# pbar Separator Sextupoles
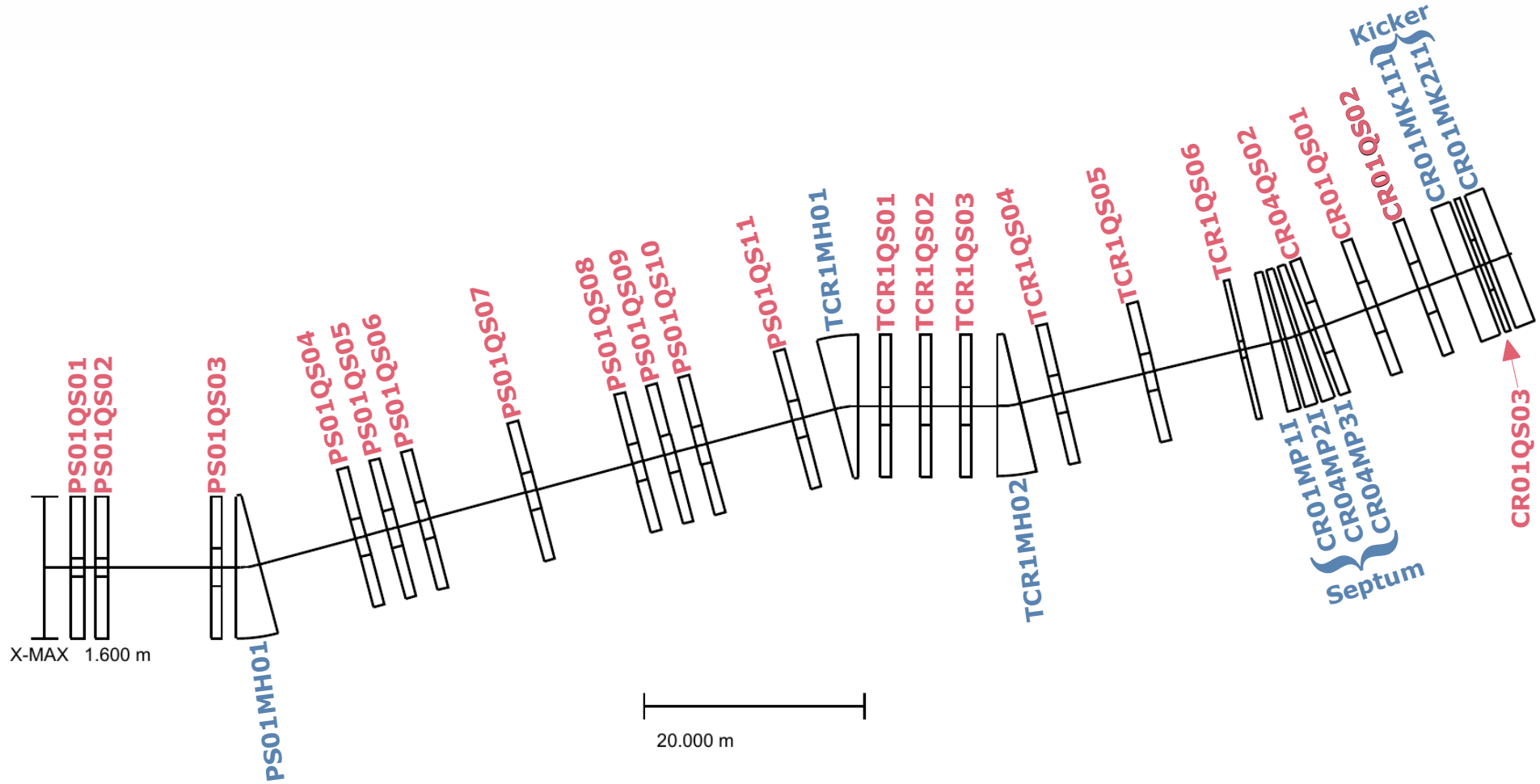
## S. Udrea

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# pbar Separator Beamline Overview

# Simulation Software

- GICOSY is an ion optics software based on COSY 5.0, developed at the University of Gießen, Germany and still maintained also at GSI (web-docs.gsi.de/~weick/gicosy/). It has been used to assess parameters such as beta and dispersion function, twiss parameters and envelopes and to generate the transfer matrices of the ion optical elements as needed by MOCADI.

- MOCADI is a Monte Carlo simulation software developed and maintained at GSI (web-docs.gsi.de/~weick/mocadi/) which has been used to assess losses using realistic aperture shapes and an initial pbar distribution due to a MARS simulation of pbar generation through proton-target interaction followed by magnetic horn focusing*.

* horn focusing simulated by dedicated software

# Remarks on Collimators used in MOCADI

- Collimators are either elementary, i.e. fully absorbing and infinitesimally thin, or composed of elementary ones.

- The horizontal-vertical (HV) collimator placed between the magnetic horn and PS01QS01, the beamline's first quadrupole, is simulated by two identical elementary collimators in 1.6 m distance from each other. The reference HV-collimator has a circular aperture with a 70 mm diameter.

- The horizontal and vertical collimators between PS01QS02 and PS01QS03 and the momentum collimator between PS01QS04 and PS01QS06 are each elementary ones.

- Quadrupole apertures* are simulated as three subsequent elementary collimators: at entrance, in the middle and at exit.

- Dipole apertures* are simulated as two subsequent elementary collimators: at entrance and at exit. **Exception:** the septum dipoles, where there are five elementary collimators per dipole.

- A special phase space collimator is used for assessing losses to be expected due to particles not within the ring's (geometric) acceptance.
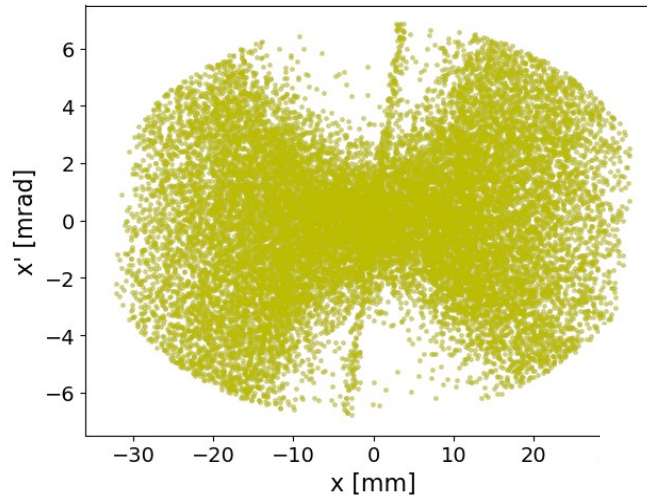
* due to yoke or vacuum chambers
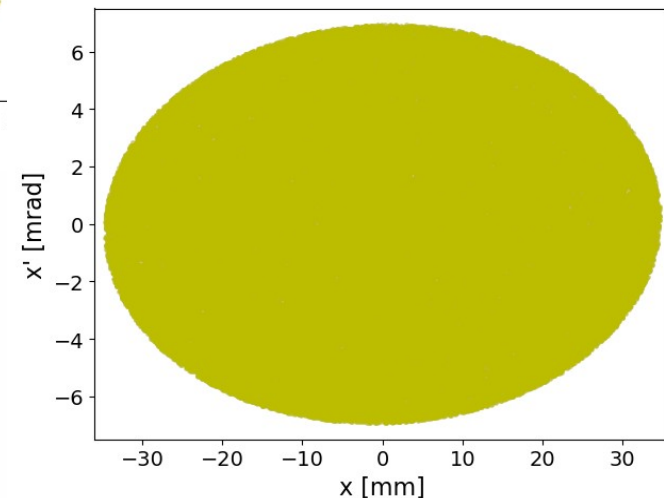
# Input Beam Distributions used with MOCADI
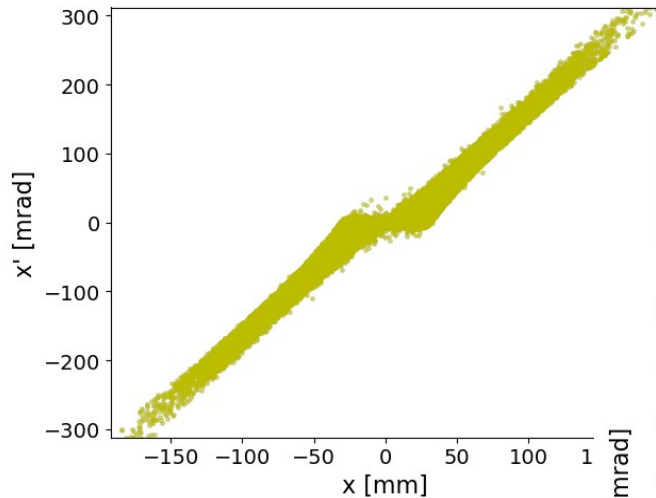


Acceptance limited, 13 Tm ± 3% selection from a MARS generated beam; in some cases 13 Tm sharp were set for all particles



