A new Electron Source for the ANKA Injector

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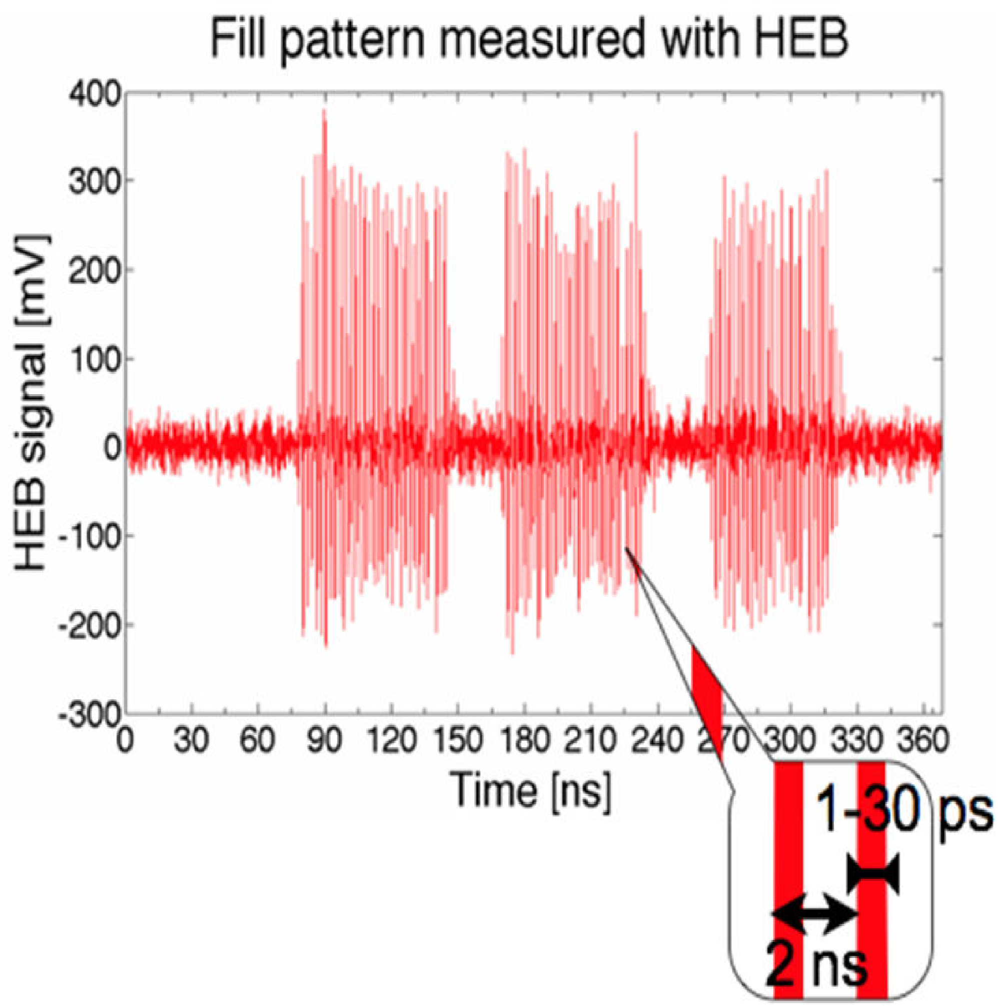
Outline

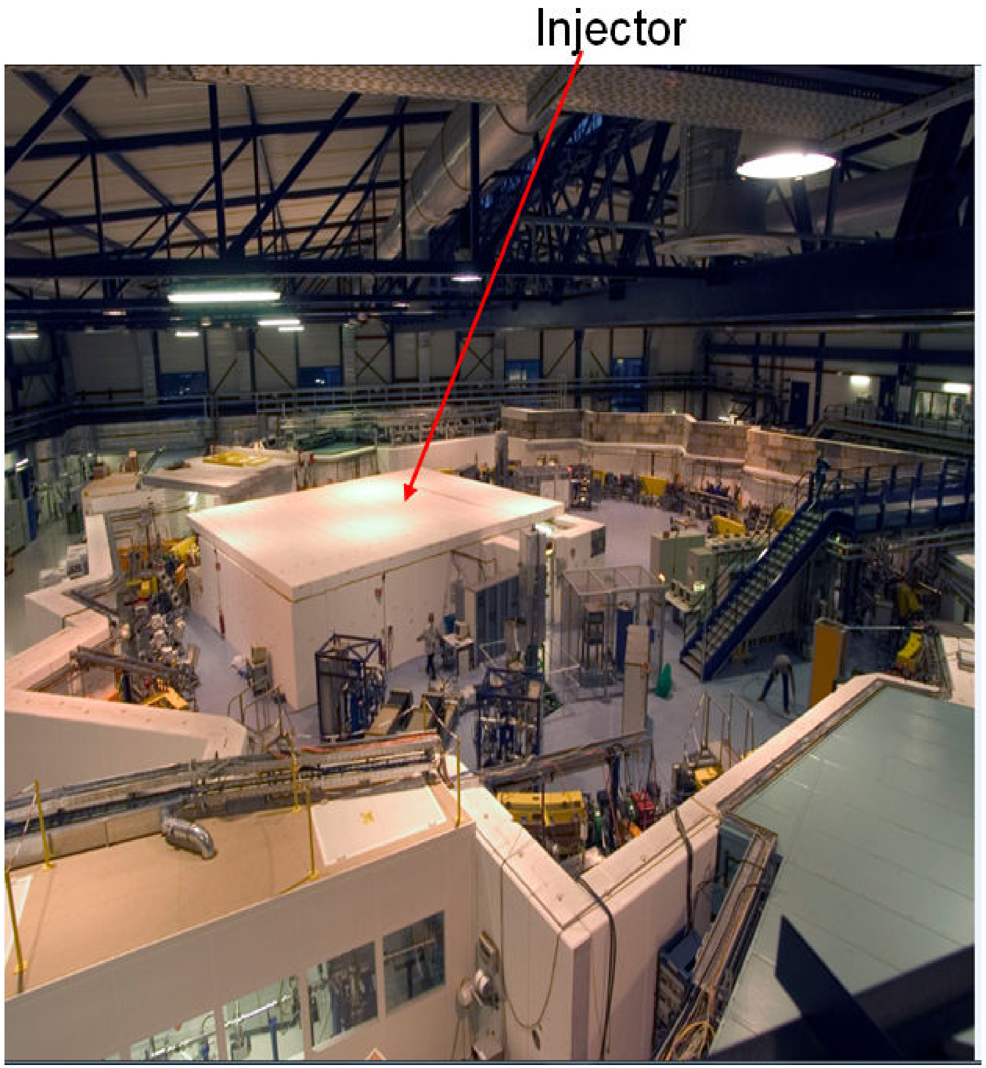
- Introduction
- The new electron source for ANKA
- Emittance measurement
- Summery and Outlook

Bunches and Trains



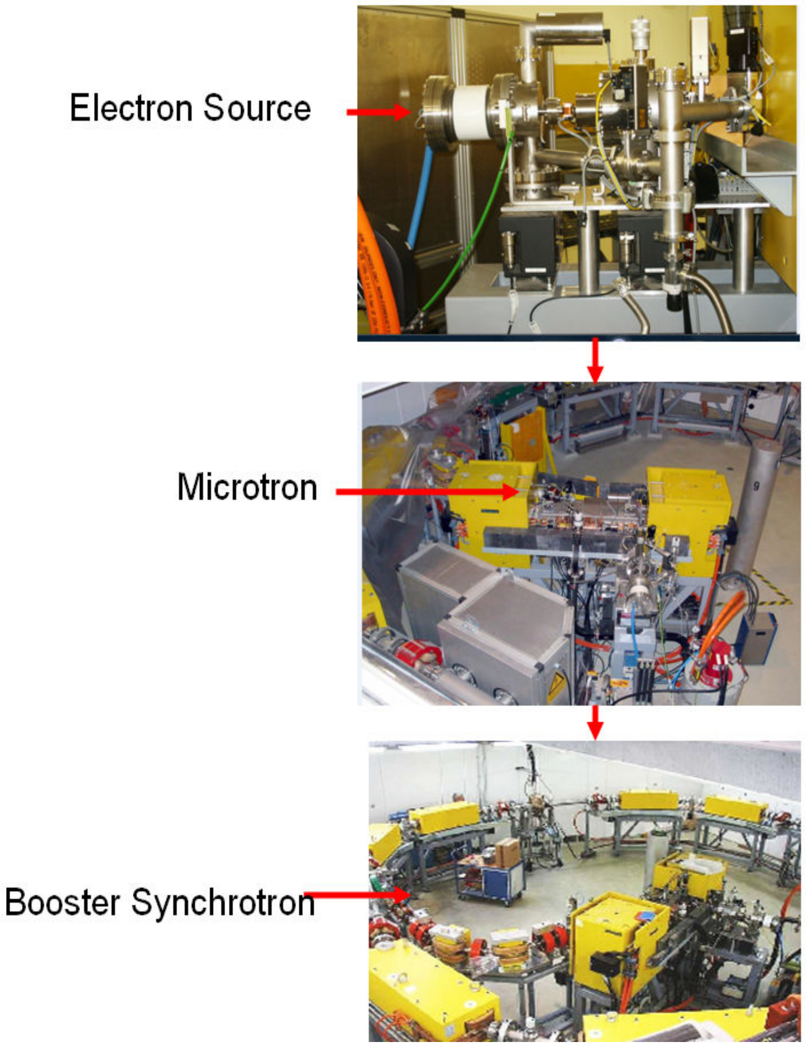
- Electrons are distributed in the form of trains of bunches
- Charges within bunch or between bunches can interact through synchrotron radiation or other collective effects
- To isolate multi bunch effects, single bunch is needed

