Update on Beam Imperfections Studies at PITZ

- Motivation
- Electron beam asymmetry studies
- Electron beam imaging studies
- Photoemission studies
- Conclusions and outlook

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DESY-TEMF-Meeting , 24.06.2016

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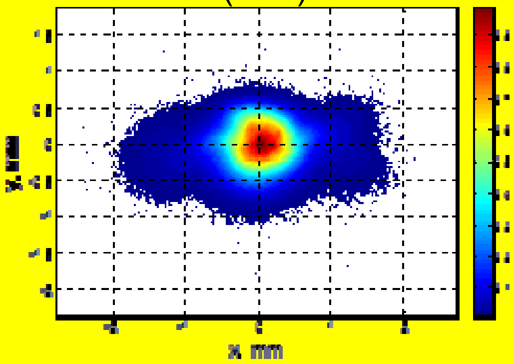
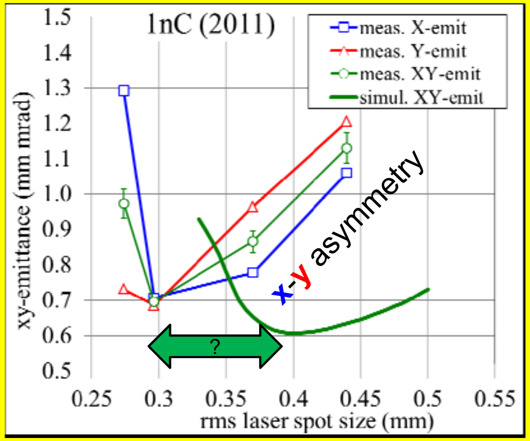
Electron Beam Imperfections at PITZ: Observations

Observed electron beam imperfections

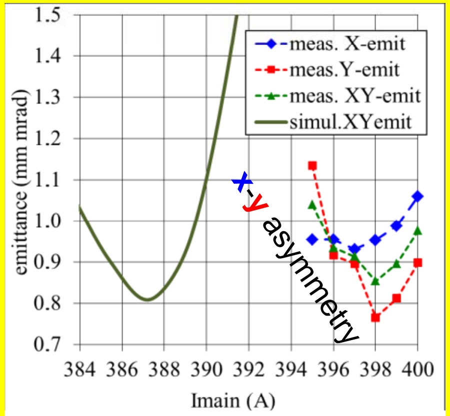
E-beam x-y asymmetry (tails)



