MMD as Beam profile monitor

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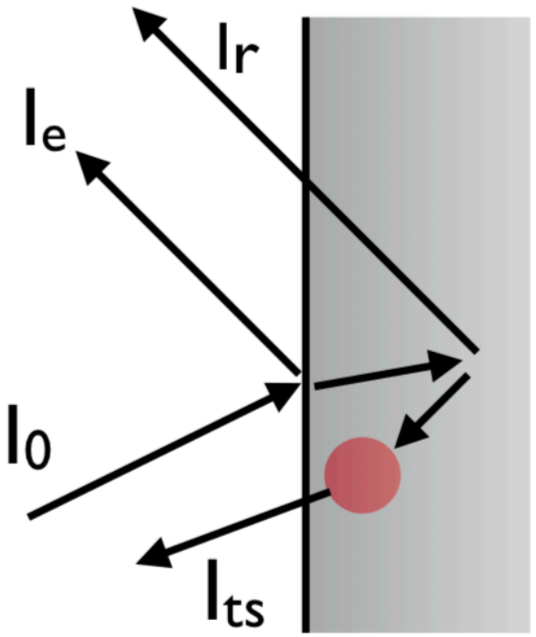
Secondary Electron Emission

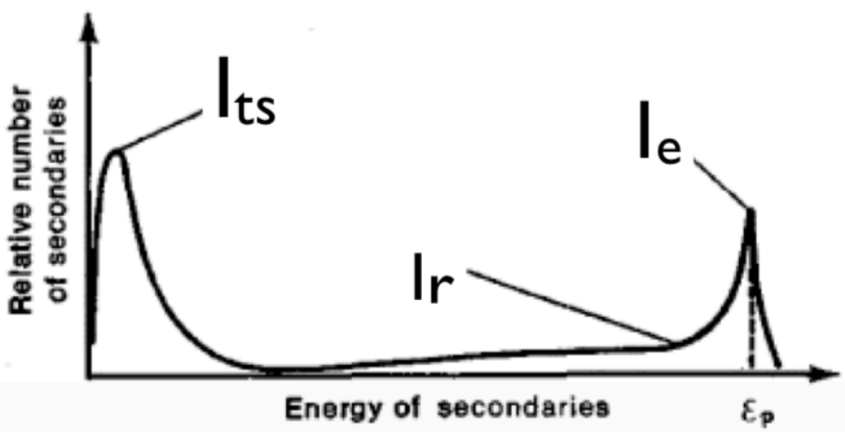
The SEE process was first discovered in 1902 by two German physicists L. Austin and H. Starke [7]

- ☑ electrons are emitted from a solid metal surface when it is bombarded by incident electrons.
- ☑ The incident electrons are called primary and the emitted electrons are called secondary



When electrons hit to a metal surface

- ☑ some portion can be *elastically backscattered* (δ_e)
- ☑ the rest penetrated into the material
  - ☑ some scattered from one or more atoms inside the metal and reflected back out, *rediffused electrons* (δ_r)
  - ☑ the rest interact with a more complicated way and inside the material and yield the *true-secondary electrons* (δ_{ts})



The secondary electron yield

$$\delta = (I_e + I_r + I_{ts})/I_0 = \delta_e + \delta_r + \delta_{ts}$$

- what is the spatial resolution we can get?

- few microns, on request.
the smallest pitch ~ 3um in one of the prototypes.

