

Longitudinal bunch profile measurements with TDS

1nC bunch:

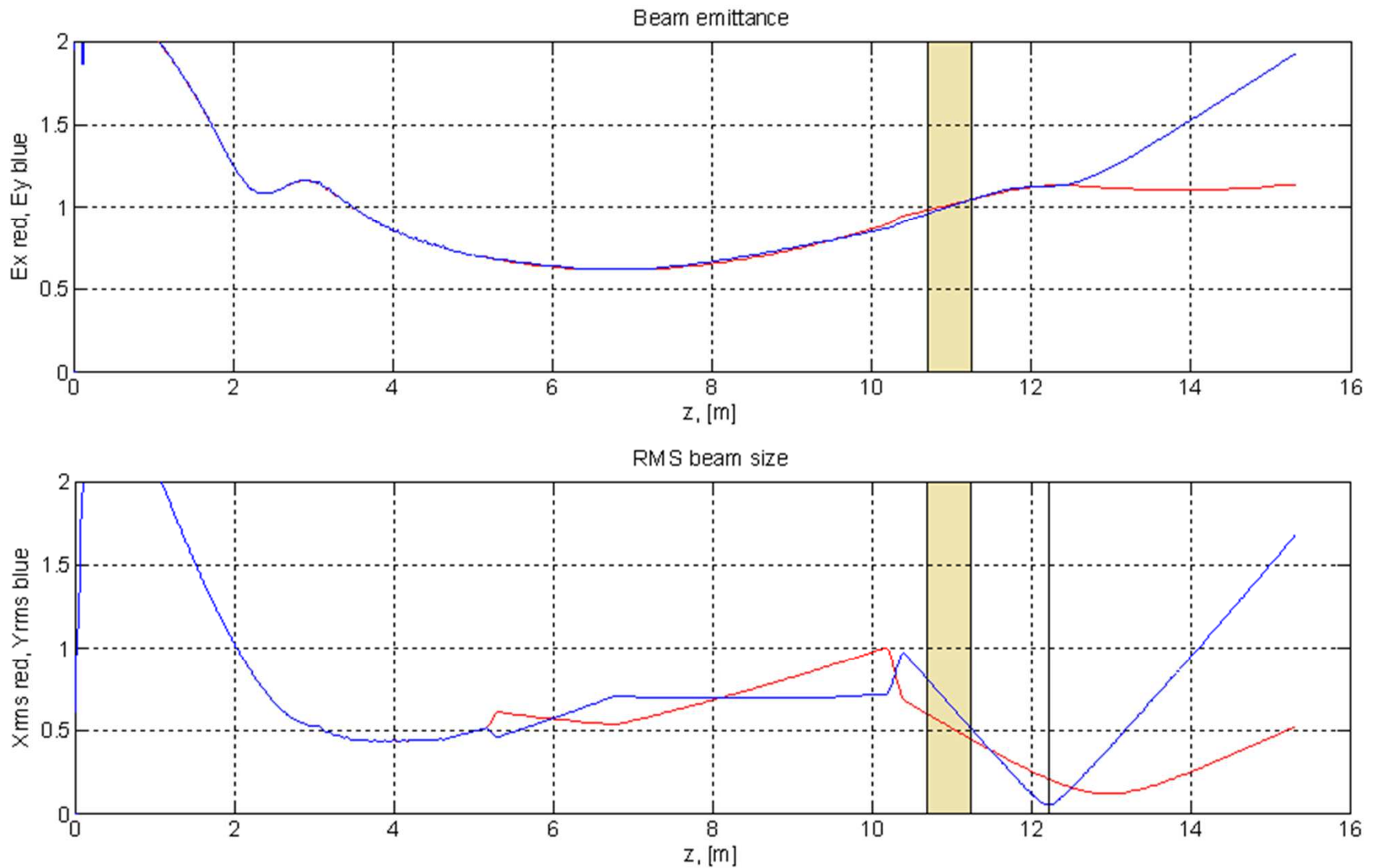
- Beam optics
- TDS calibration
- Measurement results

100pC bunch, special profile:

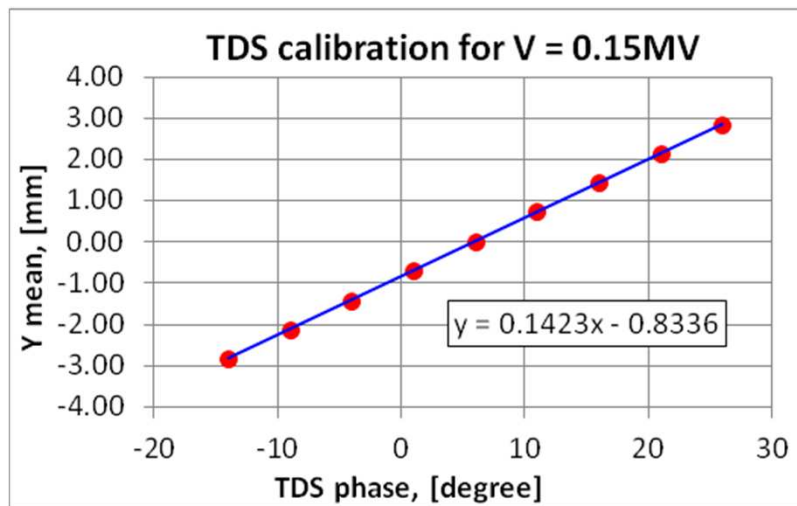
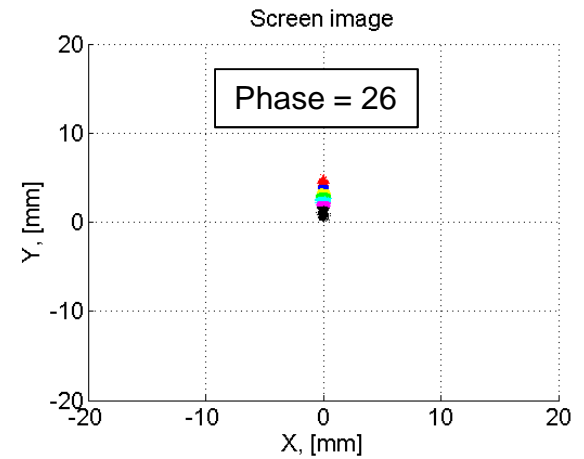
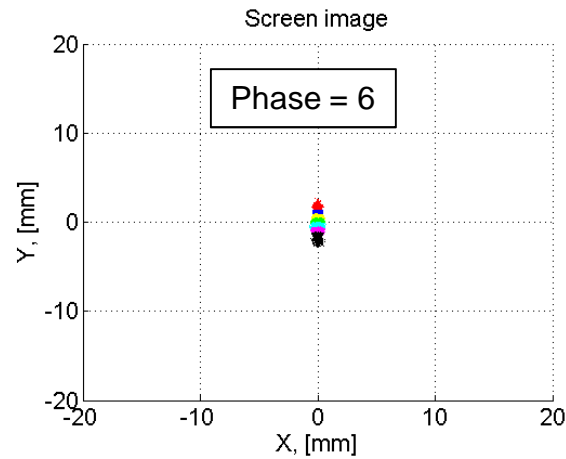
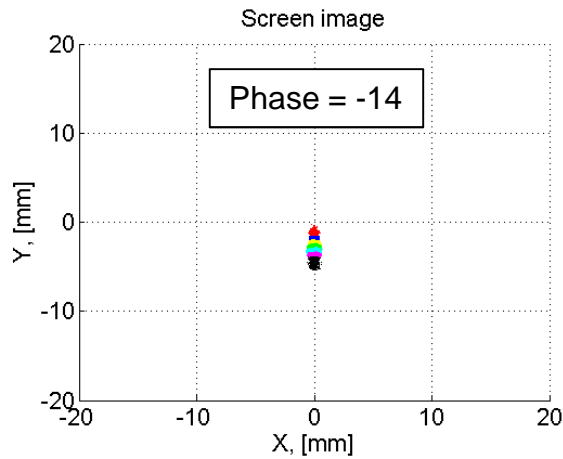
- Beam optics
- TDS calibration
- Measurement results