Emittance vs. laser XYrms

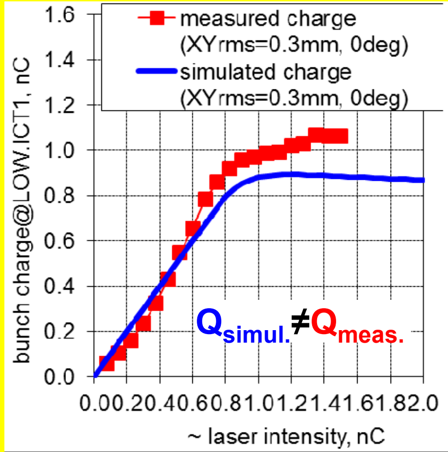


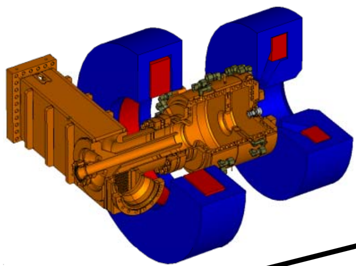
Emittance vs. Imain



Optimum: I_{main}≠→MaxB

Bunch charge vs. laser energy





Originate and characterize the **asymmetry kick**

Larmor angle experiment interpretation

E-beam dynamics **w/o space charge** Main solenoid calibration check

Beam imaging studies

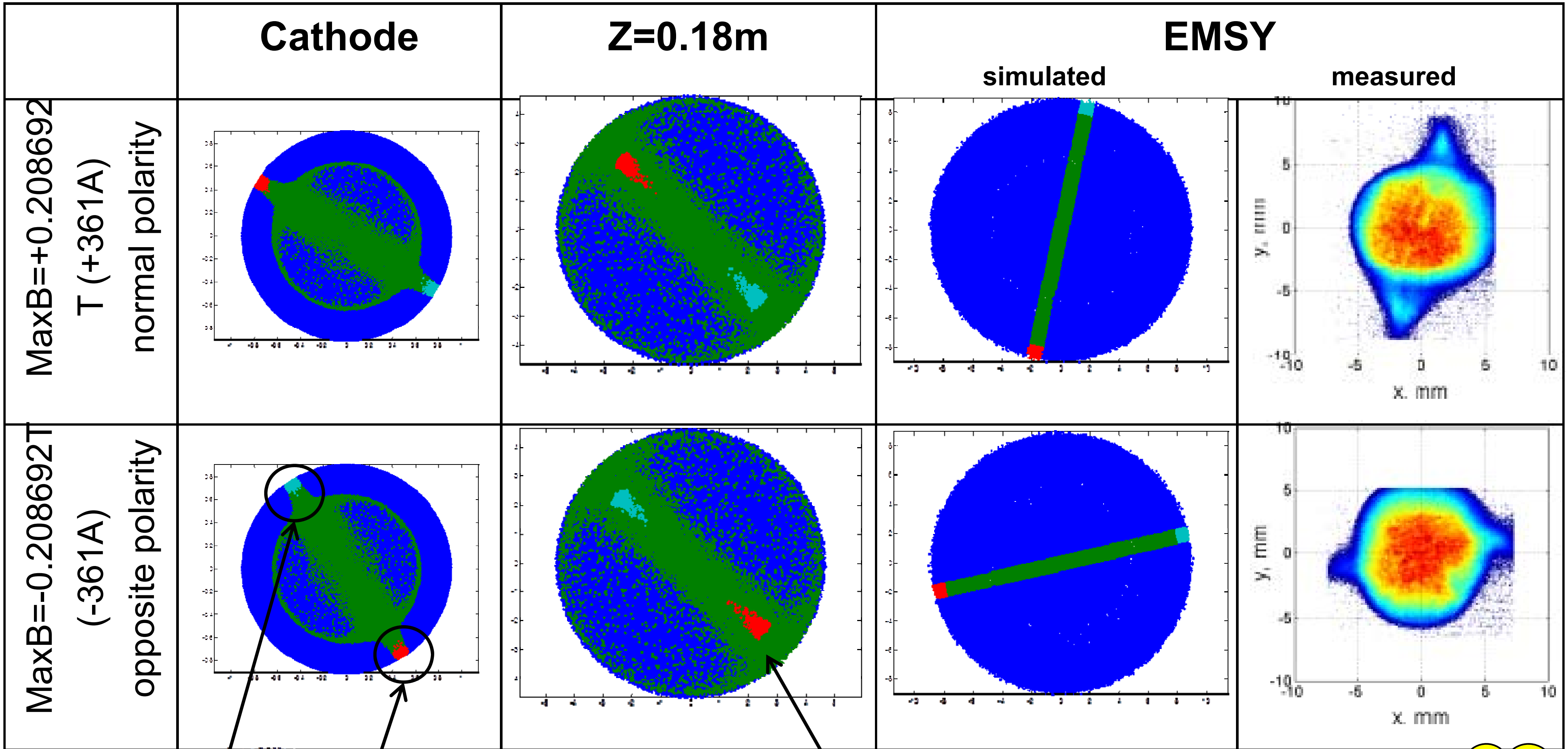
Photoemission studies **space charge!**

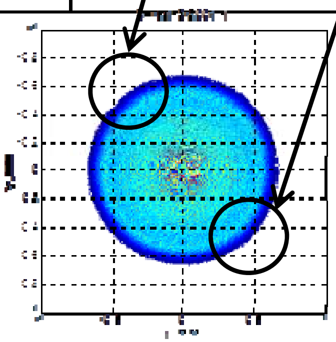
- Core+halo model
- Other mechanisms?

Simulate measured x-y distributions and **transverse phase space** of electron beam and reproduce **optimum machine setup**

Goals:
1. Precise (quantitative) understanding of beam dynamics in a photo injector
2. Reveal a source of the asymmetry kick
3. Try to minimize the kick (?compensating coils?)

Electron beam asymmetry → Larmor angle experiment: ASTRA "tracking back" towards cathode





The edge particles at EMSY coming from the edge of the laser distribution at the cathode

45° Kick at z~0.2 m → skew quadrupole?

Currently: 2 kick sources:
-normal quad from solenoid (polarity dependent)
-skew quad from RF (solenoid polarity independent)

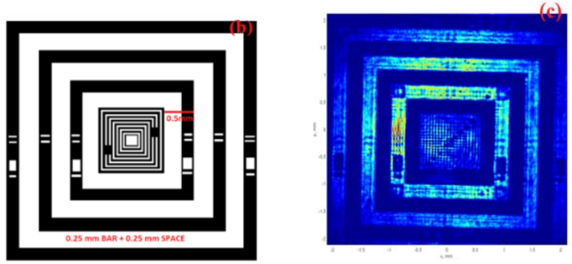
Impact onto the laser BBA?

Main solenoid calibration: Electron beam imaging studies (Q.Zhao)

Main idea: beam dynamics w/o space charge **to confirm** RF gun + solenoid electron optics, e.g. the main solenoid calibration:

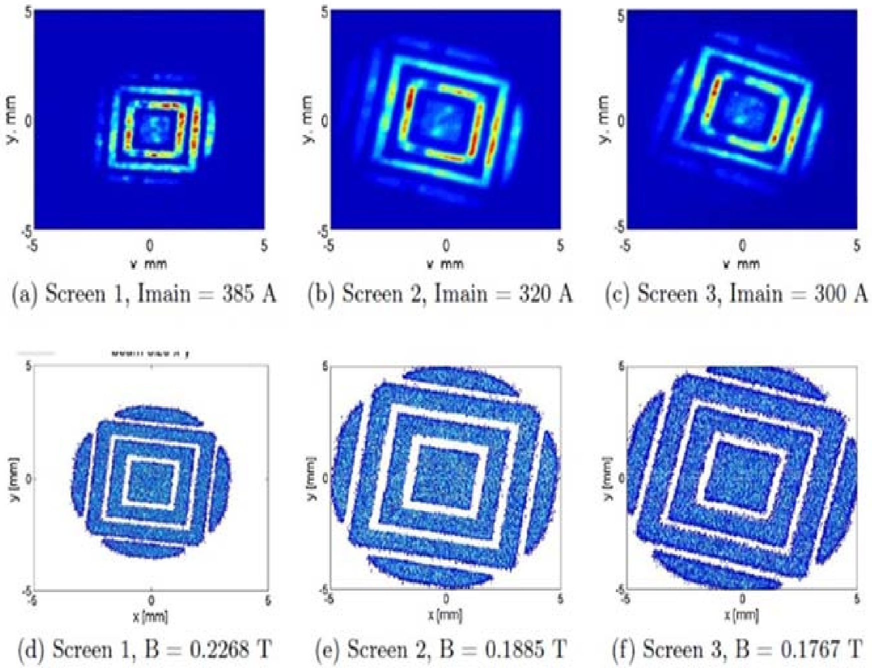
$B_{z,main}$**[T]=5.889×10^{-4}*I_{main}[A]+7.102 ×10^{-5}**

Tools: grid at the BSA location → to be imaged onto the cathode, then electron image at LOW.Scr1,2,3 for various RF peak power level (E_{cath}) by I_{main} tuning.



Grid and laser on VC2.

