COLD layout updates

S. M. Liuzzo

On behalf of the EBS Accelerator Team and the international collaboration:
SLAC, INFN, CERN, PSI, CORNELL

COLD project team @ ESRF:
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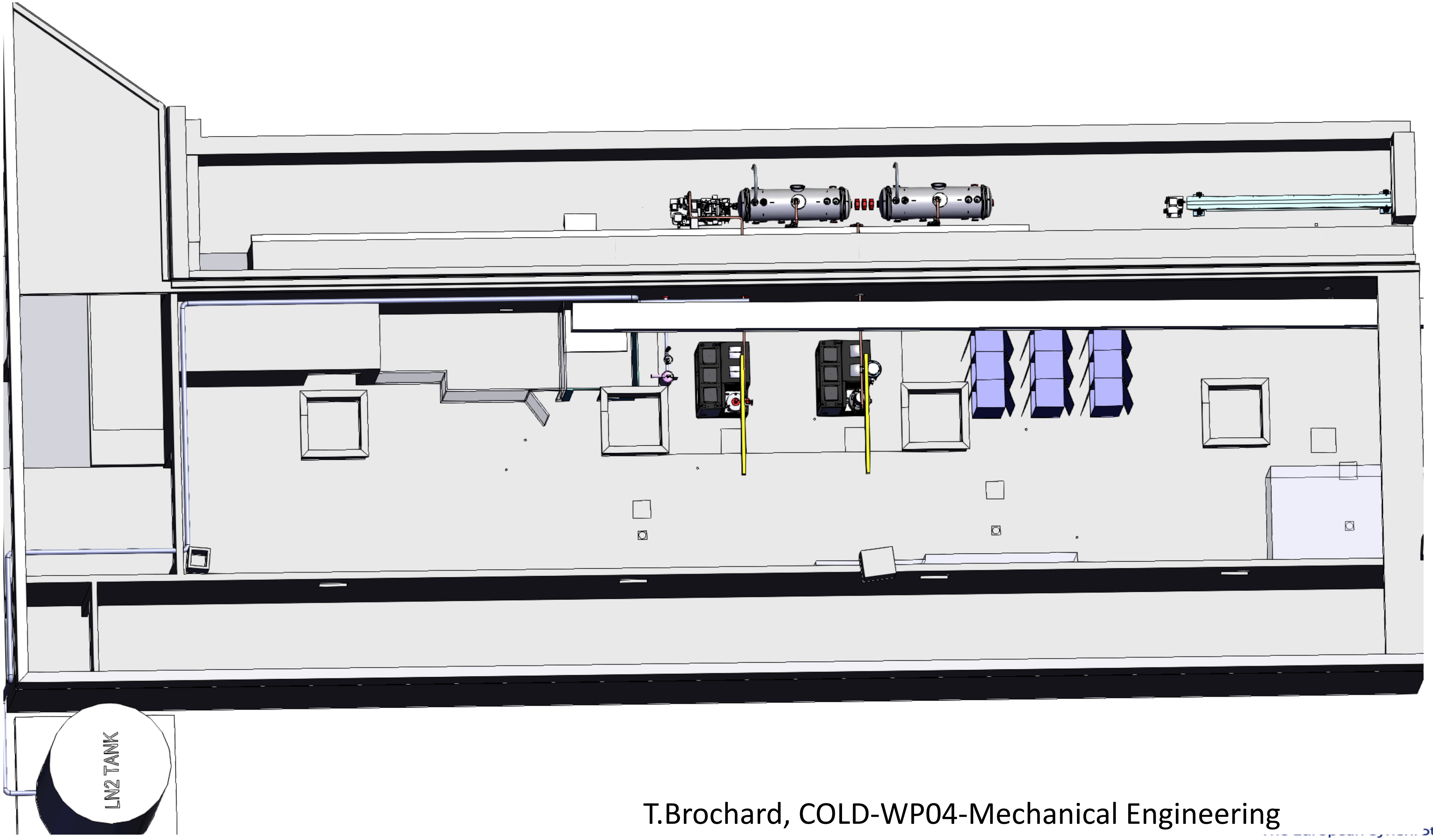
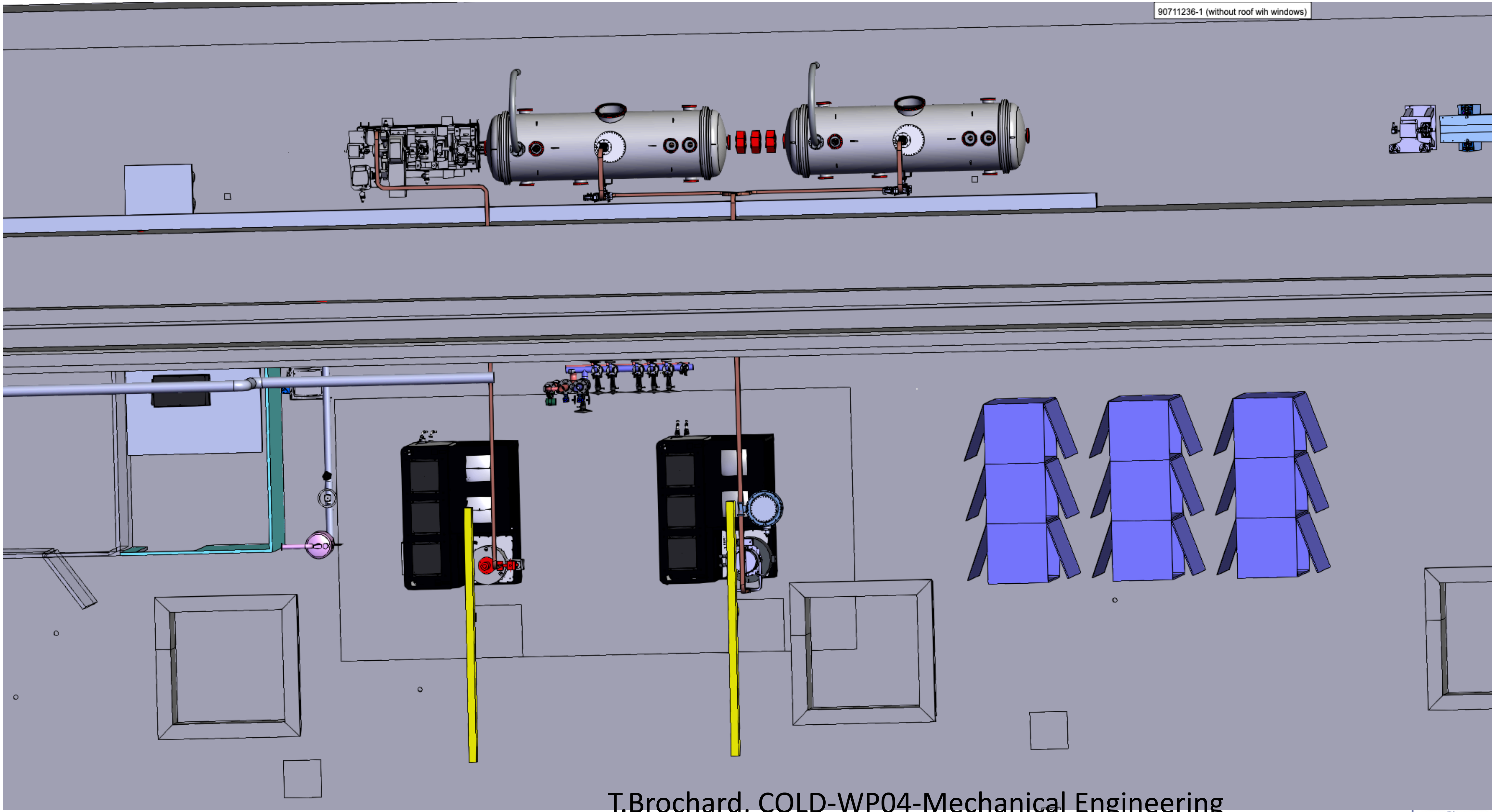


T.Brochard, COLD-WP04-Mechanical Engineering

COLD PROJECT



T.Brochard, COLD-WP04-Mechanical Engineering

TRIPLET WITH APPROXIMATE LAYOUT FROM DRAWINGS

2 possible Gun settings

(August 2026)

