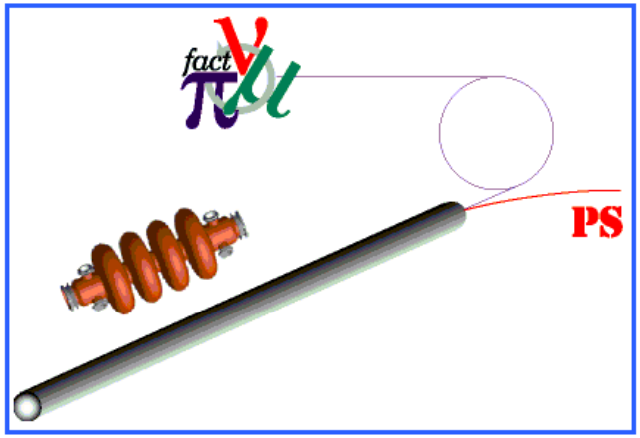
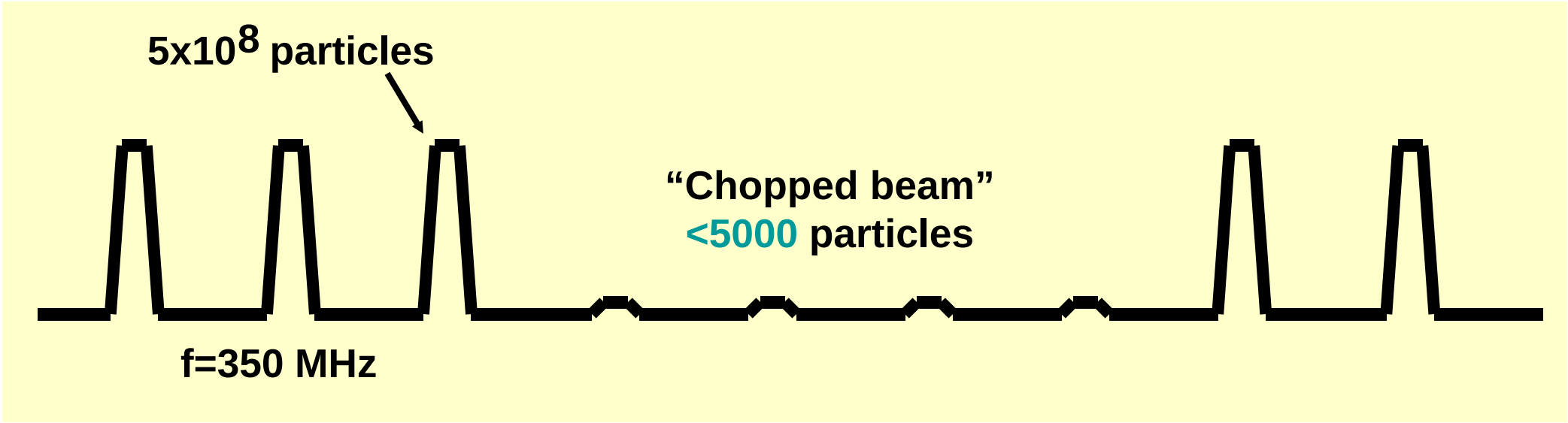
Status on the bunch shape and halo monitor for the CERN 3 MeV negative-hydrogen ion linac

M. Hori (CERN / University of Tokyo)

May, 2007



Objective 1: Time-resolved measurement



1. Measure residual H- ions contained in "chopped" buckets with 1000-particle-per bucket sensitivity.

2. Suppress "unchopped" buckets (containing $5x10^8$ H- ions).

3. Detector must be turned ON/OFF within 1 ns, gating ratio $1:10^6$

Objective 2: Spatial beam profile, halo measurement

Main beam: *d=1 cm, 10^9 H- /bunch/ cm^2*

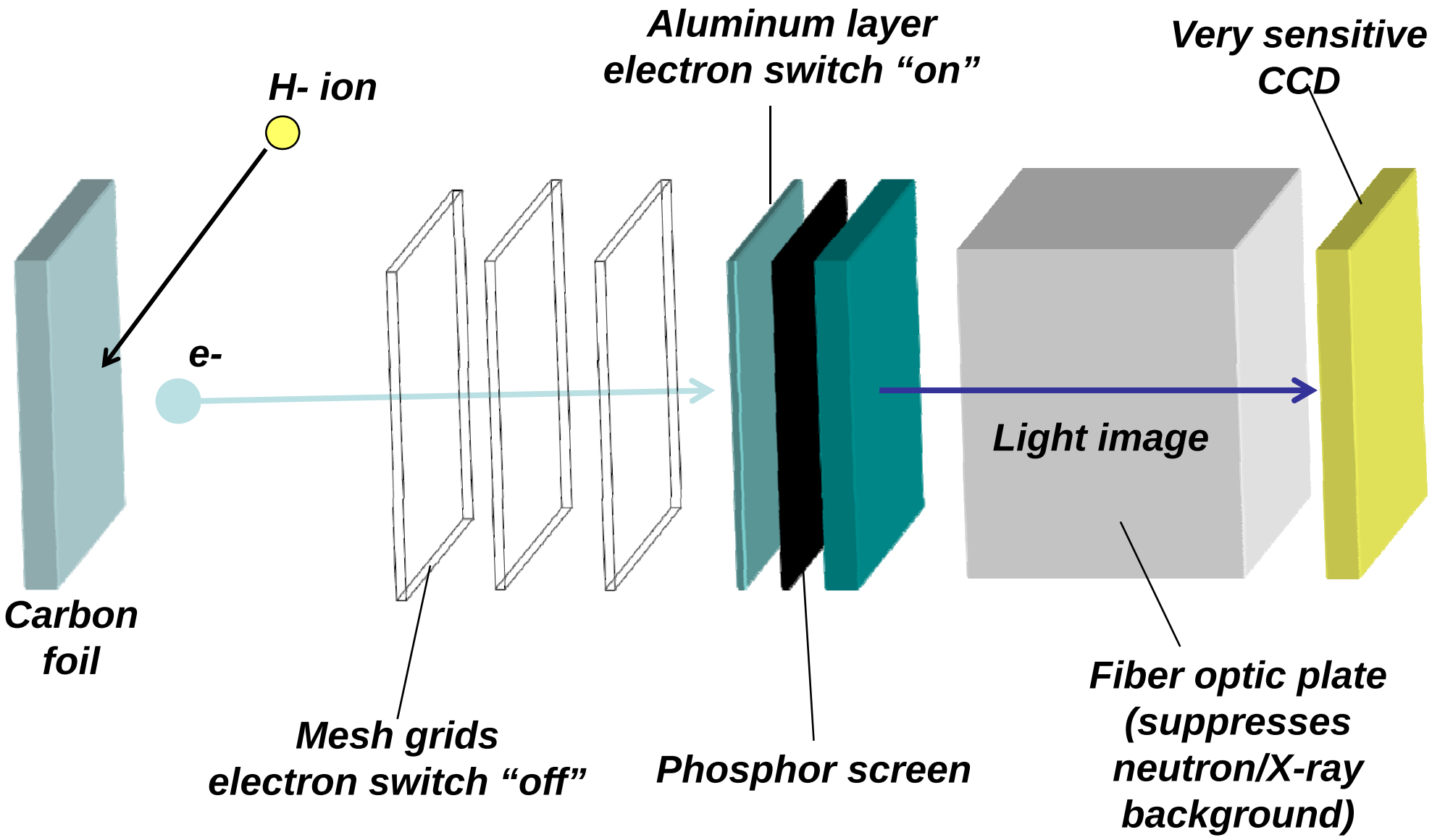
Halo: *d=4 cm, 10^3 H- /bunch/ cm^2*

Active area: *4 x 4 cm*

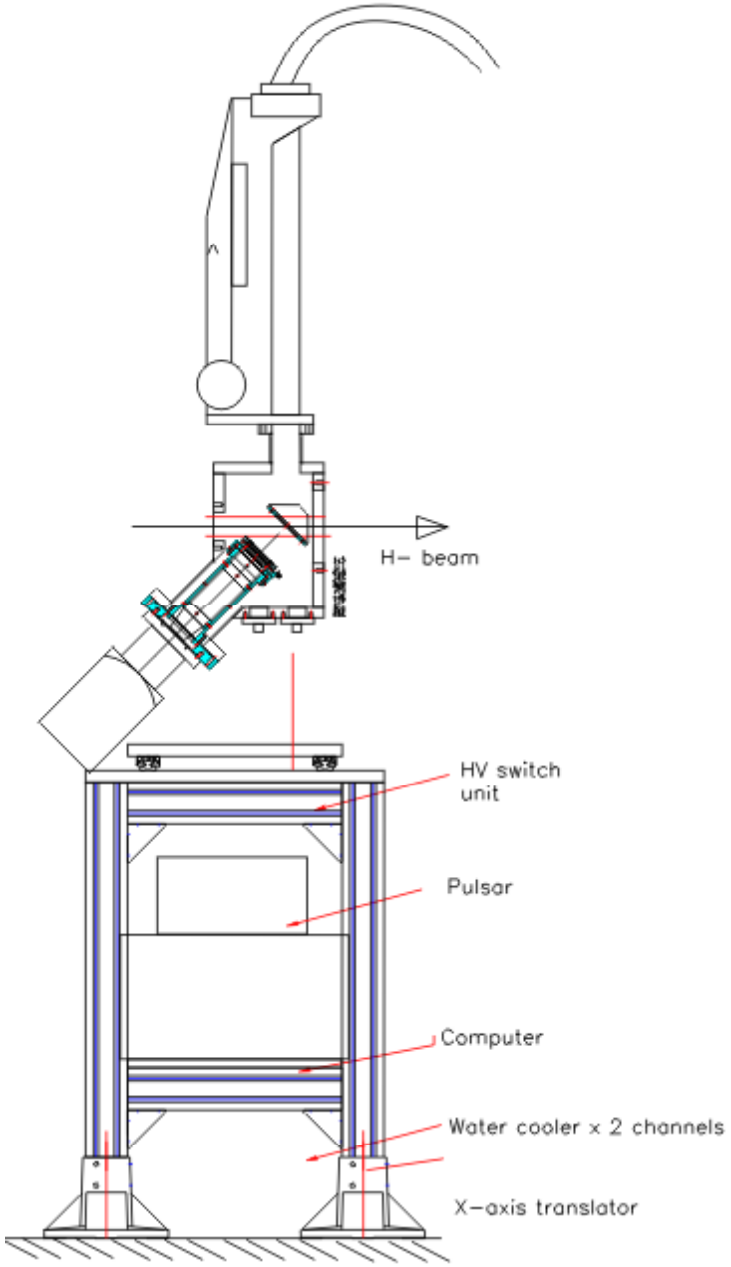
Dynamic range: *1:10^6 by integrating over several buckets*

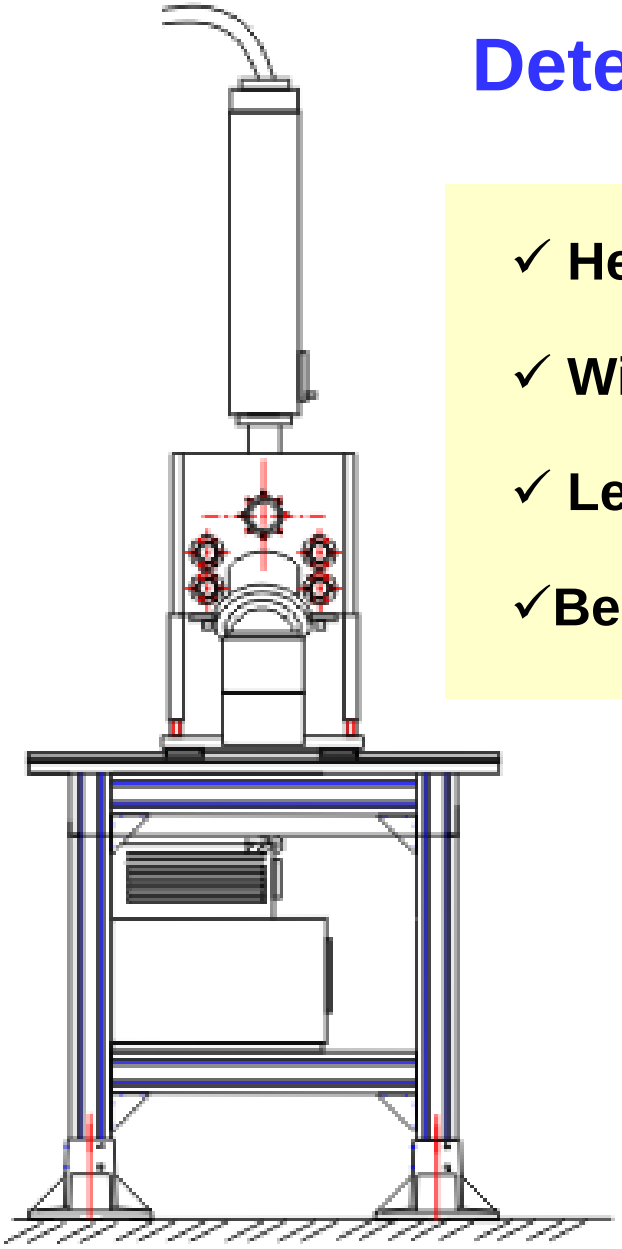
Coexistance of high speed, large dynamic range, and large active area is very challenging. To accomplish this we decided to use **electrons** (for fast gating), which is then converted into **photons** (for high spatial resolution and dynamic range imaging)