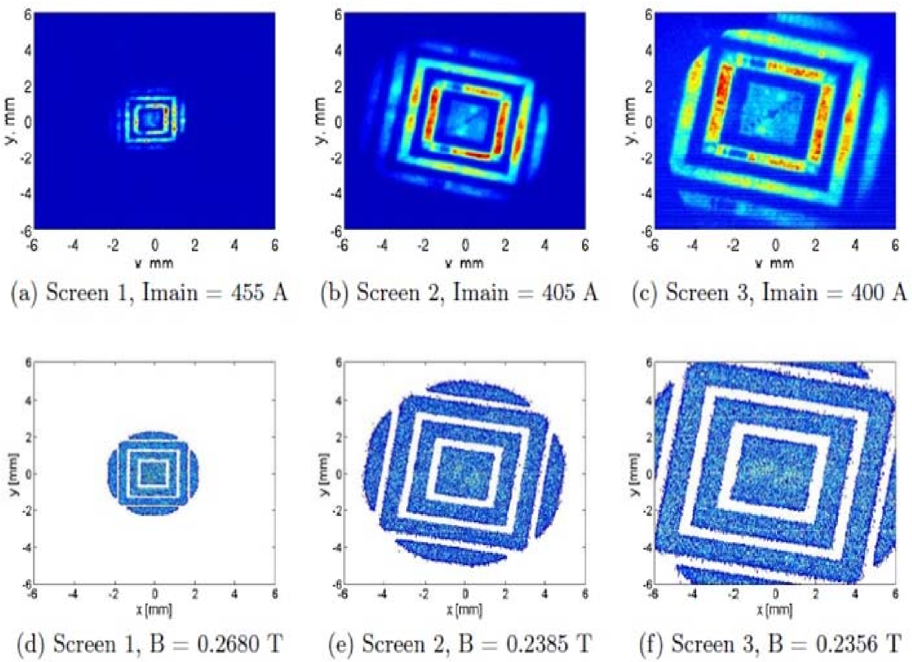
P_{gun}=3MW (42.5MV/m → 4.84MeV/c)



(a) Screen 1, Imain = 385 A (b) Screen 2, Imain = 320 A (c) Screen 3, Imain = 300 A

(d) Screen 1, B = 0.2268 T (e) Screen 2, B = 0.1885 T (f) Screen 3, B = 0.1767 T

P_{gun}=5MW (54.4MV/m → 6.07MeV/c)

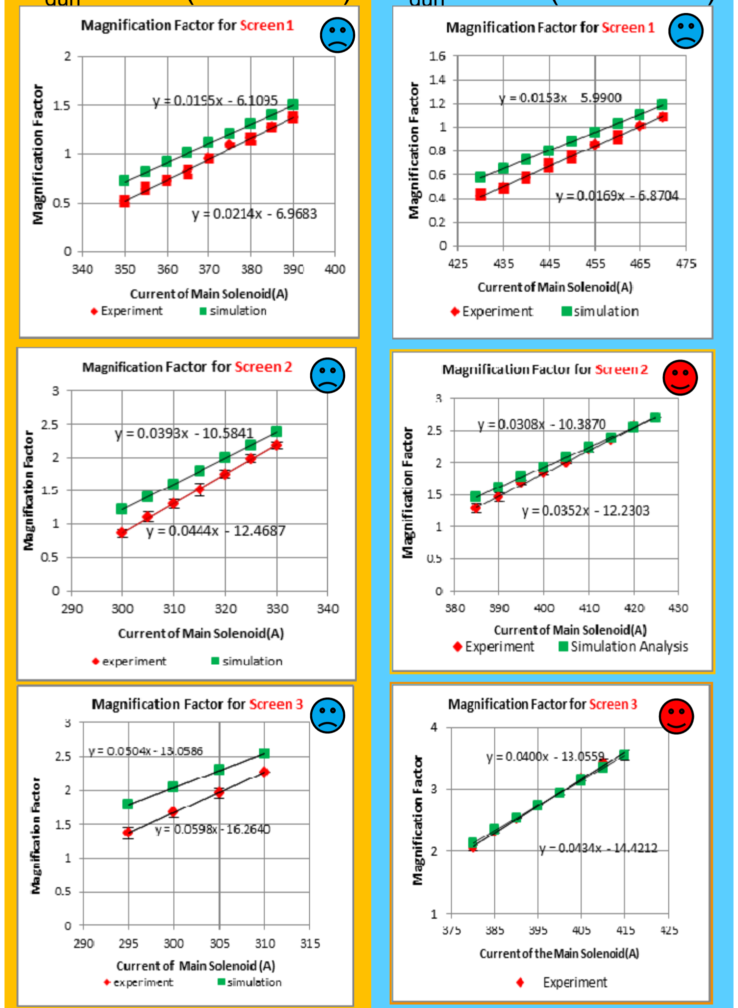


(a) Screen 1, Imain = 455 A (b) Screen 2, Imain = 405 A (c) Screen 3, Imain = 400 A

(d) Screen 1, B = 0.2680 T (e) Screen 2, B = 0.2385 T (f) Screen 3, B = 0.2356 T

E-beam Imaging: Magnification factor and images analysis

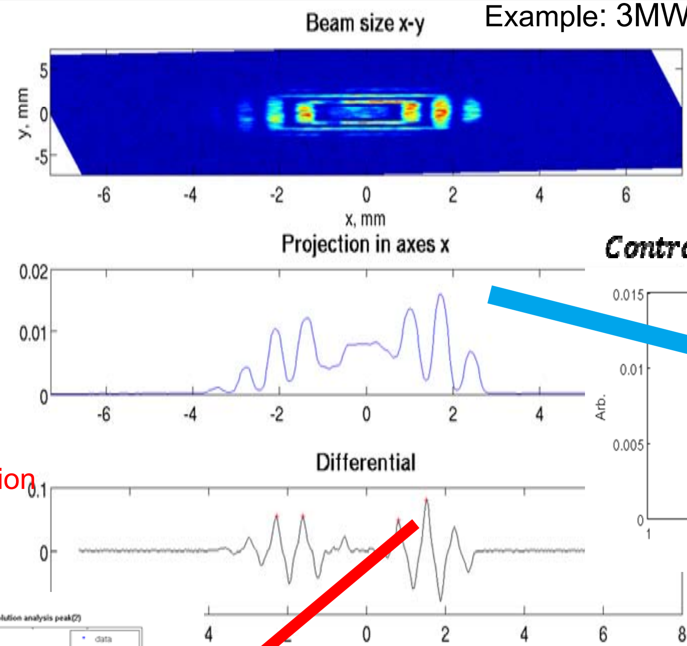
P_{gun}=**3MW** (42.5MV/m) | P_{gun}=**5MW** (54.4MV/m)



