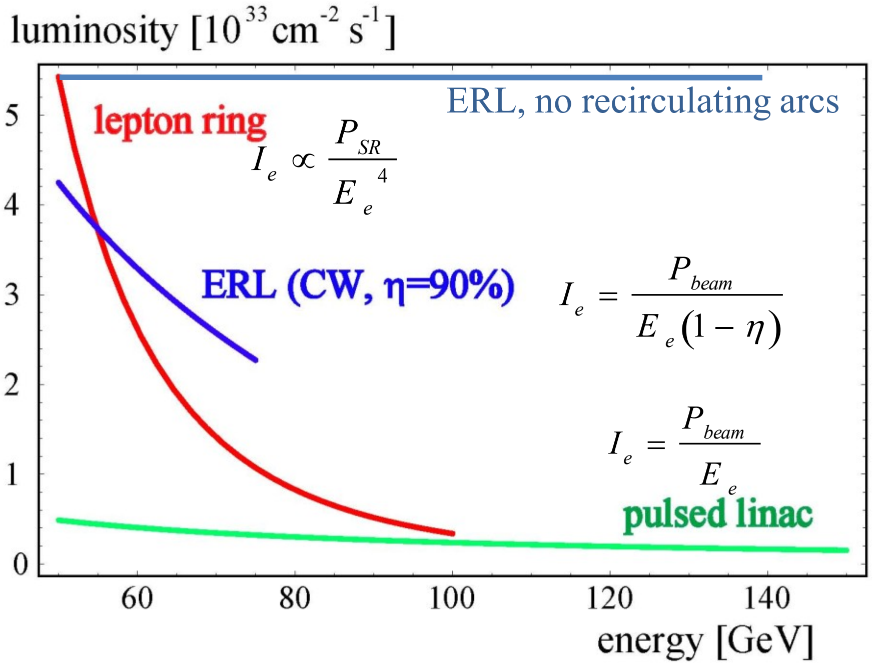
Heavy ions
3 TeV/u

Other ions?

Center mass energy range: 0.5- 2 TeV

Luminosity vs e-beam energy

for AC-plug power consumption set at 100 MW



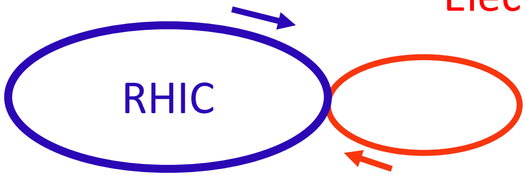
Advantages & Challenges of ERL based eRHIC

$$L = \left(\frac{4\pi\gamma_i\gamma_e}{r_i r_e}\right)(\xi_i\xi_e)(\sigma'_i\sigma'_e)f \Rightarrow L = \gamma_i f N_i \frac{\xi_i Z_i}{\beta_i^* r_i}$$

- **Allows use of RHIC tunnel for the return passes and thus allow much higher (2-3 fold) energy of electrons compared with the storage ring.**
- **High luminosity up to 10^{34} cm^{-2} sec^{-1}**
- **Allows multiple IPs**
- **Allows higher range of CM-energies with high luminosities**
- **Full spin transparency at all energies**
- No machine elements inside detector(s)
- No significant limitation on the lengths of detectors
- **Energy of ERL is simply upgradeable**
- Novel technology
- Need R&D on polarized gun
- May need a dedicated ring positrons (if ever required?)

View from 2004: How eRHIC can be realized?

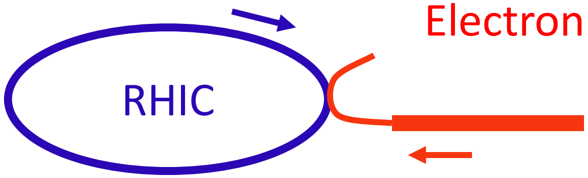
- Ring-ring:



Electron storage ring

$$L = \left(\frac{4\pi\gamma_h\gamma_e}{r_h r_e}\right)(\xi_h\xi_e)(\sigma'_h\sigma'_e)f$$

- Linac (ERL)-ring:



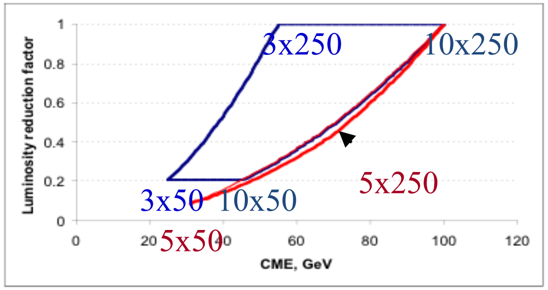
Electron linear accelerator

$$L = \gamma_h f N_h \frac{\xi_h Z_h}{\beta^*_h r_h}$$

Advantages & Challenges of ERL based eRHIC

- Allows use of RHIC tunnel
- 2-3 fold higher energy of electrons
- Higher luminosity up to 10^{34} cm^{-2} sec^{-1}
- Multiple IPs
- Higher range of CM-energies + high luminosities
- Full spin transparency at all energies
- No machine elements inside detector(s)
- No significant limitation on the lengths of detectors
- ERL is simply upgradeable
- eRHIC can be staged

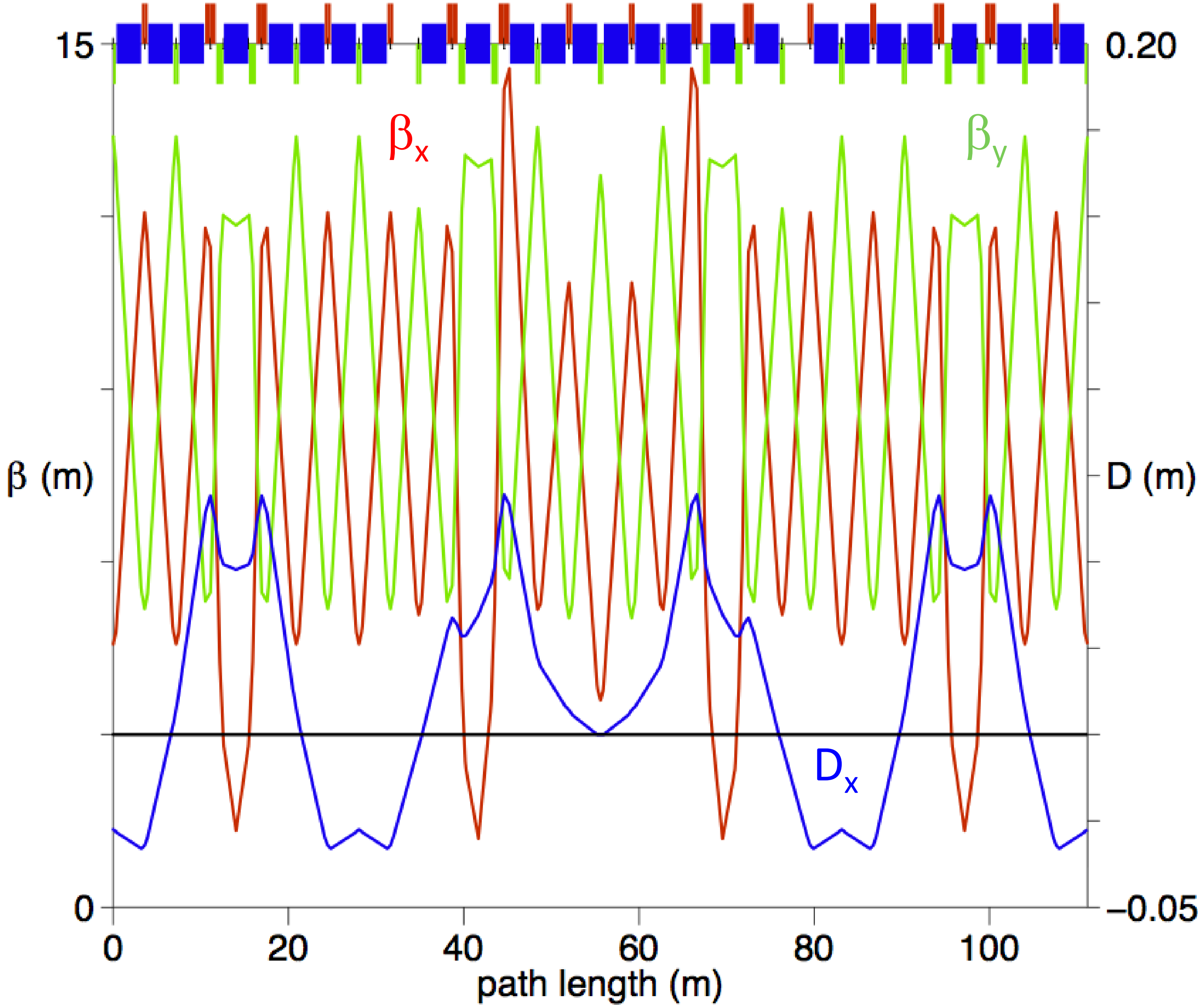
- Novel technology
- Need R&D on polarized gun
- May need a dedicated ring positrons



