



U.S. DEPARTMENT OF
ENERGY

Office of
Science

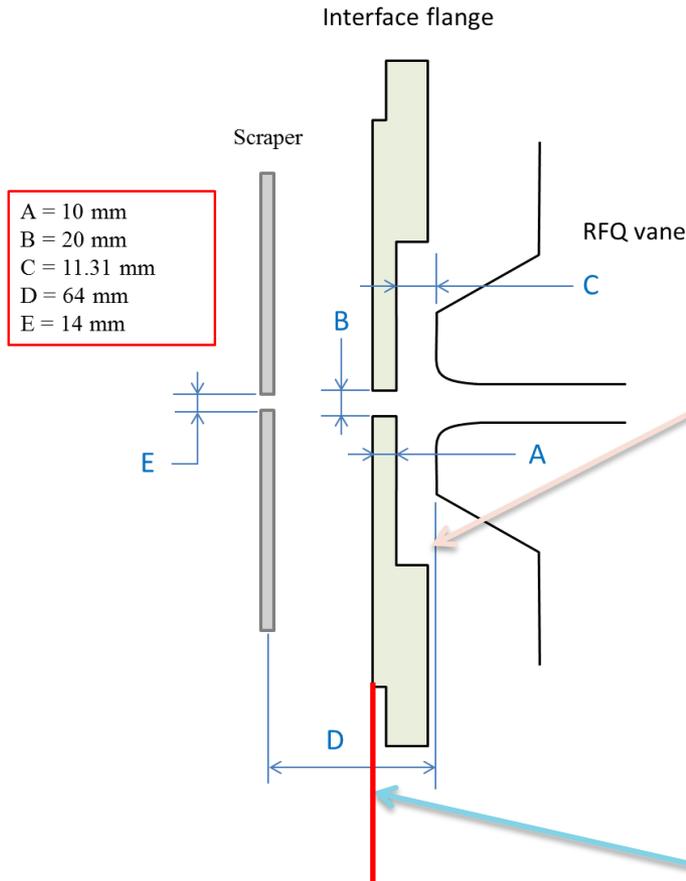
Acceptance of PXIE RFQ

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Note for the PXIE collaboration

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PXIE RFQ. Input beam and output beam.



PXIE RFQ design beam parameters.

PARMTEQ input file: 9-12-2011 , Ellipse parameters at cell 0:

	α	β , cm/rad	$\epsilon_{\text{rms_norm}}$, π mm mrad
x:	1.331	7.414	0.115
y:	1.336	7.455	0.113

Input beam is defined in the vane tip plane.

