Summary of emission studies at PITZ

Ji LI
PITZ
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HELMHOLTZ
ASSOCIATION

PITZ
Photo Injector Test Facility
Zeuthen

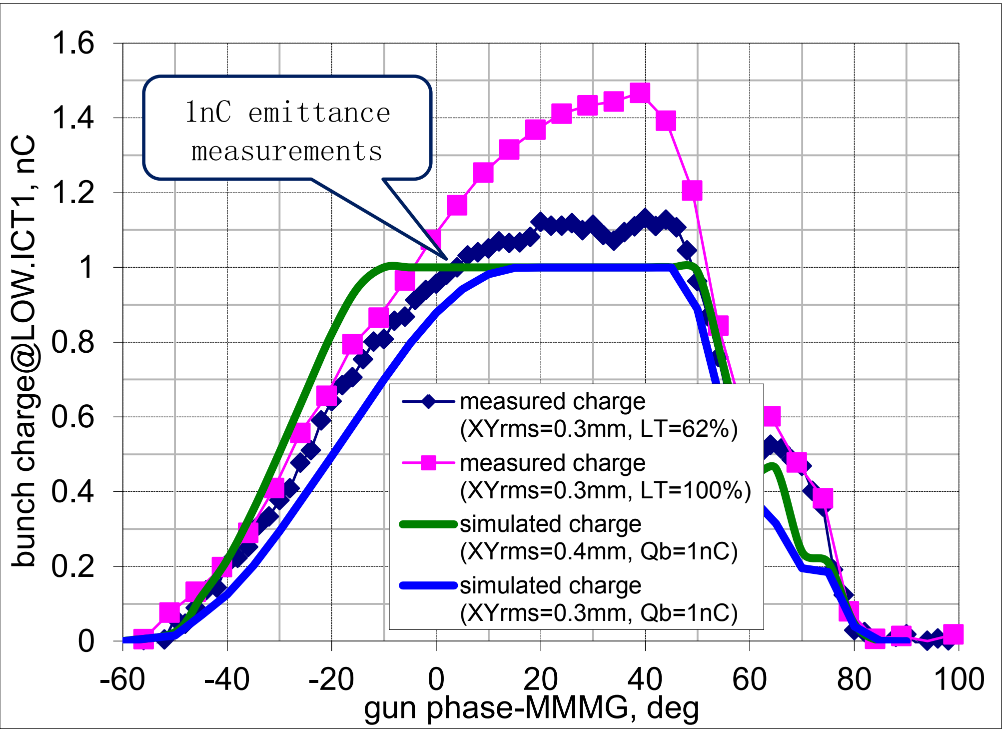
DESY

Content

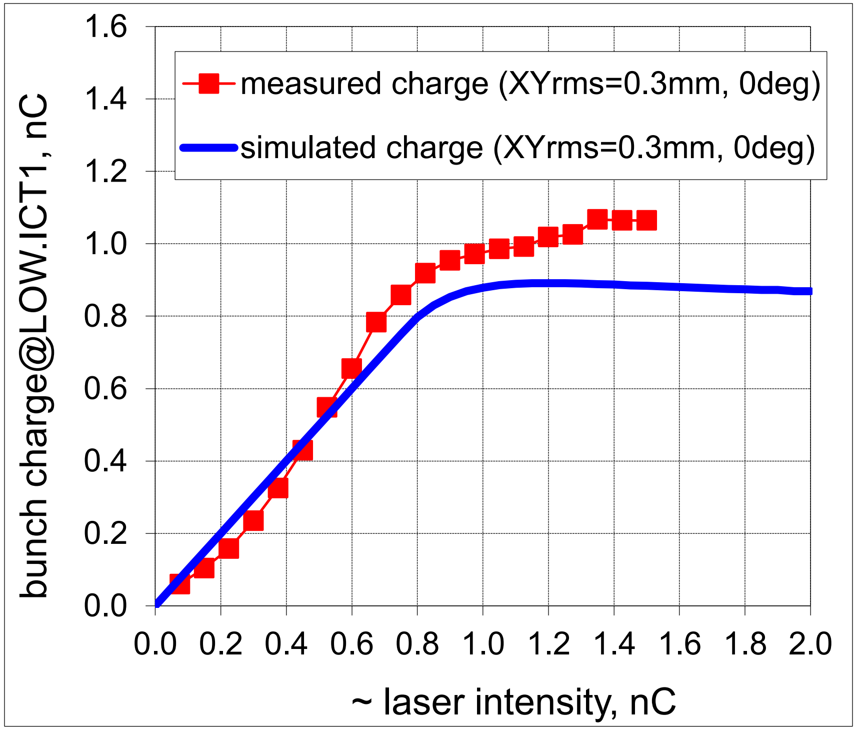
- Background and motivation
- PARMELA simulation with Schottky-like effect
- Analysis and conclusion
- Notes and suggestions

