Simulation of booster BBA at PITZ

Progress summary and project outlook

Peetermans Karel
Zeuthen, 16/8/2022
Supervisor: Xiangkun Li

Project goals and concept of the script

04/06/2022 P. Boonpornprasert, G. Adhikari

Idea:

- Beam on-axis (on average) for optimal emittance

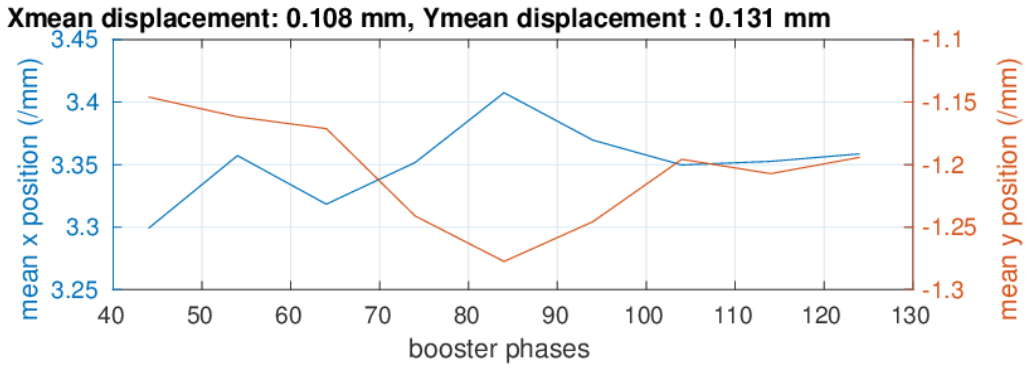
  → Tune steerers for perfect booster entry

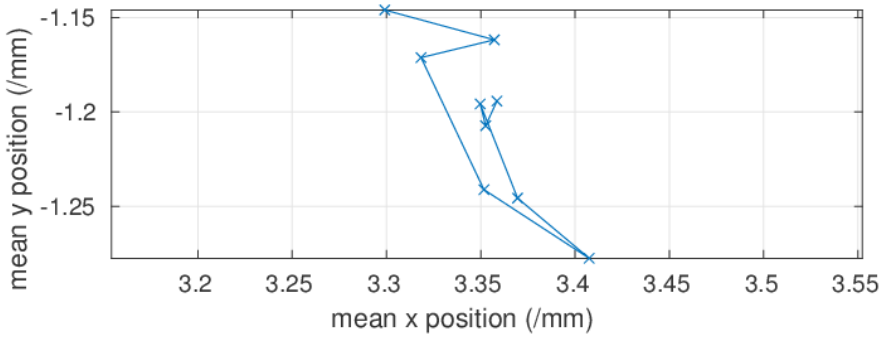
  → This is characterised by a flat booster phase-dependance (this will be our observable)

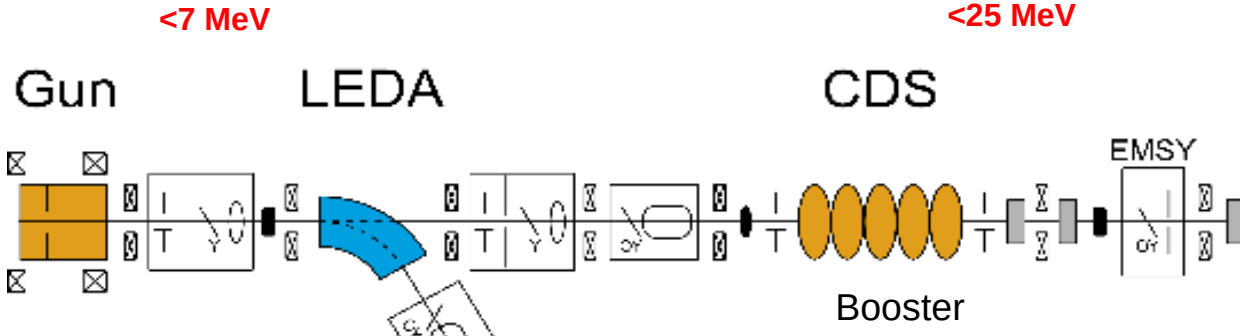
- Make situation more realistic by implementing earth mag. field and possibly other constant fields
- Better understanding of booster BBA

Method:

- Beam optics for trajectory through steerers
- Astra simulation for booster







Overview of talk

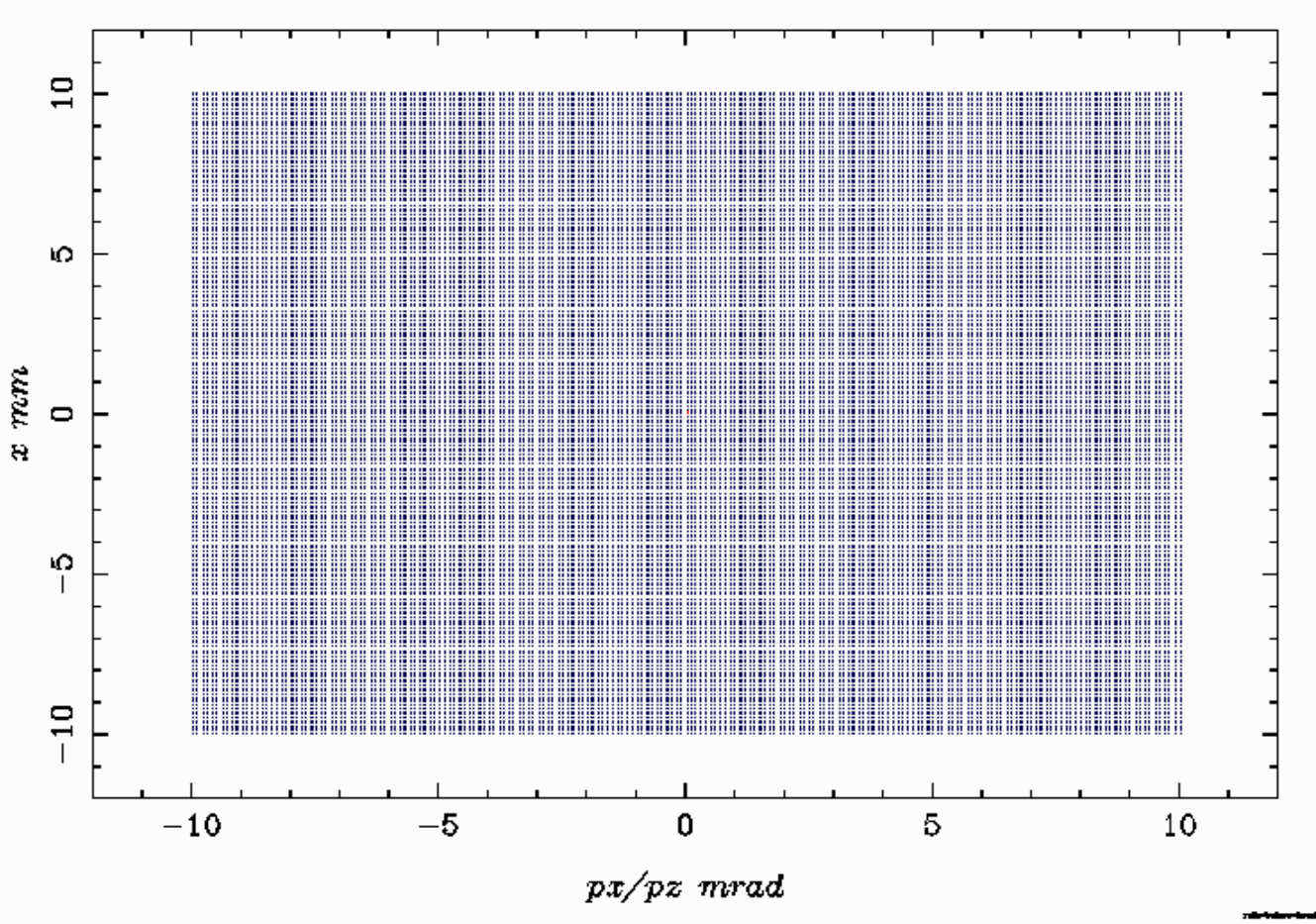
- Astra parameter scan and peak-to-peak goal function
- Backward tracking and calculating steering corrections
- Booster BBA measurements June and August 2022
- Current problems and outlook rest of project

