MPGDHCAL e sinergia PRIN

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25 Luglio 2024

Attività 2024 → 2025

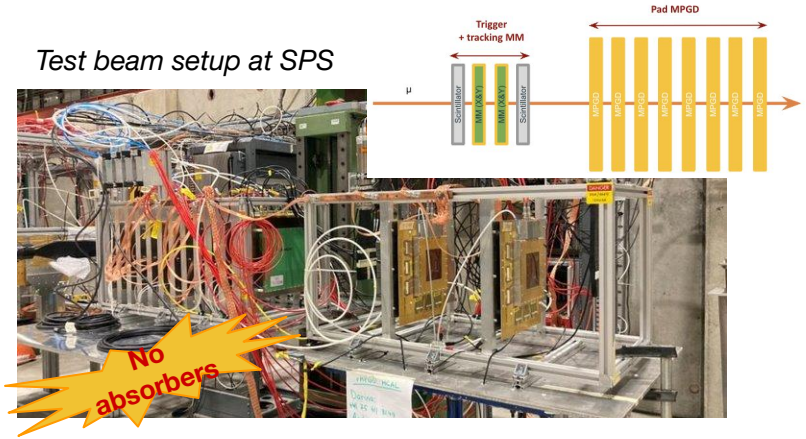
- **Sviluppo di un prototipo di calorimetro adronico a sampling basato su Micro Pattern Gaseous Detector, MPGD-HCAL (l'attività é anche inquadrata in DRD1-WP5/DRD6-WP1):**
  - analisi dati dei testbeam del 2023 → include anche la simulazione della cella calorimetrica testata
  - progettazione delle nuove camere 50x50cm2
  - progettazione della struttura meccanica della cella calorimetrica, contenente 8 camere da 20x20 cm2 e 4 camere 50x50cm2 → necessaria per i testbeam del prossimo anno (di cui uno congiunto con CRILIN)
  - test su fascio: SPS (Giugno 26-Luglio 10 2024) e PS (Luglio 10-24 2024)
  - studio della possibile elettronica alternativa → al momento si stanno utilizzando gli APV:
    - FATIC3 → 5 plugin card da testare (inizio dell'anno prossimo)
    - VMM3a → una borsista csn1 magistrale testerà una camere μRWELL and una MicroMegas con vmm al GDD lab del CERN, con la possibilità di partecipare all'ultimo testbeam di DRD1 all'sps
  - full simulation all'interno del muon collider framework:
    - studi con e senza beam induced background
    - risoluzione applicando un approccio digital/semi-digital
  - Conferenze: Pisa meeting, ICHEP, CHEP(submitted & accepted), MPGD (submitted), SIF(accepted)

MPGDHCAL: 2023 SPS & PS test beam

test beam at SPS (July 2023):

- Tracking: 2 MicroMegas (256 μm-strip)
- Under test: 12 MPGD prototypes
  (7 μRWELL, 4 MicroMegas, 1 RPWELL)
- Gas: **Ar:CO_2:C_4H_{10}(93:5:2)** (MicroMegas & RPWELL),
  Ar:CO_2:CF_4(45:15:40) (μ-RWELL)
- Particle: O(100) GeV/c **muons**

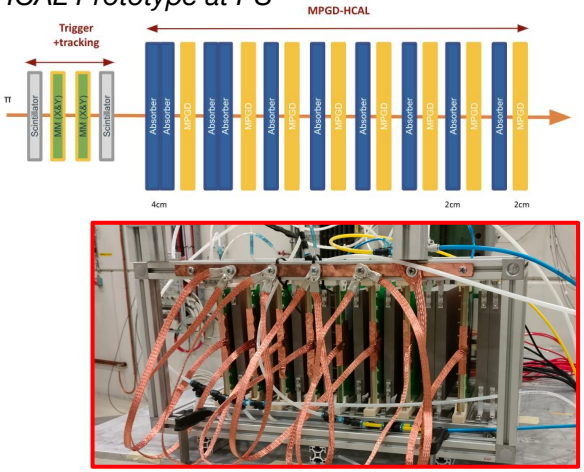
Test beam setup at SPS



test beam at PS (Aug/Sept 2023):

- Tracking system
- 1 λ_I calorimeter prototype:
  - 8 MPGDs (4μRWELL, 3 MM, 1 RPWELL)
  - First 2 layers of absorbers made of 4cm of Iron instead of 2cm to enhance showers in the first 2 layers
- Pions energy: 2-11 GeV

HCAL Prototype at PS

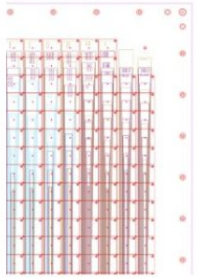


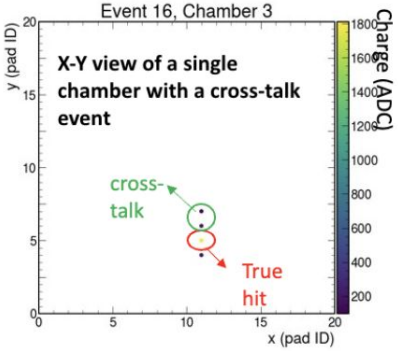
Readout **electronics**: **APV25** front-end chip (analog readout + time information) + **SRS** back-end

MPGDHCAL: 2023 SPS test beam

Test beam **analysis workflow**:

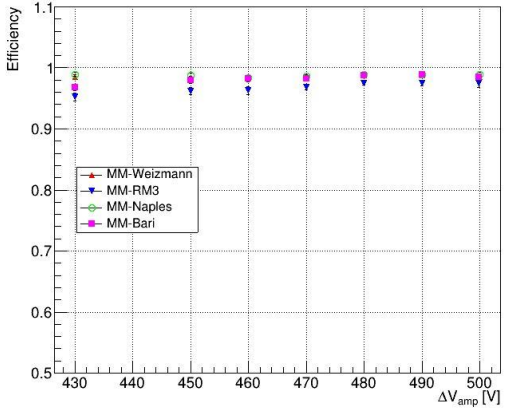
- **Tracks built using MPGDs** under test (5 out of 6 at a time):
  - **Tracking detectors unused** in reconstruction for the moment (high noise → possible to recover the tracker offline, currently ongoing).
- Observed high probability of **cross-talk** between pads *due to routing of readout vias from pads to front-end*
  - Patched **offline** by clustering pads based on charge sharing fraction

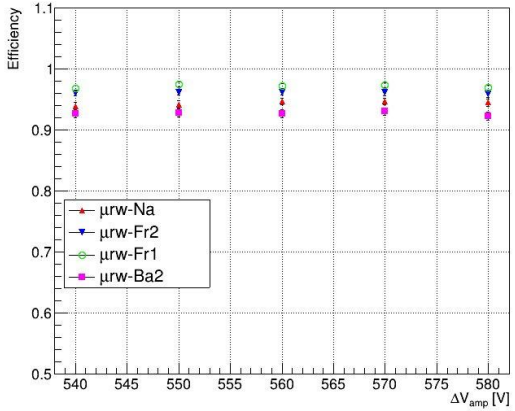


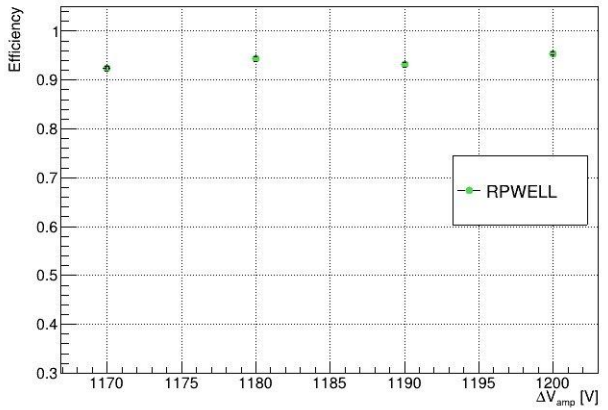


High average **efficiency** (detectors always operated at plateau)

