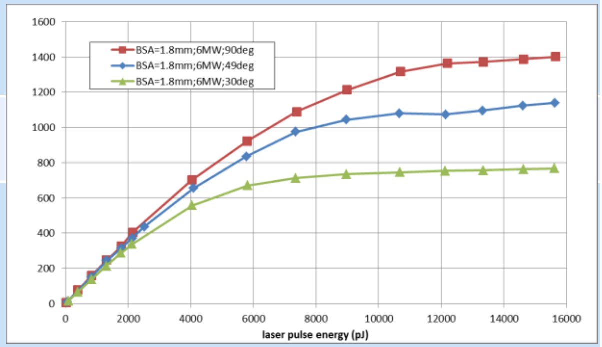
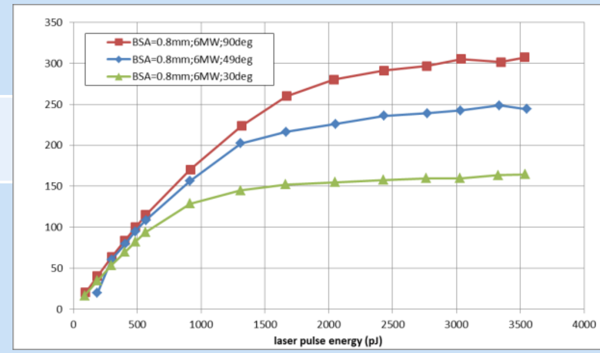
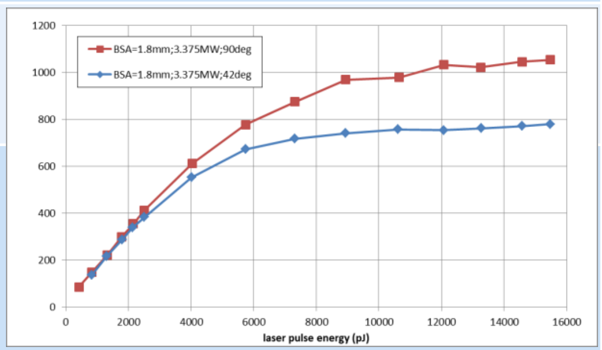
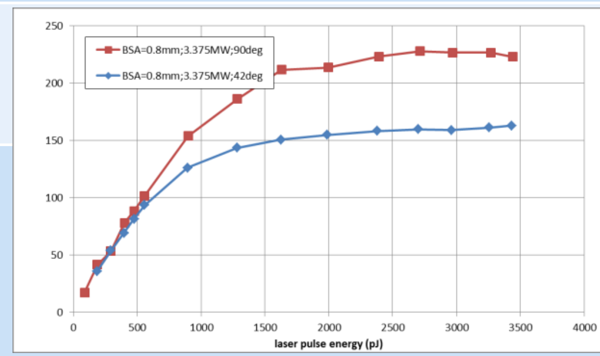
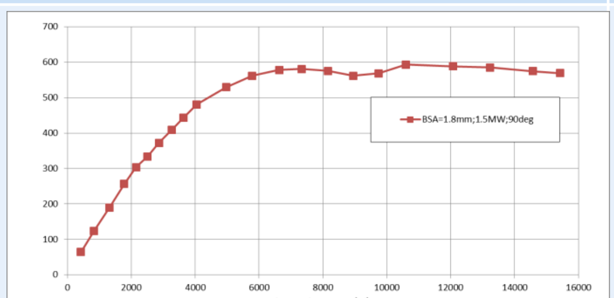
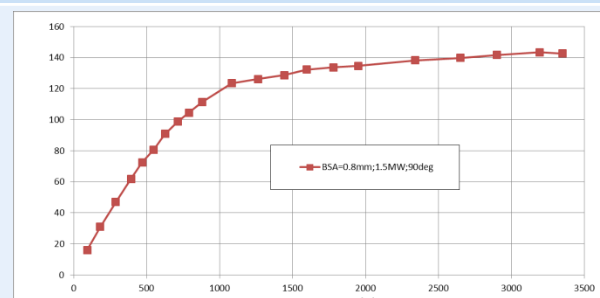
Emission studies at PITZ in October-November 2015.

M. Krasilnikov
PPS, 08.01.2016

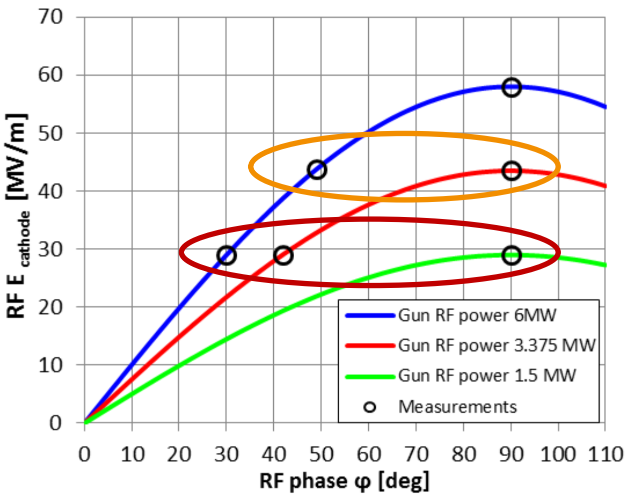
HELMHOLTZ
GEMEINSCHAFT

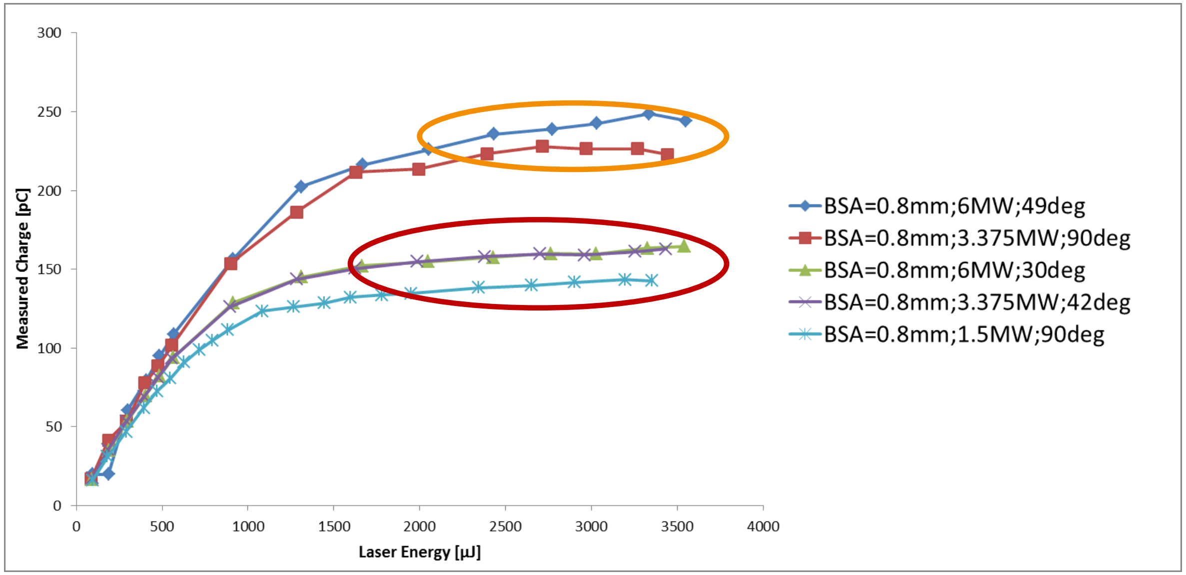
DESY

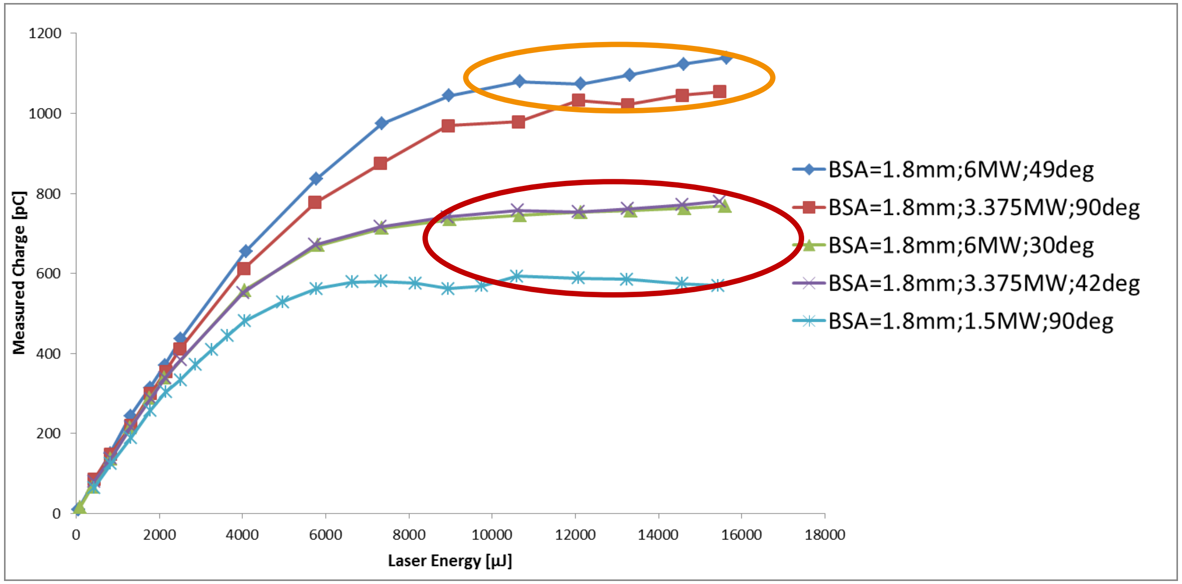
Emission studies

Pgun	Phase w.r.t. Phi0	BSA=1.8mm	BSA=0.8mm
6 MW	90 deg		
	49 deg		
	30 deg		
3.375 MW	90 deg		
	42 deg		
1.5 MW	90 deg		

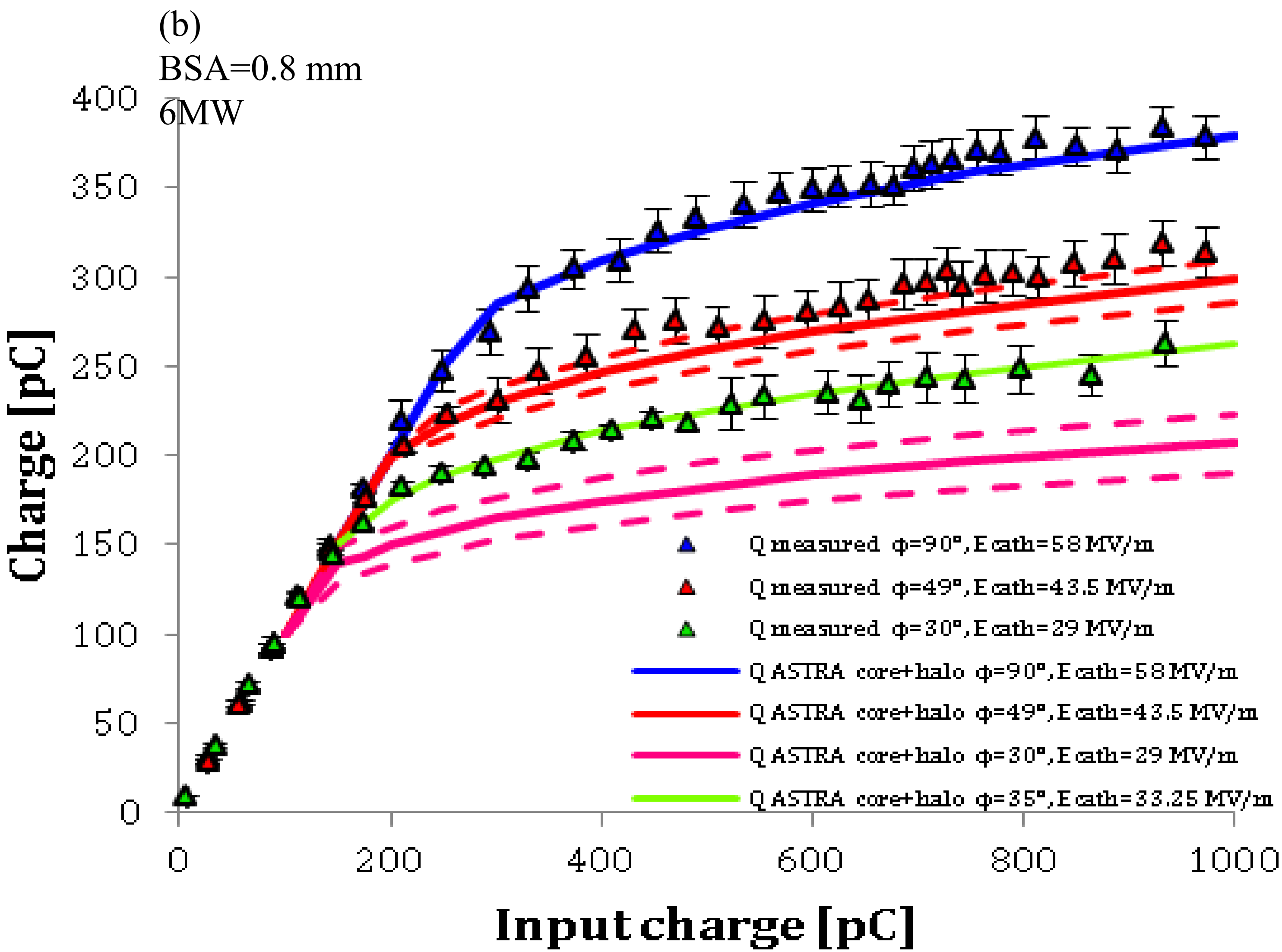
Emission studies



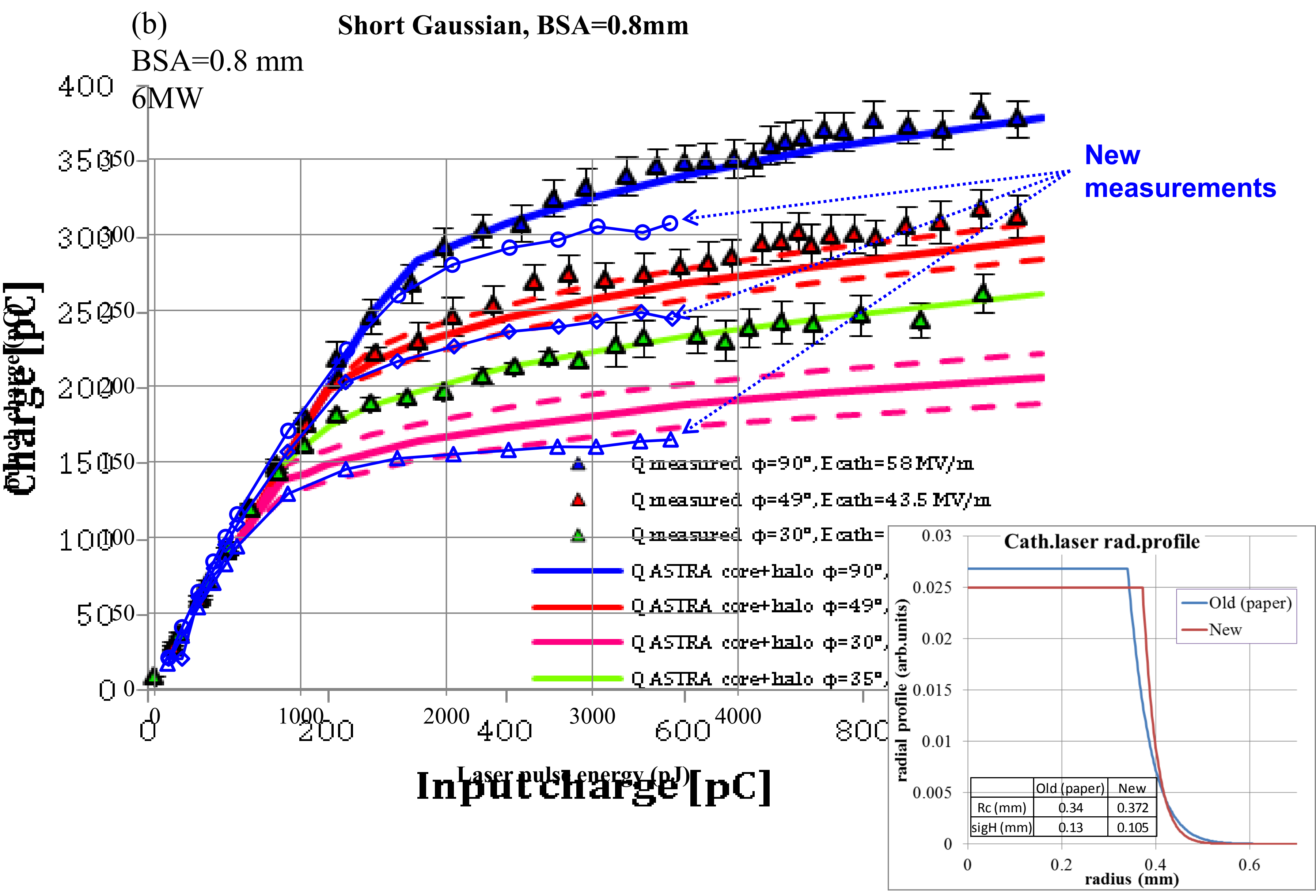




Emission studies (data used in the paper draft Fig.11b)

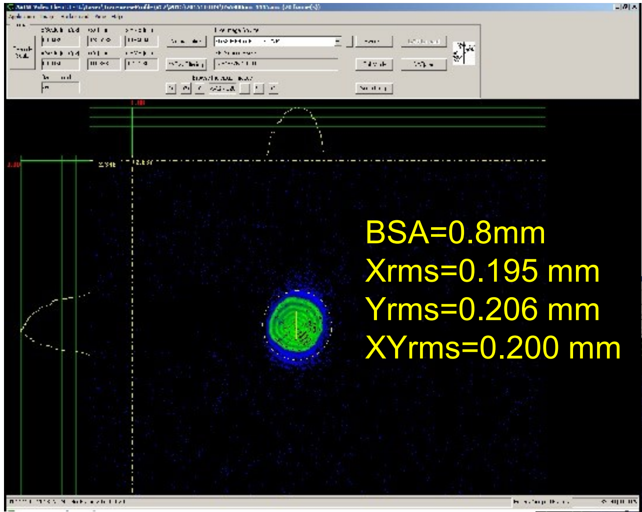


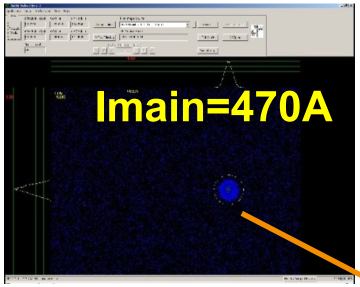
Emission studies (data used in the paper draft Fig.11b)

