Dark Current at Injector

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XFEL Beam Dynamics Meeting

Considerations for the guns

- Ultra-low slice emittance of electron beams
    - → higher gradient at the gun cavity
    - → solenoid field in the gun

- Low dark current
    - → lower gradient at the gun cavity
   - → effective collimation

- Stable operation

Dark current collimation at FLASH

Dark current source

Gun backplane

Cathode surface (5 mm diameter)

16 mm

Cu-Be Spring
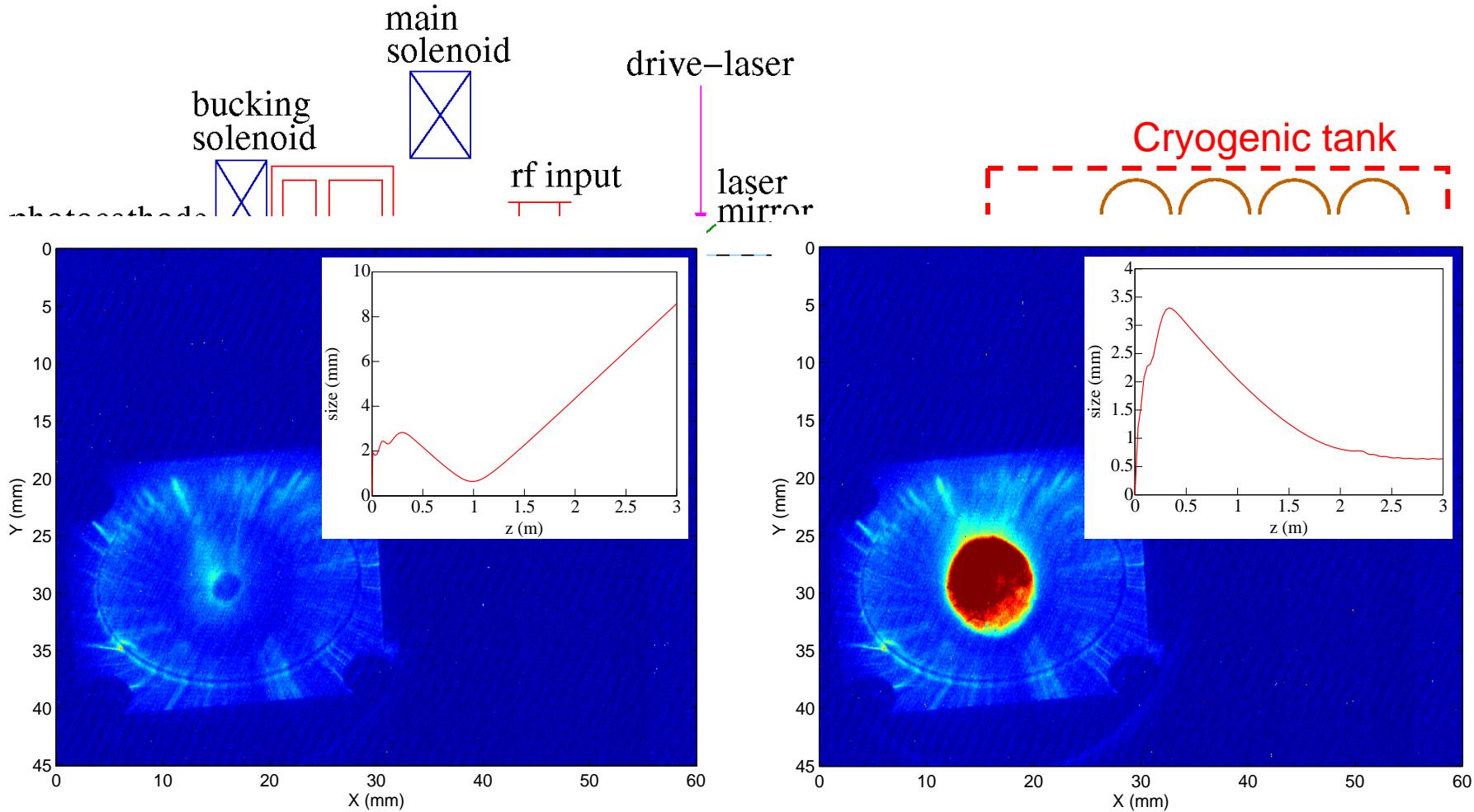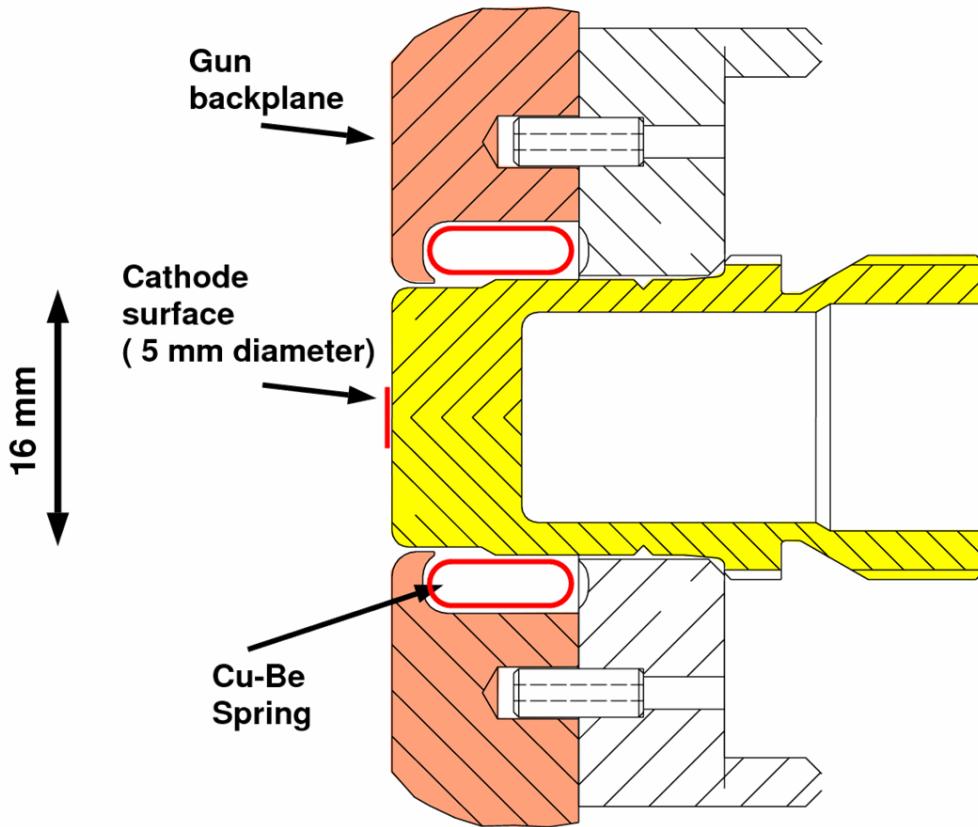
Drawing by S. Schreiber

