Optics and Beam-setup

A. Alekou, H. Bartosik

With thanks to M. Carla', R. Tomas,
Y. Papaphilippou, R. Appleby and the SPS CC team

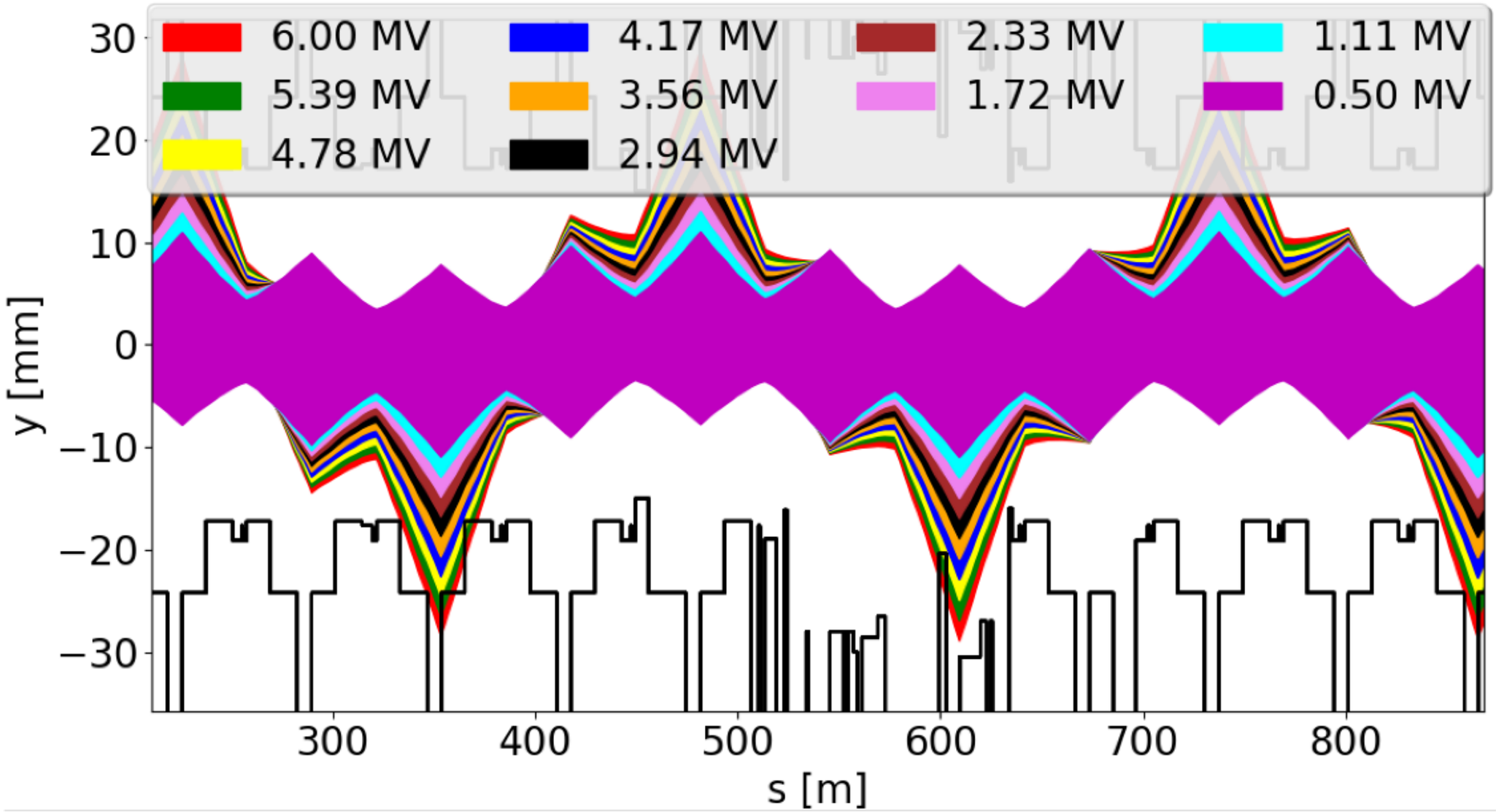
Outline

- Expected reading at Beam Instrumentation
- Dynamic Aperture studies
- Conclusions

Expected reading at Beam Instrumentation

Aperture at 26 GeV

3σ orbit, 1 dipole kick@CC1, ε_norm=2.5μm



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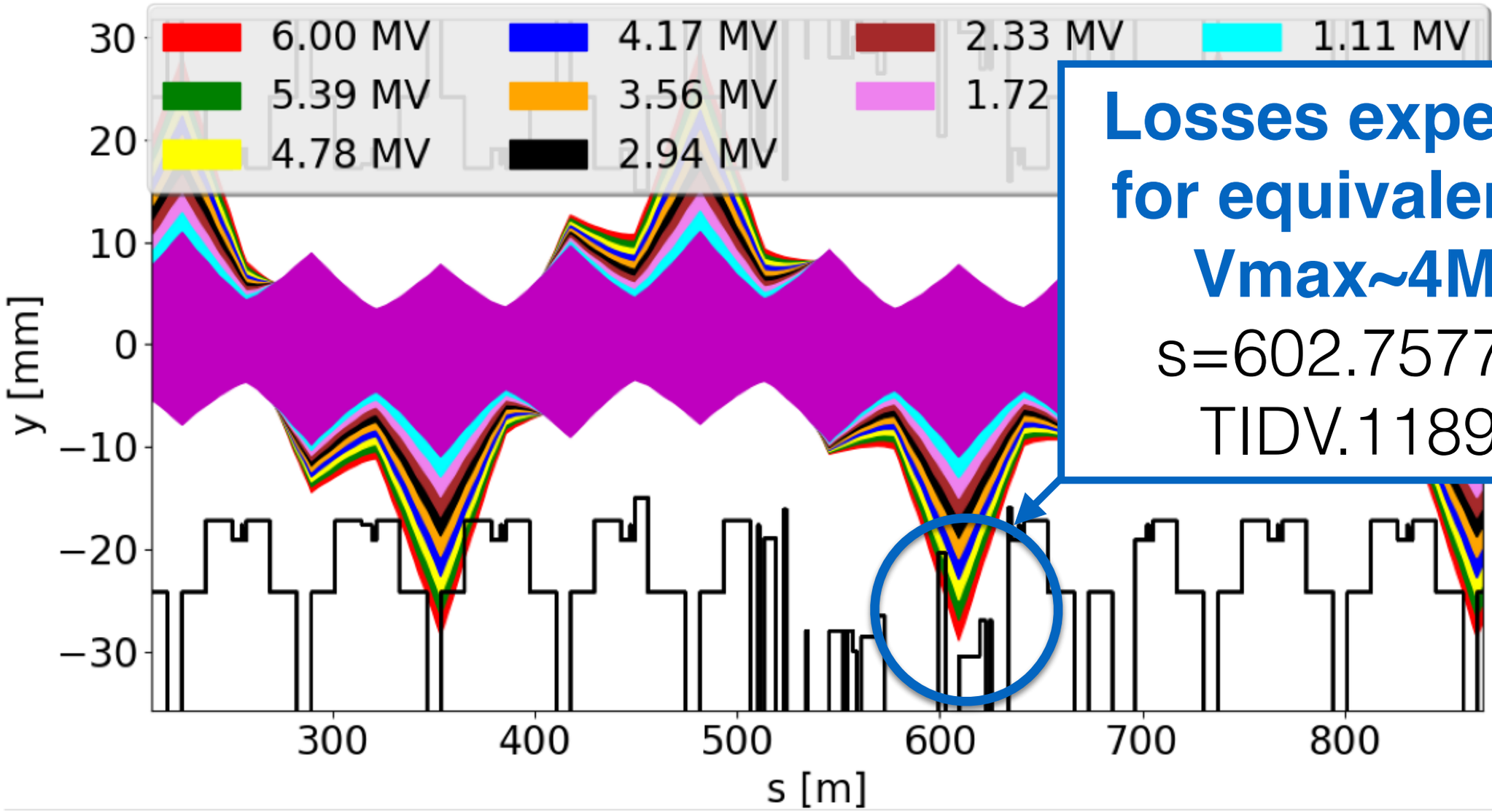


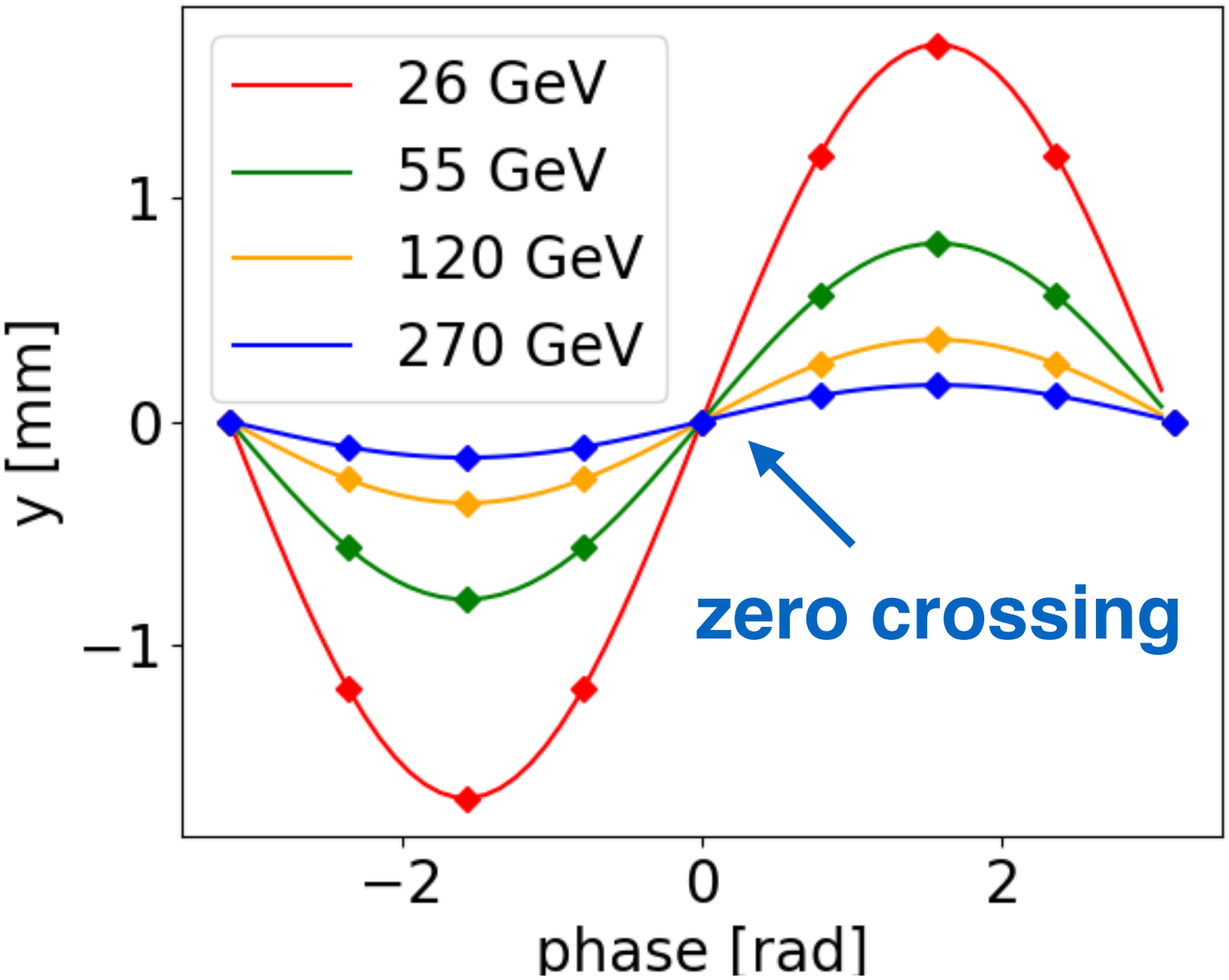
Losses expected for equivalent of Vmax~4MV

s=602.7577 m

TIDV.11892

Expected orbit measurement

4MV CC kick, ε_norm=2.5μm, 1σz=0.17m (@BWSB.41677)



Expected orbit measurement at SPS V BPMs

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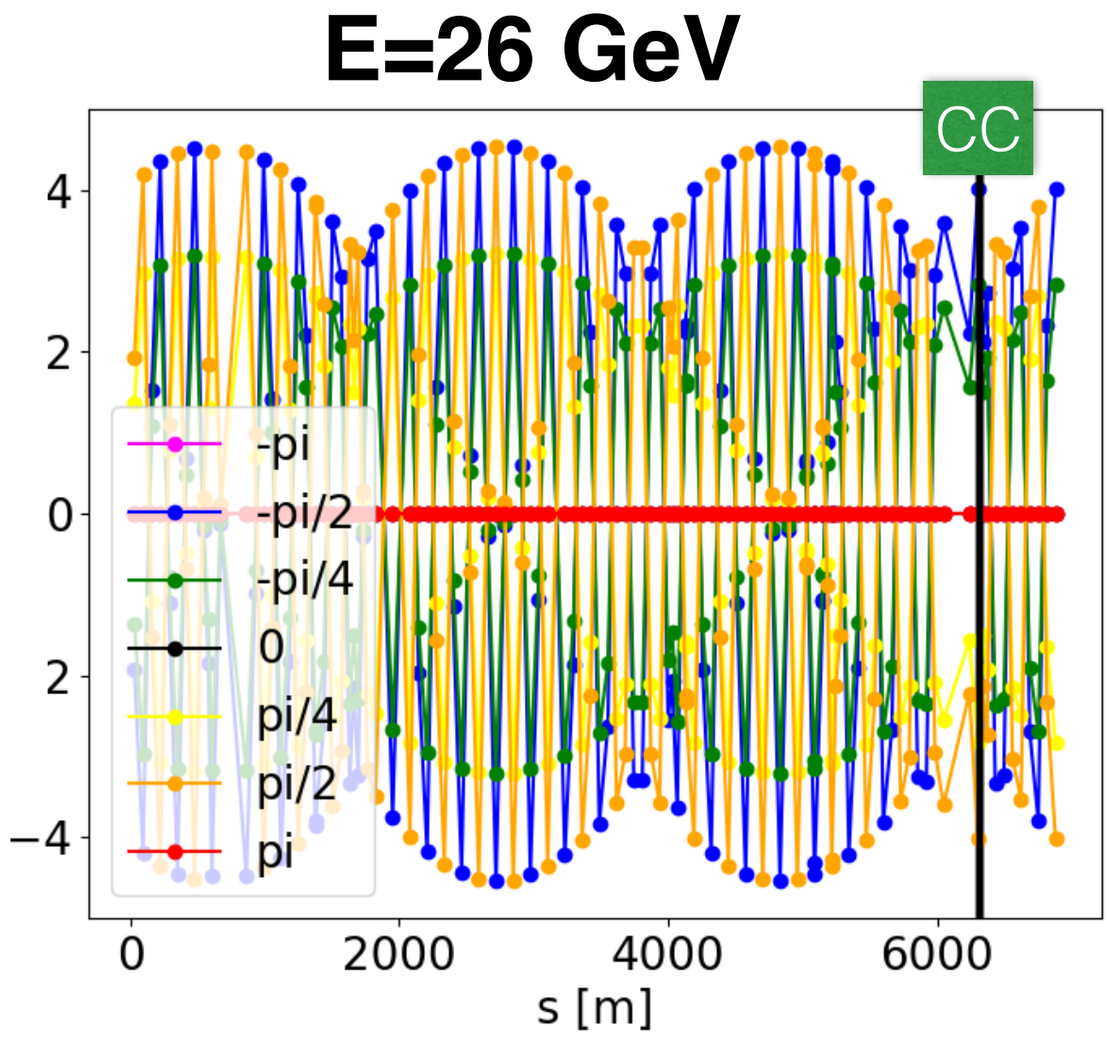

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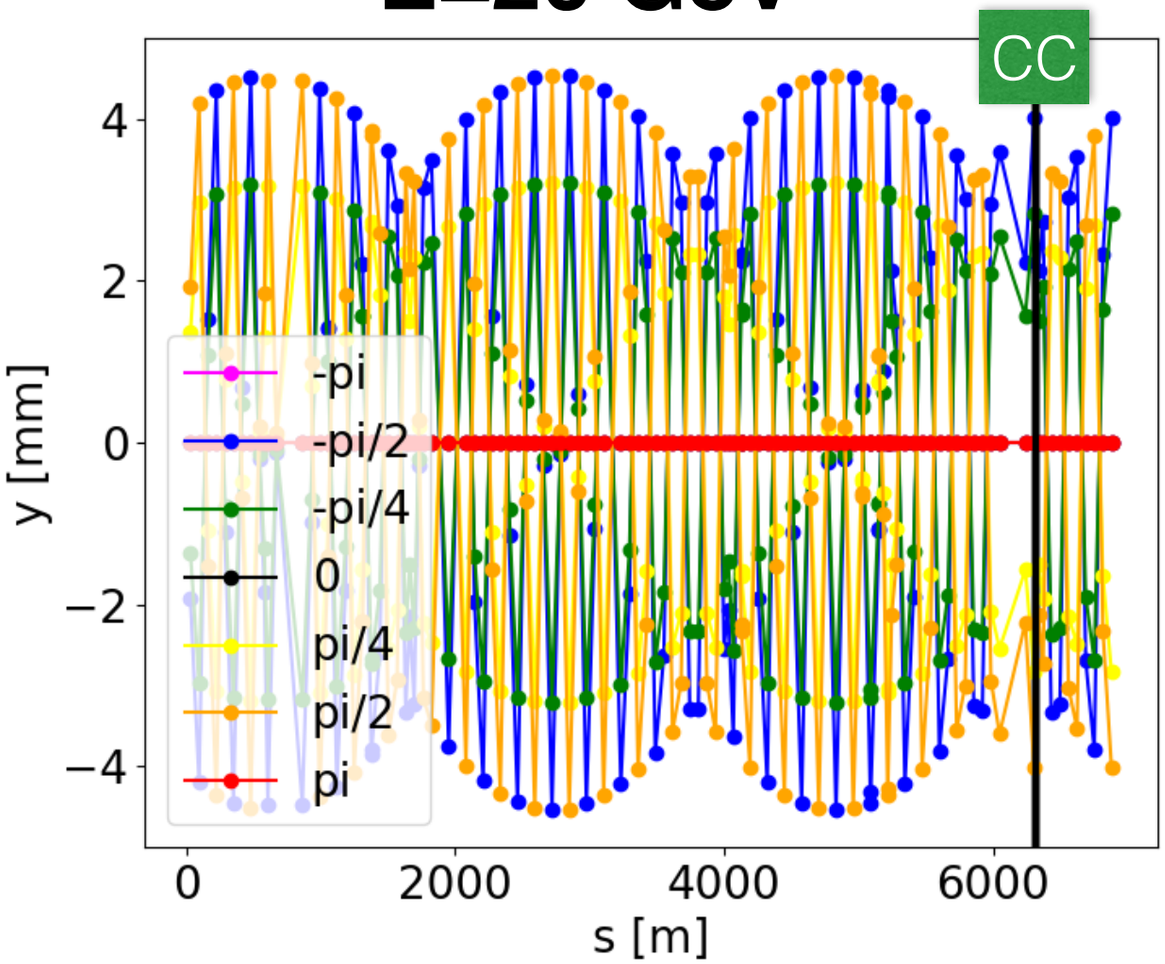
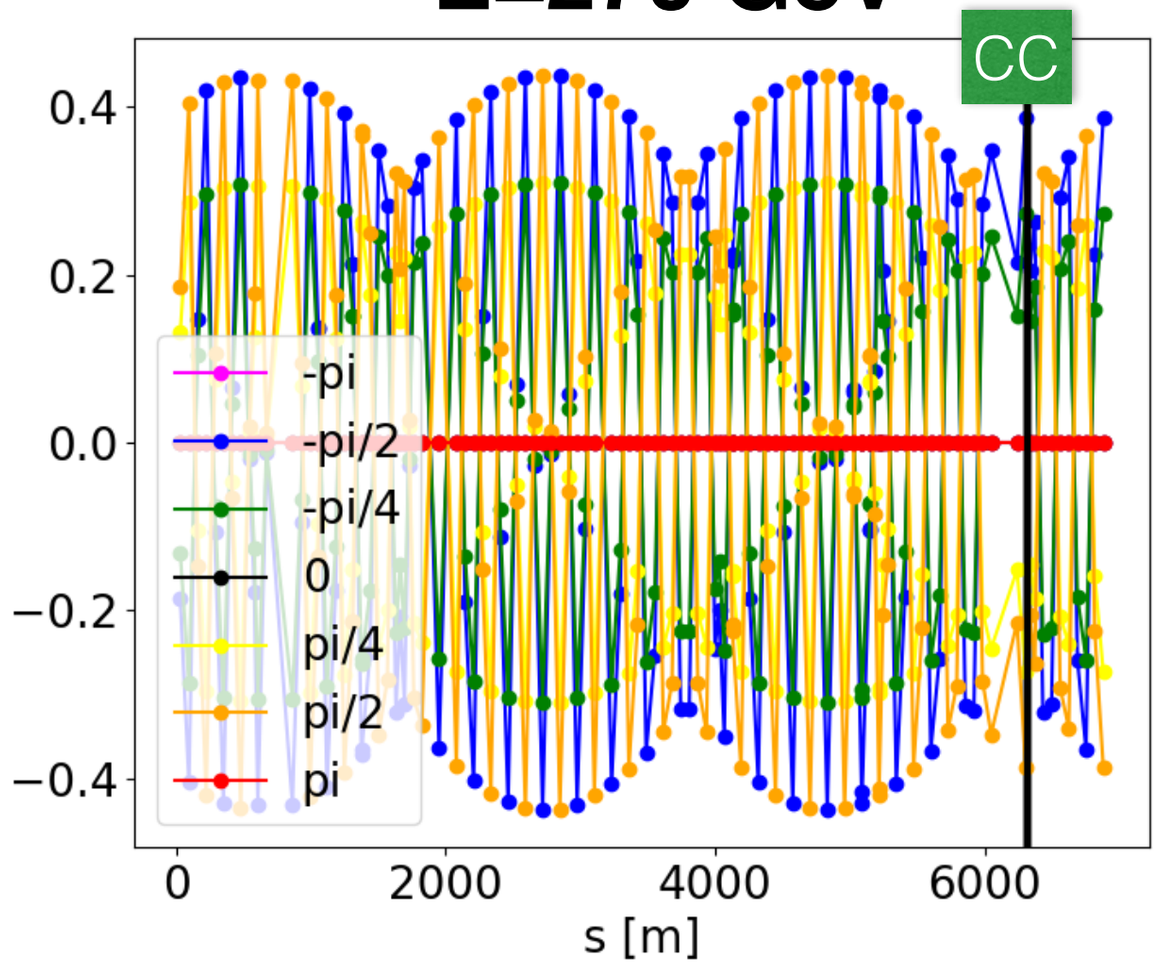
E=26 GeV



E=270 GeV



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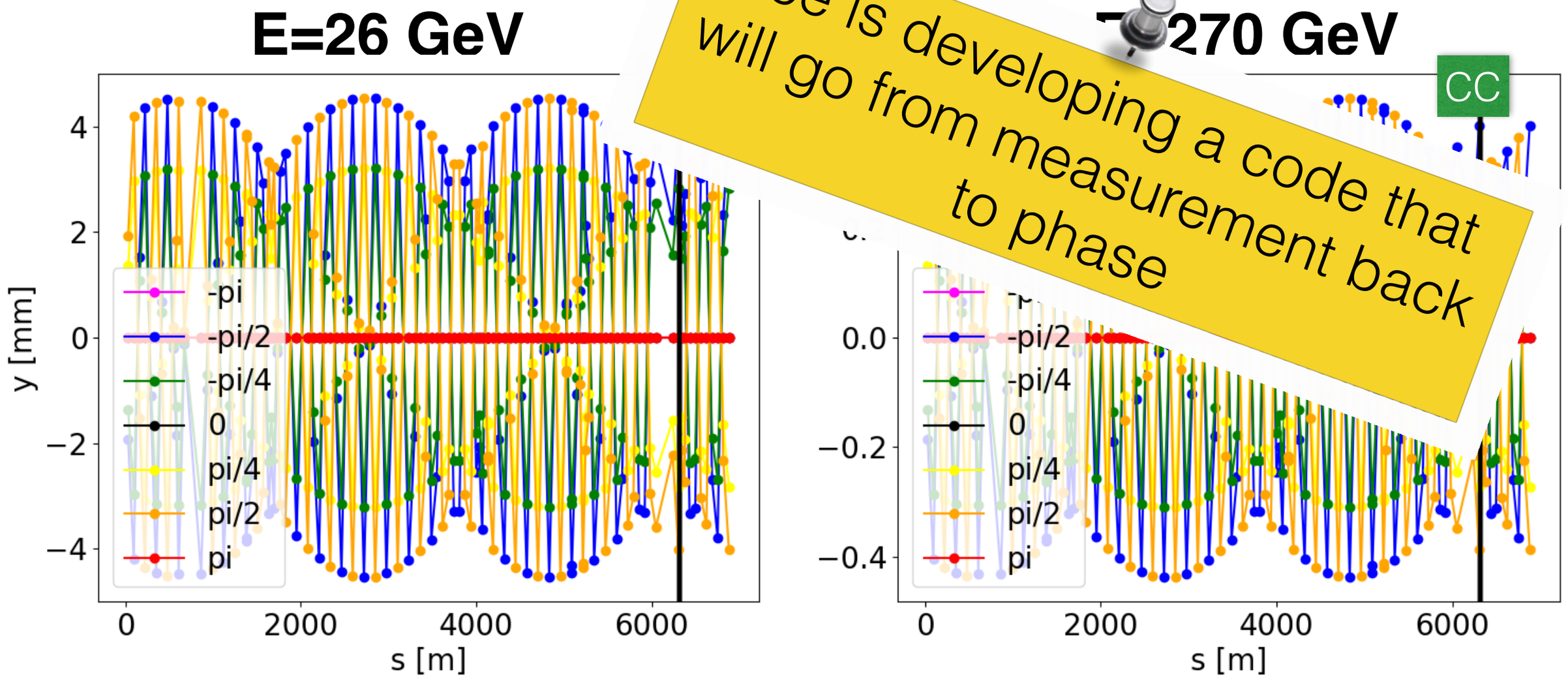

Lee is developing a code that will go from measurement back to phase

Head Tail (HT) monitor

4MV CC kick, ε_norm=2.5μm, 1σz=0.17m, BPCL.42171

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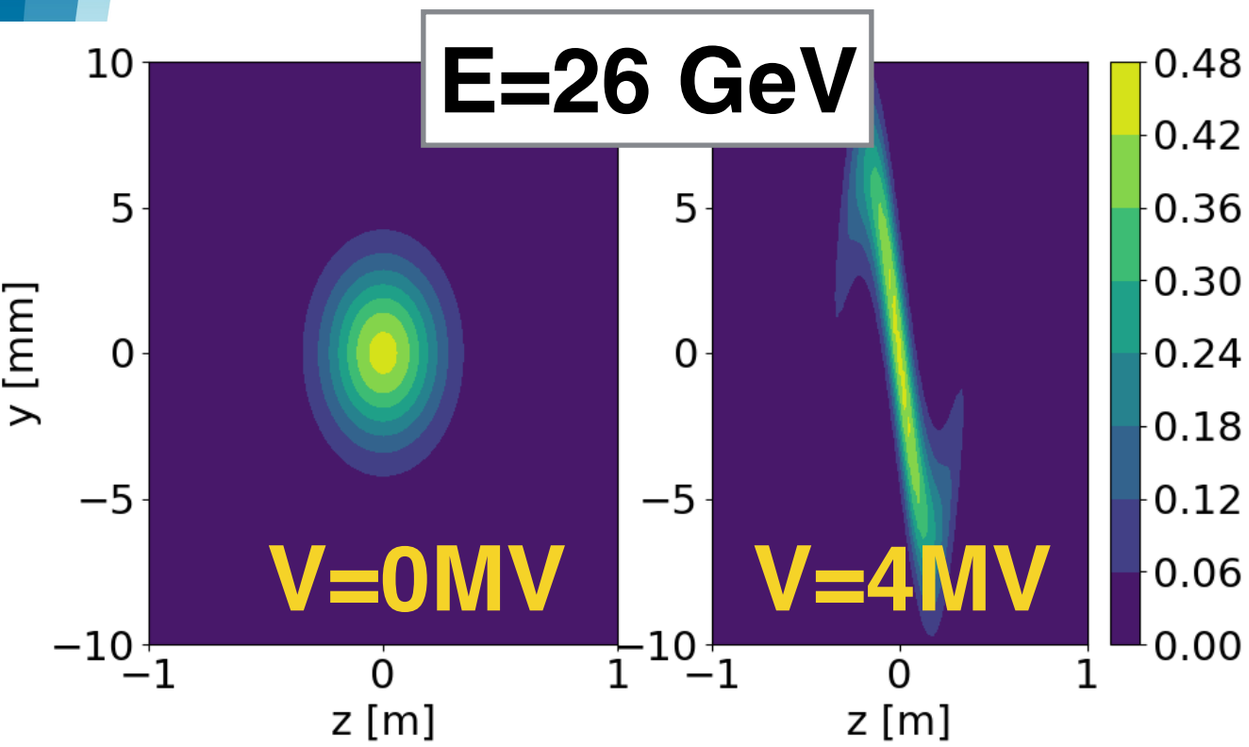