ANKA Storage Ring



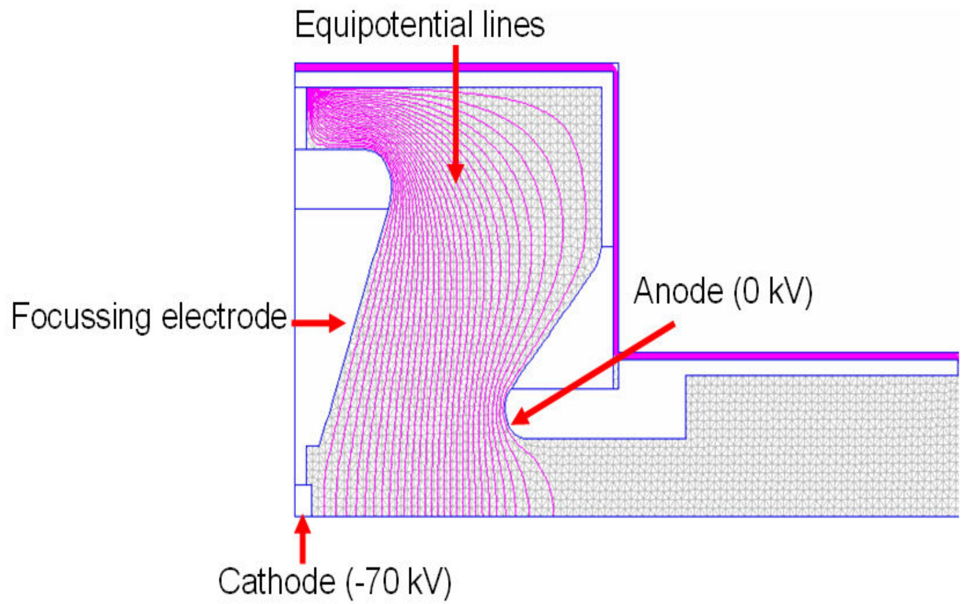
- **Circumference** **110.4 m**
- **Energy:** **2.5 GeV**
- **RF Frequency:** **500 MHz**
- **Current:** **150 mA**
- **Trains:** **maximum 3**
- **Bunches per train:** **32 to 34**

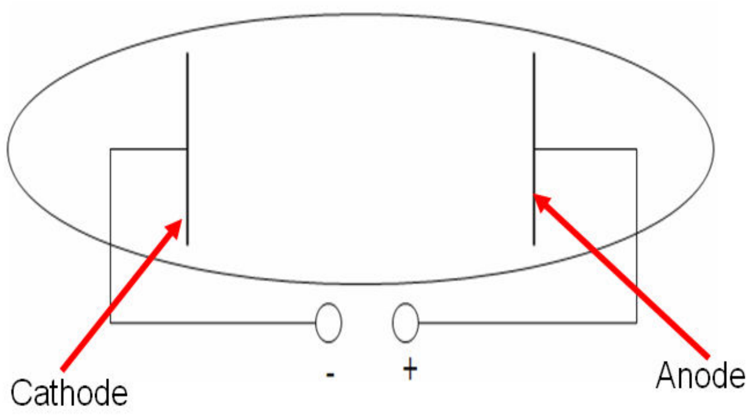
Previous ANKA Injector



- Electron Source delivers electrons with an energy of 70 keV
- Acceleration of the electrons to 53 MeV in the microtron
- The energy is increase to 500 MeV in the booster synchrotron
- Injection into the storage ring, where the energy is increased to the final state

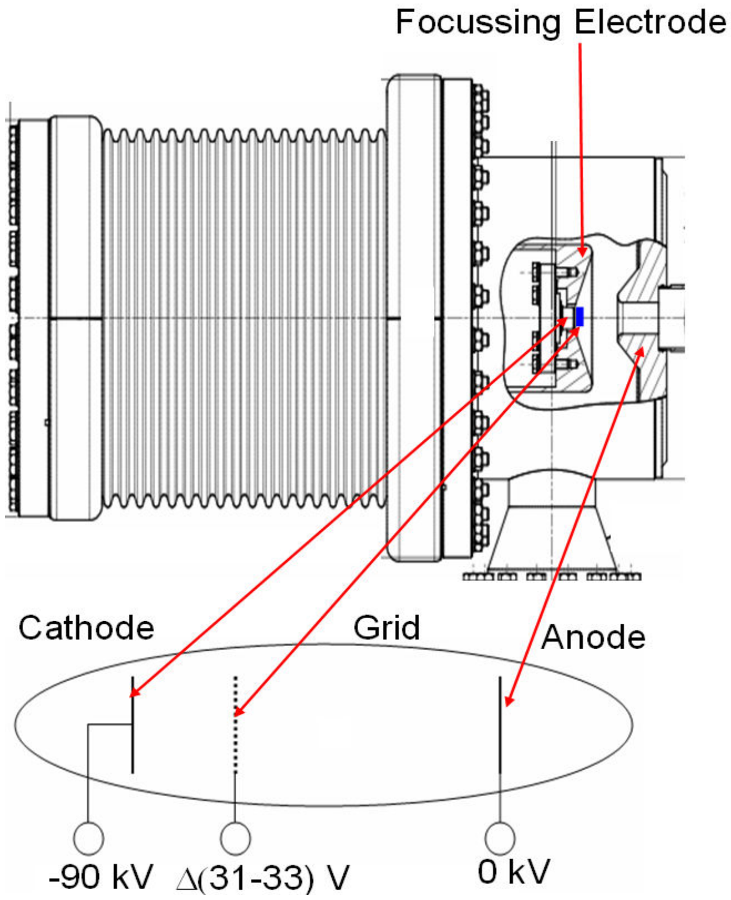
Previous electron source at ANKA





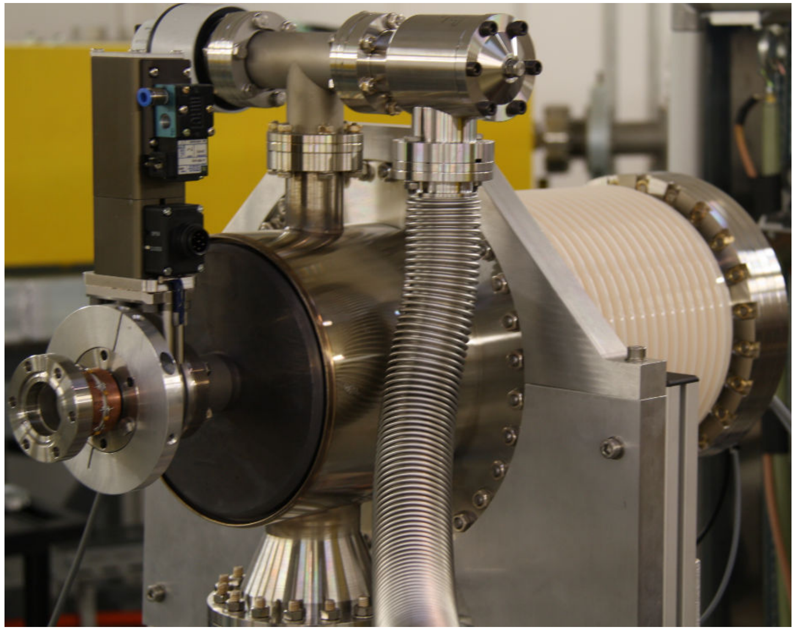
- **Electrons were generated in thermionic DC diode gun**
- **Electrons are emitted by a heated cathode (1200 ℃)**
- **Electrons are accelerated in the electric field between cathode and anode to 70 keV**
- **Only long electron pulses (1 µs long) were possible**
  -> multi bunches in the storage ring

New Electron Source

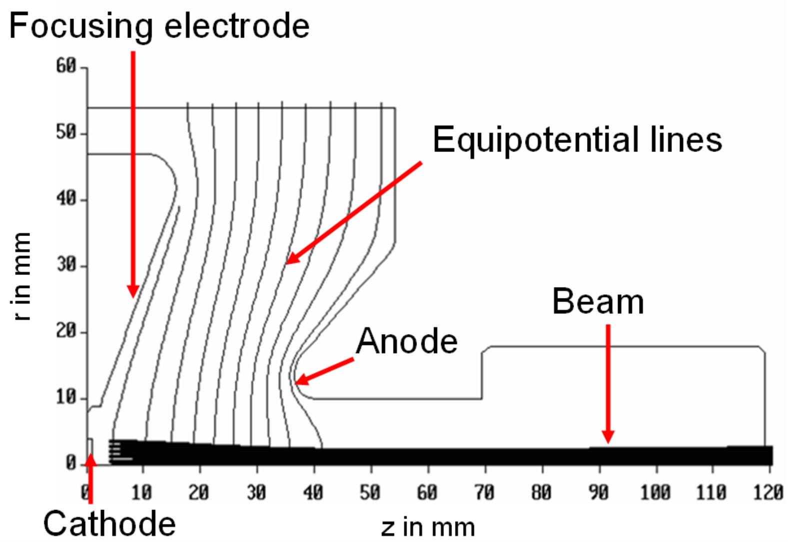


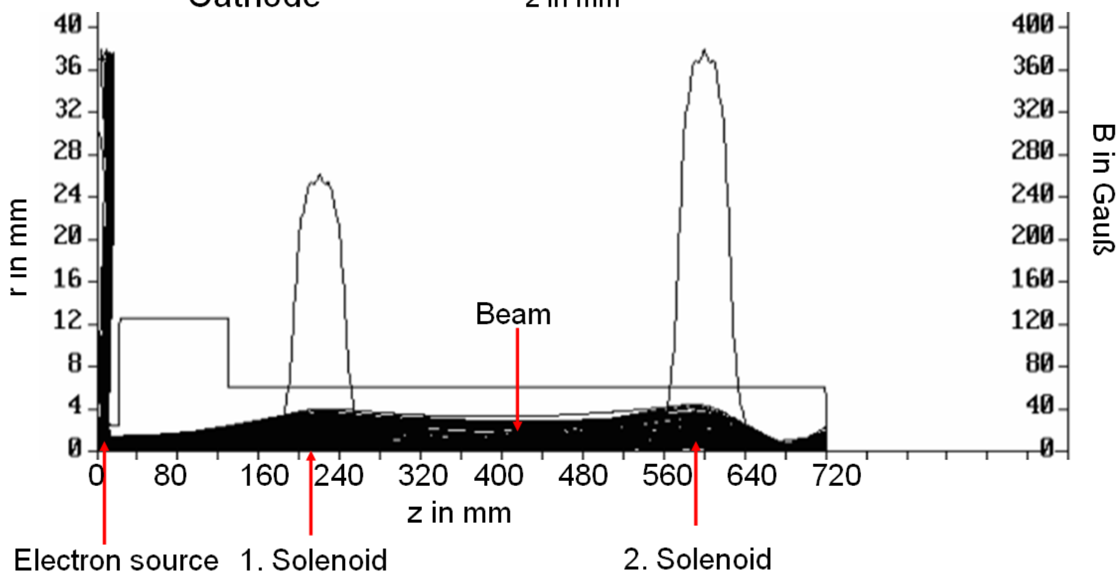
- **Generation of short pulses (1 ns) and long pulses (50 ns bis 500 ns) are possible**
  -> Single- and multibunches in the ring

