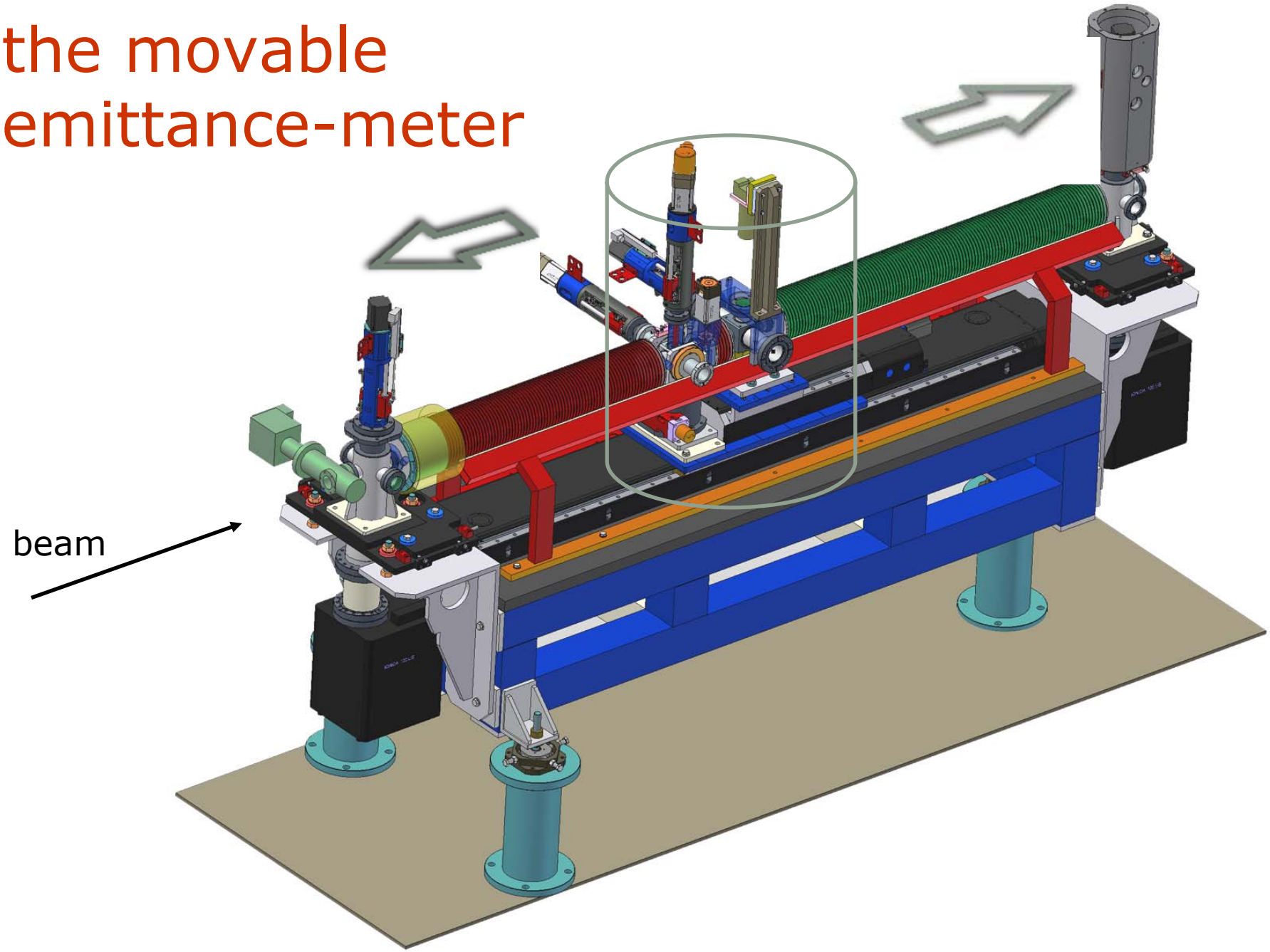
Operational experience with the movable emittance-meter at SPARC

L.Catani on behalf of the SPARC Collaboration

the movable emittance-meter



outline

- ✓ work done with e-meter during photo-injector commissioning

- x results from SPARC photo-injector commissioning *(refer to THPPH031)*
- x complete list of measurements one can do with this device

SPARC Collaboration

INFN Istituto Nazionale di Fisica Nucleare

ENEA

ULTRAS INFM NATIONAL LABORATORY FOR ULTRAFAST AND ULTRAINTENSE OPTICAL SCIENCE

La Sapienza Università degli Studi di Roma

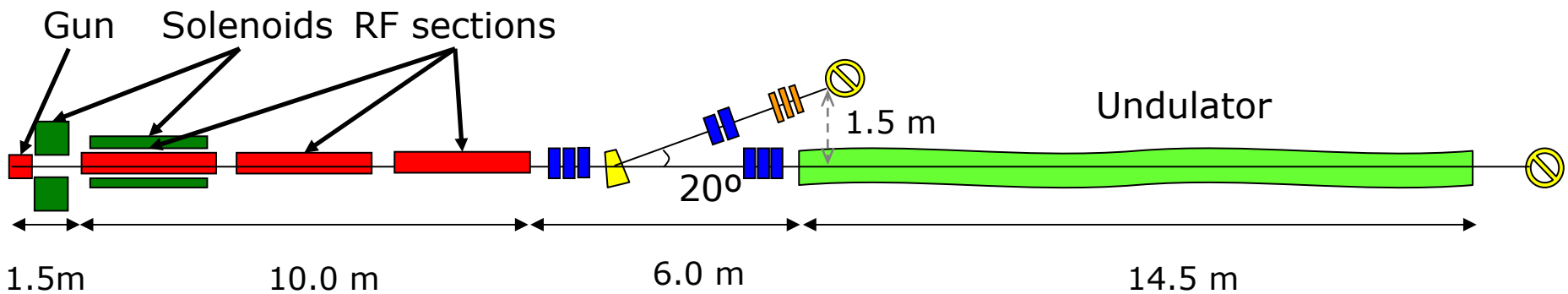
Stanford Linear Accelerator Center

UCLA

elettra Synchrotron Light Laboratory

EURO FEL

SPARC Working Point



GUN PARAMETERS

Frequency: 2856 MHz
Peak Field: 120 MV/m
Solenoid Field: 0.27 Tesla
Beam Energy: 5.6 MeV
Charge: 1.1 nC
Laser: 11.5 ps x 1 mm (Flat Top with <1 ps rise time)
Therm. emitt. 0.3 mm

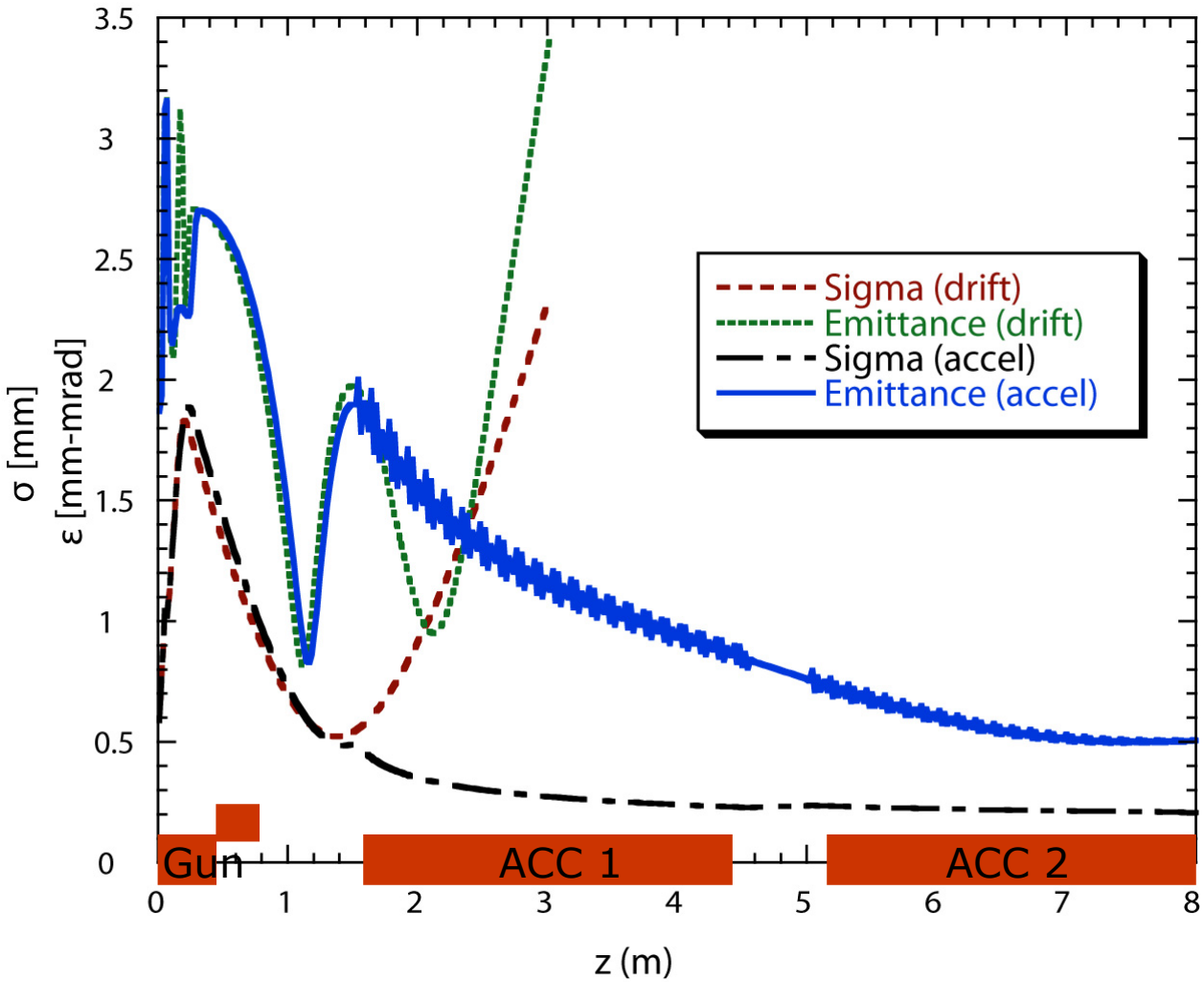
LINAC PARAMETERS

Frequency: 2856 MHz
Accelerating Field: 25-12.5-12.5 MV/m
Solenoid Field: 0.1 Tesla
Beam Energy: 155 MeV

