Studies of LCLS FEL Divergence

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SLAC

Abstract

Simulations show various impacts on x-ray divergence. With the motivation to maximize intensity at the focus, these LCLS beam studies were designed to study parameter space and beam qualities impacting divergence, and therefore aperture related clipping and diffraction. With multiple simultaneous users, beam constraints increase, requiring an improving knowledge of the mechanism of impact of changing parameters. These studies have that goal in order to improve beam control.

$$\sigma_D = \sqrt{\lambda L_{1D}/4\pi} \qquad (1)$$

$$\sigma_{ph} \approx \sqrt{\sigma_D \sigma_{el}} \qquad (2)$$

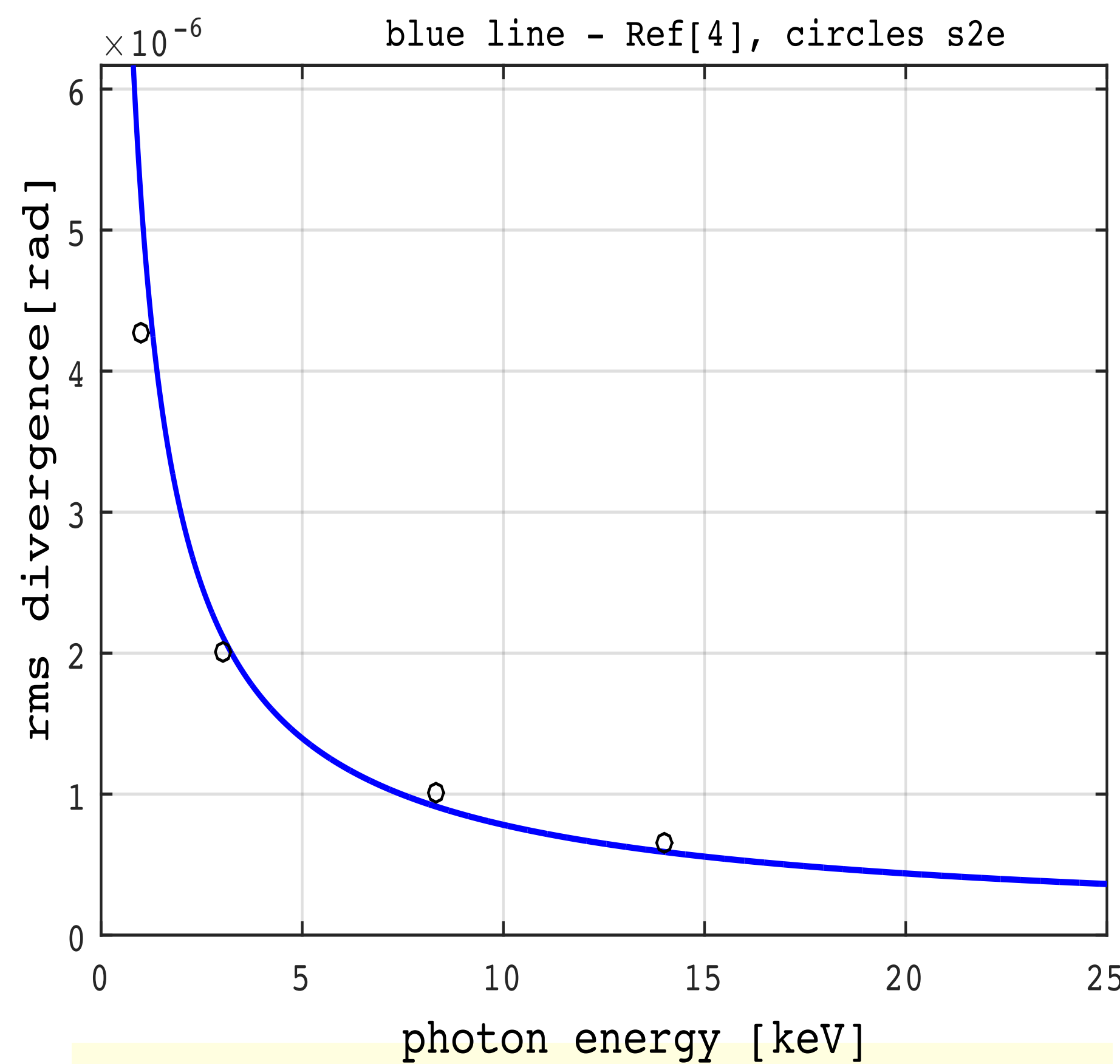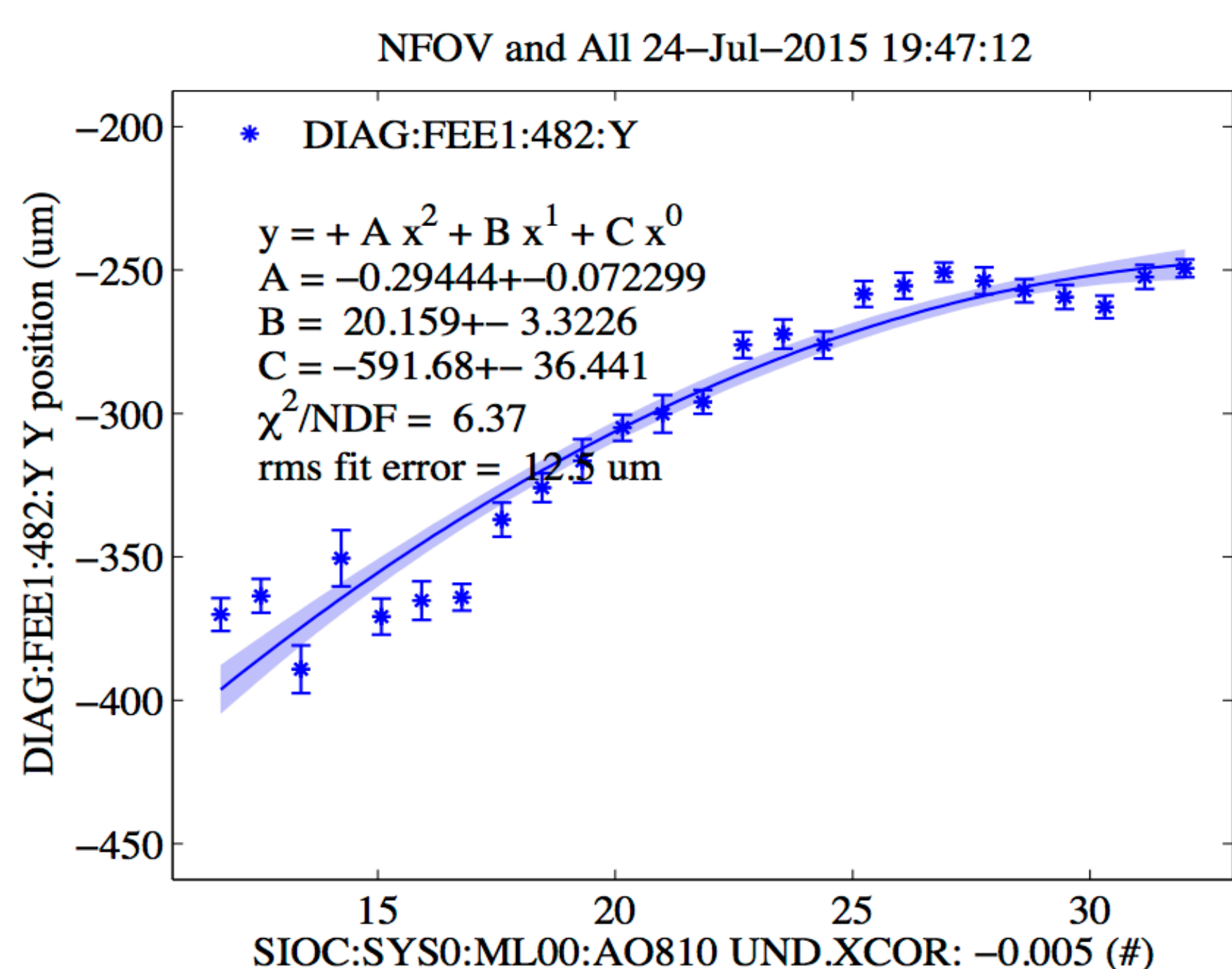$$\sigma_\vartheta = \lambda/4\pi\sigma_{ph} \qquad (3)$$

