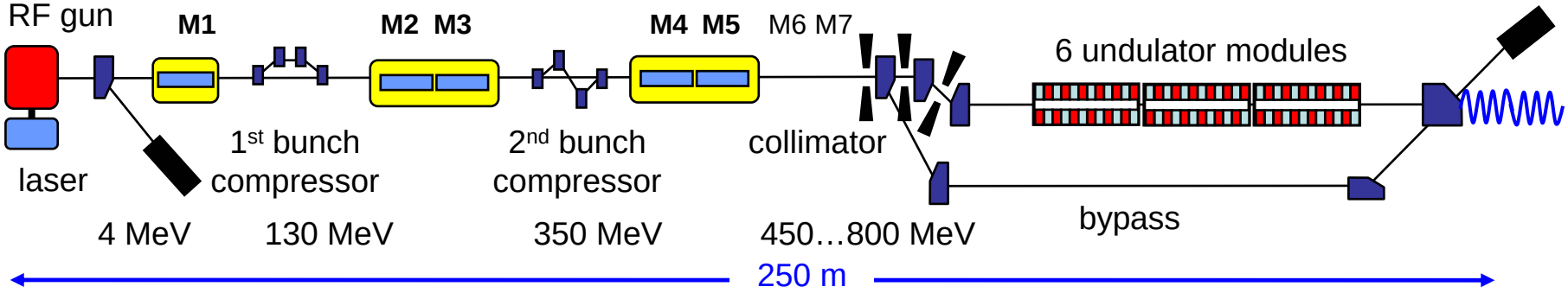
Dark current at the Euro-XFEL

Jang-Hui Han

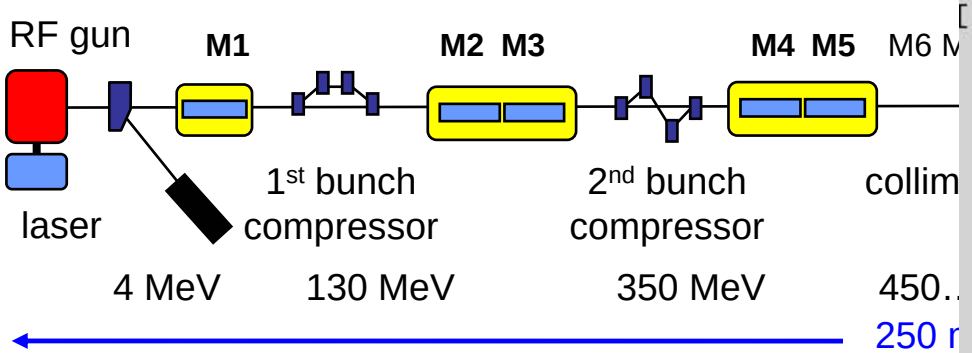
DESY, MPY

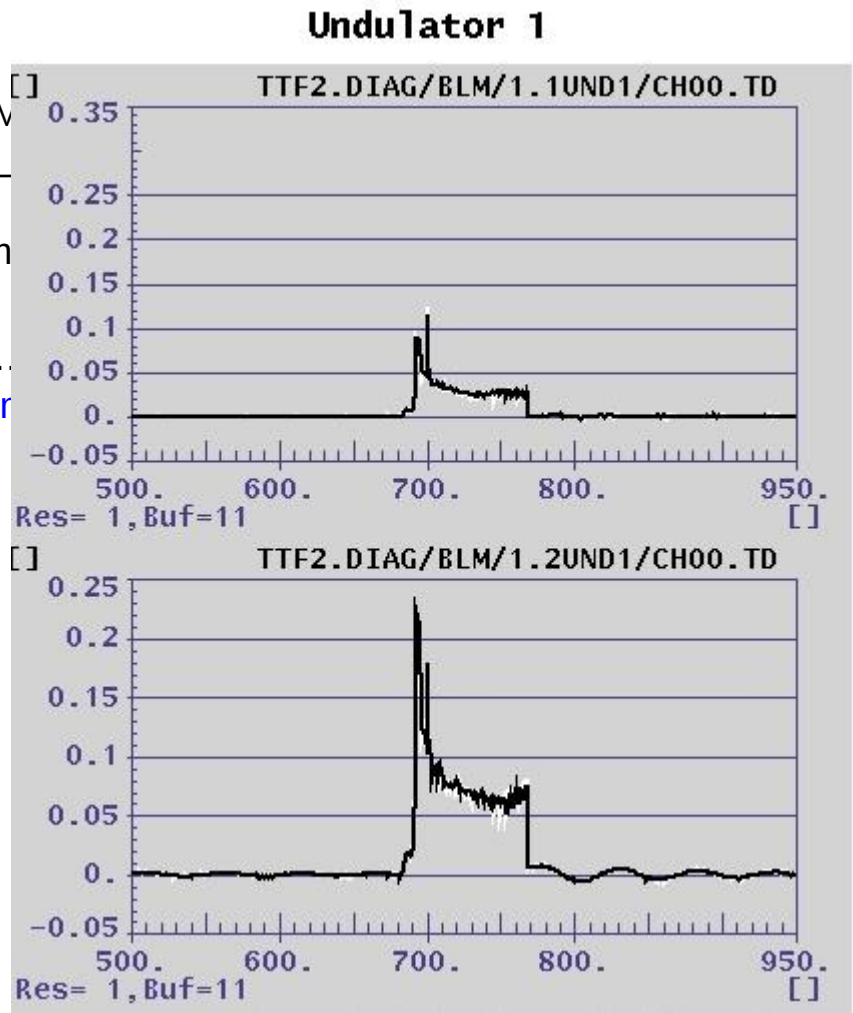
- Observations at PITZ and FLASH
- Estimation for the European XFEL
- Ideas to reduce dark current at the gun

DC at FLASH


RF gun
M1
M2 M3
M4 M5
M6 M7
6 undulator modules
laser
1st bunch compressor
2nd bunch compressor
collimator
bypass
4 MeV
130 MeV
350 MeV
450…800 MeV
250 m

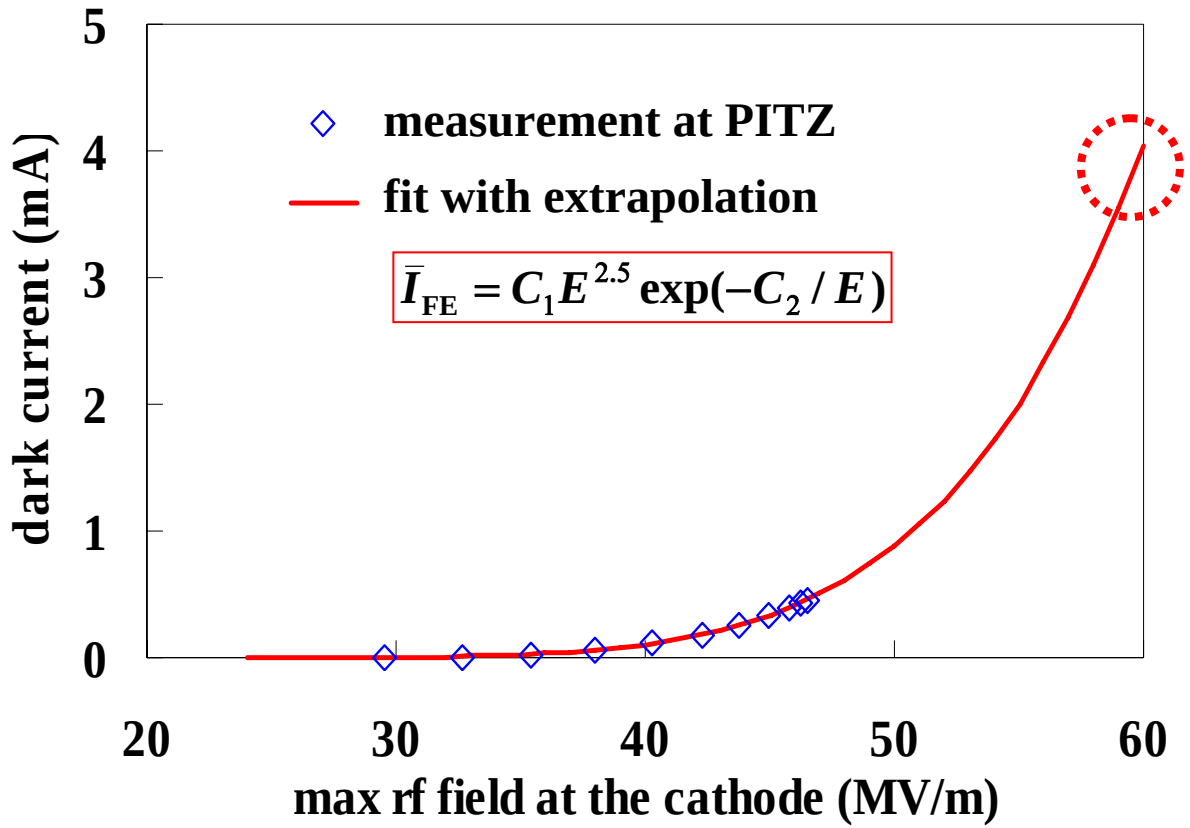
DC at FLASH





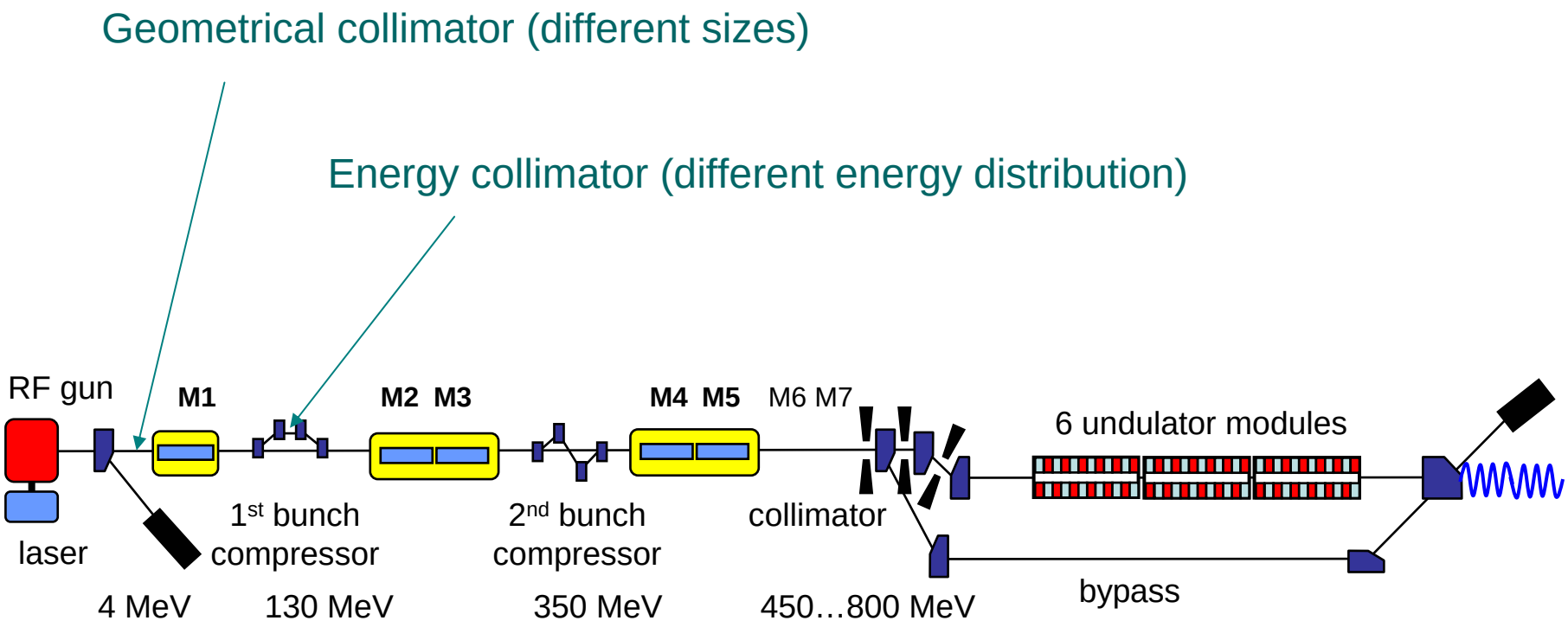
RF pulse lengths (flat region)
Gun: 70 μs
Acc. Modules: 100 μs