without beam

with beam
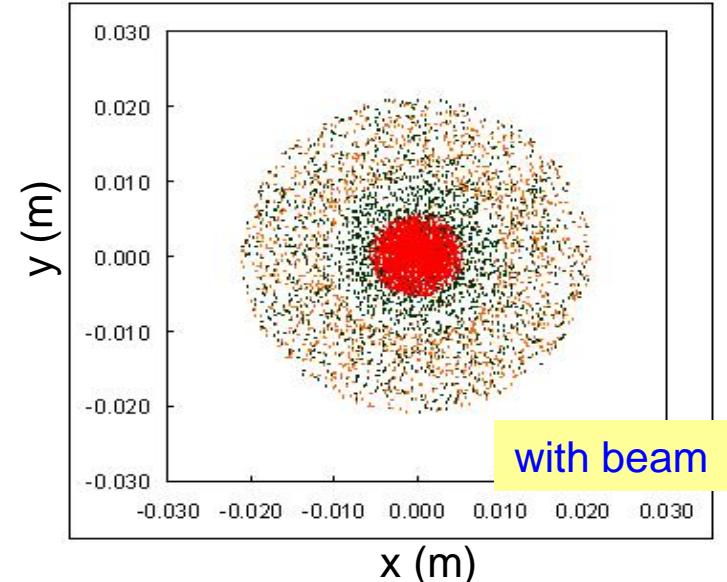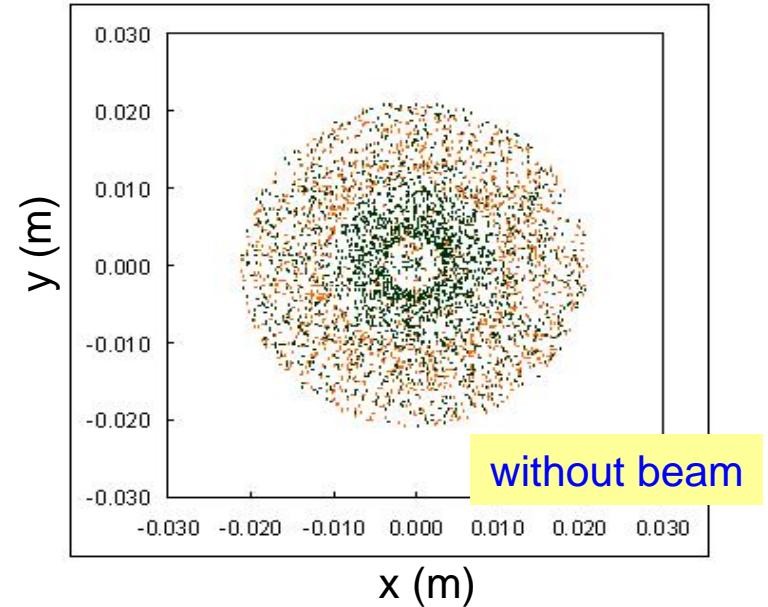
Effect of the present collimator

main solenoid

bucking solenoid

drive–laser

Cryogenic tank

rf input

photocathode (Cs$_2$Te)

coaxial coupler

rf cavity (copper, 1.5 cells)

