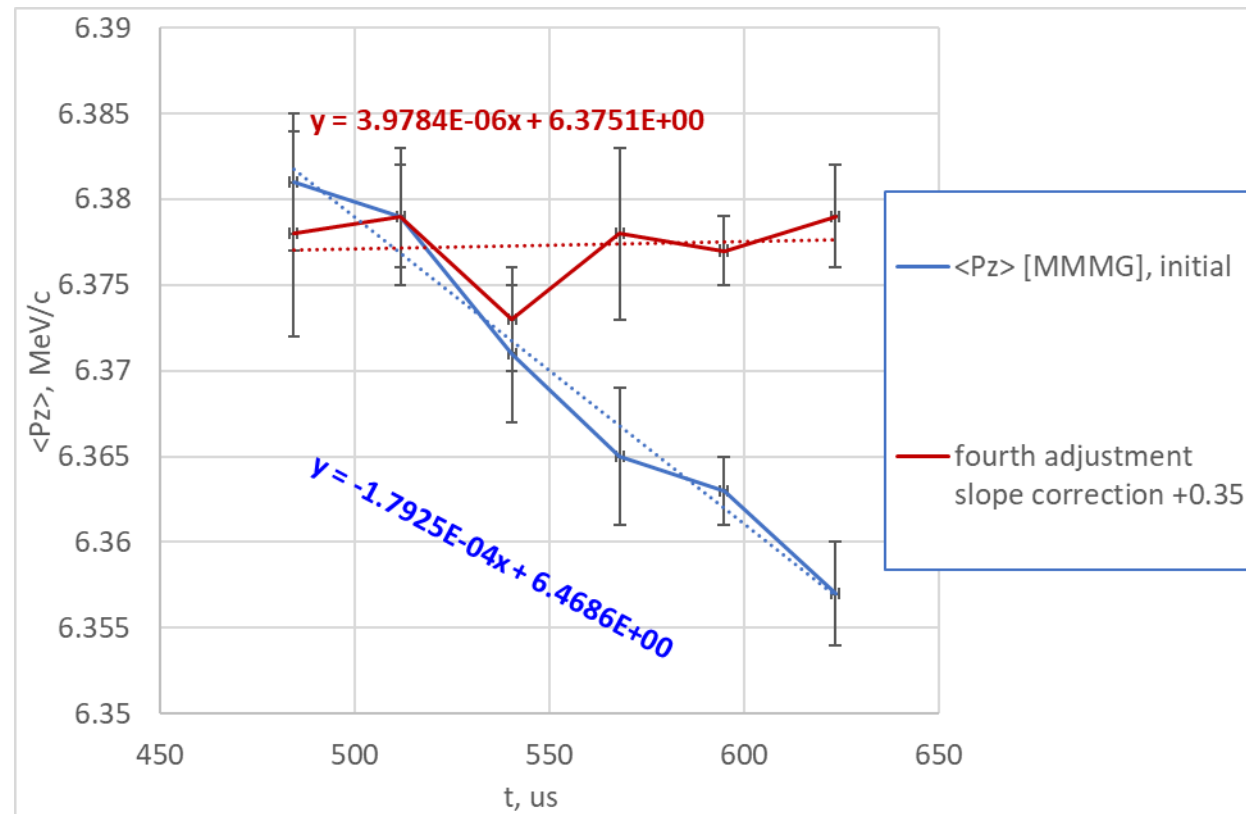


Beam energy slope at PITZ: correction studies

M. Krasilnikov, H. Qian, T. Weilbach,
S. Pfeifer, M. Hoffmann,
W. Koehler, L. Jachmann

10.06.2021

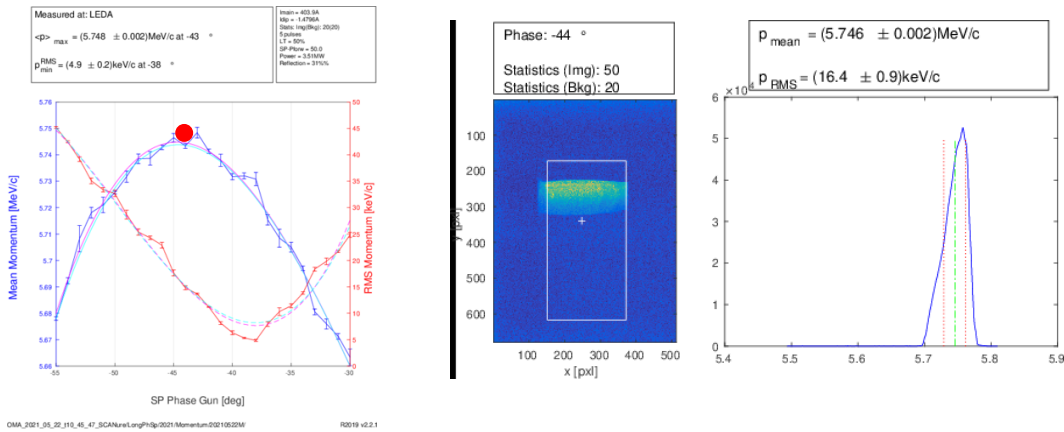


<PZ> within RF pulse, SP=50, BSA=1mm, ~280pC

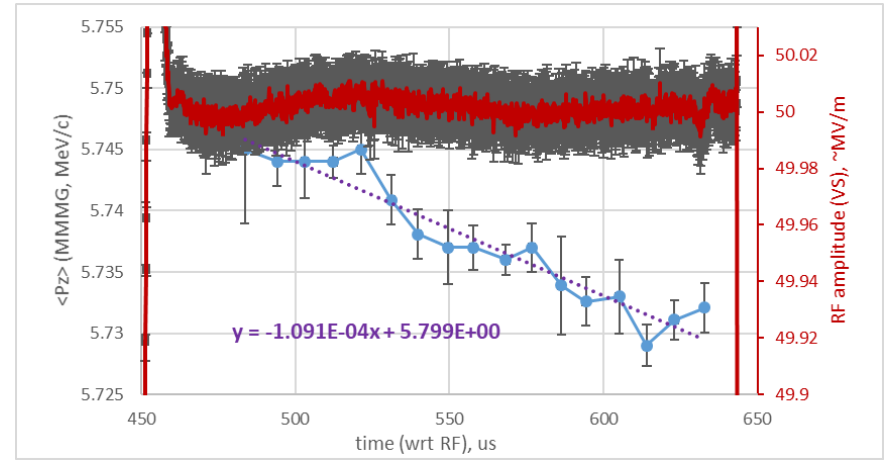
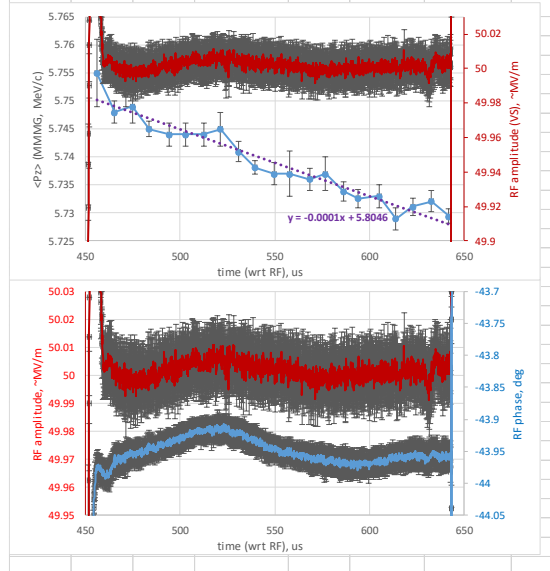
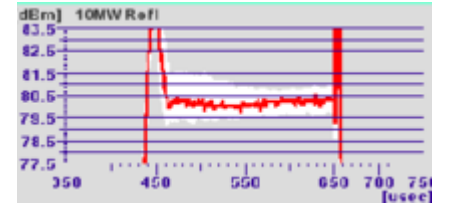
Measurements of the week 20 (21.05.2021M)

• MMMG phase, 5pulses

A3 event	1st pulse	<Pz>(MMMMG)	errPZ	PZrms	errPZrms	
1446408	455.8	5.755	0.006	15	1.1	
1447408	465.3	5.748	0.002	14.4	0.2	
1448408	474.8	5.749	0.003	13	1.1	
nominal	1449408	483.6	5.745	0.0013	15.4	0.4
1450408	494.1	5.744	0.002	14.8	0.3	
1451408	503.1	5.744	0.002	14.4	0.9	
1452408	512.4	5.744	0.002	15.8	0.2	
1453408	521.4	5.745	0.003	15.8	0.4	
1454408	531.1	5.7409	0.0018	16.23	0.11	
1455408	539.8	5.7381	0.0012	14.7	0.6	
1456408	549.6	5.737	0.002	16.4	0.7	
1457408	557.8	5.737	0.004	16.6	0.4	
1458408	568.4	5.736	0.002	17.2	0.4	
1459408	576.8	5.737	0.003	16.7	0.3	
1460408	586.4	5.7339	0.0017	15.7	0.7	
1461408	594.3	5.7326	0.0016	16.1	0.7	
1462408	605.1	5.733	0.002	15.2	0.8	
1463408	614.1	5.729	0.002	16.6	0.2	
1464408	623.1	5.7311	0.0016	15.5	0.6	
1465408	632.9	5.7321	0.0019	15.9	0.3	
1466408	642.1	5.7294	0.0013	17.6	0.13	



rf2c10mw_MC.xml PITz	
RF2C10MW	code 0
no pulse	
forward	3.64 MW
reflected	0.11 MW
power	3.53 MW
gradient	44.336 MV/m
slope	-2.057 dB/mns
reflecti...	29.9 %