Theory of detector operation

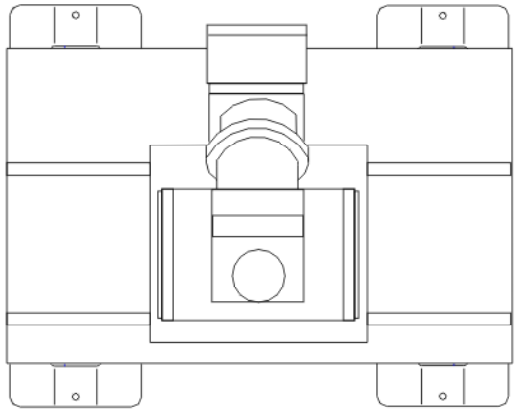


Detector full drawing

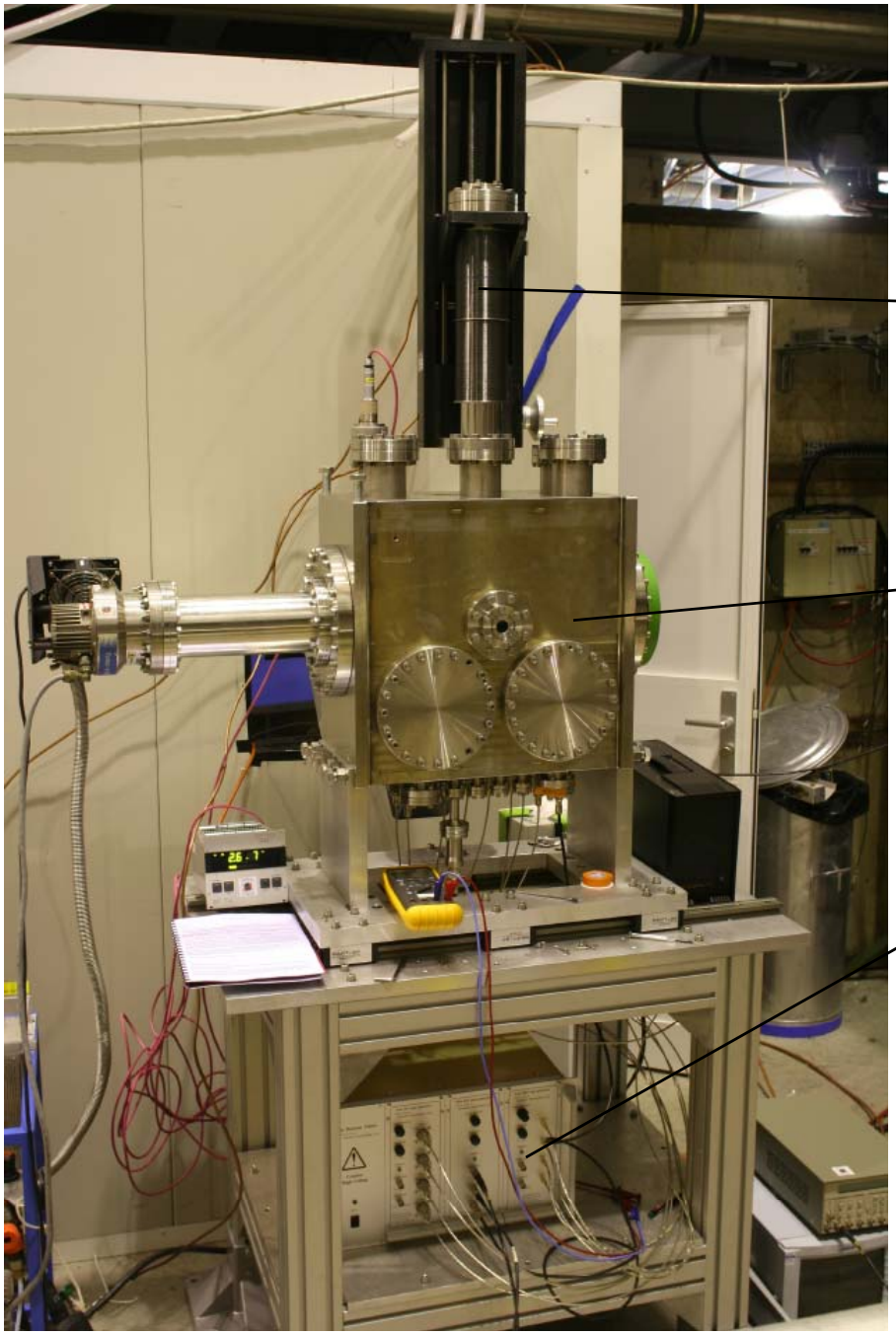




- ✓ **Height 2.6 m**
- ✓ **Width 1 m**
- ✓ **Length 50 cm**
- ✓ **Beamline length 22 cm**



Detector front view



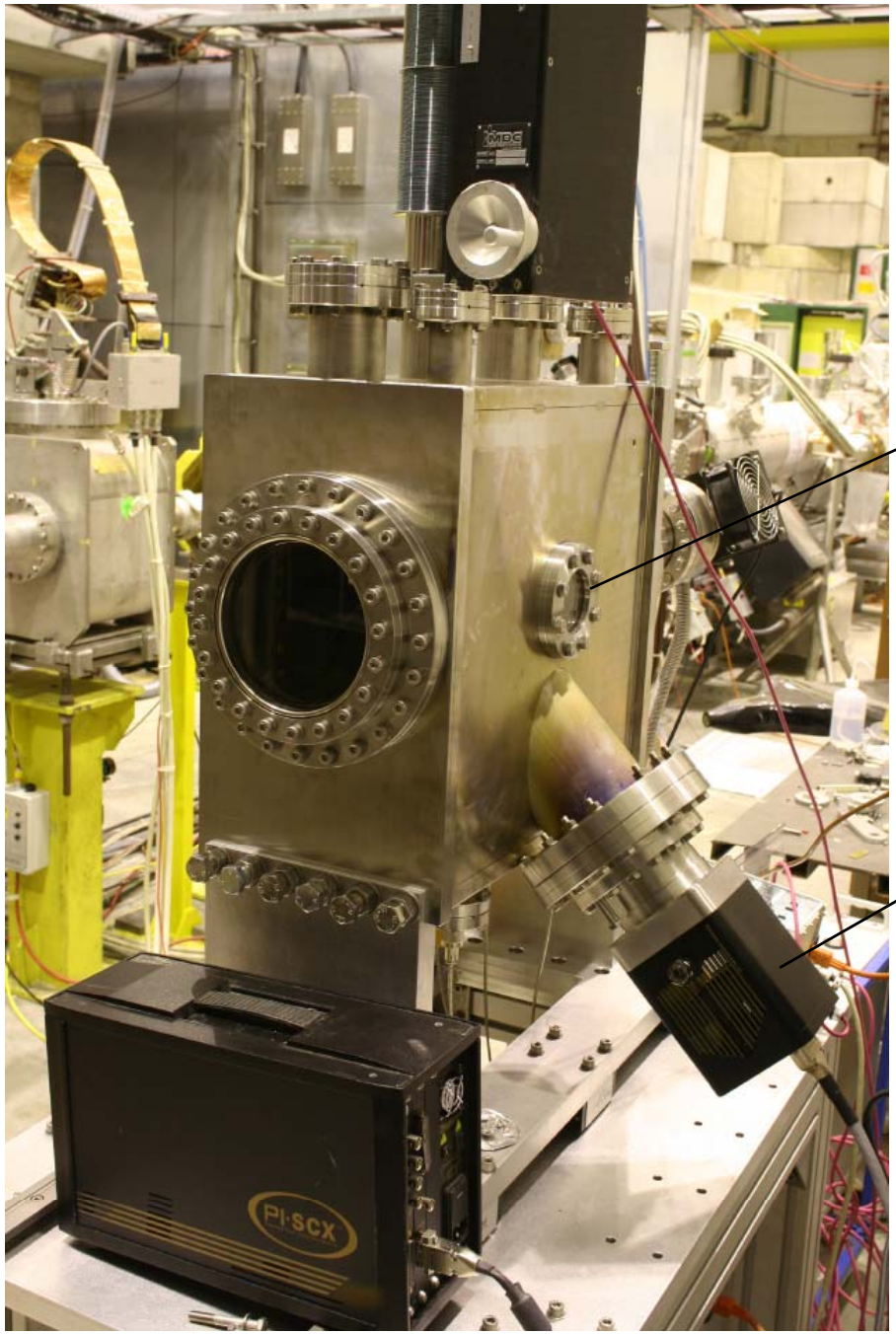
Target foil manipulator (up/down)

Detector chamber

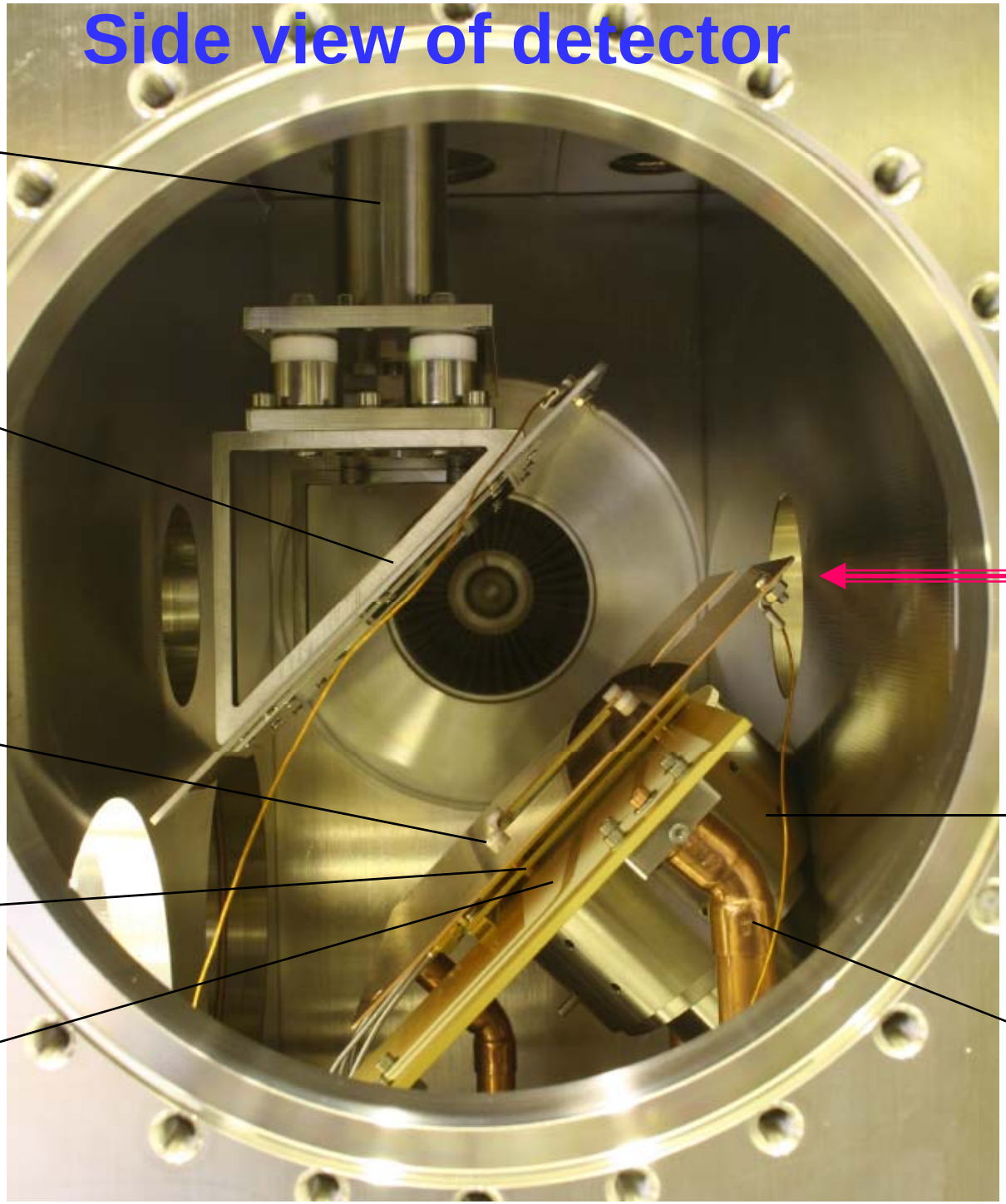
5 kV RF switches

Completed this month, being tested at the Antiproton Decelerator facility of CERN. Easily transportable

