Electron beam asymmetry compensation with gun quadrupoles at PITZ.

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Abstract

The electron beam asymmetry observed at the Photo Injector Test Facility at DESY in Zeuthen (PITZ) was traced back to multipole kicks in the gun section, namely around the location of the coaxial power coupler and the main solenoid. Several dedicated studies have been performed to quantify the kick location and strength. Based on these studies, two designs of correction quadrupole coils were proposed. The coils were fabricated and tested with an electron beam. The second updated design implies a two quadrupole setup on the same frame installed around the gun coaxial coupler close to the main solenoid centre location. Skew and normal quadrupole magnets are powered independently, enabling the flexibility in electron beam manipulations. By means of this setup, a more symmetric beam was obtained at several screens. This led also to more equal measured horizontal and vertical phase spaces and to even smaller overall emittance values. Some details of the gun quadrupole designs, magnetic measurements, and results of electron beam measurements including emittance optimization will be reported.

Motivation: asymmetric electron beam in a rotationally symmetric RF-gun:

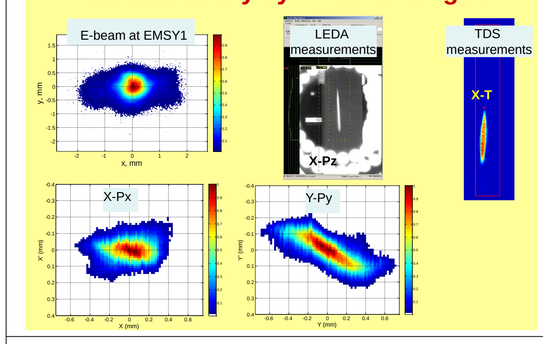
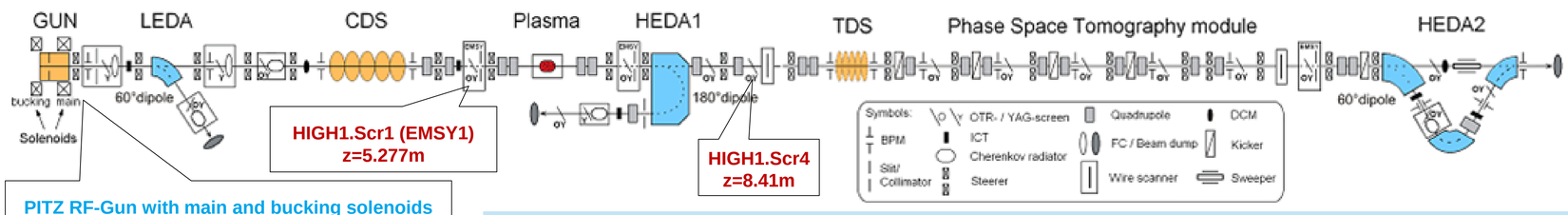
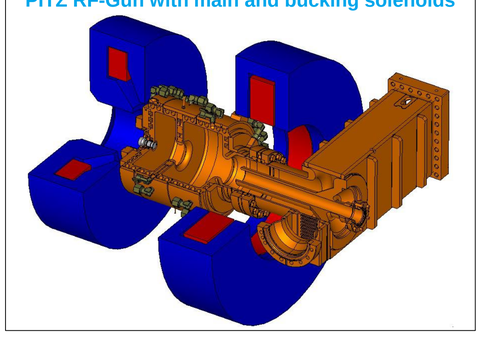


Photo Injector Test facility at DESY, Zeuthen site (PITZ)



PITZ RF-Gun with main and bucking solenoids



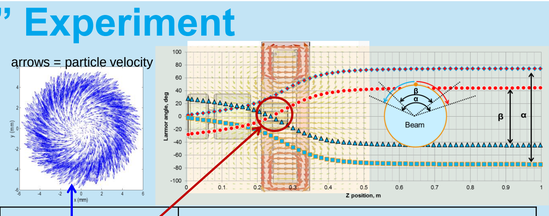
Possible sources of the beam asymmetry:

