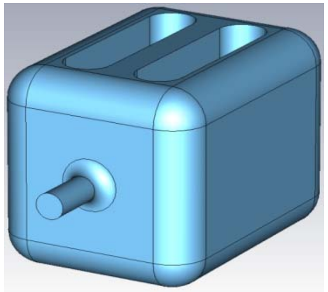
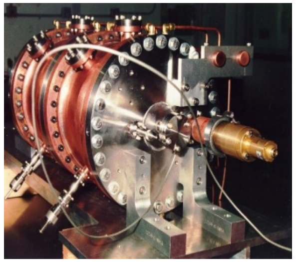
Beam Dynamics Studies of Parallel-bar Deflecting Cavities





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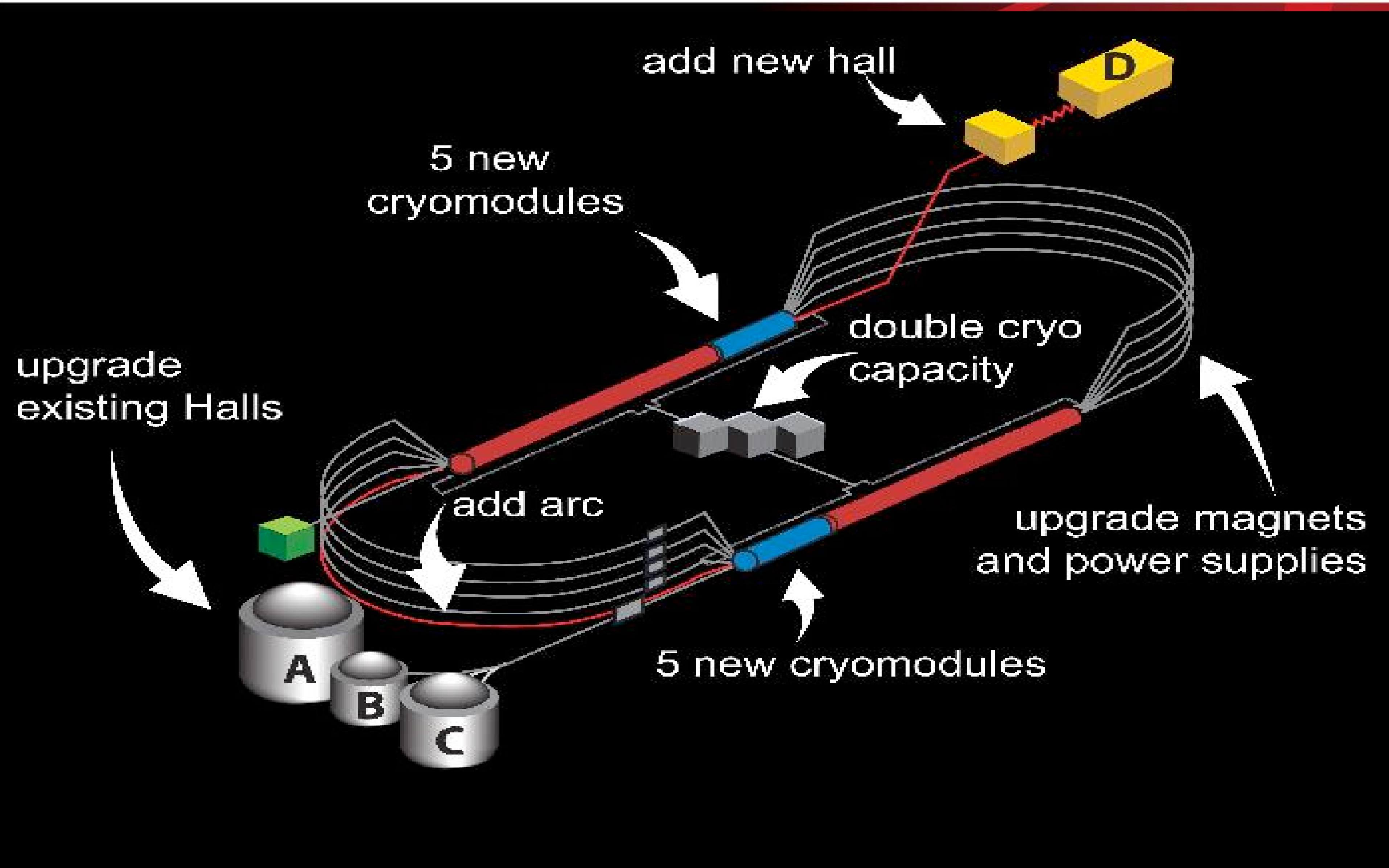
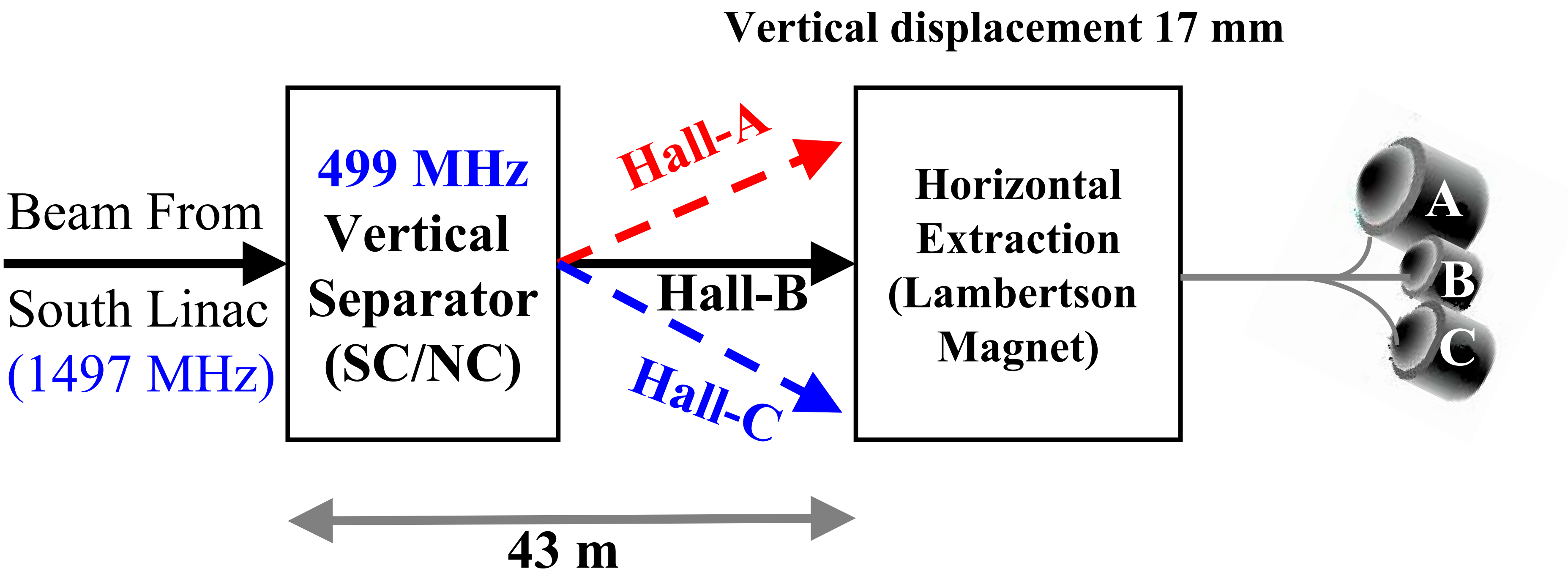
Layout of Presentation

