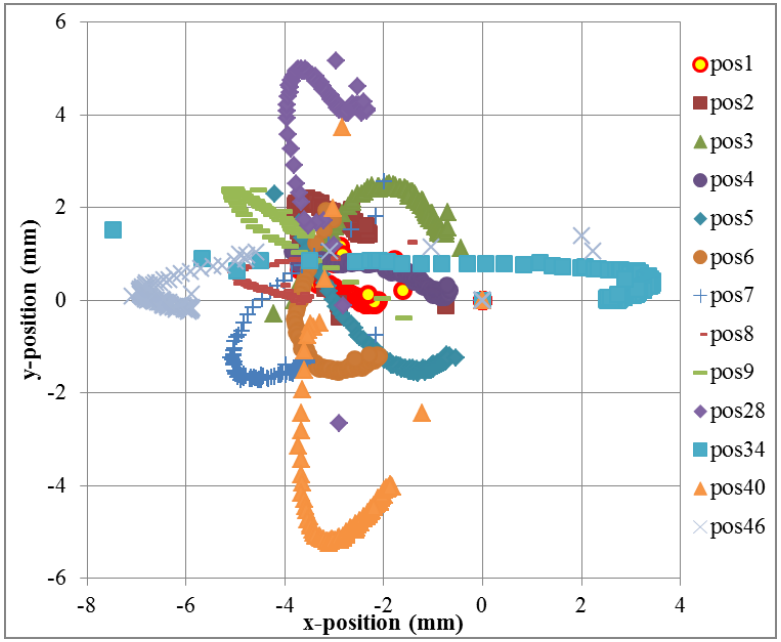
Solenoid BBA and laser grid experiments at the XFEL

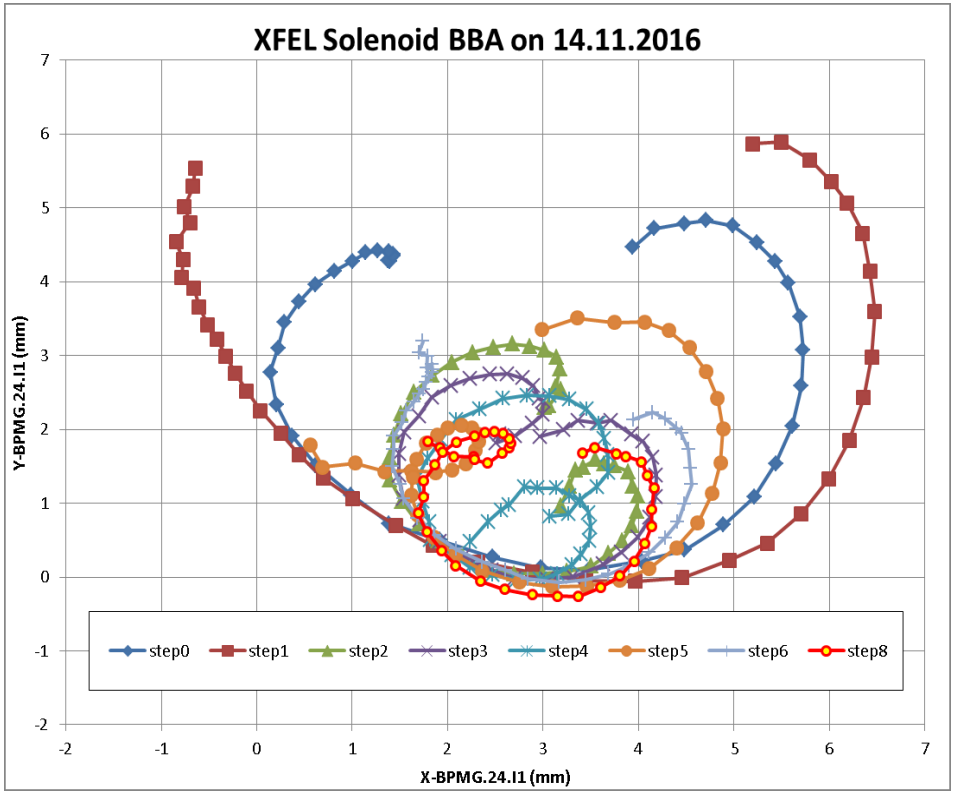
M. Krasilnikov, PPS, 09.02.2017



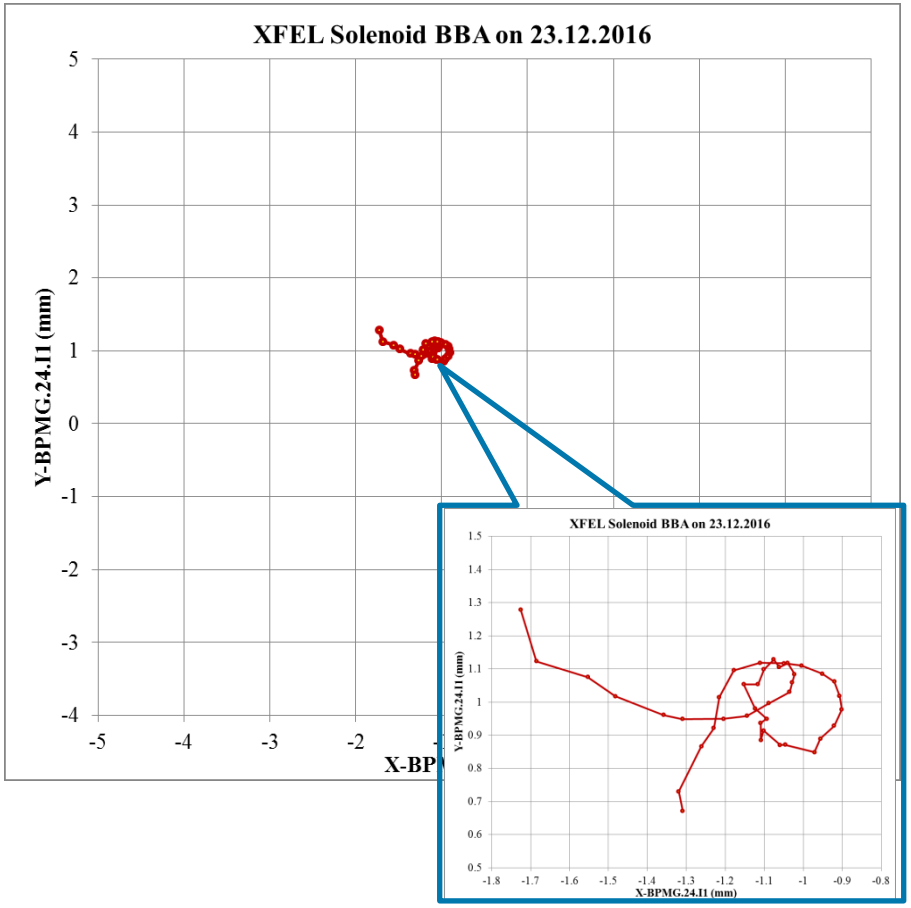
HELMHOLTZ ASSOCIATION

DESY

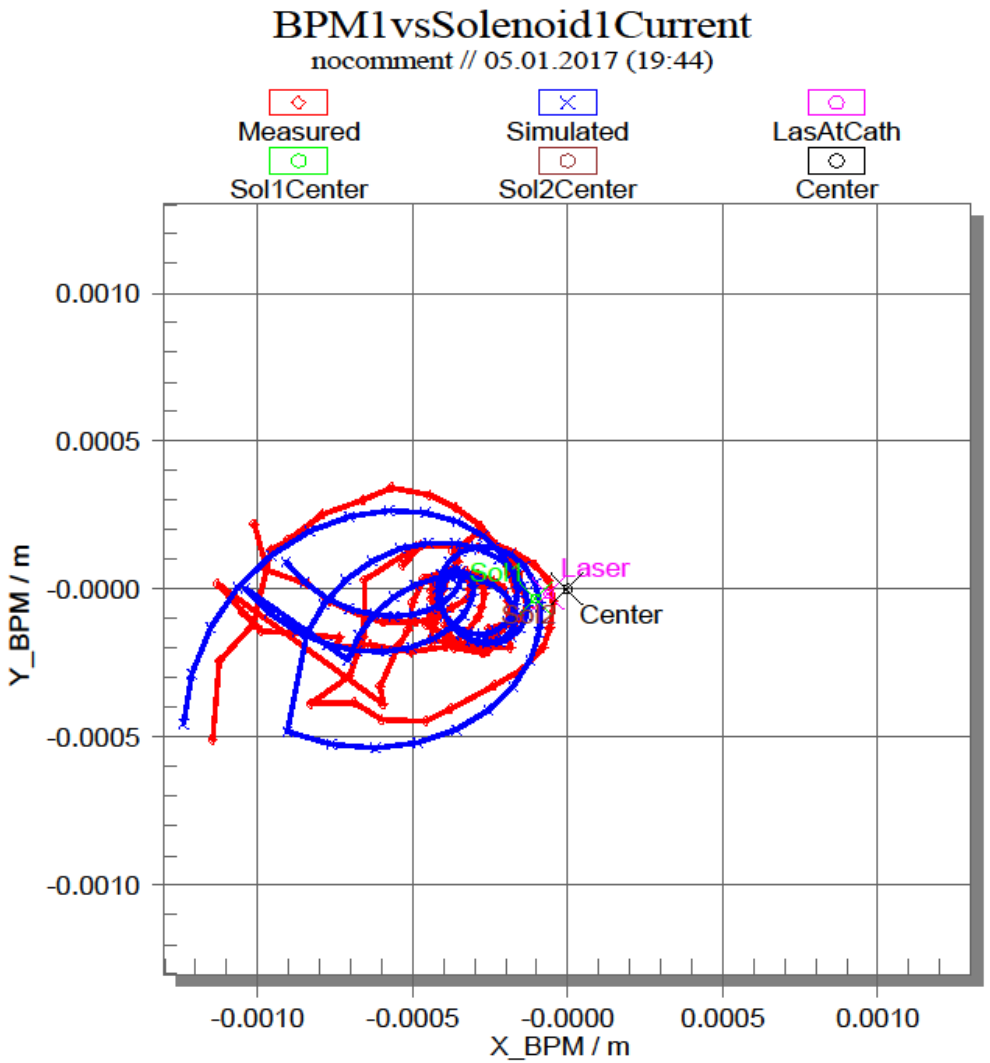
XFEL solenoid BBA: Final measurements on 23.12.2016



Imain=-400A…step 20A…+400A



New implementation: Static homogeneous magnetic field



Fit Parameters List

RF-GunPITZ : AngleXSolMain = -0.00309 deg

RF-GunPITZ : AngleYSolMain = 0.000477 deg

RF-GunPITZ : Ez_Field_At_Cathode = 30.4 MV/m

RF-GunPITZ : HxEarth = 0.000848 T

RF-GunPITZ : HyEarth = -0.0105 T

RF-GunPITZ : HzEarth = 0 T

RF-GunPITZ : Initial_Phase = -108 degree

RF-GunPITZ : Laser_Beam_CenterX = -6.07e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -1.57e-005 m

RF-GunPITZ : XSolMainCenter = -0.000102 m

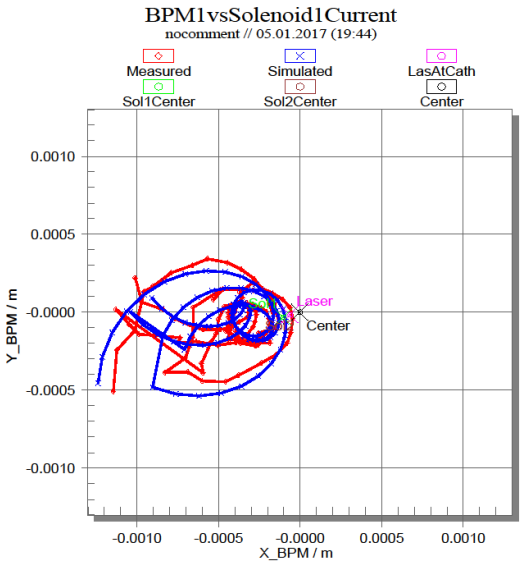
RF-GunPITZ : YSolMainCenter = -3.23e-005 m

Offsets List / [m]

X_BPM = 0.00111726

Y_BPM = 0.000603668

But: To be combined with BPM offsets

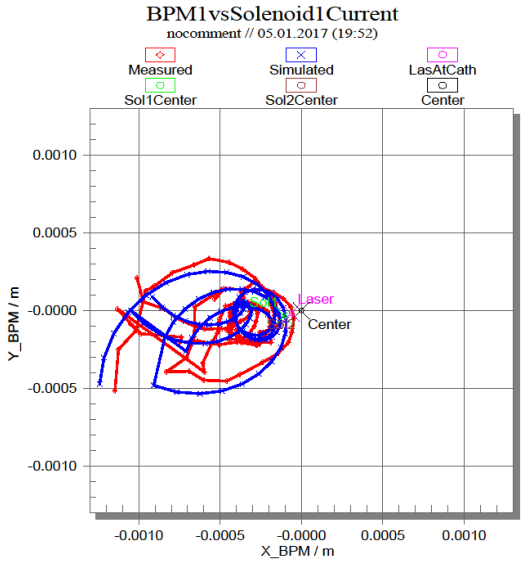


Fit Parameters List

RF-GunPITZ : AngleXSolMain = -0.00309 deg
RF-GunPITZ : AngleYSolMain = 0.000477 deg
RF-GunPITZ : Ez_Field_At_Cathode = 30.4 MV/m
RF-GunPITZ : HxEarth = 0.000848 T
RF-GunPITZ : HyEarth = -0.0105 T
RF-GunPITZ : HzEarth = 0 T
RF-GunPITZ : Initial_Phase = -108 degree
RF-GunPITZ : Laser_Beam_CenterX = -6.07e-005 m
RF-GunPITZ : Laser_Beam_CenterY = -1.57e-005 m
RF-GunPITZ : XSolMainCenter = -0.000102 m
RF-GunPITZ : YSolMainCenter = -3.23e-005 m

Offsets List / [m]

X_BPM = 0.00111726
Y_BPM = 0.000603668



Fit Parameters List

RF-GunPITZ : AngleXSolMain = -0.00317 deg
RF-GunPITZ : AngleYSolMain = 0.000401 deg
RF-GunPITZ : Ez_Field_At_Cathode = 29.9 MV/m
RF-GunPITZ : HxEarth = 0.00167 T
RF-GunPITZ : HyEarth = -0.00959 T
RF-GunPITZ : HzEarth = 0 T
RF-GunPITZ : Initial_Phase = -110 degree
RF-GunPITZ : Laser_Beam_CenterX = -6.16e-005 m
RF-GunPITZ : Laser_Beam_CenterY = -1.61e-005 m
RF-GunPITZ : XSolMainCenter = -0.000105 m
RF-GunPITZ : YSolMainCenter = -3.41e-005 m

Offsets List / [m]

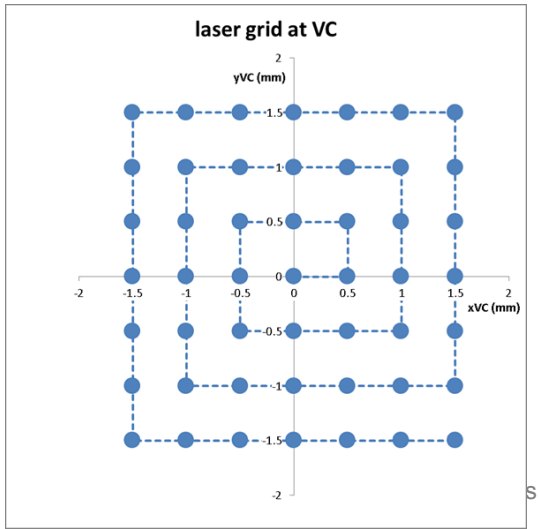
X_BPM = -0.000713545
Y_BPM = 0.00106762

(HxEarth, HyEarth, HzEarth) ←→ X_BPM, Y_BPM offsets

Proposals to measure RF-gun coupler kick at EXFEL

M. Krasilnikov (12.12.2016)

1. Power in the gun: 1.5 MW (~like for the laser and solenoid BBA), FB=On (if possible)
2. Solenoids and steerers are off, solenoid degaussed
3. Cathode laser: BSA=0.5mm (or smaller)
4. Laser BBA is (roughly) done → record the laser position (image) at the VC camera
5. Bunch charge ~ 50pC(?) – 1st BPM should deliver reliable measurements (position and bunch charge)
6. Gun phase scan in the low energy dispersive arm → Pz vs. SP Phase → MMMG phase
7. Basic measurement: beam position and bunch charge (1st BPM) vs. gun SP Phase
8. Scan cathode with 0.5 mm step (XY-grid)
    1. Record laser beam at the VC camera
    2. Gun phase scan: beam position and bunch charge (1st BPM) vs. gun SP Phase
9. (If time) Repeat 1-8 with 5 MW in the gun (nominal).



