

Electron beam imaging with a screen: nonlinearities?

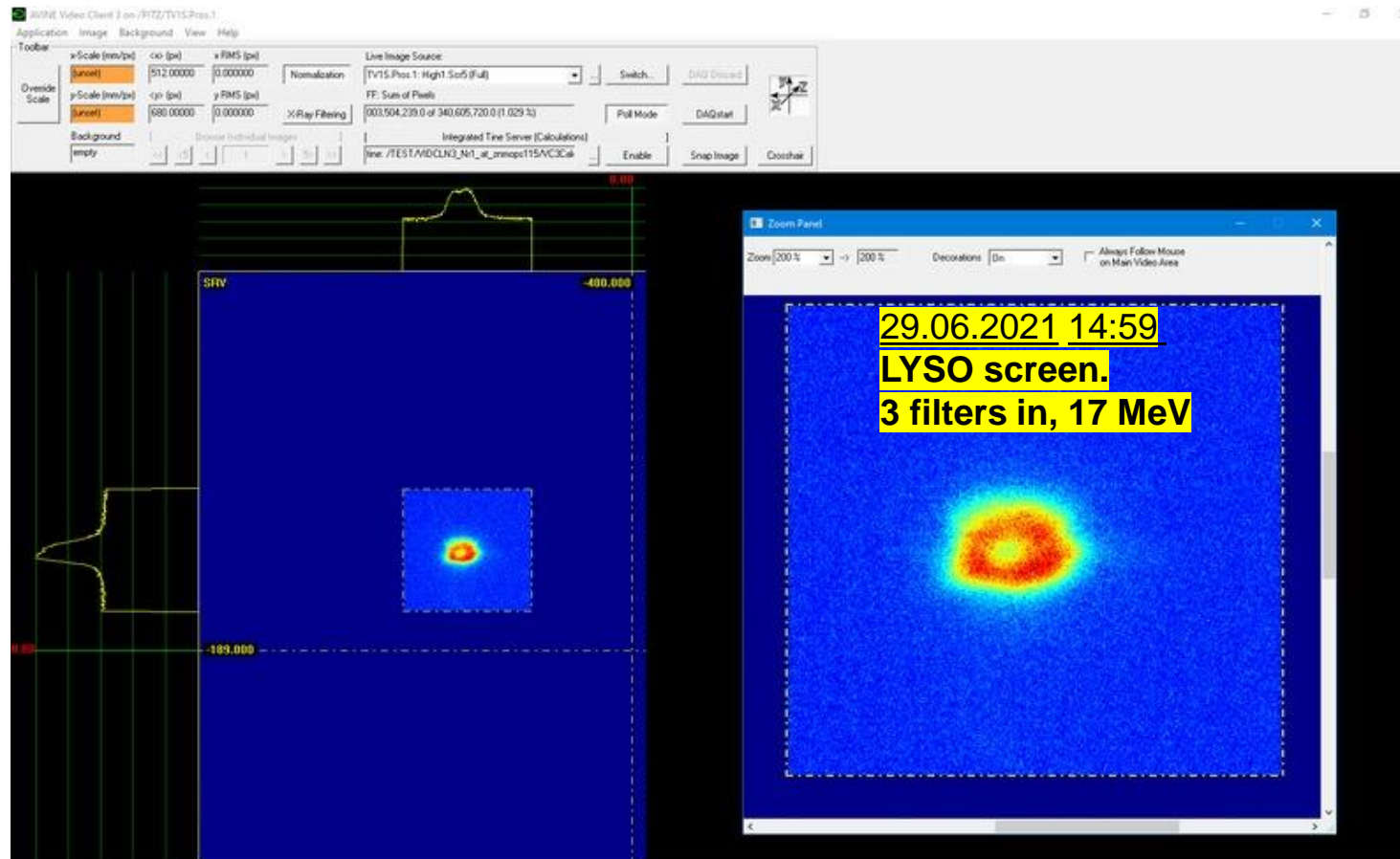
Preliminary screen nonlinearity studies at PITZ

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Motivation

Electron beam imaging with a screen

- Beam emittance (and other) measurements at PITZ are based on analysis of a beam distribution at scintillating screens
- Recent studies (Artem Novokshonov) revealed screen nonlinearities (“smoke ring” effect)

