Time-resolved SEM monitor with large dynamic range for R&D of Linac4

M. Hori
Max-Planck Institute for Quantum Optics
University of Tokyo

K. Hanke
CERN

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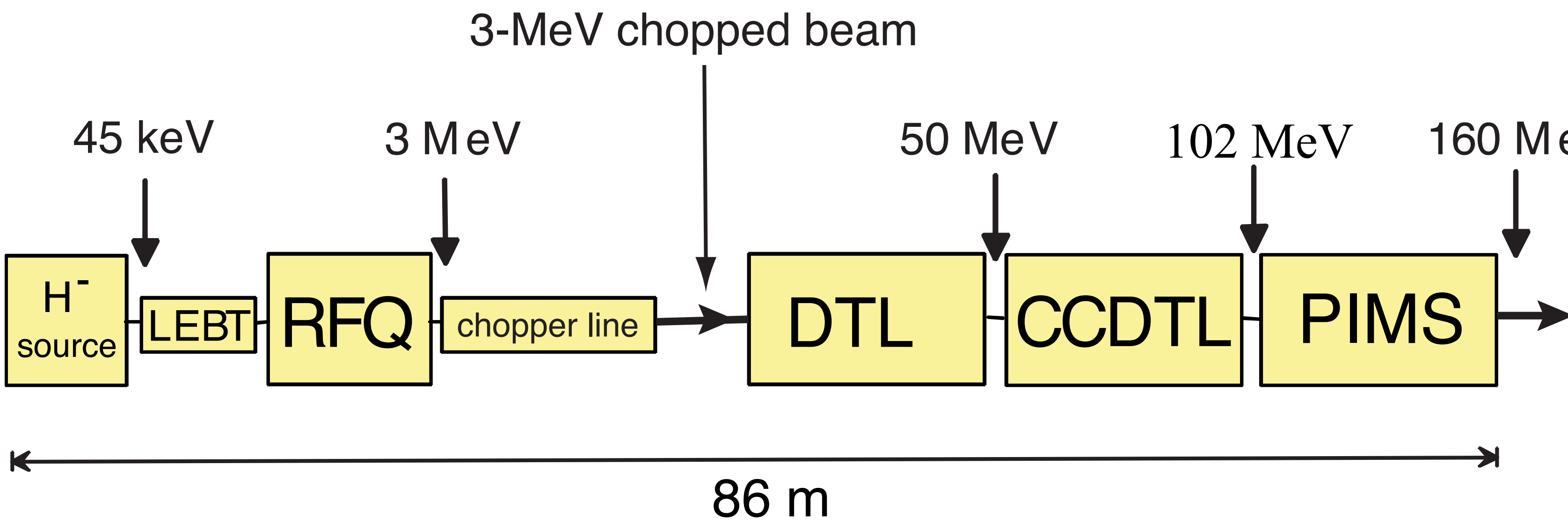
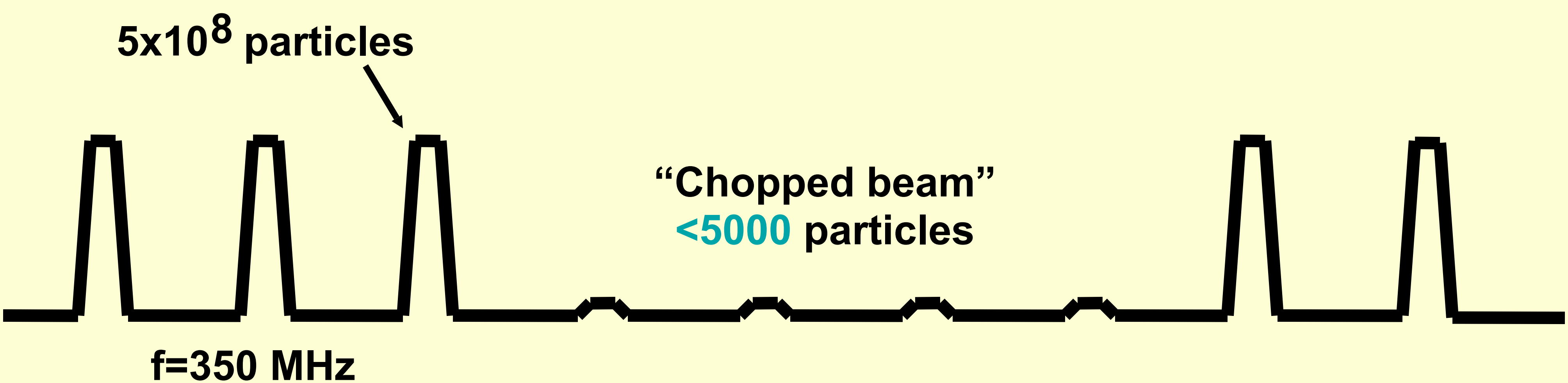
Time-resolved measurement of Linac4 chopper





Our design philosophy for Linac4 detector

1. Simplicity and ease of use - extension of “classic” interception technique + secondary electron detection (let’s not use lasers yet).

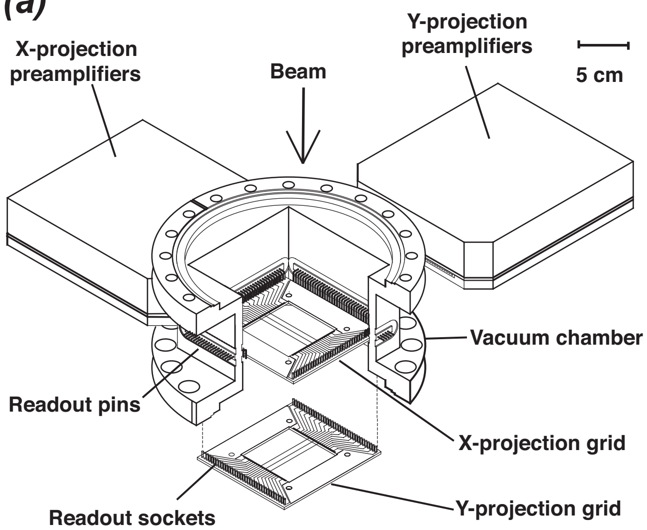
2. Robustness - stripper foils are most resistant to high beam intensities.

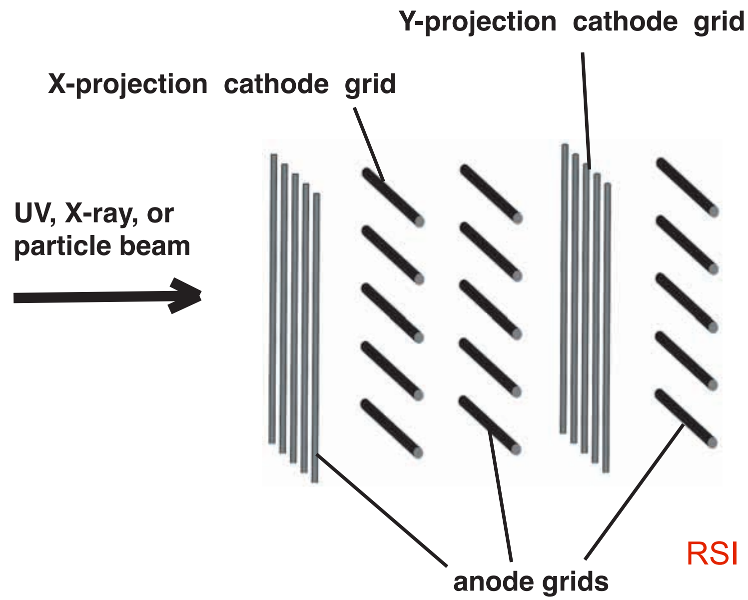
3. Use modern gating techniques, optics, and readout sensors and try to get the “best” performance.

Our work for Linac4 grew out of our previous R&D efforts at the CERN Antiproton Decelerator measuring pulsed antiproton beams using secondary electron emission monitors (SEM's).

Secondary electron emission monitor based on wires

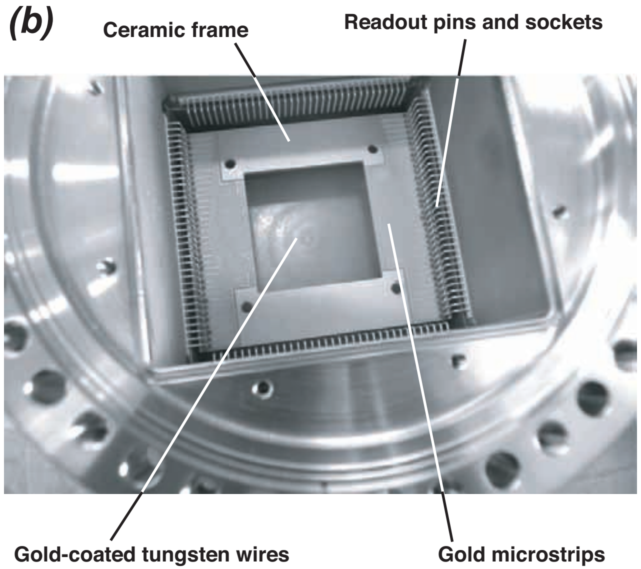
(a)





RSI 76, 113303 (2005)

(b)

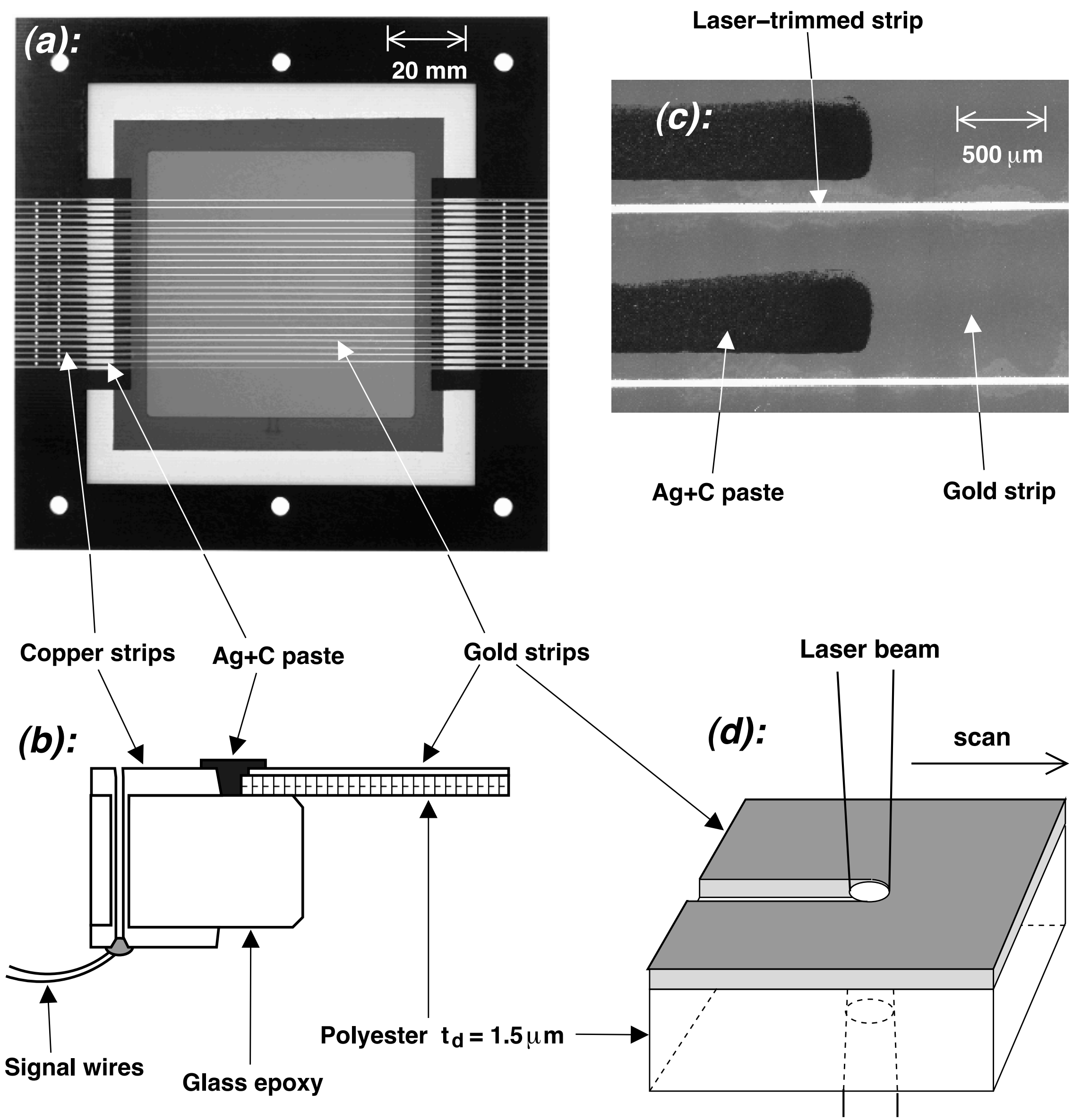


Gold-sputtered tungsten wires or carbon filaments diameter 5-30 um placed in UHV.

Wires intercept 1-3% of the beam. 97-99% travel through without being affected.

Secondary electrons detected by charge-sensitive preamplifiers with RMS equivalent noise charge 200.