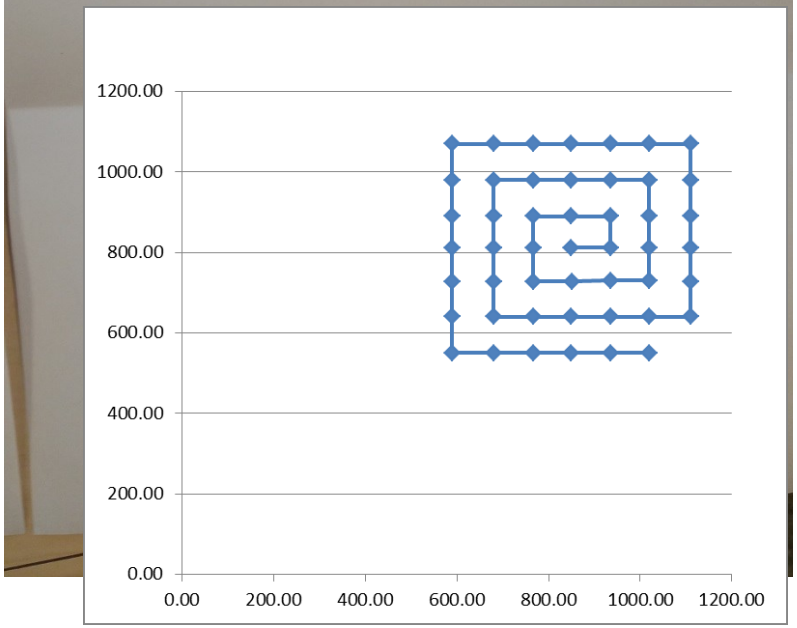
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

13.12.2016

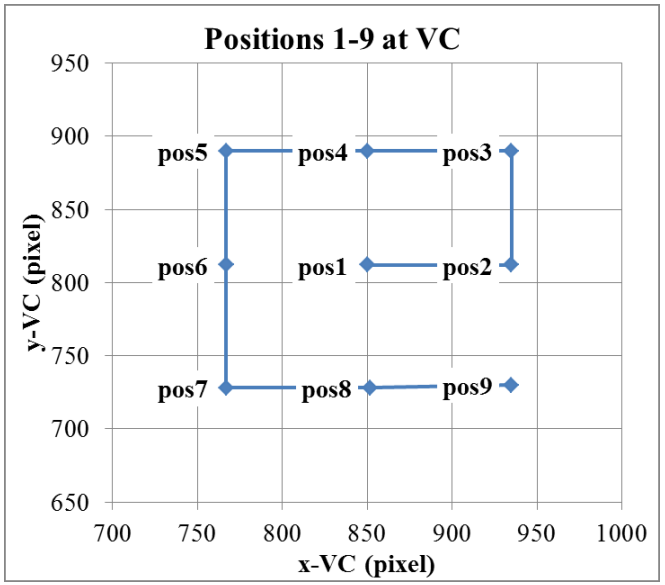
#	xVC goal	yVC goal	xVC measured	yVC measured	xBPM1 (MMMG)	yBPM1 (MMMG)	Phase scan file	commer
1	0	0	850	812	-2,50	0,06	2016-12-12T155411	14T13K0
2	0.5	0	935	812	-2,60	1,65	2016-12-12T171430	14T13
3	0.5	0.5	932	890	-1,04	1,81	2016-12-13T103800	
4	0	0.5	850	890	-1,08	0,22	2016-12-13T104649	
5	-0.5	0.5	767	890	-1,00	-1,39	2016-12-13T105550	
6	-0.5	0	767	810	-2,48	-1,41	2016-12-13T110237	
7	-0.5	-0.5	767	728	-3,92	-1,55	2016-12-13T121720	
8	0	-0.5	852	728	-3,97	0,09	2016-12-13T 122518	
9	0.5	-0.5	935	730	-3,99	1,72	2016-12-13T123311	
10	1	-0.5	1020	731	-4,02	3,81	2016-12-13T123949	
11	1	0	1020	810	-2,74	3,10	2016-12-13T124649	
12	1	0.5	1022	890	-1,29	3,22	2016-12-13T125421	
13	1	1	1021	980	0,89	3,21	2016-12-13T130602	
14	0.5	1	935	980	0,88	1,91	2016-12-13T131811	
15	0	1	850	980	0,91	0,33	2016-12-13T132500	
16	-0.5	1	767	980	0,92	-1,46	2016-12-13T133327	
17	-1	1	680	980	0,93	-3,15	2016-12-13T134019	
18	-1	0.5	680	890	-0,74	-3,14	2016-12-13T134705	
19	-1	0	680	810	-2,47	-3,11	2016-12-13T135642	
20	-1	-0.5	680	728	-3,85	-3,02	2016-12-13T140302	
21	-1	-1	680	680	-5,26	-2,89	2016-12-13T140959	
22	-0.5	-1	767	640	-5,14	-1,62	2016-12-13T141702	
23	0	-1	850	640	-5,16	-0,03	2016-12-13T142352	
24	0.5	-1	935	640	-5,22	1,56	2016-12-13T143009	
25	1	-1	1020	640	-5,21	2,89	2016-12-13T143659	
26	1.5	-1	1110	640	-4,82	3,77	2016-12-13T144314	
27	1.5	-0.5	1110	729	-4,10	4,00	2016-12-13T144932	
28	1.5	0	1110	812	-2,75	4,06	2016-12-13T153244	
29	1.5	0.5	1110	890	-1,34	3,91	2016-12-13T153856	
30	1.5	1	1110	980	0,56	4,06	2016-12-13T154529	
31	1.5	1.5	1110	1070	2,46	4,21	2016-12-13T155143	
32	1	1.5	1020	1070	2,50	3,24	2016-12-13T155923	
33	0.5	1.5	935	1070	2,71	1,85	2016-12-13T160724	
34	0	1.5	850	1070	2,89	0,13	2016-12-13T161550	
35	-0.5	1.5	767	1070	3,01	-1,49	2016-12-13T162248	
36	-1	1.5	680	1070	3,07	-3,03	2016-12-13T163045	
37	-1.5	1.5	590	1070	3,11	-4,50	2016-12-13T163809	
38	-1.5	1	590	980	1,46	-4,54	2016-12-13T164453	
39	-1.5	0.5	590	890	-0,57	-4,55	2016-12-13T165257	
40	-1.5	0	590	812	-2,33	-4,58	2016-12-13T165955	

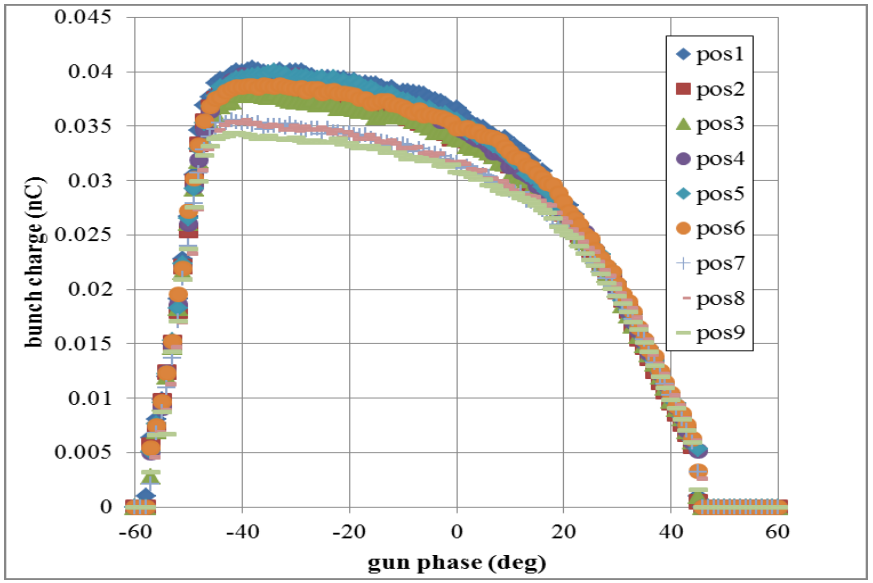
#	xVC goal	yVC goal	xVC meas	yVC meas	xBPM1 (MMMG)	yBPM1 (MMMG)	Phase scan file
41	-1.5	-0.5	590	728	-3,80	-4,58	2016-12-13T170714
42	-1.5	-1	590	640	-4,65	-4,36	2016-12-14T133650
43	-1.5	-1.5	590	550	-5,13	-4,11	2016-12-14T134505
44	-1	-1.5	680	550	-5,38	-3,04	2016-12-14T135243
45	-0.5	-1.5	767	550	-5,52	-1,52	2016-12-14T135948
46	0	-1.5	850	550	-5,87	-0,16	2016-12-14T140628
47	0.5	-1.5	935	550	-5,97	1,40	2016-12-14T141312
48	1	-1.5	1020	550	-6,12	2,64	2016-12-14T141956
49	1.5	-1.5	1110	550			

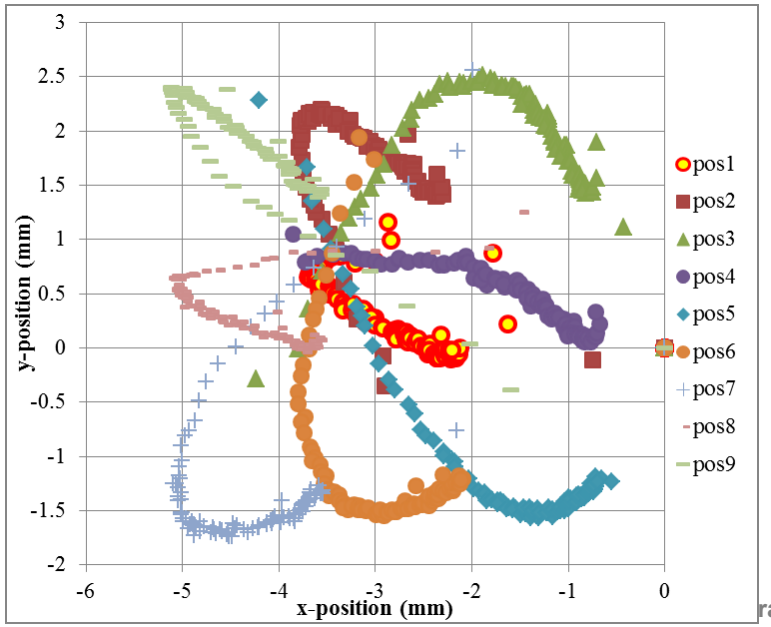


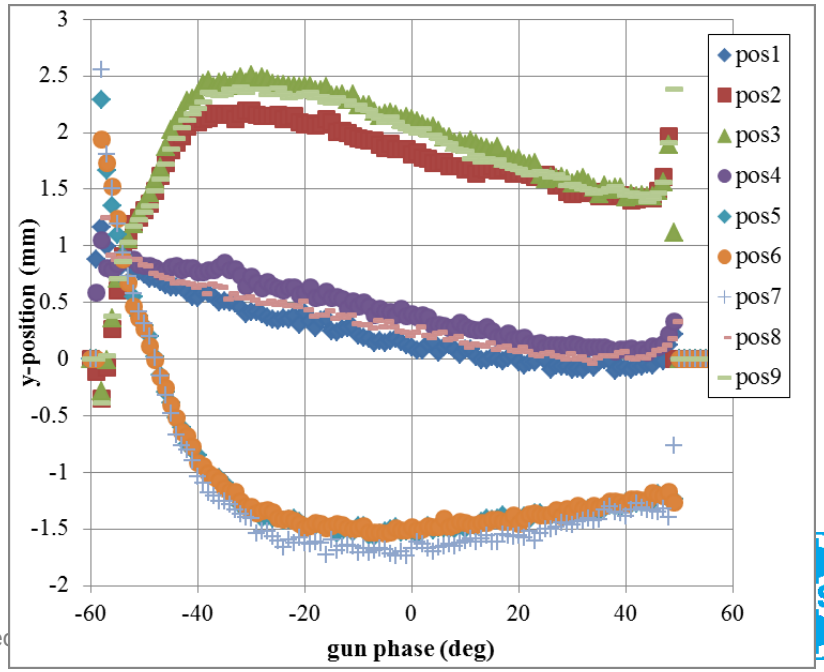
RF-gun coupler kick measurements at EXFEL

