Beam envelope comparison

viewer measurement and GPT

4-27-2021

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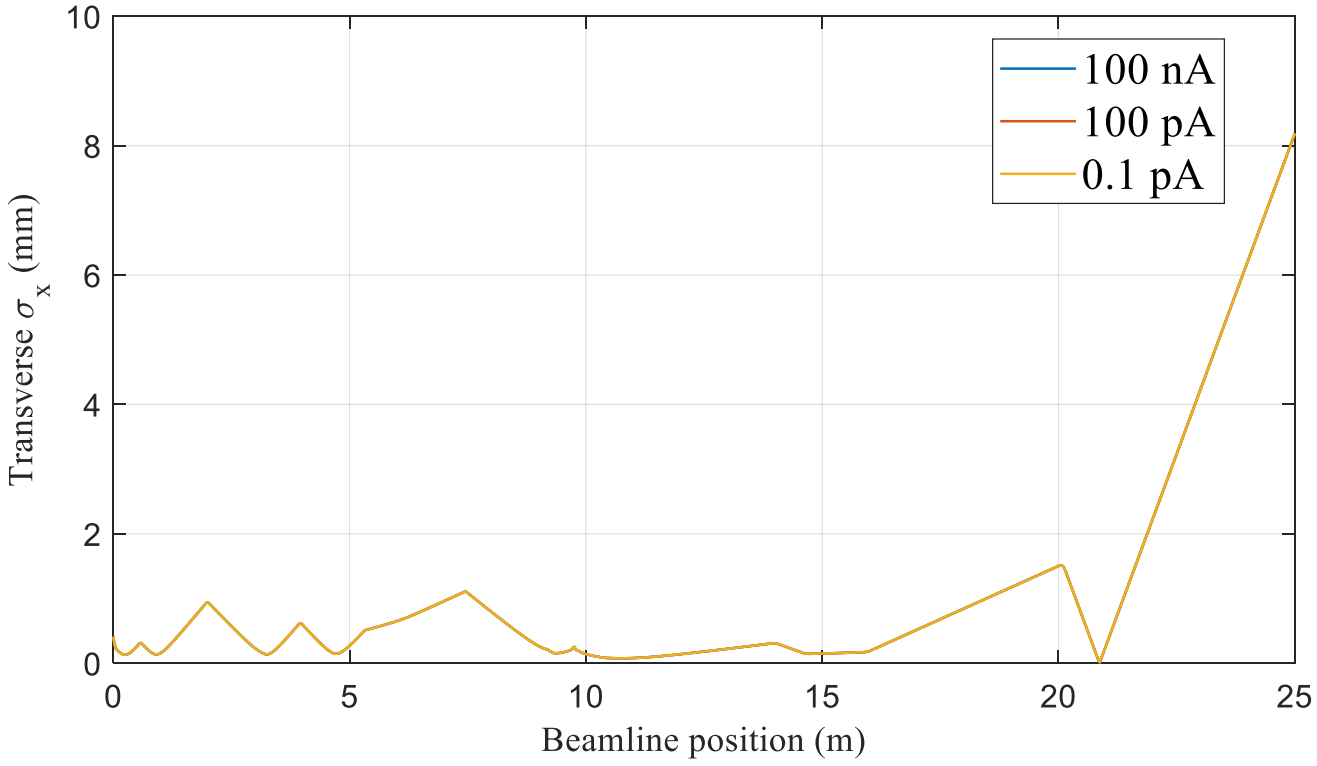
Outline

- Beam envelope under different CW beam current by GPT.
- How to convert the measurement to real size
  - Decide the viewer angle
  - Calculate the beam size
- Measurement on every viewer
  - Measurement condition, data
  - Comparison
- Measurement on the first viewer by varying MFHK101 strength
  - Measurement conditions and data
  - comparison

Beam envelope by GPT

Buncher cavity: 0.09e6 V/m, all crest energy settings for the quarter cavities.



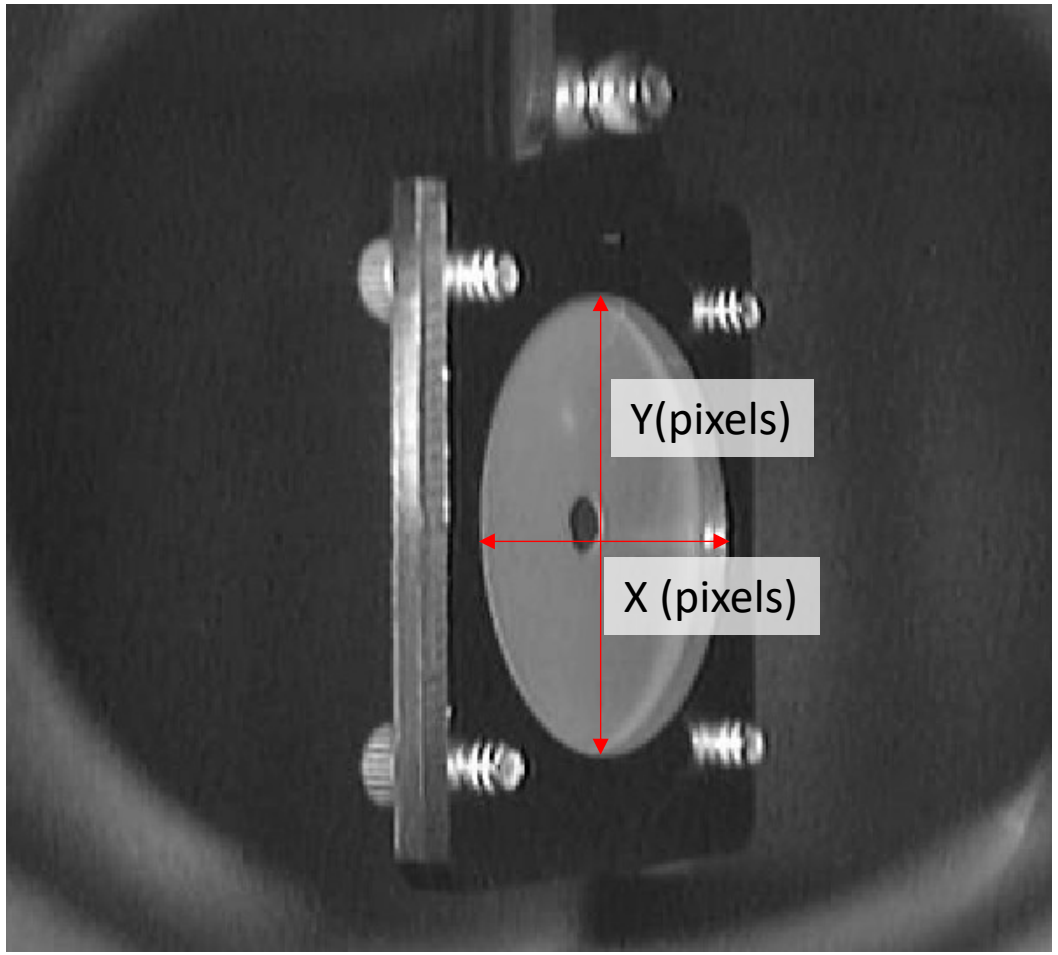
Beamline constraints:
12-19m, interior diameter 1.375” ~ 35mm, r~17.5mm.
Dipole1: ~17.4112m, 2*10.4mm diameter.
Dipole2: 18.6104m, 2*17.4625mm diameter.