Preliminary







MPGDHCAL: 2023 SPS test beam

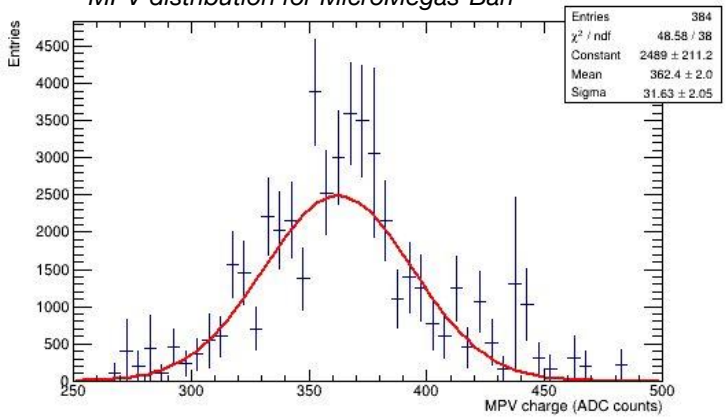
Preliminary

Gain uniformity

Response uniformity measured using clusters matching muon tracks

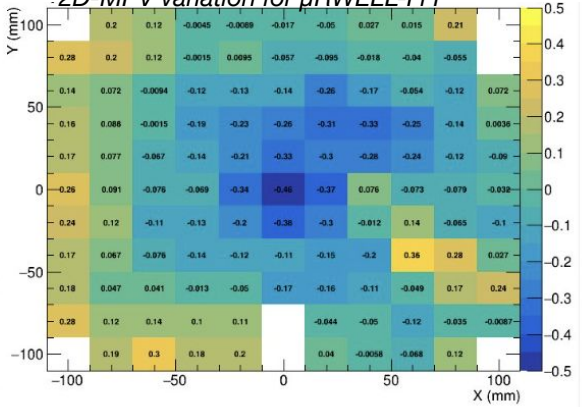
- Good uniformity for **MicroMegas** (~10%)
- Regions of non-uniformity observed on some **μ-RWELLs** → under investigation in lab
- Slightly worse uniformity for **RPWELL**

MPV distribution for MicroMegas-Bari

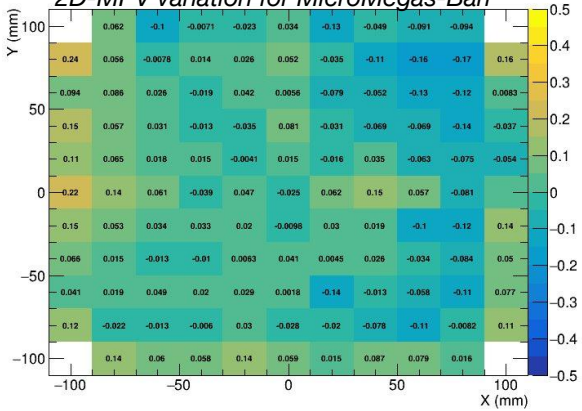


Detector	Uniformity (%)
MM-RM3	$(12.3 \pm 0.8)\%$
MM-Na	$(11.6 \pm 0.8)\%$
MM-Ba	$(8.0 \pm 0.5)\%$
RPWELL	$(22.6 \pm 4.7)\%$
μrw-Na	(11.3 ± 1.0) %
μrw-Fr2	$(16.2 \pm 1.7)\%$
μrw-Fr1	$(16.3 \pm 1.1)\%$

2D-MPV variation for μRWELL-Fr1



2D-MPV variation for MicroMegas-Bari



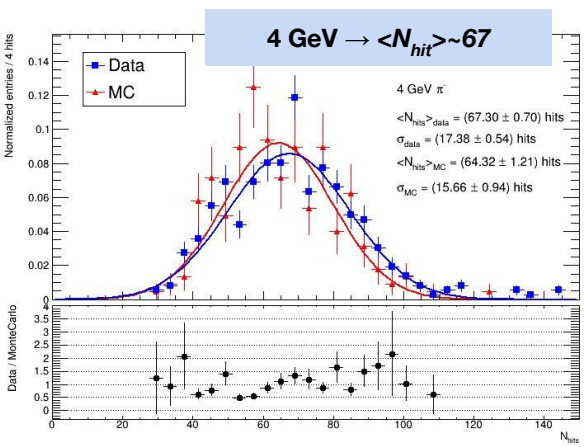
Calorimeter prototype at PS test beam

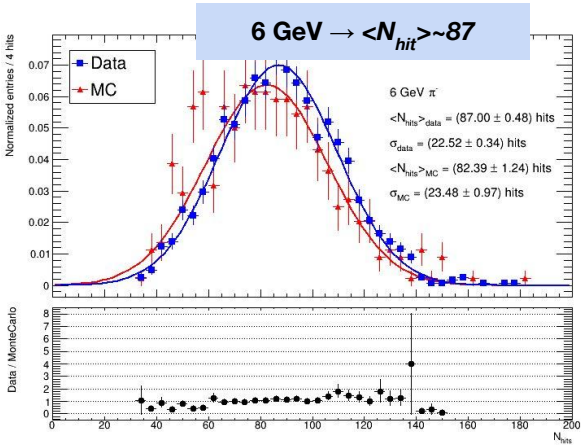
Event selection: events where pions start showering from the third layer:

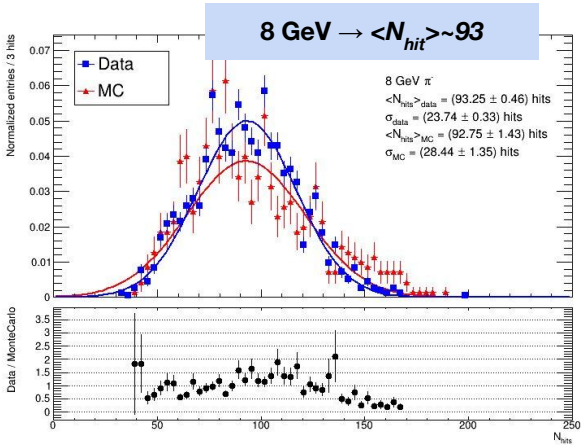
- **Issue:** problematic electronics for the first 2 MPGD layers