13 Tm ± 10% or 13 Tm ± 3% selection from a MARS generated beam, no acceptance limitation

Uniformly distributed, acceptance limited 13 Tm beam



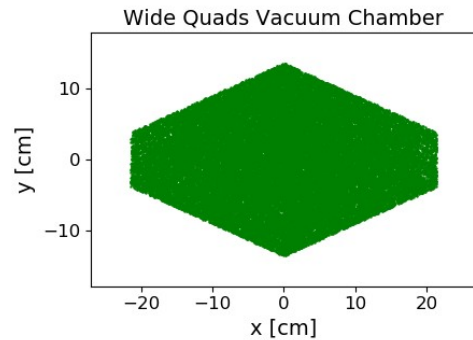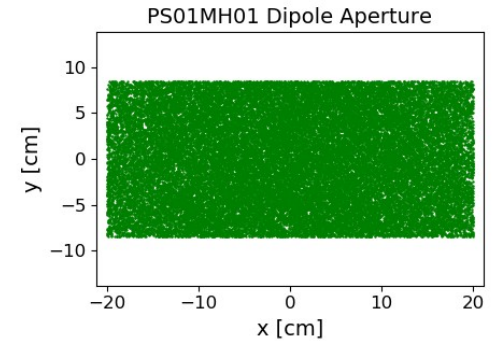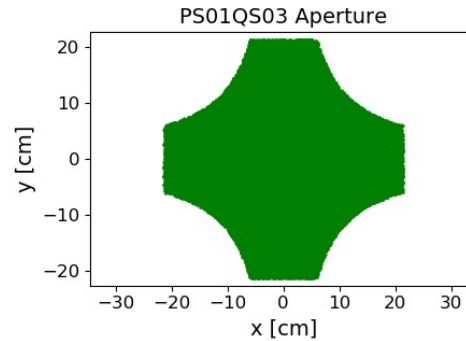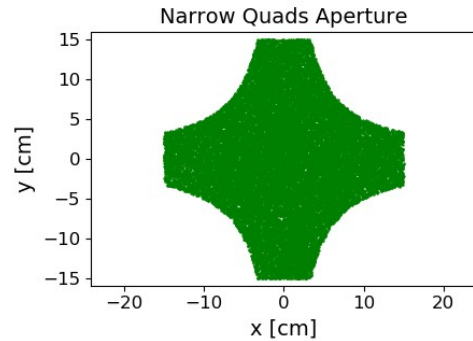**Note:** Here acceptance is to be understood as purely geometrical, i.e. as defined by the x-x' and y-y' phase space ellipses. The ellipses used for the acceptance limited beams depend on the quad settings and position of the horn's exit plane, since they have to be imaged onto those defining the CR's acceptance.

# Reference Apertures used with MOCADI
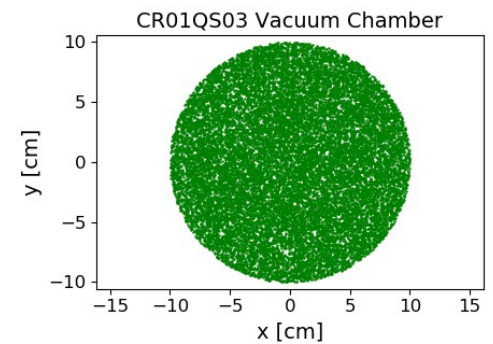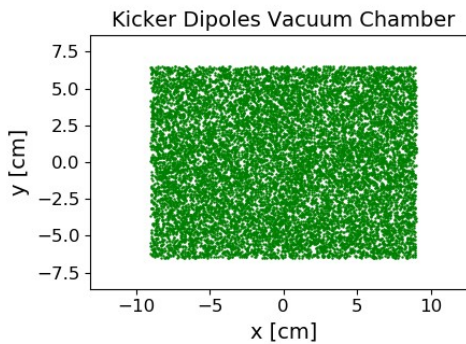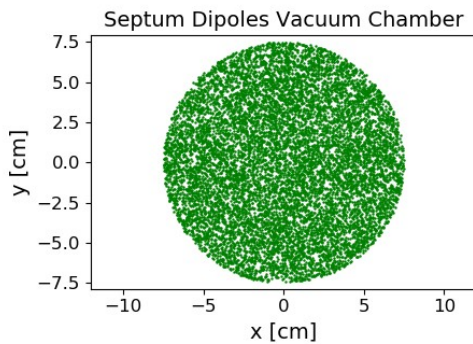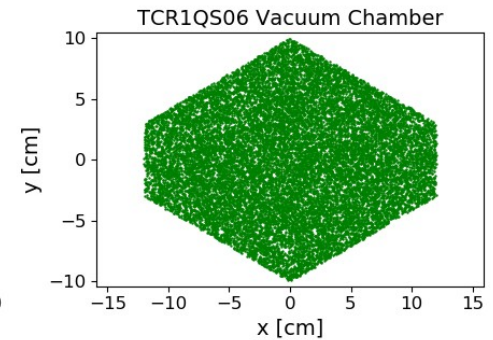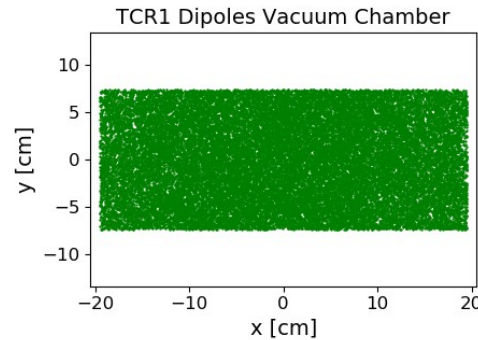
# Losses for Different Acceptance Limited Beams
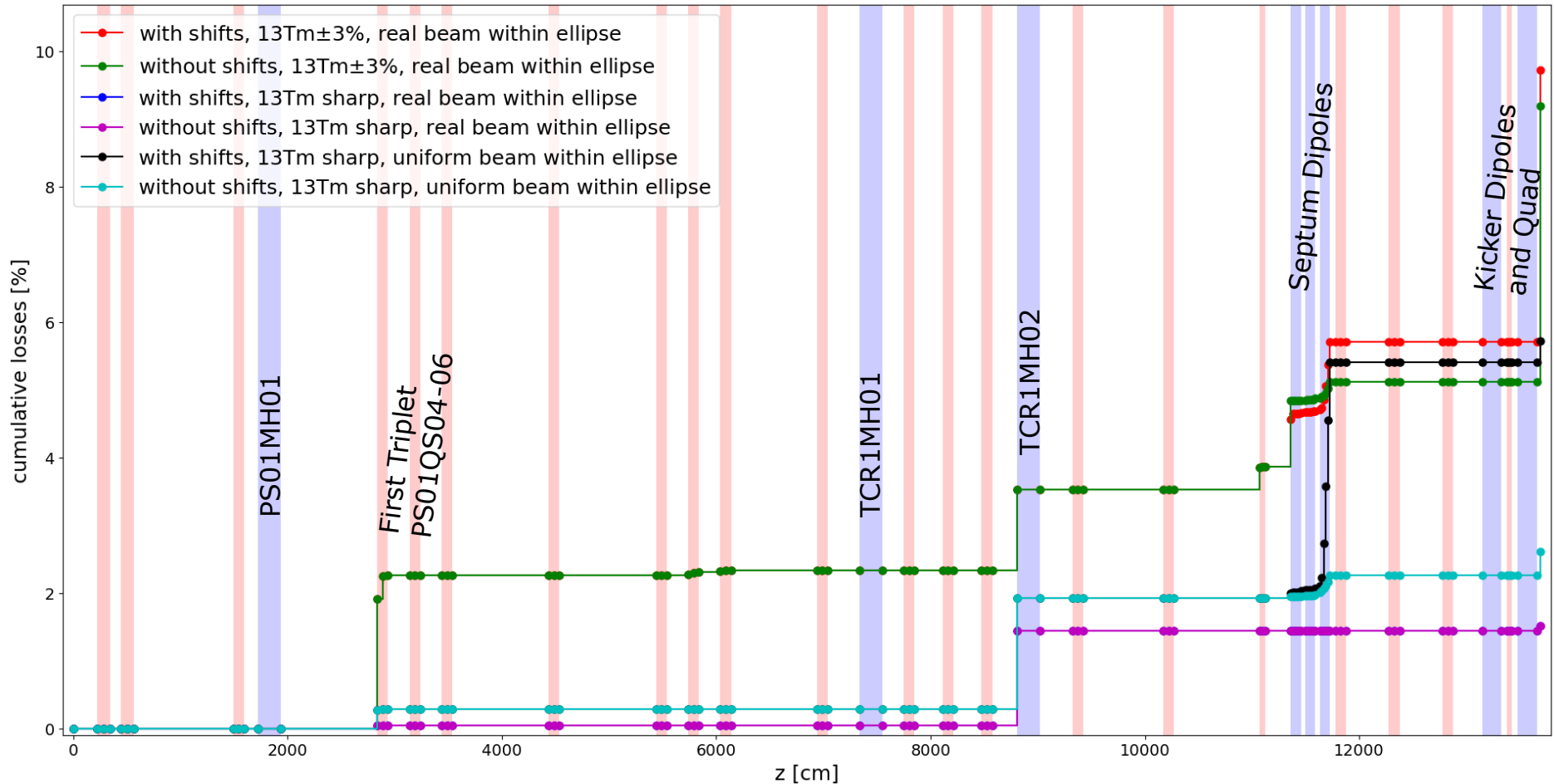


