DIAGNOSTICS OF THE PROSCAN PROTON-THERAPY BEAM LINES

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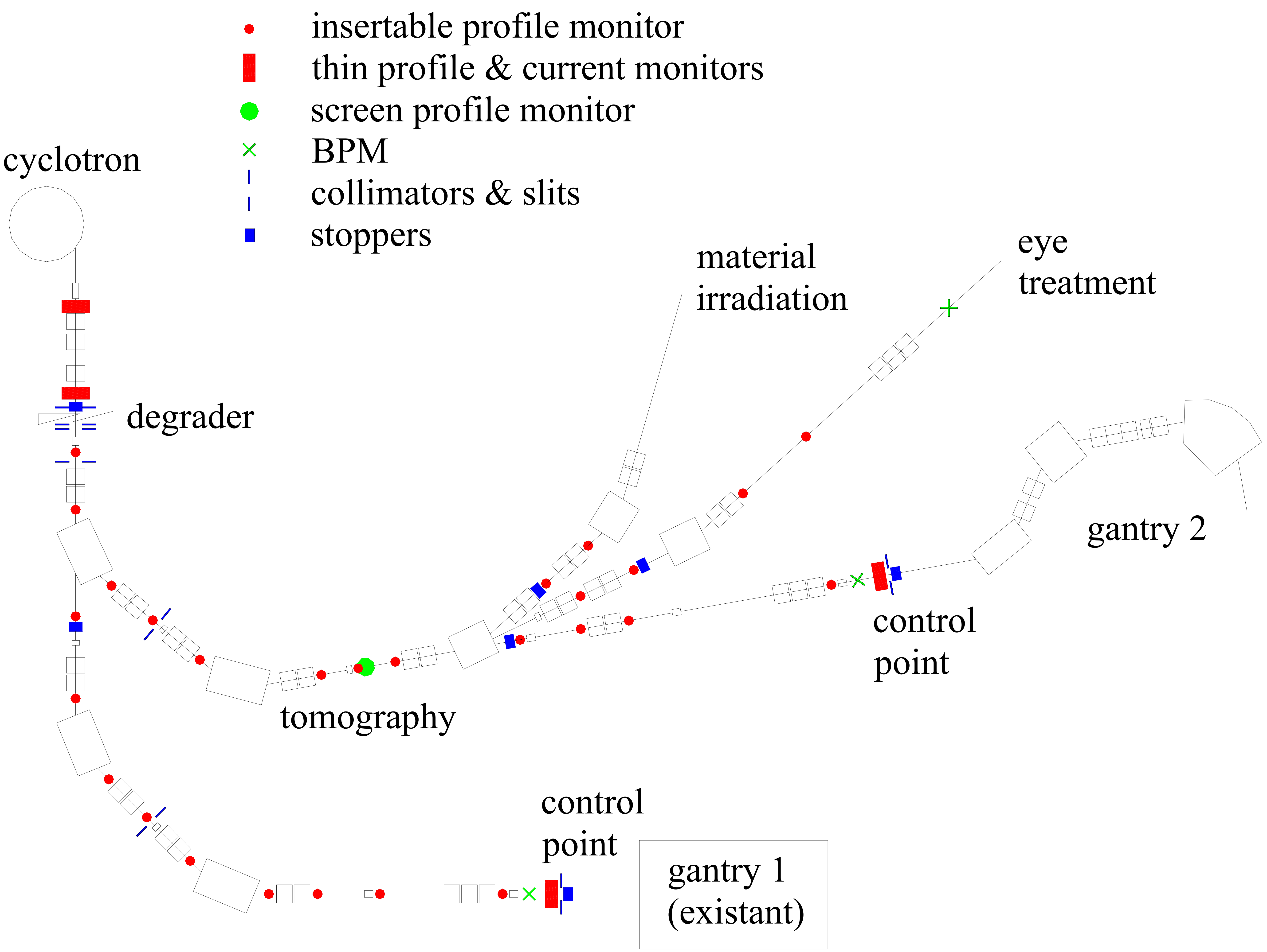
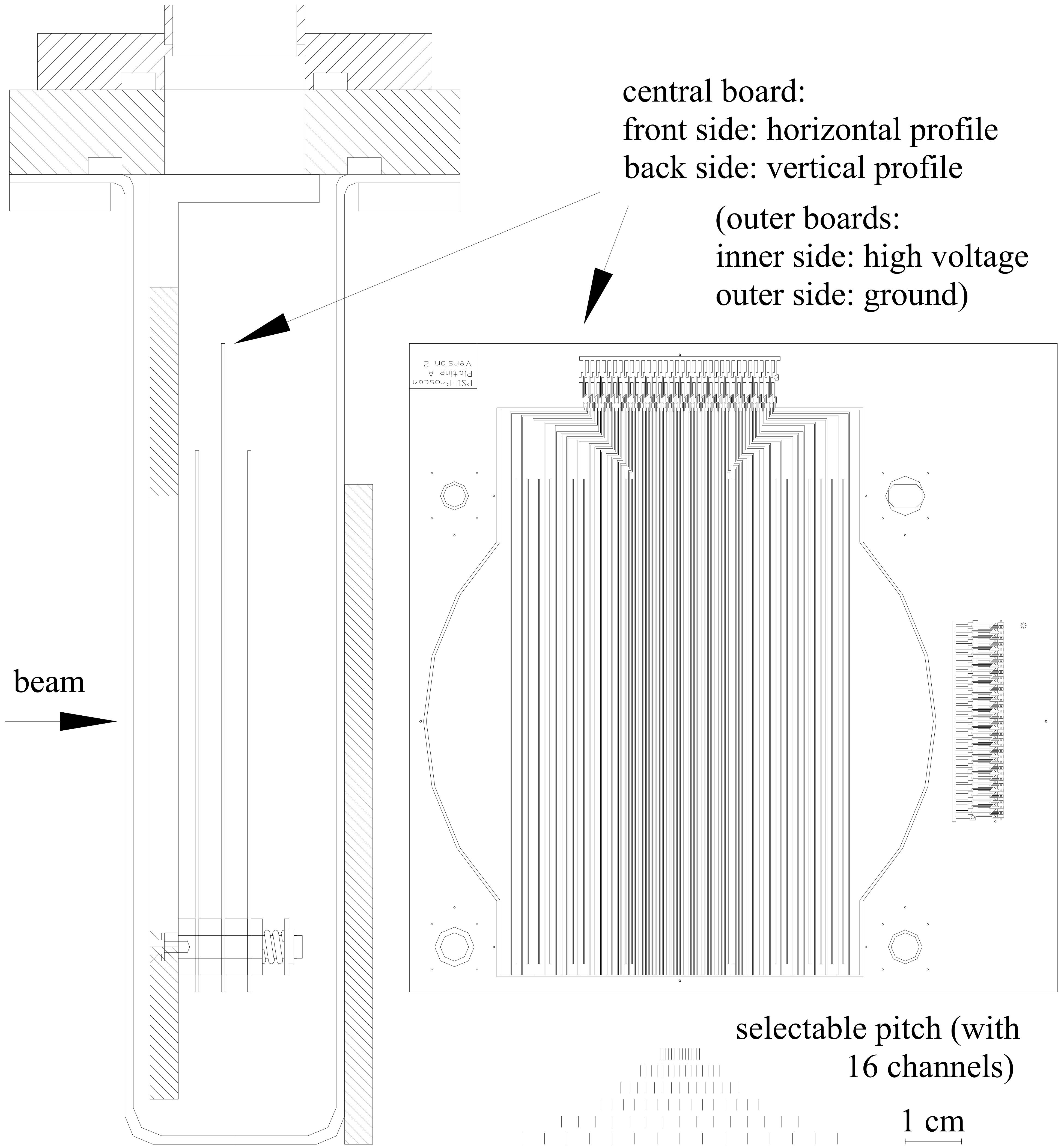
PROSCAN, an extended **medical facility** using proton beams for the treatment of deep seated tumours and eye melanoma, is in preparation at PSI [1]. A **250 MeV proton beam of 1 to 500 nA** will be extracted from the COMET cyclotron. After degradation to the **range of 230 to 70 MeV** it can be delivered (at a maximum current of **10 nA**) into one of four areas: Two gantries, an eye treatment room and a material irradiation area. **Fast changes of beam energy** are foreseen for the spot-scanning treatment of deep-seated tumours in the new gantry 2. Several diagnostics will be used to control the beam parameters in **different modes of operation**. At present most of the **components are under development** and prototypes will be tested in the next half year. An overview on the beam line diagnostics is given, with emphasis on beam profile measurement.


