Intensity-dependent effects at ATF2

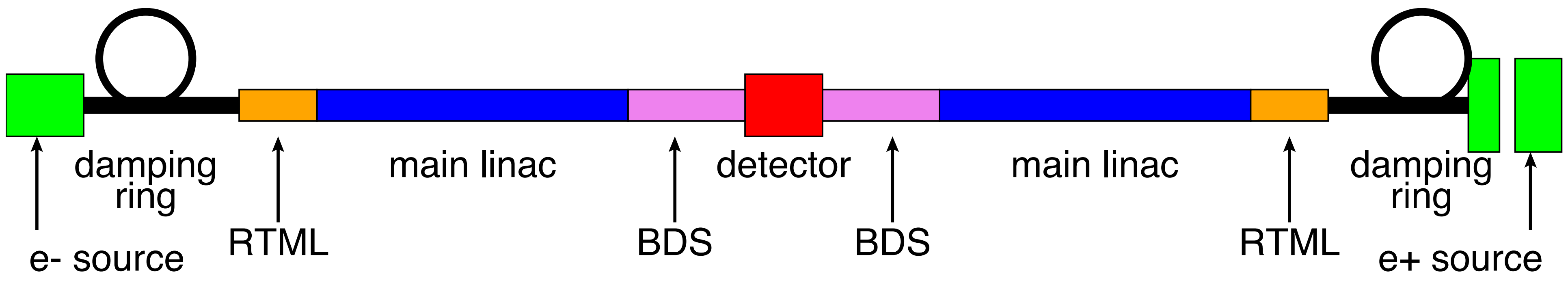
P. Korysko
CERN

Outline

- **Context.**
- **ATF2.**
- **PLACET simulations.**
- **Measurements at ATF2.**
- **Analysis: first results.**

Context

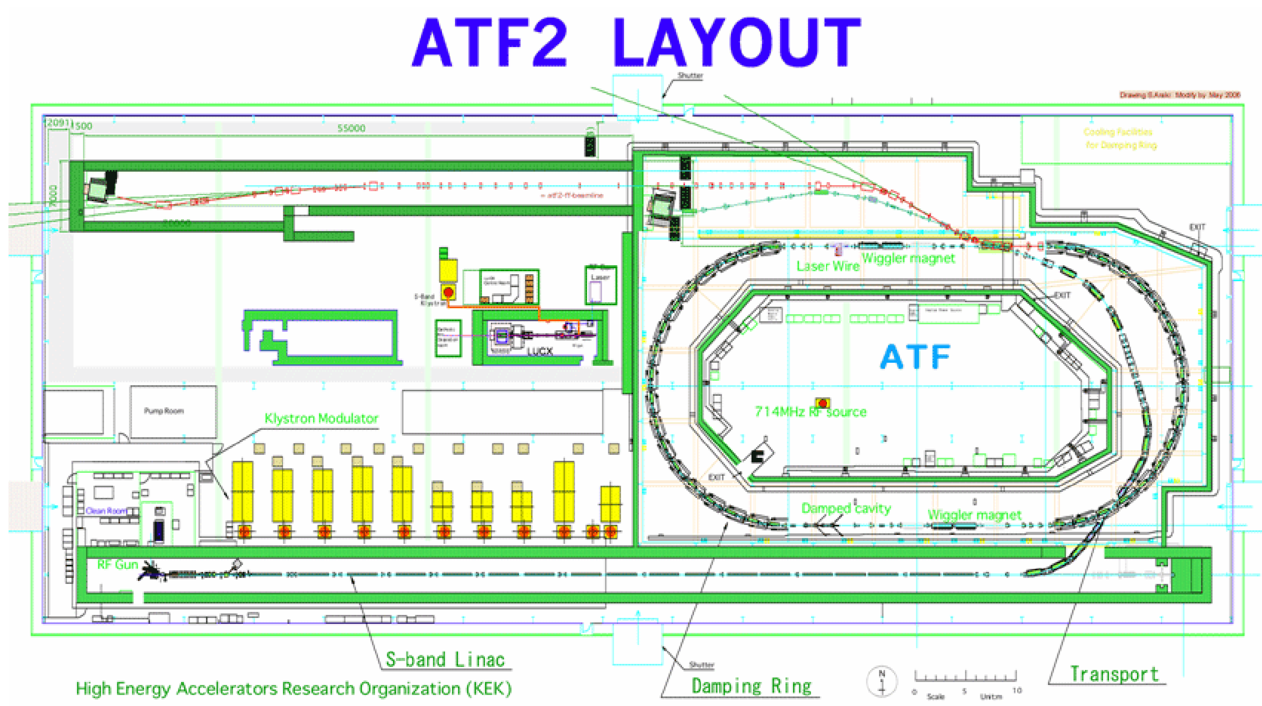
CLIC (Compact Linear Collider)



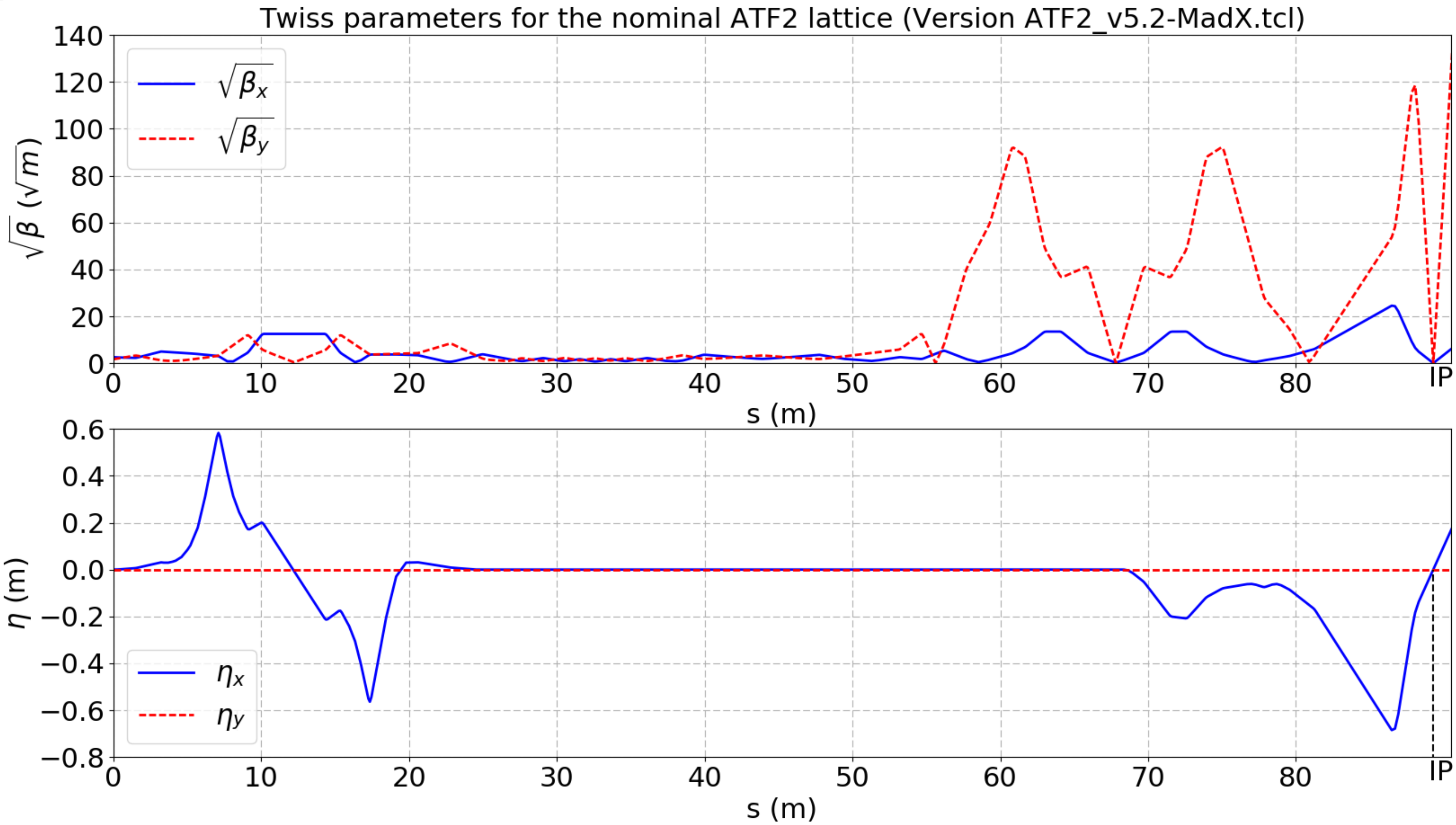
- e+/e- collision (up to 3 TeV).
- Acceleration using a drive beam.
- CLIC Final Focus System based on a local chromaticity correction scheme created by A. Seryi and P. Raimondi.

ATF2

E	1.3 GeV
Energy spread	0.08 %
Charge	1e10
εx	5200 nm.rad
εy	30 nm.rad
Bunch length	7 mm



