CONCEPT OF R EMITTANCE IN THE FRAME OF SLICE EMITTANCE STUDIES

Yevgeniy Ivanisenko
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HELMHOLTZ ASSOCIATION

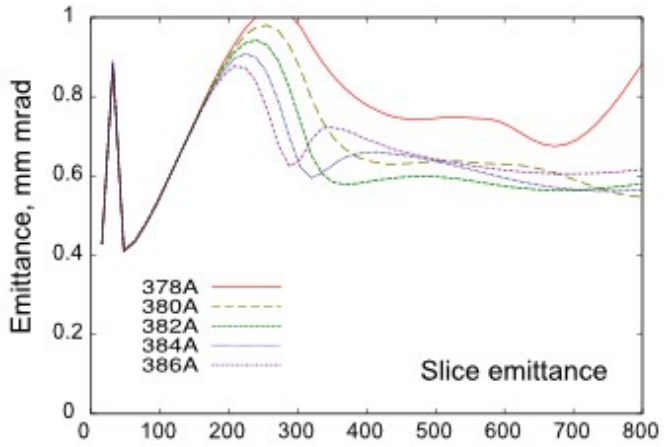
DESY

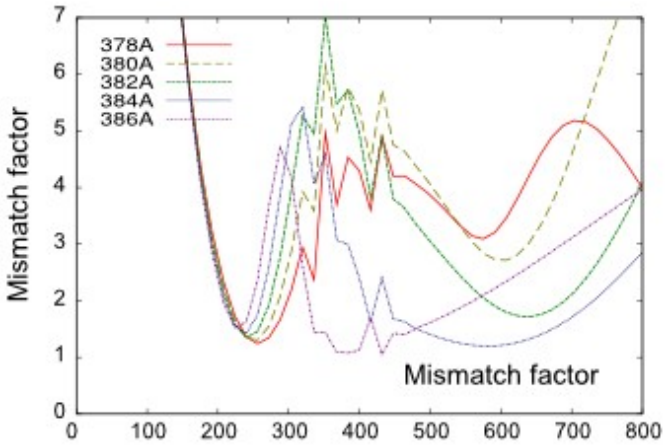
CONTENT

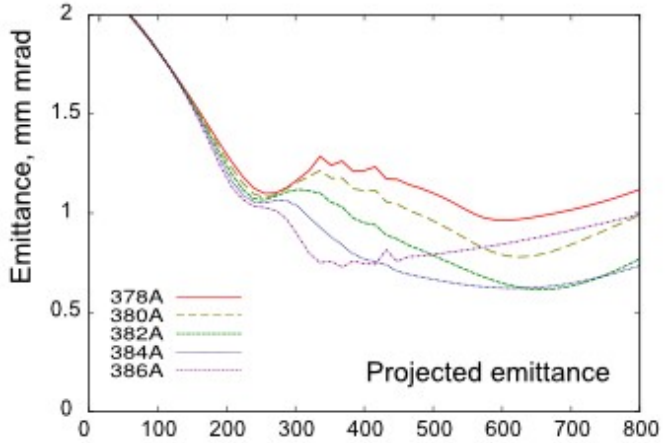
- Projected emittance formation
- R emittance introduction
- Pros and cons
- Application for the simulation studies

PROJECTED EMITTNACE

- **Projected emittance minimum is a combination of the best slice orientation match and the lowest slice emittance.**
  - **Slice emittance is expected to be rather flat along the machine, hence slice alignment is more important**
  - **Best slice emittance coincides with the best slice alignment. Why is that?**







R EMITTNACE

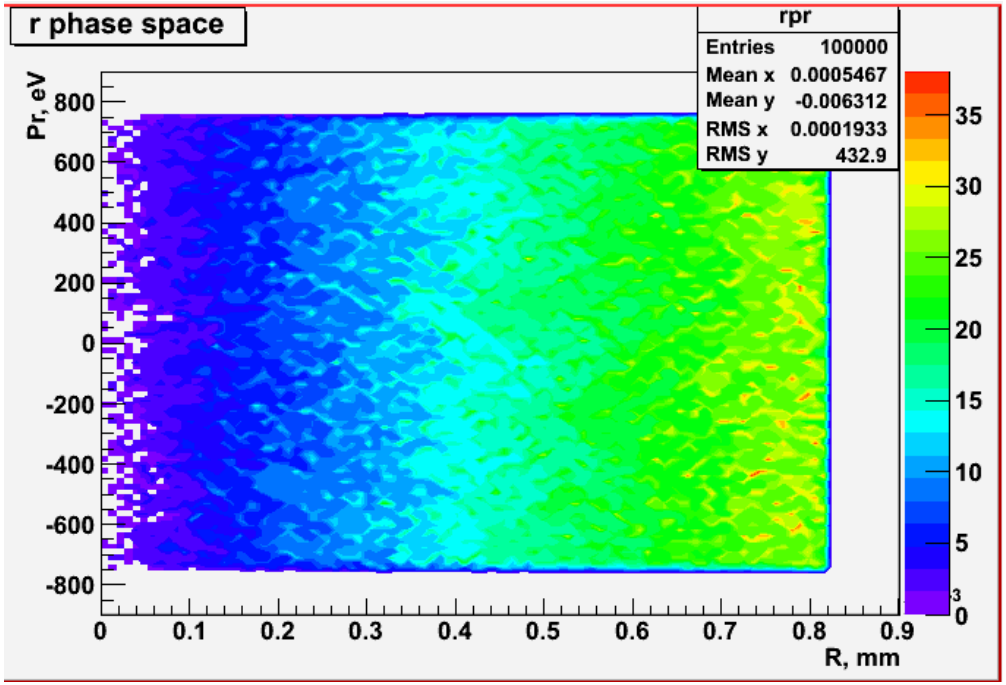
- **Cylinder symmetry: Radial component phase space**

$$\varepsilon_r = \beta\gamma\sqrt{\sigma_r^2\sigma_{r'}^2 - \langle rr' \rangle^2}$$

- **Can be calculated for simulated particle distributions.**

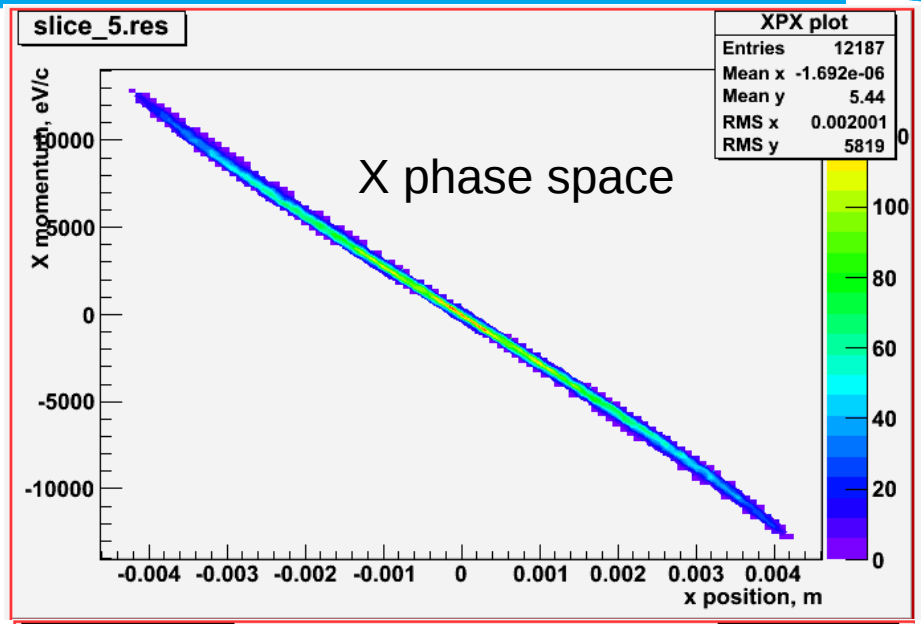
R phase space distribution at the cathode