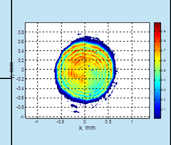
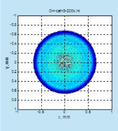
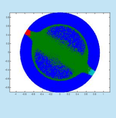
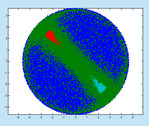
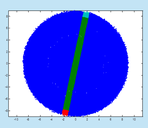
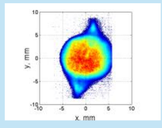
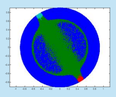
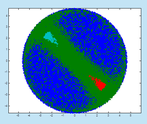
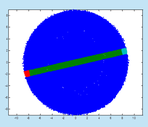
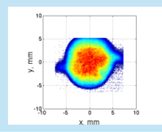
- ~~Vacuum mirror~~
- **RF coupler field asymmetry**
  → ***poster WEP005, Y. Chen et al., "Coaxial Coupler RF Kick in the PITZ RF Gun"***
- **Solenoid imperfections (anomalous quadrupole fields)**
  → ***poster WEP010, Q. Zhao "Beam Asymmetry Studies with Quadrupole Field Errors in the PITZ Gun Section"***

"Larmor angle" Experiment

Measurements (29.09.2015M-A):
- P_{gun}=5 MW (6.1 MeV/c max)
- Launch phase: MMMG
- Cathode laser:
  - Gaussian 11.5 ps FWHM
  - BSA=1.2mm (VC2)
- Charge 0.5 nC

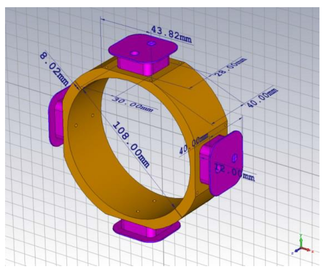
Main idea:
"track back" electron beam transverse tails observed at HIGH1.Scr1 for both main solenoid polarities until orientations of "tail particles" coincides

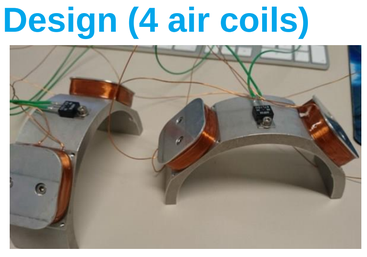


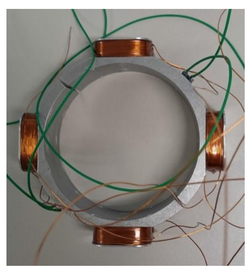
Main solenoid max[B_z], (I_{main} for meas.)	Laser X-Y distribution at cathode			Electron beam X-Y distribution simulated at z=0.18 m	E-beam X-Y distribution at z=5.277 m	
	Measured at VC2	Used in simulations			Simulated	Measured at EMSY1
-0.2087T (-360A) opposite polarity		Core + Halo 				
+0.2087T (+360A) normal polarity						

Design of compensating gun quadrupoles

1st Design (4 air coils)

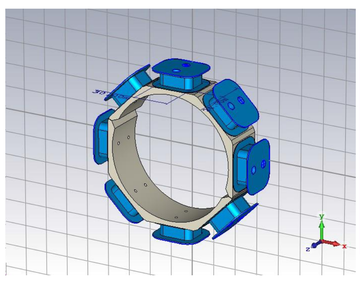


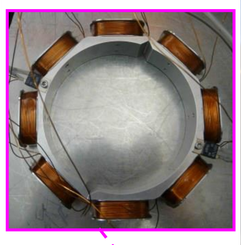


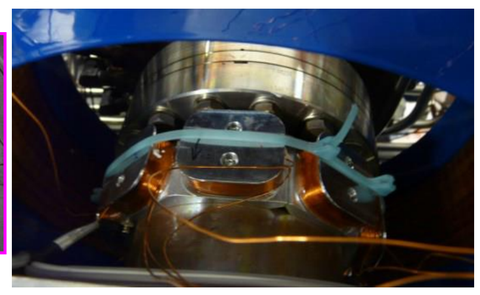


Parameters:
- Aluminum frame
- 0.56 mm copper cable
- 180 windings per coil
- 2 thermal switchers (80 degC max)
- Non-magnetic screws
- Fixed by radiation-hard cable tie
- Usage with 3A power supply
- **Q_grad = 0.0207 T/m @ 1A**