Preliminary

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



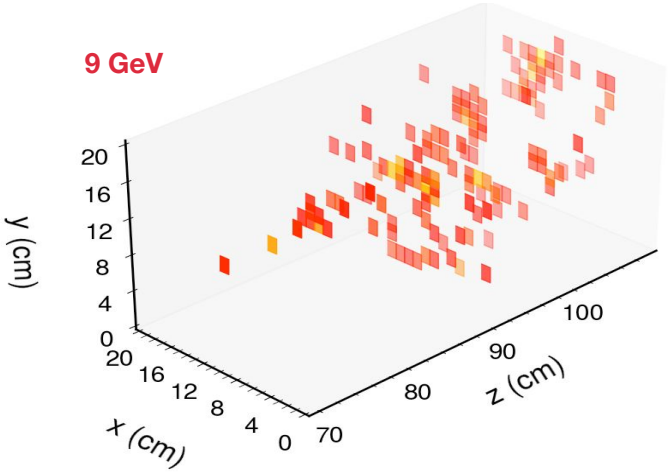


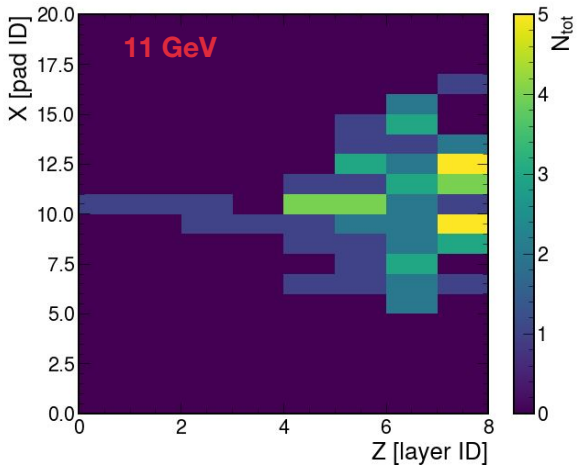


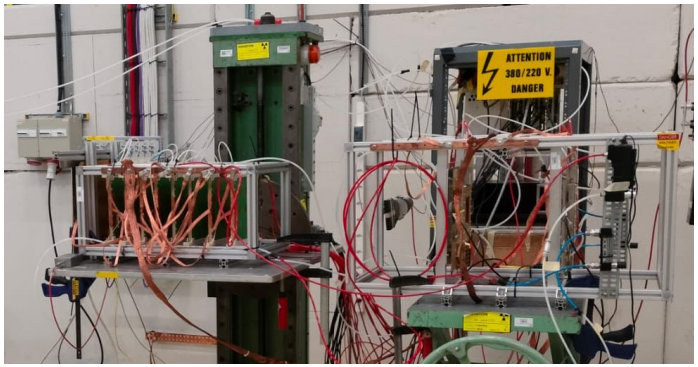
- **Good data/MC comparison**
- **Total number of hits increases as expected as a function of the energy**
- Ongoing studies to fully exploit all the data collected

2024 Testbeam

Shower events (2024)







- Consolidating results with present prototypes in two test beams in 2024:
  - SPS (June 26-July10):
    - full efficiency Vs HV curve,
    - response uniformity,
    - timing
  - PS (July 10-24):
    - test of a fully equipped 8 MPGD layers Prototype with pions beam (*E~3-11 GeV*)
    - First trial to run 2 independent APVs/SRS DAQ systems (MPGDHCAL & RHUM) but with the same trigger chain to evaluate the possibility of an offline full event reconstruction and overcome the limits of an APVs/SRS system

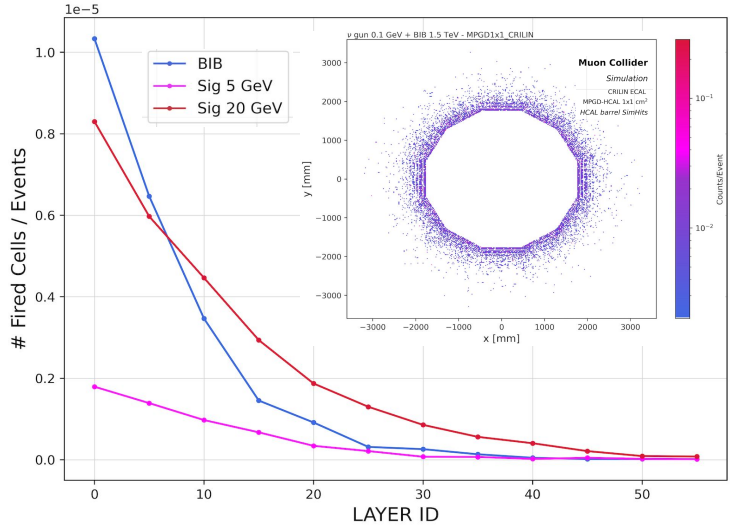
Full simulation in: HCAL BIB studies

Preliminary

- 60 layers (2.65cm layer thickness; 2cm of Iron; 3mm Ar) MPGD-based HCAL
- considered CRILIN as ECAL in the simulation
- Included BIB at 1.5 TeV

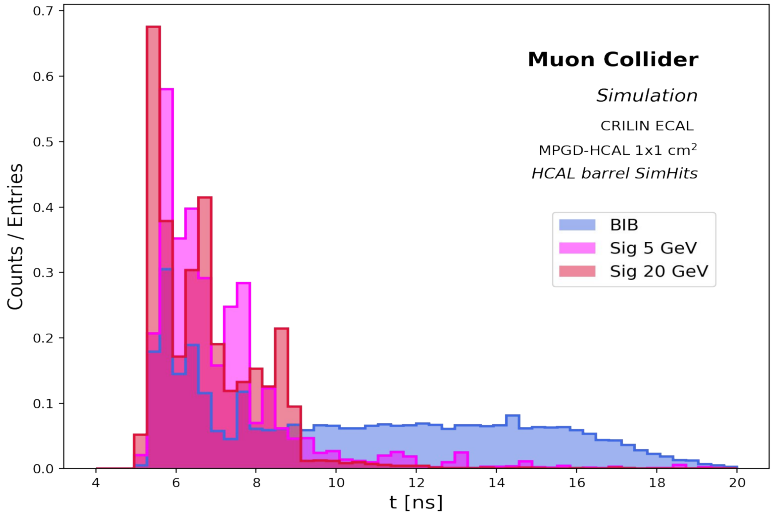
Hit Occupancy:

- **BIB** containment within the **first 20 layers** of HCAL
- Probability of a cell to be fired in the first layer :
  - **BIB** : ~ 1 x 10-5
  - **$\pi^{\pm}$ 5 GeV** : ~ 0.2 x 10-5
  - **$\pi^{\pm}$ 20 GeV** : ~ 0.8 x 10-5
- Challenge for low energy pion reconstruction

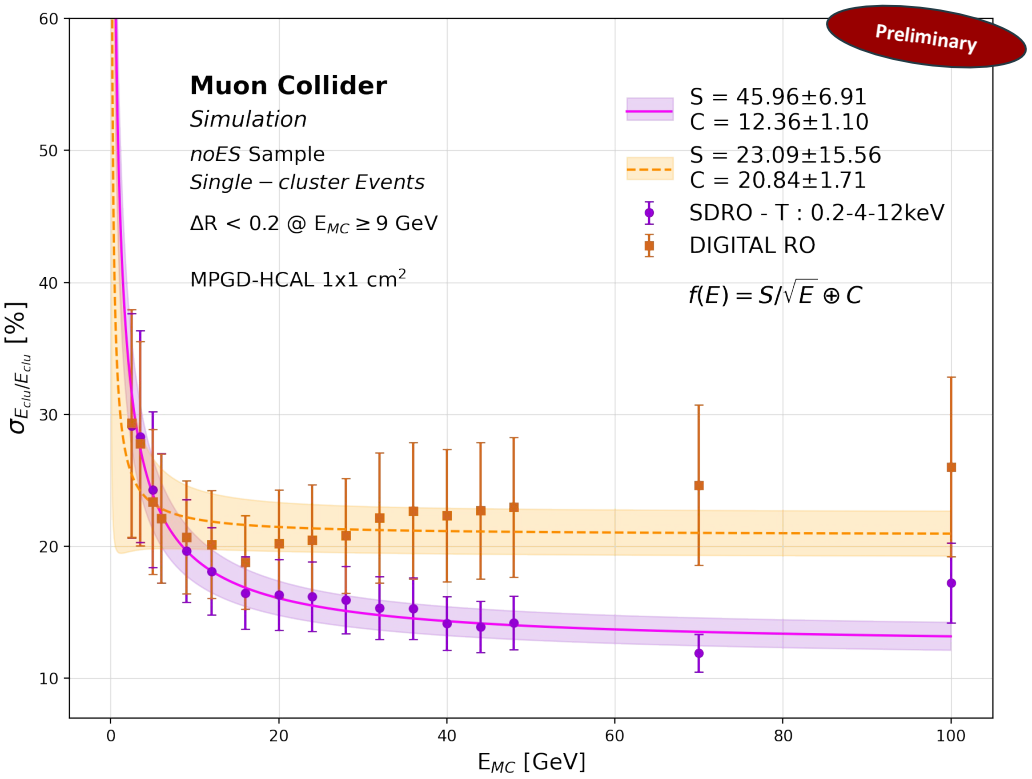


Arrival time:

- **BIB** arrival time distribution uniform in the **range 7-20 ns;**
- **signal** arrival time peaks at **~ 6ns**;
- discrimination possible for ***t>9/10 ns*** → **achievable with MPGD detectors**



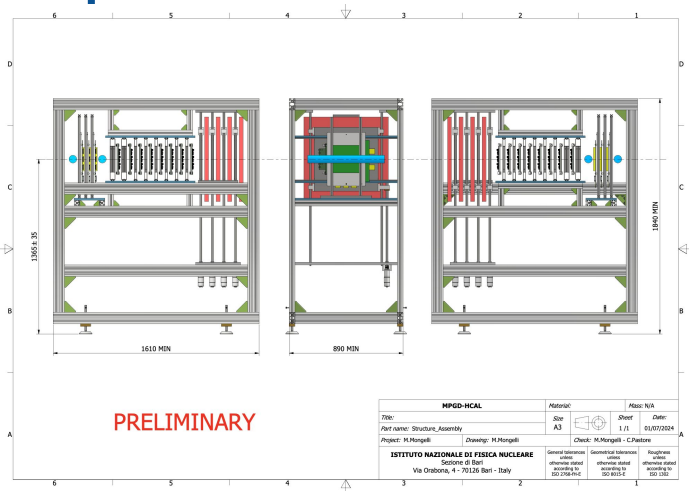
Full simulation: Digital Vs Semi-digital



- $\pi^{\pm}$ guns with energy ranging from 2.5 to 100 GeV;
- **only pions not showering in ECAL**;
- reconstruction with Digital ReadOut (RO) and SemiDigital RO SDRO:
  - Thresholds considered for SDRO: 0.2, 4, 12 keV
- fit function $f(E)=S/\sqrt{E}\oplus C$;
- comparable performances below 6 GeV between Digital RO and SDRO
- **Digital RO: saturation at high energies**
- **Overall, better performances of the SDRO**
  - **σ/E = 45.96%/$\sqrt{E}\oplus$12.36%**

MPGDHCAL: richieste/piani

- **2024:**
  - **struttura meccanica per il prototipo di ~2 λ:**
    - 8 camere 20x20cm^2
    - 4 camere 50x50cm^2
    - possibilità di far traslare gli assorbitori per la caratterizzazione delle 50x50cm^2 (link)



- **2025:**
  - **Camere 50x50cm2:**
    - Design della readout board in discussione con l'MPT workshop:
      - Idea di ridurre il cross-talk aumentando la gap fra il layer di Pad ed il primo layer di vias
    - l'offerta ricevuta dall'MPT workshop del CERN per design e produzione delle camere 50x50cm2 si è rivelata elevata (link):
      - MicroMegas x 2: 32.3 kCHF
      - μRWELL x 2: 28.7 kCHF
    - Vorremmo coprire con il PRIN: 2 μRWELL ed una MicroMegas
    - Richiesta di 17k euro per l'acquisto di una camera MicroMegas [sinergica DRD1-WP5]

MPGDHCAL: richieste/piani

- **2025:**
  - **Gas:**
    - Richiesta di 1k euro per l'acquisto del gas (Ar:CO2:Iso e/o Ar:CO2:CF4)
  - **Struttura meccanica:**
    - Richiesta di 1k euro per la spedizione della struttura da Bari al CERN
  - **Materiale per testbeam:**
    - Richiesta di 2.5k euro per affitto moduli al pool
  - **Missioni per test beam e loro preparazione:** richiesta di 24k euro che include
    - 1 settimana per la preparazione della struttura meccanica (1 tecnico al cern)
    - 6 settimane di testbeam (2 al PS, 2 all'SPS + 1x2 per la pre/post preparazione dei test beam) x 2.5 persone:
      - Il testbeam al PS è da programmare insieme a CRILIN
    - test al gdd per una prima caratterizzazione delle camere (4 settimane)
  - **Missioni per muon collider:**
    - 4.5k euro da metabolismo
    - 16.5k euro per meeting/conferenze

MPGDHCAL: richieste/piani

- **2025:**
  - **Attività DRD1-WP1&7:**
    - Studio di ecomiscele per rimpiazzo gas fluorurati:
      - l'attività si concentrerà inizialmente su studi di performance condotti su double-gap glass RPC con standard gas mixture (95.2% $C_2H_2F_4$, 4.5% iC_4H_{10} e 0.3% SF_6) ed eco friendly gas mixture, per poi vertere su un possibile sostituto per il CF_4 da utilizzare con le μRWELL
      - acquisto gas: 2k euro
      - picoTDC: 7.5k euro (link)
      - Mass flow meter: 5k euro
      - Missioni:
        - 3k euro per testbeam alla GIF++
        - 3k euro di riunioni di collaborazione DRD1

Anagrafica (3.6 FTE)

cognome	nome	note	struttura	modulo	contratto	profilo	stato	aff	perc
Ali	Muhammad		BA	G1	Associato	Scientifica Dottorandi	Attivo	1	100%
Catanesi	Maria Gabriella		BA	G1	Associato	Associazione Senior	Attivo	1	*
Colaleo	Anna		BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	10%
Creanza	Donato Maria		BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	10%
Fiore	Luigi		BA	G1	Dipendente	Primo Ricercatore	Attivo	1	30%
Iaselli	Giuseppe		BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	5	10%
Longo	Luigi		BA	G1	Dipendente	Ricercatore	Attivo	1	30%
Maggi	Marcello		BA	G1	Dipendente	Primo Ricercatore	Attivo	1	10%
Margjeka	Ilirjan		BA	G1	Dipendente	Assegno di Ricerca	Attivo	1	10%
Pellecchia	Antonello		BA	G1	Dipendente	Assegno di Ricerca	Attivo	1	20%
Radicioni	Emilio		BA	G1	Dipendente	Primo Ricercatore	Attivo	1	30%
Spina	Roberto		BA	G1	Associato	Tecnologica Ricercatori/Professori università	Attivo	1	30%
Stamerra	Anna		BA	G1	Associato	Scientifica Assegni non INFN	Attivo	1	30%
Venditti	Rosamaria		BA	G1	Associato	Incarico di Ricerca scientifica	Attivo	1	30%
Verwilligen	Piet Omer J	10% AIDAINNOVA sinergia con CMS	BA	G1	Dipendente	Ricercatore	Attivo	1	10%

Backup

MPGD prototypes

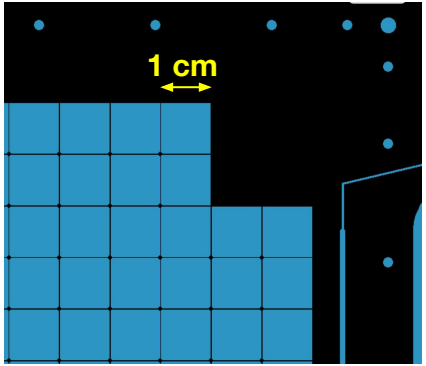
Prototypes produced and tested within **RD51 common project**:

