Mapping Characteristics of Solenoid Lenses

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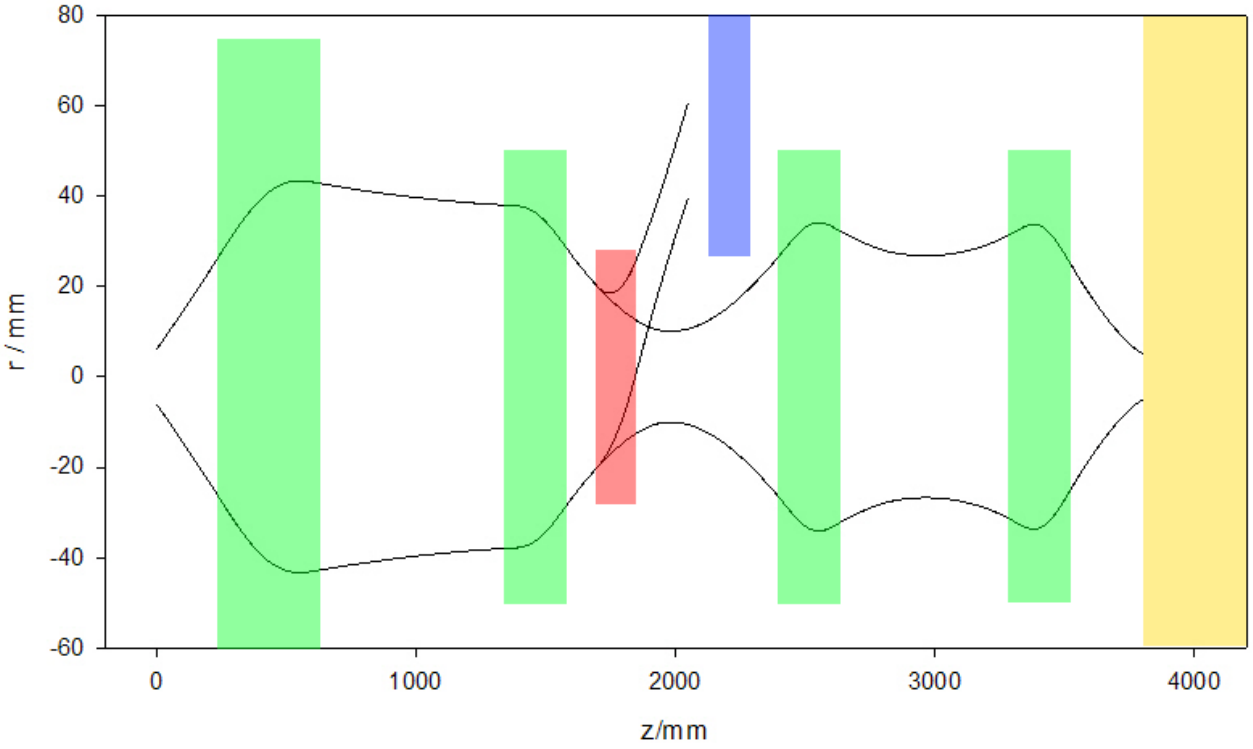
Motivation

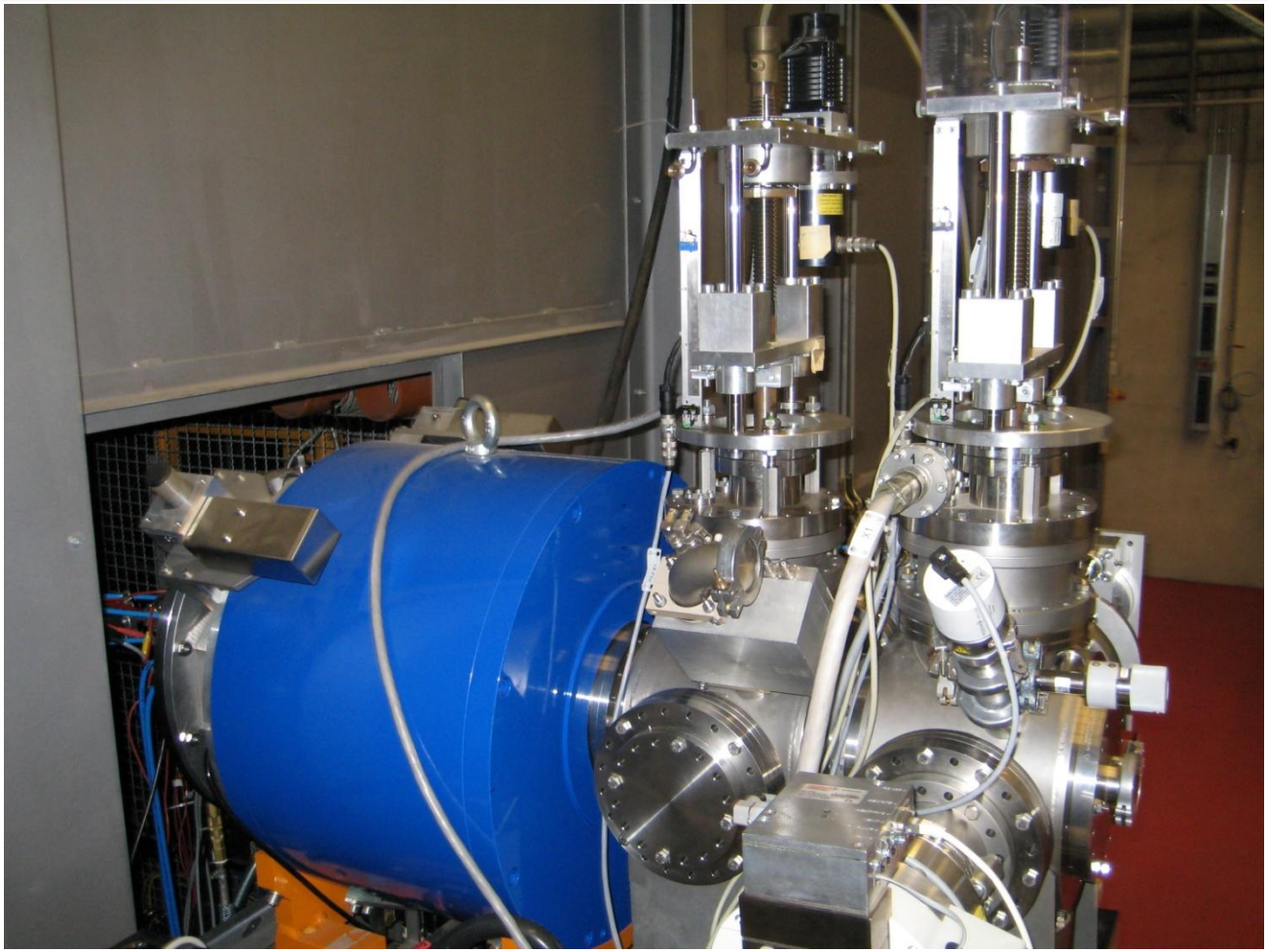
Beam simulation envelope H^+
150 mA with 10% H_2 and H_3-Fraction
Beam energy: 120 keV