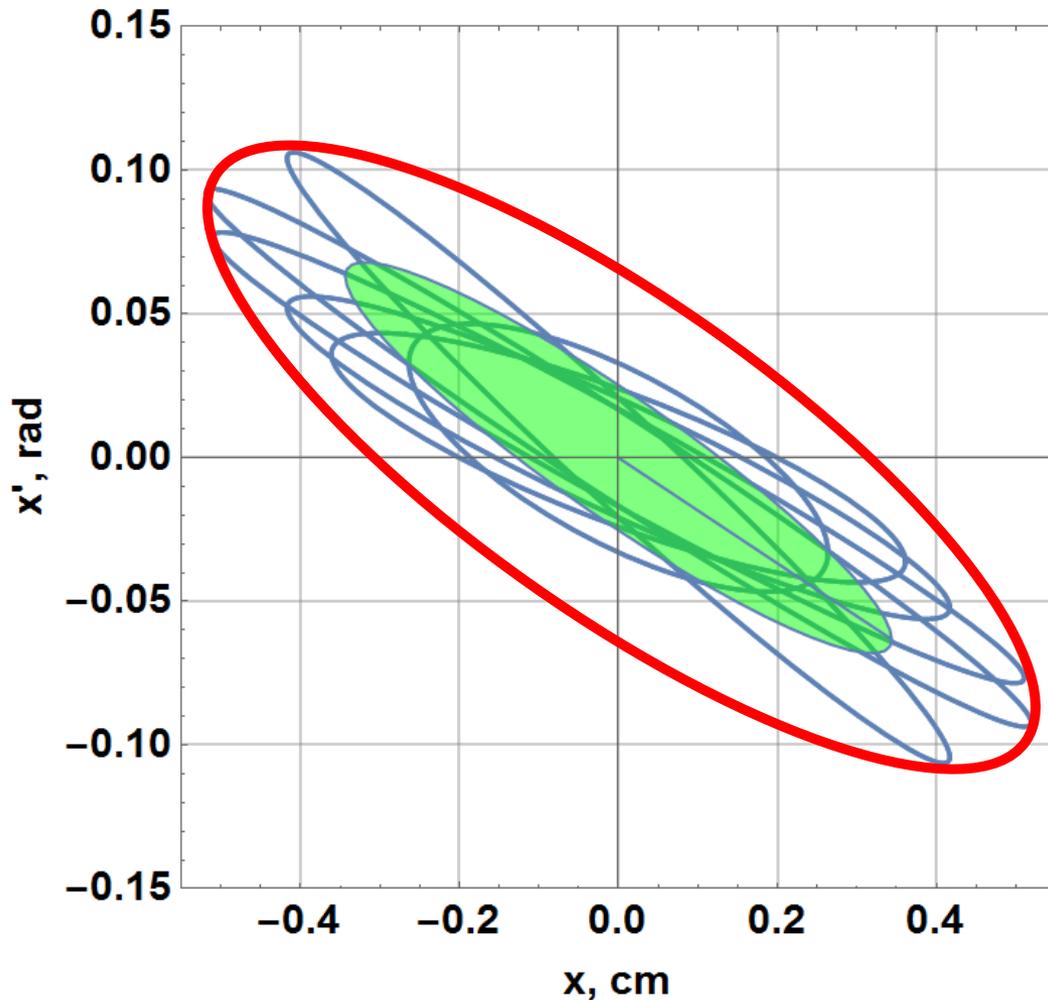
Output beam parameters at 5 mA current:

$\epsilon_{\text{rms_norm}}$, π mm mrad < 0.25 ; $|\alpha_x| < 0.2$; $|\alpha_y| < 0.2$; $|\alpha_z| < 0.1$;
Nominal output energy (kinetic) 2.1 (+/- 1%) MeV
Longitudinal $\epsilon_{\text{rms_norm}}$ 0.8 – 1.0 eV- μ s

The RFQ acceptance is defined in this plane.

RFQ aperture in TRACK model is a cylinder of 1cm diameter that begins right in this plane. This aperture at the RFQ entrance puts additional unphysical limitation on the RFQ acceptance as shown later.

Definition of RFQ acceptance



In the work the RFQ acceptance in transverse plane is defined as an area occupied by phase portraits of beams with given emittance that do not have particle losses exceeding certain level. The envelope of all these phase ellipses (red line) form the RFQ acceptance .

MATHEMATICA code swept Twiss parameters over intervals of interest (step for α was 0.25 and step for β was 0.5), generated an input axisymmetric beam of 100k particles, run TRACK and selected the Twiss parameters of beams with acceptable losses to define acceptance. Typically number of generated phase ellipses was 900-1100.

