ASTRA / OSIRIS simulation of the LAOLA@PITZ experiment

Transport of 22 MeV electron beam after plasma cell for longitudinal phase space measurements

Beam optics optimization towards HEDA2: current status

Difficulties and summary

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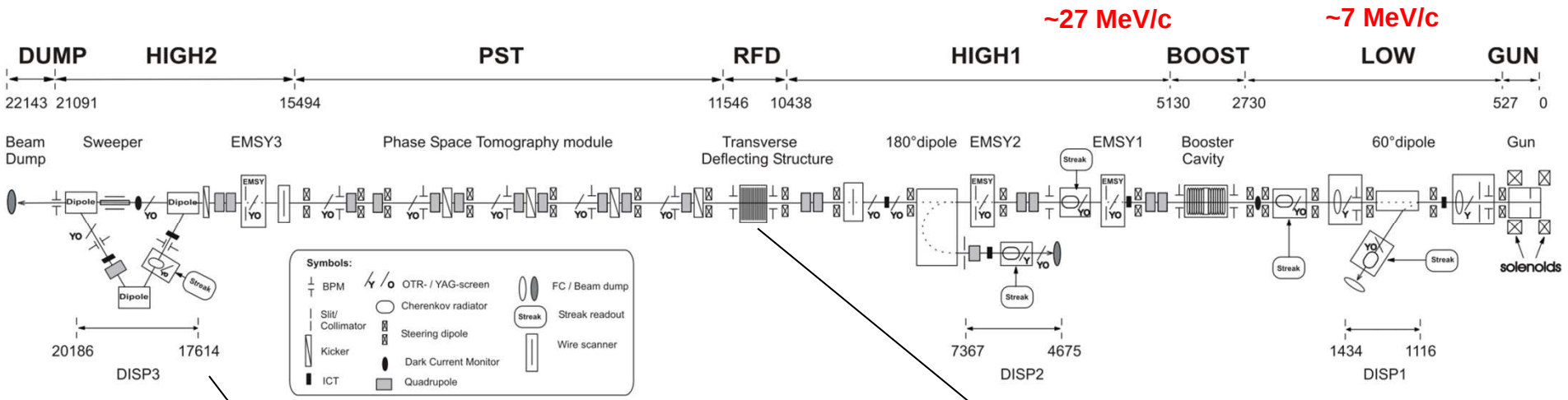
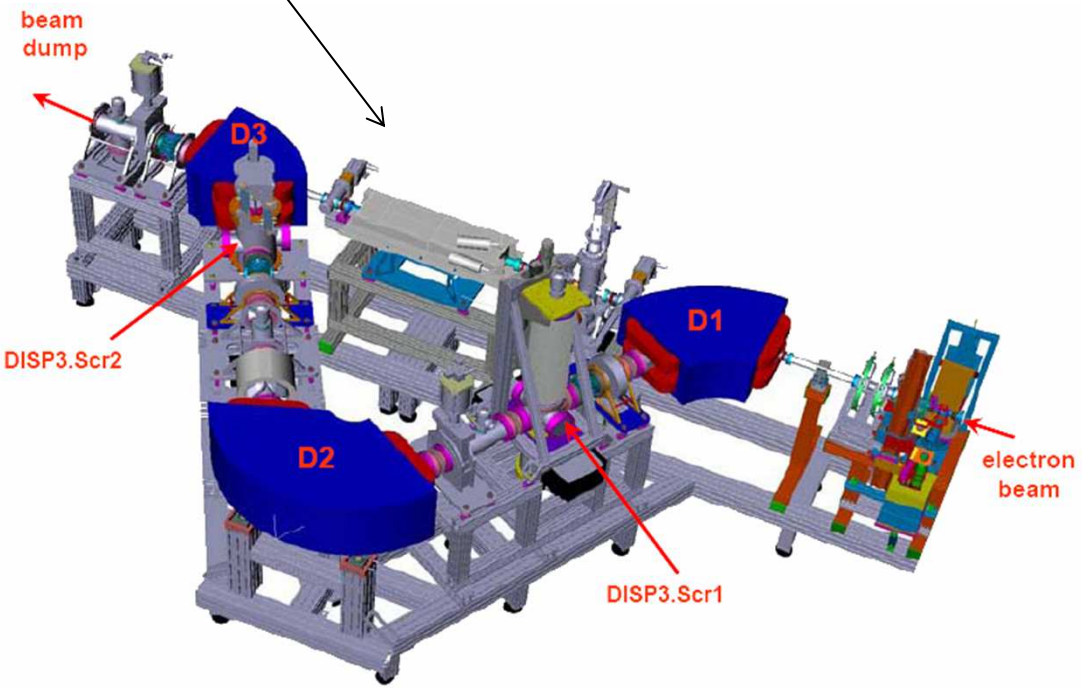
PITZ Photo Injector Test Facility Zeuthen