Discrepancy for High Q (M. Krasilnikov, J.F.Castanon)

Measured and simulated Schottky scans (1nC)



Measured and simulated laser energy scan (1nC)



- Direct plug-un machine settings into ASTRA does not produce 1nC at the gun operation phase (+6deg), whereas 1nC and even higher charge (~1.2nC) are experimentally detected
- Simulated (ASTRA) phase scans w/o Schottky effects (solid thick lines) have different shapes than the experimentally measured (thin lines with markers)

- Laser intensity (LT) scan for the MMMG phase (red curve with markers) shows higher saturation level, whereas the simulated charge even goes slightly down while the laser intensity (Qbunch) increases

Possible reason

> Field enhancement of photo emission:

- Schottky effect
  - The Schottky effect describes the lowering of the work function or potential barrier of a metal by external electric field
  - It leads to an increased electron emission from cathode
- Schottky-like effect
  - Semiconductor cathode: Cs_2Te

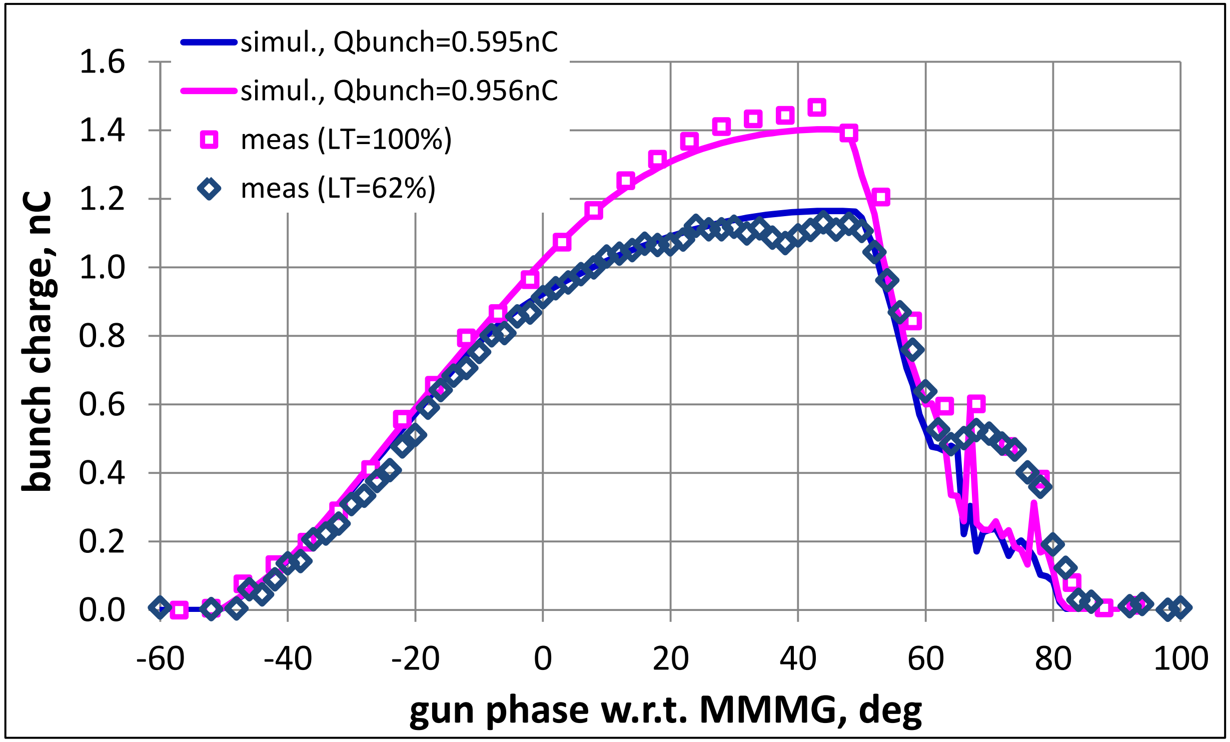
> Description of photoelectron current : $J = \alpha I(h\upsilon - \phi + b\sqrt{\beta E})^2$ (1)

