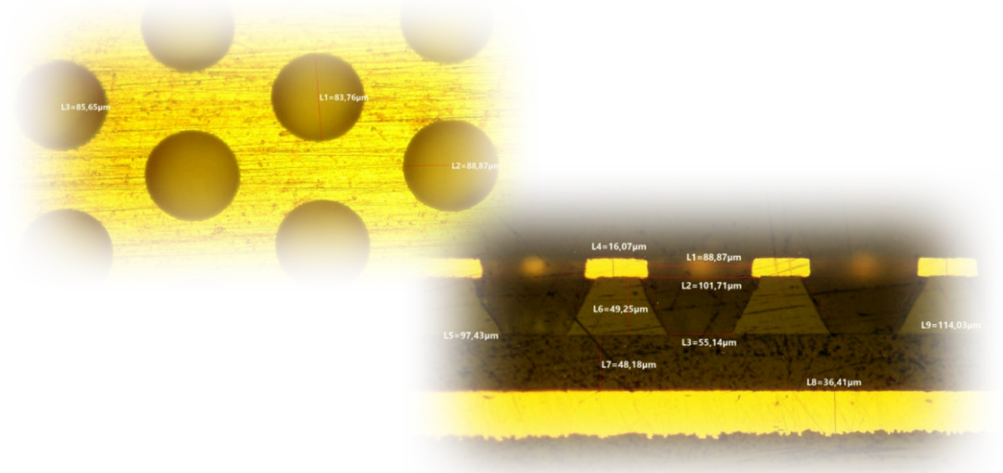
Preliminary results from the µ-RWELL Test Beam
for the Phase-II upgrade of LHCb



Matteo Giovannetti[1]

G. Bencivenni[1], F. Debernardis[2], E. De Lucia[1],
R. De Oliveira[3], G. De Robertis[2], G. Felici[1], M. Gatta[1],
F. Licciulli[2], G. Morello[1], G. Papalino[1], M. Poli Lener[1]

LNF – INFN [1]
Bari – INFN [2]
CERN [3]

Istituto Nazionale di Fisica Nucleare

3rd DRD1 Collaboration Meeting, Dec 12th 2024

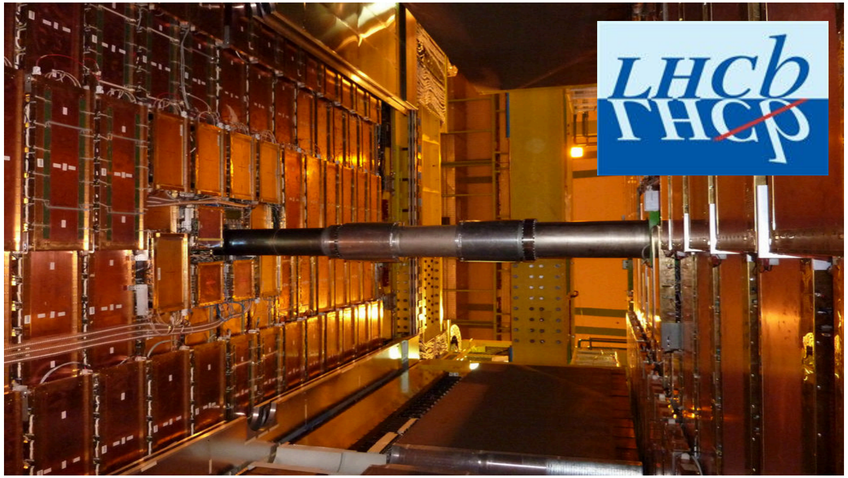
LHCb upgrade II (Run 5-6)

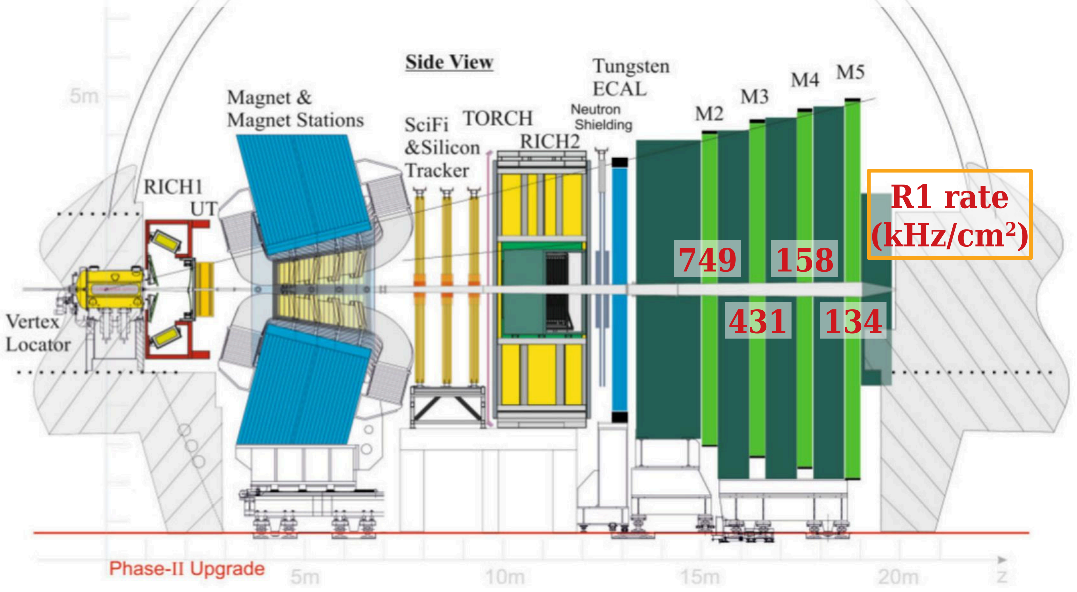
LHCb muon RUN 5-6 option: μ-RWELL → Detector requirements:

- Rate up to **1 MHz/cm²** on detector single gap
- Rate up to **700kHz** for FEE channel
- Efficiency (4 gaps) **> 96% within BX** (25 ns)
- Stability up to 1 C/cm² accumulated charge in 10y of operation

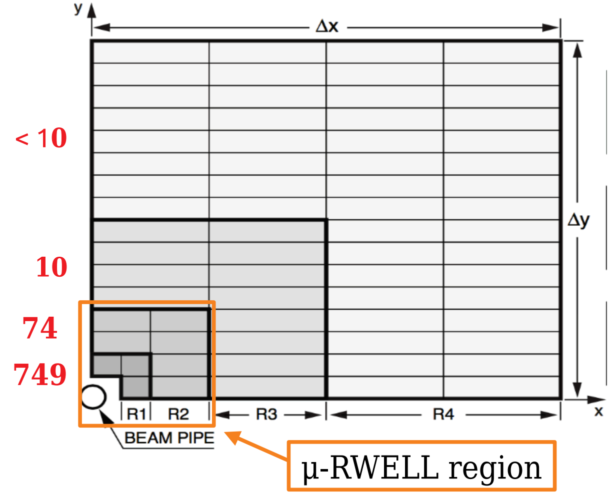
Detector size & quantity (4 gaps/chamber)

- R1 + R2 of M2-M5: **576 det.**, size 30x25 to 74x31 cm², **90 m² det**

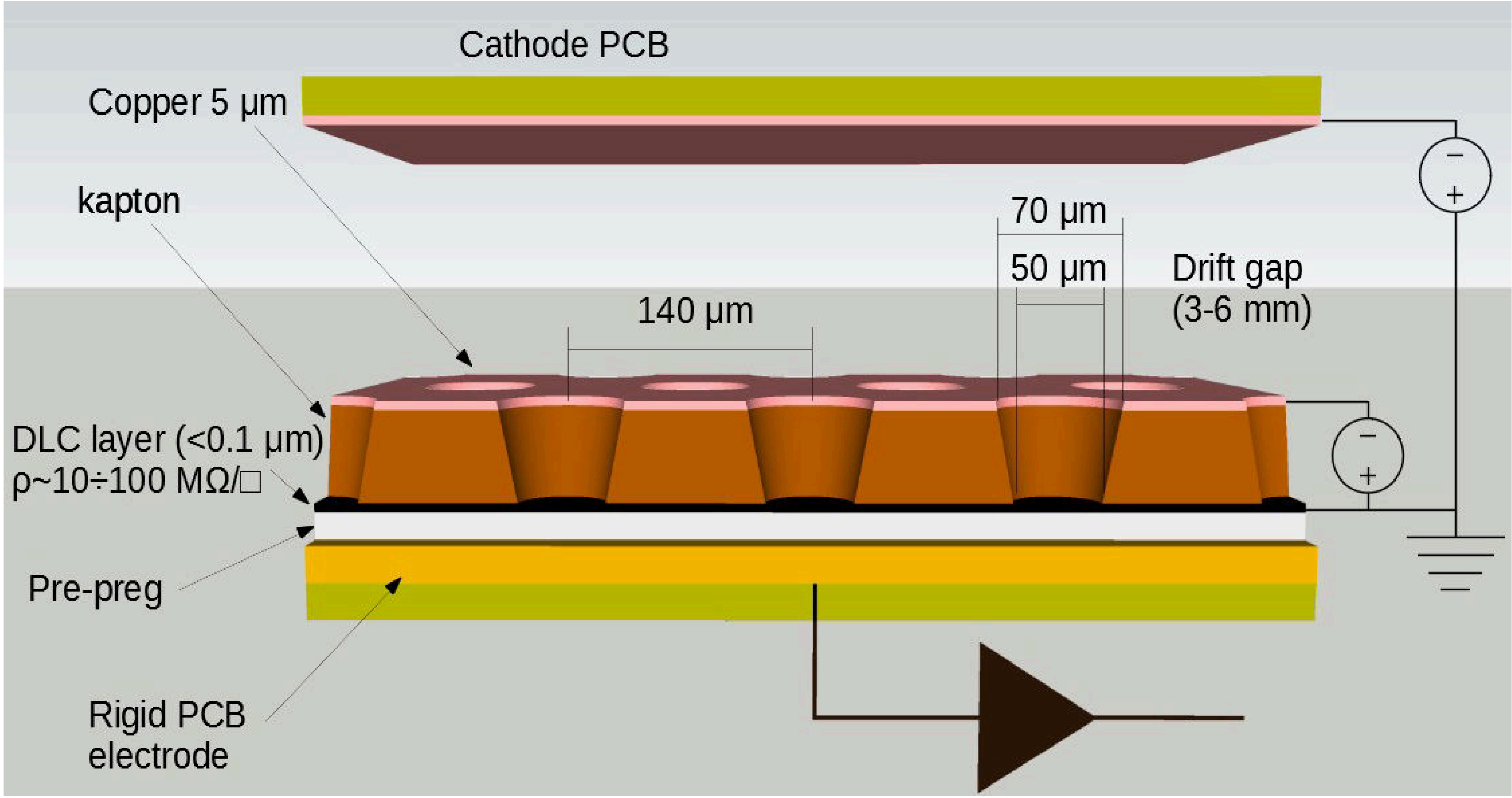




M2 station - max rate (kHz/cm²)



The µ-RWELL

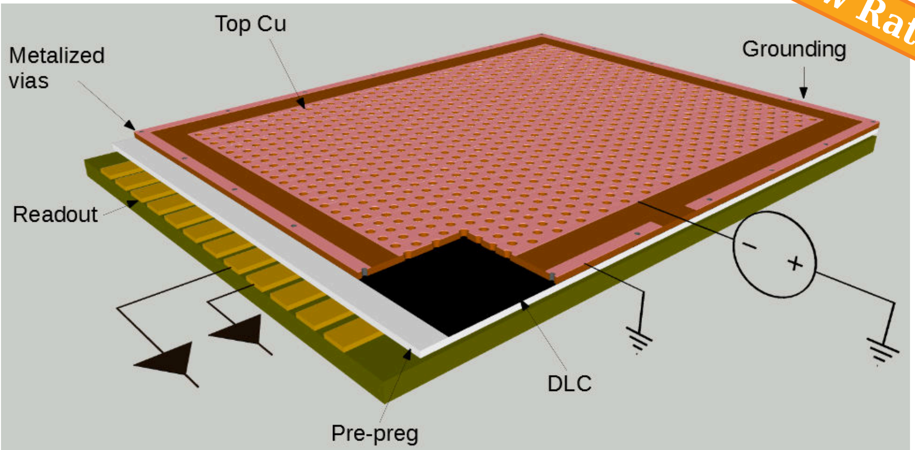


Cathode PCB
Copper 5 µm
kapton
70 µm
50 µm
Drift gap
(3-6 mm)
140 µm
DLC layer (<0.1 µm)
ρ~10÷100 MΩ/□
Pre-preg
Rigid PCB
electrode

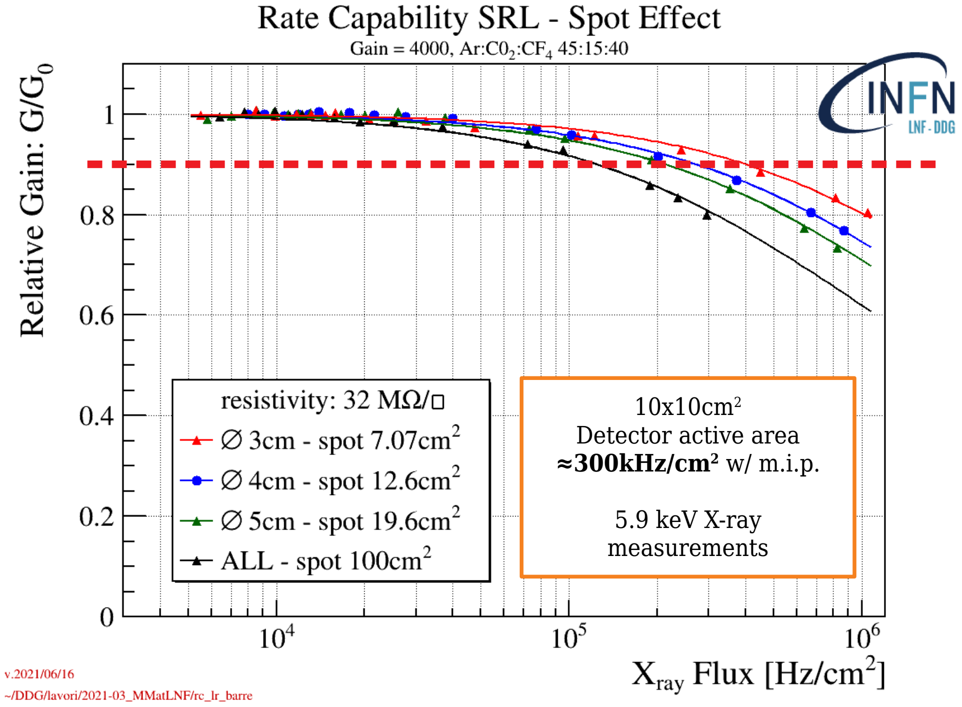
The low-rate layout: Single Resistive Layout (SRL)

- **Single DLC layer**
- **Grounding at** the **perimeter** of the active area
- **Limitation for large area:** detector response depends on particle incidence point
- **Limited rate capability**

Low Rate



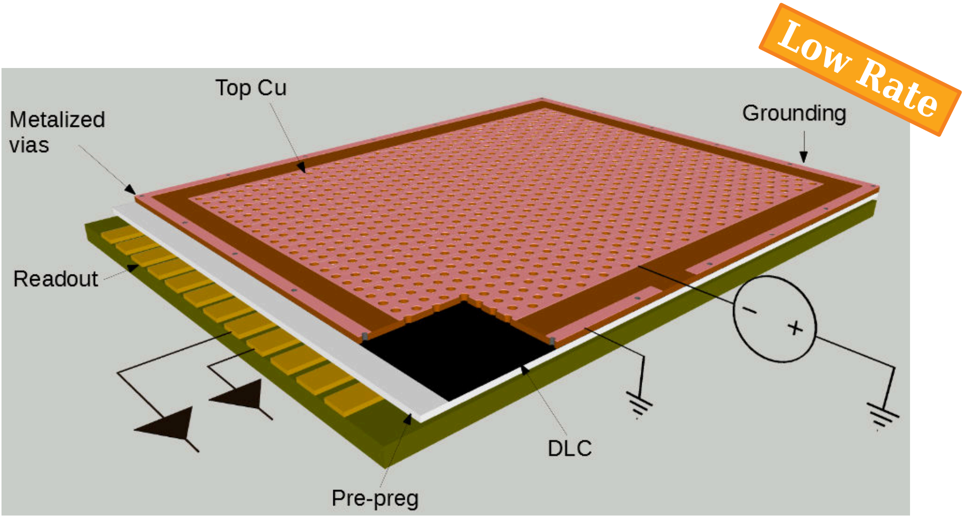
Single Resistive Layout (SRL)



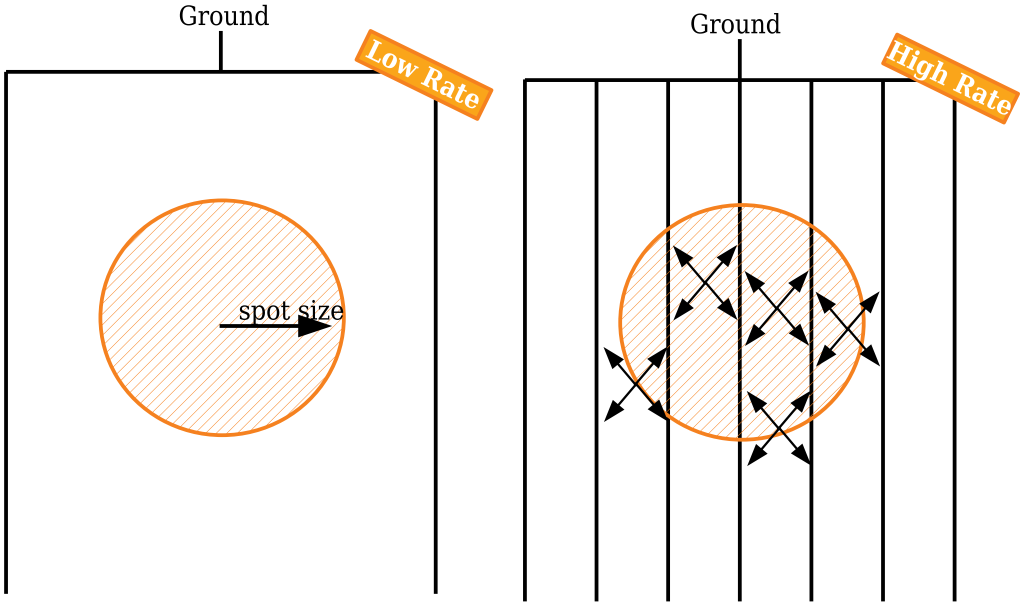
Different primary ionization ⇒ Rate Cap.$_{\text{m.i.p.}}$ = 3×Rate Cap.$_{\text{X-ray}}$!

High-rate layouts: principle of operation

To overcome the **intrinsic rate limitations** of the Single Resistive Layout, it is necessary to introduce a **high-density grounding network** for the resistive stage (DLC).



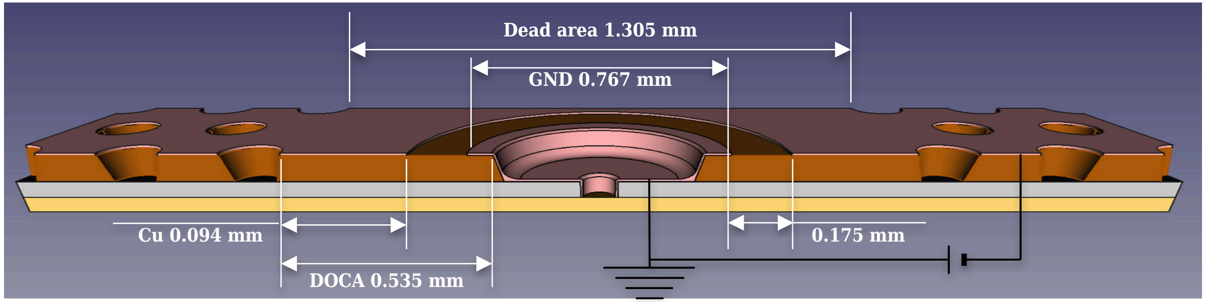
Single Resistive Layout (SRL)

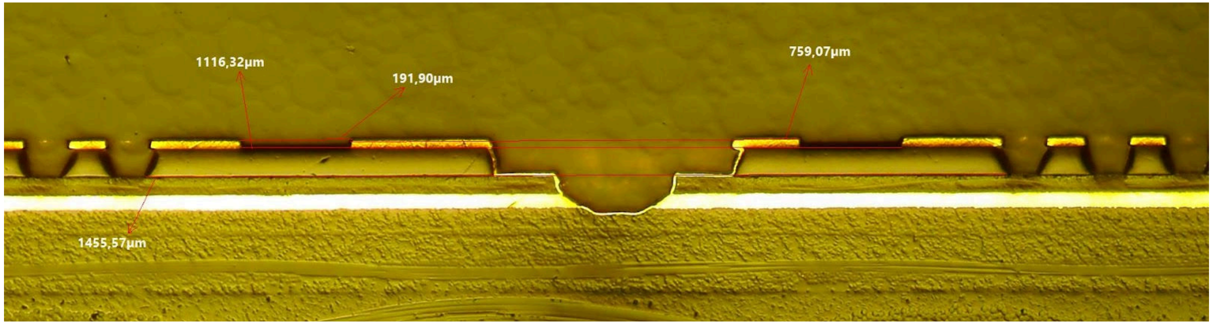


Segmentation of the DLC with conductive micro-strips/dots with a typical pitch of 1cm: a sort of **tiling** of the active area using a set of smaller SRL.

