PITZ Run Coordination (2019 / week 21)

Gun4.2 run

H. Qian
Zeuthen, 6.06.2019

Shift planning for week 21

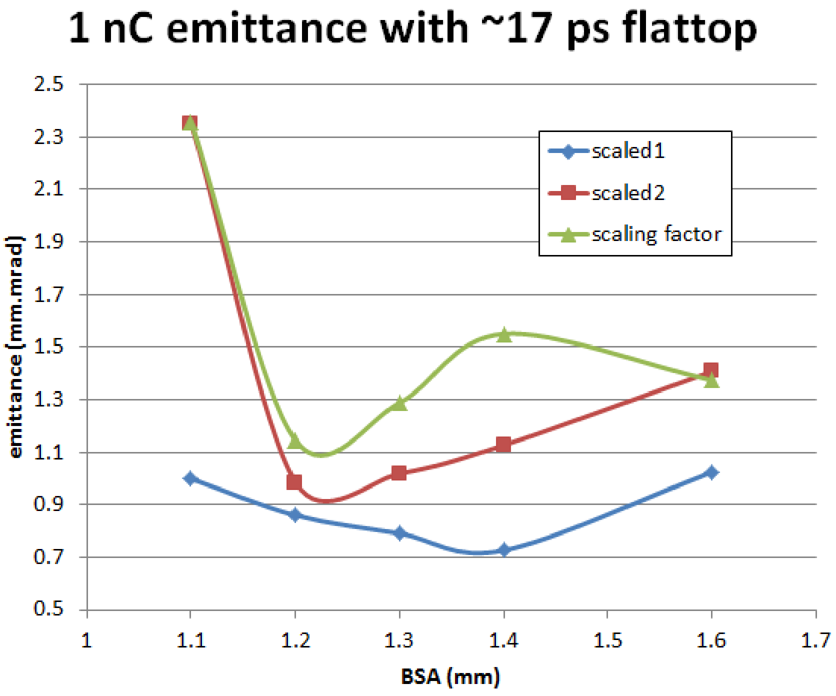
Flattop emittance 1nC (0.5nC): (MK, HQ)
- BSA=1.1mm; 1.3mm; 1.2mm (remeasure?),…
- use gun quads
- Imain scan for each BSA,
- then 3x3 statistics

Mon May-27	Tue May-28	Wed May-29
Krasilnikov Koschitzki	Flattop emittance 1nC	
Niemczyk Shu		
Automatic Conditioning	Automatic Conditioning	

1 nC emittance

BSA scan, Flattop laser ~17ps, gun 60 MV/m, EMSY1 → HIGH1.SCR4

- Finished 1 nC emittance BSA scan at 1.3 mm
  - Optimum BSA by different scaled emittance is different (1.4 mm and 1.2 mm)
    - Scaled1 = unscaled*scalingFactor,
    - Scaled2 = unscaled*scalingFactor^2

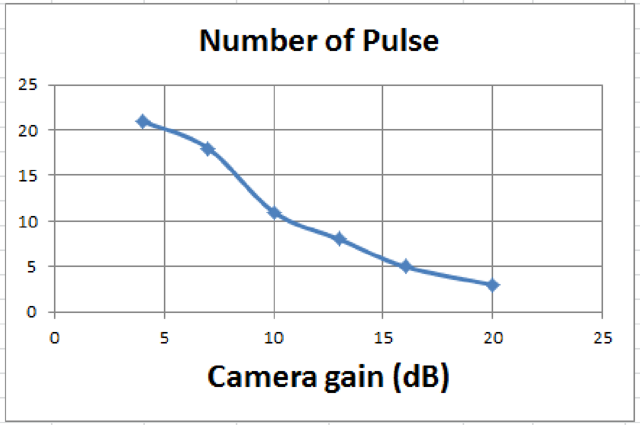


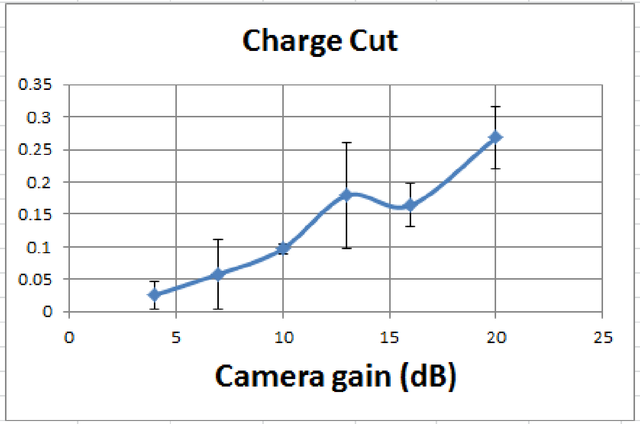
BSA	Scaled1	Scaled2	ScalingFactor
1.1	0.999	2.352	2.355
1.2	0.860	0.985	1.146
1.3	0.791	1.019	1.288
1.4	0.727	1.127	1.550
1.6	1.024	1.407	1.374

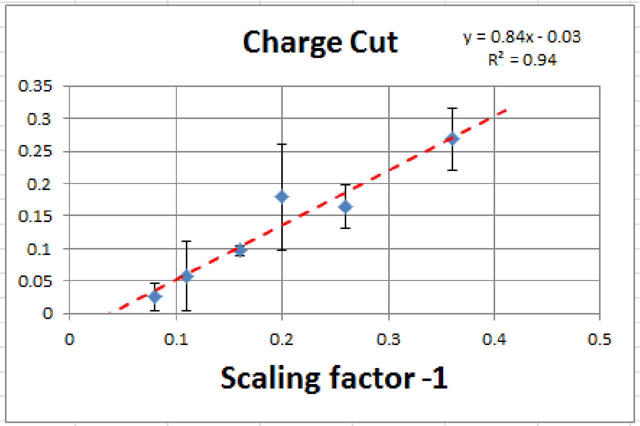
1 nC emittance

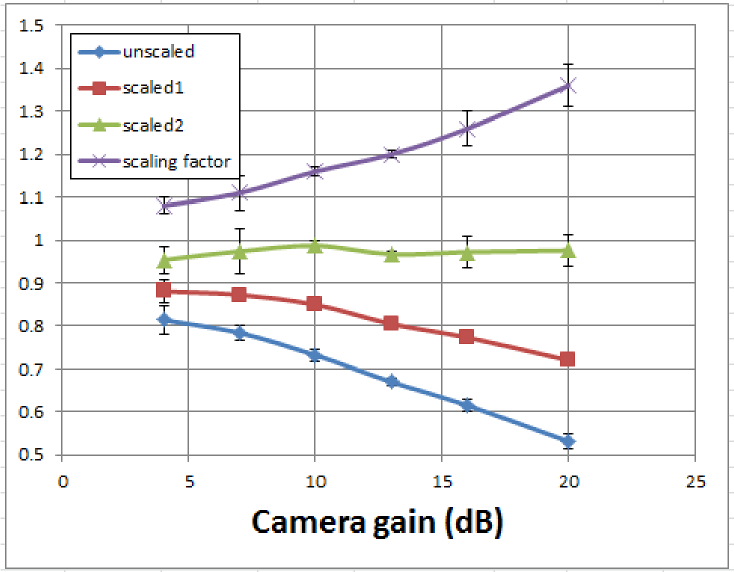
Emittance vs Camera gain

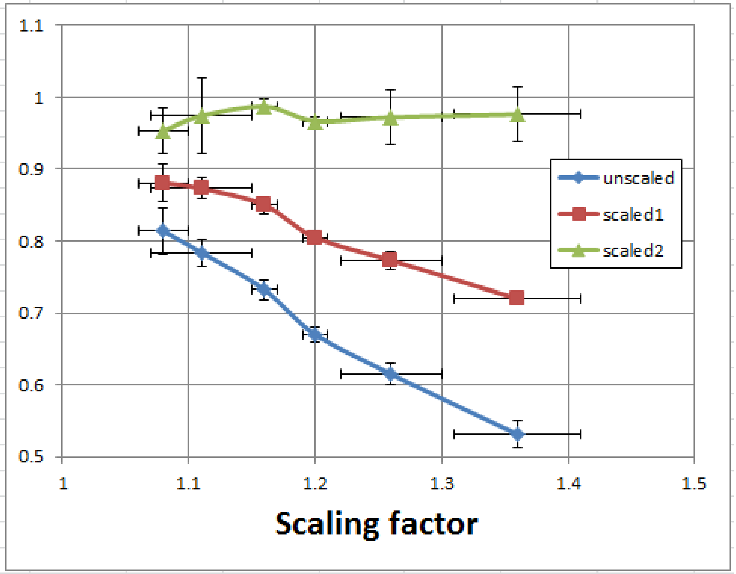
- BSA 1.3mm, Flattop laser ~17ps, gun 60 MV/m, EMSY1 → HIGH1.SCR4, X emittance comparison









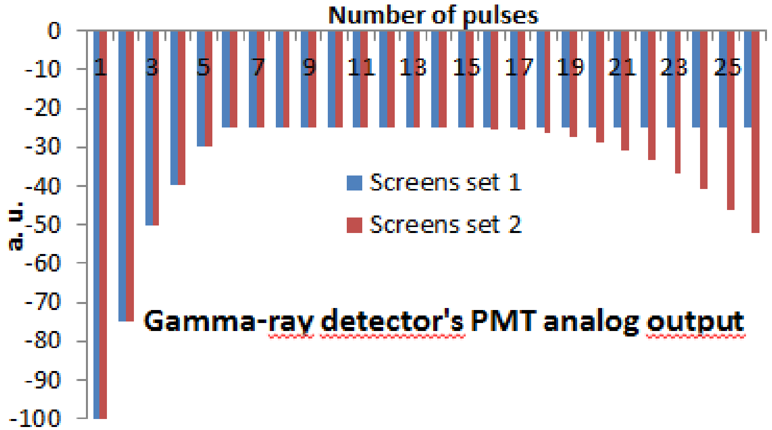


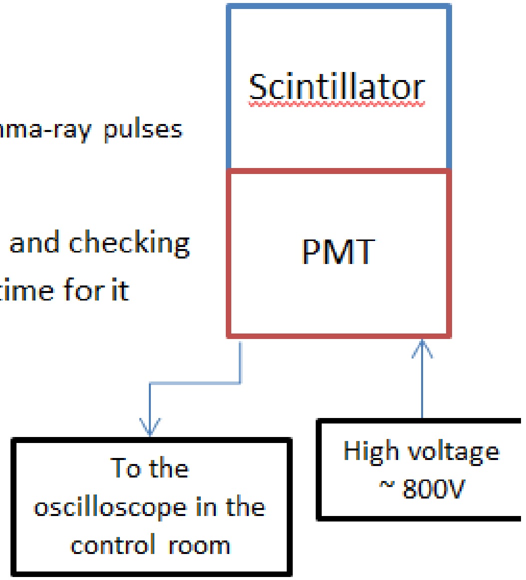
Charge cut means the lost charge in the measured phase space compared to EMSY image.

More detailed analysis will be discussed in the following PPS talk.