Estimation of dark current for the XFEL

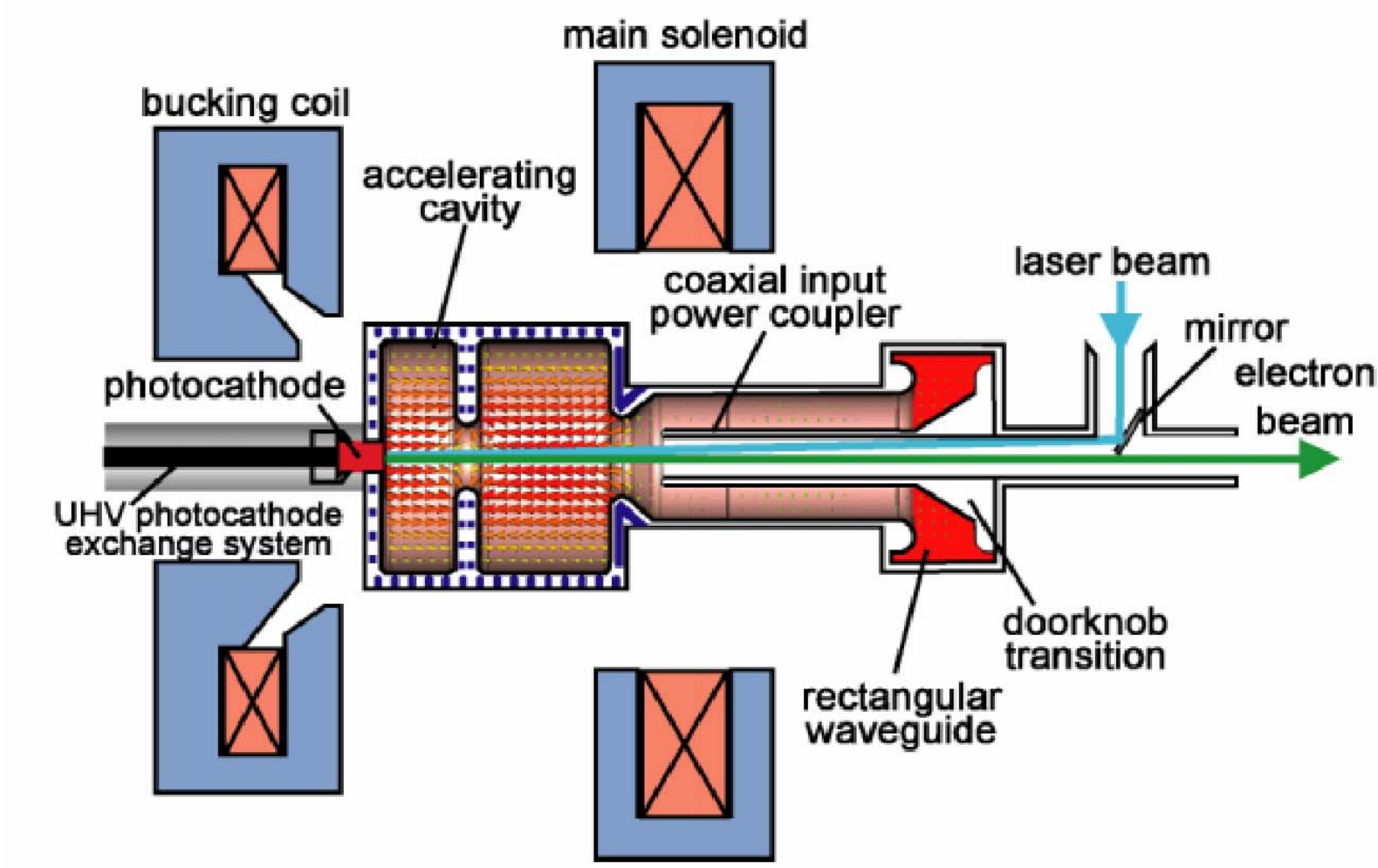


European XFEL gun

Collimator


Geometrical collimator (different sizes)
Energy collimator (different energy distribution)
RF gun
M1
M2 M3
M4 M5
M6 M7
6 undulator modules
laser
1st bunch compressor
2nd bunch compressor
collimator
bypass
4 MeV
130 MeV
350 MeV
450…800 MeV

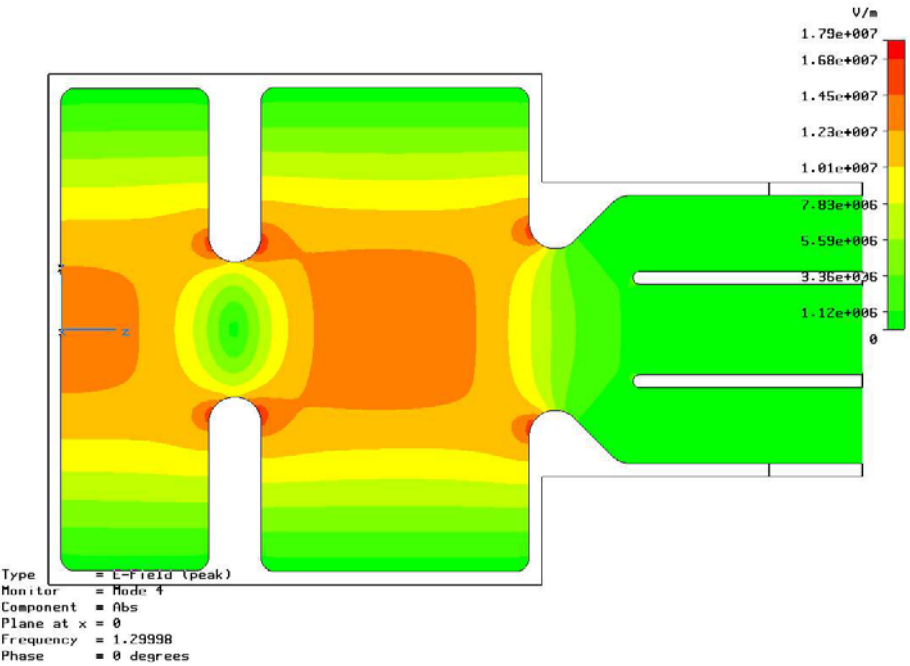
Experimental Setup at the Gun



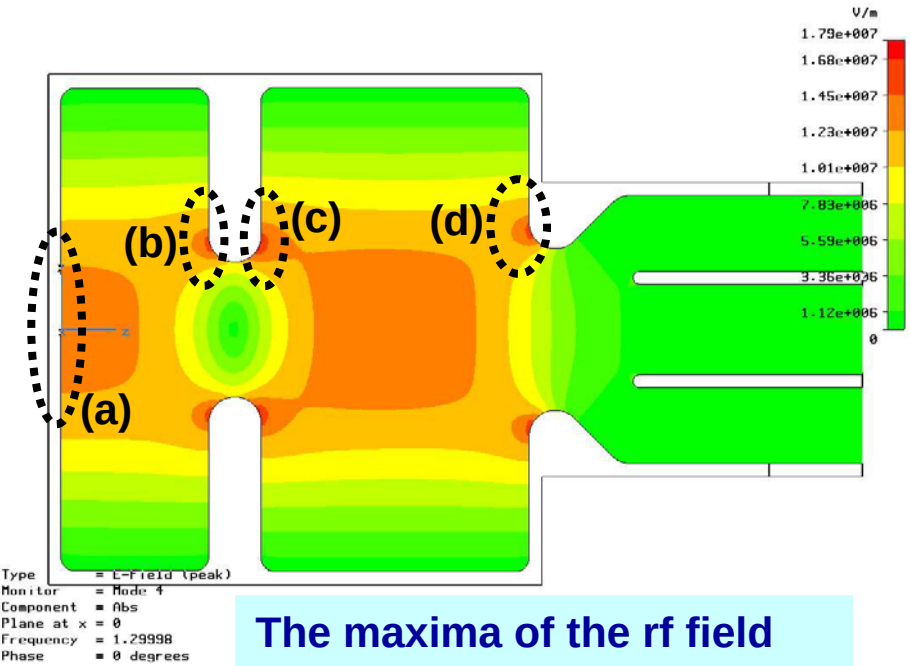
Parameter summary

		FLASH (measure)		
laser	XYrms	~1 mm		
	Lt	6~7 ps Gaussian		
	rt			
	Ek	0.55 eV		
gun	Ecath	~42 MV/m		
	ϕemit	38°		
	Bmax	0.165 T		
	Sol. position	0.276 m		
ACC1	entrance	2.48 m		
	Emax	16 MV/m		
	ACC1 ϕ	~ on crest		
beam	emittance	<2 mm mrad		