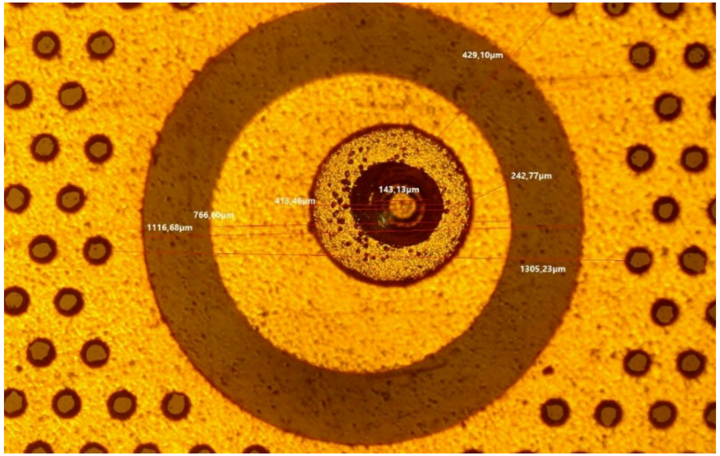
The PEP-DOT µ-RWELL

DLC-GND pitch [mm]	Dead Zone [mm]	GND width [mm]	Insulation gap [mm]	DOCA [mm]
9	1.3 (1.6%)	0.767	0.175	0.535





- The most recent high rate layout:
  Patterning–**E**tching–**P**lating
- The DLC ground connection is established by creating **metalized vias from the top Cu layer through the DLC**, down to the pad-readout of the PCB
- The dead zone is ~2%



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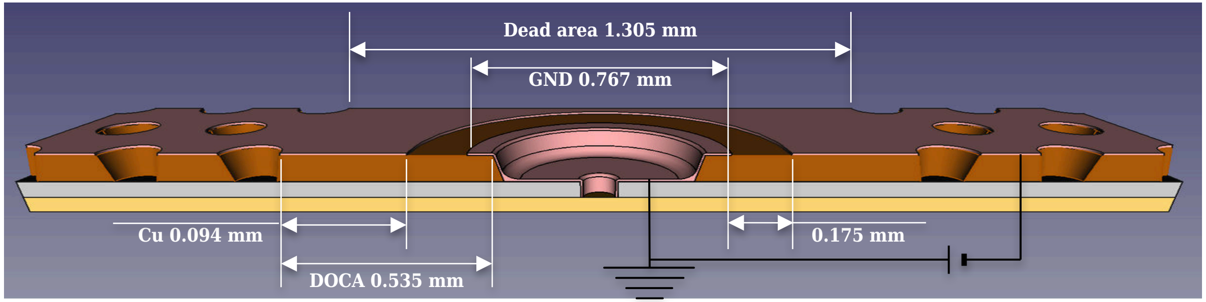
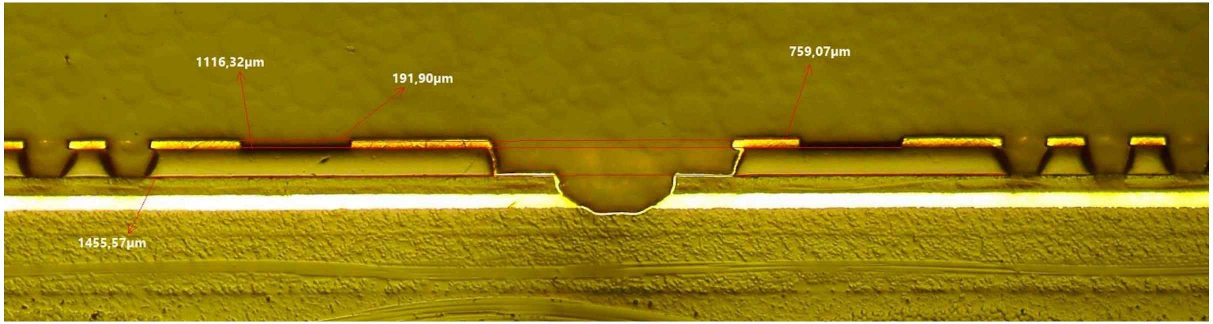
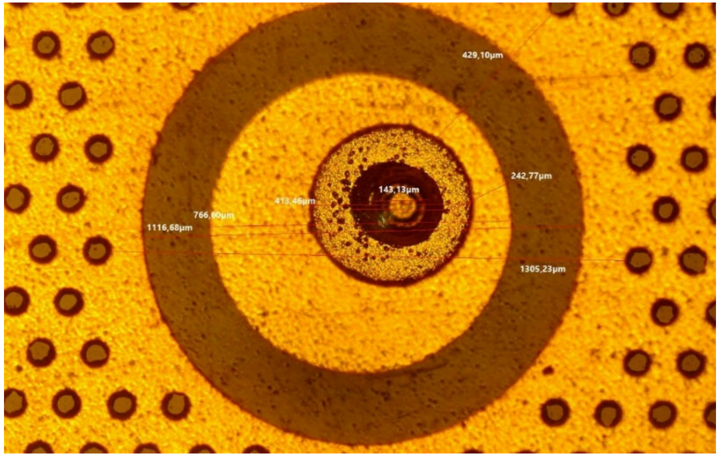


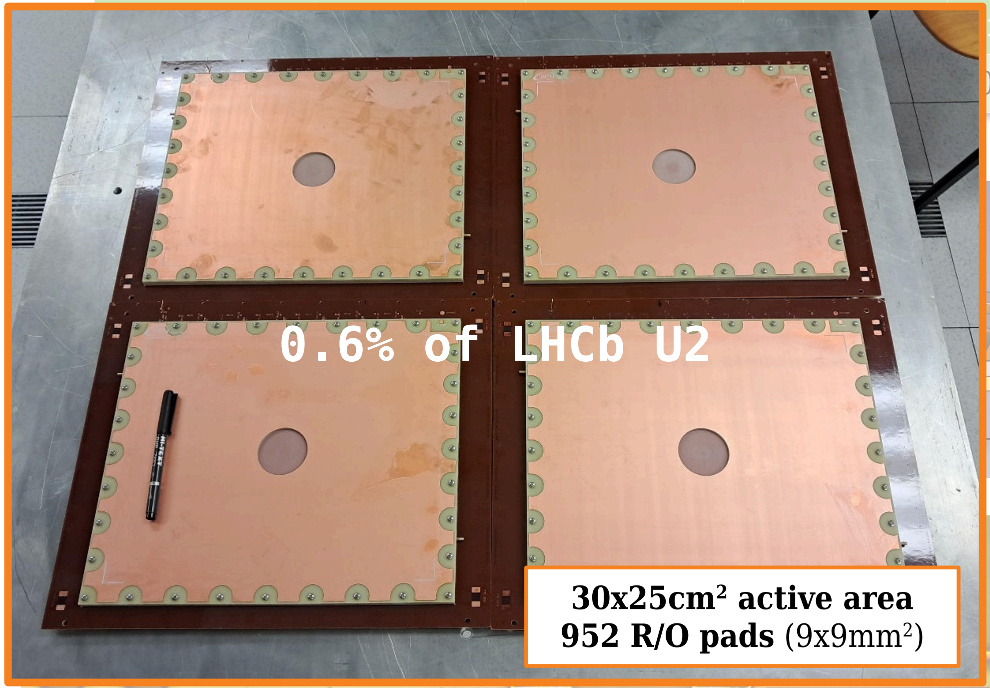




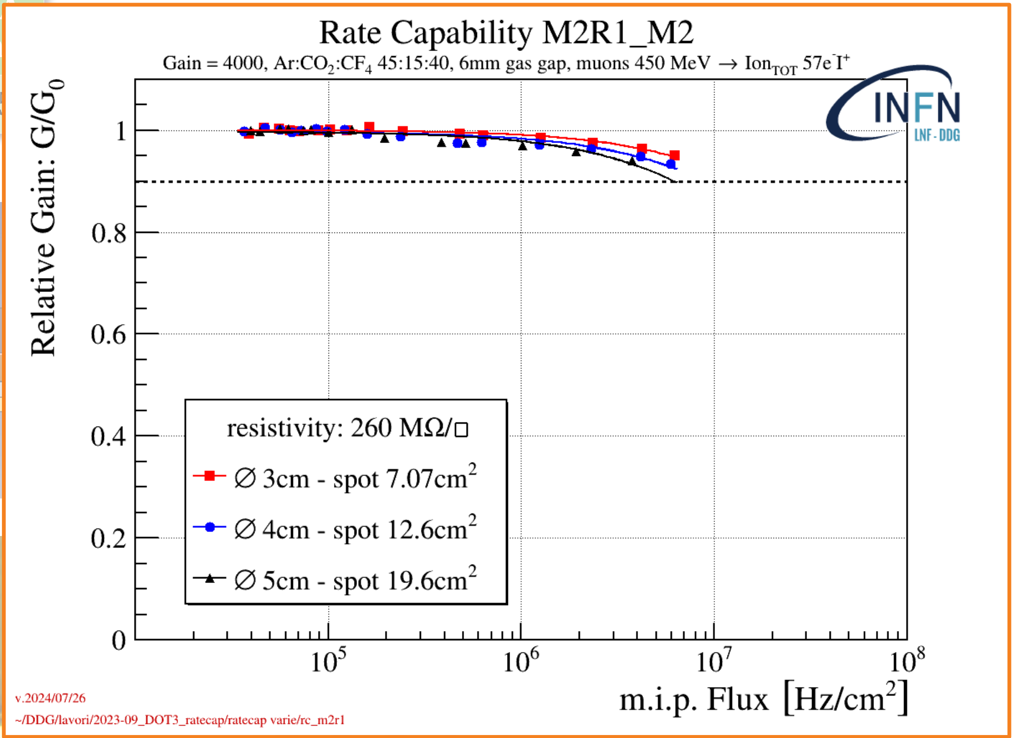
Different from the old PEP-Groove!
Pay attention to the HR Layout in use!

The PEP-DOT µ-RWELL – M2R1 prototypes

DLC-GND	Dead Zone	GND width	Insulation	DOCA mm
				0.535



30x25cm² active area
952 R/O pads (9x9mm²)



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μ-RWELL + GEM preamplification

Nuclear Inst. and Methods in Physics Research, A 936 (2019) 401–404

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ELSEVIER

Development of μ-RWELL detectors for the upgrade of the tracking system of CMD-3 detector

L. Shekhtman *, G. Fedotovich, A. Kozyrev, V. Kudryavtsev, T. Maltsev, A. Ruban

Budker Institute of Nuclear Physics, 630090, Novosibirsk, Russia
Novosibirsk State University, 630090, Novosibirsk, Russia

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Micro-RWELL
Micro-pattern gas detectors

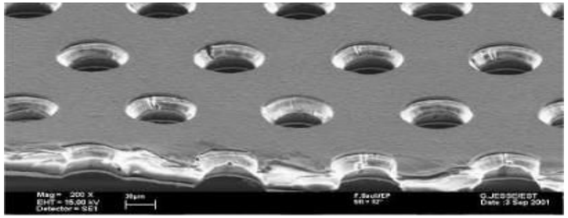
ABSTRACT

An upgrade of tracking system of Cryogenic Magnetic Detector (CMD-3) is proposed using microresistive WELL technology. CMD-3 is a general purpose detector operating at the VEPP-2000 collider at Budker Institute of Nuclear Physics and intended for studies of light vector mesons in the energy range between 0.3 GeV and 2 GeV. The new subsystem consists of double-layer cylindrical detector and the end-cap discs. Two prototypes, micro-RWELL and micro-RWELL-GEM were built and tested. Gas amplification of micro-RWELL detector was measured with several gas mixtures and maximum gain between 20000 and 30000 was observed. However, maximum gain is fluctuating from measurement to measurement by a factor of 2 and thus a safety margin of 2–3 is needed to provide reliable operation of the device. In order to increase the signal GEM was added to micro-RWELL, new prototype was tested with the same gas mixtures and gains above 10^5 have been demonstrated. Time resolution achieved for both prototypes are 7 ns for micro-RWELL and 4 ns for micro-RWELL-GEM.

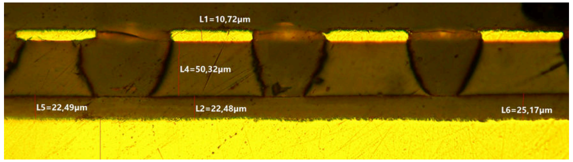
L. Shekhtman, Nuclear Inst. and Methods in Physics Research, [A 936 (2019) 401-404]

See also **E. Sidoretti's** [talk]: Test beam first preliminary results on the GEM-uRWELL prototypes for ePIC endcap tracking

Drift Gap — Shekhtman **3mm**, LNF + Roma2 **6mm**



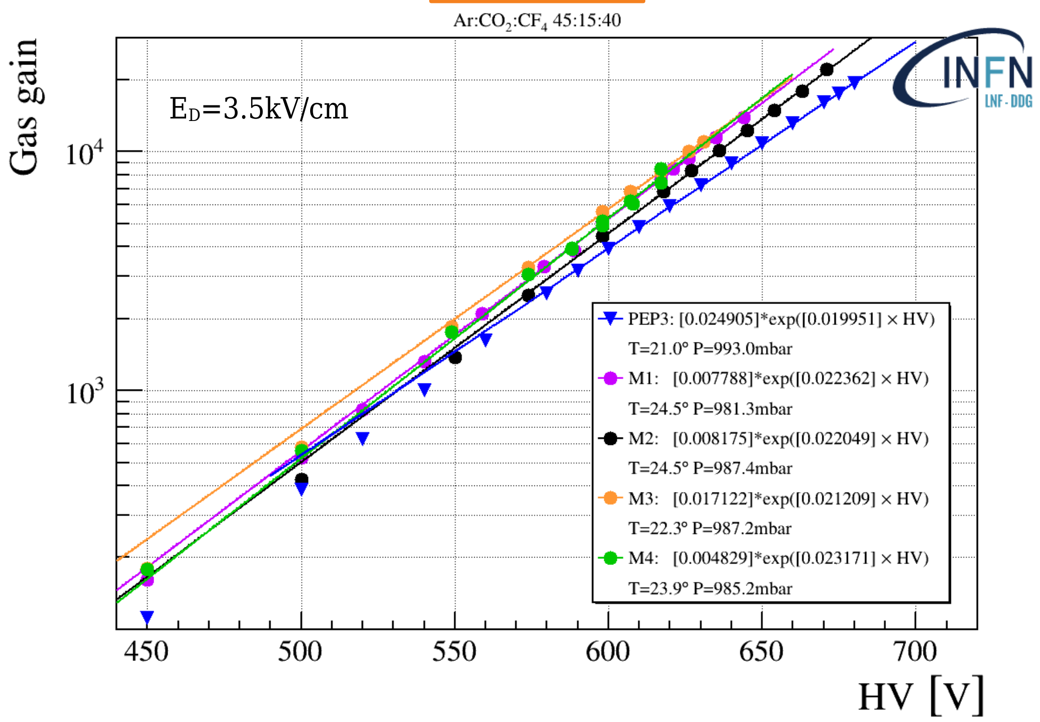
Transfer Gap — Shekhtman **3mm**, LNF + Roma2 **3mm**

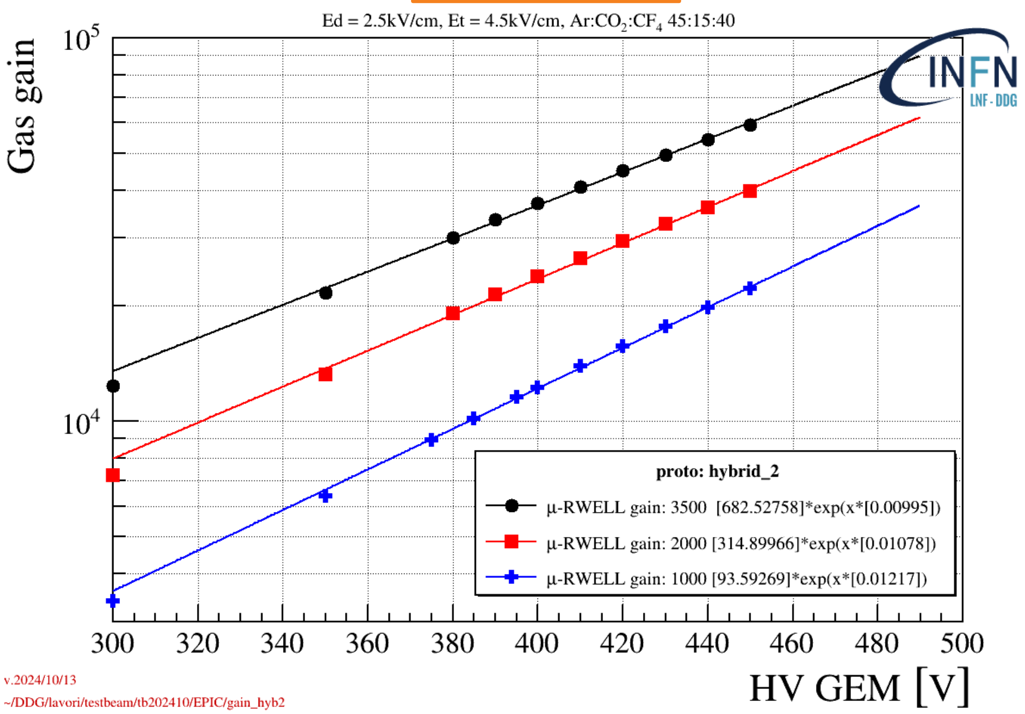


In collaboration with **Rome2 ePIC group**

Gas gain measurement – w/ X-rays

VERY PRELIMINARY: OCT'24





A very stable detector: it doesn't show any hint of instabilities even at **60k.** This measurement has been done before the test beam so there were no reason to stress the detector above 60k.

Gas gain measurement – w/ X-rays

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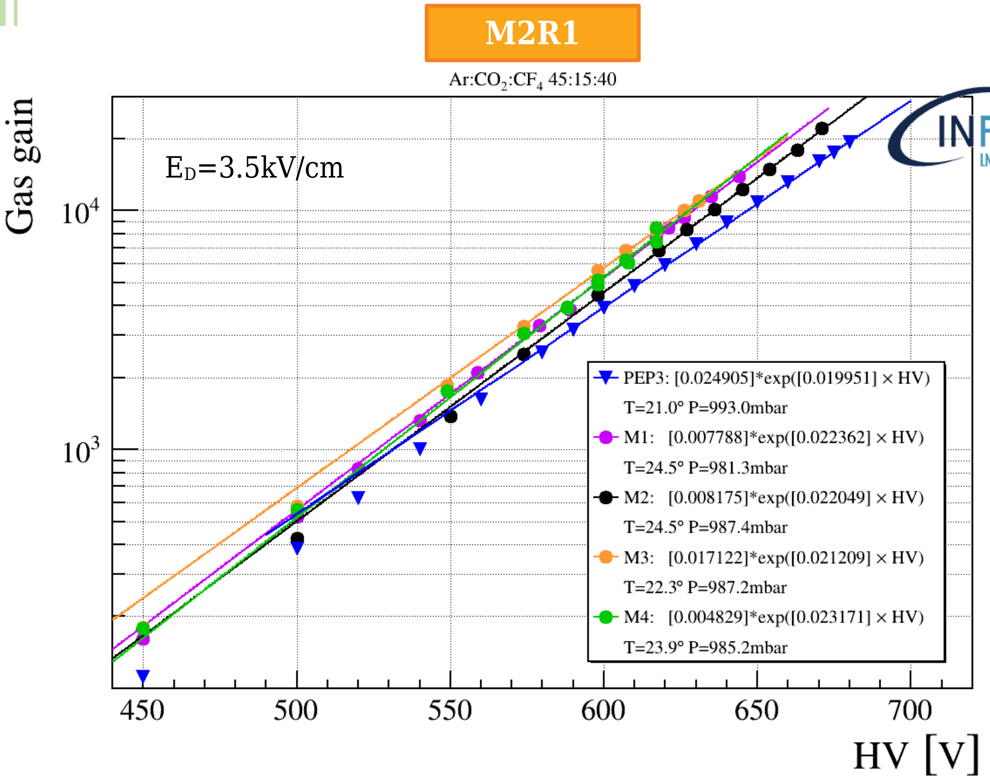
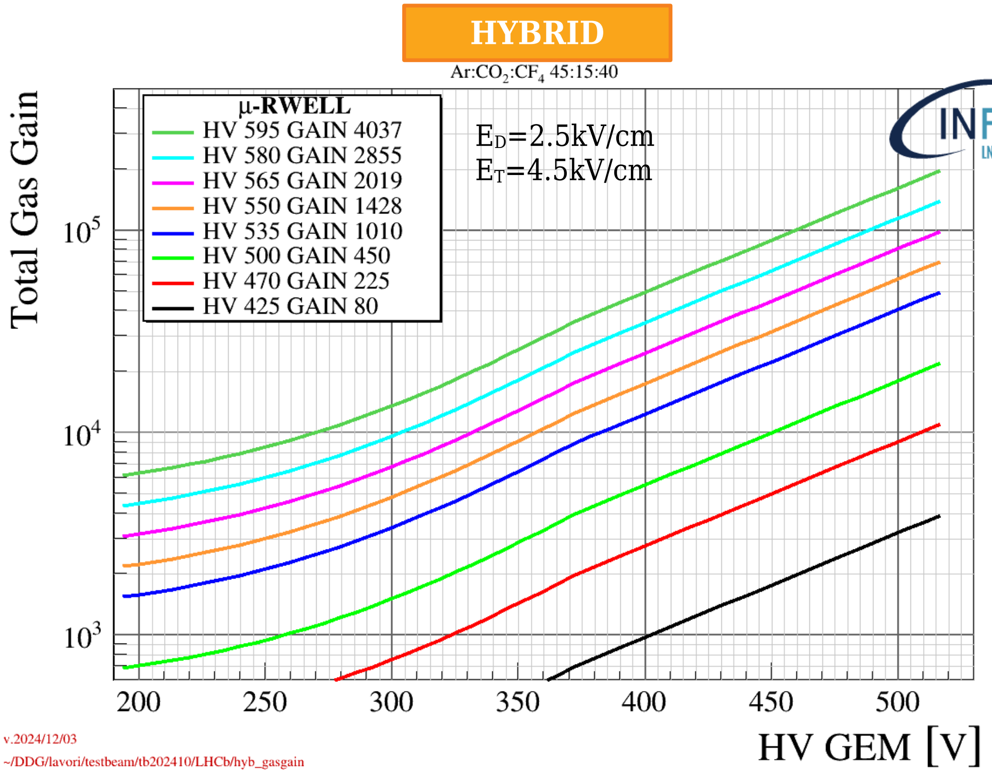
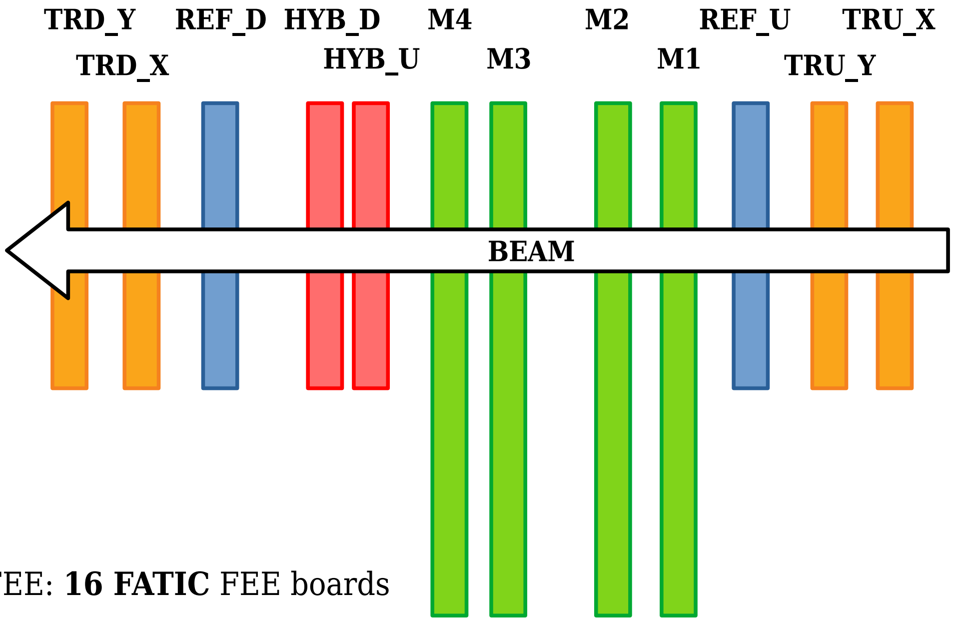




It is possible to **extrapolate** the total gas gain for different WELL HV values. The Hybrid gas gain should be considered **preliminary**. The measurement will be **done again** soon as possible, when the test beam setup will be shipped back.

Test Beam setup

Gas used: $Ar/CO_2/CF_4$ 45/15/40



FEE: **16 FATIC** FEE boards

Trackers: 10×10cm² - 1.2mm strip R/O (Capacitive Sharing)
Reference: 10×10cm² - 9×9mm² pad R/O
HYBRID: 10×10cm² - 9×9mm² pad R/O
M2R1: 30×25cm², instrumented 15×13cm² - 9×9mm² pad R/O

TB area: PS-T10 w/ 5 GeV muons

A special thanks to INFN LNF, Rome2, and Bari LHCb groups for the support during the beam test.

