ASYMMETRIC RF MOMENTUM KICK STUDIES FOR PITZ GUN WITH COAXIAL RF COUPLE

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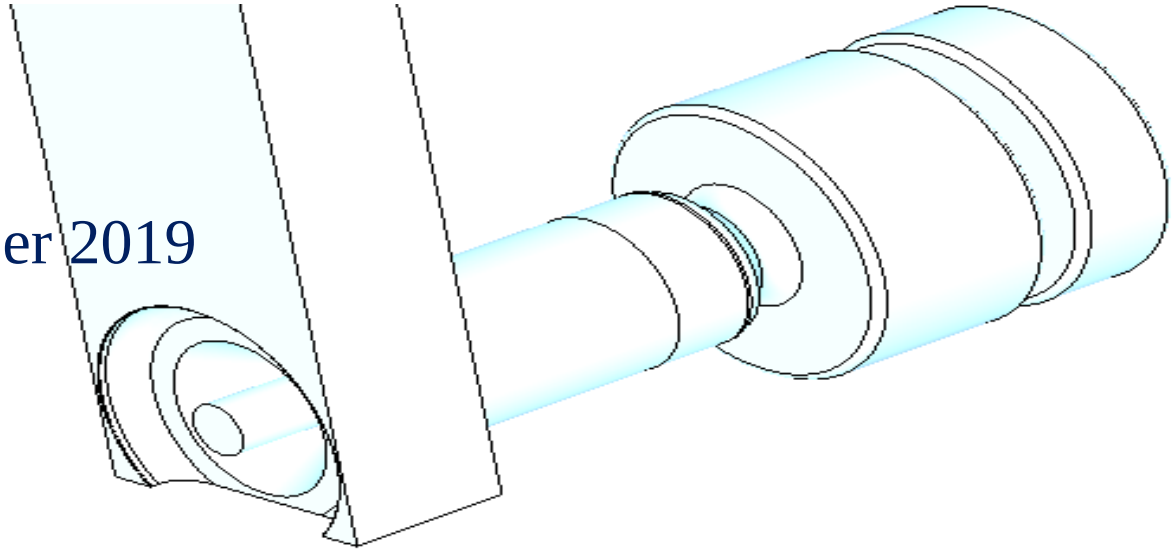
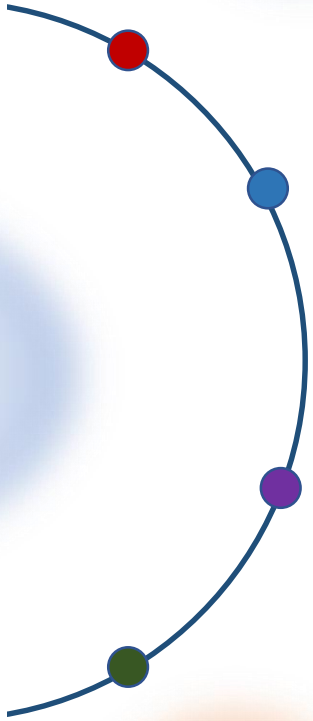
28th November 2019



Outline



Kick Calculation

Momentum kick calculation using the Lorentz force and Panofsky-Wenzel theorem within the electron gun.

Phase Dependence

Dependence of momentum kick on the initial RF phase

Detuning & Momentum Kick

Variation in the momentum kick as a function of cavity detuning

Focusing Effects

Dependence of Longitudinal beam size of the solenoid current for different phases and detuned frequencies.

Tools & Techniques

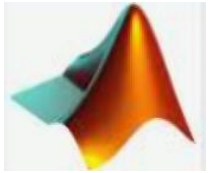
RF & Magnet Simulations

CST STUDIO FREQUENCY DOMAIN SOLVER

+

CST STUDIO M-STATIC SOLVER

Single particle dynamics



MATLAB

1. 3D Field Interpolation.
2. Lorentz Force Calculation.
3. Trajectory solver.