First observations from the gamma-ray detectors at the end of tunnel in the future hole location

- Each pulse from the gamma-ray detector's PMT has about 20ns duration
- Noisy, non-regular and considerable number of pulses produced from dark-current (normal)
- Two kind of results when beam is ON (with different set of screens on front of beam)
  - Strange amplitude in first few pulses : some internal electronic capacity during the electron line?
  - Strange amplitude increase at the end of pulses
- Saturated on low transmission (~1-2%)
  - When I lowered the electron energy by changing the booster phase
  it goes out of saturation (Scintillator single gamma-ray energy response?)
  - Strangely, non-regular pulses was vanished during beam ON
    - No or low-detections of dark-current produced gamma-rays
    - It maybe result the less integrated radiation in comparison to dark-current produced gamma-ray pulses
- My conclusion:
  - I can not trust the data before knowing more the detector characteristics, its electronics and checking
  With standard known source like caesium-137 or Cobalt-60 and also we need have program-time for it





Difficulties

- Difficulties
  - Water
    - RF5 water flow IL (To be checked during shutdown)
  - Laser
    - Laser failure from the night run (cooling water IL), temporarily fixed, to be worked on during shutdown
    - OSS is misaligned during water repair

Shift planning for weeks 24/25

Photocathode flattop laser

Startup
Timing system / LLRF/laser

Fastscan methodology study

TEM grid

Tue Jun-11	Wed Jun-12	Thu Jun-13	Fri Jun-14	Sat Jun-15	Sun Jun-16
Gross	Gross	Gross	Koschitzki	Koschitzki	Koschitzki
Jachmann	Jachmann	Jachmann	Jachmann	Jachmann	Jachmann
Rueger	Rueger	Rueger	Rueger	Rueger	Rueger
Kalantaryan	Kalantaryan	Kalantaryan	Kalantaryan	Kalantaryan	Kalantaryan
Schade	Schade	Schade	Schade	Schade	Schade
Heuchling	Heuchling	Heuchling	Heuchling	Heuchling	Heuchling
Krasilnikov	Krasilnikov	Krasilnikov	Krasilnikov	Krasilnikov	Krasilnikov
Li	Huang	Li	Huang	Li	Huang

A gray field means the status has changed since the last version

THz

Booster transfer

TEM grid

Li

Nie
Gri

Gun quads

Emission curve

Mon Jun-17	Tue Jun-18	Wed Jun-19	Thu Jun-20	Fri Jun-21	Sat Jun-22	Sun Jun-23
Koschitzki	Gross	Koschitzki	Koschitzki	Gross	Gross	Gross
Koehler	Koehler	Koehler	Koehler	Koehler	Koehler	Koehler
Maschmann	Maschmann	Maschmann	Maschmann	Maschmann	Maschmann	Maschmann
Kalantaryan	Kalantaryan	Kalantaryan	Kalantaryan	Kalantaryan	Kalantaryan	Kalantaryan
Schultze	Schultze	Schultze	Schultze	Schultze	Schultze	Schultze
Schmal	Schmal	Schmal	Schmal	Schmal	Schmal	Schmal
Vashchenko	Gross	Krasilnikov	Oppelt	Gross	Gross	Gross
Huang	Huang	GUEST	Koschitzki	Huang	Melkumyan	Melkumyan

y-2019

A gray field means the status has changed since the last version

XFEL operation	69	When
slice emittance	14	Q1-Q2
emittance vs gradient	40	Q1-Q4
bunch shape distorsion	7	Q1-Q2
Gun quads	5	
Coupler kick	3	Q1
XFEL R&D	41	
Cs2Te response time	3	Q1 ?
Green cathode test	7	Q4
Gaussian truncation & DOE	14	Q1-Q3
ELLA beam test	14	Q3-Q4
thermal imaging	3	Q1-Q2
XFEL user	14	
THz	14	Q1-Q4
PITZ budget	26	
Plasma	18	Q2
UED	6	Q1-4
BPM commissioining	2	

Discussion of a new scaled emittance & camera gain for FASTSCAN

H. Qian & M. Krasilnikov
Zeuthen, 6.06.2019

HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

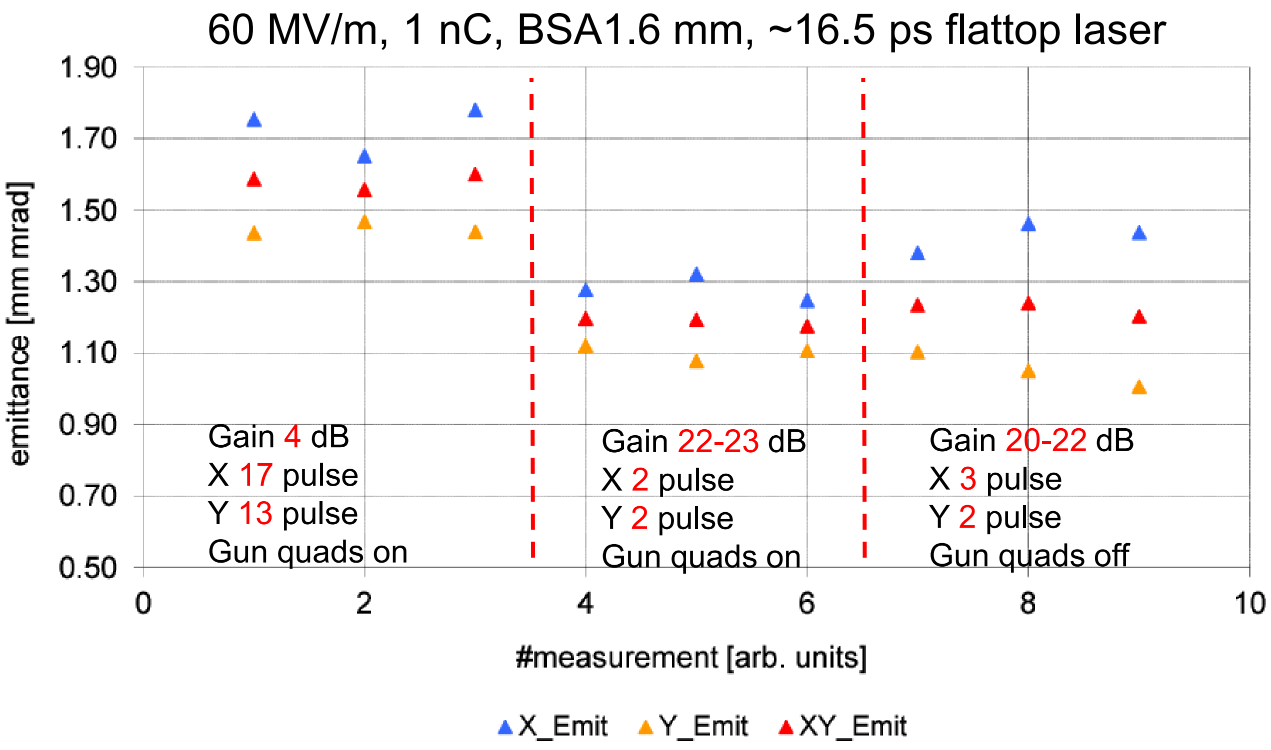
DESY.

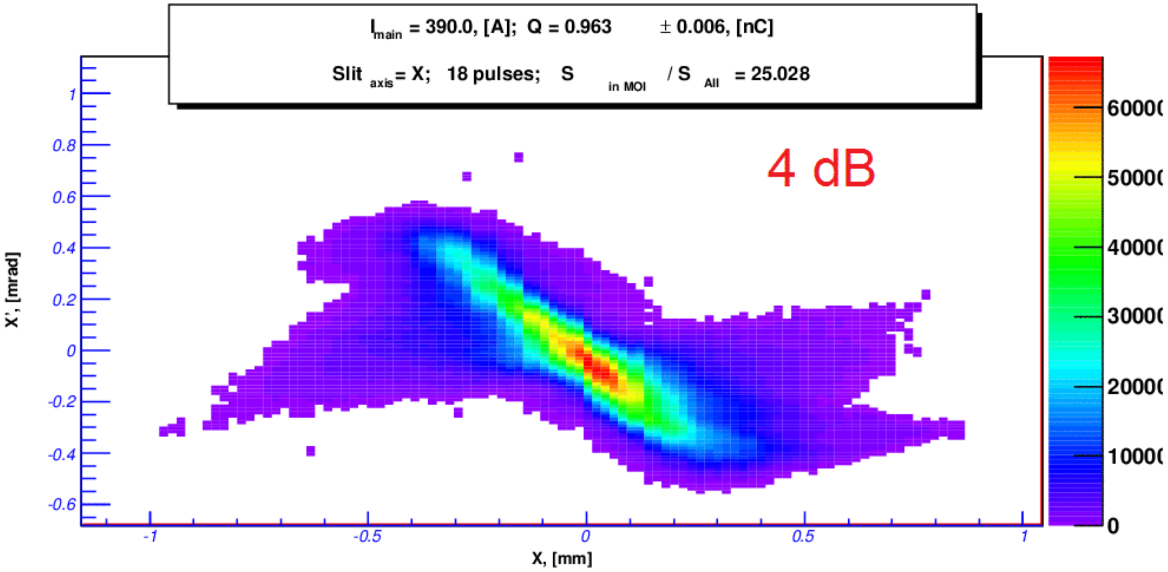
Outline

- Motivation
- Why scaled emittance for fastscan?
- How to scale up the unscaled emittance
- A simulation to compare two ways of emittance scaling
- Experiment observations
  - 1 nC @60 MV/m: emittance vs camera gain (Flattop laser)
  - 0.25 nC @XFEL gradient: measured emittance vs simulations (Gaussian laser)
  - 0.1 nC @40 MV/m: Gaussian laser vs flattop laser (covered by MK in a different talk)
- An analytical model for estimating the importance of noise floor in FASTSCAN
- Possible ways to improve SNR for future PITZ emittance measurement
- Discussions: how to proceed with fastscan now?

Motivation

- 1 nC emittance results are quite different with different camera gains
  - Raffael 'accidentally' measured 1 nC emittance with low camera gain (4 dB) and showed much larger emittance values
  - Grygorii confirm the results with more statistics

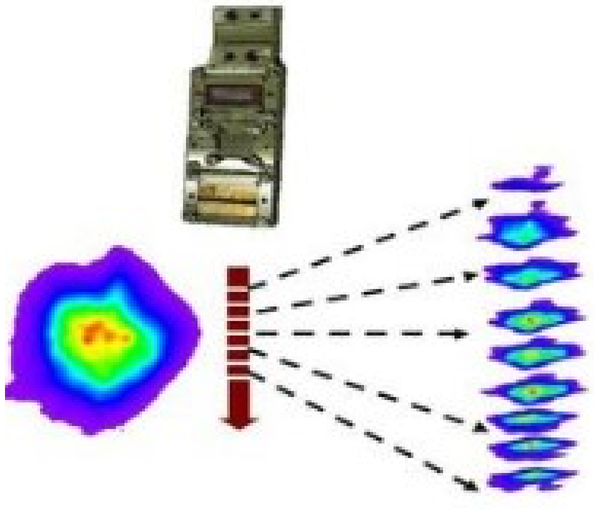


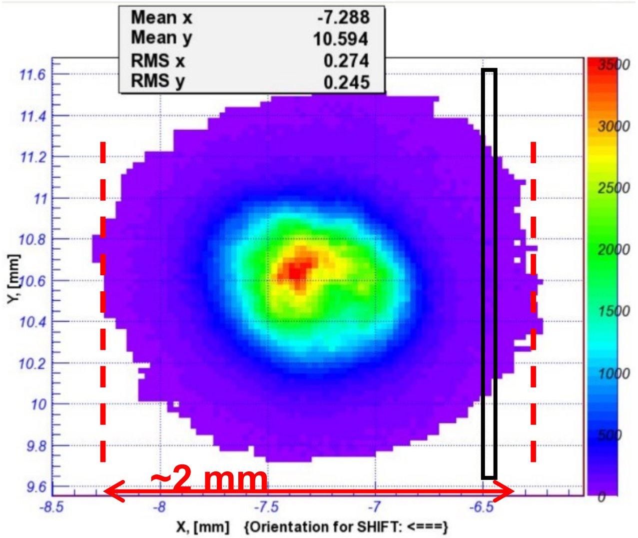


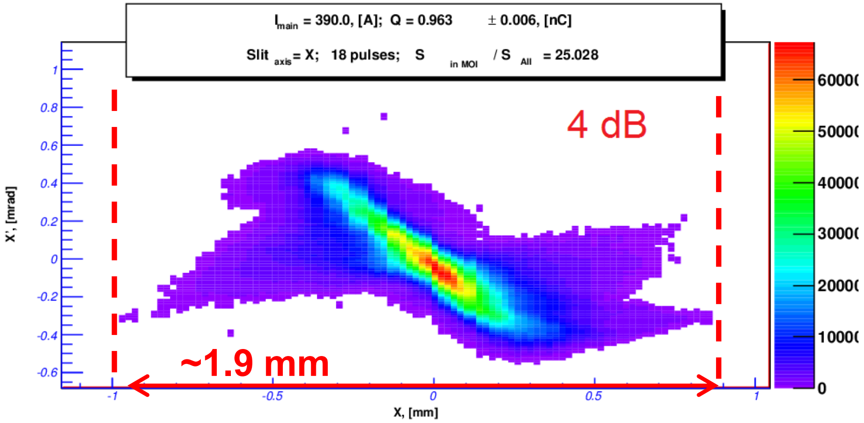
More phase space is measured for low camera gain.