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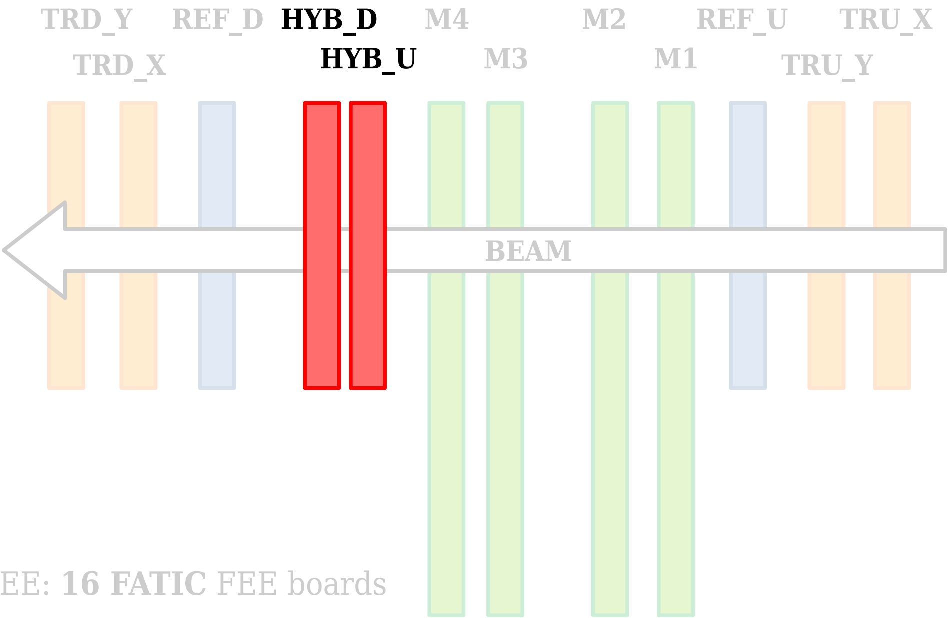
Gas used: Ar/CO_2/CF_4 45/15/40

HYBRID:
GEM+µ-RWELL



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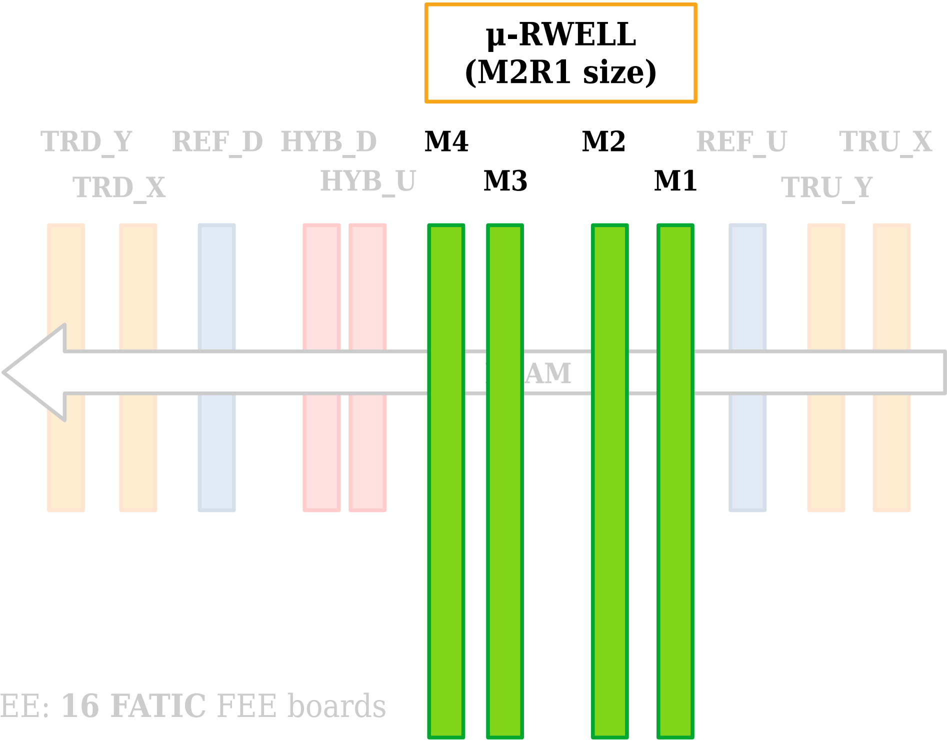

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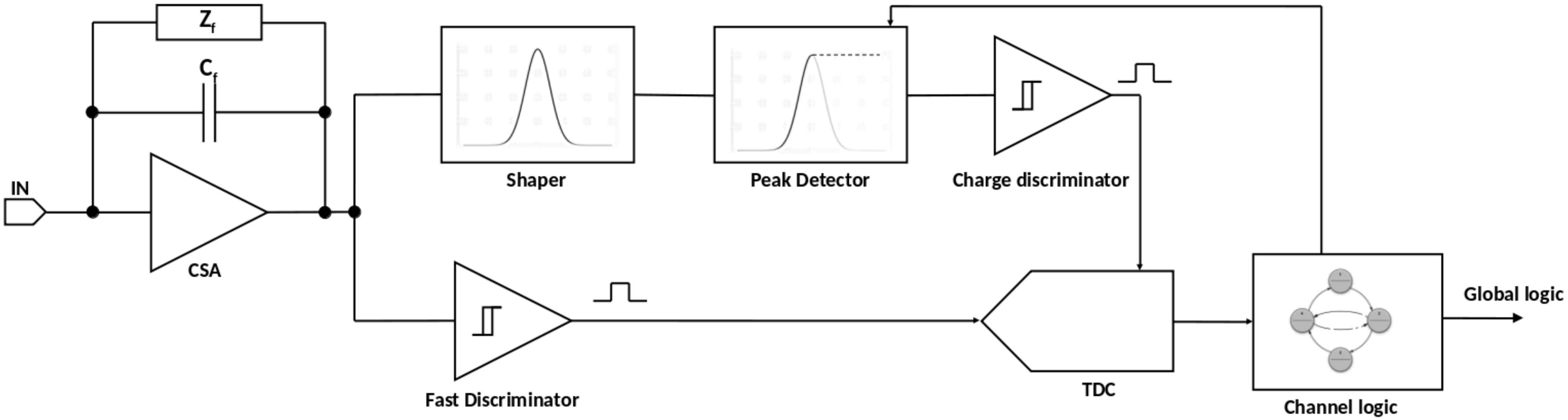
FATIC3 block diagram



Preamplifier features:

- CSA operation mode
- Input signal polarity: positive & negative
- Recovery time: adjustable

CSA mode:

- Programmable Gain: 10 mV/fC ÷ 50 mV/fC
- Peaking time: 25 ns, 50 ns, 75 ns, 100 ns

Timing branch:

- Measures the arrival time of the input signal
- Time jitter: 400 ps @ 1 fC & 15 pF (Fast Timing MPGD)

Charge branch:

- Acknowledgment of the input signal
- Charge measurement: dynamic range > 50 fC, programmable charge resolution

FATIC3 design: CAD group INFN-Bari

Dataset

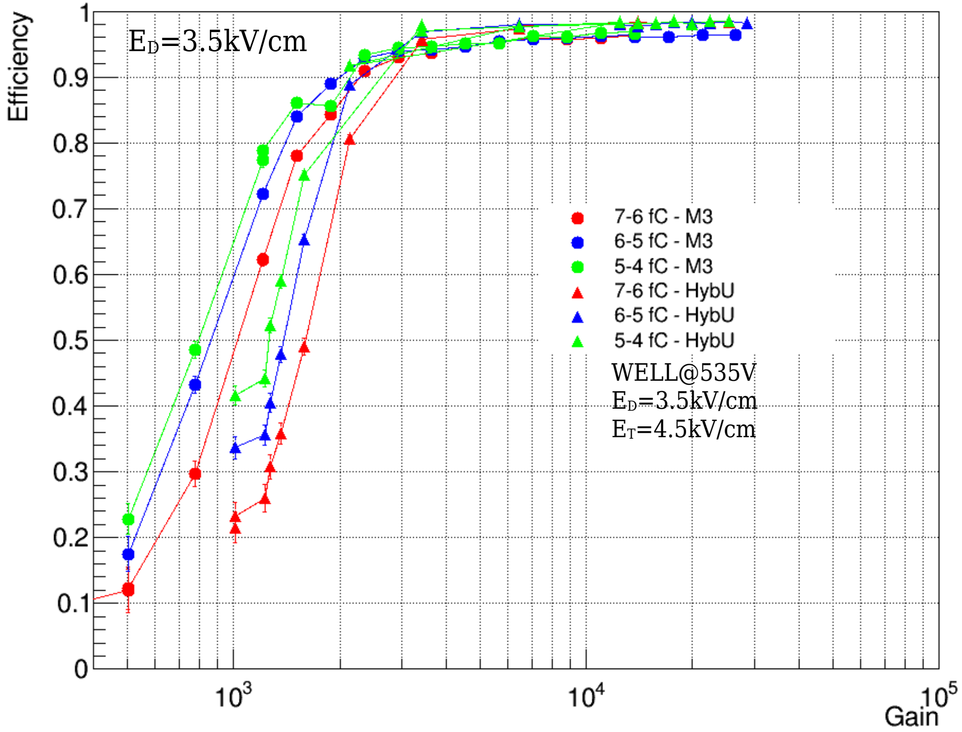
- **HV scan M2R1 e HYB (THR 7/6, 6/5, 5/4 fC)**
  - A single point M2R1 650V, HYB @535/460 @THR = 7/3.5
  - HYB: few points at high gain, **THR 4/3**, WELL@[425, 470, 500, 535, 550], GEM @[460, 480, 500]
- **M2R1 e HYB: Drift scan** M2R1@[650V], HYB@[gem535/well450]
- HYB: Transfer scan [3, 3.5, 4, 4.5, 5, 5.5] WELL @535, GEM @[350, 400, 450]
  - **HYB: Transfer scan [0.5-7.5]** WELL @[470, 500] GEM@460
- HYB: 3mm scan: HV scan @THR6/5 with Ed=0, Et=3.5, simulating an RWELL w/ drift gap 3mm
- Random trigger @ THR 7/6, 6/5, 5/4, 7.5/3
- **M2R1 High statistic run** (200k evt) x radiography
- **HYB: Scan for different WELL HV** – Ed=3.5, Et=4.5
  - WELL @425, GEM @[0-510]
  - WELL @470, GEM @[0-510]
  - WELL @500, GEM @[0-510]
  - WELL @535, GEM @[0-510]
  - WELL @550, GEM @[0-510]
  - WELL @565, GEM @[0-500]

M2R1 vs HYBRID – Efficiency

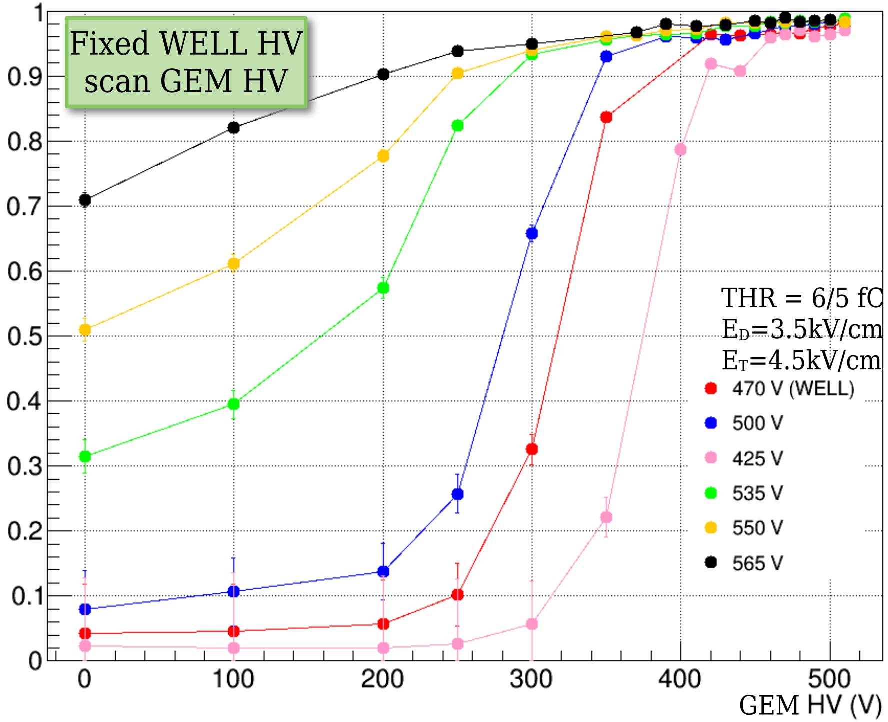
VERY PRELIMINARY: NOV'24

All data: $Ar/CO_2/CF_4$ 45/15/40

M3 vs HYB_U



HYB_U



A plateau >98% is reached for a gas gain above 8000.

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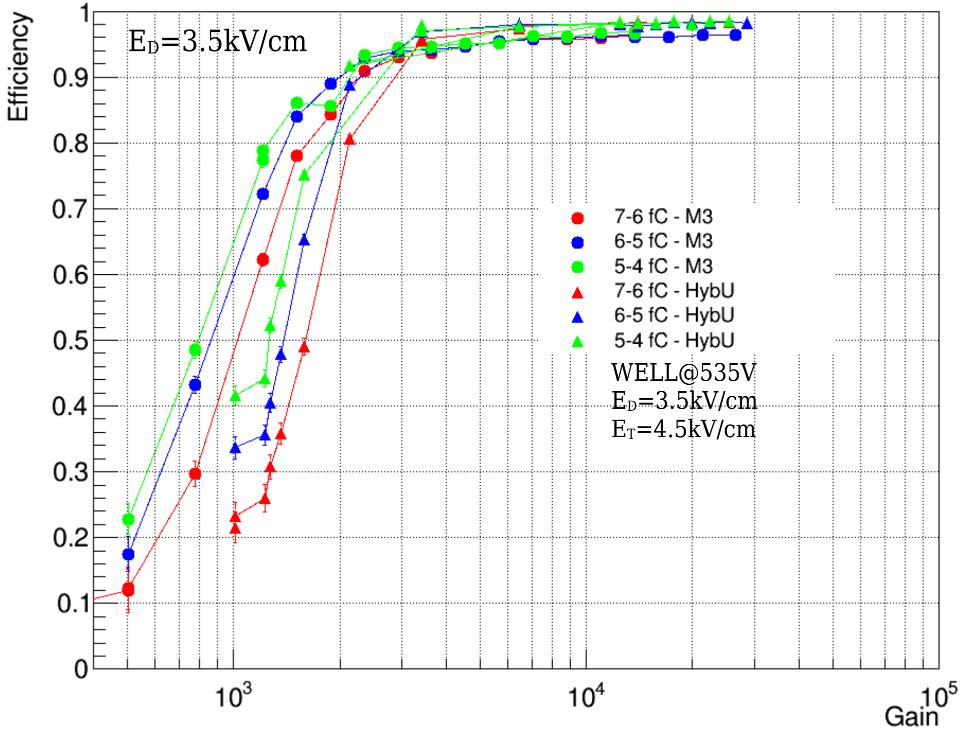
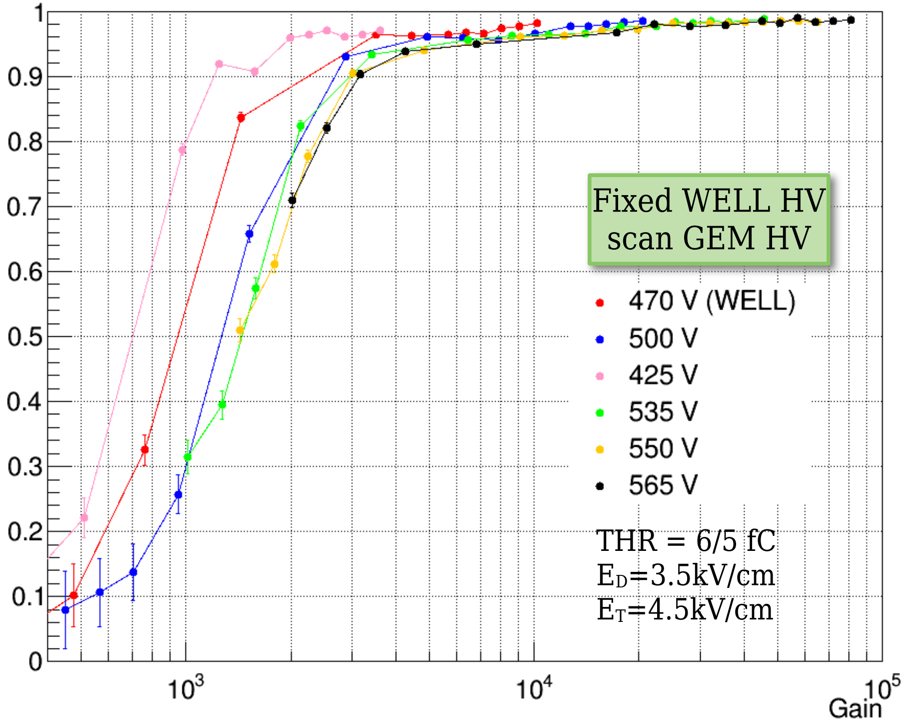


HYB_U

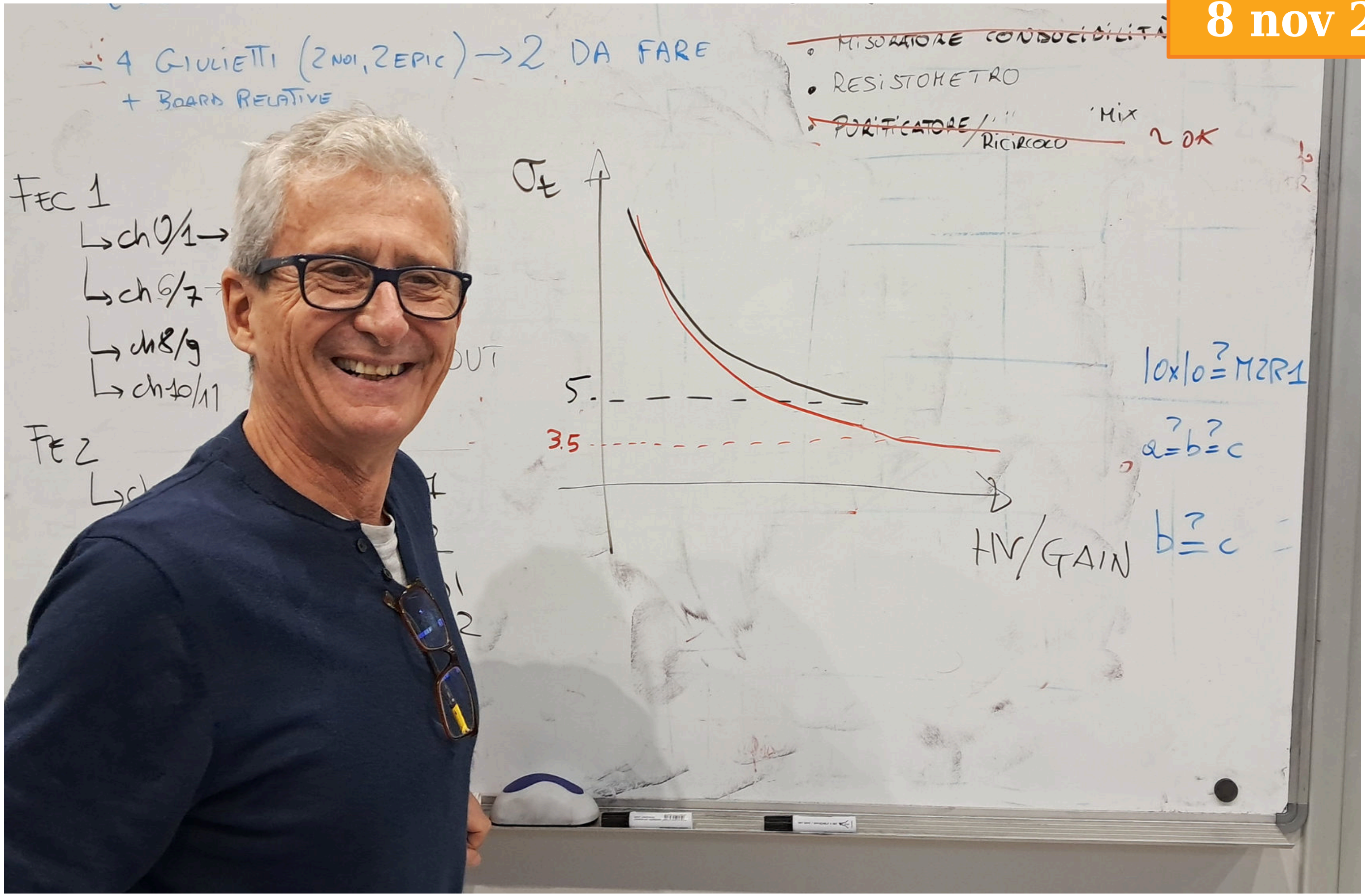


A plateau >98% is reached for a gas gain above 8000.

The gain for **PINK (WELL 425)** and **RED (WELL 470)** is extrapolated, so the curves doesn't overlap likely for this reason.

M2R1 vs HYBRID – Time resolution

8 nov 2024



A **prophecy** by Gianni just before the test:

M2R1 = 5ns
HYB = 3.5ns

M2R1 vs HYBRID – Time resolution

VERY PRELIMINARY: NOV'24

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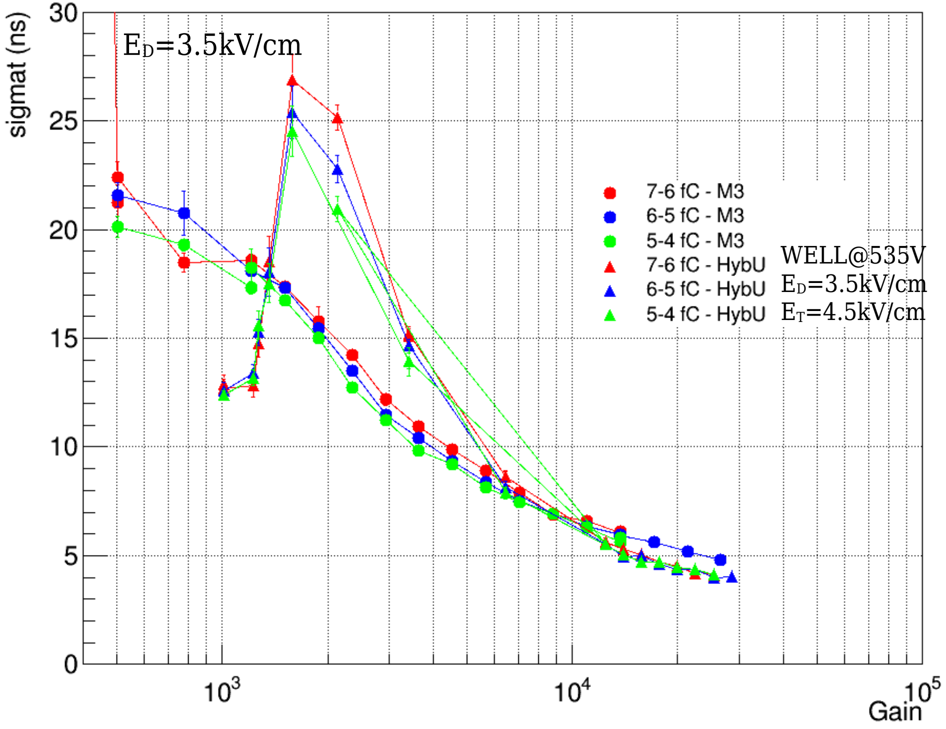
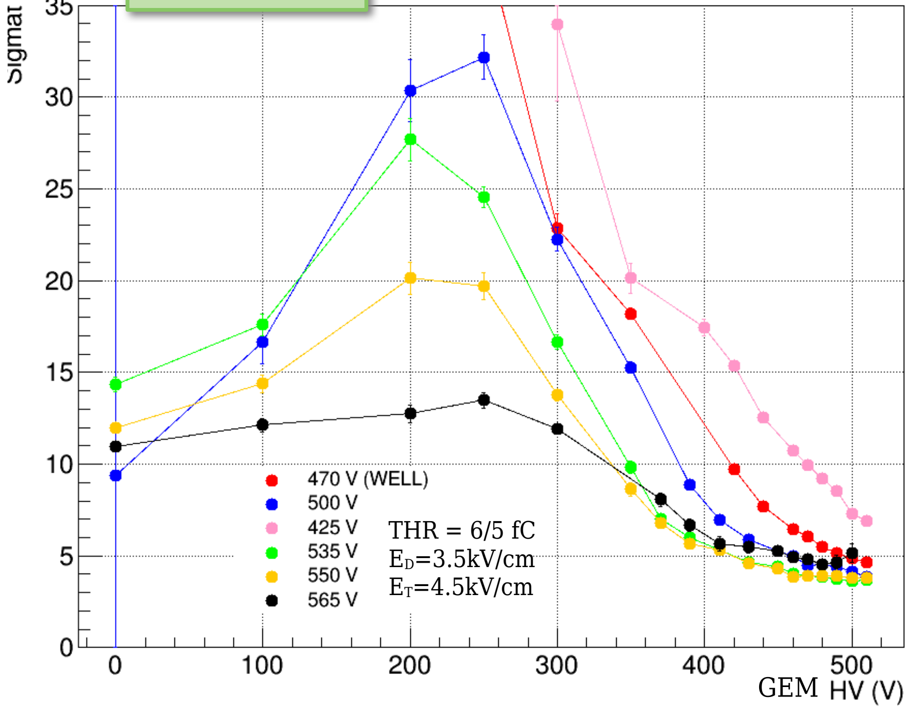


Fixed WELL HV scan GEM HV

HYB_U



Time reference: one of the scintillator of the trigger (σ_t<1ns)

σ_t: gauss fit core of the Δ_t distribution

- Why **HYB** better than **M2R1** at the **same gain**? Maybe a better efficiency on the **first cluster**
- Why the **families** for different HV_WELL? **"Biwell effect"**

M2R1 vs HYBRID – Time resolution

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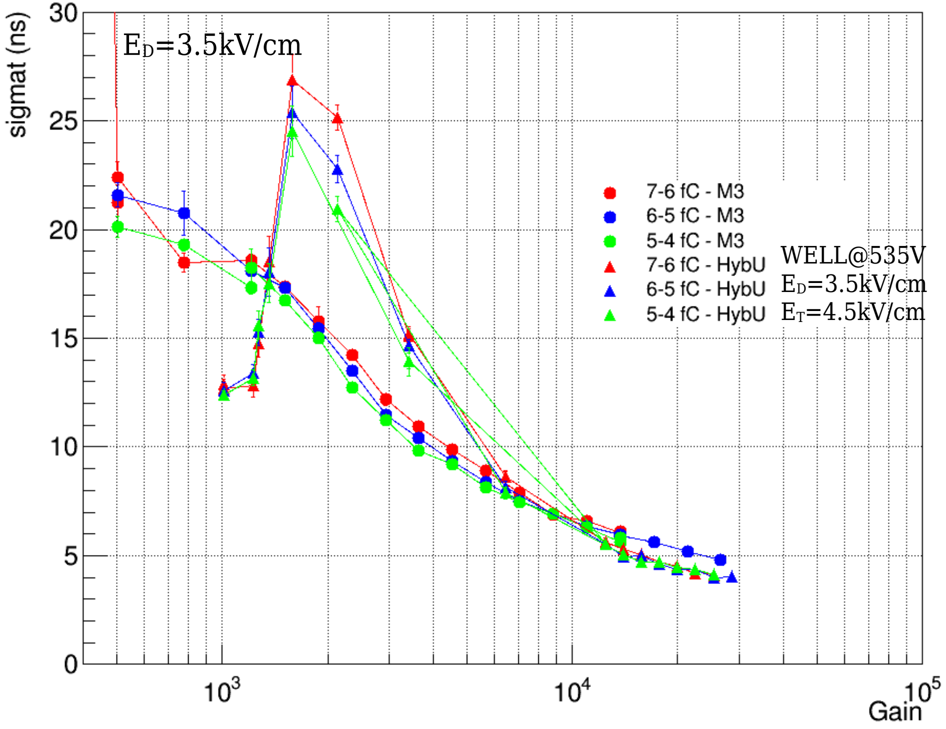
M3 vs HYB_U



