Image roundness evaluation based on the radial profile

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PPS#800

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Motivation

Round beam in a axisymmetric photo injector?

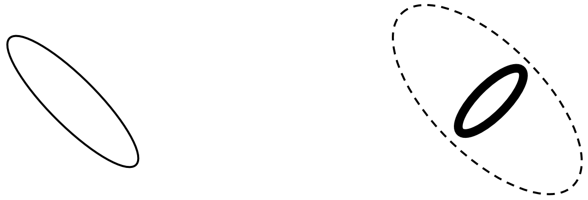
- One practical application: routine PITZ script

  GunQuadSymmetriser_Mk2.m

<u>Goal functions:</u>

- f_calcFun2Min.m

  goalval = abs(xrms/yrms -1) + abs(xycorr2);

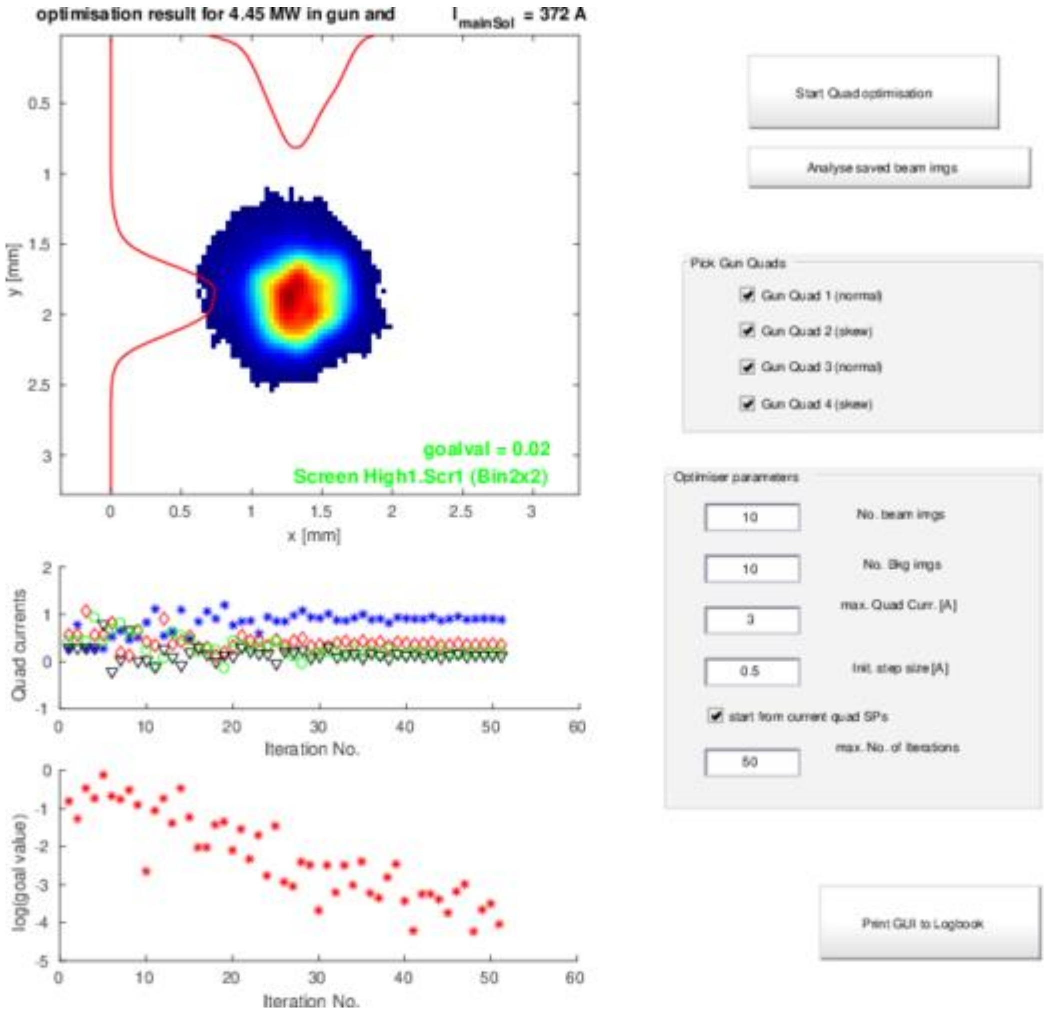


- f_calcFun2Min2,3

  Basic idea is taking ellipses of different parts of beam distribution and minimizing their helicity with charge weights...(based on ***charge cuts****)*