Astra parameter scan and fitting measurement to simulation

Parameter scan

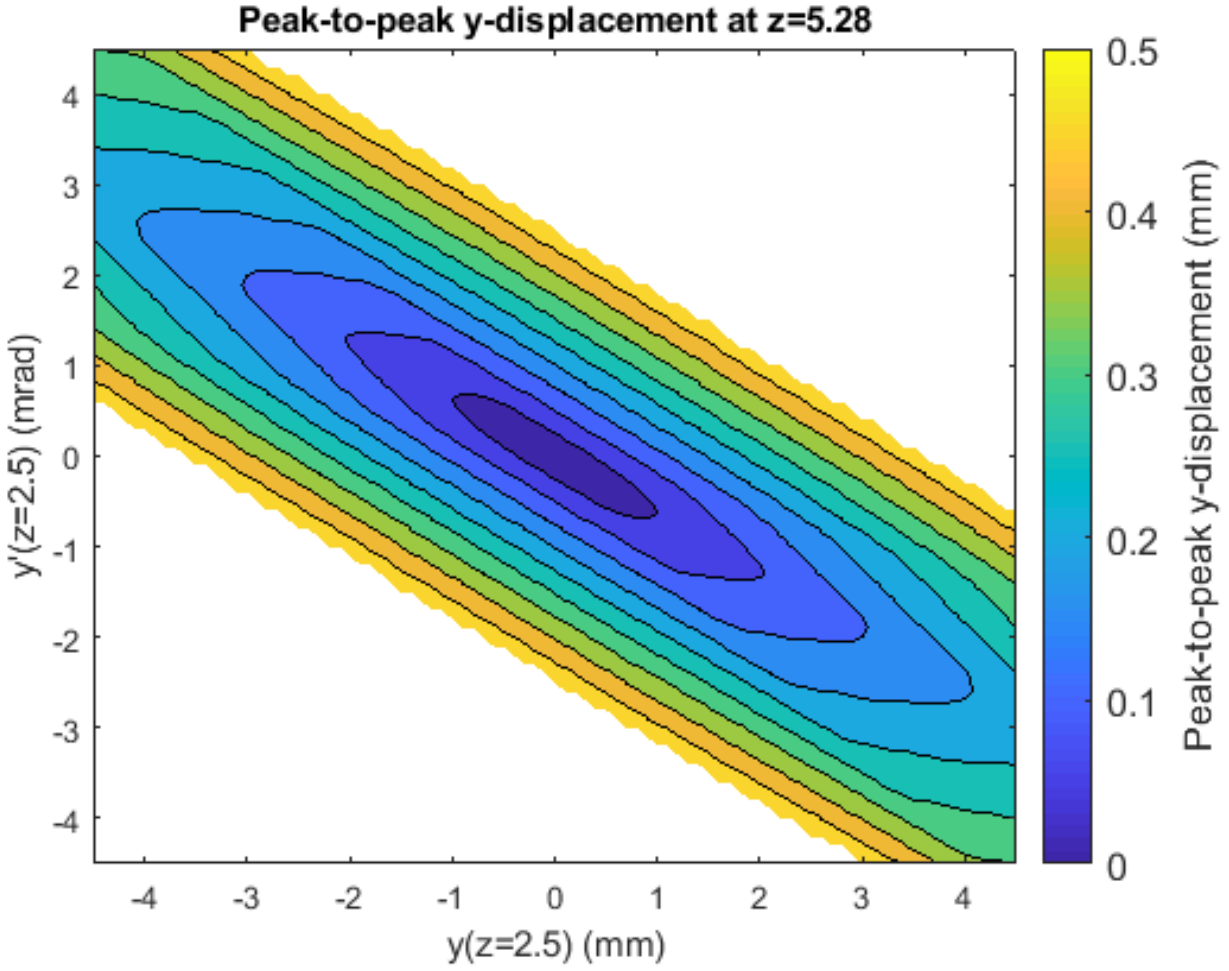
Idea:

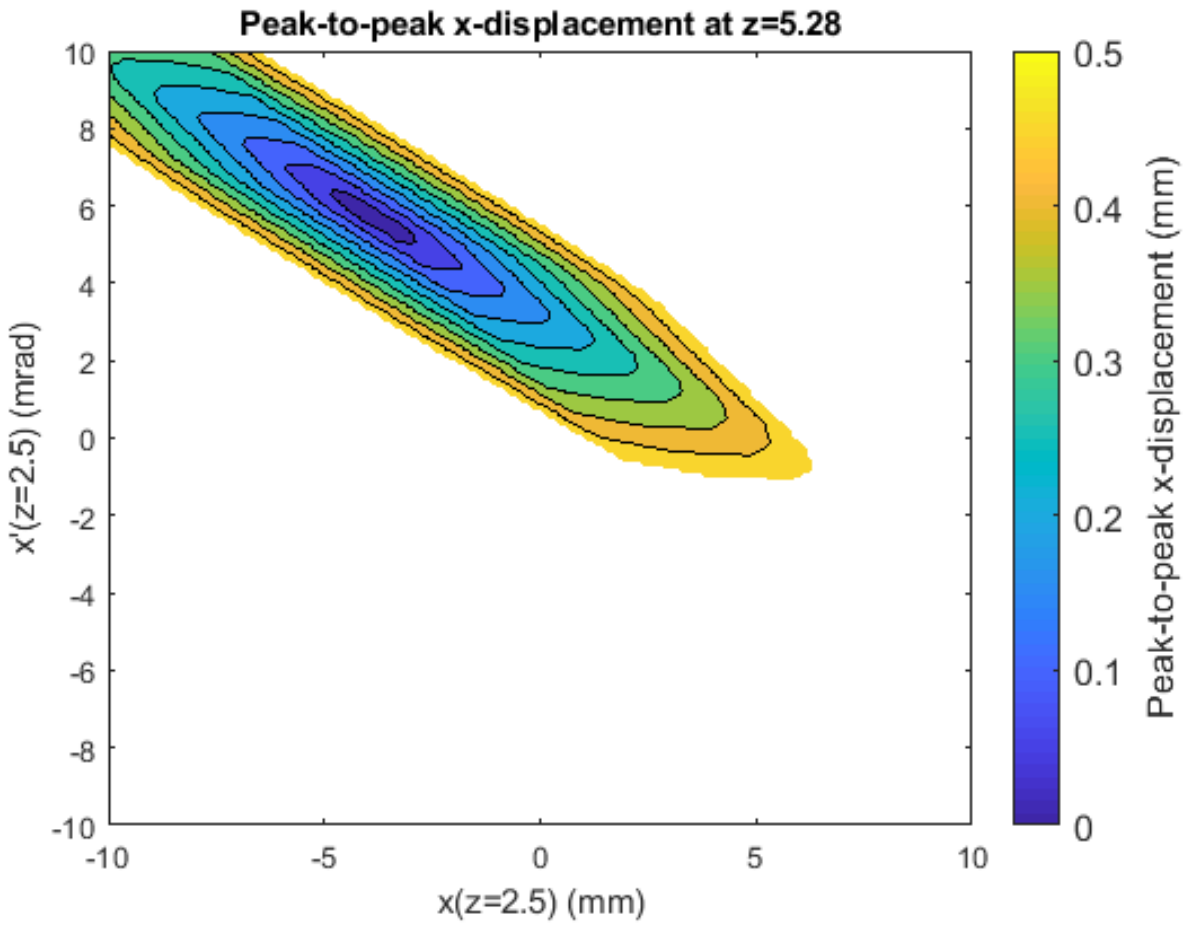
- Simulate sending macro-particles which cover full x-x' phase space through booster
- Simulate where each particle ends up, no space charge
- x_c and x_c' are the bunch center and angle; in the simulation, each particle or electron represents a bunch with a given x_c and x_c'
- Fit measured curve (x_c at EMSY1 vs booster phase) to simulated curve to know where the electron must have started
- Goal-function fit: R-sq. difference of measurement and simulated data point