DC trajectories

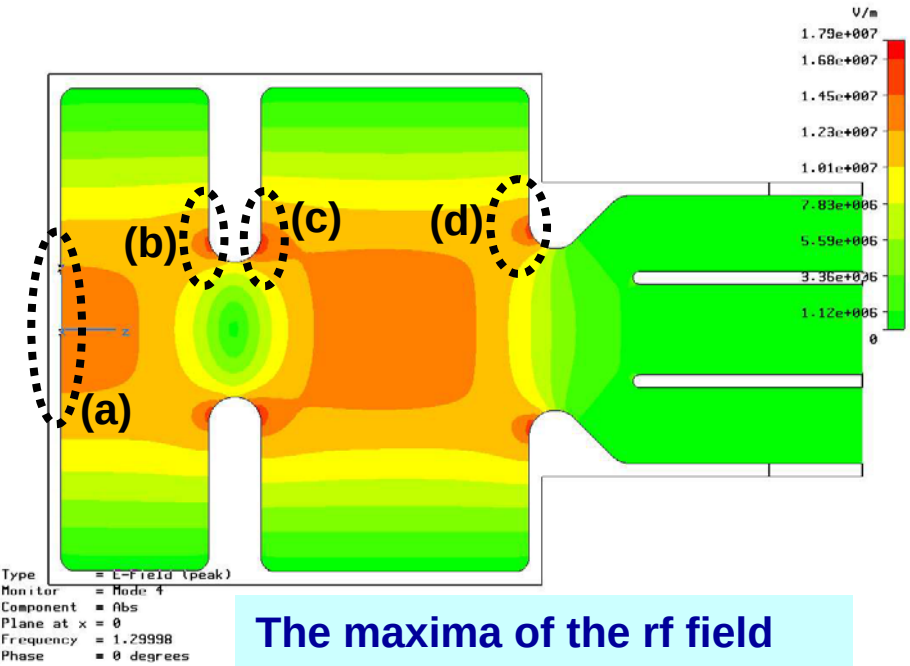


DC trajectories

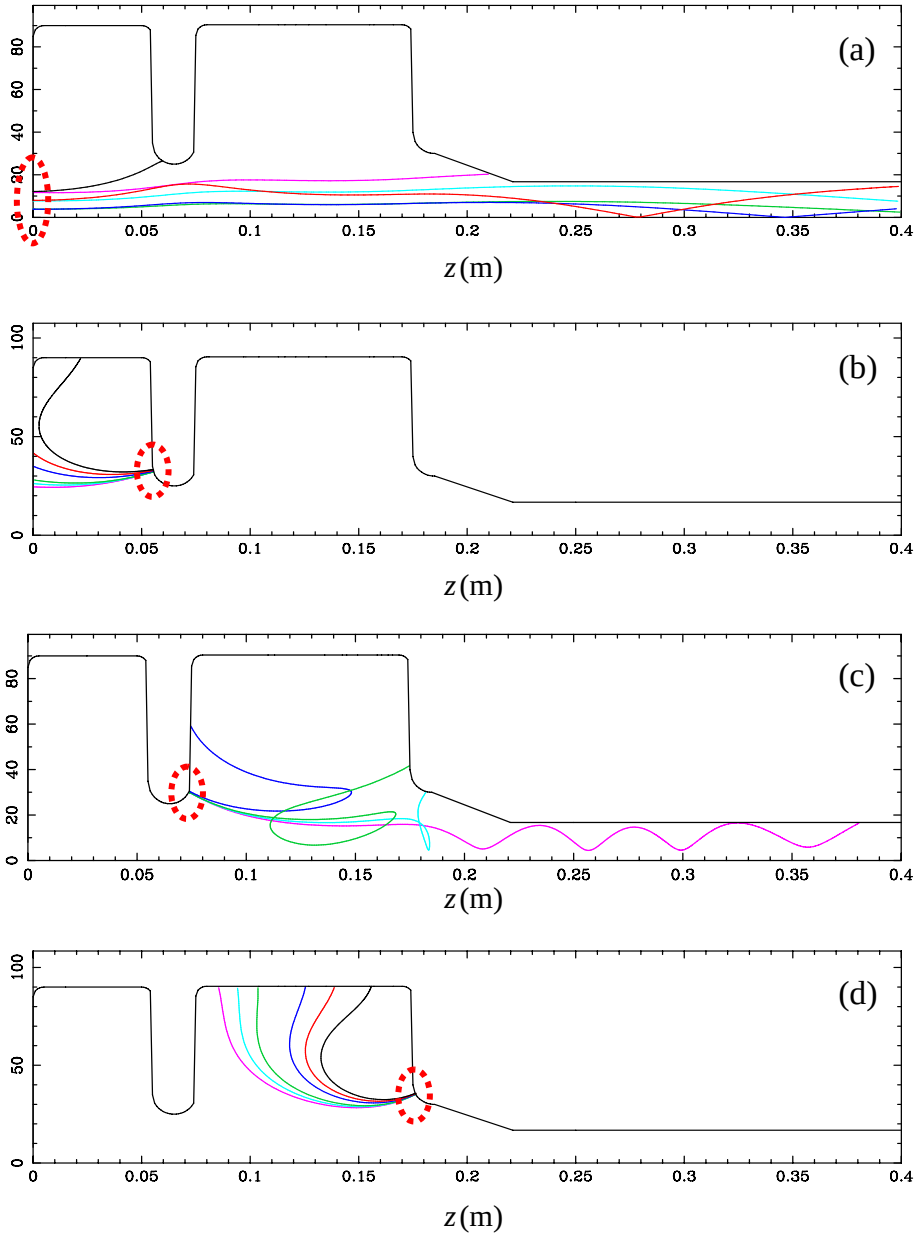


The maxima of the rf field strength can be the major source of dark current

DC trajectories

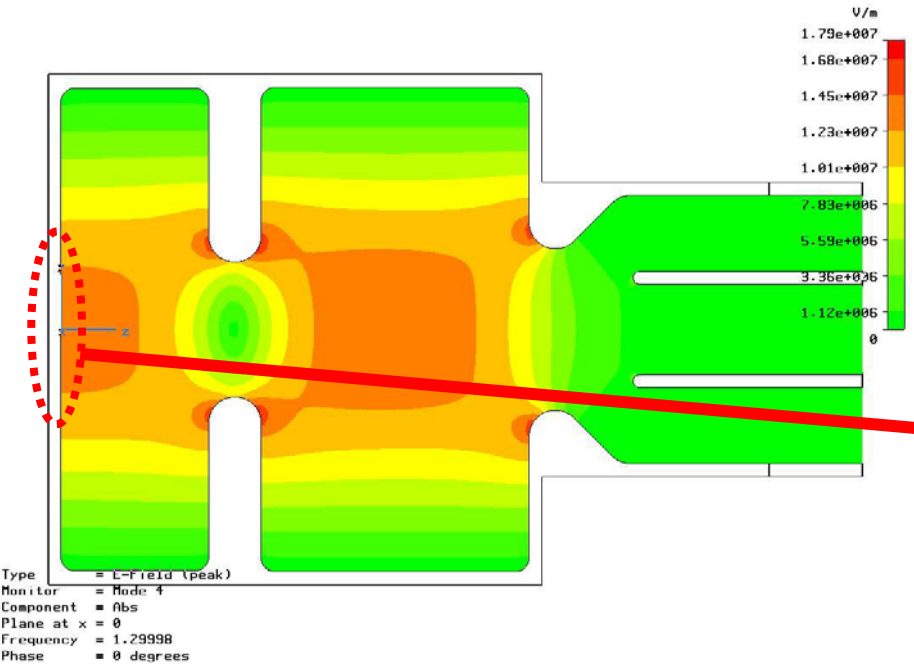


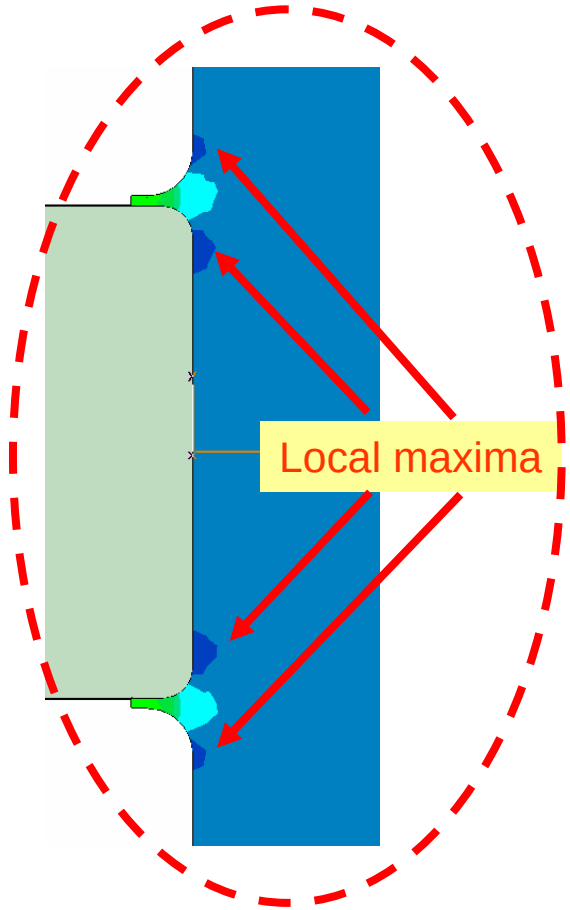
The maxima of the rf field strength can be the major source of dark current



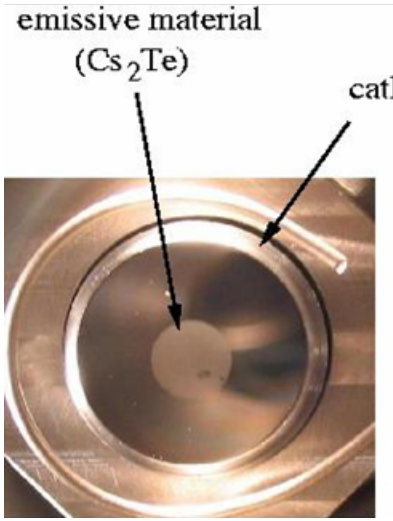
Astra simulation at 40 MV/m gradient and 300 A main solenoid current