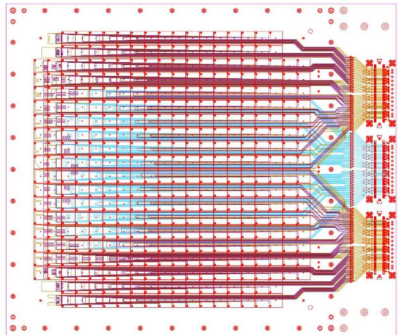
- 7 μ-RWELL
- 4 MicroMegas
- 1 RPWELL

Detector design:

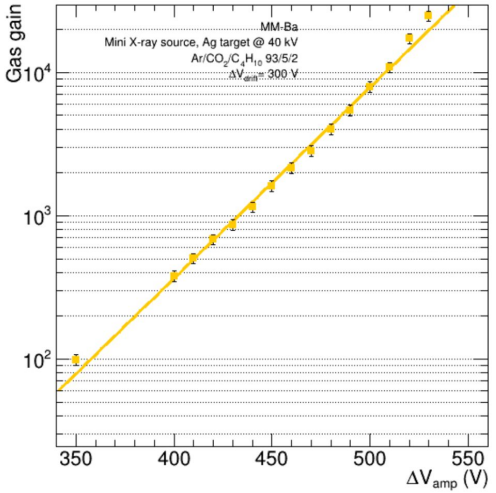
- Active area 20×20 cm^2, pad size 1×1 cm^2
- **Common readout** board

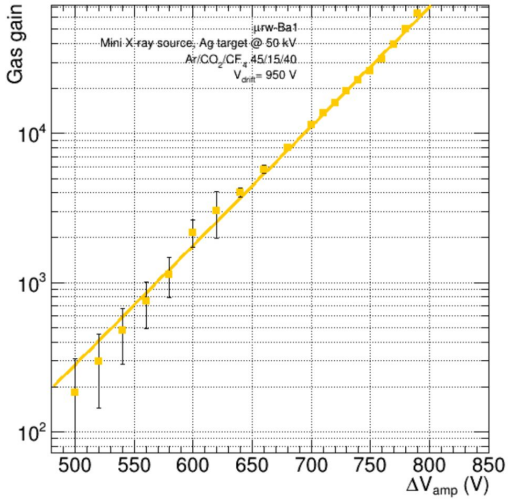
Prototypes characterization performed in different laboratories (Bari, Frascati, Naples, Rome3,Weizmann)





MicroMegas:
G = 10^4 at
E_a = 50 kV/cm
in Ar/CO_2/C_4H_{10}

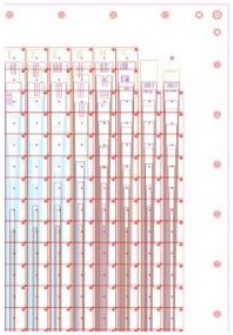


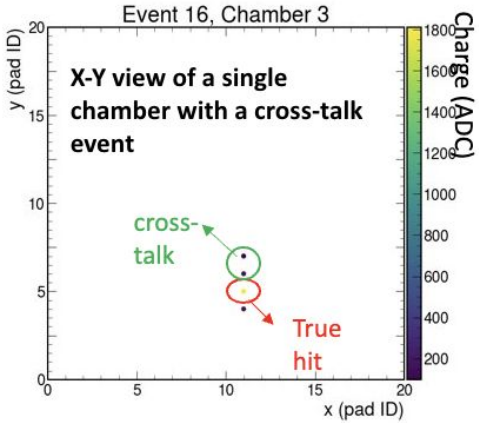


μ-RWELL:
G = 10^4 at
E_a = 140 kV/cm
in Ar/CO_2/CF_4

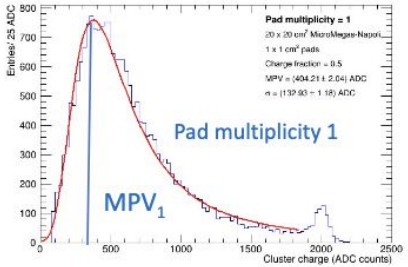
Cluster reconstruction

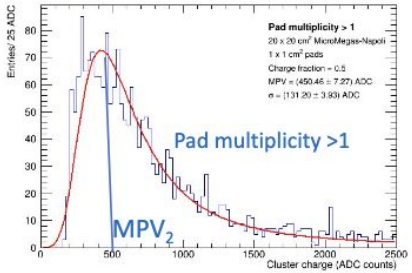
Preliminary

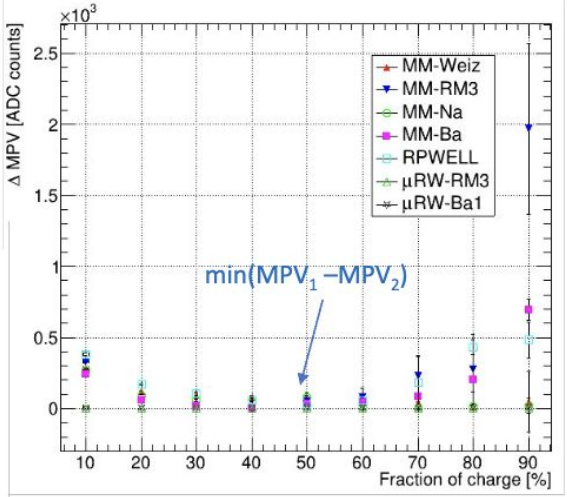




High probability of **cross-talk** effect observed among adjacent pads due to routing of the vias connecting pads to the connectors





