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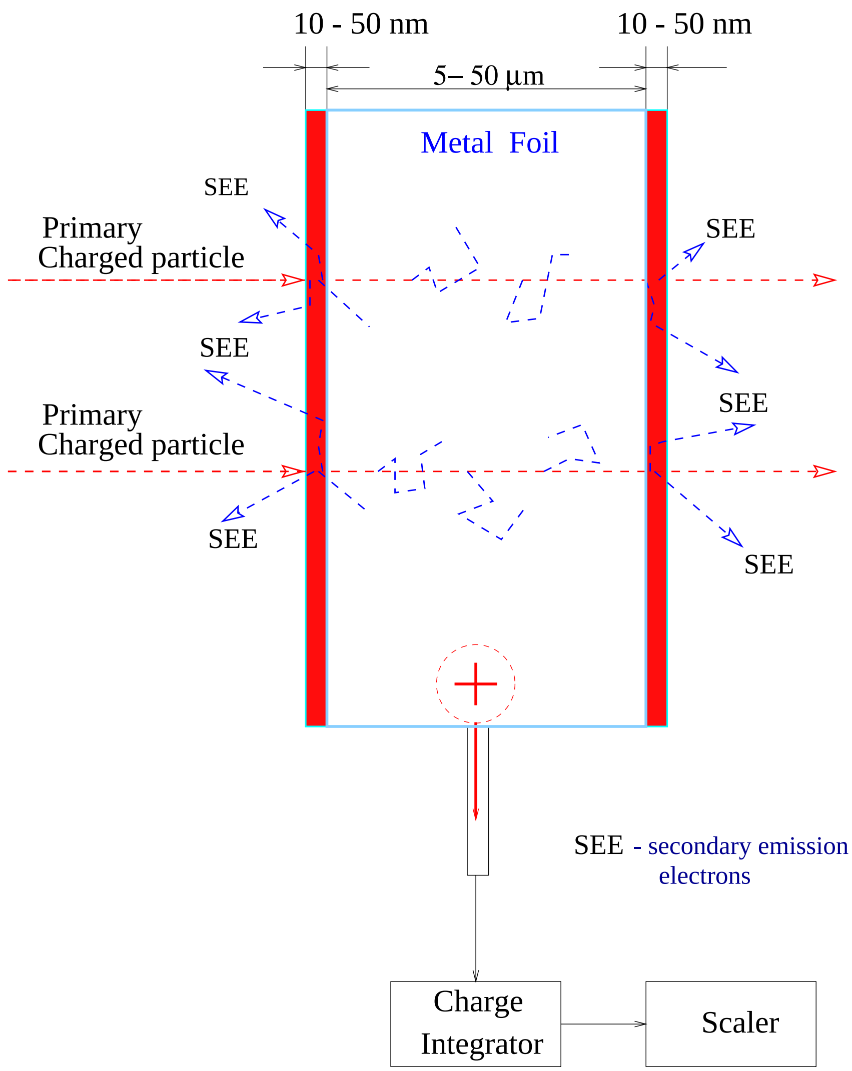
LHCb Silicon Tracker
Radiation Monitoring System.