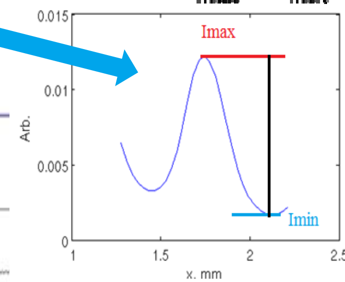
$$MF = \frac{X_{image}}{X_{object}}$$

Images resolution and contrast analysis

Example: 3MW, 390A, scr1



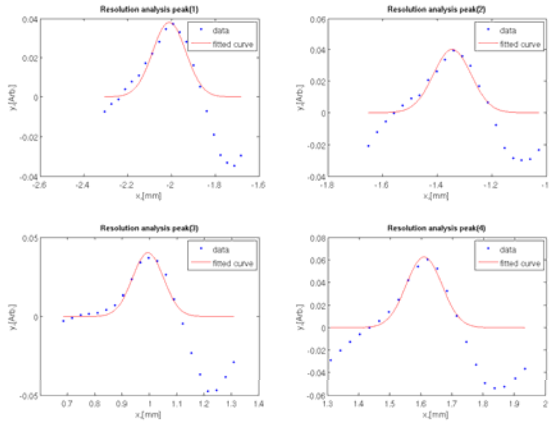
$$Contrast = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$



c ~ resolution

c/MF ---- object plane resolution

$$f(x) = a \exp\left(-\frac{(x-b)^2}{2c^2}\right)$$



- Grid magnification factor from experiment were analyzed and simulated
- The images resolution and contrast from experiment are more precisely analyzed to explain Exp-Sim discrepancy

➔Confirm that the solenoid calibration is correct:*

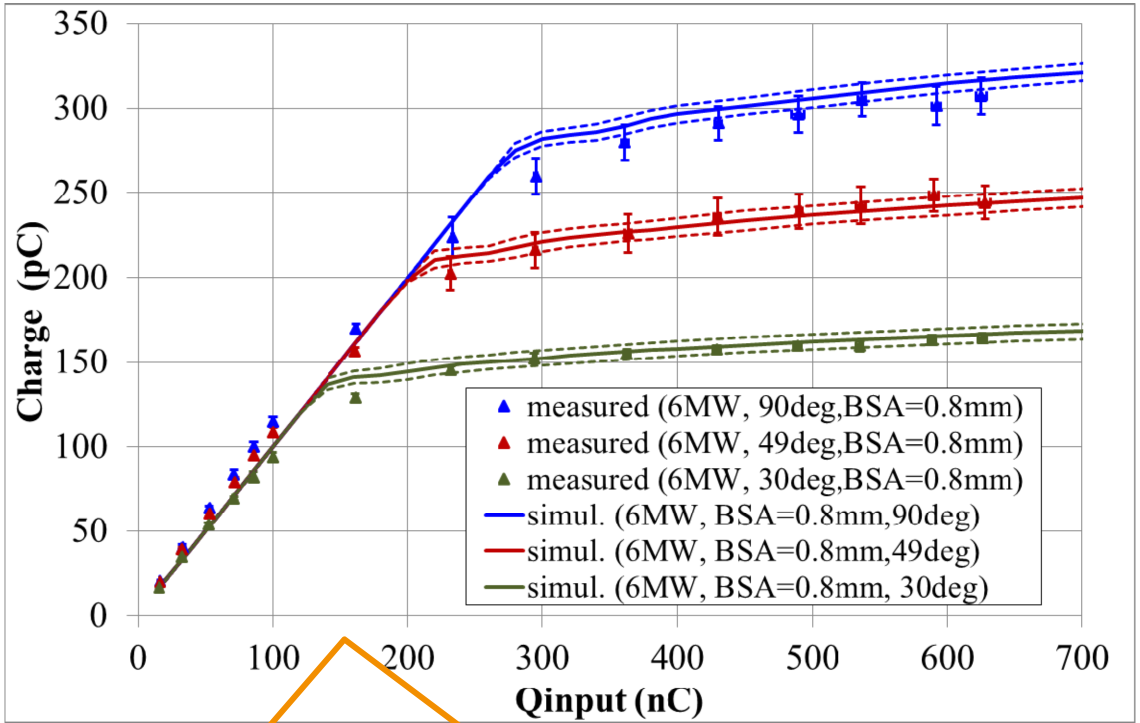
$B_{z,main}$[T]=5.889×10^{-4}*I_{main}[A]+7.102 ×10^{-5}

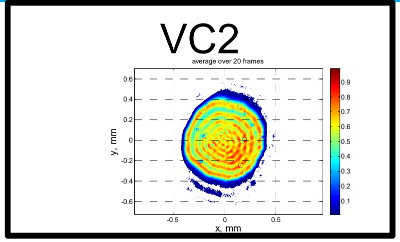
No symmetry distortion (from the kick) observed

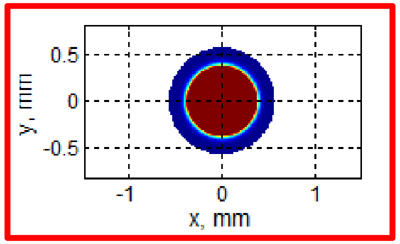
Photo emission studies (October-November 2015)

