Evaluation of the photocathode laser transverse distribution

Core + Halo Models

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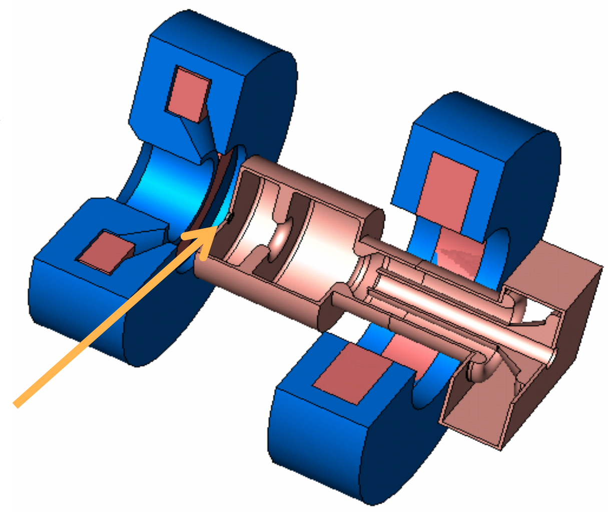
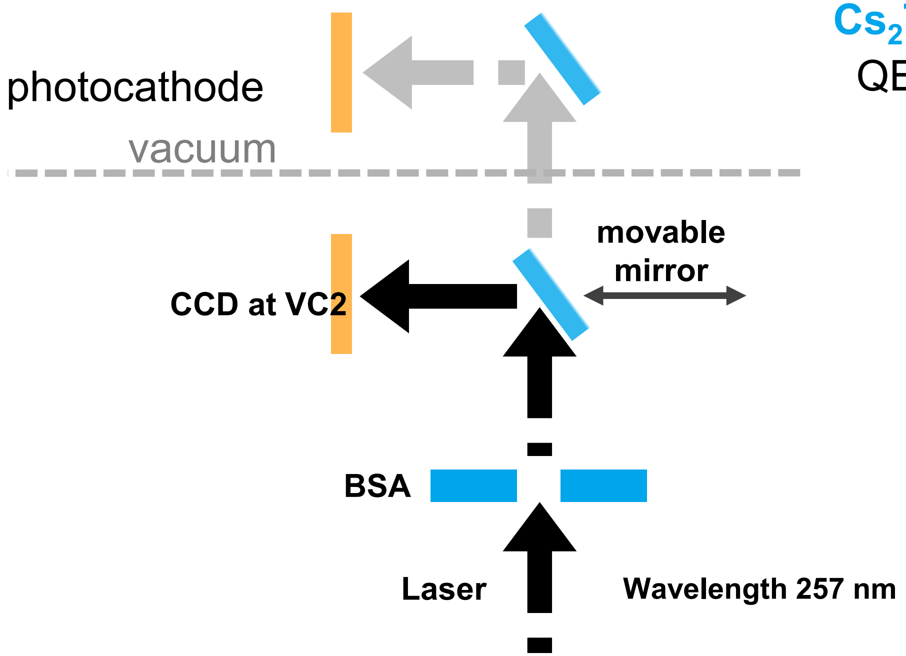
Introduction:Photo Injector Test Facility at DESY, Zeuthen site (PITZ)

