Chromaticity Properties of the Injector Beam Line and Operation at the Laser Heater for Different Working Points of the Three Stage Bunch Compressor System

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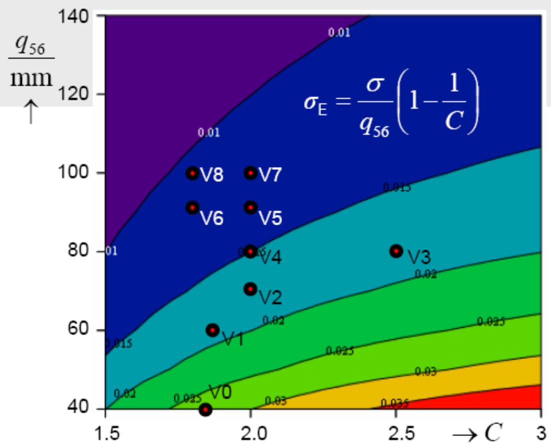
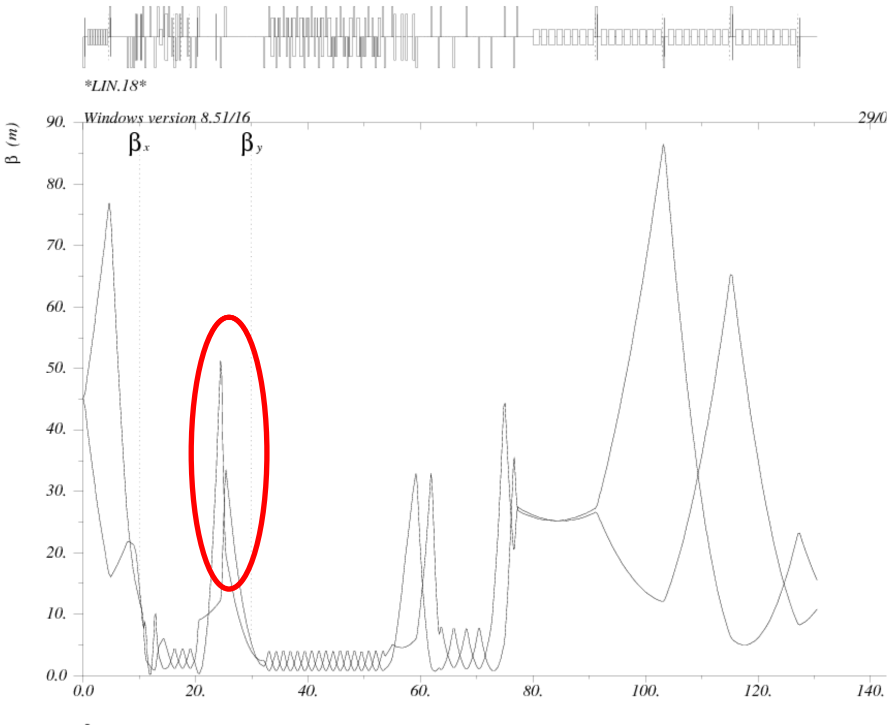
Nine working points have been proposed by M. Dohlus for the operation of the three bunch compressor scheme. Chromaticity properties and operation of the laser heater for these working points will be discussed here



