

# MPGDHCAL

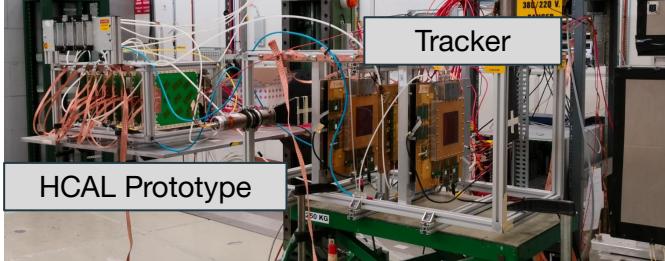
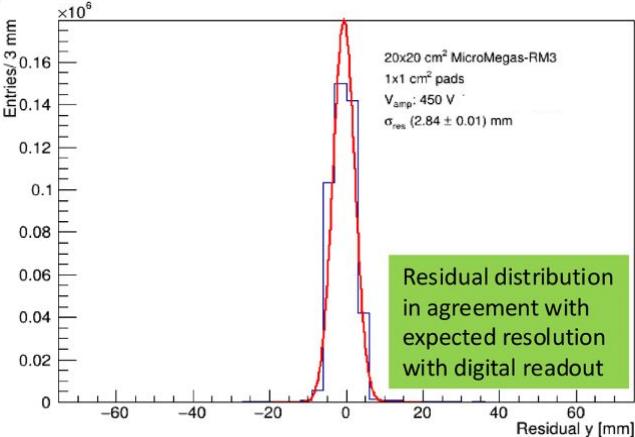
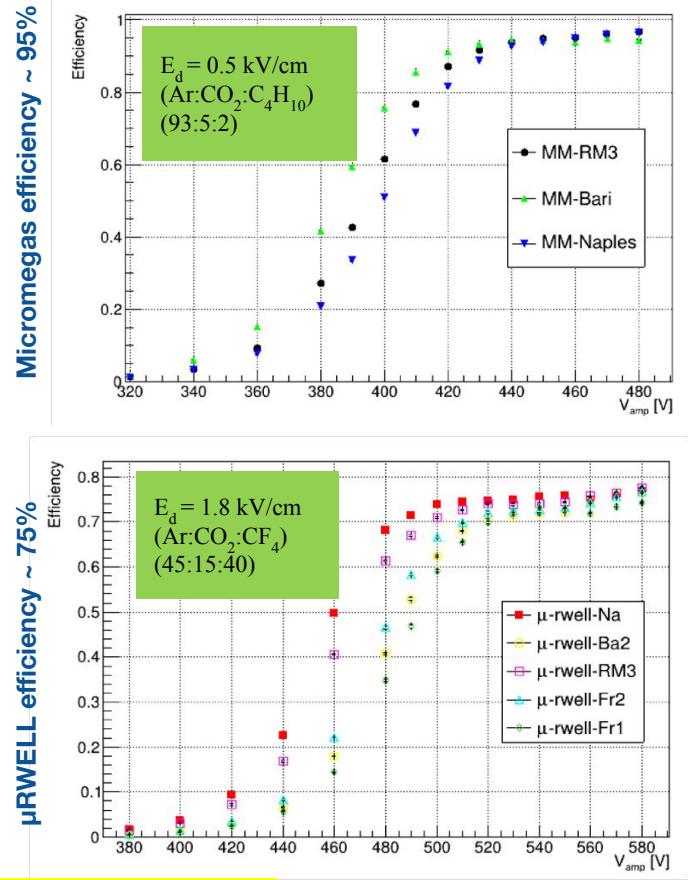
L. Longo (INFN Bari)

*22 Luglio 2025*

- Sviluppo di un prototipo di calorimetro adronico a sampling basato su Micro Pattern Gaseous Detector, MPGD-HCAL (DRD1-WP5/DRD6-WP1):
  - Testbeam 2024: SPS testbeam per caratterizzazione delle camere (SPS1:Giugno 26-Luglio 10 2024, SPS2: Settembre 18- Ottobre 2 2024), PS per la caratterizzazione del prototipo di cella calorimetrica a 8 layer (Luglio 10-24 2024):
    - SPS1: una ri-caratterizzazione delle camere in termine di efficienza, uniformità e risoluzione temporale
    - SPS2: una  $\mu$ RWELL testata con elettronica VMM3a e comparata con i risultati ottenuti con le APV (studente delle borse INFN trimestrali)
    - SPS1/SPS2: sfruttati per capire l'inefficienza delle  $\mu$ RWELL
    - PS: primi event display e controllata la linearità della risposta fra energia del pionc incidente e numero di hit nel prototipo → analisi dati ancora in corso e propedeutica per il prossimo testbeam
  - progettazione e realizzazione di 2 camere Micromegas e 2  $\mu$ RWELL 50x50cm2:
    - Progettazione terminata ad inizio anno → introdotte delle modifiche nel design per eliminare il cross-talk osservato nei prototipo 20x20cm2 e cambiato il layout delle  $\mu$ RWELL
    - Produzione delle camere prevista per settembre:
      - disuniformità nella risposta per alcuni prototipi di  $\mu$ RWELL:
        - investigata in lab a Bari, con una laureanda magistrale → potrebbe essere legata ad una disuniformità dello spessore di pre-preg
        - discussione in corso con l'MPT workshop per ottimizzare gli step di produzione
      - rimesso in funzione del vecchio cosmic teststand del GDD lab al CERN per la caratterizzazione delle 4 camere in previsione del testbeam di ottobre → al momento utilizzato per la caratterizzazione delle camere GEM che verranno usate come tracciatore (un summer student ed un borsista infn trimestrale per la caratterizzazione)

- Sviluppo di un prototipo di calorimetro adronico a sampling basato su Micro Pattern Gaseous Detector, MPGD-HCAL (DRD1-WP5/DRD6-WP1):
  - Testbeam 2025: PS per la caratterizzazione del nuovo prototipo a 12 layer, 8 20x20cm<sup>2</sup> + 4 50x50cm<sup>2</sup> (Ottobre 15-29 2025)
  - Testbeam 2026: 15 giorni al PS, con l'idea di fare 7 giorni di test combinato con CRILIN, piu' eventuale partecipazione ai testbeam di DRD1
  - progettazione e realizzazione della struttura meccanica della cella calorimetrica, contenente 8 camere da 20x20 cm<sup>2</sup> e 4 camere 50x50cm<sup>2</sup>
  - studio della possibile elettronica alternativa → al momento si stanno utilizzando gli APV:
    - VMM3a → testate durante SPS2 e, come ci si aspettava, sono un'ottima e valida alternativa
    - FATIC3 → goal: testarli entro la fine dell'anno
  - Simulation:
    - Simulazione Garfield per ottimizzare la drift gap di una  $\mu$ RWELL in funzione della time resolution ma mantenendo una efficienza elevata
    - Impatto sulle performance di MPGD-HCAL della geometria a 10 TeV di muon collider
    - Machine learning per calorimetro semi-digitale:
      - impatto di una calibrazione basata sul BDT sia per una simulazione standalone in Geant4 che per quella sviluppata all'interno del muon collider framework
      - ottimizzazione delle soglie per il semi-digital attraverso BDT
  - Conferenze/workshop: [ICHEP2024](#), [MPGD2024](#), [VCI2025](#), [IFAE2025](#), [13thBTTB](#), [CEPC2025](#), [EPS2025](#)

# MPGDHCAL: testbeam

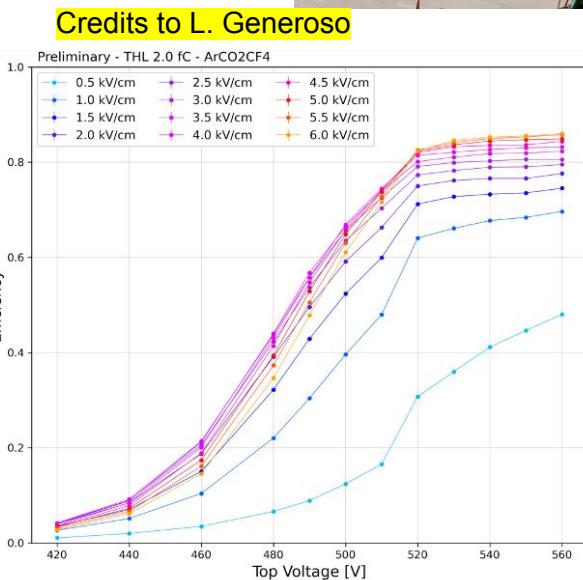
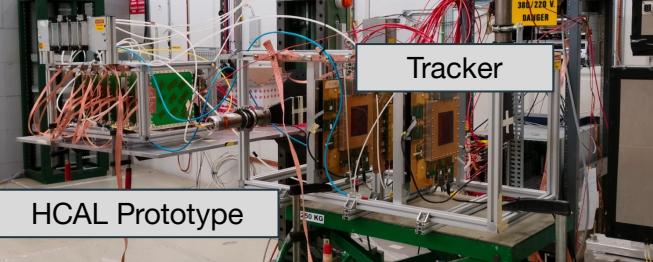
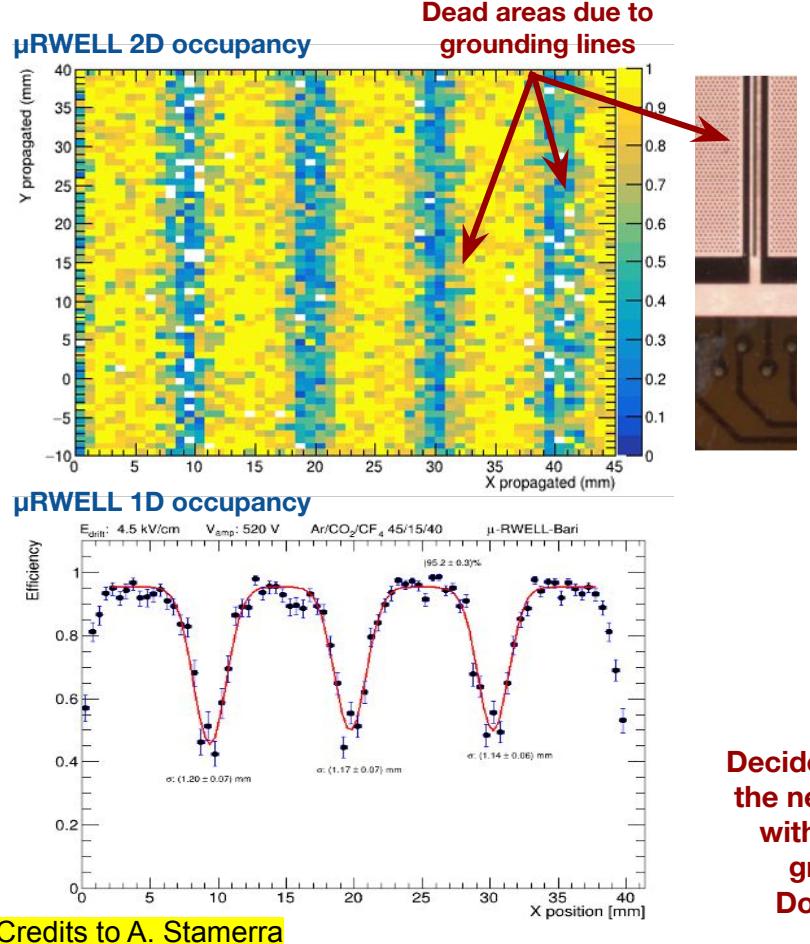