13-14.12.2016



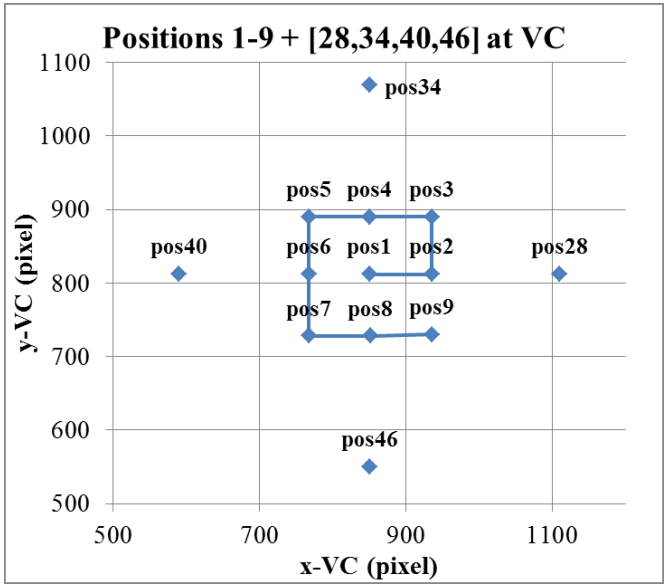


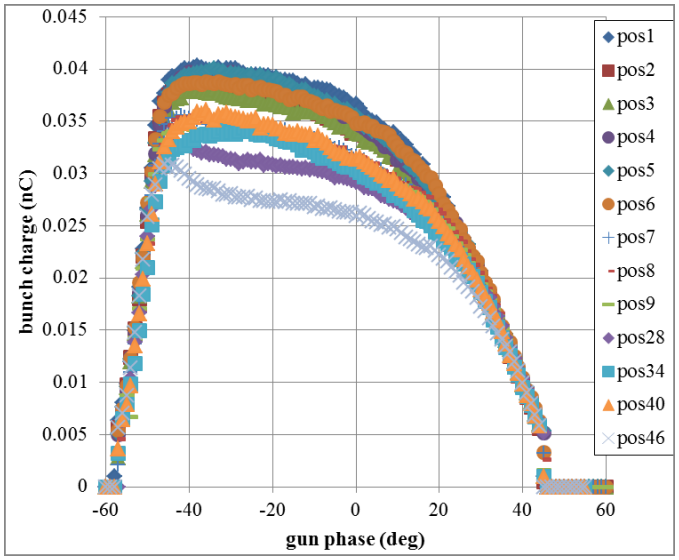


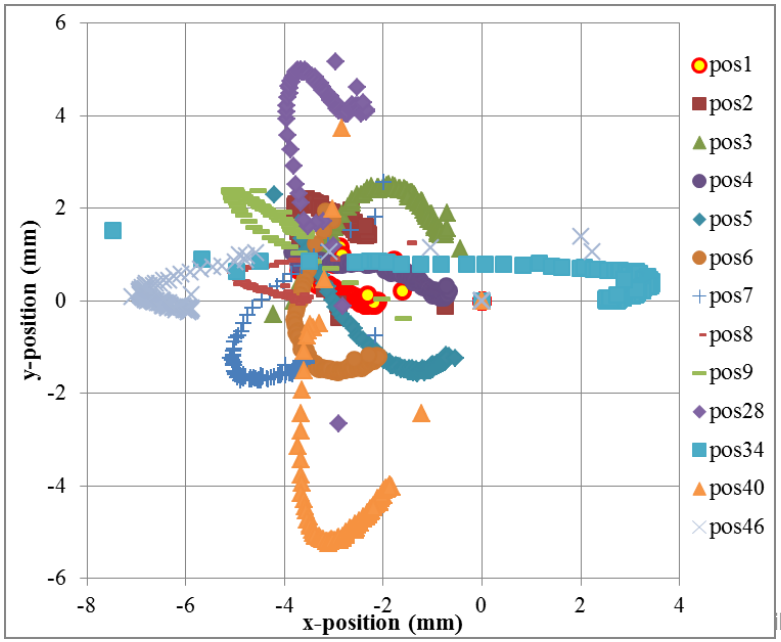


RF-gun coupler kick measurements at EXFEL

13-14.12.2016



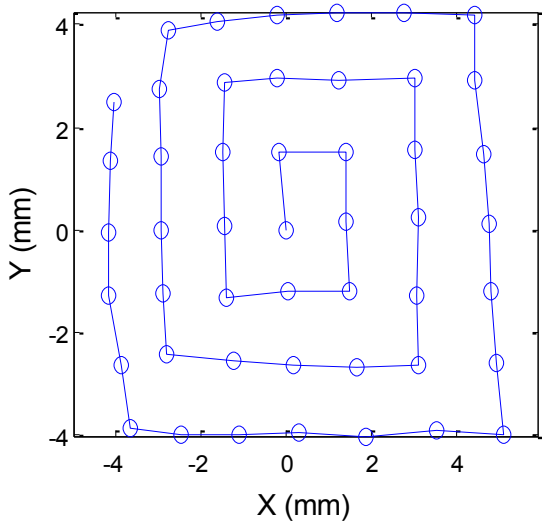




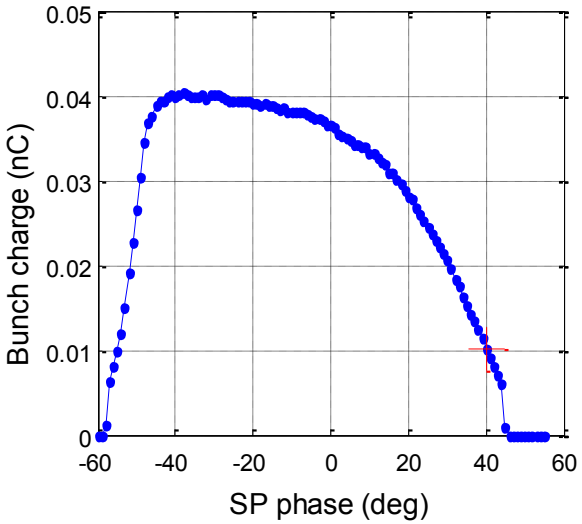
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

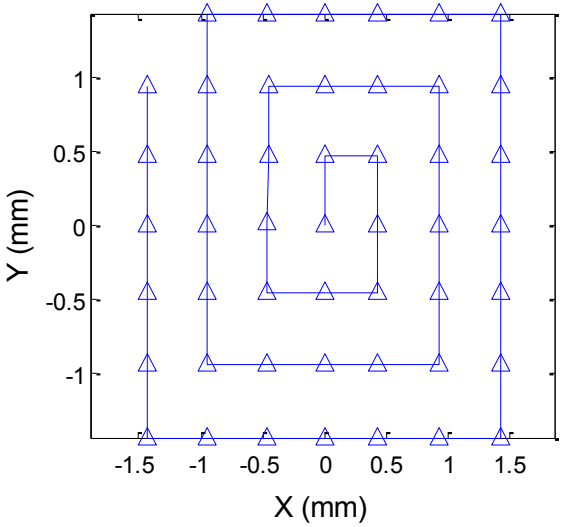
Beam position at 1st BPM, SPPhase=40



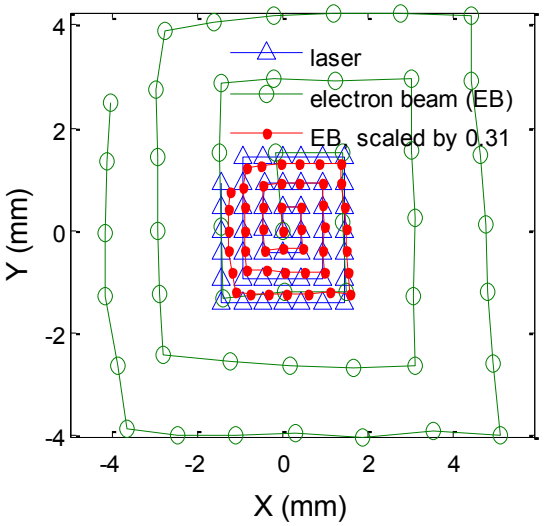
Bunch charge (Schottky) scan



Laser positions at the cathode (centered)



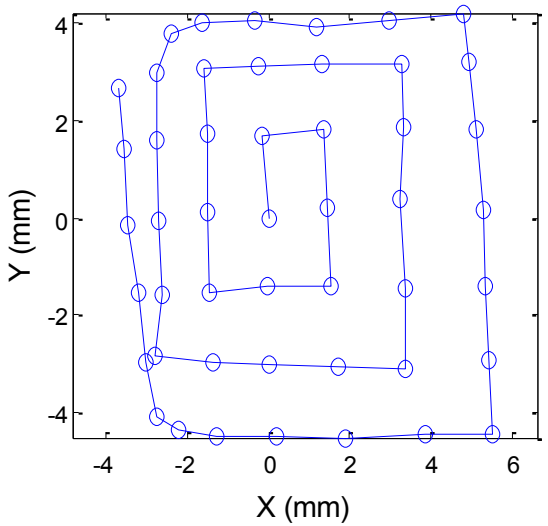
Laser/electron beam position



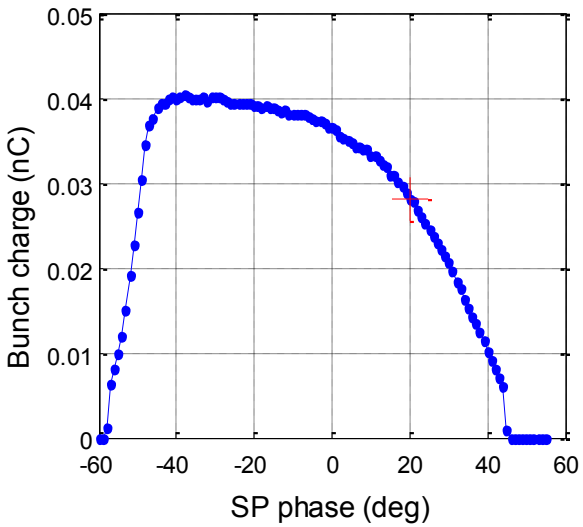
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

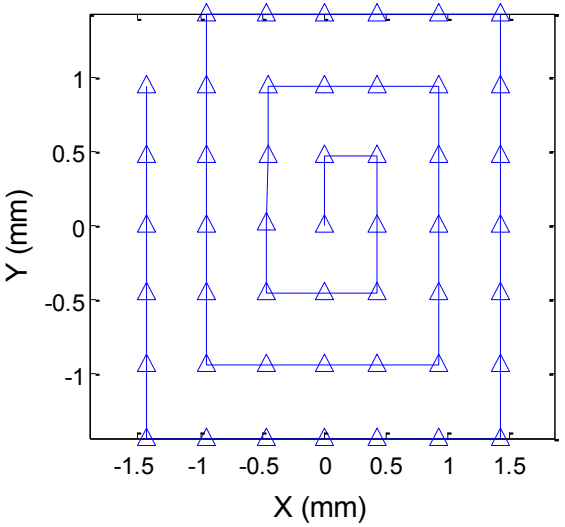
Beam position at 1st BPM, SPPhase=20



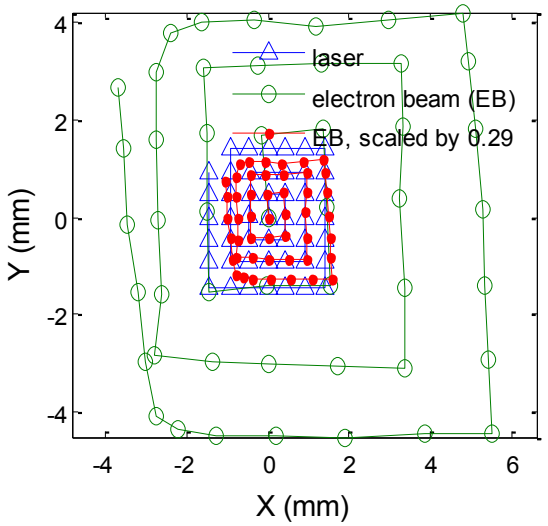
Bunch charge (Schottky) scan



Laser positions at the cathode (centered)



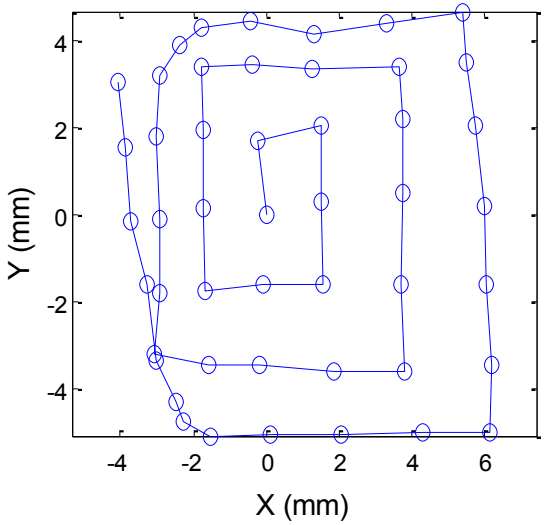
Laser/electron beam position



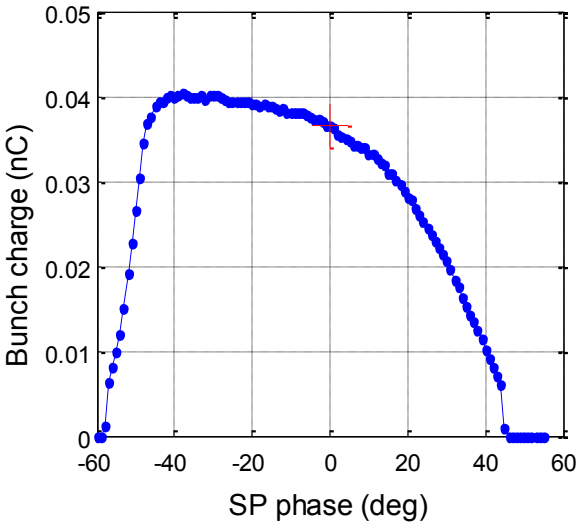
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

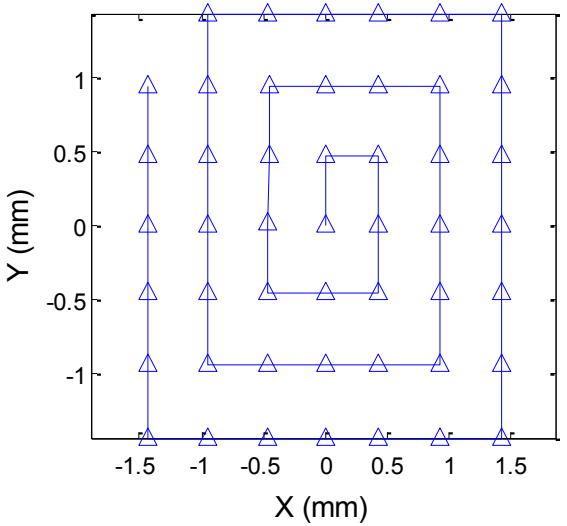
Beam position at 1st BPM, SPPhase=0



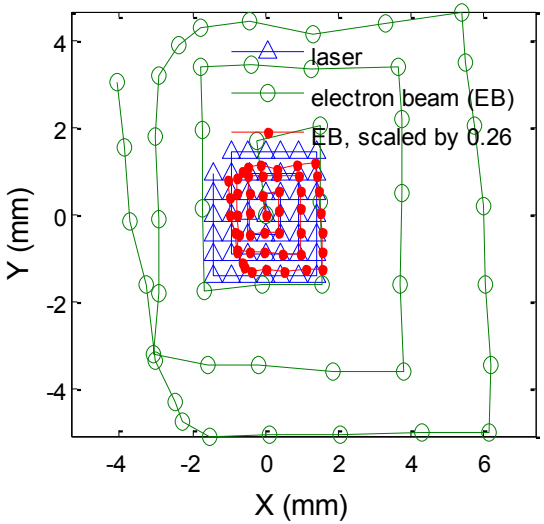
Bunch charge (Schottky) scan



Laser positions at the cathode (centered)



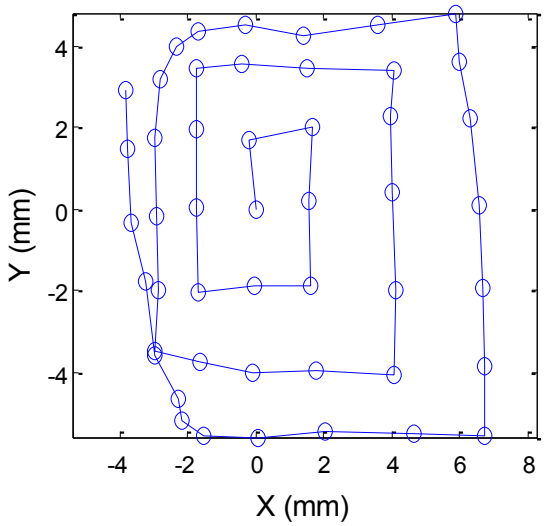
Laser/electron beam position



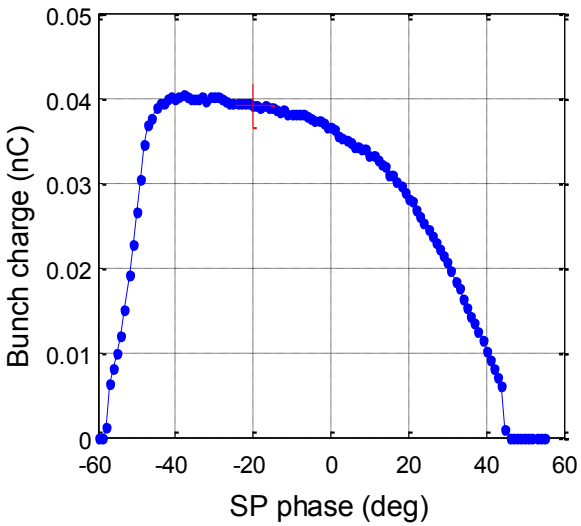
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

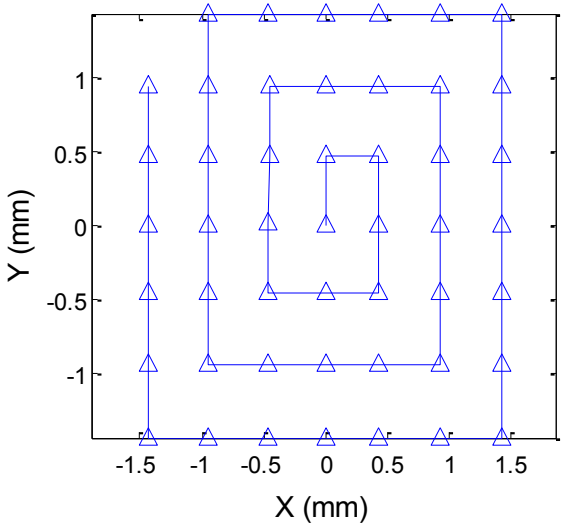
Beam position at 1st BPM, SPPhase=-20



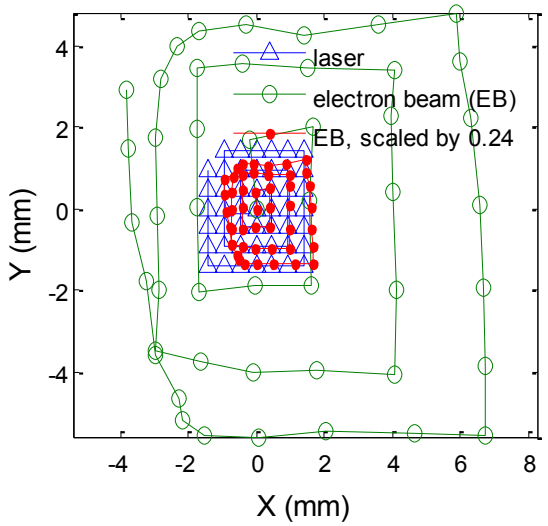
Bunch charge (Schottky) scan



Laser positions at the cathode (centered)



