

# SANDWICH Scripts

Simulations with `elegant` and **GENESIS 1.3**

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SANDWICH Scripts  
S2E Meeting, 27.03.2014

# Motivation

- > For most seeding simulations different programs have to be employed, because of their individual strengths and weaknesses
- > For our purposes (CHG, HGHG, Self-Seeding, EEHG): GENESIS 1.3 simulates electron-light-interaction (modulator and radiator)
- > For high currents dispersive sections (chicanes) are more accurately computed by codes that include collective effects -> elegant (ASTRA, CSRTrack,...)
- > **For high harmonics one needs about 8000 particles per slice and harmonic in GENESIS to suppress numerical noise to a minimum.**
- > **Normal SDDS Files can load up to 22E6 particles into GENESIS.**

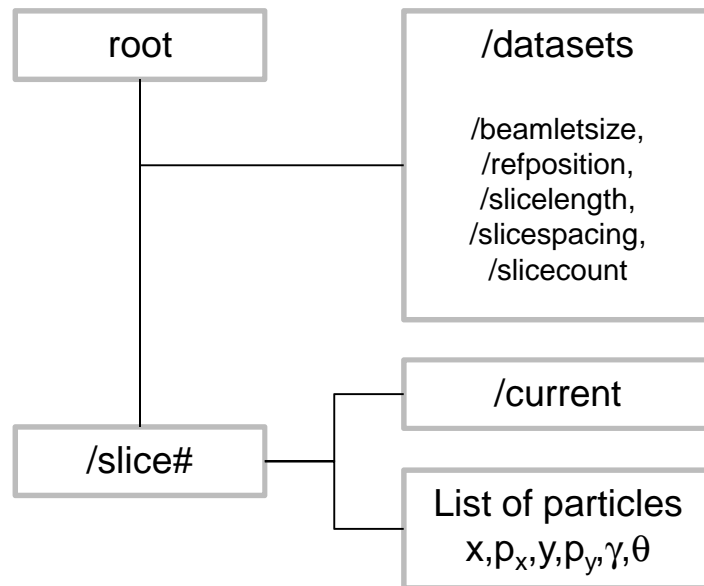
$$22E6 \text{ particles} / (500 \text{ slices} * 8000 \text{ particles/slice}) = 5.5$$



# The Challenge



## Hierarchical Data Format (HDF)



*binary, each property can contain different variable types*

## Self-Describing Data Set (SDDS)

### Header

Description of all parameters within the body including name, unit and variable type.

### Body

Contains all parameter values. In our case:

- datasets: beamletsize, reposition, slicelength, slicespacing, slicecount
- charge
- list of particles:  $x, x', y, y', \gamma, t$

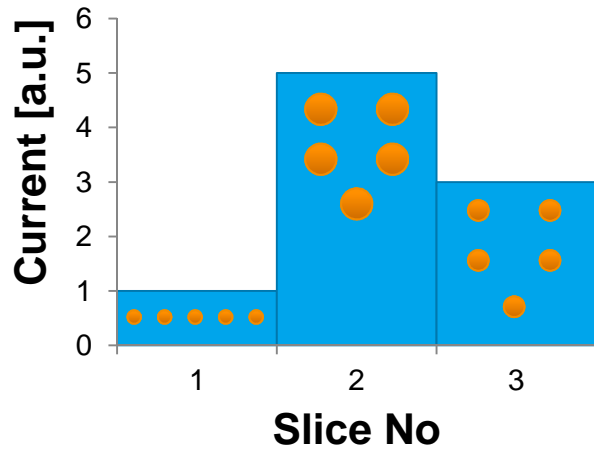
Attribution to slices is missing!

*ASCII File*



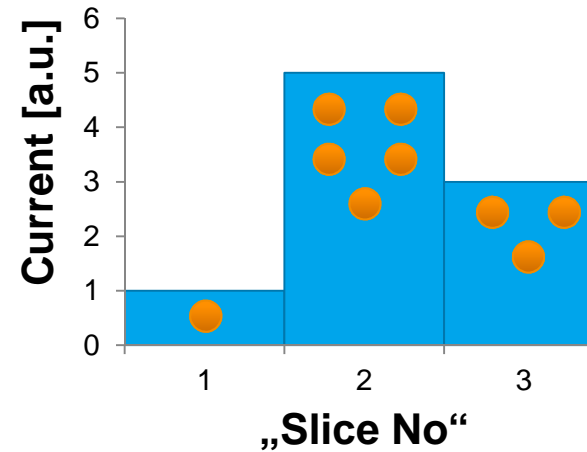
# The Challenge

GENESIS 1.3



- Different charges per particle in different slices.
- Same number of particles per slice

ELEGANT



- Same charge per particle
- Number of particles proportional to current.
- No slices!