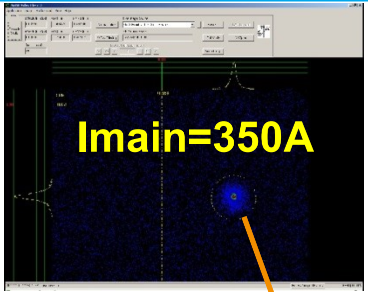


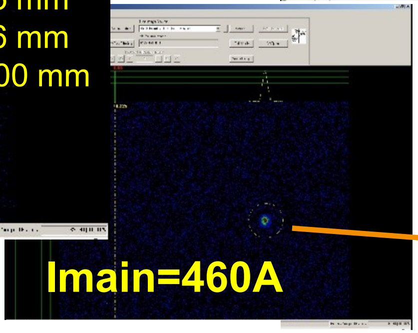
	Old (paper)	New
Rc (mm)	0.34	0.372
sigH (mm)	0.13	0.105

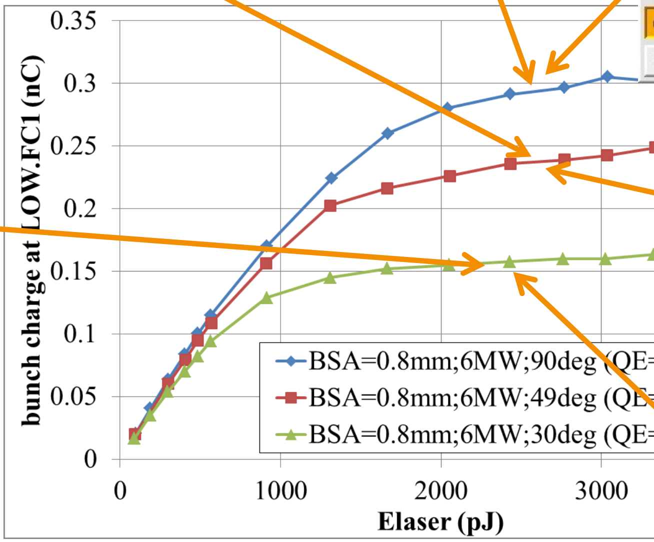
New setup for 6MW, BSA=0.8mm → 1.11.2015M-A

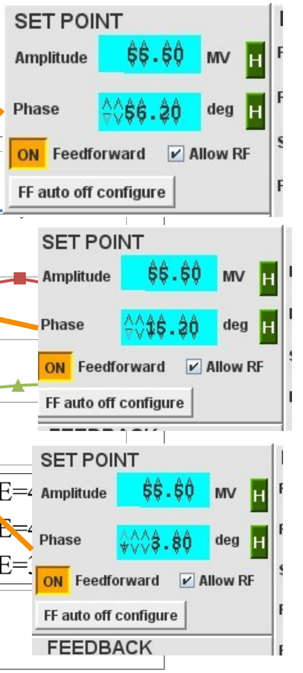


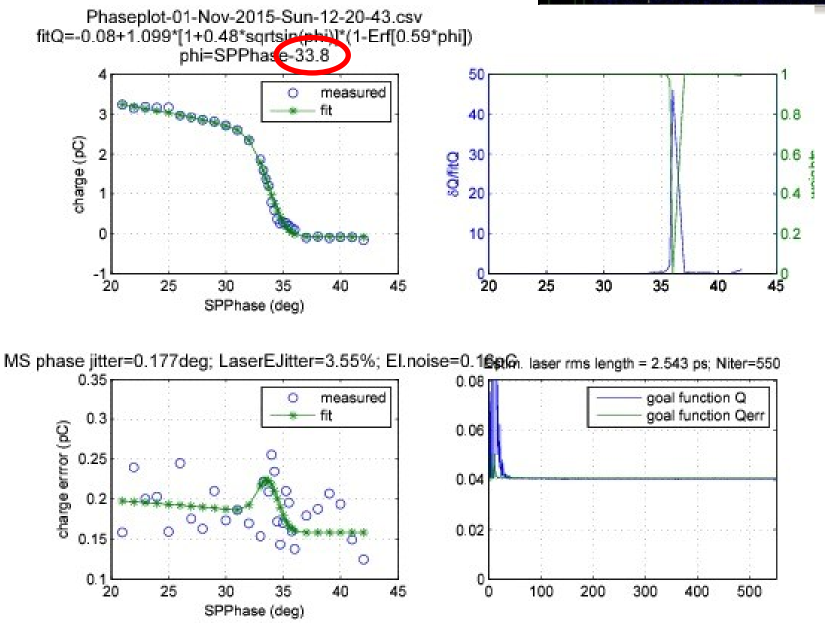


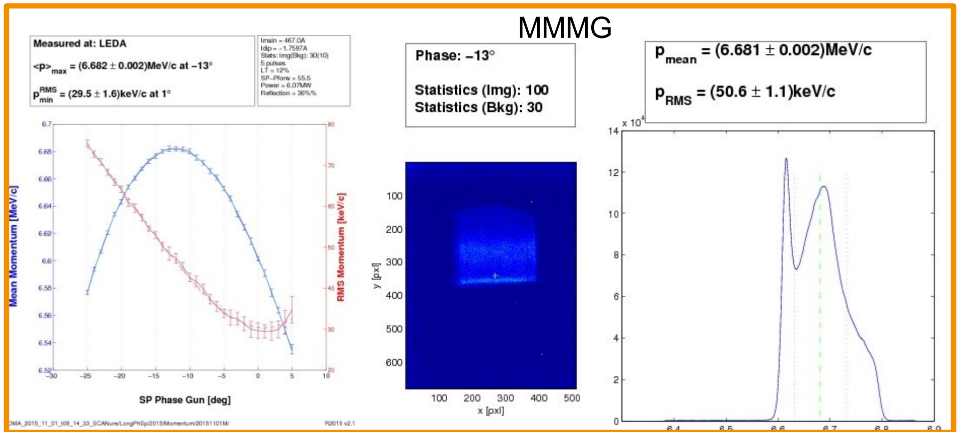








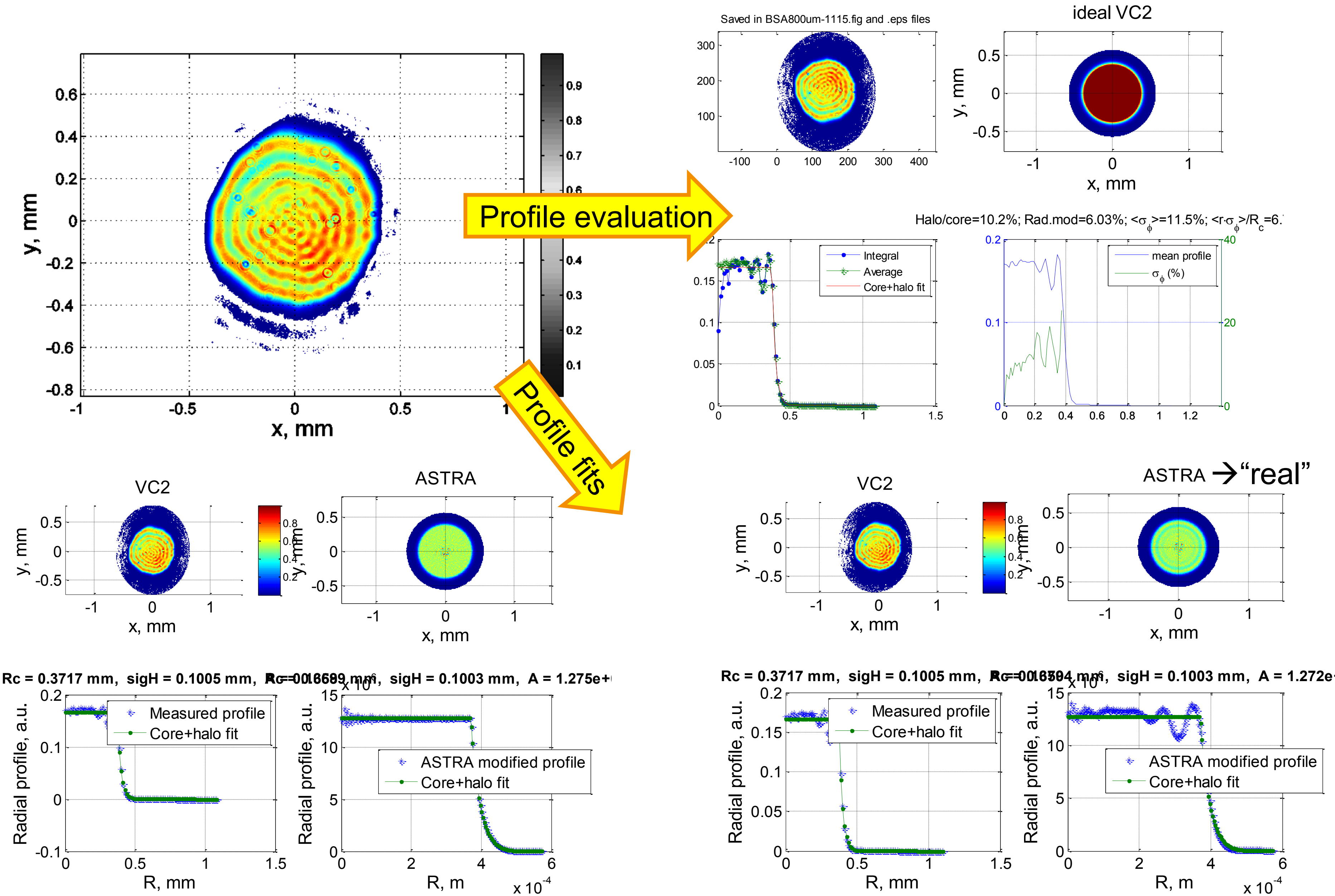




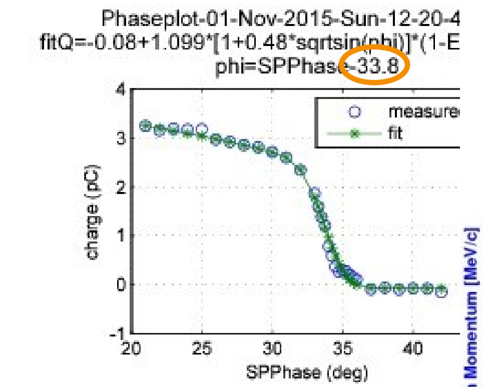
New setup for 6MW, BSA=0.8mm → strategy for simulations

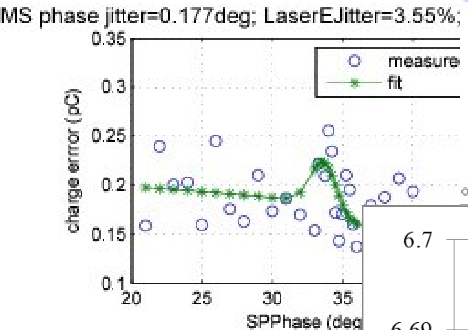
1. Uncertainty: Gaussian laser pulse length rms (fwhm) → 0.85 (2.0); 0.95 (2.24); 1.1 (2.59)ps
2. Ecath=? : maxPz=6.681MeV/c at MMMG phase
   a) Simulated MMMG phase → Pz(phase)
   b) Simulate zero crossing phase
3. Transverse distribution (XYrms=0.200mm):
   a) Radial homogeneous
   b) flattop core + Gaussian halo
   c) "real" = ring structure in the core + Gaussian halo
4. Calculate coefficient(s) for Qinput for the measured data (Elaser→Qinput)
5. Scans for phases 30;49;90deg* (*→ cross check with 2b), charge collection at LOW.FC1 (z=0.8m), Imain=460;470;350A [MaxB(1)=-(7.102e-5+5.899e-4*Imain)]

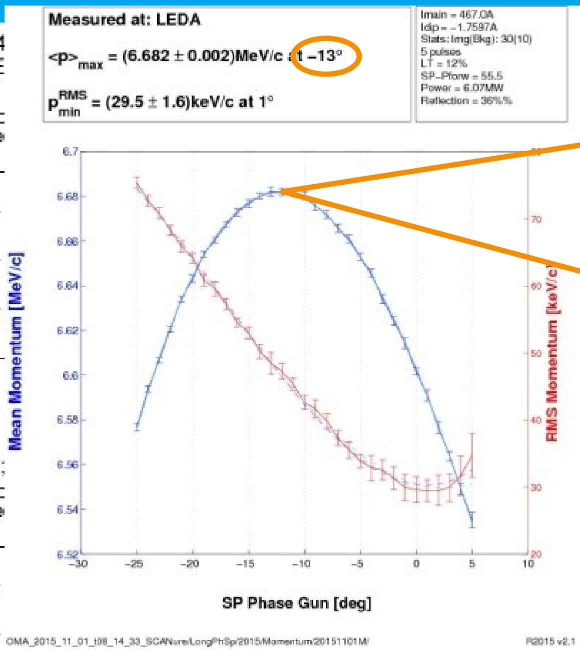
New setup for (6MW, BSA=0.8mm) → VC2

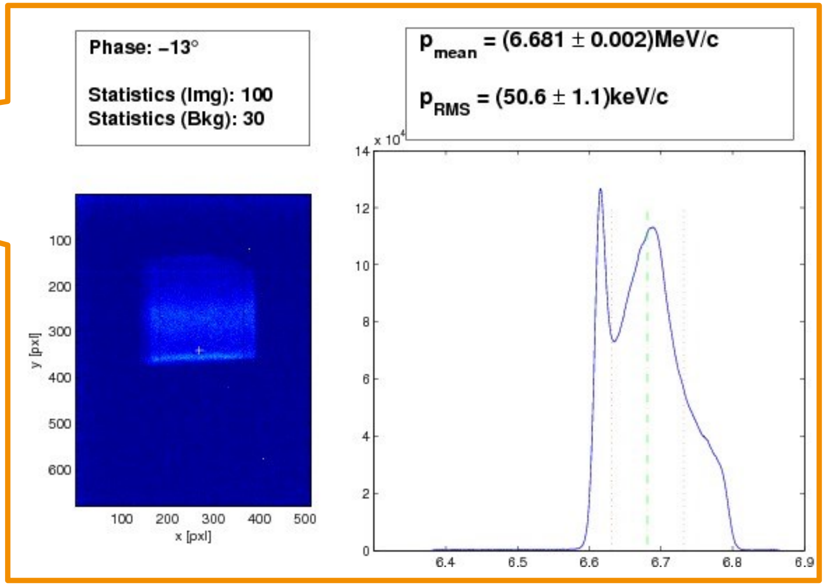


New setup for (6MW, BSA=0.8mm) → Pz

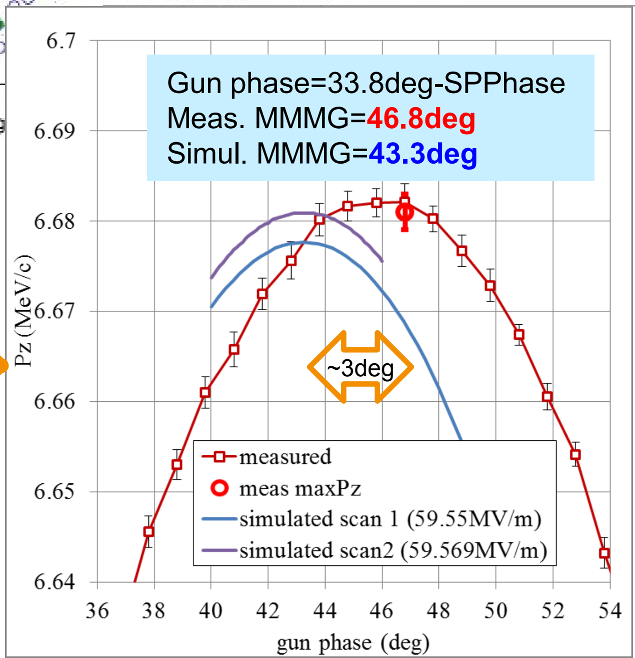


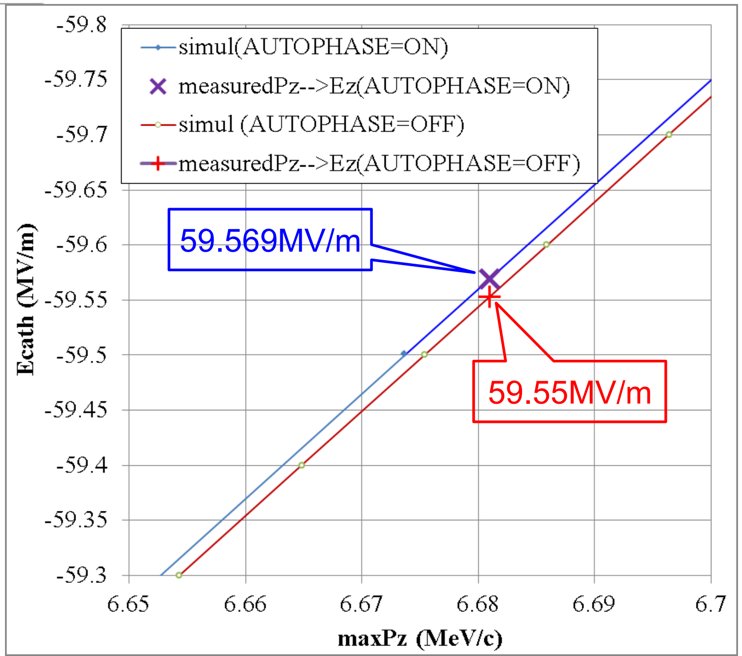




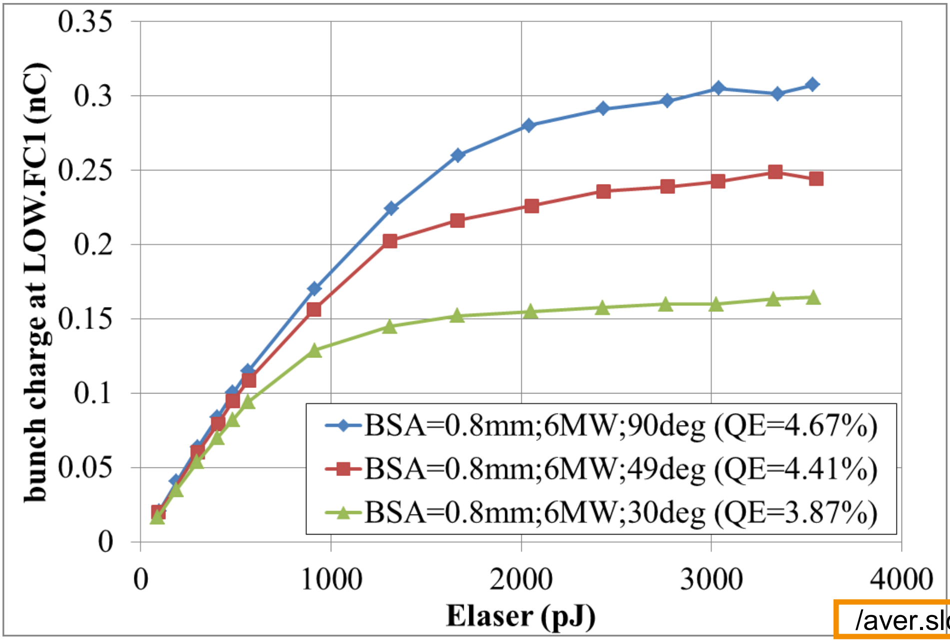


?simulate zero-crossing scan?

