BPM Low ß Calibration Test Stand

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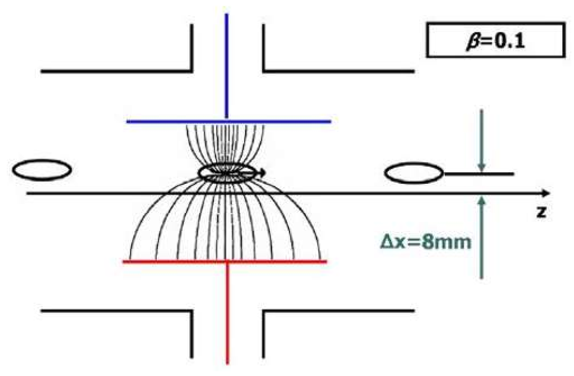
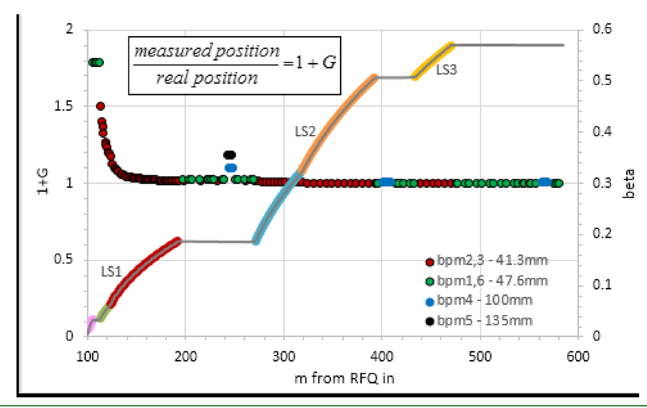
If you wish to discuss, I will be at TUPP20

Corrections for capacitative pick-ups for non-relativistic effects

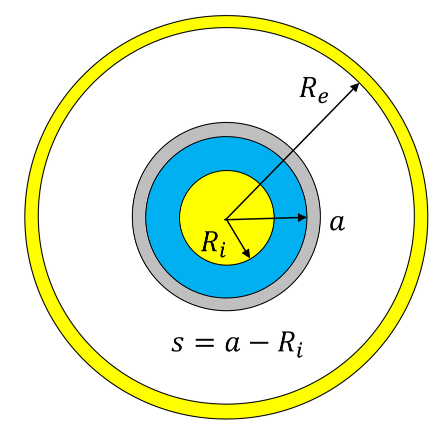
- Non-relativistic beams are not pancaked longitudinally.
  - Standard analysis does not account for non-relativistic effects to simplify results.
  - The different field extents affect the measurements
- Corrections for non-relativistic effects
  - Analytic: $x \propto \frac{1}{1+G}\frac{\Delta}{\Sigma}$, $G = \frac{g}{2}\frac{I_0(g)}{I_1(g)}$, $g = \frac{\omega D}{\beta \gamma c}$
  - Simulation: simulate response of device to non-relativistic beams
- Want benchtop test stand for measuring effects
  - Test stand must replicate field profile and velocity of beam
- Helical transmission lines can be used
  - They propagate pulses at low phase velocities