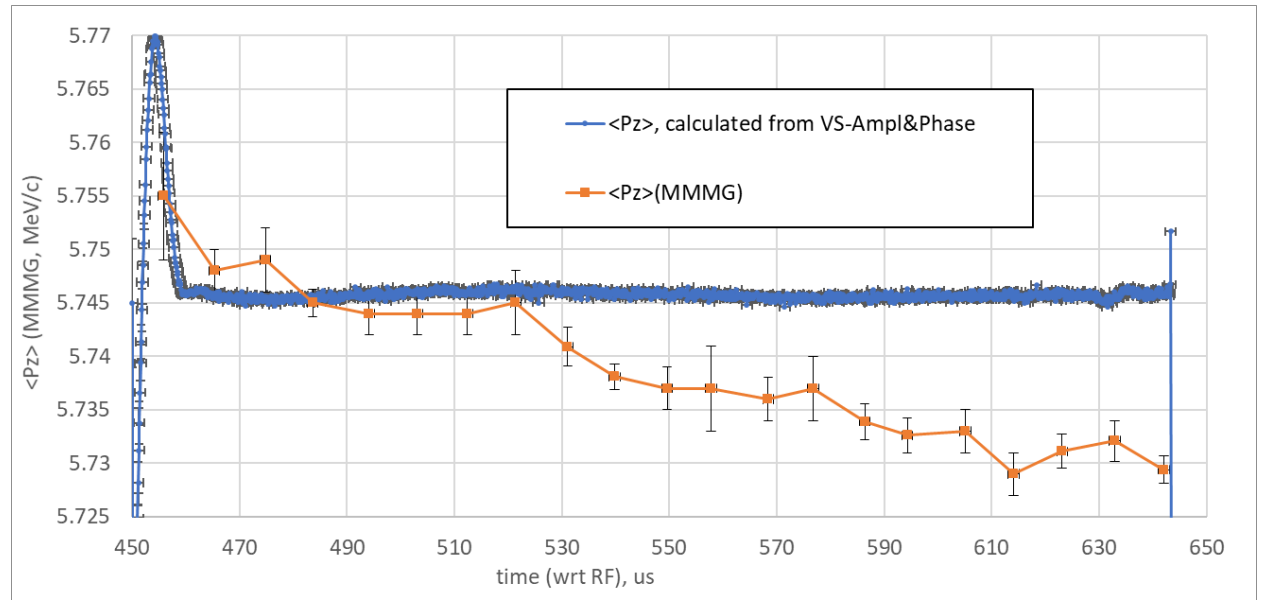
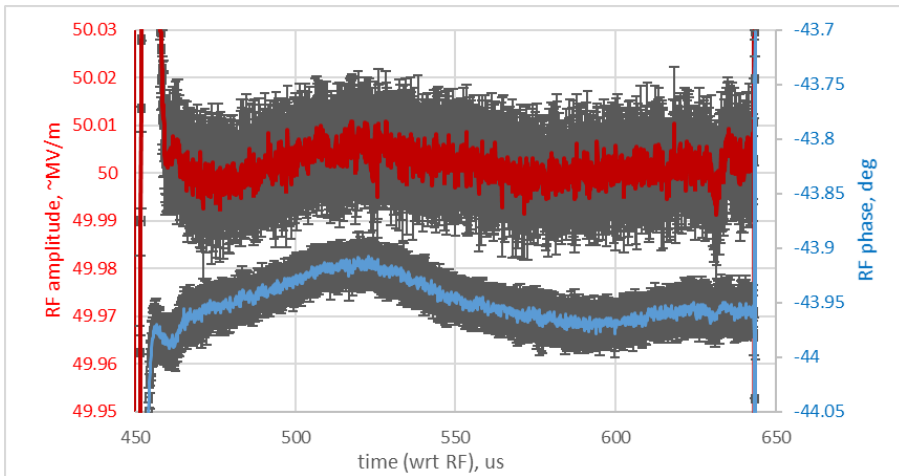
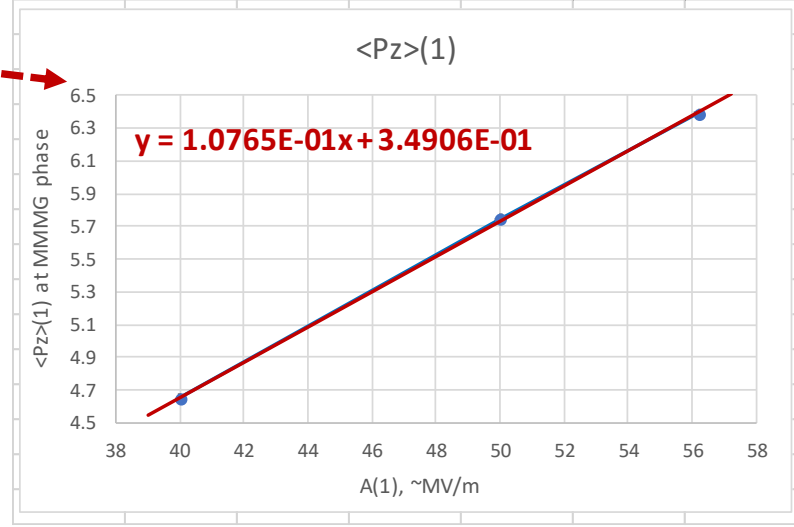
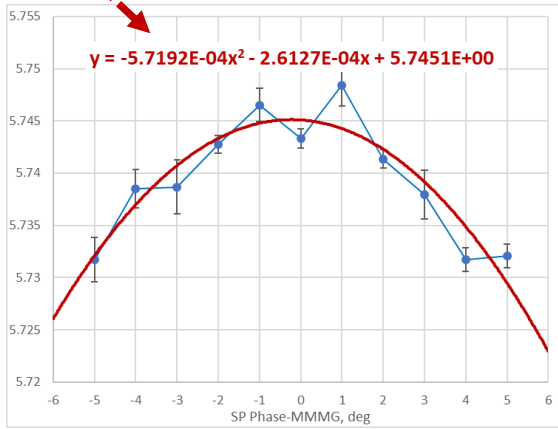