- Brief Overview of 12 GeV Upgrade related to 11 GeV RF separation
- Motivation
- Superconducting Structure
- NC Cavity Arrangements
- Comparison Between NC and SC Structures
- Summary

Accelerator Schematic with 12 GeV Upgrade Options



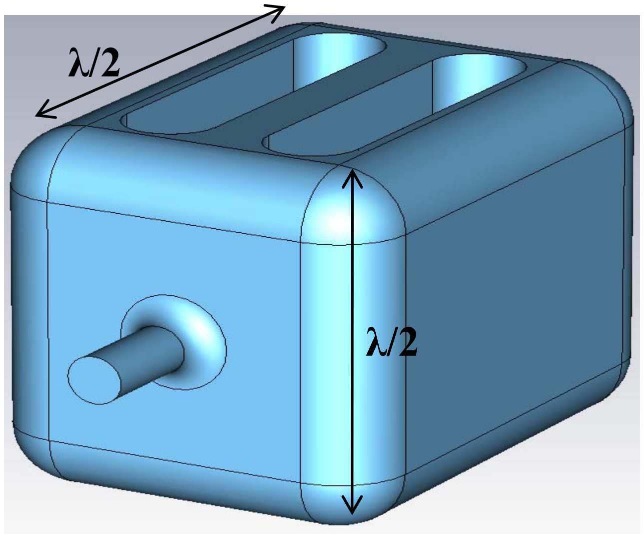
Schematic of Separation Plus Extraction System



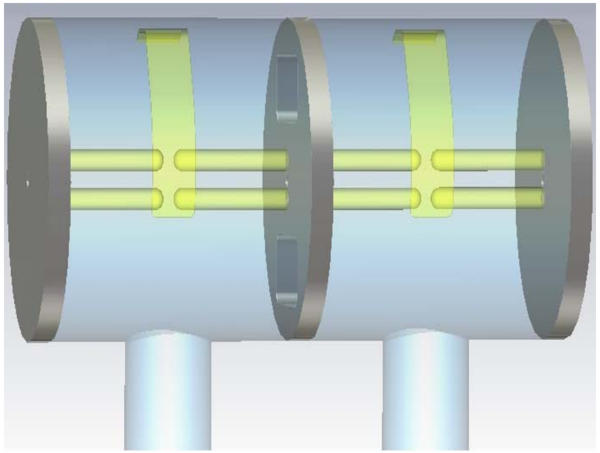
Noteworthy Points:

- ❖ Utilize existing horizontal extraction magnet (Lambertson)
- ❖ Vertical separation followed by horizontal extraction
- ❖ 17 mm vertical displacement at entrance of extraction magnet

Deflecting Cavities – NC & SC



Superconducting (SC)



Normal Conducting (NC)

Parameter	SC	NC	Unit
Frequency of π mode	499.2	499	MHz
λ/2 of π mode	300.4	300.4	mm
Cavity length	394.4	300	mm
Bars width	67	20	mm
Bars length	284	135	mm
Aperture diameter	40.0	15	mm
V_{def}^*	0.3	0.3	MV
E_p^*	1.85	3.39	MV/m
B_p^*	6.69	8.87	mT
$G = QR_S$	67.96	34.9	Ω
$[R/Q]_T$	933.98	24921	Ω
At E_T^* = 1 MV/m			

Why Need Simulations ?

