

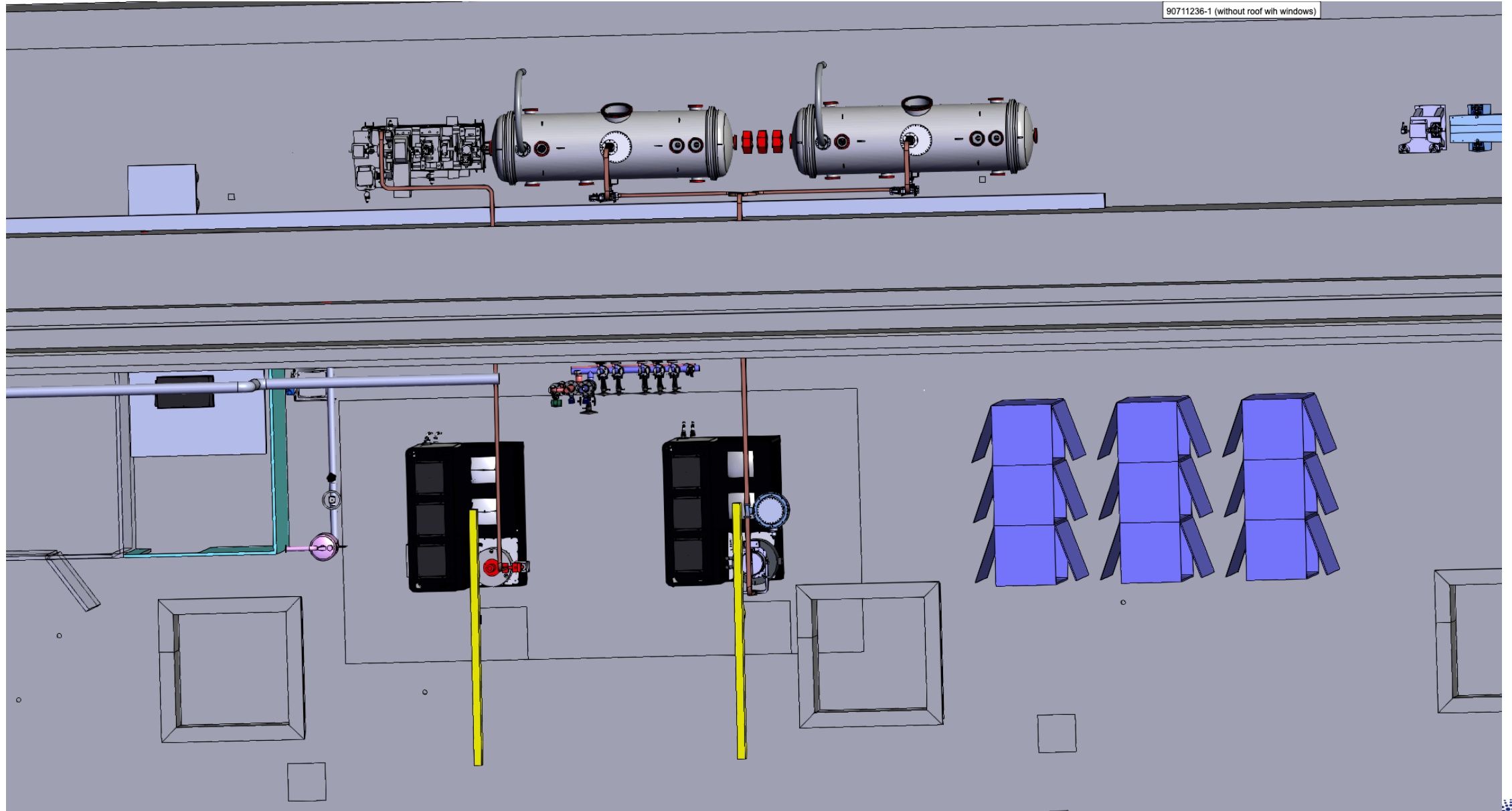


COLD tracking with errors V18

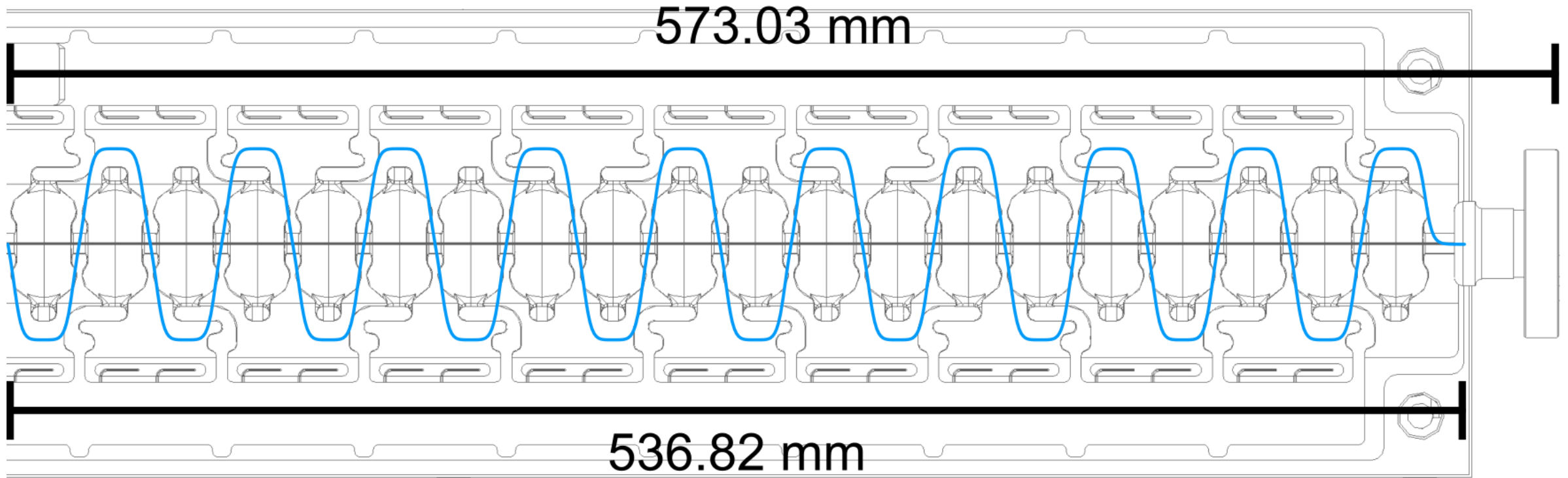
S. M. Liuzzo

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

90711236-1 (without roof with windows)



FIELD MAP OVERLAY ON STRUCTURES FROM A.DHAR (SLAC)



!!!! The map is 1.07 m long while the one I am using is 1.06m long !!!!

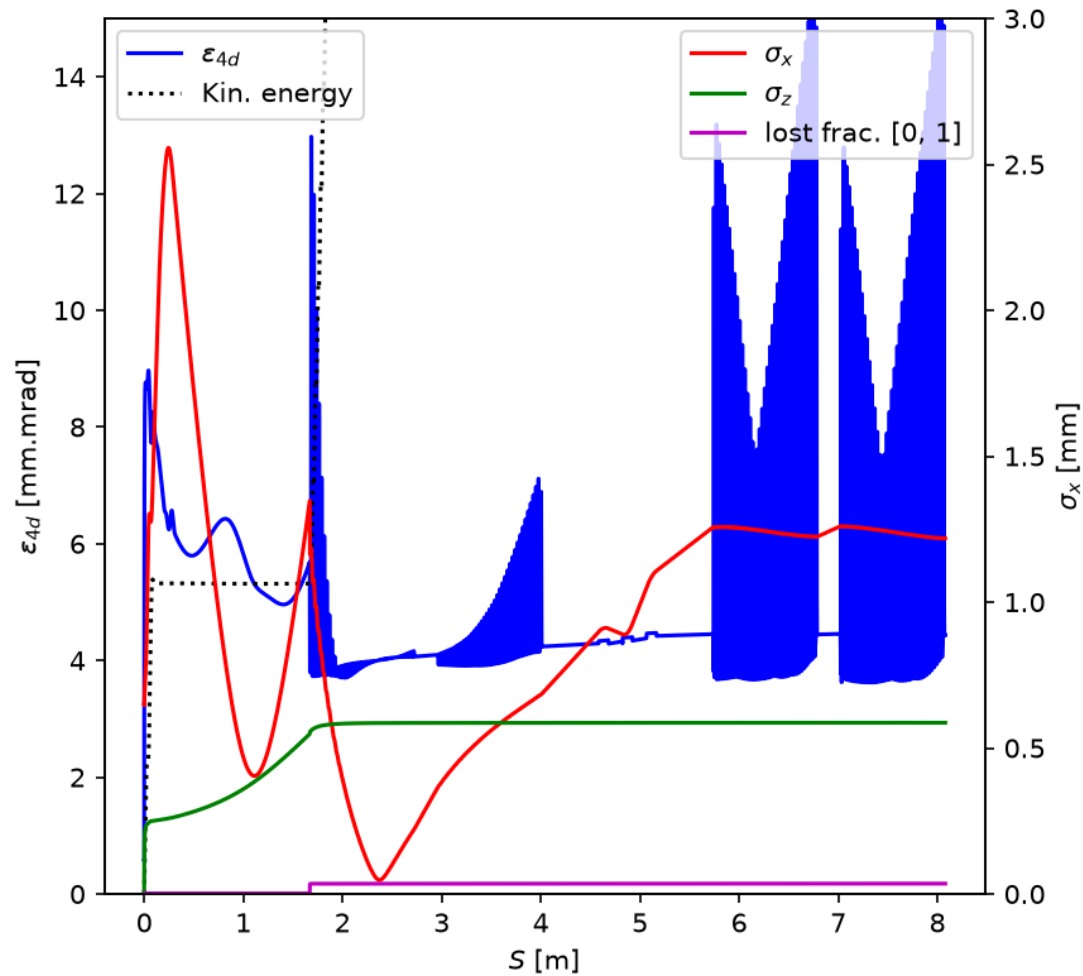
Recovered correct file sent by A.Dhar in January 2026

