Ballistic Orbit at FLASH: Latest Results

P. Castro (MPY)

Contents of this talk:

- What ballistic orbit is
- Our Motivation
- A little bit of history
- Last Results
- Outlook

What ballistic orbit is:

a beam trajectory in absence of electromagnetic fields

…and therefore straight*

(* actually parabolic due to earth gravity, $\Delta x = 0.05$ Å)

Problems and limitations:

with aperture of vacuum chamber:

- quad focusing is off, a special optics is needed

with stray fields:

- earth magnetic field
- remanent fields of getter pumps, etc.
- EMI from cables
- self-induced wakefields
- undulators have 'weak focusing'

The usual MOTIVATION …

Ballistic orbit is used to align accelerator components:
quads, BPMs, etc. (ex: see linear collider papers)

It could be used in XFEL for SASE operation
(see XFEL talk by V. Tsakanov, 3rd Sep.2008)

… but is not OUR primary motivation

Our primary MOTIVATION

to investigate the 'horizontal trajectory problem'
in the undulator

to investigate the relative alignment of the
undulator axis w.r.t. the accelerator (hor. and ver.)

FLASH logbook (10.Nov.2008): E.Schneidmiller wrote:

"between 1 and 2.5 mm above the cross of Ce:YAG screen…
…a factor two in SASE intensity more than in the middle
of the cross"

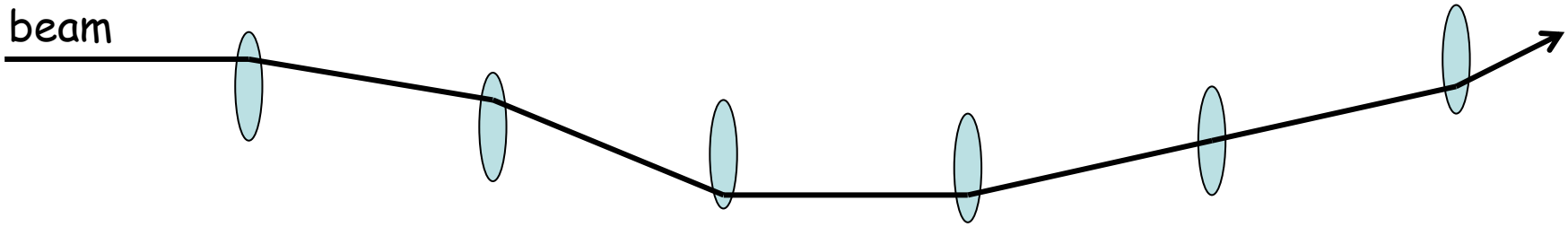
about 50 μrad from undulator axis

A little bit of history:

2005 Beam-based alignment in undulator section:

1) measure relative offset between quads and BPMs
2) center quads to the beam

Procedure



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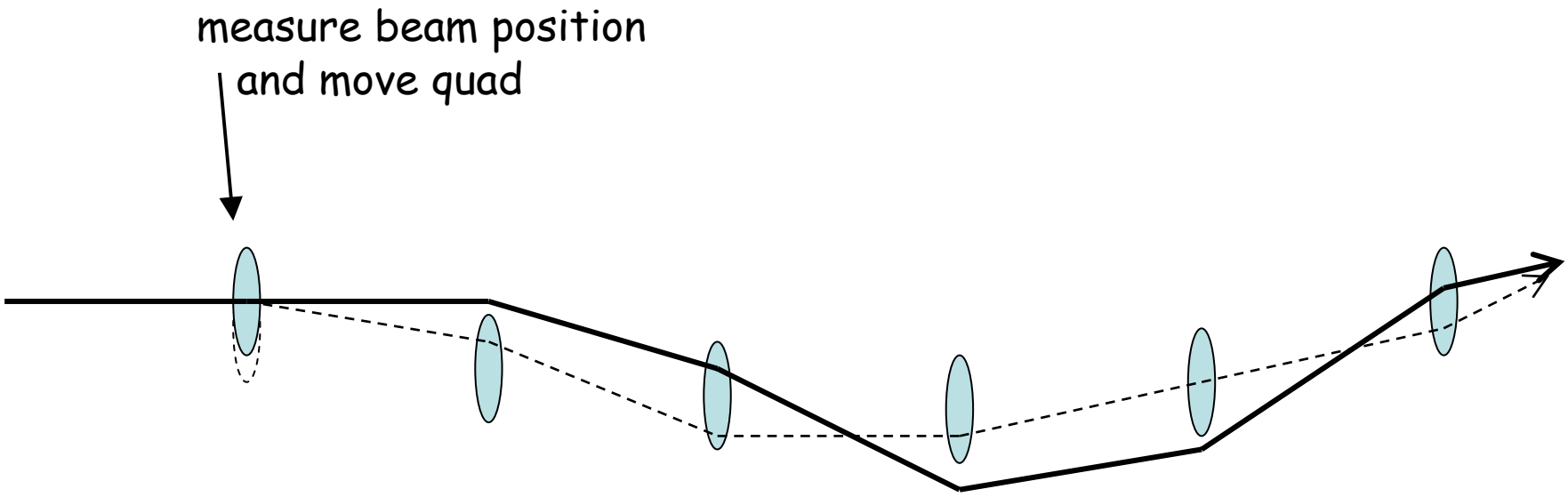

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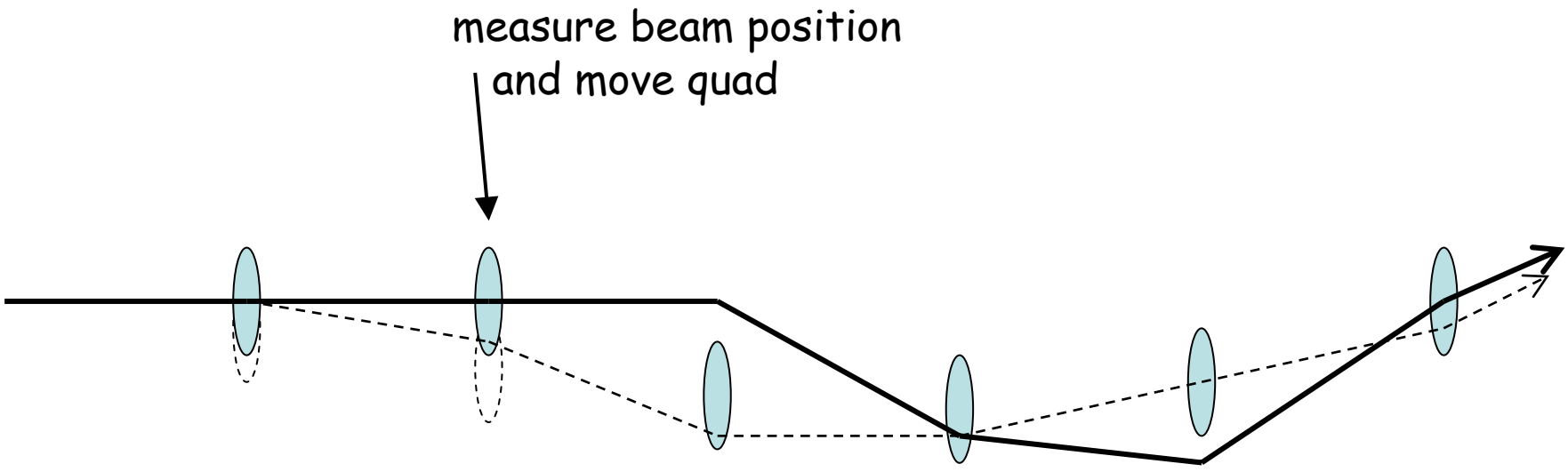