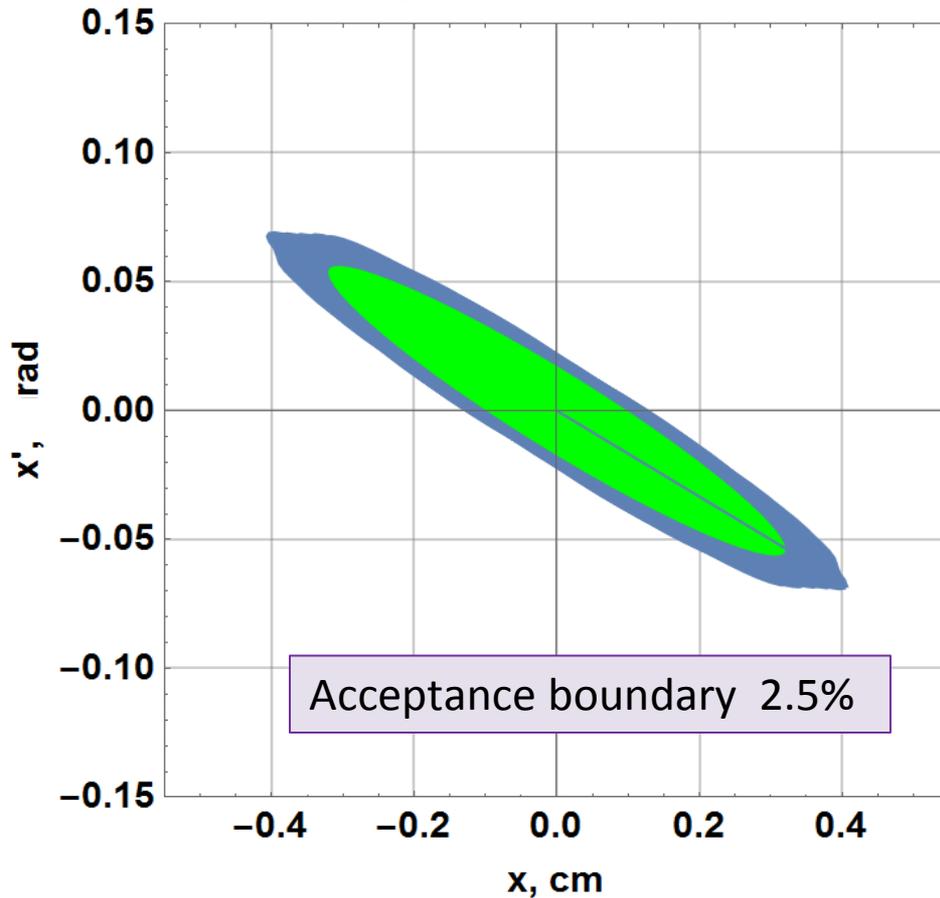
Since the emittance defined in this way depends on input beam emittance, current and type of particle distribution, the calculations were performed for two emittances (nominal and doubled) and two particle distributions (Gaussian and uniform). The