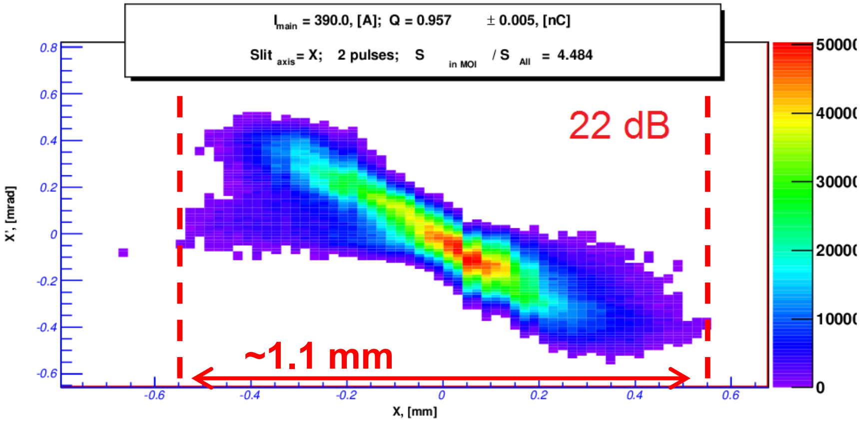
Why scaled emittance for fastscan?

- Noise floor and image filter removes the low density phase space.









Noise floor

⇩

Reduced phase space

⇩

Unscaled (reduced) emittance

⇩ Scaling factor

100% emittance
(scaled emittance)

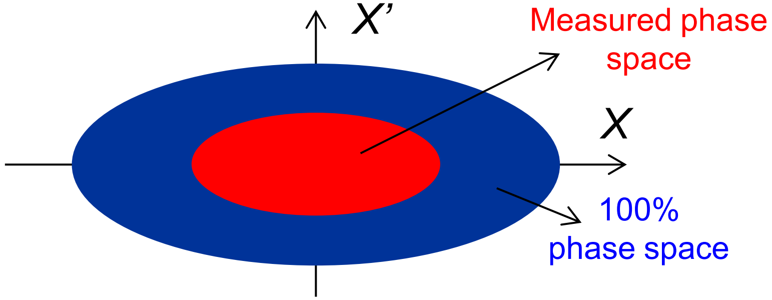
How to scale up the unscaled emittance

Current scaling factor

- RMS emittance definition

$$\varepsilon = \sqrt{\langle x^2\rangle\langle x'^2\rangle - \langle xx'\rangle^2} = \sqrt{\langle x^2\rangle}\sqrt{\langle x'^2\rangle - \frac{\langle xx'\rangle^2}{\langle x^2\rangle}} = \boldsymbol{\sigma_x \sigma_{x'}^{uncorrelated}}$$

- Scaling factor



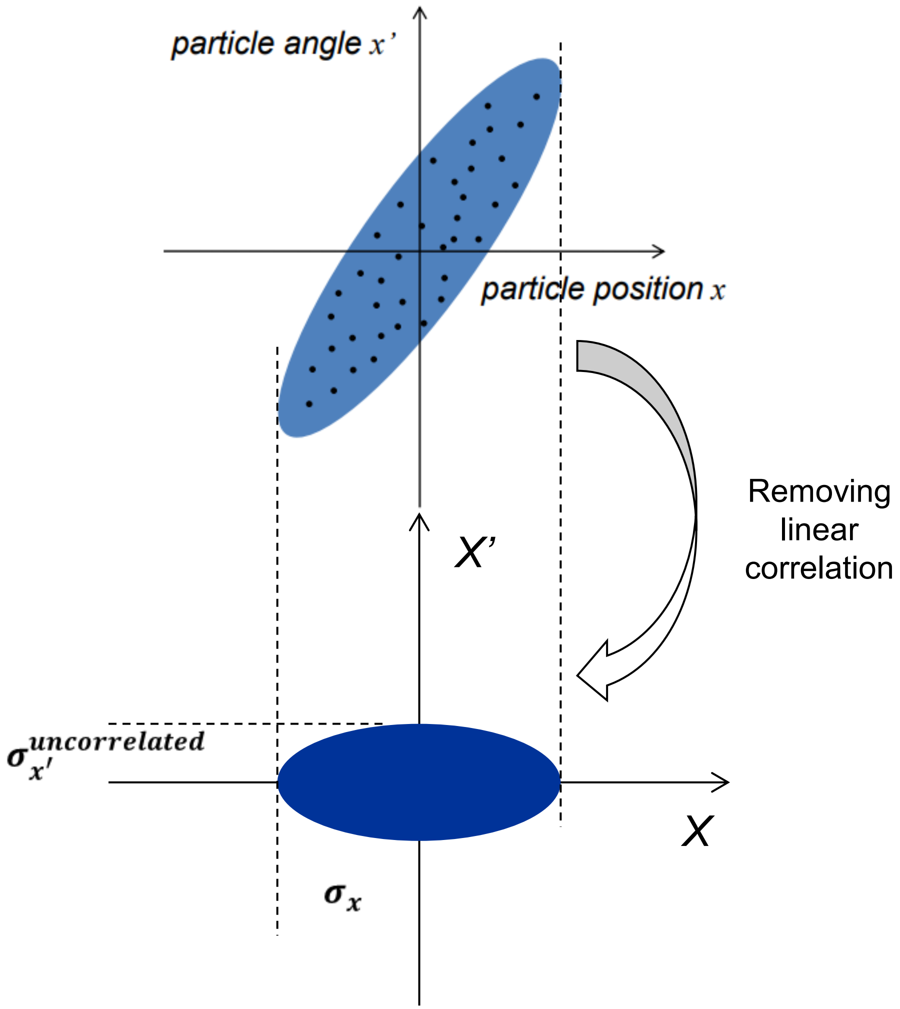
$$\varepsilon_{100} = \boldsymbol{\sigma_x^{100} \sigma_{x'}^{uncorrelated,100}} \approx \boldsymbol{\sigma_x^{EMSY} \sigma_{x'}^{uncorrelated,100}}$$

$$\varepsilon_{unscaled} = \boldsymbol{\sigma_x^{unscaled} \sigma_{x'}^{uncorrelated,unscaled}} = \boldsymbol{\sigma_x^{slit} \sigma_{x'}^{uncorrelated,slit}}$$

Scaling factor= $\frac{\varepsilon_{100\%}}{\varepsilon_{unscaled}} \approx \frac{\boldsymbol{\sigma_x^{EMSY}}}{\boldsymbol{\sigma_x^{slit}}} * \frac{\boldsymbol{\sigma_{x'}^{uncorrelated,100\%}}}{\boldsymbol{\sigma_{x\prime}^{uncorrelated,slit}}}$

Emcal scaling factor

Neglected in Emcal



How to scale up the unscaled emittance

Another way of scaling

- Another way to scale up the emittance

$$\sigma_x^2(100\%) \approx \sigma_{x,EMSY}^2 = \varepsilon_{100\%}\beta_{100\%}$$

$$\sigma_x^2(unscaled) \approx \sigma_{x,slit}^2 = \varepsilon_{\text{unscaled}}\beta_{unscaled}$$

Scaling factor $= \frac{\varepsilon_{100\%}}{\varepsilon_{unscaled}} \approx \frac{\boldsymbol{\sigma_{x,EMSY}^2}}{\sigma_{x,slit}^2} \frac{\beta_{unscaled}}{\beta_{100\%}}$

(Emcal scaling factor)^2 ~1?

- Two scaled emittance
  - Scaled1 = unscaled*($\frac{\boldsymbol{\sigma_x^{EMSY}}}{\boldsymbol{\sigma_x^{slit}}}$)
  - Scaled2 = unscaled*($\frac{\boldsymbol{\sigma_x^{EMSY}}}{\boldsymbol{\sigma_x^{slit}}}$)^2

- Current emittance scaling in Emcal

$$\varepsilon_{100} = \boldsymbol{\sigma_x^{100}\sigma_{x'}^{uncorrelated,100}} \approx \boldsymbol{\sigma_x^{EMSY}\sigma_{x'}^{uncorrelated,100}}$$

$$\varepsilon_{unscaled} = \boldsymbol{\sigma_x^{unscaled}\sigma_{x'}^{uncorrelated,unscaled}} = \boldsymbol{\sigma_x^{slit}\sigma_{x'}^{uncorrelated,slit}}$$

Scaling factor$= \frac{\varepsilon_{100\%}}{\varepsilon_{unscaled}} \approx \frac{\boldsymbol{\sigma_x^{EMSY}}}{\boldsymbol{\sigma_x^{slit}}} * \frac{\boldsymbol{\sigma_{x'}^{uncorrelated,100\%}}}{\boldsymbol{\sigma_{x'}^{uncorrelated,slit}}}$

Emcal scaling factor — Neglected in Emcal

$$\frac{\sigma_{x'}^{uncorrelated,100\%}}{\sigma_{x'}^{uncorrelated,slit}} = \frac{\sqrt{\frac{\varepsilon_{100\%}}{\beta_{100\%}}}}{\sqrt{\frac{\varepsilon_{unscaled}}{\beta_{unscaled}}}} = \sqrt{\frac{\varepsilon_{100\%}}{\varepsilon_{unscaled}}}\sqrt{\frac{\beta_{unscaled}}{\beta_{100\%}}}$$

Scaling factor $= \frac{\varepsilon_{100\%}}{\varepsilon_{unscaled}} \approx \frac{\boldsymbol{\sigma_{x,EMSY}^2}}{\sigma_{x,slit}^2} \frac{\beta_{unscaled}}{\beta_{100\%}}$ Consistent!

