Micro Pattern Gaseous Detector: GEM & μRWELL

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  - Limitation of MWPC
  - MSGC
  - MM and R-MM
  - GEM
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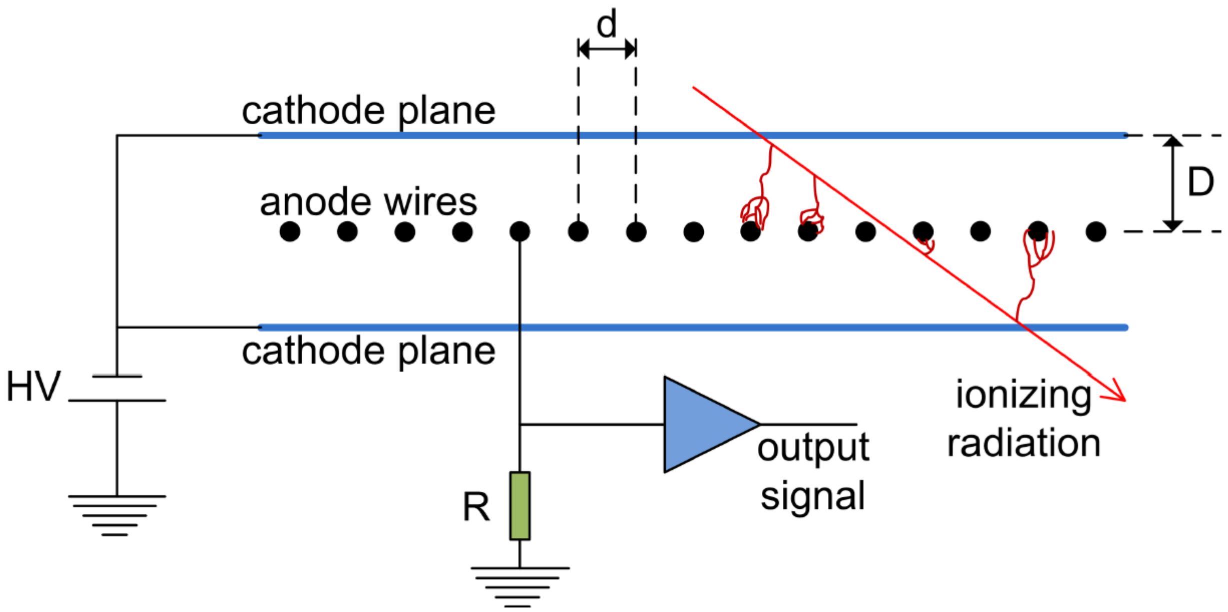
- GEM vs. μRWELL vs. R-MM

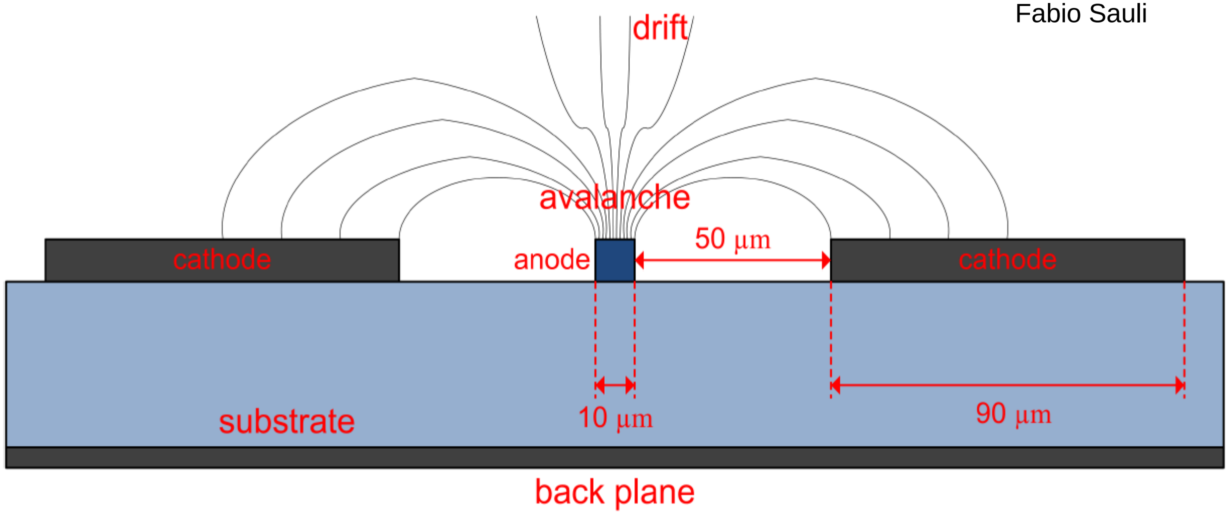
- R&D status

1. Path to GEM & μRWELL: MWPC

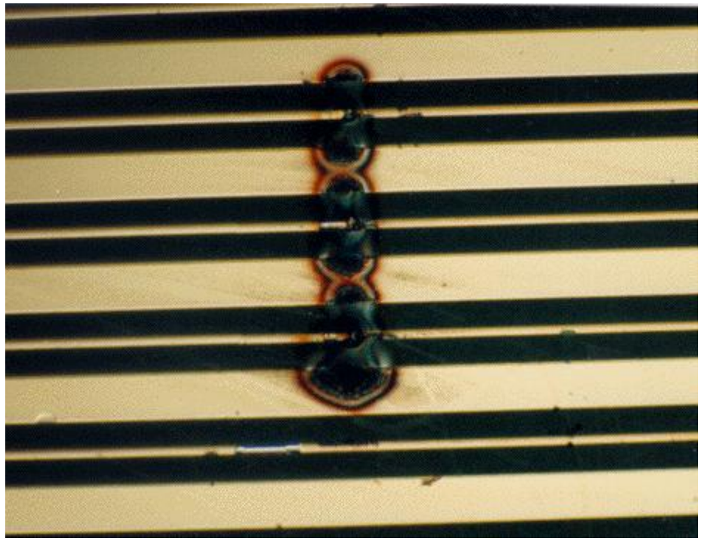


- Limitation of MWPC
  - Limited multi-track resolution ~ O(2-2.5 d)
  - Not enough rate capability ~ O(v_{ion}/D)
  - Not possible to decrease d and D due to wire buckling
  - ⇒ Clear motivation for micro pattern electrode!
  - Not mass production friendly

