Beam loss study for the implementation of dechirper at the European XFEL

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Beam dynamics meeting
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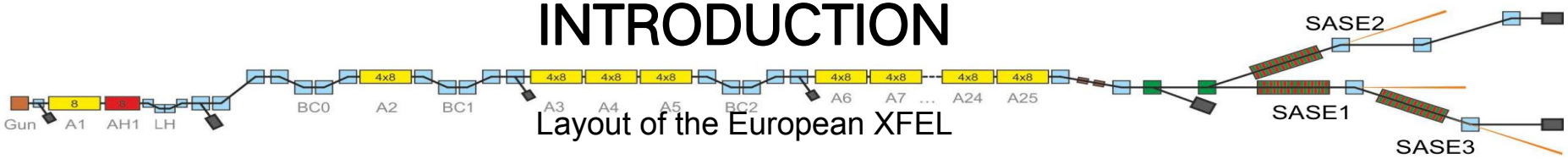
OUTLINE

- Introduction
- Beam Loss Simulation for implementation of **double-plate** dechirper with **nominal Optics**
- Beam Loss Simulation for implementation of **single-plate** dechirper with **new Optics**
- Summary, Conclusion and Discussions

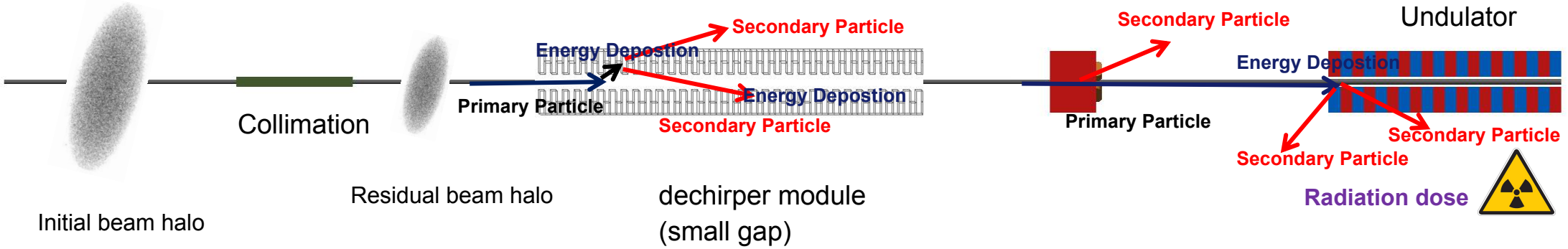
INTRODUCTION



Layout of the European XFEL

——Motivation to use Dechirper Structure (or Wakefield Structure)

- WS will allow the longitudinal and the transverse **phase space manipulations** of the electron beams
- The longitudinal wakefields introduce the correlated energy chirp along the bunch which can be used to increase or to decrease the **radiation bandwidth of SASE**
- WS as **kicker** for two color/fresh slice scheme



Initial beam halo

Residual beam halo

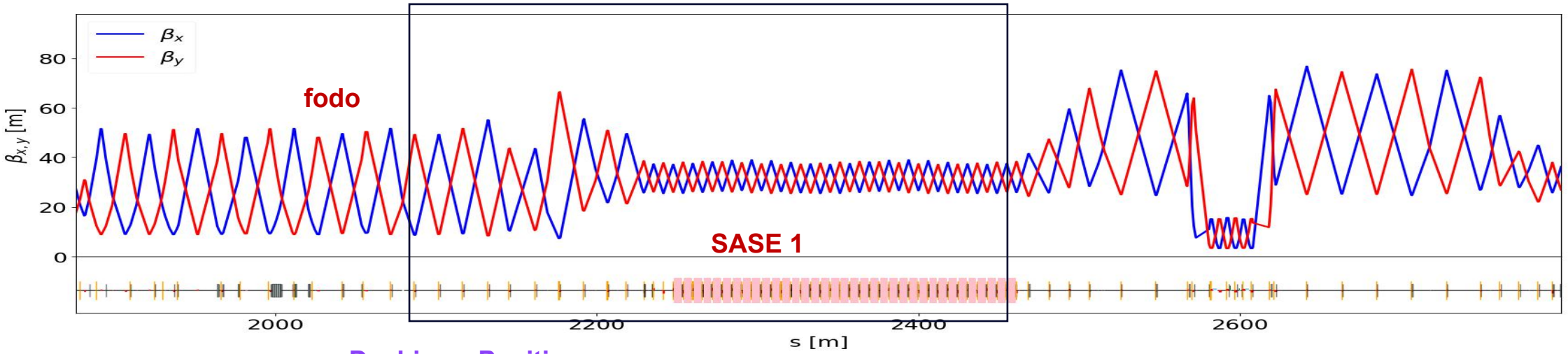
dechirper module (small gap)

Beam Delivery Simulation (BDSIM) code for tracking particles and particle–matter interactions, which uses a suite of standard high energy physics codes (Geant4, ROOT and CLHEP).

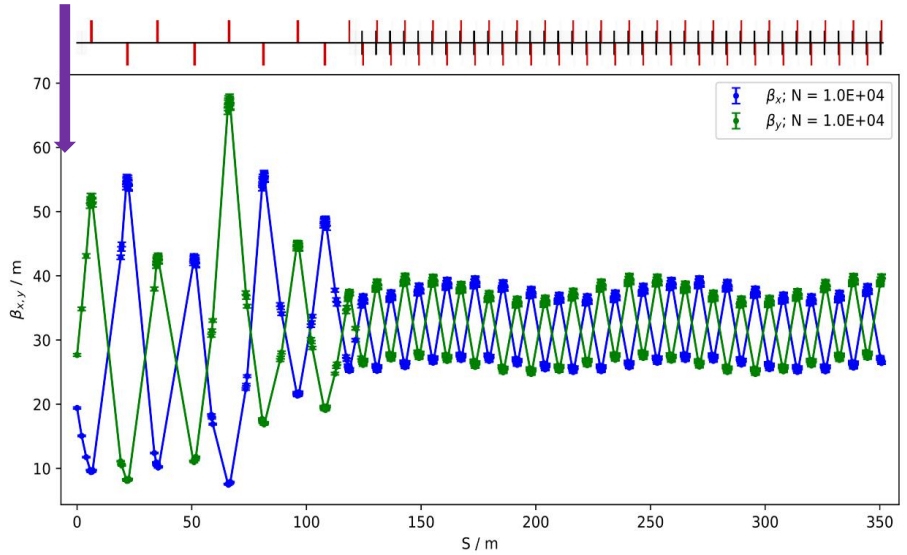
Reference: Nevay L J, Boogert S T, Snuverink J, et al. BDSIM: An accelerator tracking code with particle–matter interactions[J]. Computer Physics Communications, 2020, 252: 107200.

Beam Loss Simulation for implementation of **double-plate** dechirper with **nominal Optics**

Dechirper Position with **nominal Optics**



Dechirper Position



Optics	β_x [m]	β_y [m]
Nominal	**20**	42

Plot by BDSIM

THE GEOMETRY OF double-plate DECHIRPER STRUCTURE

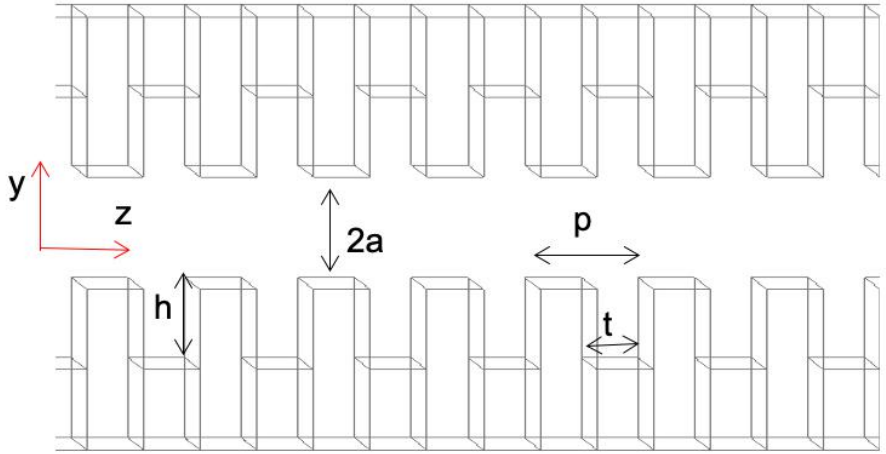
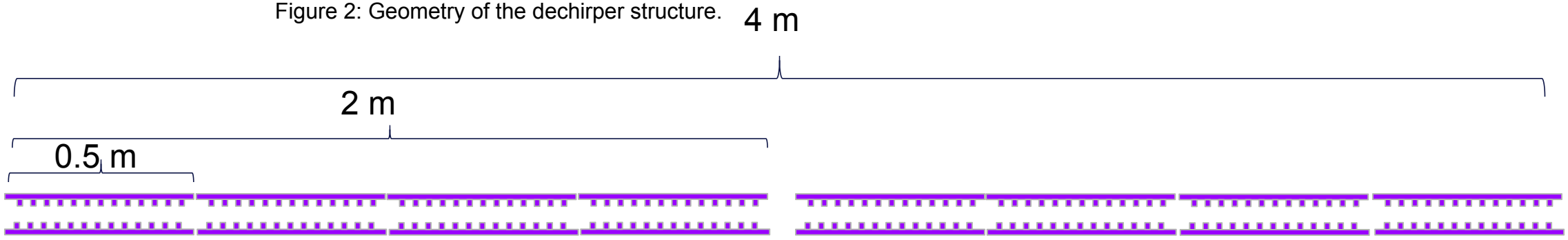


Figure 2: Geometry of the dechirper structure.

Table 1: Parameters of the dechirper structure

Parameter name	Value (mm)
Depth, h	0.5
Gap, t	0.25
Period, p	0.5
Half aperture, a	0.7
Half width, w	6
Length, L	2000

From Igor's talk



Layout of 2 dechirper module

Ref: Igor. Z, Beam Manipulation and Diagnostics with Wakefield Structure at the European XFEL,Hamburg,May 8, 2017,

BDSIM SIMULATION MODEL

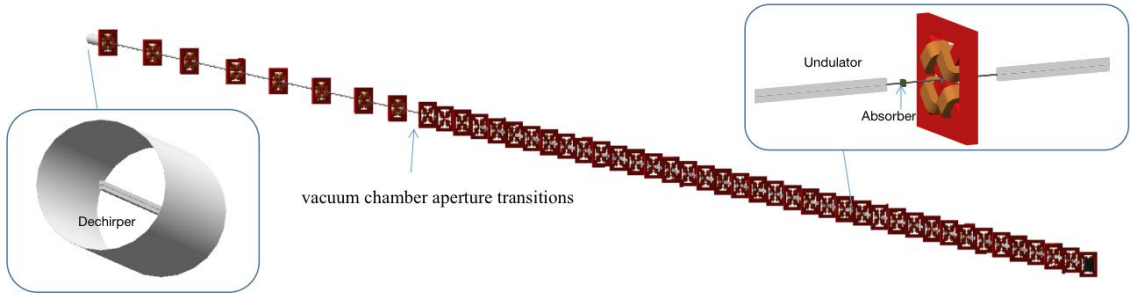


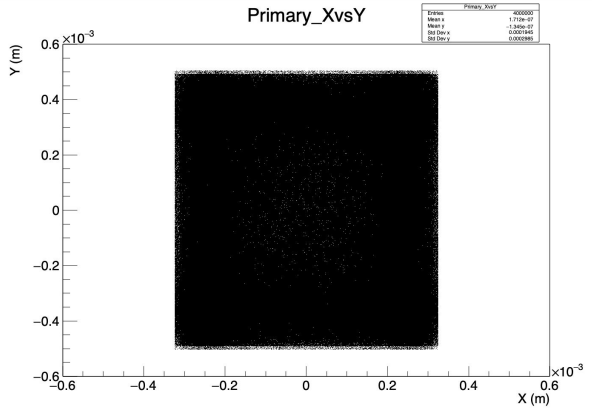
Figure 3: Geometry from dechirper to SASE1 used in the BDSIM simulation.