insertable profile monitor
thin profile & current monitors
screen profile monitor
BPM
collimators & slits
stoppers
cyclotron
degrader
material
irradiation
eye
treatment
gantry 2
control
point
tomography
control
point
gantry 1
(existant)

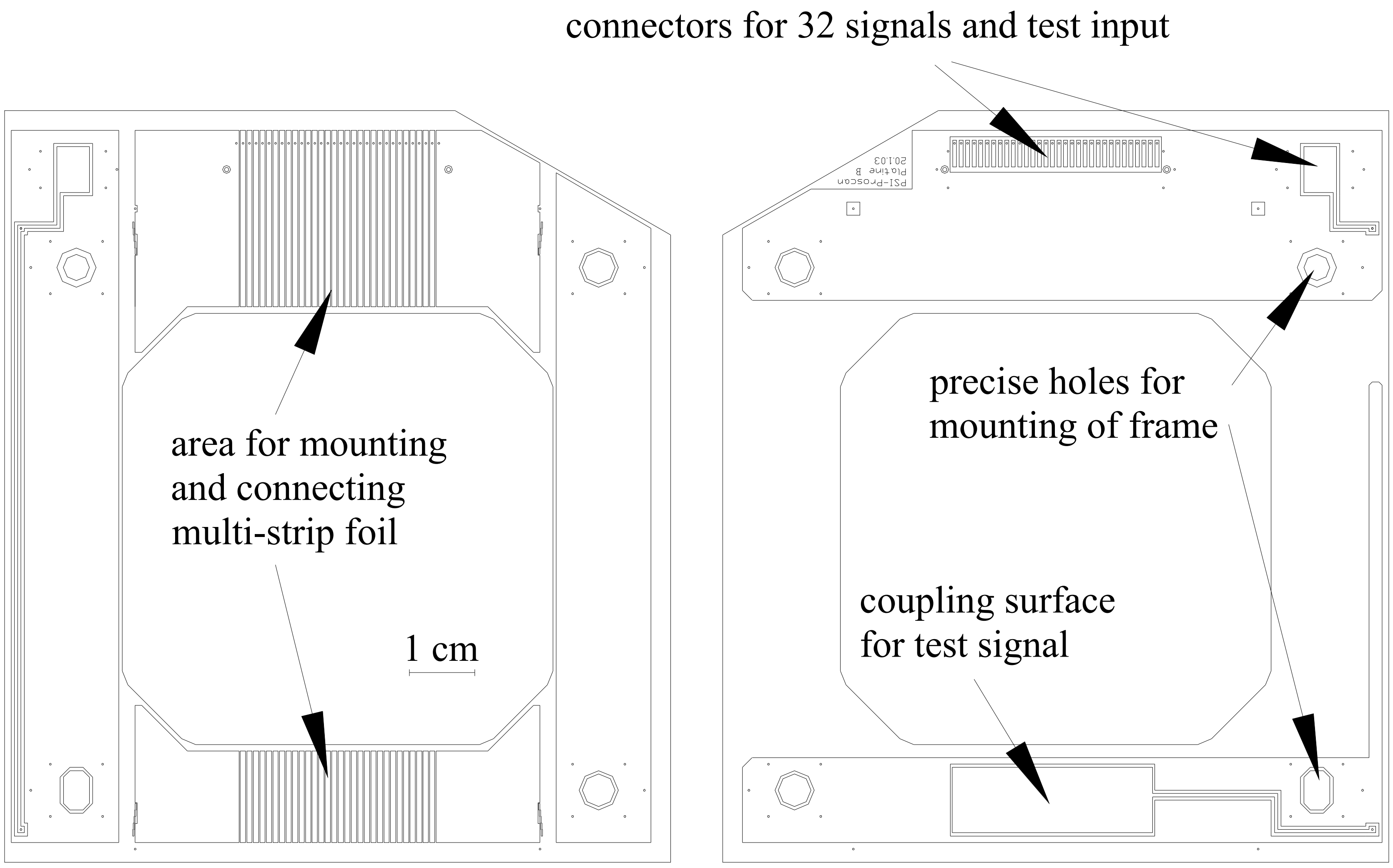
Insertable Profile Monitors

- Multi-Strip Ionisation Chambers (MSIC) at 27 locations
- chamber filled with ambient air and moved by pressured air actuator
- plane separation 4 mm, HV-bias +600 V
- 68 thick-film metallized strips (each plane) on 0.63 mm ceramic board
- read-out of 16 channels per plane (32 at few places)
- external grouping allows adaptation of strip pitch to expected range of beam profile width