3*sigma, 6*sigma (diameter)

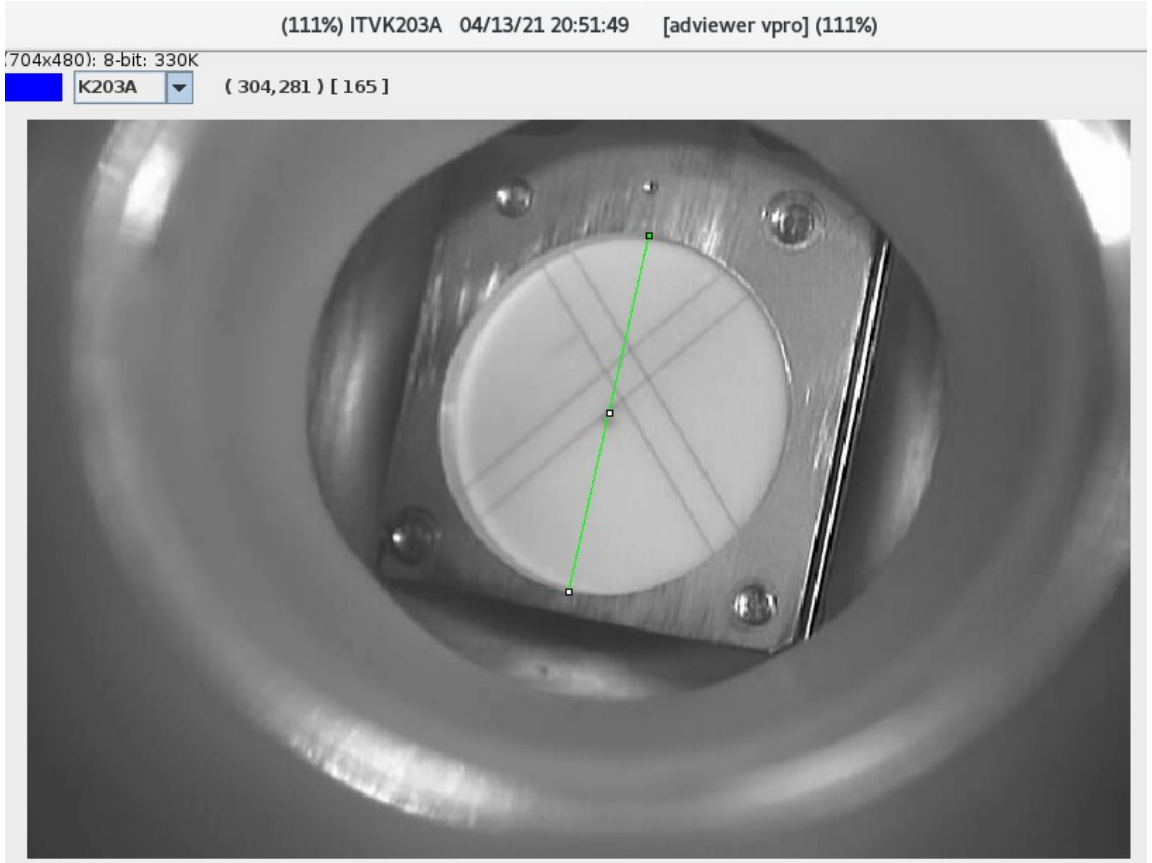
They are almost the same due to the low space charge effect.

Viewer image

Viewer, Parallel to y axis



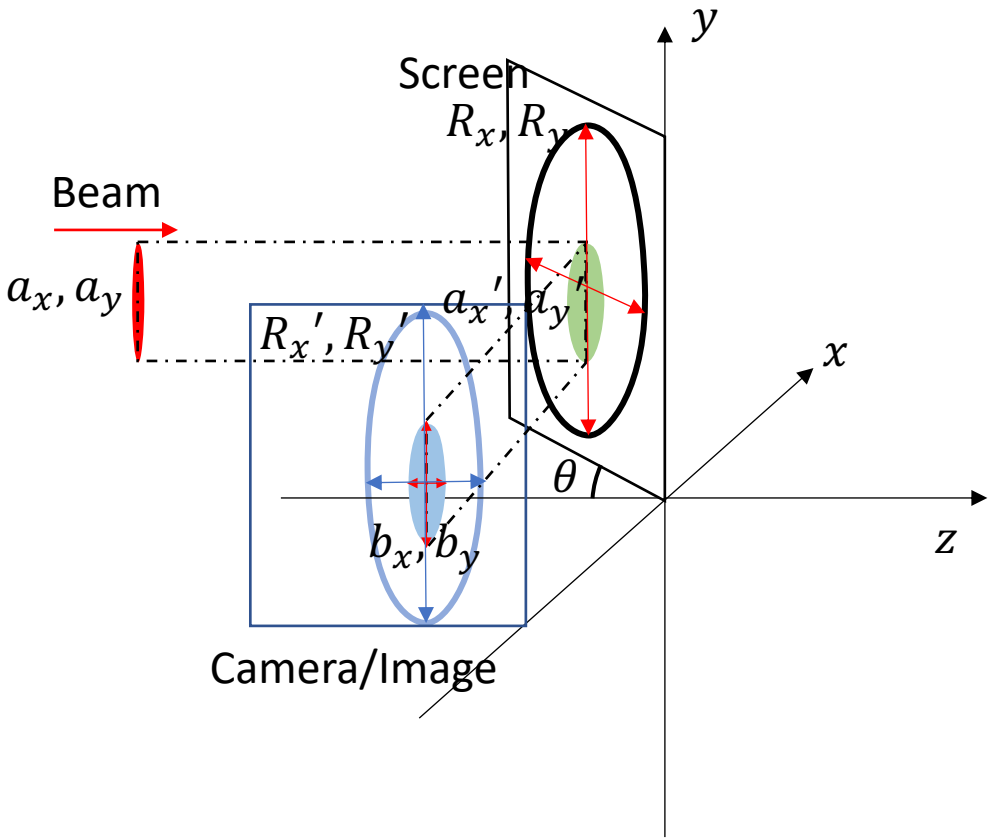
Viewer, Not parallel to y axis

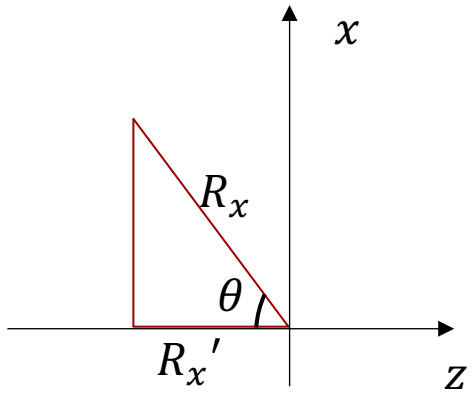


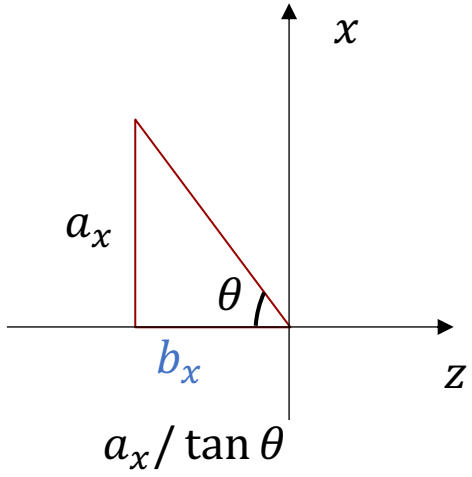
Includes K203A, K401, K402.

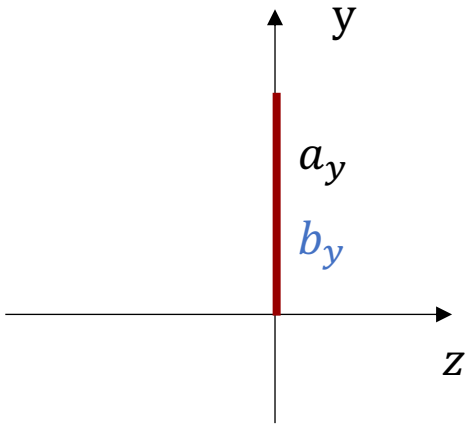
Calculate the angles and beam size

Case 1, viewer screen is parallel to y axis.