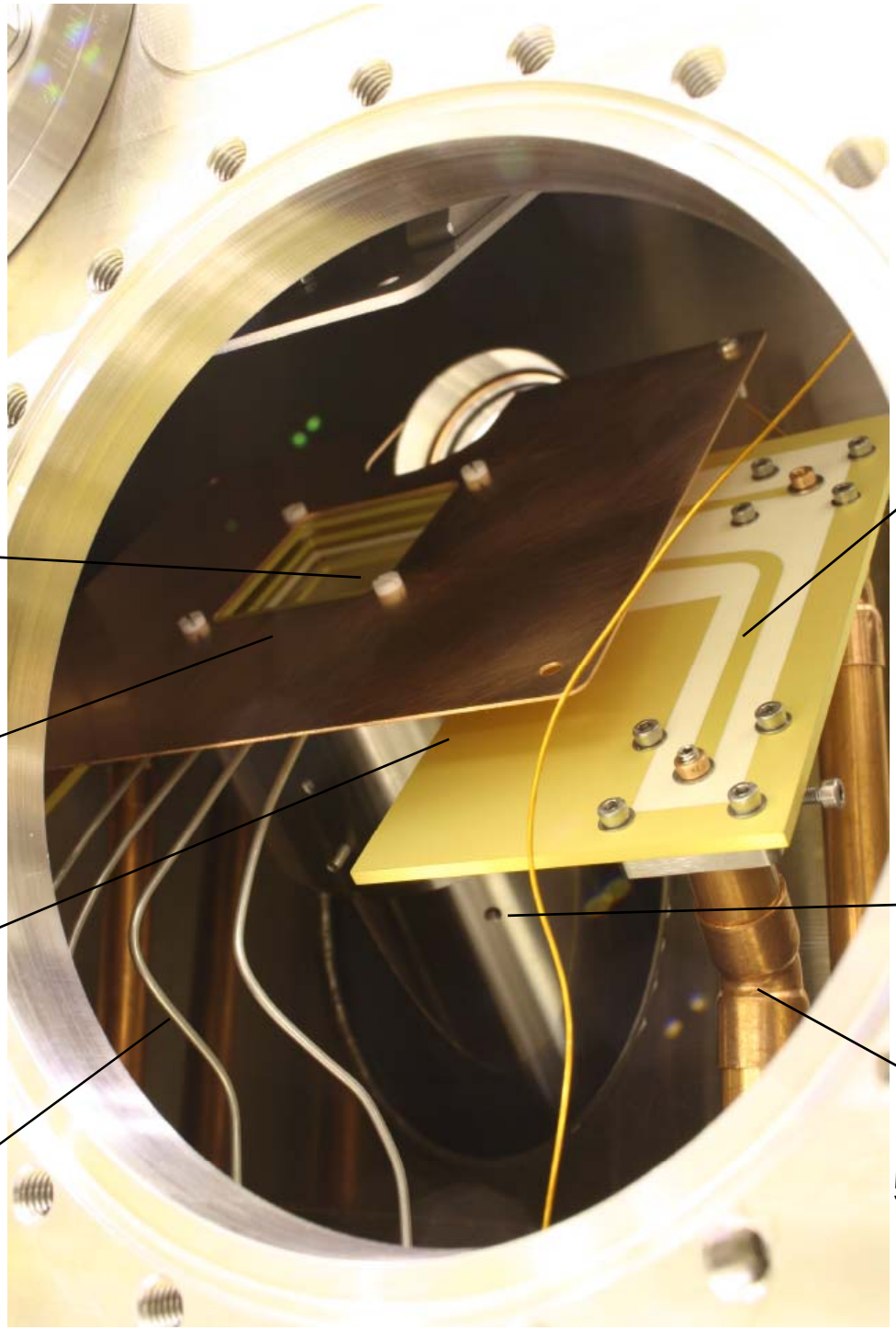
Detector back view



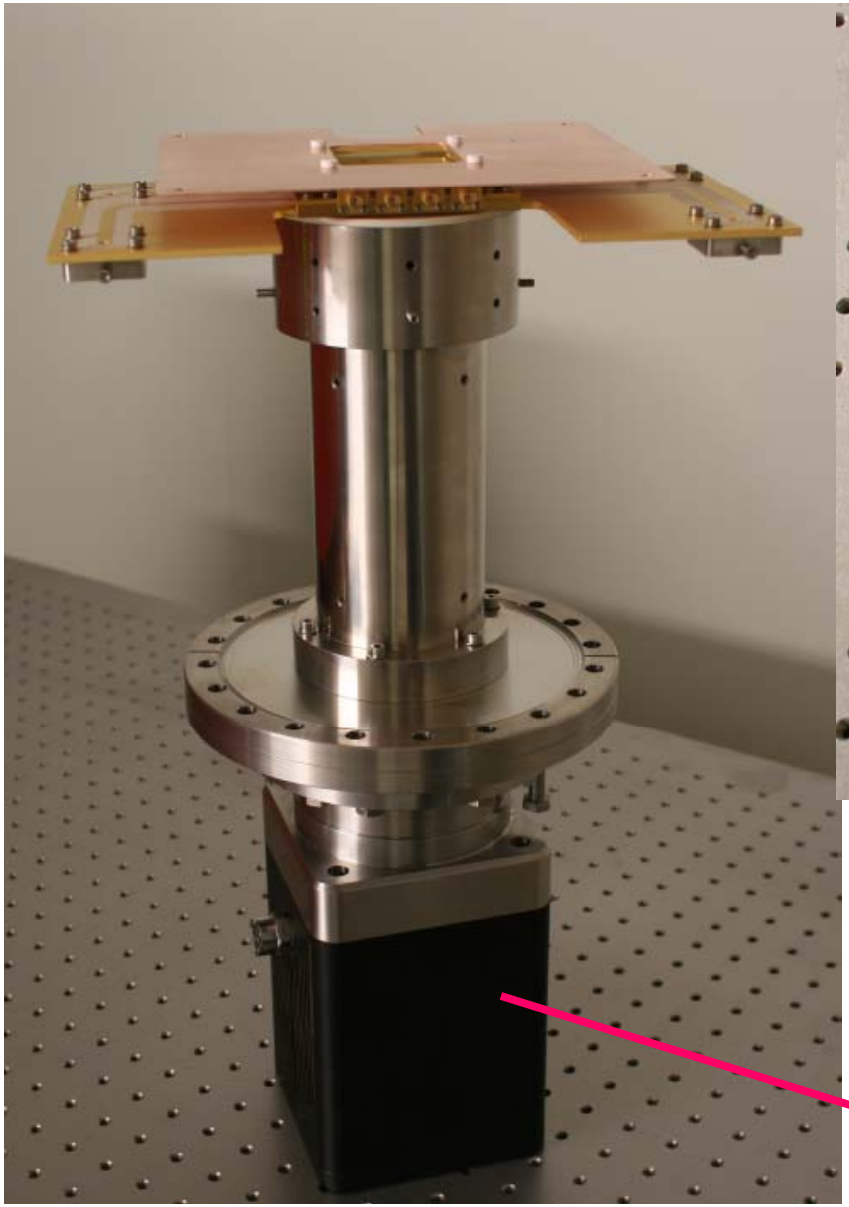
Side view of detector

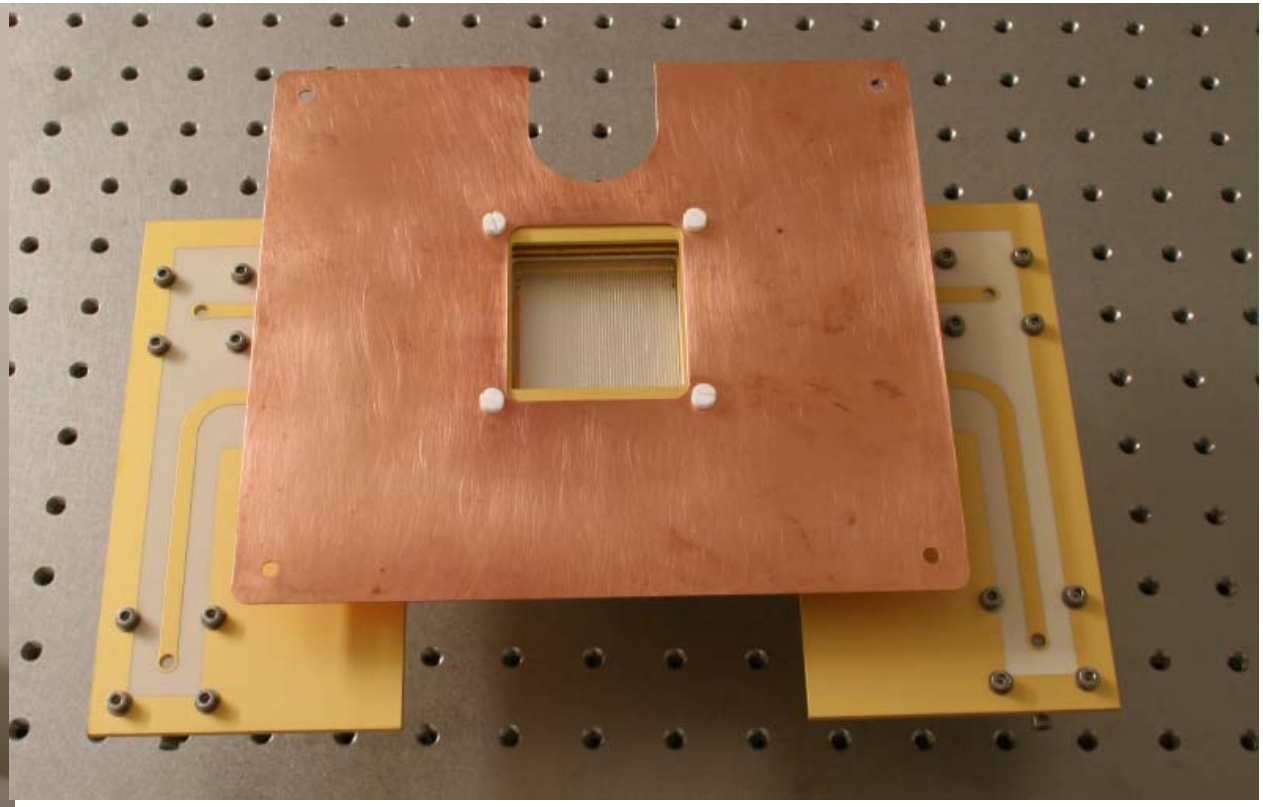


Front view


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

Electron - to - photon imager

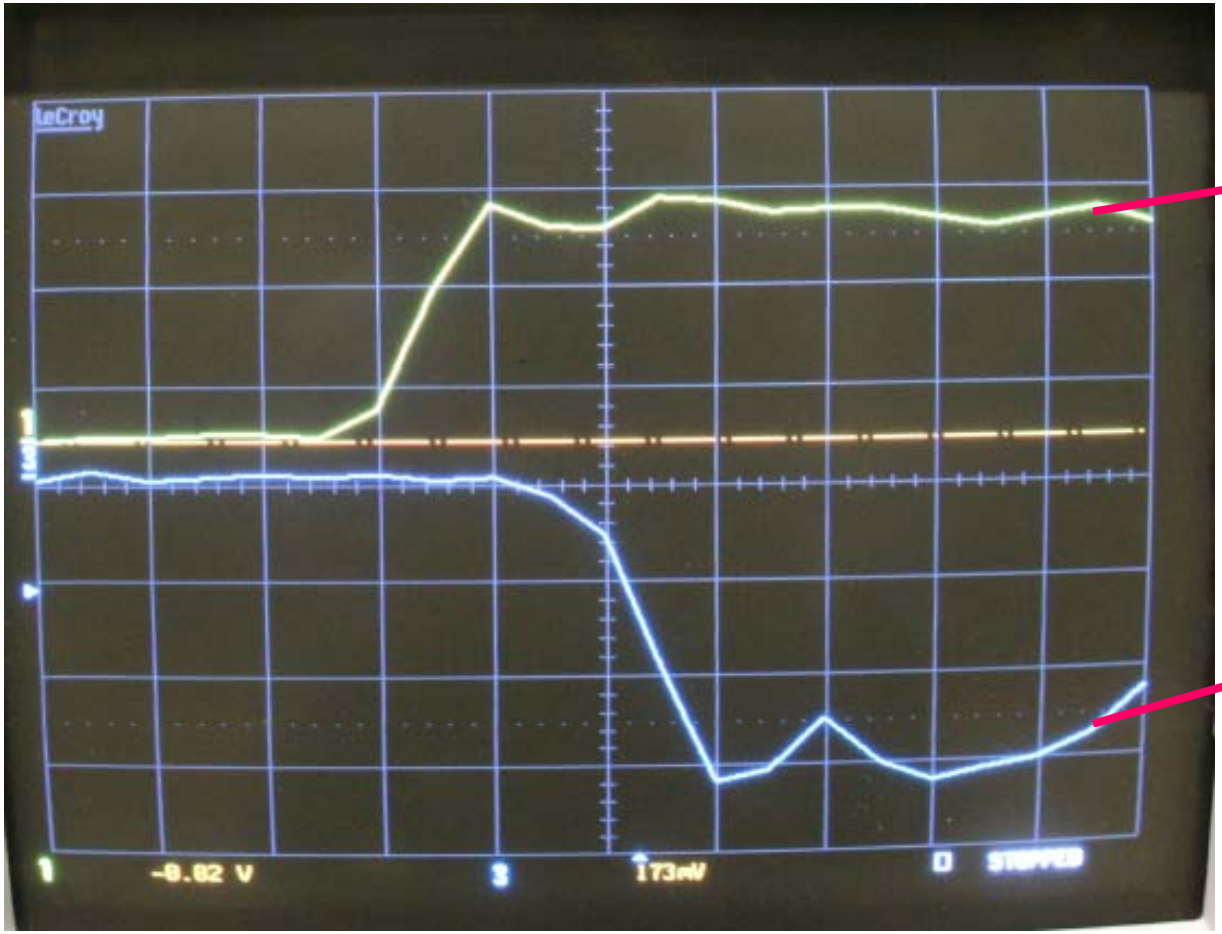




Four parallel 50-Ohm lines for effective impedance 12.5 Ohm allows fast switching of voltage potential

CCD camera

Demonstration of high-speed switching



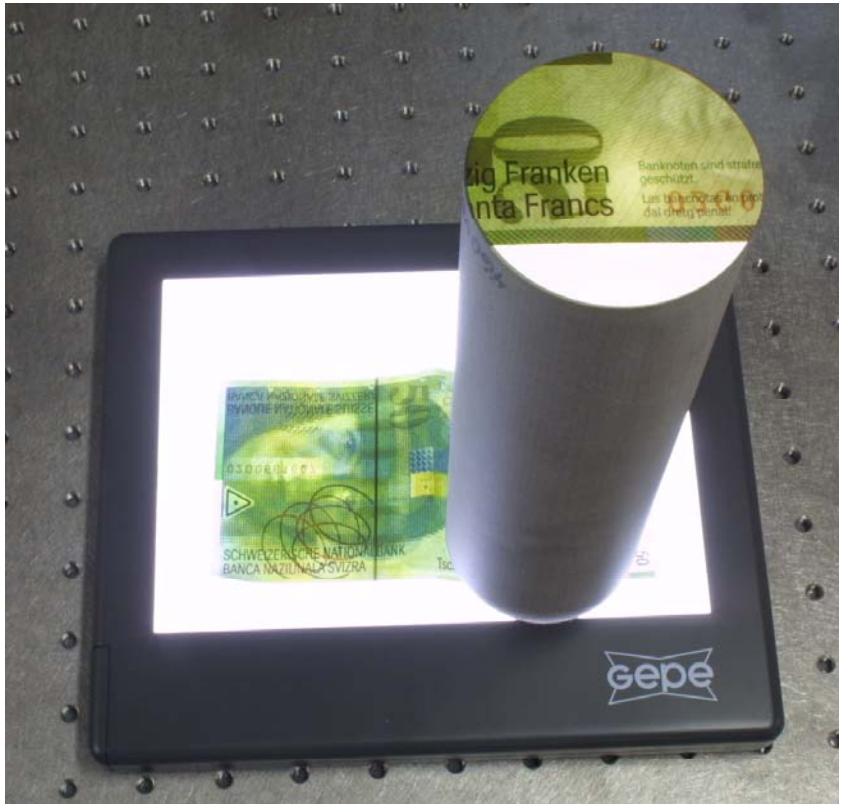