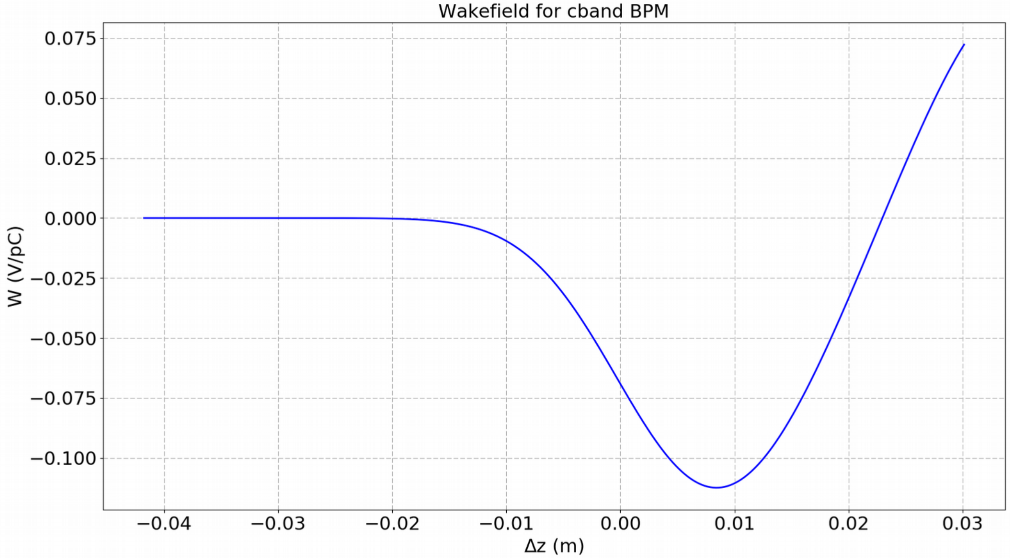
ATF2 twiss parameters with Placet

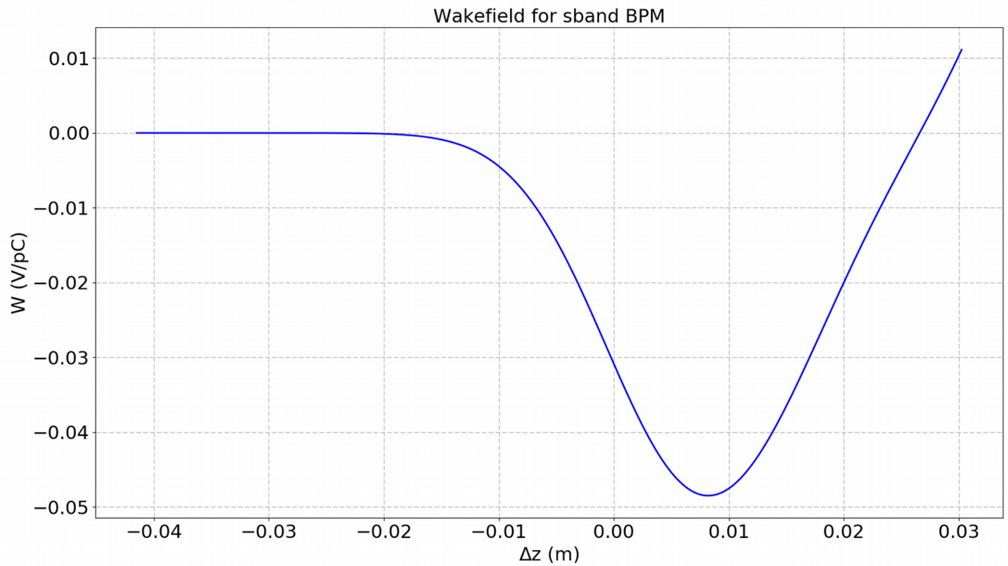


Nominal case

At IP σ_y = 37.19 nm **β_y^* = 0.10 mm**

Wakepotentials for C-band and S-band BPMs





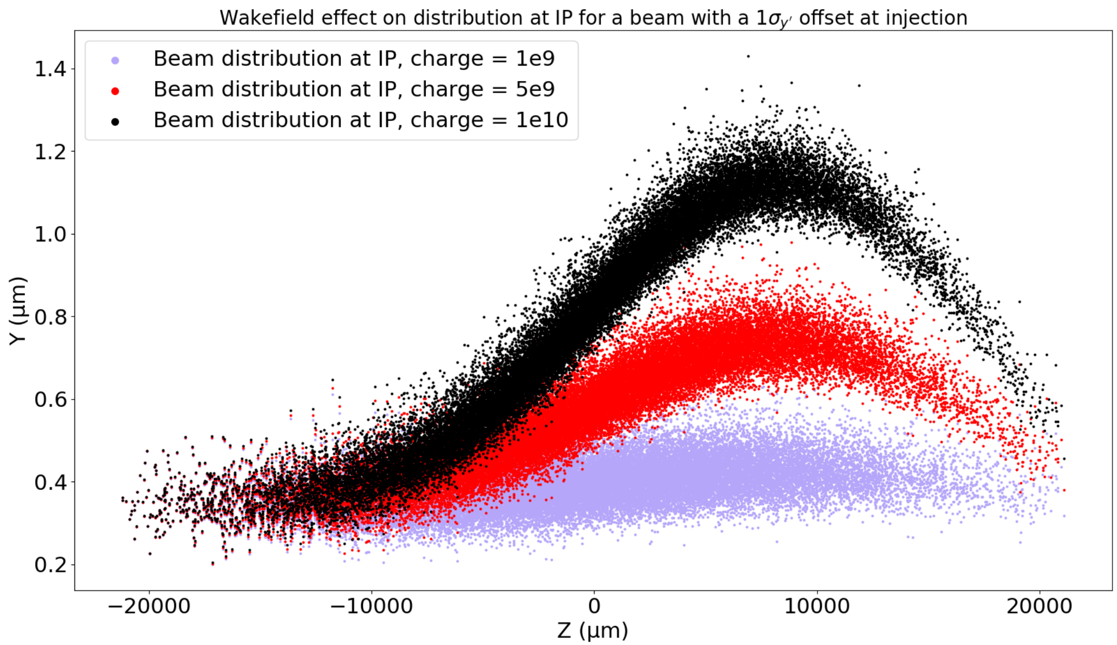
Wakepotentials used for simulations created with GdfidL by A. Lyapin.

In simulations:

- **15 stripline BPMs (not wakefield sources)**
- **26 C-bend BPMs**
- **1 S-bend BPM**

Source: A. Lyapin, J. Snuverink and al., *Measurements and simulations of wakefields at the Accelerator Test Facility 2*, Phys. Rev. Accel. Beams 19, 091002
https://journals.aps.org/prab/pdf/10.1103/PhysRevAccelBeams.19.091002

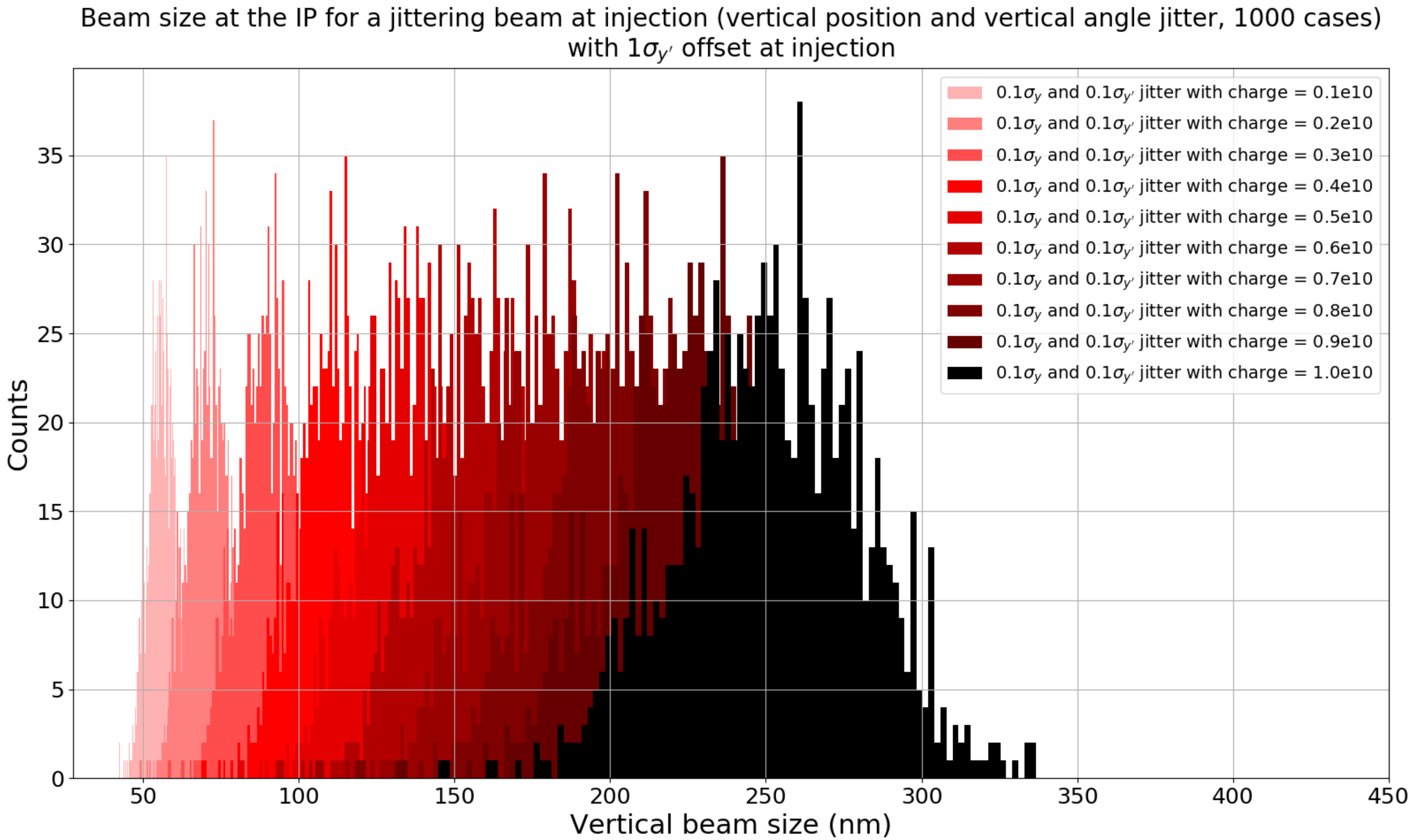
Intensity-dependent effects on bunch distribution at IP



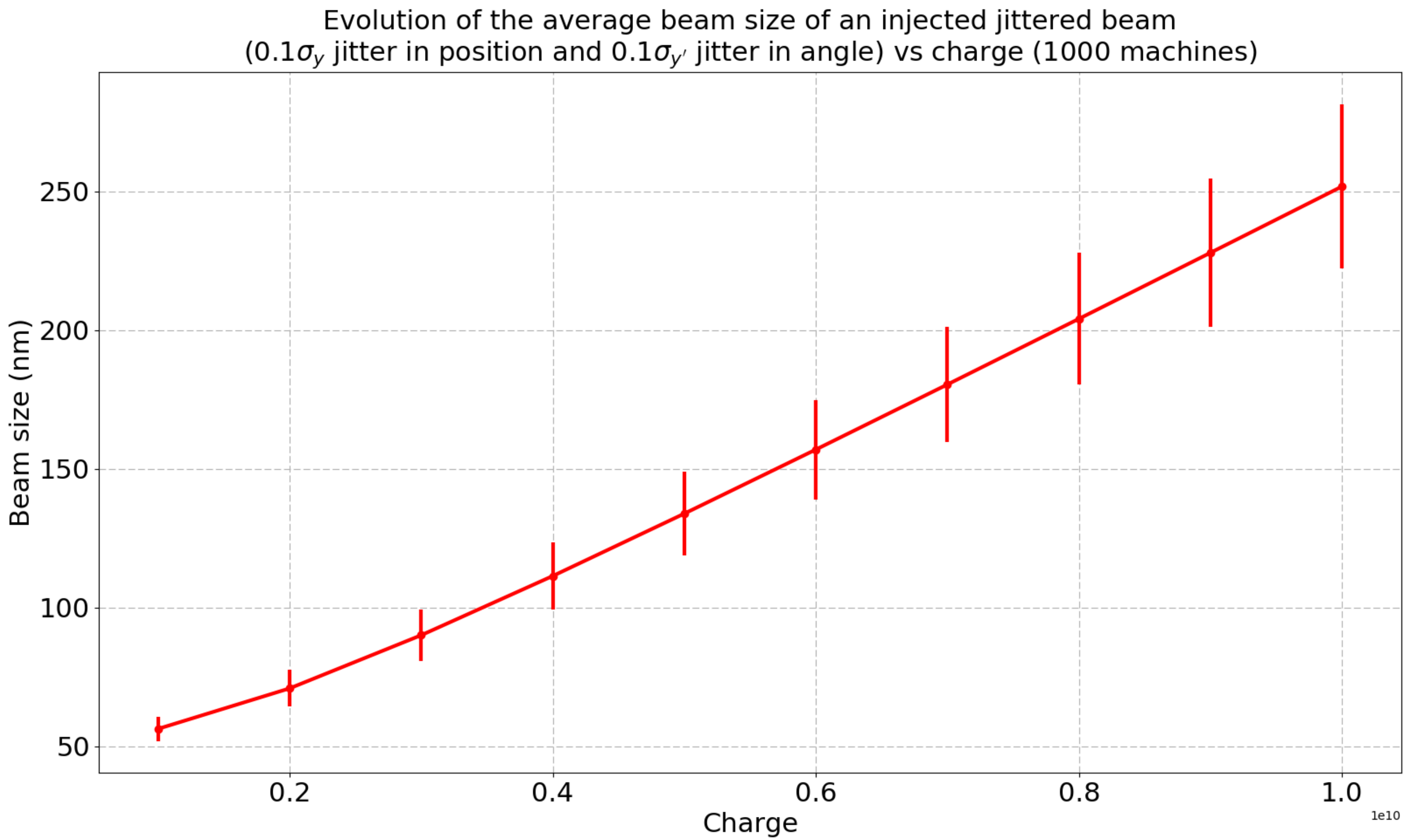
	Charge 1e9	Charge 5e9	Charge 1e10
Case	**σy (nm)**	**σy (nm)**	**σy (nm)**
No offset	37.59	37.59	37.59
1σy offset	53.95	70.00	149.90
1σy' offset	56.15	133.80	251.79

Banana effect.

Beam jitter with charge

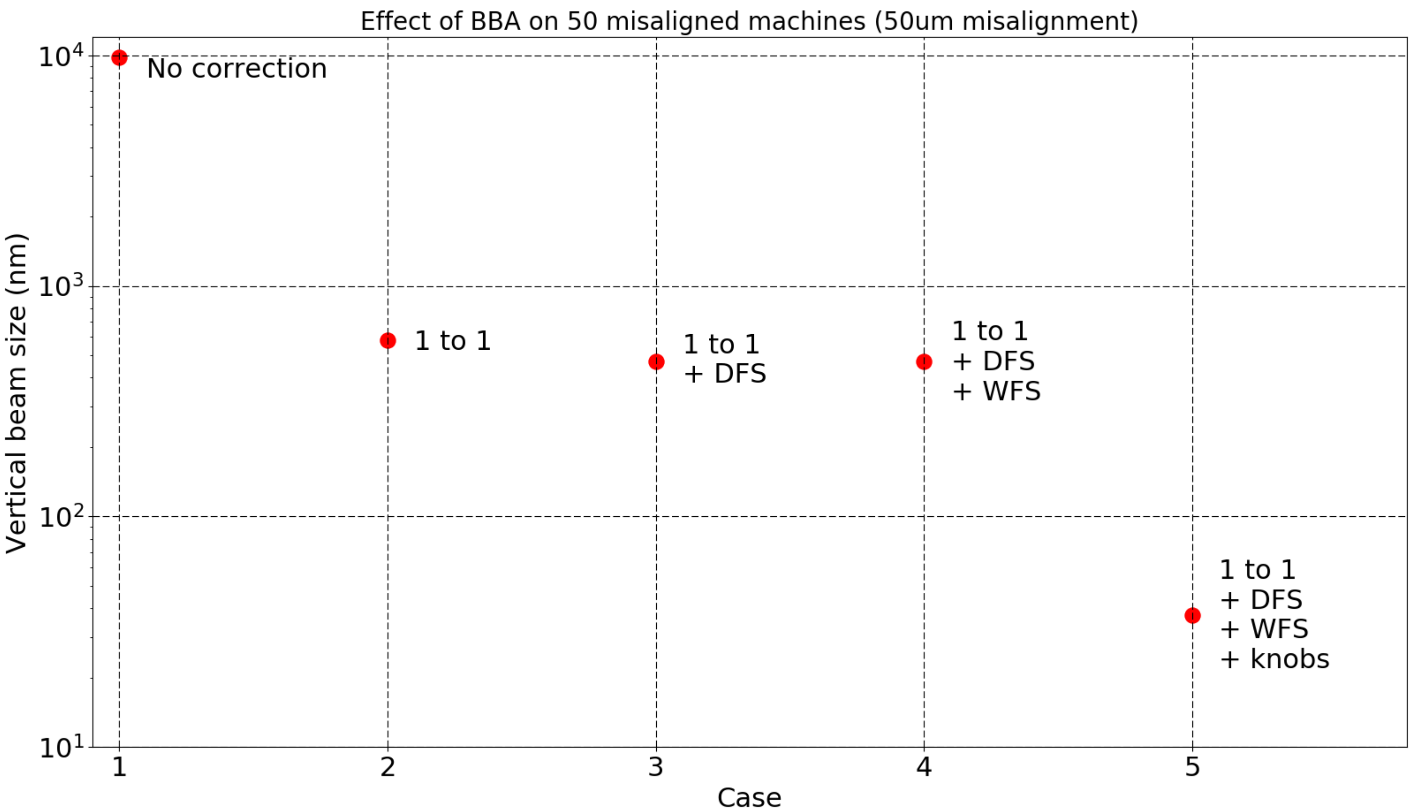


Beam jitter with charge



Intensity dependence parameter = 22.6123 nm/e9 (slope)