current was 5 mA for all input beam configurations.

In the plot the matched beam (in terms of emittance growth) is shown in green, some of the sampled beams are shown in blue.

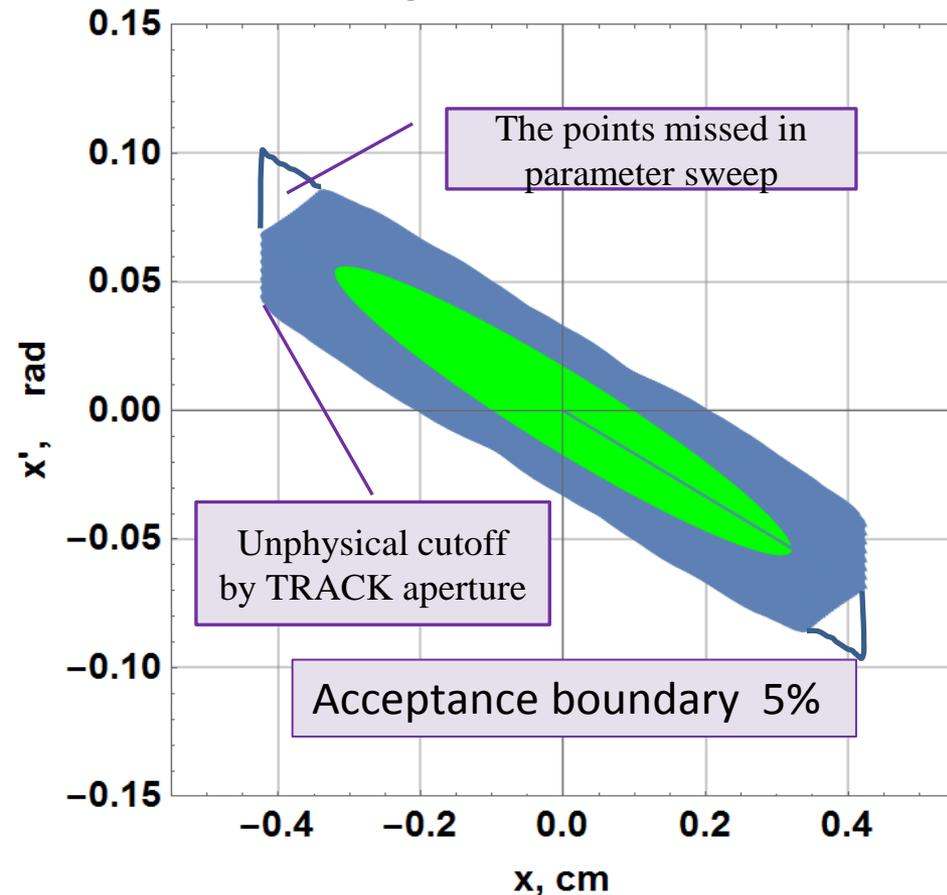
Acceptance for input beam of Gaussian distribution, 5 mA,

