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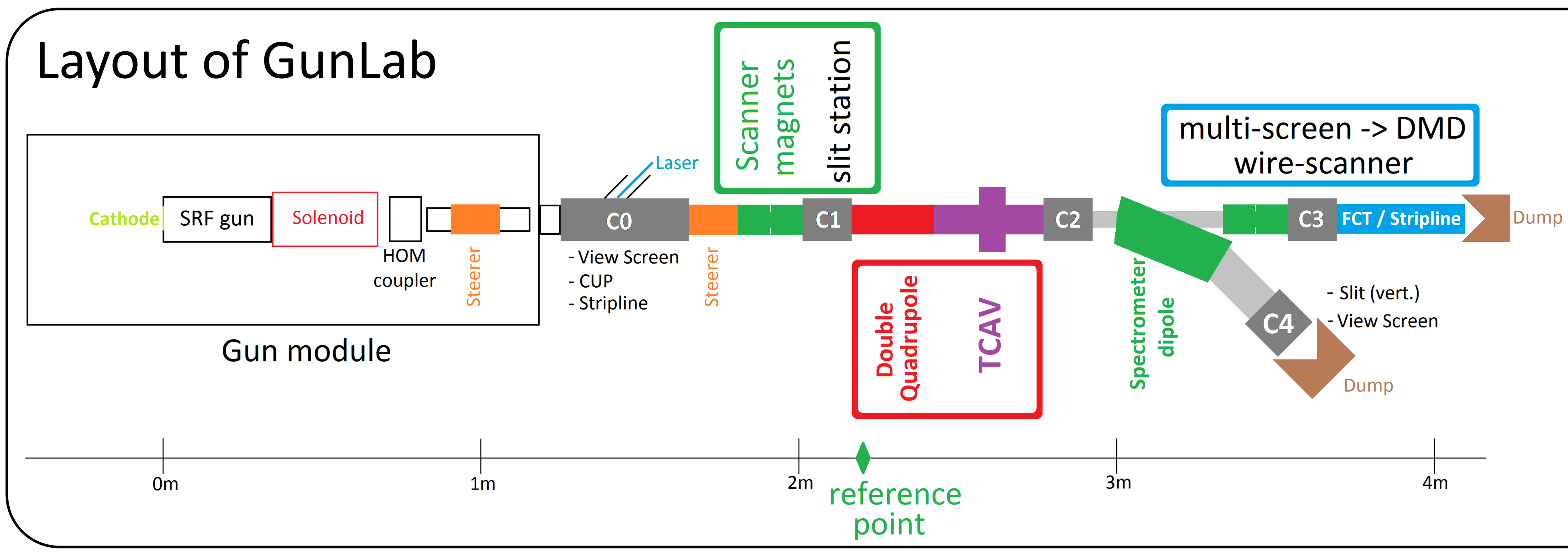
Fast Transverse Phase Space Measurement System for GunLab

- a compact Test Facility for SRF Photoinjectors -

Motivation

SRF photoinjectors are promising electron sources for high brightness accelerators with high average current and short pulse duration like FELs and ERLs. GunLab will be an independent test facility to test and commission different SRF photoinjectors, optimize the beam performance and examine photocathode materials.
Furthermore different fast phase space measurment systems will be developed and tested at GunLab.