Parameter scan

Peak-to-peak displacement after adding B=(0,-50,0) uT, P=6.3 MeV/c



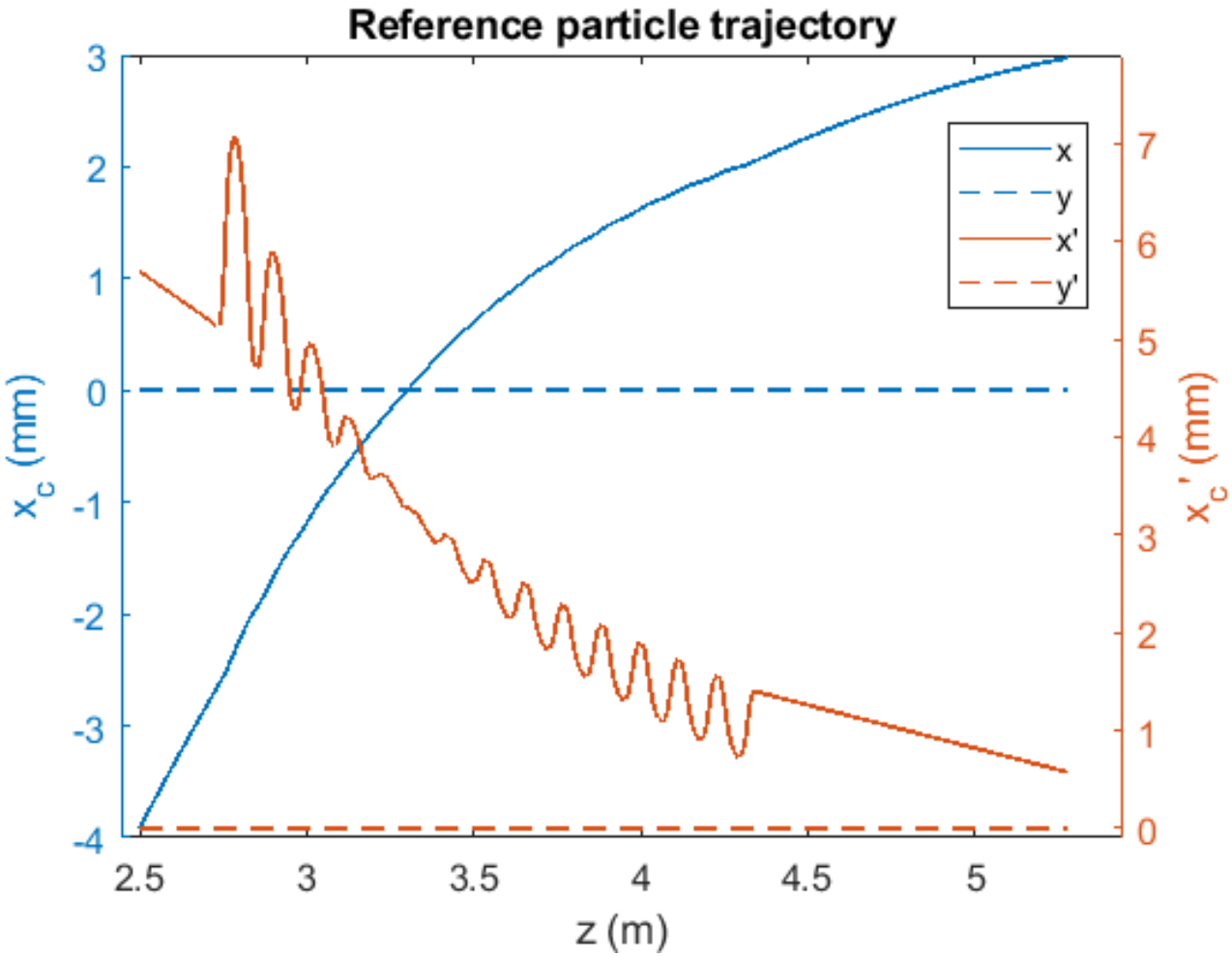


Parameter scan

Peak-to-peak displacement after adding B=(0,-50,0) uT, P=6.3 MeV/c

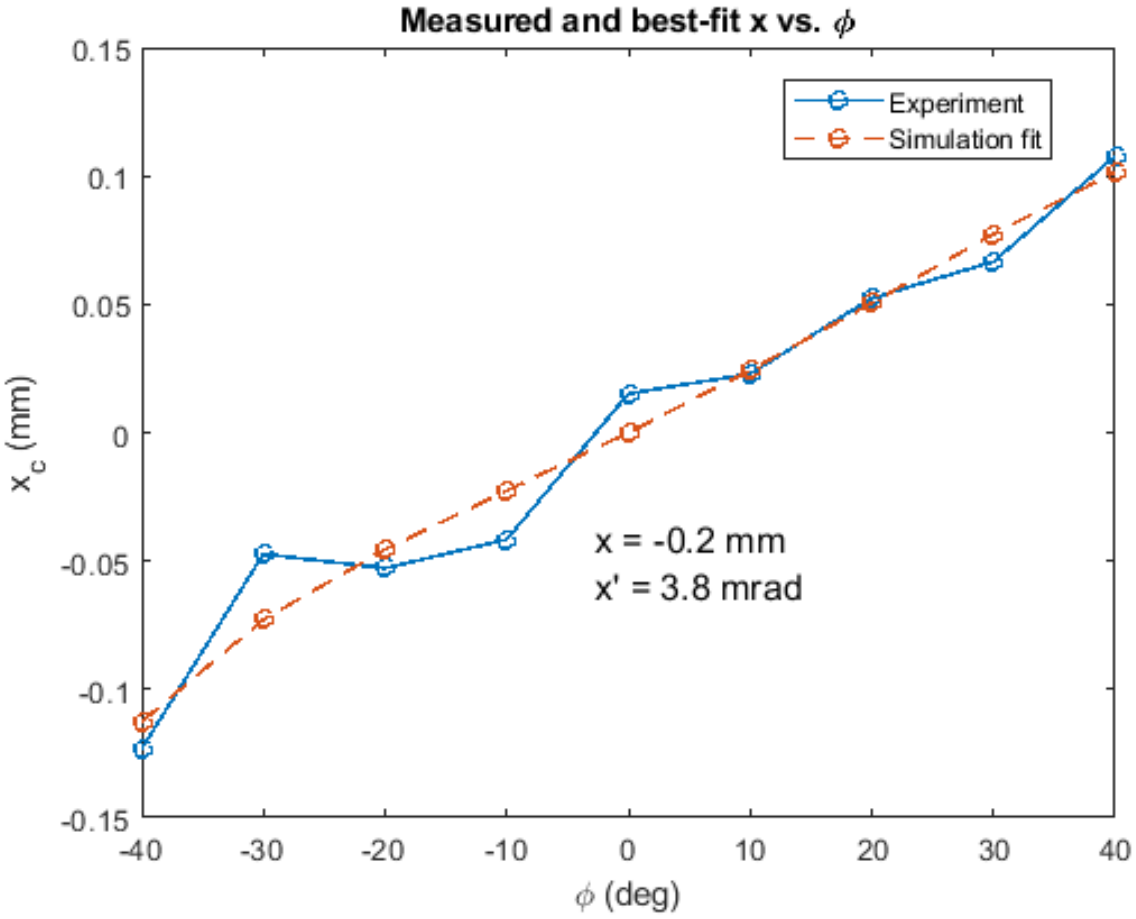
For minimal x-displacement:

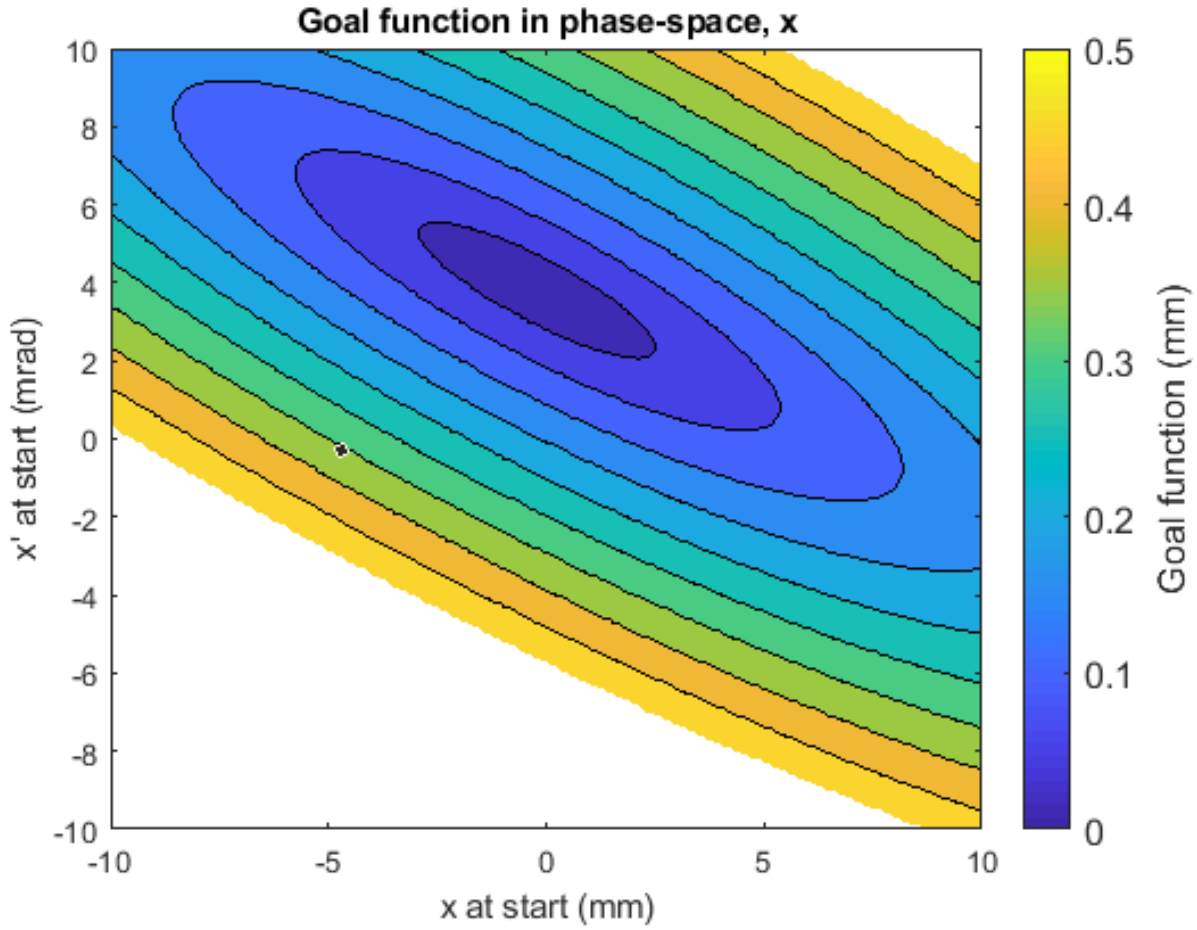
- Aim for particle to have positive angle to counteract effect of EMF
- Start with negative position so particle ends up around zero



Fitting measurement to simulation

Example of fitting measured curve (here measurement=simulation+noise)