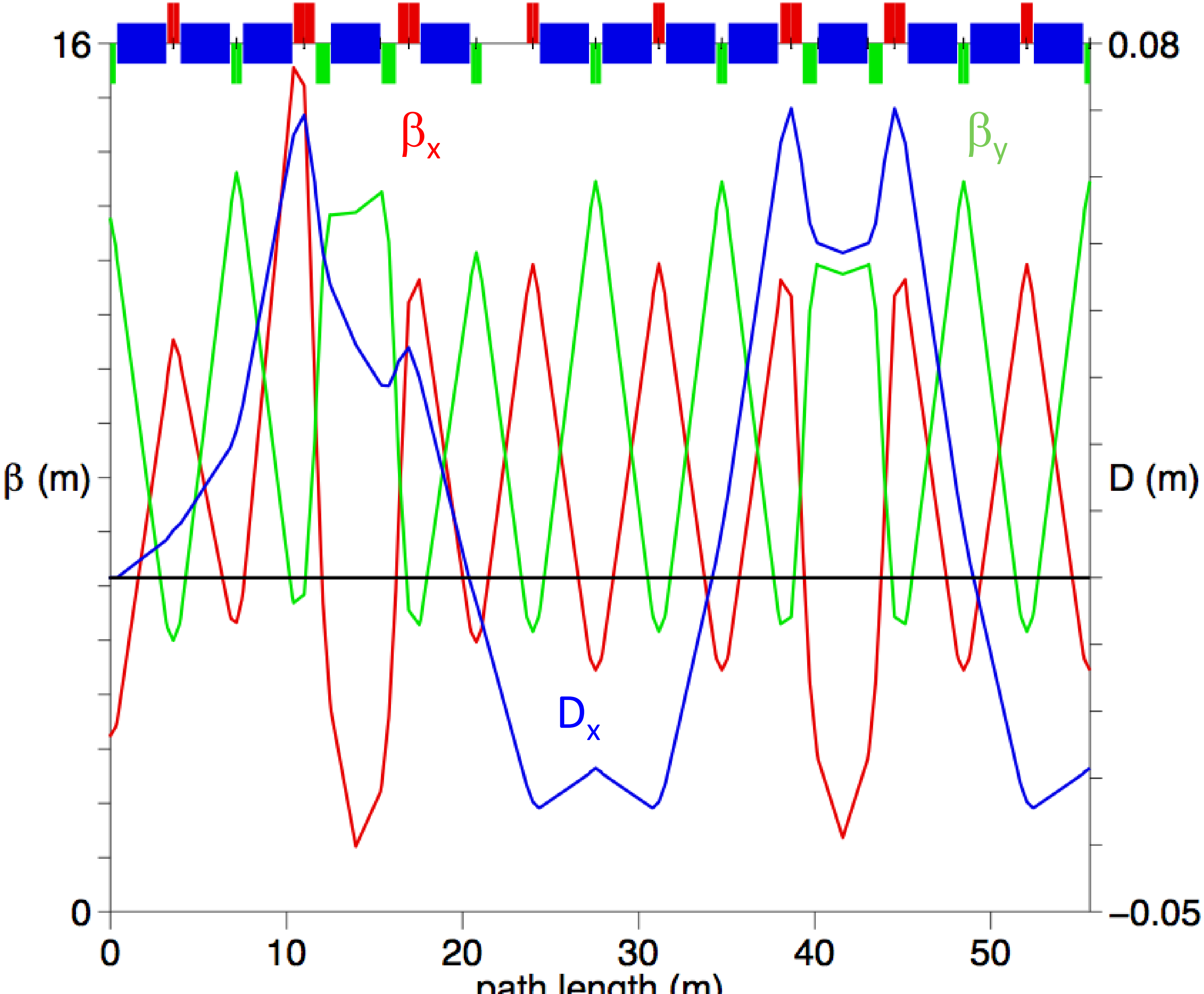
In Ring-ring luminosity reduces 10-fold for 30 GeV CME.
Required norm.emittance (for 50 GeV protons) ~3 mm*mrad