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PITZ physics seminar
Zeuthen, December 21, 2011

Beam optics, ASTRA simulation, 1nC



TDS calibration at PST.Scr1, 1nC bunch charge



$$S = \frac{K_1 \cdot 360 \cdot f}{\beta \cdot c} = 0.51$$

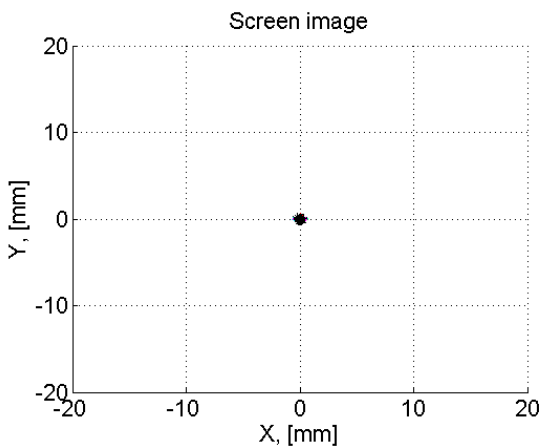
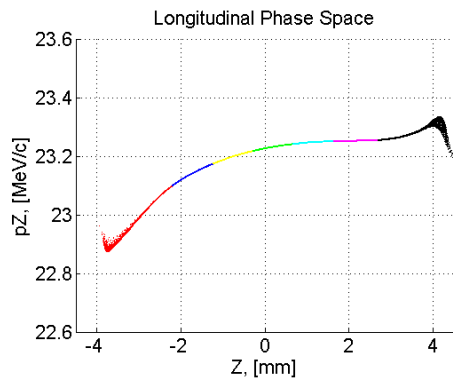
$$S(0.6MV) = 2.046$$

$$S(1.2MV) = 4.092$$



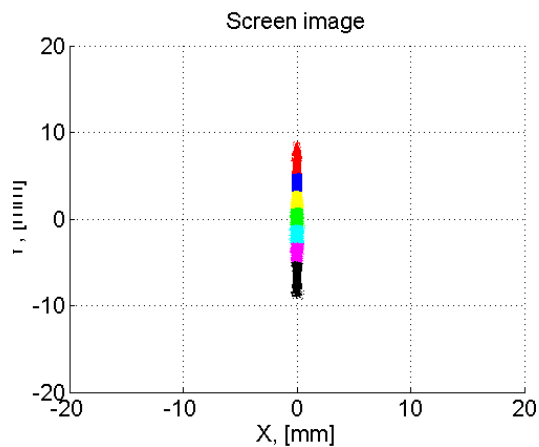
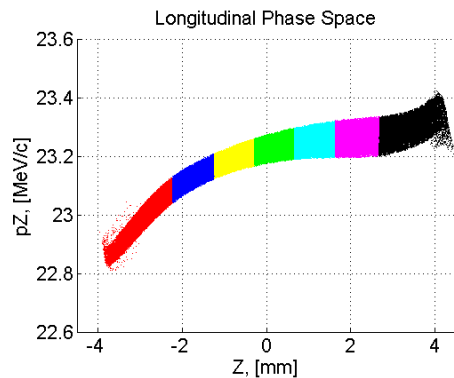
First screen after TDS at 12.238m (PST.Scr1), 1nC

$V_0=0.0\text{MV}$



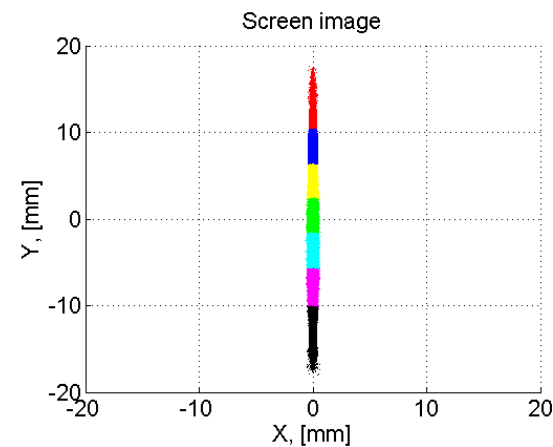
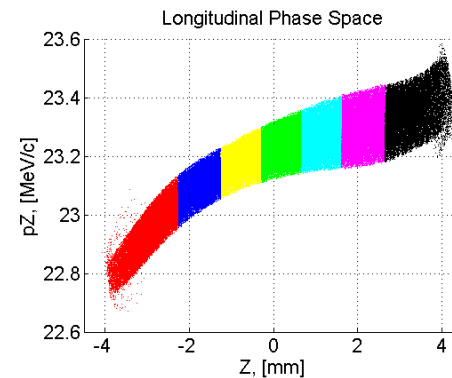
$X_{rms} = 0.21\text{mm}$
 $Y_{rms} = 0.05\text{mm}$