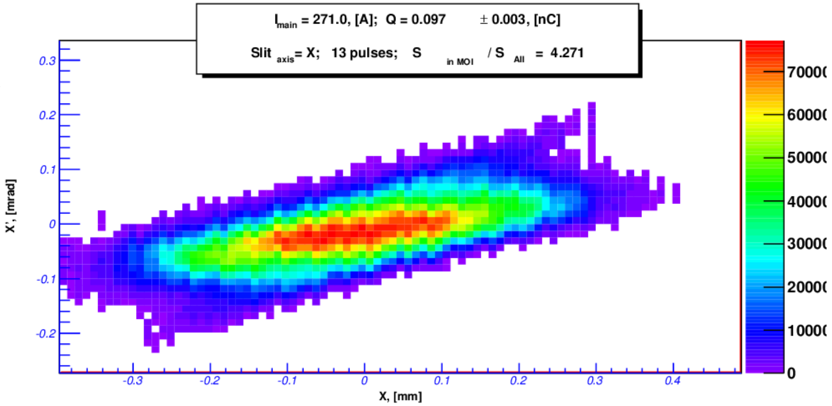
A simulation to compare two ways of emittance scaling

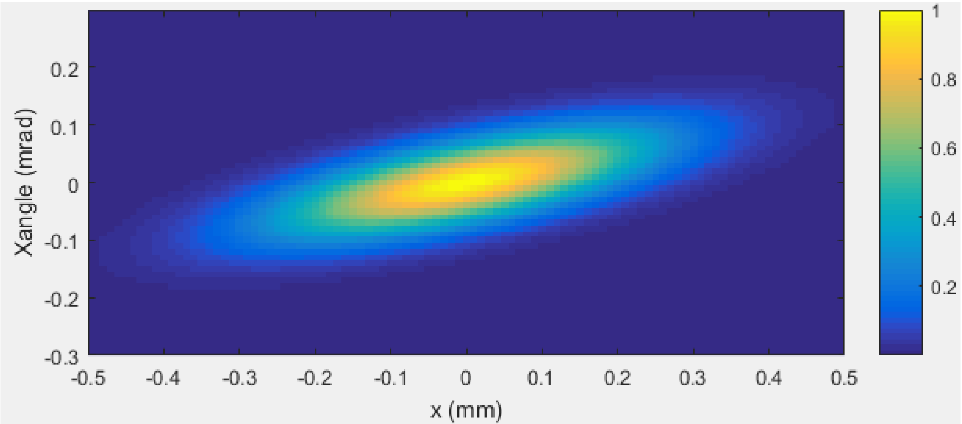
Pure Gaussian phase space

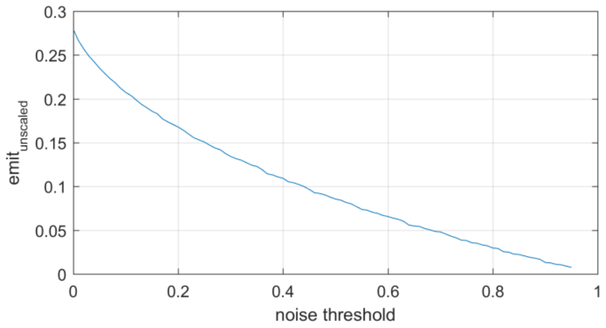
- Gaussian phase space
  - Twiss parameters

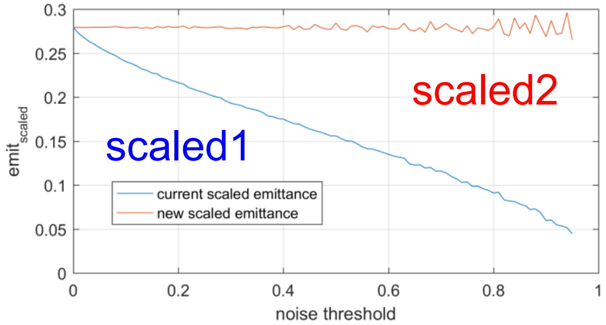
$$\rho(x,x') = \frac{Q}{2\pi\varepsilon} e^{-\frac{\gamma x^2 + 2\alpha x x' + \beta x'^2}{\varepsilon}}$$

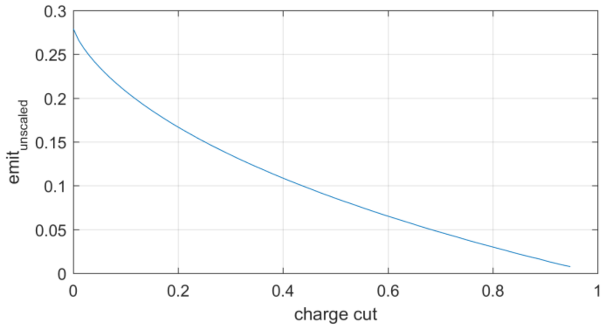
Flattop laser
40 MV/m
100 pC

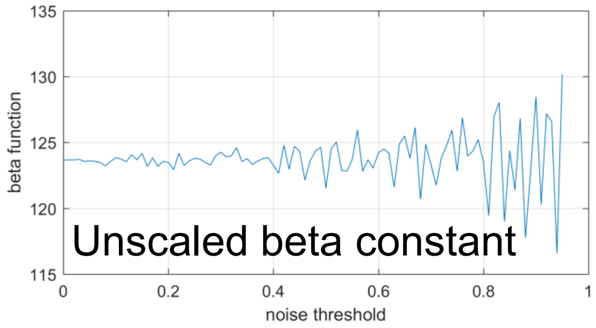


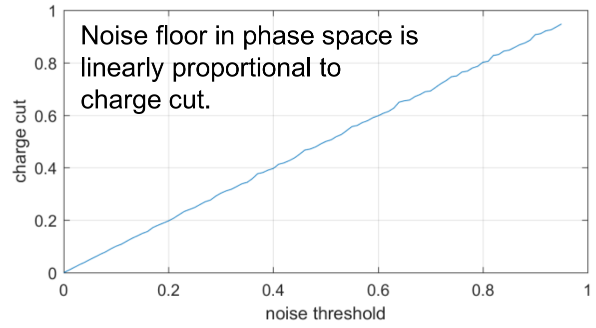


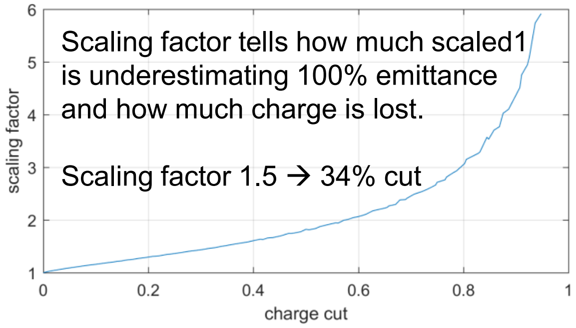








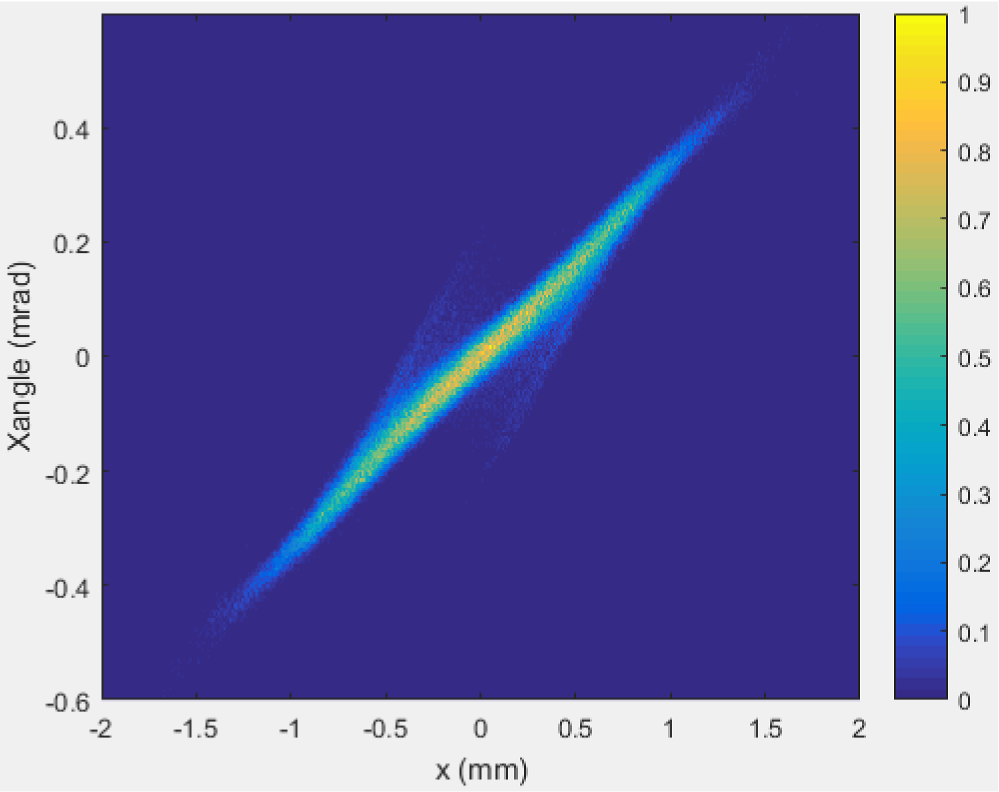


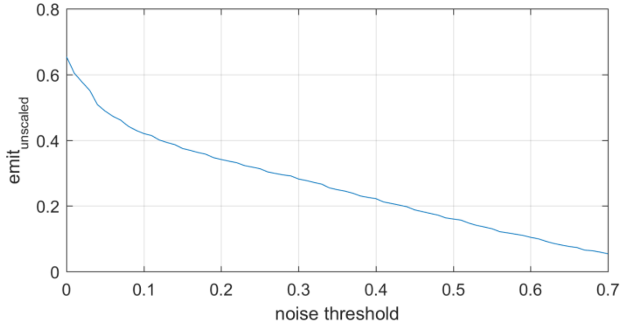


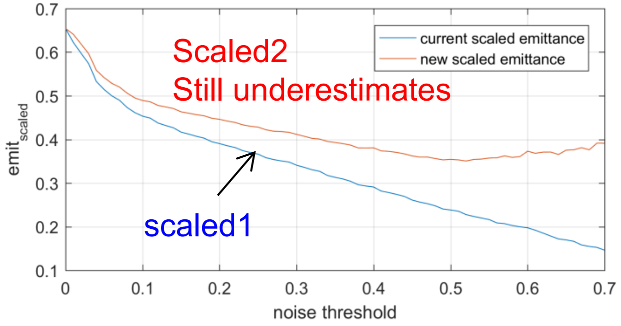
A simulation to compare two ways of emittance scaling

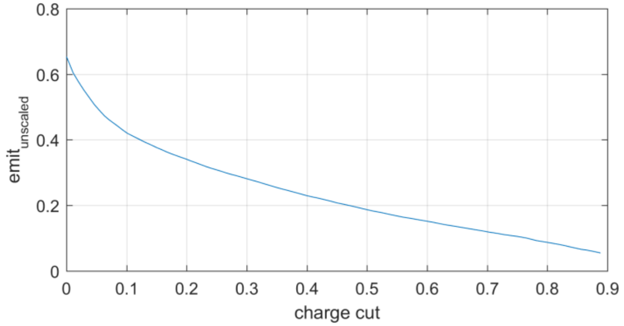
Simulated phase space from ASTRA

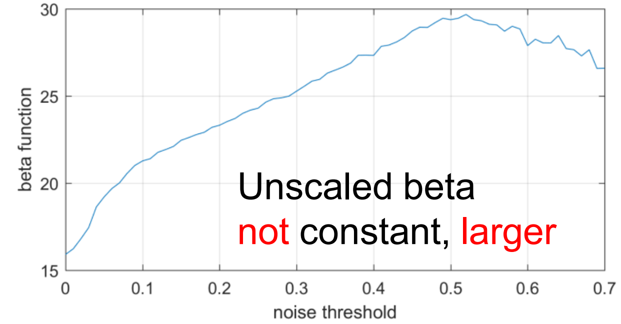
- Simulated phase space (200k macro particles)
  - 1nC, 60 MV/m, ~20 ps