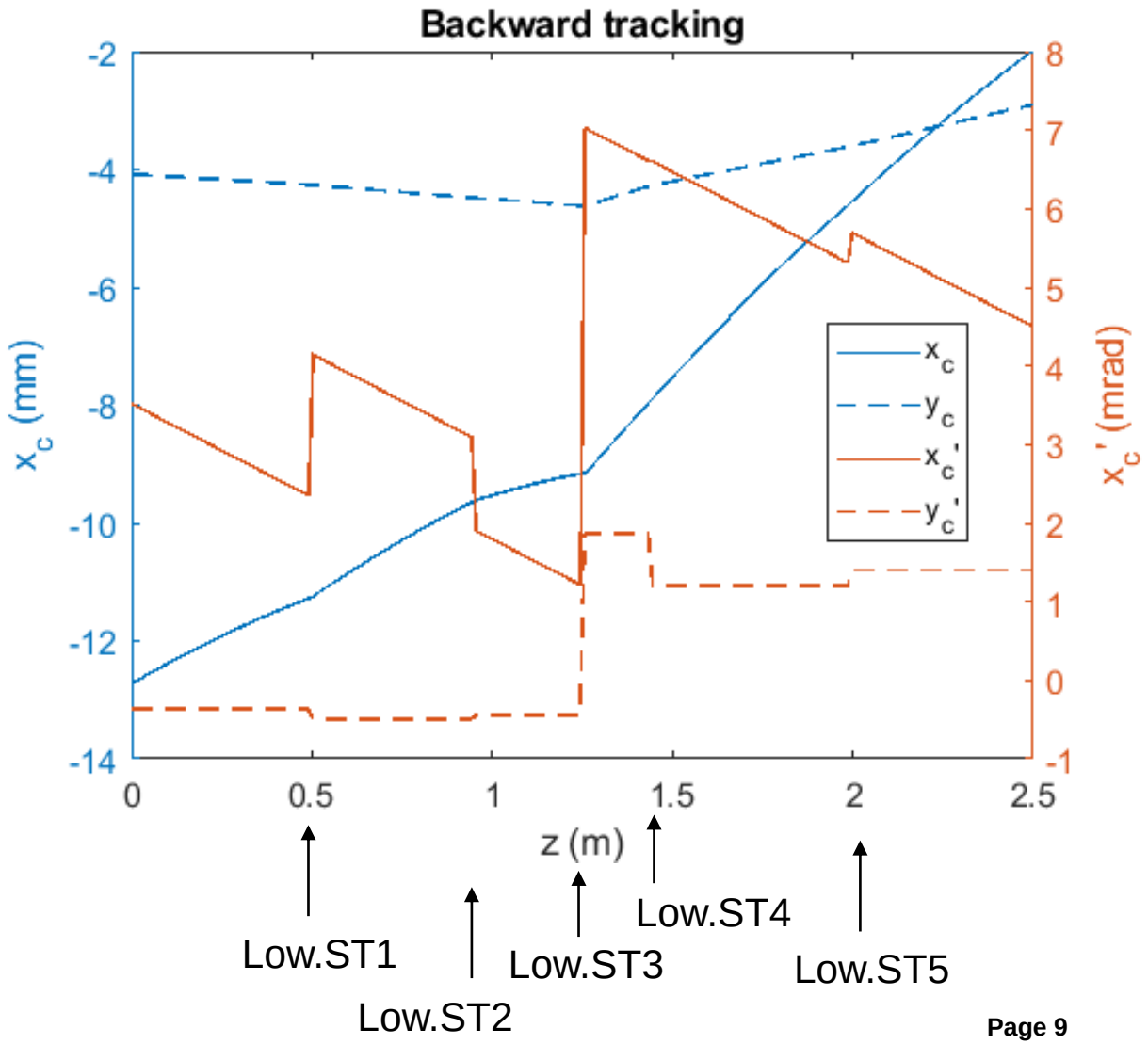


Steering

Idea:

- Now the entering angle and position is known → calculate effect of steerers
- Every steerer is assumed to be infinitesimally thin → effect is a perfect angle ‘kick’
- Backward tracking through all kicks to find coordinates at electron creation
- Include known strengths/couplings of steerers and EMF

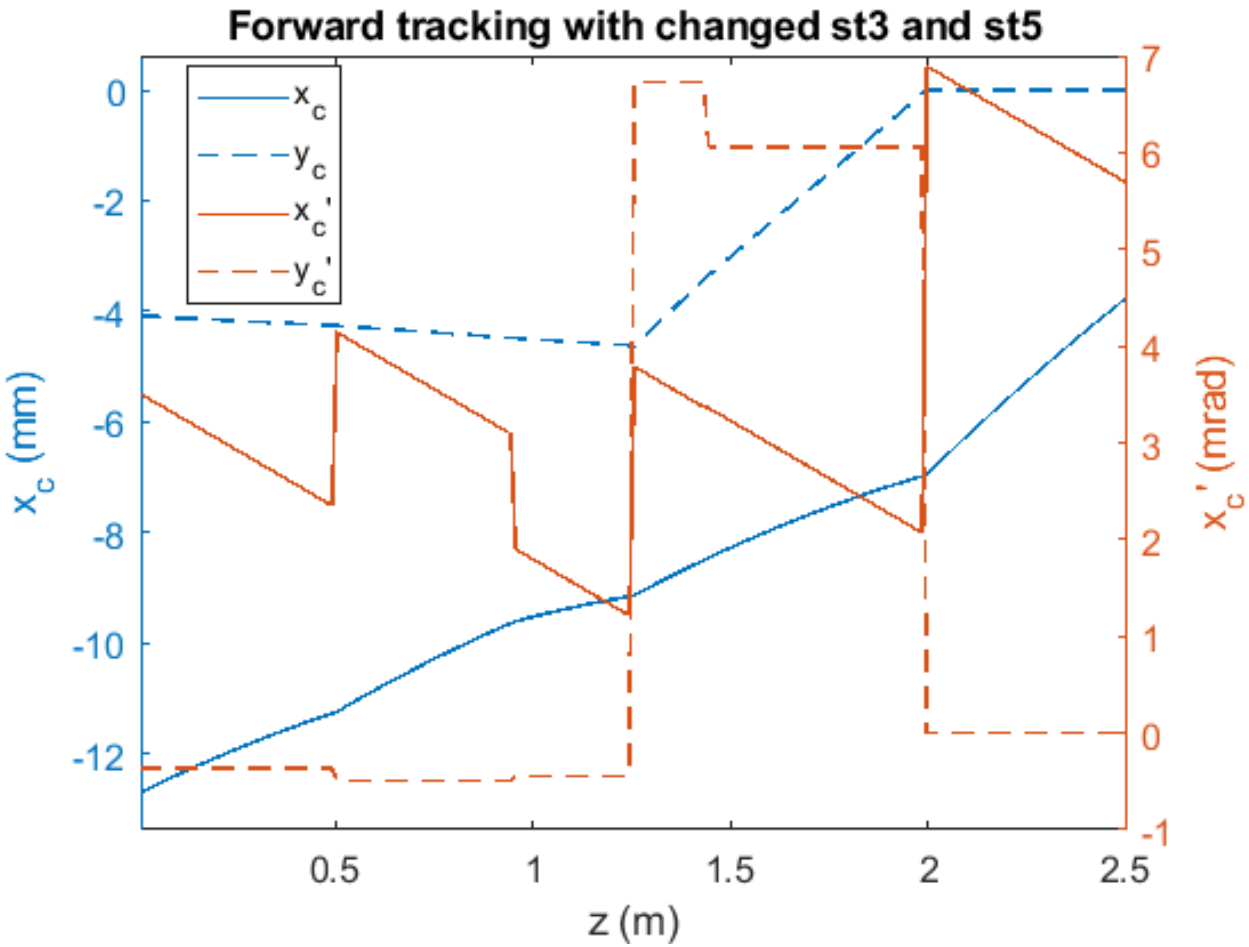
→ Change steerer currents to aim particle into optimal position/angle