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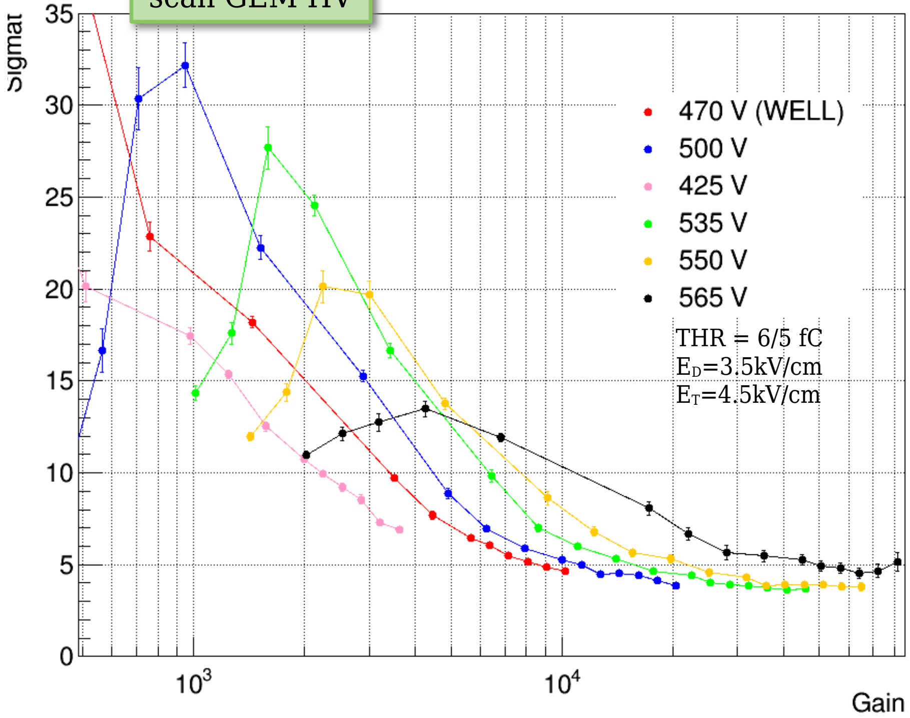
Fixed WELL HV scan GEM HV

HYB_U



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M2R1 vs HYBRID – Time resolution

27 nov 2024

VERY PRELIMINARY: NOV'24

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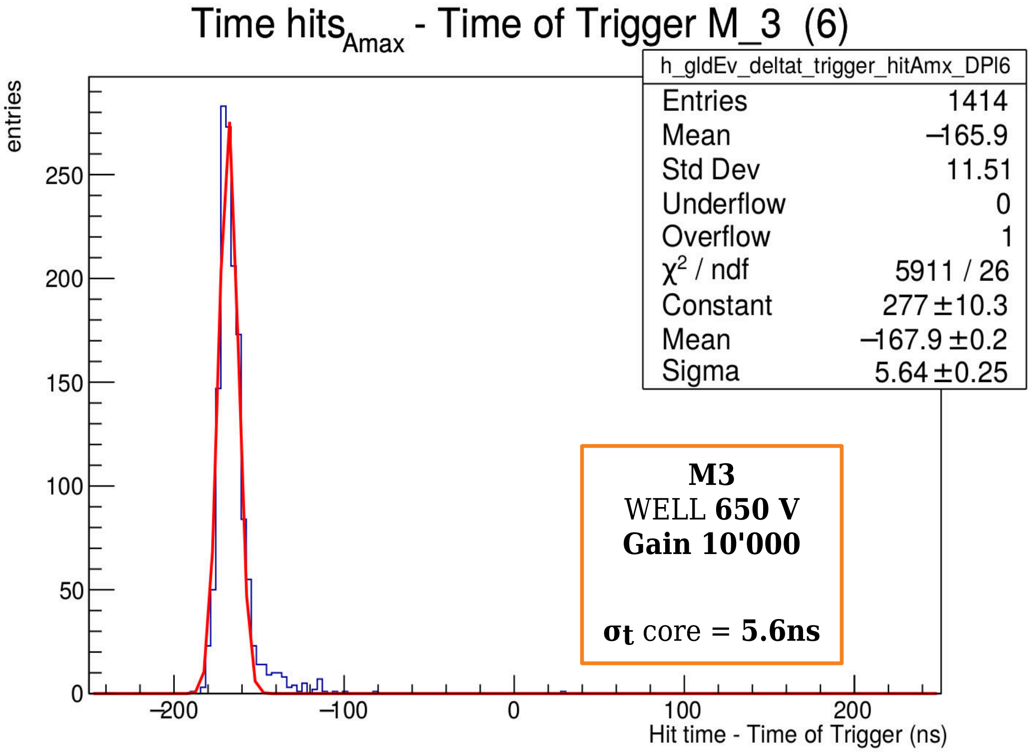
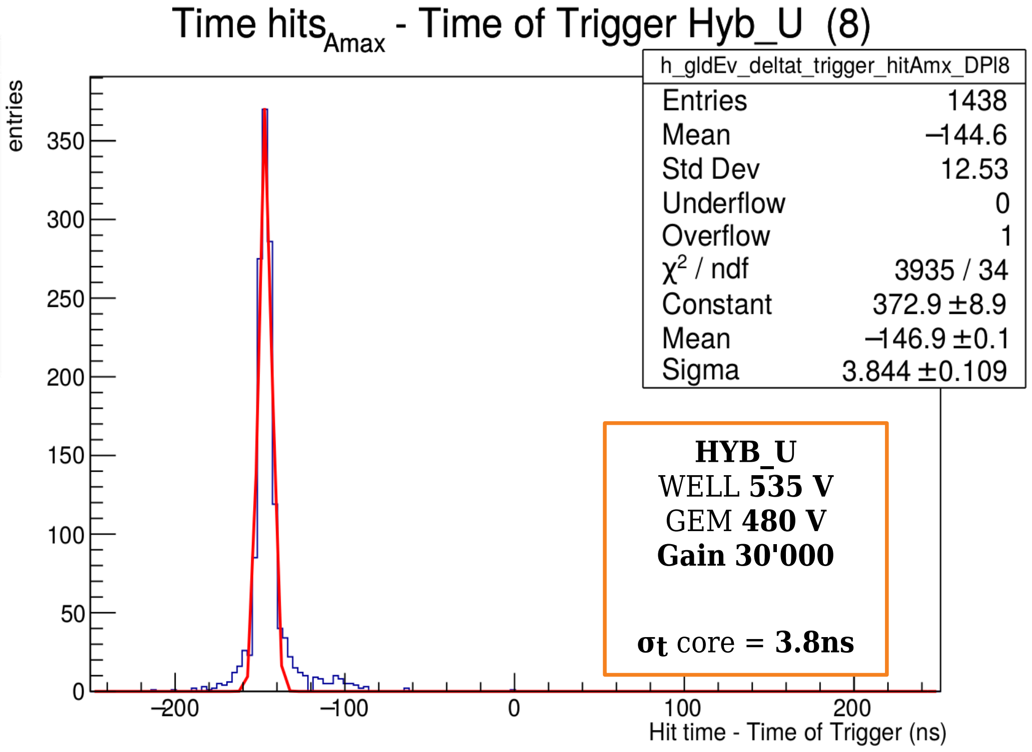


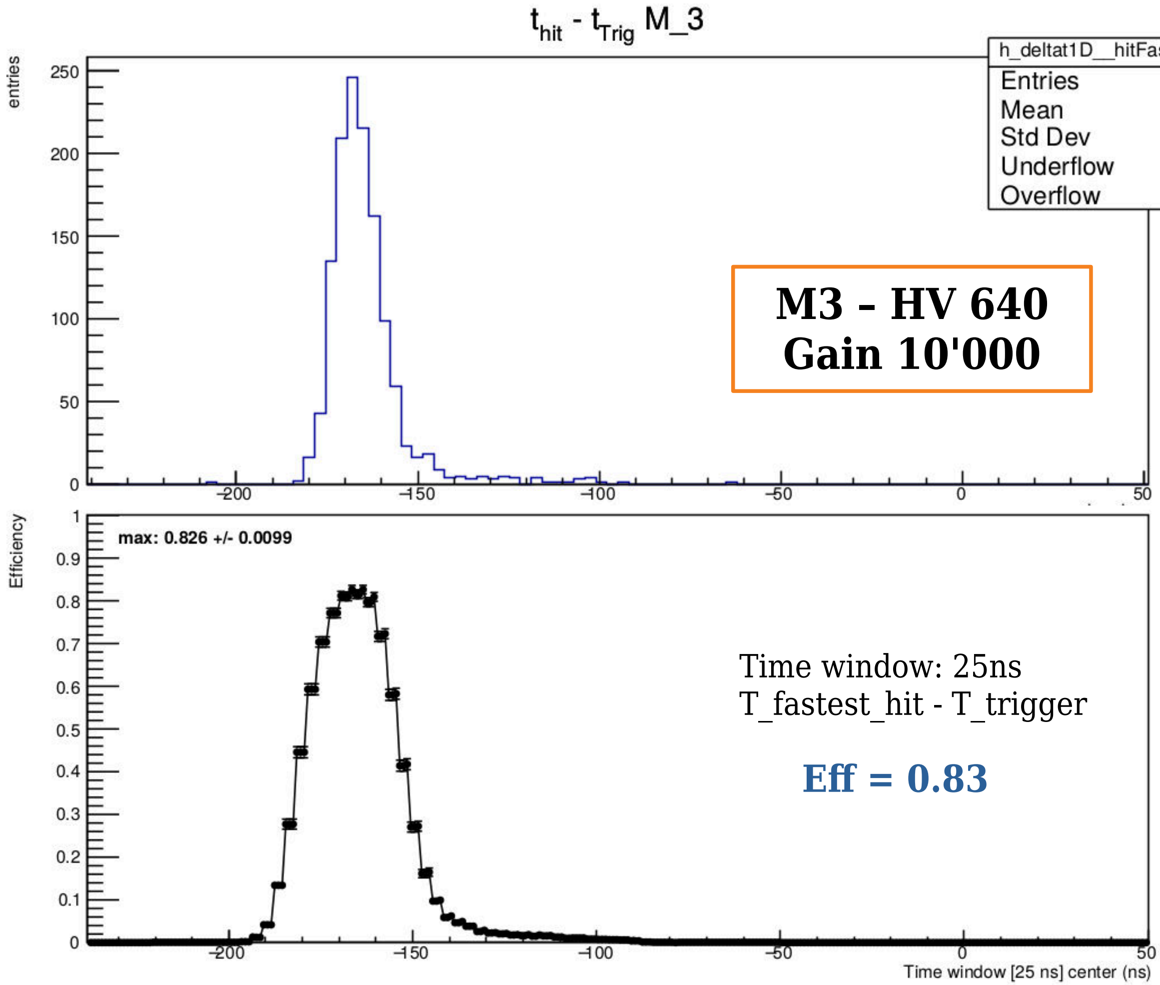


Time reference: one of the scintillator of the trigger (σ_t<1ns)

σ_t: gauss fit core of the Δ_t distribution

M2R1 – Efficiency in 25ns

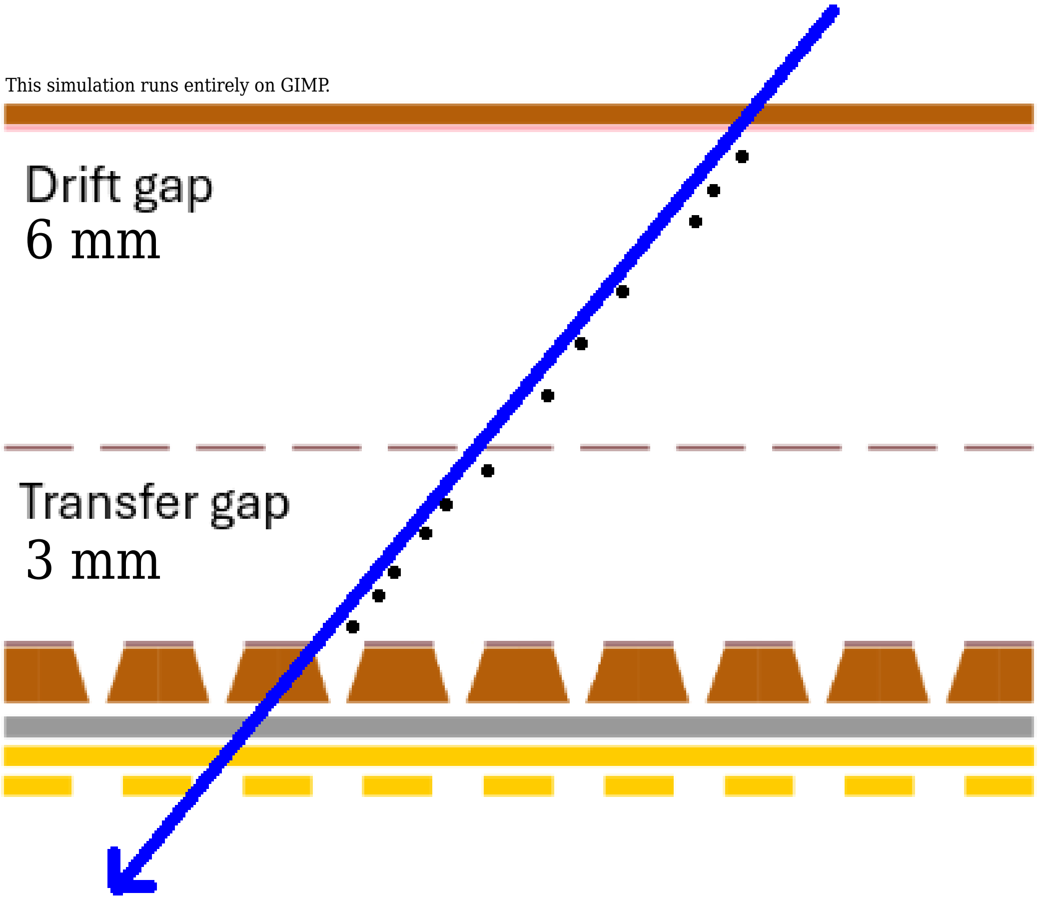
VERY PRELIMINARY: NOV'24



TDC sampling time: 3.125ns.
Window **steps**: 1ns.

Next step: **sync** of the binning and the scan

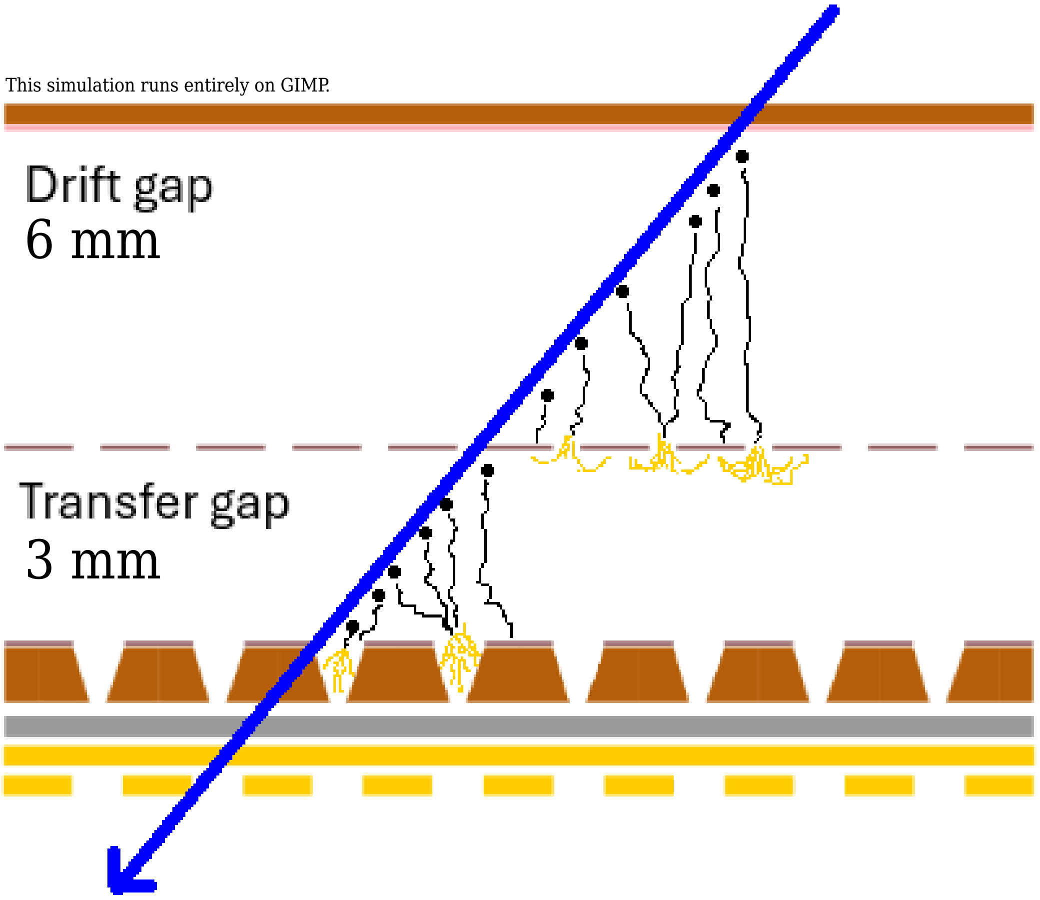
HYBRID – Biwell effect



Ionisation

The particle ionises in both the drift gap and the transfer gap

HYBRID – Biwell effect



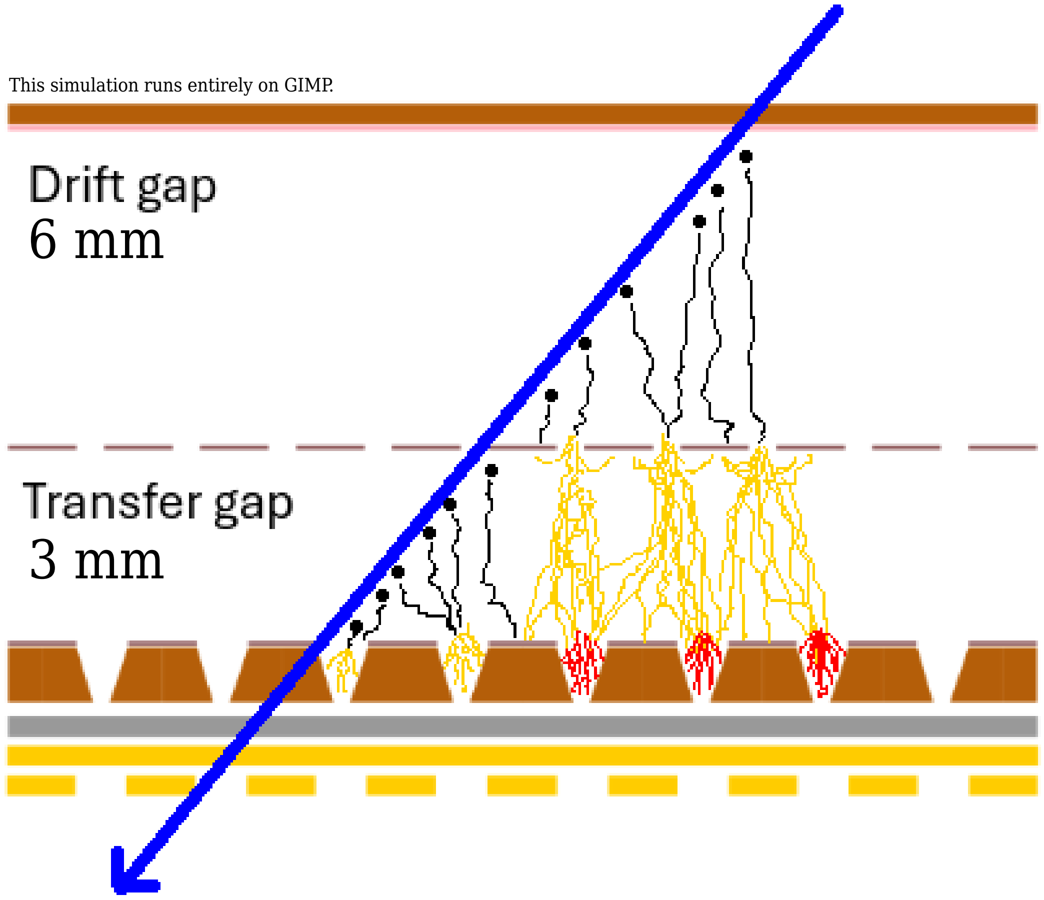
Ionisation

The particle ionises in both the drift gap and the transfer gap

GEM or RWELL

Electron from the drift gap
→ amplified from the **GEM** (gain **20**)
Electrons from the transfer gap
→ amplified by the **WELL** (gain **2000**)

HYBRID – Biwell effect



Ionisation

The particle ionises in both the drift gap and the transfer gap

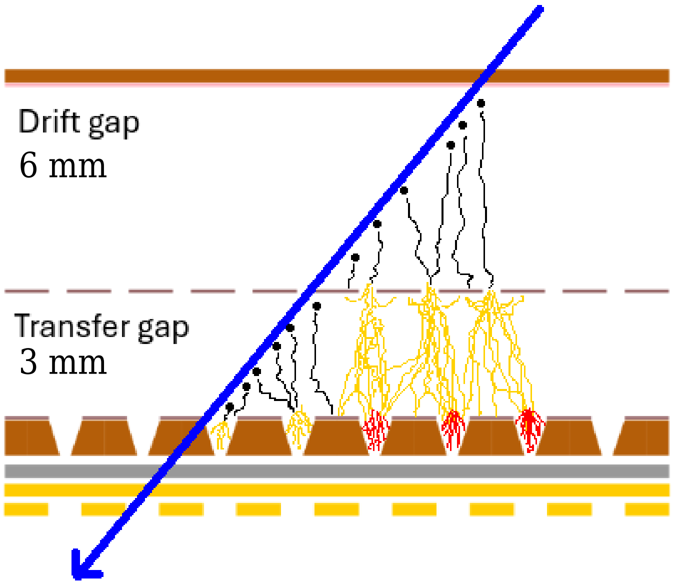
GEM or RWELL

Electron from the drift gap
→ amplified from the **GEM** (gain **20**)
Electrons from the transfer gap
→ amplified by the **WELL** (gain **2000**)

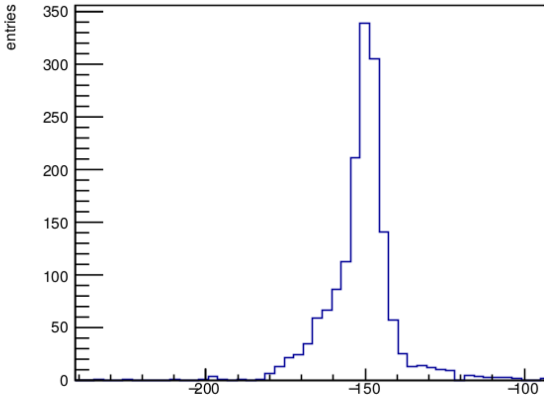
GEM + RWELL

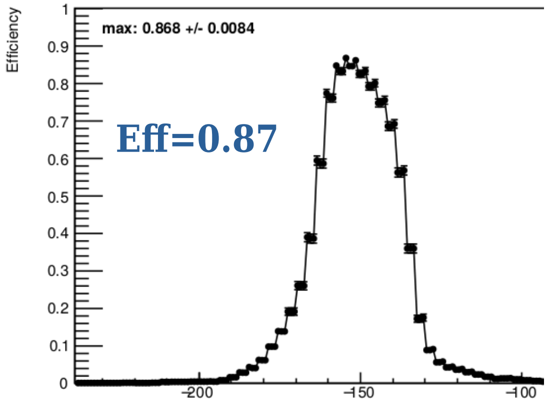
After a drift time in the “Transfer gap”, the electrons preamplified by the GEM reach the RWELL, and get amplified again.
→ **Total gas gain 40'000**