We applied Z. Huang and K. J. Kim approximation, derived in the linear regime, to calculate the photon source size (eq. 2) and the divergence (eq. 3). 1D gain length L1D, in the equation 1, was generated using the Ming Xie parameterization.
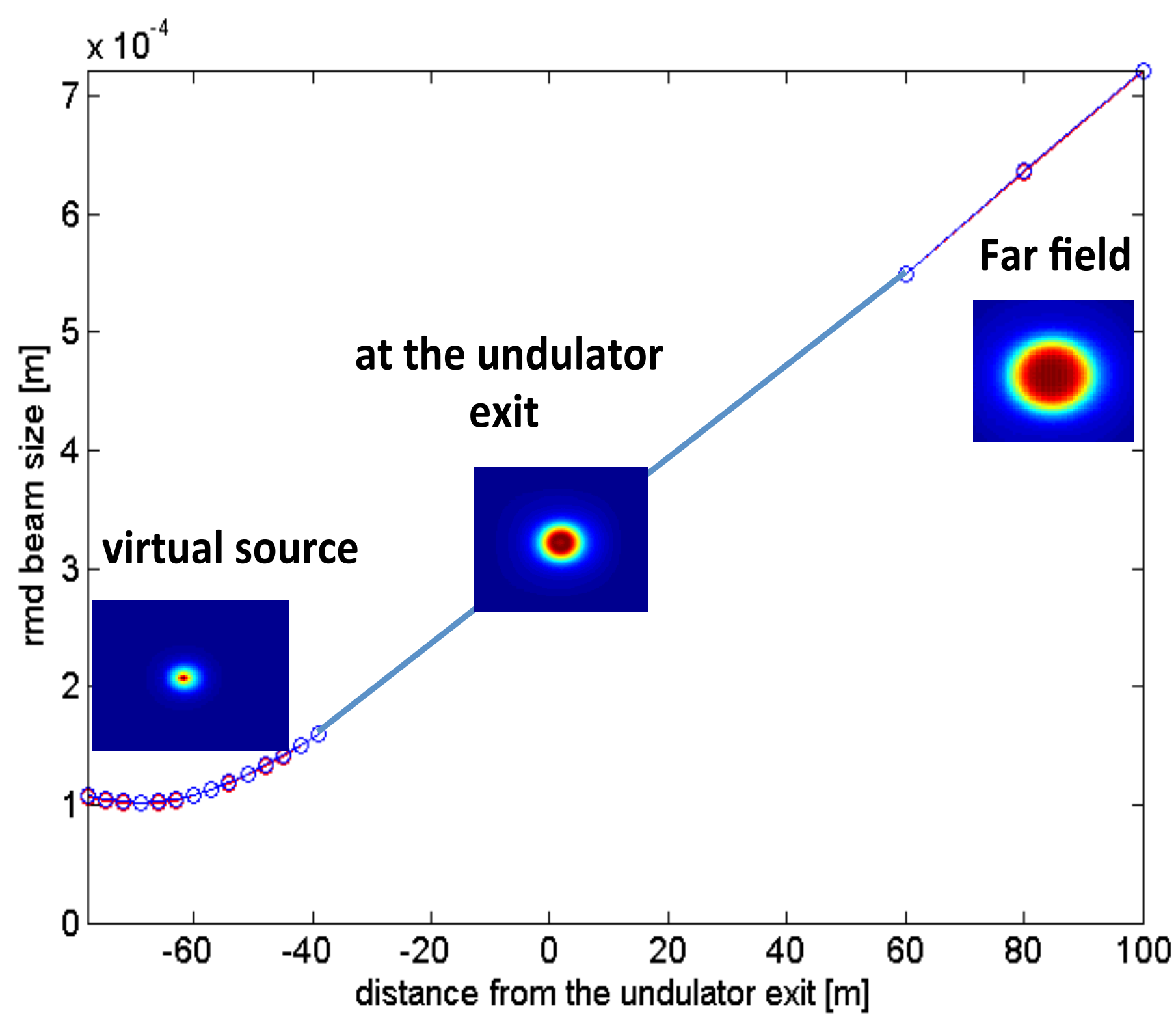

