Advancements in resistive MPGD: from µ-RWELL technology to high performance Hybrid Layouts (ID 46)

VCI – Vienna Conference on Instrumentation

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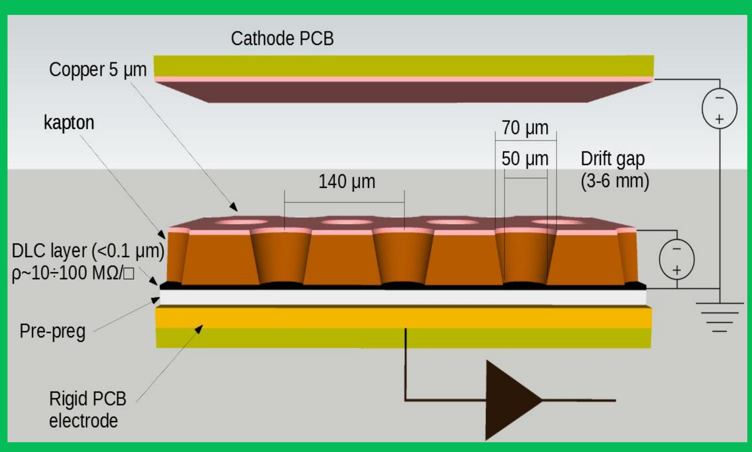
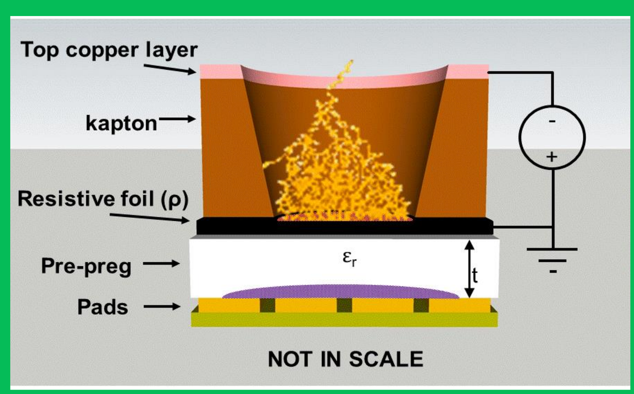
Future high-energy and nuclear physics experiments demand advanced particle detectors with exceptional tracking, timing, and robustness.
The µ-RWELL, a single-stage resistive MPGD, achieves gas gains of ~2×10^4, 100 µm spatial resolution, and 5 ns time resolution.
To meet the LHCb muon system upgrade requirements, we developed a hybrid design, G-RWELL, integrating a GEM-based pre-amplification stage over the classic µ-RWELL stage.
Recent beam tests showed gas gains up to 10^5 and time resolution down to 3.8 ns, setting a new MPGD benchmark.
This hybrid layout is also being investigated for 2D tracking at the Electron-Ion Collider (EIC), in collaboration with Roma Tor Vergata University, with preliminary results indicating sub-100 µm resolution for perpendicular tracks.
The G-RWELL emerges as a reliable and high-gain MPGD technology, offering breakthrough performance for future collider experiments.

The µ-RWELL: principle of operation

G. Bencivenni et al., 2015 JINST 10 P02008





The **µ-RWELL** is a **resistive MPGD** composed of two elements:

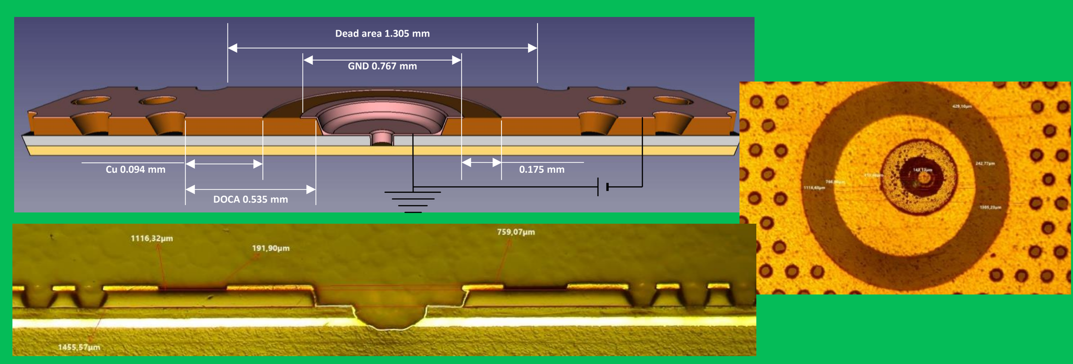
- **Cathode**
- **µ-RWELL PCB:**
  - a **WELL** patterned **kapton foil** (with **Cu-layer on top**) acting as **amplification stage**
  - a **resisitive DLC film** with **ρ~50÷100 MΩ/□**
  - a standard **readout PCB** with **pad/strip r/out**

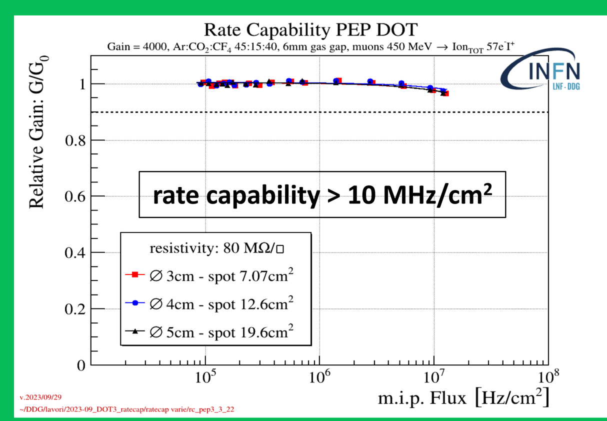
The **"WELL"** acts as a **multiplication channel,** multiplying the ionization produced in the drift gas gap.

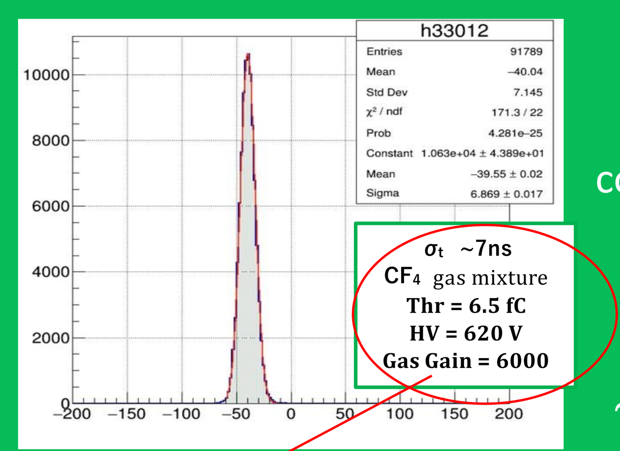
The **resistive stage** ensures **spark quenching**, crucial for stability.

Drawback: high particle flux tolerance is reduced but largely restored with proper resistive layer grounding.

High-rate layouts: PEP-DOT geometry & performance



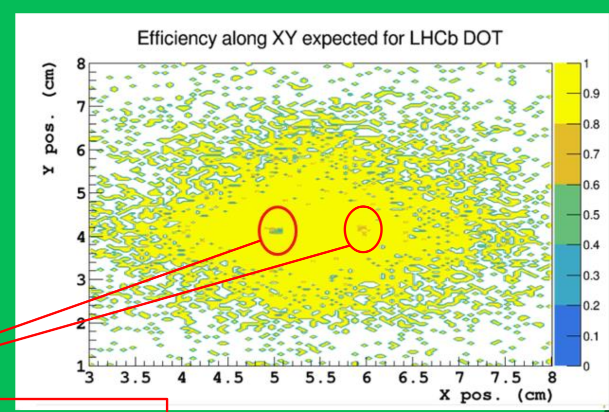




High density DLC grounding through conductive dots connecting the DLC with 9×9mm² pad r/out:

- Dot pitch = 9mm
- Dot rim = 1.3mm

~ 97% geo-acceptance

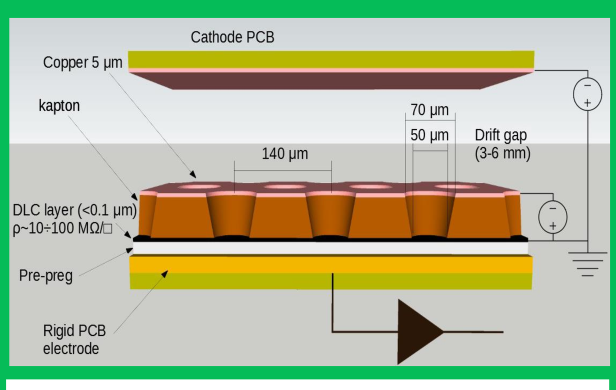


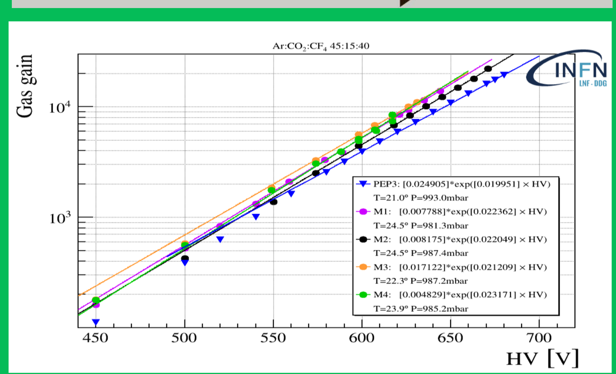
close to the max gain of the detector further R&D needed

Small and localized efficiency drop around grounding dots

The µ-RWELL vs the Hybrid layout (GEM ⊕ µ-RWELL → G-RWELL)