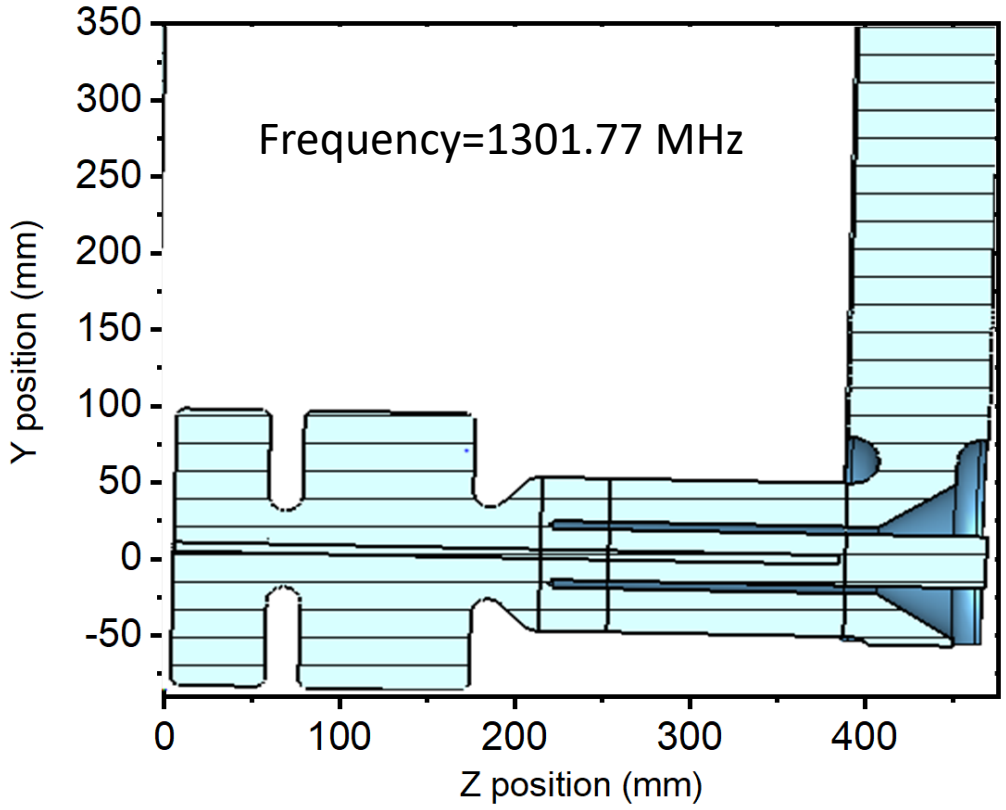
Multi-Particle Dynamics

CST STUDIO PARTICLE-IN-CELL SOLVER

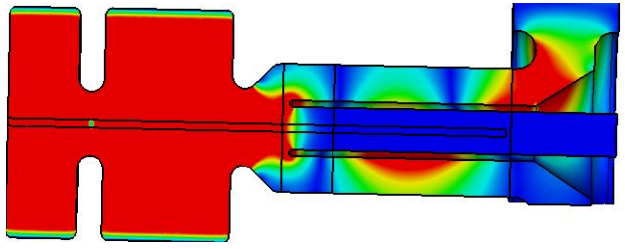
+

PARTRACK

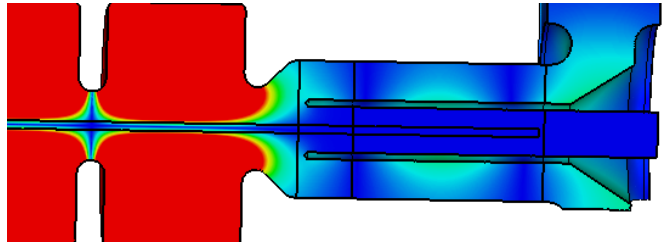
RF Simulation Results



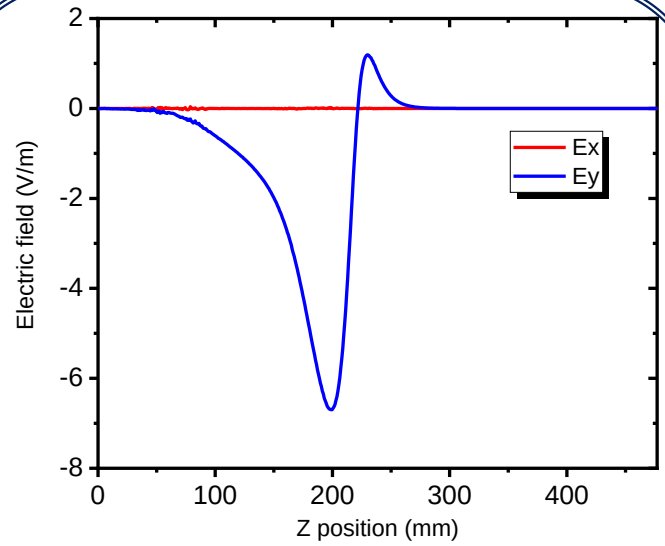
Electric field

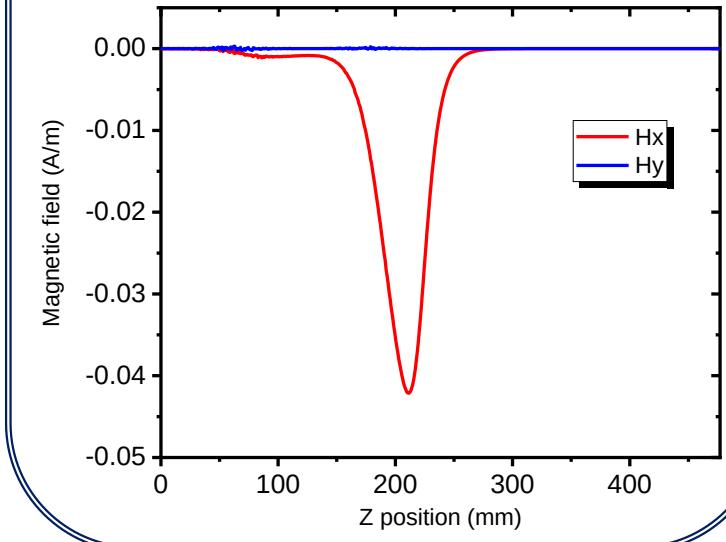


Magnetic field



AXIAL FIELDS (R=0)





Asymmetric Momentum Kick Studies

- Calculation of x and y momentum kick within the the beam path.
- Kick dependence on Phase.(with single particle dynamics)
- Kick dependence on cavity detuning.(using multi-particle dynamics)

Momentum Kick Calculations

MOMENTUM KICK CALCULATIONS USING LORENTZ FORCE

$$\Delta P_x(r,\theta)c = \int_0^L \left(\frac{E_x(r,\theta)}{\beta} - Z_0 i H_y(r,\theta) \right) e^{\frac{ikz}{\beta}} dz$$

$$\Delta P_y(r,\theta)c = \int_0^L \left(\frac{E_y(r,\theta)}{\beta} + Z_0 i H_x(r,\theta) \right) e^{\frac{ikz}{\beta}} dz$$

MOMENTUM KICK CALCULATIONS USING PANOFSKY-WENGEL THEOREM

$$\Delta P_\perp(r,\theta)\, c = \frac{i}{k} \int_0^L \nabla_\perp E_z(r,\theta) e^{\frac{ikz}{\beta}} dz$$

Beam & Fleld Parameter

Electron beam parameters at the cathode surface

Parameters	Value
Energy	0.55 eV
I_{main}	440 A
Energy spread	20 keV/c
Transverse radius	0.5 mm
Temporal length (Gaussian)	11 ps (FWHM)

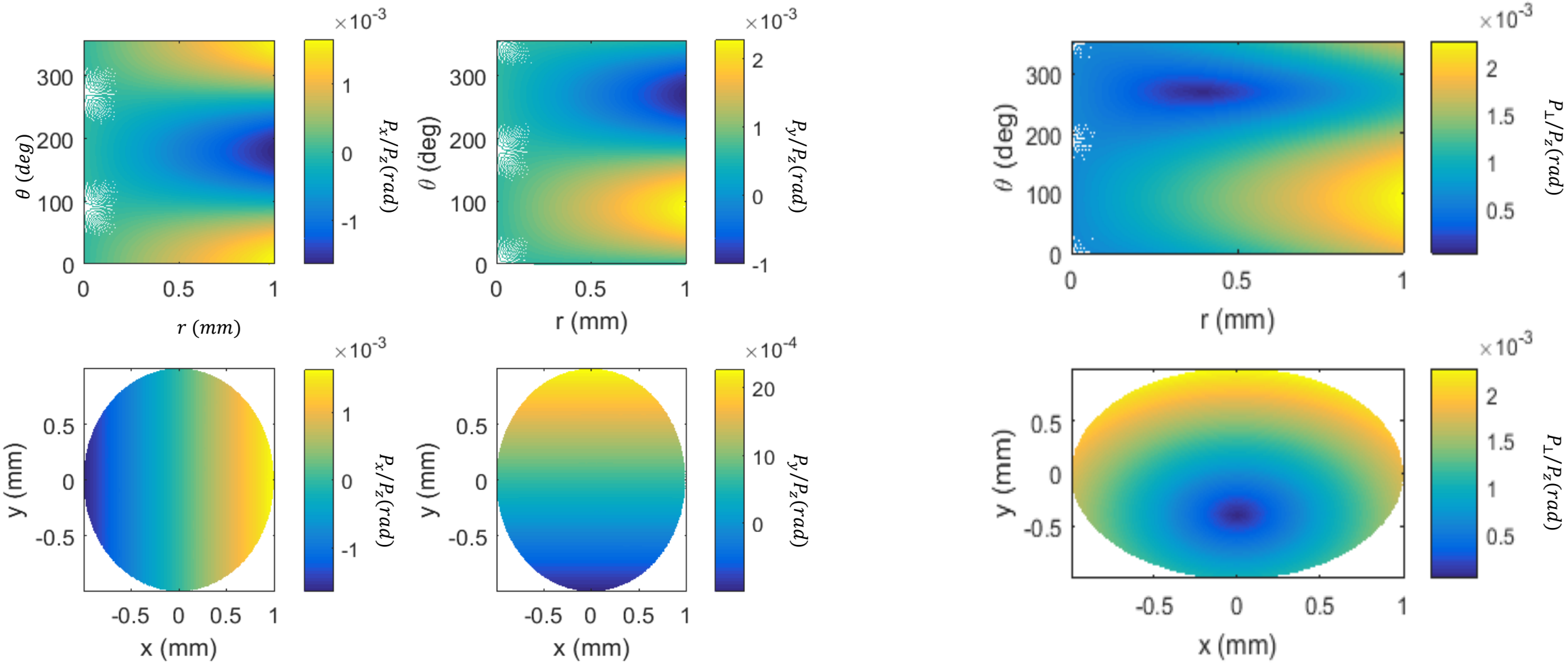
Solenoid and RF field limits and calibration0

Parameters	Value
Solenoid calibration	$5.559 \times 10^{-4} \times I_{main} + 7.102 \times 10^{-5}$
E_{maz} at Kathode plane	60 MV/m
Energy spread	20 keV/c

Assumptions

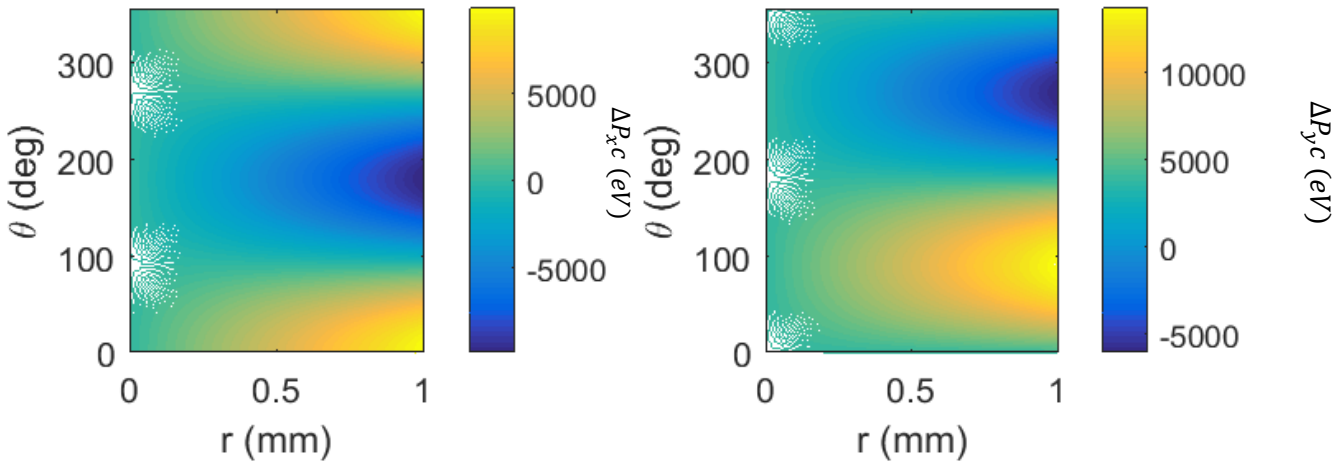
- Space-charge interaction is not considered.
- We assume an axi-symmetric solenoid focusing.