Beam Based Alignment studies



Case	Vertical beam size (nm)
No correction	9796.23
1to1	581.93
1to1 + DFS	469.46
1to1 + DFS + WFS	469.45
1to1 + DFS + WFS + knobs	37.41

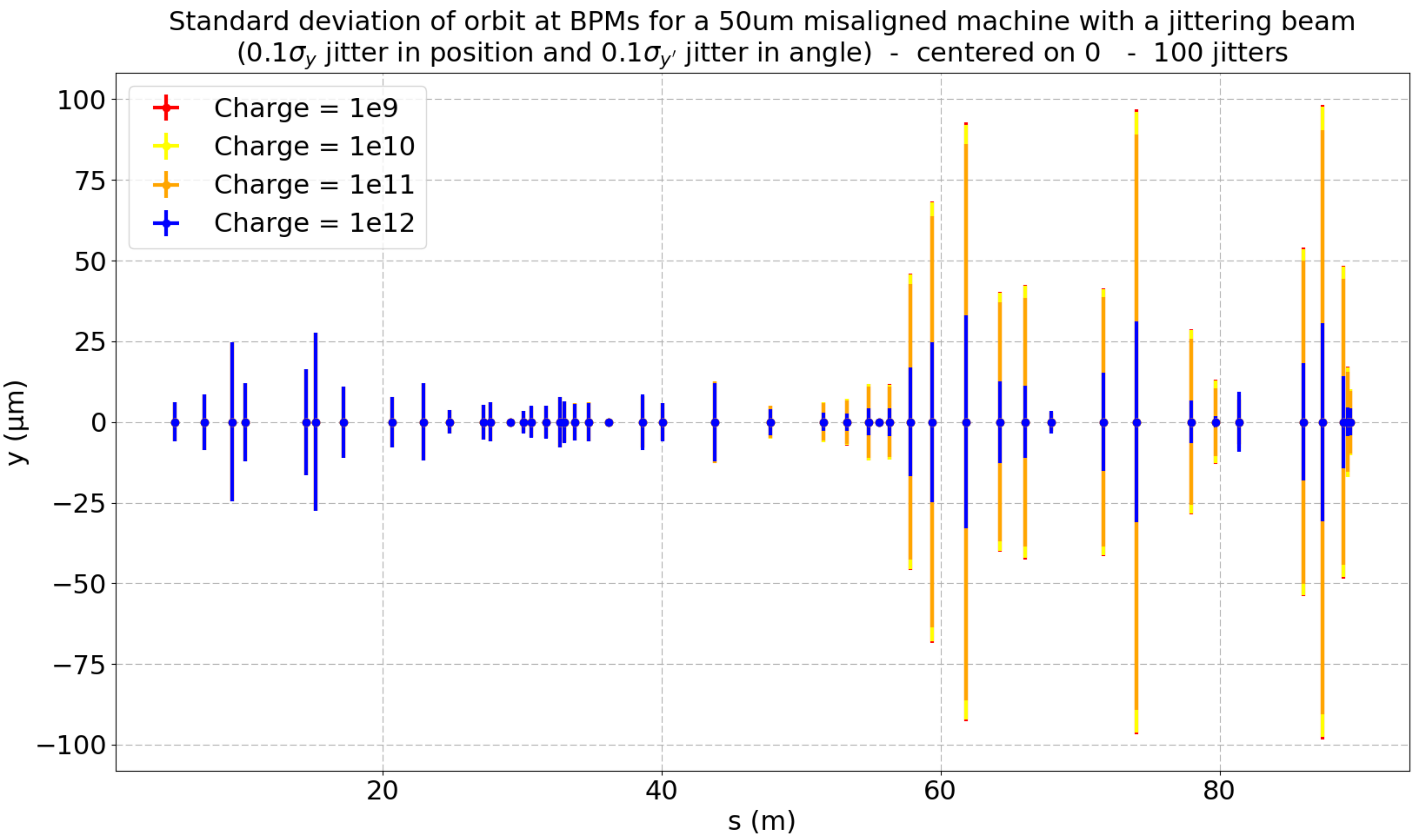
Correction schemes:
1to1, DFS, WFS and fast knobs

Fast knobs used:

1st order <y,y'> <y,E> <y,x'>

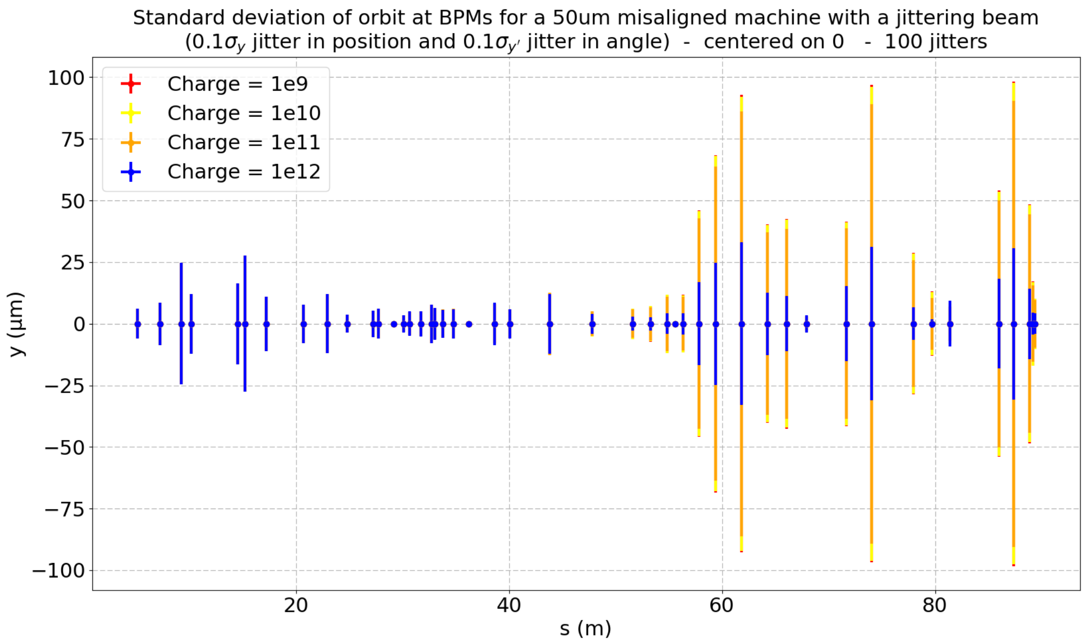
2nd order <y,x'²> <y,x'*y'> <y,x'*E>

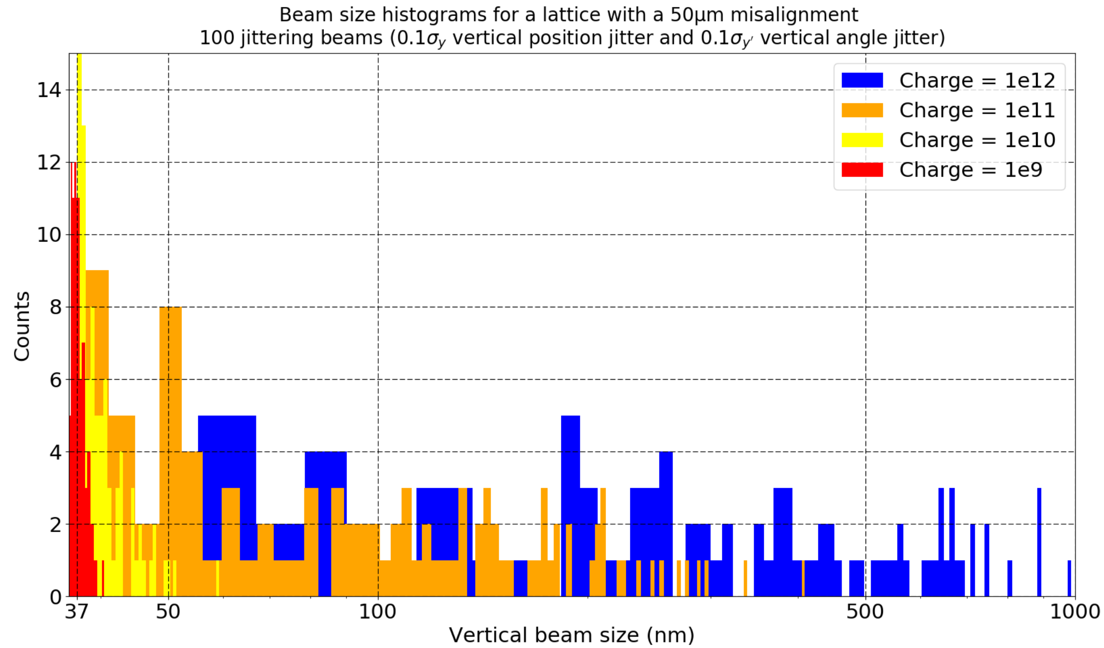
BPMs simulations



Higher charge → smaller orbit?