Copper
1082,7 mm

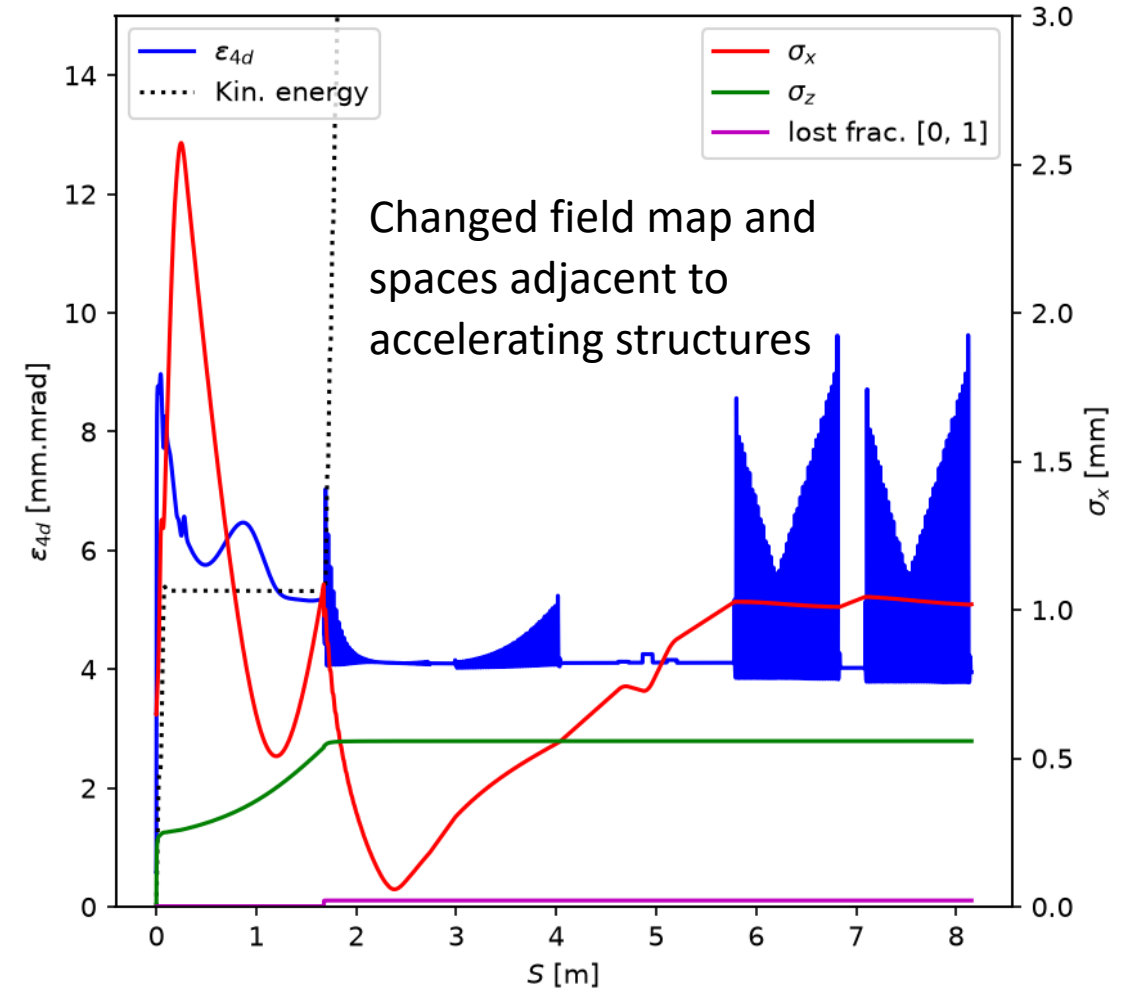
The field map is slightly shorter respect to the copper (4.53mm on each side)

EFFECT OF CHANGE IN FIELD MAP AND 4.5MM DISTANCE MAP-COPPER

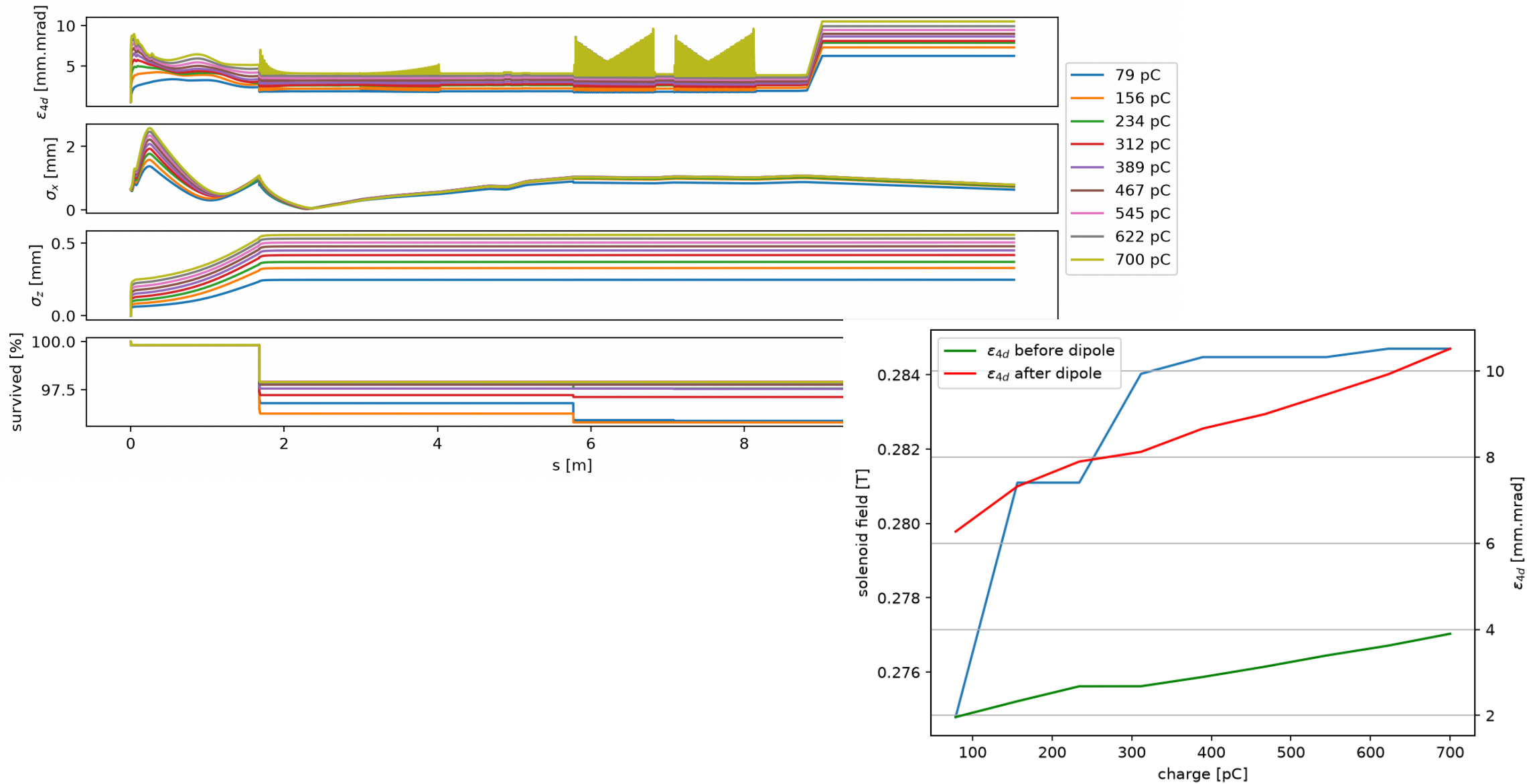
V17 (August 2026)



V18 (September 2026)

