Laser Pulse Shaping and Emittance Studies

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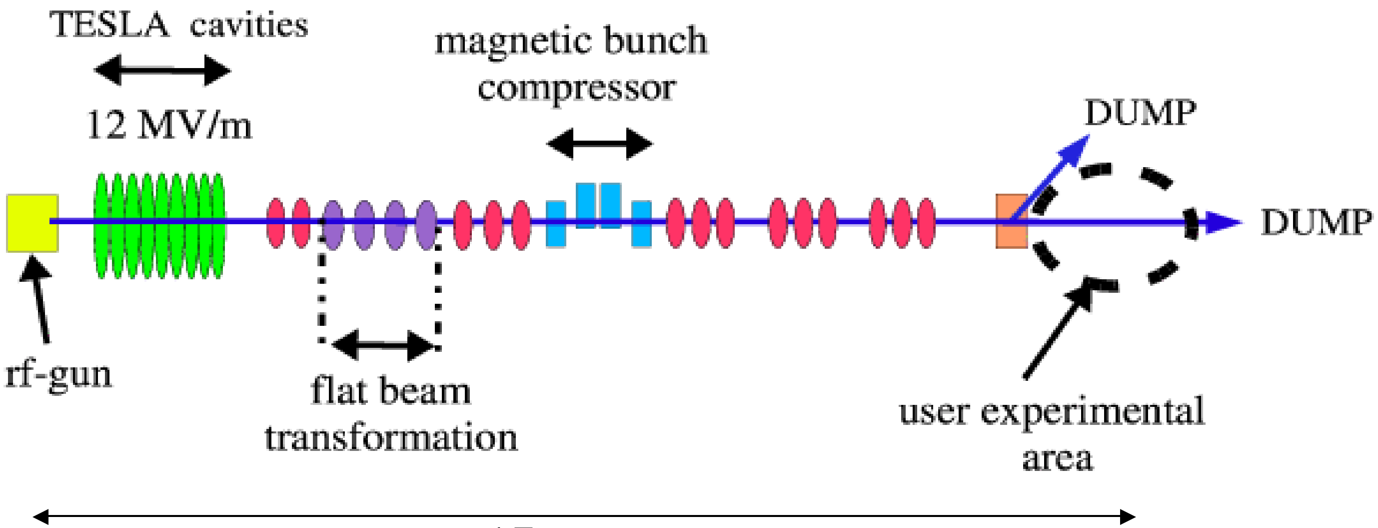
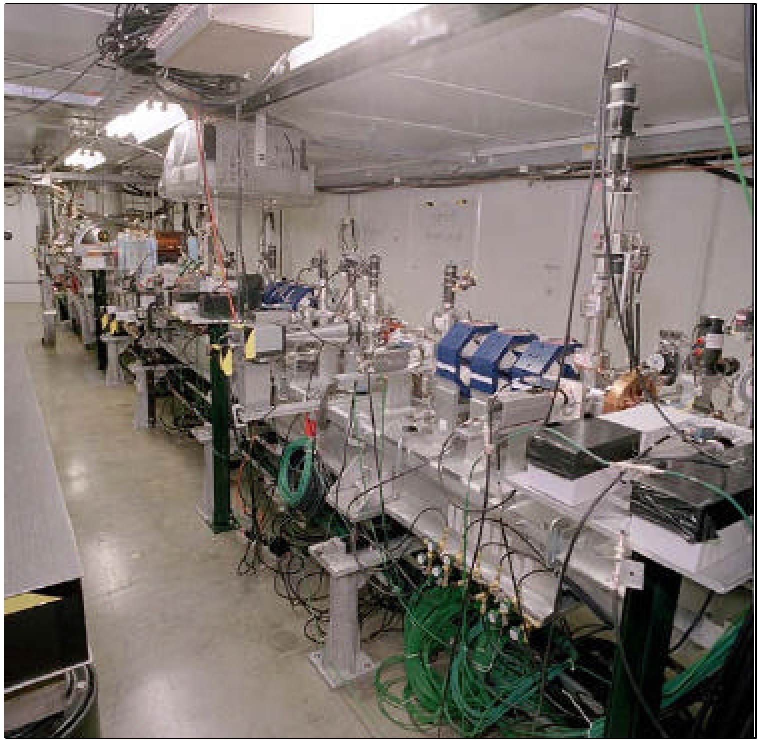
A0 PHOTOINJECTOR OVERVIEW



~15 meters

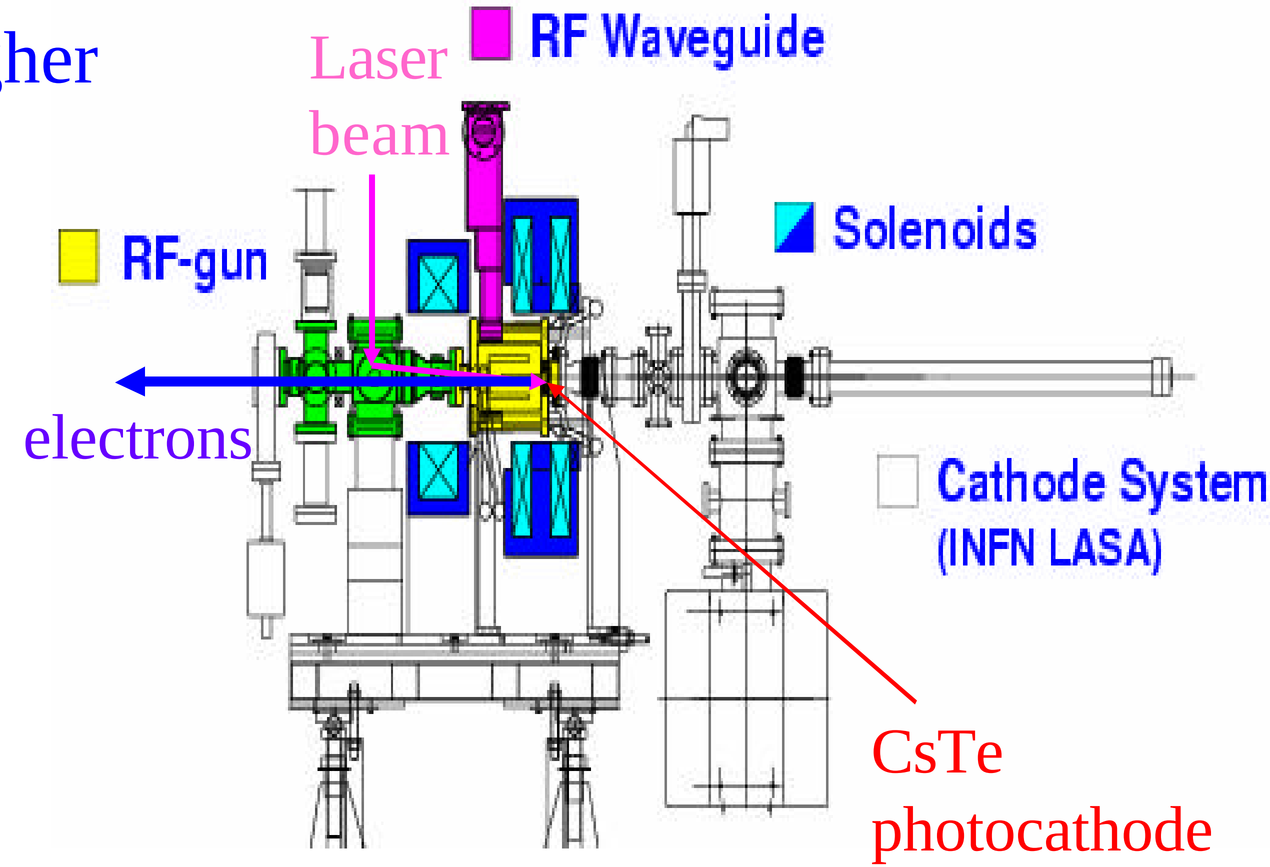
E= 15 MeV
Q= up to 20 nC,
e =3.0 mm-mrad (1 nC)