PITZ RF Photo Gun:
1½-cell copper cavity
L-band (1.3 GHz)
RF power: ~7MW peak



Cs_2Te cathode
QE~0.5-10%



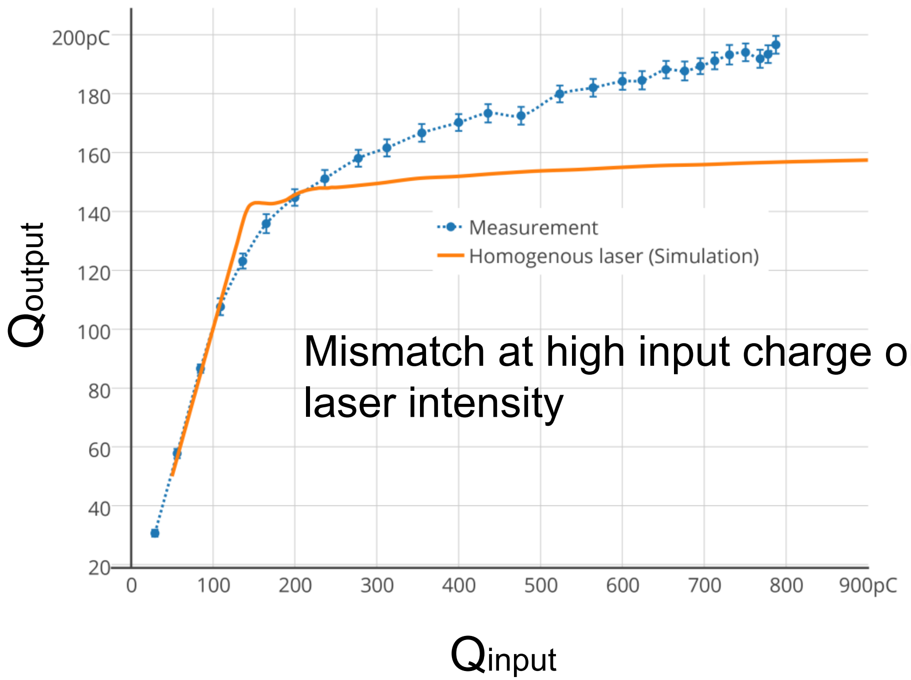
Schematic of transverse laser profile measurement

Beam Shaping Aperture (BSA) is used to control the laser beam size (diameter of the laser beam at the cathode)

In this work, the transverse laser distribution are measured using CCD camera at the image plane of the photocathode (called virtual cathode –VC2)

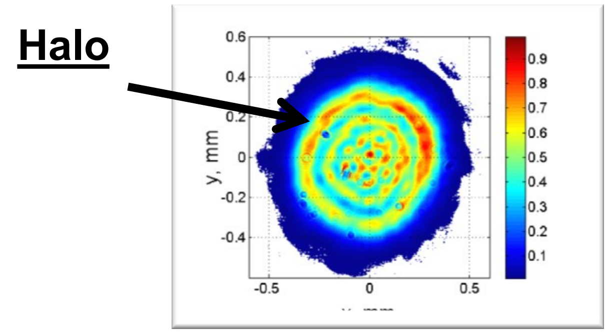
Motivation

- There is a problem concerning mismatch between output charge of beam dynamic simulation (ASTRA) and experiment.