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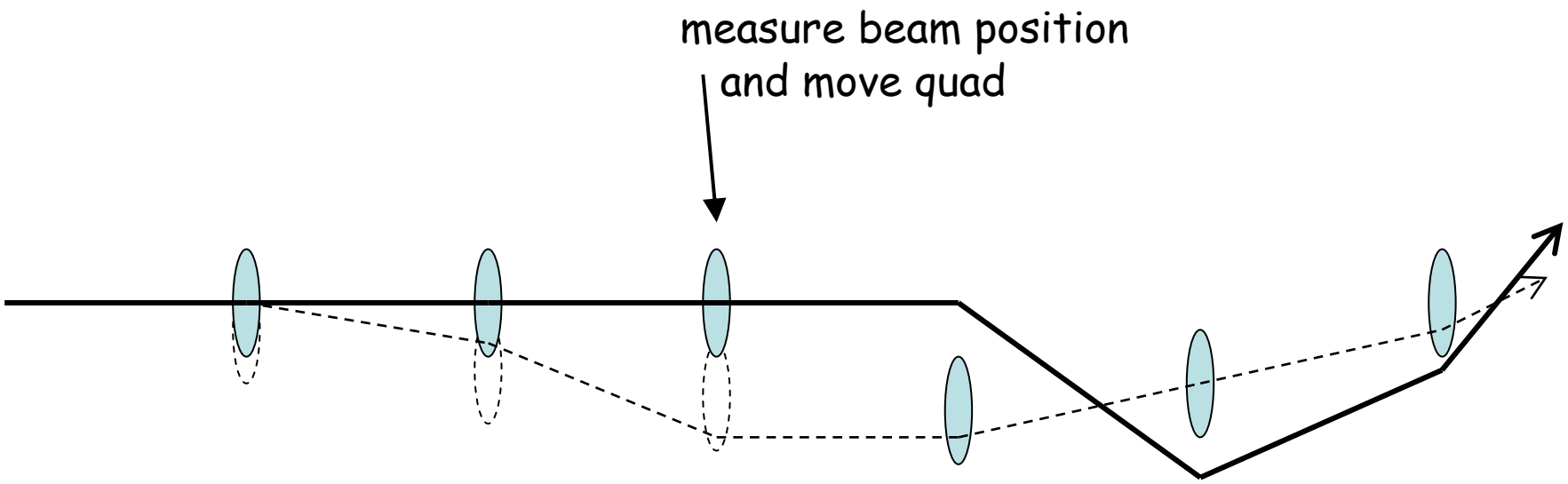

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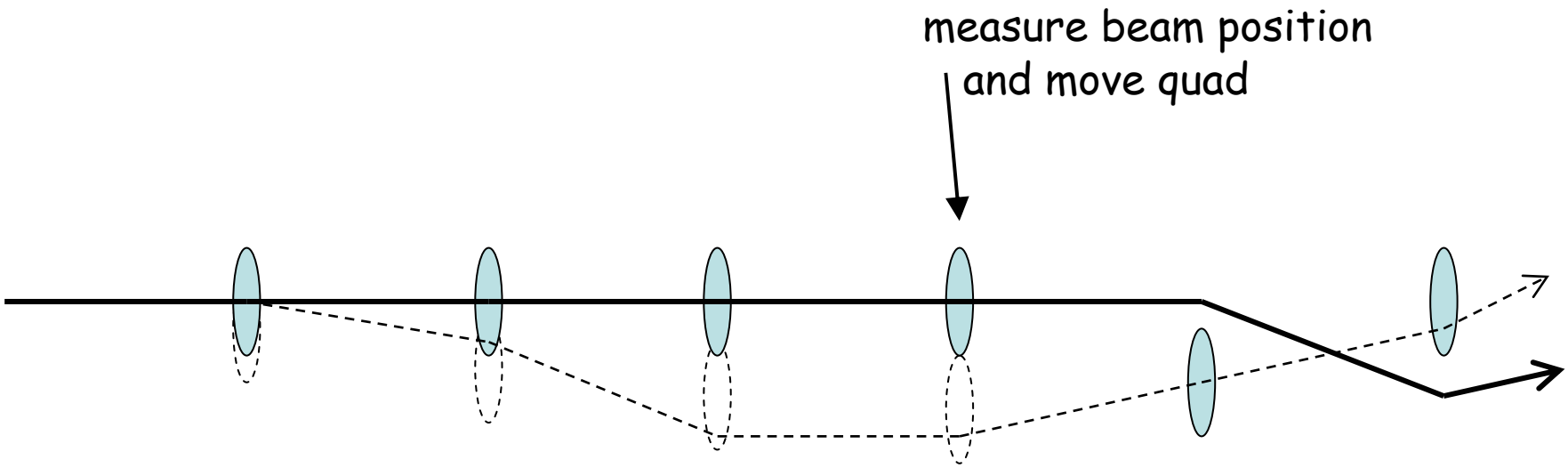

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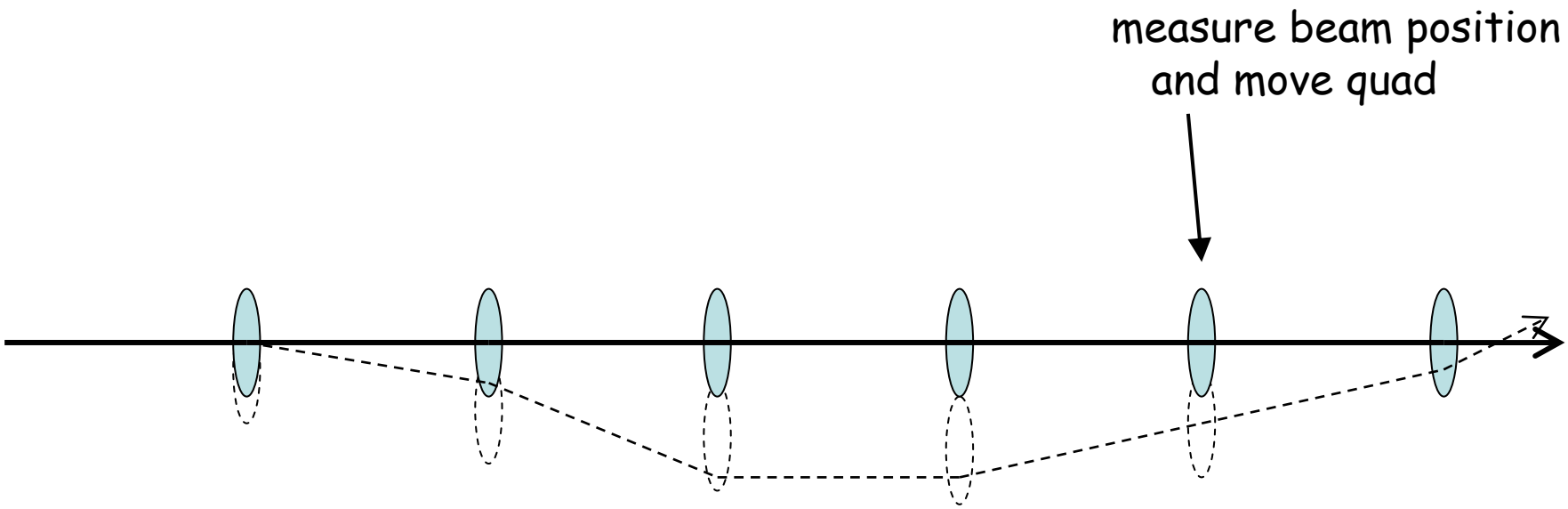