SP=50 Analysis

Measurements of the week 20 (21.05.2021M)

Phase scan at LEDA and $\langle Pz \rangle$ vs. SPAmpl

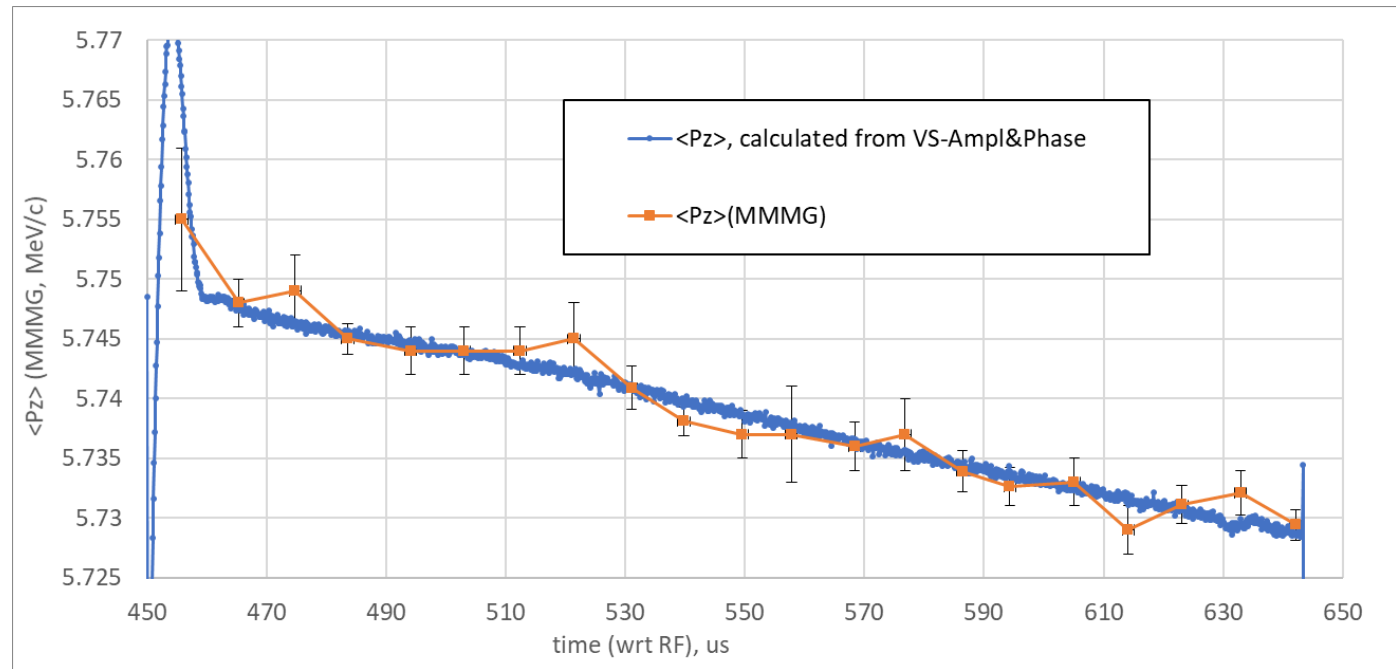
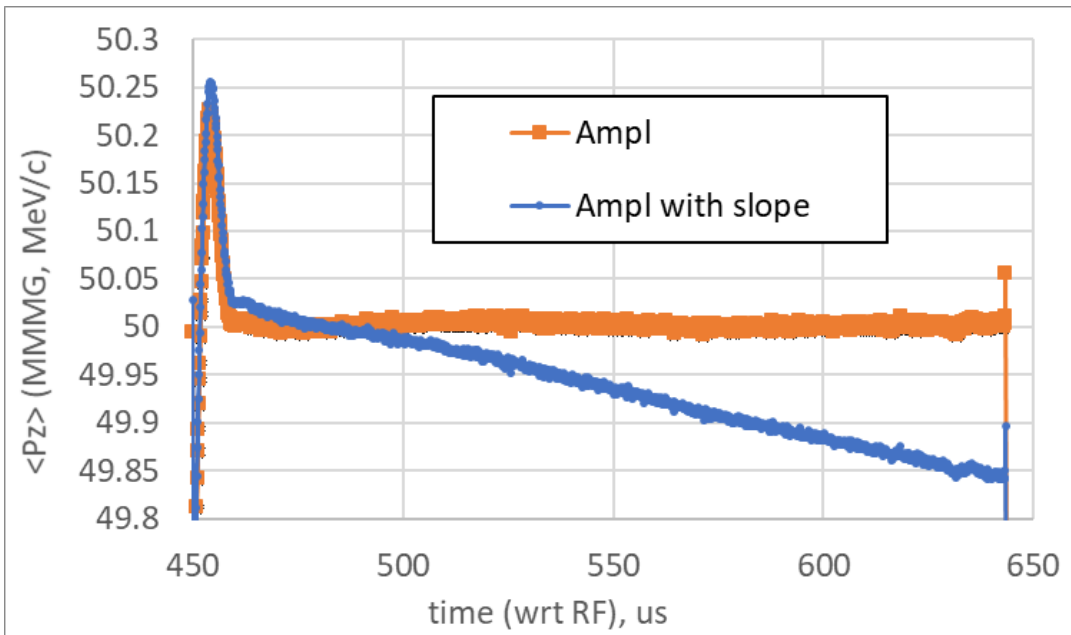
SPA	A(1)	errA(1)	Phase(1)	errPhase1	$\langle Pz \rangle(1)$	err $\langle Pz \rangle(1)$
40	39.99121	0.00904	-36.9712	0.01811	4.649	0.0013
50	49.99478	0.0101	-43.9406	0.017267	5.745	0.0013
56.2	56.20264	0.014066	-44.9427	0.016339	6.391	0.003