HYBRID – Biwell effect

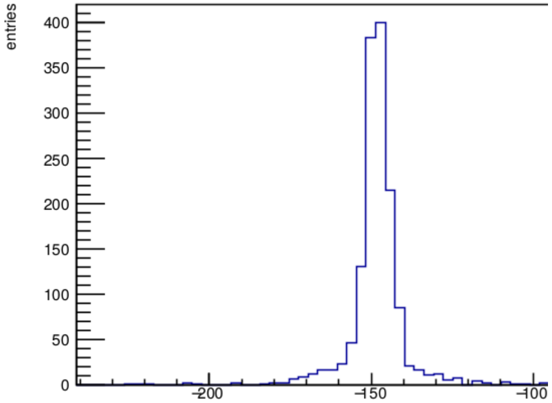


WELL **565** (gain **2000**)
GEM **460** (gain **25**)
Total Gain **50'000**

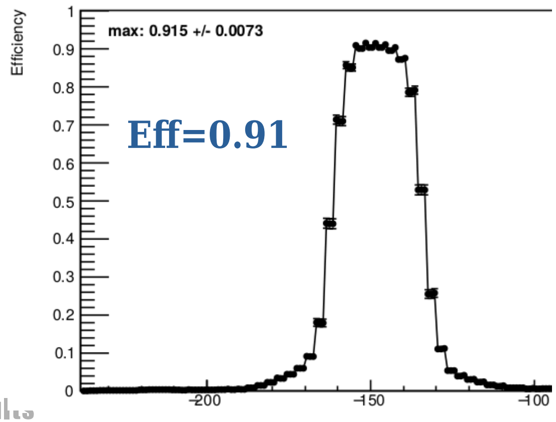




WELL **535** (gain **1000**)
GEM **510** (gain **50**)
Gain **50'000**



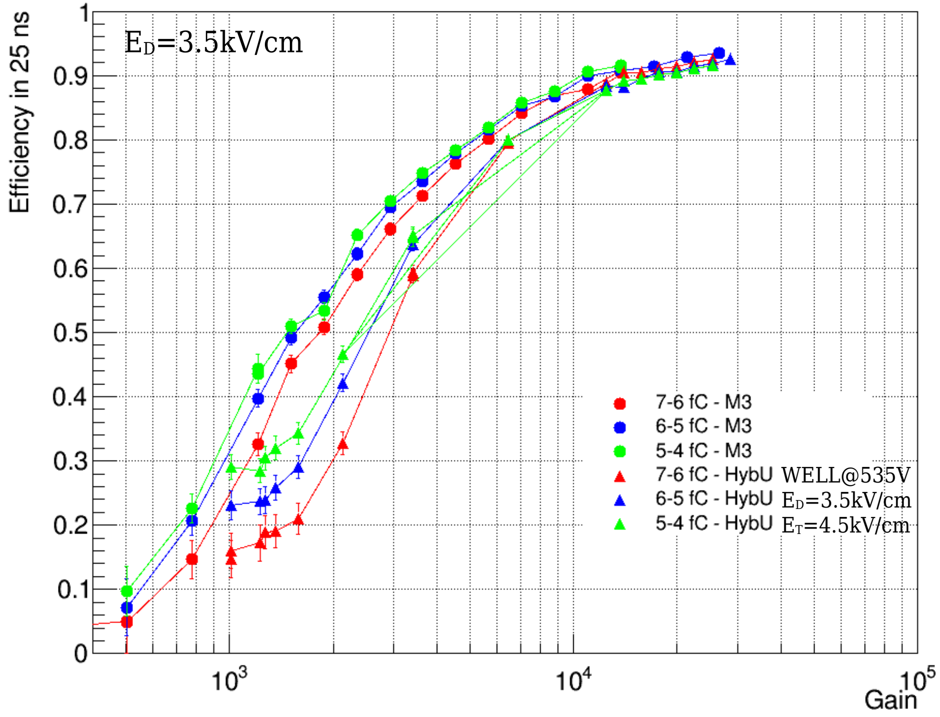
Time window: 25ns
T_fastest_hit - T_trigger



M2R1 vs HYBRID – Efficiency in 25ns

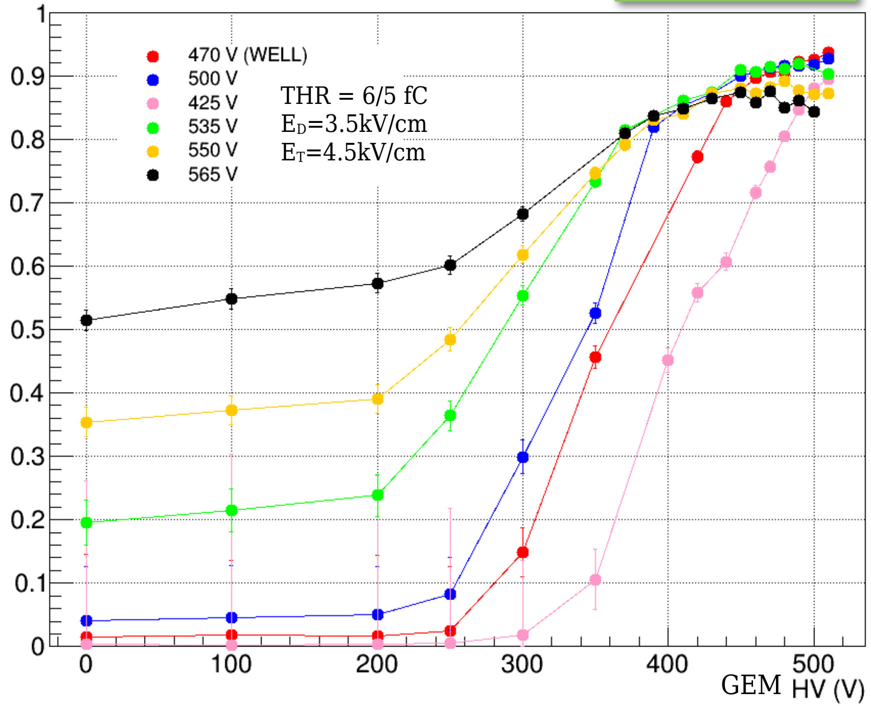
VERY PRELIMINARY: NOV'24

M3 vs HYB_U



HYB_U

Fixed WELL HV scan GEM HV



The fact that the high gain curves have a lower plateau is explained by the **"biwell" effect**. Of course the magnitude of this **effect depends** on the geometry of the detector (the **transfer** field and gap) and the **FEE threshold**.

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VERY PRELIMINARY: NOV'24

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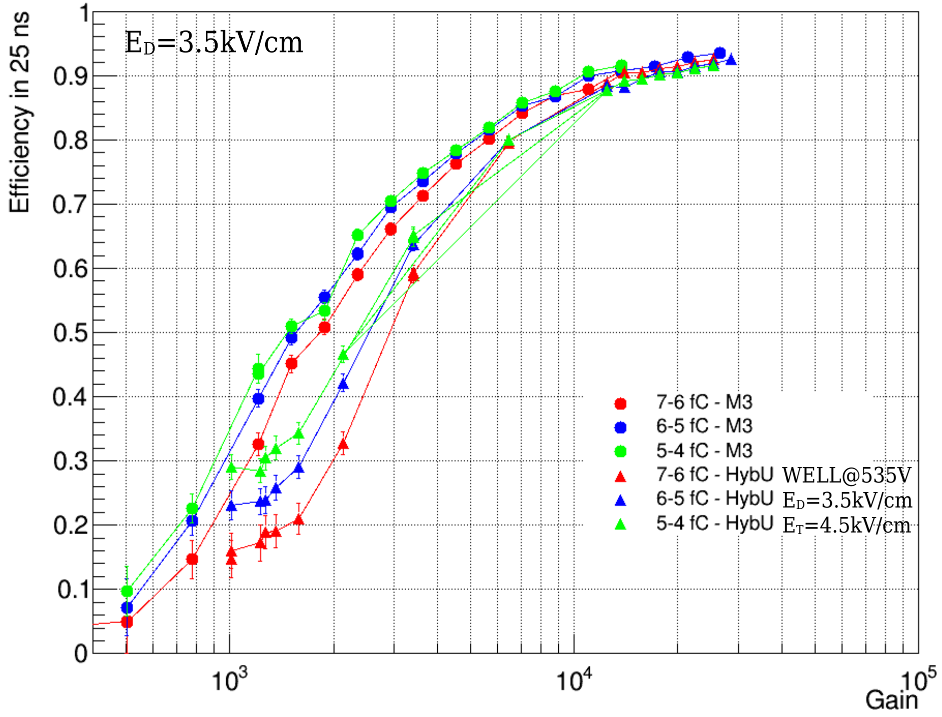
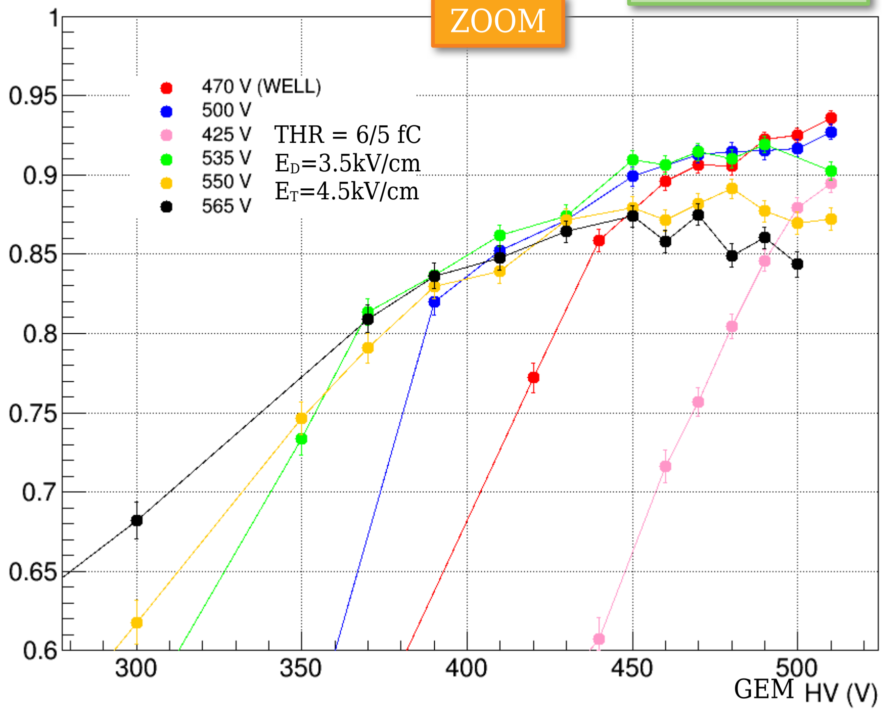


HYB_U

ZOOM

Fixed WELL HV scan GEM HV



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VERY PRELIMINARY: NOV'24

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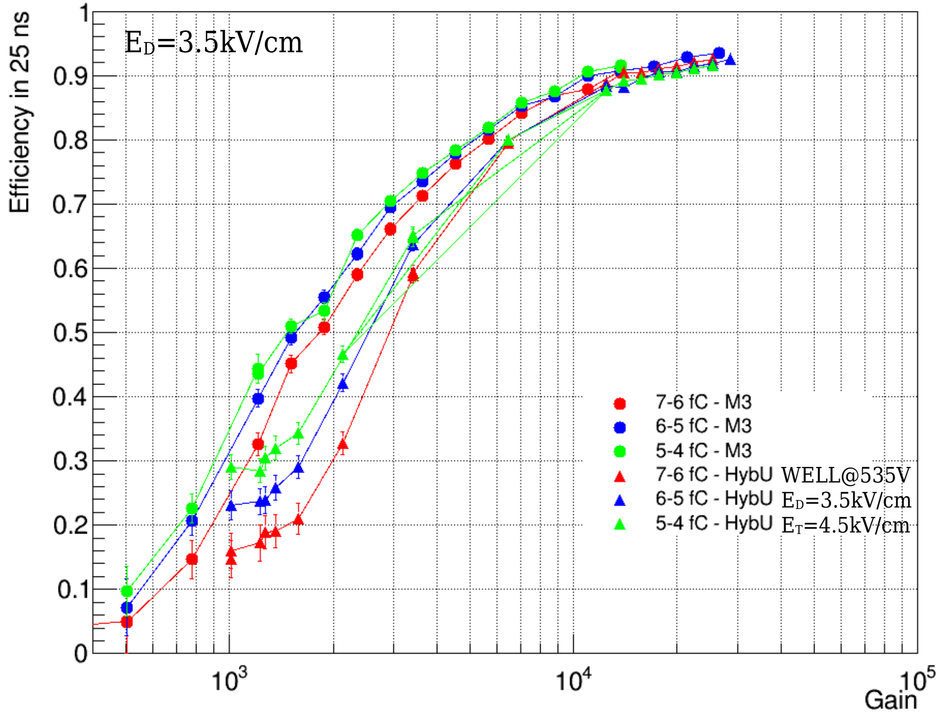
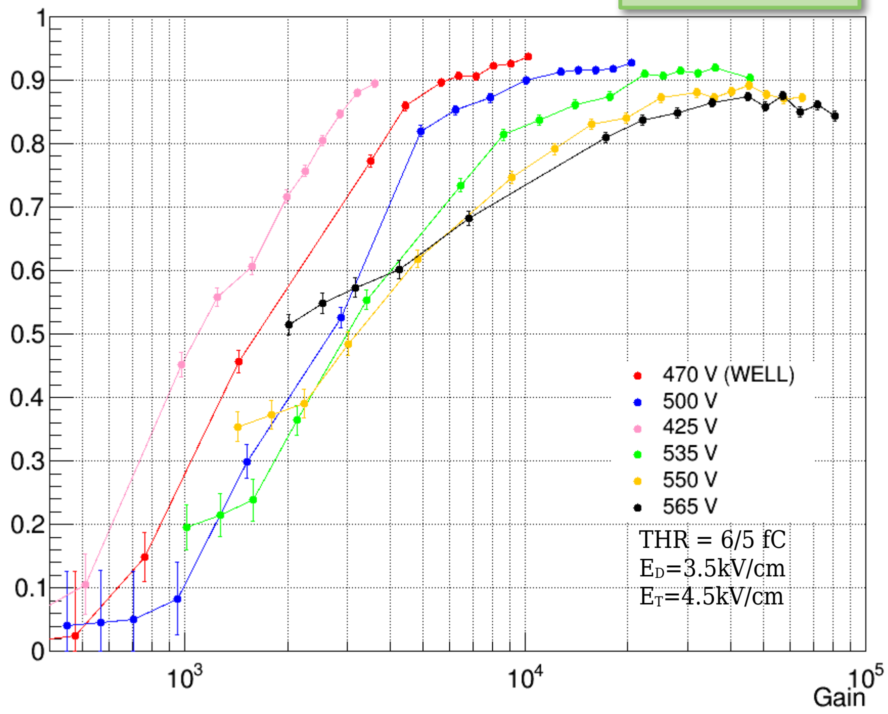


HYB_U

Fixed WELL HV
scan GEM HV



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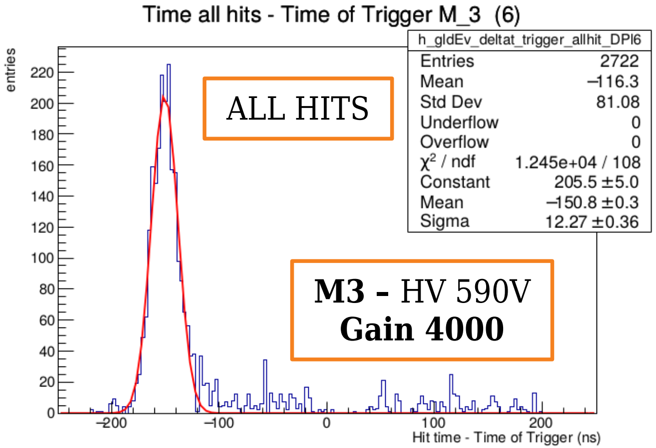
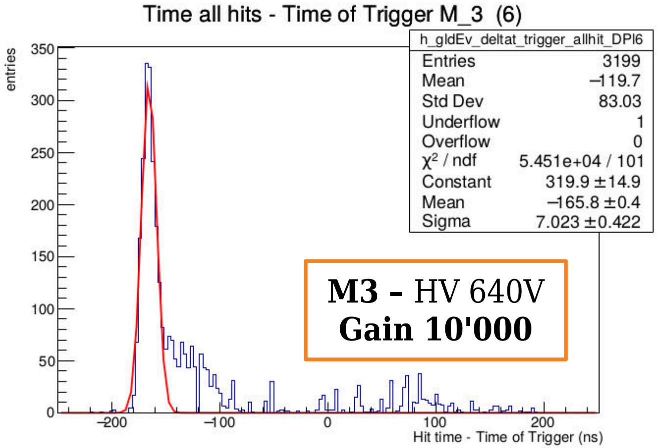
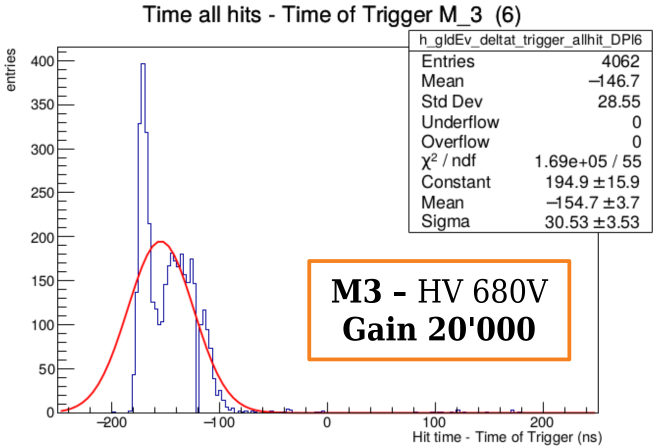
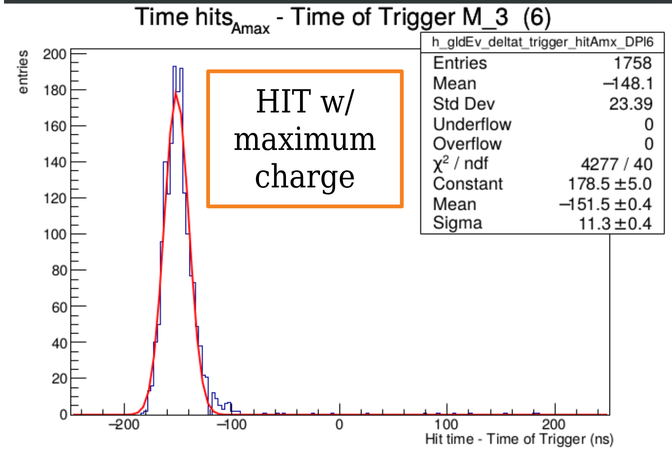
Time of all hits - M2R1

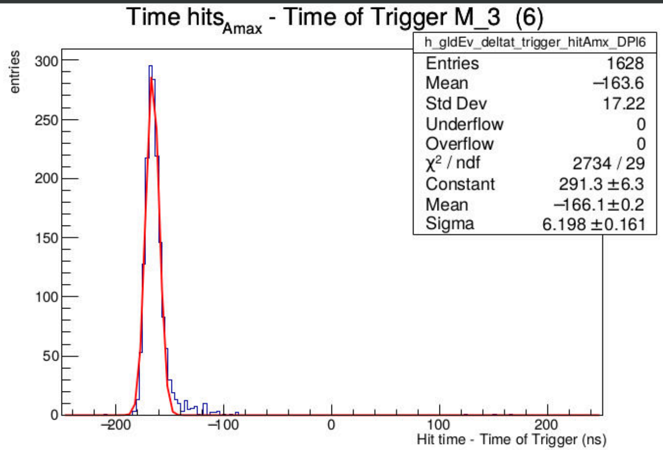
VERY PRELIMINARY: NOV'24

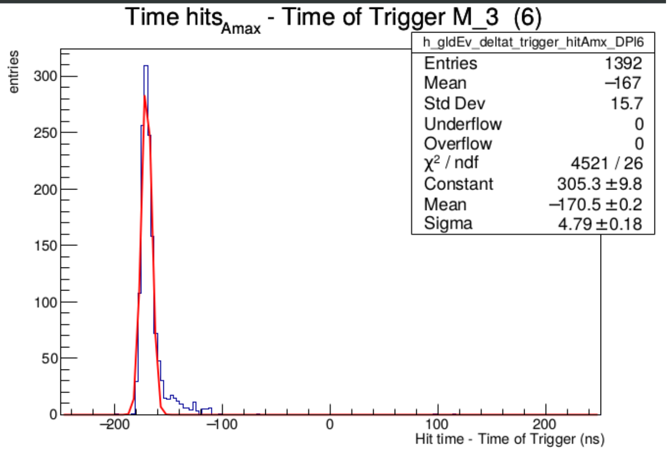






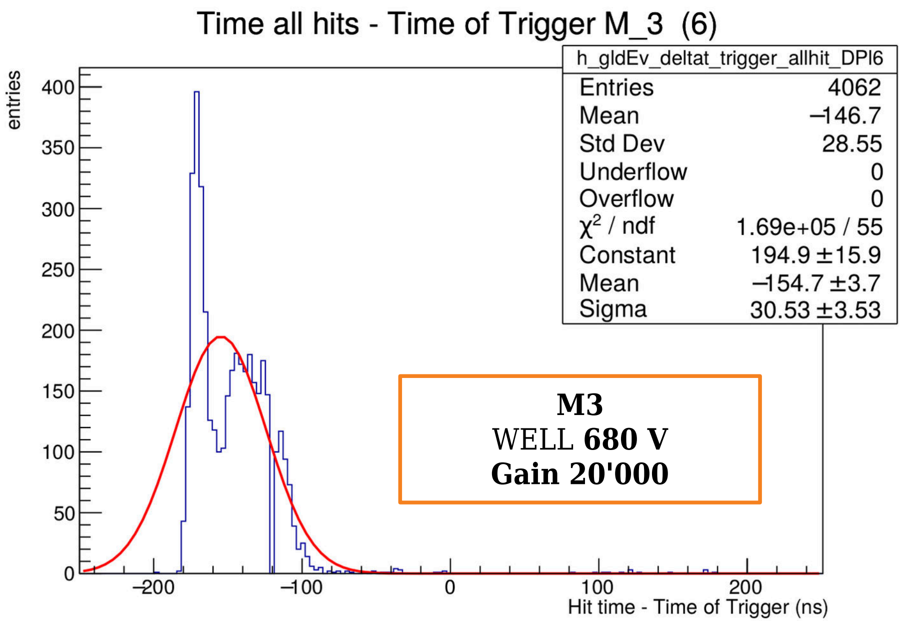


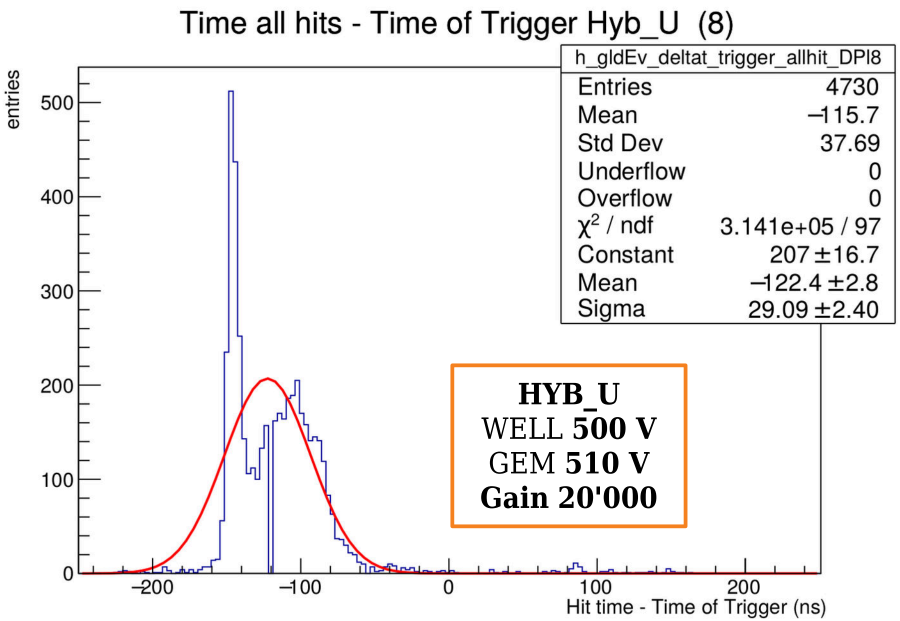




Time of all hits - M2R1 vs HYB

VERY PRELIMINARY: NOV'24





Both M2R1 and Hybrid detectors show this shoulder **@50ns** delay.

This effect is **currently under investigation.** The current hypotesis is that is similar to an effect already seen on M2R1 GEM detectors, solved adding a **blocking capacitor** to the electrode.

Next steps: study the **topology** of the events (dependancy on charge, position, cluster size, 1^{st} and 2^{nd} neighbor pads)

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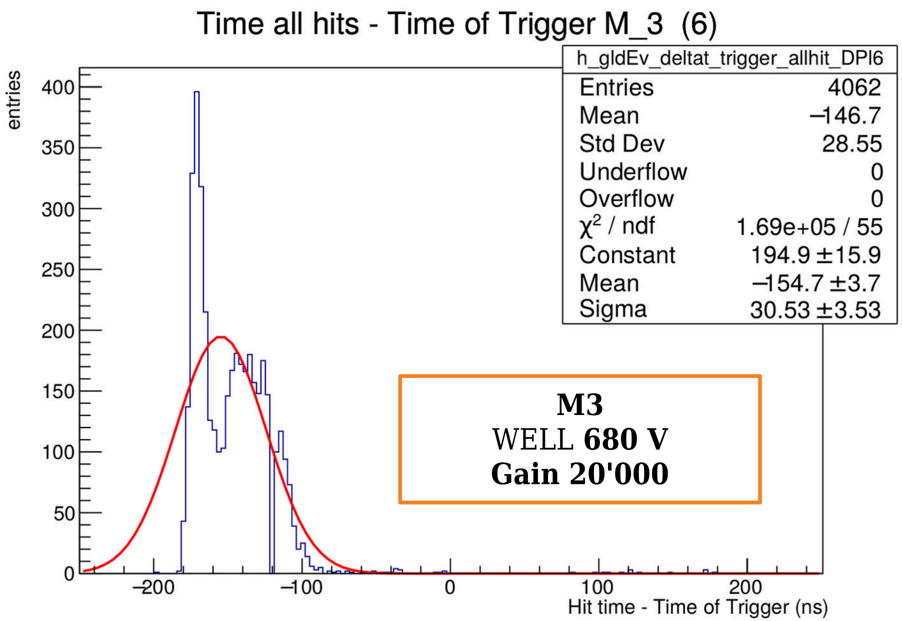
VERY PRELIMINARY: NOV'24



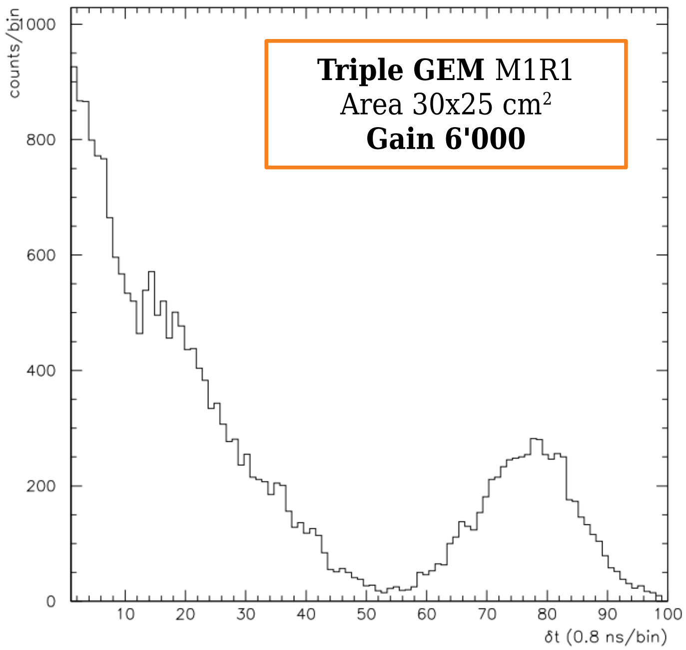


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Fig. 4.14: time difference between fastest hit and each other.