http://www.agsrhichome.bnl.gov/eRHIC/

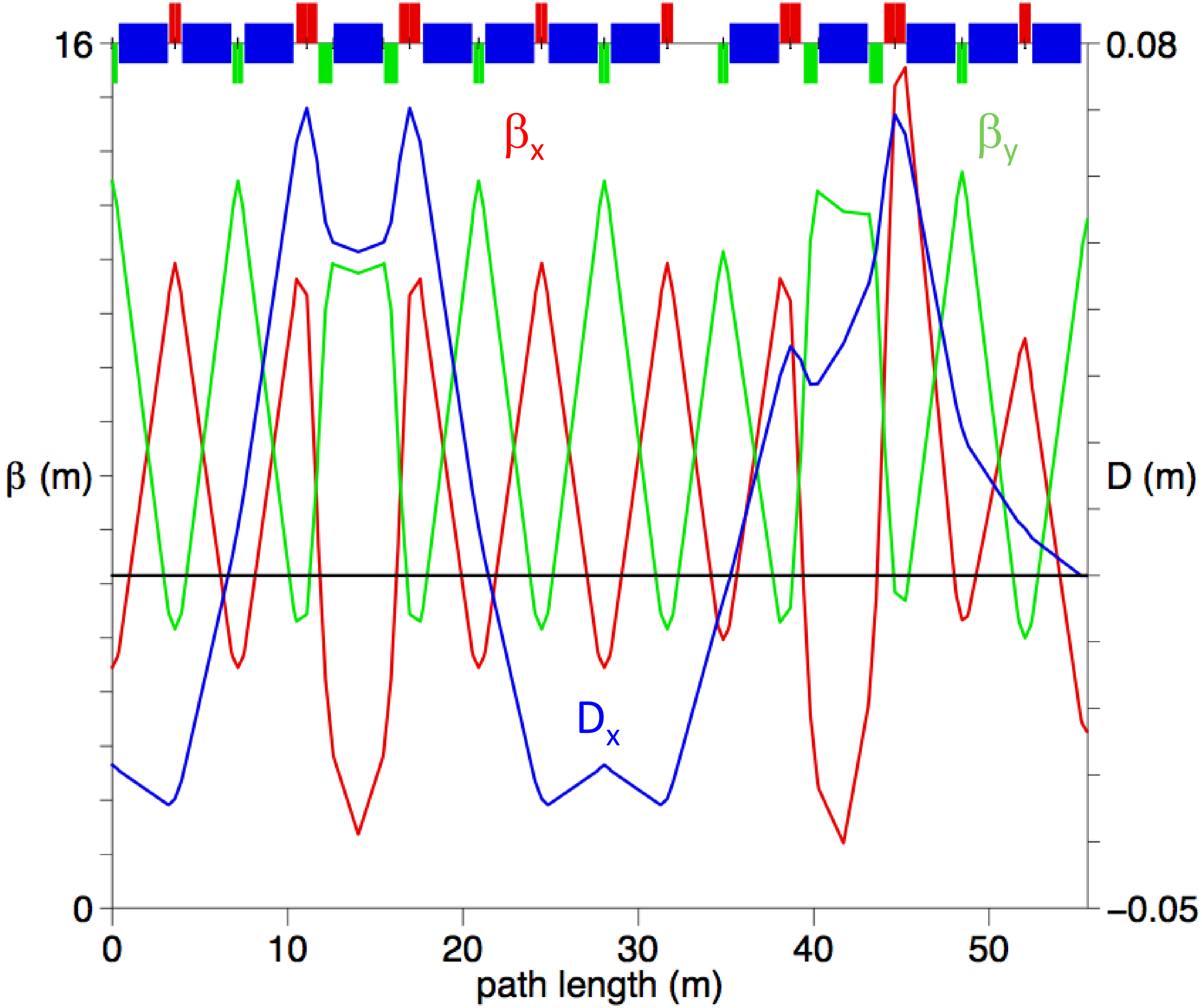
Arc and matching cell



Matching and the arc cell



Arc cell and matching cell



Arc cell

EMAX (GeV)	PC (GeV/c)	BRHO (Tm)
60.000000000	59.999999998	200.138457112

DIPOLES:

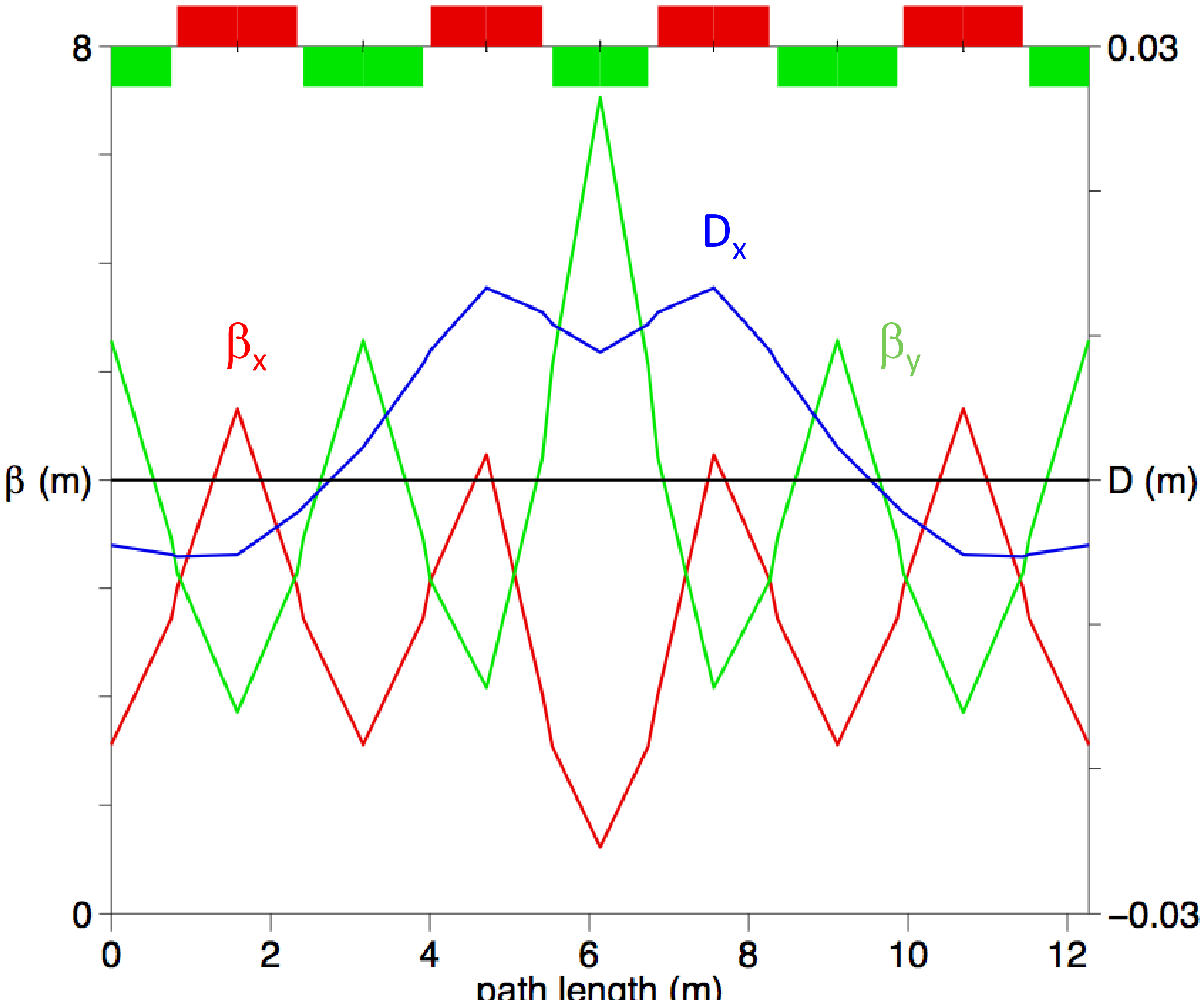
ANG	BL (m)	N_{DIP}	R_{DIP} (m)
0.004017382	2.80	1564	696.971326788

GF0 = 84.975 T/m QLF = 0.665 m
GD0 = -88.97 T/m QLD = 0.60 m

GF3 = 107.75 T/m QLF3 = 1.20 m
GD3 = -103.89 T/m QLD3 = 0.80 m
OFFW = 0.15272264 m
O1 = 0.065049881 m
O2 = 0.071114479 m

GF3S = 107.22407 T/m QLF3 = 1.20 m
GD3S = - 101.09491 T/m QLD3 = 0.80 m

Arc cell with combined function magnets



Combined function magnet Properties

EMAX	PC	BRHO
60.000000000	59.999999998	200.138457112

BL = 1.5 m
QLF3 = 1.4 m
QLD3 = 1.2 m

RDIP (m)	**Field** BY2 (T)	Length BL (m)
937.104304925	0.213571164	1.500000000

NCELL	ANG	NDIP
512.000000000	0.001600676	3925.333333333

Gradients:

GFC = 155.590 T/m
GF3 = 207.371 T/m

GDC = -148.300 T/m
GD3 = -210.235 T/m