1. Path to GEM & μRWELL: MSGC



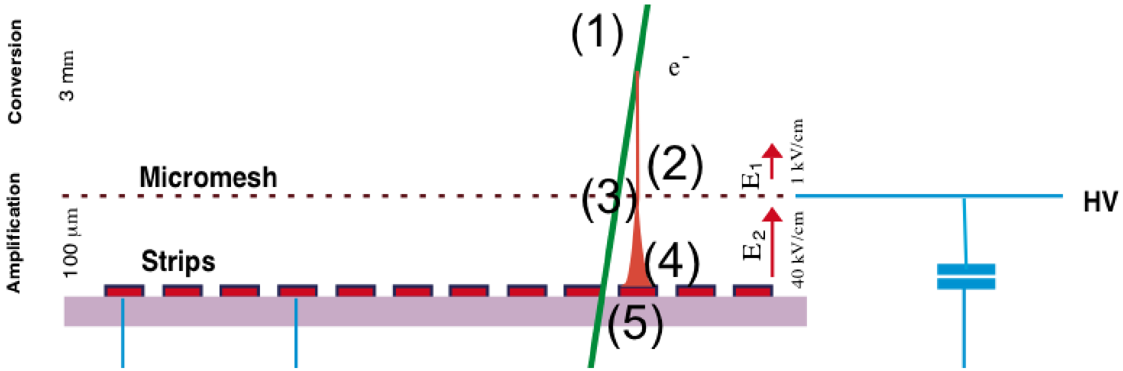
Fabio Sauli



- ×100 (×20) better rate capability (multi-track resolution) than MWPC
  - Also mass production friendly

- Short circuit problems caused by carbon paths formed on the substrate due to discharge

1. Path to GEM & μRWELL: MM and R-MM



- Key concept of MM

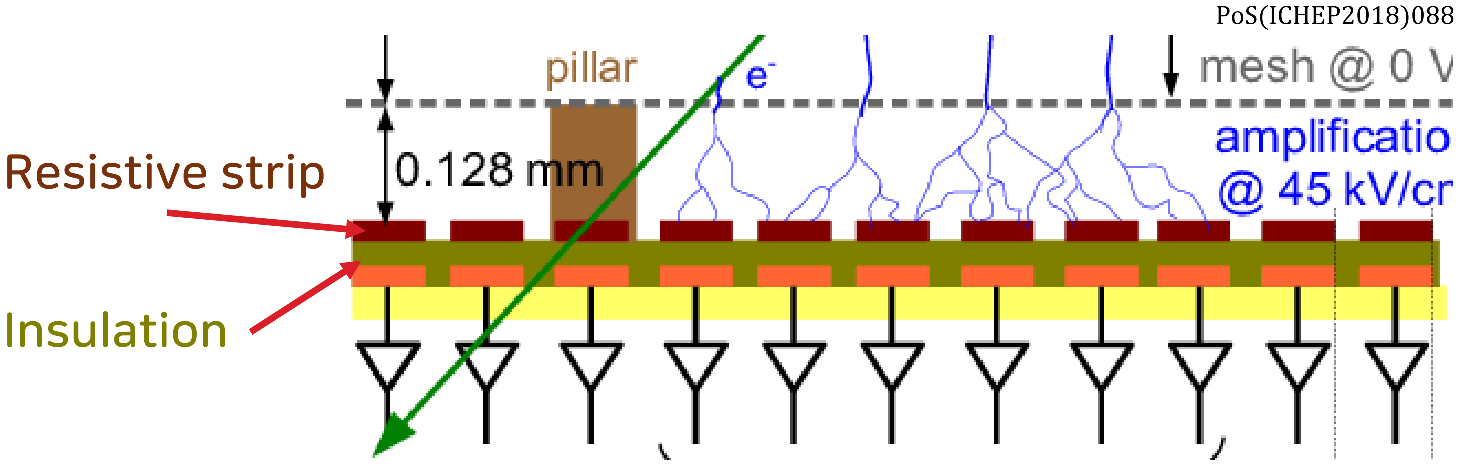
 - If direct discharge on the substrate is causing carbon buildup, why not just lift the avalanche region off the surface?

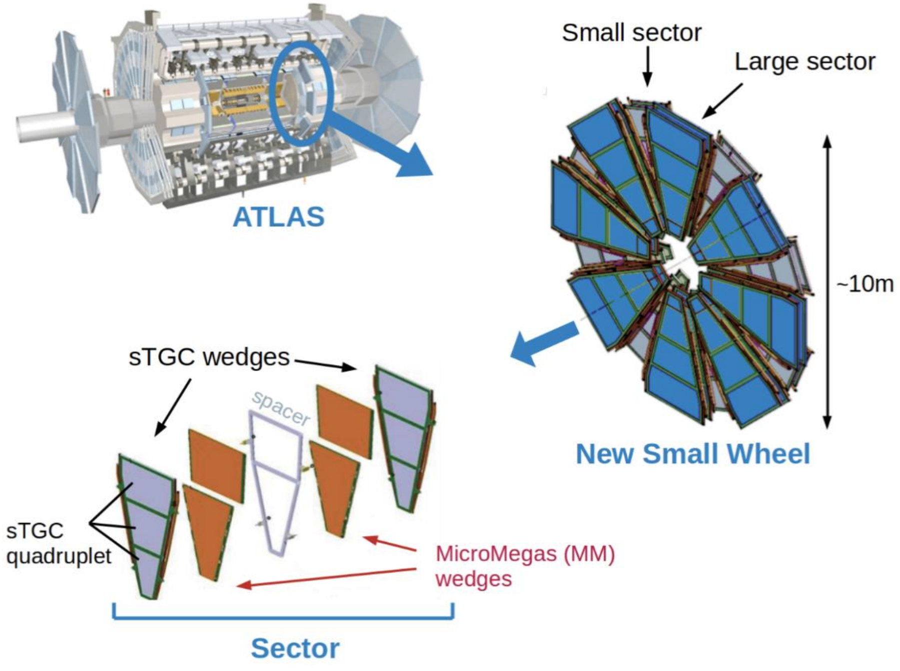
- While the sensor achieved discharge tolerance, the readout electronics remained vulnerable

 - Experience of COMPASS

 ⇒ Resistive MM!