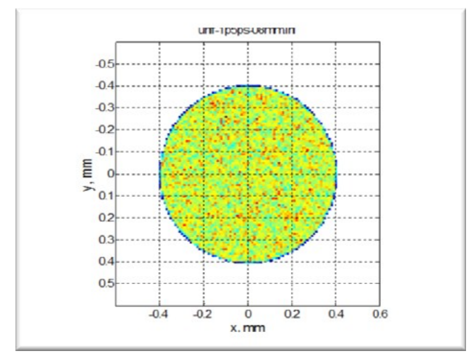


Mismatch at high input charge or high laser intensity

0.8 mm BSA



The measured transverse laser profile



The uniform charge distribution in simulation

$$Q_{input} \propto QE \cdot E_{laser}$$

QE is quantum efficiency of cathode

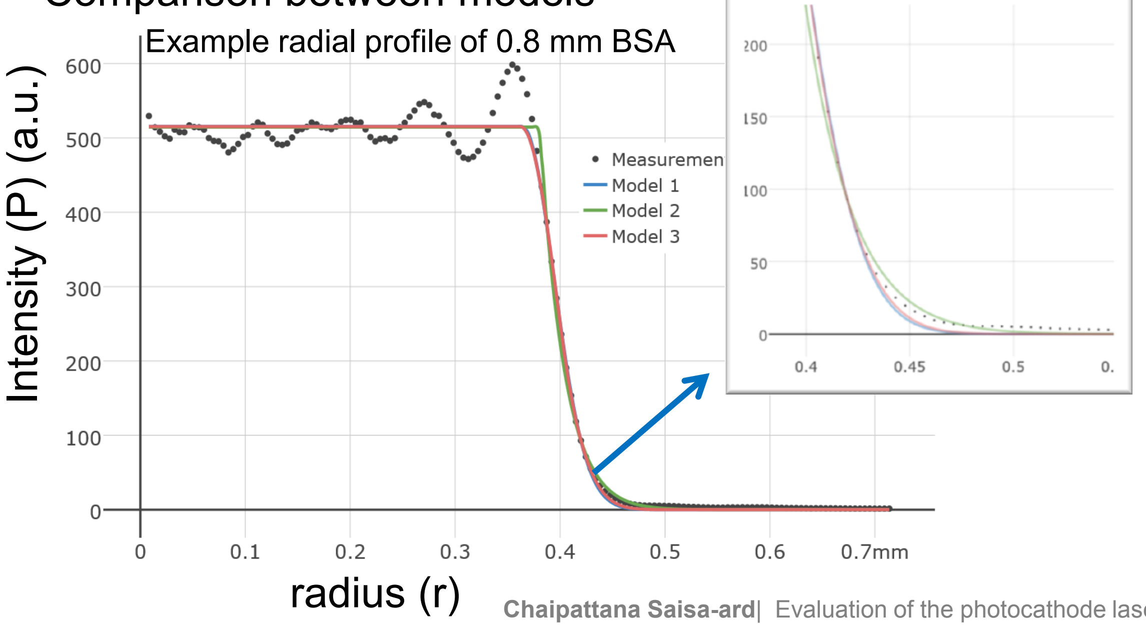
E_{laser} is laser pulse energy

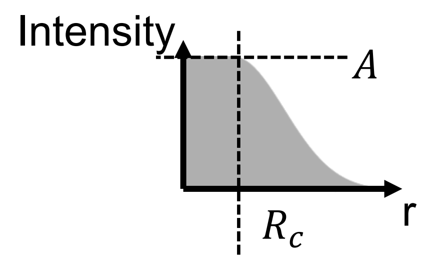
Core+Halo Models

- Assuming rotational symmetry (ASTRA emission model)
- We create three models named ‘core+halo’ to generate particle input distribution based on a measured laser transverse profile.

	Model 1.	Model 2.	Model 3.
$r < Rc$	$P(r) = A = const$	$P(r) = A$	$P(r) = A + C$
$r > Rc$	$P(r) = Ae^{-\frac{(r-R_c)^2}{2\delta^2}}$	$P(r) = Ae^{-\frac{(r^2-{R_c}^2)}{2\delta^2}}$	$P(r) = Ae^{-\frac{(r-R_c)^2}{2\delta^2}} + Ce^{-\frac{(r-R_c)^4}{2\delta^4}}$