# First Tests

GENESIS 1.3

HDF5\_2\_SDDS

ELEGANT

SDDS\_2\_HDF5

GENESIS 1.3



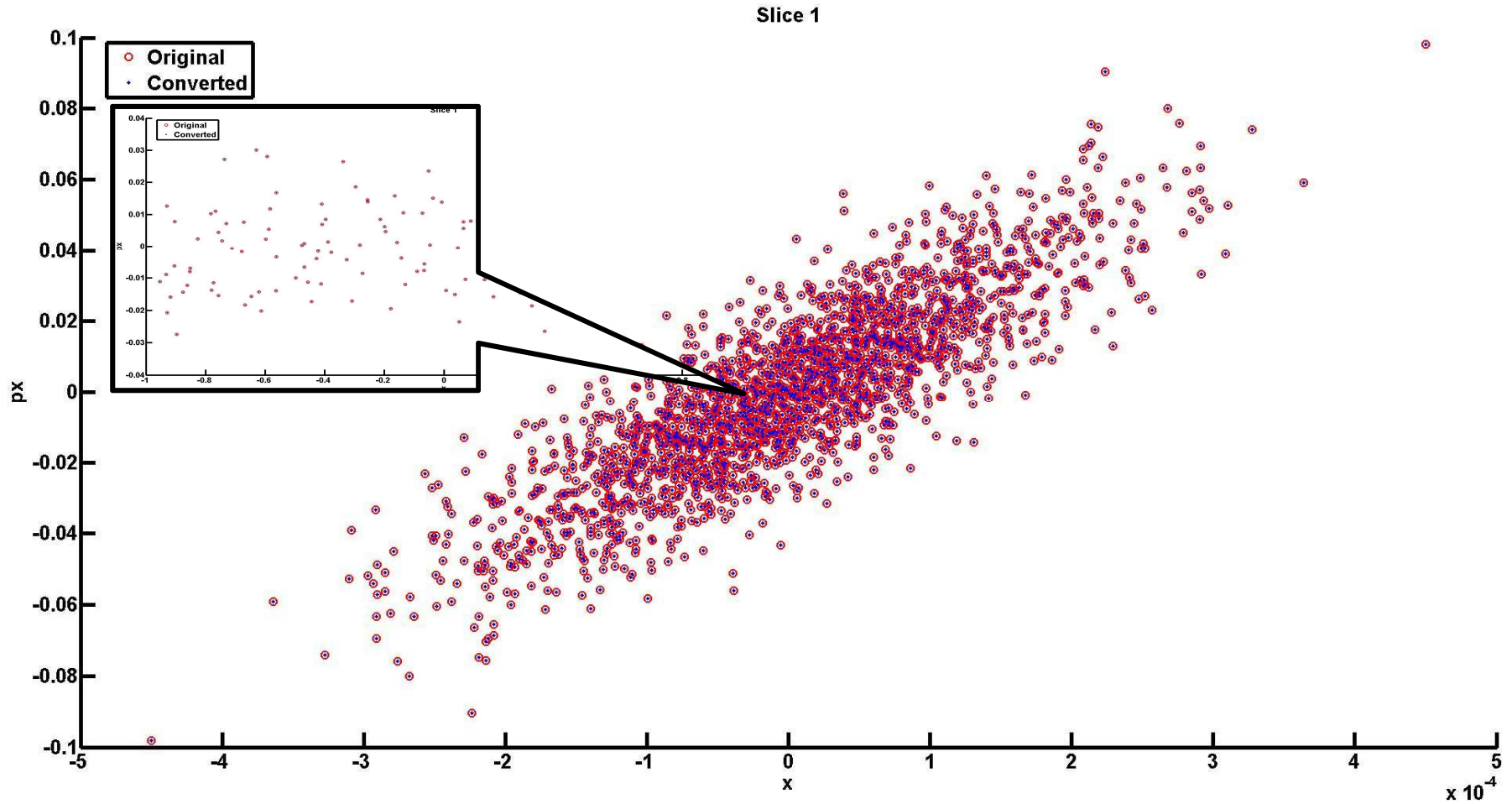
# Transverse phase space distribution

GENESIS 1.3

HDF5\_2\_SDDS

SDDS\_2\_HDF5

GENESIS 1.3



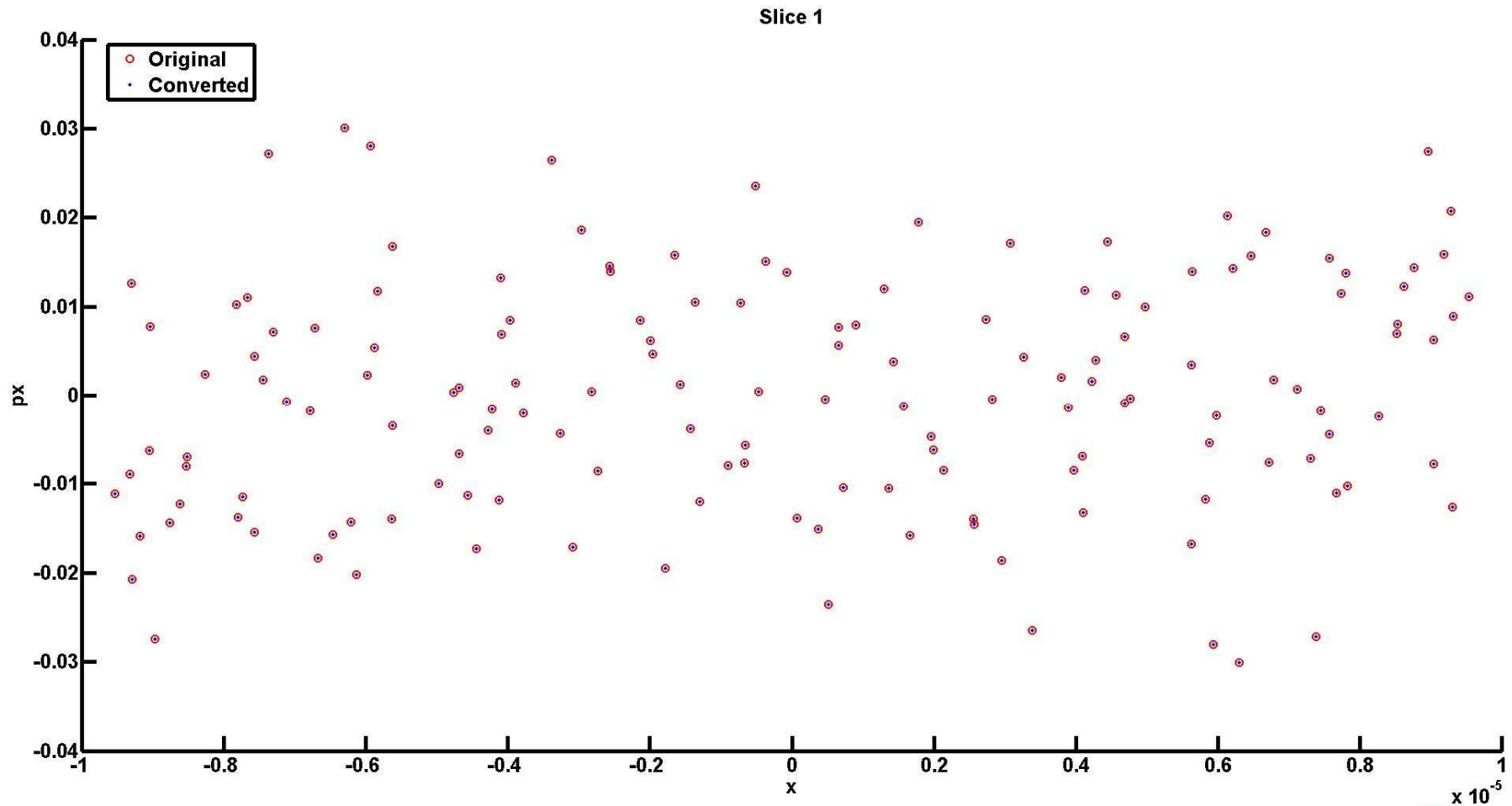
# Transverse phase space distribution

GENESIS 1.3

HDF5\_2\_SDDS

SDDS\_2\_HDF5