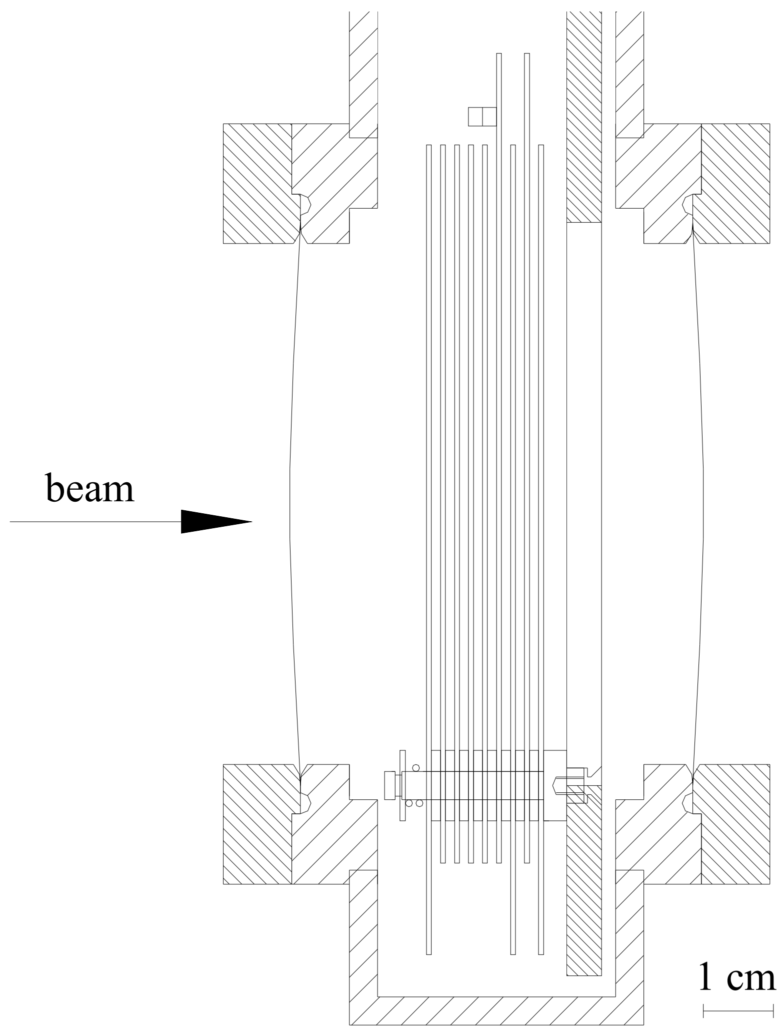


Thin Profile Monitors and Current Monitors

- 1 broader + 30 regular + 1 broader strip from 6 μm titanium foil
- as MSIC for low beam current density
- as Multi-Strip Secondary-Emission Monitor for higher current density
- at few locations, some placed permanently in the beam
- additional full planes for measurement of integral current
- etched strip pattern, pre-tensioned foil mounted/contacted to ceramic PCB:

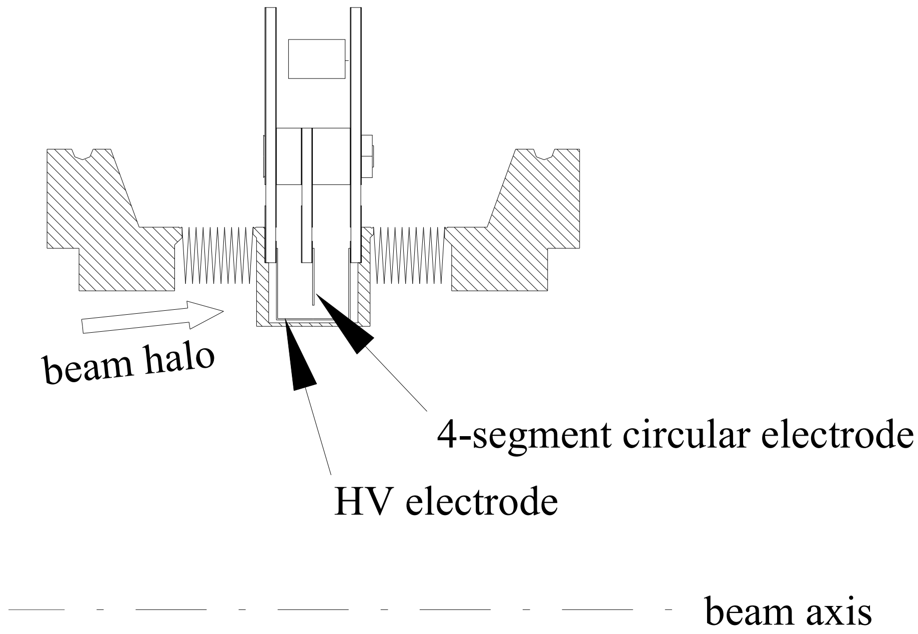


- plane separation 2 mm,
  HV-bias +2000 V for MSIC, IC
  counteracts recombination
  (up to a certain degree)
- windows 35 mm titanium foil
  clamped



Halo Monitors and Ionisation Chambers

- "**halo-monitors**" = 4-segment ionisation chambers, which protrude circumferentially 5 mm into the beam pipe of 90 mm diameter



- placed adjacent to the quadrupole doublets and triplets
- should give enough signal to detect traversing beam current fractions of below 1 pA
- also gives an online control of the stability of the beam settings
- **external ionisation chambers** located behind the dipoles close to the beam pipe (air-filled)
- only losses close to a chamber generate enough signal for the electronics used