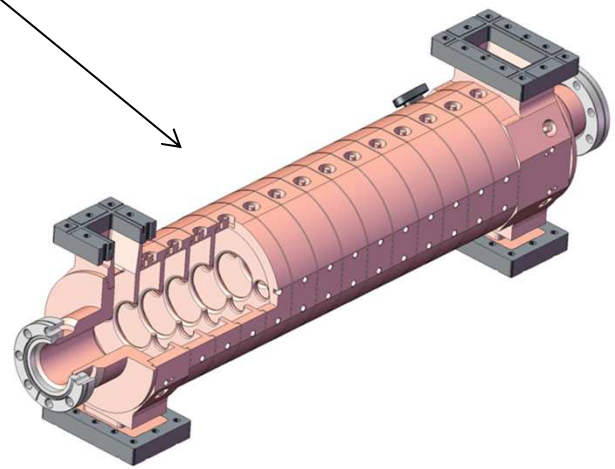
LAOLA Laboratory for Laser- and beam-driven plasma Acceleration

DESY

Diagnostic view of the current PITZ beamline





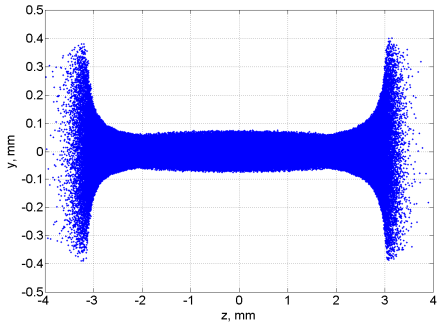


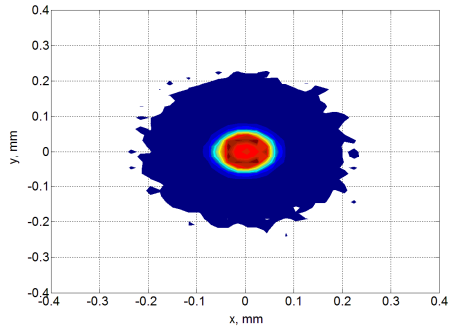
← **Direction of e-beam propagation**

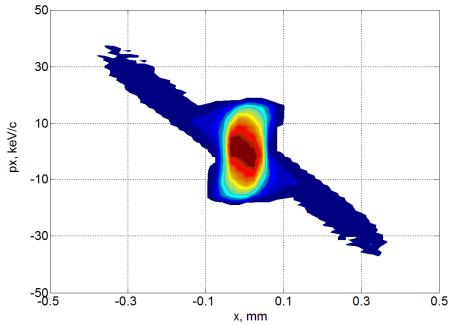
E-beam overview before and after interaction with a plasma

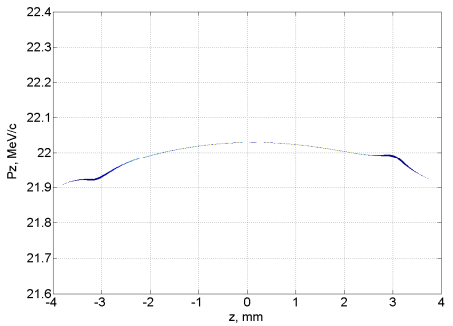
Side view | **Beam projection** | **Hor. phase space** | **Long. phase space**