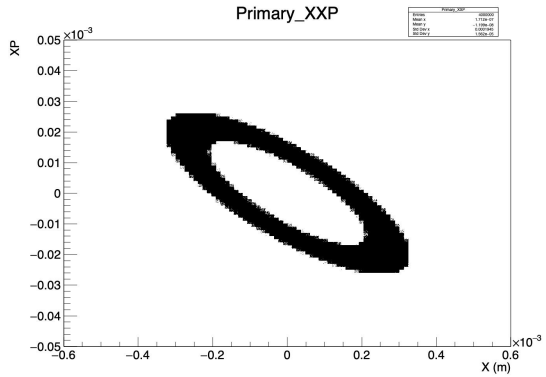
dechirper module (2m with 4 blocks)

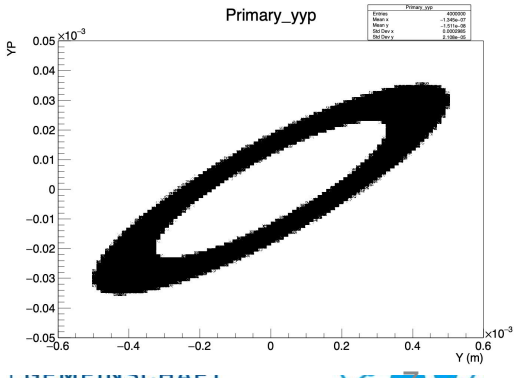
dechirper module (2m with 4 blocks)

Table 2: Beam parameters used in simulations

Parameter name	Value	Unit
Beam energy, E	14	GeV
Alpha function, α_x/α_y	1.25/-1.67	
Beta function, β_x/β_y	19.93/27.56	m
Emittance, ϵ_x/ϵ_y	0.64/1.09	μm
Number of primary particle, N	4×10^6	
Beam halo start sigma, σ	± 10	
Beam halo stop sigma, σ	$\pm$(15-20)	







Initial Beam halo uniform flat distribution with 15 sigma extension (10 sigma beam core have been removed)

ENERGY DEPOSITION AND RADIATION DOSE

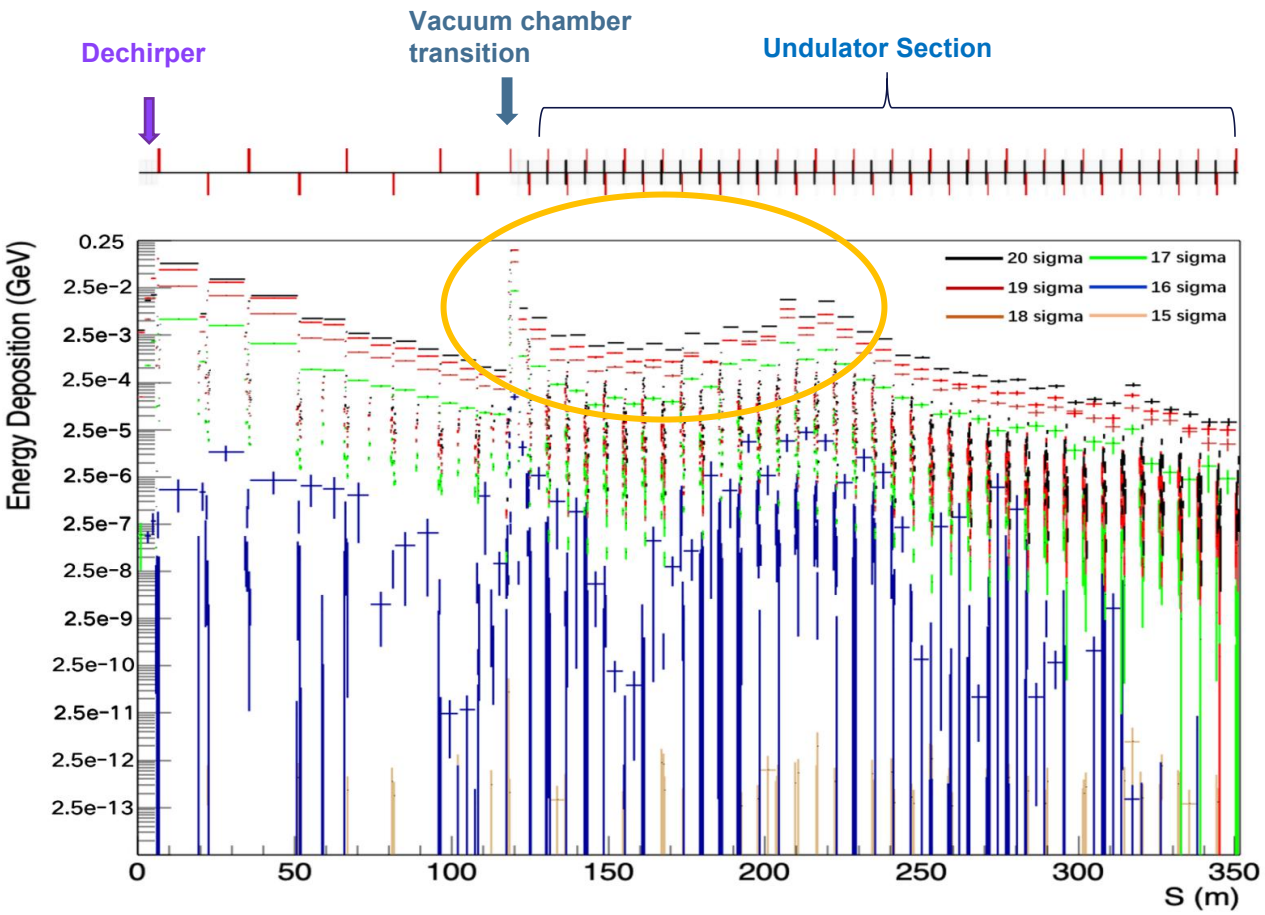
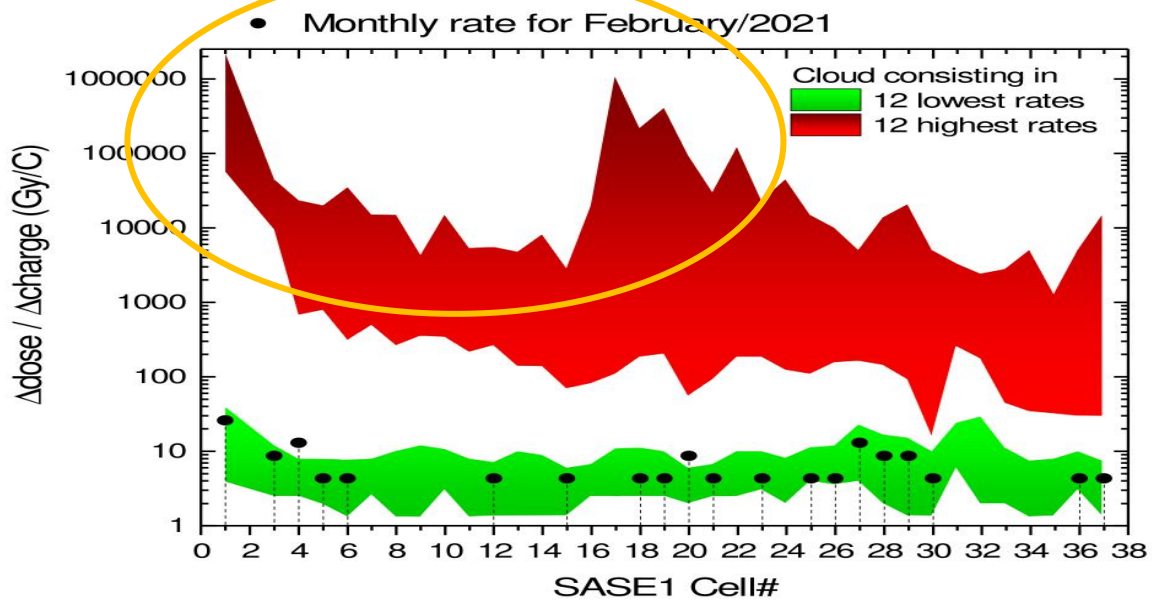
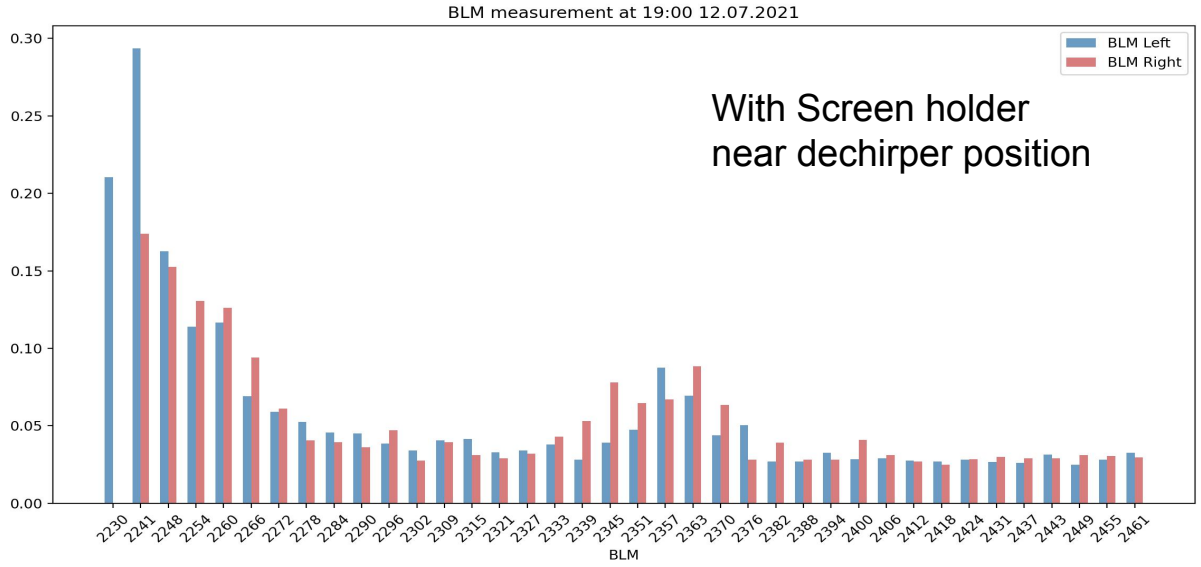
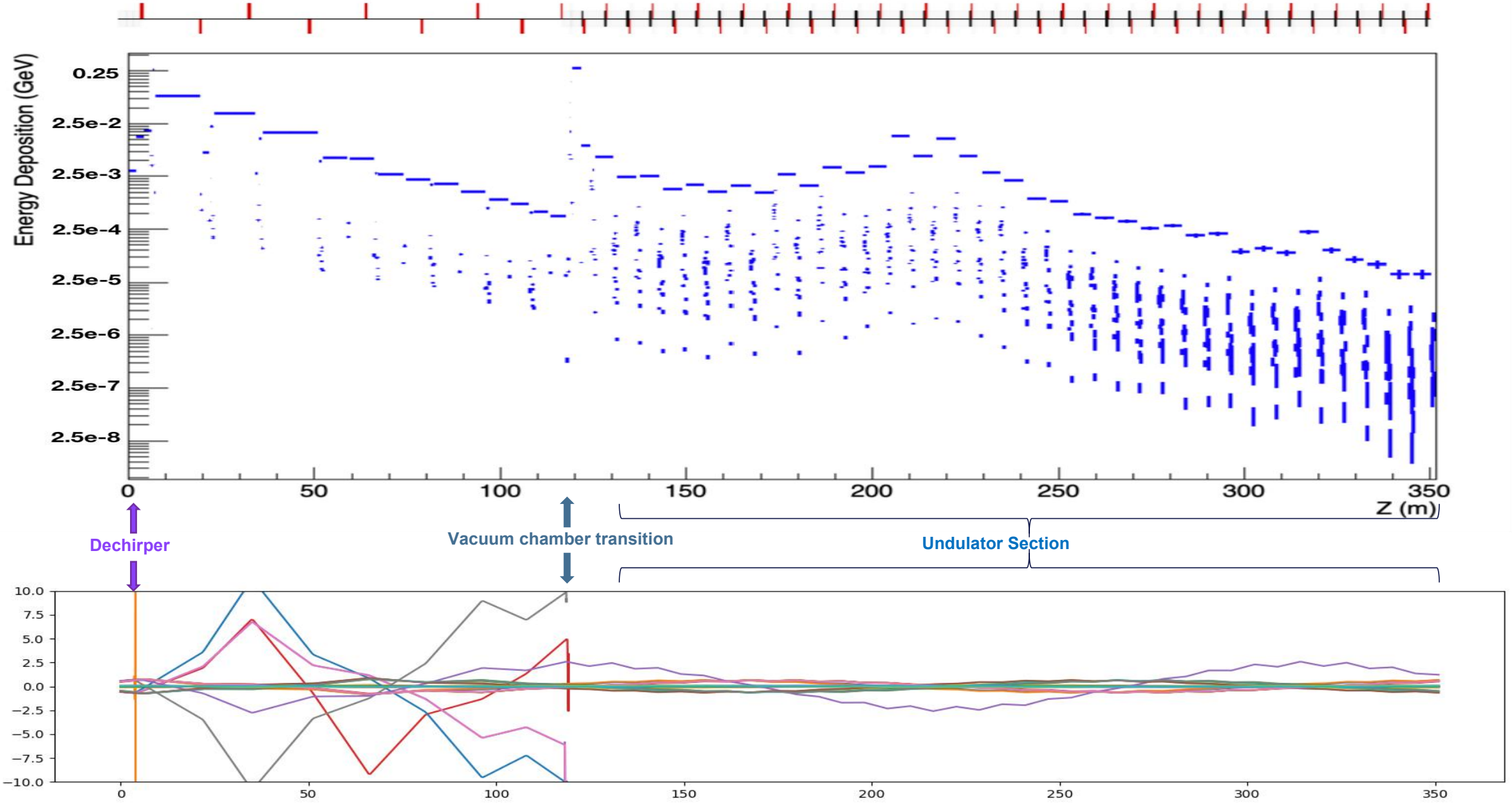