LONG bunch

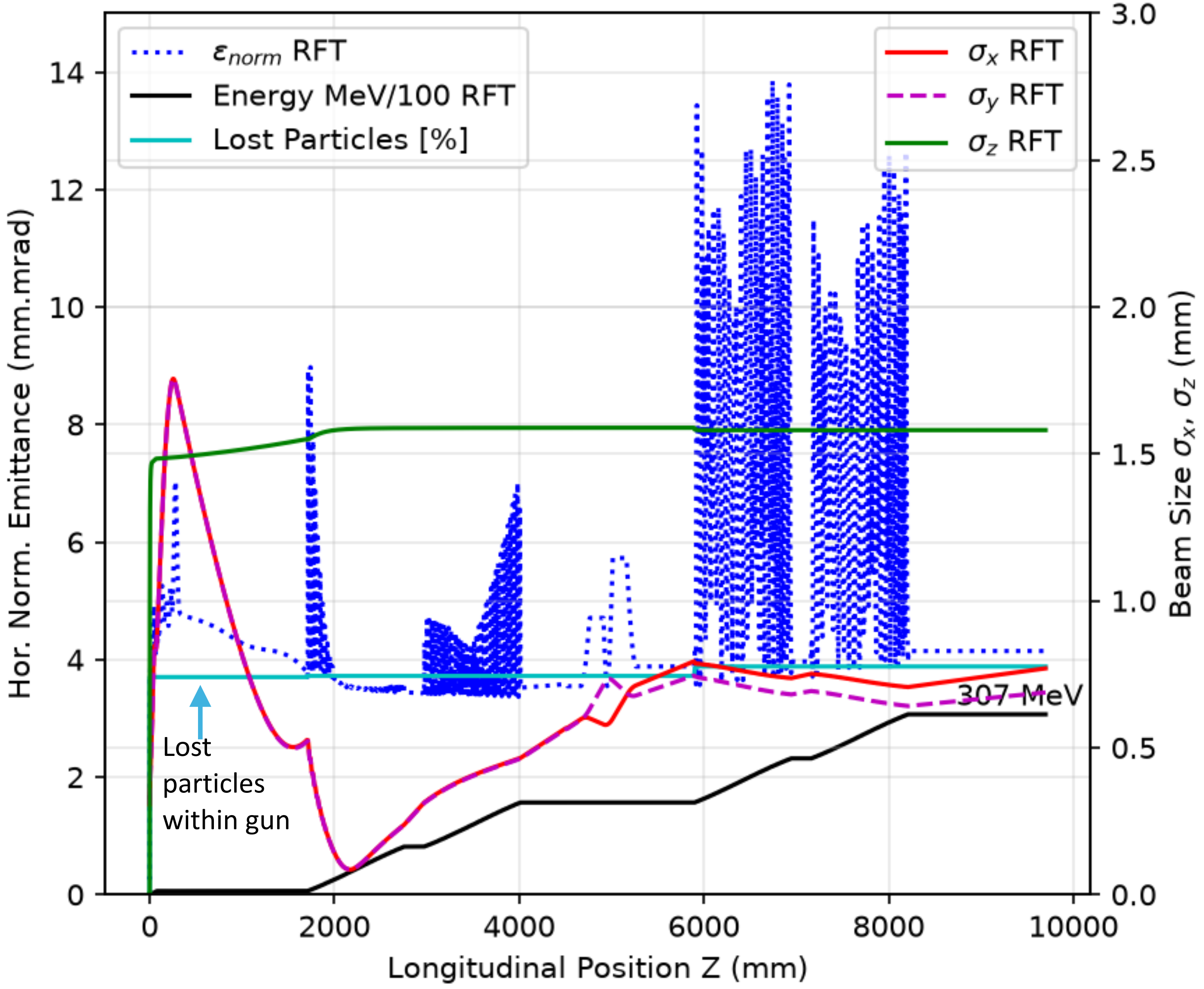
```
'Bz': 0.288306,
 'DriftGunStruct': 1.671,
 'sigr': 0.3,
 'sigt': 2.12,
K1L -3T/m,
K2L=6T/m
```

Worst case

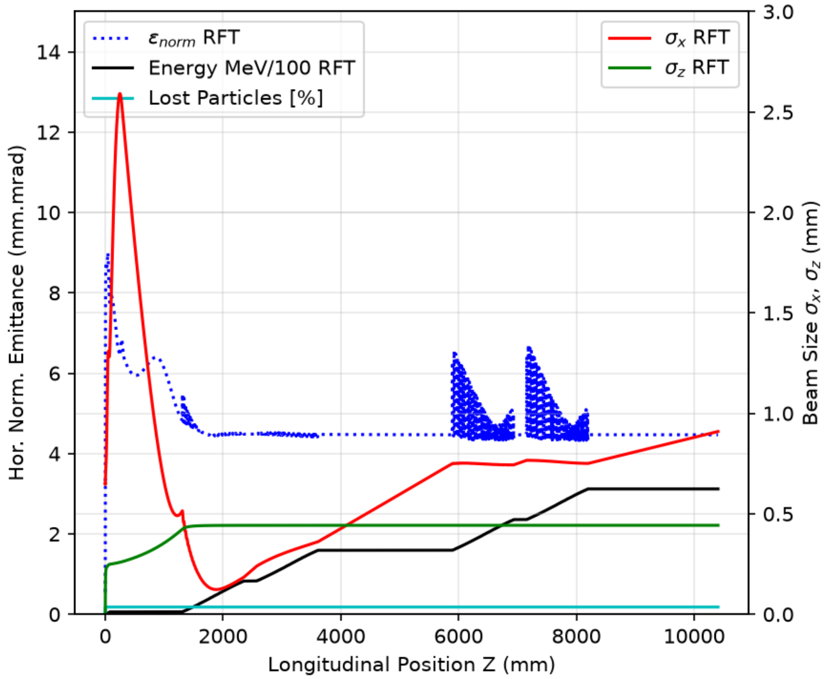
SHORT bunch

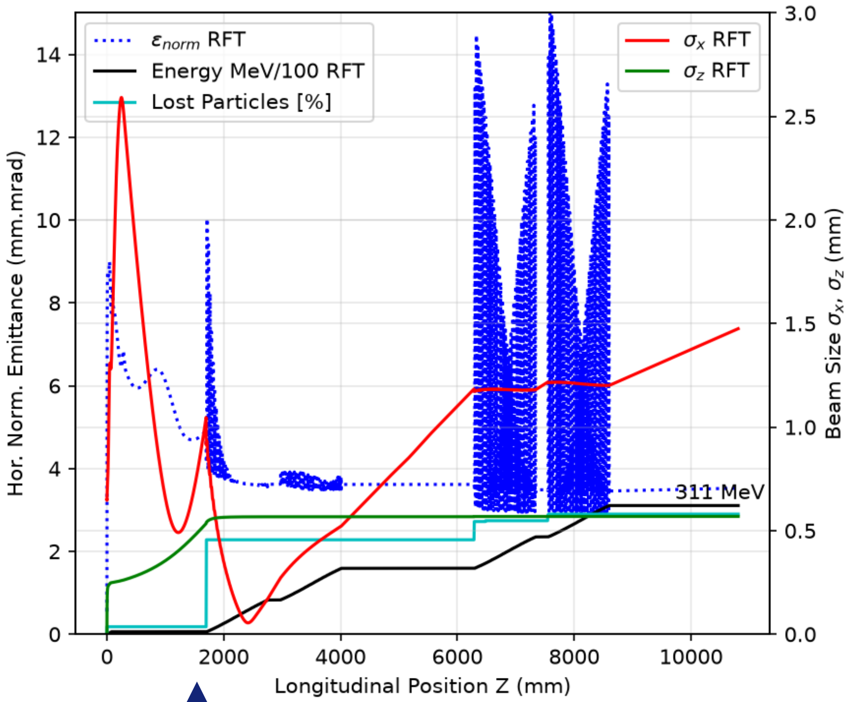
```
'Bz': 0.288306,
 'DriftGunStruct': 1.671,
 'sigr': 0.65,
 ‘sigt': 0.2,
K1L -3T/m,
K2L=6T/m
```

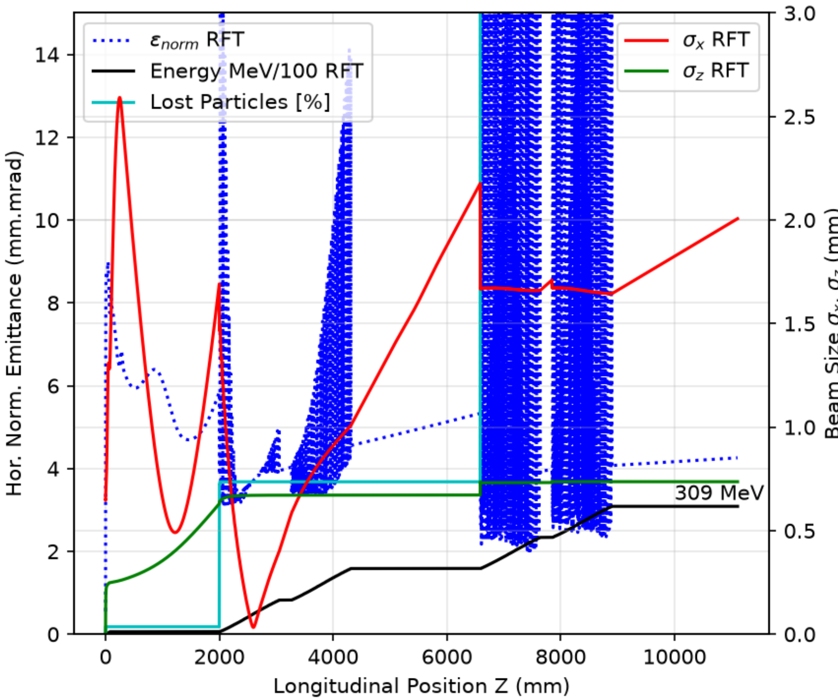
Could be reduced to 1.5m, **reducing** the overall lost particles from 3-4% to <2%



EFFECT OF THE DISTANCE GUN - FIRST STRUCTURE







1.297 m

1.7 m

Value presently in the drawings

2.0 m

January 2026 settings

```
'Bz': 0.288306,
 'DriftGunStruct': 1.29731,
 'sigr': 0.6478,
 'sigt': 0.200,
```

Lost particles at structure entrance
More emittance oscillation in structures
Longer bunch

/Users/liuzzo/Desktop/LINAC/COLD_Phase2_January2026restored/RFT_EMIT_SIGMA_50000.png