1. Path to GEM & μRWELL: MM and R-MM

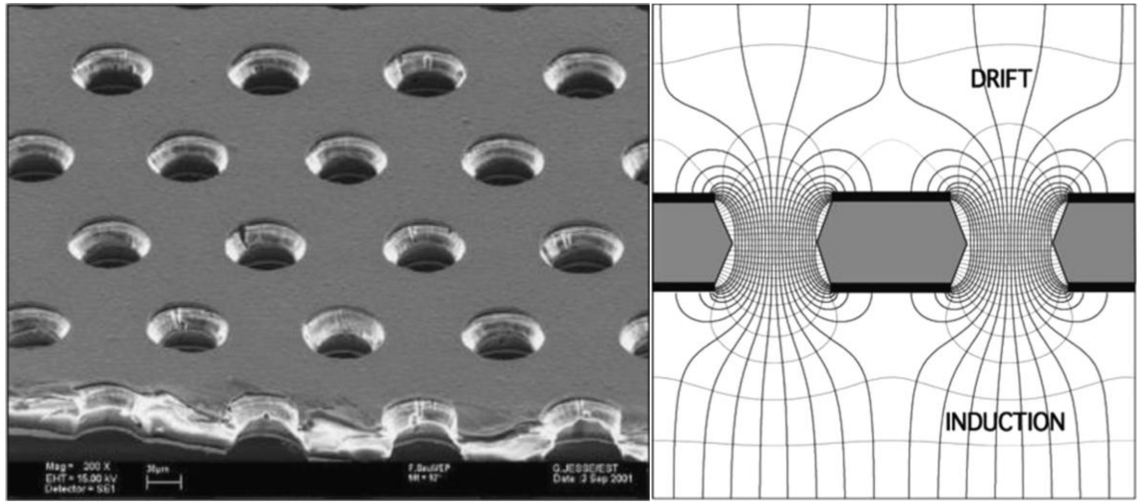




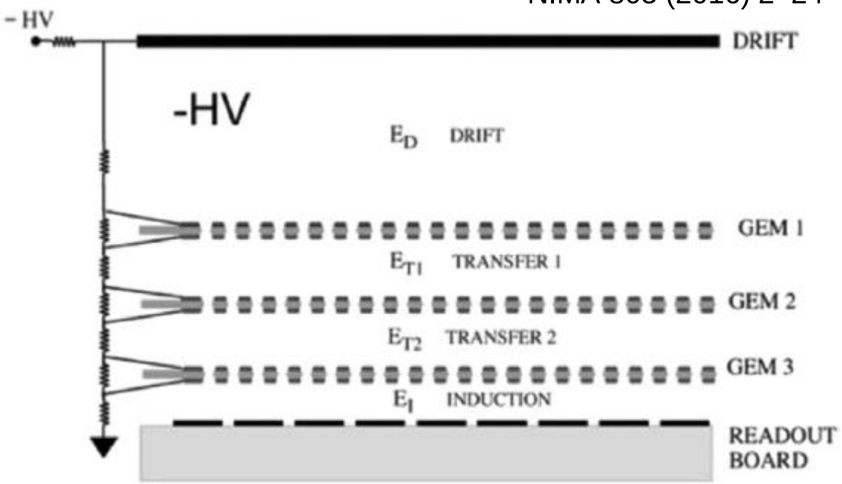
- The resistive anode strip induces a local voltage drop upon streamer formation, effectively quenching the discharge

  - RO electronics are protected!