Figure 4: Energy loss per element per event from the entrance of dechirper to the end of SASE1 beam line. The horizontal error bar indicates the length of the element and the vertical error bar indicates the statistic fluctuation of the simulation.

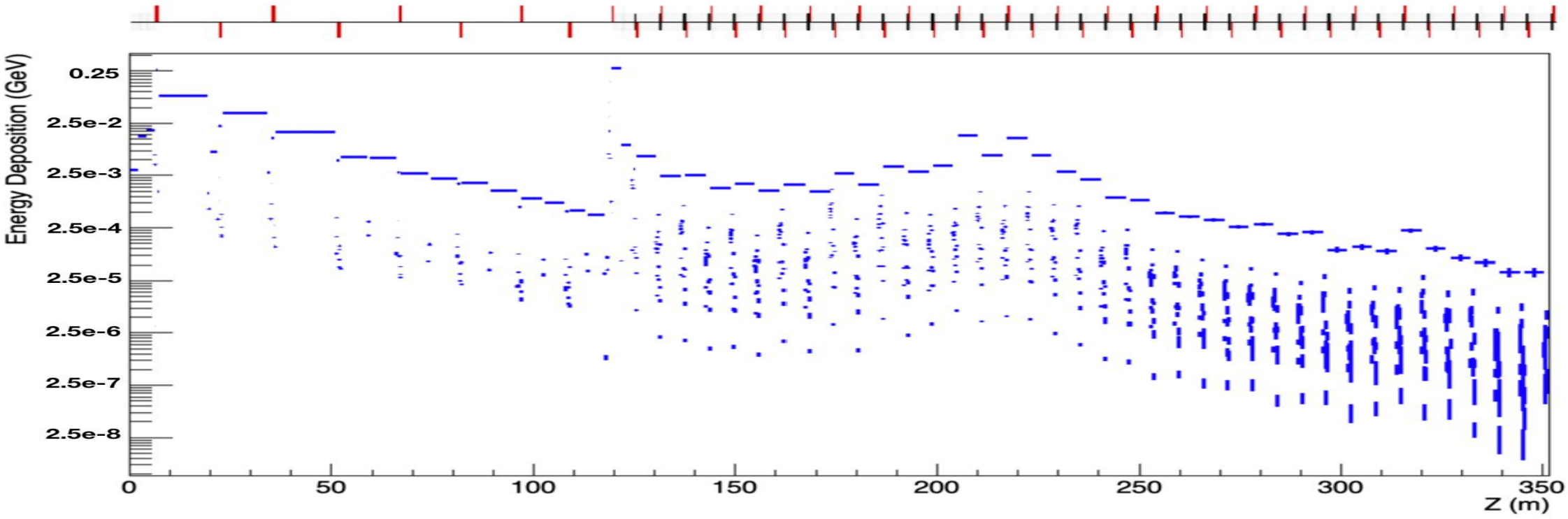


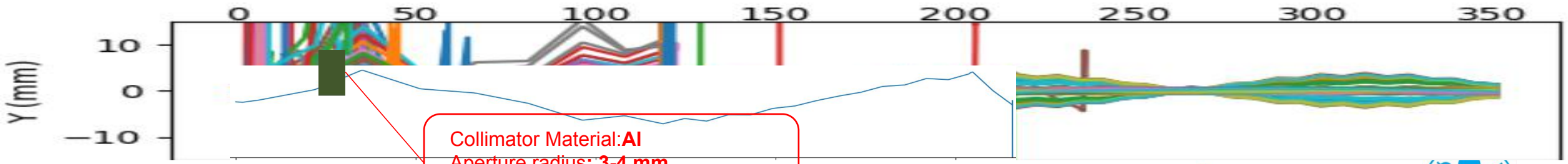


ENERGY DEPOSITION and TRAJECTORIES of PARTICLES



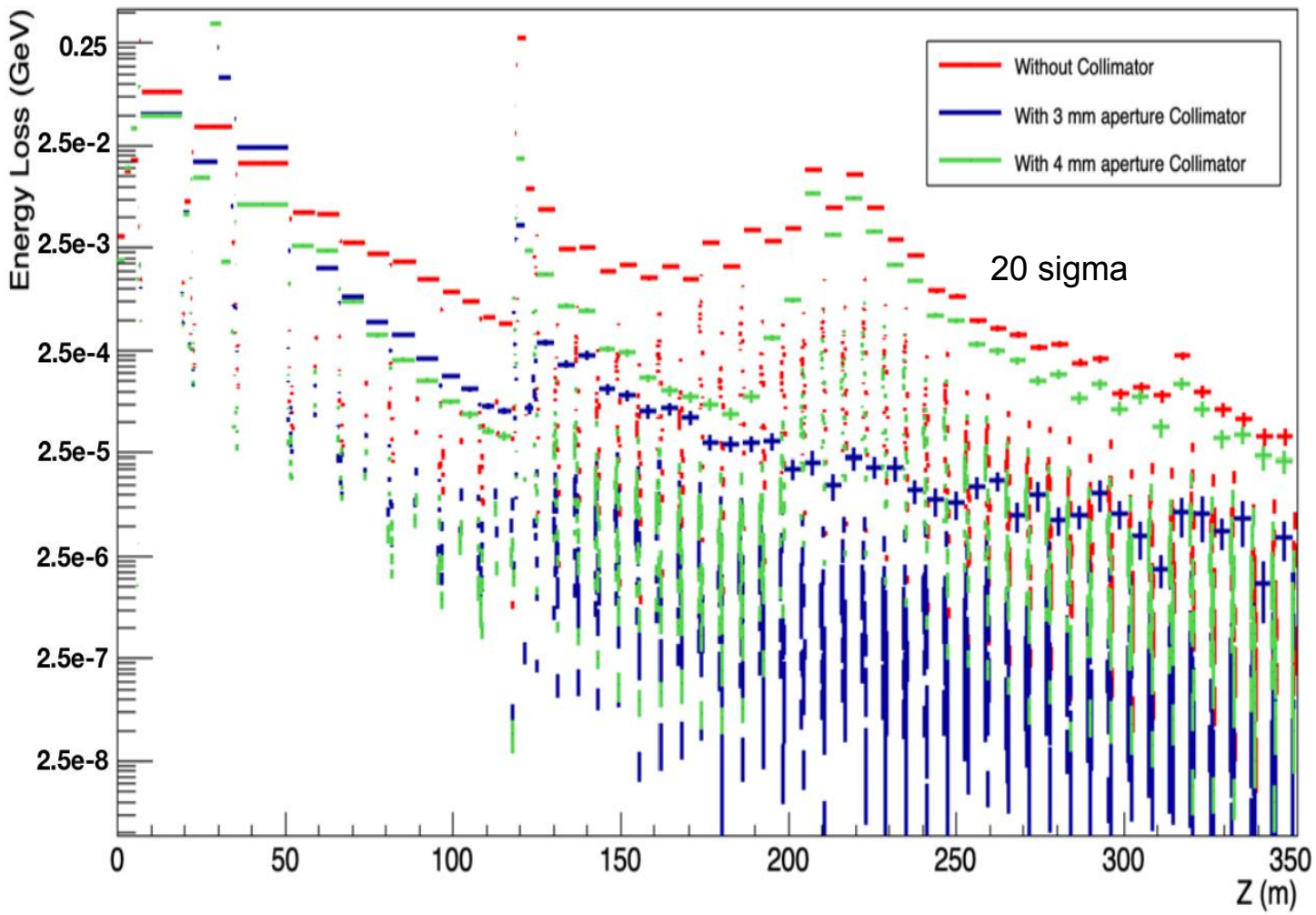
TRAJECTORIES of more PARTICLES and POSITION of COLLIMATOR