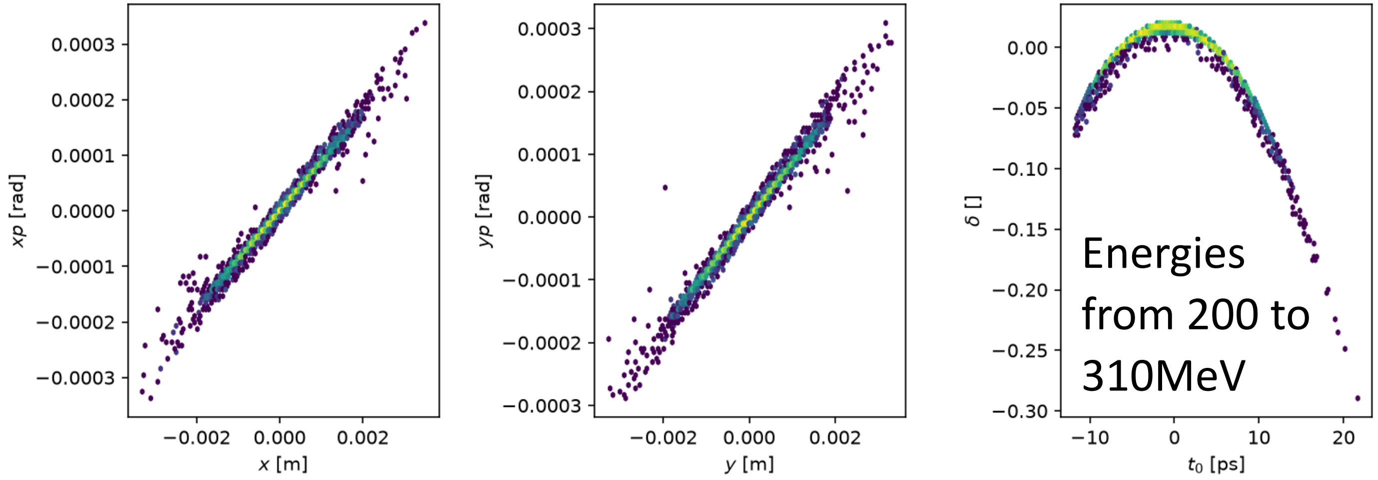
2 possible Gun settings

(August 2026)

LONG bunch

```
'Bz': 0.288306,
 'DriftGunStruct': 1.671,
 'sigr': 0.3,
 'sigt': 2.12,
K1L -3T/m,
K2L=6T/m
```

Classic, large energy spread

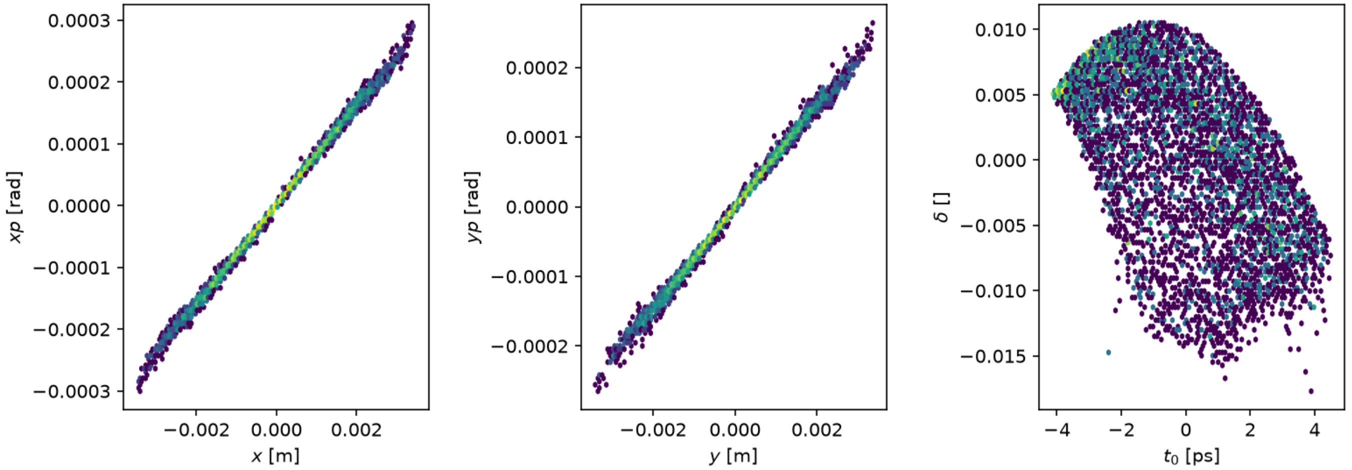


SHORT bunch

```
'Bz': 0.288306,
 'DriftGunStruct': 1.671,
 'sigr': 0.65,
 'sigt': 0.2,
K1L -3T/m,
K2L=6T/m
```

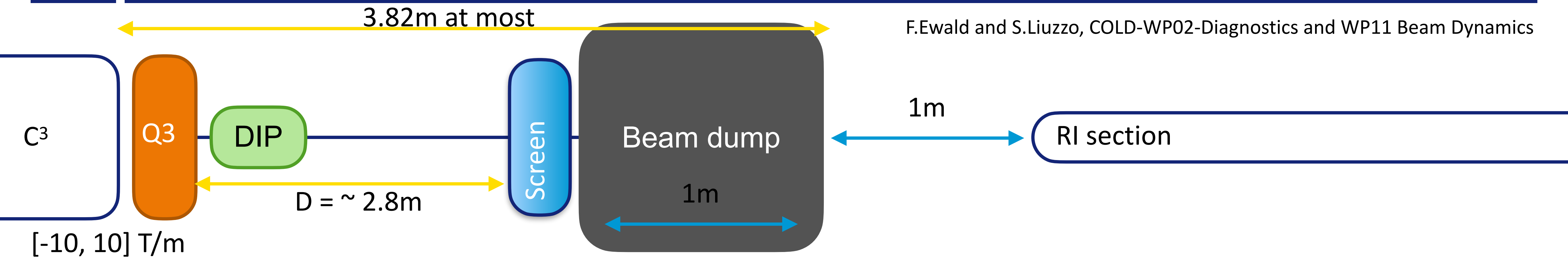
Alternative, small energy spread

R&D. Simulations give different results in different CODES.



POSSIBLE LINEAR LAYOUT FOR DIAGNOSTIC SECTION FOR ENERGY OR EMITTANCE MEASUREMENT

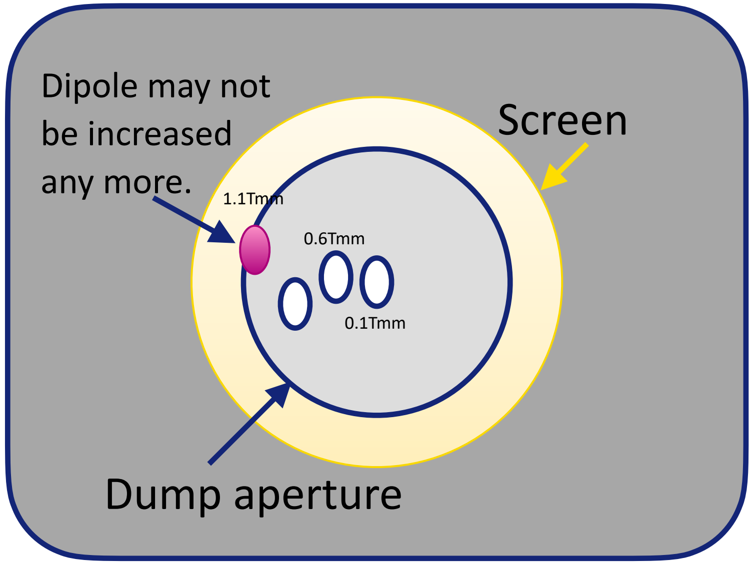
F.Ewald and S.Liuzzo, COLD-WP02-Diagnostics and WP11 Beam Dynamics



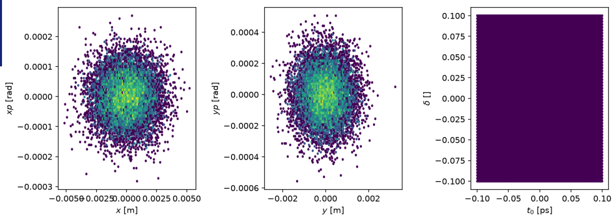
To measure **emittance**: quadrupole SCAN, dipole/corrector set to zero.
To measure **energy**: fix quadrupole and power DIPOLE to measure displacement on the screen (within Dump aperture)
To measure **bunch length**: by operating the RF-structures off-phase