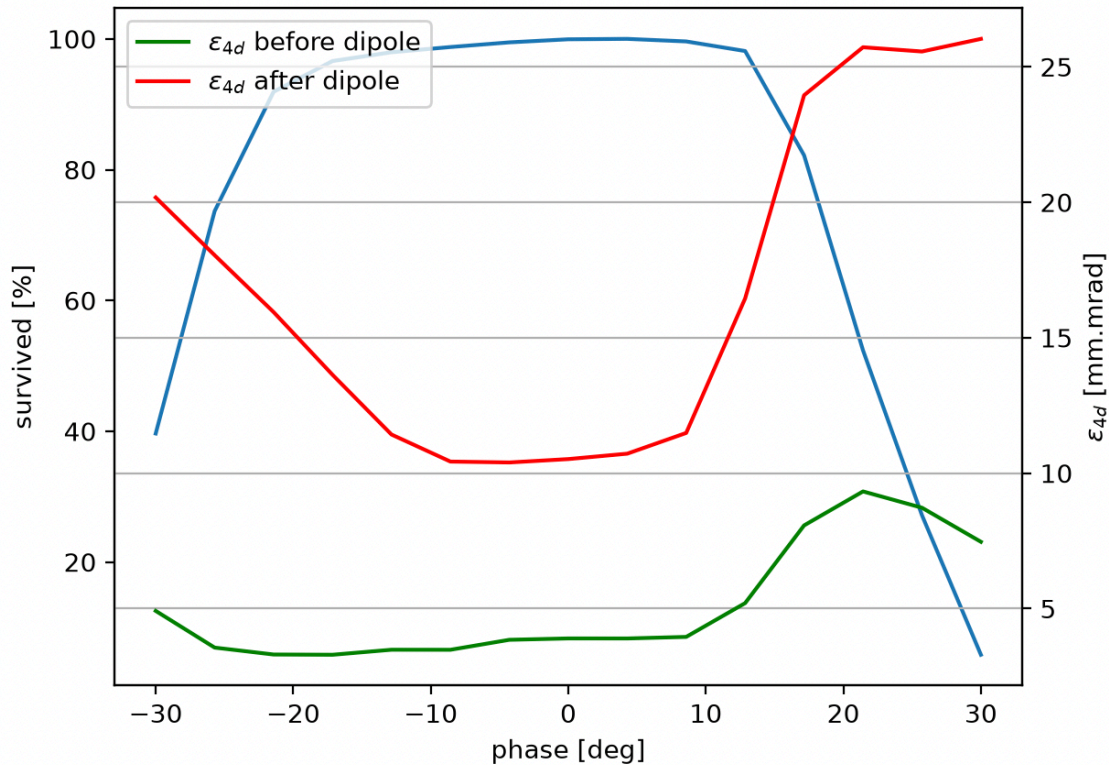


BEAM PROPERTIES VS CHARGE



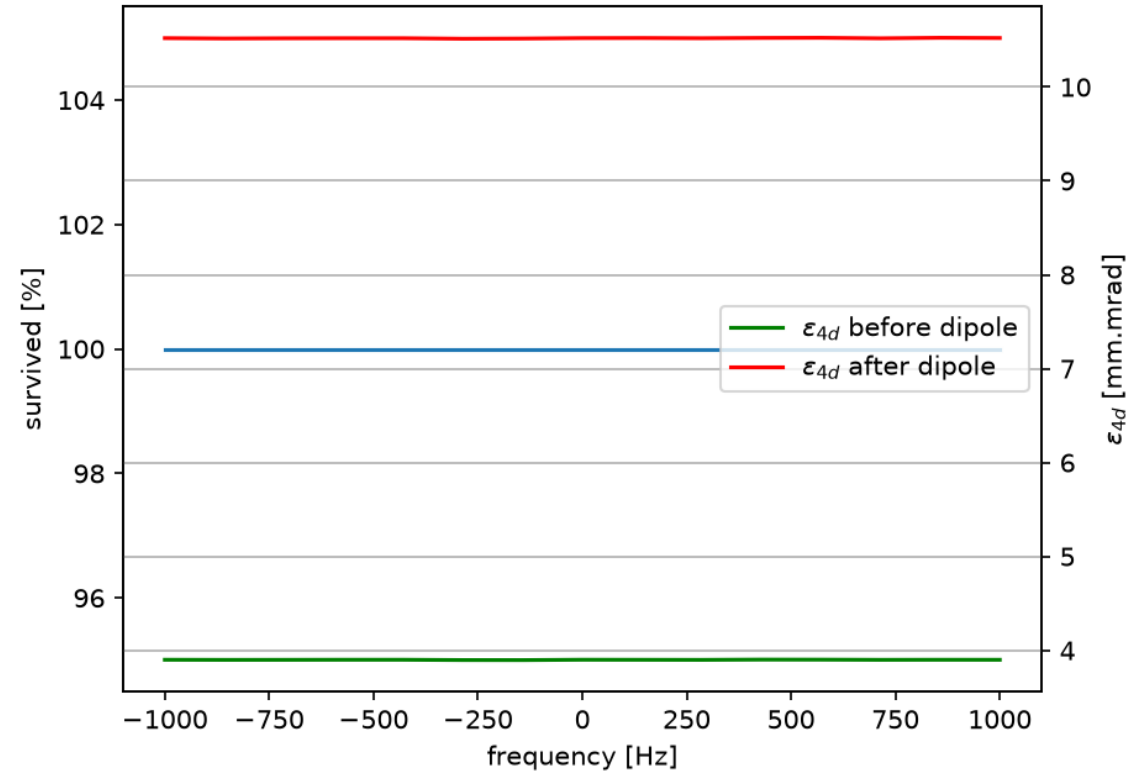
GUN ERRORS

Gun phase error: +/-10 deg ok



Only gun phase error is applied. All rest is perfect.

Gun frequency error: +/-1 kHz ok
Gun frequency error: +/-1 MHz ok

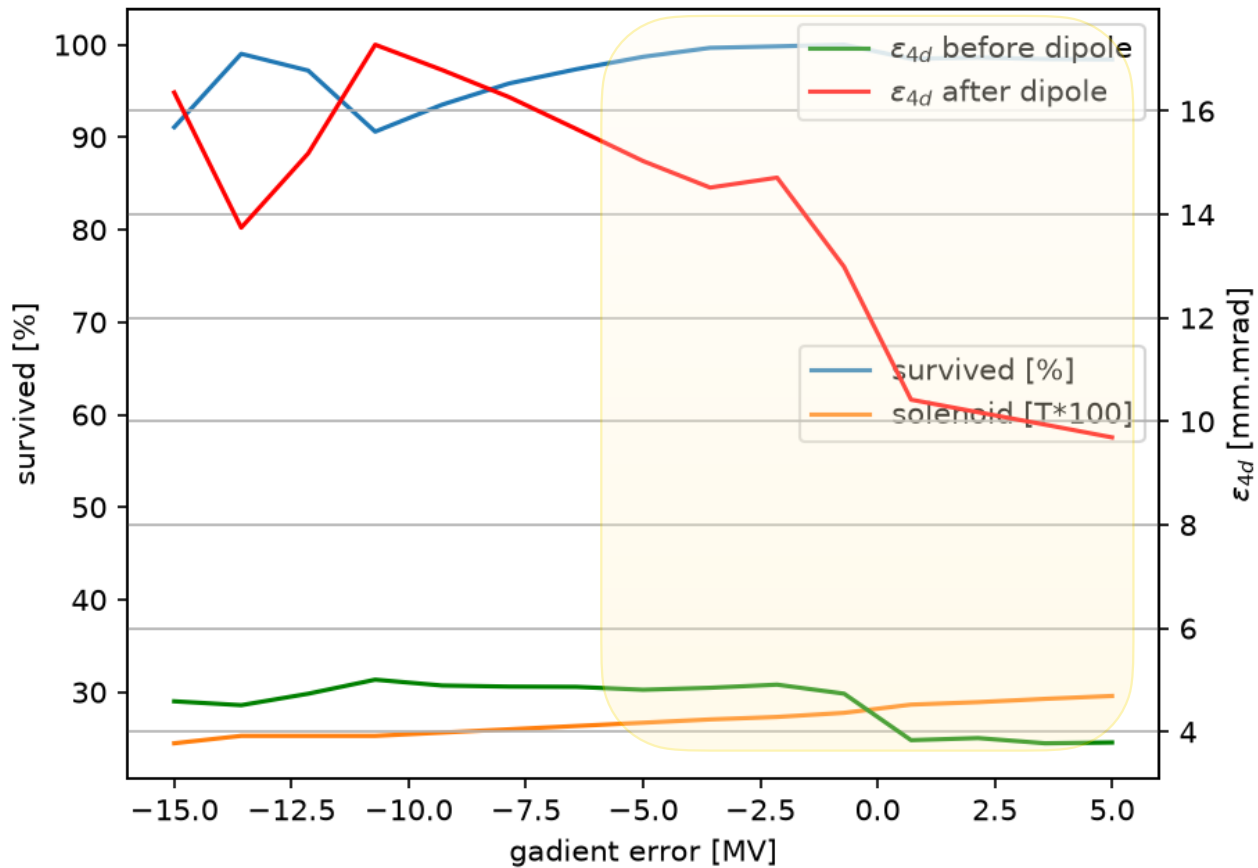


Is it taking in account the change of frequency?

Only gun frequency error is applied. All rest is perfect.

GUN ERRORS

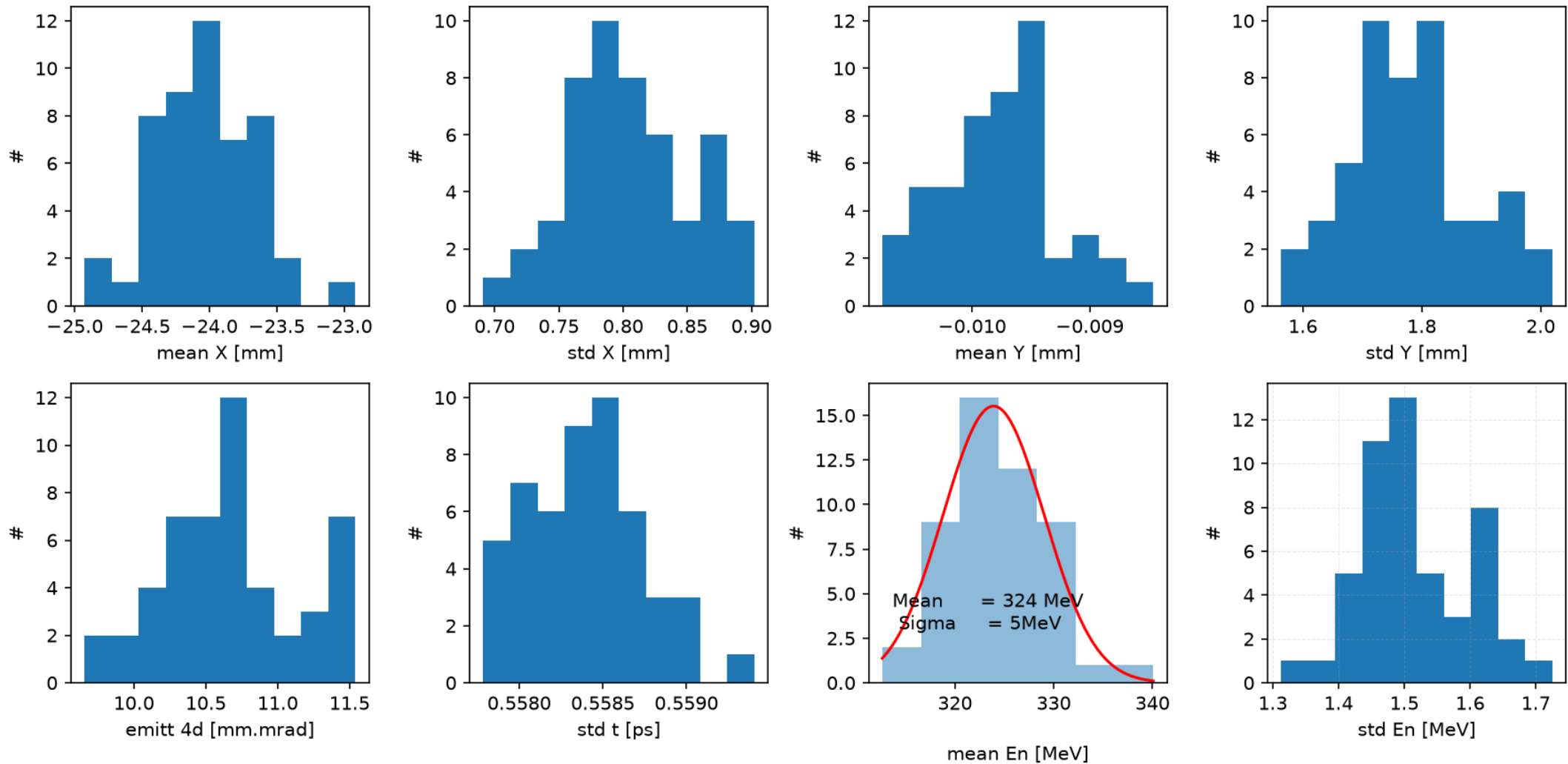
Gun gradient error: +5/-5 MV is ok
(readjusting the Solenoid accordingly)



Only gun gradient error is applied. All rest is perfect.