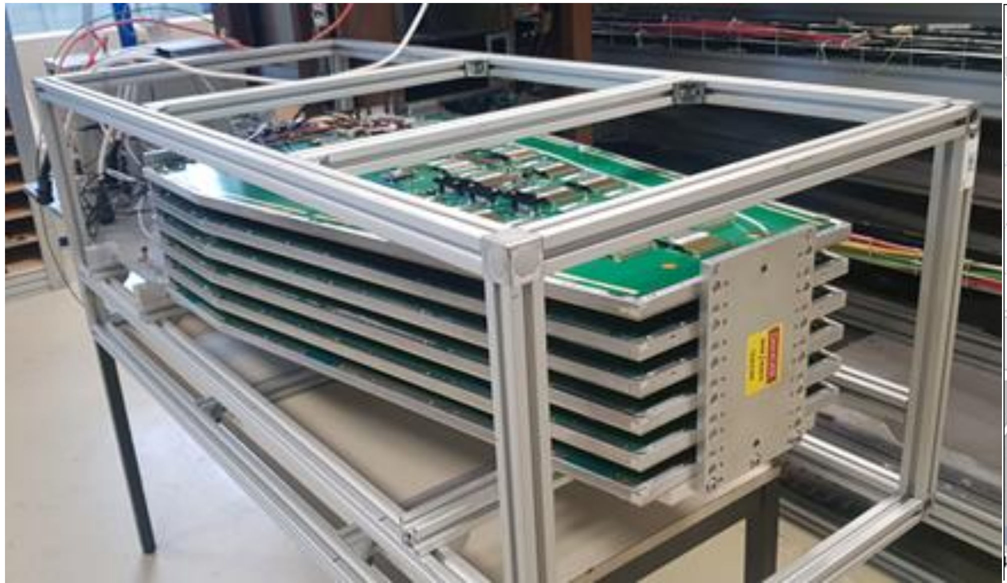
2. GEM

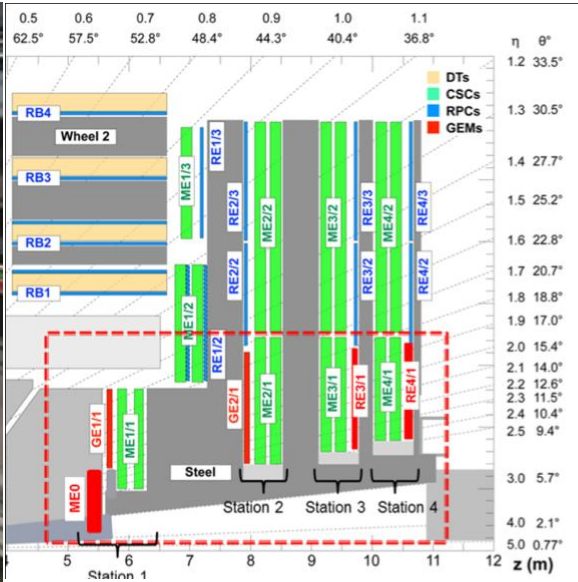


NIMA 805 (2016) 2–24

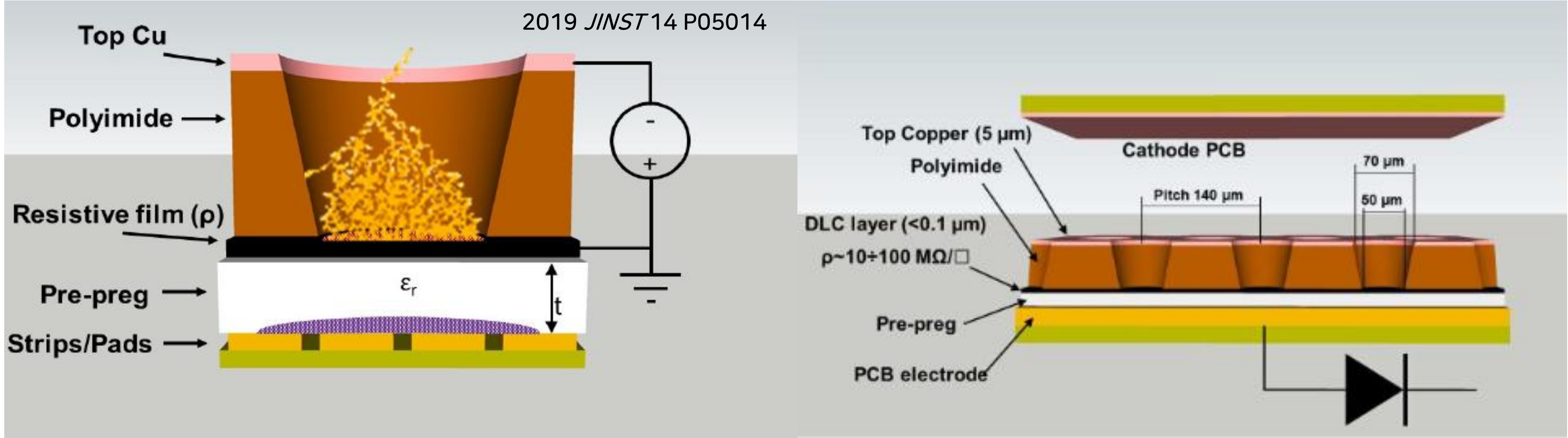


- Step-by-step amplification & separation of induction and amplification region
  - Extremely high rate capability
  - Extremely robust to aging





3. Resistive GEM - μRWELL



- Micro resistive well, the resistive variant of GEM

 - Structurally simple and robust

 → Faster assembly and low material budget

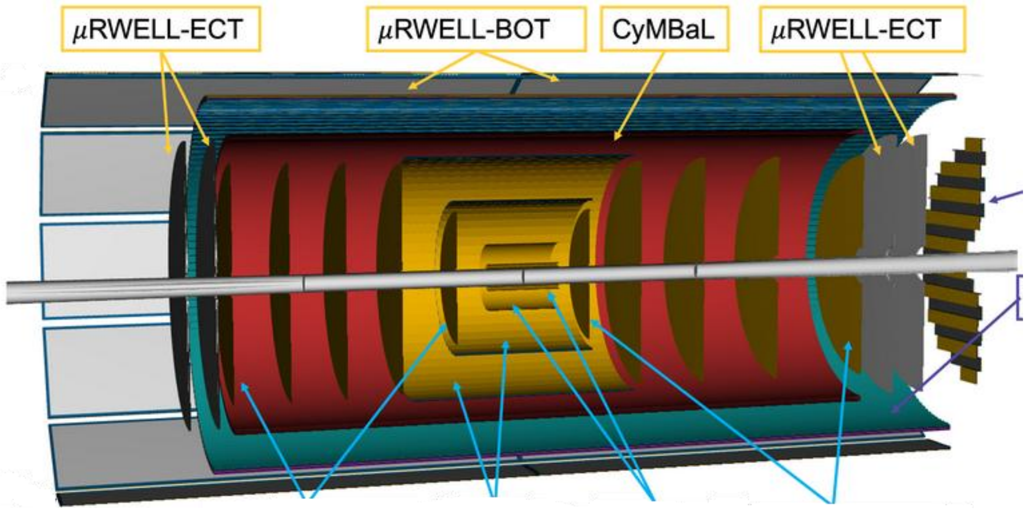
 - Industry-friendly because it is based on standard PCB technology mostly

