COMMISSIONING OF THE SPARC PHOTO-INJECTOR

Speaker: Daniele Filippetto

Authors: SPARC team @ lnf-INFN

Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

PRESENTATION OVERVIEW

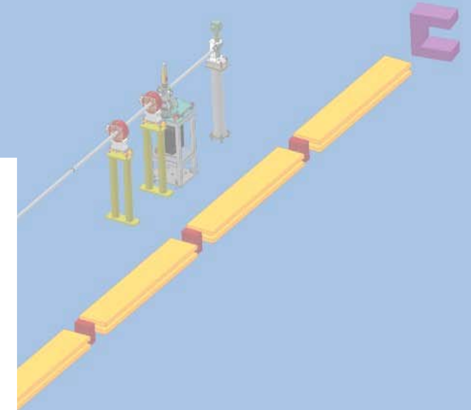
- *INTRODUCTION*
  - Sparc project
  - installation status
  - laser system
  - SPARC hall
- *LASER SYSTEM CHARACTERIZATION*
  - longitudinal measurements
  - transverse uniformity & QE
  - tilt correction
  - Laser synchronization
- *e- BEAM CHARACTERIZATION*
  - diagnostic description
  - longitudinal charact.
  - transverse charact.
  - best results and future plans

Daniele.Filippetto@lnf.infn.it

SPARC 3D CAD model

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

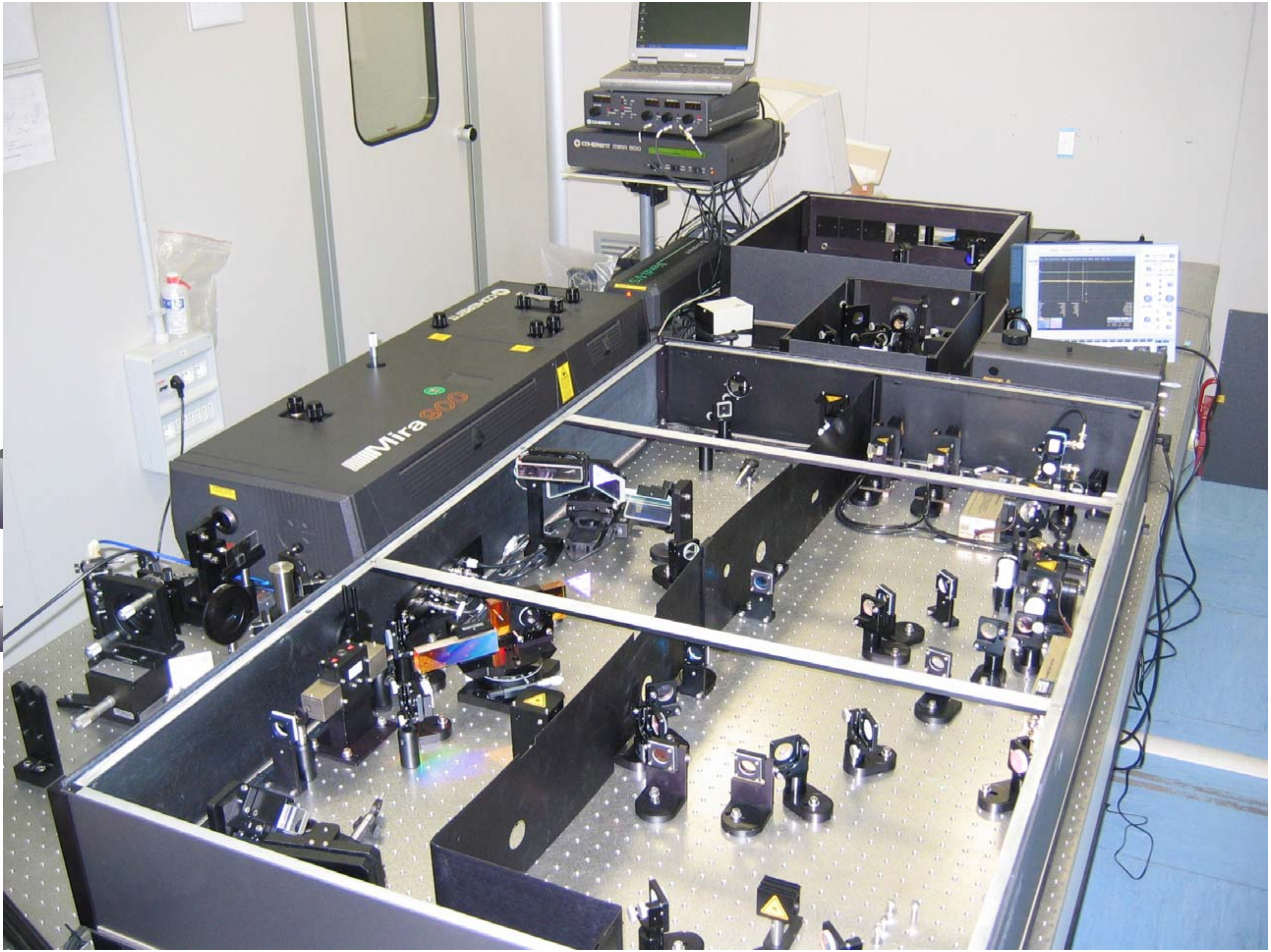
SPARC parameters



ELECTRON BEAM	
Electron Beam Energy (MeV)	155
Bunch charge (nC)	**1.1**
Repetition rate (Hz)	1-10
Cathode peak field (MV/m)	120
Peak solenoid field @ 0.19 m (T)	0.273
Photocathode spot size (mm, hard edge radius)	**1.13**
Central RF launch phase (RF deg)	**33**
Laser pulse duration, flat top (ps)	**10**
Laser pulse rise time (ps) 10%→90%	1
Bunch energy @ gun exit (MeV)	5.6
Bunch peak current @ linac exit (A) (50% beam fraction)	**100**
Rms normalized transverse emittance @ linac exit (mm-mrad); includes thermal comp. (0.3)	**< 2**
Rms slice norm. emittance (300 μm slice)	**< 1**
Rms longitudinal emittance (deg.keV)	1000
Rms total correlated energy spread (%)	**0.2**
Rms incorrelated energy spread (%)	**0.06**
Rms beam spot size @ linac exit (mm)	0.4
Rms bunch length @ linac exit (mm)	1

$$\boxed{B_{\perp} = 100 \ A / \mu m^{2}}$$

Sparc Ti:Sa laser system



Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

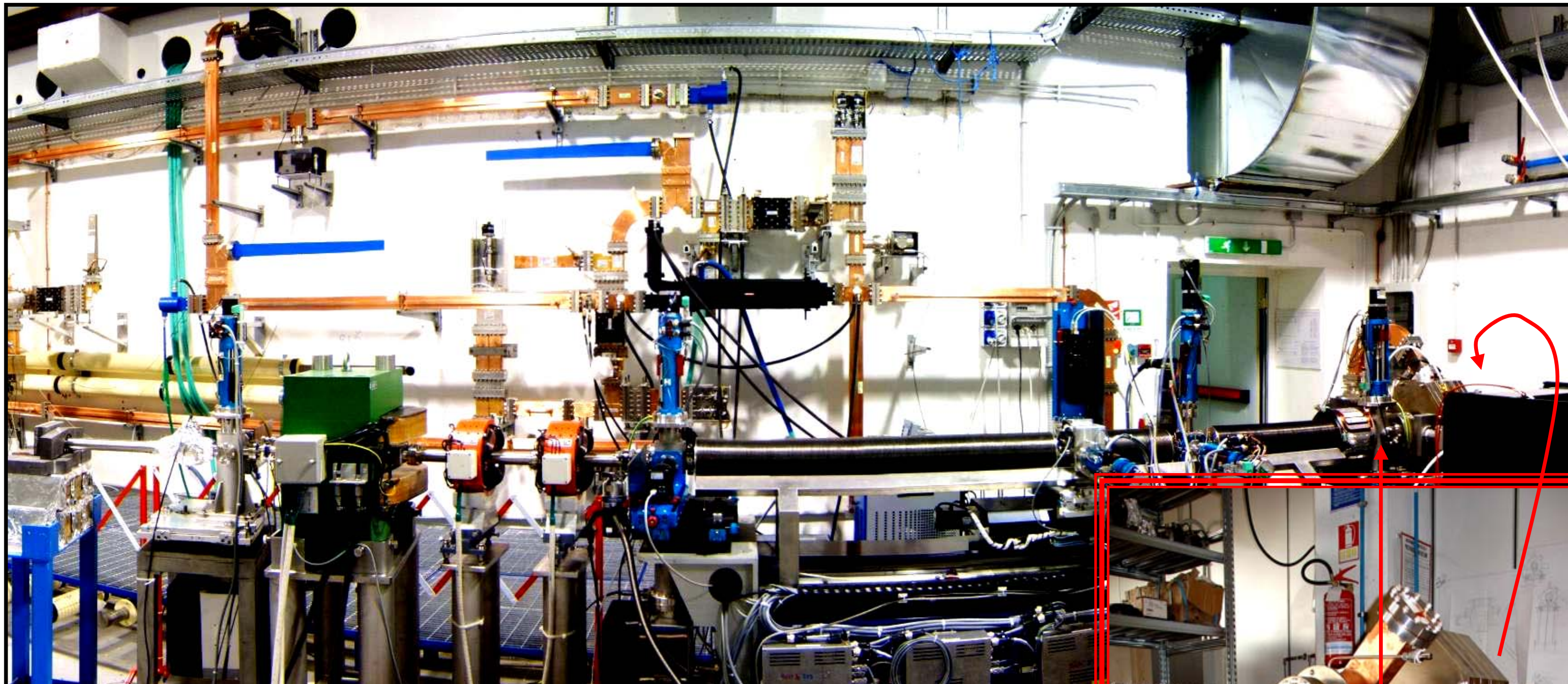
Modulators and klystrons

Present situation:

- Klystron, waveguides and gun conditioning ended
- 120 MV/m in the gun, 10 Hz
- E= 5.5MeV e-beam