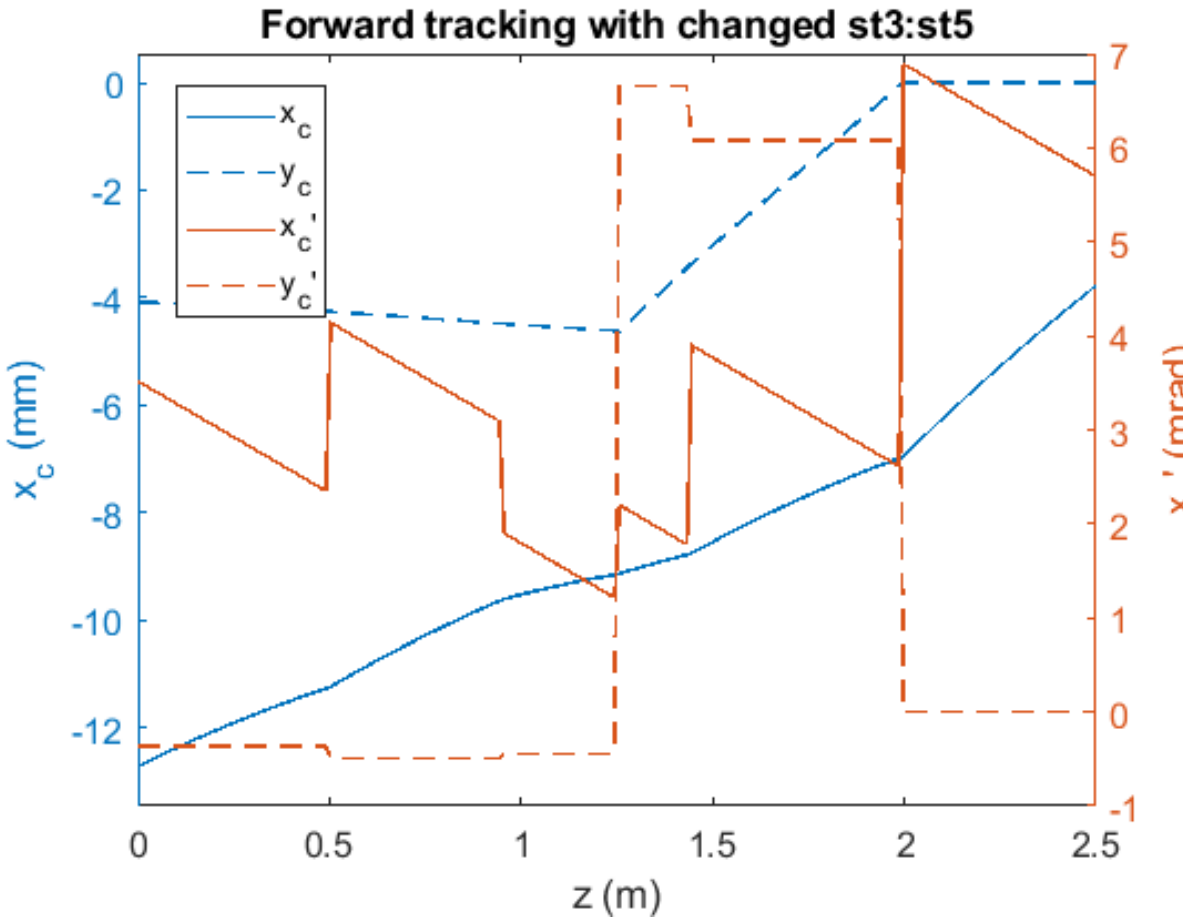


Steering

Two solutions: change four (2x/2y) or five (3x/2y) steerers

Adding more steerers → more DOF → ‘smoother’ solutions possible (minimize kick)





Measurements June 2022

Measurement prediction

Idea:

- In June 2022 booster BBA was performed, done by changing a steerer current and seeing if disp. improves
- Script should predict a new measurement starting from a prev. one if given the change in currents
- For higher accuracy two given measurements were used to predict a third
- Given two sets of currents

  → find predicted change $\Delta x/\Delta x'$ between these two (no influence of const. fields)

  → fit simulated curves to meas. while enforcing sim. must differ by $\Delta x/\Delta x'$ (room for $\pm 0.2\ mm/mrad$)

  → add term ensuring relative coordinate change between simulation is the same as in measurement

  → goal function looks like this: (the subscript 0 indicates being centered at zero)

$$G(x_1, x_2, x_{sim1}, x_{sim2}) = \left(x_{1,0} - x_{sim1,0}\right)^2 + \left(x_{2,0} - x_{sim2,0}\right)^2 + \alpha \cdot |\overline{(x_2 - x_1)} - \overline{(x_{sim2} - x_{sim1})}|$$

Measurement prediction

$$G(x_1, x_2, x_{sim1}, x_{sim2}) = \left(x_{1,0} - x_{sim1,0}\right)^2 + \left(x_{2,0} - x_{sim2,0}\right)^2 + \alpha \cdot |\overline{(x_2 - x_1)} - \overline{(x_{sim2} - x_{sim1})}|$$

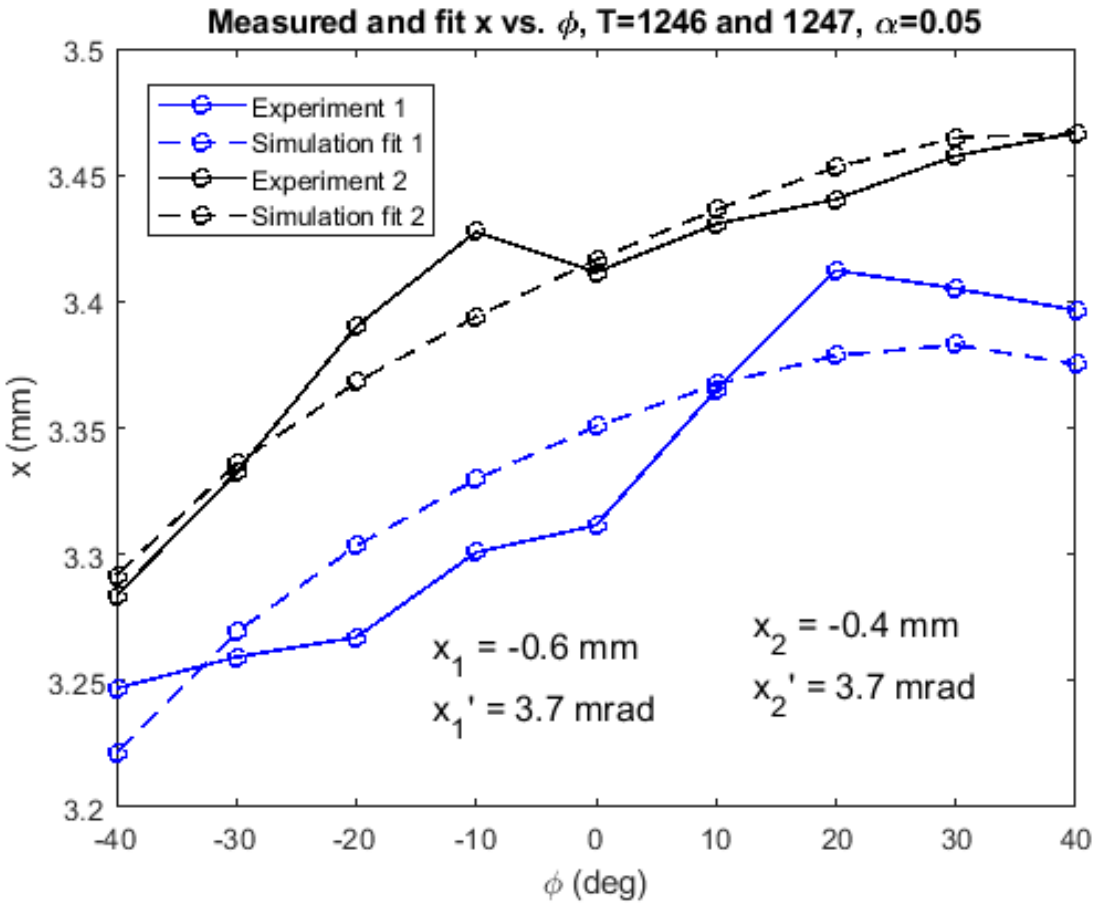
- Advantages:
  - Predict abolute measured coordinates
  - Two fits are used, influenced less by noise on one measurement
  - Control α to influence importance of relative coordinate change in fit
- Conditions for good script:
  - Visual agreement of prediction and real measurement (shape of curve)
  - x/x' are correctly predicted ('real' values found by just fitting the new measurement)
  - Absolute coordinate correctly predicted
  - Goal function correctly predicted

Measurement prediction

X-direction, $\alpha = 0.05$

- Test case: 4th of June morning shift booster BBA
- Files T=1246, T=1247 & T=1248 only change St5-Ver: I: 4.5 → 3.5 → 2.5

  → use first two to predict third
- X: shouldn't change, coupling is too small
- Measurement: increase in x of about .2mm



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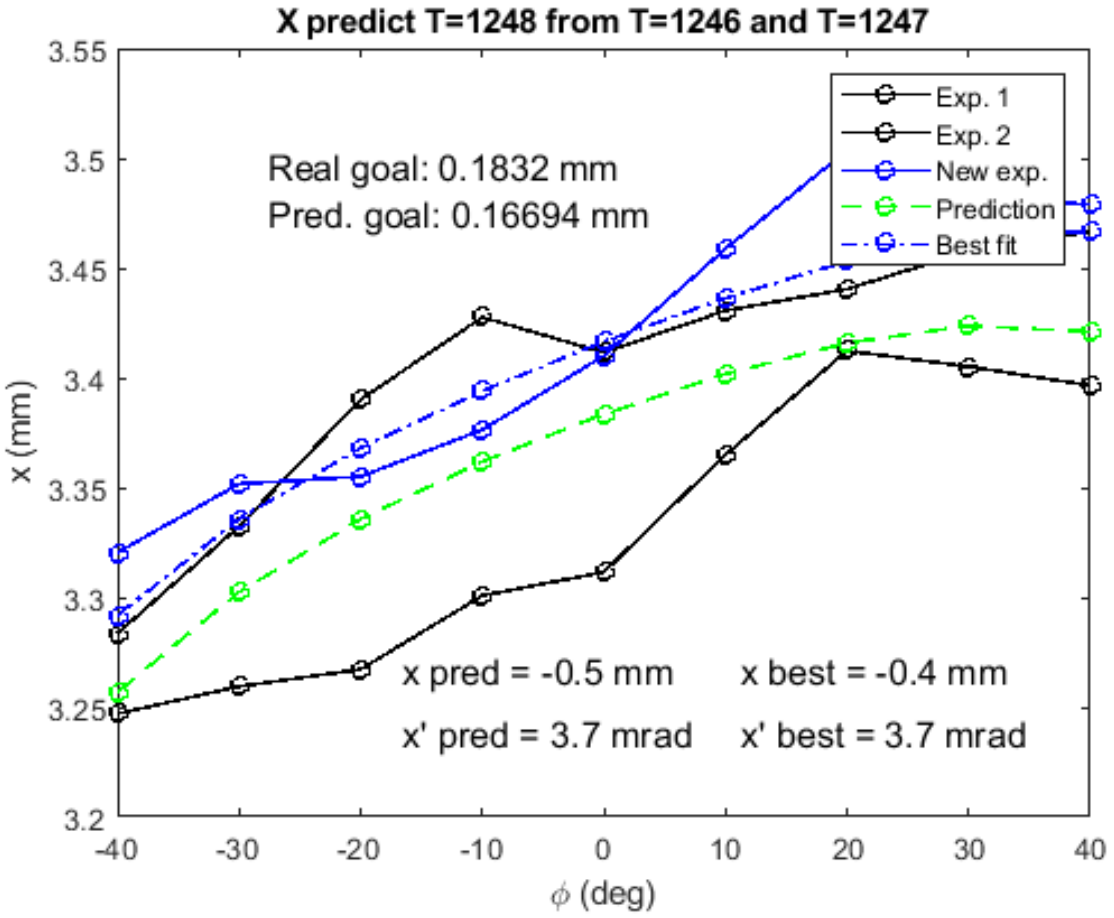
- X: shouldn't change, coupling is too small
- Measurement: increase in x of about .2mm
- Black: input measurements
  Blue: output measurement and it's best fit
  Green: predicted measurement
- Angle/pos. prediction is fine, absolute coordinate not exact