Known: radius r of the screen.
Measurement: R_x', R_y', b_x, b_y (pixels)
To calculate: a_x, a_y

Step1

$$r \sim R_y \quad \Longrightarrow mm/pixel$$

Step2

$$R_x = R_y$$
$$R_x' \neq R_x \ (\theta \neq 0)$$
$$R_y' = R_y$$
$$\theta = \operatorname{acos}\frac{R_x'}{R_x} = \operatorname{acos}\frac{R_x'}{R_y'}$$

Step3

$$a_x = b_x \cdot \tan\theta$$
$$a_y = b_y$$

Step4, convert pixels to mm.

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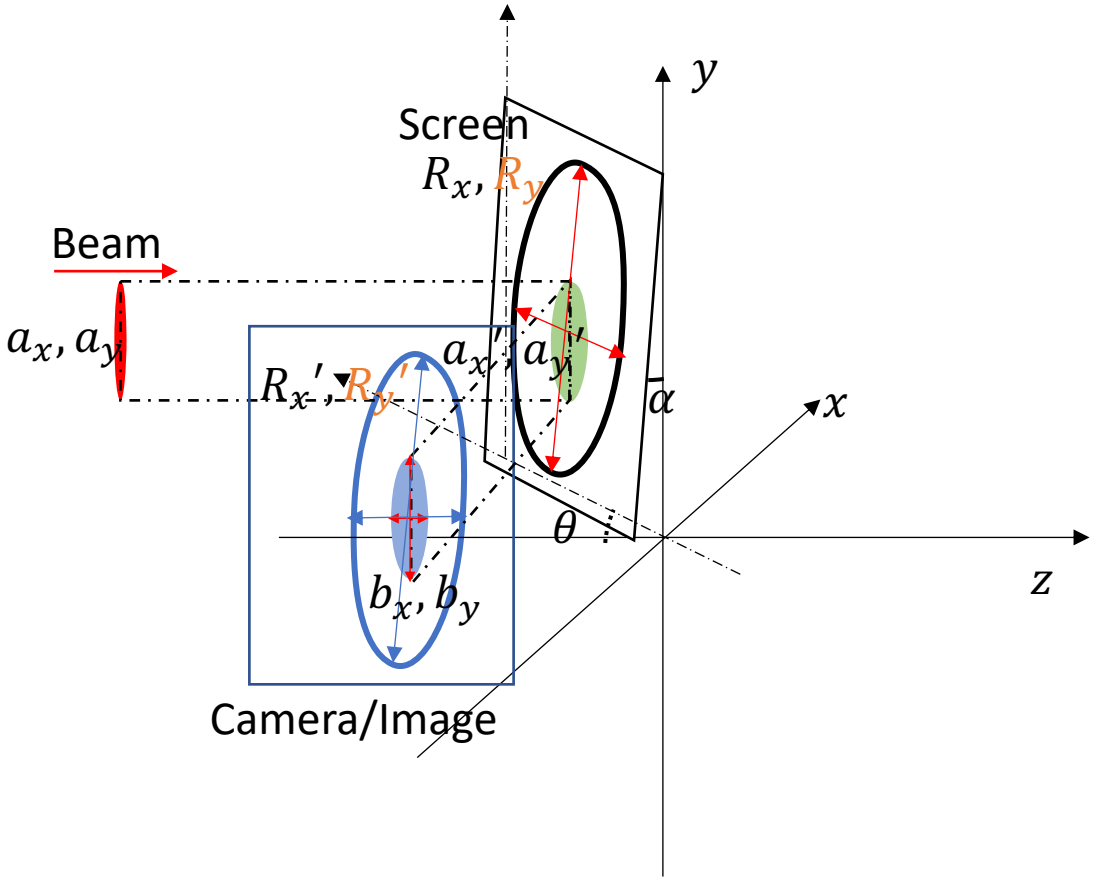
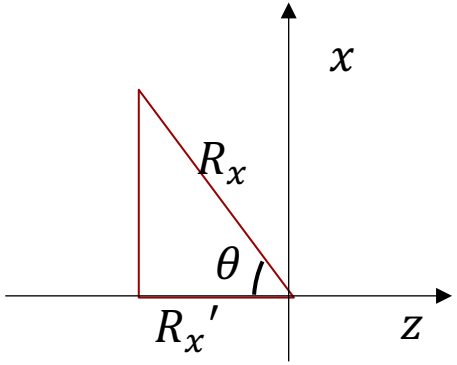
Calculate the angles and beam size

Case 2, viewer screen is not parallel to y axis.

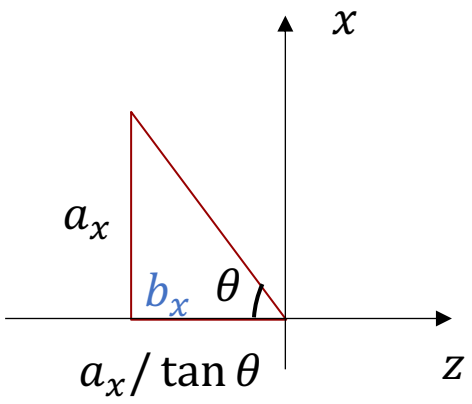




Known: radius r of the screen.

Measurement: R_x', R_y', b_x, b_y (pixels)

To calculate: a_x, a_y



Step1

$r \sim R_y \quad \Longrightarrow mm/pixel$

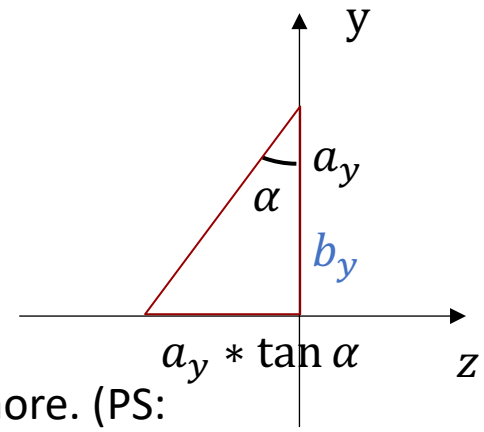
Step2

$R_x = R_y$

$R_x' \neq R_x \ (\theta \neq 0)$

$R_y' = R_y$

$\theta = \mathrm{acos}\dfrac{R_x'}{R_x} = \mathrm{acos}\dfrac{R_x'}{R_y'}$



Step3

$a_x = b_x \cdot \tan\theta \ \ if \ (\dfrac{a_x}{\tan\theta} > a_y * \tan\alpha)$

$a_y = b_y$

Step4, convert pixels to mm.

The difference is that the Ry is not vertical straight anymore. (PS: the frame of the viewer screen is round, find the diameter parallel to the camera plane. Frame is different from beam measurement.)