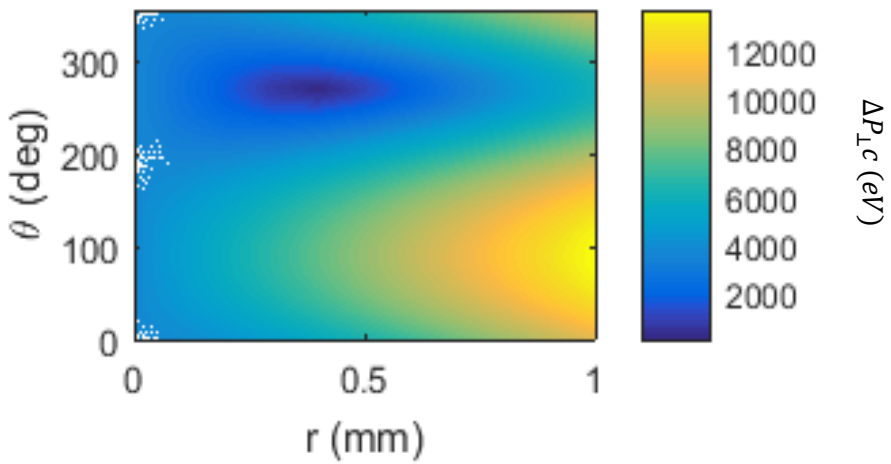
3D Momentum Kick Calculations in r, θ plane-I

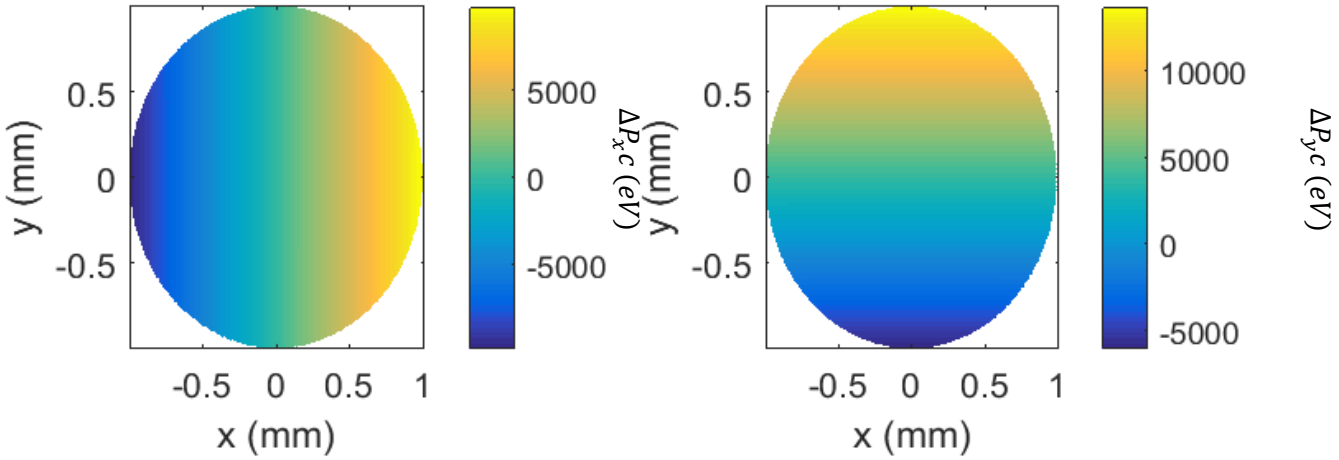


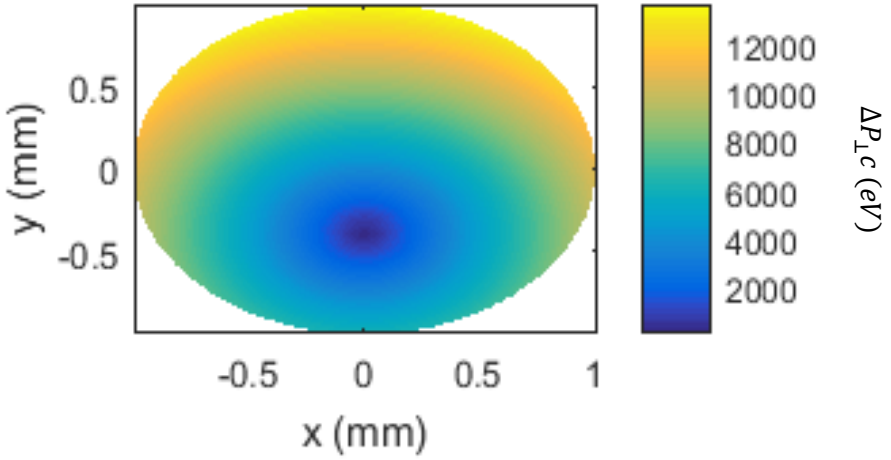
- **Results shows the dipolar nature of kick with a maximum value of 2.2 mrad..**
- **The lick is asymmetric in the y-direction**