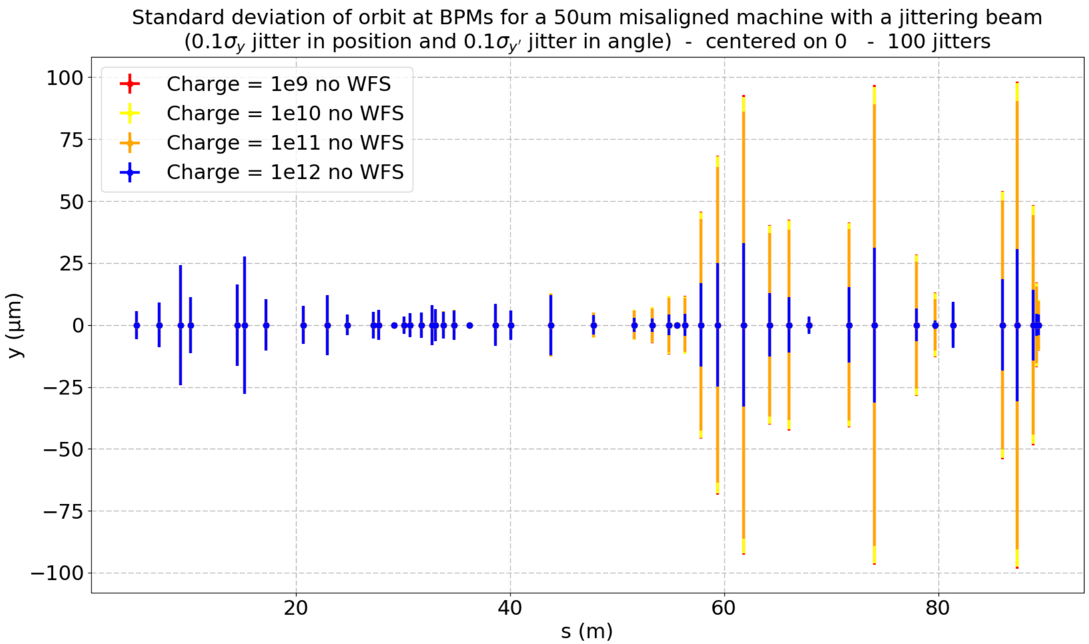
BPMs simulations

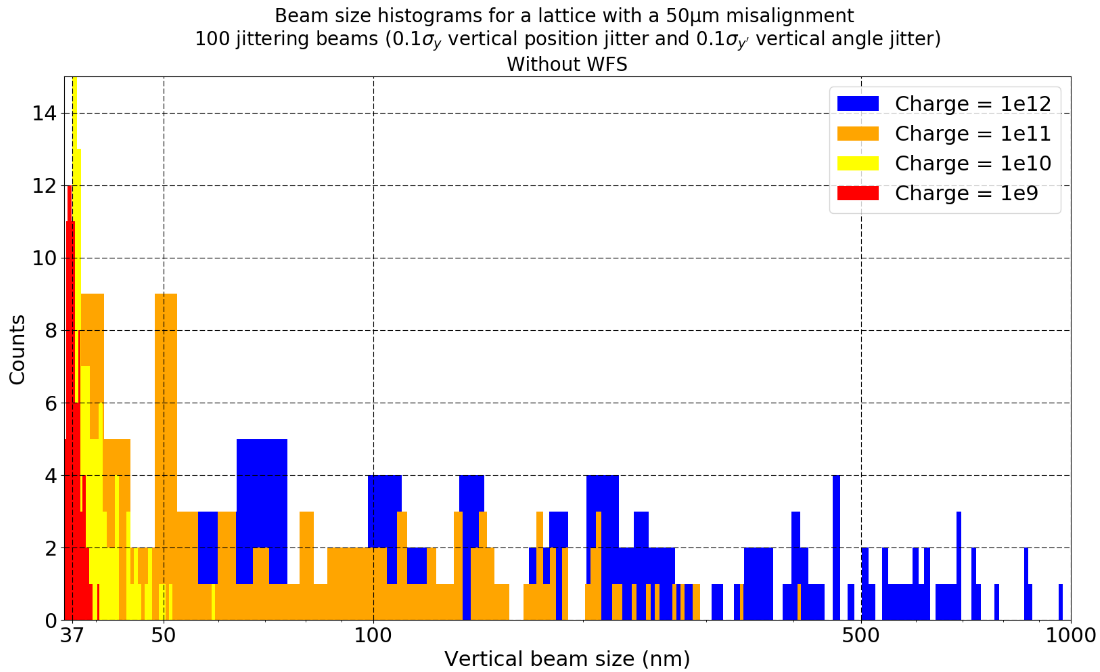




At IP, higher charge → bigger beam

BPMs simulations without WFS

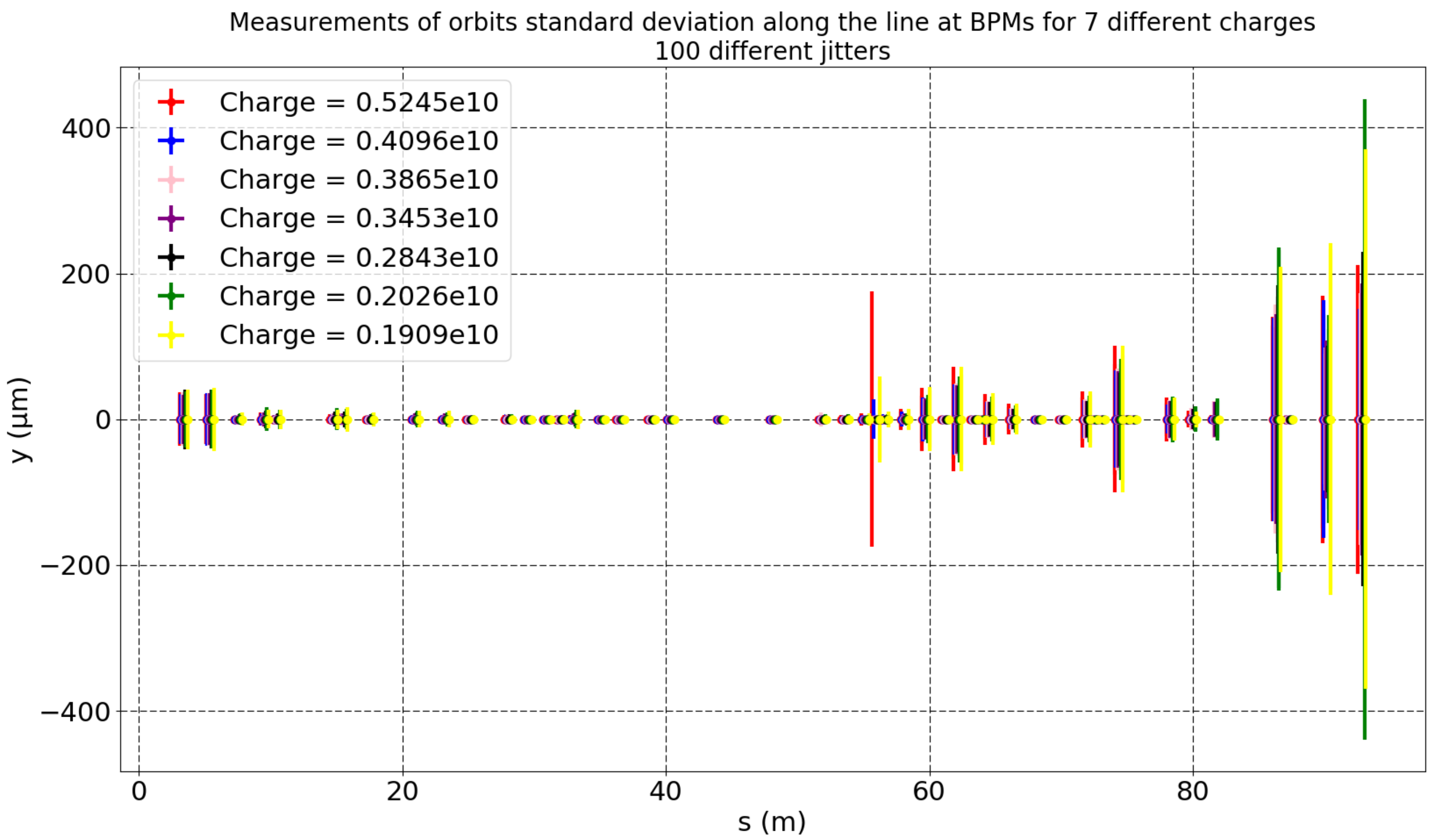




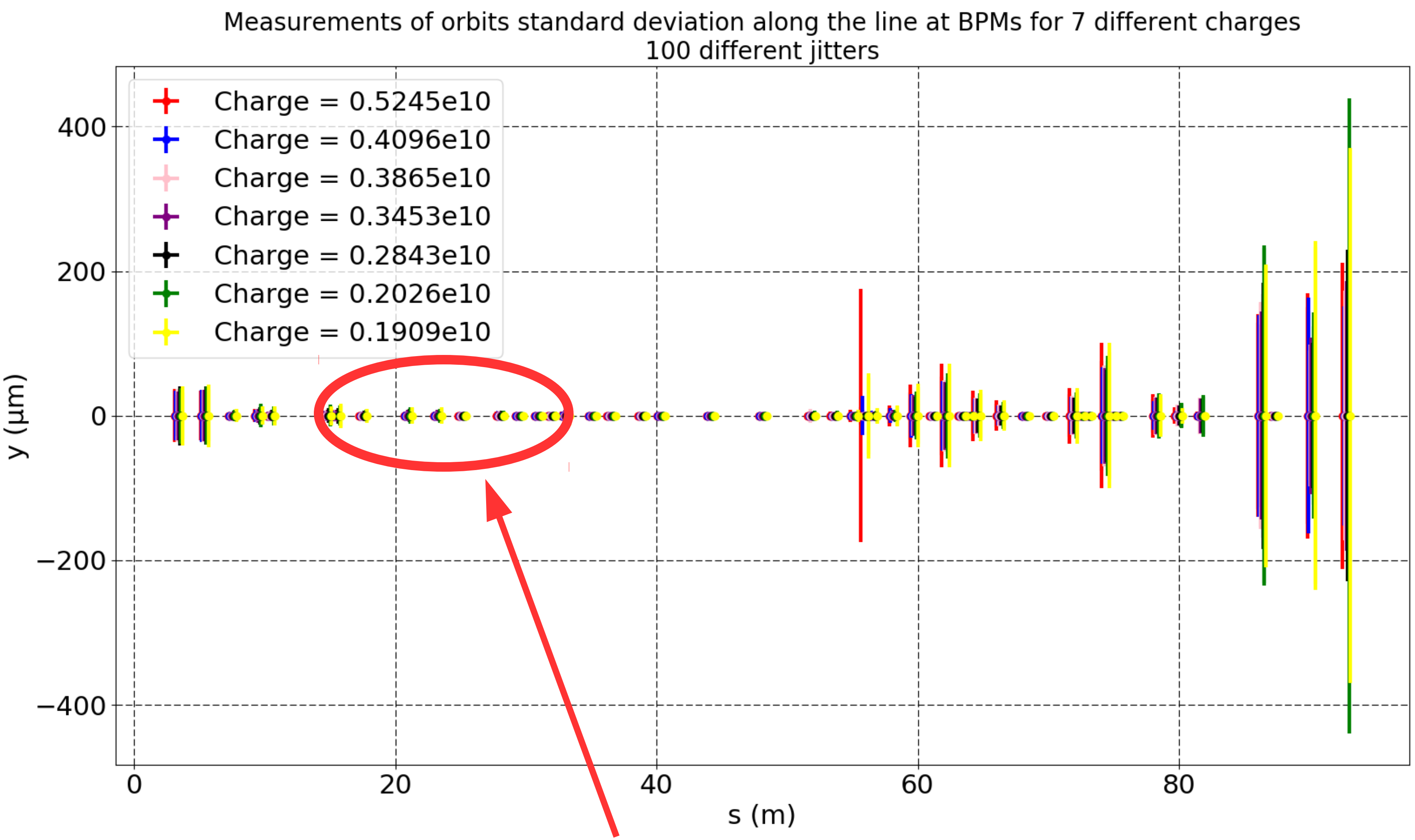
Wakefield Free Steering is not the problem