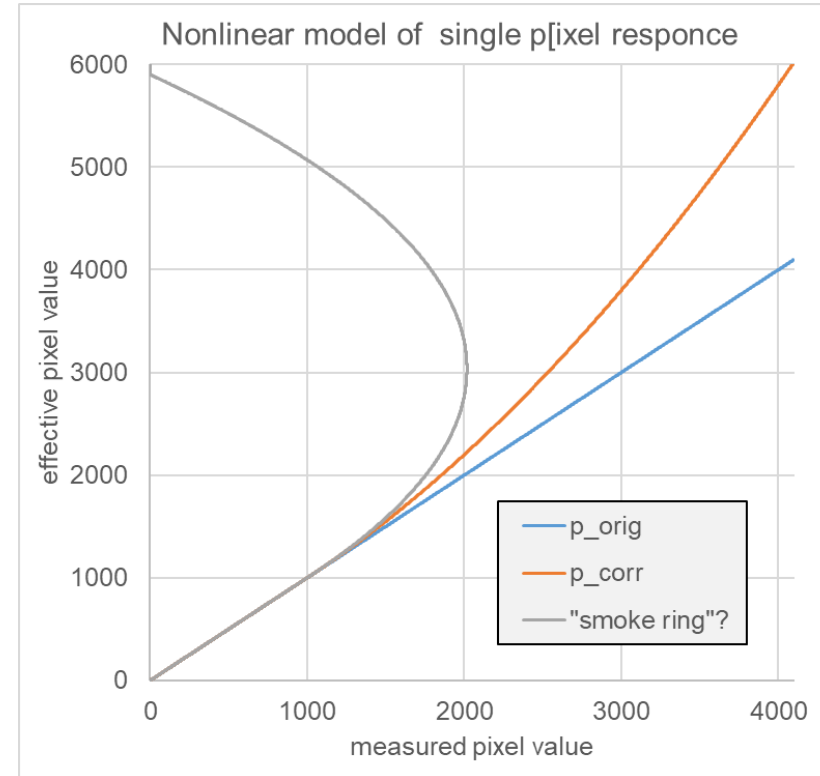
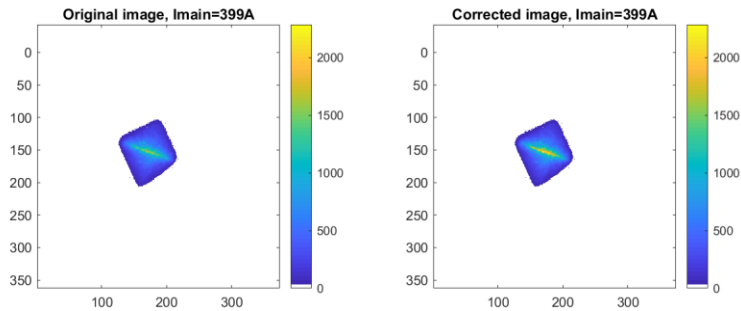


Modeling a nonlinearity of beam imaging

Simple (integral) model

- Idea: to replace the measured (original) pixel value by effective (corrected)

$$p_{corr} = p_{orig} + \begin{cases} 0, & \text{if } p_{orig} < p_0 \\ c \cdot (p_{orig} - p_0)^N, & \text{if } p_{orig} \geq p_0 \end{cases}$$



- Tests → Sum of pixels (~bunch charge) by focusing change (magnets) should be conserved:
 - E.g. vs. main solenoid current
 - +various number of pulses?

Image treatment

Preliminary tests

- LOW.Scr3, 2x2bin / HIGH1.SCr1, camera gain 0, exposure time \rightarrow 10us (not sure)
- Vary main solenoid (380A:1A:410A), for each I_{main}:
 - Take 20 frames raw image = beam + bkg
 - Take 20 frames bkg image (laser shutter closed)
- Manual MOI:
 - $\text{Beam}(I_{\text{main}}) = \langle \text{RawImage} \rangle(I_{\text{main}}) - \langle \text{Bkg} \rangle(I_{\text{main}})$
 - Superpose all beam images $\sum_{I_{\text{main}}} \text{Beam}(I_{\text{main}})$
 - Manual MOI \rightarrow to be applied to all images
- Optimizer \rightarrow fit p₀,c,N for a flat charge curve SoP(I_{main})
 - Original image treatment
 - BkgAverage, BkgStd,
 - AutoMOI(RadPixels=5,thres=0.01)
 - Modification of raw images