Secondary electron emission monitor based on foils



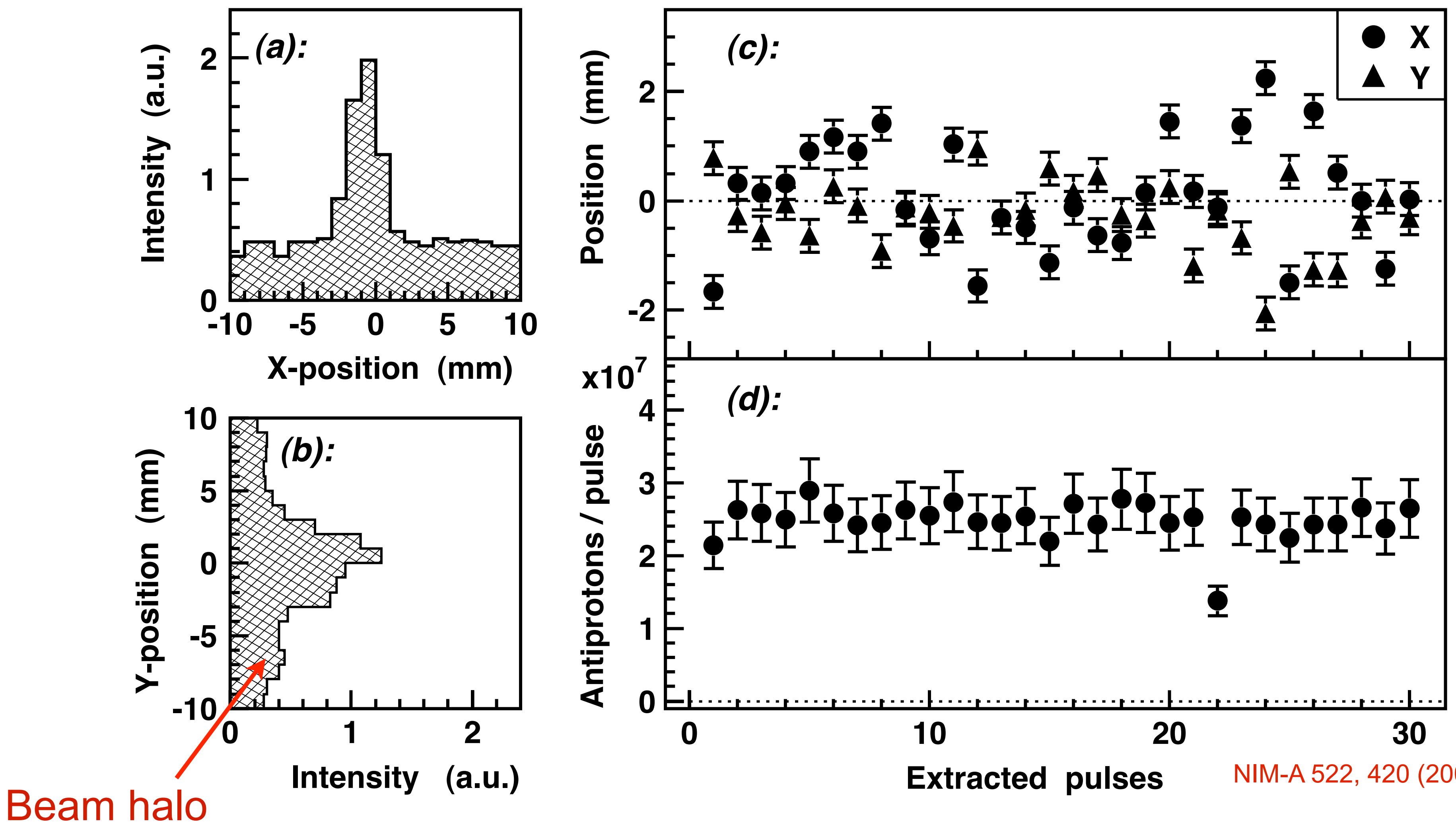
Aluminized or gold-sputtered polyester or Mylar foils.

Cutting of 80-um wide strips in metal layer using Nd:YAG or excimer nanosecond laser trimmer.

Transparent Mylar or polyester foils are left intact.

NIM-A 522, 420 (2004)

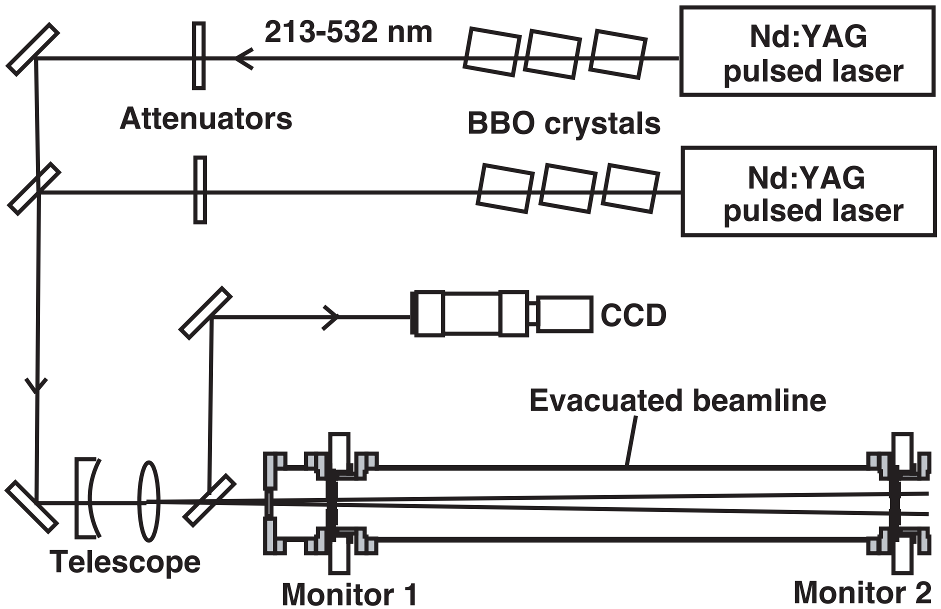
Profile measurements at the Antiproton Decelerator

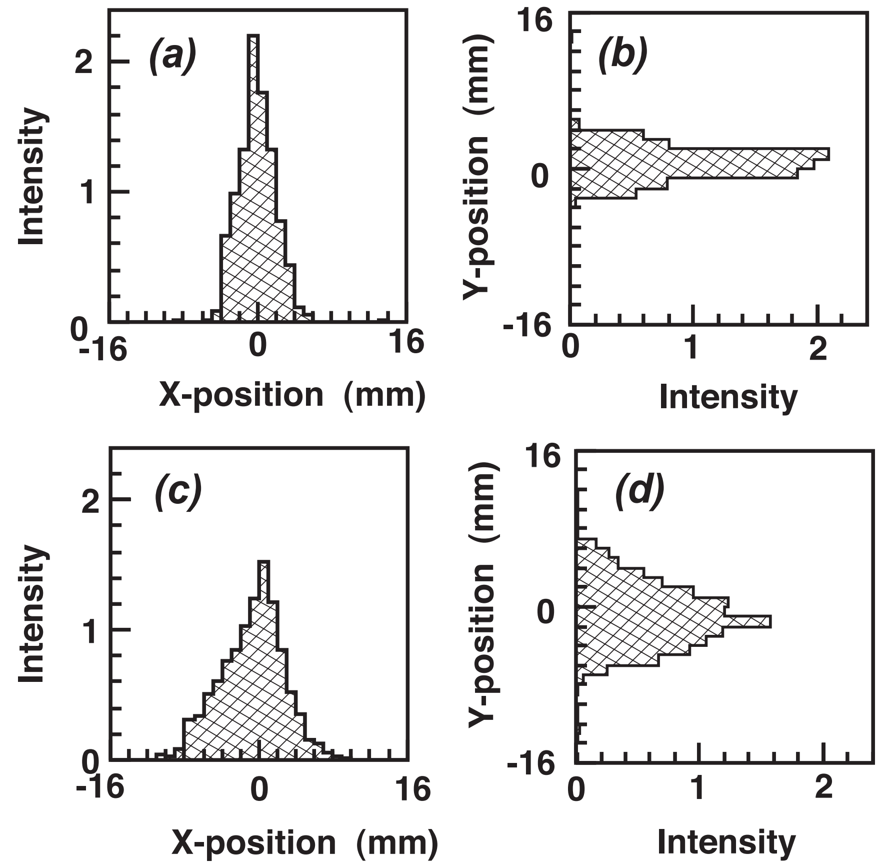


NIM-A 522, 420 (2004)

Clear profiles can be observed using the detection of secondary electron emission 10^5 - 10^7 particles/pulse

Lasers can be used to simulate particle beams



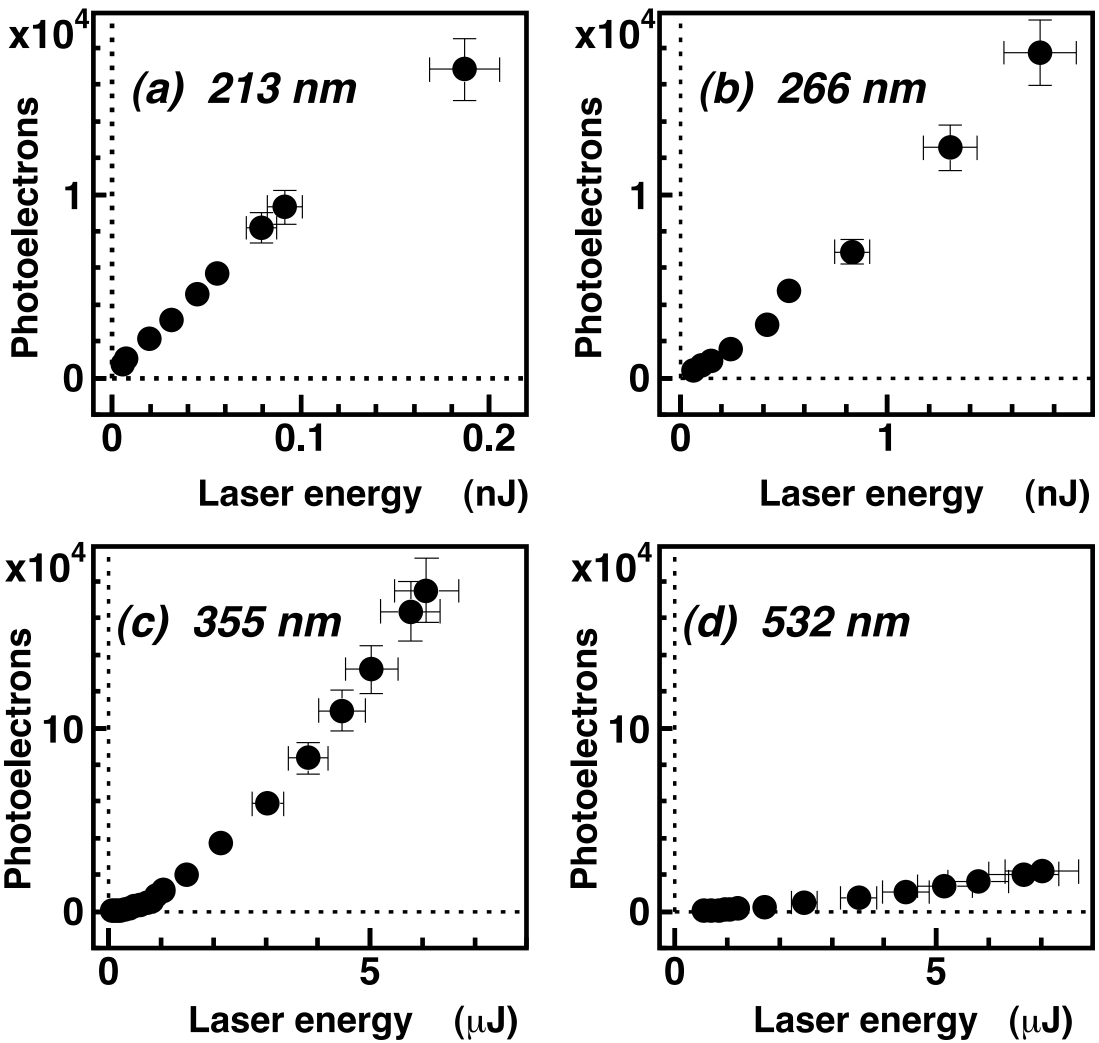


Single-shot measurement of beam profile at several point along beamline.

Enables rapid determination of beam emittance, beam tuning.

RSI 76, 113303 (2005)

Photoelectron emission efficiencies for lasers of various wavelengths



W-value of gold = 4.6 eV

213 nm (5.8 eV) g=10-4

266 nm (4.6 eV) g=10-5

proceeds via single-photon.

relatively linear.