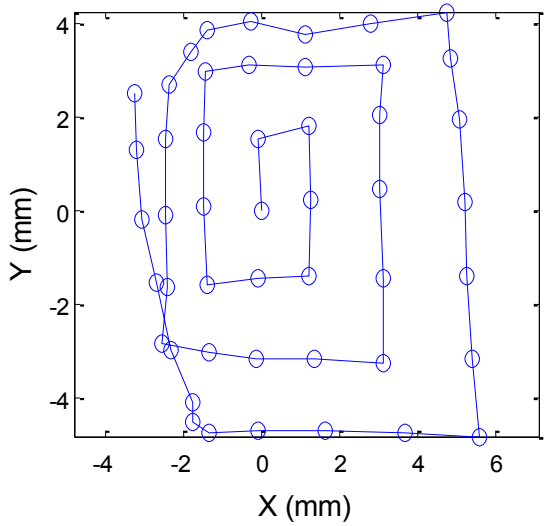
Laser/electron beam position



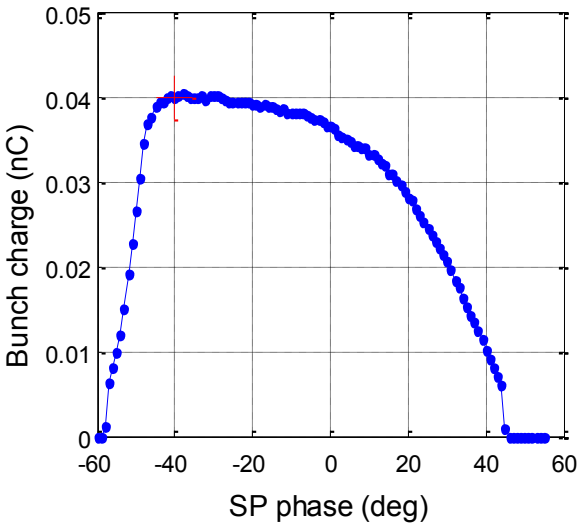
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

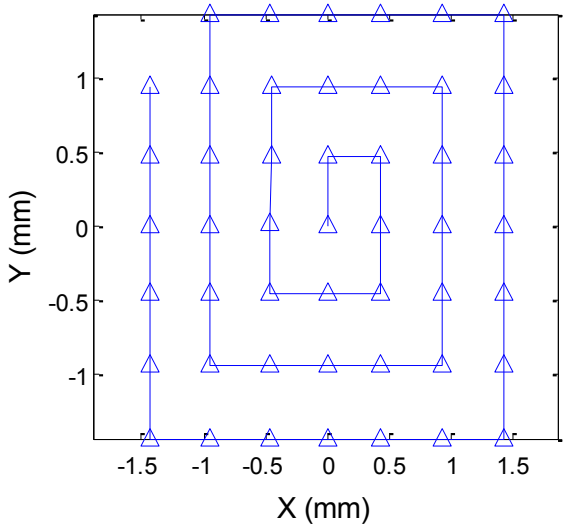
Beam position at 1st BPM, SPPhase=-40



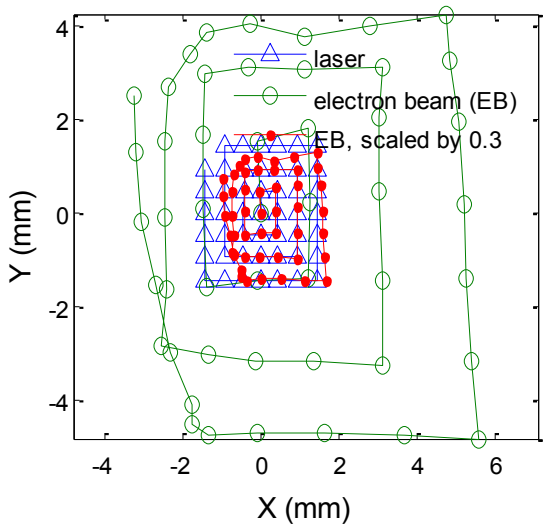
Bunch charge (Schottky) scan



Laser positions at the cathode (centered)



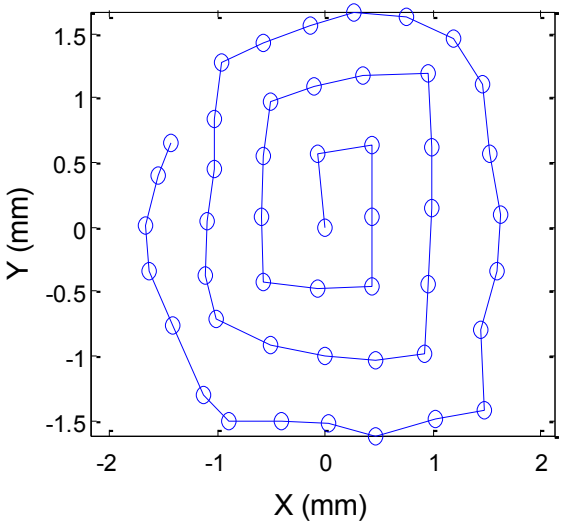
Laser/electron beam position



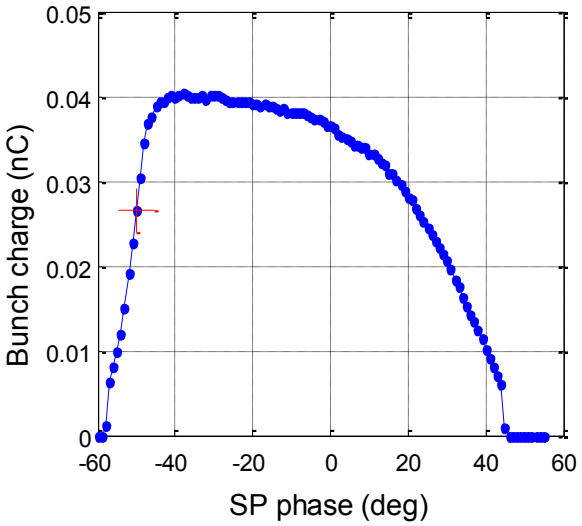
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

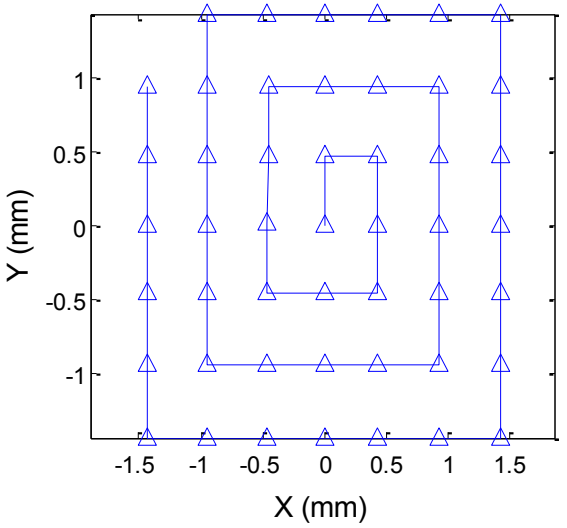
Beam position at 1st BPM, SPPhase=-50



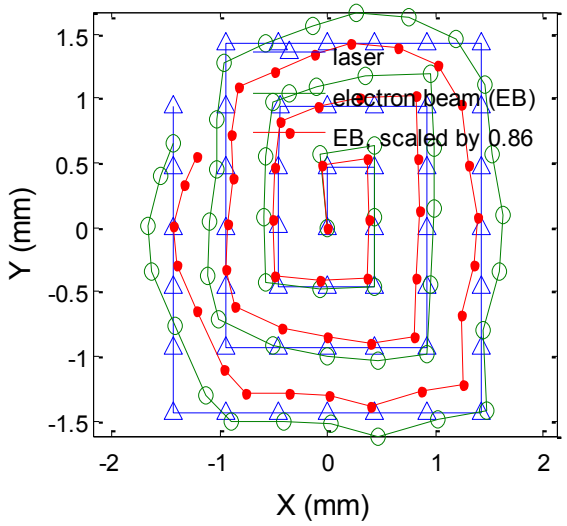
Bunch charge (Schottky) scan



Laser positions at the cathode (centered)



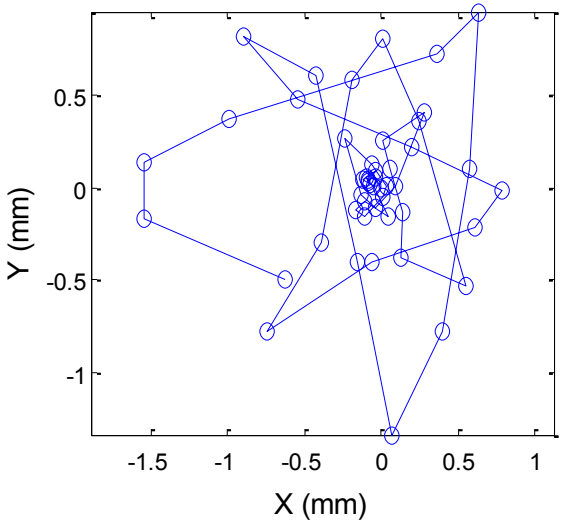
Laser/electron beam position



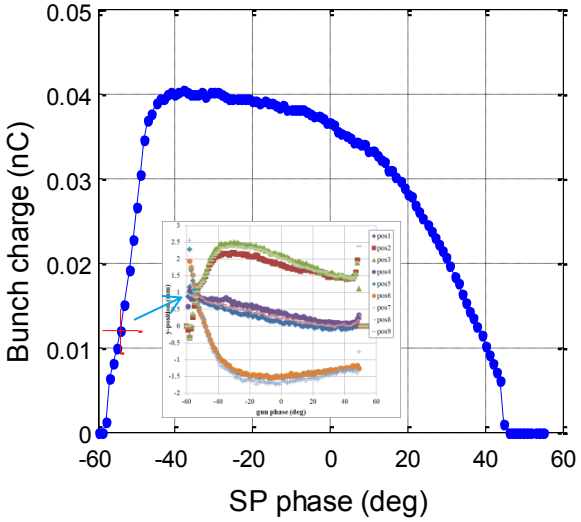
RF-gun coupler kick measurements at EXFEL

13-14.12.2016

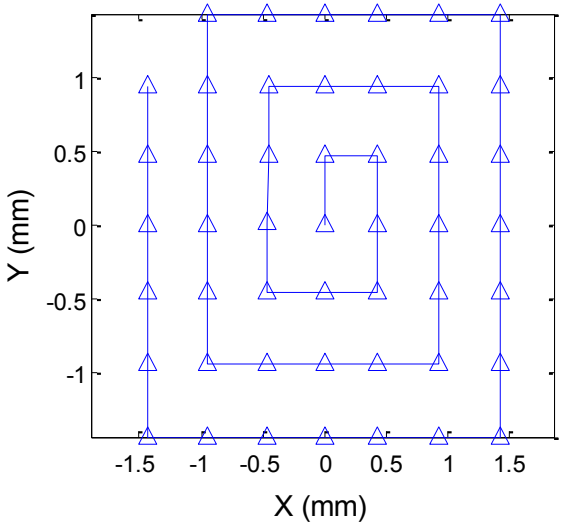
Beam position at 1st BPM, SPPhase=-54



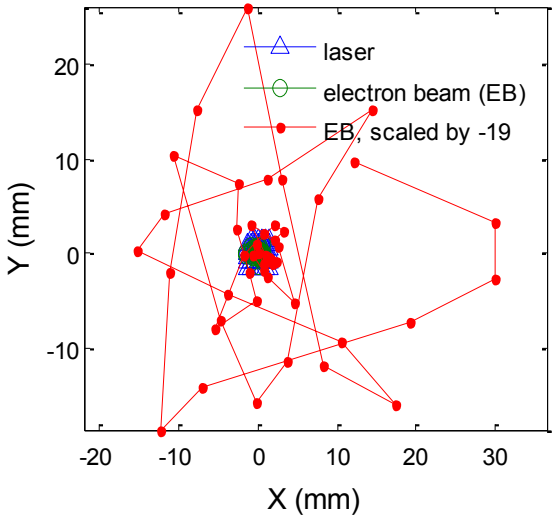
Bunch charge (Schottky) scan



Laser positions at the cathode (centered)

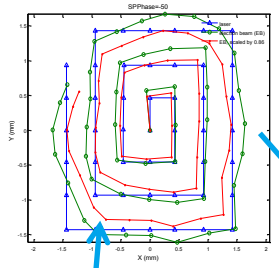


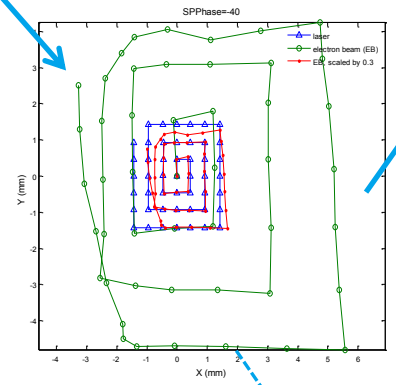
Laser/electron beam position

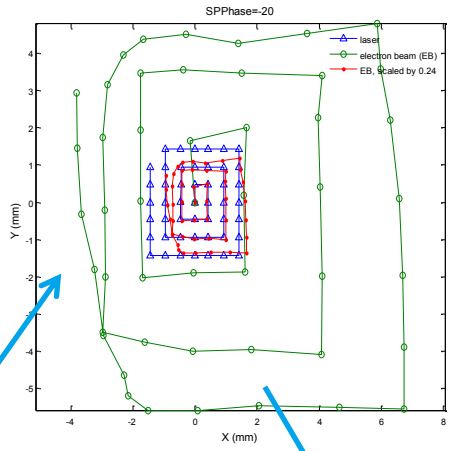


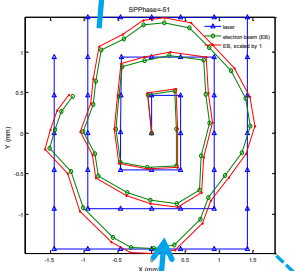
RF-gun coupler kick measurements at EXFEL