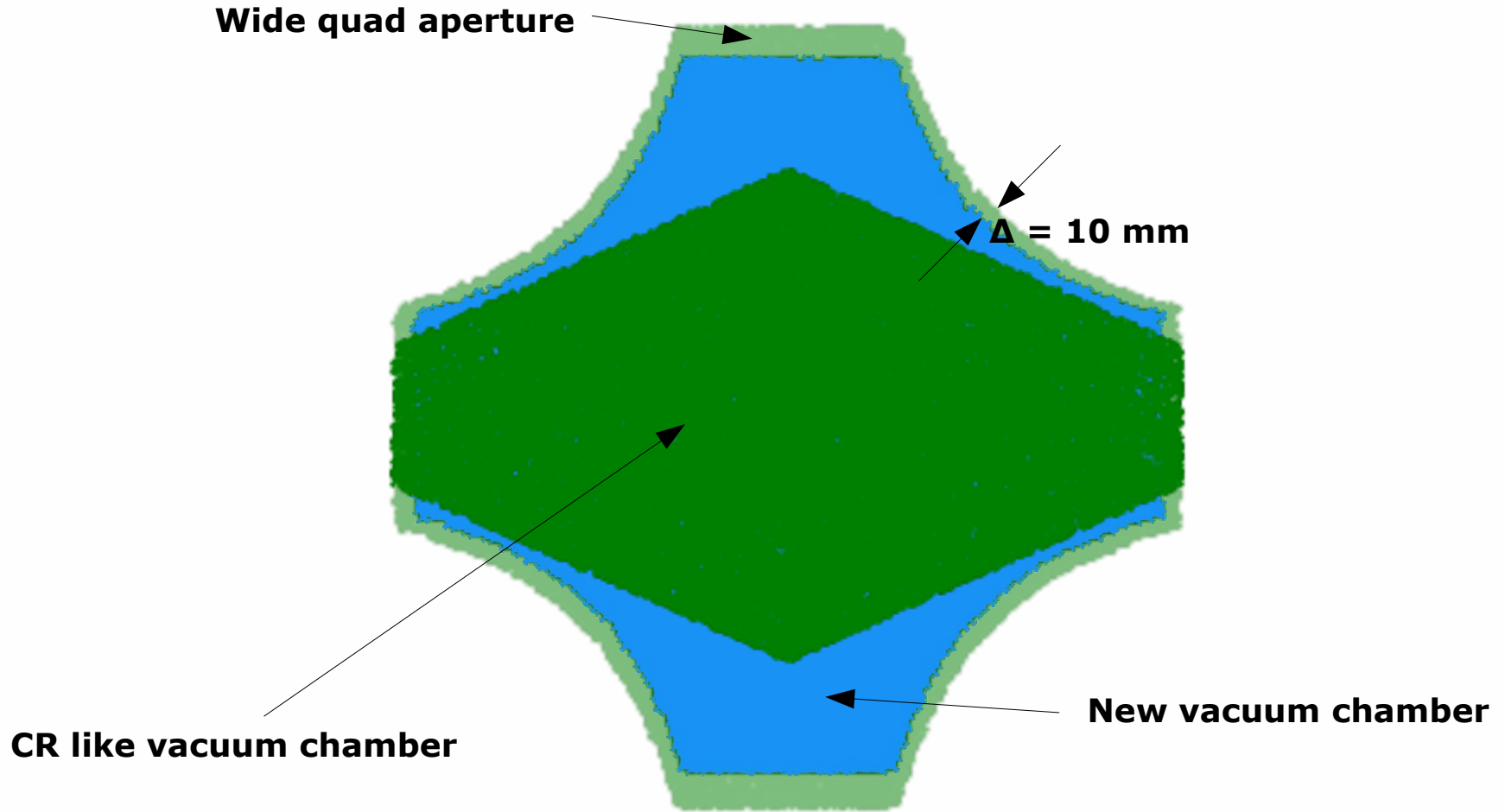**Note:** No dedicated collimators used in these simulations

# Reducing Losses by Chamber Removal/Modification



Wide quad aperture

Δ = 10 mm

CR like vacuum chamber

New vacuum chamber

# Reducing the Beam Envelope @ TCR1MH02



Field adjustments performed with backwards simulations to preserve in ring settings
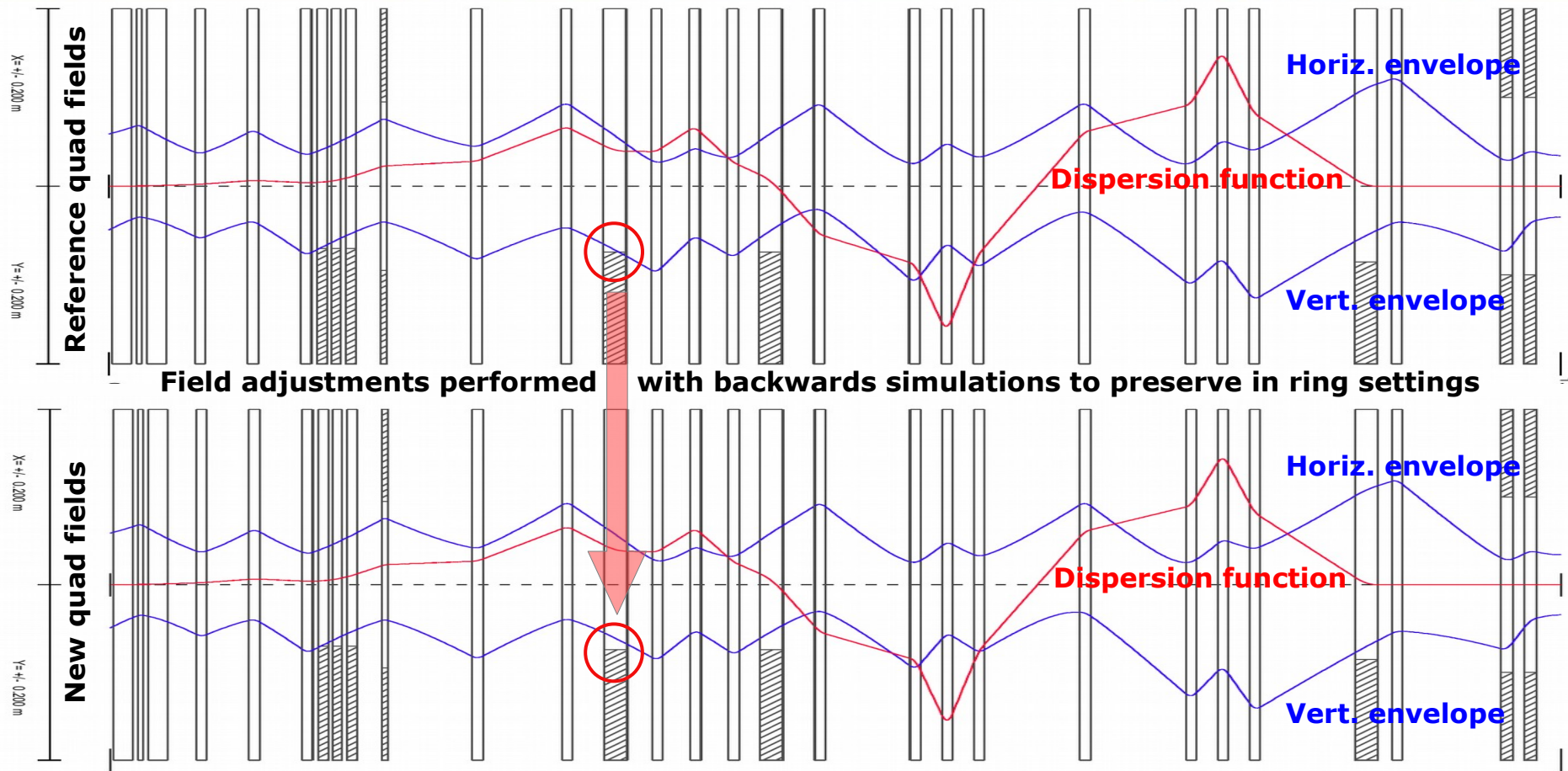
**Field gradients in T/m – only for quads with changes**

|  | PS01QS02 | PS01QS04 | PS01QS05 | TCR1QS04 | TCR1QS05 | TCR1QS06 |
|---|---|---|---|---|---|---|
| Reference | -3.24821 | -2.40617 | 3.90601 | 2.10321 | -1.79760 | 3.93614 |
| New | -2.97 | -2.23857 | 3.84080 | 2.16377 | -1.97023 | 4.09569 |