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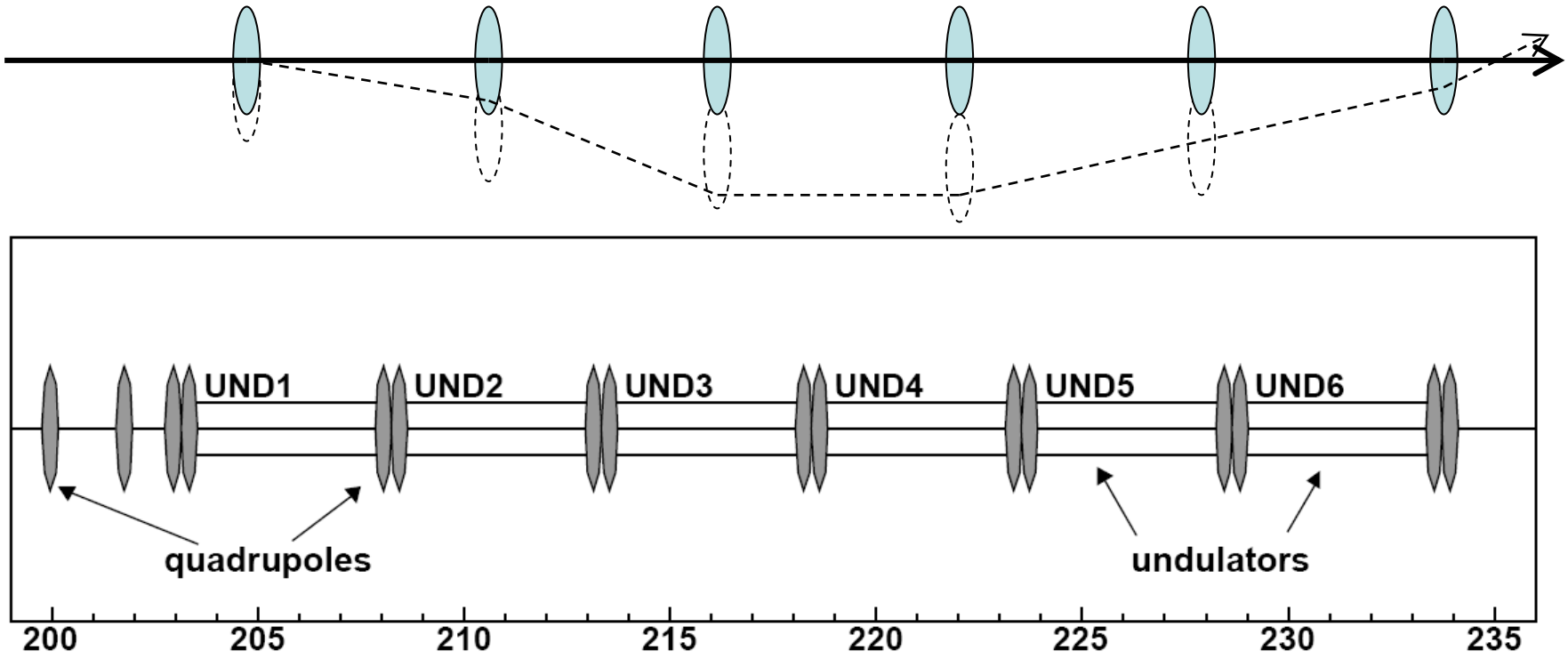

UND1
UND2
UND3
UND4
UND5
UND6
quadrupoles
undulators
200
205
210
215
220
225
230
235

A little bit of history:

2005 Beam-based alignment in undulator section:

1) measure relative offset between quads and BPMs
2) center quads to the beam

Problem: (2) failed in the horizontal plane

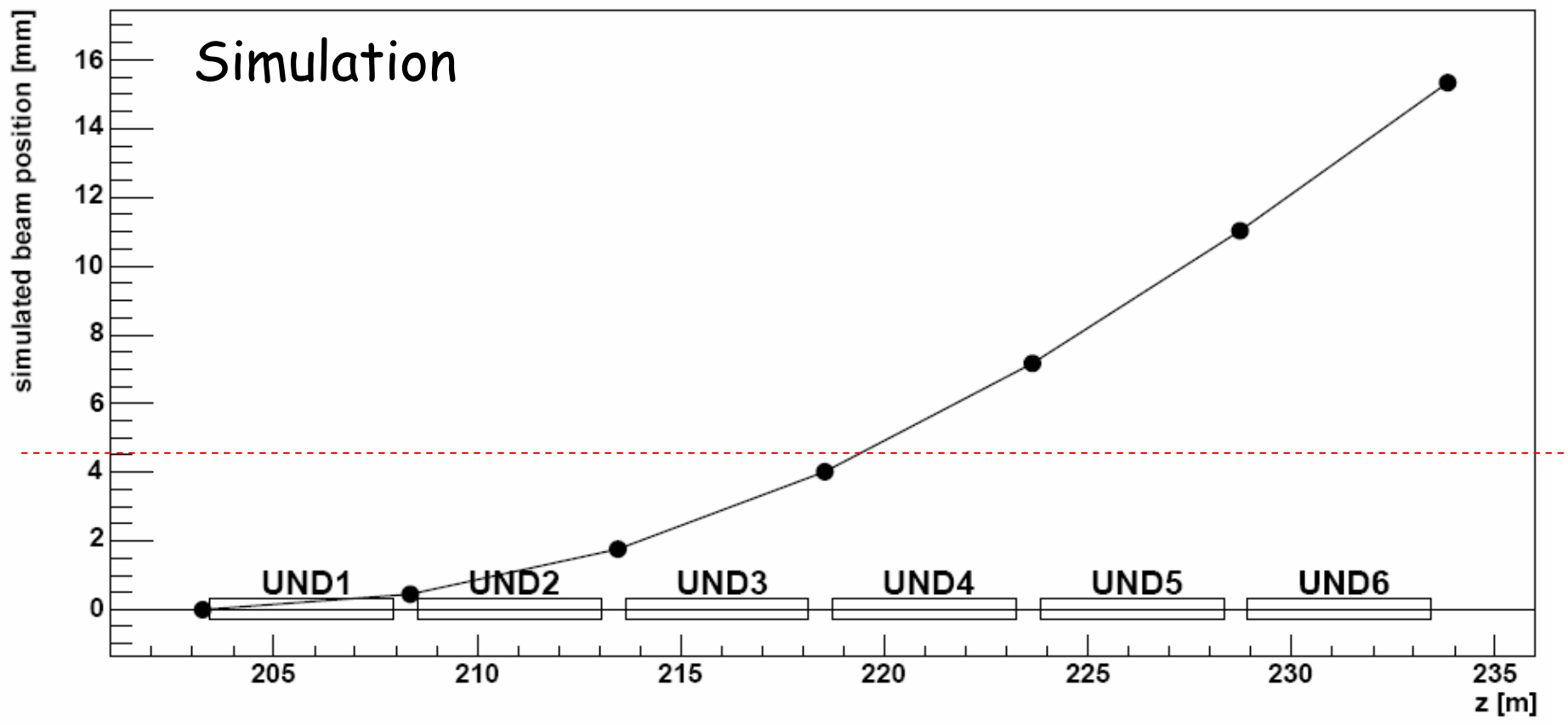
2006 1st ballistic trajectory in FLASH undulator section

The (dirty) trick: using hor. steerers (H3UND…)
(which explains the previous problem)

Problem: the steerer strength needed is large

An equivalent steerer strength will do this:

Beam deflection $\Delta x' \sim 1.1$ mrad at 0.7 GeV



Assuming: zero position and angle at the entrance !