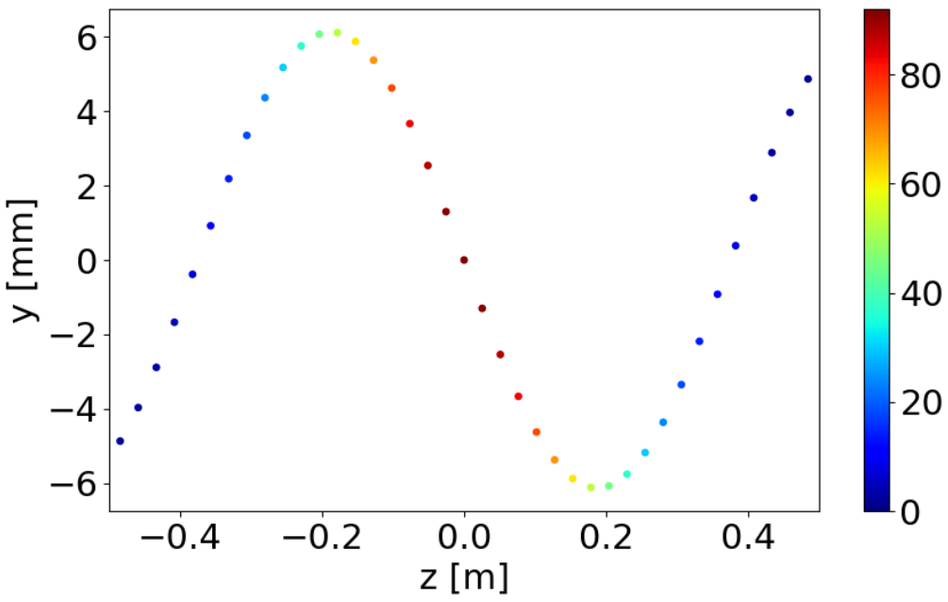

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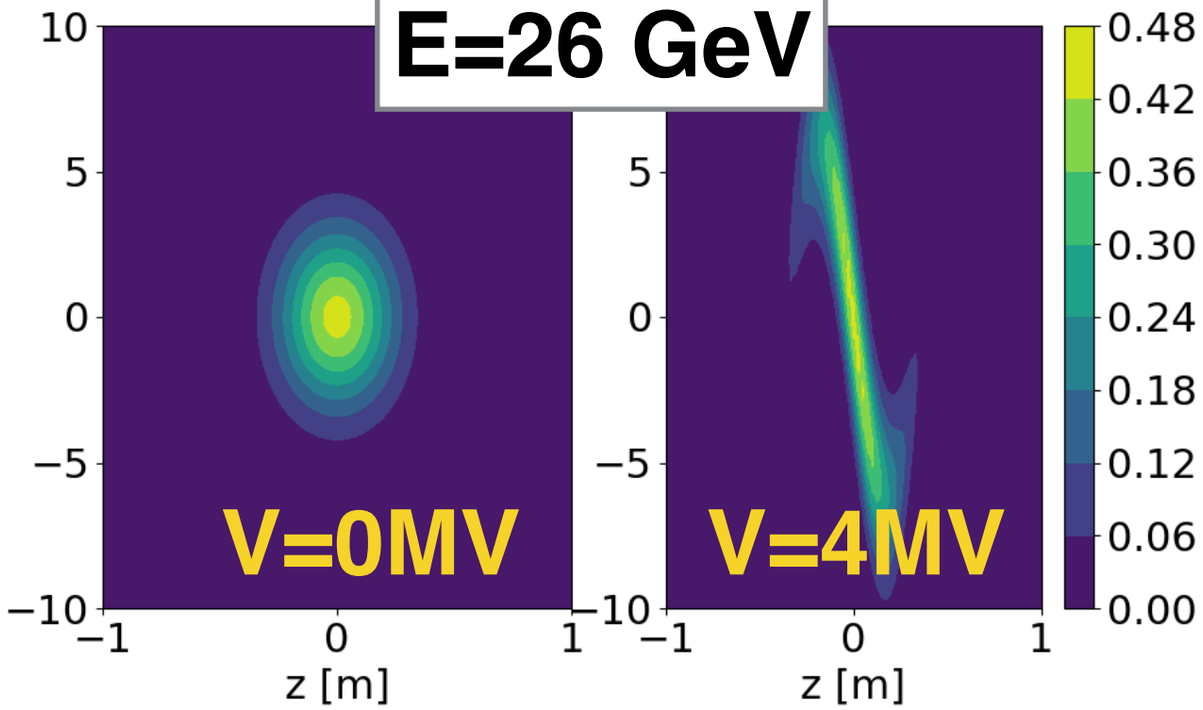

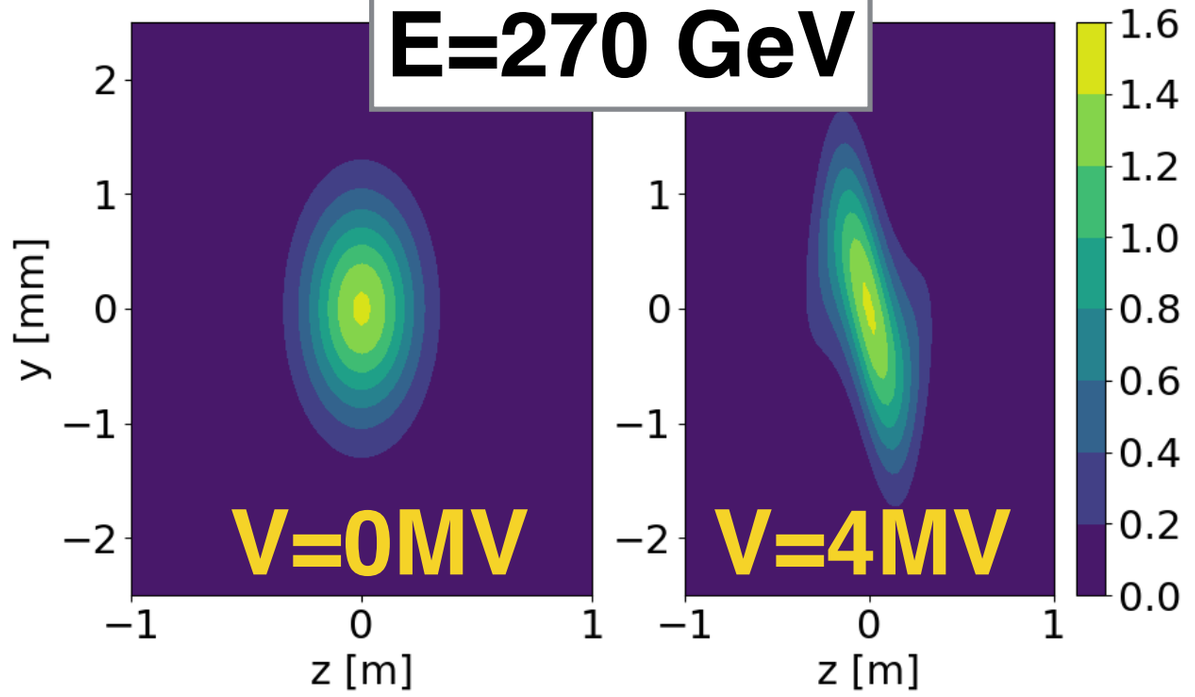

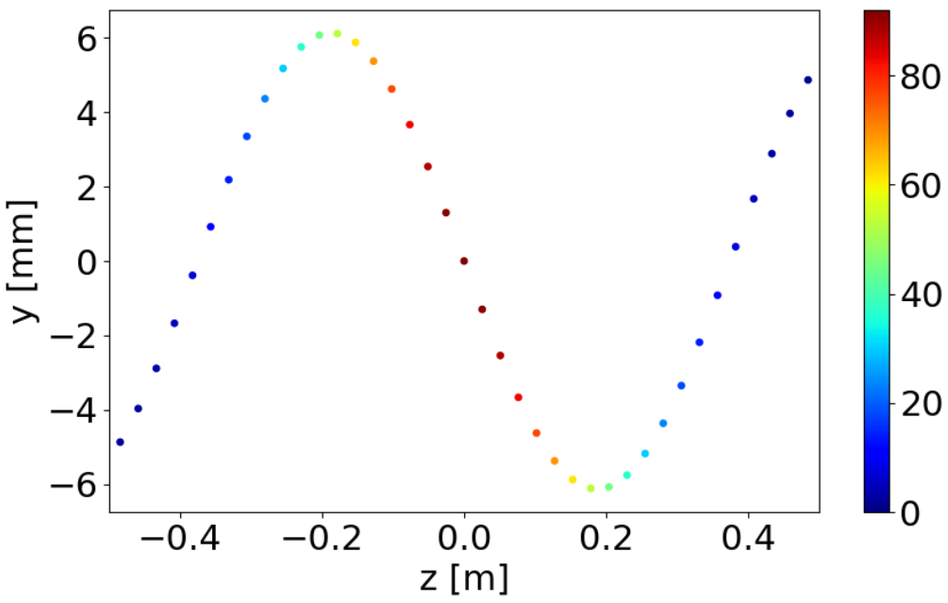

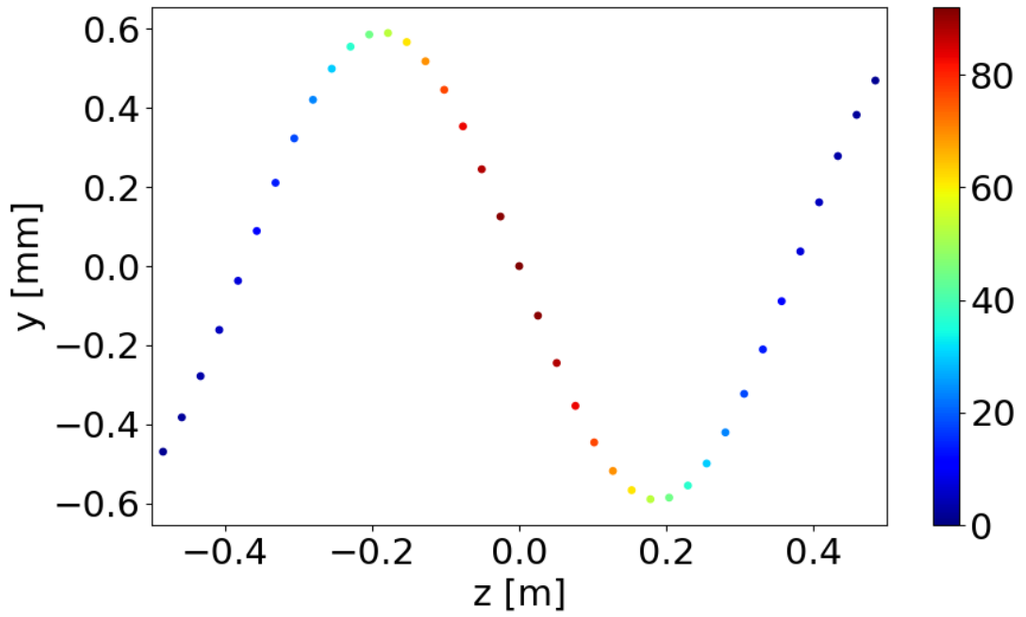

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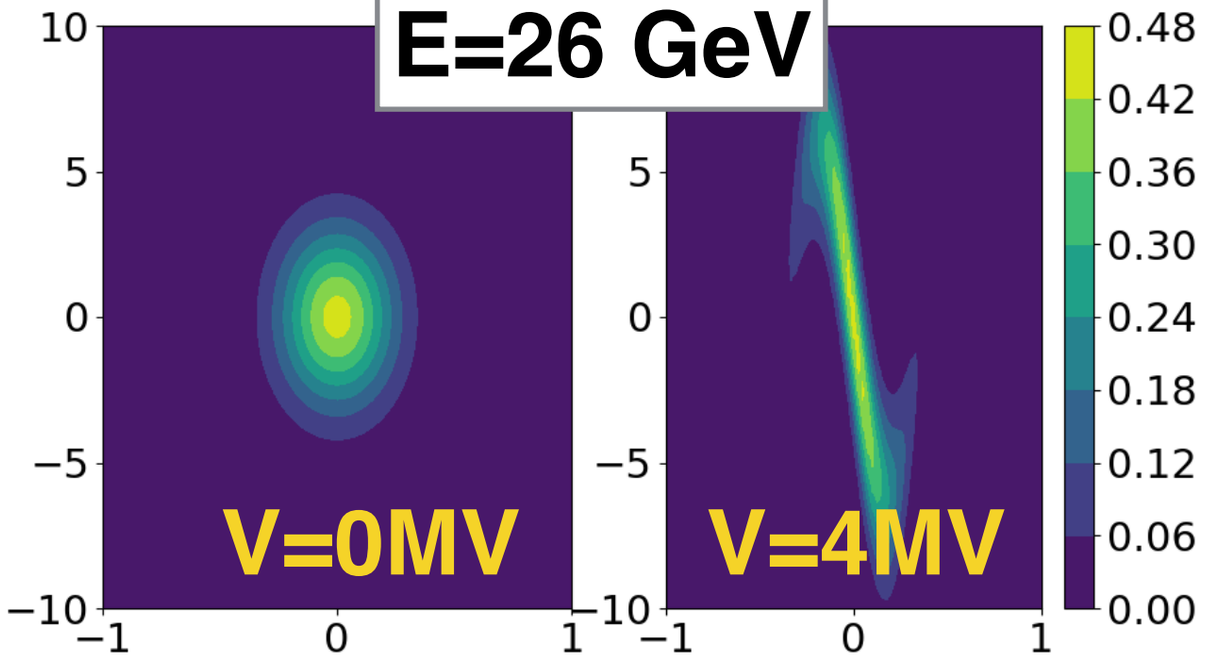
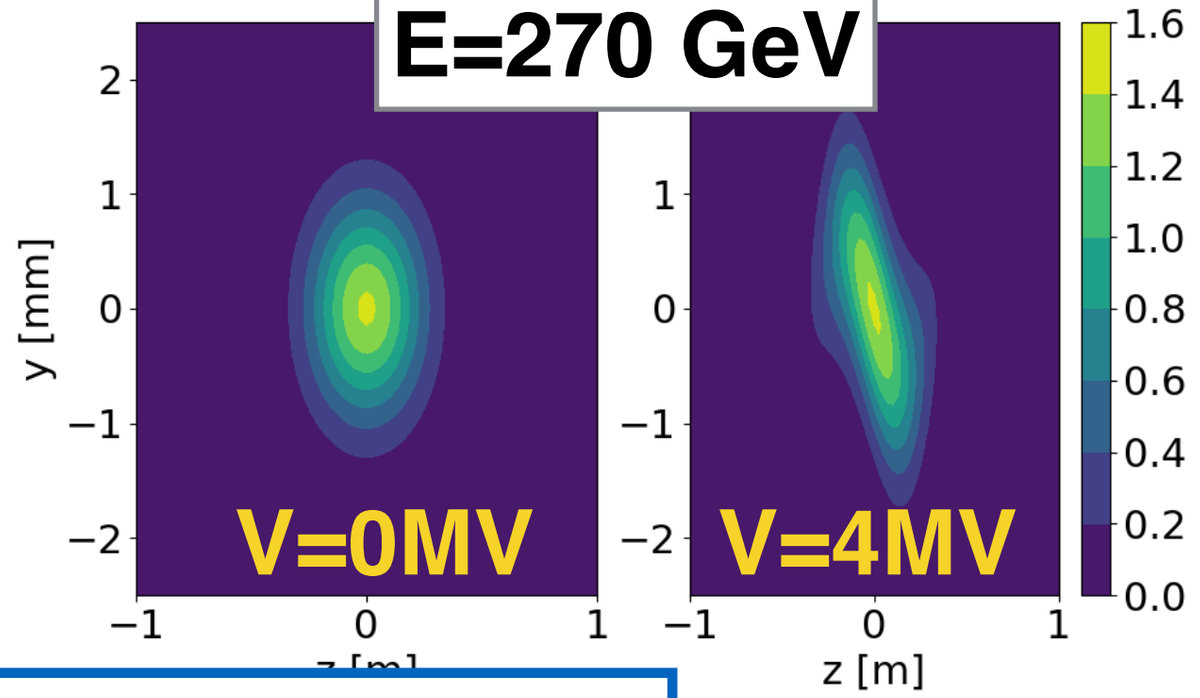
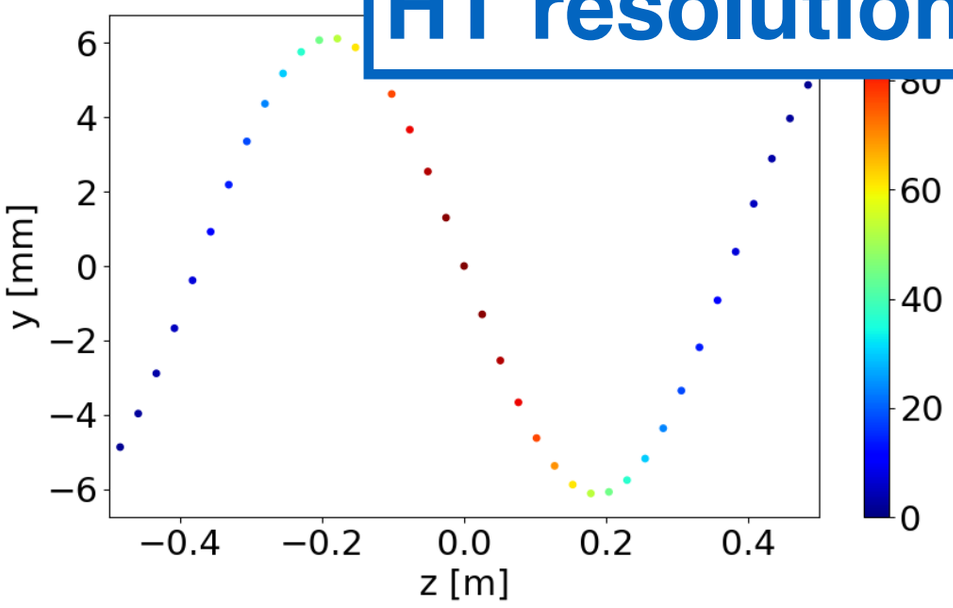
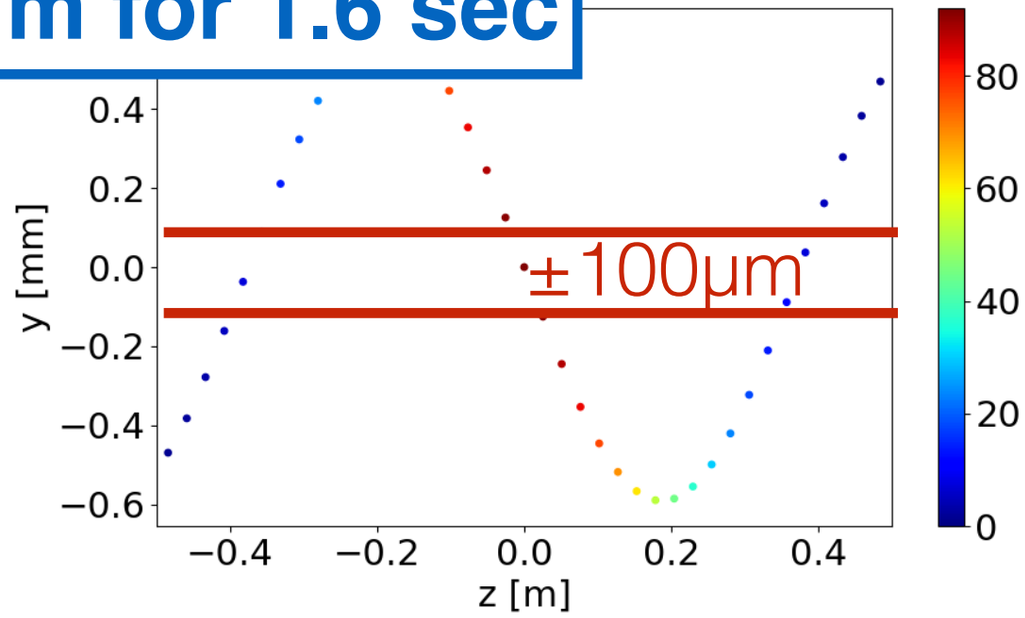




HT resolution < 100 μm for 1.6 sec





Wire Scanners (WS)

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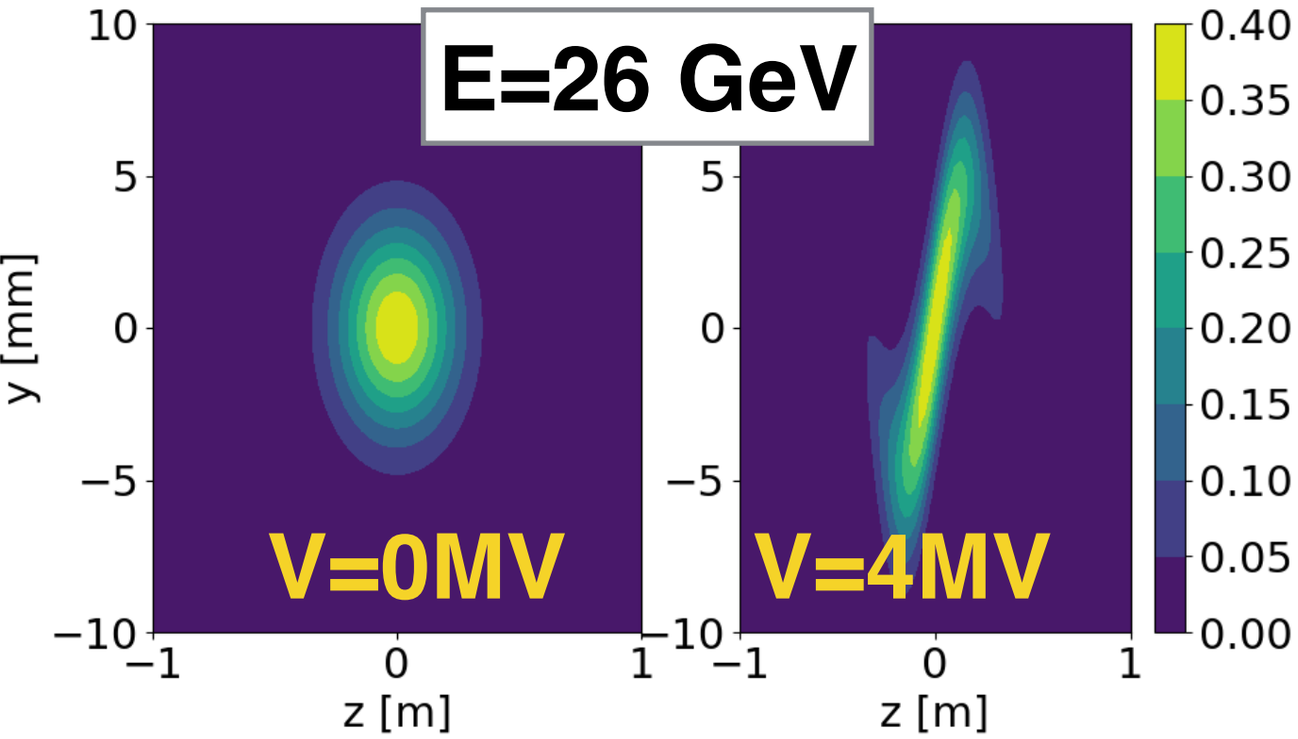

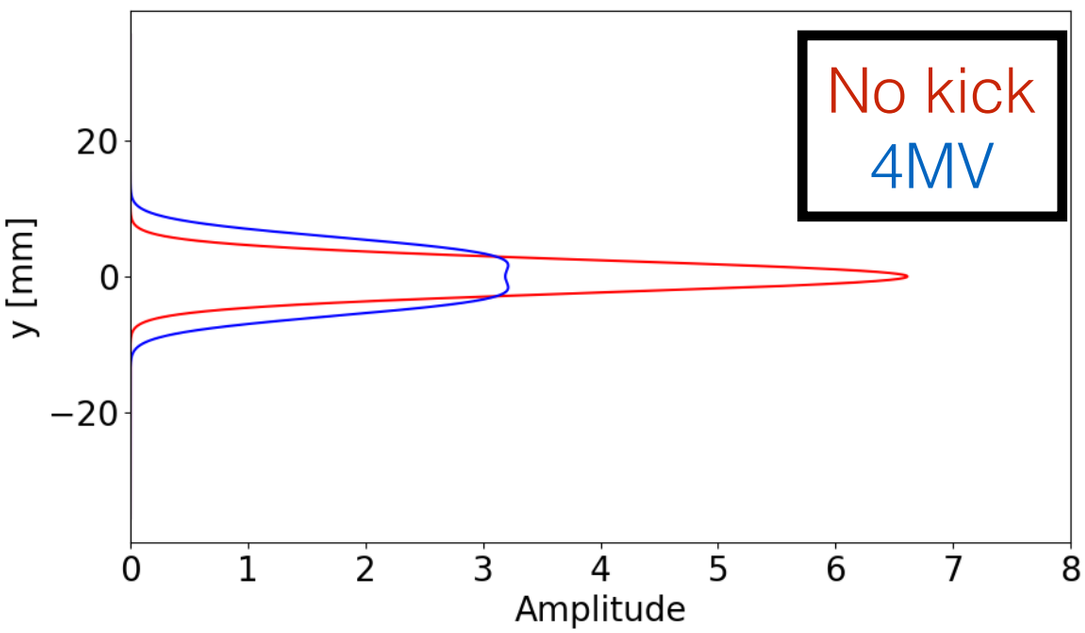

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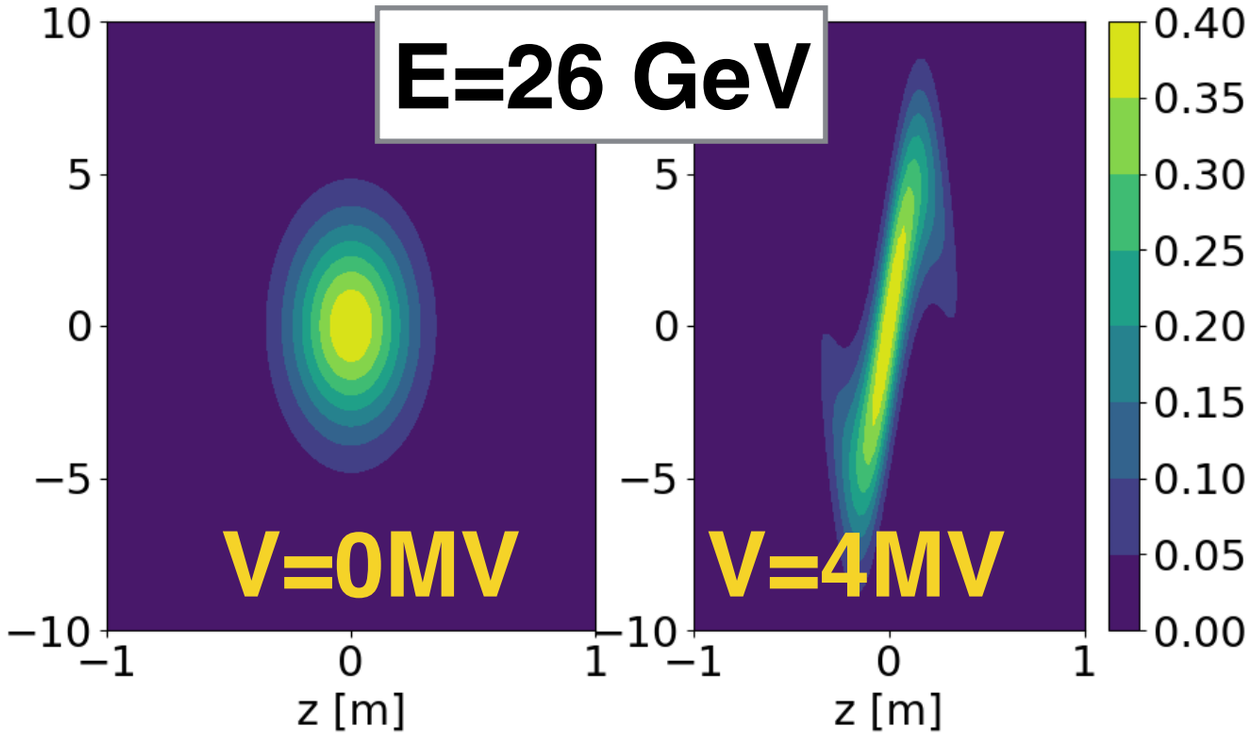