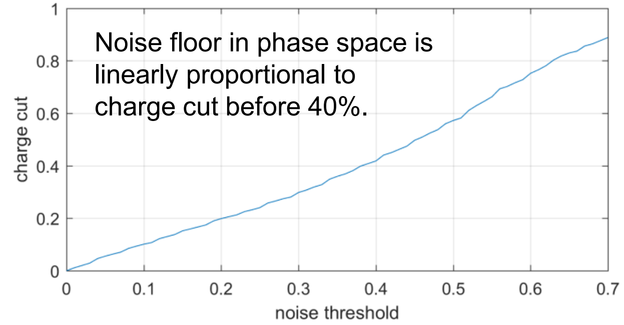


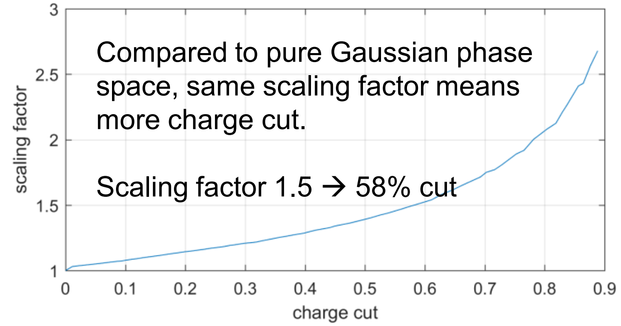








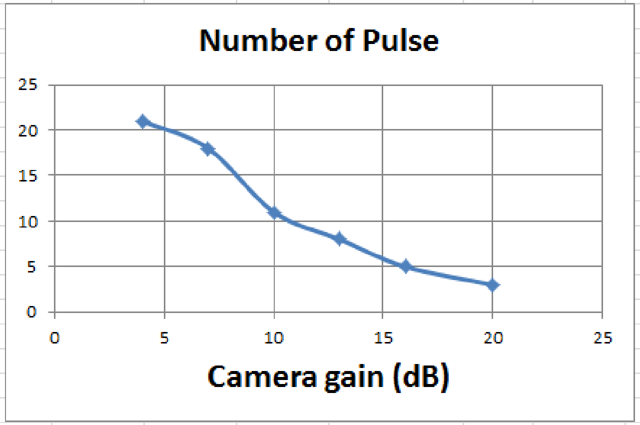


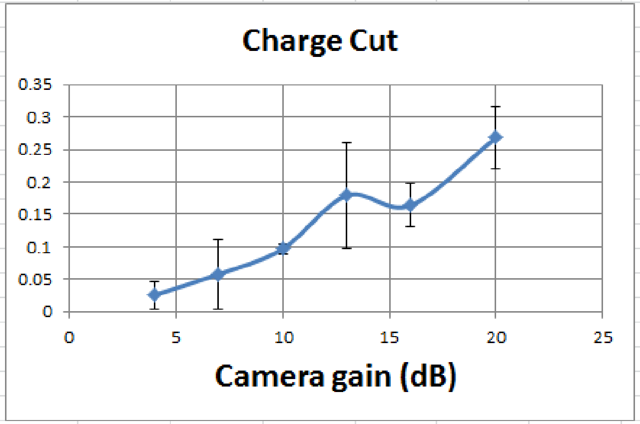


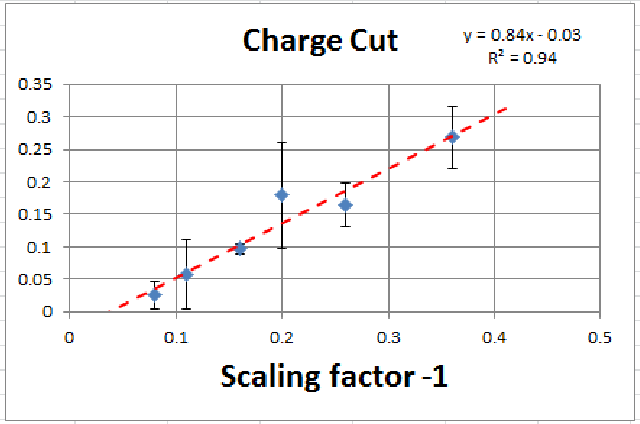
Experiment observations

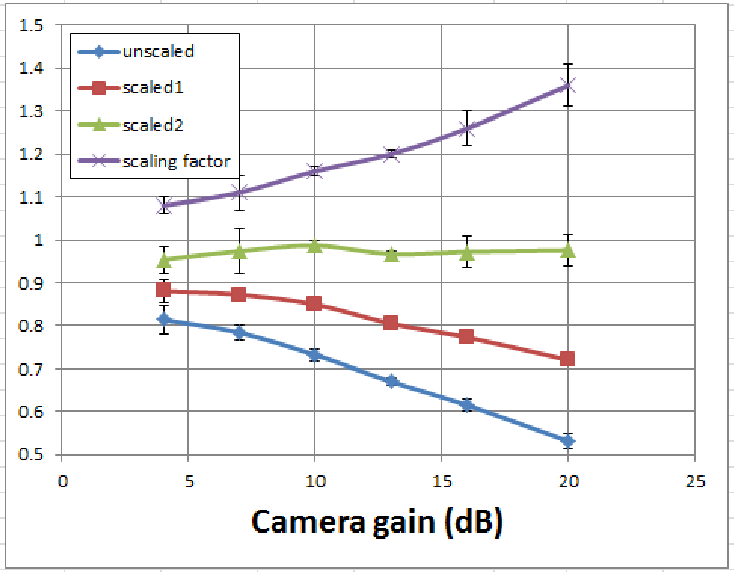
1 nC @60 MV/m: emittance vs camera gain (Flattop laser)

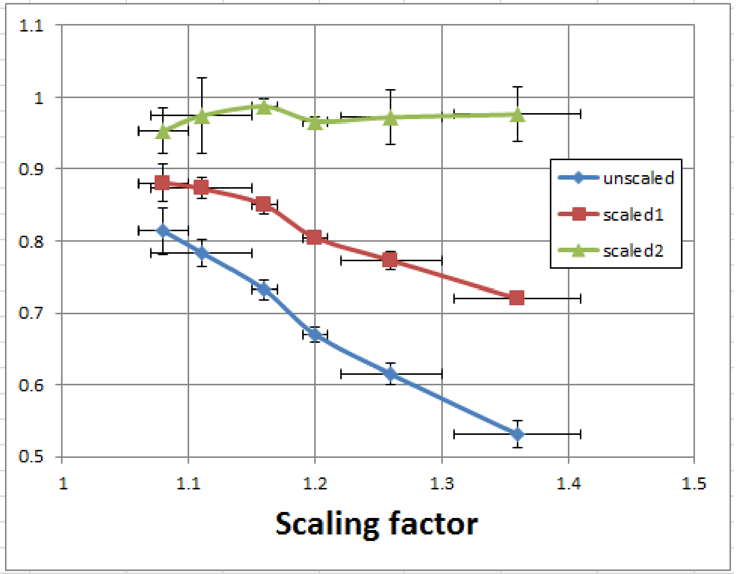
- BSA 1.3mm, Flattop laser ~17ps, gun 60 MV/m, EMSY1 → HIGH1.SCR4 (f160), X emittance comparison







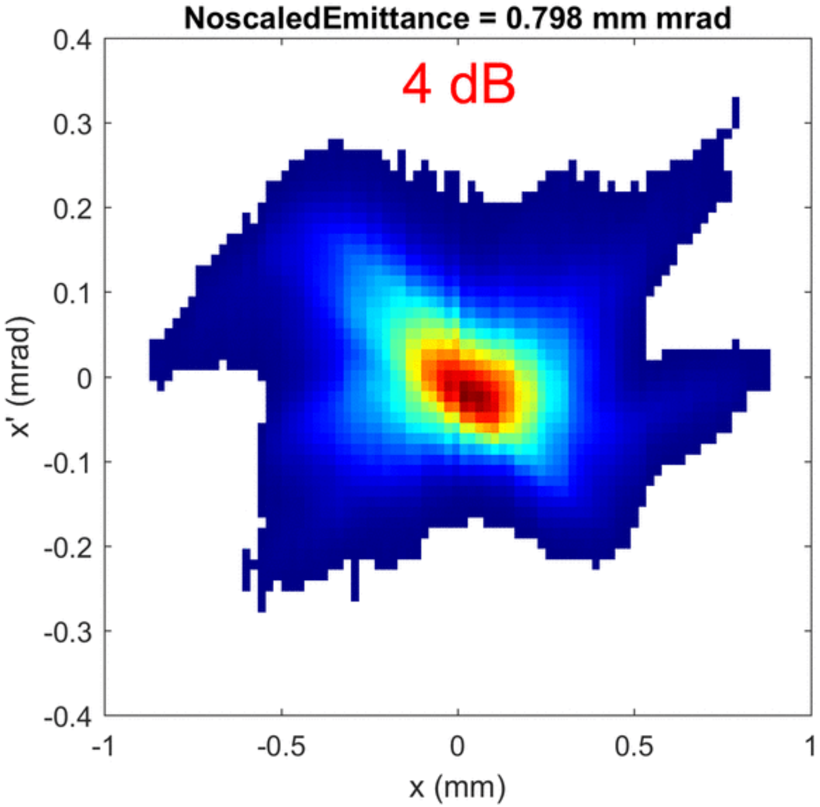


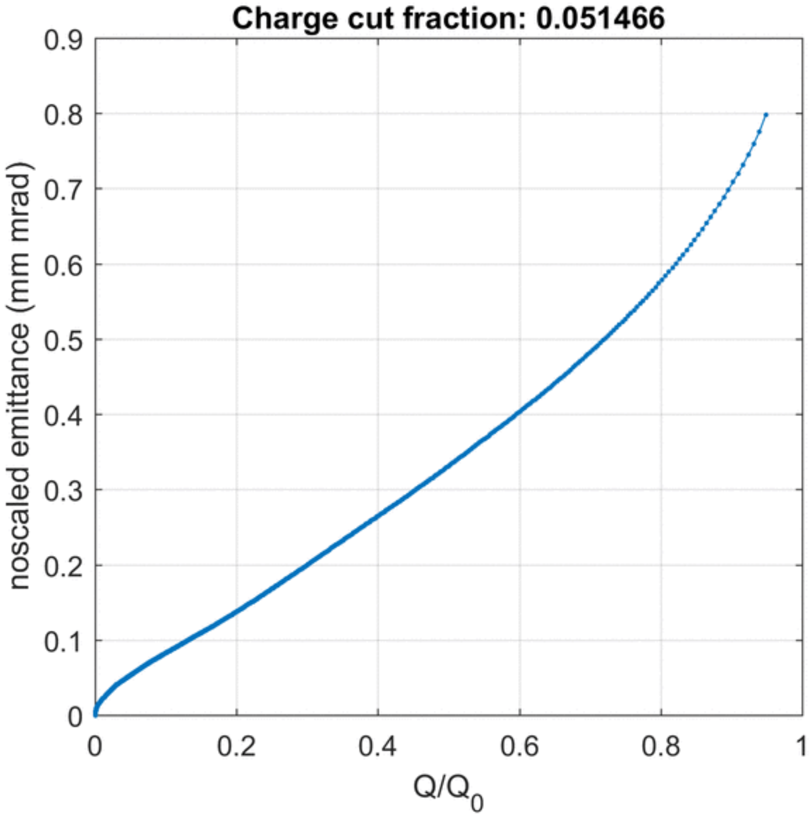


Experiment observations

1 nC @60 MV/m: emittance vs camera gain (Flattop laser)

- BSA 1.3mm, Flattop laser ~17ps, gun 60 MV/m, EMSY1 → HIGH1.SCR4 (f160), X emittance comparison