Similar spacial resolution (~3mm) for both technologies

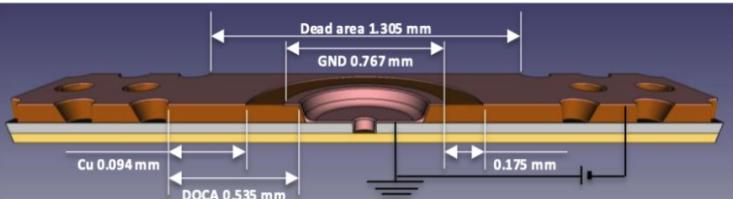
Lower efficiency for μRWELL → understood that the effect is due to the DLC ground lines



# MPGDHCAL: testbeam



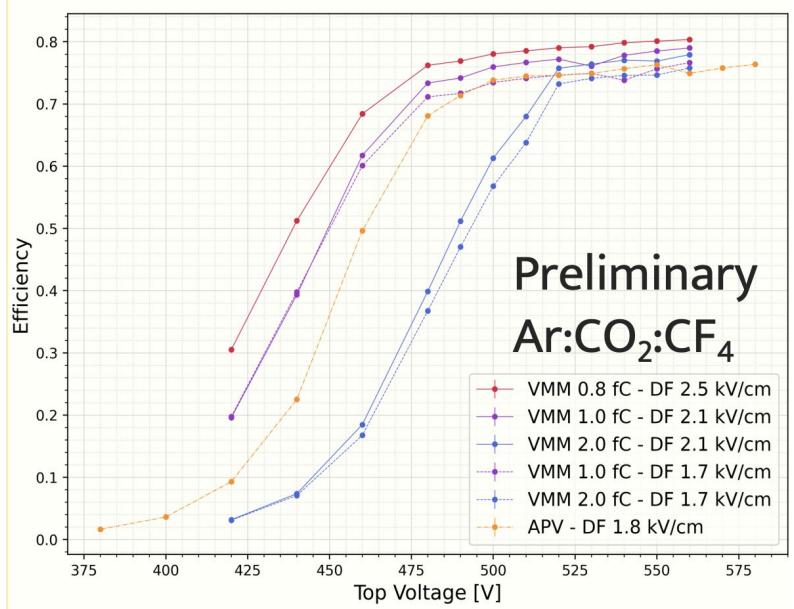
Decided to produce the new 50x50cm<sup>2</sup> with a different grounding: Dot-grounds



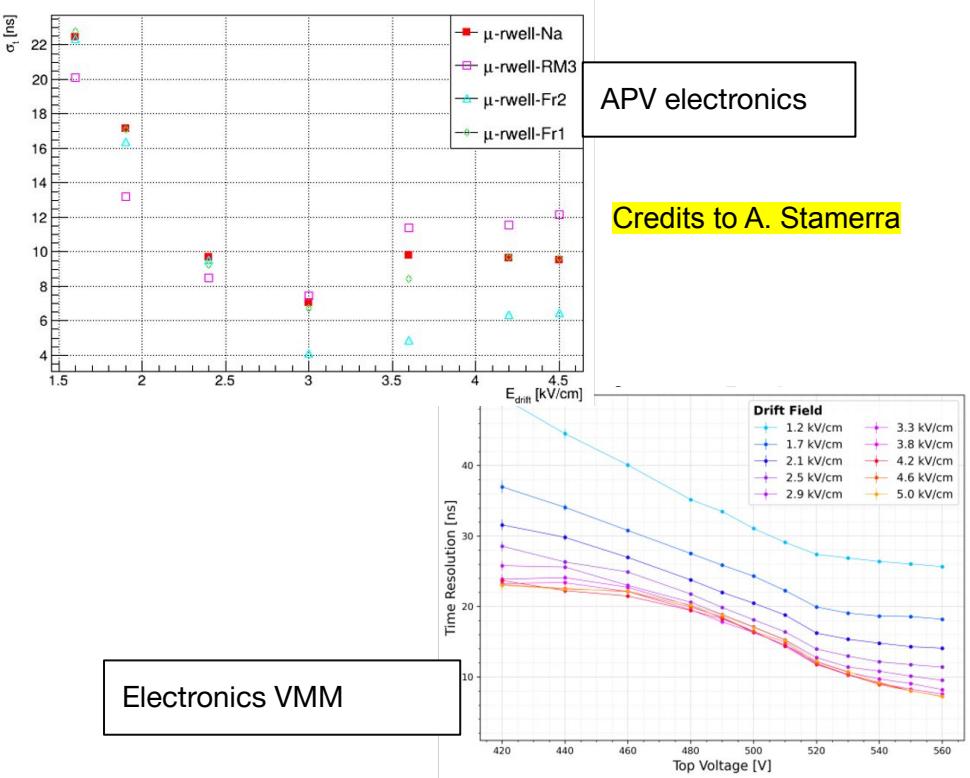
# MPGDHCAL: testbeam

$\mu$ RWELL tested with different electronics (APV vs VMM):

- Results well in agreement
- timing w/ Ar:CO<sub>2</sub>:CF<sub>4</sub> → few ns (~ 6ns) with Drift field of 3 kV/cm; similar results with different electronics



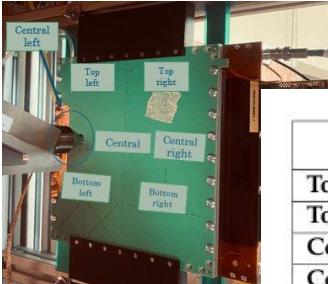
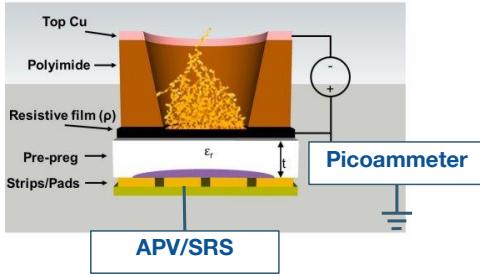
Credits to L. Generoso



# MPGD: $\mu$ RWELL disuniformity studies

## $\mu$ RWELL tested under X-ray:

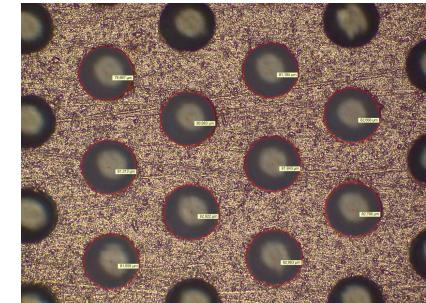
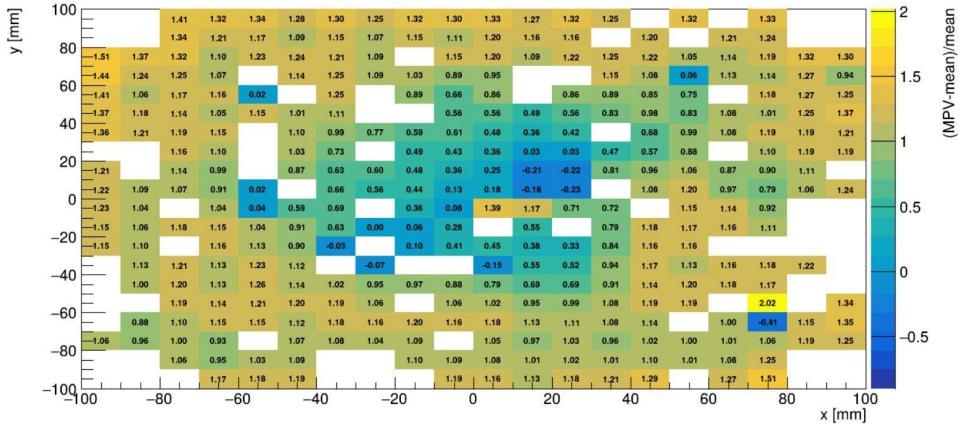
- measuring avalanche current from DLC ( $I^{DLC}$ )
- reading induced signal from readout pads via SRS/APV



DLC current

	$I^{DLC}$ [nA]
TopRight	-19 ± 1
TopLeft	-20 ± 1
CentralLeft	-19 ± 1
CentralRight	-20 ± 1
BottomRight	-20 ± 1
BottomLeft	-20 ± 1
Central	-18 ± 1

2D-MPV signal variation wrt average ~ more than 50% of variation

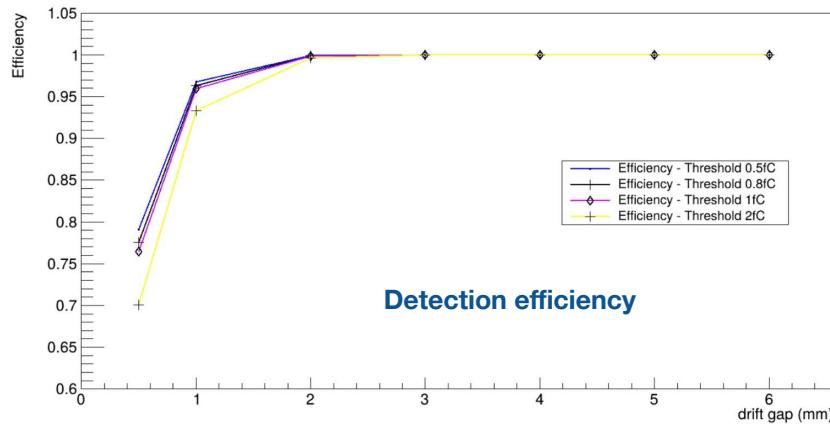
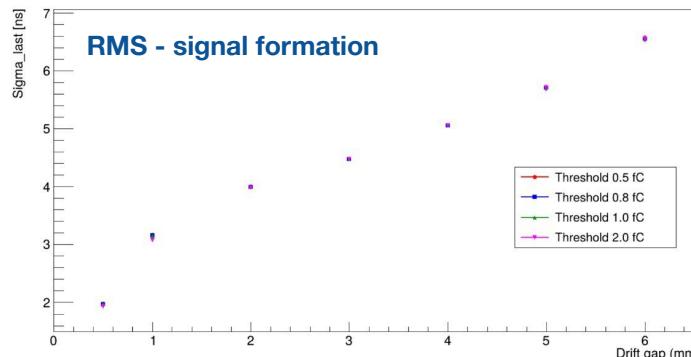
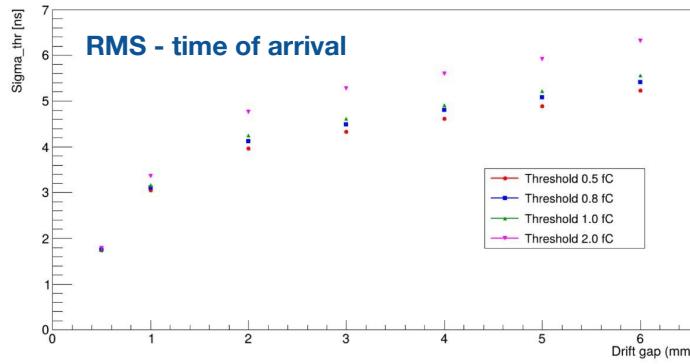


- DLC current measurements shows compatible values, even if slightly lower current was observed in the detector central area:
  - $\mu$ RWELL holes dimensions checked but no significant variation was observed
- Induced signal shows higher variation:
  - pre-preg thickness variation could be the cause → discussion with MPT workshop

# MPGD: $\mu$ RWELL drift gap optimization

Tried to improve timing performance for a  $\mu$ RWELL with a Ar:CO<sub>2</sub> (70:30) gas mixture:

- Optimizing drift gap looking at “time of arrival” or “time of full signal formation”
- Different fC thresholds considered



- Drift gap of 1-2mm would allow a reduction of the intrinsic resolution of the detector with minor efficiency loss
- The same study will be conducted on Micromegas technology
- Production of cathodes with dimensions of 0.5, 1 and/or 2 mm is fundamental to validate and support the study
- Plan to use different gas, with higher primary ionization, to enhance the timing

# INFN MPG D timing studies

The possibility to use a sub-nanosecond resolution detector could allow to better understand the performance of the MPGDs under test:

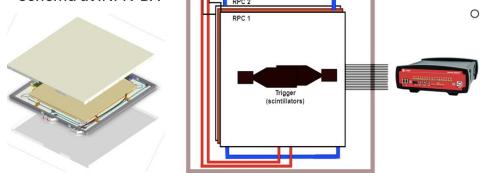
- Sub-nanosecond resolution detector can be used as time reference → thin-RPC

## Thin-RPC KRONOS

thin gaps built in  
KODEL laboratory

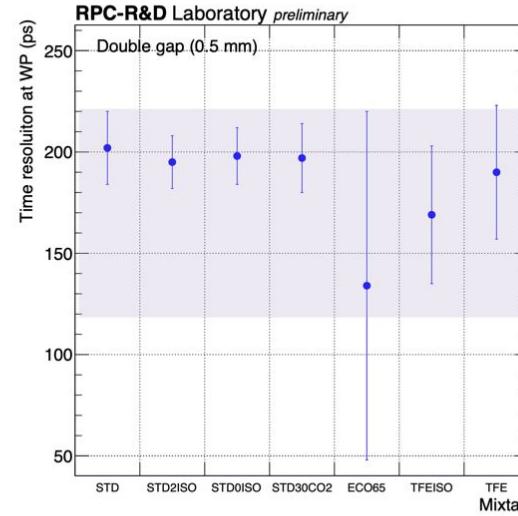


chamber and readout  
schema at INFN-BA



- Double gap** with strip readout panel in between (KODEL-GOp5-01 -> TOP, KODEL-GOp5-02 -> BOT)
  - Soda-lime glass electrodes: 1.1 mm thickness
  - Gas gap: 500  $\mu\text{m}$  thickness
  - Resistivity:  $10^{12} \Omega \cdot \text{cm}$  at 20 C
  - Strip width: 5 mm - single readout (strips terminated with 50  $\Omega$ )
- Signal readout: [CAEN Digitizer DT5742](#)
  - 16 Ch + Fast trigger @ 5Gs/s
  - Active area:  $\sim 10 \times 50 \text{ cm}^2$

- thin-RPC time resolution of the order of 200 ps → good benchmark
- Production of 2 thin-RPC prototypes to be included in the calo structure will provide an optimal timing layers for the ongoing timing studies
- thin-RPC prototypes will be tested at RPC Bari's lab
- Timing studies will be performed with standard gas mixture and alternative mixtures
- Dedicated testbeams (also at GIF++)



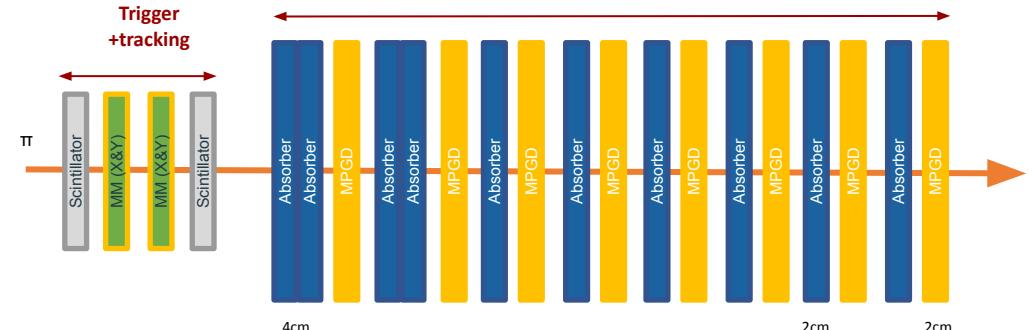


# MPGDHCAL: testbeam

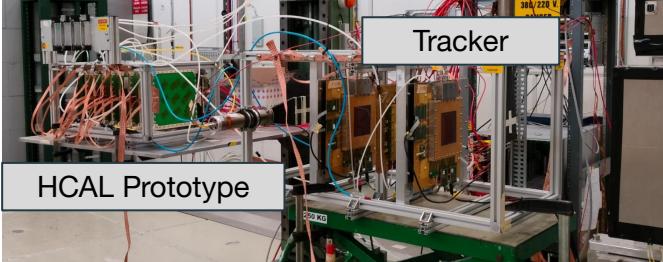
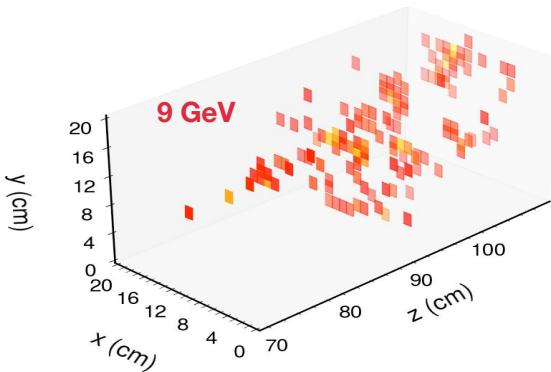
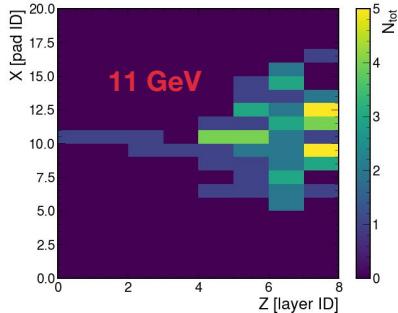
## HCAL prototype: PS testbeam data under study

Number of hits distributions for MC and data at different pion energies ( $E_\pi = f^{-1}(\langle N_{\text{hit}} \rangle)$ )

MPGD-HCAL

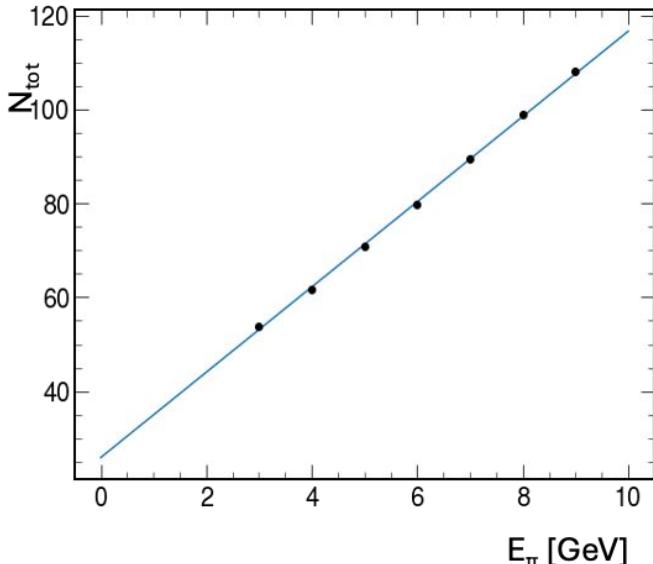


Credits to A. Pellecchia



HCAL Prototype

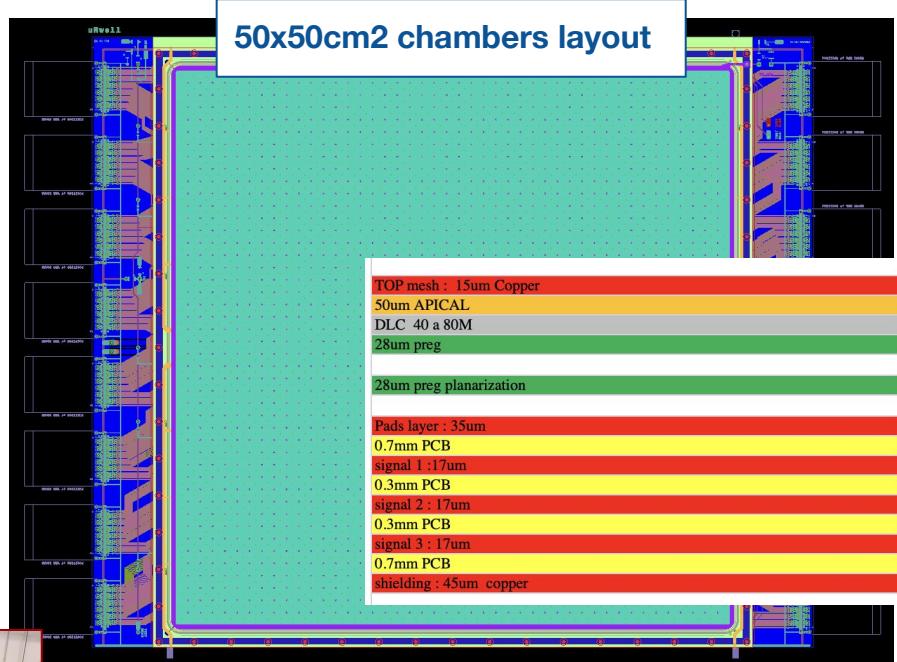
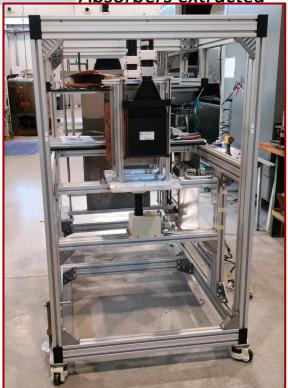
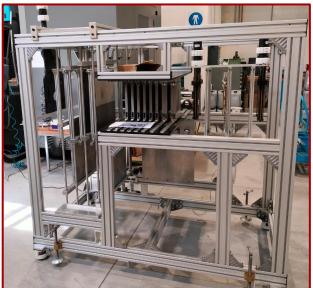
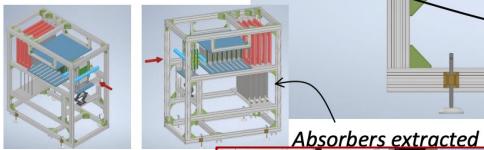
Credits to A. Stamerra



Good linearity between total number of hits and impinging pion energy

# MPGDHCAL: structure & prototypes

- Triple-GEM tracker
  - Moveable to scan entire surface
- $1\lambda$  with  $20 \times 20 \text{cm}^2$ 
  - 8 dets,  $8 \times 2 \text{cm}$  steel
- $1\lambda$  with  $50 \times 50 \text{cm}^2$ 
  - 4 dets,  $4 \times 4 \text{cm}$  steel
- Allows to insert / extract steel absorbers



- Improved the gas distribution with a dedicated manifold within the drift support frame
- Reduced the cross-talk increasing the distance between pads layer and first signal layer to 0.7mm and between signal lines
- Production expected by September (some delay occurred)

# MPGDHCAL: industrialization process



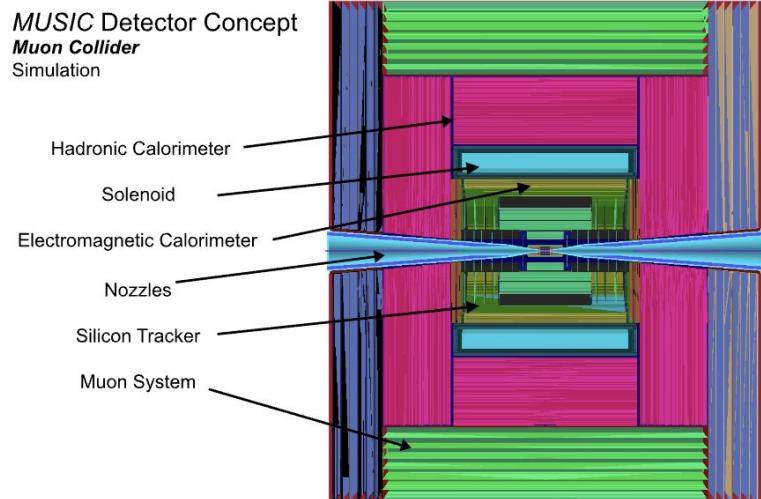
## Why an industrialization process?