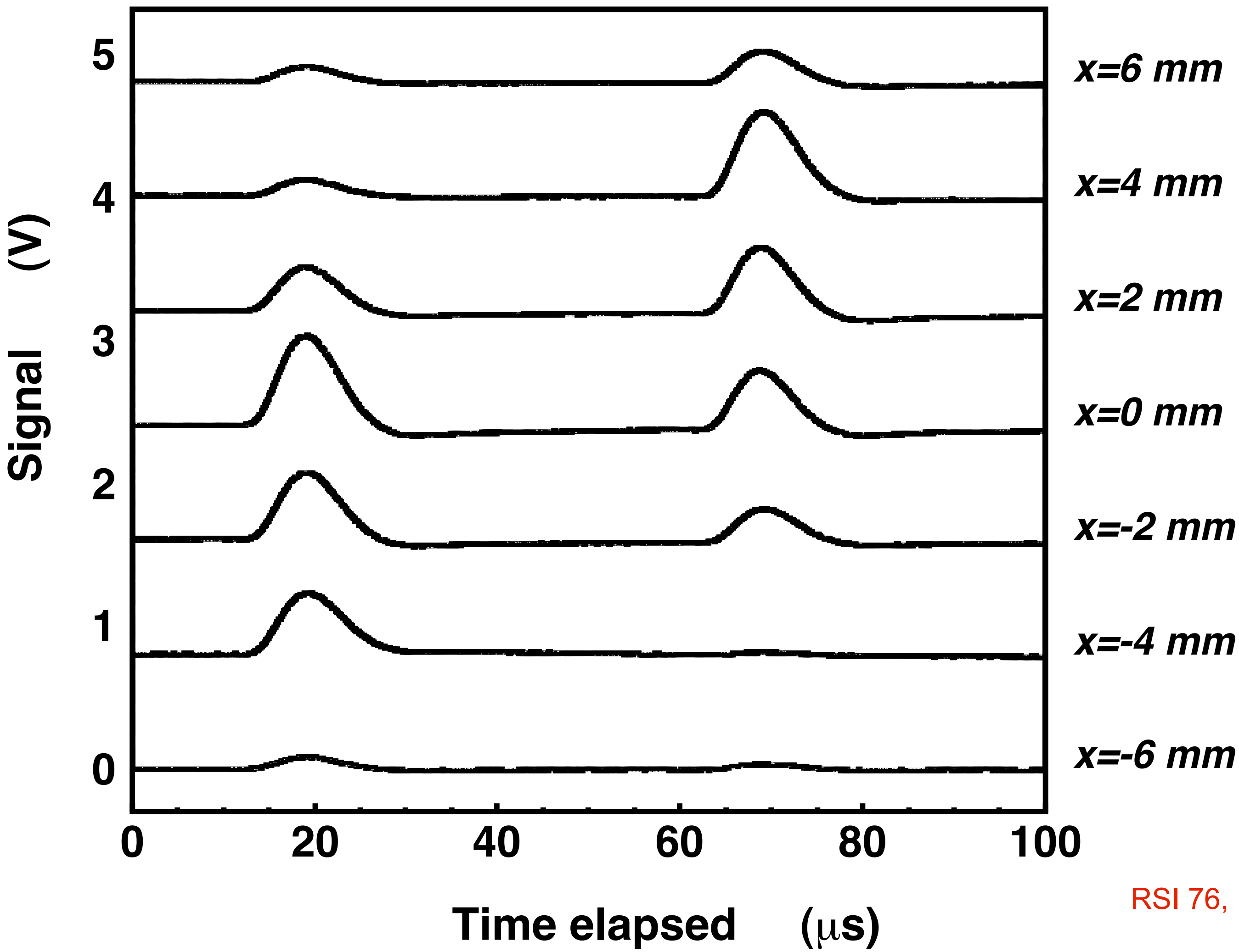
355 nm (3.5 eV) g=10-8

532 nm (2.3 eV) g=10-9

proceeds via two-photon, non-linear. Needed field =50-200 kW/cm2

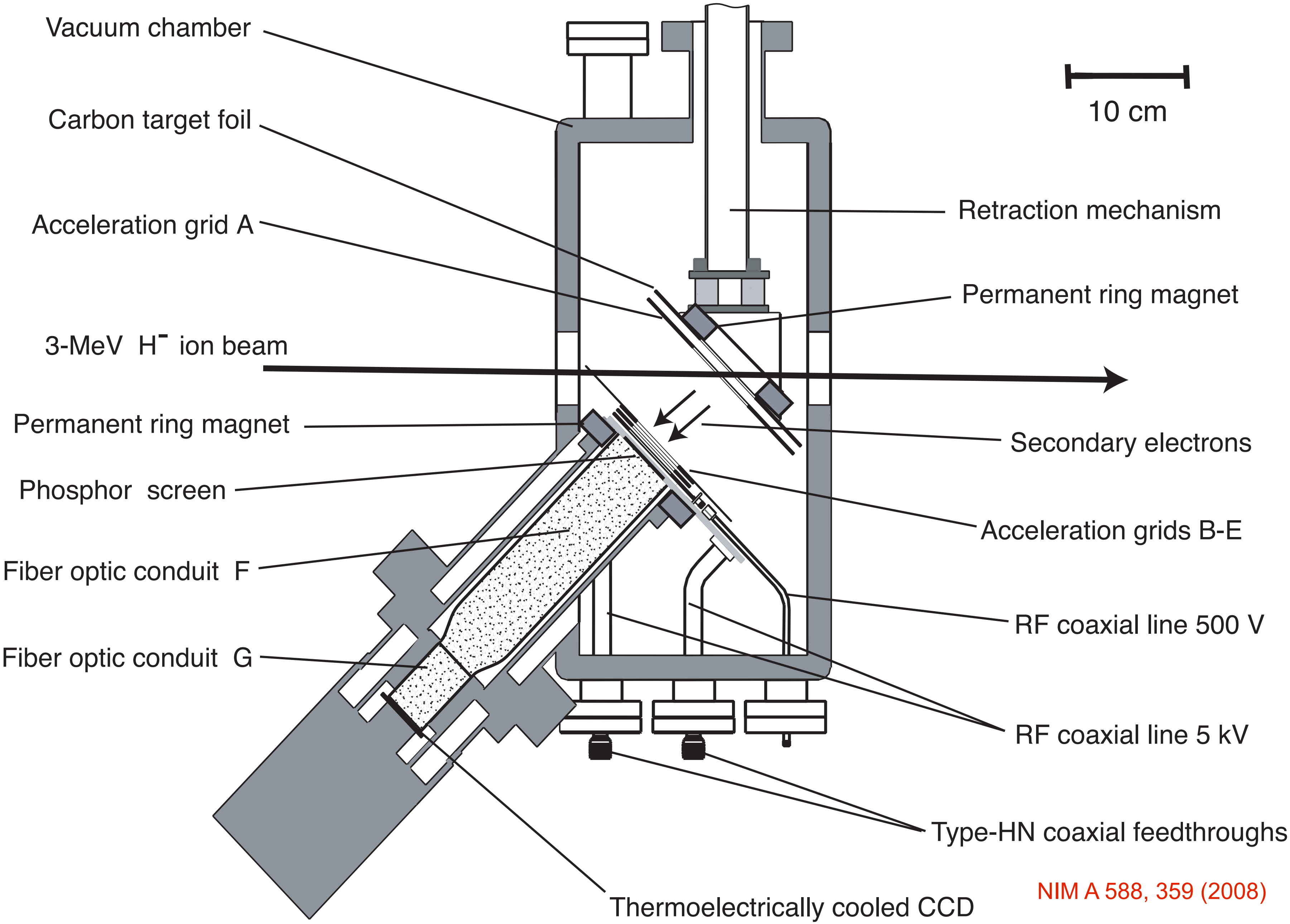
RSI 76, 113303 (2005)

These types of charge-sensitive preamplifiers can provide timing resolutions in the 100 ns to 10 us range only.....

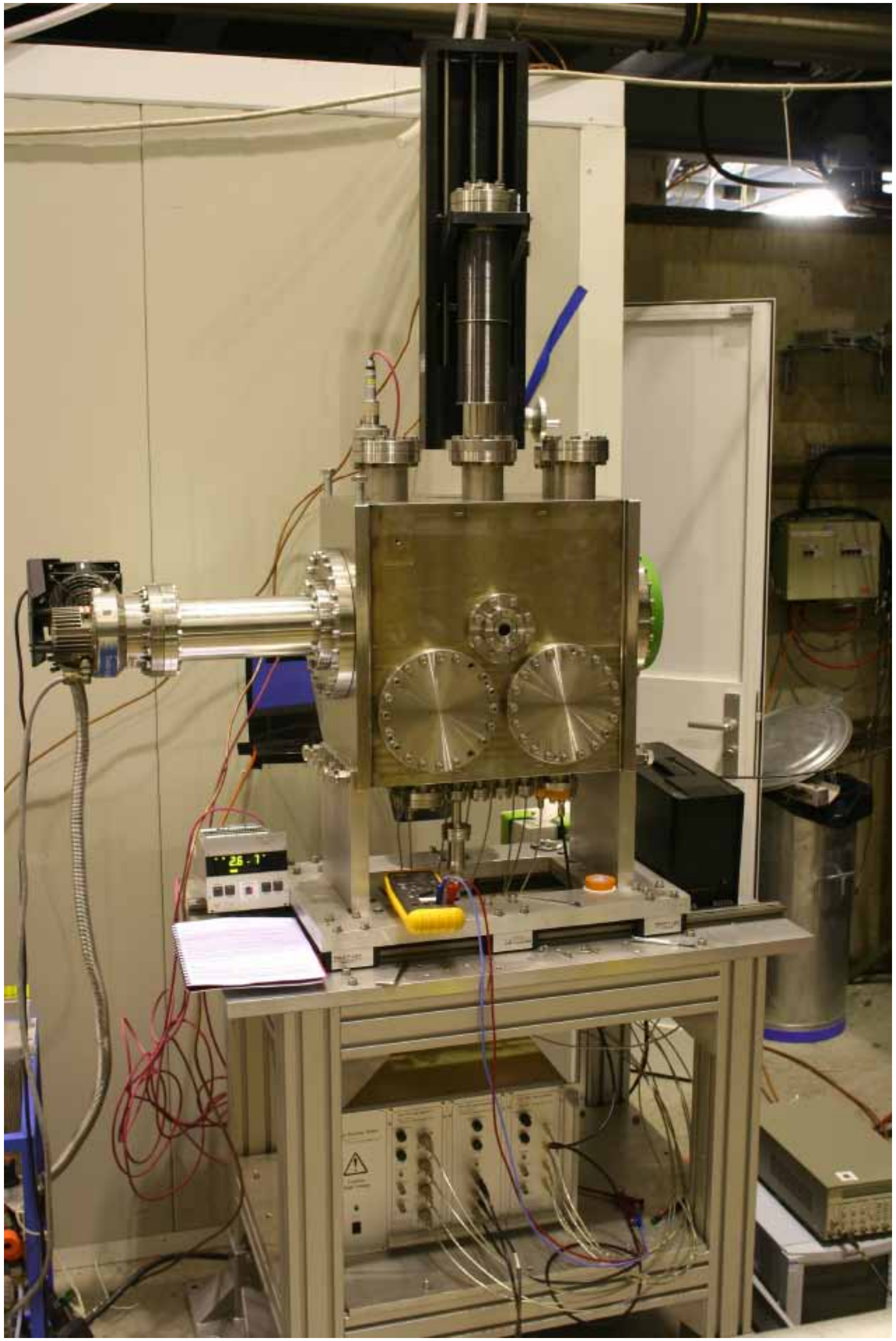


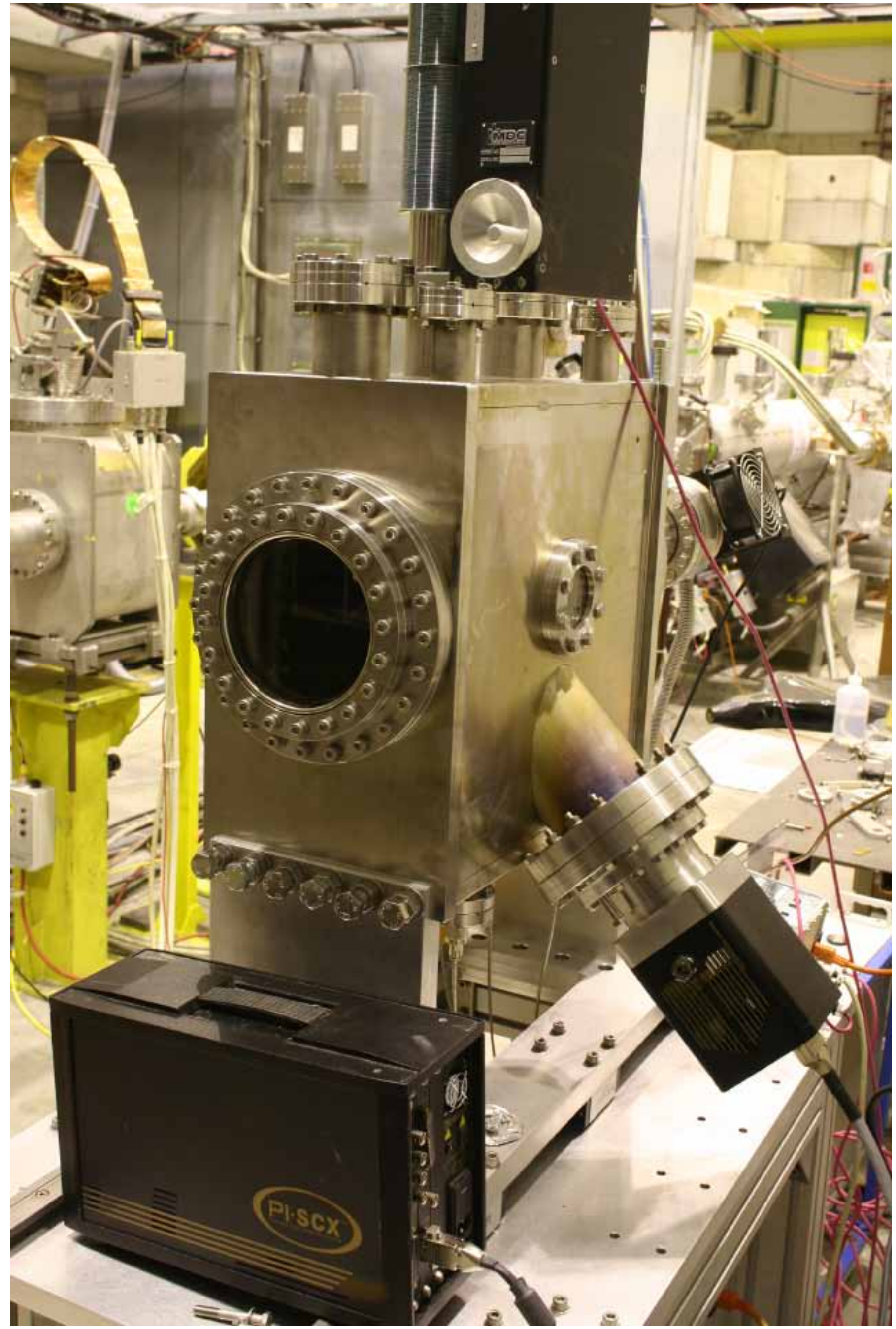
RSI 76, 113303 (2005)