superconductor acceleration module

1/2/3/4BC2
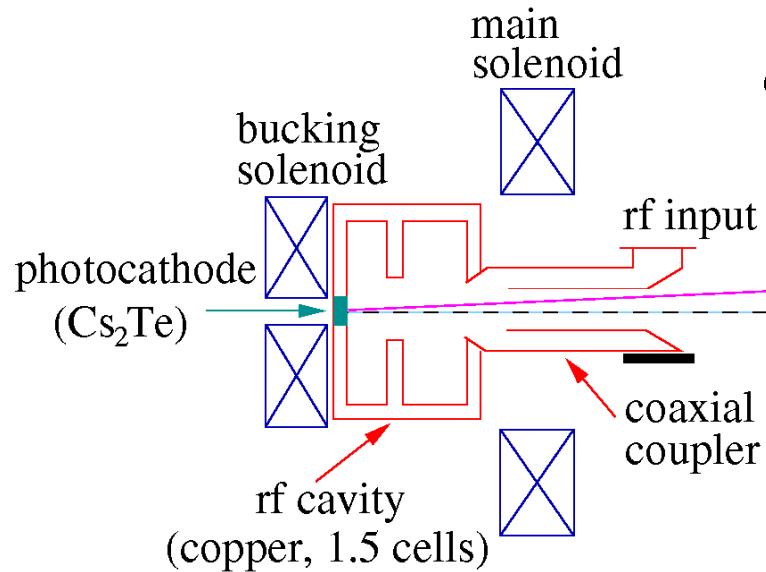
Collimator at the present position

8 mm ϕ: 46% (simulation)

FLASH logbook
2006-08-12
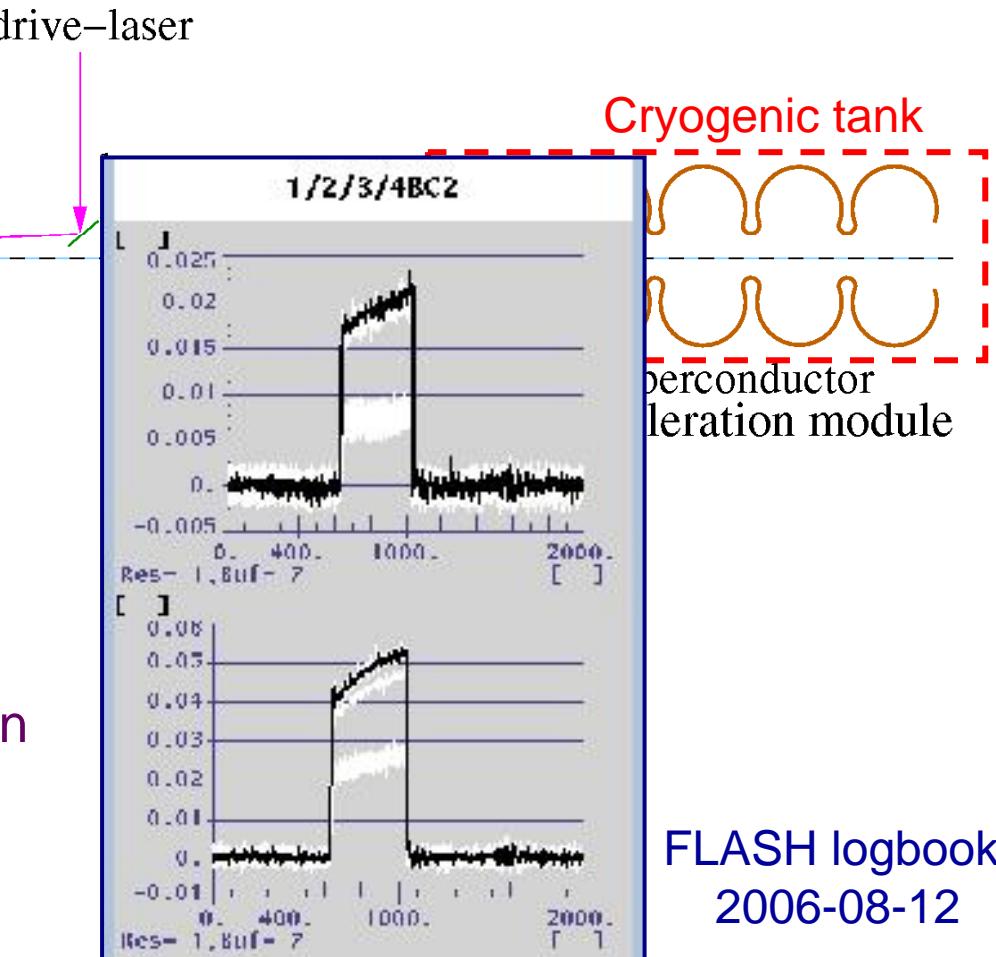
Collimator in the cryogenic tank?
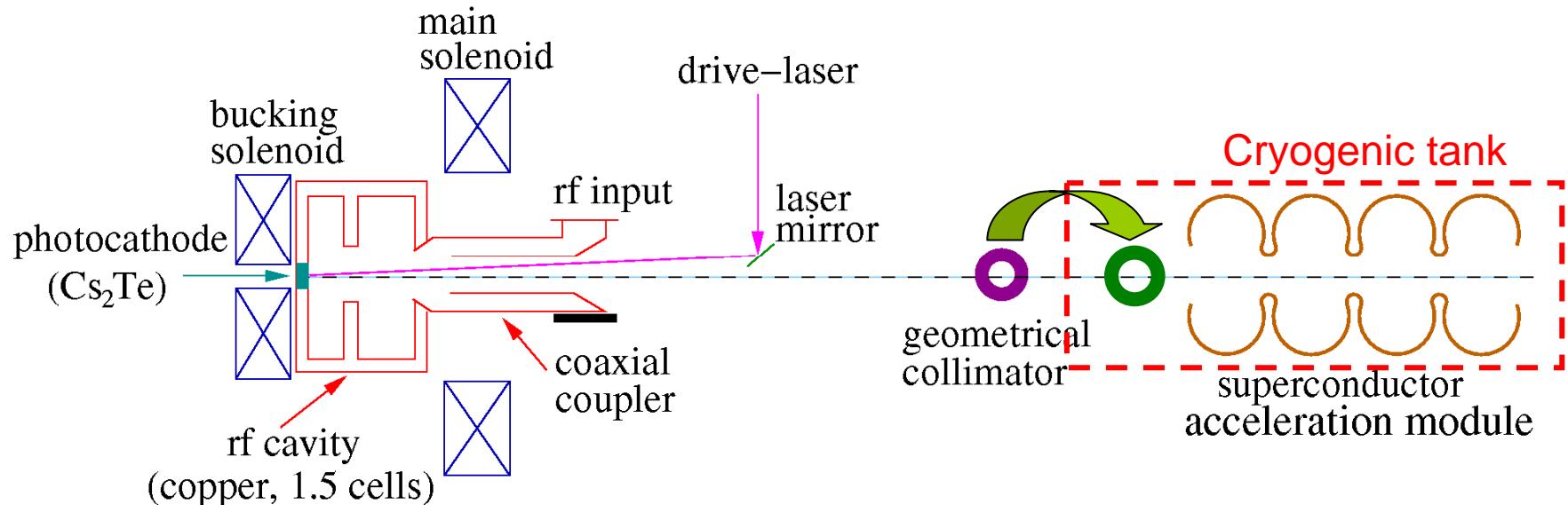
When a collimator inside the cryogenic tank (simulation)