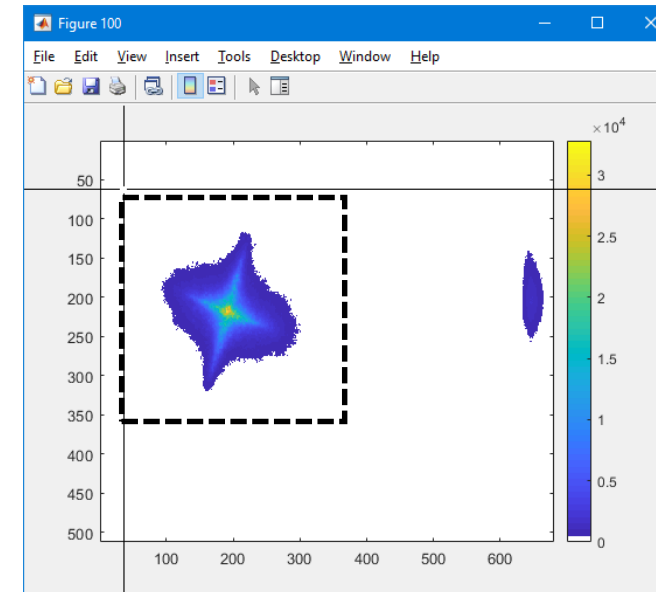


Image treatment-2

Preliminary tests

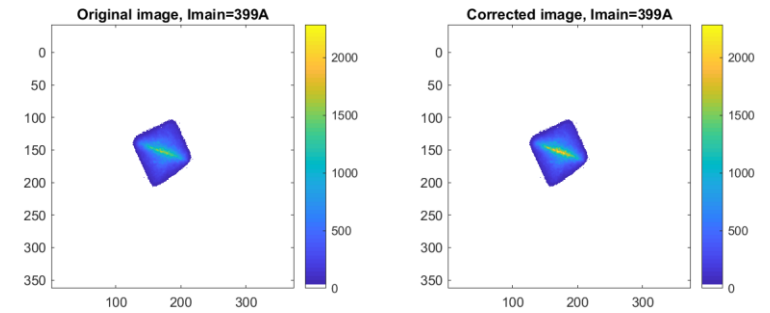
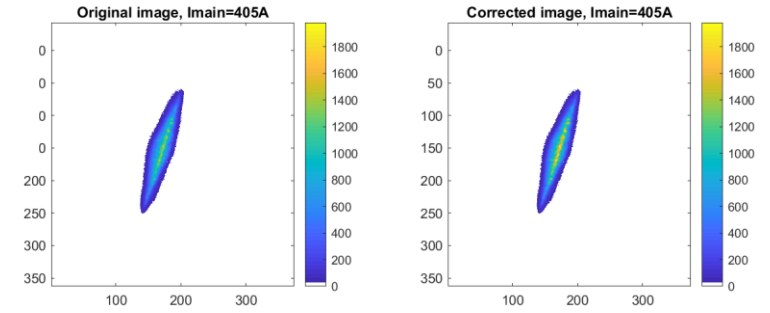
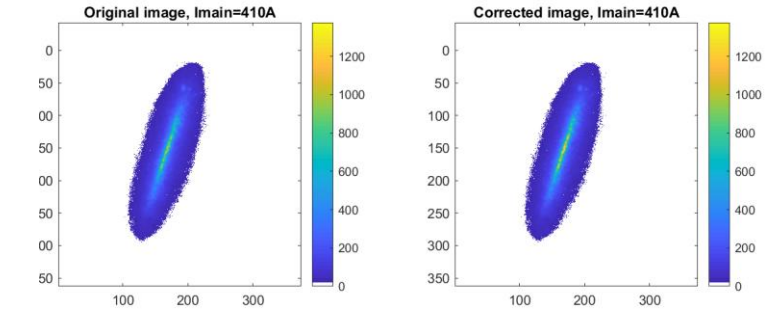
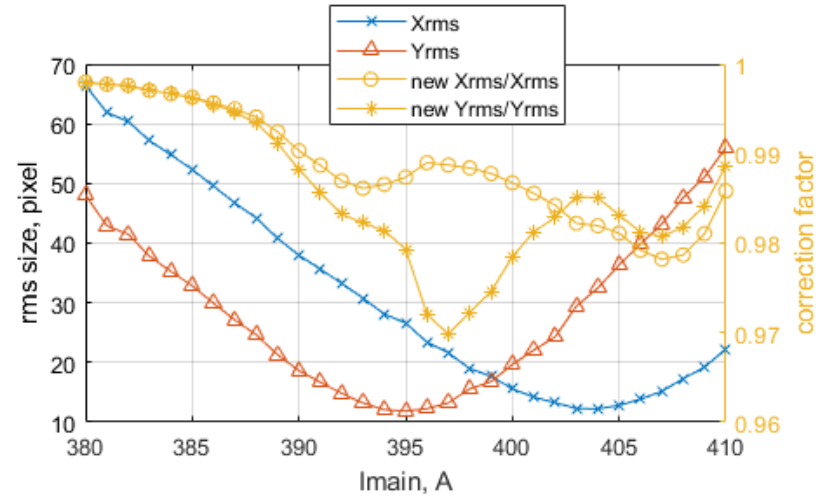
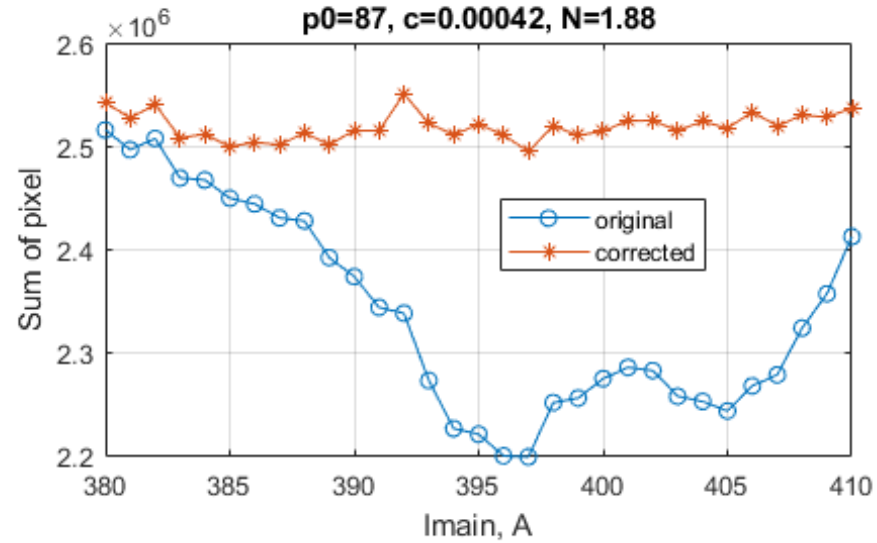
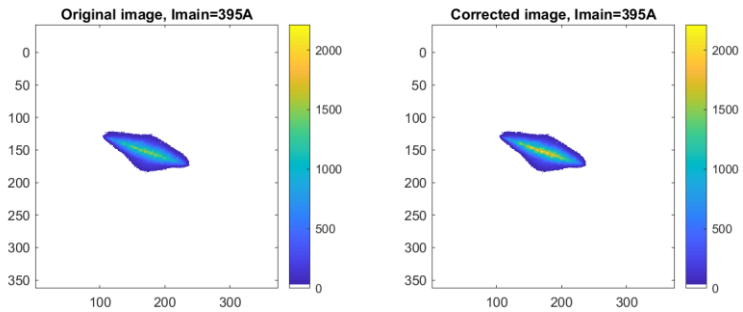
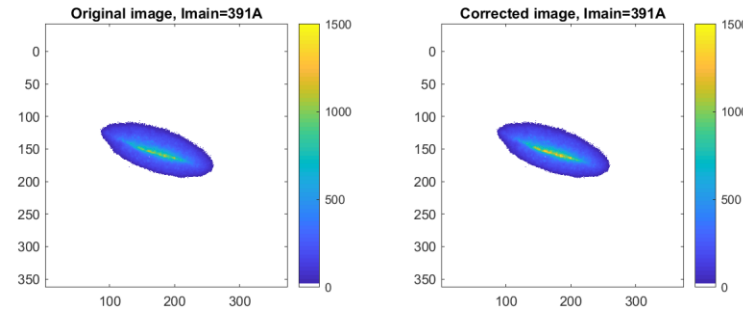
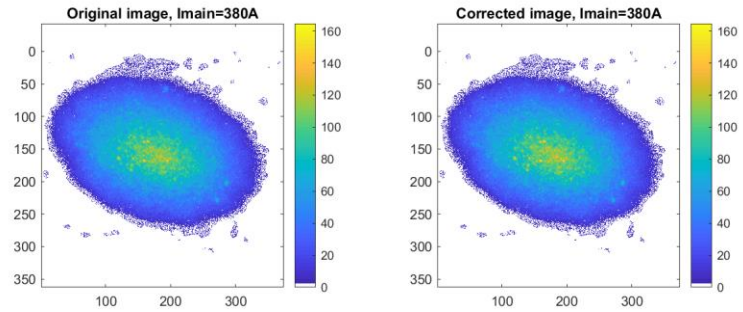
- Modification of raw images:
 - Common rectangular MOI (for all Imain) applied
 - Beam(Imain)=<RawImage>(Imain)-<Bkg>(Imain)
 - Beam AMOI=AutoMOI(Beam, RadPixels=5,thres=0.01)
 - BeamMOI=SigmaFilter(BeamAMOI,BkgStdMOI,sigcut=1)
 - BkgNew=ModifyImage(BkgMOI,p0,c,N);
 - RawNew=ModifyImage(RawMOI,p0,c,N);
 - BeamNew=(RawNew-BkgNew).*AMOI;
 - BeamNew=SigmaFilter(BeamNew,BkgStdMOI,sigcut);
- Optimizer → fit p0,c,N for a flat charge curve SoP(Imain)
 - QbkgNewArr(Imain)=SoP (BkgNew(Imain));
 - QrawNewArr(Imain)=SoP (RawNew(Imain));
 - Qbeamnew=QrawNewArr-QbkgNewArr;
 - Fgoal=std(Qbeamnew); (? or std(Qbeamnew)/mean(Qbeamnew) ?)