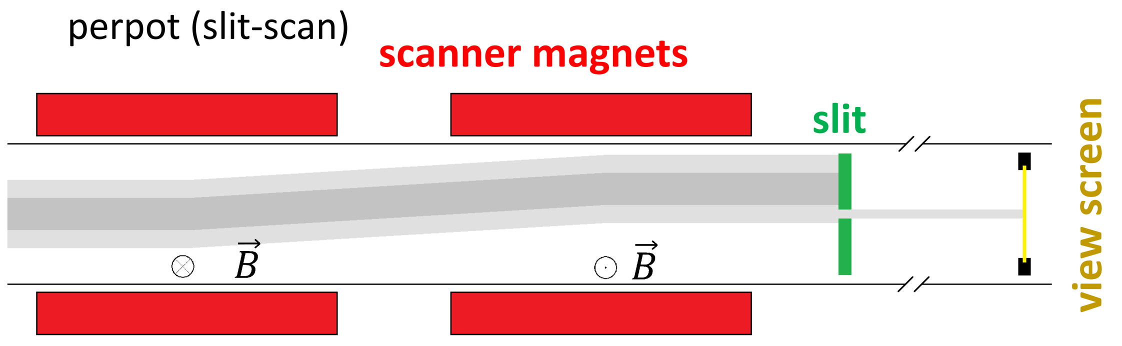
Layout of GunLab



Bunch exit energy	1 … 3.5 MeV
rel. energy spread	0.2 … 5 %
Bunch charge	0 … 100 pC
Bunch length (@z=2.5 m)	2 … 10 ps (rms)
max. average current	4 µA
Normalized emittance (@ z=2.2 m)	0.4 … 10 mm mrad
SRF gun frequency	1.3GHz
Electric peak field	30 MV/m
Launch phase	0 … 80 degL

Slit-Scanner (transverse phase space)

- the transverse phase space can be observed directly with a pep-perpot (slit-scan)



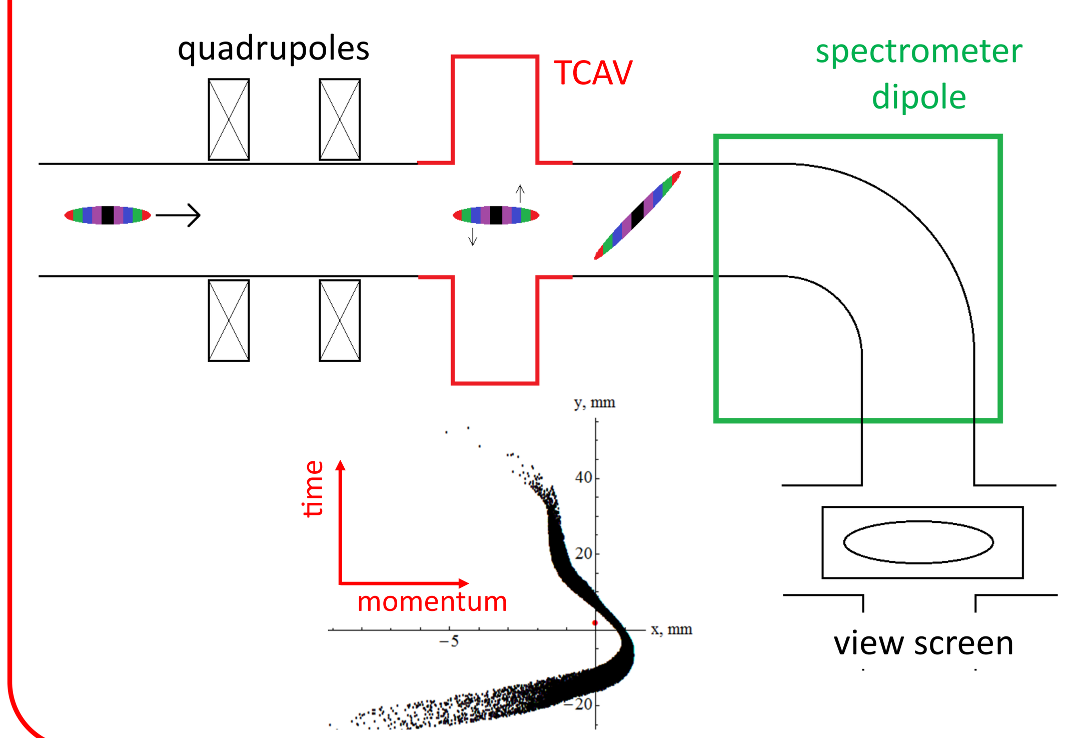
-> slit scan: moving the beam over the slit and measuring the position and beam width of the beamlets on a view screen
- two scanner coils change their B-field simultaneously
- same absolute field amplitudes but different sign