Green: Solenoids
Red: Chopper
Blue: Septummagnet
Yellow: RFQ

FRANZ
Low Energy Beam Transport Section

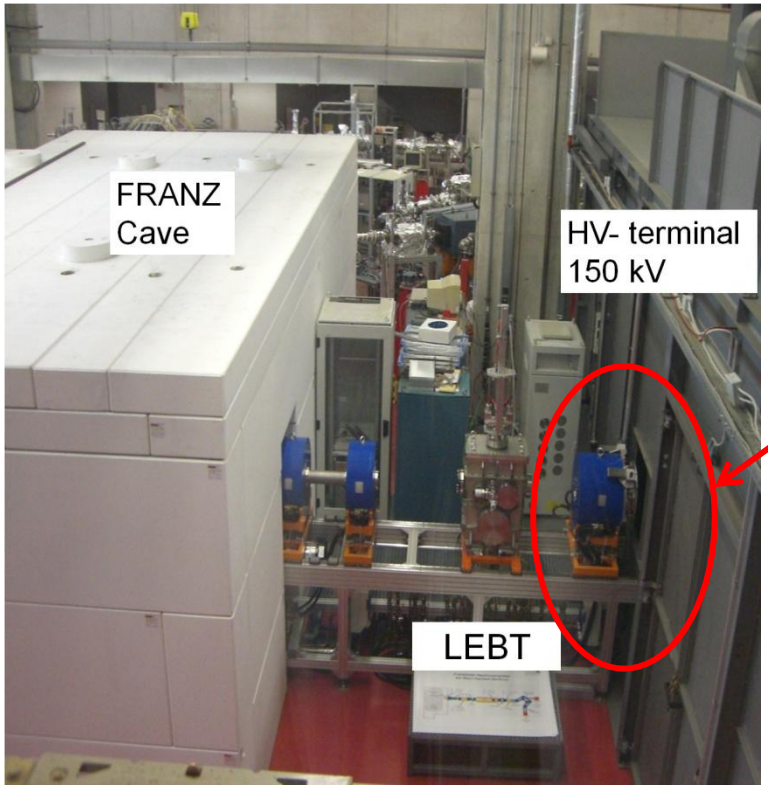


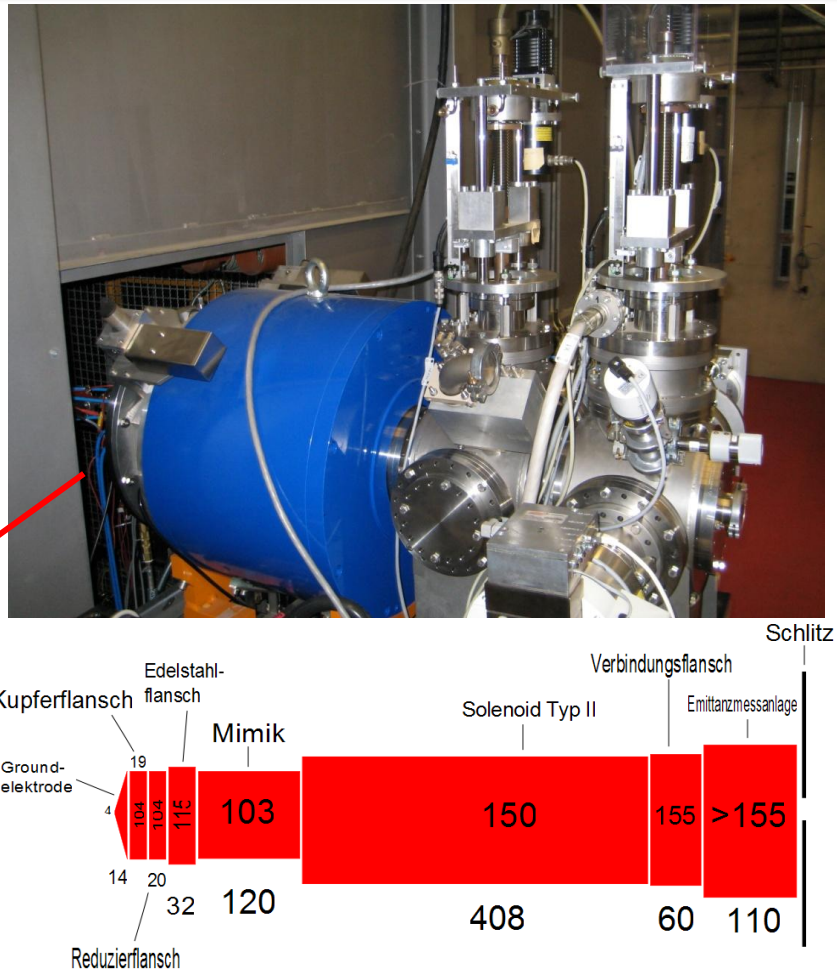
Experimental Setup



Experimental Setup

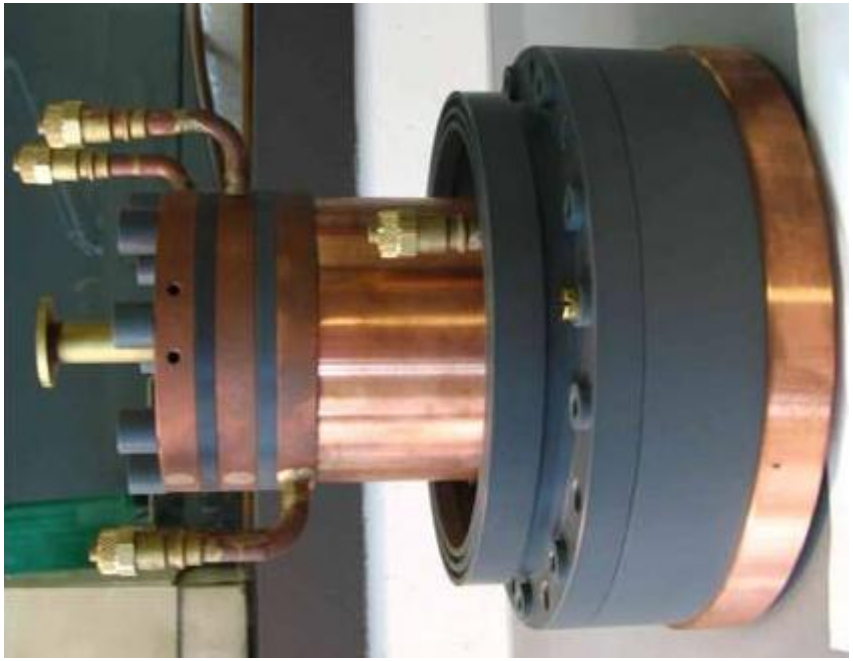
IAP Experimental hall:

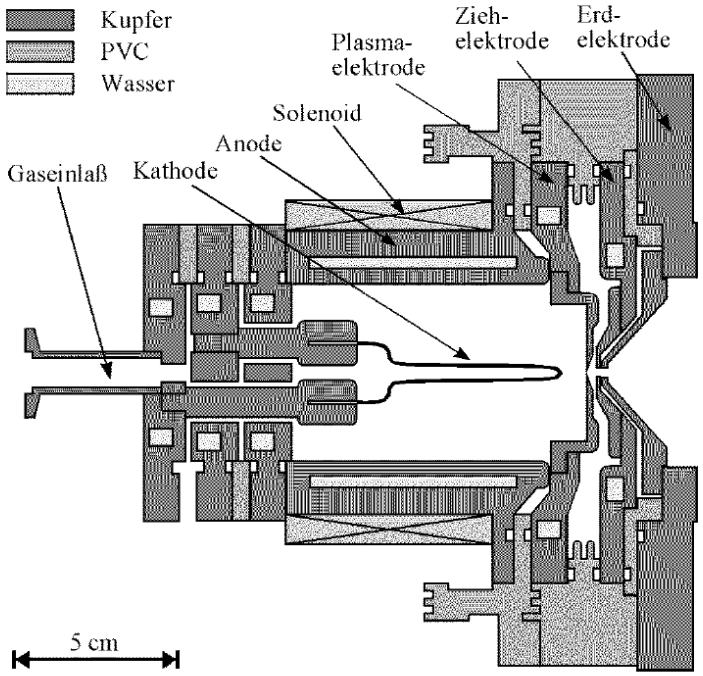




Components

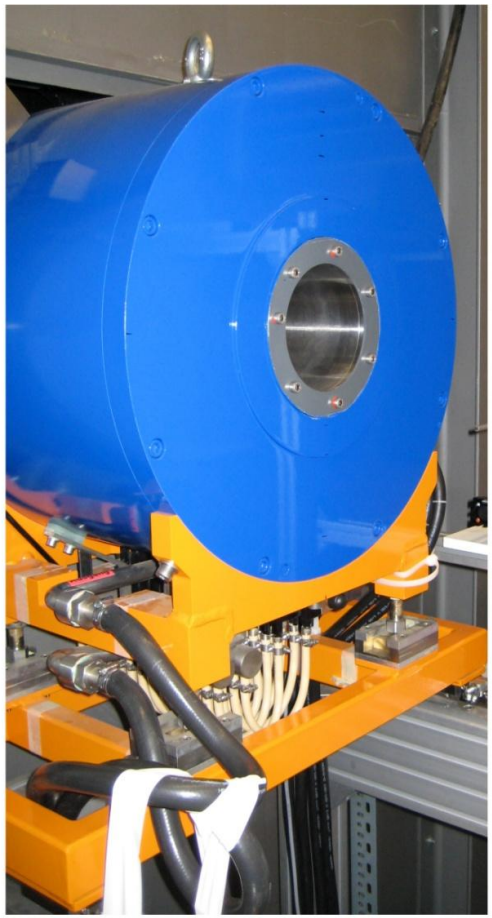
- Ion source-





Components

- Solenoid -

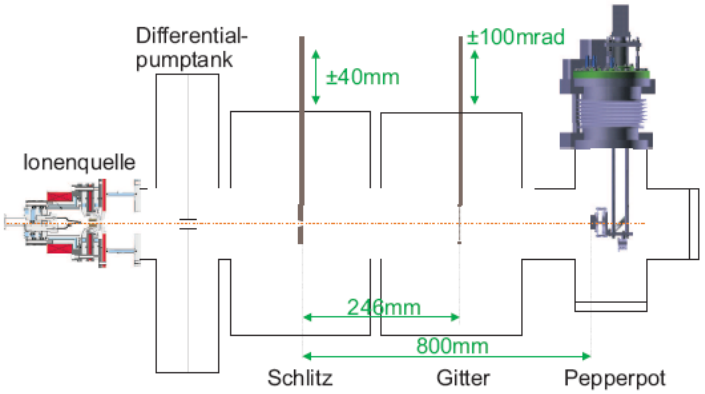


Aperture radius	75 mm
Length	408 mm
Maximum current	400 A
Maximum field on axis	791 mT

Field scales linear with current.