? p/p=0.25 % (1 nC)
Ipeak = 75-330 A (BC off)
Ipeak = 200-1700 A (BC on)



GENERATION OF ELECTRONS:

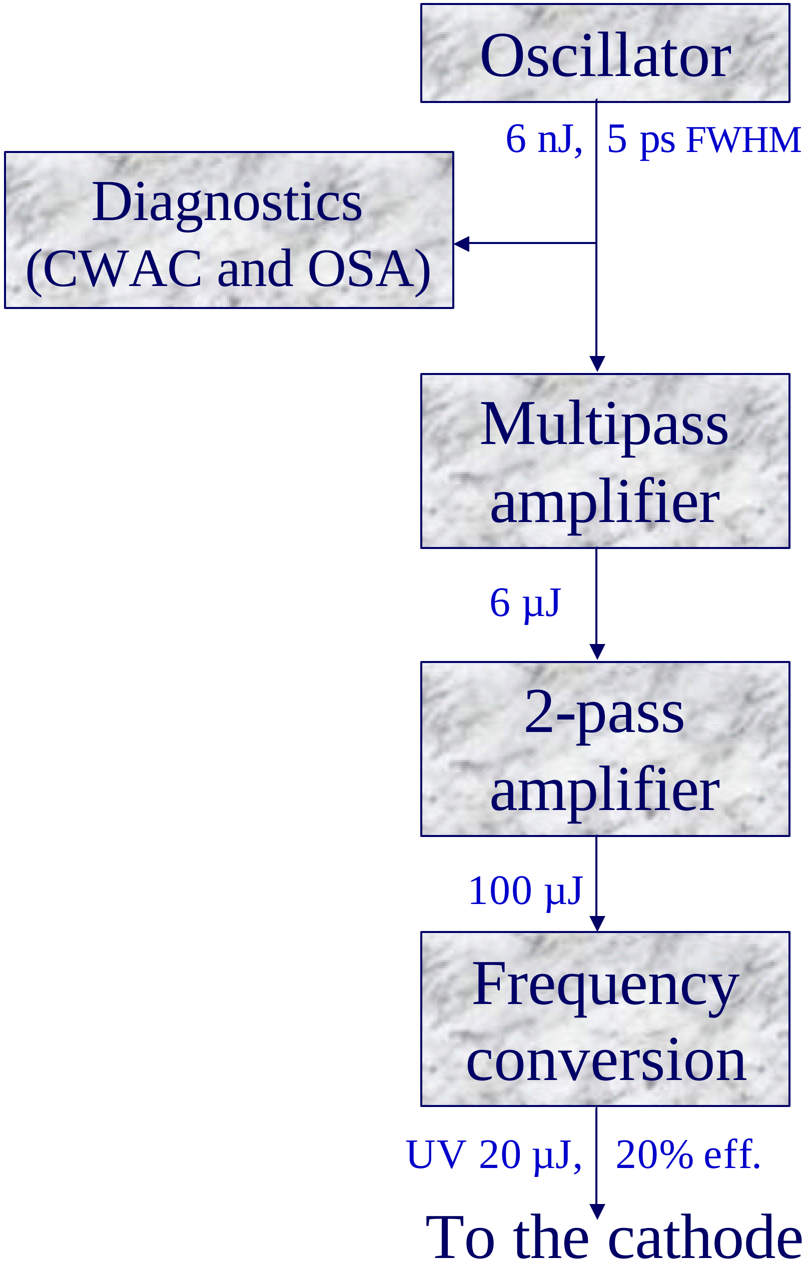
At A0 photoemission is used since it enables the production of higher charge density