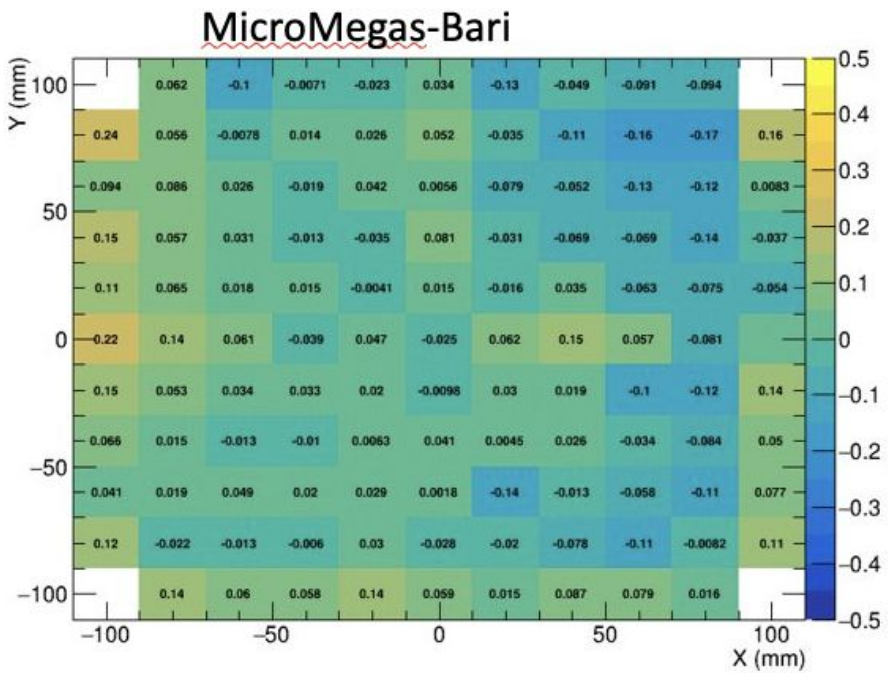


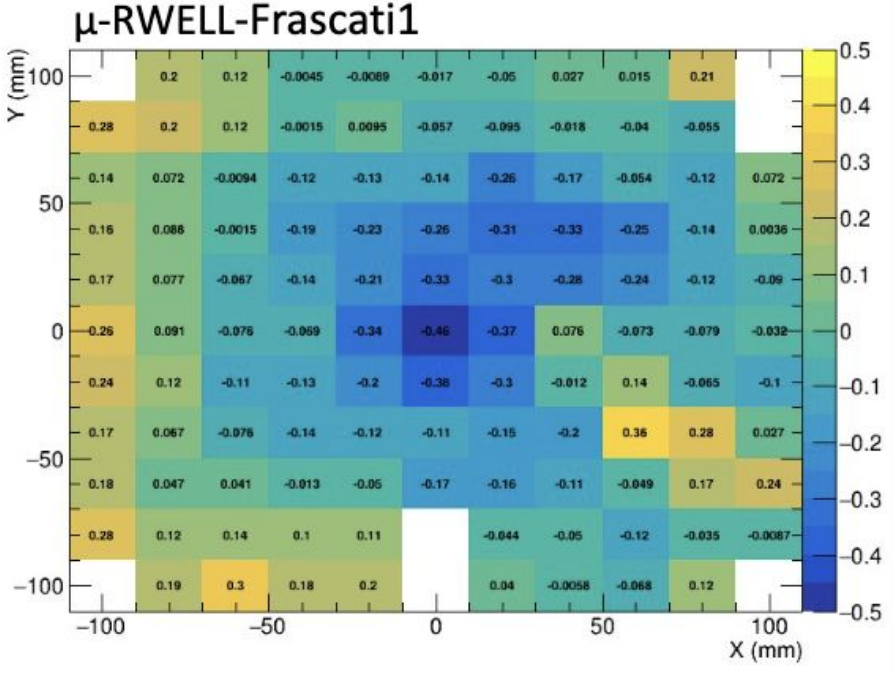
Developed ad-hoc **clustering algorithm** based on charge sharing criterium

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

Response uniformity

Preliminary

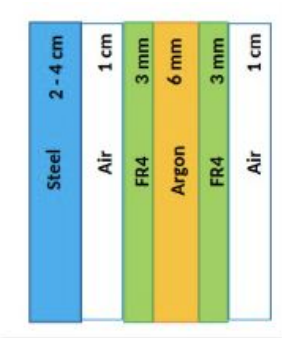




G4 simulation: small prototype

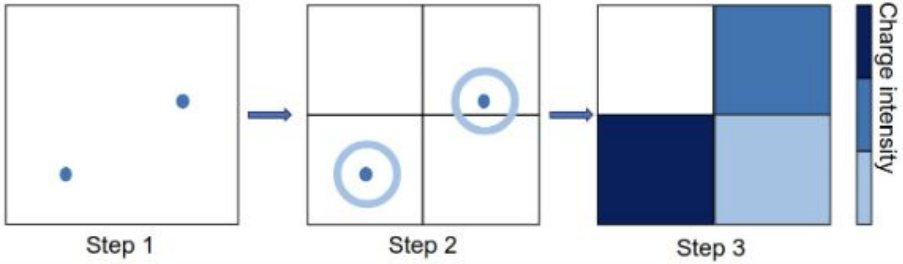
Preliminary

- Small detector geometry implemented
  - 8 layers of alternating of 2 cm stain-less steel absorbers and MPGD
    - First 2 layers with 4 cm absorbers to increase probability of shower development in the first layers
  - 20x20 cm^2 active surface
  - 1x1 cm^2 pad granularity
- Pion gun of energy range available at PS (4 – 8 GeV)

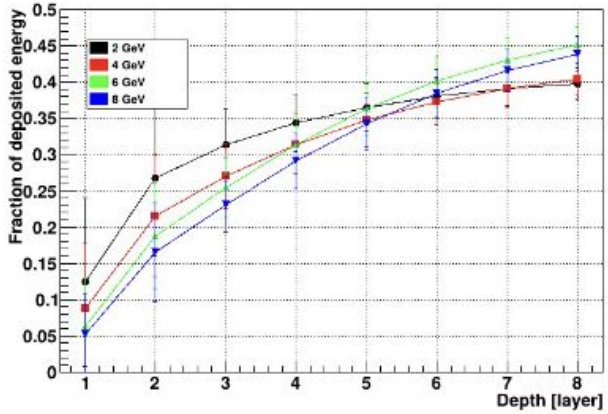


- **Digitization algorithm** implemented to account for charge-sharing among adjacent pads and detector efficiency

Digitization algorithm



Shower containment



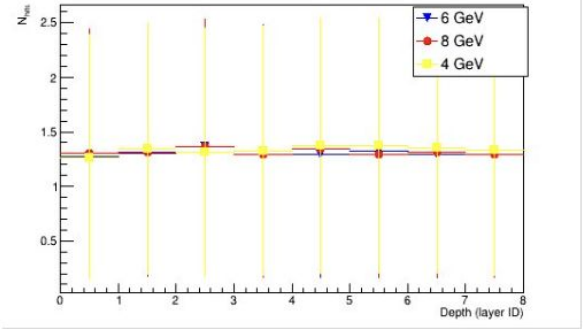
PS data / G4Sim prototype - event selection

Preliminary

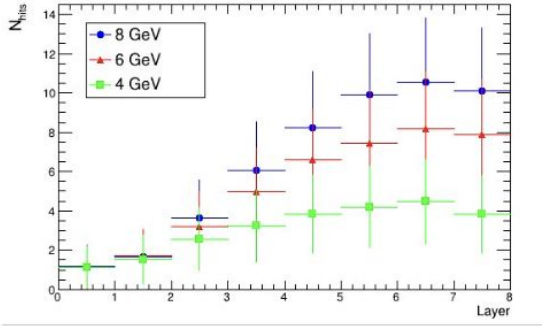
Event **selection criteria** supported by **simulation** using MC truth

- MIP-like events:
  - single hit in each layer
- Shower events:
  - more than 4 hits per layer starting from layer 3

MIP-like events - simulation

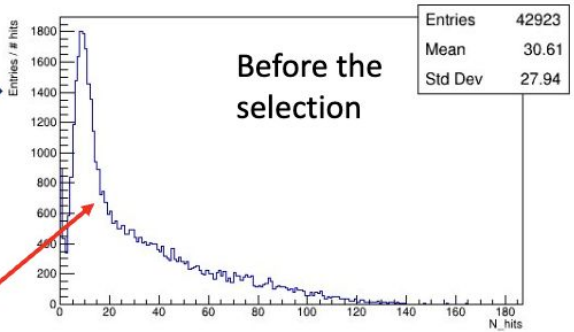


Shower events - simulation



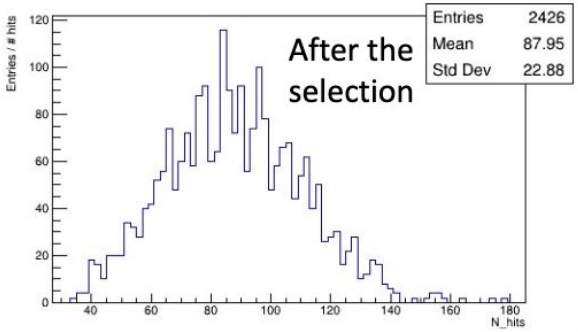
Distribution of the **number of hits** in all active layer from the **experimental data**