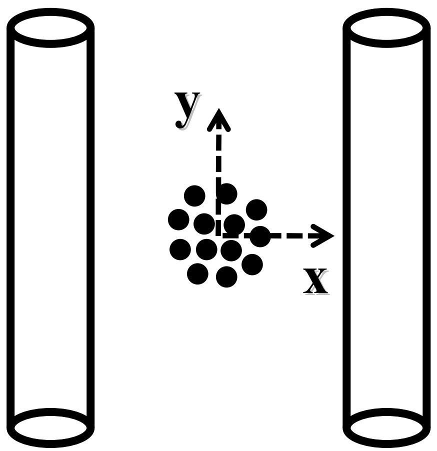
- Two different deflecting cavities : normal conducting (exists for 6 GeV CEBAF operation) and superconducting (design available)

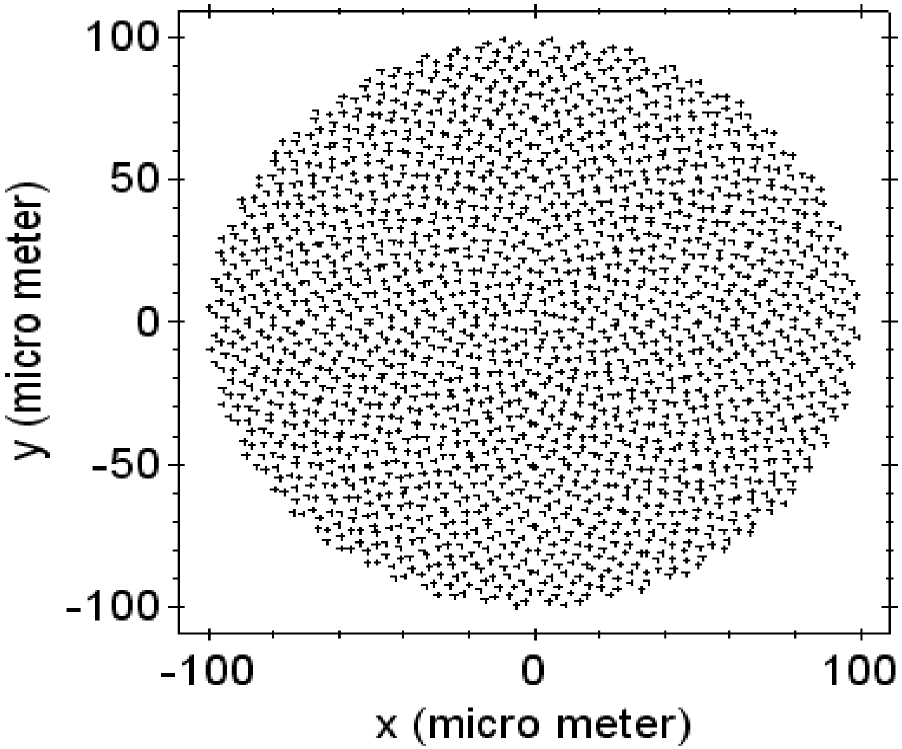
- No beam dynamics predictions available for 11 GeV separation

- Require one/two SC but six/eight NC structures
  - Aperture diameter : 40 mm for SC and ~ 15 mm for NC
  - Beam stay clear condition requires 6.5 mm from either wall (SC is OK but NC may not enough)
  - Alignment tolerance for NC arrangement
  - Emittance dilution needs to know

Beam Dynamics : Simulation Schematic

- Particle : 1000 electron ($m_e = 5.11 \times 10^{-4}$ GeV), Q = 1 pC
- E : 11 GeV , $p = \sqrt{(E^2 - m_e^2)} \sim 11$ GeV/c
- $\beta = E / p \sim 1$, $\gamma = E / m \sim 2.15264 \times 10^4$