?CsTe photocathode requires uv light

?Laser energy needed:
few µJ to produce up to 20 nC charge

A0 DRIVE LASER



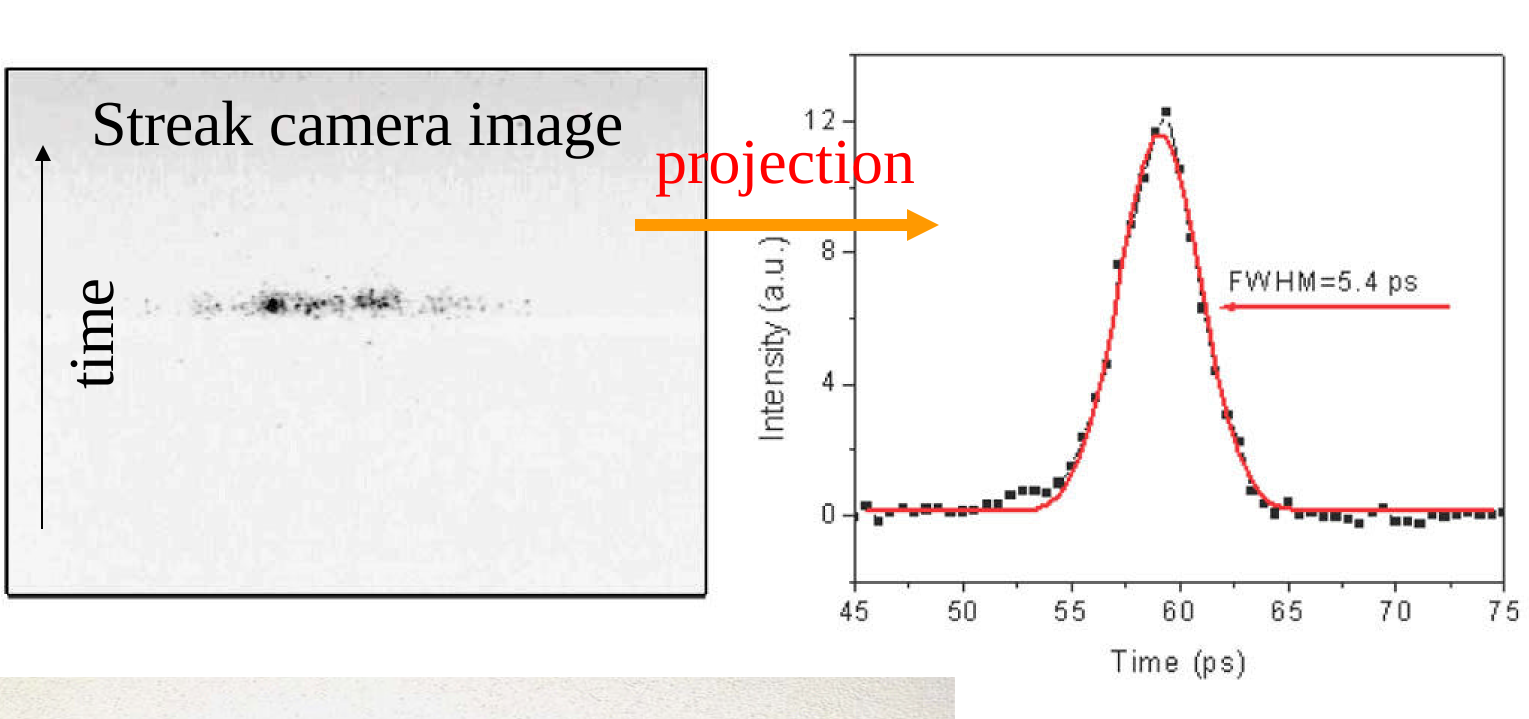
-Nd:YLF oscillator, 1054 nm, 0.5 W, 81.25 MHz pulse train

-Nd:glass amplifier, 6 round-trips, 1 MHz pulse train (1-800 pulses), amplifies up to 2000 times, 5% shot-to-shot amplitude fluctuation

-Nd:glass amplifier, 1 round-trip through double laser head, amplifies up to 70 times

-2 BBO 10 mm crystals, 50% IR to green efficiency, 40% green to UV efficiency

A0 DRIVE LASER: OSCILLATOR



Oscillator is a commercial device

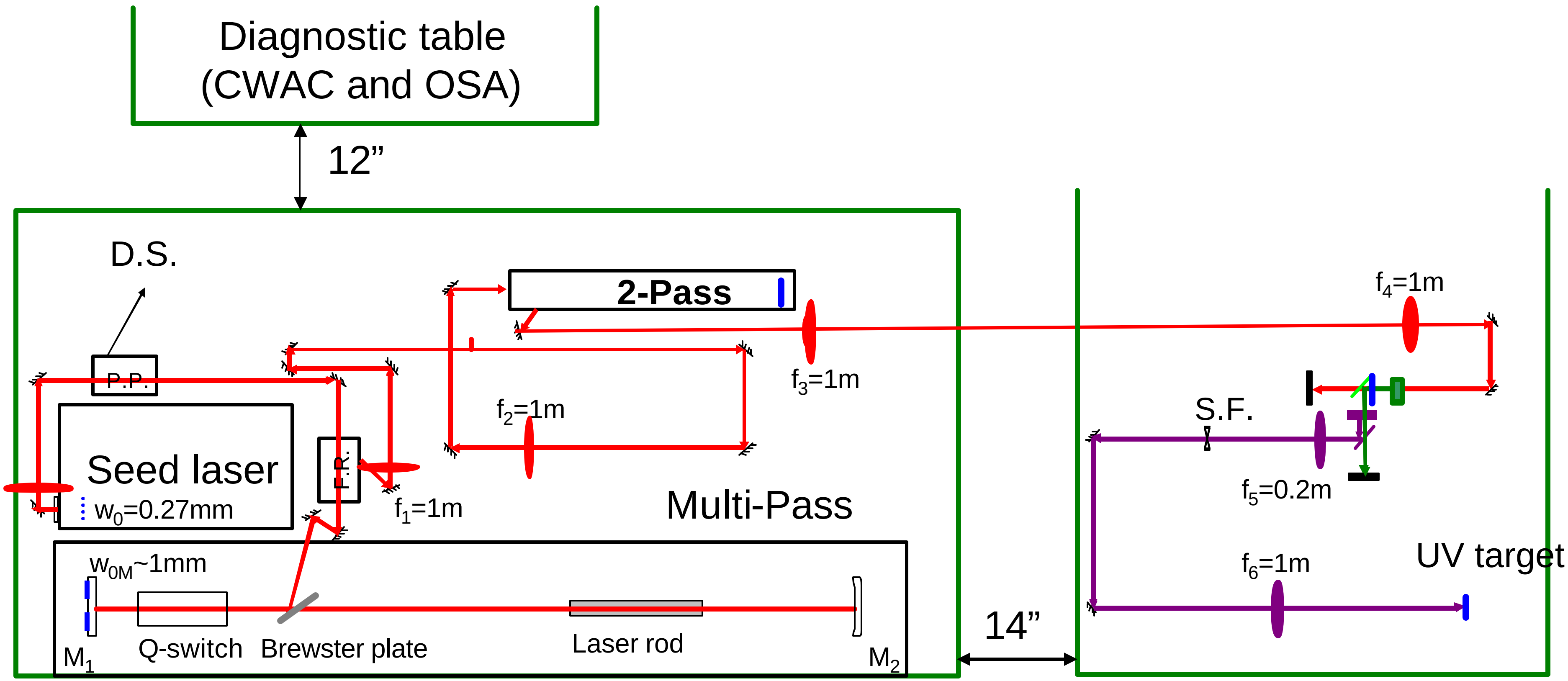
<u>seed laser output:</u>

wavelength: 1.053 μm

power: 0.5 W,

duration: 5ps (FWHM).