Simulation gives wave front at the exit of the undulator, then it is propagated backward and forward giving the waist (source) and the far field. .
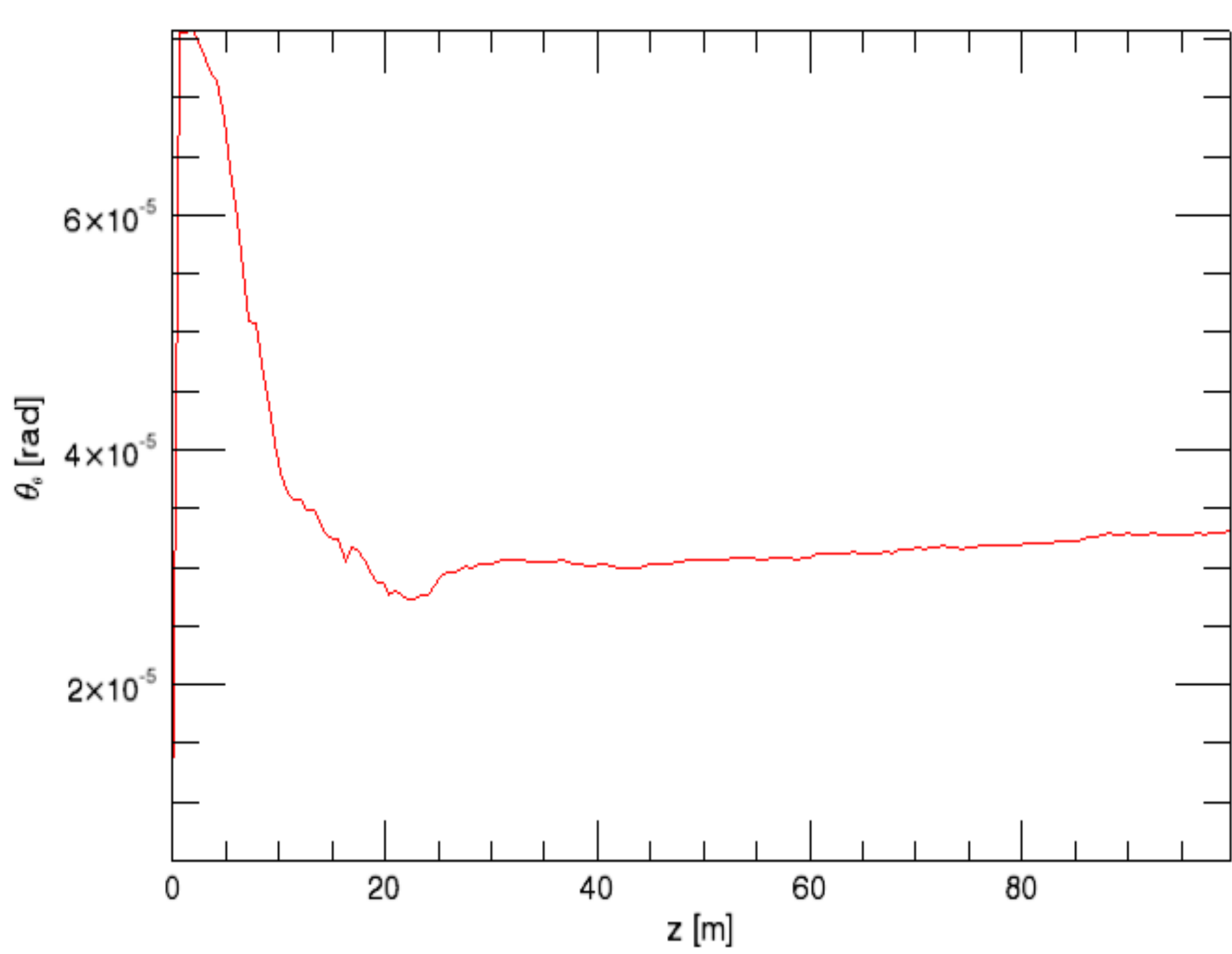

Simulation indicates that at 300 eV there is very small divergence change in the non-linear growth regime. This indicates the HK model should also predict divergence in the non-linear regime.