ASTRA output at ~6.4m

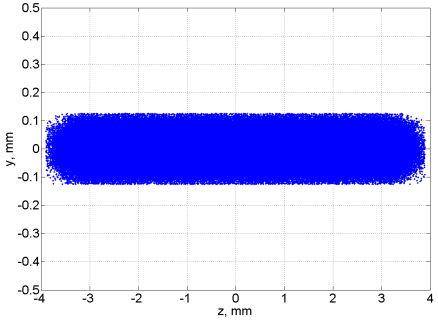


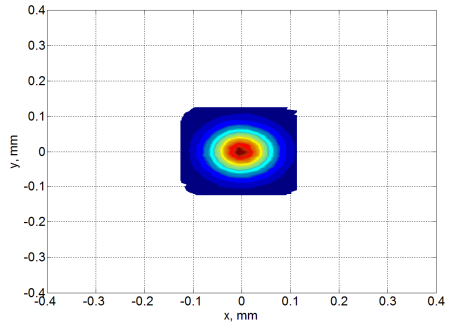


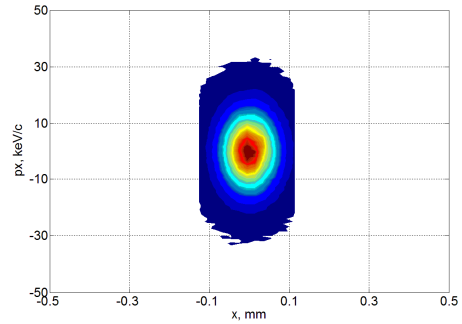


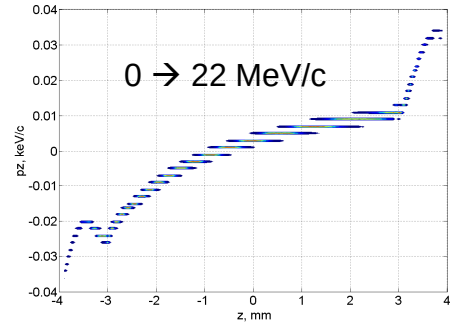


OSIRIS input at ~6.4m

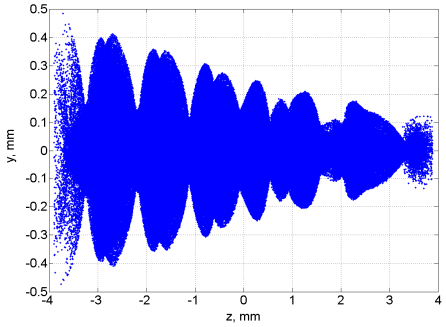


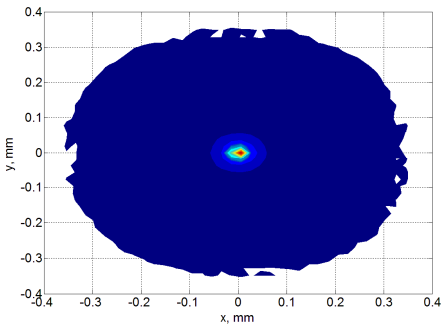


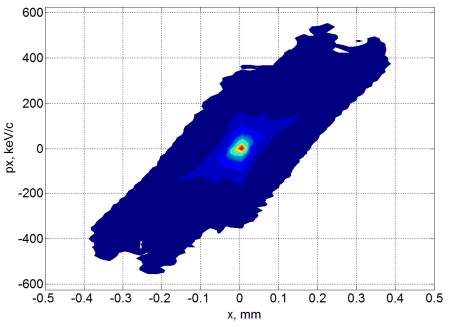


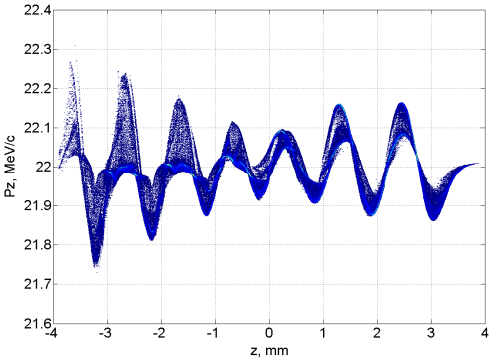


OSIRIS output at ~6.5m









Simulation setup for beam transport up to HEDA2

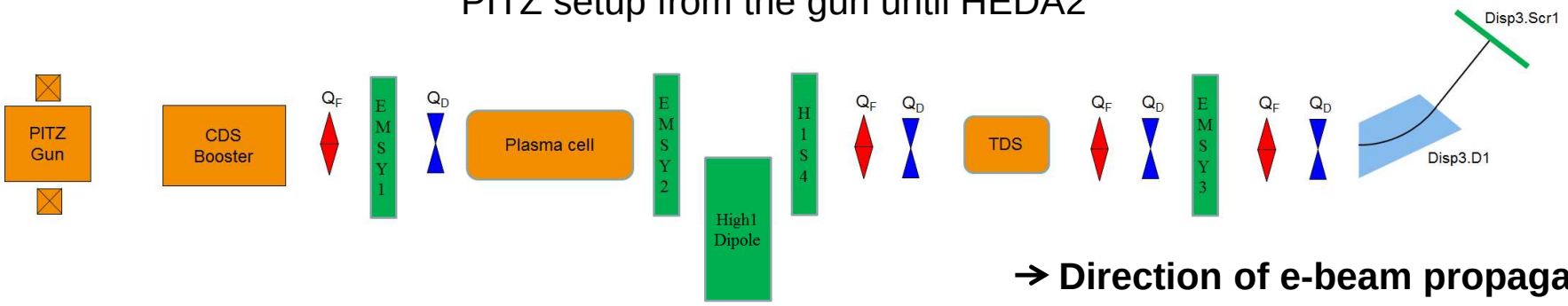
Setup for beam simulations from the cathode up to HEDA 2

- Laser: Longitudinally flat-top → 2/22\2 ps. Transverse rms spot size on the cathode → 0.3mm
- Gun: Gradient of 61 MV/m (6.73 MeV/c after gun at on-crest phase), phase fixed to on-crest
- Booster: Gradient of 17.5 MV/m (22 MeV/c final beam momentum for gun and booster on-crest phases)
- Solenoid current for e-beam focus on EMSY1
- Bunch charge 100pC
- The following quadrupoles are used for further beam transport up to HEDA2:

- High1.Q1 → position 5.19m (from cathode), focusing gradient → g [T/m]=-3.38
- High1.Q2 → position 5.29m, focusing gradient → g [T/m]=4.409
- High1.Q3 → position 5.9, focusing gradient → g [T/m]=-5.548 (to be replaced)
- High1.Q4 → position 6.0m, focusing gradient → g [T/m]=4.813 (to be replaced)
- High1.Q5 → position 7.5m, focusing gradient → g [T/m]=-4.385 (to be reconsidered in simulations)
- High1.Q6 → position 7.6m, focusing gradient → g [T/m]=4.769 (to be reconsidered in simulations)
- High1.Q? → position 9.0m, focusing gradient → g [T/m]=-4.769 (to be situated)
- High1.Q? → position 9.1m, focusing gradient → g [T/m]=4.462 (to be situated)
- PST.QT1 → position 13.228m, focusing gradient → g [T/m]=1.154
- PST.QT2 → position 13.608m, focusing gradient → g [T/m]=-1.692
- PST.QT5 → position 14.748m, focusing gradient → g [T/m]=1.748
- PST.QT6 → position 15.128m, focusing gradient → g [T/m]=-1.154
- High2.Q2 → position 16.735m, focusing gradient → g [T/m]=-0.846