- Cost of new MPGD prototype at MPT workshop has increased over the years
- Believing that MPT workshop can produce a full mass MPGD production is unrealistic:
  - there is not enough personpower
  - having only one player in the production is a risk → better to have 2 companies producing in parallel (similarly to what done for ATLAS micromegas)
- Knowledge transfer is fundamental:
  - starting the process well in advance will allow to tackle all the problematic aspects to let the company produce a fully working detector
- Decided to applied for the DRD1 Common Project call on “Industrialisation of Resistive Bulk Micromegas”:
  - Activity in collaboration with other INFN institutes (Naples and Rome3)
  - Focus on an industrialization at ELTOS

# MPGDHCAL: Simulation - 10 TeV

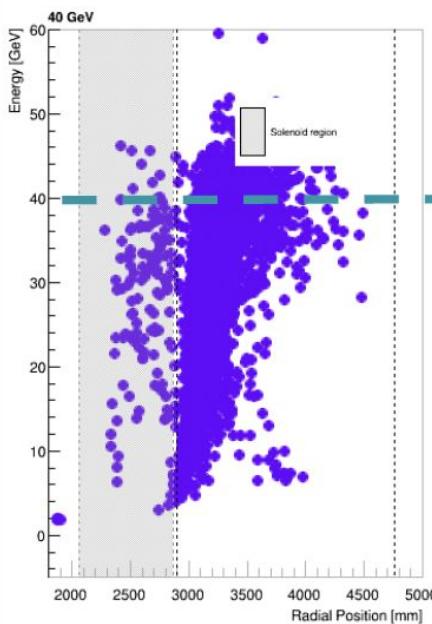
**Evaluated the impact of the MUSIC detector concept ( for a MuCol at 10 Tev) on a MPGDHCAL**

- **Solenoid between ECal and HCAL**



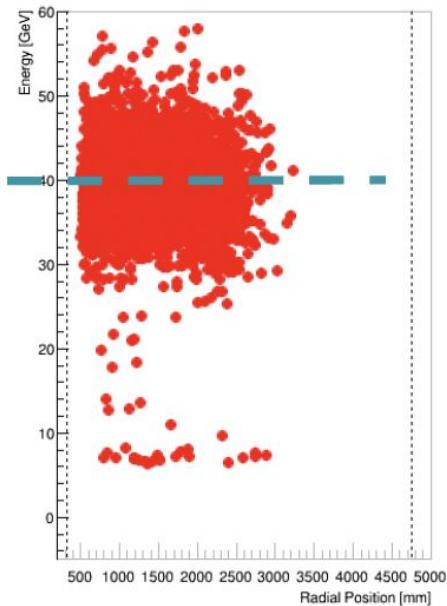
**True Energy = 40 GeV**

Barrel Cluster Energy vs Position



Credits to M. Maniscalco

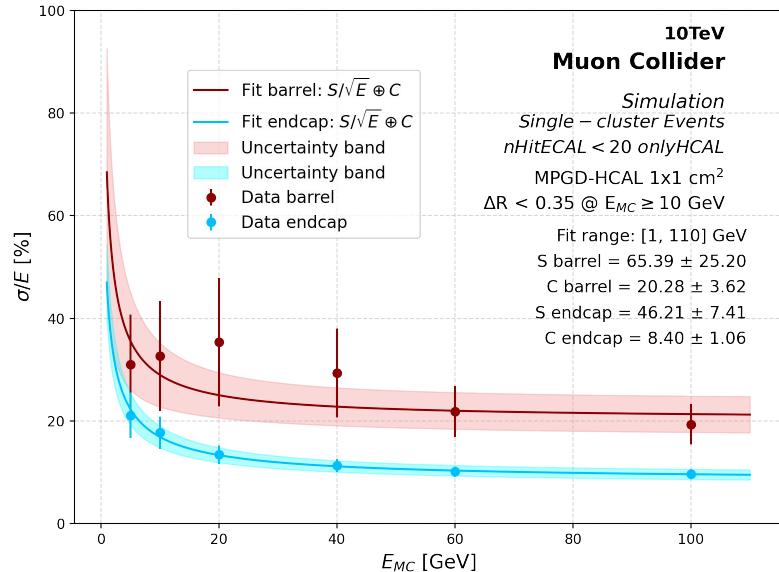
Endcap Cluster Energy vs Position



Depending of the hadrons energy, the **shower can initiate in the solenoid**:

- part of the shower is lost
- **Barycenter of the cluster** falls in the **solenoid region** or close to the **boundary** between **HCAL** and **solenoid**
- **Reconstructed energy** shifts towards **lower values**

## Impact of the solenoid on HCAL - pions gun

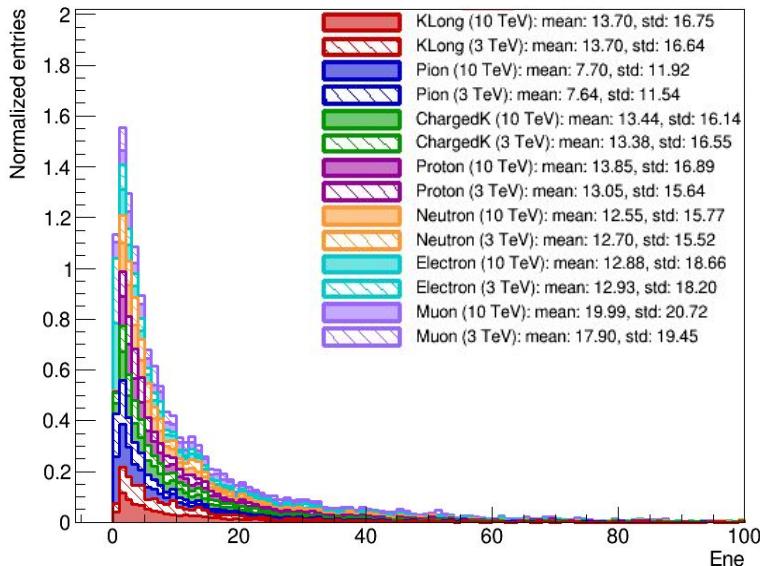


- End-cap resolution compatible with 3 TeV, even with better constant term:
  - Improvement thanks to the 10 extra layers
- Worsening of barrel resolution:
  - Further development needed to recover the hadrons showering in the solenoid

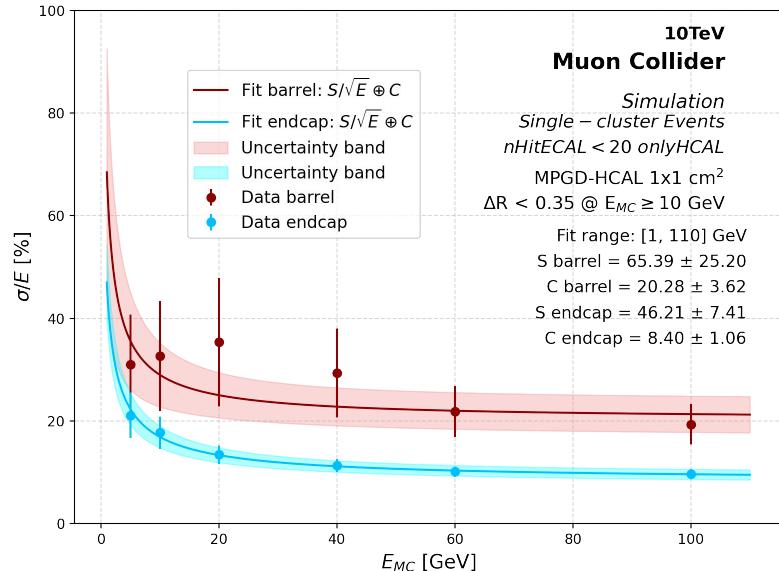
## Effect of the solenoid on MPGD-HCAL cannot be disregarded:

- $H \rightarrow b\bar{b}$  @ 10 TeV generated to assess jet composition and energy spectra of the jet constituents:
  - Similar energy spectra between 3 and 10 TeV
  - Higher constituents multiplicity