NFOV and All 24−Jul−2015 19:47:12

$y = + A\, x^2 + B\, x^1 + C\, x^0$
A = −0.29444+−0.072299
B = 20.159+− 3.3226
C = −591.68+− 36.441
χ^2/NDF = 6.37
rms fit error = 12.5 um

* DIAG:FEE1:482:Y

blue line − Ref[4], circles s2e

HK Divergence Model (blue line) compared to start-to-end simulations and forward propagation (circles).

blue line − Ref[4], circles s2e
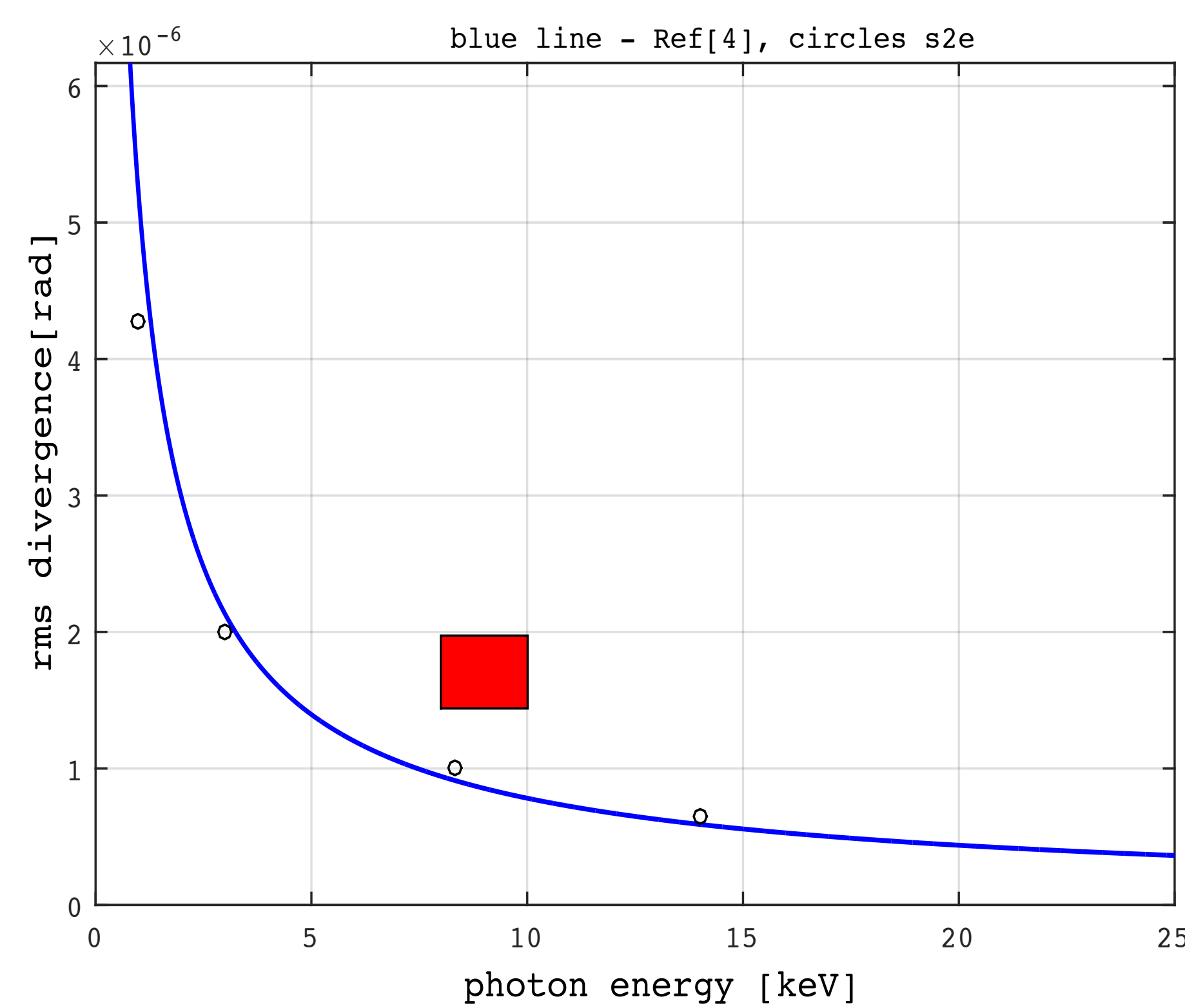
Recent hard x-ray divergence measurements over the past year are represented by the red rectangle.