Daniele.Filippetto@lnf.infn.it

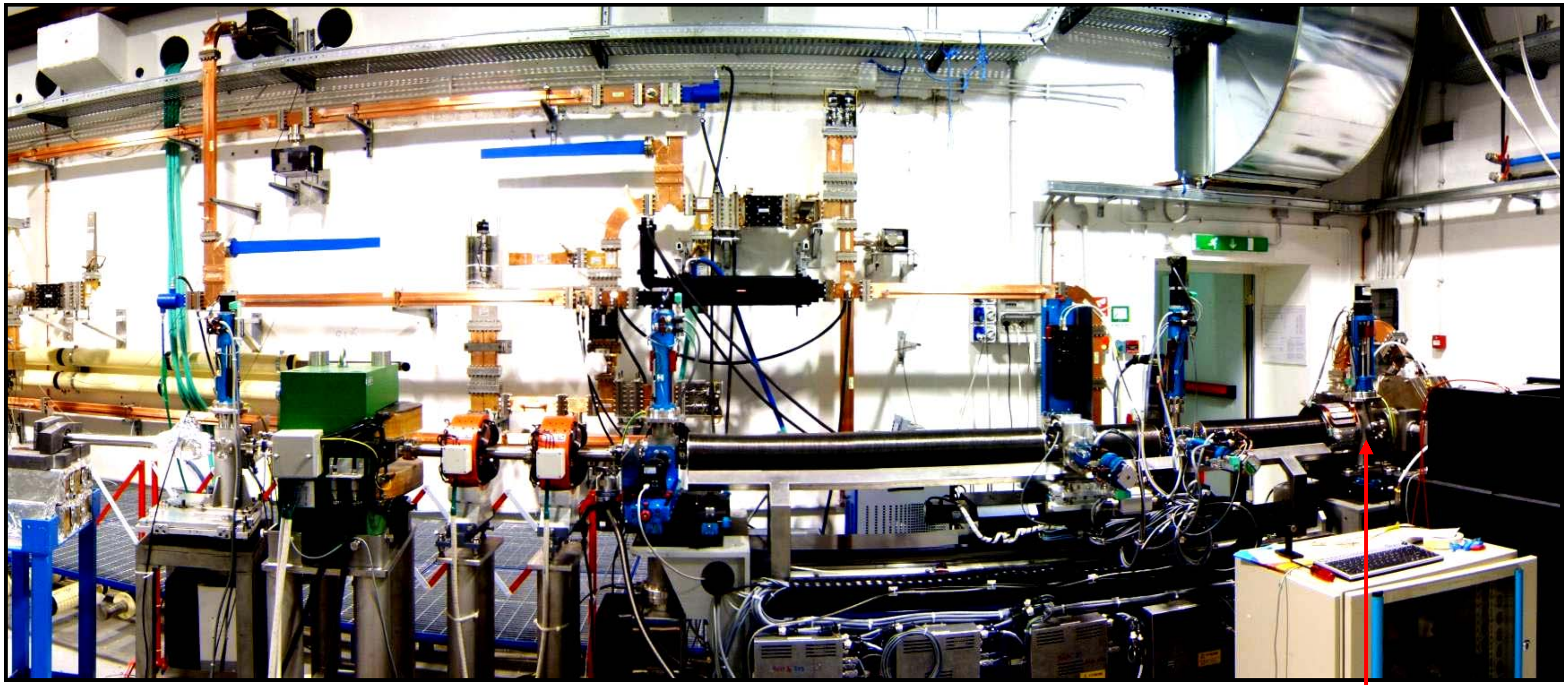
Sparc hall



Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

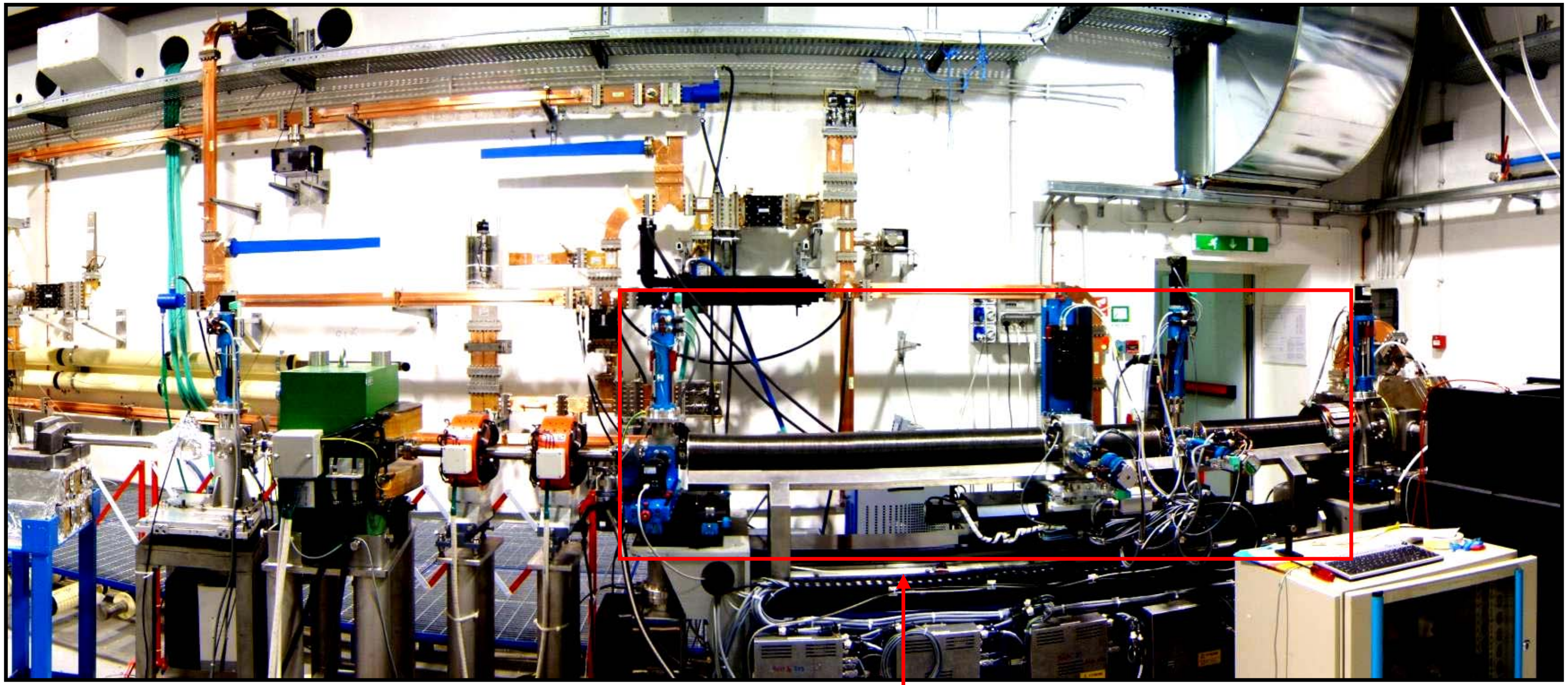
Sparc hall



Faraday cup

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

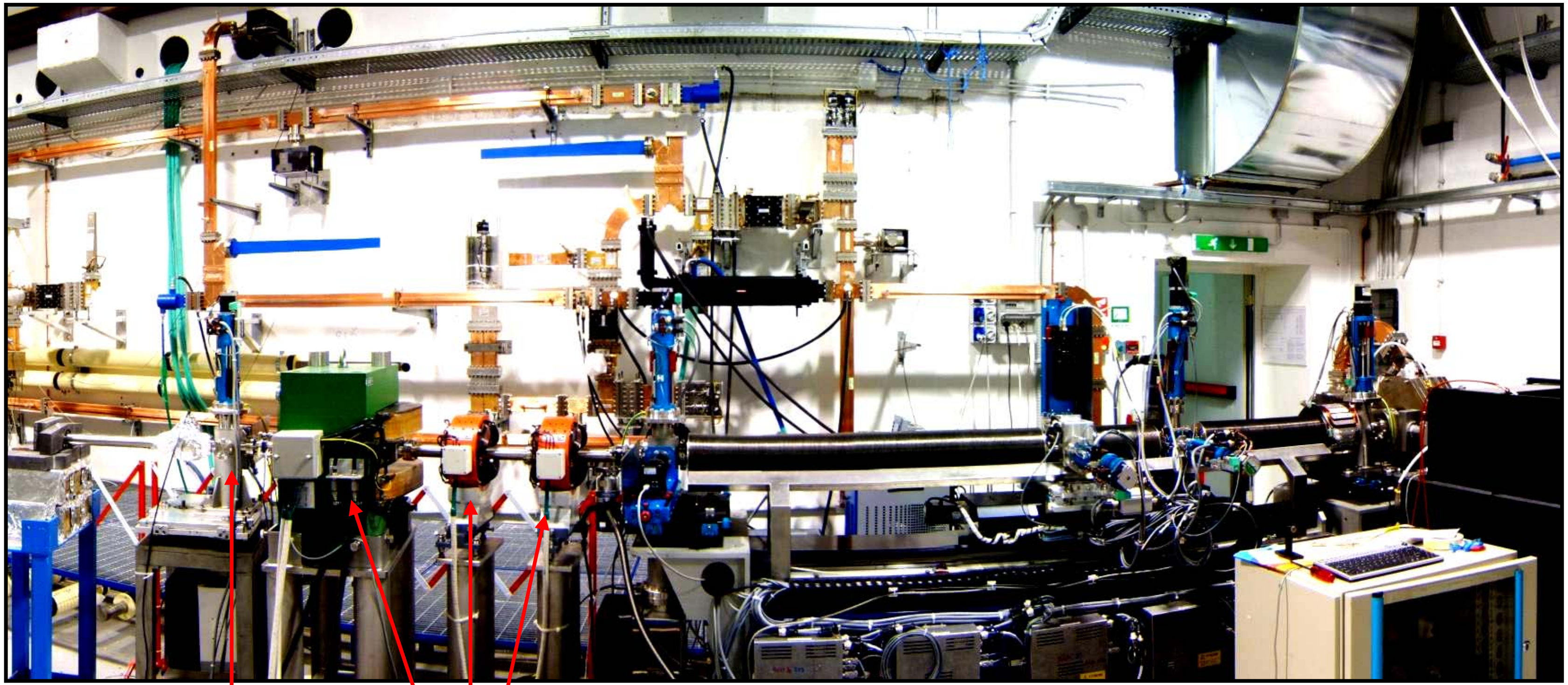
Sparc hall



E-meter

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

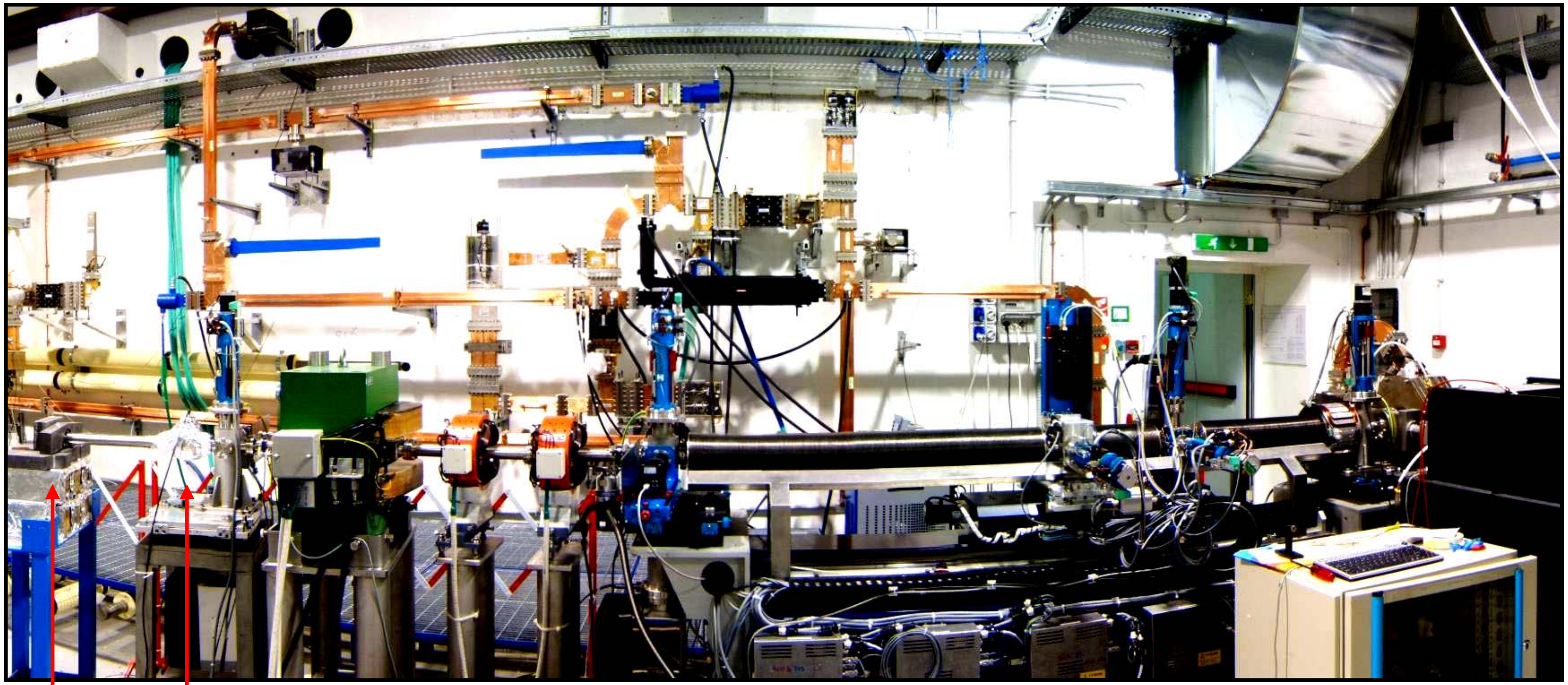
Sparc hall



Spectrometer Magnets
cross

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Sparc hall



Beam dump BCM

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

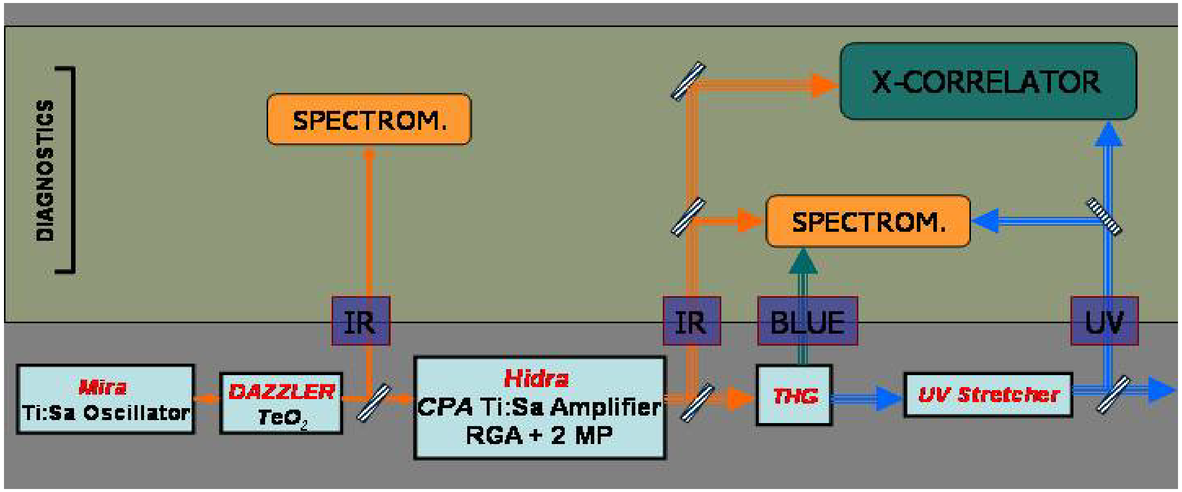
PRESENTATION OVERVIEW

- *INTRODUCTION*
  - Sparc project
  - installation status
  - laser system
  - SPARC hall
- *LASER SYSTEM*
  - longitudinal measurements
  - transverse uniformity & QE
  - tilt correction
  - Laser synchronization
- *e- BEAM CHARACTERIZATION*
  - diagnostic description
  - longitudinal charact.
  - transverse charact.
  - best results and future plans

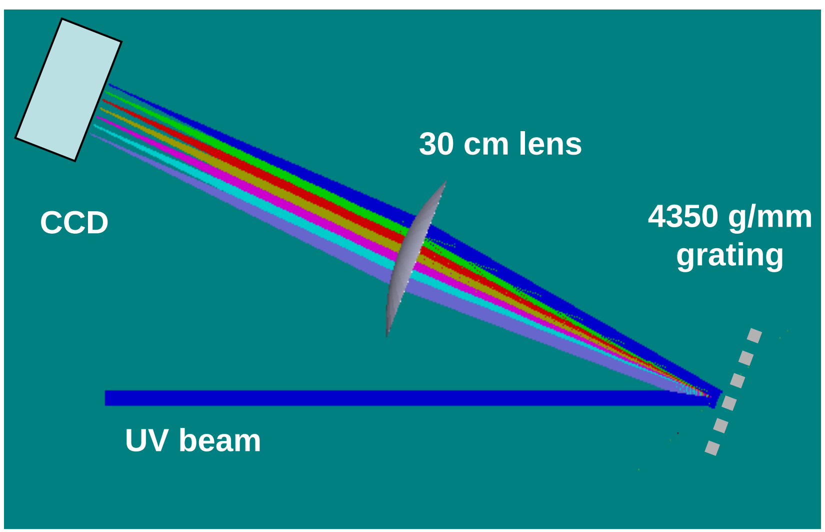
Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

