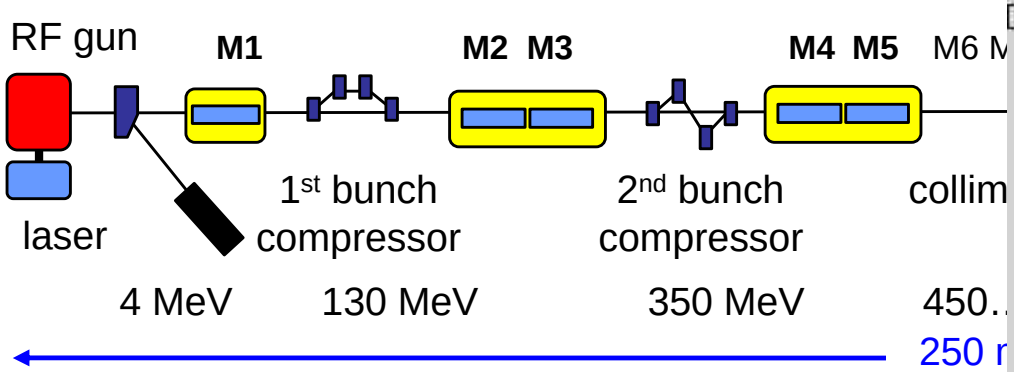
Dark current at the XFEL injector

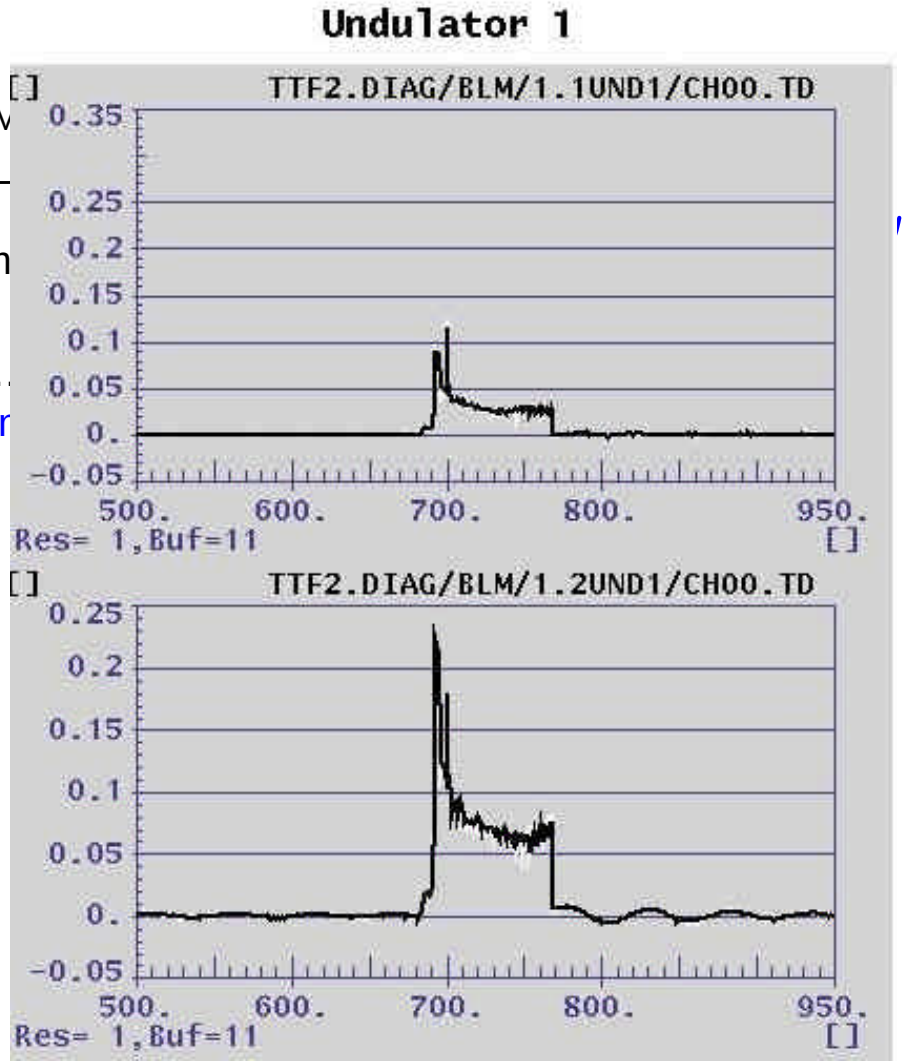
Jang-Hui Han

DESY, MPY

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

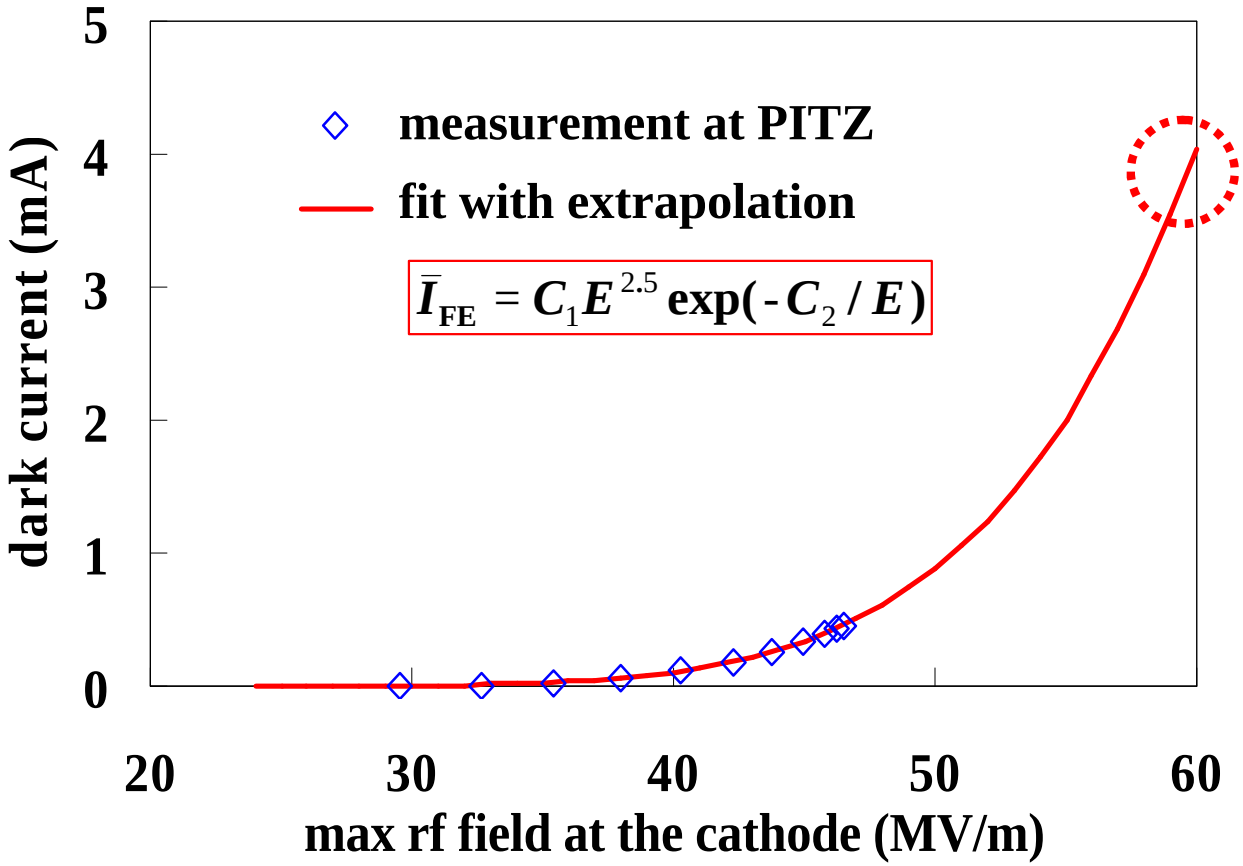
DC at FLASH





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

Estimation of dark current for the XFEL



European XFEL gun

Measurement with FC at 0.78 m downstream from cathode

Dark current might be more serious problem at the Euro-XFEL

Dark current reduction

1. Suppressing field emission
   - Improved surface preparation
   - Generation of new field emitter

Dark current reduction

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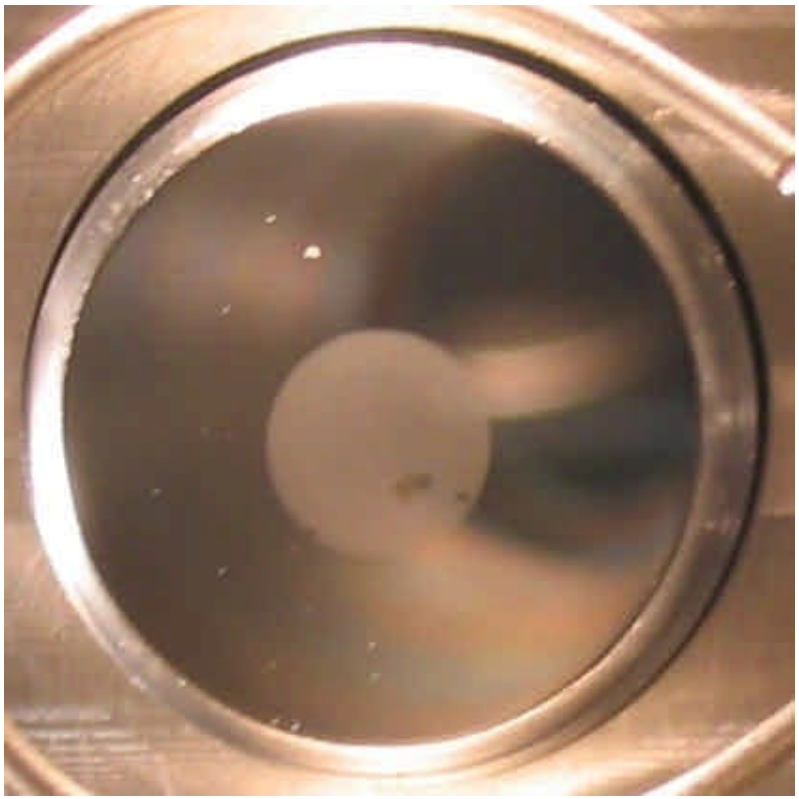


Dark current reduction

1. Suppressing field emission
   - Improved surface preparation
   - Generation of new field emitter

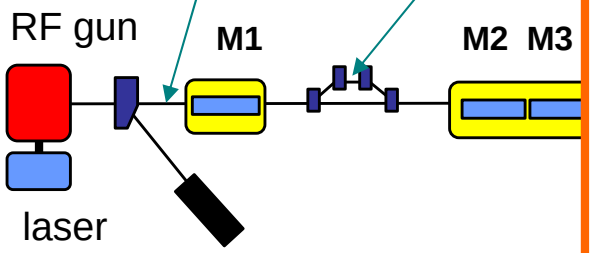
2. Lowering RF gradient at the cathode area
   - Lower amount of field emission
   - Beam quality degradation