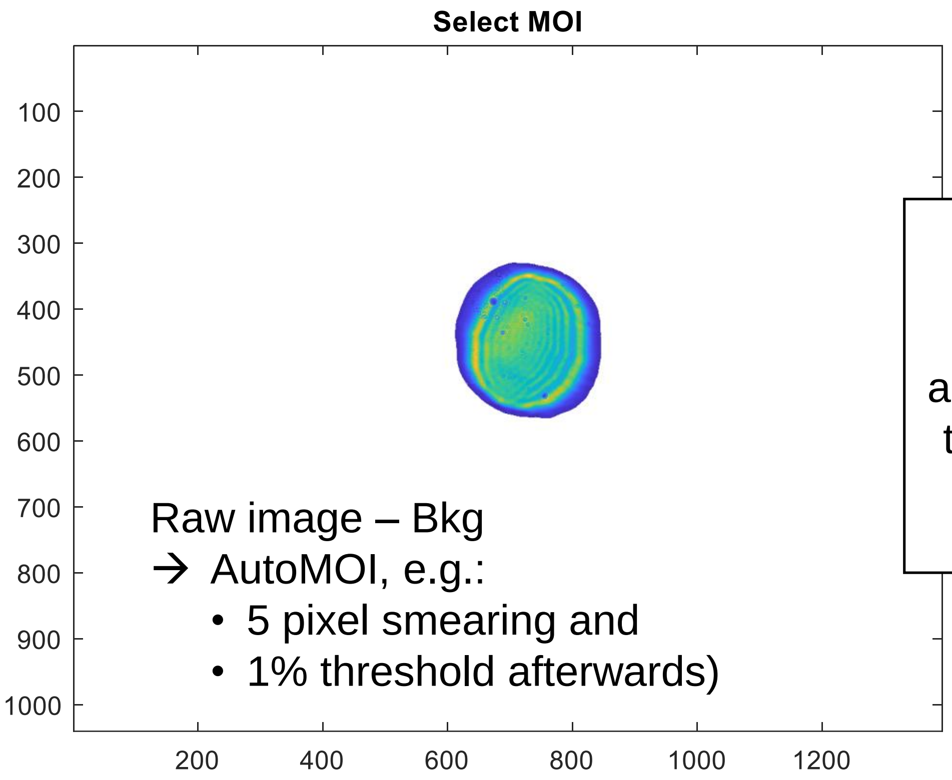
- f_calcFun2Min_BivDistr

  The beam asymmetry estimation is based on Bivariate normal distribution fit to the ***image****. Bivariate normal distribution is 2-D multivariate normal distribution.*