Correlation Plot 24−Jul−2015 20:02:40

* DIAG:FEE1:482:YRMS
BMAG=1.80
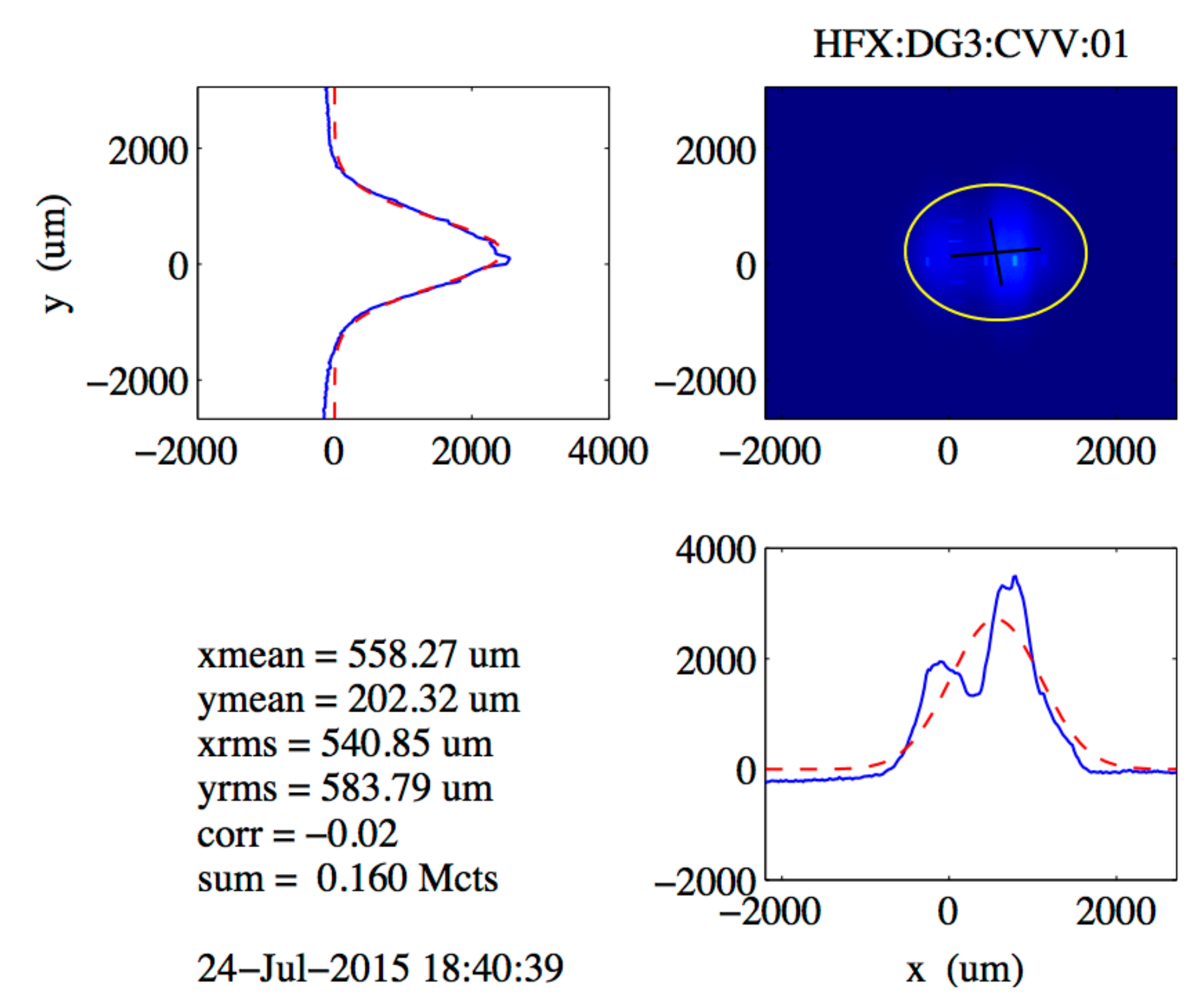BMAG=1.72
BMAG=1.18
BMAG=1.08
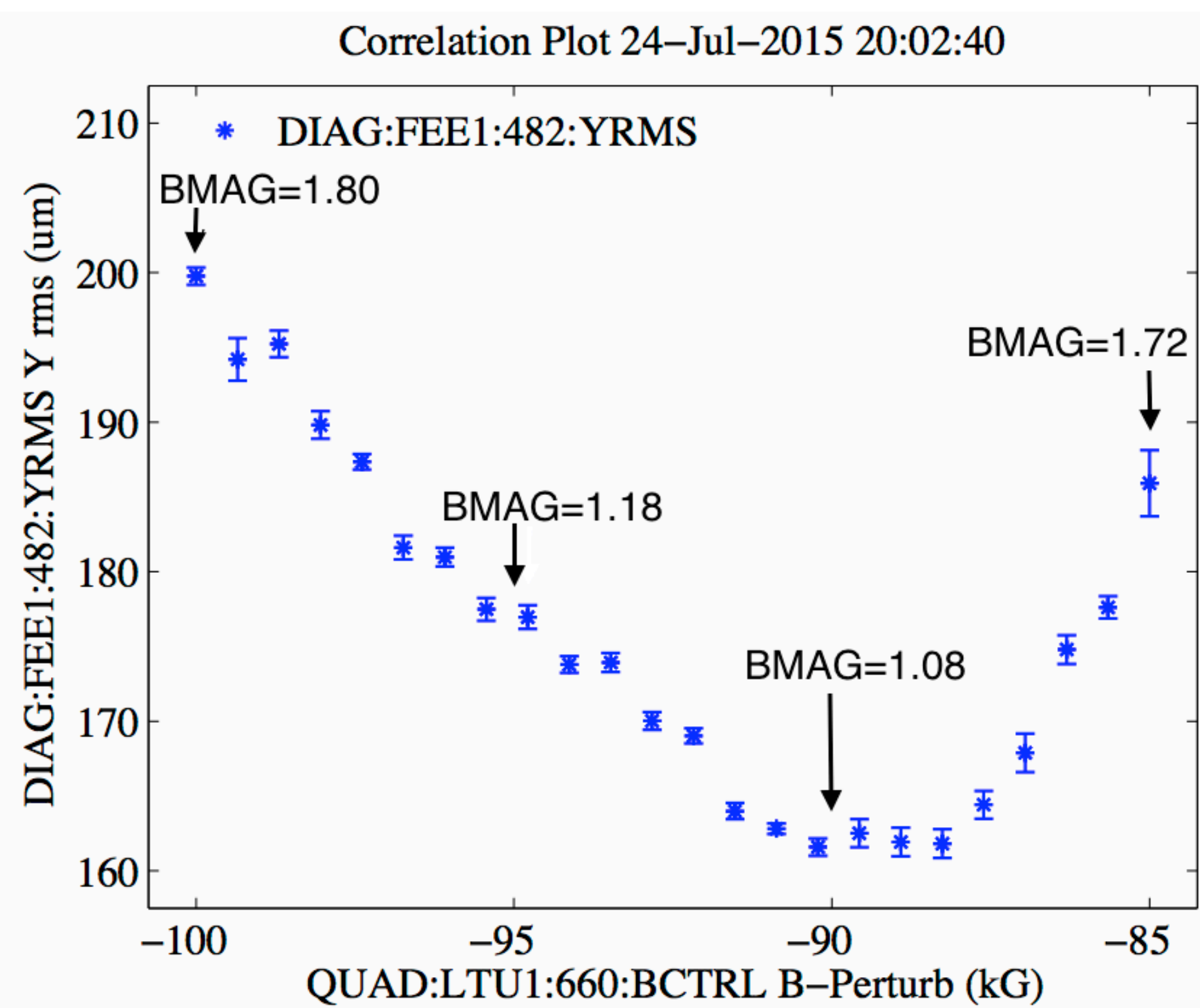
Beam divergence changes with match change in the undulator.