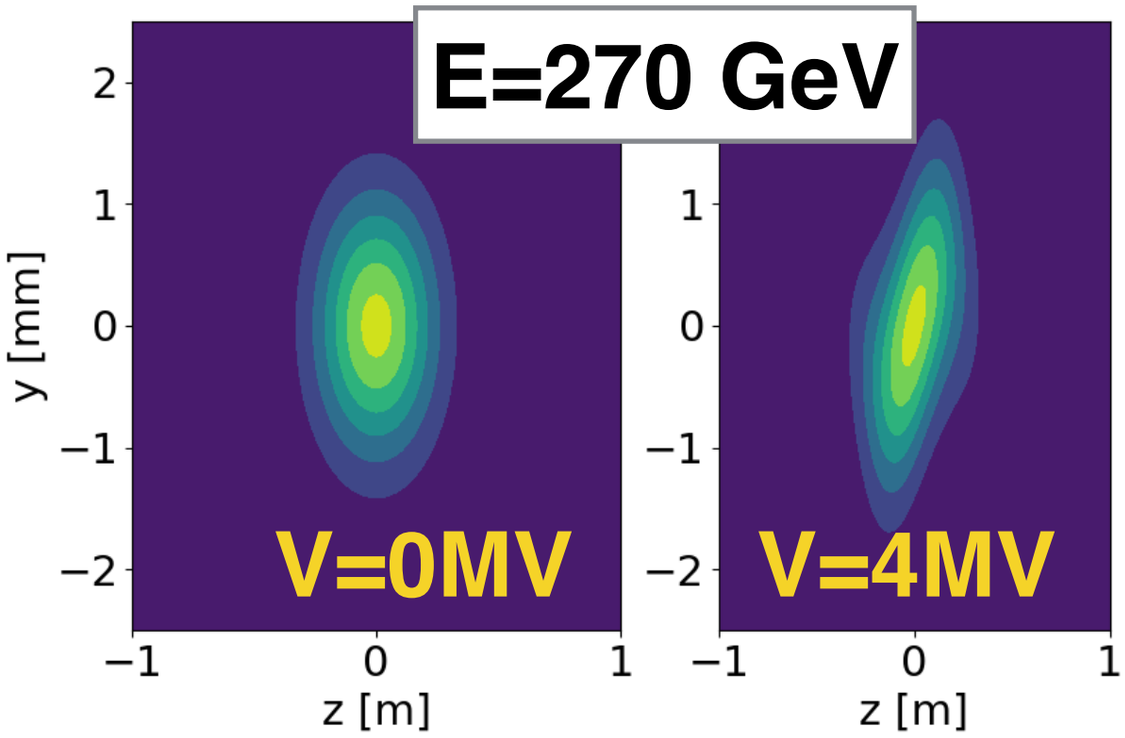

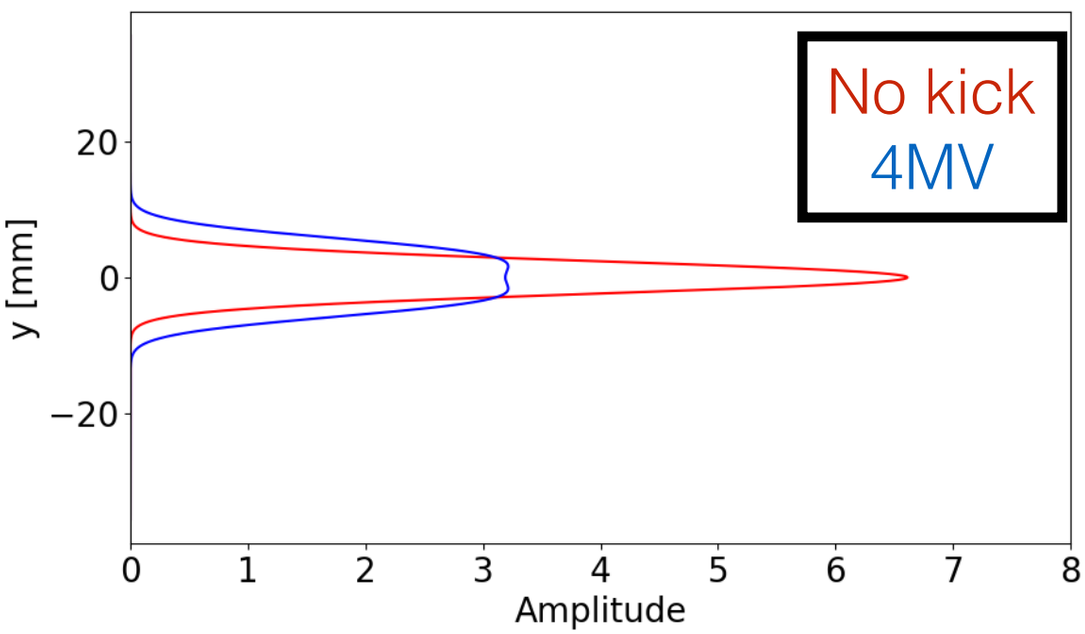

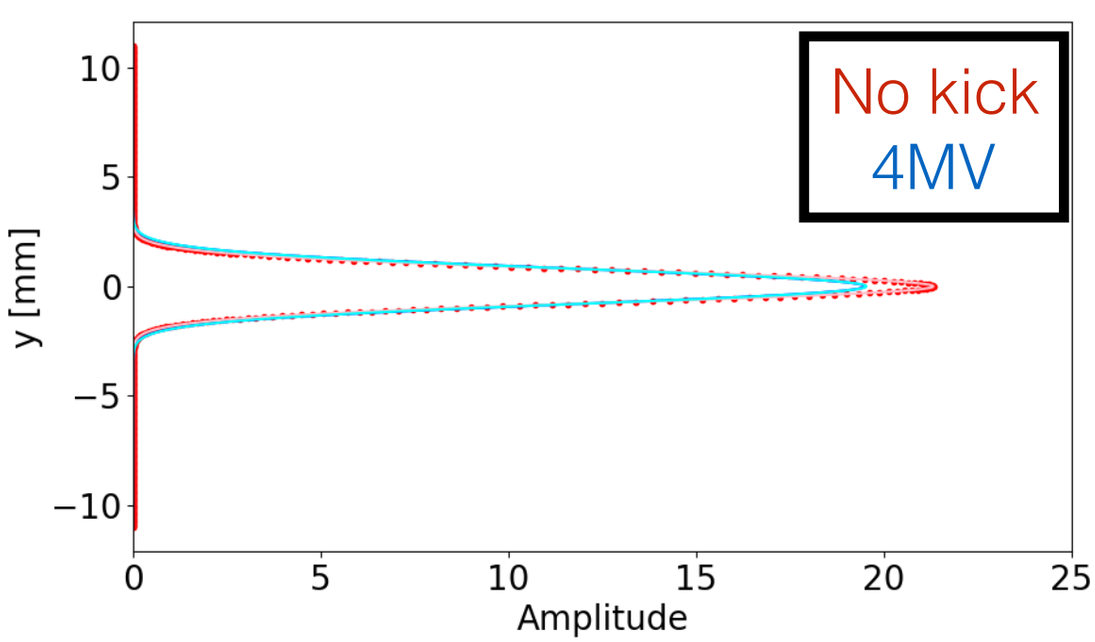

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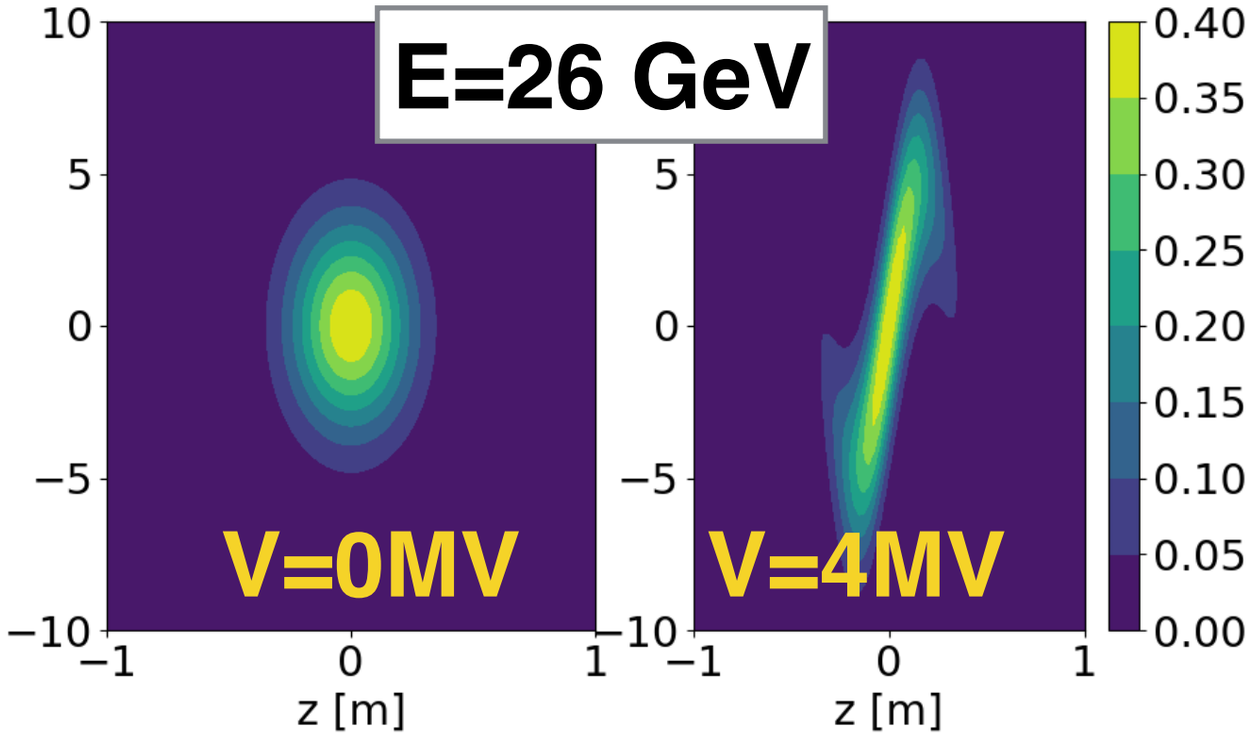

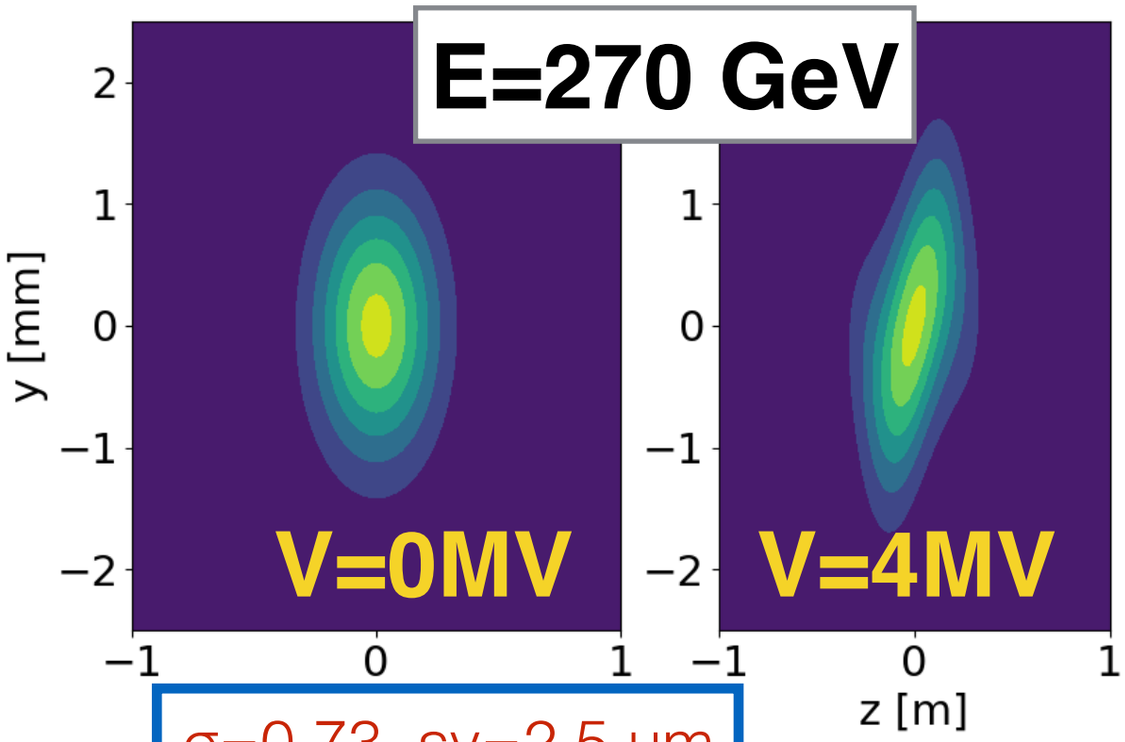

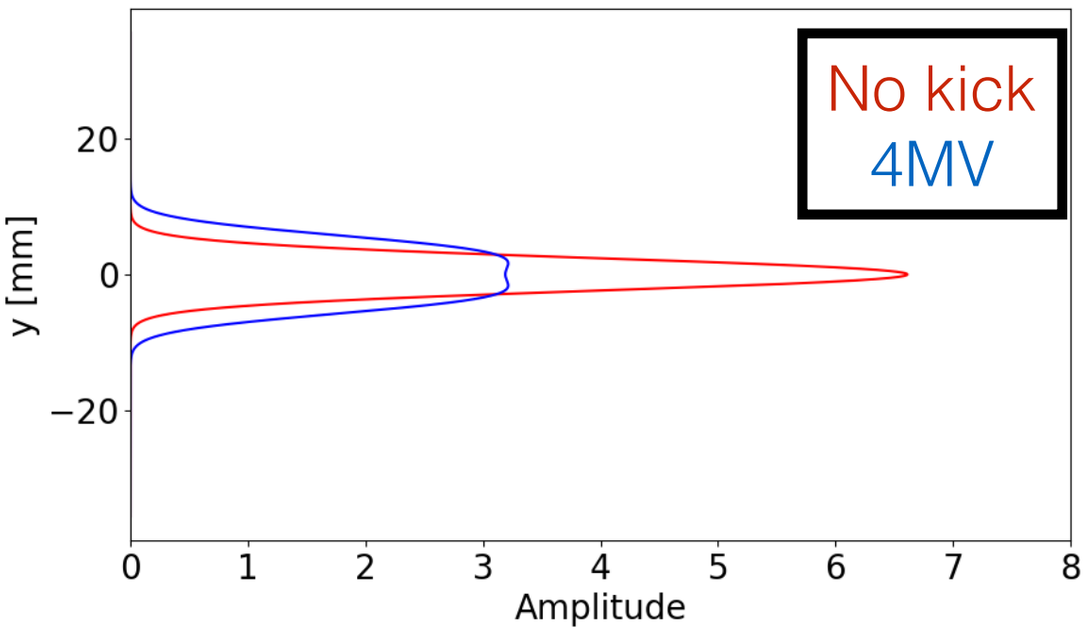

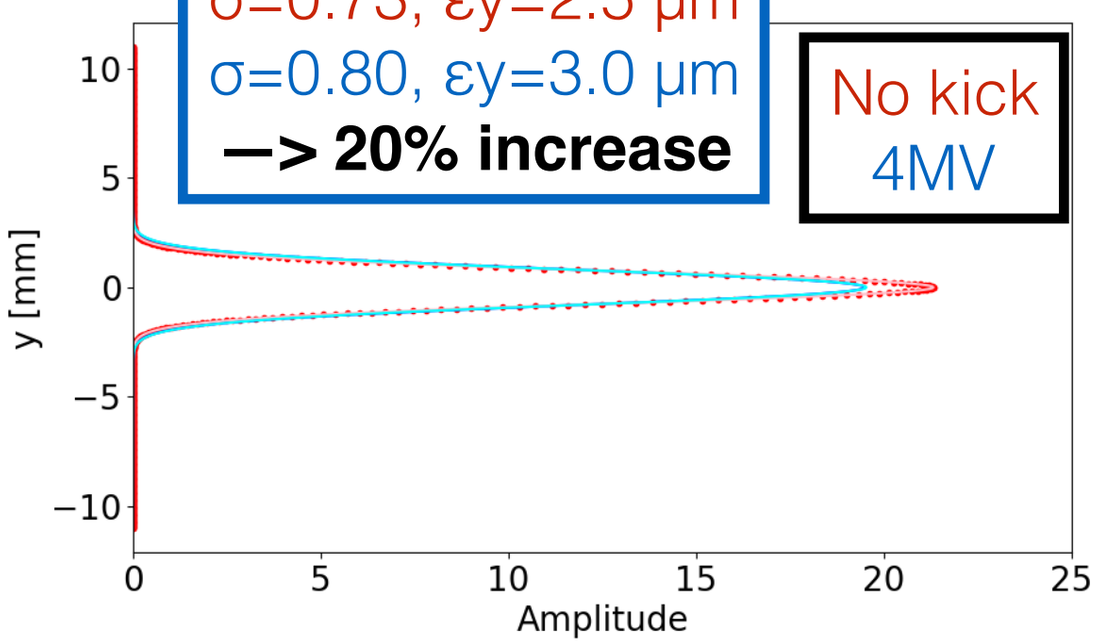

MD: a3 characterisation in present SPS

25Oct17,

A. Alekou, H. Bartosik, M. Carla, F. Carlier, N. Triantafyllou

a3 characterisation

a3 (skewed sextupole) characterisation
V bump in strong single octupole (Q20)

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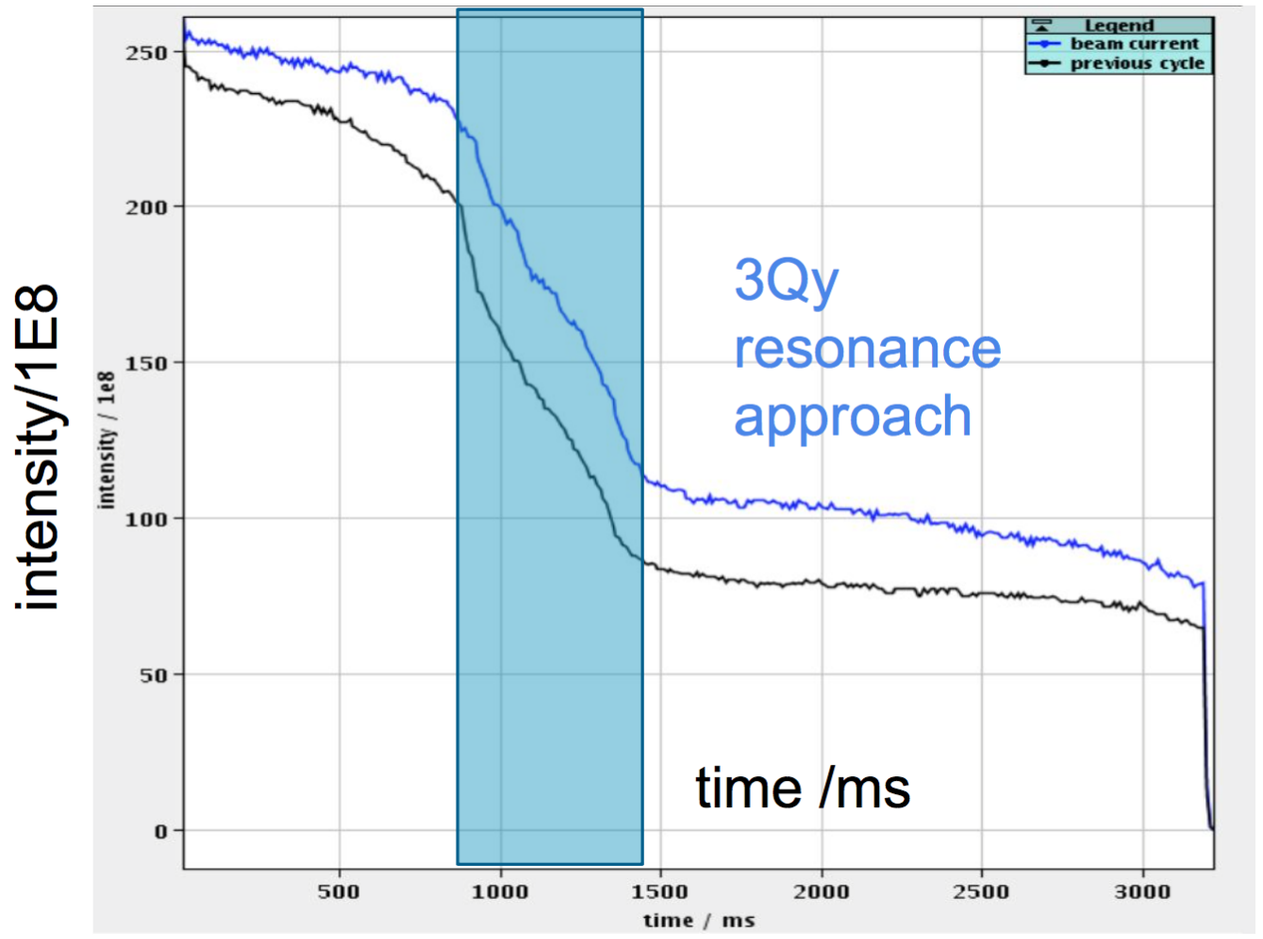
V bump in strong single octupole (Q20)

- 3Qy resonance approach and crossing for various bump and octupole settings

- Beam loss measurement yielded promising results



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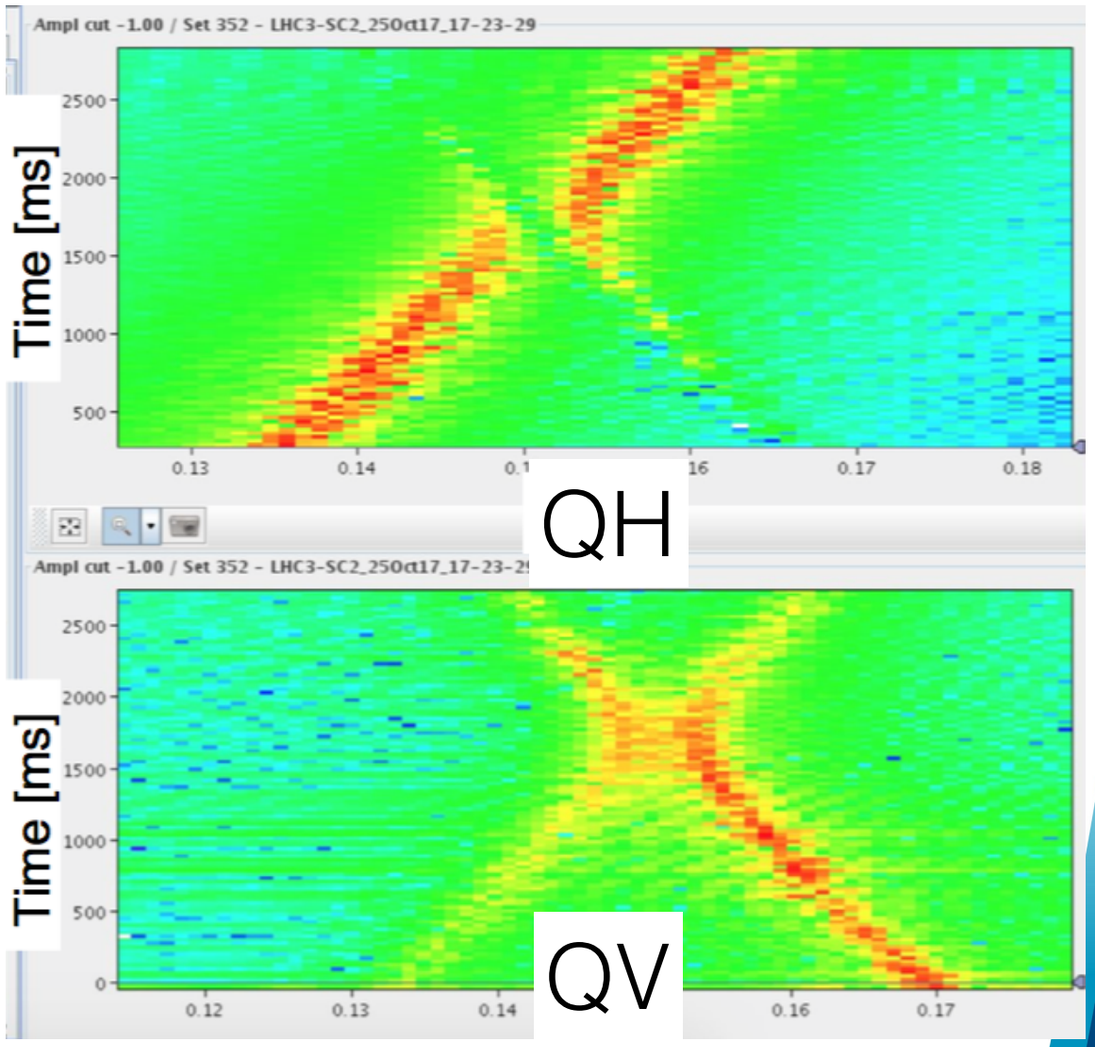

25Oct17, A. Alekou, H. Bartosik, M. Carla, F. Carlier, N. Triantafyllou

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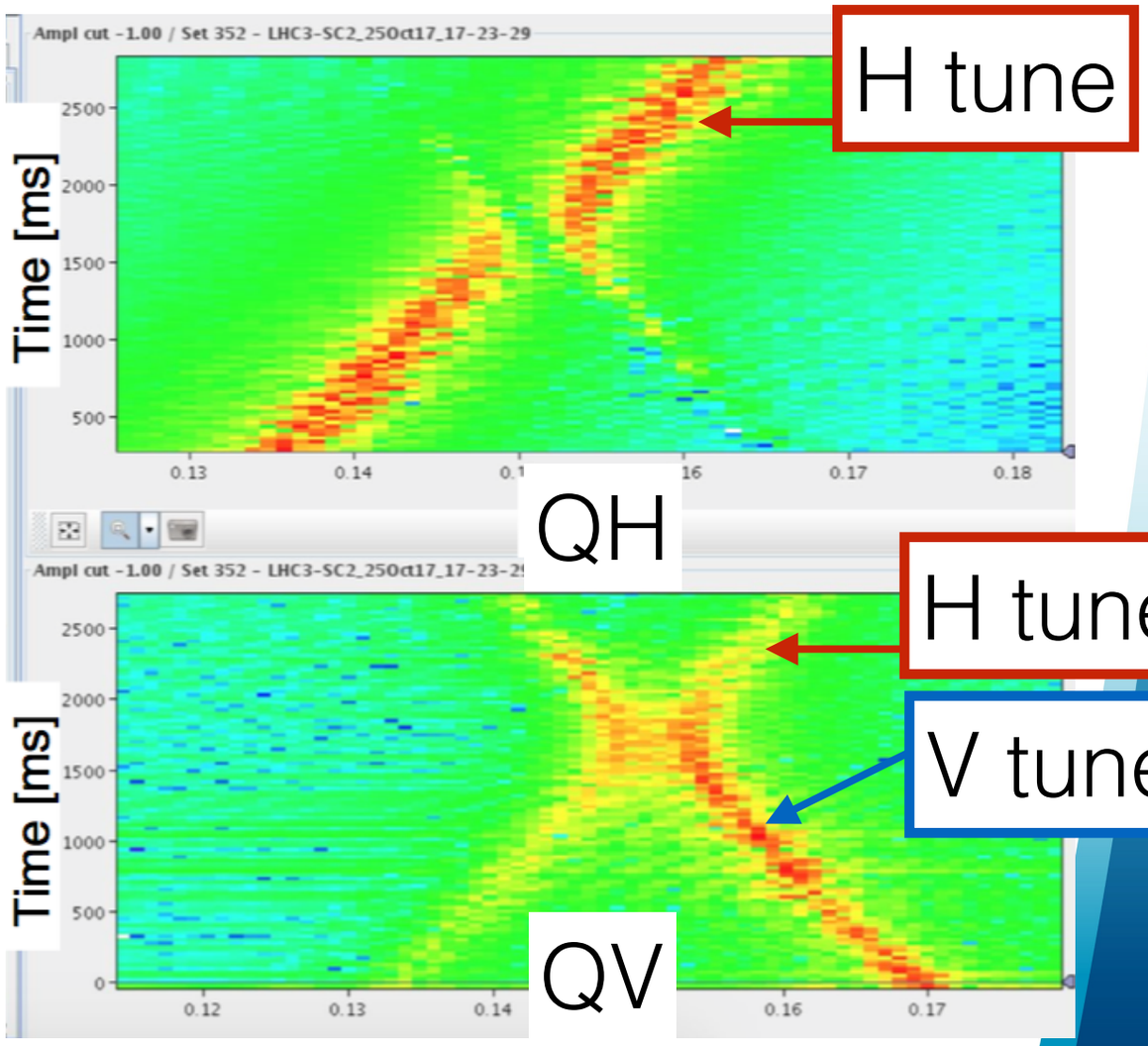

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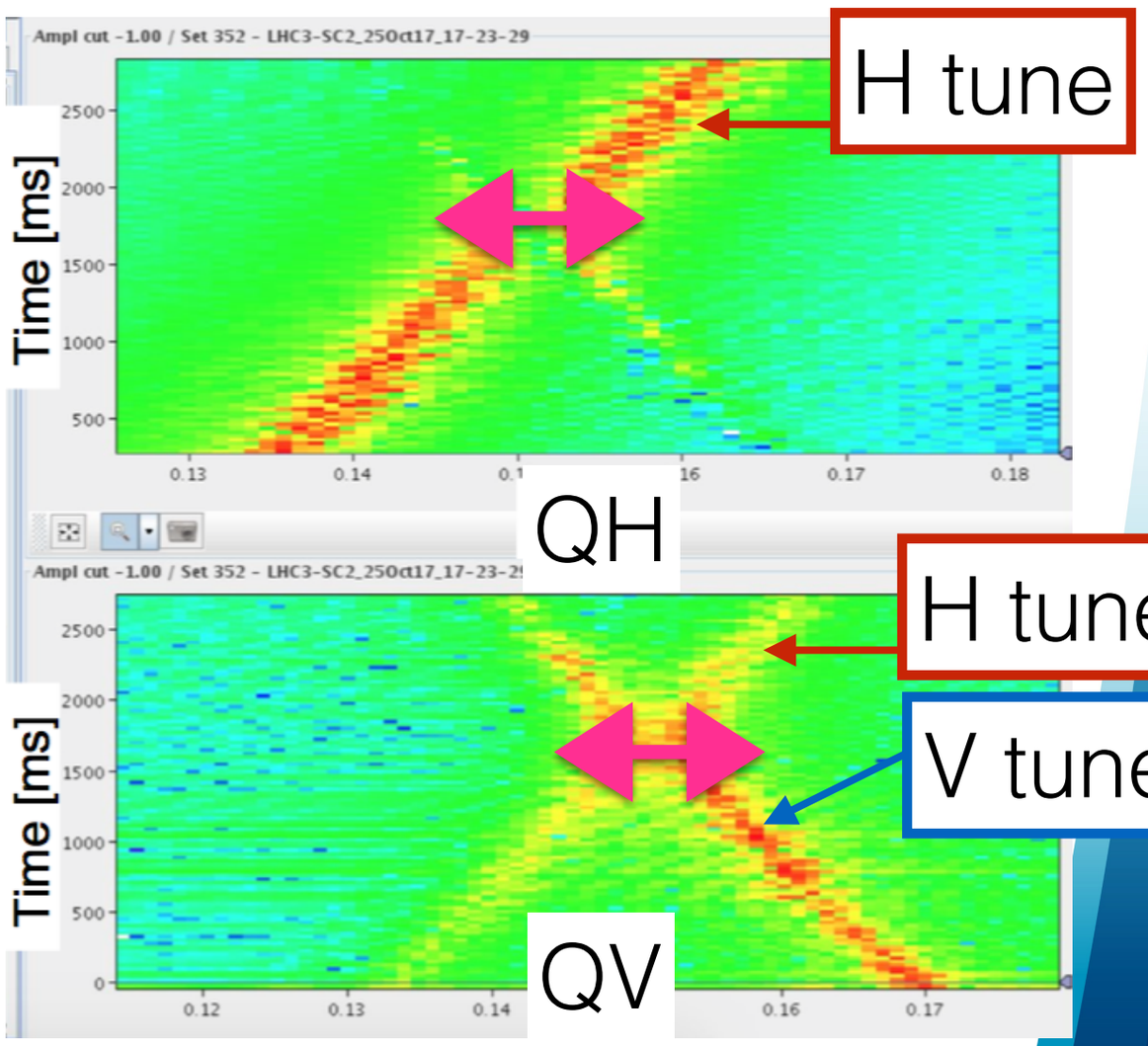
- **Distance** due to chromatic coupling changes with dp/p; **a3 characterisation**



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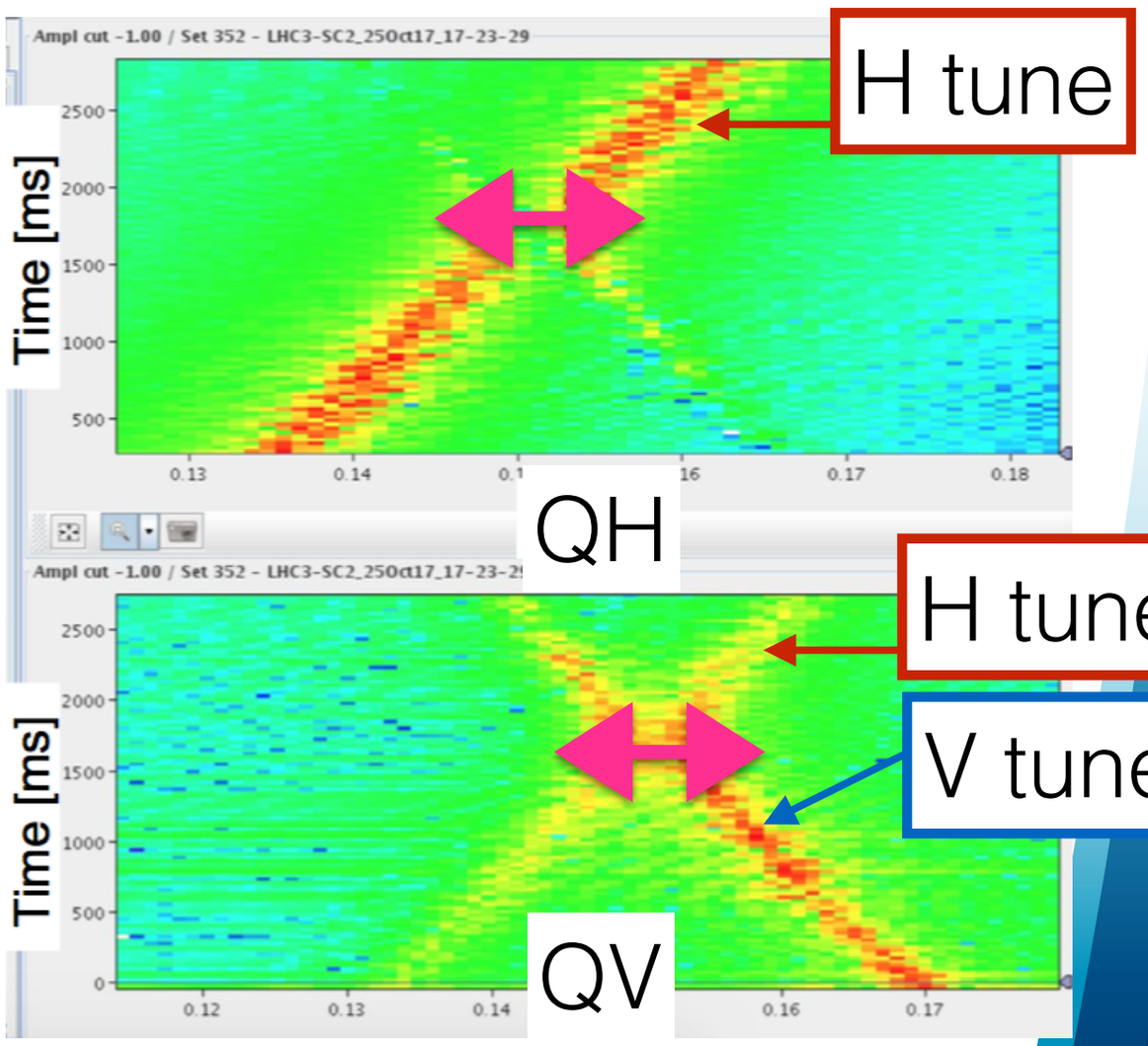
- **Ongoing** data analysis