3D Momentum Kick Calculations in r, θ plane-II

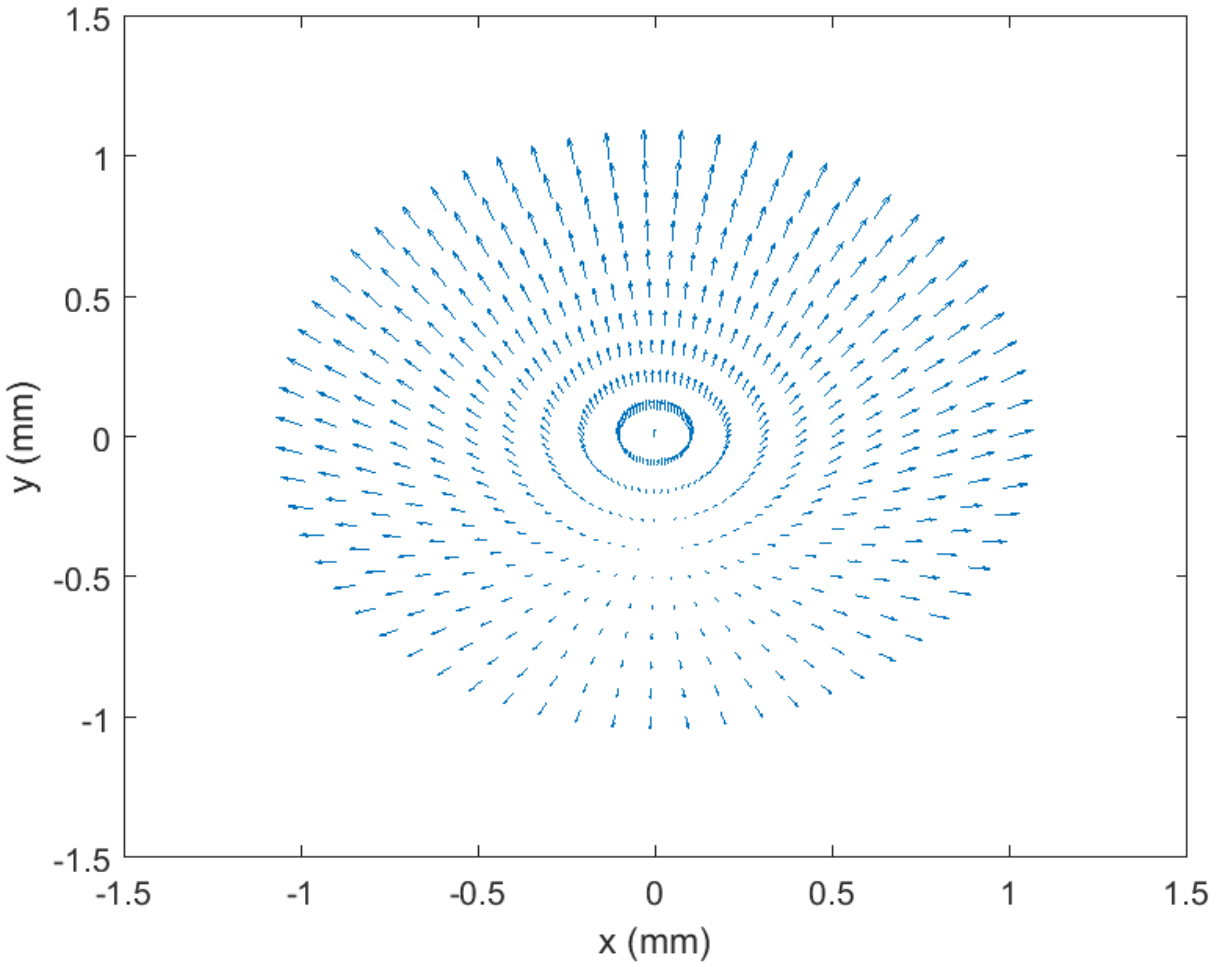




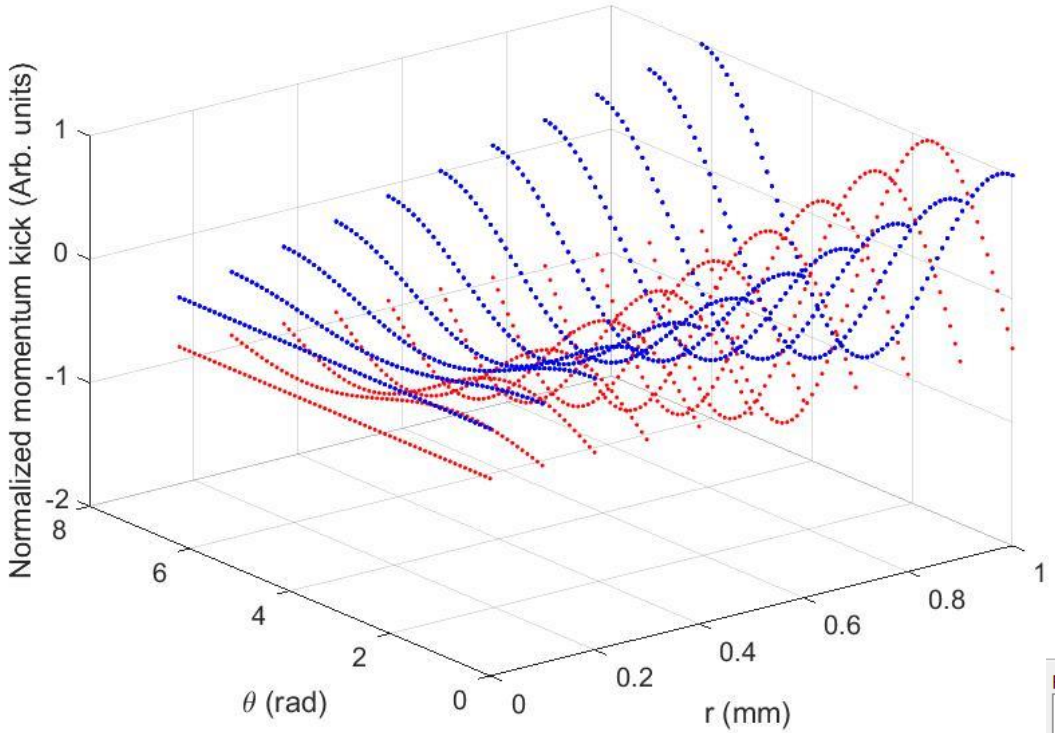




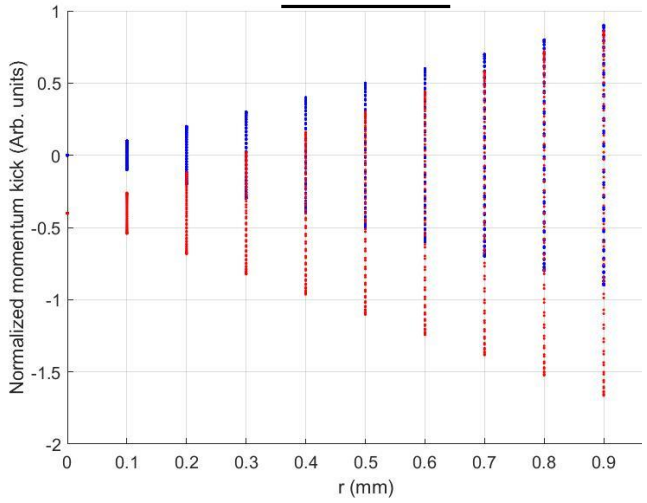
3D Momentum Kick Calculations in r, θ plane-III



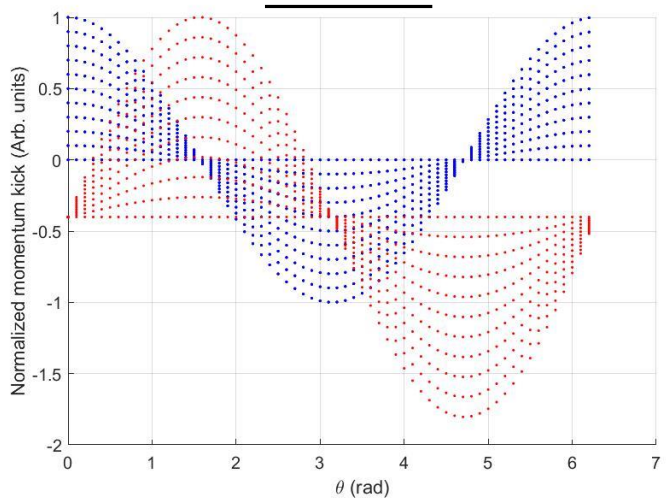
Momentum Kick & Fourier Expansion



X-Z View



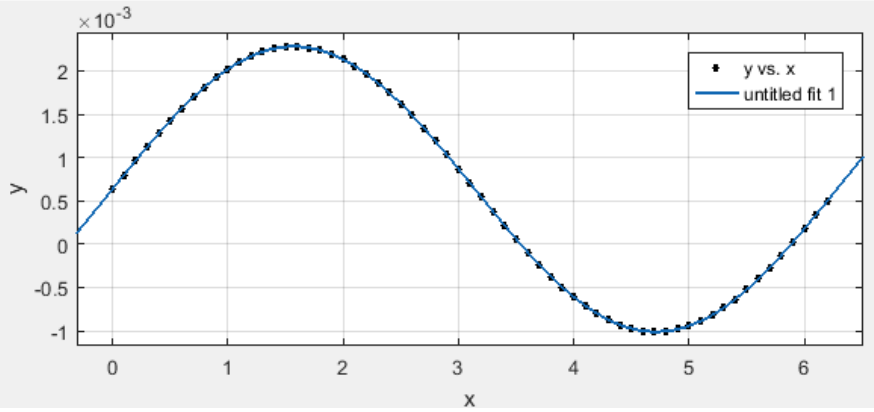
Y-Z View



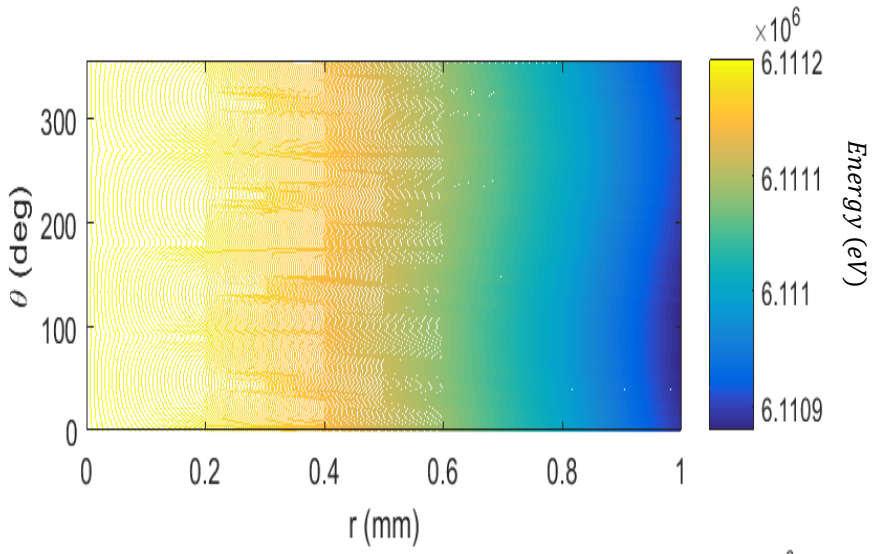
Fourier Fir

Results

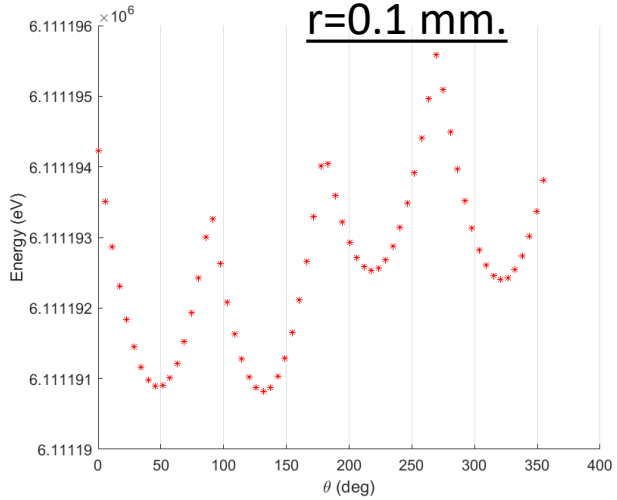
General model Fourier5:
f(x) = a0 + a1*cos(x*w) + b1*sin(x*w) +
a2*cos(2*x*w) + b2*sin(2*x*w) +
a4*cos(4*x*w) + b4*sin(4*x*w) +
Coefficients (with 95% confidence bounds
a0 = -0.8459 (-49.7, 48.01)
a1 = 1.082 (-65.21, 67.37)
b1 = 0.9383 (-48.35, 50.22)
a2 = -0.1212 (-14.43, 14.19)
b2 = -0.847 (-48.01, 46.31)
a3 = -0.1871 (-6.731, 6.357)
b3 = 0.2908 (-18.47, 19.05)
a4 = 0.08204 (-3.87, 4.035)