Left: Curvature of the electron orbit in the undulator was measured in the matched, 4 meter gain-length, 8.2 keV condition Electron beam is kicked at different points to suppress lasing beyond each point. X-ray position is measured at the imager 87 meters after the undulator.
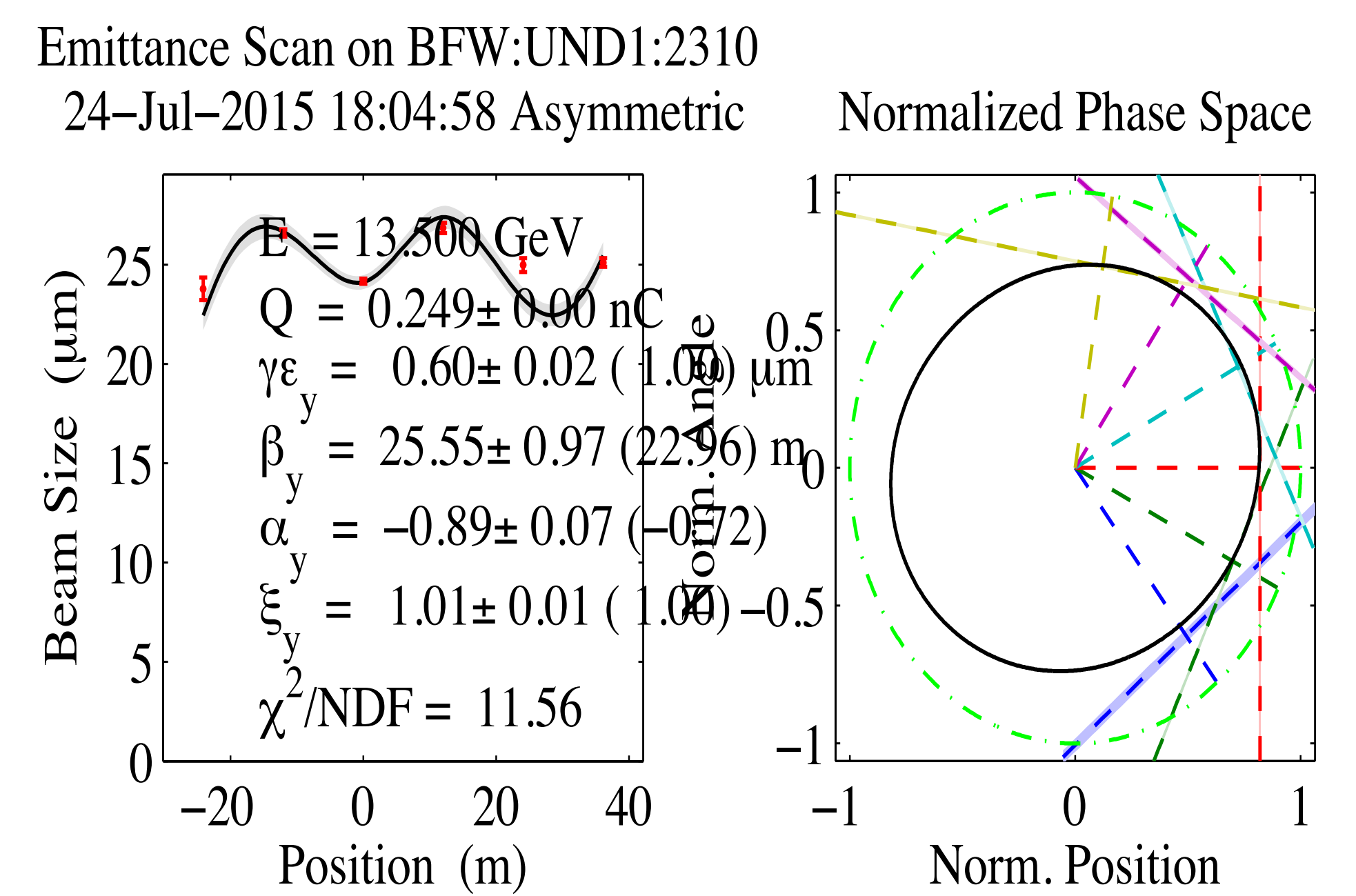