- Parameters:
  - J: total electron current density
  - hv: photo energy
  - I : laser intensity
  - Φ: work funtion
  - α : constant related to the material propties ; β: field enhancement factor
  - b: $b = \sqrt{(e/4\pi\varepsilon_0)}$

Simulated bunch charge for XYrms=0.32 mm with ASTRA

$$Q = Q_0 + Srt\_Q\_Schottky \cdot \sqrt{E} + Q\_Schottky \cdot E \qquad (2)$$

Using XYrms=0.30mm it was not possible to produce measured charges for any combination (*Q0;Srt_Q_Schottky;Q_Schottky*) ➔ light increase of laser spot size? (e.g. from 0.30 mm to 0.32 mm rms)



ASTRA simulations:

- Ecath=60.58MV/m
- Meas. Phase →+8 deg (not +6deg!)
- Laser XYrms=0.32mm (not 0.3mm!)
- Qbunch(62%)=0.595nC; Q_Schottky=0.01nC; SRT_Q_Schottky=0.05nC

Simulation with PARMELA

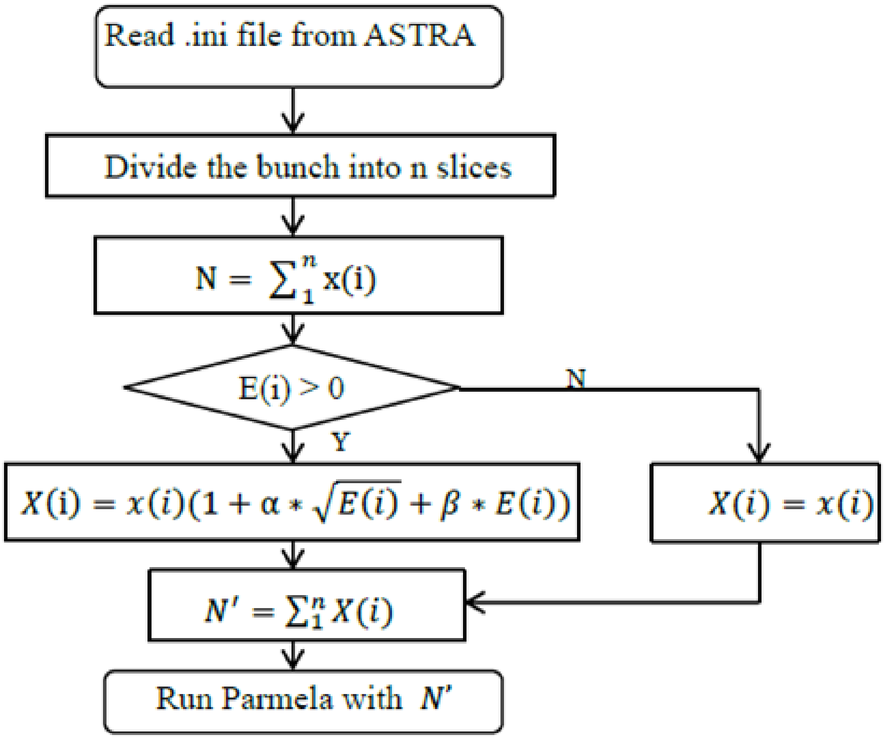
> PARMELA code:

- Widely used in linac design and dynamic analysis
- Field distribution for PARMELA
  - 2D or 3D field maps generated from electromagnetic calculation code.
  - The field distribution for ASTRA is the field on the axis.
- No Schottky (or Schottky-like) effect feature
  - MATLAB scripts are used to add this feature