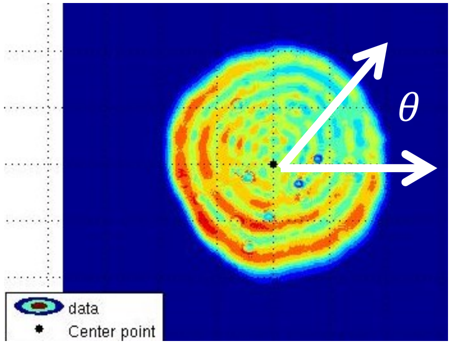
Comparison between models





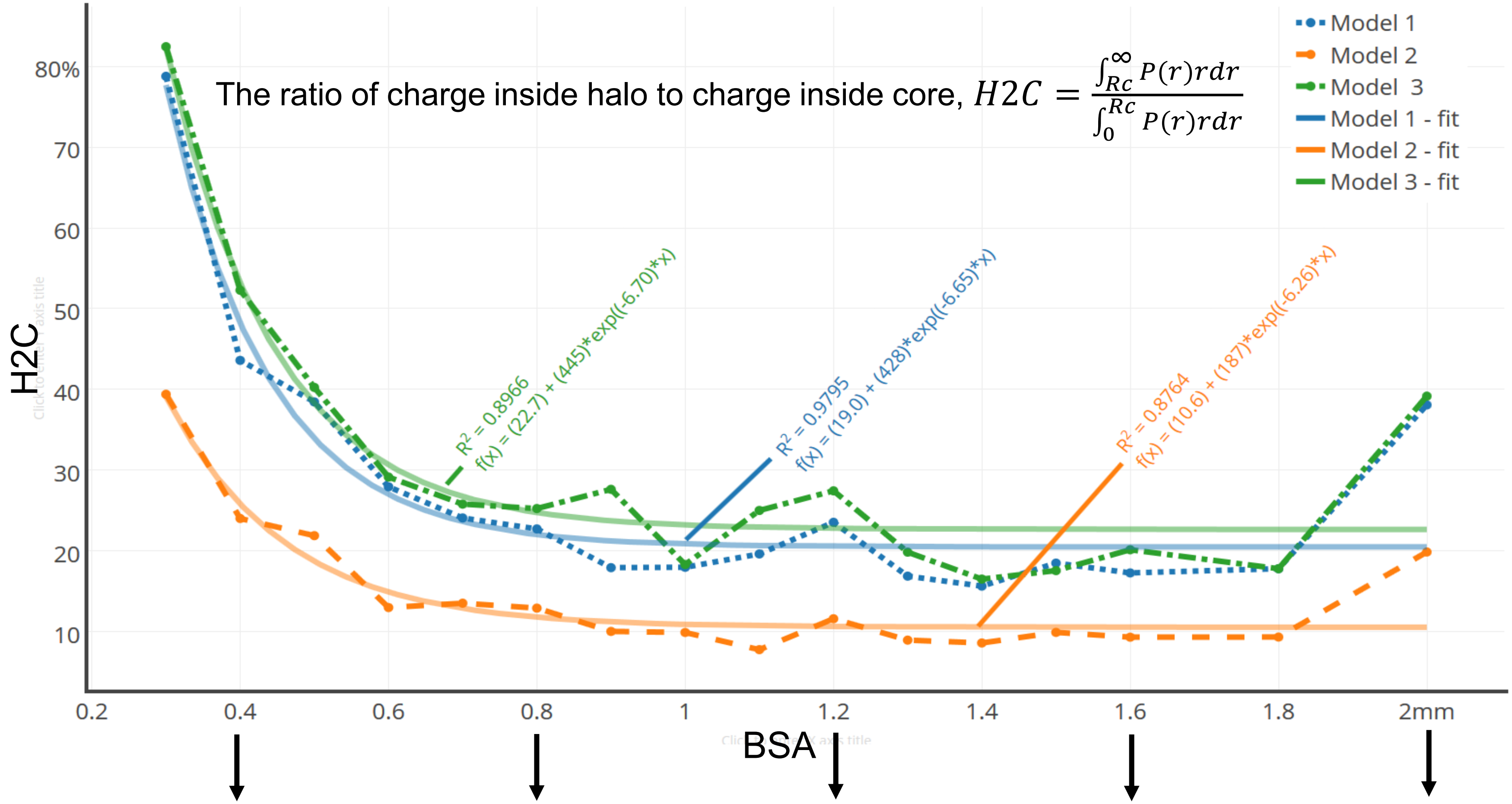
	Model 1.	Model 2.	Model 3.
A	515.2	514.6	462.5
R_c	0.363	0.380	0.362
δ	0.032	0.95	0.032
C	-	-	52.7

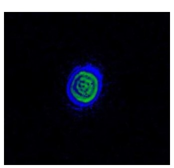
Procedure of Transverse Laser Profile Analysis