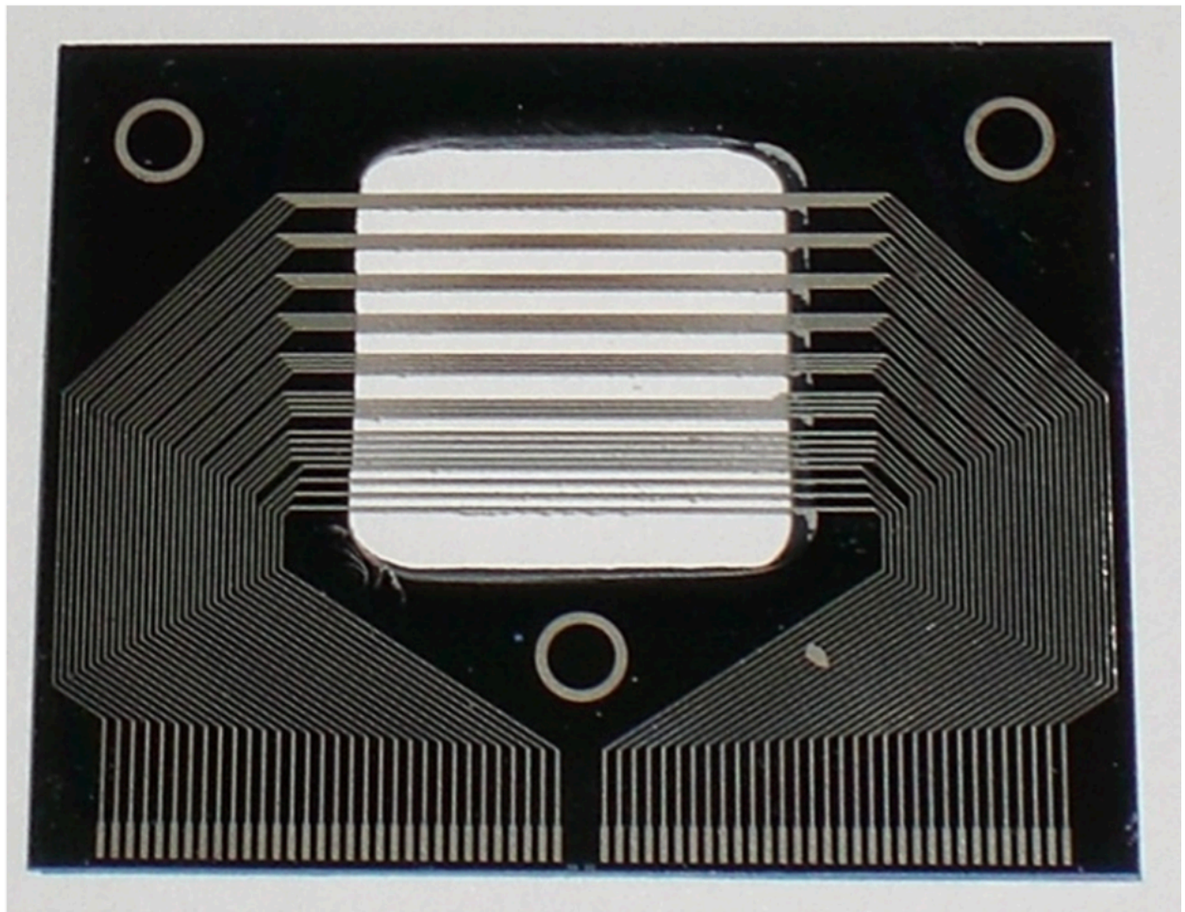


Photo of the MMD with variable pitch (8 groups of strips with pitch varying from 3 to 300 μm)

■ how well can one estimate the response channel by channel?

- preliminary calibration allows for reaching uniform response of all channels within 0.1%

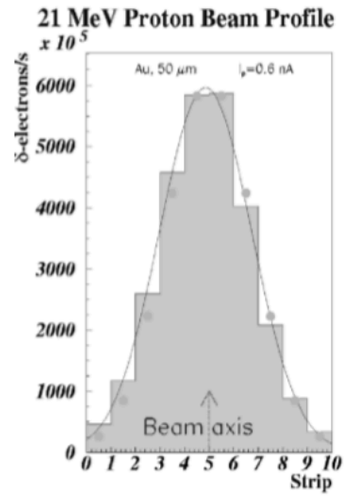
■ how stable is the response versus time? [E.g. has it been operators in high-rate environment stably for hours, days weeks?]

- Operational for days in HERA-B, also at ESRF, HIT, PETRA, KINR Tandem. It was not tested for longer periods.

