Quadrupole scan in ASTRA

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2. Old simulation results and problems
3. New simulation results
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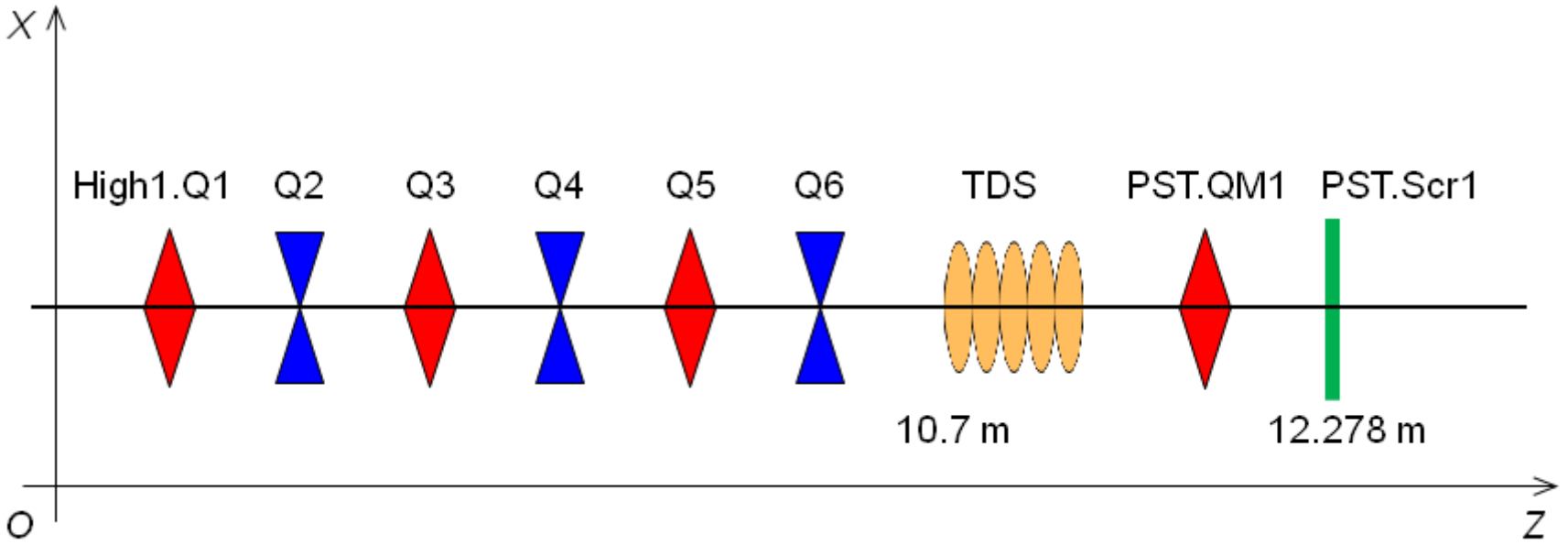
DESY

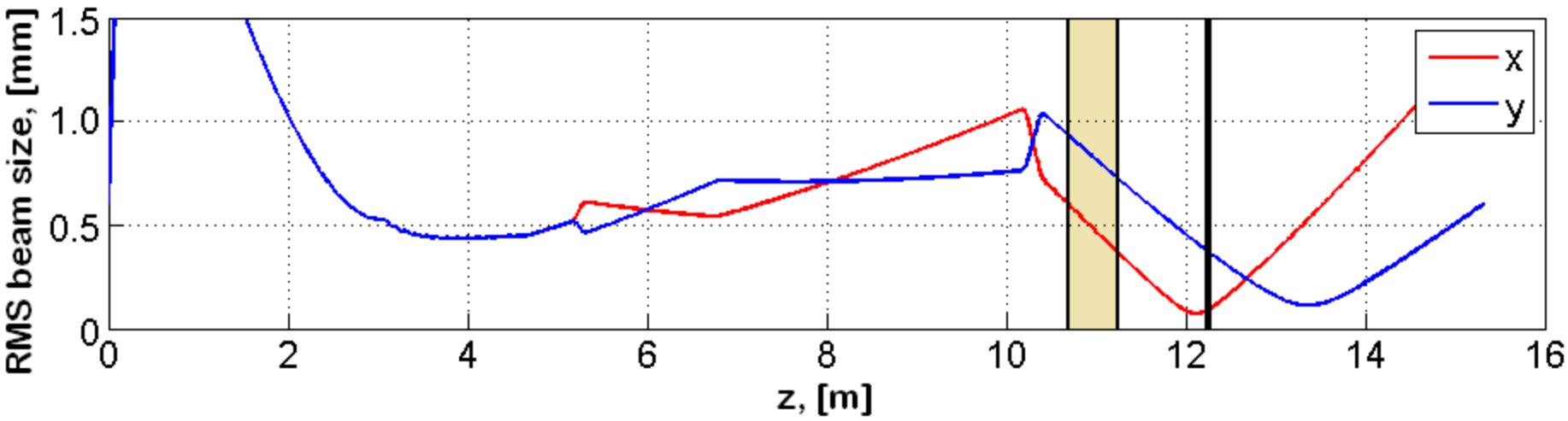
Measurement setup for slice emittance measurements