$V_0=0.6\text{MV}$



$S = 2.0$
 $\sigma_z = 25\mu\text{m} = 80\text{fs}$

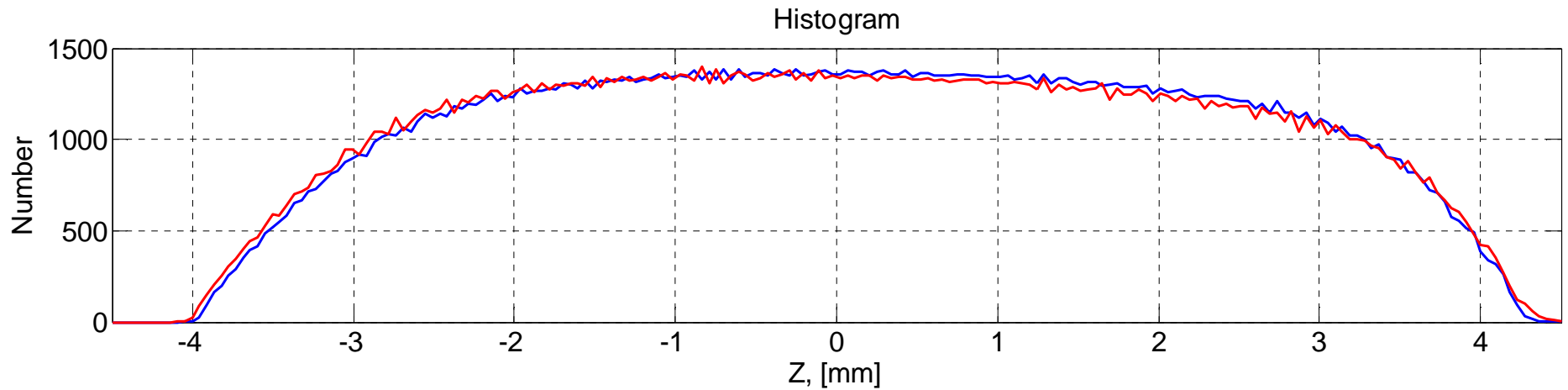
$V_0=1.2\text{MV}$



$S = 4.0$
 $\sigma_z = 12\mu\text{m} = 40\text{fs}$



Bunch longitudinal profile, 1nC

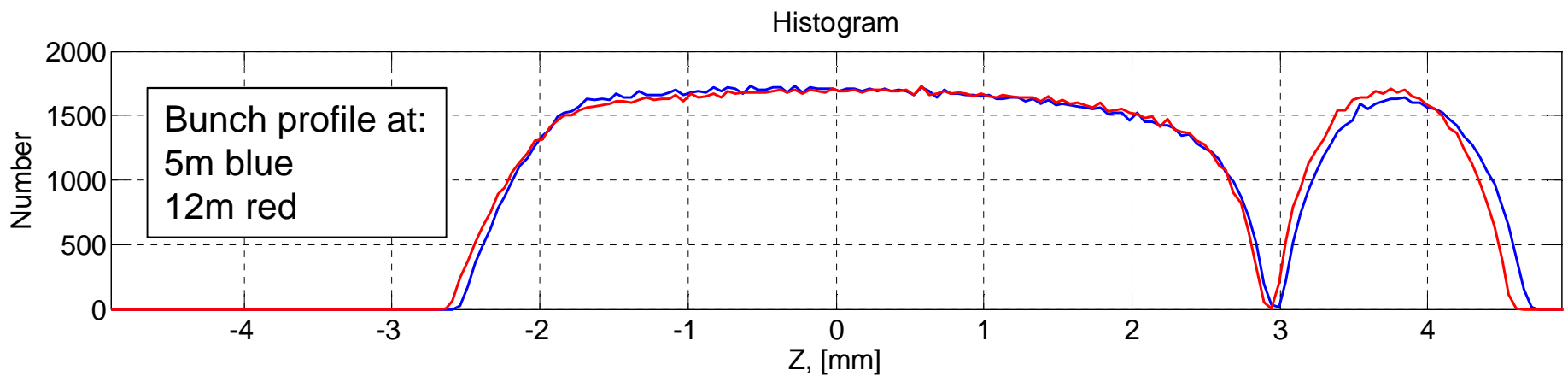
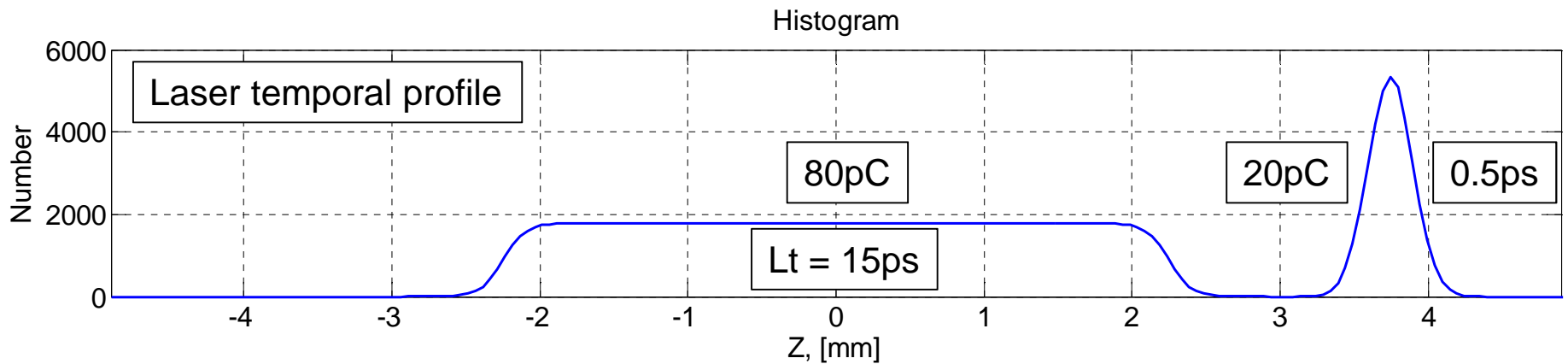