DC trajectories

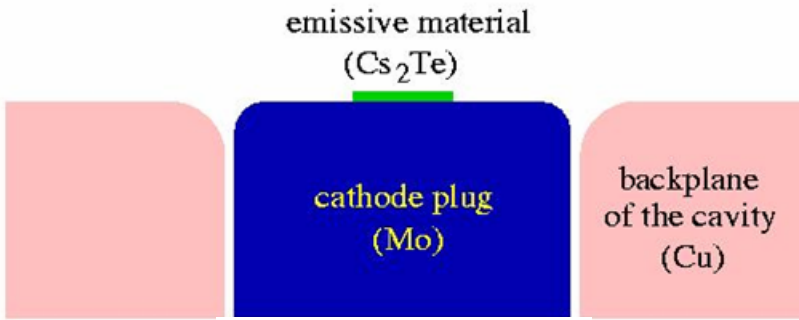




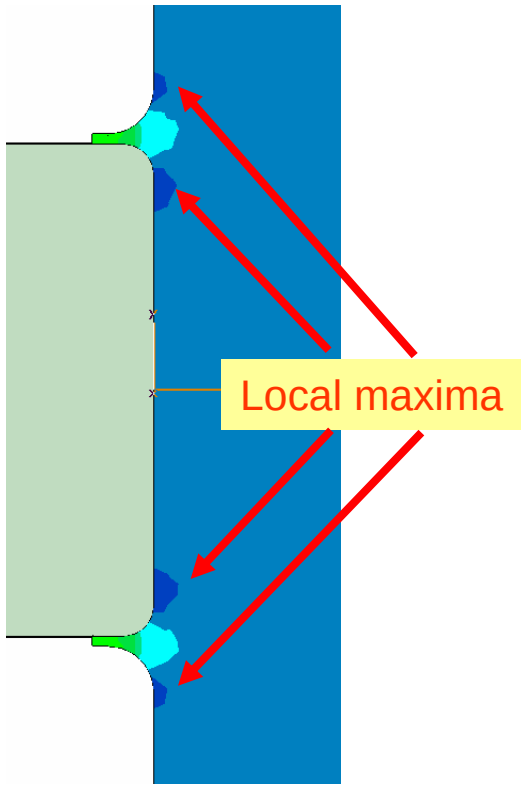
DC trajectories



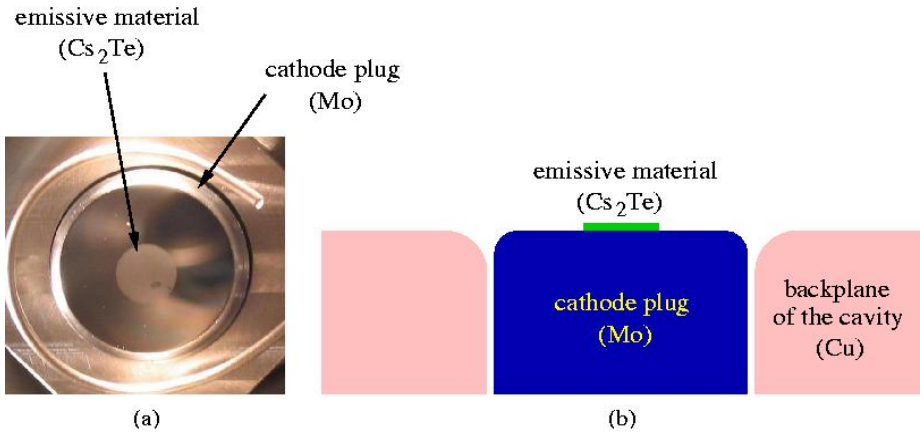
front view in the cathode chamber



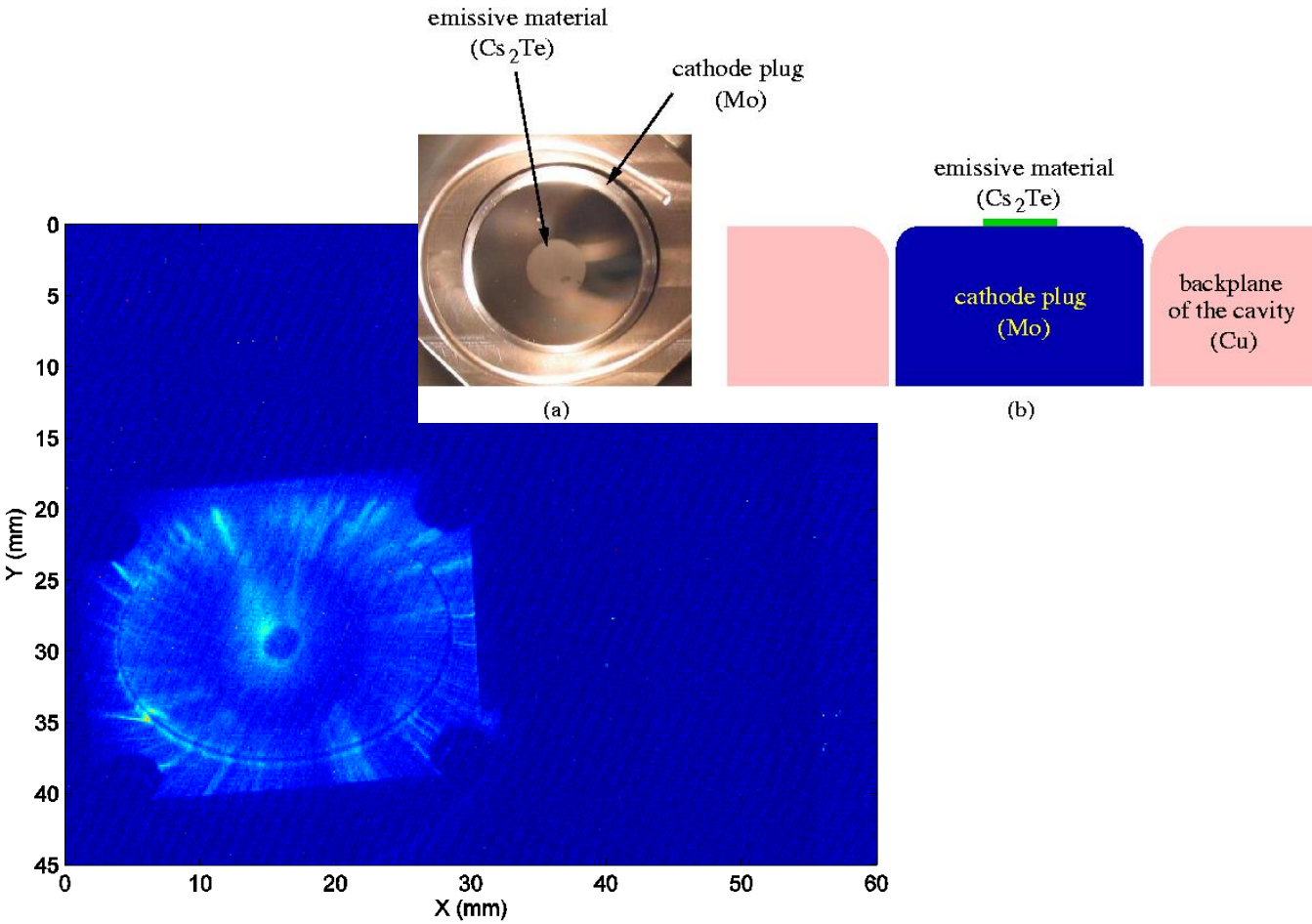
side view in the gun cavity



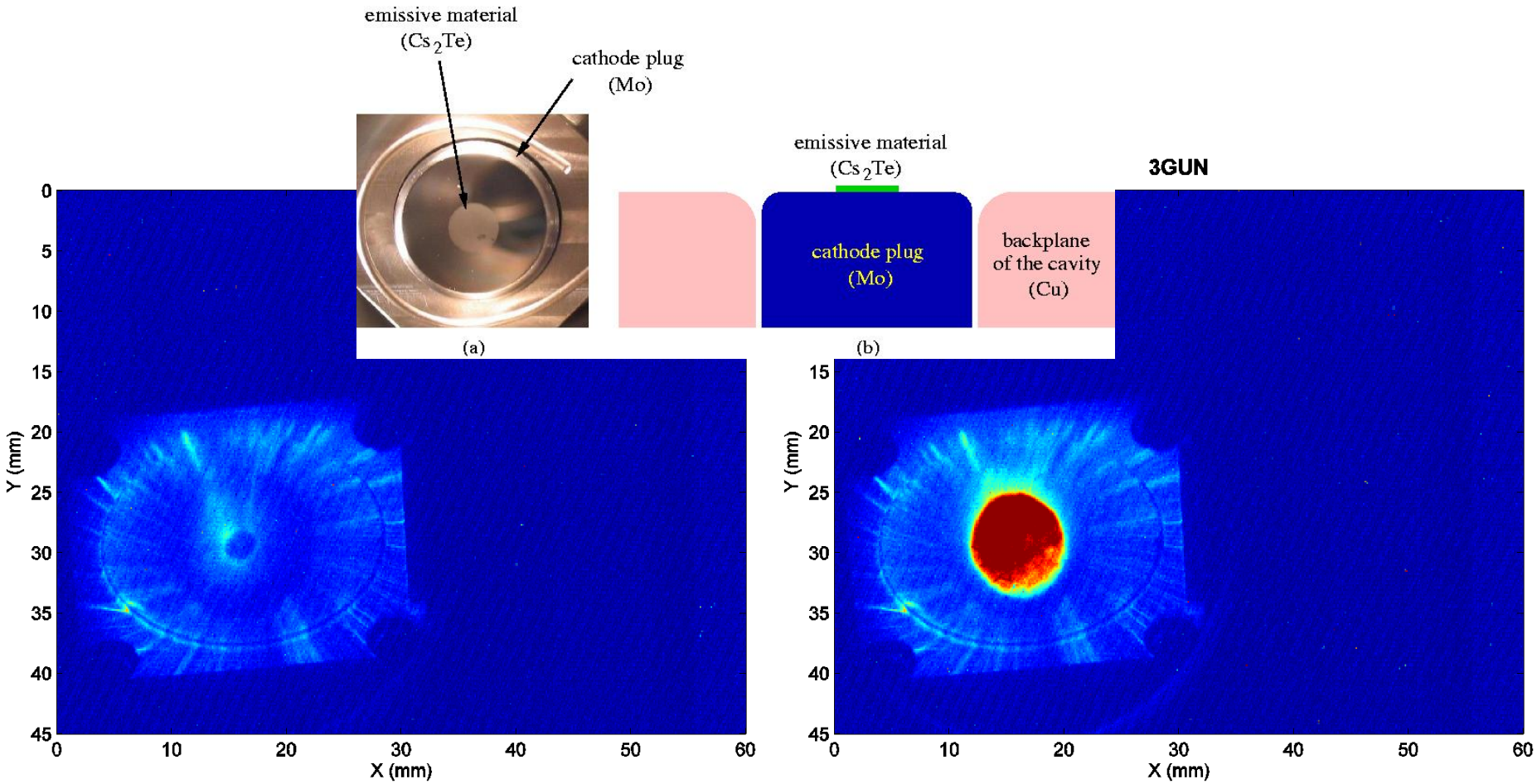
DC Image analysis



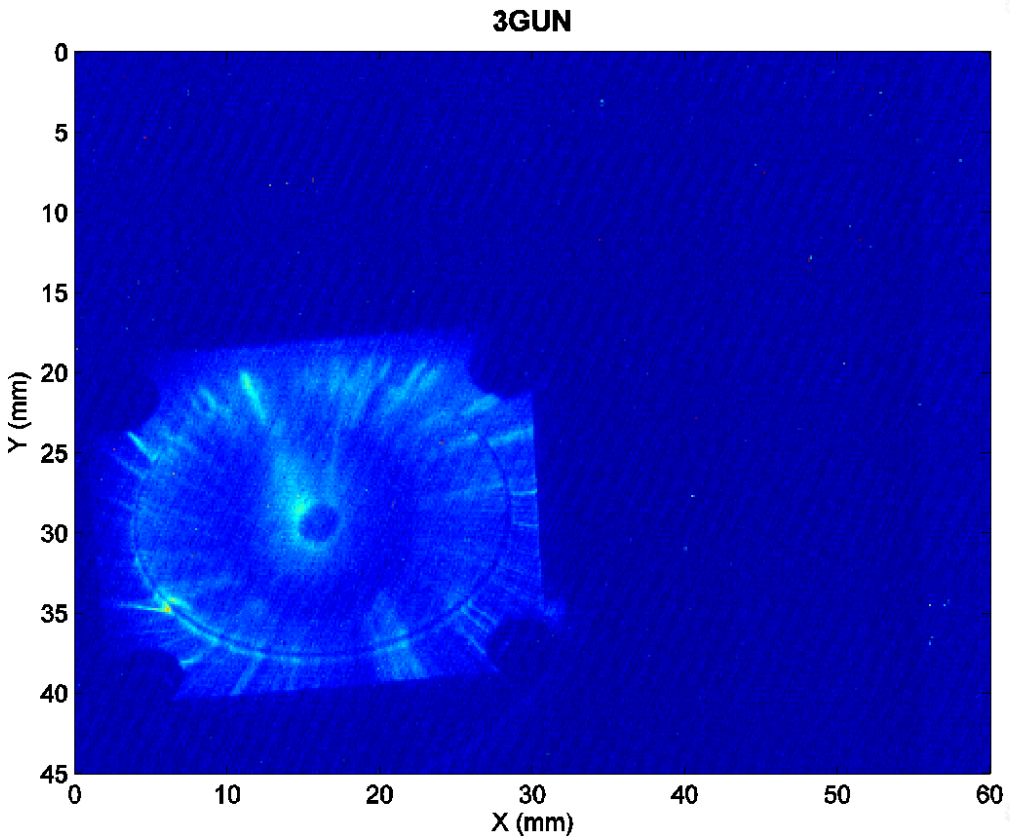
DC Image analysis

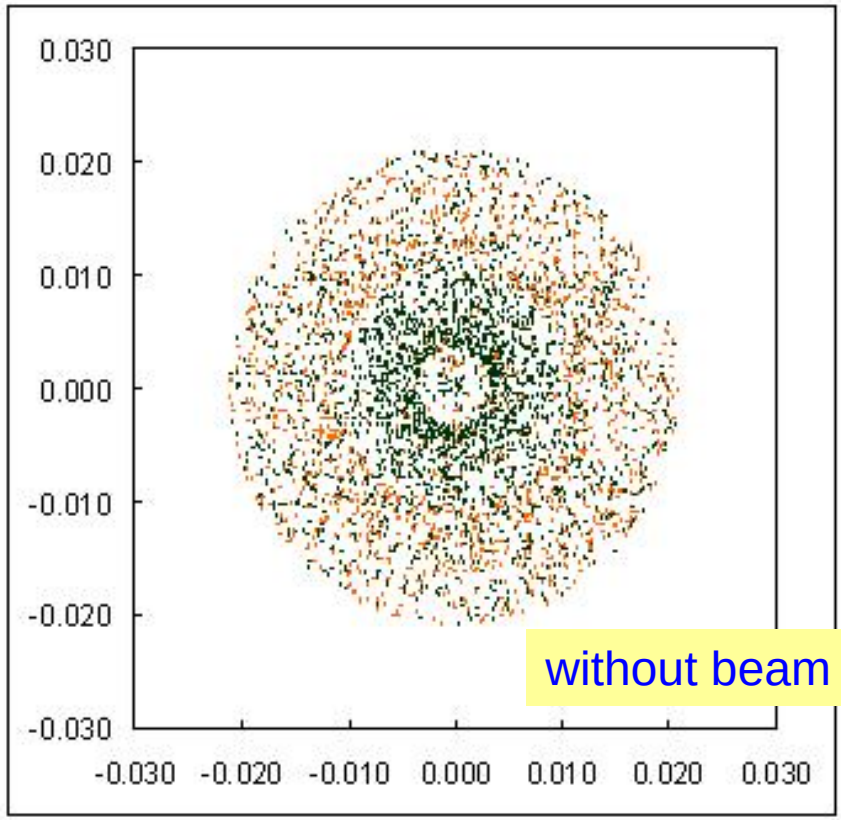


DC Image analysis



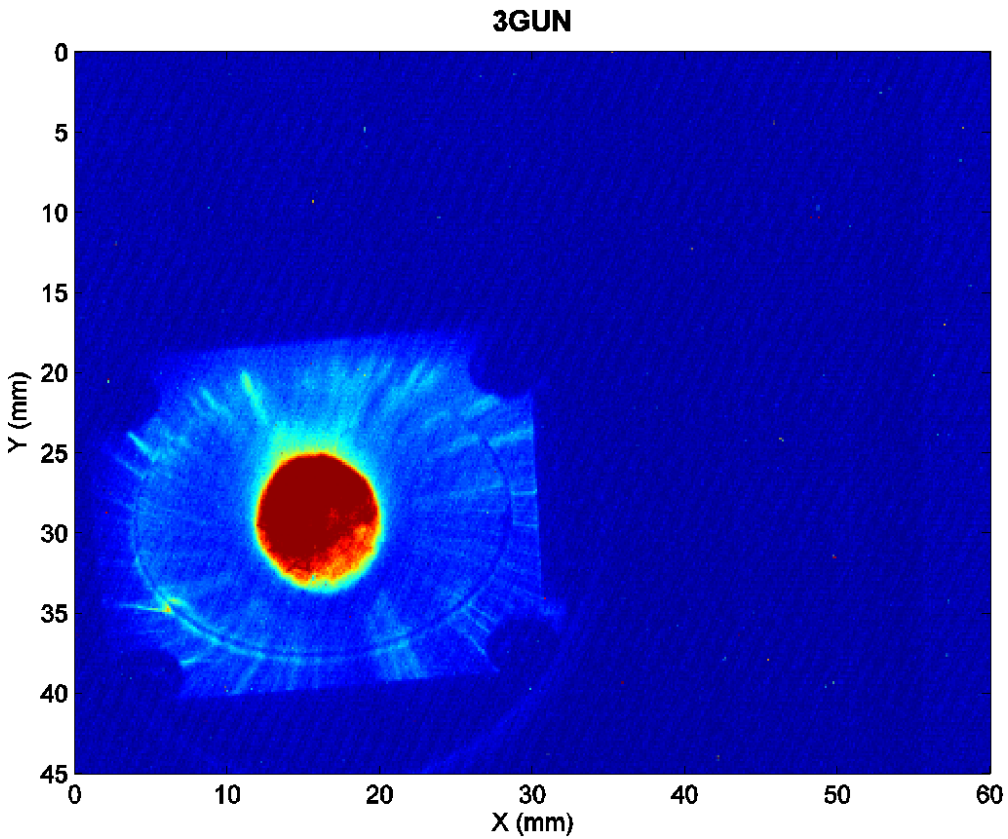
DC Image analysis

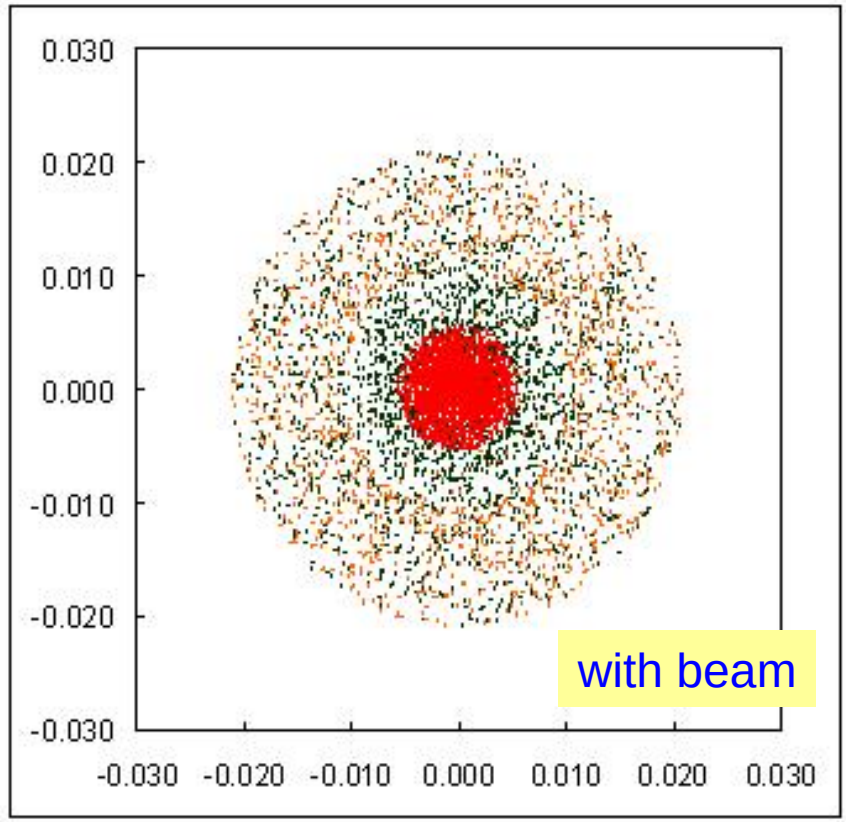