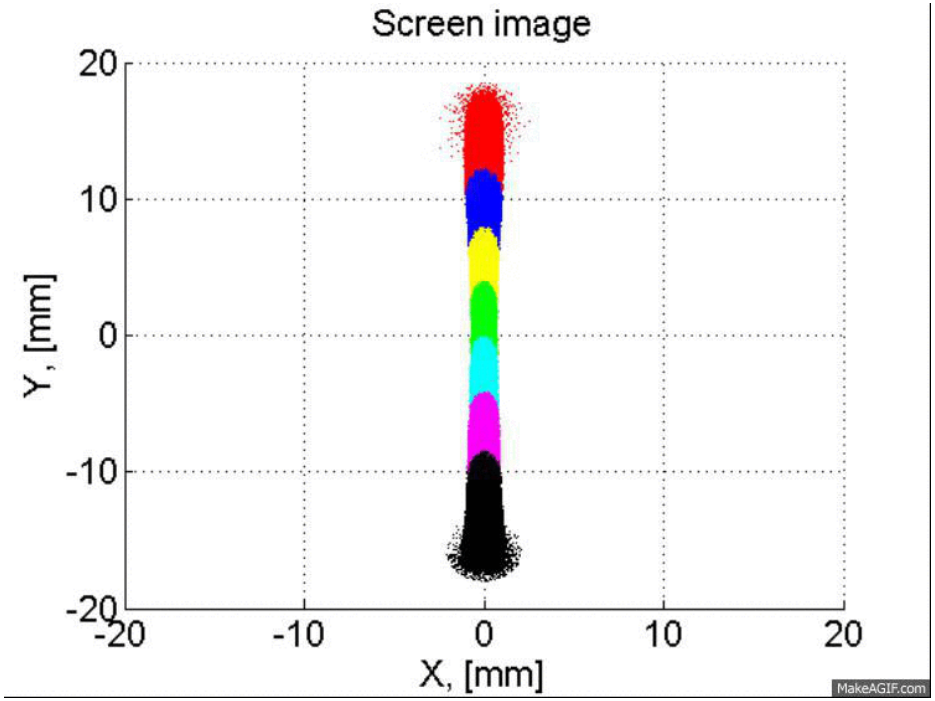
Quadrupole magnets High1.Q1 – Q5 are used for the beam transport and High1.Q6 is used to perform quadrupole scan.

PST.QM1 can be used for additional focusing of the beam on the observation screen PST.Scr1.