FEL PARAMETERS

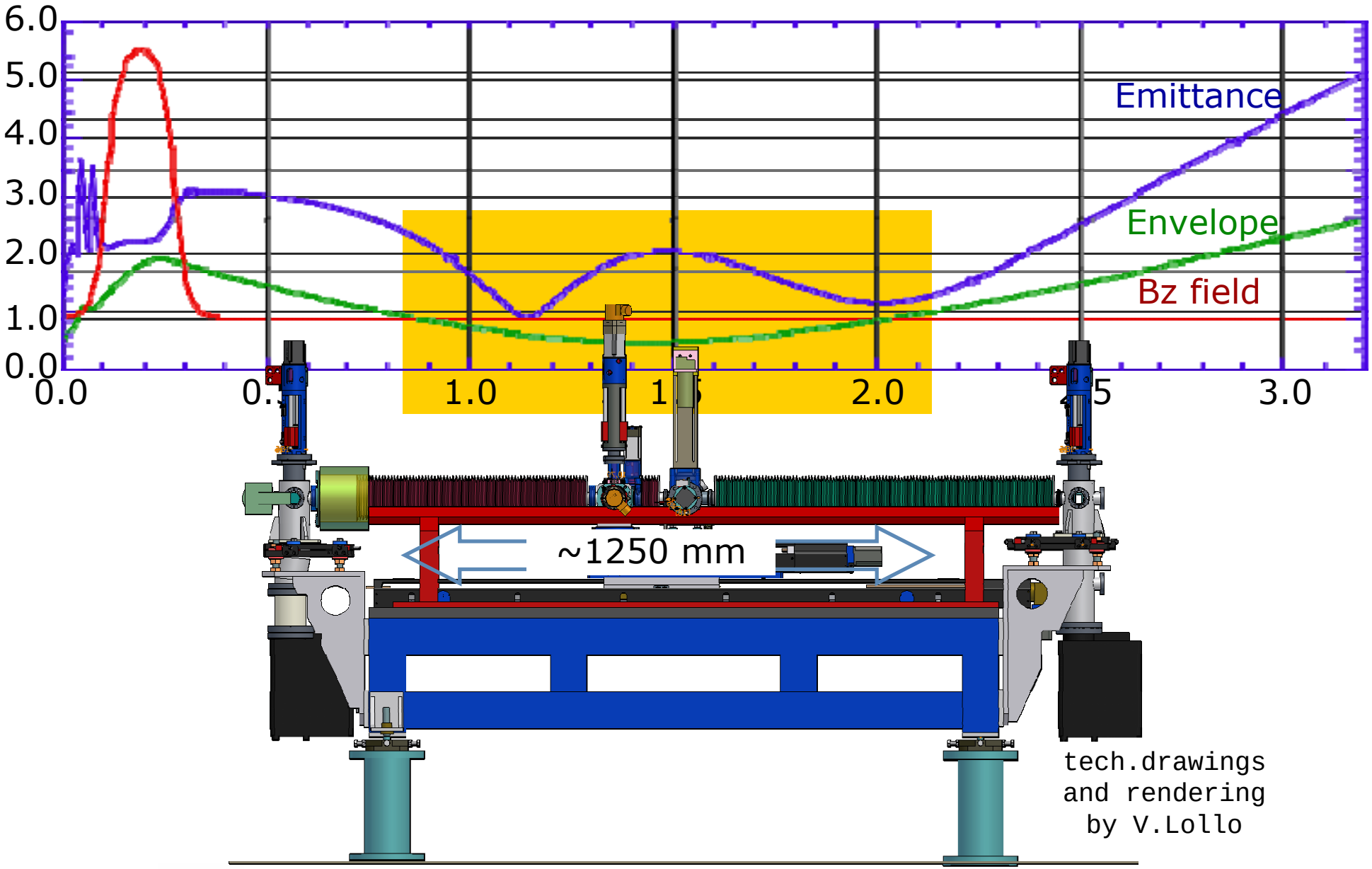
Wavelength: 530 nm
Coop. Length: 300 mm

Motivations for the movable emittance meter



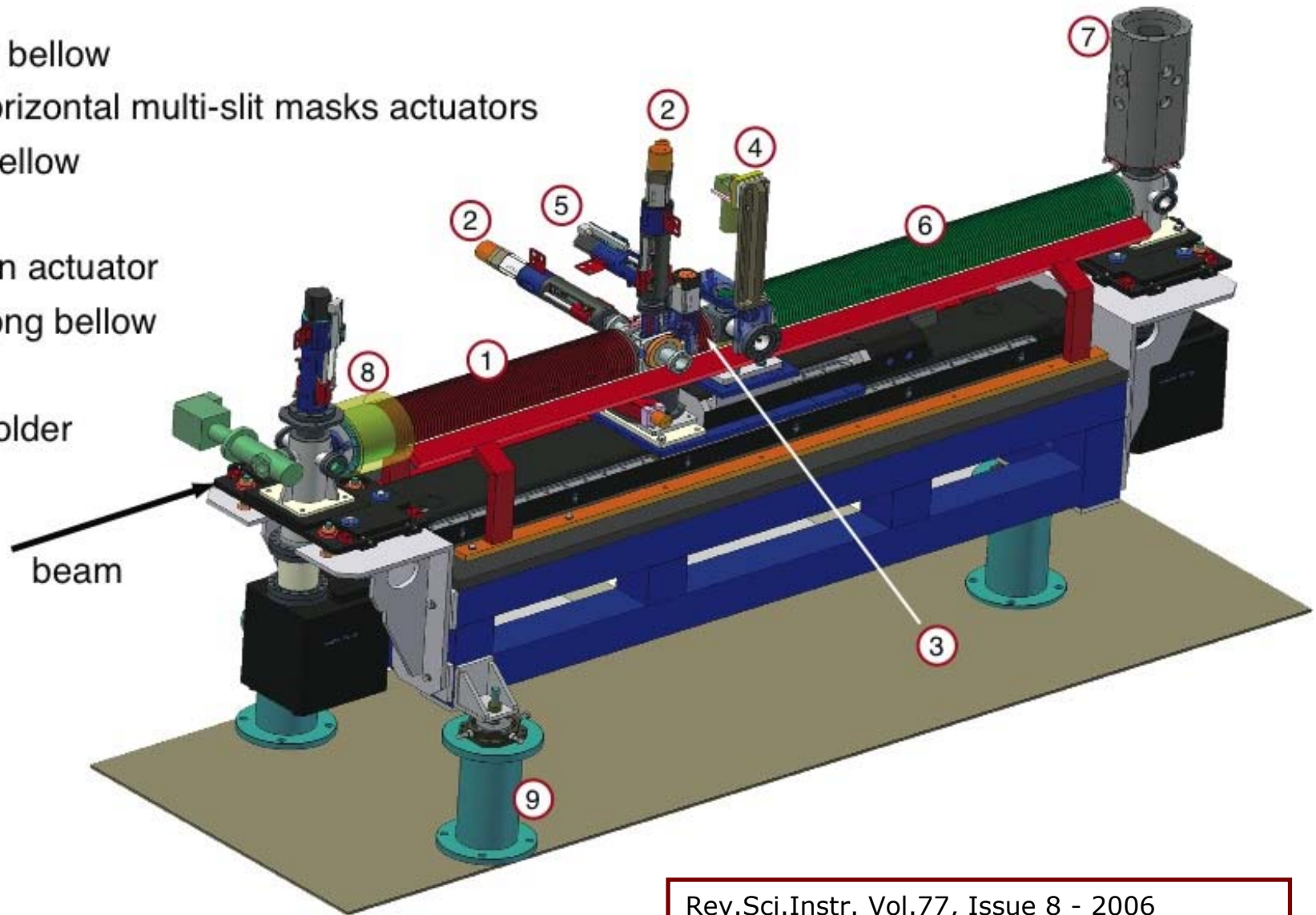
Emittance Compensation: Controlled Damping of Plasma Oscillations
(Homdyn simulations by M.Ferrario and SPARC-BD group)

movable emittance-meter concept



a closer look

1 - upstream long bellow
2 - vertical and horizontal multi-slit masks actuators
3 - intermediate bellow
4 - CCD camera
5 - Ce:YAG screen actuator
6 - downstream long bellow
7 - alignment tool
8 - steering coil holder
9 - leg extender



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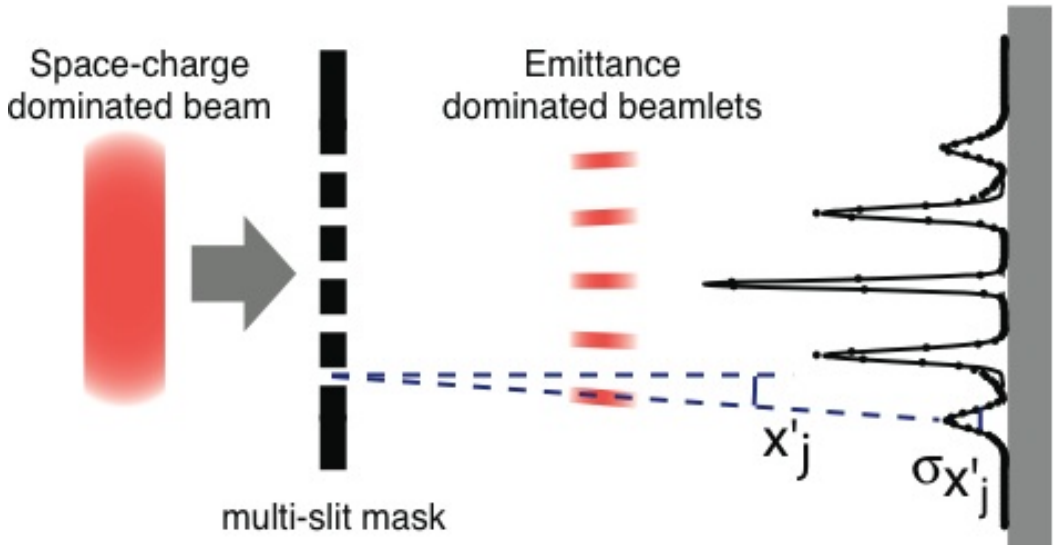
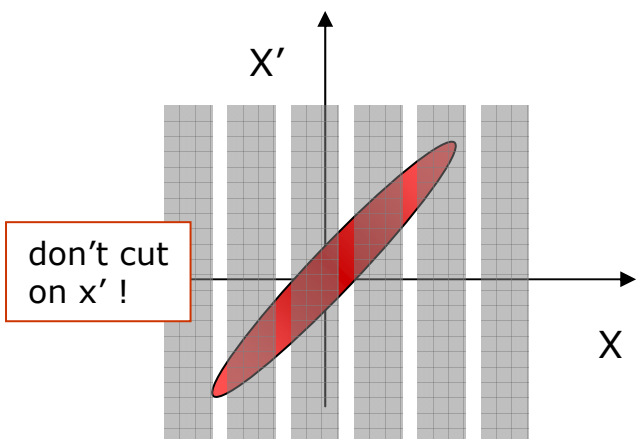
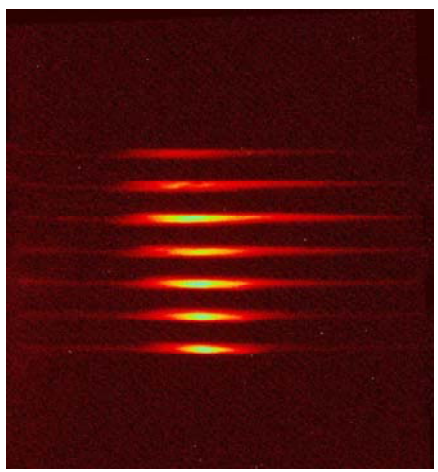
the emittance measurement



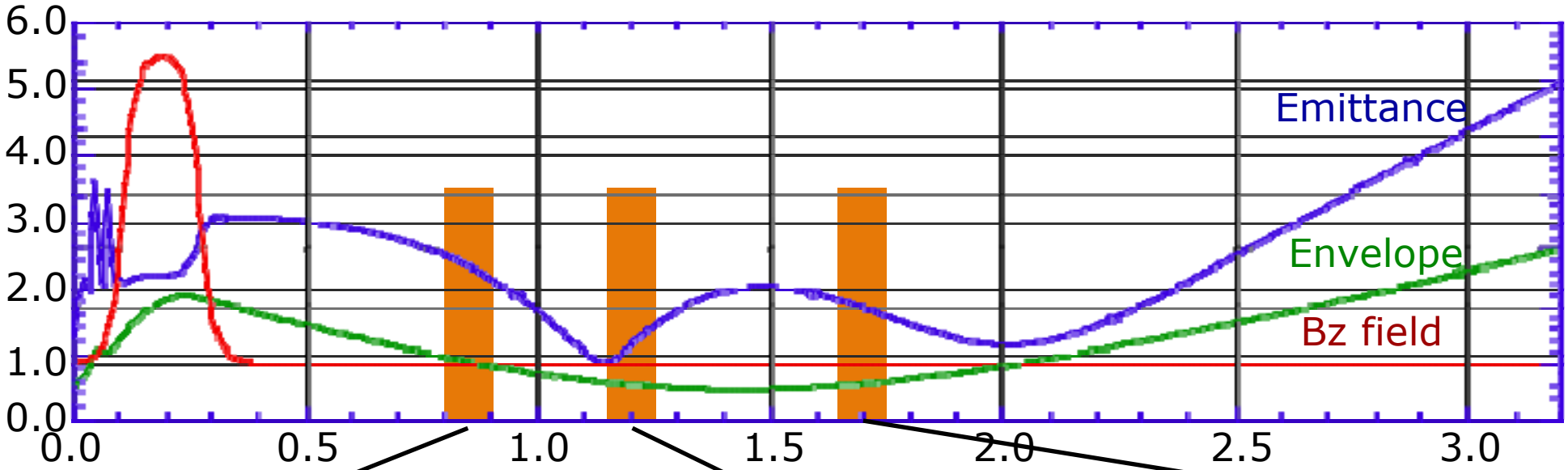




$$\varepsilon_n^2 = \frac{1}{N^2}\left\{\sum_{j=1}^{p}\left[n_j\left(x_{sj} - \bar{x}\right)^2\right]\cdot \sum_{j=1}^{p}\left[n_j\sigma_{x'_j}^2 + n_j\left(\bar{x}'_j - \bar{x}'\right)^2\right] + -\left[\sum_{j=1}^{p} n_j x_{sj}\bar{x}'_j - N\bar{x}\bar{x}'\right]^2\right\}$$