Components

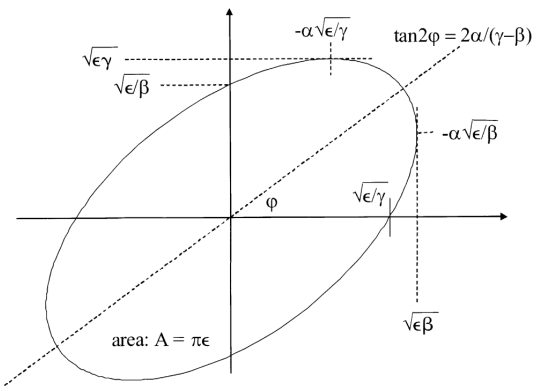
- Emittance measurement device -



Analytics

- Drift and Solenoid -

Phase space ellipse:



Ellipse equation:

$$\gamma x^2 + 2\alpha x x' + \beta x'^2 = \epsilon$$

Mapping of twiss parameters:

Drift:

$$\begin{pmatrix} \beta & -\alpha \\ -\alpha & \gamma \end{pmatrix} = \begin{pmatrix} 1 & L \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} \beta_0 & -\alpha_0 \\ -\alpha_0 & \gamma_0 \end{pmatrix} \cdot \begin{pmatrix} 1 & 0 \\ L & 1 \end{pmatrix}$$

$$\alpha = \alpha_0 - L\gamma_0$$
$$\beta = \beta_0 - 2L\alpha_0 + L^2\gamma_0$$
$$\gamma = \gamma_0$$

L: drift length

Solenoid:

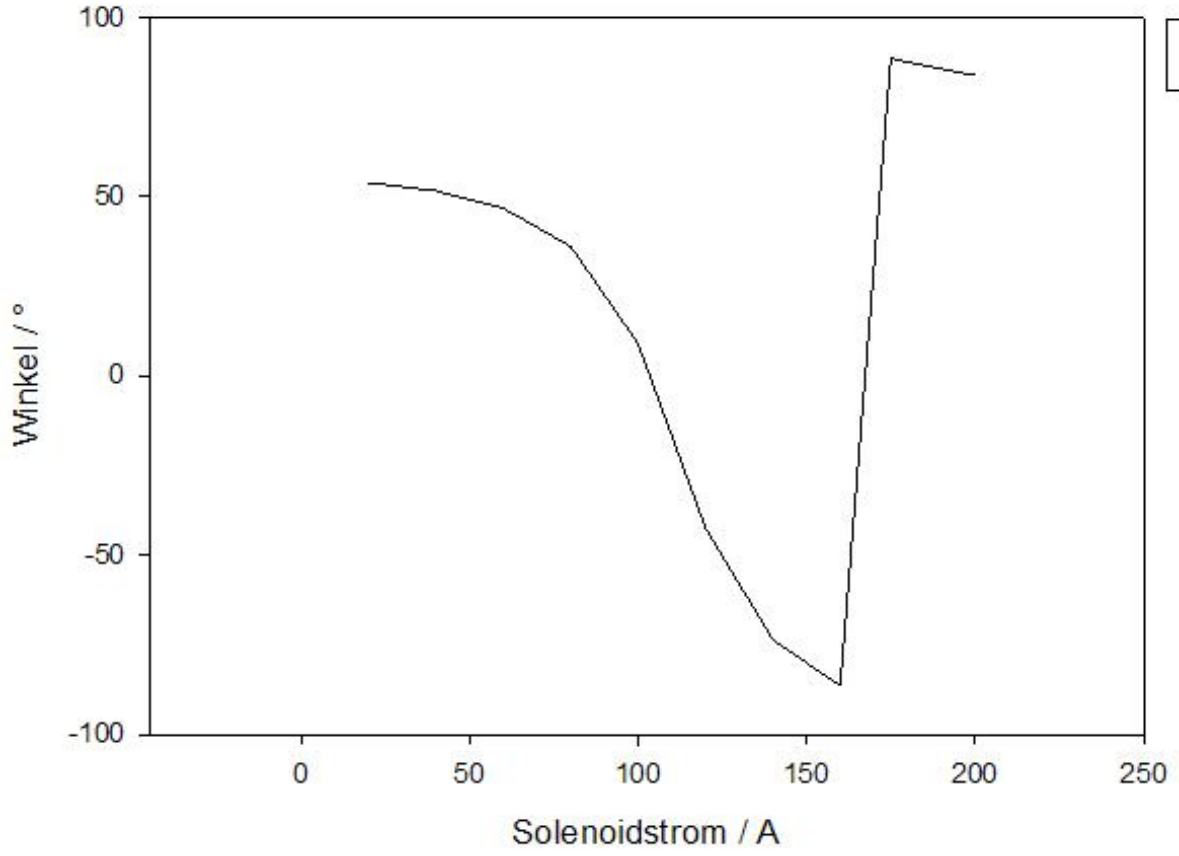
$$\begin{pmatrix} \beta & -\alpha \\ -\alpha & \gamma \end{pmatrix} = \begin{pmatrix} cos^2(ks) & \frac{sin(ks)}{k} \\ -ksin(ks) & cos(ks) \end{pmatrix} \cdot \begin{pmatrix} \beta_0 & -\alpha_0 \\ -\alpha_0 & \gamma_0 \end{pmatrix} \cdot \begin{pmatrix} cos^2(ks) & -ksin(ks) \\ \frac{sin(ks)}{k} & cos(ks) \end{pmatrix}$$

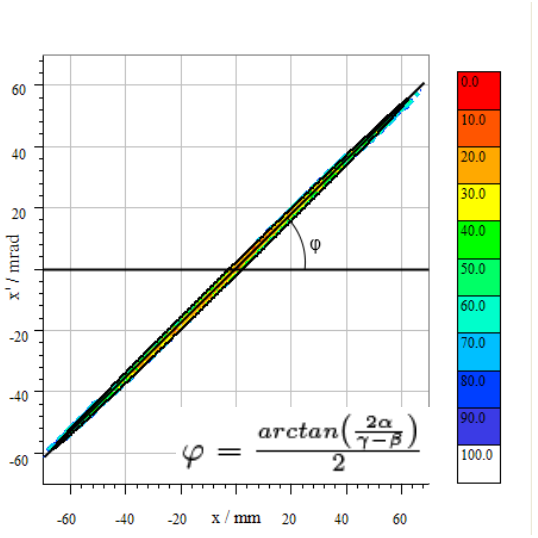
$$\alpha = kcos(ks)sin(ks)\beta_0 - sin^2(ks)\alpha_0 + cos(ks)^2\alpha_0 - \frac{cos(ks)sin(ks)}{k}\gamma_0$$
$$\beta = cos(ks)^2\beta_0 - 2\frac{cos(ks)sin(ks)\alpha_0}{k} + \left(\frac{sin(ks)}{k}\right)^2\gamma_0$$
$$\gamma = ksin^2(ks)\beta_0 + 2ksin(ks)cos(ks)\alpha_0 + cos^2(ks)\gamma_0$$

$$k = \frac{eB_{0,max}}{2p}$$

s: Effective field length
B: Maximum axis field
p: Particle momentum

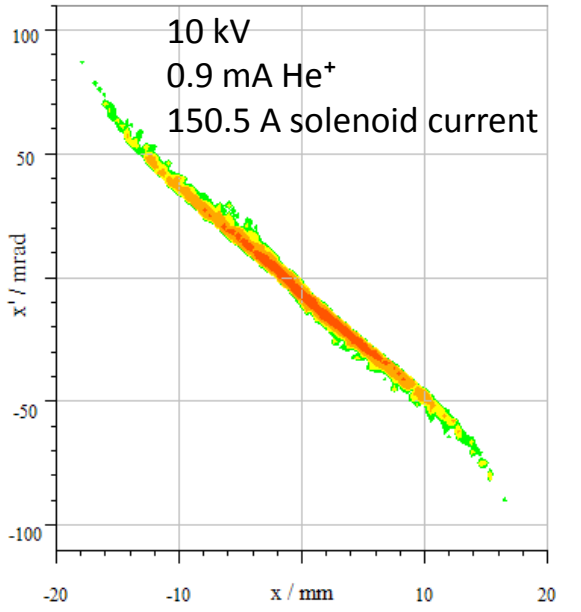
Analytics


Analytische Rechnung
Winkel / °
Solenoidstrom / A
100
50
0
-50
-100
0
50
100
150
200
250

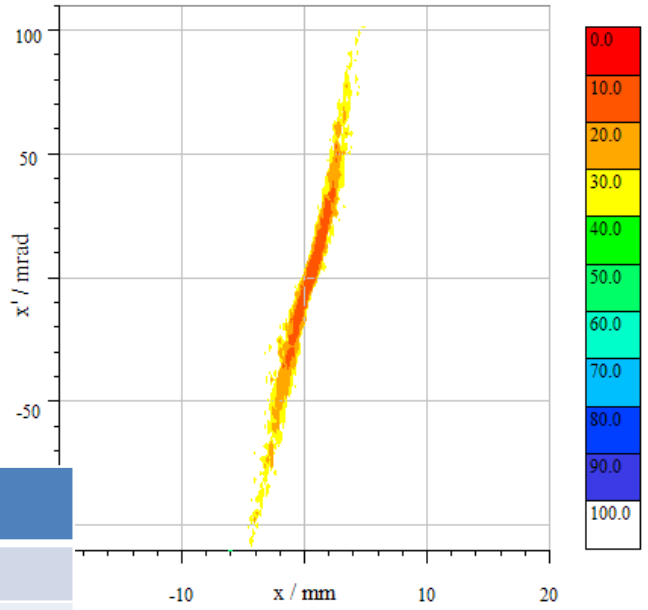

x' / mrad
x / mm
φ
$\varphi = \frac{arctan\left(\frac{2\alpha}{\gamma-\beta}\right)}{2}$
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
100.0