25Oct17, A. Alekou, H. Bartosik, M. Carla, F. Carlier, N. Triantafyllou

Dynamic Aperture (DA) studies

$$\phi CC_1 = \phi CC_2 = 0^o$$

CC kicks adds up

Parameter	Value
norm $\varepsilon_{x,y}$ [μm]	2.5
E0 [GeV]	26
Qx, Qy	26.13/26.18
Chrom [H, V]	0, 0
f CC [MHz]	400
V RF [MV]	2
f RF [MHz]	200

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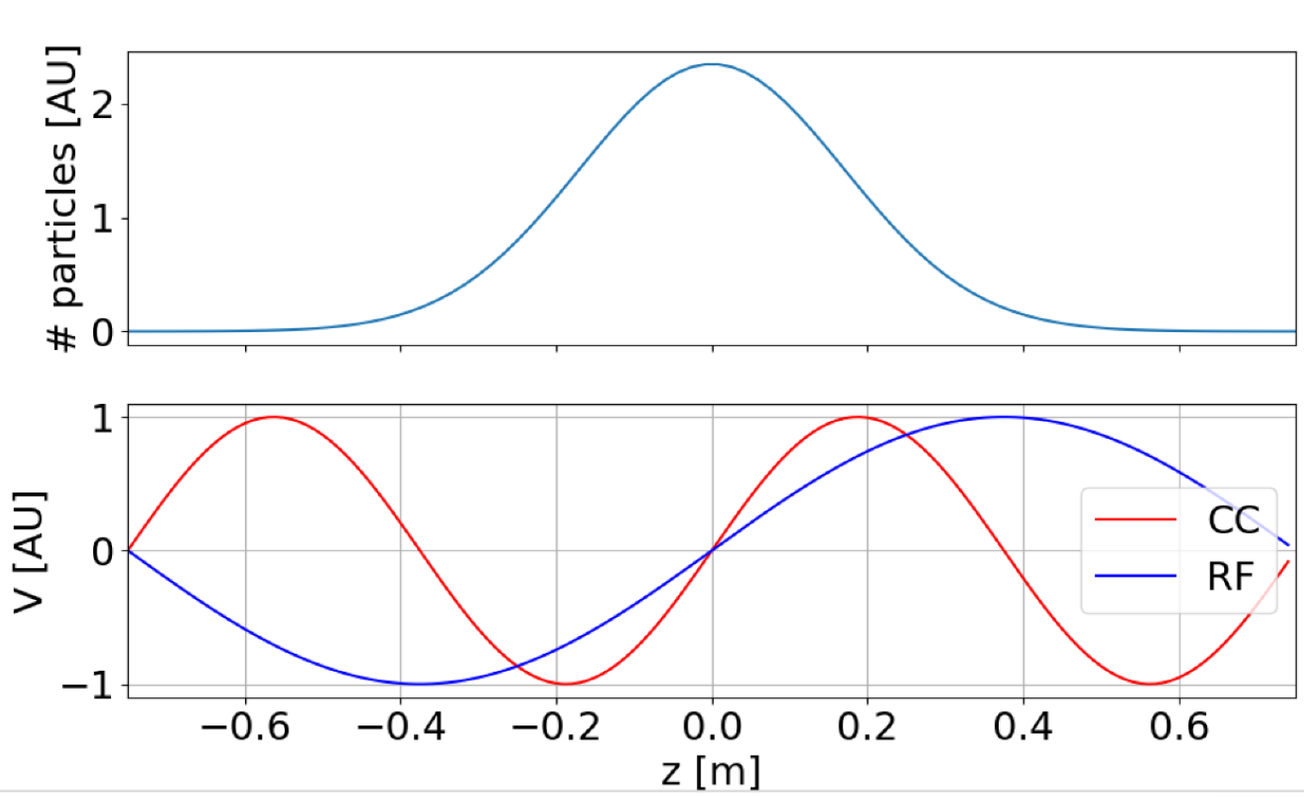

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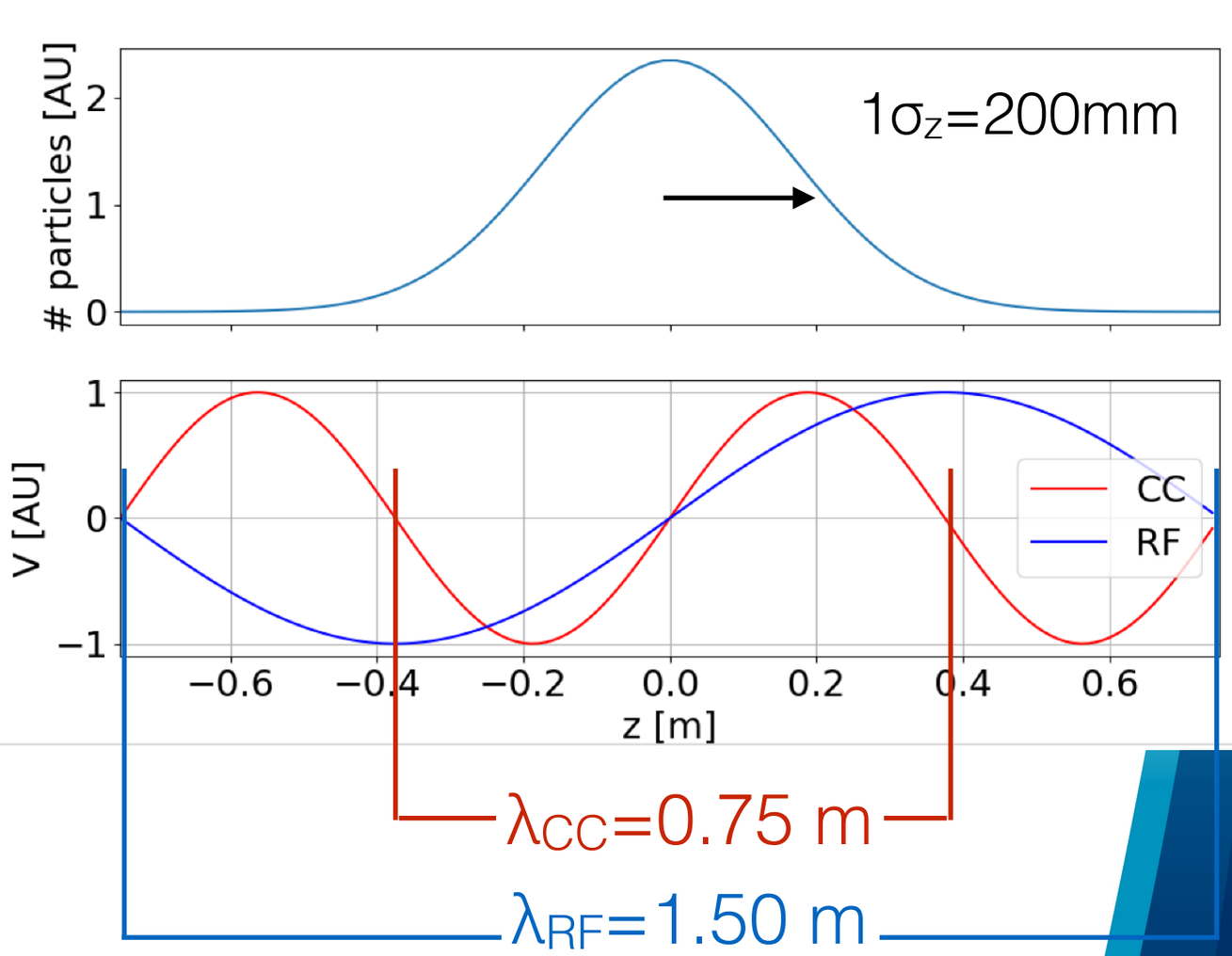


SPS lattice with multipole errors, 26 GeV

(with machine errors*, up to b5)

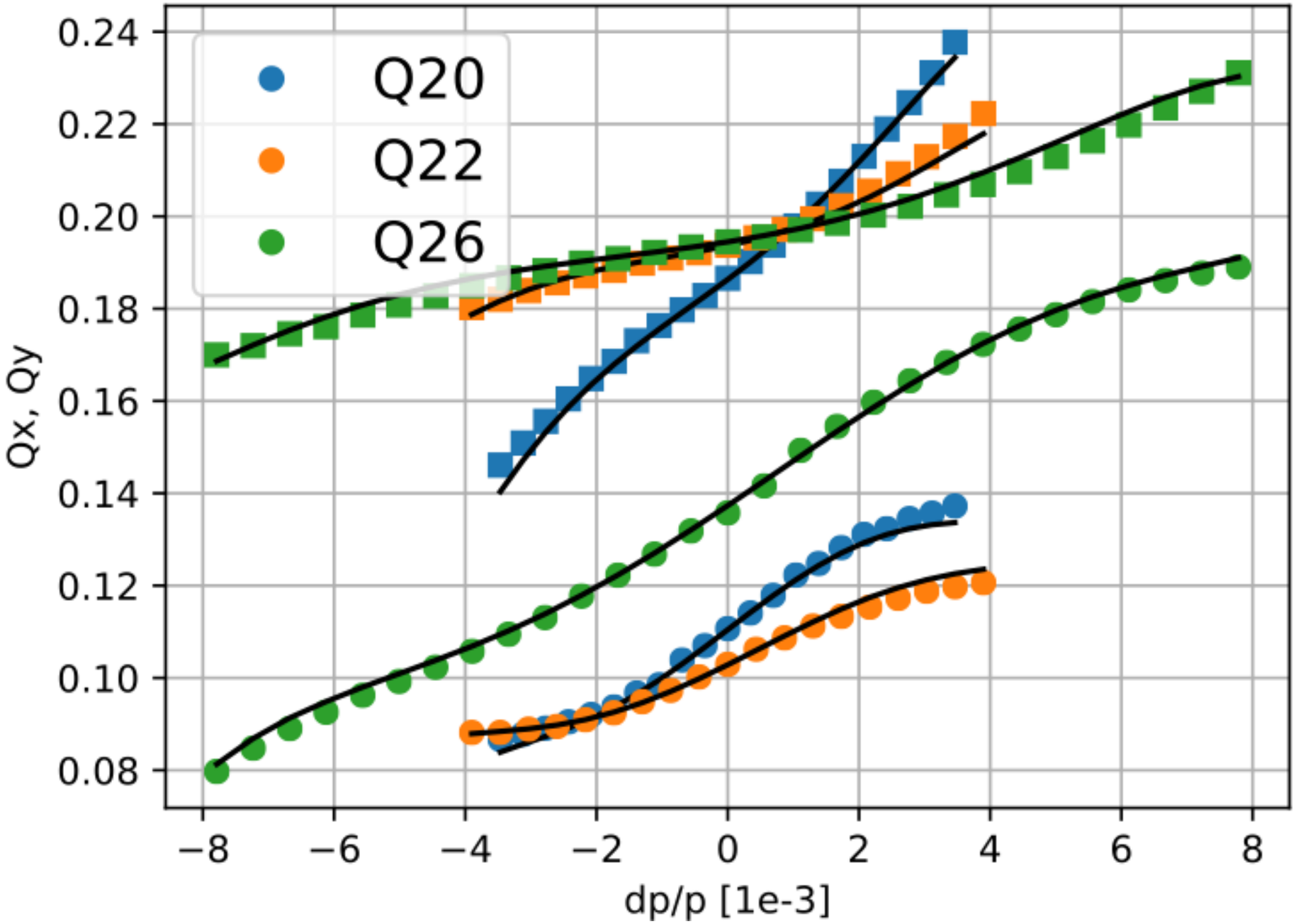
SPS lattice with multipole errors, 26 GeV

(with machine errors*, up to b5)

*calculated by M. Carla' based on measurements of SPS non-linear chromaticity

Non-linear chromaticity measurement

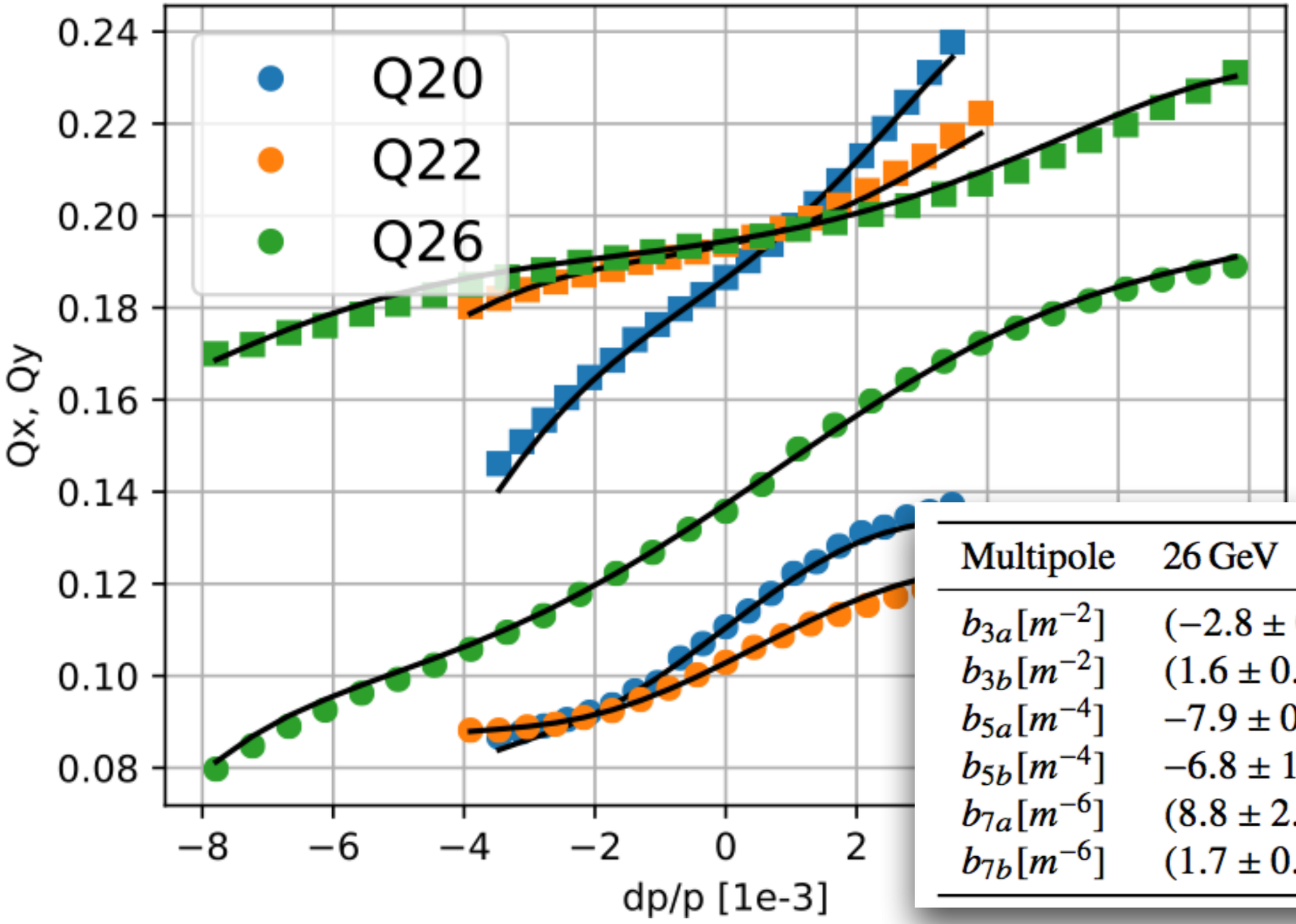
H ●
V ■



Michele Carla’

Non-linear chromaticity measurement

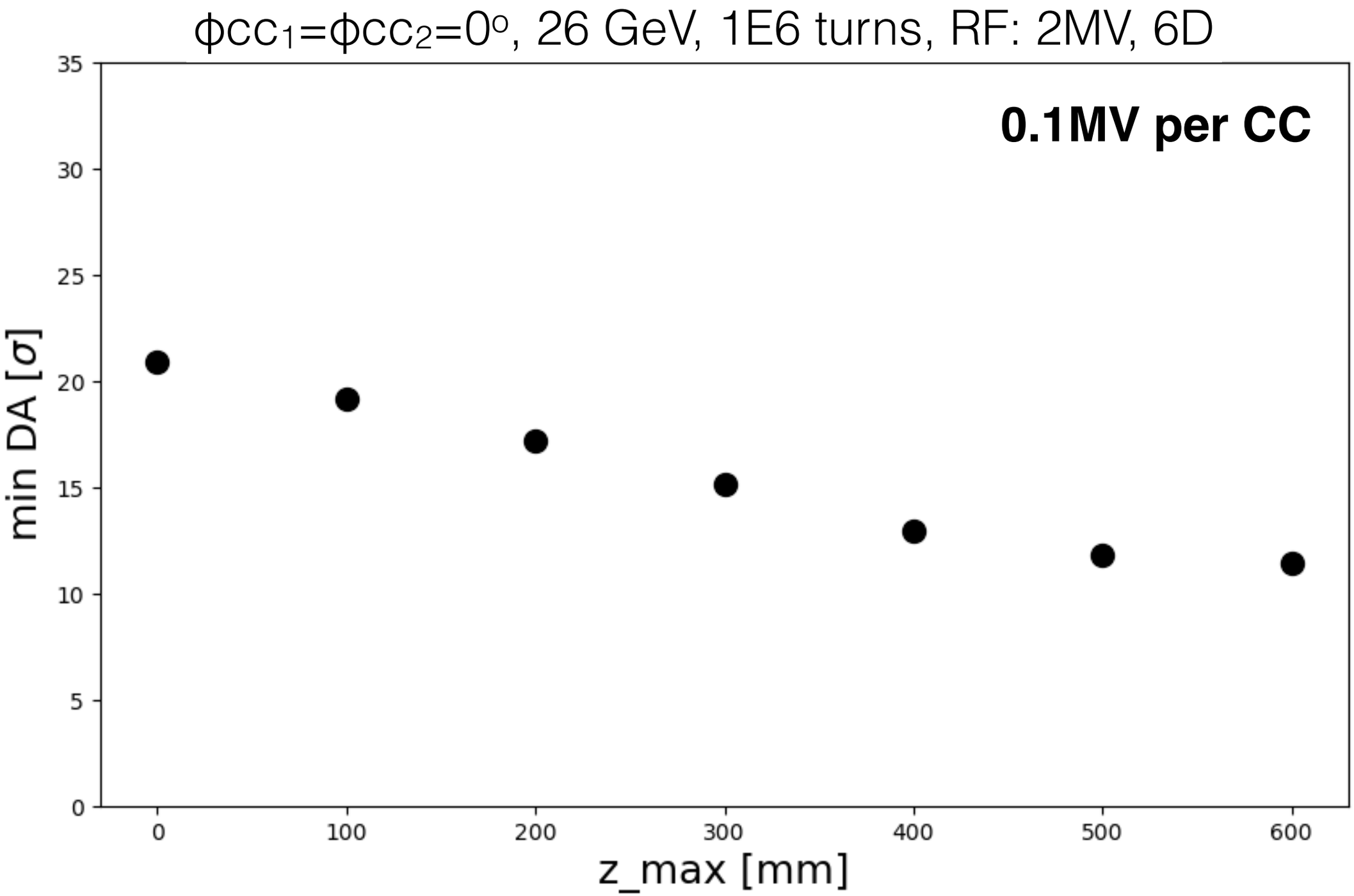
H ●
V ■



Multipole	26 GeV
$b_{3a}[m^{-2}]$	$(-2.8 \pm 0.6) \cdot 10^{-3}$
$b_{3b}[m^{-2}]$	$(1.6 \pm 0.3) \cdot 10^{-3}$
$b_{5a}[m^{-4}]$	-7.9 ± 0.5
$b_{5b}[m^{-4}]$	-6.8 ± 1.5
$b_{7a}[m^{-6}]$	$(8.8 \pm 2.6) \cdot 10^{4}$
$b_{7b}[m^{-6}]$	$(1.7 \pm 0.8) \cdot 10^{5}$

Michele Carla’

including machine errors up to b5



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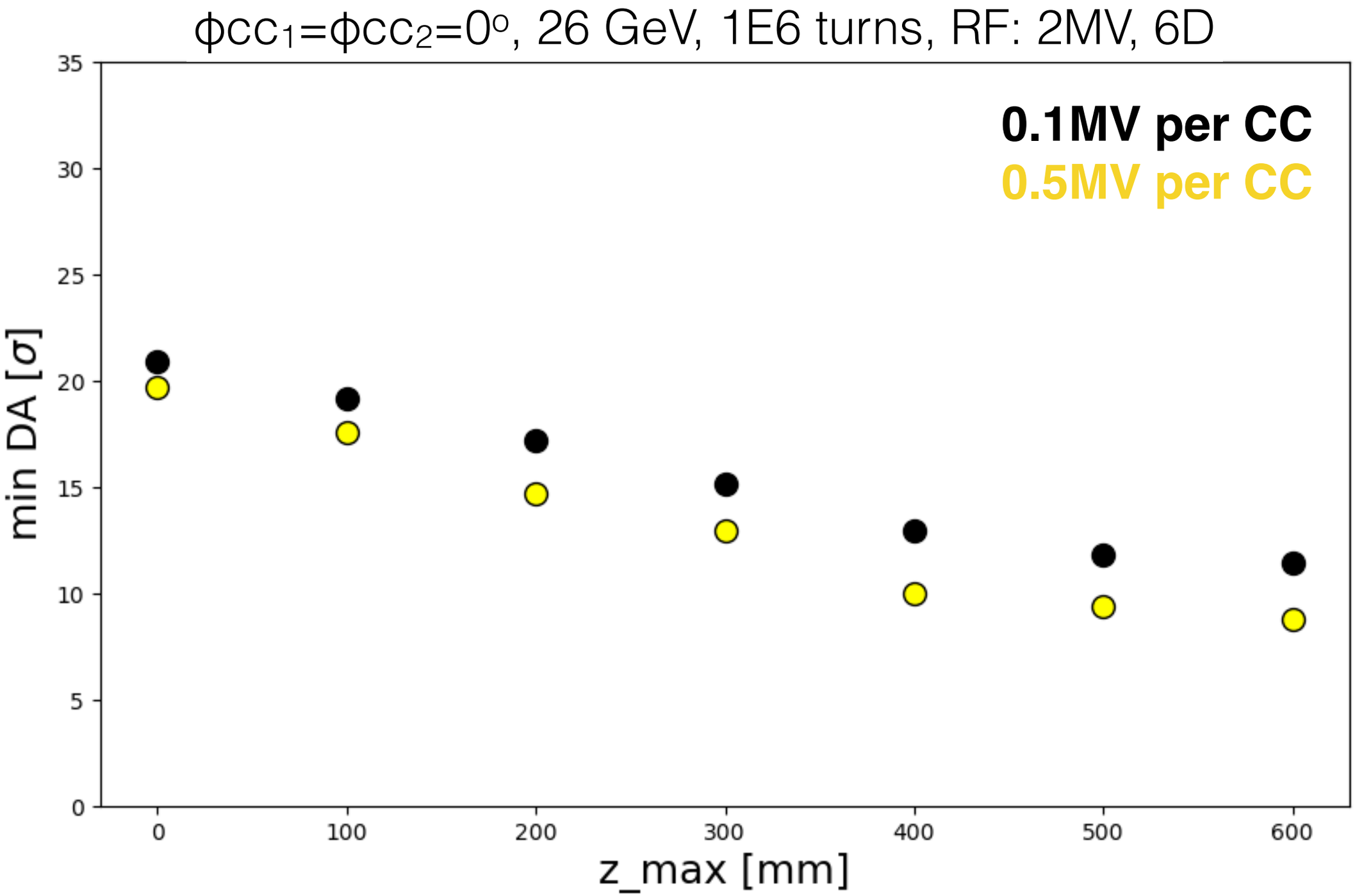

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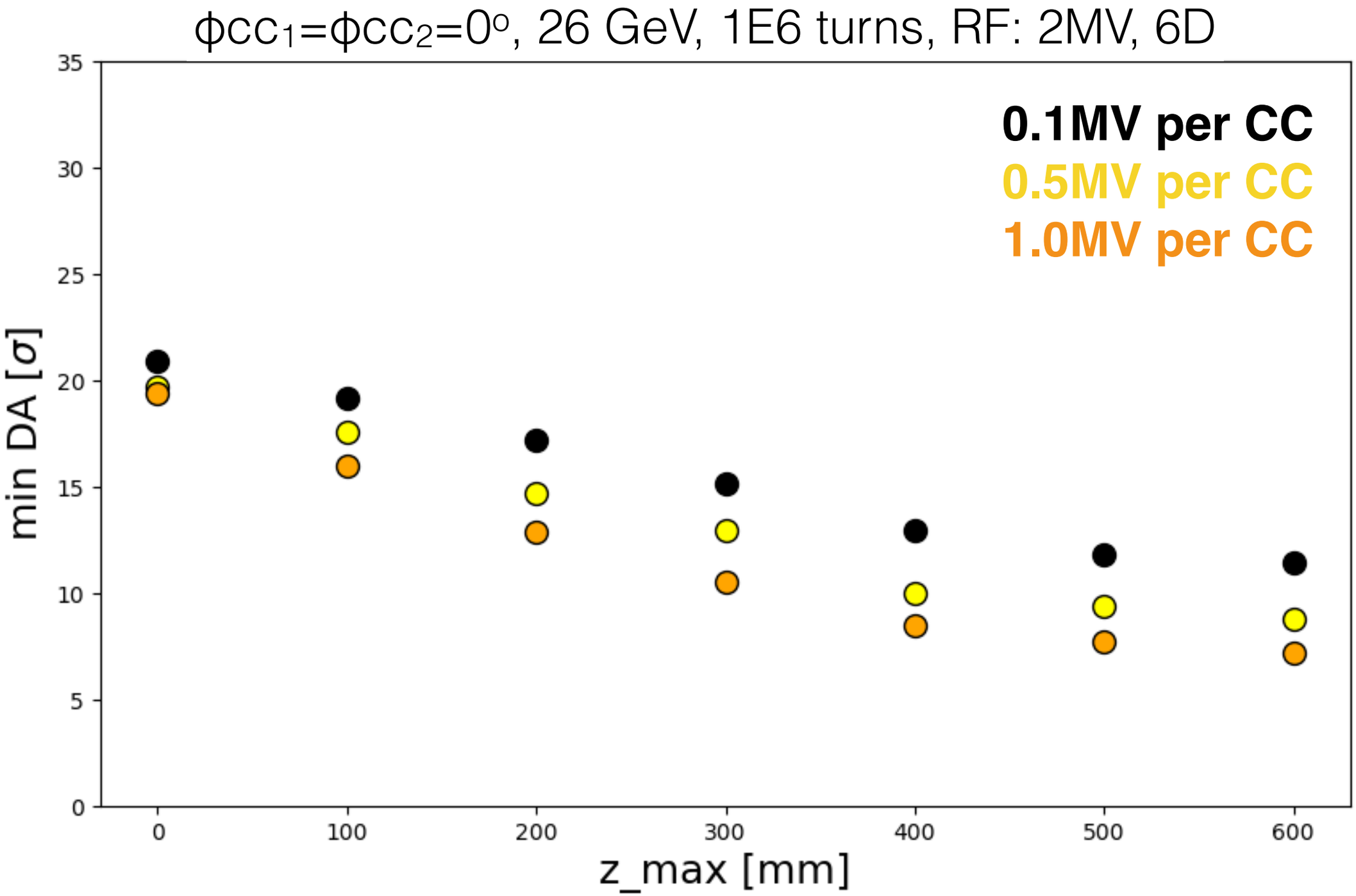

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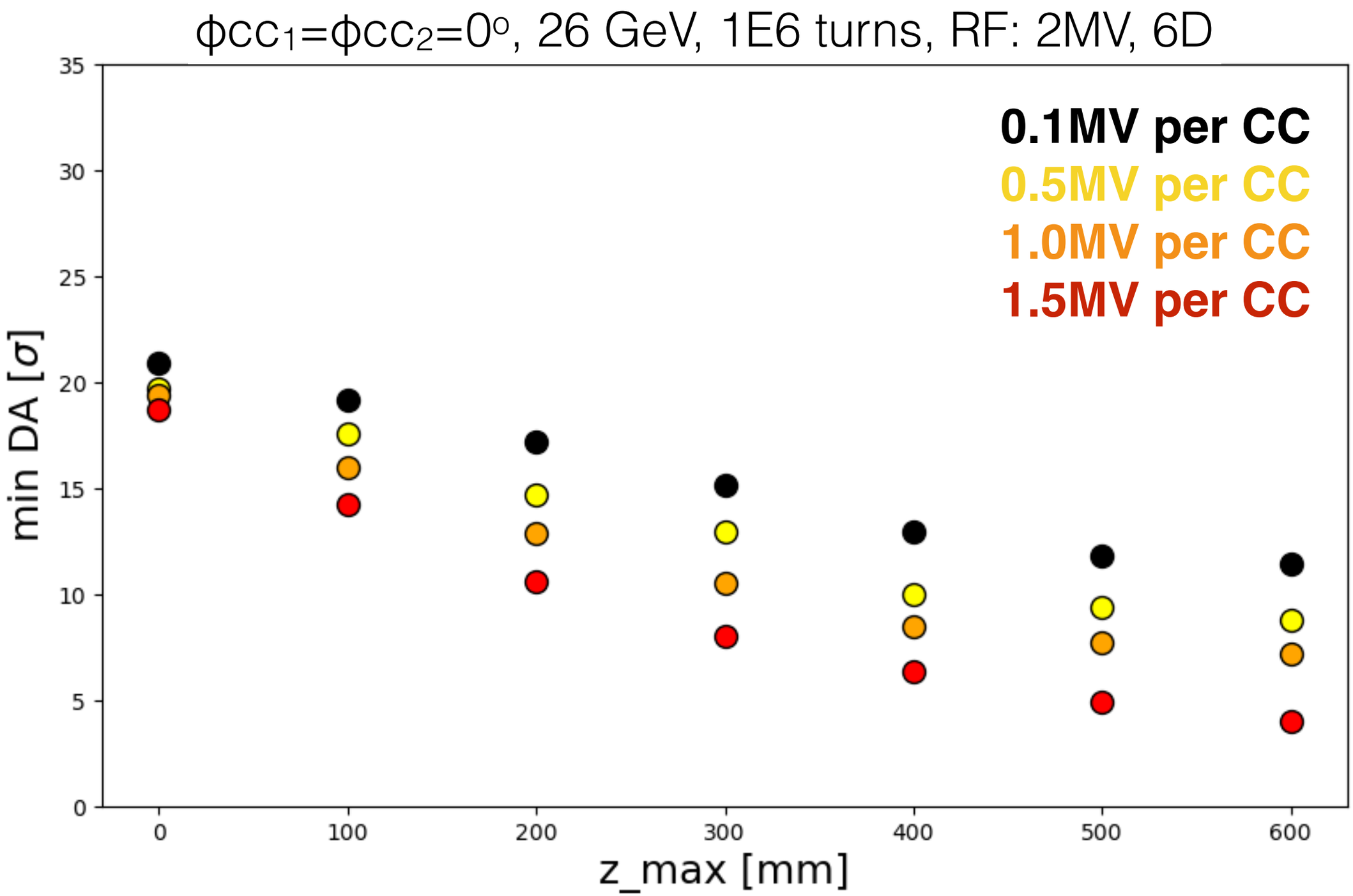