Detector developed for Linac4 R&D

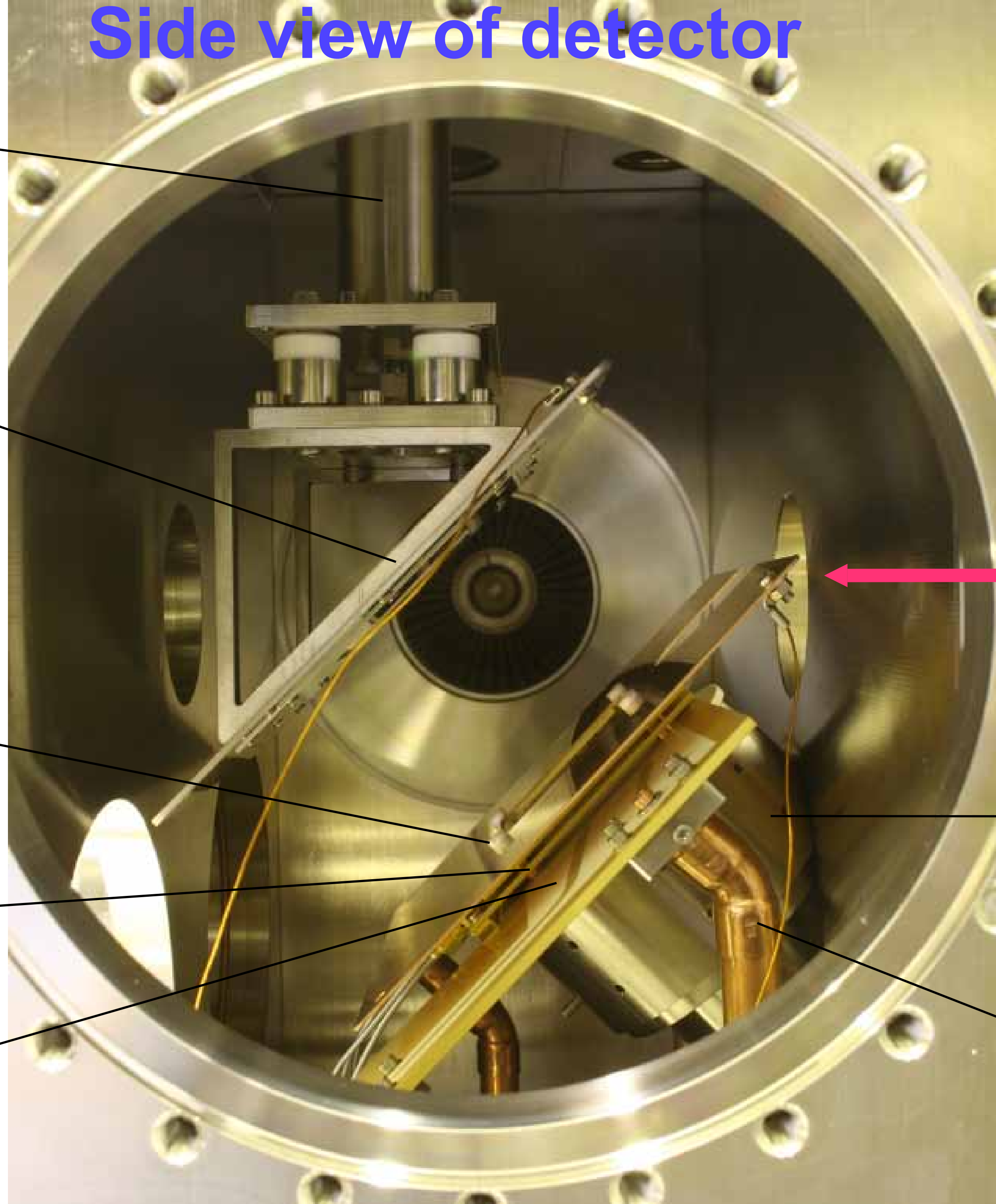


NIM A 588, 359 (2008)

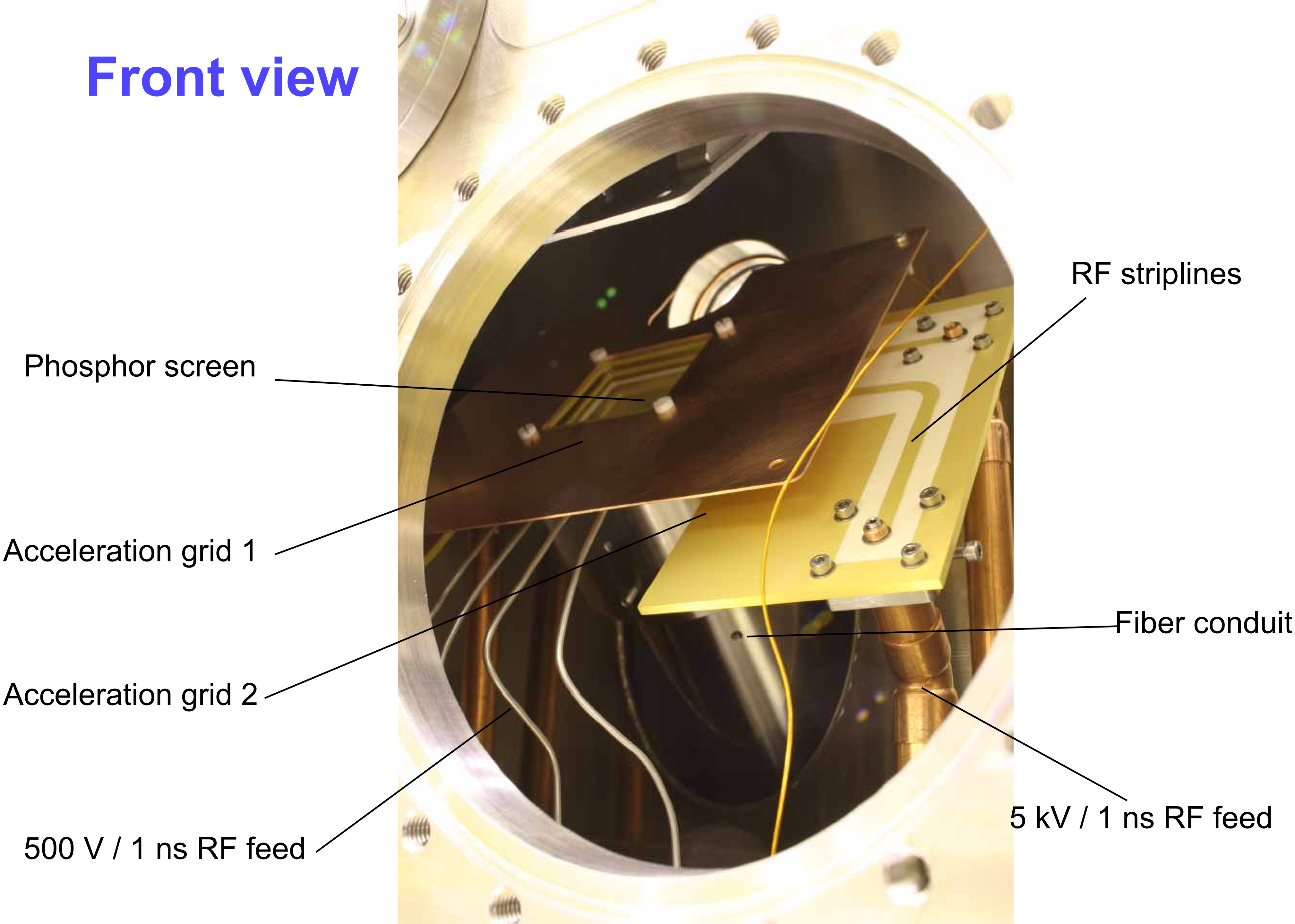



PI·SCX

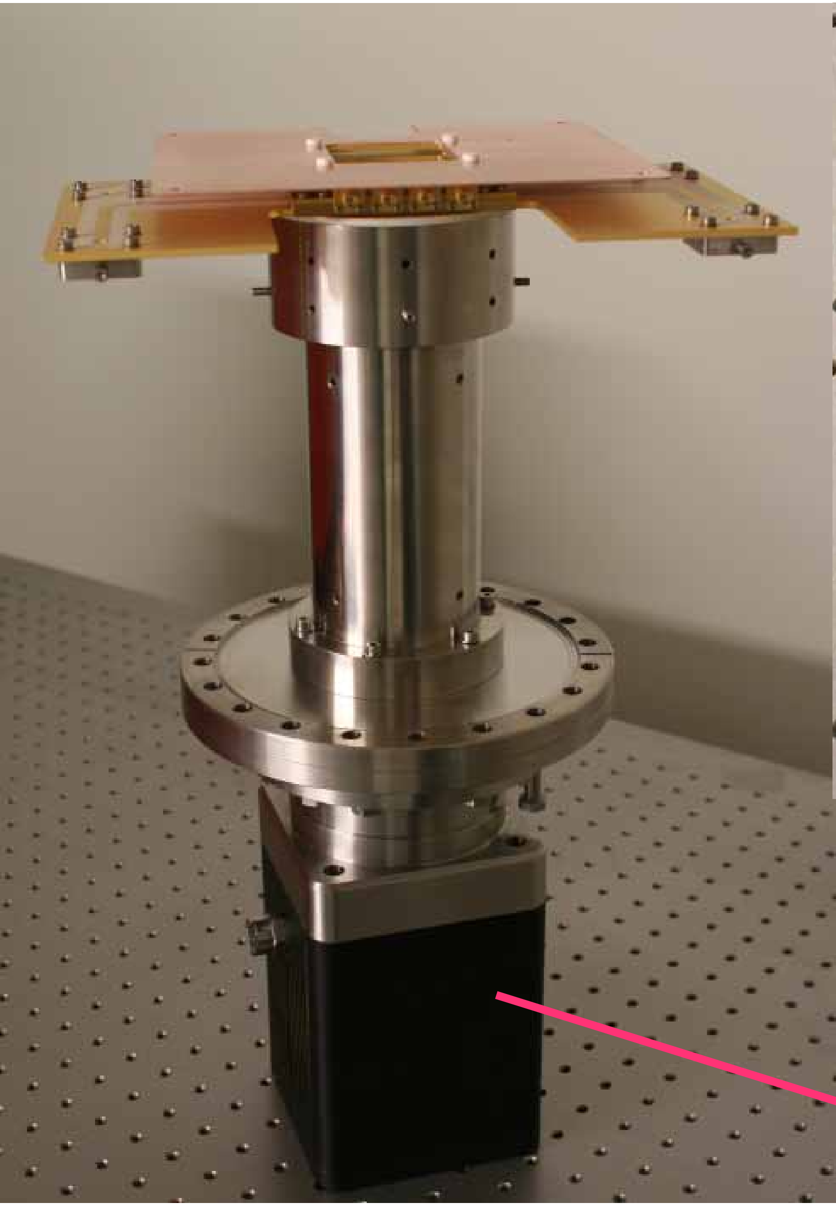
Side view of detector

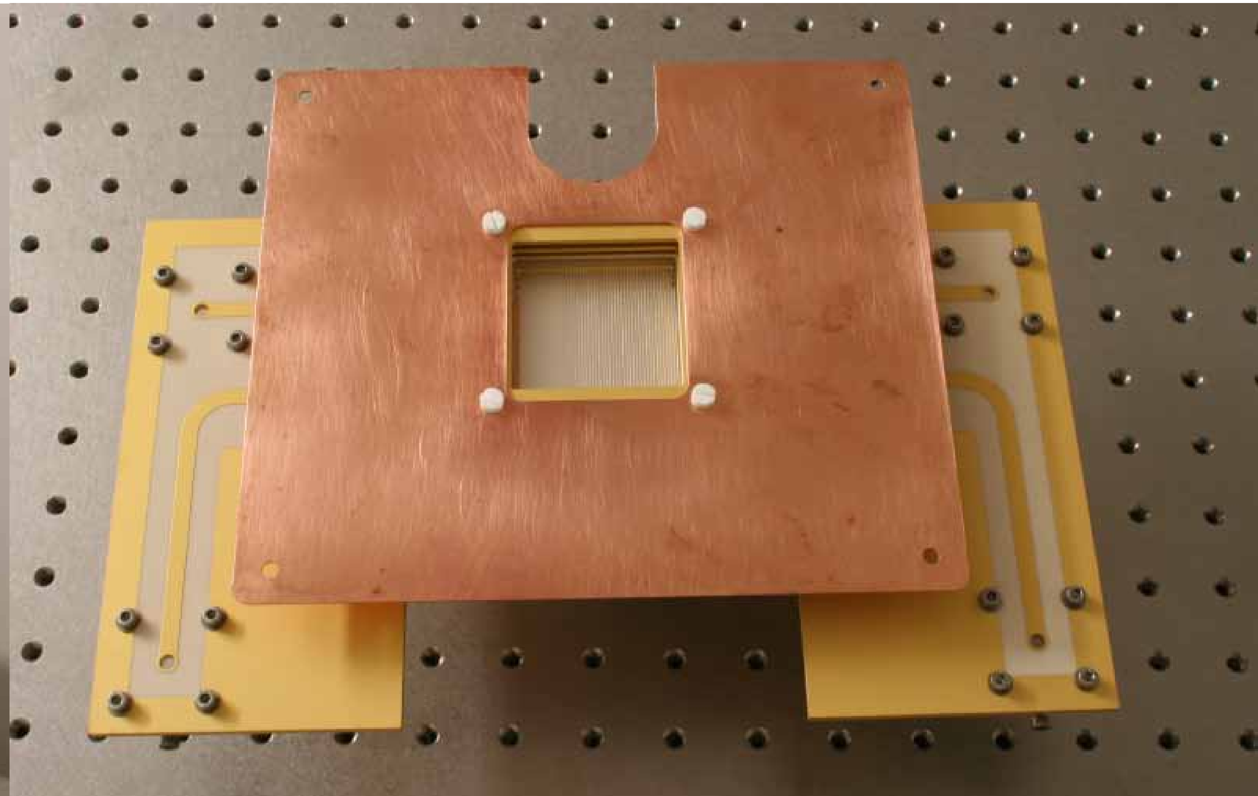


Front view


RF striplines
Phosphor screen
Acceleration grid 1
Fiber conduit
Acceleration grid 2
5 kV / 1 ns RF feed
500 V / 1 ns RF feed