Beam size along the beamline

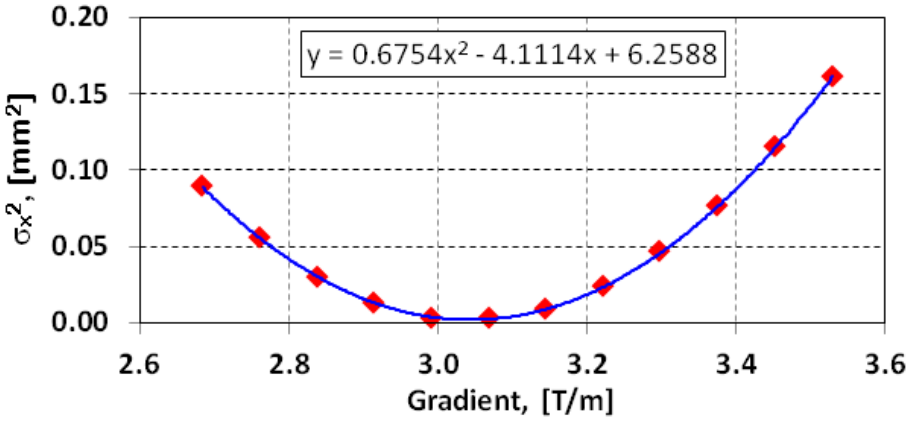


Idea of the quadrupole scan

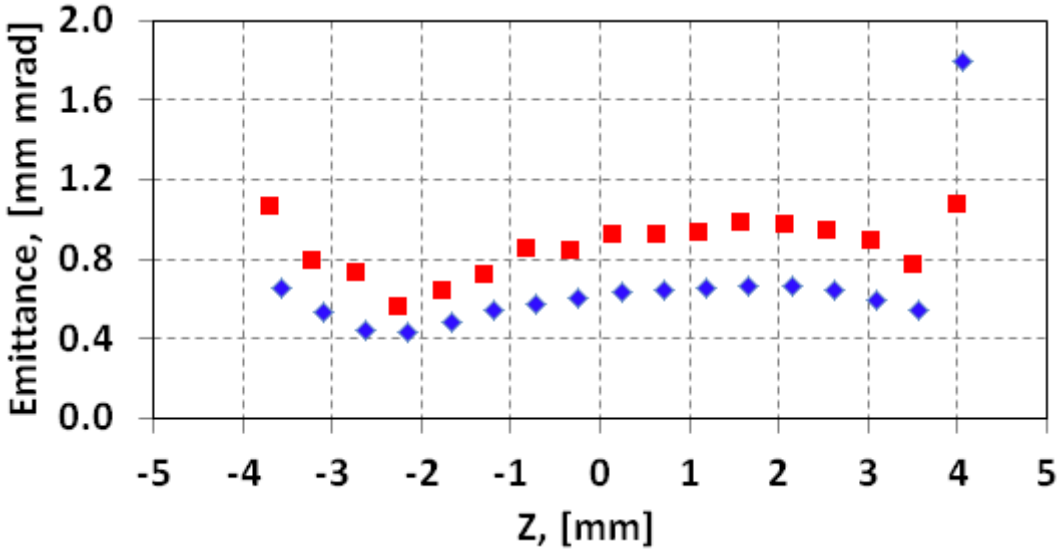


Seven colors correspond to the seven consequent longitudinal slices of the bunch with equal charge.

See details at the PPS on 23.02.2012 and 30.03.2012



Old simulated results and problems



Red – simulated measurements results of the slice emittance quadrupole scan

Blue – simulated slice emittance

Simulation of measurements using quadrupole scan technique gives the emittance value about 30% higher than the simulated one.

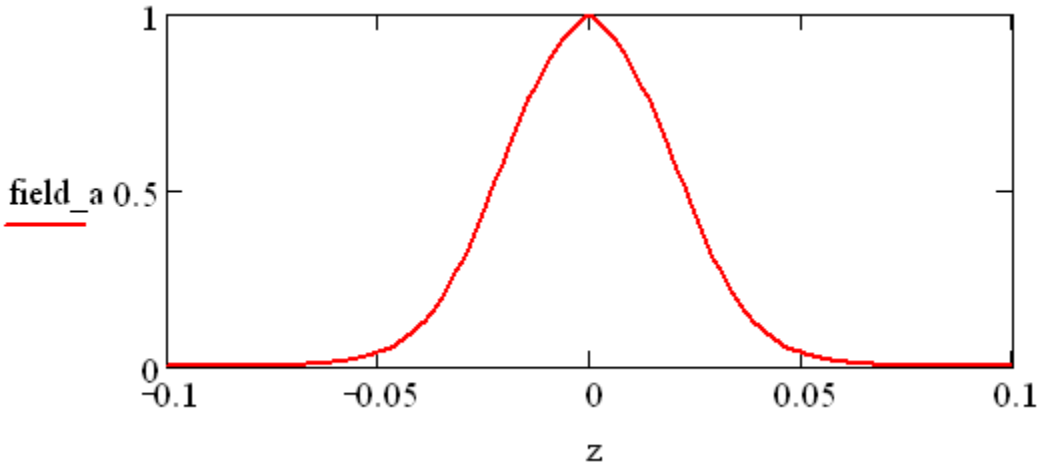
Possible sources of the error

- space charge forces
- energy spread
- mixing of neighboring longitudinal slices
- different quadrupole field profile in ASTRA and calculation algorithm