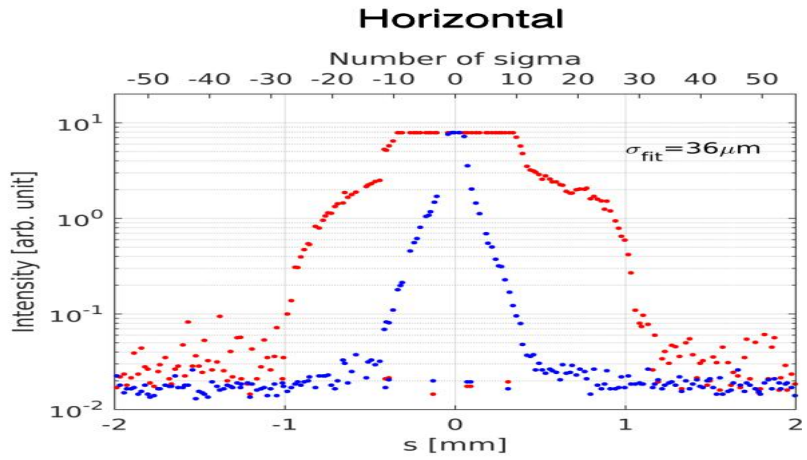


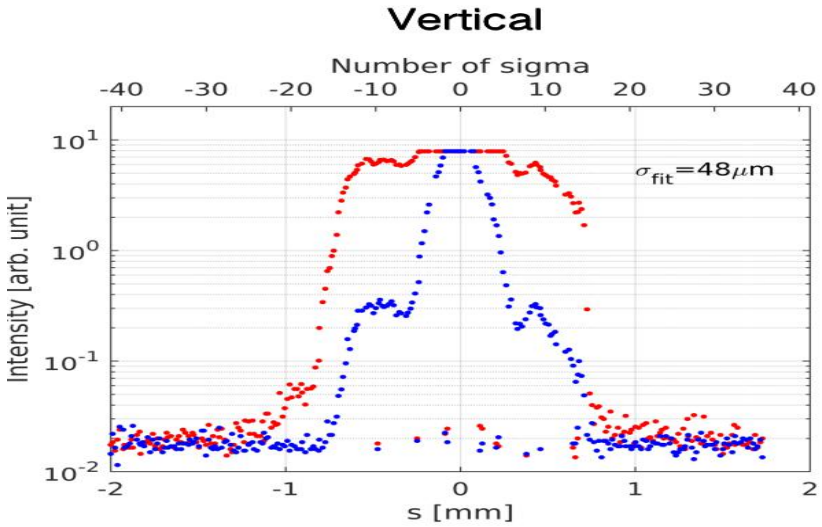


Collimator Material:**Al**
Aperture radius: **3-4 mm**
Length: 0.5 m

Energy Loss Comparison without and with (3&4 mm radius) Collimator



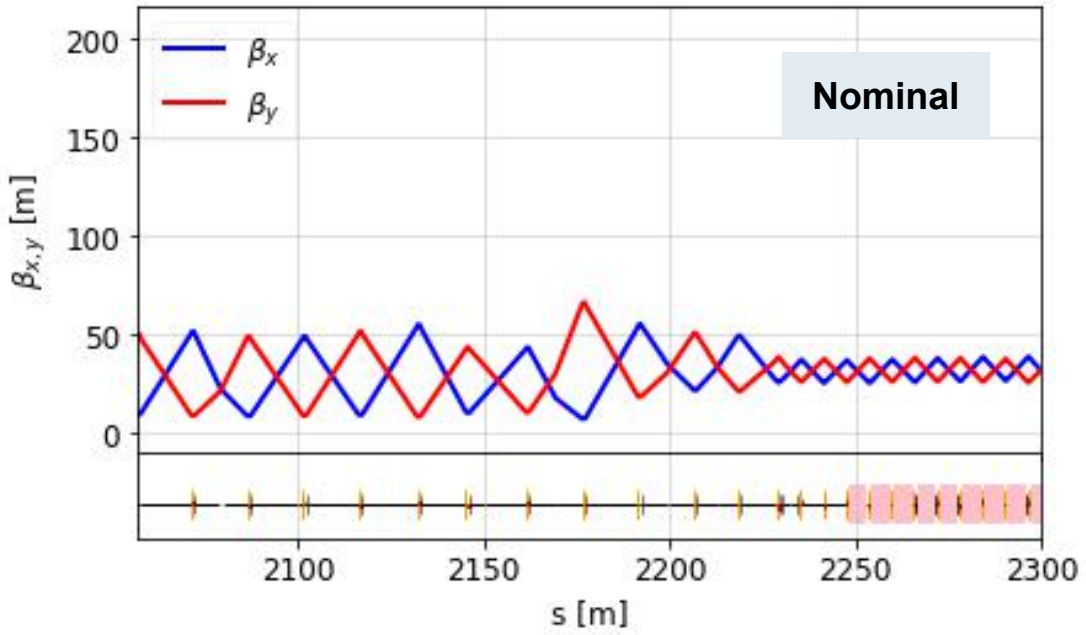


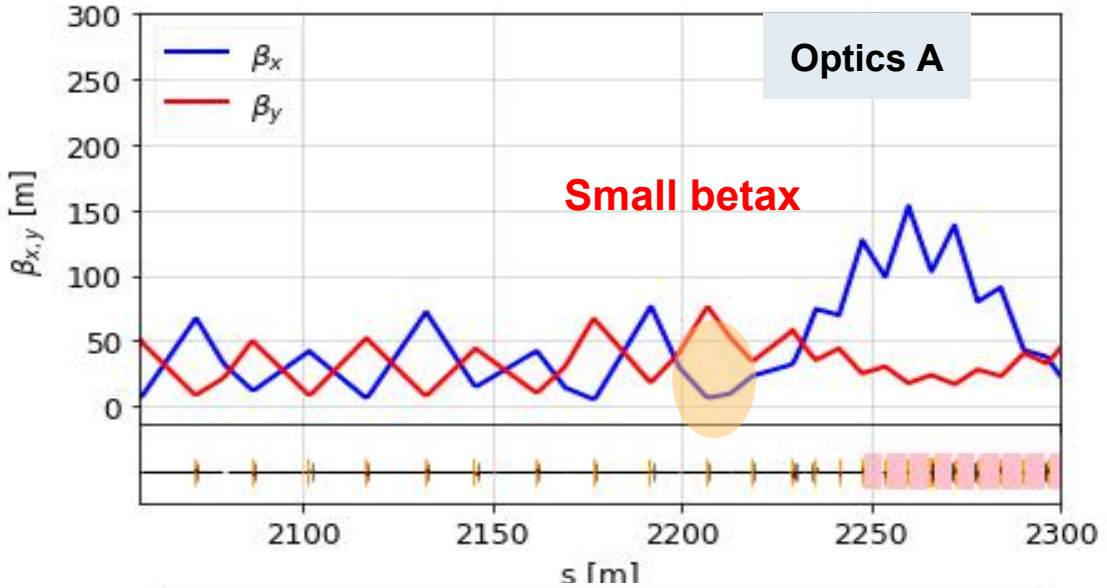


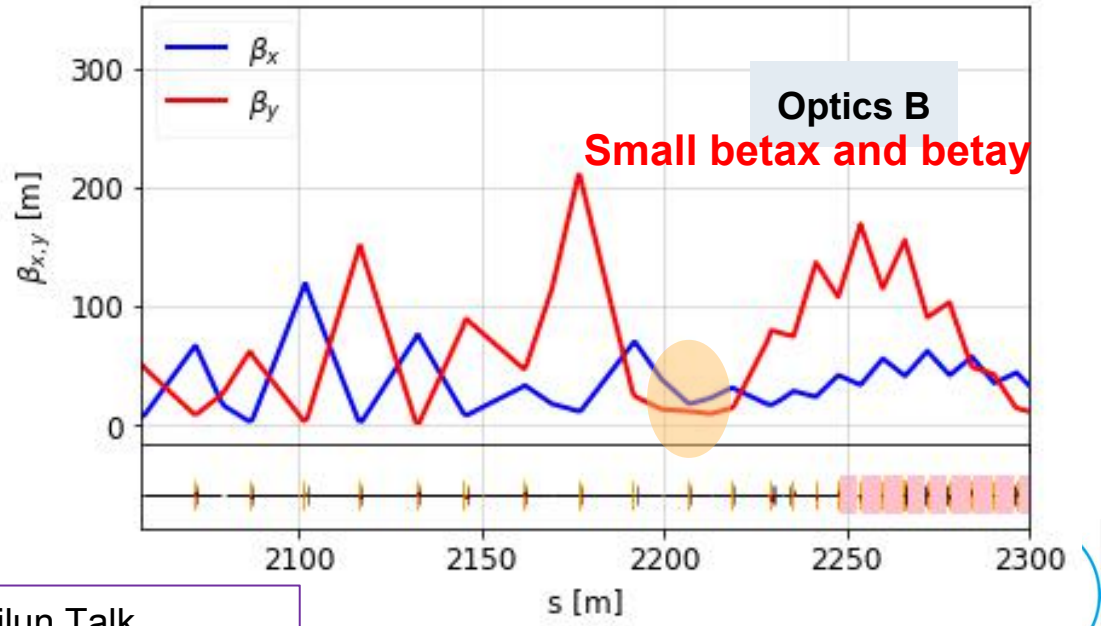
Measurements done with 8 mm diameter collimators in the collimation section

Beam Loss Simulation for implementation of **single-plate** dechirper with **new Optics**

Special optics @ Wire location 2212m







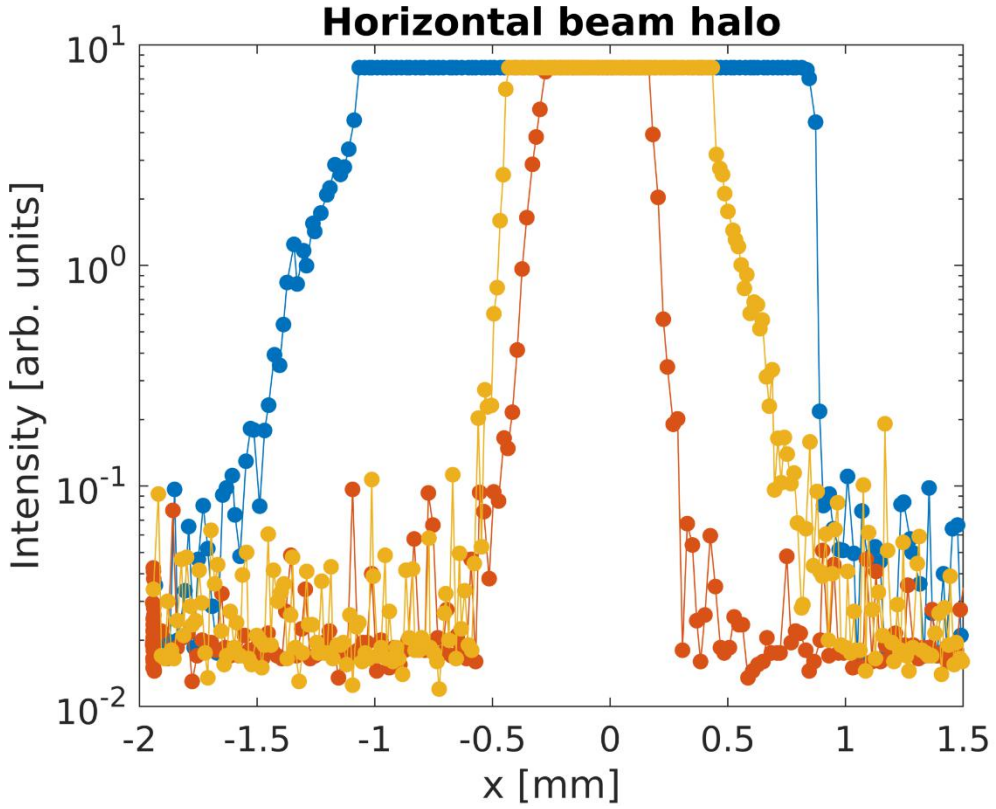
Optics	Quads	β_x [m]	β_y [m]
Nominal	-	**32**	36
Optics A	QF.2192.T2 (79.7 → 105.7)	**9**	54
Optics B	QF.2072.T2 etc (95.4 → 120.4), total 5 quads	23	10