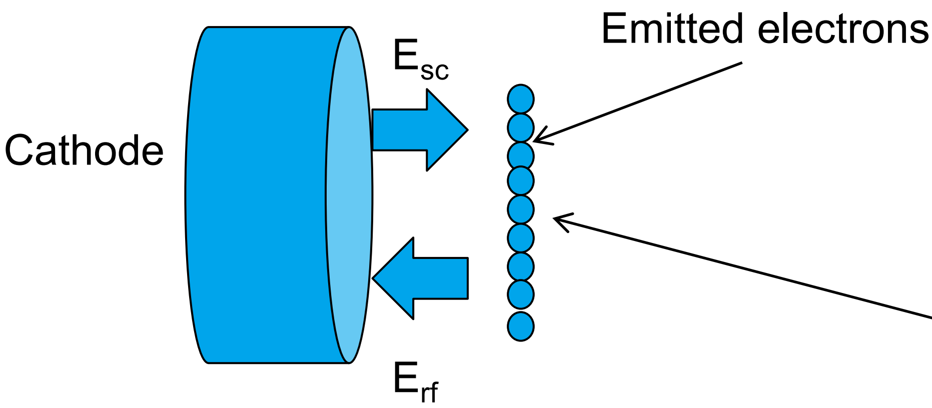
MATLAB scripts:

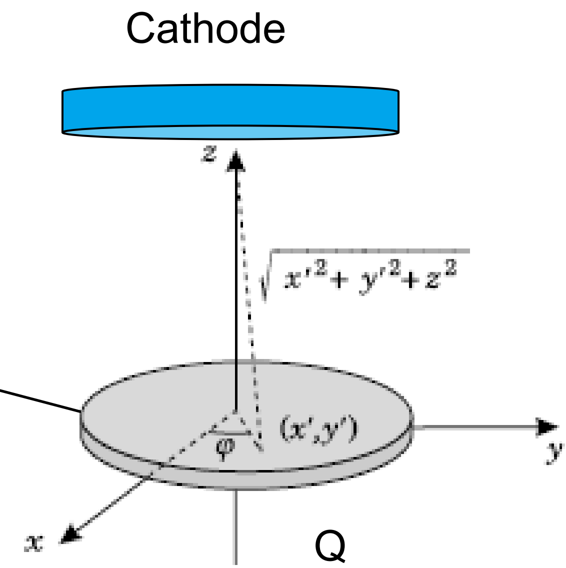
$$Q = Q_0 + \partial \cdot \sqrt{E} + \beta \cdot E \qquad (4)$$

E(i): the strength of field on cathode when the i_th slice emitting from the cathode.
N : the total number of slices in the bunch.
x(i) : the number of marcoparticles of each slice.
X(i): the number of marcoparticles of each slice considering the Schottky-like effect.
N' : the total number of the initial bunch considering the Schottky-like effect.