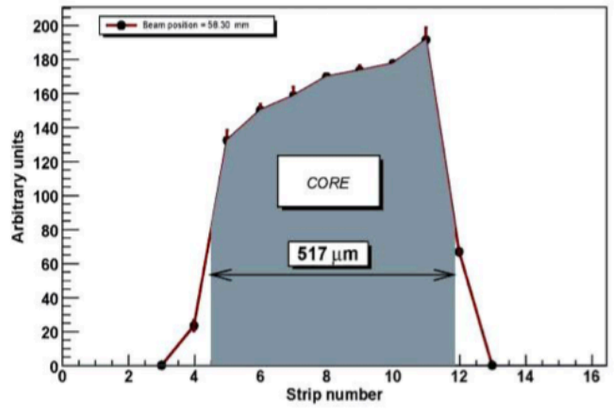
■ what is the rad-hardness?

- 100MGy. after 100 MGy it is expected that transmutation impact in hadron beams may change the response(no idea about the impact of photons - presumably the hardness will be even higher).

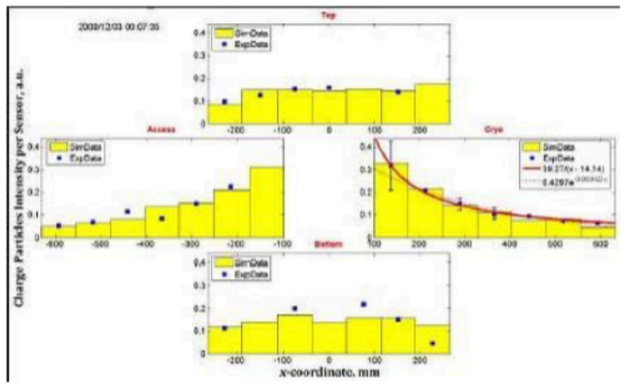
■- what applications has it been used for that are similar?



- HERA-B Luminosity monitoring
- LHCb Radiation Monitoring system
- BPM for 21 MeV proton beam (tandem MPIfK)
- BPM for the LHCb (ST) test beam studies
- 21 keV Synchrotron BPM at HASYLAB



Metal Foil Detector technology allows for Building any size beam monitoring systems



Metal detectors are suitable for measuring and imaging beams of charged particle in the energy range from keV to TeV as well as synchrotron radiation.

Summary

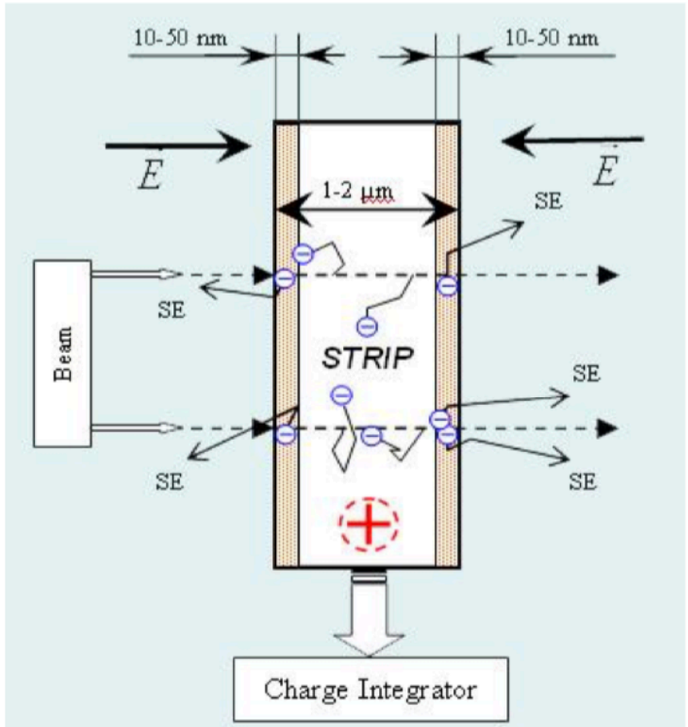
- Metal microstrip detectors seem to be capable of measuring photon beam profile for LUXE.
- Existing prototypes were used for X-rays (N_{gamma} = 10^16 s^{-1} mm^{-2}), proton and ion beams profile measurements.
- Observed position resolution is in the range of 5...25 μm depending on design (pitch).
- Design for LUXE can be studied in simulations and requires secondary electron emission process modelling for signal generation.
- We can get a prototype for beam test and more information about capabilities of current production technology.