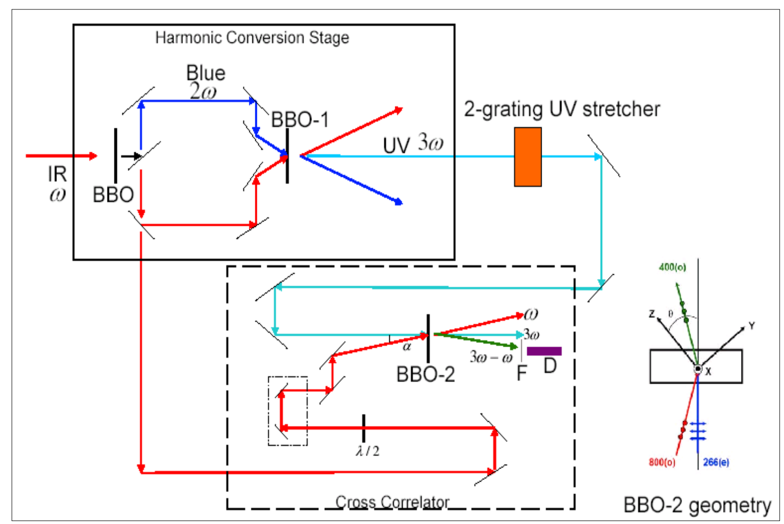
Longitudinal diagnostic



0.02 nm resolution spectrometer



200 fs resolution UV xcorrelator



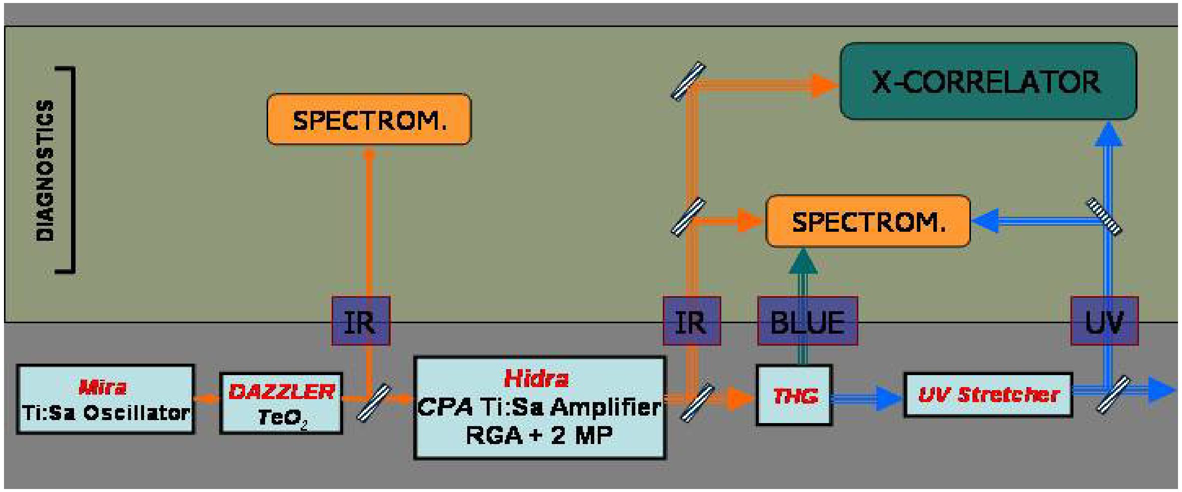
Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

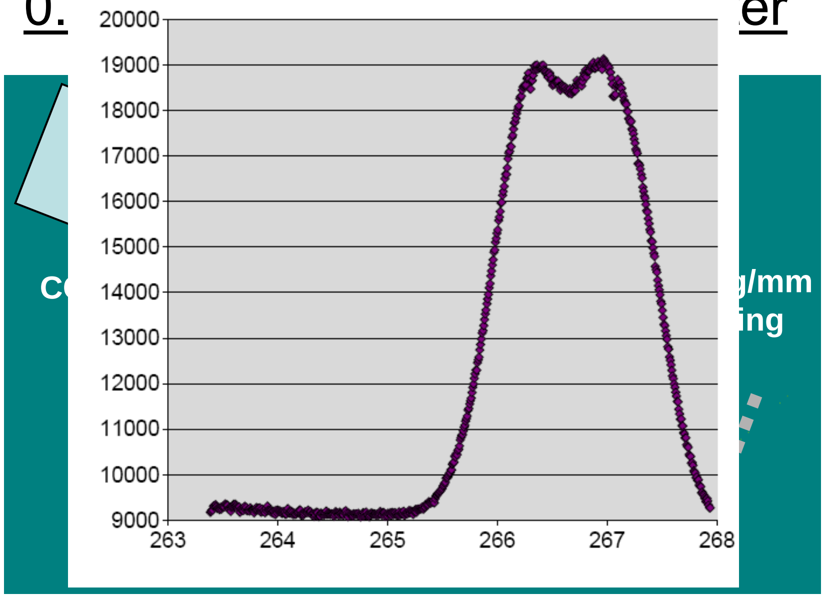
Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

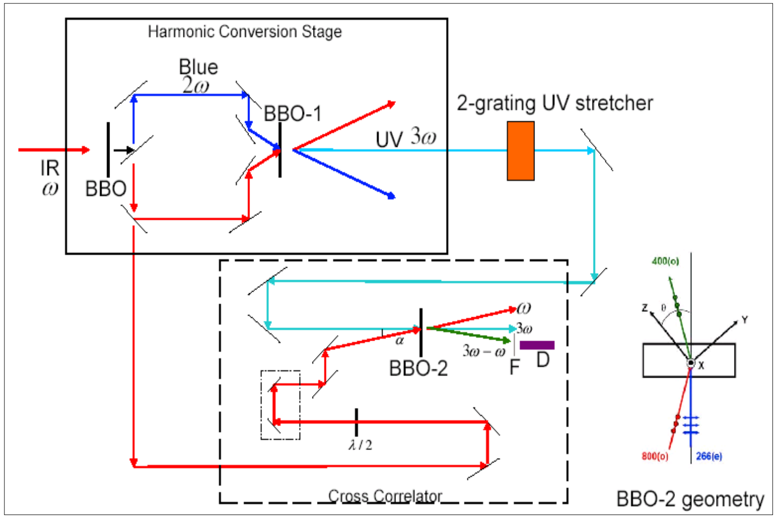
Longitudinal diagnostic



0.02 nm resolution spectrometer

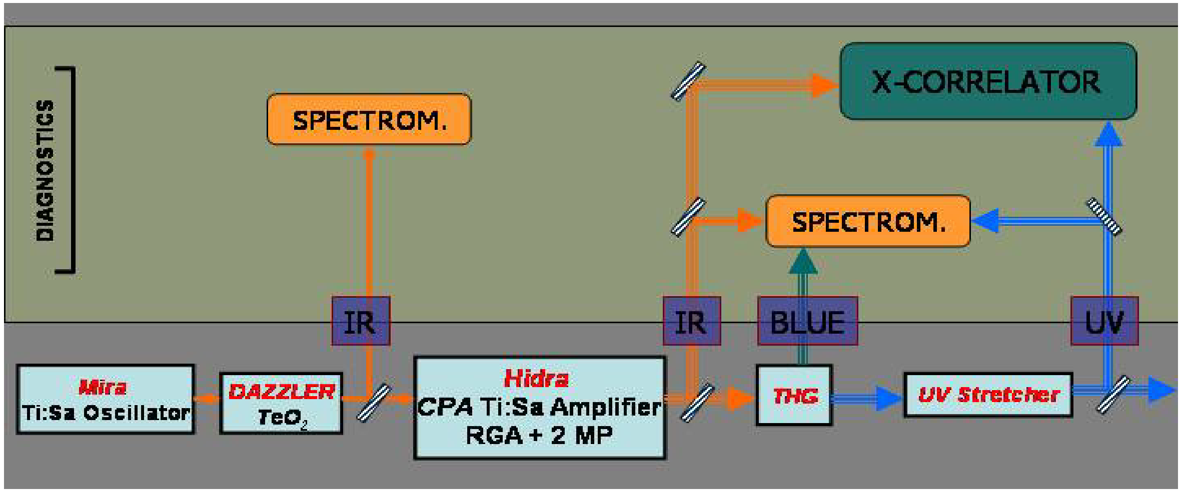


200 fs resolution UV xcorrelator

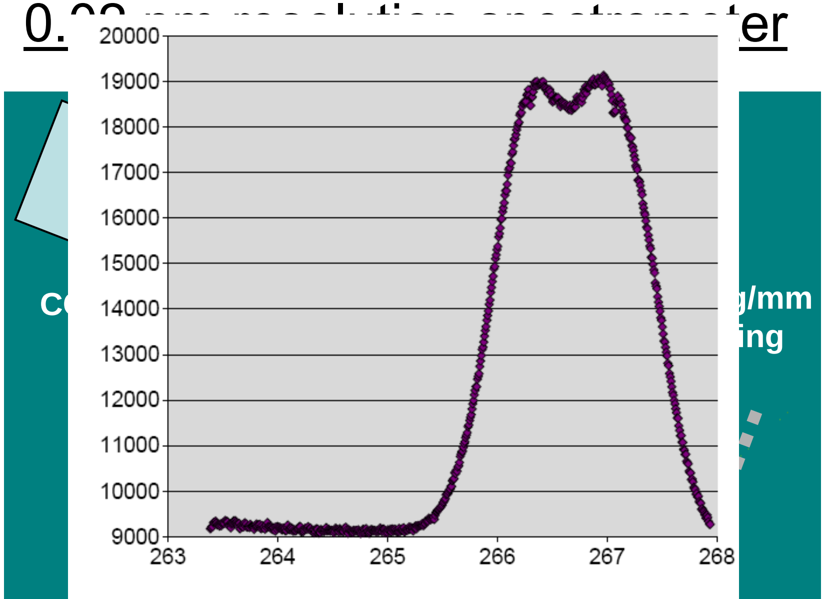


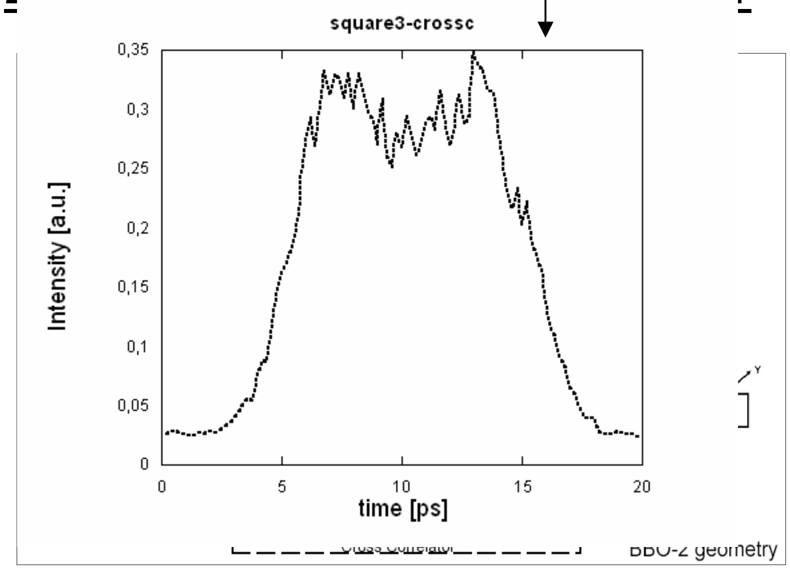
Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Longitudinal diagnostic



With longitudinal pulse shaping, but not optimized

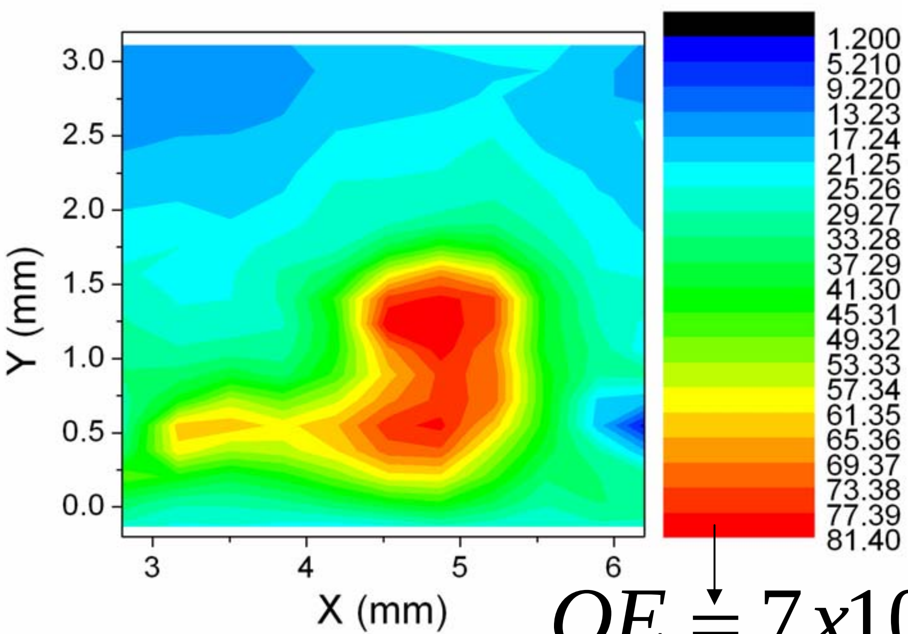




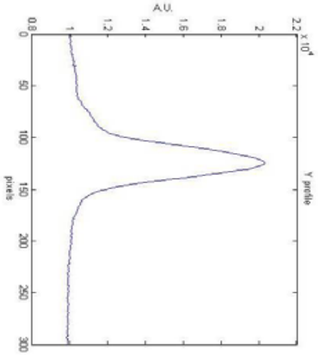
QE & transverse uniformity

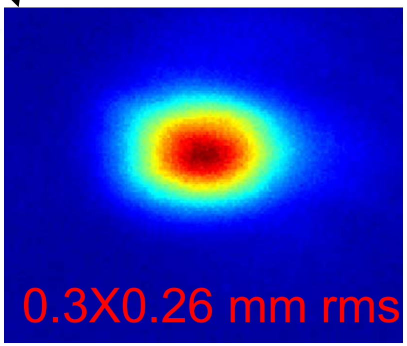
Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