12 mm ϕ: 71%
10 mm ϕ: 79%
8 mm ϕ: 86%

Projected Emittance at FLASH
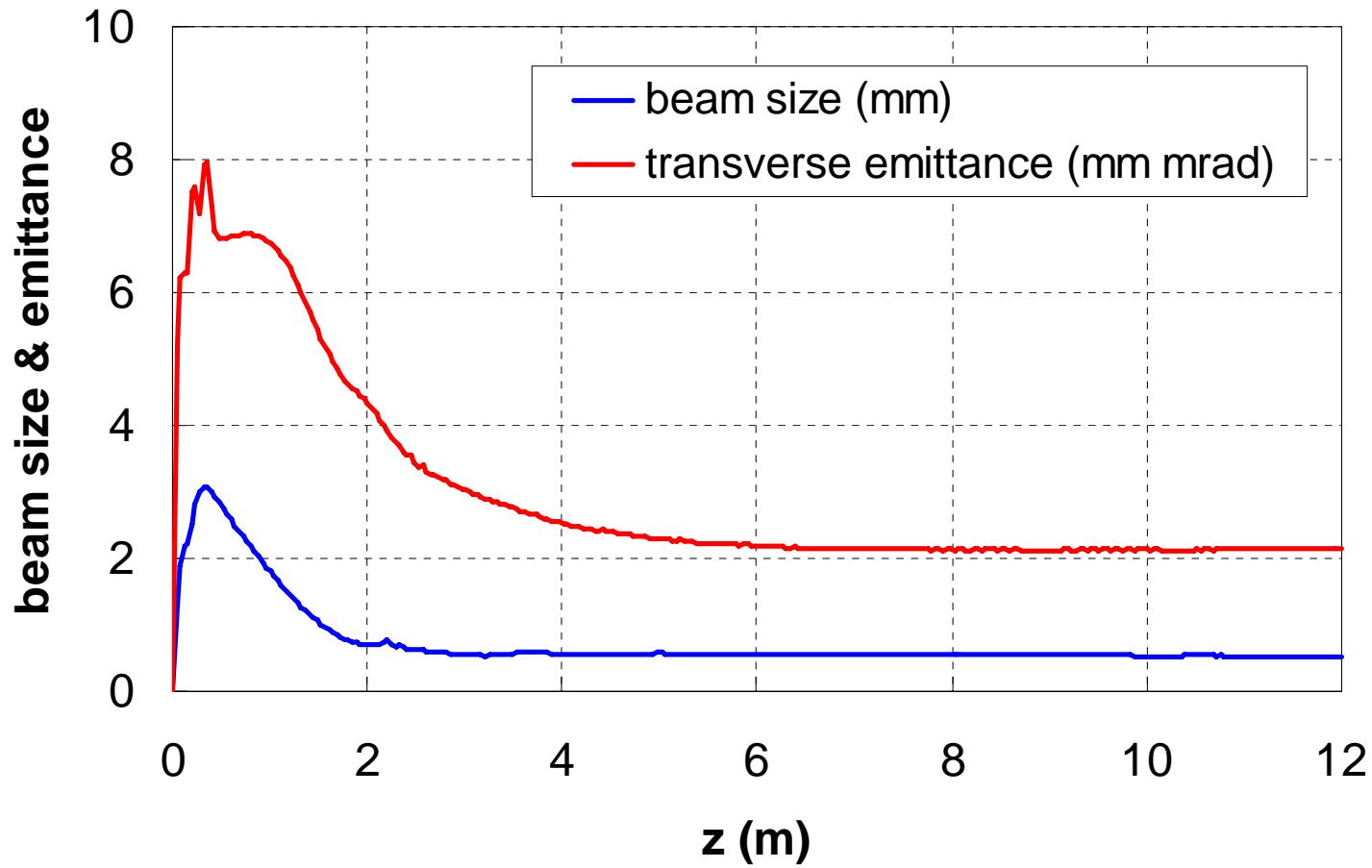
Input Parameters
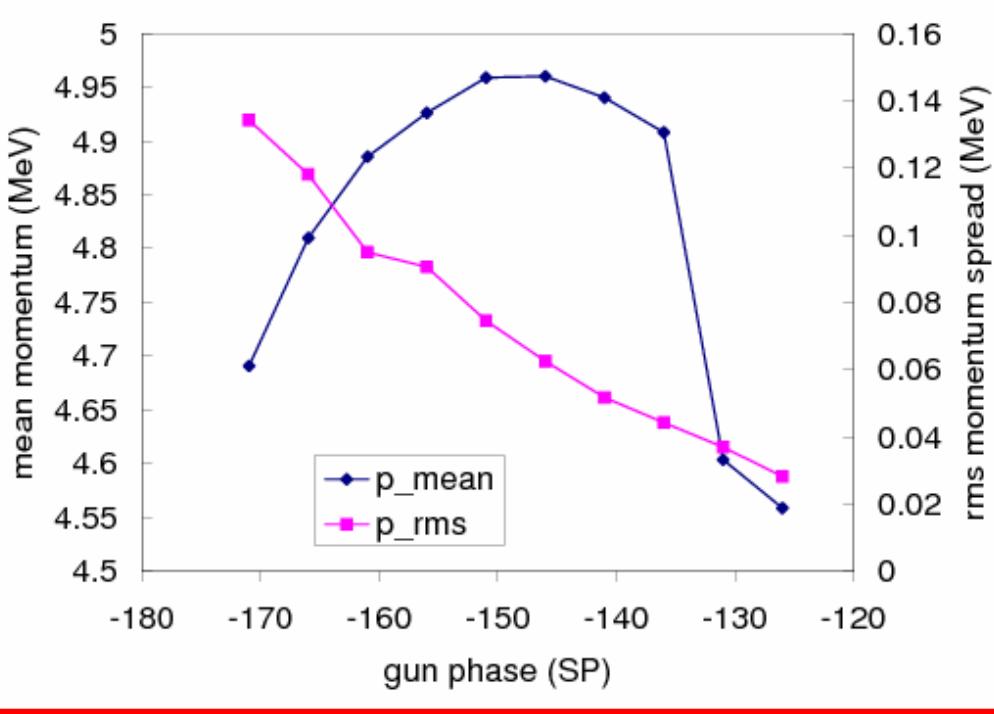
Max E gun = 44 MV/m