Possible reasons (speculations and hypotheses):

1) a stray magnetic field along the undulator

direction: pointing to the ceiling

0.4 T.mm per undulator segment or 0.8 Gauss

J. Pflueger: impossible!

measured 2nd field integral < 10 T.mm²

(equivalent to Δx=10 μm at 1 GeV)

<u>To check:</u>

a stray field is independent of beam energy

→ the compensation has to be also independent

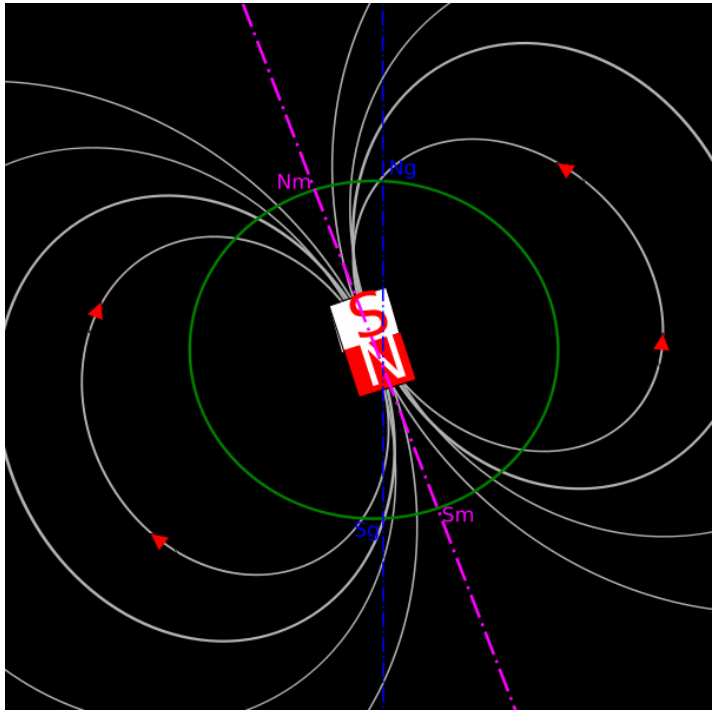
Possible reasons (speculations and hypotheses):

1) a stray magnetic field along the undulator

direction: pointing to the ceiling

0.4 T.mm per undulator segment or 0.8 Gauss

Earth magnetic field?



in Hamburg: about 0.3 Gauss

vert. component:

pointing down, < 0.3 Gauss

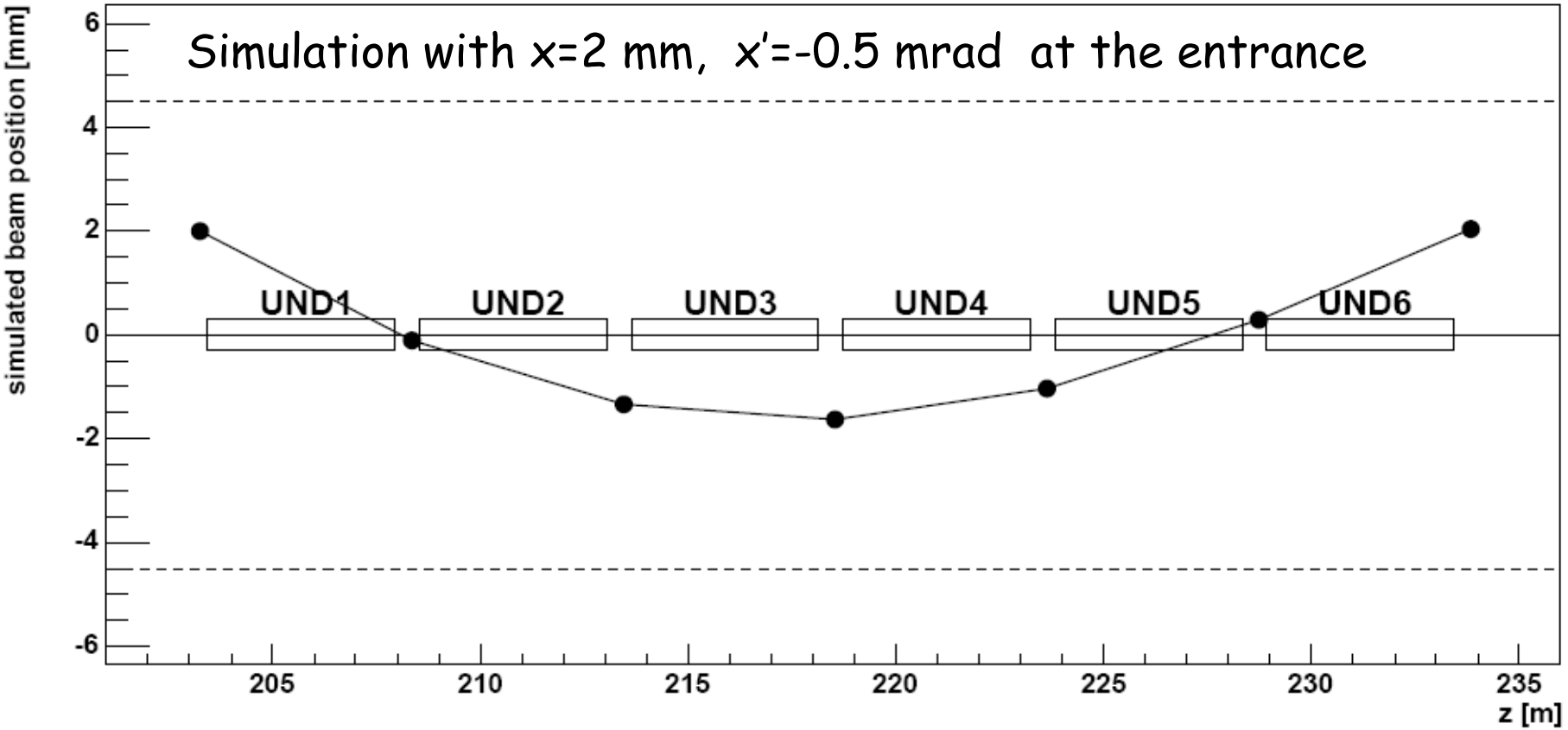
hor. component:

parallel to FLASH

direction dump

Possible reasons (speculations and hypotheses):

2) a strong kick upstream of undulator



However: beam position meas. do NOT show that

To check: switch off all magnets upstream → ballistic orbit

Possible reasons (speculations and hypotheses):

3) the undulator axis is bent to an arc
about 1.1 mrad in 30 m (or 15 mm offset)

To check: the compensation has to be proportional to E

To decide which is the most plausible hypothesis:

- extend the ballistic trajectory upstream the und.

- do the experiment at high and low beam energies

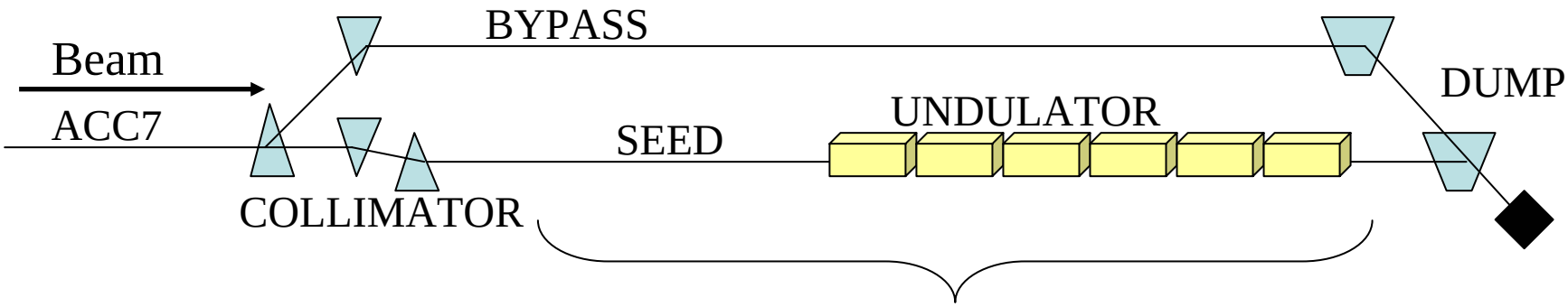
… and this we have done in Nov. 2008

‘Extended ballistic’ experiment (Nov. 2008):