where

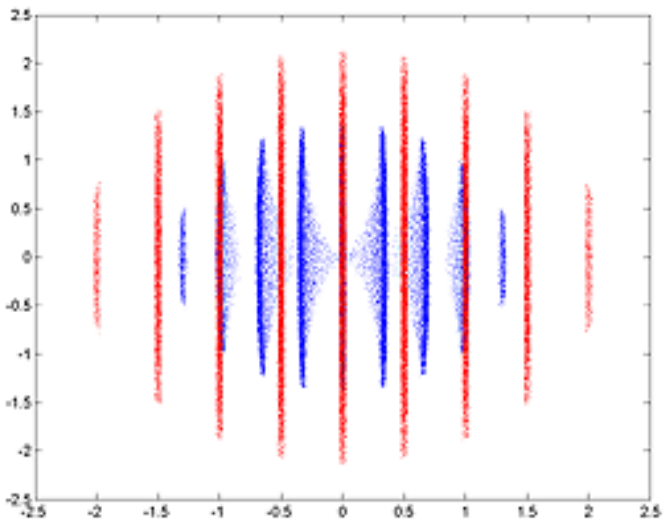
p	=	total number of slits
n_j	=	particles in the beamlet from the j-th slit
x_{sj}	=	position on the j-th slit on the slit-mask
$\bar{x}$	=	mean position of all the beamlets
$\bar{x}'_j$	=	mean divergence of the j-th beamlet
$\bar{x}'$	=	mean divergence of all beamlets
$\sigma_{x'_j}$	=	RMS divergence of the j-th beamlet