# Adding a Sextupole to Reduce Losses in Septum
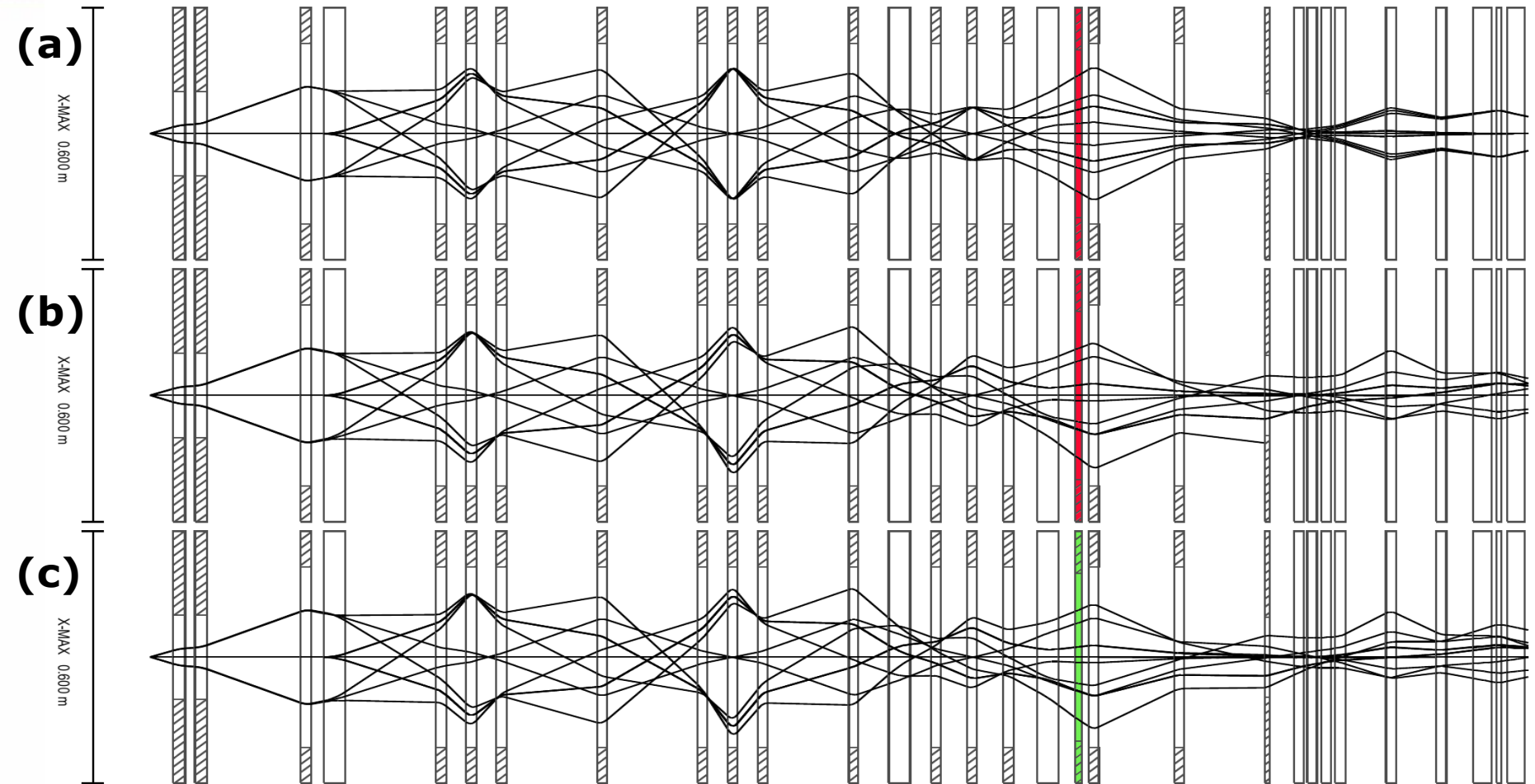


Ray tracing simulations performed with GICOSY. A point source emits along three different directions respectively three rays of different energies, including the reference one. **a)** 1st order simulation, sextupole is **off** (but also irrelevant); **b)** 3rd order simulation, sextupole is **off**; **c)** 3rd order simulation, sextupole is **on**.
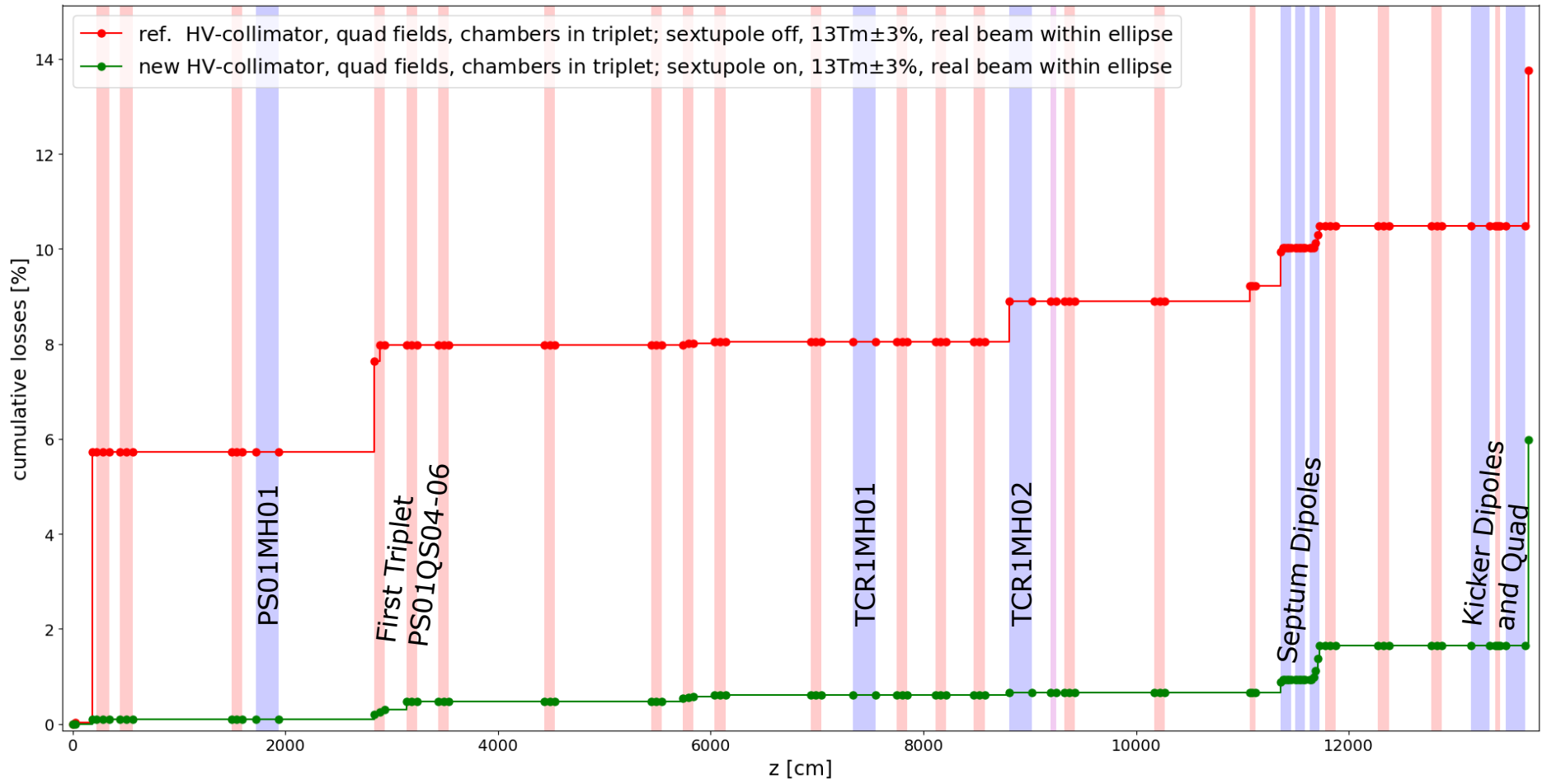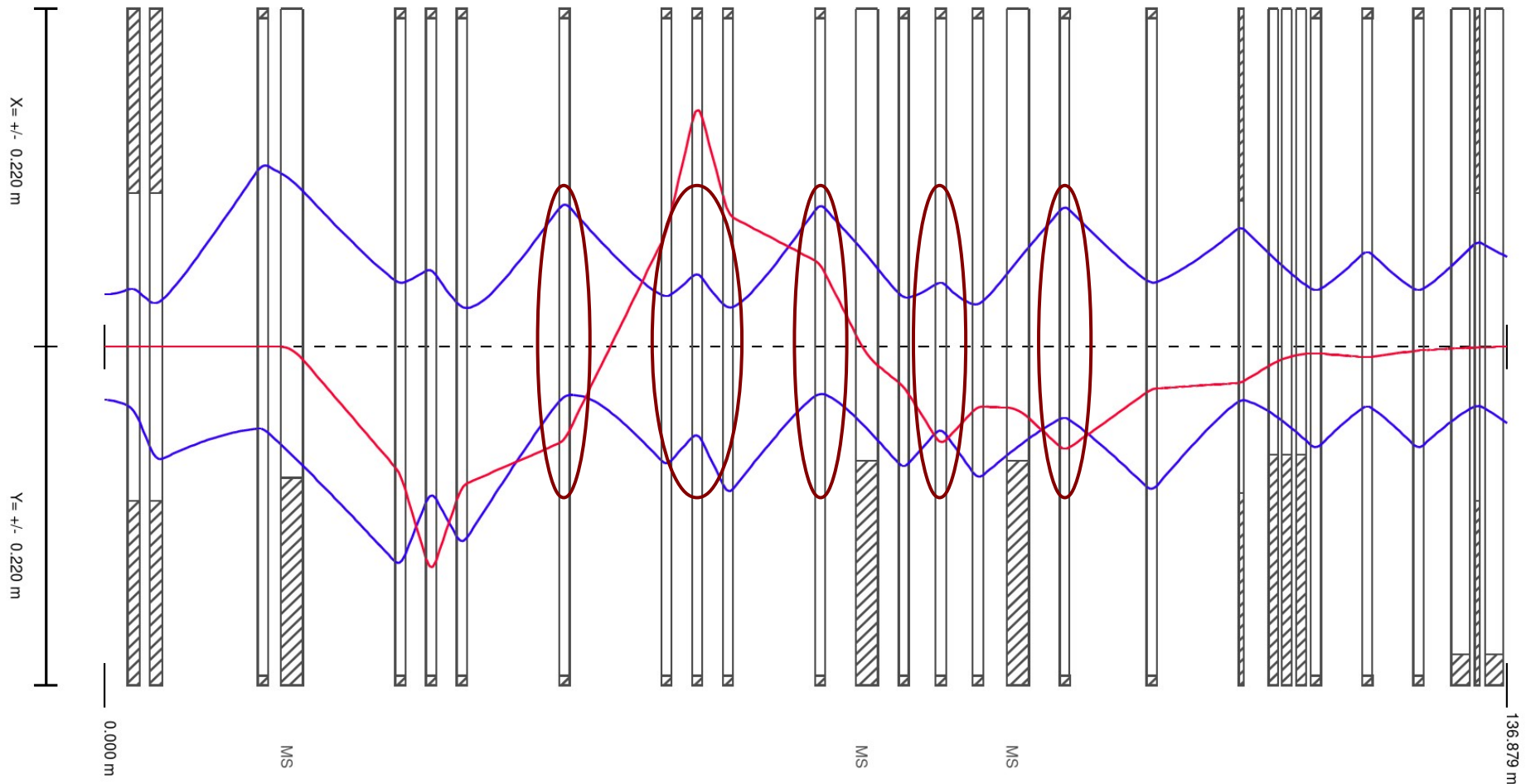
# Choosing HV-Collimator's Shape and Size
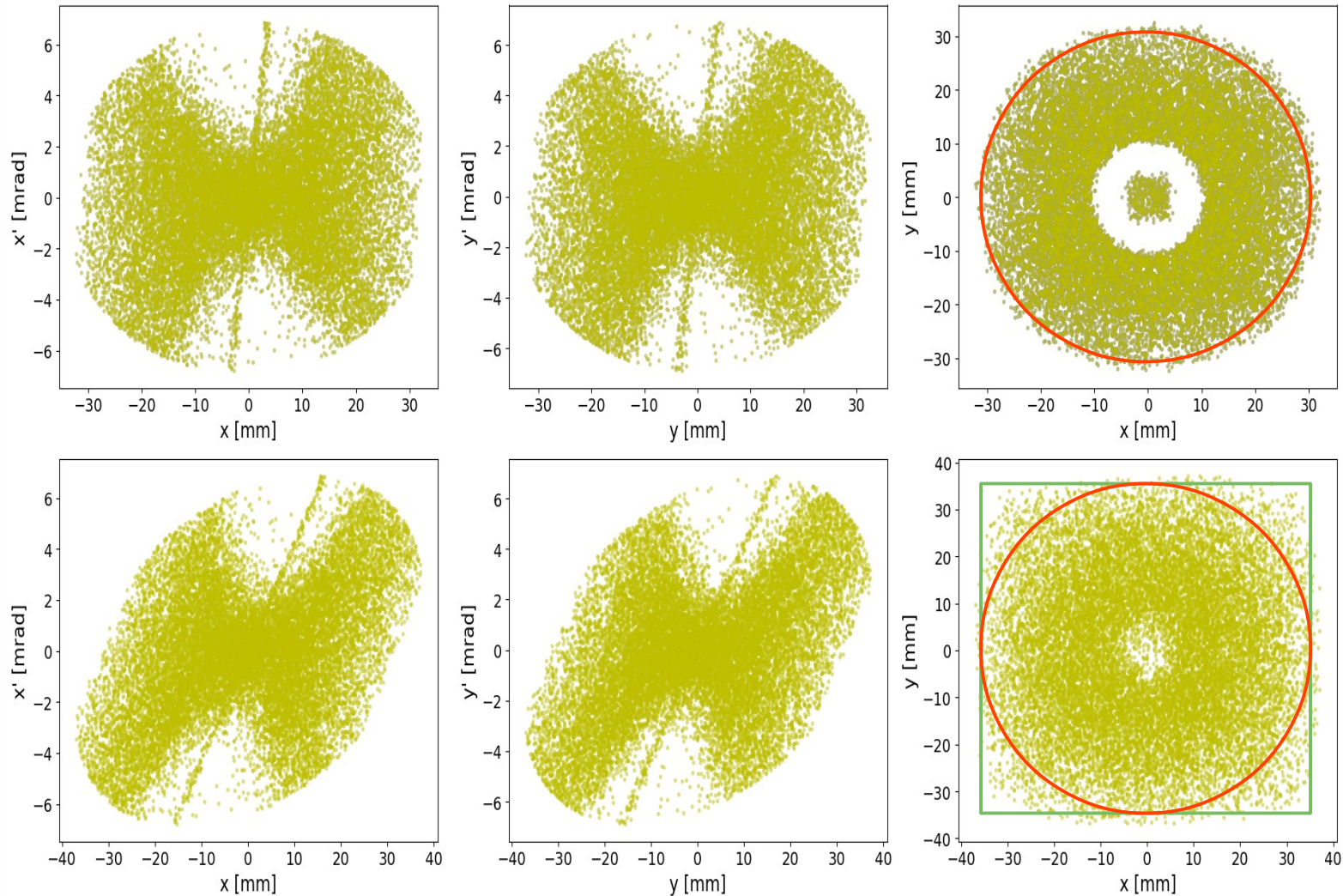


**Note:** Particle distributions at horn's exit plane (upper graphs) and after a drift to the position of the collimator's exit plane. No collimator used for this simulation!

# Losses Comparison: Reference vs. New Set-Up

# Adding more Sextupoles: Where to Place Them?



Beam envelopes (in blue) and horizontal dispersion function (in red) along the pbar separator beam line. A rule of thumb for placing sextupoles one can use is: large horizontal dispersion (at best a maximum), low vertical beta function (lower than the horizontal one is better). Some options are indicated on the image above. However, there are no obviously ideal positions. Several configurations have been tested.

# Adding more Sextupoles: Strengths and Solution*

GICOSY offers the possibility to automatically search for the optimum of a configuration by varying given parameters such as to zero a target function depending on them. The target function used for optimizing the sextupole strengths for each of the tested configurations achieved zero if for a test particle the non-linear contributions were a small fraction of the linear ones (ideally zero).

Present solution:

| Name | Position | Strength [$T/m^2$] |
|------|----------|-------------------|
| PS01KS01 | 0.7m upstream of PS01QS07 | -2.60875 |
| PS01KS02 | 0.7m downstream of PS01QS10 | -1.28035 |
| PS01KS03 | 0.7m upstream of PS01QS11 | 3.57125 |
| PS01KS04 | 0.7m downstream of PS01QS11 | -4.25000 |
| TCR1KS01 | 0.7m upstream of TCR1QS02 | -0.10861 |
| TCR1KS02 | 0.7m upstream of TCR1QS04 | -1.02500 |