SP=50, + Amplitude slope

Artificial Amplitude slope to reproduce $\langle Pz \rangle(t)$

$$\text{slope} = -0.001 \frac{\text{MV/m}}{\mu\text{s}}$$



Beam energy slope correction with amplitude slope

09.06.2021M (TW, MK)

How to introduce Amplitude/Phase slope

The image displays a complex control interface for an LLRF system. It includes several key components:

- gun_shift_window.xml**: A control panel for the PITZ GUN with sections for SET POINT (Amplitude: 56.30 MV, Phase: -38.00 deg), PULSE TIMING (Filling: 30, Raising: 15, Flattop: 185, Falling: 1), FEEDBACK (Output Vector Corr, Fast Feedback, Feedforward Corr), and Output Scaling (Scale: 0.98, Phase: -102.10). It also shows status indicators for ADC/limiter, LFF, and ORC.
- Amplitude and Phase Plots**: Two graphs showing the beam's amplitude (MV/m) and phase (deg) over time (test). The amplitude plot shows a step increase from ~55.5 to ~56.5 MV/m, and the phase plot shows a corresponding step change from ~-45 to ~-48 degrees.
- LLRF Setpoint Params**: A window showing Setpoint Tables and Hardware RBV plots, both displaying a step function over 1600 test units.
- Setpoint Control**: A control panel with checkboxes for Feedforward, SP Corr Enable, and SP Smoothing Enable. It features Setpoint Value controls (A: 5.00 MV/m, P: -49.00 deg) and Slope Corr controls (A: ±0.35, P: ±0.00).
- Slope Corr Panel**: A detailed view of the slope correction controls, showing the A and P slope correction values (±0.35 and ±0.00) with green 'H' buttons.
- Feed Forward + Learning FF**: A panel with checkboxes for Feed Forward On, Correction Tables, and I FF Enable. It includes an Output Vector Correction table with columns for A, P, and Ratio.
- Feedback**: A panel with checkboxes for FR, MIMO, and Output limiter (Enable). It also includes Pulse settings (Delay, Filling, Hattp) and a Pulse OK? indicator.
- Virtual Probe**: A panel with buttons for I Analyzer, Info, Timing, Ref, ADC 3, ADC 4, VM, Pulse, SmPred, VP CAL, and Step Corr.
- System Status**: A bottom section showing Watchdog (LLRF RF Z (Gun)), System (xZlimer, llrctrl), and a button for RPC test.