- **Thermionic DC triode gun**
- **Additional grid between cathode and anode**



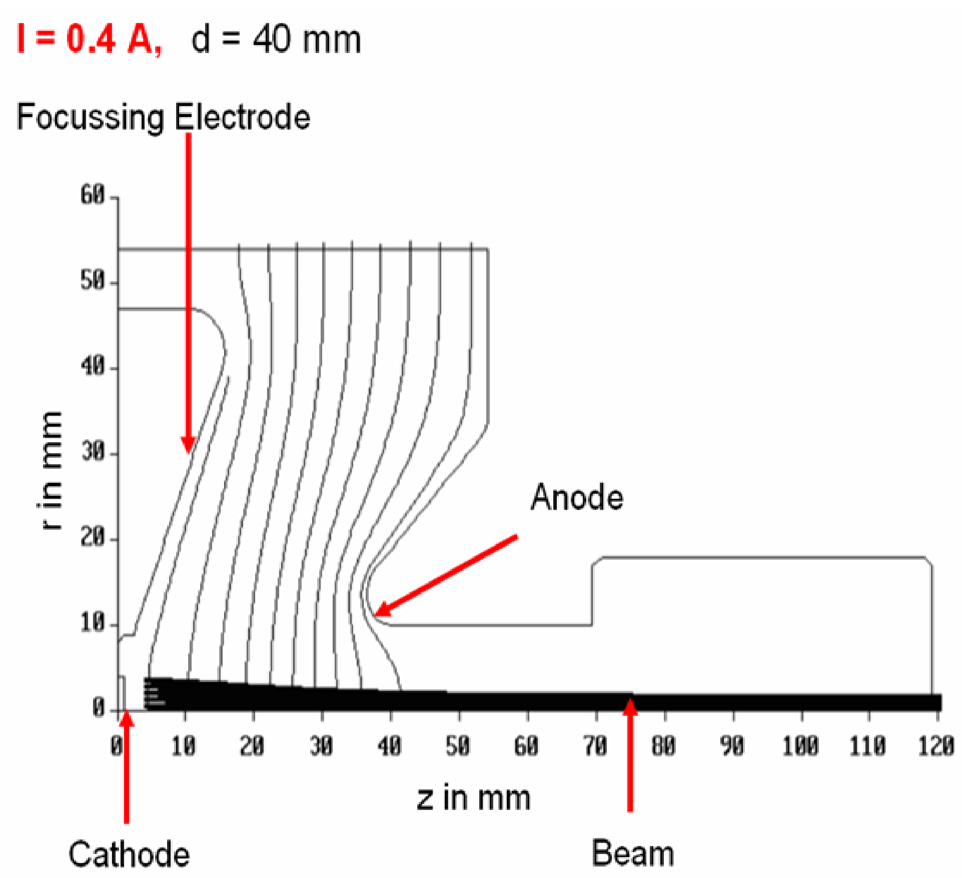
Simulations to optimise the Design

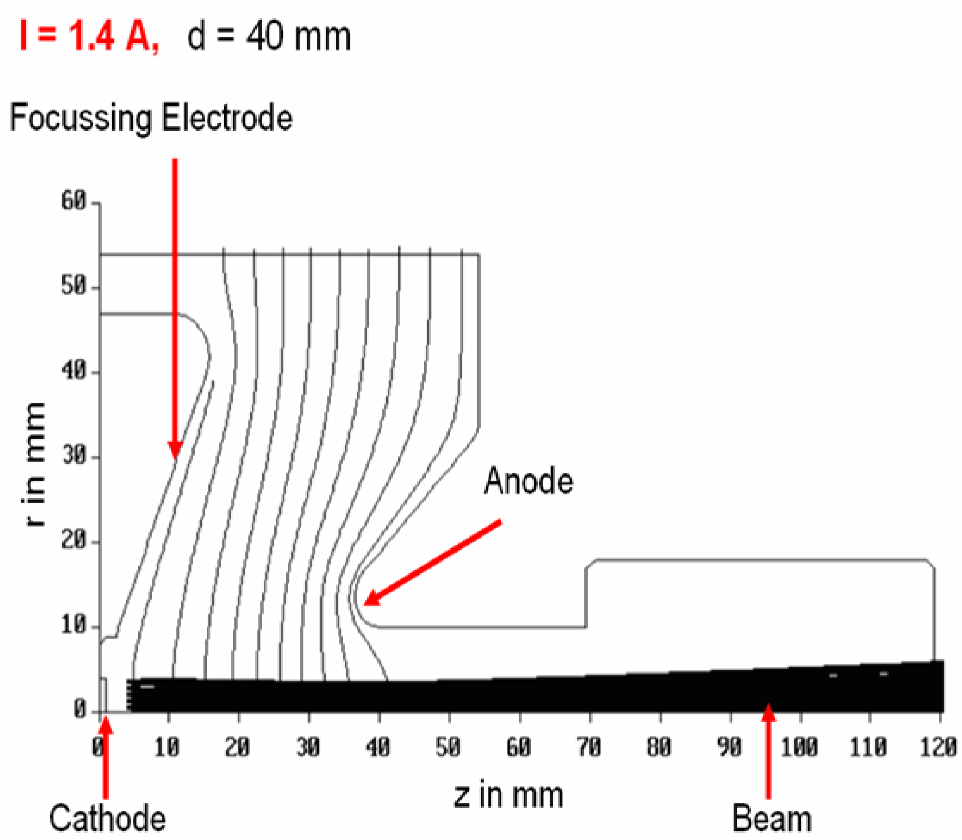




- **Current and Emittance depend on the design of the gun**
- **Simulations to obtain the maximum current for a small emittance (EGUN) were done**
- **Variations of the distance d cathode – anode, nominal d = 40 mm**
- **Investigation of two cathodes with different radius r_1 = 4 mm und r_2 = 5.6 mm**

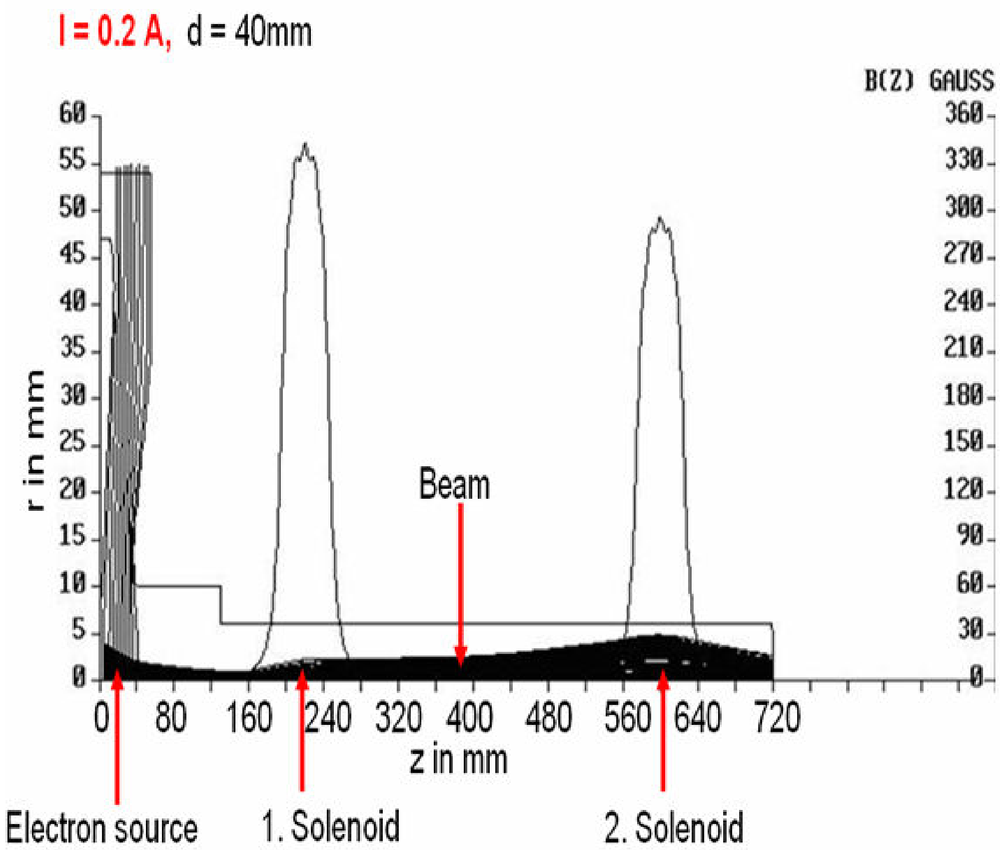
Beam transport for different currents for r_1 = 4 mm