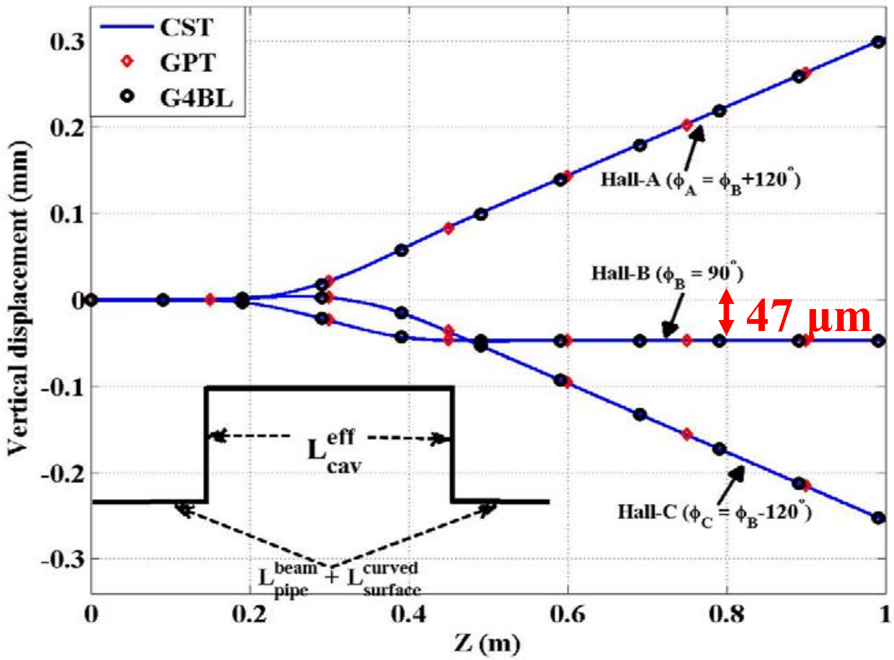


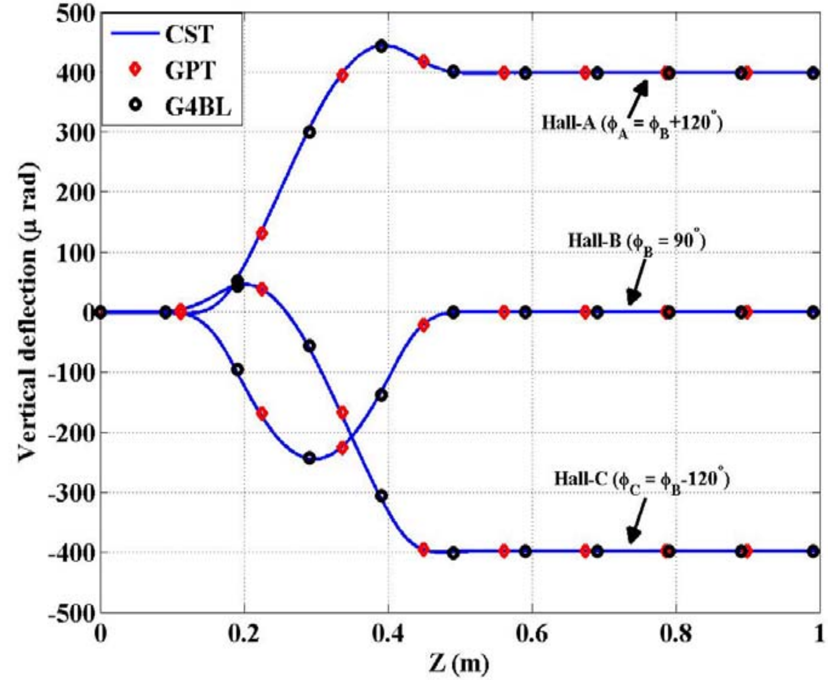


Distribution : uniform
Initial Emittance : zero

First discussion for SC structure followed by comparison with NC

Transverse Displacement & Deflection





$$x_f' = x_0' + \frac{q_e V_{def}}{E_b} Cos\phi$$

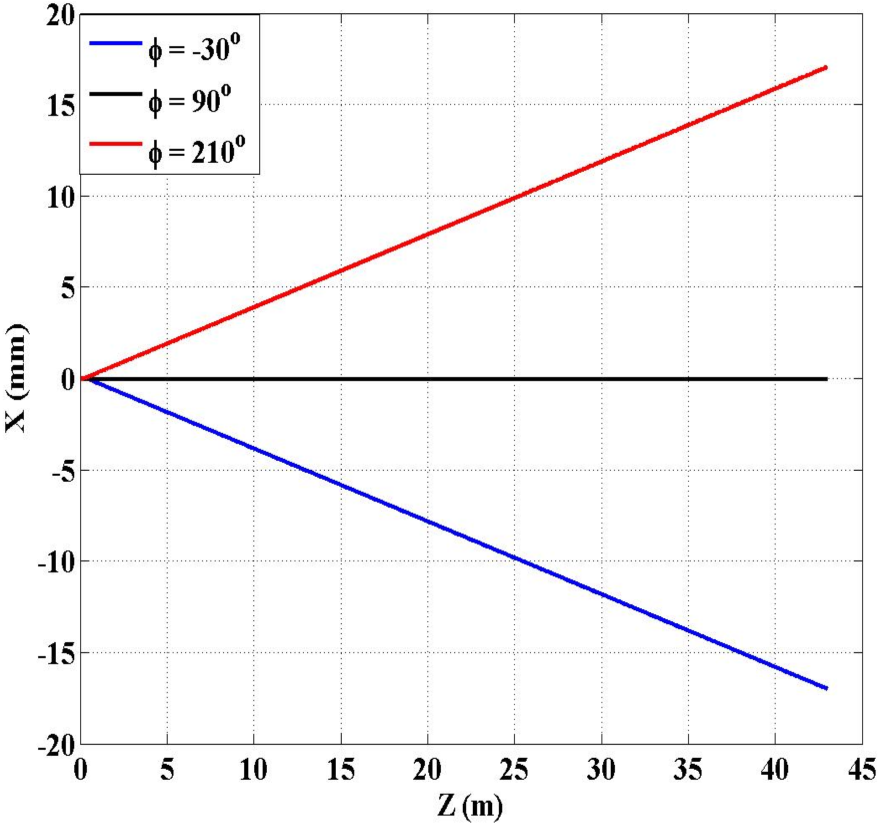
$$x_f = x_0 + \frac{L}{2}\left(x_0' + x_f'\right) + \frac{q_e V_{def}}{kE_b} Sin\phi$$