BPMs

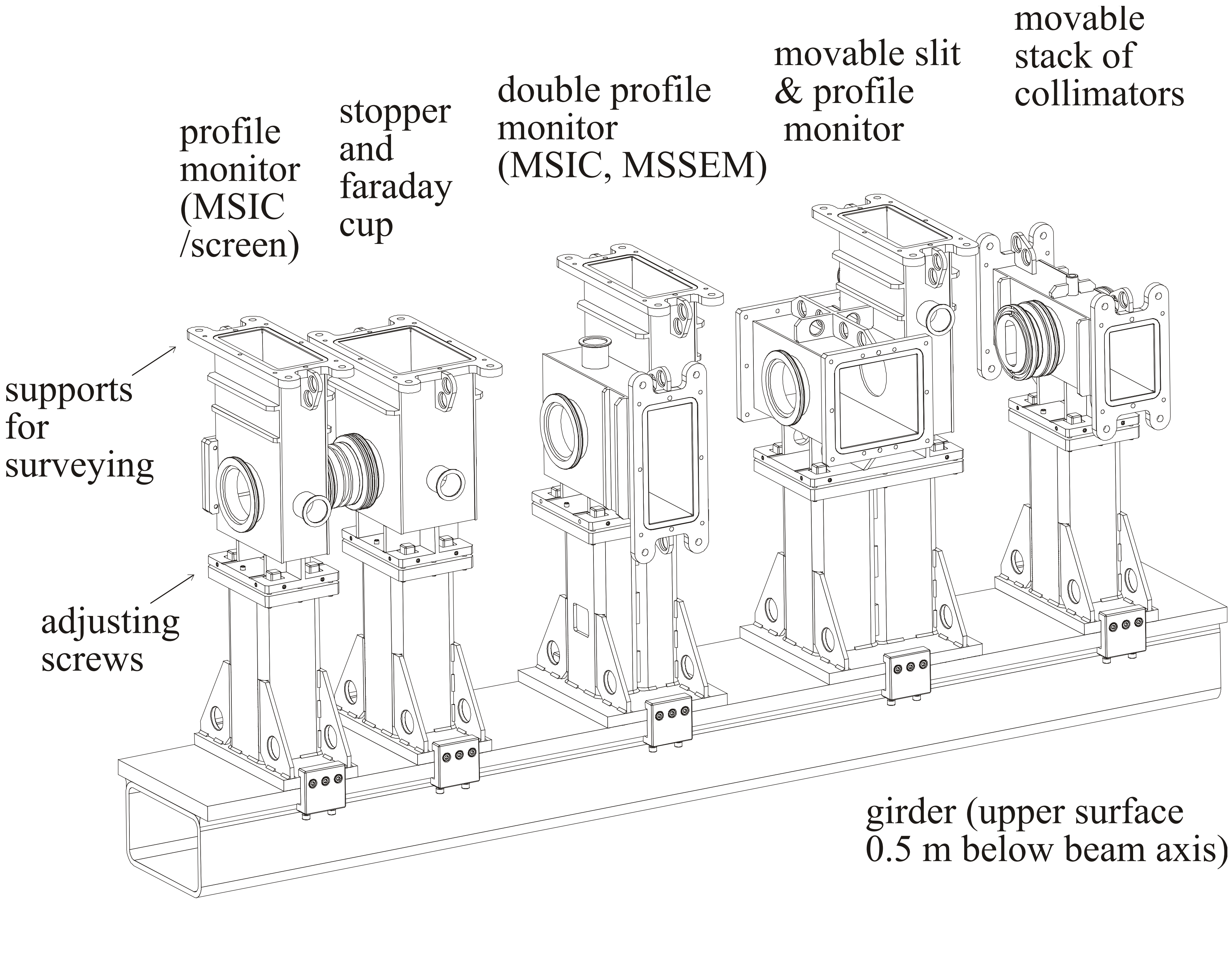
- stripline-BPMs with Q ~180 in front of gantries and eye treatment room

Electronics and Shielding

- all currents (incl. stoppers, slits) measured with **multi-channel logarithmic-amplifier modules**
- current range 10 pA to >200 μA
- single channel readout or up to 4096 profiles with a minimum time step of 1 ms
- algorithms for data evaluation and the generation of interlocks
- trigger input for simultaneous operation of several modules
- 16-channel CAMAC-module in first phase/later 32-channel and 4x4-channel (4 separate isolated grounds) VME-modules
- **omission of ground loops** by connecting amplifier "ground" only via the internal shield of the measurement-cable (~40 m) to ground at beam line (differential amplifier)
- additional **shielding** by enclosing measurement- and HV-cables from one diagnostic head together in a second shield (copper braid)
- own support for diagnostic cables, separate from water pipes/magnet cables

Vacuum Boxes

- individually adjustable on an (already nearly accurately placed) girder of several meters length
- main flange of the box includes 4 "ears" with precision holes: adjustment can be surveyed with or without diagnostic head installed (head with drive is pre-adjusted on a corresponding gauge)
- box design allows an inexpensive production using water cutting, brazing and only minimal machining of the stainless steel parts



References

[1] PSI Annual Report 2002, vol. VI, p. 51-73.
[2] G. Mie, Der elektrische Strom in ionisierter Luft in einem ebenen Kondensator, Ann. Phys. (Leipzig) 13 (1904) 857.
See also H. Attix, Introduction to radiological physics and radiation dosimetry, Wiley, 1986.