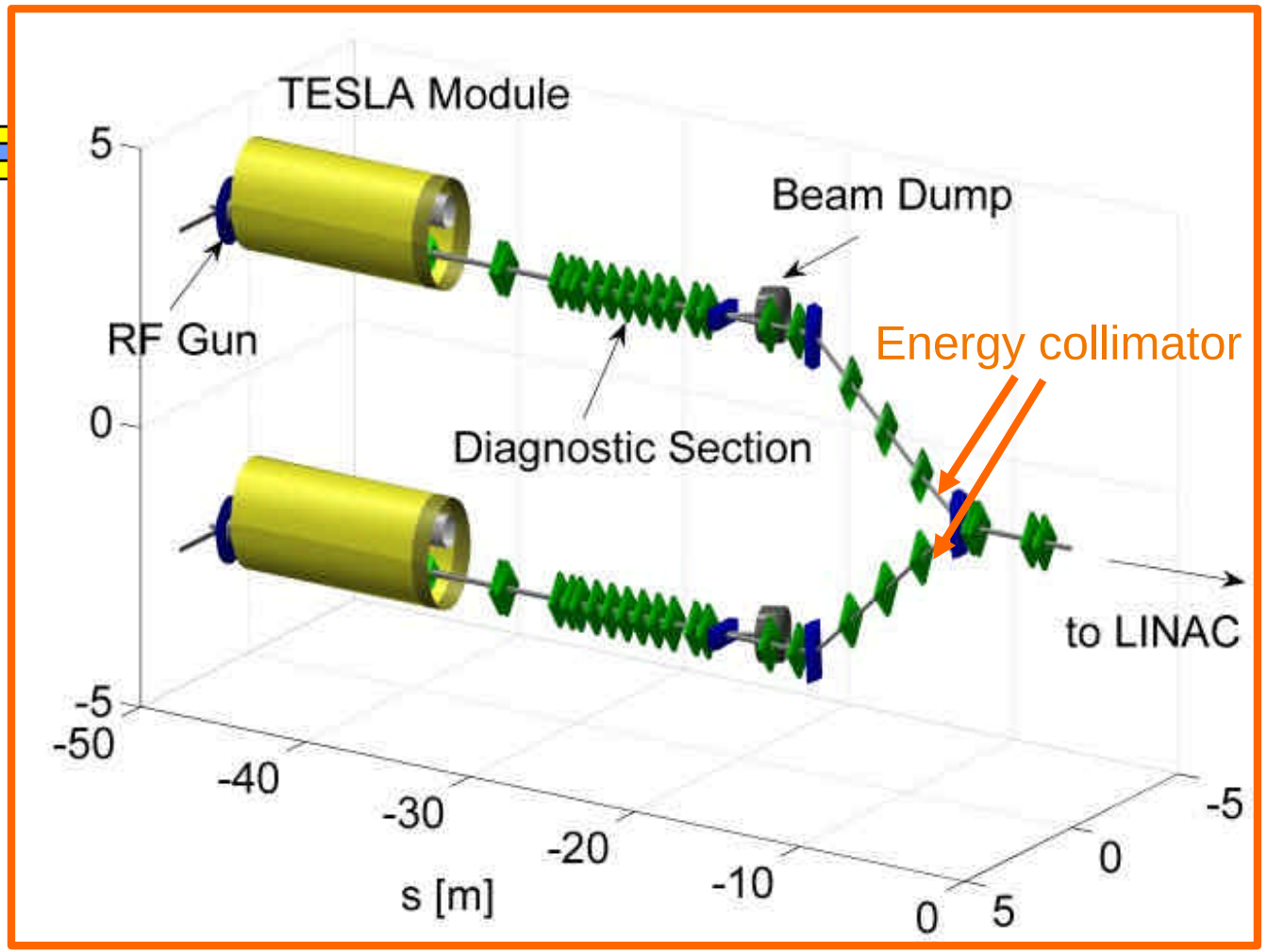
3. Applying collimators

Collimator

Geometrical collimator (different size)

Energy collimator (different energy distribution)





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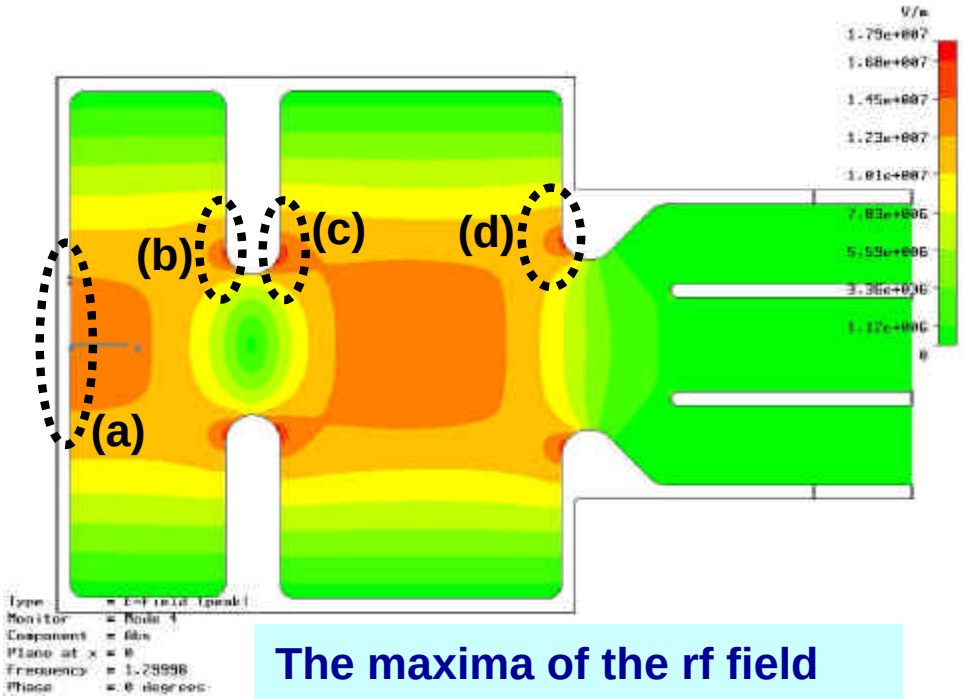
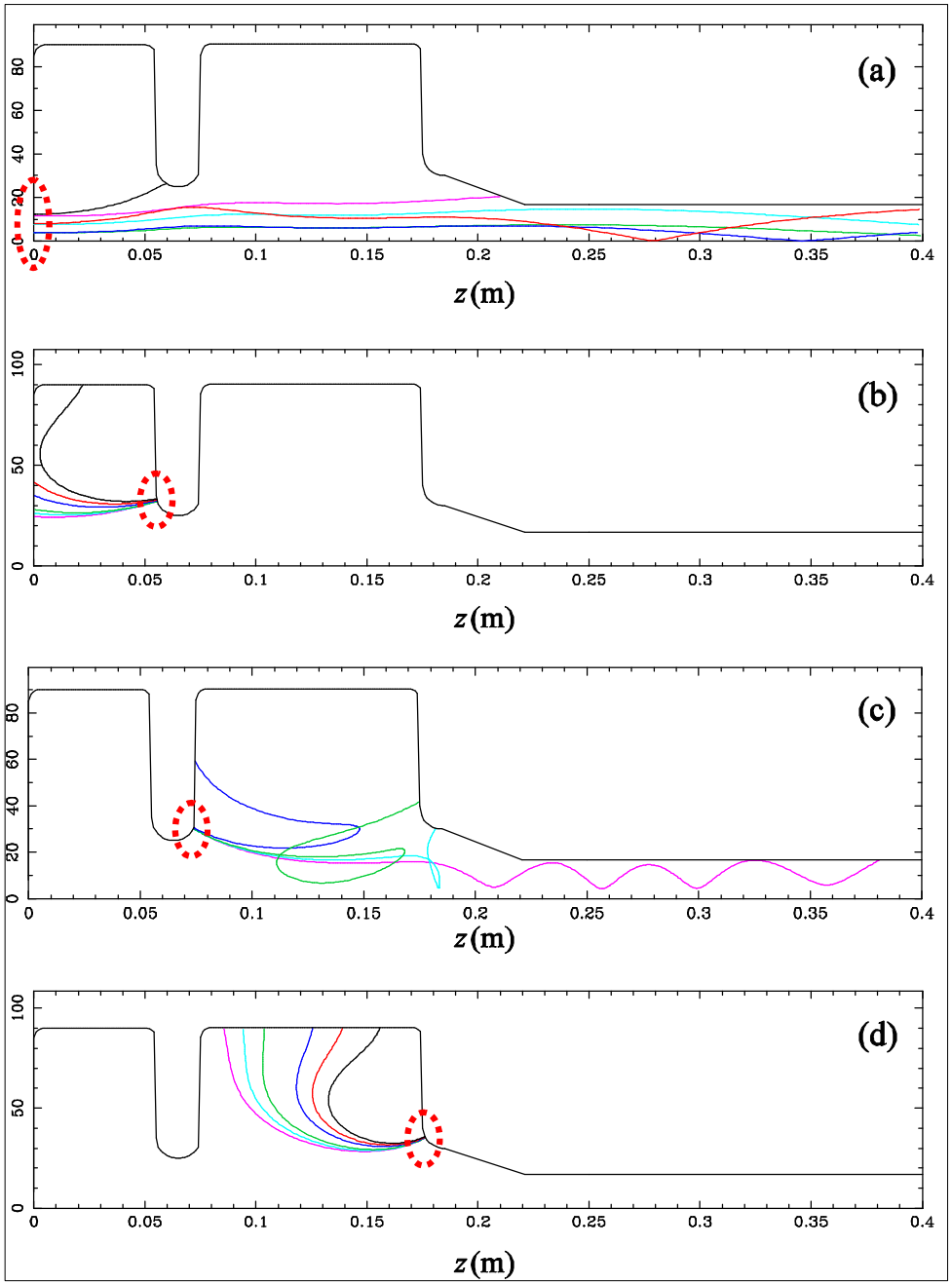
Parameter summary