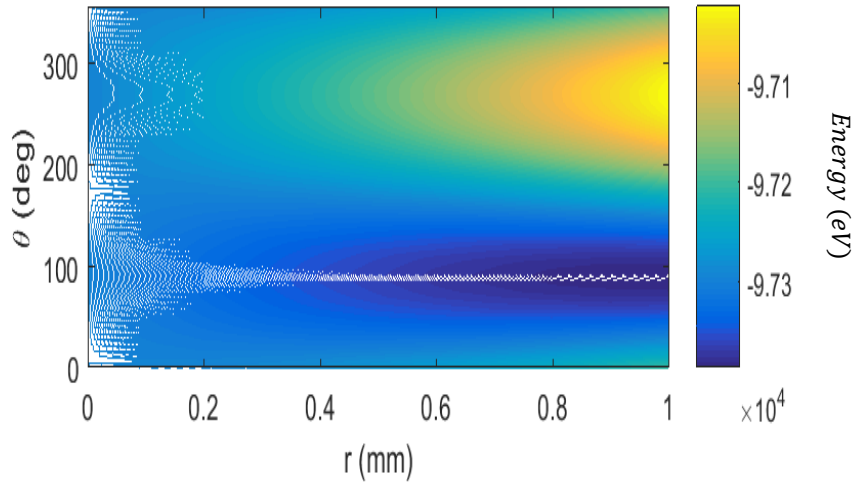
Z-Momentum

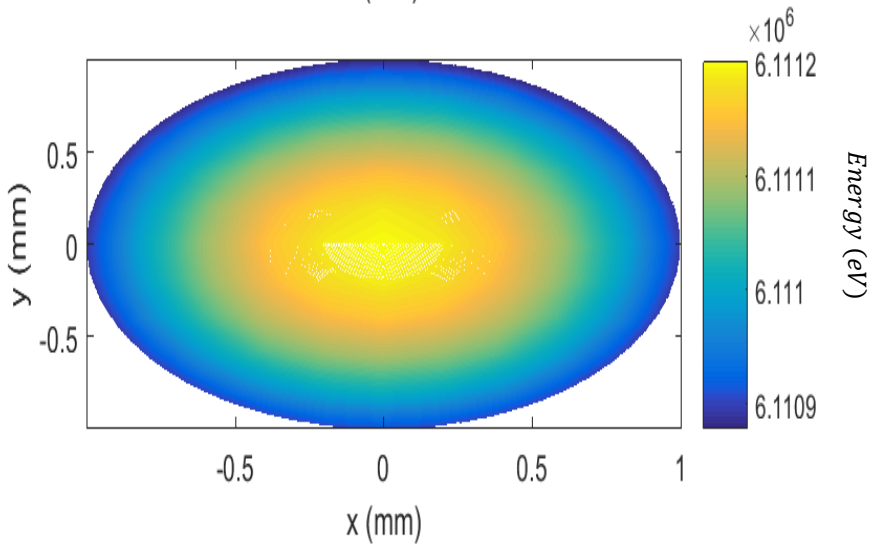


r=0.1 mm.

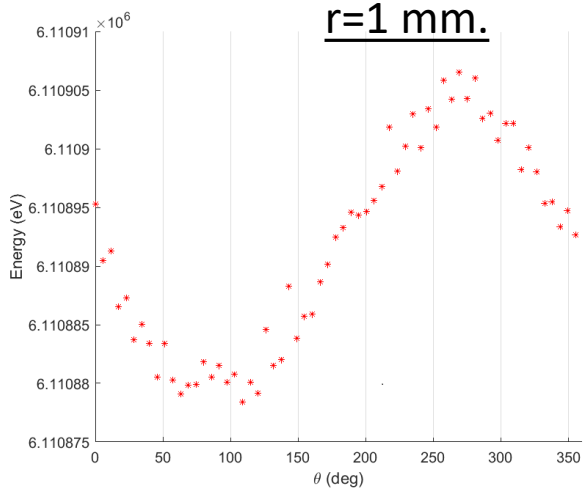


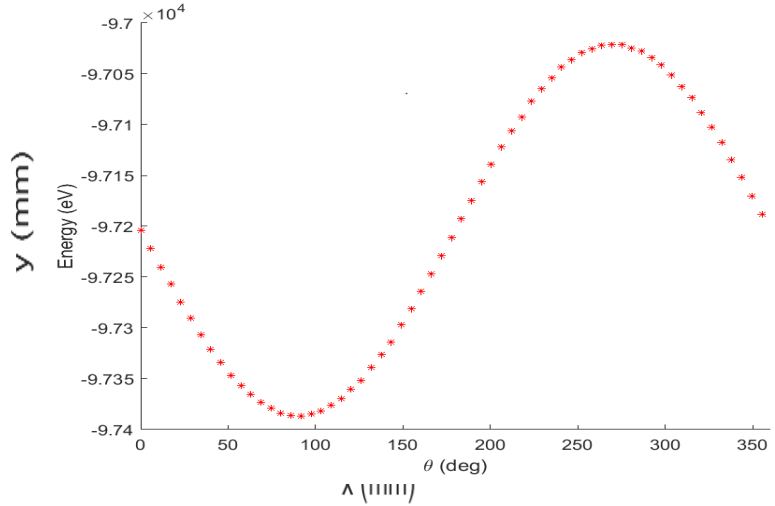
From z=200 mm to 527 mm



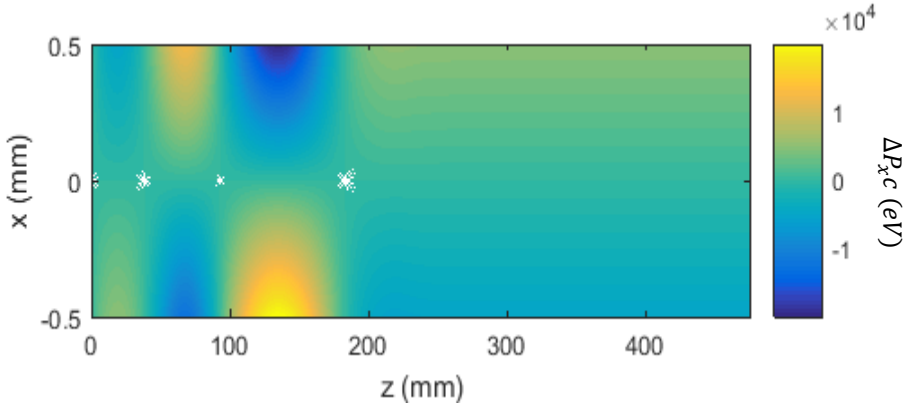


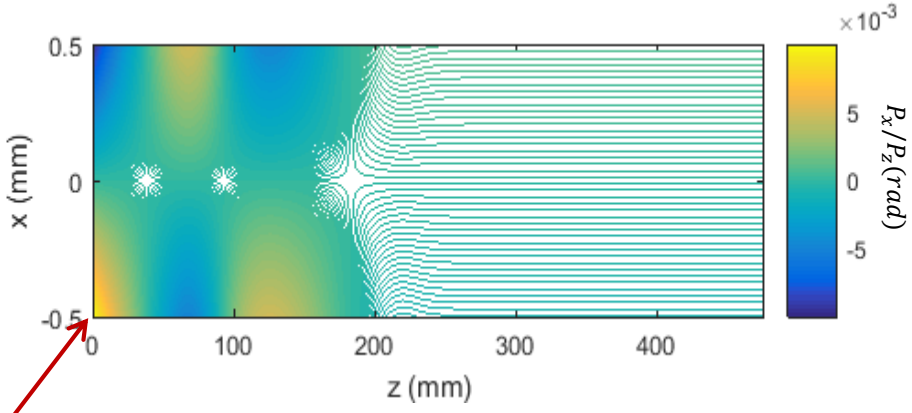
r=1 mm.