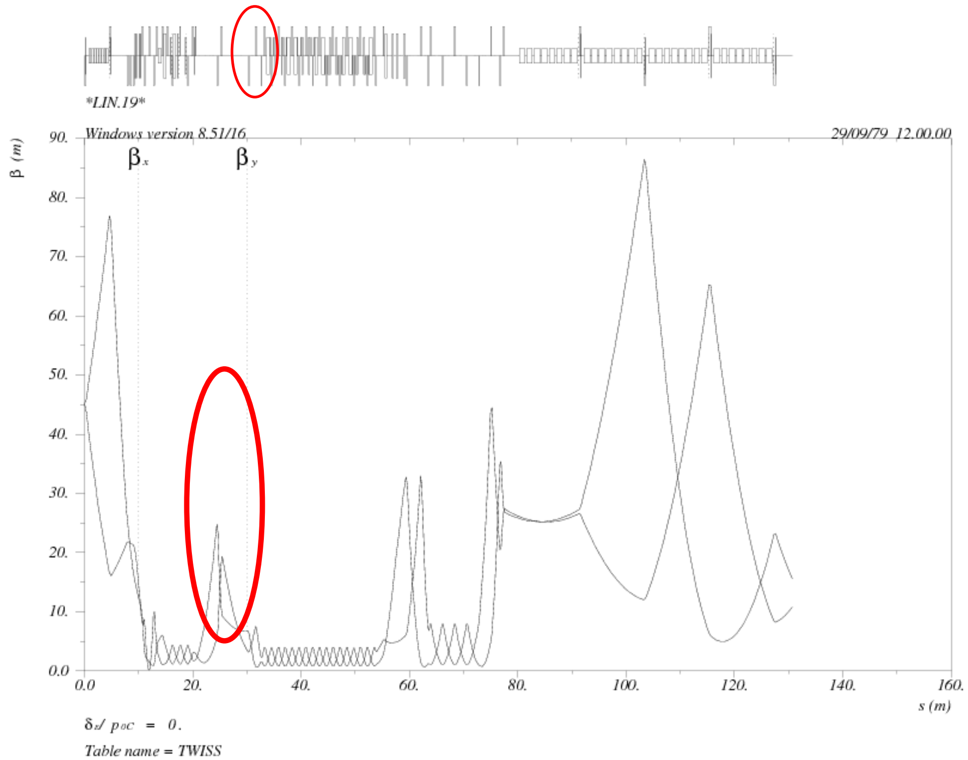
	q56 /mm	C	σE *100	tol. *1000	V3.9 MV	end-chirp MV@1σ	noise A	
V0	40	1.85	2.7	0.732	30.2	7.4	68	
V1	60	1.87	1.9	0.709	28.9	7.4	112	
V2	70	2.00	1.7	0.664	26.6	7.7	163	
V3	80	2.5	1.8	0.539	26.9	6.2	123	
V4	80	2.0	1.5	0.453	36.0	7.2	137	
V5	90	2.0	1.3	0.439	29.3	7.7	217	cto
V6	90	1.8	1.2	0.302	50.6	8.6	276	cto
V7	100	2.0	1.2	0.394	32.2	7.8	242	cto
V8	100	1.8	1.1	0.273	50.6	8.6	307	**cto**