Setup of self-modulation experiment

PITZ setup from the gun until HEDA2



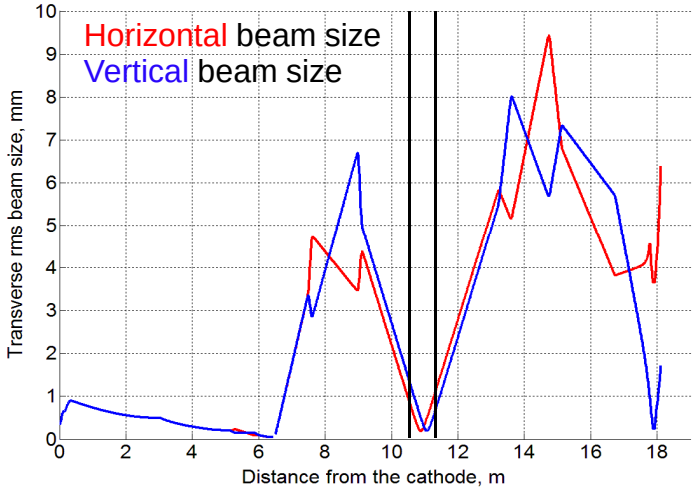
➔ **Direction of e-beam propagation**

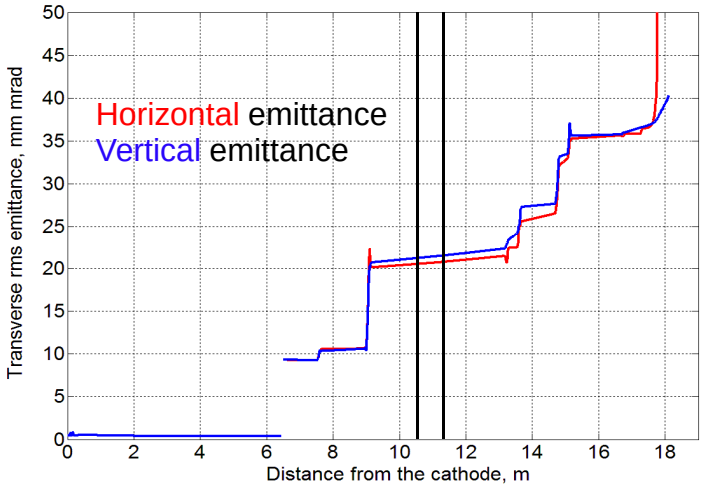
Beamline component	σ_x, mm	σ_y, mm	$\delta P/P, \%$	$\varepsilon_x, mm\,mrad$	$\varepsilon_y, mm\,mrad$
EMSY1 (no quad. applied)	0.18	0.18	0.1	0.38	0.38
At the entance of plasma cell (ASTRA)	0.042	0.042	0.1	0.37	0.37
At the entance of plasma cell (OSIRIS)	0.042	0.042	0	0.37	0.37
After plasma cell	0.12	0.12	0.33	9.3	9.4
At the entrance of TDS	1.7	2.2	0.33	20.4	21.1
At the entrance of the first dipole in HEDA2	3.6	4.1	0.33	37.3	39.2

Beamline component	Start, m	End, m
EMSY1	5.6	5.9
Plasma cell	~6	~6.9
EMSY2	7.0	7.25
High1.Dipole	7.4	8.0
High1.Scr4	8.3	8.5
TDS	10.65	11.3
EMSY3	16.2	16.4
Disp3.Dipole1	17.2	18.0

Beam optics up to HEDA2: current setup (left) compared to the optimized (right) case