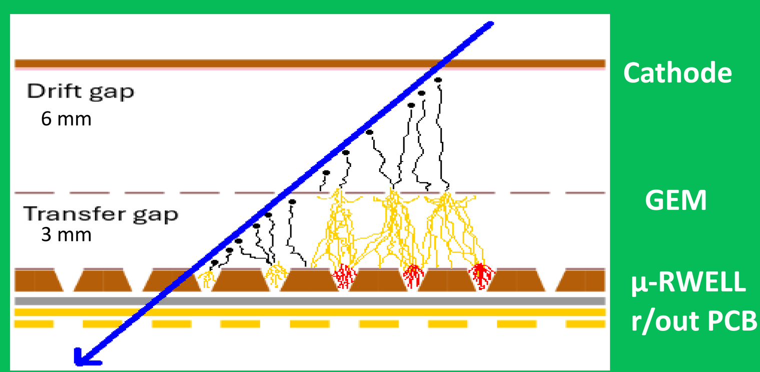
µ-RWELL

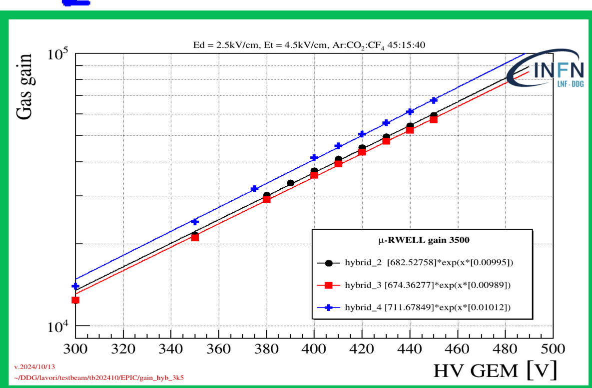




Classic µ-RWELL: max gain ≈2×10^4

G-RWELL



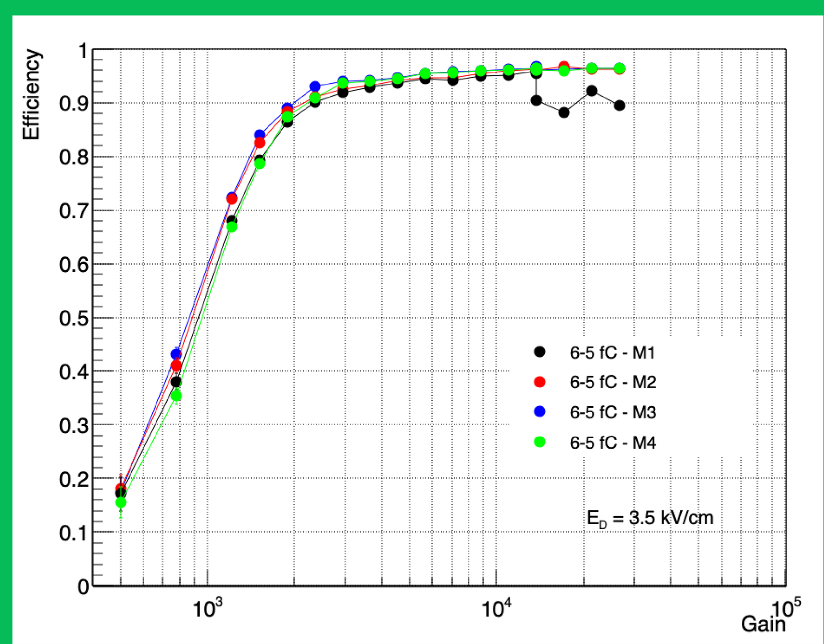


G-RWELL:

- Global gain = $G_{GEM} \otimes G_{RWELL}$
- max gain >> 10^4

µ-RWELL vs G-RWELL: global efficiency

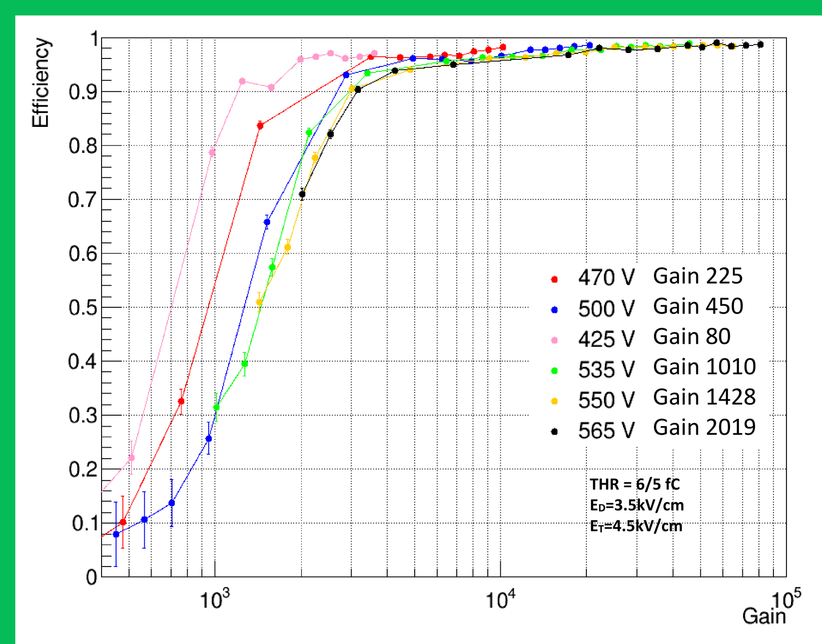
µ-RWELL



Classic µ-RWELL global effiiency:

- Max efficiency ~ 96%

G-RWELL

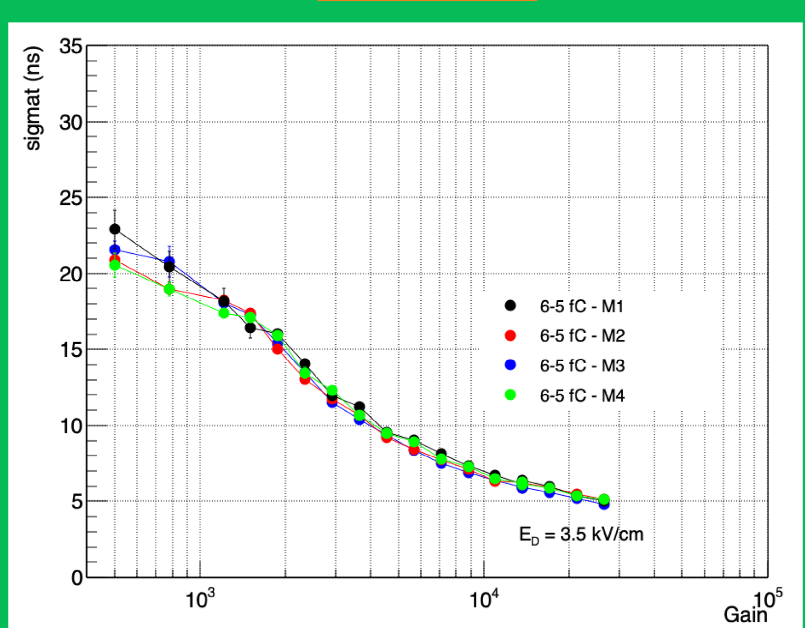


G-RWELL global efficiency:

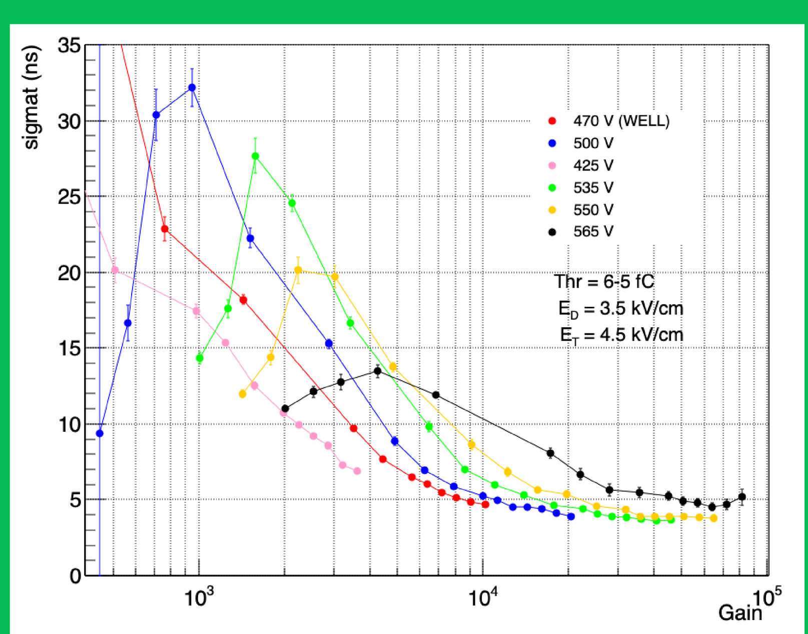
- Efficiency curves for different µ-RWELL gain
- Max efficiency ~ 99% (for very high gain)

µ-RWELL vs G-RWELL: time resolution

µ-RWELL



G-RWELL

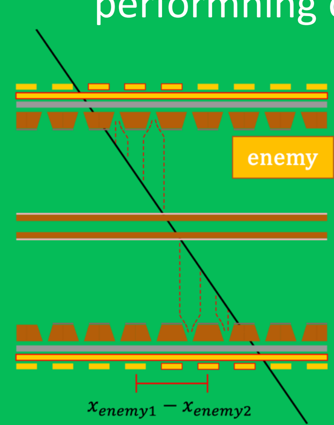


The HYBRID exhibits better time performance than M2R1 at the same gain, thanks to higher efficiency in the first ionization cluster. Differences among the families at varying HV_WELL values can be attributed to a well-known effect in multi-step amplification layouts, commonly referred to as the "Biwell effect."