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

DC trajectories

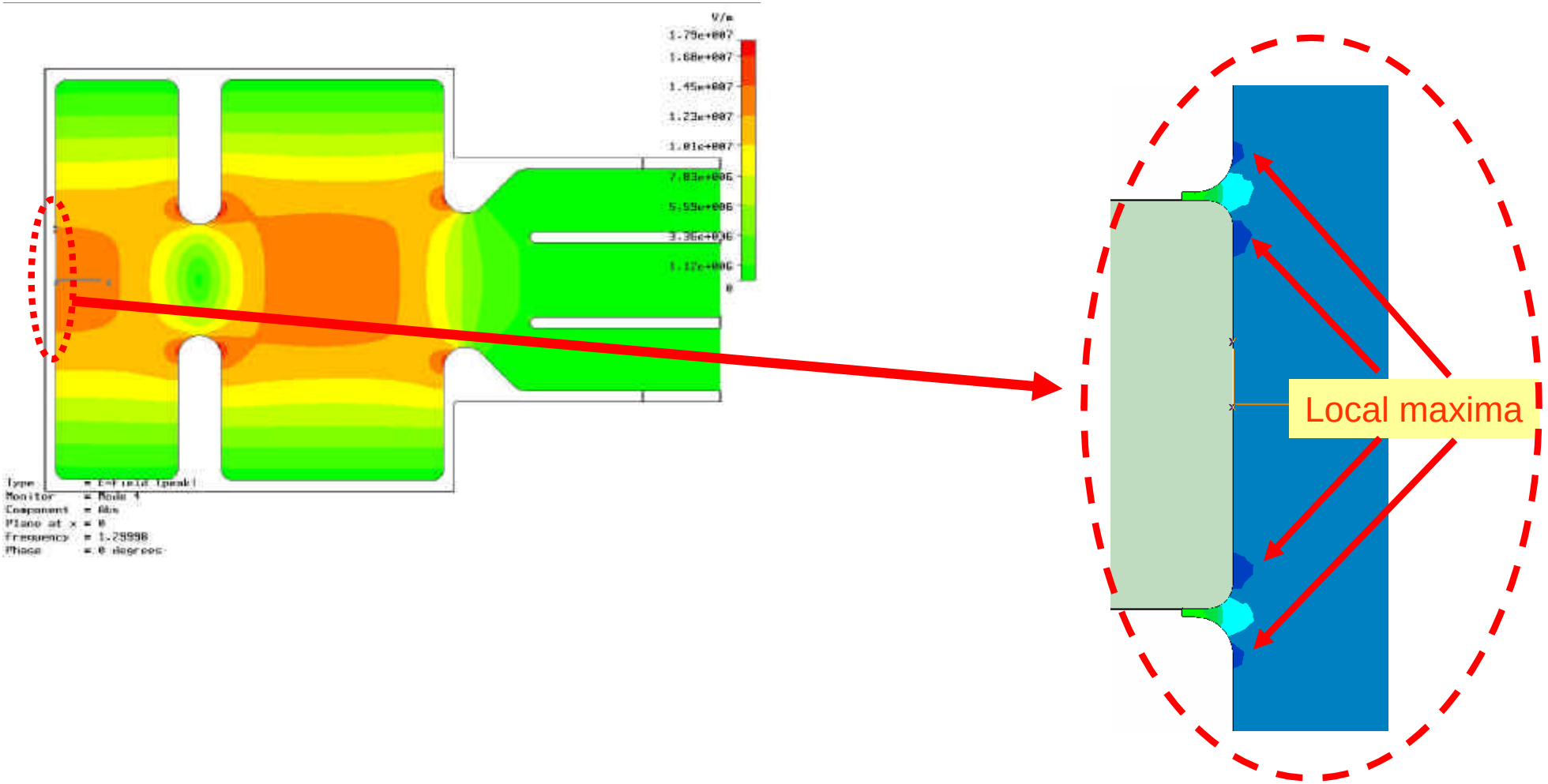


The maxima of the rf field strength can be the major source of dark current

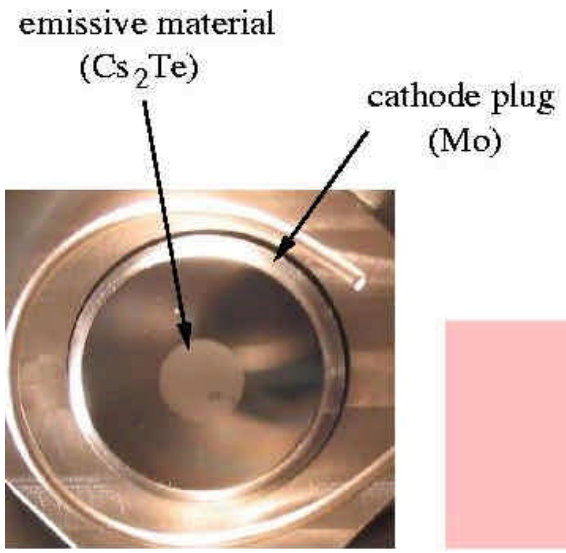


Astra simulation at 40 MV/m gradient and 300 A main solenoid current

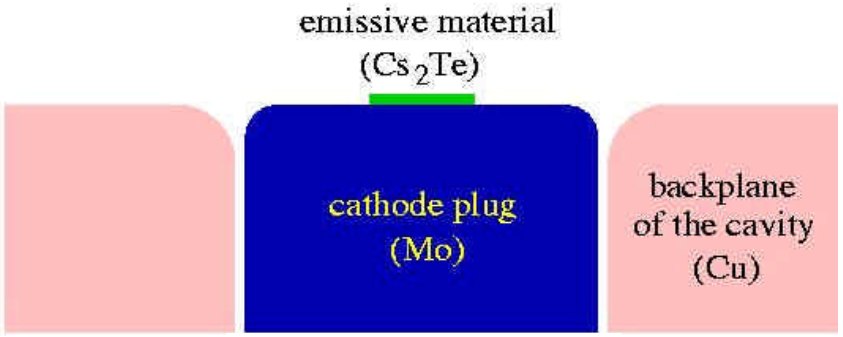
DC trajectories



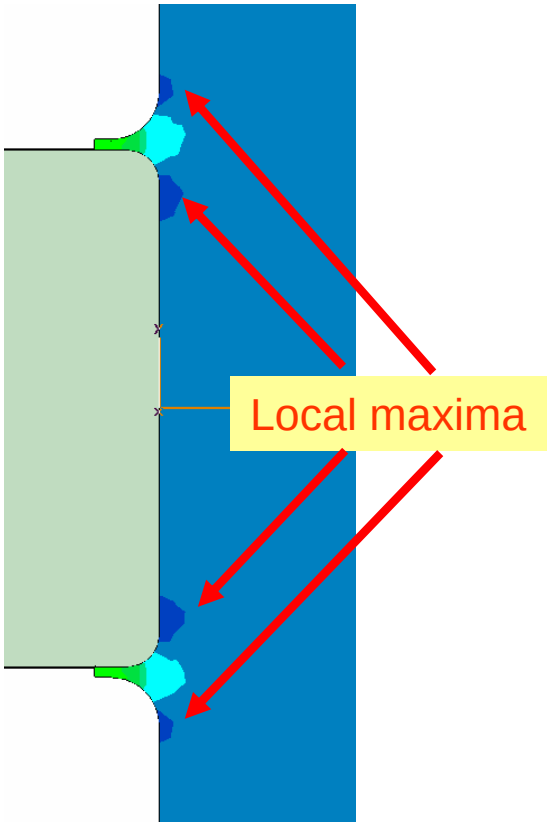
DC trajectories



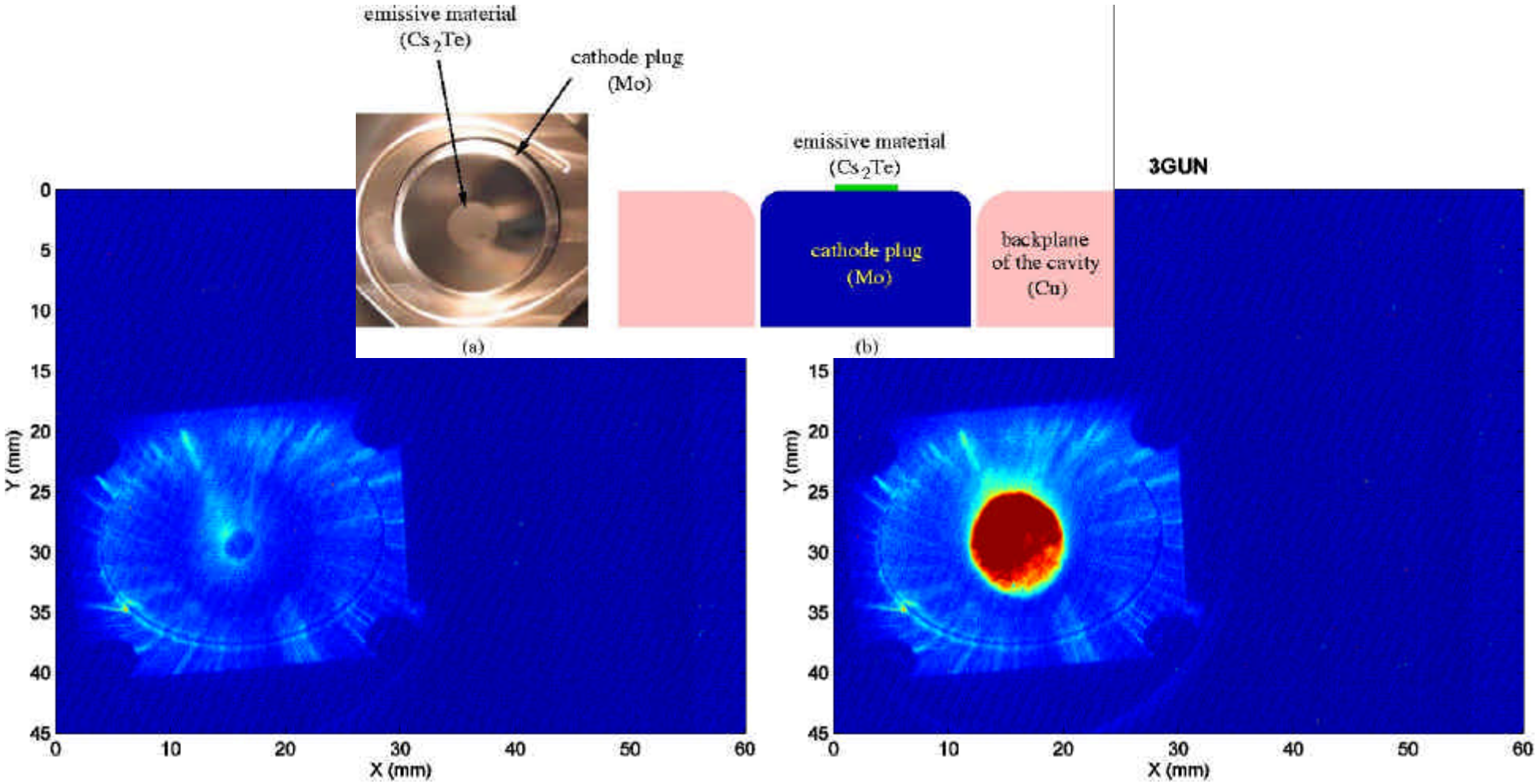
front view in the cathode chamber



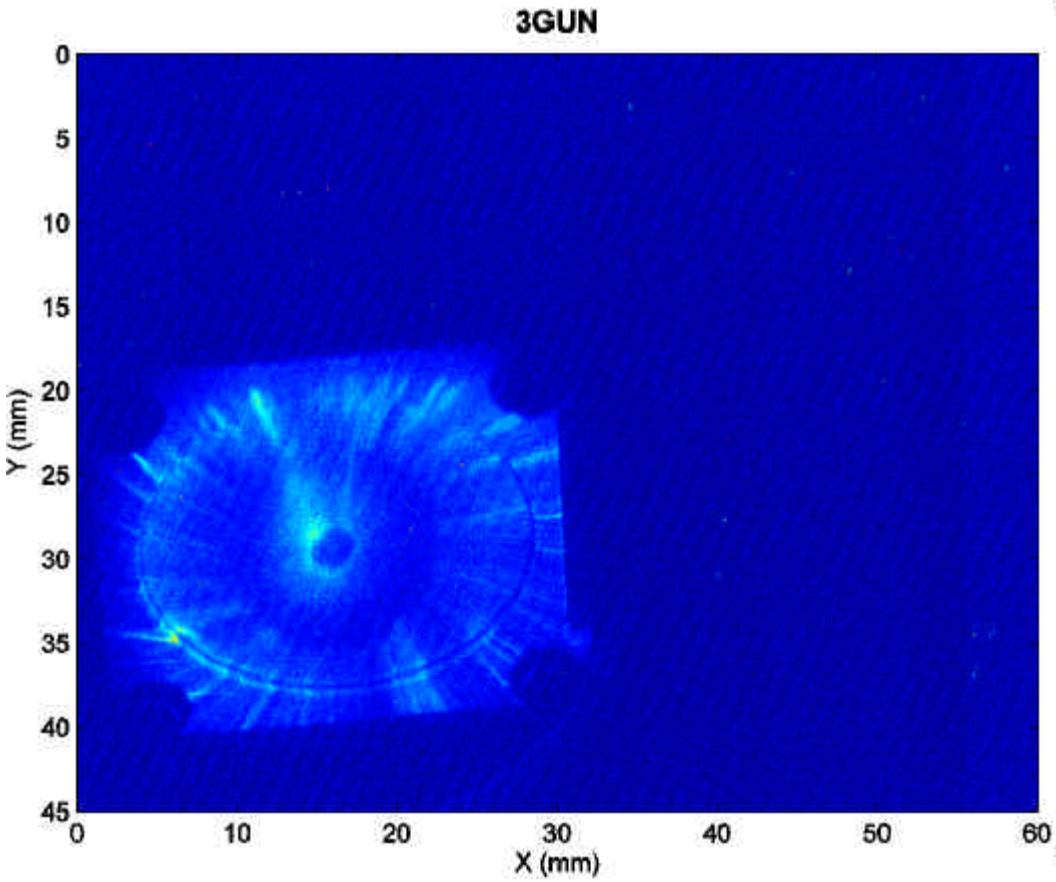
side view in the gun cavity