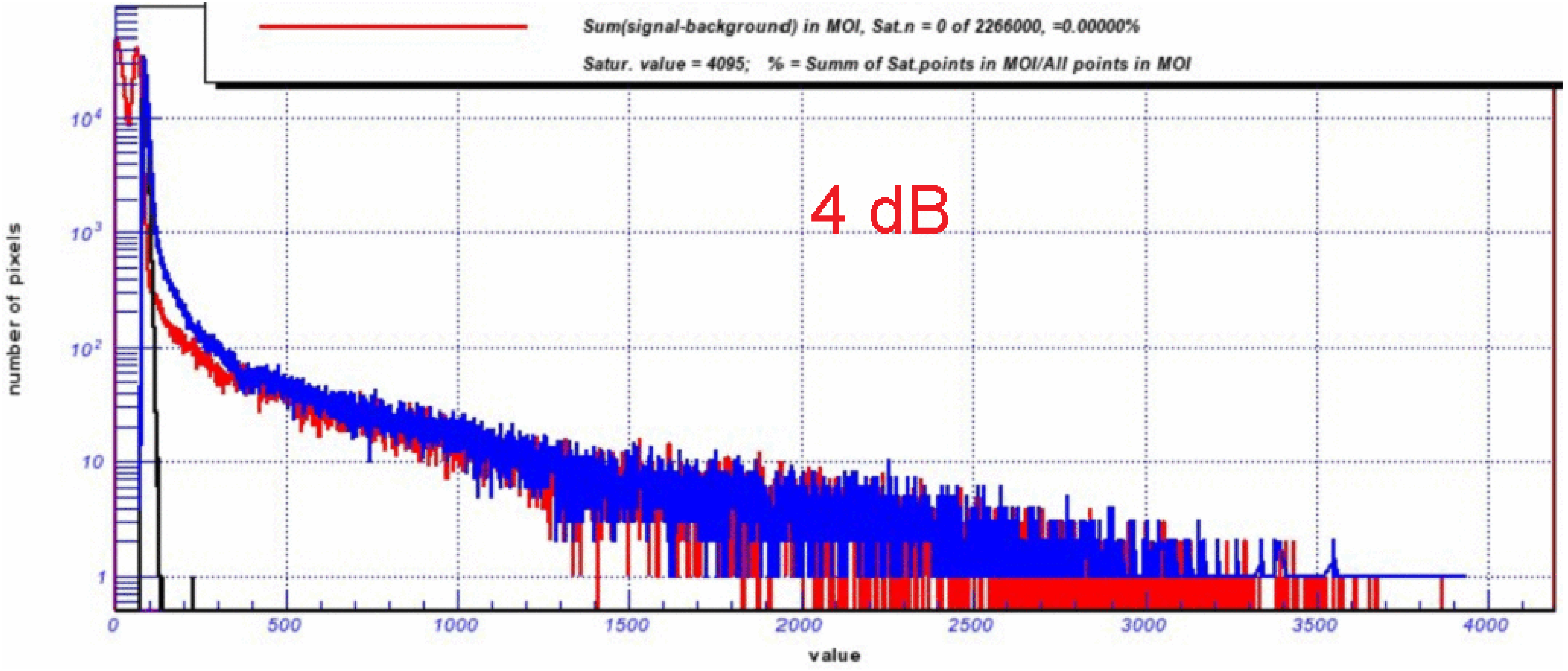




Experiment observations

1 nC @60 MV/m: emittance vs camera gain (Flattop laser)

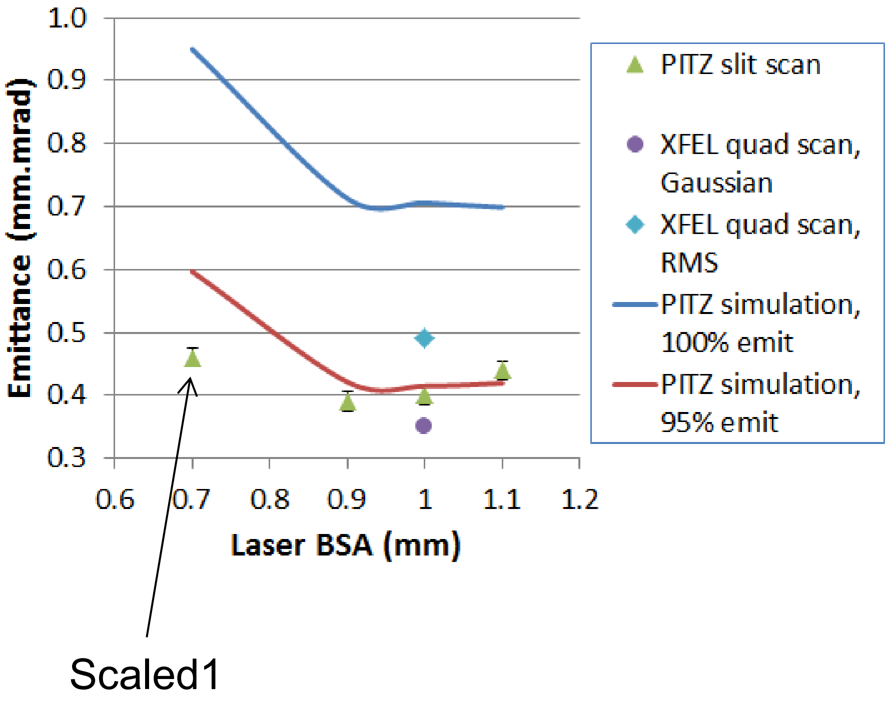
- BSA 1.3mm, Flattop laser ~17ps, gun 60 MV/m, EMSY1 → HIGH1.SCR4 (f160), X emittance comparison

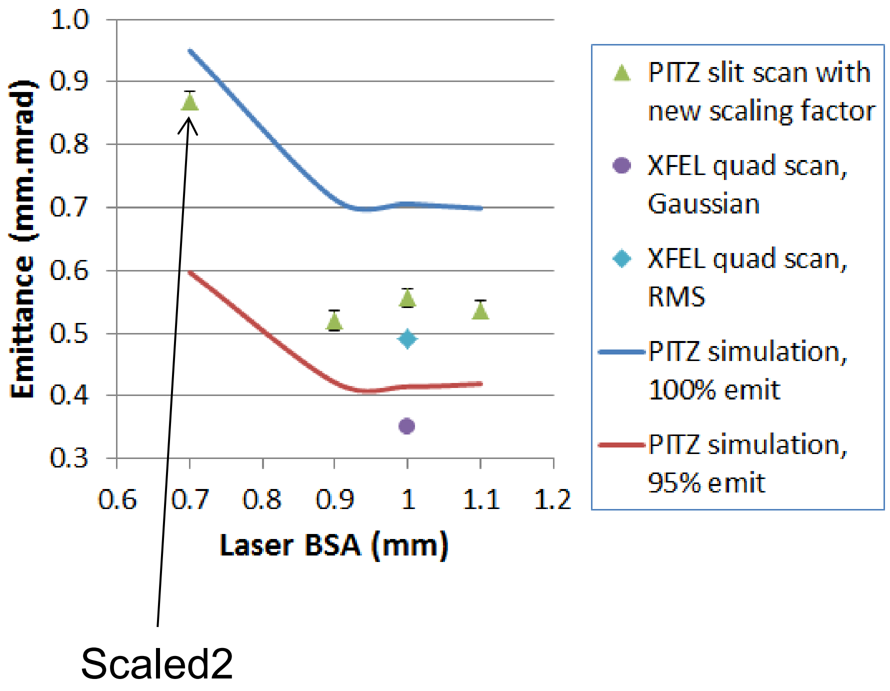


Experiment observations

0.25 nC @XFEL gradient: measured emittance vs simulations (Gaussian laser)

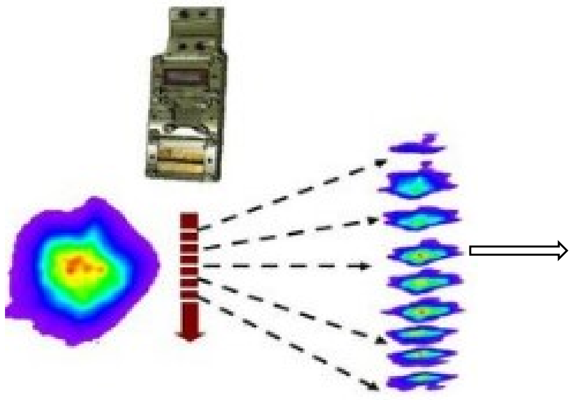
- Gaussian laser ~7ps, gun 6.3 MeV/c, EMSY1 → HIGH1.SCR4 (f160)

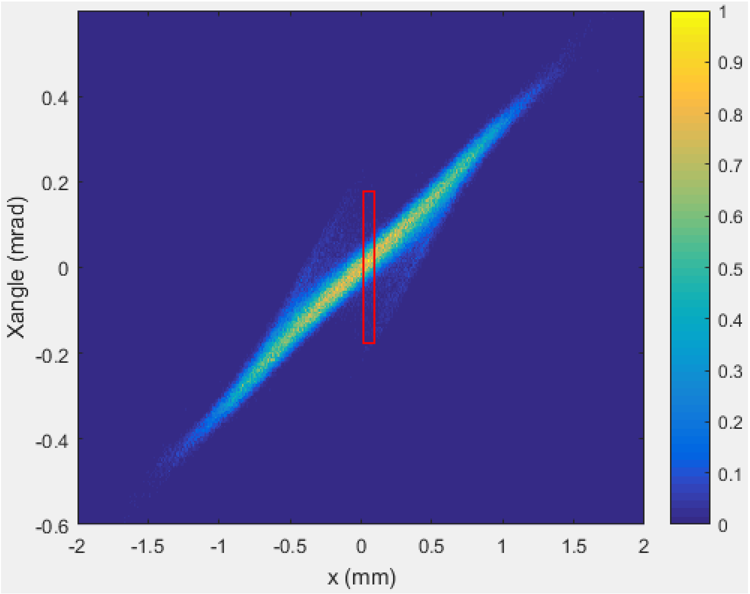




An analytical model for estimating the importance of noise floor in FASTSCAN

- Simplification in the model
  - Pure Gaussian phase space
  - no coupling between x and y phase space
- What's different between noise floor in phase space and noise floor in FASTSCAN
  - One point in phase space is a projection of one column of pixels in beamlet
  - The noise floor in FASTSCAN should be defined in the beamlet image





An analytical model for estimating the importance of noise floor in FASTSCAN

- The model

$$\rho(x,x') = \frac{Q}{2\pi\varepsilon} e^{-\frac{\gamma x^2 + 2\alpha x x' + \beta x'^2}{\varepsilon}}$$

$\Downarrow$ Removing linear correlation will not change the emittance and beamlet distribution.

$$\rho(x,x') = \frac{Q}{2\pi\varepsilon} e^{-\frac{x^2/\beta + \beta x'^2}{\varepsilon}}$$

$\Downarrow$ Phase space passing the slit

$$\rho(x_{slit},x') = \frac{Q}{2\pi\varepsilon} e^{-\frac{x_{slit}^2/\beta + \beta x'^2}{\varepsilon}} = \frac{Q}{2\pi\varepsilon} e^{-\frac{x_{slit}^2}{\sigma_x^2}} e^{-\frac{x'^2}{\sigma^2_{x'uncorrelated}}}$$

