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PROGRESS OF THE DIAGNOSTICS AT THE PROSCAN BEAM LINES

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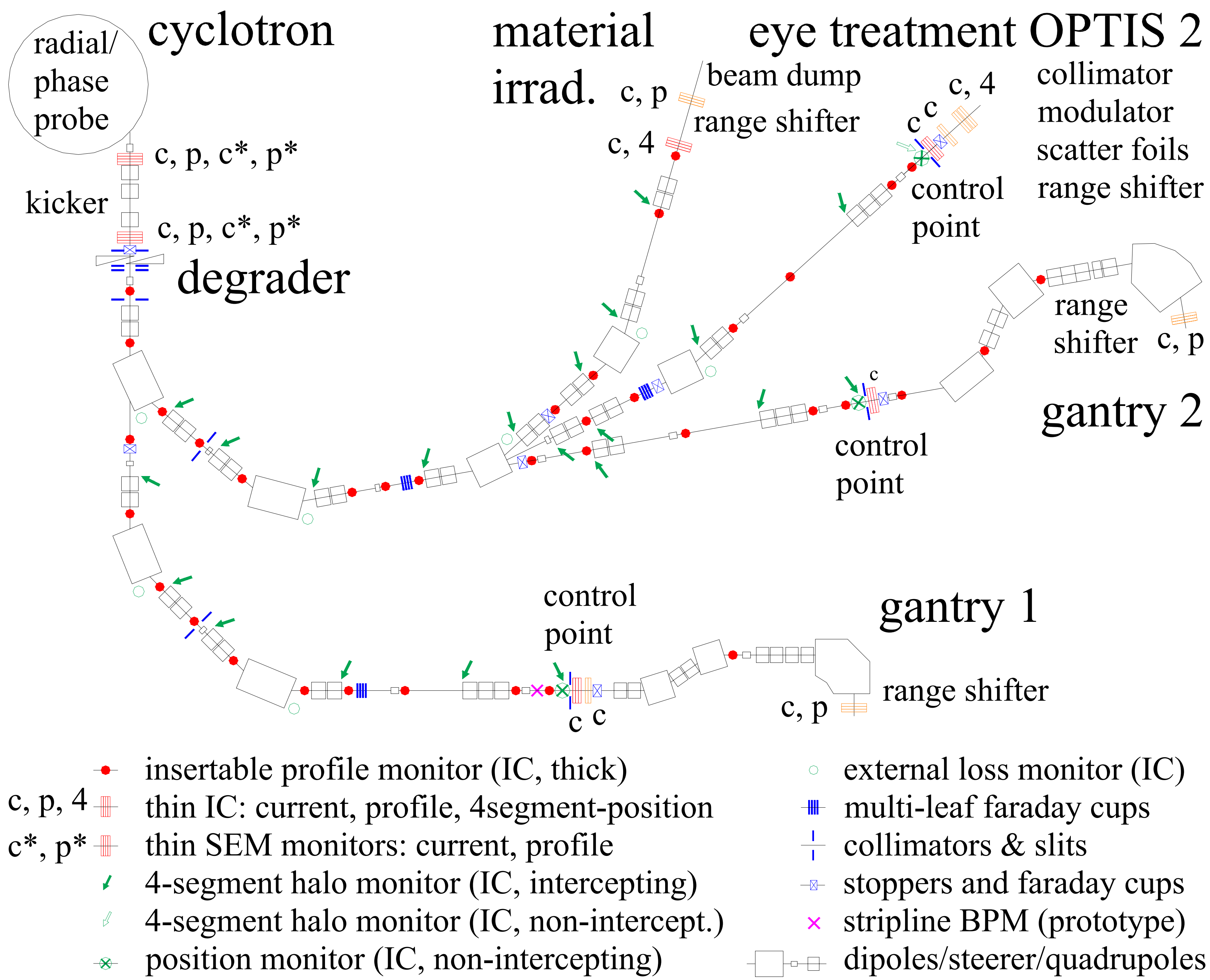
PROSCAN,

the dedicated new medical facility at PSI using proton beams for the treatment of deep seated tumours and eye melanoma, has restarted routine operation with Gantry 1. The other beam lines will be commissioned in this year. Air and N_2 filled ionisation chambers and secondary emission monitors in several configurations are used as current, profile, halo, position and loss monitors [1]. New variants of a multi-leaf faraday cup and an ionisation chamber position monitor for the beam line to OPTIS 2 are presented together with as an improved profile evaluation technique.

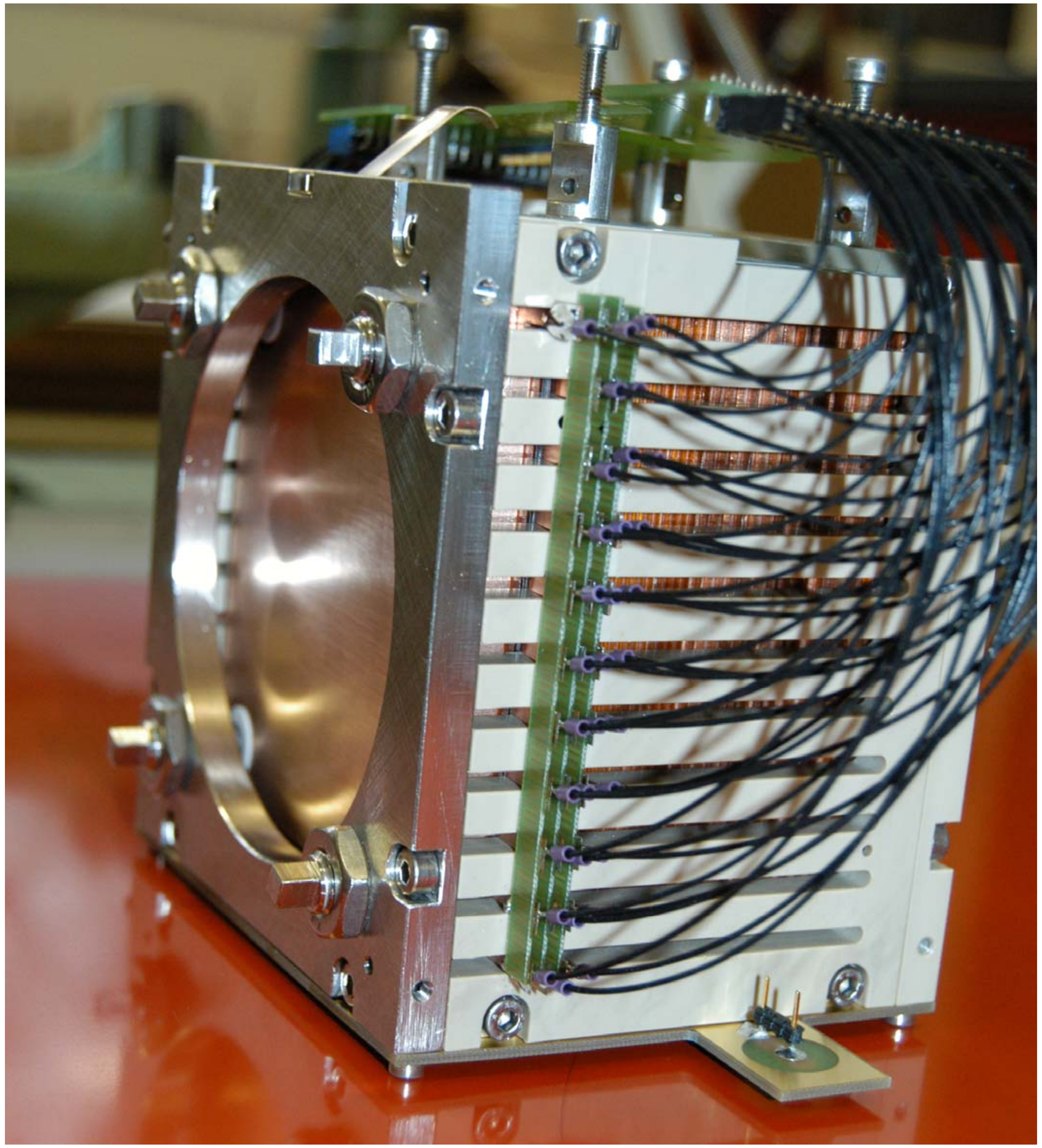
- proton beam 250 MeV, 1 to 500 nA
- <10 nA after degradation (230 to 70 MeV)
- fast changes of beam energy (~50ms)