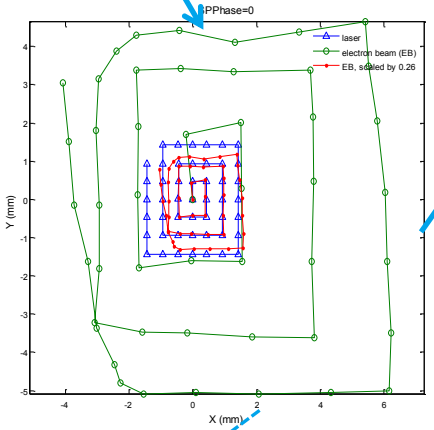
13-14.12.2016

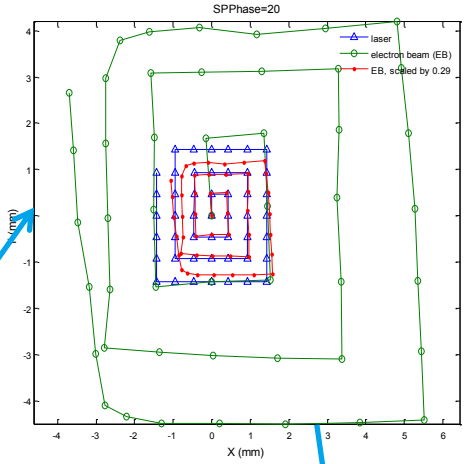


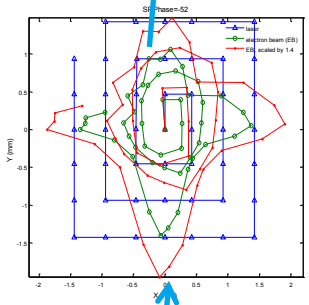


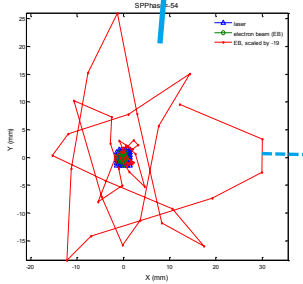


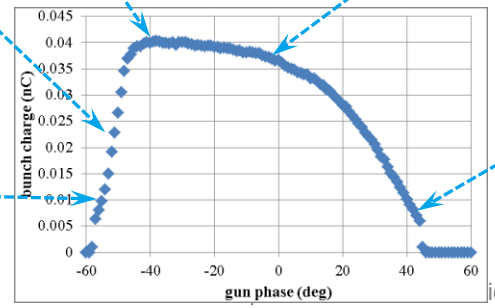


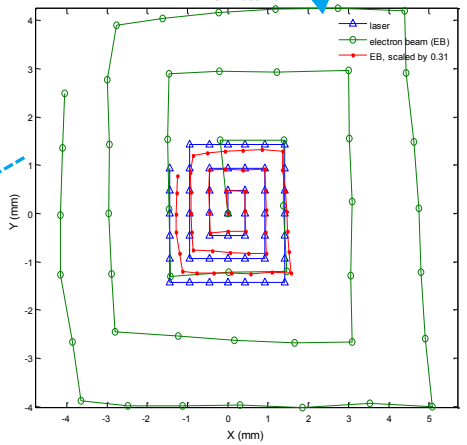








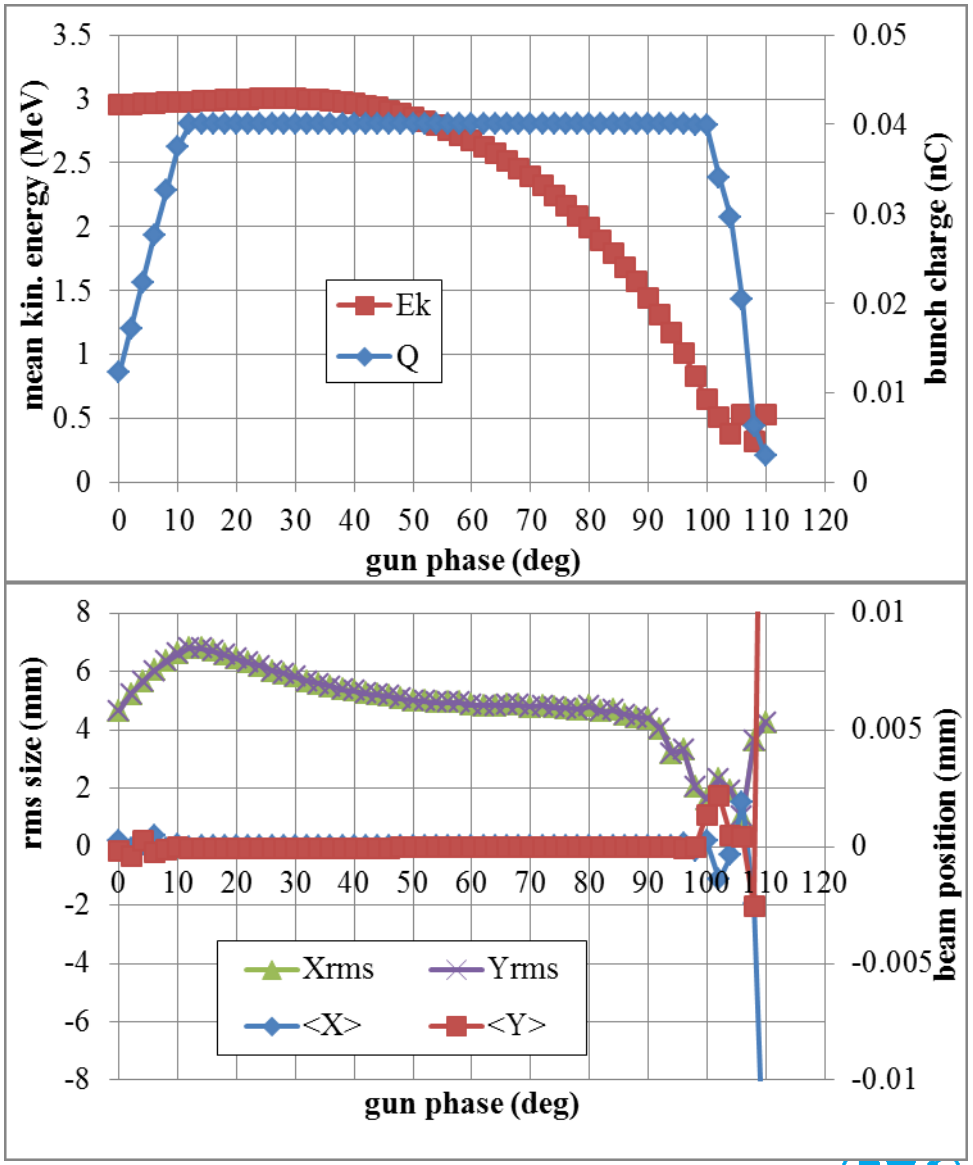




ies at PITZ in 201

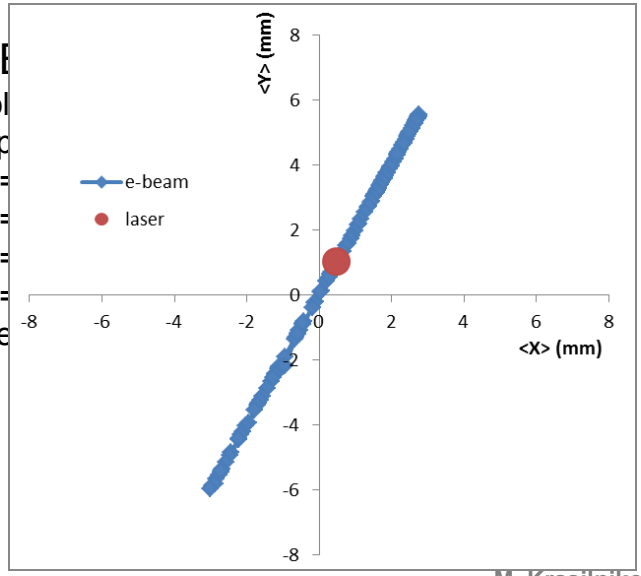
ASTRA simulations

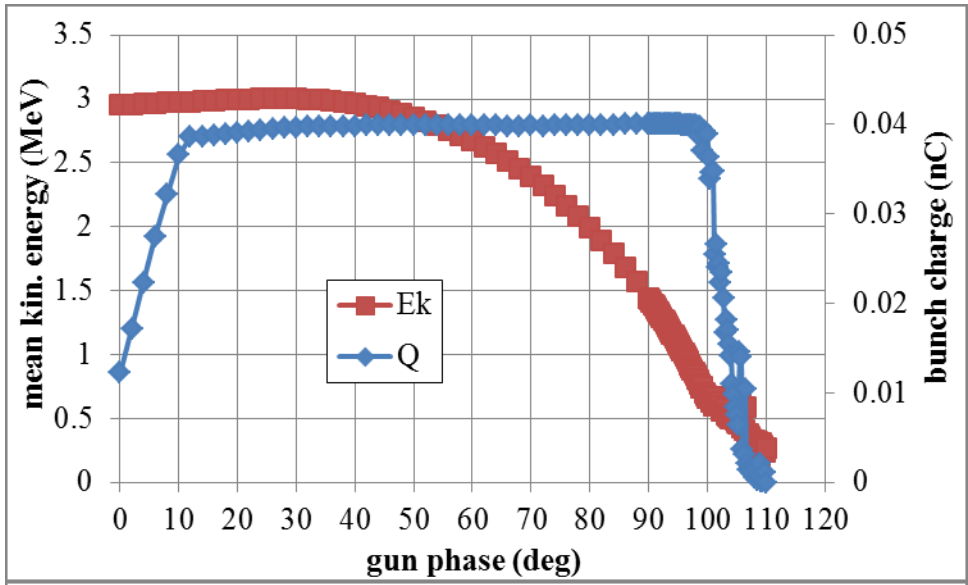
- Cathode laser
  - Distribution = 'cathGL_200k.ini' → long Gaussian
  - Xoff=0, Yoff=0
  - AUTO_PHASE=f
  - XYrms= 0.2mm
  - Trms=4.88ps
  - Qbunch=0.04nC
- ZSTOP=1.05 → 1st BPM
- Gun:
  - MaxE(1)=-29.9526 MV/m
- Solenoid → off
- &DIPOLE
  - LDipole=.F,
  - D_Type(1)='hor'
  - D1(1)=(1,-1)
  - D2(1)=(-1,-1)
  - D3(1)=(1,2)
  - D4(1)=(-1,2)
  - D_strength(1)=0.0001...0.001T

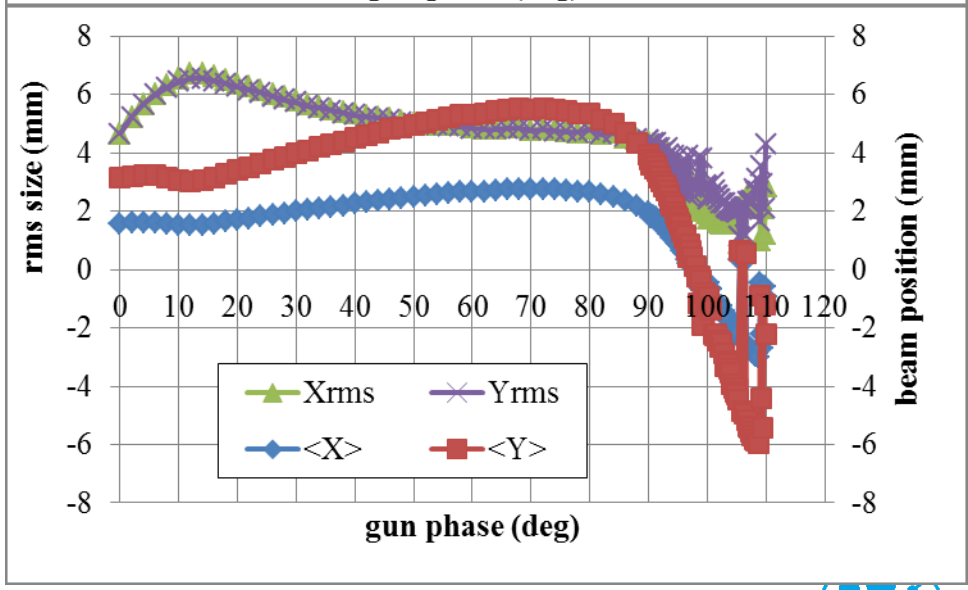


ASTRA simulations

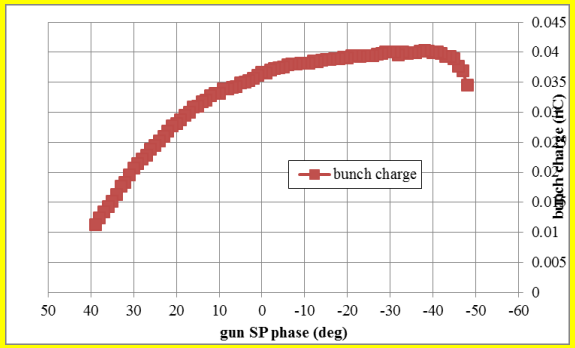
- Cathode laser
  - Distribution = 'cathGL_200k.ini' → long Gaussian
  - **Xoff=0.5mm, Yoff=1.0 mm**
  - AUTO_PHASE=f
  - XYrms= 0.2mm
  - Trms=4.88ps
  - Qbunch=0.04nC
- ZSTOP=1.05 → 1st BPM
- Gun:
  - MaxE(1)=-29.9526 MV/m
- Solenoid → off
- &DIPOLE
  - LDipol
  - D_Typ
  - D1(1)=
  - D2(1)=
  - D3(1)=
  - D4(1)=
  - D_stre

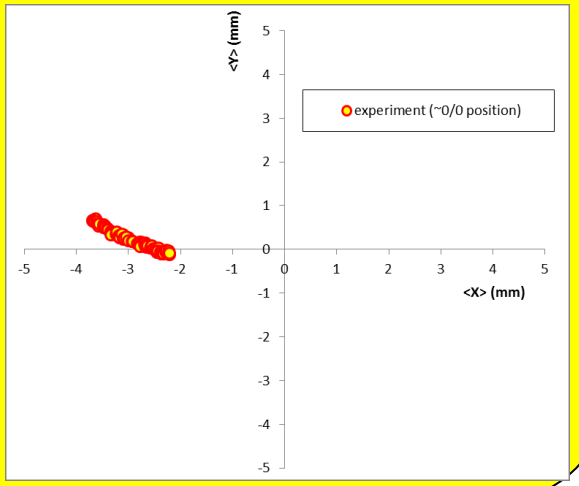


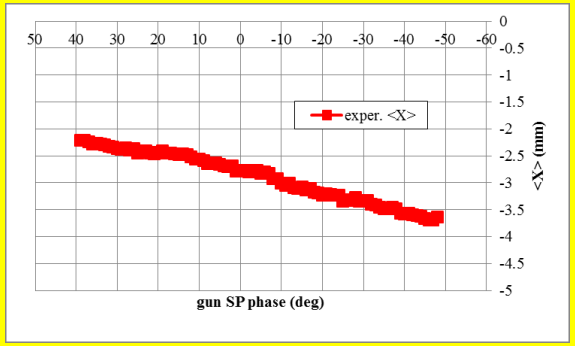


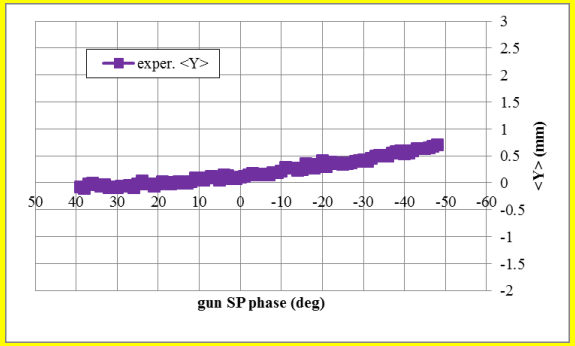


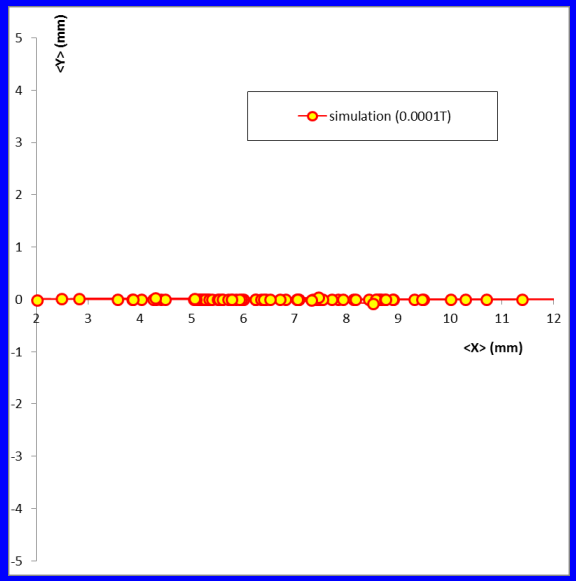
ASTRA simulations vs. experiment for 0/0 position

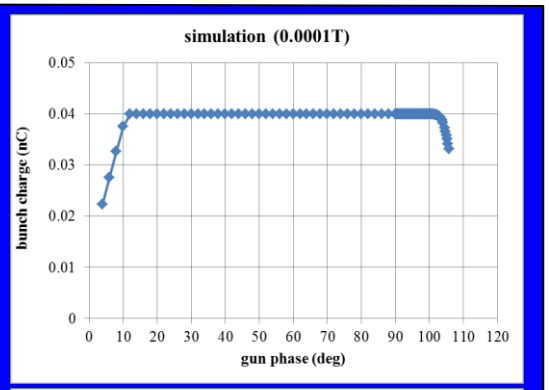


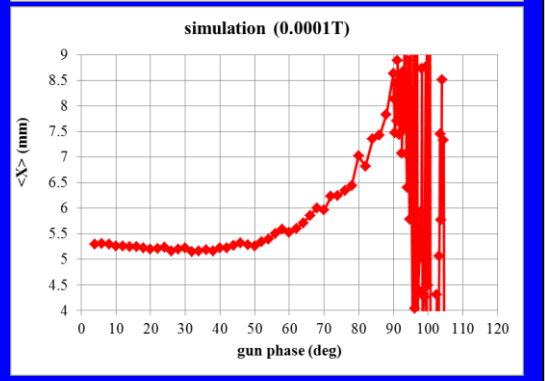


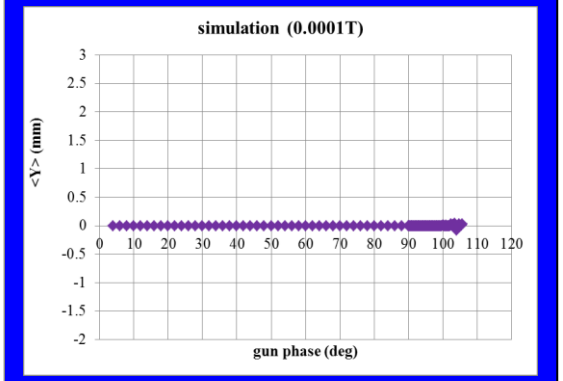












- D3(1)=(1,2)
- D4(1)=(-1,2)
- **D_strength(1)=0.0001T** /5?