Conclusion:
We actually observe that: higher charge → smaller orbit

BPMs measurements

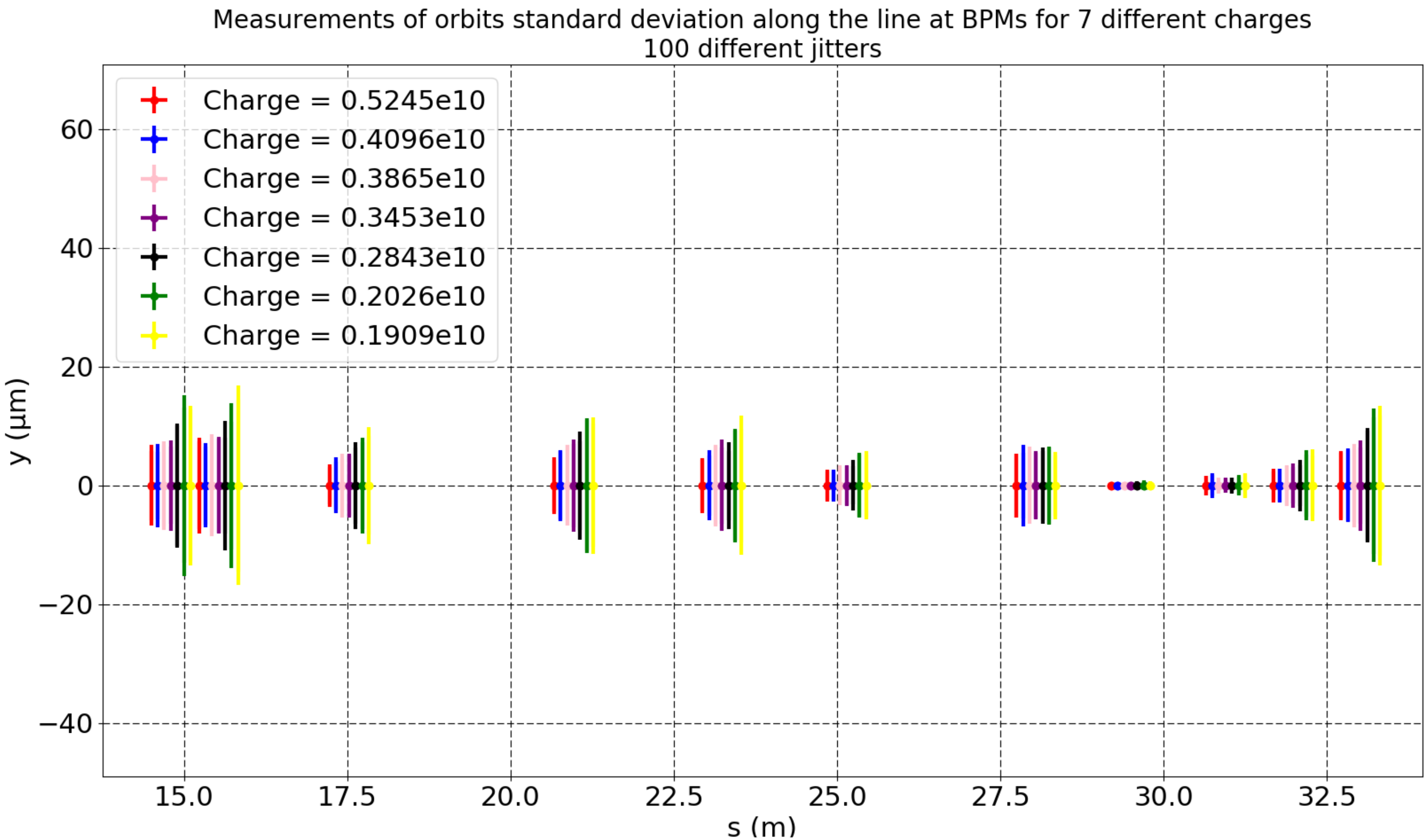


BPMs measurements



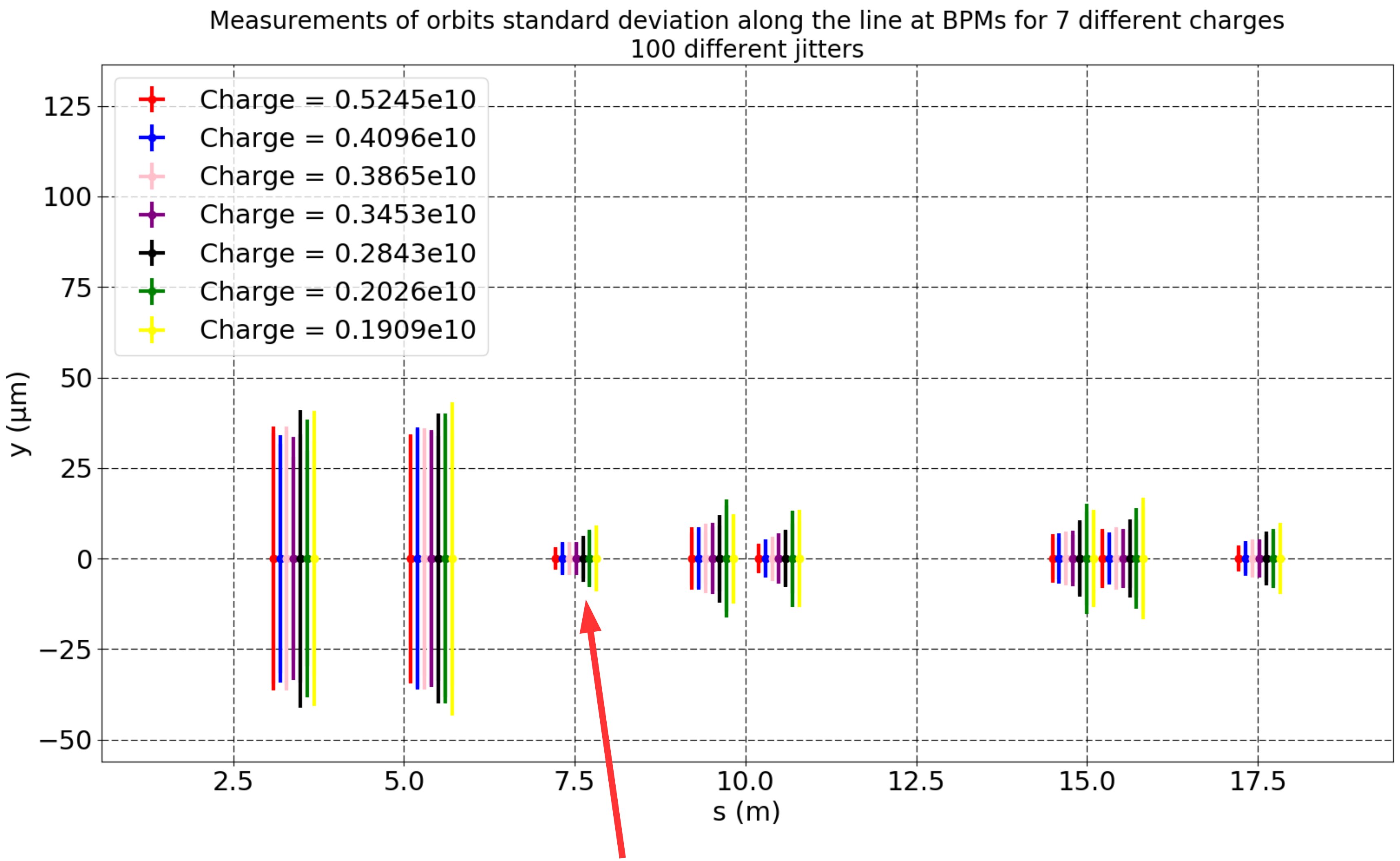
Zoom in.

BPMs measurements



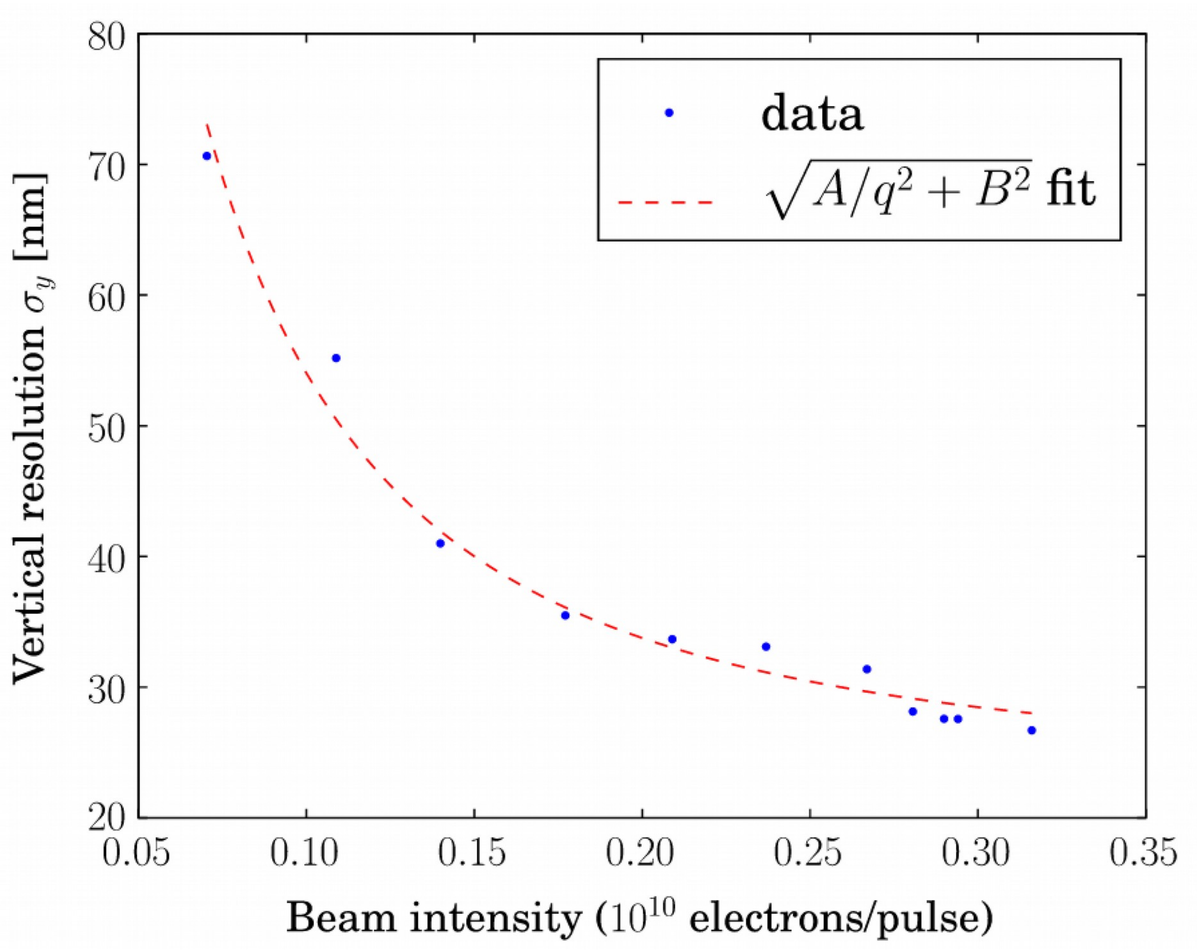
Same behavior as in simulations:
Higher charge → smaller orbit

BPMs measurements (remark)



Intensity dependent effects start from here?