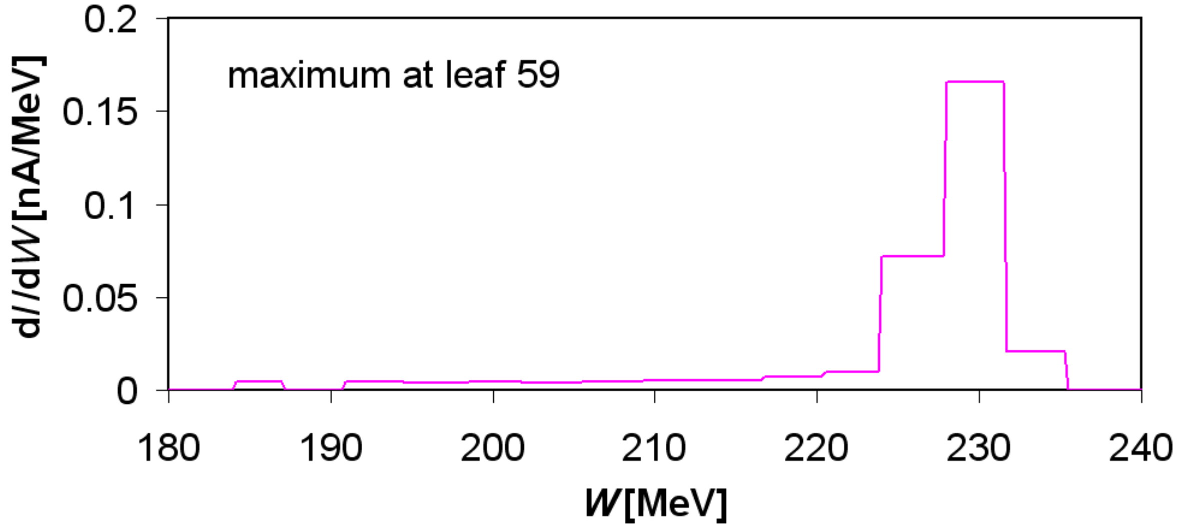


[1] R. Dölling, AIP Conf. Proc. 868 (2006) 271

Multi-Leaf Faraday Cups

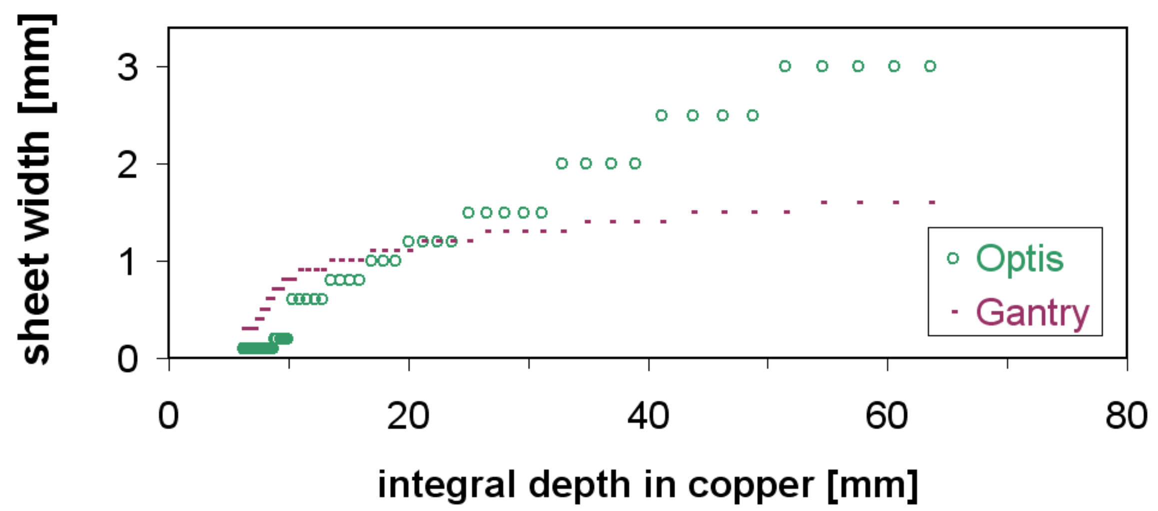
- the beam energy distribution is determined from the measured range distribution
- the beam is stopped in a stack of 64 copper sheets of varying thickness
- the copper sheets are separated by Kapton foils
- the 64 currents (>10 pA) are measured with two standard 32-channel VME logarithmic-amplifier boards outside the vault
- MLFC is mounted on a compressed-air actuator
- in vacuum, no active cooling --> max. 200 kJ/day
- an electrode at the bottom allows capacitive coupling of a test pulse for a system test
- two variants: for OPTIS 2: 65 - 86 (- 252) MeV, for gantries: 68 - 252 MeV