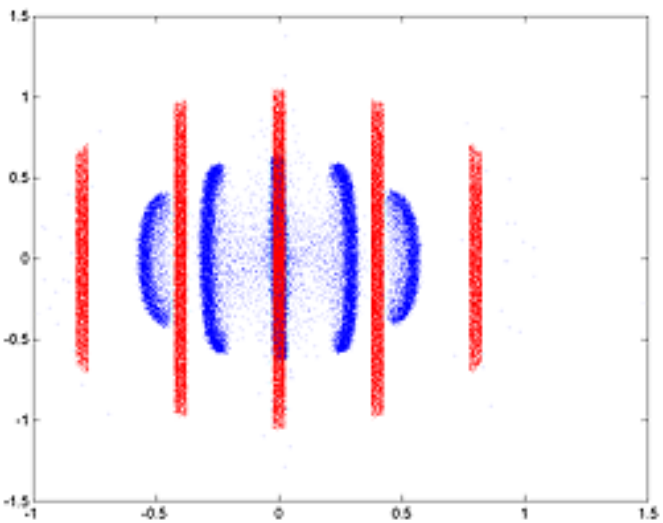


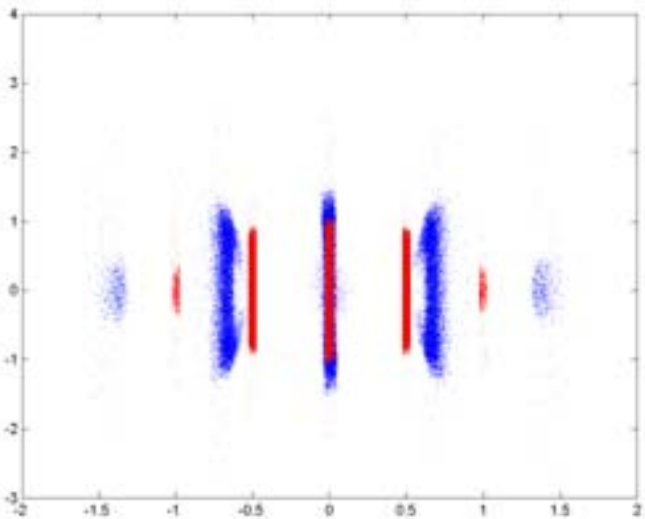
Z= 85 cm

Z= 120 cm

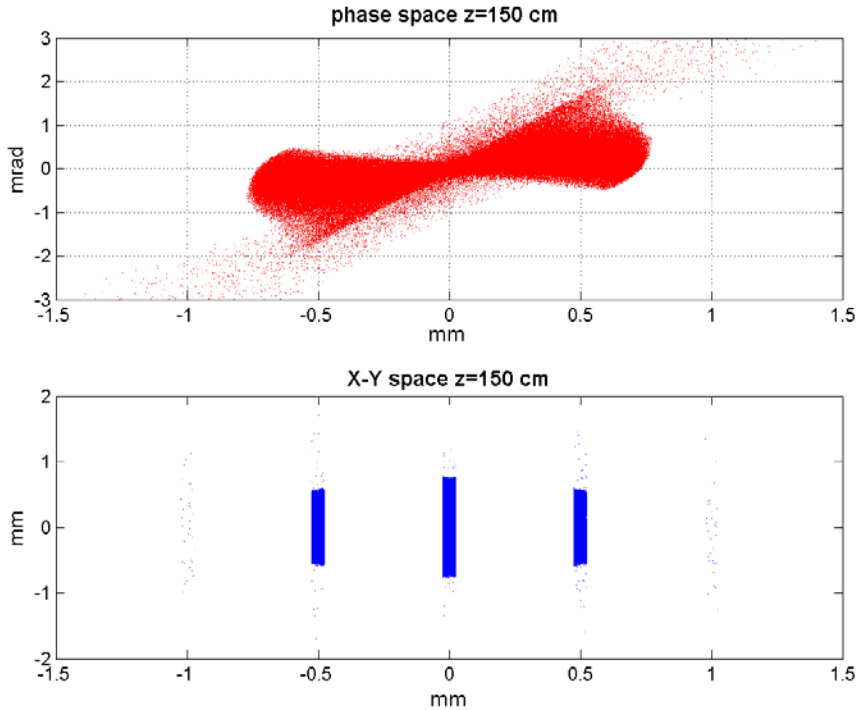
Z= 170 cm

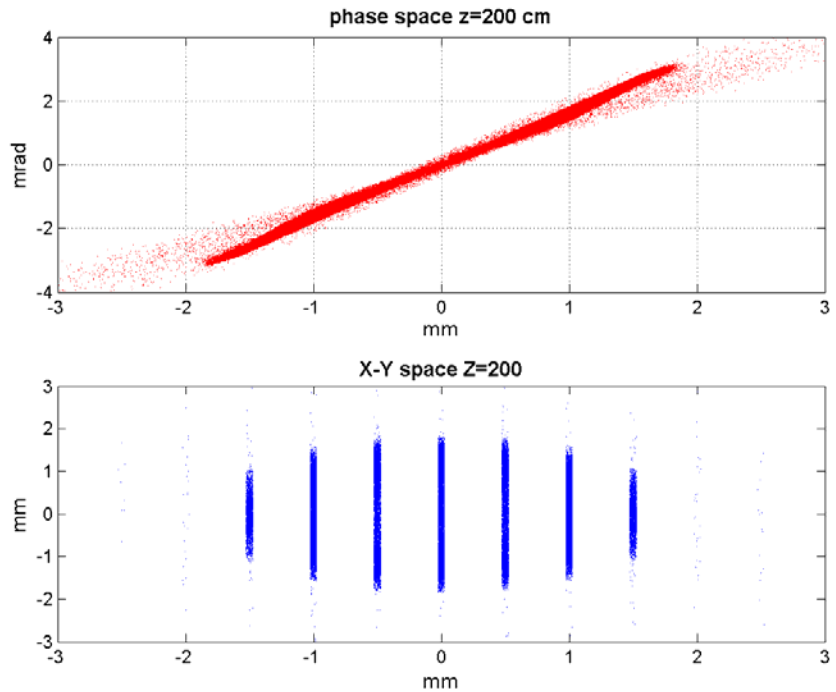






Multi-slits or multi-shot measurements

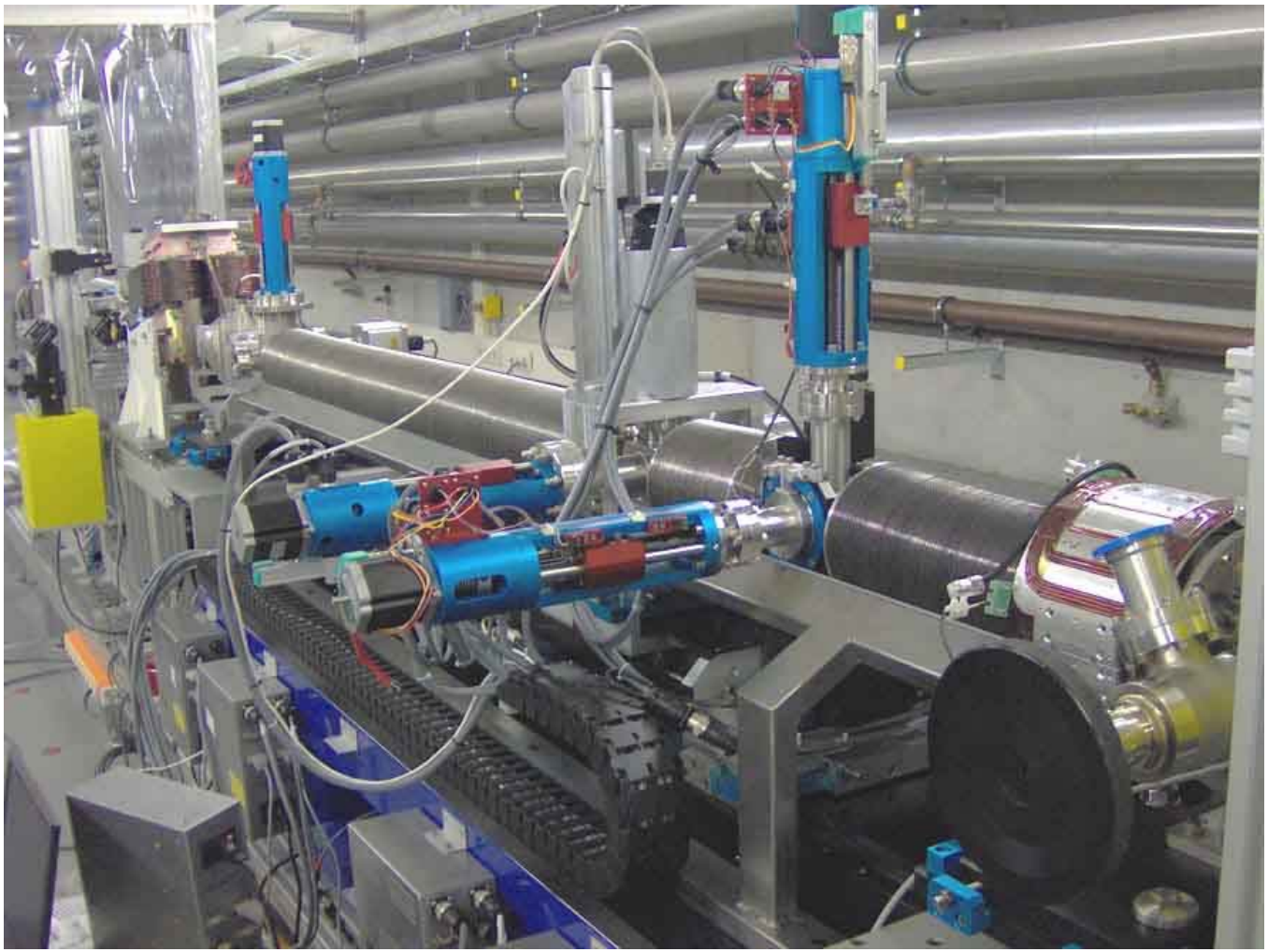




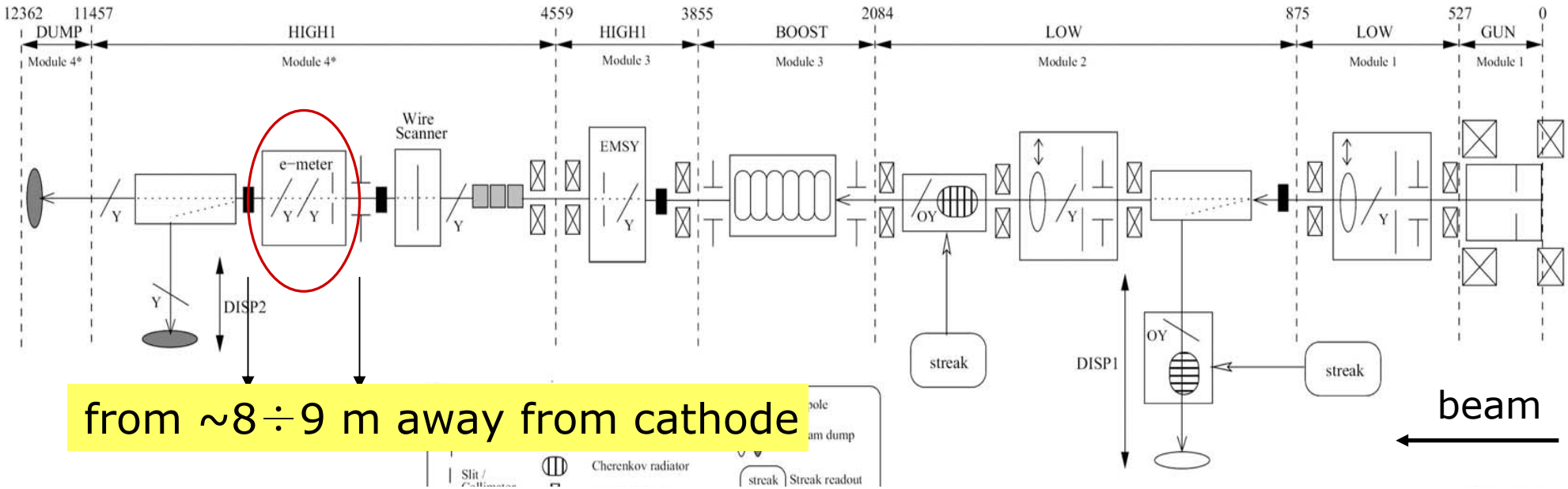
In the waist area, or at positions where the beam is too small to use multi-slits mask, we plan to use a single slit be moved transversally with respect to the beam. For this multi-shot measurement the step size, and as consequence the number of the samples of the beam, can be varied to improve the accuracy.

Multi-slits mask with a fixed distance (0.5 mm) between slits will be used where the beam is large (right) but this cannot be a good choice if its size is small as in the beam waist region (left).

Test and preliminary commissioning @PITZ (INFN&DESY-Zeuthen teams)

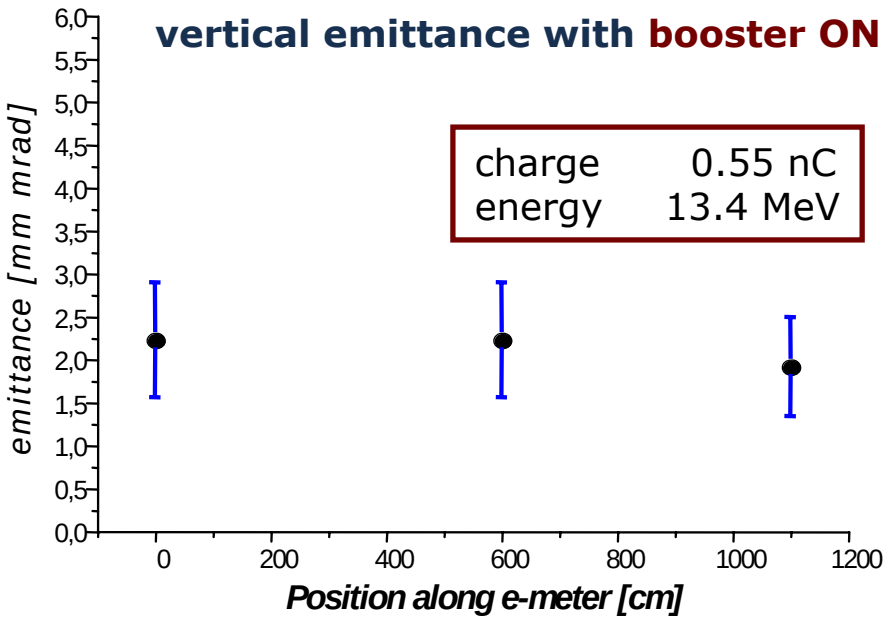


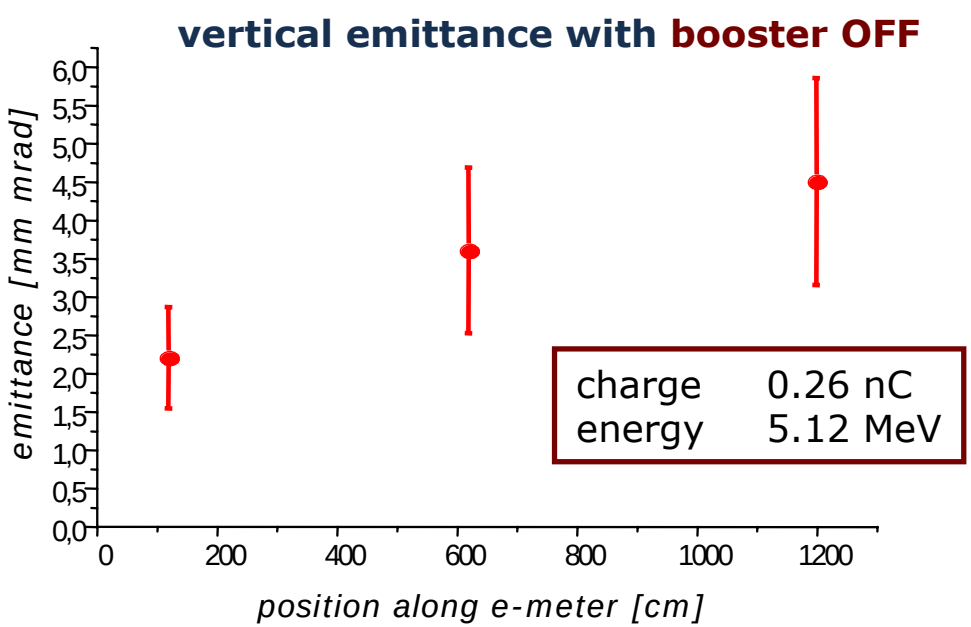
TEST @ PITZ (INFN&DESY-Zeuthen Teams)

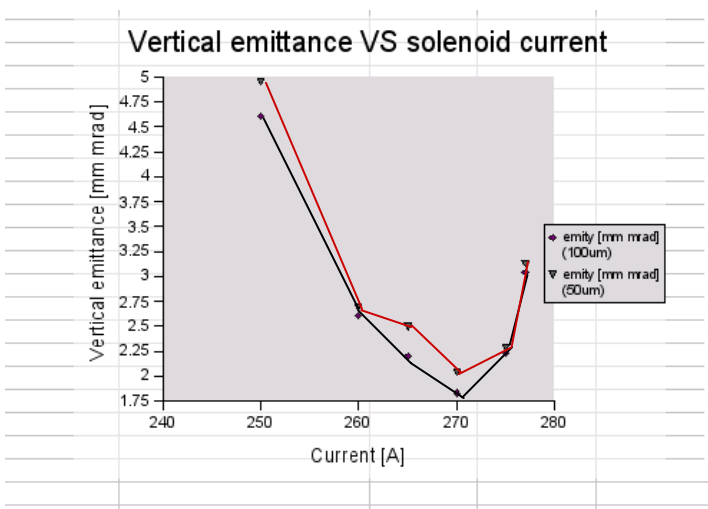


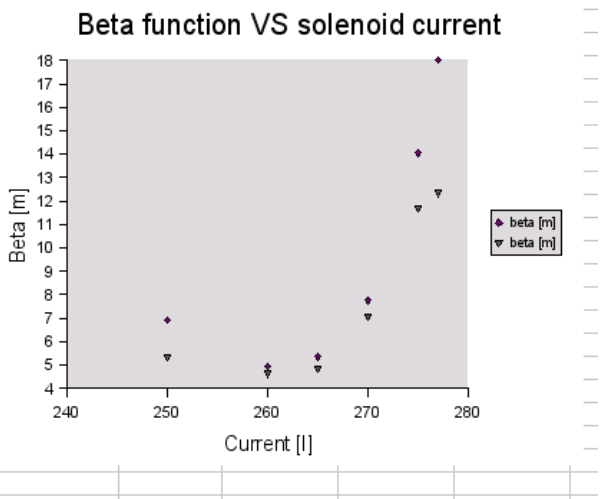
- A good chance to debug and test the system on the field.
- Cross-check results with PITZ EMSY measurements.
- Energy too high (with booster on) to have some changes of emittance vs. z

Measurements @ PITZ (INFN&DESY-Zeuthen teams)