close to overcompression = cto

old



new

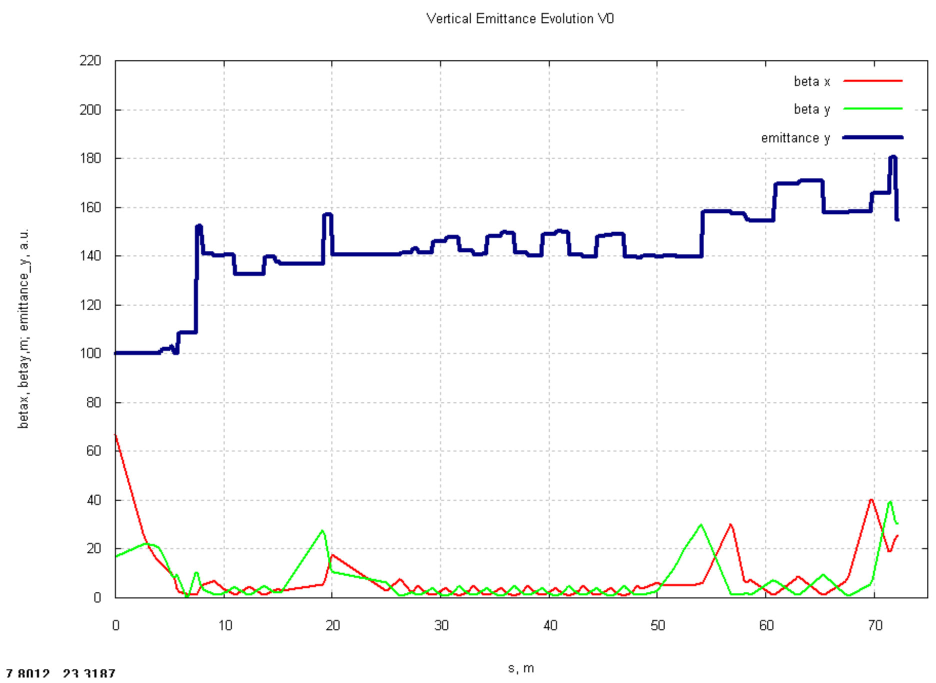


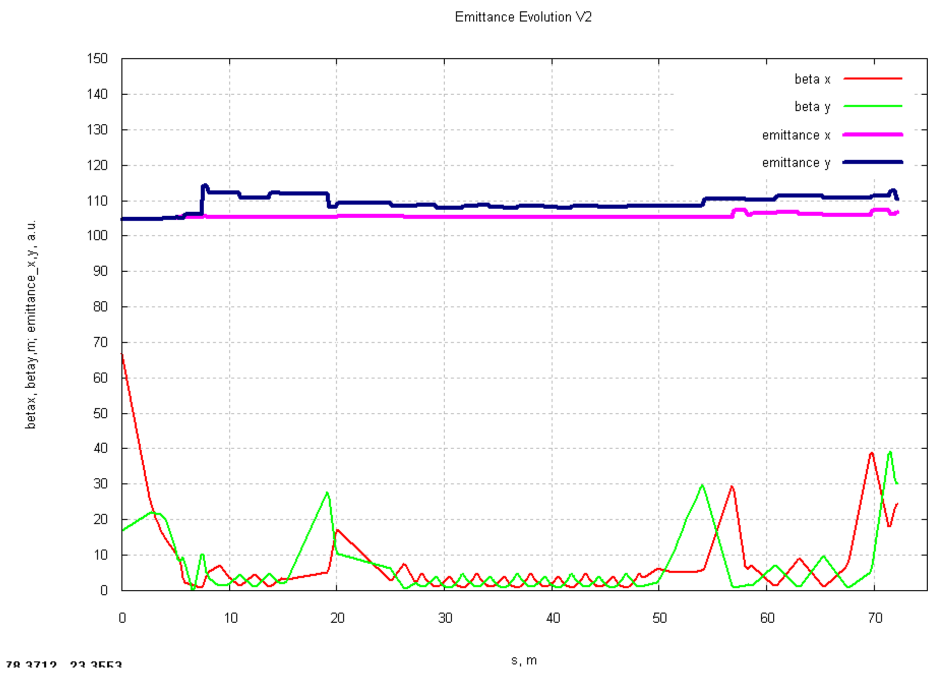
- 2 more quadrupoles have been added at the end of shielding
- 1 quadrupole could be spared after the diagnostics

→Whole system requires now 49 instead of 48 quadrupoles

→ vertical beta function in the shielding could be reduced by factor of 2 leading to proper chromatics conditions.

Emittance Evolution due to Chromatics





Main sources for emittance blow up:
- Matching to the diagnostics
- Shielding. The Impact of shielding was dominating in the previous optics version

It could be reasonably mitigated by introduction of two quadrupoles at the end of shielding

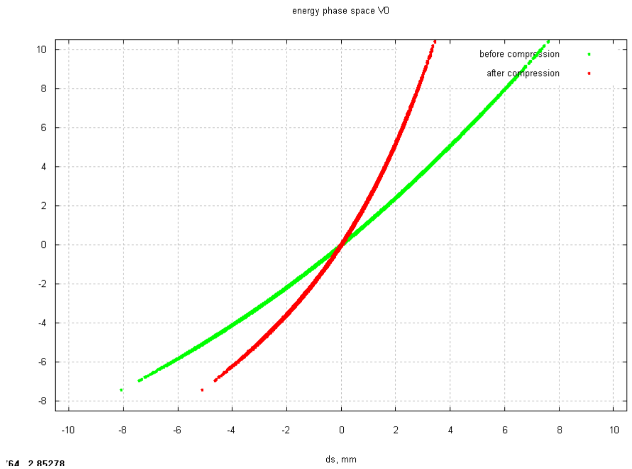
Chromaticity Properties for Different Working Points