## Ene Stacked (10 vs 3 TeV)



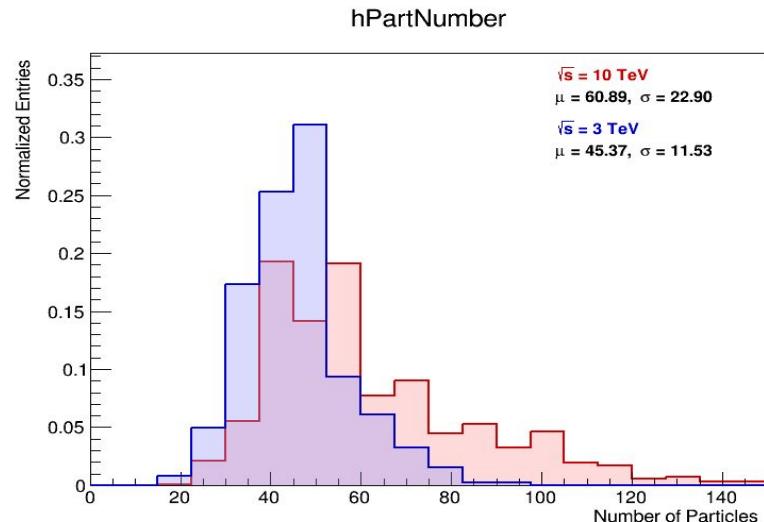
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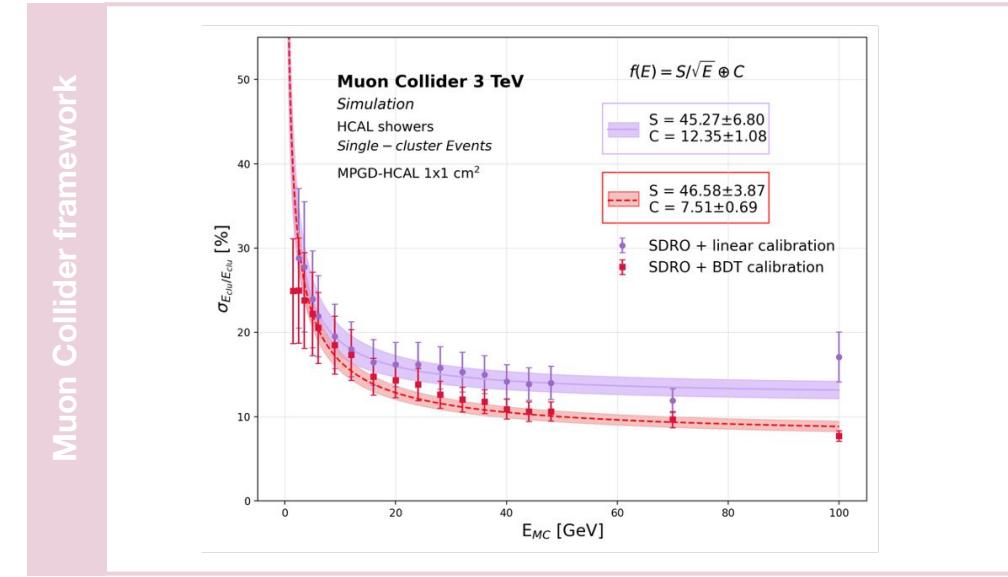
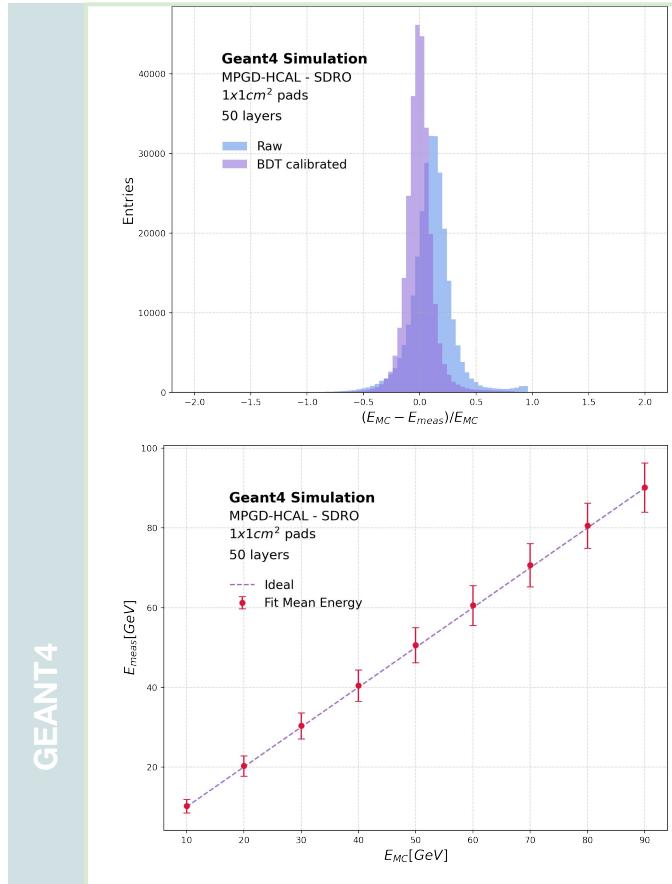
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# MPGDHCAL: Simulation - Energy BDT calibration

Calibrated energy = BDT output coefficient x Raw cluster energy, estimated with semi-digital readout

Credits to L. Generoso

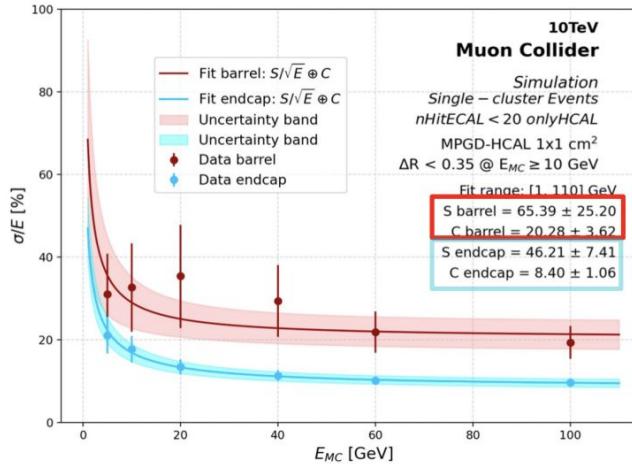


- **GEANT4:**
  - **Energy response improved** in the BDT calibrated shower energy: tighter peak, symmetrically centered in 0
  - **Good linearity** of the **reconstructed energy** with respect to the **MC true energy**
- **MuColl:**
  - compatible stochastic term  $S \sim 45\%$
  - **Significant reduction of the constant term C:  $12\% \rightarrow 7\%$**

# MPGDHCAL: Simulation - Energy BDT calibration

Credits to M. Maniscalco

## Only Semi-Digital ReadOut (SDRO)

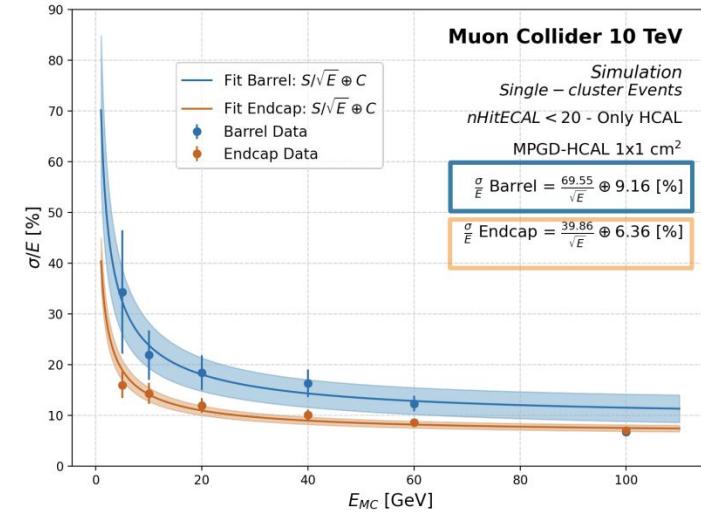


- Just SDRO considered
  - Different calibrations for barrel and endcap
- Barrel:  $\sigma/E = 65.39\%/\sqrt{E} \oplus 20.8\%$   
 Endcap:  $\sigma/E = 46.21\%/\sqrt{E} \oplus 8.40\%$

## 10 TeV case:

- barrel region:** similar results for stochastic term but **large improvement in the constant term**
- endcap region: stochastic term lower ~ 40%, further reduction of the constant term**

## SDRO x BDT calibration



- ✓ Separated calibration for barrel and endcap
- **improved results at high energies C ~9.16% barrel, 6.36% in endcap**

# MPGDHCAL: Semi-digital threshold optimization with BDT

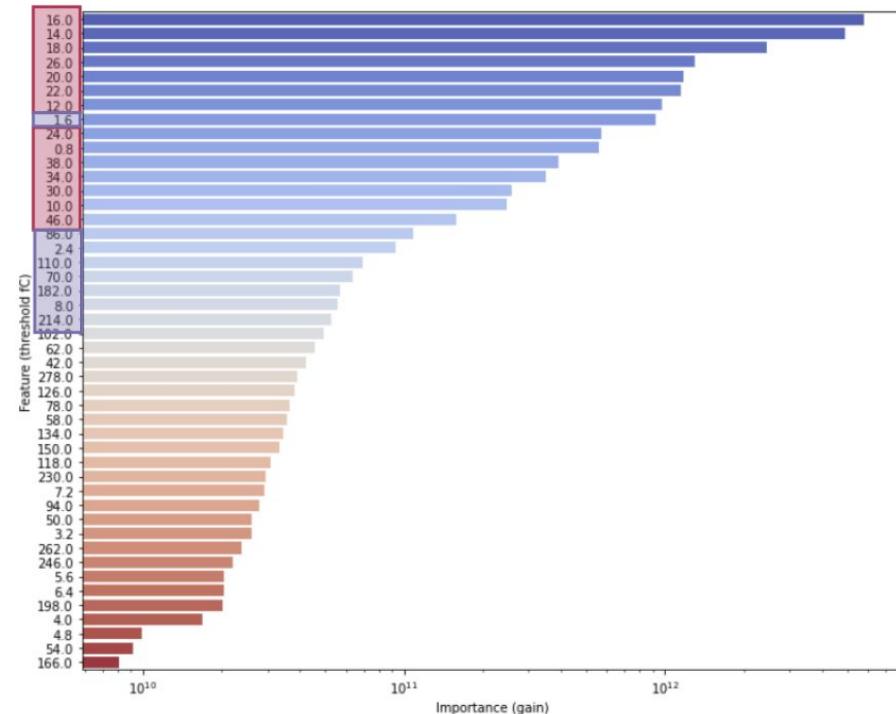
## SDRO threshold optimization

Credits to L. Generoso

### Strategy:

**Let the BDT define the most useful/discriminating thresholds**

- Define a set of thresholds in a reasonable charge range [0.8, 278] fC
- Use as input features for the training:
  - **Number of hits above each threshold**
- Train the model
- Rank the features by their training importance
- Group similar thresholds with similar importance
- For each group, define 4 thresholds as a weighted average :
  - 1.6 fC - 17 fC - 32 fC - 90 fC

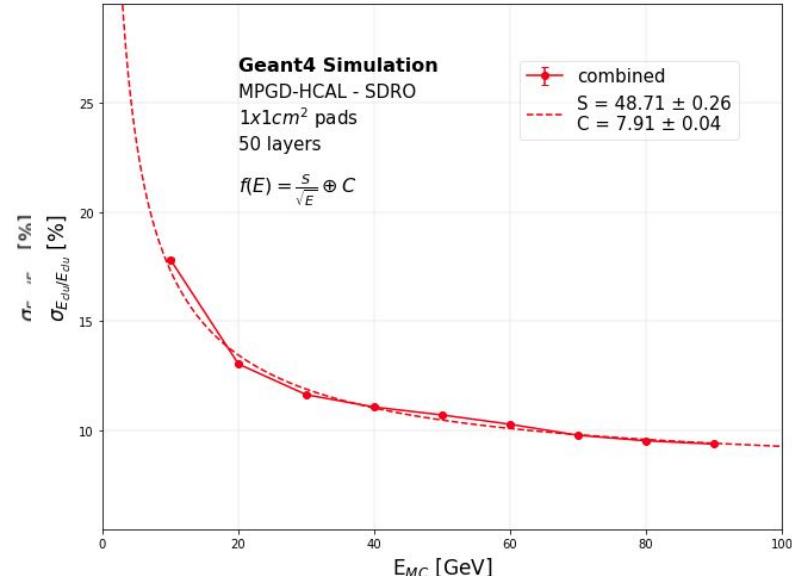
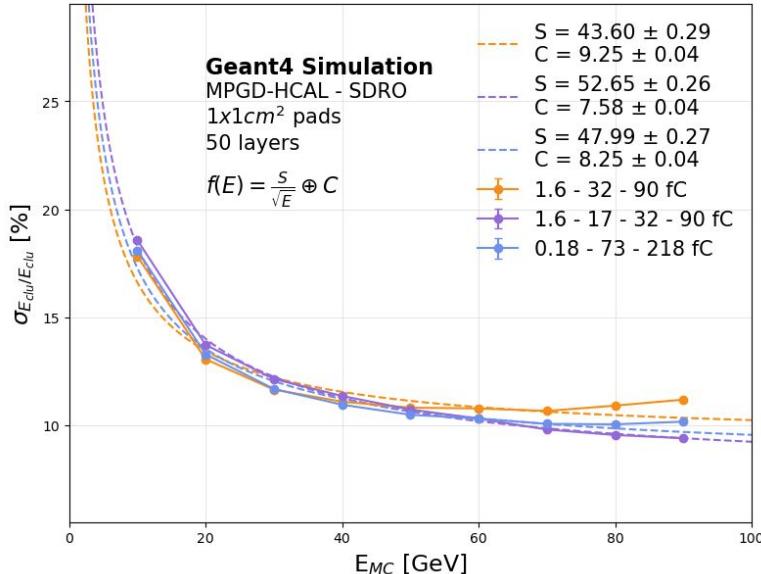