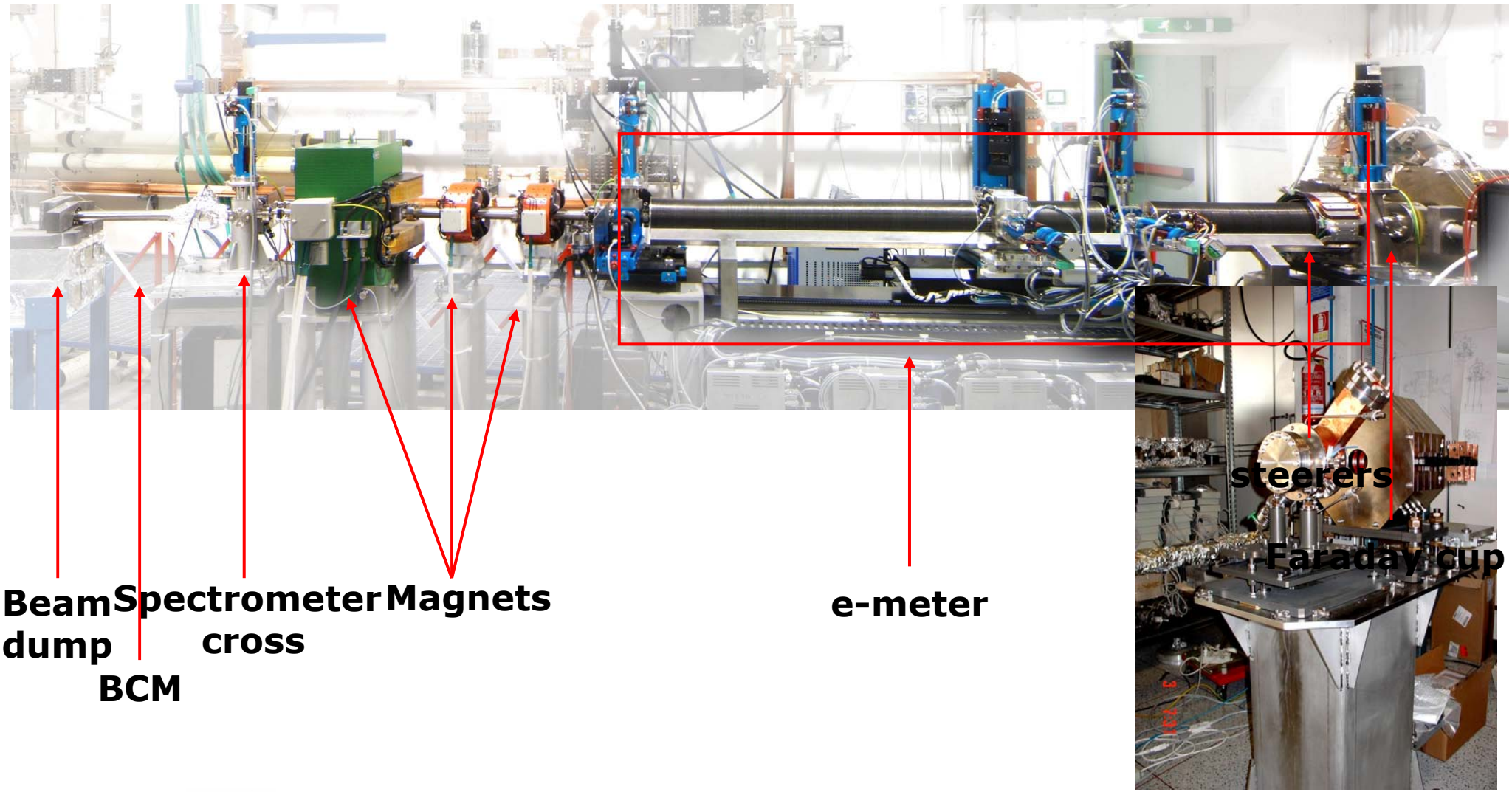








installation @ SPARC

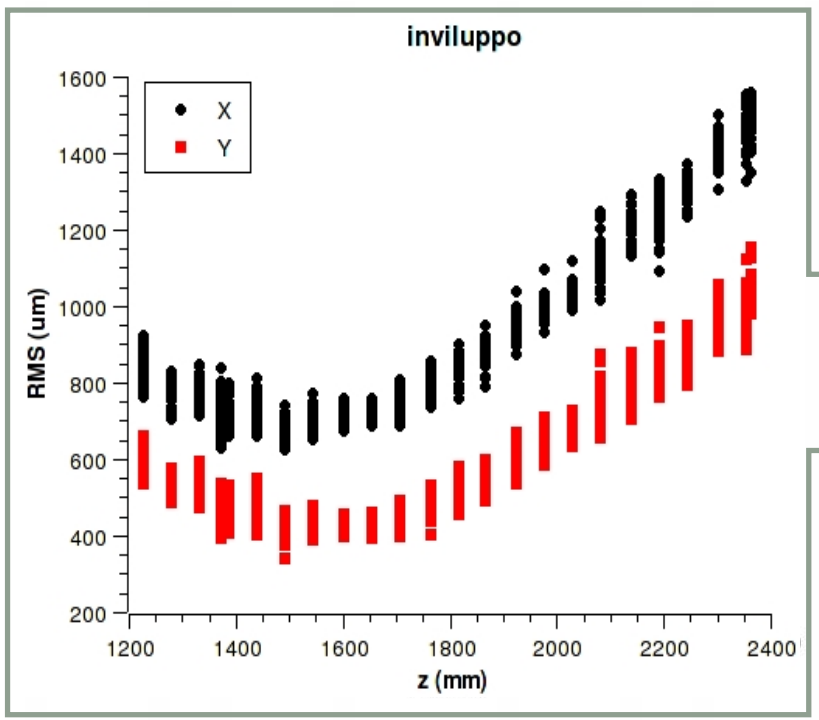


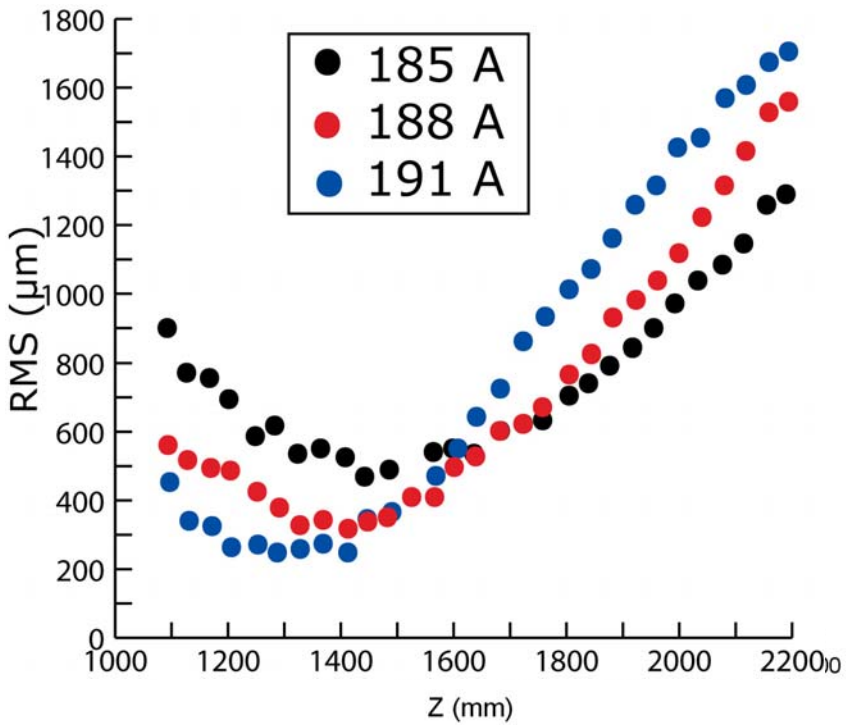
beam envelope vs. z (A.Cianchi)

it's the "level 0" measurement with e-meter

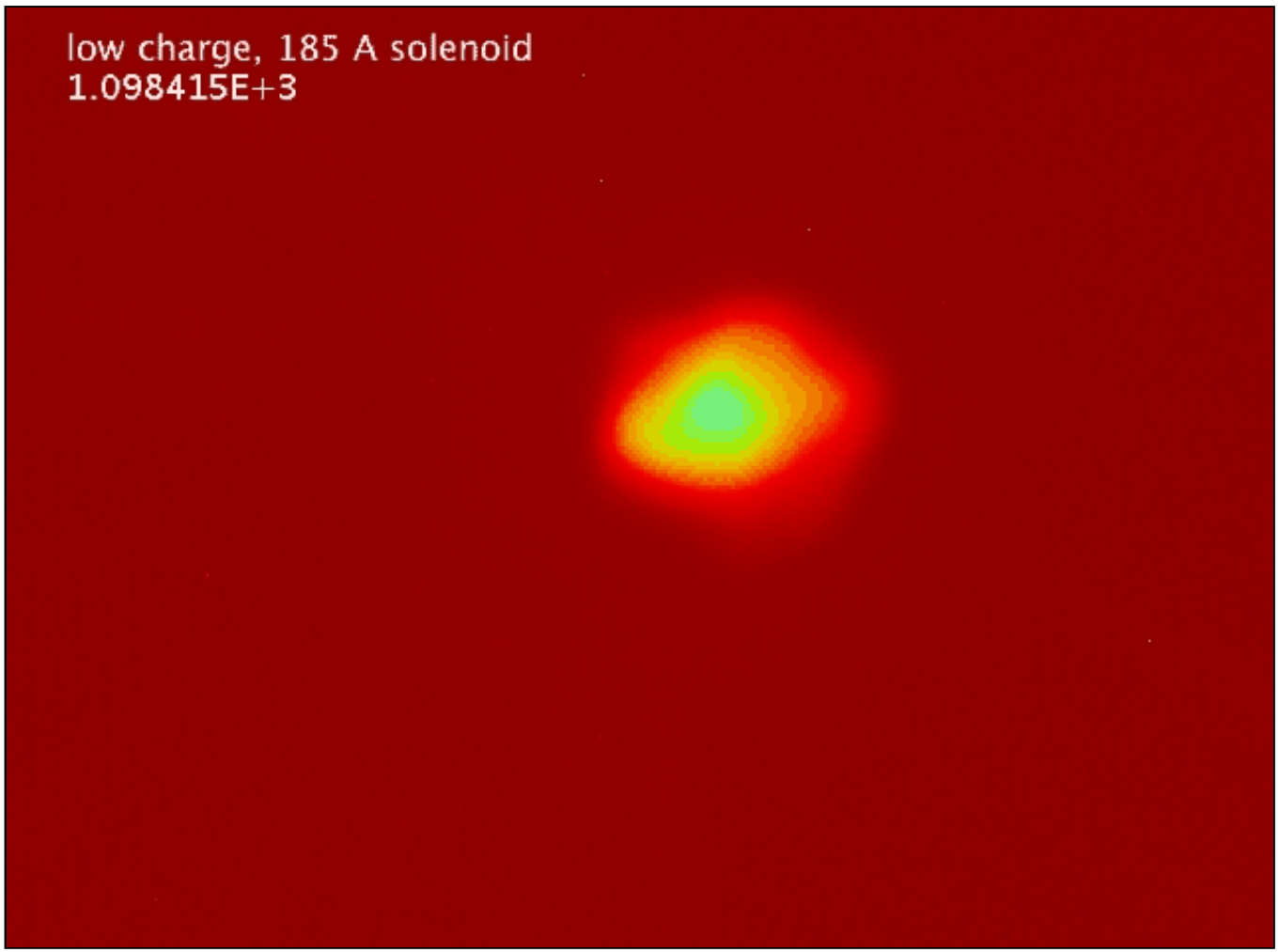
Provides information about:

- one click measurement
- complete scan takes ≈5 min.
- beam size ≈120 ÷ >1000 μm RMS
  - solenoid focusing
  - beam roundness
  - solenoid alignment
  - laser incidence angle