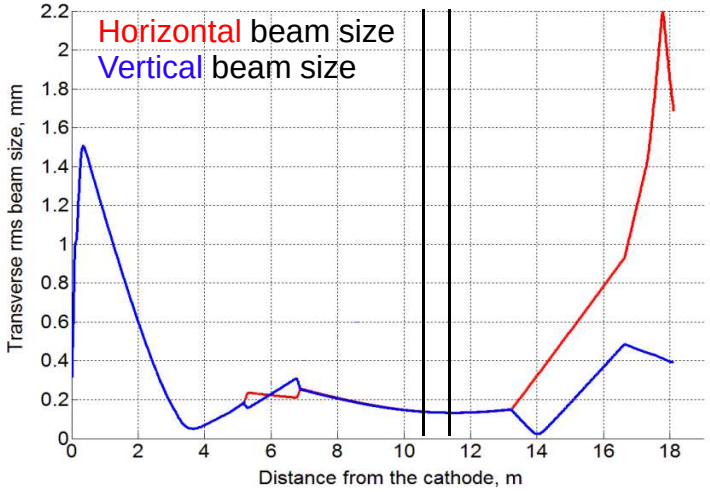
Current status with TDS off

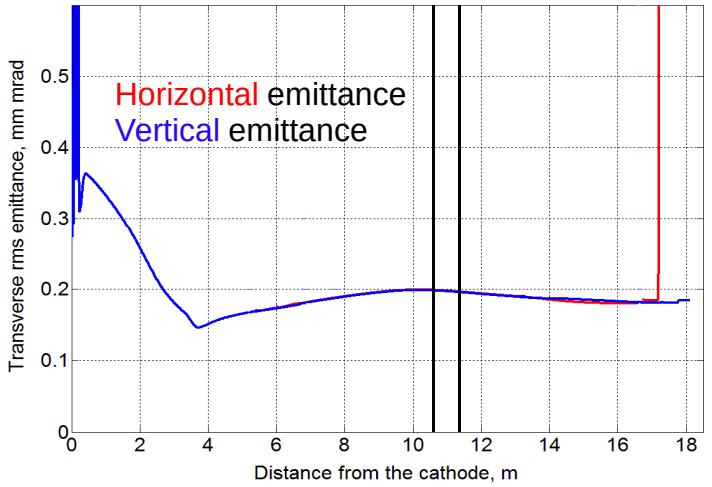




Optimized setup for the high mom. resolution

Longitudinal resolution 0.1 mm, momentum resolution15 keV/c



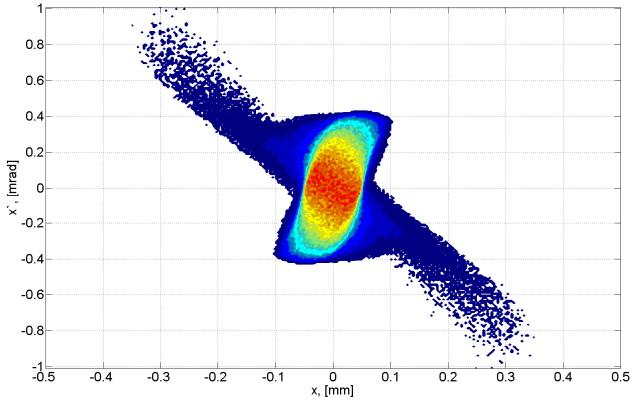


Electron beam transverse properties from cathode towards to HEDA2.