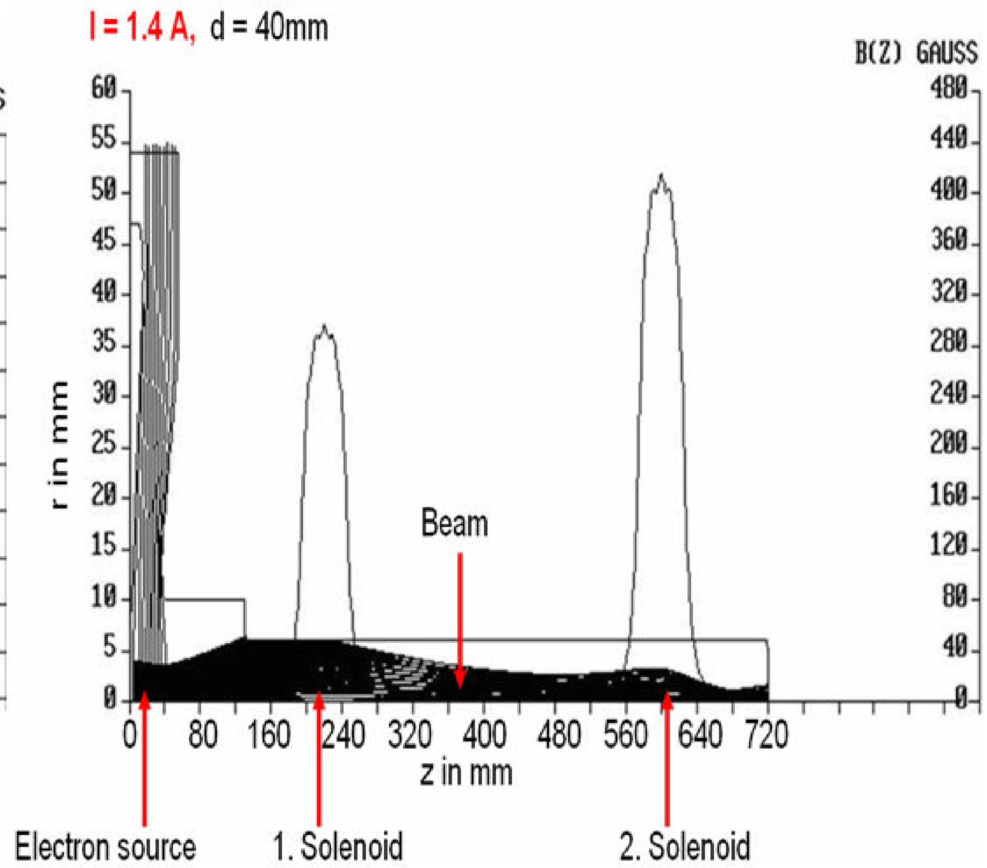




- **Width of the beam increase for higher currents due to space charge effects**

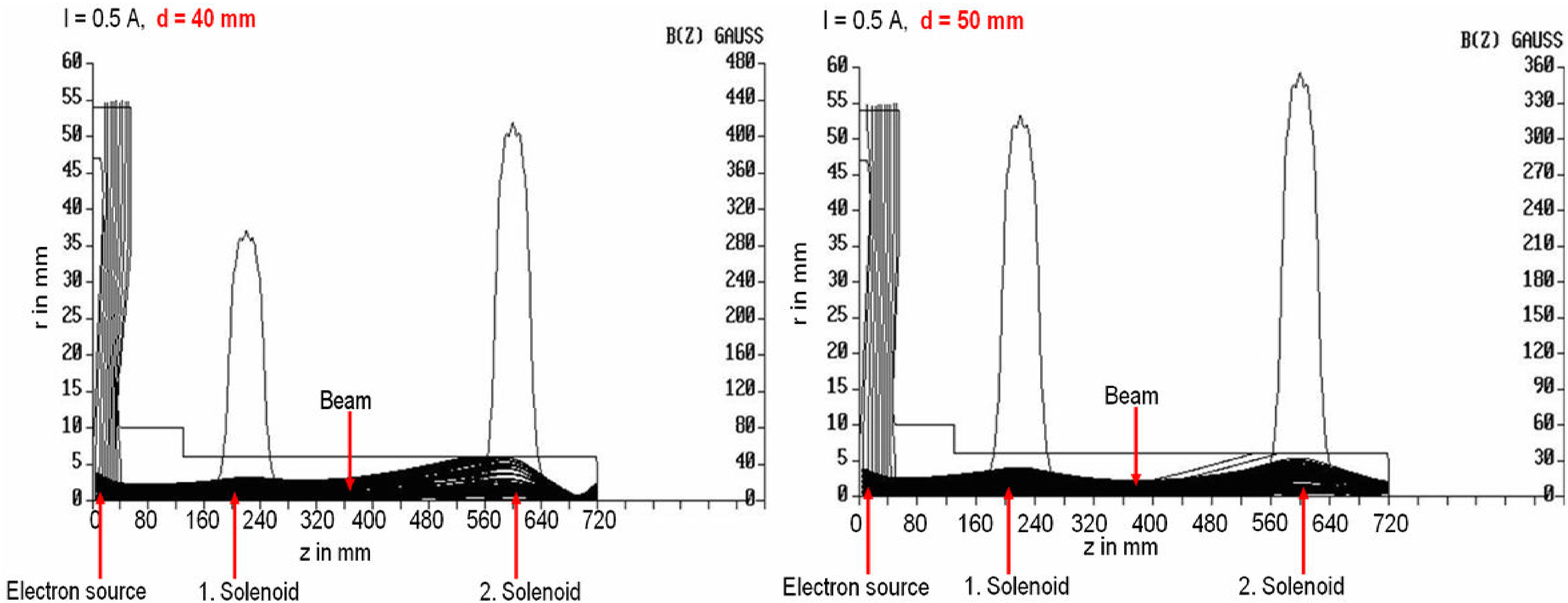
Beam transport for different currents for r_1 = 4 mm





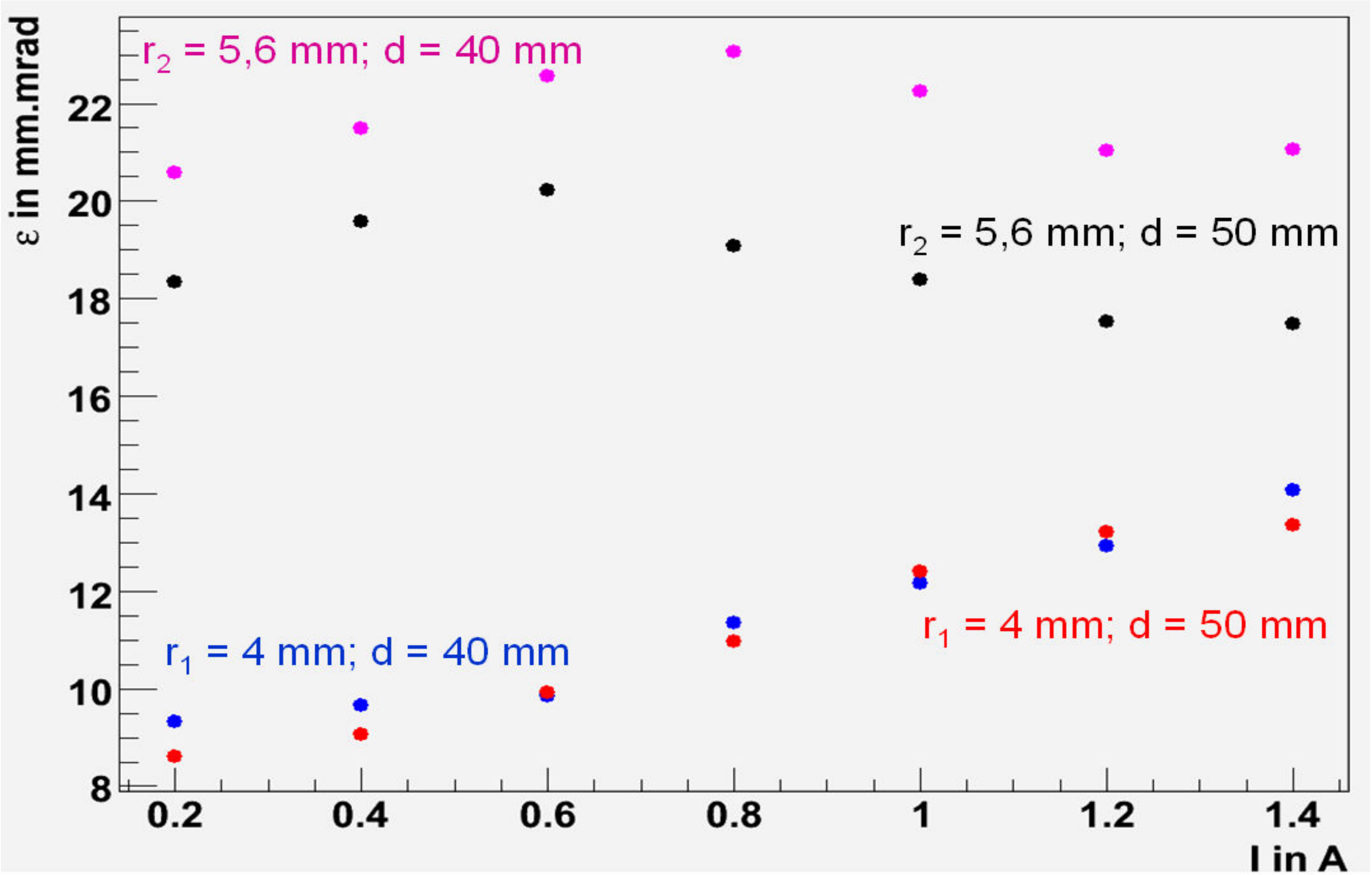
- **Problems with the beam transport for higher currents**
- **Maximum current should be less then 0.5 A**

Beam Transport for different d for r_1 = 4 mm



- **Slightly higher currents are possible for a larger distances cathode – anode**

Emittance calculation from simulation results for different I and d

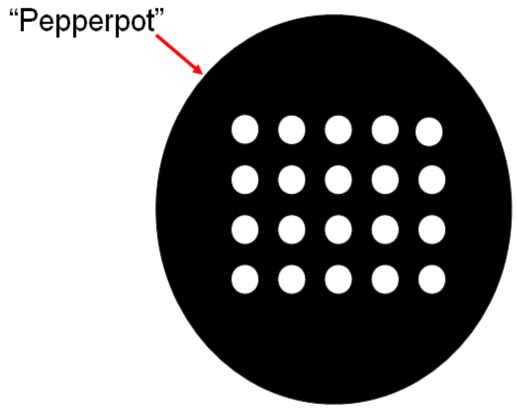


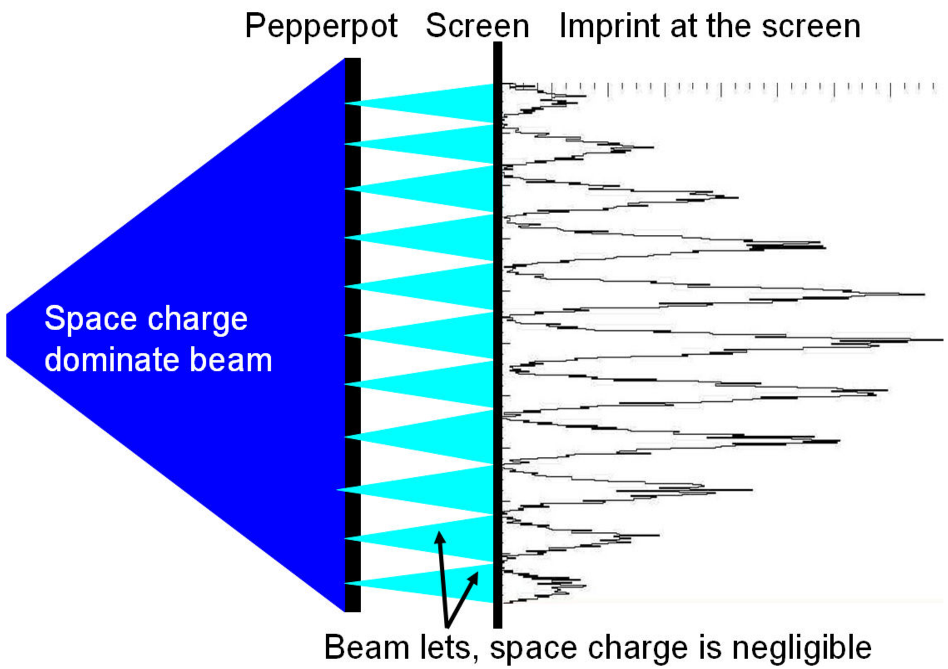
- **Emittance increases for r_1 for higher currents, no dependence of d**
- **Emittance higher for r_2, depend of d**