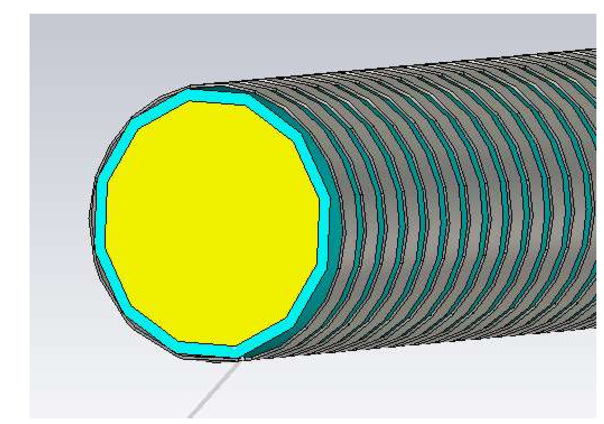


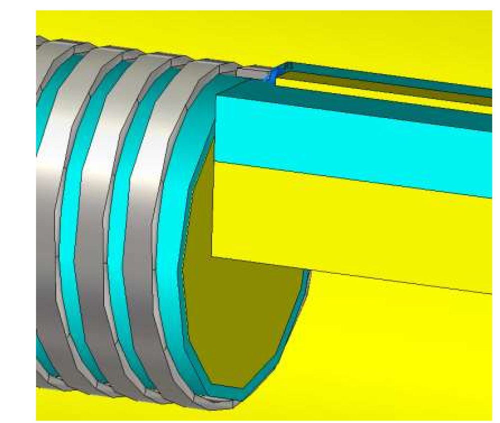


Geometry

- The helix has pitch angle ψ and radius a. In simulations it has thickness Δa
- Centered in the helix is a conducting rod of radius R_i
- The inner conductor is covered in a dielectric of thickness $s = a - R_i$ and dielectric constant ϵ_r. This supports the helix
- The helix is inside a pipe with radius R_e
- The signal is input into the internal region using a microstrip with the same impedance as the helix