A0 DRIVE LASER

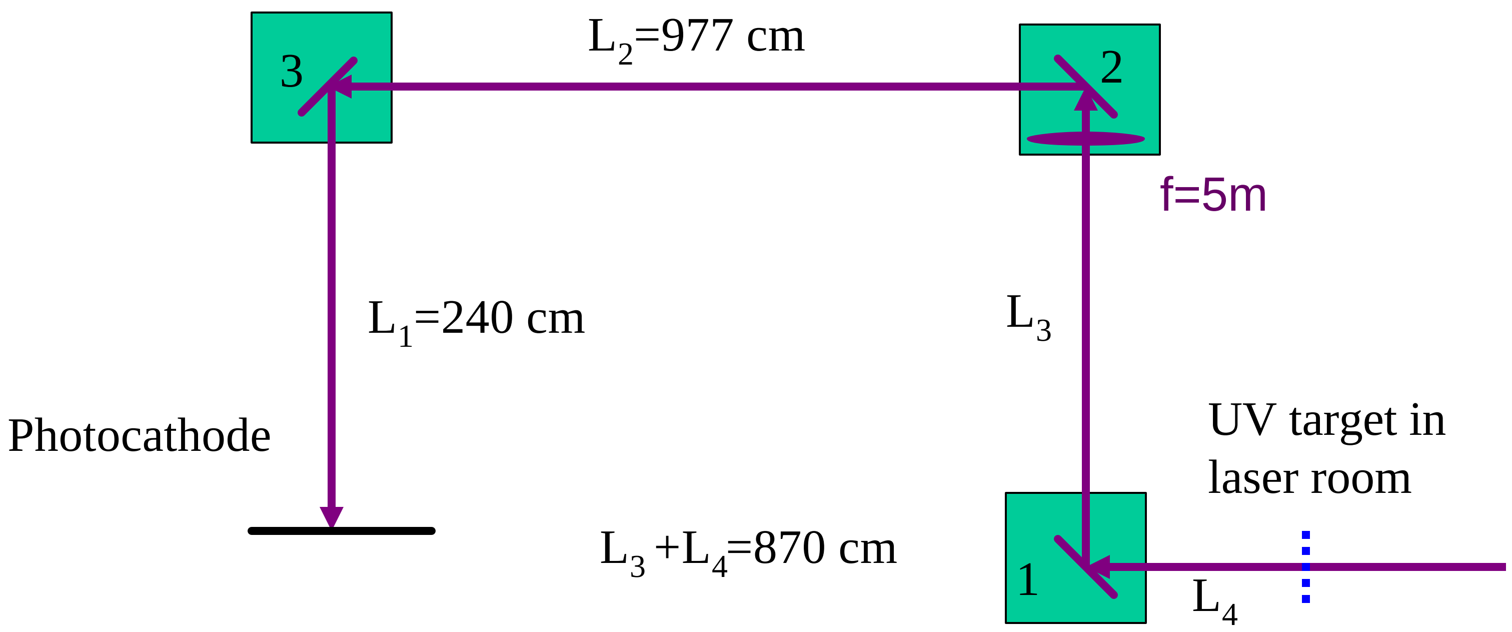


A0 laser system schematic.

A0 DRIVE LASER

The location of the laser room is 20 meter from the accelerator enclosure

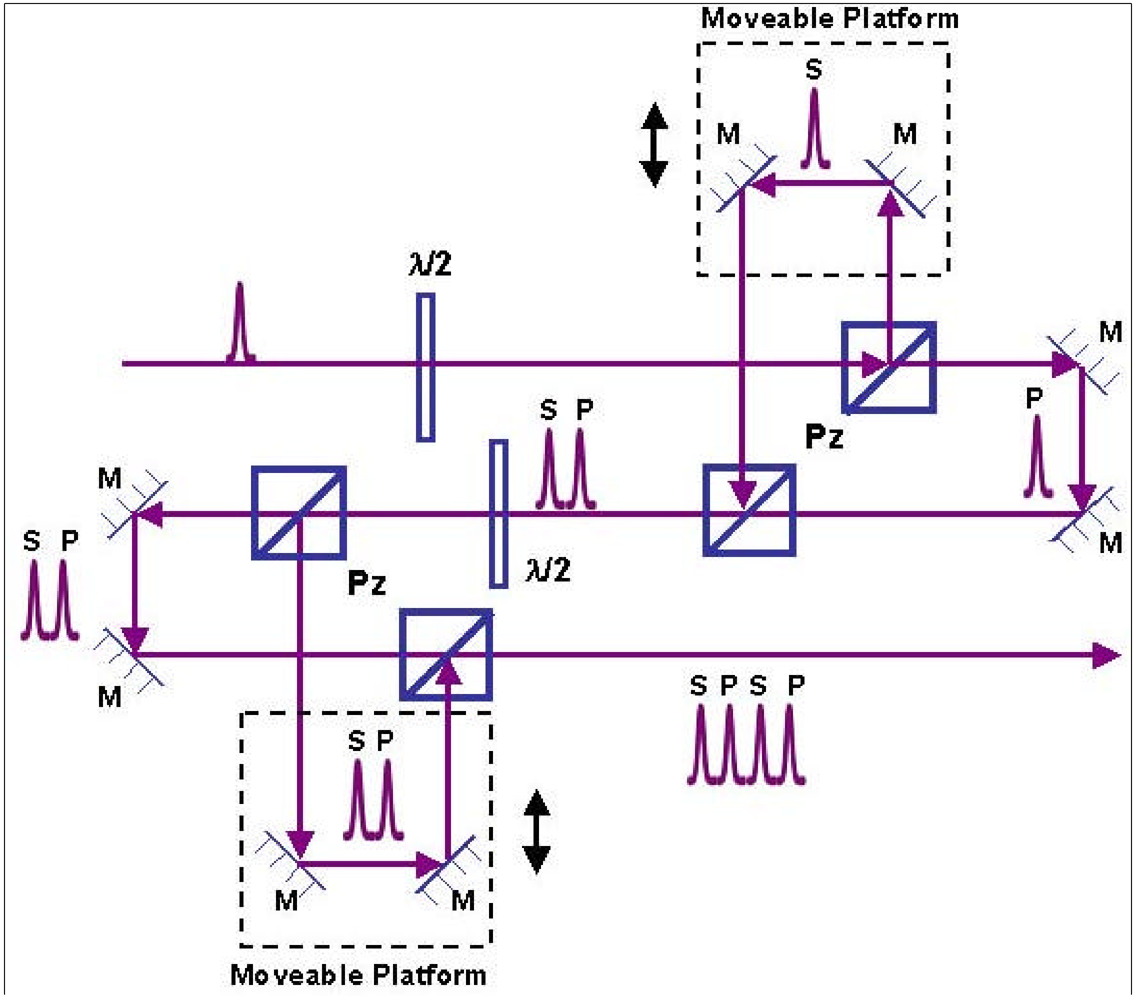
A relay-imaging system was installed to transport the laser beam from the laser room to the photocathode system