Measurement prediction

Y-direction, $\alpha = 0.05$

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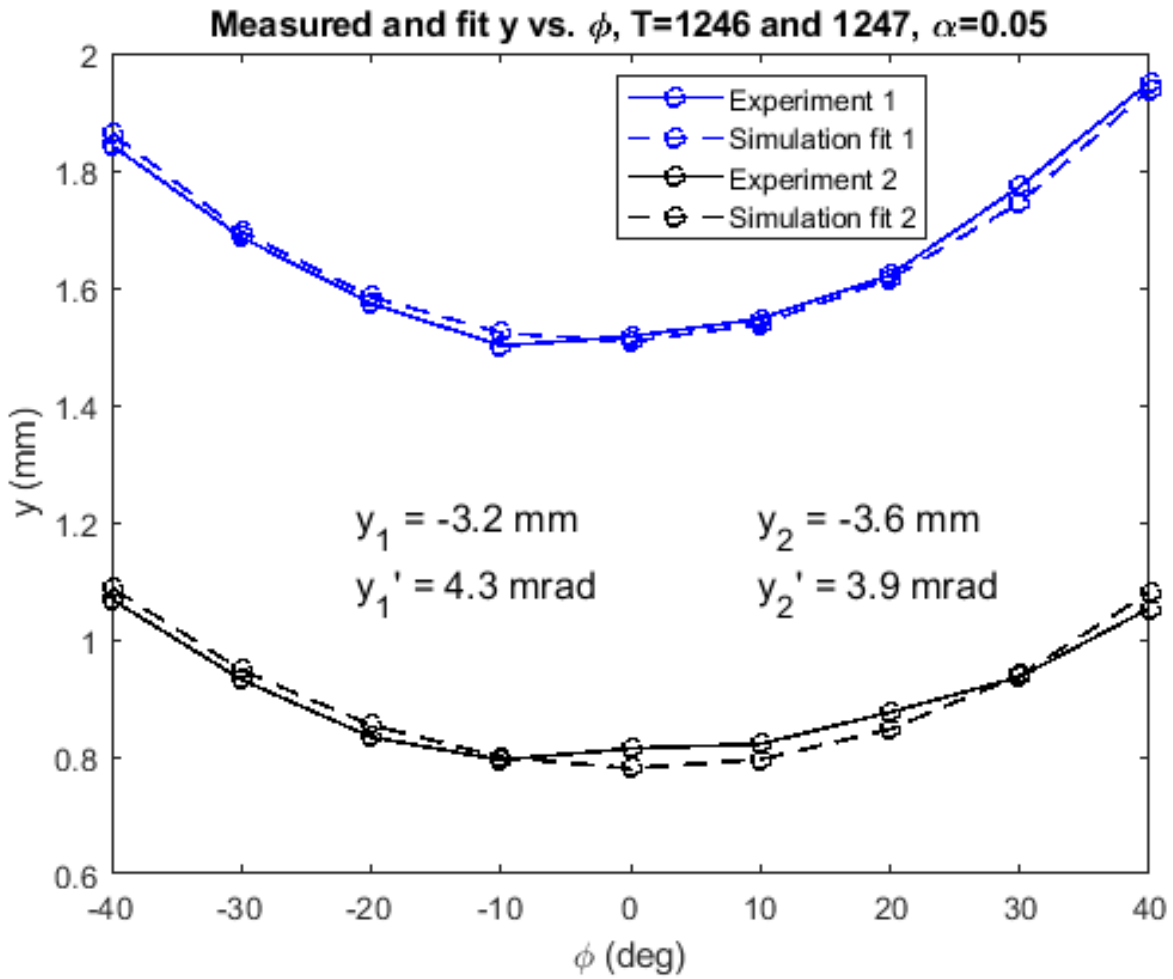
  → use first two to predict third

- Y: decreases every time, which is correct



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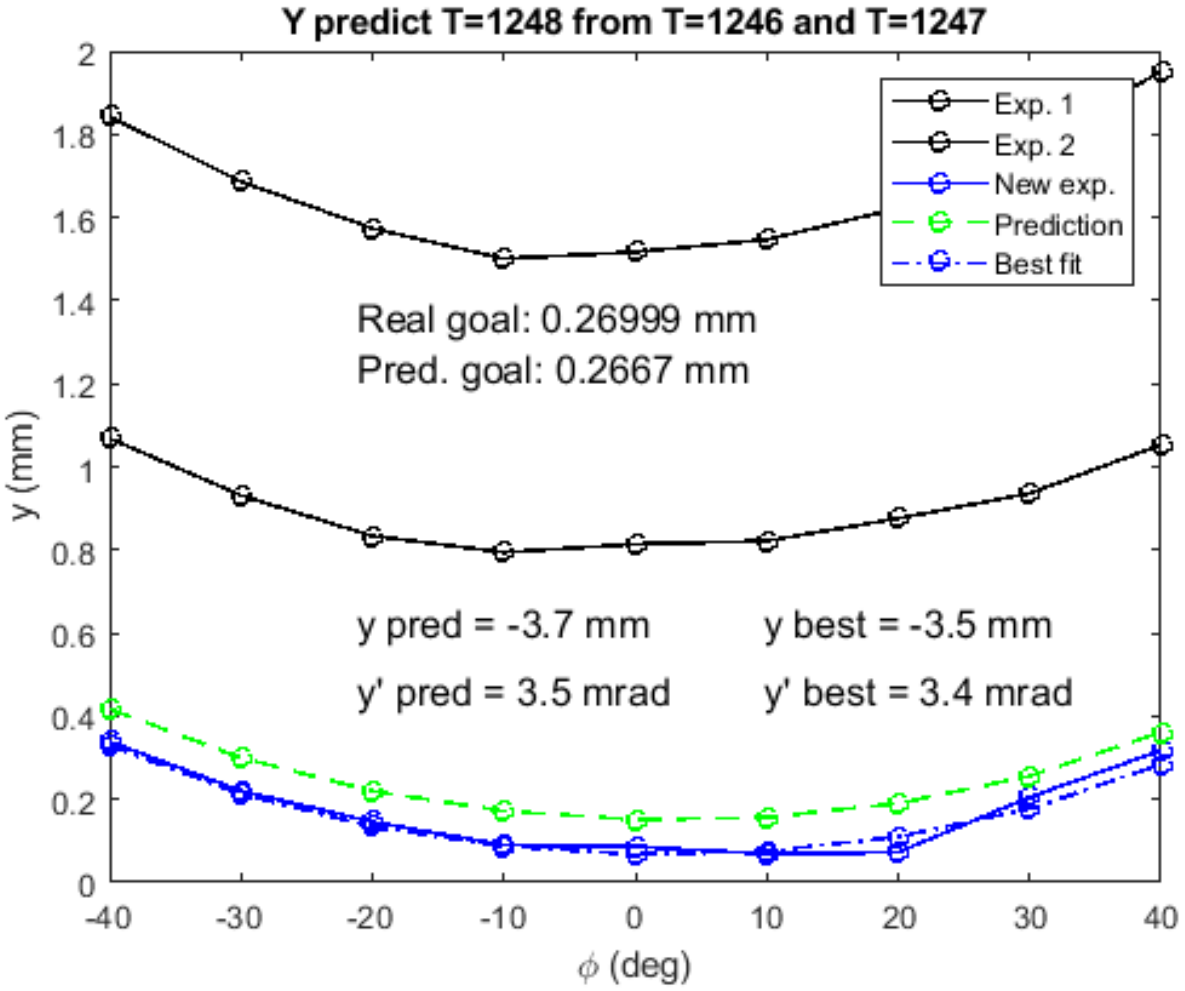
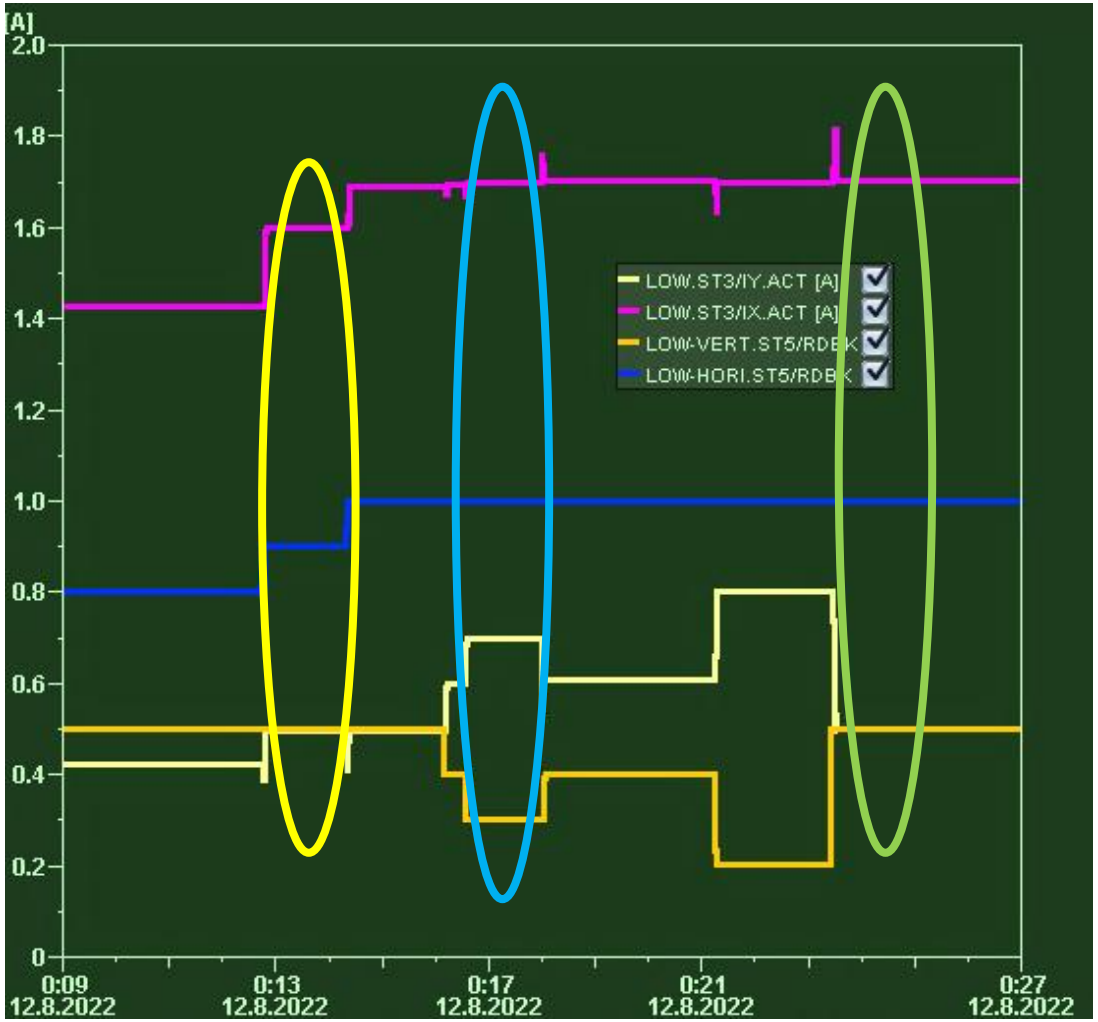