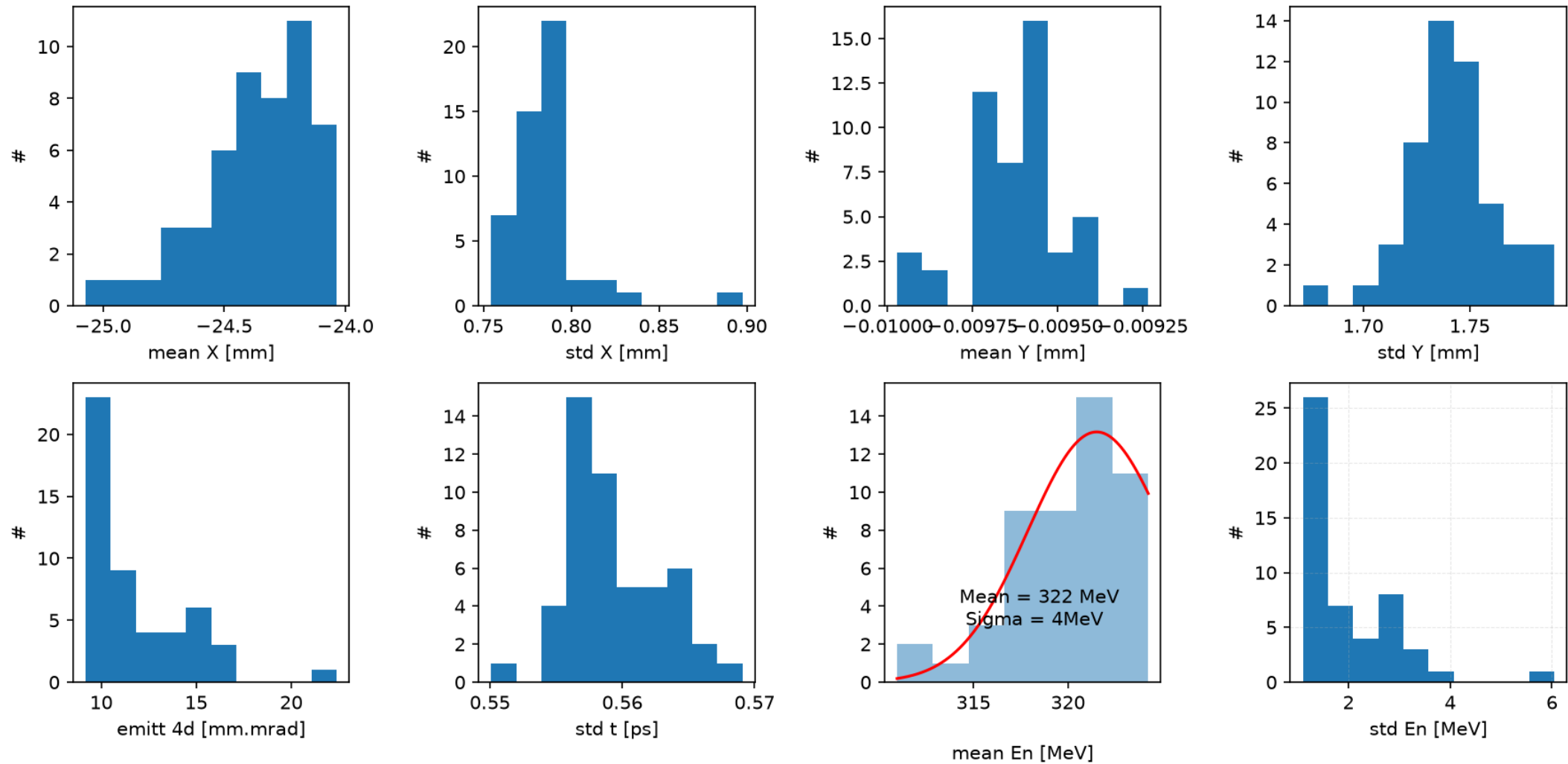
STRUCTURES GRADIENT ERRORS

5MV gradient error random in the 4 structures (50 seeds). Energy jitter = $\sim 5\text{MeV}$