Beam energy slope correction with amplitude slope

09.06.2021M (TW, MK)

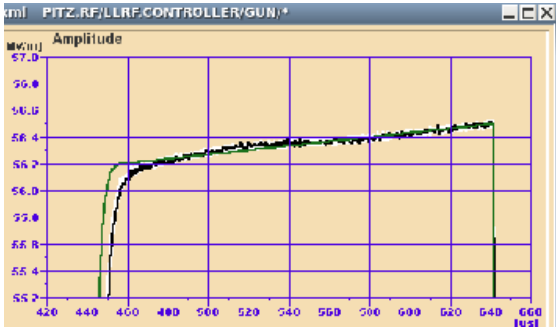
How to introduce Amplitude/Phase slope

The image displays a complex control interface for an LLRF system. It includes several key components:

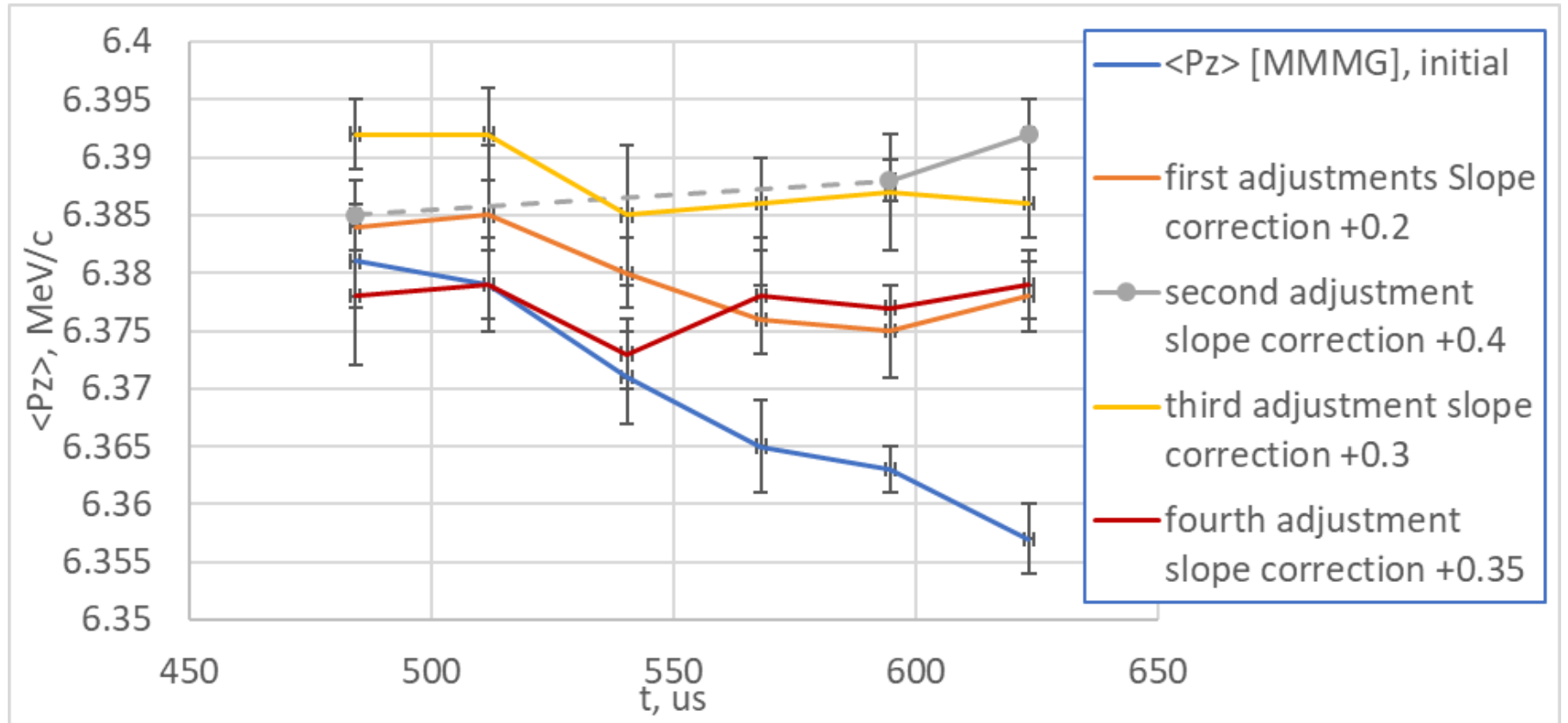
- SET POINT (PITZ GUN):** Parameters for Amplitude (56.30 MV), Phase (-38.00 deg), and various feedback options like Output Vector Corr and Feedforward.
- Amplitude and Phase Plots:** Two graphs showing the beam's response over time (420-660 test). The Amplitude plot shows a step increase from ~55.5 MV to ~56.5 MV. The Phase plot shows a step change from ~-48.0 deg to ~-49.0 deg.
- LLRF Setpoint Params:** A window with two graphs: 'Setpoint Tables' and 'Hardware RBV', both showing a step function. Below these are control parameters for Setpoint Value (A: 5.00 MV/m, P: 49.00 deg) and Slope Corr (±0.35 and ±0.00).
- Slope Corr Panel:** A detailed view of the slope correction parameters, showing two rows of controls with values ±0.35 and ±0.00, each with an 'H' button.
- Feedback and Output Scaling:** Panels for Feed Forward + Learning FF, Feedback (MIMO), and Output Vector Correction.
- System Status:** Bottom panels showing Watchdog (LLRF RF Z (Gun)), System (xZlimer, llrfctrl), and various diagnostic buttons like 'RPC test' and 'Overview'.