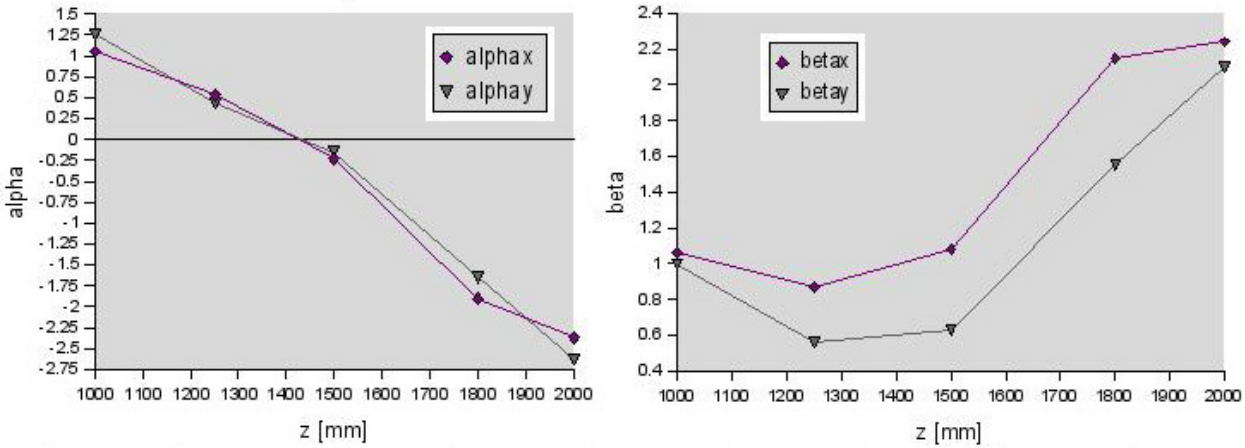


envelope.vs.z movie

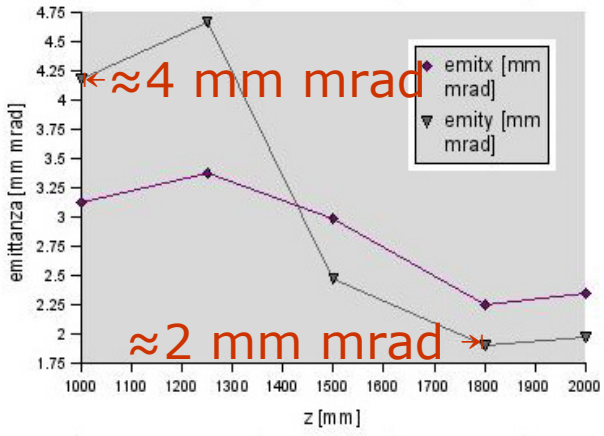


Results from emittance measurements

α and β along z



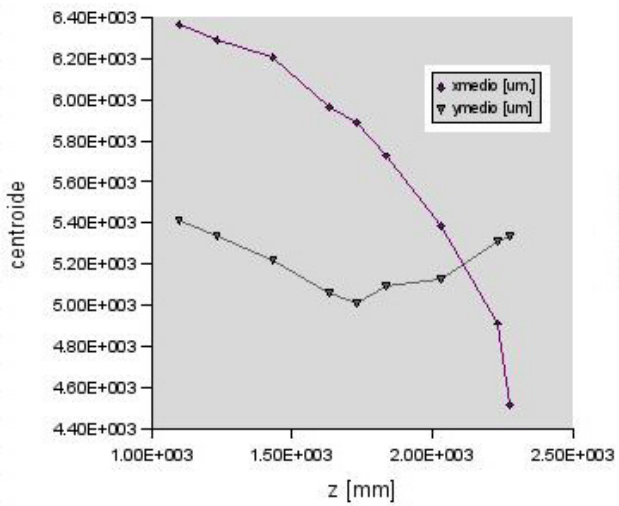
ε along z

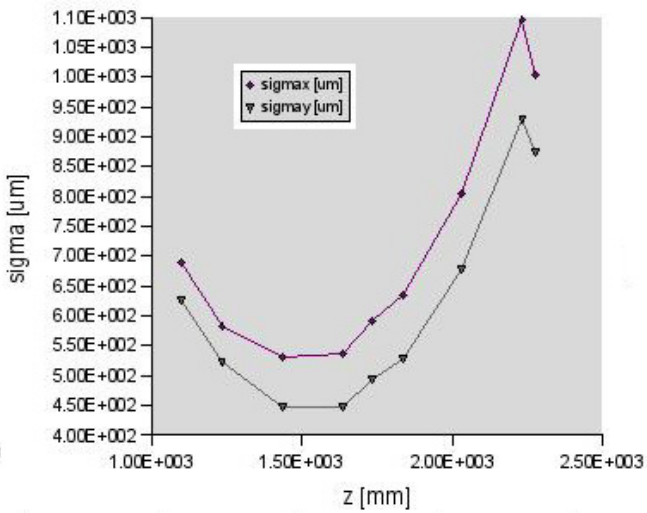


≈4 mm mrad

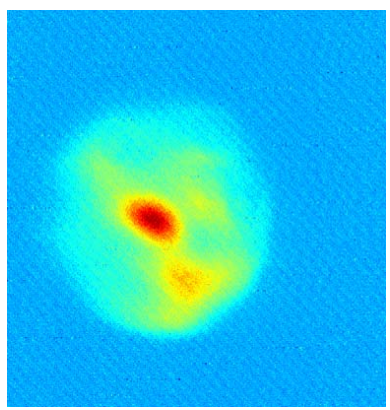
≈2 mm mrad

check beam alignment and size



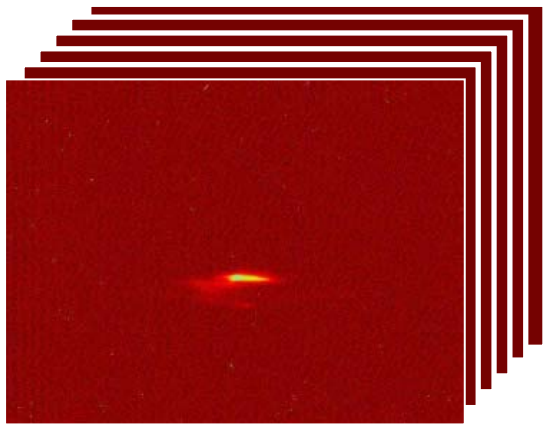


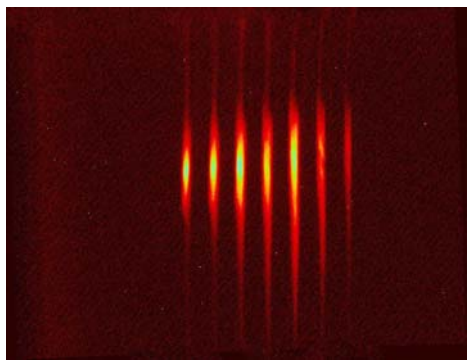
I_{sol} = 125 A
Q = 200 pC



experience from emittance measurements

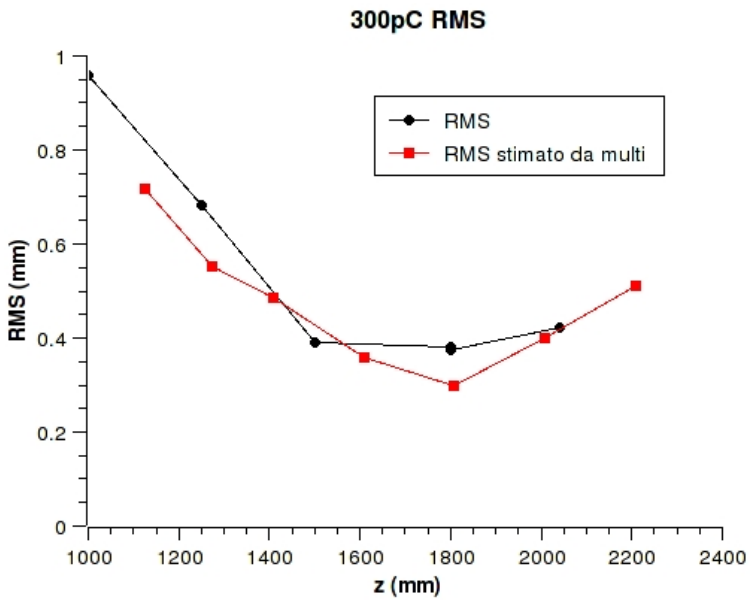
- We used both single-slit and multi-slits masks. Multi-slits is a single shot measurement (faster), single-slit gives more sampling points (more accurate - usually 9 beamlets are OK)





- Multi-slit is not preferable when beam is either converging or too small (because of fixed distance between slits produces low transverse sampling)
- Good agreement between single slit and multi slits measurements.

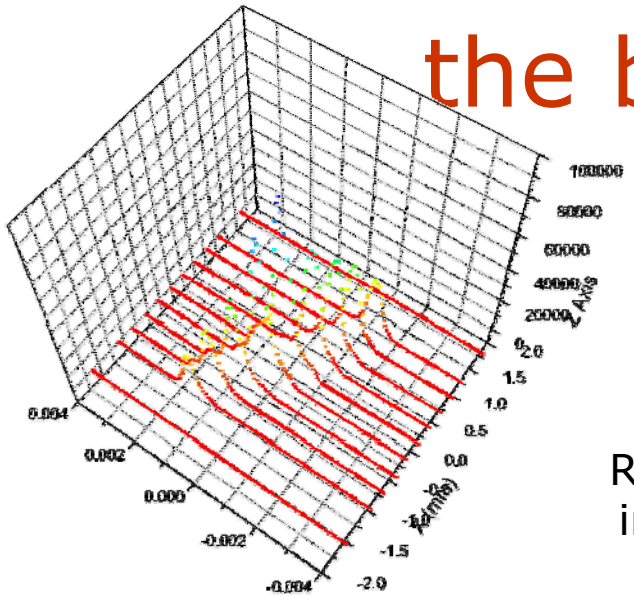
experience from emittance measurements



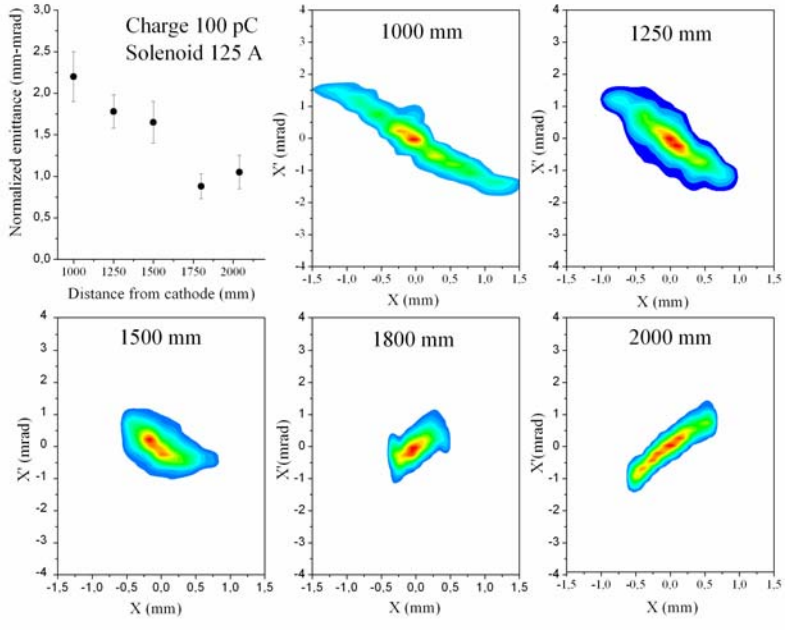
- We cross-check the results of emittance calculation comparing the measured RMS beam size (with a screen at slit-mask position) and the value obtained from Twiss parameters produced by the analysis routine.

Reconstruction of the beam phase space

(P.Musumeci)

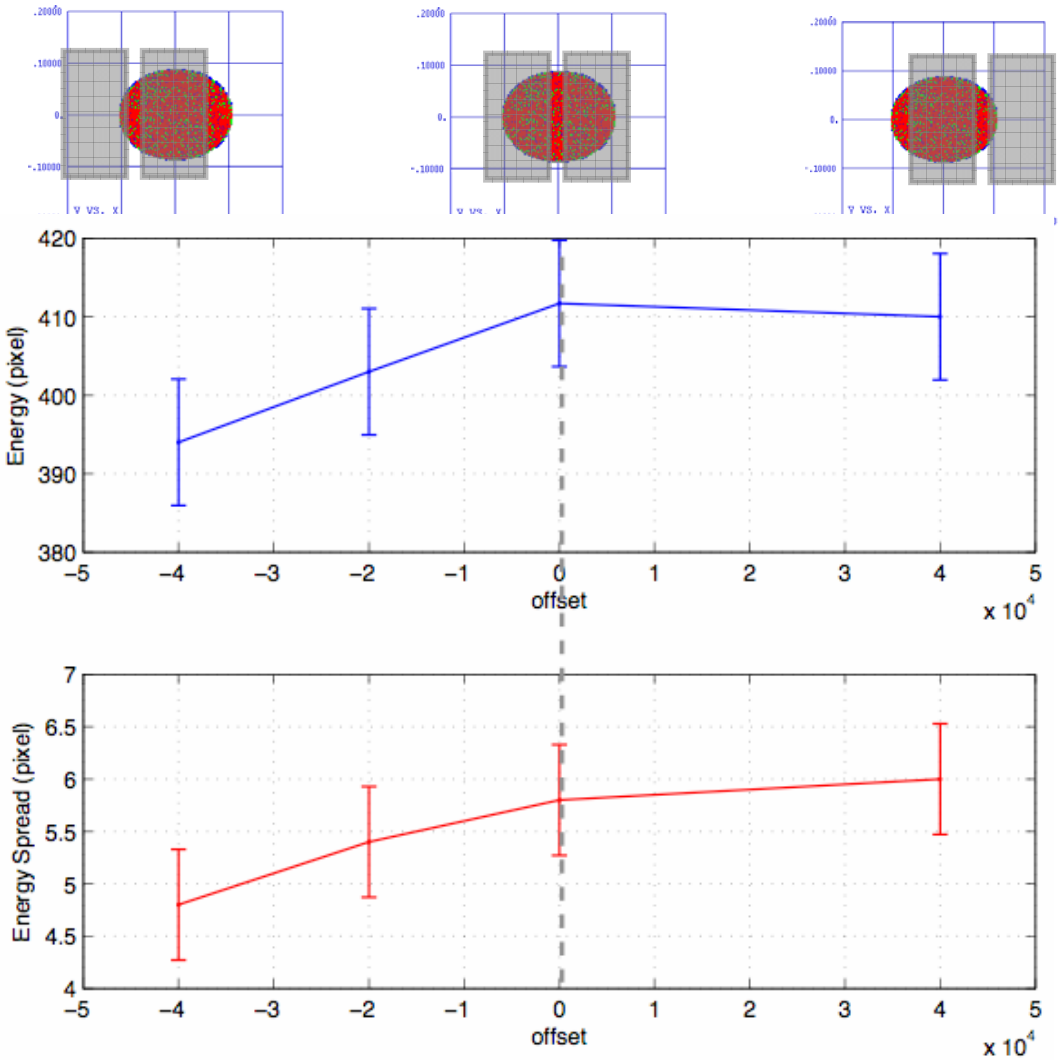


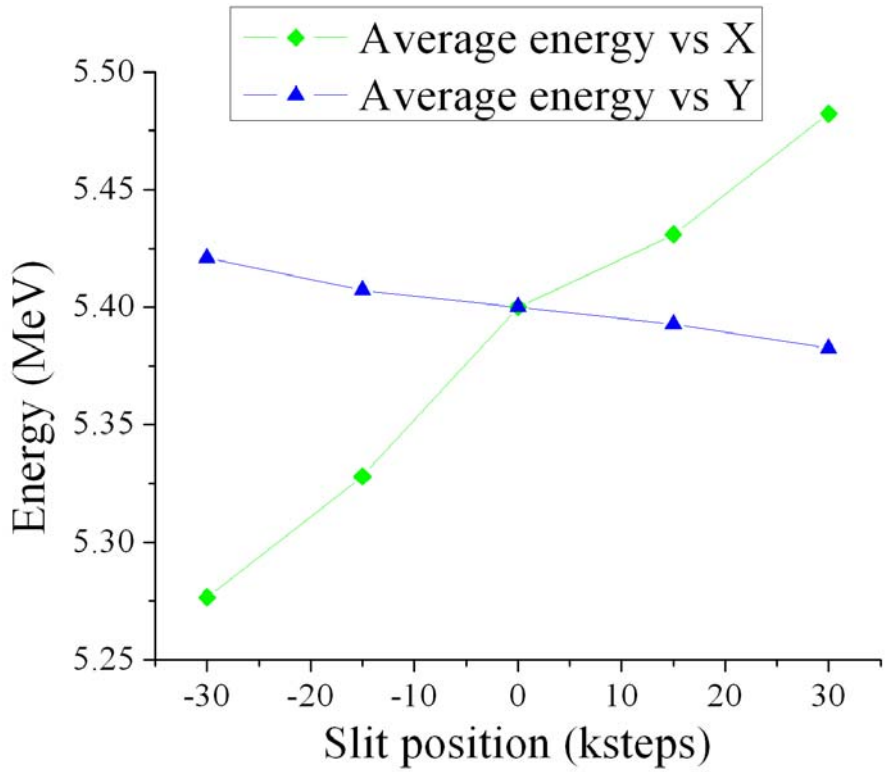
Renka-Cline method used to interpolate beamlets profile