D. Raspino, Ph.D. thesis (2006), *"Il rivelatore a tripla GEM per il sistema di muoni dell'esperimento LHCb"*

Summary

Final **M2R1 size** 30×25cm^2 - 4 µ-RWELL tested:

- @ gas **gain 4000**: efficiency **95%**, **σ_T 10ns**
- **Stable** operation at **gain 10k** (stable), maximum gain above 20k (some instabilities)

While good for every day use, the LHCB requirement is the efficiency in a 25ns time window:
→ for a **µ-RWELL: eff 25ns >90% @ gas gain >10k**

Test of **HYBRID GEM+µ-RWELL** 10x10cm^2: large gain (up to 90k) and very stable operation

- **Efficiency comparable** to a µ-RWELL, for same gas gain
- **σ_T** slightly better (under investigation, maybe due to the fact that there are two ampl. Stages)
  - Best result: **σ_T = 3.8ns** (core) for **gain 30'000**, **GEM=480V**, **WELL=535V**, Ed=3.5kV/cm, Et=4.5kV/cm
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Beam test nov'24: **HYBRID µ-RWELL** tested for **timing** (us) and for **2D tracking** (CC and uTPC) (Epic group).

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TB analysis ongoing:

- study of the **"Biwell effect"**
- **Tracking implementation** for studying the PEP-DOT area and pad-pad crosstalk effects
- Drift scan and Transfer scan analysis

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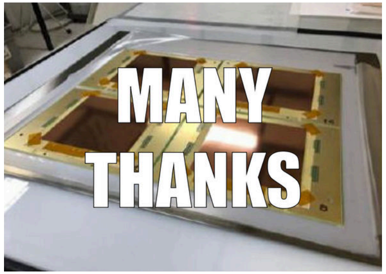
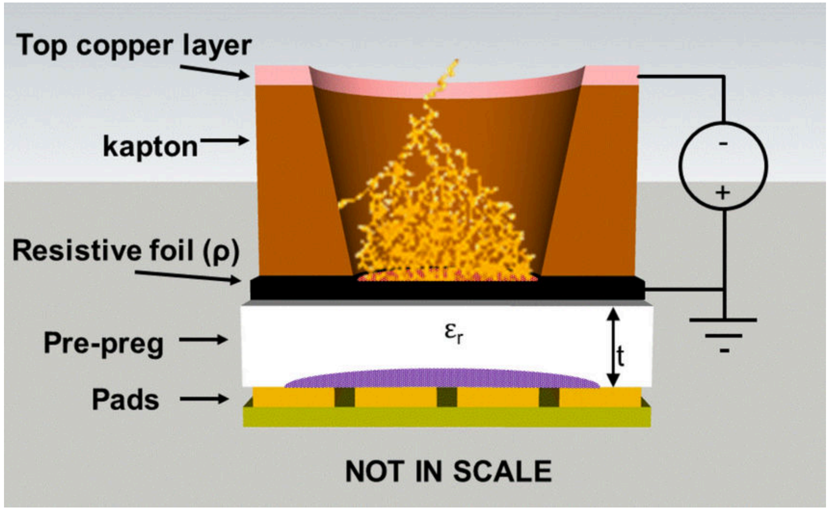


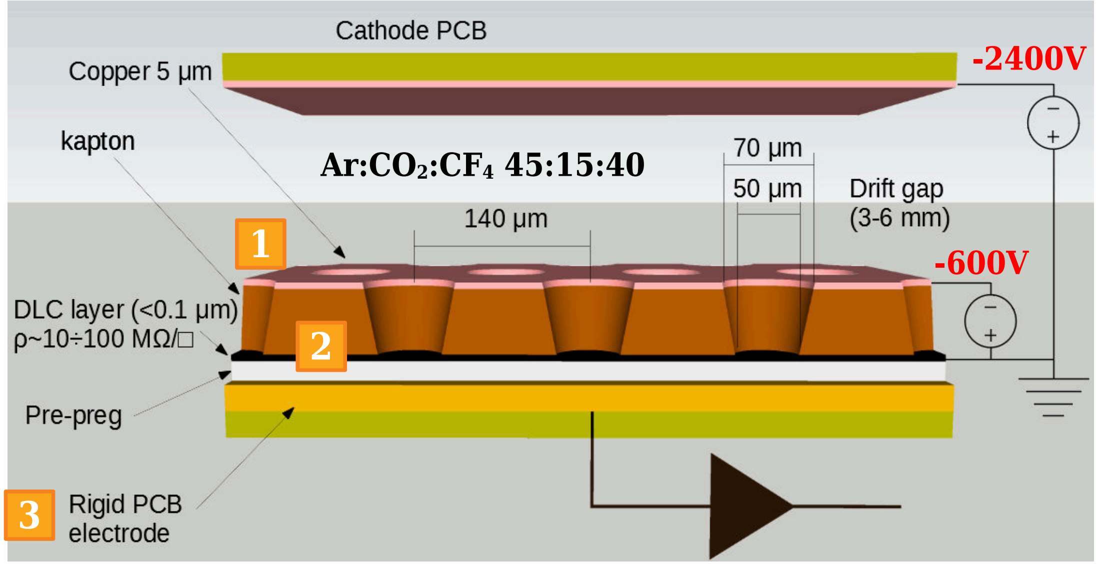
Spare

The µ-RWELL: detector scheme

The µ-RWELL is a Micro Pattern Gaseous Detector (MPGD) composed of only two elements: the µ-RWELL_PCB and the cathode. **The core is the µ-RWELL_PCB**, realized by coupling three different elements:



Applying a suitable voltage between the **top Cu-layer and the DLC** the WELL acts as a **multiplication channel for the ionization** produced in the conversion/drift gas gap.



1 **a WELL** patterned kapton foil acting as **amplification stage** (GEM-like)

2 a **resistive DLC layer (Diamond-Like-Carbon)** for discharge suppression with surface resistivity ~ 50÷100 MΩ/□

3 a standard readout PCB

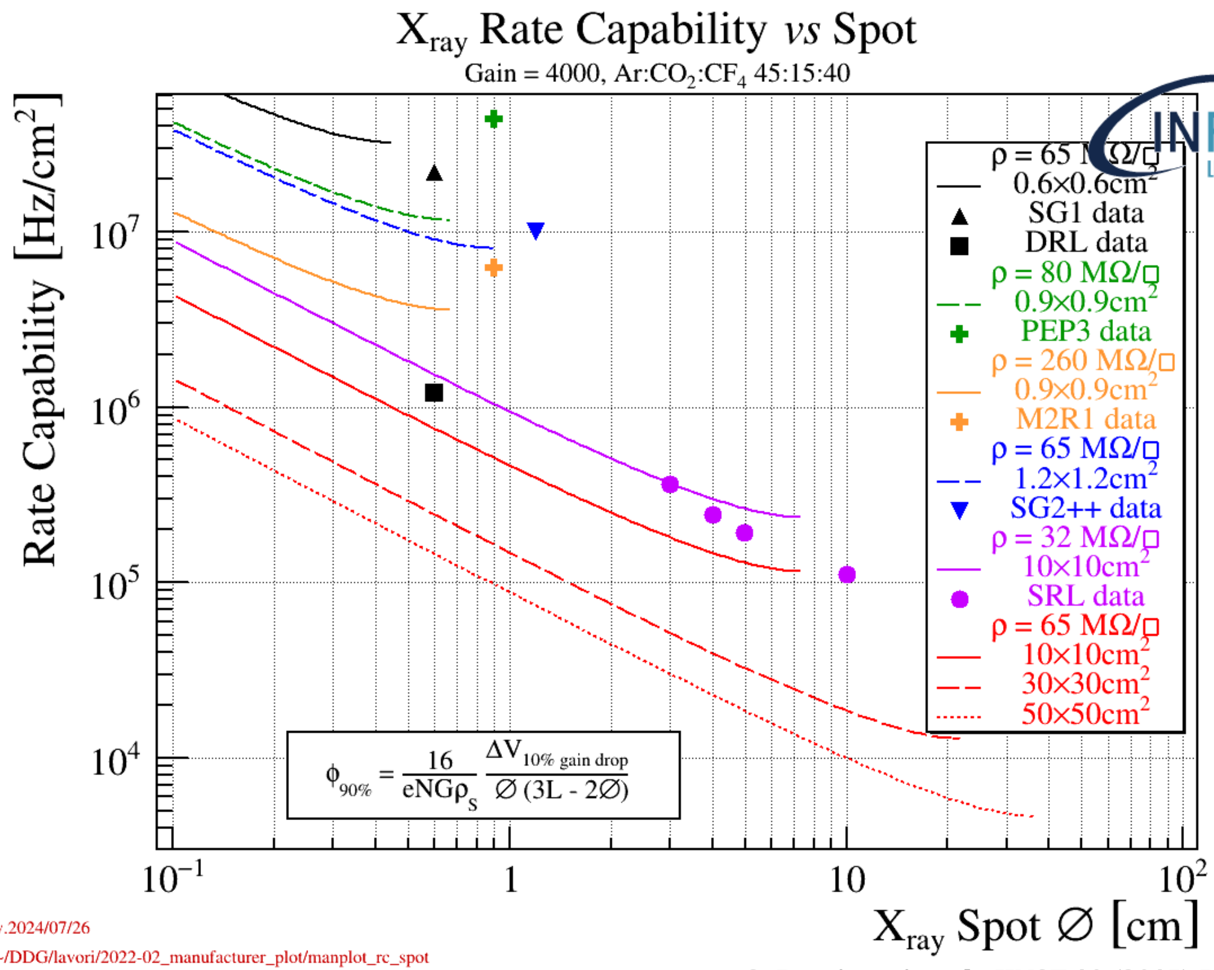
Rate capability vs spot-size & detector size

Comparison between a **model** of the resistive stage and **measurements** of the rate capability for SRL.

1. detectors with same size (d) but different resistivity exhibit a rate capability scaling as the inverse of their resistivity.

2. for the SRL, increasing the active area from 10x10 cm2 to 50x50 cm2 the rate capability should go down few kHz/cm^2.

3. By using a **DLC** ground **sectoring every 10 cm**, large (50x50cm2) detectors could achieve **rate capability up to 100kHz/cm²** (with X-ray).



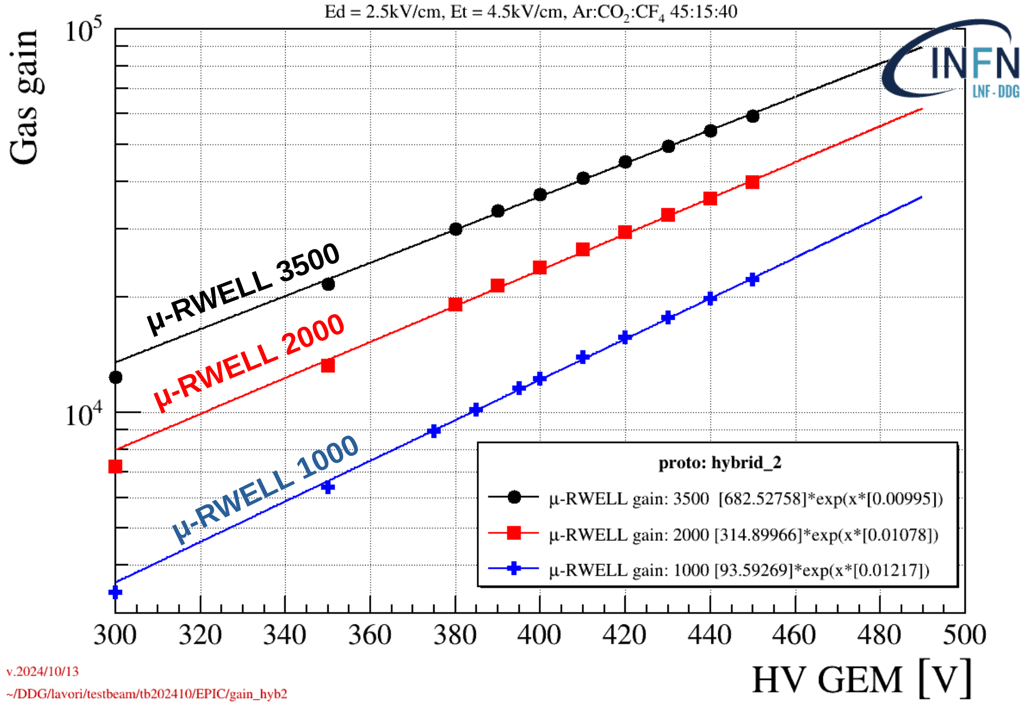
G. Bencivenni et al., JINST 10 (2015) P02008

Different primary ionization ⇒ Rate Cap.$_{m.i.p.}$ = 3×Rate Cap.$_{X\text{-}ray}$

μ-RWELL + GEM – gas gain

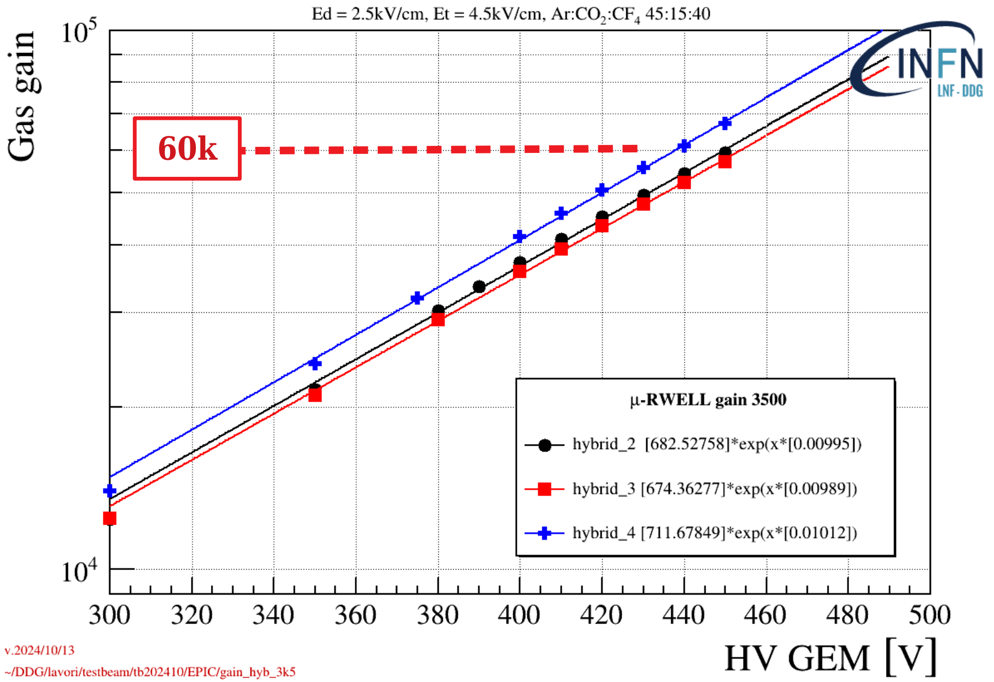
VERY PRELIMINARY: OCT'24

3 different gains for the μ-RWELL



3 different detectors

μ-RWELL gain @ 3500



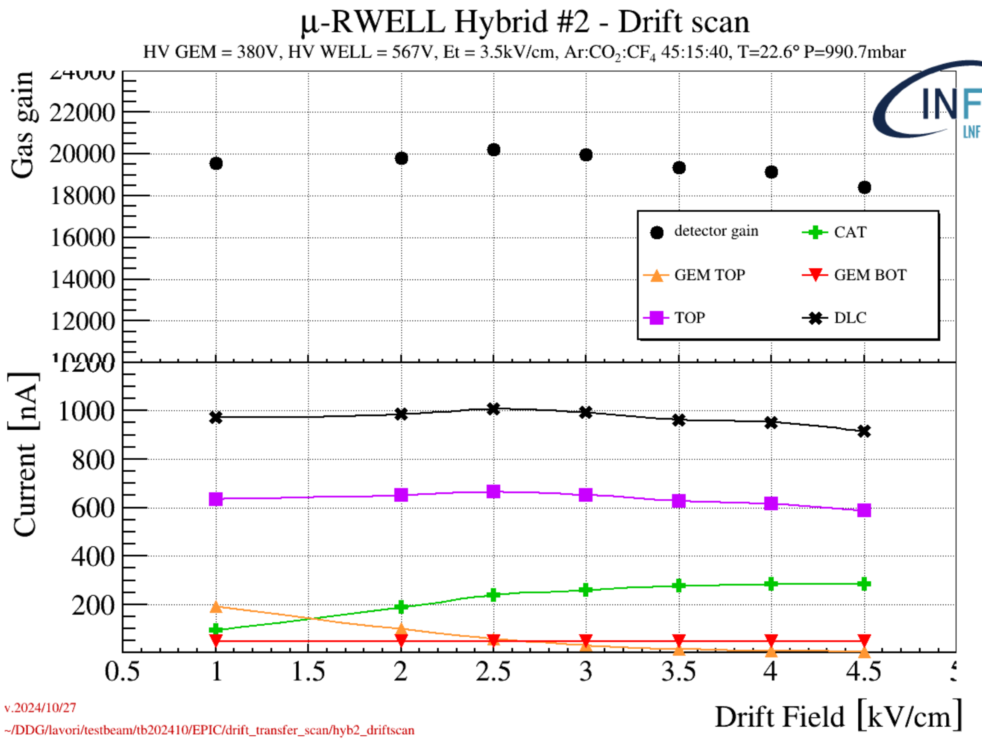
GEM gain @ 450V ≈ 20

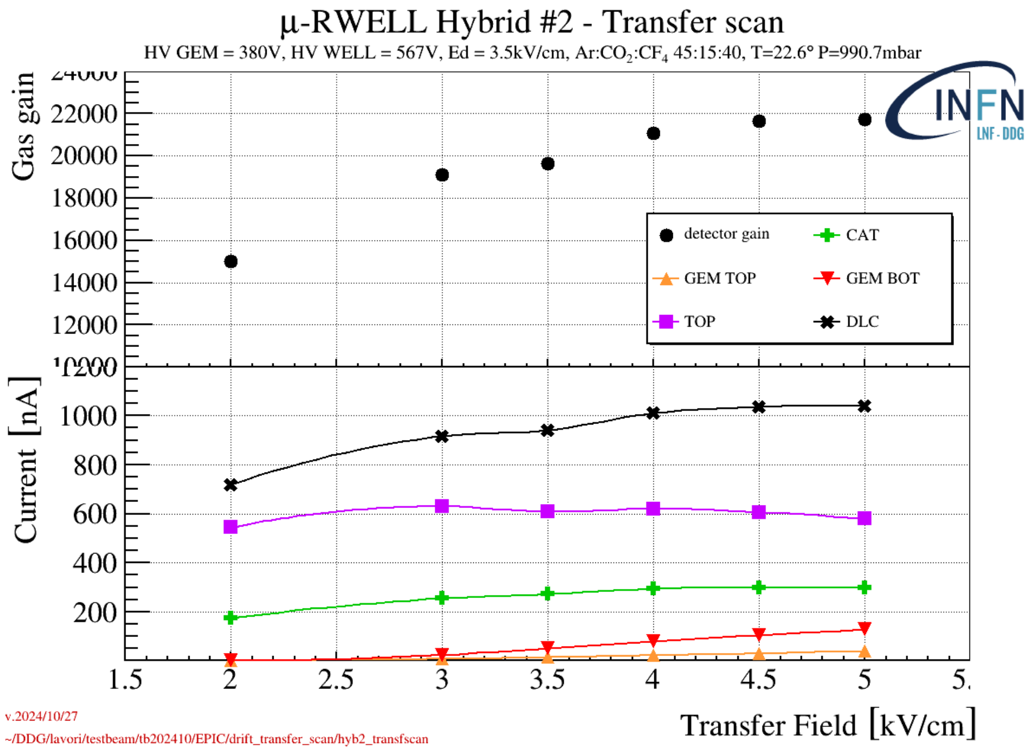
A very stable detector: it doesn't show any hint of instabilities even at **60k.** We stopped because the FEE will surely saturate at that point

Planned to be tested as soon as possible with APV25.
Goal: space resolution with a COMPAS-like readout.

Hybrid – Ed Et scan

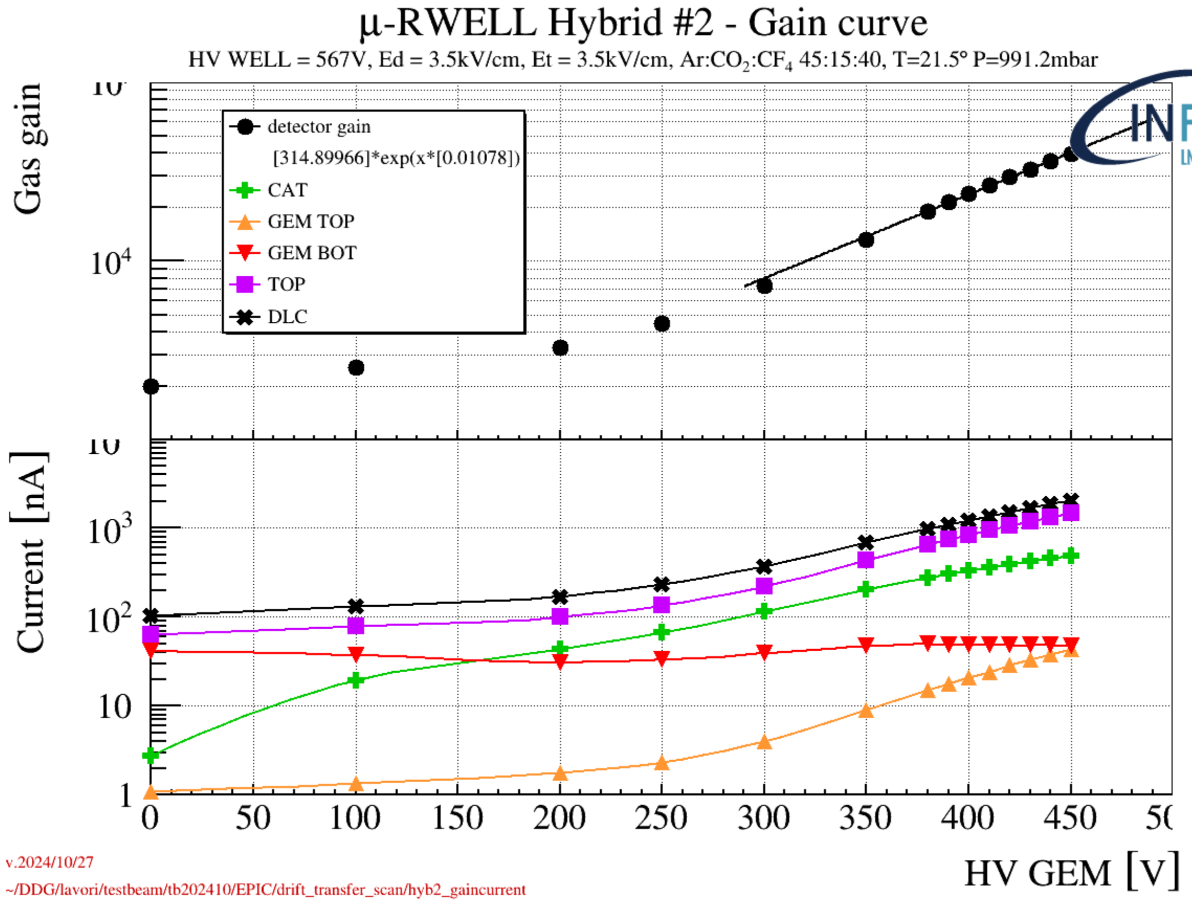
VERY PRELIMINARY: OCT'24





Hybrid – gas gain

VERY PRELIMINARY: OCT'24



µ-RWELL Technology Transfer

Step 0 – Detector **PCB design** @ LNF + CERN-MPT

Step 1 – CERN_INFN **DLC sputtering machine** @ CERN (+INFN)
- In operation since Nov. 2022
- Production by LNF-INFN crew