Summary

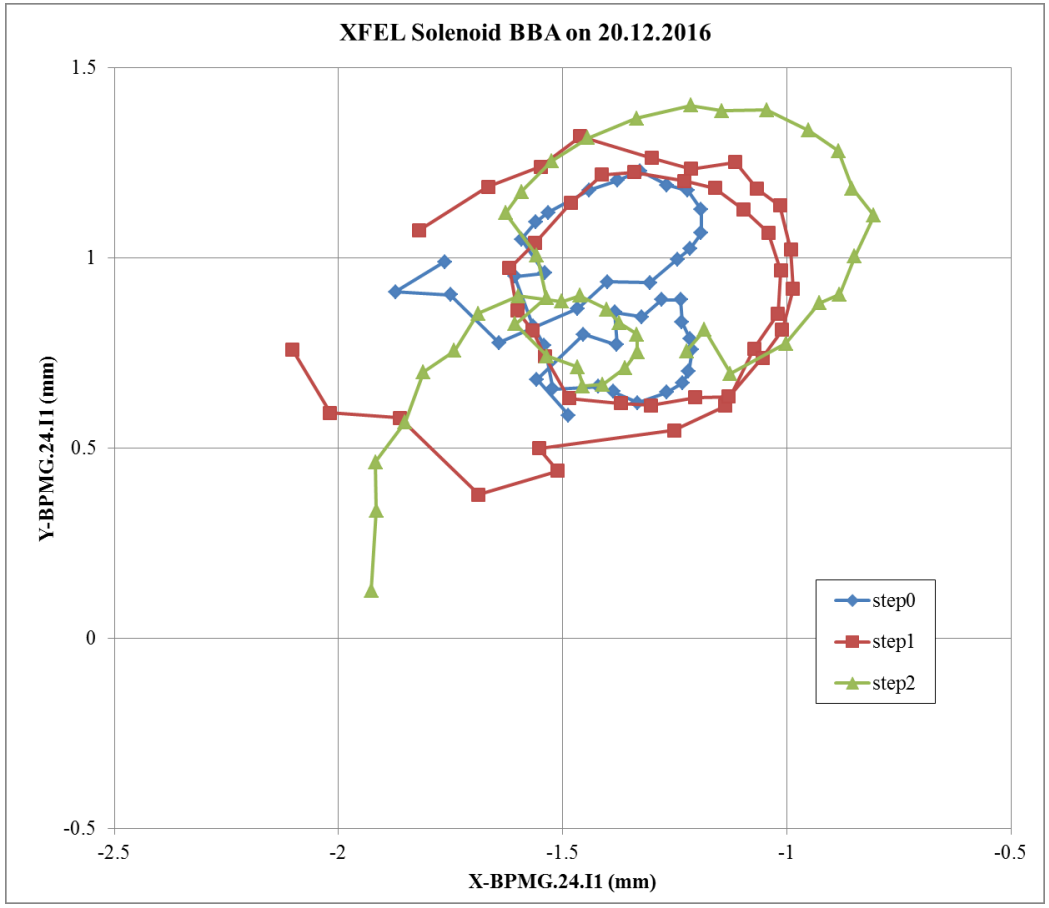
- XFEL gun solenoid was aligned with available precision (Angles ~0.001 and smaller, offsets <100um)
- Systematic limitation for the solenoid BBA – stray magnetic fields in the gun region and possible RF coupler/solenoid quad kicks
- One way to estimate these effects – RF coupler kick measurements performed on 13-14.12.2016 for 1.5MW in the gun cavity measuring beam position for all gun phases w/o solenoids. Similar measurements for e.g. 5MW would be of interest
- ASTRA simulations have been performed
  - For 30MV/m, phase scan→ phase range is larger by ~10deg, the Schottky scan curve shaper is rather different
  - Next → try to fit “absolute” measurements (+orientation), but BPM offset has to be put into consideration
- …

Backup slides

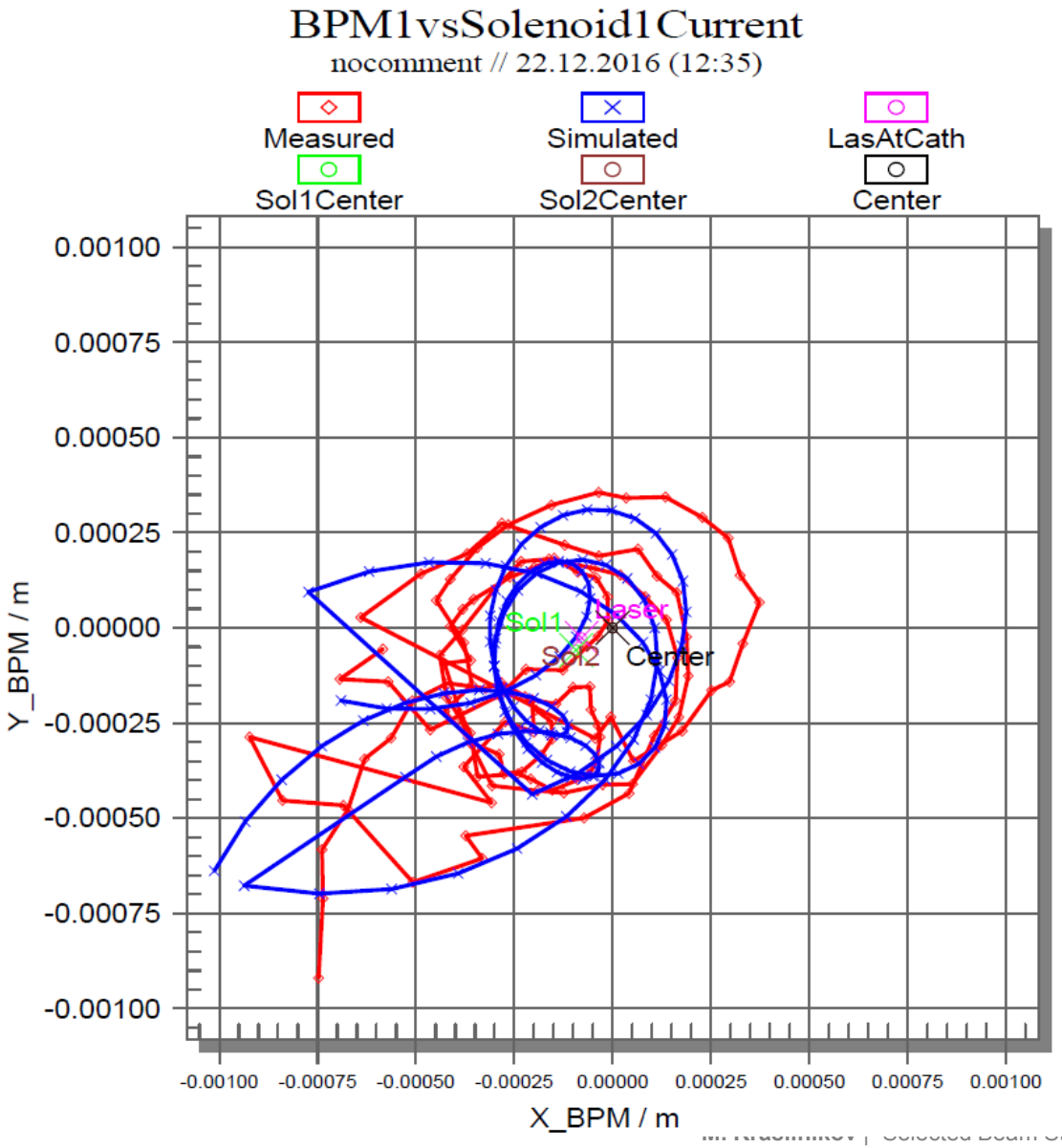
- Solenoid BBA at XFEL photo injector

Measurements 21.12.2016N

roll	yaw	pitch	x	y	file	DXsol	DYsol	steps
-2	2.1	-2.95	-0.27	0.22	2016-12-22T042904	0	0	step0
-2	2.1	-2.95	-0.17	0.22	2016-12-22T051855	0.1	0	step1
-2	2.1	-2.95	-0.27	0.32	2016-12-22T054553	0	0.1	step2



Simulations (Ez=30MV/m, Phi=-153deg →fixed)



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0.000312 deg

RF-GunPITZ : AngleYSolMain = -0.00196 deg

RF-GunPITZ : Laser_Beam_CenterX = -7.87e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.64e-005 m

RF-GunPITZ : XSolMainCenter = -9.29e-005 m

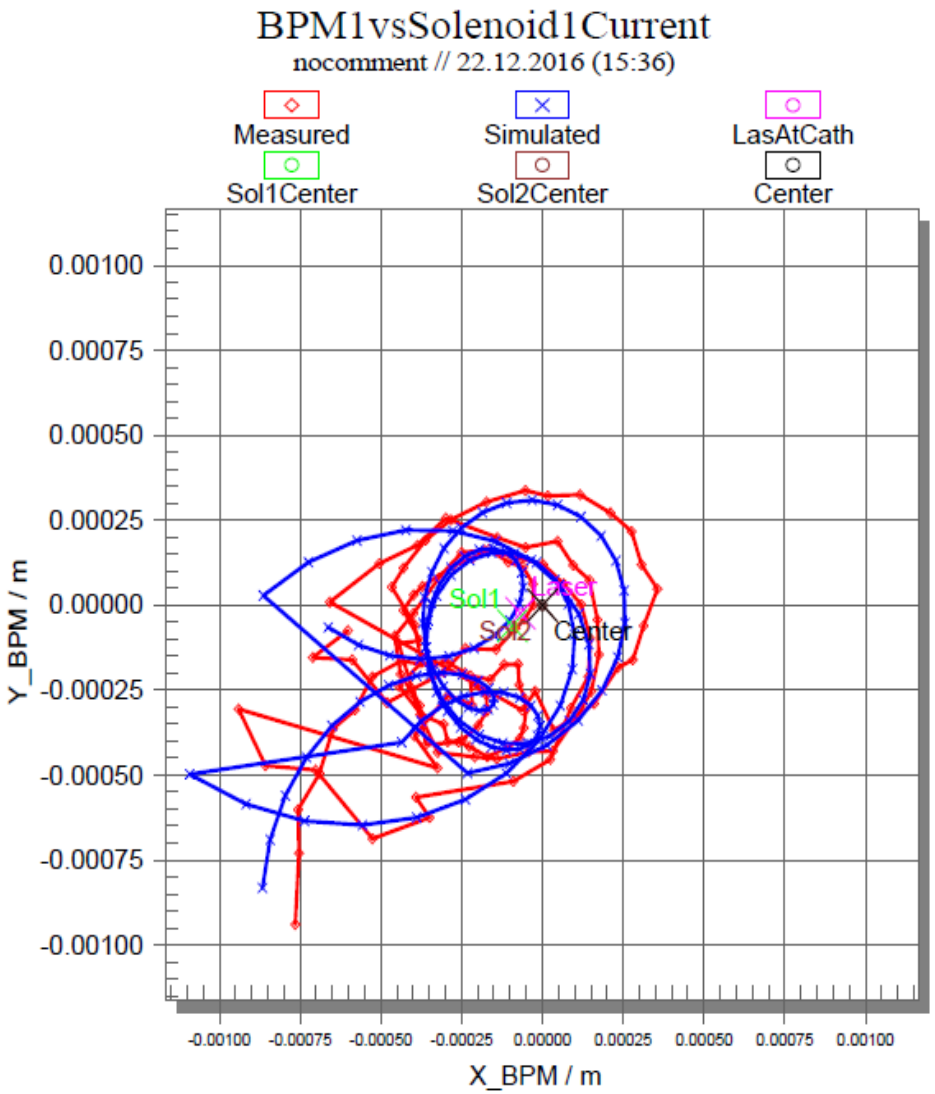
RF-GunPITZ : YSolMainCenter = -5.92e-005 m

Offsets List / [m]

X_BPM = 0.000653181

Y_BPM = 0.000590166

Simulations (Ez, Phi →tuned)



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0.00107 deg

RF-GunPITZ : AngleYSolMain = -0.00176 deg

RF-GunPITZ : Ez_Field_At_Cathode = 30 MV/m

RF-GunPITZ : Initial_Phase = -117 degree

RF-GunPITZ : Laser_Beam_CenterX = -6.77e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.34e-005 m

RF-GunPITZ : XSolMainCenter = -9.33e-005 m

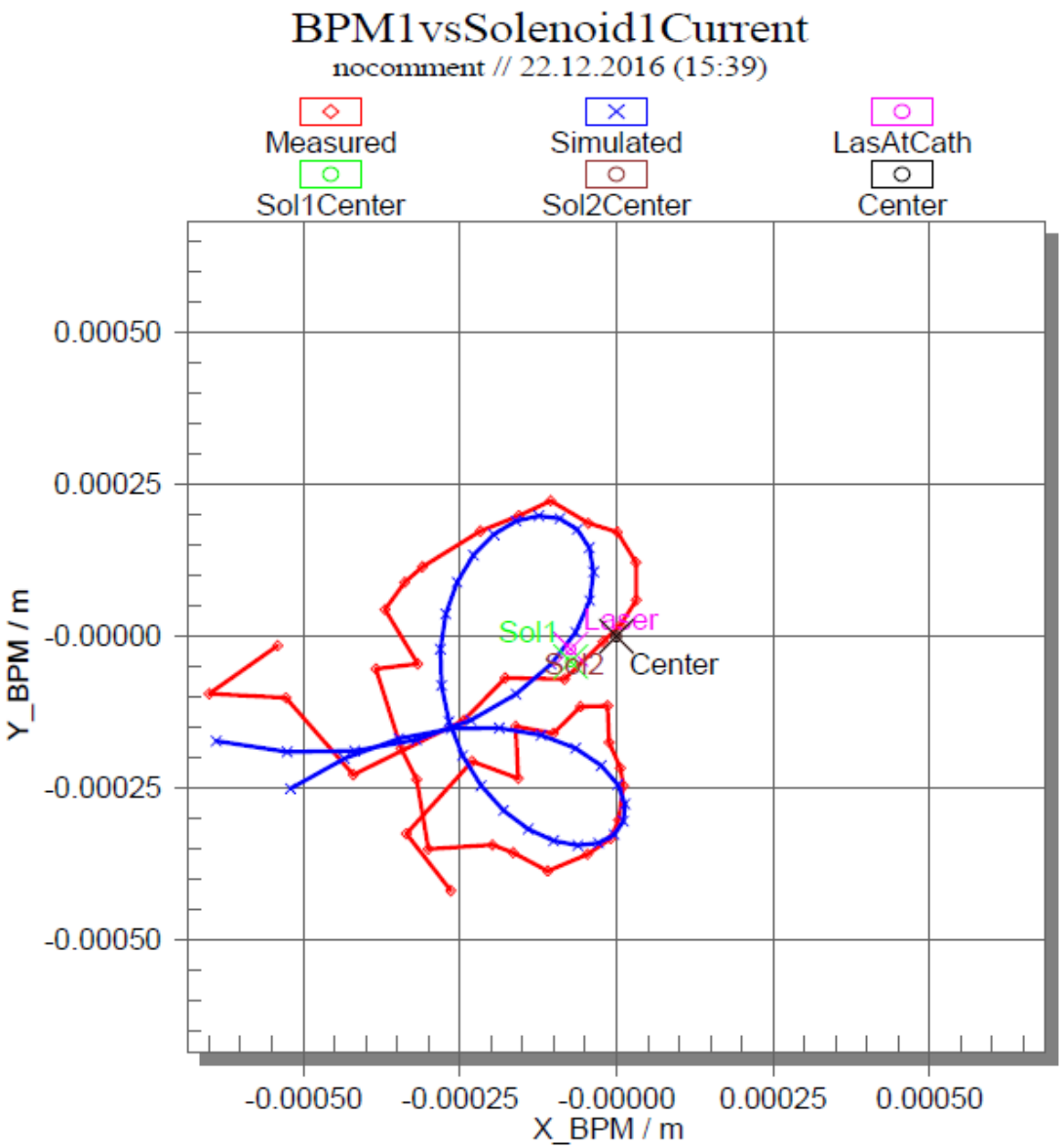
RF-GunPITZ : YSolMainCenter = -6.11e-005 m