Voltage on switch-on electrode +5 kV

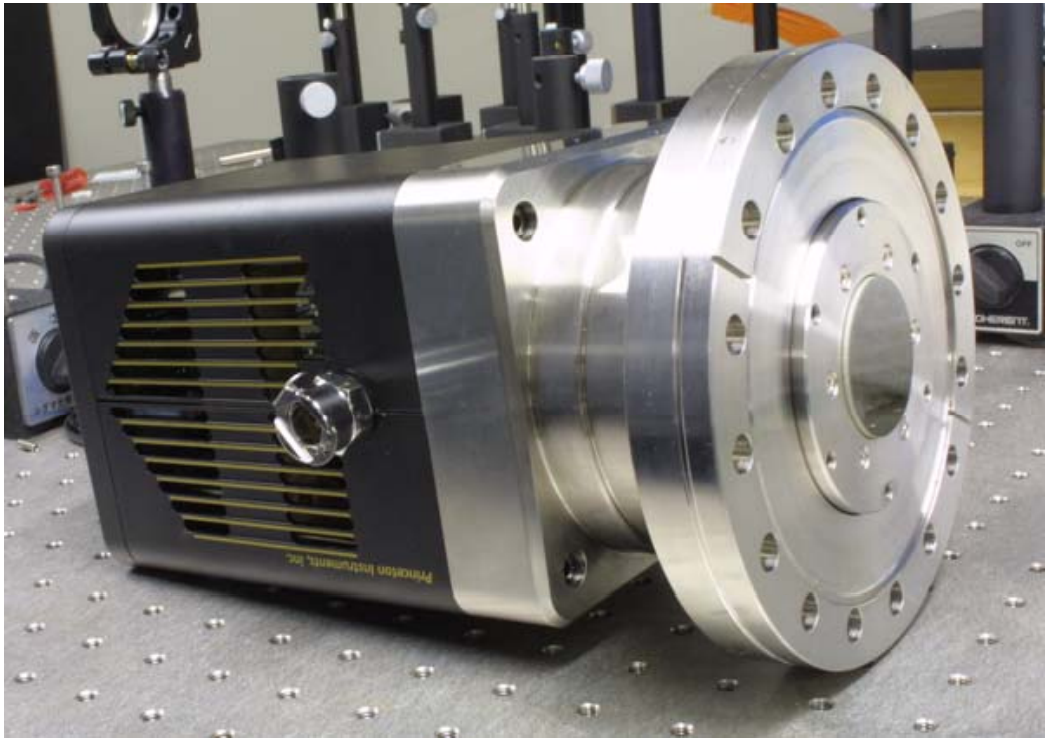
Voltage on switch-off electrode -500 V

0.5 ns per division

Rise and fall times of potential on grids which gate the signal electrons is indeed less than 1 ns.

Optical imaging system to “photograph” the beam profile

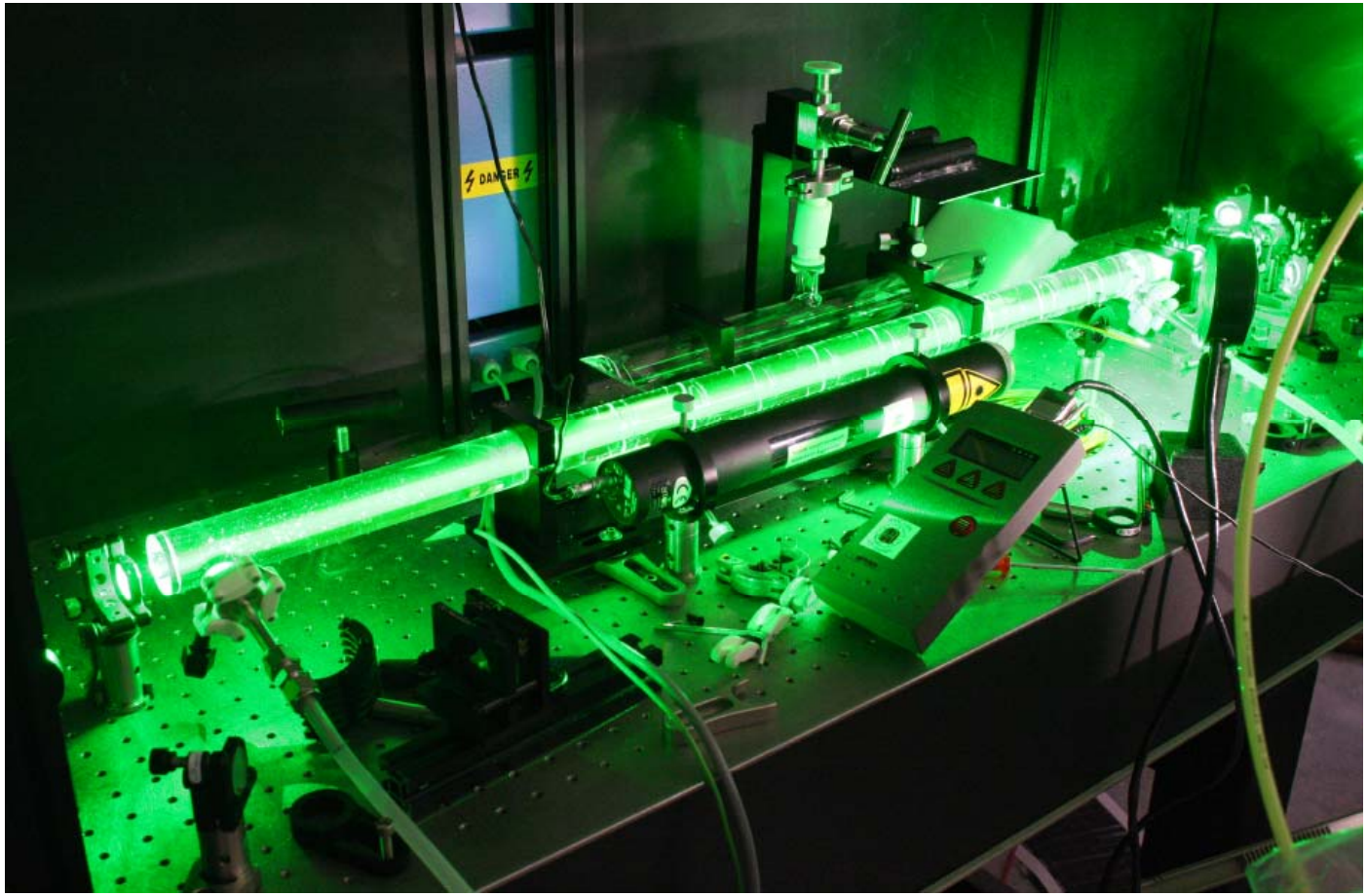


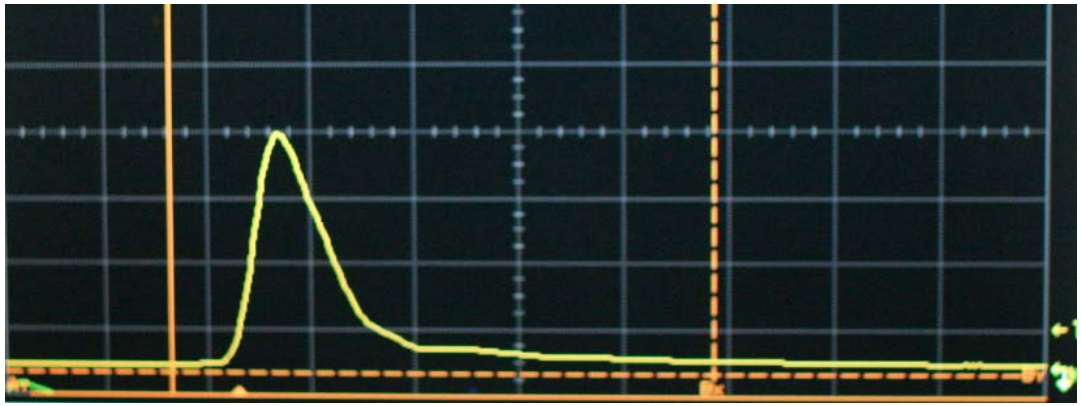


- ✓Active area 50 mm diam.
- ✓50 million fibers.
- ✓Magnification 1.8 x
- ✓Provides shielding against X-rays and neutrons.