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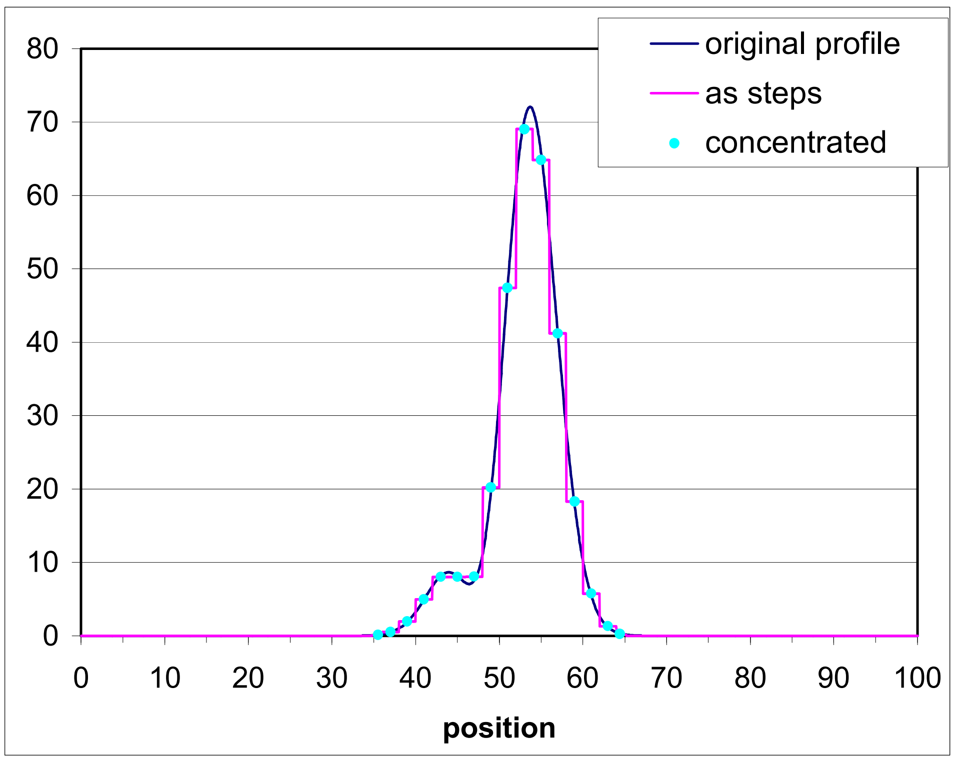
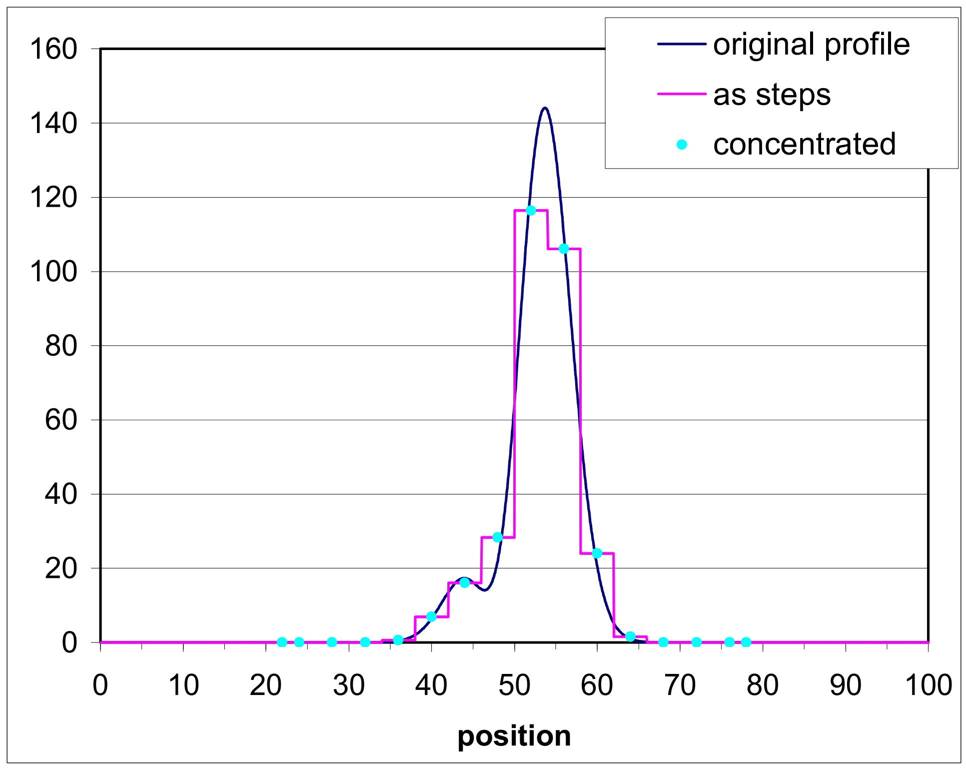
Number of strips needed for the determination of beam width and position

- Evaluation of simulated profiles (noise not included)
- 1 broader + 14 regular + 1 broader strip (evaluation of broader strips needs right treatment [2])
- original width (2.35 σ) = 10, original center = 53
- width evaluated from step-profile or concentrated currents has a little systematical error, which can be roughly corrected



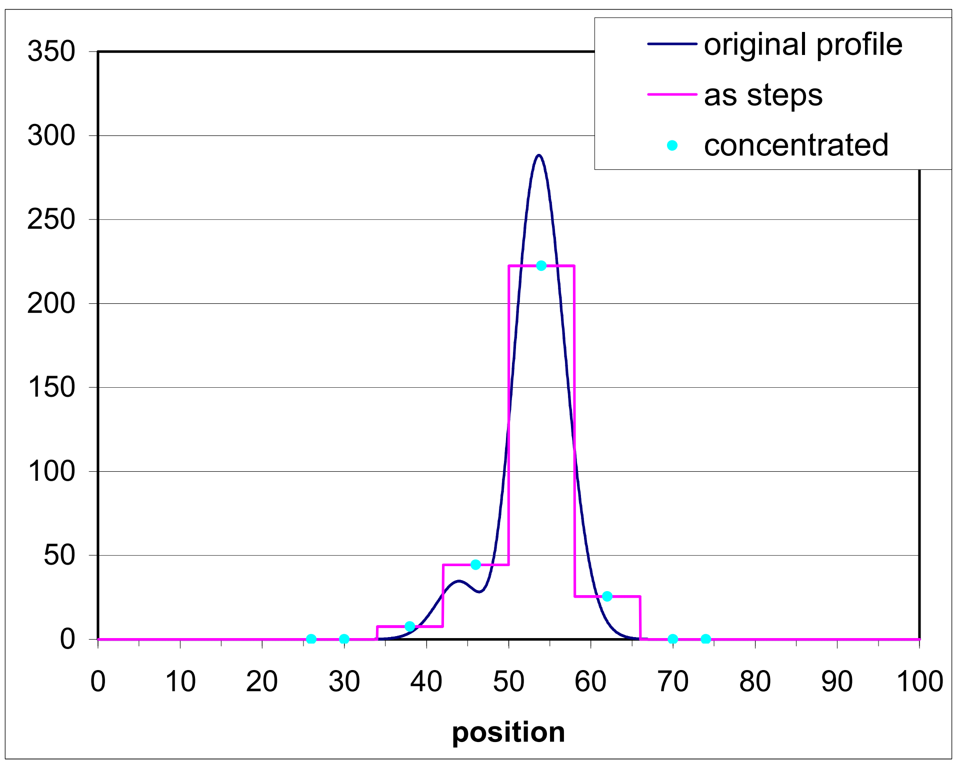
1) very good adaptation of strip pitch

width: 10.1 corrected width: 10.0 center: 53.0



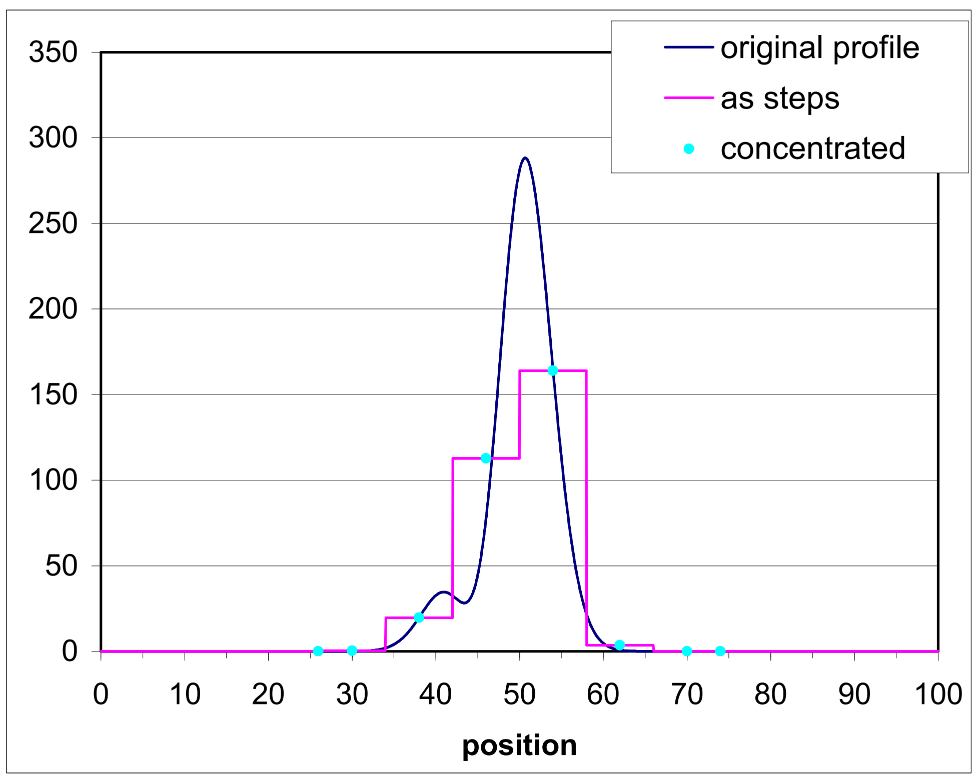
2) medium adaptation of strip pitch (broad)