# MPGDHCAL: Semi-digital threshold optimization with BDT

- Energy resolution obtained from :
  - Cluster energy 3 thresholds (**clene3**)
  - Cluster energy 4 thresholds (**clene4**)

Credits to L. Generoso

- **Combined resolution :**
  - **clene3** for  $E_{MC} < 60$  GeV
  - **clene4** for  $E_{MC} \geq 60$  GeV



- RPC SDRO threshold (0.18 -73 -218 fC) does not always show the best performance in terms of energy resolution
- Better performance with 3 (1.6 - 32 - 90 fC) or 4 (1.6 - 17 - 32 - 90 fC) MPGD thresholds
- Needed studies on the possible electronics to be used



# RD\_MuColl: richieste

## MPGDHCAL: richieste

Capitolo	Descrizione	Costi (K-EUR)	Commenti
<b>consumo</b>	Gas: Fornitura di gas tecnici per operazioni di test su MPGD e rivelatori associati [DRD1-WP5, DRD6-WP1]	5.00	
<b>consumo</b>	Produzione di 2 prototipi di catodo (50x50cm <sup>2</sup> ) con drift gap sottile da utilizzare nei layer attivi di MPGDHCAL; la richiesta e' funzionale agli R&D sul timing [DRD1-WP5, DRD6-WP1]	5.00	Studi di timing
<b>consumo</b>	Testboard per il chip di lettura CALOROC (o chip analogo) ai fini della valutazione delle prestazioni di questo ASIC accoppiato con i rivelatori Micromegas e micro-rwell utilizzati nel prototipo di MPGDHCAL, in vista della scelta dell'elettronica di lettura finale. La stima e' fatta basandosi sui costi della serie di chip ROC prodotti dalla WeeROC ( <a href="https://www.weeroc.com/read-out-chips/">https://www.weeroc.com/read-out-chips/</a> ). [DRD1-WP5, DRD6-WP1]	3.50	Importante per individuare l'elettronica da utilizzare in futuro
<b>consumo</b>	Frontend board con chip di lettura PSIROC A5205/DT5205 (con picotdc) distribuito dalla CAEN. La quotazione non e' attualmente disponibile (la board non e' sul catalogo 2025 ma sara' inclusa nel catalogo 2026) ma il prezzo dovrebbe essere simile al frontend board FERS-5200 [DRD1-WP5, DRD6-WP1].	8.50	
<b>consumo</b>	Produzione di adattatori da connettori HRS a connettori per modulo FERS o testboard da impiegare sia su camere 50x50cm <sup>2</sup> che su camere 20x20cm <sup>2</sup> ai fini della valutazione delle prestazioni di questo ASIC accoppiato con i rivelatori Micromegas e prwell utilizzati in MPGDHCAL, in vista della scelta dell'elettronica di lettura finale [DRD1-WP5, DRD6-WP1].	0.50	
<b>consumo</b>	Elettronica VMM per equipaggiare un rivelatore MPGD 50x50 cm <sup>2</sup> per studi di caratterizzazione (efficienza e risoluzione temporale) al variare della gap di drift e della miscela di gas. Il sistema VMM comprende le seguenti voci [DRD1-WP5, DRD6-WP1]: 1) 16 ibridi VMM (12.2 ke) 2) 2 schede DVMM (3.8 ke) 3) 2 schede FEC (3.7 ke) 4) 1 crate SRS (1.5 ke) 5) 2 power box per gli ibridi complete di cavi di distribuzione (1k). Le quotazioni si riferiscono ai costi indicati sul mercato del CERN..	22.50	I'elettronica con APV comincia ad essere problematica in termini di rumore e canali morti; fondamentale trovare un'alternativa per lo meno per la fase di R&D
<b>trasporti</b>	Material transportation: Spedizione di moduli e componenti per HCAL verso siti di test	2.00	



# RD\_MuColl: richieste

Per il calorimetro, si è applicato alla call di Common Project di DRD1 con il progetto *Industrialisation of Resistive Bulk Micromegas*, con contatto locale L. Longo

## MPGDHCAL: richieste

Capitolo	Descrizione	Costi (K-EUR)	Commenti
<b>consumo</b>	Richiesta funzionale alla proposta del CommonProject di DRD1 relativa alla industrializzazione di una Micromegas resistiva di tipologia Bulk presso ELTOS spa. La richiesta riguarda acquisto di materiale per la realizzazione di prototipi di test at ELTOS. L'idea alla base e' di porre le basi per una industrializzazione di una delle tecnologie del calorimetro adronico a MPGD in vista di una produzione di massa. [DRD1-WP5]	5.00	COMMON PROJECT
<b>consumo</b>	Acquisto di materiale per la modifica della struttura meccanica di MPGDHCAL per renderla un cosmic stand (o realizzazione di un piccolo setup) da sfruttare per la caratterizzazione delle camere con drift gap sottili e nuove miscele durante LS3. Funzionale in vista del periodo di LS3, durante il quale avremo una carenza di facility per test sul fascio. [DRD1-WP5]	5.00	
<b>consumo</b>	Materiale per testbeam, includendo l'affitto dei moduli al pool	2.5	
<b>consumo</b>	Realizzazione di due prototipi RPC a timing spinto (risoluzione temporale di 200ps), da impiegare all'interno della struttura calorimetrica come reference temporale per studi di timing su MPGD [DRD1-WP7]	7.00	Studi di timing
<b>consumo</b>	Mass Flow Meter per studi di miscele di gas per R&D su timing [DRD1-WP1]	5.00	Studi di timing
<b>manutenzione</b>	Spese manutenzione laboratorio MPGD per quelle che riguarda i sensori sulla sicurezza	1.00	
<b>missioni</b>	Missioni per test alla GIF++ per studi su ecomiscele	3.00	
<b>missioni</b>	Missione per testbeam MPGDHCAL da effettuare nella prima meta' del 2026 al PS, insieme a CRILIN, e testbeam per caratterizzazione di prototipi. Il testbeam combinato con CRILIN è previsto di 7 giorni.	22.00	



# Anagrafica

- TotFTE: 5.5, in crescita rispetto allo scorso anno

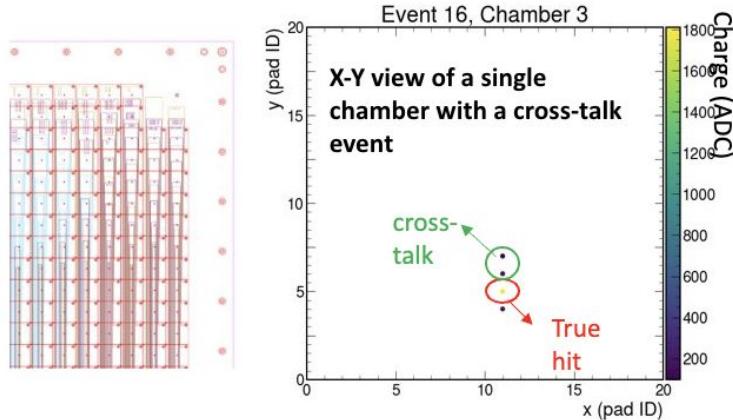
cognome	nome	struttura	modulo	contratto	profilo	stato	aff	perc
<b>Ali</b>	Muhammad	BA	G1	Associato	Scientifica Dottorandi	Attivo	1	100%
<b>Catanesi</b>	Maria Gabriella	BA	G1	Associato	Associazione Senior	Attivo	1 *	
<b>Colaleo</b>	Anna	BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	20%
<b>Creanza</b>	Donato Maria	BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	20%
<b>Fiore</b>	Luigi	BA	G1	Associato	Associazione Senior	Attivo	1	30%
<b>Generoso</b>	Lisa	BA	G1	Associato	Scientifica Dottorandi	Attivo	1	20%
<b>Iaselli</b>	Giuseppe	BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	5	50%
<b>Longo</b>	Luigi	BA	G1	Dipendente	Ricercatore	Attivo	1	30%
<b>Maggi</b>	Marcello	BA	G1	Dipendente	Primo Ricercatore	Attivo	1	30%
<b>My</b>	Salvatore	BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	10%
<b>Pellecchia</b>	Antonello	BA	G1	Dipendente	Assegno di Ricerca	Attivo	1	30%
<b>Pugliese</b>	Gabriella	BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	10%
<b>Radicioni</b>	Emilio	BA	G1	Dipendente	Primo Ricercatore	Attivo	1	30%
<b>Radogna</b>	Raffaella	BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	10%
<b>Ramos Lopez</b>	Dayron	BA	G1	Associato	Scientifica Assegni non INFN	Attivo	1	10%
<b>Simone</b>	Federica Maria	BA	G1	Associato	Scientifica Ricercatori/Professori università	Attivo	1	20%
<b>Spina</b>	Roberto	BA	G1	Associato	Tecnologica Ricercatori/Professori università	Attivo	1	30%
<b>Stamerra</b>	Anna	BA	G1	Associato	Scientifica Assegni non INFN	Attivo	1	30%
<b>Venditti</b>	Rosamarie	BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	30%
<b>Verwilligen</b>	Piet Omer J	BA	G1	Dipendente	Ricercatore	Attivo	1	10%
<b>Zaza</b>	Angela	BA	G1	Dipendente	Assegno di Ricerca	Attivo	1	30%



# Backup

# Cluster reconstruction

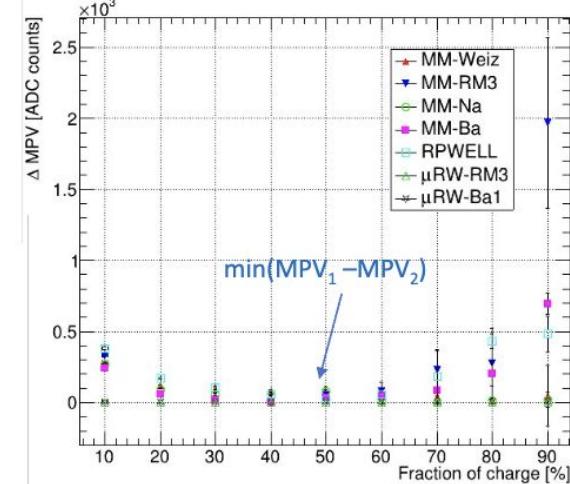
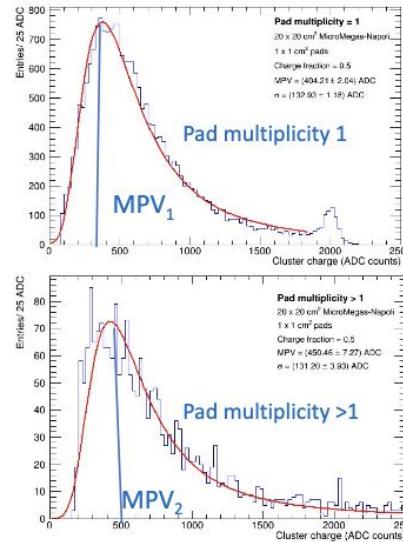
Preliminary



High probability of **cross-talk** effect observed among adjacent pads due to routing of the vias connecting pads to the connectors