- ✓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

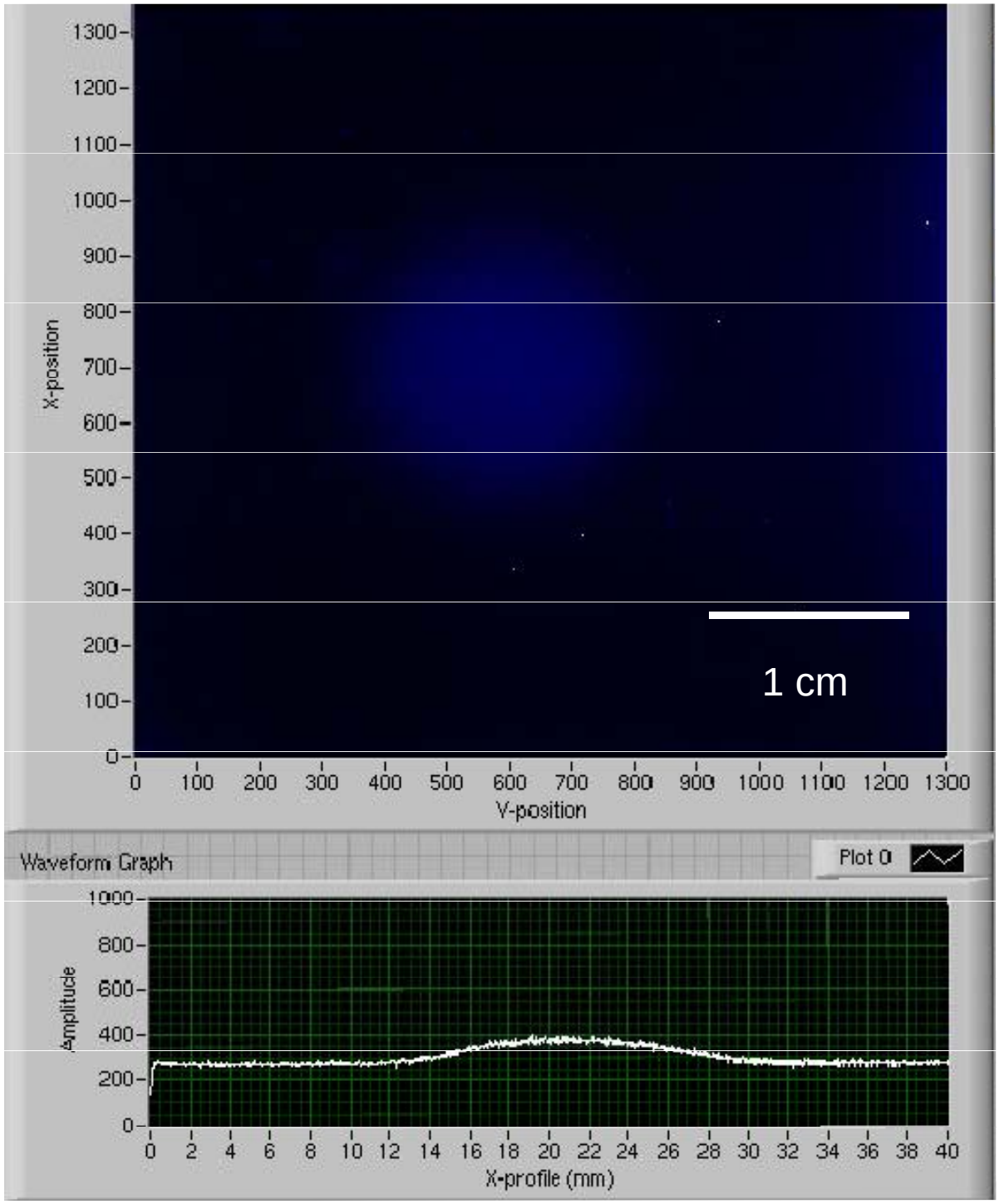
Ultraviolet laser pulse generator to simulate Linac-4 beam





SBS process to compress Nd:YAG laser pulses to < 500 ps (trace 1 ns / division)
266 nm UV laser
10 Megawatt peak power

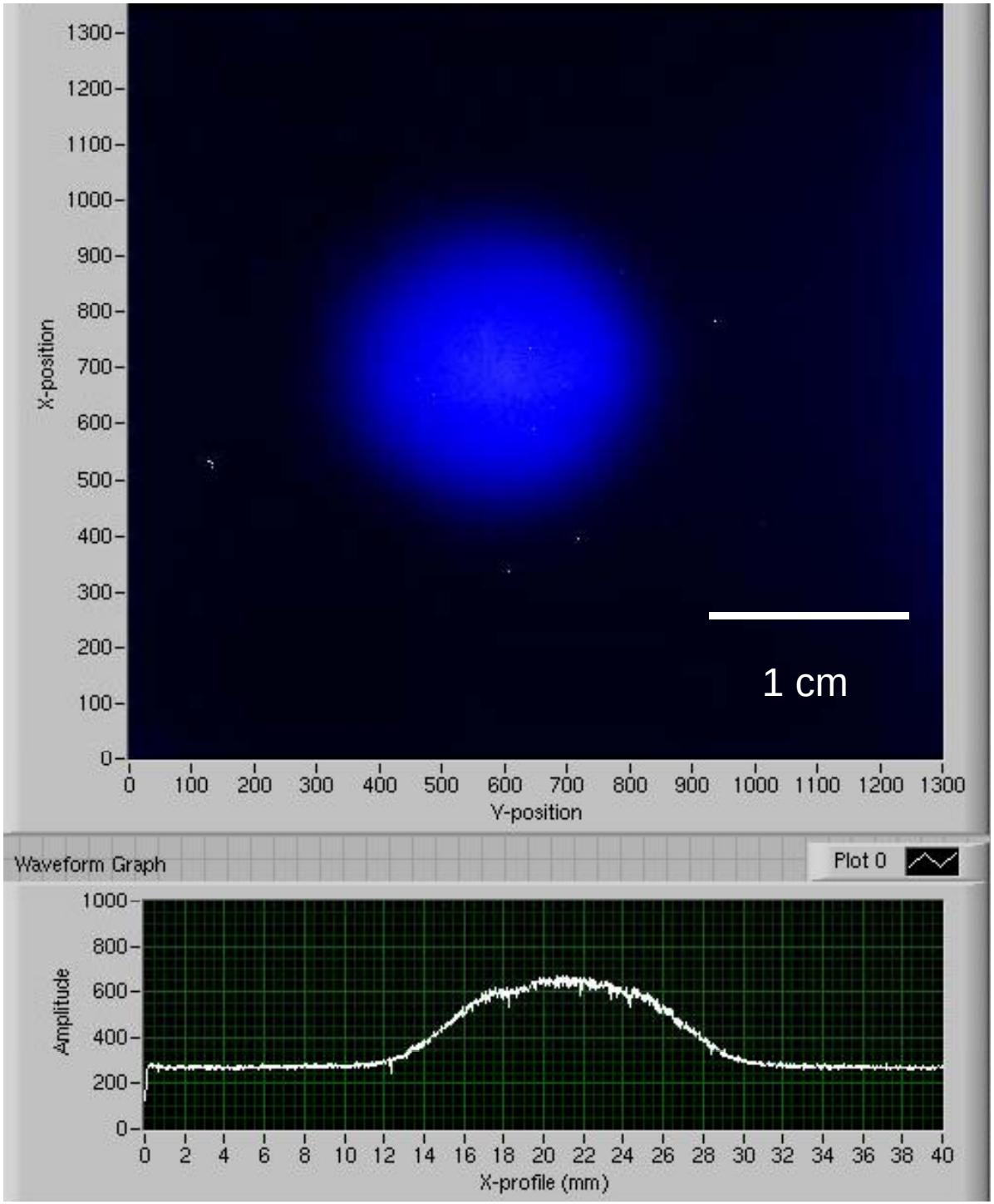
Time-resolved measurement of pulsed UV beam



Irradiated detector with laser pulse, and imaged photoelectrons.

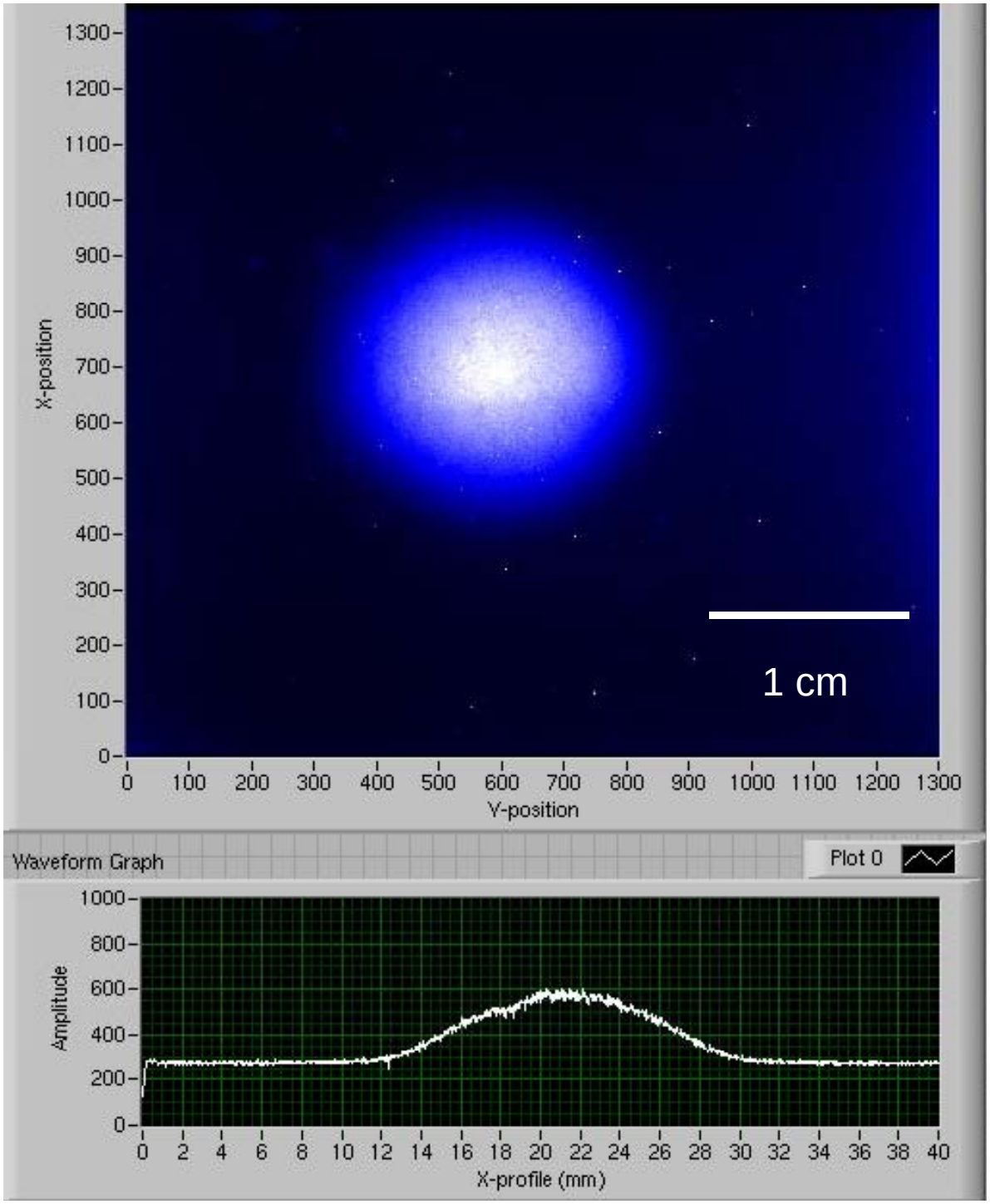
- Pulse length 3 ns.
- Energy 10 microjoule/pulse,
- Diameter 2 mm