Measured Distribution and Calculated Starting Distribution

Measured distribution at the slit of the emittance measurement device:

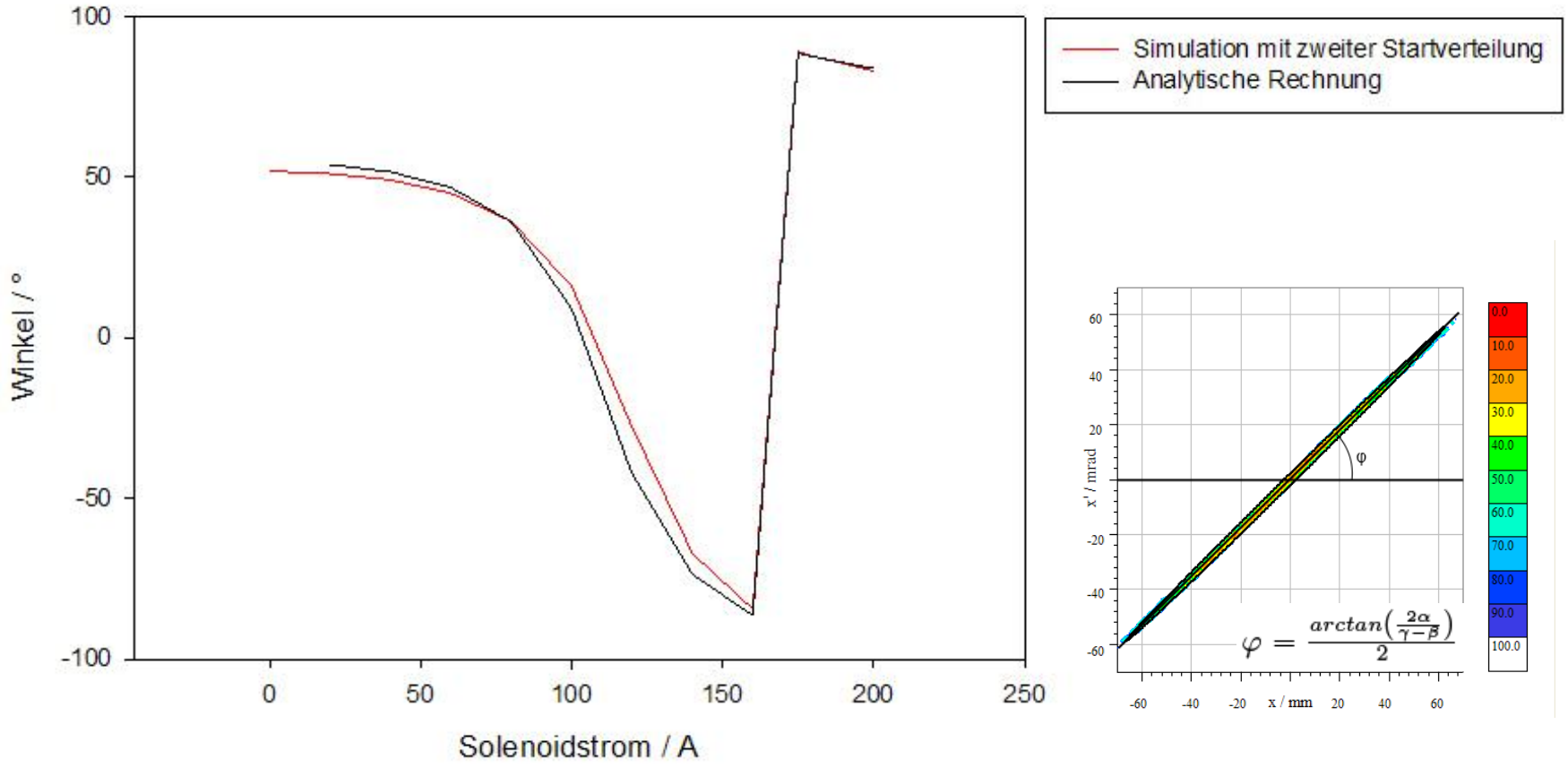


Starting distribution at the copper flange:

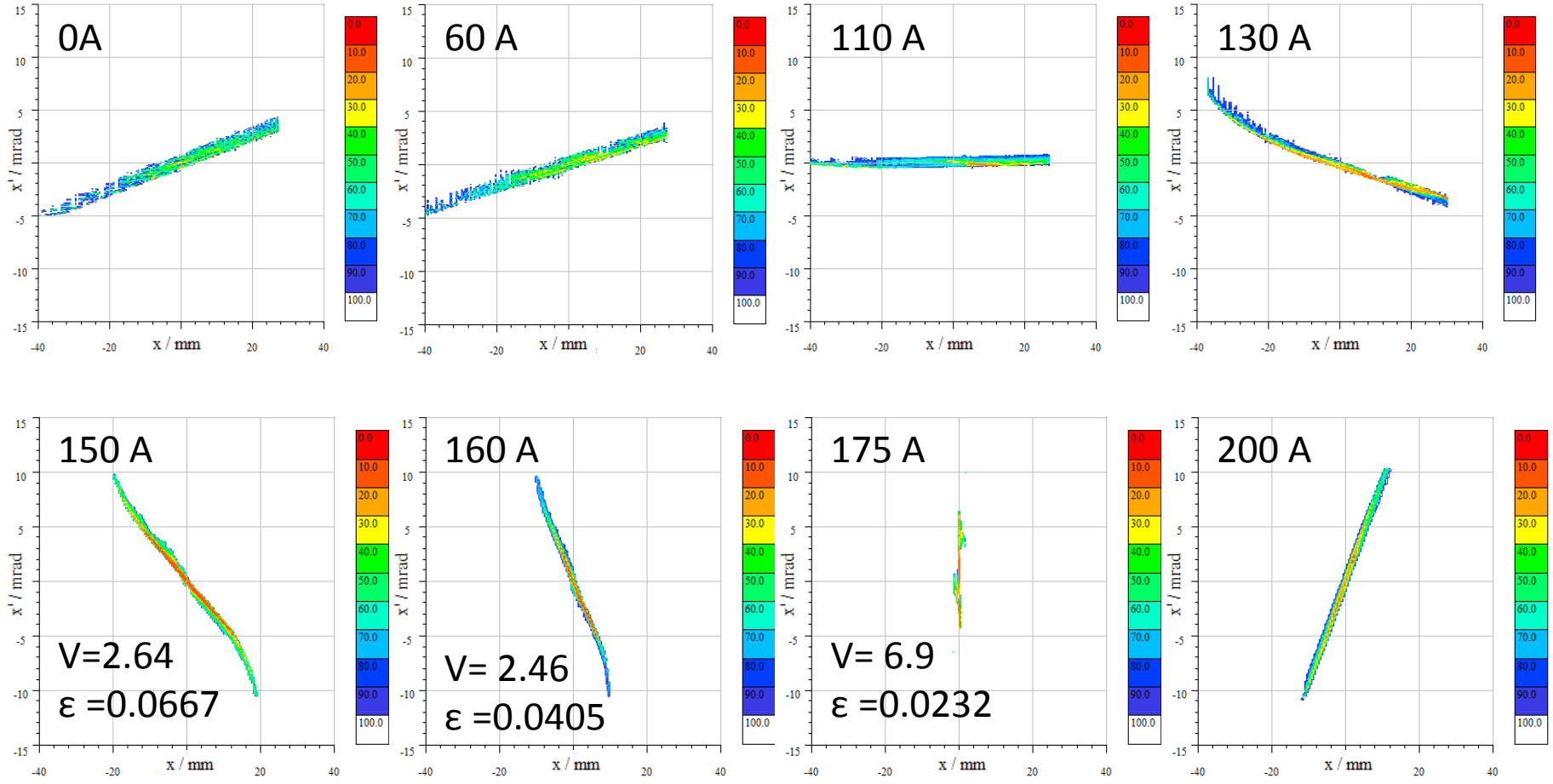


	Measured	„starting distribution“
Vtx	2.402	2.352
Vty	2.401	2.360
εx	0.0748	0.0773
εy	0.0763	0.0789
X	-18.33/18.74	-6.45/6.91
X‘	-109.1/101.7	-130.1/136.2