Offsets List / [m]

X_BPM = 0.000670787

Y_BPM = 0.000609132

Simulations: step 0 only (“best”)



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0.000524 deg

RF-GunPITZ : AngleYSolMain = -0.00112 deg

RF-GunPITZ : Laser_Beam_CenterX = -7.36e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.12e-005 m

RF-GunPITZ : XSolMainCenter = -7.28e-005 m

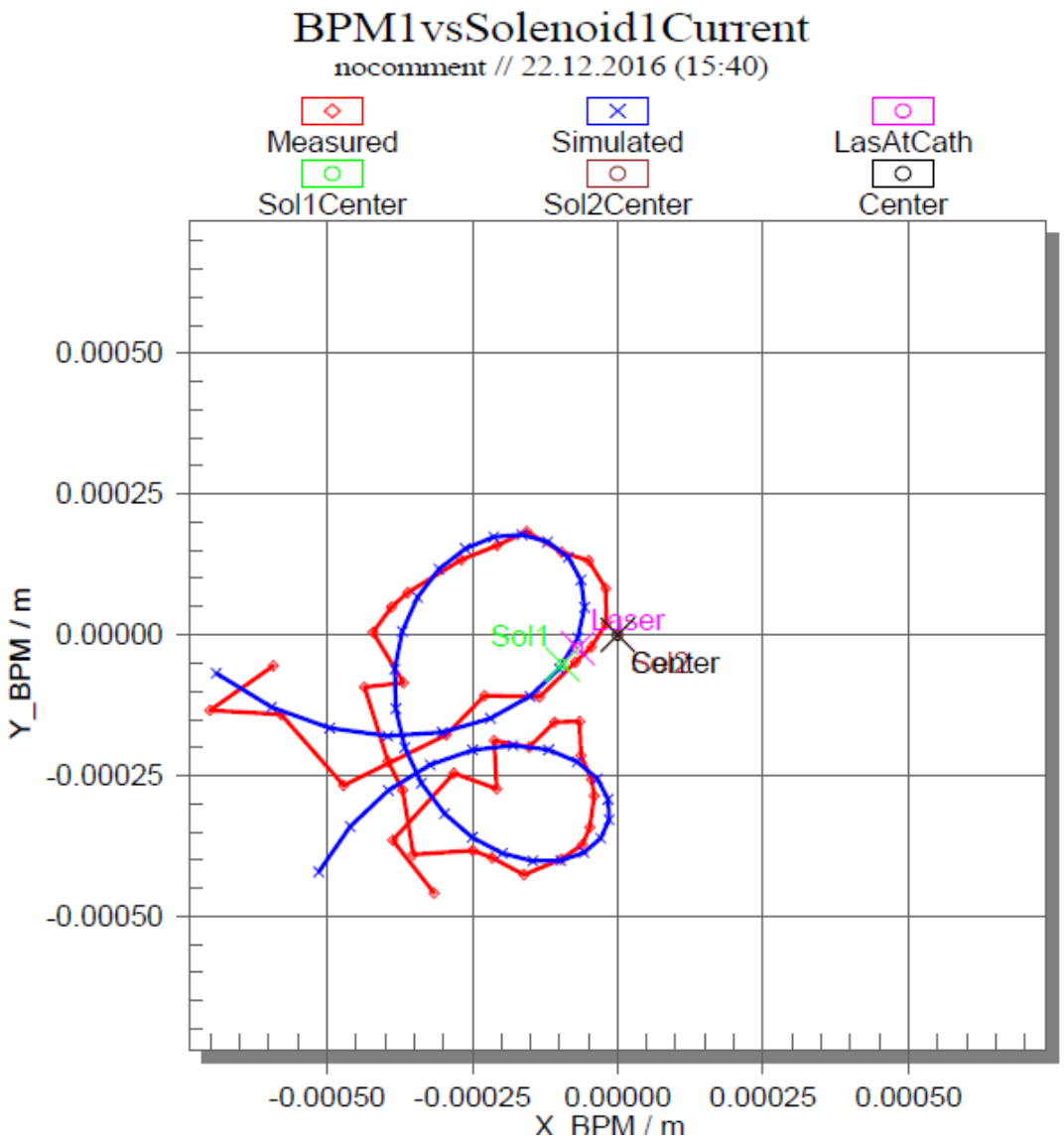
RF-GunPITZ : YSolMainCenter = -4.16e-005 m

Offsets List / [m]

X_BPM = 0.000609963

Y_BPM = 0.000549828

Simulations: step 0 only ("best", Ez,Phi tuned)



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0.000959 deg

RF-GunPITZ : AngleYSolMain = -0.00141 deg

RF-GunPITZ : Ez_Field_At_Cathode = 31.9 MV/m

RF-GunPITZ : Initial_Phase = -106 degree

RF-GunPITZ : Laser_Beam_CenterX = -6.91e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.36e-005 m

RF-GunPITZ : XSolMainCenter = -9.5e-005 m

RF-GunPITZ : YSolMainCenter = -5.23e-005 m

Offsets List / [m]

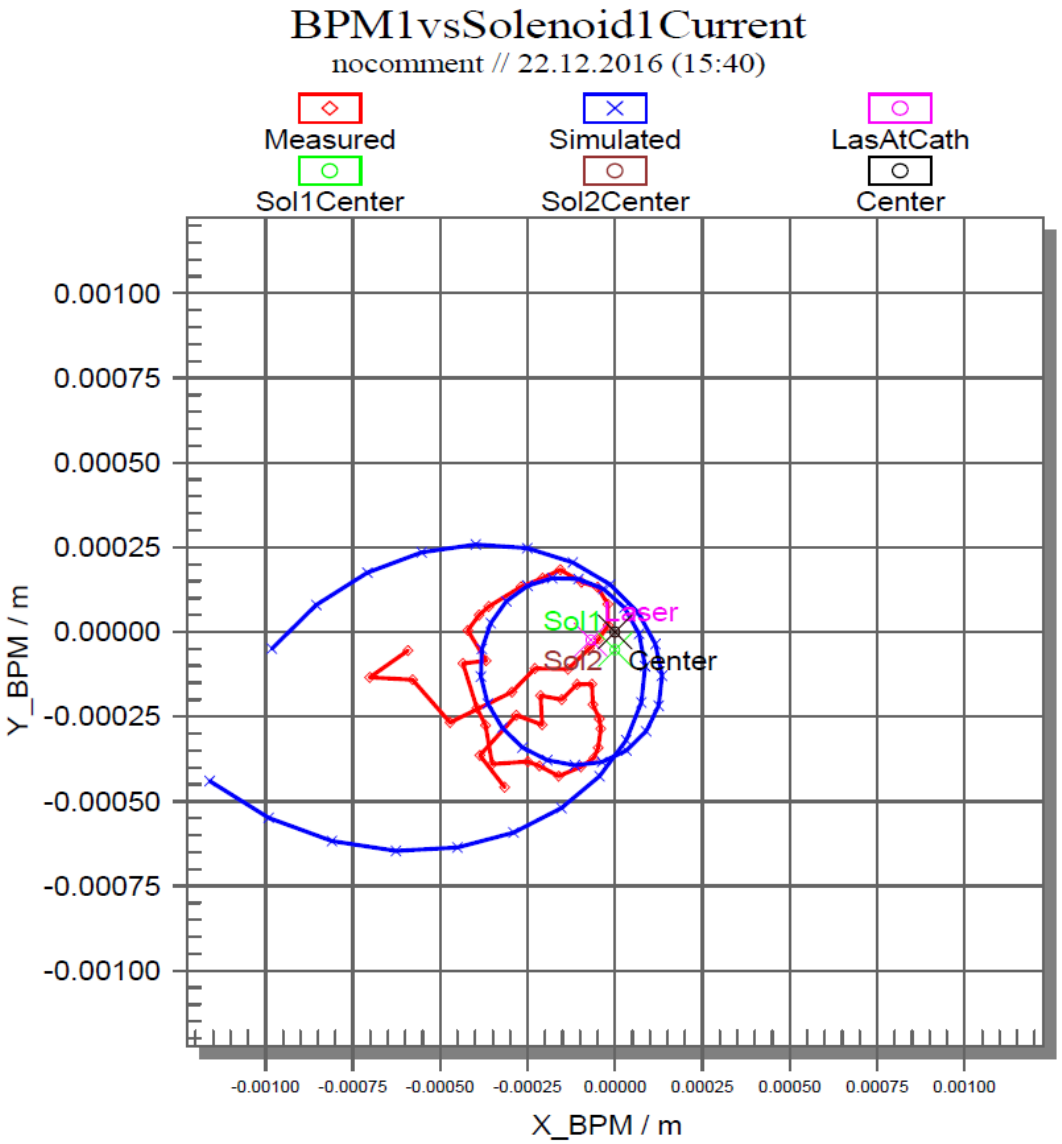
X_BPM = 0.000661434

Y_BPM = 0.00058932

Next Steps (?)

- We are probably coming to systematic limit of the procedure (measurements + solenoid positioning)
- Angles ~0.001 and smaller, offsets <100um
- Improve stability/reliability of BPM measurements (curves should be smoother). ?Increase BSA to 1-1.2mm?
- ?try 2D (Xsol,Ysol), step 50 um scan w.r.t. the actual position?

Simulations: step 0 only: Xsol→0



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0.000959 deg

RF-GunPITZ : AngleYSolMain = -0.00141 deg

RF-GunPITZ : Ez_Field_At_Cathode = 31.9 MV/m

RF-GunPITZ : Initial_Phase = -106 degree

RF-GunPITZ : Laser_Beam_CenterX = -6.91e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.36e-005 m

RF-GunPITZ : XSolMainCenter = 0 m

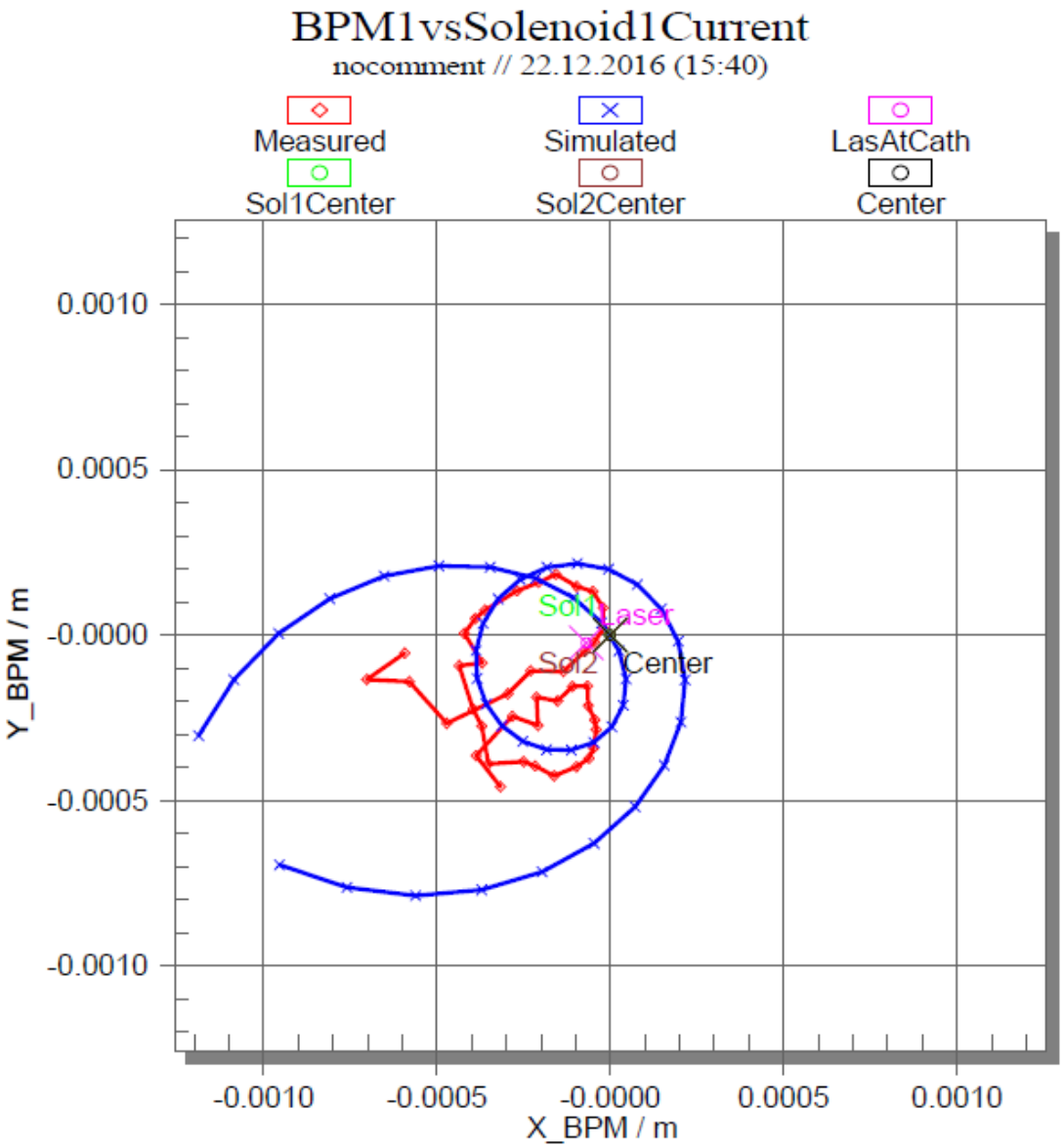
RF-GunPITZ : YSolMainCenter = -5.23e-005 m

Offsets List / [m]

X_BPM = 0.000661434

Y_BPM = 0.00058932

Simulations: step 0 only: Xsol→0; Ysol→0



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0.000959 deg

RF-GunPITZ : AngleYSolMain = -0.00141 deg

RF-GunPITZ : Ez_Field_At_Cathode = 31.9 MV/m

RF-GunPITZ : Initial_Phase = -106 degree

RF-GunPITZ : Laser_Beam_CenterX = -6.91e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.36e-005 m