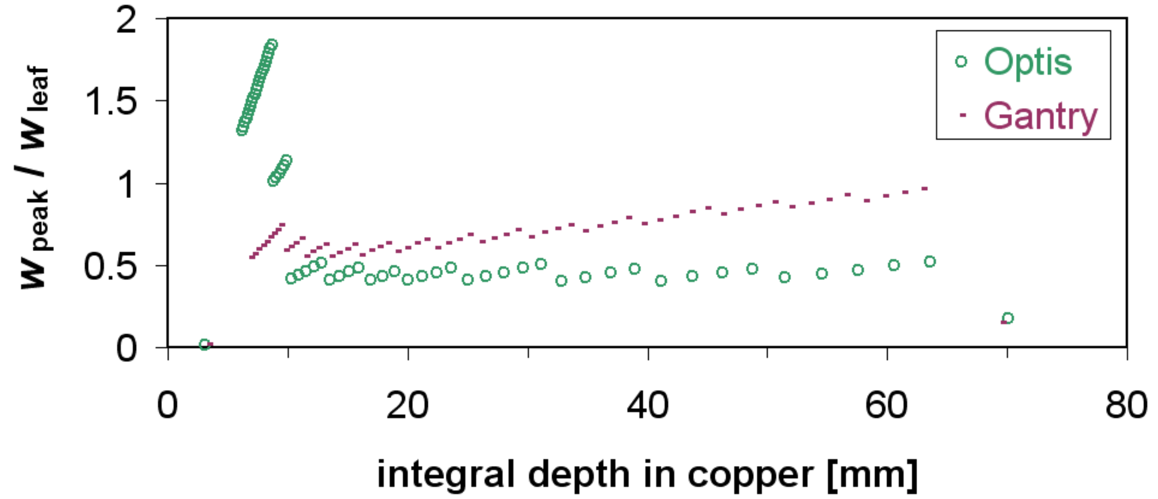




The **Copper sheet thicknesses** are chosen according to

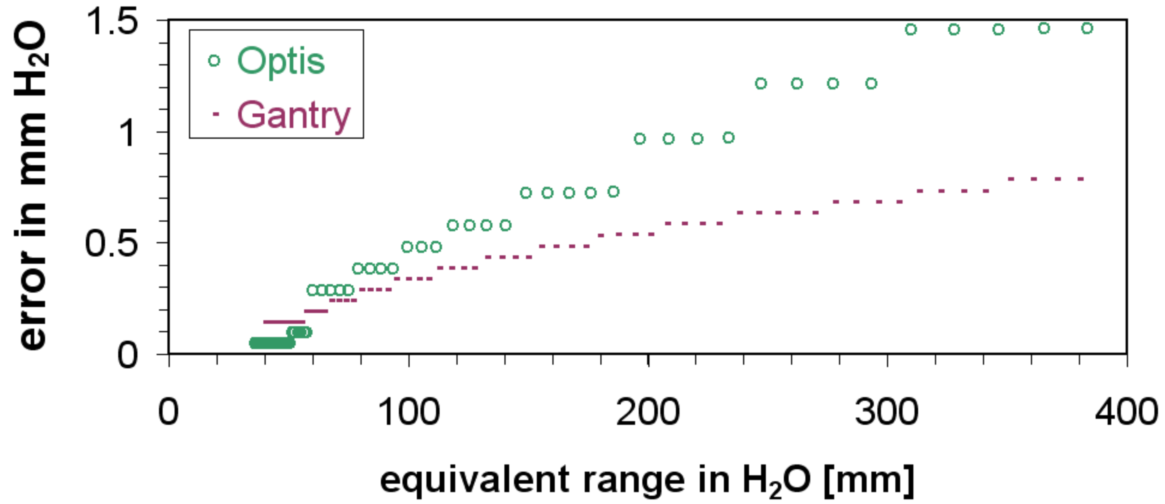
- the peak width should distribute to only a few sheets, since signals must stay above the lower range limit of 10 pA of the logarithmic amplifiers
- the peak width w_{peak} must equal or exceed the copper sheet width w_{leaf} for an accurate measurement (see below)
- the peak width can be estimated by contributions from the straggling in copper: σ_{stragg}[mm] = 0.0105 R and the beam momentum spread dp/p: σ_{beam}[mm] = 3.2 dp/p R (with Range R [mm]) [2]
- Optis-MLFC: dp/p = 0 is sufficient below 86 MeV
  Gantry-MLFC: dp/p = 0.2% - 0.5% is needed





The accuracy of the range determination is estimated with assumed current errors of ±2% (see below):

- accuracy [mm H_2O] ≈ w_{leaf} at peak location [mm] / 2
- for the OPTIS-MLFC results an accuracy of:
  ~0.05 mm H_2O in the range of 35.5 - 50.7 mm H_2O
  ~0.1 mm H_2O in the range of 50.7 - 58.4 mm H_2O

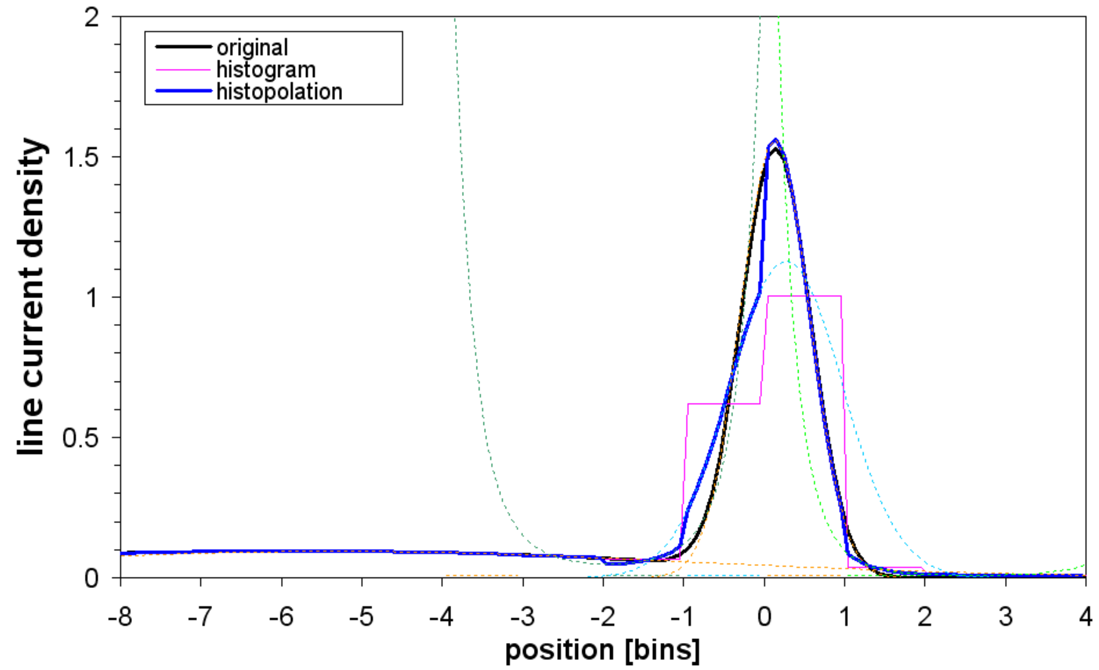


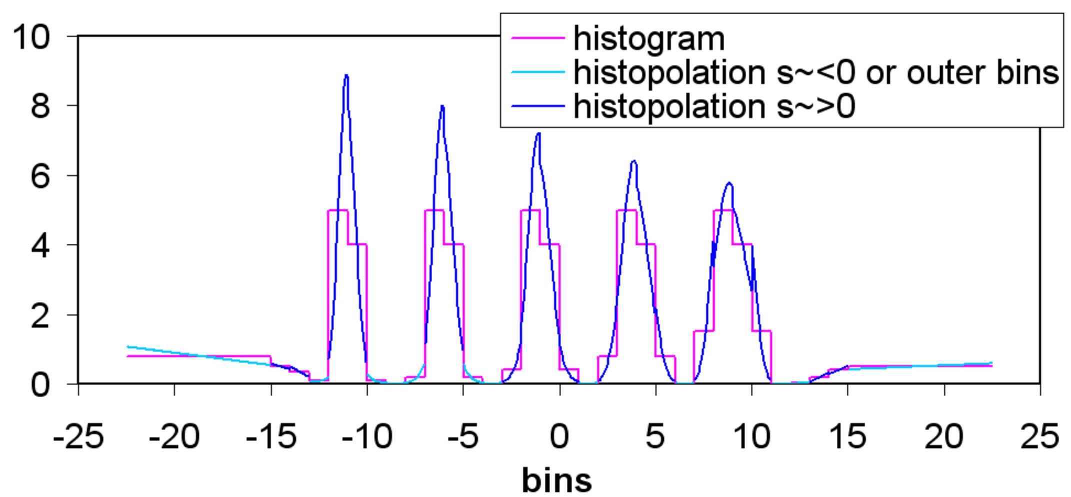
[2] P. Wittendorp, PROSCAN Document P24/WP85-401

Histogram Evaluation

The **"Gaussian histopolation"** is a technique for the derivation of a distribution from a histogram:

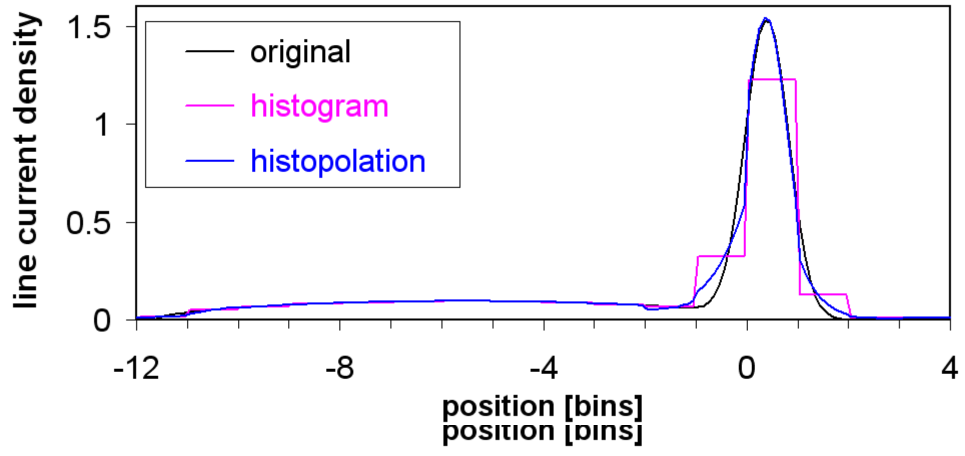
- data from MSIC profile monitors and MLFCs are basically represented by histograms
- our standard technique for the evaluation of beam centre and width: take the 1st and 2nd moment of the step distribution following the histogram shape
- an alternative technique: take the 1st and 2nd moment of a constructed distribution
- the "Gaussian histopolation" constructs a distribution from an area-true representation of the actual bin and its both neighbours by an "extended" Gaussian: $j(x) = j_0\, e^{-(x-x_0)^2/(2\tilde{s})}$ with $-\infty < \tilde{s}, x_0 < \infty$ and $j_0 \geq 0$ (solutions for each bin are provided by an iterative algorithm)
- advantage 1: the better approximation of very narrow peaks of nearly Gaussian shape
- advantage 2: the resulting smoother curve allows to cut-off a distribution below a cut-off level, without being to sensitive to the relative position of the peak to the histogram bin grid

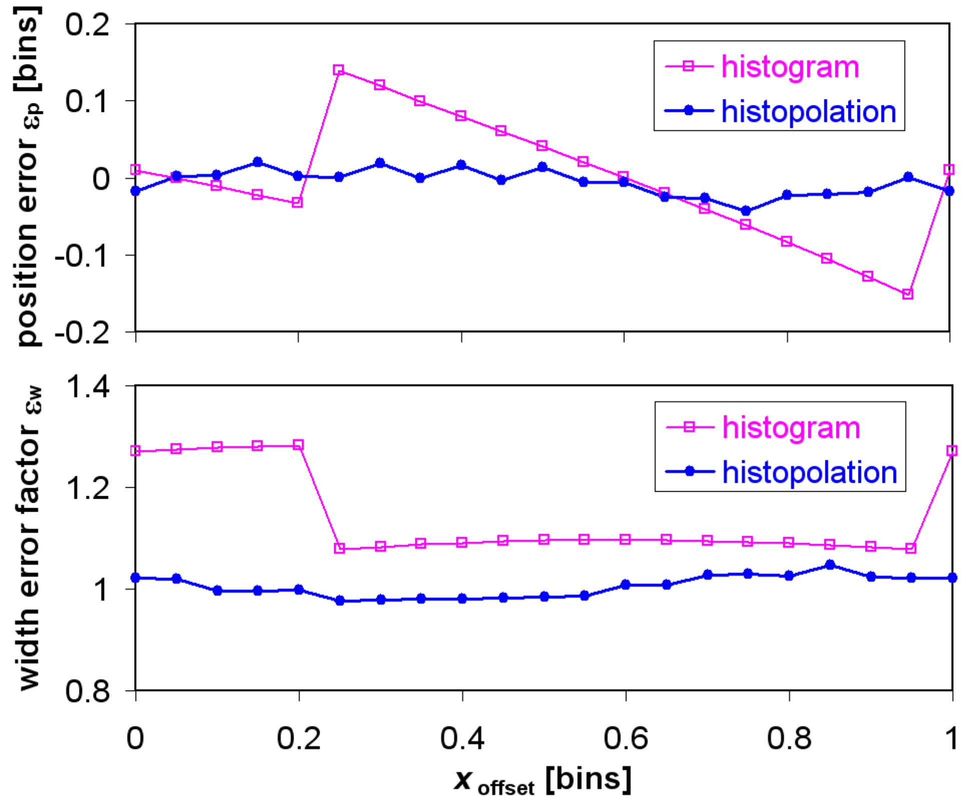


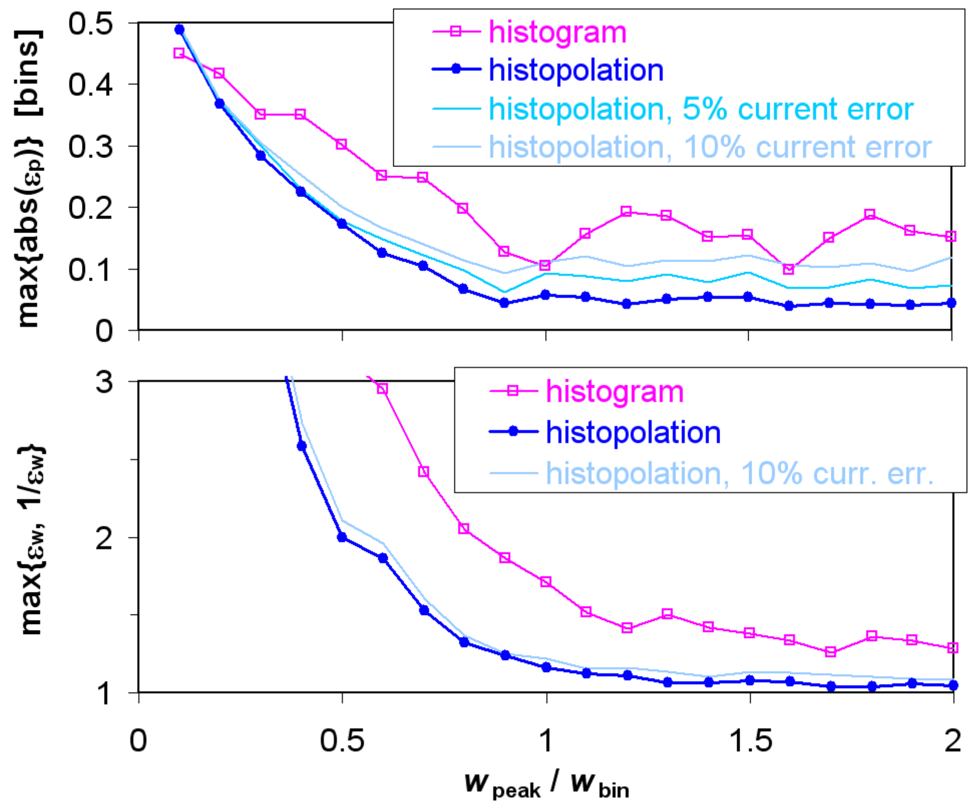


Simulation for the **estimation of the accuracy** of the determination of beam position and width:

- the histogram is derived from an original distribution (resembling an MLFC energy spectrum) which is shifted by x_{offset} relative to the histogram bin grid
- the original distribution, the histogram-shaped distribution and the Gaussian-histopolation distribution are all cut off below a level of 25% and evaluated for position and width
- position and width errors of the evaluations for the histogram-shaped distribution and the Gaussian-histopolation distribution are determined by comparison with the original distribution
- the advantage of the smoother Gaussian-histopolation distribution is clearly visible
- by changing the peak width w_{peak} of the original distribution compared to the histogram bin width w_{bin}, the effect of this ratio can be studied: a ratio of ≥ 1 is required for good accuracy
- by introducing current errors, its effect can be studied