Measurements week 32 of 2022

Measurement prediction

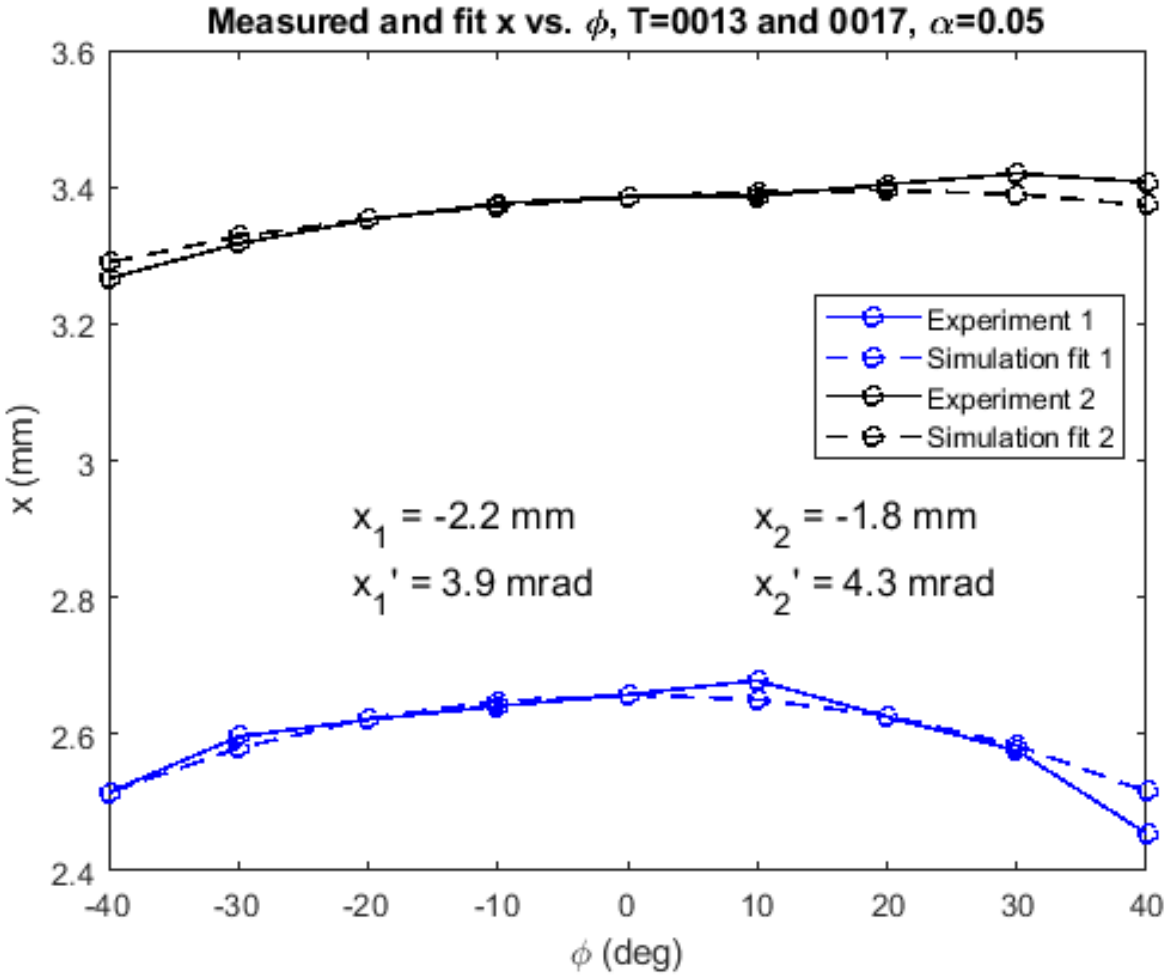
- Test case: use two measurements to predict final booster BBA in less steps
- Use T=0013 and T=0017 since all four used steerer-currents are different

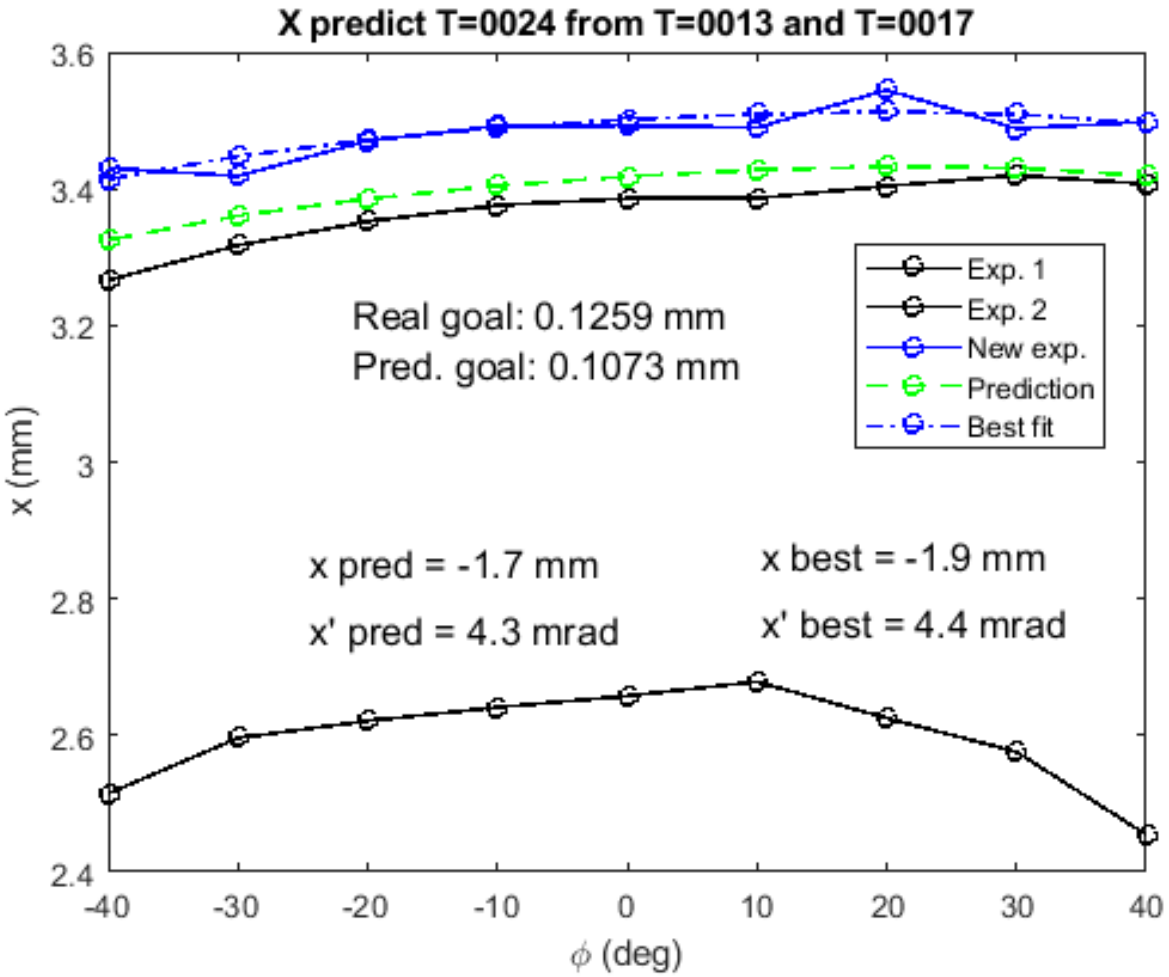
→ Predict T=0024 (final booster BBA)