Developed ad-hoc clustering algorithm based on charge sharing criterium

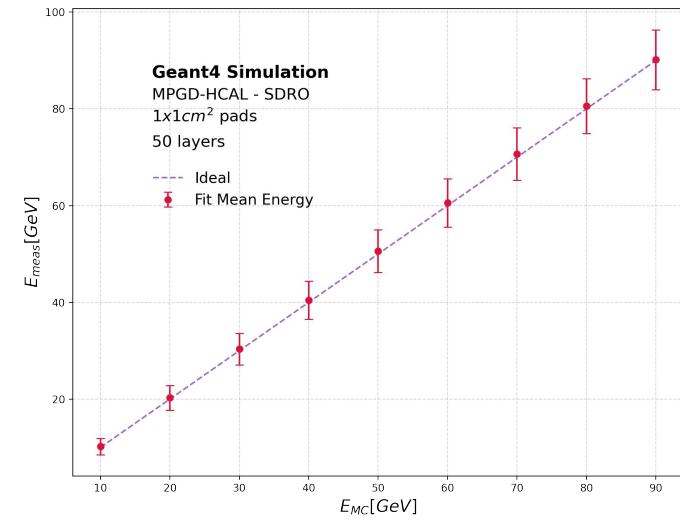
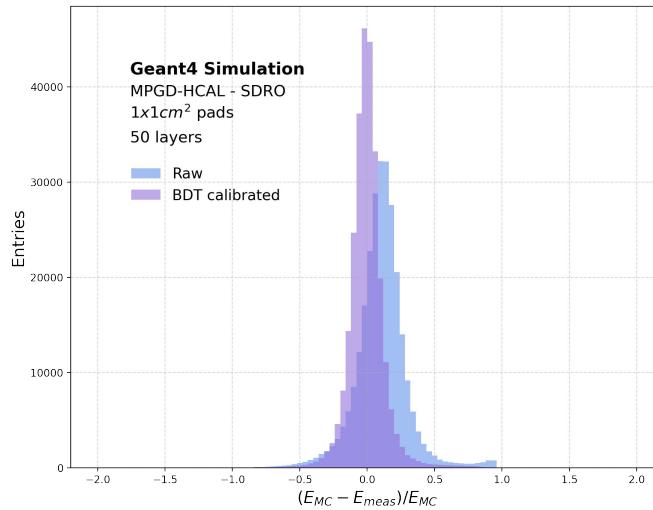
- Selected pad with **highest charge  $Q_{\max}$**
- Add a second pad if  $Q = 50\% Q_{\max}$



# Simulation: BDT for energy calibration

**Purpose: improve the energy calibration, linearity and resolution of monochromatic  $\pi^\pm$  guns in the GEANT4 Simulation**

- only 50 layers considered
- energy range: [10,90] GeV
- calibrated energy = **BDT coefficient** X Semi-digital energy estimate
- **Input Features :**
  - Number of hits in the whole HCAL
  - Shower energy reconstructed with 3-level semi-digital read-out
  - Number of hits in the 3 energy ranges
  - Number of hits per layer
  - Energy Fraction per layer
  - X, Y, and Z centroid (weighted by the hit energy)
  - Standard dev of hit coordinate X & Y per layer



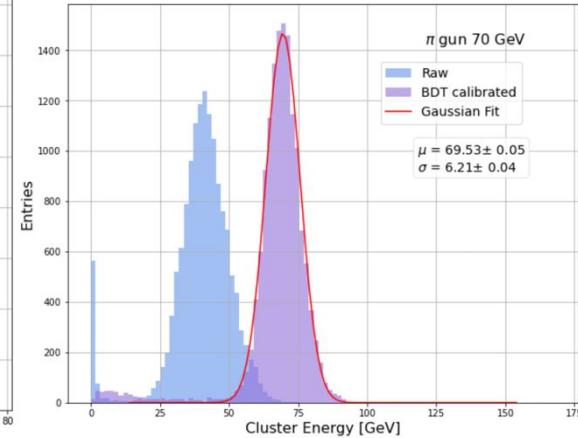
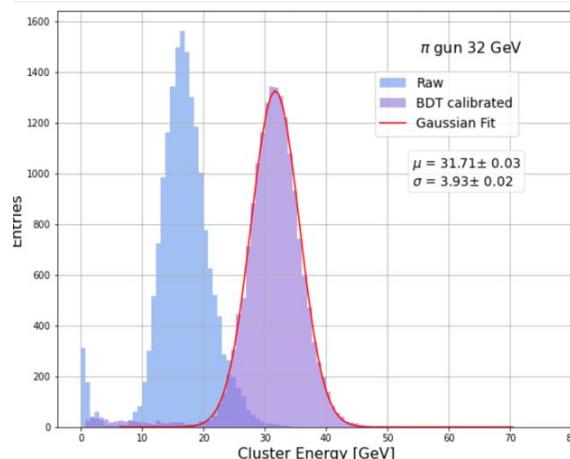
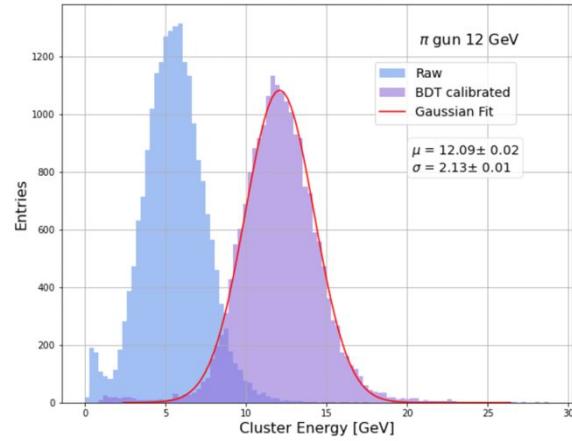
- **Energy response improved** in the BDT calibrated shower energy:
  - Tighter peak, symmetrically centered in 0
- **Good linearity** of the reconstructed energy with respect to the **MC true energy**

# Semi-digital readout with BDT calibration

Calibrated energy = **BDT output coefficient** x **Raw cluster energy**

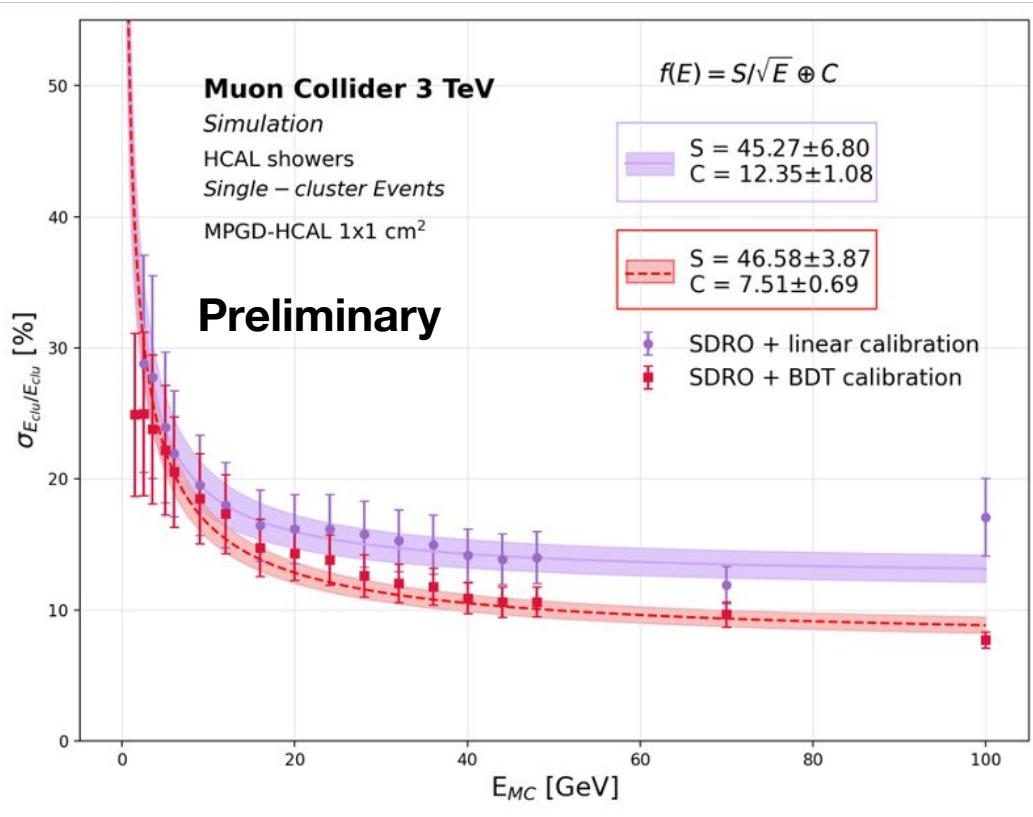
## BDT implementation details

- **XGBoost** squared-error regression
- **Features dataset from pandora:**
  - Cluster energy and 3D centroid position
  - $(\text{Cluster size}) / \ln(\text{cluster energy} + 1)$
  - Number of hits in ECAL and in HCAL
  - Number of HCAL hits below and above the 2nd threshold of the semi-digital RO
  - Total energy in ECAL and in HCAL
  - Total fraction of hits/energy in ECAL and in HCAL
  - Number of hits for each layer of ECAL and HCAL
  - Energy Fraction for each layer of ECAL and HCAL



# Semi-digital readout with BDT calibration

Calibrated energy = BDT output coefficient x Raw cluster energy

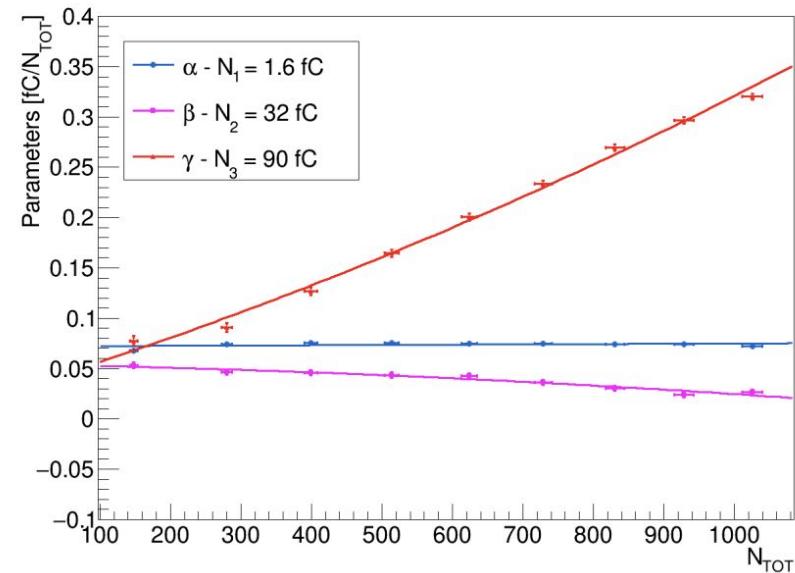
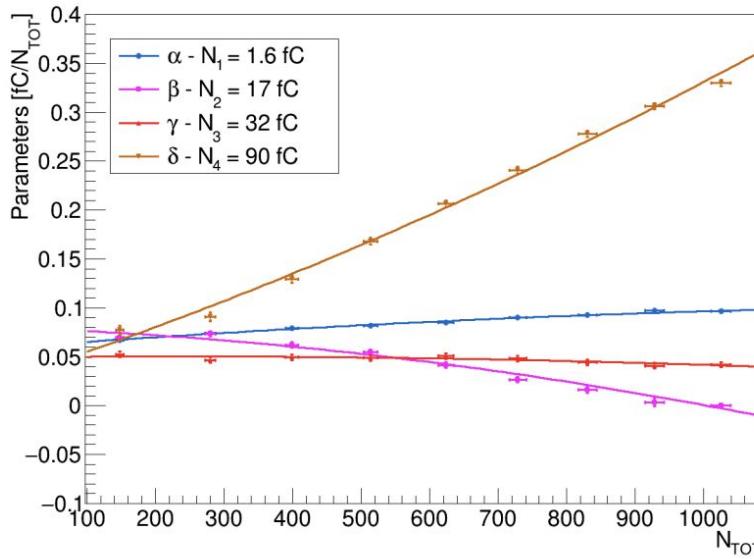