The green points are the electrons from the boarder of Cs_2Te.
The orange points are the electrons from the edge of Mo plug.

DC Image analysis

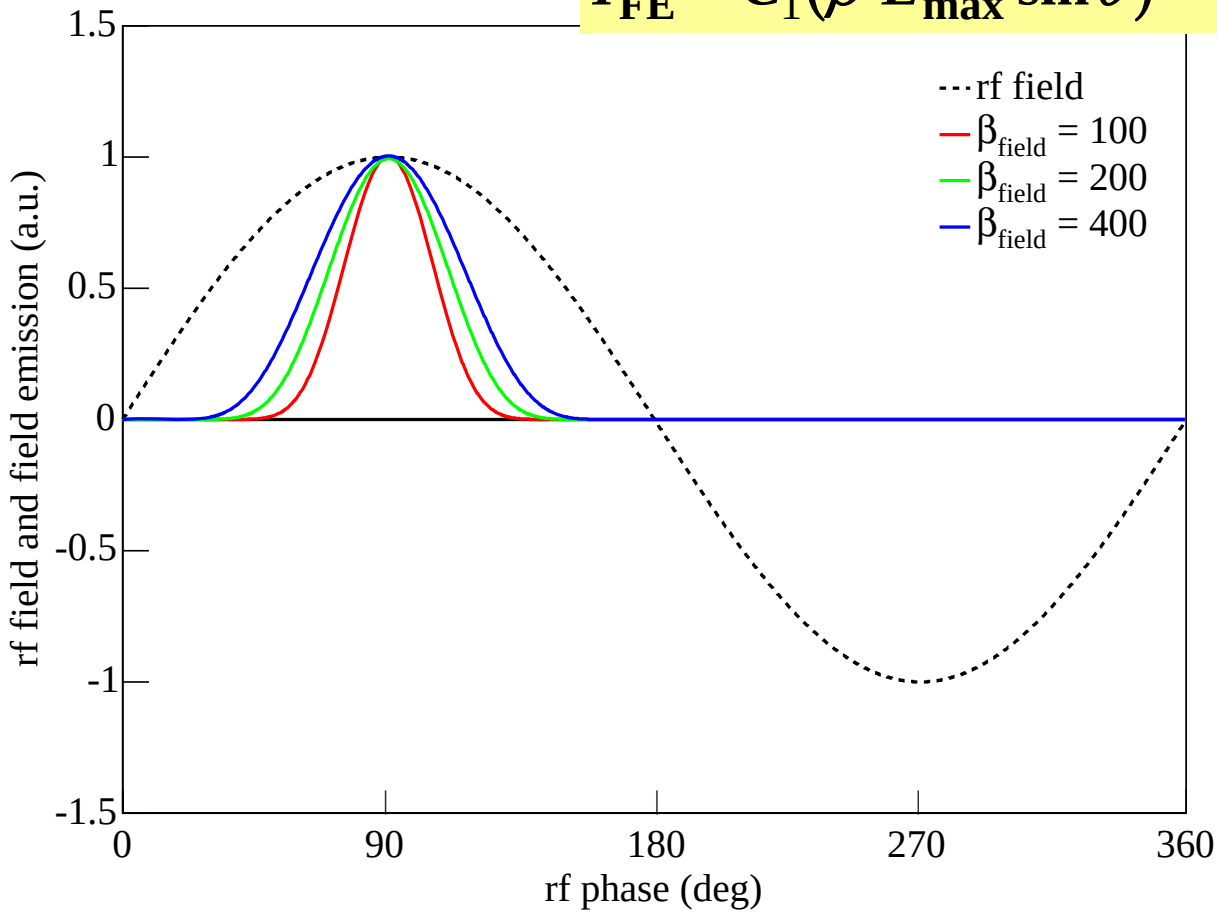




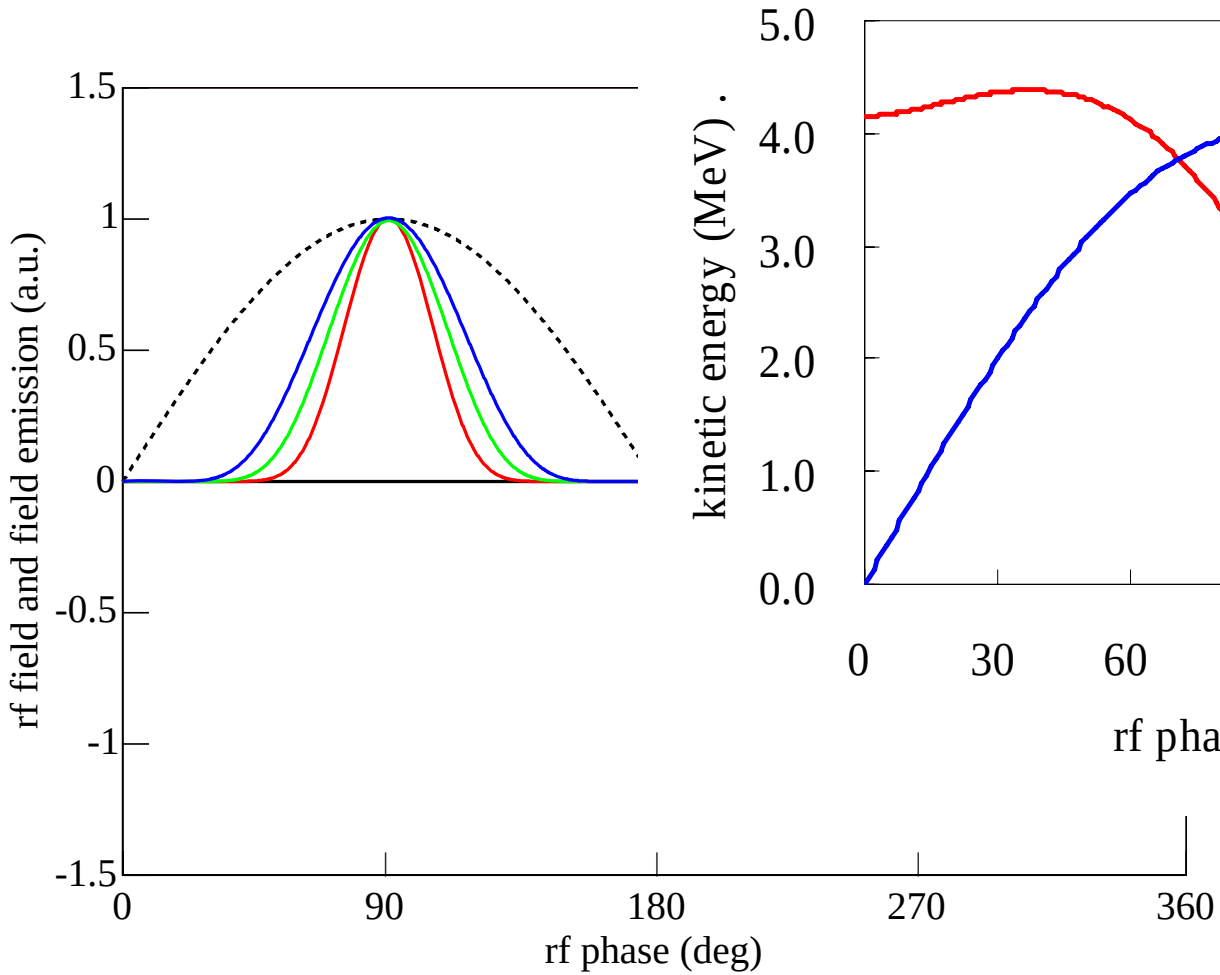
The green points are the electrons from the boarder of Cs_2Te.
The orange points are the electrons from the edge of Mo plug.
The red points are the electron beams.

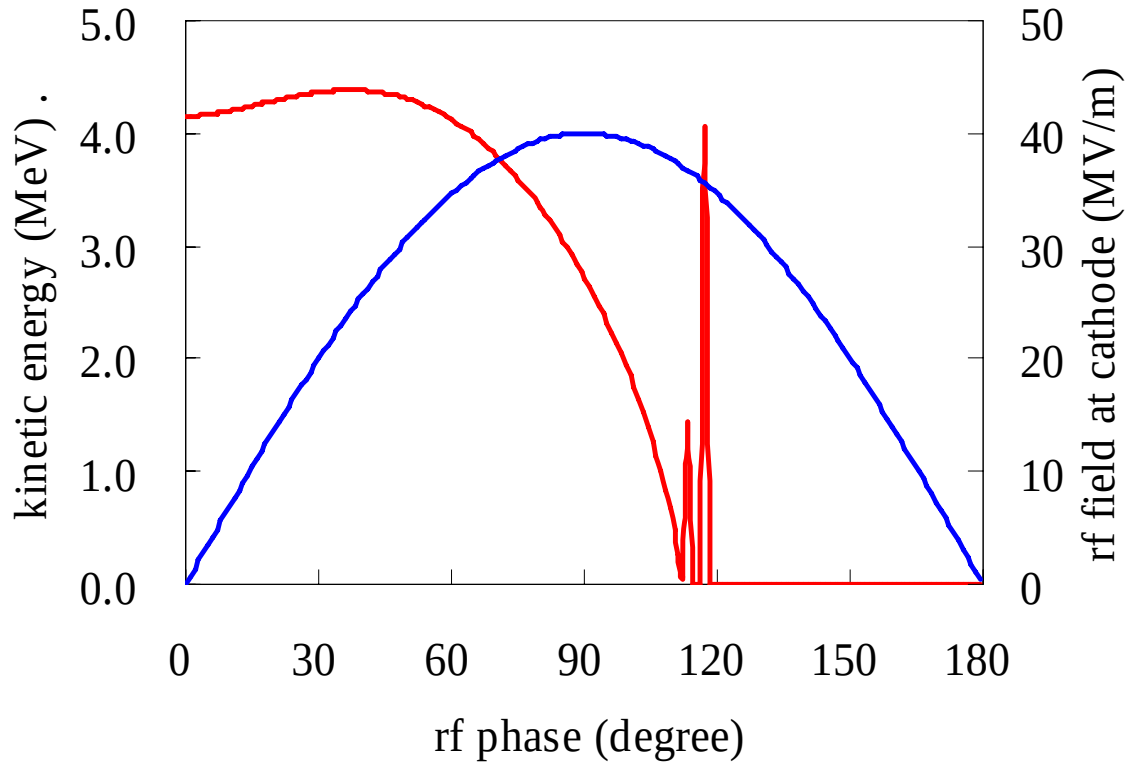
Field emission Vs. emission phase

$$\bar{I}_{FE} = C_1 \left(\beta E_{max} \sin\theta\right)^{2.5} \exp\left[-C_2 / \left(\beta E_{max} \sin\theta\right)\right]$$