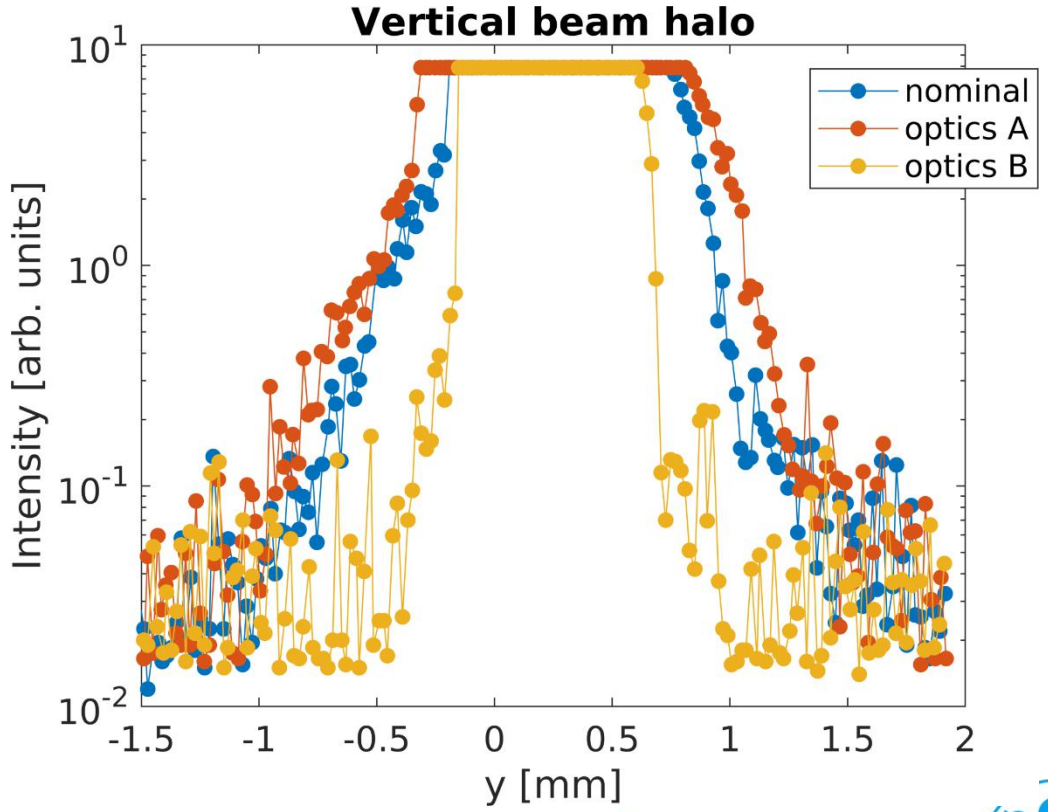
From Weilun Talk

Wire scan measurement

Optics	β_x [m]	β_y [m]
Nominal	**32**	36
Optics A	**9**	54
Optics B	23	10

- Optics A: squeezed halo full extension in x to about 1mm (more than optics prediction)
- Optics B: squeezed halo full extension in both x and y to about 1.6mm (a little bit less than optics)





Exp. @ 18.05.2021

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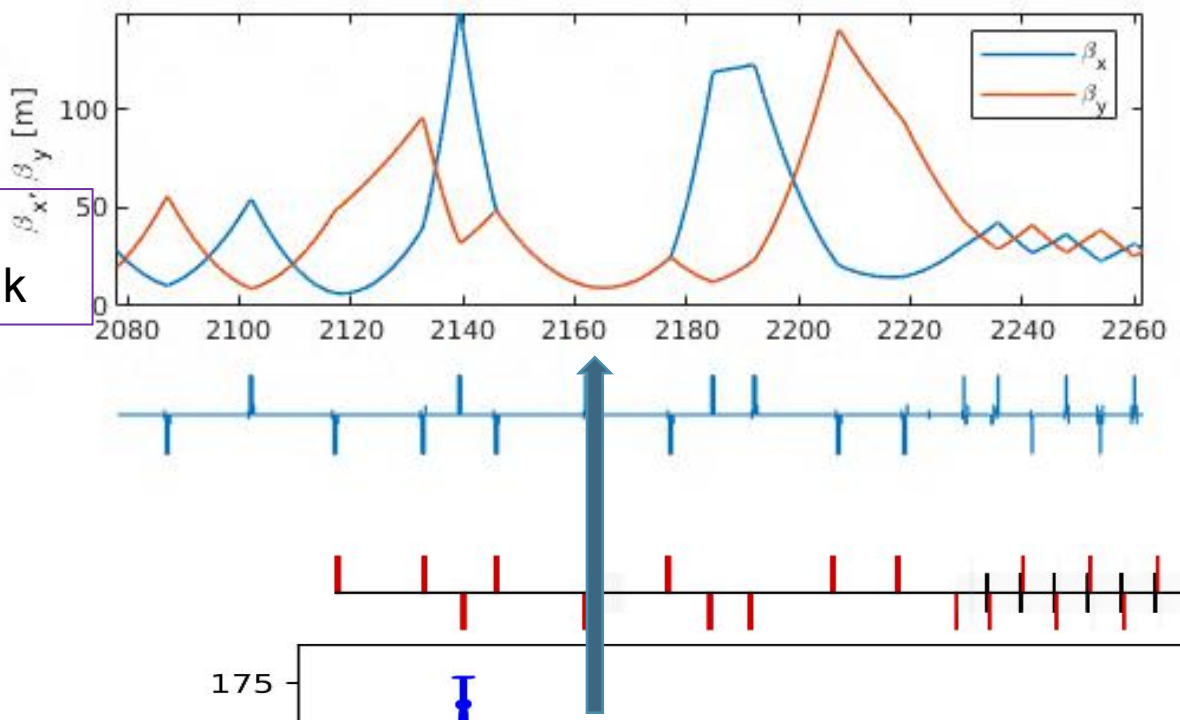
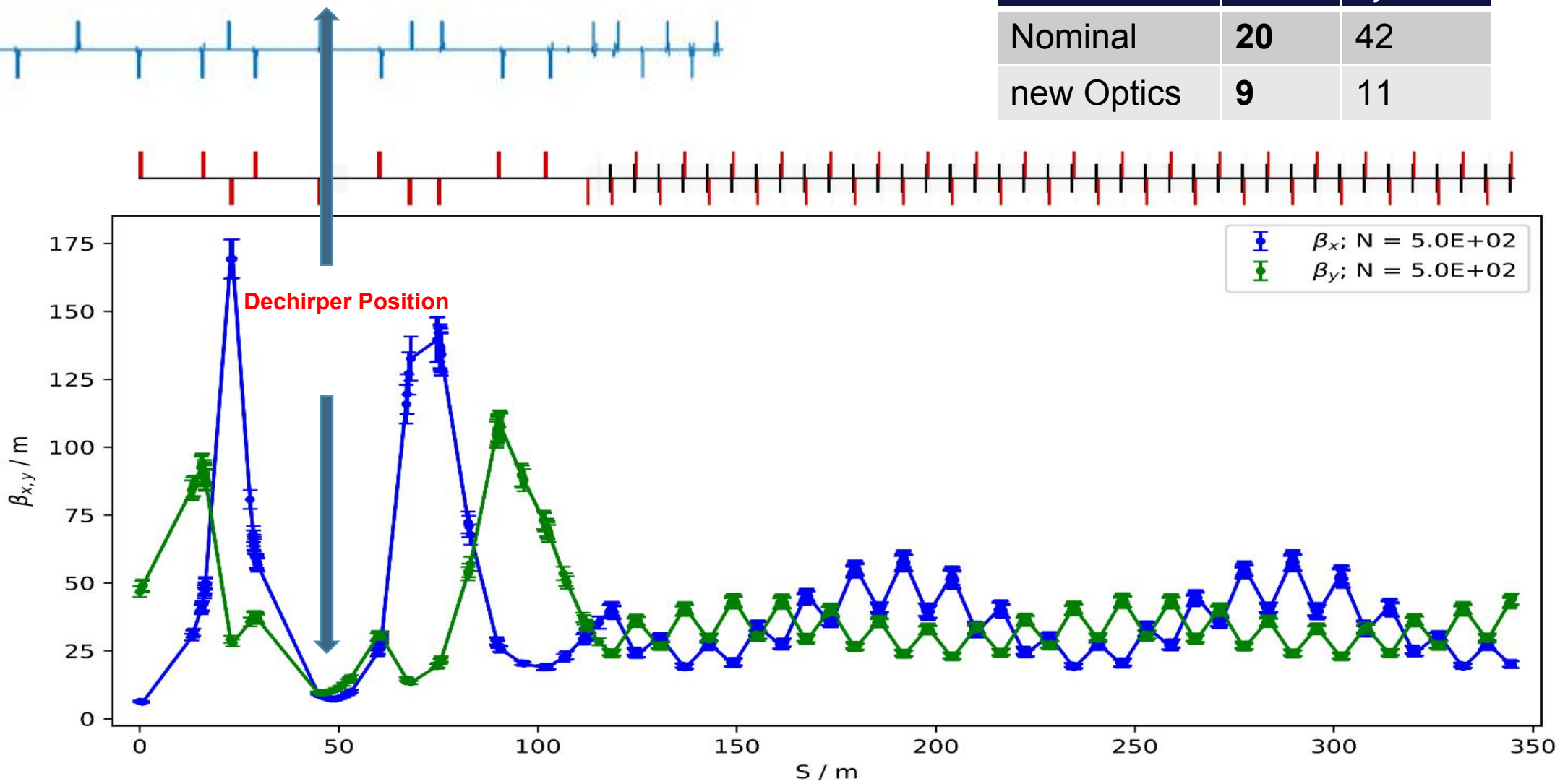


Dechirper Position with new Optics

Optics	β_x [m]	β_y [m]
Nominal	**20**	42
new Optics	**9**	11

BDSIM simulation



THE GEOMETRY OF single-plate DECHIRPER STRUCTURE

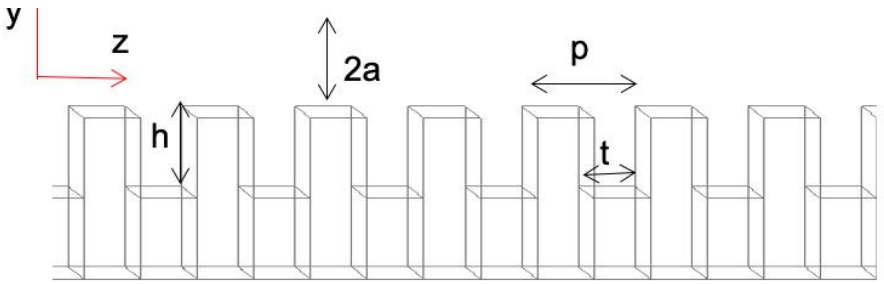


Figure 2: Geometry of the dechirper structure.