Conclusions for the Gun design

- The cathode with the radius r_1 = 4 mm is used
- Change in the distance from cathode to anode was not required (d = 40 mm)
- The maximum current is 0.4 A to 0.5 A, the emittance must be smaller then ε = 10 mm.mrad

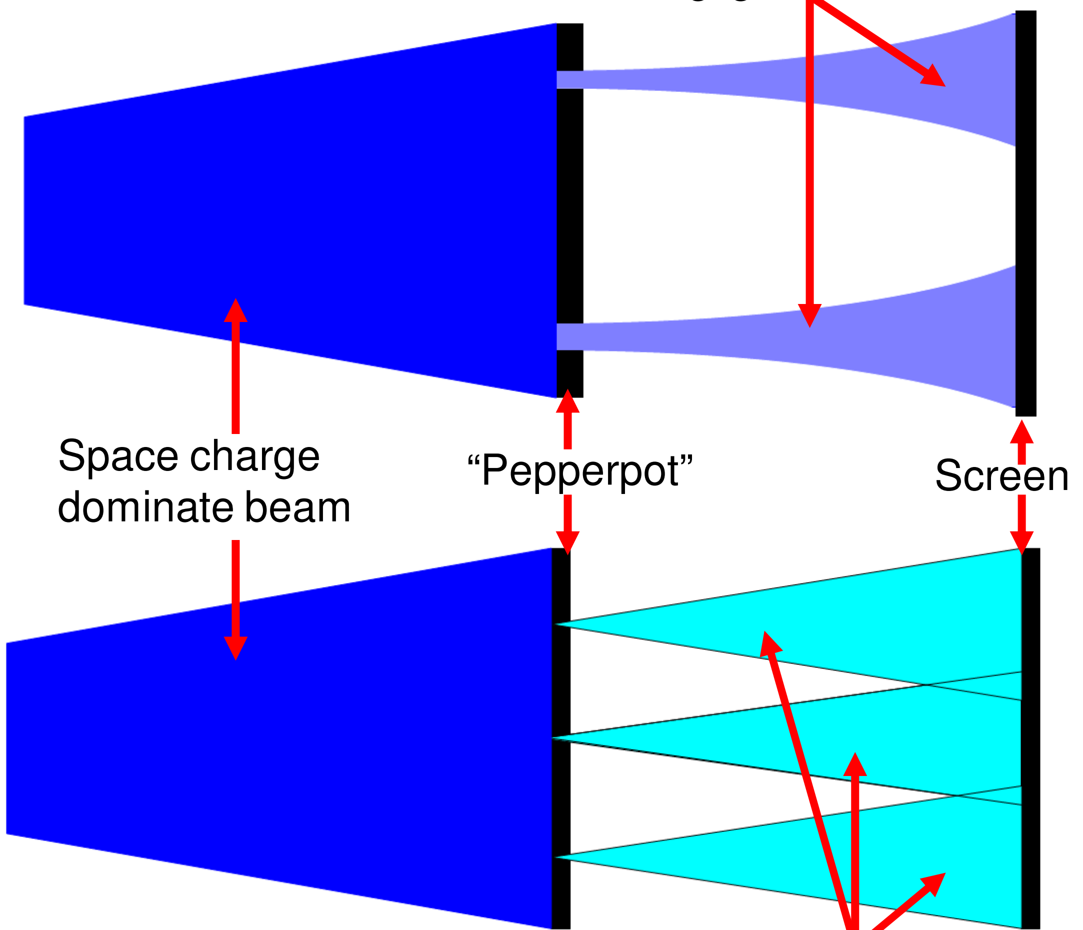
Emittance measurement with a “Pepperpot”





- Space charge dominated beam hit a hole mask
- Creation of beam lets, space charge in the beam lets is negligible
- Beam lets are detect on a screen
- Emittance can be estimated from the size of the imprint of the beam lets on the screen

Properties of “Pepperpot” and Distance from Screen



- **Diameter of the holes too big**
  -> Space charge not negligible

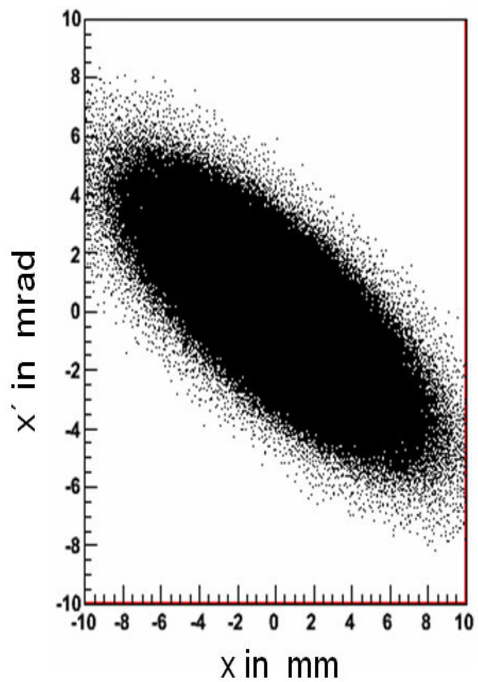
  Diameter of the holes too small
  -> Intensity to low

- **Distance of the holes too small or distance “Pepperpot” – screen too big**
  -> Overlap of the beam lets

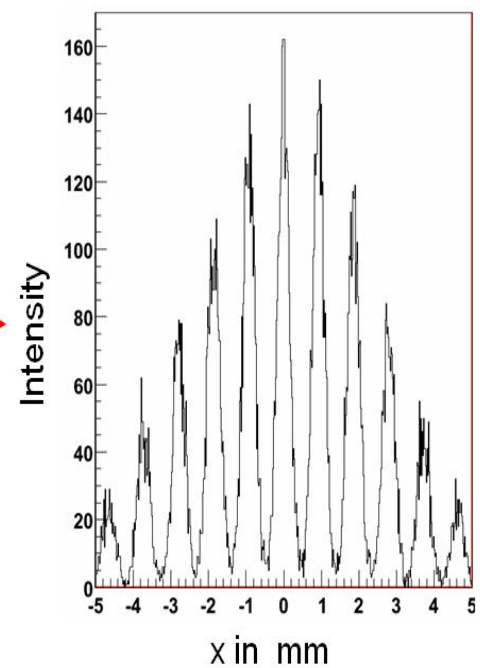
  Distance “Pepperpot” – screen too small
  -> poor resolution