$$p_{corr} = p_{orig} + \begin{cases} 0, & \text{if } p_{orig} < p_0 \\ c \cdot (p_{orig} - p_0)^N, & \text{if } p_{orig} \geq p_0 \end{cases}$$

Screen Nonlinearity Studies

30.06.2021M, LOW.Scr3, main solenoid scan

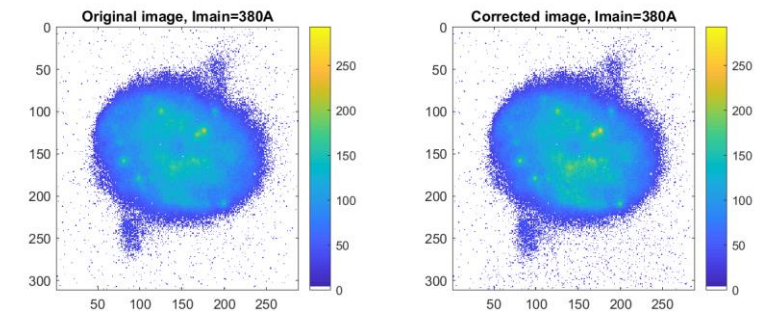
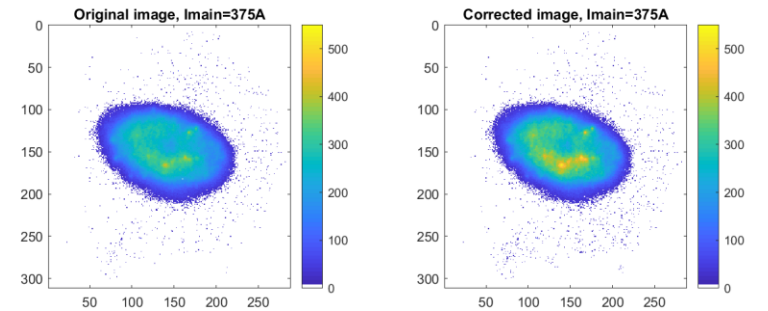
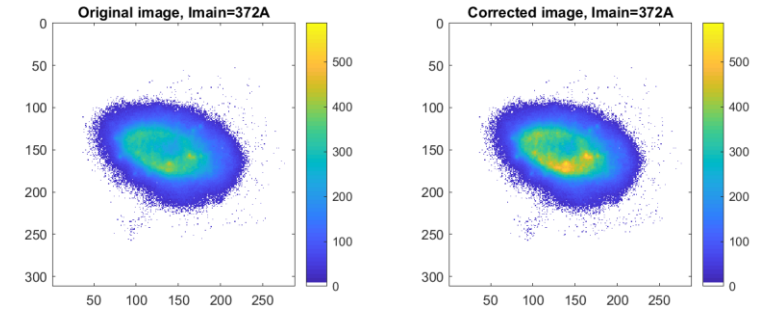
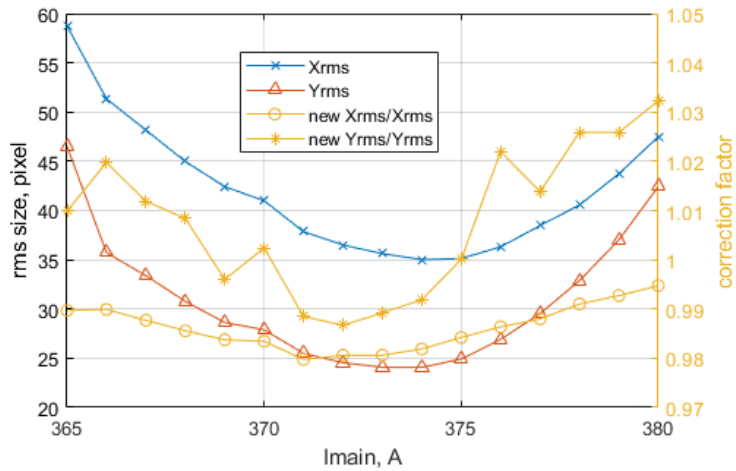