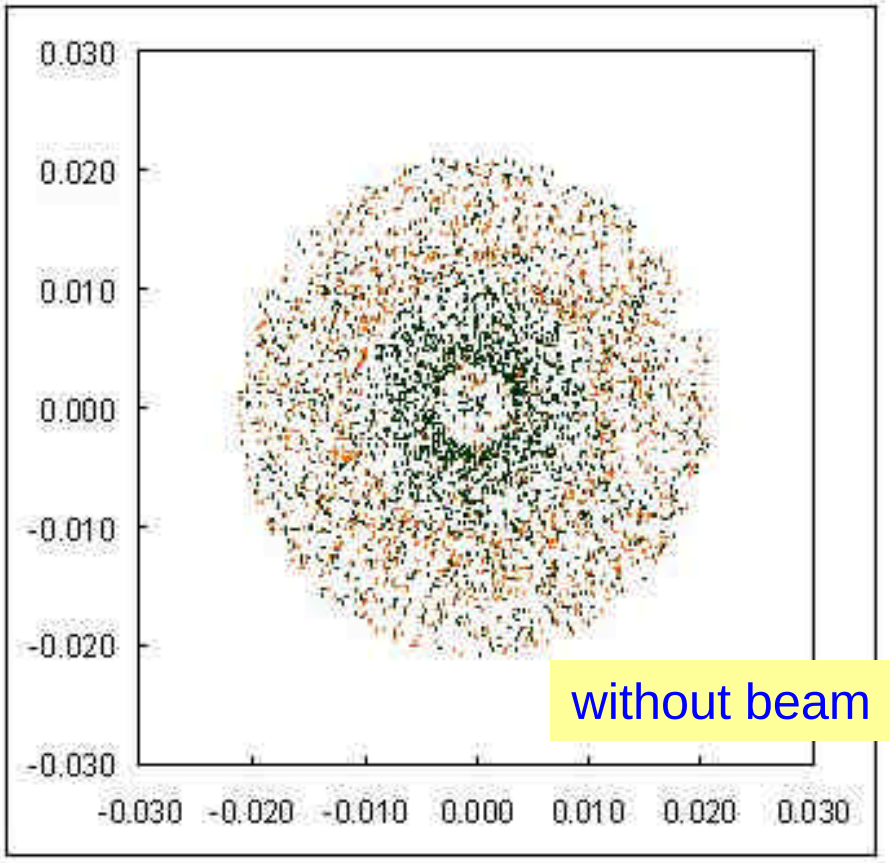


DC Image analysis



DC Image analysis





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

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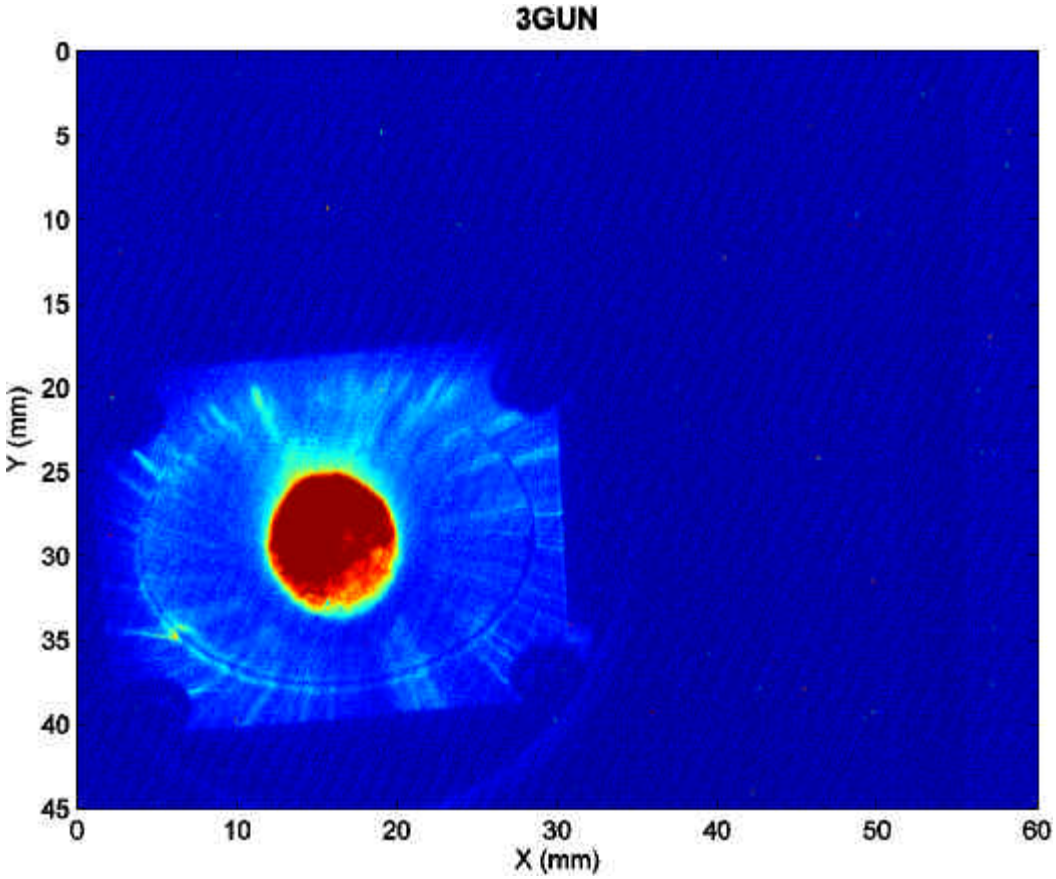
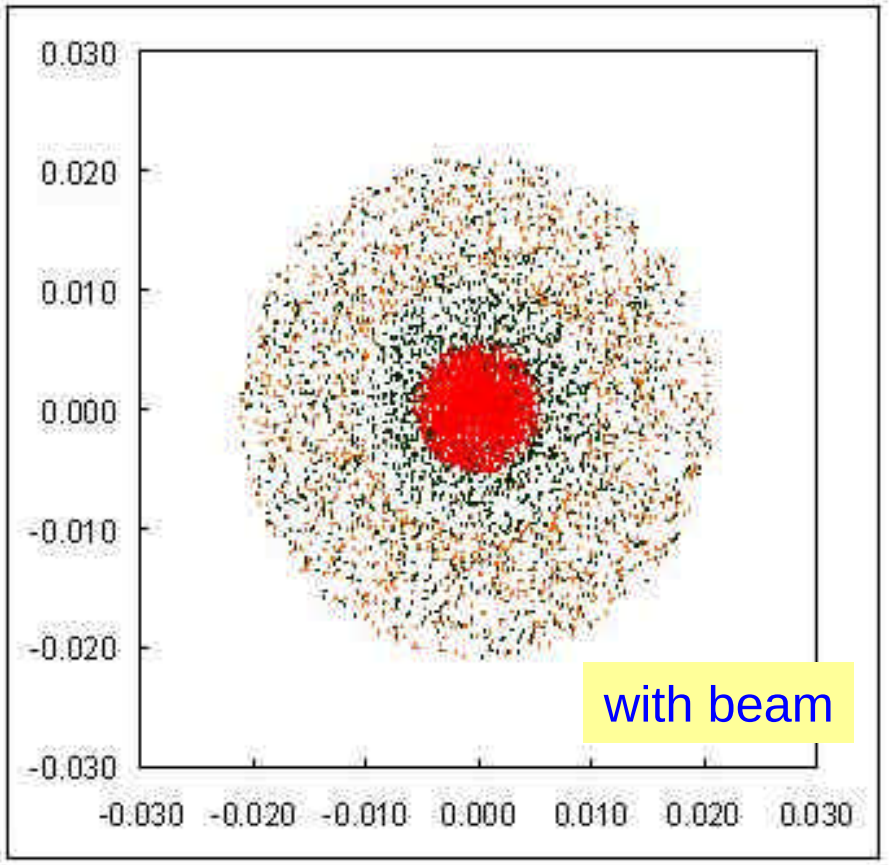
DC Image analysis

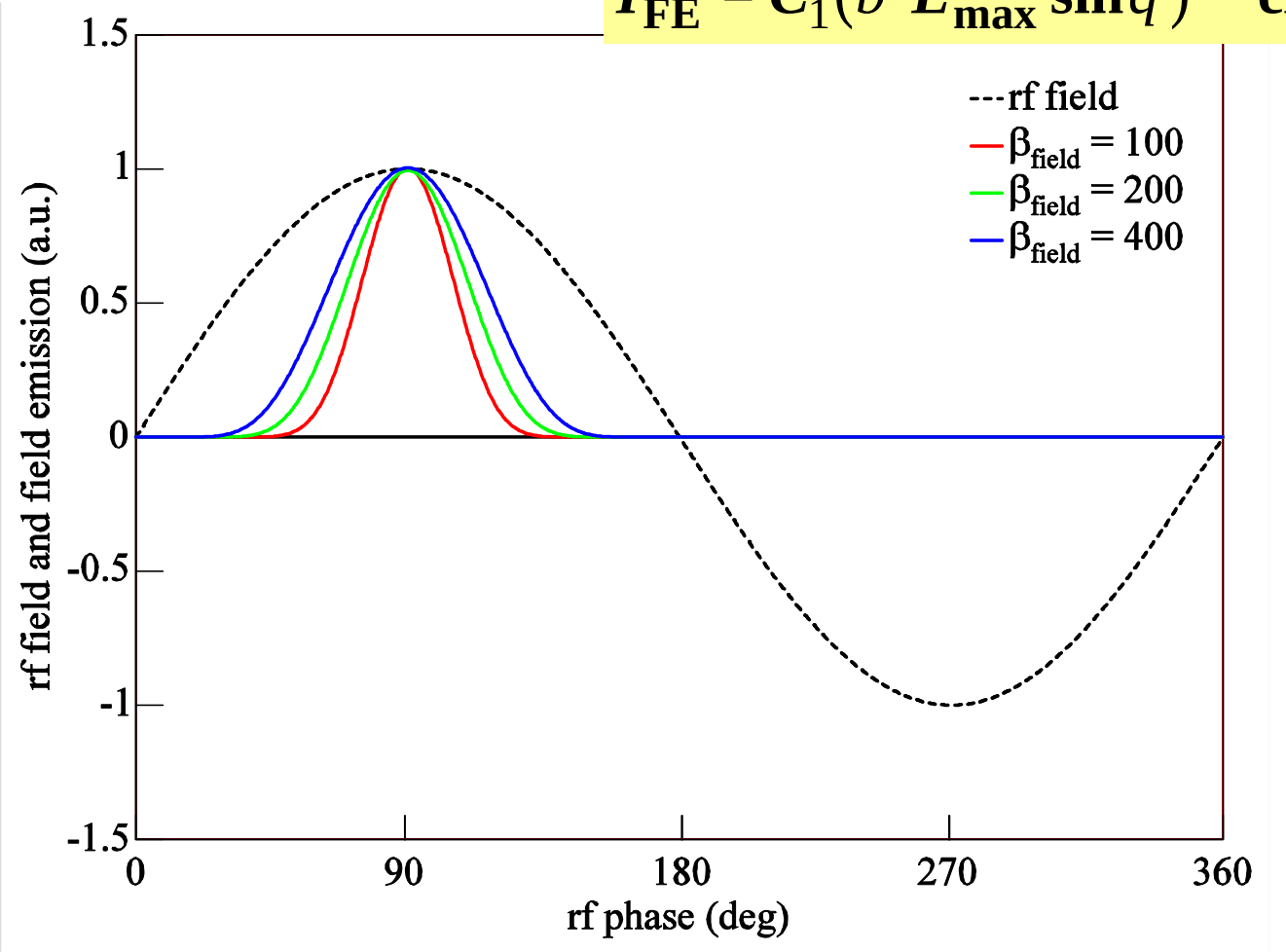




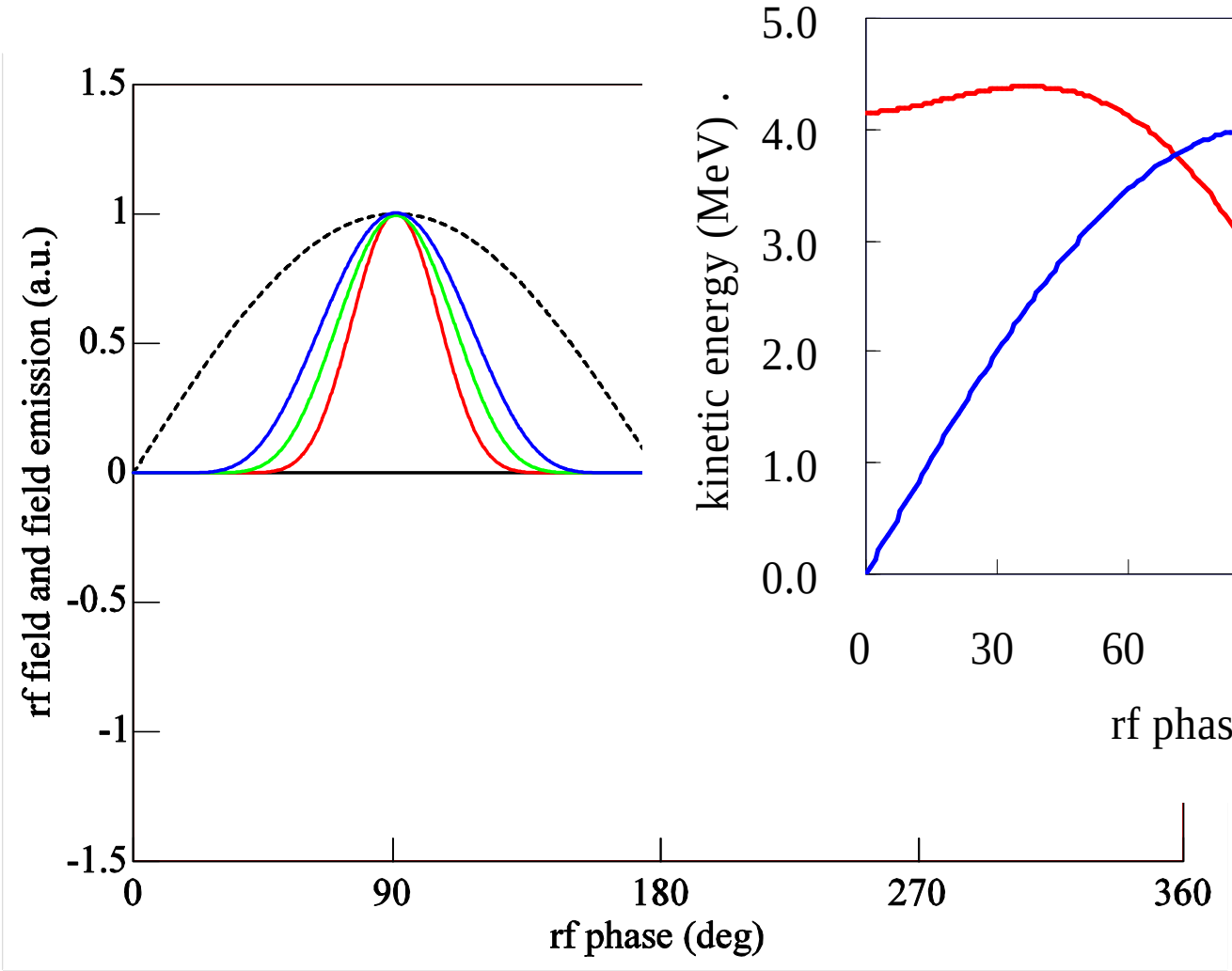
The green points are the electrons from the boarder of Cs_2Te.
The orange points are the electrons from the edge of Mo plug.
The red points are the electron beams.