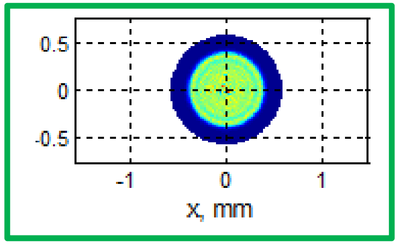
Measurements (1.11.2015M-A):

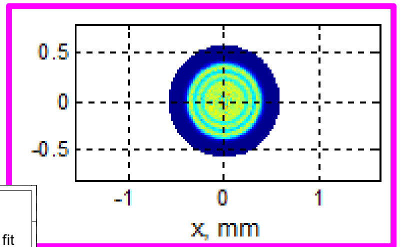
- P_{gun}=6MW (6.68MeV/c max)
- Launch phase 30; 49; 90 deg w.r.t. “0”
- Cathode laser:
  - Short Gaussian 2 ps FWHM (expected)
  - BSA=0.8mm (VC2)
- I_{main}=460; 470; 460A (tuned to focus e-beam)
- Charge measured using LOW.FC1 (z=0.8m)









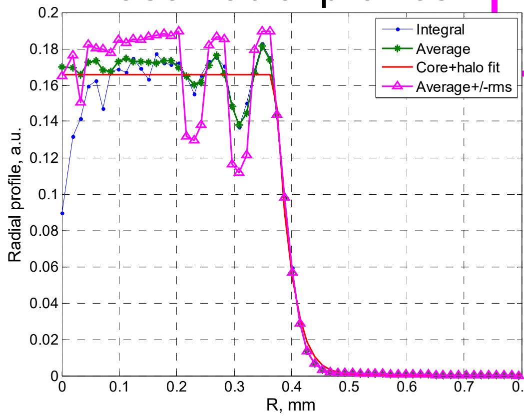


Solid curves = mean (runs4,13,14,17,10)
Dashed curves = min and max (runs4,13,14,17,10)

ASTRA Simulations for uncertainty estimation

<table>
<tr><th>Run</th><th>σ_t (ps)</th><th>Ecath (MV/m)</th><th>ΔΦ (deg) phase</th><th>Radial profile: XX-core + Gaussian halo</th></tr>
<tr><td>4</td><td rowspan="5">0.85</td><td rowspan="4">59.569</td><td>0</td><td>Flattop core</td></tr>
<tr><td>13</td><td>-1</td><td>Average core</td></tr>
<tr><td>14</td><td>0</td><td rowspan="2">Average core ± σ_ϕ</td></tr>
<tr><td>17</td><td>-1</td></tr>
<tr><td>10</td><td>58</td><td>-1</td><td>Flattop core</td></tr>
</table>