GENESIS 1.3



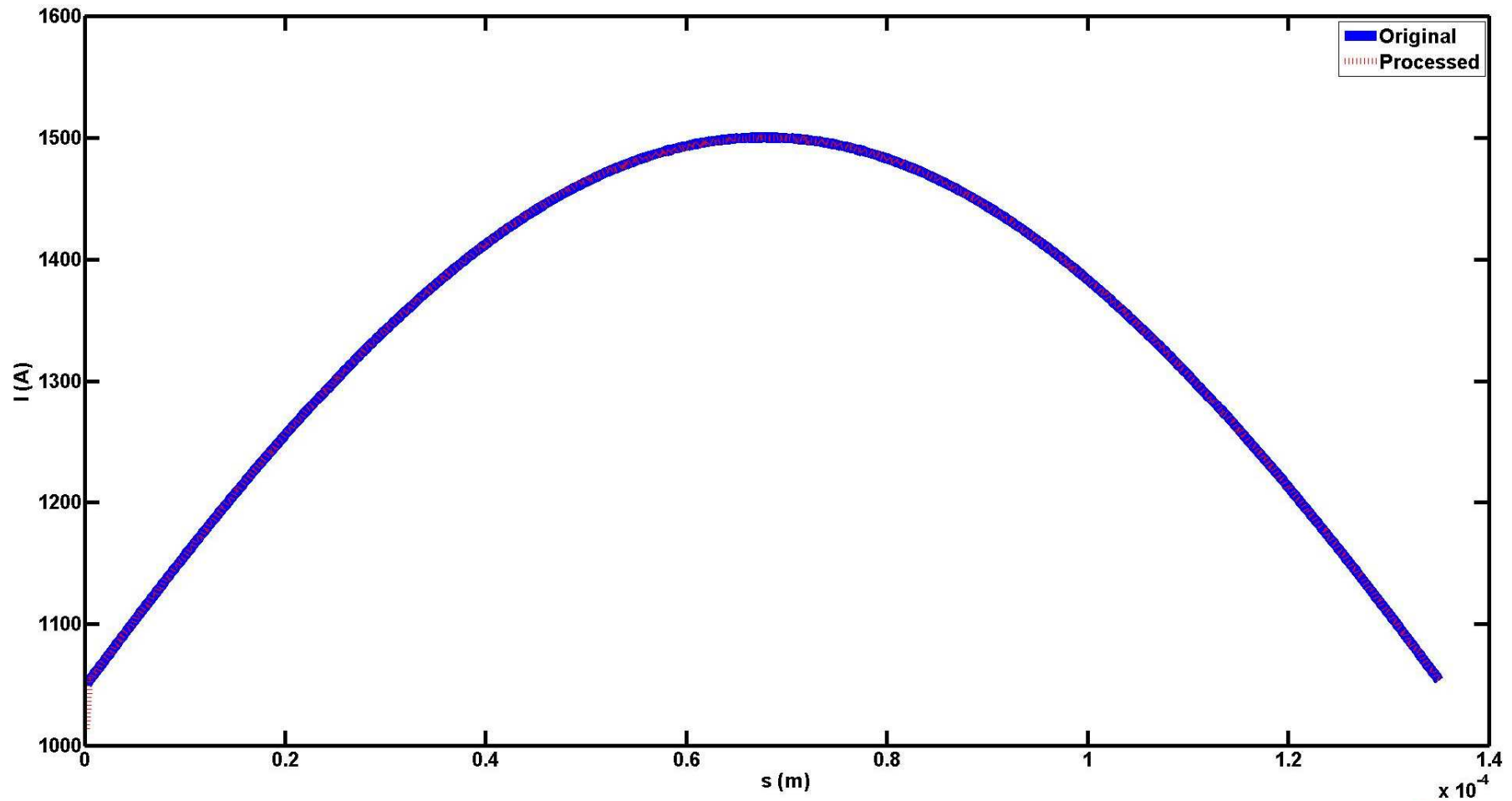
# Current distribution

GENESIS 1.3

HDF5\_2\_SDDS

SDDS\_2\_HDF5

GENESIS 1.3





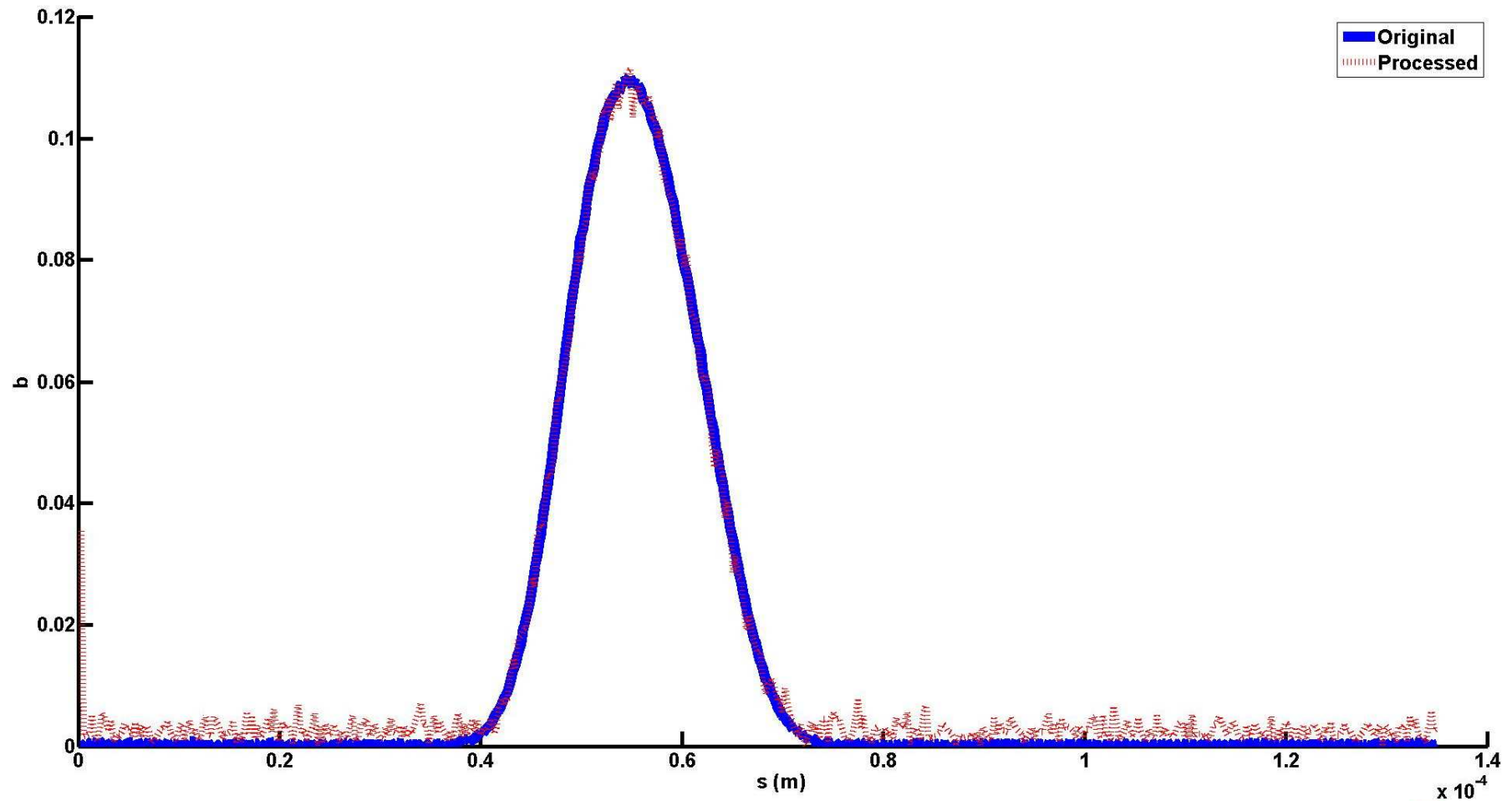
# Bunching (Fundamental)

GENESIS 1.3

HDF5\_2\_SDDS

SDDS\_2\_HDF5

GENESIS 1.3



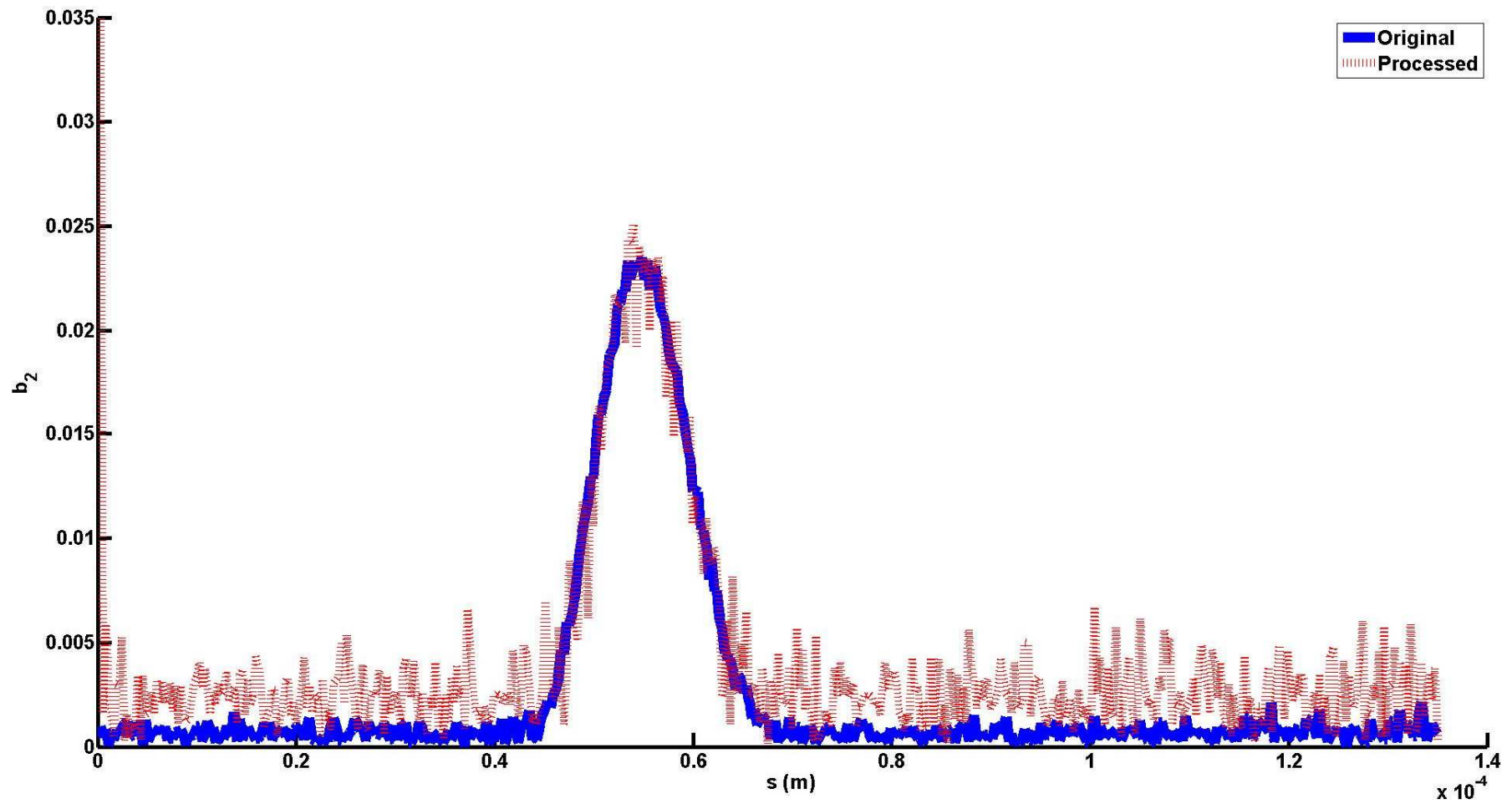
# Bunching (2<sup>nd</sup> harmonic)