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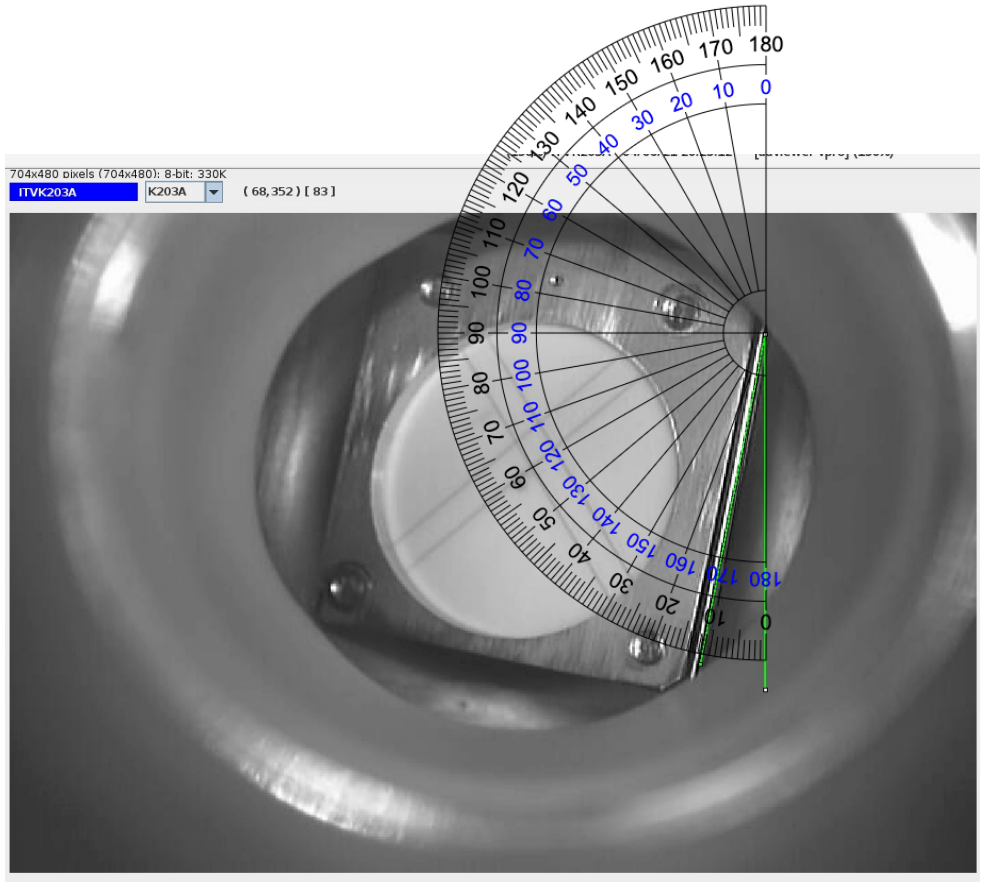
Angle alpha



Assume the alpha can be measured from the image as the left figure shows.

And it is found, for all the three viewers

$$a_y * \tan\alpha < b_x$$

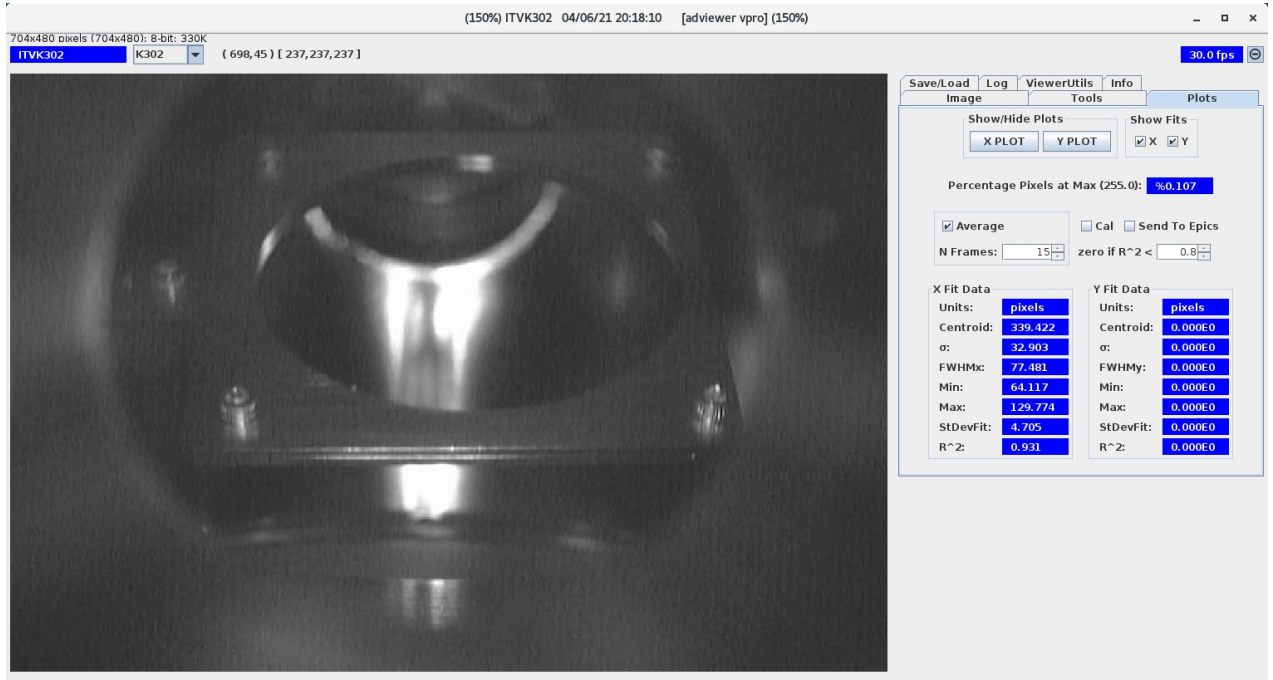
Hence, it is true that

$$a_x = b_x \cdot \tan\theta$$

Can be used for case 2.

Theta and Alpha

Viewer	theta (degree)	Alpha (degree)
K201	57.88813541	
K201A	12.46074571	
K203A	16.59676783	11.12
K302	53.32445543	
K401	10.91261775	14.0
K402	39.45609426	1.8
K403	39.9560783	
M201	64.49523484	
M401	57.4400471	
M504	43.65486109	
M601	56.14734286	



Camera from top/bottom.

Similar when camera is on the bottom.