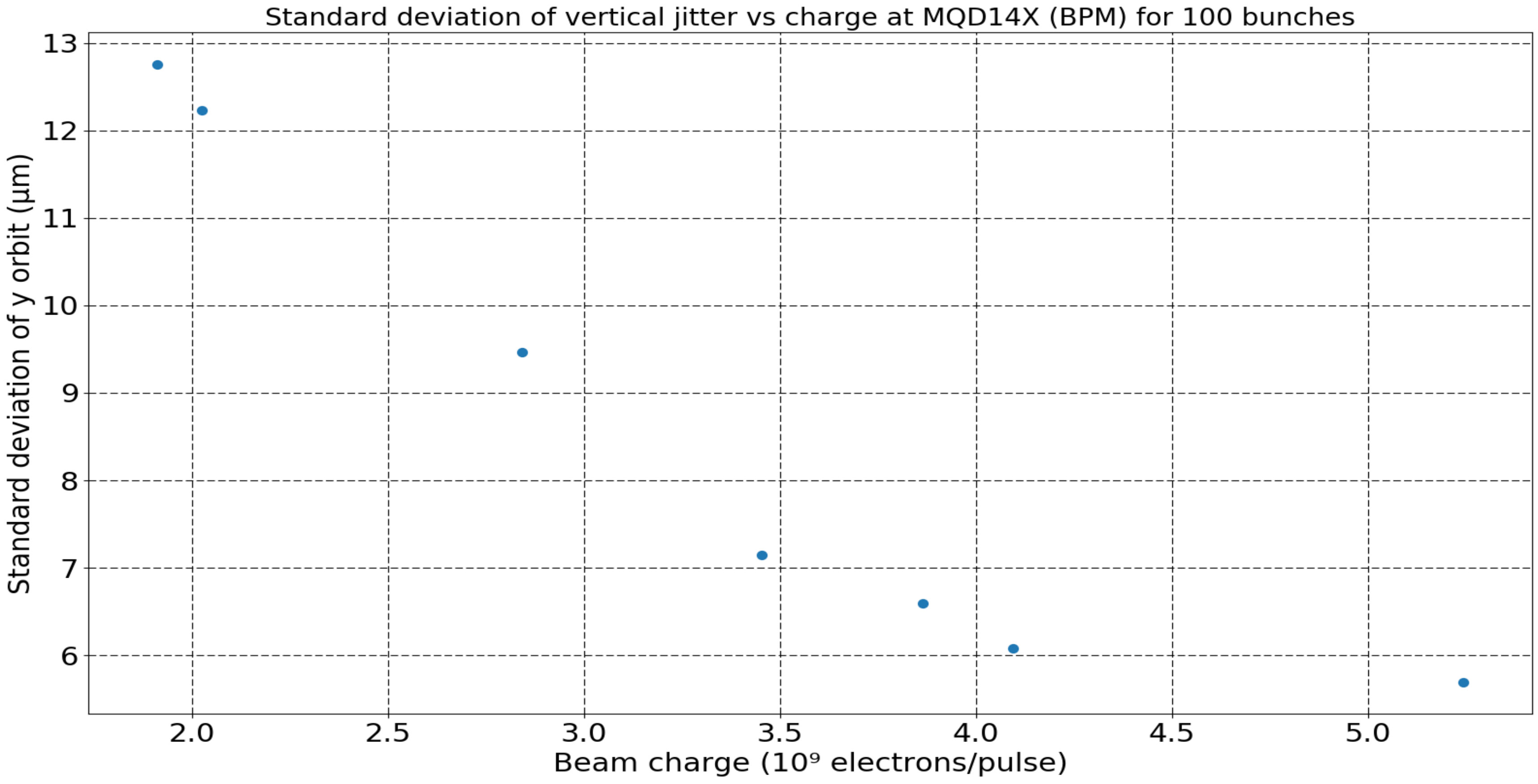
BPMs resolution



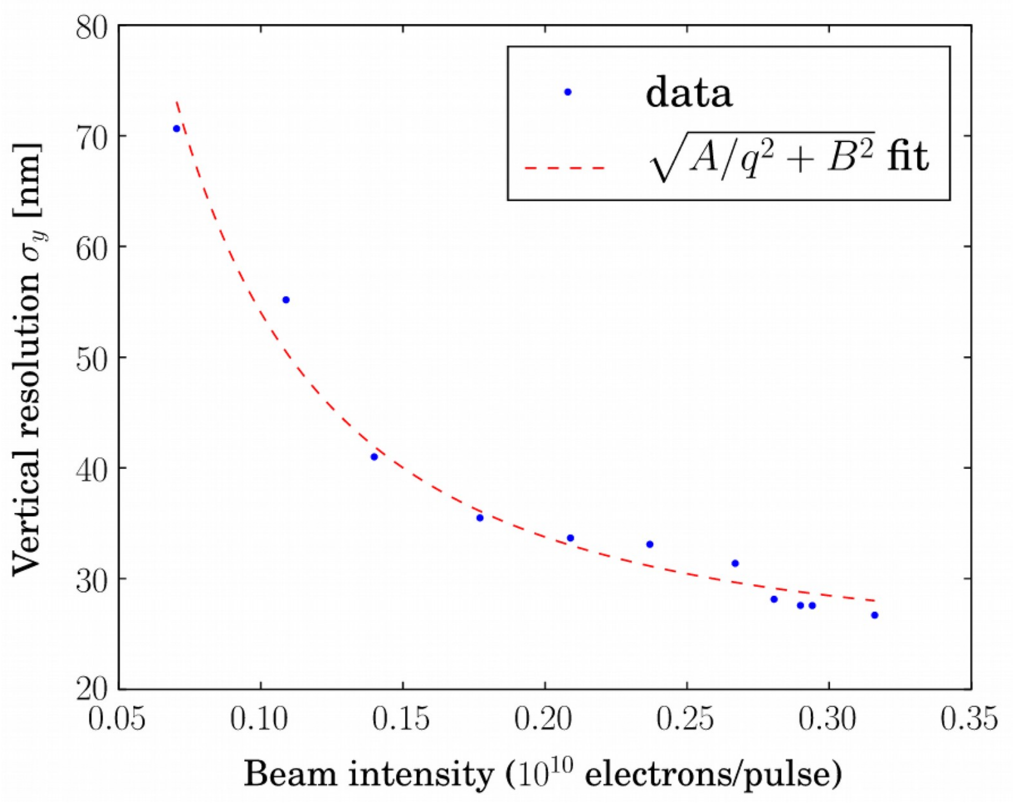
BPMs resolution depends on the charge

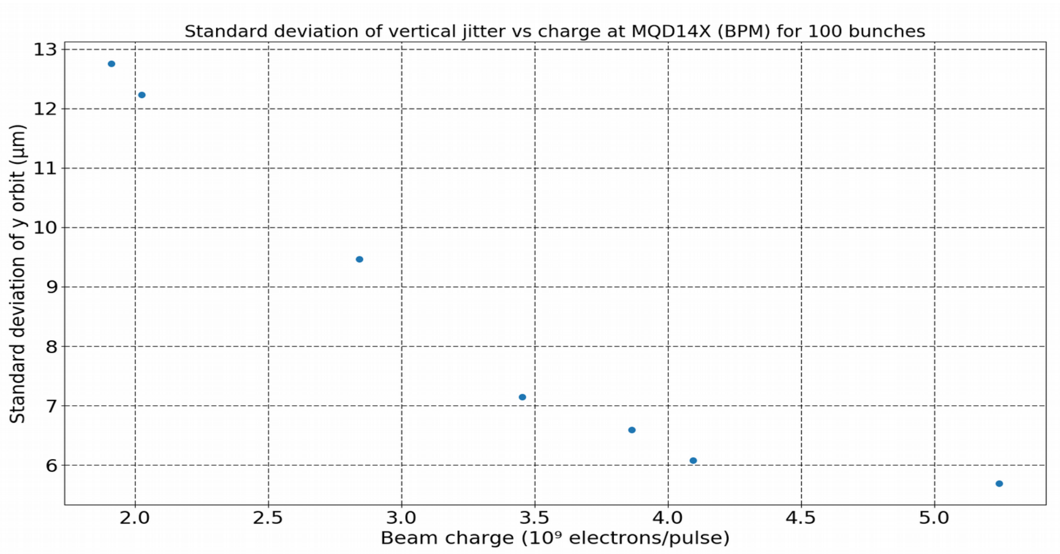
Source: Y. I. Kim et al., Cavity beam position monitor system for the Accelerator Test Facility 2. Phys. Rev. ST Accel. Beams 15, Apr 2012.
https://journals.aps.org/prab/pdf/10.1103/PhysRevSTAB.15.042801

BPMs resolution

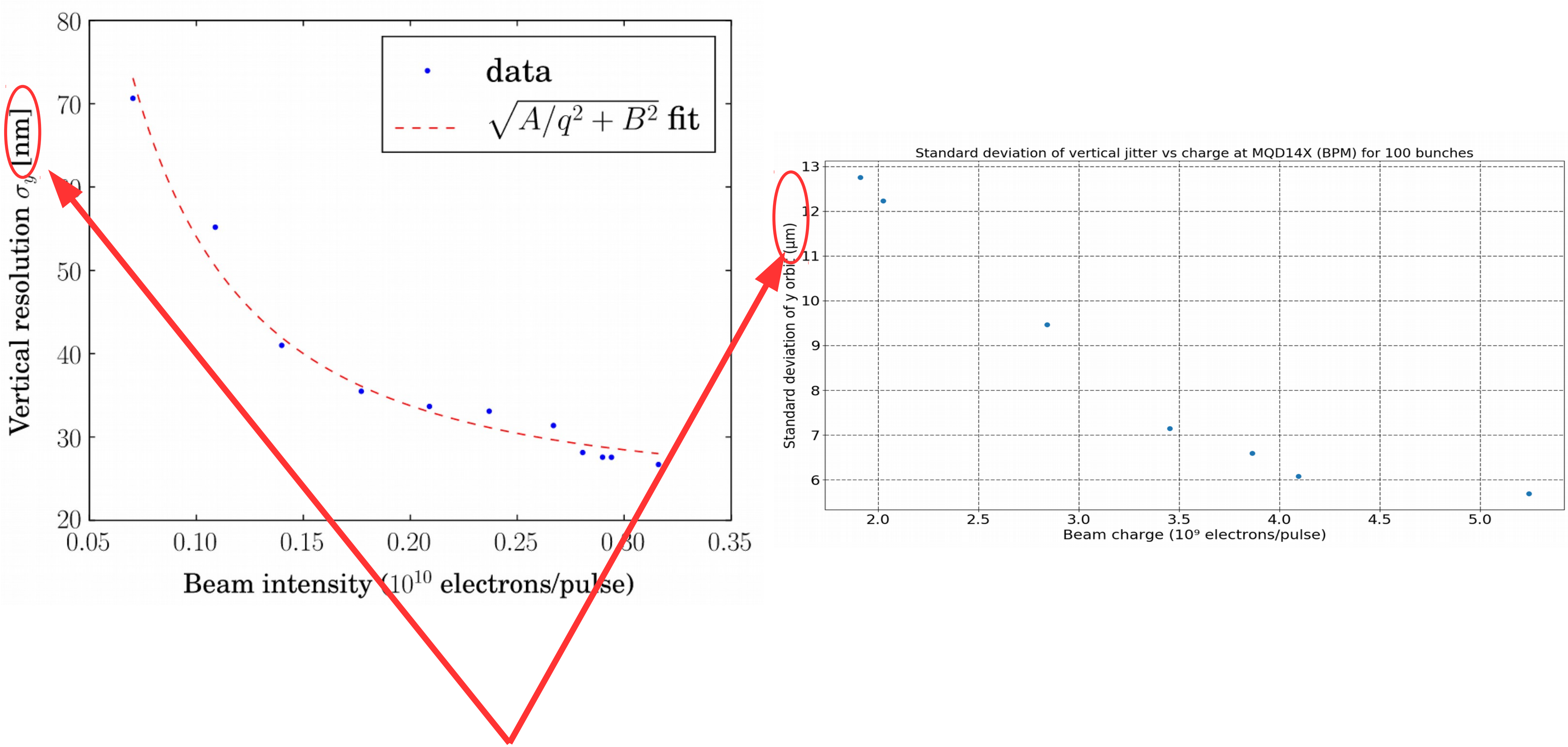


BPMs measurements



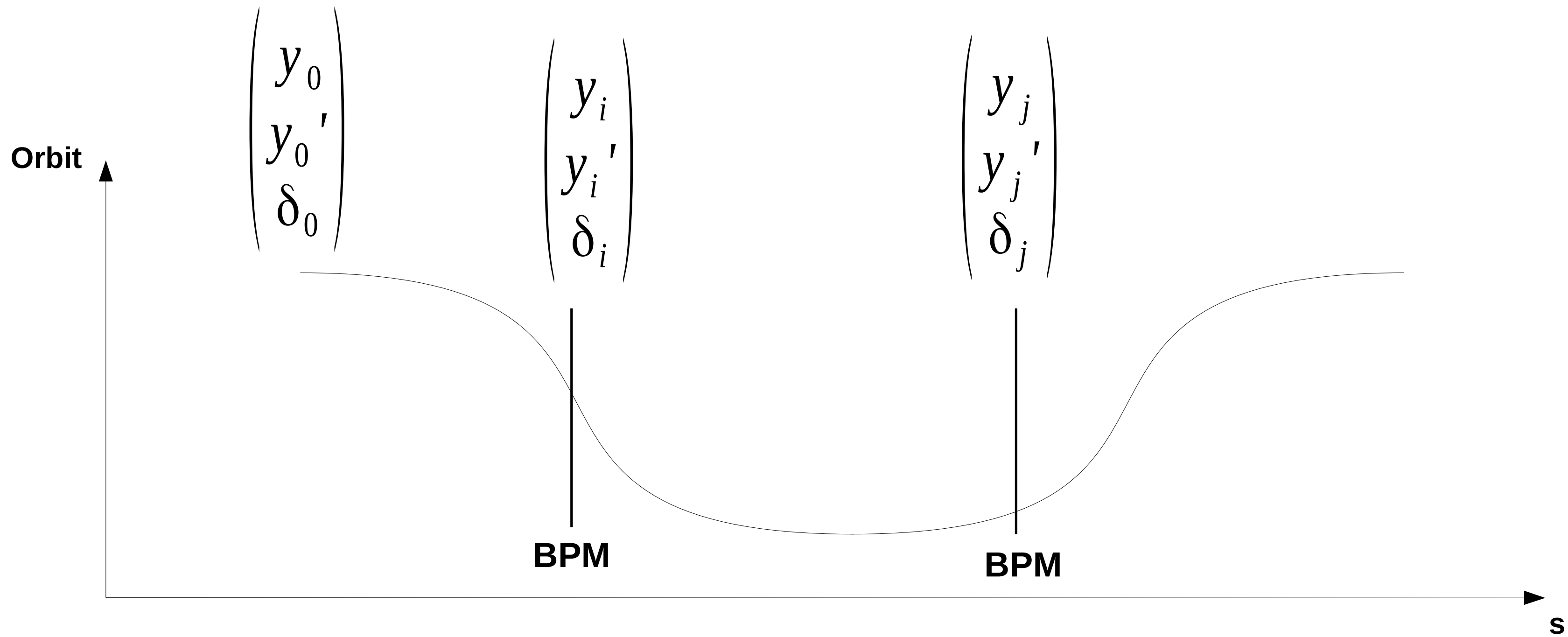


BPMs measurements



The BPMs "charge-dependence-resolution" doesn't seem to be the source of the problem.

Calculating the initial jitter



$$\begin{pmatrix} y_i \\ y_i' \\ \delta_i \end{pmatrix} = R_{0\rightarrow i} \begin{pmatrix} y_0 \\ y_0' \\ \delta_0 \end{pmatrix} \qquad \begin{pmatrix} y_j \\ y_j' \\ \delta_j \end{pmatrix} = R_{0\rightarrow j} \begin{pmatrix} y_0 \\ y_0' \\ \delta_0 \end{pmatrix}$$

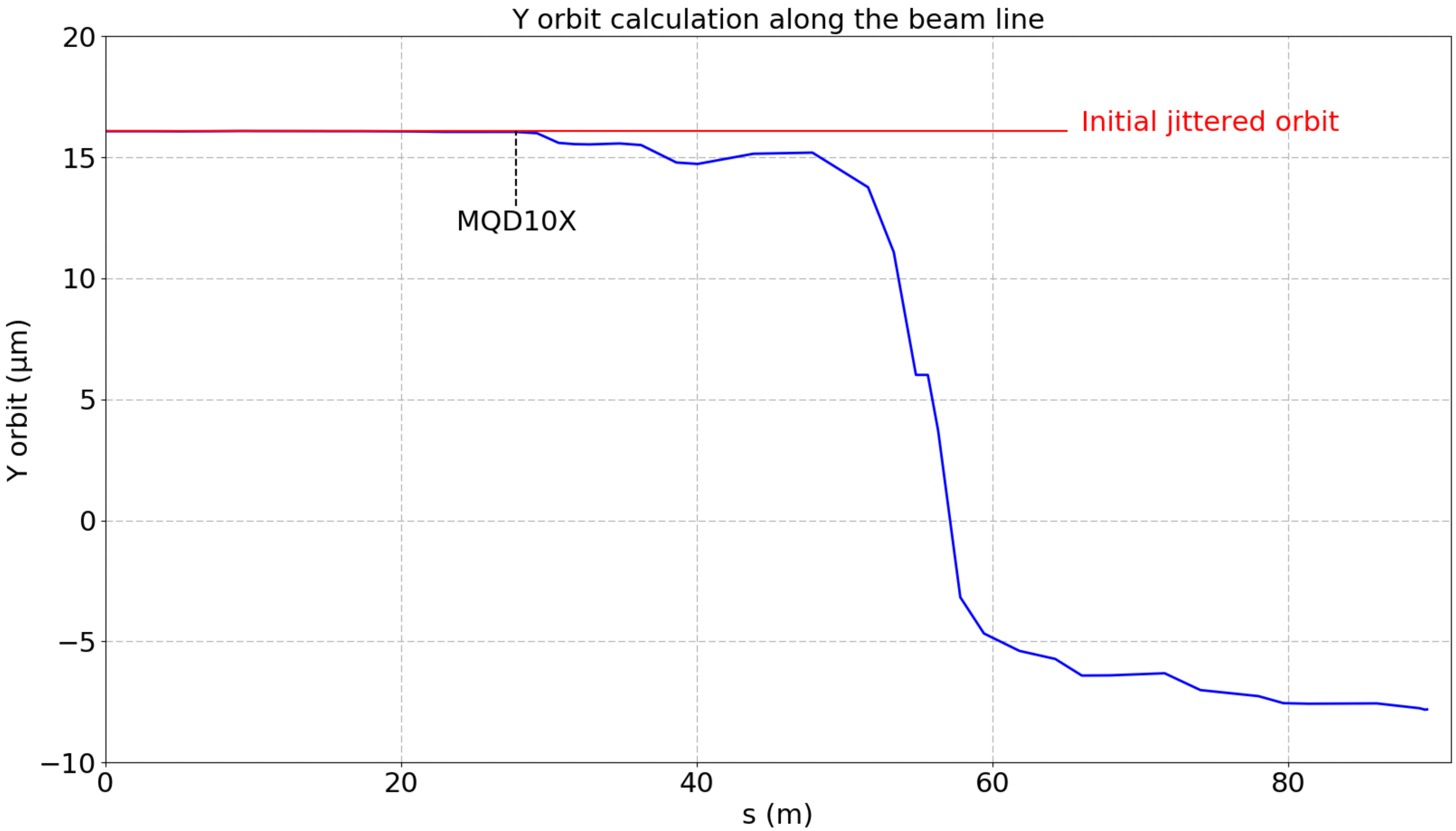
Calculating the initial jitter

$$\begin{pmatrix} y_1 \\ y_2 \\ \cdot \\ \cdot \\ \cdot \\ y_n \end{pmatrix} = \begin{pmatrix} R_{0\to 1,33} & R_{0\to 1,34} & R_{0\to 1,36} \\ R_{0\to 2,33} & R_{0\to 2,34} & R_{0\to 2,36} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ R_{0\to n,33} & R_{0\to n,34} & R_{0\to n,36} \end{pmatrix} \begin{pmatrix} y_0 \\ y_0' \\ \delta_0 \end{pmatrix}$$