x’ change along z evidences the space-charge dominated regime

beam energy vs.transverse position

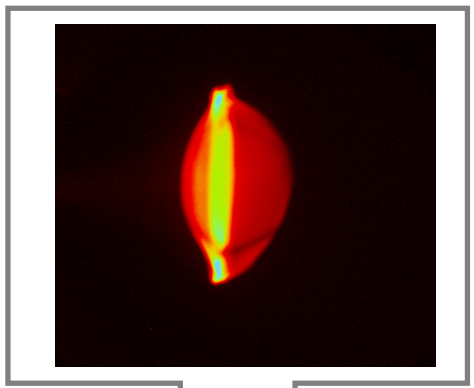




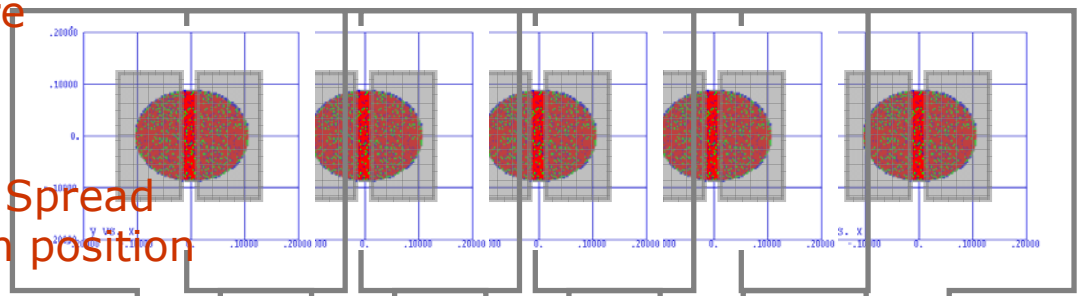
correlation between energy and transverse position is probably caused by laser incidence at 70° .

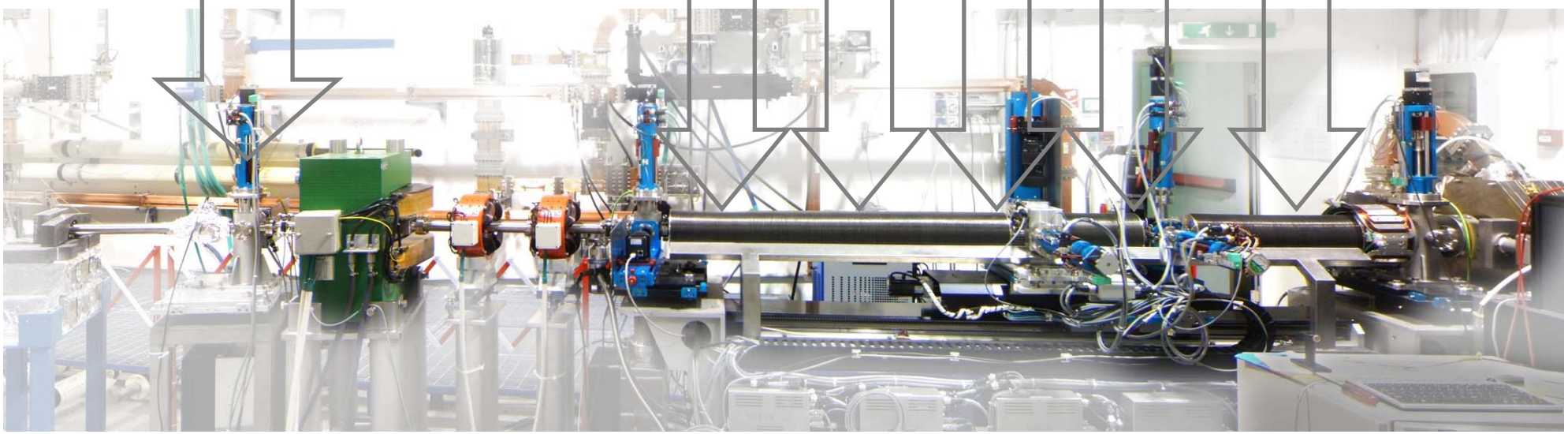
we now moved to normal incidence.

beam energy spread vs. Z



measure
Energy
and
Energy Spread
for each position

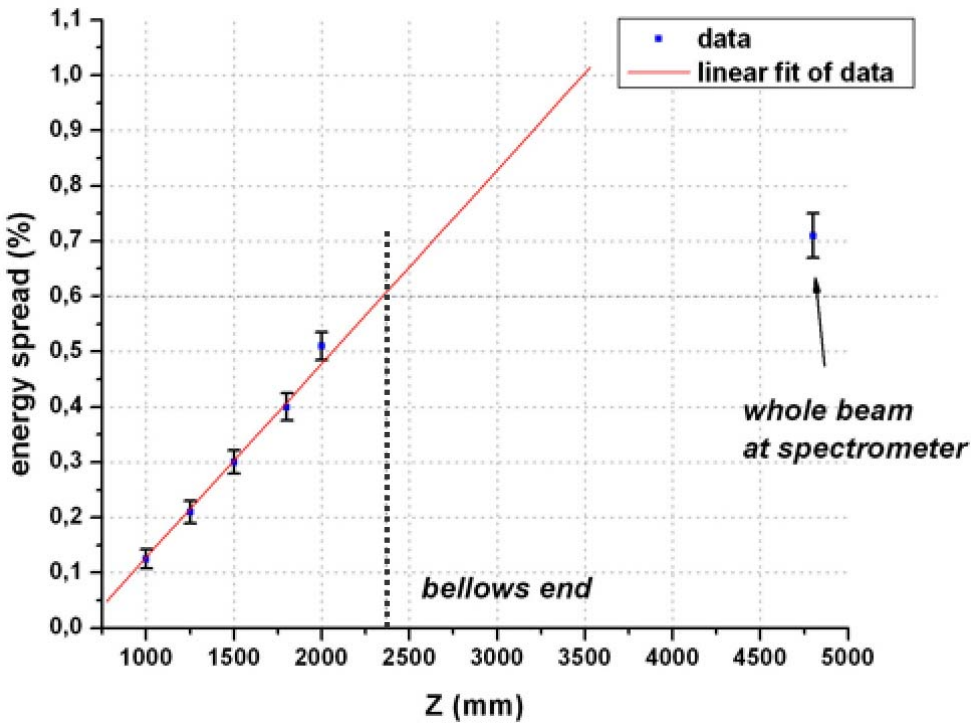


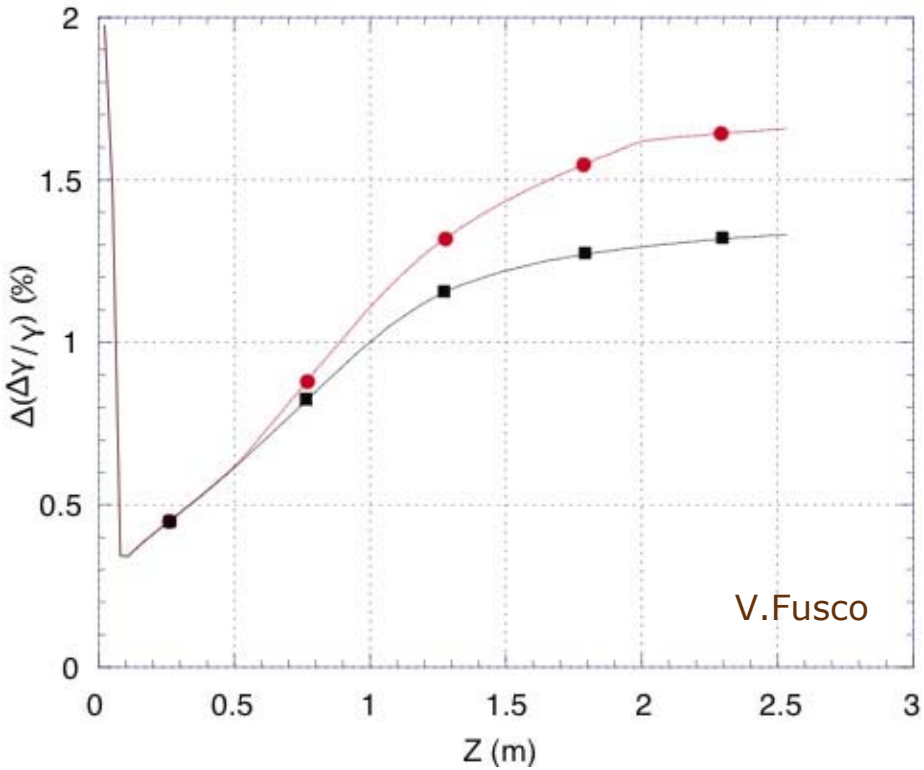


beam energy spread vs. Z

The central part of the beam is selected with the 50 um slit (beam charge is reduced down to ≈5%) and the energy spread is measured after the dipole moving the mask at different z.