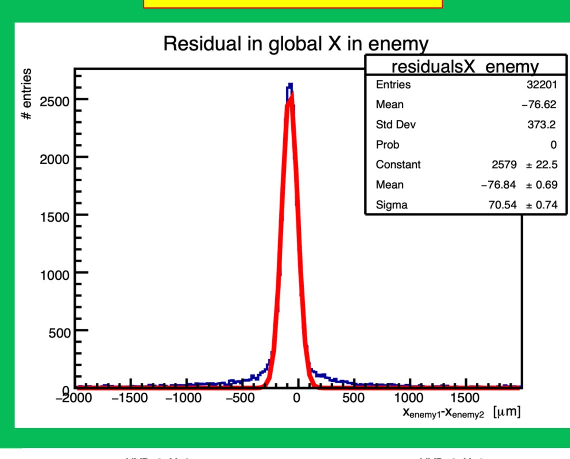
Tracking with G-RWELL (*)

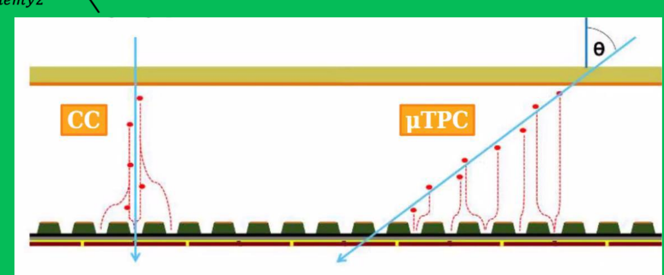
work in progress

A high gain (>10^4) is also recommended for safe and performning operation in 2D tracking

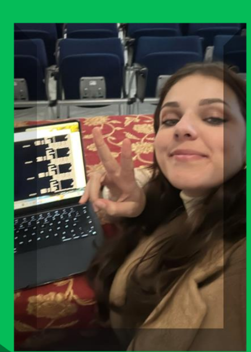


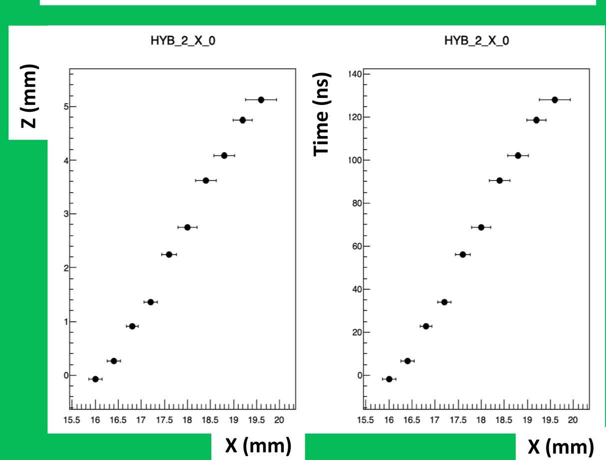
Residual of the distance between the reconstruct track centers inside the detector gaps (enemy mode).
90° track incidence





Reconstructed track inside the gap





(*) Collaboration with the ePIC- Tor Vergata group - Poster ID 34, E. Sidoretti

Future High Energy and Nuclear Physics challenges, which impose stringent requirements on time and spatial resolution, drive the R&D toward detectors capable of achieving gas gains greater than 10^4 while maintaining high operational stability in harsh environment.
The hybrid technology, combining a GEM-based pre-amplification stage with the classic µ-RWELL (G-RWELL), appears to meet these requirements.
The G-RWELL demonstrates remarkable performance: highly stable operation at gas gains approaching 10^5 without instability, and improved time resolution down to 3.8 ns.Preliminary results on its 2D tracking capabilities indicate excellent spatial resolution (σ_x < 100 µm).

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