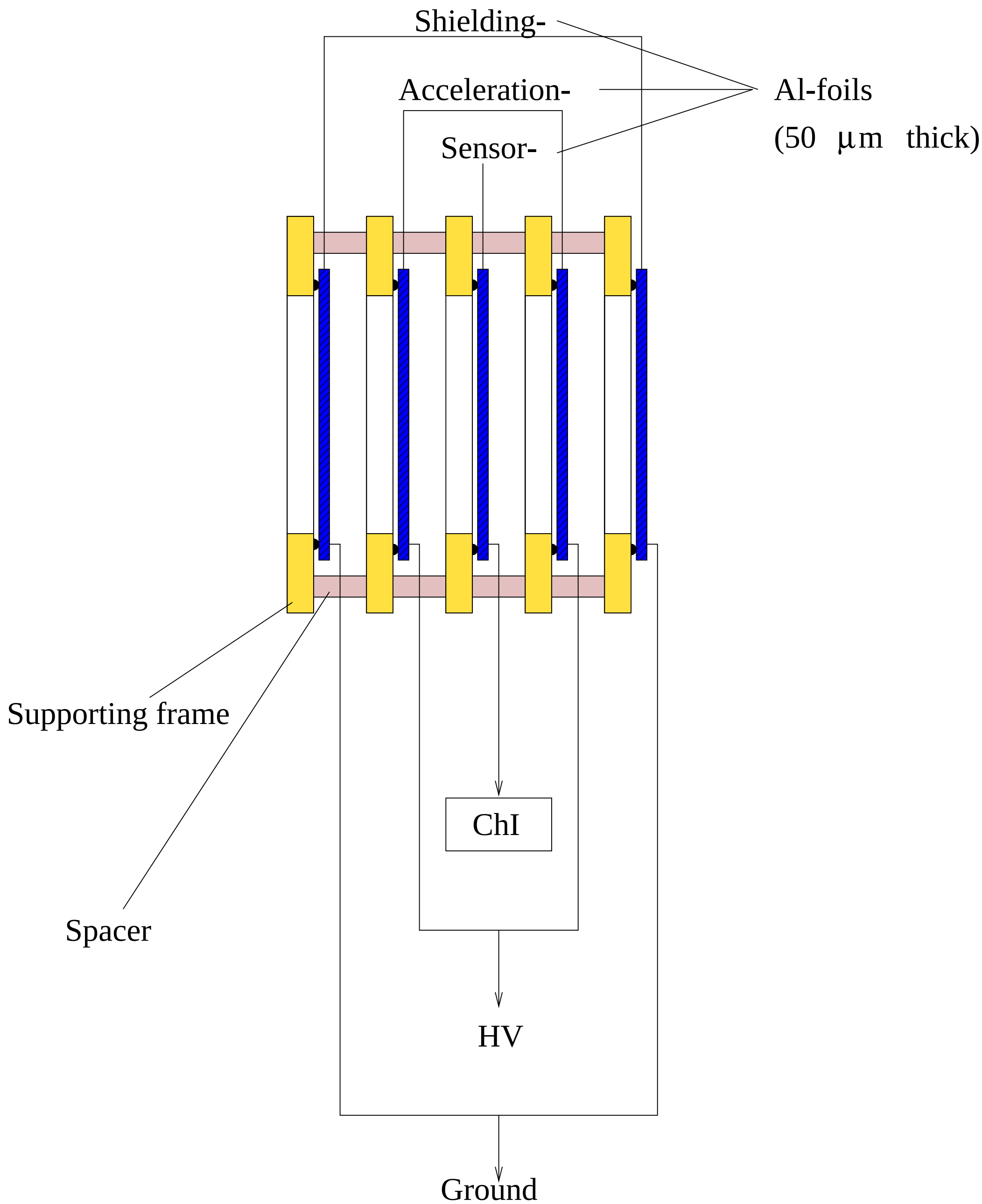
- RMS design basis:
  - ⇒ Highest possible radiation hardness
  - ⇒ Permanent, reliable operation
  - ⇒ The calculated flux of primary charged particles at the nominal luminosity (16 MHz - Interaction Rate) is at the level of 8×10^5 $cm^{-2}s^{-1}$ at the closest to the beam line sensors position.
  - ⋄ 1.4E+14 MIP/cm^2 in 10 years.
- The radiation dose distribution over silicon sensors has to be measured.

- The choice was made at the LHCb ST TDR:
  - ⇒ **Metal Foil Detector (MFD) technology for the ST RMS**
  - ⋄ Principle: fast particle hitting a metal foil initiates electron emission (mainly from its surfaces) - 10-50 nm, only.
  - ⇒ Secondary Electron Emission (SEE).
  - ⇒ The yield of the SEE exceeds directly produced δ-electrons by factor of 10.

Metal Foil Detector



- Registration of the electron emission by a charge integrator connected to the isolated metal foil.
  - ⇒ NOTICE! This is a member of the NANO-club.
  - ◇ **The thinnest detectors ever built are possible!**
  - ⇒ 1 μm thick microstrip MFD is under the test at DESY.
  - ⇒ 0.1 μm thickness is the currently the closest aim.