Estimation of electric field on the cathode





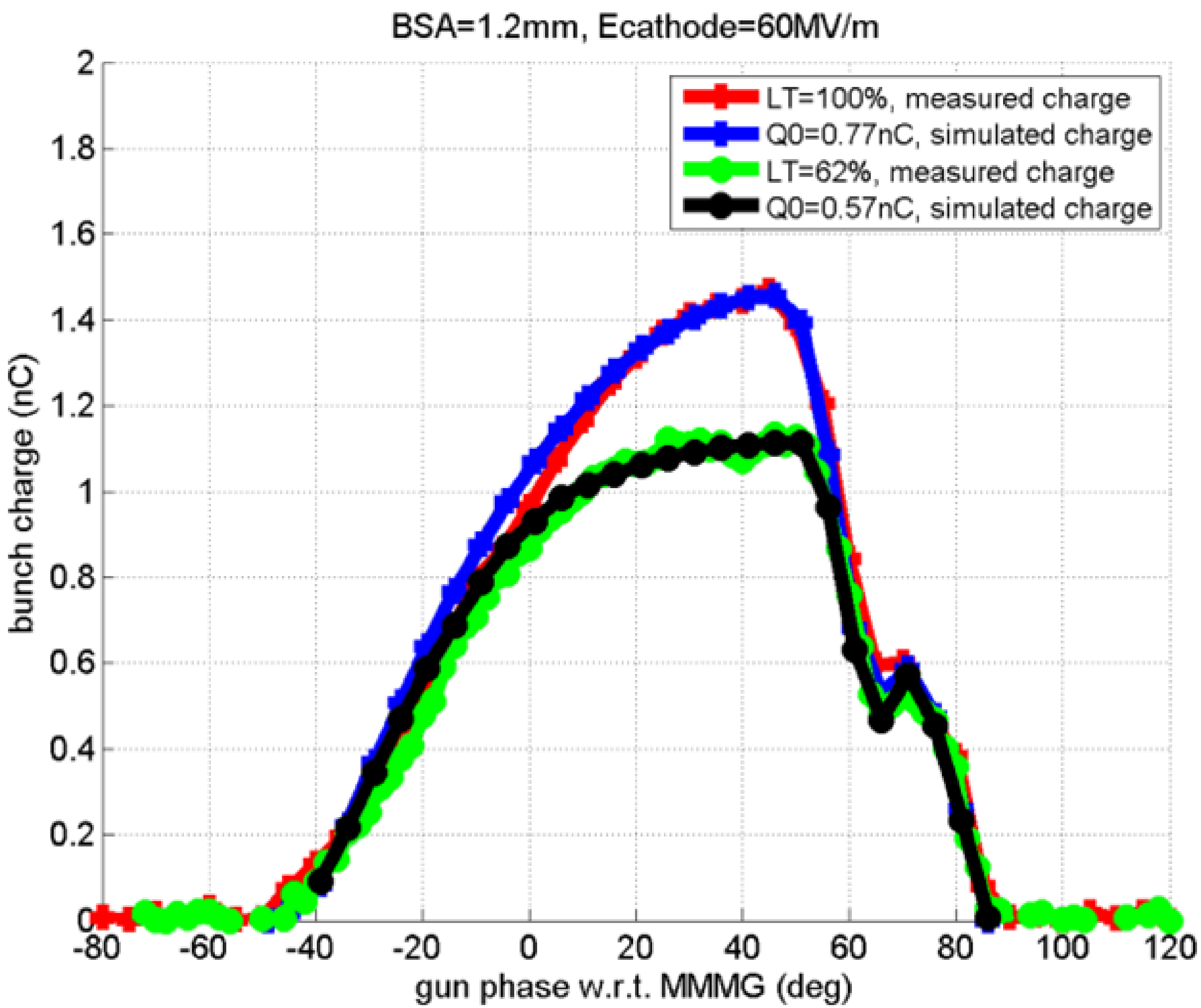
$$E = E_{rf} - Esc \qquad (5)$$

$$E_{rf} = E_0 \sin(\omega t + \varphi_0) = E_0 \sin(\varphi_{rf}) \qquad (6)$$