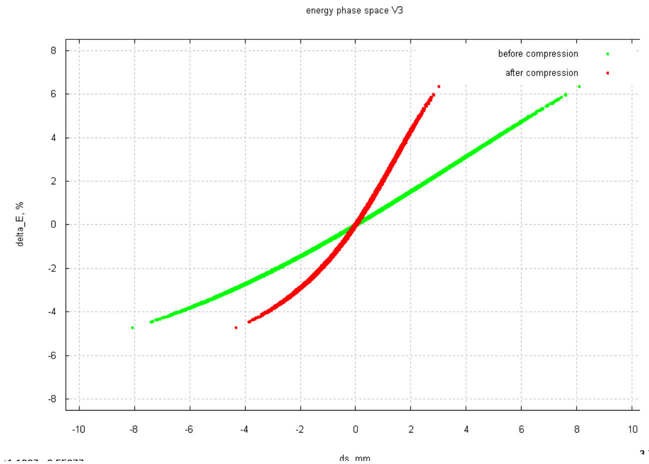
	V0	V1	V2	V3	V4	V5	V6	V7	V8
σ_δ%	2.76 (2.7)	1.84 (1.9)	1.70 (1.7)	1.76 (1.8)	1.44 (1.5)	1.30 (1.3)	1.10 (1.2)	1.16 (1.2)	0.99 (1.1)
C	1.85 (1.85)	1.84 (1.87)	1.97 (2.00)	2.42 (2.5)	1.92 (2.0)	1.93 (2.0)	1.67 (1.8)	1.91 (2.0)	1.67 (1.8)
$\Delta\varepsilon_x$, %	7.84	4.02	3.67	3.72	3.13	2.72	2.27	2.43	2.01
$\Delta\varepsilon_y$, %	54.24	19.5	15.87	17.51	9.80	7.38	4.52	4.97	3.38

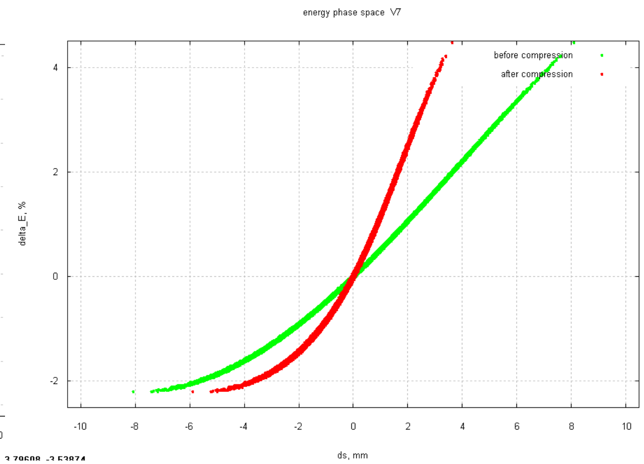
Calculated from water bug model for the longitudinal and energy distribution with σ_s=2.394mm, $\sigma_{\delta(uncorrelated)}$=30keV
(…) - *„3 BC Working Points“* (M. Dohlus)

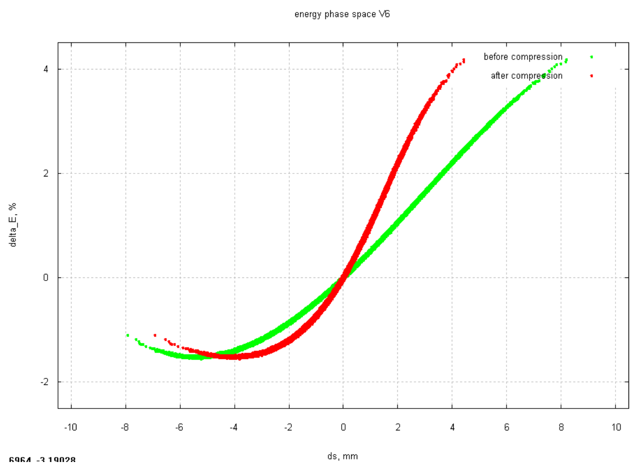
Longitudinal Space Phase for some Working Points

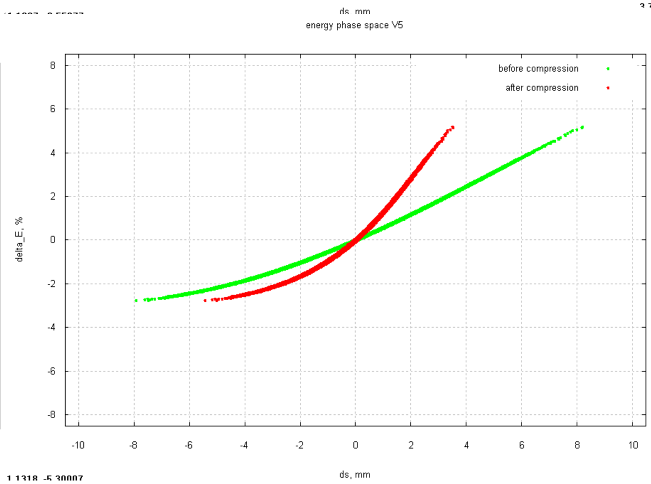
The distributions are not always completely linear → discrepancies to $\sigma_E = \frac{\sigma}{q_{56}}\left(1 - \frac{1}{C}\right)$