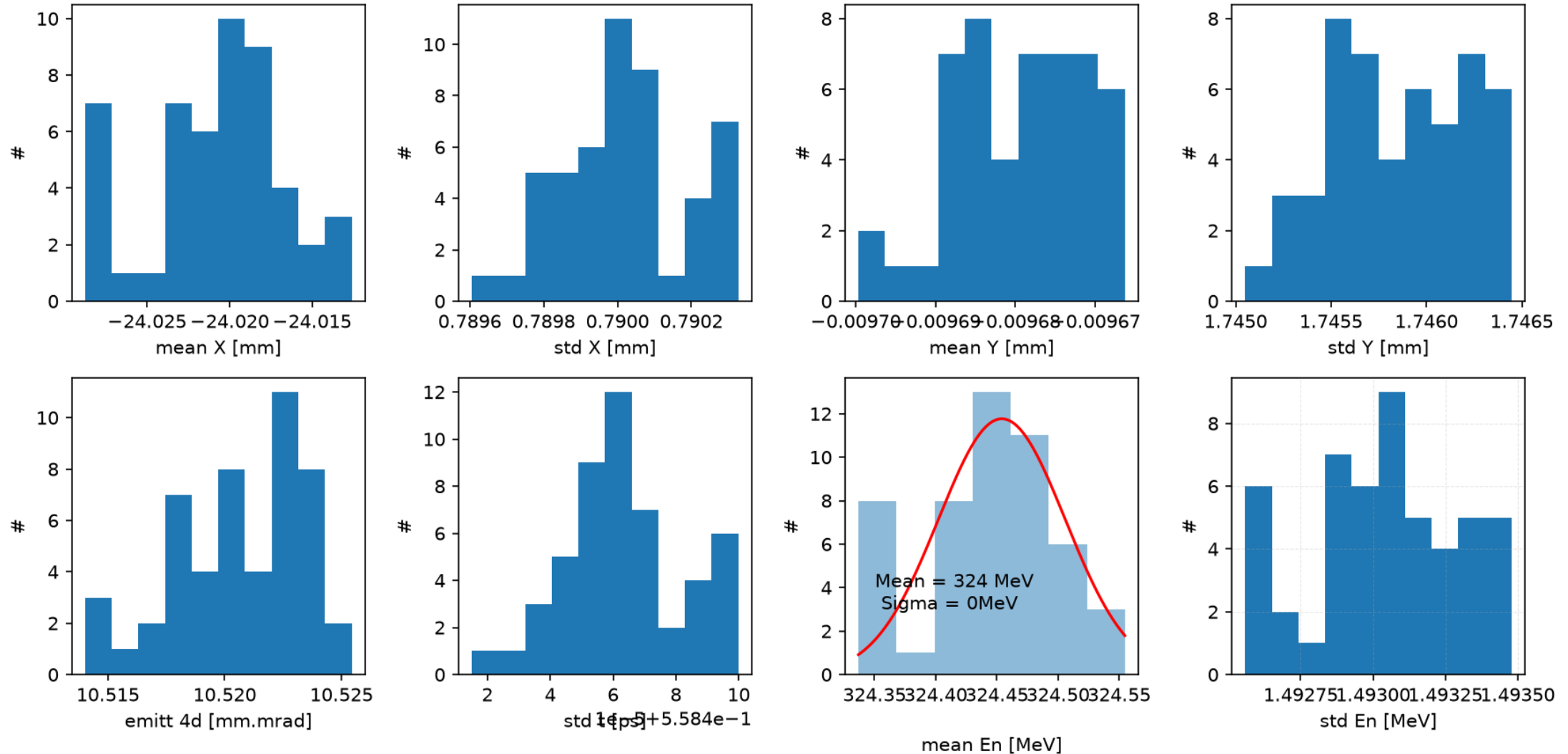
STRUCTURES PHASE ERRORS

10deg phase error random in the 4 structures (50 seeds). Energy jitter = 4 MeV

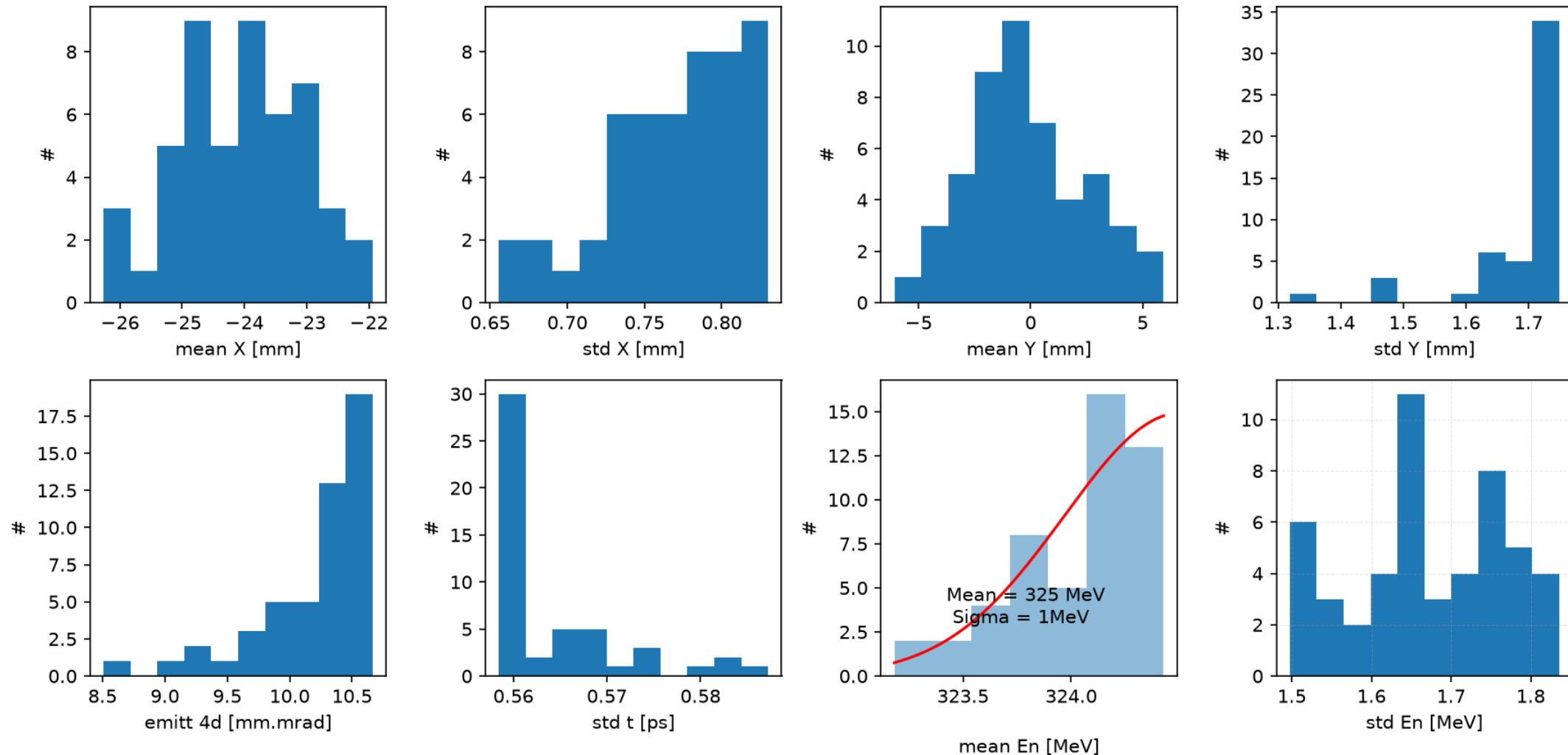


STRUCTURES FREQUENCY ERRORS

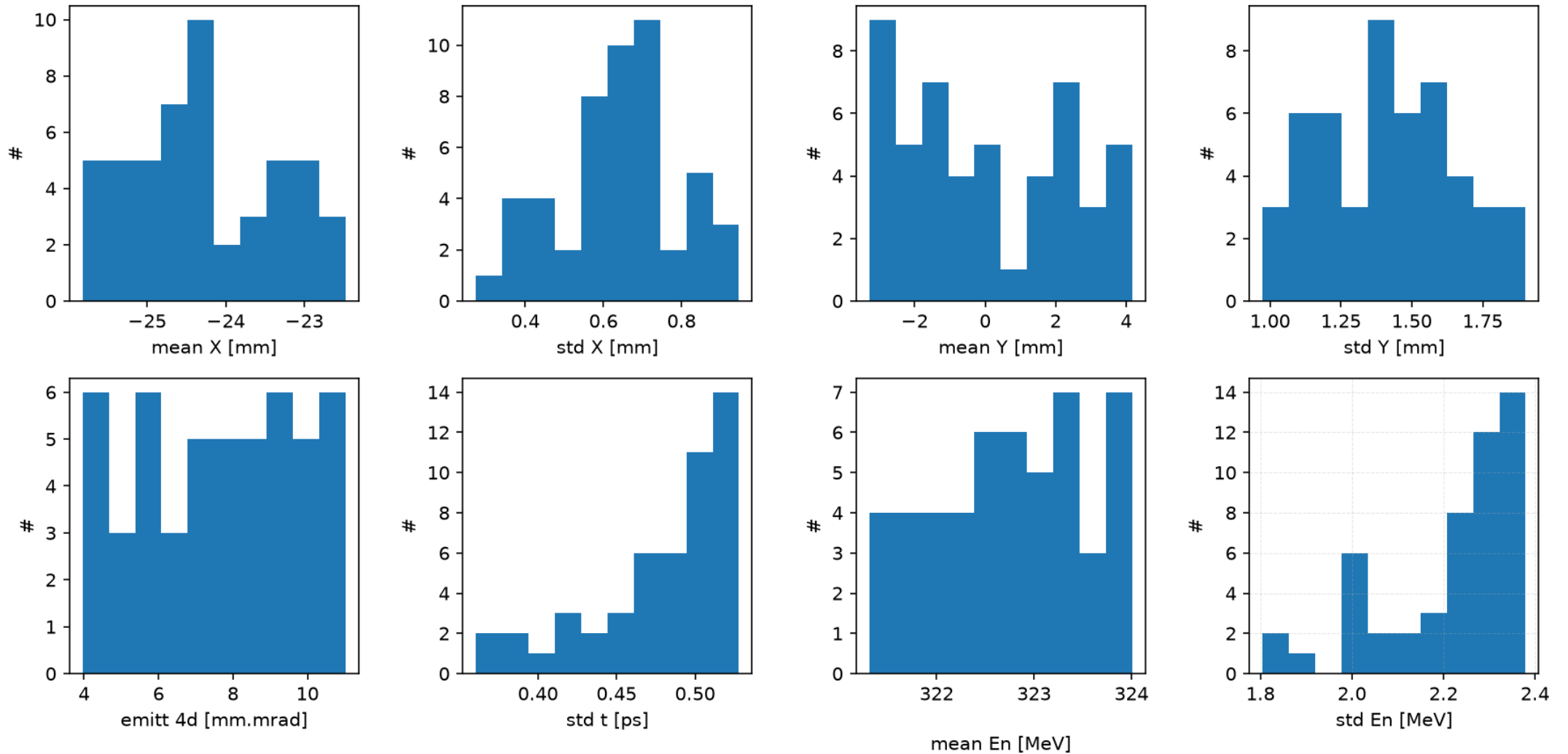
2K random temperature —> frequency error random in the 2 cryomodules (50 seeds). Energy jitter = 0 MeV
180KHz / 5.712GHz