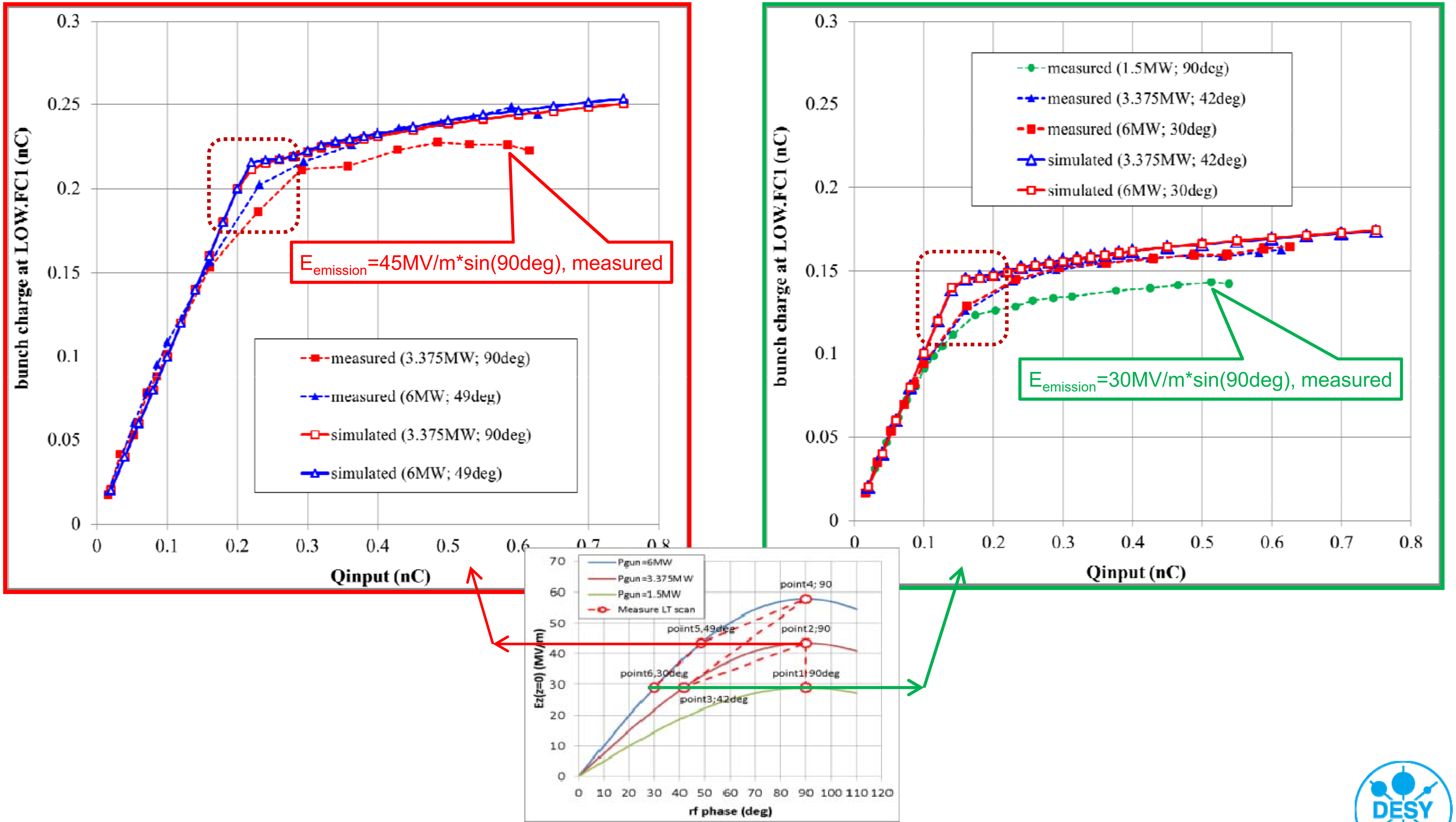
Laser radial profiles



Update on photo emission studies: 90 deg phase

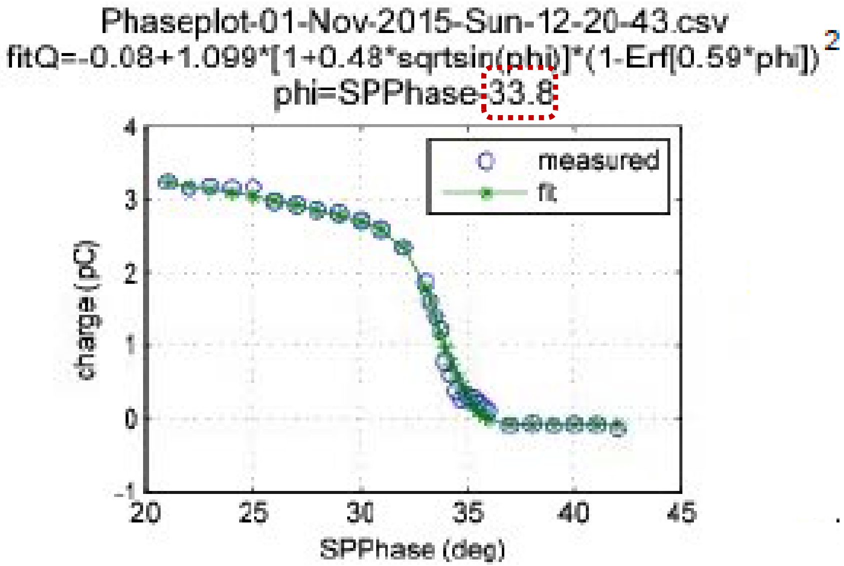
Measured charge for 90deg w.r.t zero-crossing phase (short 2ps FWHM Gaussian pulses, BSA=0.8mm):

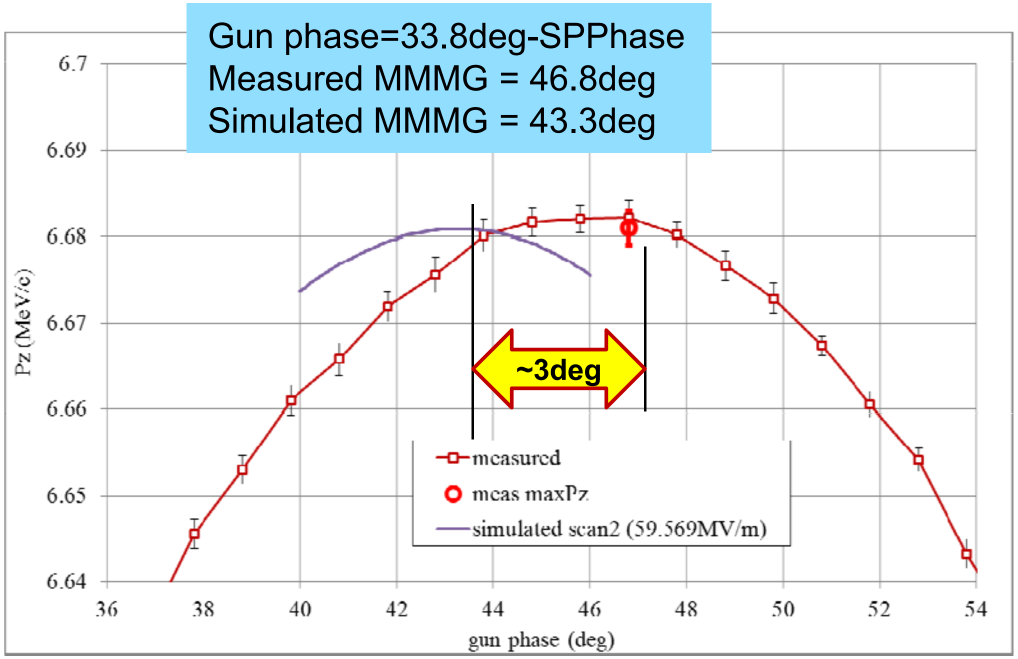
- systematically lower than corresponding simulations (especially at QE→SC transition)
- systematically lower than the charge measured at lower phases (30, 49deg) with higher gradients (E_{cath}), but same $E_{emission}$

