Intensity-dependent effects at ATF2: first measurements

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Recap: Goals of ATF2 measurments

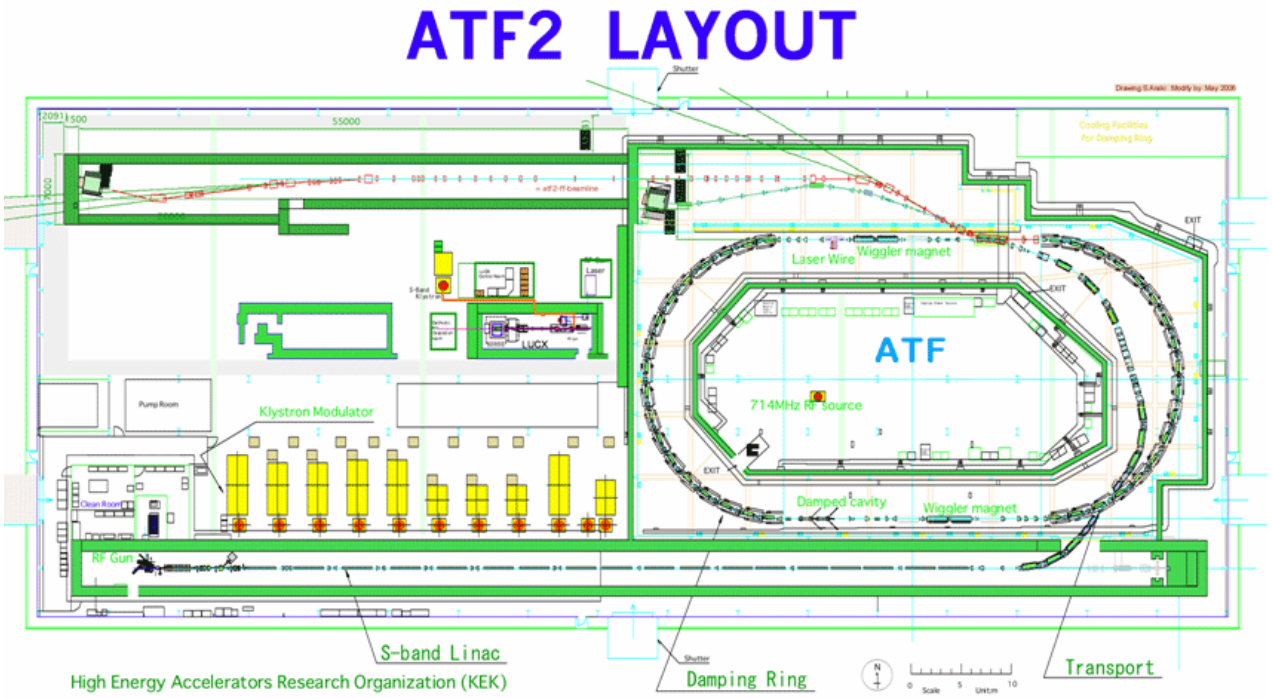
- **Validate jitter simulations.**
- **Measure incoming beam jitter.**

Outline

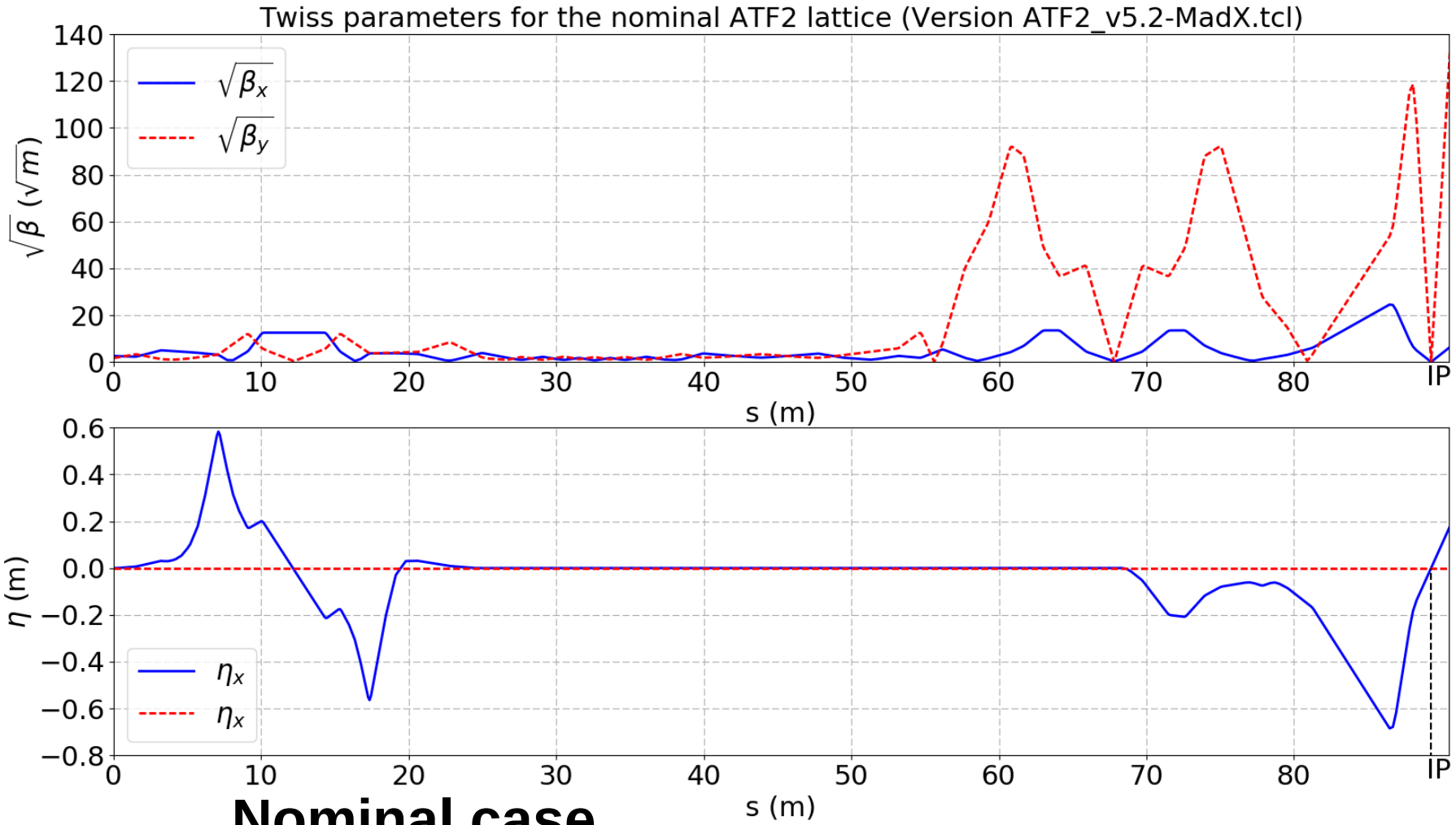
- **Recap: ATF2.**
- **Recap: simualtions.**
- **Measurements at ATF2.**
- **Analysis: first results.**

ATF2

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



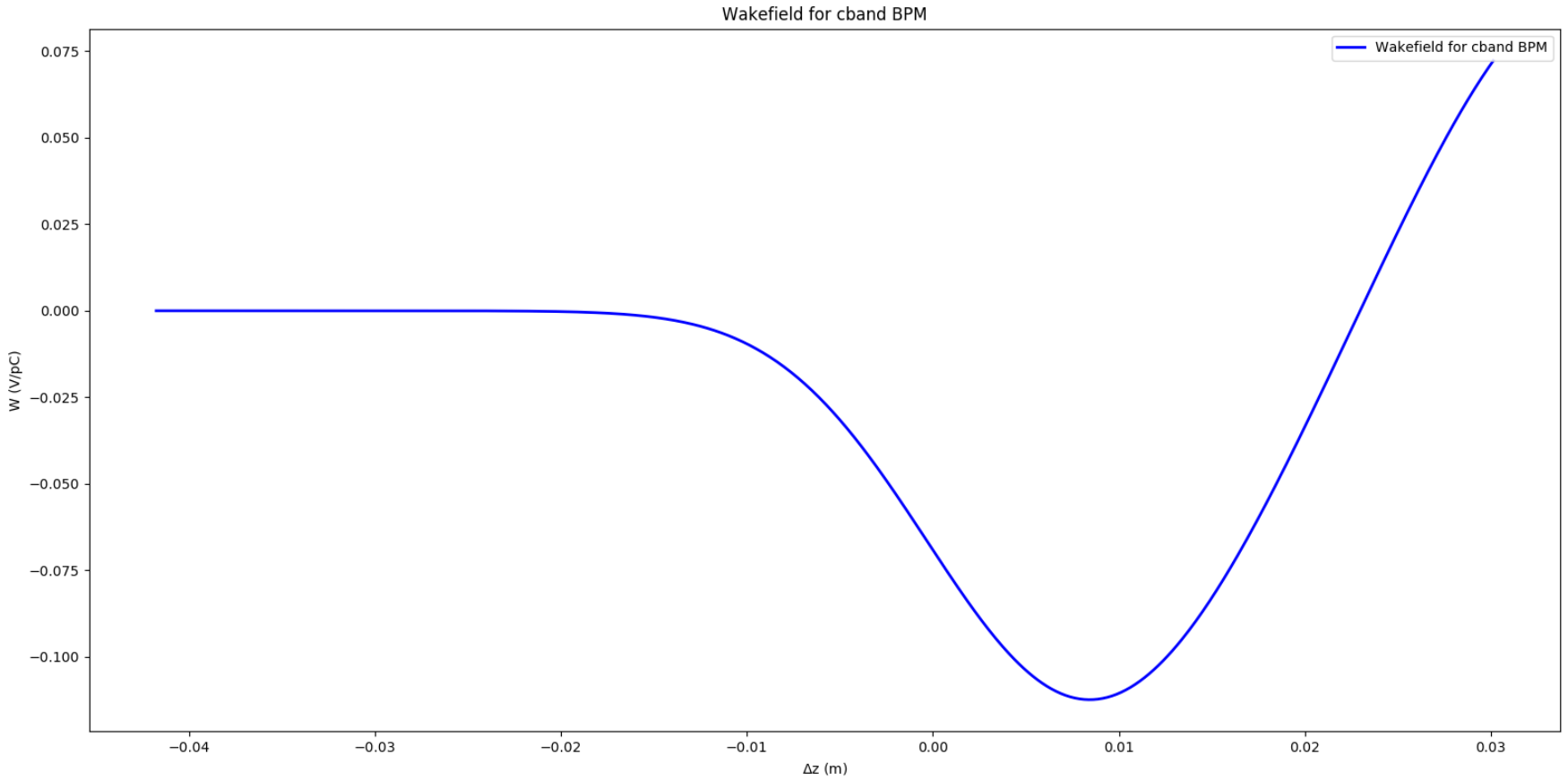
ATF2 twiss parameters with Placet



Nominal case

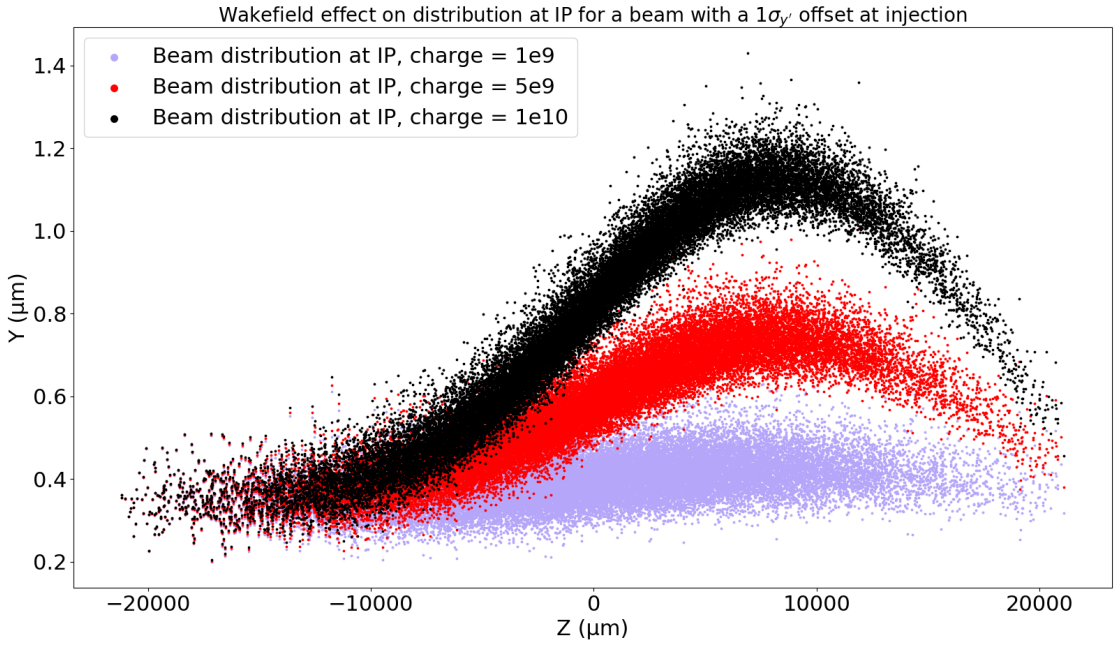
At IP σ_y = 37.19 nm **β_y* = 0.10 mm**

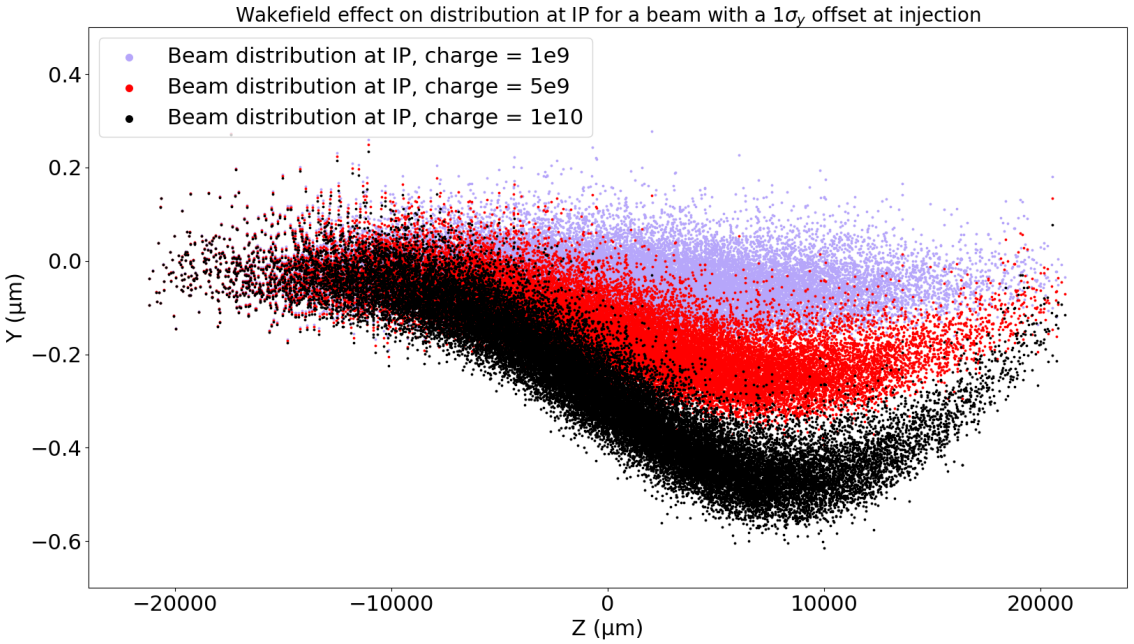
Single bunch wake



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.