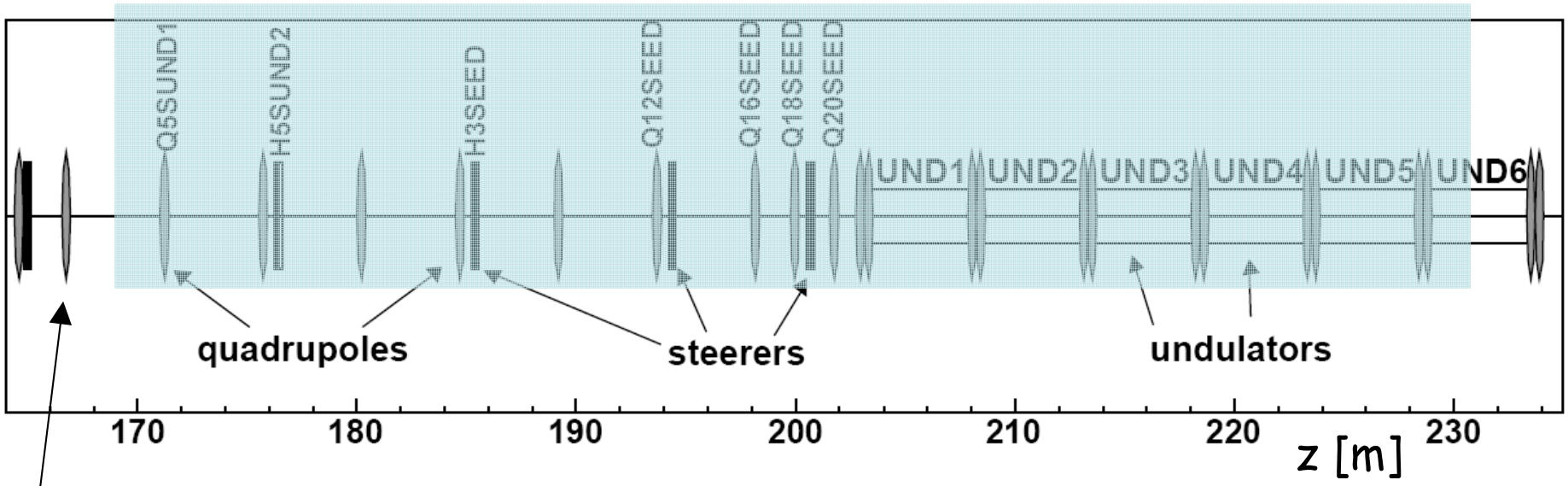
V. Balandin, B. Faatz, N. Goluveba

thank you!

'Extended ballistic' experiment (Nov. 2008):



all quads and steerers degaussed (except H3UND...)



last magnet on

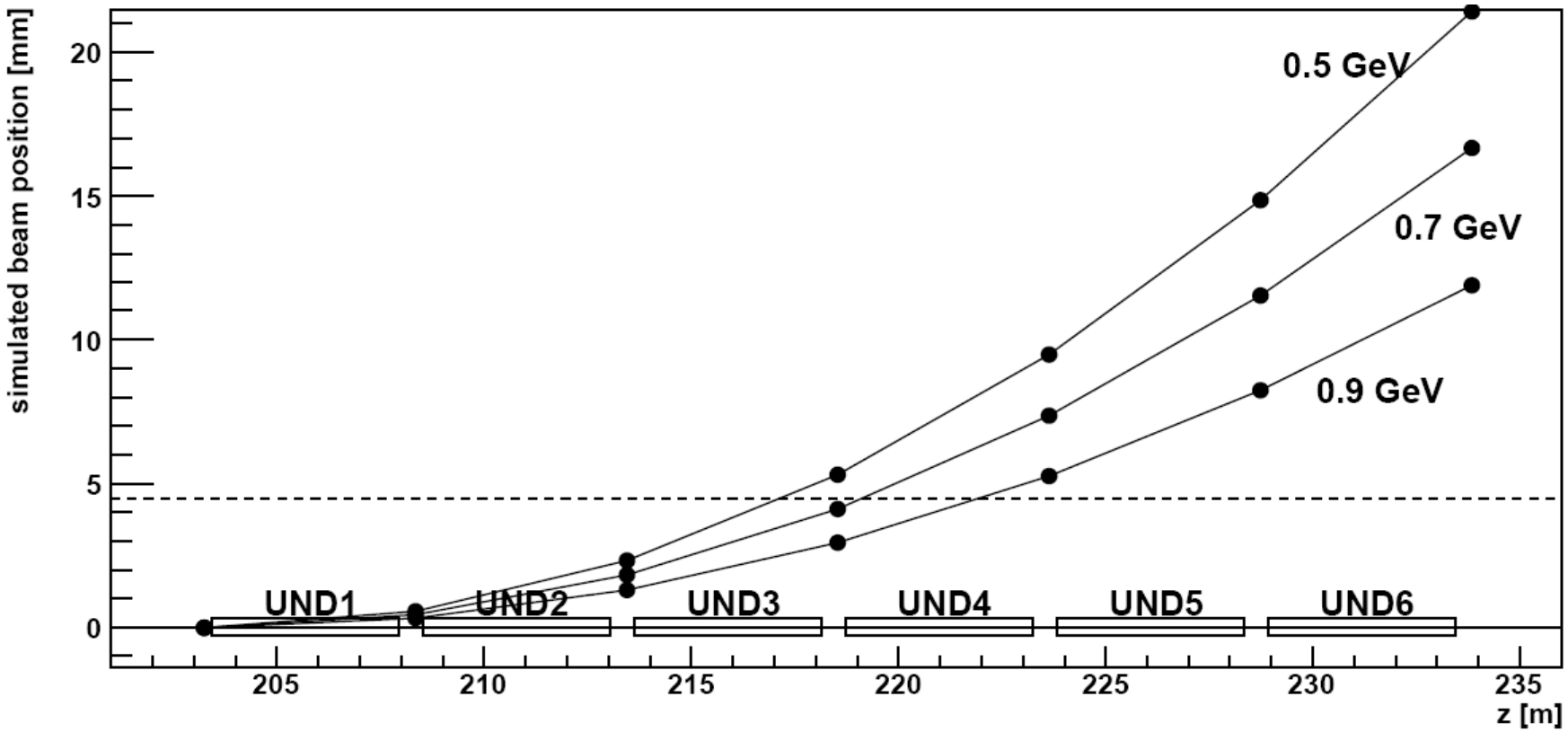
Results from 'Extended Ballistic Orbit' Experiment

1) Dependence on beam energy:

Beam Energy	Steerer current needed
0.5 GeV	-3.8 ± 0.1 A
0.9 GeV	-3.7 ± 0.1 A

Results from 'Extended Ballistic Orbit' Experiment

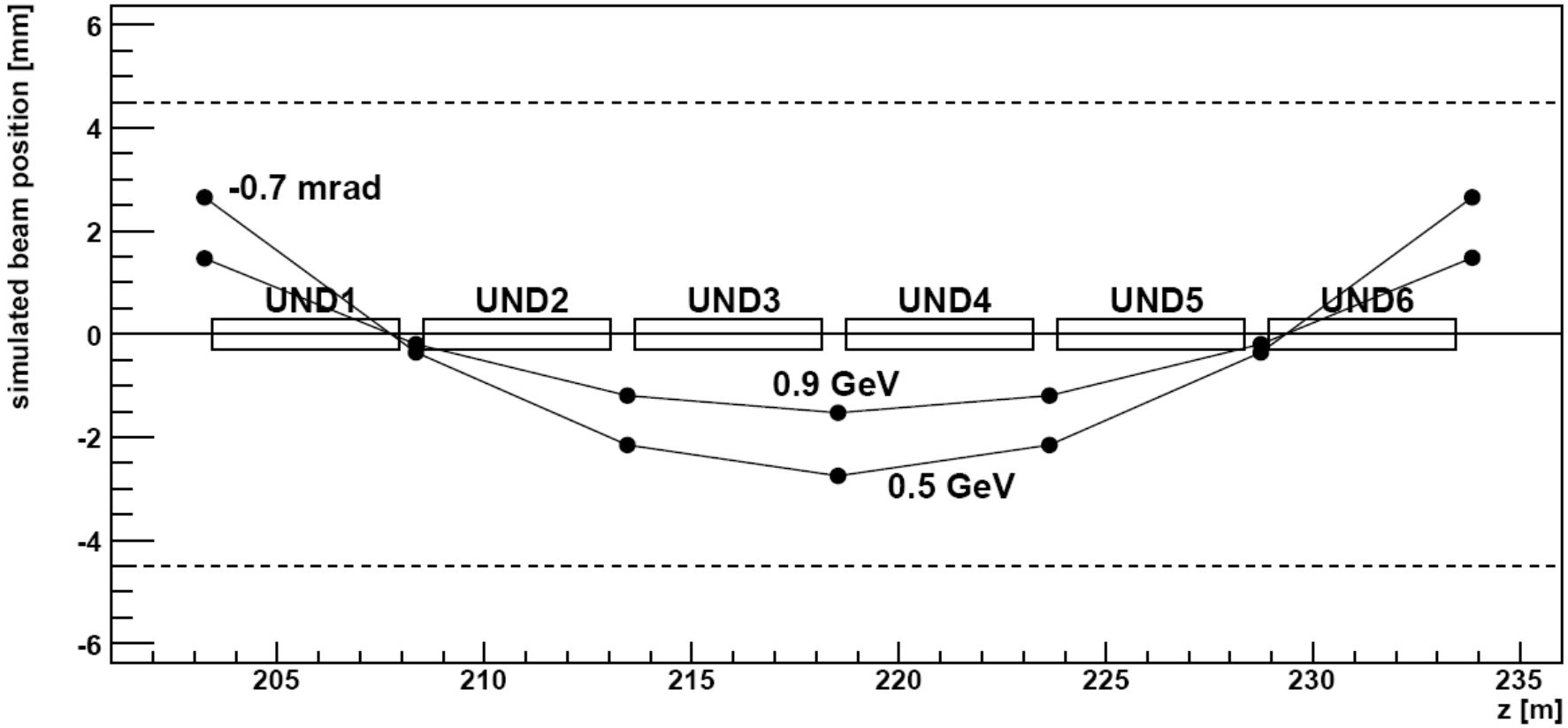
1) Dependence on beam energy:



Results from 'Extended Ballistic Orbit' Experiment

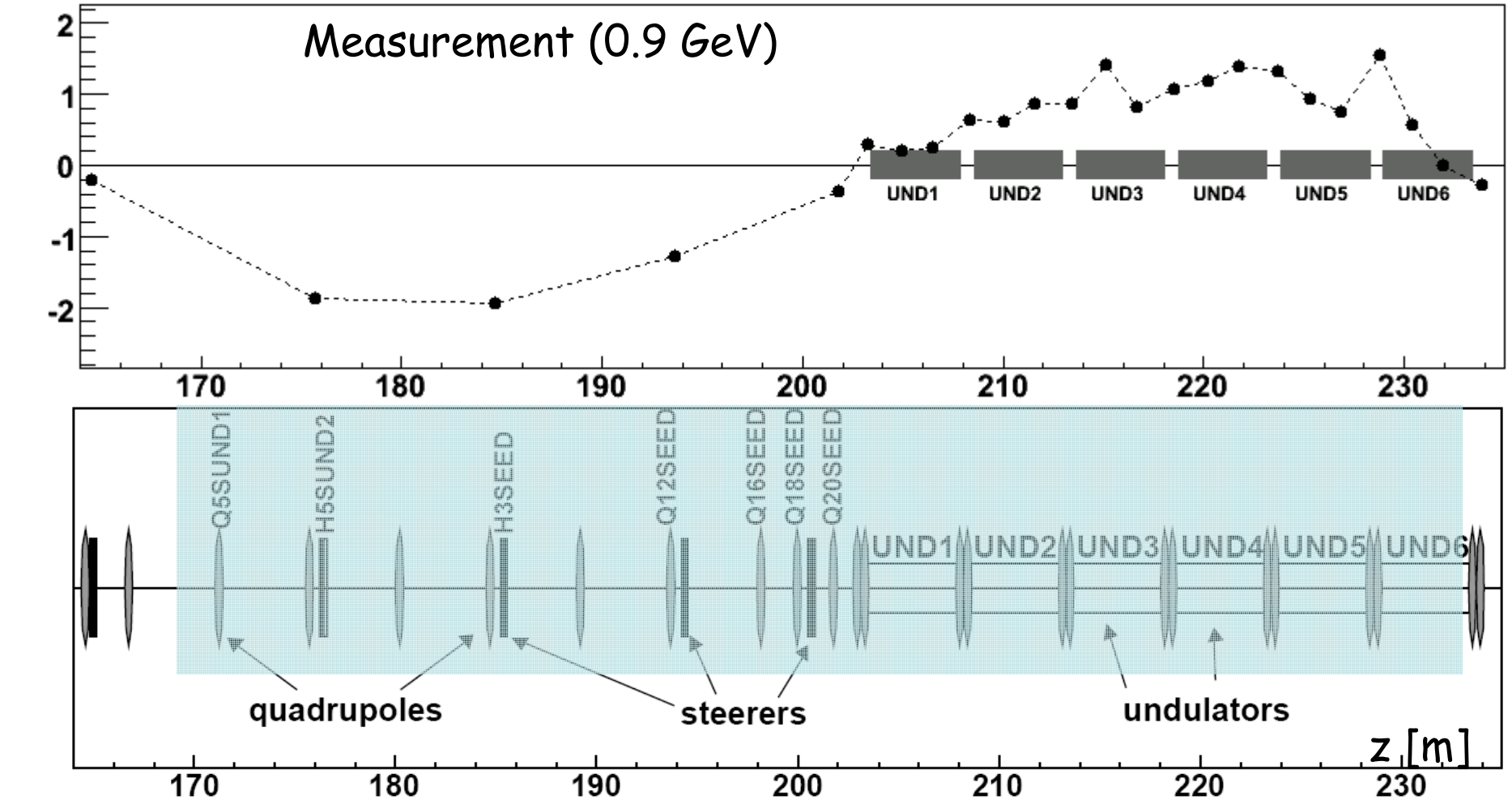
1) Dependence on beam energy:

hypothesis (2) a strong kick upstream of undulator ?



Results from 'Extended Ballistic Orbit' Experiment

2) Horizontal trajectory: BPM offsets ?