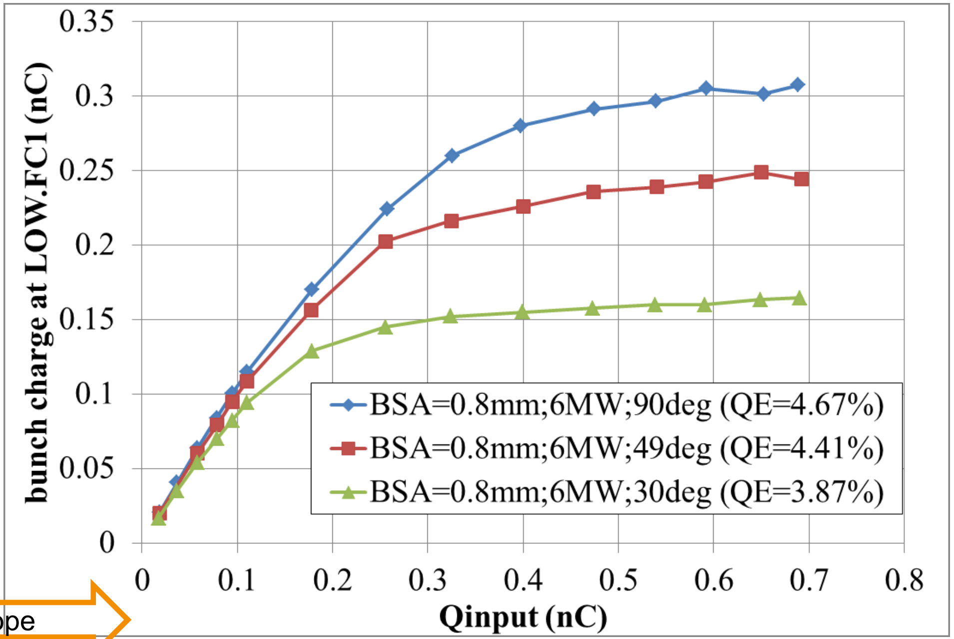


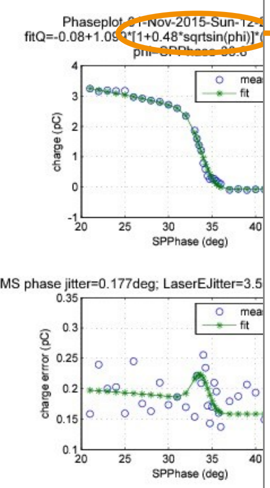


Qinput determination

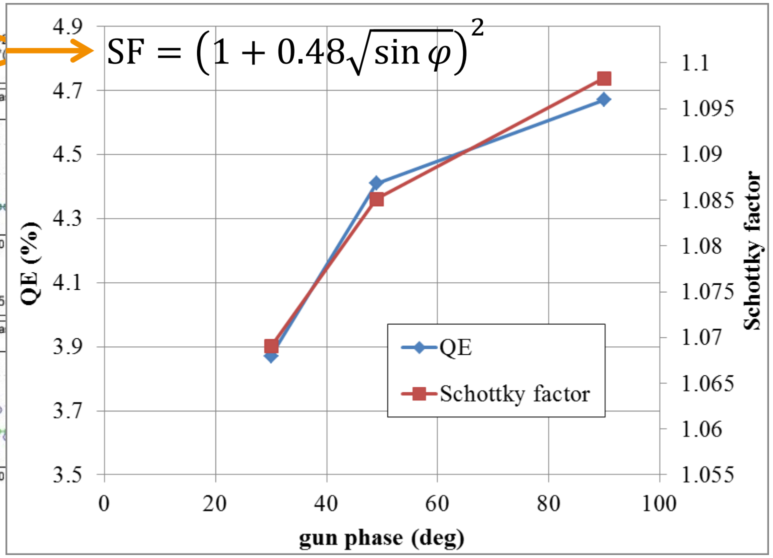


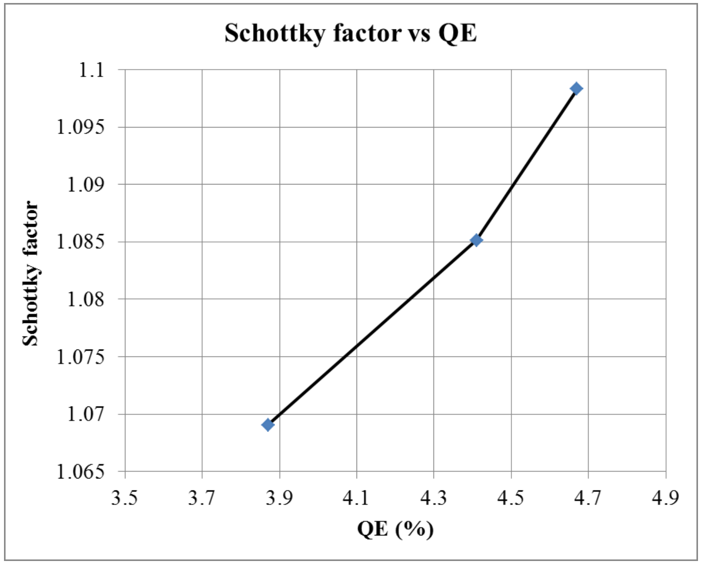
/aver.slope



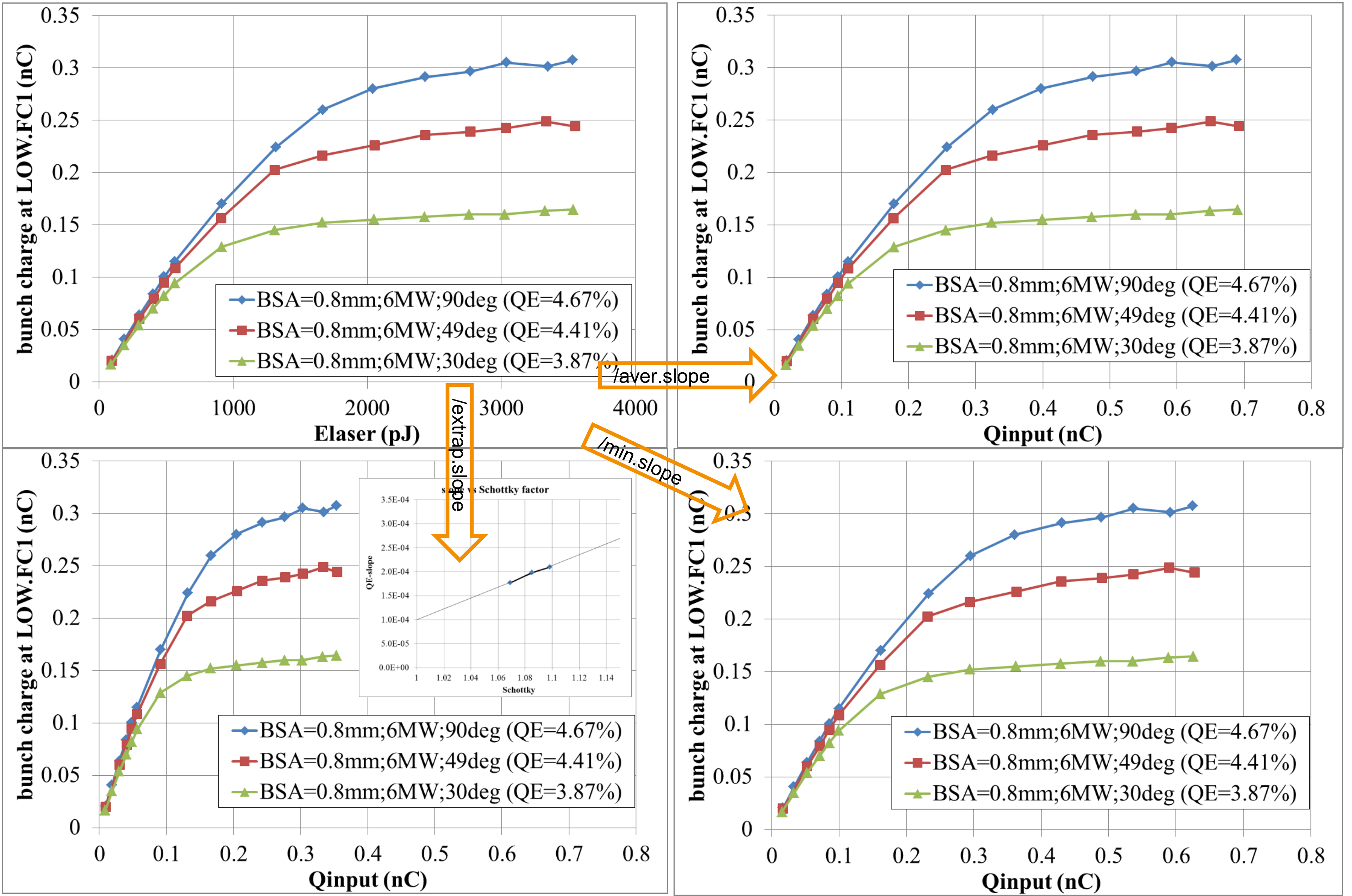


$$\mathrm{SF} = \left(1 + 0.48\sqrt{\sin\varphi}\right)^2$$



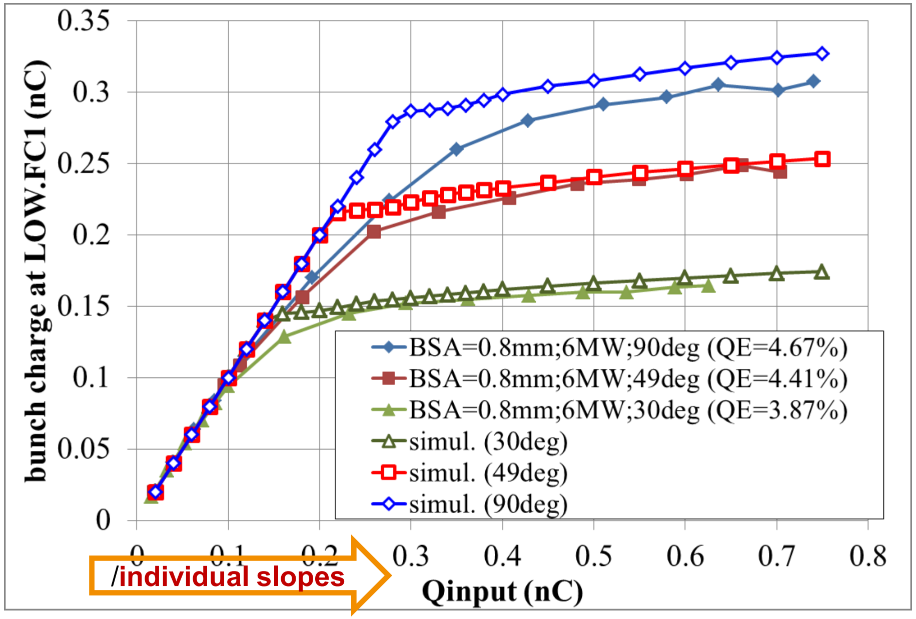


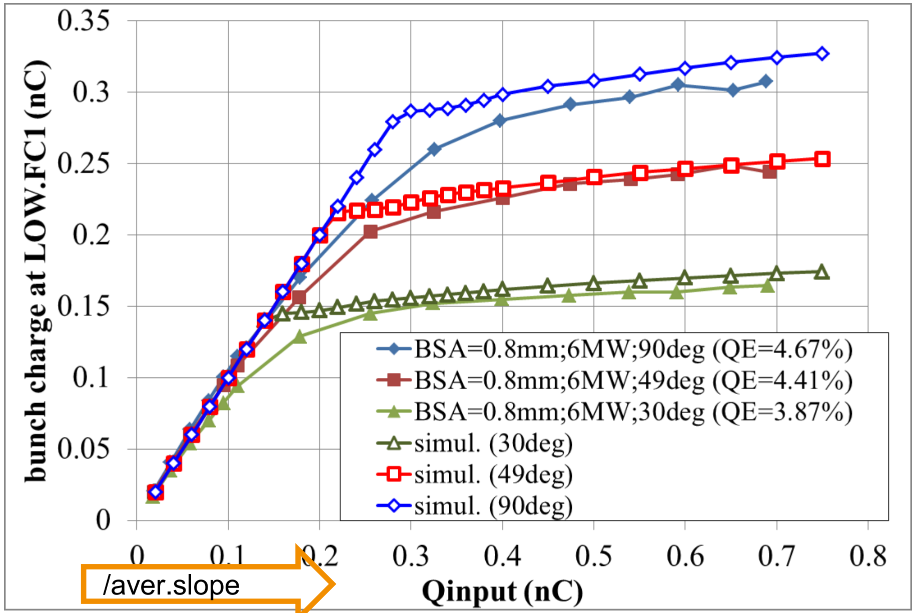
Qinput determination

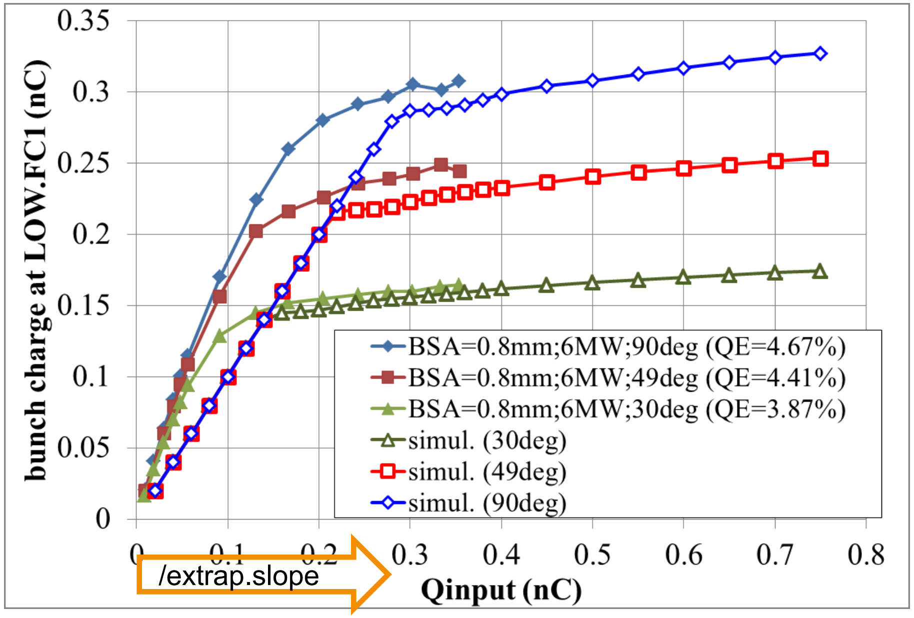


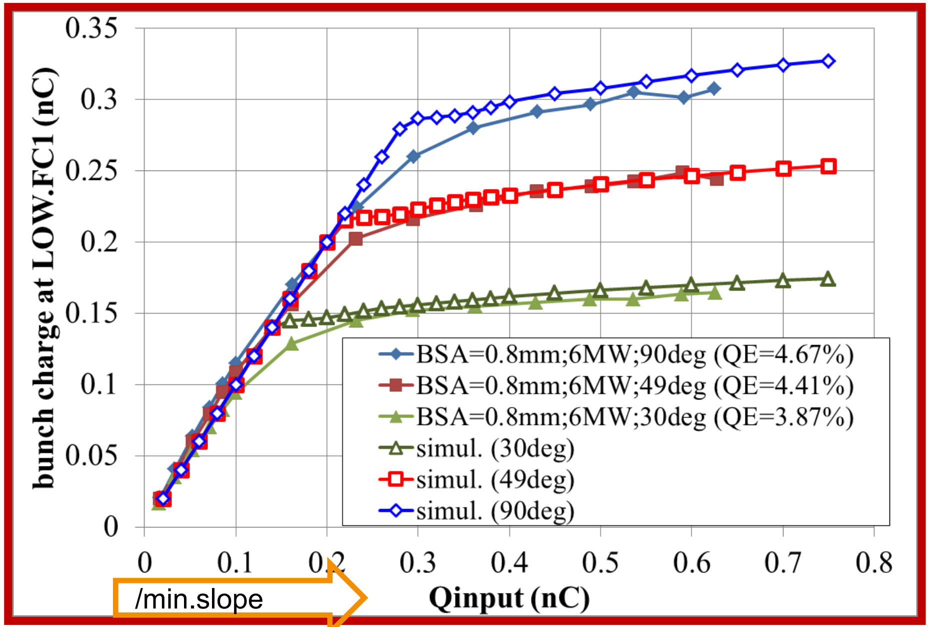
Run 4 (first guess)

Laser temporal Trms(fwhm)=0.85ps (2.0ps)
Laser transverse: core+halo(MK), 0.2mm rms
RF gun MaxE(1)=-59.569MV/m
ASTRA: 200k particles, no Schottky