Electron - to - photon imager

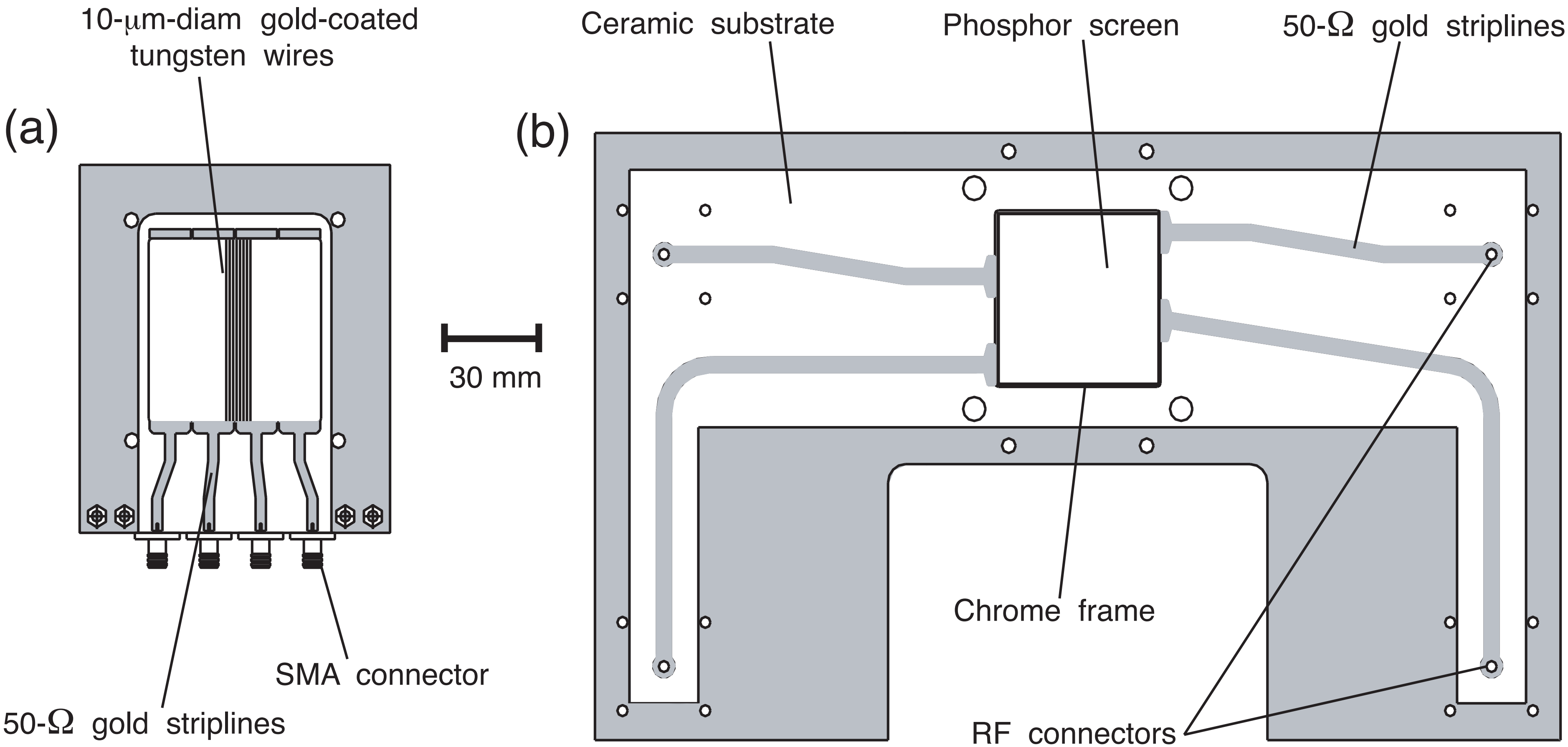




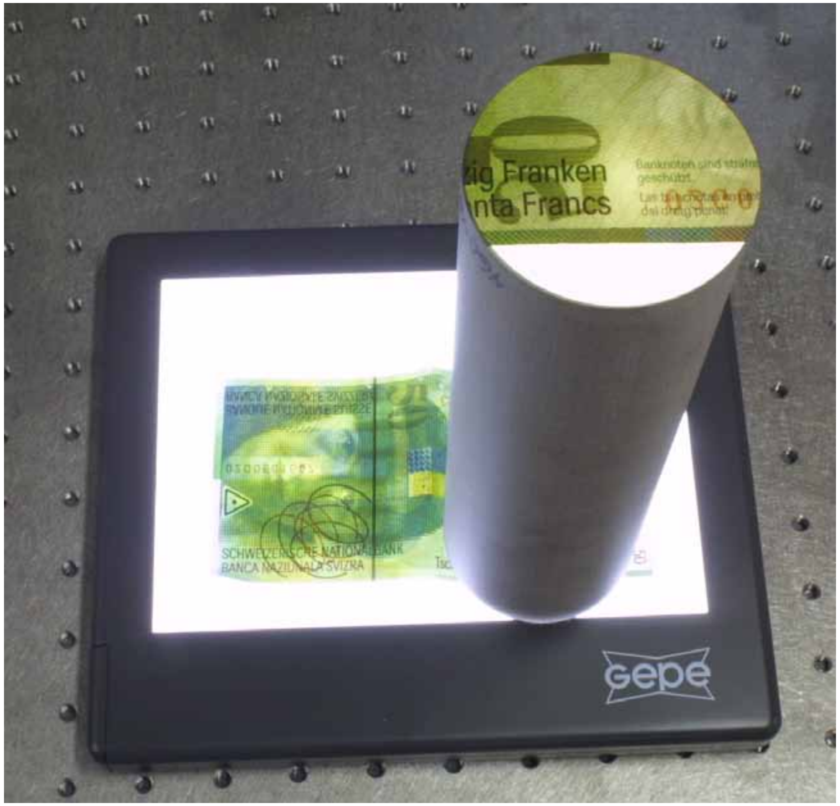
Four parallel 50-Ohm lines for effective impedance 12.5 Ohm allows fast switching of voltage potential

CCD camera

Switching grid and phosphor screen



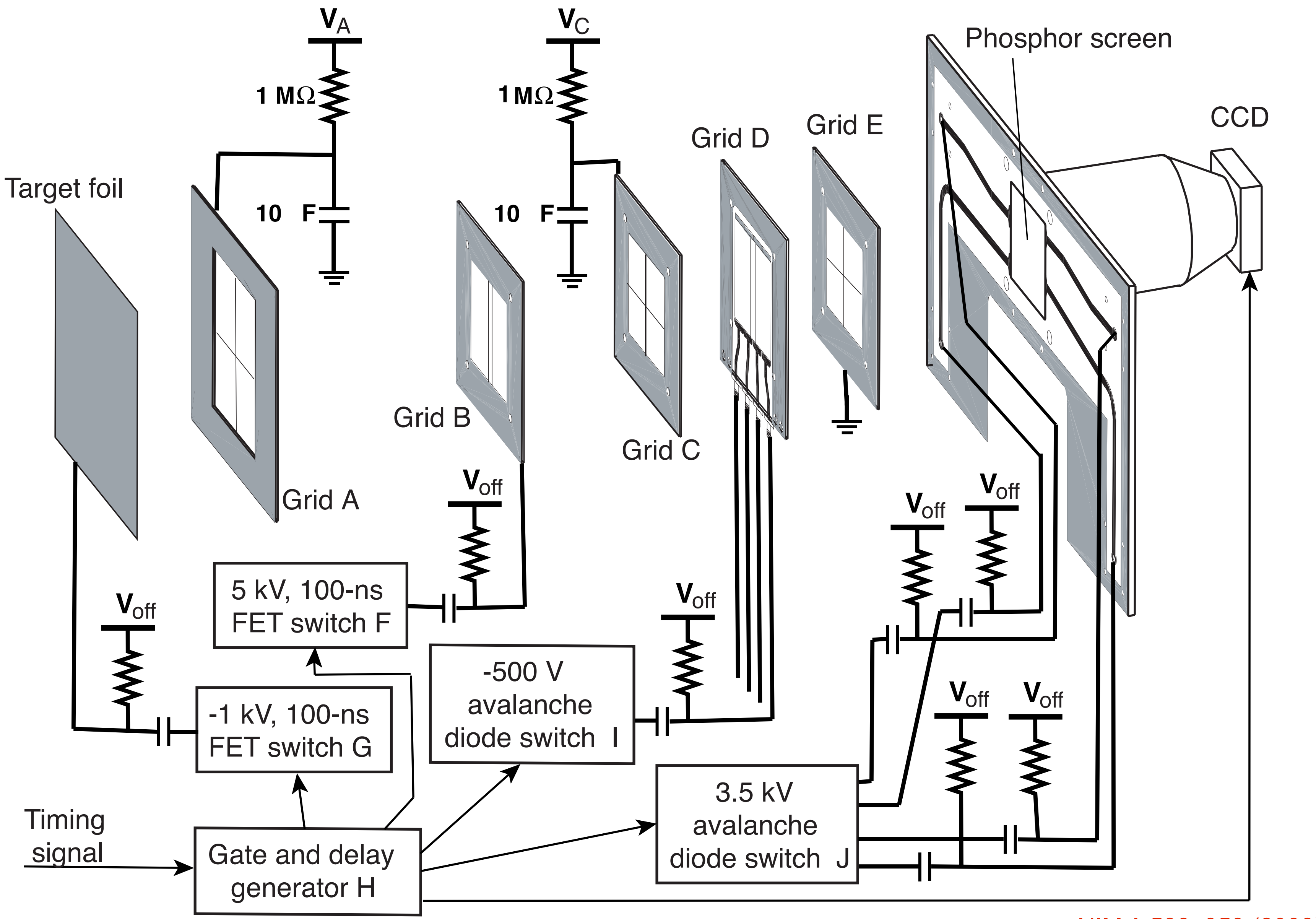
Optical imaging system to "photograph" the beam profile



- ✓Active area 50 mm diam.
- ✓50 million fibers.
- ✓Magnification 1.8 x
- ✓Provides shielding against X-rays and neutrons.