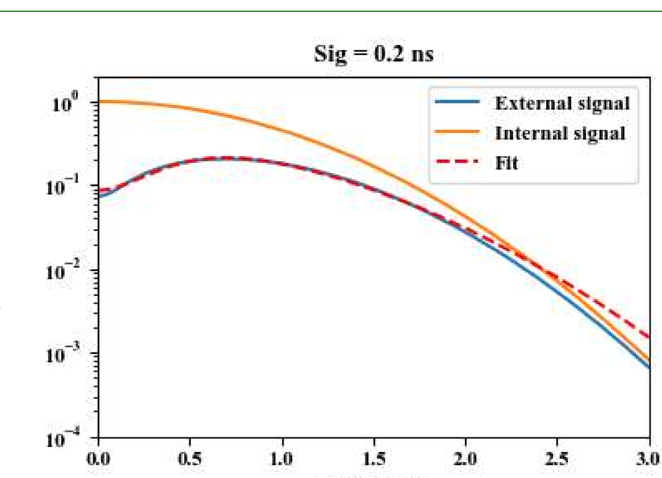




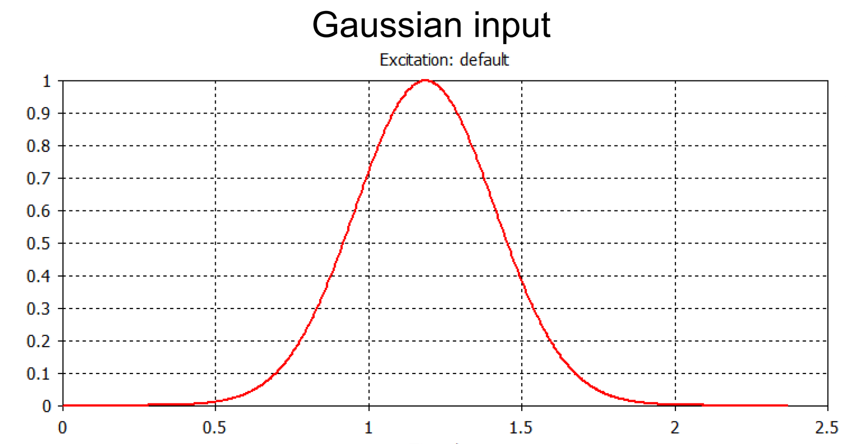


Internal-External Coupling

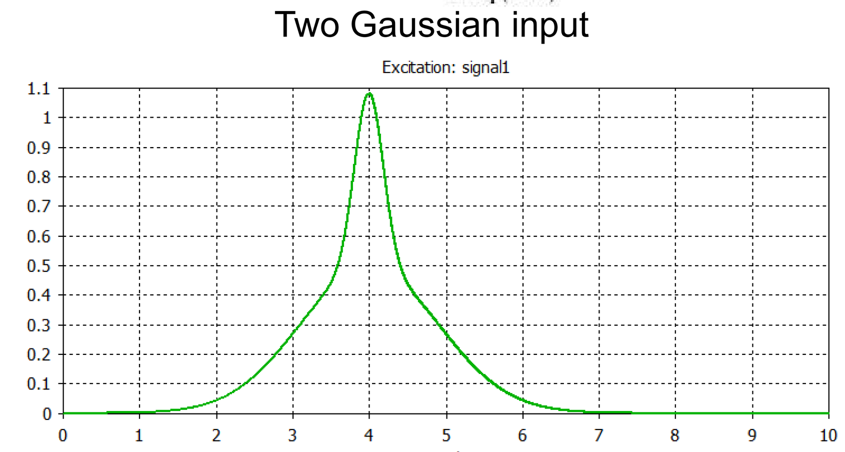
- Signal is input into internal region, need field in external region to replicate a beam
  - The coupling suppresses low frequency components
- The signals are input in the internal region, therefore the input signal must be tailored to correct for this effect
  - The sum of two Gaussians can be used to approximate a Gaussian pulse in the external region