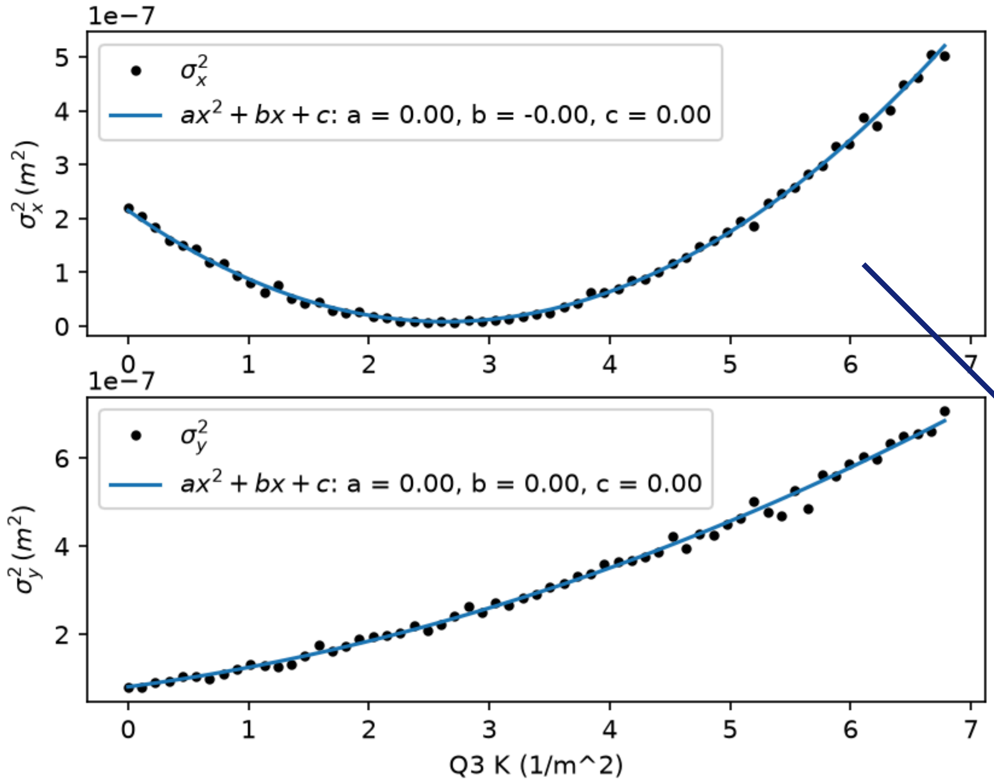
In this set up the dipole is set to ZERO. It is powered to measure energy ramping from 0 in steps of at most 0.1Tmm and interlocked to a given radial position on the screen (if larger than the beam dump aperture, then ramp is locked). In case of failure of any element the dipole has to be set to zero to restart the linac.

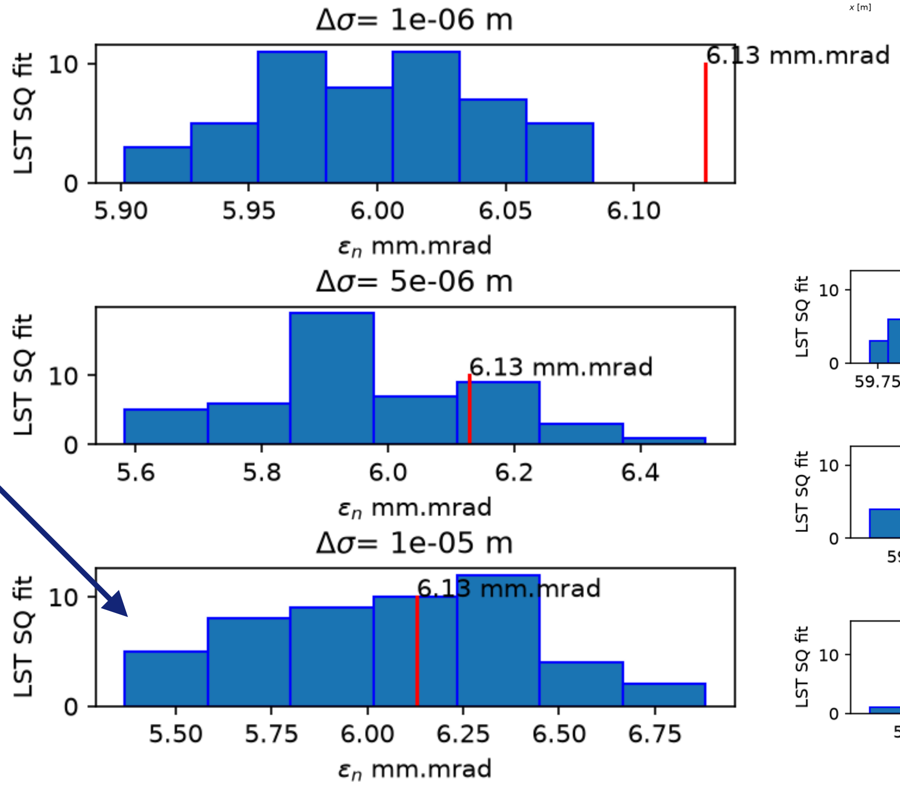
No other element in the beam line can move the beam by as much as the dipole in present simulations, even in presence of errors. If this will be the case, also this elements could be interlocked.

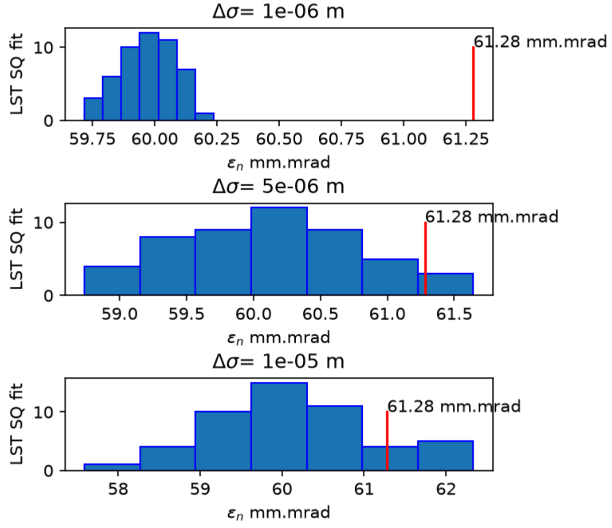


EMITTANCE MEASUREMENT PYAT SIMULATIONS







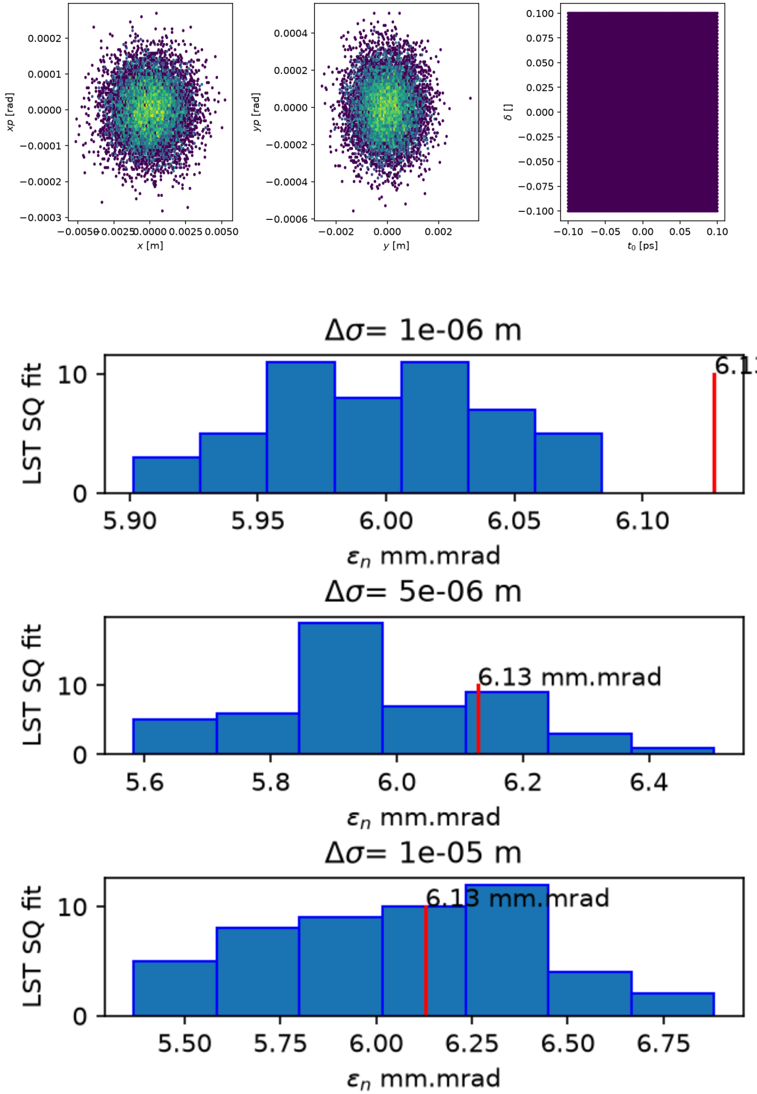


PyAT gaussian beam is working
Works for any input emittance and for realistic errors
There is a small systematic error