Angle has cosine function

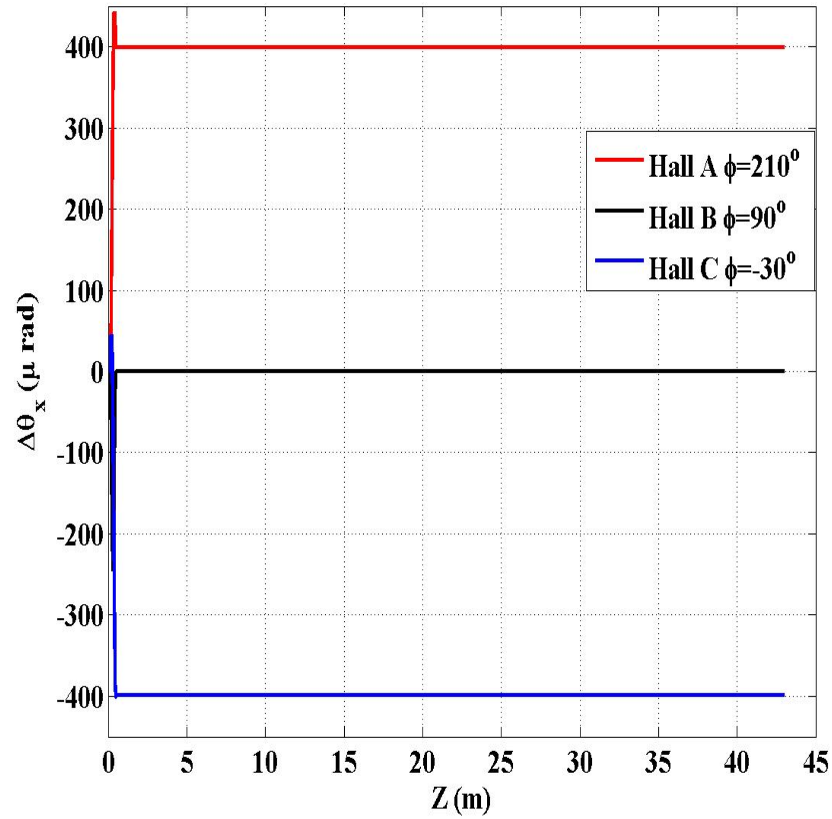
Displacement has sine function

Displacement & Deflection @ Lambertson Magnet

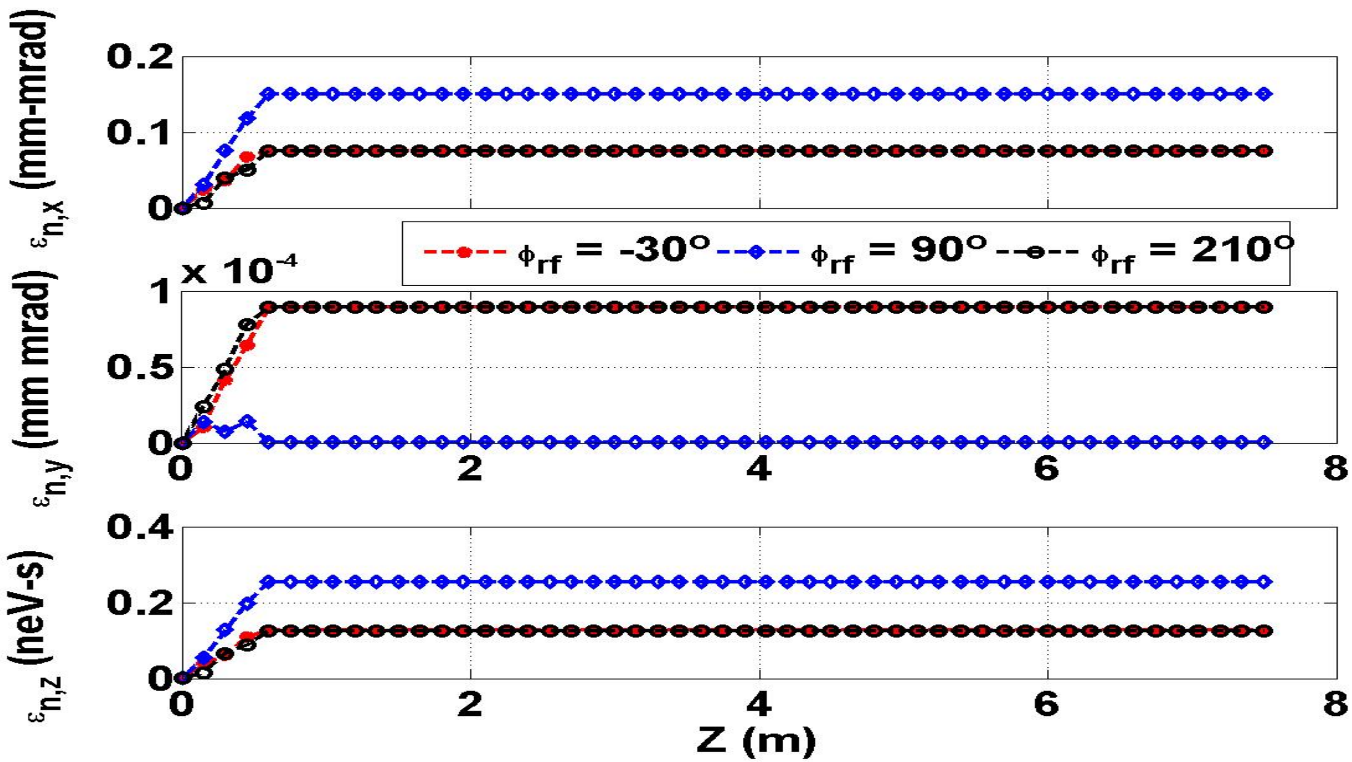
Displacement



Deflection



Normalized RMS Emittance

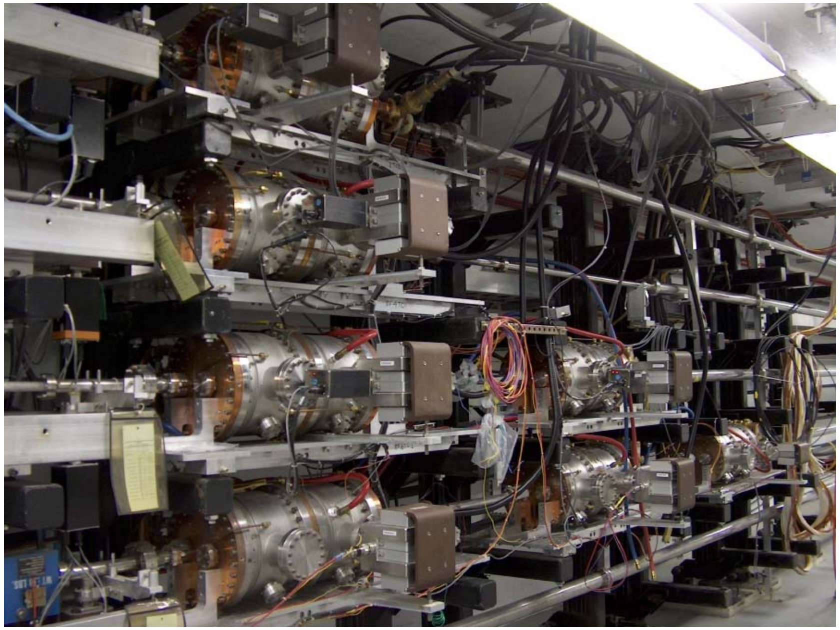


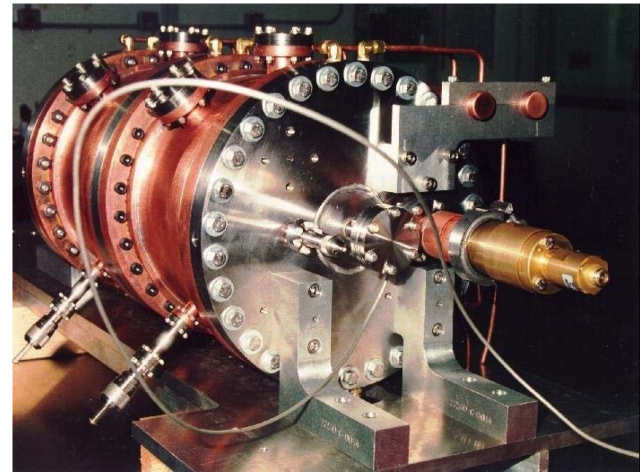