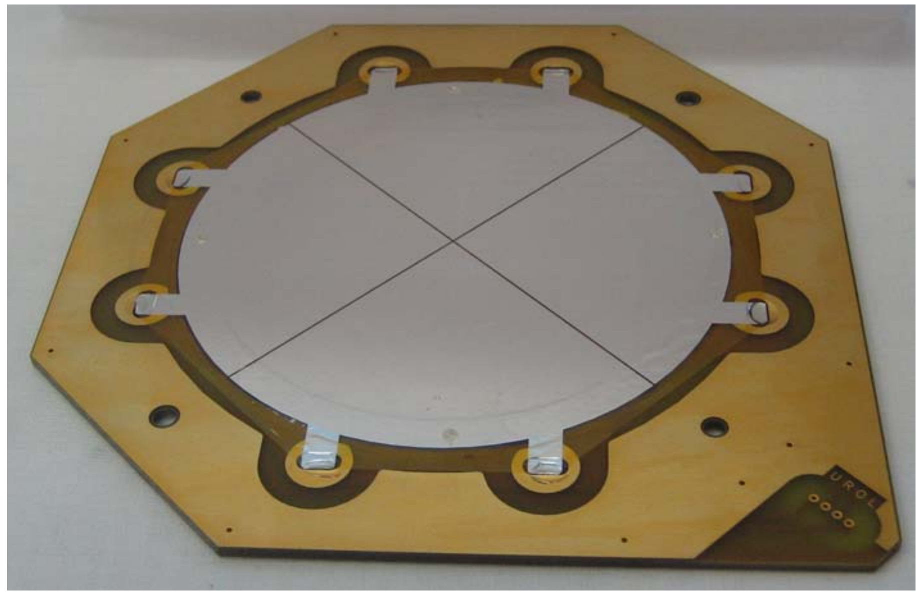




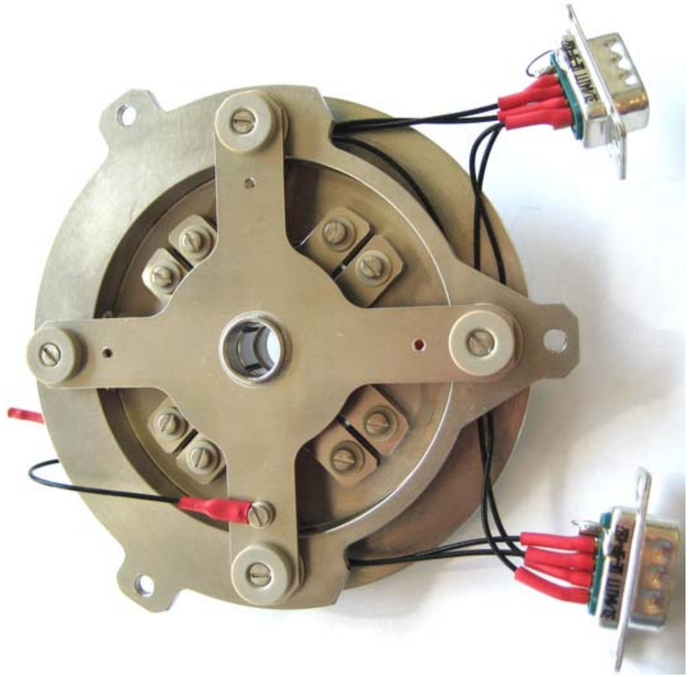


4-Segment Ionisation-Chamber Position Monitors

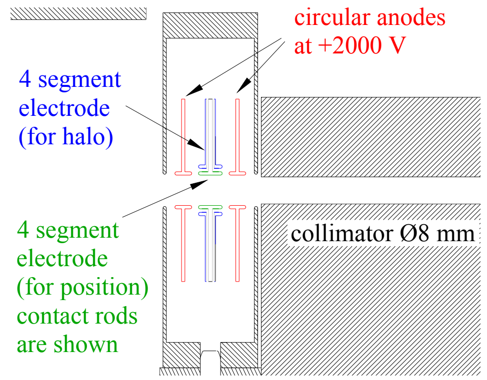
Three variants will be operated permanently at the beam lines:



- a conventional "thin" IC made from 12 µm thick aluminised Kapton foils, with one of the measurement electrodes segmented to 4 quadrants (at the exit of the material irradiation beam line)



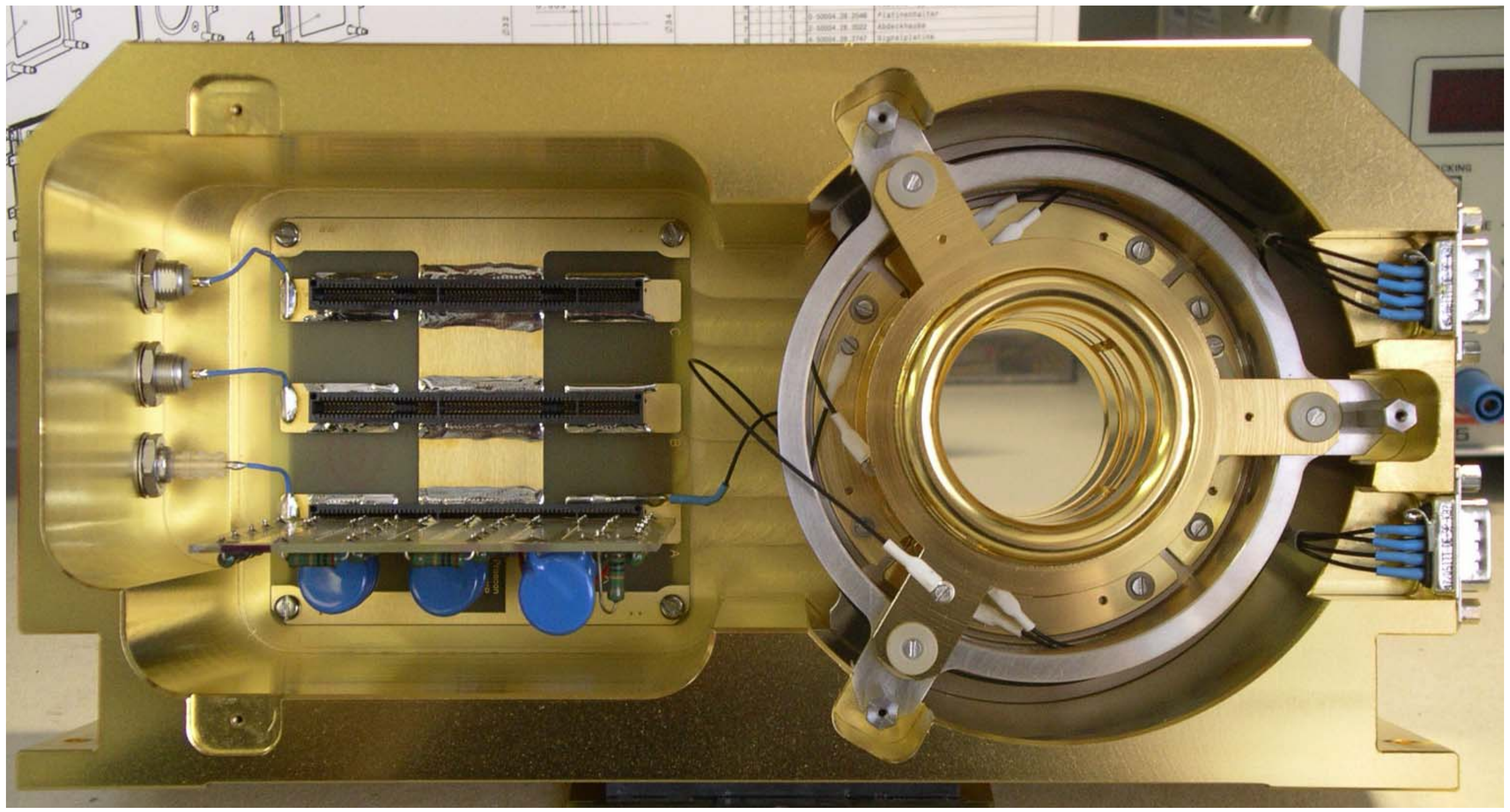
- a non-intercepting position monitor of only 9 mm diameter with an intercepting circumferential 4-segment halo monitor (at the control points in front of gantries, already in use at gantry 1)