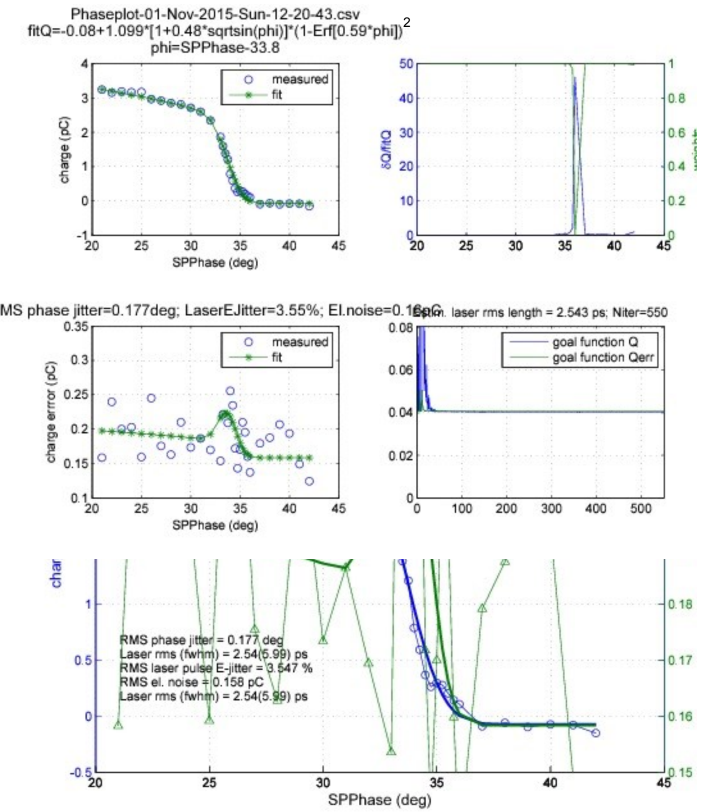


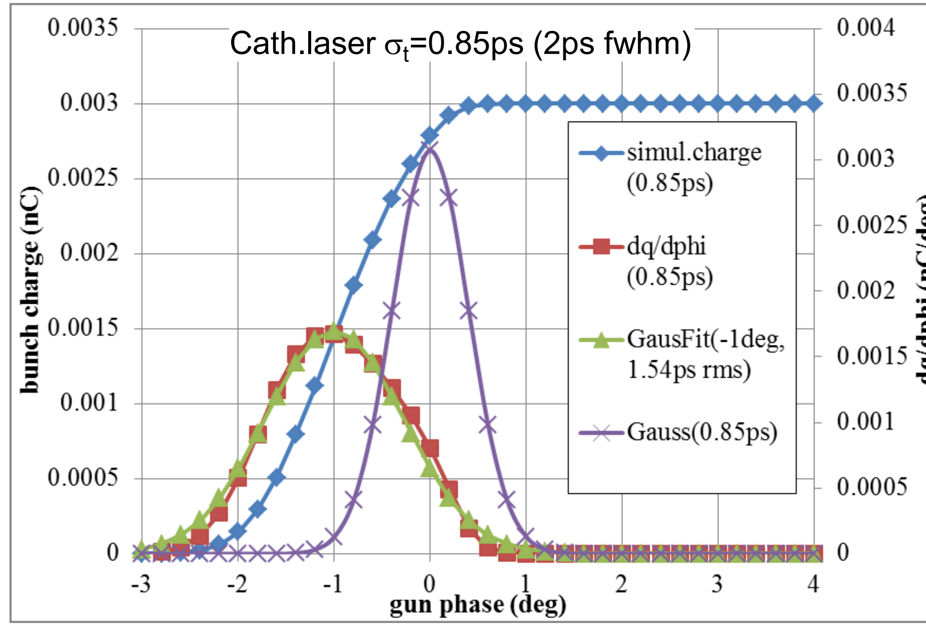


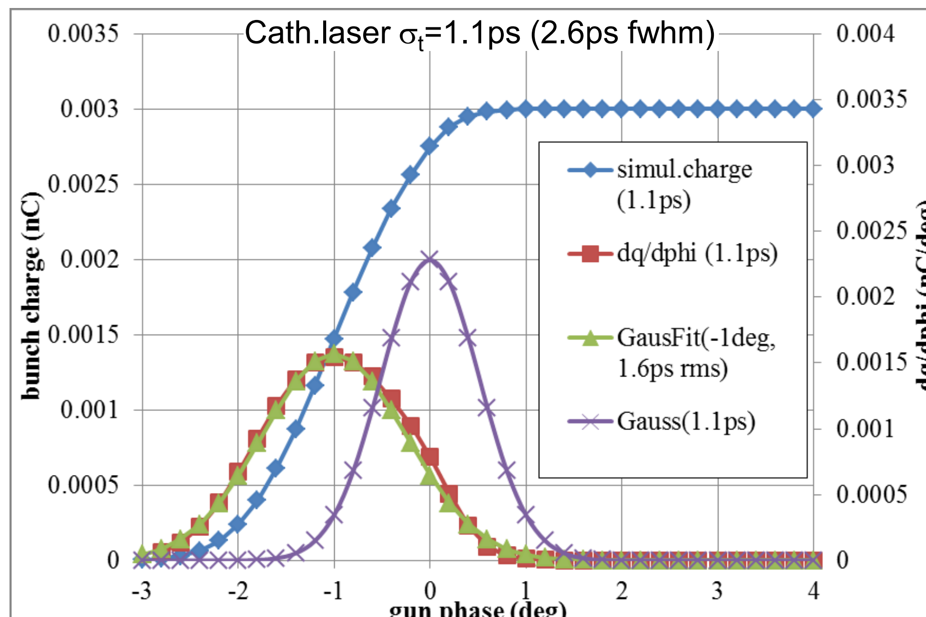




Zero-crossing phase simulations







cathode laser		delta phi	dq/dphi-Gauss.fit	fit-σ_t/σ_t
σ_t (ps)	fwhm (ps)	deg	fit-σ_t (ps)	
0.85	2	-1	1.54	1.81
1.1	2.6	-1	1.6	1.45

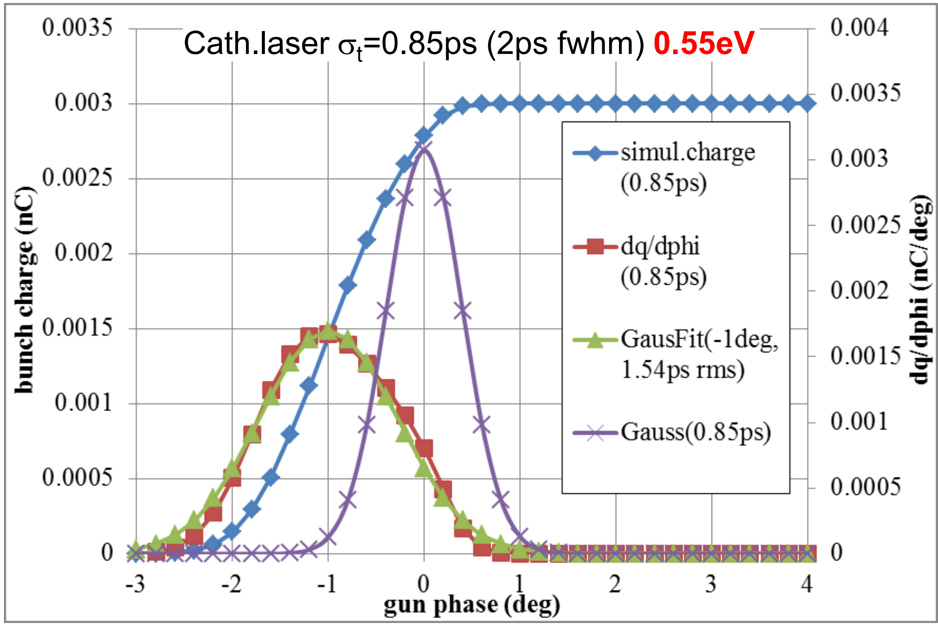
- 1deg (of 3deg MMMG determination discrepancy) [30;49;90deg]→[29;48;89deg]?
- Wider Gaussian fit (but not 2,5ps from experiment!)
- ?Cathode response time (dependent on E@cath)

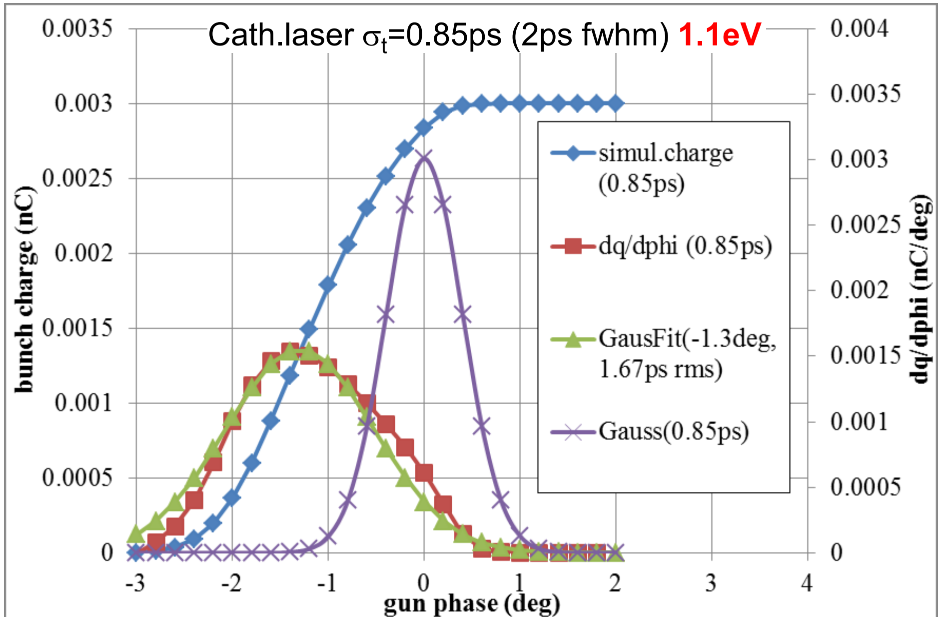
Zero-crossing phase simulations – Ekin impact!

cathode laser		Ekin (eV)	delta phi	dq/dphi-Gauss.fit	fit-σ_t/σ_t
σ_t (ps)	fwhm (ps)		deg	fit-σ_t (ps)	
0.85	2	0.55	**-1**	1.54	1.81
0.85	2.6	1.1	**-1.3**	1.67	1.96

?Twice thermal emittance ➔ phase shift: -1 → -1.3deg

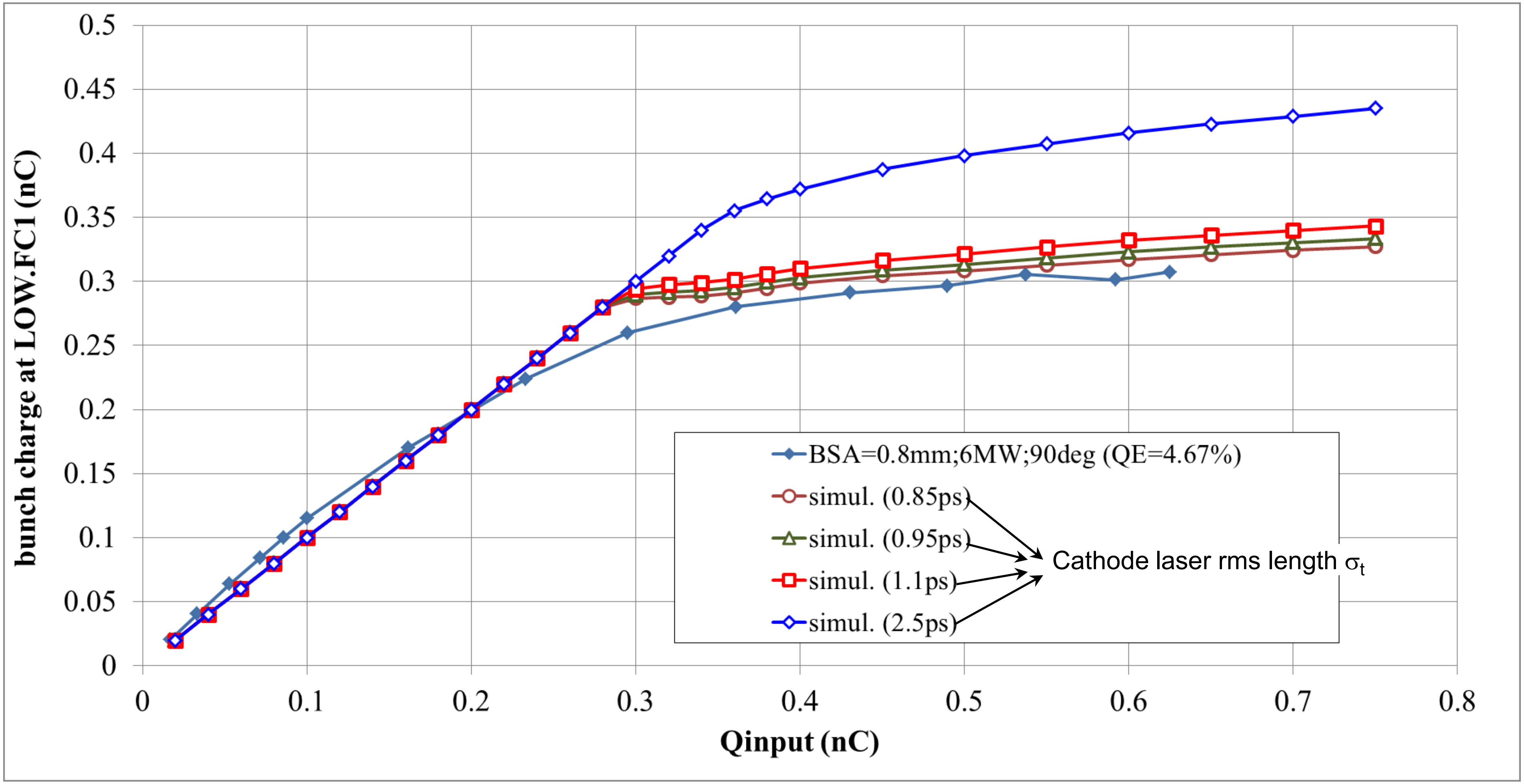
What is "real physics" → zero-phase emission?





Impact of the cathode laser length onto LT-scan (run5)

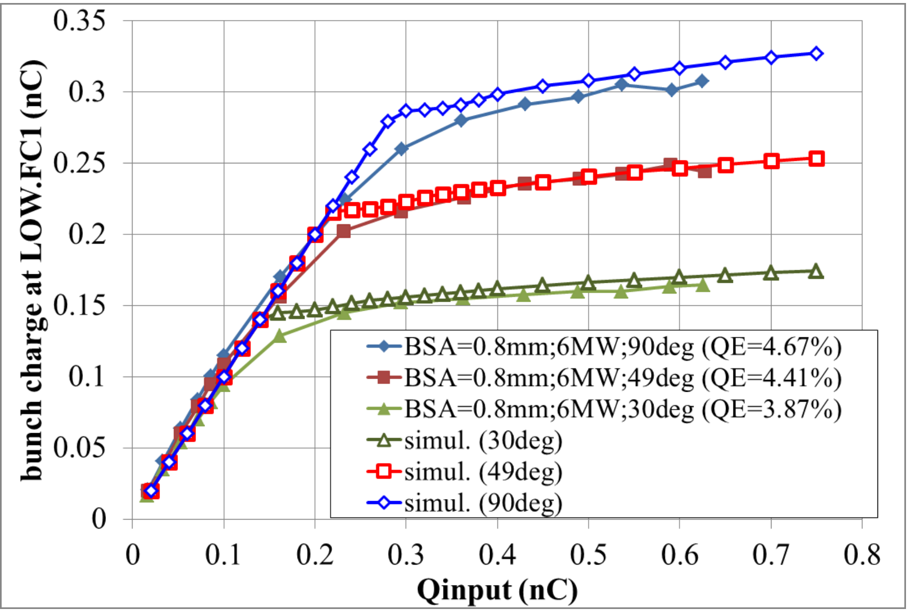
- Ecath=59.569MV/m
- Gun phase =90deg (AUTOPHASE=OFF)
- Laser transverse (flattop core +Gaussian halo, XYrms=0.2mm)



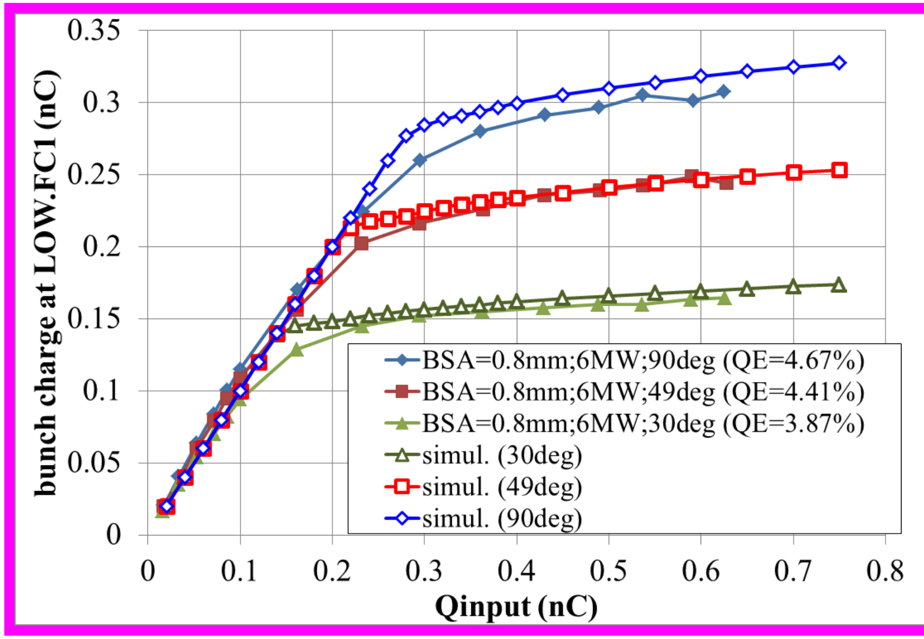
- σ_t=0.85ps (2ps fwhm) → closer, but still Qinput~0.3nC→ large discrepancy