t=0



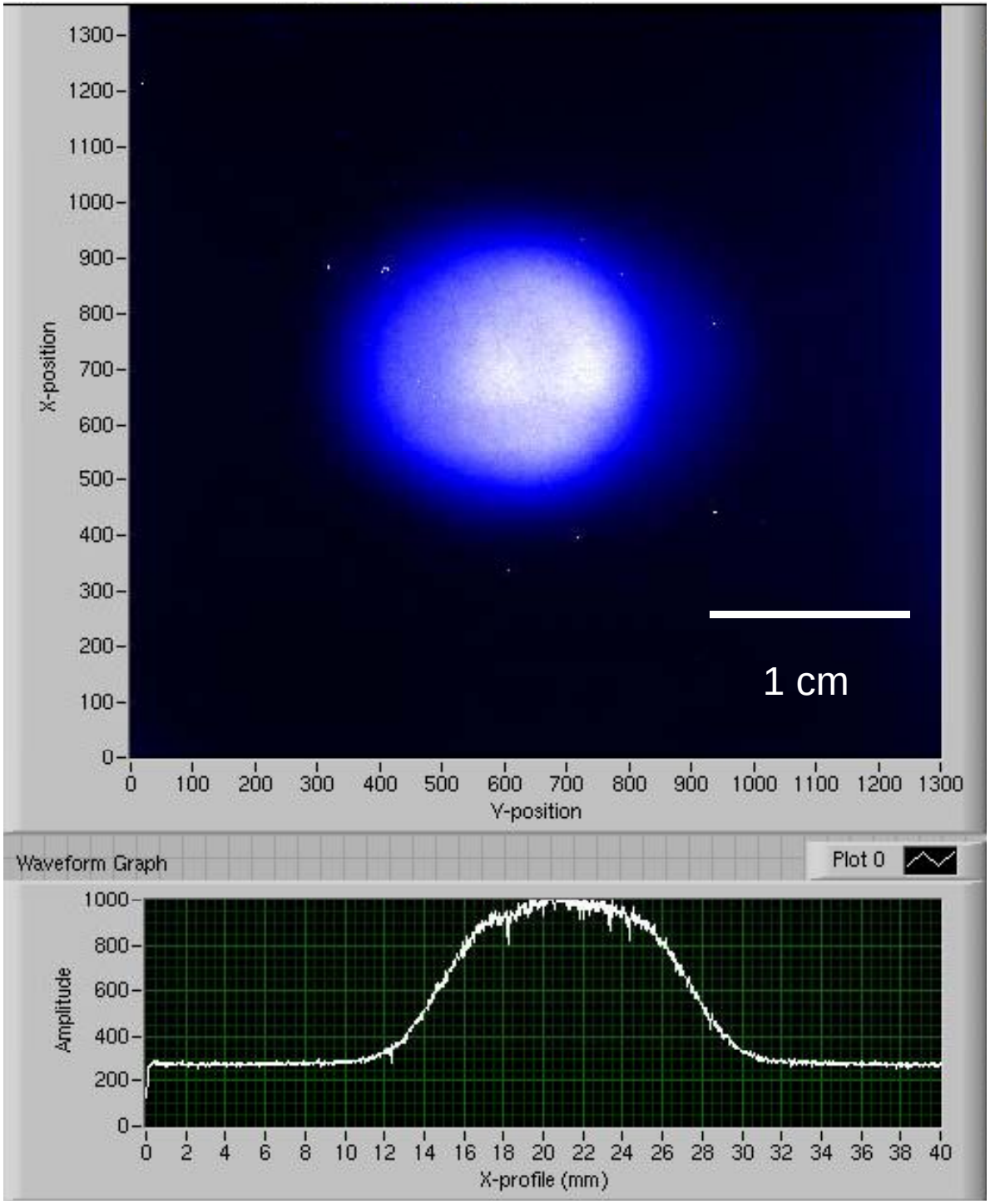
Time-resolved measurement of pulsed UV beam

t=+1 *ns*



Time-resolved measurement of pulsed UV beam

t=+2 *ns*

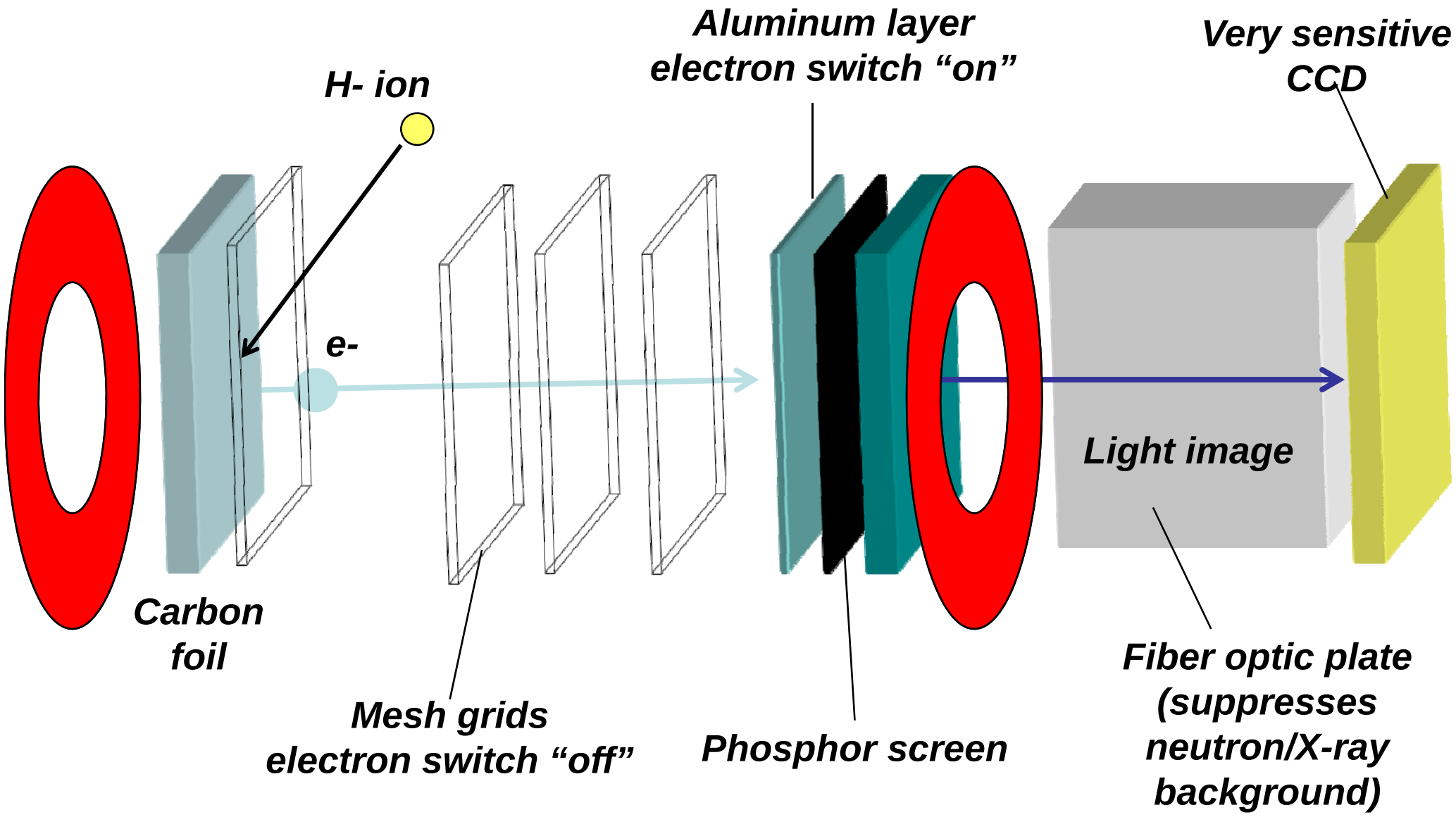


Time-resolved measurement of pulsed UV beam

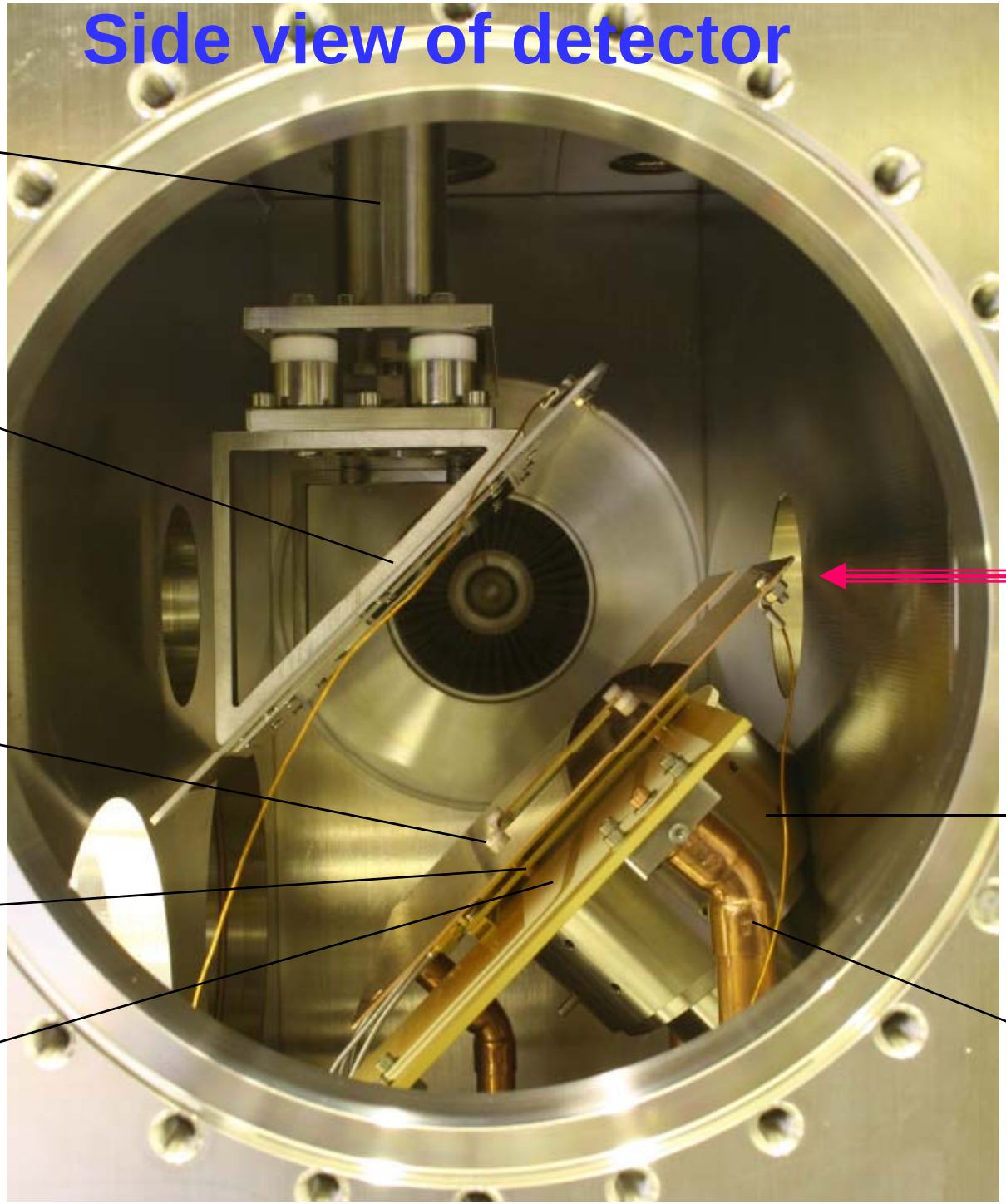
Time resolution 3-4 ns,
Spatial resolution 5 mm