- **Optimisation is necessary**

Calculations of these Parameters



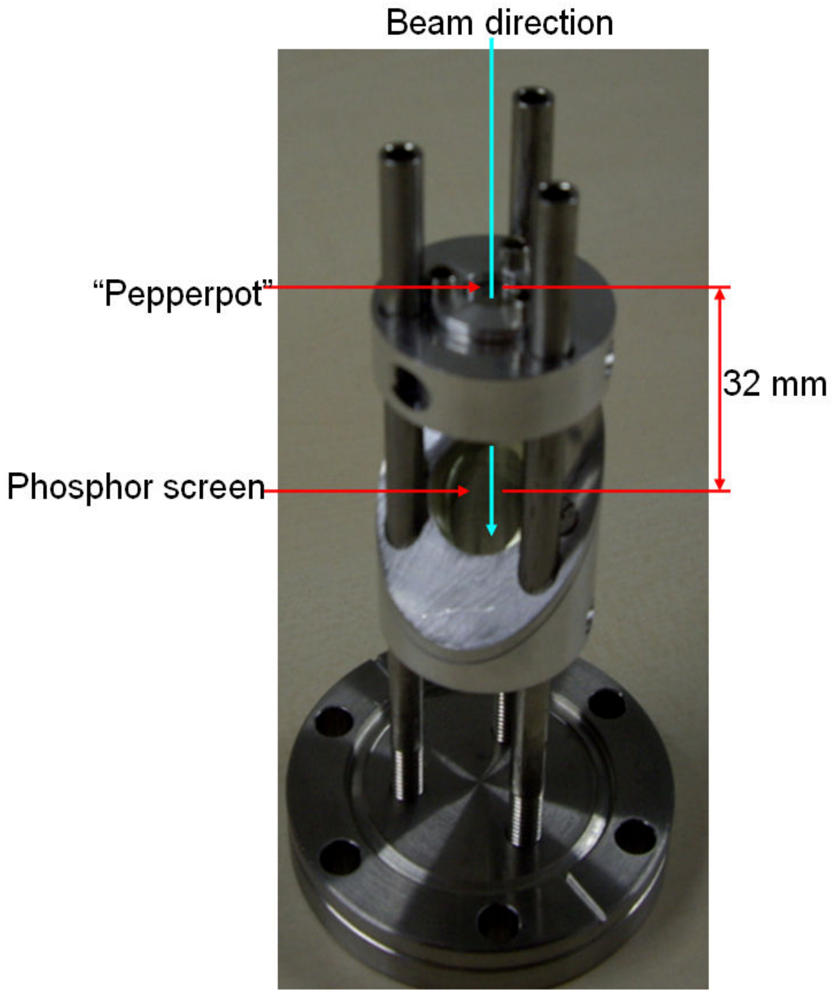
Generated particle distribution



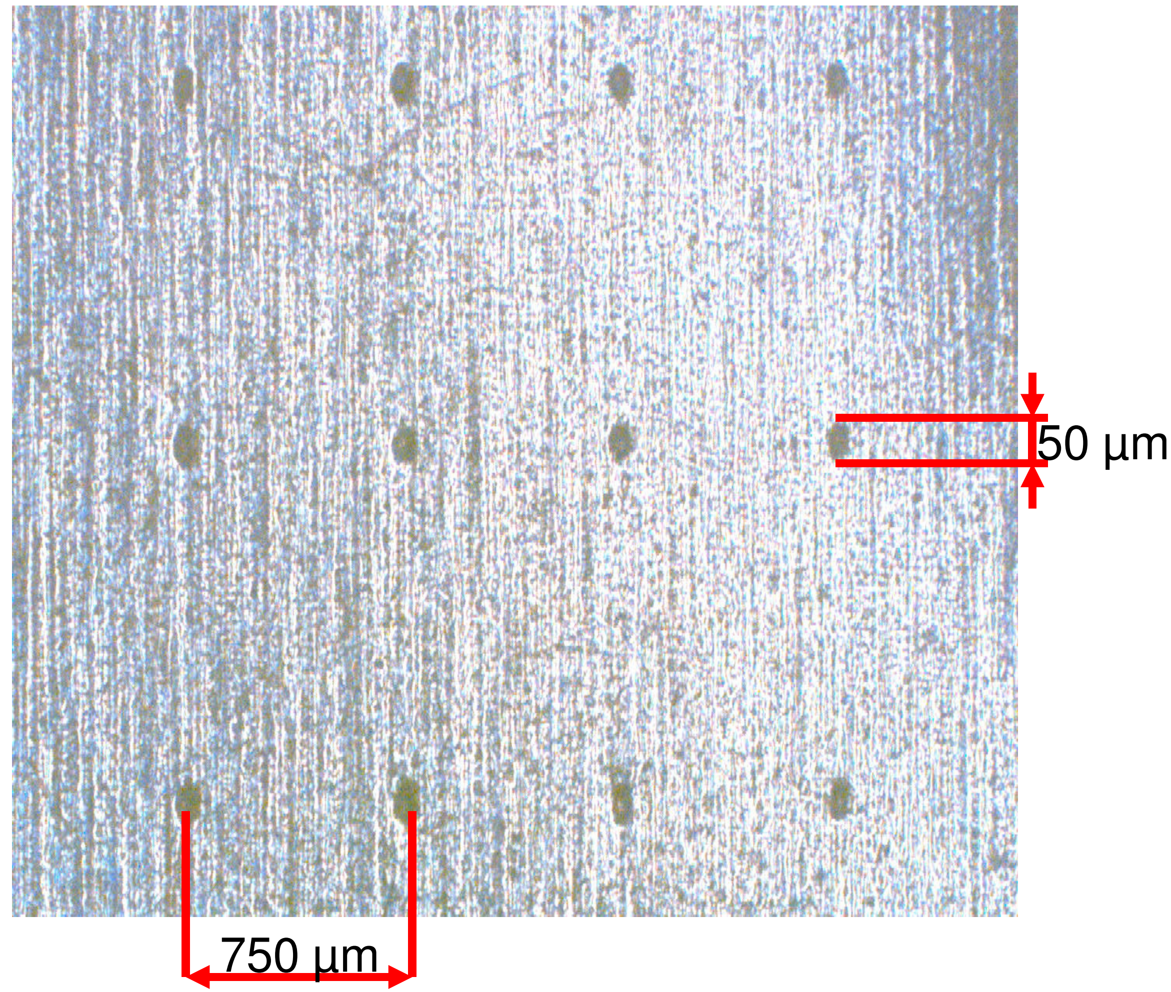
Distribution on the screen

- Generation of a start distribution with a known emittance
- Conforms that space chare is negligible
- Calculations of the trajectories
- Reconstruction of the emittance

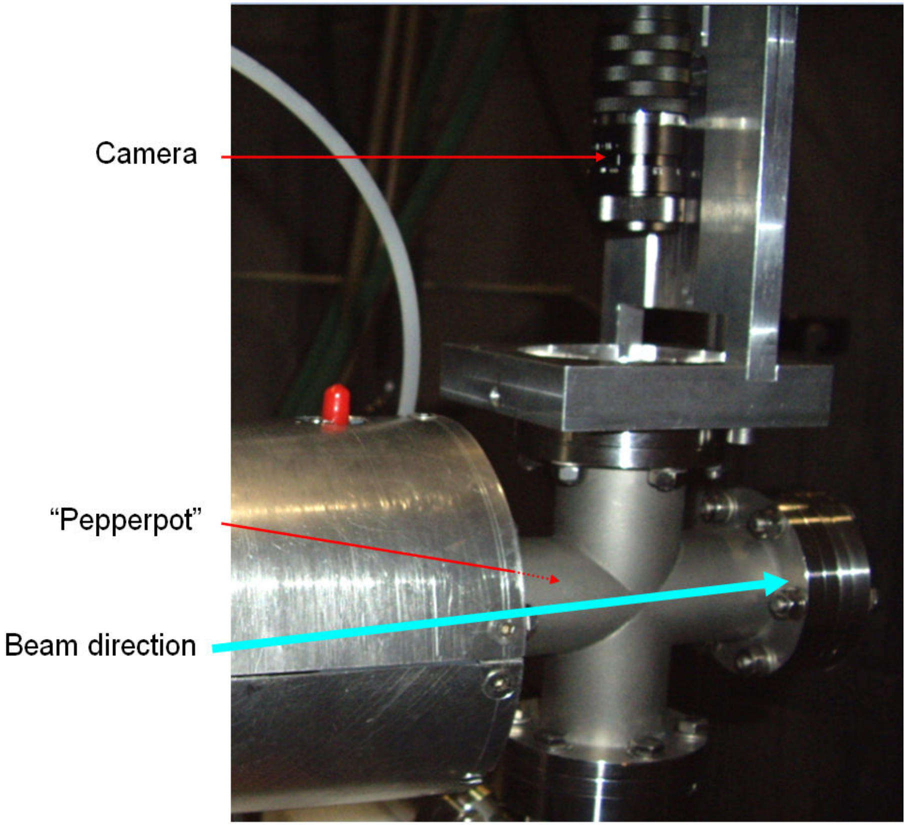
"Pepperpot"