Simulation procedures

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

Fast knobs used:
1st order: <y,y'> <y,E> <y,x'>

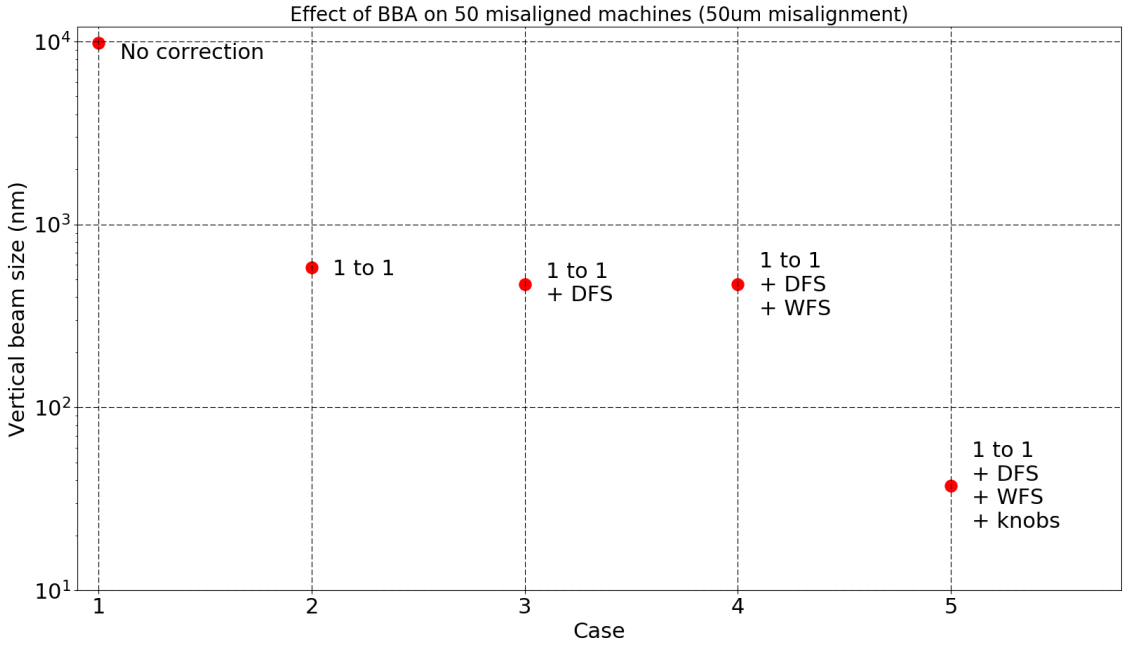
2nd order: <y,x'²> <y,x'*y'> <y,x'*E>

44 BPMs (post November 2016 lattice).

In most simulations:

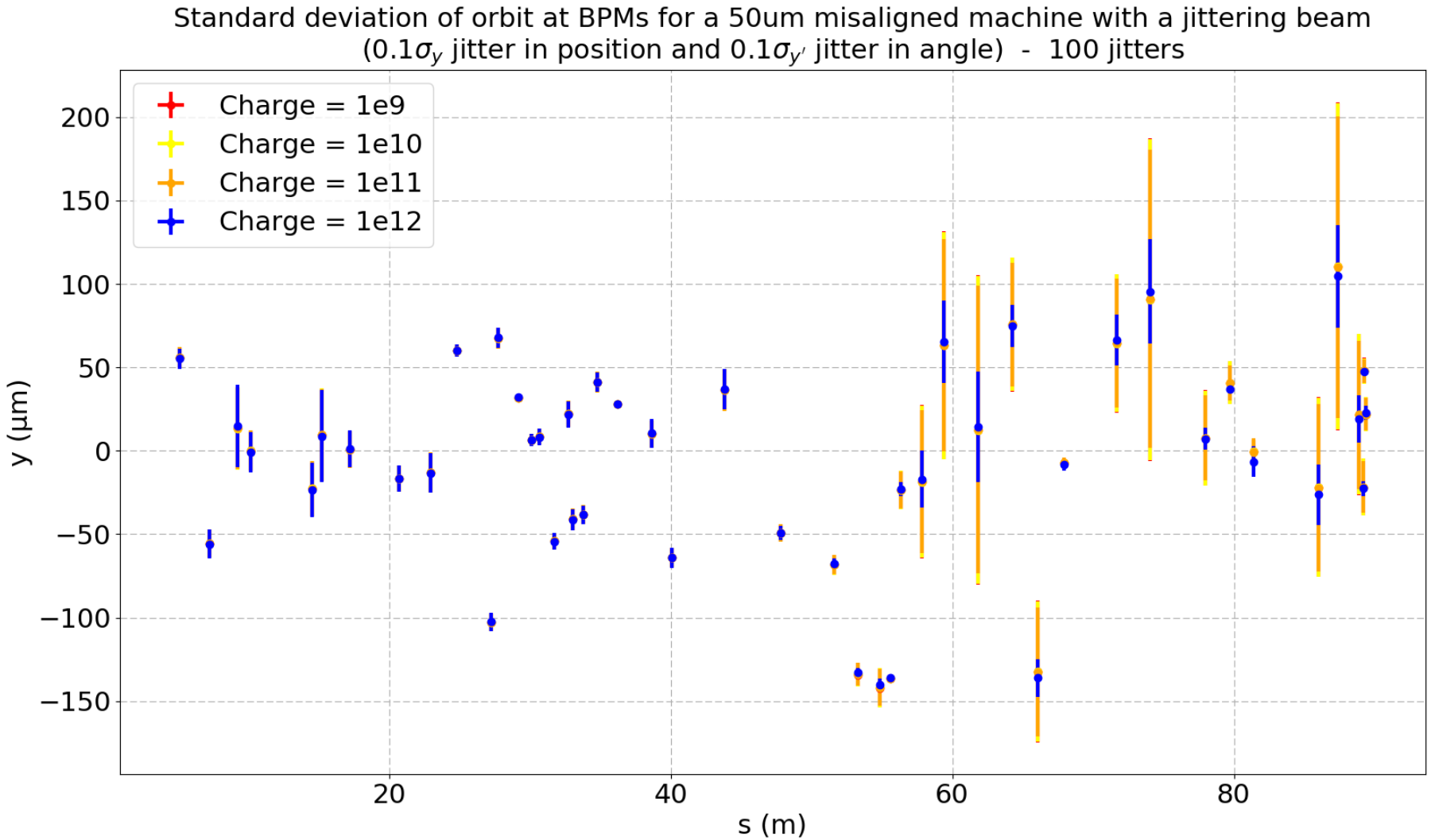
Jitter 0.1σ_y in position and 0.1$\sigma_{y'}$ in angle.

Misalignment of 50 μm.

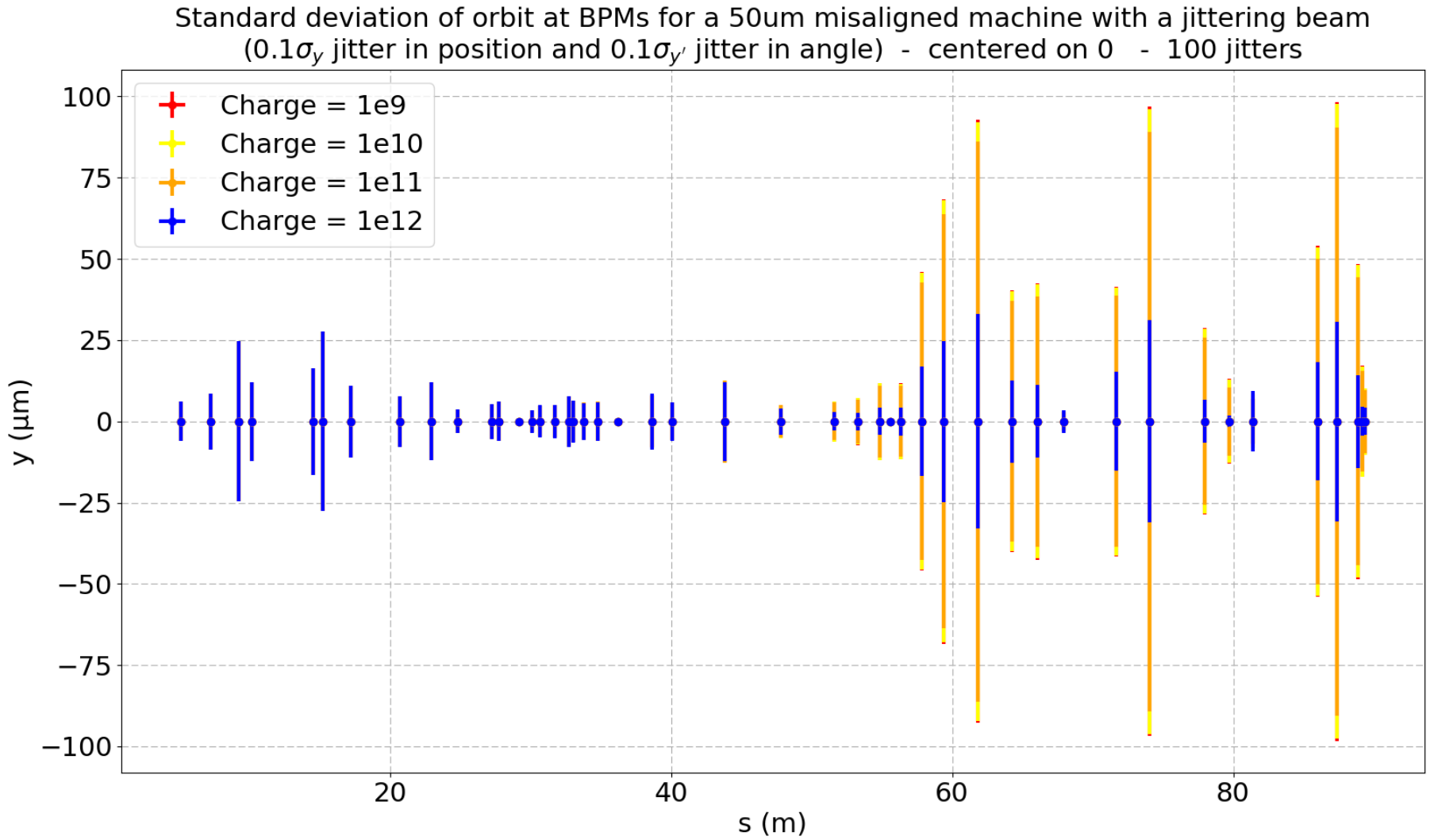


Case	Vertical beam size (nm)
No correction	9796.23
1to1	581.93
1to1 + DFS	469.46
1to1 + DFS + WFS	469.45
1to1 + DFS + WFS + knobs	37.41

BPMs simulations

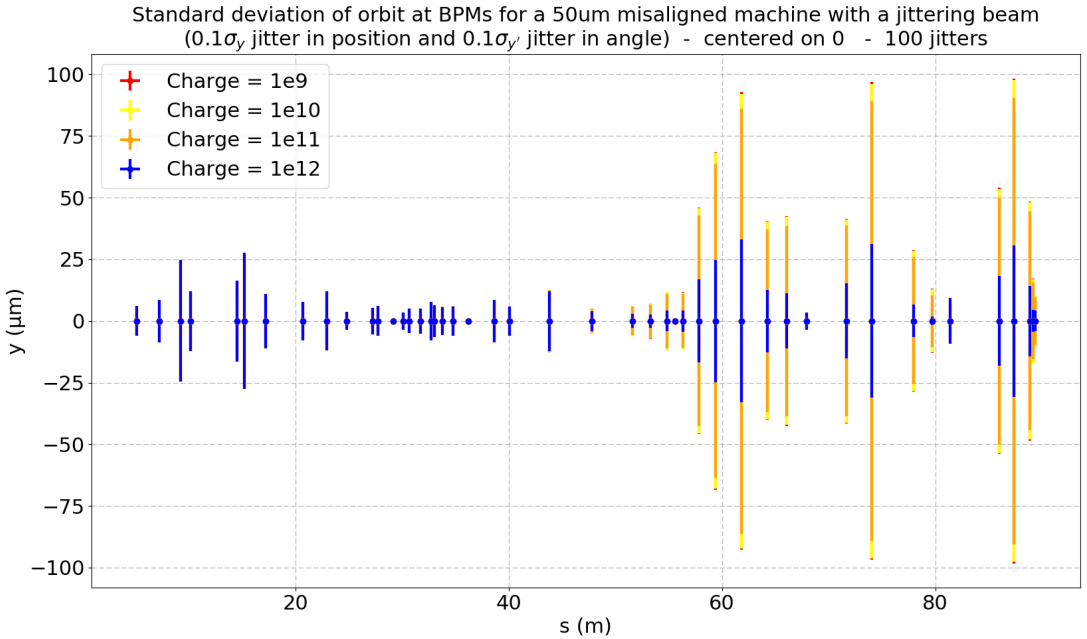


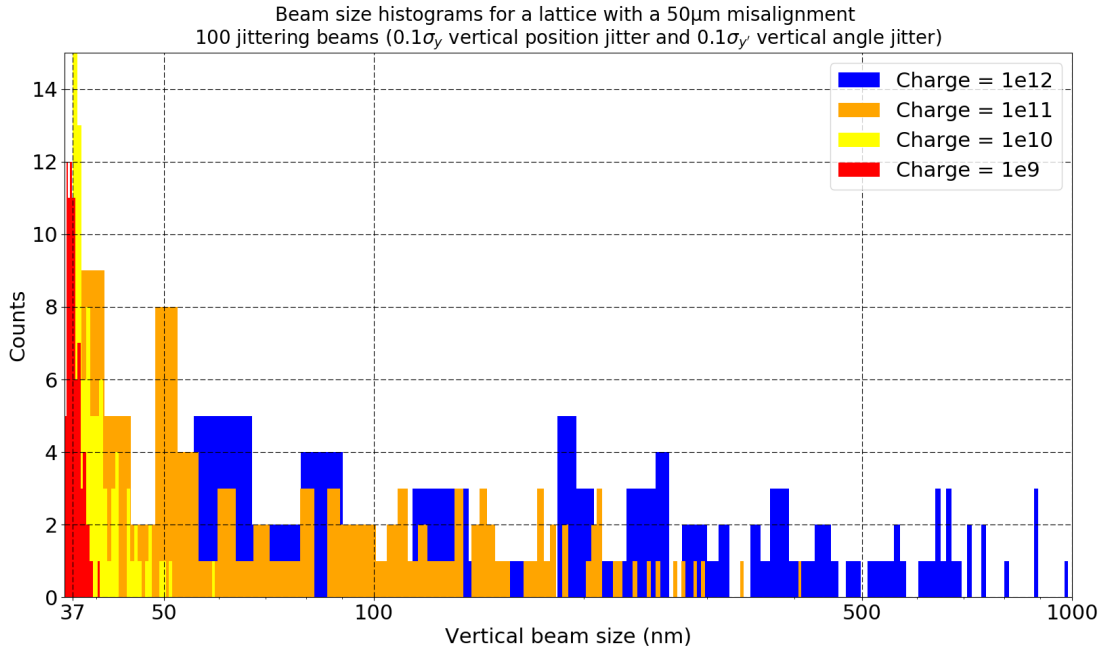
BPMs simulations



Higher charge → smaller orbit?