Q bunch = 1 nC, T rms = 5.5 ps,
Max B = 0.1728 T
Max E ACC1 = 30 MV/m
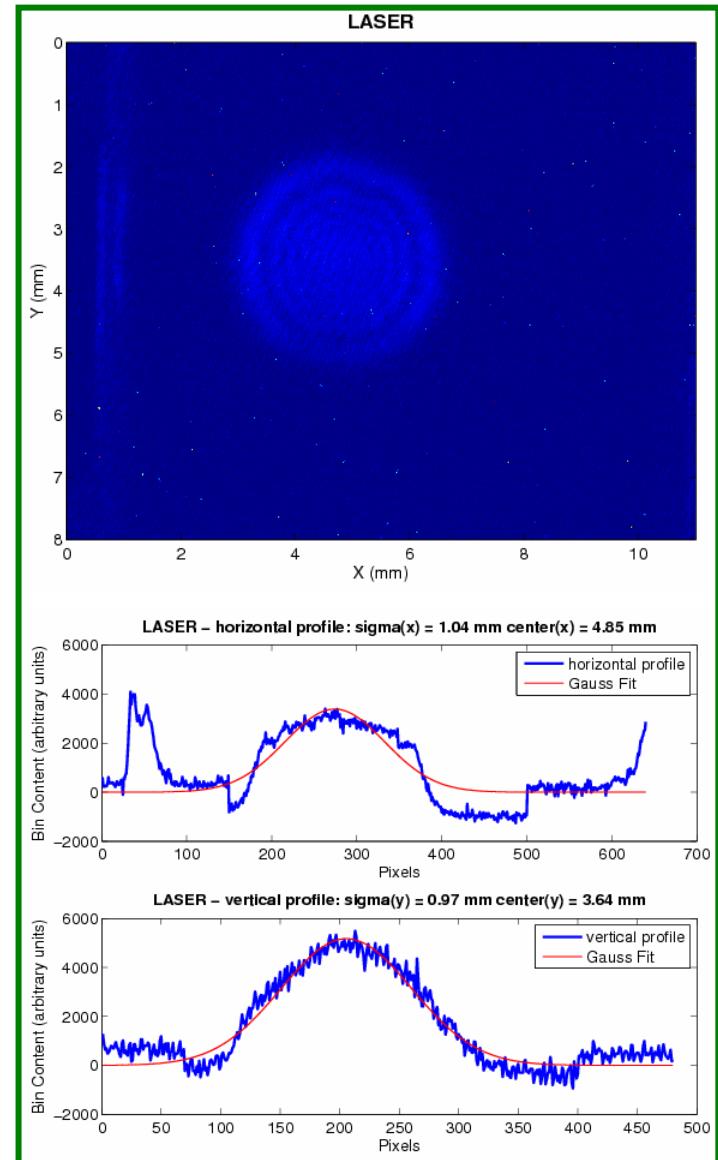
XY rms = 0.9 mm