width: 10.4 corrected width: 10.0 center: 53.0



3) poor adaptation of strip pitch (broad)

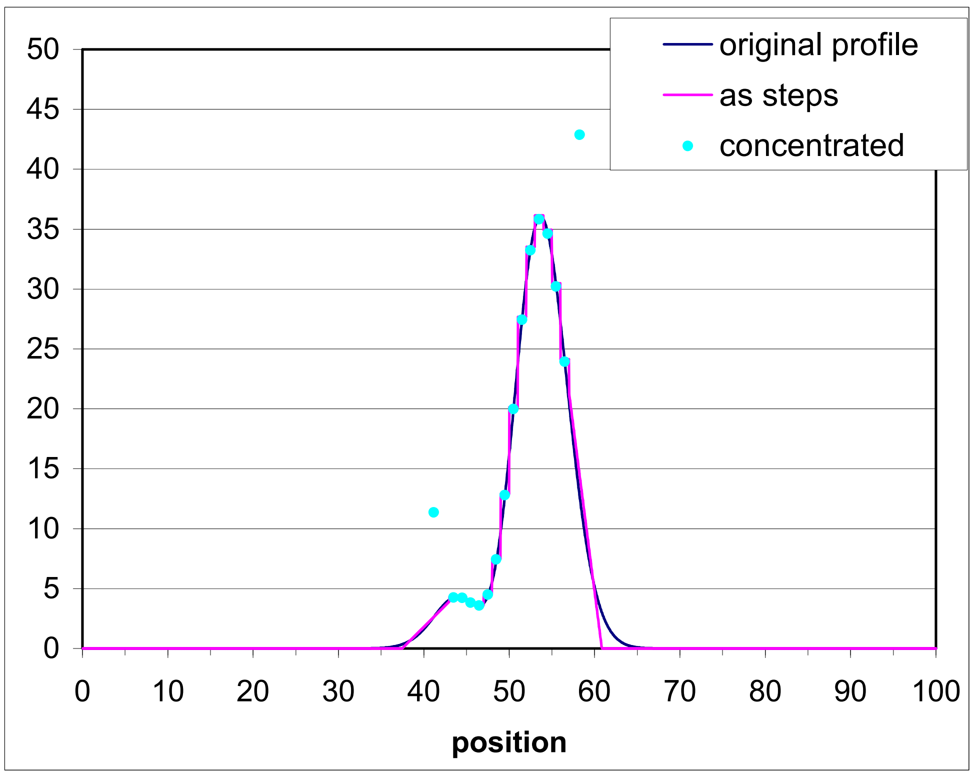
width: 10.7 corrected width: 9.2 center: 53.1



3a) same, original position = 50

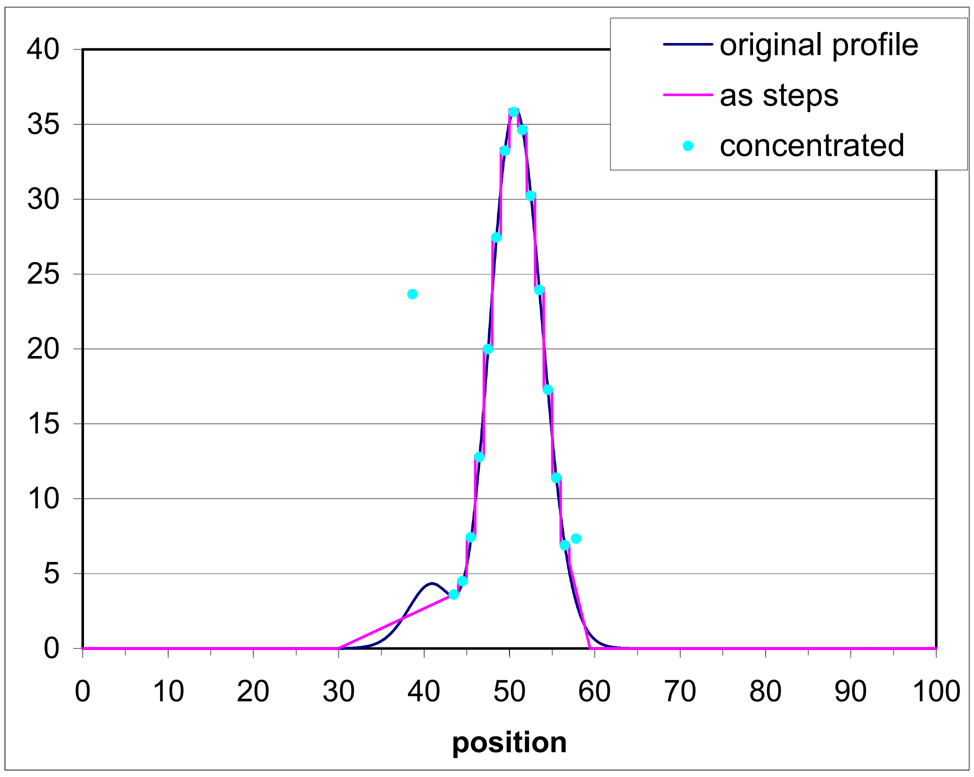
width: 12.1 corrected width: 10.8 center: 50.0

(all other shifted positions better)