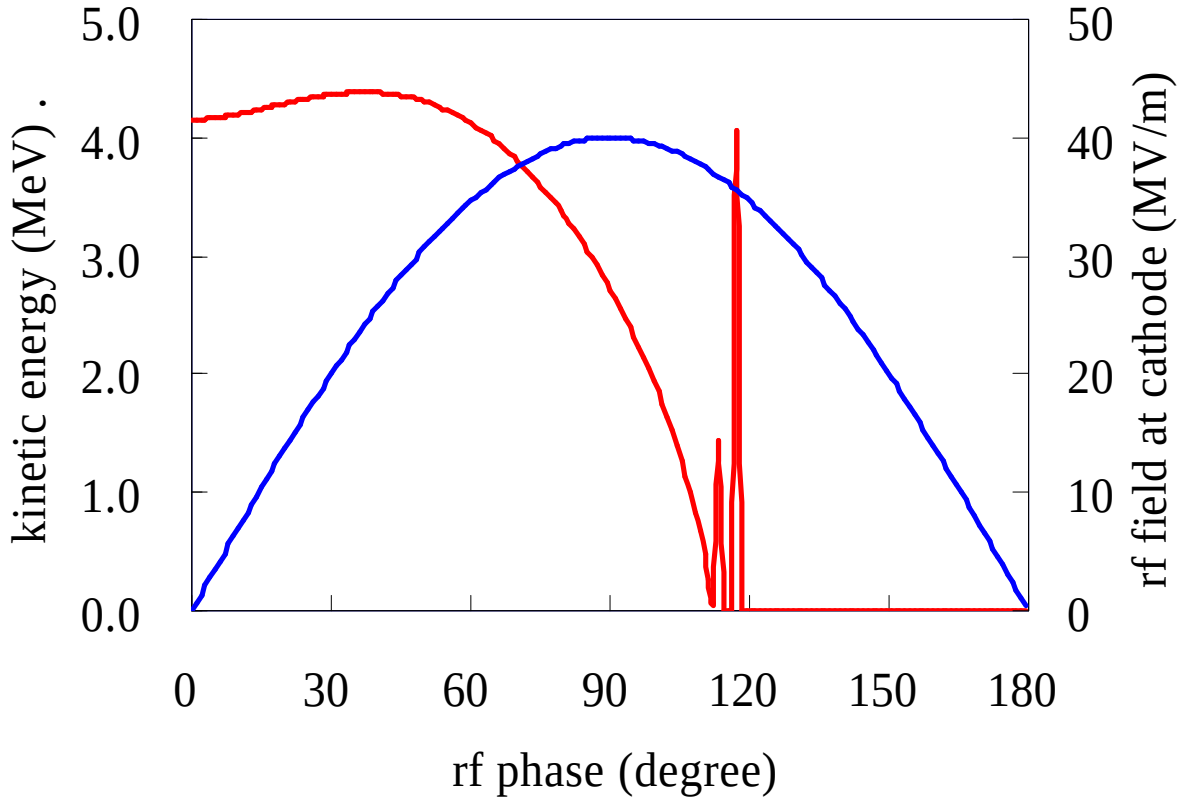
Field emission Vs. emission phase

$$\bar{I}_{FE} = C_1 (b\ E_{max} \sin q)^{2.5} \exp[-C_2 / (b\ E_{max} \sin q)]$$

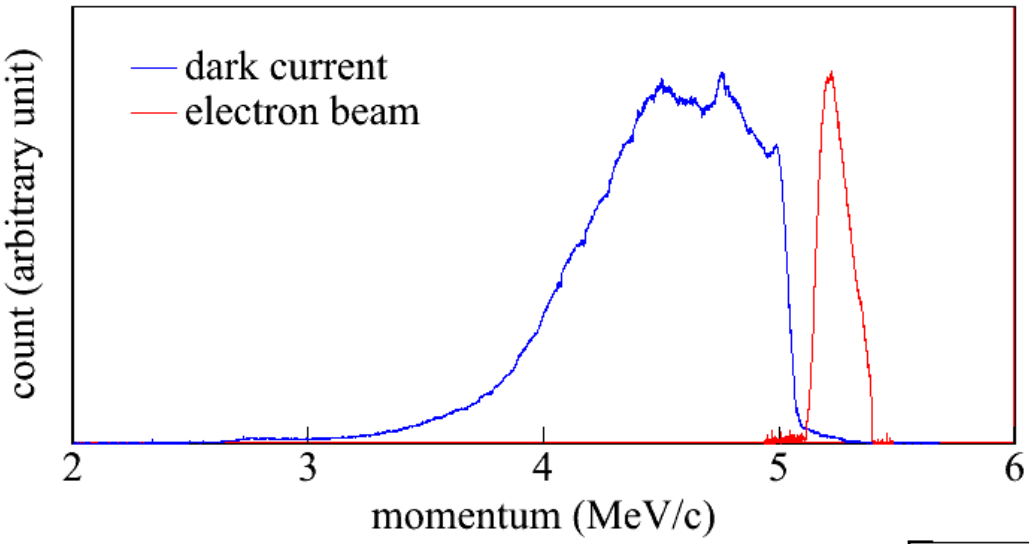


Field emission Vs. emission phase (FLASH)



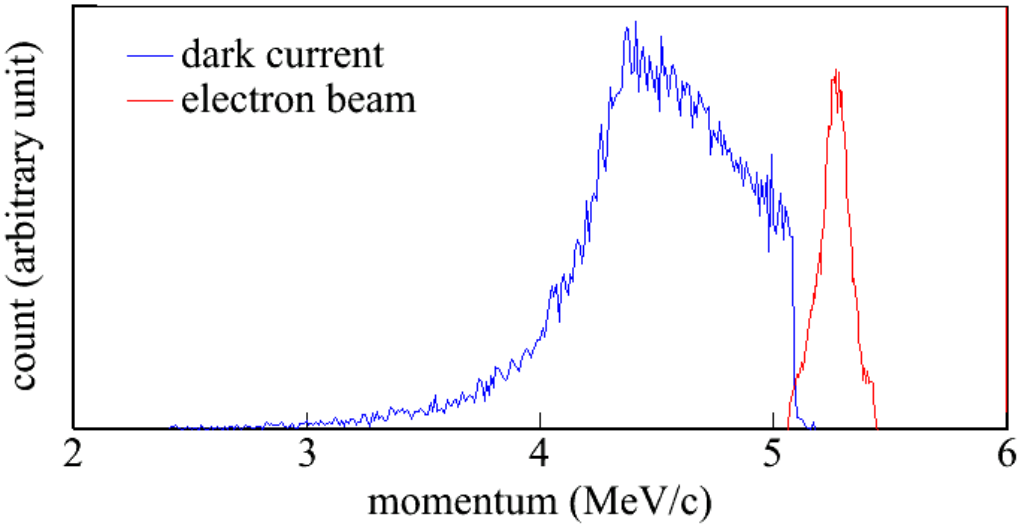


Momentum distribution after gun (measurement at PITZ)