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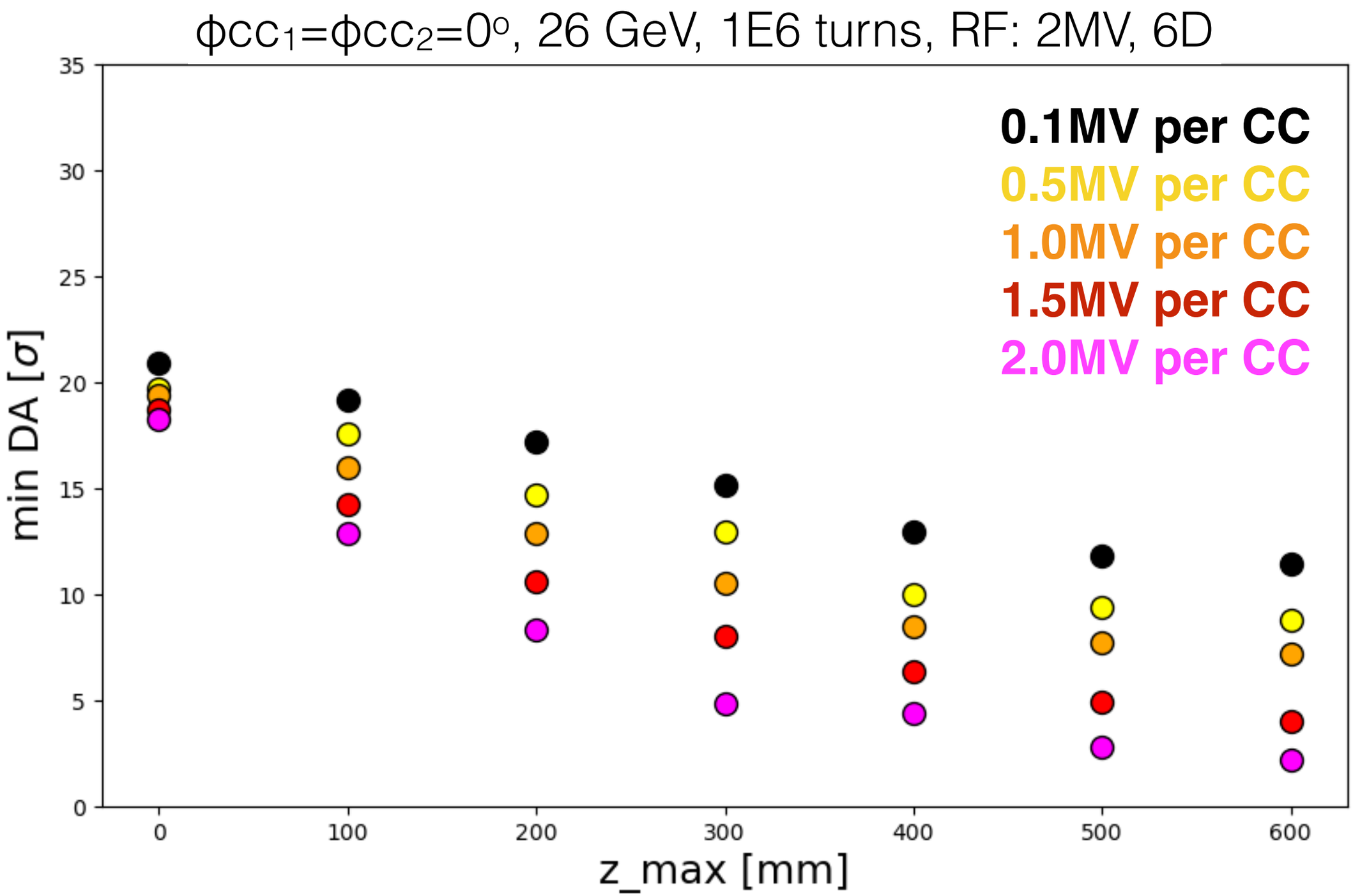

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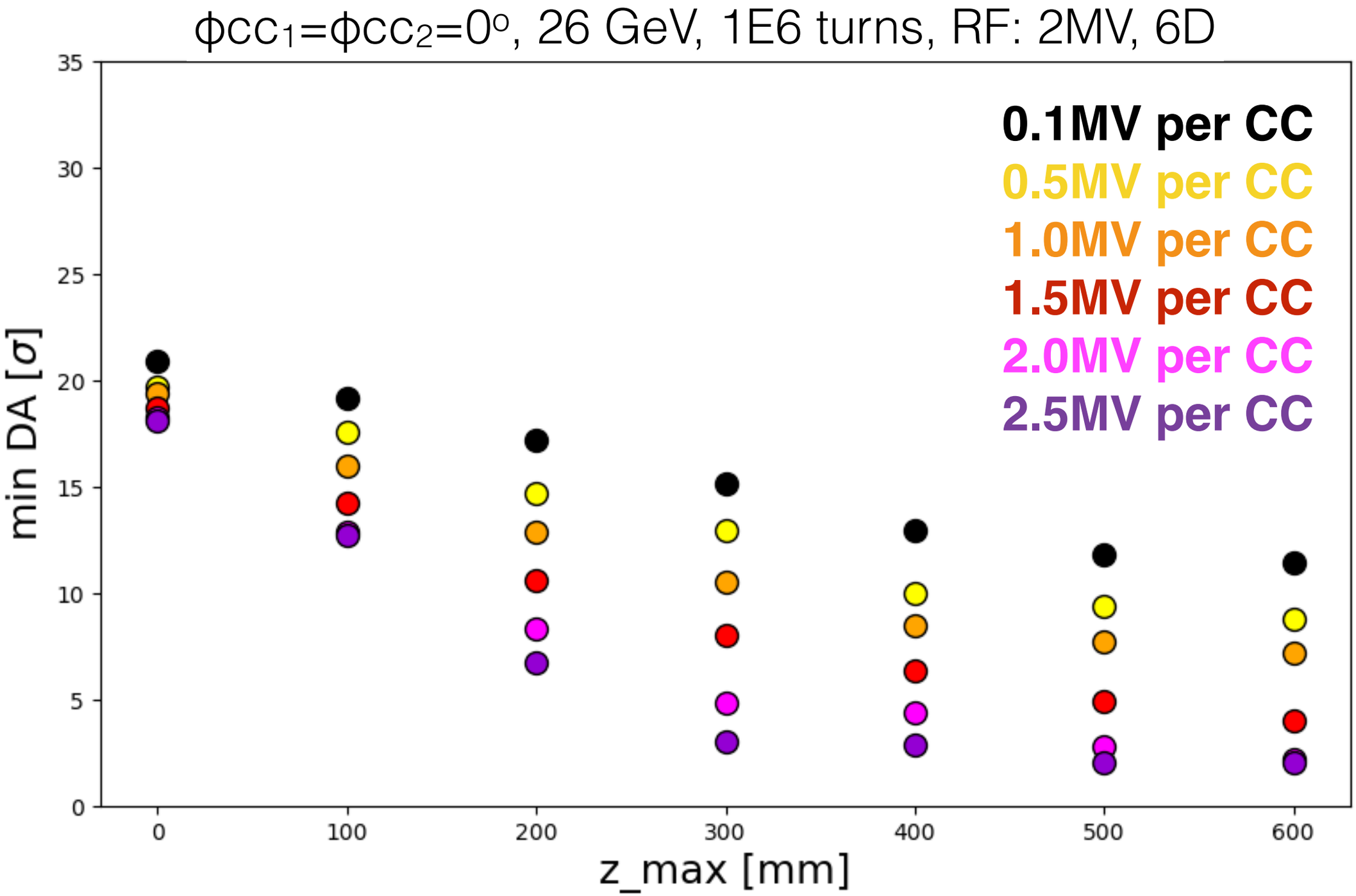

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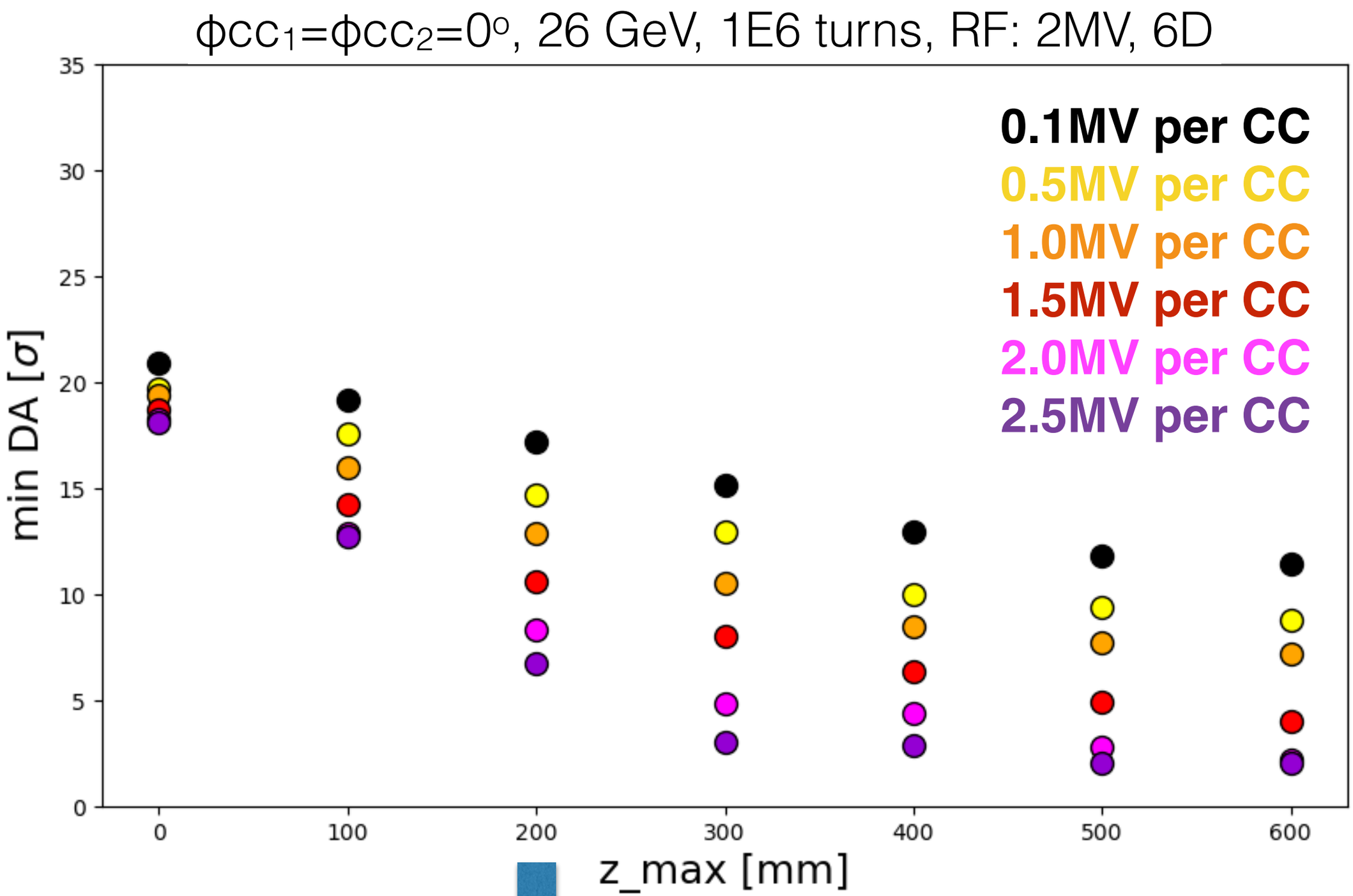
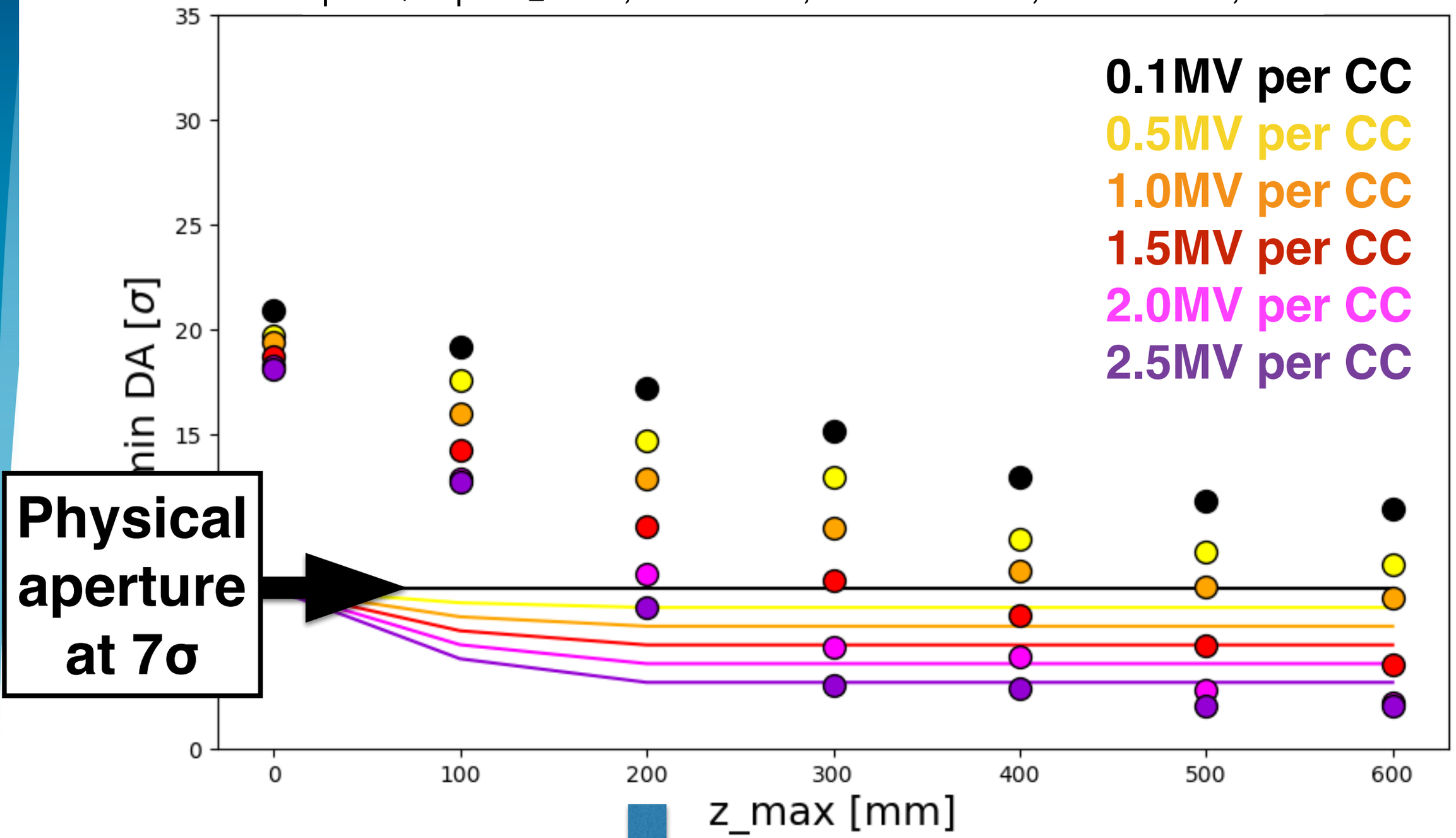


1σ nominal bunch length @E_{inj}

including machine errors up to b5

$\phi cc_1=\phi cc_2=0^o$, 26 GeV, 1E6 turns, RF: 2MV, 6D

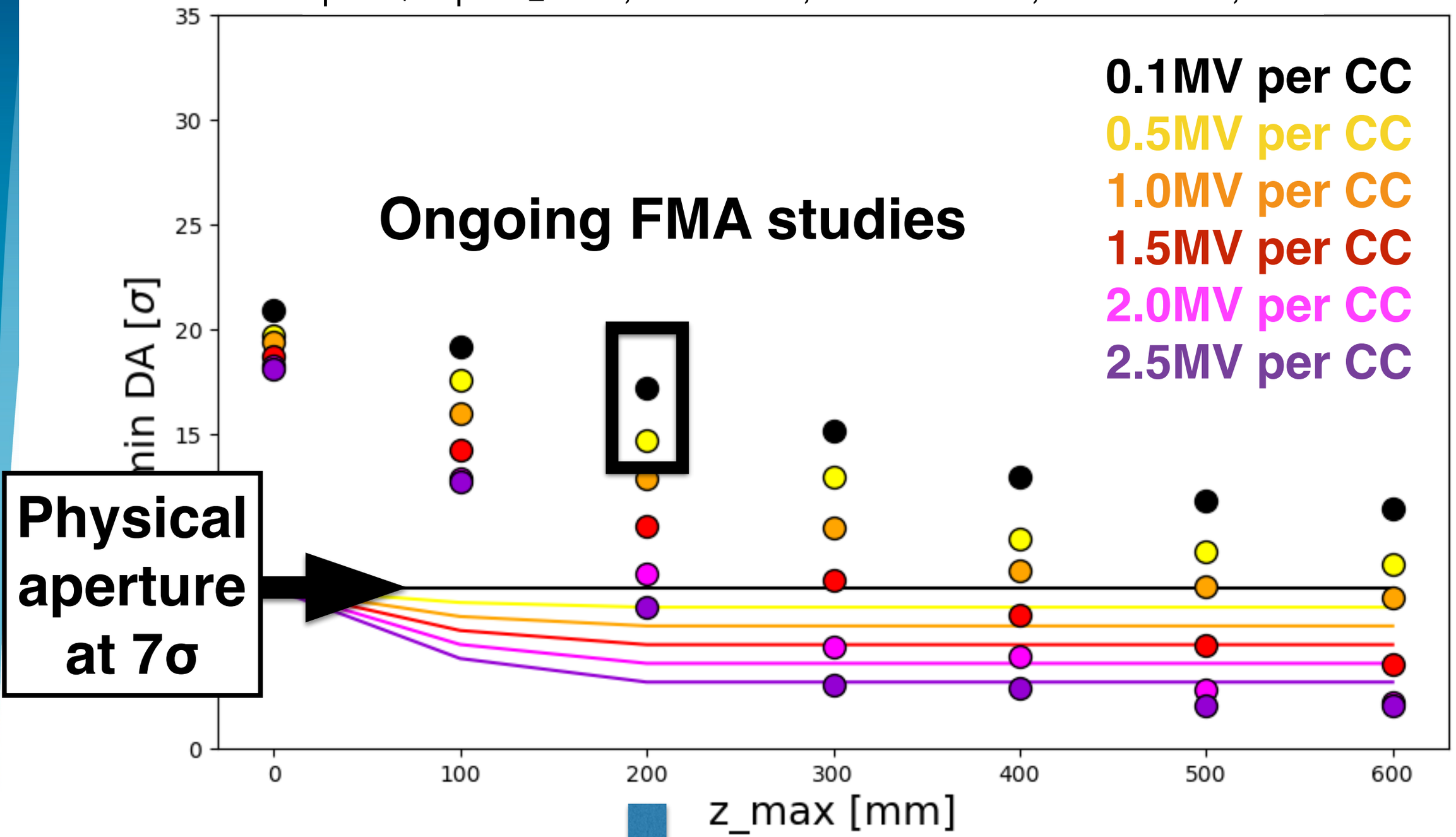


Physical aperture at 7σ

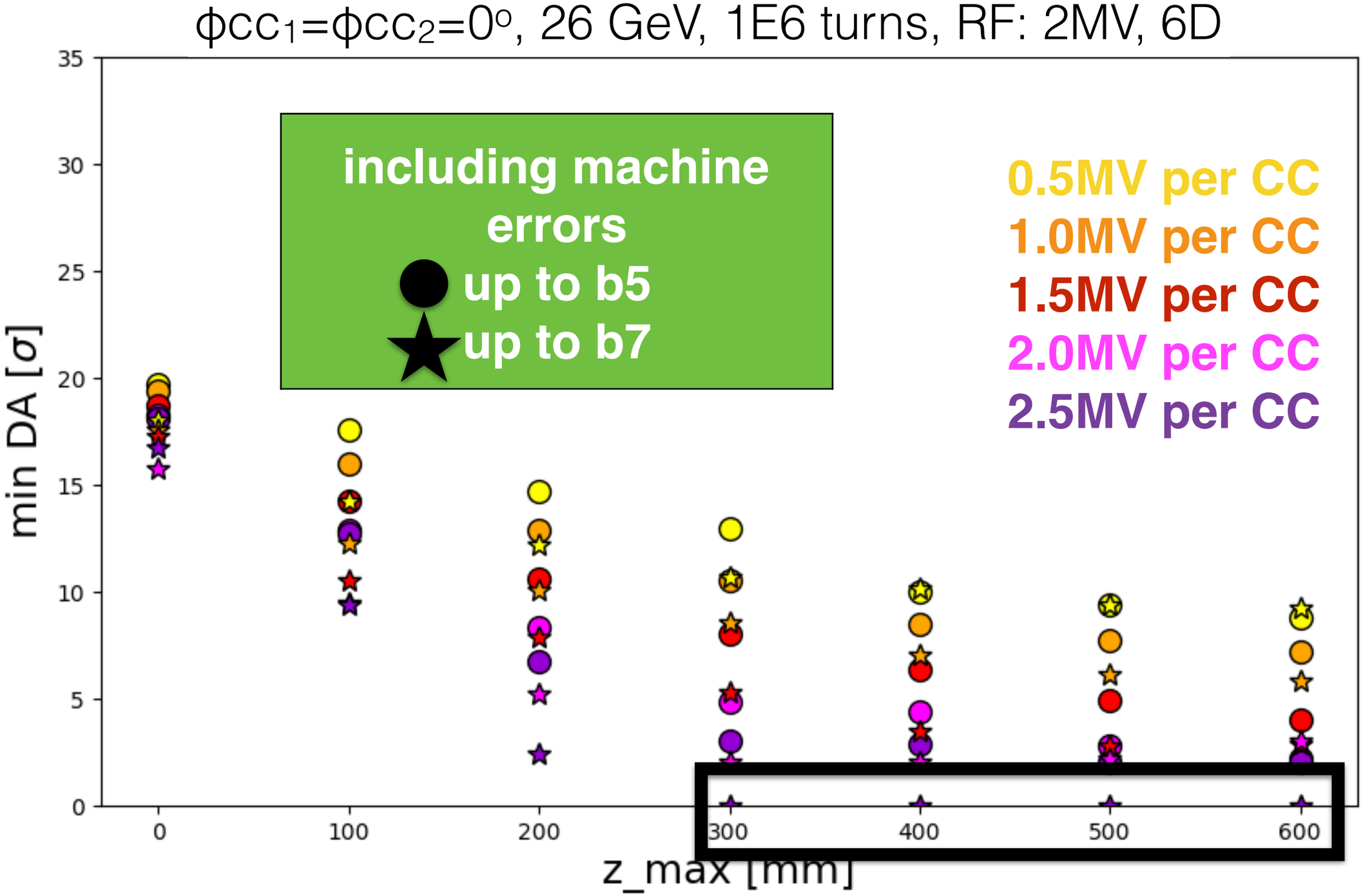
1σ nominal bunch length @E_{inj}

including machine errors up to b5

$\phi cc_1 = \phi cc_2 = 0^o$, 26 GeV, 1E6 turns, RF: 2MV, 6D



1σ nominal bunch length @E_{inj}



Sixtrack DA calculation with large uncertainty or all particles lost

Conclusions

- **Crabbing expected to be clearly measurable at 26 GeV** with BPMs, HT monitor and WS
  - at 270 GeV reading can be enhanced by going closer to an integer resonance

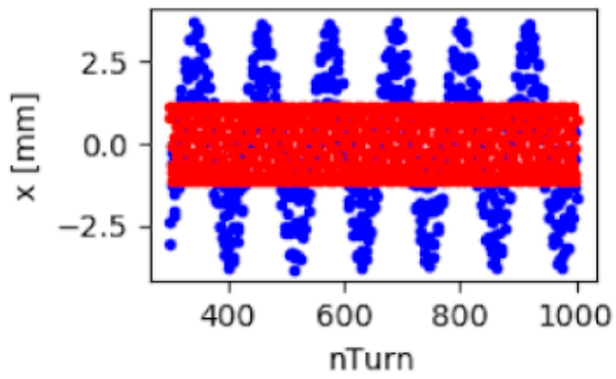
- **However**, possible DA issues for particles with large longitudinal amplitudes
  - could overcome these DA issues with **smaller longitudinal emittance** (see Lee's presentation) and/or low CC voltages

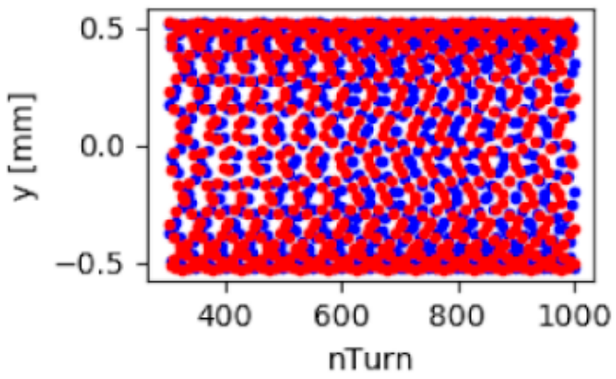
Thank you!