ASTRA quadrupole field

$$field\_a_i := \frac{1 + \exp\left[\frac{4\left(|0| - \frac{ld}{2}\right)}{d}\right]}{1 + \exp\left[\frac{4\left(|z_i| - \frac{ld}{2}\right)}{d}\right]}$$

d – quadrupole inner diameter
ld – quadrupole effective length



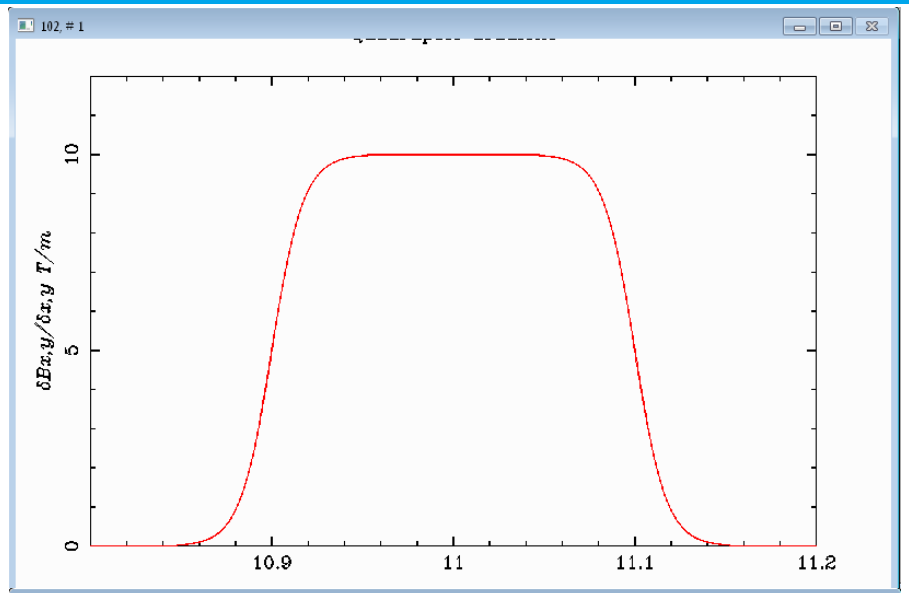
d = 0.035 m

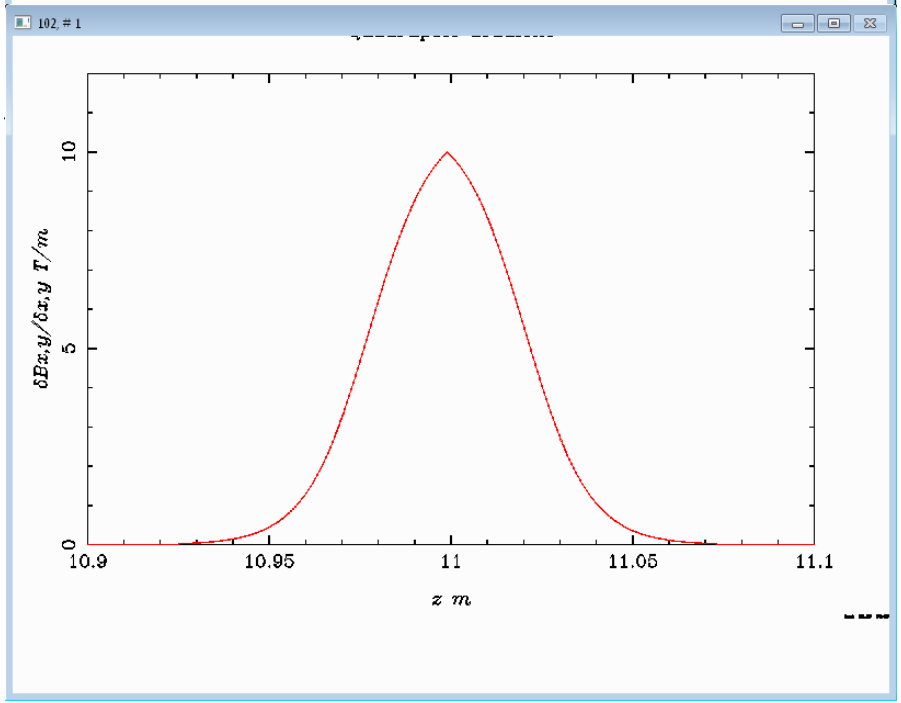
ld = 0.043 m

$$L_{effective} = \frac{\int f dz}{f_{max}}$$