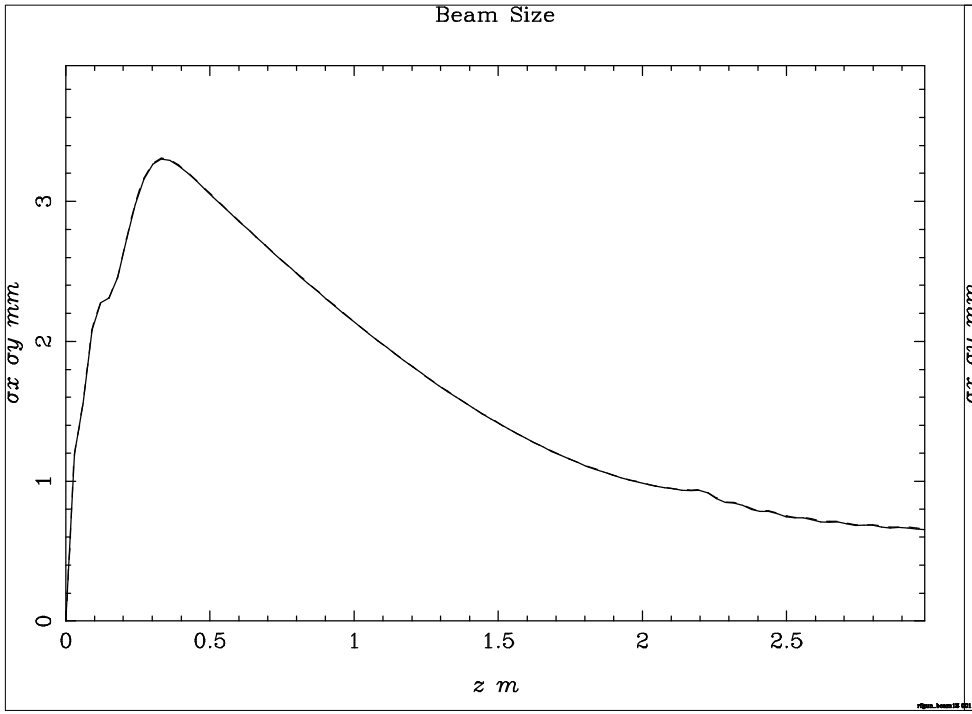


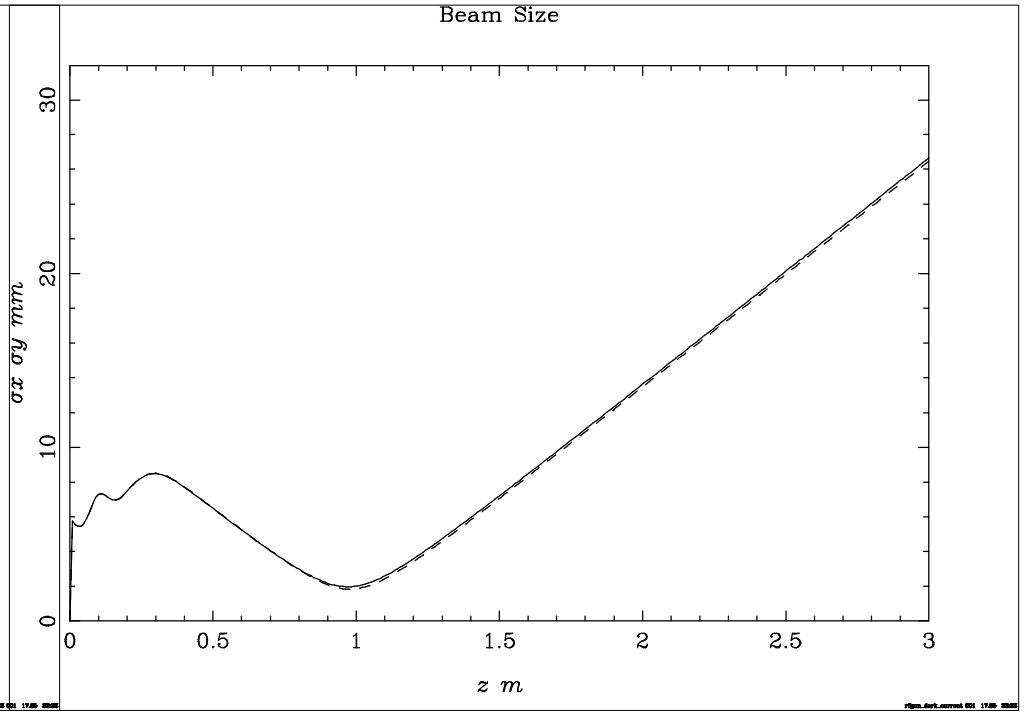
measurement

simulation



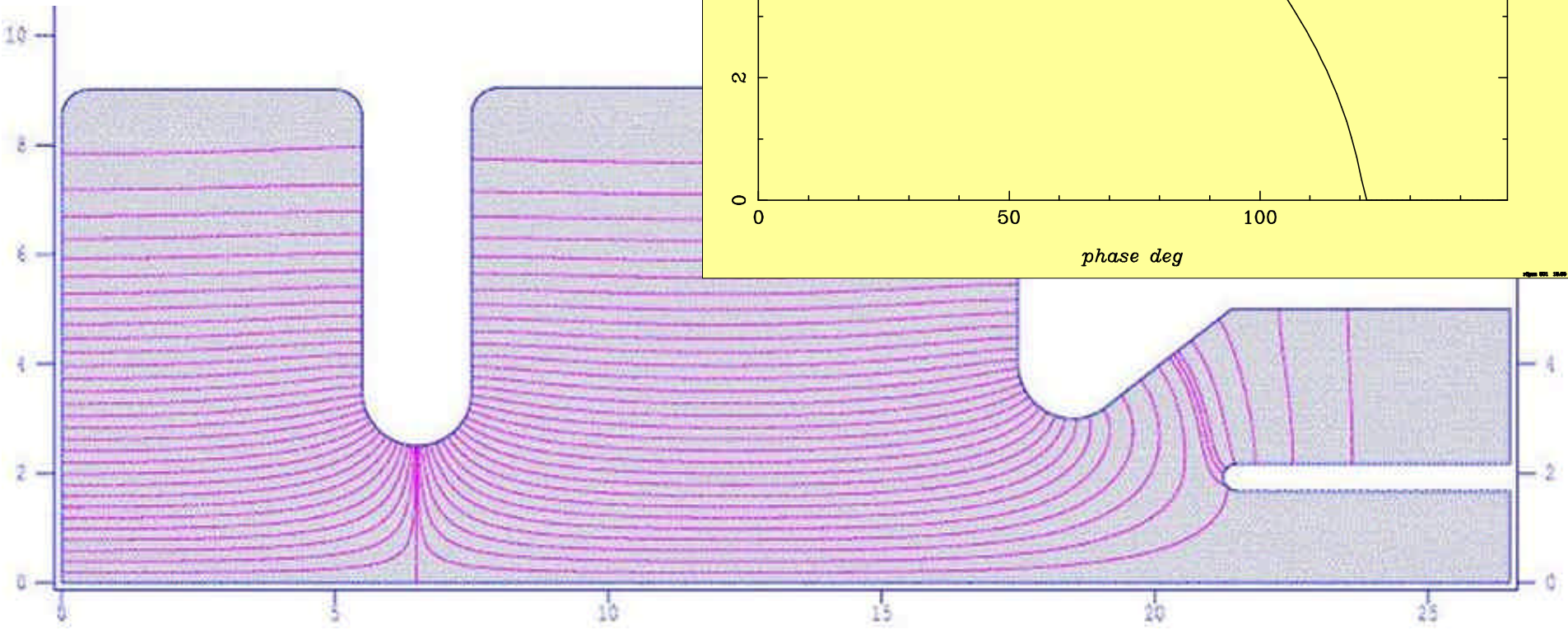
XY size of beam & dark current (FLASH)

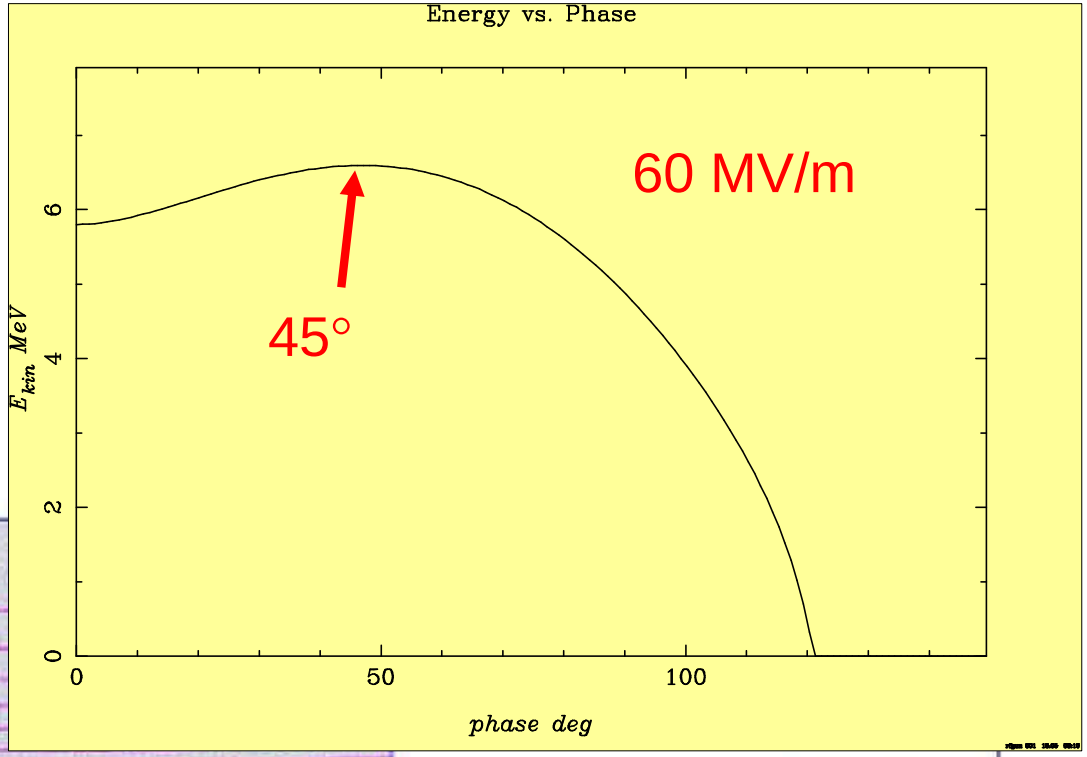




Gun for PITZ and FLASH

F = 1300.1361 MHz, Q = 26754





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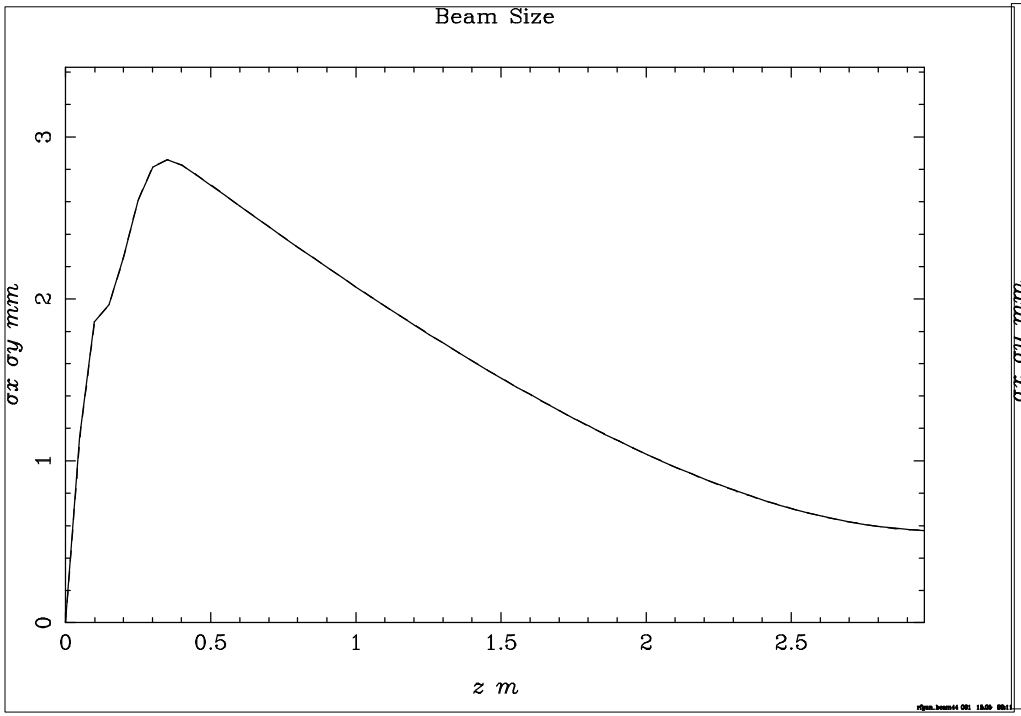
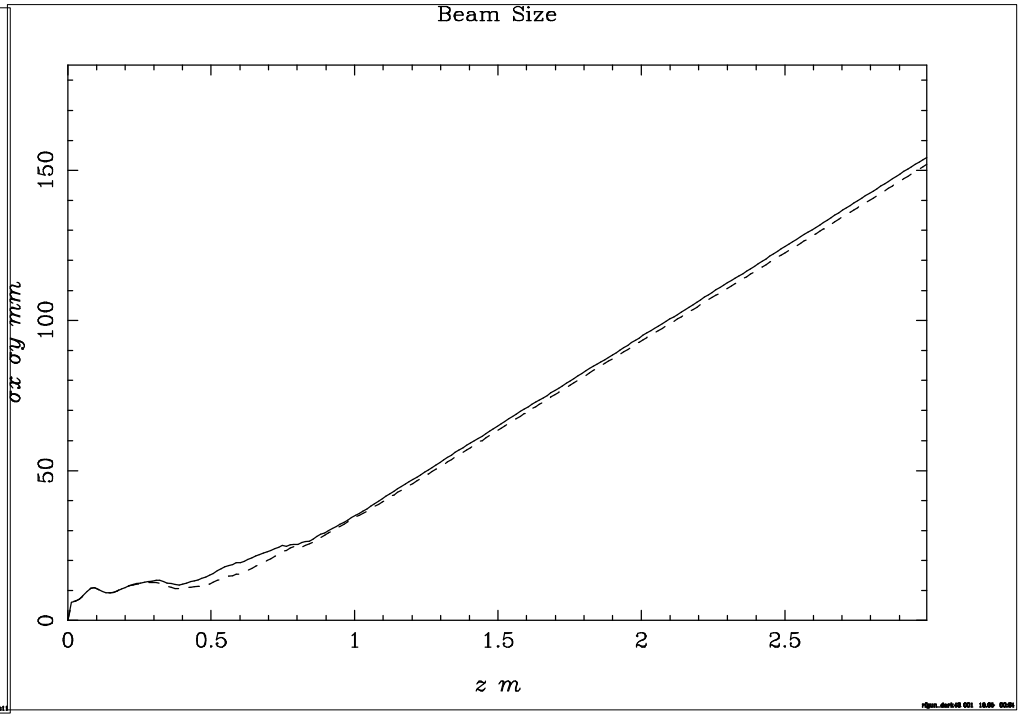
Parameter summary

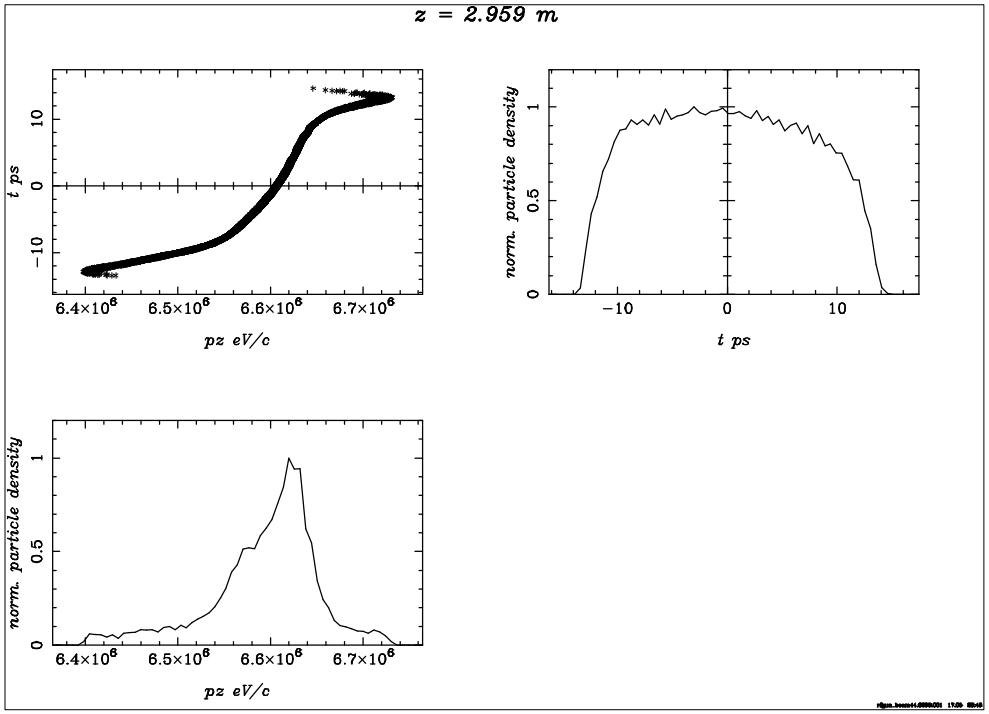
		FLASH (measure)	**XFEL (original)**	
laser	XYrms	~1 mm	0.44 mm	
	Lt	6~7 ps Gaussian	20	
	rt		2	
	Ek	0.55 eV	0.55 eV	
gun	Ecath	~42 MV/m	60 MV/m	
	$f$emit	38°	46°	
	Bmax	0.165 T	0.225 T	
	Sol. position	0.276 m	0.276 m	
ACC1	entrance	2.48 m	3.2 m	
	Emax	16 MV/m	21.5 MV/m	
	ACC1 f	~ on crest	-16°	
beam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