Blue line – bunch longitudinal profile at screen position

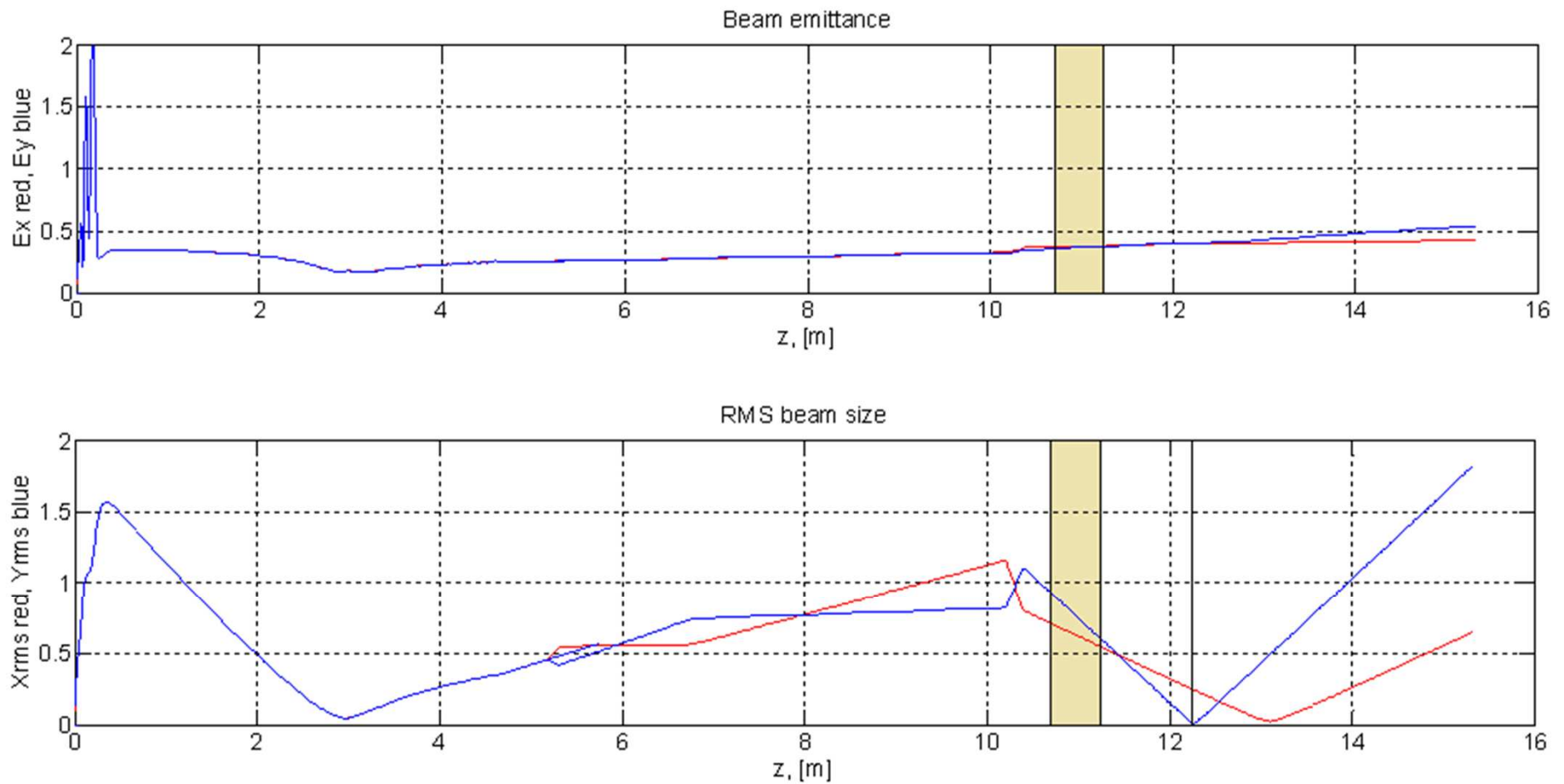
Red line – vertical profile of bunch image at screen scaled with $S = 4.1$.



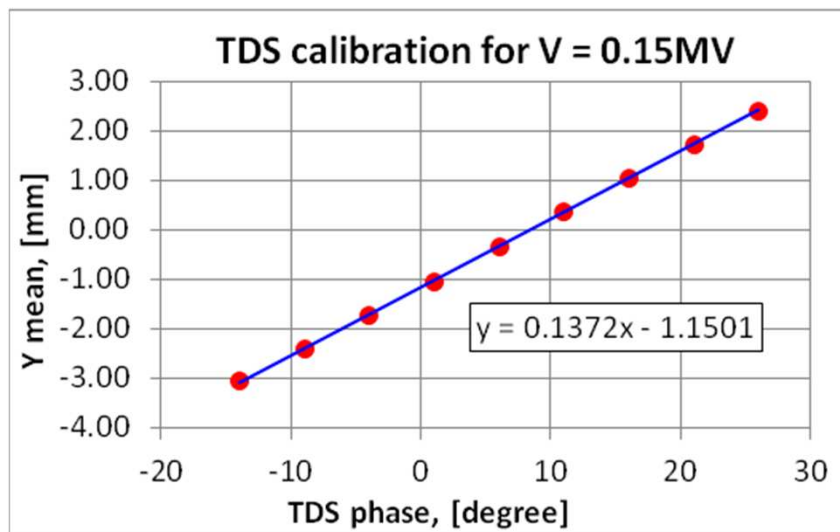
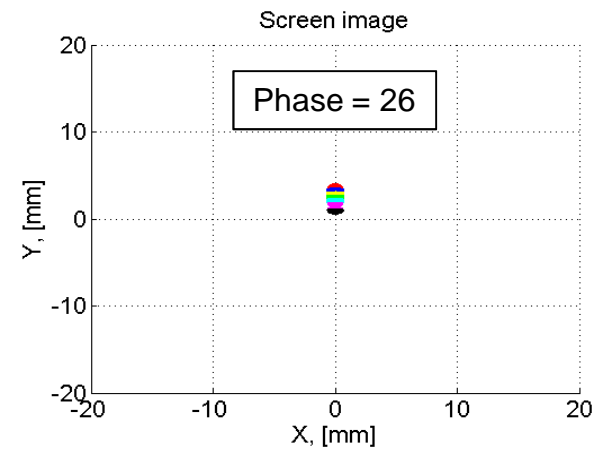
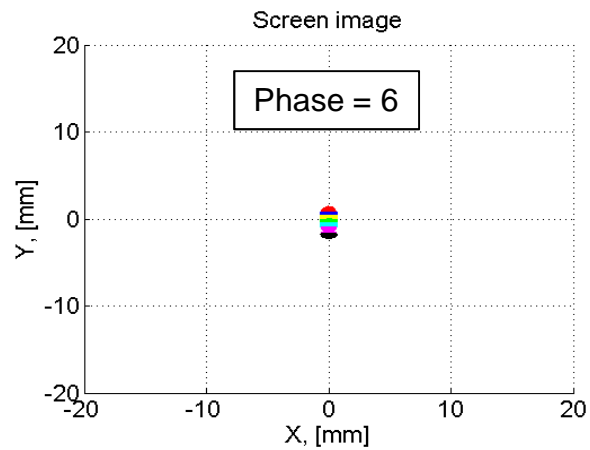
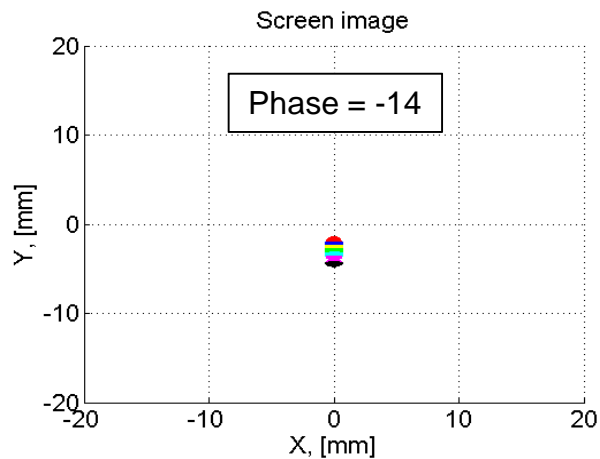
Simulation with 100pC, special profile