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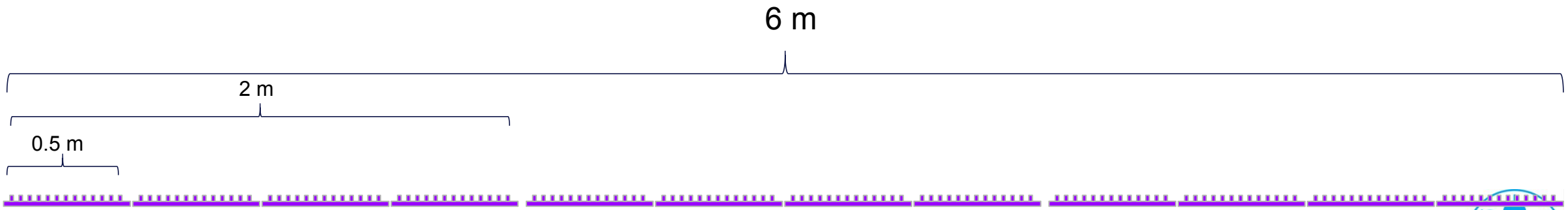


Layout of 3 single-plate dechirper module

ENERGY DEPOSITION AND RADIATION DOSE

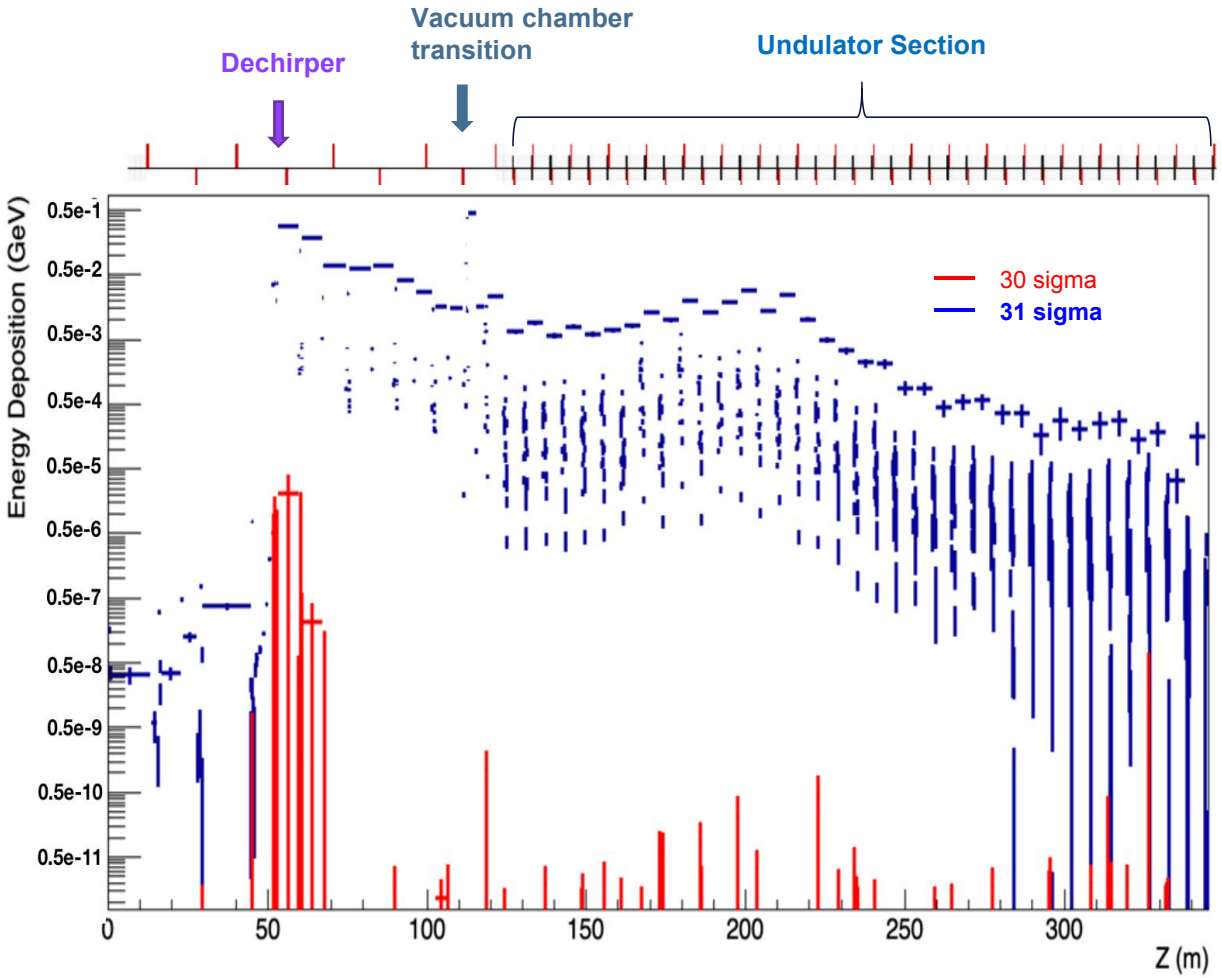


Figure 8: Energy loss per element per event along SASE1 beam line. Energy deposition have been observed in the undulator section only with above 30 sigma.

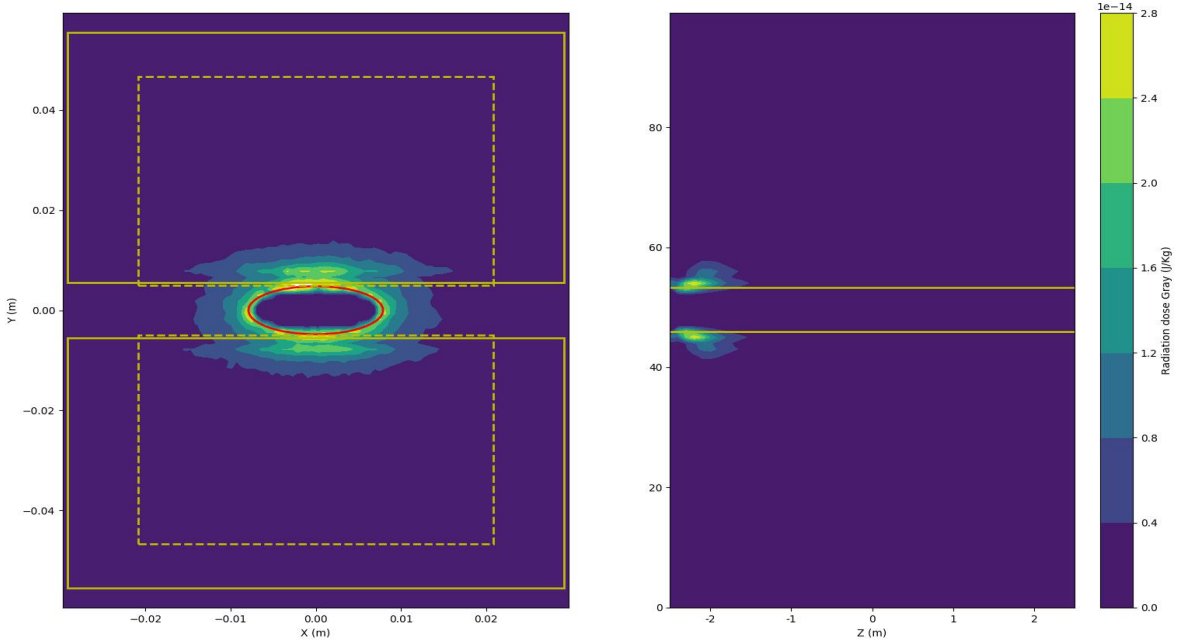
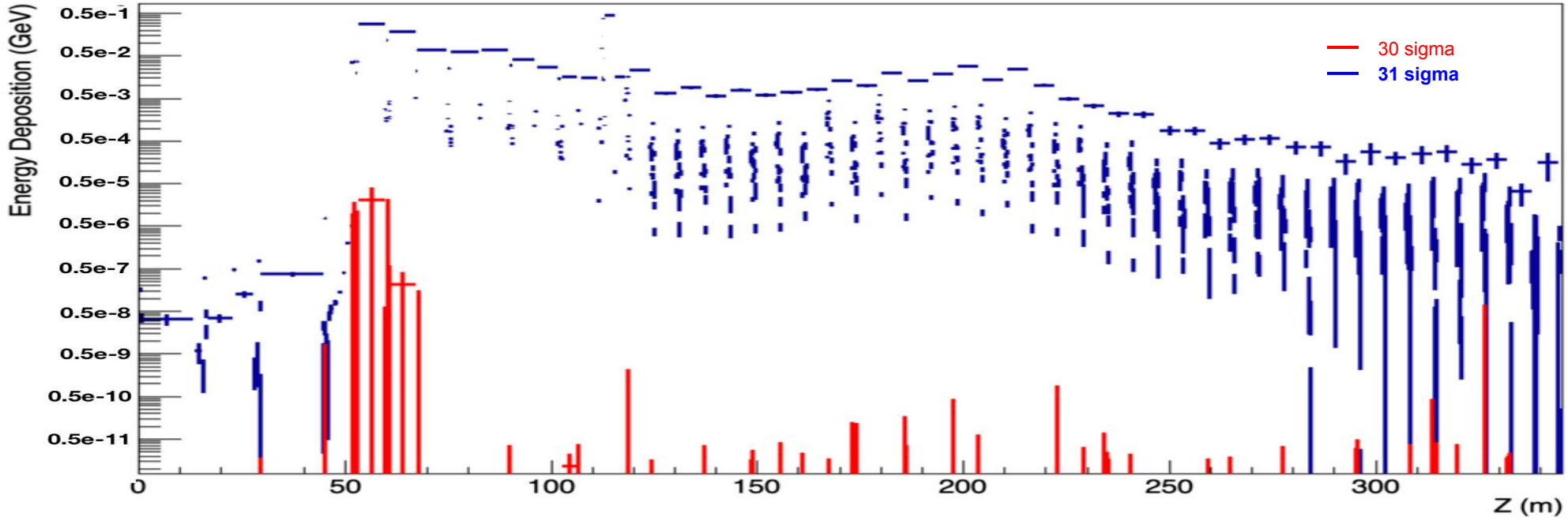
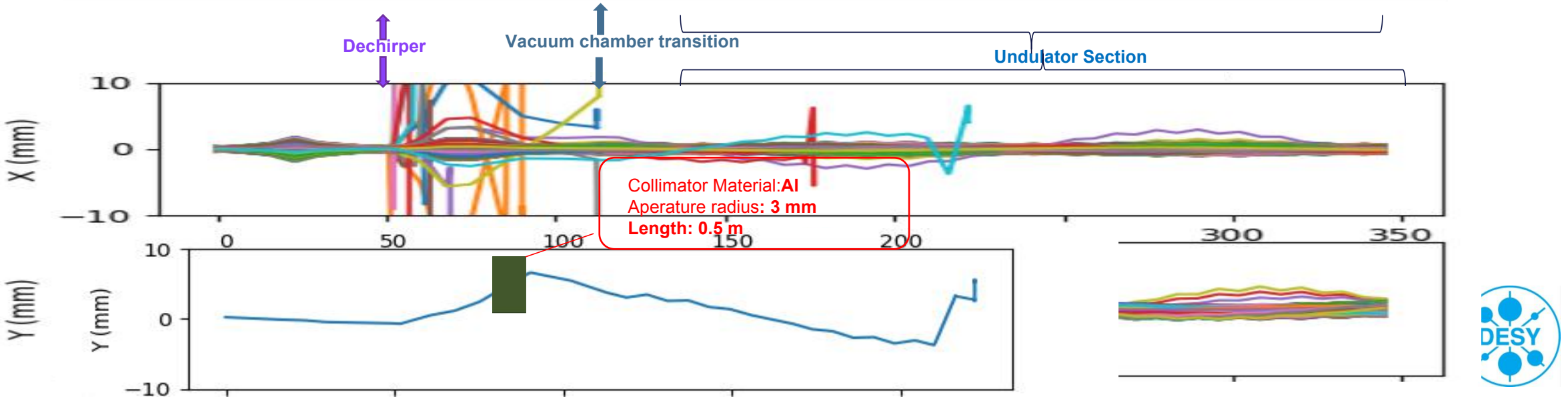


Figure 9: Example of scoring map of undulator cross-section for beam halo extension with 31 sigma. D-per hour = 0.4 gray per hour with 31 sigma.