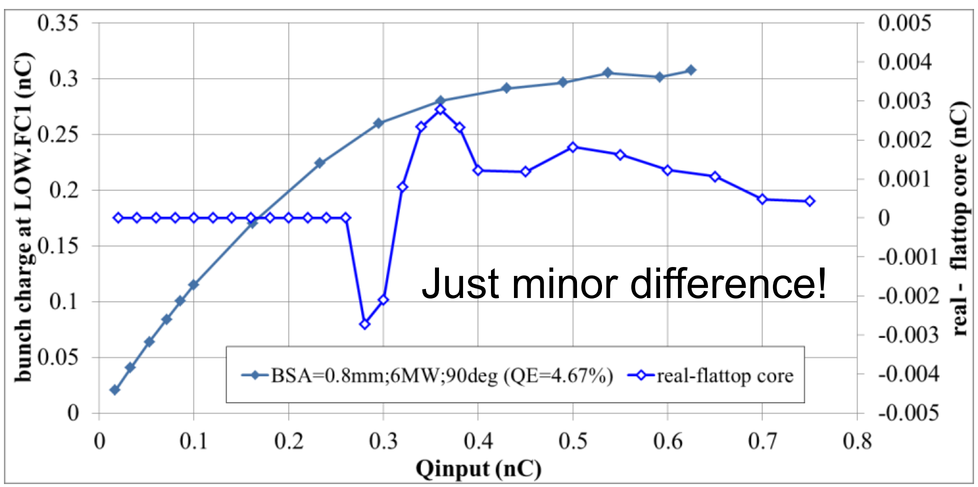
Run 6: (0.85ps; 59.569MV/m; “real” distribution)

flattop core + Gaussian halo



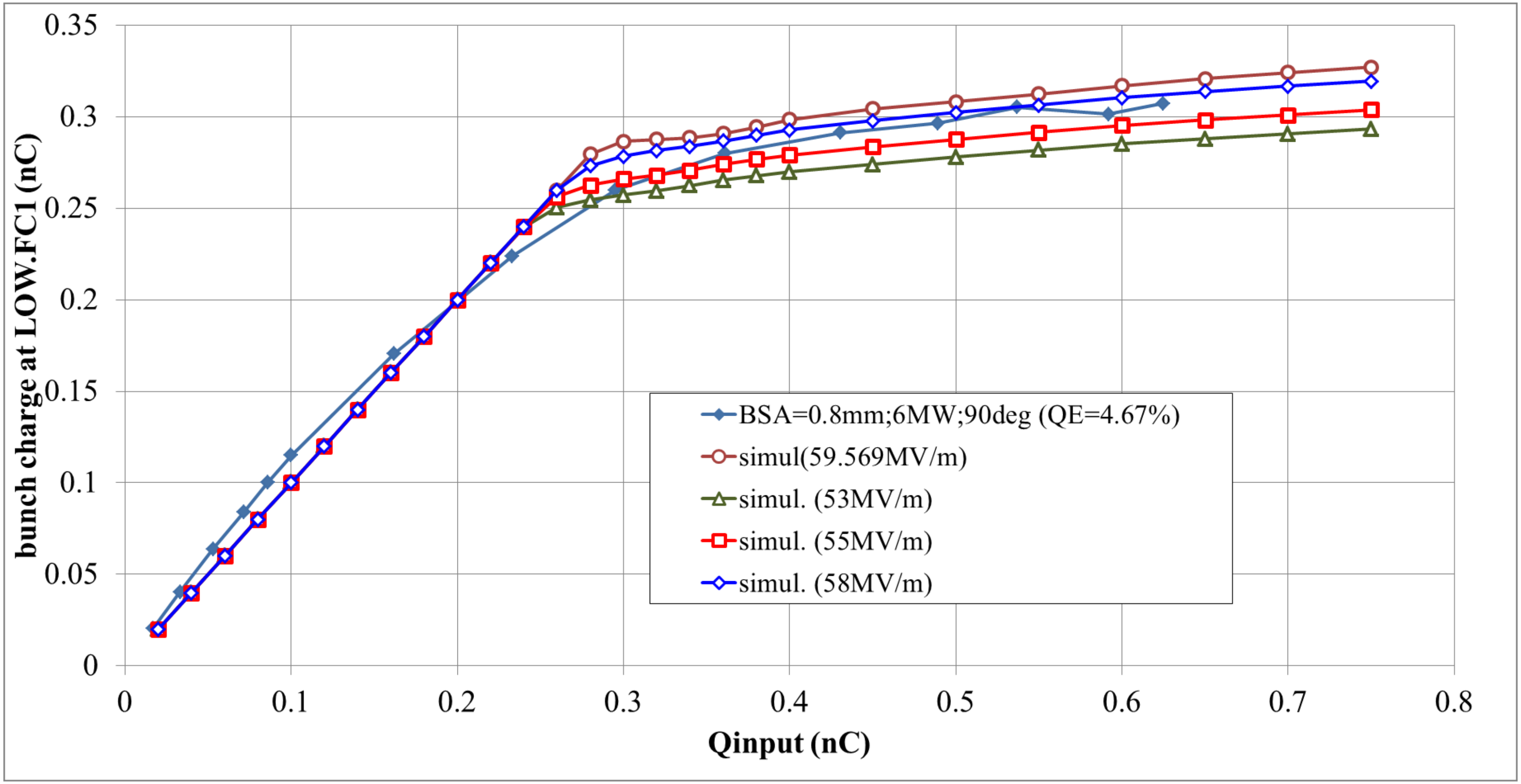
“real” = ring structure in the core + Gaussian halo





Impact of the Rf gun gradient onto LT-scan (run7)

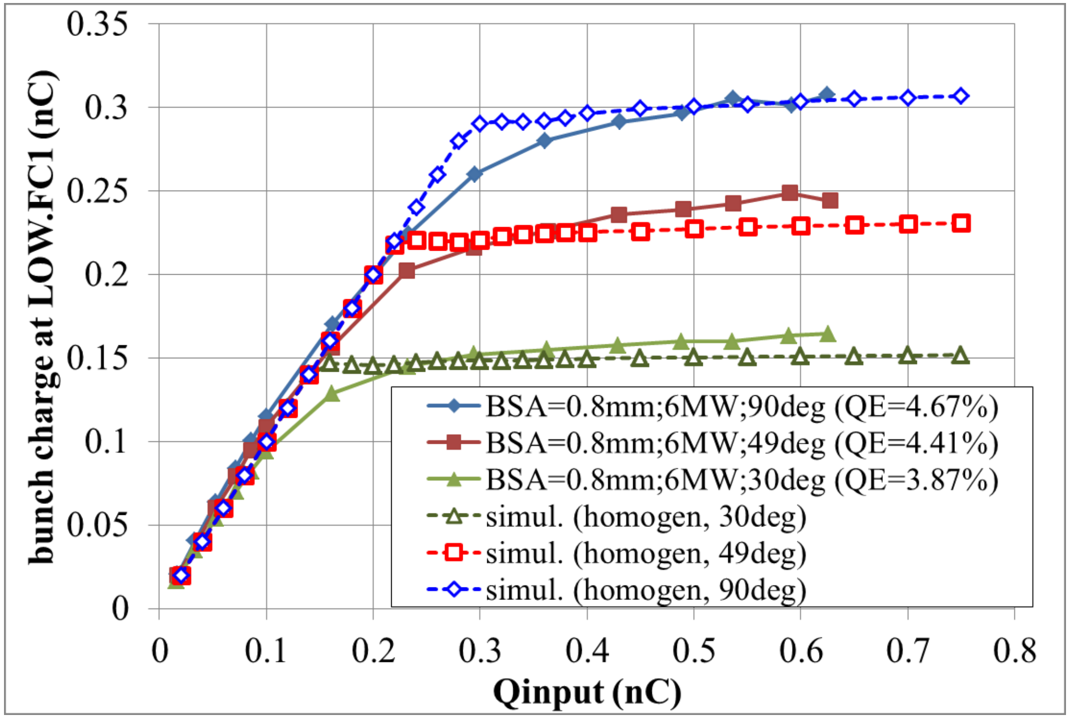
- σ_t=0.85ps (2ps fwhm) Gun phase =90deg (AUTOPHASE=OFF)
- Laser transverse (flattop core +Gaussian halo, XYrms=0.2mm)

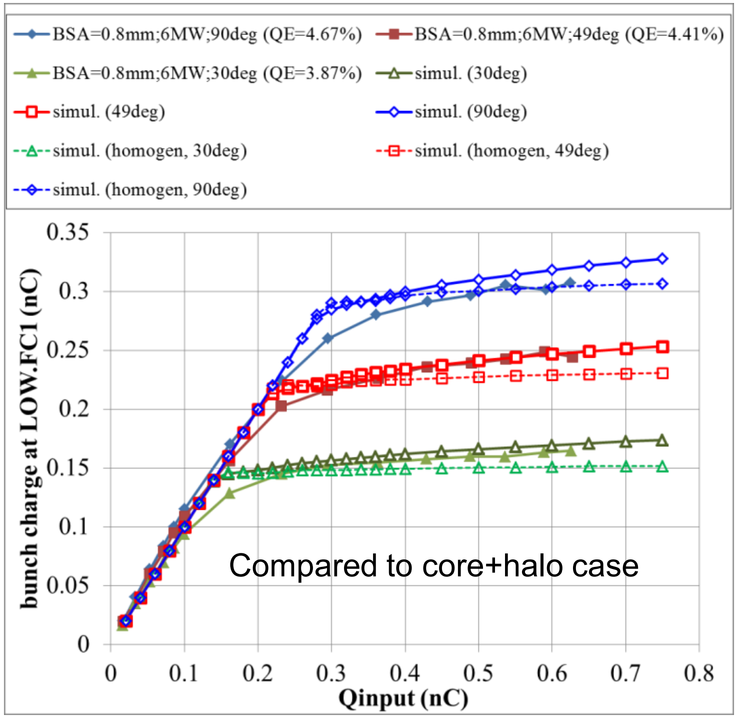


Ecath=58MV/m → better?

LT-scans simulations for the radially homogeneous laser distribution (run8)

- Ecath=59.569MV/m
- σ_t=0.85ps (2ps fwhm)
- Laser transverse (radial homogeneous, XYrms=0.2mm) → no halo

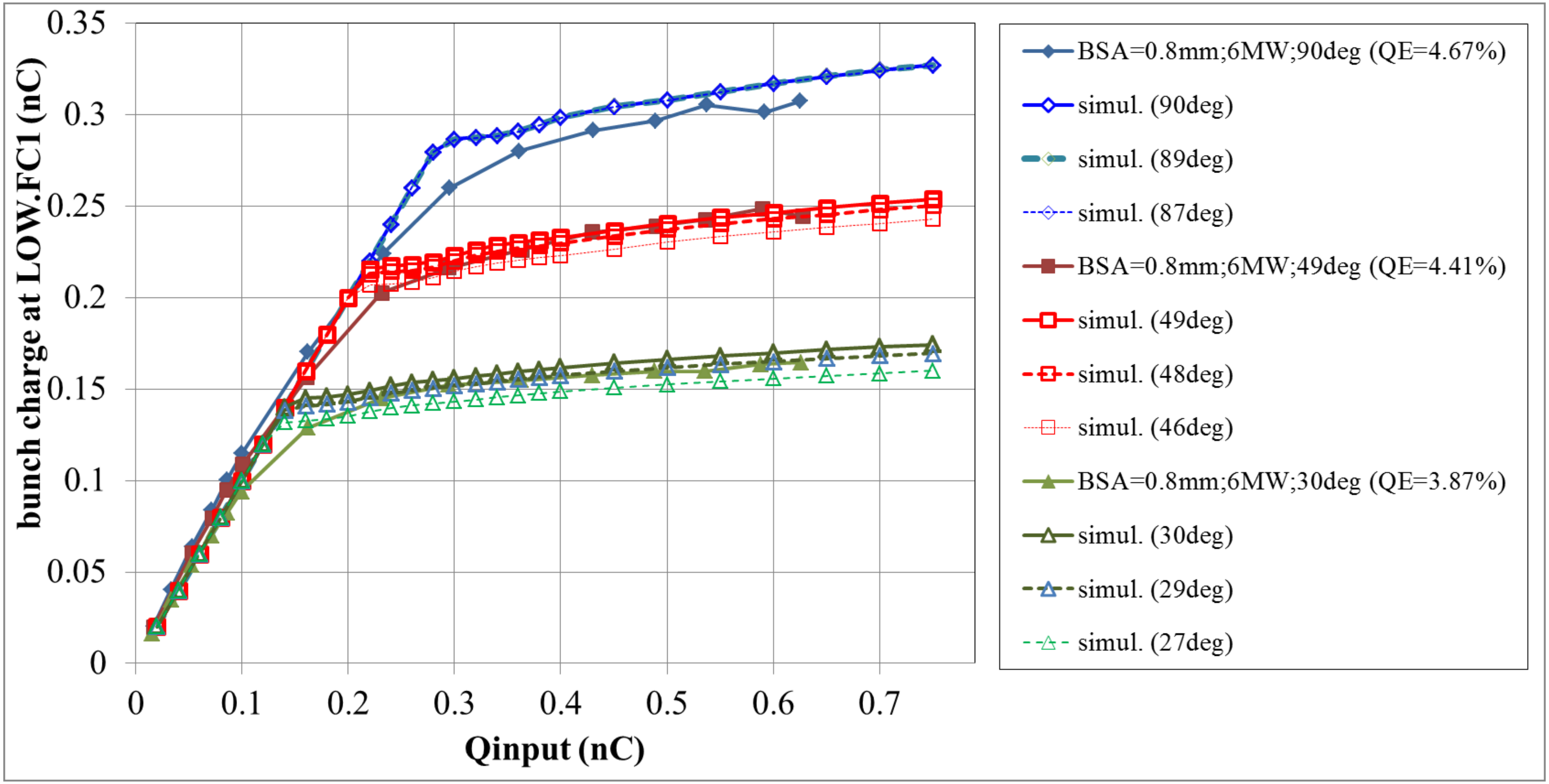




→ Flat after the saturation

LT-scans simulations for 1 and 3deg (~>zero-crossing) phase offset (runs 9+11)

- Ecath=59.569MV/m
- σ_t=0.85ps (2ps fwhm)
- Laser transverse (flattop core+Gaussian halo, XYrms=0.2mm)

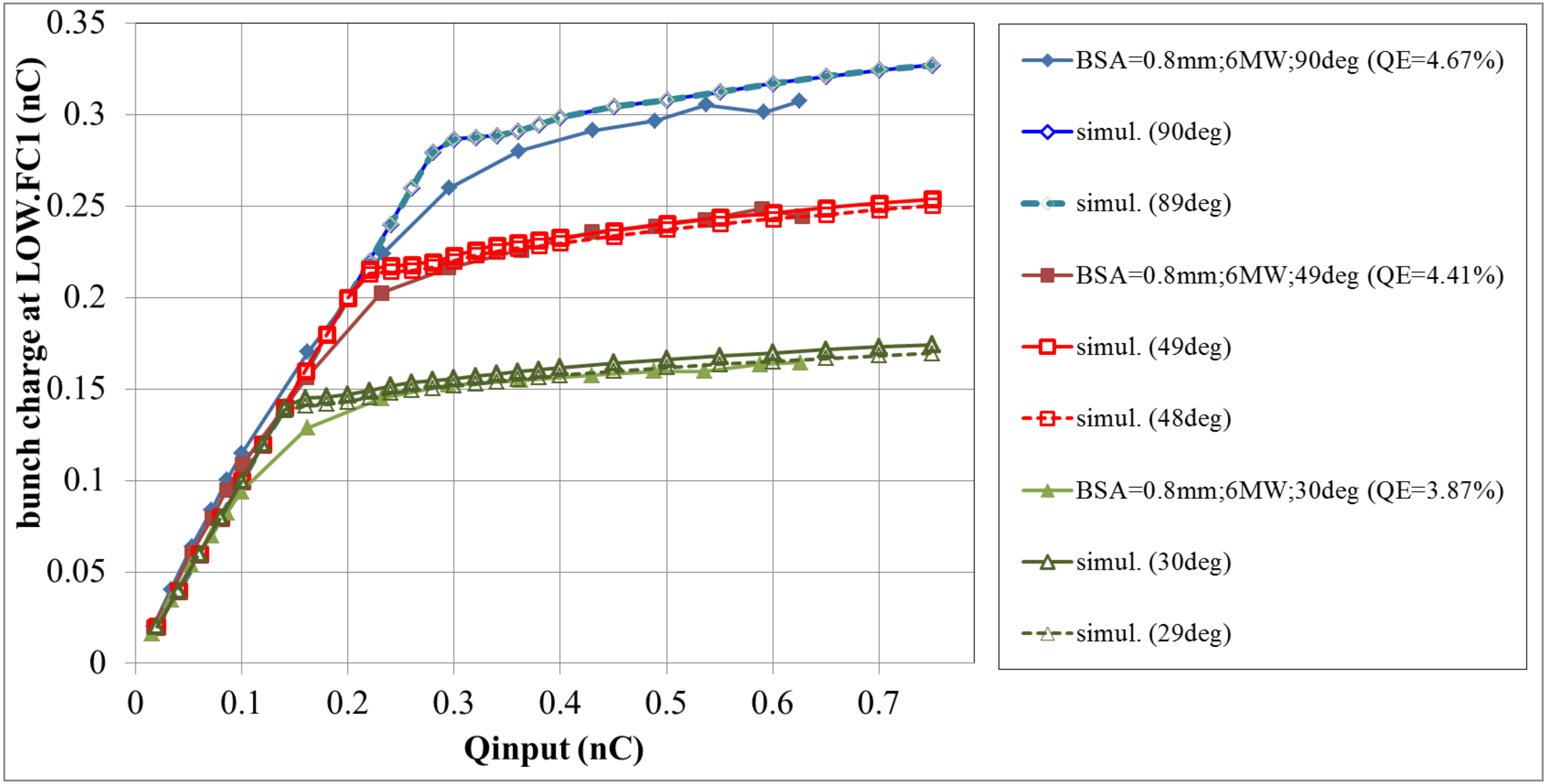


➔ 1 deg:
- better agreement for 49 and 30deg
- No difference for 90deg

➔ 3 deg:
- Overestimation for 49 and 30deg
- No difference for 90deg

LT-scans simulations for 1deg (~>zero-crossing) phase offset (run 9)

- Ecath=59.569MV/m
- σ_t=0.85ps (2ps fwhm)
- Laser transverse (flattop core+Gaussian halo, XYrms=0.2mm)