K302

$$a_x = b_x$$
$$a_y = b_y \cdot \tan\theta$$

Viewer measurement conditions

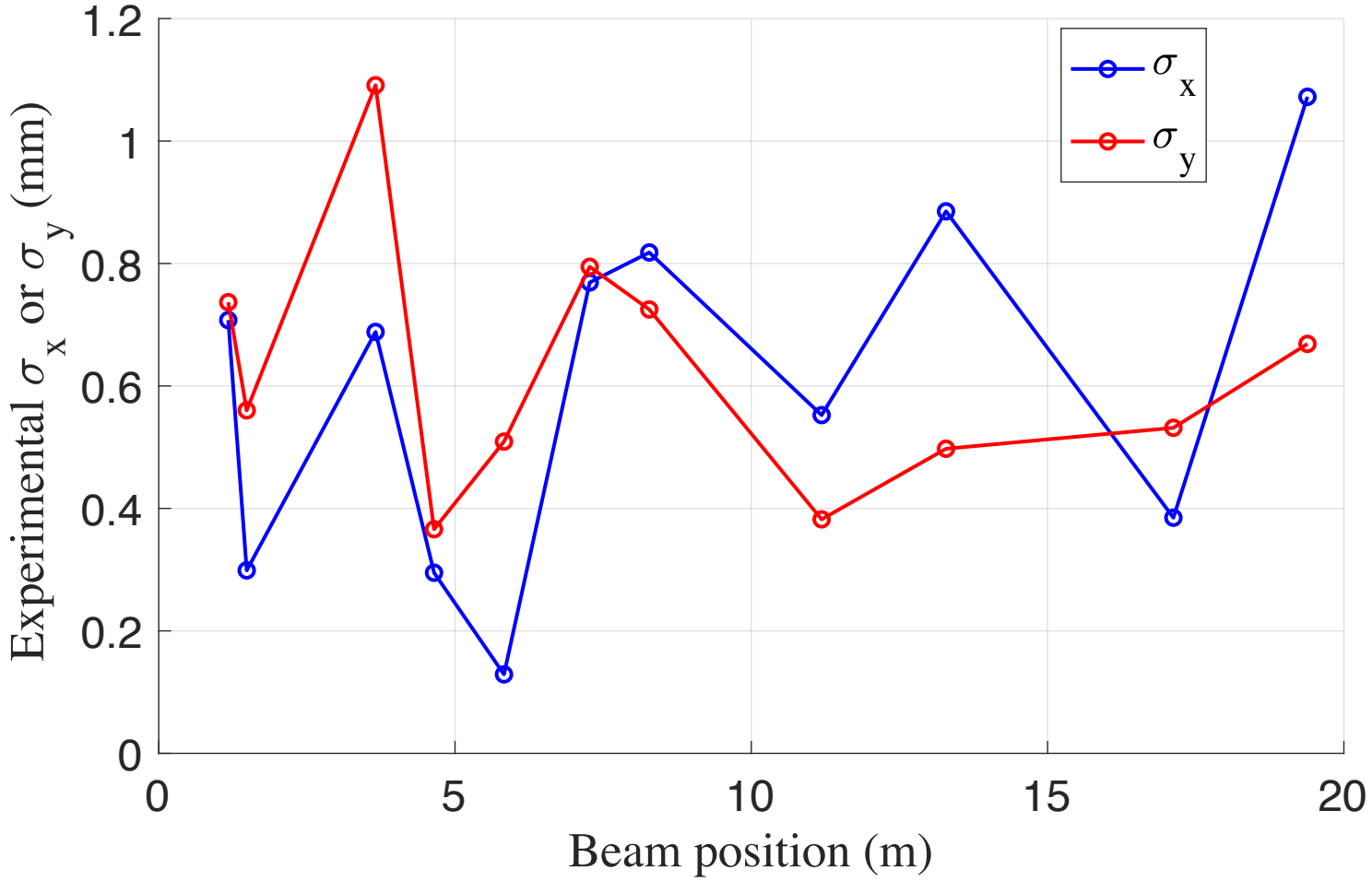
The beam size is increasing with the laser attenuator increasing.

	Laser attenuator: 400		Laser attenuator: 600	
	sigmaX (mm)	sigmaY (mm)	SigmaX (mm)	sigmaY (mm)
M201	0.552394	0.382167012	0.5800057	0.412416968
M401	0.8851622	0.49749075	0.9834503	0.564330273

All the data are taken under attenuator: 400.
Average on three measurements for every viewer.

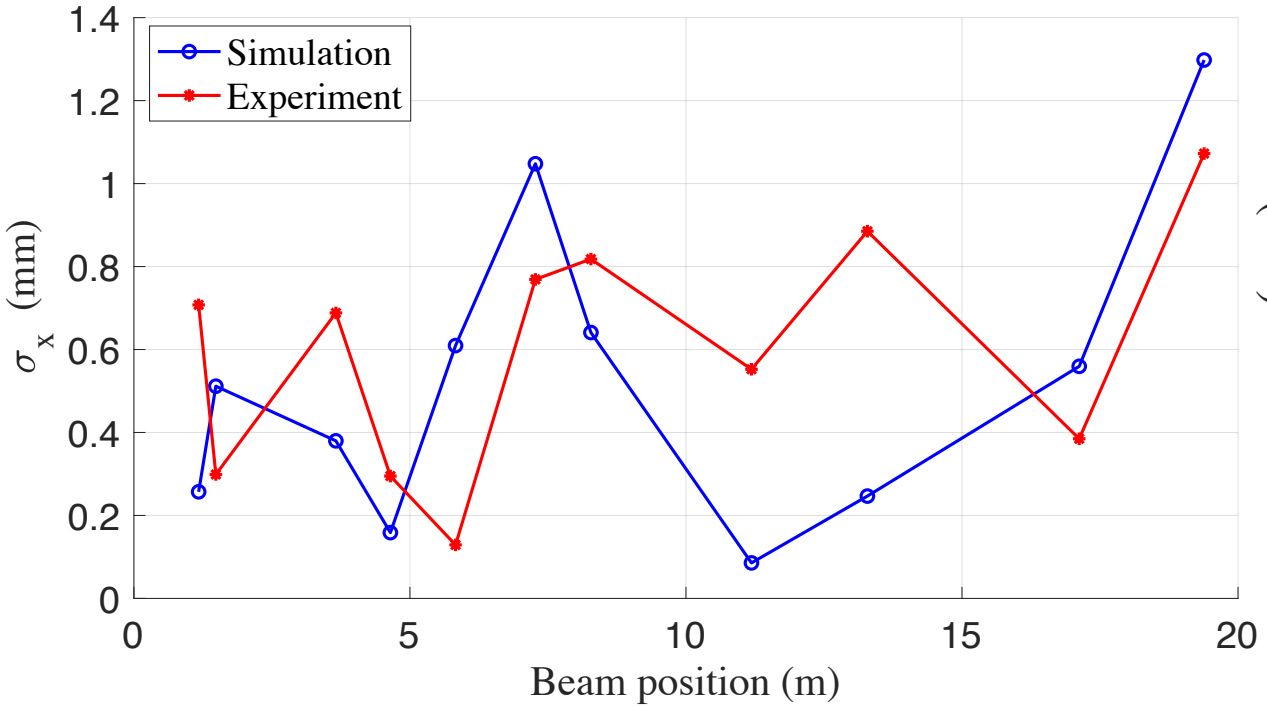
		Simulation by GPT	Experiment: 4-5-2021	
Viewername	Viewerlocation(m)	sigmax(mm)	sigmaX(mm)	sigmaY (mm)
ITVK201	1.173	0.25700973	0.70756217	0.73680947
ITVK201A	1.4846	0.51159456	0.2988179	0.56012598
ITVK203A	3.6588	0.37987287	0.688237563	1.09116386
ITVK302	4.6462	0.15862352	0.396103916	0.272578603
ITVK401	5.8264	0.60946039	0.12899396	0.509168342
ITVK402	7.273	1.04779843	0.76900345	0.79463728
ITVK403	8.2783	0.64089367	0.81802032	0.72493774
ITVM201	11.1867	0.08563157	0.55239395	0.38216701
ITVM401	13.2864	0.24670768	0.88516219	0.49749075
ITVM504	17.123	0.55946052	0.38485641	0.53167622
ITVM601	19.3857	1.29782106	1.07228457	0.66870913