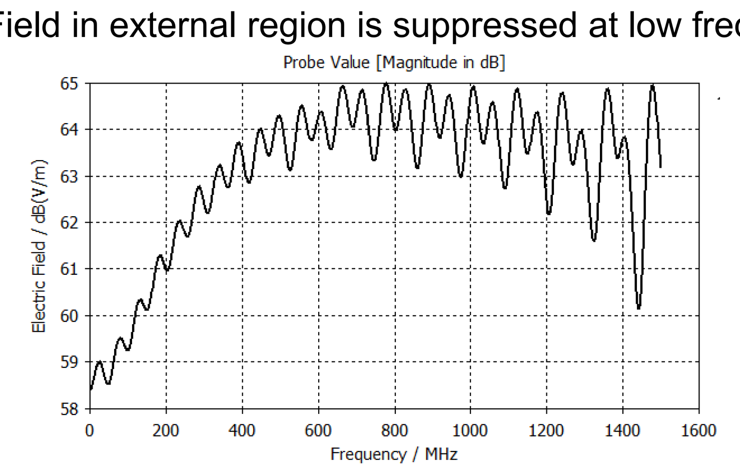
Gaussian input



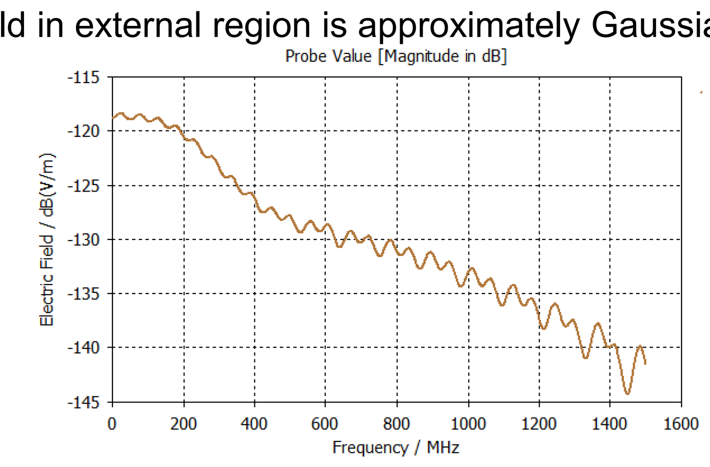
Two Gaussian input



Field in external region is suppressed at low frequency

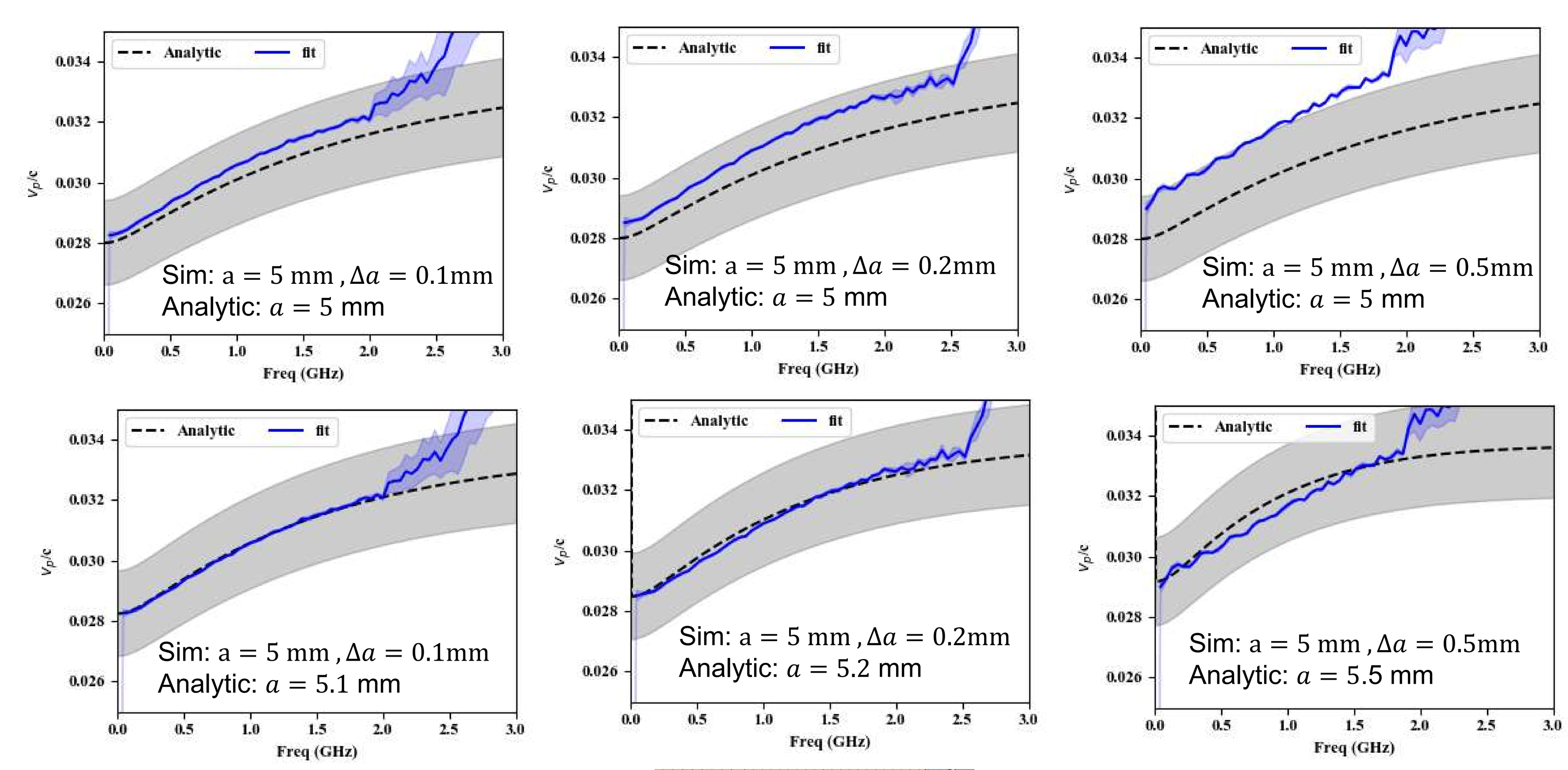


Field in external region is approximately Gaussian



Phase velocity

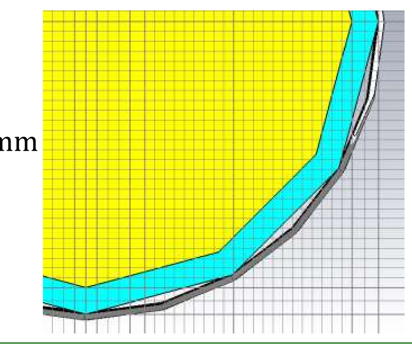
- The helical transmission line can theoretically support arbitrarily low phase velocities to match the velocities of non-relativistic beams
  - Simulations with the given parameters have $v_p \approx 0.03c$ which is sufficiently low for the FRIB MEBT with beam velocity $v_b = 0.032c$
- The phase velocity in simulations agree well with analytic results
  - However, better agreement can be achieved by assuming $a \rightarrow a + \Delta a$ in the analytic solution. This works for a range of Δa. Currently, this phenomenon is not understood