all are operated with a high voltage of 2 kV in ambient air

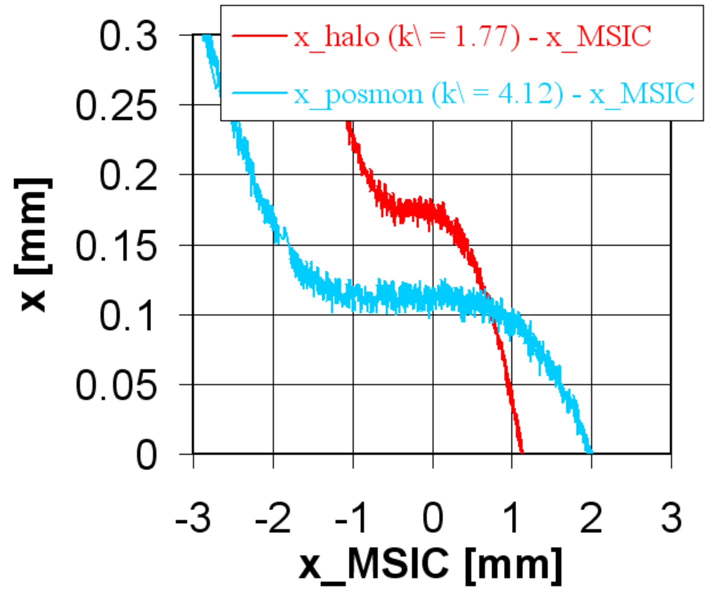
- a non-intercepting position and halo monitor (at the control point in front of OPTIS 2)

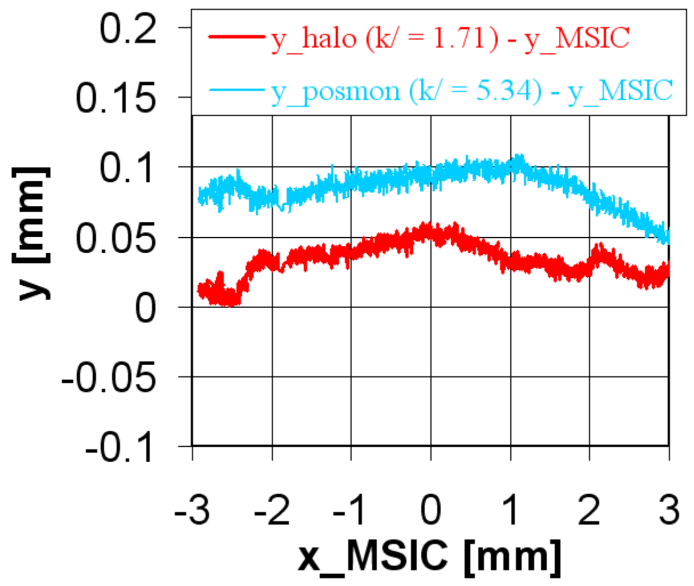
electrode configuration from outside to centre:
ground/
high voltage/
halo-monitor/
position-monitor
(= centre electrode)



The accuracy of the beam-centre detection is illustrated by a measurement with the gantry-type monitor:

Horizontal and vertical beam position, determined from halo and position monitor, referenced to the position from a close-by MSIC. The beam is scanned horizontally. (Integration time 20 ms/point. k-values are fitted for horizontal central slopes [1].) The differences stem from misalignments or errors of the current readings: ±5% current error at the halo monitor or ±3% at the position monitor (worst case configuration) will yield a position error of ~±0.1 mm.