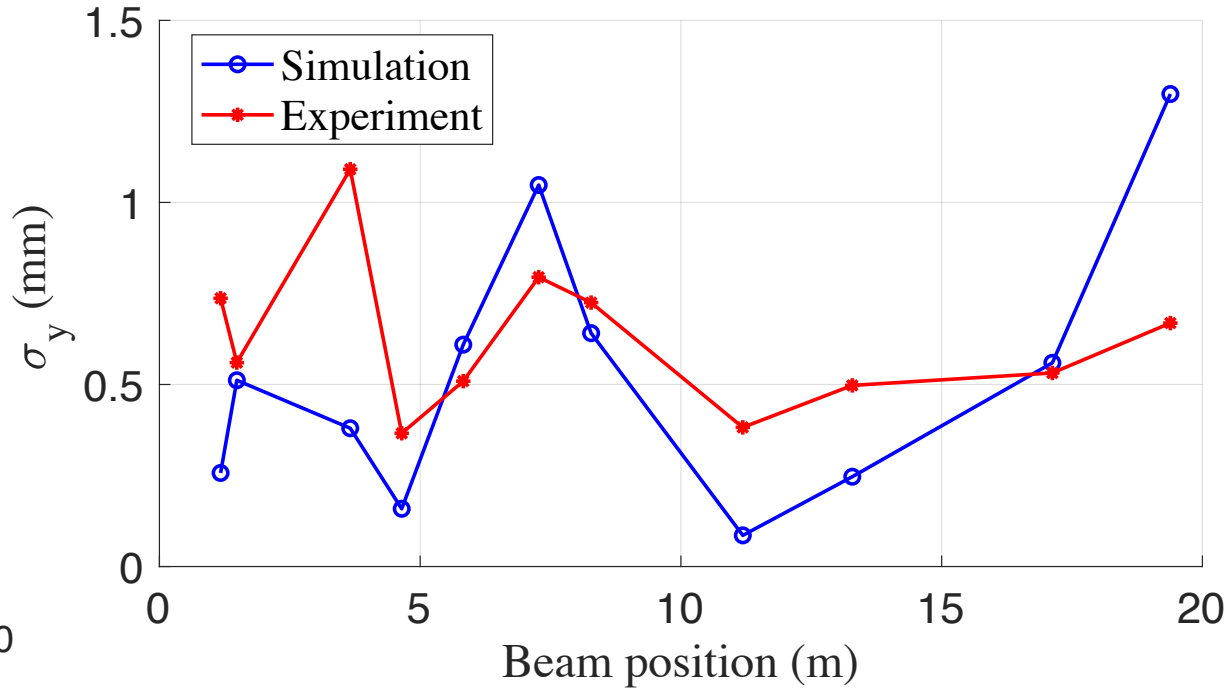
Experimental plot



It is not a round beam.

Sigmax comparison





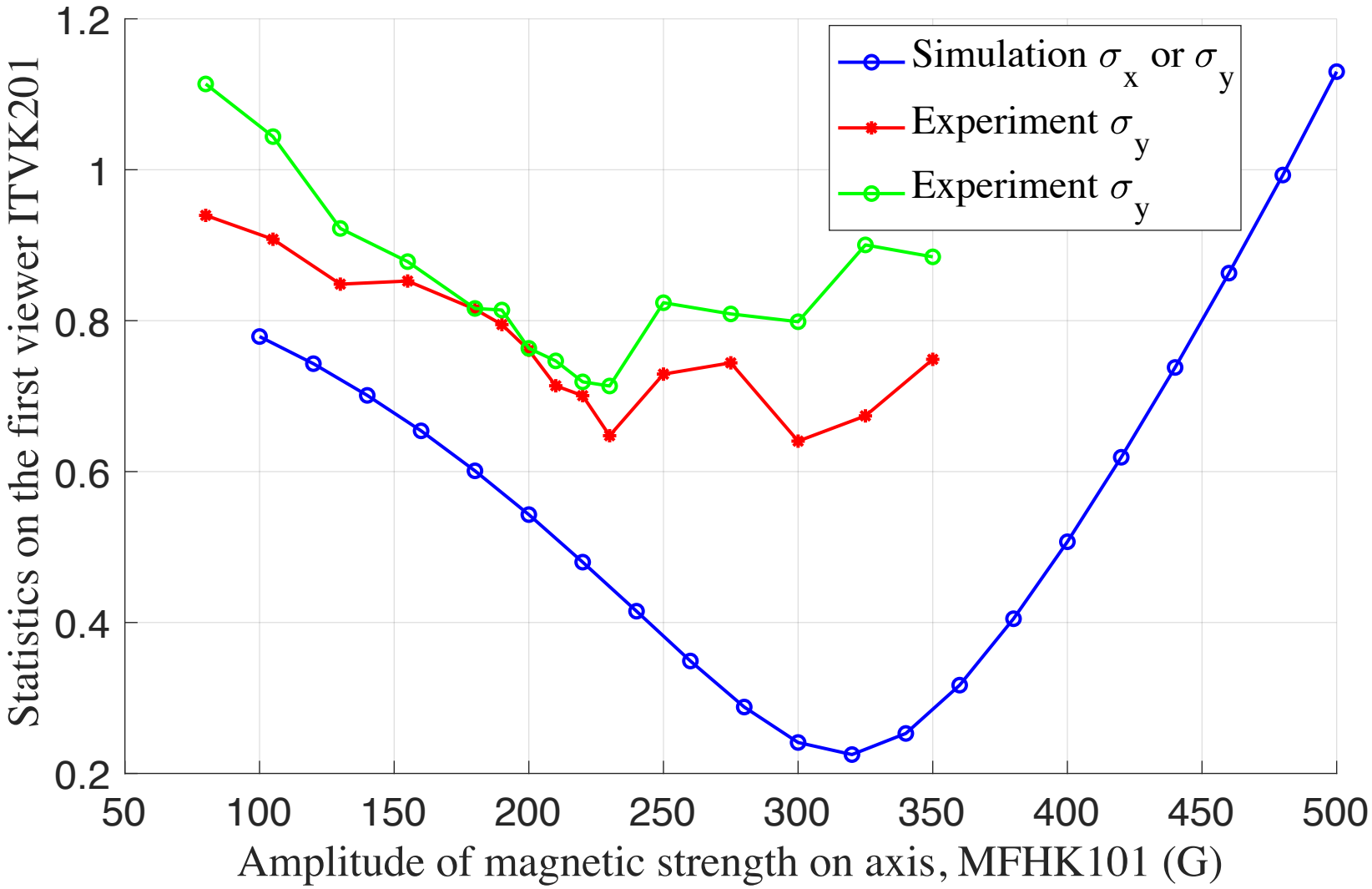
For such laser condition, the order of sigmax is comparable.

Data on ITVK201 vs MFHK101

Laser attenuator: 400
One measurement for every magnetic strength

Simulation by GPT		Experiment		
MaxB1 (G)	sigmax (mm)	MaxB1(G)	sigmax (mm)	sigmay(mm)
1.00E+02	7.79E-01	80	0.93955399	1.11369783
1.20E+02	7.43E-01	105	0.90788363	1.04388973
1.40E+02	7.01E-01	130	0.84840515	0.92221032
1.60E+02	6.54E-01	155	0.85252487	0.87825707
1.80E+02	6.01E-01	180	0.8151899	0.81620542
2.00E+02	5.43E-01	190	0.79484877	0.81410471
2.20E+02	4.80E-01	200	0.76086107	0.76336456
2.40E+02	4.15E-01	210	0.71374176	0.7467205
2.60E+02	3.49E-01	220	0.70061014	0.71892653
2.80E+02	2.88E-01	230	0.64756873	0.71343238
3.00E+02	2.41E-01	250	0.72919071	0.82380028
3.20E+02	2.25E-01	275	0.7441247	0.80893374
3.40E+02	2.53E-01	300	0.64035922	0.7985918
3.60E+02	3.17E-01	325	0.67383195	0.90039529
3.80E+02	4.05E-01	350	0.74875939	0.88455919
4.00E+02	5.07E-01			
4.20E+02	6.19E-01			
4.40E+02	7.38E-01			
4.60E+02	8.63E-01			
4.80E+02	9.93E-01			
5.00E+02	1.13E+00			