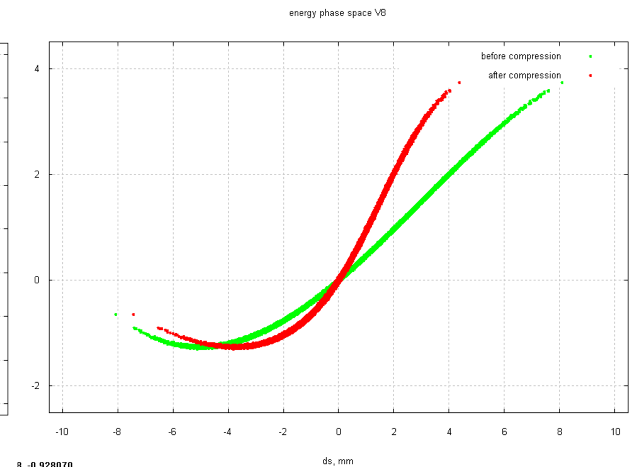












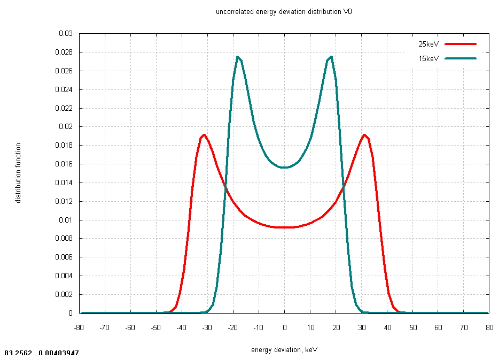
Formulas

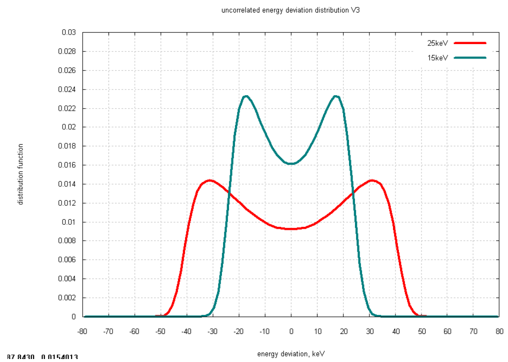
$$f_0(z_0, \Delta\gamma_0, r) = \frac{I_0}{ec\sqrt{2\pi}\sigma_{\gamma_0}} \exp\left[-\frac{(\Delta\gamma_0 - \Delta\gamma_L(r)\sin k_L z_0)^2}{2\sigma_{\gamma_0}^2}\right] \times \frac{1}{2\pi\sigma_x^2} \exp\left(-\frac{r^2}{2\sigma_x^2}\right)$$

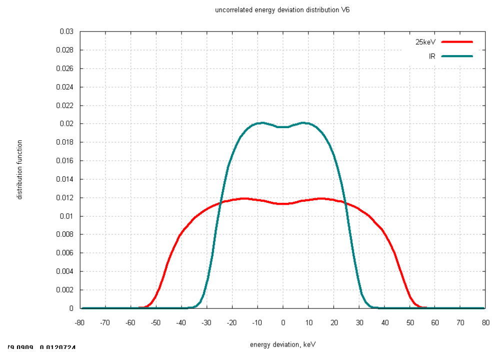
$$\Delta\gamma_L(r) = \sqrt{\frac{P_L}{P_0}} \frac{K L_u}{\gamma_0 \sigma_r} \left[J_0\left(\frac{K^2}{4+2K^2}\right) - J_1\left(\frac{K^2}{4+2K^2}\right)\right] \exp\left(-\frac{r^2}{4\sigma_r^2}\right)$$

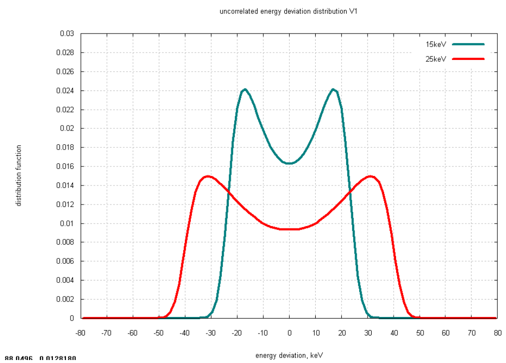
$$\begin{aligned} V(\Delta\gamma_0) =& 2\pi \int r dr \int dz_0 f_0(z_0, \Delta\gamma_0, r) \\ =& \frac{1}{\pi\sigma_x^2\sqrt{2\pi}\sigma_{\gamma_0}} \int r dr \exp\left(-\frac{r^2}{2\sigma_x^2}\right) \int \frac{d\xi}{\sqrt{\Delta\gamma_L(r)^2 - (\Delta\gamma_0 - \xi)^2}} \exp\left(-\frac{\xi^2}{2\sigma_{\gamma_0}^2}\right) \end{aligned}$$