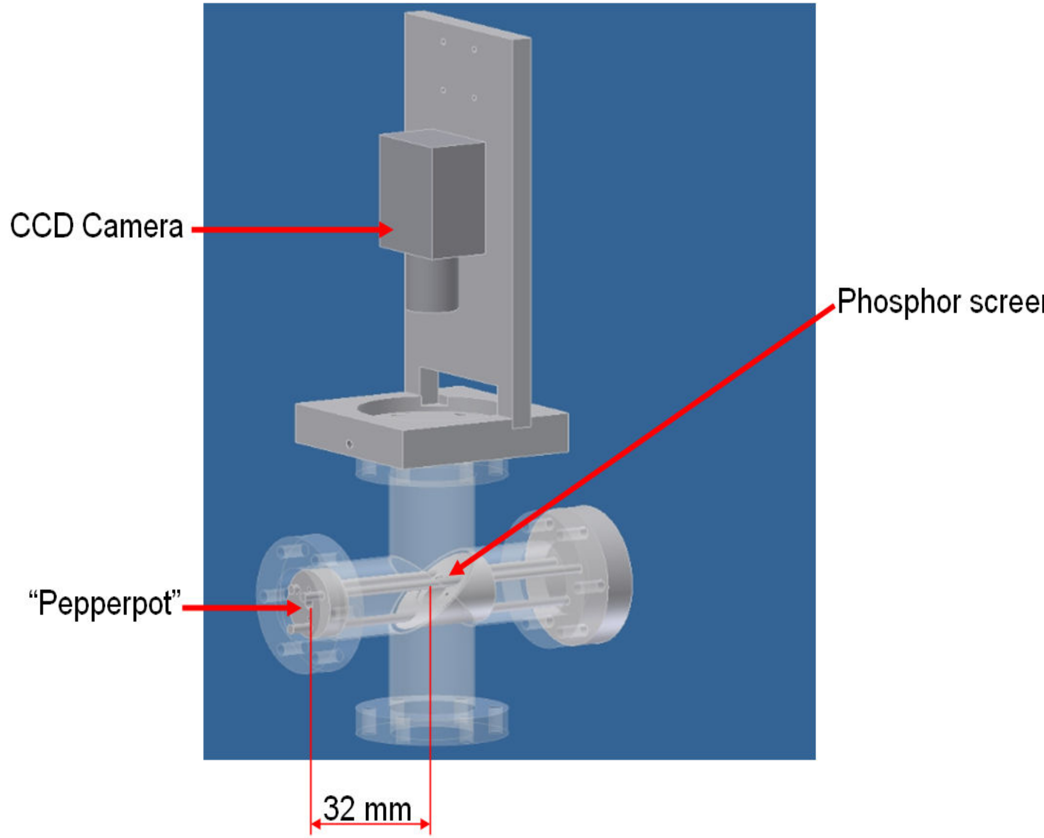


Total: 9 x 9 holes



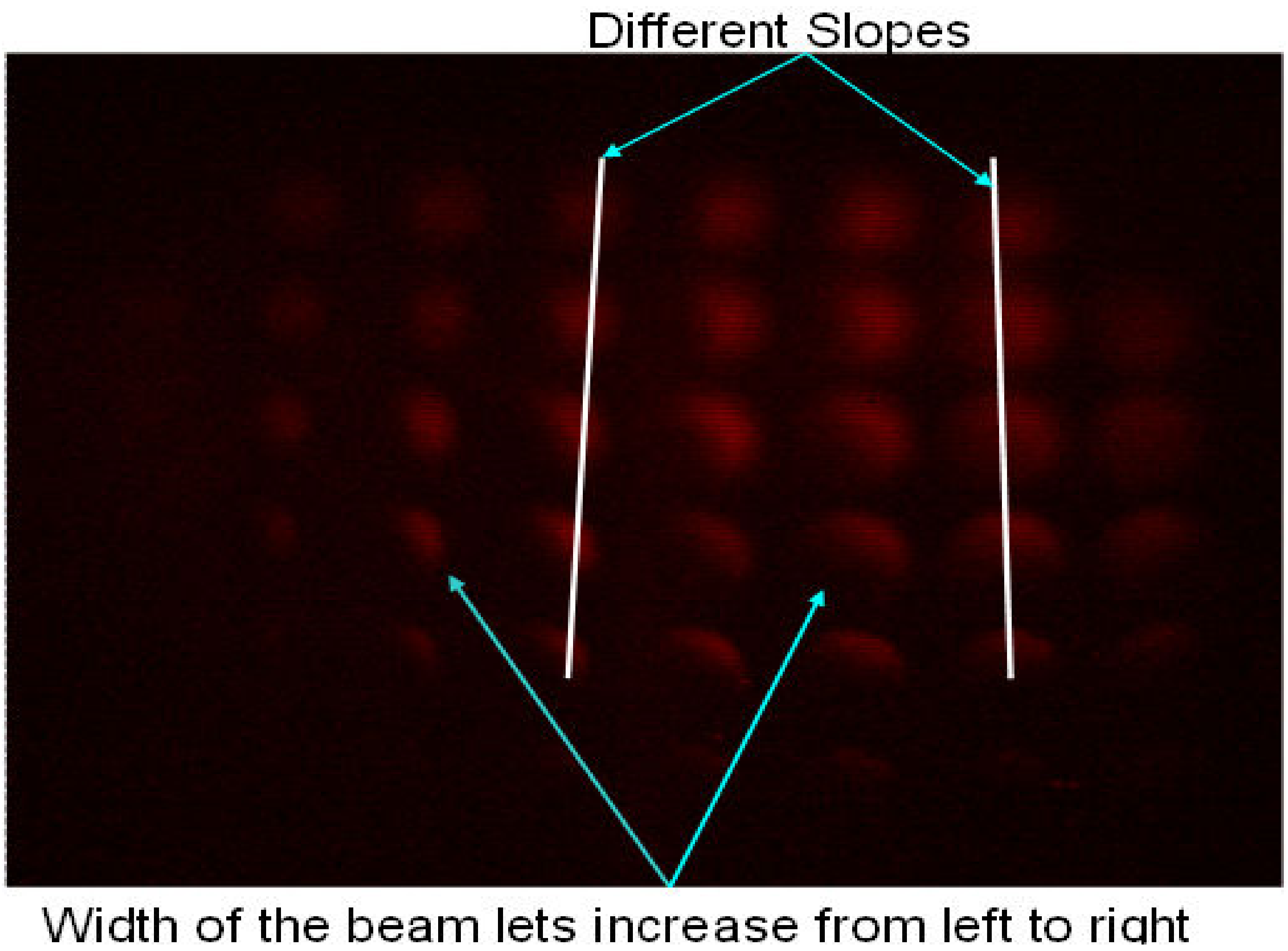
Experimental set up





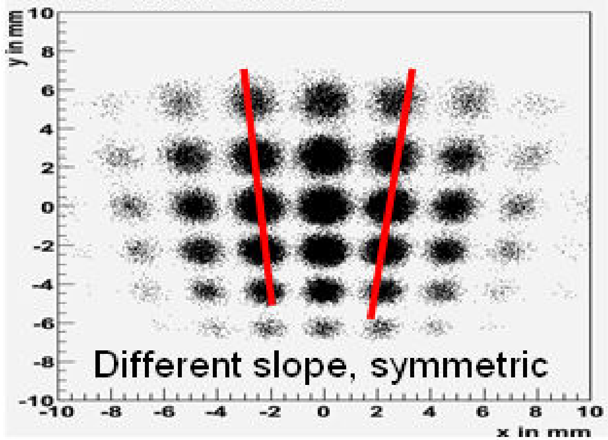
- **CCD camera was controlled with Matlab**

Imprint on the screen from a measurement

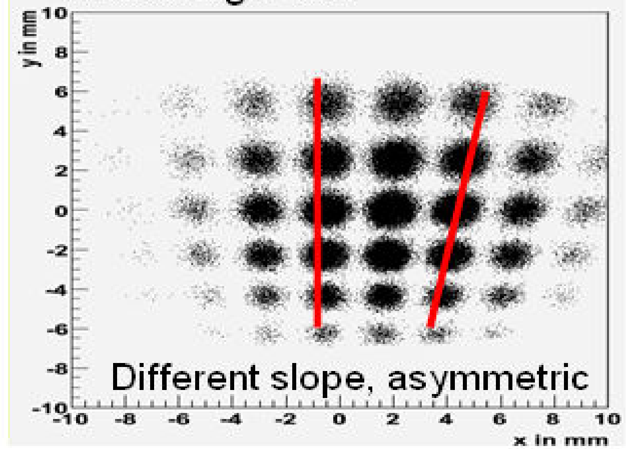


Difficulties

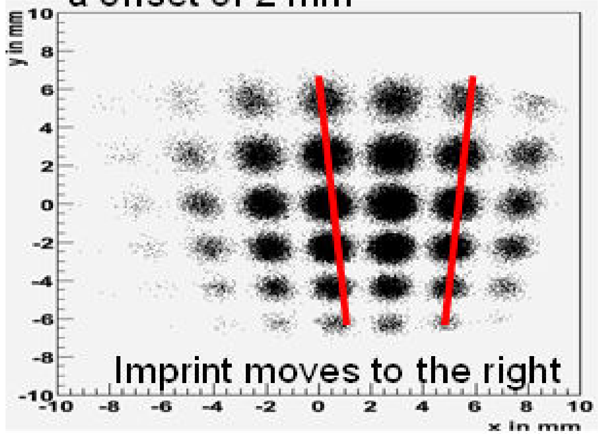
45° tilted screen



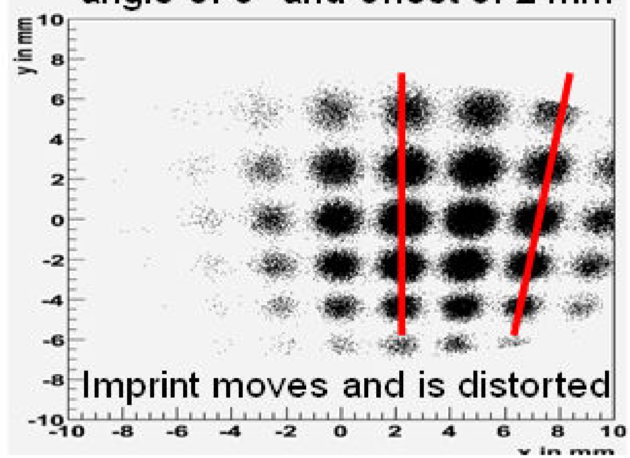
Beam hits the Pepperpot with a angle of 3°



Beam hits the Pepperpot with a offset of 2 mm

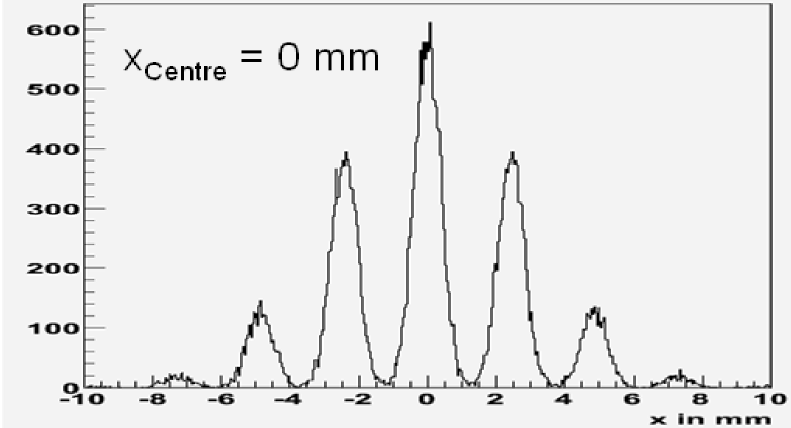


Beam hits the Pepperpot with a angle of 3° and offset of 2 mm

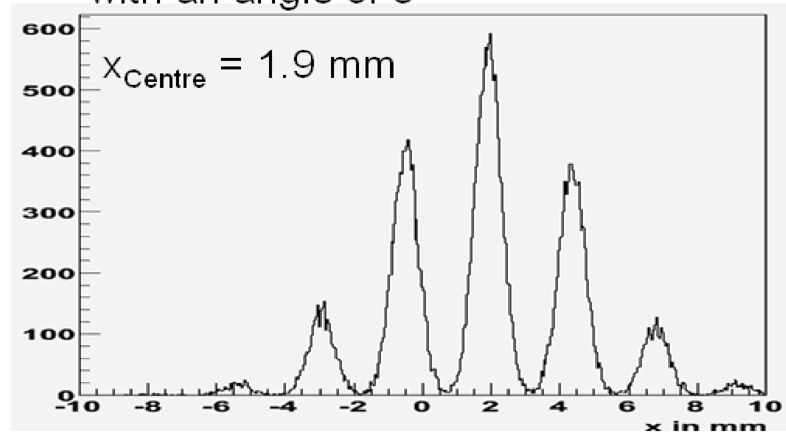


Difficulties

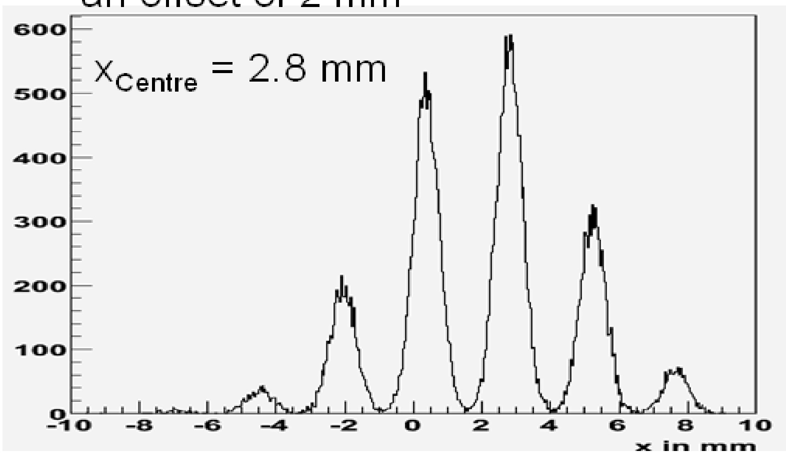
45° tilted screen



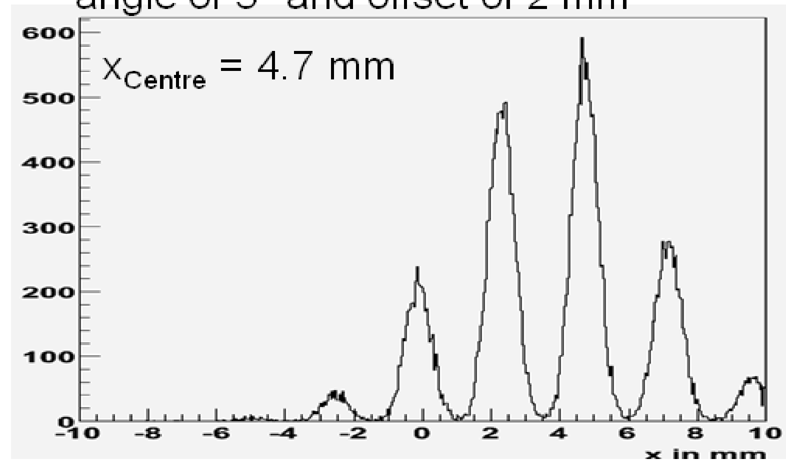
Beam hits the Pepperpot
with an angle of 3°