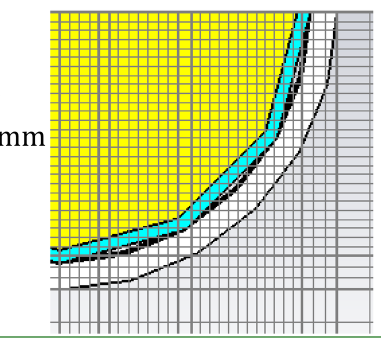
Shaded region is ±5%

- R_pipe = 20 mm
- R_helix = 5 mm
- R_rod = 4.5 mm
- Pitch = 0.05 rad
- ε_r = 3.5
- Wire width = 1mm

Mesh for $\Delta a = 0.1$mm



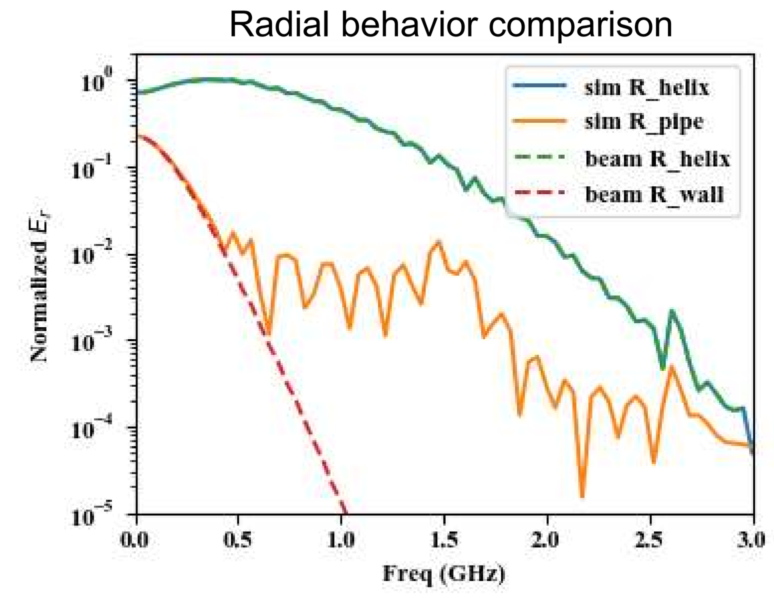
Mesh for $\Delta a = 0.1$mm

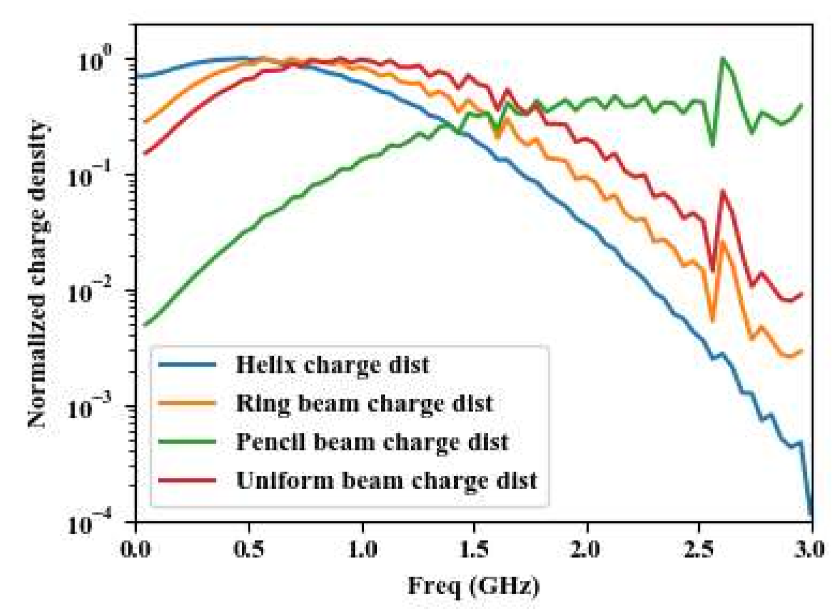


Beam Comparison

- An analytic beam profile was made to exactly match the electric field at the helix
  - The field from the beam at the pipe wall matches the helix simulations until the signal becomes noisy
- Different transverse profiles of the analytic beam were matched the helix field
  - The helix charge distribution best represents a ring beam