The schematic view of the MFD-components.

⇒ MFD is a 5-layer structure made out of thin metal foils.

- ◇ 25 μm thick Al foils are glued to the supporting frames (0.5 mm thick epoxy plates).
- ◇ Auxiliary (two accelerating and two grounding) foils hermetize the sensor from both sides and stabilize the SEE yield, which is measured by a sensitive Charge Integrator with built-in current-to-frequency converter.
- ⇒ This reduces the external impact (leakage currents, temperature/humidity impact, r/f pick-up etc) , essentially.
- ⇒ The ChI output rate saturates already at 20 V applied to the accelerating foils in a perfect agreement with the expected prevailing yield of low-energy secondary electrons. The sensitivity of the MFD went up by factor of 5.

Some examples of the experience with MFD.

- MFD prototypes and real devices have been built and tested at accelerators of KINR (Kiev), DESY (Hamburg), M.P.I. für Kernphysik (Heidelberg) and CERN (Geneva), recently.
  - ◇ Designed and built by us charge integrators have the sensitivity of 1 kHz per 1 pA, while output fluctuations are at the level of few Hz, only.
  - ⇒ This allows for the measurement of the fast charged particle fluxes exceeding 5×10^3 s^{-1} per MFD sensor.
  - ⇒ The dose profile is reconstructed from the charge distribution in a set MFDs.

Beam Profile Monitor for the LHCb ST X7-testbeam at CERN.

⇒ 16 X- and 16 Y-sensors (Al, 50 μm thick, 5 mm wide, 6 mm pitch) covering the area of 96 x 96 mm^2 were connected by 3 m long cables to Charge Integrators. The X- and Y- sensors were separated (3 mm distance) by accelerating and shielding Al foils.

- **Infrastructure:**

◇ **in the tunnel:**

⇒ Charge Integrators at NIM crate (7 x 5 = 35 units)

⇒ NIM-ECL convertor - 32 twisted pair cables, 50 m long.

◇ **in the Control Room:**

⇒ ECL-NIM convertor

⇒ NIM Gate-and-Delay Generator

⇒ 32-channels VME-scaler

⇒ VME-crate + POWER PC-CETIA + Ethernet + PC

◇ **Read-out Software allows for:**

⇒ Tuning of the data taking periods,

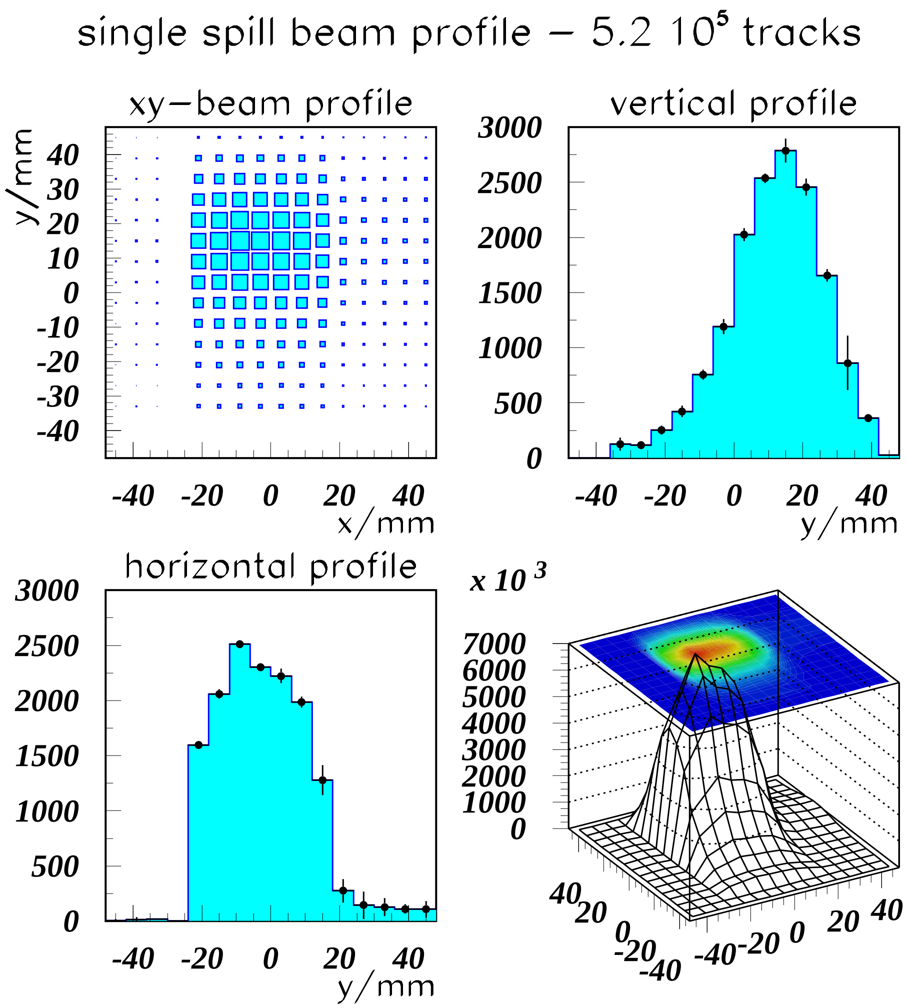
⇒ monitoring/correction of the ChIs baseline,