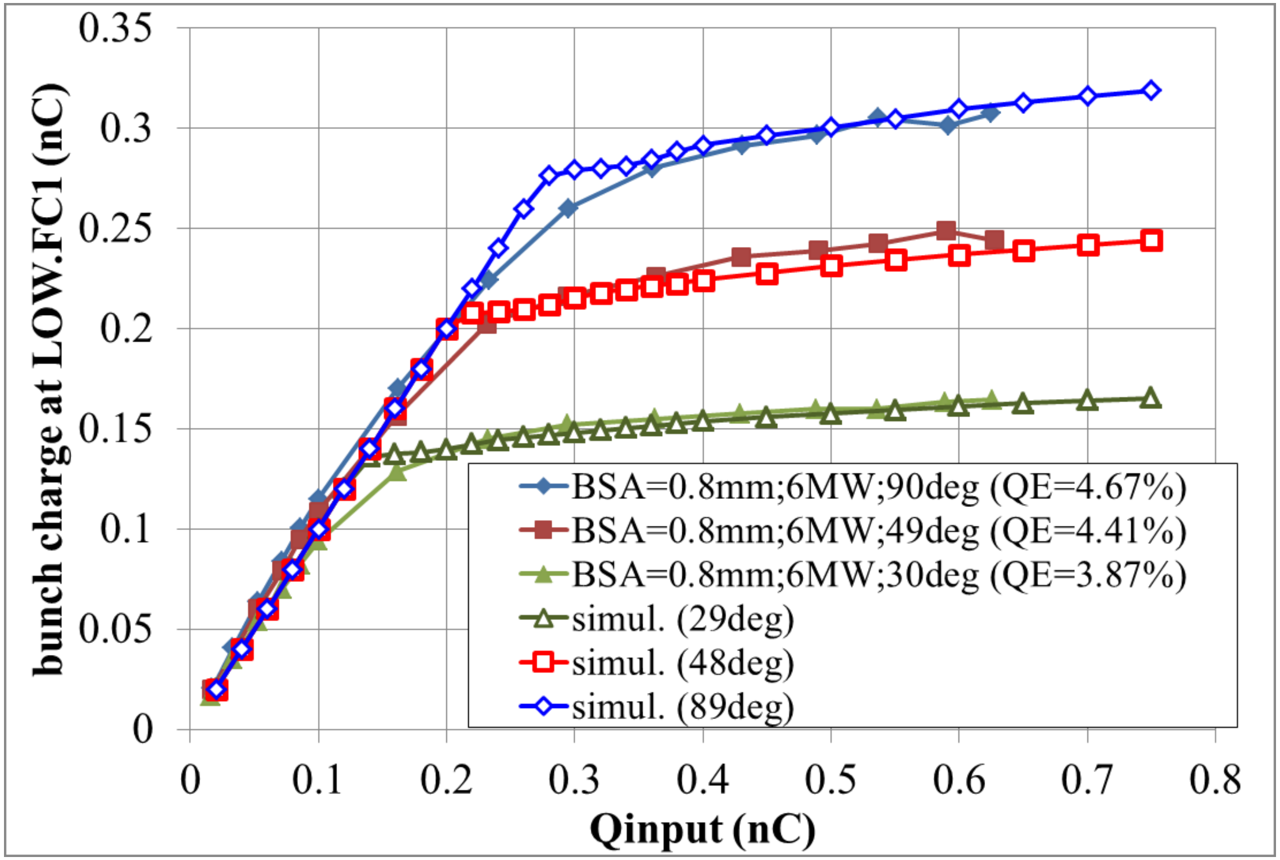


➔ 1 deg:

- better agreement for 49 and 30deg
- No difference for 90deg

LT-scans simulations for 58MV/m and 1deg (~>zero-crossing) phase offset (run 10)

- **Ecath=58MV/m**
- σ_t=0.85ps (2ps fwhm)
- Laser transverse (flattop core+Gaussian halo, XYrms=0.2mm)

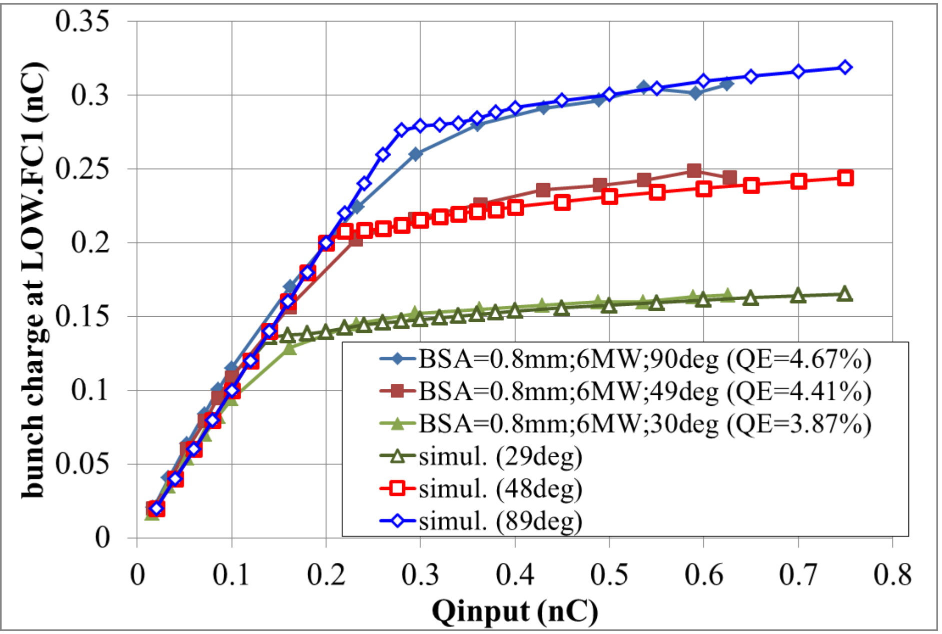


- better agreement for 90deg
- but worse for 49deg
- But the max PZ momentum is by 2.5% less (6.518MeV/c instead 6.681MeV/c)

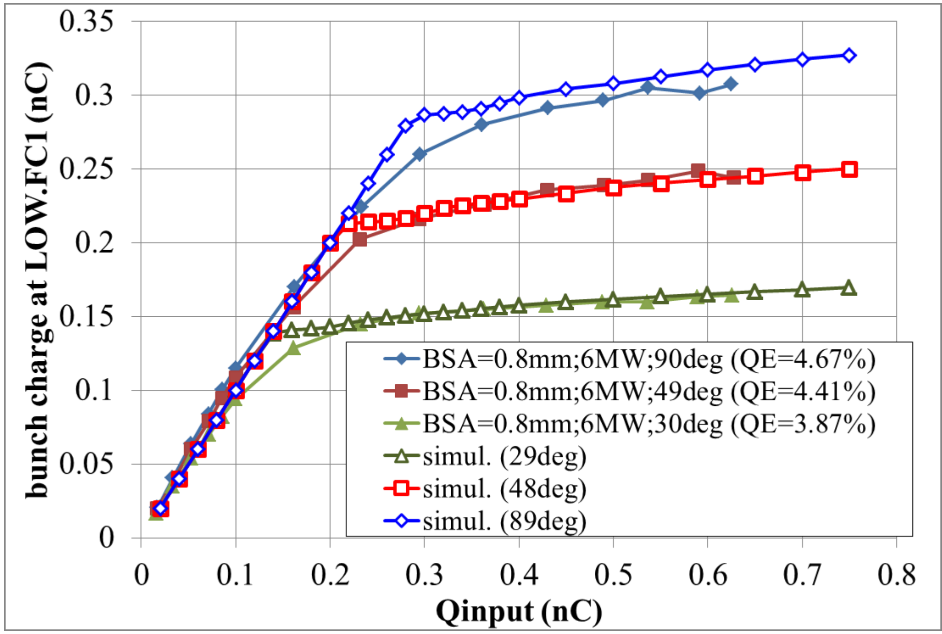
LT-scans simulations 1deg (~>zero-crossing) phase offset (58MV/m vs. 59.569MV/m)

- σ_t=0.85ps (2ps fwhm)
- Laser transverse (flattop core+Gaussian halo, XYrms=0.2mm)

58MV/m



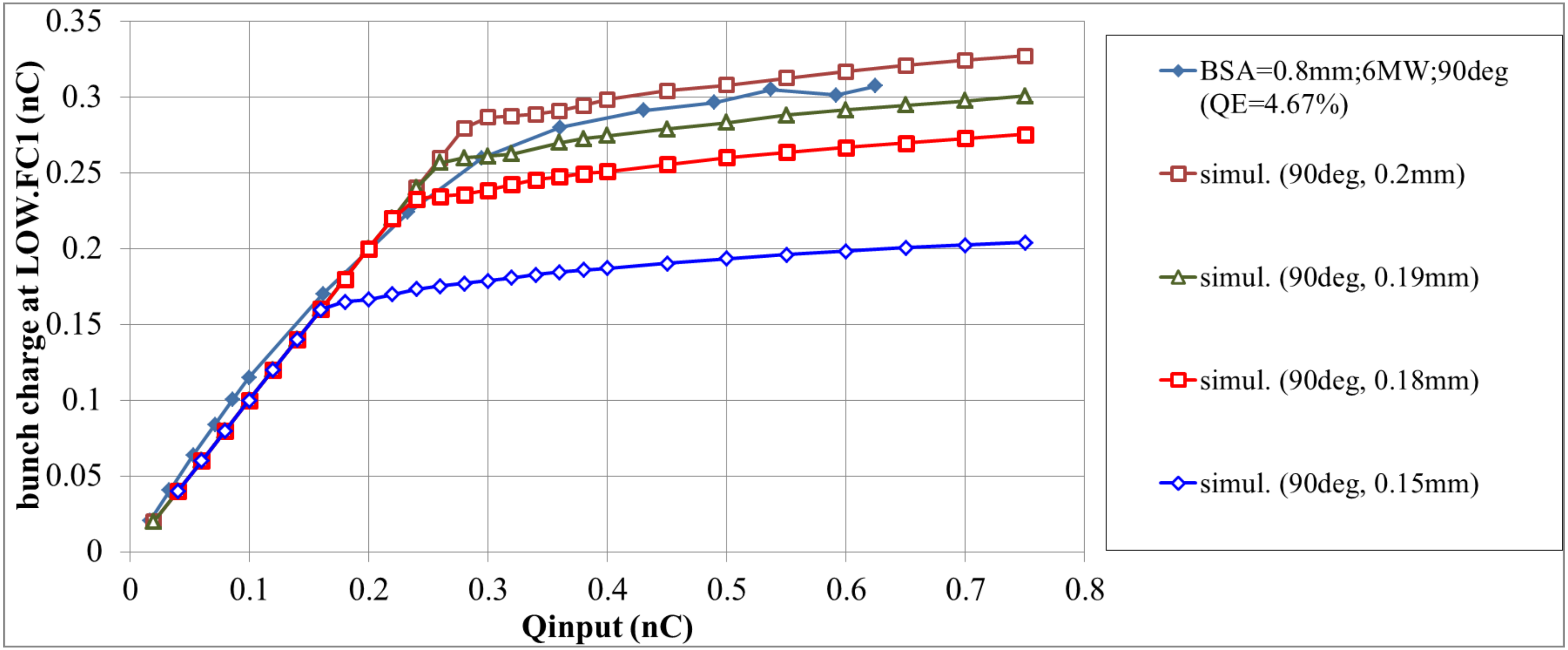
59.569MV/m



- But the max PZ momentum is by 2.5% less (6.518MeV/c instead 6.681MeV/c)

Impact of the cathode transverse rms size (run12)

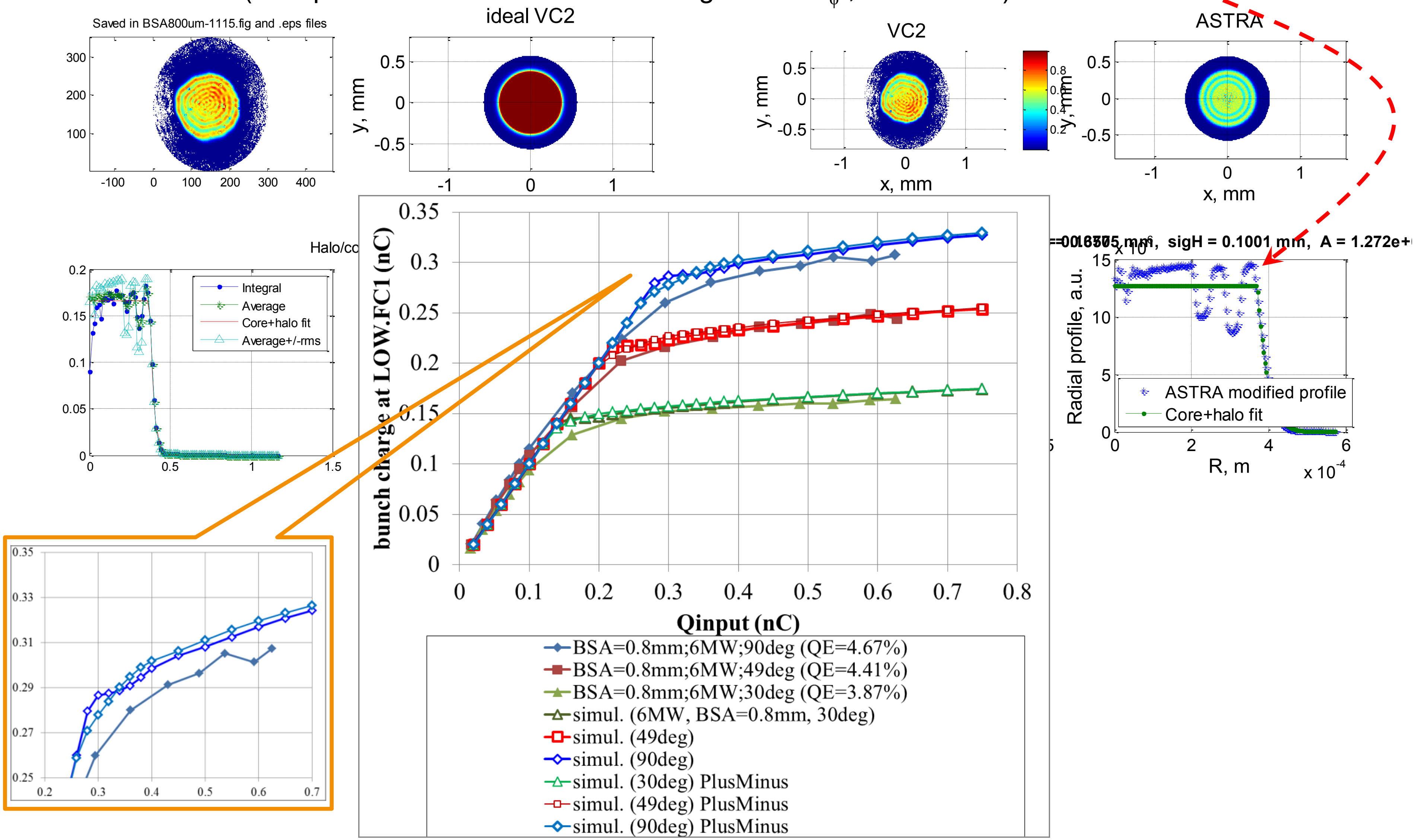
- Ecath=59.569MV/m
- Gun phase =90deg (AUTOPHASE=OFF)
- Laser transverse (flattop core +Gaussian halo, XYrms=0.2; 0.19;0.18 and 0.15mm)



- It seems that XYrms=0.2mm (default) is the best choice (or 0.195mm?)

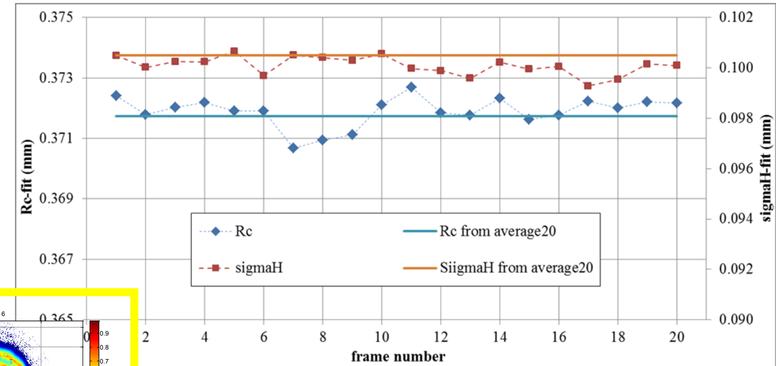
Impact of the cathode transverse distribution (run14)

- Ecath=59.569MV/m
- Laser transverse (flattop core +Gaussian halo➔"average+/-stdev$_{\phi}$", XYrms=0.2) ➔ **PlusMinus**

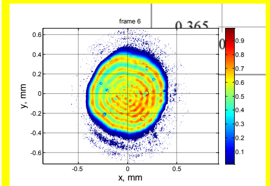


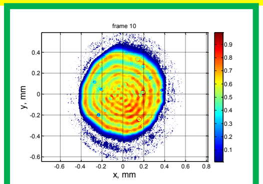
- More smooth transition, e.g. for 90deg around Qinput=0.3nC, but for 30deg almost no difference

VC2 analysis: average image vs. average profile

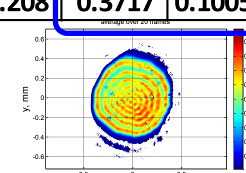


Frame#	<X>	<Y>	Xrms	Yrms	Rc	sigmaH	Halo/core	Rad.mod	<SigmaPhi>	<rSigPhi>/R_c
1	0.0019	-0.0035	0.195	0.204	0.372	0.100	9.8	5.4	12.0	7.0
2	0.0017	-0.0007	0.195	0.204	0.372	0.100	9.5	5.9	11.7	6.8
3	0.0038	-0.0014	0.195	0.205	0.372	0.100	9.7	6.2	11.7	6.8
4	0.0035	-0.0002	0.195	0.206	0.372	0.100	10.0	6.3	11.3	6.6
5	0.0004	0.0000	0.195	0.205	0.372	0.101	10.0	6.1	11.7	6.8
6	0.0036	-0.0046	0.195	0.206	0.372	0.100	9.8	5.3	11.9	6.9
7	0.0018	-0.0007	0.195	0.205	0.371	0.101	9.5	6.5	12.1	7.0
8	0.0010	-0.0018	0.195	0.206	0.371	0.100	9.7	6.6	12.0	7.0
9	0.0007	-0.0015	0.195	0.206	0.371	0.100	9.8	6.3	11.8	6.9
10	0.0022	-0.0004	0.195	0.205	0.372	0.101	9.9	6.5	11.7	6.8
11	0.0002	-0.0044	0.195	0.206	0.373	0.100	10.0	5.7	12.1	7.1
12	0.0044	-0.0007	0.195	0.205	0.372	0.100	9.7	6.3	11.8	6.9
13	0.0016	-0.0045	0.195	0.206	0.372	0.100	9.7	5.9	11.9	7.0
14	0.0030	-0.0035	0.196	0.207	0.372	0.100	10.1	5.3	12.1	7.1
15	0.0011	-0.0039	0.195	0.206	0.372	0.100	9.8	6.1	12.0	7.1
16	0.0016	-0.0039	0.195	0.206	0.372	0.100	9.8	5.3	12.2	7.2
17	0.0028	-0.0042	0.196	0.206	0.372	0.099	9.9	5.6	12.0	7.0
18	0.0034	-0.0033	0.195	0.206	0.372	0.100	9.9	5.6	12.0	7.0
19	0.0009	-0.0029	0.195	0.206	0.372	0.100	10.1	5.8	11.9	7.0
20	0.0004	-0.0016	0.196	0.206	0.372	0.100	10.1	5.4	11.8	6.9
mean	0.0020	-0.0024	0.195	0.206	0.3719	0.1001	9.8	5.9	11.9	6.9
std	0.0013	0.0016	0.0003	0.0007	0.0005	0.0004	0.2	0.4	0.2	0.1
			0.13%	0.36%	0.13%	0.36%	1.85%	7.37%	1.72%	1.99%