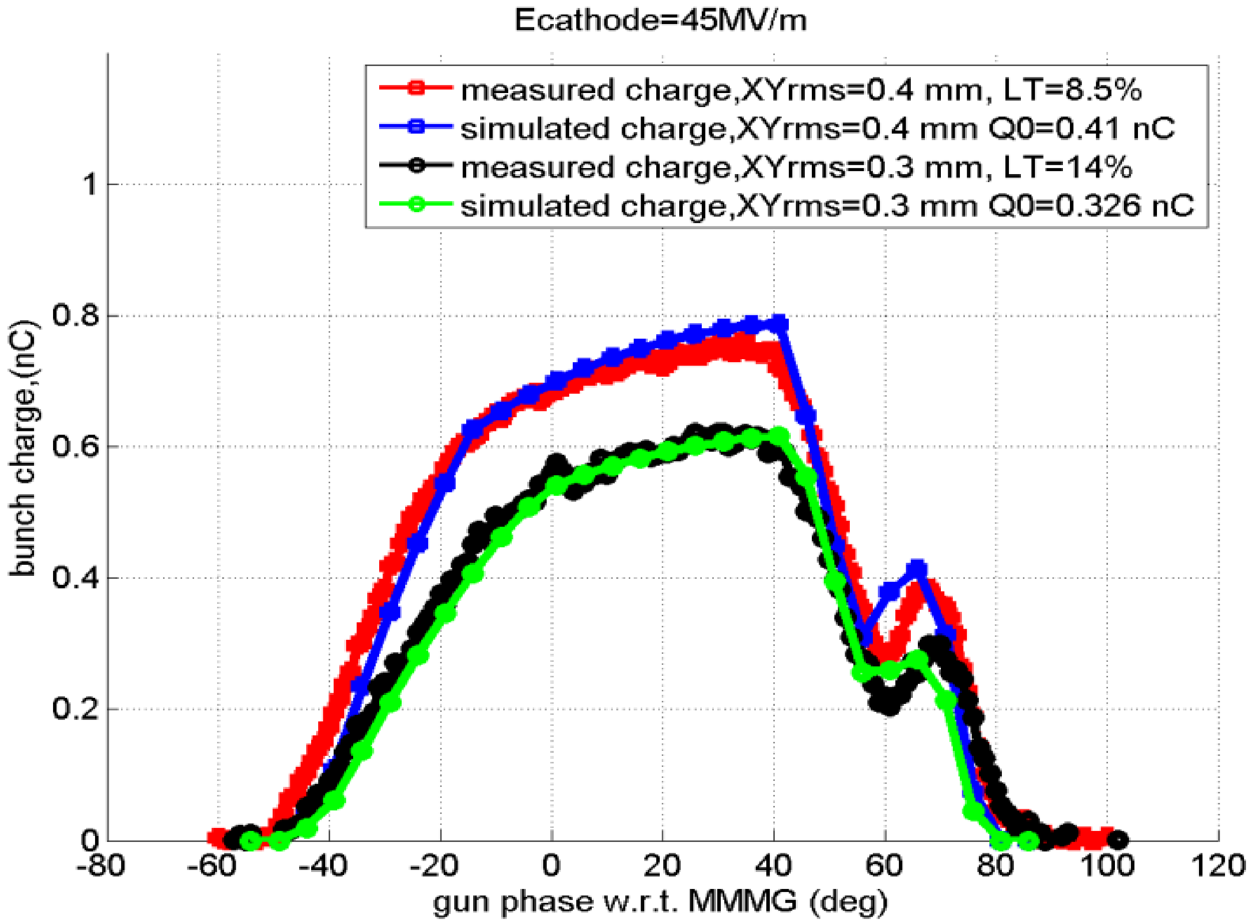
$$E_{sc}(i) = E_{Q-emitted} \qquad (7)$$

$$E_Q = \frac{Q}{2\pi\varepsilon_0 R^2}\left(1 - \frac{z}{\sqrt{R^2 + z^2}}\right) \qquad (8)$$