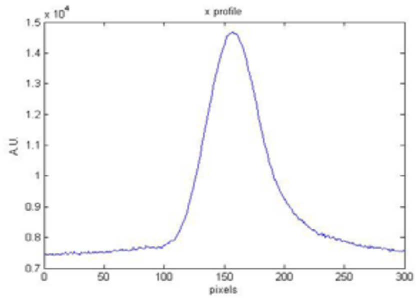
- In order to have uniform density beam charge distribution a uniform QE and a uniform transv. profile are needed
- QE map done by scanning cathode surface with a small beam (100 um) and looking at the charge on the faraday cup.
- Red zone is the higher QE zone, and it's also the actual working point, so cathode has been cleaned during operations.
- To run at higher charge we need bigger laser spot sizes → LASER CLEANING
- Lot of work has been done on transverse laser uniformity
- Charge is variable (min=50pC , max=1.5nC)



$$QE \doteq 7x10^{-5}$$

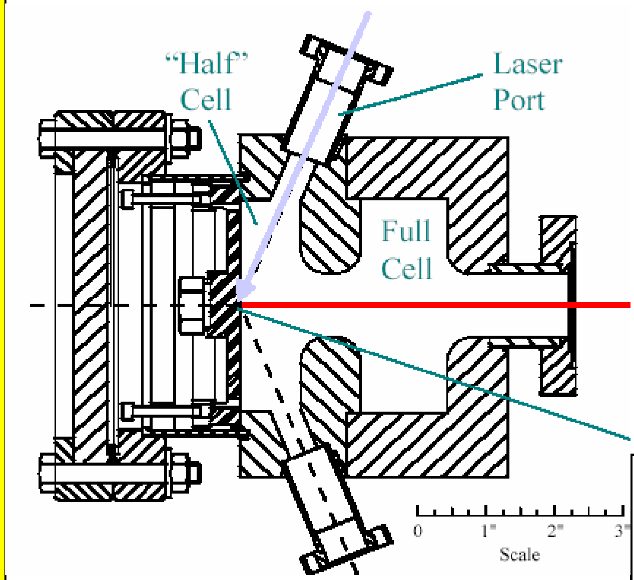




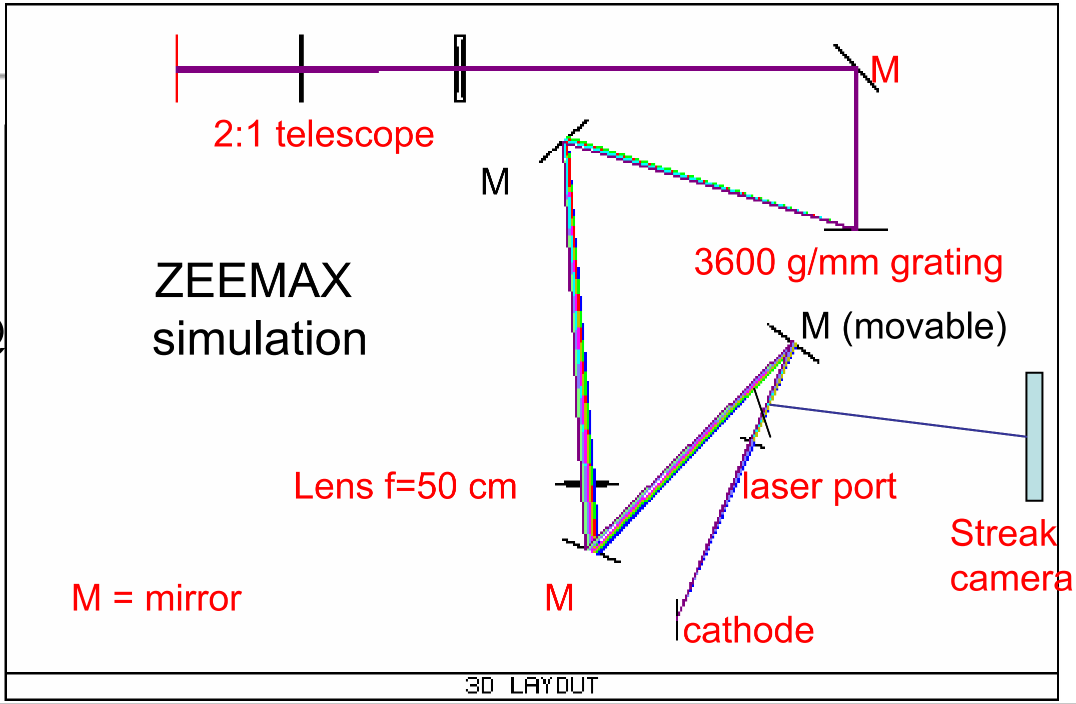


72 deg. tilt correction

Two unwanted effects :
- elliptical spot on the cathode
- Time skew

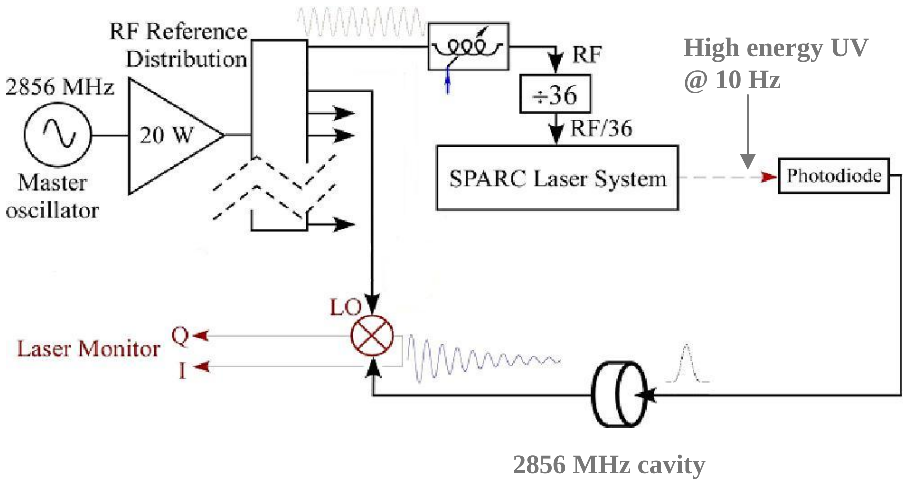


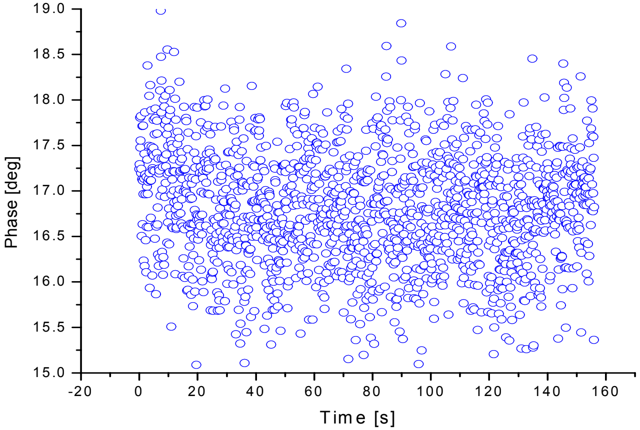
- 72 deg tilted wavefront after grating
- Lens to image the beam @ grating exit to cathode

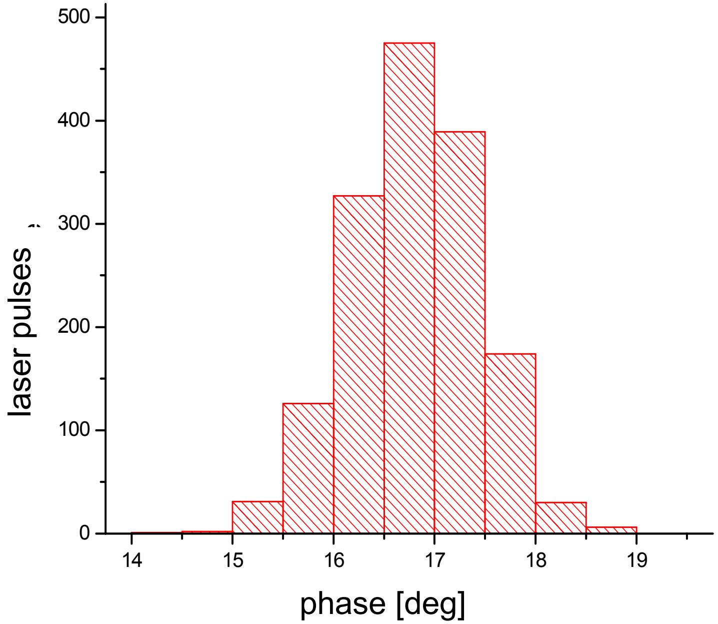


Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Synchronization







On time scale of few minutes (enough to see possible drifts) the phase jitter is within σ_{RMS} 0.63 deg ***0.61 ps***

Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Present situation

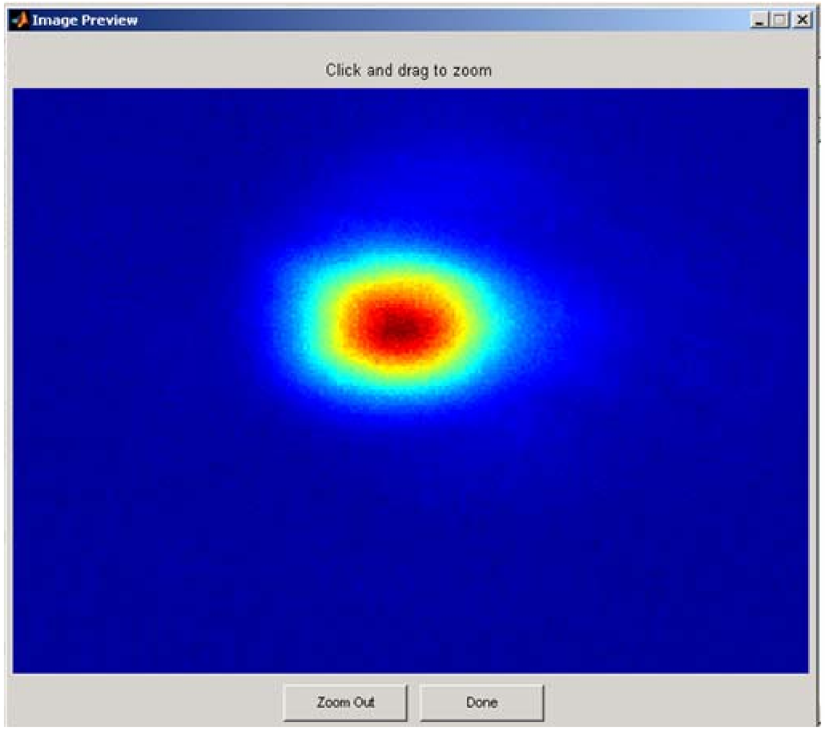
- Energy ok
- Gaussian transverse and longitudinal profile (dazzler in autocompensation mode)
- tilt compensation works but critical

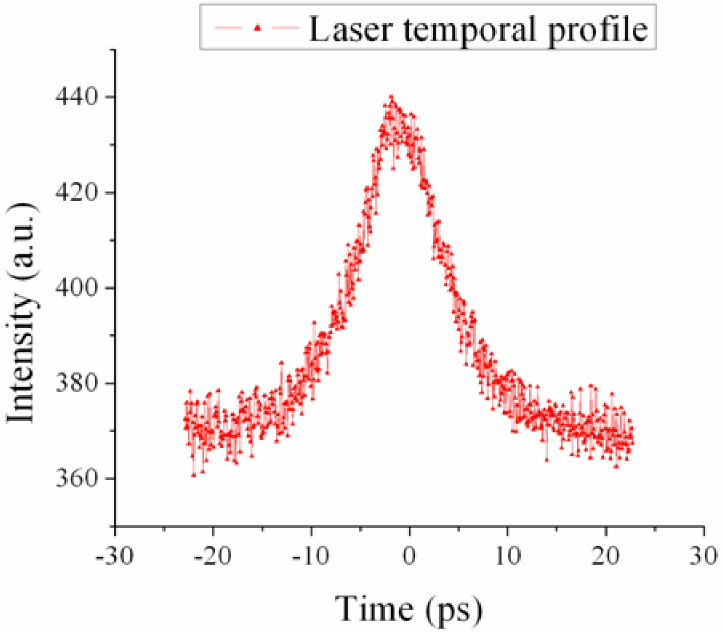
Future plans

- laser cleaning
- longitudinal pulse shaping
- transverse homogenization
- 0 deg incidence ?

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Present situation





- laser cleaning
- longitudinal pulse shaping
- transverse homogenization
- 0 deg incidence ?