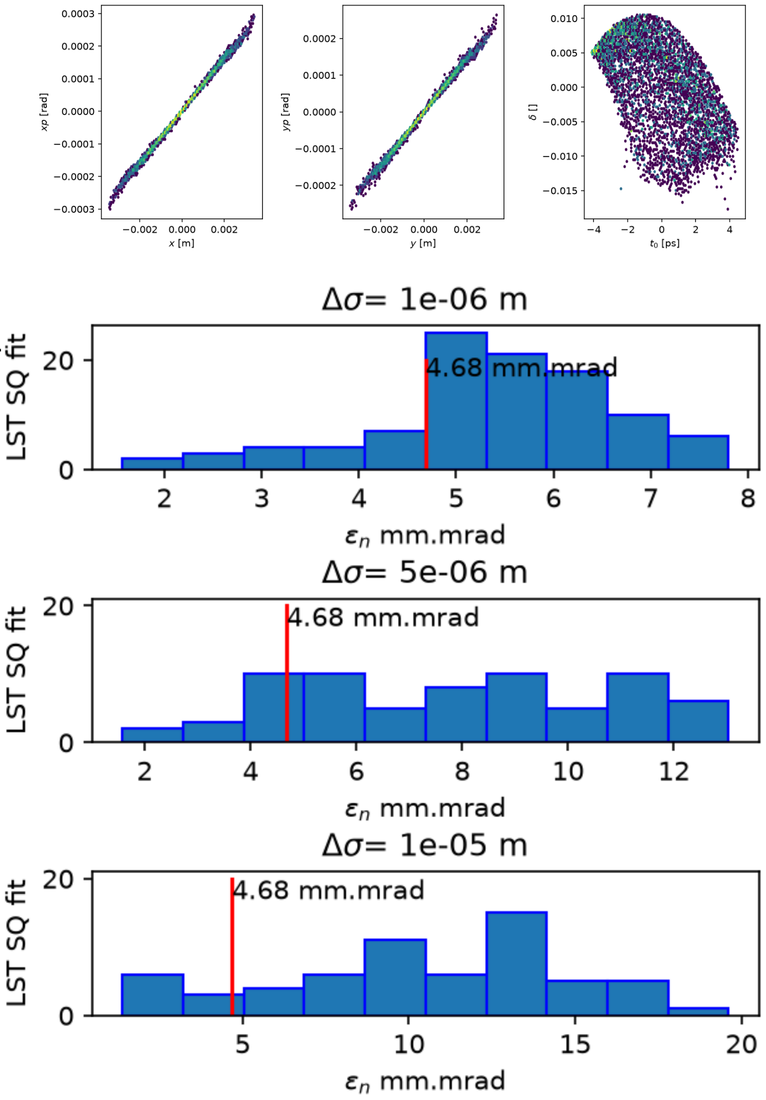
A FACTOR /2 in emittance computation is introduced empirically to get this results, likely due to dispersion at the screen location.

PYAT SIMULATIONS, INPUT BEAM FROM RF-TRACK TRACKING

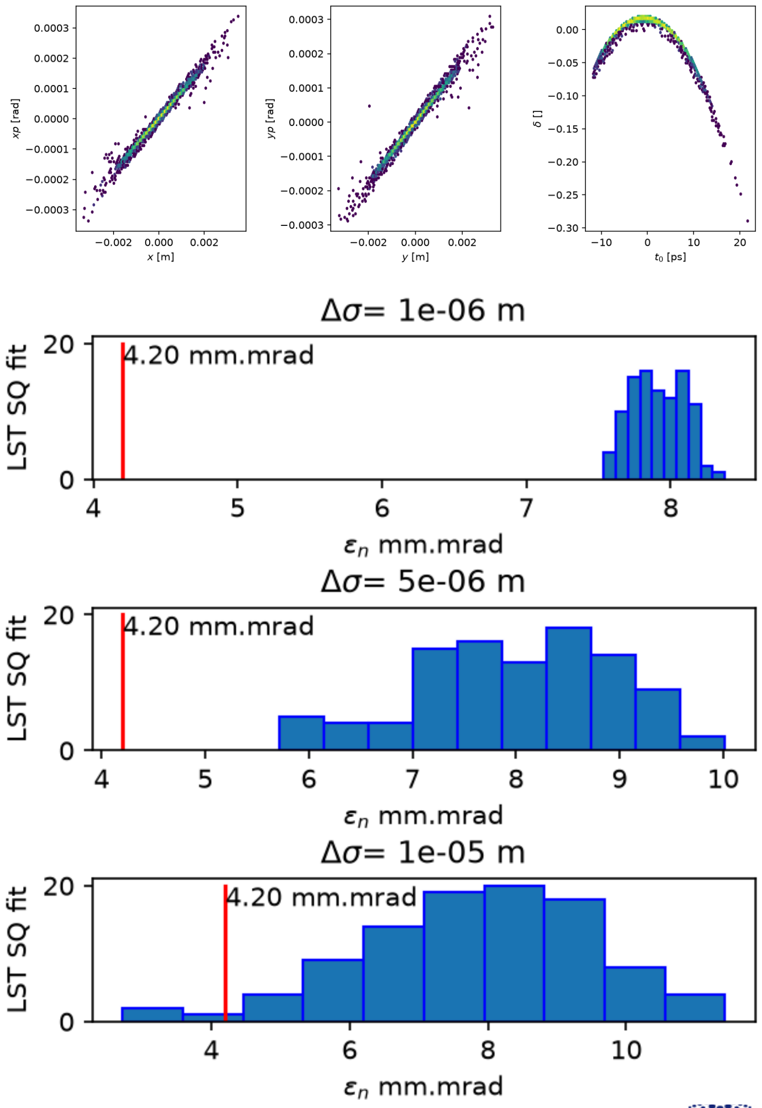
IDEAL BEAM



Realistic beam (RF-Track) SHORT

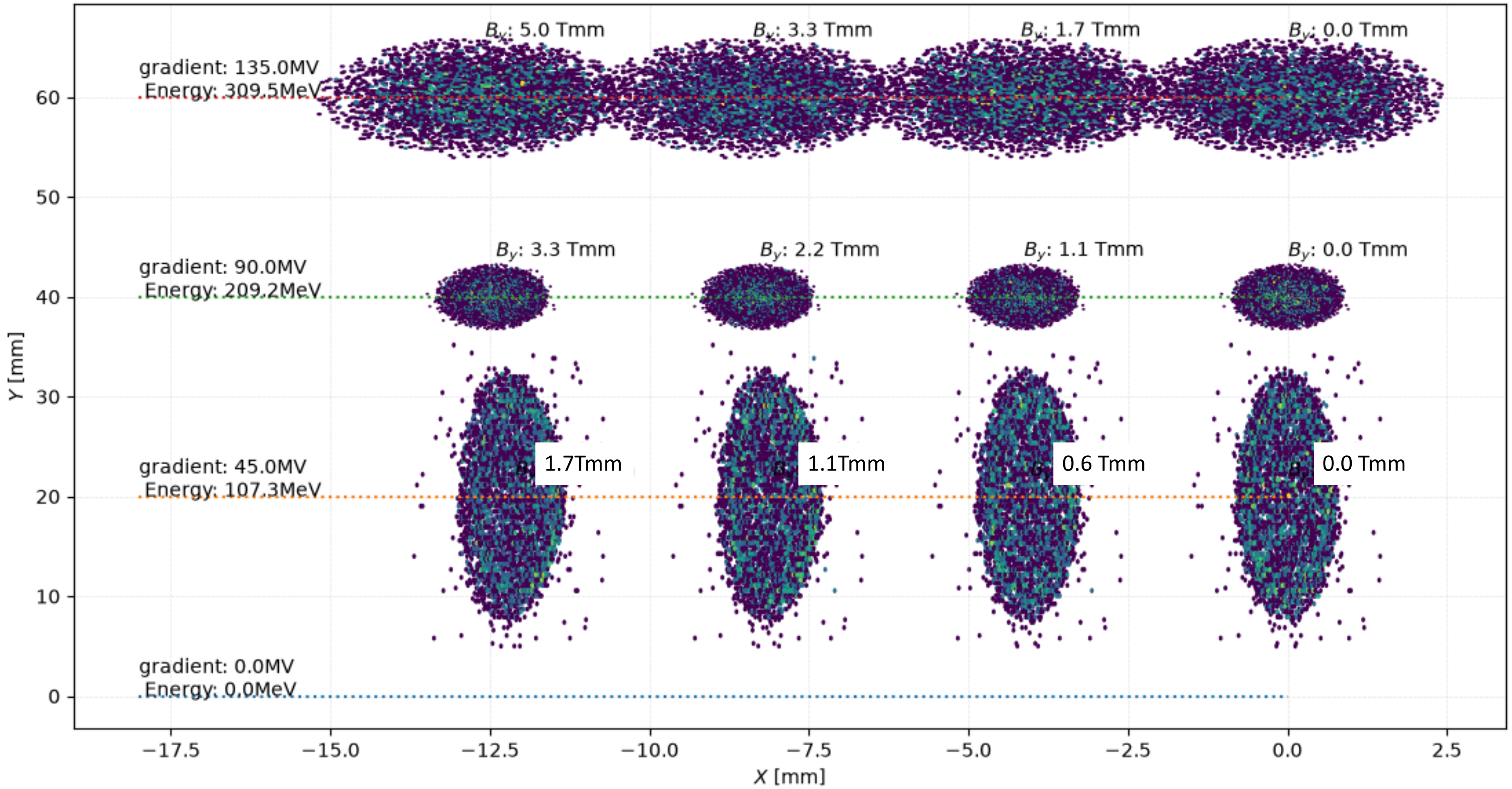


Realistic beam (RF-Track) LONG



Slice emittance would work like the ideal case.

ENERGY MEASUREMENT WITH DIPOLE/CORRECTOR



Measurement error:
- centroid error
- Magnetic field error
- Minimum field

Energy = C B/x

If we can detect changes in position by dx = 10um and B is know with an error of 1e-4Tmm, then we know the energy with ~0.1% precision (0.3MeV for 300MeV).