⇒ background subtraction,

⇒ on-line data presentation.

MFD BPM performance at X7 test beam facility at CERN:

⇒ 120 GeV π-meson beam with 5.2 * 10^5 particle per 2.4 s spill.



⇒ The MFD BPM data have shown perfect correspondence with a similar data measured by a regular BPM devices at CERN (multi-wire proportional chambers).

- MFD Luminosity monitor at HERA-B (proton beam energy 920 GeV).
- The 12 sector MFD Luminosity monitor has been installed around the beam pipe at the exit window of the Vertex Detector System.
  - ◇ Calibrating currents of 25 pA running in parallel to the signals from the sector's sensor foils create a baseline of ChIs at the level of 25 kHz with a rather good long term stability (2000 hours.)
  - ⇒ The baseline monitoring allows for the correction (if necessary) of the charge integrators sensitivity.
  - ⇒ A perfect linear response of the MFD monitors to the Interaction Rate measured by scintillator hodoscopes in the range up to 140 MHz has been established.

MFD advantages:

- ⇒ Extremely low mass (up to few tens nano-meter thickness) of the detecting material;
- ⇒ Simple structure (thin metal foils supported by the isolating frame);
- ⇒ Any shape and size;
- ⇒ Low operating voltage;
- ⇒ Simple read-out electronics (charge integrators and scalers);
- ⇒ High radiation tolerance;
- ⇒ Perfect long term performance without any maintenance;
- ⇒ Cheap.