Beam optics, ASTRA simulation, 100pC



TDS calibration at PST.Scr1, 100pC bunch charge



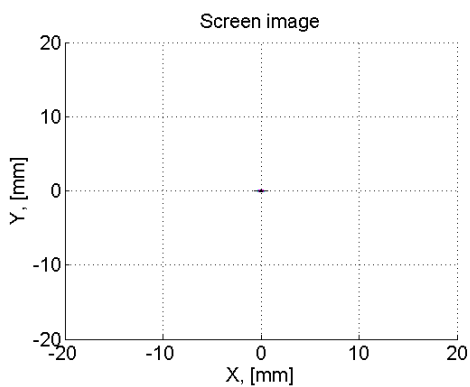
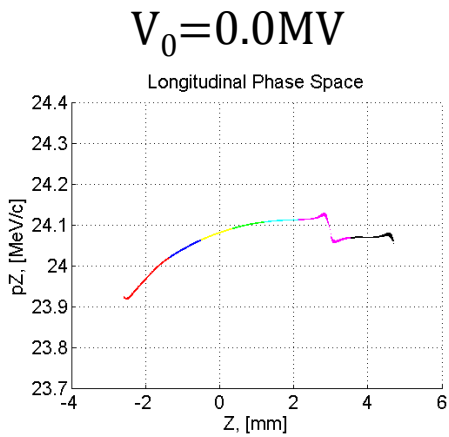
$$S = \frac{K_1 \cdot 360 \cdot f}{\beta \cdot c} = 0.49$$

$$S(0.6MV) = 1.977$$

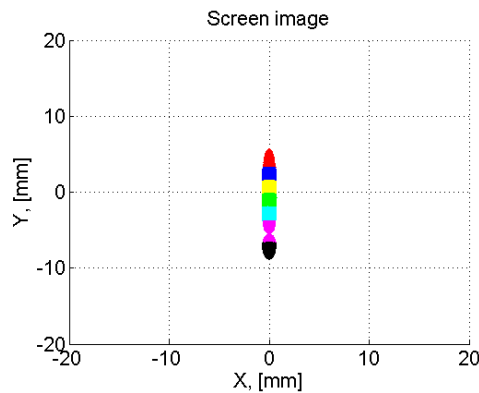
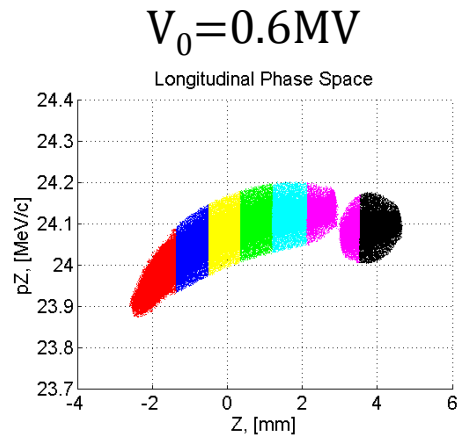
$$S(1.2MV) = 3.954$$



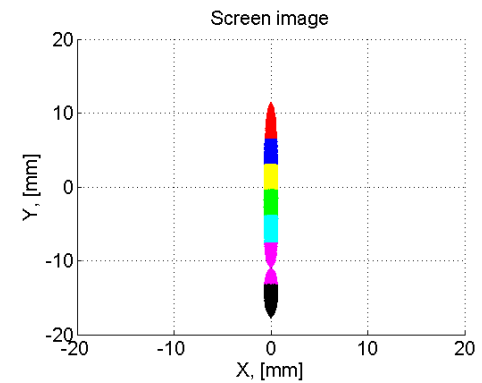
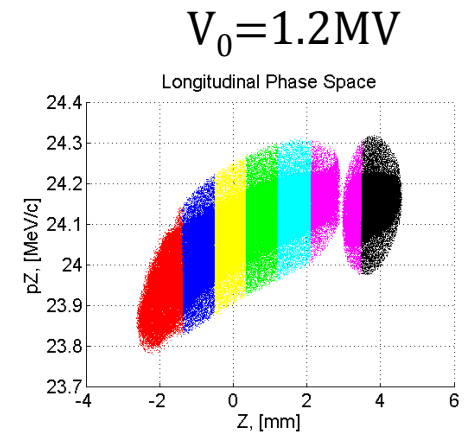
First screen after TDS at 12.238m (PST.Scr1), 100pC



$X_{rms} = 0.256\text{mm}$
 $Y_{rms} = 0.024\text{mm}$



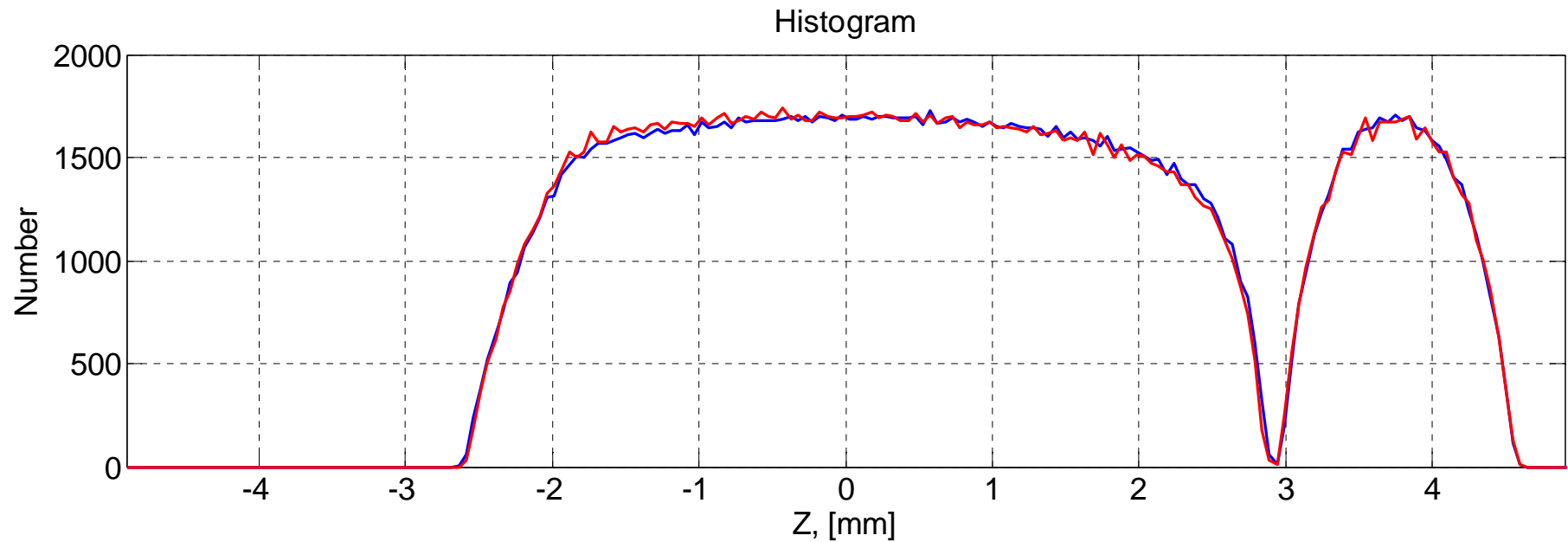
$S = 2.0$
 $\sigma_z = 12\mu\text{m} = 40\text{fs}$