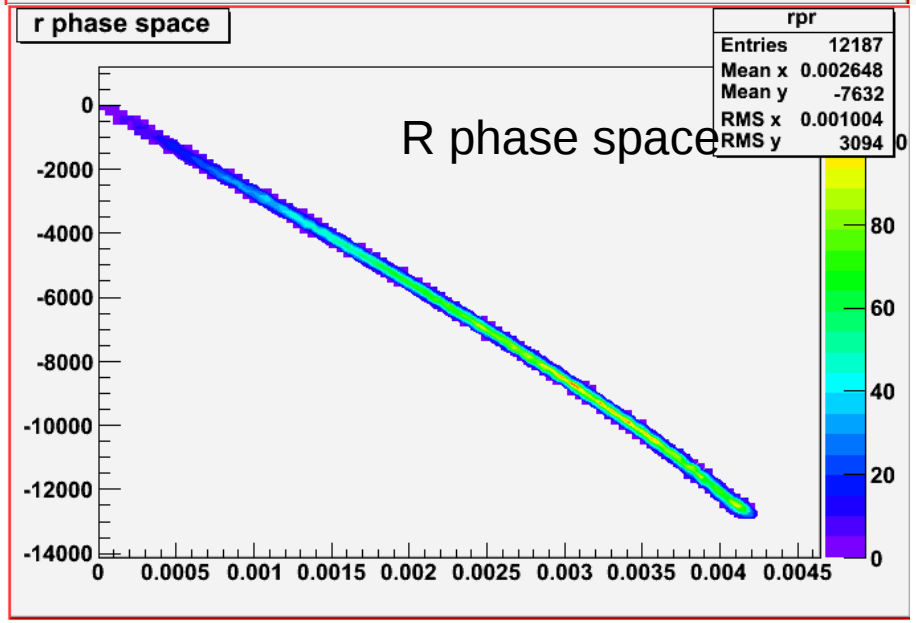
Equal bins along R



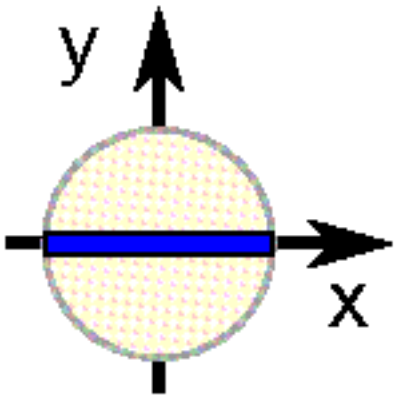
AFTER THE GUN

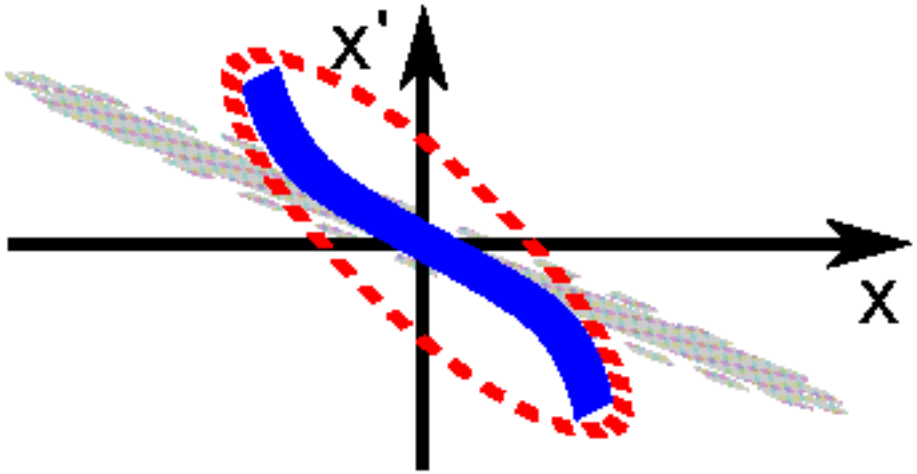
- **Central slice phase space distribution, solenoid effect is subtracted (further on)**

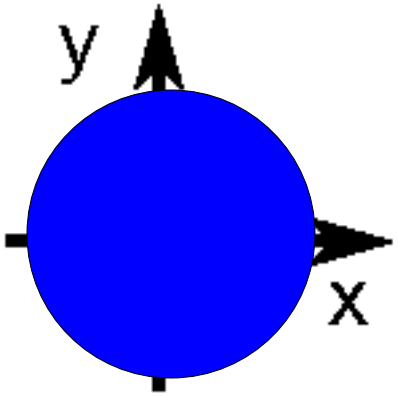


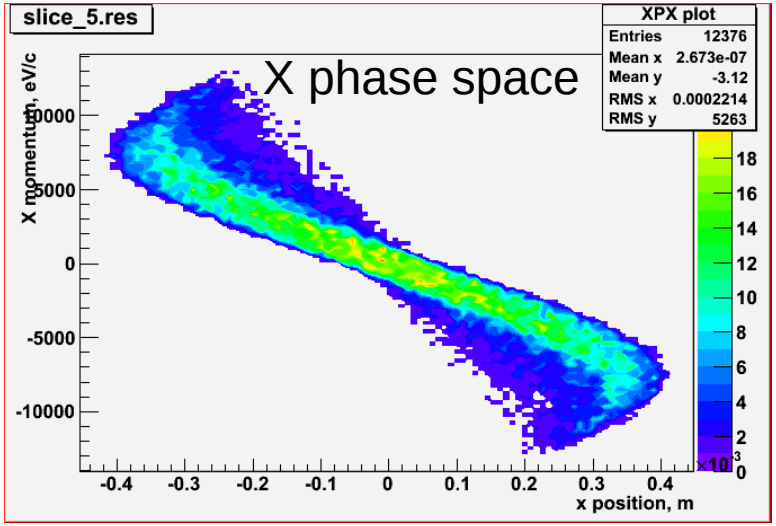


Background of R emittance application

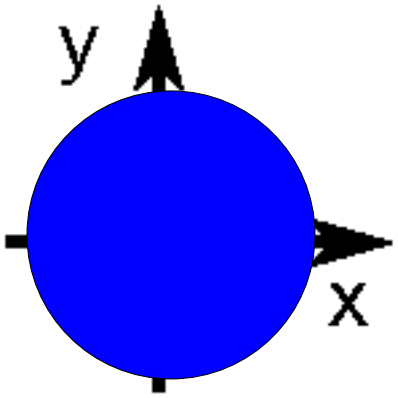




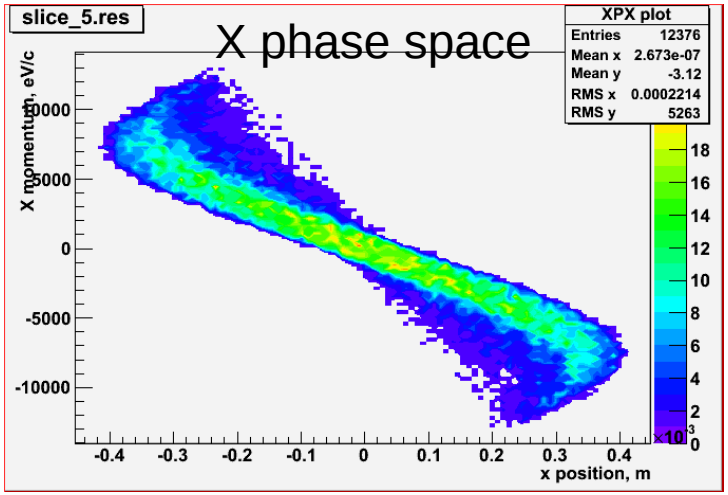




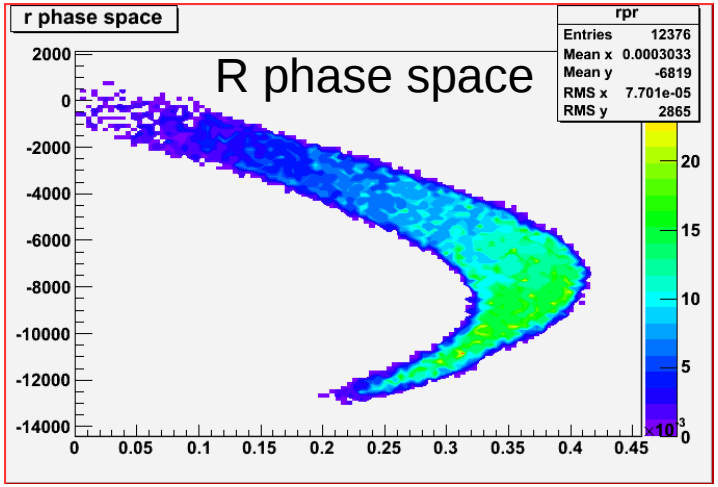
PROS AND CONES



- **X slice emittance does not reflect the non-linearity correctly.**
- **Therefore one can use R emittance. Non-linear transformations can be well recognized and characterized**