Back up

Outline of questions

- what is the spatial resolution we can get?
- how well can one estimate the response channel by channel?
- how stable is the response versus time? [E.g. has it been operators in high-rate environment stably for hours, days weeks?]
- what is the rad-hardness?
- what applications has it been used for that are similar?

MMD Principle of operation



Signal – positive charge created by the electron emission under the impinging particles.
Conversion factor – electrons/particle: ranges from 0.1 (for MIP) to few hundreds (for the fast Heavy Ion)

Noise – thermoelectric emission, r/f pickup, fluctuation of the leakage current, …
Determined by the connecting cable and readout electronics:
ENC: (100 – 500) electrons

Thickness – 1 μm (transparent, non-destructive device for the measured beam)

Position resolution – up to 10 μm

This technology works with x-rays, protons and other ion beams!

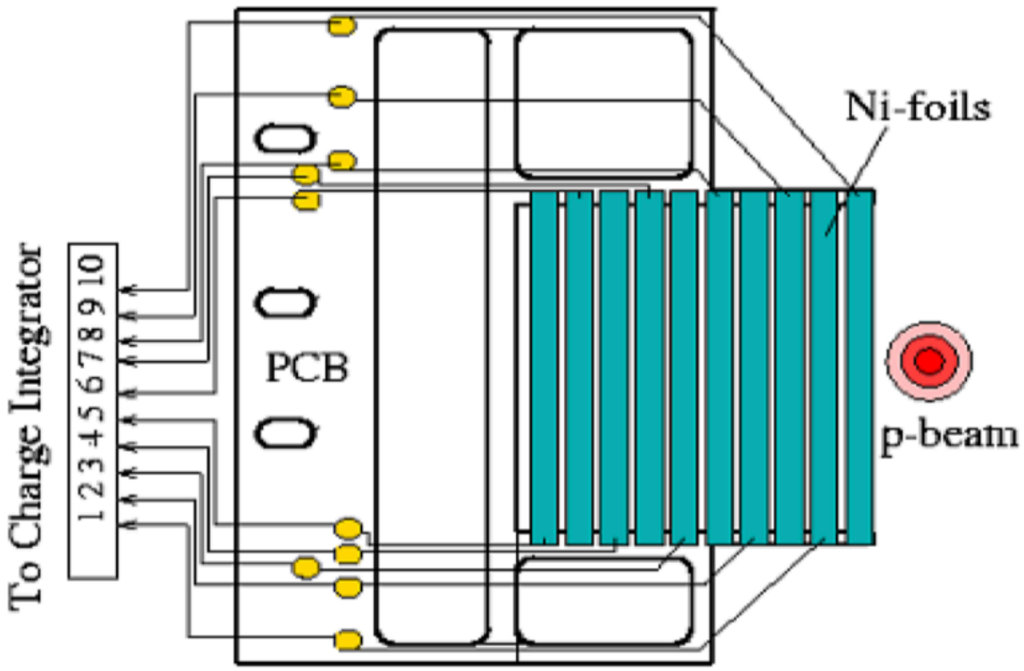
Radiation hardness - more than 100 MGy

Stable operation at X-ray intensity

- up to 10^{16} photons·s^{-1}·mm^{-2}

Stable operation at proton beam intensity

- up to 10^{10} protons·s^{-1}·mm^{-2}



Metal Microstrip Detectors (MMD)