-> Scanner magnets are cosθ–coils:
- produce dipole fields and suppress higher magnetic multi-poles
- did not have remanent magnetic fields
- can shift the beam up to 10mm off-axis (pc<6MeV) with a uncertainity of distortion and deflection less than 1‰

longitudinal phase space

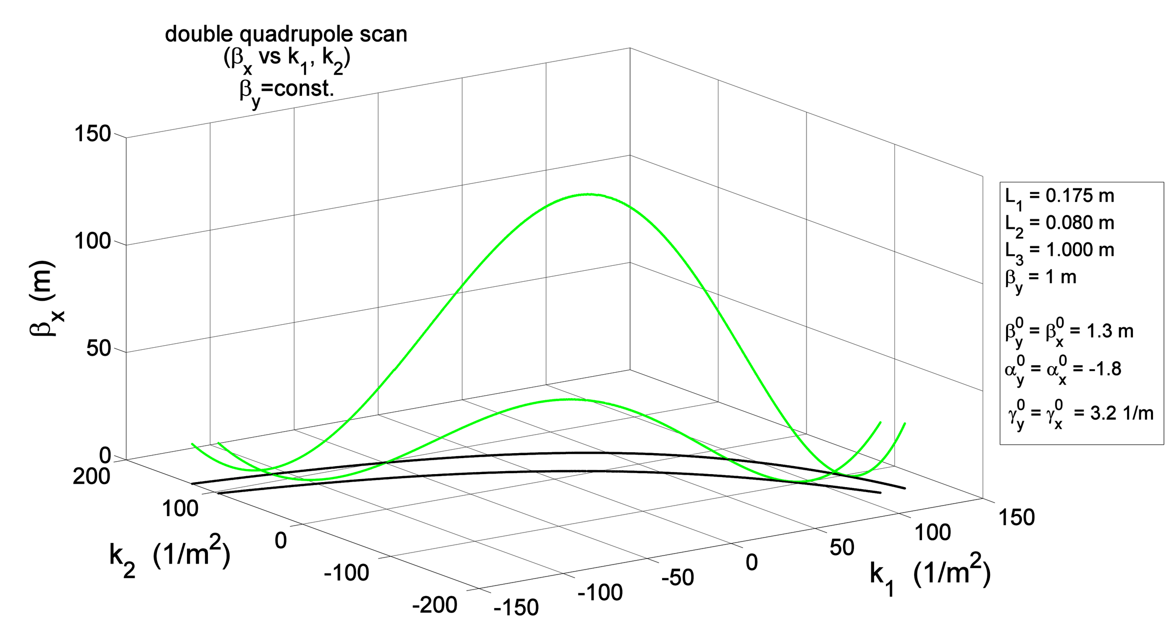
- the beam will streaked by the transverse deflecting cavity (TCAV) in vertical direction and bended by spectrometer dipole in horizontal direction

-> longitudinal phase space is visible directly on the view screen in the dispersive section



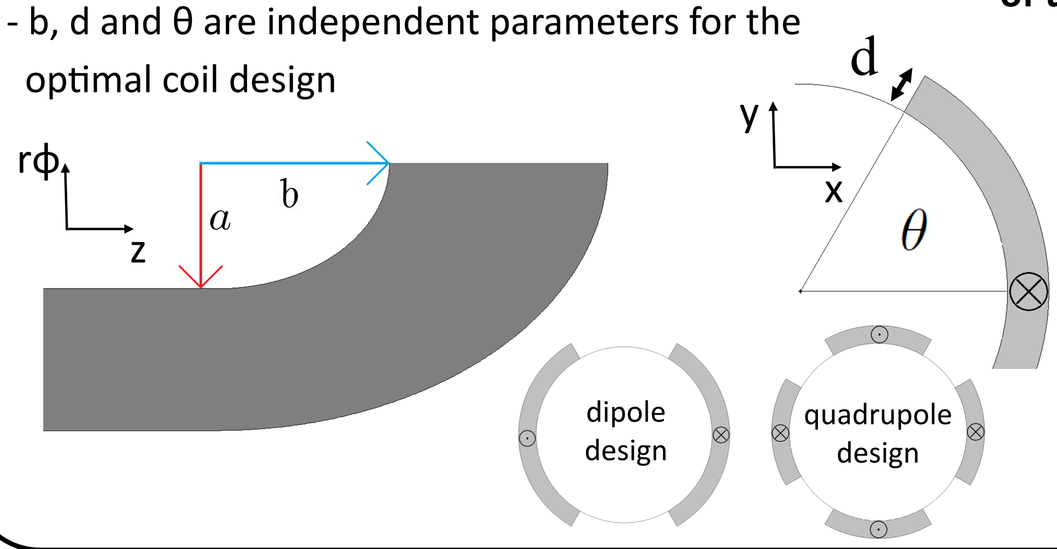
slice emittance

Double quadrupole scan + TCAV:
- both quadrupole strengths will be manipulated simultaneously
  - -> beam width in streaked direction stays constant on screen
  - -> the beam width in the perpendicular direction will be used to reconstruct the phase space distribution at the reference point.



