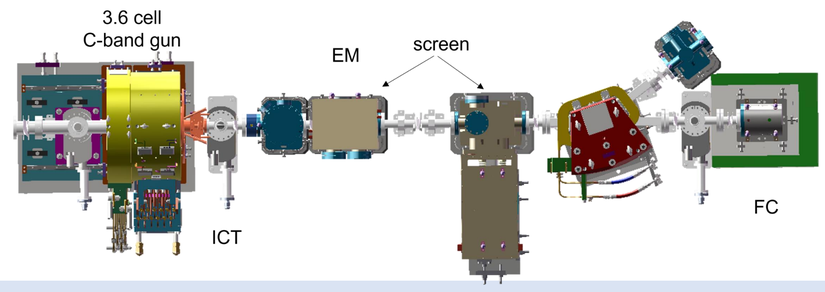
Optimized design of an consecutive double-slit emittancemeter for the C-band Photocathode RF gun

W. Chen[1,2], S. Jiang[1,2], R. Liu[1,2], T. Yang[1,2], R. Yang[1,2], X. Li[3], X. LI[1,2], S. Wang[1,2]

[1]IHEP(CAS), Beijing, China, [2]CSNS, Dongguan, China, [3]Deutsches Elektronen-Synchrotron, Zeuthen, Germany

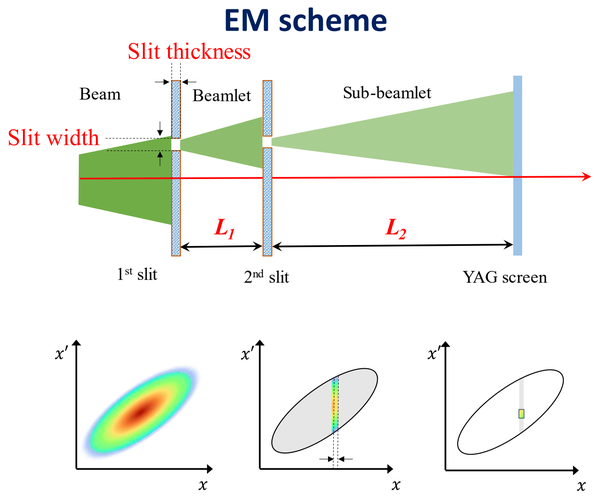
Abstract

- Face on the challenge of measure small beam emittance (<0.2 mm.mrad), we design a new emittancemeter base on the consecutive double-slit method.
- The EM parameters had been optimized, including slit width, slit thickness and the drift length.
- EM was designed for the C-band photoinjector test facility beamline on the CSNS campus.
- The primary dynamic error is the displacement accuracy and the optical system resolution.
- The measurement error is down to 7.3% for our emittancemeter using the 10 um slit.