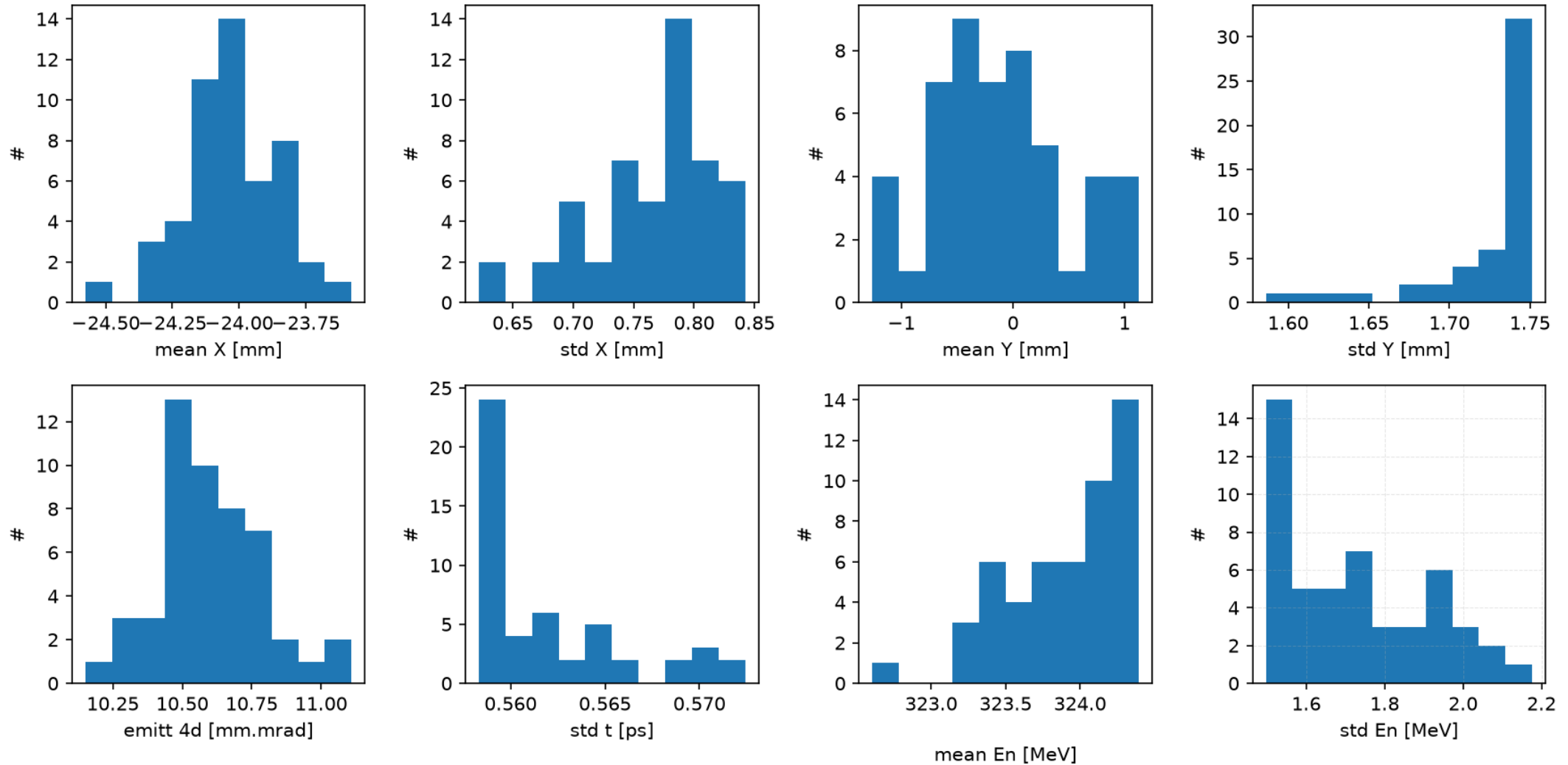
Quadrupoles alignment errors



Cathode alignment errors

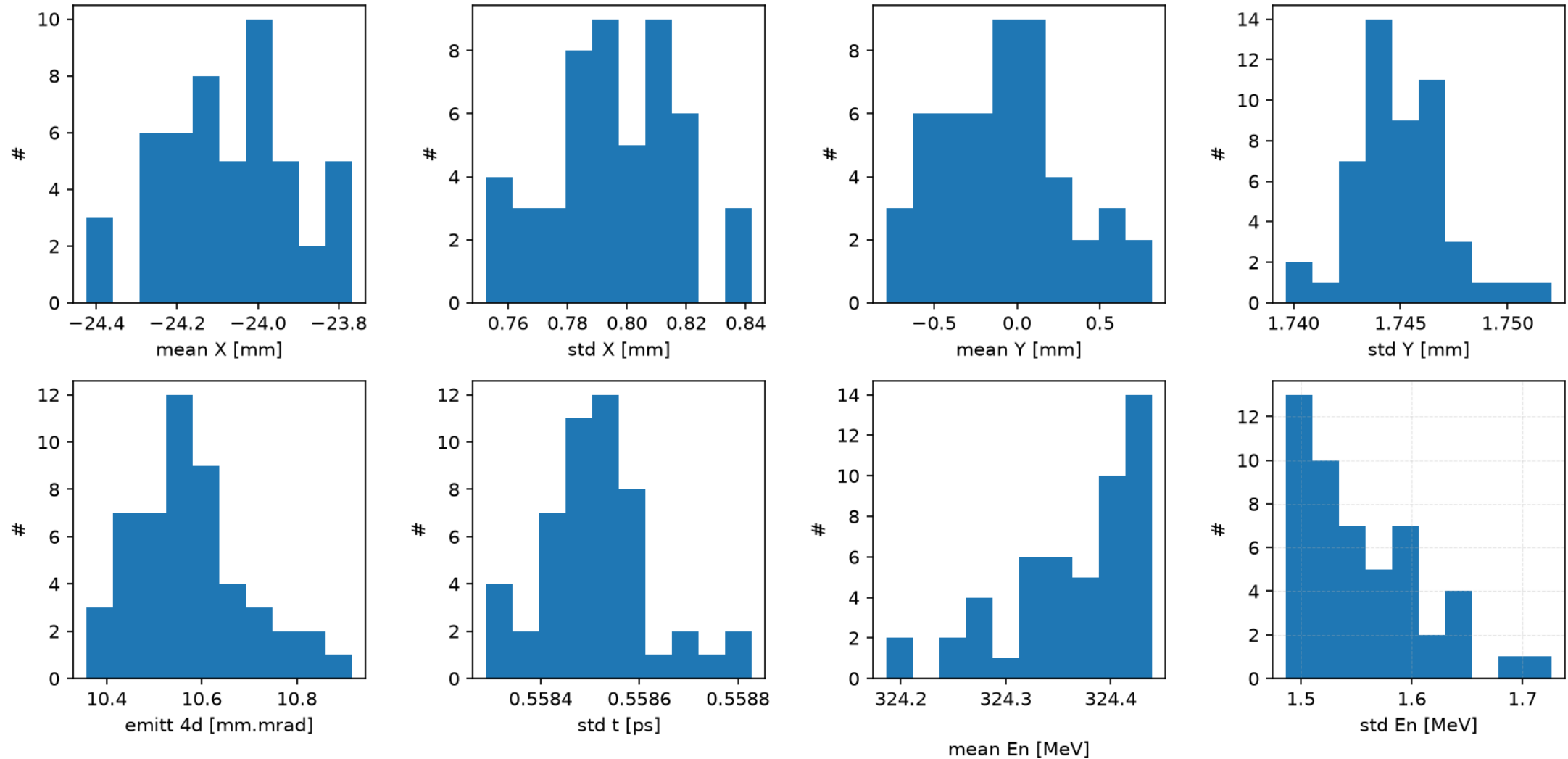


RF alignment errors



SOLENOID ERRORS

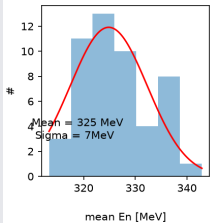
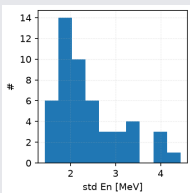
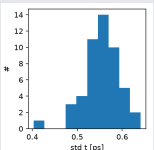
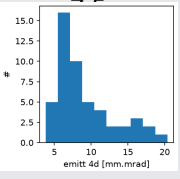
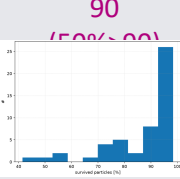
Dx, Dy, Dz, roll, yaw, pitch



SUMMARY EFFECT OF ERRORS (NO CORRECTIONS)

Element	Amplitude	ΔPosition	ΔBeam size	ΔEnergy	ΔEnergy spread	Δ Bunch length	Δ Emittance	Survived %
Units	(X , Y)	mm	mm	MeV	MeV	ps	mm.mrad	%
Structures gradient	5 MeV	1.0, 0.001	0.1, 0.2	5	1.7	0.0005	1.0	98
Structures phase	10 degrees	0.5, 0.0005	0.05, 0.05	4	6.0	0.01	5	98
Structures Frequency	2K = 182 KHz	0.005, 0.0001	0.0003, 0.0007	0	0	0	0	98
Quadrupoles alignment	300 μm	2.0, 5.0	0.07, 1.7	1	1.8	0.02	1.2	95 (min 70)
Cathode alignment	300 μm	1.5, 3.0	0.3, 0.3	1.5	2.4	0.05	3	40
RF alignment	300 μm	0.4, 1.0	0.2, 0.05	0.5	2.1	0.05	0.4	95 (min 91)
Solenoid alignment	25 μm	0.3, 0.6	0.04, 0.005	0.2	1.7	0.0002	0.2	98
All above	Quad 100 μm Cathode 200 μm Gun phase 10deg Gun field 5MV	1.5, 3.0	0.4, 0.8	7.0	5.0	0.15	2.5	16
All above	Quad 100 μm RF 100μm Cathode 100 μm Gun phase 10deg Gun field 5MV Str Freq 10K	1.5, 2.5	0.4, 0.8	7.0	5.0	0.15	2.5	31
All above	Quad 100 μm RF 100μm Cathode 0 μm Gun phase 10deg Gun field 5MV Str Freq 10K	0.6, 2.0	0.3, 0.7	6.0	5.0	0.1	3.0	80
All above	Quad 100 μm RF 100μm Cathode 0 μm Gun phase 5deg Gun field 2.5MV Str Freq. 5K	0.6, 2.0	0.2, 0.7	4.0	4.0	0.1	3.0	81

SUMMARY EFFECT OF ERRORS (WITH CORRECTIONS)

Correction	Amplitude	ΔPosition	ΔBeam size	ΔEnergy	ΔEnergy spread	Δ Bunch length	Δ Emittance	Survived %
NO correction	Quad 100 μm RF 100μm Solenoid 25 μm Cathode 100 μm Gun phase 10deg Gun field 5MV Str Freq 10K Str Phase 10deg	1.5, 2.5	0.4, 0.8	7.0	5.0	0.15	2.5	31
A) Solenoid Field optimized. B) Trajectory correction with: 3 steerers and 3 BPMs	Quad 100 μm RF 100μm Cathode 100 μm Solenoid 100 μm Gun phase 10deg Gun field 5MV Str Freq. 10K Str Phase 10deg	2.0, 5.0	0.5, 1.0	11.0	4.0	0.2	7.0	39 ± 12
A) Solenoid Field optimized. B) Trajectory correction with: 3 steerers and 3 BPMs	Quad 100 μm RF 100μm Cathode 50 μm Solenoid 50 μm Gun phase 10deg Gun field 5MV Str Freq. 10K Str Phase 10deg	2.0, 4.0	0.2, 0.5	10	3.0	0.07	5.0	43 ± 8
A) Solenoid Field optimized B) Trajectory correction with: 3 steerers 3 stripline BPMs	Quad 100 μm RF 100μm Cathode 100 μm Cathode 0 μrad Solenoid 100 μm Gun phase 10deg Gun field 5MV Str Freq. 10K Str Phase 10deg	Cathode pitch and yaw are very sensitive						

shot-to-shot
energy jitter

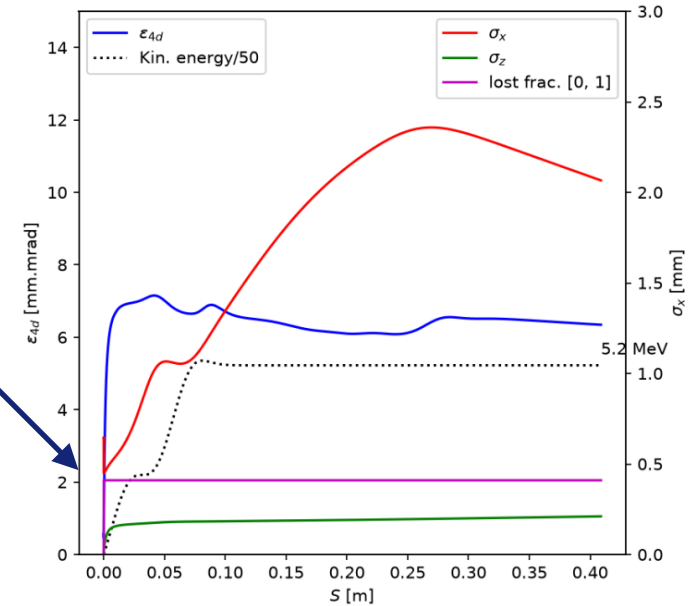
shot-to-shot
emittance jitter

CATHODE ALIGNMENT ERRORS

Quad 100 μm
 RF 100 μm
 Cathode 50 μm
 Solenoid 50 μm
 Gun phase 10deg
 Gun field 5MV
 Str Freq. 10K
 Str Phase 10deg