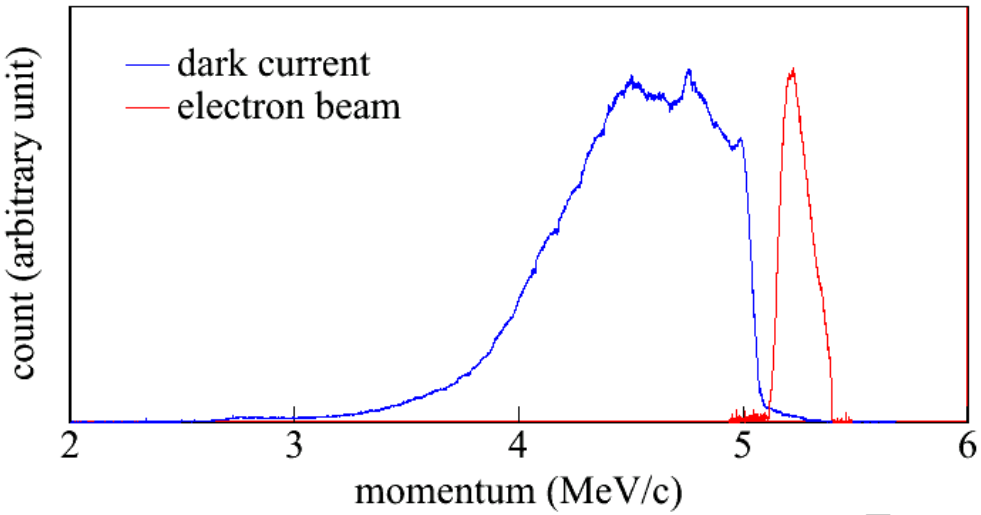


Field emission Vs. emission phase (FLASH)



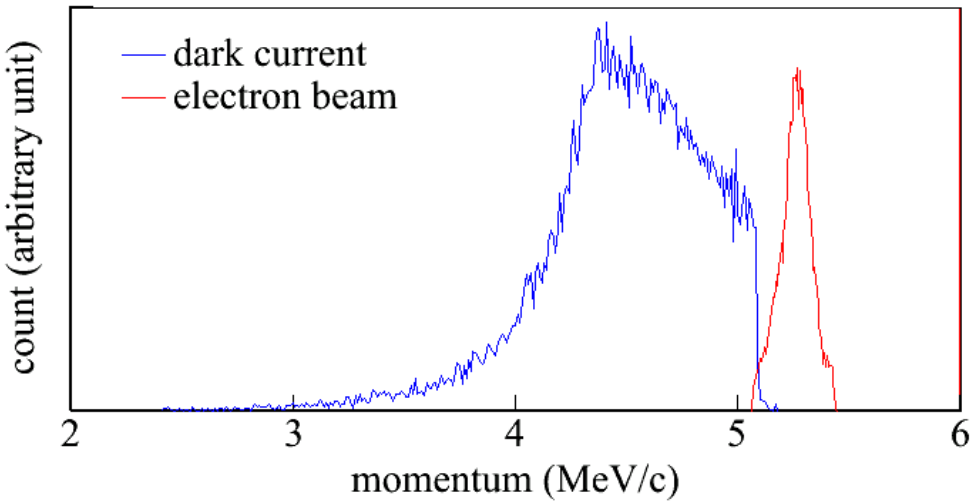


Momentum distribution after gun (measurement at PITZ)

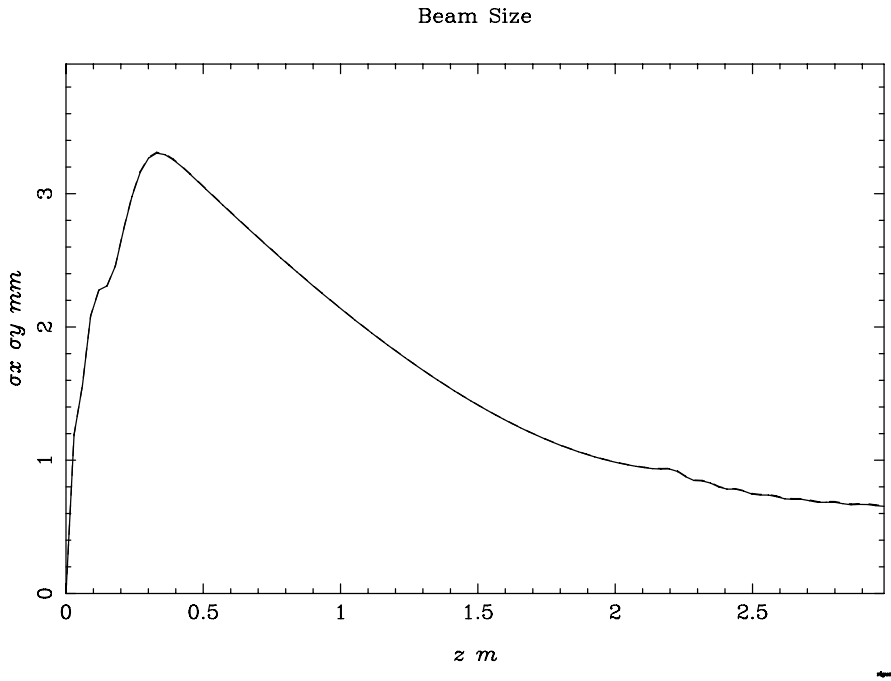


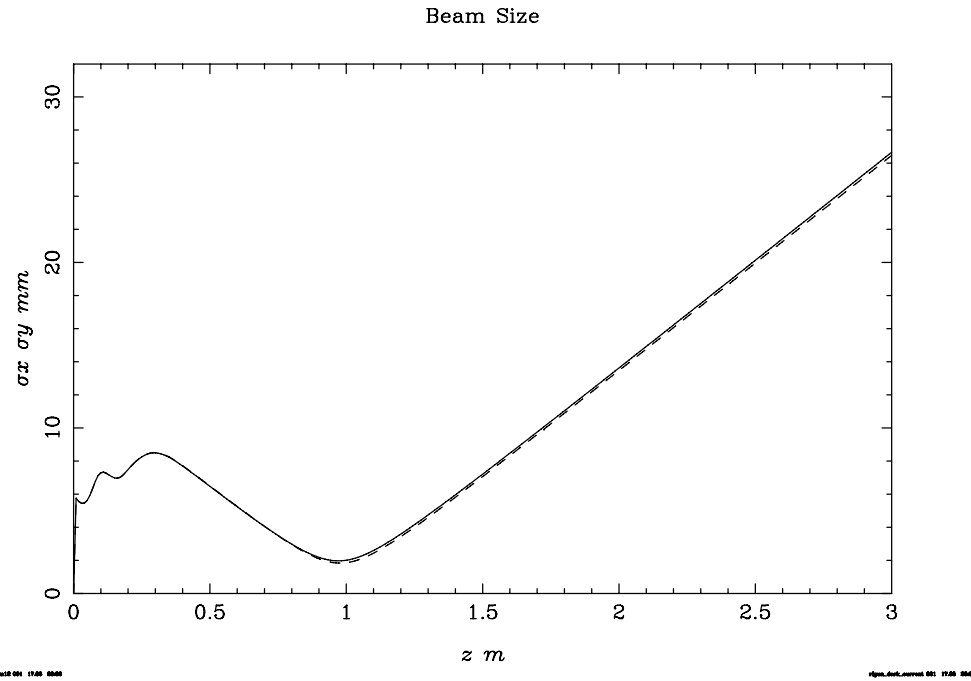
measurement

simulation

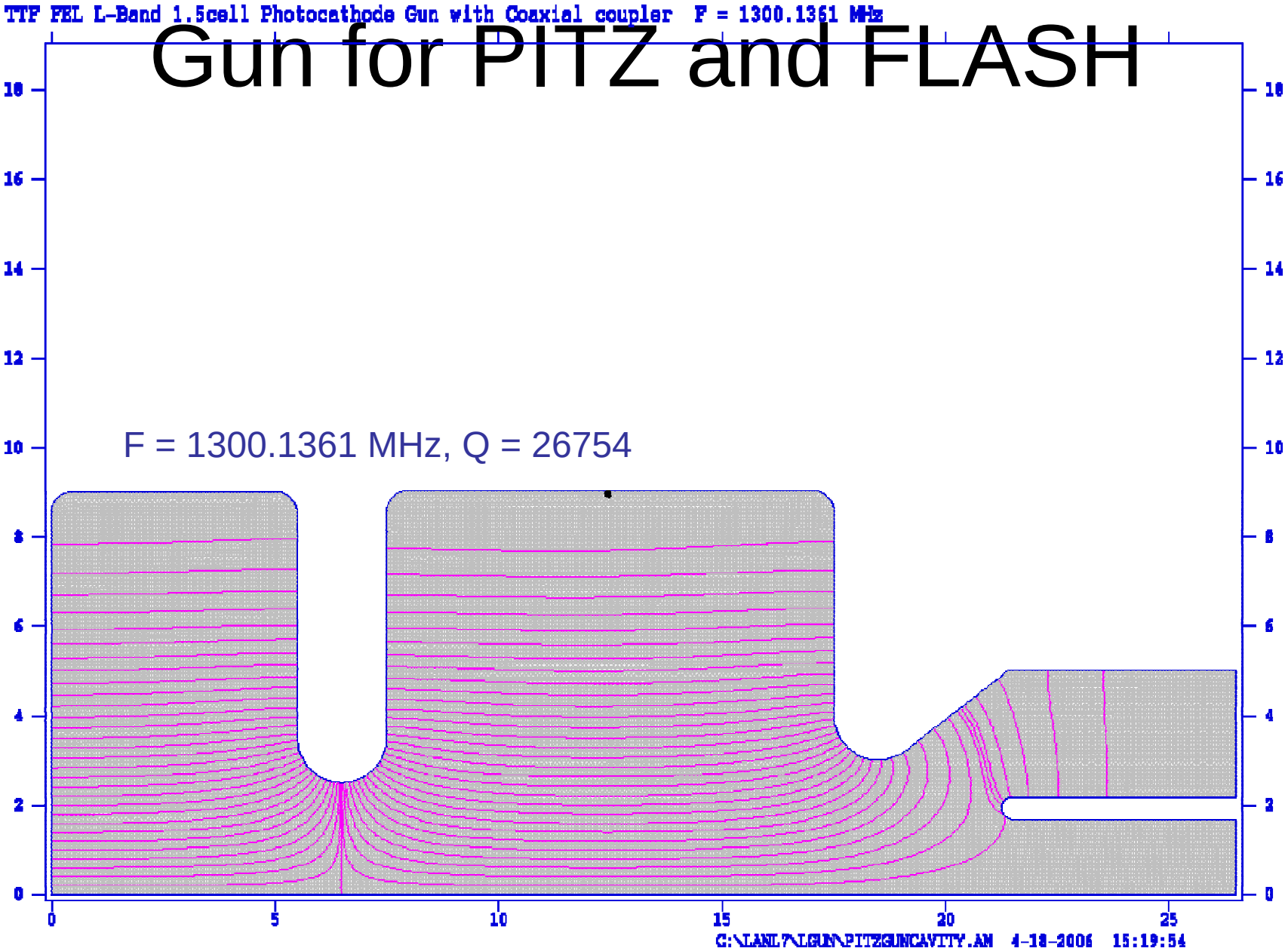


XY size of beam & dark current (FLASH)