$S = 4.0$
 $\sigma_z = 6\mu\text{m} = 20\text{fs}$



Bunch longitudinal profile, 100pC

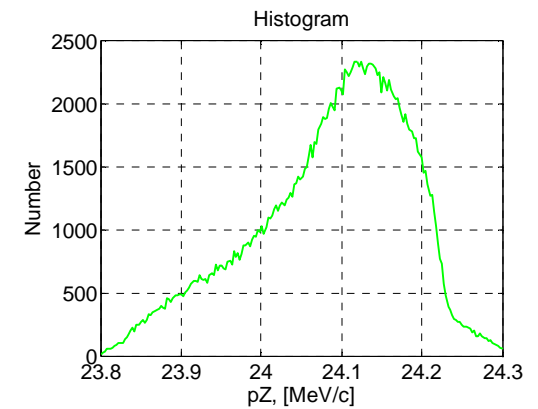
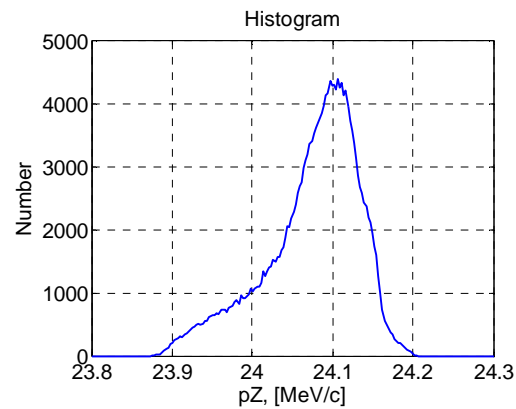
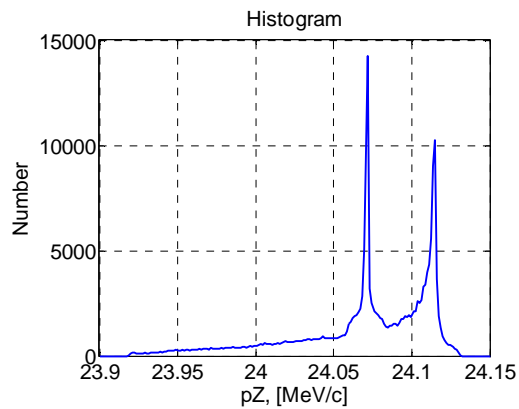
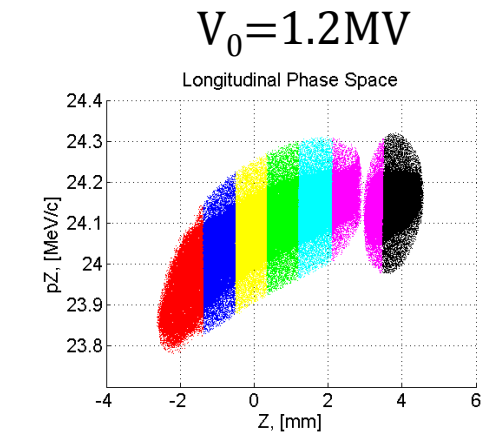
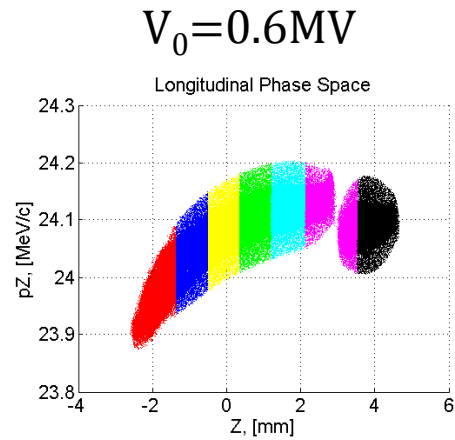
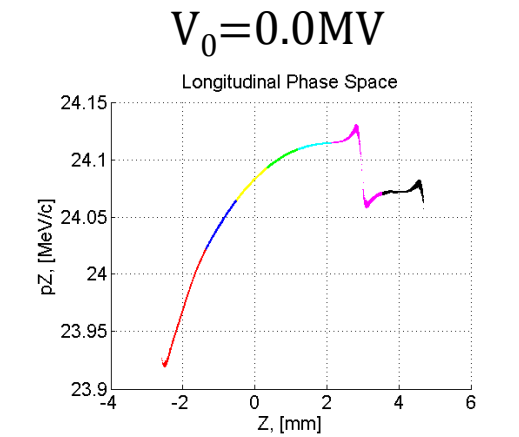