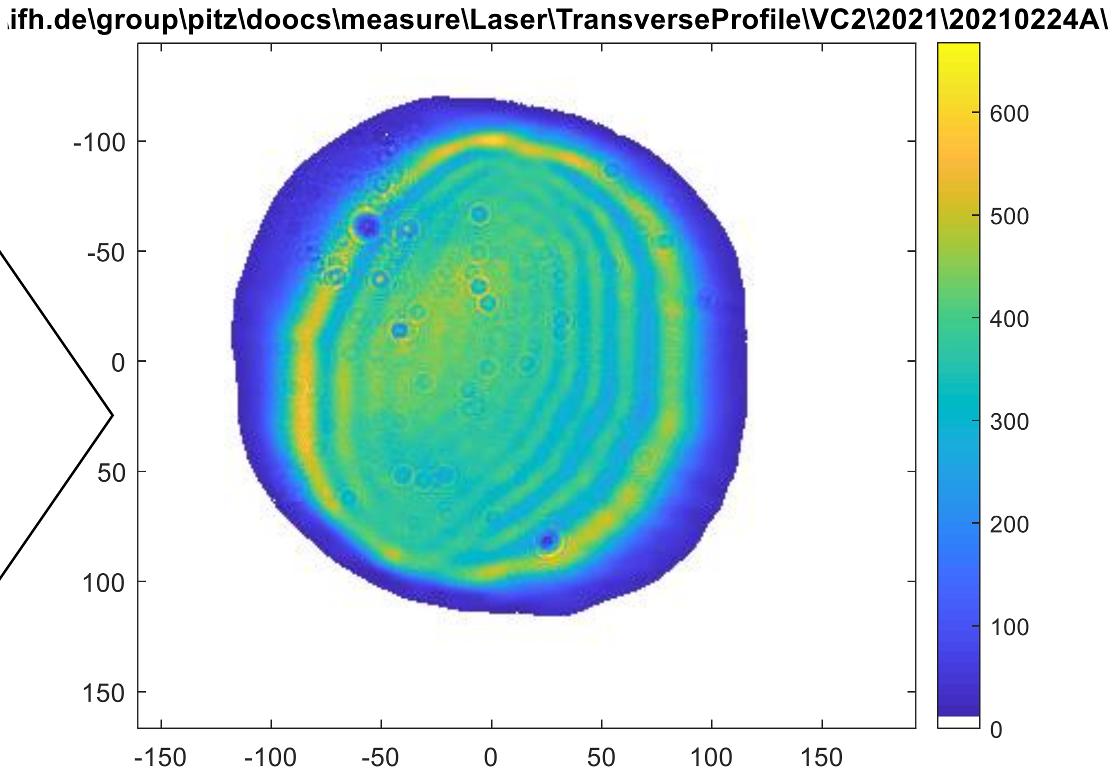


Goal: axially symmetric (beam) image

E.g. to be used for the gun quad optimizer as a goal function



Manual MOI applied (to reduce the image array)



Characterization of the transverse profile of the PITZ photocathode laser

M.Sc. Thesis of Roman Martin, 2013

- The goal → **homogeneous** radial laser profile
- Parametrization:
  - Exponent G of the Super-Gaussian fit function and the ratio of the semi-axes → relative standard deviation $\sigma_{aij}/\langle a \rangle$, that quantifies the height of the inhomogeneities + spatial correlation Λ or the relative covariance
  - Radial Fourier projection $p_r(m)$ and/or Bessel projection $p_r(m_B)$

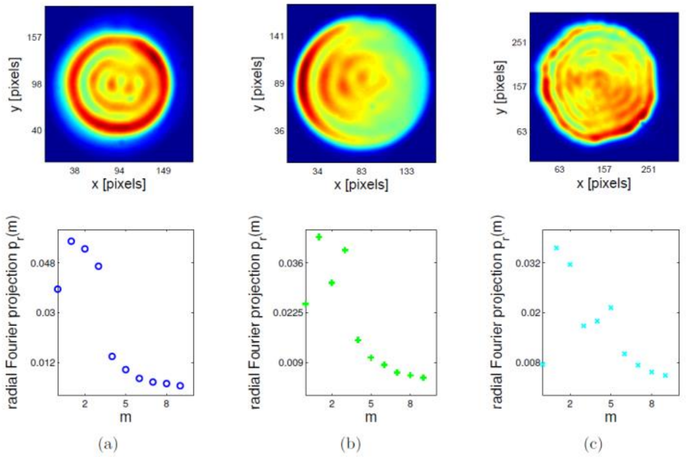


Figure 4.16: Radial Fourier projections of the laser spots shown in Fig. 4.9 - 4.11.

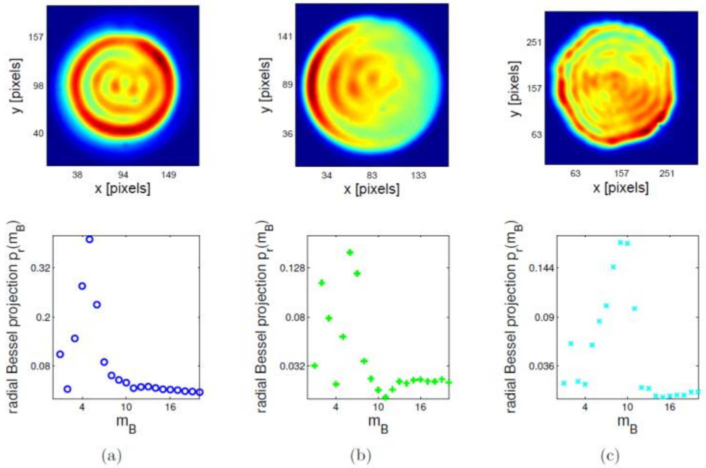
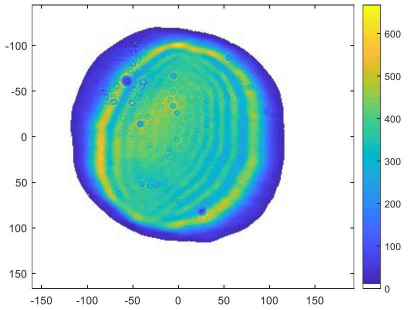