- only pions not showering in ECAL;
- fit function  $f(E)=S/\sqrt{E}+C$ ;
- Better energy resolution for  $E_{MC}>10$  GeV
- compatible stochastic term  $S \sim 45\%$
- Significant reduction of the constant term  $C$ :  $12\% \rightarrow 7\%$

# Boosted Decision Tree for GEANT4 simulation

## SDRO threshold optimization

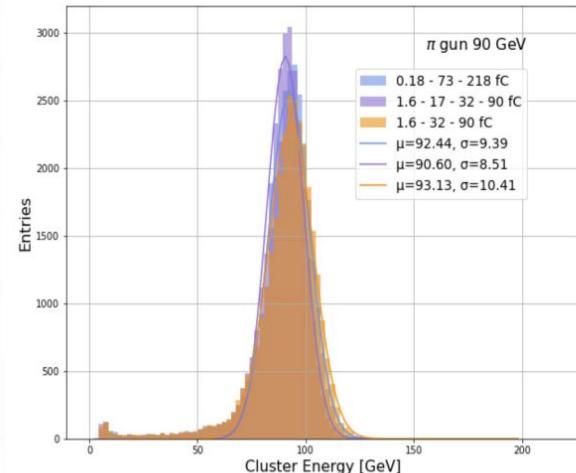
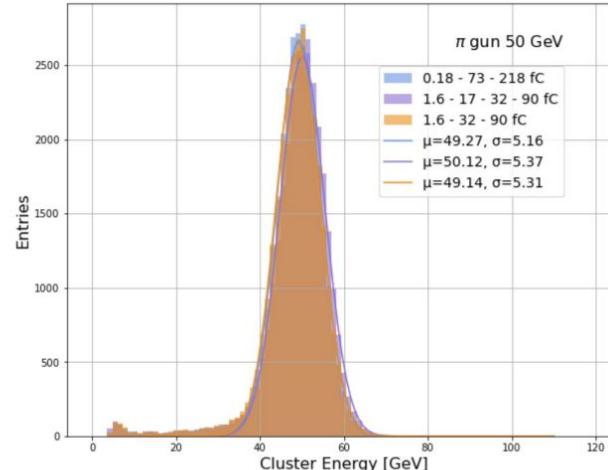
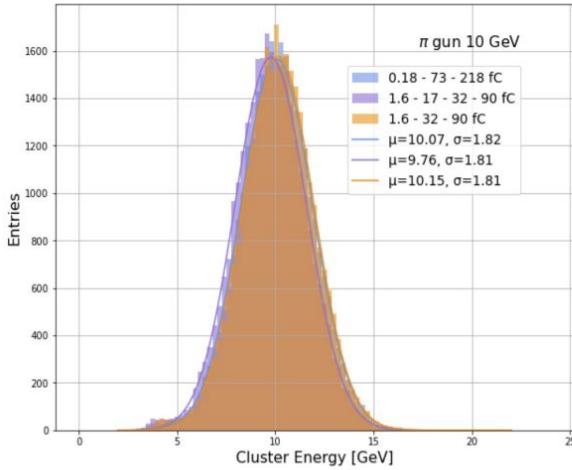
- SDRO parameters computation with chi-squared minimization for 3 and 4 thresholds



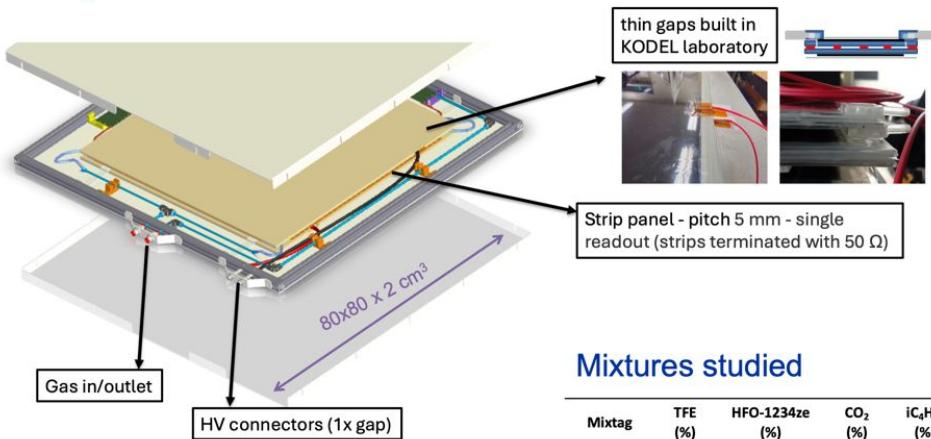
# BDT for threshold optimization

## Energy reconstruction comparison with different threshold sets

- **RPC-based thresholds** do not reconstruct the peak correctly
- **3thr SDRO** outperforms **4thr SDRO** below 50 GeV
- Above 50 GeV, 4thr reconstructs thinner peaks



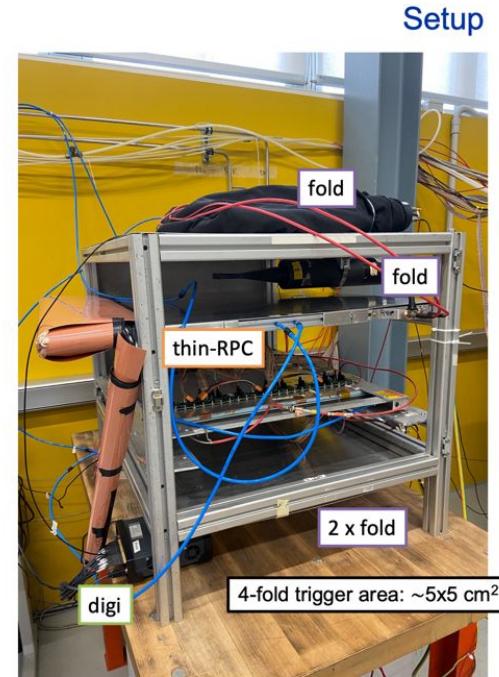
# Cosmic tests on thin-RPC



- **Double gap** with strip readout panel in between
  - Soda-lime glass electrodes: 1.1 mm thickness
  - Gas gap: 500 um thickness
- Signal readout: [CAEN Digitizer DT5742](#) for signal detector study

## Mixtures studied

Mixtag	TFE (%)	HFO-1234ze (%)	$\text{CO}_2$ (%)	$i\text{C}_4\text{H}_{10}$ (%)	SF6 (%)
STD	95.2	-	-	4.5	0.3
STD2ISO	97.7	-	-	2	0.3
STD0ISO	99.7	-	-	-	0.3
STD3CO2	65	-	30	4	1
ECO65	-	65	30	4	1
TFEISO	95	-	-	5	-
TFE	100	-	-	-	-
Density (g/l)	4.68	5.26	1.98	2.69	6.61
GWP	1430	7	1	3	22800

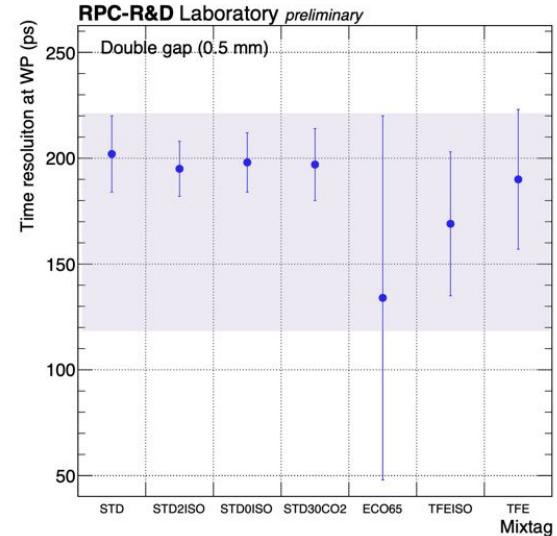
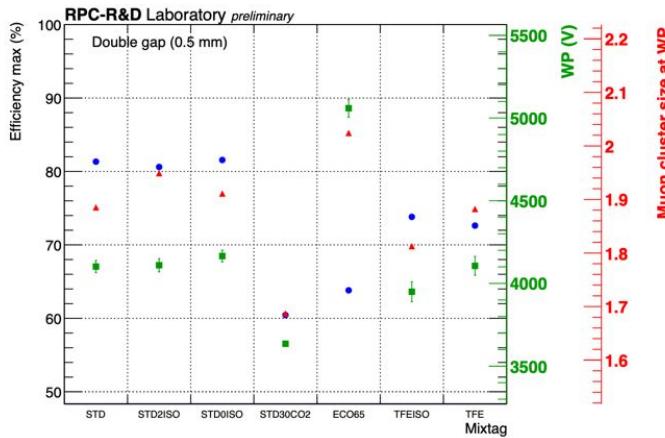


# Summary: preliminary results

## Efficiency and Working Point (operation voltage)

$$\varepsilon(HV) = \frac{\varepsilon_{max}}{1 + e^{-\beta(HV - HV_{50})}}$$

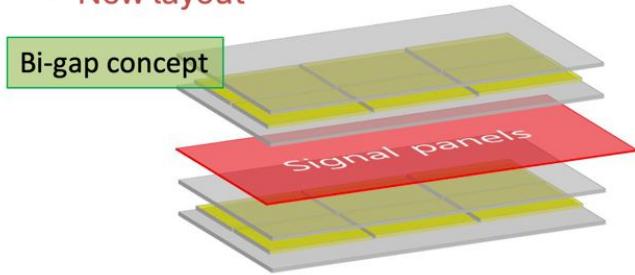
$$WP = \frac{\log 19}{\beta} + HV_{50} + 150 \text{ V}$$



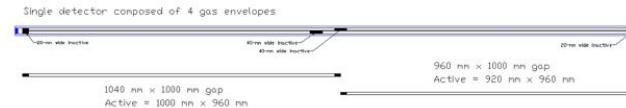
- Low efficiency at WP, roughly 70-80% (without FEE/preamplification)
- WP ~ 4 kV, around +1kV for ECO65
- Cluster size lower than 2 strips (strip pitch 5 mm)
- Chamber time resolution ~ 200 ps for all mixtures

# Foreseen steps

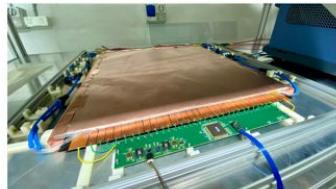
- New layout



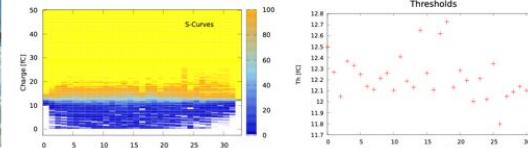
- 1 mm **RPC segmented** by a thin layer of a floating dielectric electrode, in two 0.5 mm sub-gaps
- Expected: 100-200 ps time resolution spatial resolution better than 1 mm with 3 mm wide pick-up strips



- **FEE – low charge operation**  
Tests with FATIC3-RPC version



Pre: FATIC2 on double gap glass RPC



- **Improve granularity and charge centroid algorithm**  
DRD1 test beams (July and November)
- **Sustainability test:** Low flux RPC operation