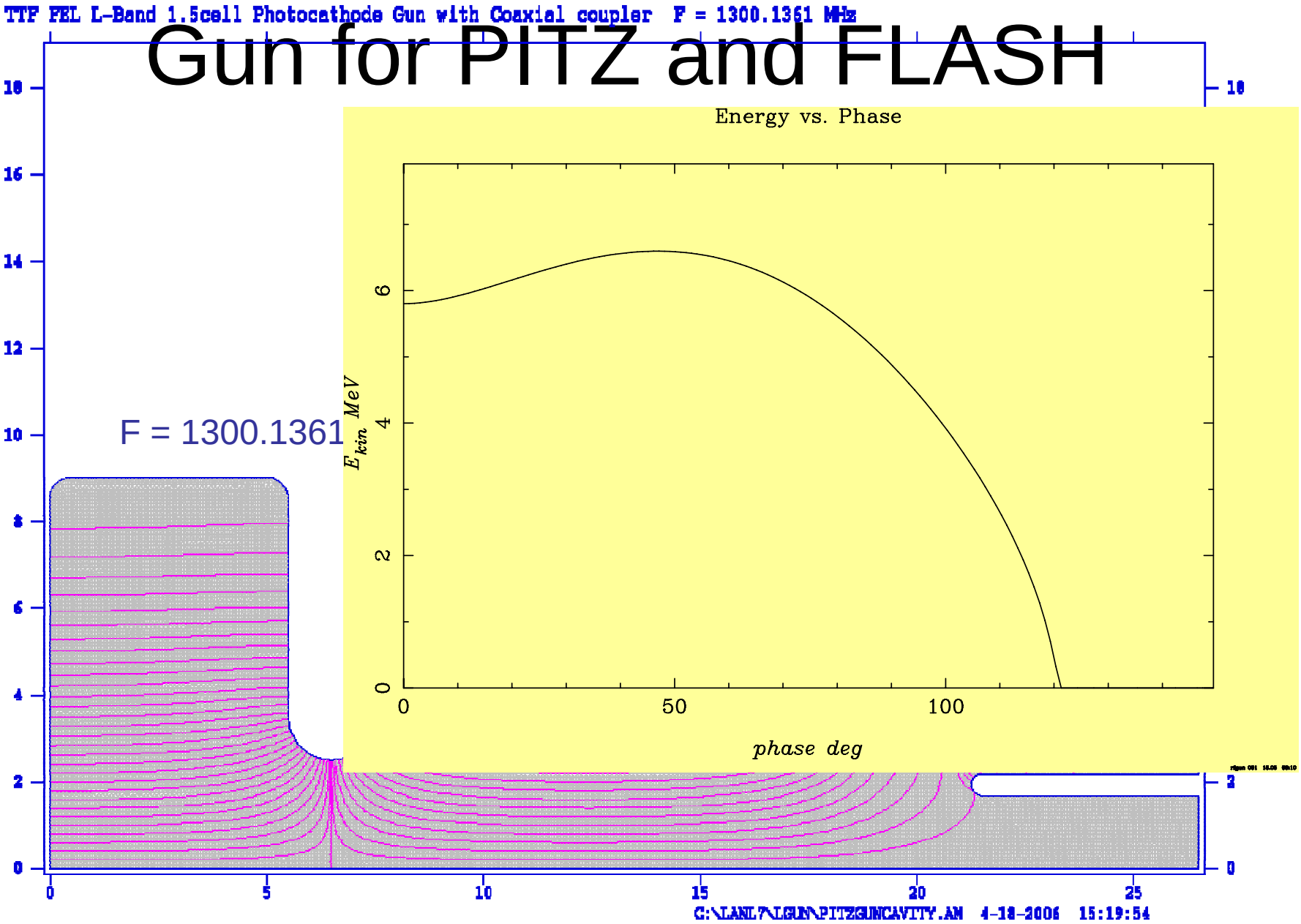




Gun for PITZ and FLASH



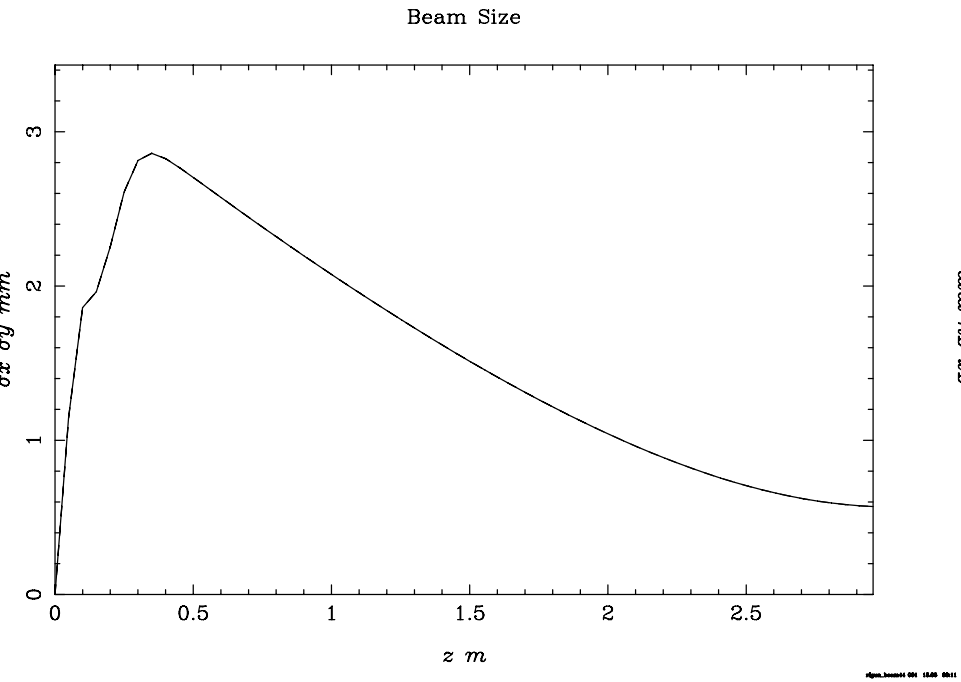
Gun for PITZ and FLASH

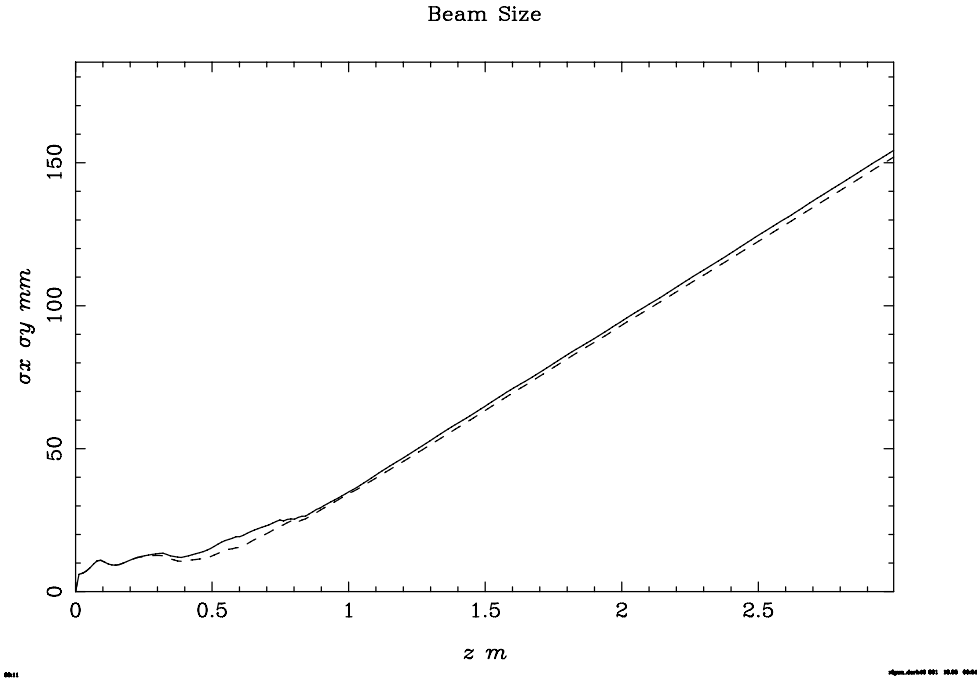


Parameter summary

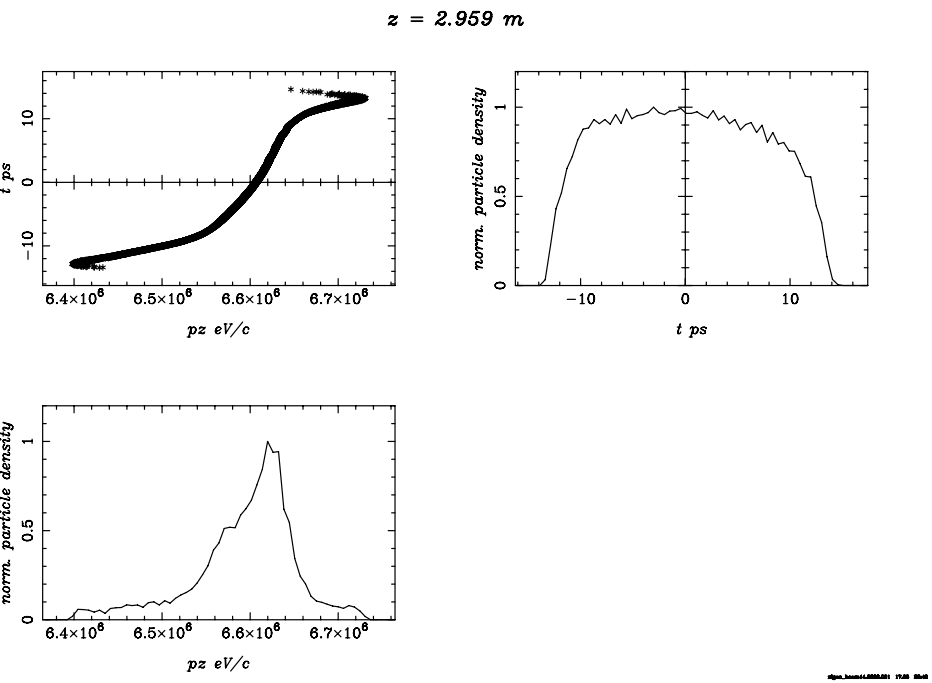
		FLASH (measure)	**XFEL (original)**	
laser	XYrms	~1 mm	0.44 mm	
	Lt	6~7 ps Gaussian	20	
	rt		2	
	Ek	0.55 eV	0.55 eV	
gun	Ecath	~42 MV/m	60 MV/m	
	ϕemit	38°	46°	
	Bmax	0.165 T	0.225 T	
	Sol. position	0.276 m	0.276 m	
ACC1	entrance	2.48 m	3.2 m	
	Emax	16 MV/m	21.5 MV/m	
	ACC1 ϕ	~ on crest	-16°	
beam	emittance	<2 mm mrad	0.7 mm mrad	

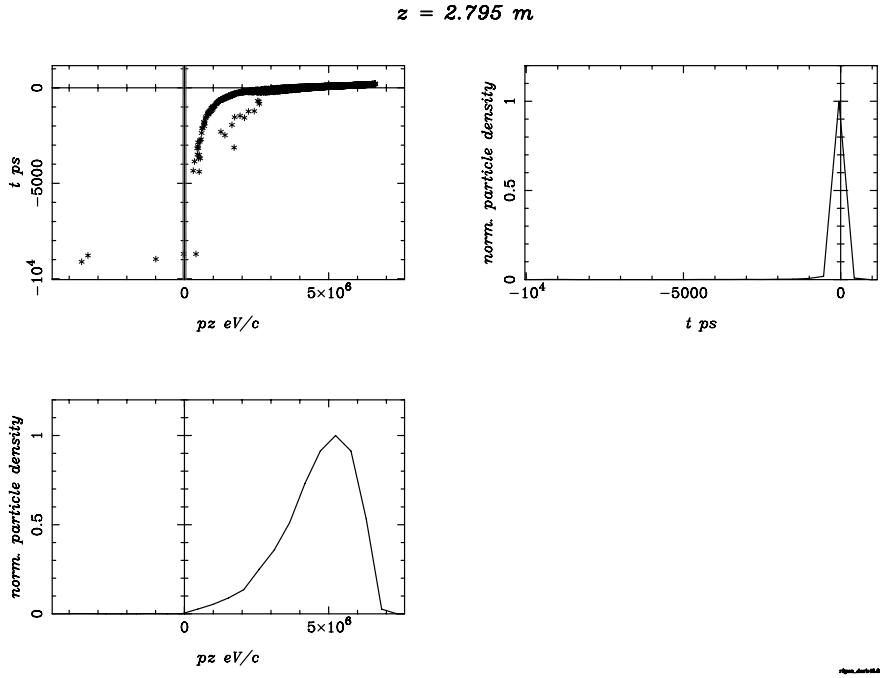
XY size of beam & dark current (XFEL, original)