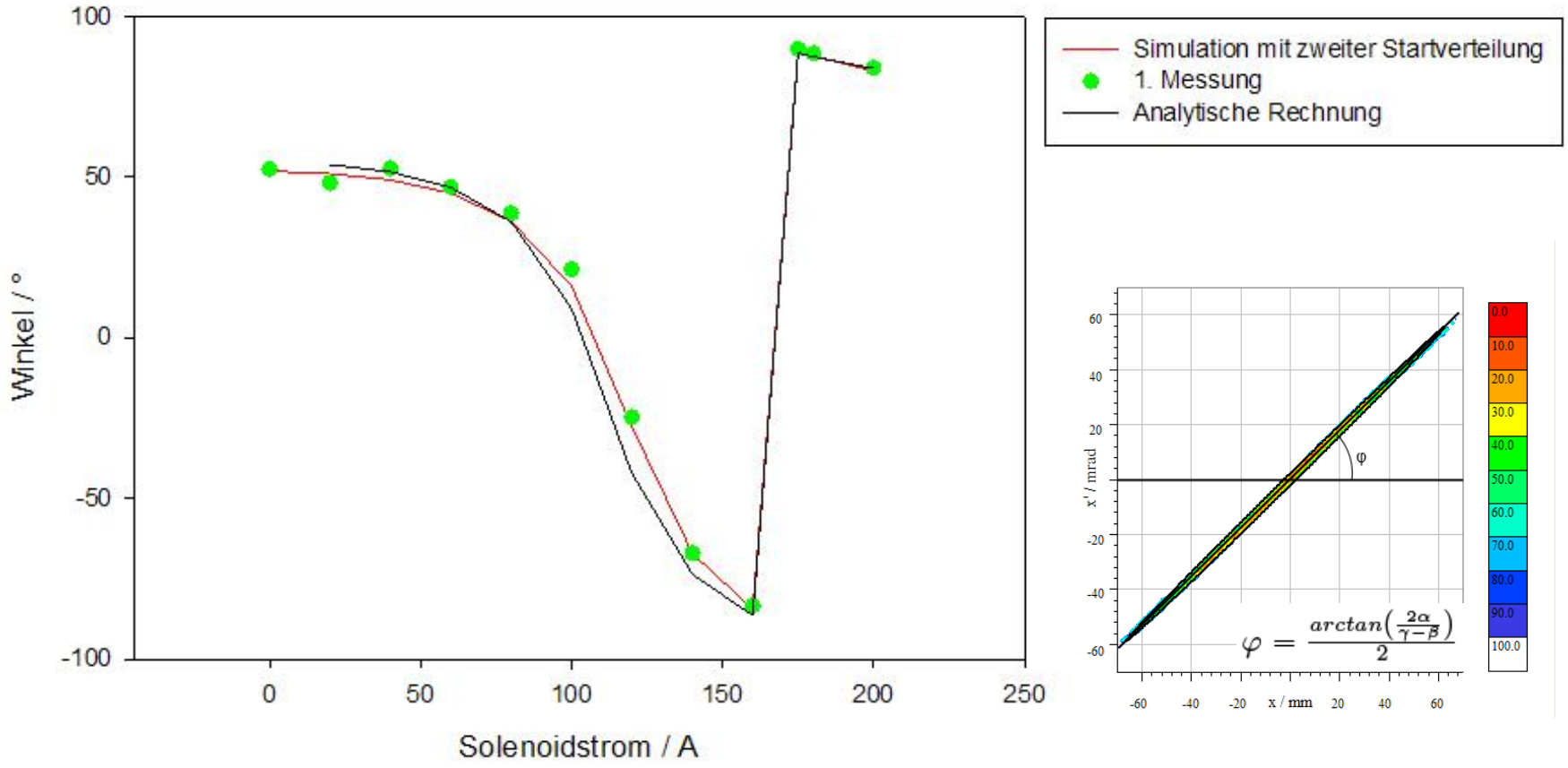
Comparison Between Analytics and Simulation



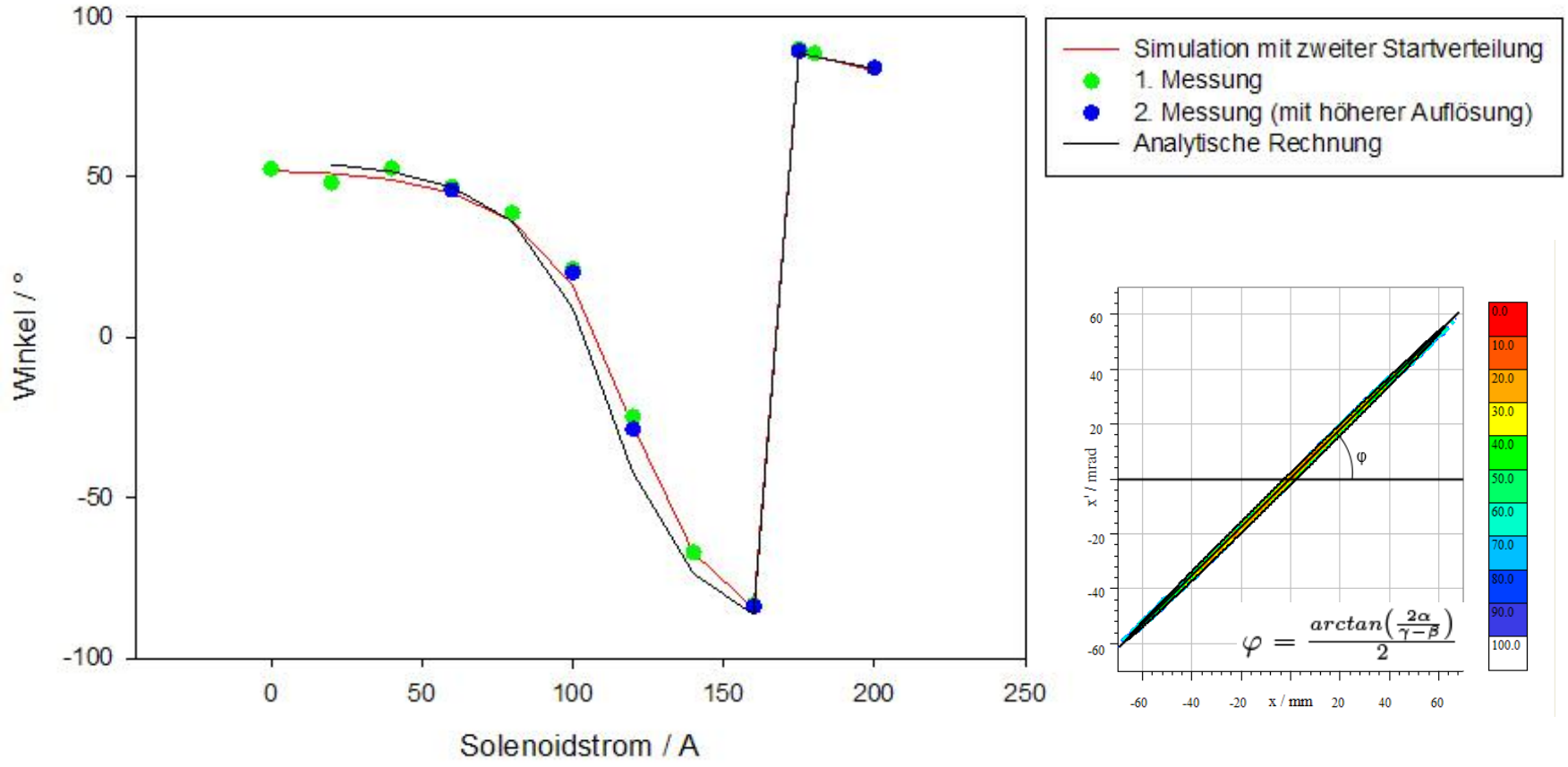
Emittance Measurement



Comparison Between Analytics, Simulation and Measurement



Comparison Between Analytics, Simulation and Measurement



Conclusion

- Analytics, simulations and measurement show good agreement
- Emittance seems to be reduced with higher solenoid current -> lower beam radius in solenoid aperture