flux

Intensity in the focus
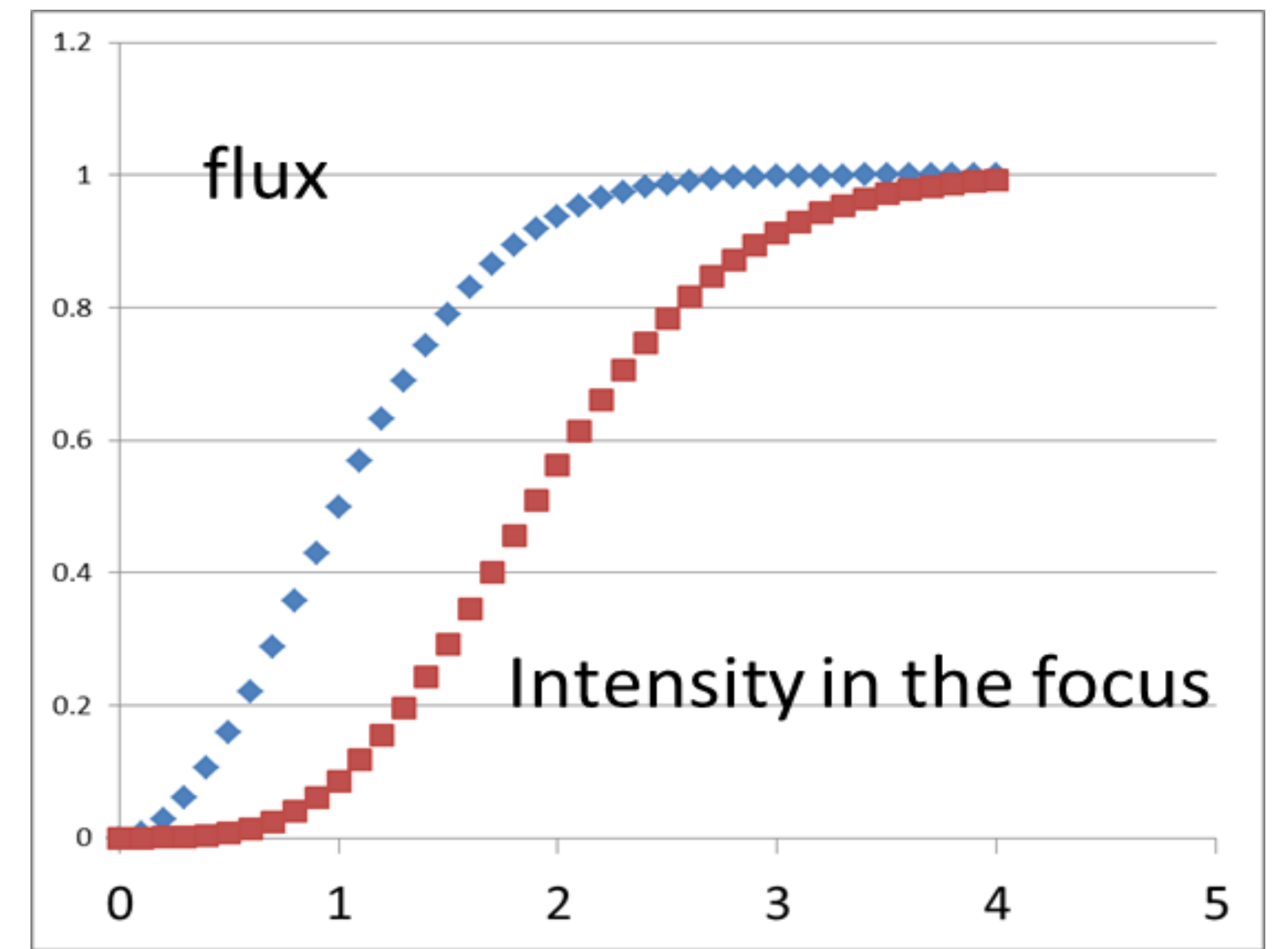
Acceptance (FWHM)

Vertical axis is relative intensity, horizontal axis acceptance of mirror systems cutting in both planes. Blue line is the intensity cut off by mirrors. Red line is the intensity at a downstream focus. Diffraction effects are taken into account.