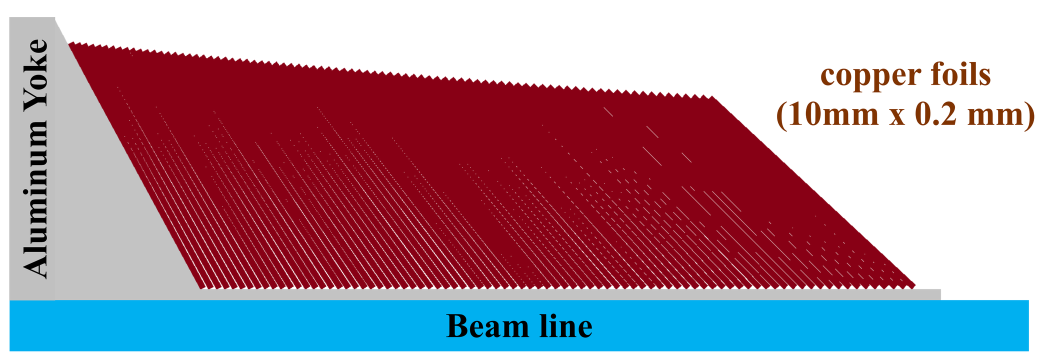
Design of cos(nθ)-coils

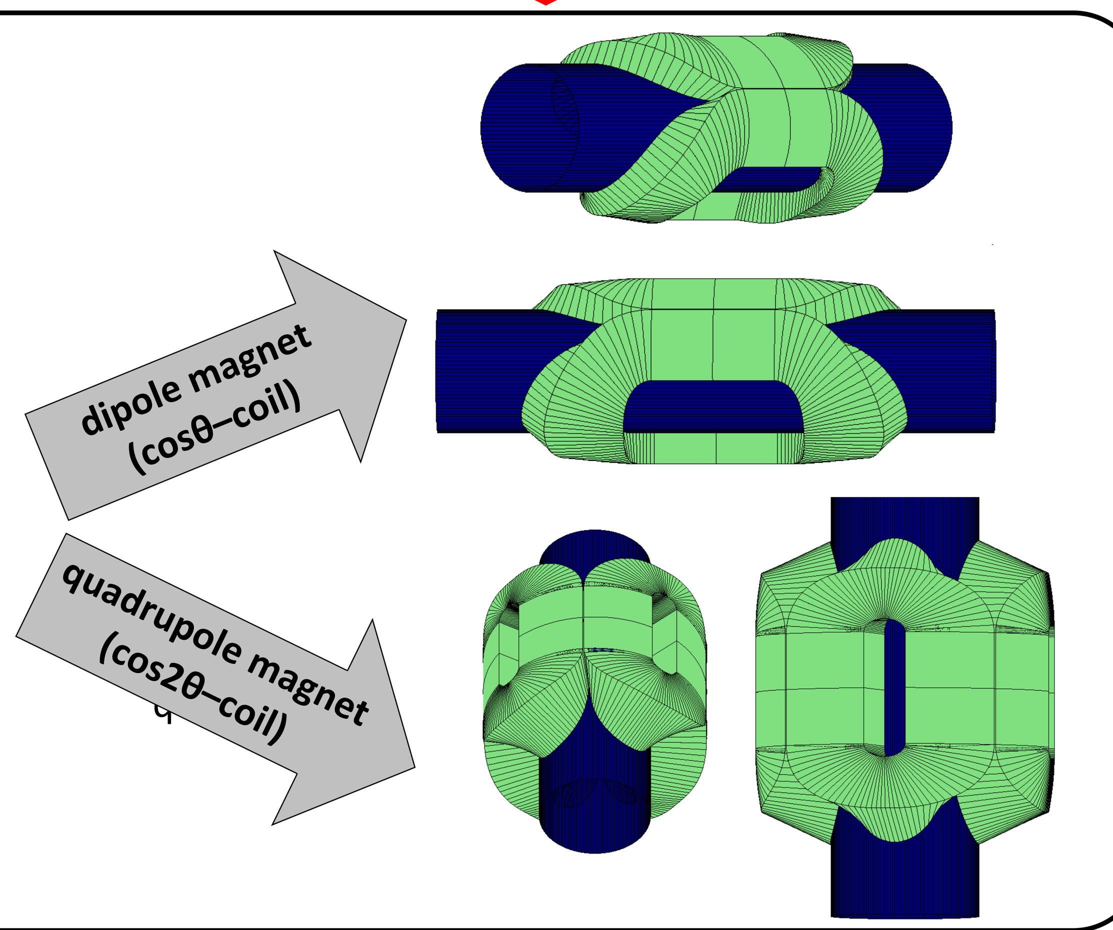
- cosnθ-magnets consist of 2n identical coils azimuthal distributed in 180°/n steps
- each with an opening angle θ and thickness d
- the end caps have a 2d elliptical shape with a and b as the principal axes
- b, d and θ are independent parameters for the optimal coil design