* as good as I could get it

# Losses Comparison: Acceptance Limited Beam
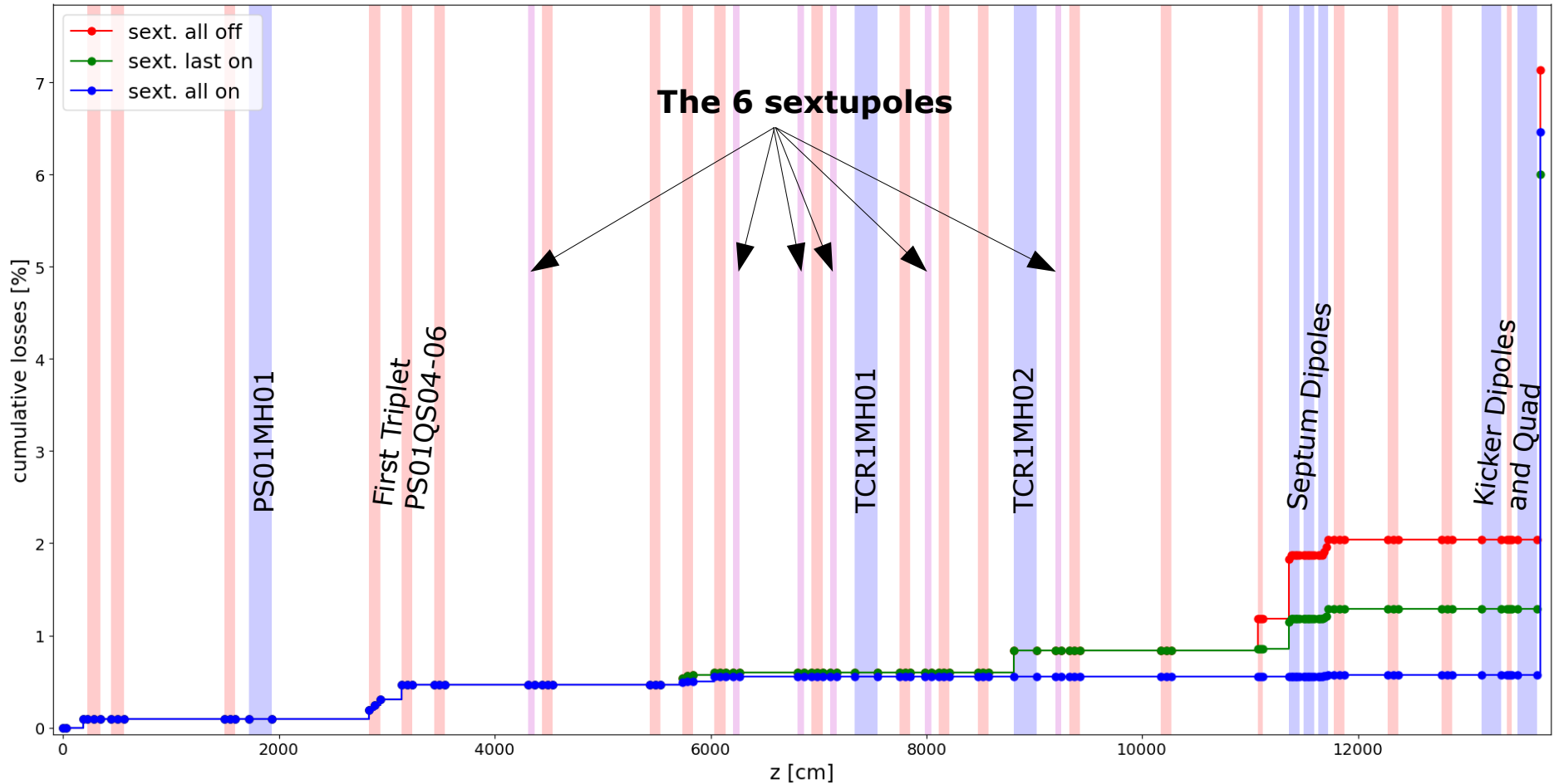


**Note:** When used alone, TCR1KS02 has the previously assessed strength of -1.5 T/m$^2$
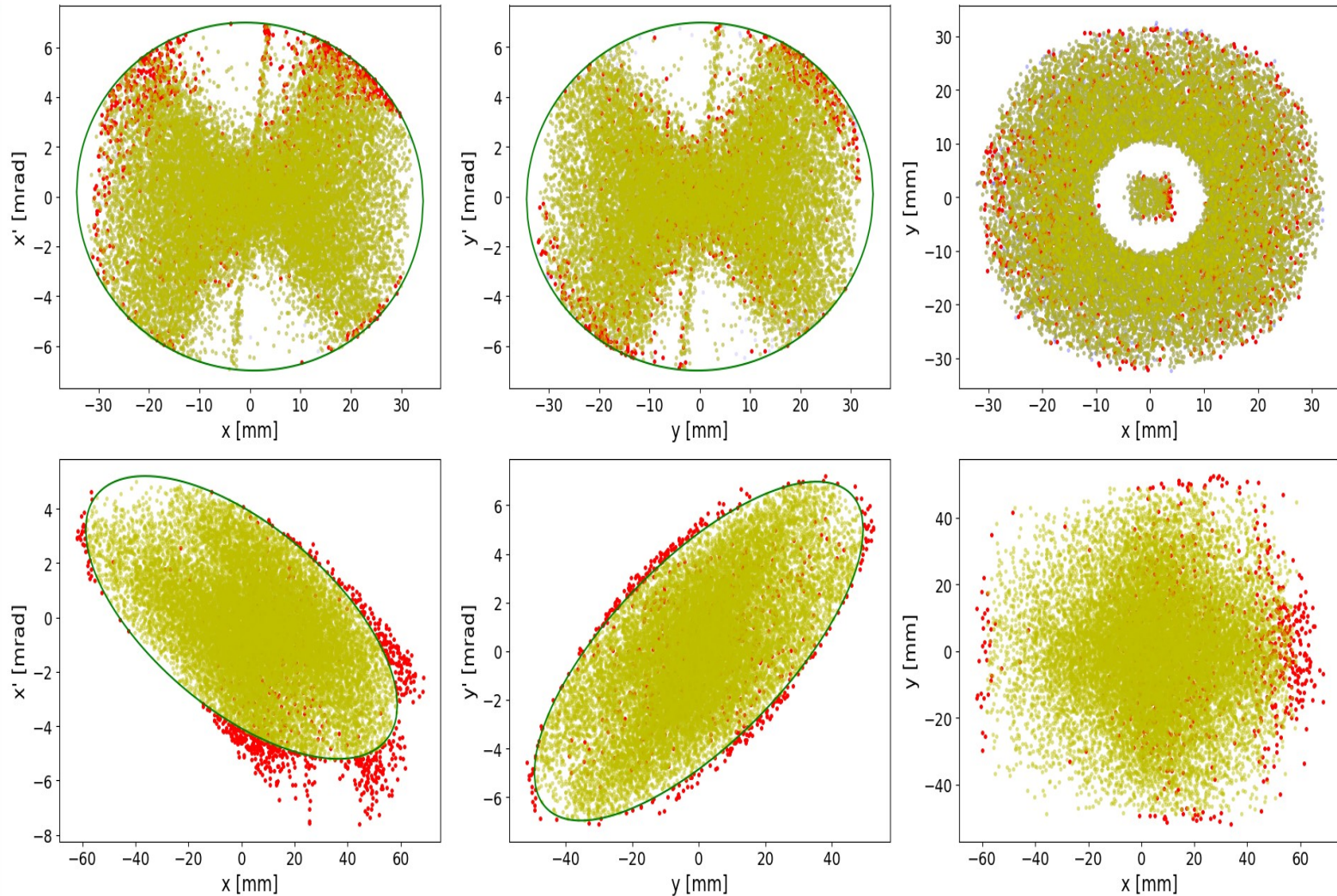
# Phase Space at Input and Output, No Sextupoles
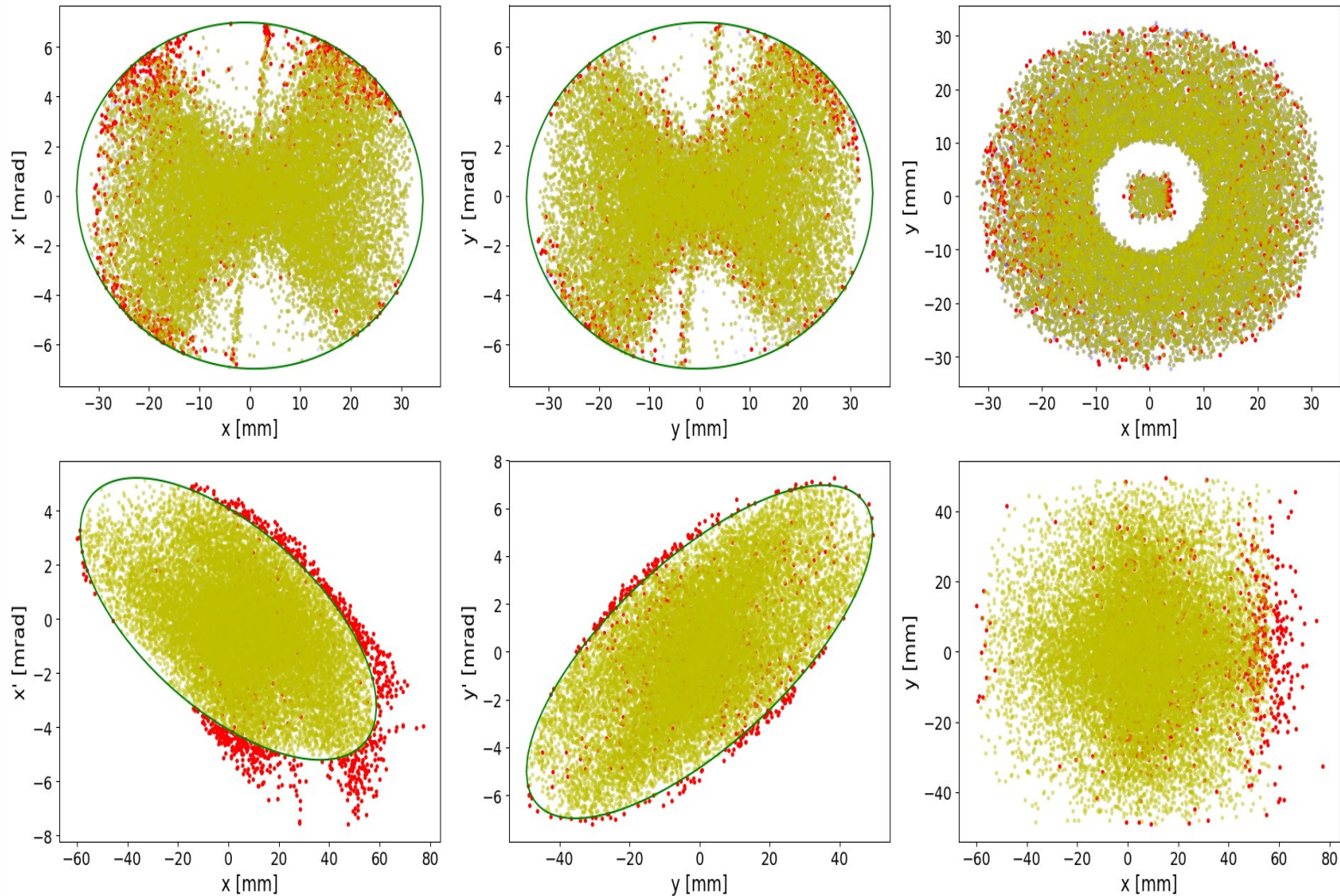