60MV,BSA=1.2mm



45MV

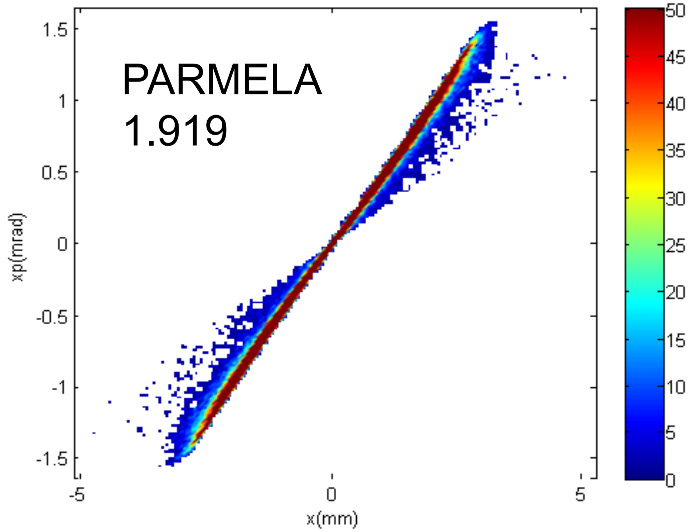


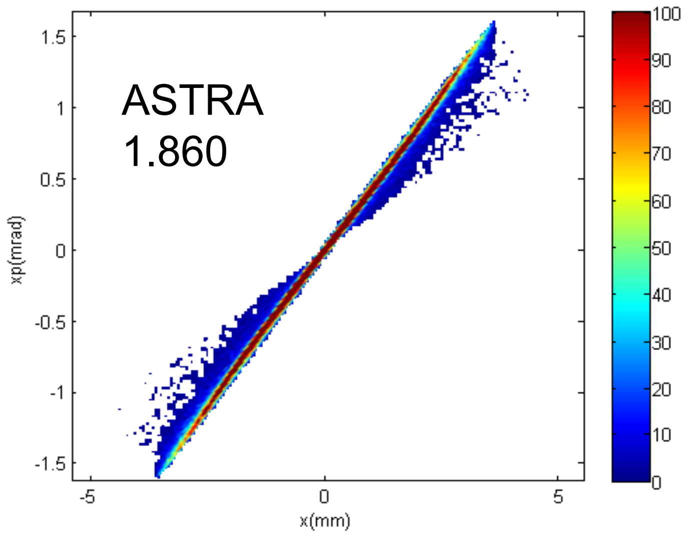
Ecathode=45MV/m
measured charge,XYrms=0.4 mm, LT=8.5%
simulated charge,XYrms=0.4 mm Q0=0.41 nC
measured charge,XYrms=0.3 mm, LT=14%
simulated charge,XYrms=0.3 mm Q0=0.326 nC
bunch charge,(nC)
gun phase w.r.t. MMMG (deg)
0
0.2
0.4
0.6
0.8
1
-80
-60
-40
-20
0
20
40
60
80
100
120

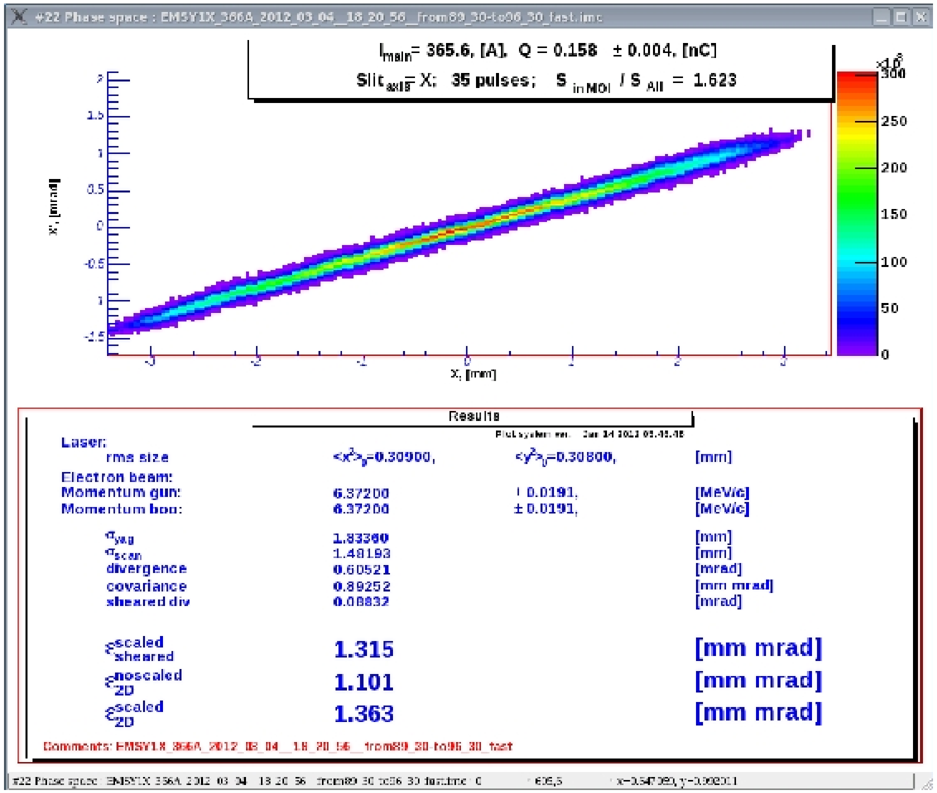
Conclusion:

- PARMELA can be applied to emission studies with MATLAB
- The simulation results fit to measured data well.
- Eq.1 , Eq.2, Eq3 can be used to explain the discrepancy for High Q.