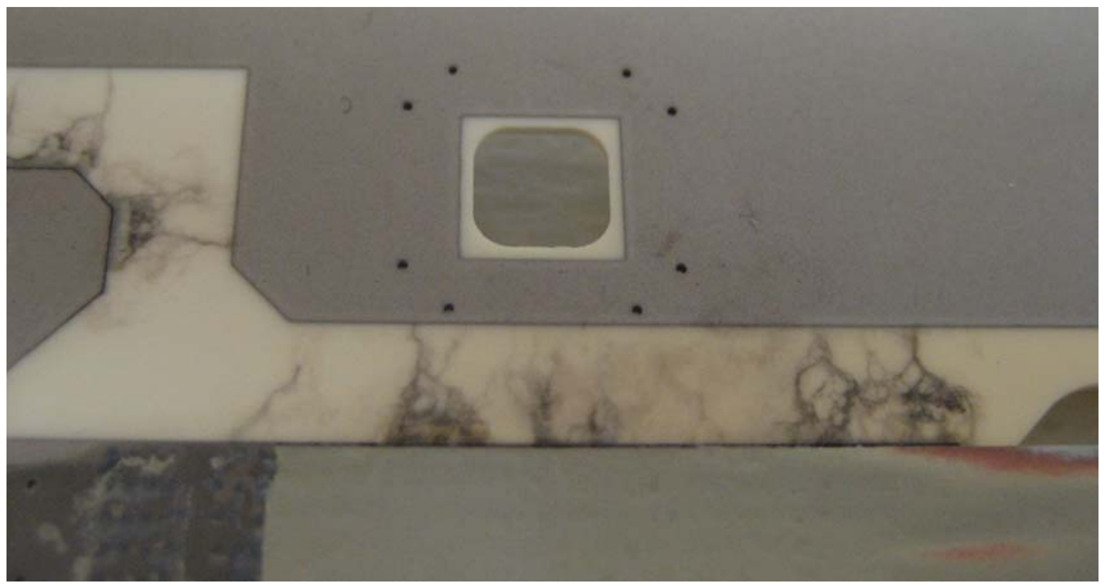


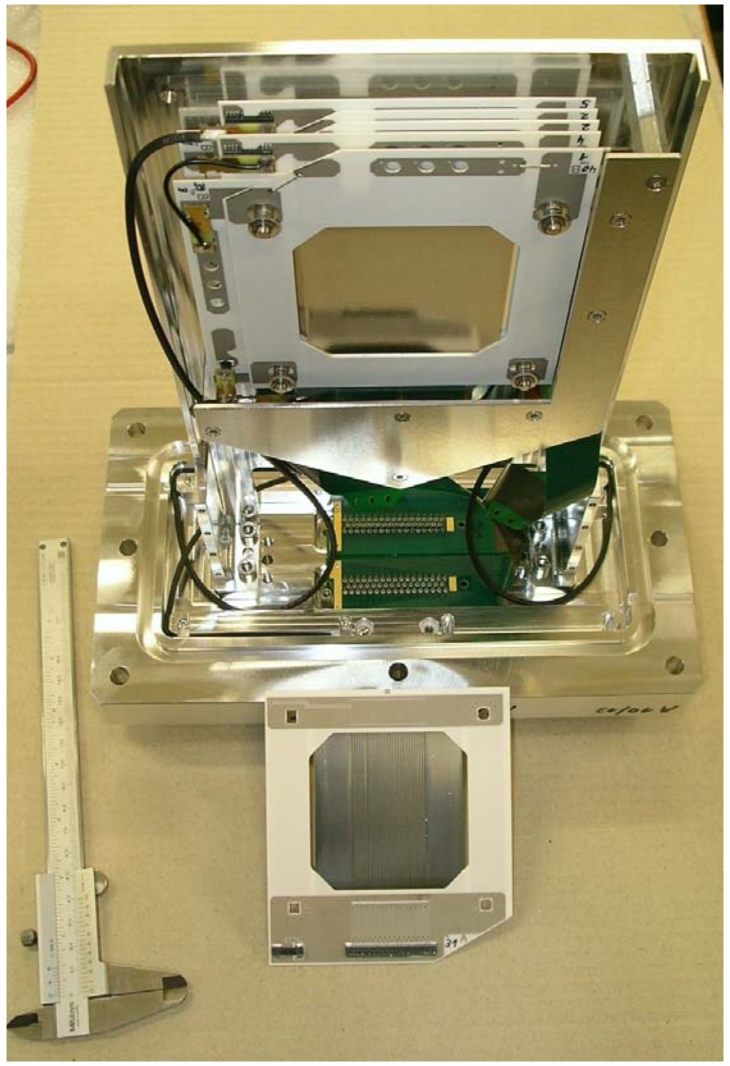


Current, Profile and Halo Monitors

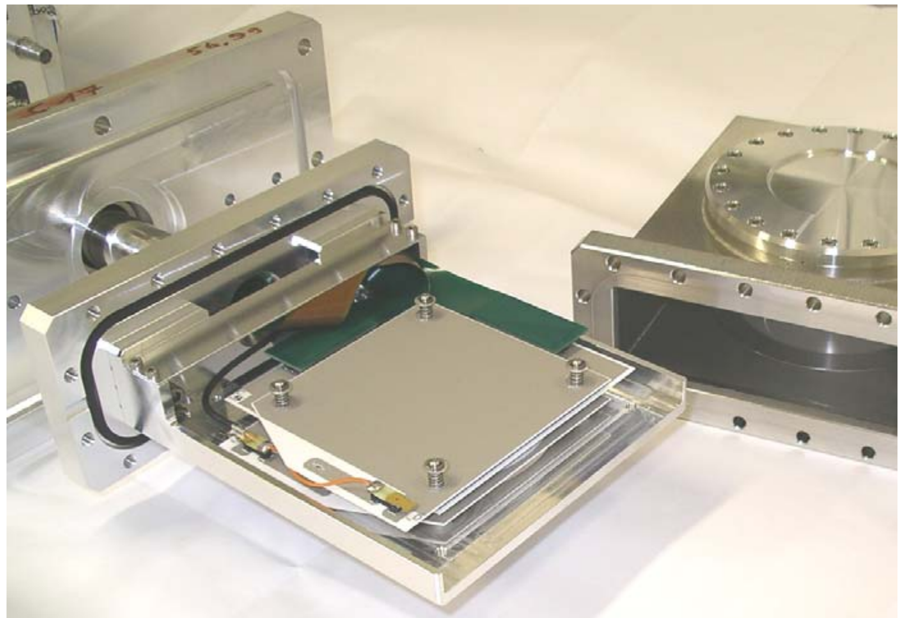
Most of these are already in routine operation.

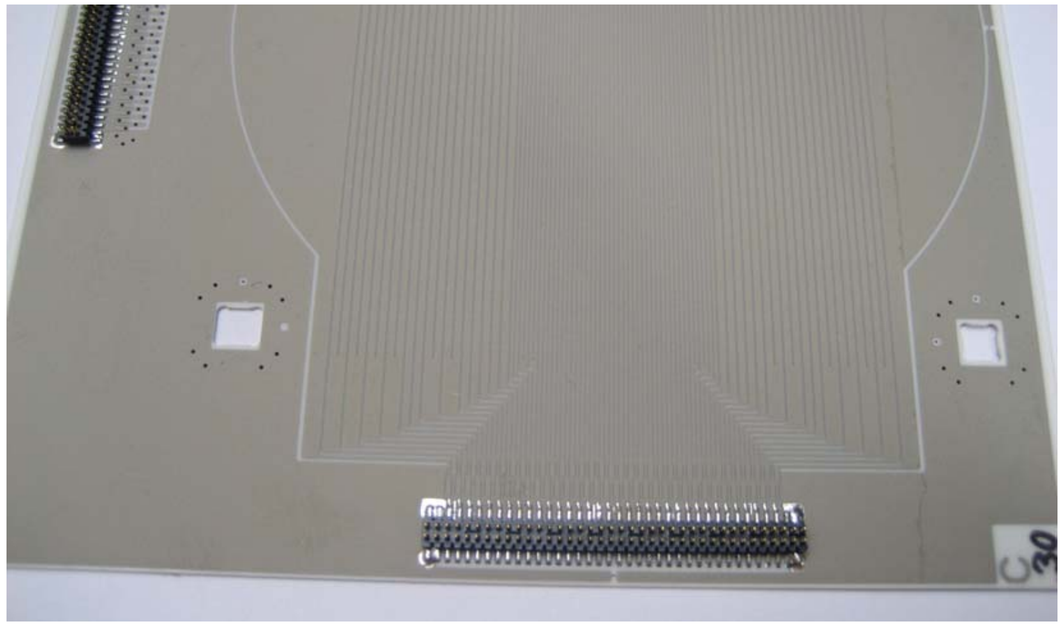
- "thin" current and profile monitors: An electrochemical-migration problem occurred due to minimal remnants of hygroscopic solder flux and air humidity. It was remedied by improved cleaning and using a flow of dry nitrogen (1.5 litre/h) instead of ambient air as the chamber gas.