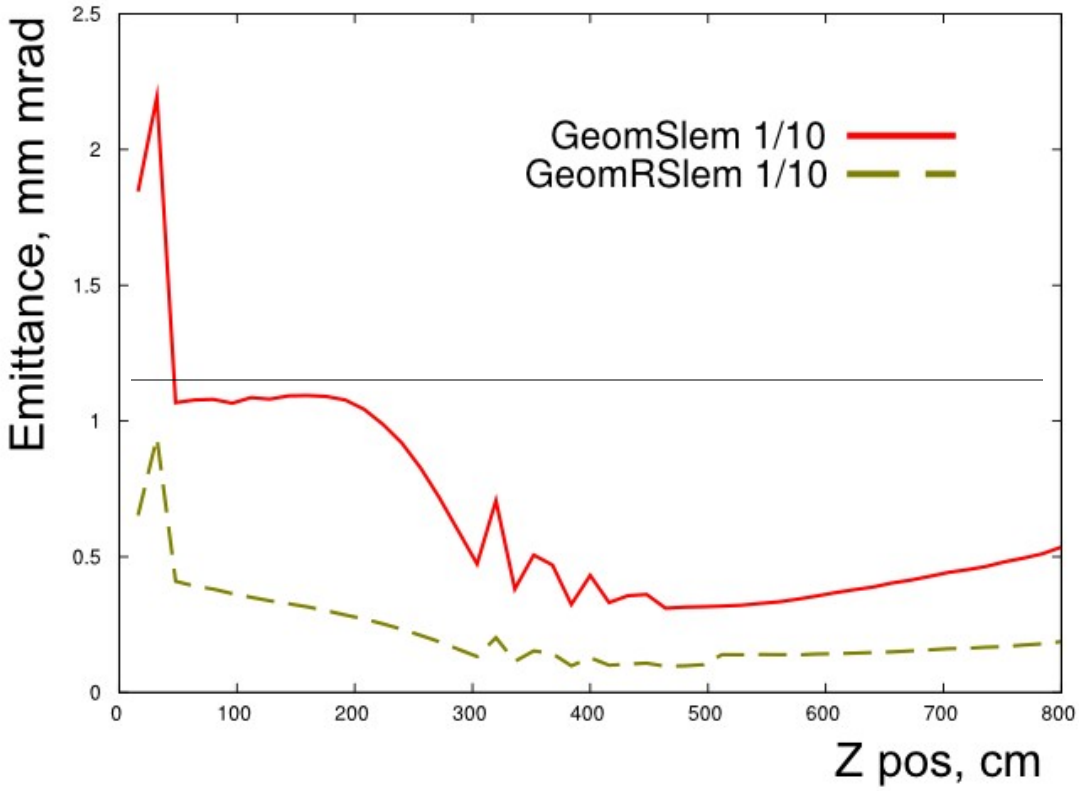
Pr



r

GEOMETRICAL EMITTANCE

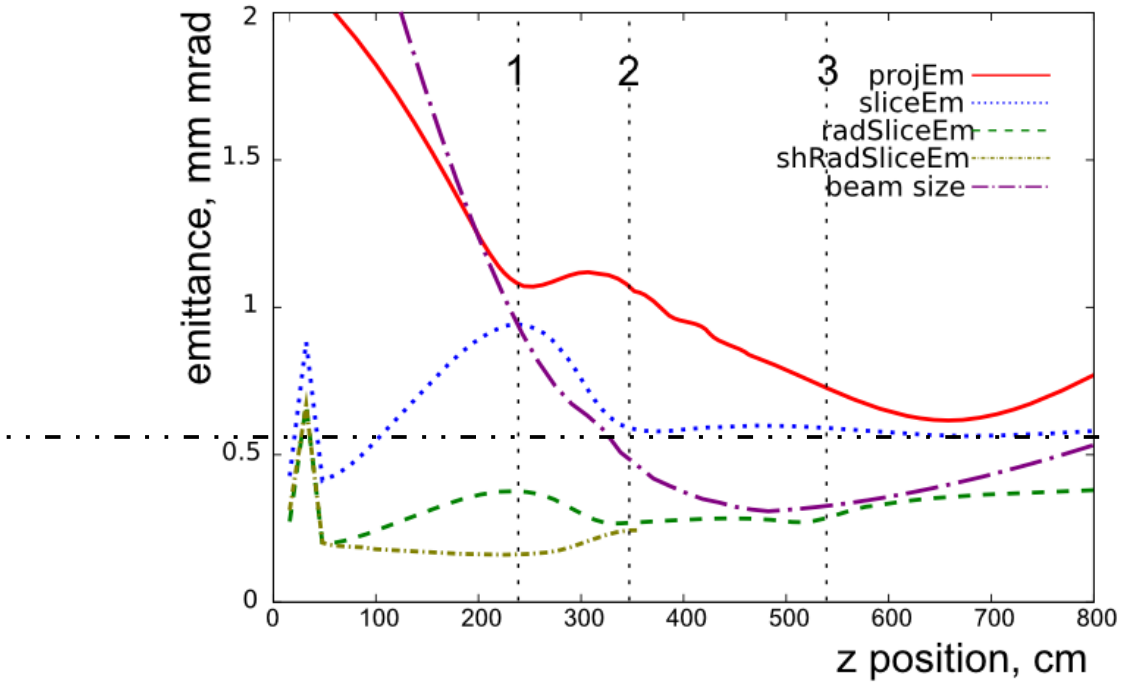
- Geometrical – the area occupied with particles in phase space (a binned distribution, sum of bins with Npart>0)
- Geometrical emittance of X and R distributions along Z
- No conservation or other rule exists for this type of emittance
- R emittance is reducing after the gun, but the X component slightly grows



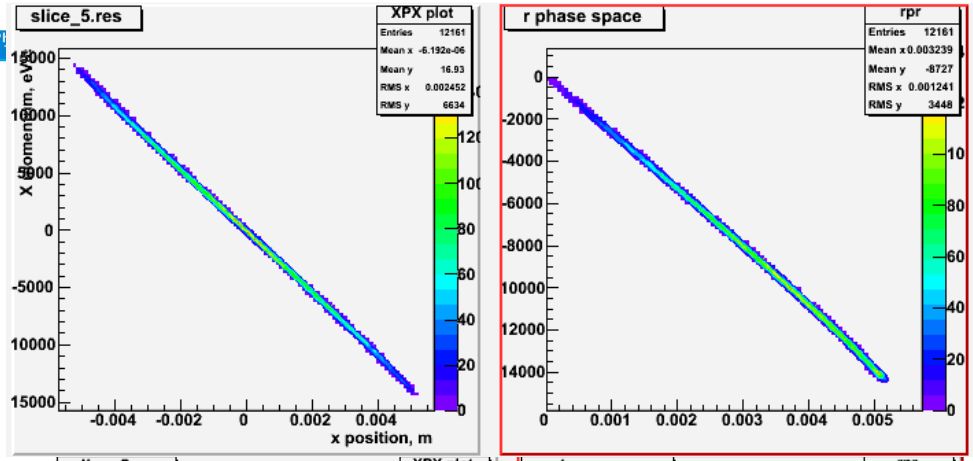
EMITTANCE ALONG THE SETUP

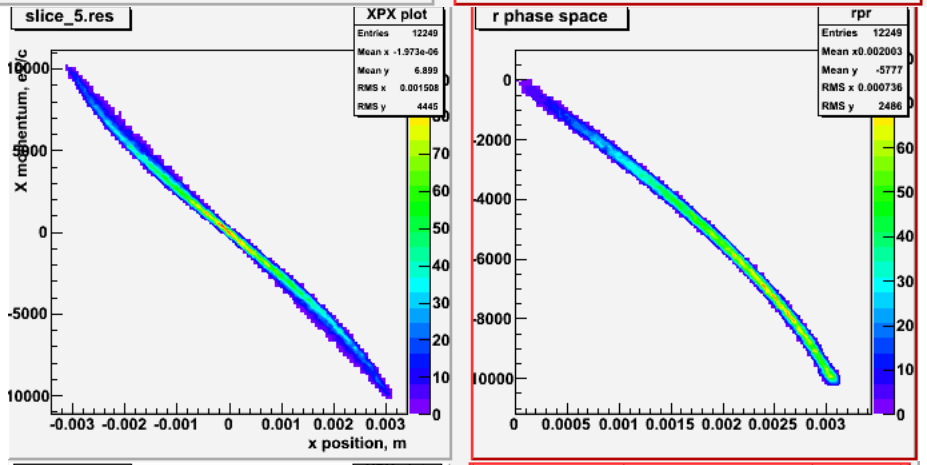
- **Case of the optimized projected emittance at EMSY1 position 0.41 mm, 382A**
  - **1 maximum of X and R slice emittances due to non-linear distortion**
  - **2 the R phase space distribution forms a hook**
  - **3 roll over particles appear**