GENESIS 1.3

HDF5\_2\_SDDS

SDDS\_2\_HDF5

GENESIS 1.3



# CHG R56 Scan

GENESIS 1.3

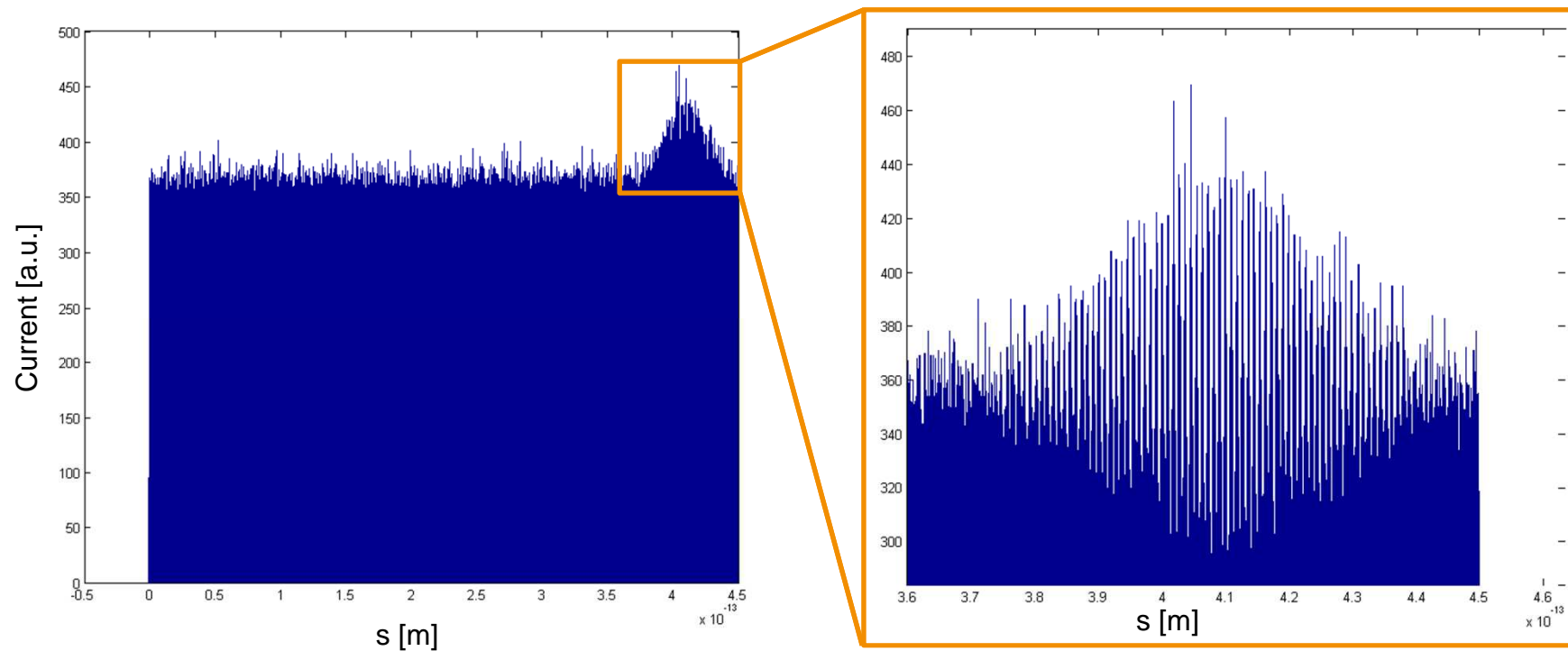
HDF5\_2\_SDDS

ELEGANT

SDDS\_2\_HDF5

GENESIS 1.3

Change deflecting angle of dipoles within chicane. (50A, 20 $\mu$ J Run)



# CHG R56 Scan

GENESIS 1.3

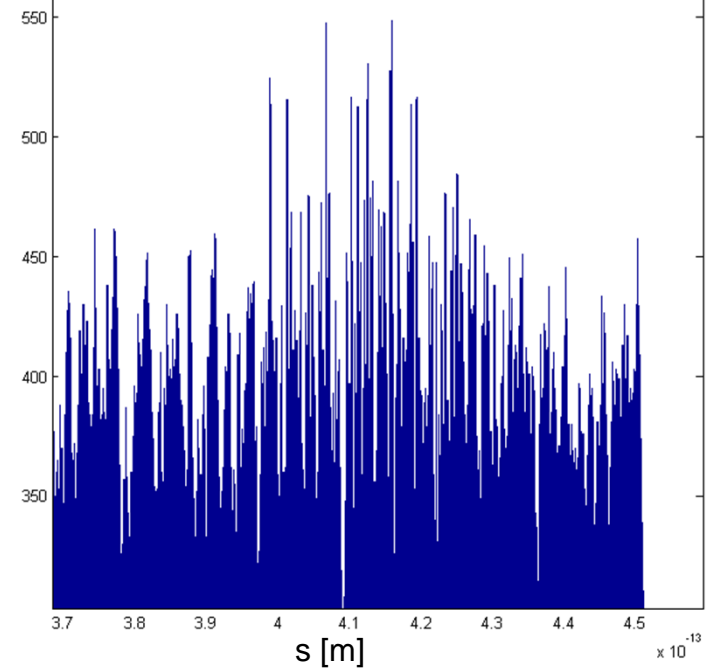
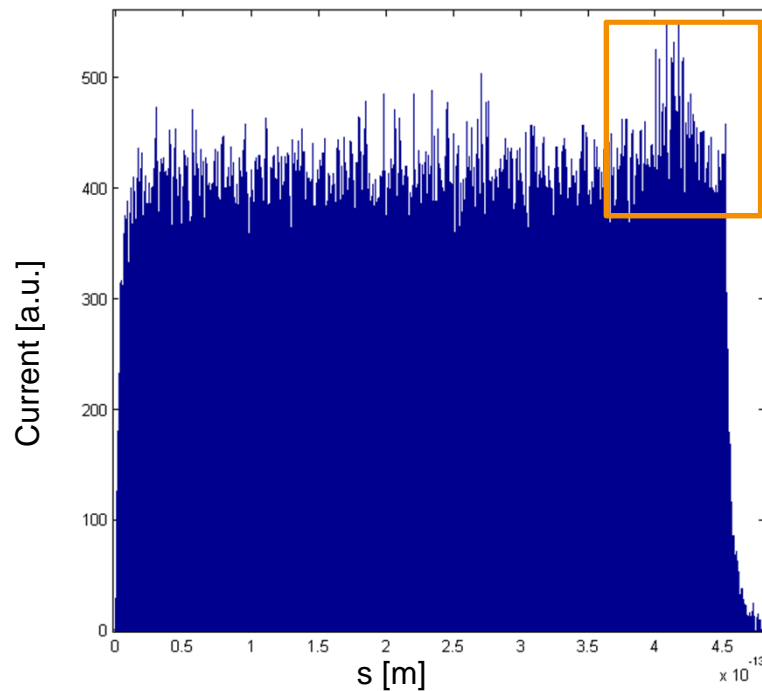
HDF5\_2\_SDDS

ELEGANT

SDDS\_2\_HDF5

GENESIS 1.3

Change deflecting angle of dipoles within chicane. (50A, 20 $\mu$ J Run)



# CHG R56 Scan

GENESIS 1.3

HDF5\_2\_SDDS

ELEGANT

SDDS\_2\_HDF5

GENESIS 1.3

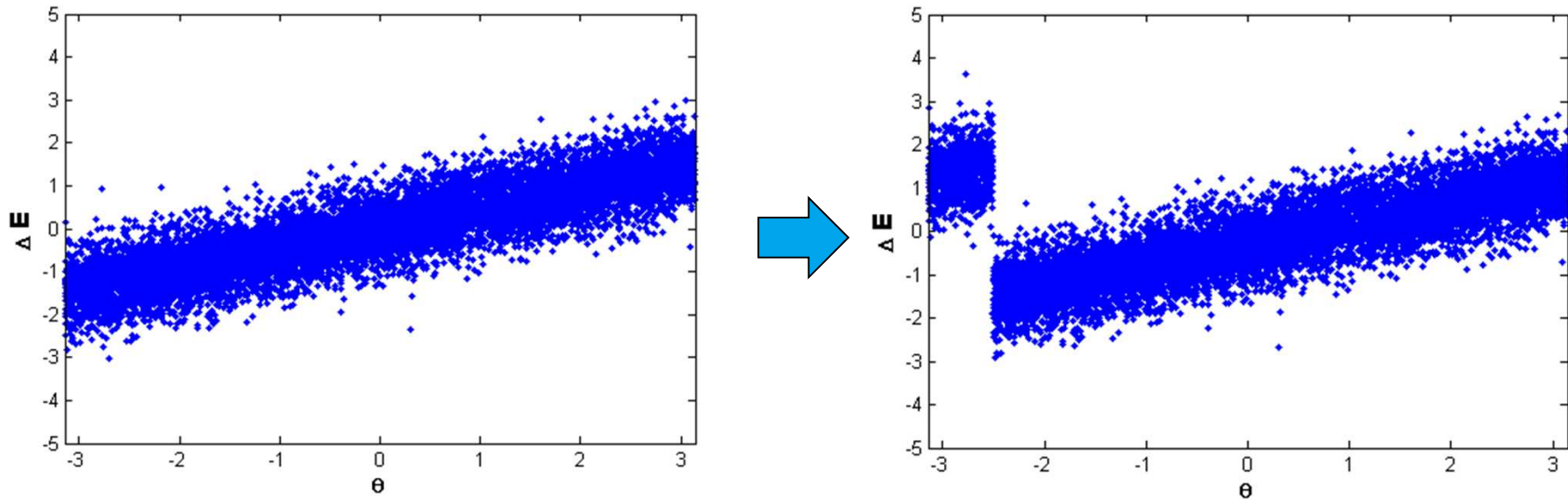
Change deflecting angle of dipoles within chicane. (50A, 20 $\mu$ J Run)

Bunching on different harmonics in $\cdot 10^4$	R56 [ $\mu$ m]	0	-10	-40	-110
1st		5.0	10.4	28.3	28.2
2nd		1.7	1.1	12.0	3.3
3rd		1.5	1.6	2.9	4.2
4th		2.0	2.8	6.0	3.2
5th		2.2	1.3	4.8	5.1



# Challenges

- Particles that leave a slice due to their movement come back into the slide from the other side.



- Can this cause problems in GENESIS 1.3 calculations?
- Compare: beamfile input with particle input.

# Conclusion

- > We have a tool capable of the generation of HDF5 Particle Distribution Files from SDDS files and vice versa.
- > GENESIS 1.3 and elegant accept these files and understand them correctly
- > Since the phase space distribution manipulation takes place in elegant (which does not know anything about harmonics), one can reach any harmonic



# Outlook

- > Is GENESIS 1.3 suitable for seeding simulations?
- > Substitute elegant with some other SDDS capable tracking code?
- > Substitute modulator calculations by elegant module?
- > Test the framework with physics runs for future CHG and HGHG experiments





# First Tests

GENESIS 1.3

HDF5\_2\_SDDS

ELEGANT

SDDS\_2\_HDF5

GENESIS 1.3

GENESIS 1.3 can handle the chicane by transfer matrices, too. What is the difference to elegant?