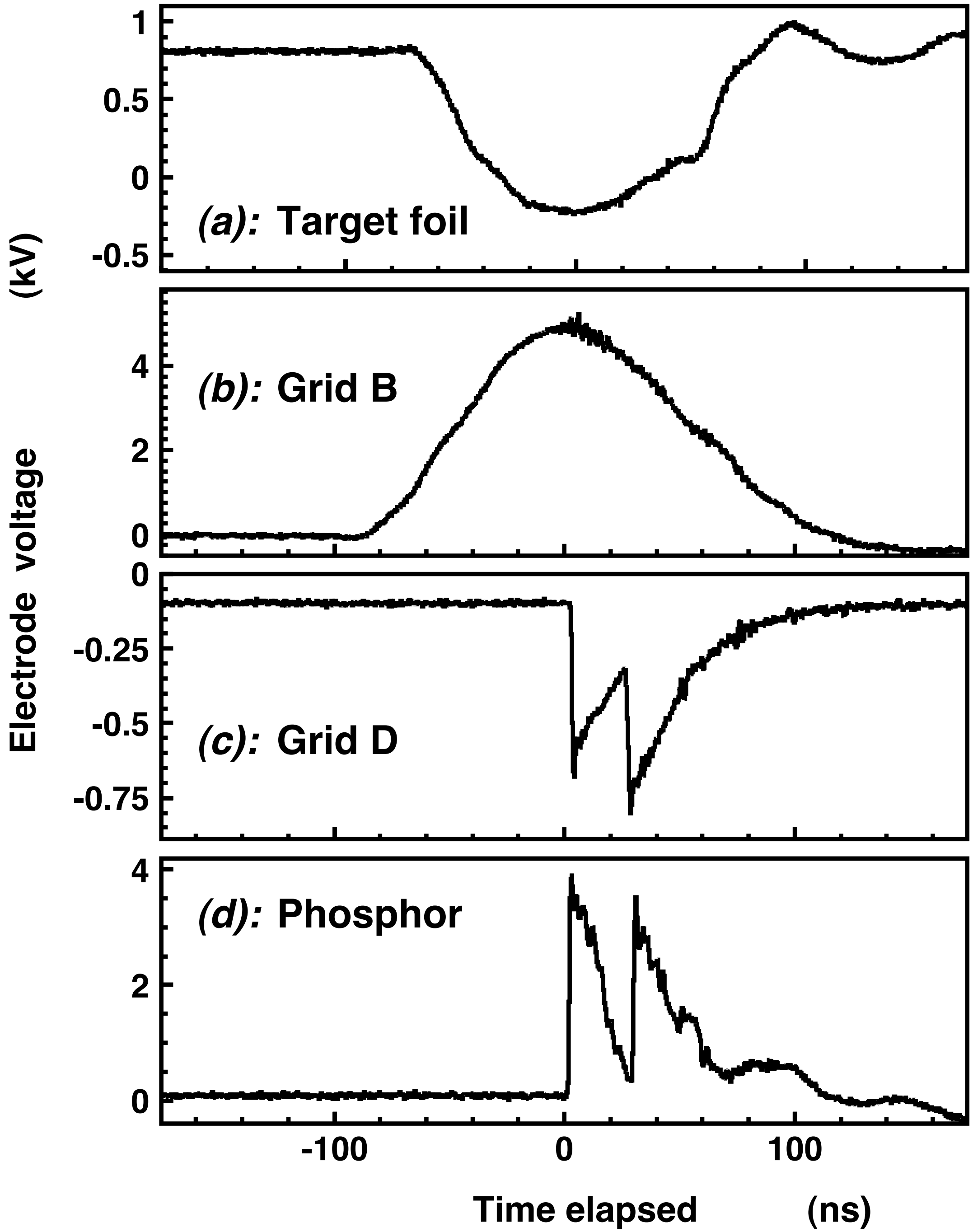
- ✓UHV compatible
- ✓1300 x 1300 pixels.
- ✓ Read noise 5 electrons
- ✓16 bit ADC, 200,000 e- full range
- ✓ Speed 1.8-18 sec full frame

Electronic gating and acquisition system

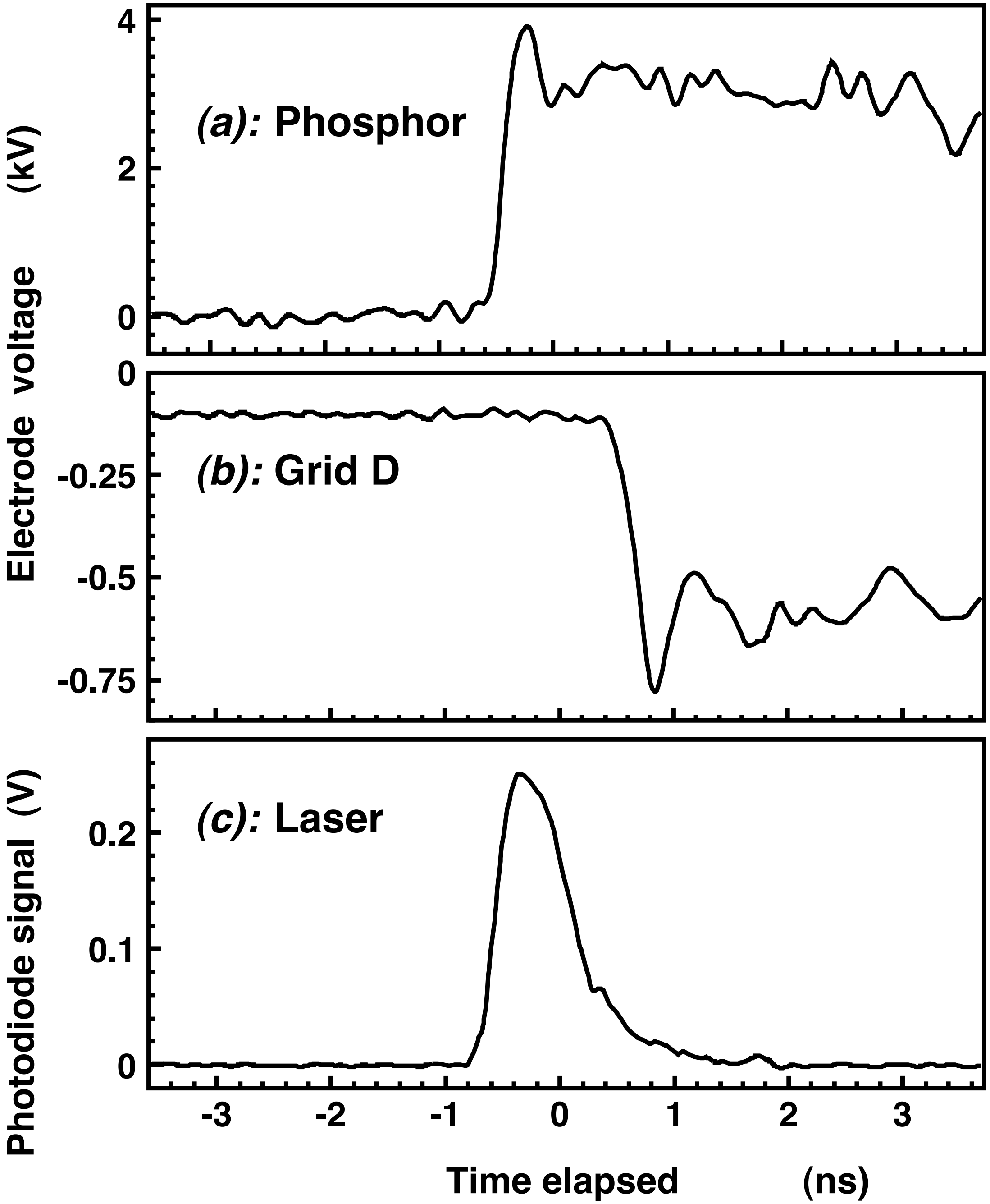


NIM A 588, 359 (2008)

High voltages applied to electrodes

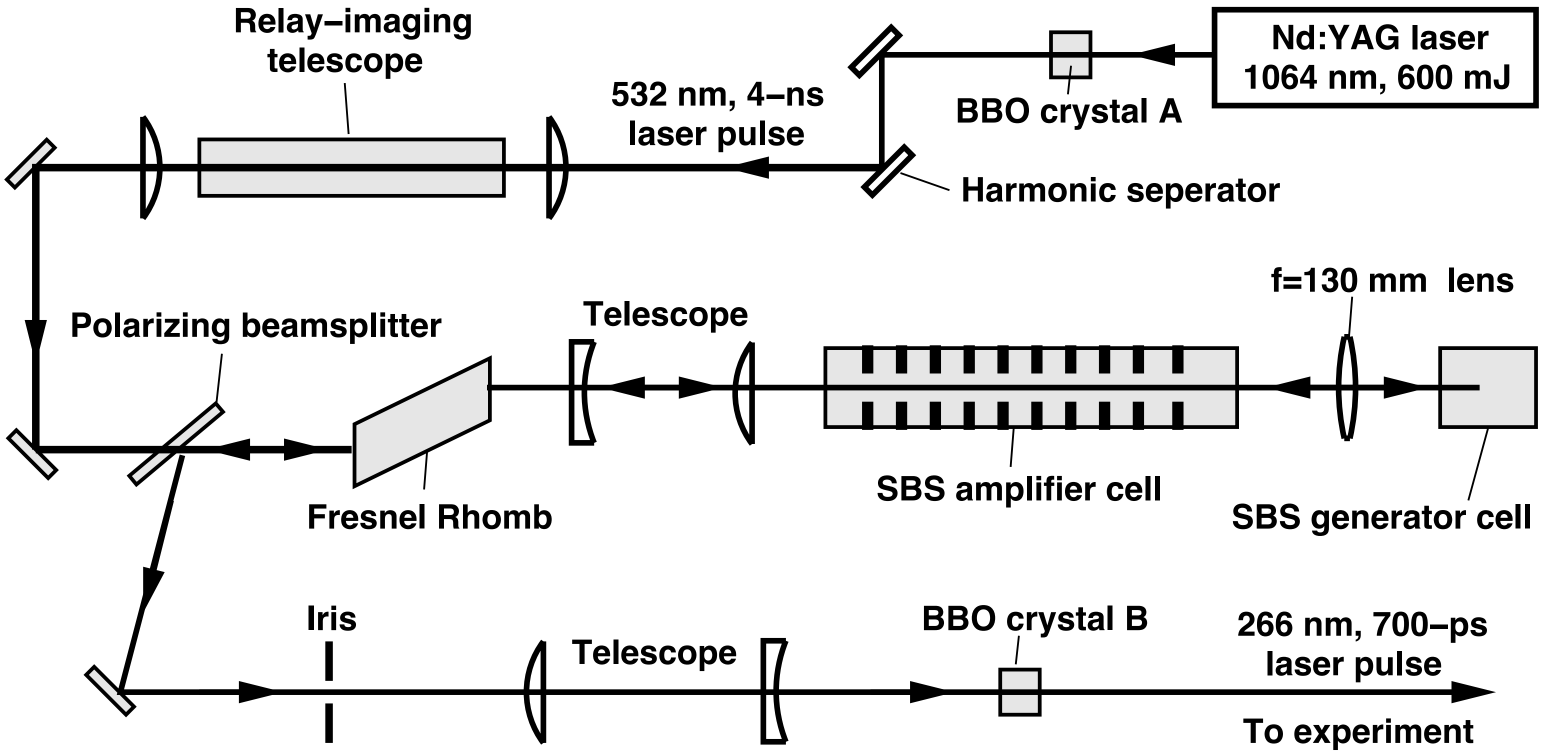


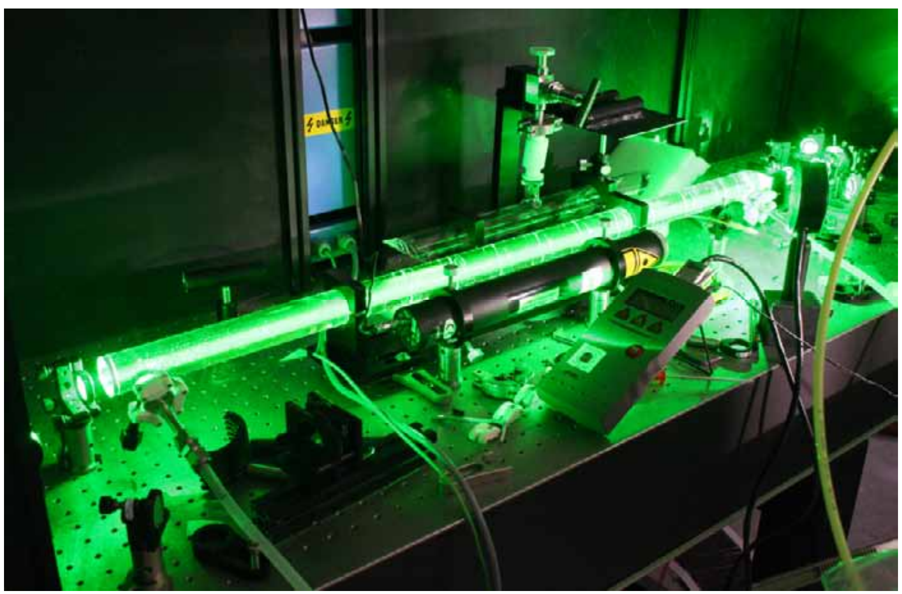
- Two FET switches
- Two avalanche diode switches
- Open circuit at end of coaxial lines.



Time-resolved measurement of pulsed UV beam

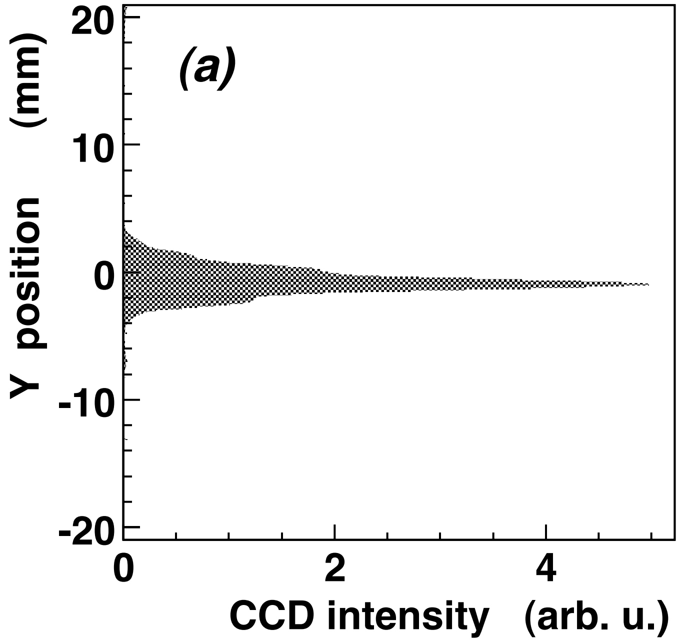
- Rise and fall time of gates 500 ps.
- UV laser pulse 700 ps.