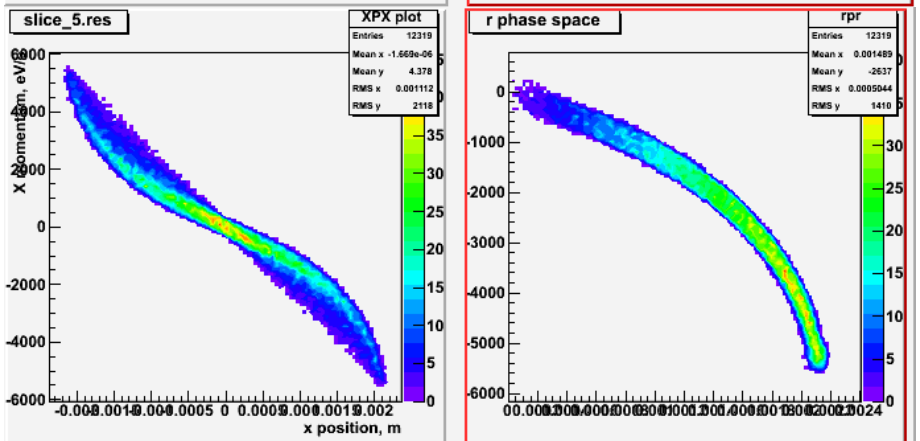
Slice emittance does not reach initial value