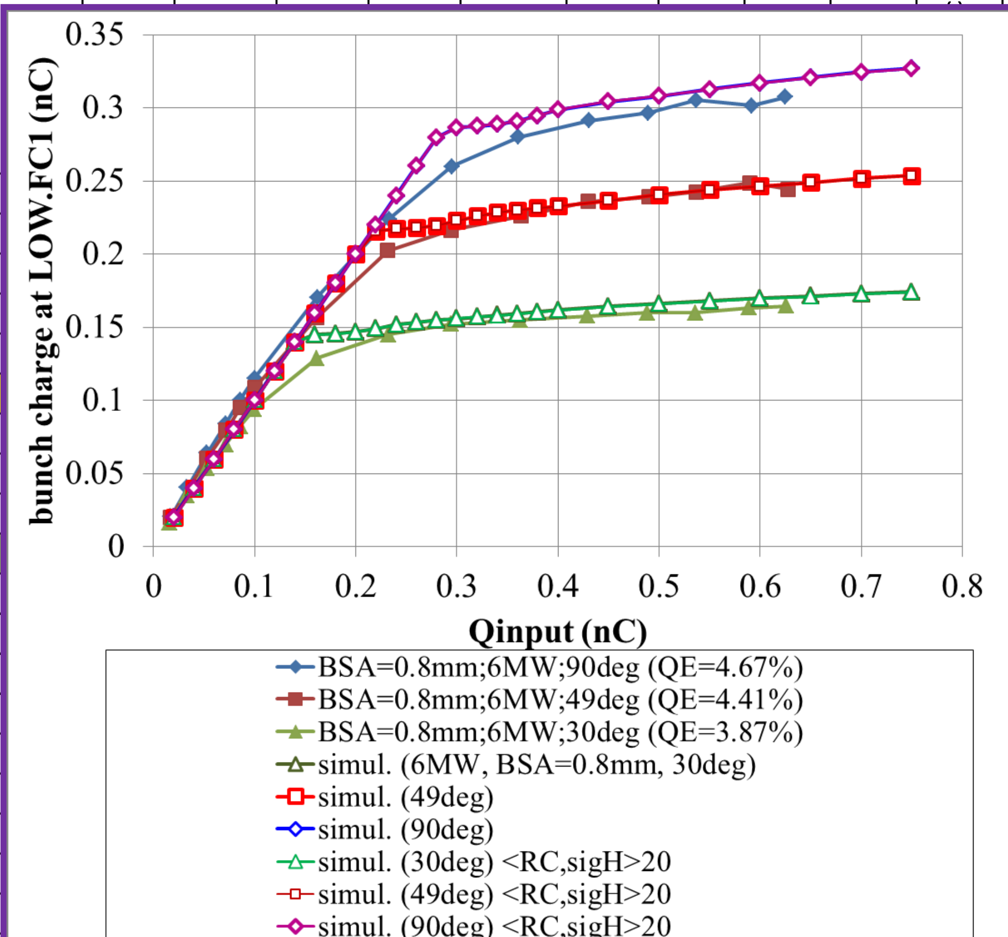


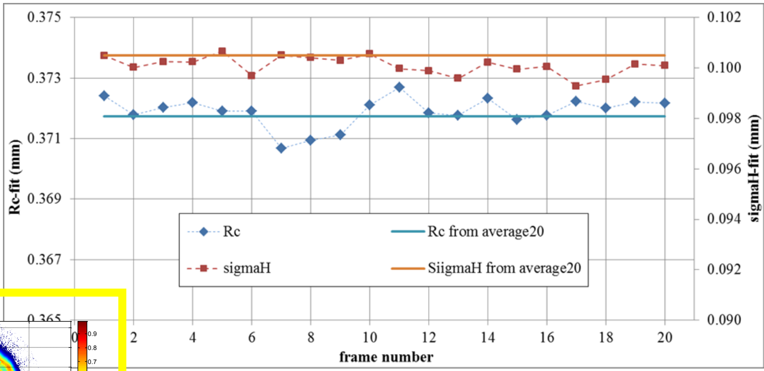


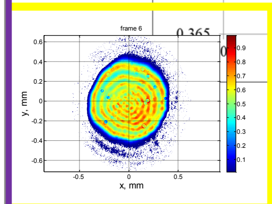
<X> from average20	<Y> from average20	Xrms from average20	Yrms from average20	Rc from average20	SigmaH from average20	Core/halo from average20	Rad.modul. from average20	<SigmaPhi> from average20	<rSigPhi>/R_c from average20
0.0022	-0.0007	0.196	0.208	0.3717	0.1005	10.2	6.0	11.5	6.7

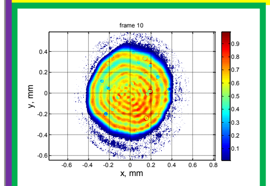


VC2 analysis: average image vs. average profile



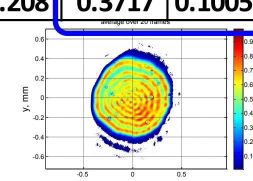






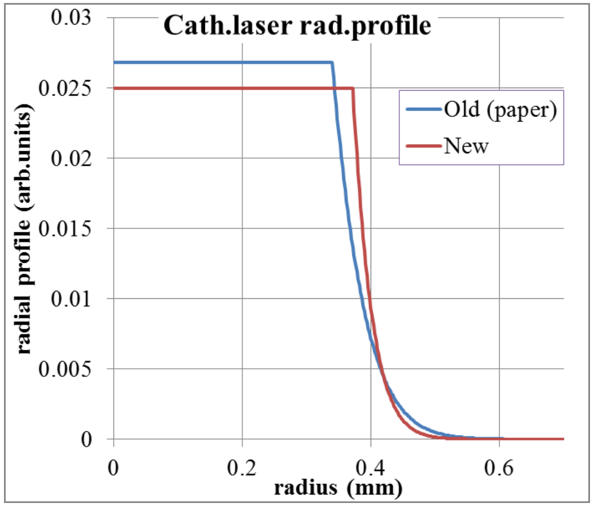
20	0.0004	-0.0016	0.196	0.206	0.372	0.100	10.1	5.4	11.8	6.9
mean	0.0020	**-0.0024**	0.195	0.206	0.3719	0.1001	9.8	5.9	11.9	6.9
std	0.0013	0.0016	0.0003	0.0007	0.0005	0.0004	0.2	0.4	0.2	0.1
			0.13%	0.36%	0.13%	0.36%	1.85%	7.37%	1.72%	1.99%

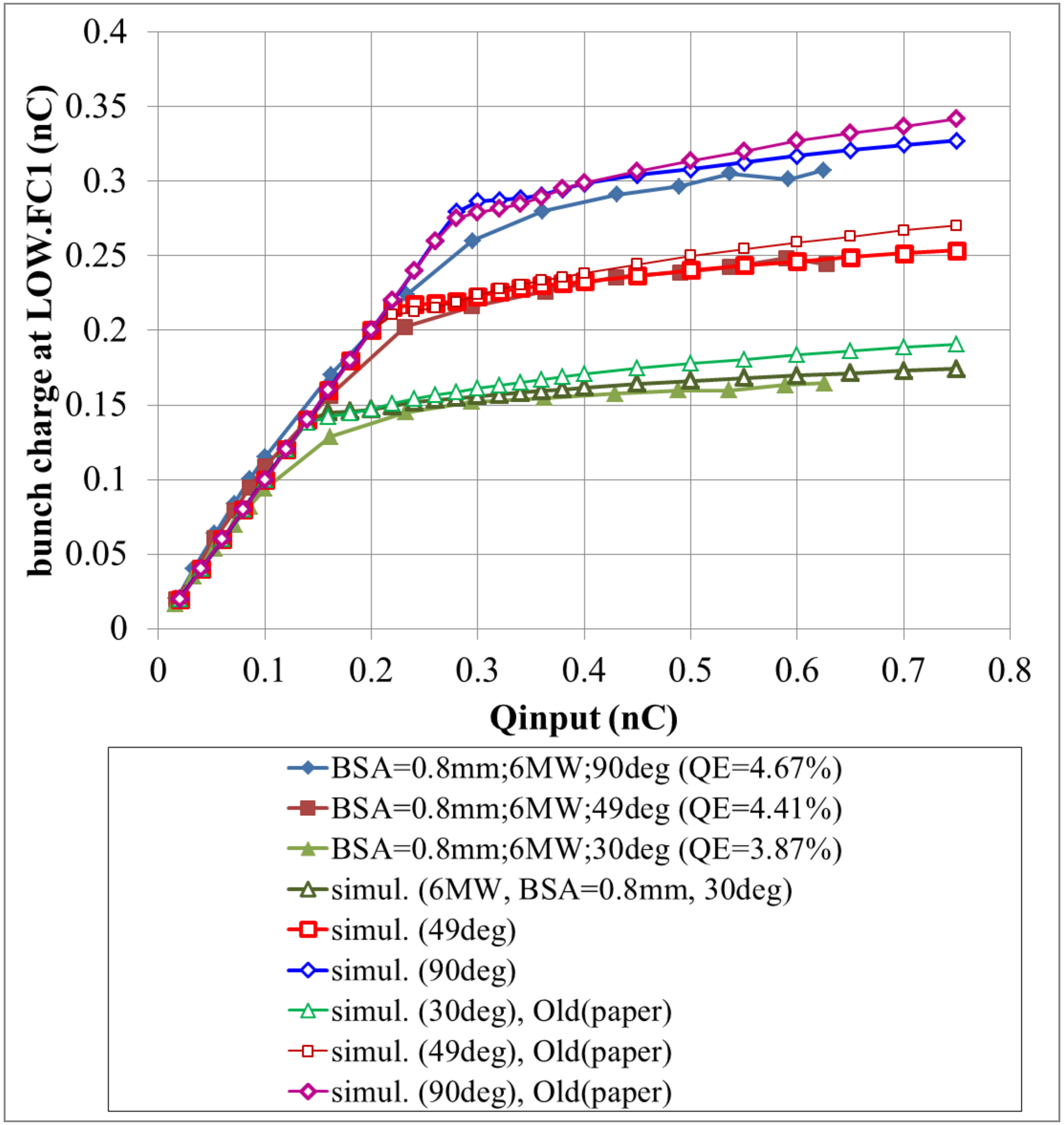
<X> from average20	<Y> from average20	Xrms from average20	Yrms from average20	Rc from average20	SigmaH from average20	Core/halo from average20	Rad.modul. from average20	<SigmaPhi> from average20	<rSigPhi>/R_c from average20
0.0022	**-0.0007**	**0.196**	**0.208**	**0.3717**	**0.1005**	**10.2**	**6.0**	**11.5**	**6.7**



- No difference (as expected → ΔR_c d $\Delta\sigma_H$ are also very small)