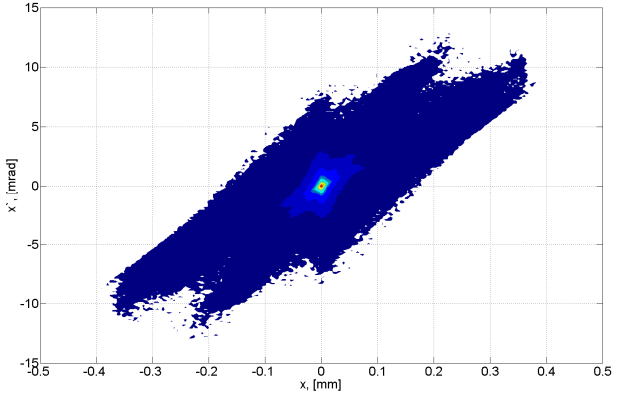
Difficulties…

Transverse phase spaces before and after the plasma

Before plasma



After plasma

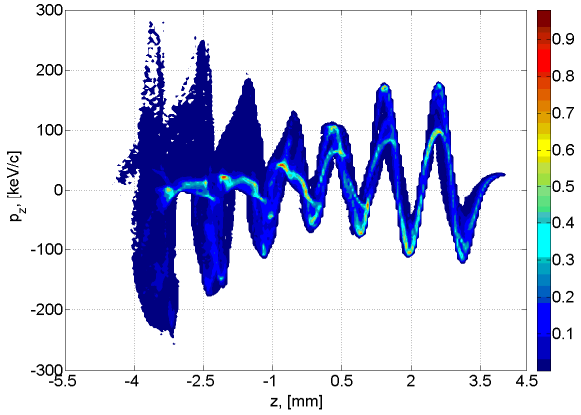


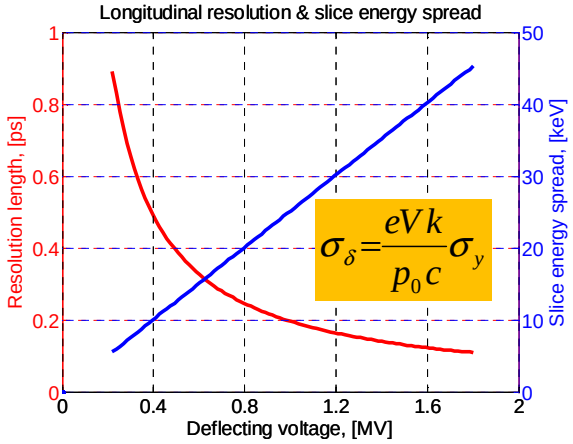
$$x' = 10mrad$$
$$r_{\max} = 20mm$$
$$L = r_{\max} / x' = 2m$$

We need a pair of quadrupoles after the plasma cell within 2m !!

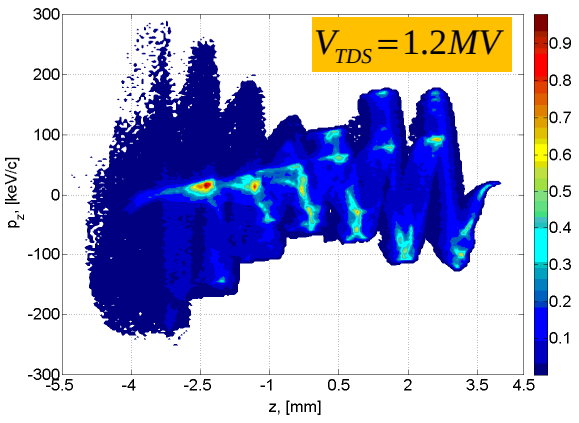
Longitudinal phase spaces before and after TDS: preliminary results

Before TDS after plasma





After TDS before HEDA2 dipole



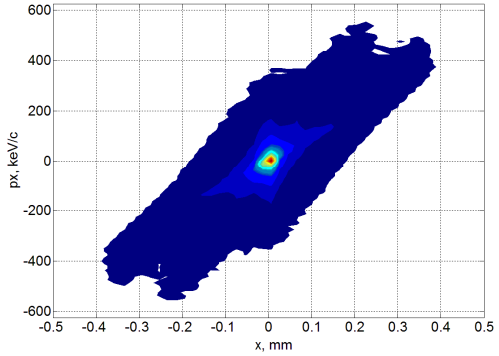
Summary and to do

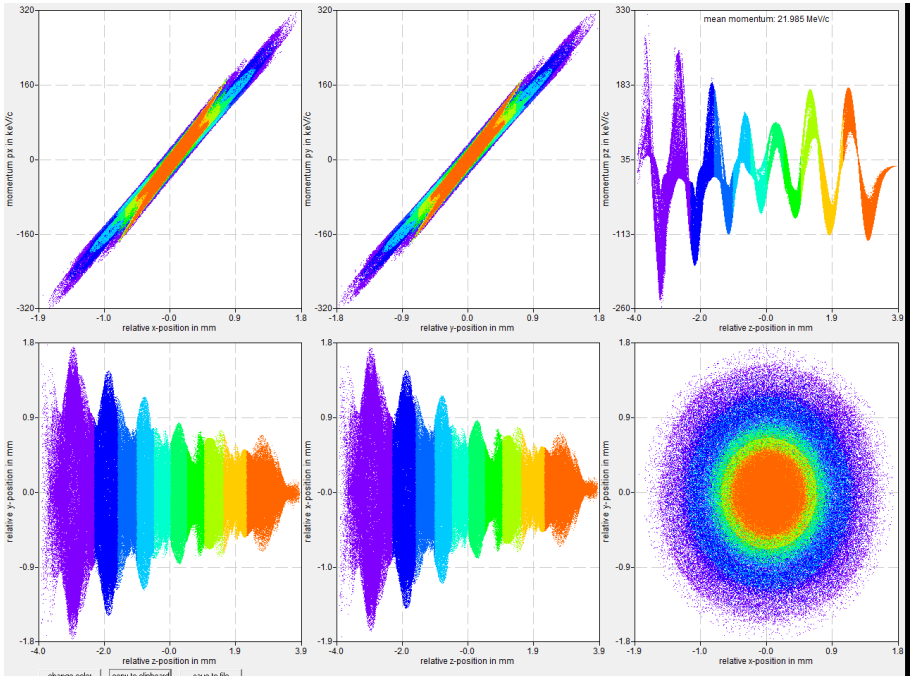
- Monitoring of the electron beam parameters after plasma !
- E-beam after plasma has large values of the transverse emittance what make further optics optimization difficult