**Note:** Particle distributions at input (horn's exit plane) are shown in the upper graphs. Particles shown in red would get lost because they don't fit into the CR's acceptance!
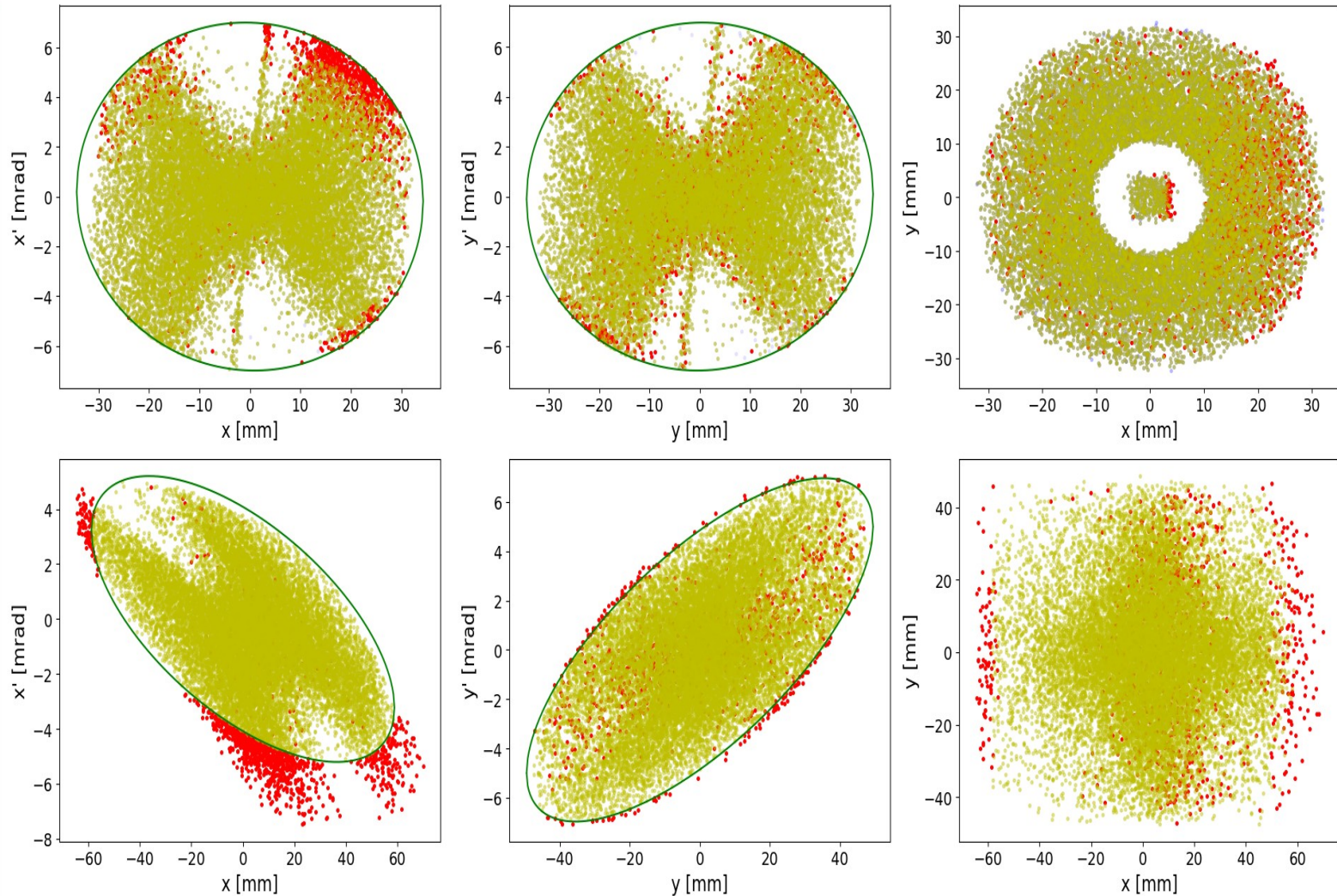
# Phase Space at Input and Output, 1 Sextupole



**Note:** Particle distributions at input (horn's exit plane) are shown in the upper graphs. Particles shown in red would get lost because they don't fit into the CR's acceptance!