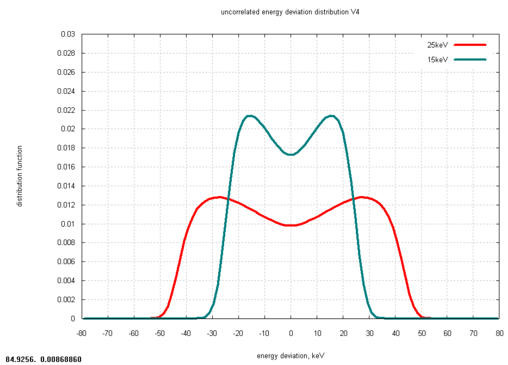
Energy Distributions after Interaction with Laser Heater for V0 –V8

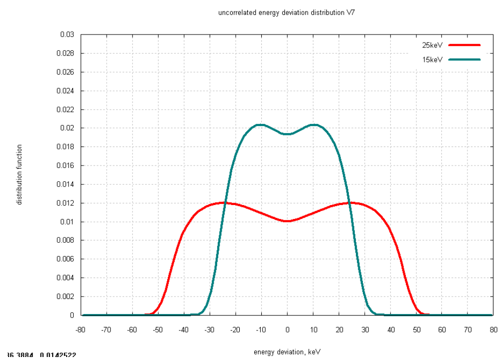


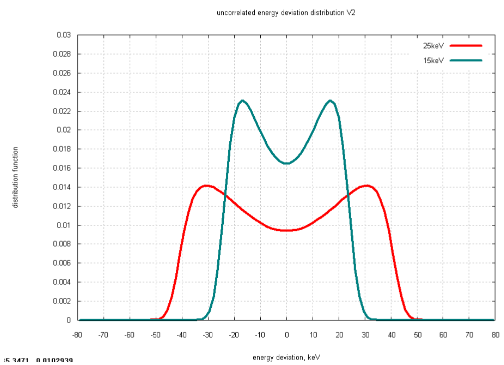


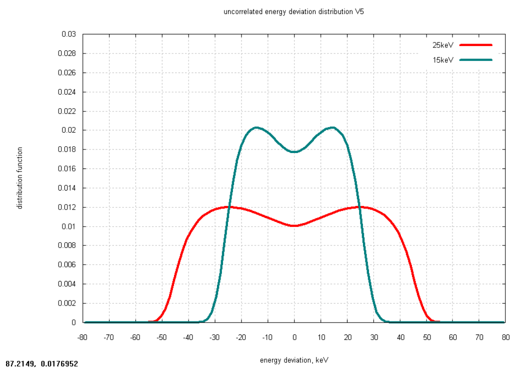


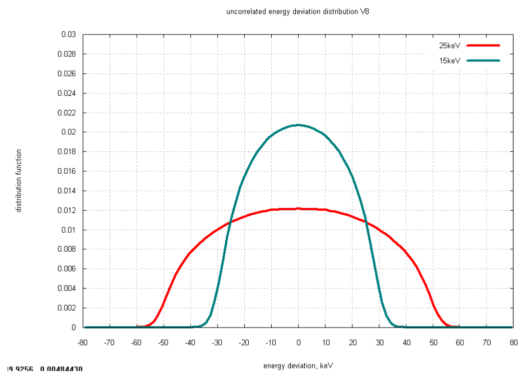










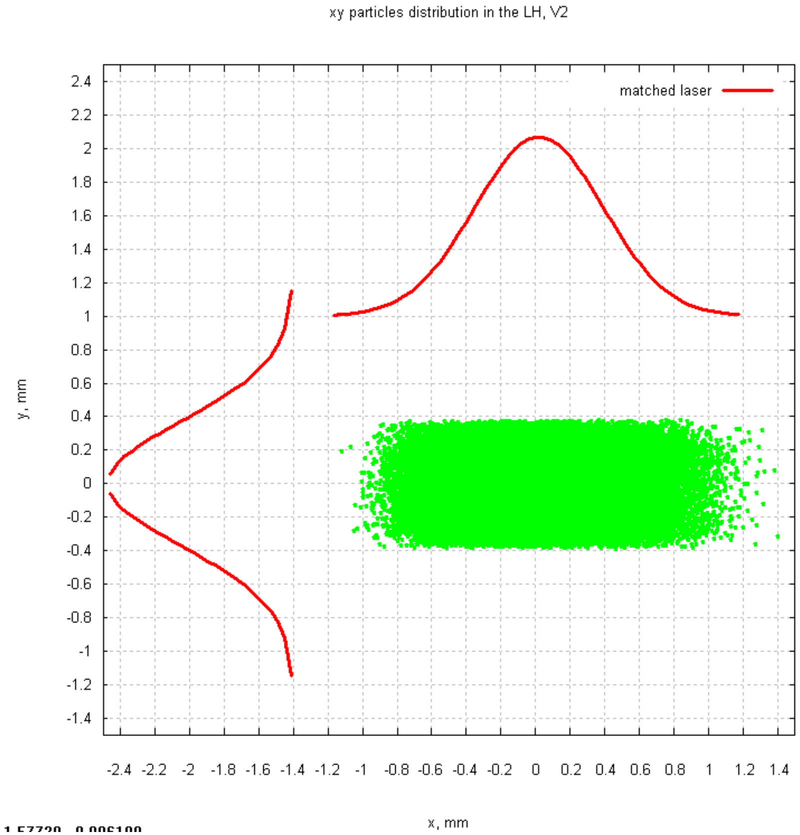


Some Parameters Concerning Laser Heater Operation for Different Working Points

Working point	σ_x, µm	$\sqrt{\sigma_x \sigma_y}, \mu m$	Laser peak power, MW, 25keV	Laser peak power, MW, 15keV	$\frac{\sigma_r}{\sigma_y}$	$\frac{\sigma_r}{\sqrt{\sigma_x \sigma_y}}$	$\frac{f_{\max}}{f(0)}$
V0	569	317	2.10	1.29	3.21	1.79	1.75
V1	399	265	1.20	0.74	2.25	1.51	1.48
V2	372	257	1.10	0.68	2.10	1.45	1.40
V3	385	261	1.18	0.73	2.18	1.48	1.45
V4	327	241	0.95	0.58	1.85	1.36	1.26
V5	303	232	0.90	0.55	1.71	1.31	1.16
V6	270	219	0.77	0.47	1.53	1.23	1.02
V7	279	222	0.78	0.48	1.58	1.26	1.06
V8	251	211	0.73	0.45	1.42	1.19	1.00

σ_y=177µm

Ideal Case: Laser Matched at Least in One Dimension



Matching shown for the Working Point 2

Formulas (ideal case)