Number of hits for all events



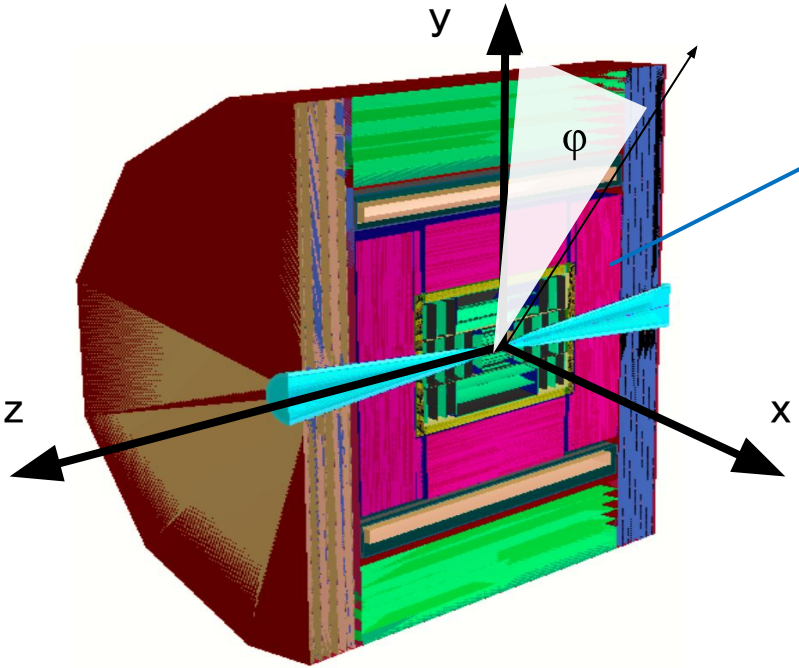
Peak at ~ 10 hits
-> MIP-like events

Number of hits for showers event



Simulation: HCAL BIB studies

Geometry considered for the hadronic calorimeter



MPGD-based HCAL

60-layer SAMPLING CALORIMETER

Layer thickness: **2.65 cm** - cell: **1 cm²**

HCAL LAYER COMPOSITION:

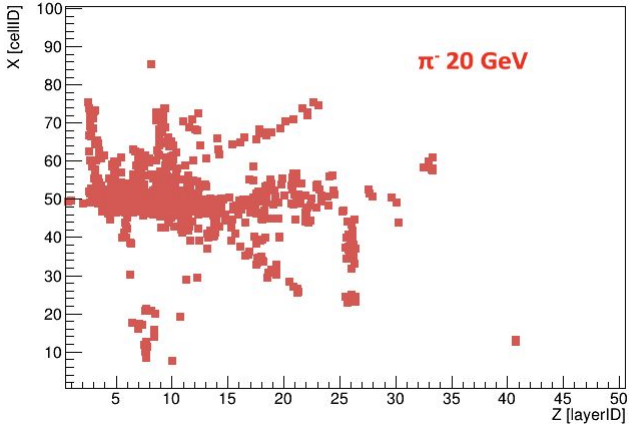
Iron (absorber)	20 mm
Argon (active material)	3 mm
Copper (RO electronics)	0.1 mm
PCB (RO electronics)	0.7 mm
Air (environment)	2.7 mm

BIB simulated for a center of mass energy (ECM) of 1.5 TeV; CRILIN (more details in R. Gargiulo Talk) assumed as ECAL

Simulation: Digital and Semi-digital HCAL

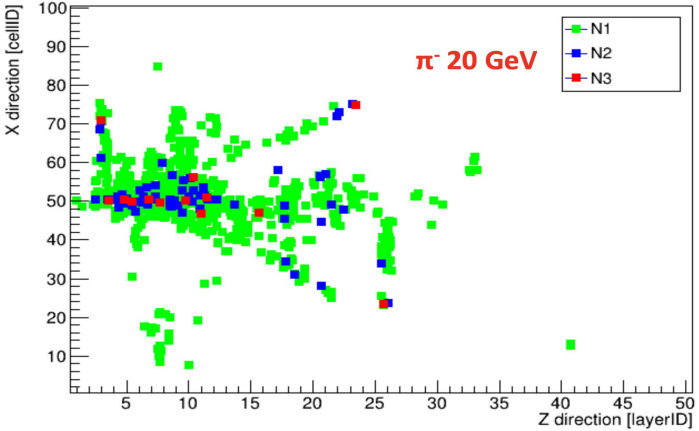
Digital Readout (Digital RO)

- **Digitization:** 1 hit=1cell with energy deposit higher than the applied threshold
- **Calorimeter response function:** $\langle N_{hit} \rangle = f(E_\pi)$
- **Reconstructed energy:** $E_\pi = f^{-1}(\langle N_{hit} \rangle)$



Semi-digital Readout (SDRO)

- **Digitization:** defined multiple thresholds
- **Reconstructed energy:** $E_\pi = \alpha N_1 + \beta N_2 + \gamma N_3$ with:
  - $N_{i=1,2,3}$ number of hits above *i*-threshold
  - α, β, γ parameters obtained by χ^2 minimization procedure

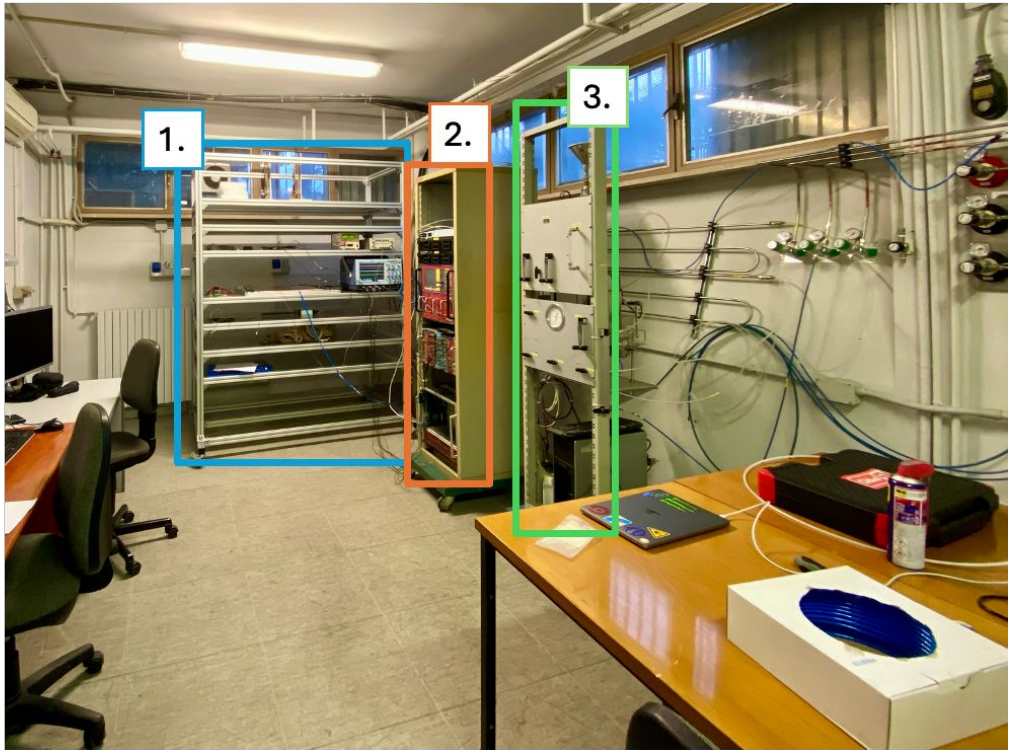


DRD1-WP1 & 7

INFN RPC Laboratory at Department of Physics of Bari University

Equipment

1. Cosmic stand: 2 MRPC + 2 scintillators for cosmic trigger
2. Electronics rack: trigger logic + webdcs + network hub + HV power supply
3. Gas rack for CMS standard mixture: 3 mass flow controllers (1 more needed to operate RPC with 4 primaries gaseous mixtures → ecofriendly candidates) + mixer + humidifier