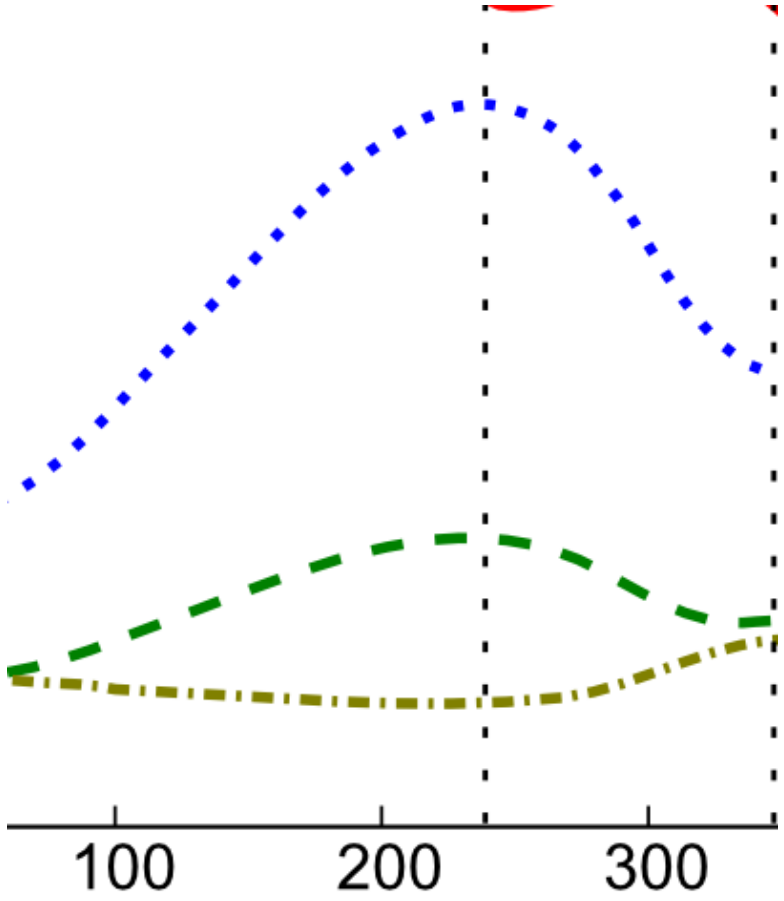


1 MAXIMUM OF SLICE EMITTNACE



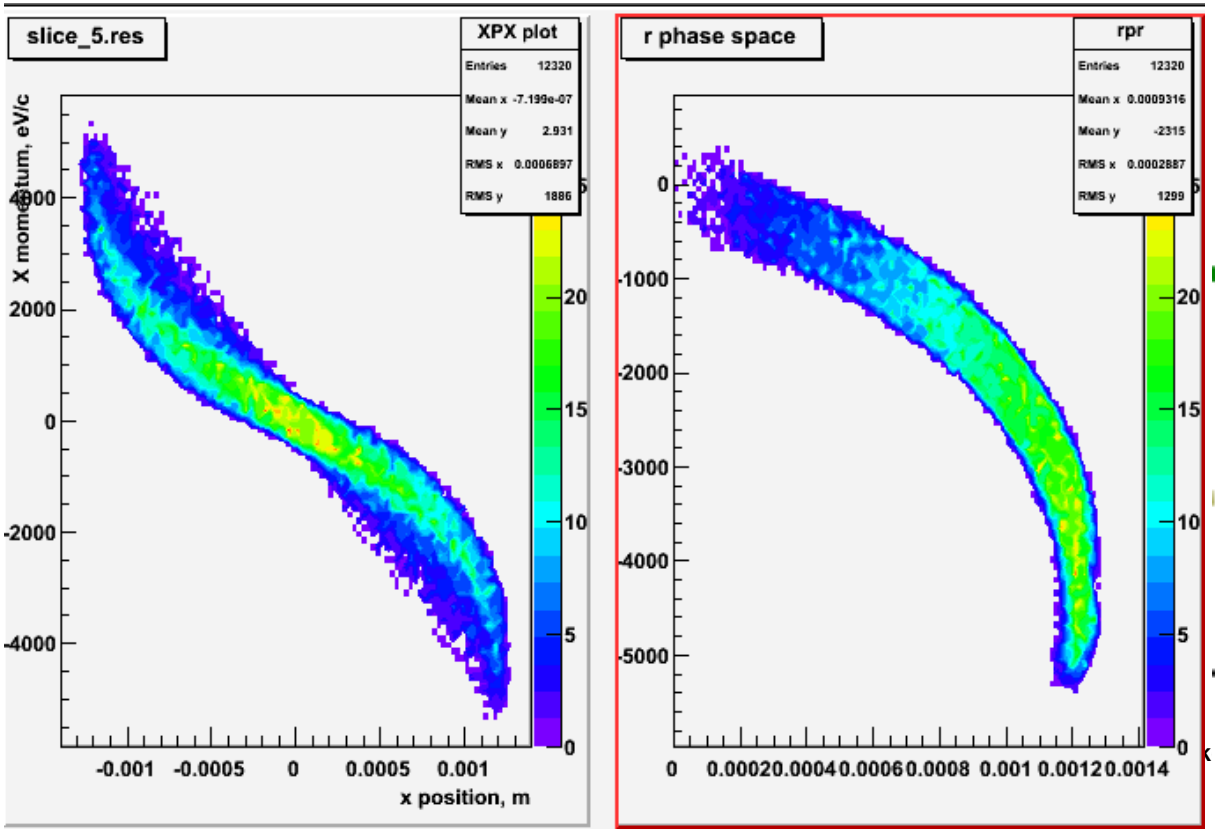


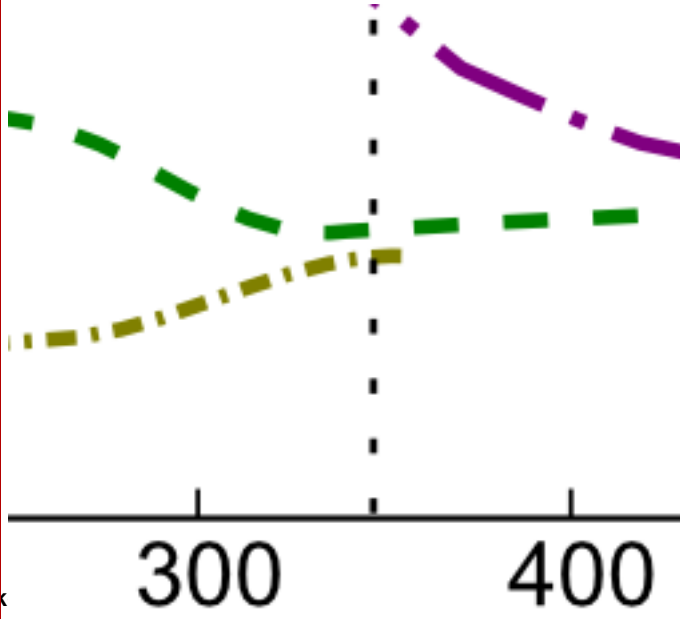




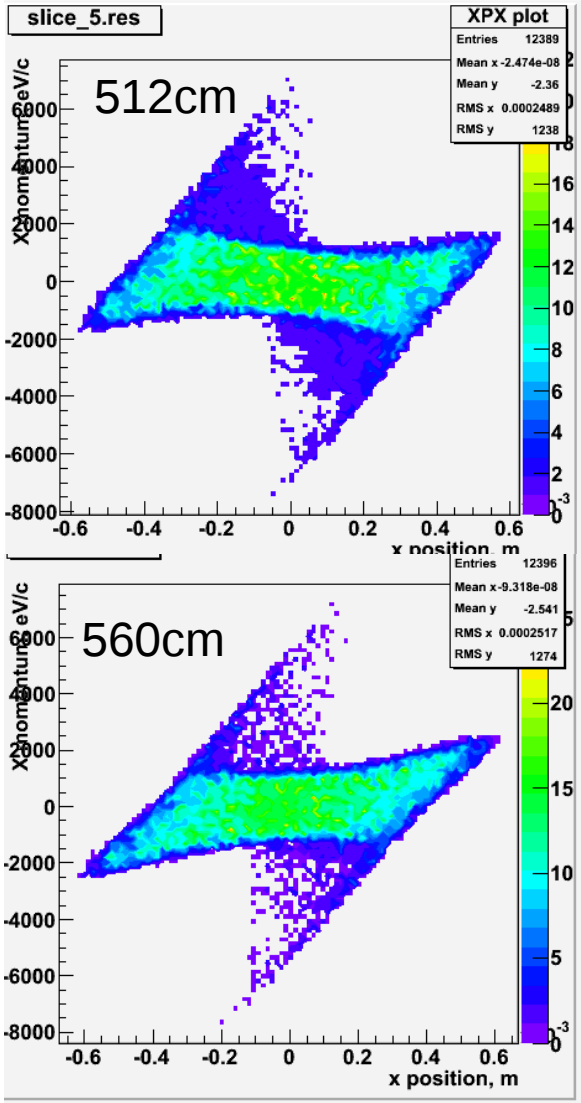
2 R PHASE SPACE HOOK

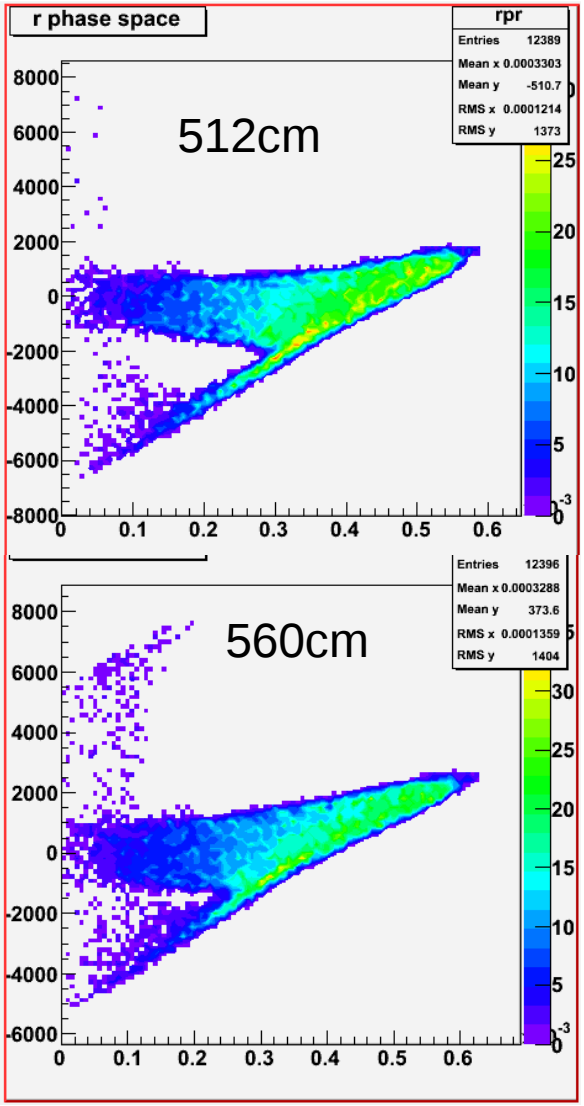
- **Shearing is not applicable any more. A work around would be to use geometrical emittance.**

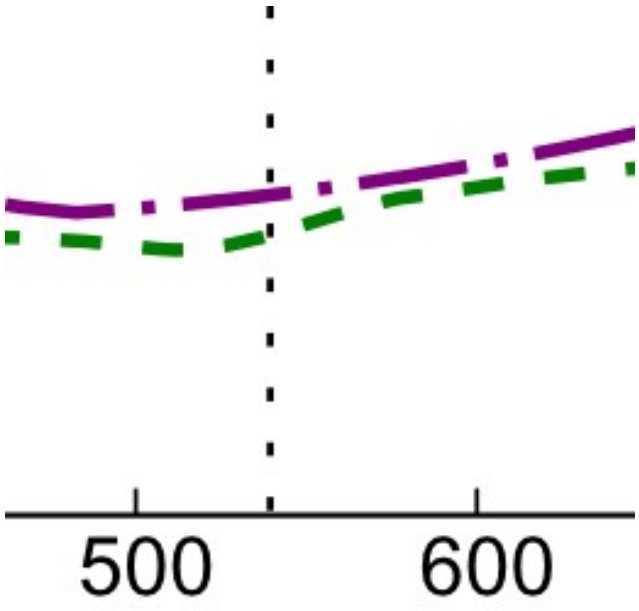




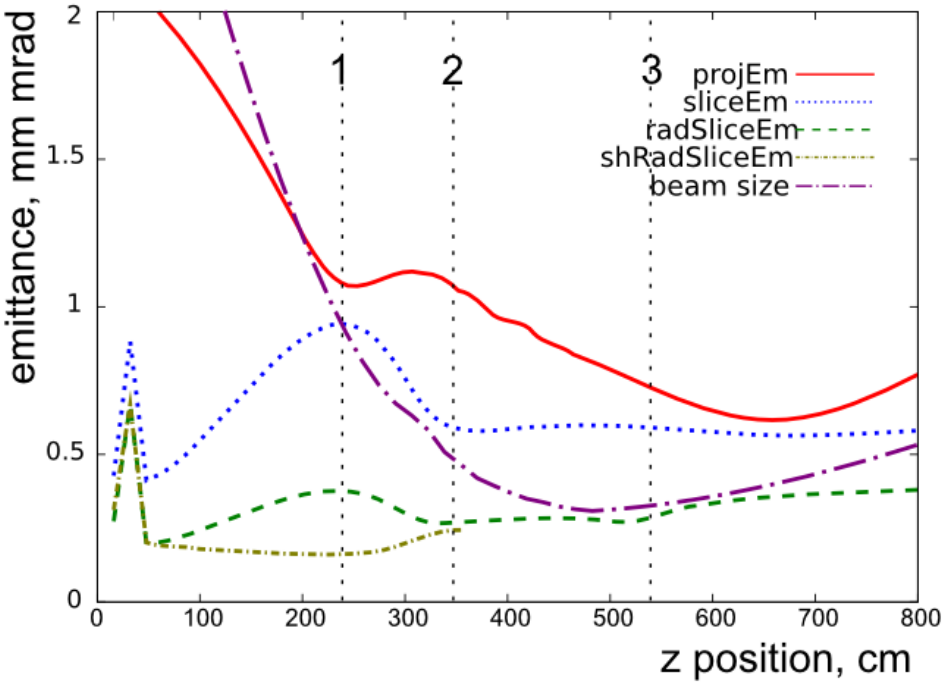
ROLL OVER PARTICLES







- **R emittance is growing after check point 3, but the X slice emittance still has a smooth minimum**
  - **R and X emittance values demonstrate a similar behavior until the roll-over particles appear**