$\Downarrow$ beamlet distribution on screen

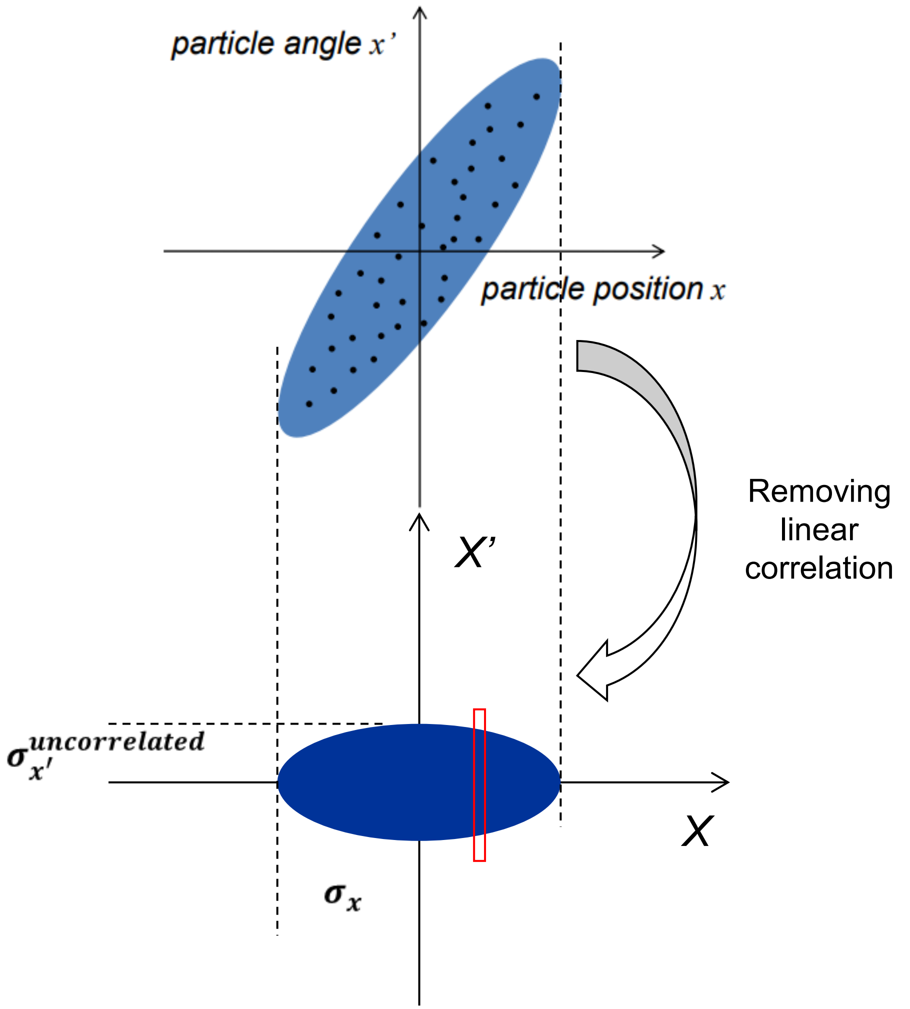
$$\frac{Q\delta x_{slit}}{(2\pi)^{1.5}\sigma_x \sigma_{x_{scr}} \sigma_{y_{scr}}} e^{-\frac{x_{slit}^2}{\sigma_x^2}} e^{-\frac{x^2}{\sigma_{x_{scr}}^2}} e^{-\frac{y^2}{\sigma_{y_{scr}}^2}}$$

$\sigma_x, \sigma_{x_{scr}}, \sigma_{y_{scr}}$ *are constants*

$\Downarrow$

$$\frac{Q\delta x_{slit}}{(2\pi)^{1.5}\sigma_x \sigma_{x_{scr}} \sigma_{y_{scr}}}$$

Peak intensity in all beamlets during the slit scan



An analytical model for estimating the importance of noise floor in FASTSCAN

- The model (cont'd)

$$\frac{Q\delta x_{slit}}{(2\pi)^{1.5}\sigma_x\sigma_{x_{scr}}\sigma_{y_{scr}}} e^{-\frac{x_{slit}^2}{\sigma_x^2}} e^{-\frac{x^2}{\sigma_{xscr}^2}} e^{-\frac{y^2}{\sigma_{yscr}^2}}$$

$$\Downarrow$$

$$\frac{Q\delta x_{slit}}{(2\pi)^{1.5}\sigma_x\sigma_{x_{scr}}\sigma_{y_{scr}}}$$

Peak intensity in all beamlets during the slit scan

$$\Downarrow$$

Define a noise floor for the imaging system in slit scan

$$\frac{Q\delta x_{slit}}{(2\pi)^{1.5}\sigma_x\sigma_{x_{scr}}\sigma_{y_{scr}}}\Delta$$

$$\Downarrow$$

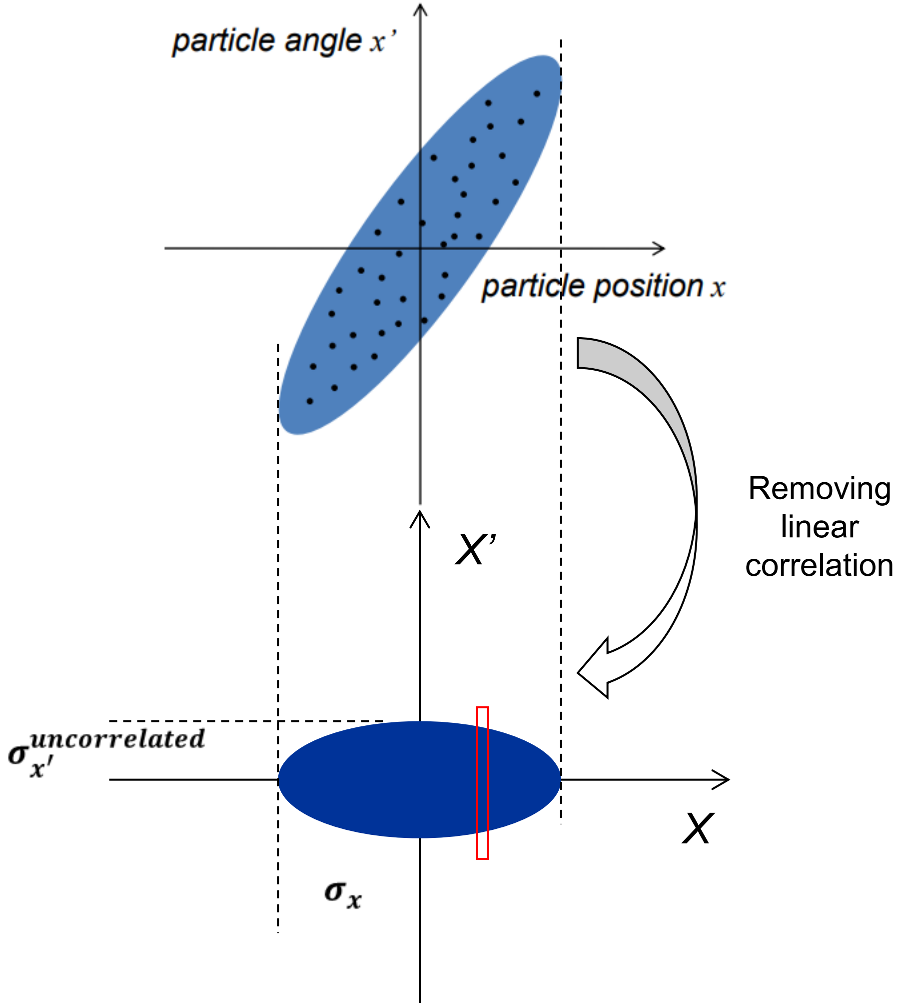
Condition that charge will be counted in phase space

$$e^{-\frac{x_{slit}^2}{\sigma_x^2}} e^{-\frac{x^2}{\sigma_{xscr}^2}} e^{-\frac{y^2}{\sigma_{yscr}^2}} > \Delta$$

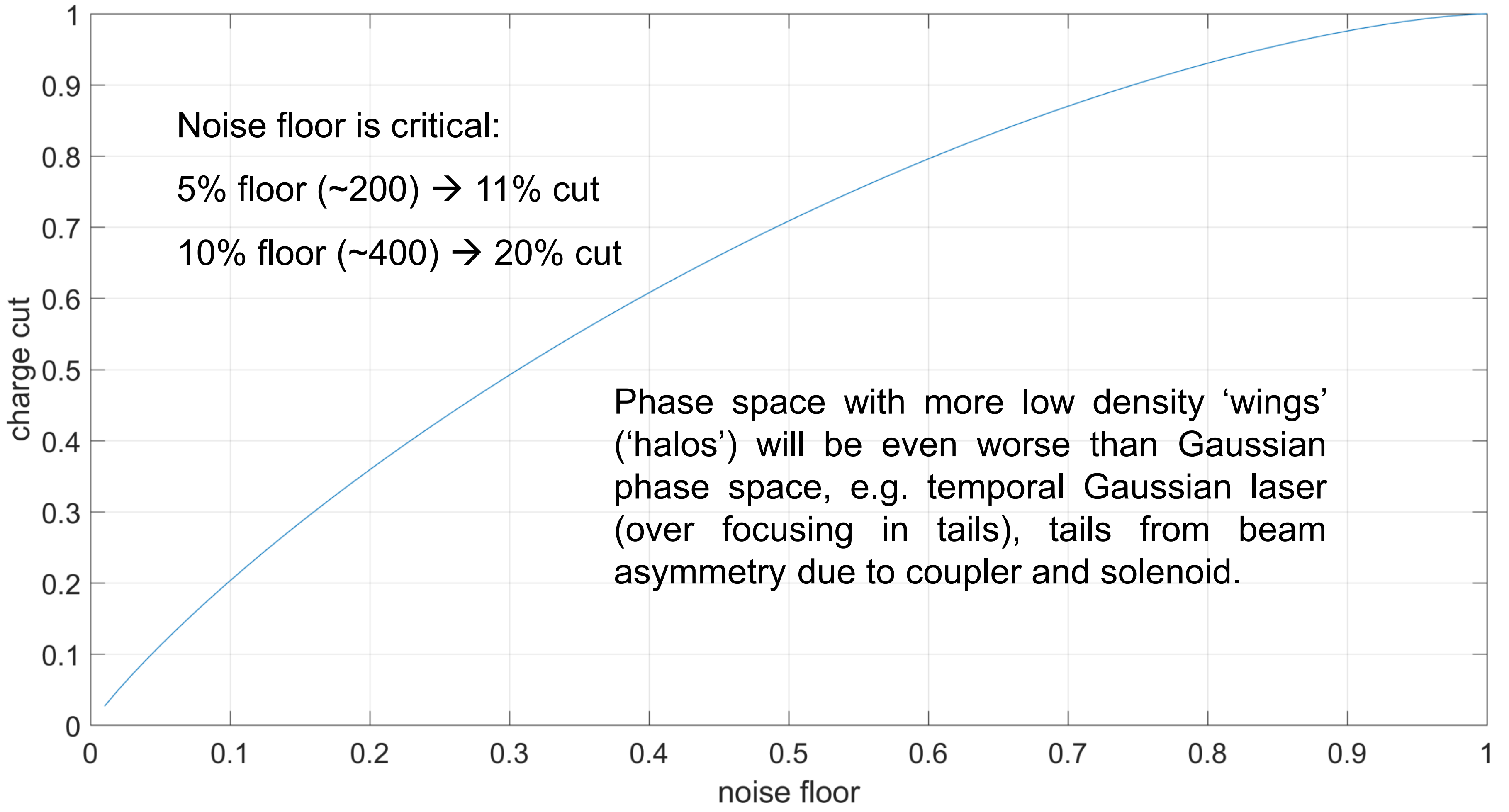
$$\Downarrow$$

Total charge measured in phase space

$$\iiint_{e^{-\frac{x_{slit}^2}{\sigma_x^2}} e^{-\frac{x^2}{\sigma_{xscr}^2}} e^{-\frac{y^2}{\sigma_{yscr}^2}} > \Delta} \frac{Q dx_{slit} dx_{scr} dy_{scr}}{(2\pi)^{1.5}\sigma_x\sigma_{x_{scr}}\sigma_{y_{scr}}} e^{-\frac{x_{slit}^2}{\sigma_x^2}} e^{-\frac{x^2}{\sigma_{xscr}^2}} e^{-\frac{y^2}{\sigma_{yscr}^2}} = Q\frac{\sqrt{2\pi}\,\mathrm{erf}\left(\sqrt{-Ln\Delta}\right) - 2\Delta\sqrt{-2Ln\Delta}}{2.506}$$