 ⇒ Cost-effective

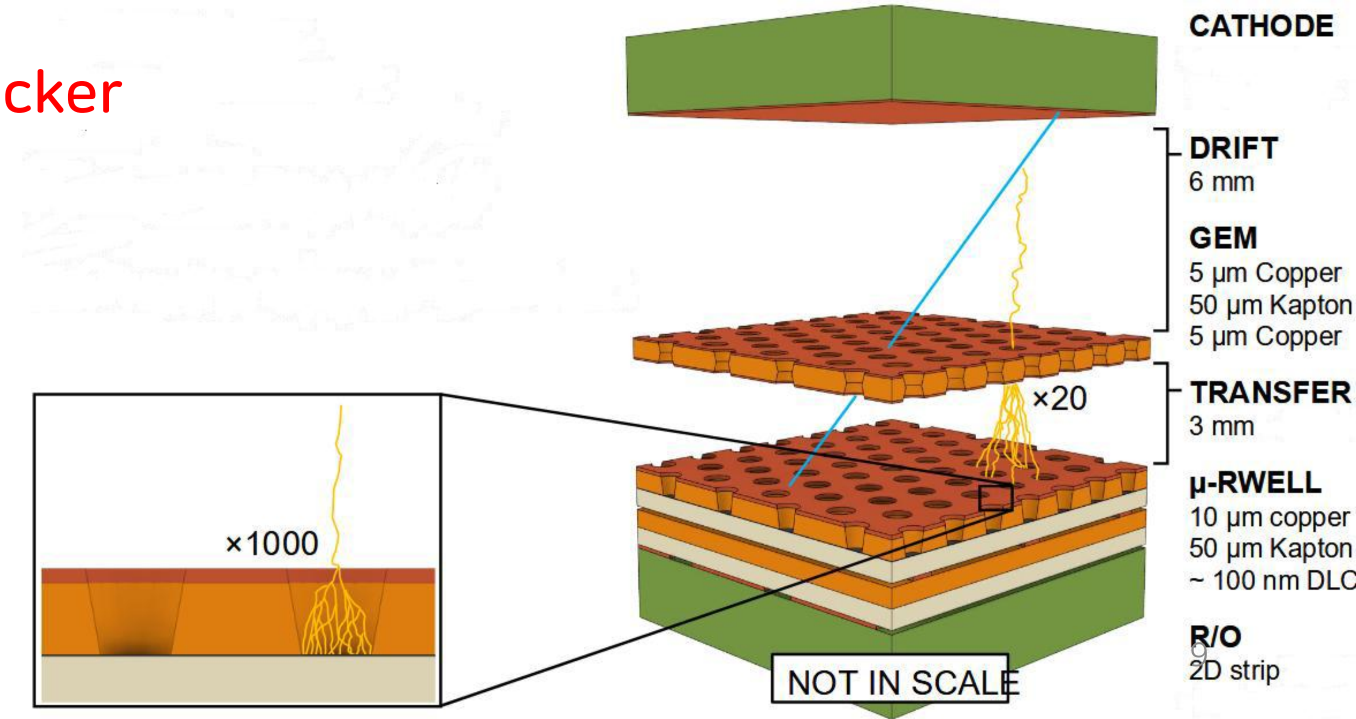
- However, having CERN as the single supplier creates a severe bottleneck in procurement

3. Resistive GEM - μRWELL

- Experiment planning to use μRWELL
  - ePIC central tracker: GEM+μRWELL hybrid, low material budget
  - LHCb muon tracker: GEM+μRWELL hybrid, replacing MWPC due to Lumi. upgrade, high rate μRWELL
  - CLAS12 tracker: replacing DC due to Lumi. upgrade, high rate μRWELL
  - DAMSA tracker & pre-shower: good position resolution, neutron tolerance, cost effective
  - IDEA @ FCC-ee pre-shower & muon tracker



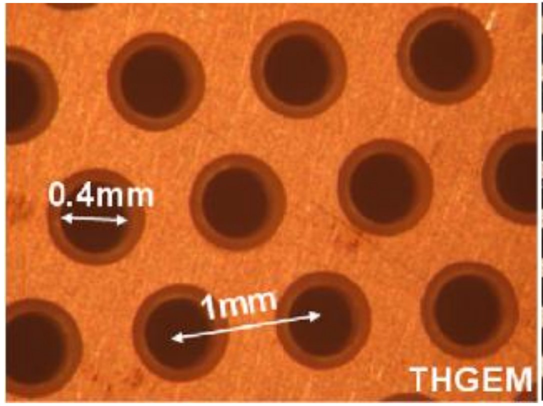
Annalisa



4. Other MPGDs

- THGEM
  - Robust, high gain, cheap, mass production friendly
  - Poor multi-track resolution, charging up, discharge
  - Glass THGEM?

NIMA 598 (2009) 107-11



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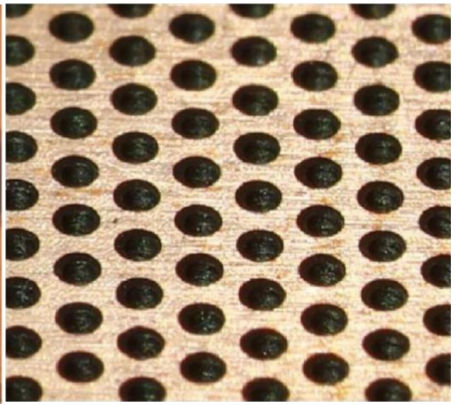
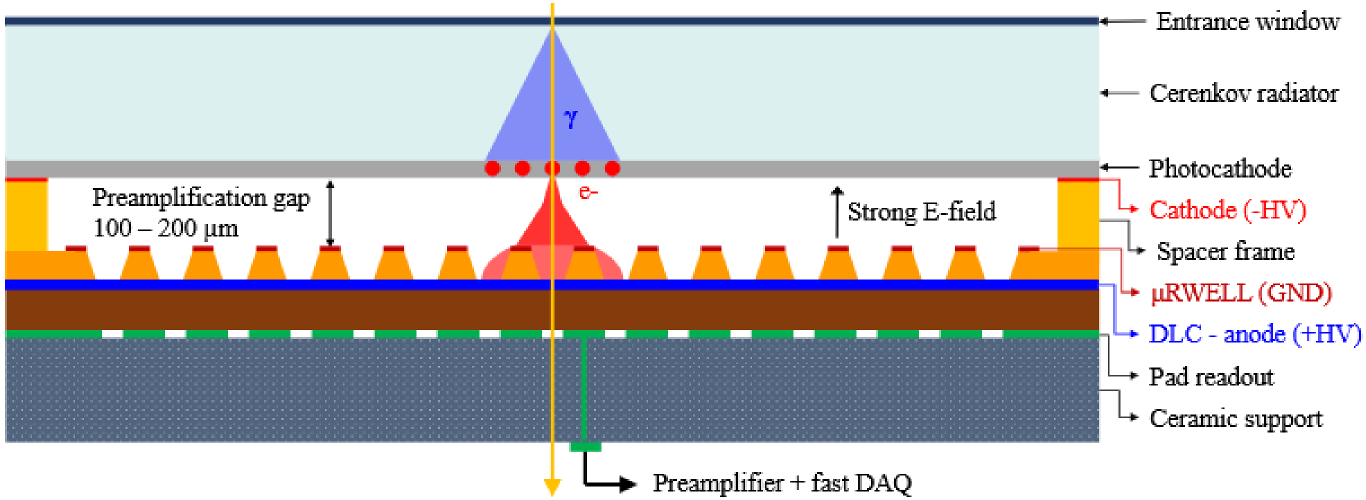