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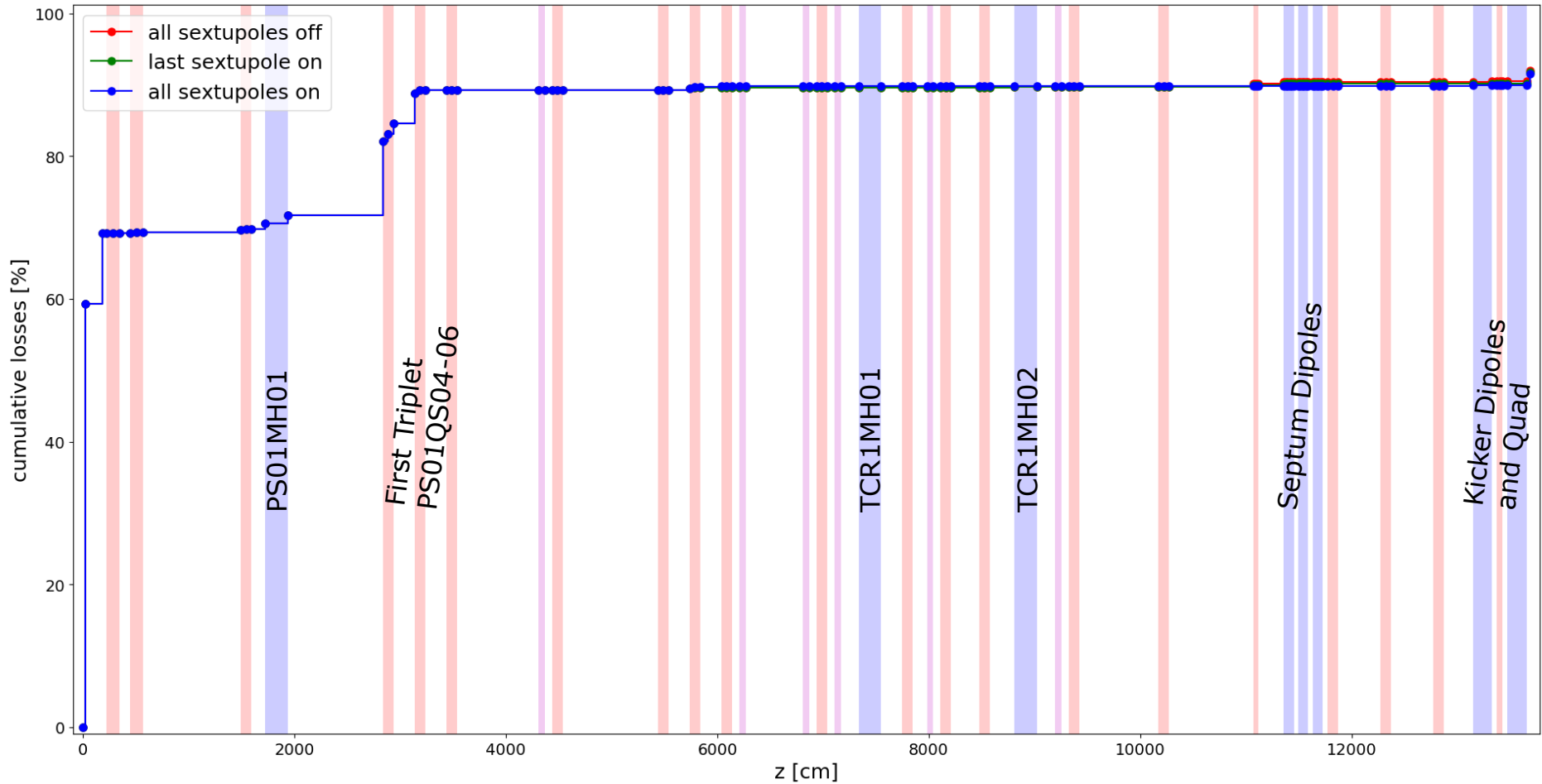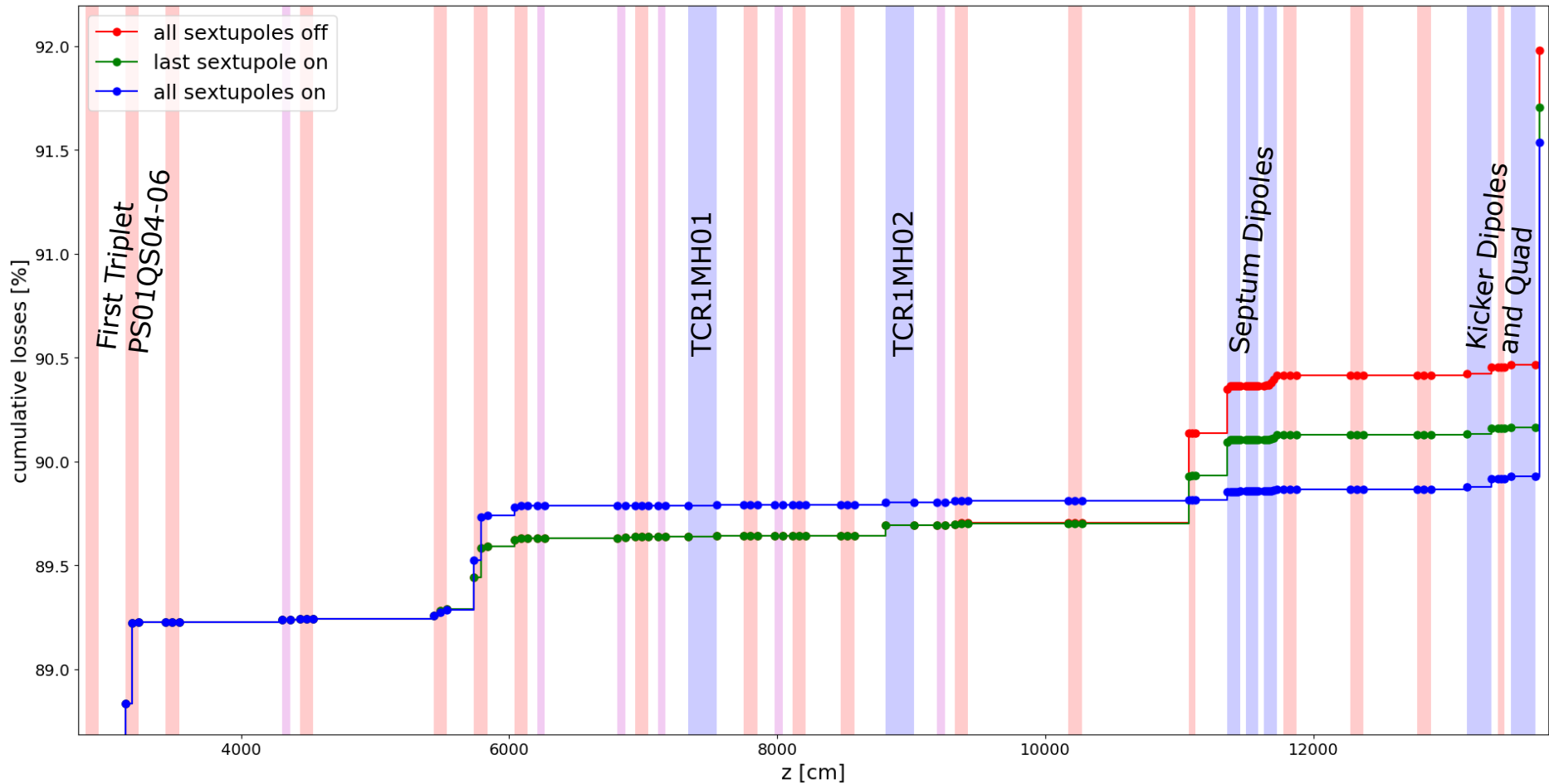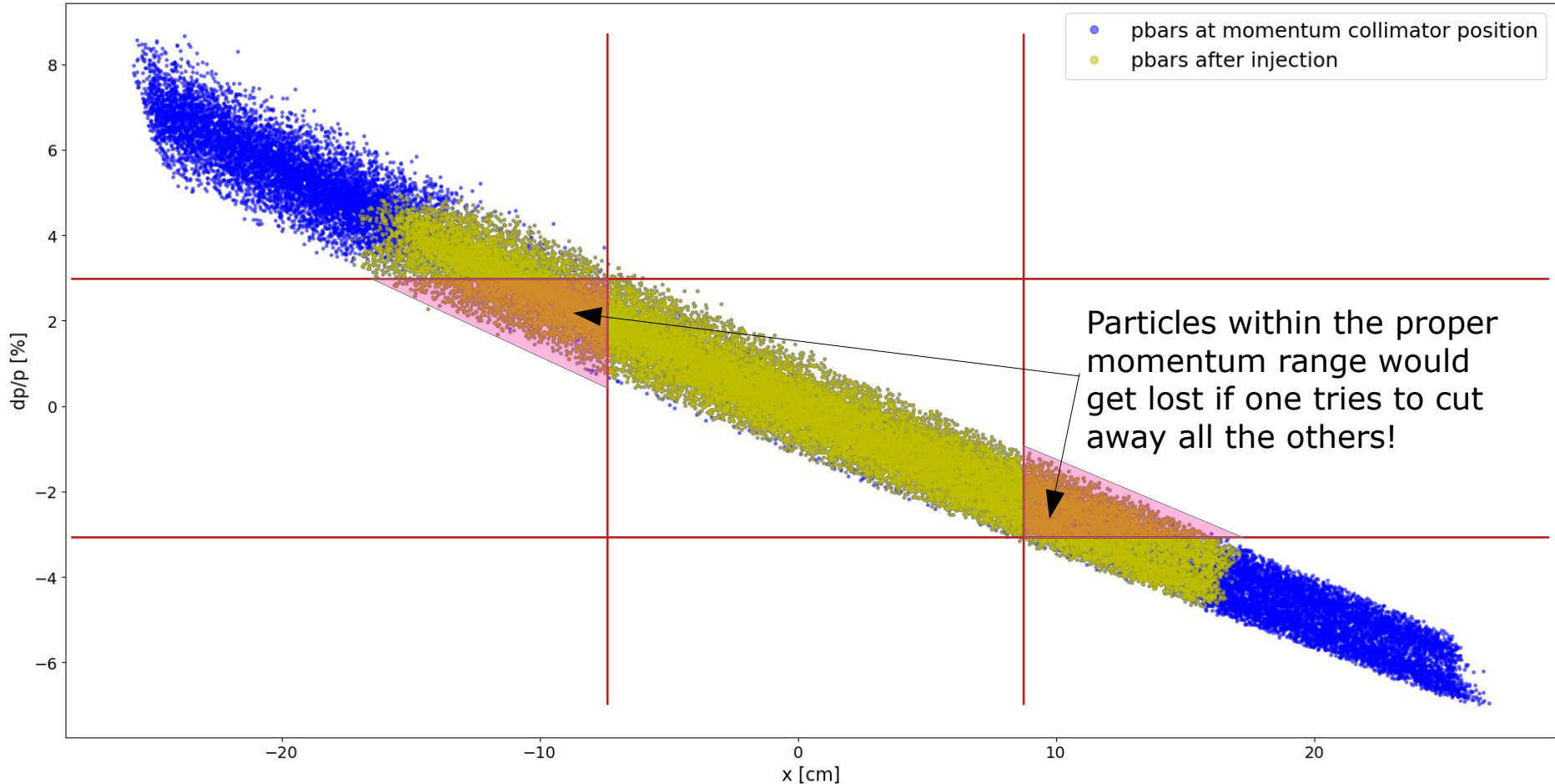
**Note:** When used alone, TCR1KS02 has the previously assessed strength of -1.5 T/m$^2$

**Note:** When used alone, TCR1KS02 has the previously assessed strength of -1.5 T/m²

# Momentum Collimation: Should It Be Permissive?



**Note:** Simulation performed with all sextupoles on and full beam (Δp/p = ±10%), momentum collimator assumed between PS01QS04 and PS01QS05. Within the simulation a dedicated momentum collimator doesn't appear to be needed.

# Final Remarks

- Relatively small changes applied to the reference ion optical set-up may sensibly improve the transmission to the ring.

- Adding sextupoles to the set-up appears to be useful, at least for reducing losses in the septum. The simulation using the full beam generated with MARS ($\Delta p/p = \pm 10\%$) shows also some advantage in terms of transmission. Apparently some particles initially out of the acceptance are driven into it.

- Next step: driving the beam through the CR.