40% of particles lost at cathode

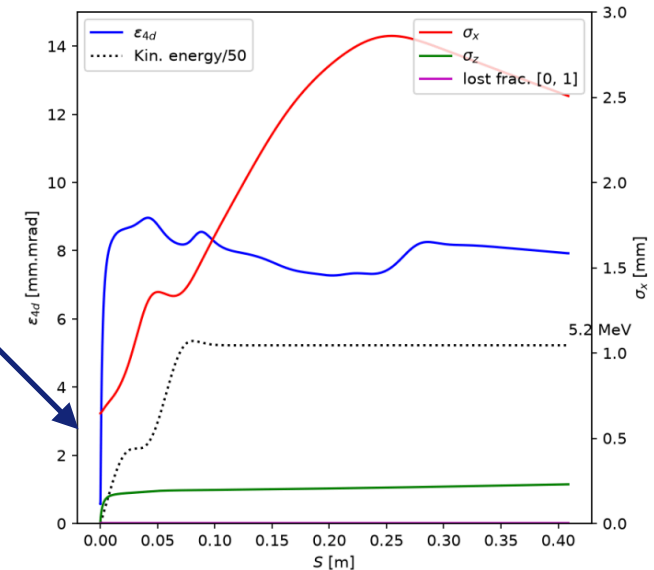
X, Y, Yaw (μrad), Pitch (μrad)



Quad 100 μm
 RF 100 μm
 Cathode 0 μm
 Solenoid 100 μm
 Gun phase 10deg
 Gun field 5MV
 Str Freq. 10K
 Str Phase 10deg

0% of particles lost at cathode

X, Y, Yaw (μrad), Pitch (μrad)

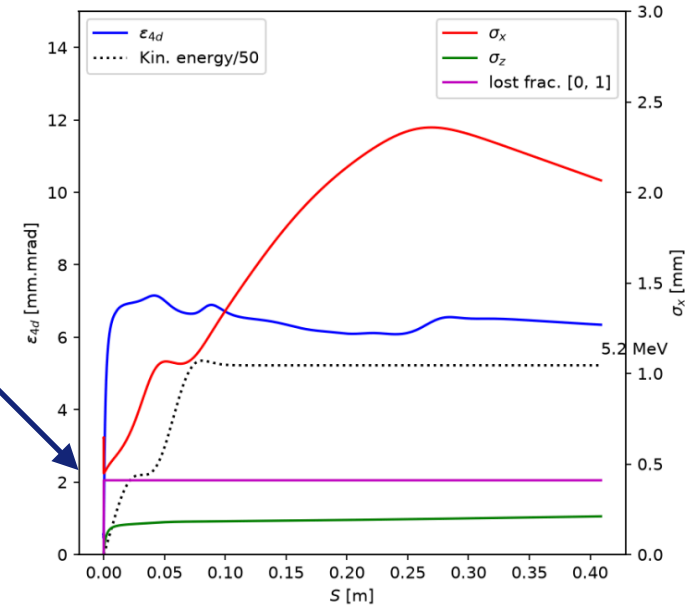


CATHODE ALIGNMENT ERRORS

Quad 100 μm
 RF 100 μm
 Cathode 50 μm
 Solenoid 50 μm
 Gun phase 10deg
 Gun field 5MV
 Str Freq. 10K
 Str Phase 10deg

40% of particles lost at cathode

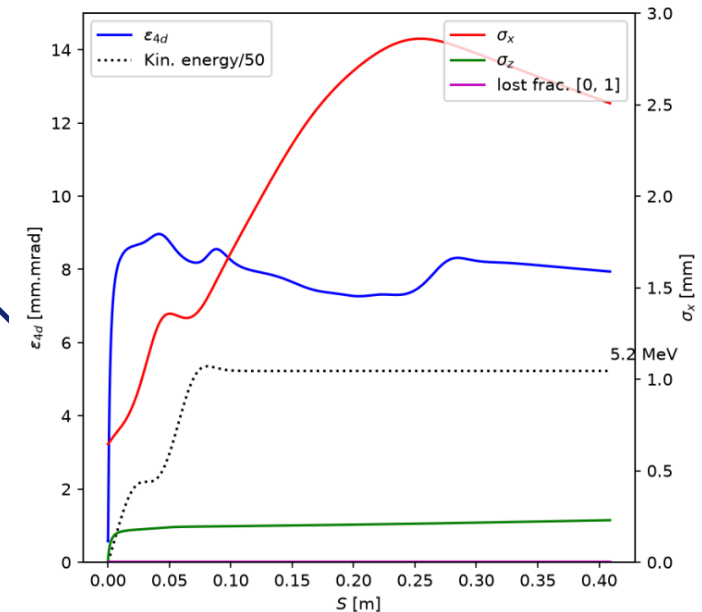
X, Y, Yaw (μrad), Pitch (μrad)



Quad 100 μm
 RF 100 μm
 Cathode 50 μm
 Solenoid 50 μm
 Gun phase 10deg
 Gun field 5MV
 Str Freq. 10K
 Str Phase 10deg

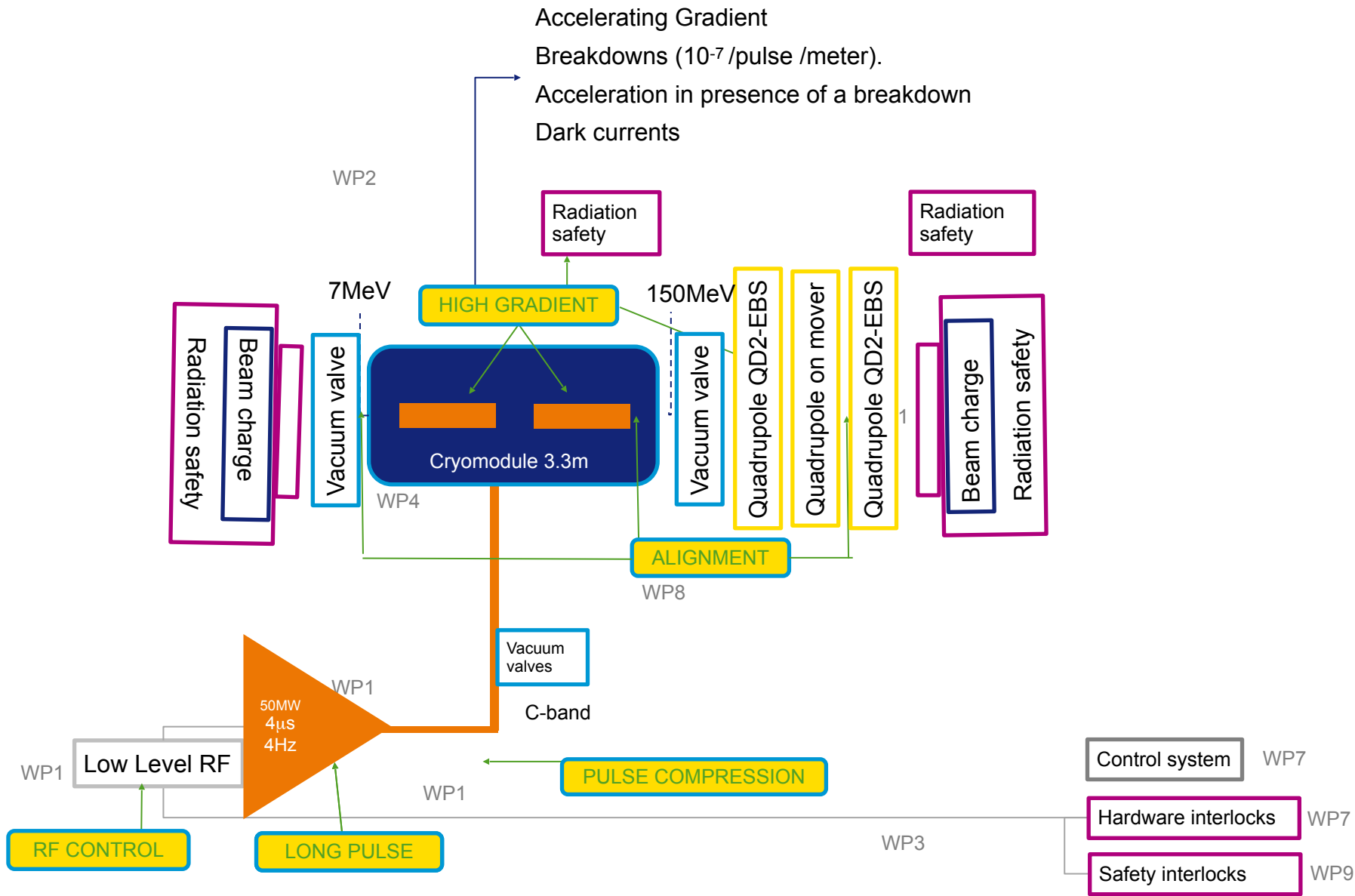
0% of particles lost at cathode

X, Y, Yaw (μrad), Pitch (μrad)