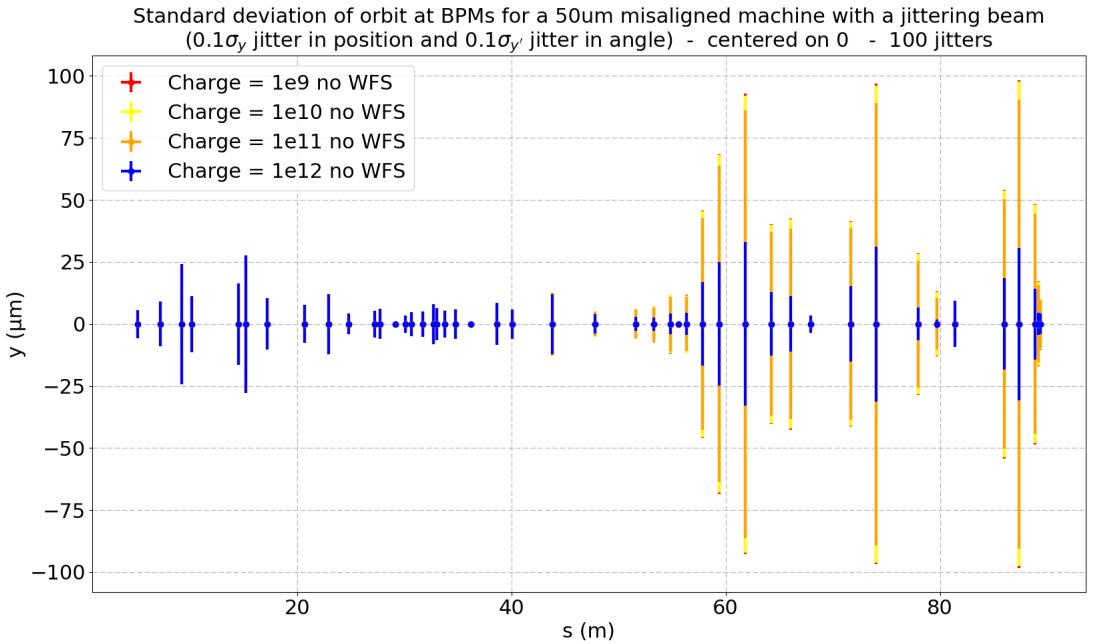
BPMs simulations

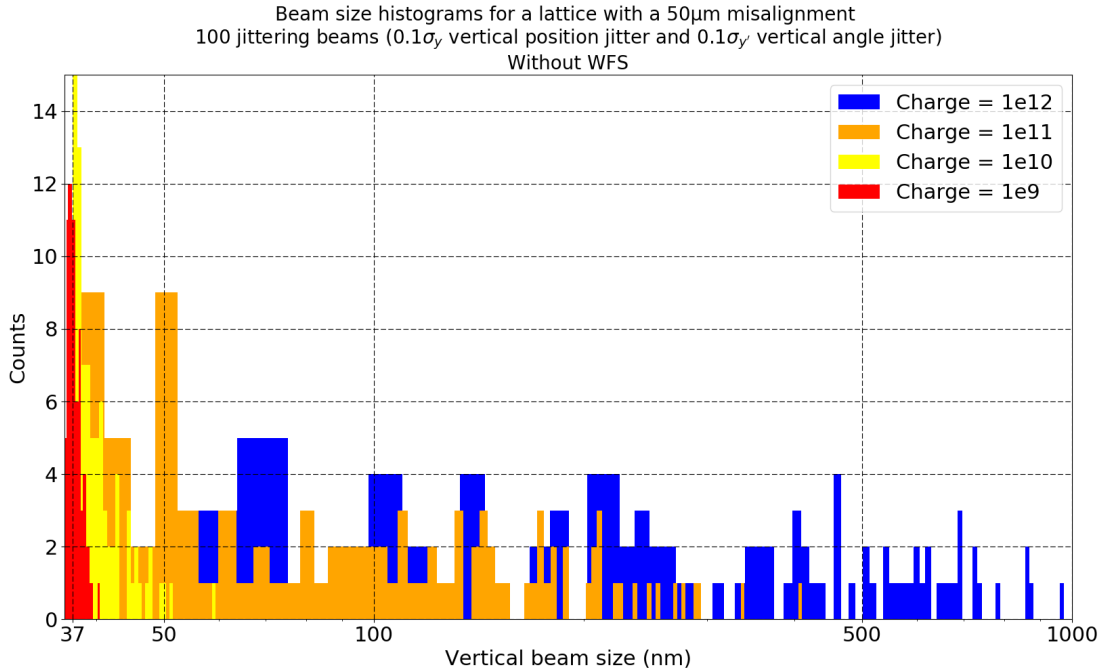




At IP, higher charge → bigger beam

BPMs simulations without WFS

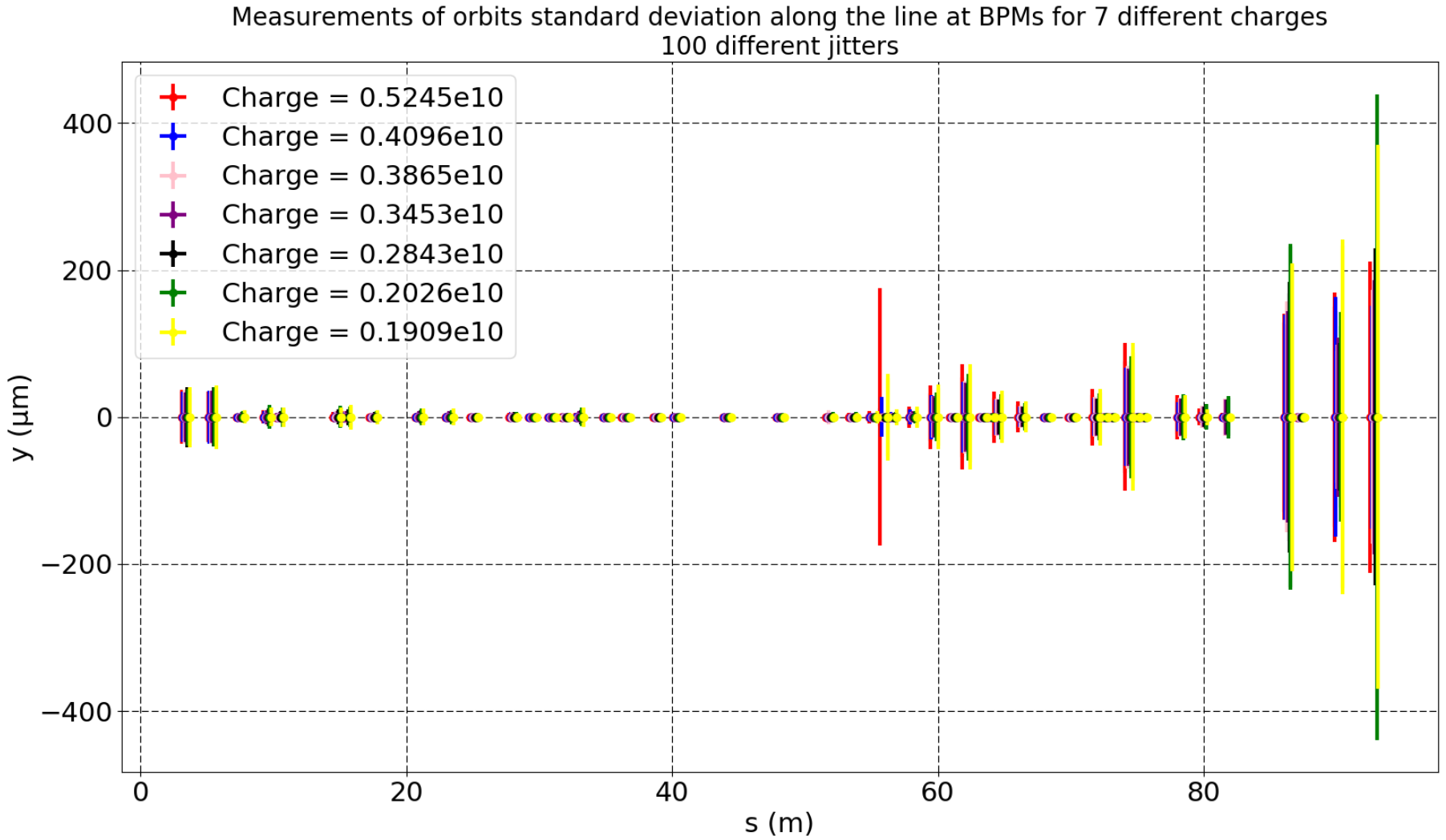




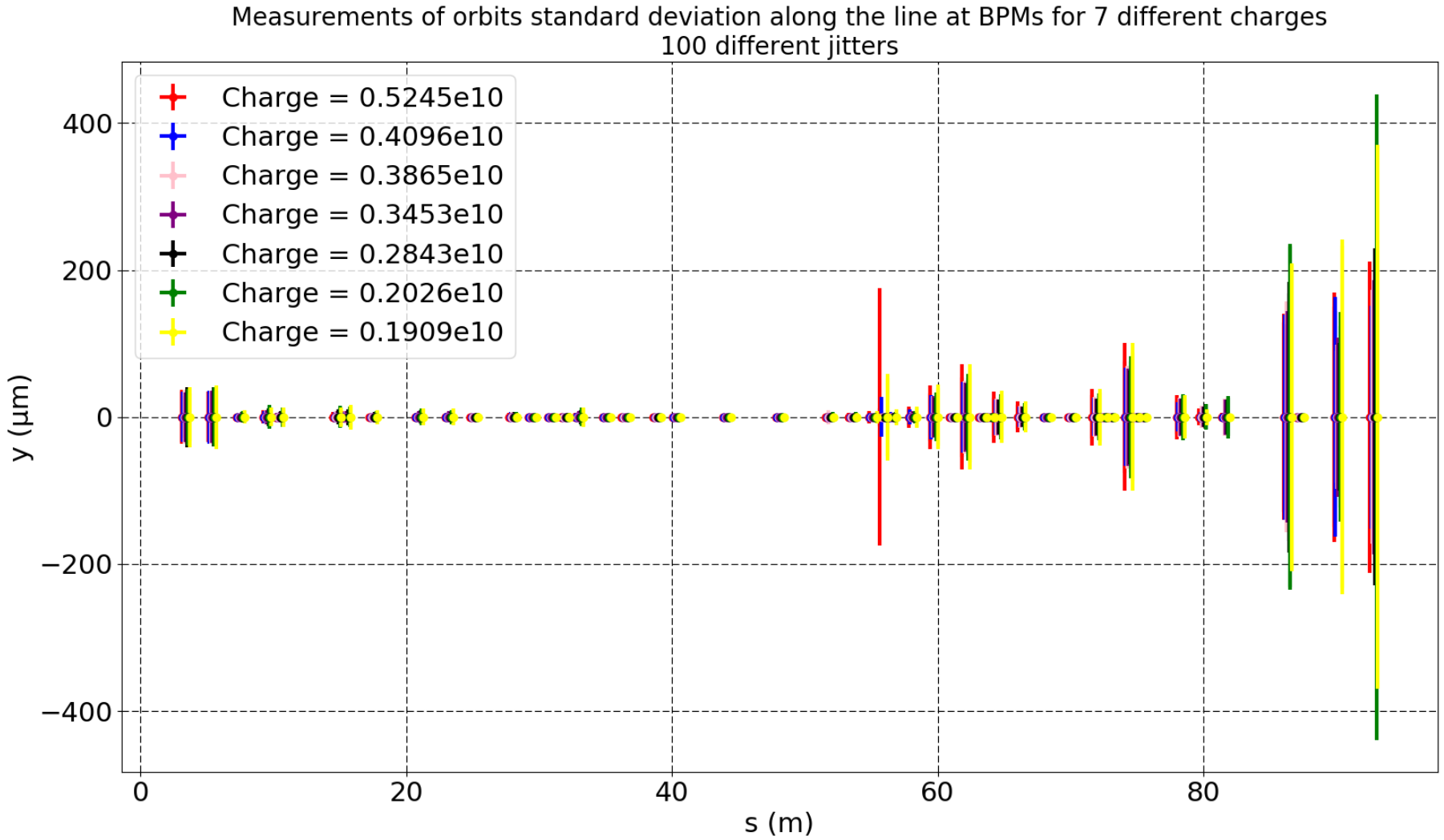
Wakefield Free Steering is not the problem