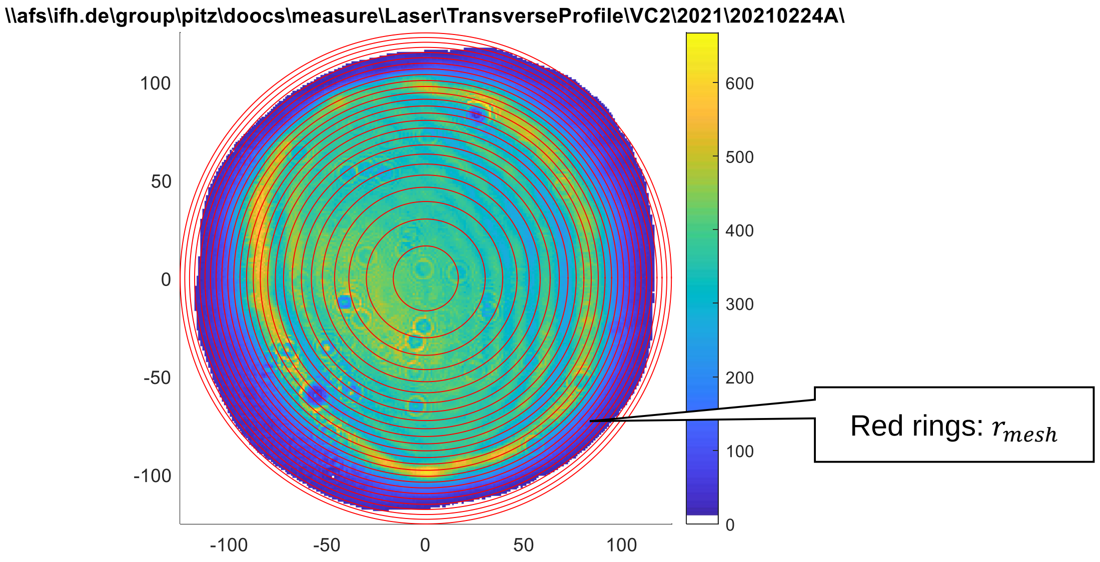
Figure 4.17: Radial Bessel projections of the laser spots shown in Fig. 4.9 - 4.11. A better separation of the lines can be observed, but the relative impact can not be compared anymore.