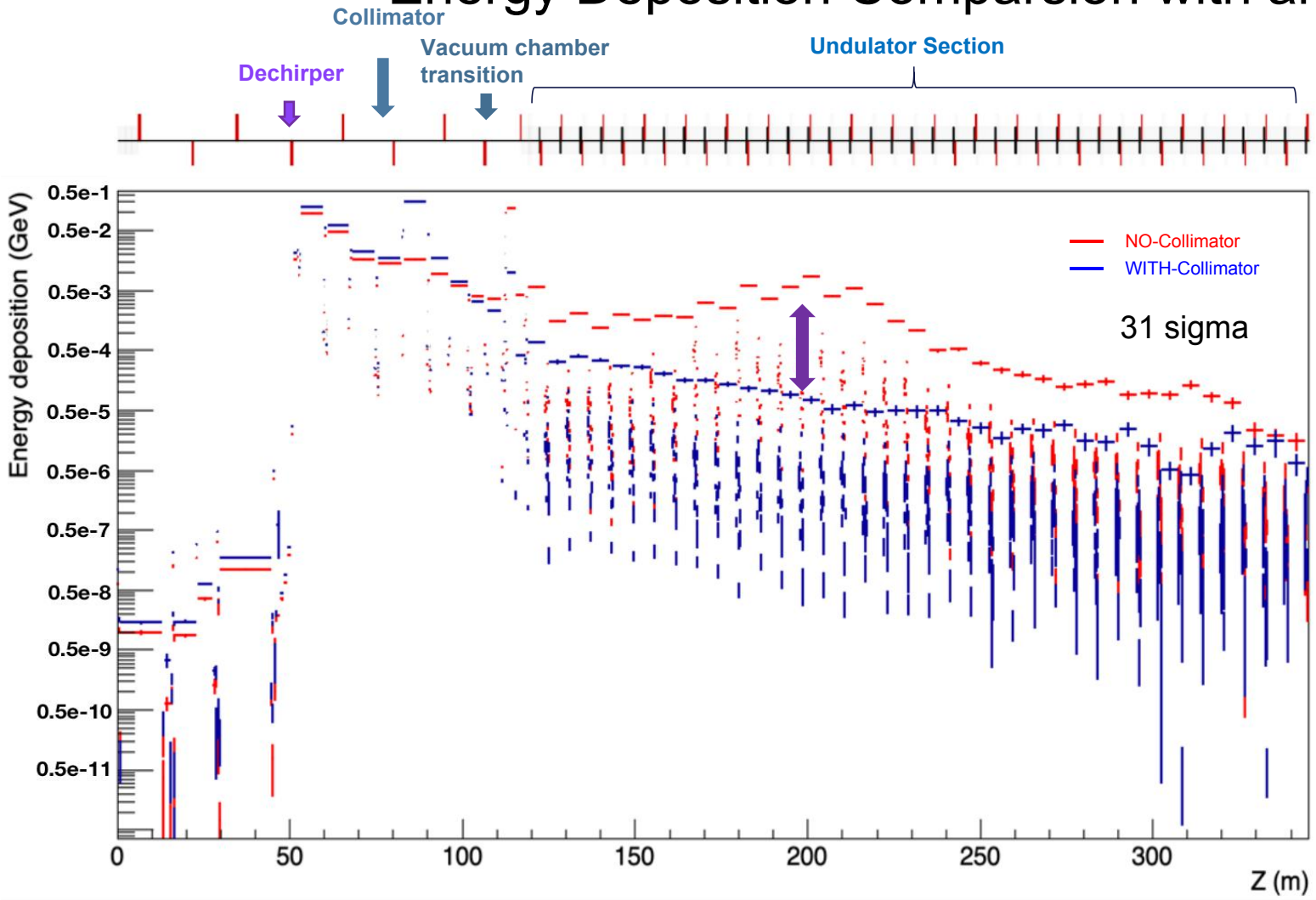
Optics	β_x [m]	β_y [m]	Maximum Beam halo extension (No Enegy Loss)
Nominal	**20**	42	15 sigma
new Optics	**9**	11	30 sigma

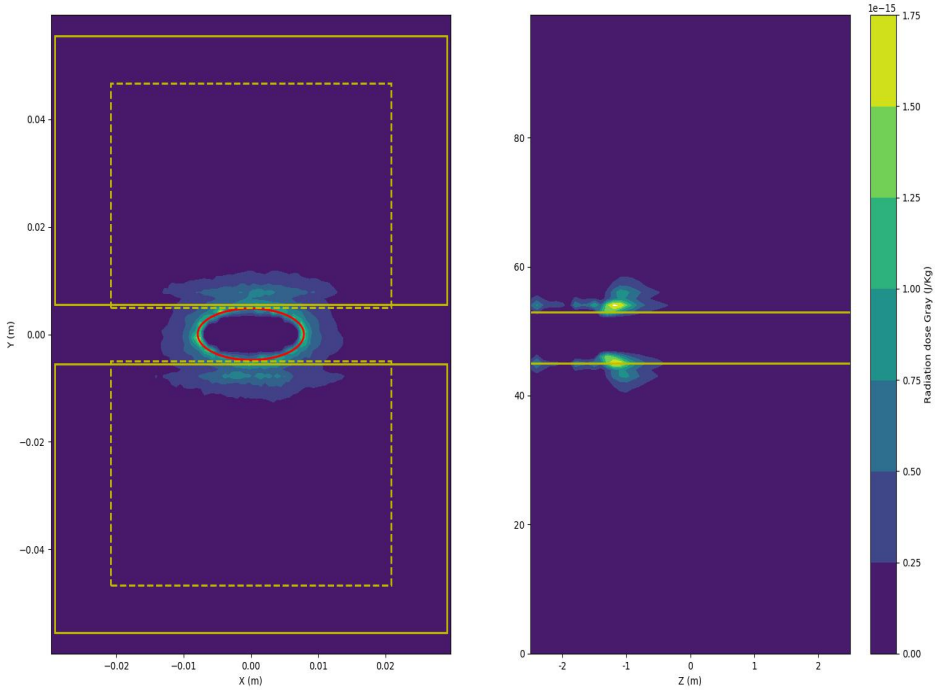
TRAJECTORIES of more PARTICLES and POSITION of COLLIMATOR





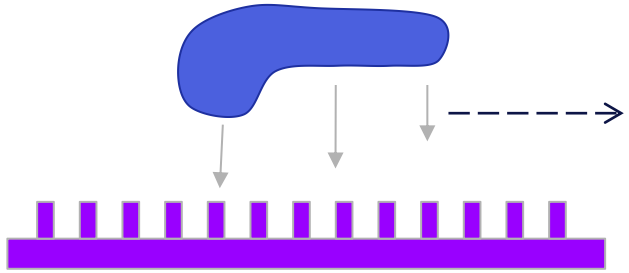
Energy Deposition Comparsion with and without Collimator



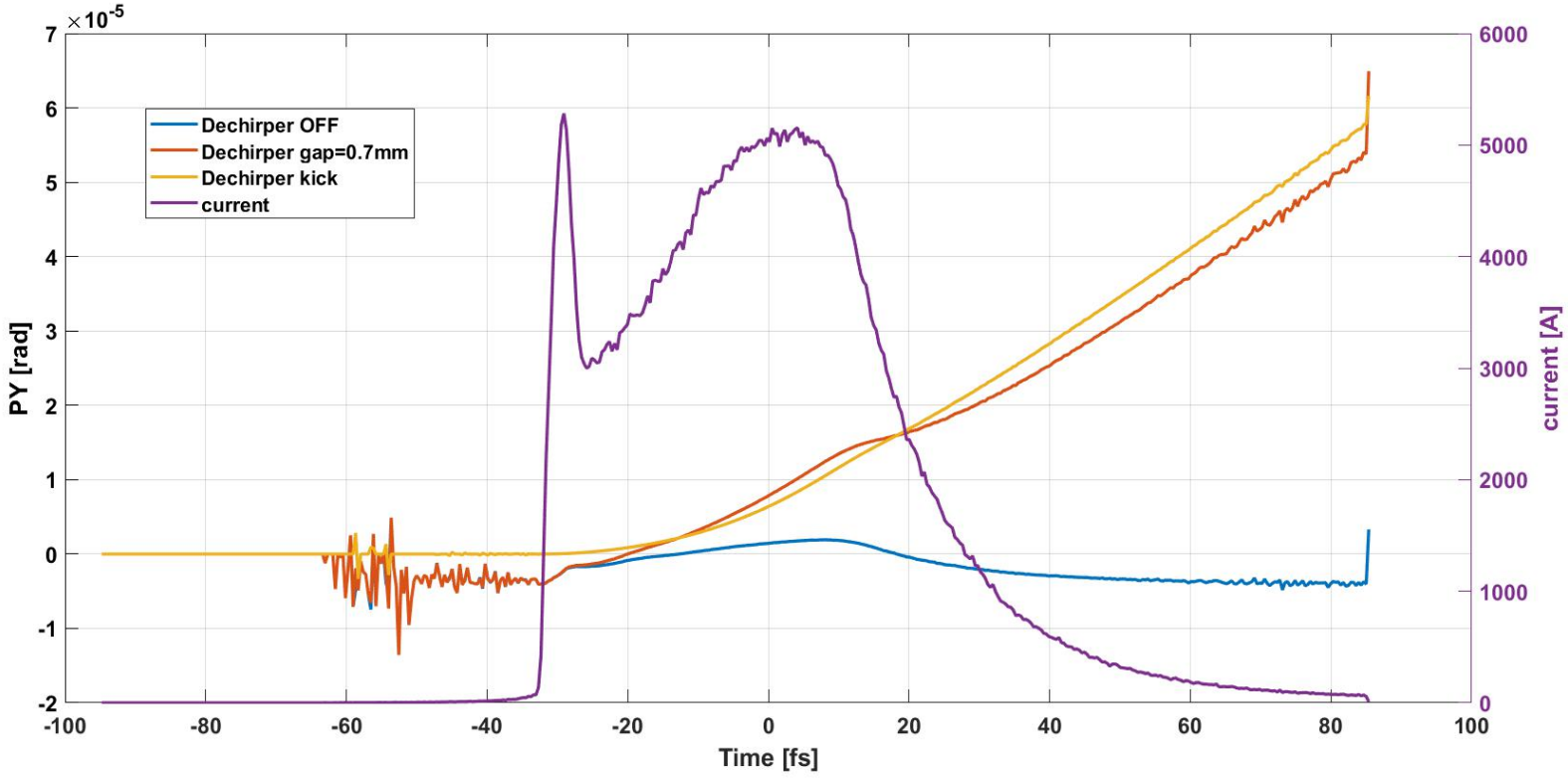


D-per hour = 0.01 gray per hour with collimator,
-> 560 hours/year of run with dechiper is acceptable