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

BPMs measurements

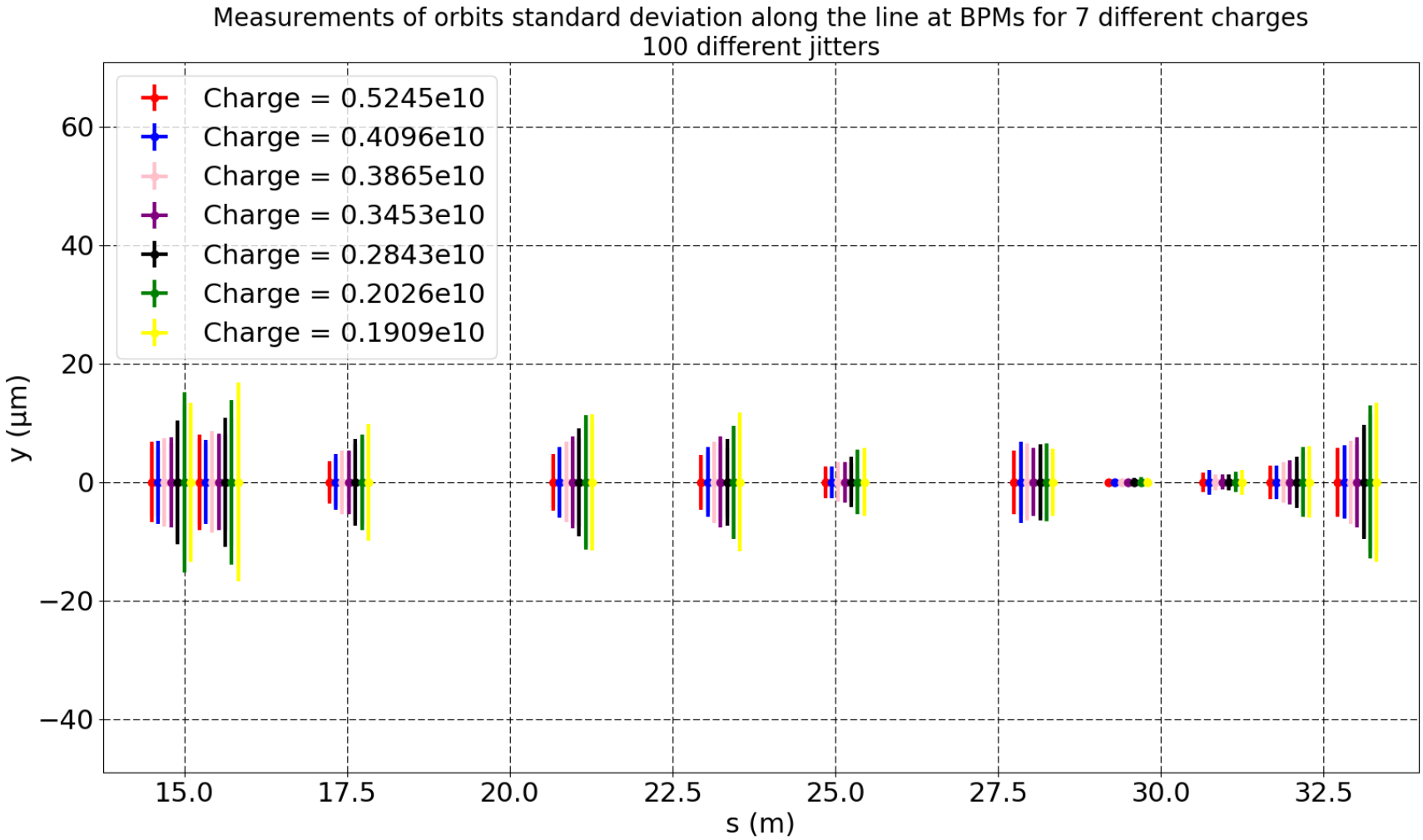


BPMs measurements



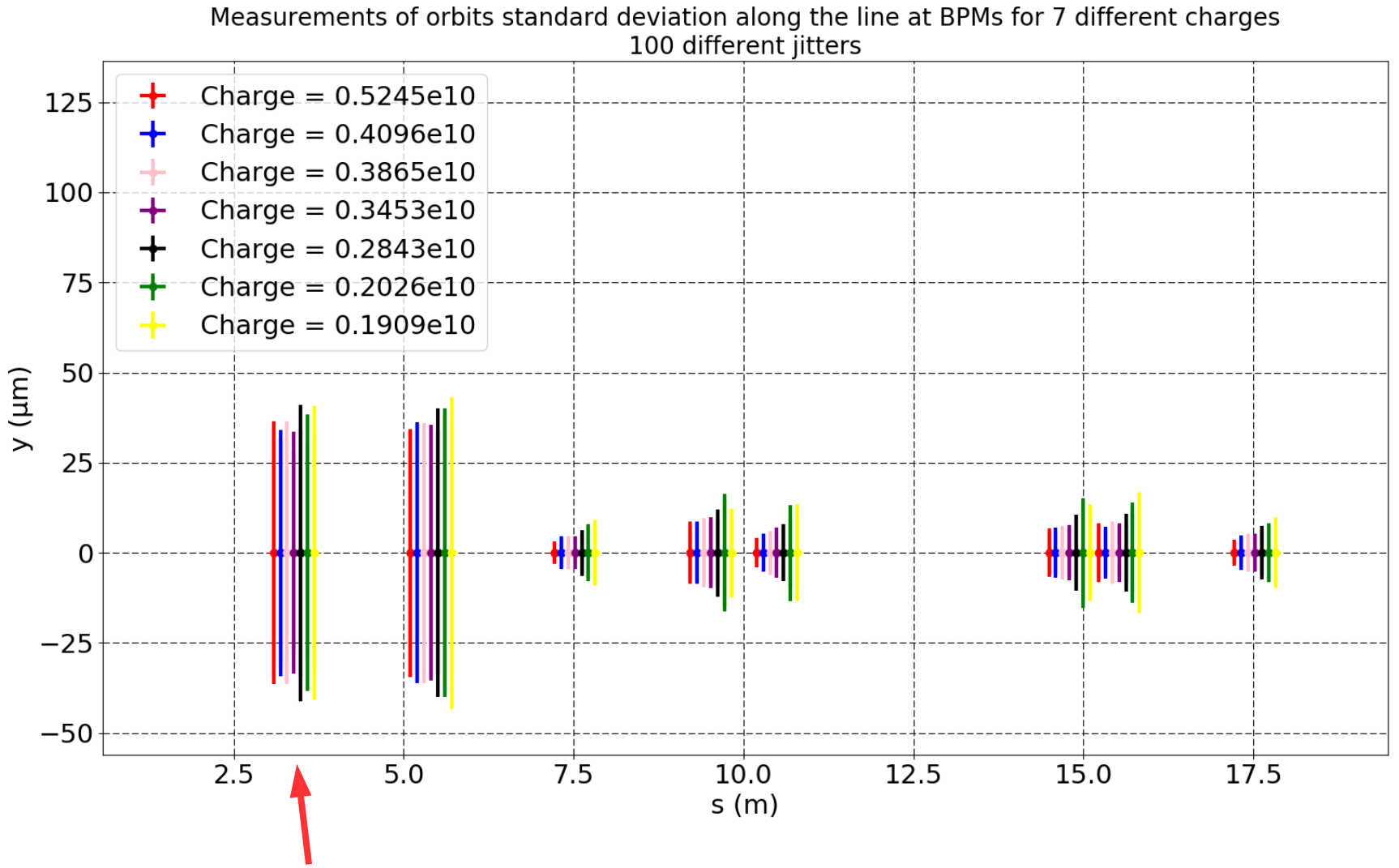
Let's zoom in.

BPMs measurements



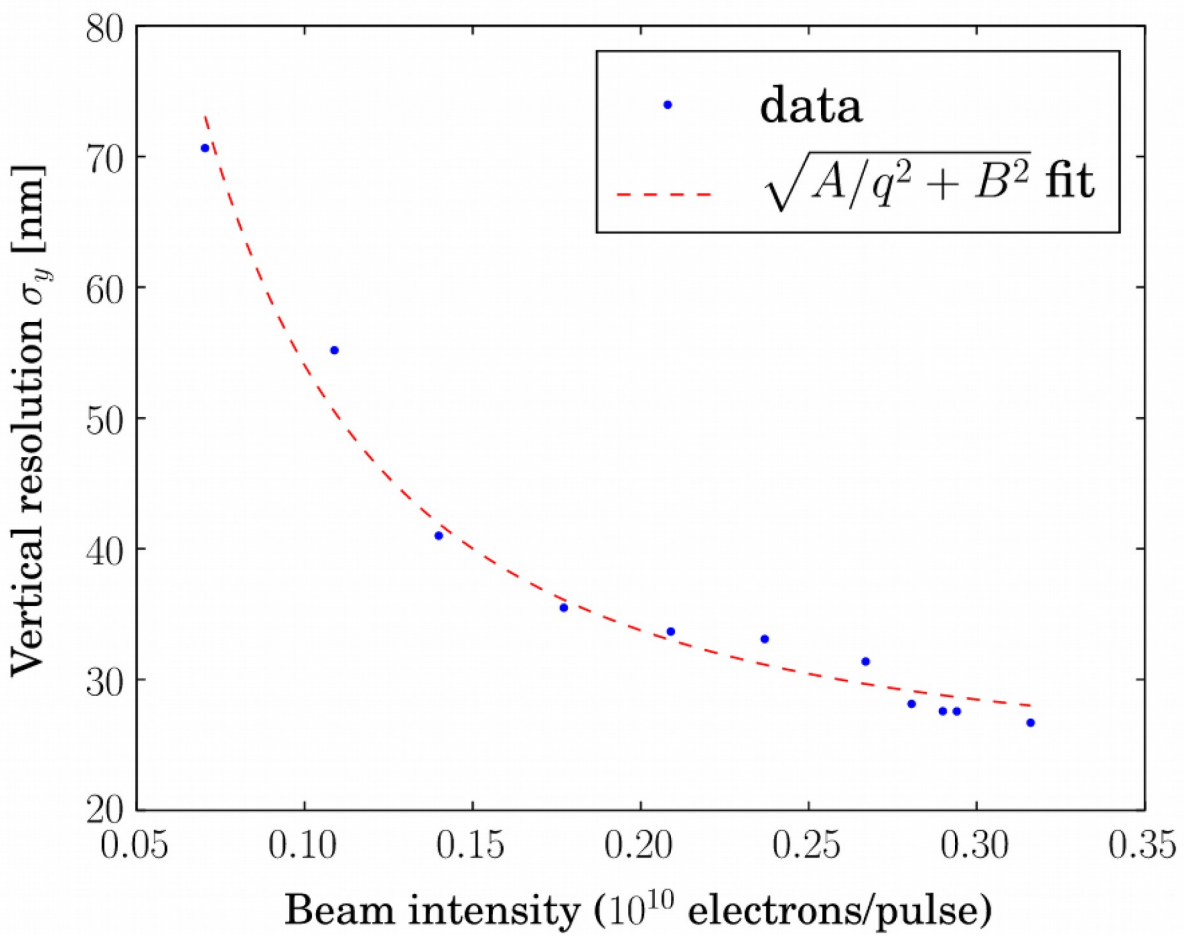
Same behavior as in simulations:
Higher charge → smaller orbit

BPMs measurements (remark)



Intensity dependent effects start at the beginning of the line.

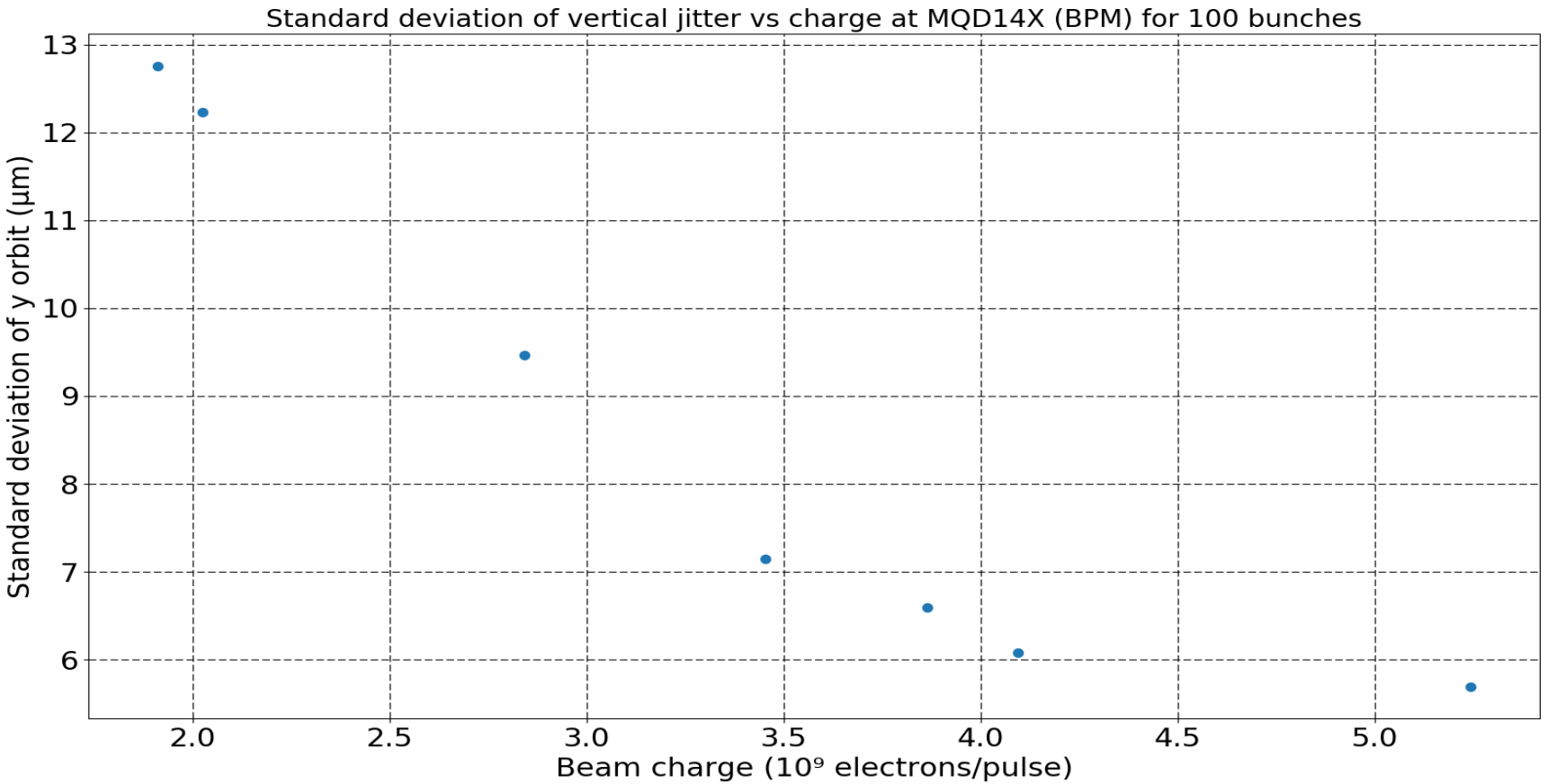
BPMs resolution



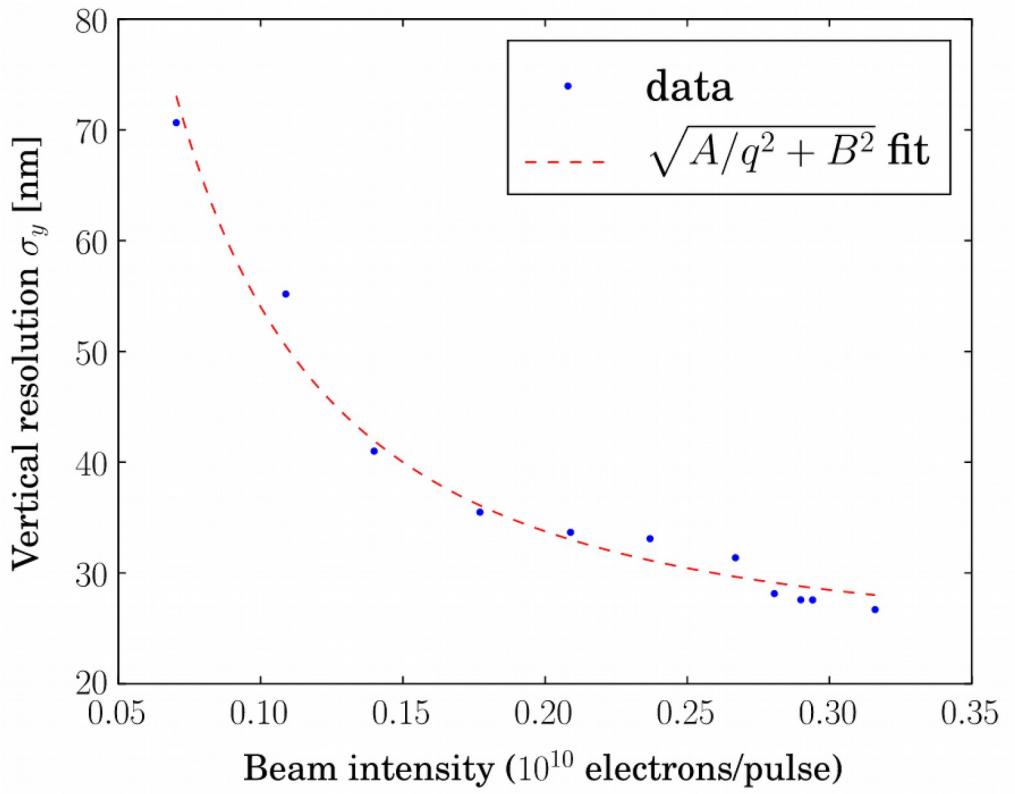
BPMs resolution depends on the charge

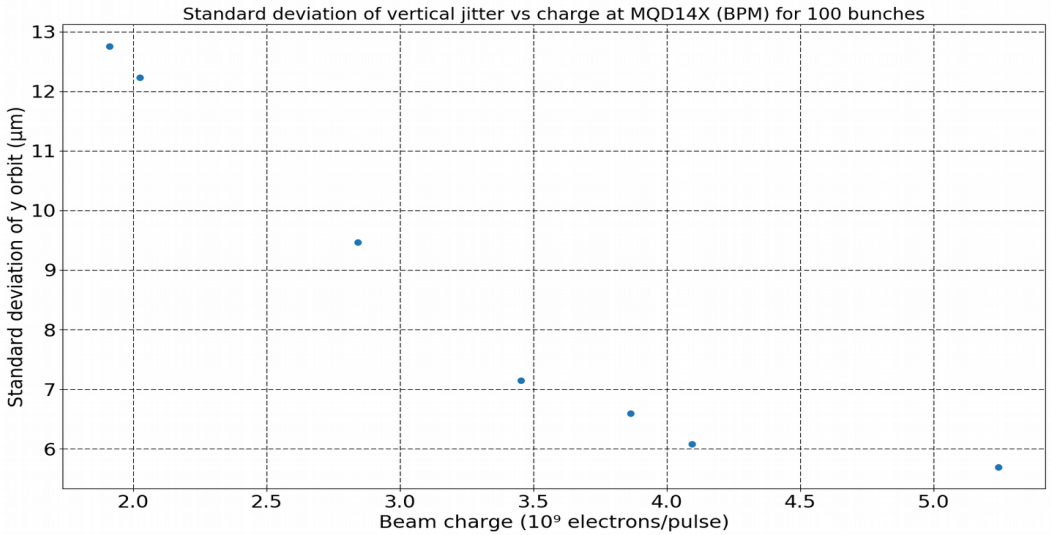
Source: Y. I. Kim et al., Cavity beam position monitor system for the Accelerator Test Facility 2. Phys. Rev. ST Accel. Beams 15, Apr 2012. https://journals.aps.org/prab/pdf/10.1103/PhysRevSTAB.15.042801