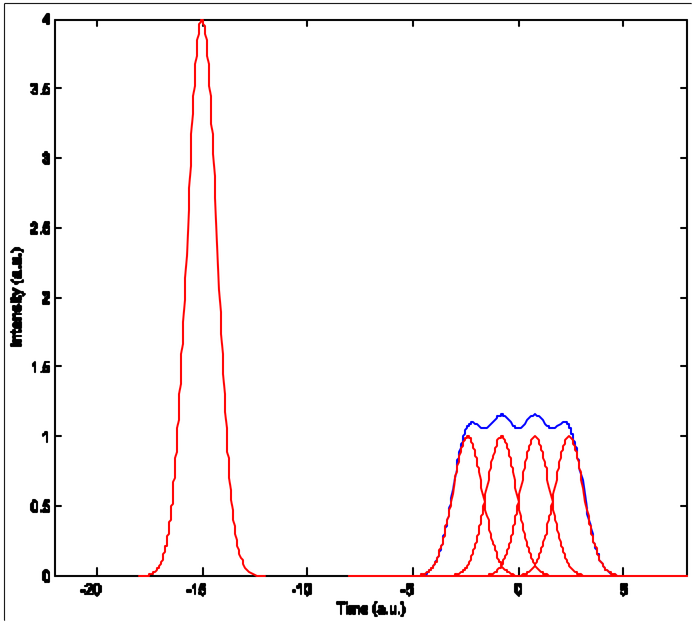


Laser-to-Cathode Imaging System

A0 LASER TEMPORAL SHAPING

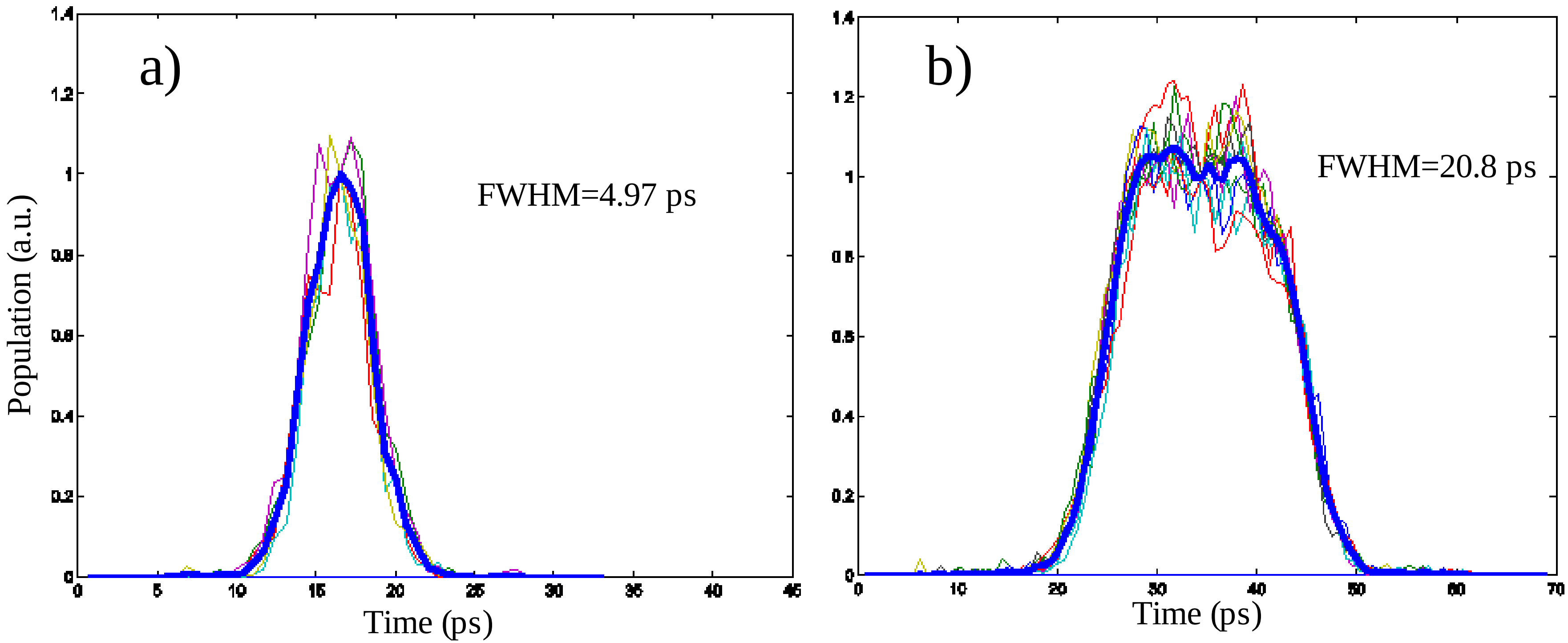
To reduce the space charge effect, a square pulse in longitudinal domain should be used.





- “flat-top” pulse generated using a pulse stacking scheme
- polarization flipping avoids interferences

PHOTOINJECTOR LASER TEMPORAL SHAPING



Streak camera images of **a)**: single and **b)**: stacked (four) pulses.