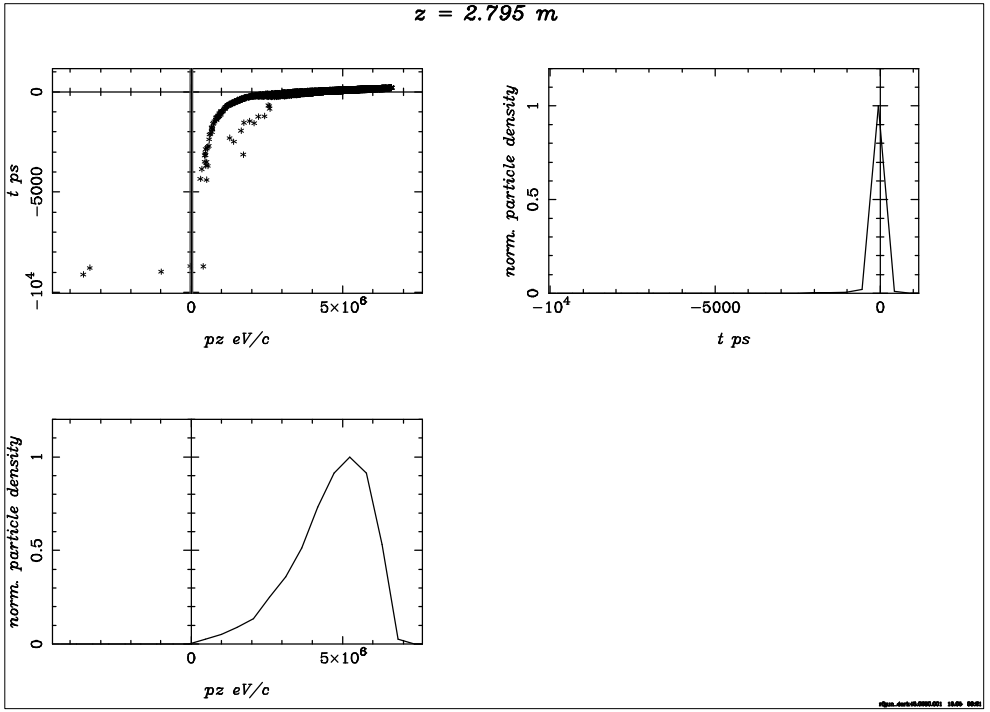
XY size of beam & dark current (XFEL, original)





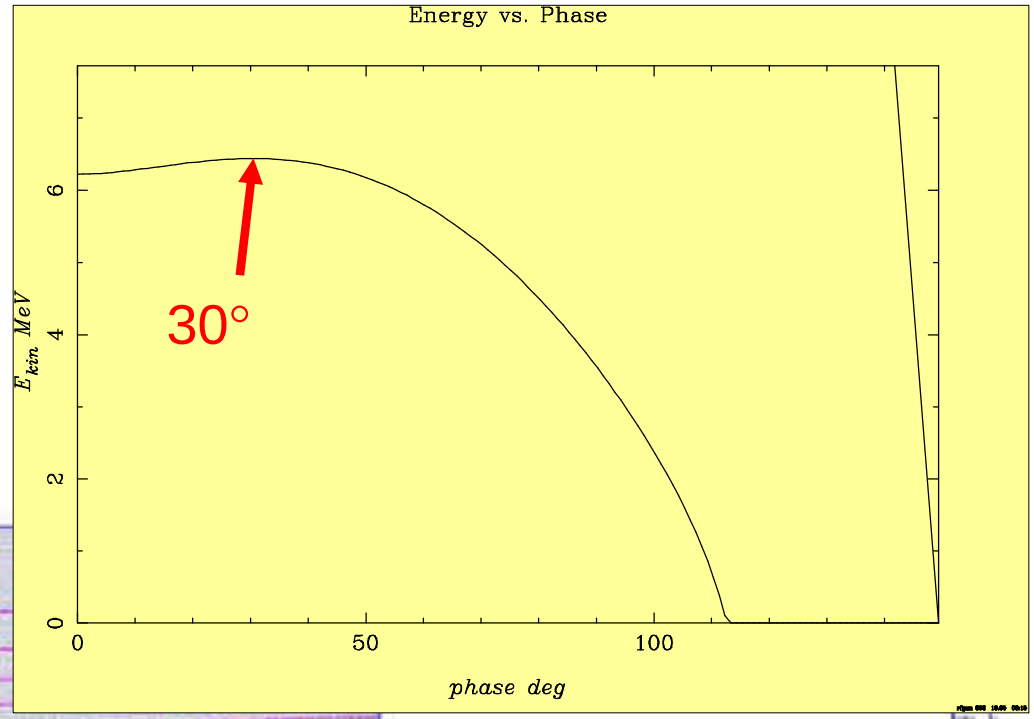
Momentum of beam & dark current (XFEL, original)

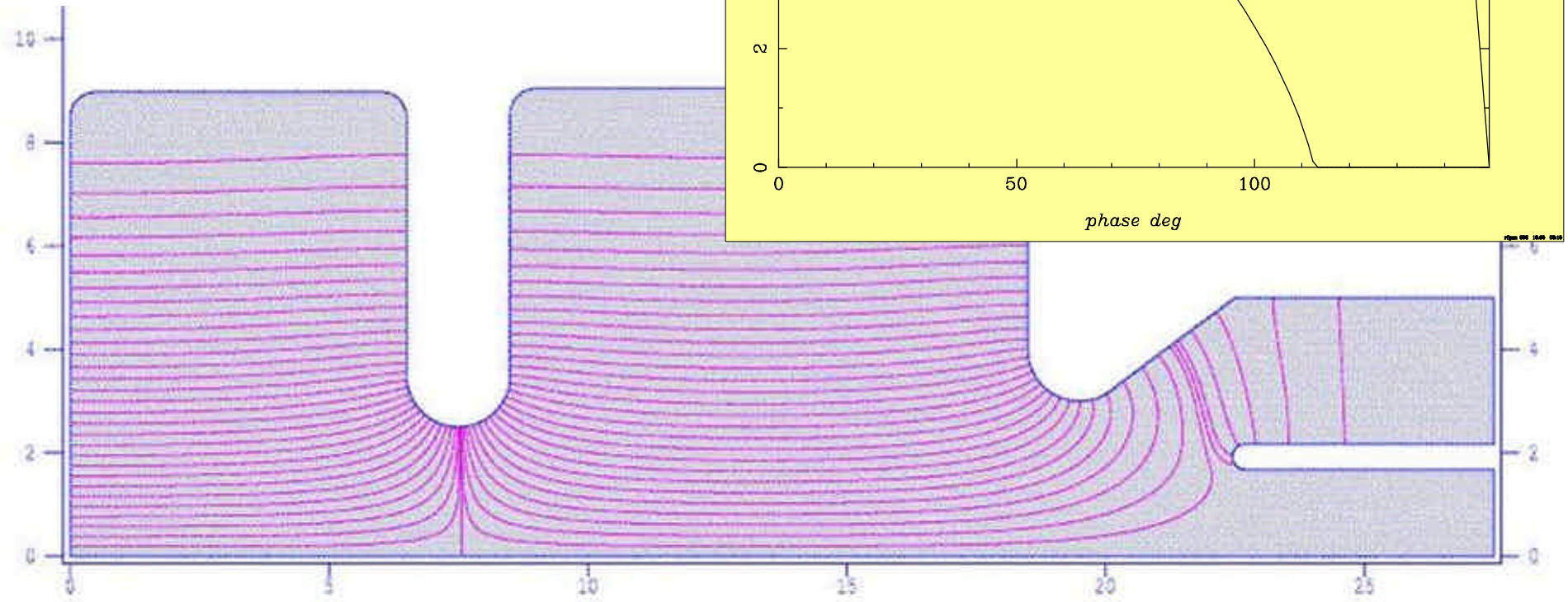




New design for the XFEL

F = 1300.0112 MHz, Q = 27621





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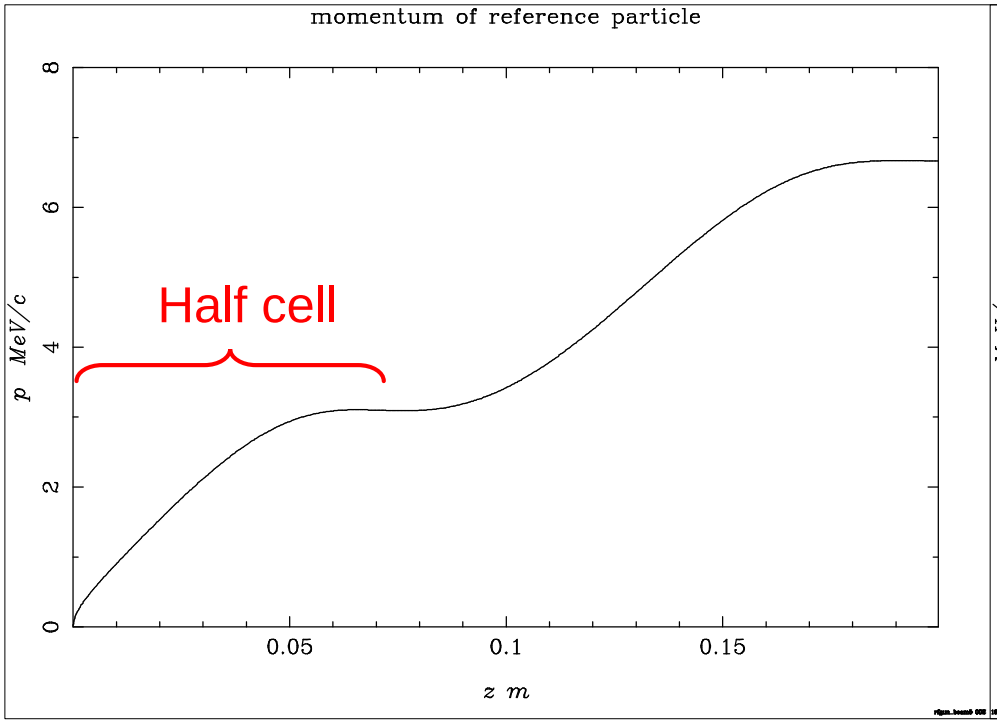
Parameter summary

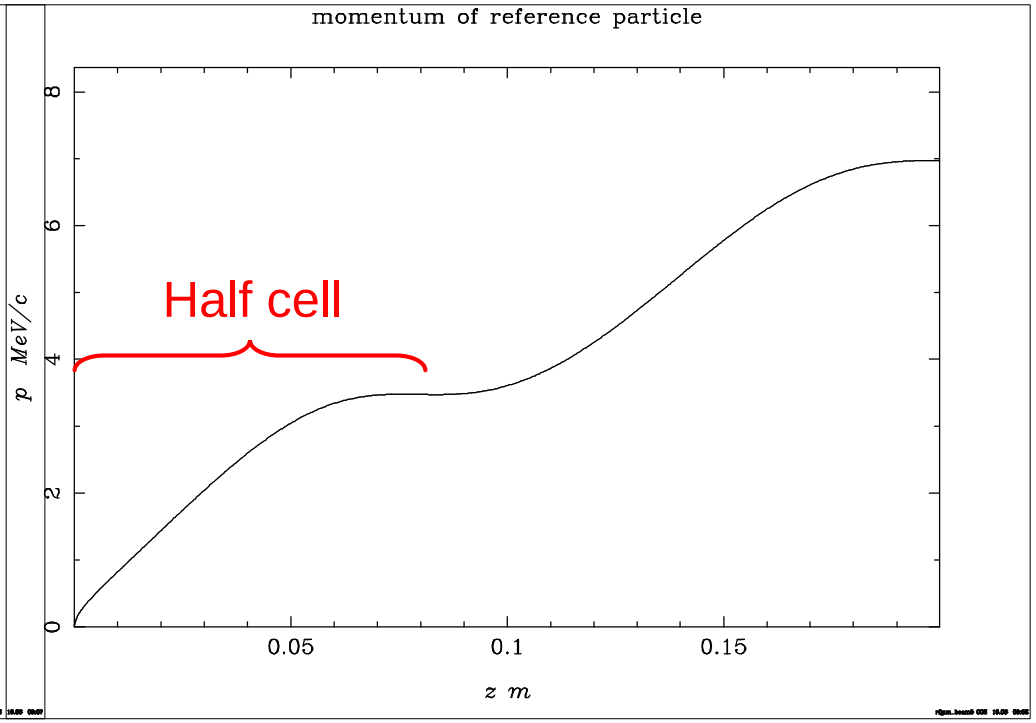
		FLASH (measure)	**XFEL (original)**	**XFEL (new)**
laser	XYrms	~1 mm	0.44 mm	0.55 mm
	Lt	6~7 ps Gaussian	20	23.5
	rt		2	2
	Ek (assumed)	0.55 eV	0.55 eV	0.55 eV
gun	Ecath	~42 MV/m	60 MV/m	60 MV/m
	$f$emit	38°	46°	30°
	Bmax	0.165 T	0.225 T	0.233 T
	Sol. position	0.276 m	0.276 m	0.286 m
ACC1	entrance	2.4 m	3.2 m	2.4 m
	Emax	16 MV/m	21.5 MV/m	20 MV/m
	ACC1 f	~ on crest	-16°	-16°
beam	emittance	<2 mm mrad	0.7 mm mrad	0.7 mm mrad