The magnet needs to be able to reach 5Tmm (for 300MeV beam)

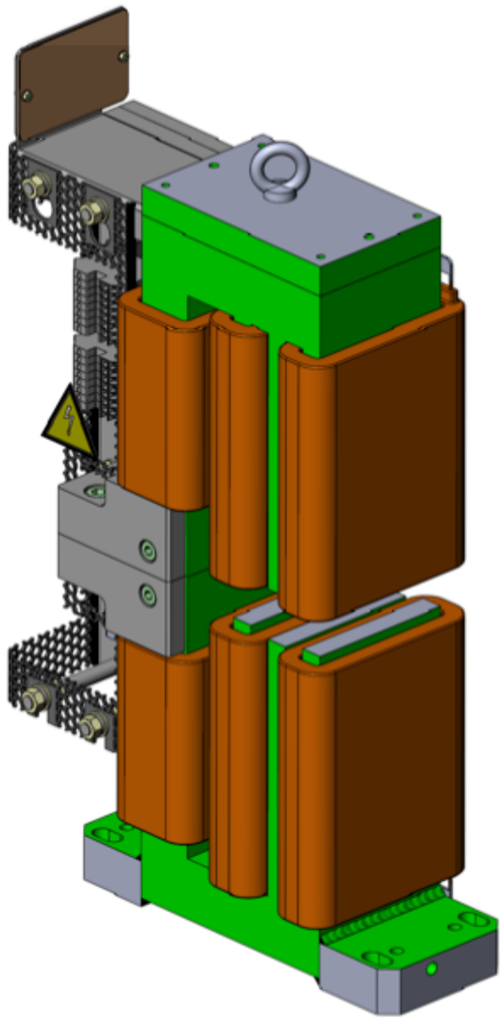
/Users/liuzzo/Desktop/LINAC/COLD_Phase2_August2026/diag_studies_energy_V17.py

POSSIBLE CORRECTOR MAGNET: EBS SPARE CORRECTORS

This corrector can produce an integrated field of up to **10 T·mm** at a current of **2 A**.

The yoke length in the beam direction is **100 mm**, and the total length, including the coils and protective grid, is approximately **150 mm**.

We have spare units of this corrector available, and we can make one or two of them available to you for an extended period.



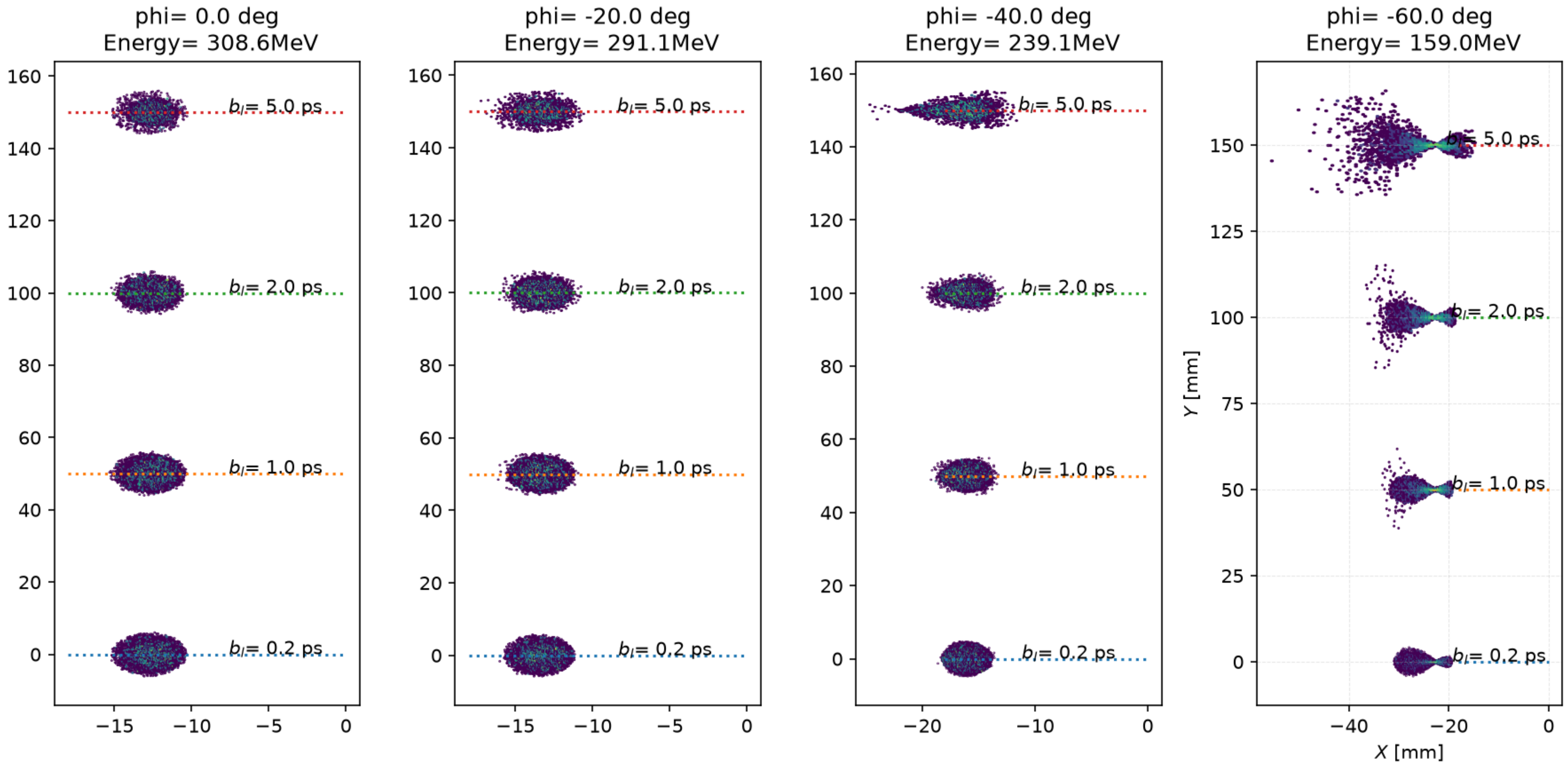
C. Benabderrahmane, COLD-WP10-Magnets and PS

BUNCH LENGTH

Off crest operation (phase of accelerating structures)

Lower energy, but correlation of energy with longitudinal position in the bunch (late particles have lower energy)

Dispersive Image on the screen with dipole (corrector) on (5 Tmm).

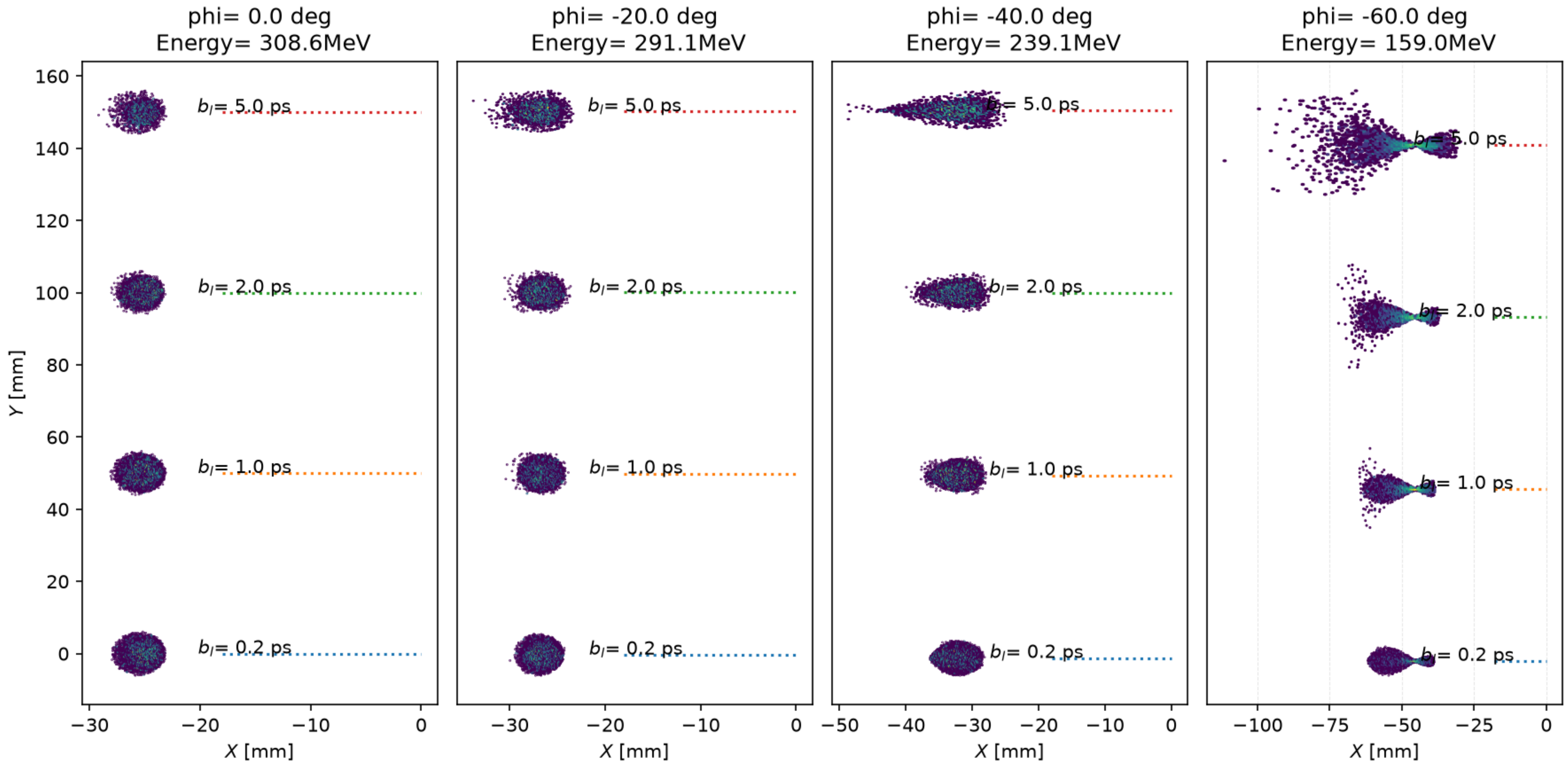


BUNCH LENGTH

Off crest operation (phase of accelerating structures)