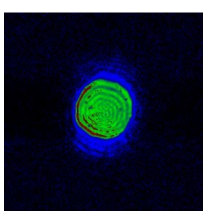


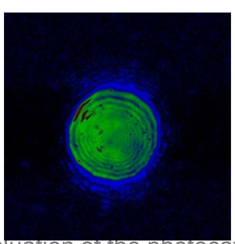
- Define the center of a laser beam profile by $\sum_{i=1}^{all} x_i \times I_i(x,y) = x_c$
- Average profile around the center, $P_{meas}(r) = < P_\alpha >$
- The difference between the laser beam profile and a model, $\Delta(A, R_c, \delta, (C)) = \frac{\int_0^{R_c} |I_{meas} - I_{model}| r dr}{\int_0^{\infty} I_{meas} r dr} \rightarrow minimized$
- Core-halo qualities: ratio of halo to core, core modulation
- There are about 100 profiles within 0.3-2.0 mm BSA in 2015. All of them are analyzed with MATLAB

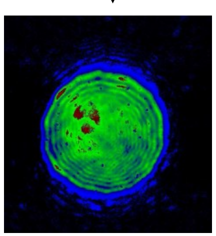
Results: Halo to Core Ratio

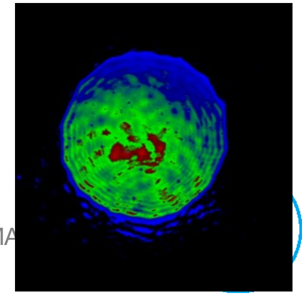








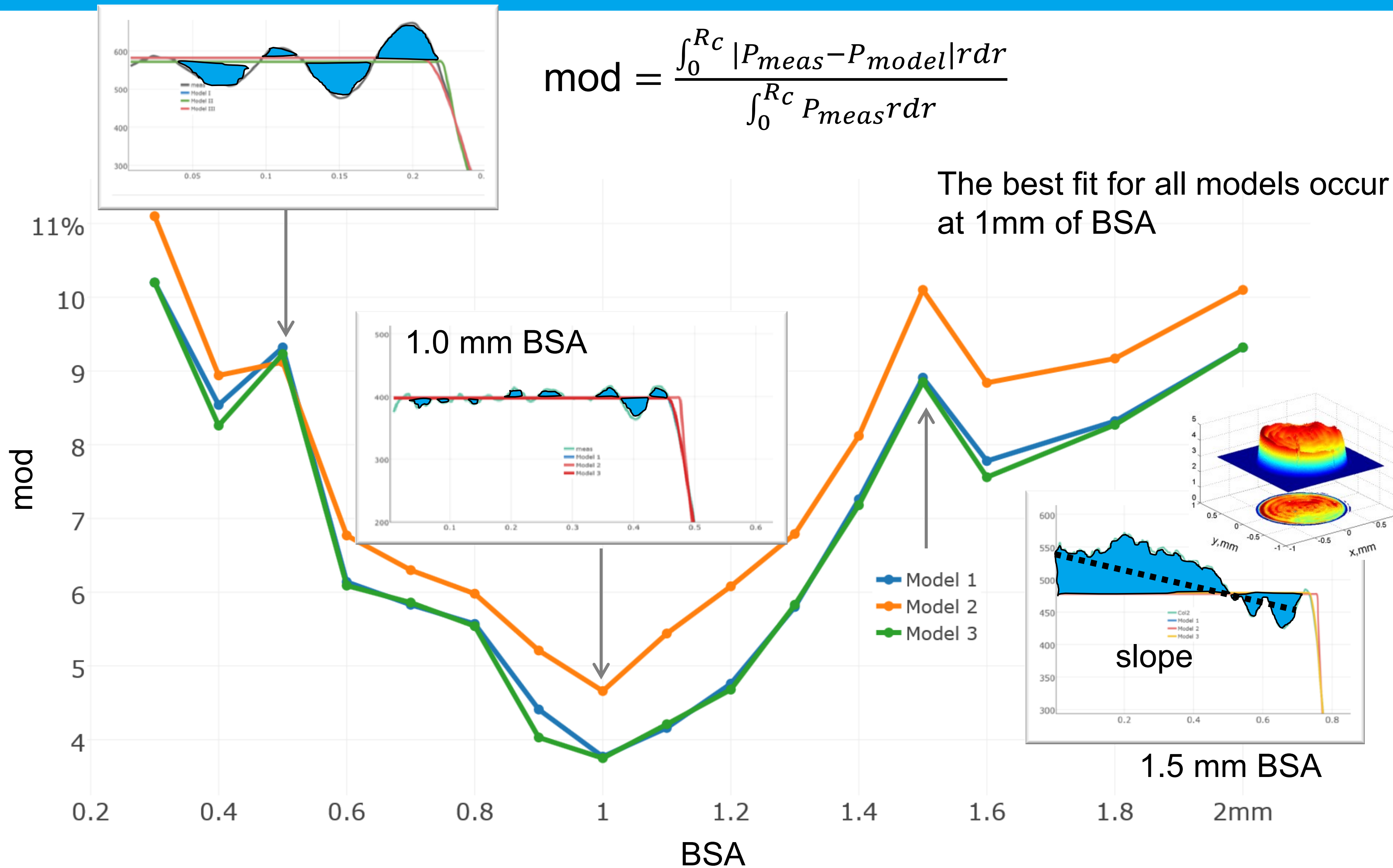




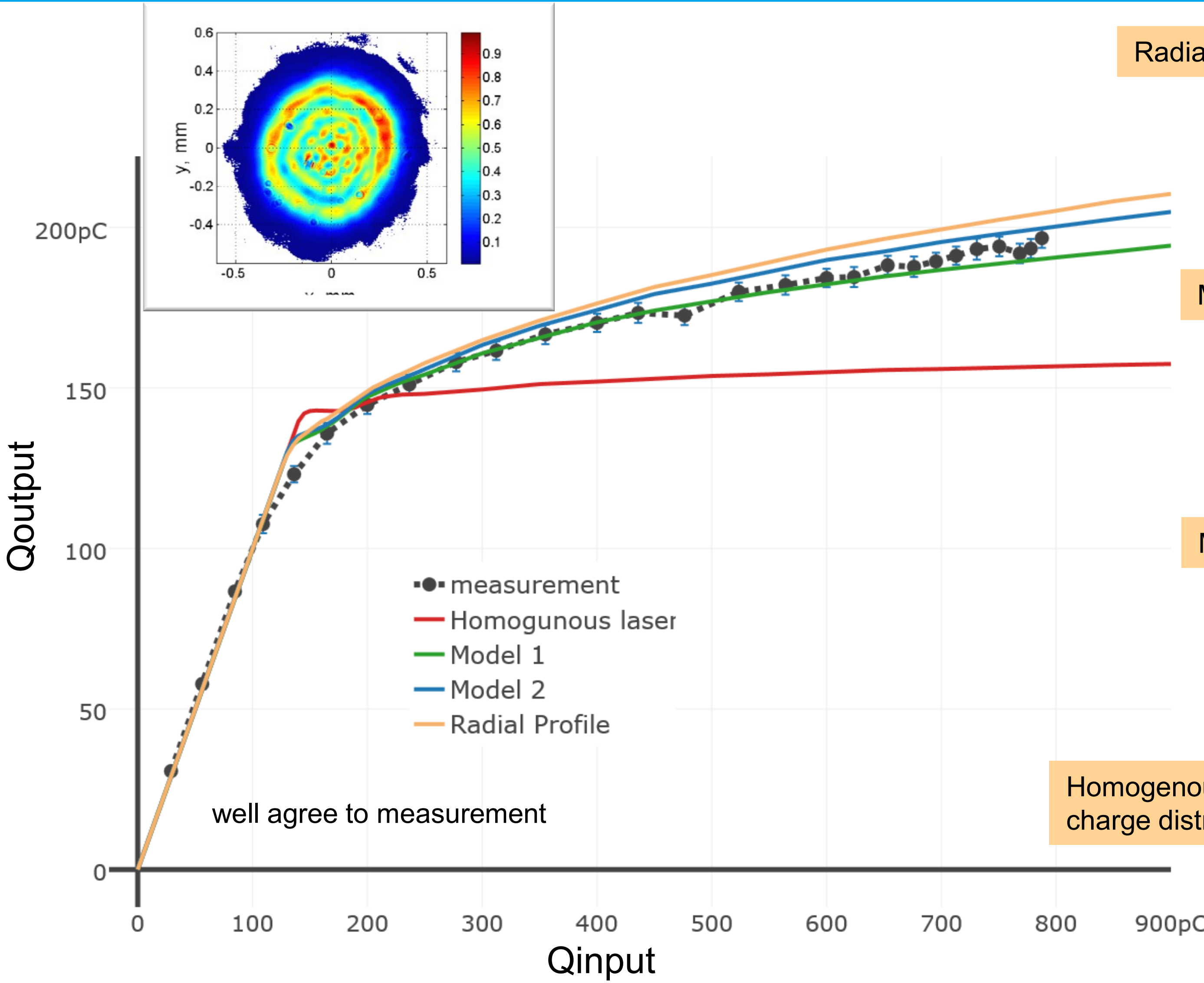
Results: Core Modulation (mod) Quality

$$\text{mod} = \frac{\int_0^{Rc} |P_{meas} - P_{model}| r dr}{\int_0^{Rc} P_{meas} r dr}$$

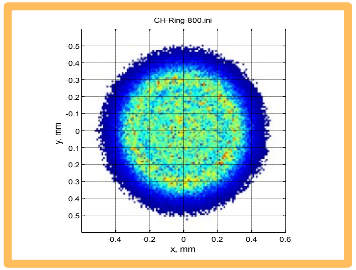
The best fit for all models occur at 1mm of BSA



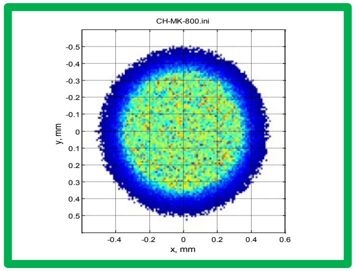
Results: Comparison of Charge Emission between Measurement and Simulations with/without Halo



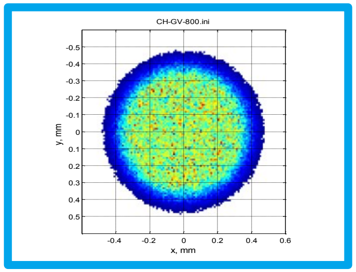
Radial profile



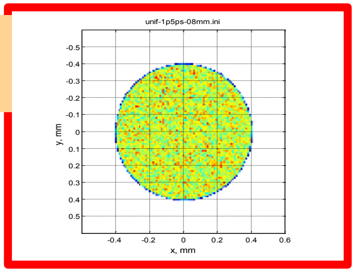
Model 1



Model 2



Homogenous charge distribution



Conclusions & Outlook

Conclusions

- Figure of merit was introduced for qualitative evaluation of the laser profile by implemented core+halo models.
- The growth of BSA decreases the halo effect
  - H2C $\propto$ exp(-6.65*BSA) for model 1
  - H2C $\propto$ exp(-6.26*BSA) for model 2
  - H2C $\propto$ exp(-6.70*BSA) for model 3
- For smaller BSA, the core modulation is occurred by diffraction while larger BSA it is occurred by non homogeneous core.
- Using core+halo models in beam dynamic simulation, the output charge results agree well to measurement.

Outlook

- The azimuthal homogeneity to be considered for qualitative evaluation.

Thank you for attention