- PICOSEC
  - Cherenkov+photoelectric+MPGD
  - ~20 ps for CsI or
    ~ 35 ps for DLC photocathode

arXiv:2512.10137

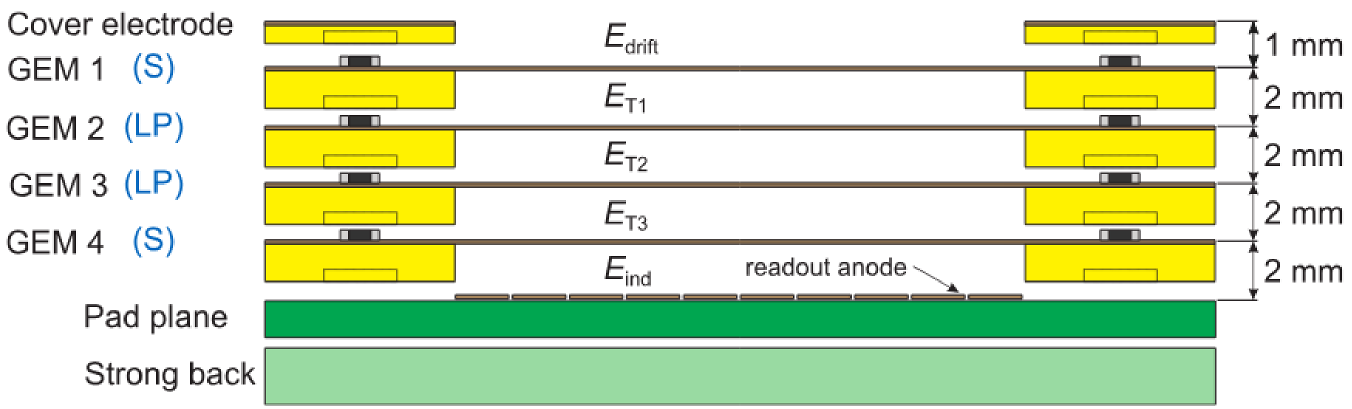


5. GEM vs. μRWELL vs. R-MM

- In general, GEM, R-MM and μRWELL exhibit comparable performance
  - Position resolution: $\sim 60\ \mu m$
  - Energy resolution: R-MM $\sim$ μRWELL > GEM
  - Time resolution: R-MM $\sim$ μRWELL > GEM

- Aging: GEM $\gg$ R-MM $\sim$ μRWELL

- Ion back flow: μRWELL > R-MM > GEM
  - The ALICE continuous TPC achieved an ion backflow of 0.7% using 4 GEM readout



5. GEM vs. μRWELL vs. R-MM

- Rate capability: GEM > μRWELL ~ R-MM

  - GEM: voltage drop @ protection resistor, resistive detectors: voltage drop @ resistive layer

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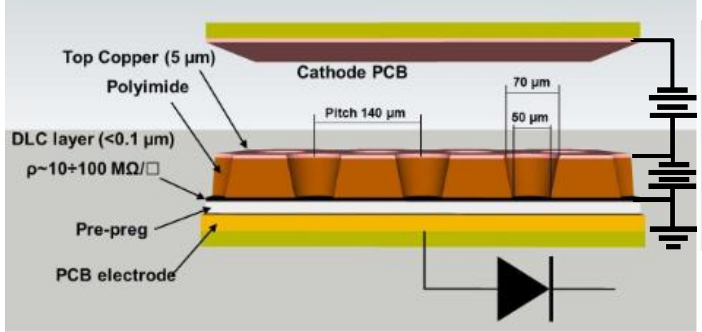
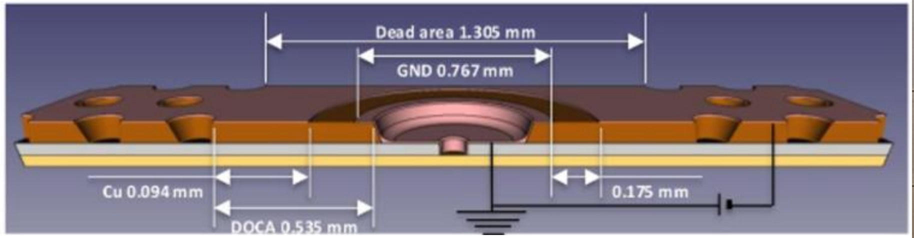
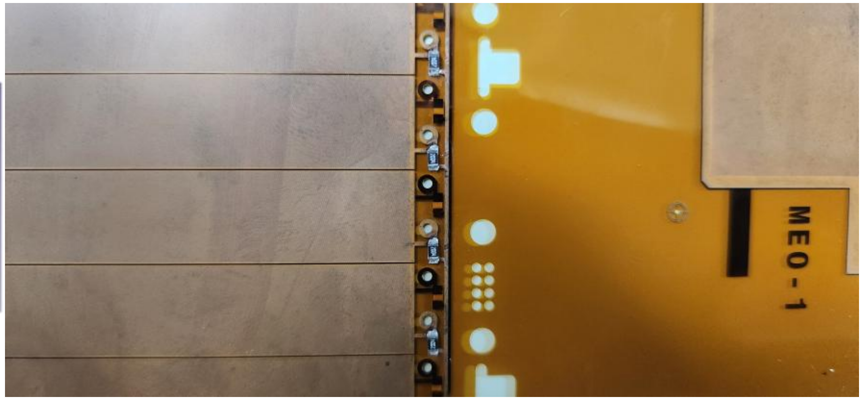