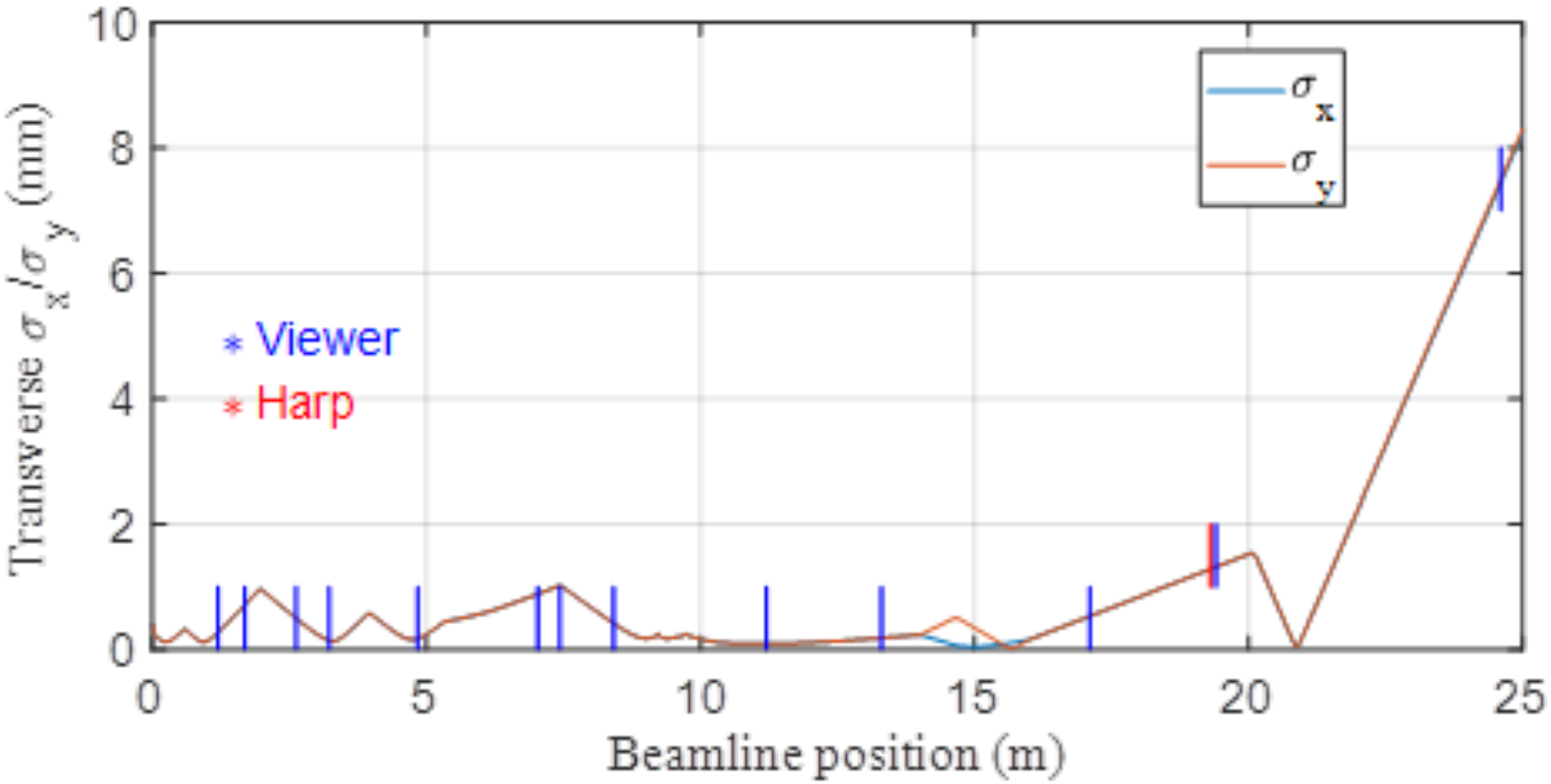
Statistics vs MFHK101



The experiment has the same trend with the simulation, while the real beam is bigger than that by the simulation.

Appendix A: Viewer position.

Viewers and Harps.



Appendix B: decide the angle theta

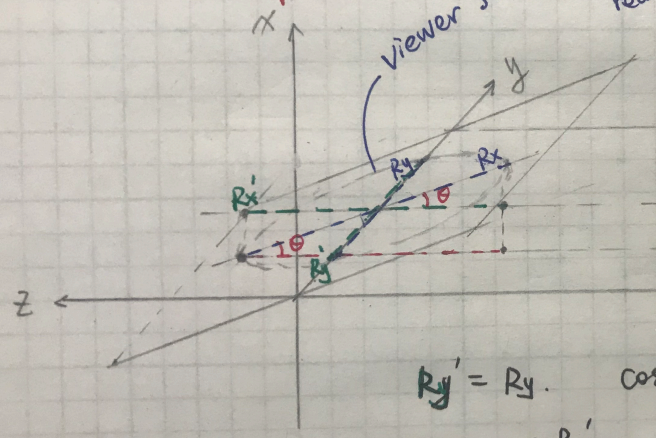
Decide θ and Pixels/mm. or mm/pixel.

Case1: viewer screen // y

parallel.

viewer screen: (R_x, R_y) $R_x = R_y$.

real radius: r (mm)



measurement.

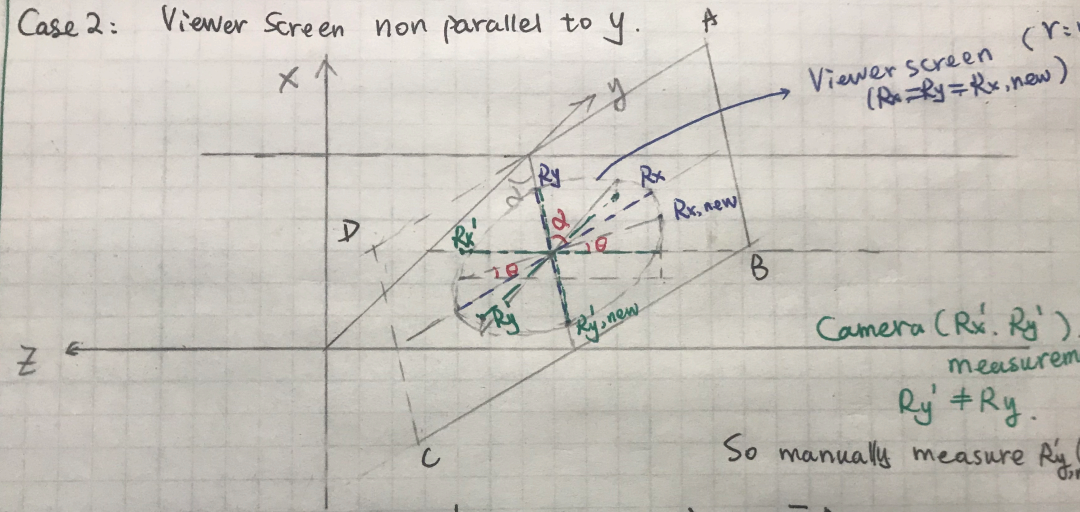
Camera. (R_x', R_y') projection

$R_y' = R_y$. $\cos\theta = \frac{R_x'}{R_x} = \frac{R_x'}{R_y} = \frac{R_x'}{R_y'}$

$\theta = \arccos\left(\frac{R_x'}{R_y'}\right)$.

Pixels/mm $= \frac{R_y'}{r}$. mm/pixel $= \frac{r}{R_y'}$

Case 2: Viewer Screen non parallel to y.



Viewer screen (r: mm).
($R_x = R_y = R_{x,new}$)

Camera (R_x'. R_y').
measurement.

$R_y' \neq R_y$.

So manually measure $R_{y,new}'$ (R_y // AB // CD).