## Sim Parameters

Particles	8192
Electron $\gamma$	1369
Energy Spread	0.1 $\gamma$
Laser Power	100 $\mu$ J
Laser Duration (FWHM)	30 fs
Laser Wavelength	270 nm



# First Tests

GENESIS 1.3

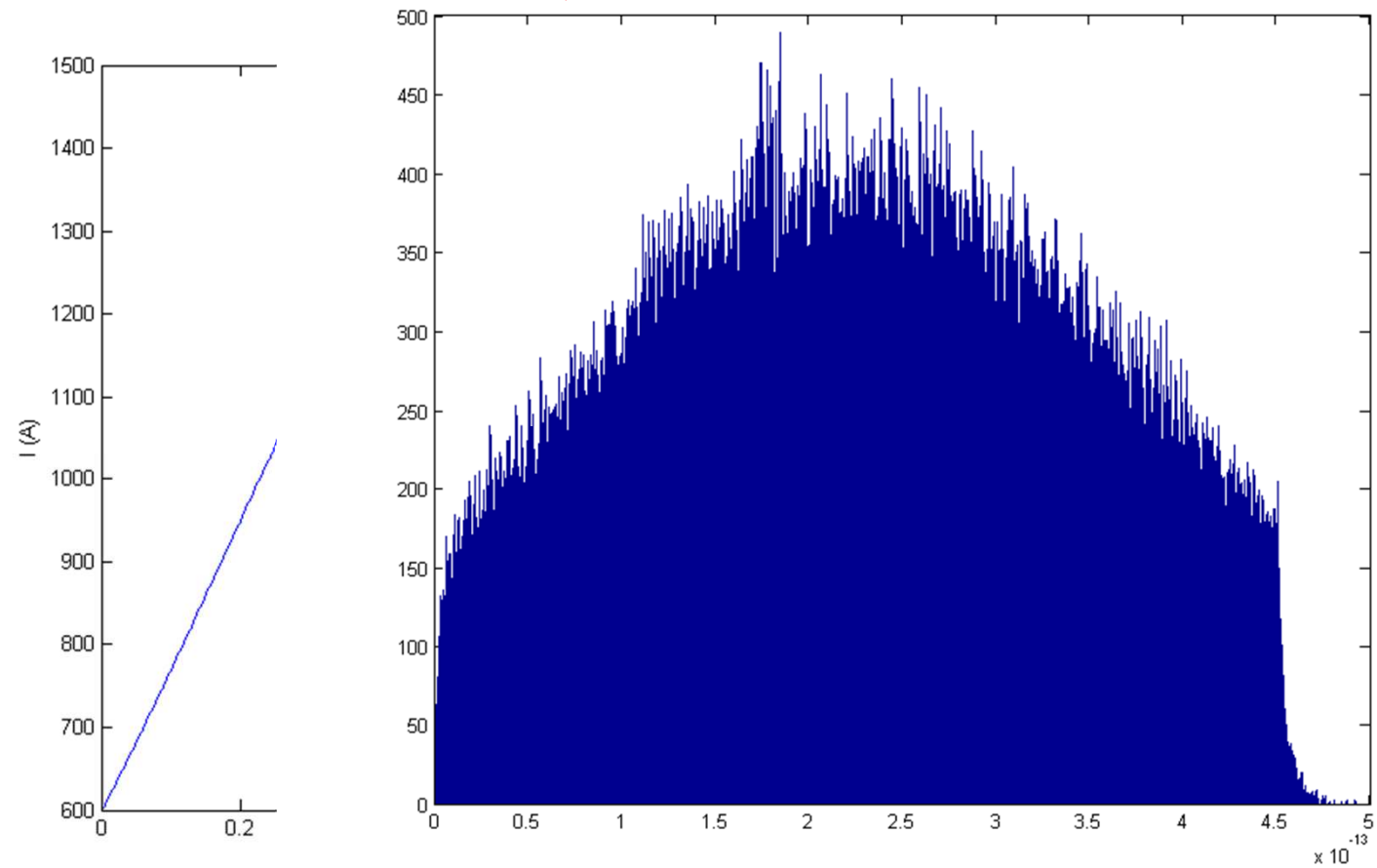
HDF5\_2\_SDDS

ELEGANT

SDDS\_2\_HDF5

GENESIS 1.3

1.5 kA Run:



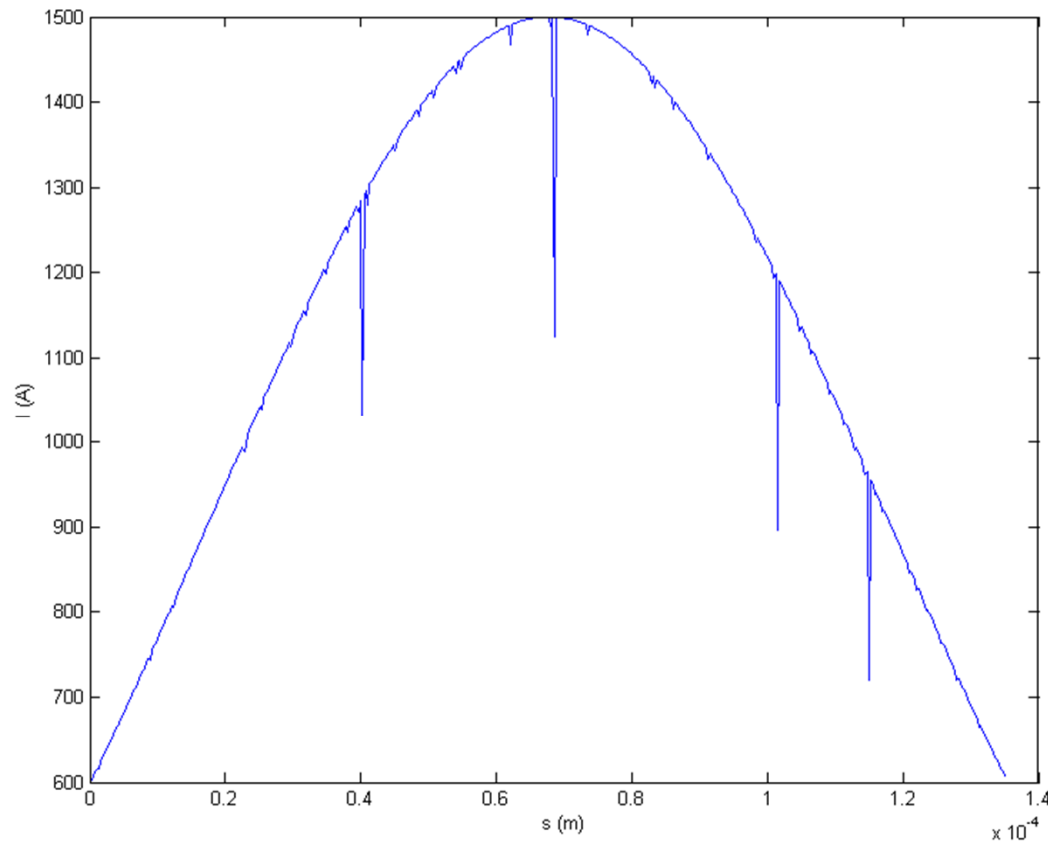
# First Tests

GENESIS 1.3

GENESIS Run with Trama

GENESIS 1.3

1.5 kA Run:



# Simulation Programs

	GENESIS	ELEGANT
Version	3.2.1, 22M7	25.2.2
Architecture	64 bit	
Parallel	Yes	(... should be compiled...)
Maximum No. of Particles	~ 22 M	(... parallel: $2^{63} - 1$ )
Used number of Particles	~ 150 k ~ 75 M	
Highest Harmonic	7th (in s...)	
Used for	Dr...	Tracking and e Effects
File Format	HDF5	
Longitudinal Coordinates	$\gamma, \theta, k_{\text{slice}}$	$\gamma, \tau$
Transverse Coordinates	$x, y, p_x, p_y$	$x, y, x', y'$
Charge per particle	Constant in one slice	Constant for each particle

For experts:

- NHARMMAX during compilation limits the highest harmonic in the simulated spectra
- The radiator can lase on ANY harmonic of the modulator
- There are several options
  - Sort particles to narrower slices
  - Use MULTCONV, CONVHARM, and ZSEP



# Requirements



- Remodel particle distribution according to current profile.
- Convert GENESIS slice structure with ponderomotive phases  $[-3.3;3.3]$  to intra bunch coordinate.

- Divide particle distribution into slices with the same number of particles.
- Each slice has to contain the same number of particles. This number has to be a multiple of  $4 \cdot \text{NBINS}$  (128).

A huge amount of particles is lost in the conversion. Depending on current profile this can be up to the order of 50%.