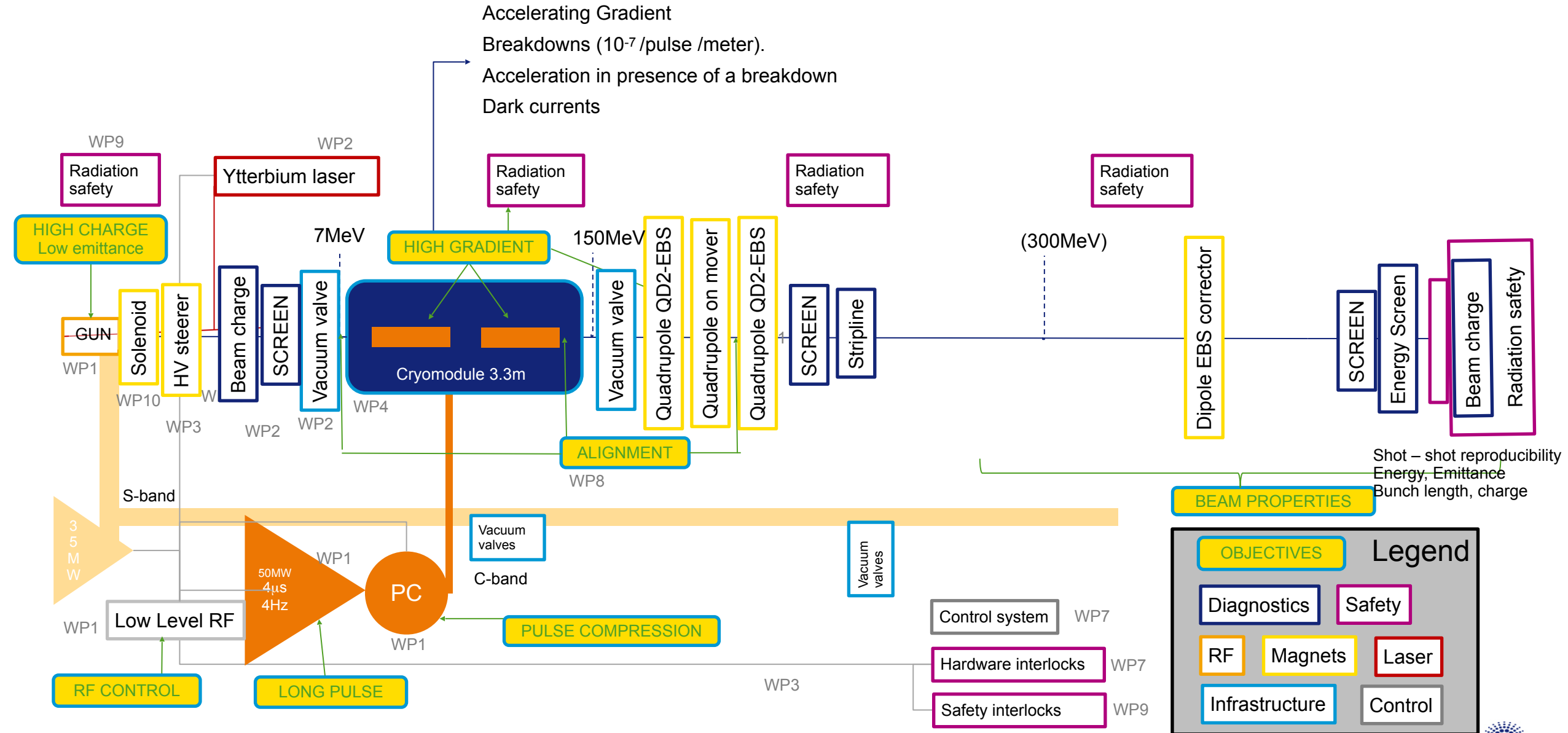


Cathode Yaw and Pitch errors are beam killers.

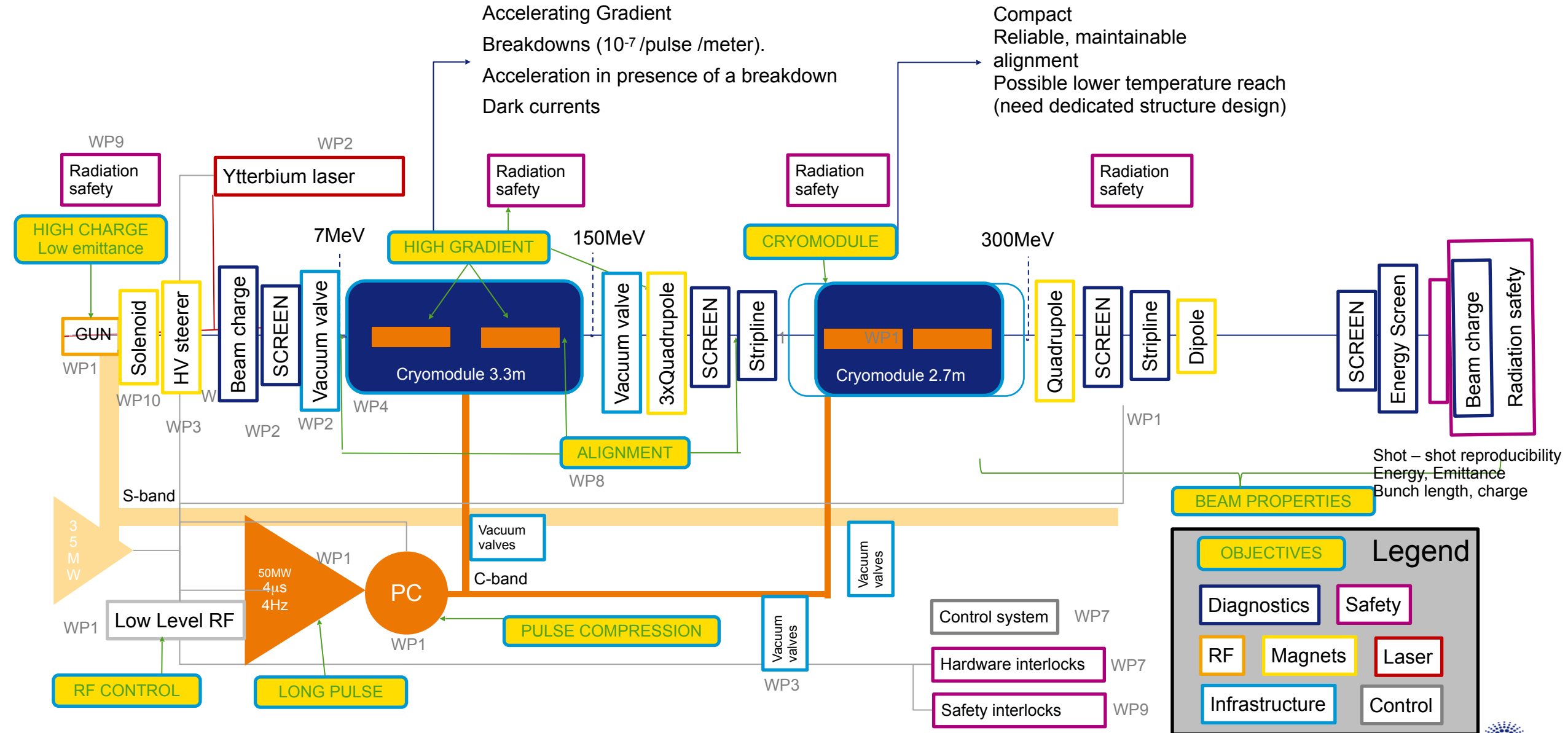
C-BAND LINAC ~150-300 MEV PRE-INJECTOR: PHASE 0



C-BAND LINAC ~150-300 MEV PRE-INJECTOR: PHASE 1



C-BAND LINAC ~150-300 MEV PRE-INJECTOR: PHASE 2



solenoid alignment tolerances

Jitter energia shot-to-shot

Starting position of beam at gun

Phase errors in the structures (structure by structure)

Phase errors cell by cell in the structures

Quadrupole and RF structures alignment: $X = 100 \text{ } \mu\text{m}$, $Y = 100 \text{ } \mu\text{m}$, $Z = 1 \text{ mm}$

Break down scenarios

Beam variations with Frequency changes induced by temperature change. LN2 temperature is $\pm 2\text{K}$.

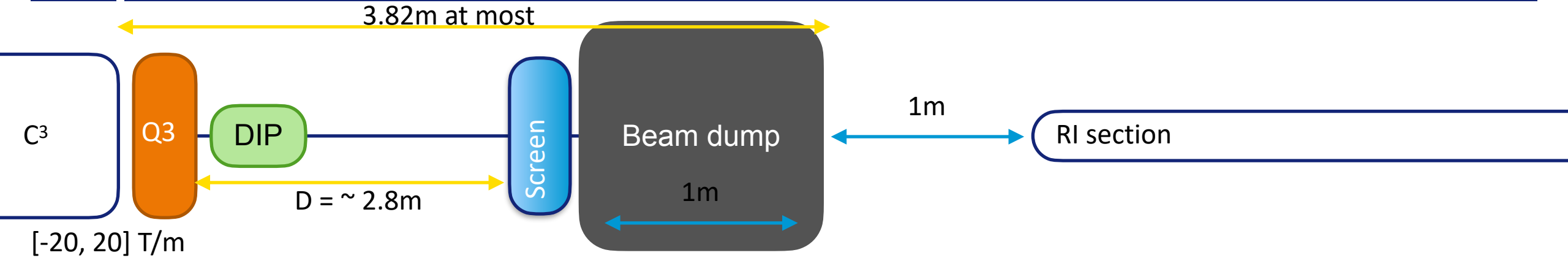
Check:

Emittance blow-up

Impact on energy/bunch length measurement

Trajectory along linac

POSSIBLE LINEAR LAYOUT FOR DIAGNOSTIC SECTION FOR ENERGY OR EMITTANCE MEASUREMENT



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: ?

LLRF JITTER 100FS → 0.2 DEGREES IN PHASE

$1/5.712e9$ (1 period) /360 (dt for 1 degree phase) = 0.5 ps for 1 degree phase error

100 fs == 0.2 degrees phase error

Solenoid alignment 20um rms. Above RF-Track fails.

Transverse and longitudinal quad and RF alignment errors: up to 300um / 300um / 1mm (FOR COLD only, much tighter for 6GeV linac, simulations will be performed in the framework of the PhD thesis of B.Tommasini)

Gradient errors of **1 / 135 MV lead** to significant (but sustainable) **Energy Jitter (5/300MeV)**

Simulations including all errors (no correction) show reasonable parameter variation at the end of the COLD linac.

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