RF-GunPITZ : XSolMainCenter = 0 m

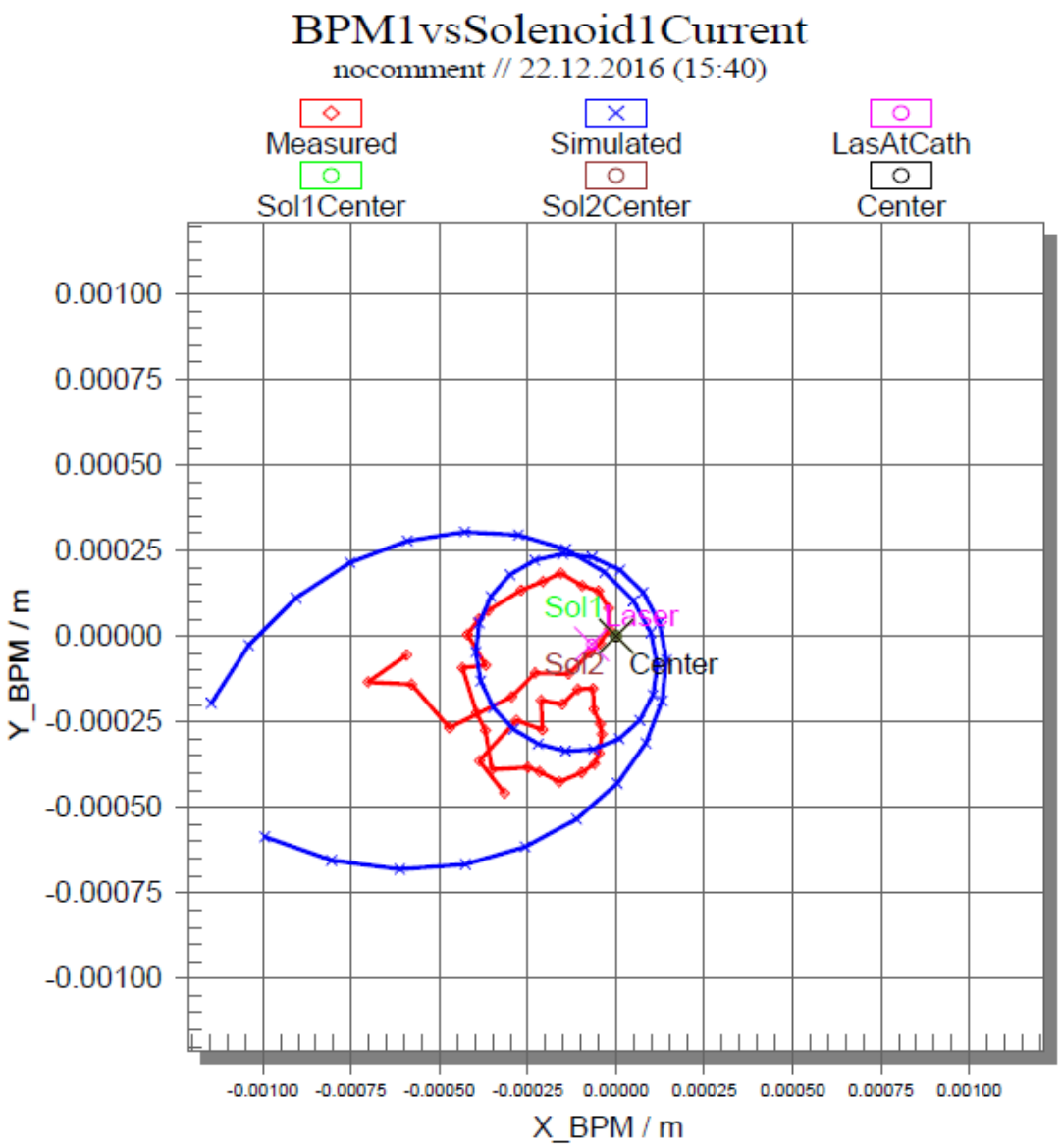
RF-GunPITZ : YSolMainCenter = 0 m

Offsets List / [m]

X_BPM = 0.000661434

Y_BPM = 0.00058932

Simulations: step 0 only:
Xsol→0; Ysol→0; Y-angle→0



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0.000959 deg

RF-GunPITZ : AngleYSolMain = 0 deg

RF-GunPITZ : Ez_Field_At_Cathode = 31.9 MV/m

RF-GunPITZ : Initial_Phase = -106 degree

RF-GunPITZ : Laser_Beam_CenterX = -6.91e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.36e-005 m

RF-GunPITZ : XSolMainCenter = 0 m

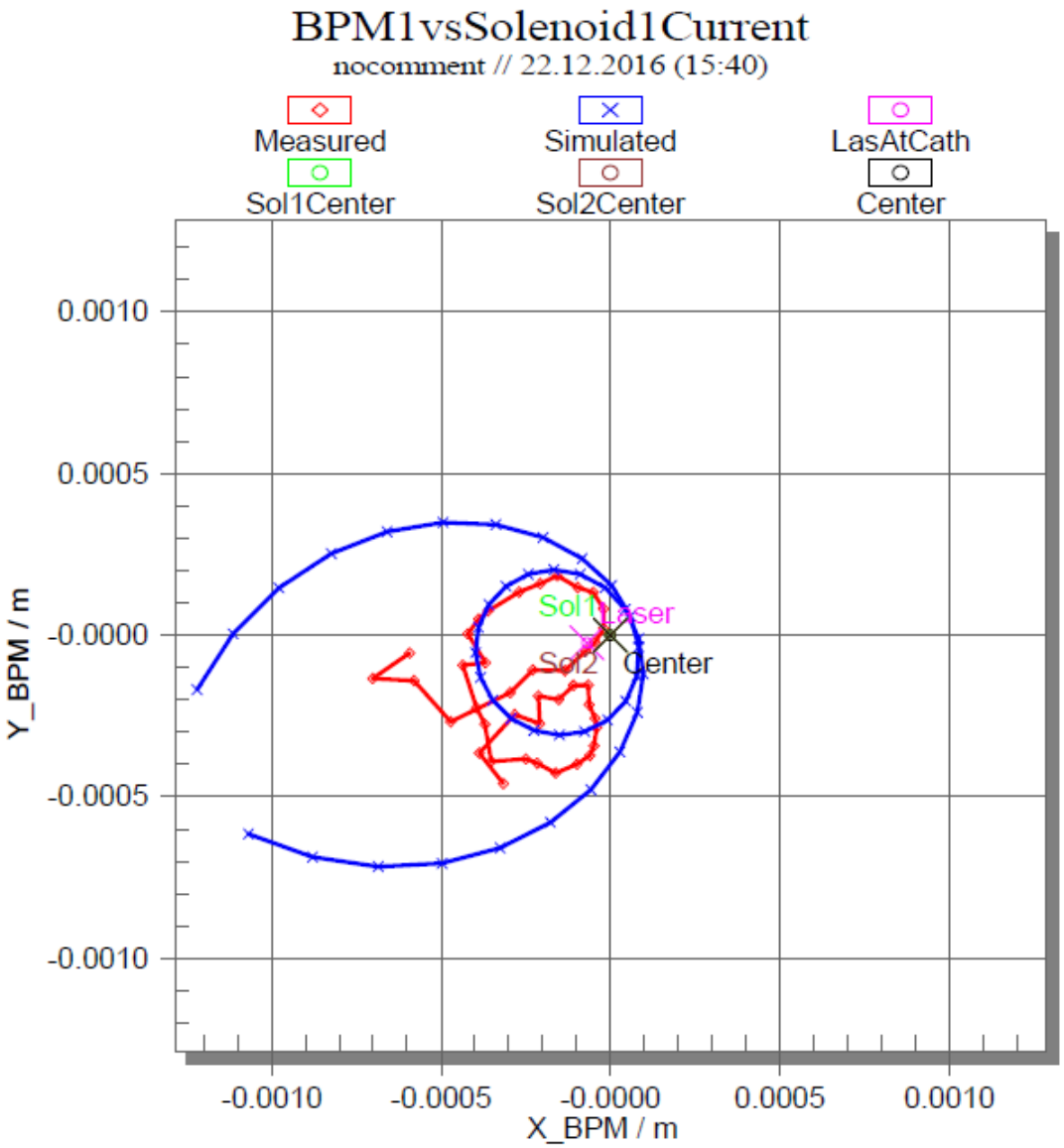
RF-GunPITZ : YSolMainCenter = 0 m

Offsets List / [m]

X_BPM = 0.000661434

Y_BPM = 0.00058932

Simulations: step 0 only:
Xsol→0; Ysol→0; Y-angle→0 ; X-angle→0



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0 deg

RF-GunPITZ : AngleYSolMain = 0 deg

RF-GunPITZ : Ez_Field_At_Cathode = 31.9 MV/m

RF-GunPITZ : Initial_Phase = -106 degree

RF-GunPITZ : Laser_Beam_CenterX = -6.91e-005 m

RF-GunPITZ : Laser_Beam_CenterY = -2.36e-005 m

RF-GunPITZ : XSolMainCenter = 0 m

RF-GunPITZ : YSolMainCenter = 0 m

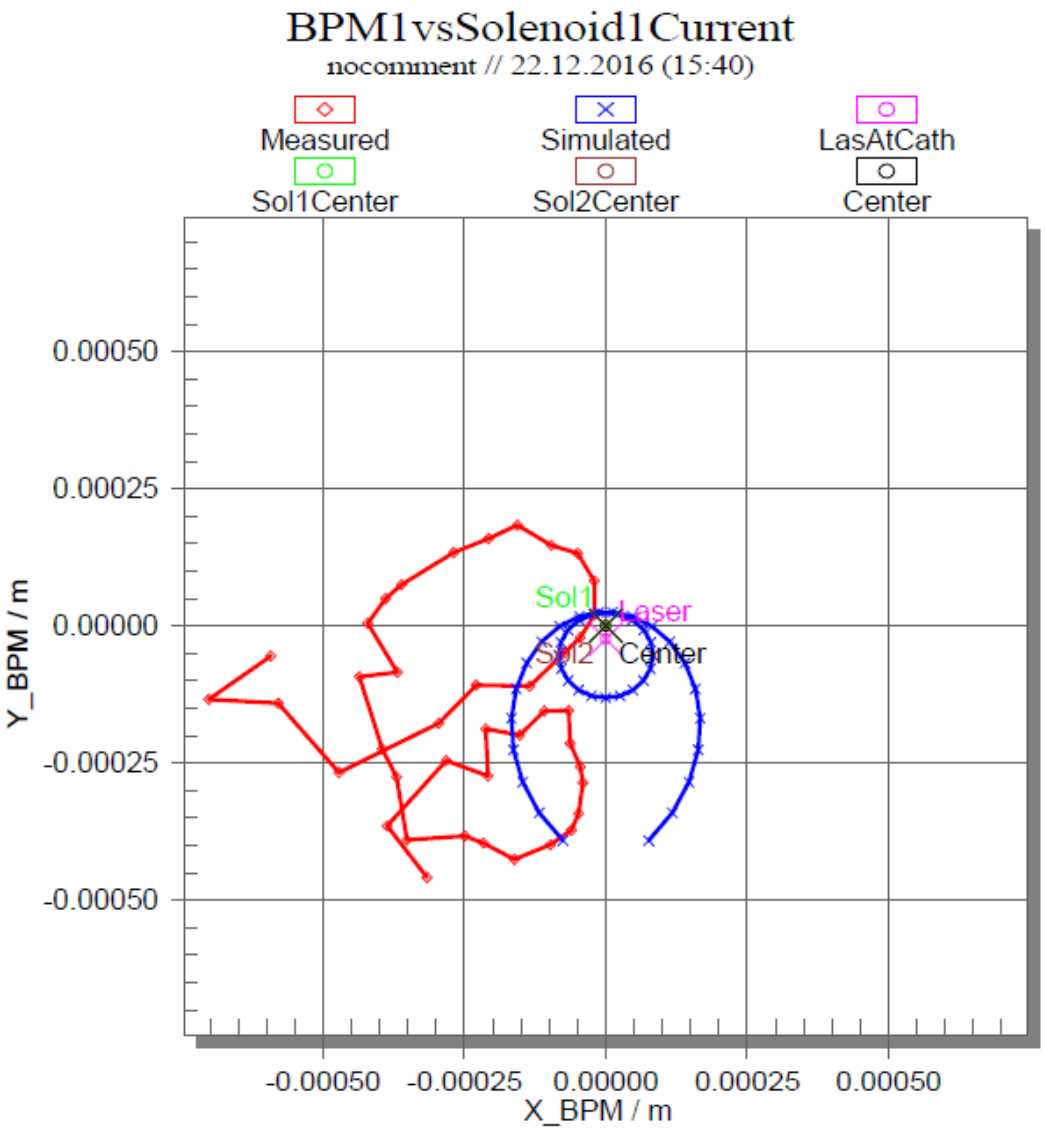
Offsets List / [m]

X_BPM = 0.000661434

Y_BPM = 0.00058932

Simulations: step 0 only:

Xsol→0; Ysol→0; Y-angle→0 ; X-angle→0 ; Y-angle→0; Xlas→0



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0 deg

RF-GunPITZ : AngleYSolMain = 0 deg

RF-GunPITZ : Ez_Field_At_Cathode = 31.9 MV/m

RF-GunPITZ : Initial_Phase = -106 degree

RF-GunPITZ : Laser_Beam_CenterX = 0 m

RF-GunPITZ : Laser_Beam_CenterY = -2.36e-005 m

RF-GunPITZ : XSolMainCenter = 0 m

RF-GunPITZ : YSolMainCenter = 0 m

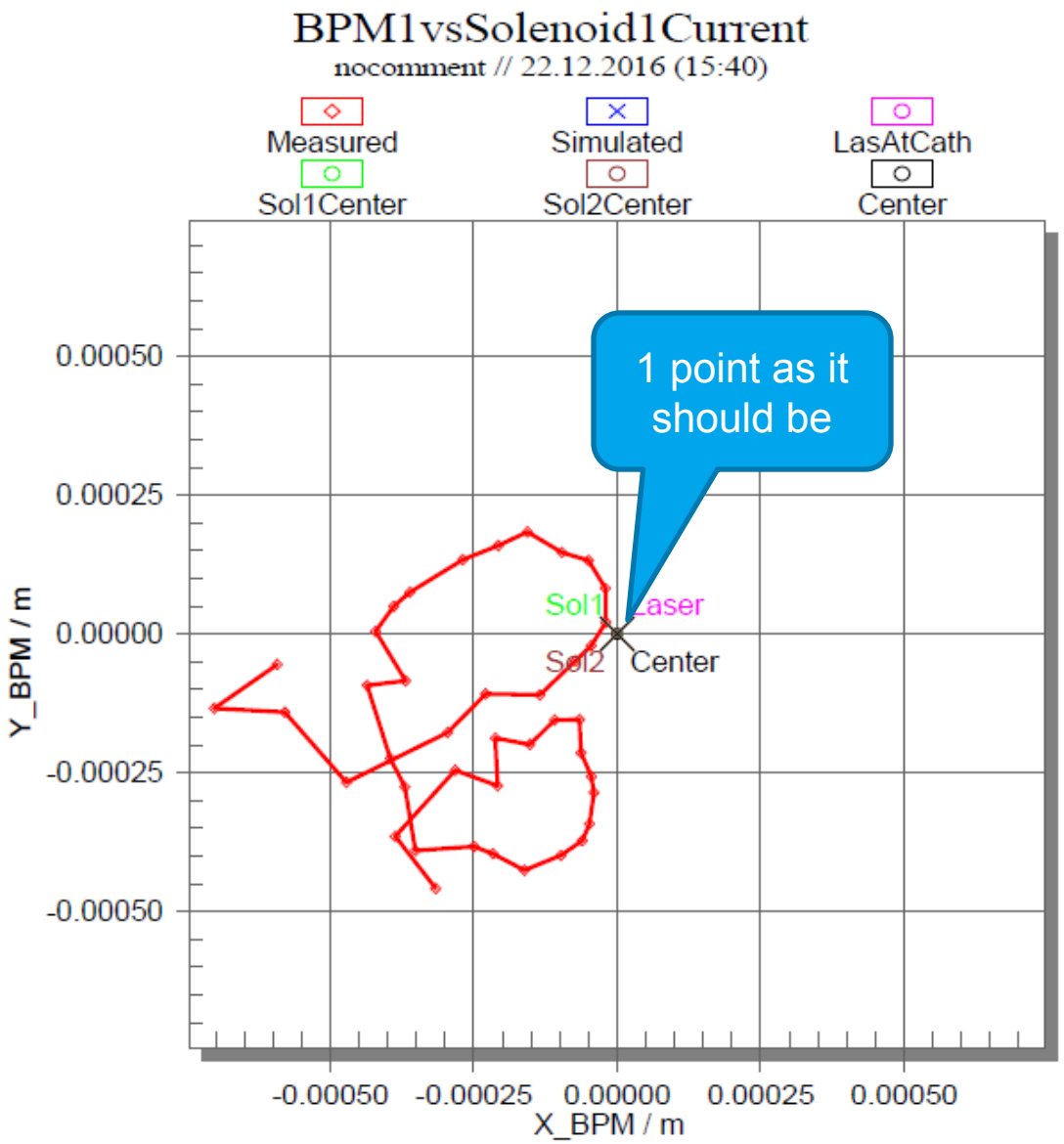
Offsets List / [m]

X_BPM = 0.000661434

Y_BPM = 0.00058932

Simulations: step 0 only:

Xsol→0; Ysol→0; Y-angle→0 ; X-angle→0 ; Y-angle→0; Xlas→0; Ylas→0



Fit Parameters List

RF-GunPITZ : AngleXSolMain = 0 deg

RF-GunPITZ : AngleYSolMain = 0 deg

RF-GunPITZ : Ez_Field_At_Cathode = 31.9 MV/m

RF-GunPITZ : Initial_Phase = -106 degree

RF-GunPITZ : Laser_Beam_CenterX = 0 m

RF-GunPITZ : Laser_Beam_CenterY = 0 m

RF-GunPITZ : XSolMainCenter = 0 m

RF-GunPITZ : YSolMainCenter = 0 m

Offsets List / [m]

X_BPM = 0.000661434

Y_BPM = 0.00058932