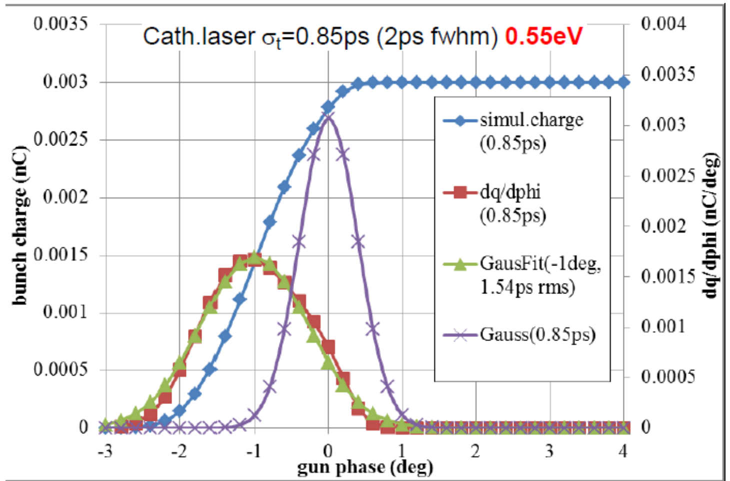


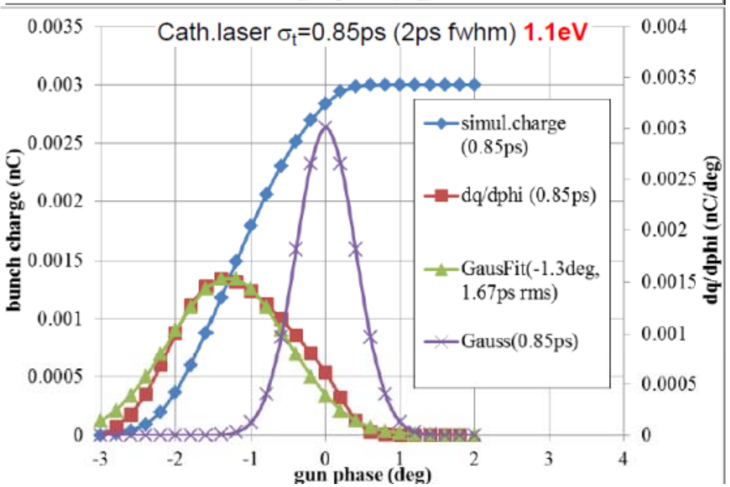
Update on photo emission studies: zero-crossing phase

Still not understood: Zero-crossing phase ←→ MMMG phase ➔ 2-3 deg phase shift between measurements and simulations









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

δE-program at PITZ (new)

Idea: establish δE measurements (best resolution and flexibility) and measure δE for various conditions (temporal profiles, SC effect, etc.)

Motivation from DESY-HH:

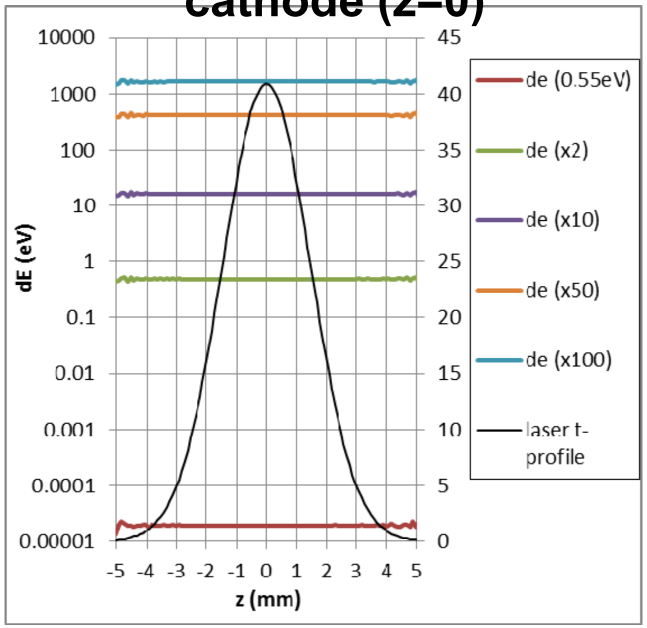
- Initial δE for micro-bunching instability studies (M. Dohlus)

Motivation from PITZ:

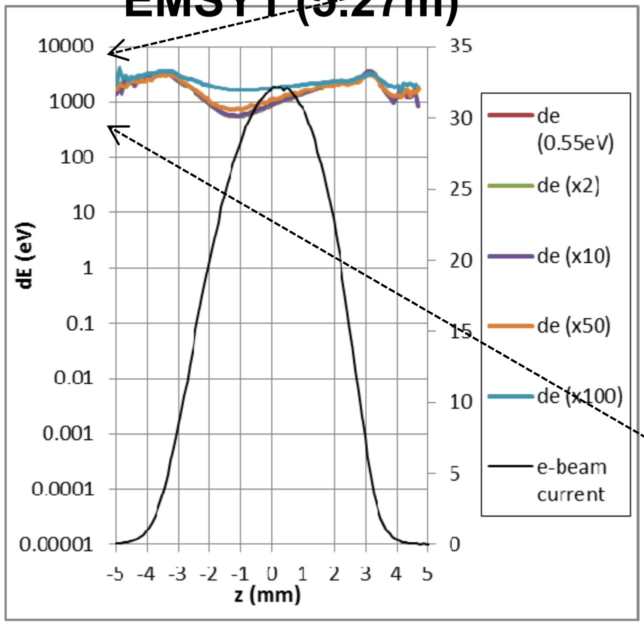
- Measurements vs. simulations
- Improve measured σE (projected) understanding
- ?Detailed emission modeling (e.g. zero-crossing phase)

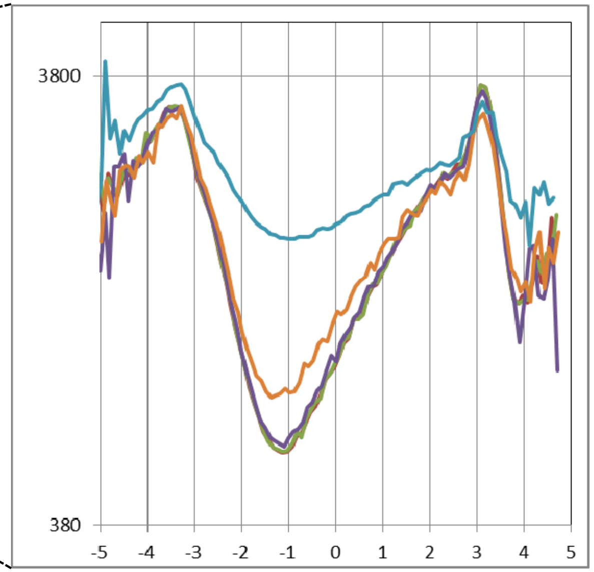
ASTRA simulations with "Pz-heater" at cathode

cathode (z=0)