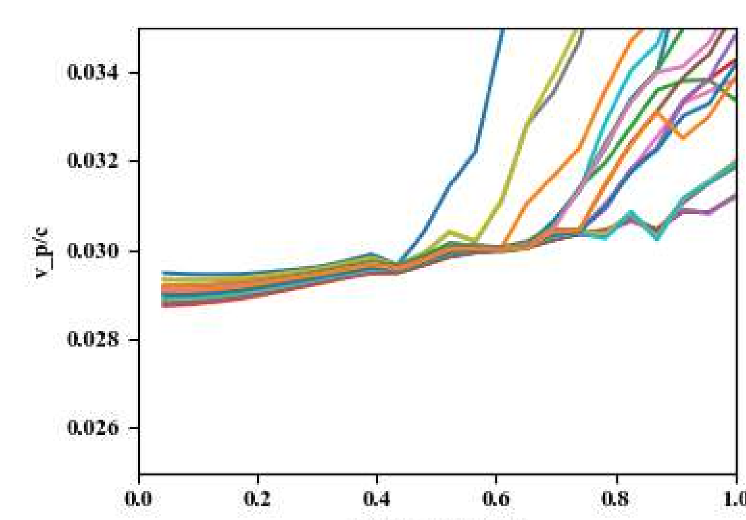
Radial behavior comparison

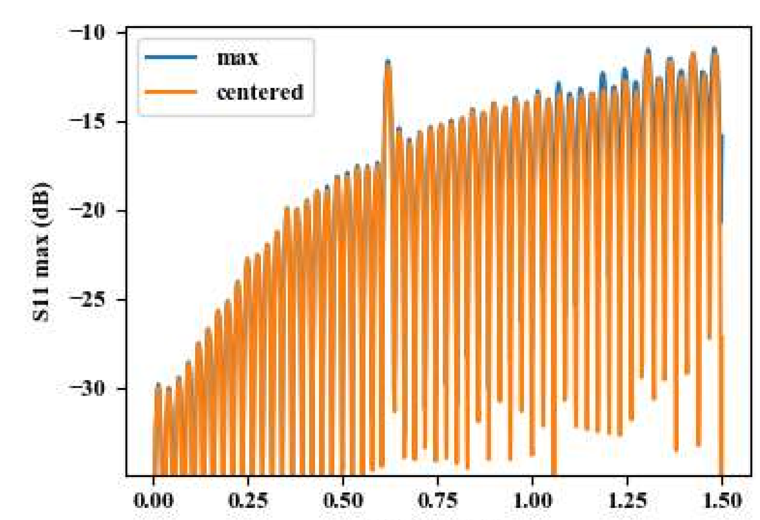


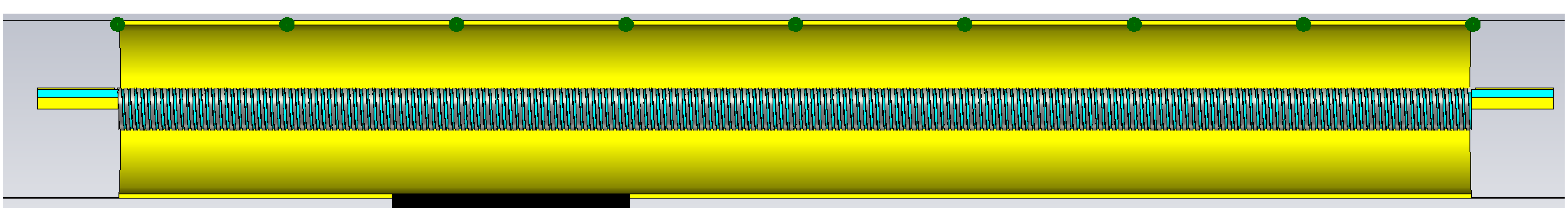


Off Center Helices

- The helix needs to be offset to replicate the fields from offset beam.
- In simulations, the helix was offset in a grip up to 10 mm in 2 mm steps
  - No significant changes to dispersion or S11 are seen
  - Therefore no special considerations for the offset need to be made







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