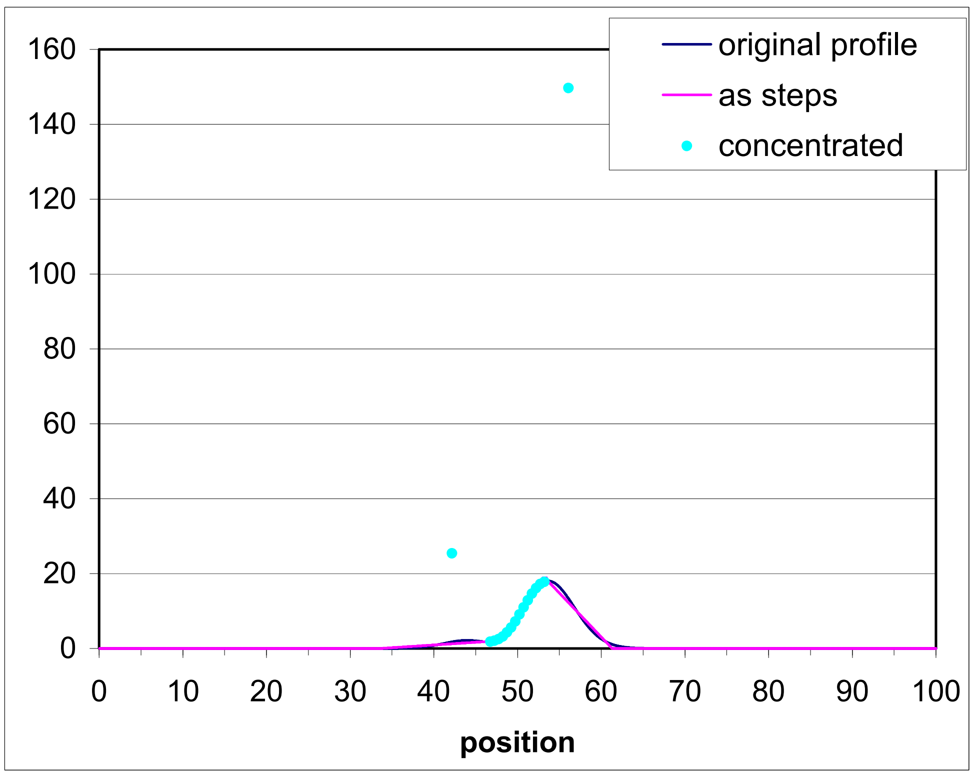
4) medium adaptation of strip pitch (narrow) and position

width: 9.7 corrected width: 9.6 center: 52.9



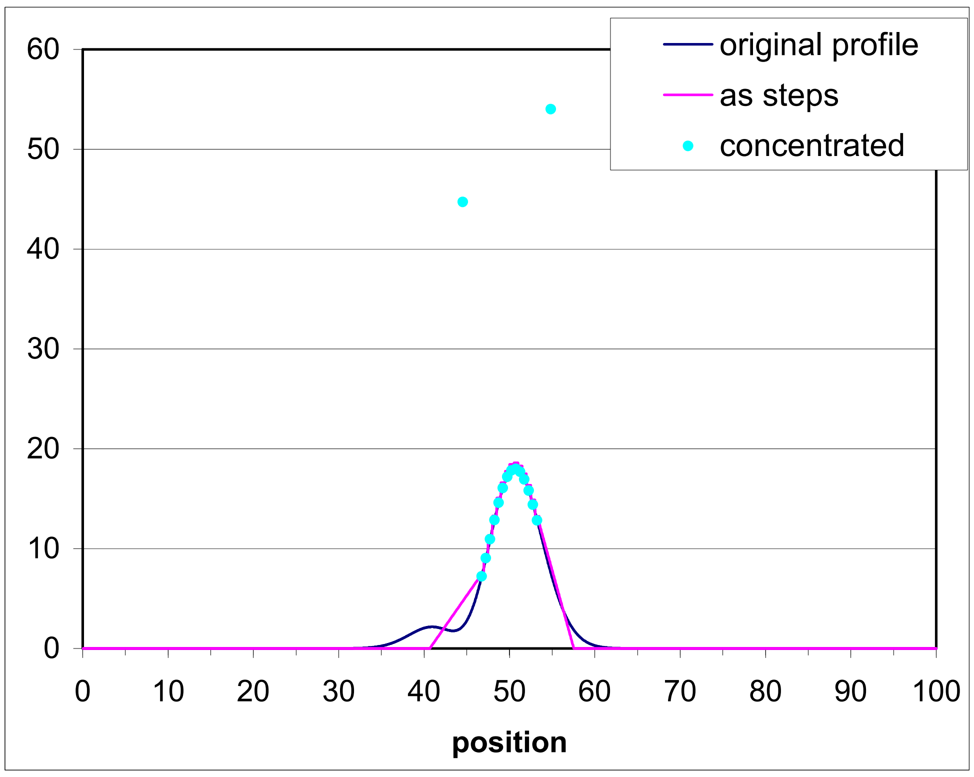
4a) same, position better (50)
(notice the treatment of the broader strips)