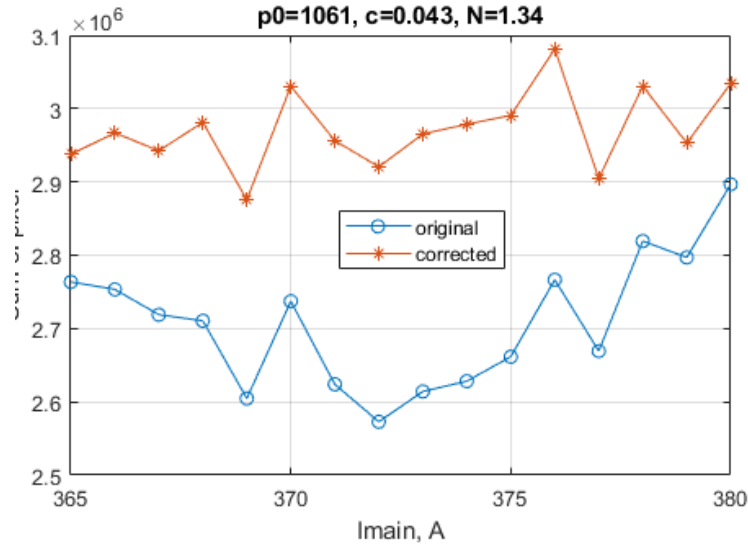
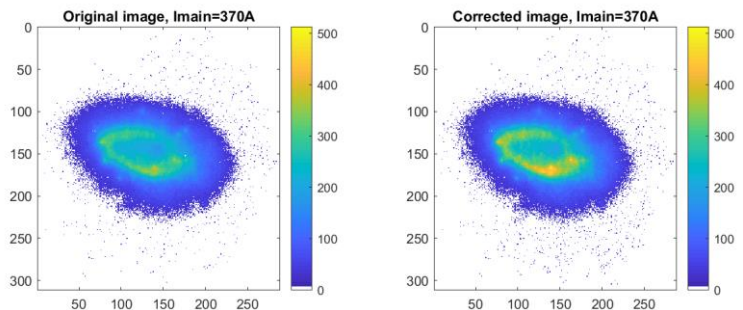
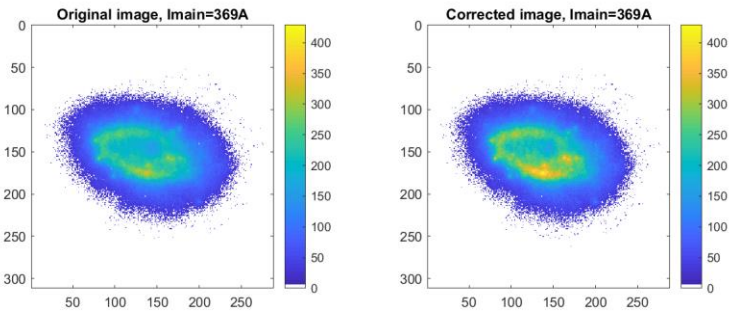
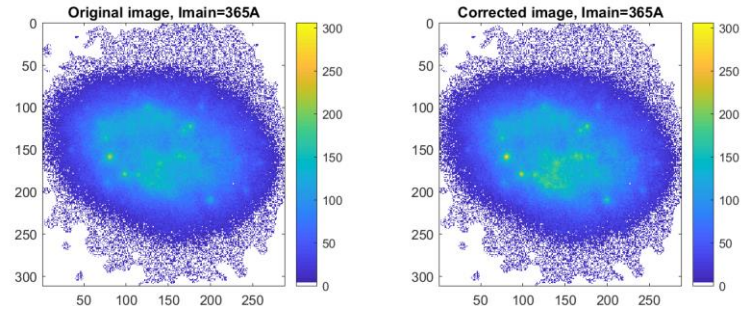
$$\text{Pixel value correction } p_{corr} = p_{orig} + \begin{cases} 0, & \text{if } p_{orig} < p_0 \\ c \cdot (p_{orig} - p_0)^N, & \text{if } p_{orig} \geq p_0 \end{cases}$$