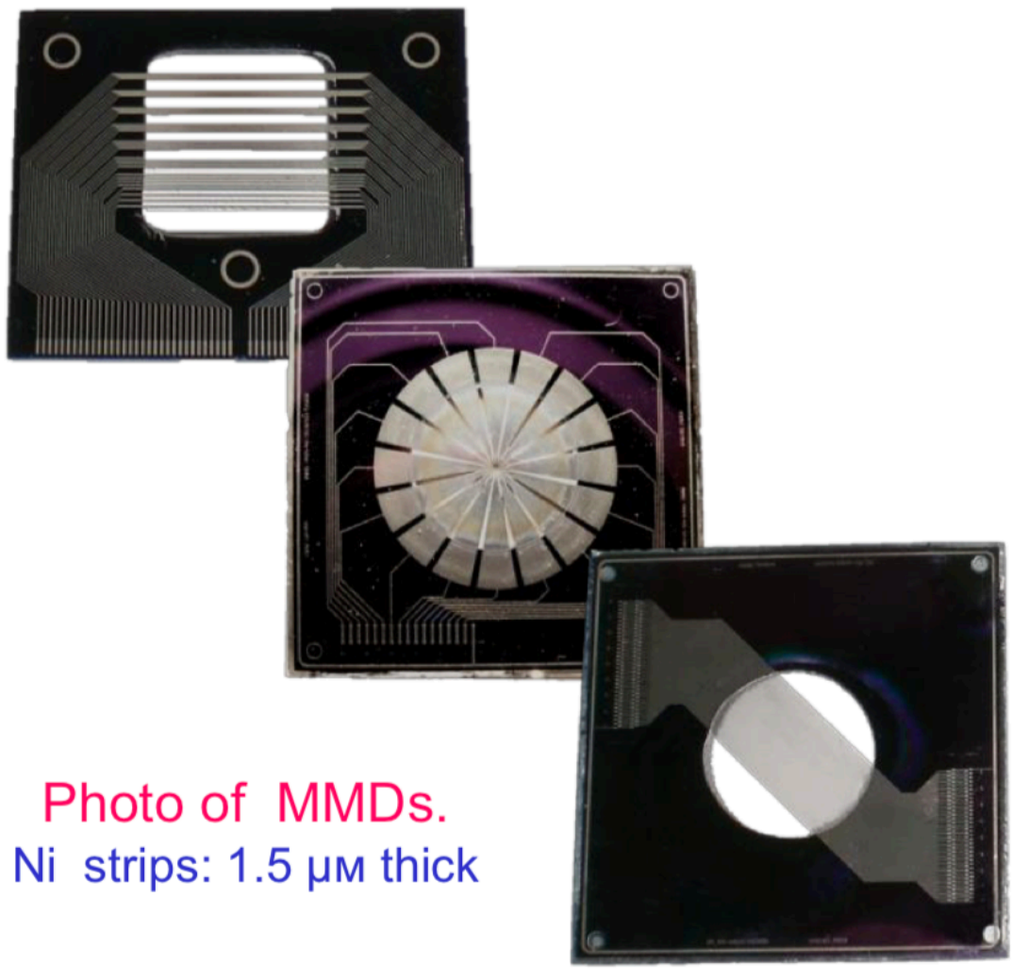


Photo of MMDs.
Ni strips: 1.5 μм thick

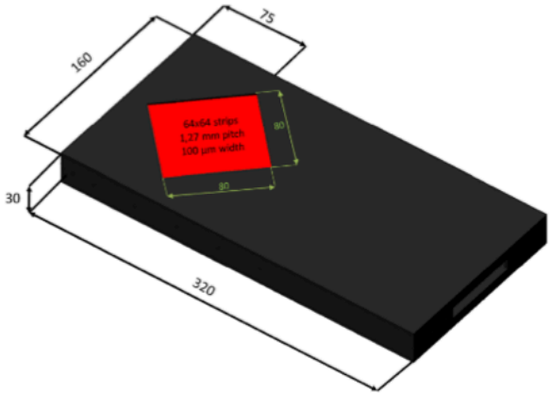
Advantages of the MMD:

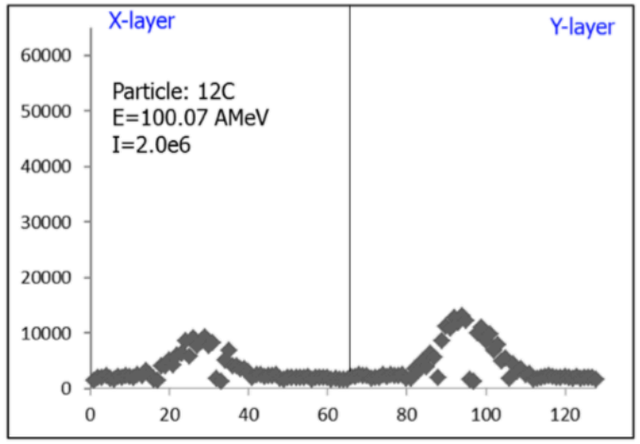
- High Radiation tolerance (10-100 MGy)
- Nearly transparent sensor – 1 μm thickness
  the thinnest detector ever made
  for the particle detection
- Low operation voltage (20 V)
- Perfect spatial resolution (10 μm)
- Unique, well advanced production technology
- Commercially available readout hardware
- and software.

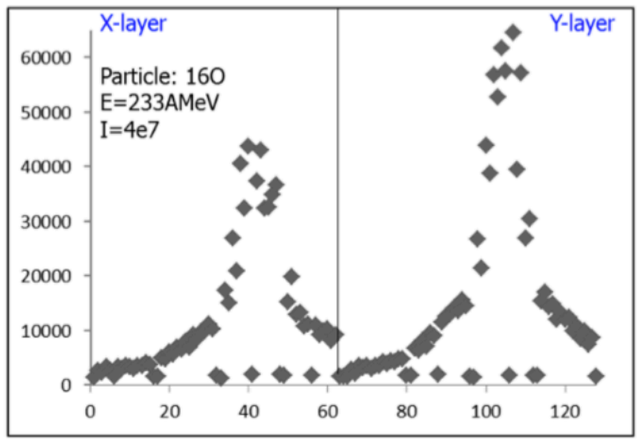
MMD applications:

- Non-destructive beam profile monitoring
- Precise dose distribution measurements for micro-biology, medicine etc.
- Imaging X-ray and charged particle beams
- Detectors at the focal plane of mass-spectrometers and electron microscopes

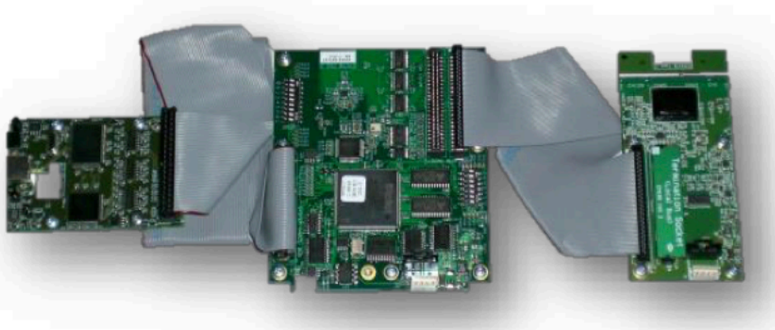
HIT. Beam profile monitor

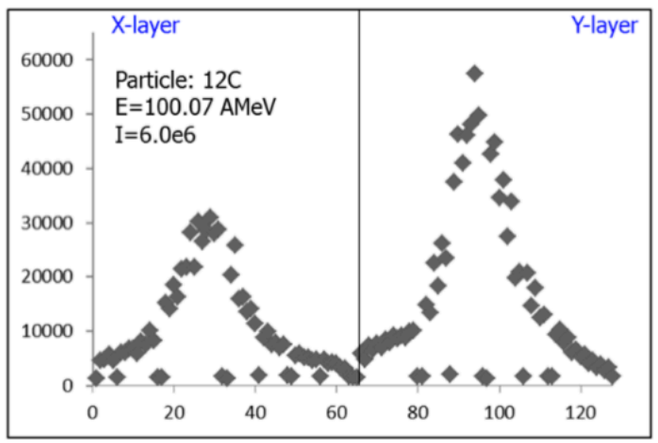






Working area: 80x80 mm^2
Channels: 64+64
Resolution: 0,4 mm
Sensitivity: >10^3 p/(strip*s)
Dynamic range: 10^3





performance of the MMD in measuring and imaging the primary carbon ions beam features

Spatial (Horizontal and Vertical) Ion Beam Profiles