PRESENTATION OVERVIEW

- *INTRODUCTION*
  - Sparc project
  - installation status
  - laser system
  - SPARC hall
- *LASER SYSTEM CHARACTERIZATION*
  - longitudinal measurements
  - transverse uniformity & QE
  - tilt correction
  - Laser synchronization
- *e- BEAM CHARACTERIZATION*
  - diagnostic description
  - longitudinal charact.
  - transverse charact.
  - best results and future plans

Daniele.Filippetto@lnf.infn.it

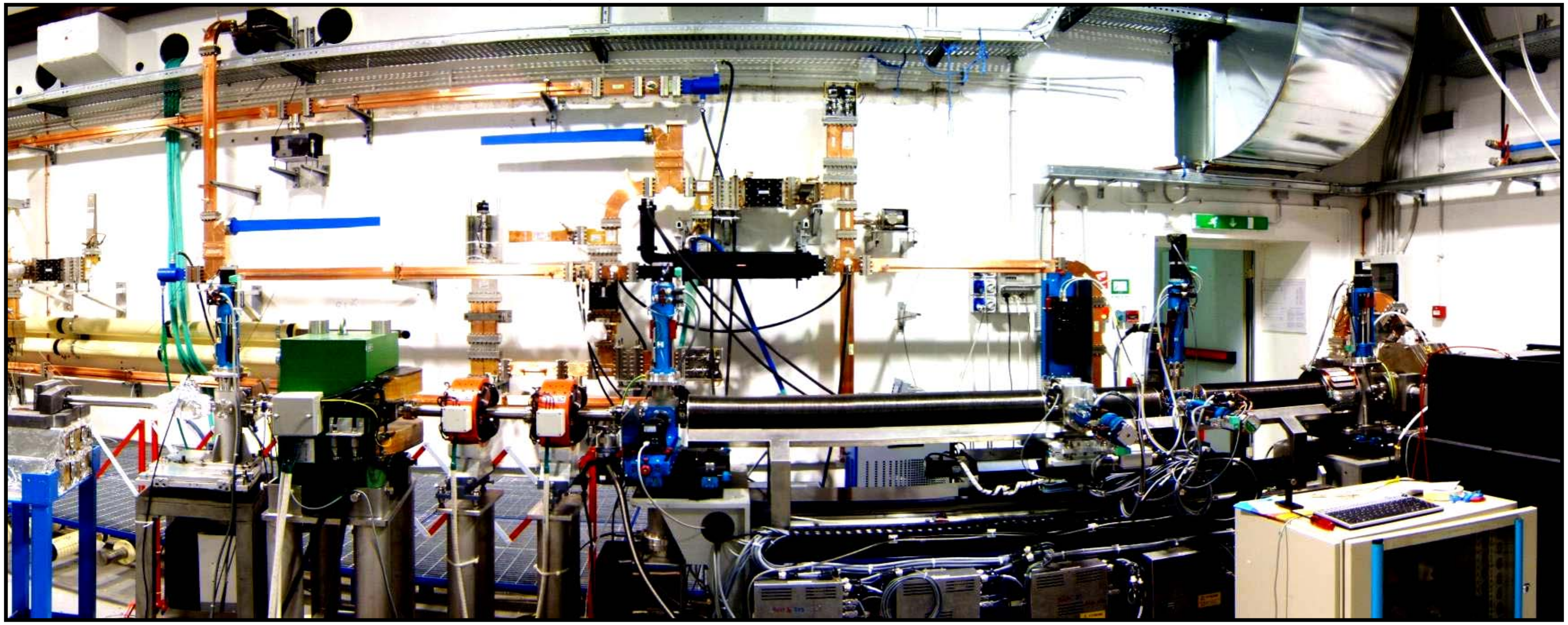
Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Diagnostic overview

- 60 cm: faraday cup to measure the charge at gun exit, and
  Cromox screen to see and center the beam;
- 85-200 cm: E-meter (slits cross, Yag and CCD cross);
  Emittance, beam envelope, beam parameters
  as function of trnsv. coordinates;
- 220 cm : aerogel + streak camera; beam duration;
- 250-280 cm :FODO;
- 300 cm : dipole;

} prepares the beam to E & ΔE meas.

- 330 cm : spectrometer cross (Yag+ CCD) ; E & ΔE meas.
- 350 cm : BCM (beam charge)



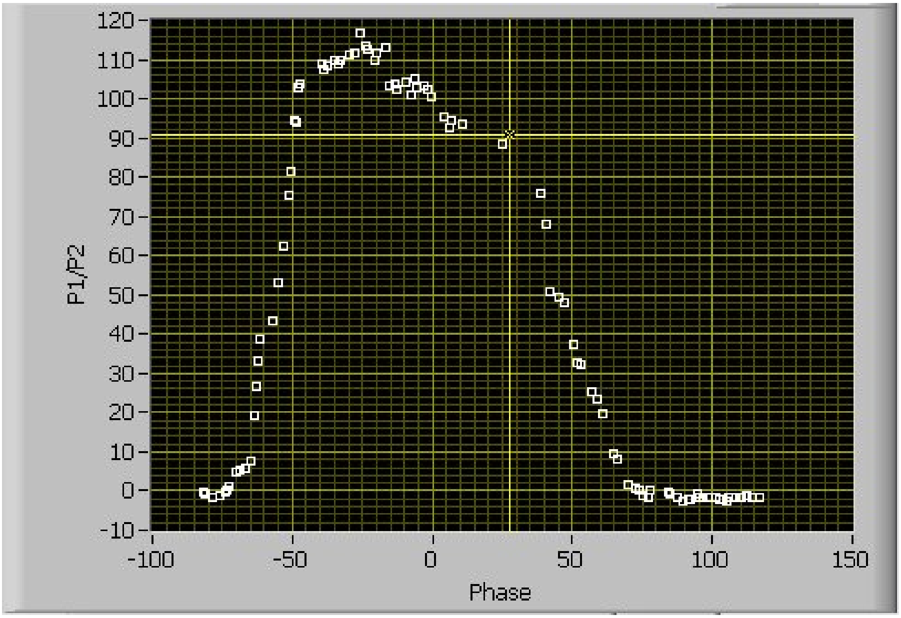
INFN Istituto Nazionale di Fisica Nucleare

Daniele.Filippetto@lnf.infn.it

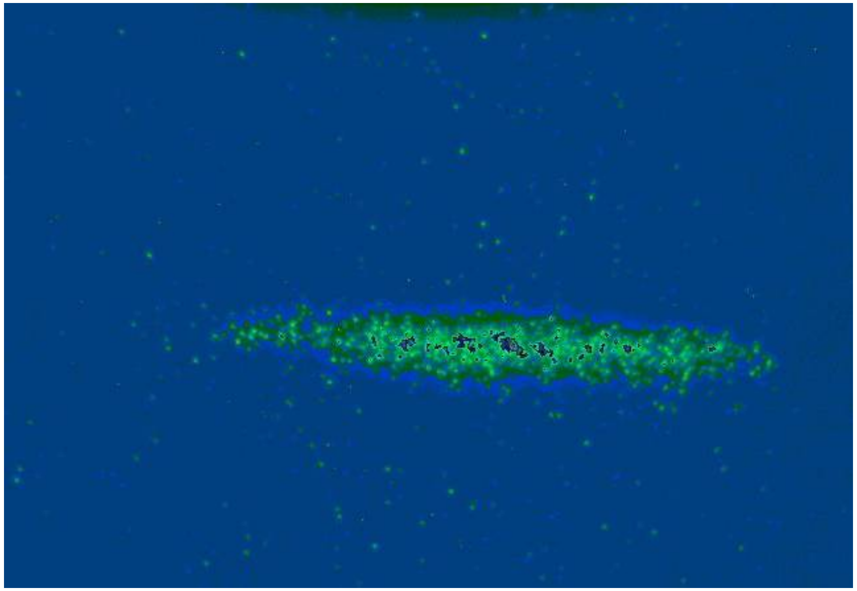
ICFA FLS 2006

SPARC

Longitudinal e- beam characterization



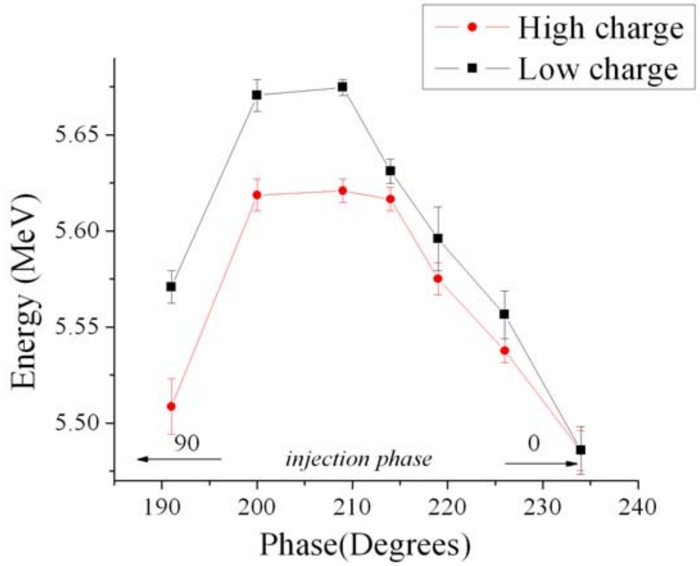
120MV/m

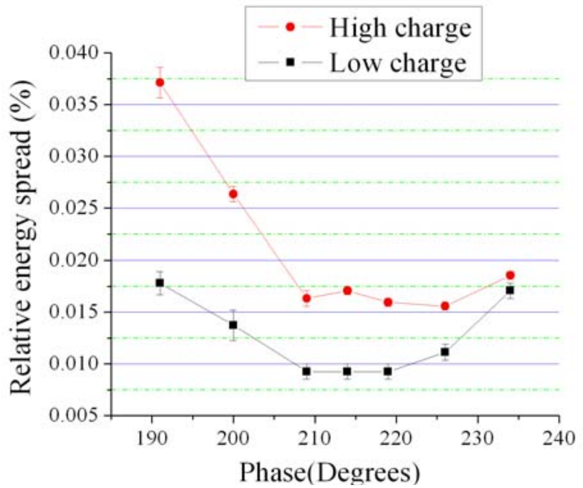


Streak image of Cherenkov Light coming from aerogel

T=12 ps

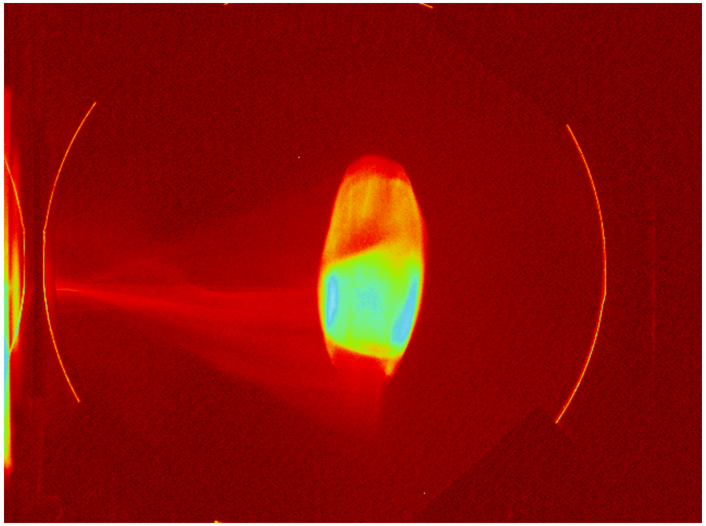
E dependencies on Q





Q=200 pC

Fixed phase



POSSIBLE CAUSES

- longitudinal wakefields due to the bellows
- longitudinal space charge
- image charge on cathode

Low charge 200pC

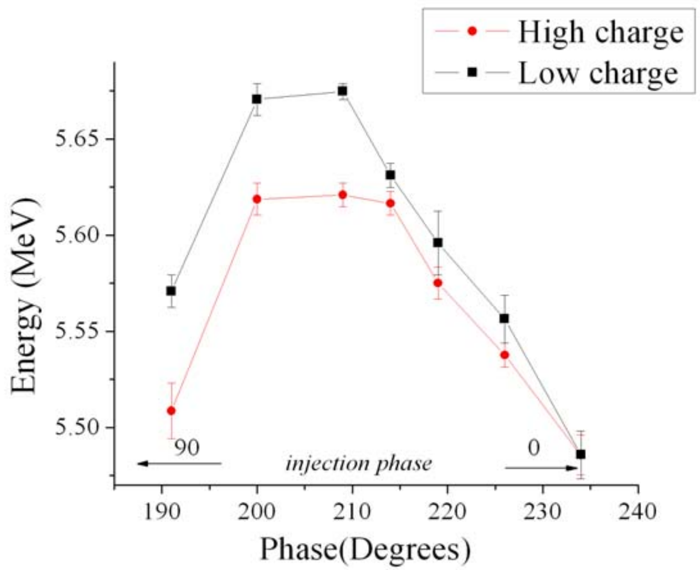
High charge from 400 to 1000pC

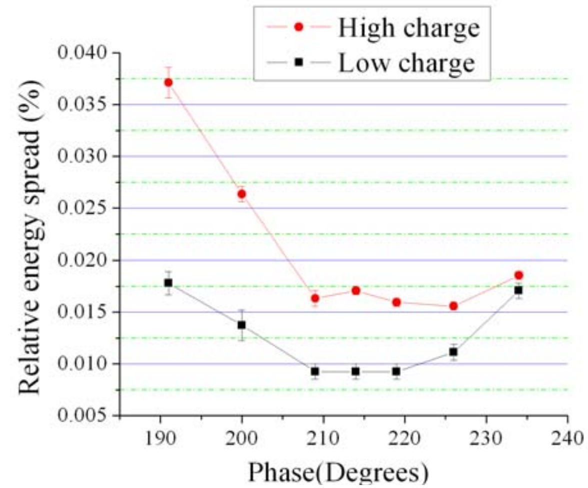
Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