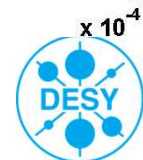
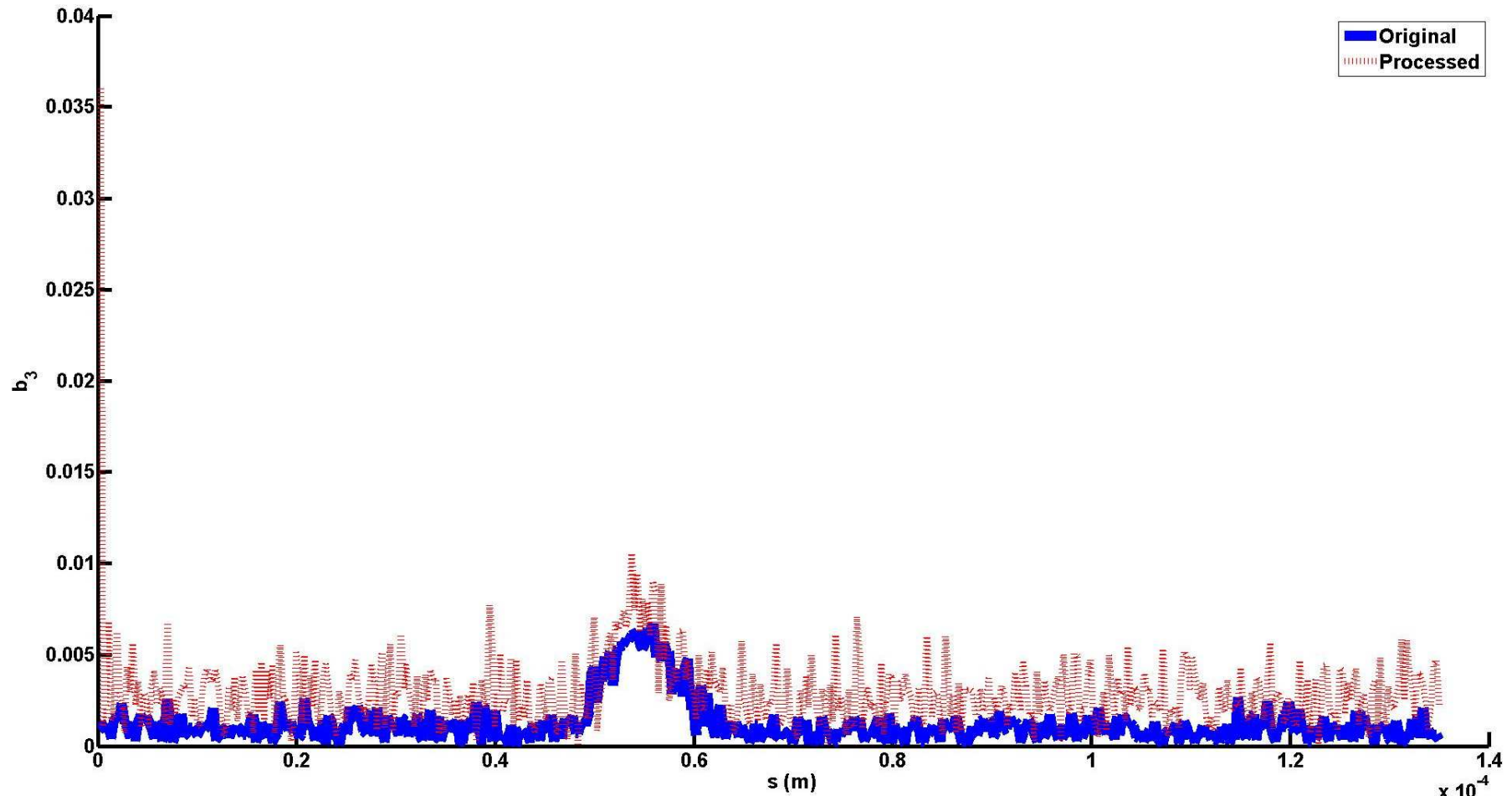
# Bunching (3<sup>rd</sup> harmonic)