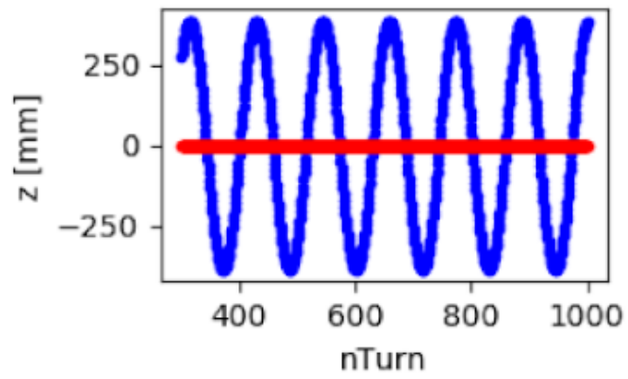
Extras

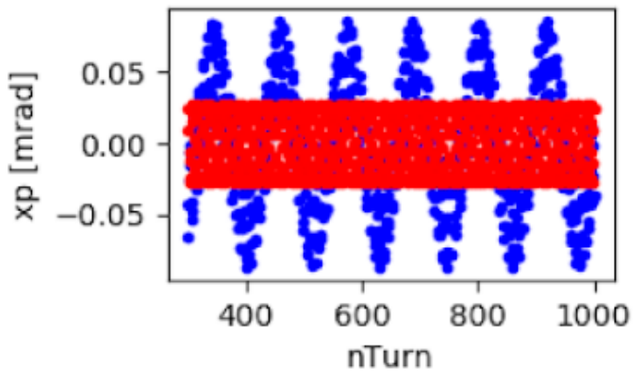
noCC

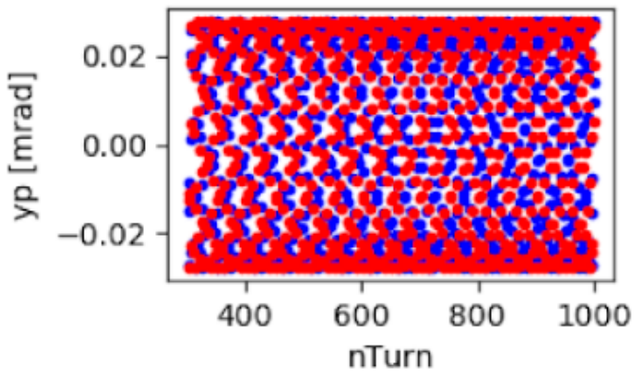
dpp=0 vs dpp=2e-3

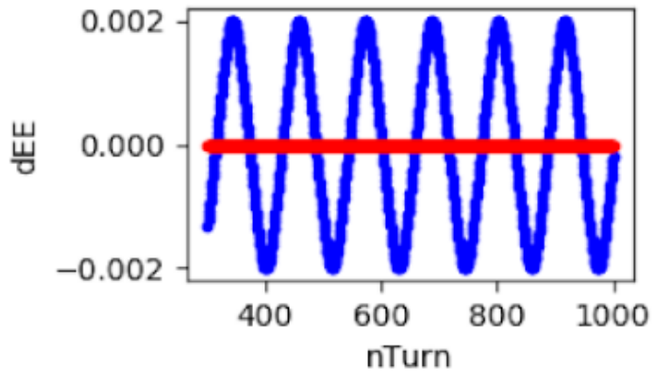


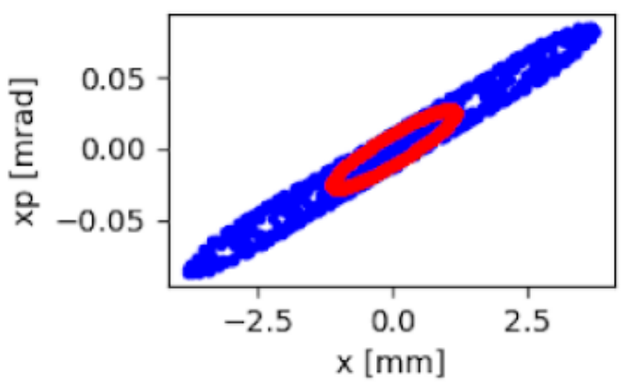


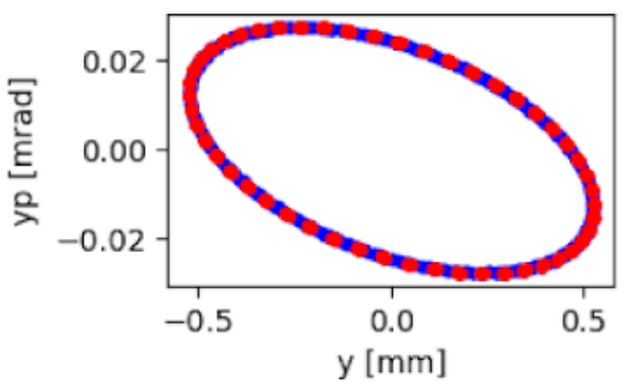


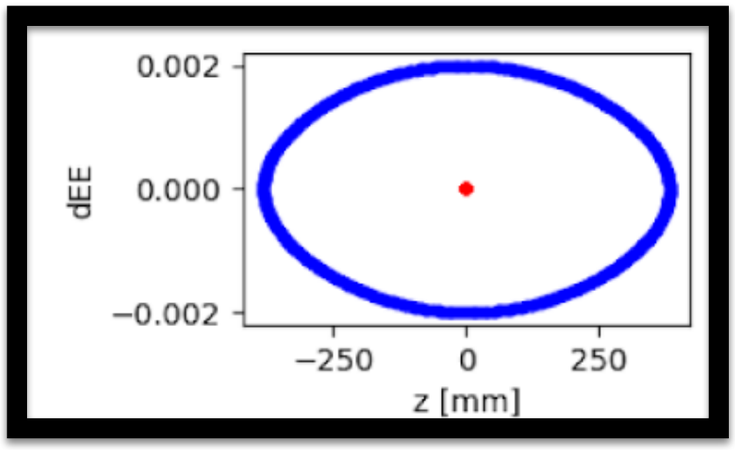










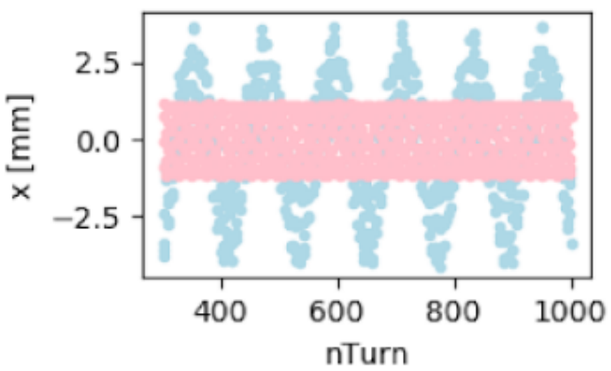


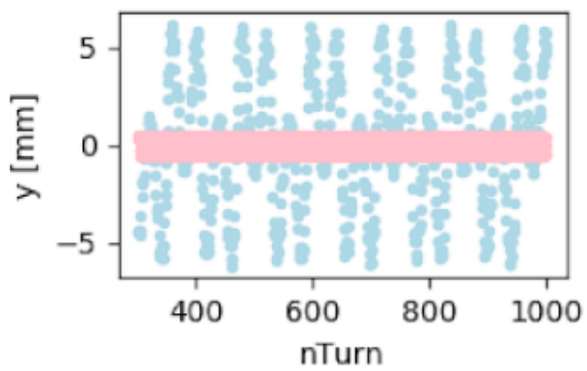
noCC, dpp2 with RF, z=0 noCC, dpp0 with RF, z=0

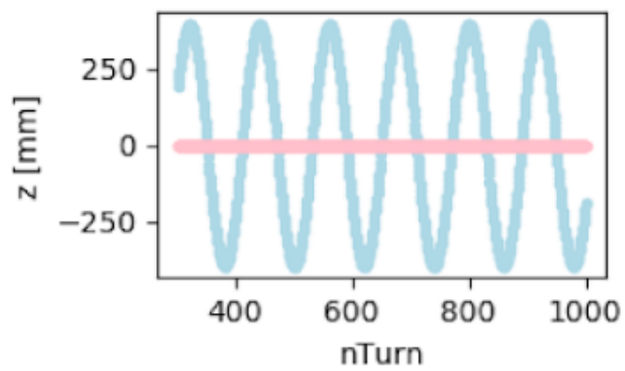
withCC

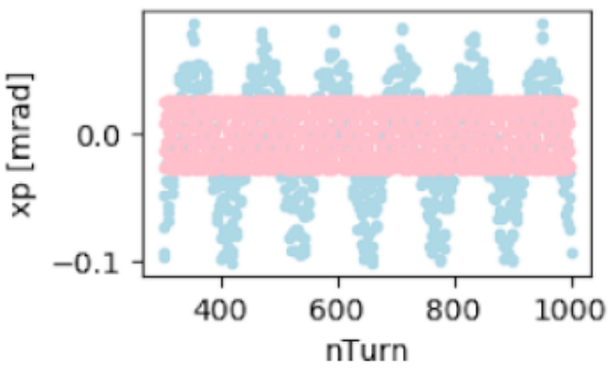
dpp=0 vs dpp=2e-3

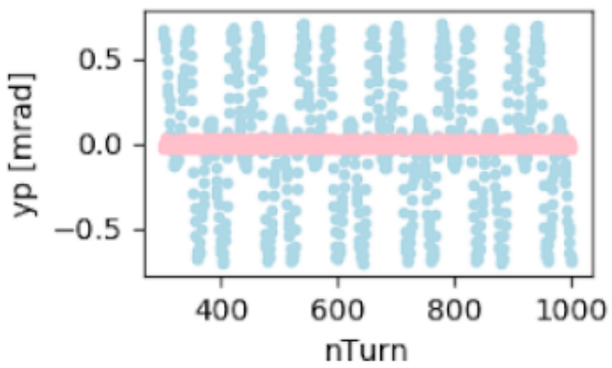
2CCs, 3.4MV each, same phase (0deg), i.e. 6.8MV

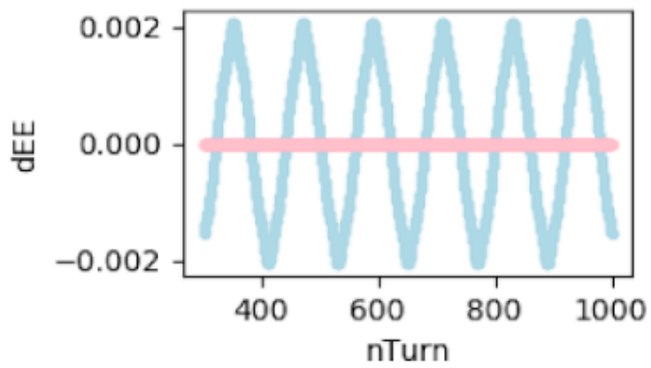


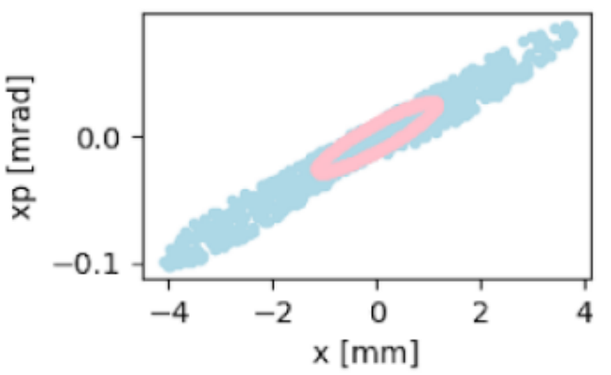


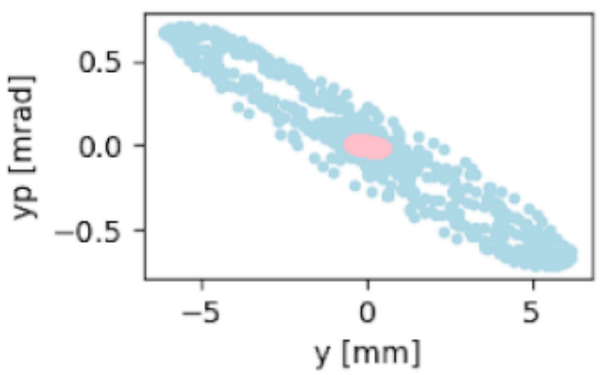


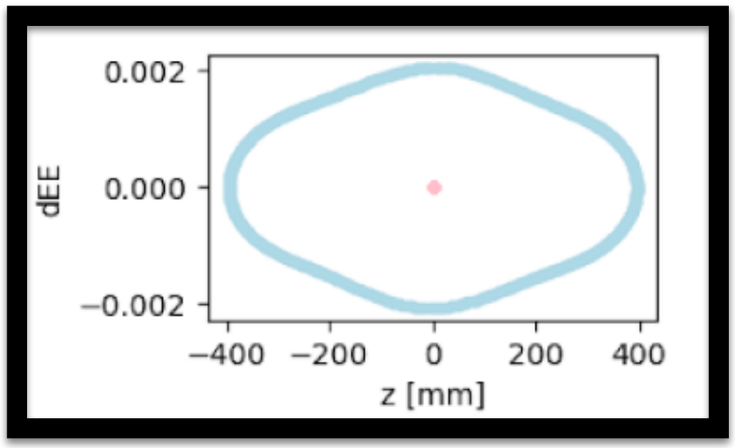








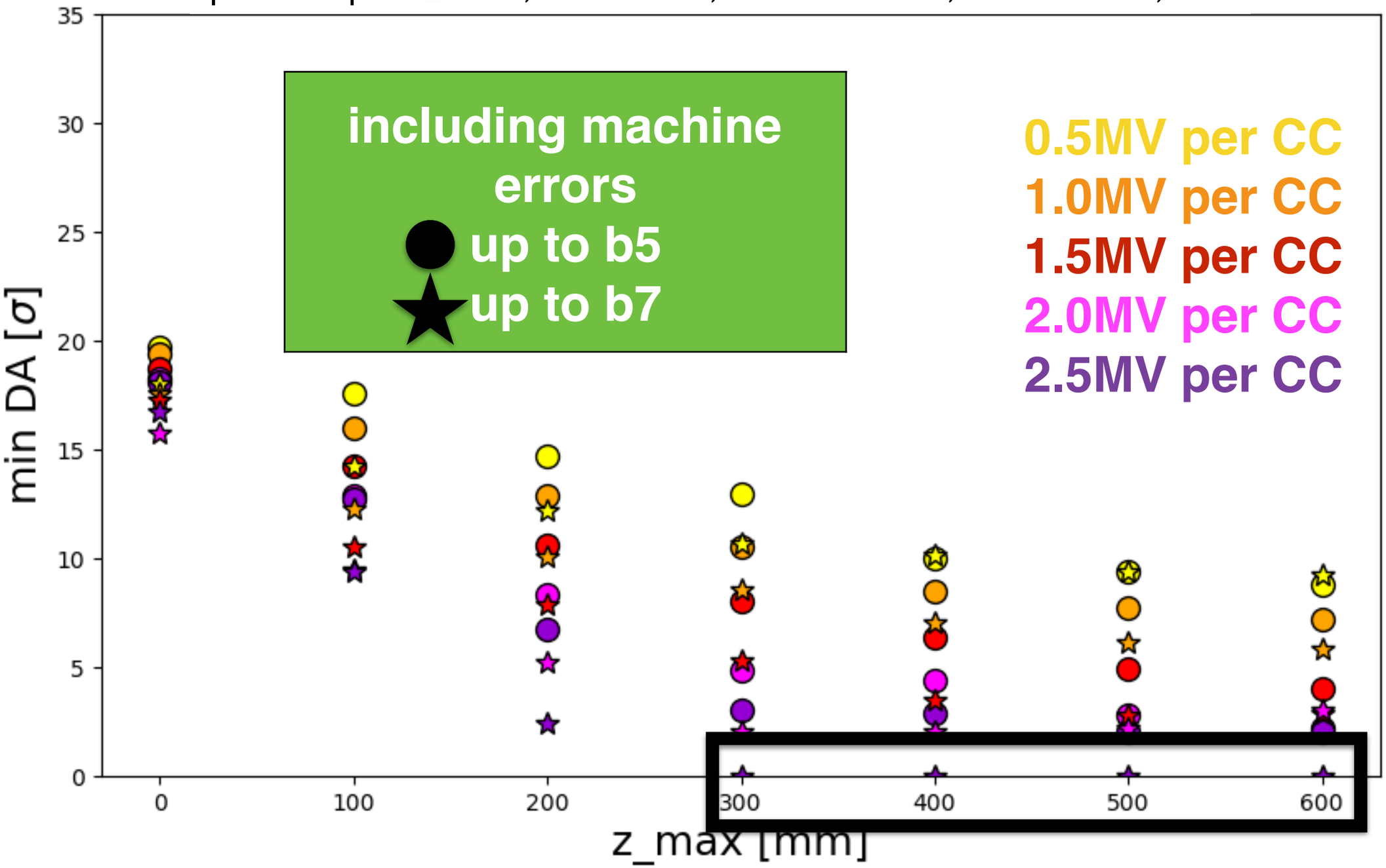




with, dpp2 with RF, z=0 withCC, dpp0 with RF, z=0

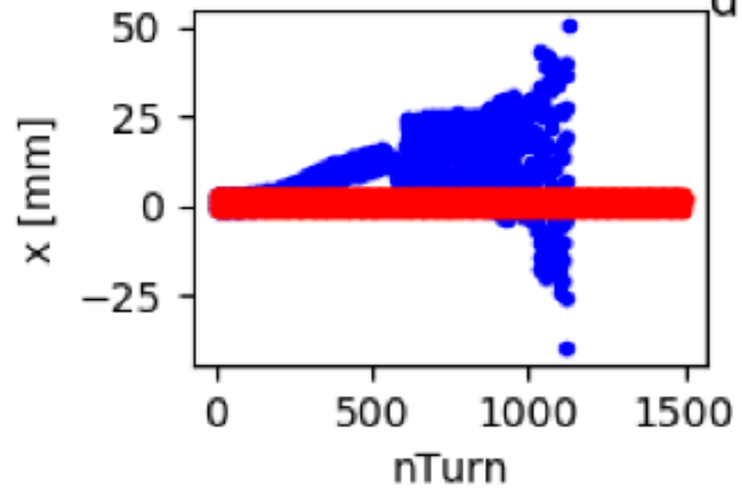
Not elliptical shape anymore!
Non-negligible longitudinal kick from CC!!

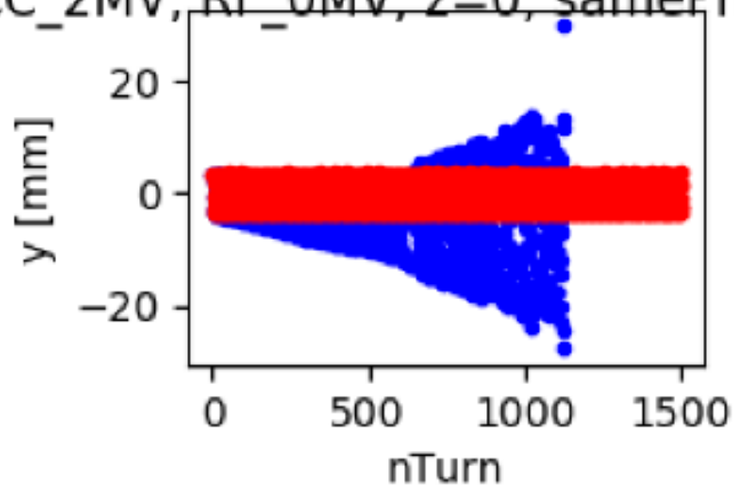
$\phi cc_1 = \phi cc_2 = 0^o$, 26 GeV, 1E6 turns, RF: 2MV, 6D