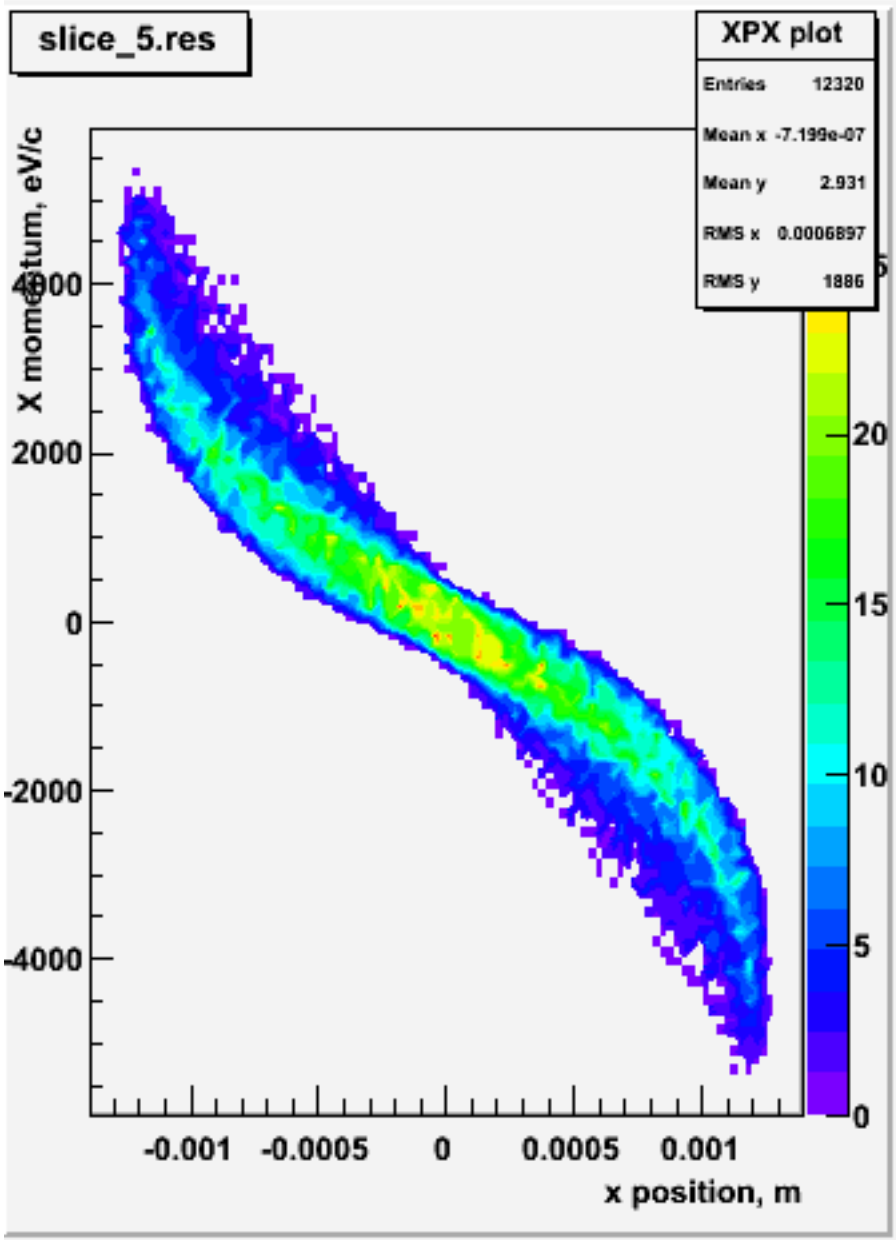


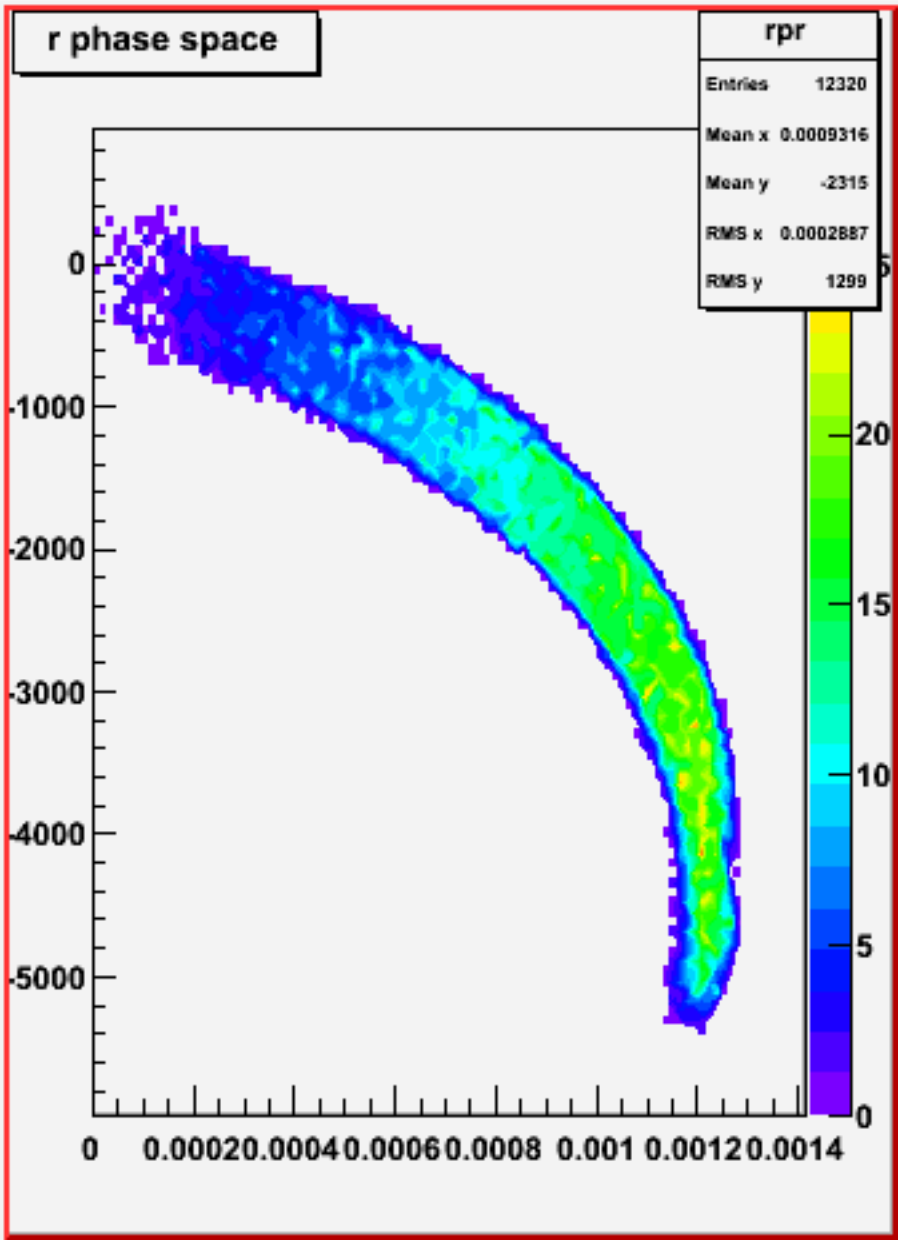
Conclusions

- Slice emittance is rather flat along the setup after the booster but changes with the solenoid current due to non-linear deformations of the phase space distribution.
- R emittance is a useful numerical tool to study non-linear phase space deformations. It's only a component of transverse emittance (the second is azimuthal emittance) which makes it only straight forward to apply for cylinder symmetric distributions.
- The best slice emittance is about 20% higher than the initial. Is there something useful in setup optimization in terms of R emittance? Optimization here would mean the laser shape predominantly.

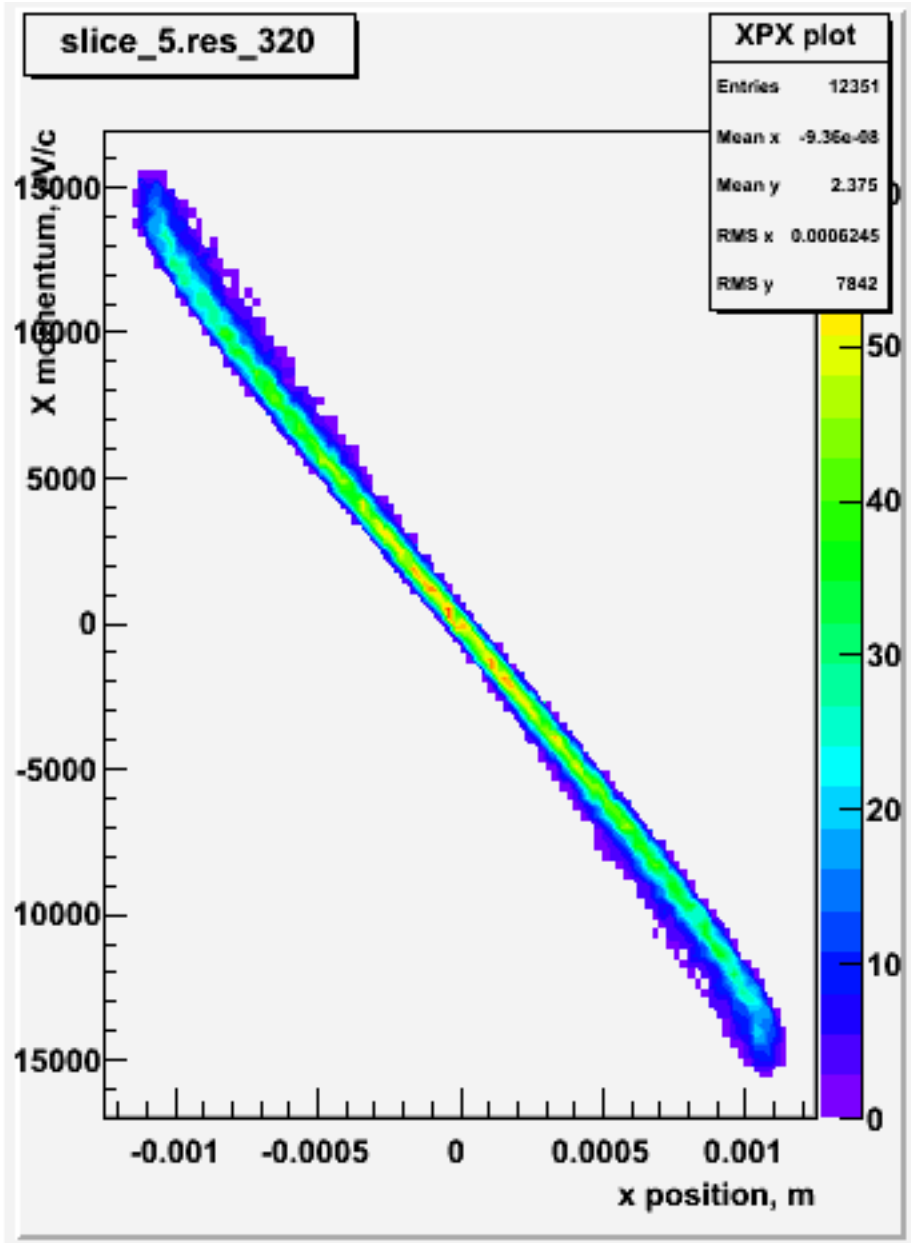
Thank you for attention!