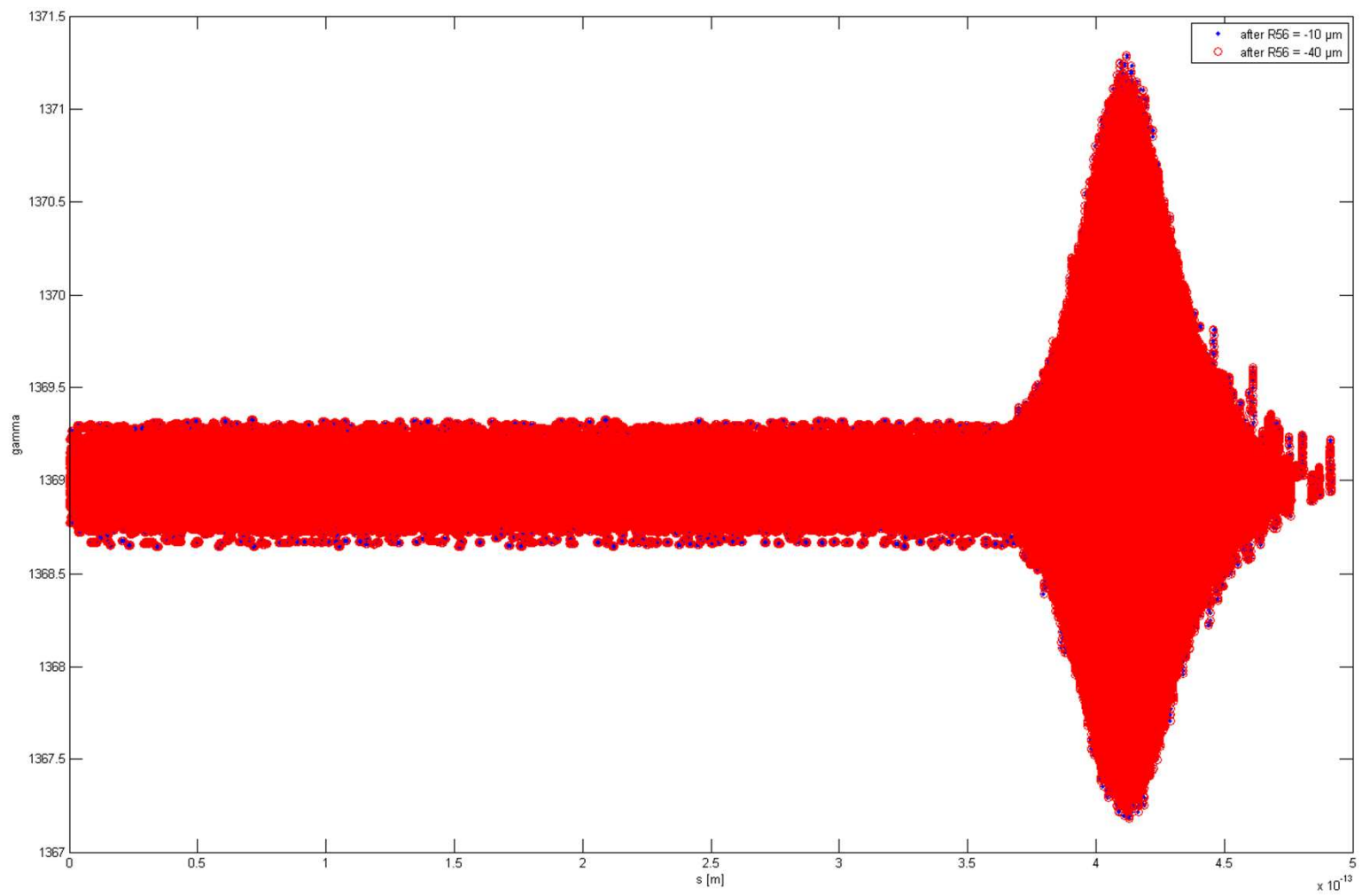
GENESIS 1.3

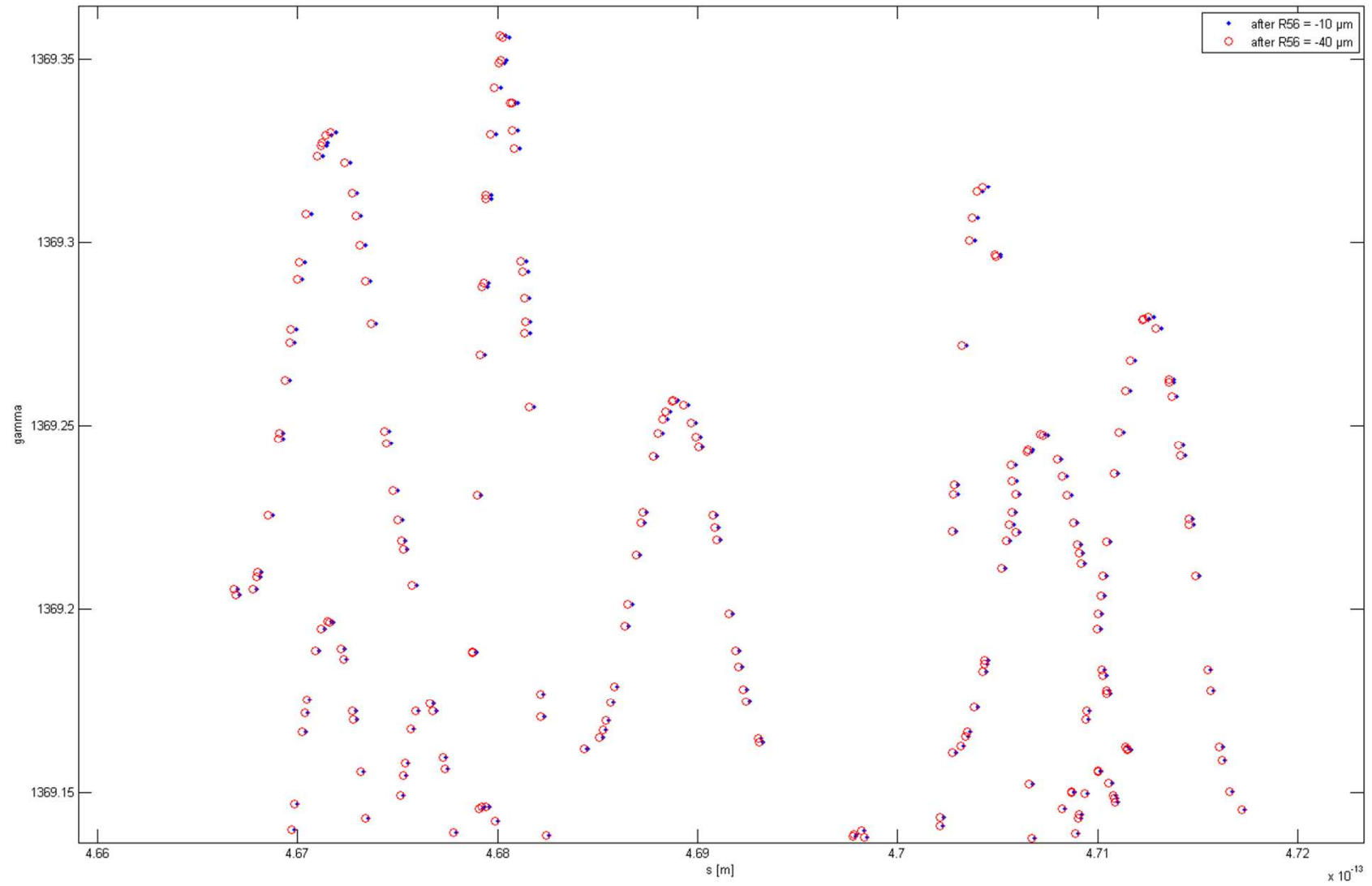
HDF5\_2\_SDDS

SDDS\_2\_HDF5

GENESIS 1.3

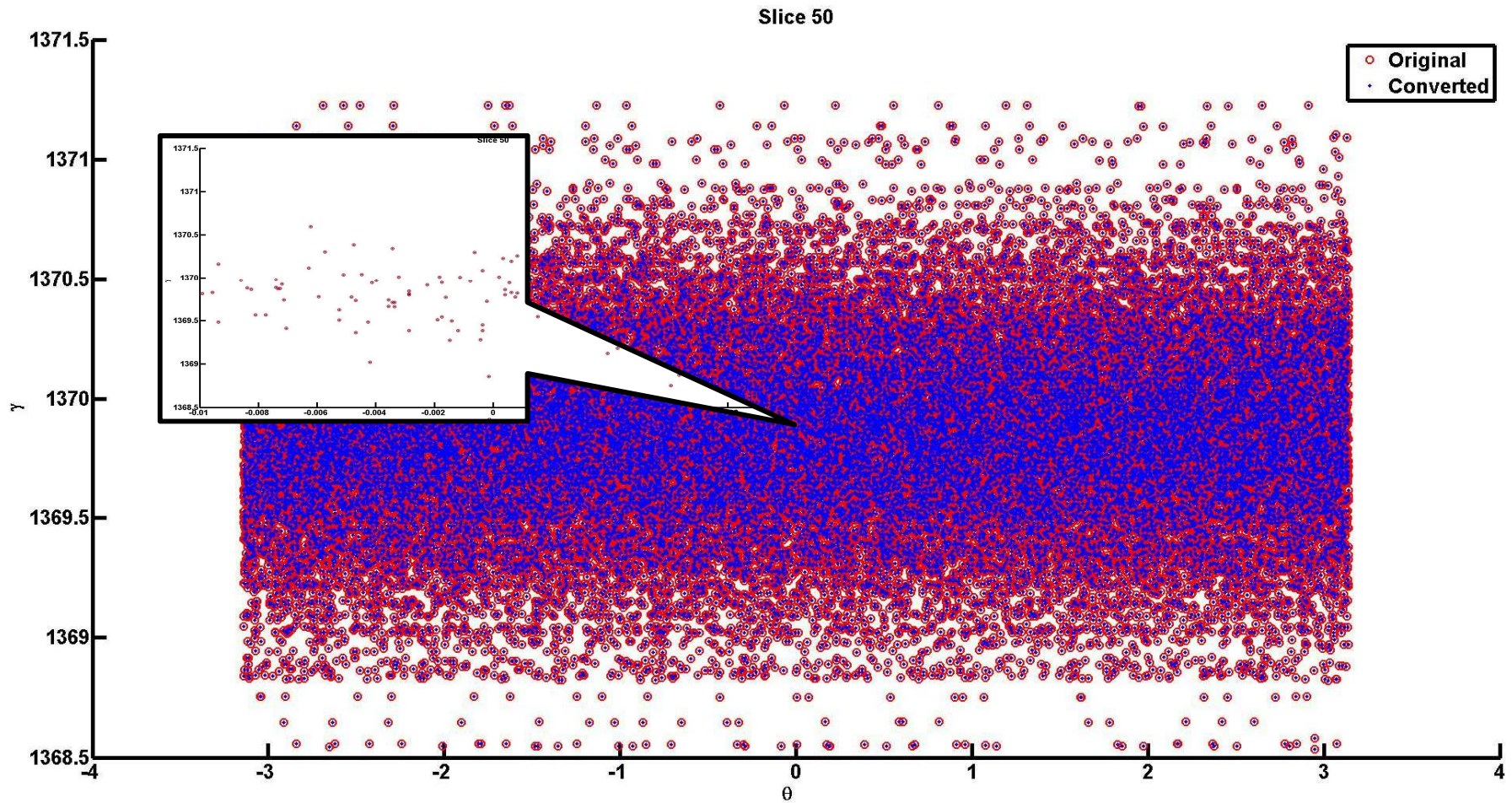




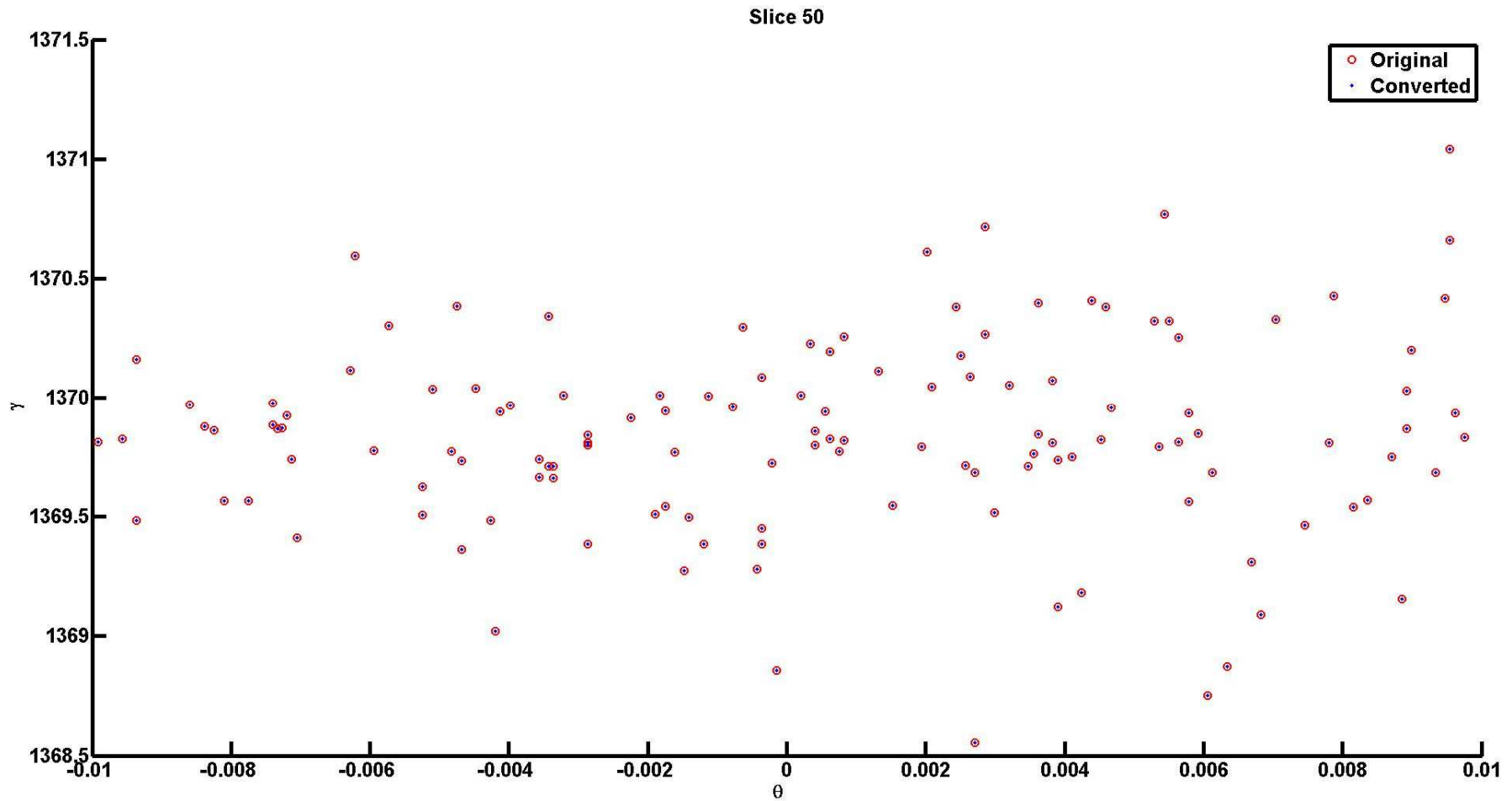




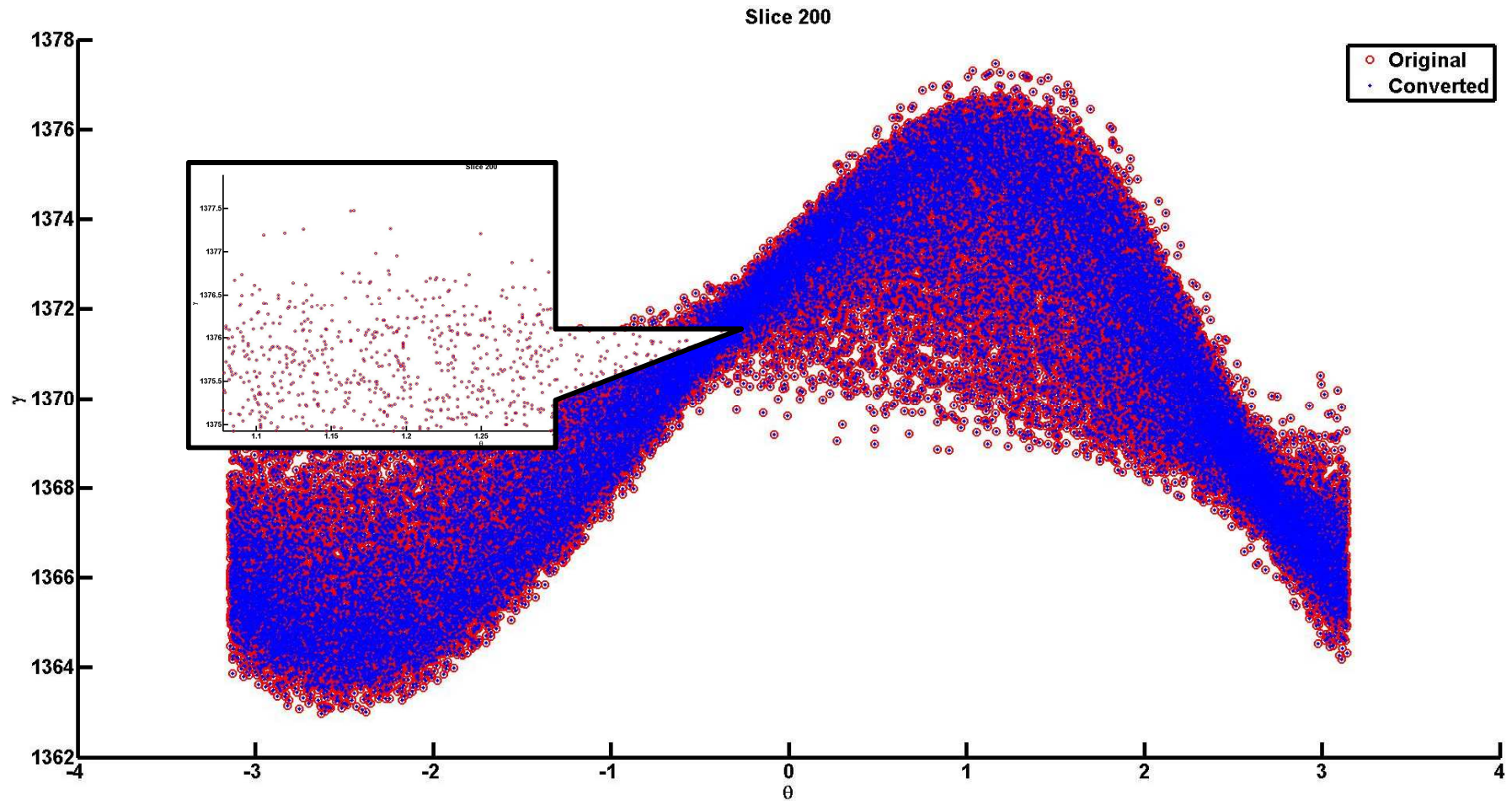