Slice Emittance at FLASH

Slice Emittance
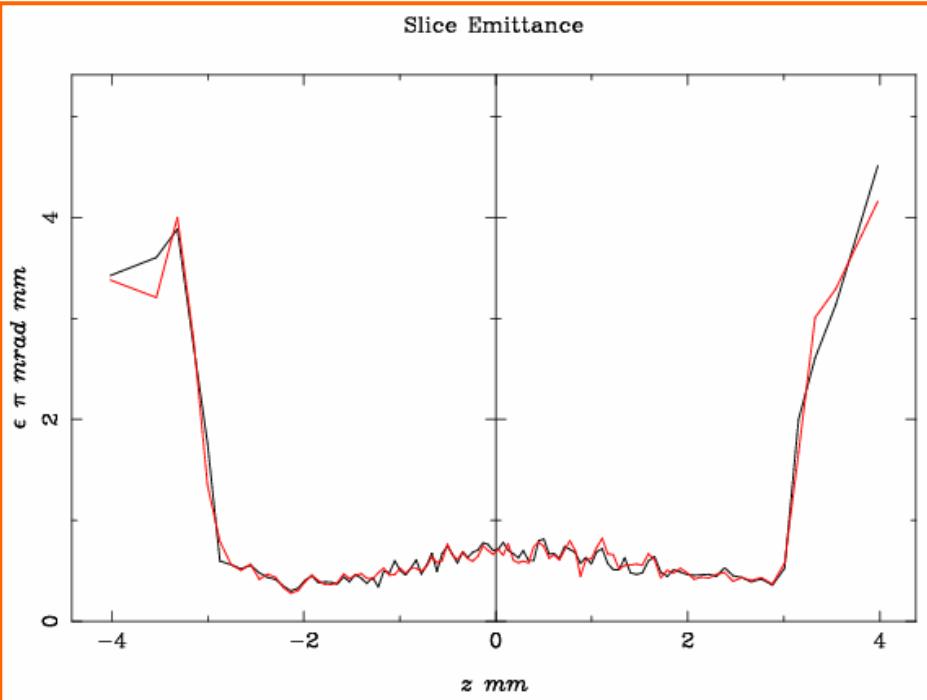
Thermal emittance not included

For E_k = 0.55 eV
→ ε ~ 1 mm mrad

With considering the thermal ε
measurement at PITZ
→ ε ~ 1.3 mm mrad

Longitudinal Distribution
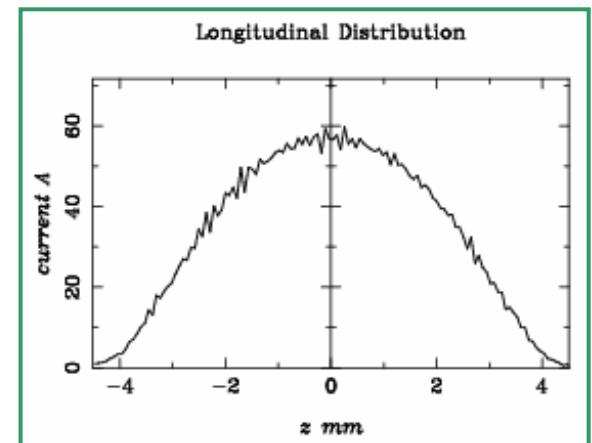
Change of Gun Section?

- Longer distance to ACC1?
    - Different parameters from the original design (drive-laser profile, electron bunch charge, higher gradient …)
    - New optimization required or possible

- Longer distance to collimator
    - Possibly better collimation

Summary for the FLASH injector

- Dark current getting problematic for long pulse operation

- Present collimator at the gun section is not very efficient

- Injector optimization required considering dark current collimation

Collimation at the XFEL

- Gun gradient increase (44 $\rightarrow$ 60 MV/m ?)
  $\rightarrow$ More dark current