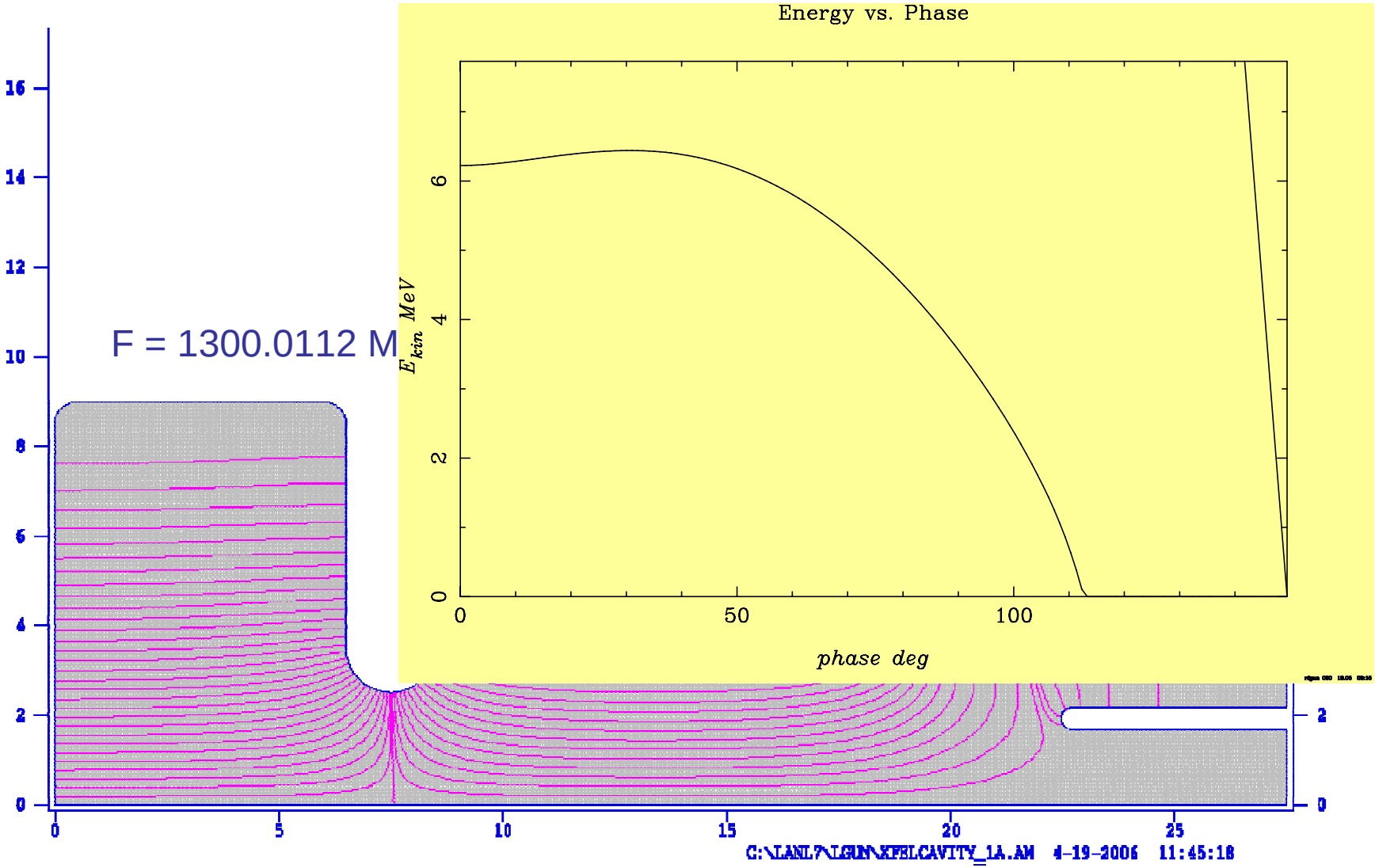


Momentum of beam & dark current (XFEL, original)





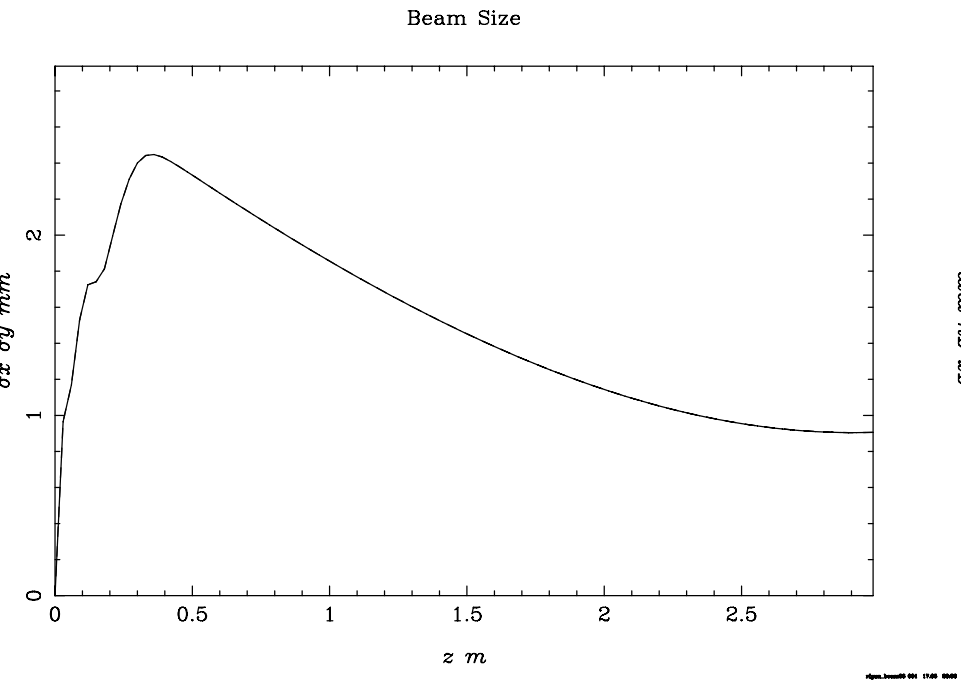
New design for the XFEL

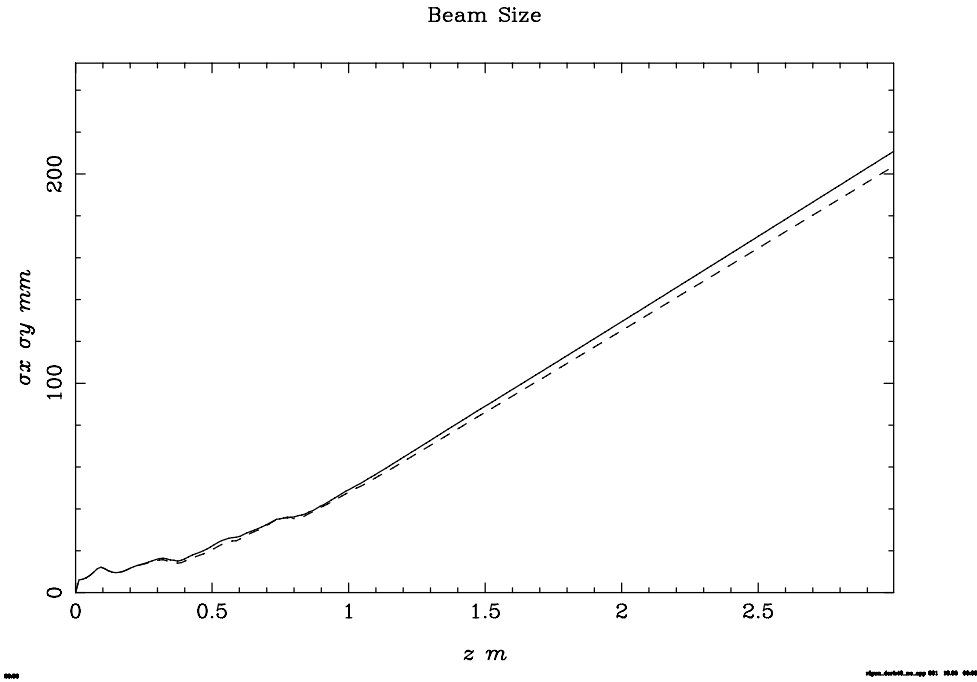


Parameter summary

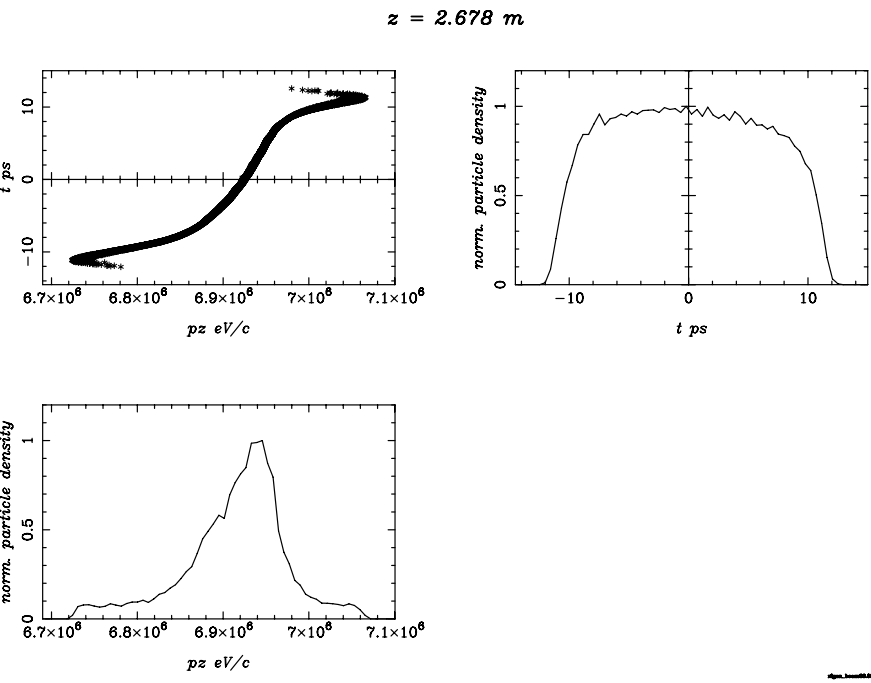
		FLASH (measure)	**XFEL (original)**	**XFEL (new)**
laser	XYrms	~1 mm	0.44 mm	0.65 mm
	Lt	6~7 ps Gaussian	20	20
	rt		2	2
	Ek	0.55 eV	0.55 eV	0.55 eV
gun	Ecath	~42 MV/m	60 MV/m	60 MV/m
	ϕemit	38°	46°	30°
	Bmax	0.165 T	0.225 T	0.228 T
	Sol. position	0.276 m	0.276 m	0.276 m
ACC1	entrance	2.48 m	3.2 m	3.4 m
	Emax	16 MV/m	21.5 MV/m	13 MV/m
	ACC1 ϕ	~ on crest	-16°	-16°
beam	emittance	<2 mm mrad	0.7 mm mrad	0.85 mm mrad

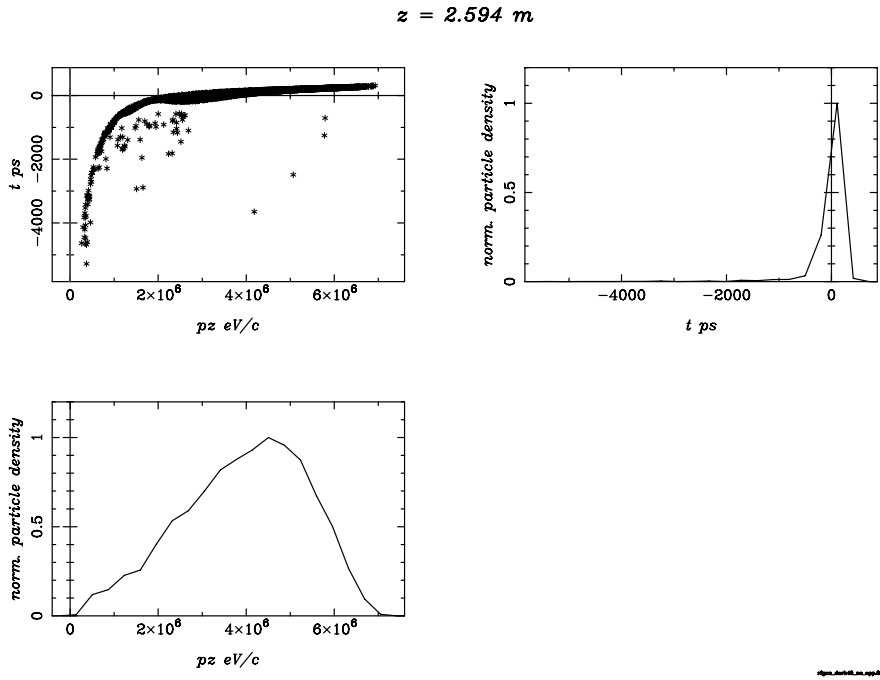
XY size of beam & dark current (XFEL, new design)





Momentum of beam & dark current (XFEL, new design)





Conclusion and outlook

- Dark current might be more serious problem at the Euro-XFEL
- Most of dark current at the gun is originated from the cathode area
- For XFEL case, higher solenoid field makes dark current over-focused quickly
- With enlarging the half cell length, the momentum distribution of beams and dark current can be separated.

- Further optimization of the cell length ratio and machine parameters are necessary.
- Find optimum position and size of collimators