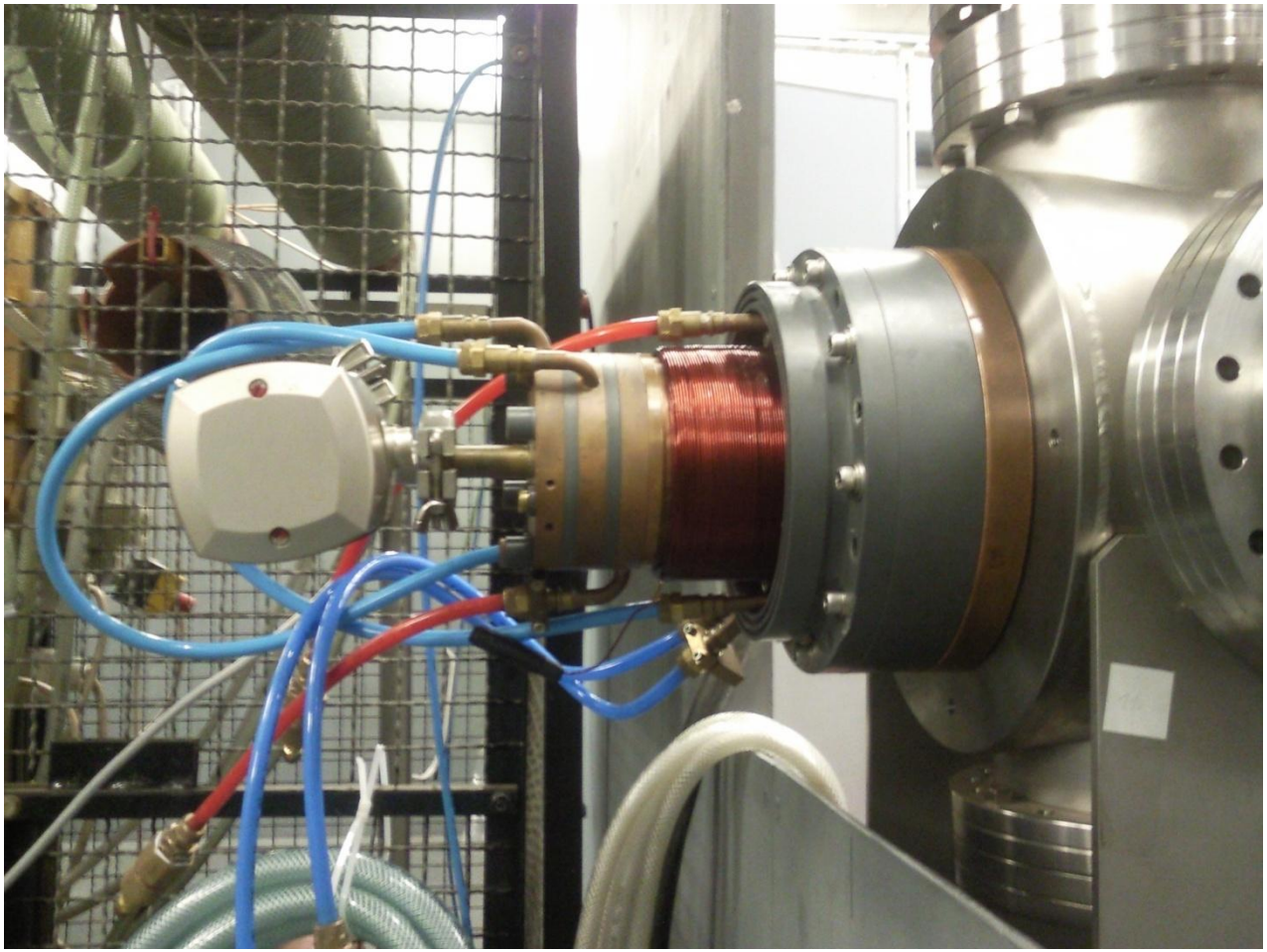
Outlook

- Emittance measurements with solenoid currents between 150 and 180 A
- Measurements with the y-plane
- Measurements with momentum and perveance equivalent (30kV, 9.375 mA)
- Analysis of emittance growth as a function of first solenoid filling degree
- Ion source extraction with position and angular offset

Thank you for your attention

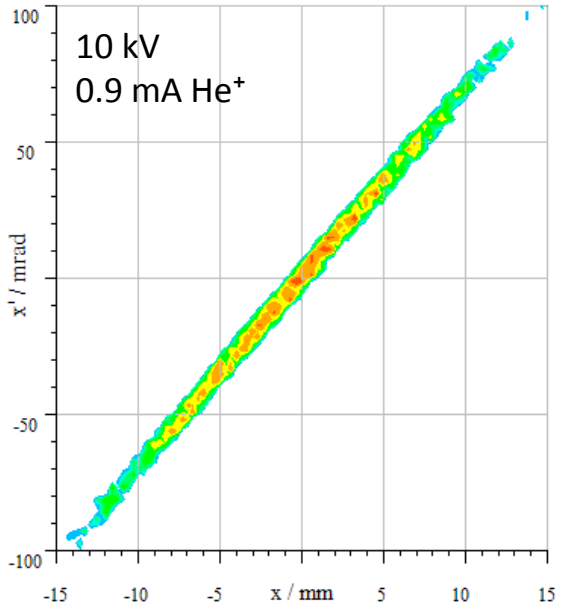
Direkte Emittanzmessung

- Erster Aufbau –

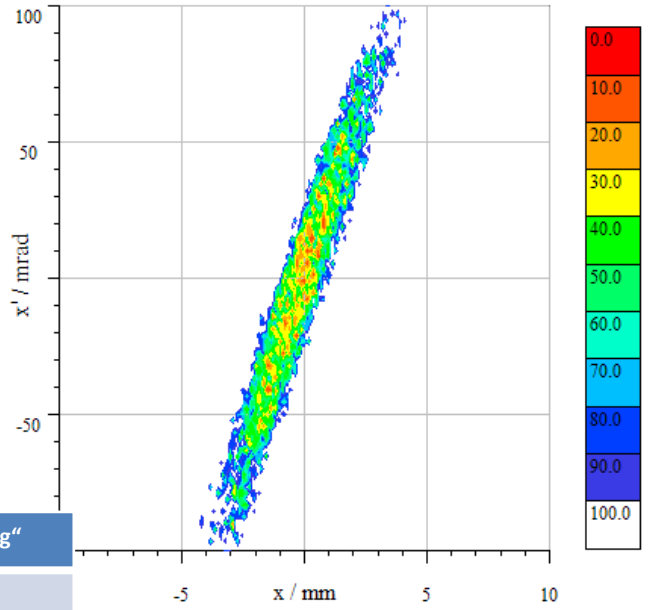


Gemessene Verteilung und errechnete Startverteilung

Gemessene Verteilung am Schlitz der Emittanzmessanlage:

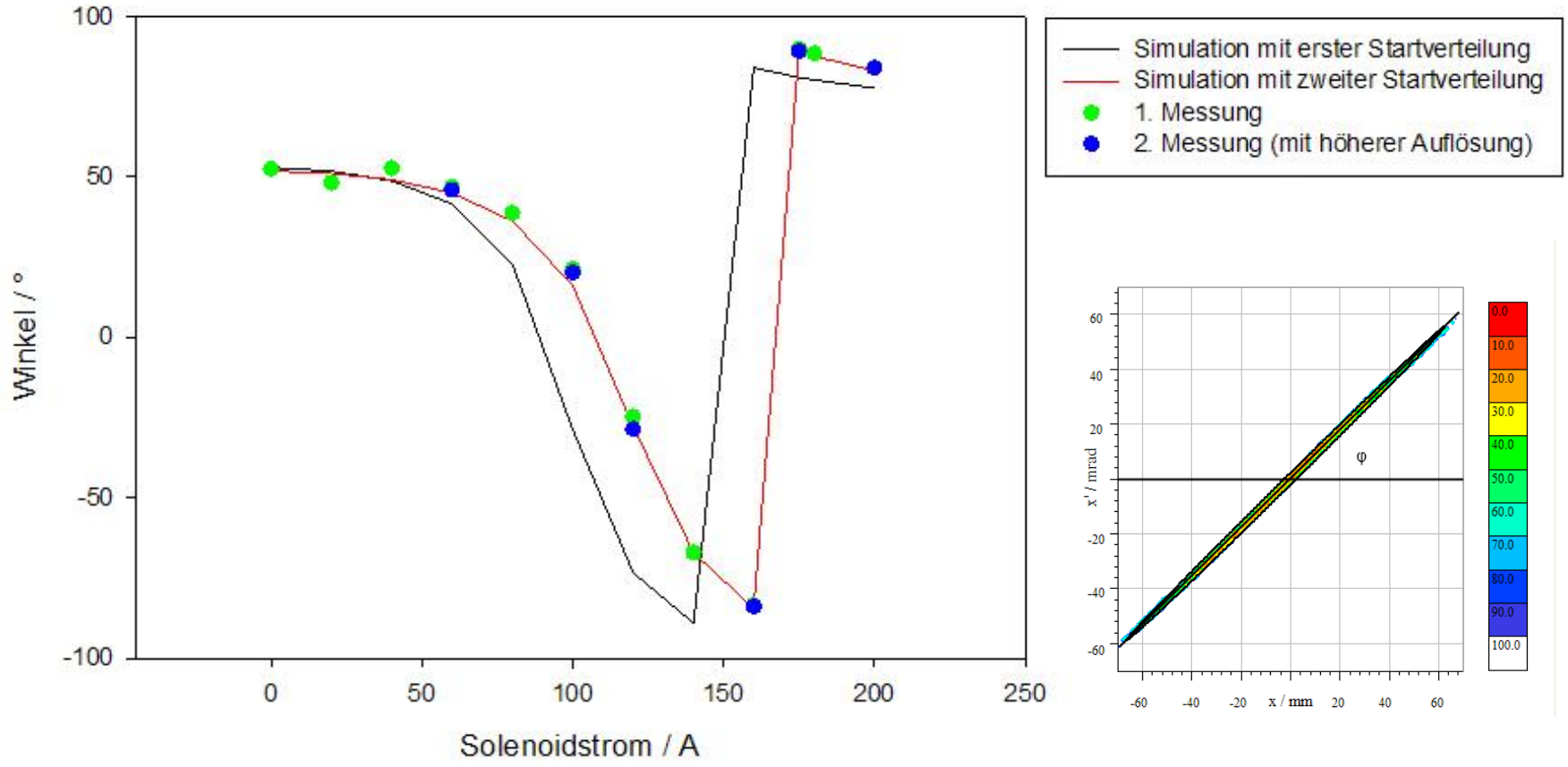


Zum Kupferflansch zurückgerechnete „erste Startverteilung“:

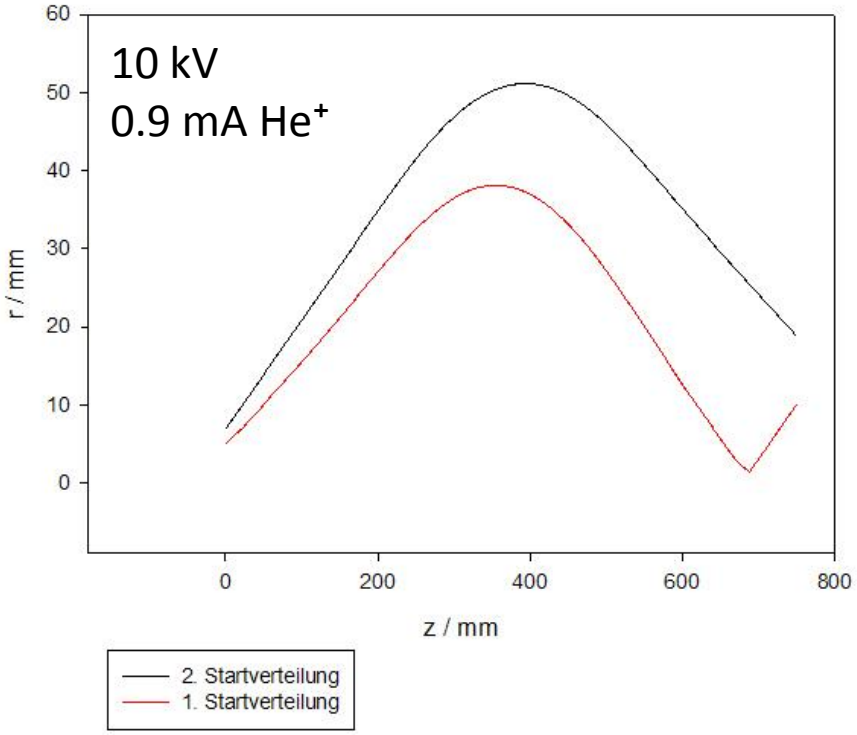


	Gemessen	„Startverteilung“
Vtx	2.242	2.371
Vty	2.216	2.336
εx	0.0597	0.0595
εy	0.0601	0.0599
X	-16.19/16.40	-4.78/4.87
X‘	-113.7/113.3	-110.2/109.9

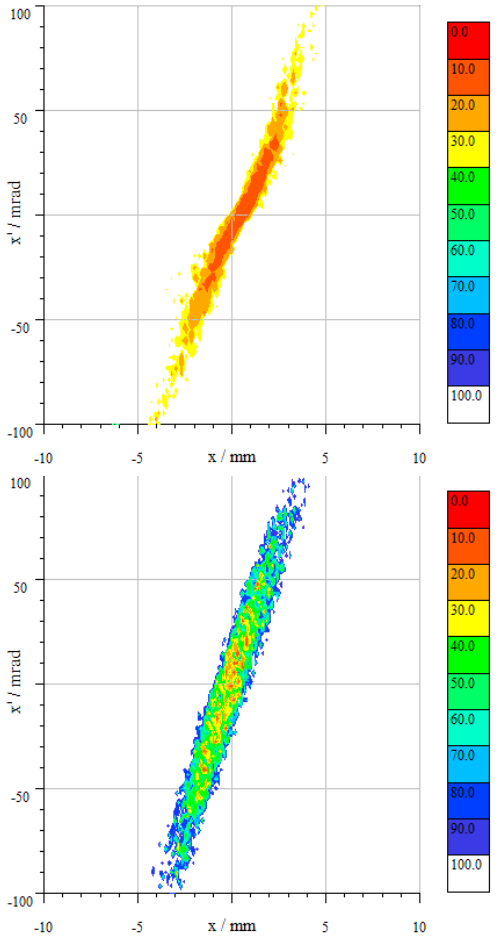
Vergleich Simulation und Messung



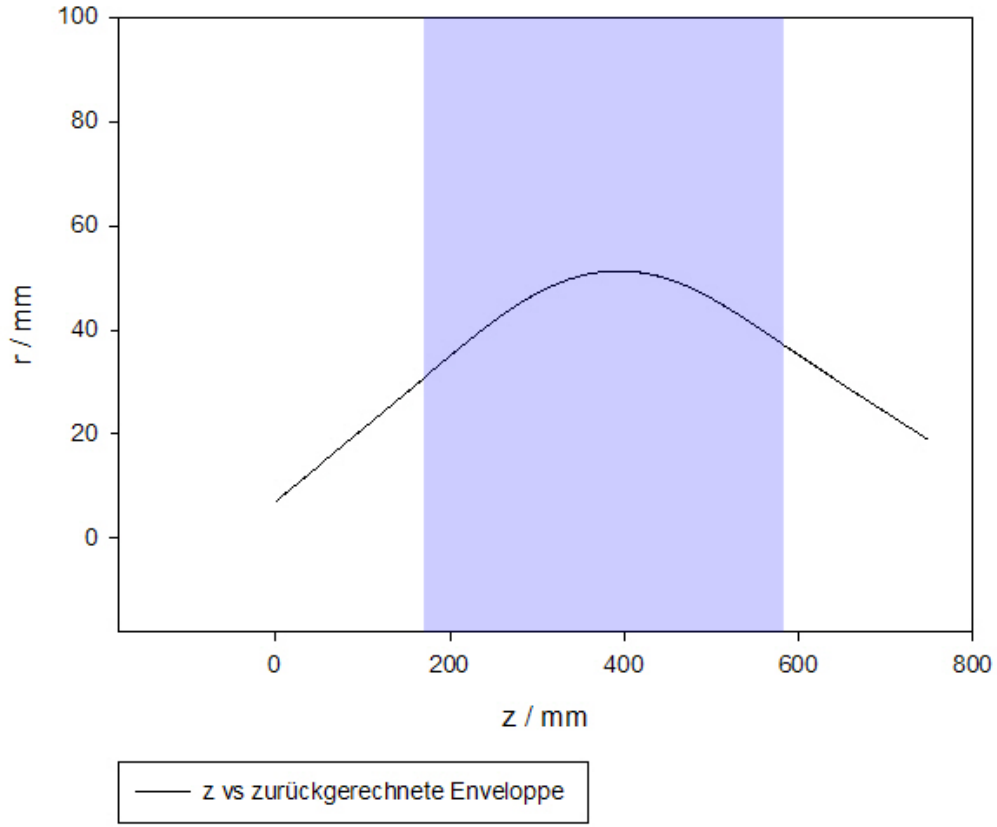
Simulation mit unterschiedlichen Startverteilungen



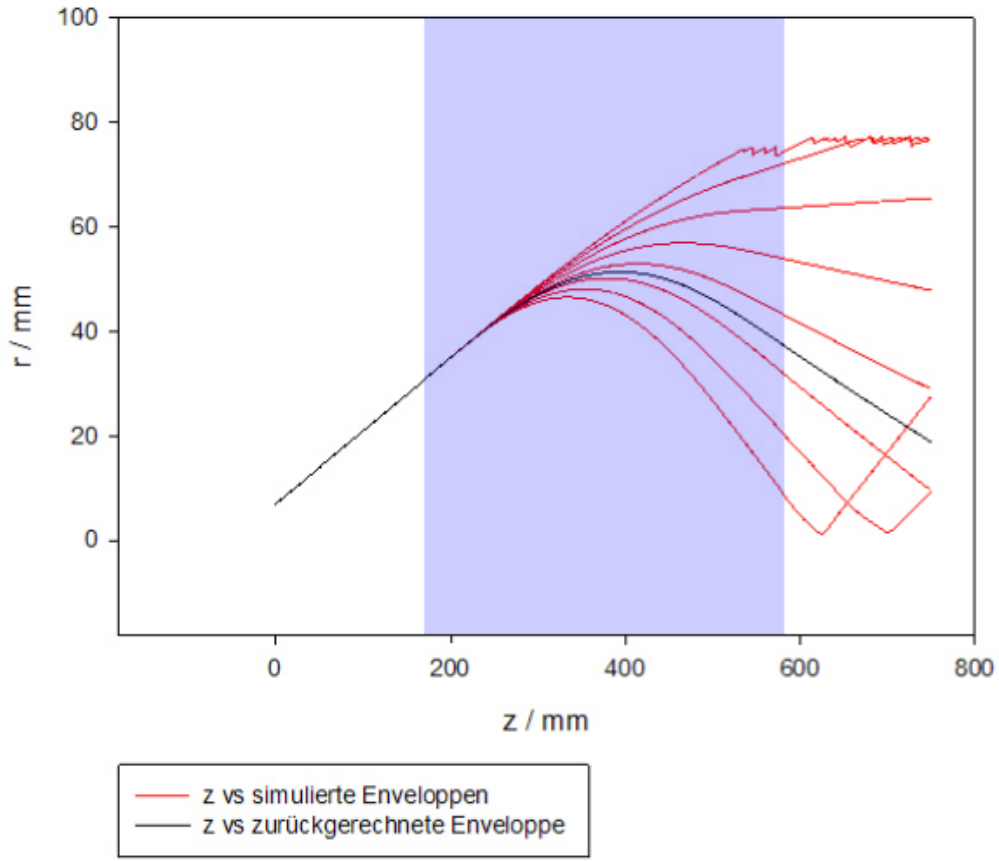
	2. Verteilung	1. Verteilung
Vtx	2.35	2.371
Vty	2.36	2.336
εx	0.07727	0.0595
εy	0.07894	0.0599
X	-6.45/6.91	-4.78/4.87
X‘	-130.1/136.23	-110.2/109.9