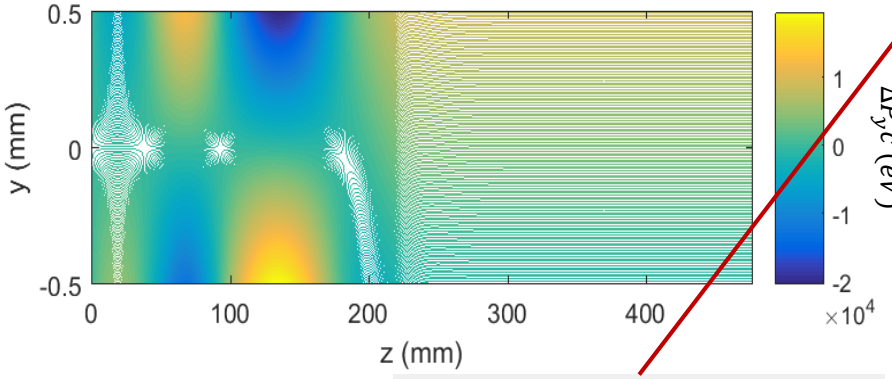


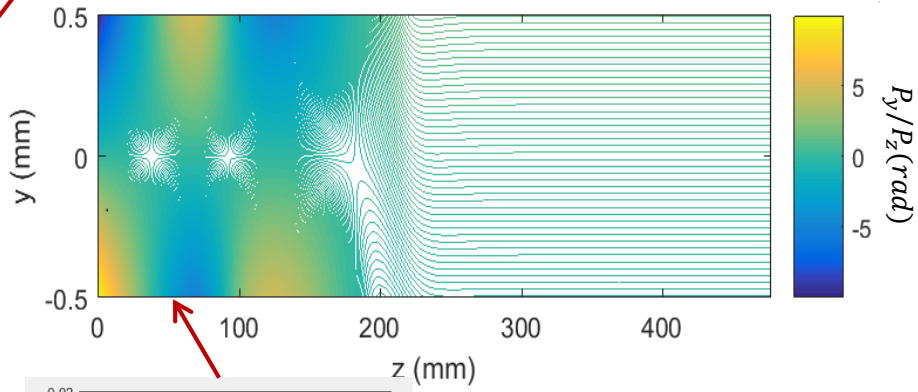


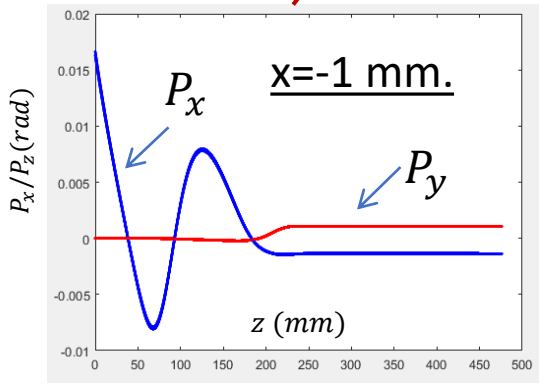
Momentum Kick In x-z & y-z plane-II

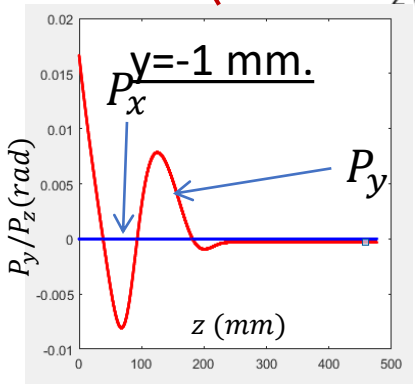




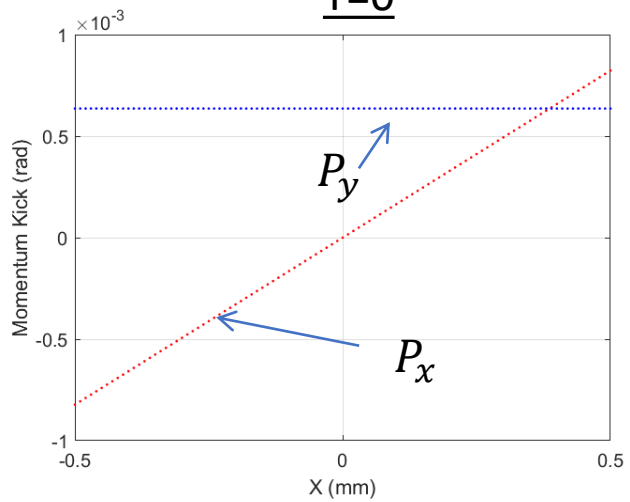




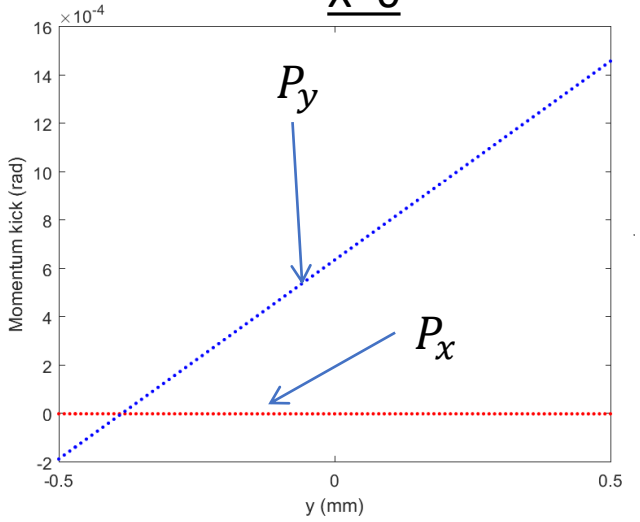




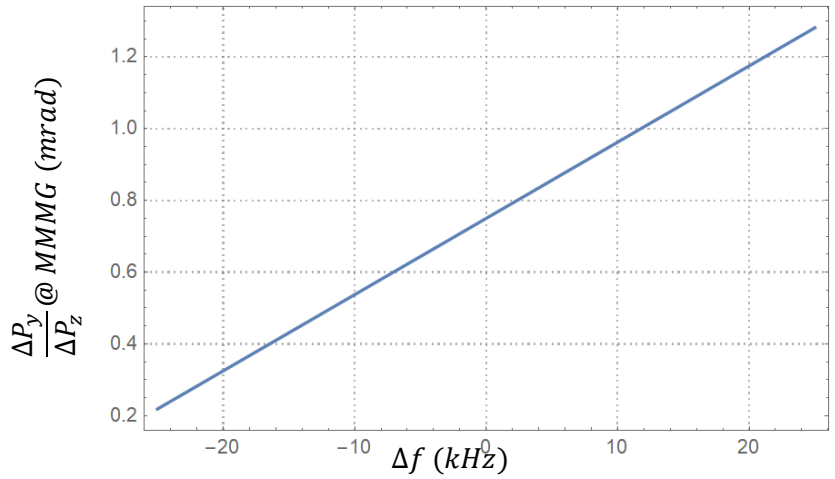
Y=0

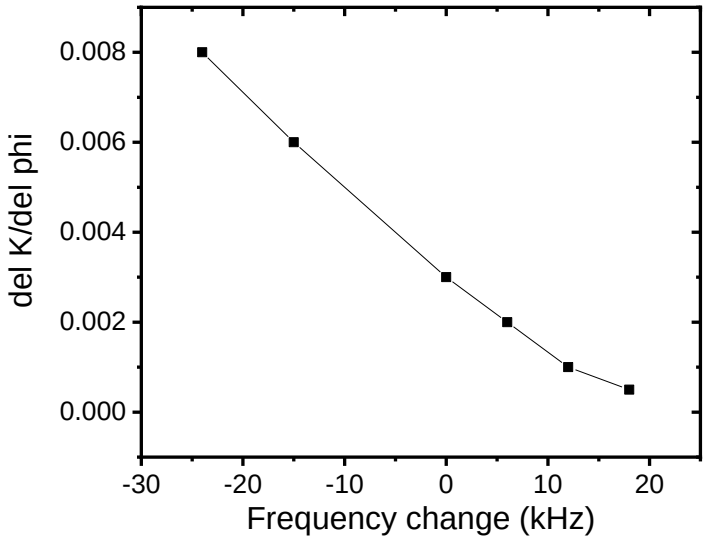