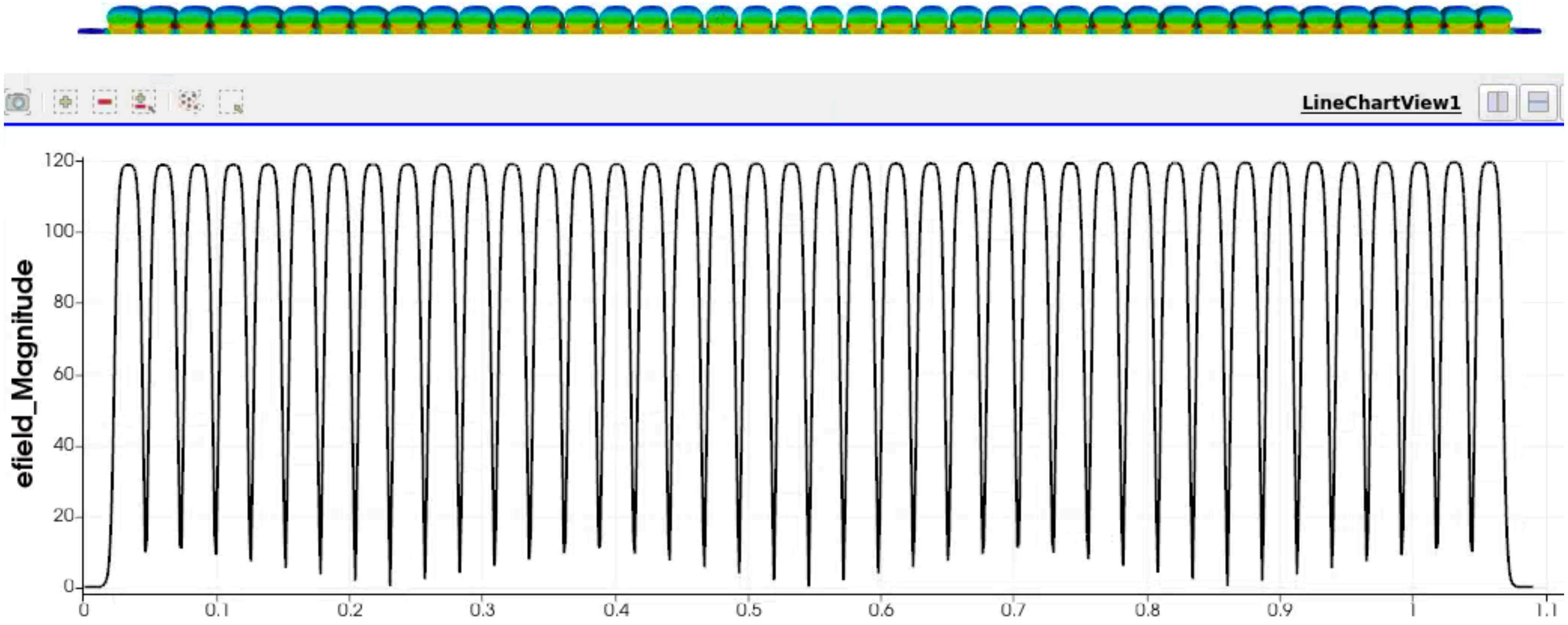
Lower energy, but correlation of energy with longitudinal position in the bunch (late particles have lower energy)

Dispersive Image on the screen with dipole (corrector) on (10 Tmm).



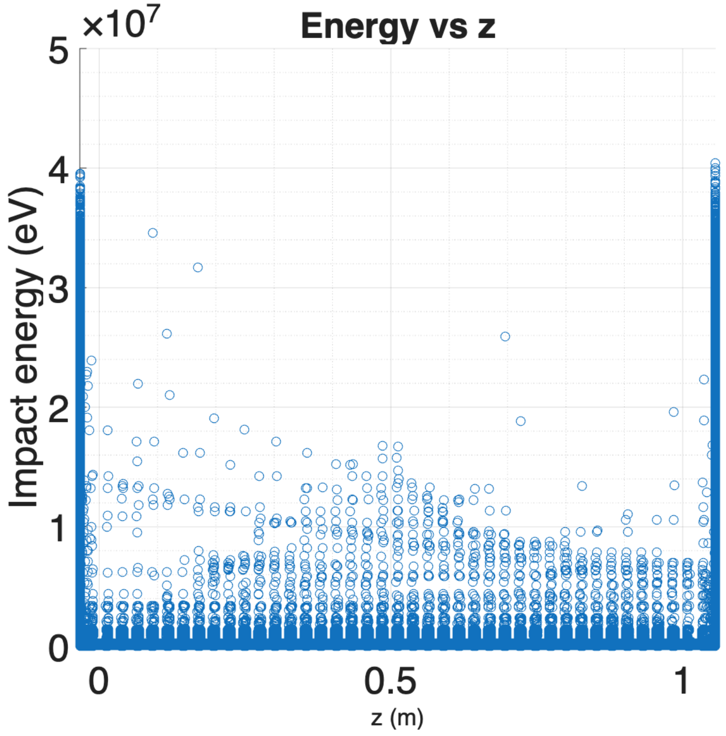
/Users/liuzzo/Desktop/LINAC/COLD_Phase2_August2026/diag_studies_bunch_length_V17.py

40-cell Cband Structure Field Profile for DC Simulation

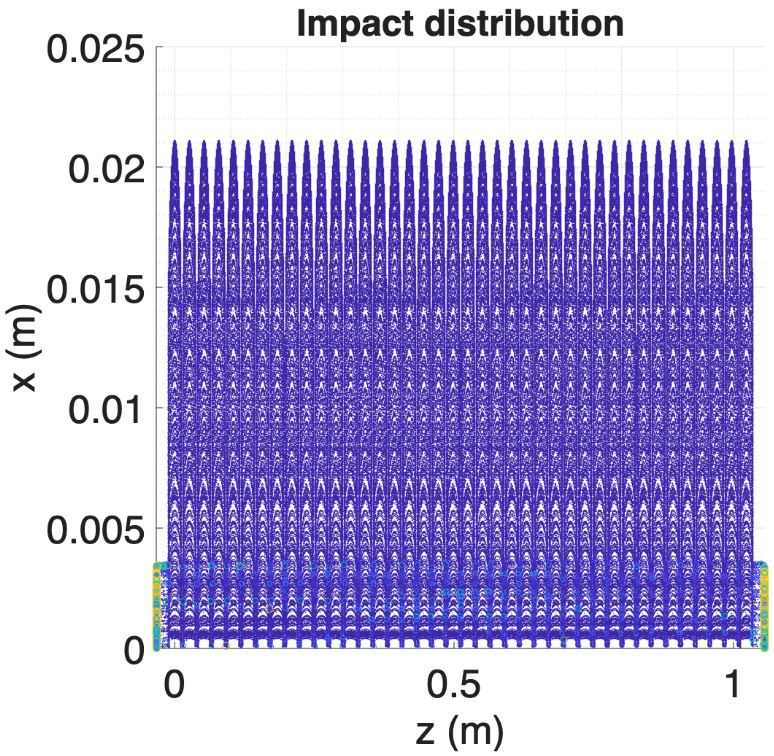


Field emission dark current (beta=45, E=40 MV/m)

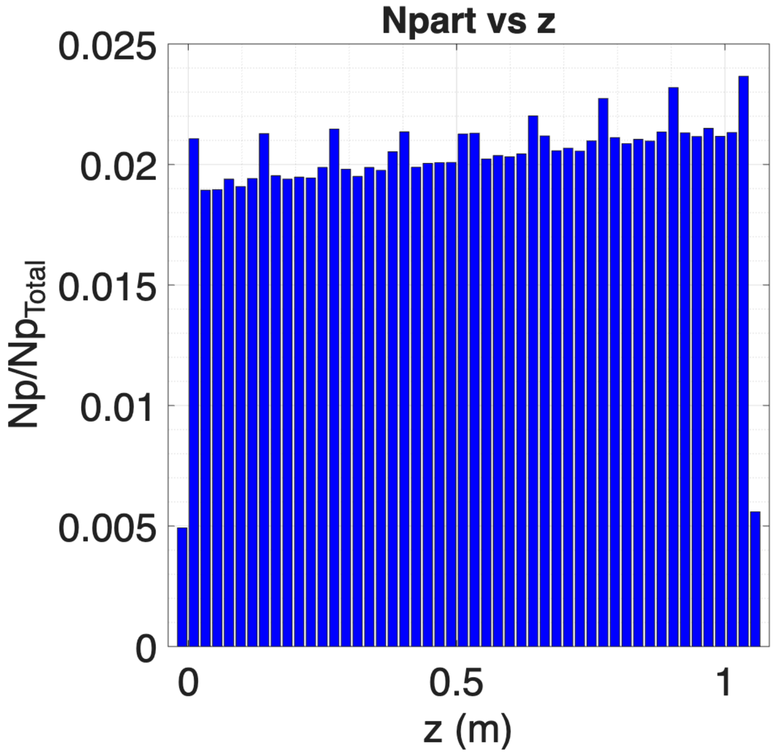
80 MV/m for our case



Electron energy vs impact position



Electron impact on cavity surface



Electrons exited beam pipe: 0.5%

Sent by E.Nanni SLAC, 27-Aug-2026

SUMMARY EFFECT OF ERRORS (NO CORRECTIONS, SHORT BUNCH)