Step 2 – **Producing readout PCB** by ELTOS
- pad/strip readout

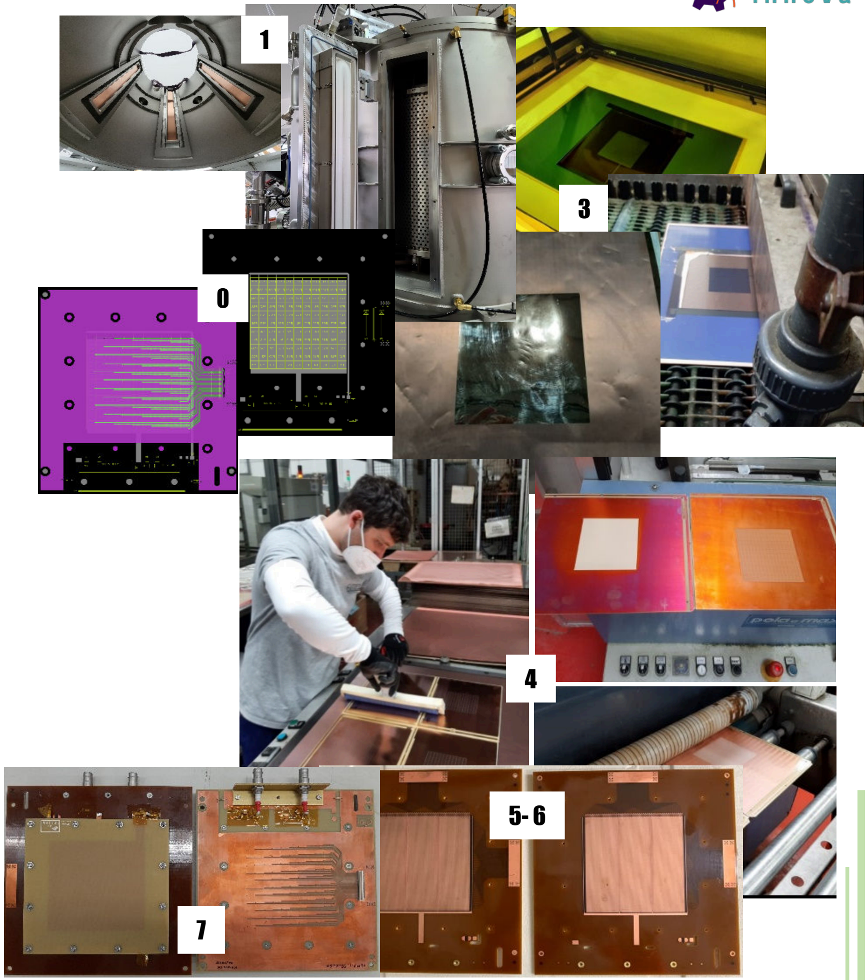
Step 3 – **DLC patterning** by ELTOS
- photo-resist → patterning with BRUSHING-machine

Step 4 – **DLC foil gluing** on PCB by ELTOS
- Large press available, up to 16 PCBs workable at the same time

Step 5 – **Ground network connections** creation by CERN
- **PEP** layout: Cu **P**atterning → PI **E**tching → Cu **P**lating

Step 6 – **Amplification stage** patterning by CERN
- Cu amplification holes image and HV connections by Cu etching
- PI etching → plating → amplification-holes

Step 7 – **Electrical cleaning** and detector closing @ CERN



This research has been supported by the E.U. Project AIDAInnova Task 7.3 (European Union's Horizon 2020 Research and Innovation programme, grant agreement N.101004761)

Update on the DLC Sputtering

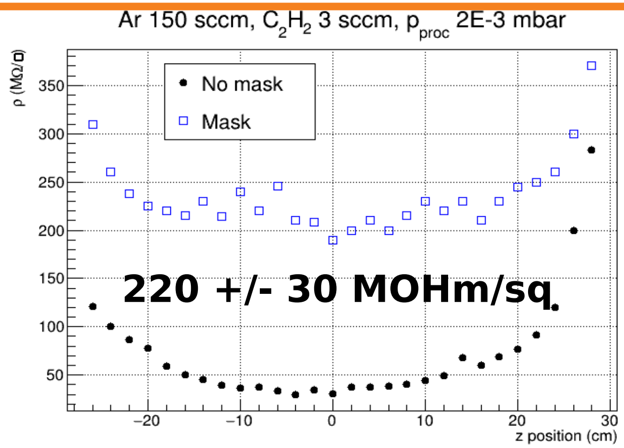
The **CID** (CERN-INFN-DLC) sputtering machine, a **joint project between CERN and INFN**, is used for preparing the **base material of the detector**. The potential of the DLC sputtering machine is:

- **Flexible substrates** up to **1.7×0.6m²**
- **Rigid substrates** up to **0.2×0.6m²**

In **2023,** the activity on CID focused on the **tuning** of the **machine on small foils: good** results in terms of **reproducibility and uniformity.**

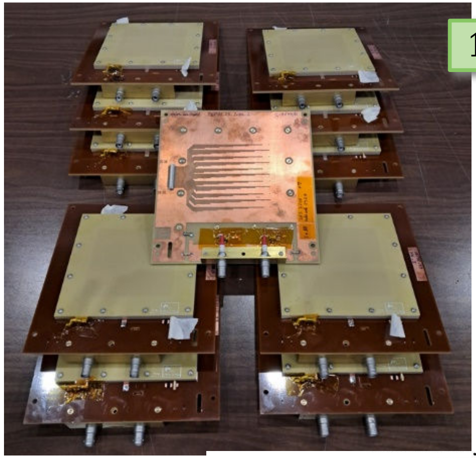
In **2024**, the challenge is the **sputtering of large foils:**

- **DLC+Cu** sputtering on 0.8×0.6m² successfully done (May/June 2024)
- **DLC on 1.7×0.6m²** large 0/50/0 Apical foils successfully done (June 2024)
- **DLC on 1.7×0.6m²** large 5/50/0 Apical foils successfully done (July 2024)



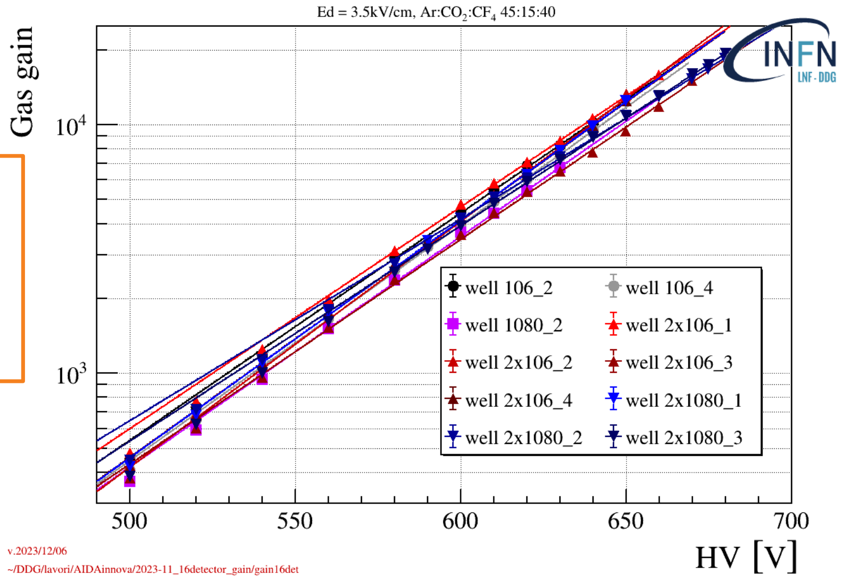
Many thanks to the CID team!!

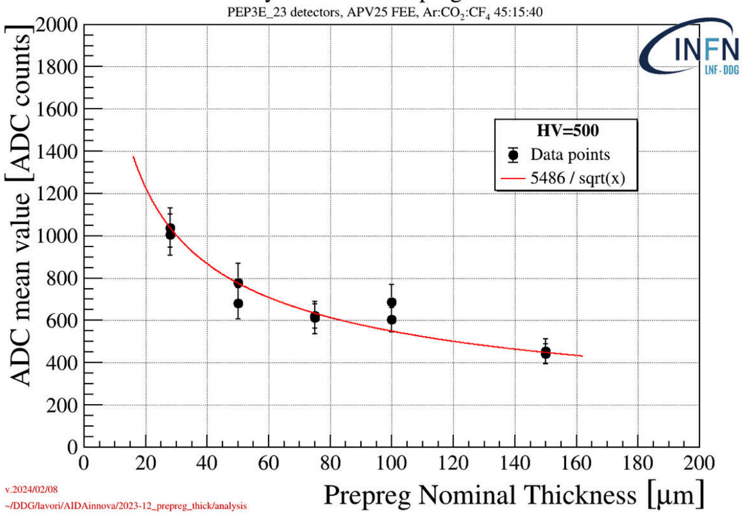
2023 – 10x10 co-production pilot test



10×10cm²

- **16** co-produced protos have been **produceded**
- **15/16 are fine → 94% yield**
- 1 should be re-cleaned

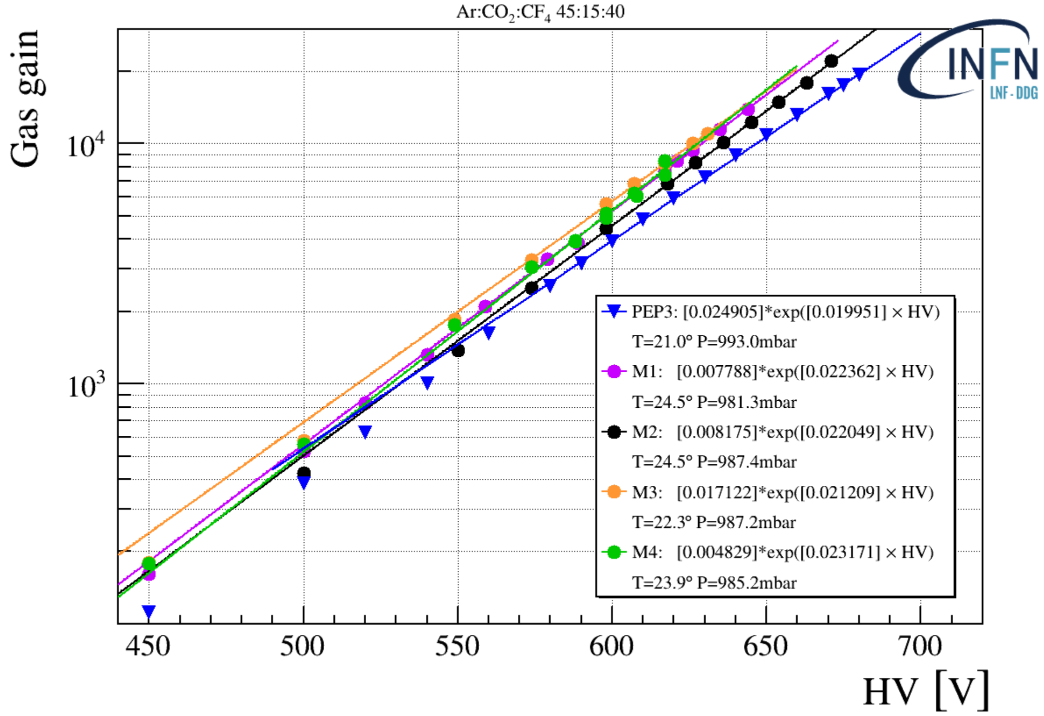


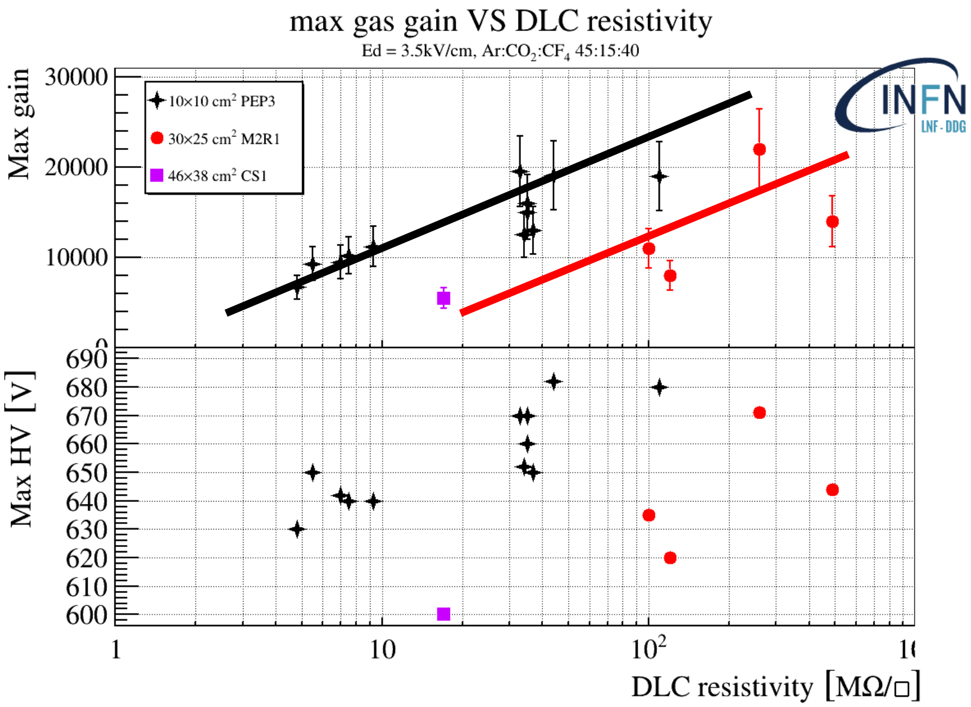


- Characterized with **X-ray gun → Gas gain** measurement
- Measure of the **pulse amplitude** (APV25) vs Gas gain

28µm thick prepreg maximize both the **amplitude of the signa**l induced on the pad readout, and **S/N ratio** (measurement done with APV25)

10x10 and M2R1 - summary





The **gas gain calibration** curve are **very similar**, thus the process for creating the amplification stage is stable and **doesn't depend on the size of the detector.**

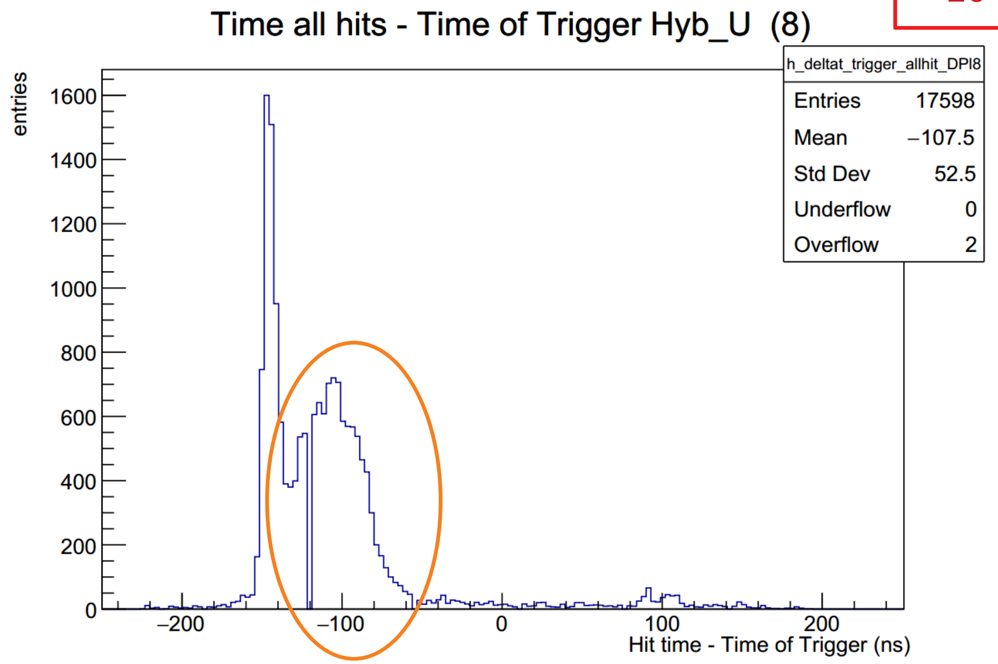
Correlation: the **max-gain** increases with the DLC **resistivity**.

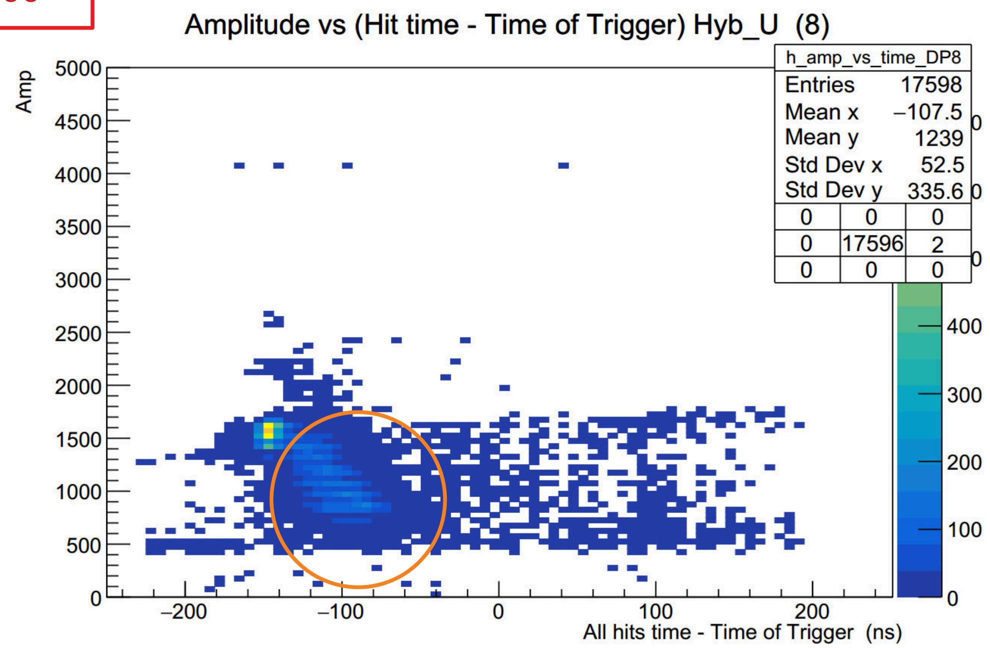
It seems that large size detector maximum gain islower that the 10x10 one.

Eventi in ritardo di 50ns - T vs Q

HYB 500/510 gain 20'000 DAQ_20241124_183044

GAIN 20'000

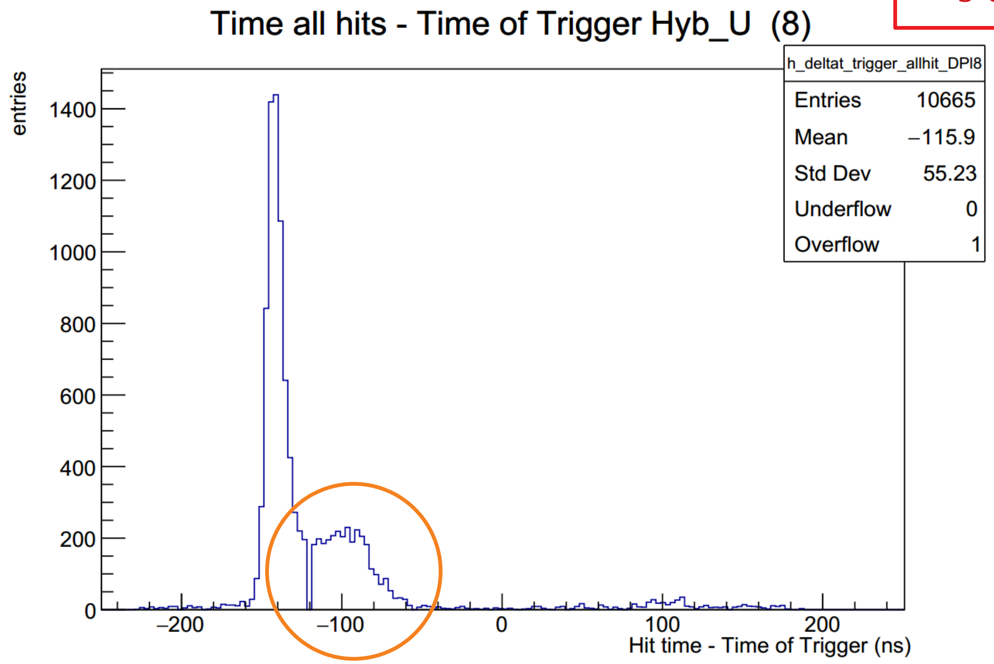


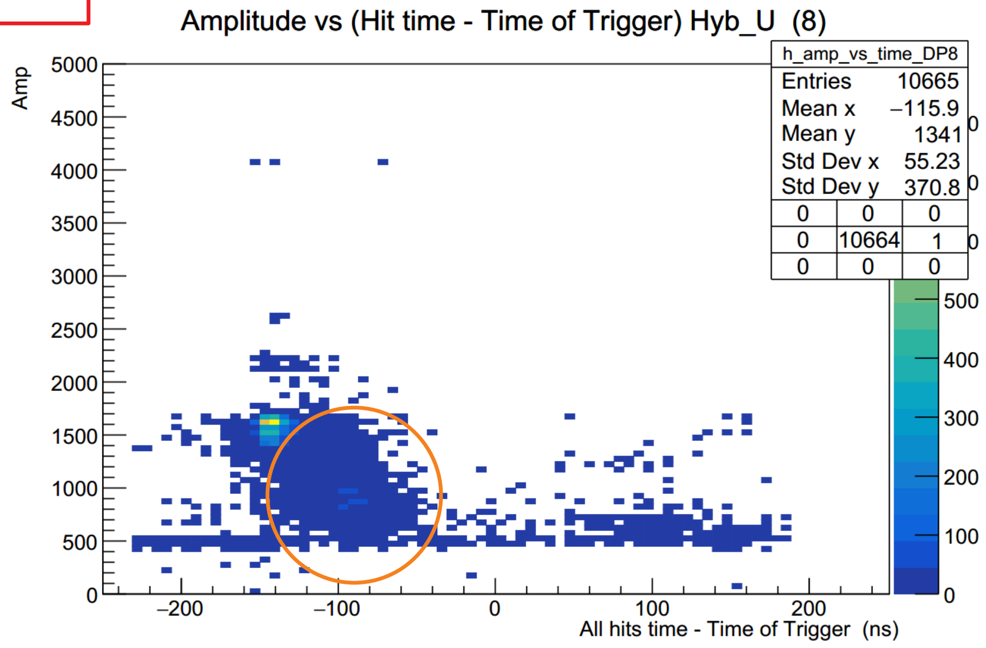


Eventi in ritardo di 50ns - T vs Q

HYB 470/500 gain 9000 DAQ_20241126_011150

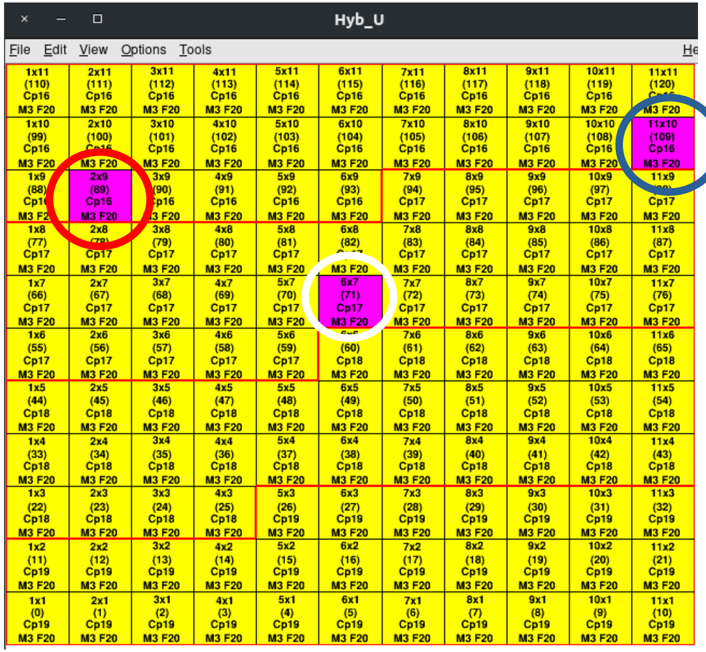
GAIN 9'000

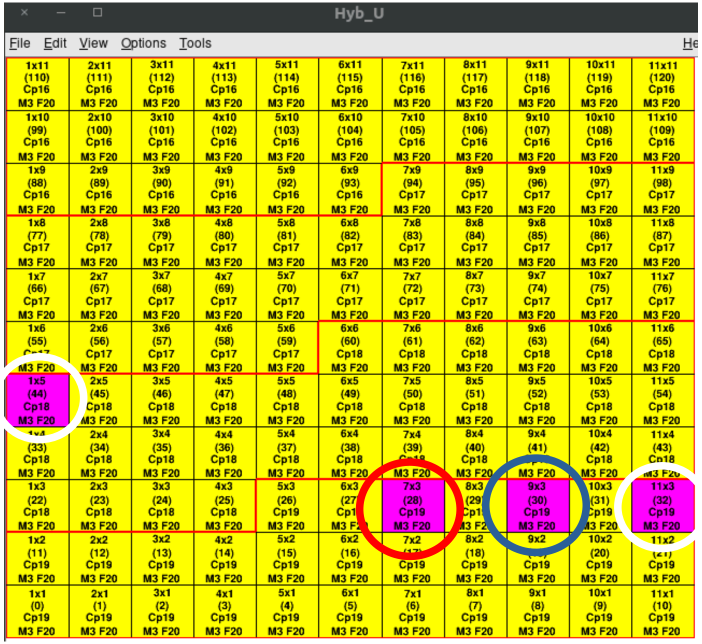




Eventi in ritardo di 50ns - Mappa HYBRID

HYB 500/510 gain 20'000 DAQ_20241124_183044





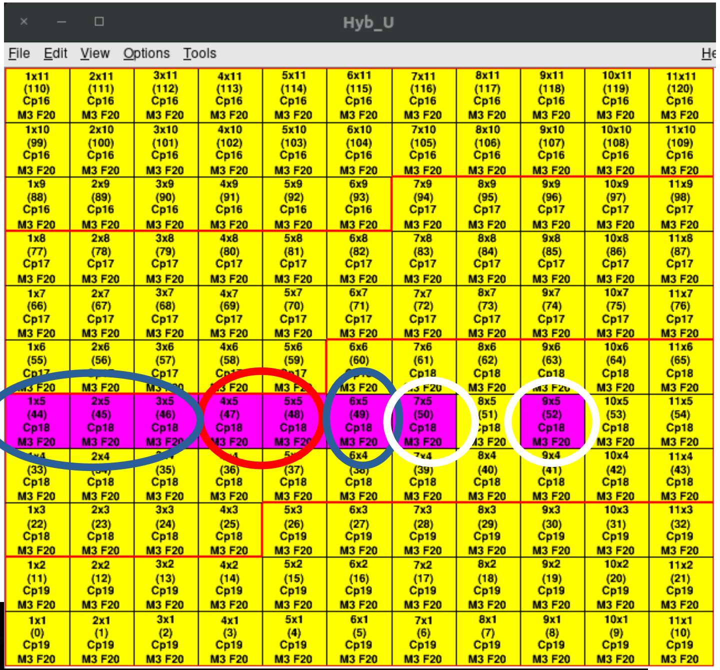
VERDE: biwell
ROSSO: good
BLU: delay
BIANCO: doppio delay

```
Evento 5_1:
 REF_U:
   pad 2x9   (89)    Msc_1 Chip_9  chl_2    amp= 1504    dt= -140.62
Warning in <TCanvas::Constructor>: Deleting canvas with same name: REF_U
 Hyb_U:
   pad 11x10   (109)    Msc_3  Chip_16  chl_24     amp= 832    dt= -103.12
   pad 2x9   (89)    Msc_3 Chip_16  chl_26    amp= 1504  dt= -143.75
   pad 6x7   (71)    Msc_3 Chip_17  chl_20    amp= 480    dt= -65.62
Warning in <TCanvas::Constructor>: Deleting canvas with same name: Hyb_U
 REF_D:
   pad 2x10   (100)    Msc_1  Chip_12  chl_25     amp= 1568    dt= -150.00
```

```
Evento 9_1:
  REF_U:
    pad 7x3   (28)    Msc_1  Chip_11  chl_1      amp= 1440    dt= -146.88
Warning in <TCanvas::Constructor>: Deleting canvas with same name: REF_U
  Hyb_U:
    pad 1x5   (44)    Msc_3  Chip_18  chl_7      amp= 480    dt= 87.50
    pad 9x3   (30)    Msc_3  Chip_19  chl_5      amp= 1376   dt= -121.88
    pad 11x3   (32)    Msc_3  Chip_19  chl_7      amp= 800    dt= -71.88
    pad 7x3   (28)    Msc_3  Chip_19  chl_3      amp= 1504   dt= -146.88
  REF_D:
    pad 7x2   (17)    Msc_1  Chip_15  chl_10      amp= 1536    dt= -159.38
```