Screen Nonlinearity Studies

02.07.2021A, HIGH1.Scr1, main solenoid scan, 2 pulses

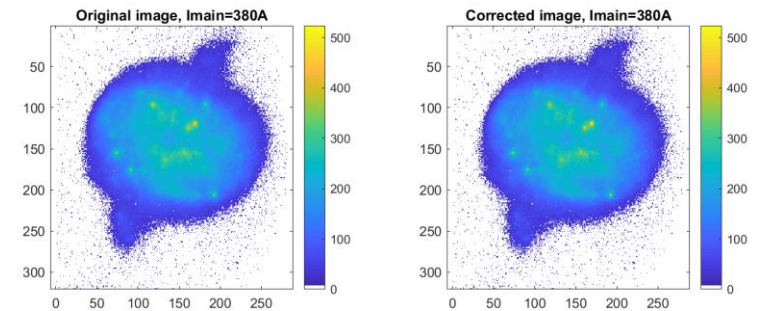
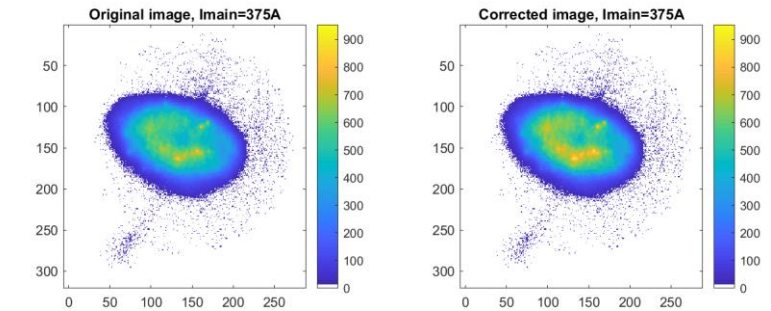
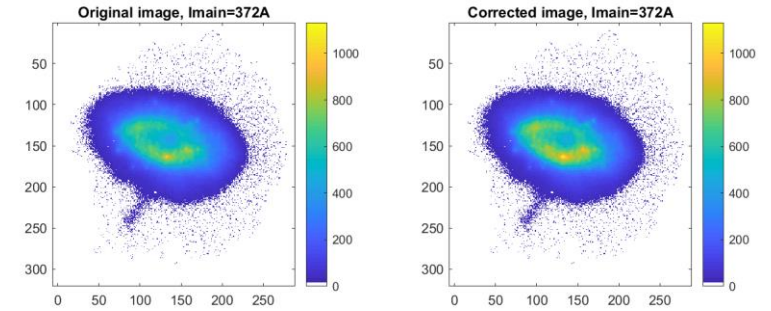
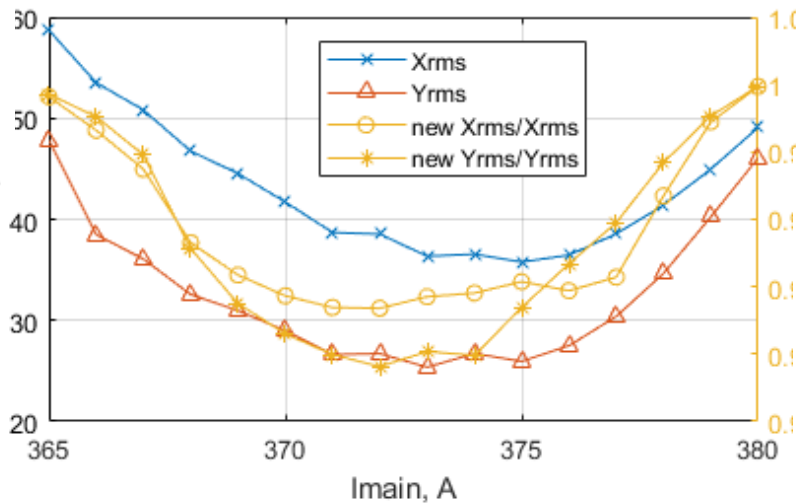
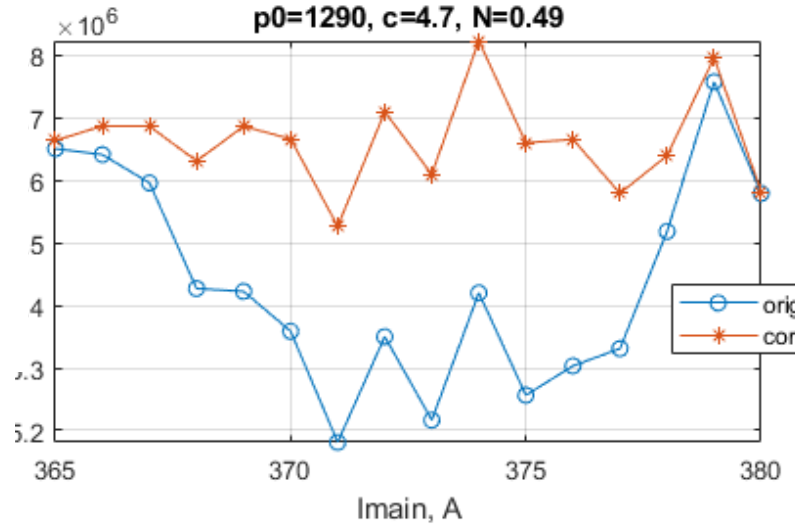
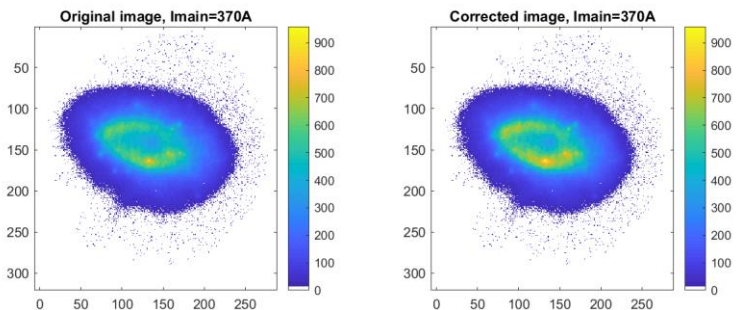
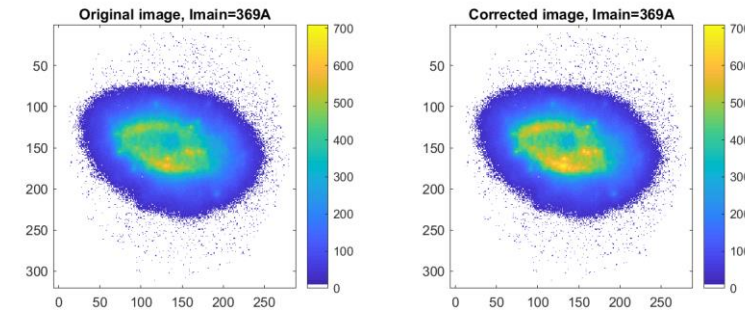
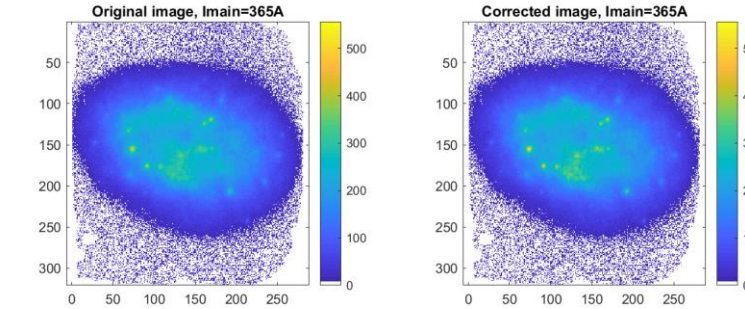
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Screen Nonlinearity Studies

02.07.2021A, HIGH1.Scr1, main solenoid scan, 4 pulses

$$\text{Pixel value correction } p_{corr} = p_{orig} + \begin{cases} 0, & \text{if } p_{orig} < p_0 \\ c \cdot (p_{orig} - p_0)^N, & \text{if } p_{orig} \geq p_0 \end{cases}$$



Beam imaging nonlinearity

Preliminary studies at PITZ

- Observation: Sum of pixels for various beam distributions of equal charge is not constant
- Possible reasons:
 - Screen nonlinearities and inhomogeneities
 - Camera nonlinearities and inhomogeneities
 - Filtering procedures
 - Beam issues (losses, space charge,...)
 - Dark current
 - Electronic noise
- Objective: to reconstruct beam distribution maintaining (at least) SoP invariance:
 - Model proposed (linear-nonlinear)
 - Up to now beam size difference ~3%, but maybe for smaller beams will be larger?
 - Use various number of pulses?
 - Individual for each setup (even location at the screen)
 - ...