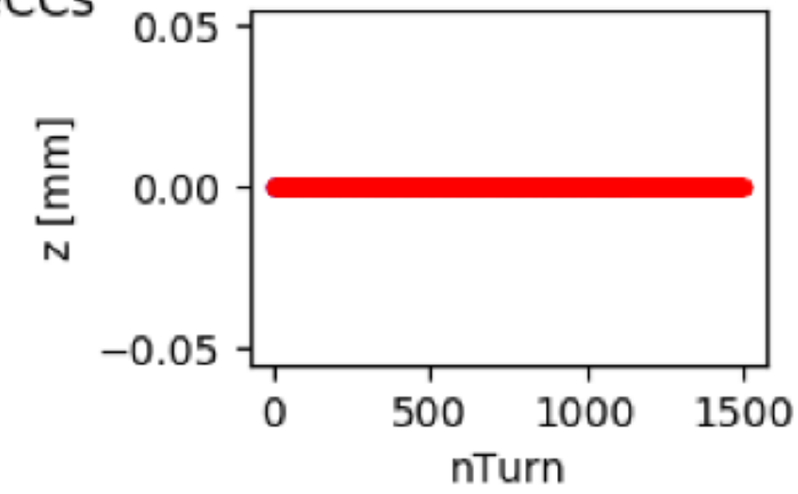


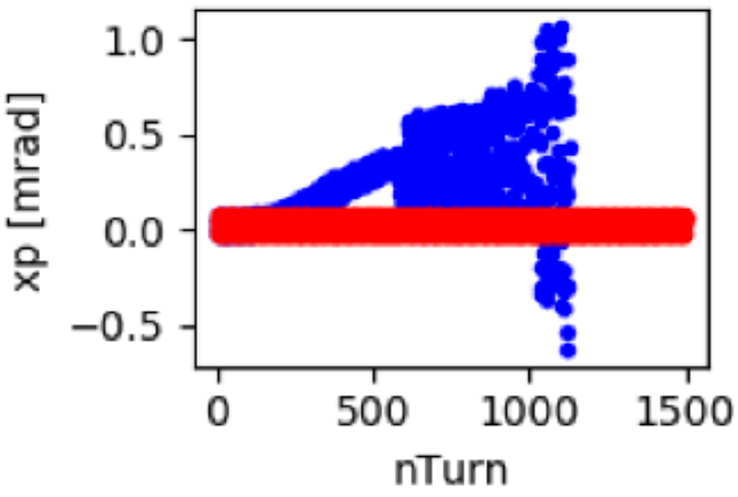
Sixtrack cannot calculate the DA

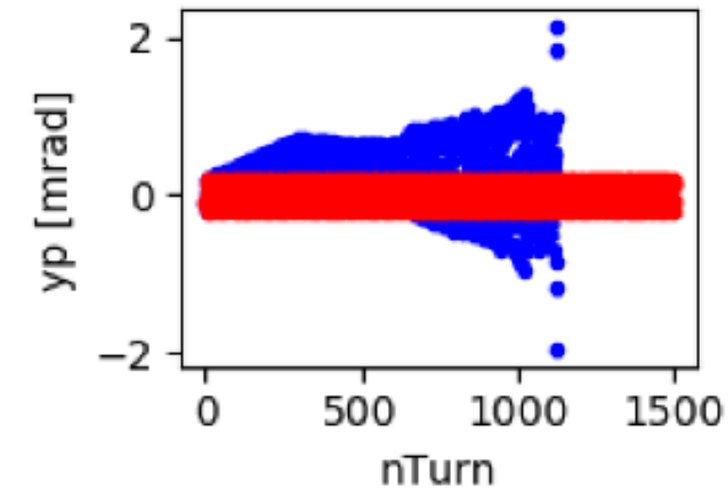
dpp1, CC_2MV, RF_0MV, z=0, samePhaseCCs

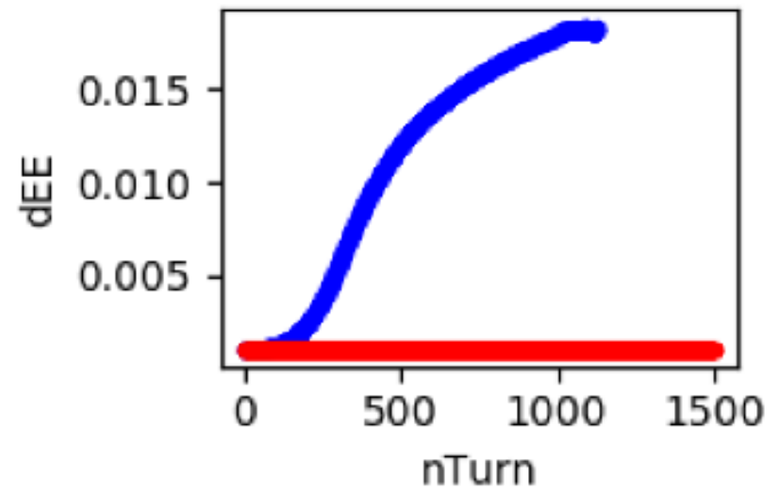


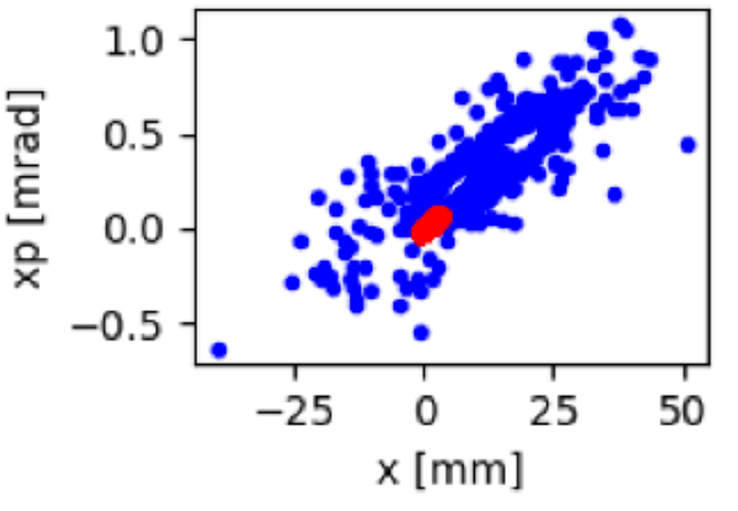


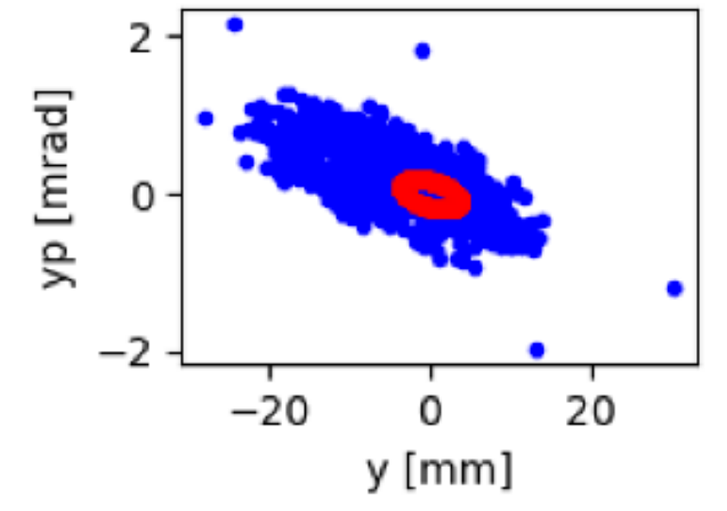


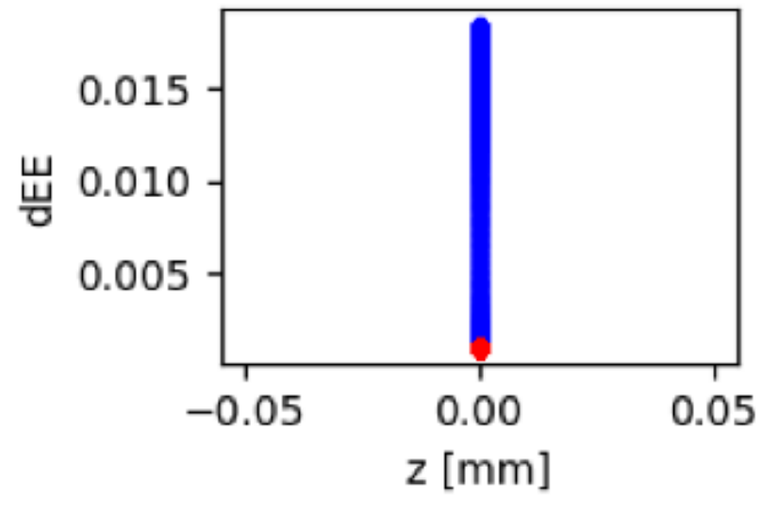






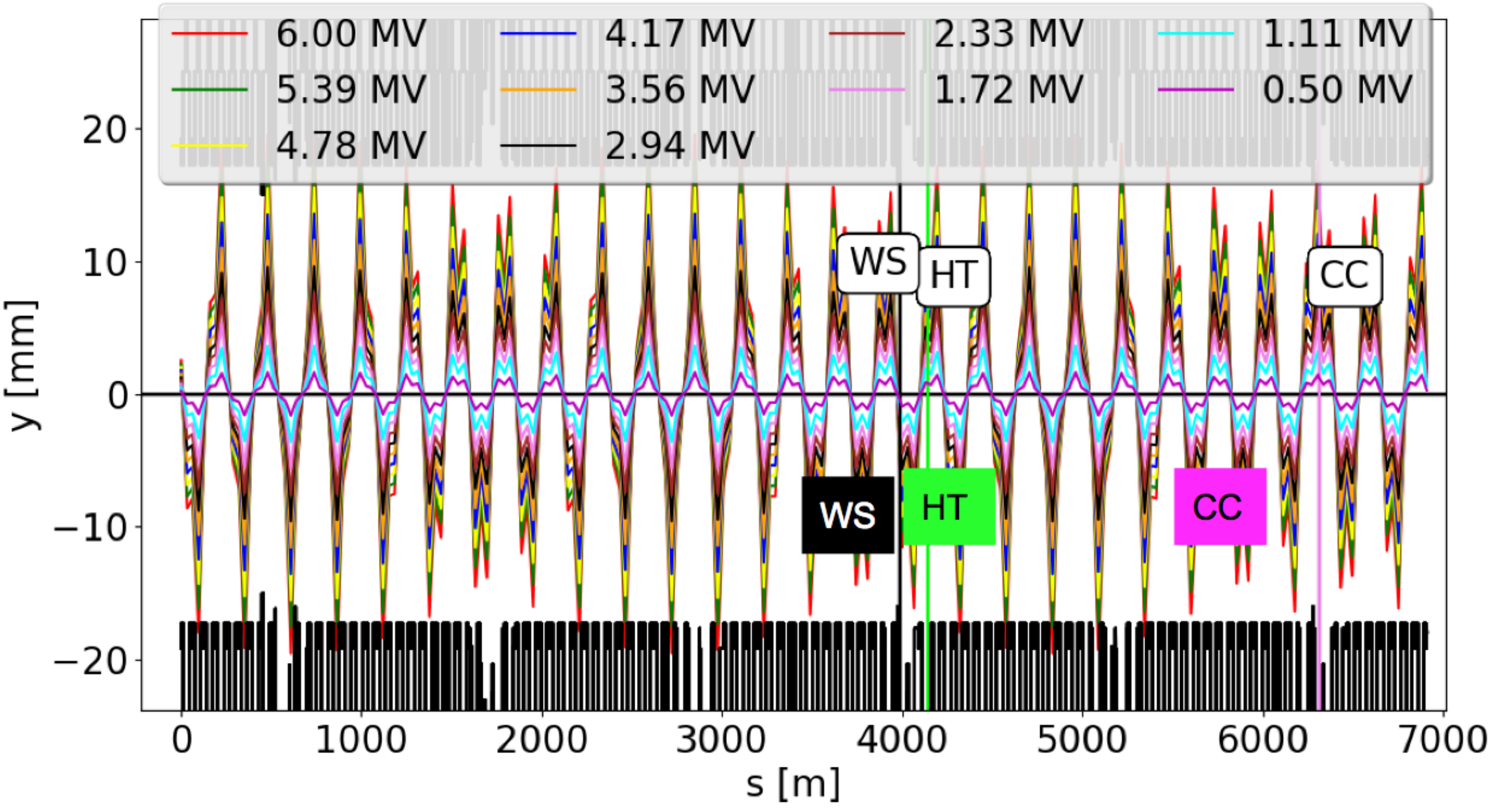




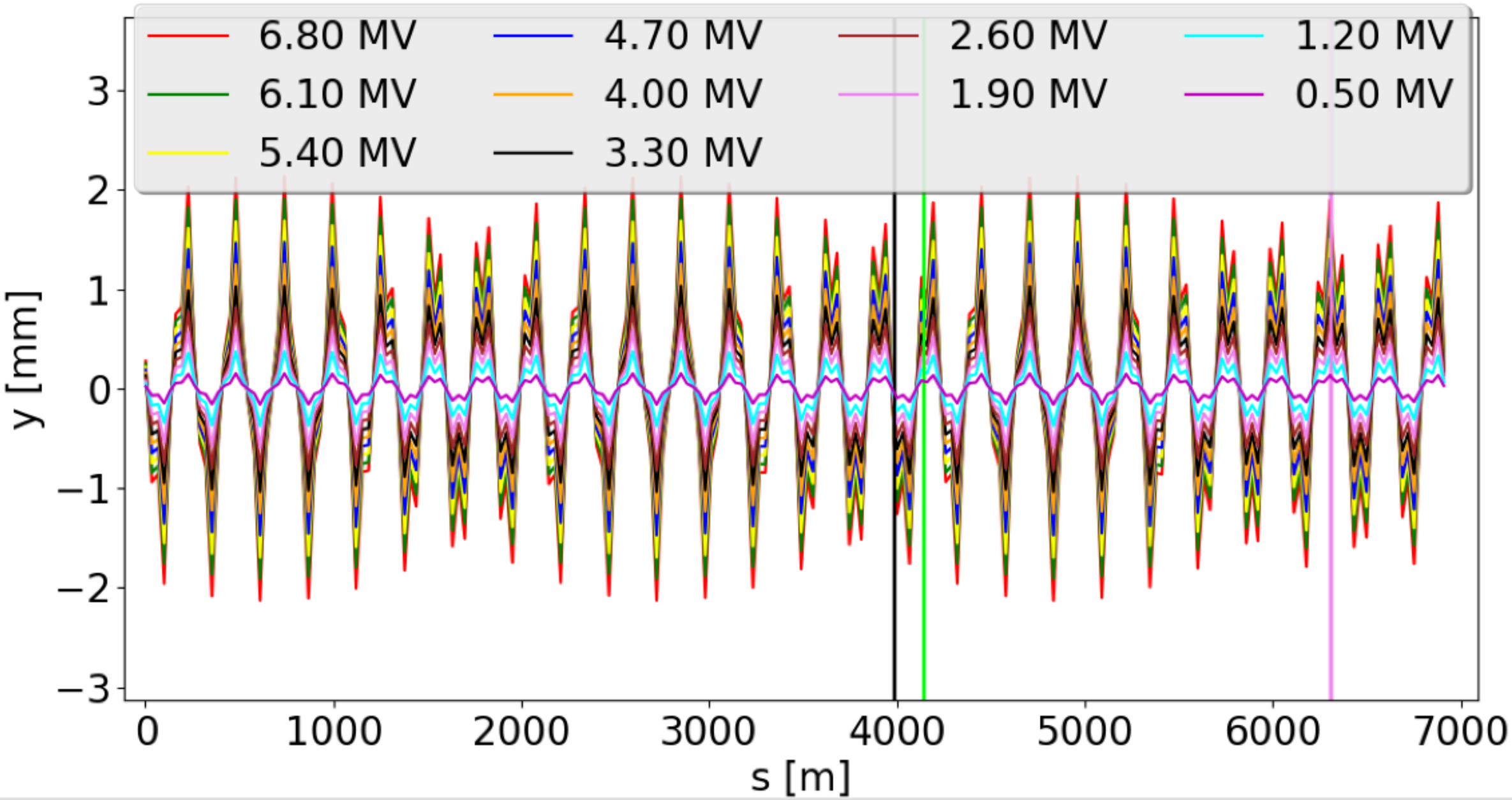


LAG_0.1 LAG_0.0

y-orbit, 26 GeV

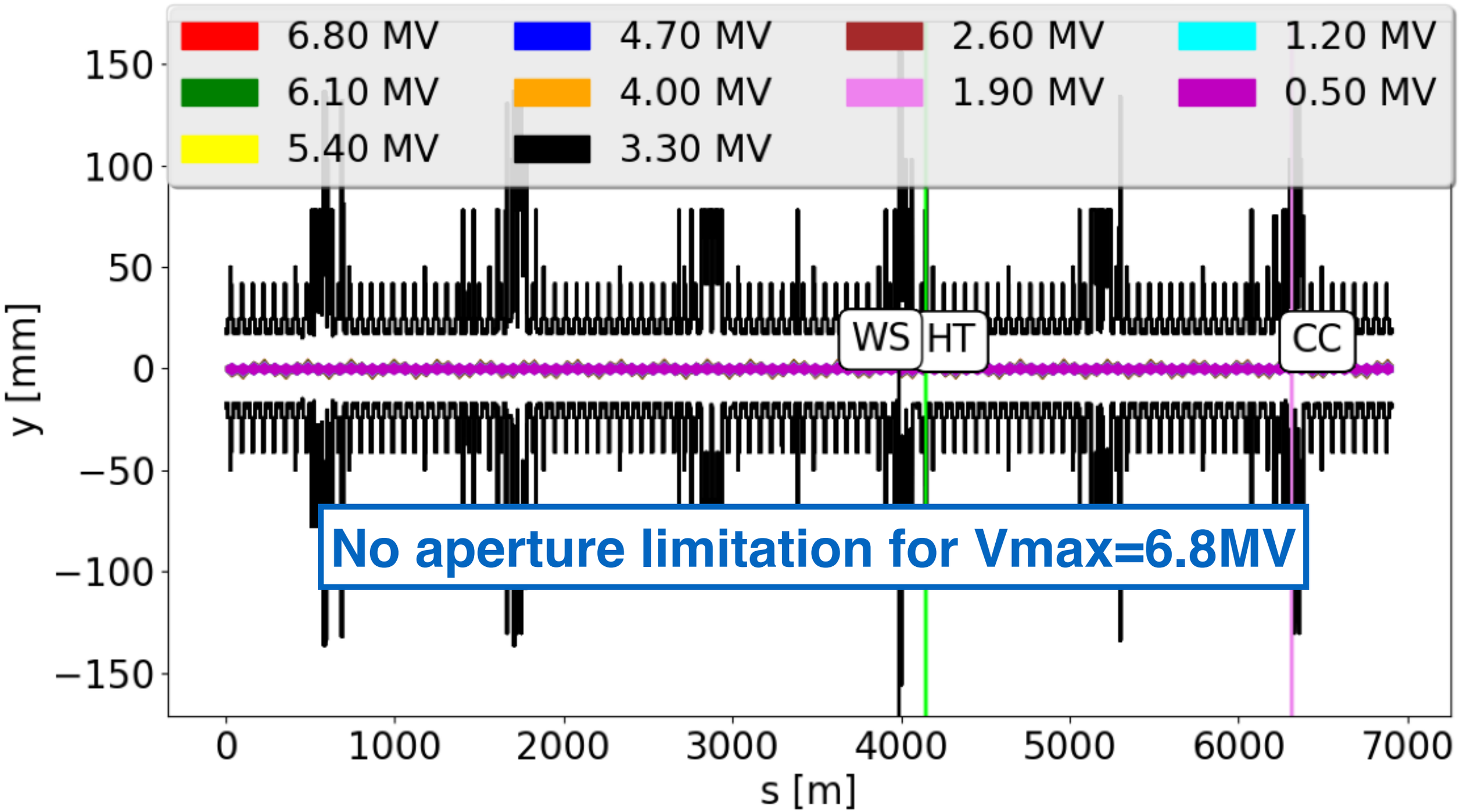


y-orbit, 270 GeV

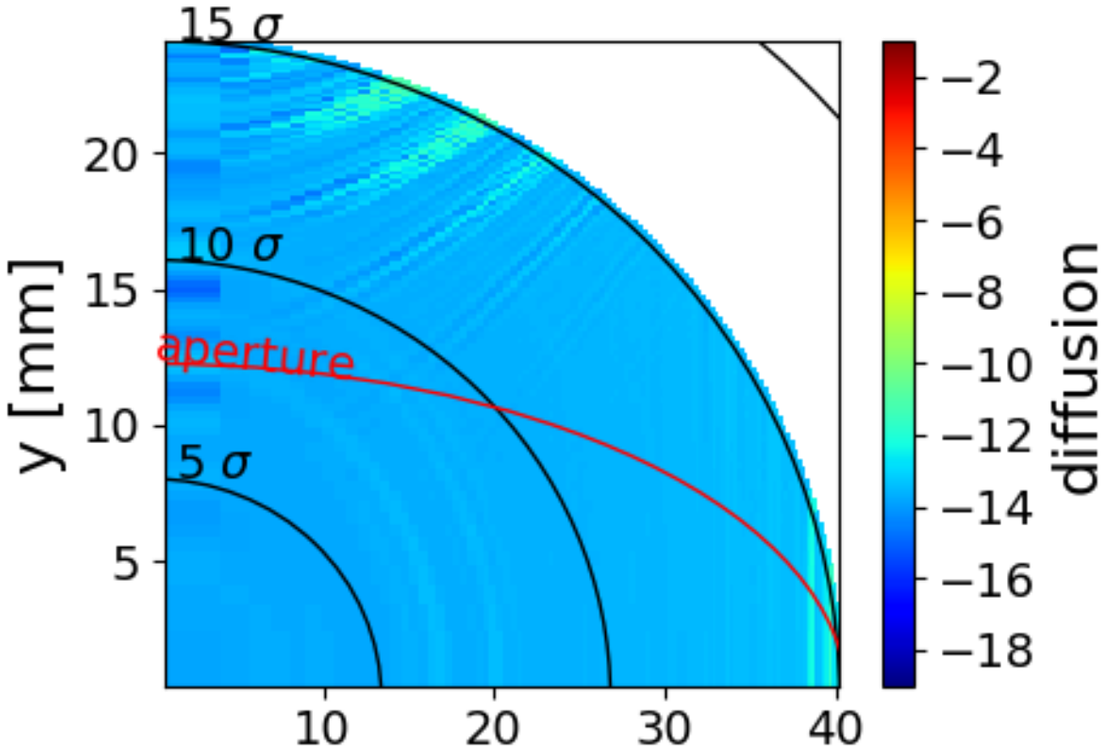


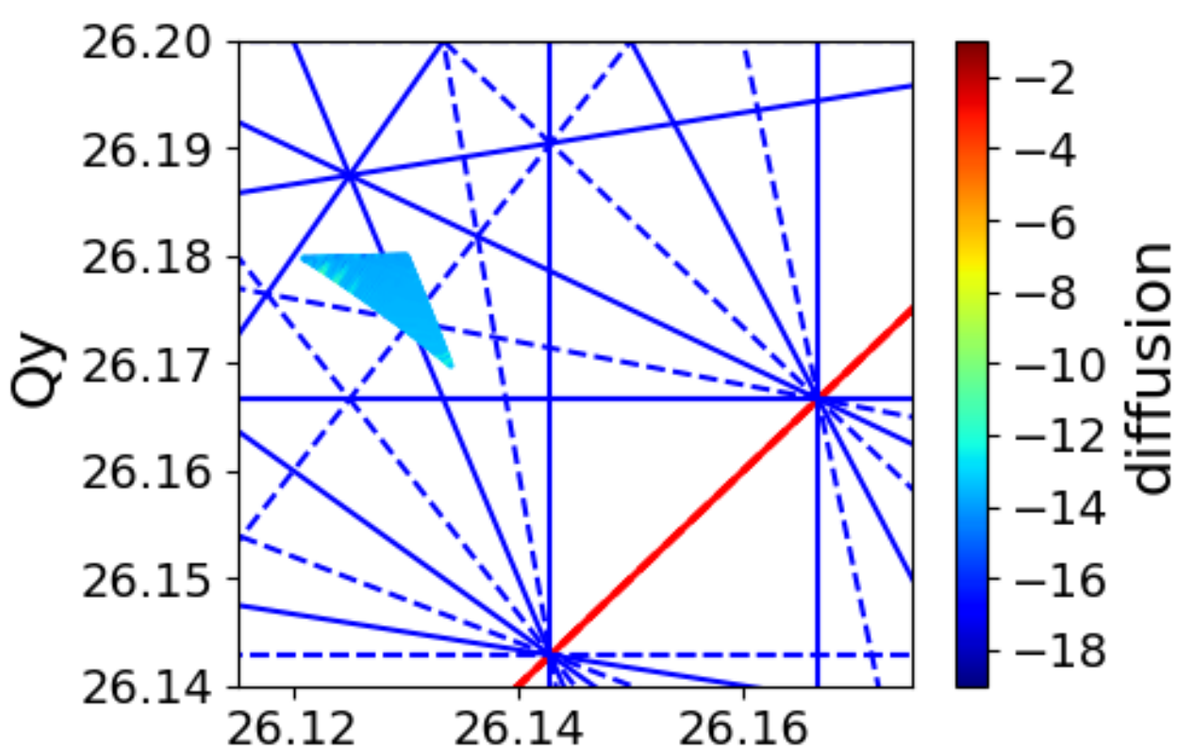
Aperture at 270 GeV

3σ orbit, 1 dipole kick@CC1, ε_norm=2.5μm

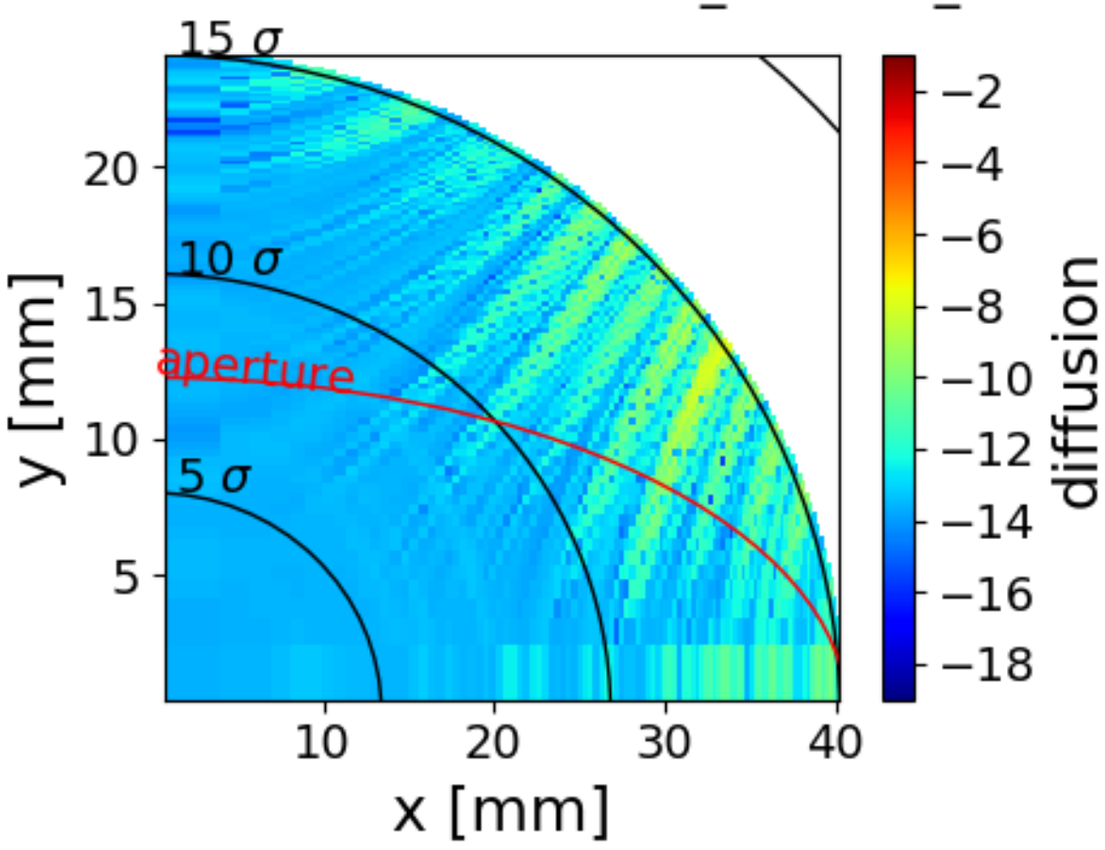


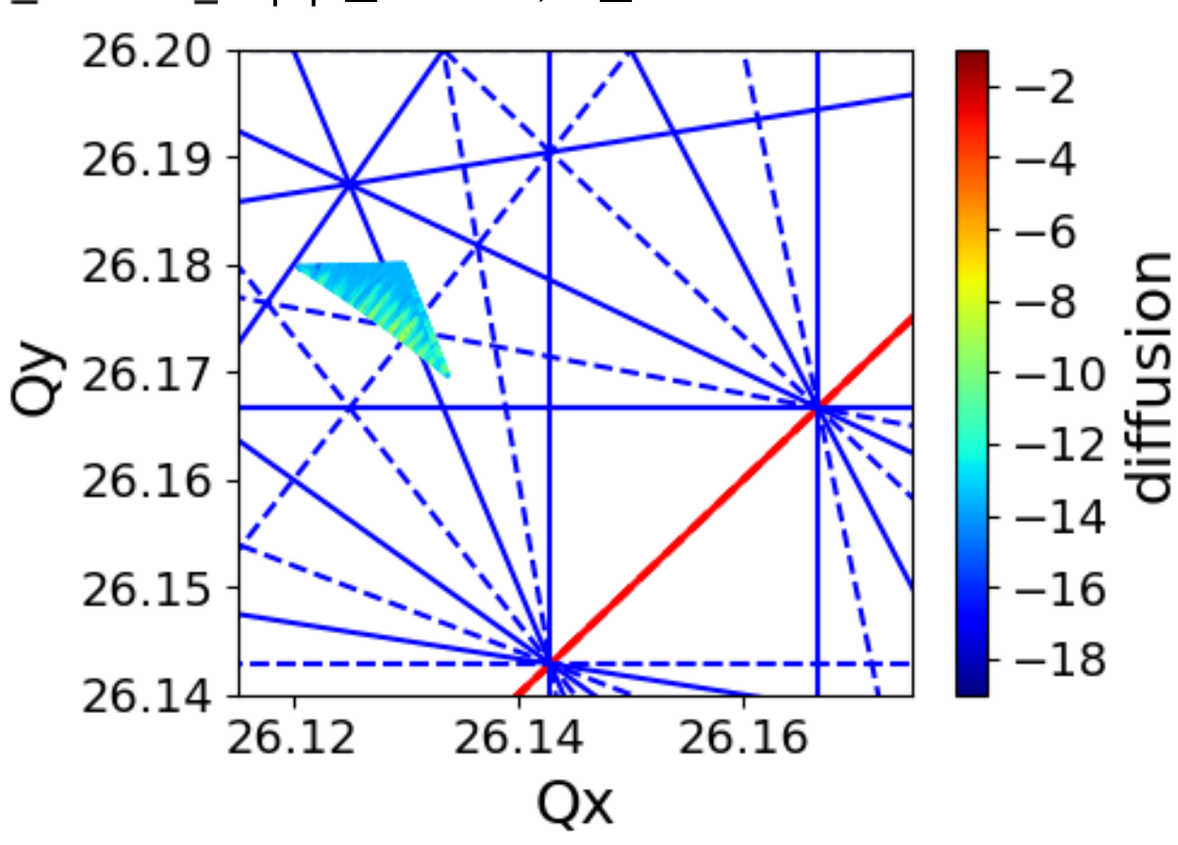
no_SPSmult_withCC_0MV_ dpp_init=0, z_init=200mm



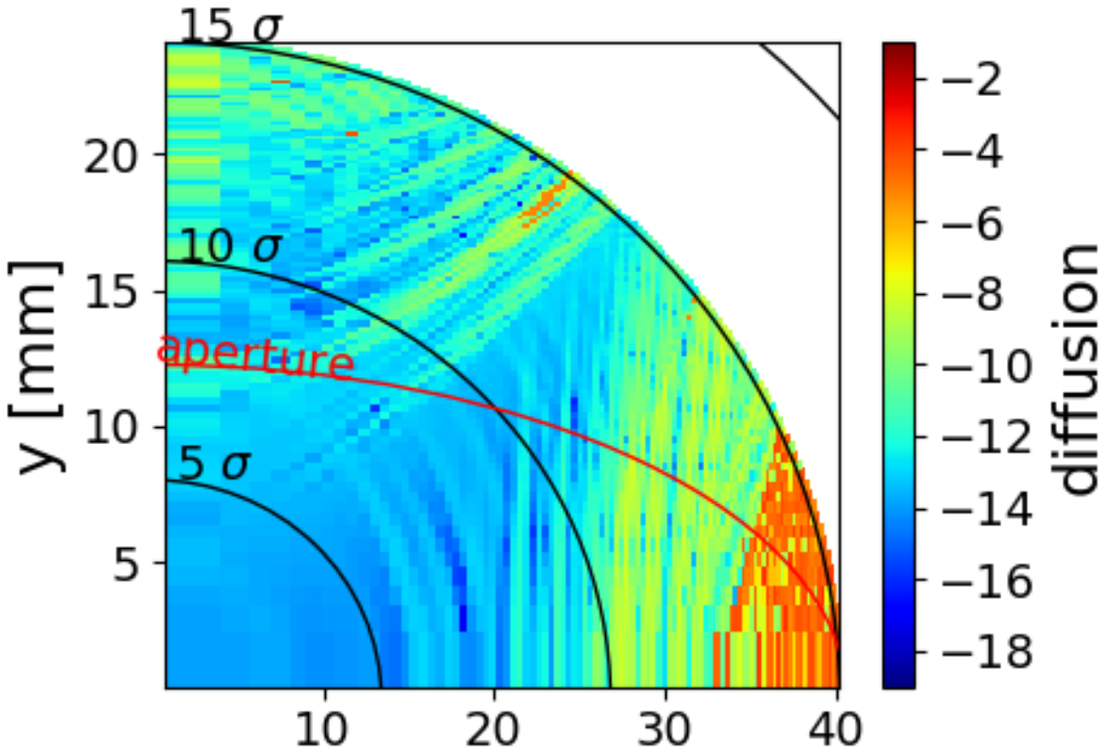


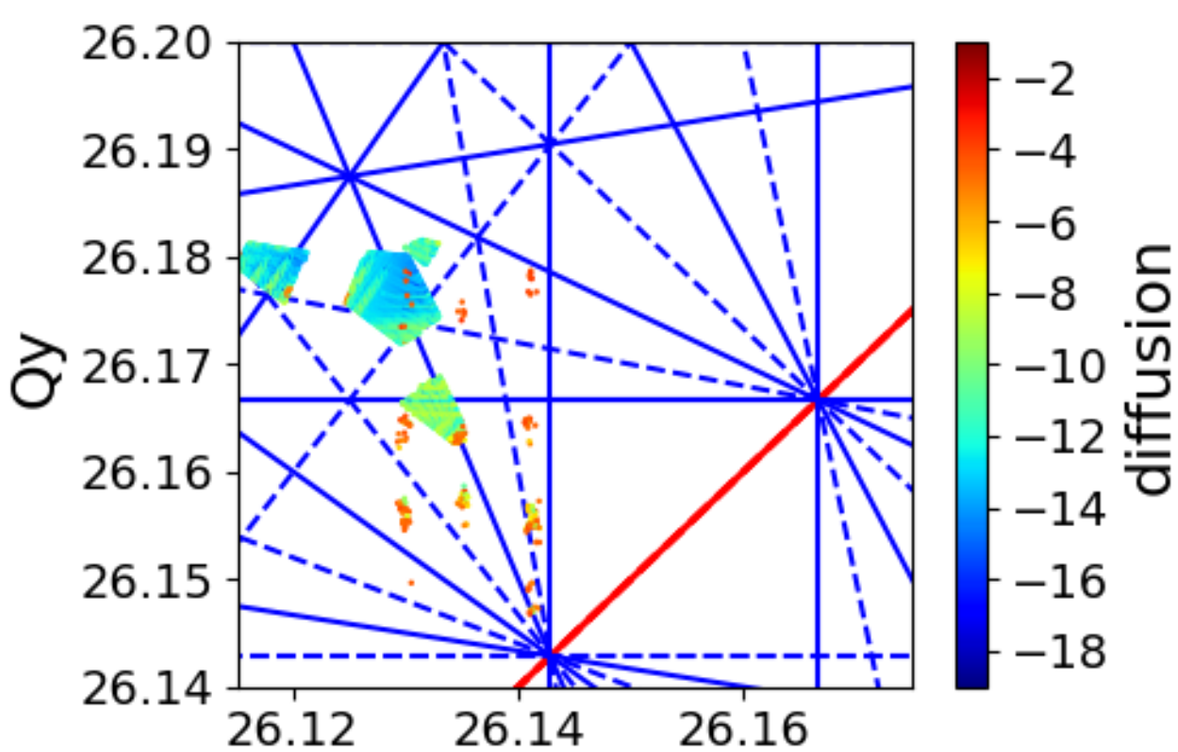
no_SPSmult_withCC_0.5MV_ dpp_init=0, z_init=200mm



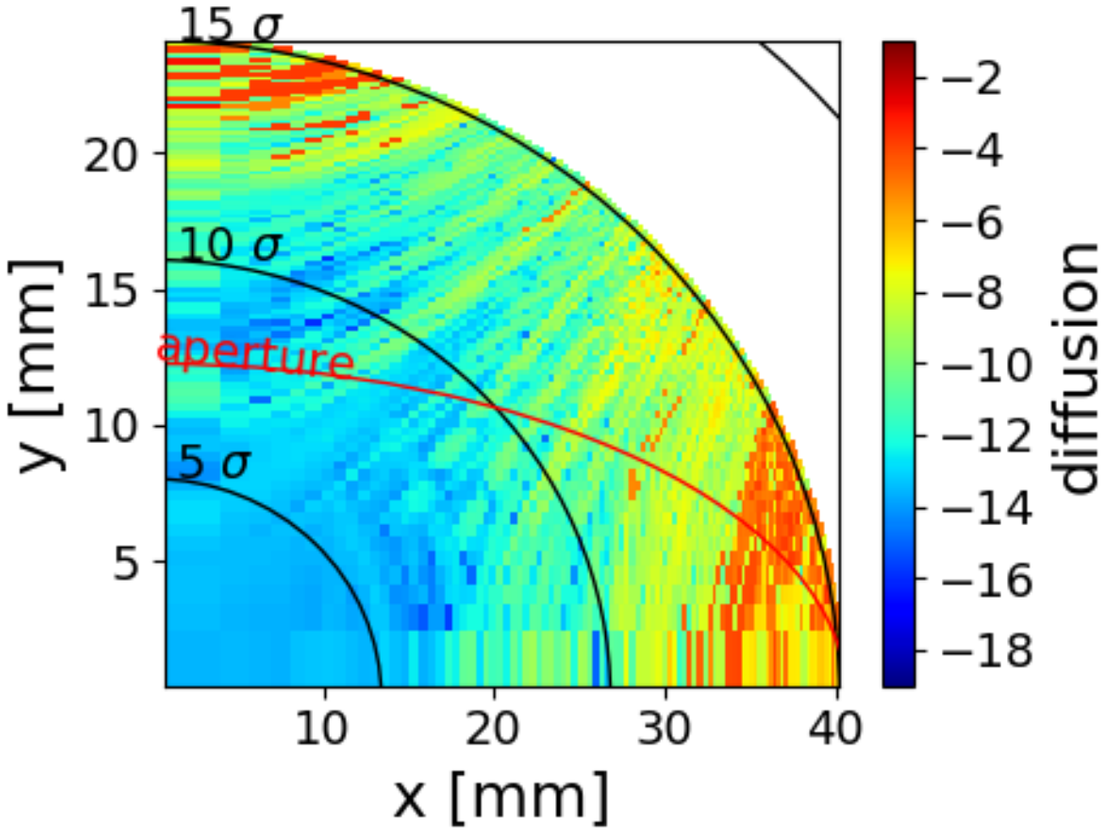


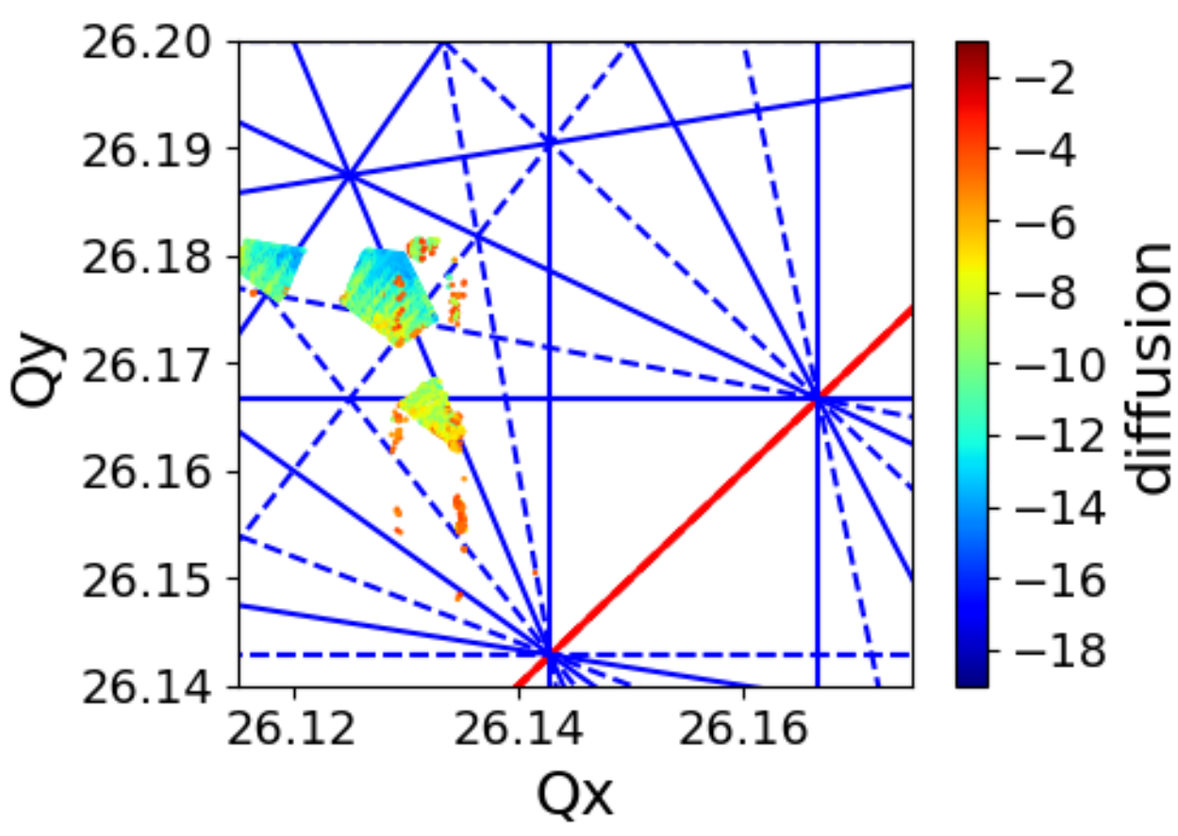
b3b5_withCC_0MV_ dpp_init=0, z_init=200mm