width: 10.4 corrected width: 10.4 center: 49.9



5) poor adaptation of strip pitch (narrow) and position

width: 9.7 corrected width: 9.7 center: 52.9



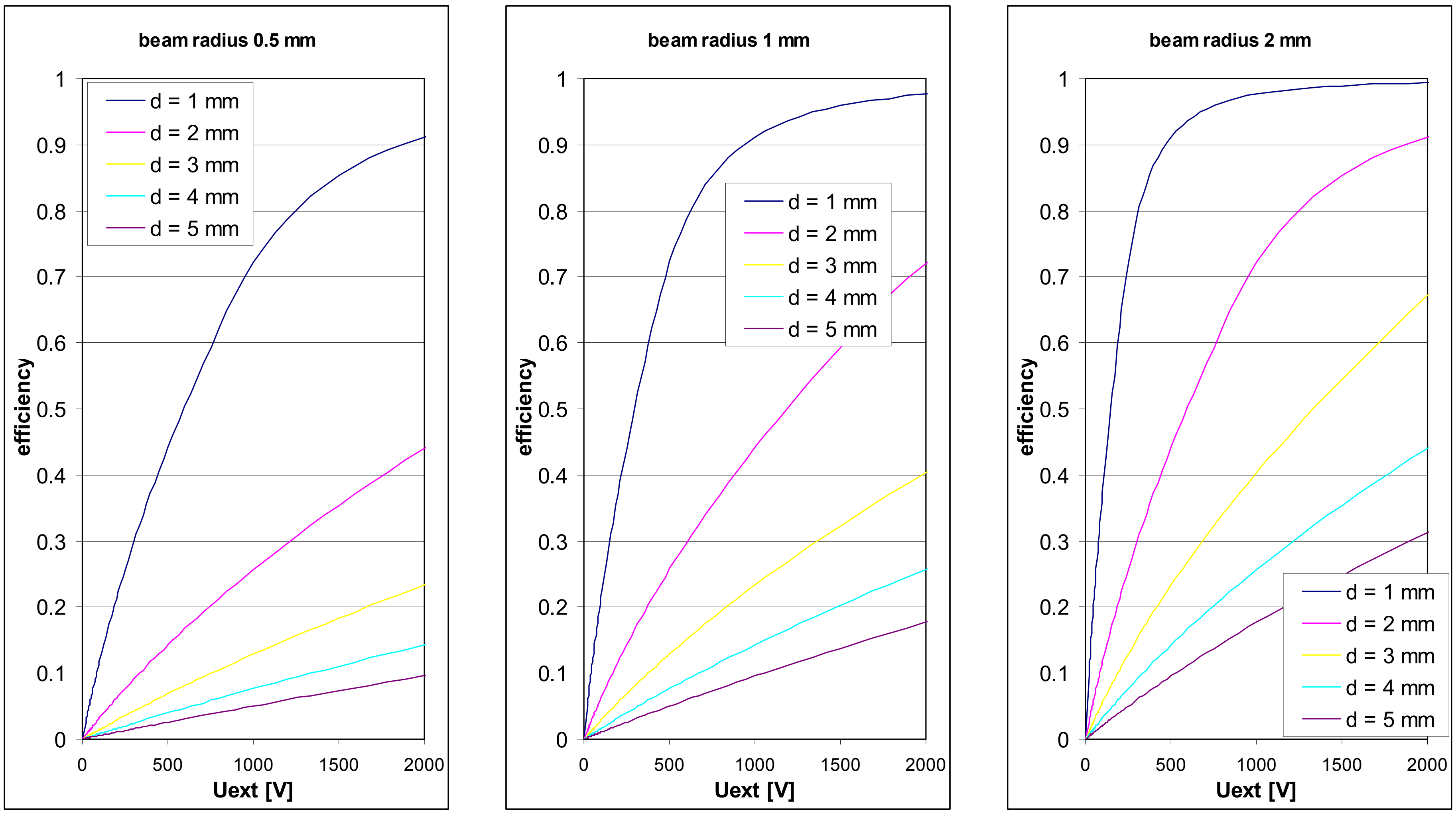
5a) same, position better (50)

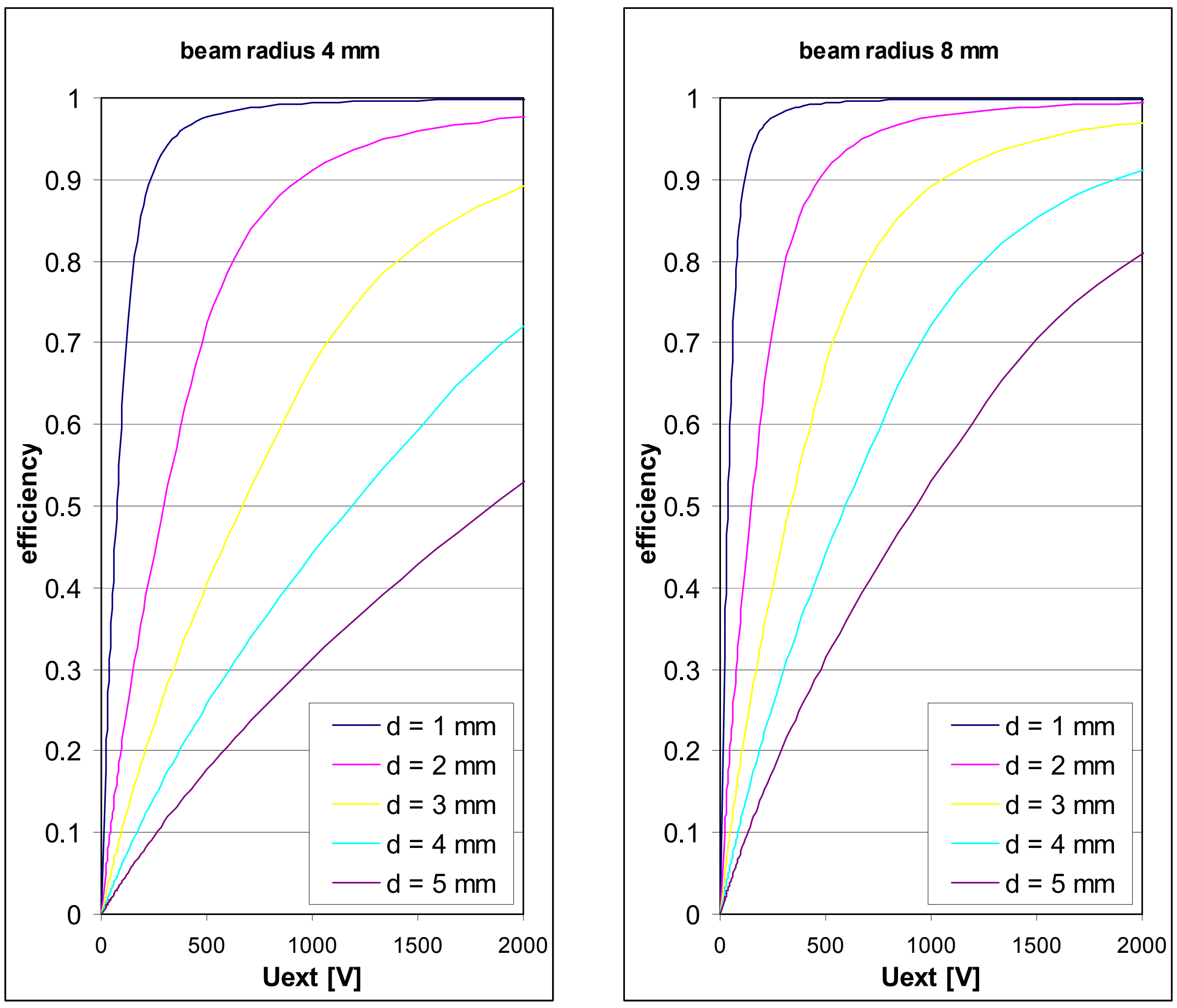
width: 7.8 corrected width: 7.8 center: 50.2

==> for 16 channels, beam position and width can be measured accurately if the FWHM beam width is in the range 1x to 10x strip pitch and the profile is of conventional shape

Effect of Recombination

- Recombination decreases the current output of the ionisation chamber
- plane separation d is most critical parameter
- calculation of collection efficiency according to [2]:
  (250 MeV proton beam of 500 nA, homogeneous)





==> even at 2000 V/2 mm recombination is significant at lower beam radii