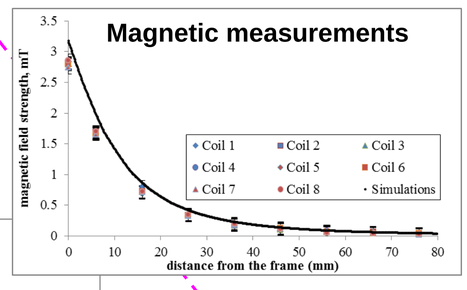
2nd Design (8 air coils)

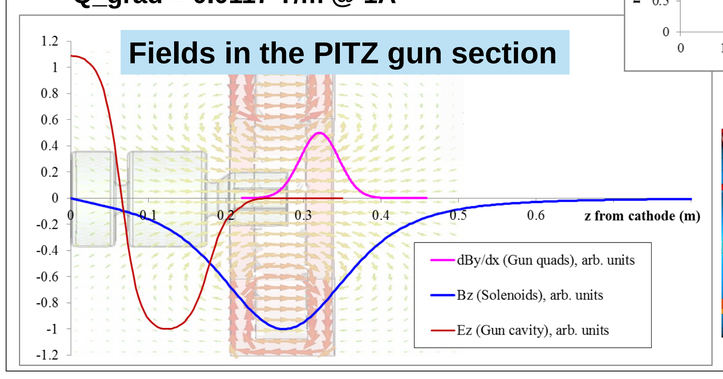


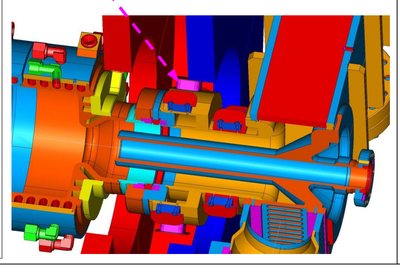




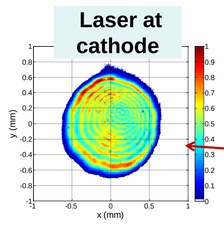
Parameters:
- Combination of a **normal (Gun.Quad1)** and a **skew (Gun.Quad2)** quads
- Aluminum frame
- 0.56 mm copper cable
- 140 windings per coil
- 2 thermal switchers (80 degC max)
- Non-magnetic screws
- Fixed by radiation-hard cable tie
- **Q_grad = 0.0117 T/m @ 1A**





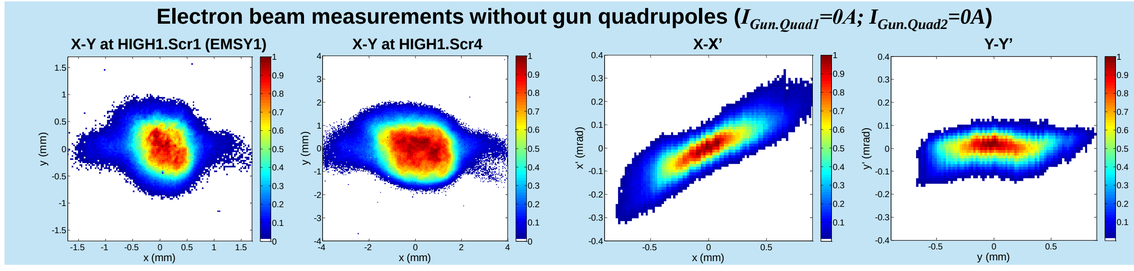


First tests with electron beam

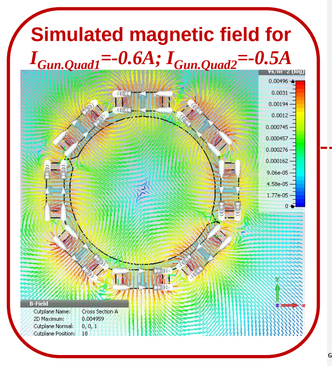


Machine parameters:
- P_{gun}=6.6MW, MMMG → <P_z>=6.5MeV/c
- $P_{booster}$=3.0MW, MMMG → <P_z>=22.3MeV/c
- Photocathode laser (11.5ps FWHM, ∅=1.2mm
- Bunch charge→ 0.5nC