Wake Dipole Kick of SIngle-plate dechirper



Dipole kick of Short-range wake

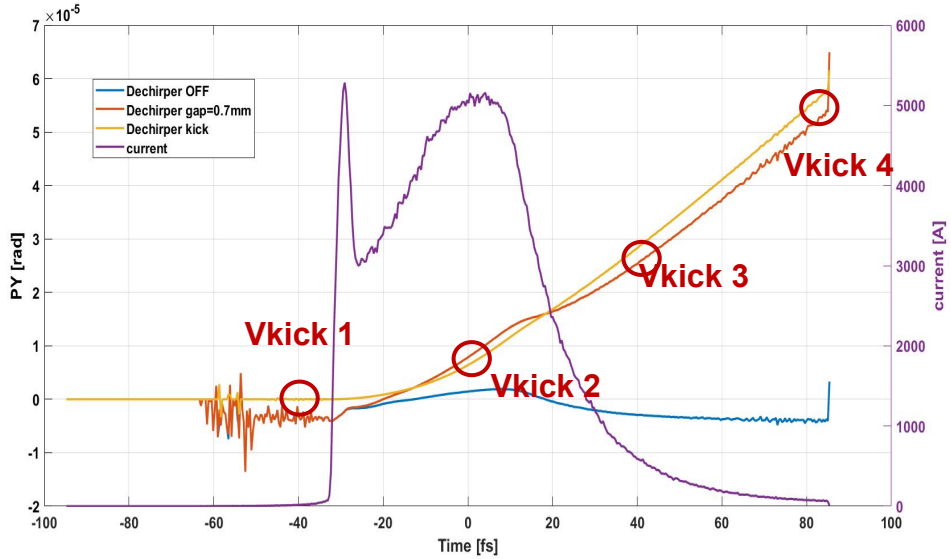


Ref: Bane K, Stupakov G, Zagorodnov I. Wakefields of a Beam near a Single Plate in a Flat Dechirper[J]. arXiv preprint arXiv:1611.09460, 2016

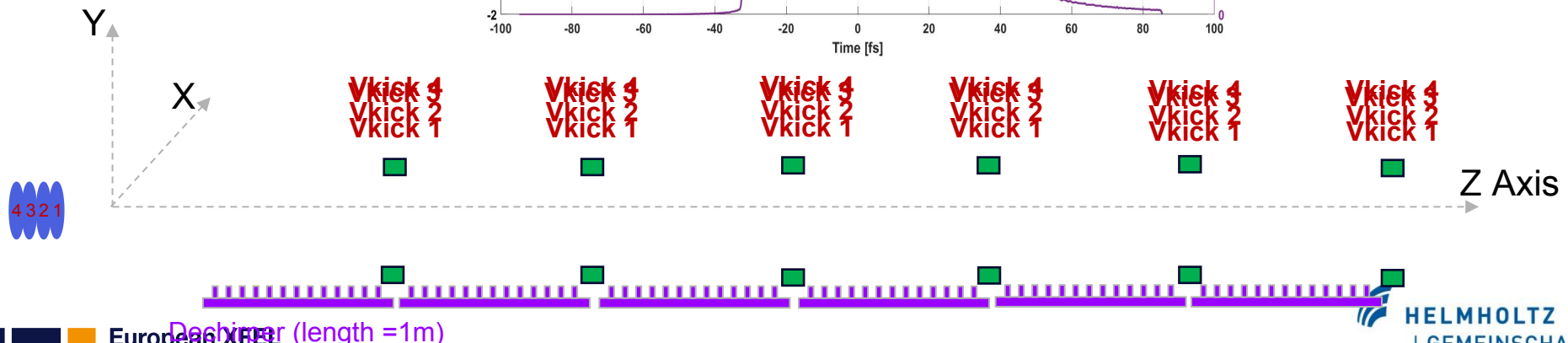
Wake Dipole Kick in BDSIM simulation

BDSIM cannot be imported into wakefield distribution, so we use **Vkicker component** of BDSIM instead of wakefield. *(We just consider dipole kick of transverse wake , not longitudinal wake and quadrupole mode of transverse wake)*

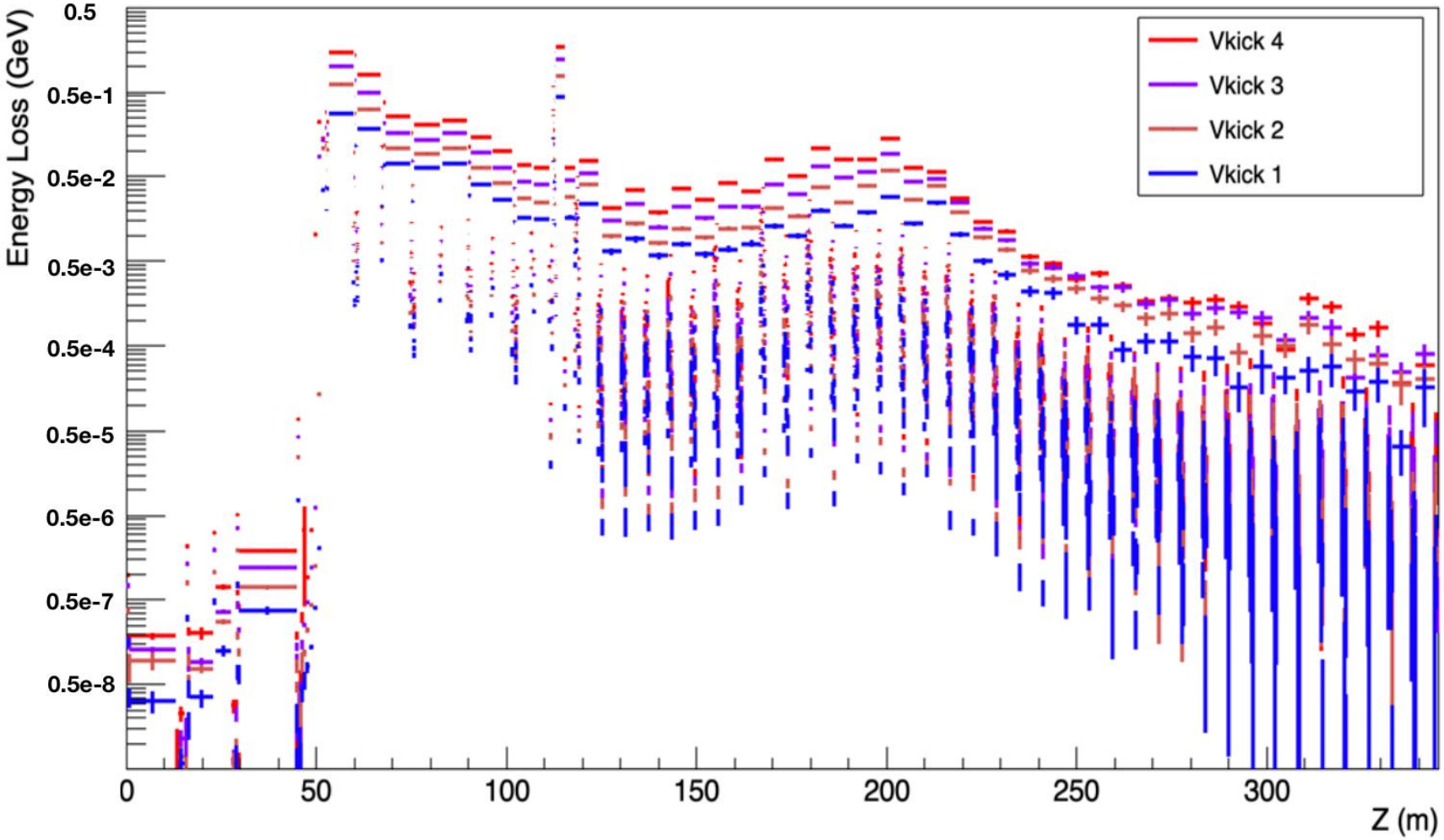
Vkicker component of BDSIM
VK: vkicker, vkick=1.32084e-6, **l=0*m**;



Vkick 1	0
Vkick 2	7.9e-6/6= 1.3e-6
Vkick 3	2.8e-05/6=4.7e-6
Vkick 4	5.4e-05/6=9.1e-6



Energy Loss Comparsion with Vkick 1,2, 3 and 4

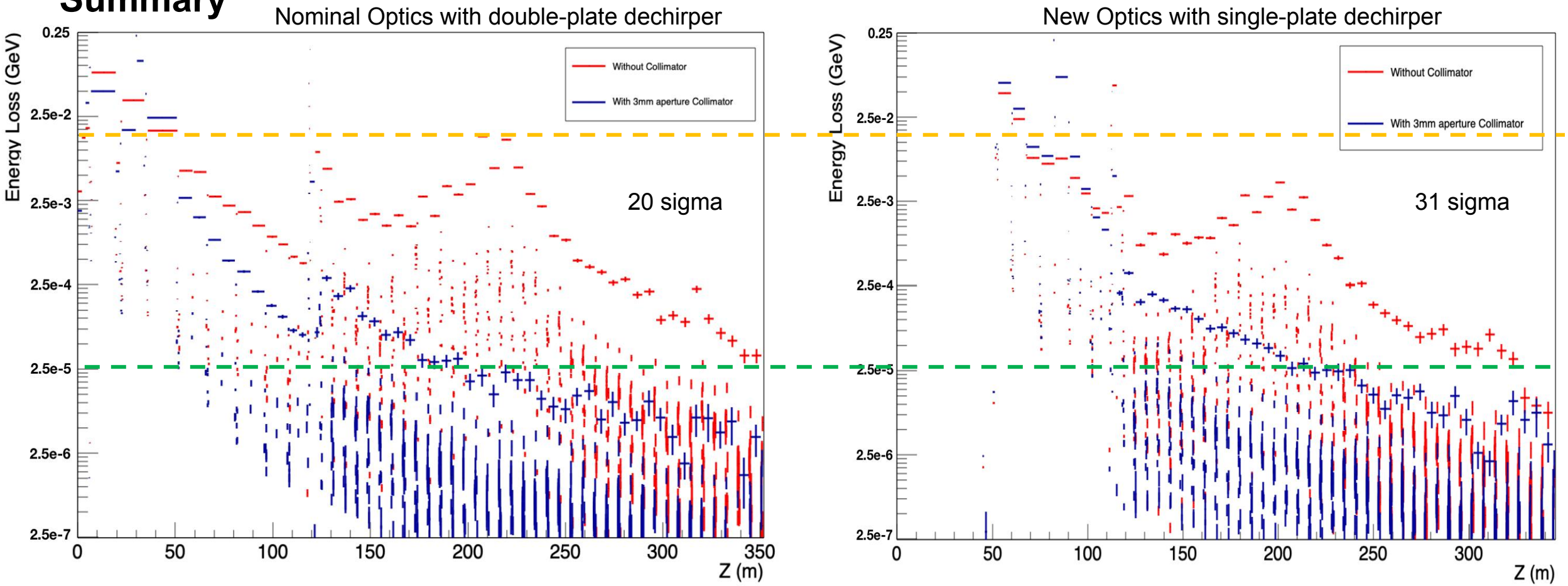


Vkick 1	0
Vkick 2	1.3 e-6
Vkick 3	4.7 e-6
Vkick 4	9.1 e-6

This looks similar as the energy loss increase with increase of beam halo extention

Figure 11: Energy loss per element per event along SASE1 beam line with Vkick 1,2, 3 and 4 for beam halo extension with 31 sigma

Summary



- Energy loss of new optics (31 sigma) is smaller than nominal optics (20 sigma) without collimator
- Energy loss with Collimator is 100 times smaller than without Collimator

Summary

Optics	β_x [m]	β_y [m]	Maxi. Beam halo extension (no energy loss)	Peak radiation dose w/o collimator	Acceptable run time per year
Nominal	**20**	42	15 sigma	2.9 Gy/hr (20 sigma)	2 hr/year w/o collimator (20 sigma)
					17 hr/year w/o collimator (17 sigma)
new Optics	**9**	11	30 sigma	0.4 Gy/hr (31 sigma)	14 hr/year w/o collimator (31 sigma)
					560 hr/year with collimator (31 sigma)

Conclusion and discussions

- With the new optics and single-plate dechirper one can accept up to 30 sigma of beam halo extension without additional losses
- Run with above 30 sigma would require an additional collimator
- With 50 cm long Al collimator with 3 mm radius, one can reduce the loss by 100 times -> any additional effect from this collimator?
- Wake Dipole Kick can cause additional losses (within one order of magnitude)-> can be collimated with collimator?

Thankyou for your attention!