- Improve the electron beam parameters given to OSIRIS
- Further optimization of beam optics after plasma to HEDA2 with the TDS

Thank you for your attention !!

E-beam overview after the plasma compared to cut beam case

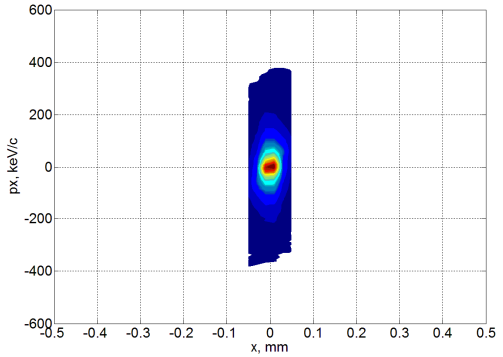


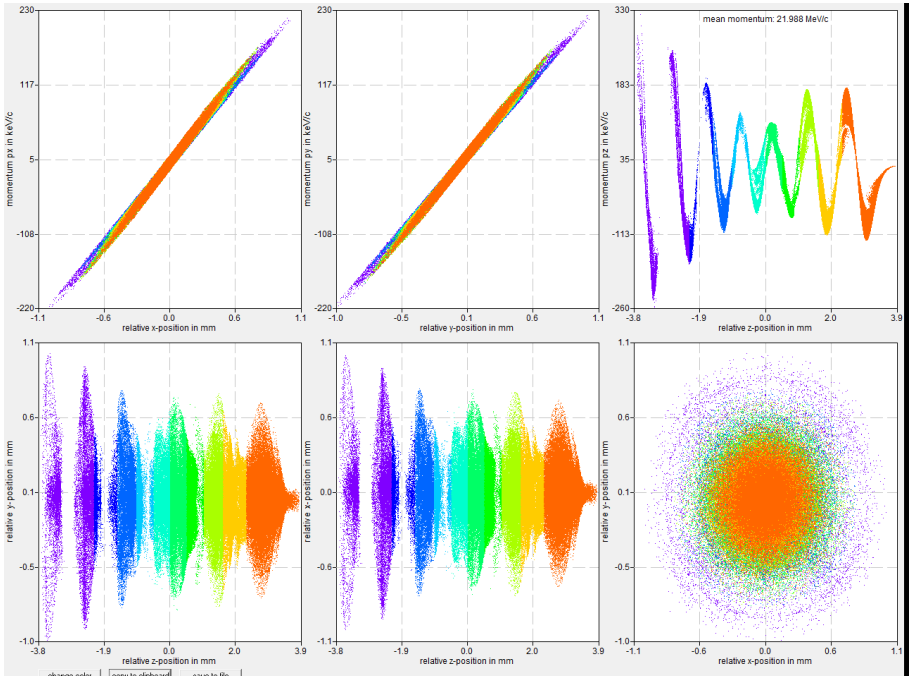


Transverse emittance = 9.3 mm mrad

Beam rms spot size = 0.42 mm

Charge 100 pC





Transverse emittance = 1.8 mm mrad

Beam rms spot size = 0.2 mm

Charge 50 pC