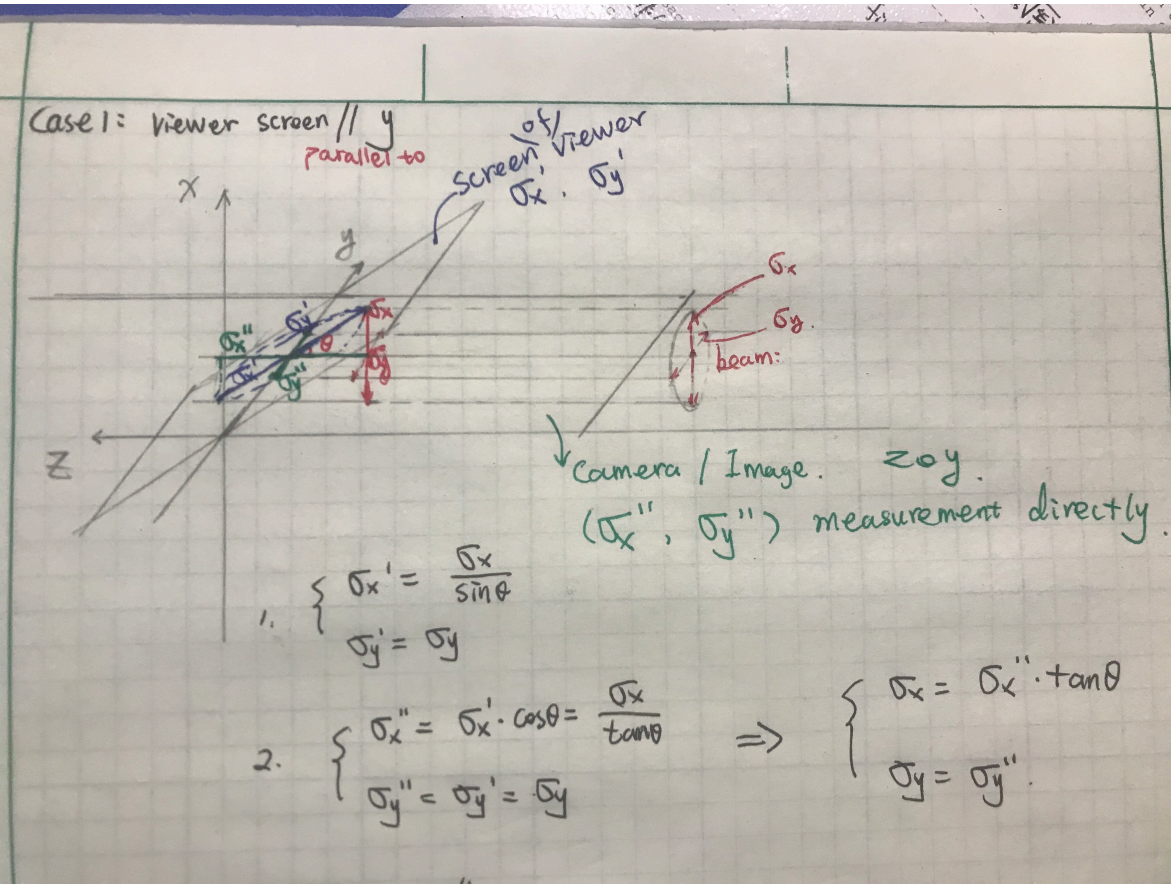
$R_{y,new}' = R_y$. $R_{x,new} = R_y = R_{y,new}'$.

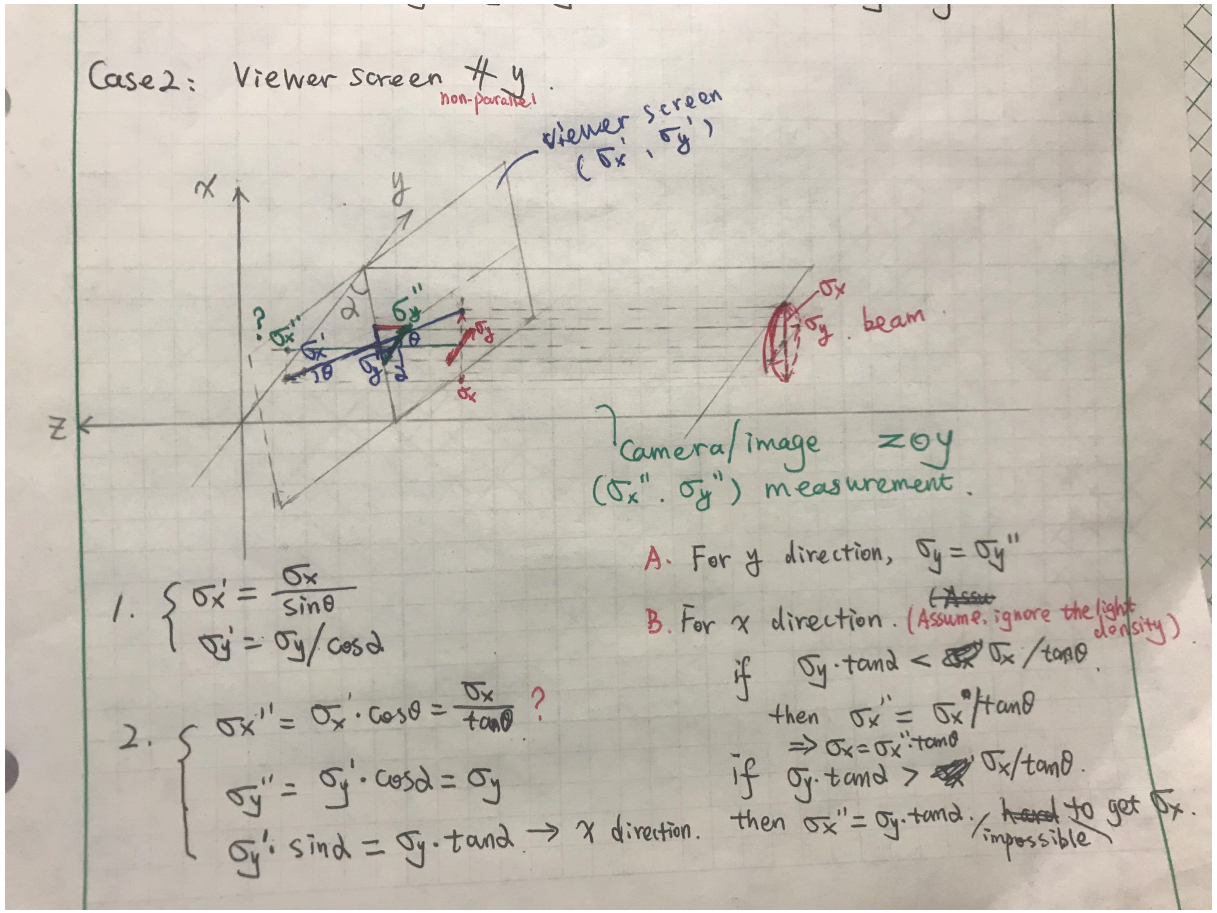
$\cos\theta = \frac{R_x'}{R_{x,new}} = \frac{R_x'}{R_{y,new}'}$.

$\therefore \theta = \arccos\left(\frac{R_x'}{R_{y,new}'}\right)$

mm/pixel $= \frac{r}{R_{y,new}'}$.

Appendix B: Beam size calculation





For case 2, It is good to get the angle between the viewer screen and the camera plane, and the conversion from pixel to mm. However, sometimes it confuses the beam horizontal size measurement. Therefore, the viewer screen is better to be installed parallel to y.

Appendix D: Parameters of components

cathode		200kV	200kV
solenoid	MFHK101	0.035 T	230 G
dipole	MDSK201		-59.601 G-cm
solenoid	MFBK202	0.02 T	190 G
solenoid	MFQK203	0.02 T	131 G
solenoid	MFAK301	0.03 T	292 G
solenoid	MFDK302A	0 T	123.786 G
solenoid	MFDK302B	0 T	95 G
solenoid	MFAK303	0.02 T	362 G
solenoid	MFQK403	0.0168 T	-124 G
2-cell		4.363 MV/m, 169 degree	2.5 MV/m, 48.7 degree
7-cell		18.63 MV/m, 234 degree.	9.52 MV/m, -56.9 degree
quad	MQJM501	-0.0328 T	207.049 G
quad	MQJM502	0.0514 T	-165.664 G
quad	MQJM503	0 T	186.403 G
quad	MQJM504	0.047 T	-191 G