If one will calculate: $L_{effective}$ = 0.0482

ASTRA quadrupole profiles examples





Set $L_{effective}$ = 0.2 d = 0.035 m

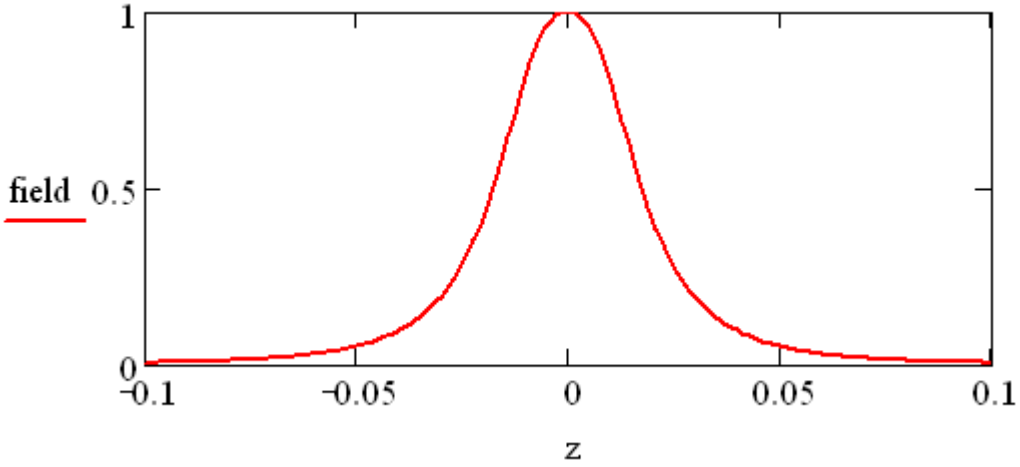
You get $L_{effective}$ = 0.2

$$\text{field\_a}_i := \frac{1 + \exp\left[\frac{4\left(|0| - \frac{ld}{2}\right)}{d}\right]}{1 + \exp\left[\frac{4\left(|z_i| - \frac{ld}{2}\right)}{d}\right]}$$