HFX:DG3:CVV:01

xmean = 558.27 um
ymean = 202.32 um
xrms = 540.85 um
yrms = 583.79 um
corr = −0.02
sum = 0.160 Mcts

24−Jul−2015 18:40:39

Beam size measured at the Far Hall 335 meters from the end of the undulator. Energy is 8.2 keV. Note the horizontal distortion is due to mirror figure error and diffraction effects.

Emittance Scan on BFW:UND1:2310
24−Jul−2015 18:04:58 Asymmetric   Normalized Phase Space

E = 13.500 GeV
Q = 0.249± 0.00 nC
$\gamma\varepsilon_y$ = 0.60± 0.02 (1.00) um
β_y = 25.55± 0.97 (22.96) m
α_y = −0.89± 0.07 (−0.72)
ξ_y = 1.01± 0.01 (1.00)
χ^2/NDF = 11.56

Vertical beta measurement in the undulator using 6 "beam finder wires". Beta match parameter is 1.01 +/- 0.01 with perfect being 1.0. Electron beam size at the source point is included in this measurement.

GL=4.16+−0.26m,13.50GeV,3.6kA,LH= 4.5uJ,GDet,2015−07−24−1935
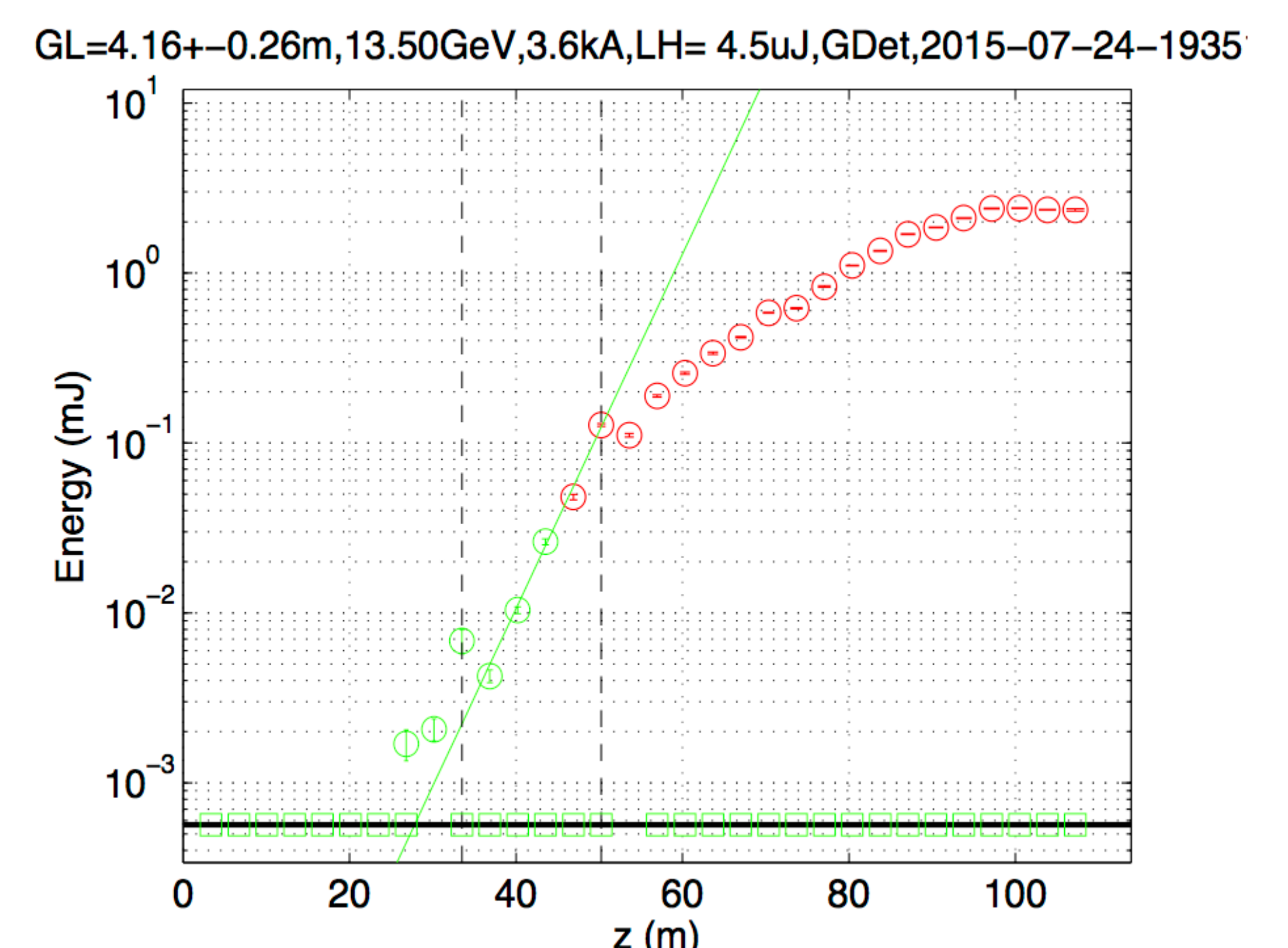
The gain length is measured by a system of gas detector PMTs (photomultiplier tubes) at different high voltage settings to achieve a large dynamic range.