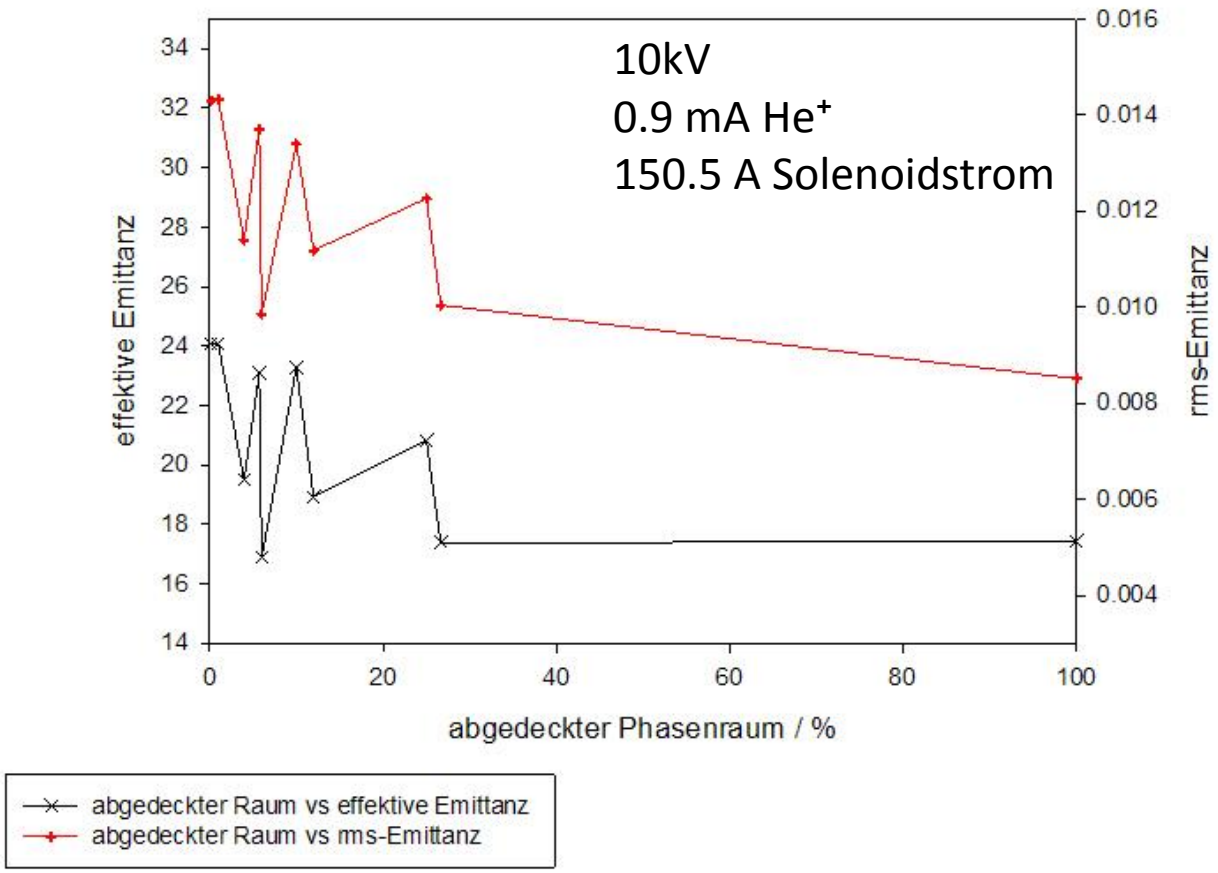
Die Simulation



Die Simulation



Abhängigkeit der Emittanz von der Auflösung der Emittanzmessanlage



Vergleich Simulation und Messung: Twiss-Parameter

Twiss-Parameter

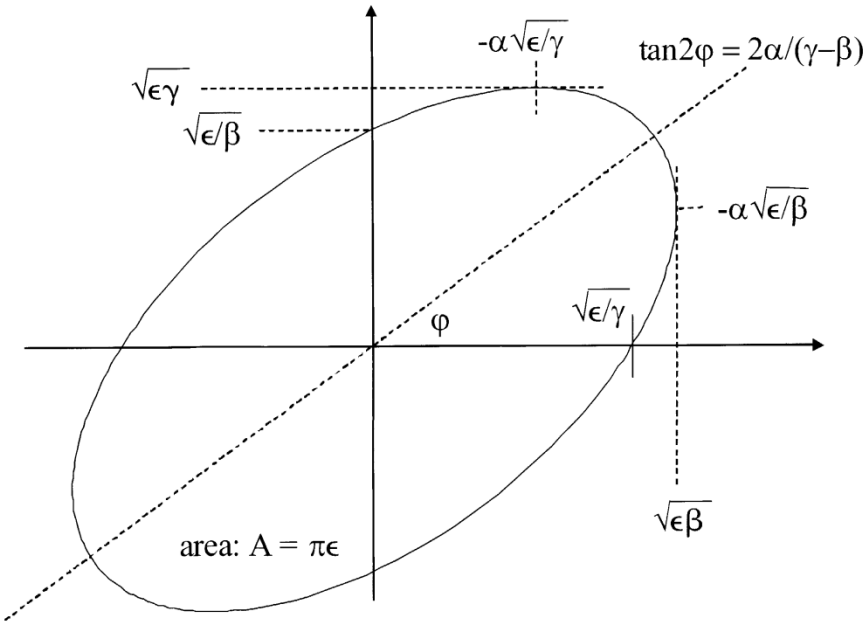
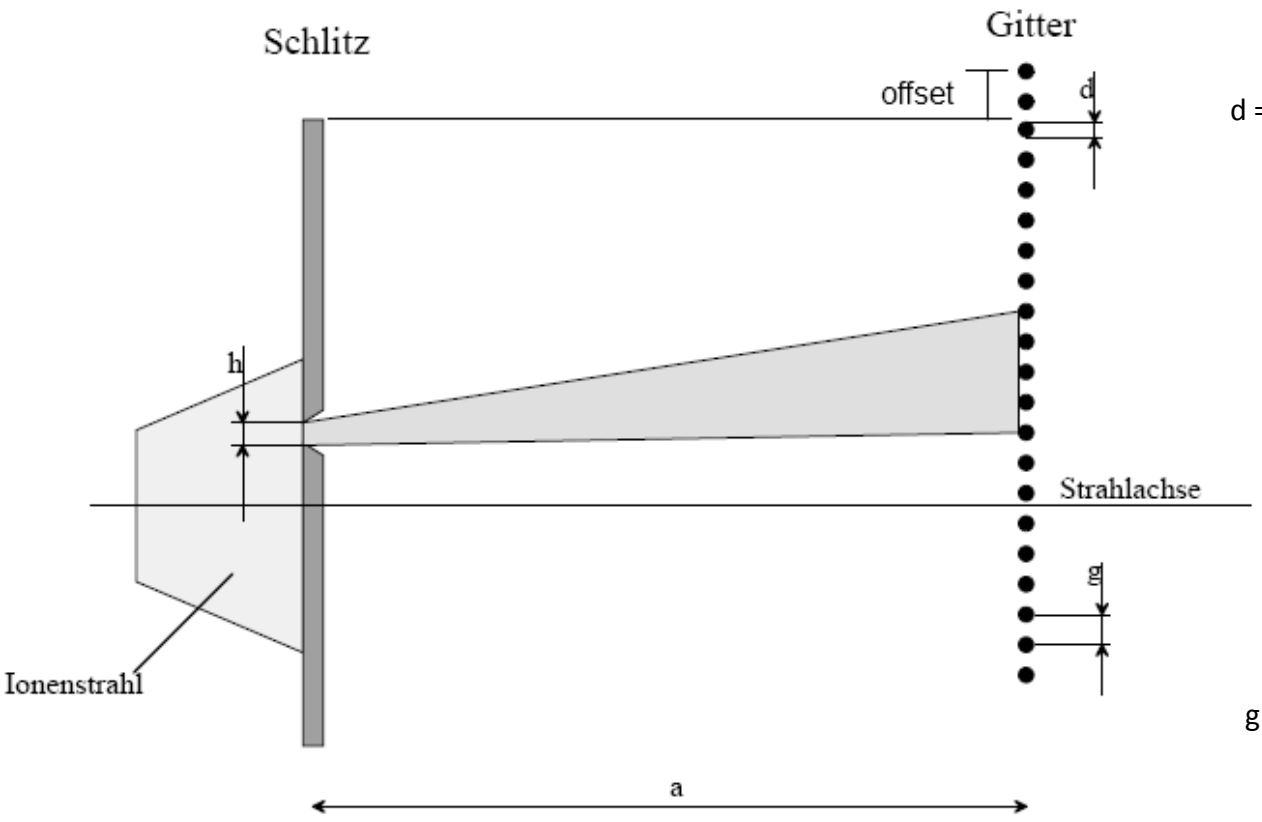


Fig. 5.2. Phase space ellipse

aus: Wiedemann, Particle Accelerator Physics

Components

- Slit grid measurement device -



d = 0.1 mm

h = 0.1 mm

g = 1 mm

a = 246 mm