EMSY1 (5.27m)





Summary and Conclusions

> E-beam asymmetry:
  - The experiment on Larmor angle:
    → **skew quad** (→RF) kick at z~0.18m
    → normal quad (→ solenoid) kick at z~0.34m

> Beam imaging studies:
  - Main **solenoid calibration** + RF field dynamics ~> seems to be OK, but still more investigations are to be done

> Photo emission:
  - **Core+halo** model of the laser transverse distribution → better agreement in bunch charge vs. laser pulse energy. But not much improved discrepancy in measured-to-simulated phase spaces and optimum machine setup
  - Still to be understood:
    → measured curves $Q(E_{laser})$ for 90 deg w.r.t. "0"
    → "0"-phase determination

> δE-program at PITZ

Beam Imperfection Studies project

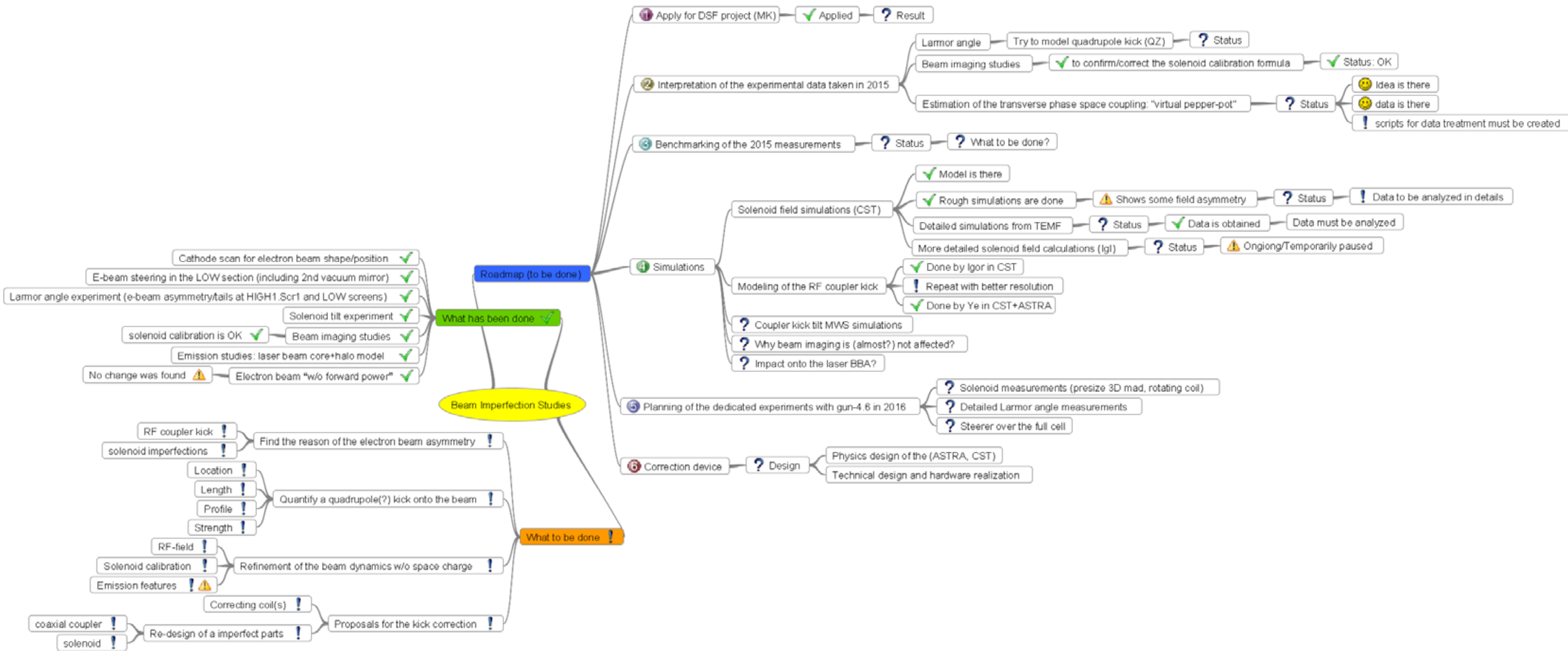


Photo injector setups for emission studies

Setup	BSA diameter (mm)	Laser temporal profile	Laser pulse length FWHM (ps)	Gun RF power (MW)	Gun RF Phase (deg)	$E_{cathode}$ at moment of emission (MV/m)
1	1.2	Gaussian	2.7	4.000	MMMG	29
2	1.2	Gaussian	2.7	7.750	MMMG	45
3	1.2	Flattop	17.0	4.000	MMMG	29
4	1.2	Flattop	17.0	7.750	MMMG	45
5	0.8	Gaussian	3.5	1.500	90	29
6	0.8	Gaussian	3.5	3.375	90	43.5
7	0.8	Gaussian	3.5	6.000	90	58
8	0.8	Gaussian	2.0	6.000	90	58
9	0.8	Gaussian	2.0	6.000	49	43.5
10	0.8	Gaussian	2.0	6.000	30	29

Studies on charge production from Cs_2Te photocathodes in the PITZ L-band normal conducting radio frequency photo injector
C. Hernandez-Garcia, M. Kraslinikov, G. Asova, M. Bakr, P. Boonpornprasert, J. Good, M. Gross, H. Huck, I. Isaev, D. Kalantaryan, M. Khojoyan, G. Kourkafas, O. Lishilin, D. Malyutin, D. Melkumyan, A. Oppelt, M. Otevrel, G. Pathak, Y. Renier, T. Rublack, F. Stephan, G. Vashchenko, and Q. Zhao