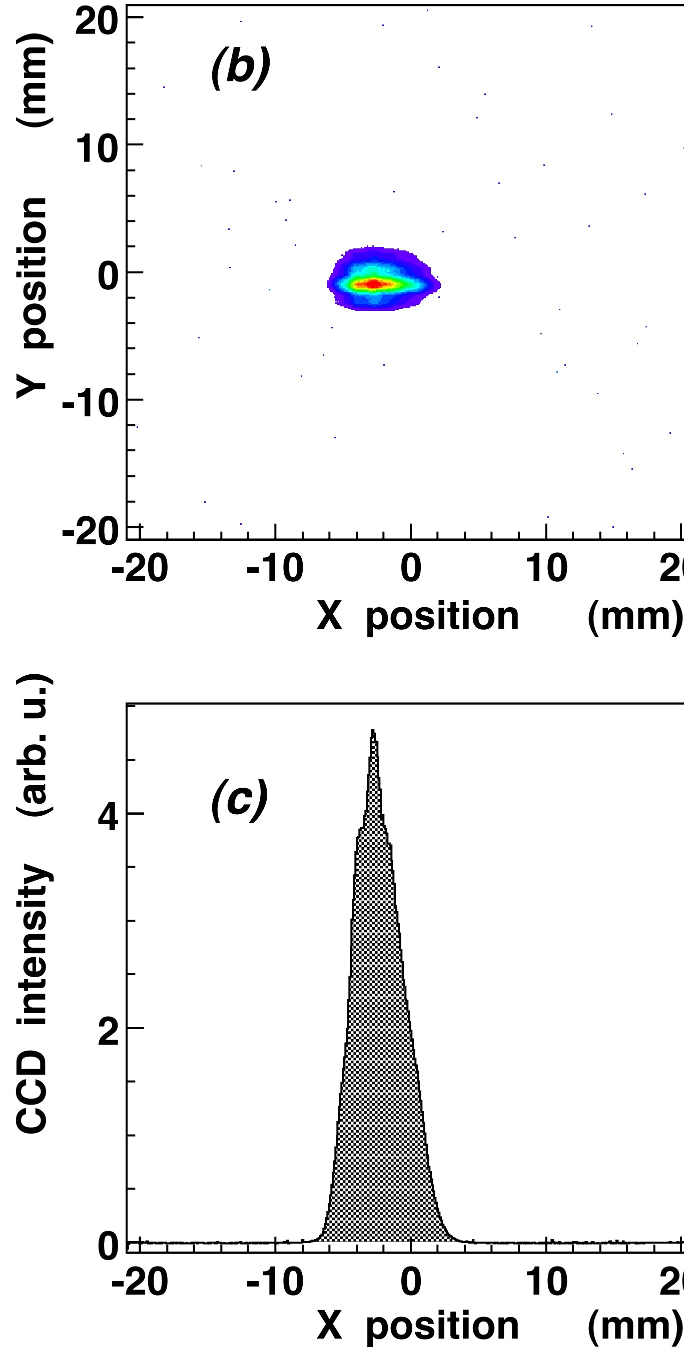




Ultraviolet laser pulse generator to simulate Linac-4 beam

SBS process to compress Nd:YAG laser pulses to < 700 ps, 266 nm UV laser
10 Megawatt peak power

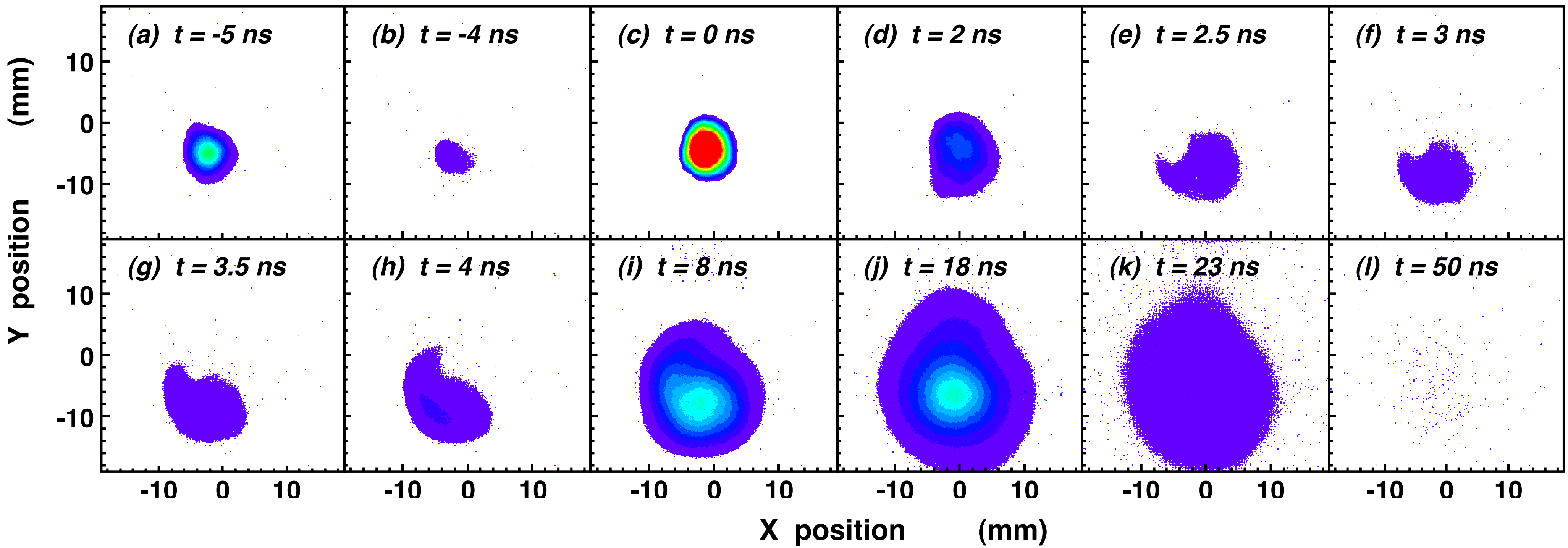




$5x10^7$ photoelectrons
2 mm spatial resolution

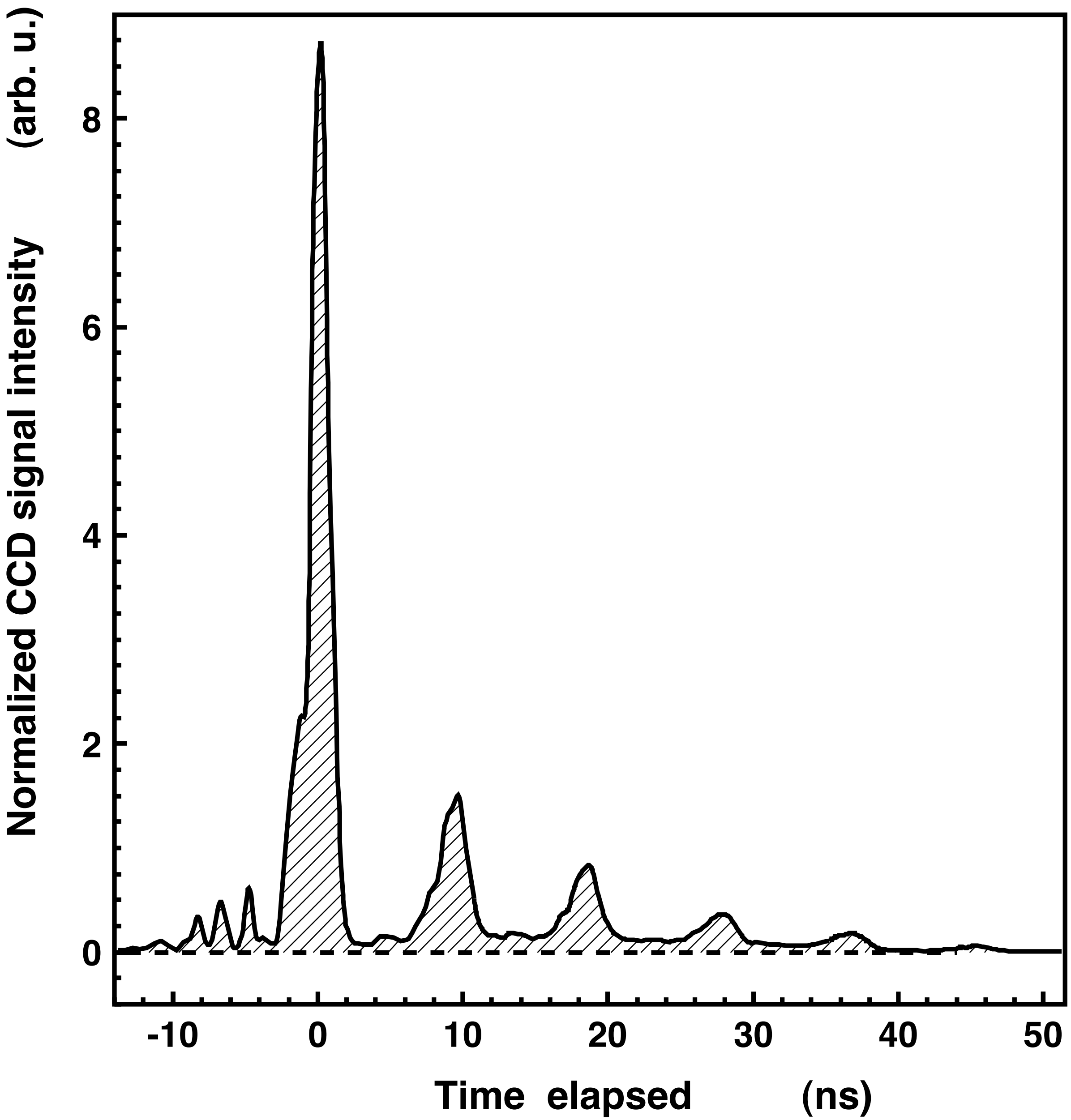
Magnetic field 100 Gauss, acceleration voltage 1 kV

“Stop motion pictures” of the beam



$5x10^8$ photoelectrons, similar to Linac4 intensites.
“Swirling” effect due to cyclotron motion.

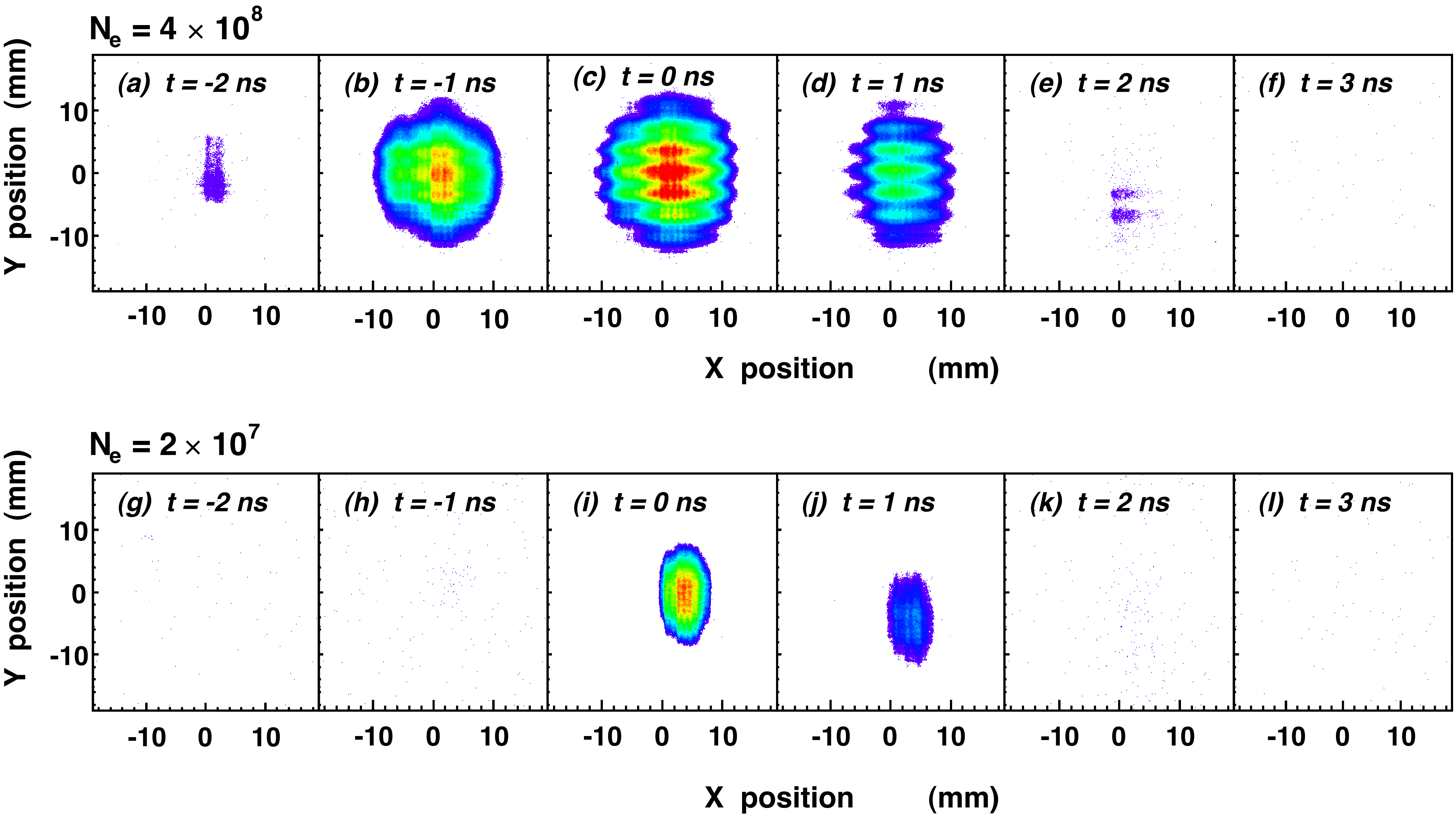
Magnetic field, acceleration voltage 1 kV