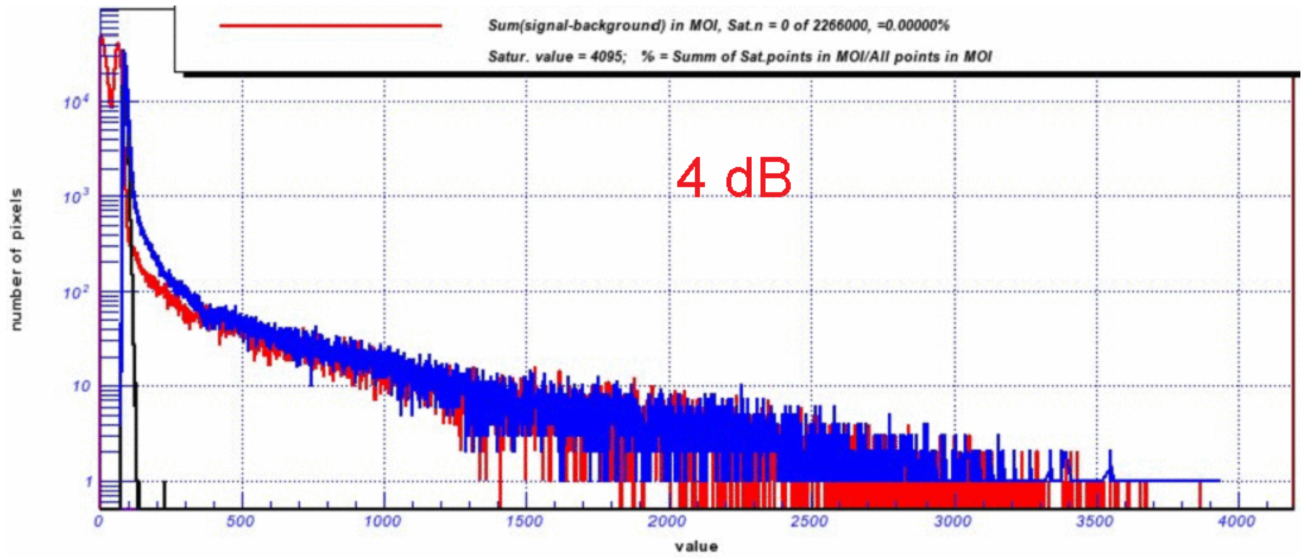


An analytical model for estimating the importance of noise floor in FASTSCAN



Possible ways to improve SNR for future PITZ emittance measurement

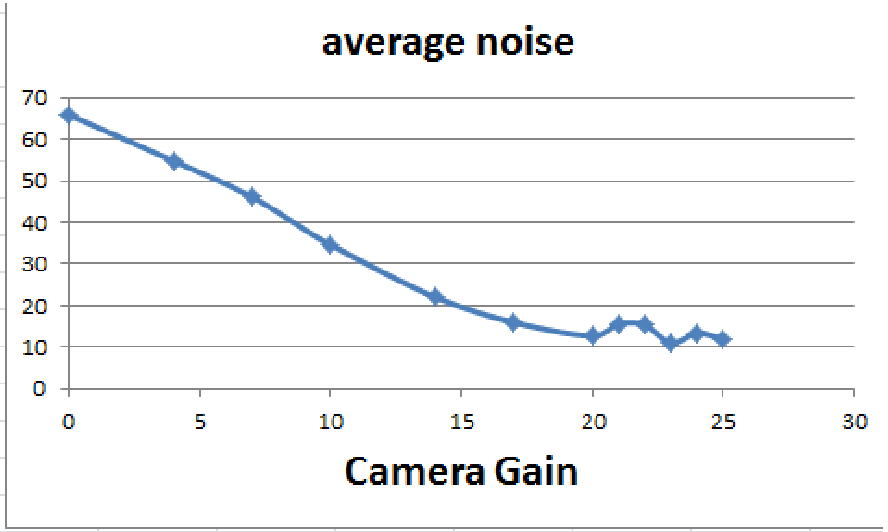
- Use low camera gain (10-13 dB max?)
  - Use lyso screen or more efficient screen
  - Increase pulse number until max (<20 pulse?)
  - If pulse number too high, then improve light collection efficiency for optics, bigger lens, closer to vac window?
  - Improve image filter or data taking.
    - Current EMCAL image filter are cutting signals which can be distinguished by eye on video client
    - Probably due to strange noise pattern at high camera gain and single frame for signal.

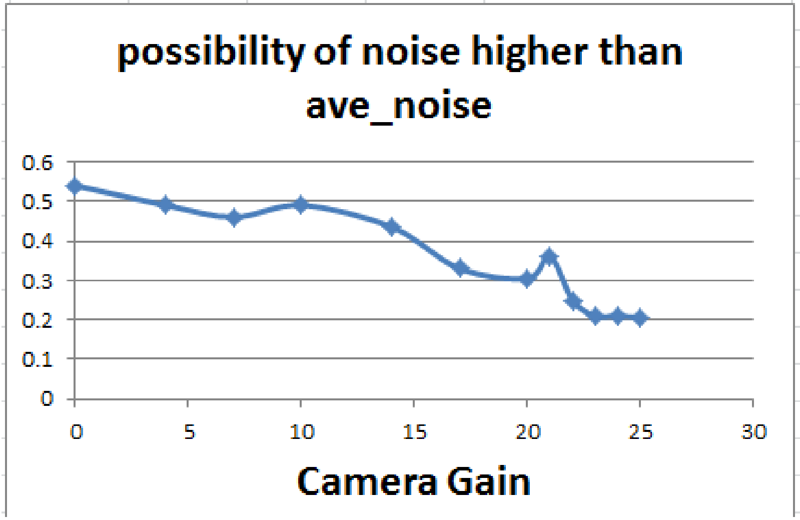


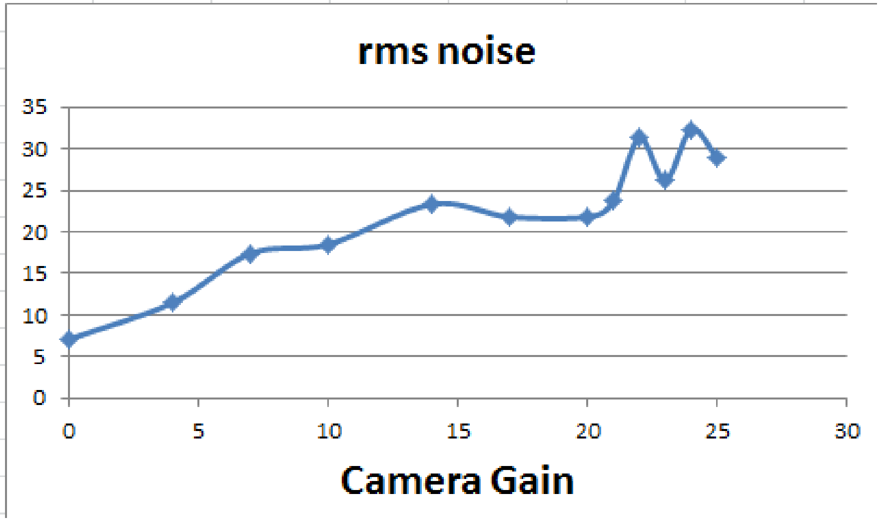
Camera noise vs gain

For a single pixel

Gain	median	average	rms	possibility of noise higher than ave_noise
0	66	65.84	7.1	0.54
4	54	54.76	11.5	0.49
7	44	46.13	17.4	0.46
10	33	34.6	18.5	0.49
14	17	22.06	23.3	0.435
17	4.5	15.95	21.8	0.33
20	0	12.76	21.8	0.305
21	0	15.64	23.7	0.36
22	0	15.34	31.25	0.25
23	0	11.02	26.16	0.21
24	0	13.4	32.3	0.21
25	0	11.9	28.9	0.205

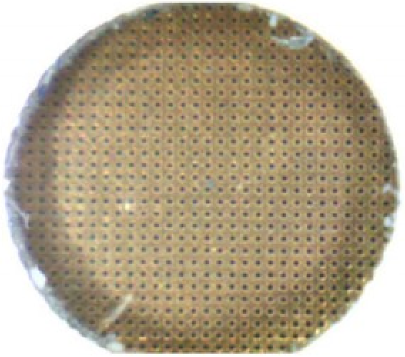






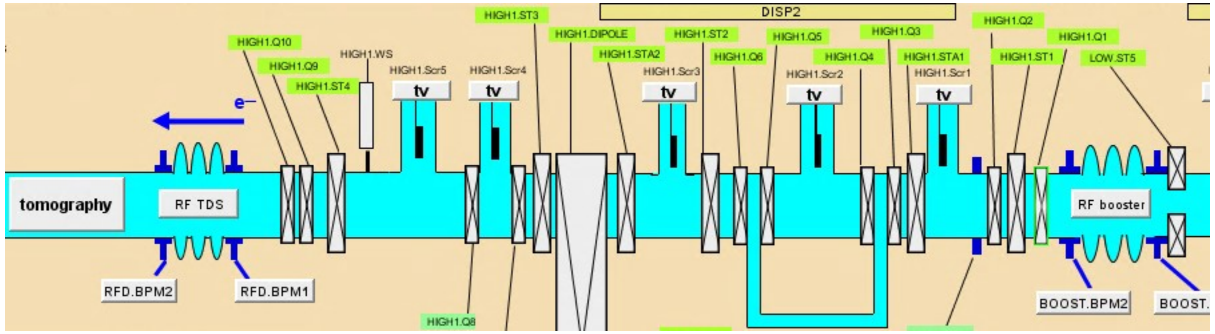
Possible ways to improve SNR for future PITZ emittance measurement

- Another way to measure PITZ emittance
  - Insert a pepper pot mask at EMSY station (remove space charge effect)
  - Use quadrupole scan to measure both projected and slice emittance (improved SNR)
    - Compared to low charge beamlet during slit scan, the charge is much higher



Example from UCLA:

- laser-drilled pepper pot
- circular holes of 15 μm diameter
- 85 μm spacing
- ~3% transmission.



Pros:

1) both issues of space charge & SNR are improved.
2) In principle only single to few pulses are needed with efficient imaging system (good for facilities without long pulse linac or high energy (>~50 MeV) linac).

Cons:

1) Needs good uniformity of holes
2) Scattering signal may be focused again by quadrupoles
   - intensity of scattering signal
   - emittance of scattering (scattering angle)
   - beam aperture between mask and quadrupole
3) Need good calibration of quadrupole model

Discussions: how to set up fastscan for the next run

- Max camera gain?
- YAG or LYSO?
  - a program is planned to compare both screens next week vs camera gain
- Max pulse number?
- Scaling factor?
  - Scaled1 or scaled2
- Optimum BSA and solenoid current based on
  - scaled1 or scaled2?
- …