Set $L_{effective}$ = 0.043

You get $L_{effective}$ = 0.0482

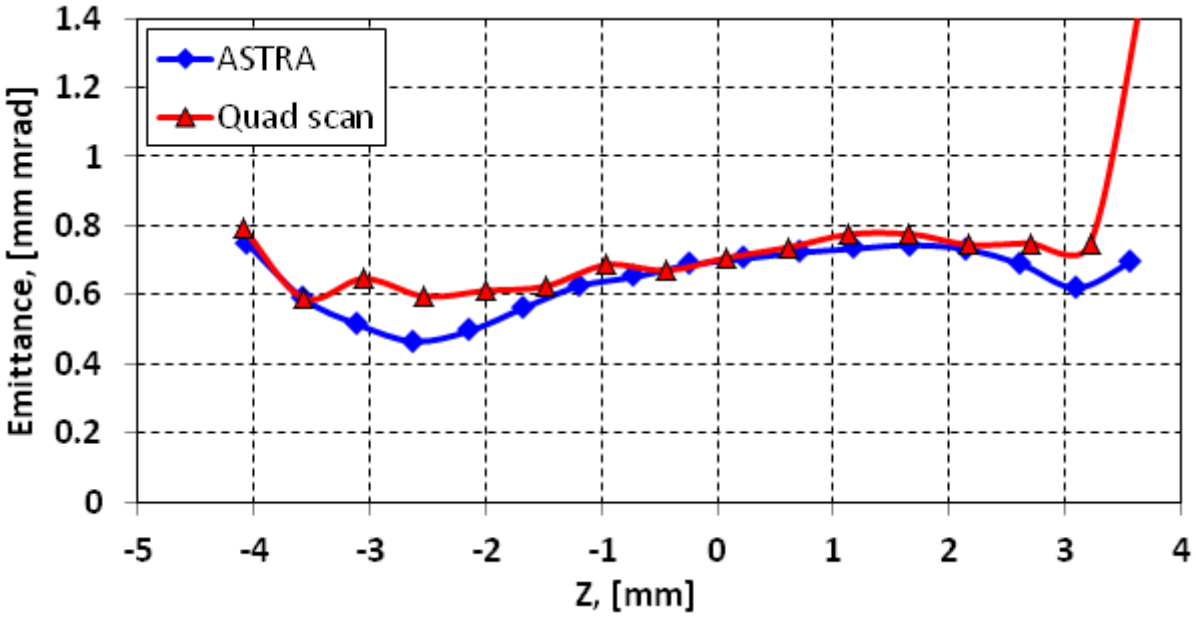
Measured quadrupole field profile



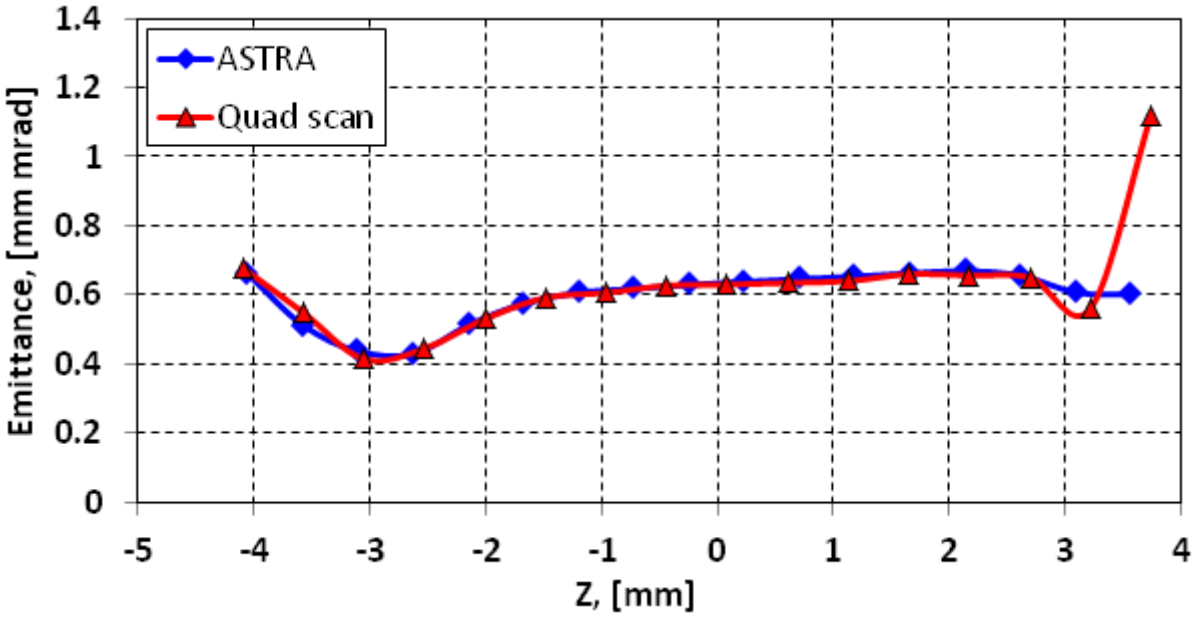
$$L_{effective} = \frac{\sum f dz}{f_{max}}$$

If one will calculate: $L_{effective}$ = 0.0428

Simulated results with space-charge forces



Simulated results without space-charge forces



Conclusion

- Setting too short effective length of the quadrupole magnet in ASTRA can cause not physical field profile and result in not correct quadrupole effective length.
- Quadrupole scan technique together with the TDS cavity gives the reasonable slice emittance values close the real one (simulations).
- Space-charge forces can significantly affect the results of the quadrupole scan, as they are not included in data analysis.