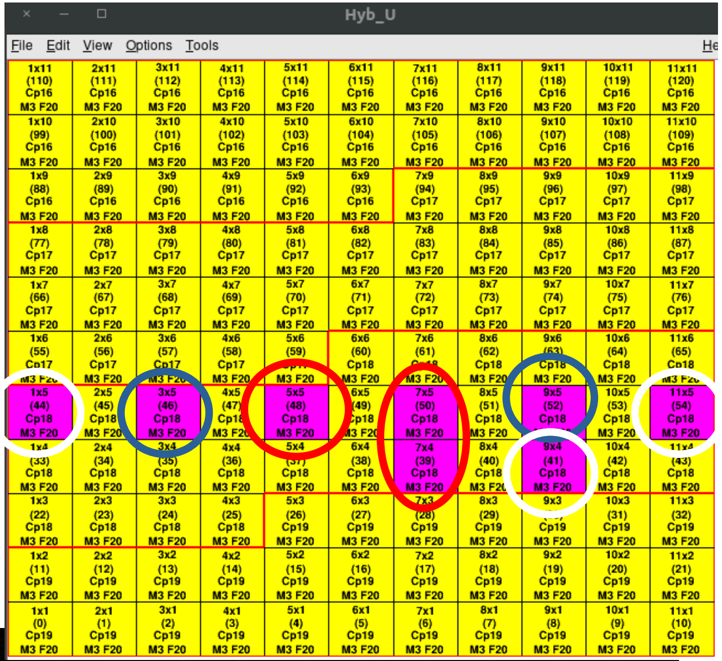
Eventi in ritardo di 50ns - Mappa HYBRID

HYB 500/510 gain 20'000 DAQ_20241124_183044



1x11 (110) Cp16 M3 F20	2x11 (111) Cp16 M3 F20	3x11 (112) Cp16 M3 F20	4x11 (113) Cp16 M3 F20	5x11 (114) Cp16 M3 F20	6x11 (115) Cp16 M3 F20	7x11 (116) Cp16 M3 F20	8x11 (117) Cp16 M3 F20	9x11 (118) Cp16 M3 F20	10x11 (119) Cp16 M3 F20	11x11 (120) Cp16 M3 F20
1x10 (99) Cp16 M3 F20	2x10 (100) Cp16 M3 F20	3x10 (101) Cp16 M3 F20	4x10 (102) Cp16 M3 F20	5x10 (103) Cp16 M3 F20	6x10 (104) Cp16 M3 F20	7x10 (105) Cp16 M3 F20	8x10 (106) Cp16 M3 F20	9x10 (107) Cp16 M3 F20	10x10 (108) Cp16 M3 F20	11x10 (109) Cp16 M3 F20
1x9 (88) Cp16 M3 F20	2x9 (89) Cp16 M3 F20	3x9 (90) Cp16 M3 F20	4x9 (91) Cp16 M3 F20	5x9 (92) Cp16 M3 F20	6x9 (93) Cp16 M3 F20	7x9 (94) Cp17 M3 F20	8x9 (95) Cp17 M3 F20	9x9 (96) Cp17 M3 F20	10x9 (97) Cp17 M3 F20	11x9 (98) Cp17 M3 F20
1x8 (77) Cp17 M3 F20	2x8 (78) Cp17 M3 F20	3x8 (79) Cp17 M3 F20	4x8 (80) Cp17 M3 F20	5x8 (81) Cp17 M3 F20	6x8 (82) Cp17 M3 F20	7x8 (83) Cp17 M3 F20	8x8 (84) Cp17 M3 F20	9x8 (85) Cp17 M3 F20	10x8 (86) Cp17 M3 F20	11x8 (87) Cp17 M3 F20
1x7 (66) Cp17 M3 F20	2x7 (67) Cp17 M3 F20	3x7 (68) Cp17 M3 F20	4x7 (69) Cp17 M3 F20	5x7 (70) Cp17 M3 F20	6x7 (71) Cp17 M3 F20	7x7 (72) Cp17 M3 F20	8x7 (73) Cp17 M3 F20	9x7 (74) Cp17 M3 F20	10x7 (75) Cp17 M3 F20	11x7 (76) Cp17 M3 F20
1x6 (55) Cp17 M3 F20	2x6 (56) Cp17 M3 F20	3x6 (57) Cp17 M3 F20	4x6 (58) Cp17 M3 F20	5x6 (59) Cp17 M3 F20	6x6 (60) Cp18 M3 F20	7x6 (61) Cp18 M3 F20	8x6 (62) Cp18 M3 F20	9x6 (63) Cp18 M3 F20	10x6 (64) Cp18 M3 F20	11x6 (65) Cp18 M3 F20
1x5 (44) Cp18 M3 F20	2x5 (45) Cp18 M3 F20	3x5 (46) Cp18 M3 F20	4x5 (47) Cp18 M3 F20	5x5 (48) Cp18 M3 F20	6x5 (49) Cp18 M3 F20	7x5 (50) Cp18 M3 F20	8x5 (51) Cp18 M3 F20	9x5 (52) Cp18 M3 F20	10x5 (53) Cp18 M3 F20	11x5 (54) Cp18 M3 F20
1x4 (33) Cp18 M3 F20	2x4 (34) Cp18 M3 F20	3x4 (35) Cp18 M3 F20	4x4 (36) Cp18 M3 F20	5x4 (37) Cp18 M3 F20	6x4 (38) Cp18 M3 F20	7x4 (39) Cp18 M3 F20	8x4 (40) Cp18 M3 F20	9x4 (41) Cp18 M3 F20	10x4 (42) Cp18 M3 F20	11x4 (43) Cp18 M3 F20
1x3 (22) Cp18 M3 F20	2x3 (23) Cp18 M3 F20	3x3 (24) Cp18 M3 F20	4x3 (25) Cp18 M3 F20	5x3 (26) Cp19 M3 F20	6x3 (27) Cp19 M3 F20	7x3 (28) Cp19 M3 F20	8x3 (29) Cp19 M3 F20	9x3 (30) Cp19 M3 F20	10x3 (31) Cp19 M3 F20	11x3 (32) Cp19 M3 F20
1x2 (11) Cp19 M3 F20	2x2 (12) Cp19 M3 F20	3x2 (13) Cp19 M3 F20	4x2 (14) Cp19 M3 F20	5x2 (15) Cp19 M3 F20	6x2 (16) Cp19 M3 F20	7x2 (17) Cp19 M3 F20	8x2 (18) Cp19 M3 F20	9x2 (19) Cp19 M3 F20	10x2 (20) Cp19 M3 F20	11x2 (21) Cp19 M3 F20
1x1 (0) Cp19 M3 F20	2x1 (1) Cp19 M3 F20	3x1 (2) Cp19 M3 F20	4x1 (3) Cp19 M3 F20	5x1 (4) Cp19 M3 F20	6x1 (5) Cp19 M3 F20	7x1 (6) Cp19 M3 F20	8x1 (7) Cp19 M3 F20	9x1 (8) Cp19 M3 F20	10x1 (9) Cp19 M3 F20	11x1 (10) Cp19 M3 F20

VERDE: biwell
ROSSO: good
BLU: delay
BIANCO: doppio delay




```
Evento 10_1:
 REF_U:
   pad 5x6   (59)    Msc_1  Chip_10  chl_0      amp= 1152    dt= -143.75
Warning in <TCanvas::Constructor>: Deleting canvas with same name: REF_U
Error in <TCanvas::ResizePad>: Cannot resize pad. No current pad available.
 Hyb_U:
   pad 6x5   (49)    Msc_3  Chip_18  chl_10      amp= 1472    dt= -131.25
   pad 9x5   (52)    Msc_3  Chip_18  chl_15      amp= 1152    dt= -93.75
   pad 2x5   (45)    Msc_3  Chip_18  chl_6      amp= 1568    dt= -137.50
   pad 1x5   (44)    Msc_3  Chip_18  chl_7      amp= 1472    dt= -118.75
   pad 3x5   (46)    Msc_3  Chip_18  chl_9      amp= 1632    dt= -131.25
   pad 7x5   (50)    Msc_3  Chip_18  chl_13      amp= 1408    dt= -96.88
   pad 5x5   (48)    Msc_3  Chip_18  chl_11      amp= 1600    dt= -140.62
   pad 4x5   (47)    Msc_3  Chip_18  chl_8      amp= 1632    dt= -150.00
 REF_D:
   pad 5x6   (59)    Msc_1  Chip_14  chl_0      amp= 1568    dt= -159.38
```

```
Evento 13_1:
 REF_U:
   pad 5x5   (48)    Msc_1  Chip_10  chl_13      amp= 1504    dt= -159.38
 Hyb_U:
   pad 1x5   (44)    Msc_3  Chip_18  chl_7      amp= 1024    dt= -96.88
   pad 3x5   (46)    Msc_3  Chip_18  chl_9      amp= 1504    dt= -121.88
   pad 7x5   (50)    Msc_3  Chip_18  chl_13      amp= 1600    dt= -140.62
   pad 9x5   (52)    Msc_3  Chip_18  chl_15      amp= 1376    dt= -118.75
   pad 11x5   (54)    Msc_3  Chip_18  chl_17      amp= 960    dt= -71.88
   pad 7x4   (39)    Msc_3  Chip_18  chl_22      amp= 1568    dt= -146.88
   pad 9x4   (41)    Msc_3  Chip_18  chl_24      amp= 1120    dt= -84.38
   pad 5x5   (48)    Msc_3  Chip_18  chl_11      amp= 1568    dt= -143.75
 REF_D:
   pad 5x6   (59)    Msc_1  Chip_14  chl_0      amp= 1536    dt= -162.50
```

Eventi in ritardo di 50ns - Mappa HYBRID

HYB 500/510 gain 20'000 DAQ_20241124_183044

Hyb_U

File Edit View Options Tools He

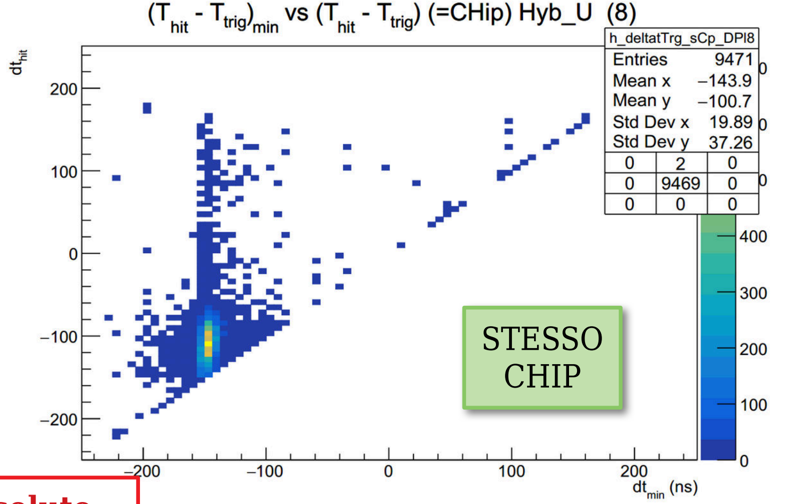
1x11 (110) Cp16 M3 F20	2x11 (111) Cp16 M3 F20	3x11 (112) Cp16 M3 F20	4x11 (113) Cp16 M3 F20	5x11 (114) Cp16 M3 F20	6x11 (115) Cp16 M3 F20	7x11 (116) Cp16 M3 F20	8x11 (117) Cp16 M3 F20	9x11 (118) Cp16 M3 F20	10x11 (119) Cp16 M3 F20	11x11 (120) Cp16 M3 F20
1x10 (99) Cp16 M3 F20	2x10 (100) Cp16 M3 F20	3x10 (101) Cp16 M3 F20	4x10 (102) Cp16 M3 F20	5x10 (103) Cp16 M3 F20	6x10 (104) Cp16 M3 F20	7x10 (105) Cp16 M3 F20	8x10 (106) Cp16 M3 F20	9x10 (107) Cp16 M3 F20	10x10 (108) Cp16 M3 F20	11x10 (109) Cp16 M3 F20
1x9 (88) Cp16 M3 F20	2x9 (89) Cp16 M3 F20	3x9 (90) Cp16 M3 F20	4x9 (91) Cp16 M3 F20	5x9 (92) Cp16 M3 F20	6x9 (93) Cp16 M3 F20	7x9 (94) Cp17 M3 F20	8x9 (95) Cp17 M3 F20	9x9 (96) Cp17 M3 F20	10x9 (97) Cp17 M3 F20	11x9 (98) Cp17 M3 F20
1x8 (77) Cp17 M3 F20	2x8 (78) Cp17 M3 F20	3x8 (79) Cp17 M3 F20	4x8 (80) Cp17 M3 F20	5x8 (81) Cp17 M3 F20	6x8 (82) Cp17 M3 F20	7x8 (83) Cp17 M3 F20	8x8 (84) Cp17 M3 F20	9x8 (85) Cp17 M3 F20	10x8 (86) Cp17 M3 F20	11x8 (87) Cp17 M3 F20
1x7 (66) Cp17 M3 F20	2x7 (67) Cp17 M3 F20	3x7 (68) Cp17 M3 F20	4x7 (69) Cp17 M3 F20	5x7 (70) Cp17 M3 F20	(71) Cp17 M3 F20	(72) Cp17 M3 F20	8x7 (73) Cp17 M3 F20	9x7 (74) Cp17 M3 F20	10x7 (75) Cp17 M3 F20	11x7 (76) Cp17 M3 F20
1x6 (55) Cp17 M3 F20	2x6 (56) Cp17 M3 F20	3x6 (57) Cp17 M3 F20	4x6 (58) Cp17 M3 F20	5x6 (59) Cp17 M3 F20	6x6 (60) Cp18 M3 F20	7x6 (61) Cp18 M3 F20	8x6 (62) Cp18 M3 F20	9x6 (63) Cp18 M3 F20	10x6 (64) Cp18 M3 F20	11x6 (65) Cp18 M3 F20
1x5 (44) Cp18 M3 F20	2x5 (45) Cp18 M3 F20	3x5 (46) Cp18 M3 F20	4x5 (47) Cp18 M3 F20	5x5 (48) Cp18 M3 F20	6x5 (49) Cp18 M3 F20	7x5 (50) Cp18 M3 F20	8x5 (51) Cp18 M3 F20	9x5 (52) Cp18 M3 F20	10x5 (53) Cp18 M3 F20	11x5 (54) Cp18 M3 F20
1x4 (33) Cp18 M3 F20	2x4 (34) Cp18 M3 F20	3x4 (35) Cp18 M3 F20	4x4 (36) Cp18 M3 F20	5x4 (37) Cp18 M3 F20	6x4 (38) Cp18 M3 F20	7x4 (39) Cp18 M3 F20	8x4 (40) Cp18 M3 F20	9x4 (41) Cp18 M3 F20	10x4 (42) Cp18 M3 F20	11x4 (43) Cp18 M3 F20
1x3 (22) Cp18 M3 F20	2x3 (23) Cp18 M3 F20	3x3 (24) Cp18 M3 F20	4x3 (25) Cp18 M3 F20	5x3 (26) Cp19 M3 F20	6x3 (27) Cp19 M3 F20	7x3 (28) Cp19 M3 F20	8x3 (29) Cp19 M3 F20	9x3 (30) Cp19 M3 F20	10x3 (31) Cp19 M3 F20	11x3 (32) Cp19 M3 F20
1x2 (11) Cp19 M3 F20	2x2 (12) Cp19 M3 F20	3x2 (13) Cp19 M3 F20	4x2 (14) Cp19 M3 F20	5x2 (15) Cp19 M3 F20	6x2 (16) Cp19 M3 F20	7x2 (17) Cp19 M3 F20	8x2 (18) Cp19 M3 F20	9x2 (19) Cp19 M3 F20	10x2 (20) Cp19 M3 F20	11x2 (21) Cp19 M3 F20
1x1 (0) Cp19 M3 F20	2x1 (1) Cp19 M3 F20	3x1 (2) Cp19 M3 F20	4x1 (3) Cp19 M3 F20	5x1 (4) Cp19 M3 F20	6x1 (5) Cp19 M3 F20	7x1 (6) Cp19 M3 F20	8x1 (7) Cp19 M3 F20	9x1 (8) Cp19 M3 F20	10x1 (9) Cp19 M3 F20	11x1 (10) Cp19 M3 F20

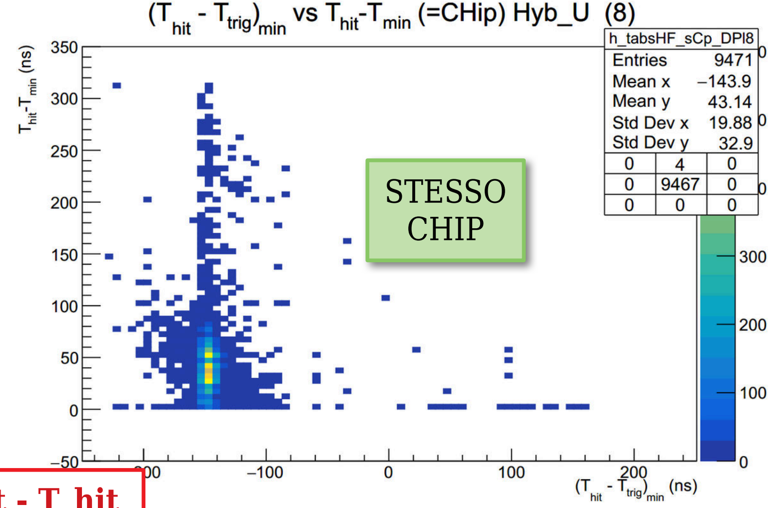
VERDE: biwell
ROSSO: good
BLU: delay
BIANCO: doppio delay

```
Evento 24_1:

  REF_U:

    pad 7x8   (83)    Msc_1  Chip_9   chl_8       amp= 1376     dt= -165.62
    pad 6x8   (82)    Msc_1  Chip_9   chl_11       amp= 1344     dt= -165.62

Warning in <TCanvas::Constructor>: Deleting canvas with same name: REF_U
  Hyb_U:

    pad 6x7   (71)    Msc_3  Chip_17  chl_20       amp= 704     dt= -143.75
    pad 7x7   (72)    Msc_3  Chip_17  chl_23       amp= 960     dt= -159.38
    pad 9x8   (85)    Msc_3  Chip_17  chl_12       amp= 864     dt= -93.75
    pad 7x8   (83)    Msc_3  Chip_17  chl_10       amp= 1408     dt= -143.75
    pad 6x8   (82)    Msc_3  Chip_17  chl_11       amp= 1312     dt= -193.75

  REF_D:

    pad 6x8   (82)    Msc_1  Chip_13  chl_11       amp= 1504     dt= -150.00
```

Eventi in ritardo di 50ns - stesso chip?

HYB 500/510 gain 20'000 DAQ_20241124_183044

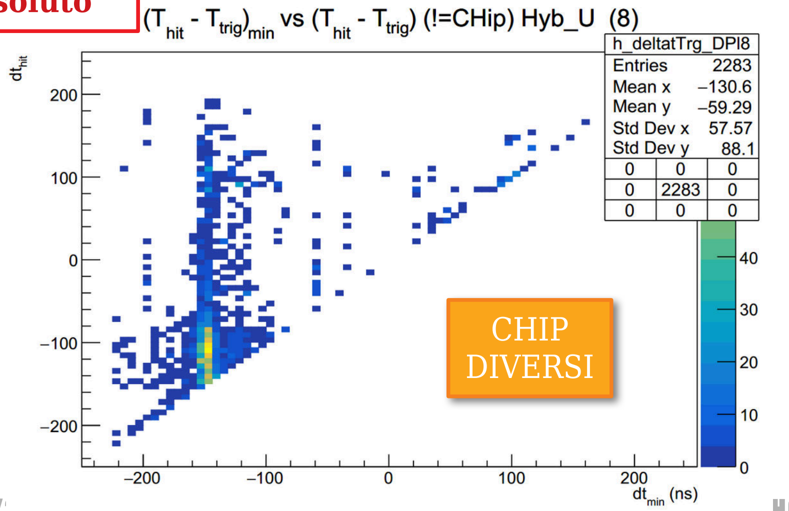


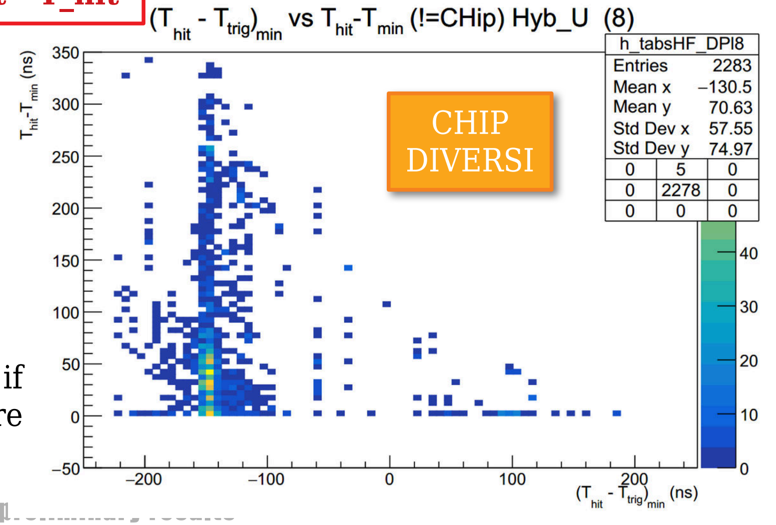


GAIN 20'000

T assoluto

T_fast - T_hit





NB: fill only if Nhit>1 (x levare piedistallo a 0)