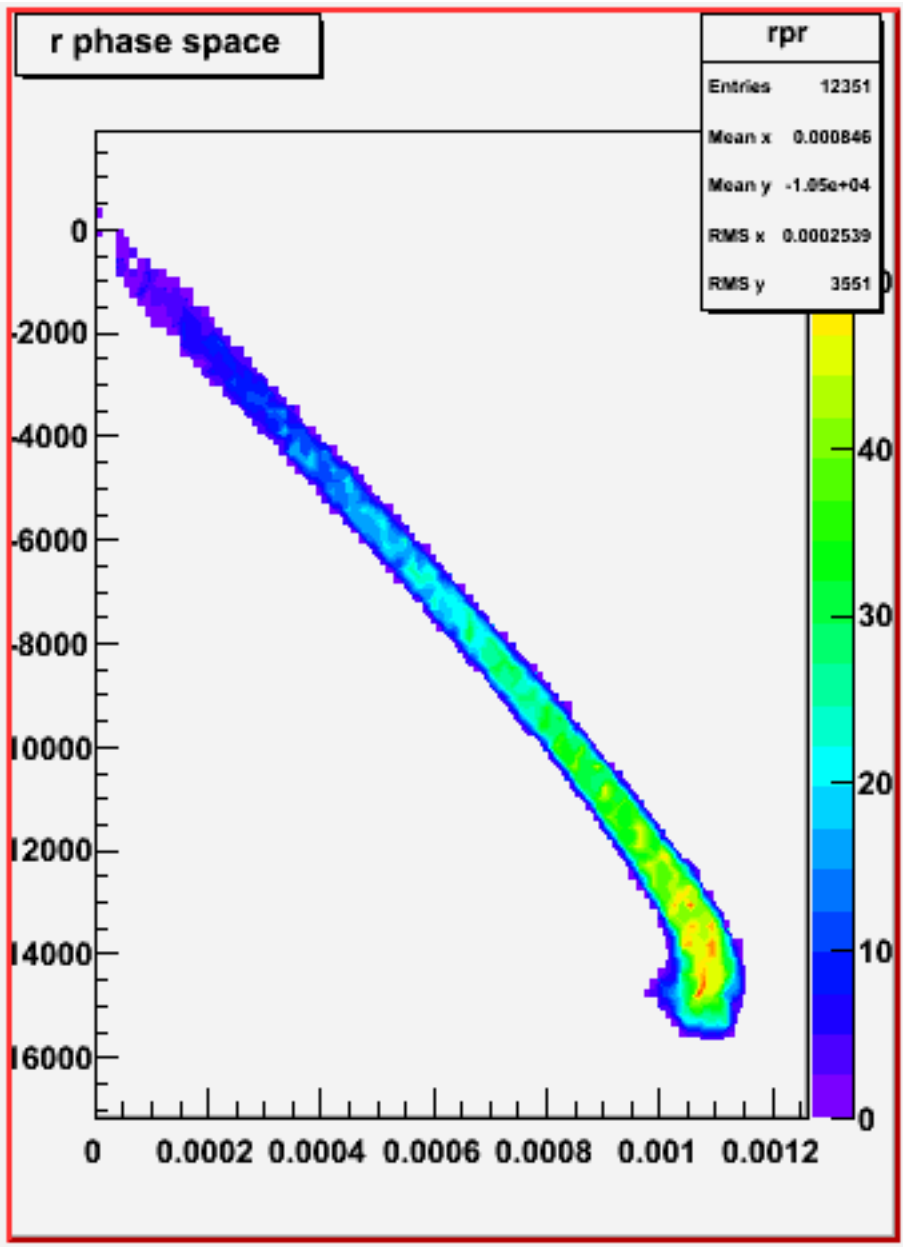
IN FRONT OF THE BOOSTER



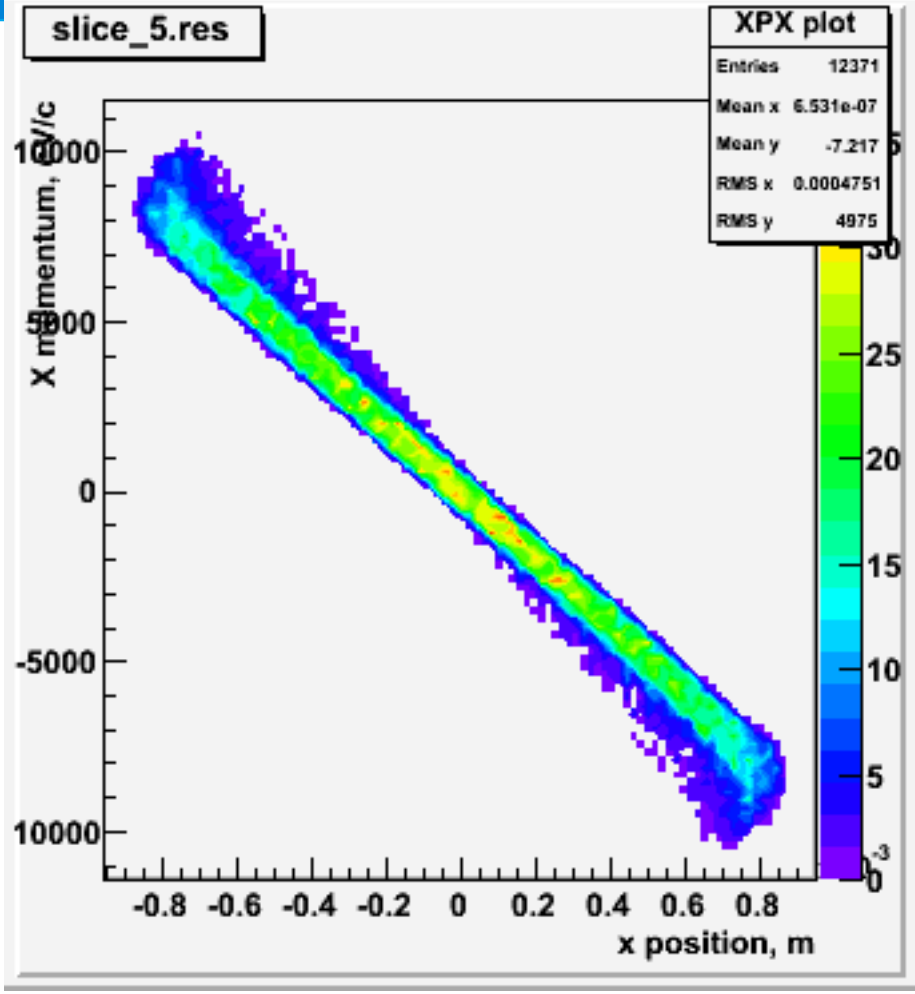


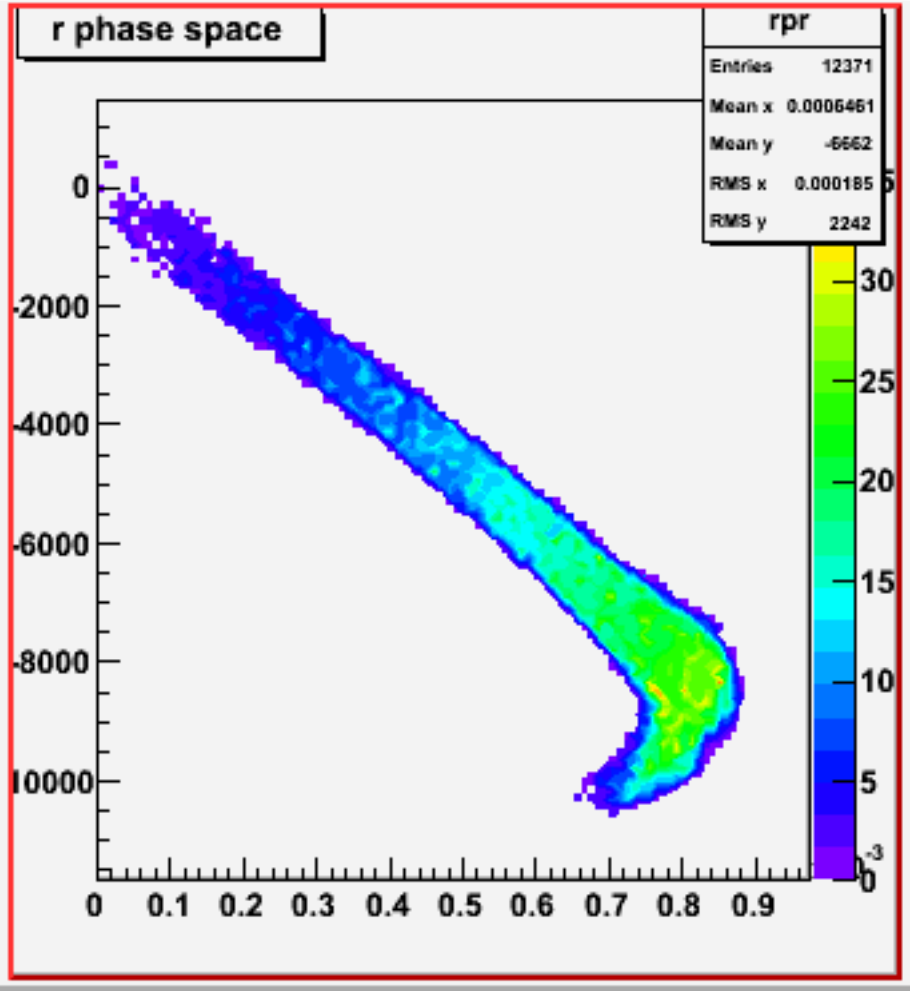
320 cm


slice_5.res_320
XPX plot
Entries 12351
Mean x -9.36e-08
Mean y 2.375
RMS x 0.0006245
RMS y 7842
X momentum, MeV/c
15000
10000
5000
0
-5000
10000
15000
-0.001
-0.0005
0
0.0005
0.001
x position, m
50
40
30
20
10
0

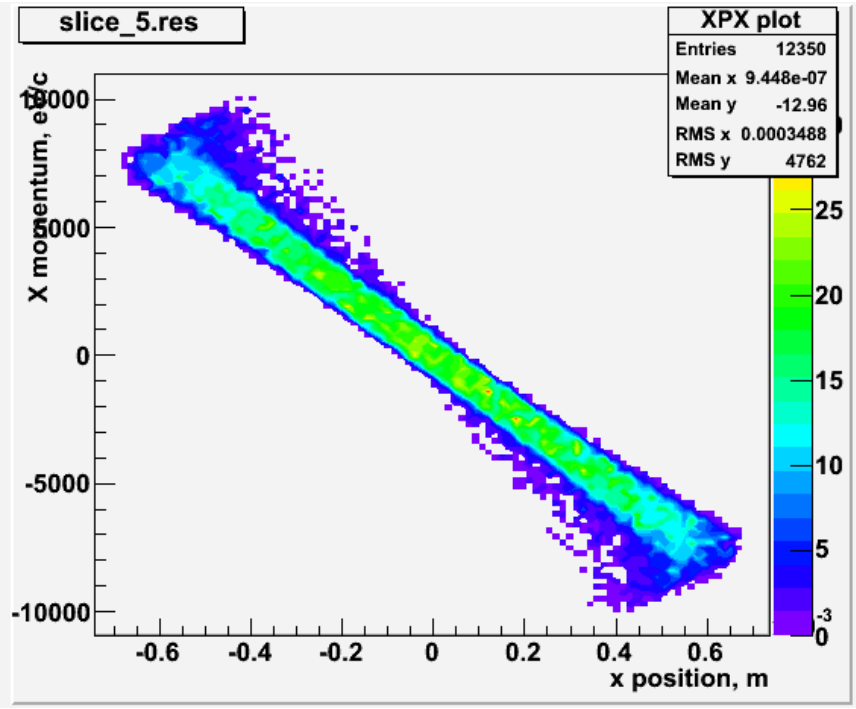

r phase space
rpr
Entries 12351
Mean x 0.000846
Mean y -1.05e+04
RMS x 0.0002539
RMS y 3551
0
-2000
-4000
-6000
-8000
10000
12000
14000
16000
0
0.0002
0.0004
0.0006
0.0008
0.001
0.0012
40
30
20
10
0

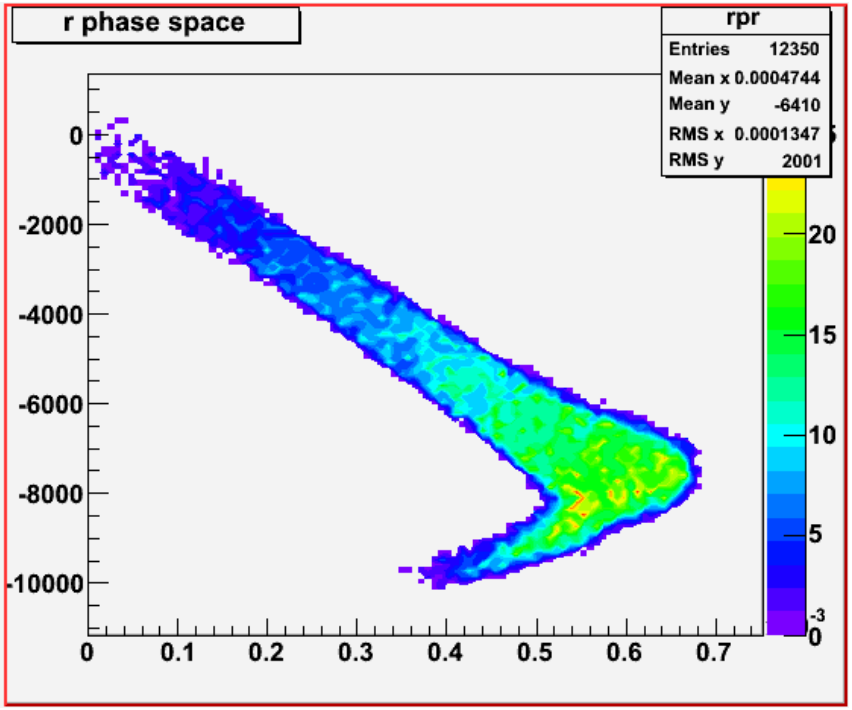
350 cm


slice_5.res
XPX plot
Entries 12371
Mean x 6.531e-07
Mean y -7.217
RMS x 0.0004751
RMS y 4975
X momentum, eV/c
10000
5000
0
-5000
10000
-0.8 -0.6 -0.4 -0.2 0 0.2 0.4 0.6 0.8
x position, m
30
25
20
15
10
5
0


r phase space
rpr
Entries 12371
Mean x 0.0006461
Mean y -6662
RMS x 0.000185
RMS y 2242
0
-2000
-4000
-6000
-8000
10000
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
30
25
20
15
10
5
0

400 cm


slice_5.res
XPX plot
Entries 12350
Mean x 9.448e-07
Mean y -12.96
RMS x 0.0003488
RMS y 4762
X momentum, eV/c
x position, m


r phase space
rpr
Entries 12350
Mean x 0.0004744
Mean y -6410
RMS x 0.0001347
RMS y 2001

PHSP LINEARIZATION IN BOOSTER

- **Is only a visual impression in fact the non-linearity stays the same but the linear component introduced by the booster is significant to mask it.**