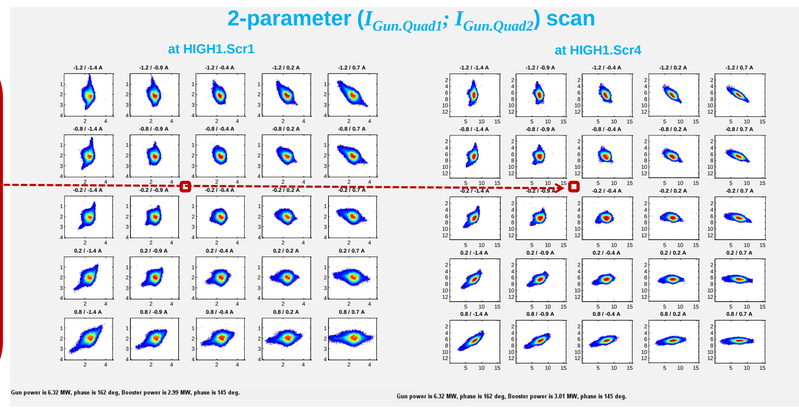
Electron beam measurements without gun quadrupoles ($I_{Gun.Quad1}$=0A; $I_{Gun.Quad2}$=0A)



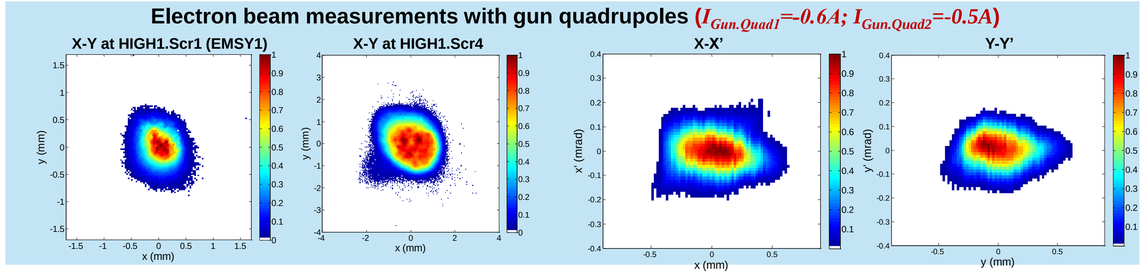
Simulated magnetic field for $I_{Gun.Quad1}$=-0.6A; $I_{Gun.Quad2}$=-0.5A

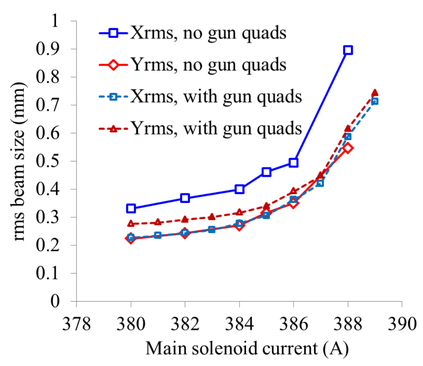


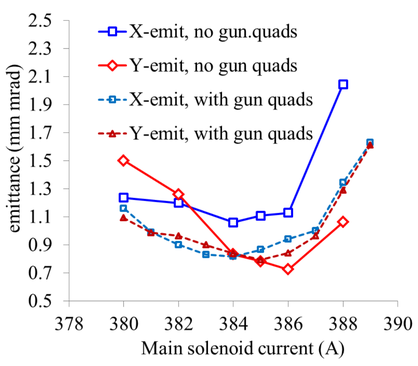
2-parameter ($I_{Gun.Quad1}$; $I_{Gun.Quad2}$) scan



Electron beam measurements with gun quadrupoles ($I_{Gun.Quad1}$=-0.6A; $I_{Gun.Quad2}$=-0.5A)







	No gun quads	With gun quads
I_{main}(A)	386	384
$I_{gun.quad1}$ (A)	0	-0.5
$I_{gun.quad2}$ (A)	0	-0.6
σ_x@HIGH1.Scr1(mm)	0.50	0.28
σ_y @HIGH1.Scr1(mm)	0.35	0.32
$\varepsilon_{x,n}$ (mm mrad)	**1.13**	**0.82**
$\varepsilon_{y,n}$ (mm mrad)	**0.73**	**0.84**
$\sqrt{\varepsilon_{x,n}\varepsilon_{y,n}}$ (mm mrad)	**0.91**	**0.83**
β_x (m)	6.53	3.18
β_y (m)	6.49	3.24
γ_x (mrad)	0.56	0.32
γ_y (mrad)	0.16	0.31