BPMs resolution

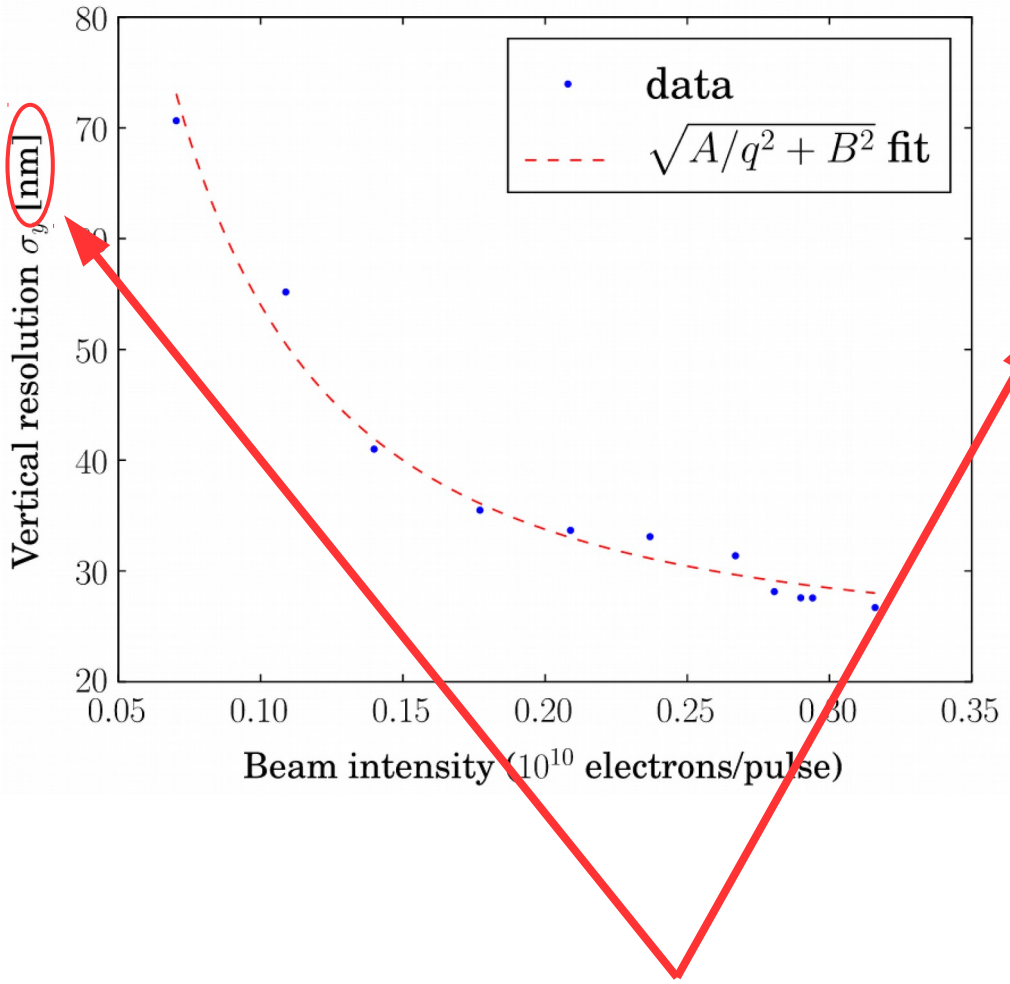


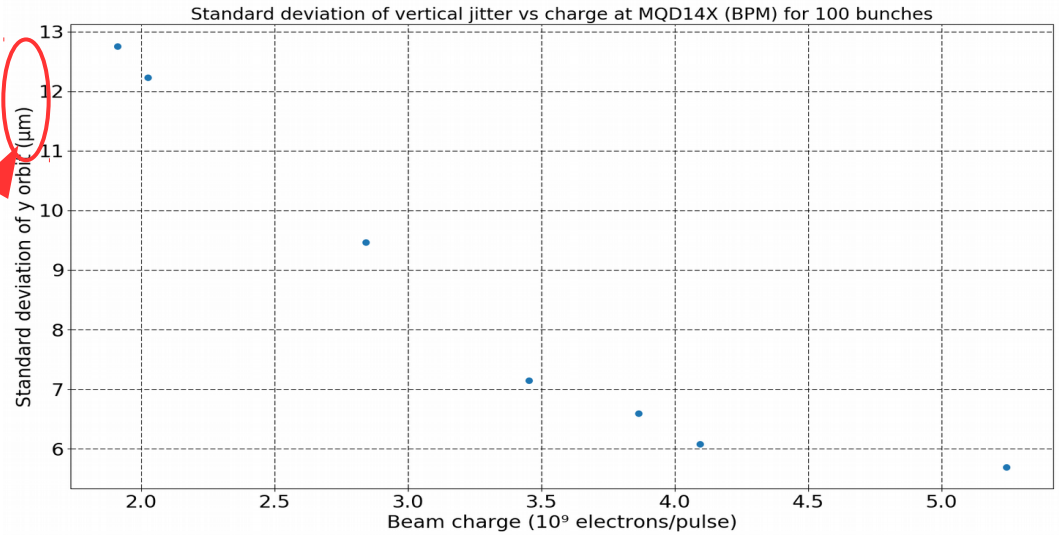
BPMs measurements





BPMs measurements





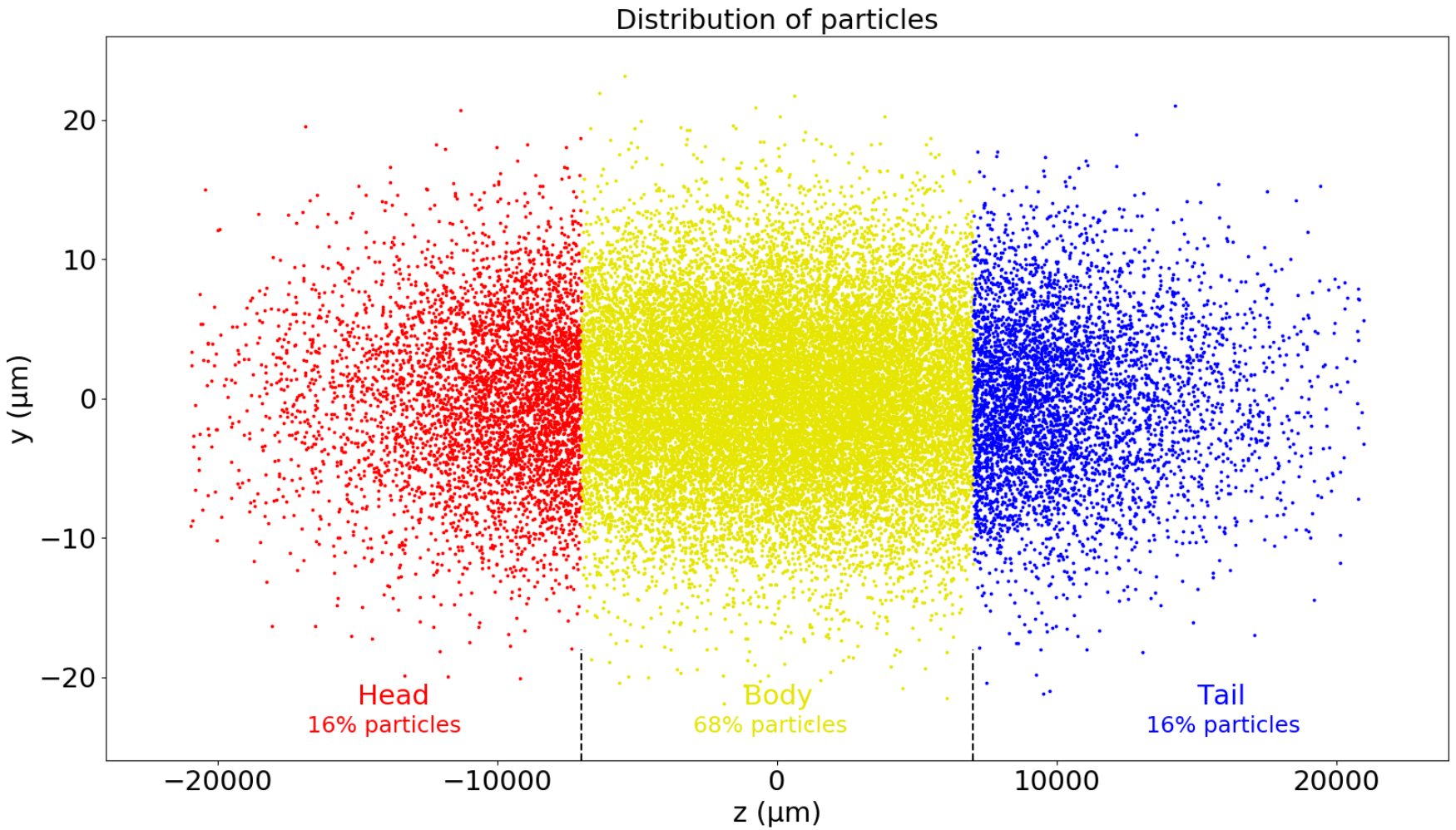
The BPMs “charge-dependence-resolution” doesn’t seem to be the source of the problem.

Further investigations

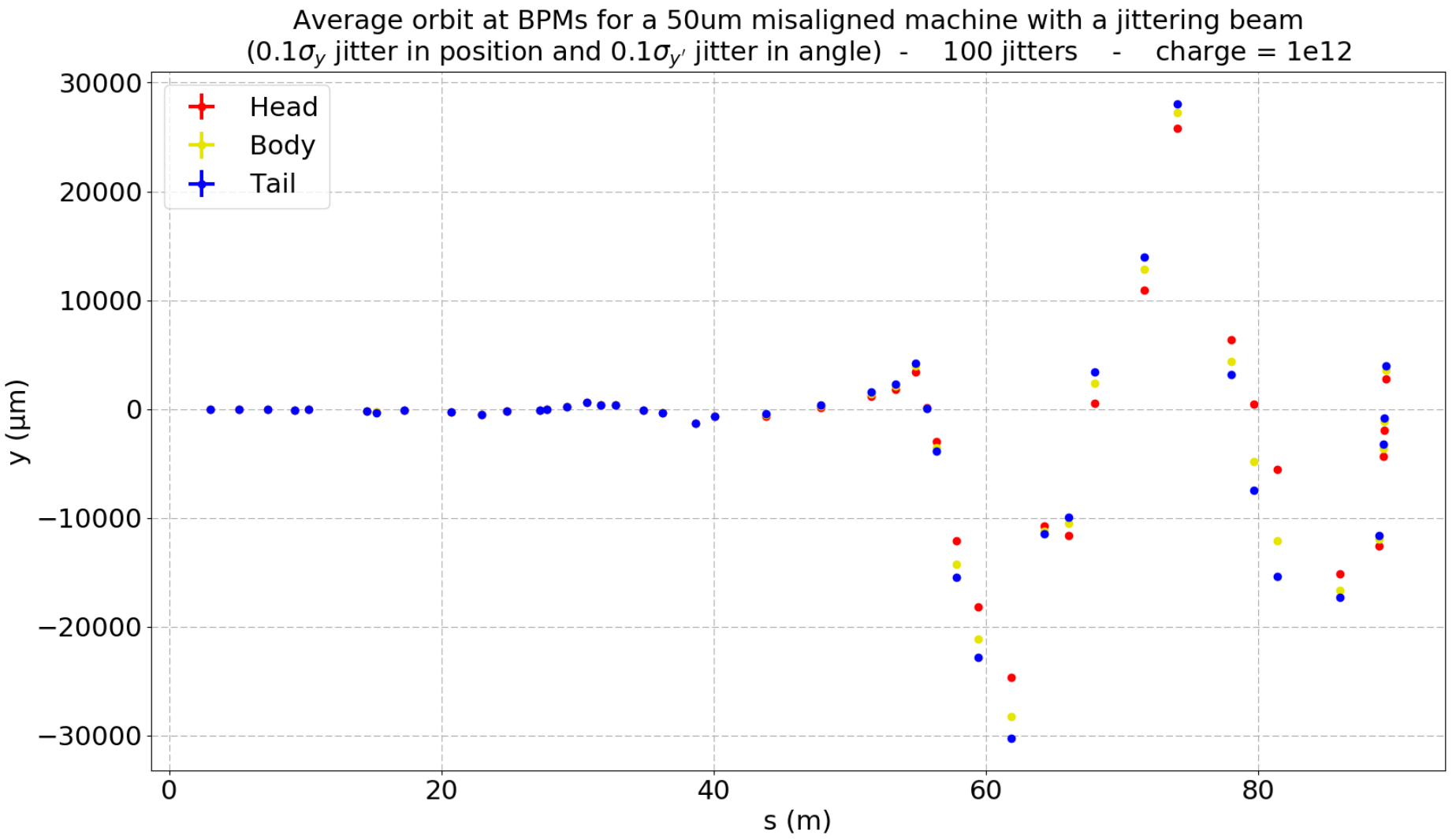
Let’s study the following cases:

- **The behavior of a sliced beam with jitter.**
- **The behavior of a sliced beam without jitter in a perfect machine.**
- **The effect of the longitudinal wakefield on the whole bunch.**