EM parameters design

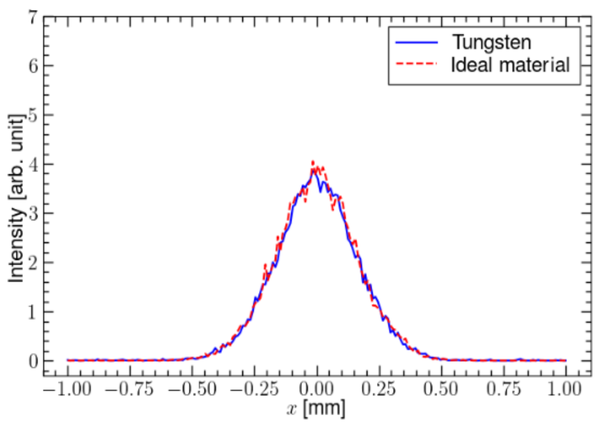
EM scheme



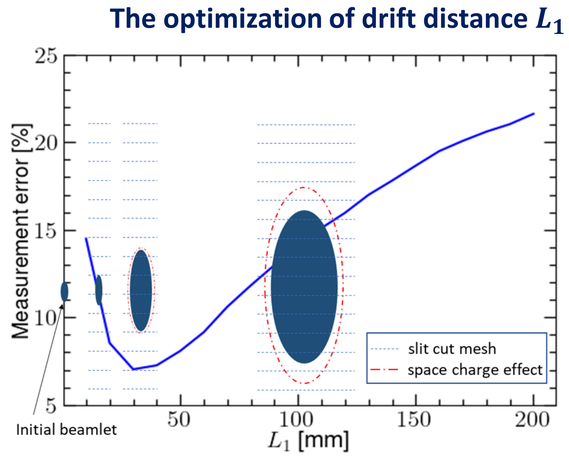
Beam parameters

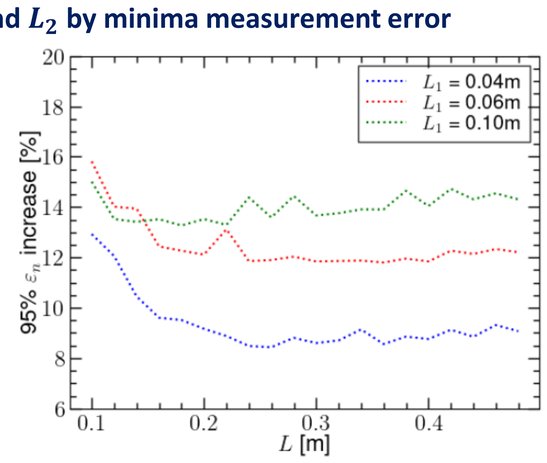
	value	unit
Energy	7.3	MeV
Bunch charge	100	pC
Rms beam size	42.5	μm
Rms beam divergence	36.9	mrad
Beam emittance	0.175	mm-mrad

Beamlet distribution at downstream after beam through the mask(MCNP-X)



The optimization of drift distance L_1 and L_2 by minima measurement error



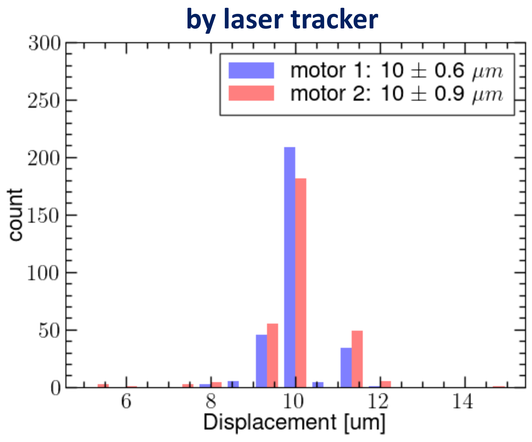


- The slit mask must effectively block or deflect the peripheral particles ⇒ slit mask thickness = 1 mm
- The beamlet should be divided into the sub-beamlets with lower bunch charge before the distribution is significantly altered. ⇒ A appreciated L_1 = 0.04 m
- After being further attenuated by the second slit, the sub-beamlet is **emittance dominant** when the drift distance is sufficiently large.

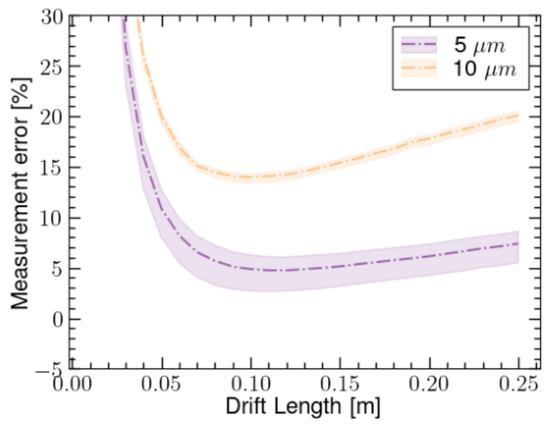
Optimization with dynamic error

- The displacement accuracy measurement result : ~1 μm
- The resolution of observation system: <10 μm
- The optimization of drift distance for single-slit scan ⇒ a 5 μm slit width is need (error < 10%).
- To minimal the measurement error for the consecutive double-slit scan ⇒ $L_2 = 0.24$ m

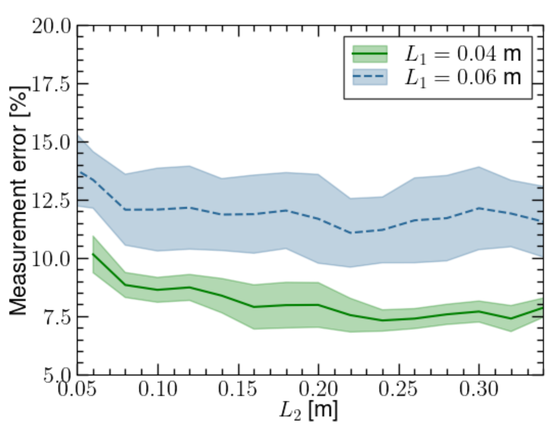
The displacement accuracy measured by laser tracker