Beam energy slope correction with amplitude slope (SP=56.2)

09.06.2021M (TW, MK)



Slope=0.35 over
185us RF flattop

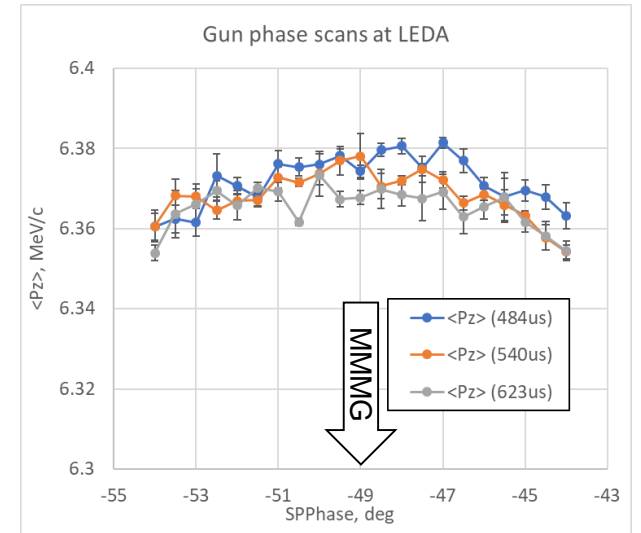
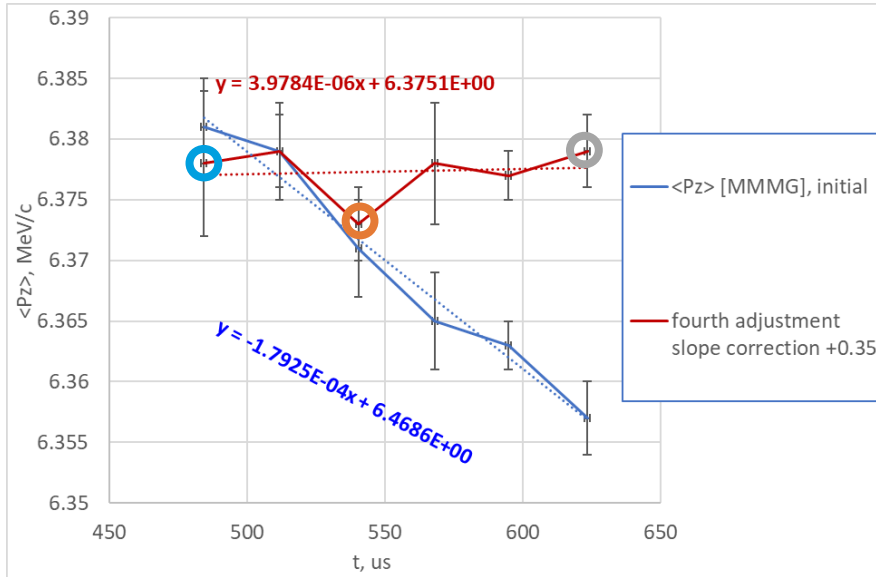


Beam energy slope correction with amplitude slope (SP=56.2)

09.06.2021M (TW, MK)