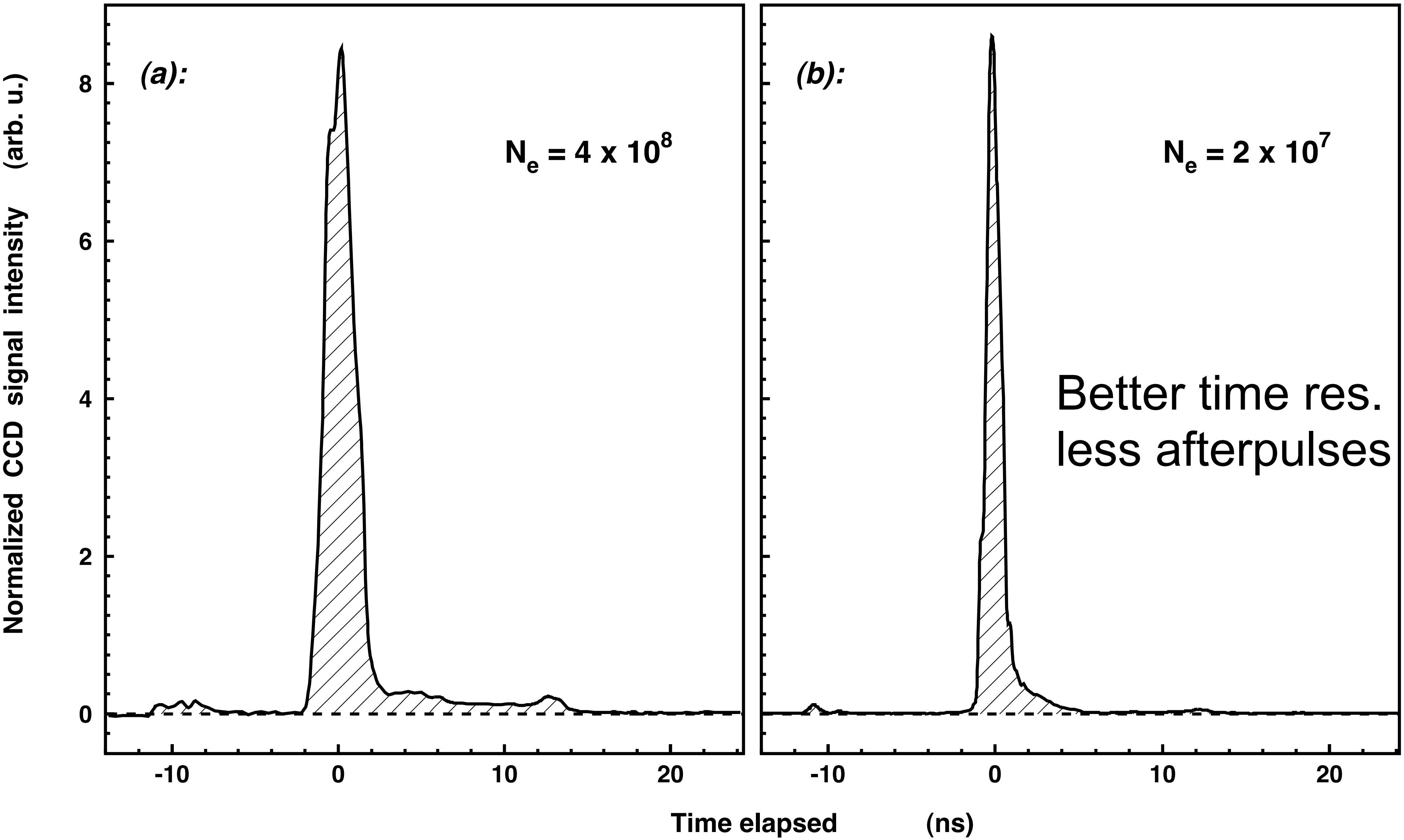
$5x10^8$ photoelectrons, similar to Linac4 intensites.

Many prepulses and afterpulses appear at regular intervals !?

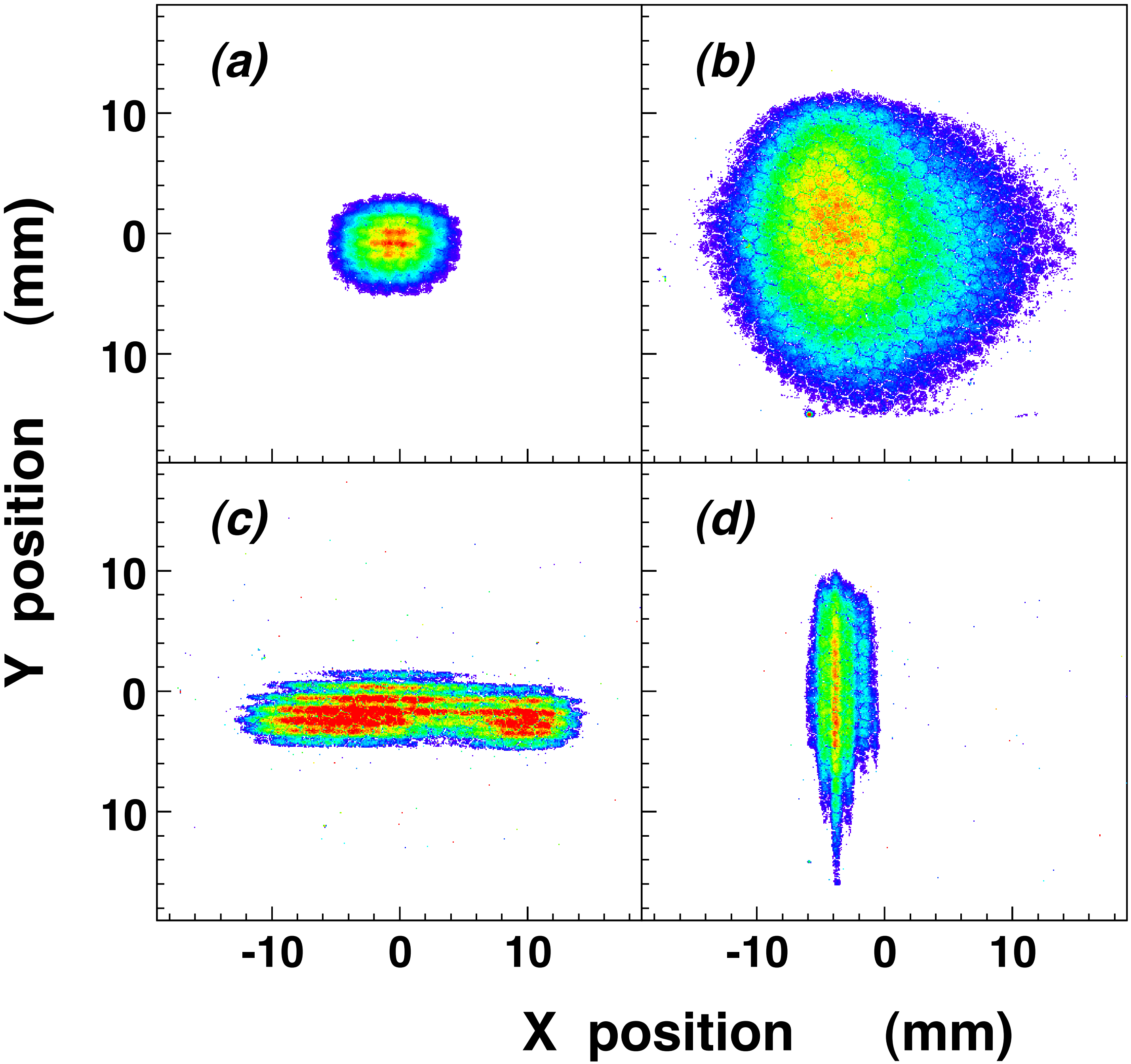
No magnetic field, lower acceleration voltage (some distortion due to space-charge seen)



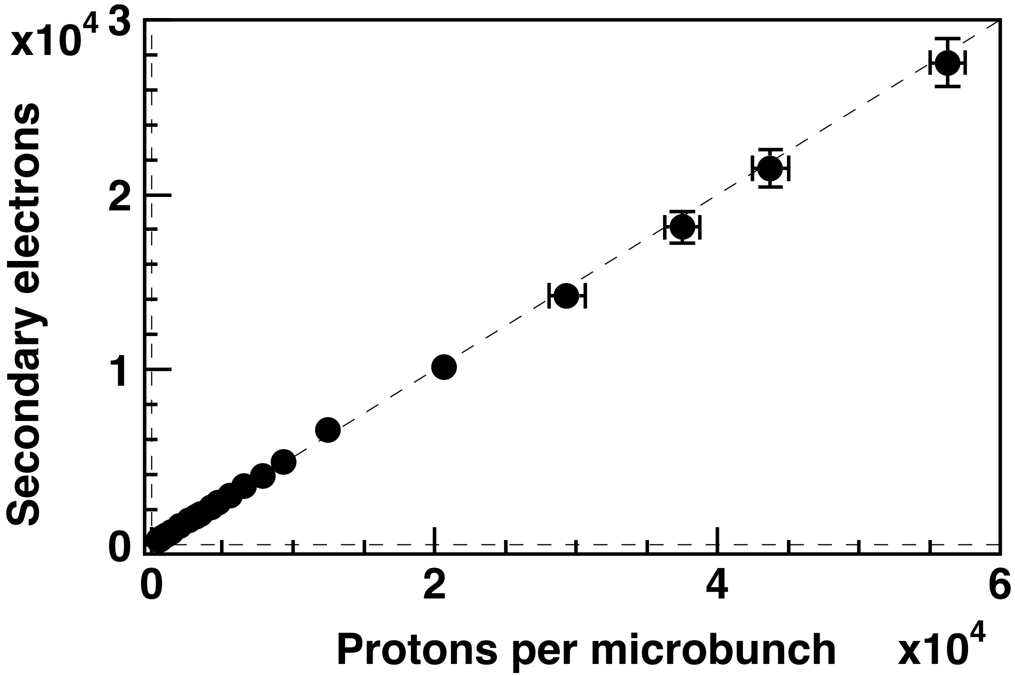
No magnetic field, lower acceleration voltage

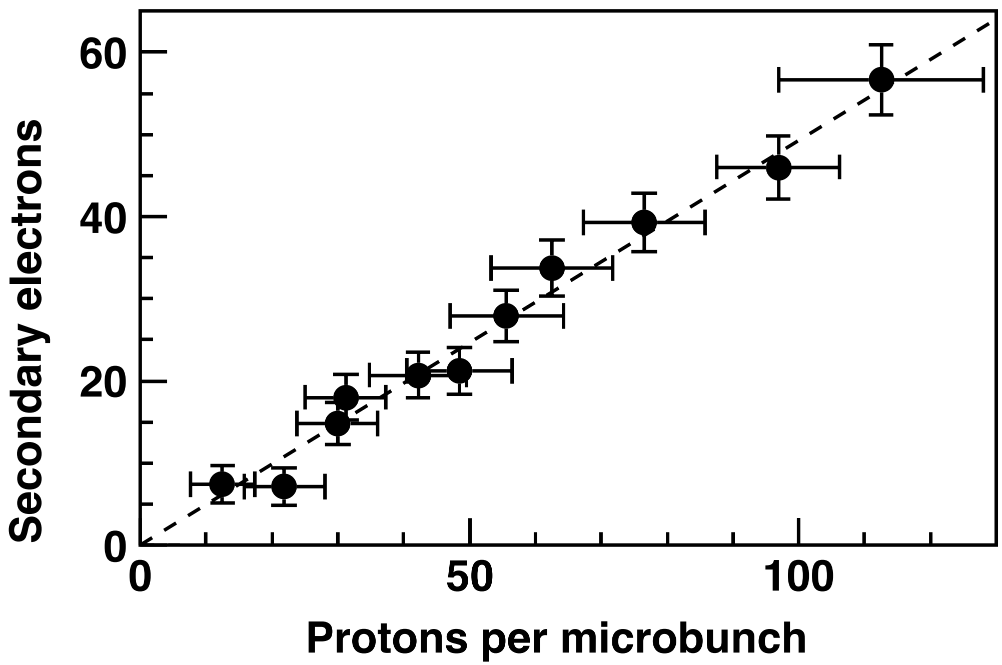


Better time res.
less afterpulses



Beam profile for various focusing settings of the Orsay beamline





Linearity measurements

Beam diam 1 cm, f=10 MHz
Integrated 1000 pulses
Linear response between
N_p=10 and 6x10^4 protons/pulse

Conclusions

Spatial profile monitor with timing resolution was developed.

1. 2 mm spatial, 1 ns timing resolutions.

2. Afterpulse and prepulses <0.5% of main pulse

3. High sensitivity - measured N_p=10 protons/pulse at Orsay Tandem.

4. Wide dynamic range - measured between N_e=5 and $5x10^8$ secondary electrons or photoelectrons.

5. Detector performance is adequate for diagnosing chopped beam in Linac4-to-PS Booster mode.

6. Future R&D needed for Linac4-SPL level performance.

Remaining problems for higher-intensity operation (SPL):

1. Wire and foil damage

2. Space-charge effects

3. Prepulses and afterpulses

These problems appear to be difficult to solve in an classic “interception”-type monitor.

All these problems can be solved using a laser monitor.
Use Nd:YAG laser beam with this monitor and selectively photoneutralize the H- ions