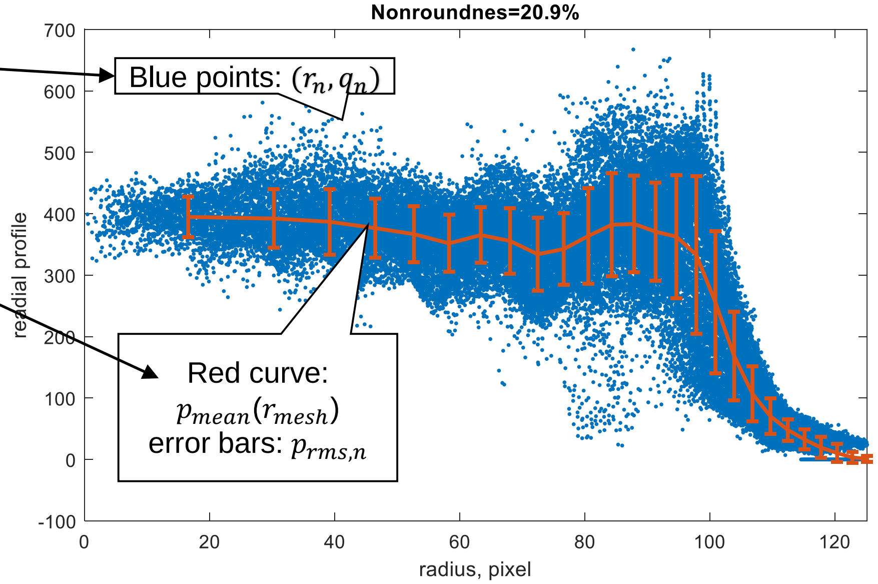
Radial profile calculation

Proposed algorithm



1. Find x0, y0 – center of mass
2. Center the image
   x=xscr-x0; y=yscr-y0;
3. Calculate X_{rms} , Y_{rms} and $R_{rms}\sqrt{X_{rms}^2 + Y_{rms}^2}$
4. From the image 2D matrix A_{ij} and x_j and y_i :
   a) Produce 1D arrays $r_n = \sqrt{x_j^2 + y_i^2}$ and $q_n = A_{ij}$
   b) sort (r_n) $\rightarrow$ update q_n
5. Input parameter $NR0$ → radius of the 1st radial grid step, e.g., $NR0$ =3;
6. Calculate $R_0 = R_{rms}/NR0$
7. Calculate N_0 - number of pixels (particles) within R_0 circle
8. Bin all pixels (particles) on N_0 base (every N_0 pixels to one bin):
   a) $r_{mesh,n}$→ mean radius value of the *n-th* bin
   b) $p_{mean,n}$→ mean intensity (charge) value of the *n-th* bin divided by $r_{mesh,n}$
   c) $p_{rms,n}$→ rms intensity (charge) fluctuation within the *n-th* bin





Roundness evaluation

Based on the radial profile

1. Input from the radial profile $\{r_{mesh,n}; p_{mean,n}; p_{rms,n}\}$
2. Calculate $\delta v_n = \frac{p_{rms,n}}{p_{mean,n}}$ (skip NaNs from $p_{mean,n} = 0$)
3. Calculate weights w_n

$$W_1 = \pi \cdot \left(\frac{r_{mesh,1}+r_{mesh,2}}{2}\right)^2 \cdot p_{mean,1}$$

$$W_{n>1} = 2\pi r_{mesh,n} \left(\frac{r_{mesh,n+1}+r_{mesh,n-1}}{2}\right) \cdot p_{mean,n}$$

$$w_n = \frac{W_n}{\sum_n W_n}$$

The non-roundness:

$$GF = \sum_n w_n \delta v_n \times 100\%$$

Matlab function

[Del,rmesh,pmean, prms,ra,qa,x,y]=GetNonroundness(A,NR0)

→ *Could be already used for GunQuadOptimizer?*

@NFS\Measure\scripts\Development\RoundnessEstimator

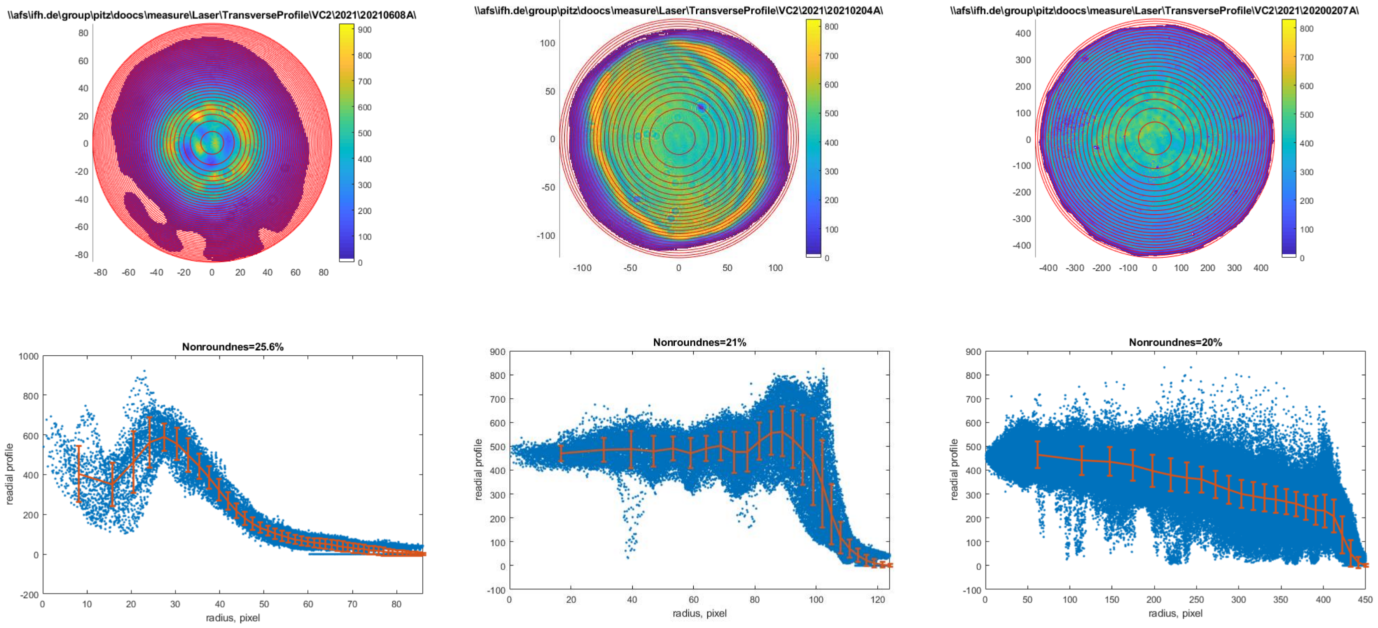
%A - image
%NR0 --> radius of the 1st circle Rrms/NR0
%x,y - coordinate of the centered image
%ra qa - radiaa and charge of pixels, sorted
%rmesh - radial mesh - mean radii N0 particles
%pmead - radial profile - mean value of pixels
%prms - radial profile - rms value of pixels
%Del - weighted area of prms/pmean