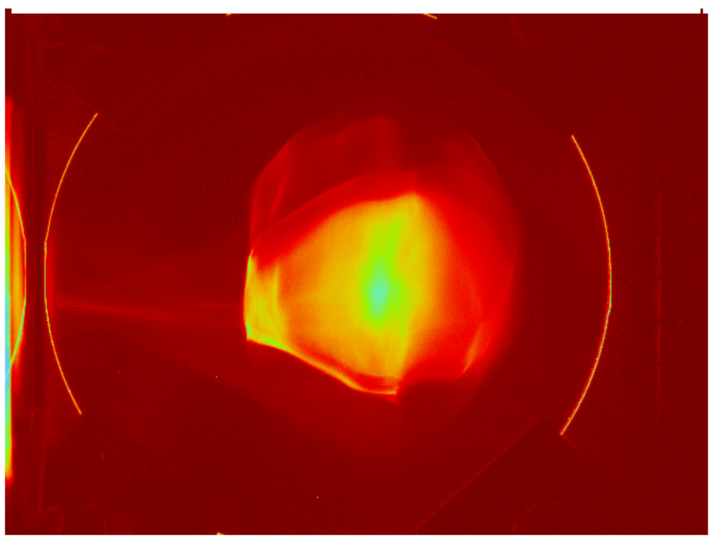
Daniele.Filippetto@lnf.infn.it

E dependencies on Q





Q=840 pC, Fixed phase



POSSIBLE CAUSES

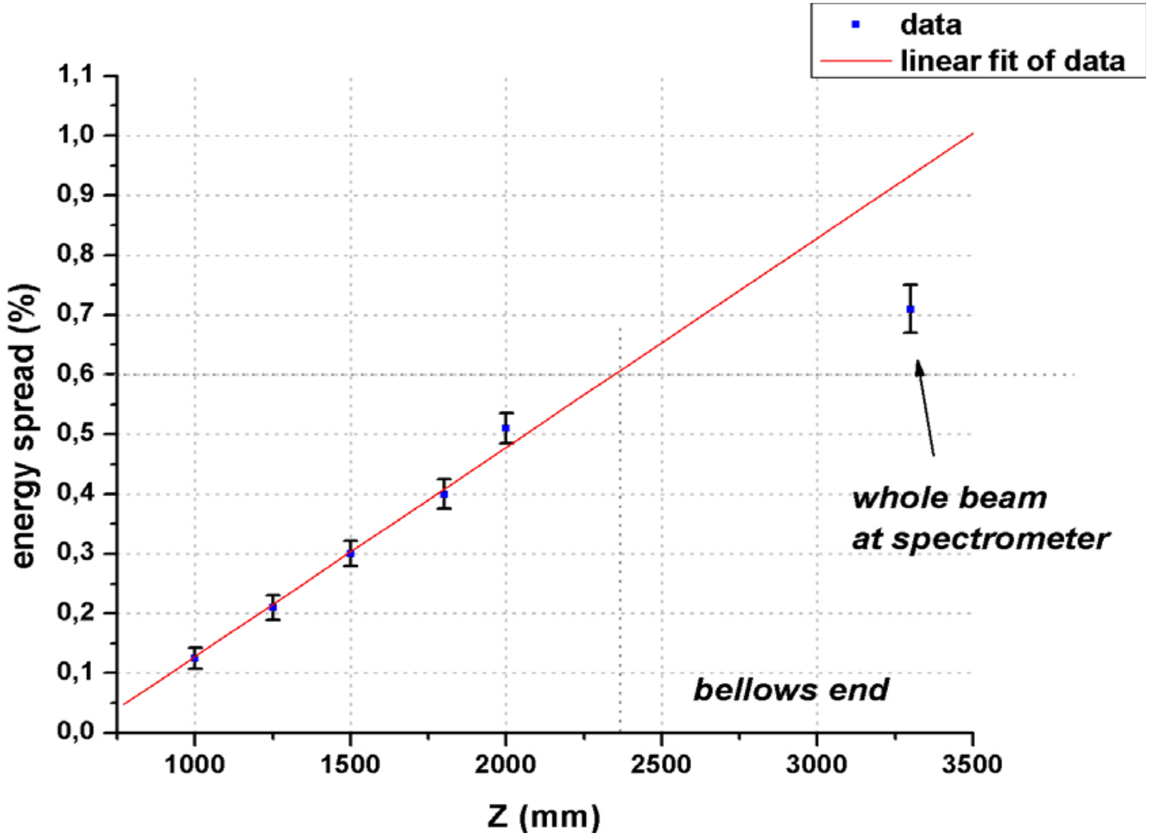
- longitudinal wakefields due to the bellows
- longitudinal space charge
- image charge on cathode

Low charge	200pC
High charge	from 400 to 1000pC

Energy spread Vs Z

Reducing the charge by cutting the central part of the beam with 50 um slit, lets the beam after the cut propagate without longitudinal SP and WF anymore.

One can say that the energy spread freezes after cut.

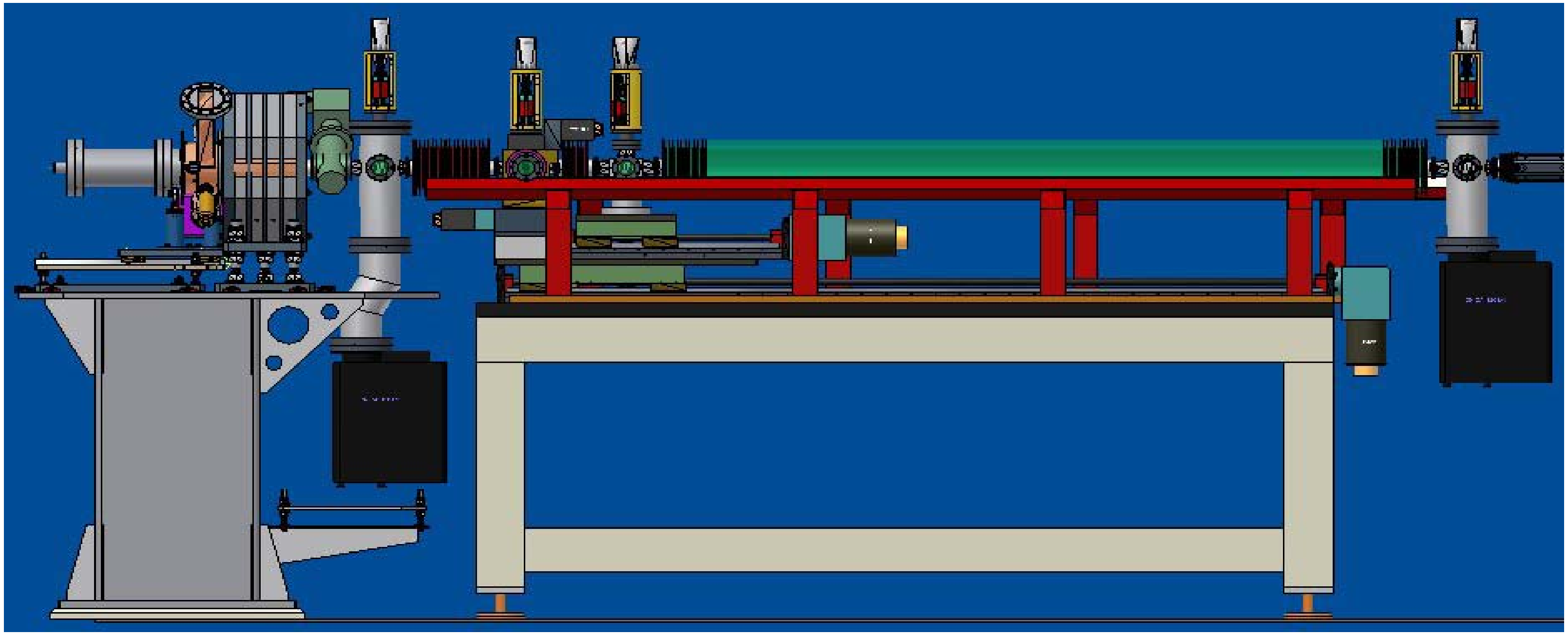


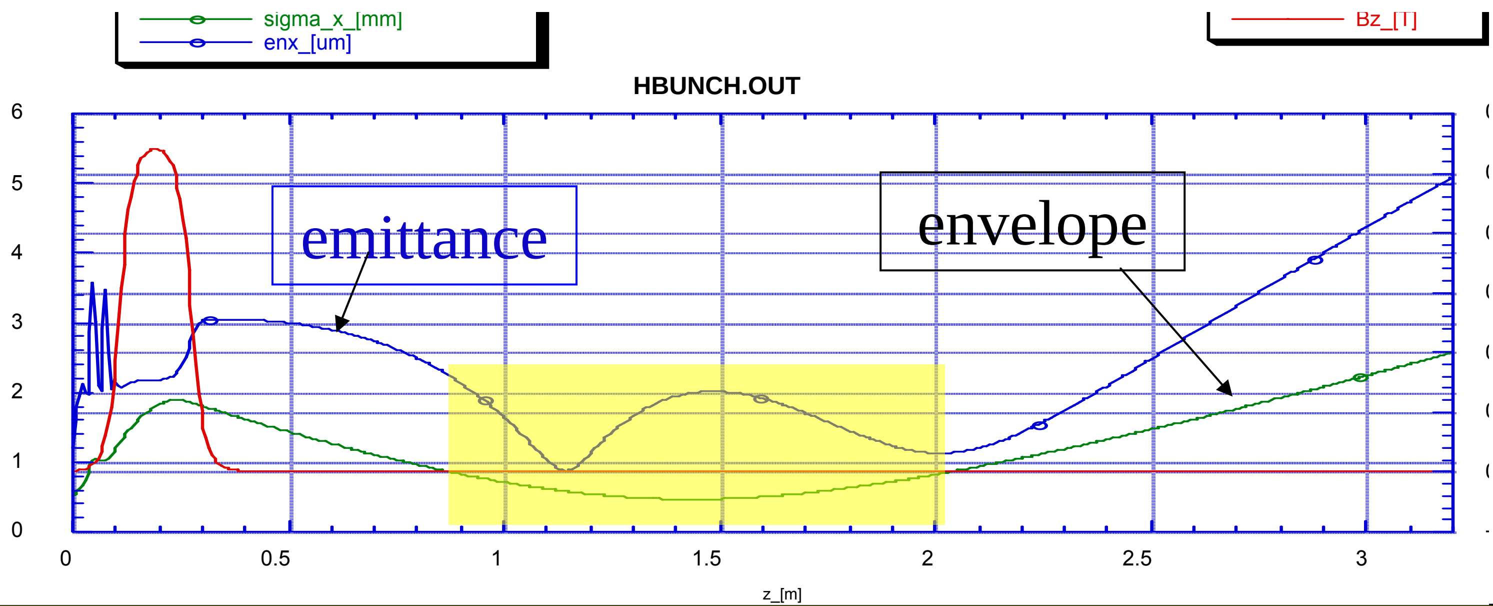
Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Daniele.Filippetto@lnf.infn.it

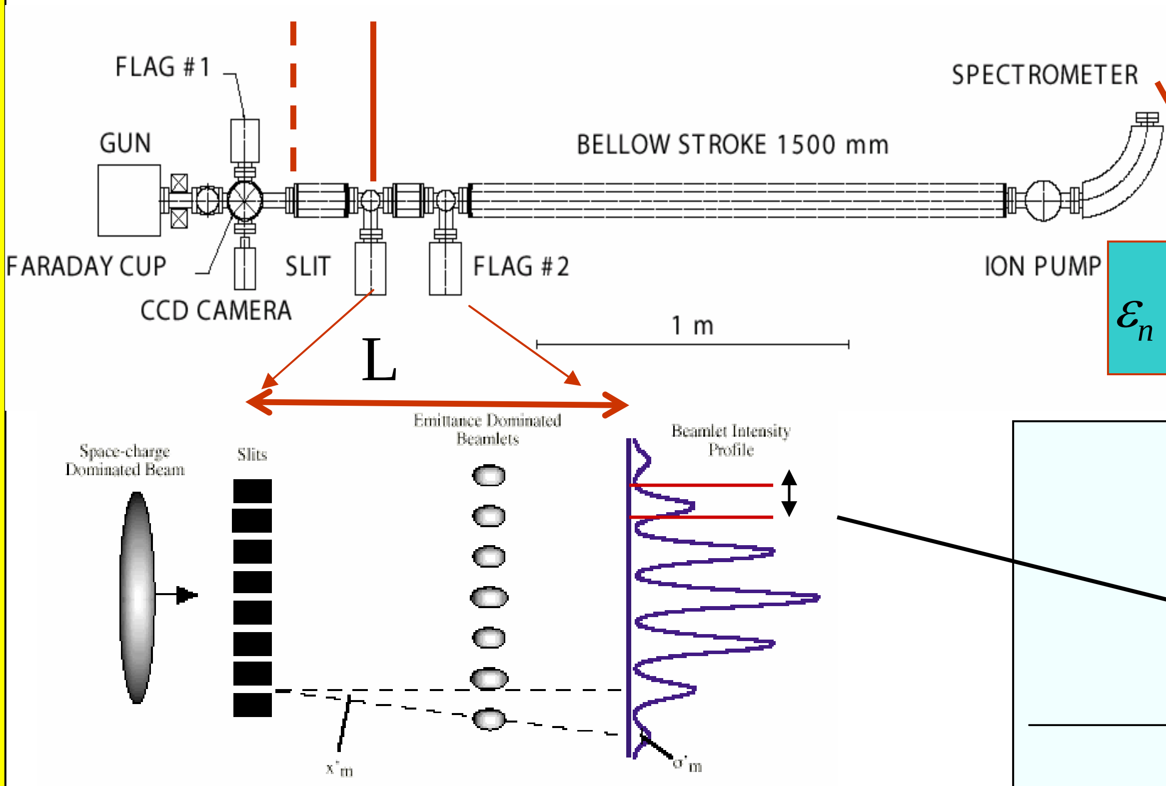
ICFA FLS 2006

Transverse emittance measurements

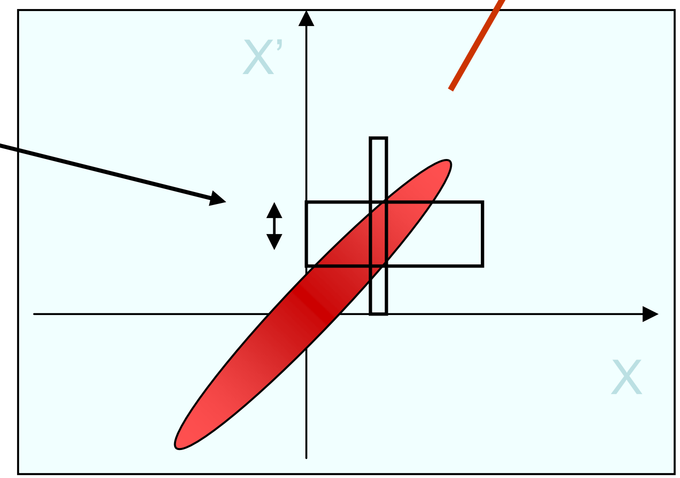


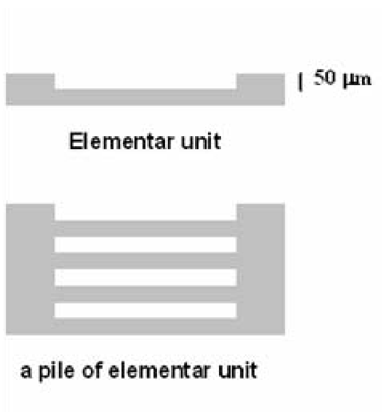


Measuring the emittance



$$\varepsilon_n = \langle\gamma\rangle\sqrt{\langle x^2\rangle\langle (x')^2\rangle - \langle xx'\rangle^2}$$