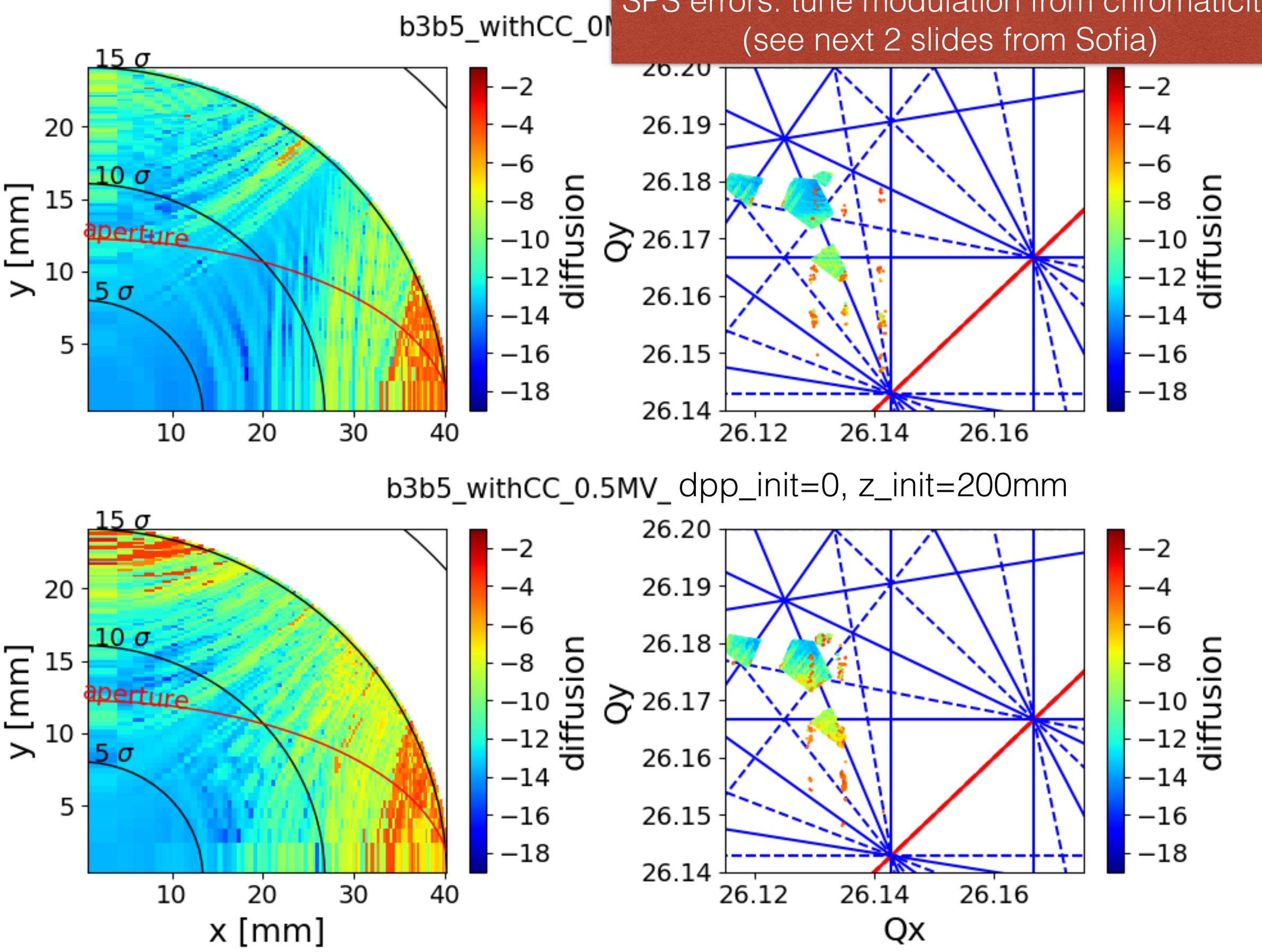


b3b5_withCC_0.5MV_ dpp_init=0, z_init=200mm





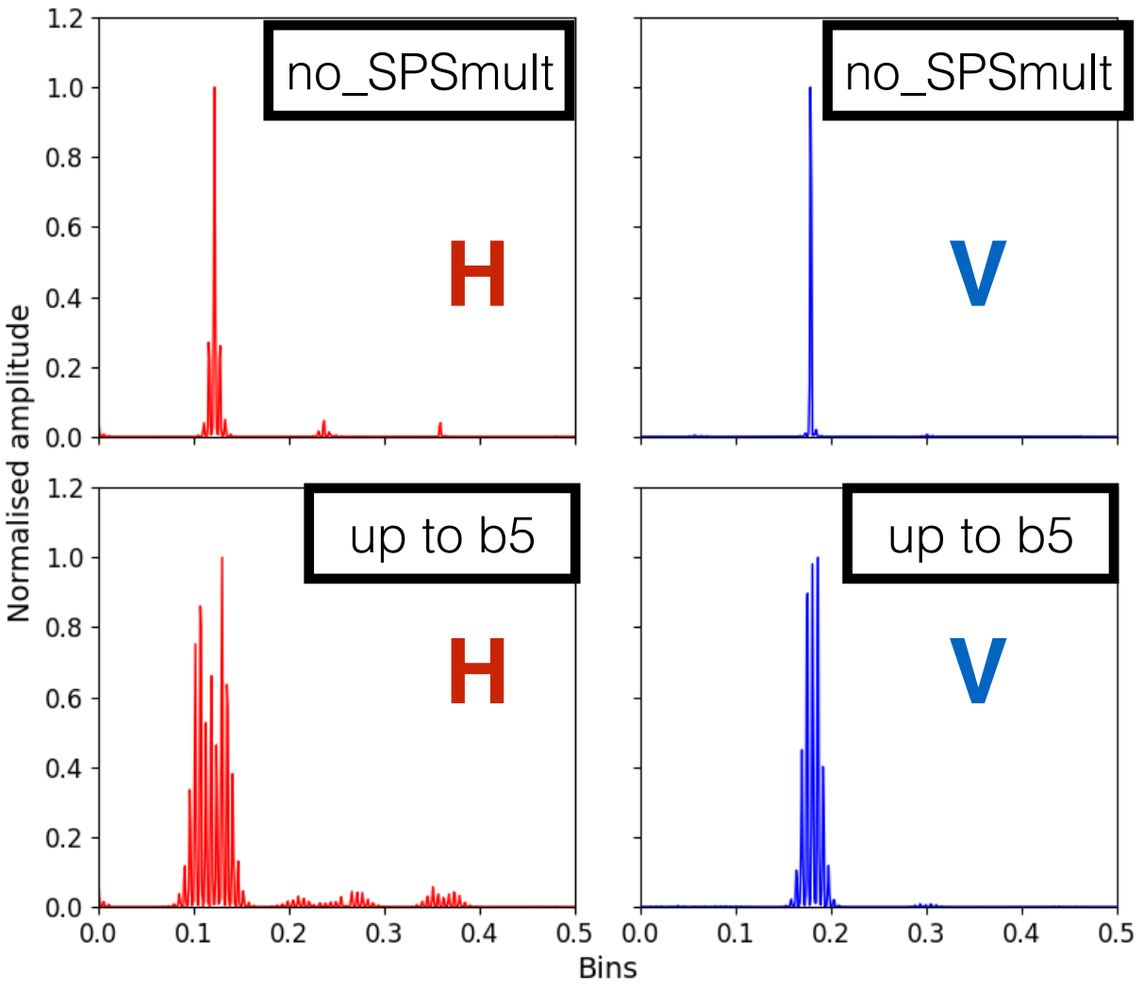
SPS errors: tune modulation from chromaticity
(see next 2 slides from Sofia)



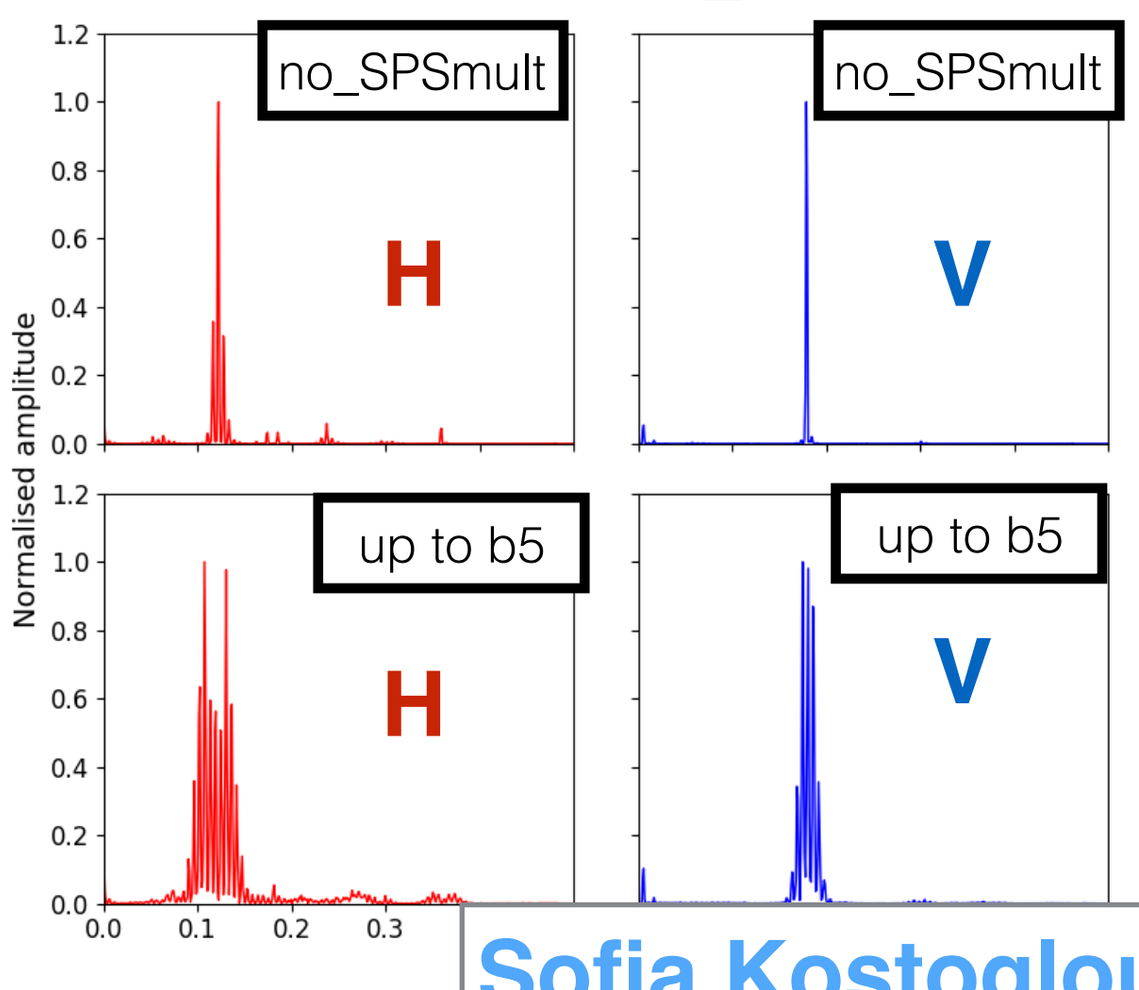
Modulation from synchrotron motion

- Fourier integrals from TbT data
- Sidebands from synchrotron motion
- Chroma increase when b3+b5 present

26 GeV, CC 0MV, z_init=200mm



26 GeV, CC 0.5MV, z_init=200mm



Sofia Kostoglou

Modulation from synchrotron motion

- NAFF detects the peak with the largest amplitude as the betatron tune

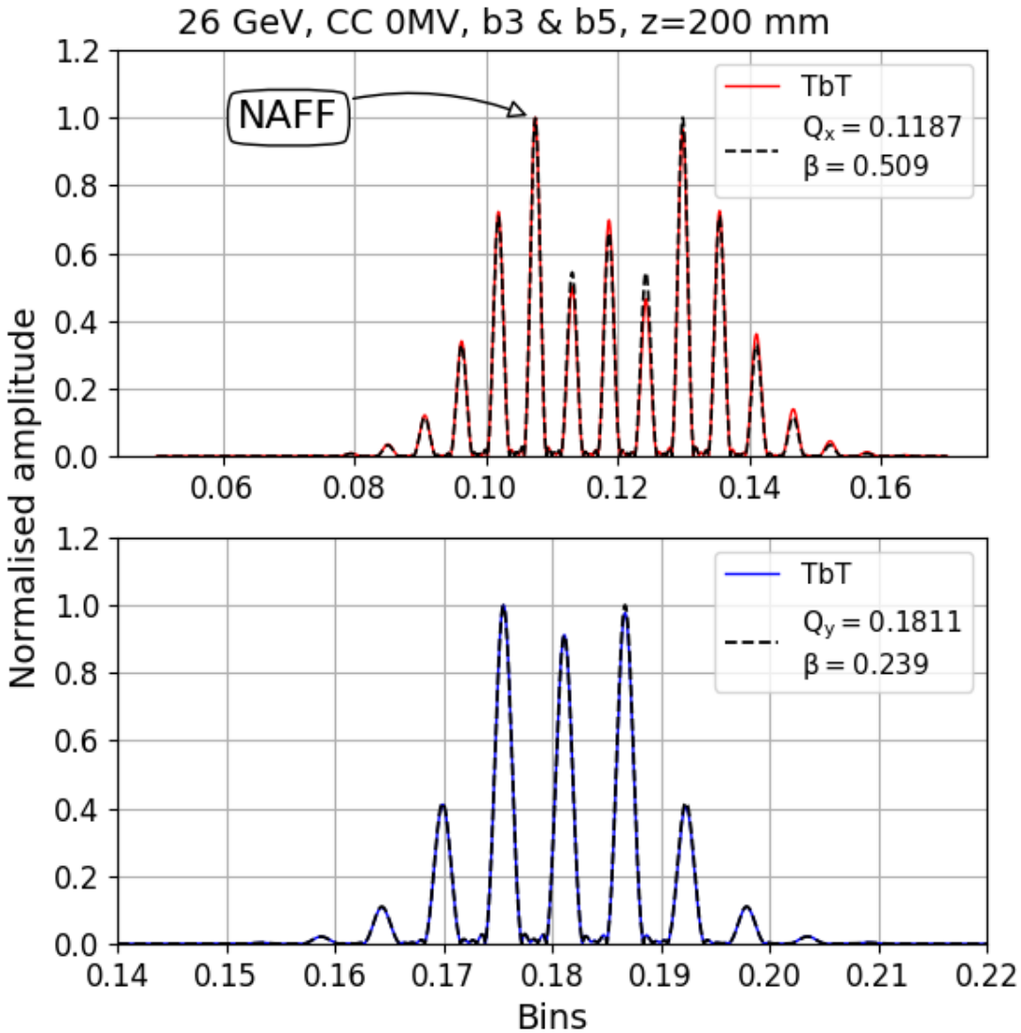
- In case of modulation, it will return a sideband if the modulation index > 1.5

- Reconstruction of signal with Bessel functions of the first kind in order to retrieve true fundamental

- For linear longitudinal motion & no initial phase:

$$z(N) = \sum_{m=-\infty}^{\infty} J_m(\beta)\cos(2\pi(Q_0 + mQ_s)N)$$

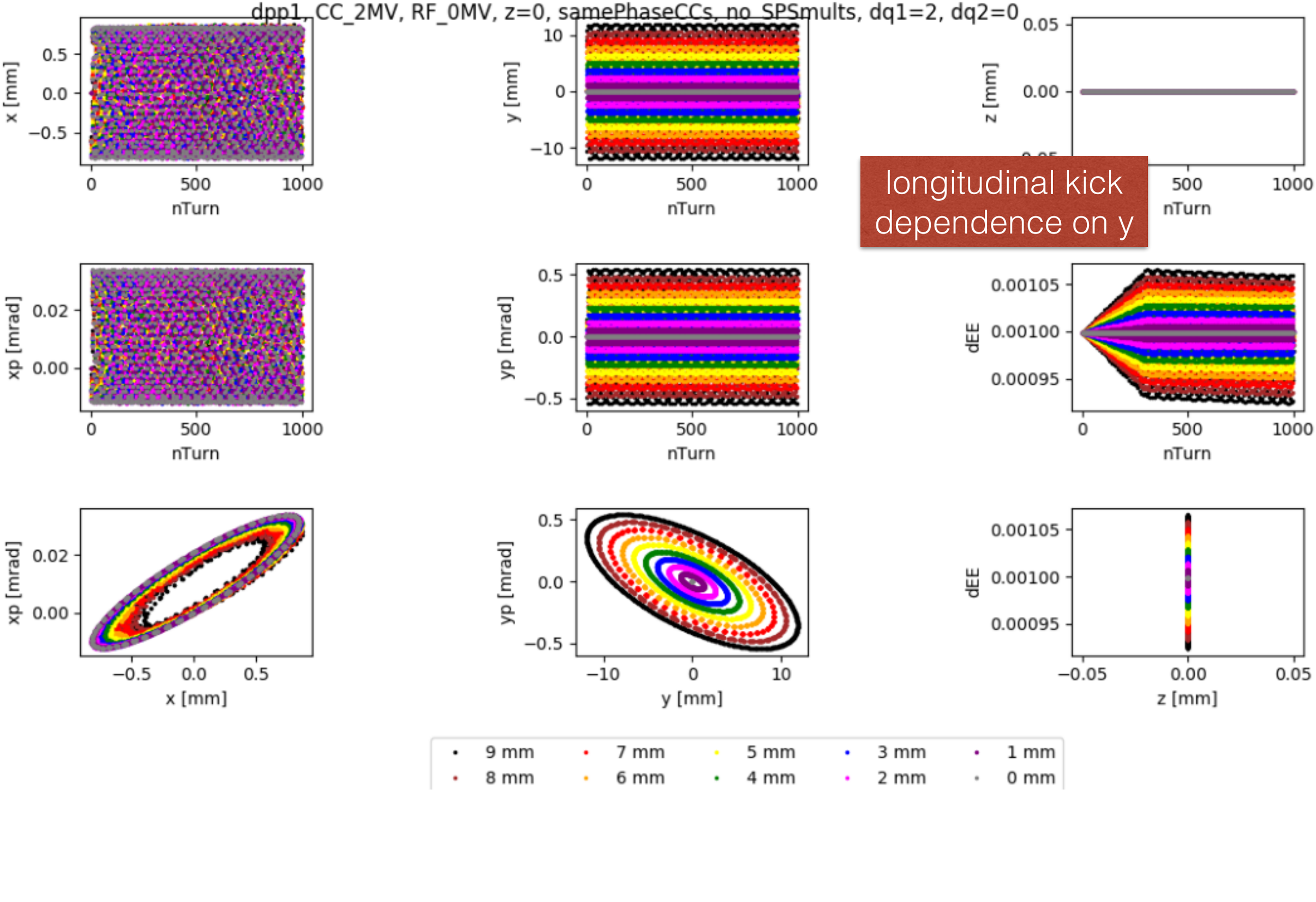
$$\beta = \frac{Q'\Delta p/p}{Q_s}$$



Sofia Kostoglou

5D simulations

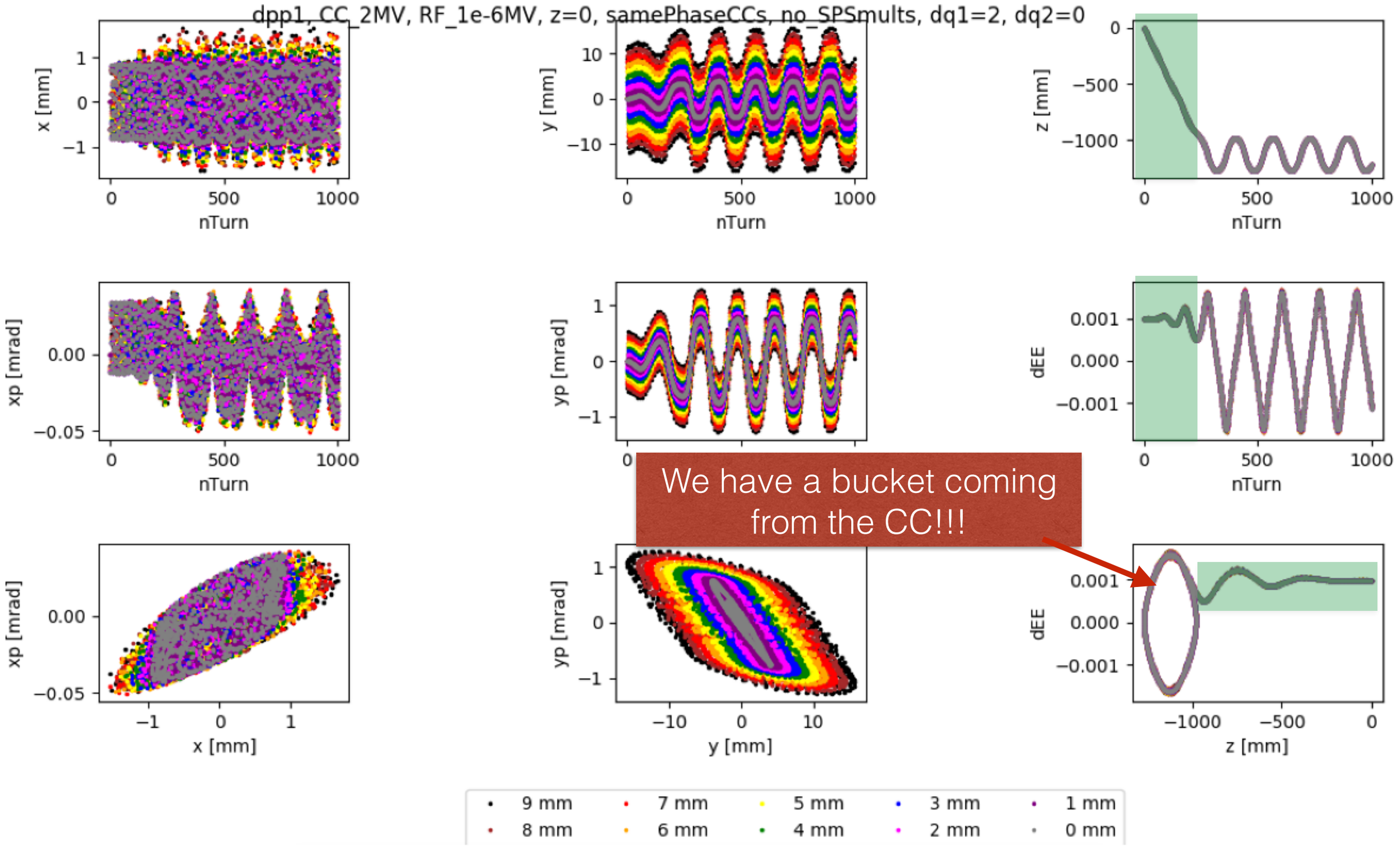
RF=0MV, dpp_init=1e-3, z_init=0
initial distribution set to zero
y=0-9mm


dpp1, CC_2MV, RF_0MV, z=0, samePhaseCCs, no_SPSmults, dq1=2, dq2=0
x [mm]
y [mm]
z [mm]
xp [mrad]
yp [mrad]
dEE
nTurn
longitudinal kick dependence on y
x [mm]
y [mm]
z [mm]
9 mm
8 mm
7 mm
6 mm
5 mm
4 mm
3 mm
2 mm
1 mm
0 mm

6D simulations

RF=1E-6MV, dpp_init=1e-3, z_init=0
initial distribution set to zero
y=0-9mm

$V_{CC,\,min}$ —> $V_{CC,\,max}$: 300 turns

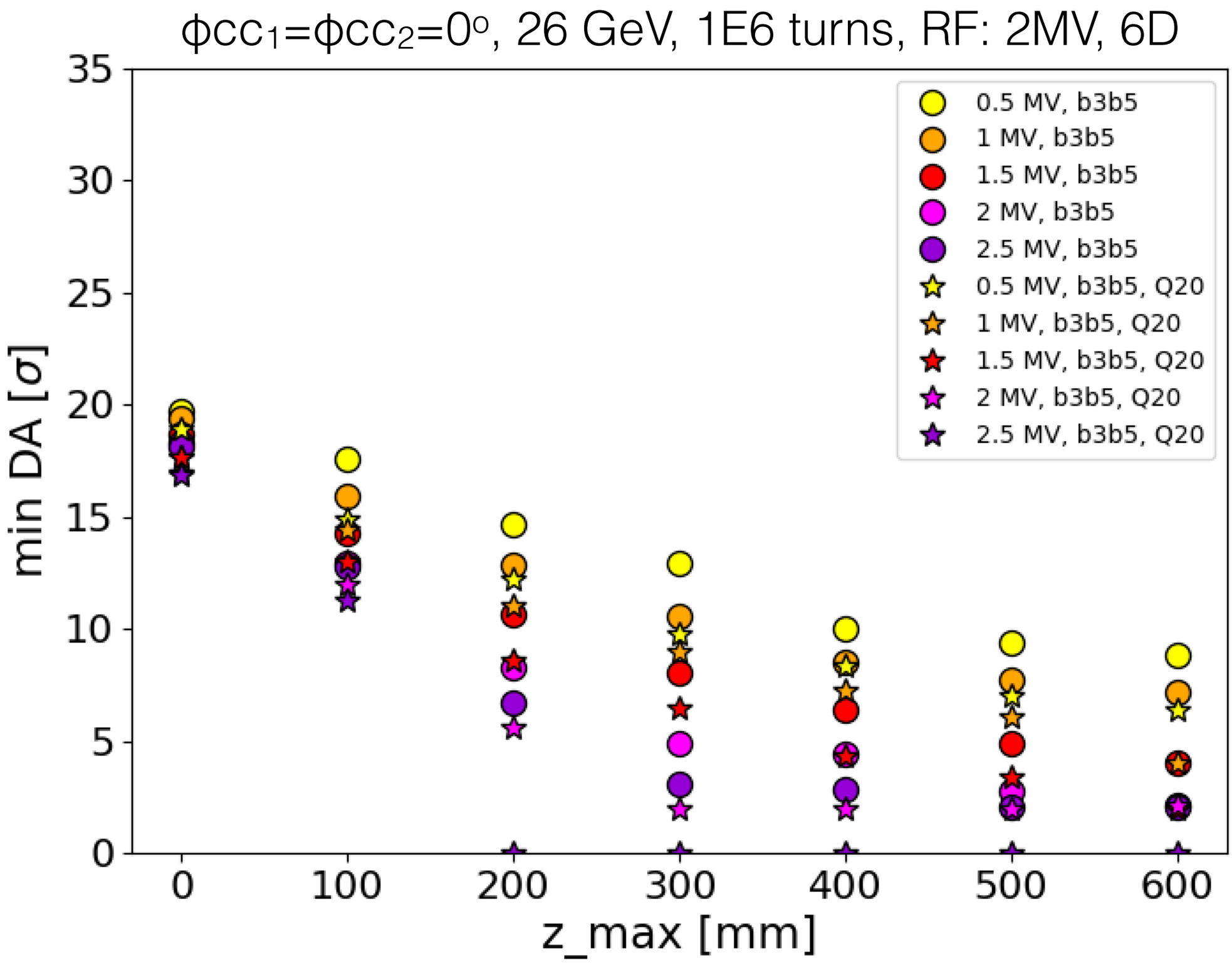


Setting DA to 0 when I get:

Angle: 15.00
Dynamic Aperture below: 2.04 Sigma
Minimum: **-2.04** Sigma at Seed #: 1
Maximum: 9.97 Sigma at Seed #: 1
Average: 9.97 Sigma

OR

Warning: all particle lost for angle 15.0 and seed 1


ϕcc1=ϕcc2=0°, 26 GeV, 1E6 turns, RF: 2MV, 6D
min DA [σ]
z_max [mm]
0
5
10
15
20
25
30
35
0
100
200
300
400
500
600
0.5 MV, b3b5
1 MV, b3b5
1.5 MV, b3b5
2 MV, b3b5
2.5 MV, b3b5
0.5 MV, b3b5, Q20
1 MV, b3b5, Q20
1.5 MV, b3b5, Q20
2 MV, b3b5, Q20
2.5 MV, b3b5, Q20

CC multipole values taken from "Long term dynamics of the high luminosity Large Hadron Collider with crab cavities", J. B. García et al

PHYSICAL REVIEW ACCELERATORS AND BEAMS **19,** 101003 (2016)

Long term dynamics of the high luminosity Large Hadron Collider with crab cavities

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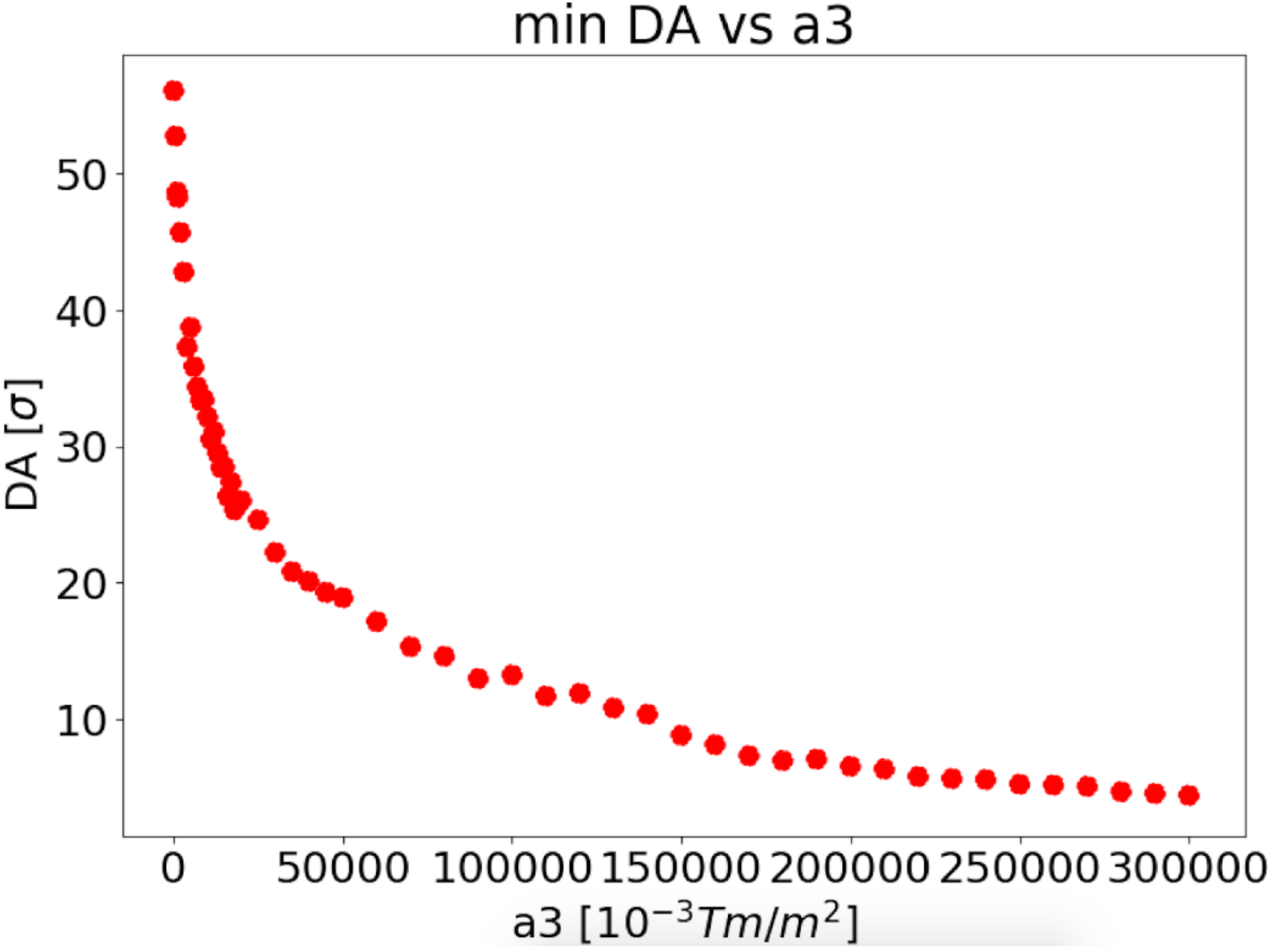
(Received 23 June 2016; published 11 October 2016)

TABLE II. Values of the multipolar rf multipoles for the crab cavity prototypes at nominal deflecting voltage: $V_{cc} = 10$ MV in units of mTm/m^{n-1}.

		Lorentz method		Panofsky-Wenzel		Helmholtz decomposition @20 mm
		@10 mm	@20 mm	@10 mm	@20 mm	
4RCAV	b_2	−0.06	−0.05	−0.06	−0.06	−0.10
2012	b_3	1159	1159	1161	1161	1156
	b_4	−4	100	65	27	57
RWCAV	b_2	0.01	0.00	0.00	0.01	0.02
2012	b_3	4511	4511	4495	4495	4518
	b_4	−4	−7	−21	7	10
QWCAV	b_2	111.42	111.40	111.43	111.48	113.06
2011	b_3	1266	1267	1257	1260	1279
	b_4	1776	1776	1401	1836	2102
QWCAV	b_2	0.29	0.29	0.29	0.29	0.24
2012	b_3	1074	1073	1078	1078	1073
	b_4	50	67	6	64	22

b3 stronger than other multipoles: sextupolar term: 1st allowed multipole for dipole


min DA vs a3
DA [σ]
50
40
30
20
10
0
50000
100000
150000
200000
250000
300000
a3 [$10^{-3}Tm/m^2$]