EMITTANCE

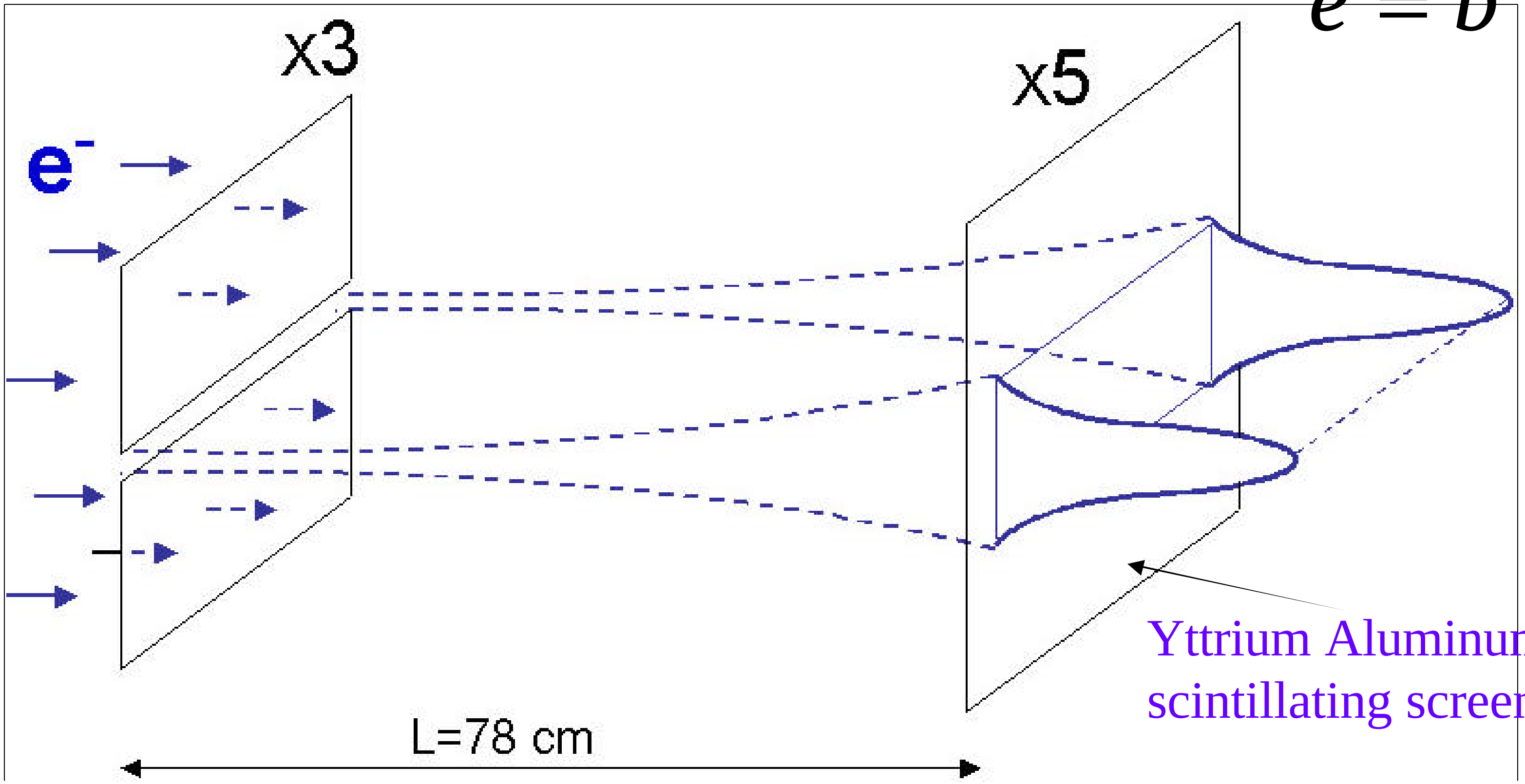
- According to Liouville's theorem, the volume of an ensemble of non-interacting particles in a six-dimensional phase space $(\vec{r}, \vec{p})$ is invariant
- The statistical definition of transverse emittance is given by

$$e_{n,x}^{rms} \equiv \frac{1}{mc}\sqrt{\langle x^2\rangle\langle p_x^2\rangle - \langle xp_x\rangle^2}, \qquad (1)$$

TRANSVERSE EMITTANCE MEASUREMENT

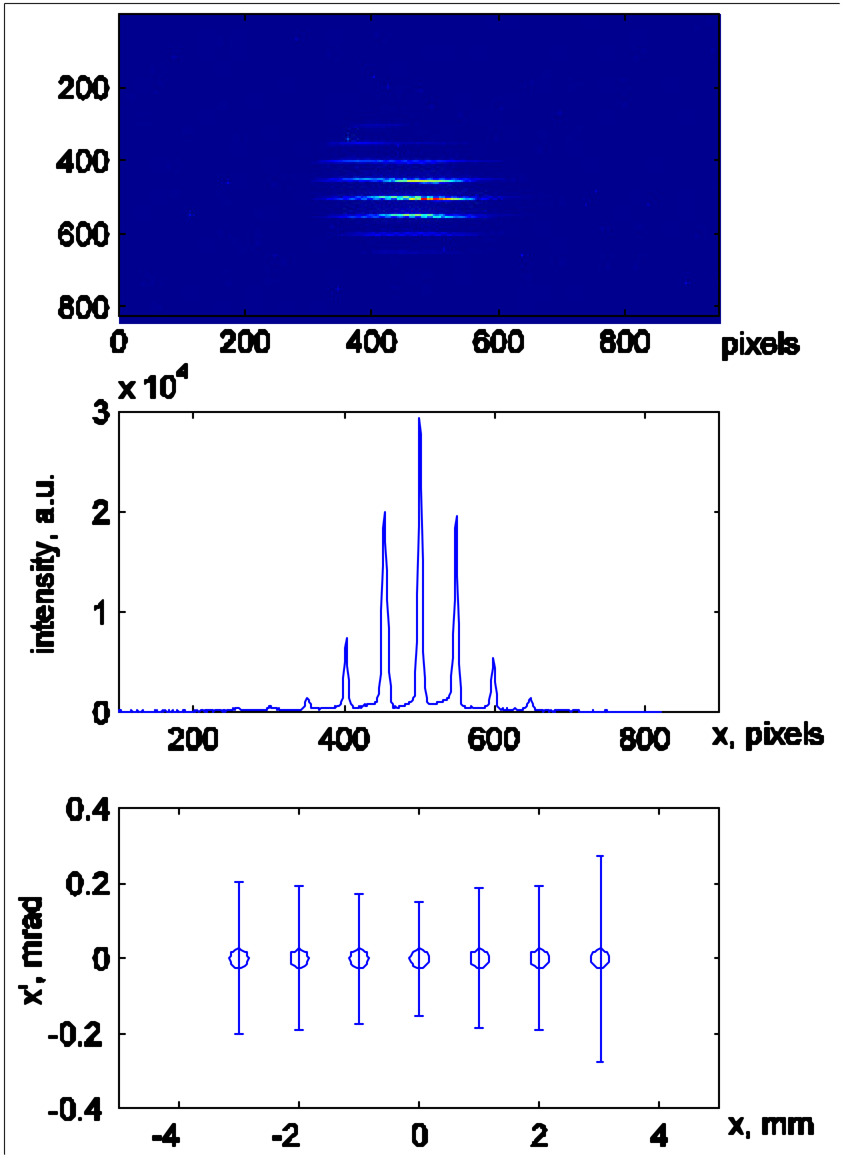
The slit technique was used to measure emittance:

$$e = b\, g s_x s_{x'}$$



The radiation is captured with a CCD camera focused on the YAG screen; the setup is installed downstream of the 9-cell cavity.