X=0

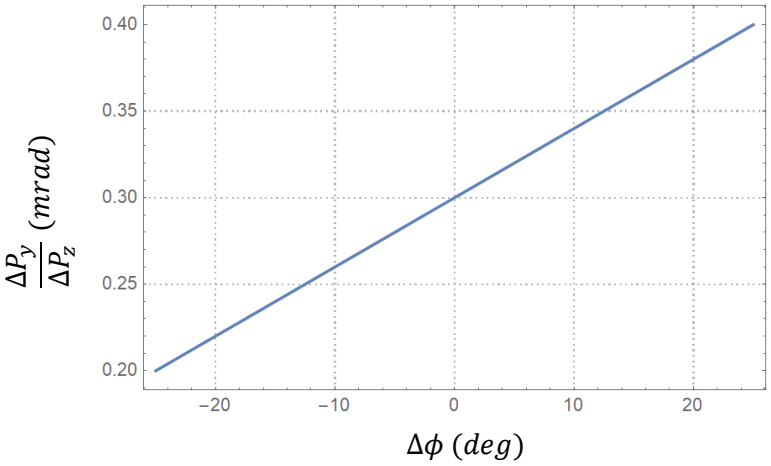


Fewquency Detuning & Phase dependence Studies

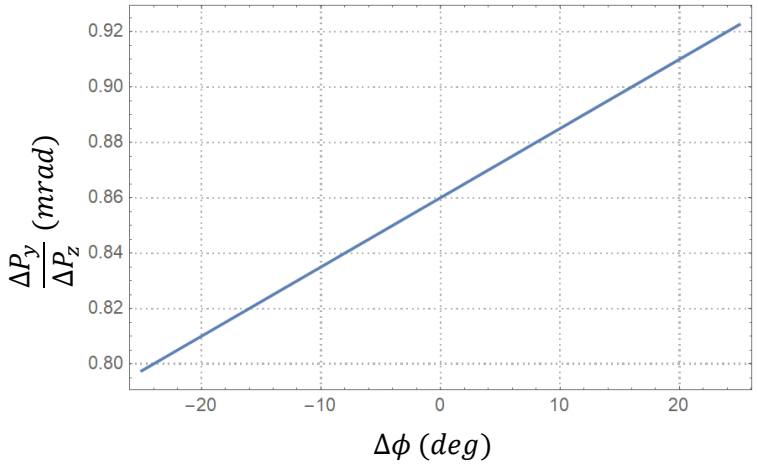




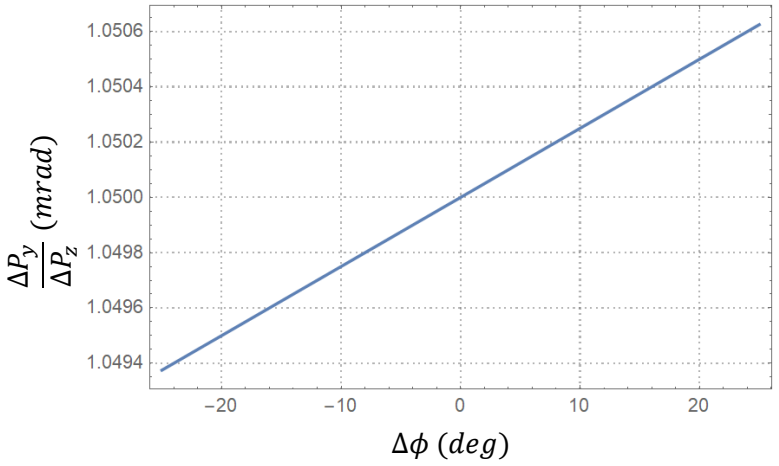
Δf =-25 (kHz)



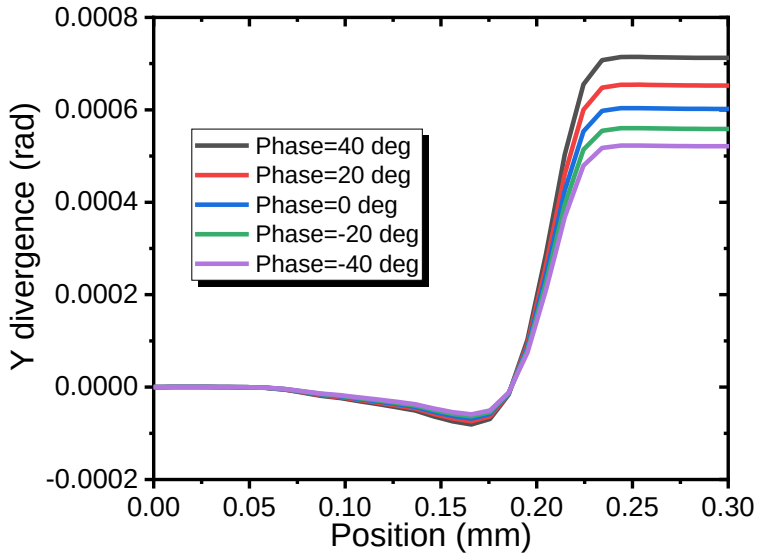
Δf = 6 (kHz)

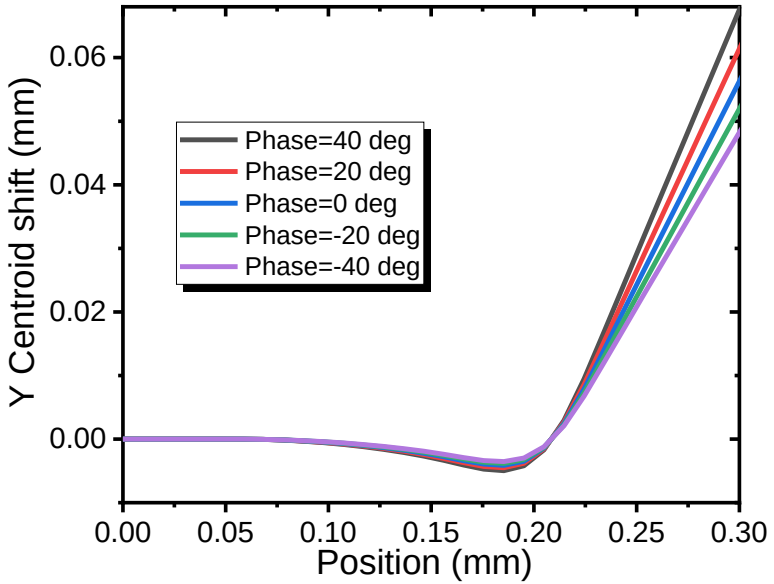


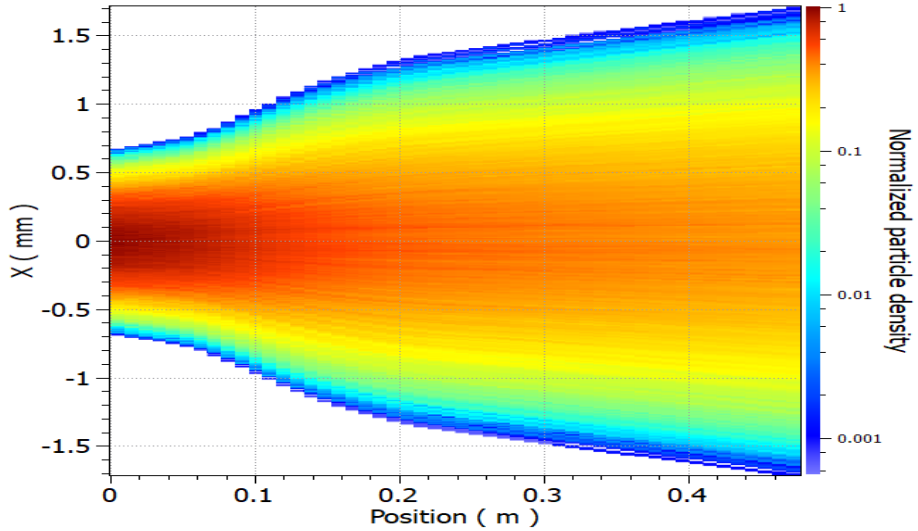
Δf = 20 (kHz)