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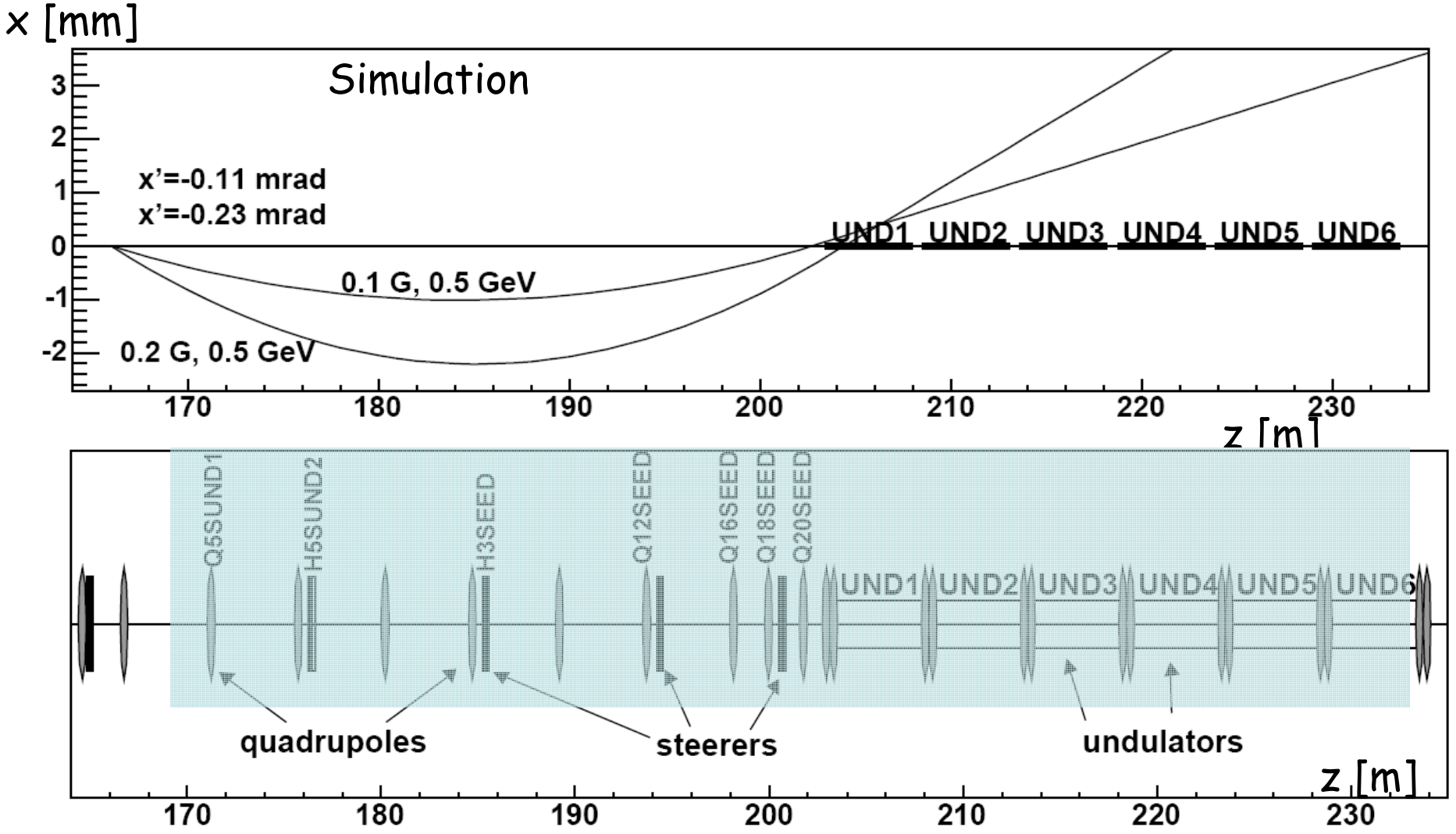

Results from 'Extended Ballistic Orbit' Experiment

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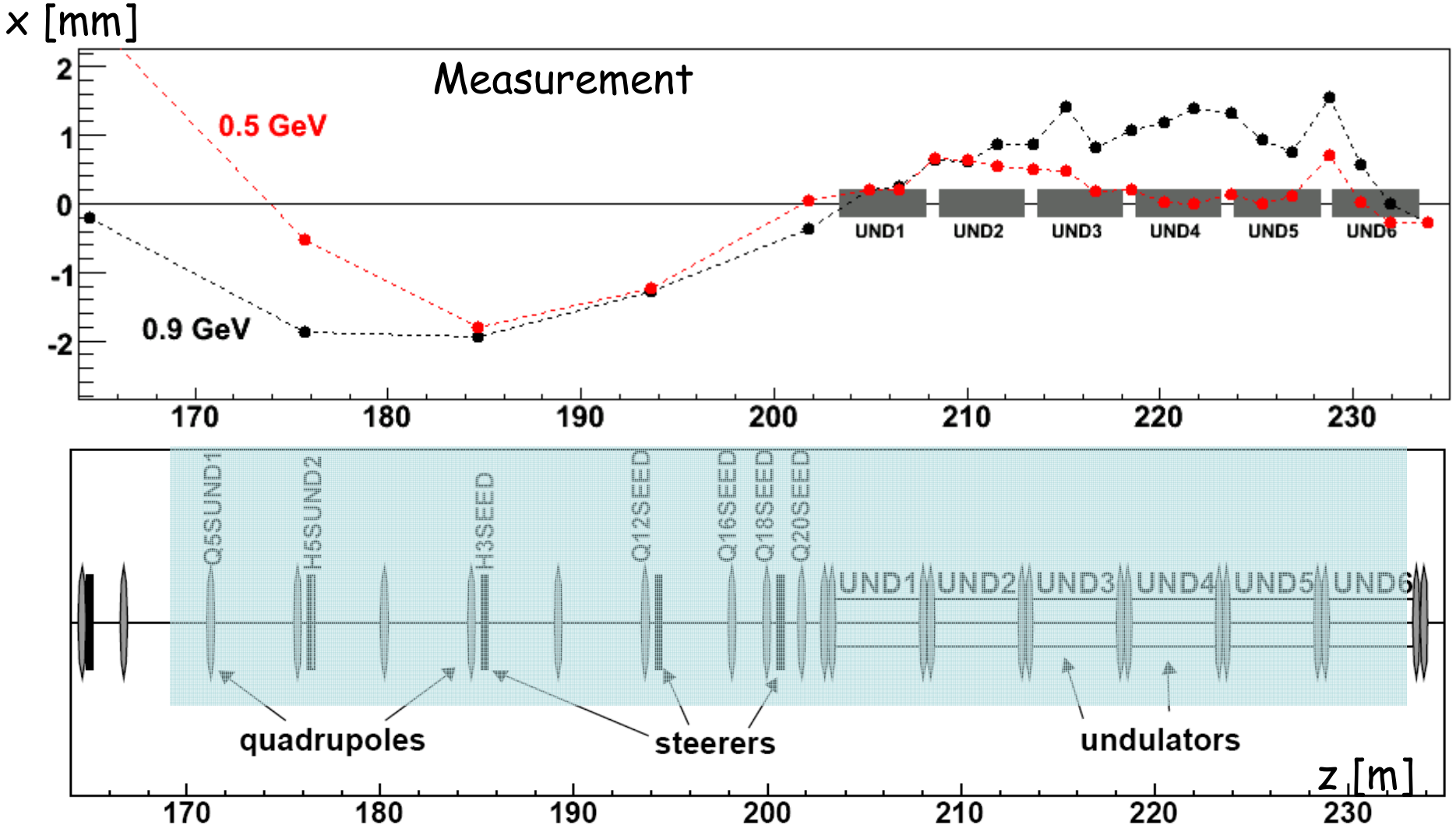