single-slit scan



Consecutive double-slit scan



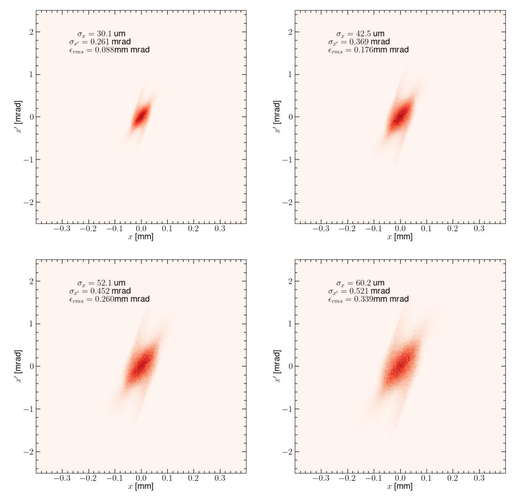
The scope of applications

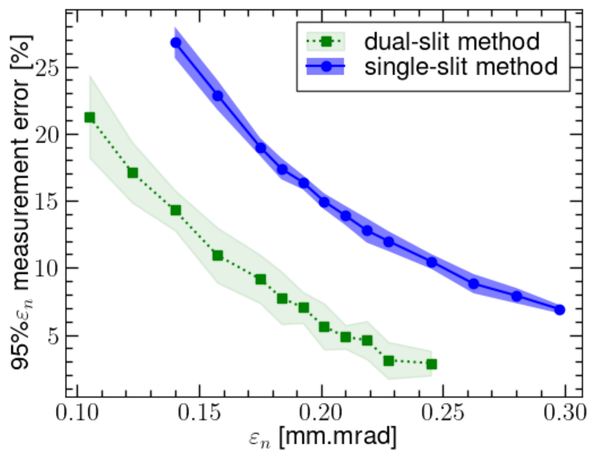
- We simultaneously alter x and x', thereby varying the emittance.

$$\begin{pmatrix} y \\ \mathcal{P}_y \end{pmatrix} = \sqrt{\beta}\,\mathrm{B}^{-1} \begin{pmatrix} y \\ y' \end{pmatrix}$$

$$\begin{pmatrix} y \\ y' \end{pmatrix} = \frac{1}{\sqrt{\beta}}\,\mathrm{B} \begin{pmatrix} y \\ \mathcal{P}_y \end{pmatrix}$$

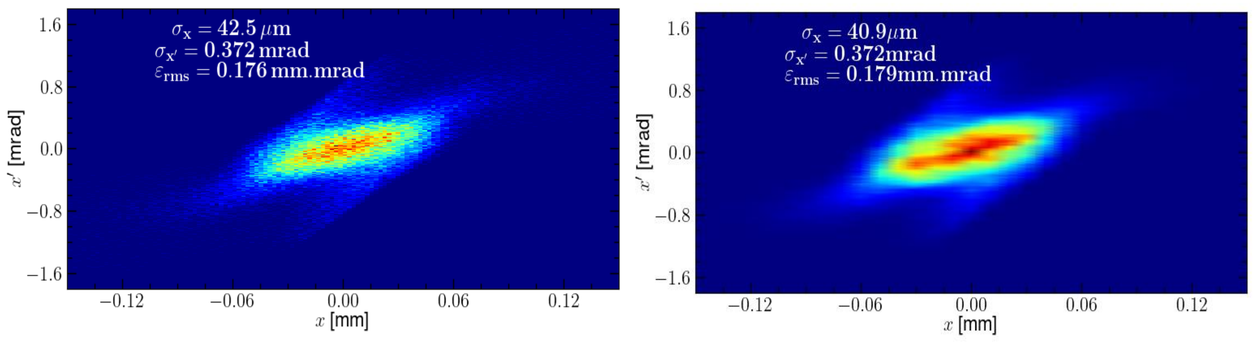
- For an emittance of 0.15-0.25 mm-mrad, the measurement error of consecutive double-slit scan remains below 10%
- A fast measurement can be achieved by using one of the two slits when measuring large emittances





Conclusion & perspective

The initial phase space and the reconstructed phase space



- The predicted minimum measurement error is 7.3% with the following parameters: a 10 μm slit width, a 1 mm slit thickness, a 0.04 m beamlet drift, and a 0.24 m sub-beamlet drift.
- The applicability of the EM is determined as measuring emittances over 0.15~mm-mrad with a measurement error of less than 10\%.
- A new EM with orthodoxies slit is designing