Blue line – bunch longitudinal profile at screen position

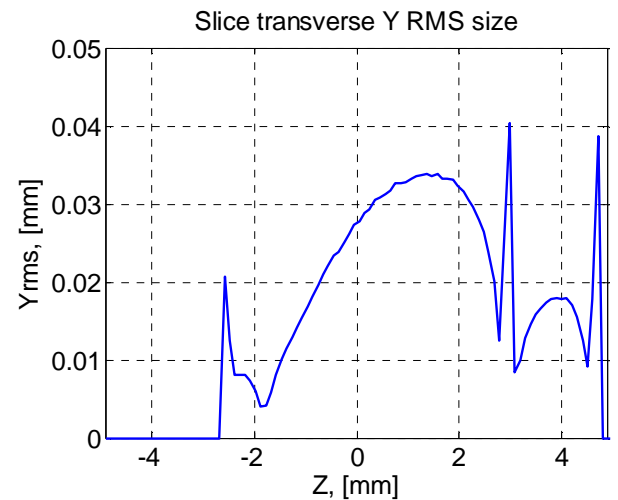
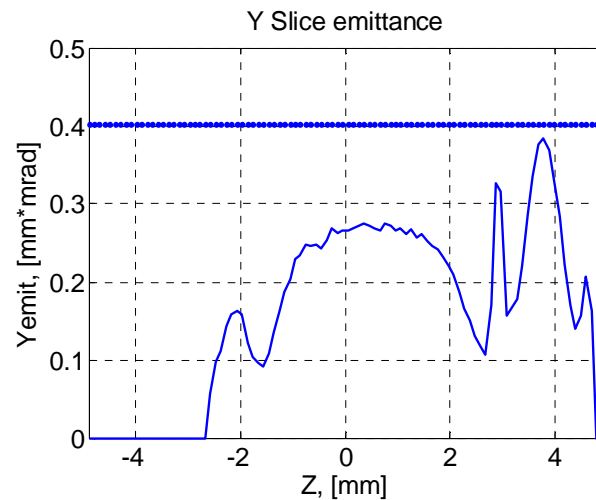
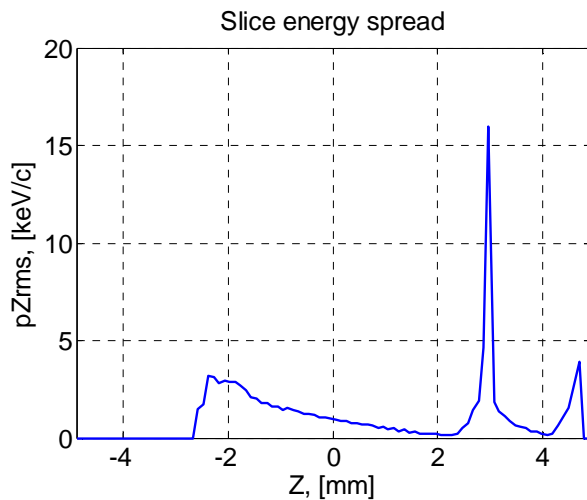
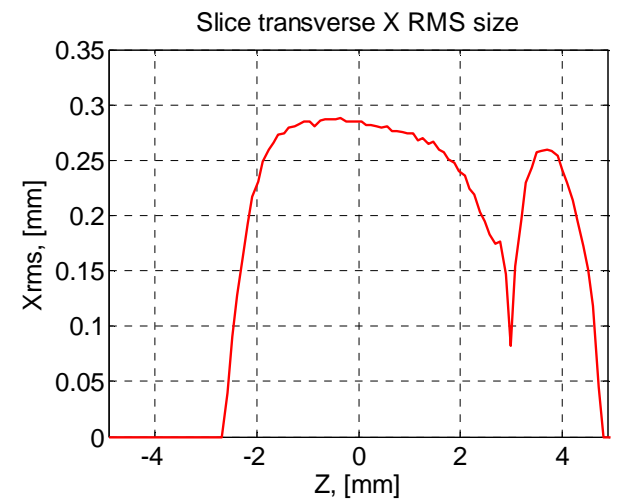
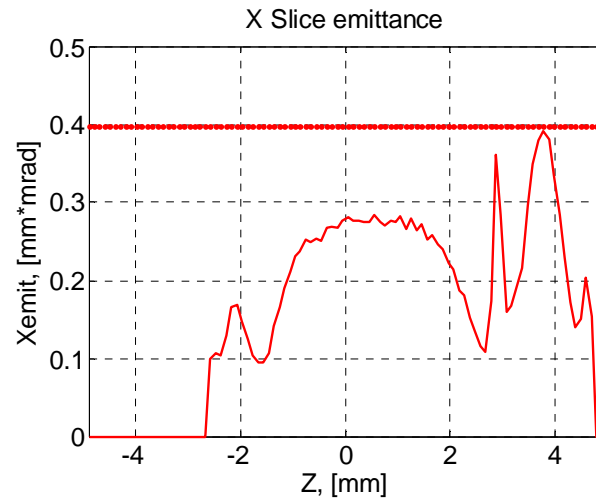
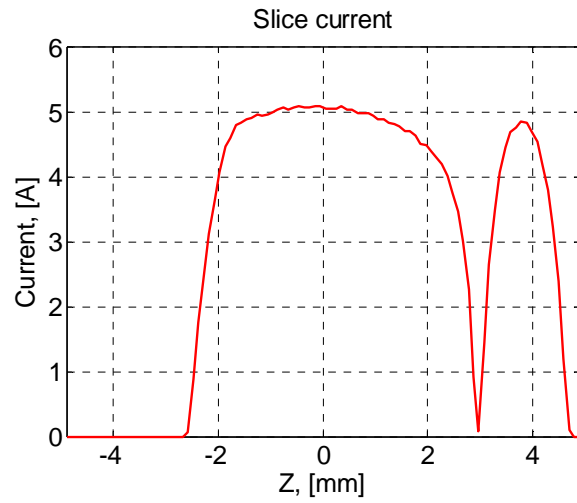
Red line – vertical profile of bunch image at screen Scaled with $S = 4$



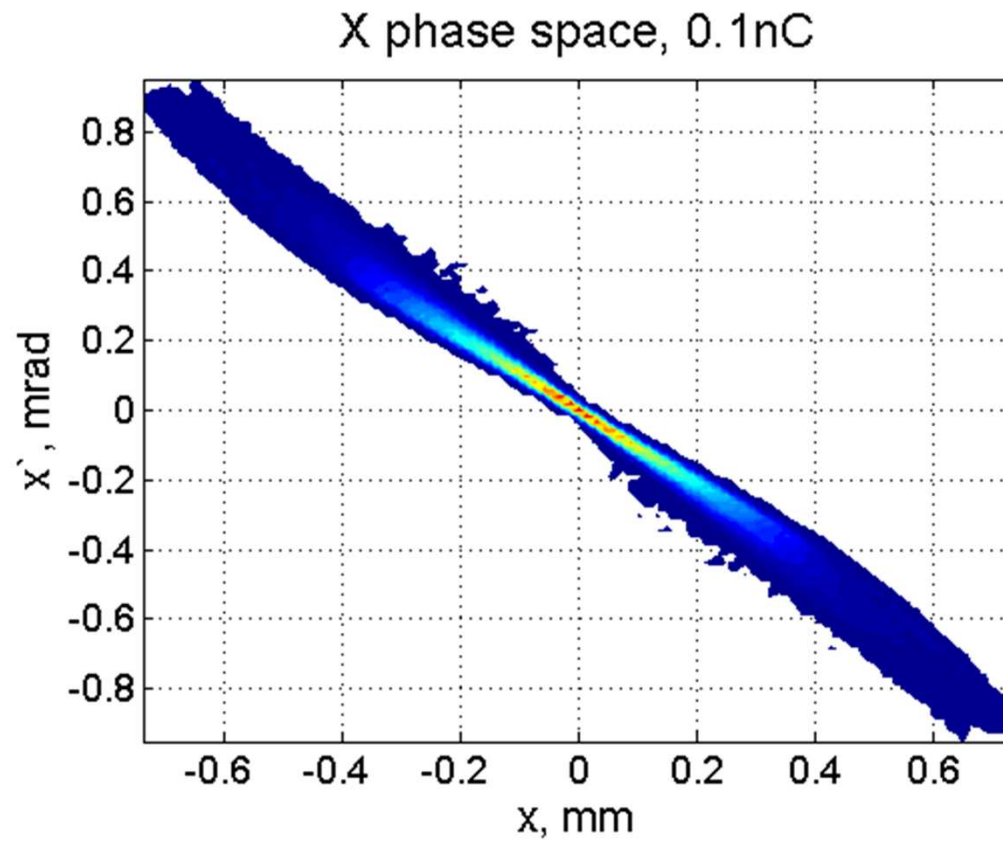
First screen after TDS at 12.238m (PST.Scr1), 100pC