$$\epsilon_{\text{norm_rms}} = 0.011 \pi \cdot \text{cm} \cdot \text{mrad}$$

Acceptance of PXIE RFQ



Acceptance of PXIE RFQ

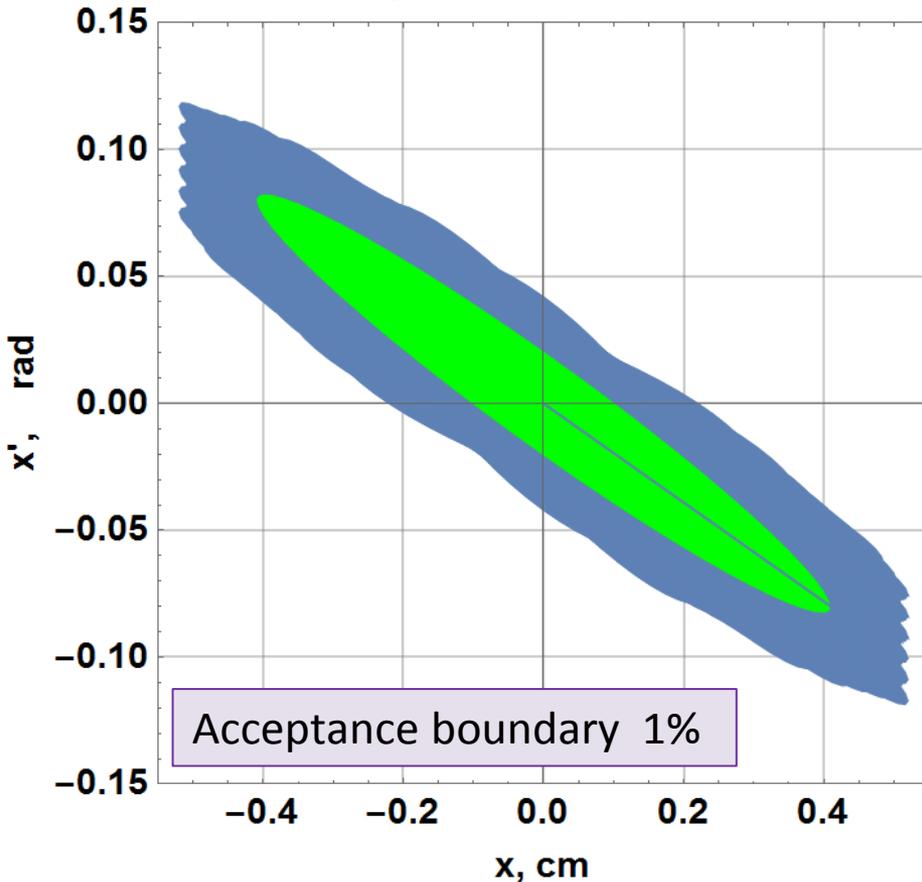


The beam in green has minimal losses of 2.44%

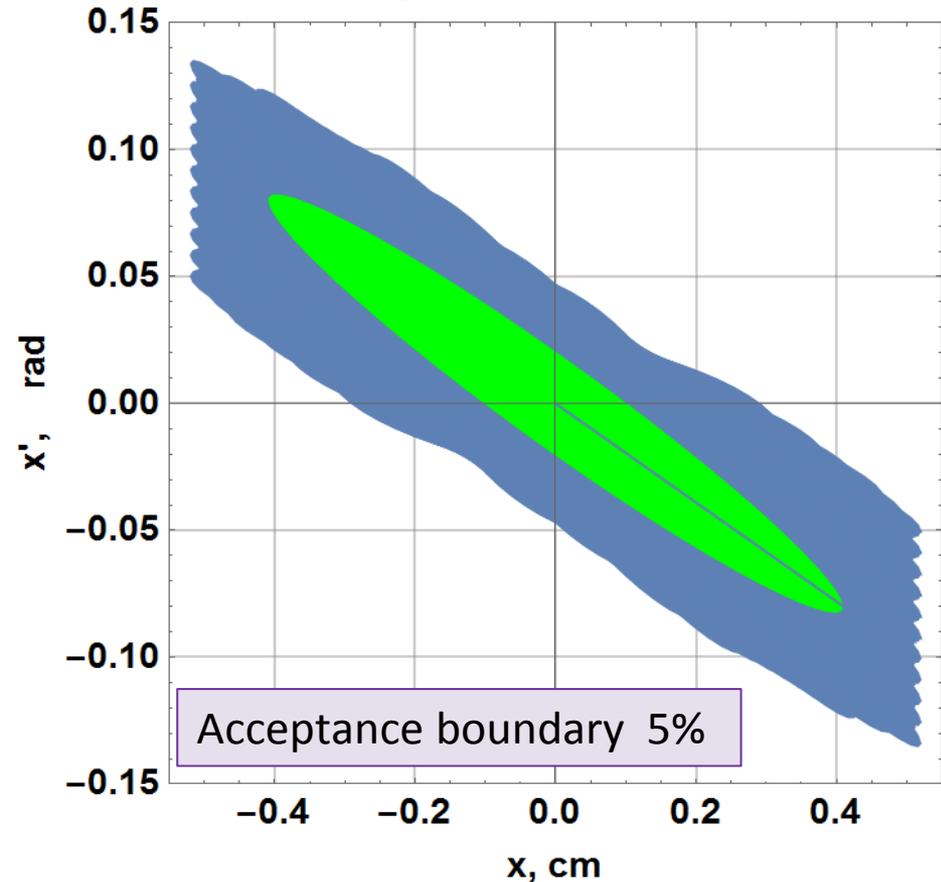
Acceptance for input beam of uniform distribution, 5 mA,