Comparison of phase spaces at EMSY1,158pC







Notes for PARMELA

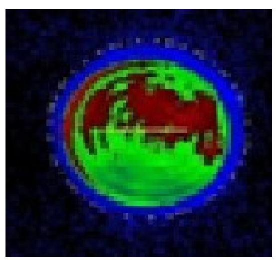
> The difference between setting phase and real rf phase

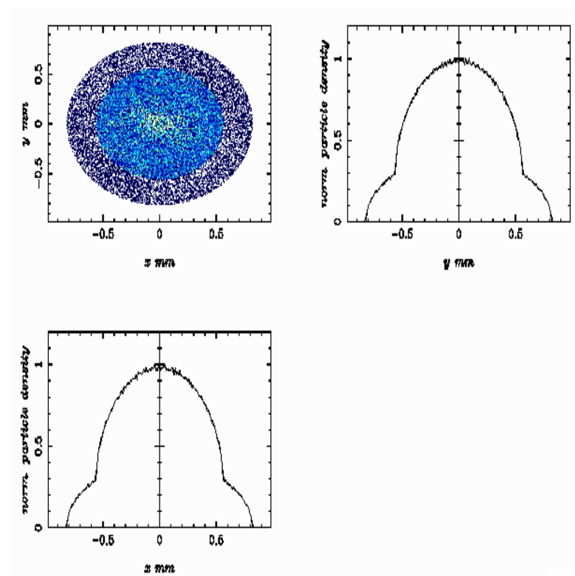
- Compared with the results form ASTRA, one phase scan or simulation at proper phase without Schottky-effect should be run to find the difference
- The difference will be considered for the calculation of increased electron emission due to Schottky-like effect.

Notes for PARMELA

> Accurate model of initial distribution with halo

- Modeling the initial bunch distribution with halo by combining ***input 9*** lines with different transverse sizes

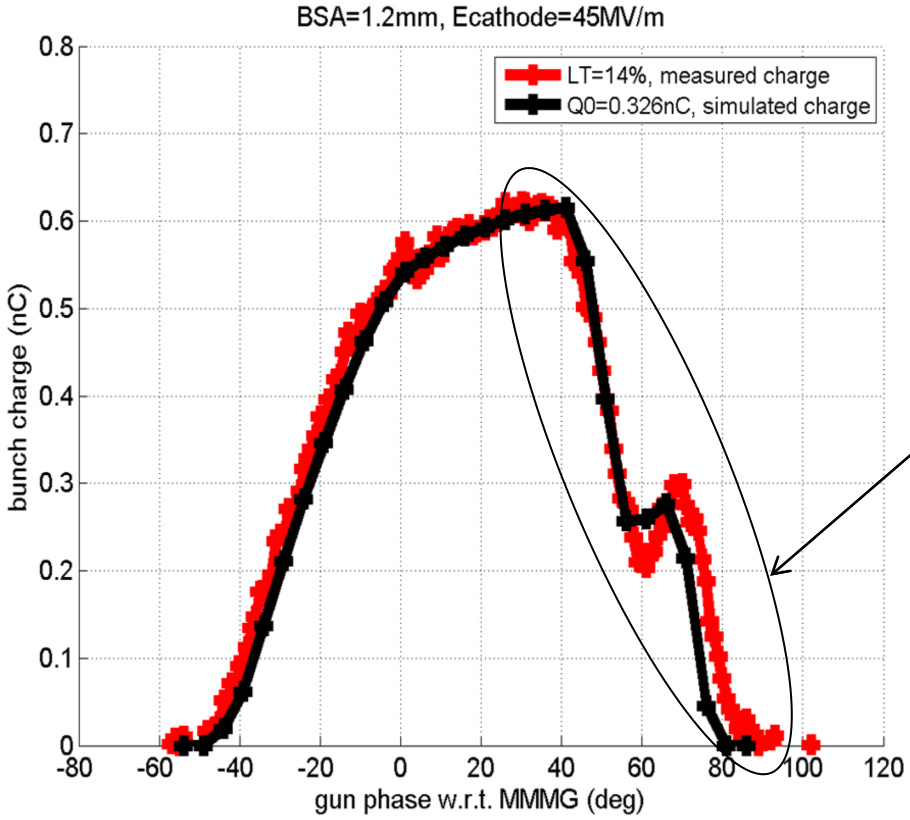




Suggestions for measurement

> To check which device was used in the phase scans

- FC1 @ 0.803m
- LOW ICT1 @ 0.903m



Position of device is important for this part.

Suggestions for PARMELA

> To analyze the distribution of laser spot on the photocathode

- A script to display the density of laser current.

Thank you for your attention!

Acknowledgment and best wishes to all colleagues in PITZ group!