RESULTS: example of trace space measurement



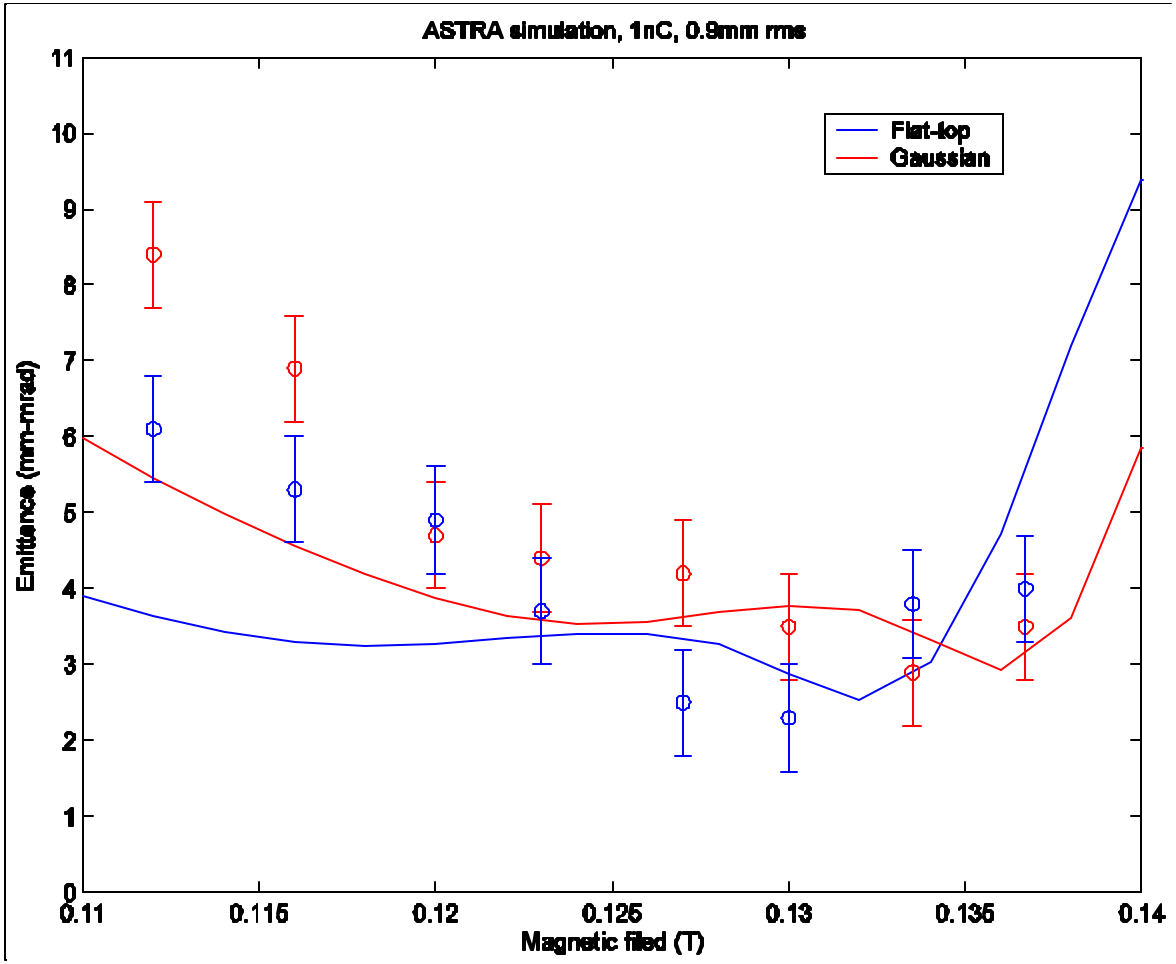
-Slits image at X5

-and its projection along x-axis.

- Measurement of divergence as a function of distance from the center.

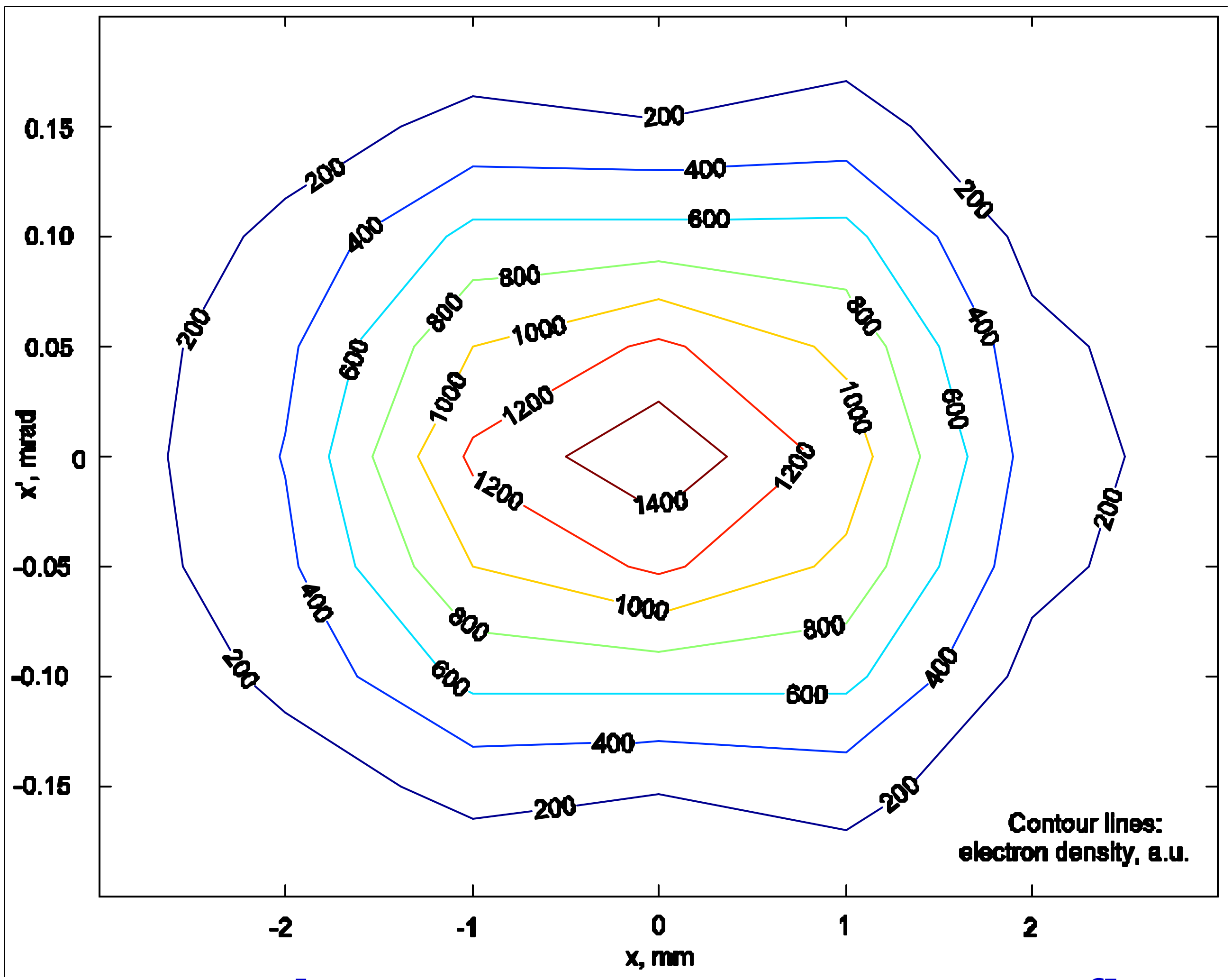
- Due to non-linear space charge effects on the edge of the beam, the divergence there is greater.