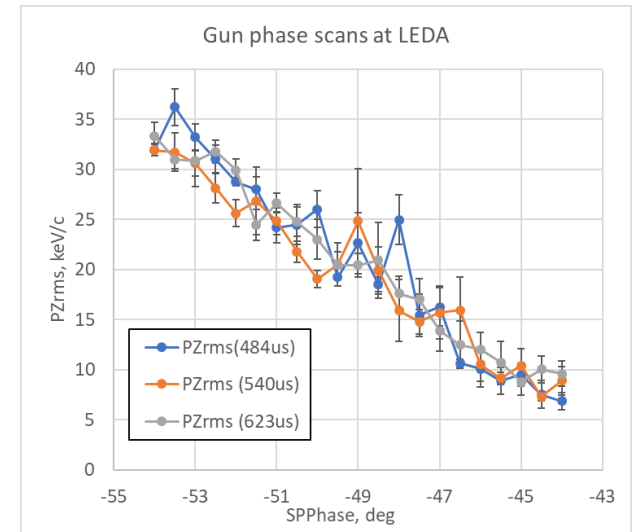
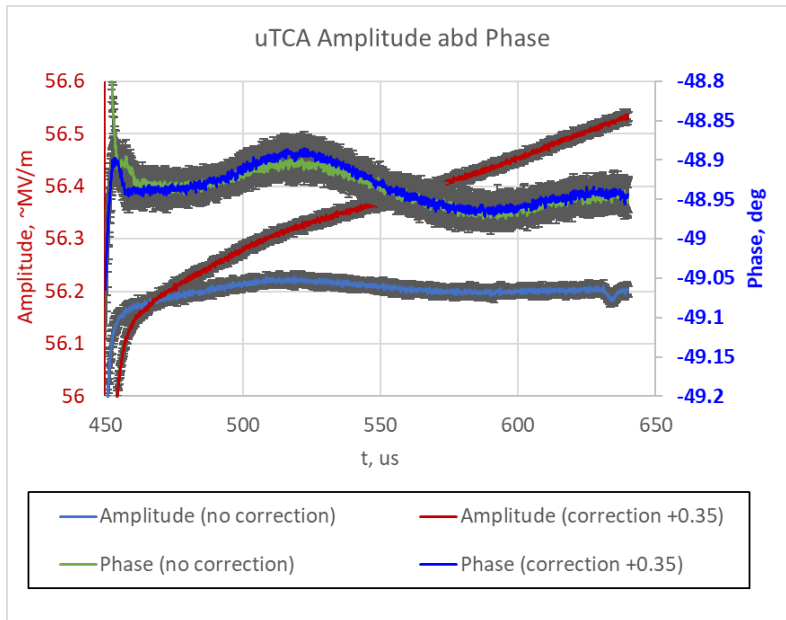
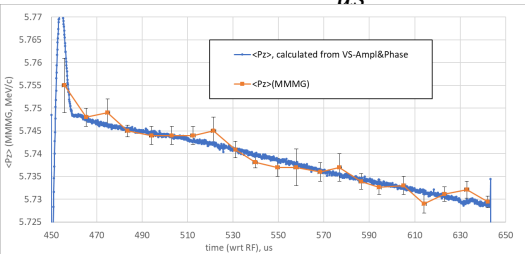
used

$$\text{slope} = \frac{0.35}{185} = 0.00189 \frac{\text{MV/m}}{\mu\text{s}}$$



NB: Estimated for SP=50

$$\text{slope} = -0.001 \frac{\text{MV/m}}{\mu\text{s}}$$



Summary

Beam energy slope correction

- Electron beam energy slope along the RF gun pulse has been observed for the nominal settings at PITZ
 - LEDA measurements by scan A3 (laser)
 - Slopes $\sim -3 \cdot 10^{-5} \frac{d \log \langle P_z \rangle}{dt}$ are well measurable at e.g. MMMG phase
 - Cannot be explained by measured amplitude/phase profiles (very flat)
- The $\langle P_z \rangle$ slope can be compensated by introducing a positive amplitude slope
 - For SP=56.2 the slope -0.35 over 185 μs flattop RF pulse ($0.0019 \frac{\text{MV}/\text{m}}{\mu\text{s}}$)
→ the momentum slope $\sim +6 \cdot 10^{-7} \frac{d \log \langle P_z \rangle}{dt}$ (0 within error bars)
 - Well agreed with estimated slope $-0.001 \frac{\text{MV}/\text{m}}{\mu\text{s}}$ to explain results for SP=50
- Still it is not clear where the slope comes from (RF power coupler kick, beam loading, uTCA measurement artifact ($\beta(t)$ -?) , ...?)
- How to improve the tuning procedure:
 - Long pulse train (low charge, small BSA, e.g. Pharos 0.1 MHz) → minimize energy spread at LEDA at MMMG phase?
 - Fine tuning resonance/FB
 - ...?

Backup

Regular studies of the beam energy slope along the RF pulse

Measurement program

1. SPA=SPA0=56.2(?), Sharp gun resonance ($|\text{slope}| \sim < 5$), stabilize water (incl. valves), setup FB
2. Find first pulse location w.r.t. VS signals (uTCA) --> Ampl(1),Phase(1) (I still have some questions to the procedure, see the last slide in the attached file)
3. LEDA scan around MMMG using 1 pulse (if possible), recording VS-amplitude&phase especially at the location of the 1st pulse (found in p.2) --> $\langle Pz \rangle(\text{Ampl}(1), \text{Phase}(1))$ --> vector
4. SPA=SPA+/-0.5, repeat 1-3
5. Form a matrix $\langle Pz \rangle(\text{Ampl}(1), \text{Phase}(1))$, based on that we can plot expected $\langle Pz \rangle$ profile along the RF pulse $\langle Pz \rangle(\text{Ampl}(n), \text{Phase}(n))$ for e.g., SP0, then we can compare it with the measured $\langle Pz \rangle$ by shifting A3 event (laser).