$\vec{Y}$ $\qquad R \qquad$ $\vec{Y_0}$

$$\vec{Y_0} = \left(R^T R\right)^{-1} R^T \vec{Y}$$

Calculating the initial jitter
Wakefield map using BPMs orbit calculation (Simulation)



Remarks and conclusions

- **2 wakefield effects :**

  - Banana effect (transverse: z-(x,y) correlation).

  - Energy loss (longitudinal: z-E correlation).

- **Simulations and measurements seem to go in the same direction.**

Outlook

● **Short term studies:**

- Pursue the studies on the intensity dependent effect observed at BPMs.
- Analyse experimental data using SVD to extract jitter, correlations, effective BPMs resolution, etc.
- Include more wakefield sources in the simulations.
- Try to reproduce in simulation the measured intensity dependence plot.
- Assess incoming beam jitter from experimental data.

● **Long term studies:**

- Find mitigation technics to achieve nominal IP beam size at 100% of nominal charge.
- Extrapolate these results to CLIC and ILC.

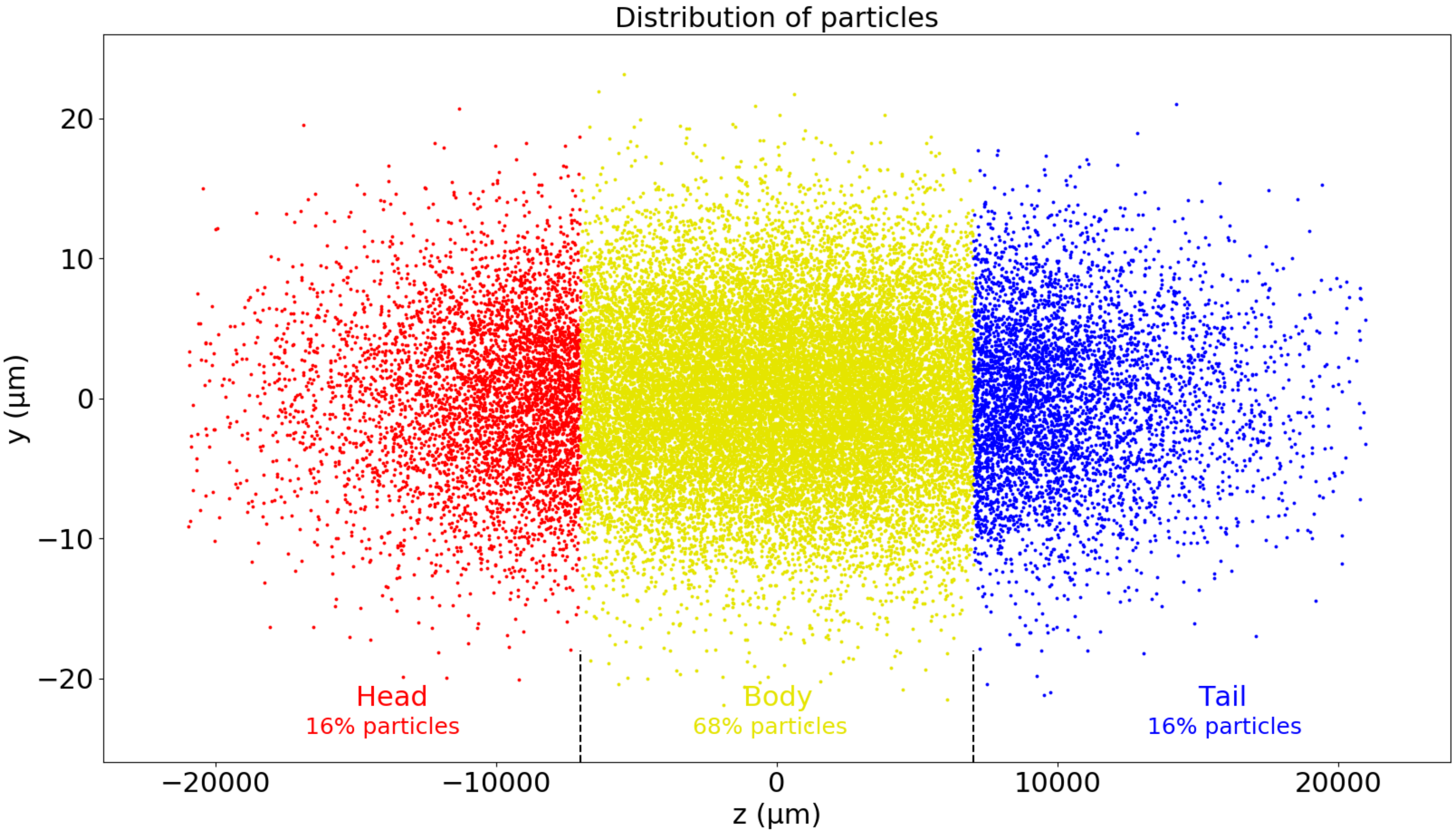
Reserve

Further investigations

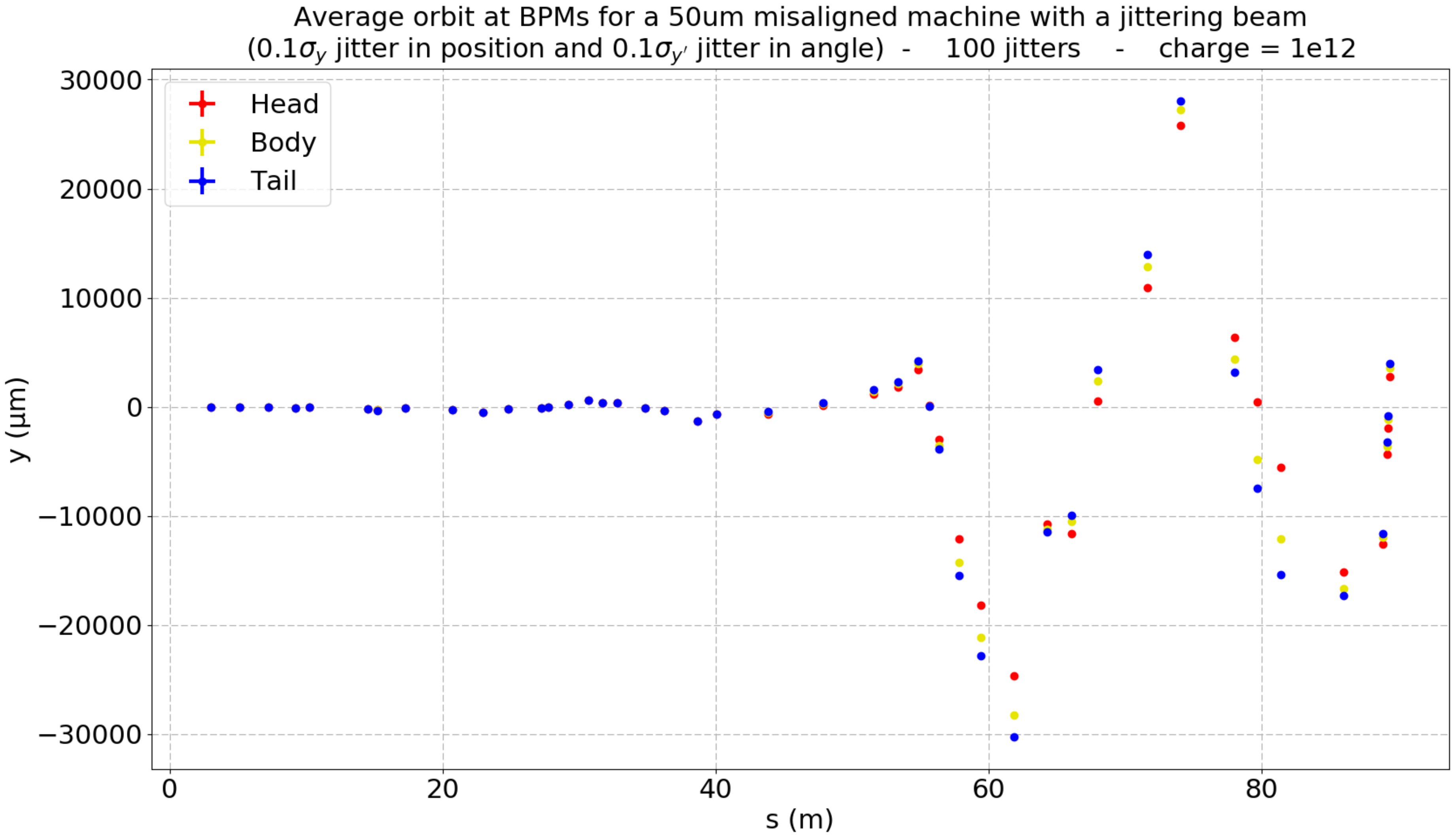
Try to answer these questions:

- **What is the behavior of a sliced beam?**
- **What is the evolution of beam energy along the beam line?**