EMITTANCE MEASUREMENTS



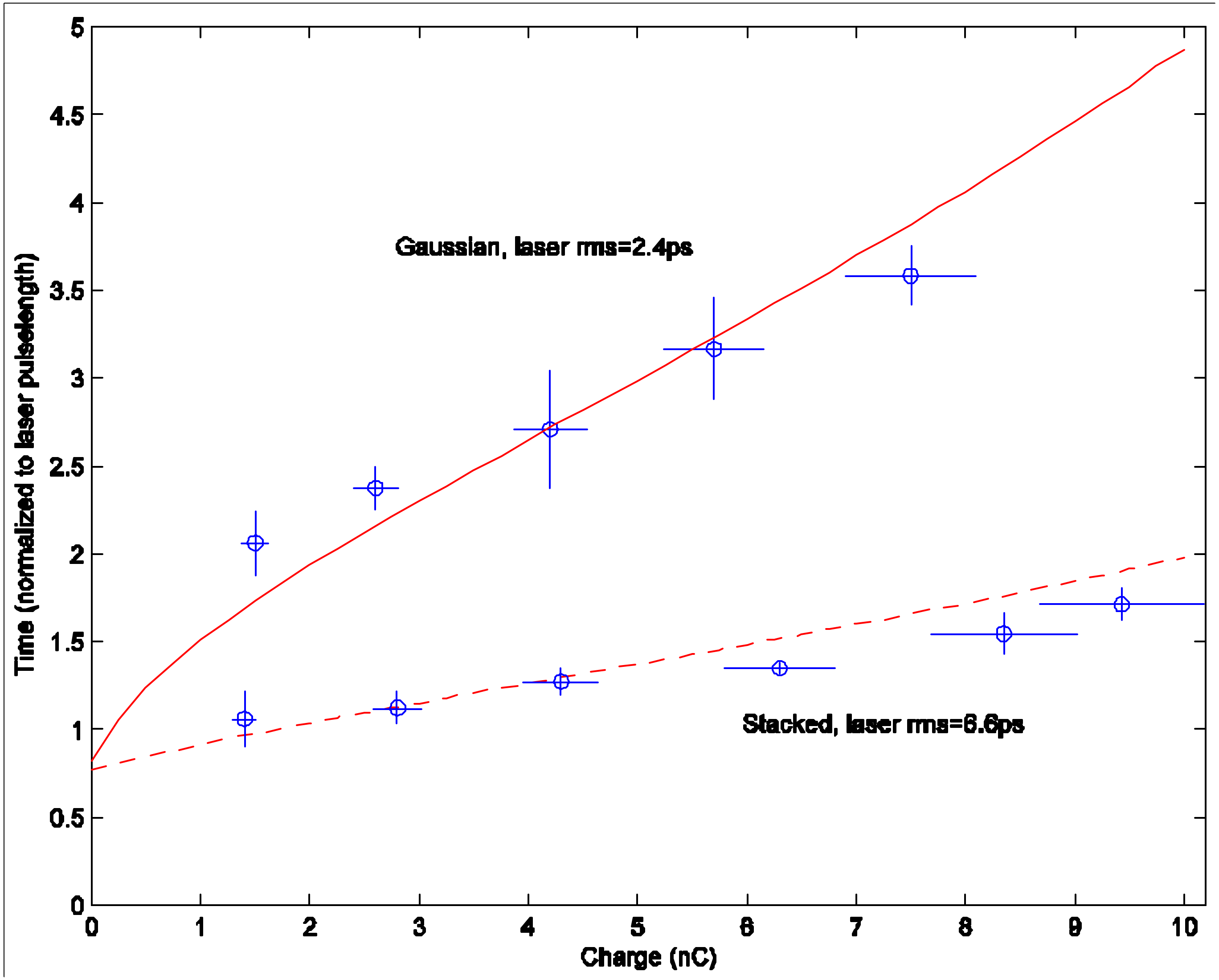
Emittance measurements after the 9-cell cavity; flat-top versus Gaussian laser pulse (1nC).

RESULTS



Transverse phase space map at x3; 1nC, flattop.

BUNCH LENGTH MEASUREMENTS



Electron bunch length as a function of charge.

RESULTS

- We have measured the emittance for both Gaussian and flat-top pulses as a function of rf-gun solenoid current. The minimum value for a Gaussian pulse is 3.0 mm-mrad (190A); and for stacked is 2.5 mm-mrad (200A). The stacked pulse has relatively lower emittance. This agrees well with the ASTRA simulation.
- The divergence of the beam was measured as a function of transverse distance. As expected the divergence is smallest in the center of the beam and it grows as we move away from the center (transversely).
- Electron bunch elongation as a function of charge was studied. The growth for the longer flattop is significantly slower.

ACKNOWLEDGEMENT

My special thanks to professors Adrian Melissinos and Philippe Piot for their support and advice.

I am also grateful to

Helen Edwards

Jianliang Li

Daniel Mehalcea

Grigory Kazakevich

for their help.