$$\epsilon_{\text{norm_rms}} = 0.011 \pi \cdot \text{cm} \cdot \text{mrad}$$

Acceptance of PXIE RFQ

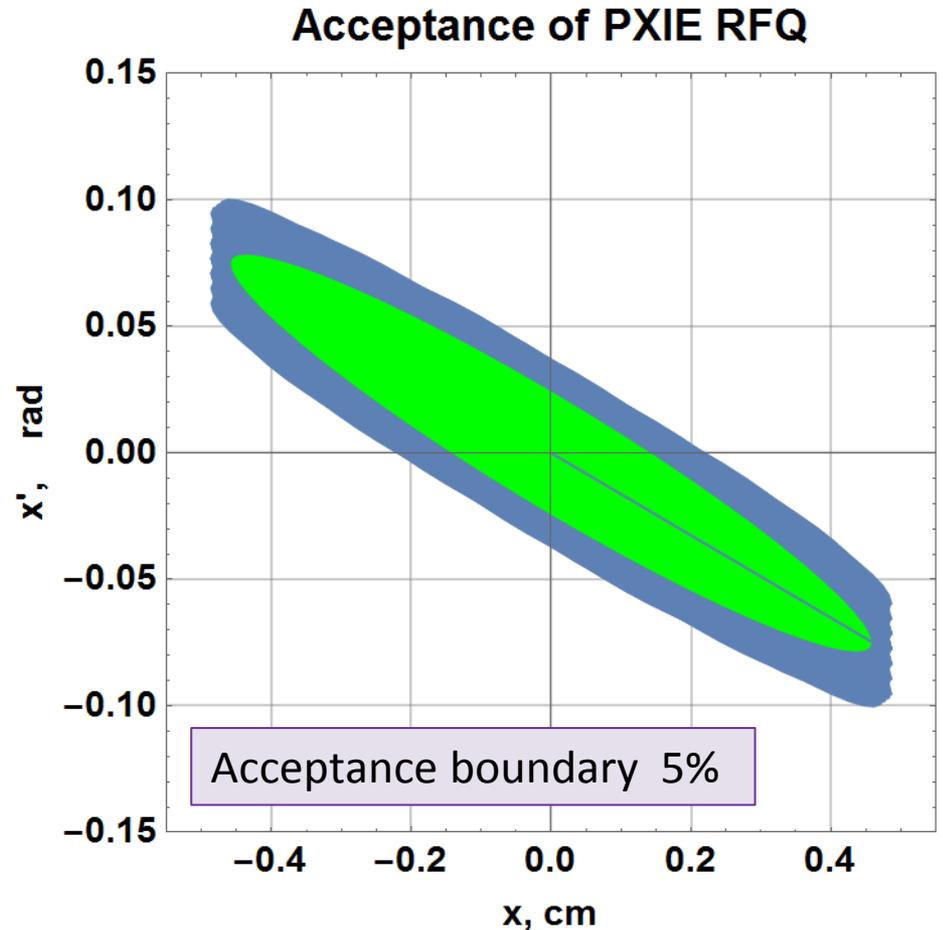
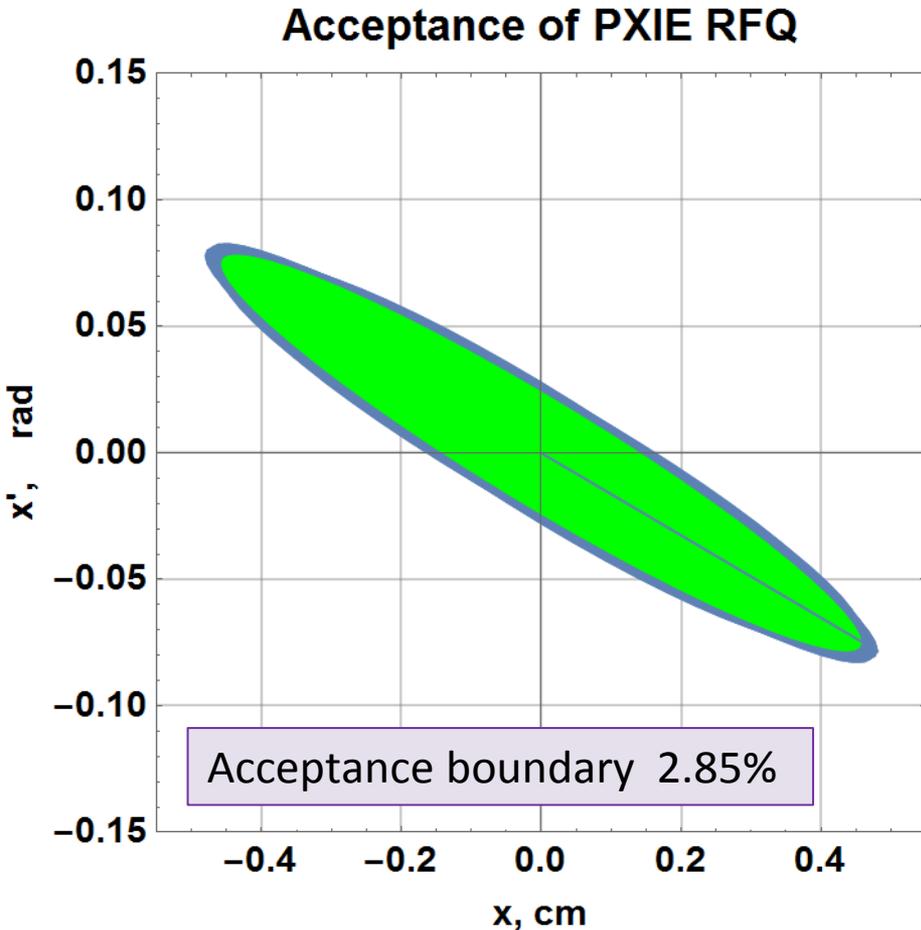