- Longer distance to ACC1
  $\rightarrow$ More dark current lost at beam pipe

Beam dynamics simulation
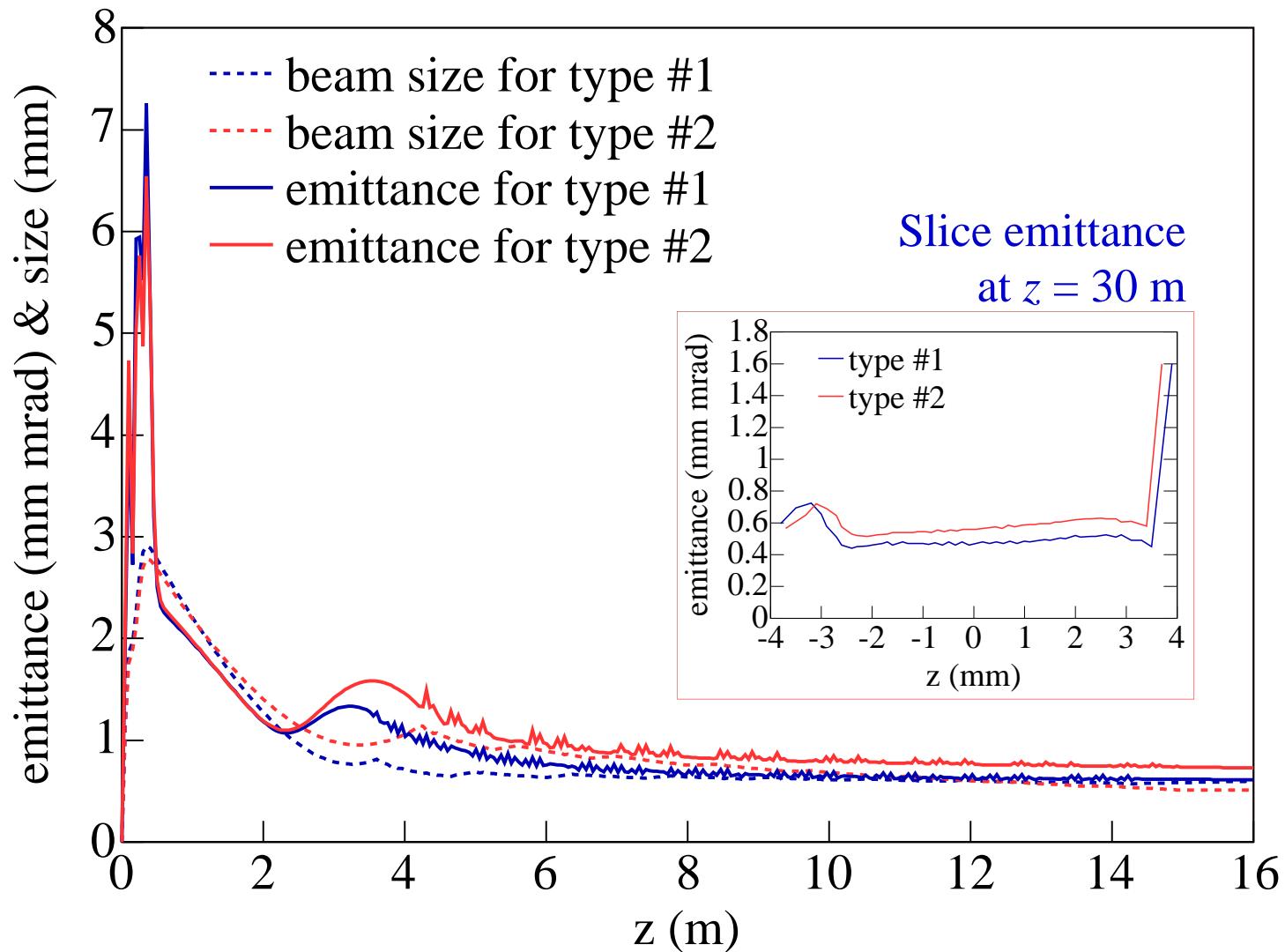
Simulation parameters

Parameters	Type #1	Type #2
Initial distributions of electrons		
Transverse	0.45 mm rms	0.55 mm rms
Temporal (flat-top)	2 ps rise/fall and 20 ps fwhm	
Thermal ε	0.37 mm mrad	0.47 mm mrad
Gun		
Max rf field	60 MV/m	60 MV/m
Emission phase	45°	31°
E field at emission	42 MV/m	31 MV/m
Max solenoid field	0.222 T at 0.28 m	0.226 T at 0.29 m
Accelerator (ACC1)		
Max rf field	20 MV/m	20 MV/m
Start of 1st module	3.43 m	4.05 m
Simulation result		
Transverse projected ε	0.60 mm mrad	0.64 mm mrad
Transverse slice ε	0.47 mm mrad	0.56 mm mrad
Bunch length	2.05 mm	1.95 mm
Mean energy	90.1 MeV	90.4 MeV
Energy spread	1.19 MeV rms	1.12 MeV rms

Dark Current Collimation at the XFEL

Dark current at the entrance of the 1st module

10 mm ϕ collimator 2.2 m from cathode (1.2 m upstream of the 1st module)