DRD1-WP1 & 7

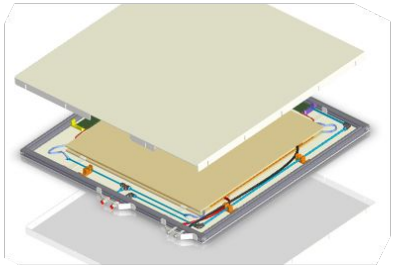
2024 activities

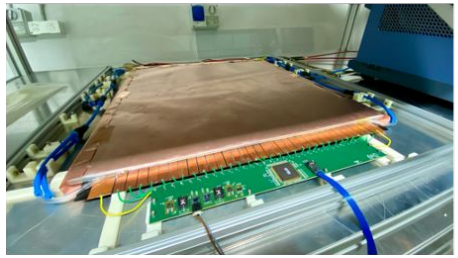
1. **New Double-gap glass RPC** (1.4 mm gap and 1.1 mm electrode thickness) tested with readout electronics: **new electronics based on FATIC2 chip** adapted for RPC signals TDC time resolution **∼100 ps**

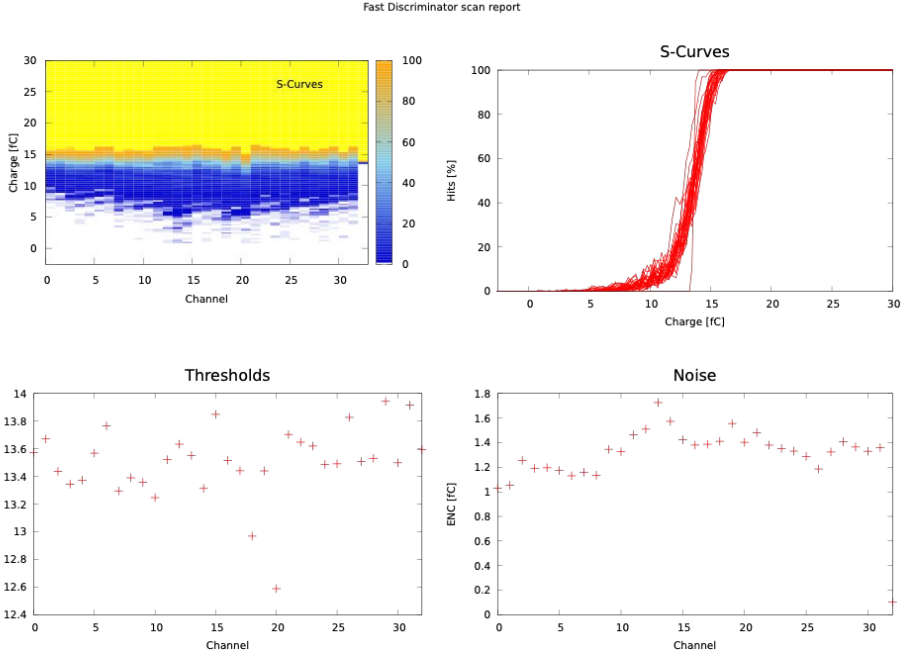
Preliminary calibration (S-Curves and threshold scans) of the new electronics performed at INFN RPC Lab in Bari → low charge thresholds tests (DRD1 WP7B)

2025 plans

Fine tuning of prototype equipped with FATIC (Noise-signal ratio), performance studies with cosmics operated with CMS standard gas mixture and ecofriendly mixture candidates







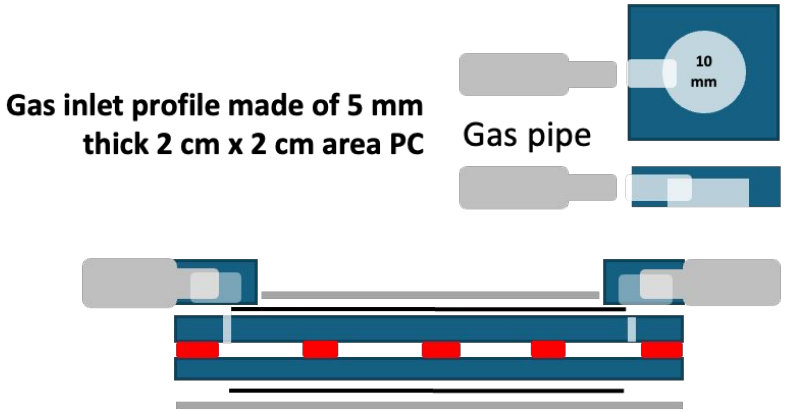
DRD1-WP1 & 7

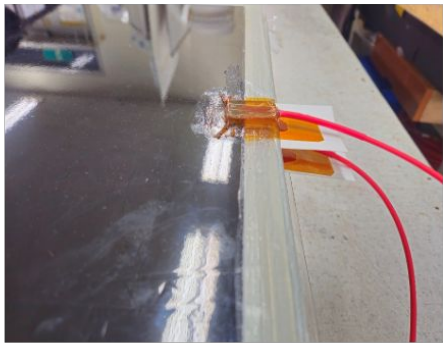
2024 activities

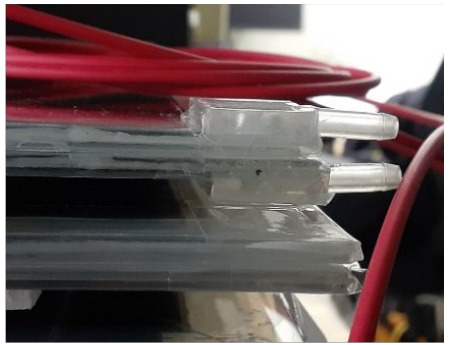
2. Four 50x50 cm2 prototype gas gaps were produced at Korea University with gas thickness of 0.52 mm for fast timing RPC prototype (DRD1 WP7B)

2025 plans

- Time resolution measurements of the prototypes with data aquisition based on CAEN PicoTDC with cosmics in Bari Laboratory. The timing performance will be comparing between different mixtures (CMS standard and ecofrindly candidates)
- Beam test at GIF++ for performance studies at different radiation intensities







Contributions RPC Bari group 2024

Presentations

Dayron Ramos	Performance and ageing studies on Eco-Friendly Resistive Plate Chamber detectors	42ND INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS 18-24 July 2024
Gabriella Pugliese	Operations and Performance Summary of CMS Muon System for LHC Run 3	42ND INTERNATIONAL CONFERENCE ON HIGH ENERGY PHYSICS 18-24 July 2024
D. Ramos López (PO)	Longevity study of CMS Muon Detector facing the High Luminosity LHC phase	25th International Workshops on Radiation Imaging Detectors
D. Ramos López (PO)	New RPC Gas Mixtures for Sustainable Operation in the CMS Experiment	PM2024 - 16th Pisa Meeting on Advanced Detectors

Publications

- Preliminary results on the long term operation of RPCs with eco-friendly gas mixtures under irradiation at the CERN Gamma Irradiation Facility, Quaglia L., Ramos D. and ECOgas@GIF++ Collaboration https://doi.org/10.48550/arXiv.2311.17574

Person power

- Senior professors: Giuseppe Iaselli, Gabriella Pugliese, Marcello Abbrescia
- PostDocs: Dayron Ramos López, Umesh Shas
- PhD student: Nicola Ferrara