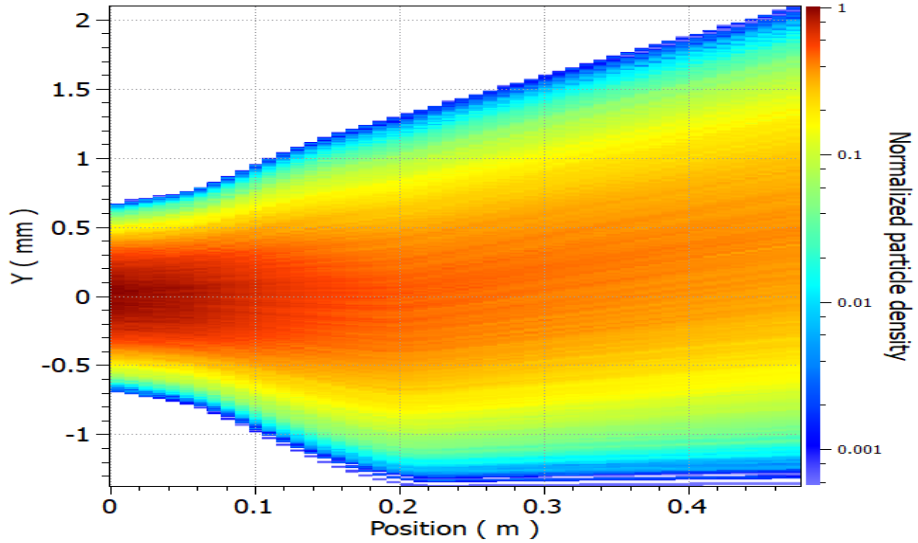


Particle Dynamics

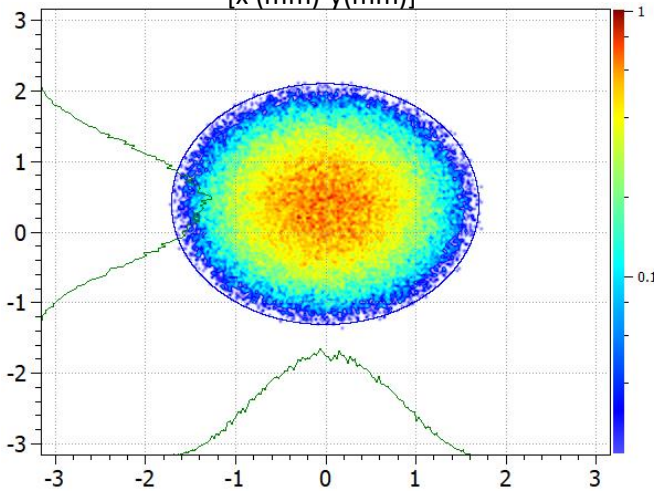








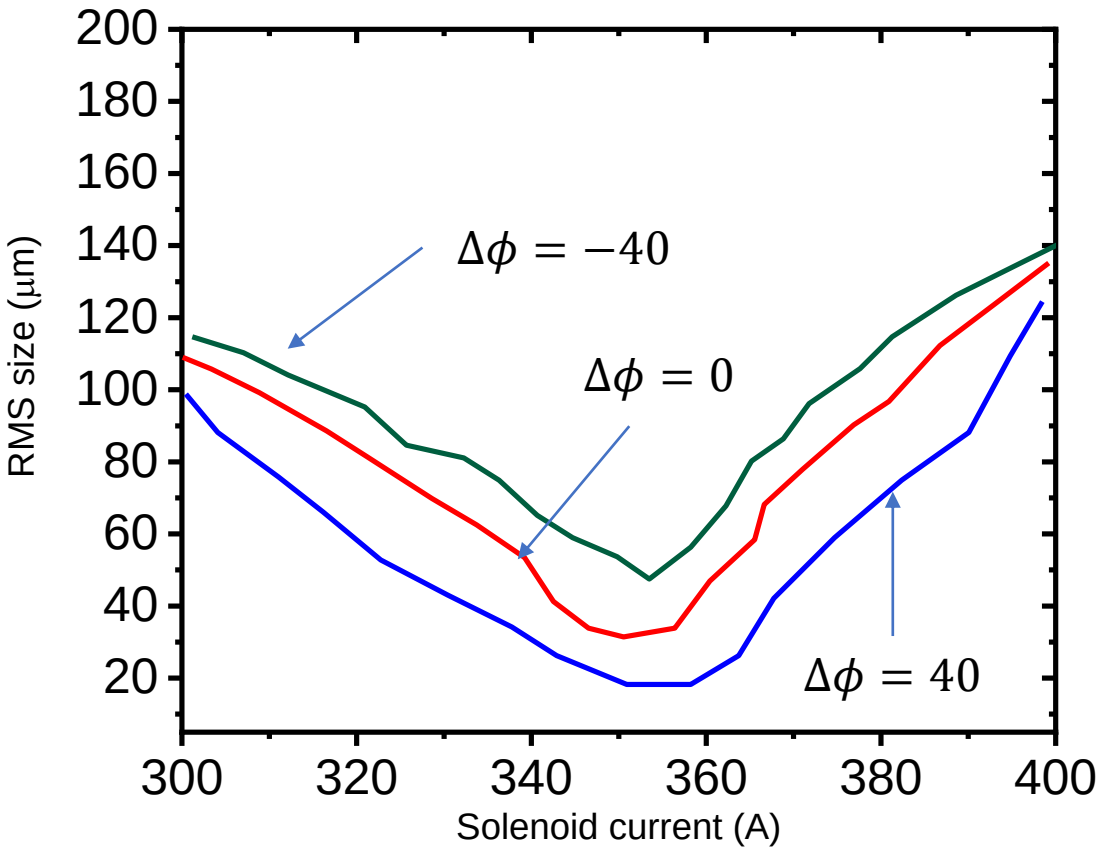
Output Distribution
[x (mm)-y(mm)]

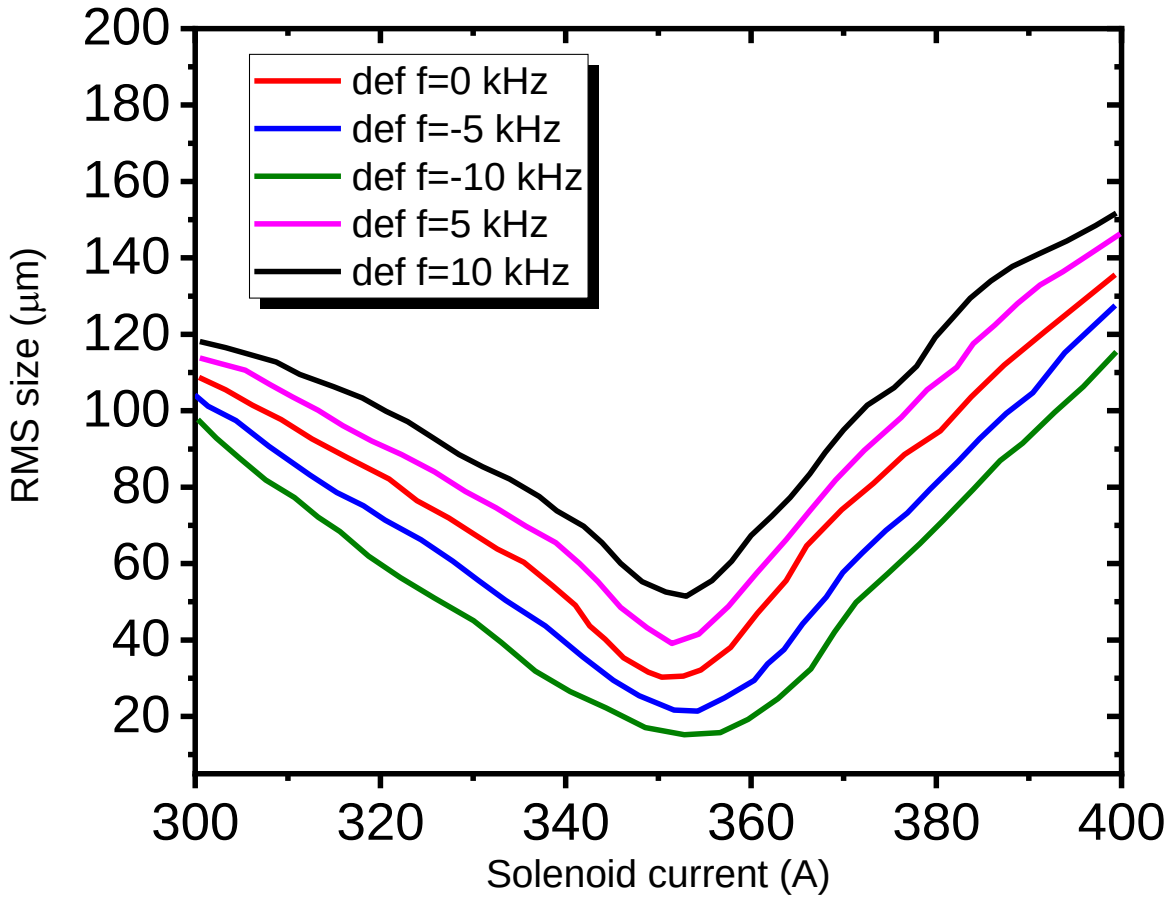


Conclusion

- Transverse momentum kick was calculated in the electron gun and an asymmetric behavior in the y-kick was identified.
- Dependence of transverse momentum kick on the phase and cavity detuning was studied and quantified.
- Multi-particle dynamics was performed to investigate the beam behavior change because of asymetric RF kick.

Longitudinal Focusing





Thank You!