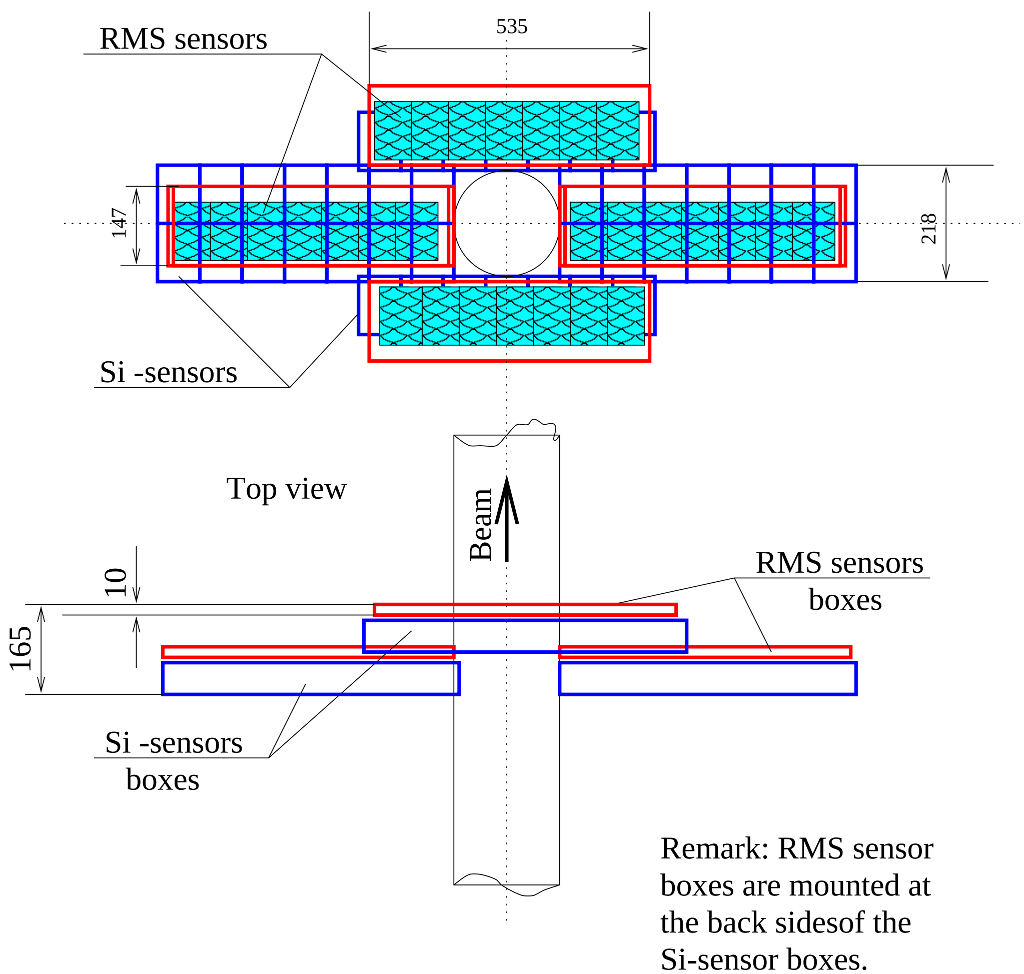
- MFDs proved to be a reliable tool for the charged particle radiation monitoring in a wide range of applications.

RMS for the LHCb Silicon Tracker.

- The design of the Radiation Monitoring System (RMS) has to provide a minimum of construction material, while keeping the whole assembly still mechanically stable as well as shielded against the pick-up and/or cross-talk.
- The place for the RMS:

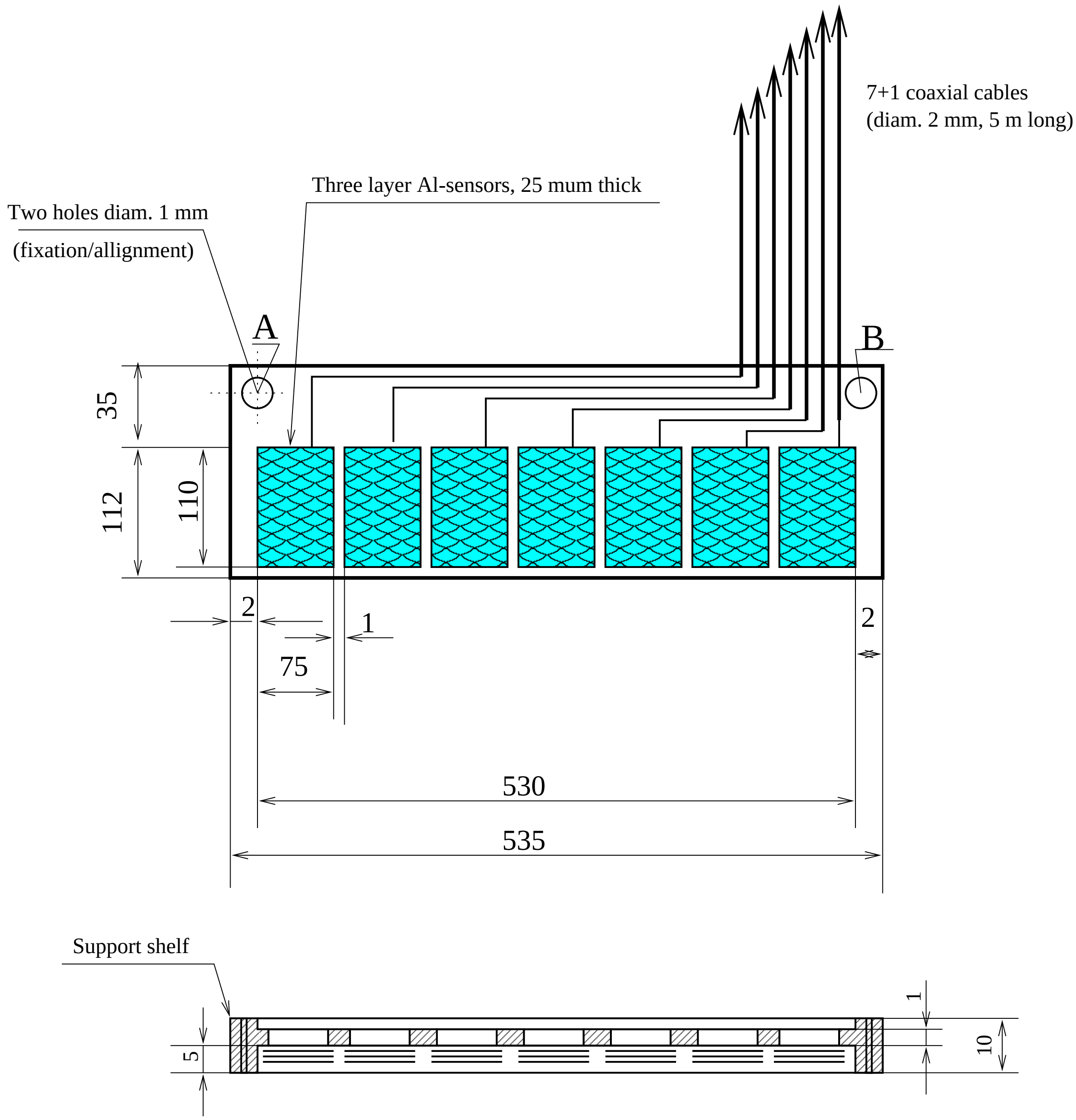
  ⇒ the location of the Inner Tracker Station IT-2 (requires the LHCb Z-space of 10 mm).

RMS position at the IT-2 .



◇ Scheme of a single MFD-Ladder for IT-2 ST LHCb (28 channels, 5 layers technology).

Scheme of a single ladder of the Radiation Monitoring System to be mounted at the IT-2 station



- For making the material contribution of the ST RMS as small as possible (as well as for minimizing the number of the read-out channels) we have designed the MFD-ladder and manufactured its first prototype as follows:
  - ◇ It is based on a use of a thin (20 μm) poly-imide foil carrying 25 μm thick Al sensor-foil (size 8 x 11 cm^2).
  - ◇ To improve the MFD performance the sensor foil will be placed between two accelerating foils and the whole structure will be shielded from both sides by thin foils connected to a perfect ground.
  - ◇ It includes 28 channels, poly-imide based MFDs for measuring a radiation load distribution (ladder-type).
  - ⇒ Reduced mass and less sensitivity to the environment variations (humidity, temperature, r/f pick-up etc).
  - ◇ DETECTOR offers as an option 5-10 μm thick Al-layers deposited on 15 μm thick poly-imide foil. The width of connecting lines on the micro-cable will be 70 μm (could be reduced up to 40 μm by UKRTEX Company).
  - ◇ The supporting frame (similar to the HERA-B Luminosity Monitor) will be produced out of the 500 μm thick epoxy plates, strengthened by a supporting grid of a 50 μm thick nylon wires.
  - ◇ The cables connecting sensors and Charge Integrators will be laid out outside of the physical acceptance. The connection from the sensors to the coaxial cables will be provided by micro-cables (DETECTOR production). Design of the connecting micro-cables is such that an error in the fluence arising from the connecting cables will not ever exceed 0.2 per cent. Silver glue combined with the epoxy glue will provide the contact between the micro-cables and coaxial cables.
  - ◇ Charge integrators (5 units in a single NIM standard block) with the digitized output of 1000 Hz/pA planned to be installed in the NIM crate located up to 10-15 m away from the MFD sensors.