Errors	Position	Beam size	energy	Energy spread	Bunch length	Emittance

err_sol_sigx = 2e-5 # m
err_sol_sigy = 2e-5 # m
	(0.3, 0.3) mm	(0.015, 0.0075) mm	0.02MeV	1.22MeV	0.0002 ps	0.1mmmrad

# quad and RF alignment 	
errsigx = 1e-4 # m
errsigy = 1e-4 # m
errsigz = 1e-3 # m
	(0.6, 0.6) mm	(0.03, 0.01) mm	0.1MeV	1.31MeV	0.00075 ps	0.15mmmrad

# quad and RF alignment 	
errsigx = 2e-4 # m
errsigy = 2e-4 # m
errsigz = 2e-3 # m
	(1.2, 1.2) mm	(0.07, 0.02) mm	0.4MeV	1.55MeV	0.00125 ps	0.25mmmrad

# quad and RF alignment 	
errsigx = 3e-4 # m
errsigy = 3e-4 # m
errsigz = 1e-3 # m
	(2.0, 2.0) mm	(0.75, 0.03) mm	0.75MeV	1.8MeV	0.03 ps	0.4 mmmrad

# quad and RF alignment 	
errsigx = 1e-3 # m
errsigy = 1e-3 # m
errsigz = 1e-2 # m
	(>10, 10) mm	(6, 1) mm	100MeV	8MeV	0.3 ps	10mmmrad

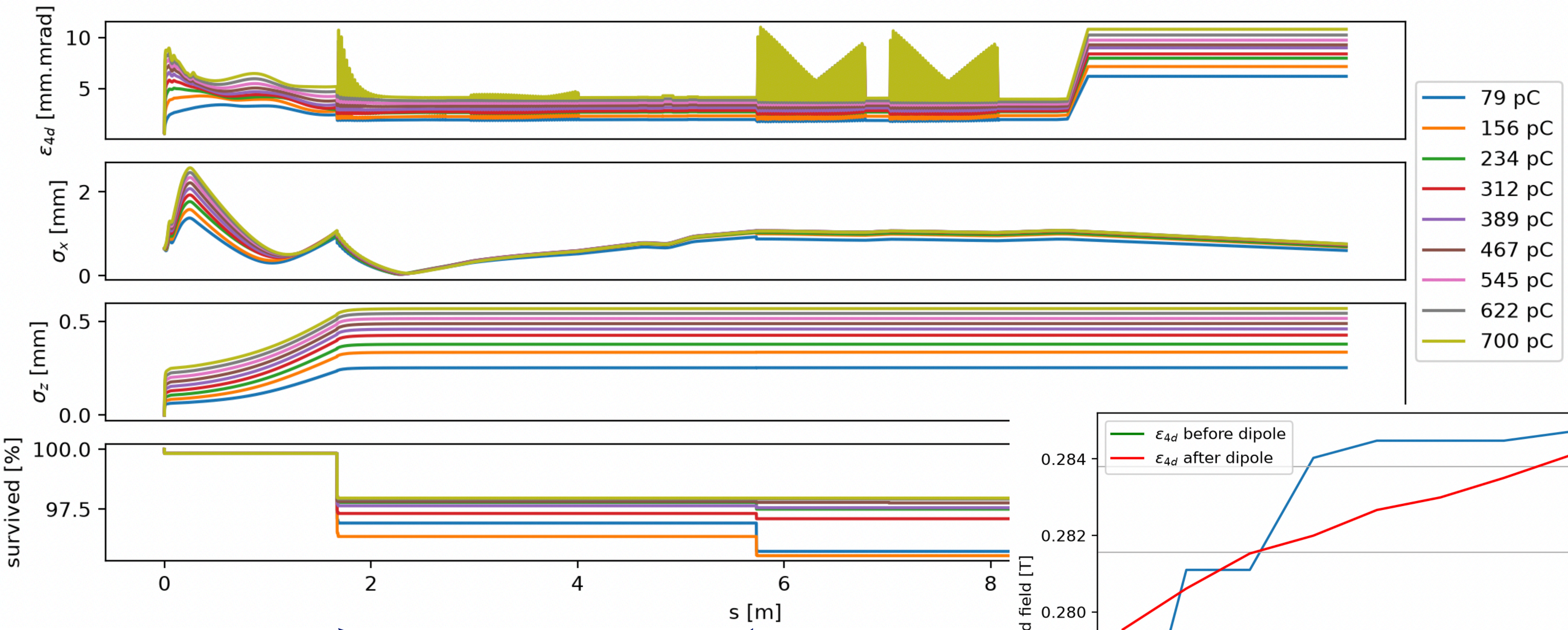
err_gradient = 1.0 # MV
err_phase = 1.0 # deg
	(0.03, 0.03) mm	(0.02, 0.0002) mm	5MeV	1.55MeV	0.02 ps	2mmmrad

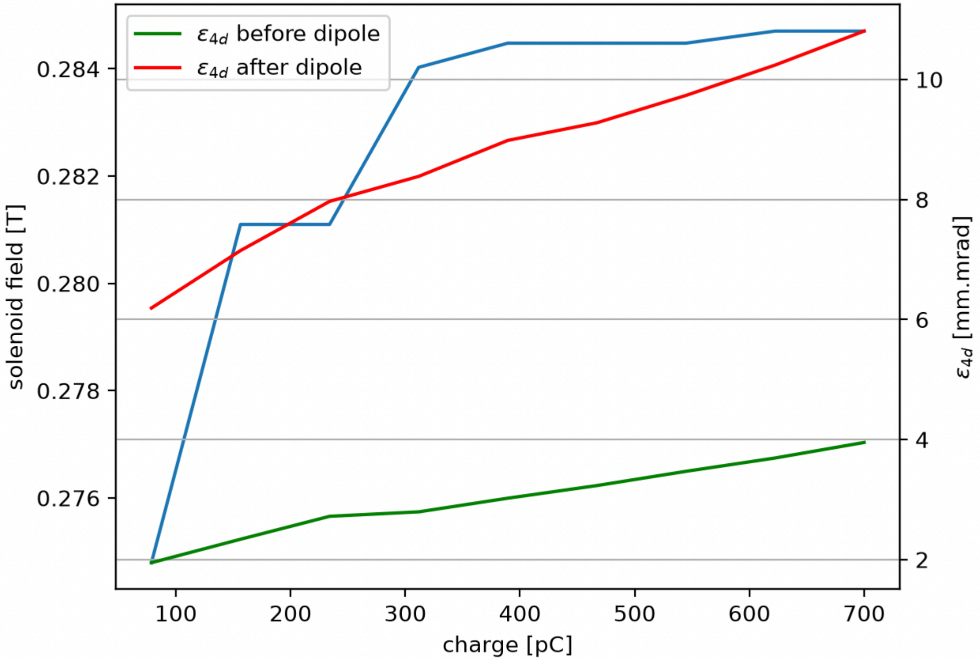
err_phase = 1.0 # deg	(0.03, 7e-4) mm	(0.0705, 0.0075) mm	0.3MeV	1.7MeV	0.003 ps	1.5mmmrad

errfreq = -91.4*1e3 * TempVarKelvin # Hz / K * K
err_phase1 = 0.5 # deg
	(0.01, 3e-4) mm	(0.0002, 2e-5) mm	0.1MeV	1.2 MeV	0.0001 ps	0.05mmmrad

err_gun_gradient = 0.5*1e6 # V
err_gun_phase = 1.0 # deg
err_sol_field = 0.0001 # T
errfreq = -91.4*1e3 * TempVarKelvin # Hz / K * K
err_phase1 = 0.5 # deg (for each structure)
err_sol_sigx = 2e-5 # m
err_sol_sigy = 2e-5 # m
# quad and RF alignment 	
errsigx = 1e-4 # m
errsigy = 1e-4 # m
errsigz = 1e-3 # m
	(0.75, 2.0) mm	(0.07, 0.15) mm	0.4MeV	1.6MeV	0.15 ps	1.0mmmrad

BEAM PARAMETERS AS A FUNCTION OF CHARGE FROM THE GUN, SHORT BUNCH, SOLENOID OPTIMIZED





Losses at entrance in the accelerating structures

/Users/liuzzo/Desktop/LINAC/COLD_Phase2_August2026_RFT2.7.1/plot_params_vs_charge_sol.py

CONCLUSION

The COLD layout is fixed. Only the distance gun to structure could become shorter, reducing the overall lost particles.

Two operation beam scenarios are considered. The hardware enables both options and the optimal configuration will be determined experimentally.

A diagnostic section is proposed. It allows to measure the beam properties with a simple layout and using existing hardware.

Dark current simulations have started at SLAC.

Error studies. No major issue observed. The linac is rather tolerant despite 3.55mm iris radius.

Parameters and solenoid settings vs bunch charge. Overall at most 3% losses localized at the entrance of the accelerating structures.