Measurement prediction

X-direction, $\alpha = 0.05$

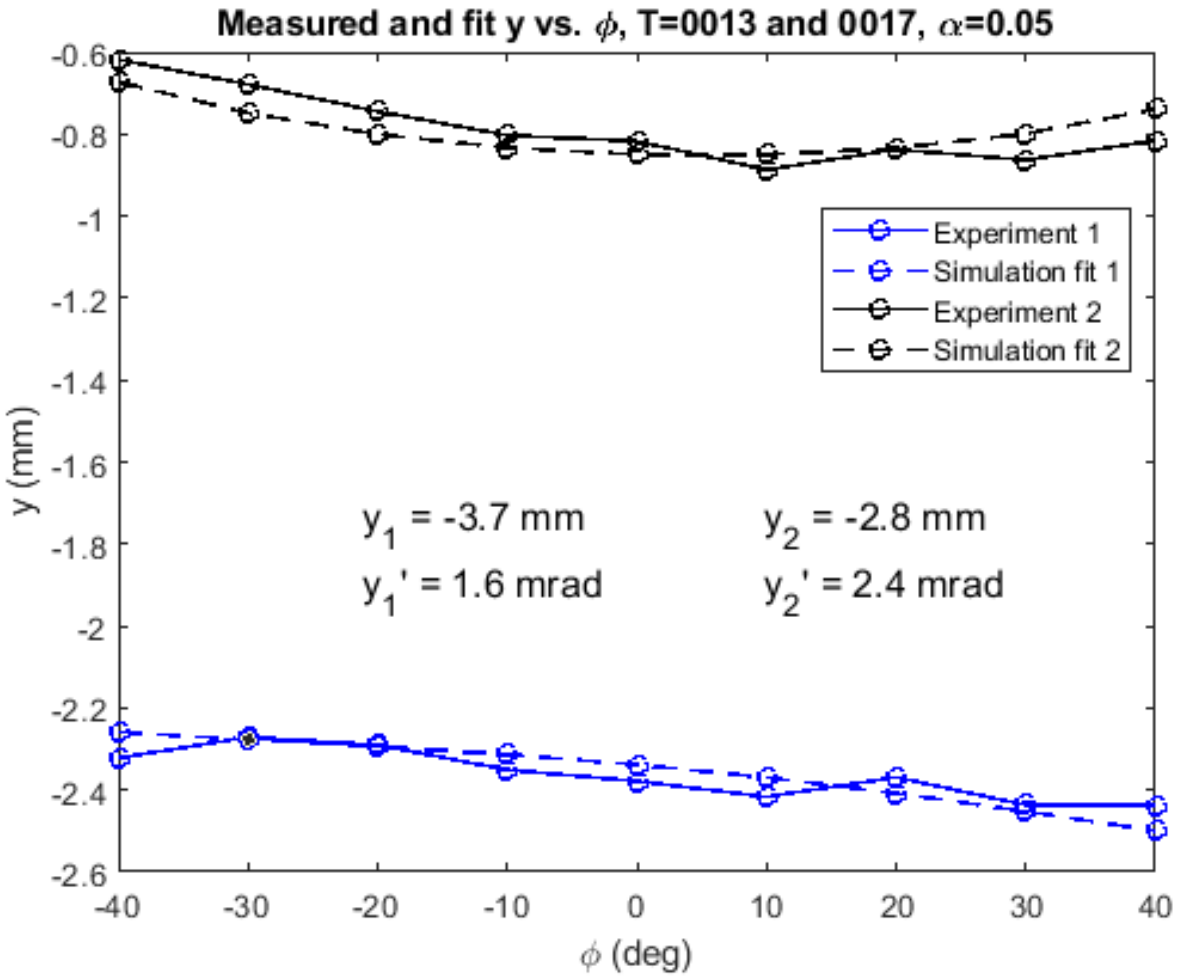


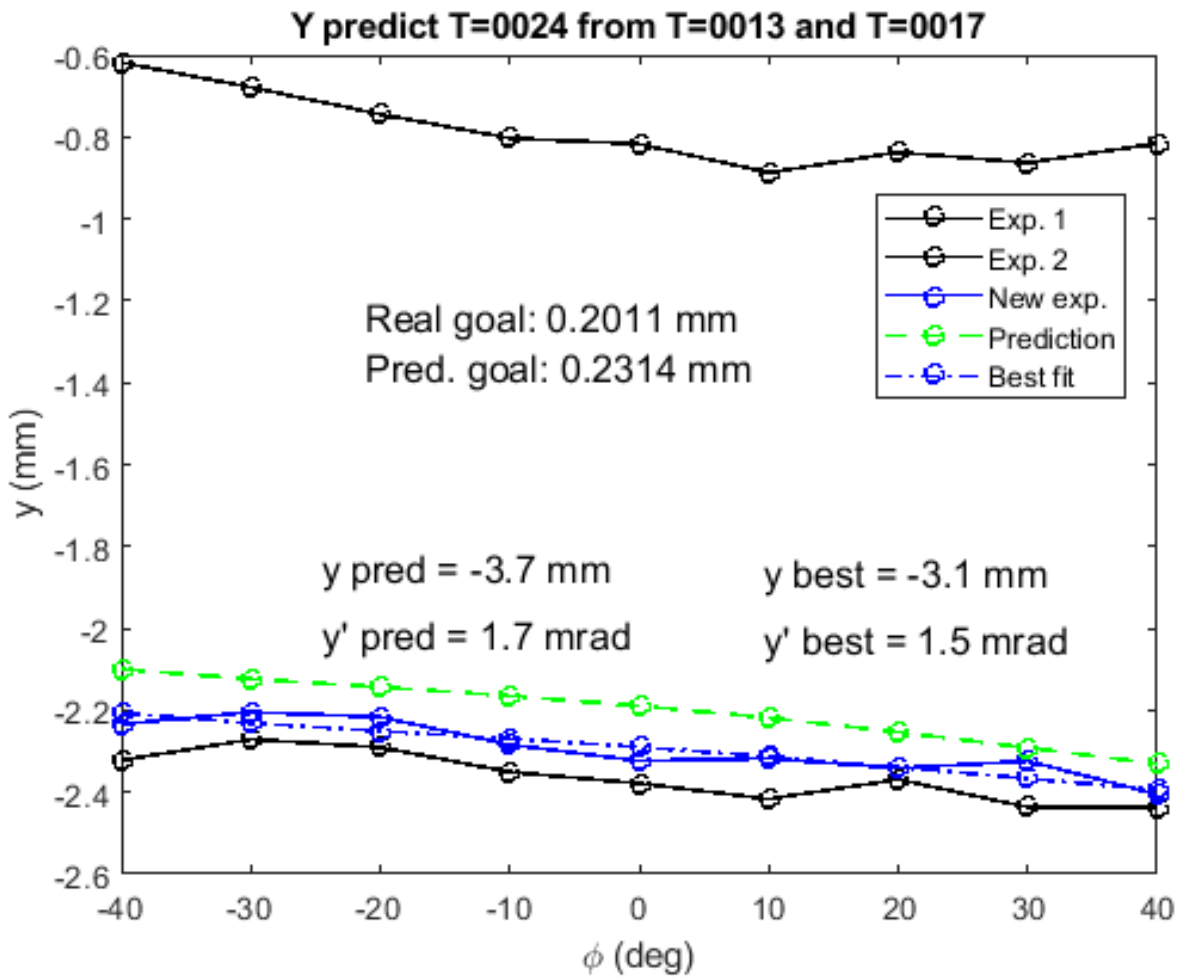


Measurement prediction

Y-direction, $\alpha = 0.05$

- Fit less good → prediction less good as well





Current problems and outlook

rest of project

Current problems and outlook rest of project

Conclusion based on measurement data:

- Data fit and steerer correction method have been developed
- Angles are predicted well enough, resulting positions not always great

  → these are the same ‘symptoms’ as something being wrong with calibration/coupling measurements (dating back to 2019) or the Astra sim. (the EMF used in simulation may not be good)

To do:

- Redo calibration (some steerers were removed and reinstalled during installation gun 5)
- Test script for predicting optimal steerer currents, if necessary do it iteratively
- Somehow measure/calculate exact static fields across booster for improved Astra sim. and fitting