Acceptance of PXIE RFQ



The beam in green has minimal losses of 0.044%

Acceptance for input beam of Gaussian distribution, 5 mA, $\epsilon_{\text{norm_rms}} = 0.023 \pi \cdot \text{cm} \cdot \text{mrad}$

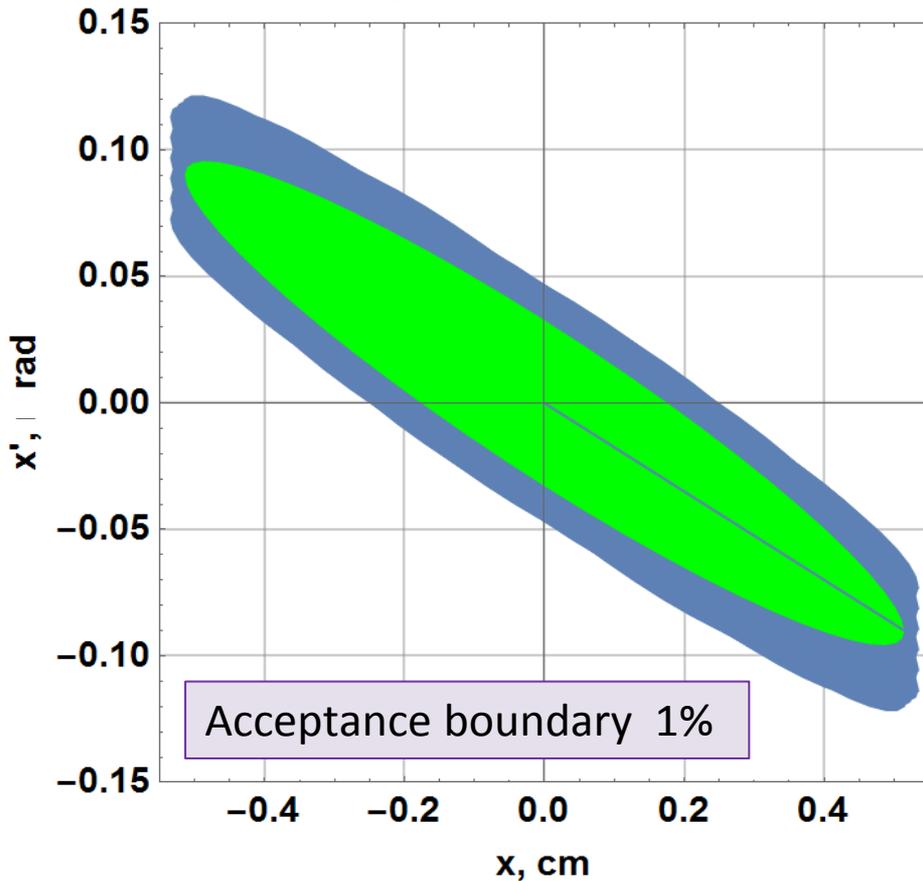


The beam in green has minimal losses of 2.72%

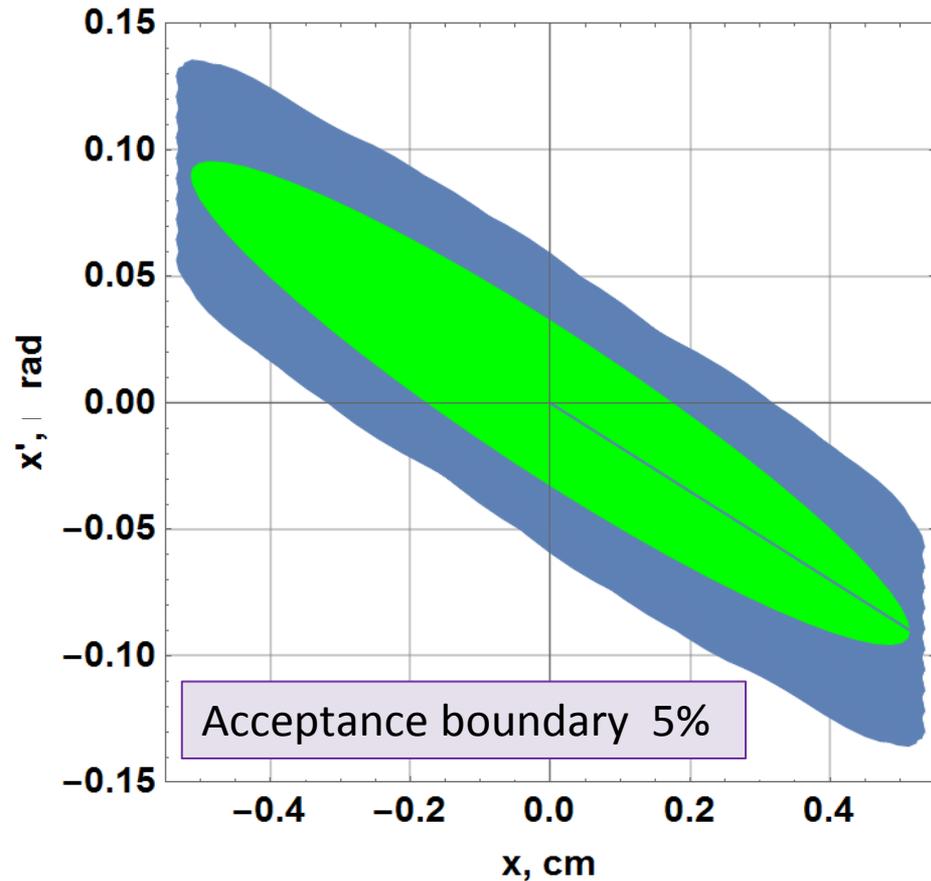
Acceptance for input beam of uniform distribution, 5 mA,

$$\epsilon_{\text{norm_rms}} = 0.023 \pi \cdot \text{cm} \cdot \text{mrad}$$

Acceptance of PXIE RFQ



Acceptance of PXIE RFQ



The beam in green has minimal losses of 0.07%

Conclusion

- The PXIE RFQ acceptances were defined for two different transverse input beam rms emittances and two different spatial particle distributions.
- The described approach can be used with real beam parameters from LEBT.
- Though an impact of input beam misalignment was not studied explicitly, it can be estimated that the 5mA beam with rms normalized emittance of $0.023 \pi \cdot \text{cm} \cdot \text{mrad}$ and either particle distributions is accelerated in the RFQ with losses $<5\%$ with some margin for injection errors, i.e. $\approx \pm 1 \text{mm}$ offset and $\pm 10 \text{ mrad}$ angular error for the optimally matched beam.
- Note, that the beams with transverse phase ellipses within appropriate acceptance will have limited particle losses, but they will not be necessarily matched in terms of emittance growth.