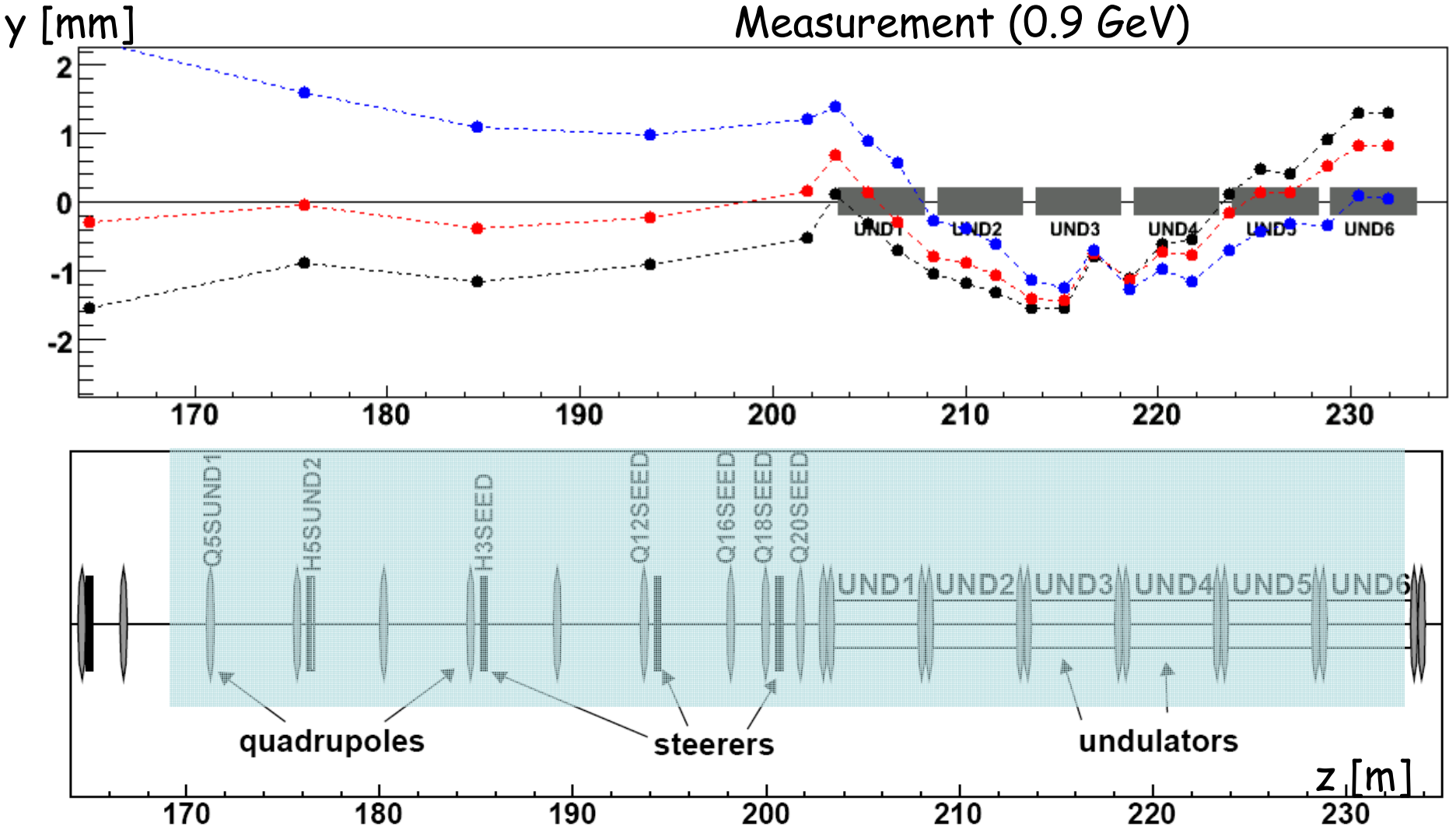
Results from 'Extended Ballistic Orbit' Experiment

2) Horizontal trajectory: BPM offsets ?

a precise measurement of mag. field
in the FLASH tunnel is <u>needed</u>

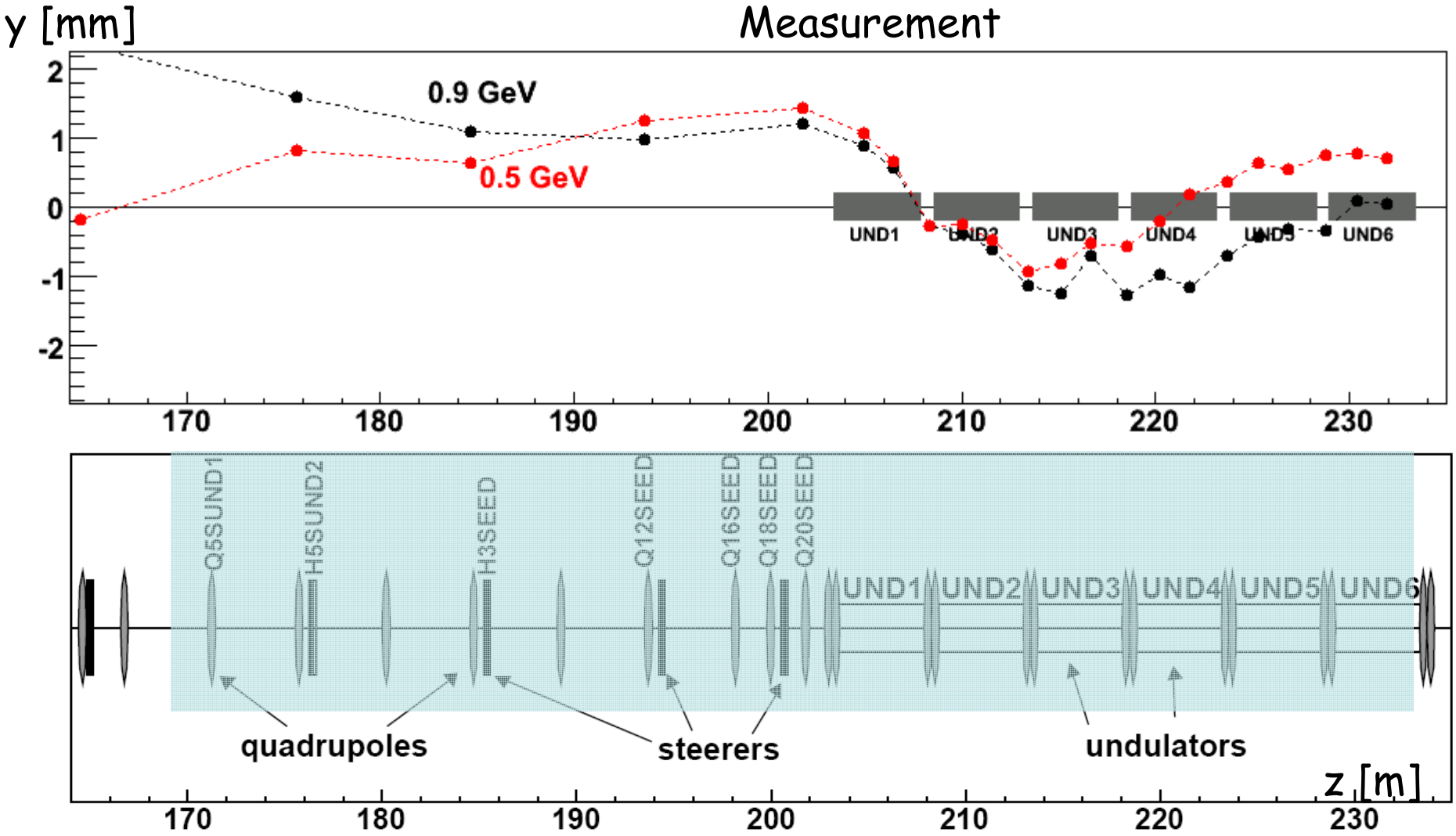
Results from 'Extended Ballistic Orbit' Experiment

3) Vertical trajectory: fits with E.Schneidmiller observation?



Results from 'Extended Ballistic Orbit' Experiment

3) Vertical trajectory:



Conclusions and Outlook

1) The horizontal steering needed along the undulator is independent of beam energy

… in my opinion:

hypothesis	**probable?**
stray field	++
bent trajectory	-
bent undulator axis	- - -

Solutions:

- use always steerers with same currents
- add a coil along the undulator

Suggestions:

- measure undulator field inside tunnel

Conclusions and Outlook

2) A ballistic orbit can be used to align BPMs, quads upstream the undulator if we know the strength of the earth magnetic in the FLASH tunnel (vertical comp.)

(→ this could be a nice work for a summer student)

3) Does the meas. vertical trajectory along the undulator fit with the observations of E. Schneidmiller ?

"optimum SASE between 1 and 2.5 mm above the cross of Ce:YAG screen" (any ideas?)

4) Dispersion measurements: What can we learn?

expected problems:

- incoming dispersion
- enough BPM resolution
- (if combined with BO) sensitive orbit, small ΔE

(→ this could be a nice work for a 'Diploma' student)

Thank you for your attention !

pedro.castro@desy.de