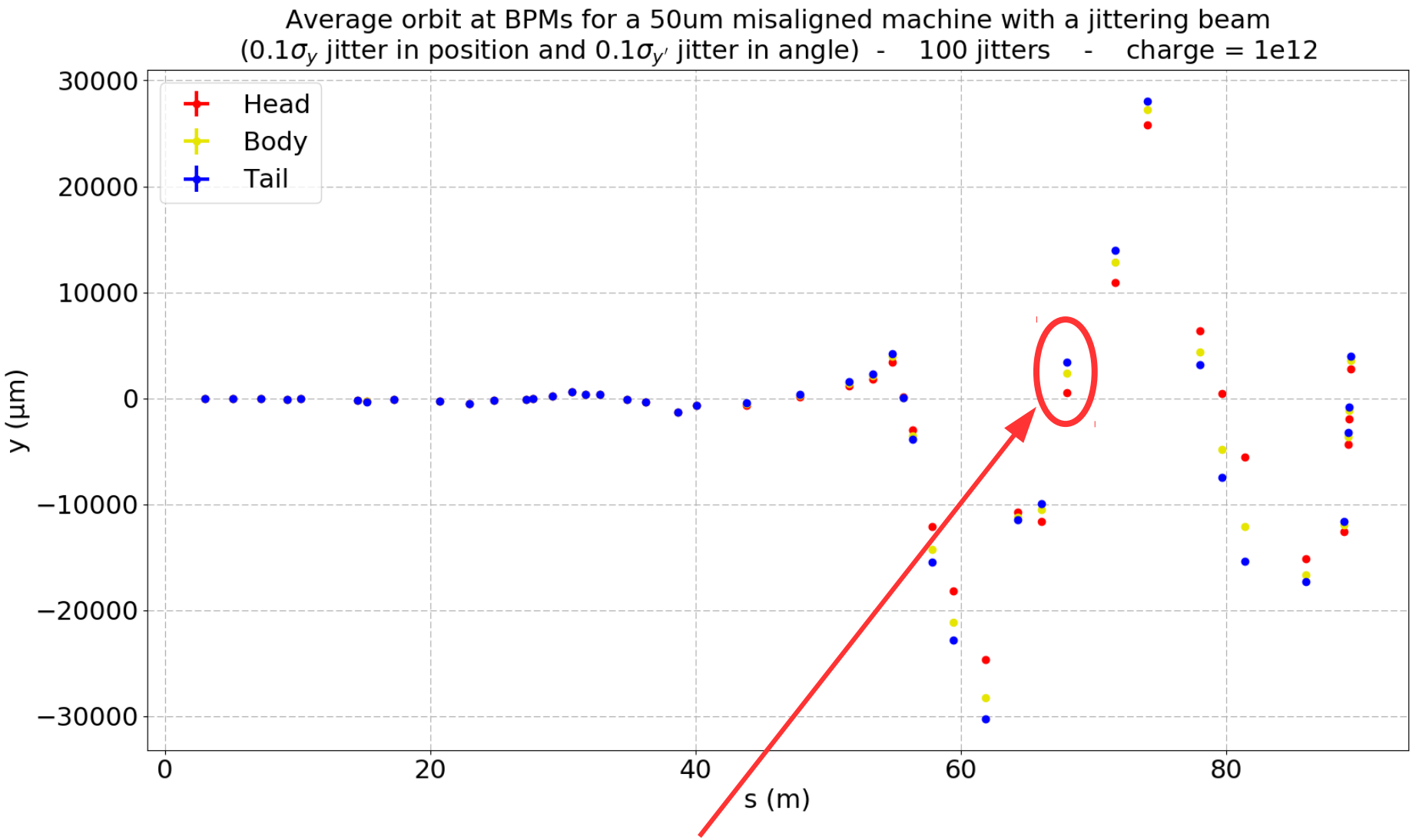
Distribution of particles



BPMs simulations

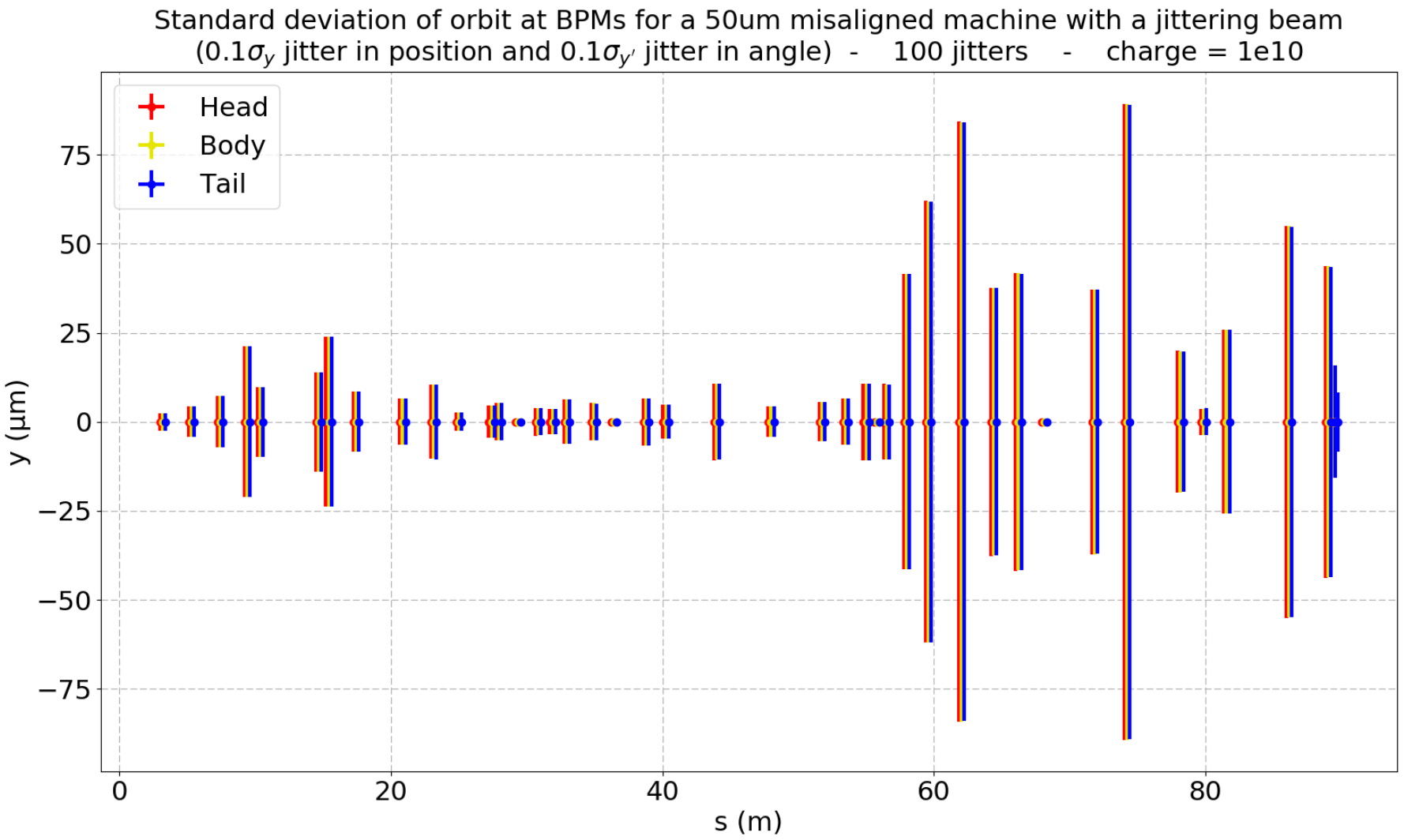


BPMs simulations

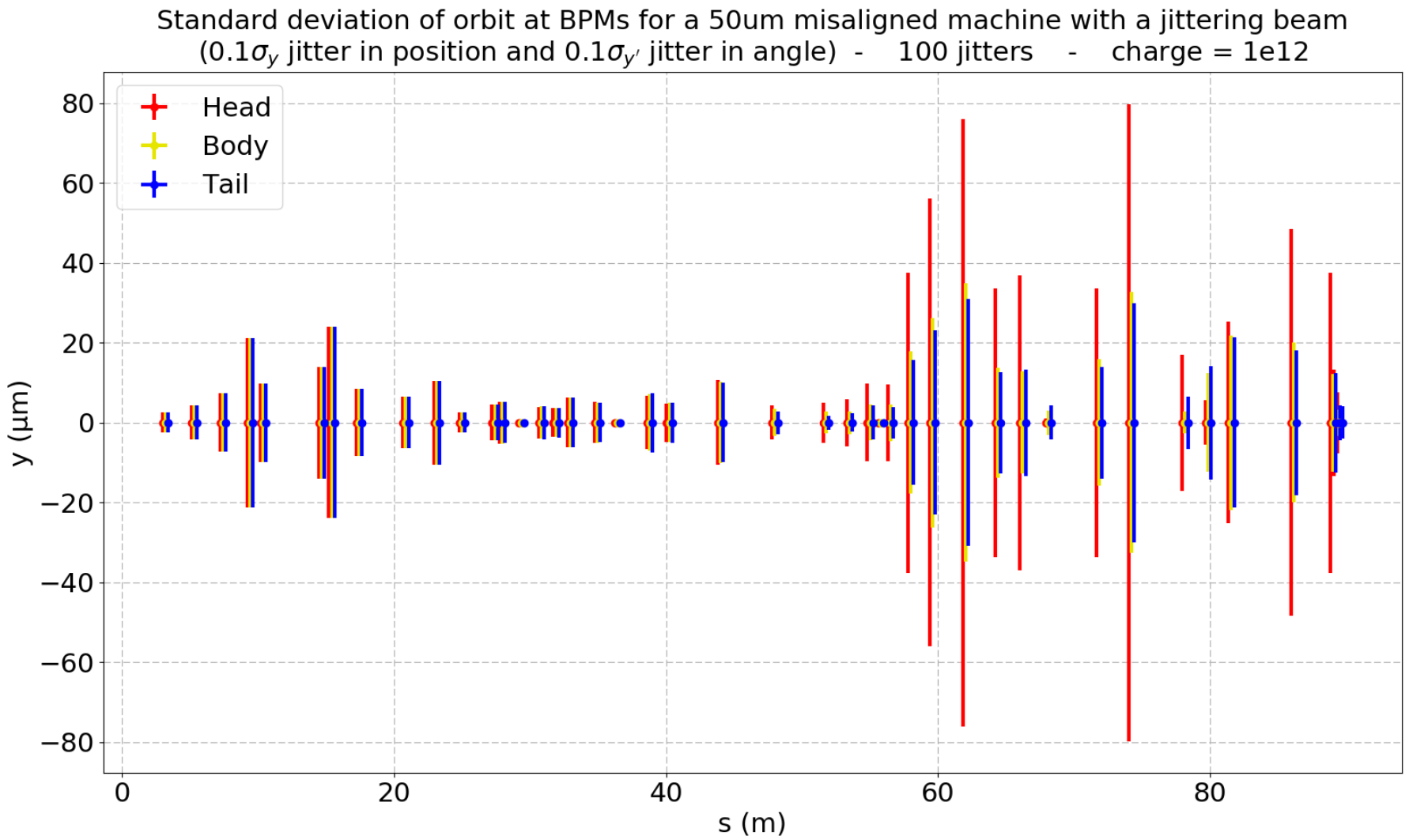


Banana effect clearly visible

BPMs simulations

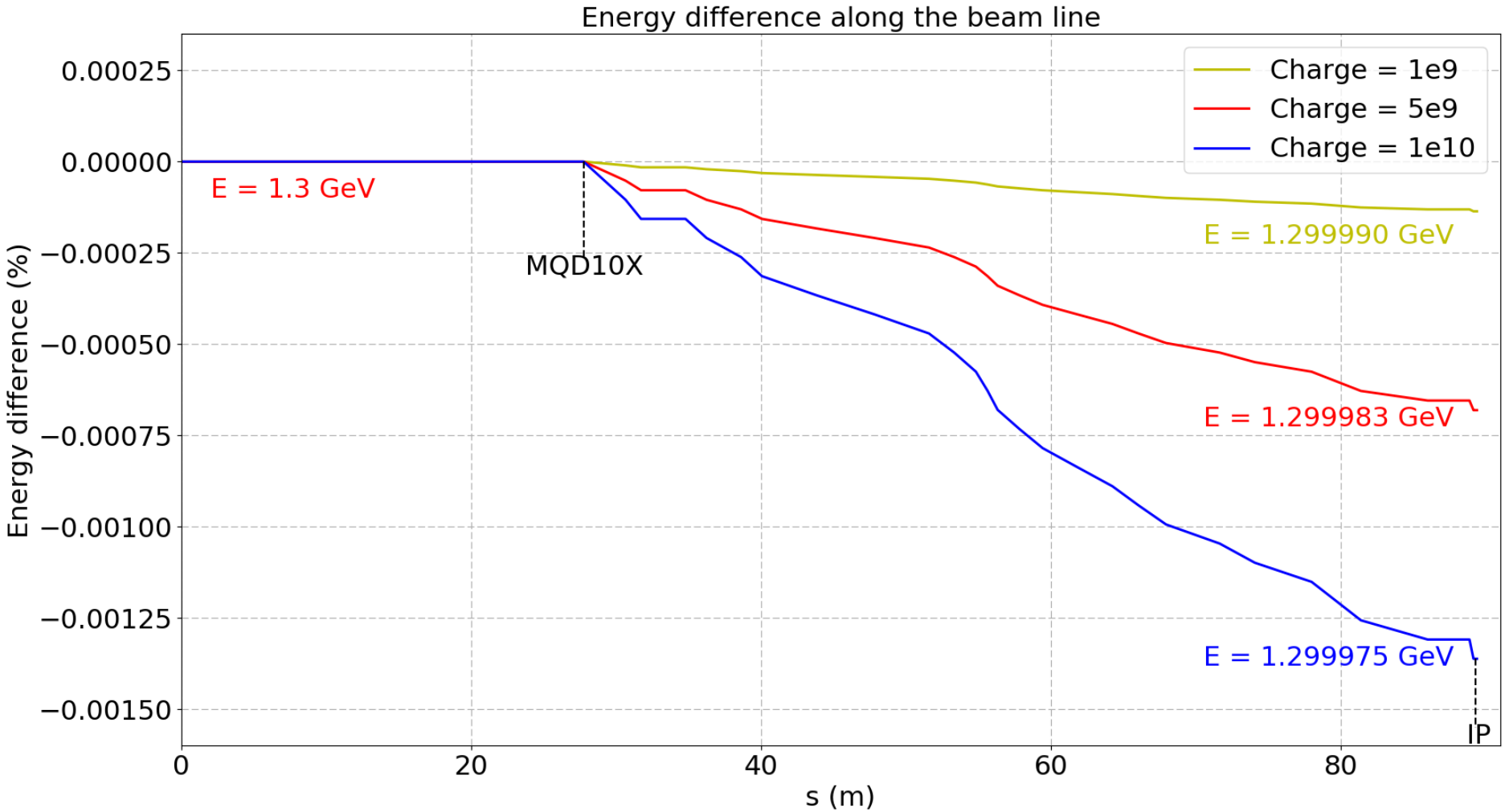


BPMs simulations



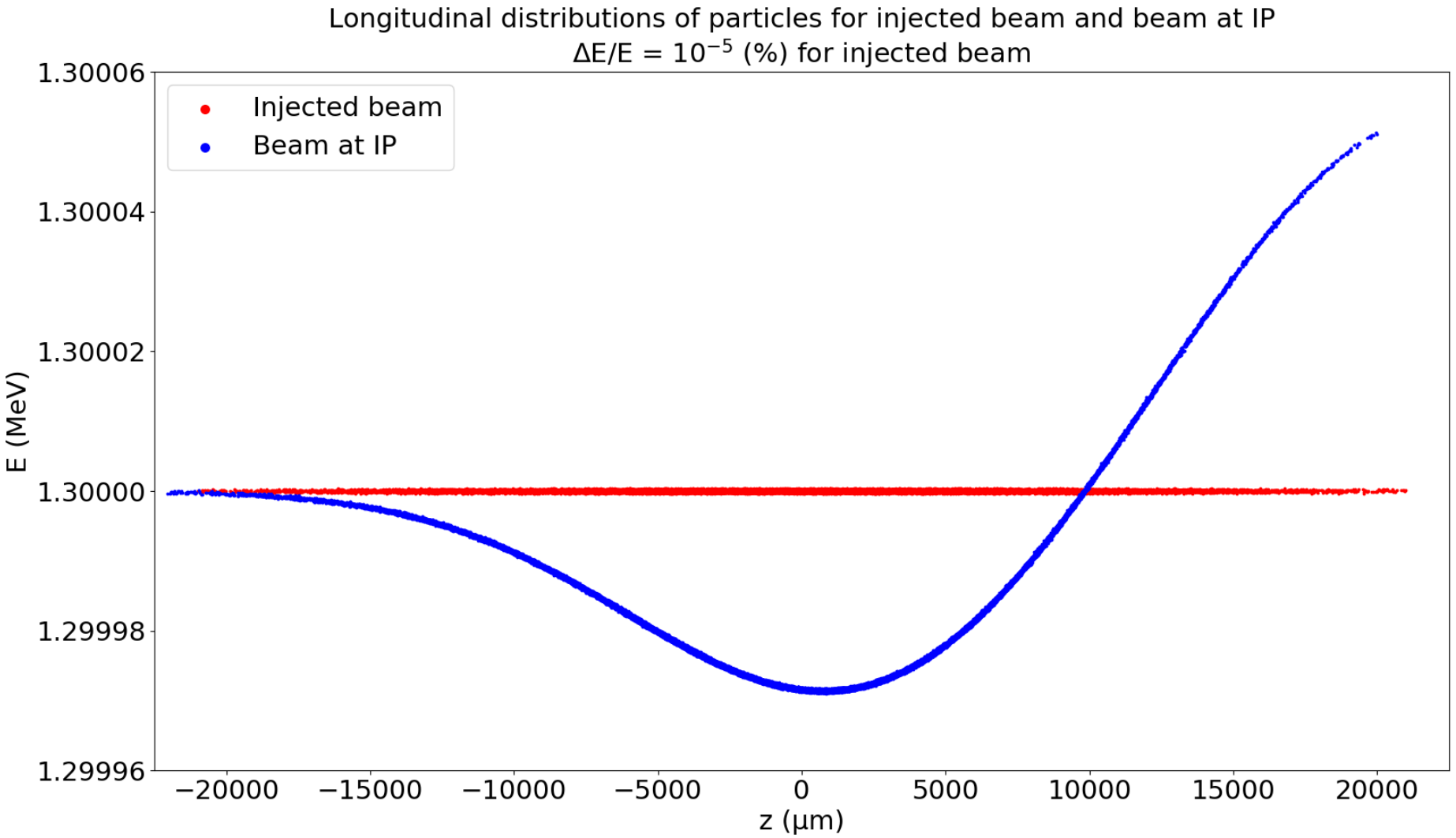