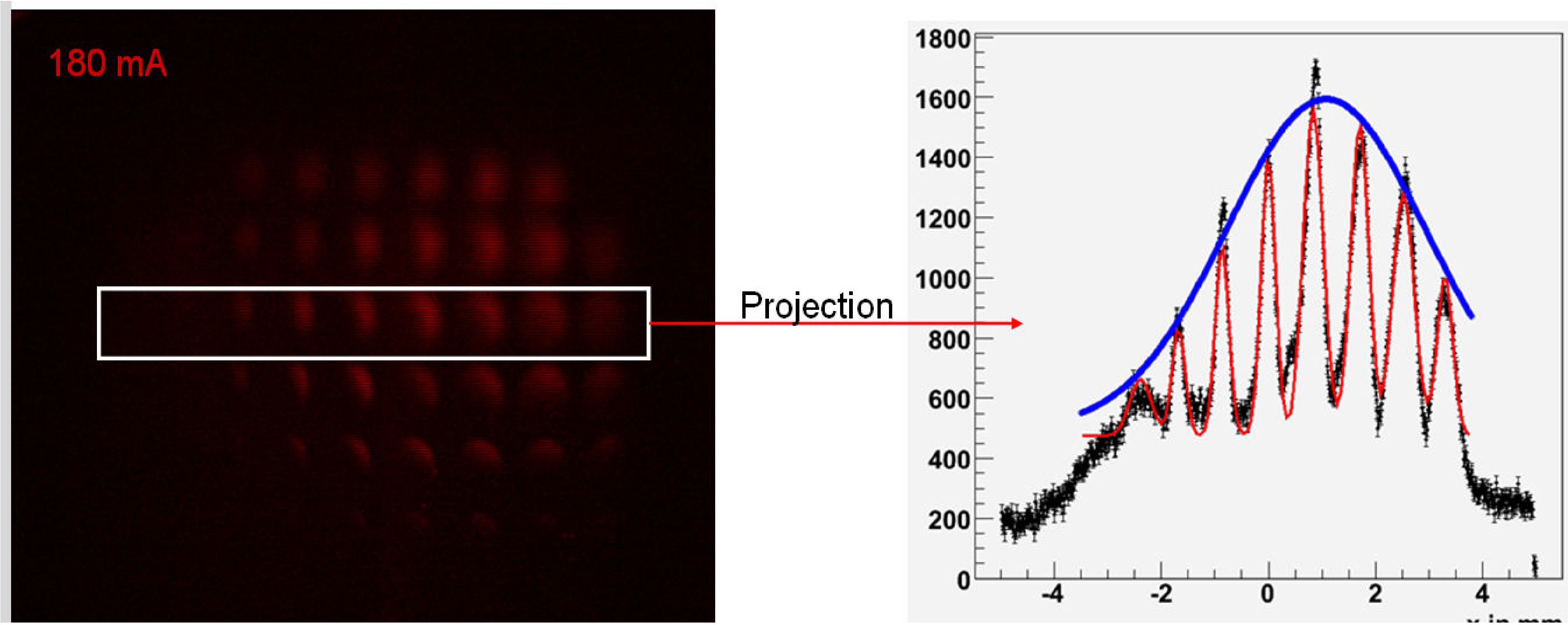
Beam hits the Pepperpot with
an offset of 2 mm



Beam hits the Pepperpot with an
angle of 3° and offset of 2 mm

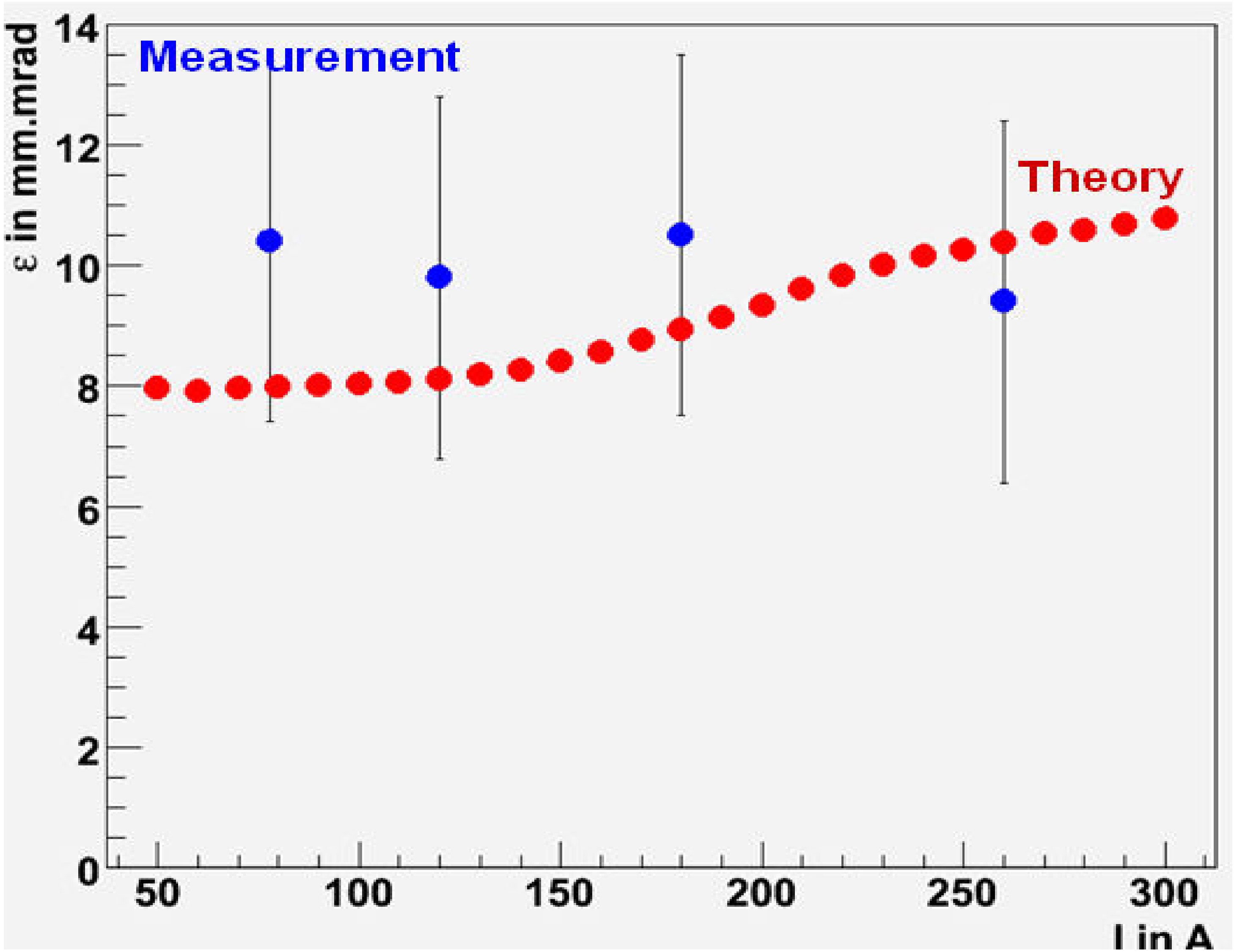


Evaluation of the Data Sets



$$f = \sum_i \left[A \cdot \exp\left(-\frac{1}{2} \cdot \left(\frac{x_i - x_{Envelop}}{\sigma_{Envelop}} \right)^2 \right) \cdot \exp\left(-\frac{1}{2} \cdot \left(\frac{x_i - x_{i,Peak}}{\sigma_{i,Peak}} \right)^2 \right) \right] + const$$

Estimation of the Order of the Emittance



Summary and Outlook

Karlsruhe Institute of Technology

- Installation of a new thermionic DC triode gun at ANKA
- Optimisation of the designs to achieve a high current and low emittance
- Measuring the emittance with a “Pepperpot”,
- Evaluation is in progress
- Installation of the new gun was done in January

Acknowledgment

- Thomas Fischböck
- Ralf Lang
- Daniel Ritz
- Richard Stricker
- Andreas Völker

Thank you for your attention

Emittance Formular

$$\varepsilon^2 = \frac{1}{N^2}\left\{\left[\sum_{j=1}^{p} n_j\left(x_{sj}-\bar{x}\right)^2\right]\left[\sum_{j=1}^{p}\left[n_j\sigma_{x'_j}^2 + n_j\left(\bar{x}'_j-\bar{x}'\right)^2\right]\right] - \left[\sum_{j=1}^{p} n_j x_{sj}\bar{x}'_j - N\bar{x}\bar{x}'\right]\right\}$$

p = Total number of slits

x_{sj} = j – th slitt´s position

n_j = Intensity int the j – th slit [1]

$\bar{x}$ = Mean position of all beam lets

$\bar{x}'_j$ = Mean divergence of j – th beam let

$\bar{x}'$ = Mean divergence of all beam lets

$\sigma_{x'_j}$ = RMS divergence of j – th beamlet

[1] M. Zhang, “Emittance Formula for Slits and Pepper-pot Measurements”, FERMILAB-TM-1988