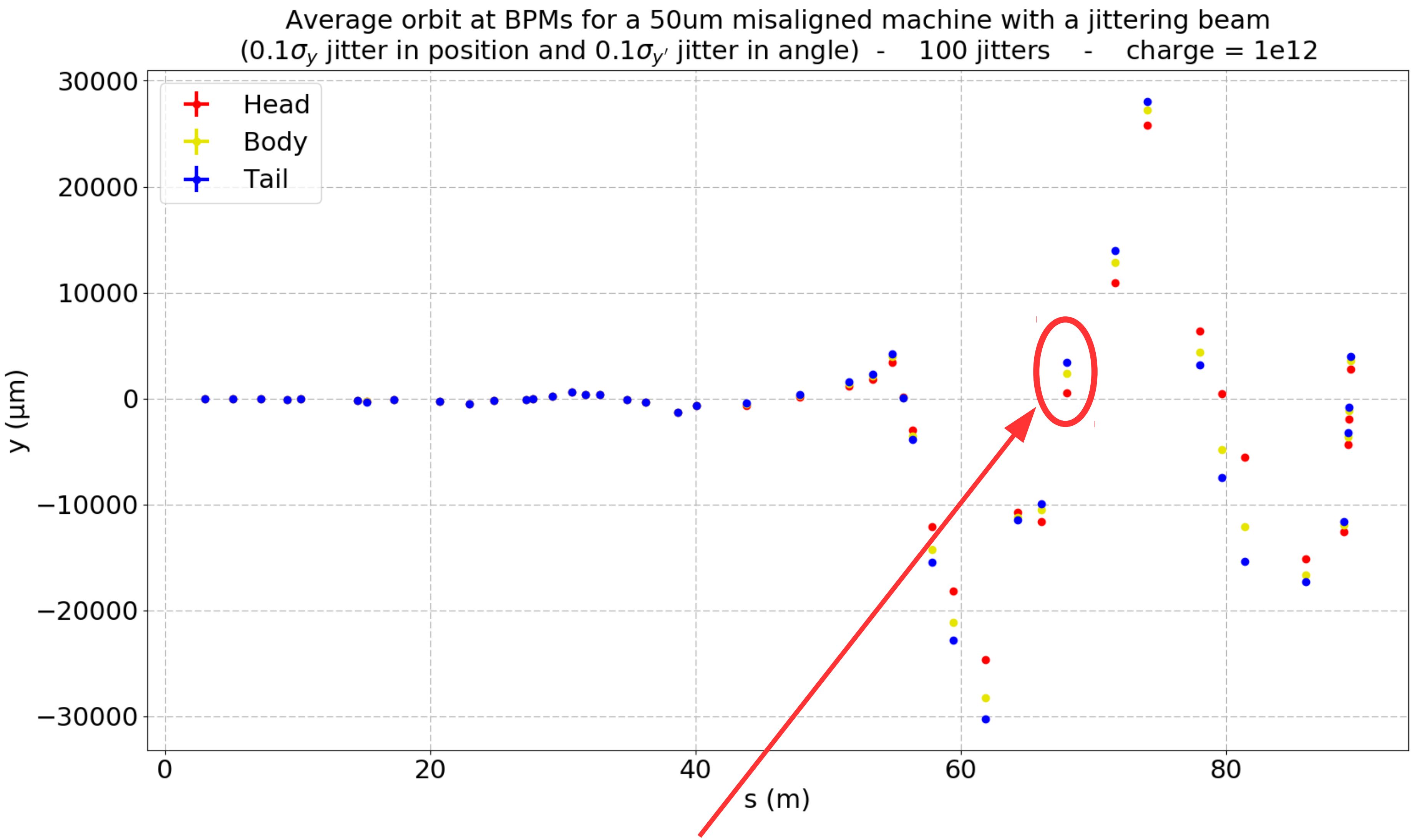
Distribution of particles



BPMs simulations

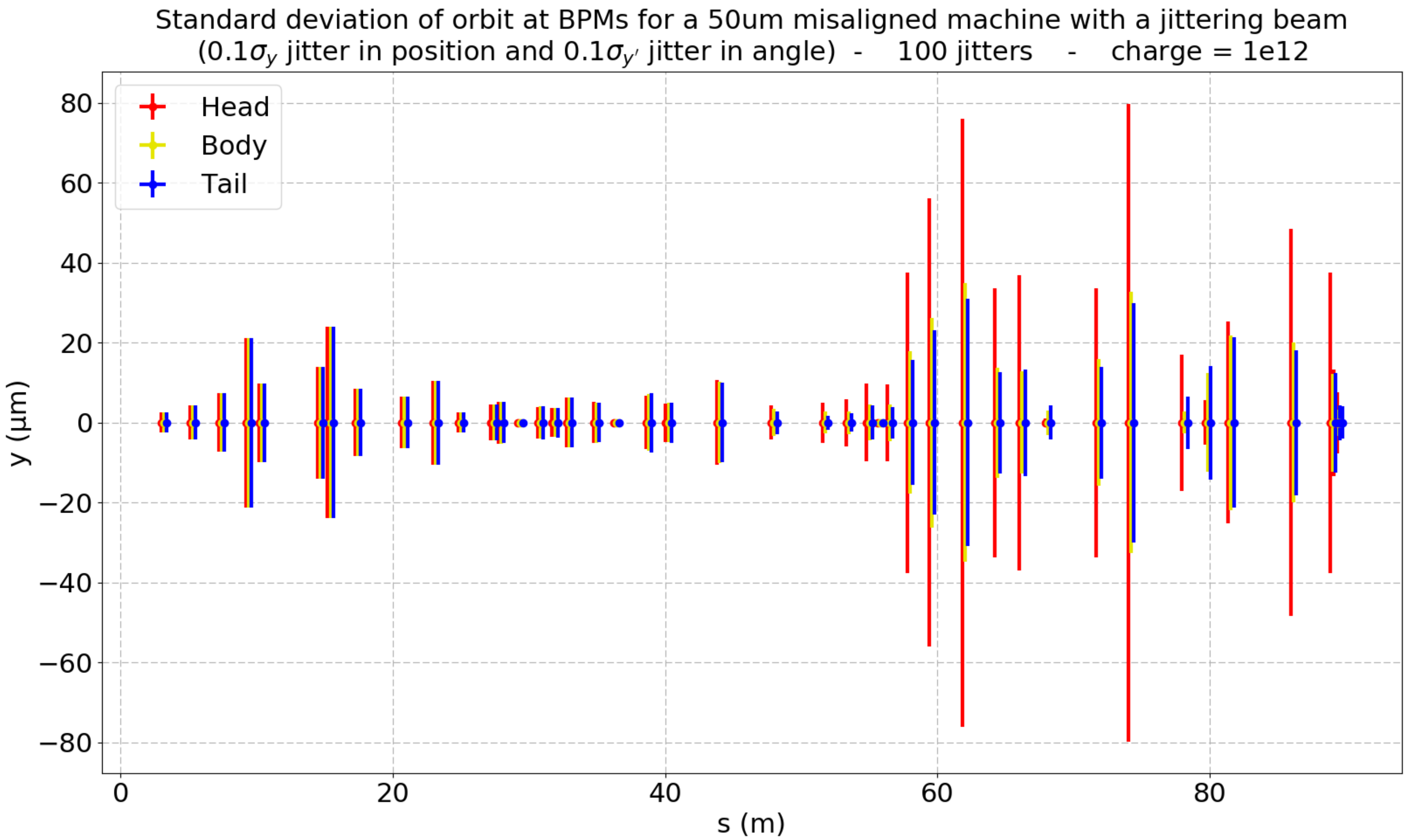


BPMs simulations



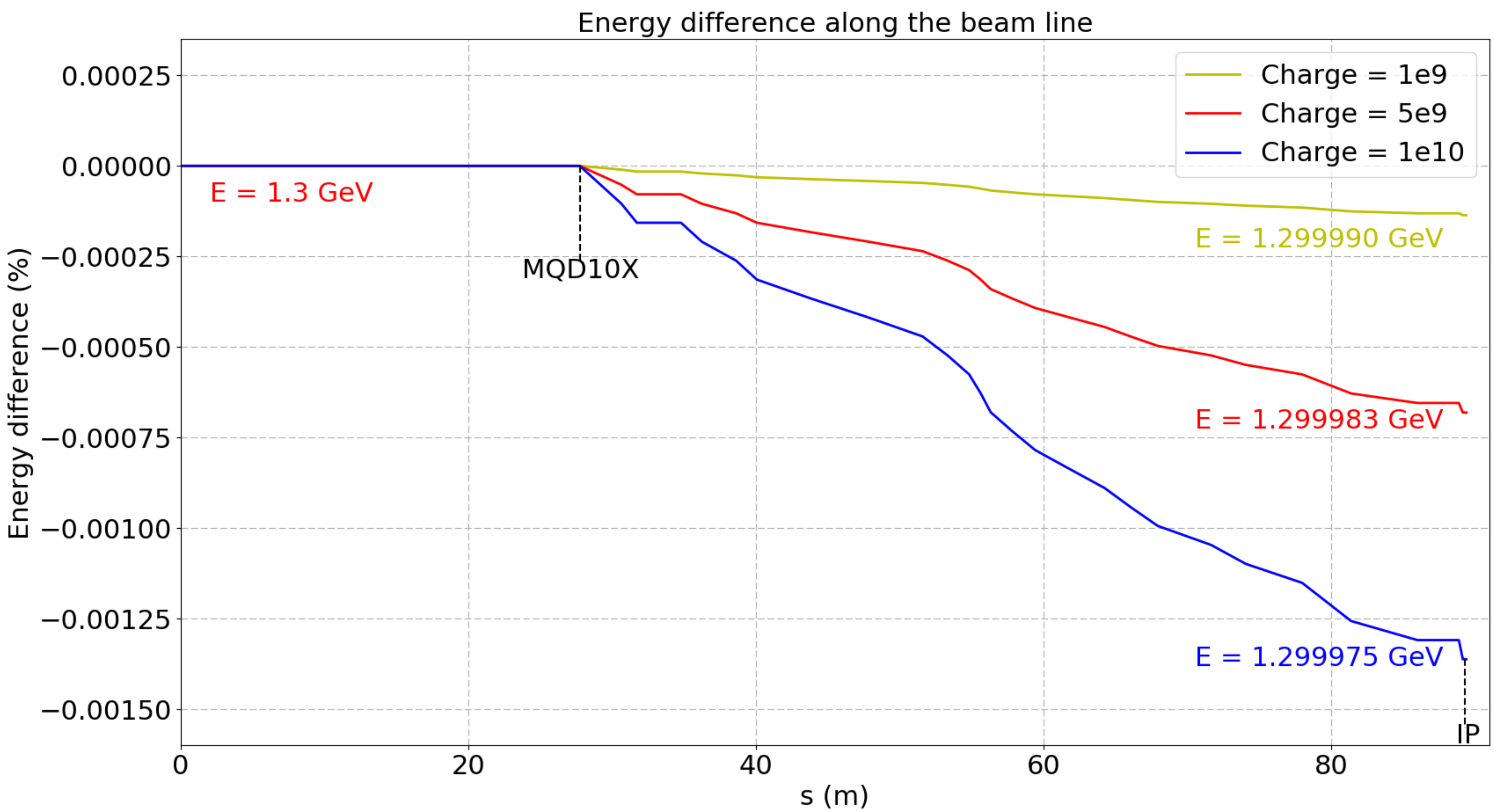
Banana effect clearly visible

BPMs simulations



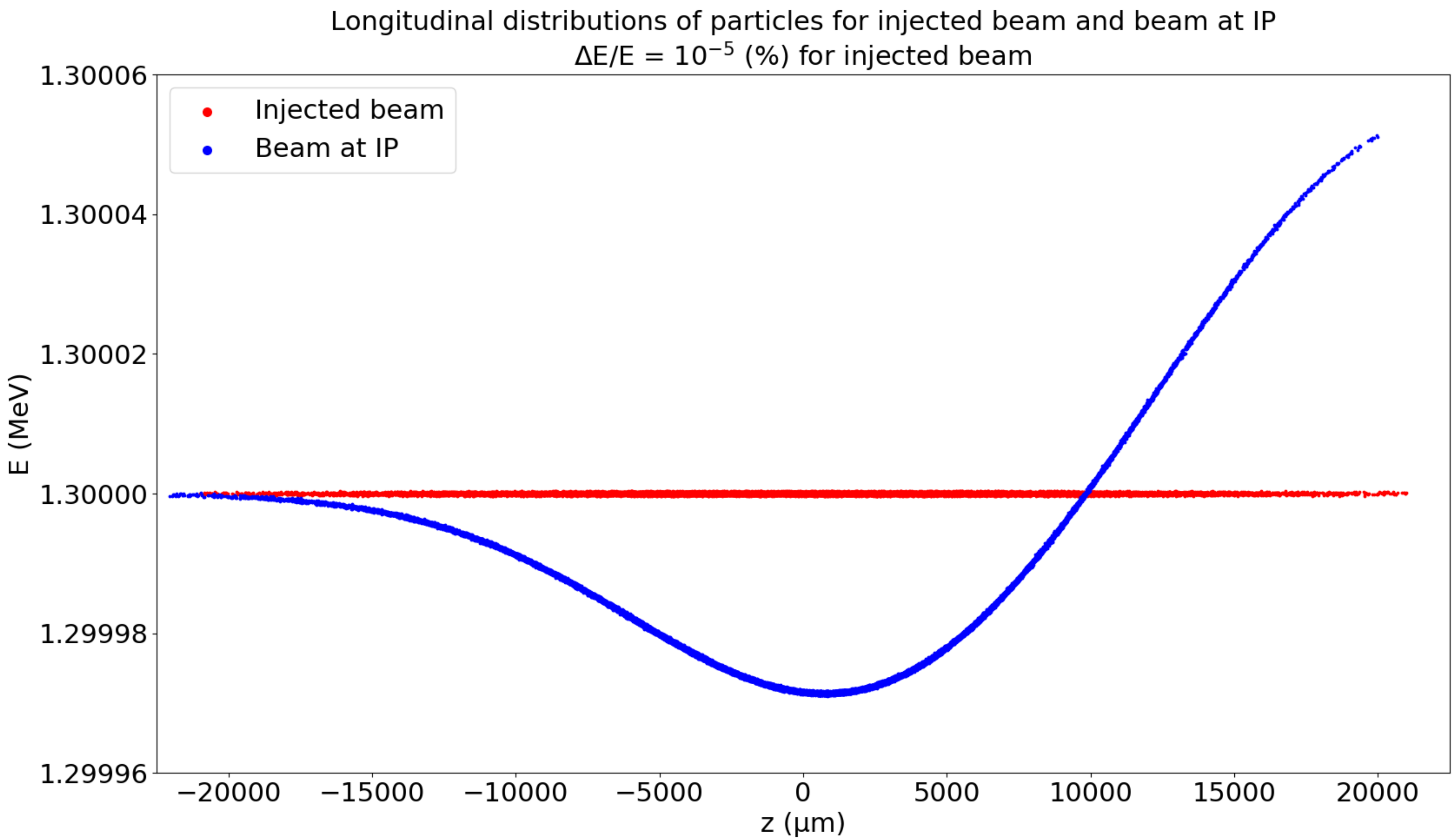
Off energy slices have a smaller standard deviation of jitters?

BPMs simulations



In simulations, the first source of wakefield is BPM MQD10X (C-band).

Wakefield simulations



Body and tail are off-energy.
Tail has a higher energy than body.