Off energy slices have a smaller standard deviation of jitters?

BPMs simulations



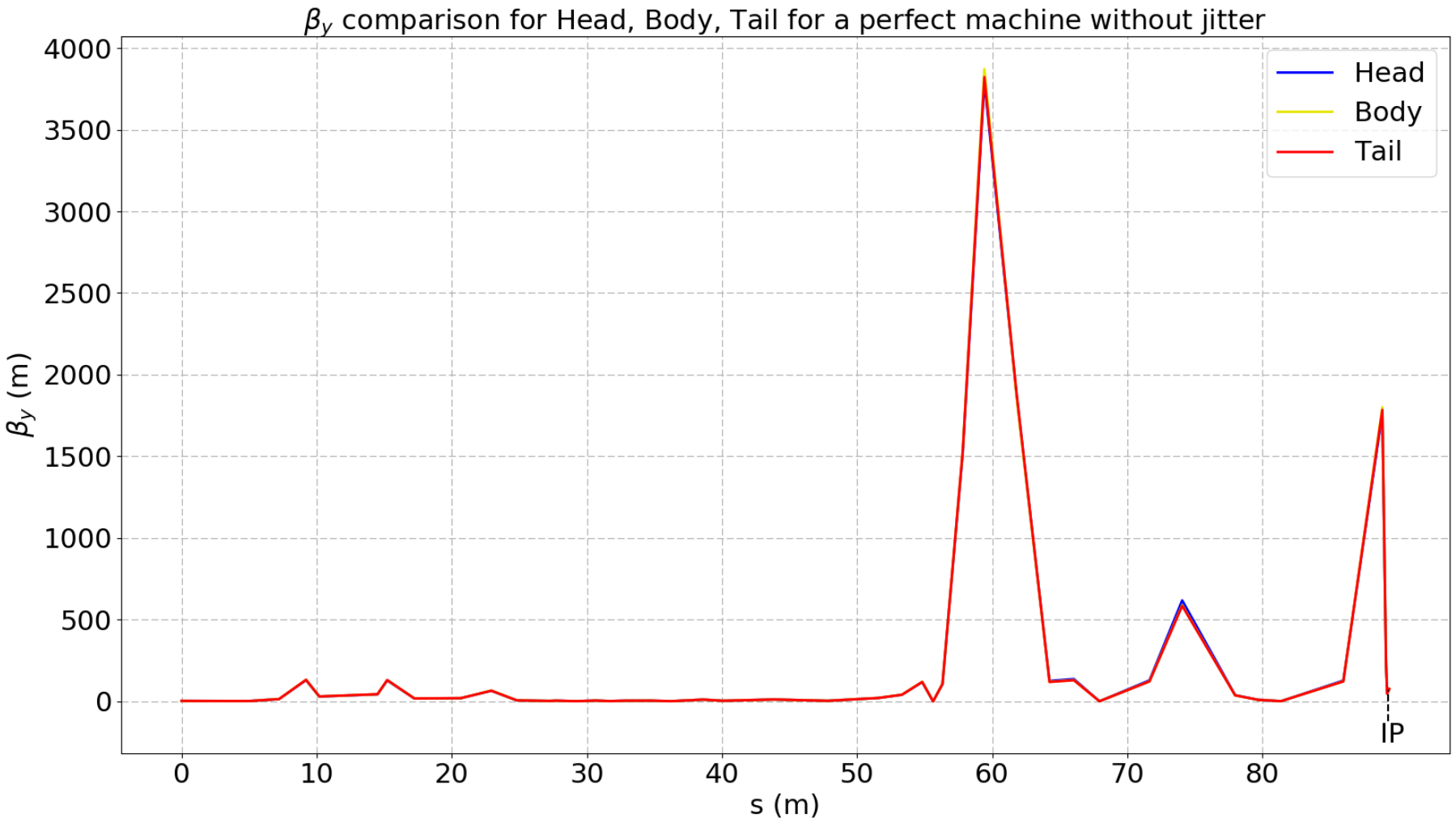
In simulations, the first source of wakefield is BPM MQD10X.

Wakefield simulations

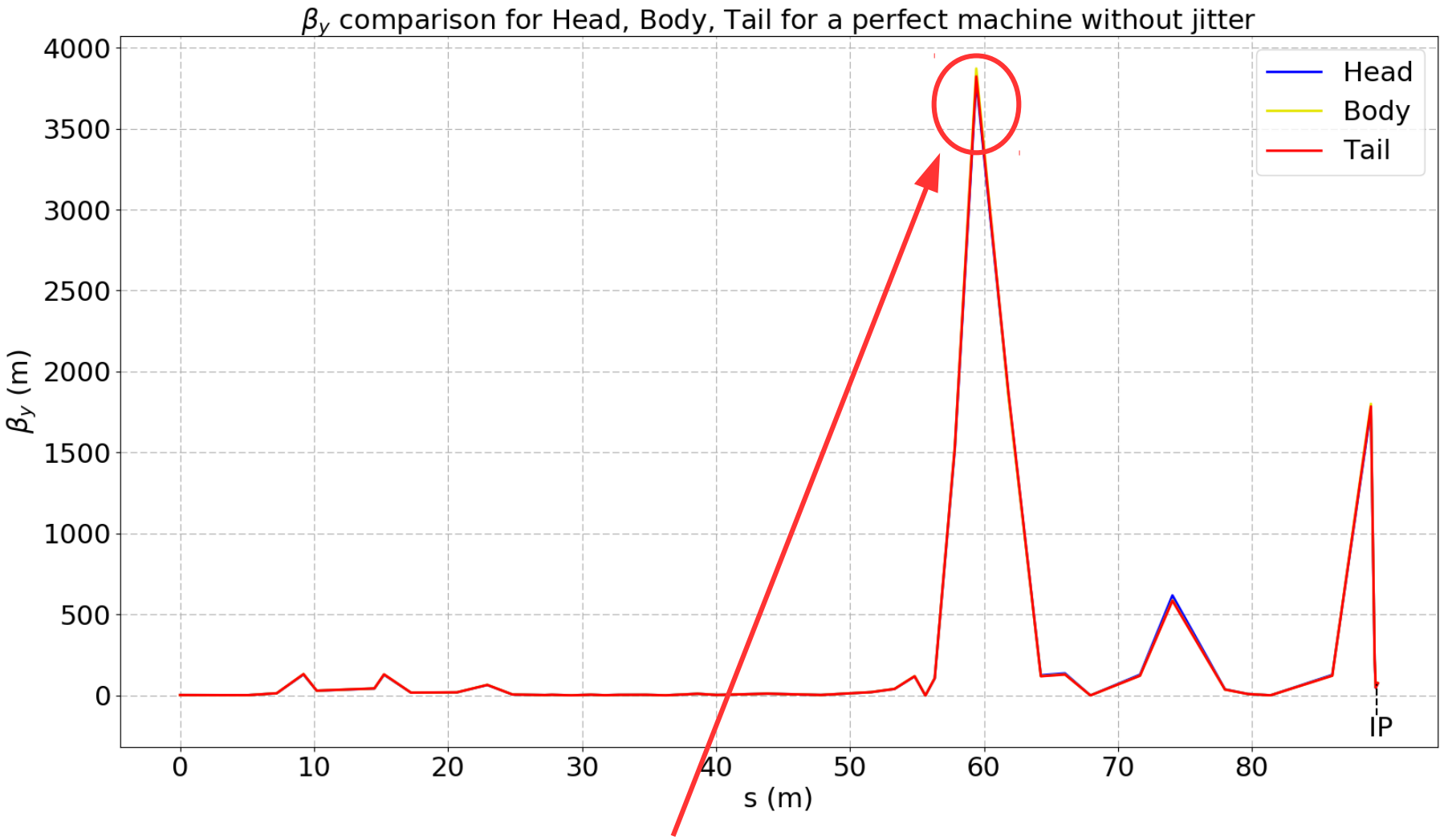


Body and tail are off-energy.
Tail has a higher energy than body.