For uniform distribution corresponding to $\varphi = \varphi_{ref}$:

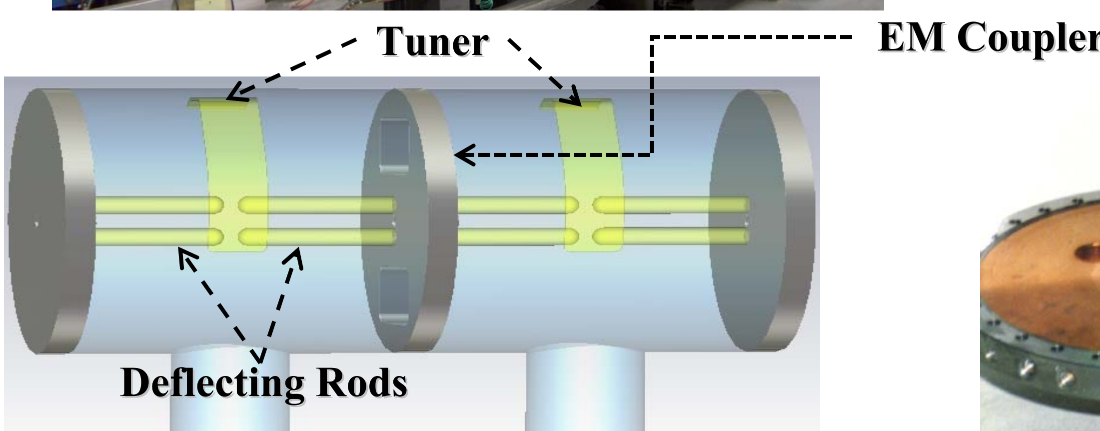
$$\varepsilon_{n,\,rms} = \frac{q_e V_{def}}{4\sqrt{3} m_e c^2} k r_b l_b$$ = 0.15 mm-mrad agrees with simulation

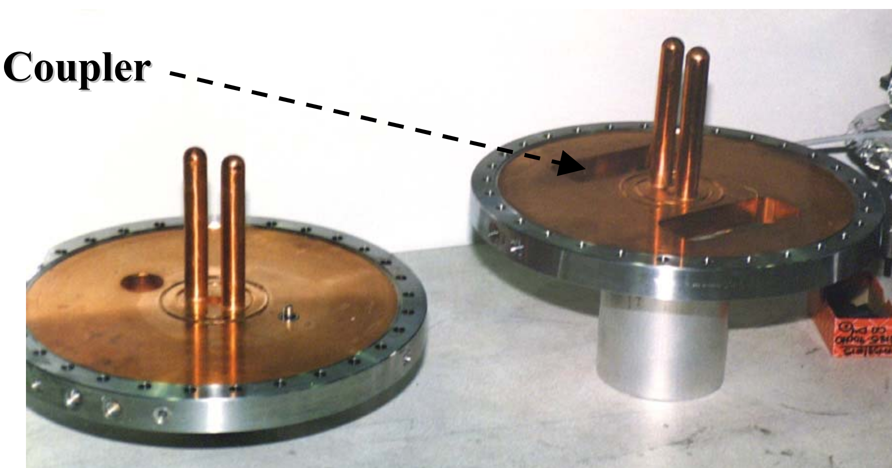
$\varepsilon^{def}_{n,\,rms} = 0.5 \times \varepsilon^{ref}_{n,\,rms}$; as deflecting gradient is half.