Electron acceleration at half cell

Present gun

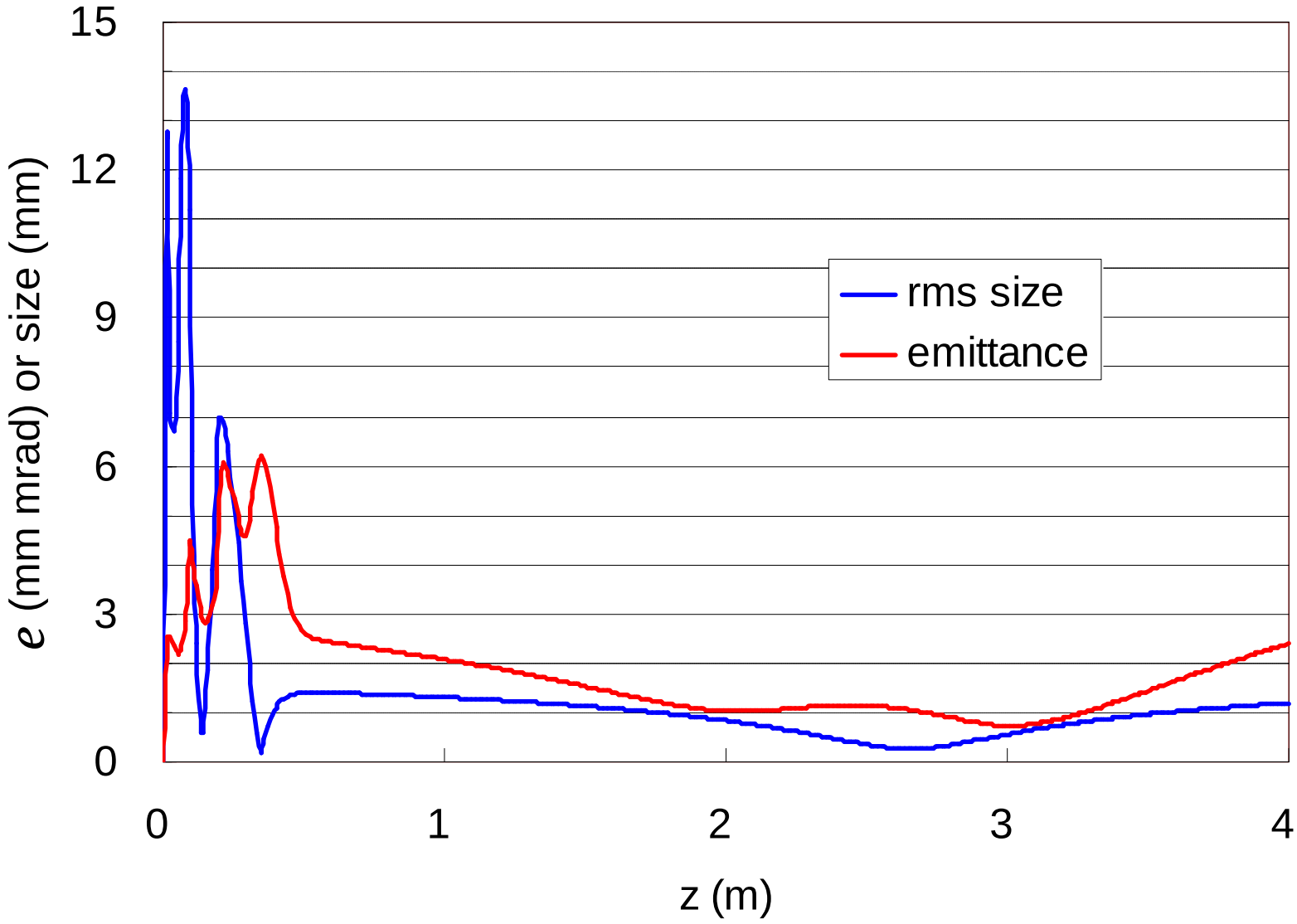


New design

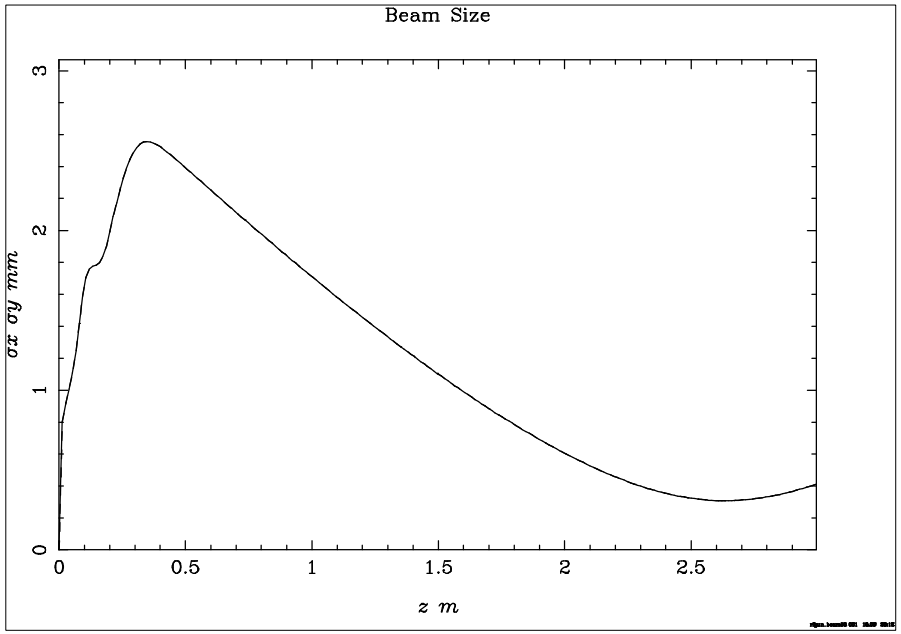


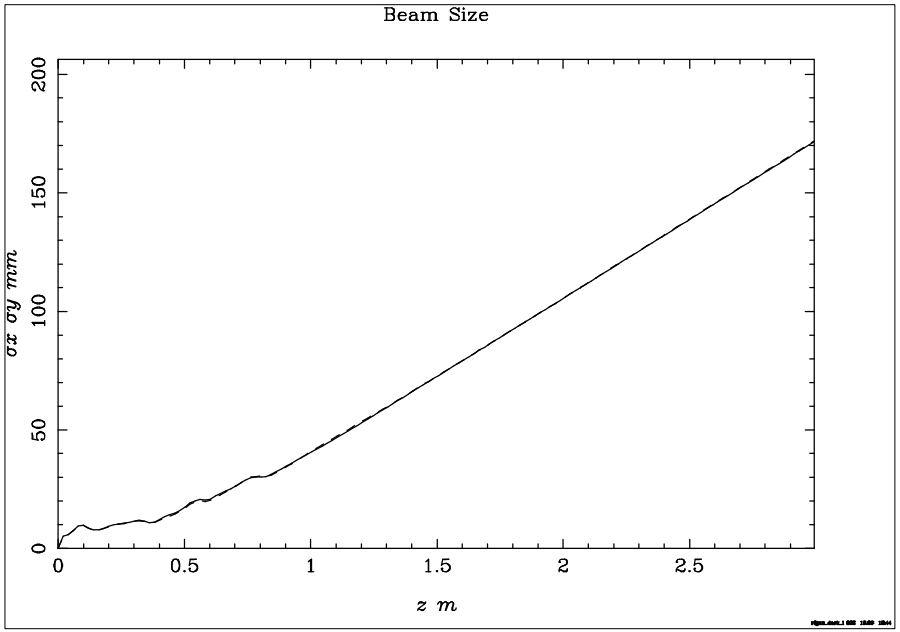
Lower gradient at the cathodes, but even more acceleration at the half cell
→ Able to get a low emittance!

Beam at the new design gun

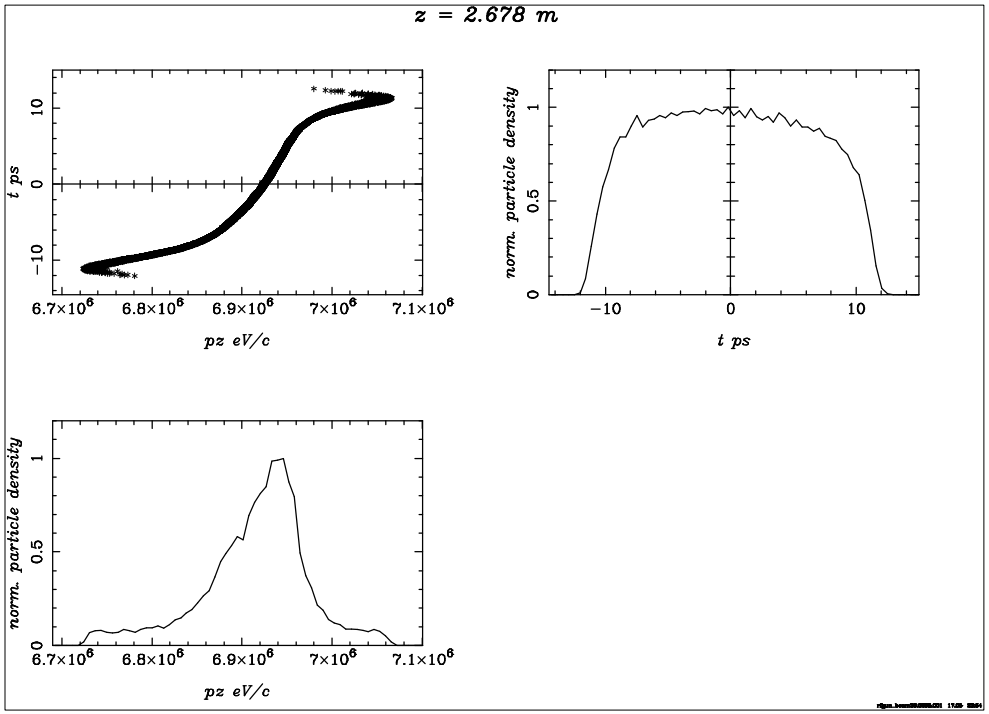


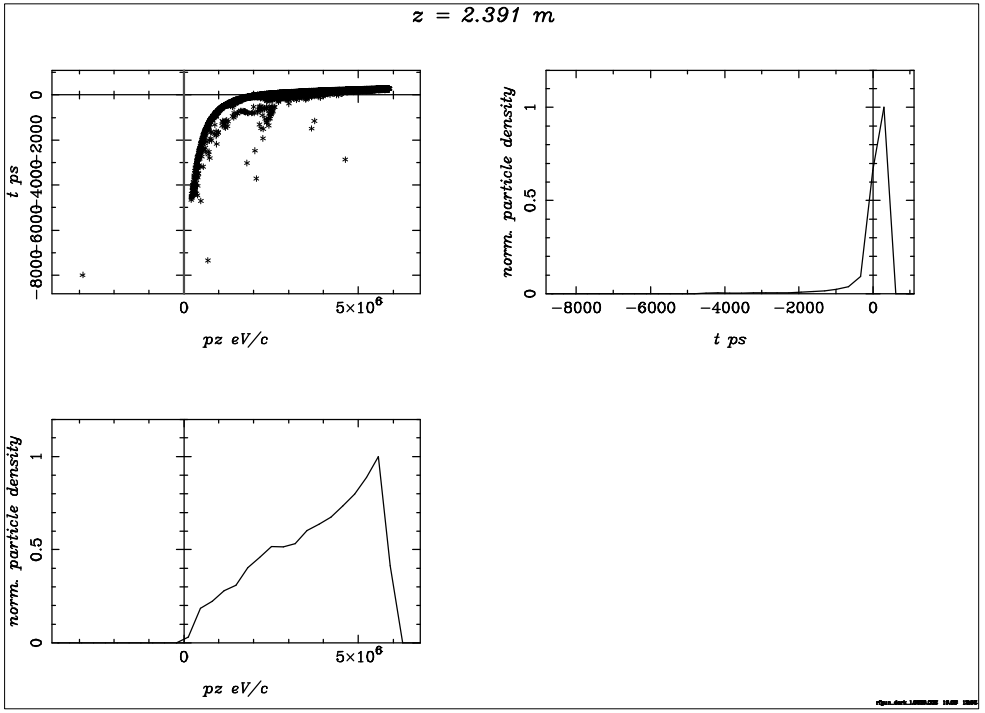
XY size of beam & dark current (XFEL, new design)





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





Conclusion and outlook

• 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 including the first accelerator module