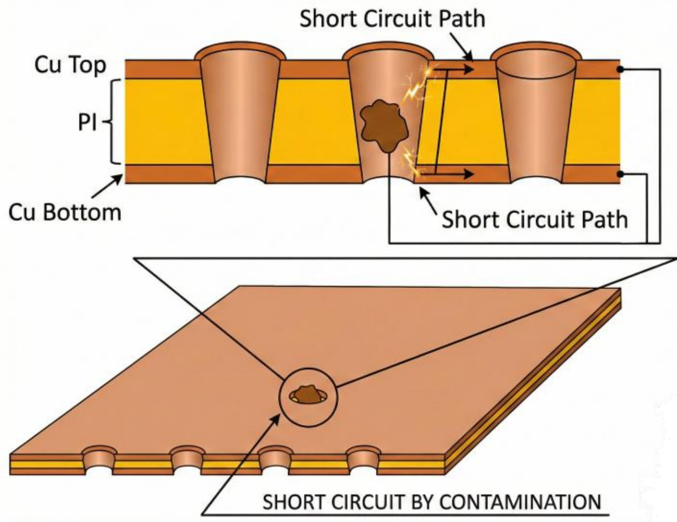
arXiv:2411.13734





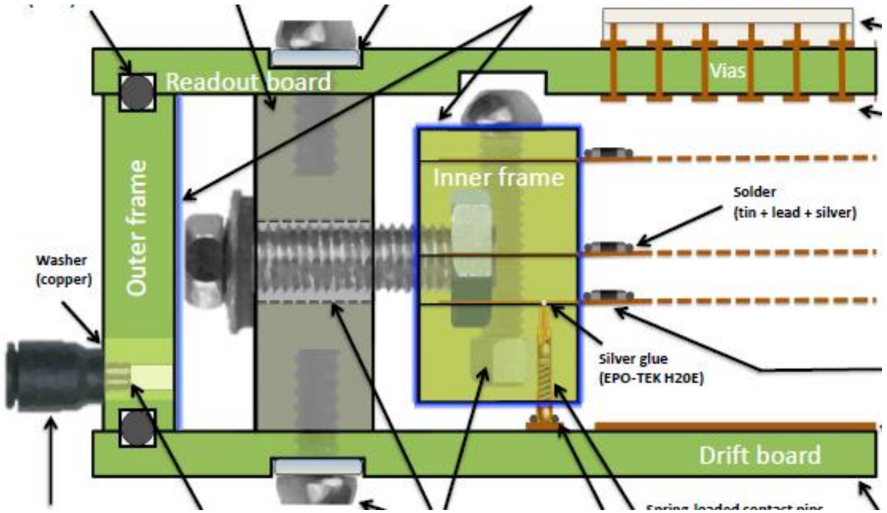
- Sector loss due to short circuit: μRWELL ~ R-MM $\ll$ GEM

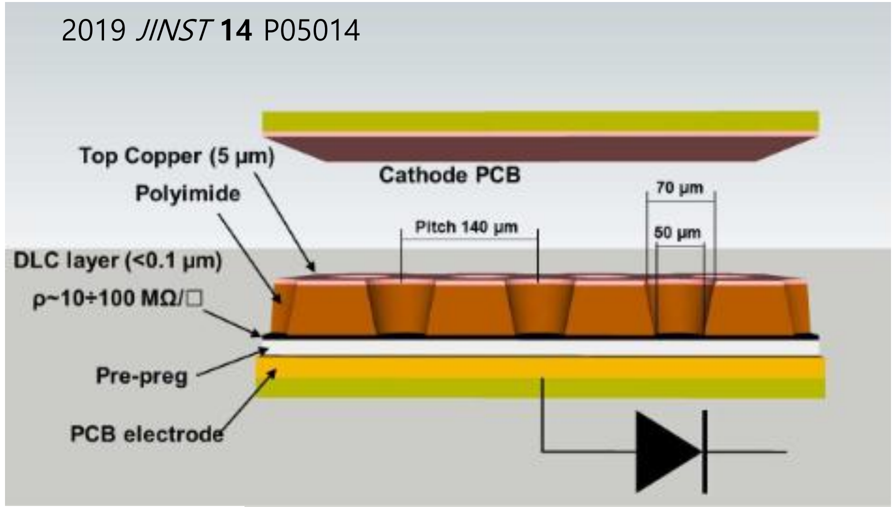
  - A short circuit causes a full sector loss in GEMs, while it results in only a point loss for resistive detectors

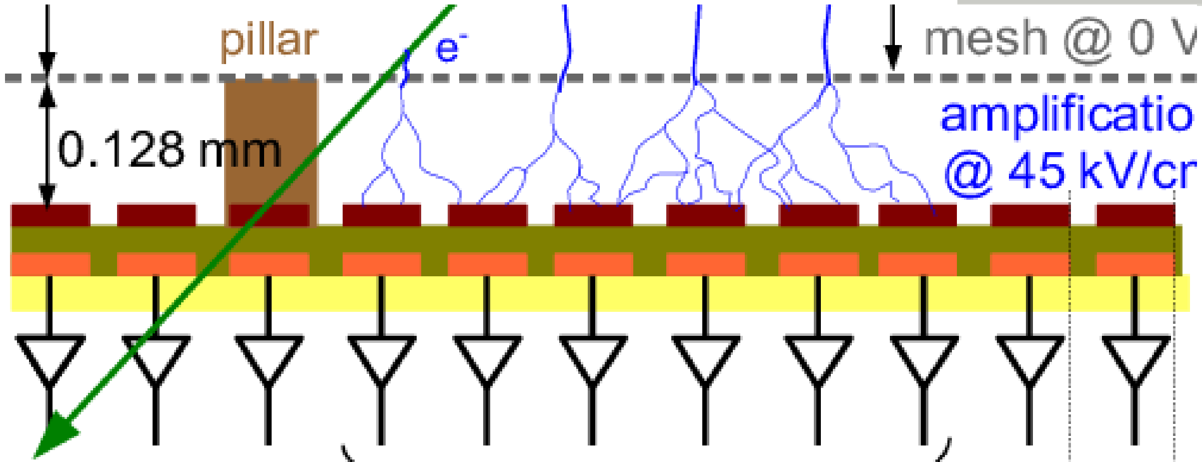


5. GEM vs. μRWELL vs. R-MM

- Structural complexity: μRWELL $\ll$ R-MM $<$ GEM
  - So is material budget
  - Flexible μRWELL using FPC based readout