BPMs simulations

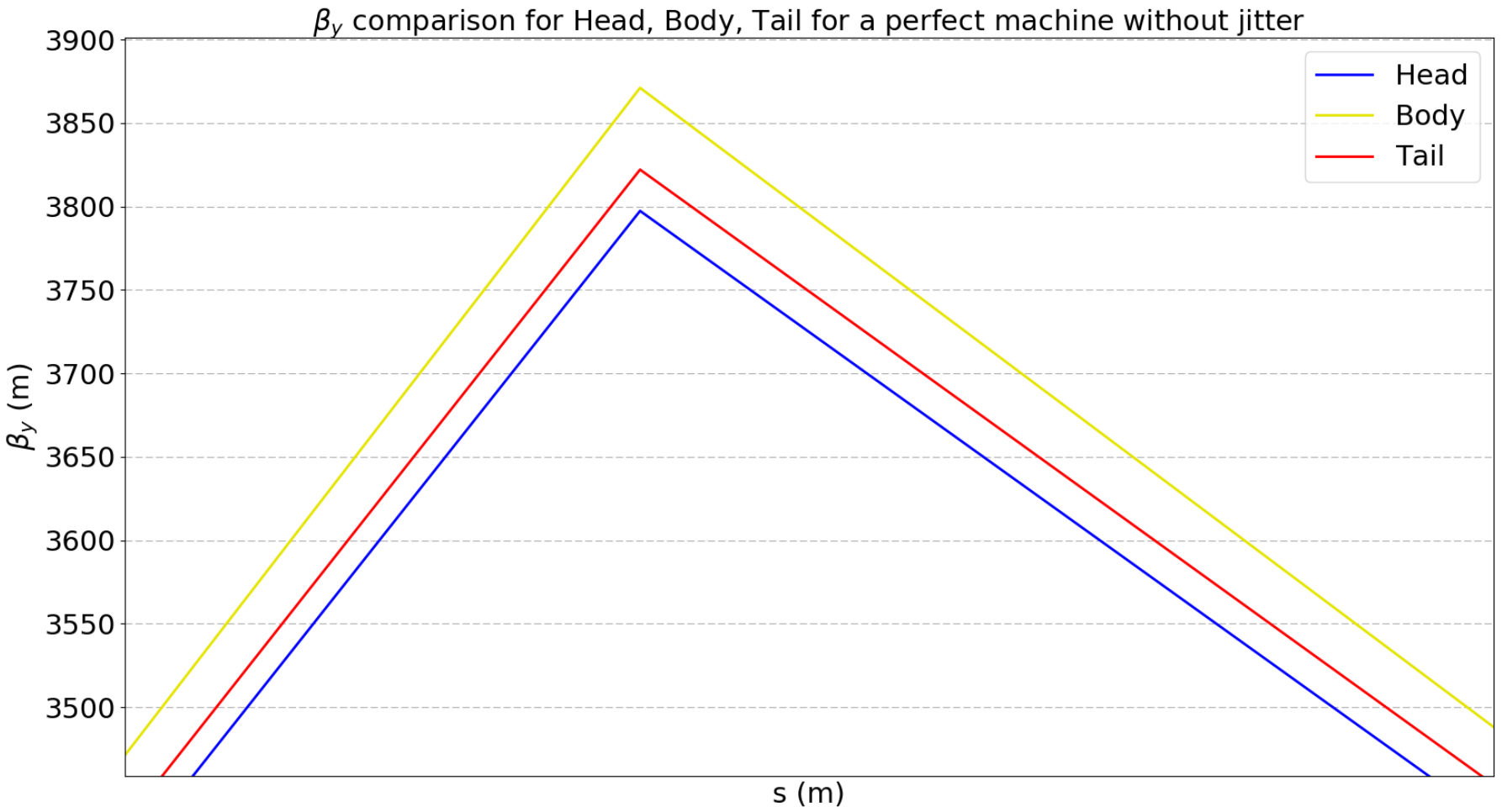


BPMs simulations



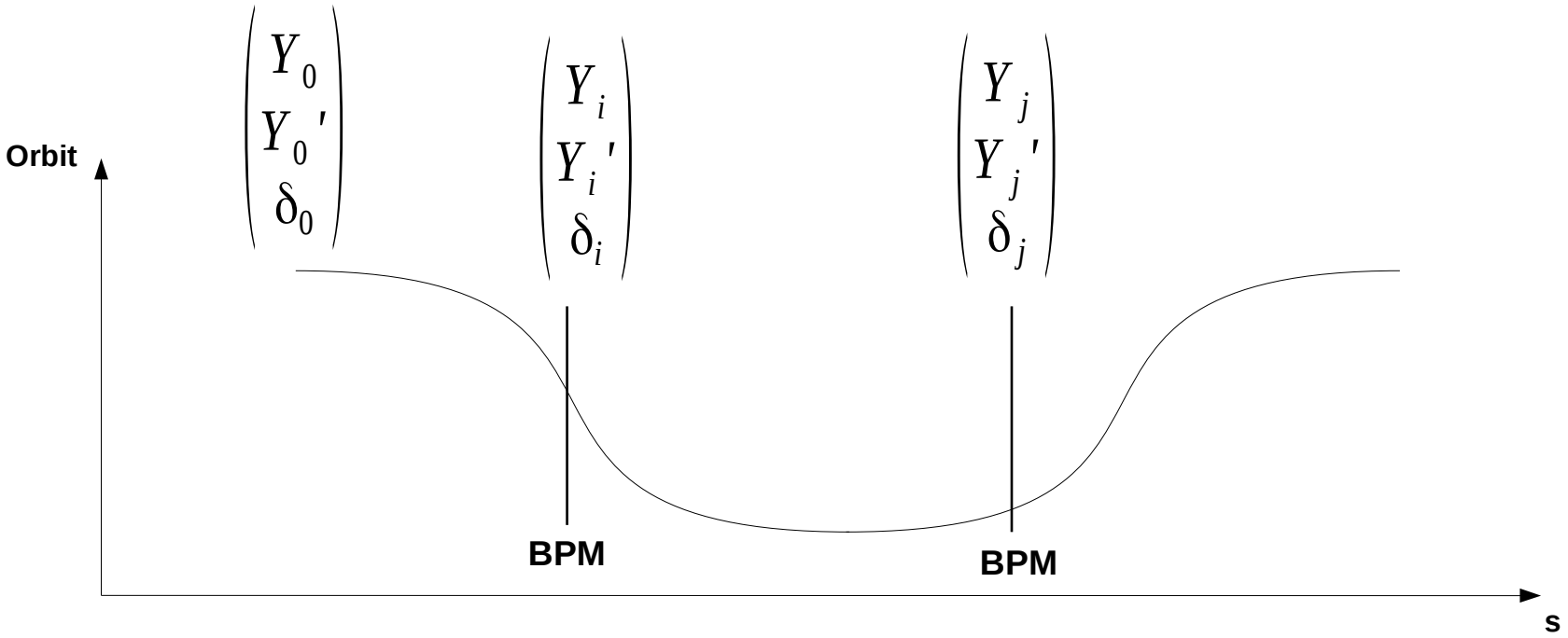
Zoom on the peak

BPMs simulations



Higher energy should lead to bigger focal length → higher beta

Calculating the initial jitter



$$\begin{pmatrix} Y_i \\ Y_i' \\ \delta_i \end{pmatrix} = R_{0\to i} \begin{pmatrix} Y_0 \\ Y_0' \\ \delta_0 \end{pmatrix}$$

$$\begin{pmatrix} Y_j \\ Y_j' \\ \delta_j \end{pmatrix} = R_{0\to j} \begin{pmatrix} Y_0 \\ Y_0' \\ \delta_0 \end{pmatrix}$$

Calculating the initial jitter

$$\begin{pmatrix} Y_1 \\ Y_2 \\ \cdot \\ \cdot \\ \cdot \\ Y_n \end{pmatrix} = \begin{pmatrix} R_{0\to 1,11} & R_{0\to 1,12} & R_{0\to 1,16} \\ R_{0\to 2,16} & R_{0\to 2,16} & R_{0\to 2,16} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ R_{0\to n,11} & R_{0\to n,12} & R_{0\to n,16} \end{pmatrix} \begin{pmatrix} Y_0 \\ Y_0{}' \\ \delta_0 \end{pmatrix}$$

$$\vec{Y} \qquad\qquad R \qquad\qquad \vec{Y}_0$$

$$\vec{Y}_0 = R \setminus \vec{Y}$$

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

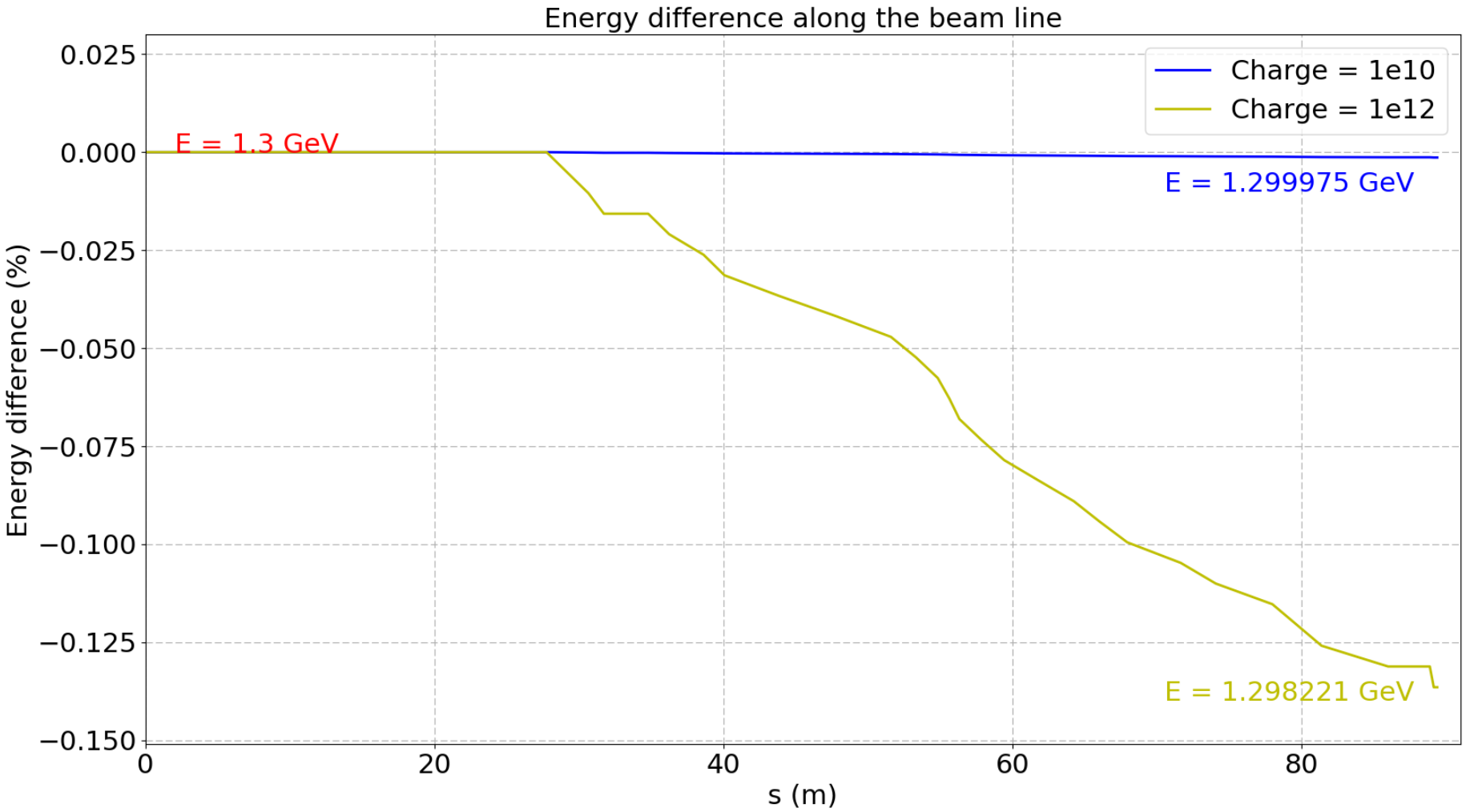
- **Pursue the studies on the intensity dependent effect observed at BPMs.**

- **Simulate the wakefield with more precision.**

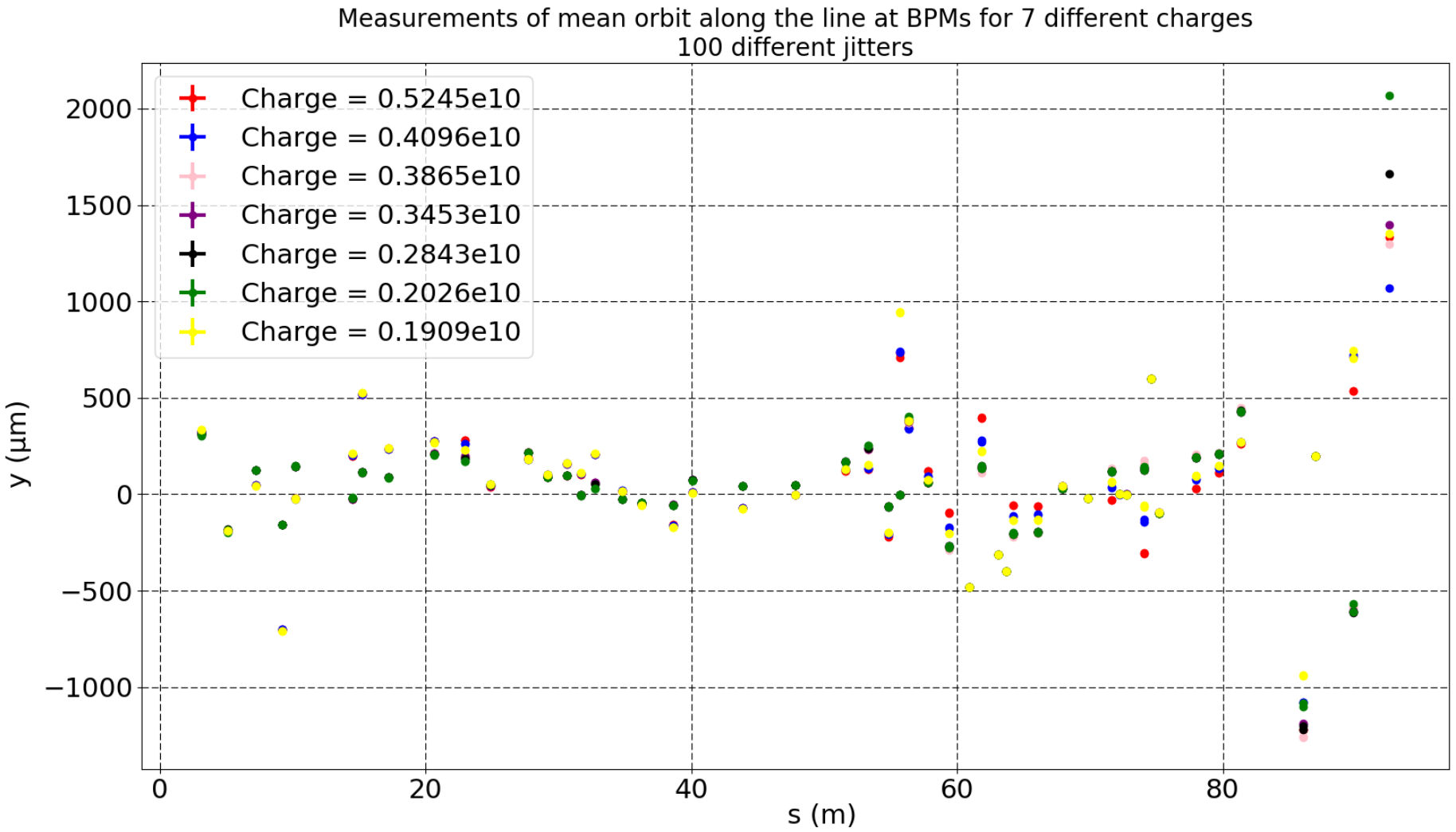
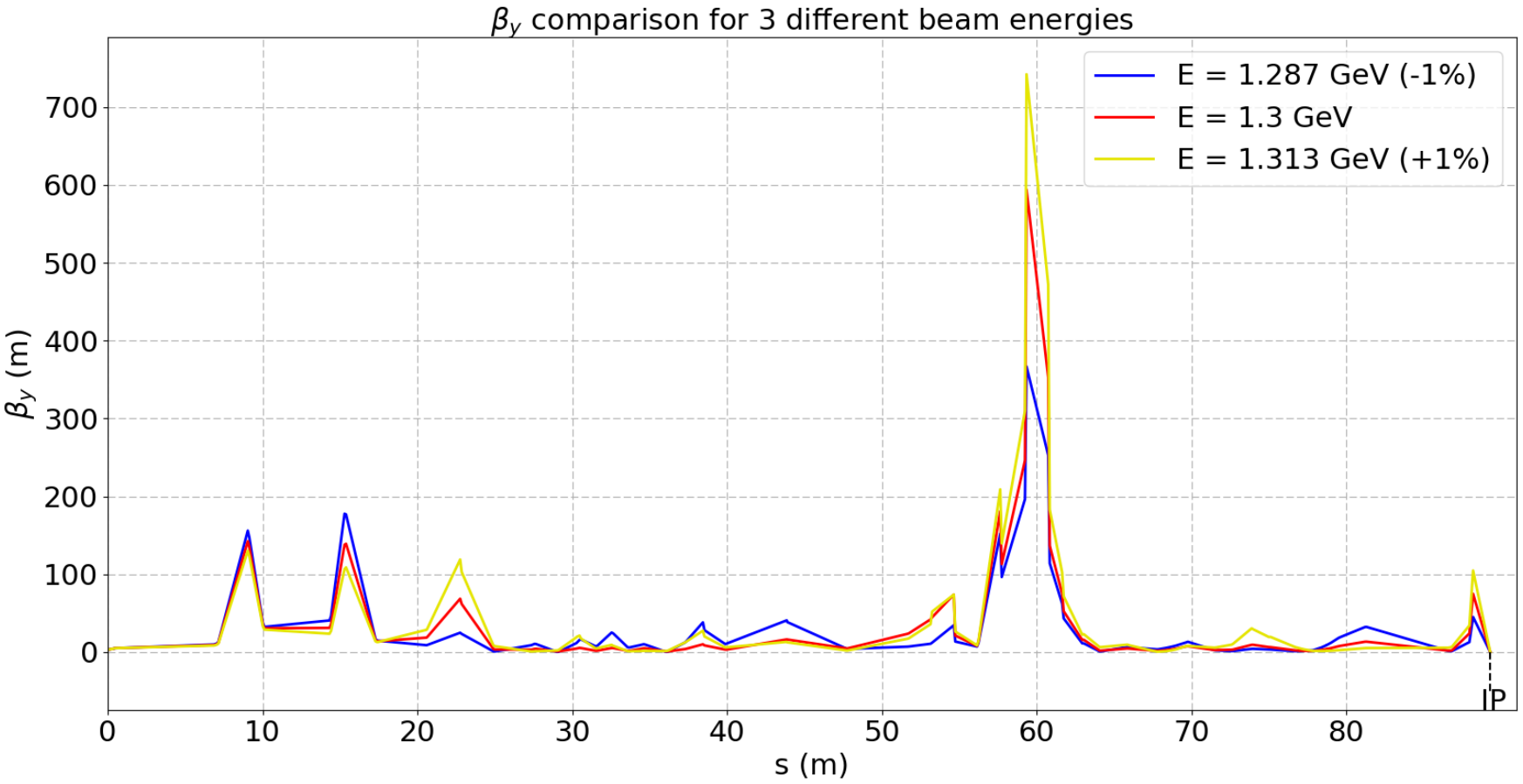
- **Try to reproduce in simulation the measured intensity dependence plot.**

- **Assess incoming beam jitter from experimental data.**

Backup slides



Backup slides



Backup slides