Normal Conducting Cavity

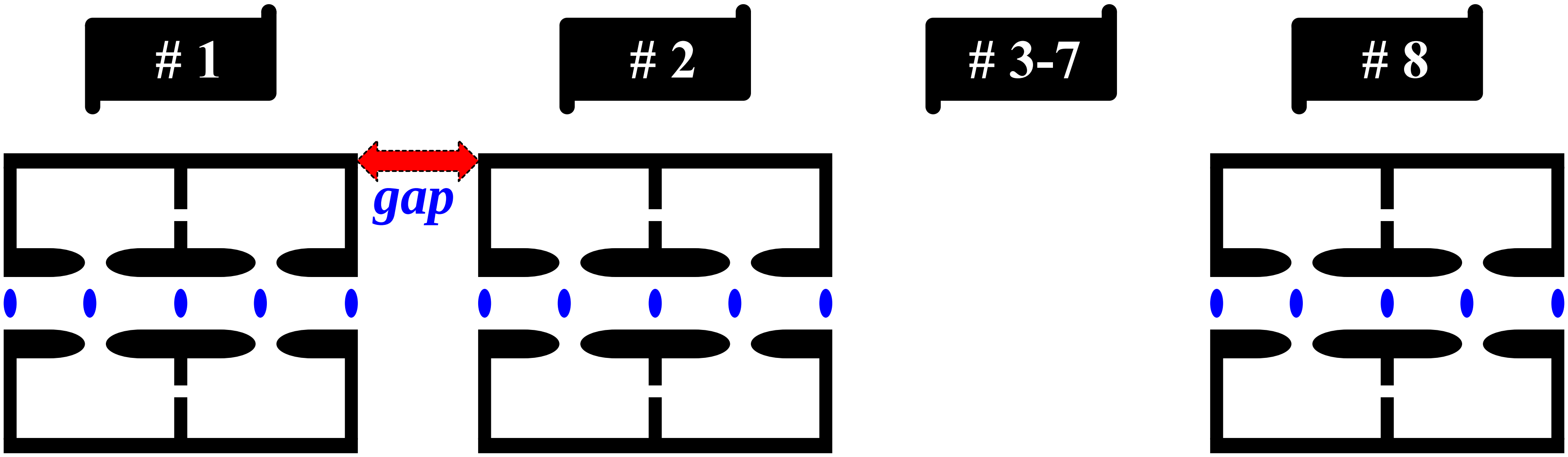








8-Cavity Arrangement



Cavity Length = 601.2 mm @ f = 499 MHz , c = 3 x 10^8 m/s

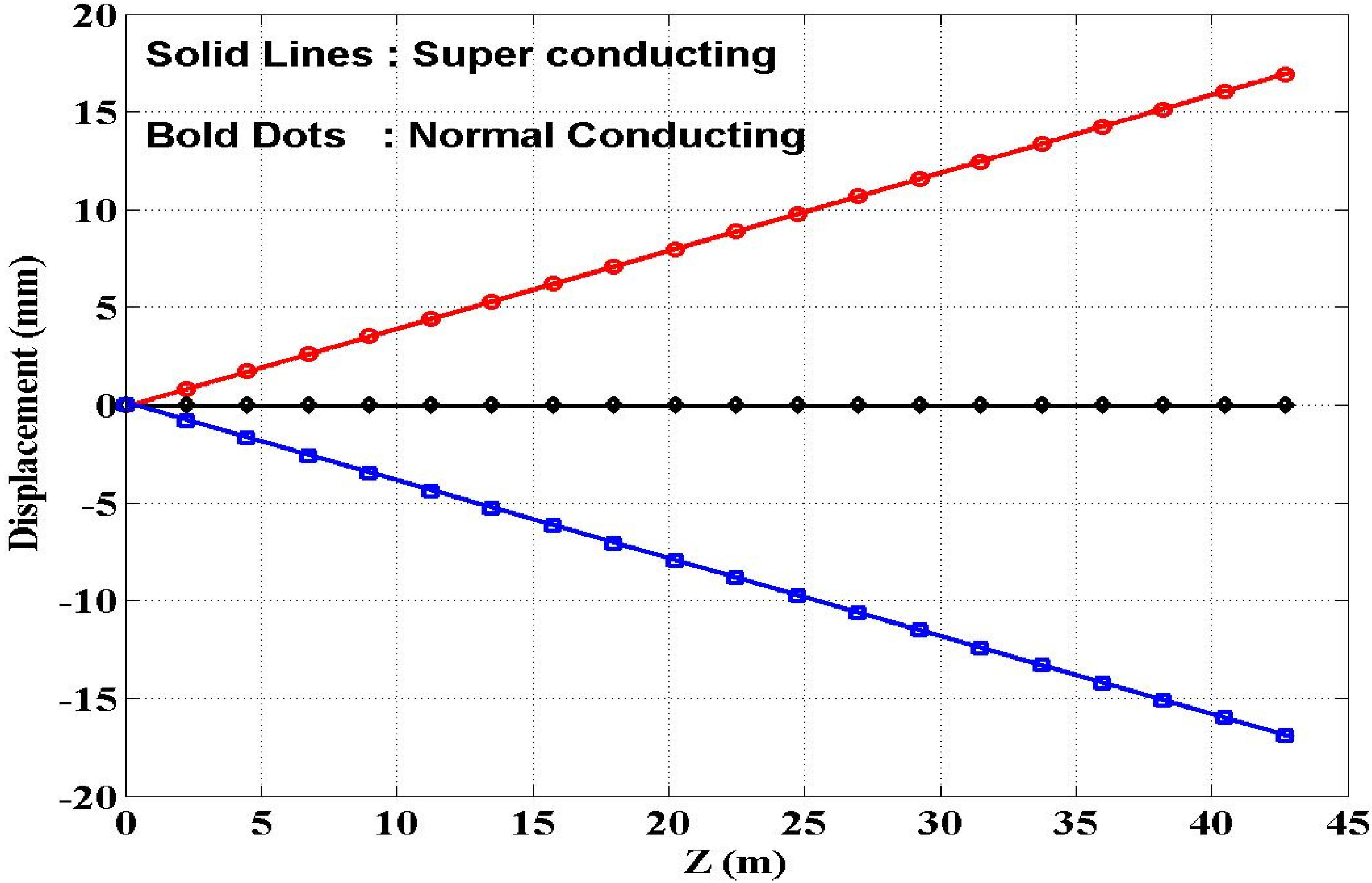
Gap = 130.06 mm

Center-to-center distance = 731.26 mm

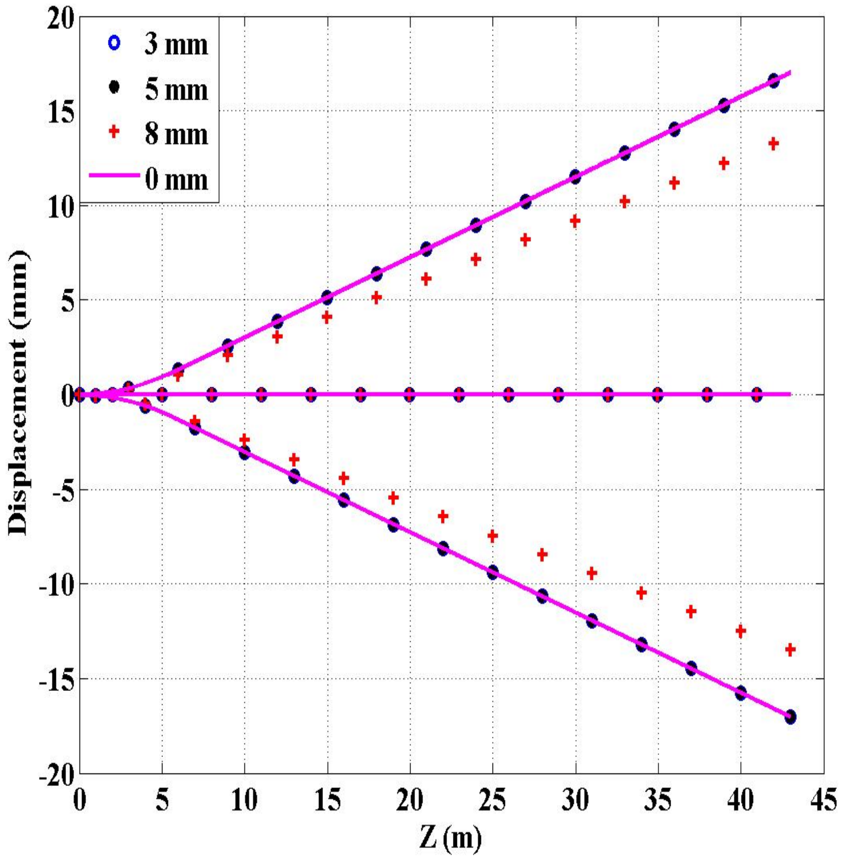
Time-Delay = $(731.26 \times 10^{-3}) / (3 \times 10^{8}) = 2.44$ ns

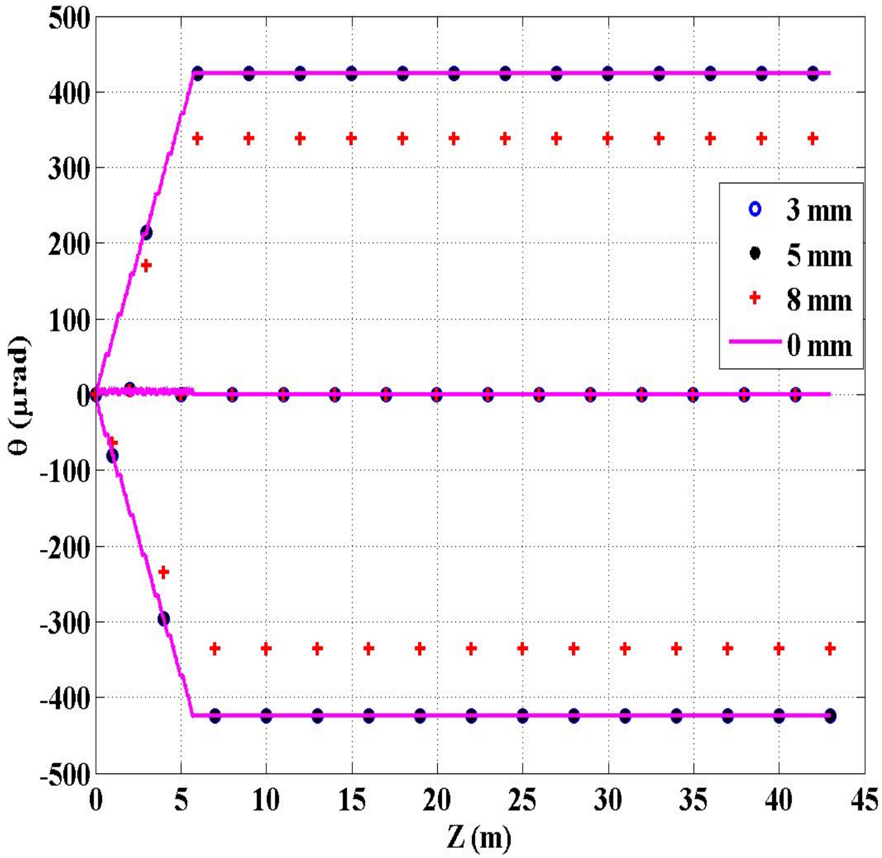
Phase Delay = $2\pi f$ x Time-Delay = 437.88 deg

NC Versus SC


Solid Lines : Super conducting
Bold Dots : Normal Conducting
Displacement (mm)
Z (m)
20
15
10
5
0
-5
-10
-15
-20
0
5
10
15
20
25
30
35
40
45

Mechanical Vibration : Displacement & Deflection





Conclusion

- One/two SC or an array of NC structures can be used to provide required vertical displacement
- Emittance dilution is small
- Array of NC cavities demonstrated stability against mechanical vibration
- Both SC and NC structures are suitable for 11 GeV separation in 12 GeV upgrade of CEBAF