One more check: old (paper) profile

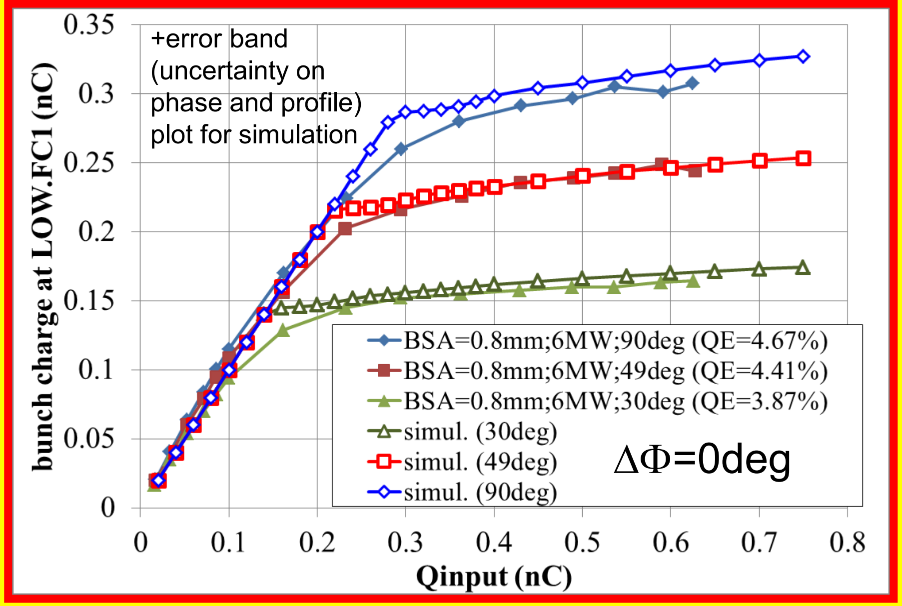


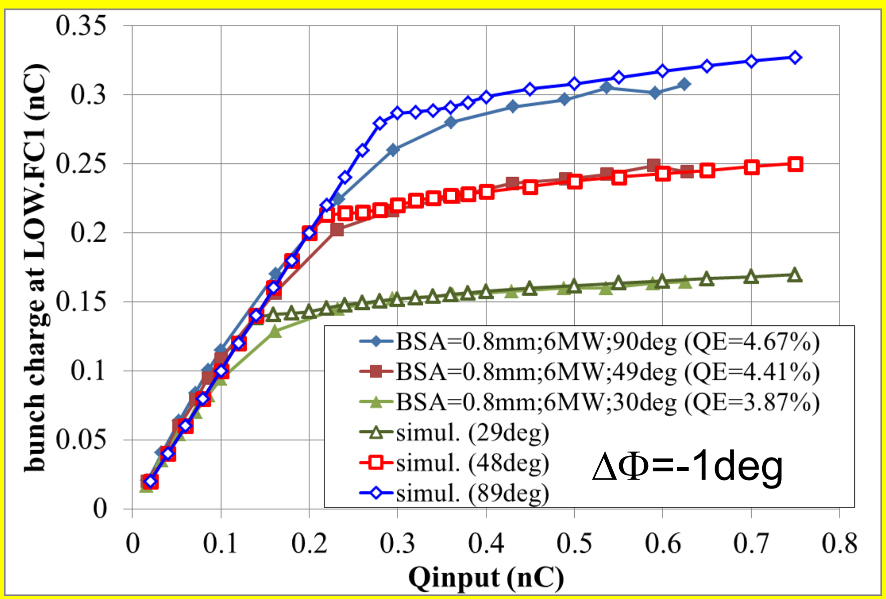


- Analysis of the actual VC2 image using core+halo model ➔ correct trend

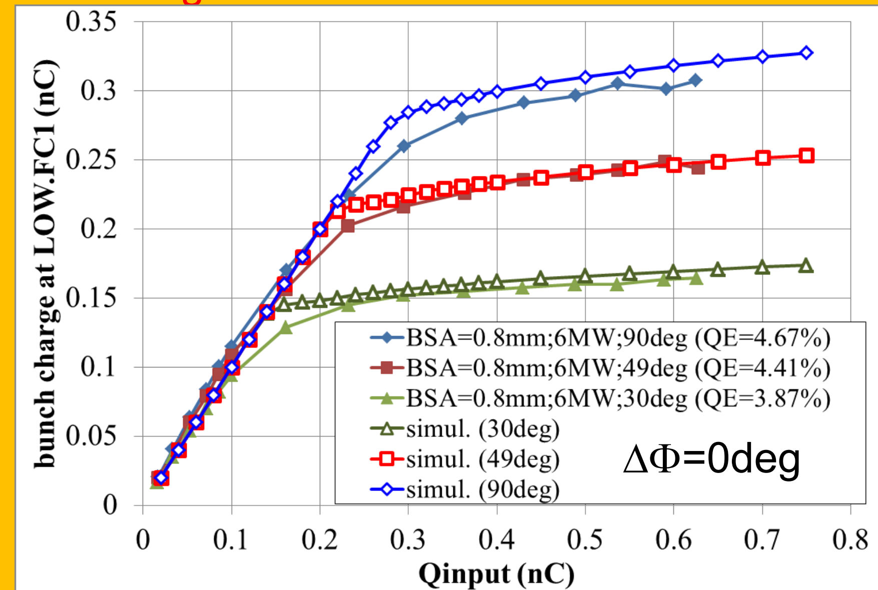
Figure 11b: proposals

flattop core + Gaussian halo





“real” = ring structure in the core + Gaussian halo



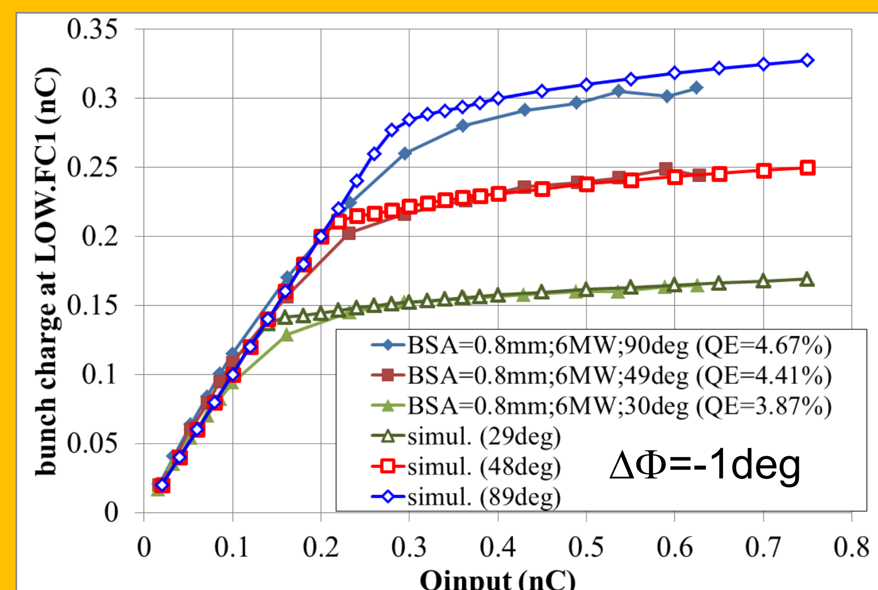
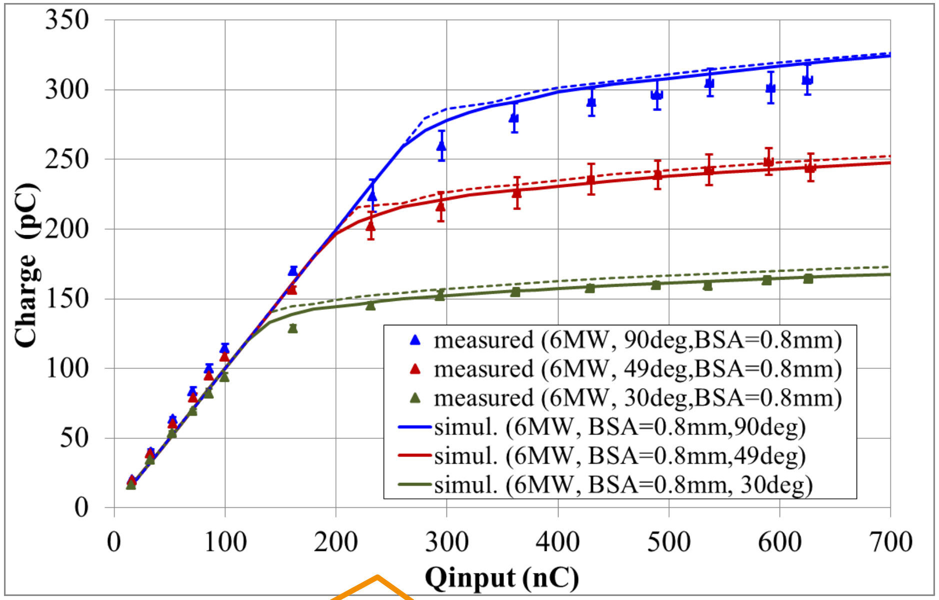
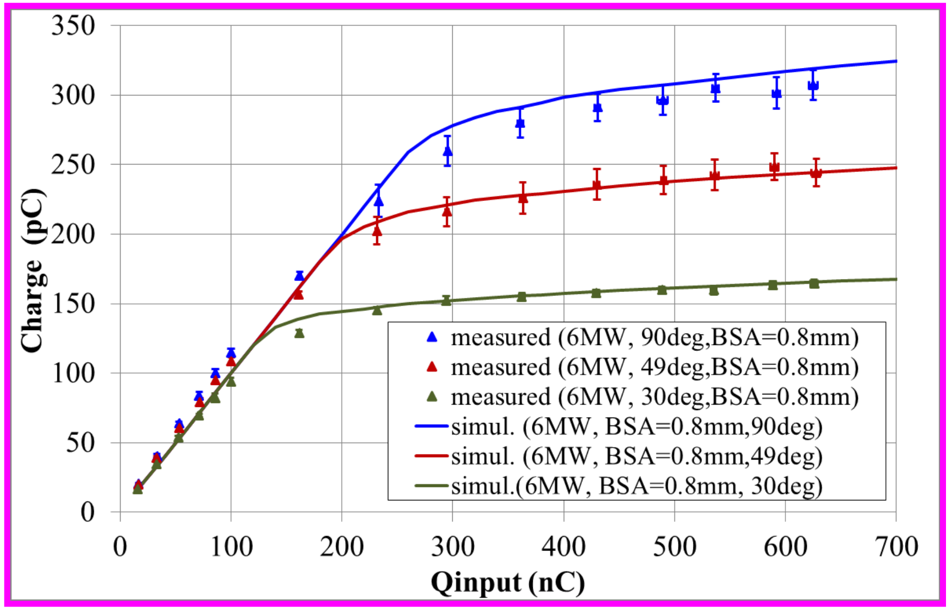


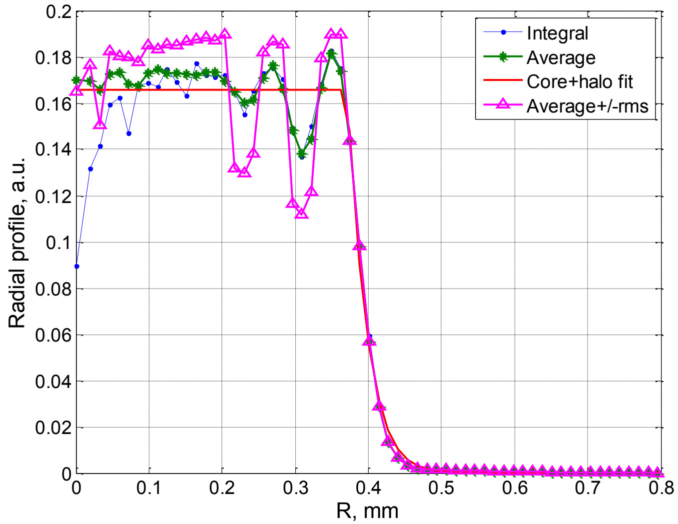
Figure 11b: proposals → tolerances





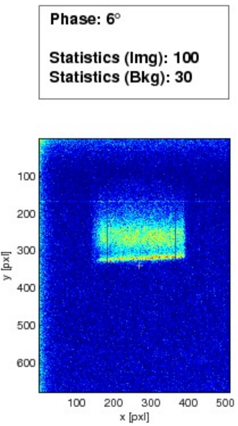
Solid curves = min (runs4,13,14,17)
Dashed curves = max (runs4,13,14,17)

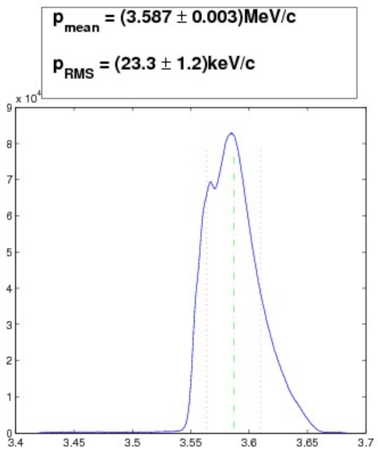
Run	σ_t (ps)	Ecath (MV/m)	ΔΦ (deg)	Radial profile: XX-core + Gaussian halo
4	0.85	59.569	0	Flattop core
13			-1	Average core
14			0	Average core ± σ_ϕ
17			-1	

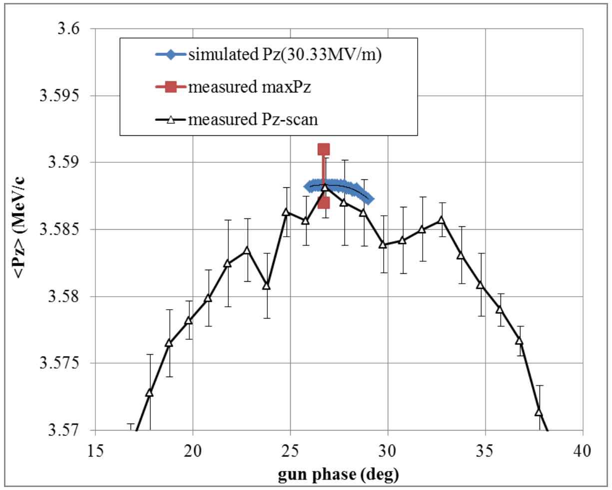


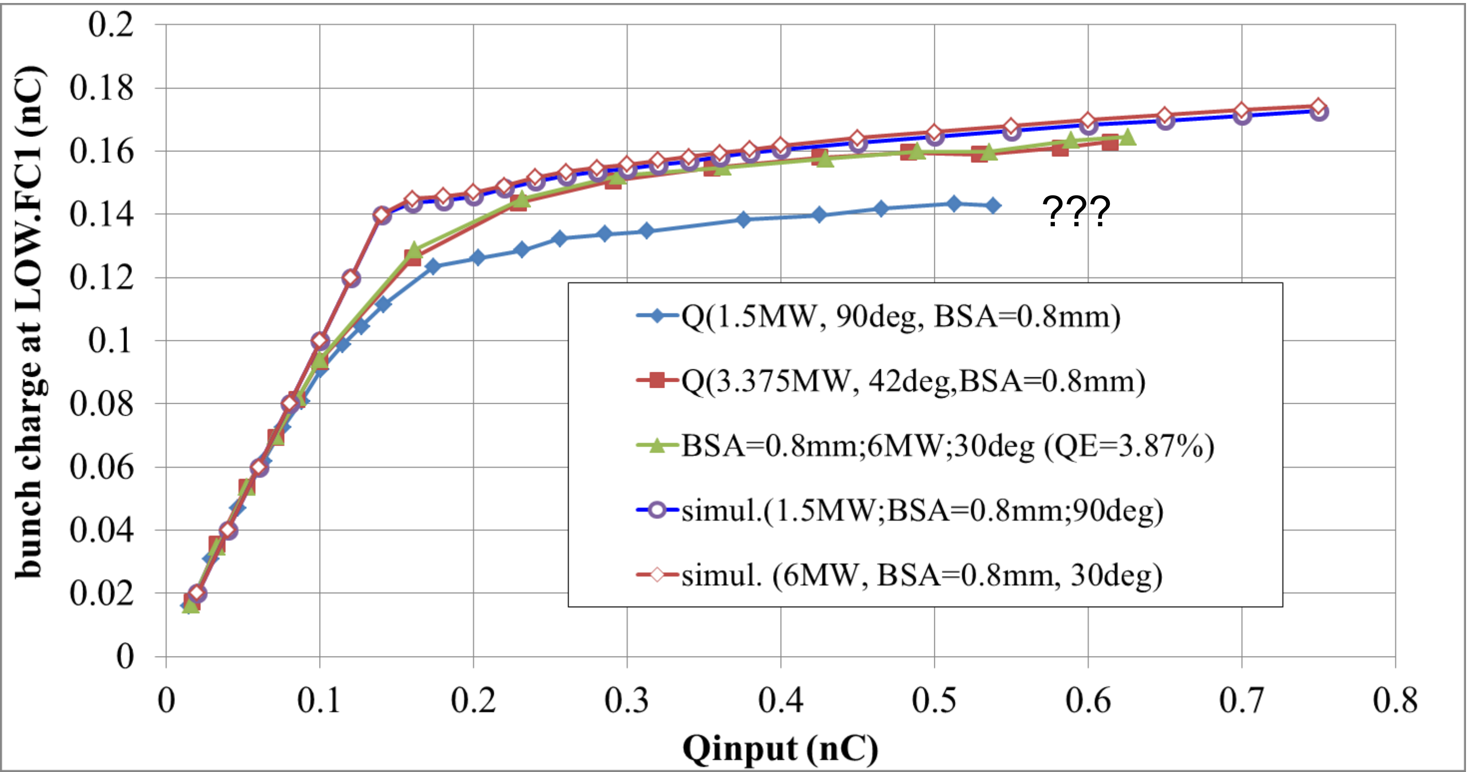
BSA=0.8mm, other RF power in the gun

BSA=0.8mm, 1.5MW in the gun

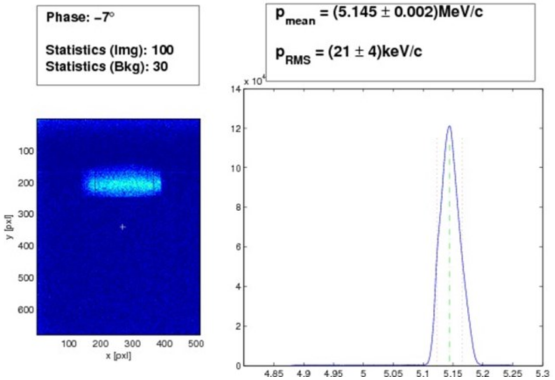


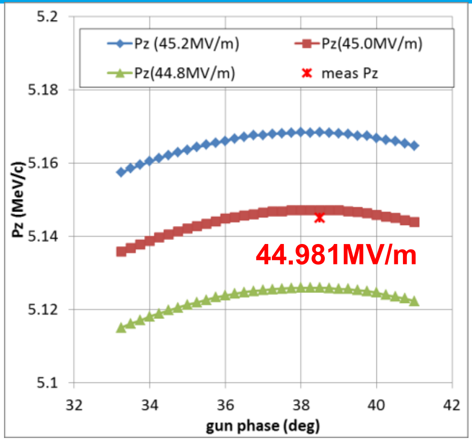


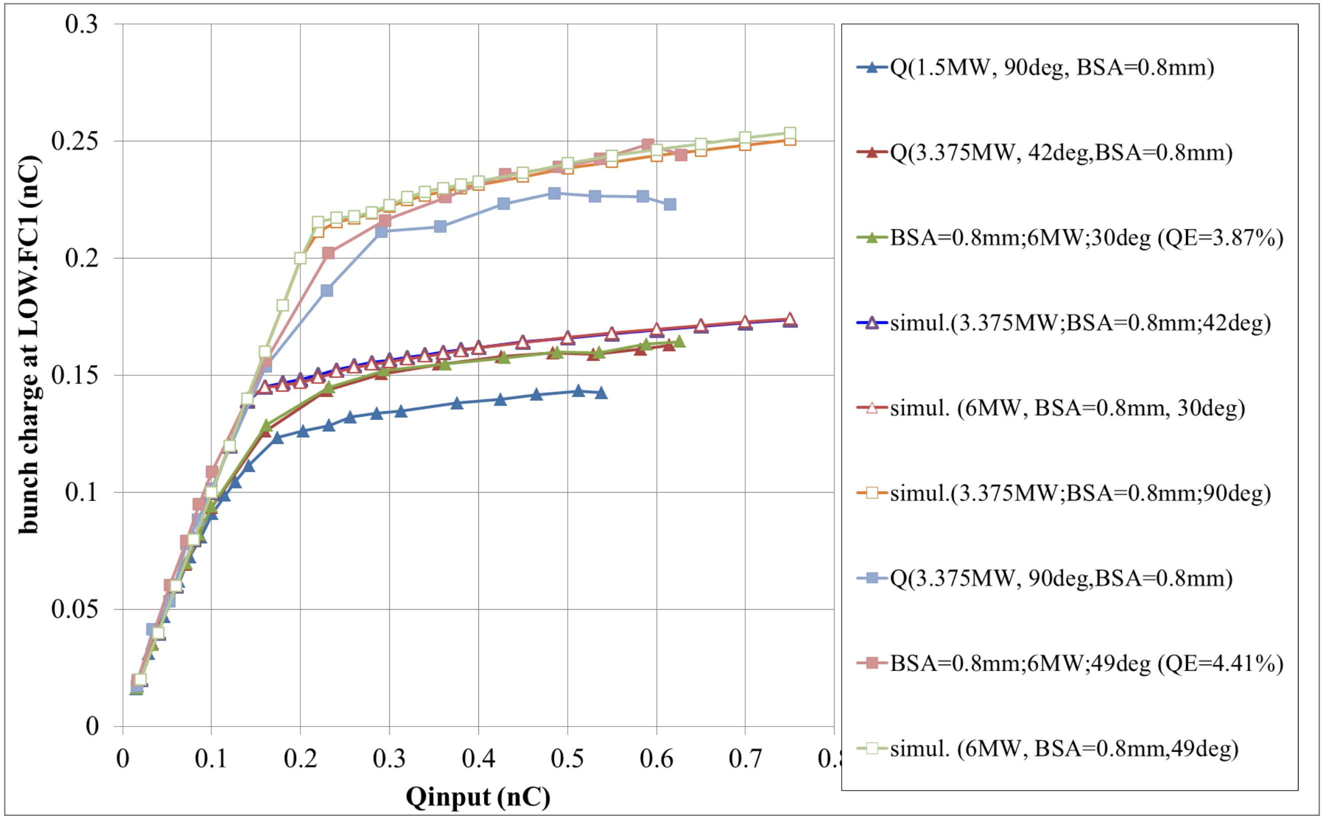




+ BSA=0.8mm, 3.375MW in the gun







Summary

- Fitted:
  - Ecath=59.569MV/m →maxPz=6.681MeV/c at the MMMG phase
  - MMMG phase: simulated → 43deg, measured 46.8-1deg. 2deg are still not well-understood
- Gaussian laser pulse length rms (fwhm) → chosen 0.85ps (2.0ps) → better coincidence, esp. for 90deg data
- Simulated zero crossing phase → -1deg phase shift + widening of the “reconstructed” laser profile (image space charge effect). Ekin is responsible for the shift!
- Transverse distribution (XYrms=0.200mm):
  - Radial homogeneous → flat curves after saturation
  - flattop core + Gaussian halo
  - “real” = ring structure in the core + Gaussian halo → not much improvements
  - “real+/-rms_{ϕ}” → a bit better transition from QE to SC
- RMS laser spot size fine tuning does not improve agreement. Increase of the core modulation (by azimuthal rms errors) smooths the simulated curve (especially for 90 deg), but still the saturated level is generally higher that the measured one. Larger variation of the core+halo parameters (old “paper” profile) results in changed simulated charge curves
- Calculate coefficient(s) for Qinput for the measured data (Elaser→Qinput), minimum slope yields better coincidence with experimental data (Schottky effect is hardly to be implemented into ASTRA by using the core+halo model)
- Scans for phases 30;49;90deg for charge measured at LOW.FC1 (z=0.8m), solenoid default calibration used Imain=460;470;350A [MaxB(1)=-(7.102e-5+5.899e-4*Imain)] delivered simulations close to the measurements, but still not perfect agreement
- Fine tuning (-1deg phase shift) slightly improves agreement (-3deg is too much)
- E_{cath} was varied (53;55;58MV/m vs. 59.569MV/m), 58MV/m delivers a bit better agreement, but the max Pz is ~2.5% lower that the measured one
- No big difference in fitted core+halo profiles and simulated charge curves was found while applying the core+halo fit to the frame-by-frame data compared to the averaged image fit
- Other RF power levels (3.375MW and 1.5MW) were also simulated for BSA=0.8mm
  - Ecath=30.33MV/m →maxPz=3.587MeV/c at MMMG phase for 1.5MW
  - Ecath=44.981MV/m →maxPz=5.145MeV/c at MMMG phase for 3.375MW