b, d, θ and R_0 define also the design of the coil end caps

coil end cap design:
- each foil has to be skewed to follow the defined path on the beam tupe
- the rotation angle on top of the tube is given by: $\tan(\beta) = \frac{b}{R_0 \alpha^2}$





Optimization of design parameters (example of the dipole magnete)

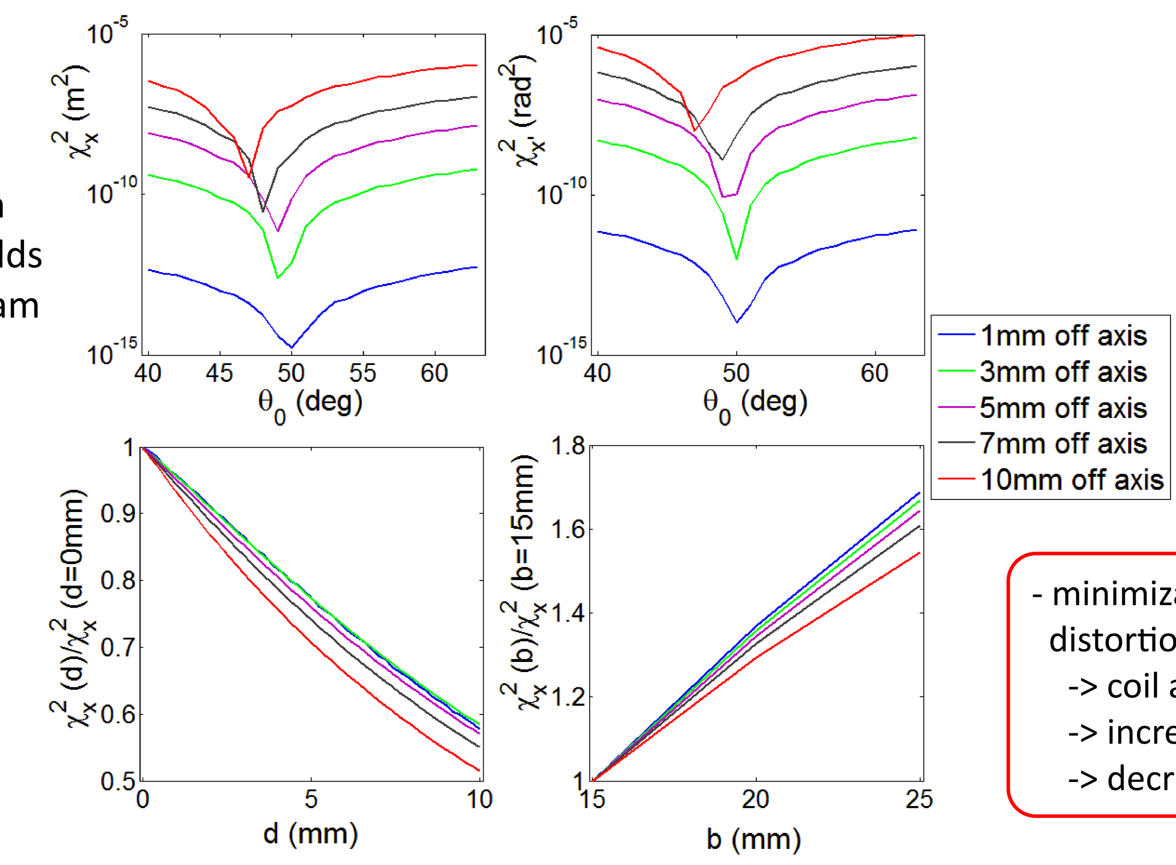
- definition of coil-parameter (b, d, θ)
  - -> field calculation by MATLAB
  - -> field tracking as 3d field in ASTRA
- b, d and θ was optimized by the minimization of phase space distorsions by the magnet fields
- coil length L (depends on b, d and θ) and beam tube radius R_0 are given parameters