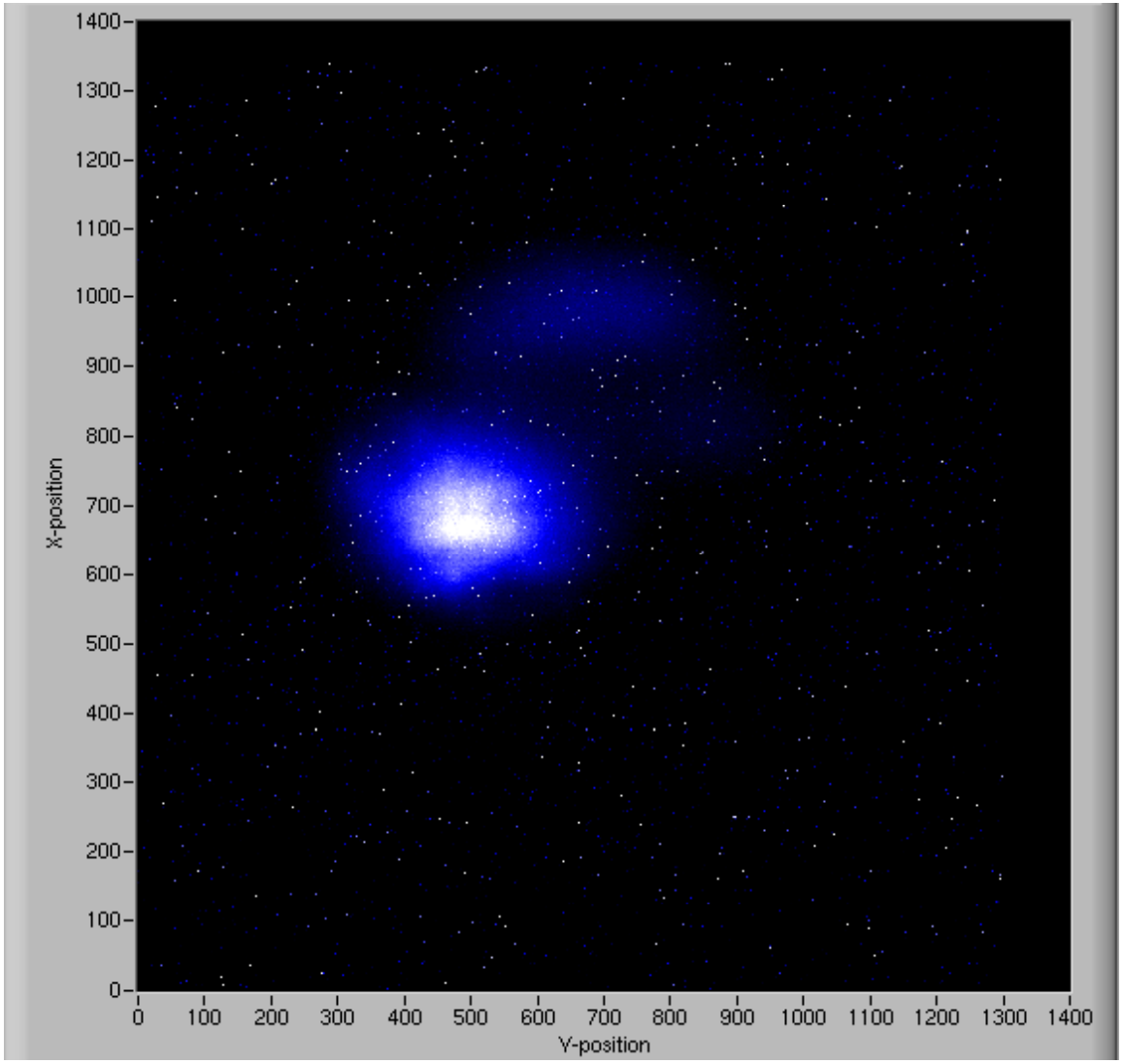
t=+3 *ns*

Added 200-gauss permanent magnets + new acceleration grid (carbon 5 micron)



Side view of detector



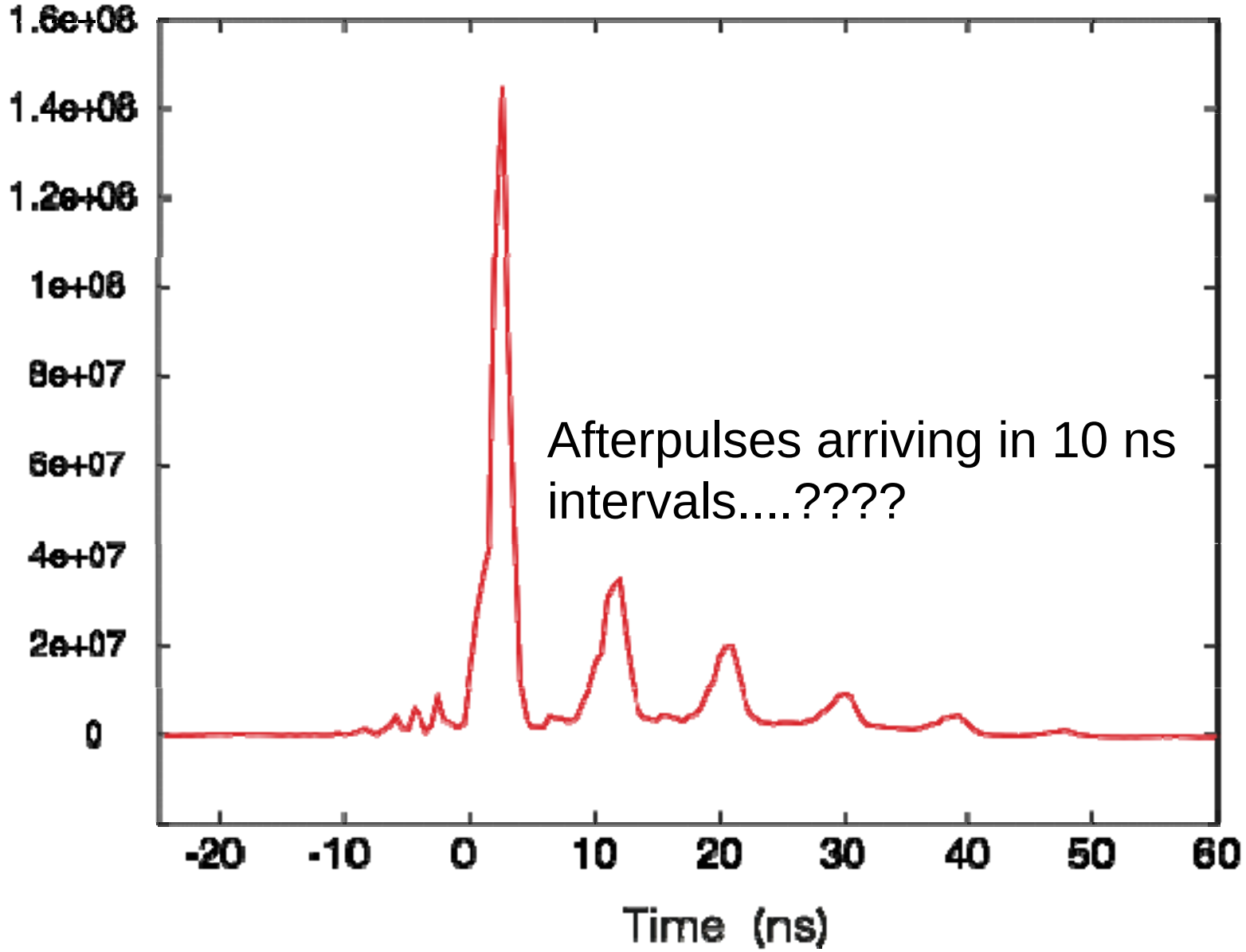


With 100 gauss field and kV acceleration:

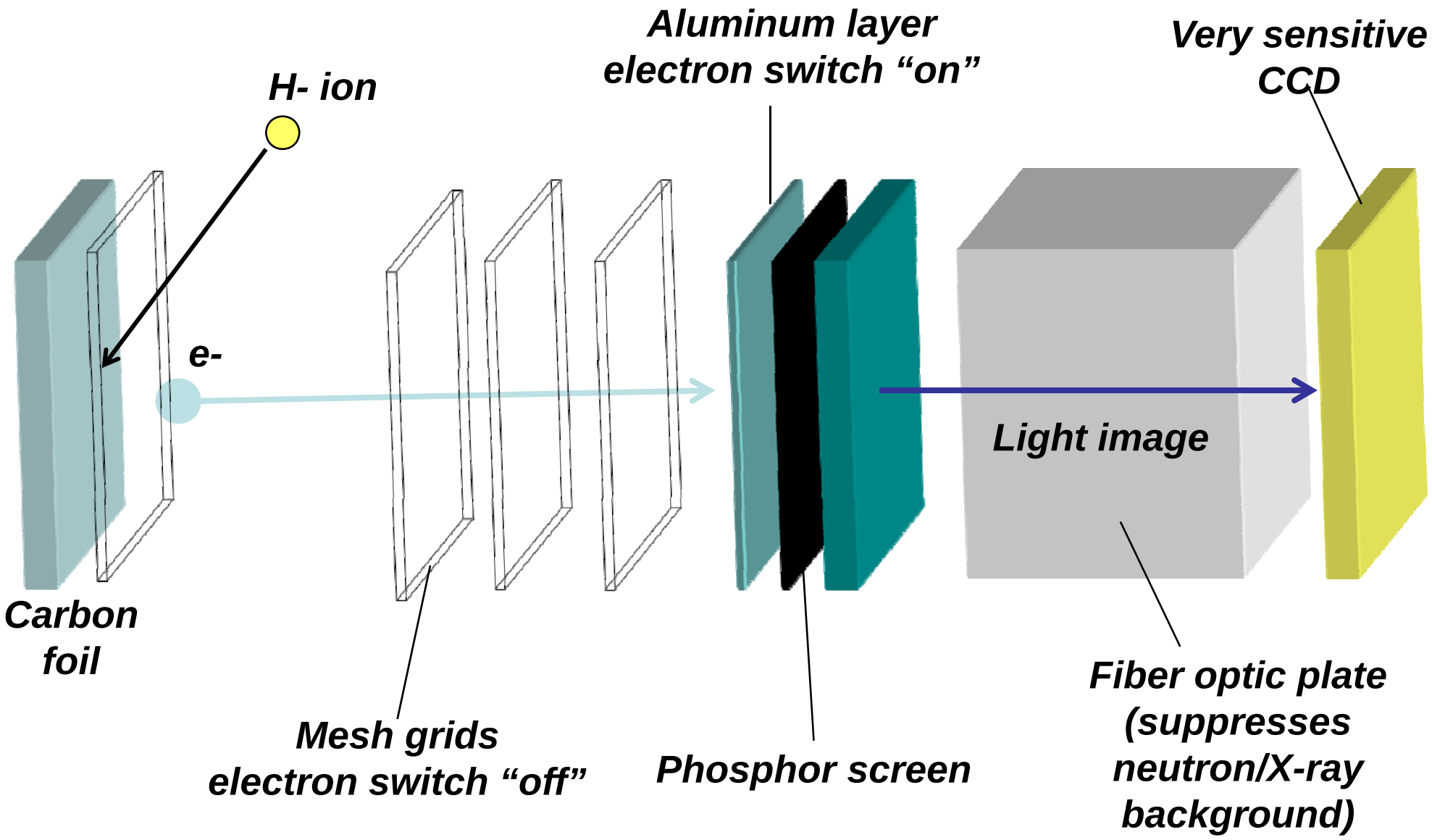
FWHM <5 mm image observed for 4 mm input beam. Best resolution.

Halo measurement seems OK (so far...)

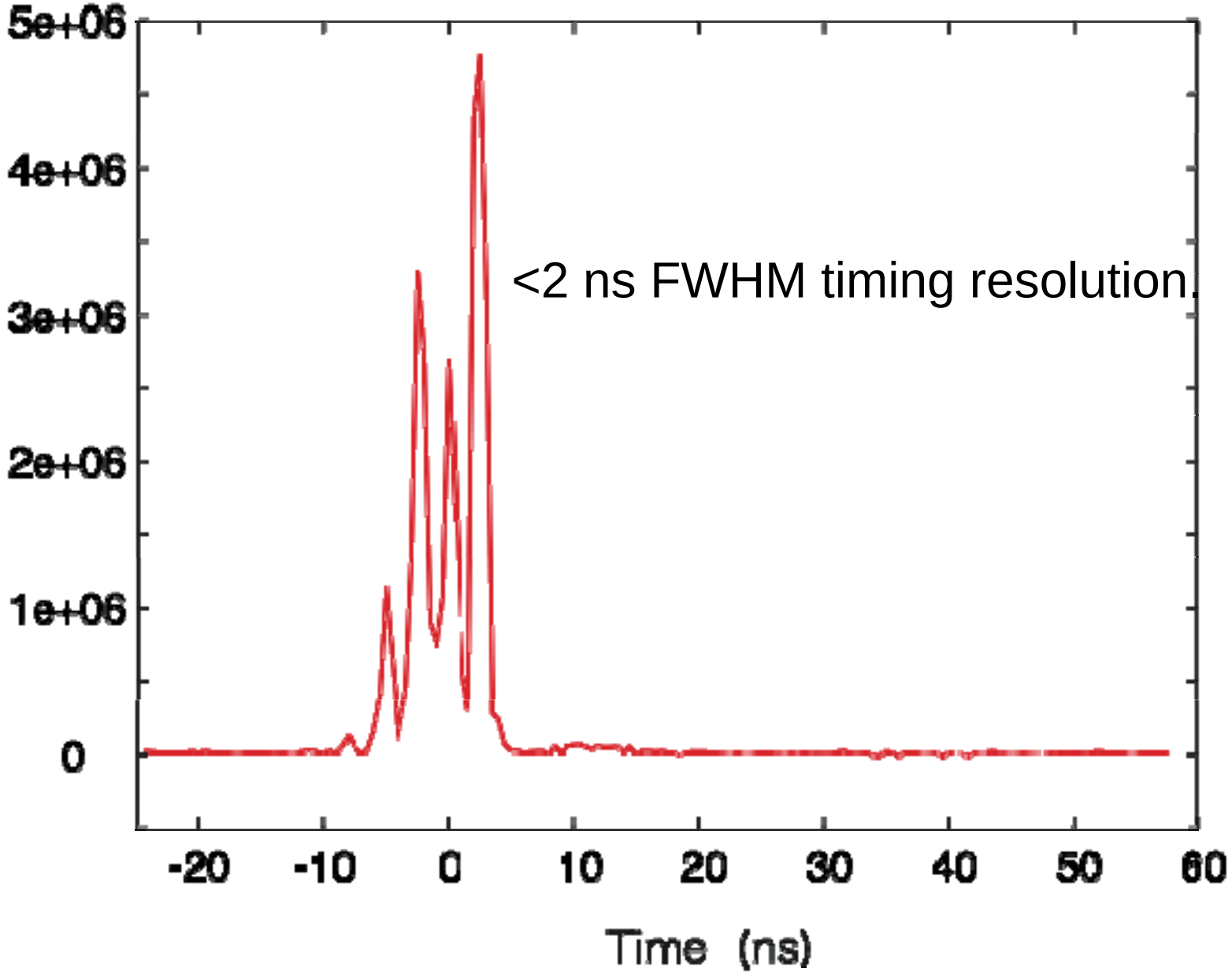
6-electrode configuration, magnetic field 100 gauss