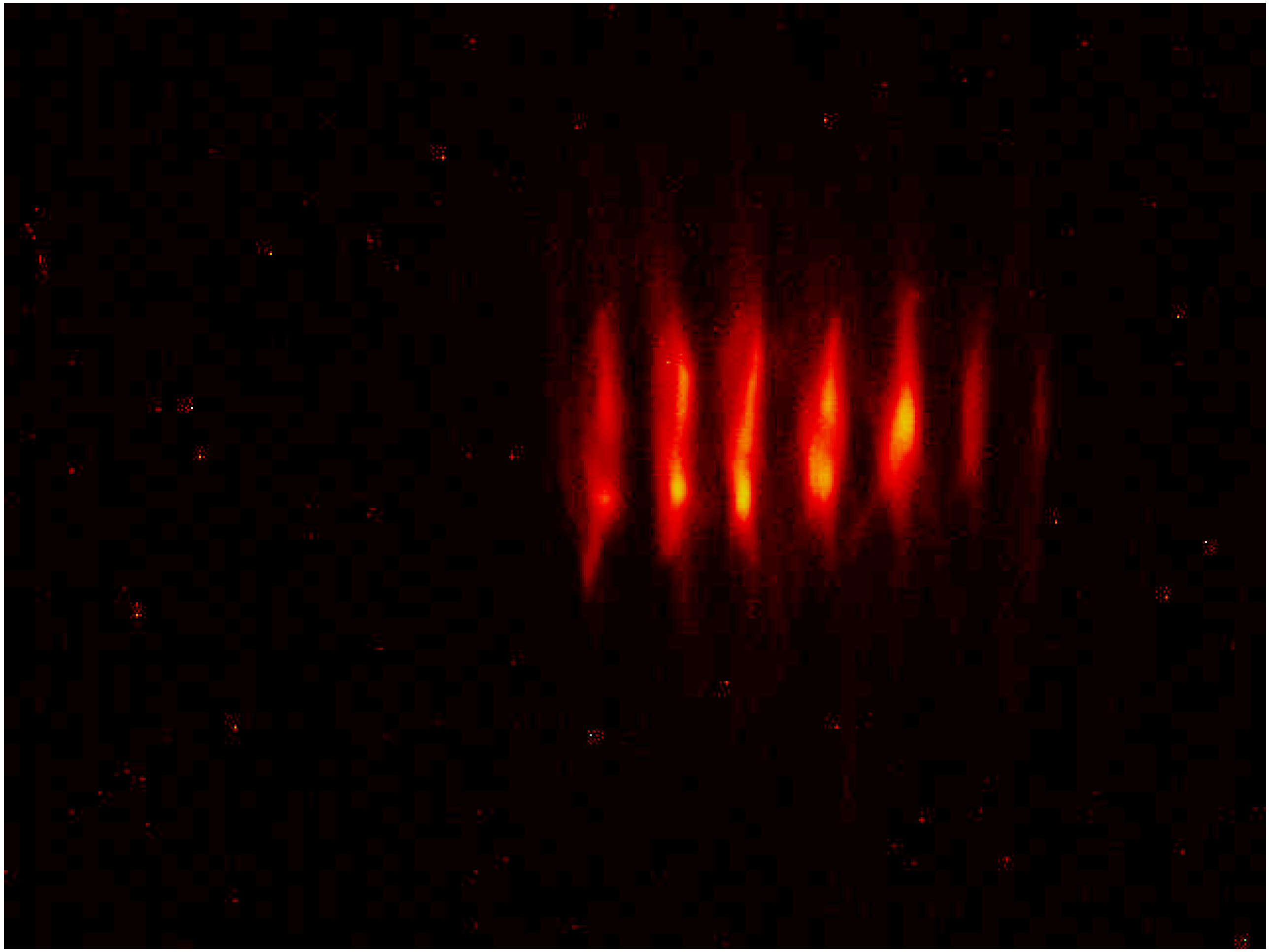




Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

Sampling the beam



Multislits

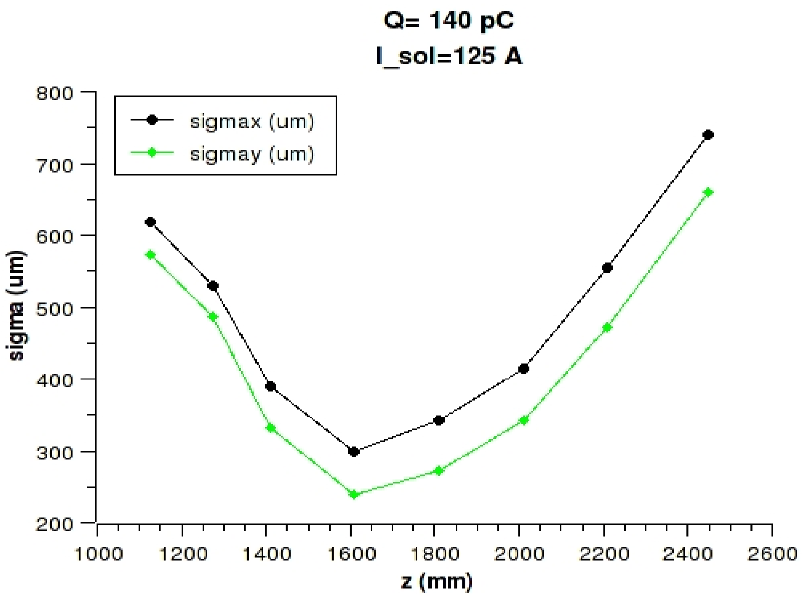
Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

INFN Istituto Nazionale di Fisica Nucleare
Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006
SPARC

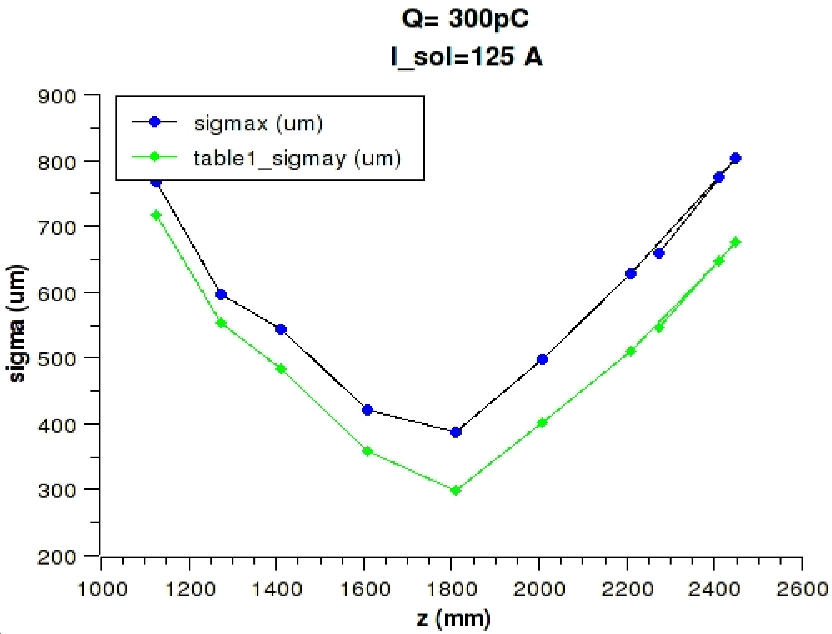
Comparison:

- Measure with both single slits and multi slits
- Multi slits is a single shot measure, single slit gives more sampling points
- Excellent agreement between single slit and multi slits.
- Multi slit not so good with convergent and too small beams (fixed distance between slits)
- Excellent the agreement between the measured (with a screen) RMS beam size and the estimated from $\sqrt{\beta\varepsilon}$

Transverse phase space



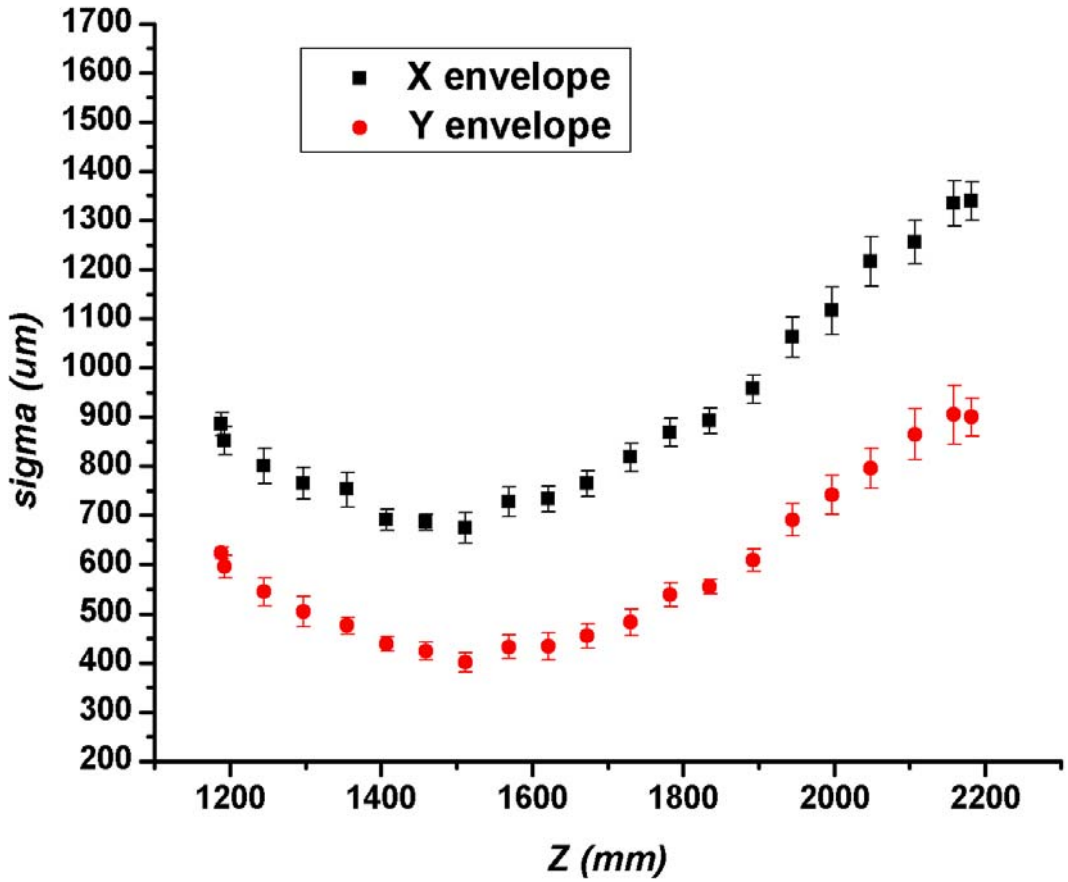
Two beam envelopes
With same solenoid current
But different beam charge



We are able to measure
Beam envelopes without
Stopping E--meter

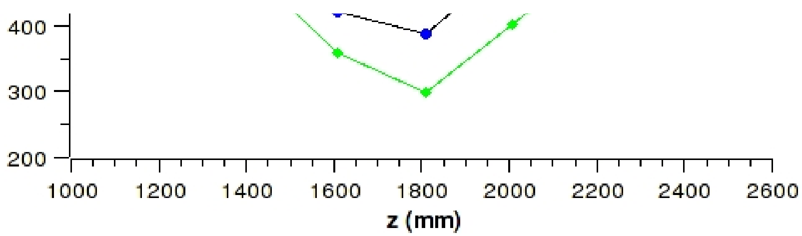
Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