minimization of:

$$\chi^2 = \Sigma_i^N (x_i^{(f)} - x_i^{(i)})^2 / N$$

final and initial phase space coordinates

# of particles

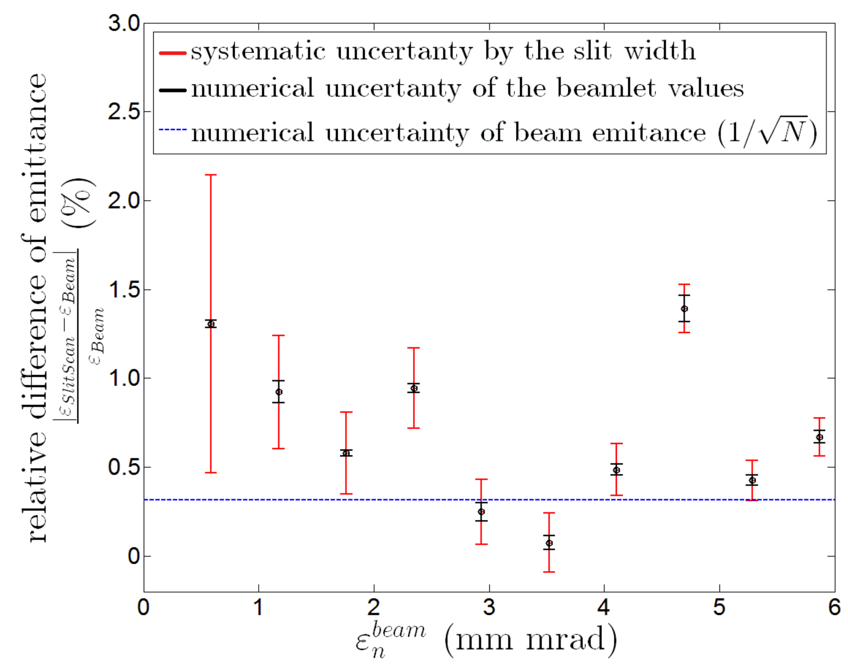


numerical test of a slit scanner measurement

gaussian bunch with :
- # of particle 10^5
- momentum of 3MeV/c
- momentum spread <10^-4
- geometric emittances 0.1 … .1 mm mrad

slit width 100µm
Scanner magnets:
- 25 steps between −6…+6mm

- minimization of phase space distortions by dipole field for:
  - -> coil angles of ≈48°
  - -> increasing the coil thickness
  - -> decreasing the end cap radius



differences between emittance values reconstruct by slit scanner and original bunch are dominated by numerical uncertainties and systematic errors of the methode (finite slit width)

Partners

EuCARD, HZDR Helmholtz Zentrum Dresden Rossendorf, Max-Born-Institut, Brookhaven National Laboratory, technische universität dortmund, National Centre for Nuclear Research Świerk, Jefferson Lab Thomas Jefferson National Accelerator Facility, DESY, МГУ имени М.В.Ломоносова

Outlook

- final designs for dipole magnets (scanner magnets) and quadrupole magnets are fixed
- final calculations to suppress numerical uncertainties are work in progress
- construction, field measurement and test with electron beams are planed for the next 6 month
- **First beam in GunLab is planned for summer 2015**