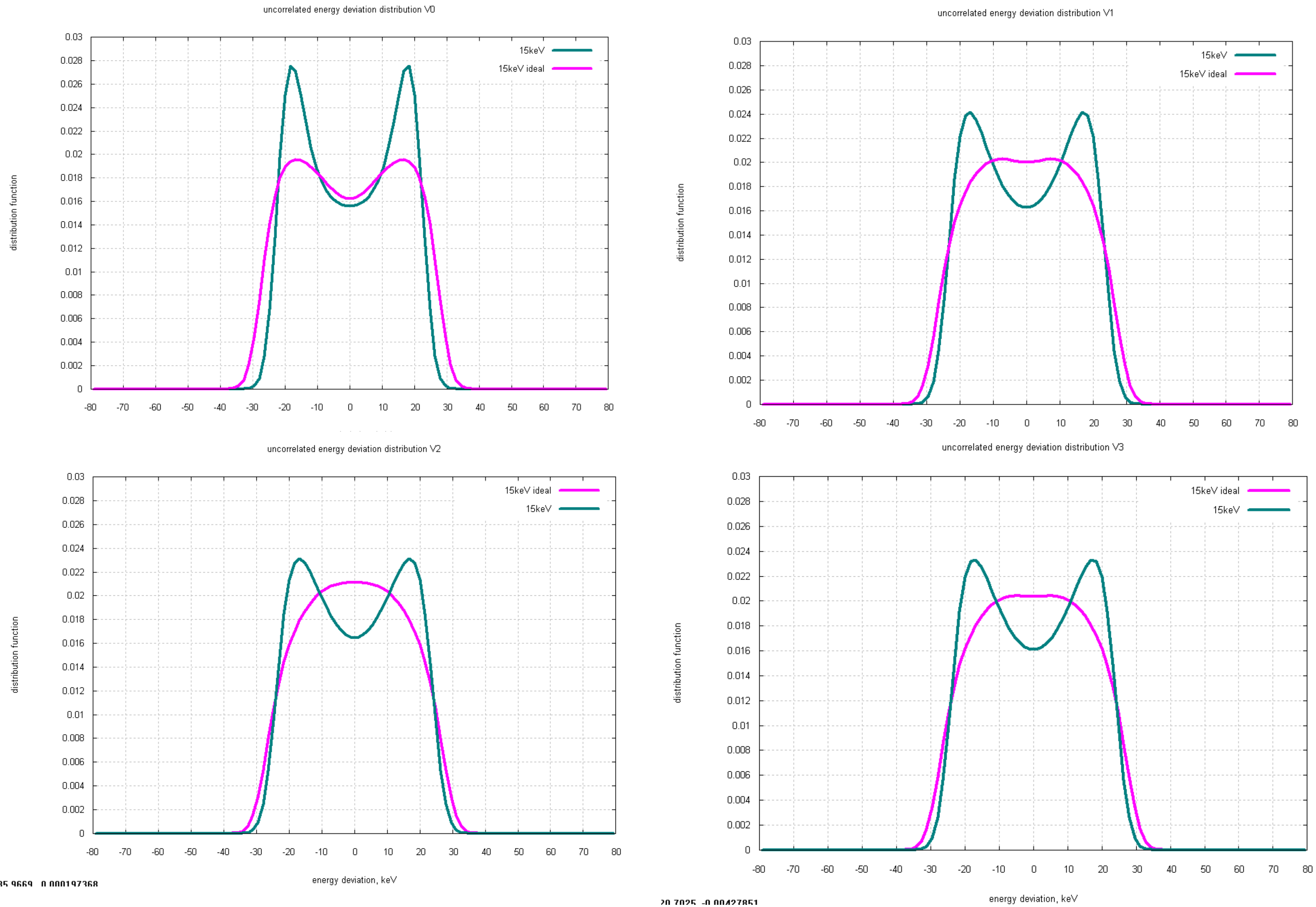
$$f_0(z_0, \Delta\gamma_0, r) = \frac{I_0}{ec\sqrt{2\pi}\sigma_{\gamma_0}} \exp\left[-\frac{(\Delta\gamma_0 - \Delta\gamma_L(r)\sin k_L z_0)^2}{2\sigma_{\gamma_0}^2}\right] \times \frac{1}{2\pi\sigma_x^2}\exp\left(-\frac{r^2}{2\sigma_x^2}\right)$$

replace σ_x by $\sqrt{\sigma_x \sigma_y}$

$$\Delta\gamma_L(r) = \sqrt{\frac{P_L}{P_0}}\frac{KL_u}{\gamma_0\sigma_r}\left[J_0\left(\frac{K^2}{4+2K^2}\right) - J_1\left(\frac{K^2}{4+2K^2}\right)\right]\exp\left(-\frac{r^2}{4\sigma_r^2}\right)$$

$$\begin{aligned} V(\Delta\gamma_0) &= 2\pi\int r dr \int dz_0 f_0(z_0, \Delta\gamma_0, r) \\ &= \frac{1}{\pi\sigma_x^2\sqrt{2\pi}\sigma_{\gamma_0}}\int r dr \exp\left(-\frac{r^2}{2\sigma_x^2}\right)\int \frac{d\xi}{\sqrt{\Delta\gamma_L(r)^2 - (\Delta\gamma_0 - \xi)^2}}\exp\left(-\frac{\xi^2}{2\sigma_{\gamma_0}^2}\right) \end{aligned}$$

Energy Distributions after Interaction with Laser Heater for V0 –V3 (ideal case)



Conclusions, margins and outlook for improvements

- Working points V5-V8 seem to be ok from the point of view chromaticity and laser heater operation. Emittance blow up is well below 10% there and the energy distribution after interaction with the laser heater has still a smooth form.

-The transverse beam form at the laser heater could be changed by change of the beam optics → it could be possible to make beta_x twice as large as beta_y and thus forse the beam to assume more round shape.

- Alternative position for the laser heater (after the dogleg) could be considered