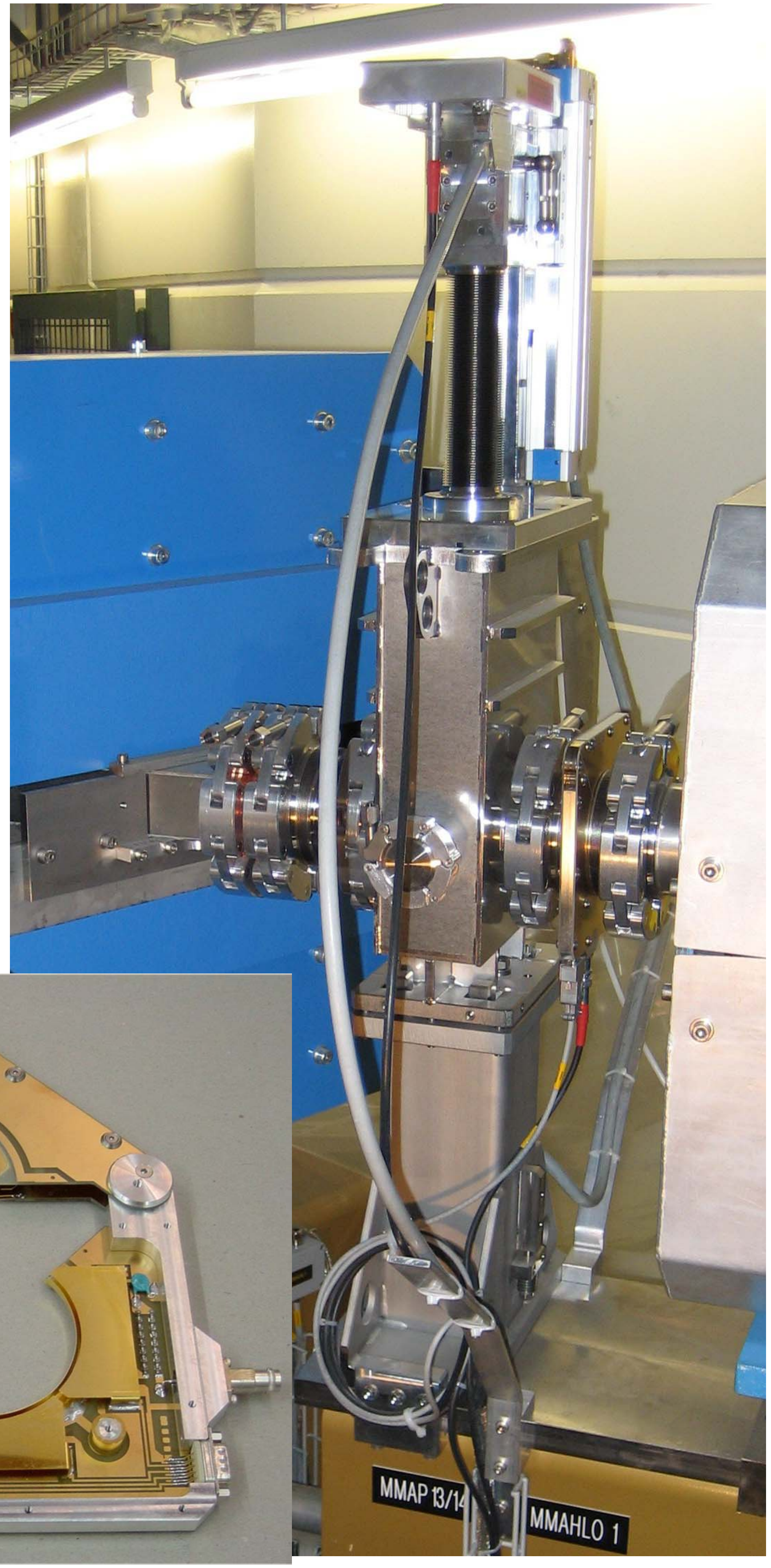




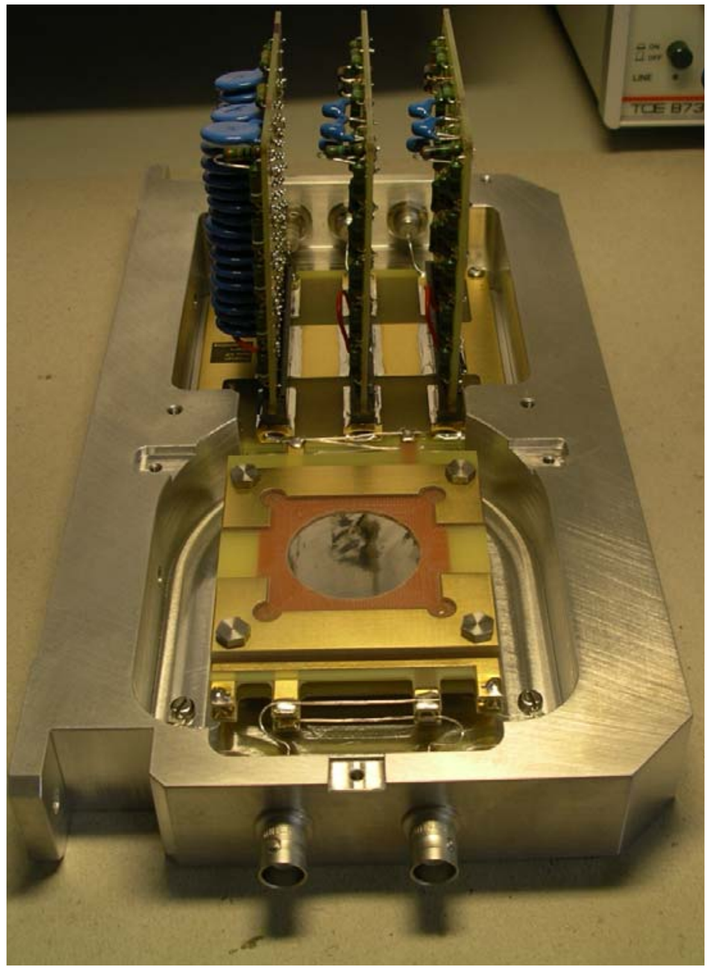
• "thick" MSIC profile monitors for set-up and tuning

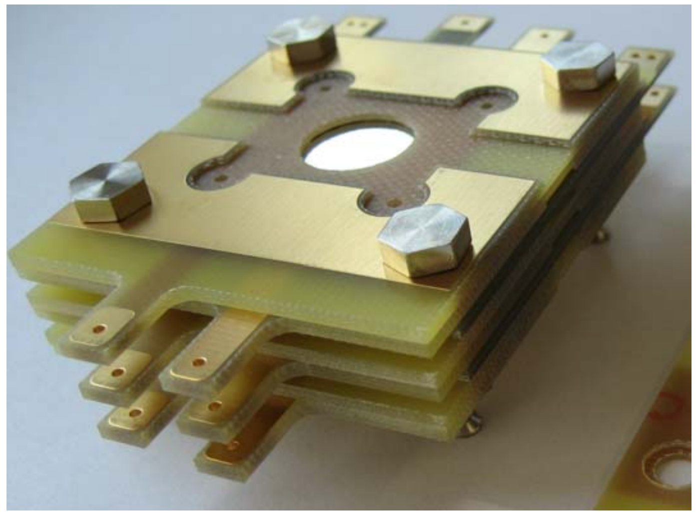


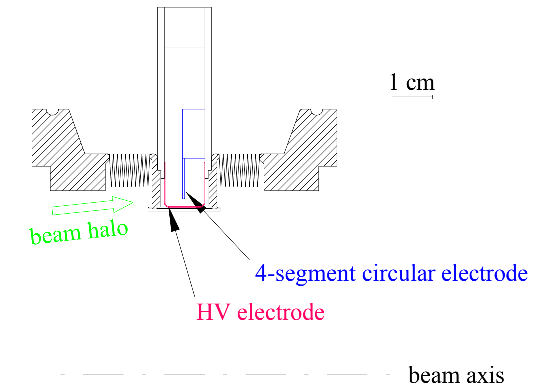




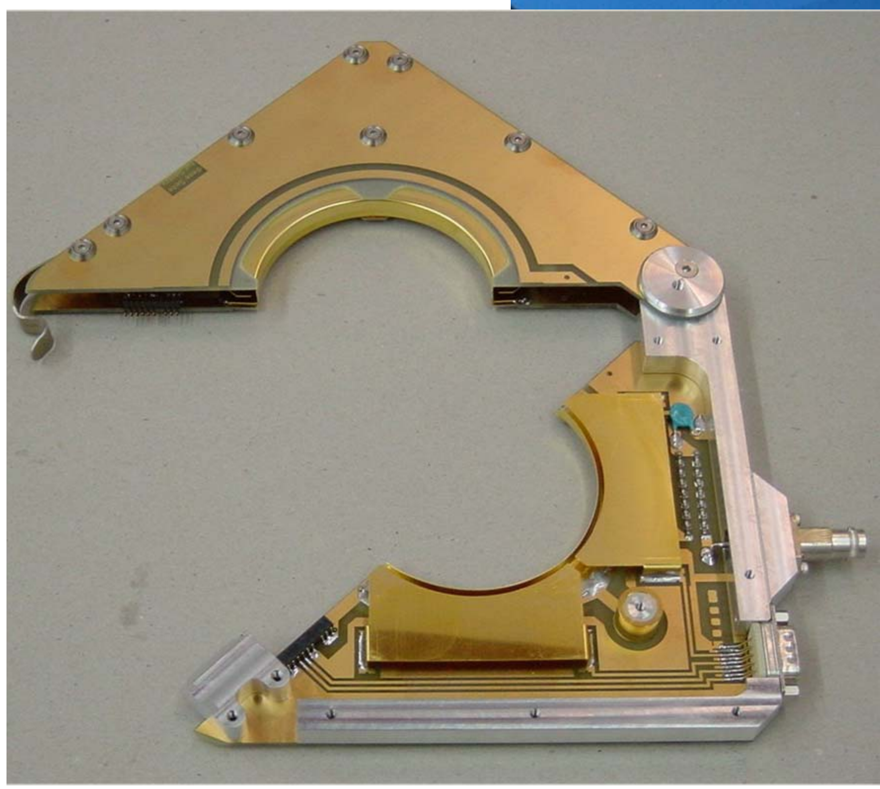
• "thin" current monitors at control points
in front of OPTIS 2 and of gantries







• halo monitors



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