Downstream the slit mask the beam propagates without SC and longitudinal WF and energy spread "freezes" after the cut.





check simulations against measurement (SPARC-BD group)

INPUT BEAM

Q = 700 pC

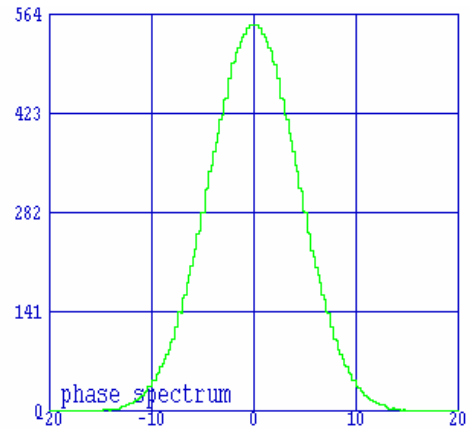
Energy = 5.14 MeV

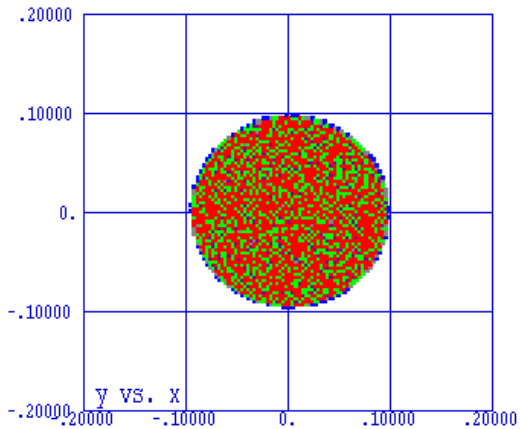
σ_z=4.35 psec

(gaussian longitudinal distribution)

$\sigma_x = \sigma_y \approx 0.5$ mm

(round beam)

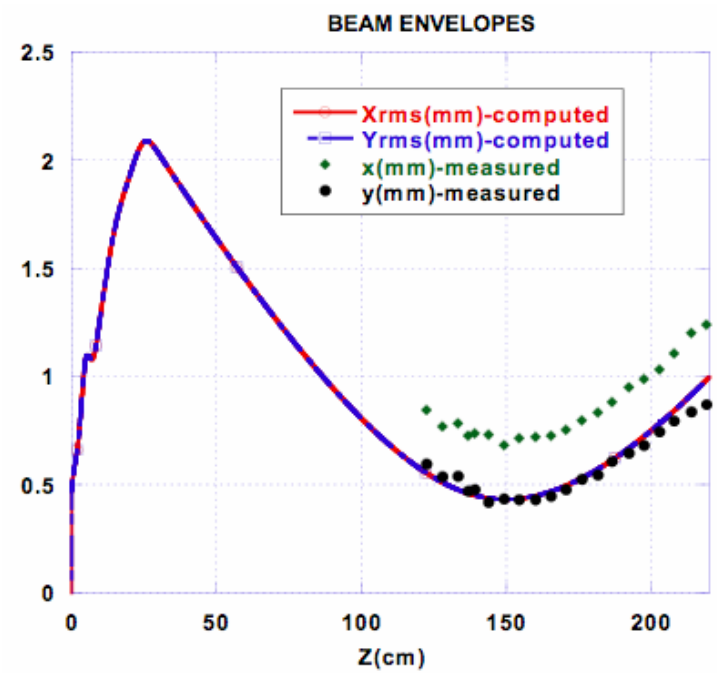


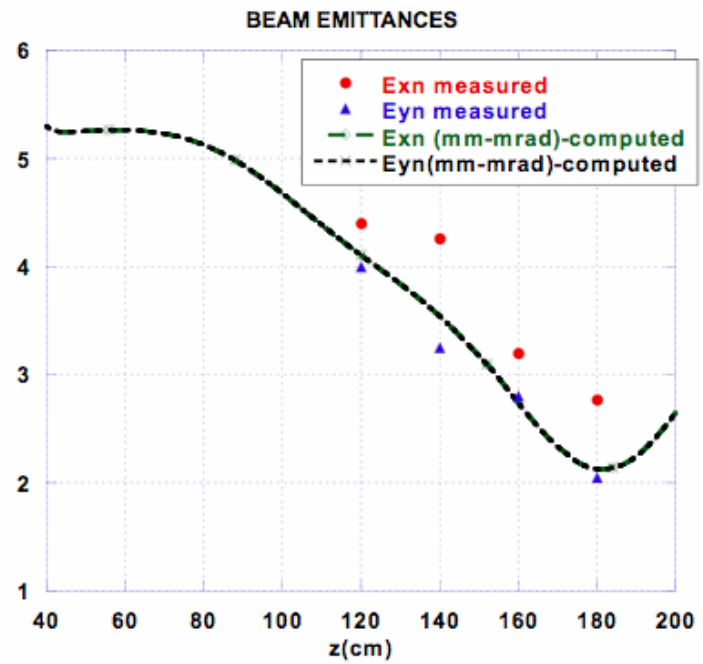


σ_y fits pretty well with meas.

the **same is for ε_y**

X-plane ?





compare measurements-computations

INPUT BEAM

Q = 700 pC

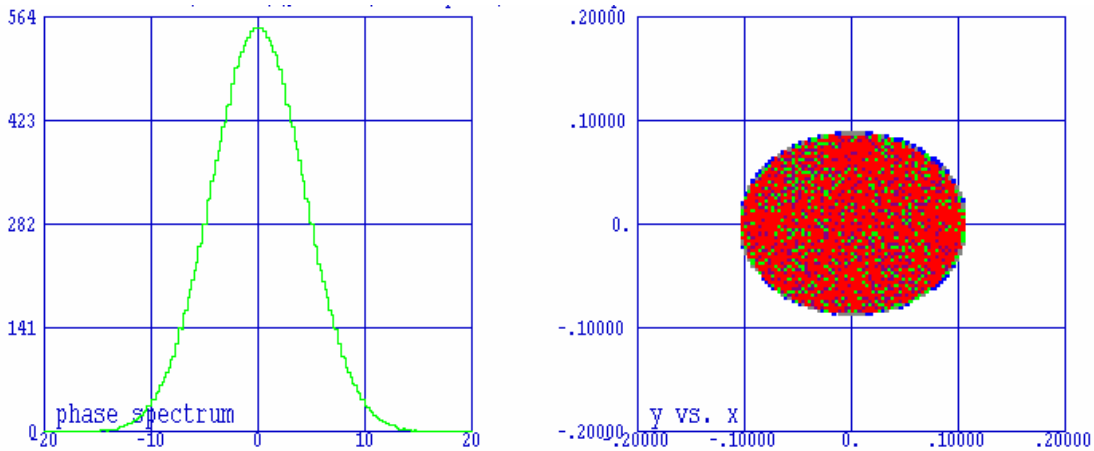
Energy = 5.14 MeV

σ_z=4.35 psec

(gaussian longitudinal distribution)

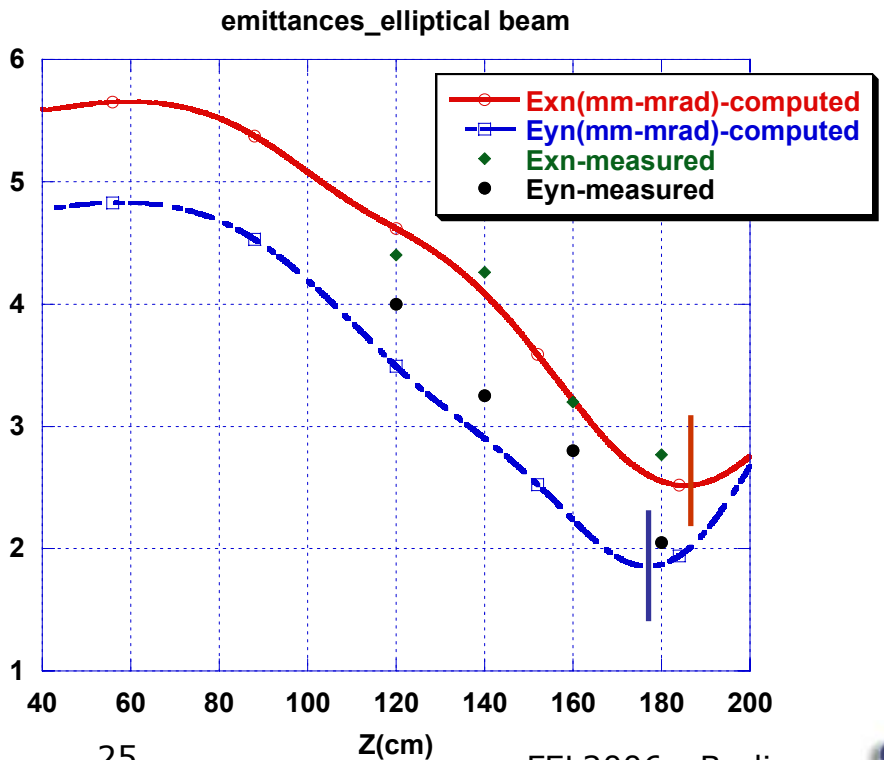
σ_x / σ_y = 1.2

(elliptical beam)

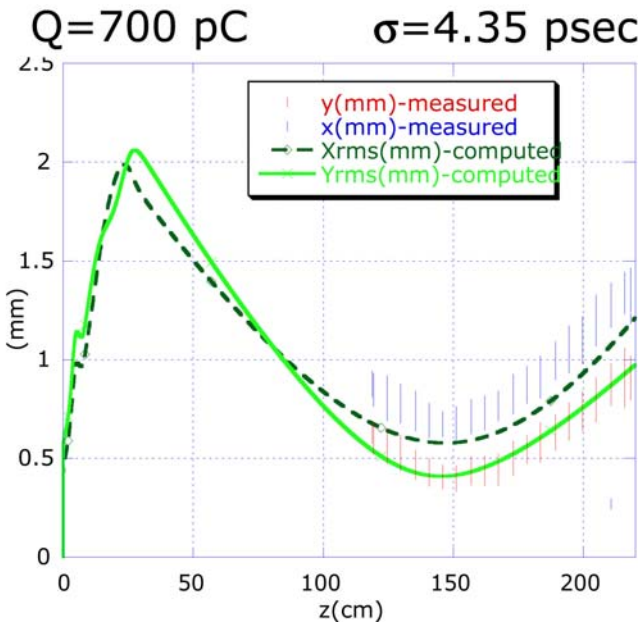


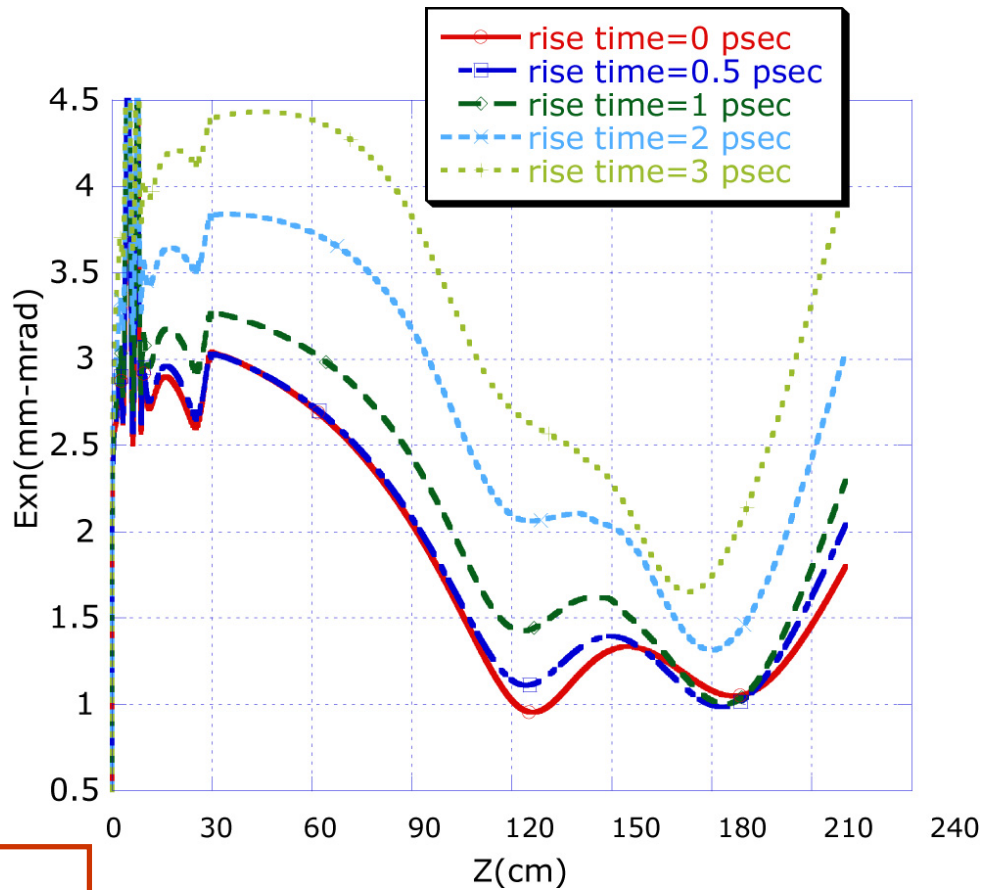
now **σ_x fits better** (though we lost something on the y-plane)

Moreover ε_x and ε_y should have minima with different z:
we can check both if we increase focusing to move minima inside the e-meter z-range.



compare measurements-computations





dependence on longitudinal rise time

Conclusion

- more systematic measurements of SPARC the photo-injector are scheduled for the next weeks. Comparisons made with simulations look promising.

- probably we are still at the beginning in exploring the possible applications of the movable emittance-meter

- more than a simple improvement over more conventional emittance diagnostic this device defines a new strategy for characterizing high performance photo-injectors as it allows a detailed analysis of the beam dynamic over a section of the accelerator where crucial beam shaping takes place