Transverse phase space



elopes
enoid current
eam charge

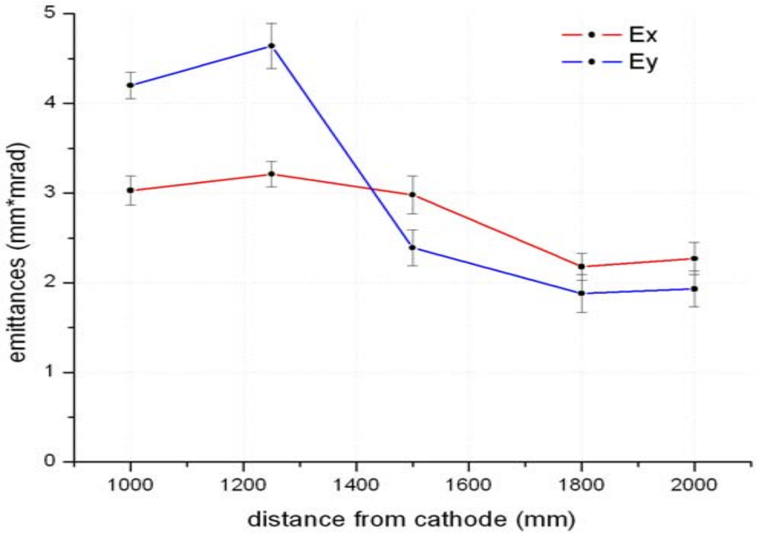
measure
es without
eter

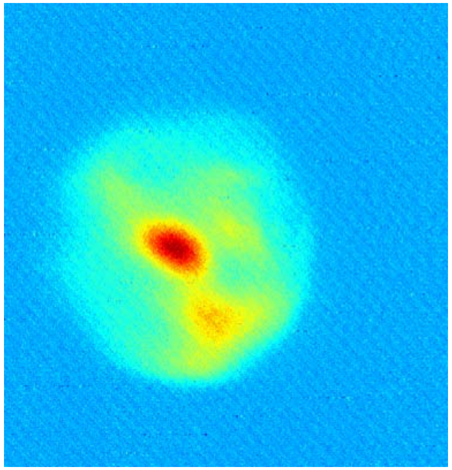


Daniele.Filippetto@lnf.infn.it

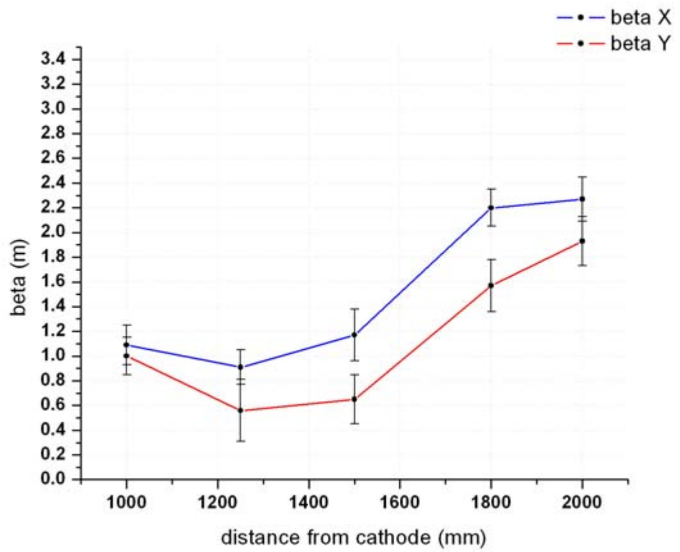
ICFA FLS 2006

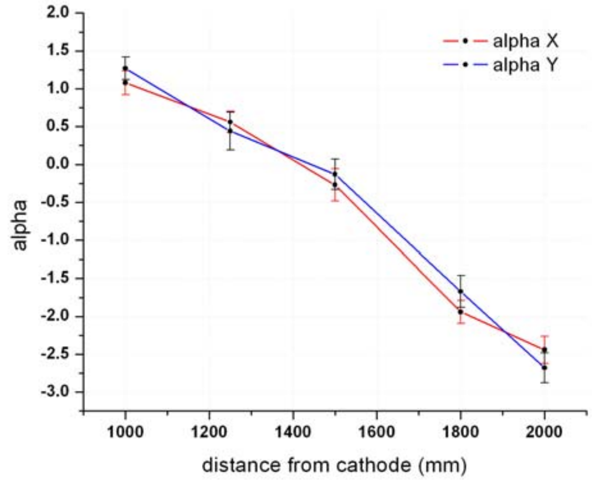
Emittance behavior along z





Sol 125 A
Q=200 pC





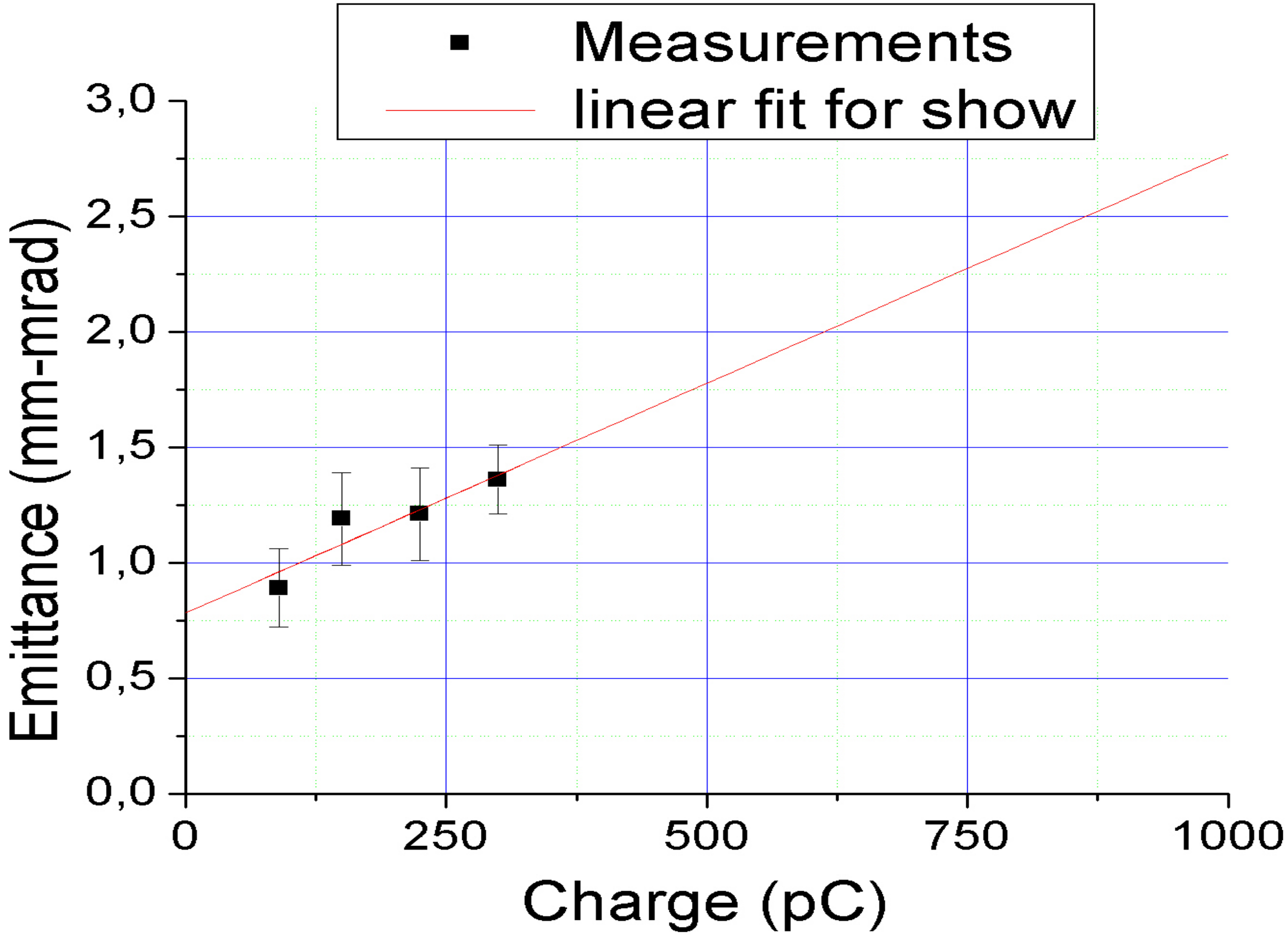
Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

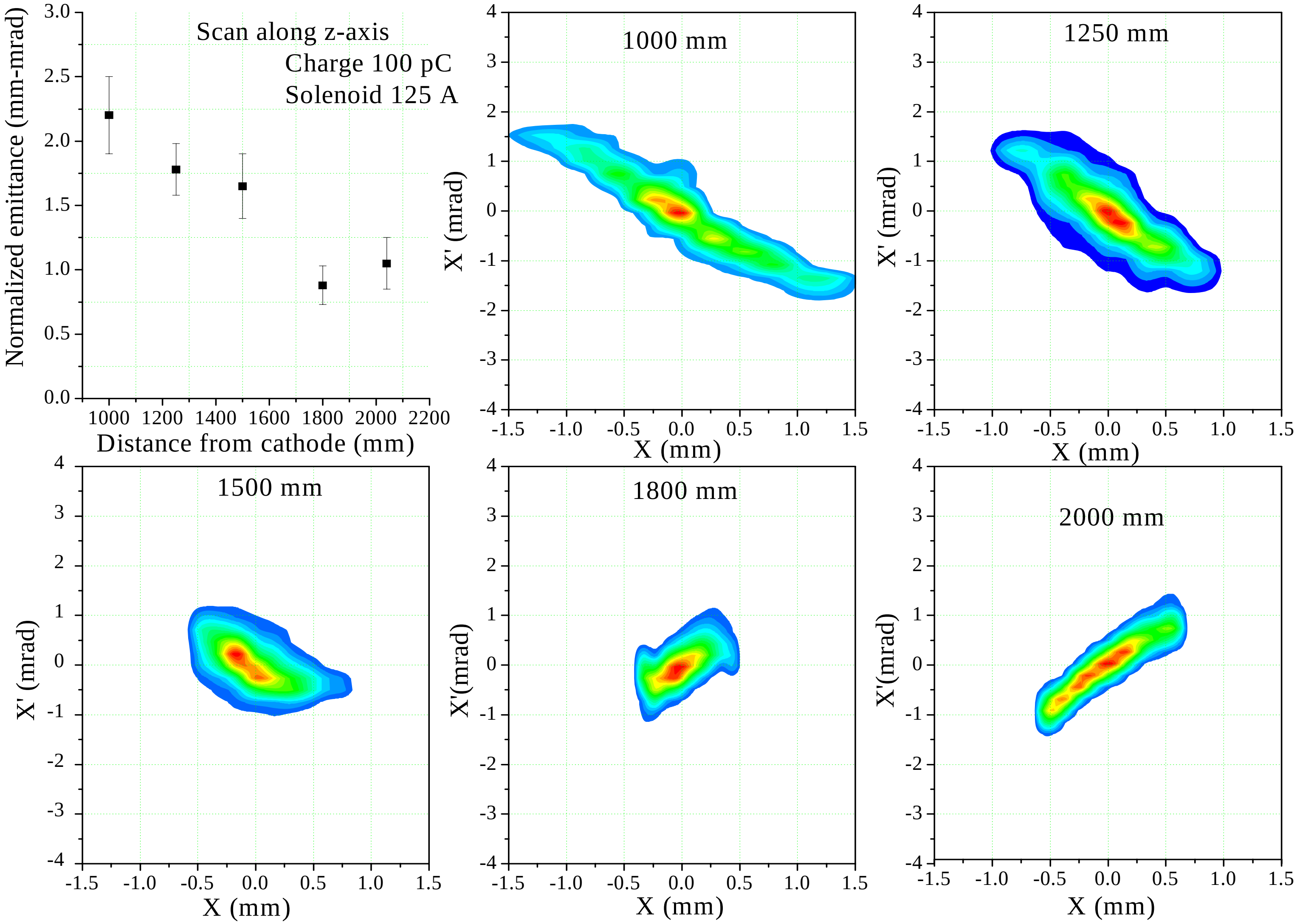
"low charge" data

Daniele.Filippetto@lnf.infn.it
ICFA FLS 2006

No direct emitt. Scaling with Q; increase charge just increasing electron density (laser energy);
Linear fit just ***"for show"***



Phase space evolution



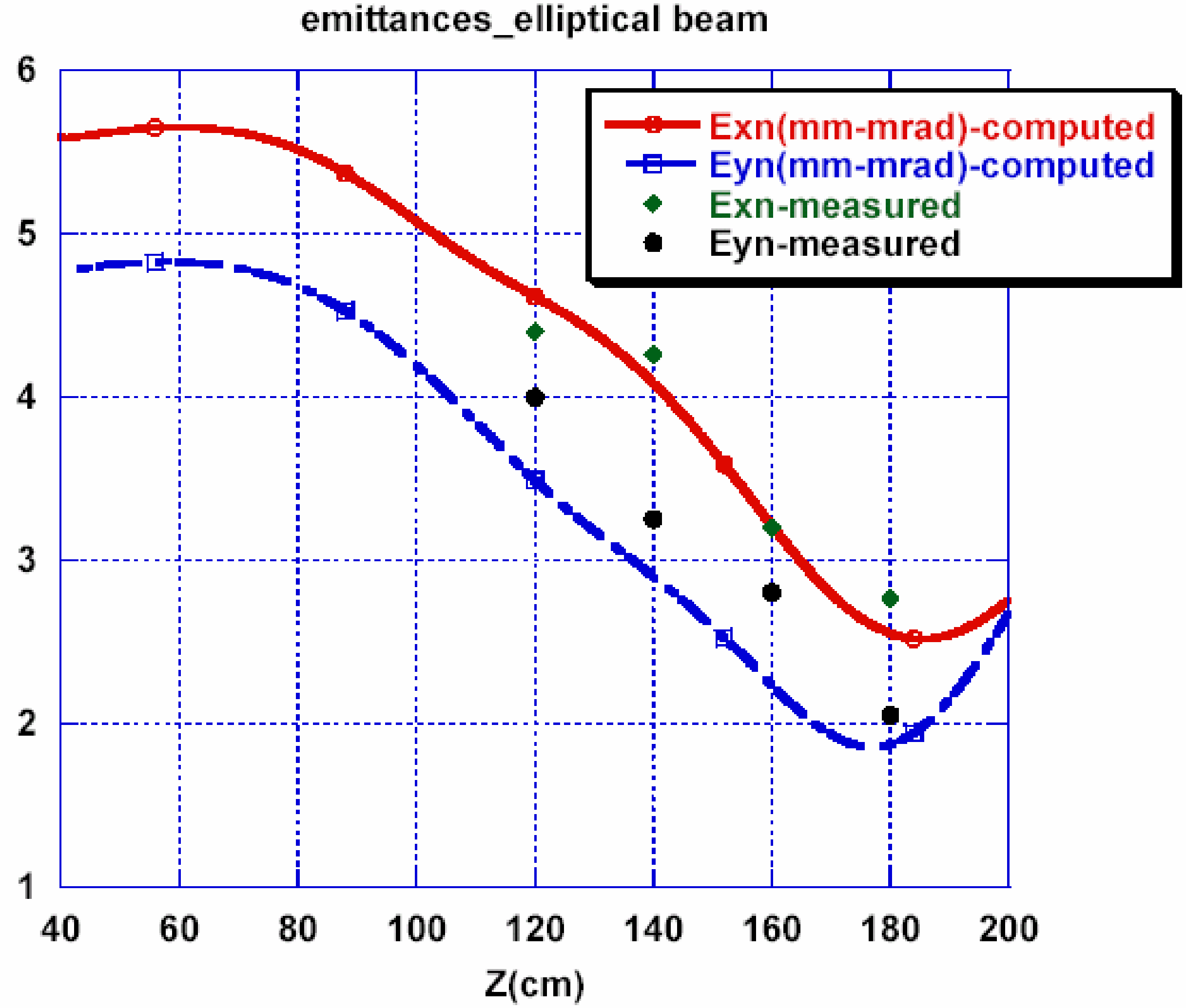
With single slit method, phase space reconstruction is possible;
Using E-meter one can investigate its evolution.

Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

Simulations

Elliptical input beam



Thanks to Titti Ronsivalle

Daniele.Filippetto@lnf.infn.it

ICFA FLS 2006

Daniele.Filippetto@lnf.infn.it

Conclusions & future plans

- ***Best achieved results***
  - ***2.1 mm-mrad @ 700 pC , 10 ps***
  - ***0.7 mm-mrad @ 160 pC, 10 ps***
- More work on laser beam
- Understanding dipole and quadrupole components in solenoid (mask, different fields in each coil and different configurations,…)
- high charge (up to 1.1 nC) emittance measurements
- Comparison with simulation ongoing (next step real transverse and longitudinal profile)
- Main linac installation scheduled to start in the summer