Proposal for the Emergency RMS based on the MFD-sensors.

- Some figures for the radiation monitoring at the LHCb site for the emergency case.

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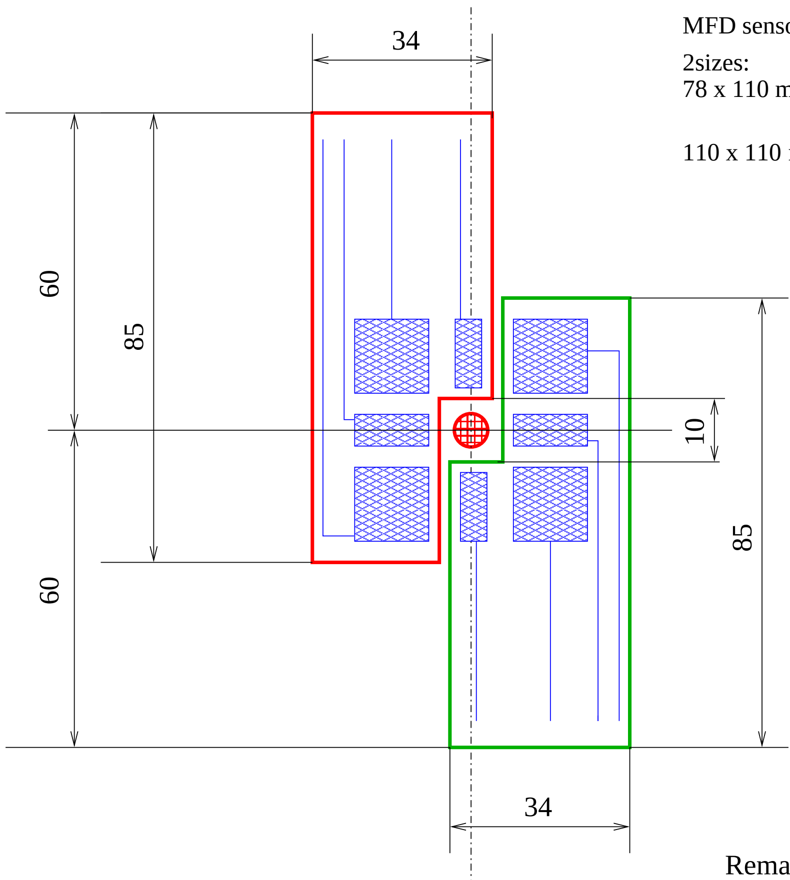
Layout of the Emergency Radiation Monitoring System

(Position at the forward/backward wall of the TT).



MFD sensors are 25 µm thick Al foils.
2sizes:
78 x 110 mm^2

110 x 110 mm^2

Remark: Sizes in cm.

◇ Currently used MFD have the sensitivity of 9 kHz per 1 MHz Interaction rate, while the overall fluctuations for the sensor sizes indicated at the figure are in the range of 20 Hz.

⇒ Thus, if the emergency rate will be, let us say, 100 MHz, the integration even over 0.1 s will produce 90 000 counts at the MFD output. This signal is large enough to guarantee a proper reaction.

Conclusions.

- The Metal-Foil-Detector technology has been chosen for the Radiation Monitoring at the Silicon Tracker.
- MFD + poly-imide RMS (28 channels) (Ladder type) is proposed as a final design.

⇒ The prototype is built - plan to test it and calibrate at the CERN test beam facility.

◇ Once calibrated ST RMS will serve as a perfect LHCb Luminosity Monitor as well.

◇ The best approach would be to build 2 RMS : one positioned at the VELO vacuum vessel exit window (or at the TT-station); the 2nd one - at the IT-2. To cover more than 50 per cent of the LHCb acceptance.

Metal Foil Detectors are available in any shape and sizes:

⇒ Microstrip MFD for micro-beam profiling (thickness less than 1μ m);

⇒ Large area MFD (1 m^2 and more), including space apllications etc.,

⇒ We should be happy to share our know-how with those who would like to build similar Metal Foil Detectors.