To try run the algorithm: ***RadProfileTester.m*** → examples next slide

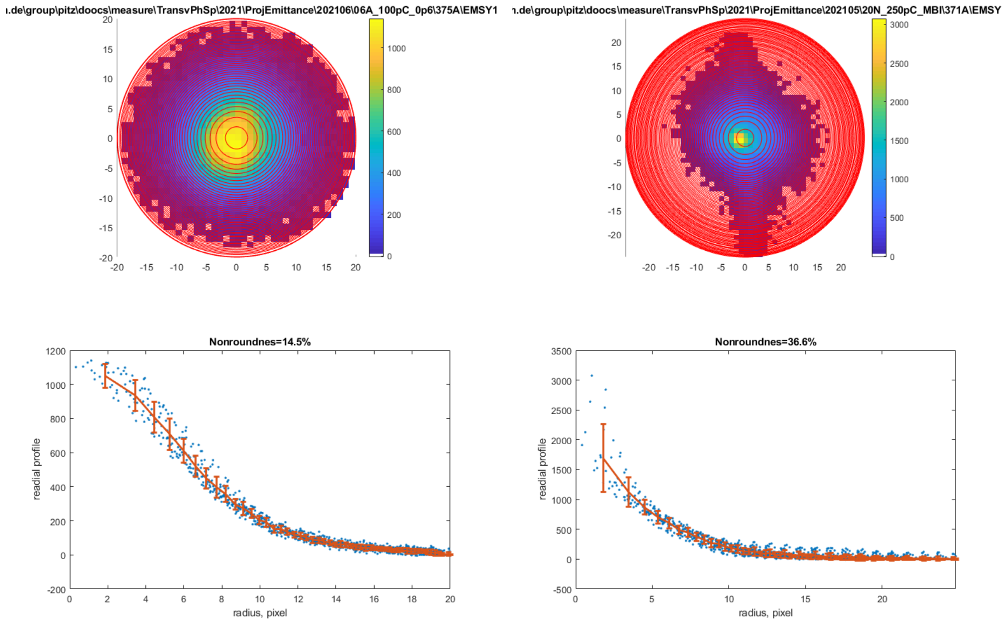
Examples of the experimental images

Image roundness evaluation based on the radial profile

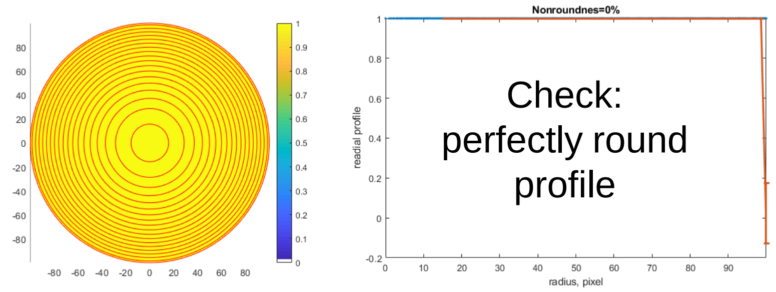
Laser at VC2



Electron beam at HIGH1.Scr1



- Next step(s)
  - Try to use it as a goal function in the GunQuadOptimizer
  - Improve by filtering in azimuthal angle?
  - Any other ideas are welcomed!



Conclusions

Image roundness evaluation based on the radial profile

- Radial profile calculation method:

  → same statistics (number of pixels) for each radial bin
- Figure of merit for a *n-th* ring:

  → standard deviation of all pixels within the ring (drawback: noise)
- Figure of merit for a entire image:

  → Weighted sum of rms intensity fluctuations

Outlook:

- Try to use for ***GunQuadSymmetriser_Mk2.m***?
- Improve the algorithm by noise filtering (low pass azimuthal filter for each ring intensity)?