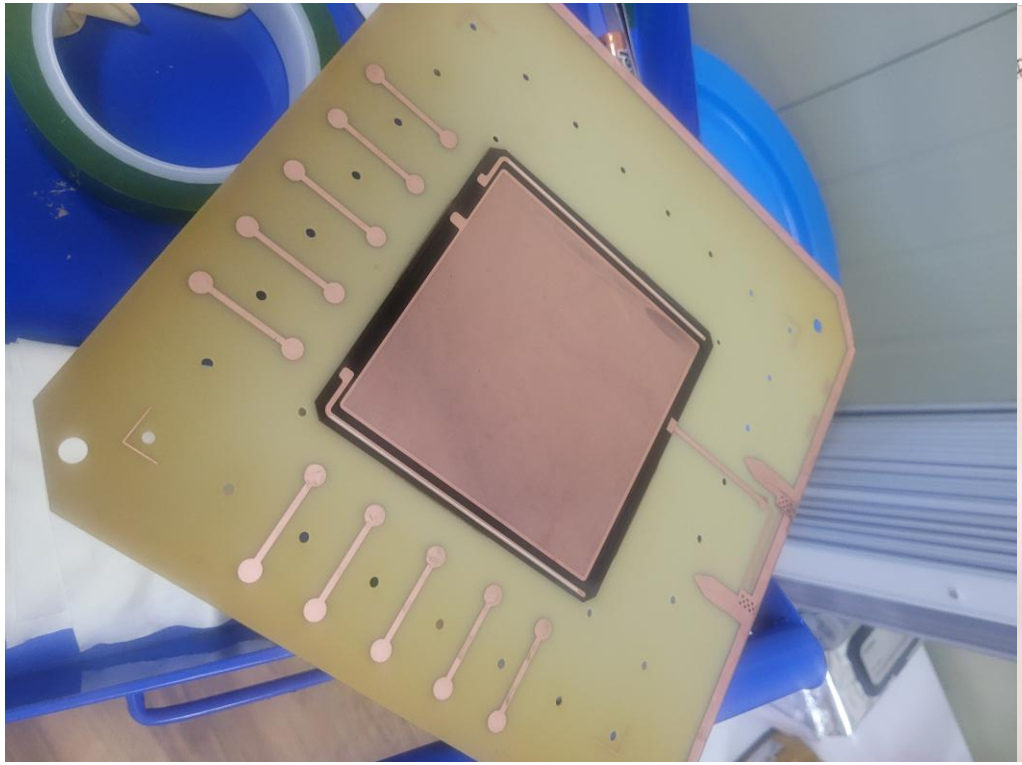
6. Outlook

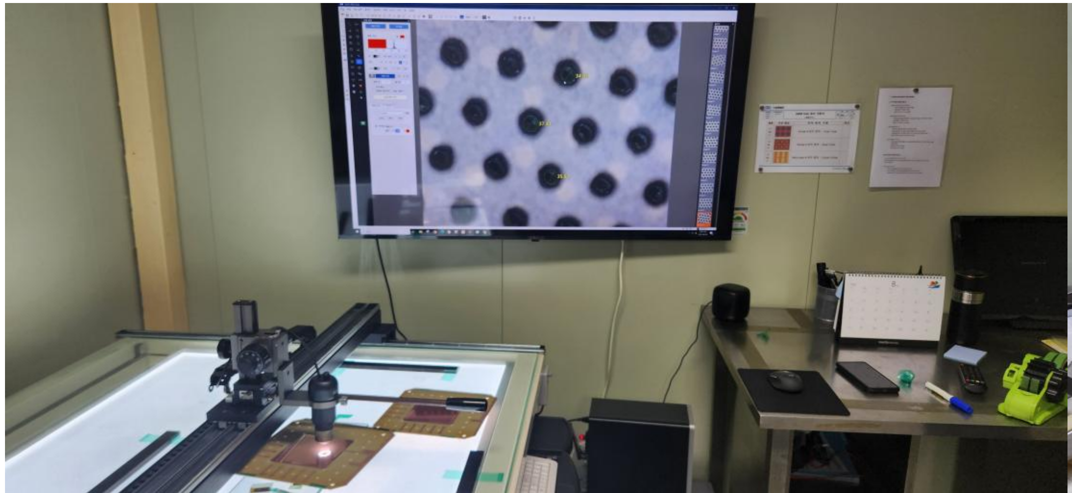
- μRWELL is expected to become the most important detector in the MPGD

- The popularity of GEM is expected to decline significantly compared to now
  - μRWELL is expected to replace a large share of GEM
  - No upcoming experiments that require the exceptional rate capability and aging resistance of GEM
  - Could GEMs be used as imaging detectors in industrial applications outside of physics?
  - Nevertheless, GEM technology will remain relevant for TPC and pre-amplifier

- R-MM usage may decline a bit, but it will continue to be a staple technology

7. R&D Status





Summary

• Efforts to improve the multi-track resolution and rate capability of gas detectors led to the birth of MPGD

• While various MPGDs are being researched, the most widely adopted technologies are GEM, R-MM, and μRWELL

• I believe μRWELL will become the most significant technology in the MPGD

- Working on μRWELL production research using the GEM manufacturing infrastructure available in Korea