# Longitudinal phase space distribution (tail)



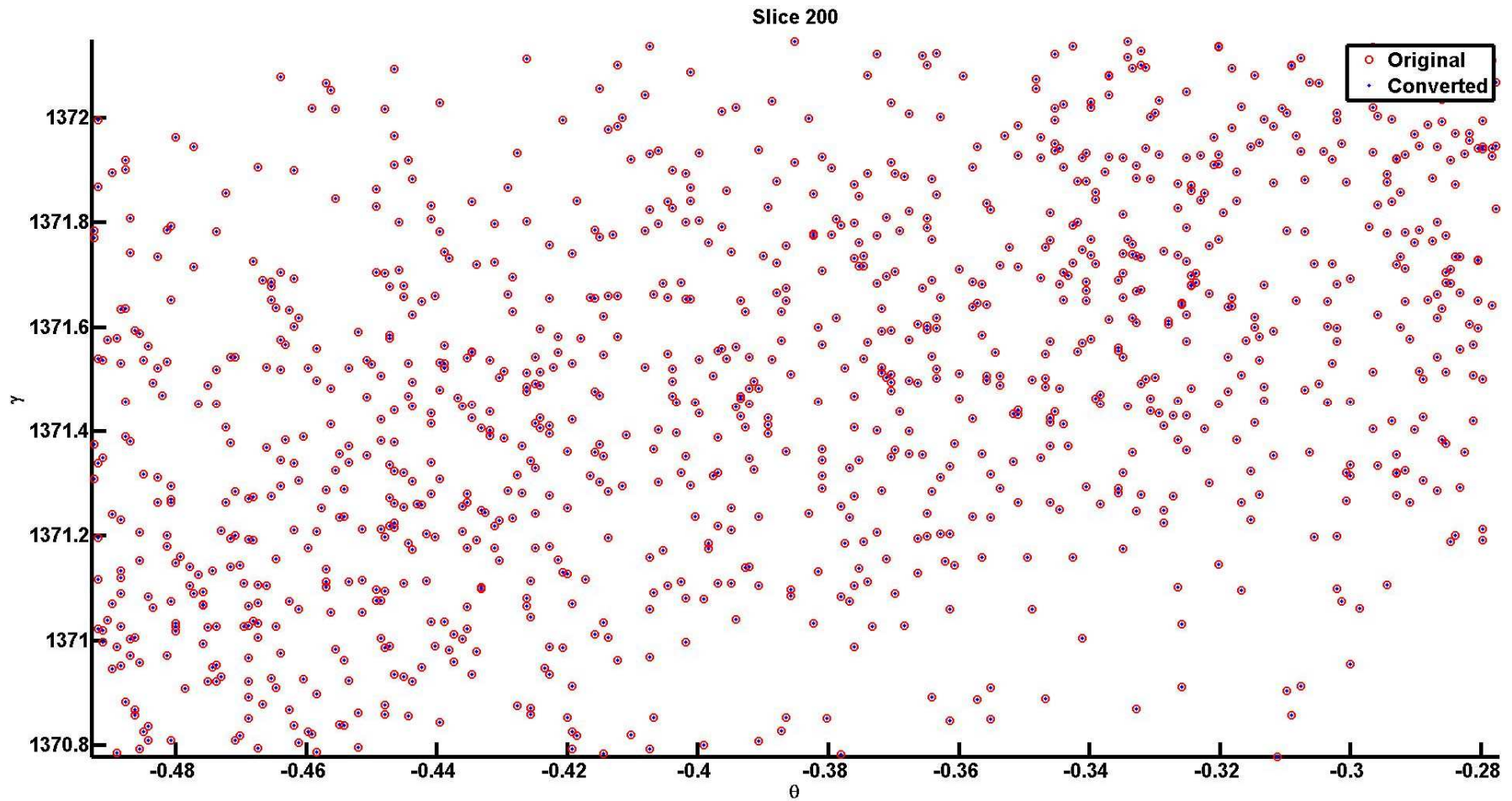
# Longitudinal phase space distribution (tail)



# Longitudinal phase space distribution (at modulation)



# Longitudinal phase space distribution (at modulation)



# Longitudinal phase space distribution (at modulation)