Dark current reduced by 66%

Large overlap of the dark current & the beam in the momentum spectra
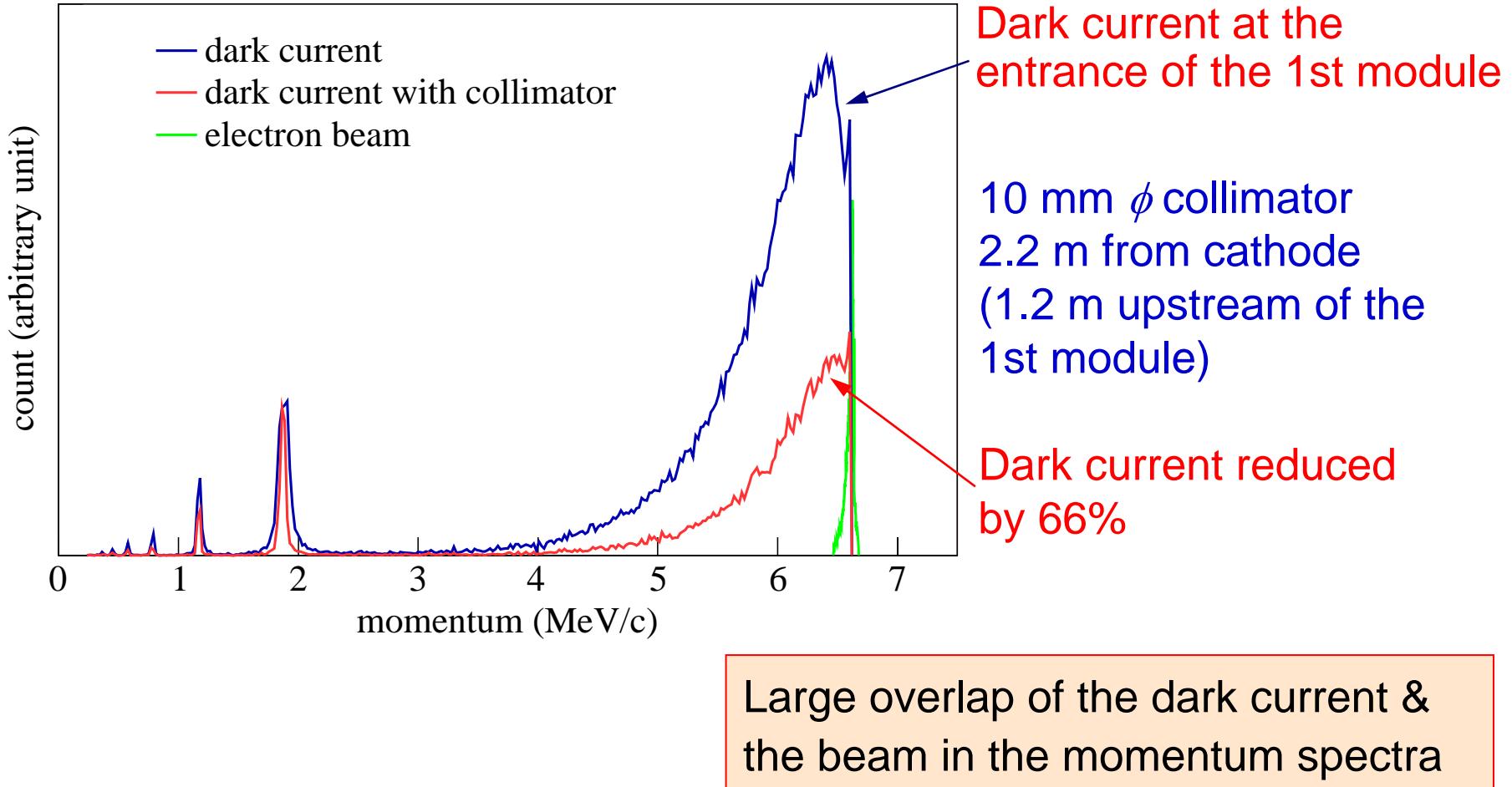
Collimation with modified gun

Longer half cell by 10 mm
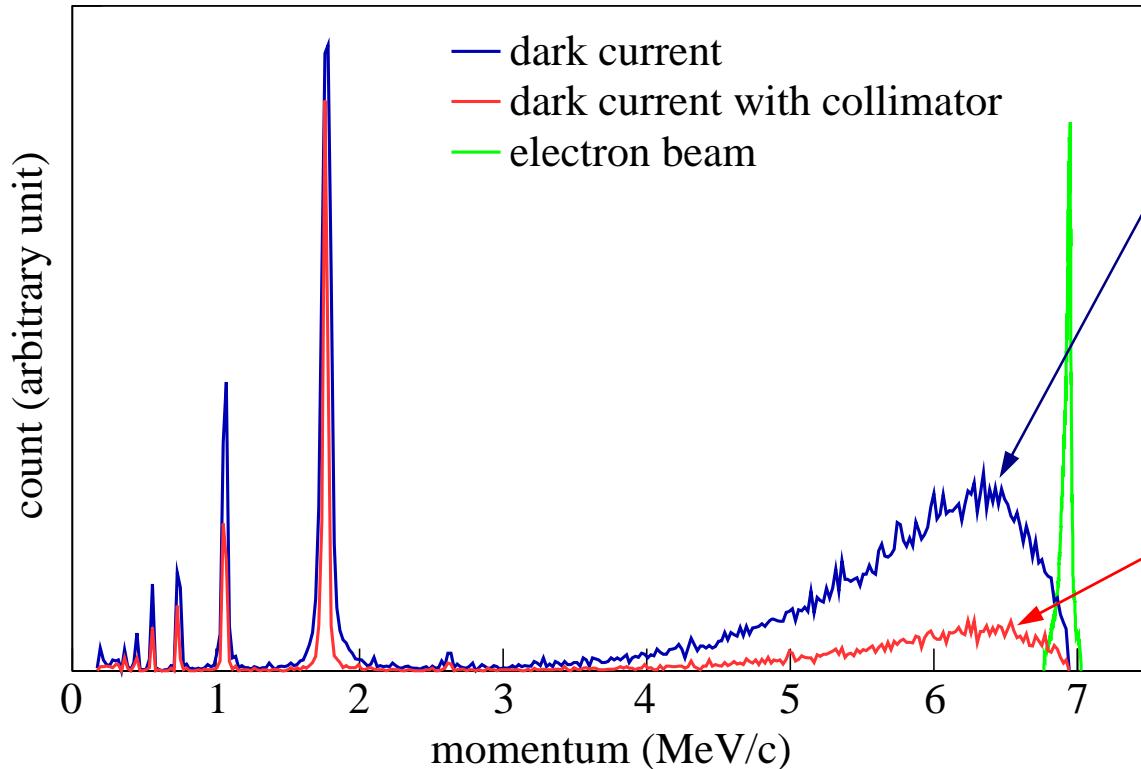
Dark current reduced by 63% without collimator compared to FLASH gun

10 mm ϕ collimator 2.8 m from cathode
Dark current reduction by 70%
especially near the beam

Very small overlap in the momentum spectra

Discussion and Further studies

- For actual operation, dark current issue should be considered in addition to the electron beam dynamics

- Gun cavity modification, lower gradient (than 60 MV/m), another solenoid field profile …