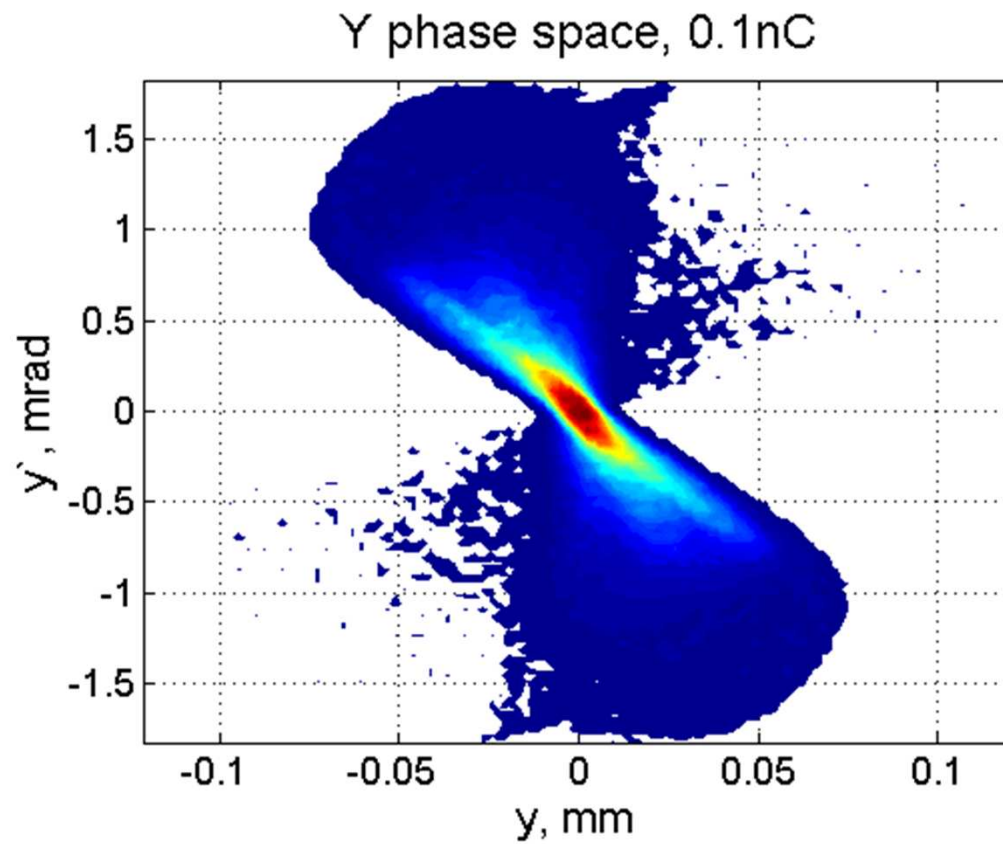
Slice parameters at PST.Scr1 position



X plane



Y plane

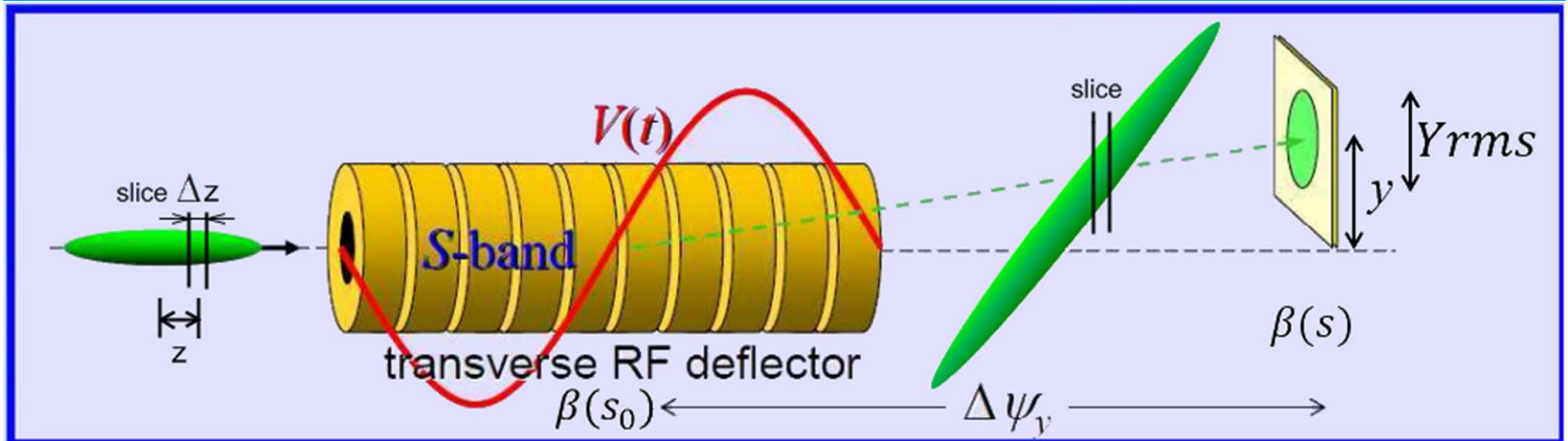


Conclusion

- > Measured bunch longitudinal profiles look identical to the reals.
- > Achieved longitudinal resolution is **6 μm** or **20fs** for **100pC** bunch, and **12 μm** or **40fs** for **1nC** bunch charge.



TDS resolution



$$S = \sqrt{\beta(s) \cdot \beta(s_0)} \cdot \sin(\Delta\psi_y) \cdot \frac{eV_0 k}{pc} \quad (1)$$

$$\sigma_z = \frac{\sigma_y}{S} \quad (2)$$

TDS resolution

$$\sigma_z = \frac{\sqrt{\varepsilon}}{\sqrt{\beta(s_0)}} \cdot \frac{pc}{eV_0 k} = \frac{\varepsilon \gamma mc^2}{\sigma_y(s_0) eV_0 k} = \frac{\varepsilon_N}{\sigma_y(s_0)} \cdot \frac{mc^2}{eV_0 k}, \quad (3) \quad k = \frac{2\pi f}{c}$$

PITZ:
$$\sigma_z = \frac{0.4 \cdot 10^{-6} m \cdot rad}{800 \cdot 10^{-6} m} \cdot \frac{0.5 MeV}{1.2 MeV \cdot 63 m^{-1}} = 3.4 \cdot 10^{-6} m, \text{ or } 11 \text{ fs}$$



TDS induced slice energy spread

$$\sigma_\delta = \frac{eV_0 k}{p_0 c} \sigma_y(s_0), \quad (4)$$

$$\text{where } \delta = \frac{\Delta p}{p}.$$

PITZ:
$$\sigma_\delta = \frac{1.2 \text{ MeV} \cdot 63 \text{ m}^{-1}}{23 \text{ MeV}} \cdot 800 \cdot 10^{-6} \text{ m} = 2.6 \cdot 10^{-3} \text{ or } 60 \text{ keV}$$