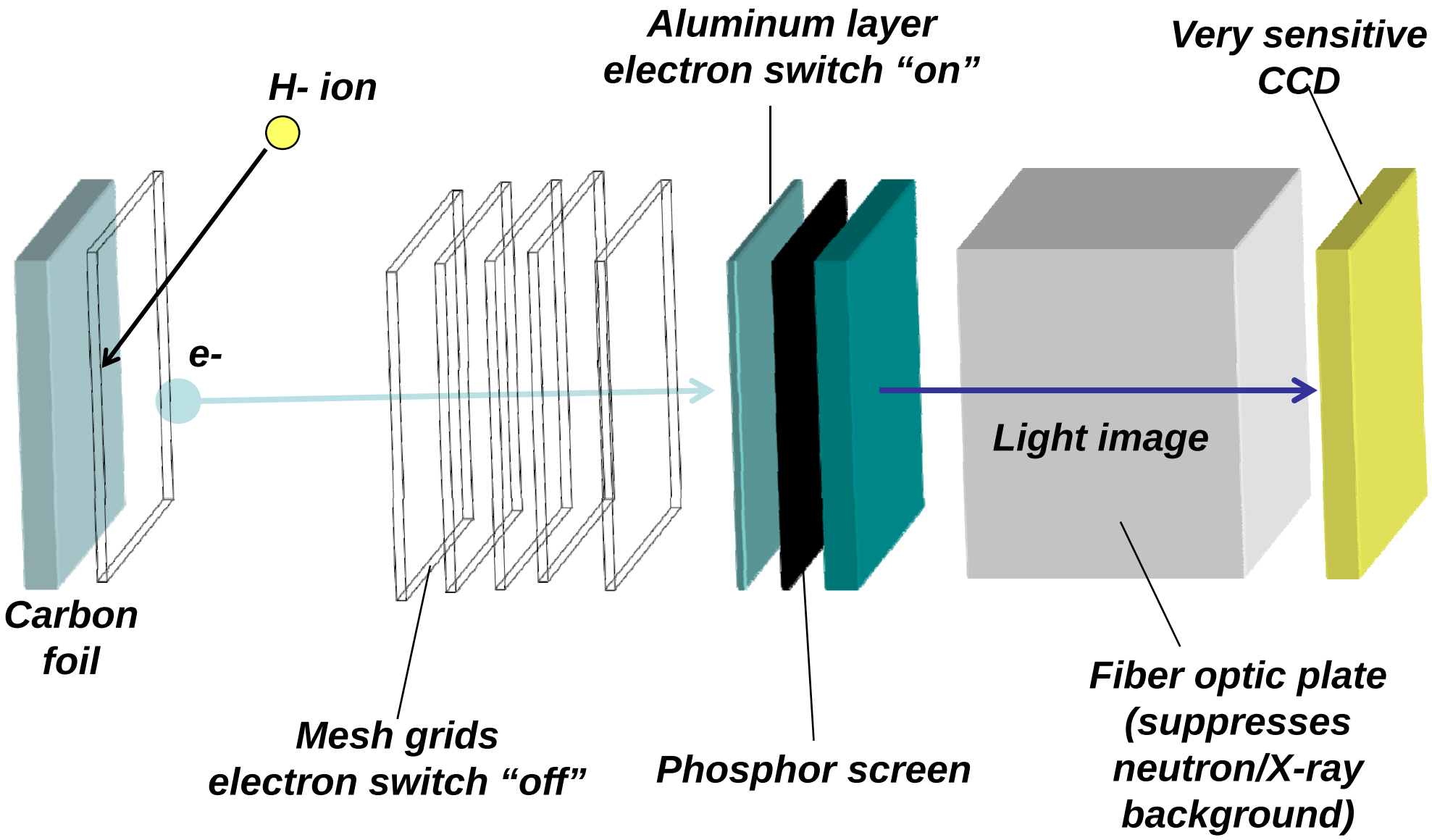
Theory of detector operation



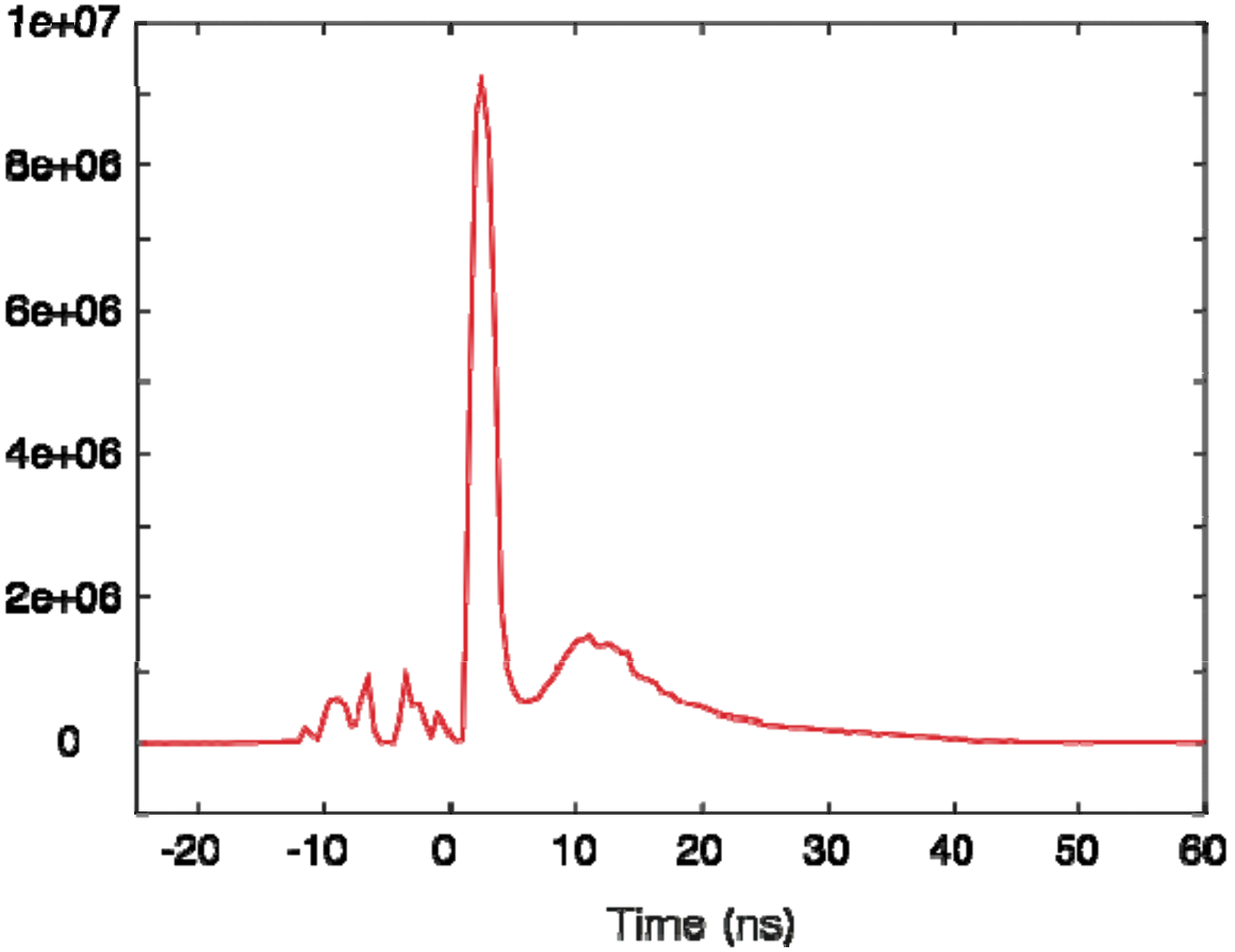
6-electrode configuration, kV initial acceleration, no B-field



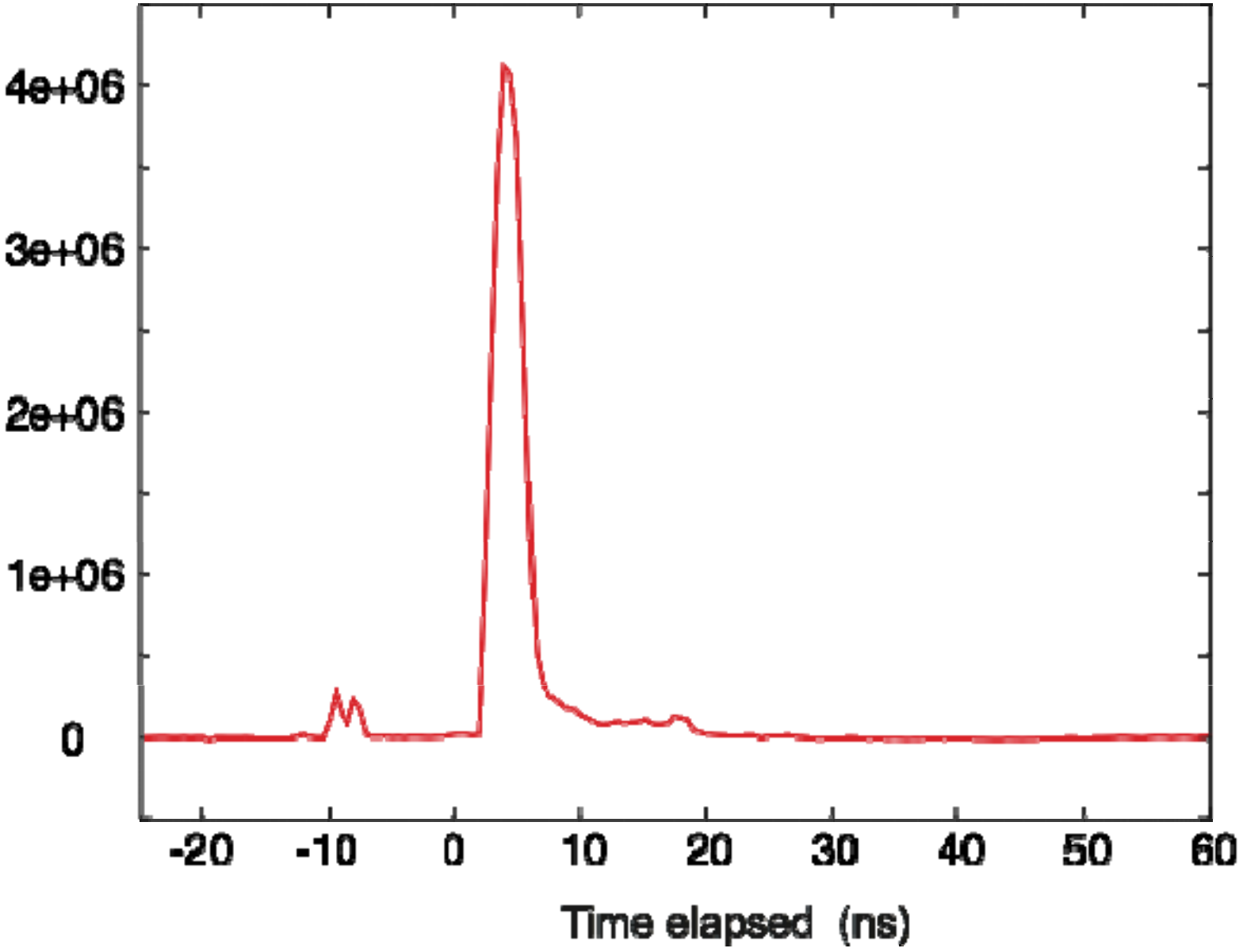
Theory of detector operation



9-electrode configuration, increased distances between grids, no initial acceleration, no B-field



10-electrode configuration, kV initial acceleration, no B-field sweeping electrons.



Conclusions

Spatial profile monitor with timing resolution was developed, and tested with a simulated “chopper” beam.

1. mm-scale resolution achieved.

2. < 2 ns timing resolution achieved.

3. Extinction ratio problem!! (afterpulse and prepulse)

Further optimization + beam dynamics simulation needed