RD_MuColl – INFN Bari
Anagrafica e Richieste servizi di sezione

L. Longo

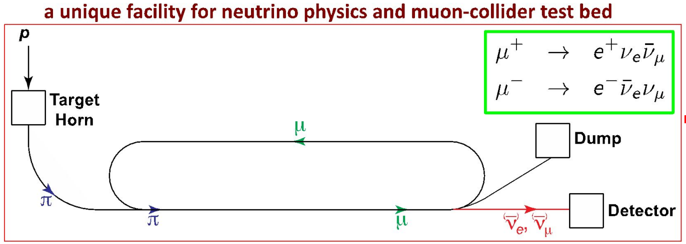
Meeting CSN1 Bari - 27 Giugno 2024

Attività 2024 → 2025

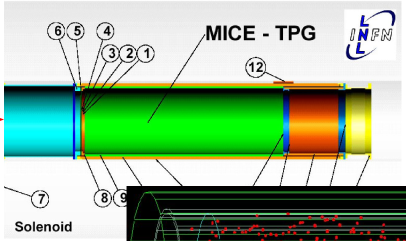
- **Sviluppo di un prototipo di calorimetro adronico a sampling basato su Micro Pattern Gaseous Detector, MPGD-HCAL (DRD1-WP5/DRD6-WP1):**
    - analisi dati dei testbeam del 2023 → include anche la simulazione della cella calorimetrica testata
    - progettazione delle nuove camere 50x50cm2
    - progettazione 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 semi-digital ed ottimizzazioni della threshold
    - Conferenze: Pisa meeting, ICHEP, CHEP(submitted), SIF(2 abstract submitted)

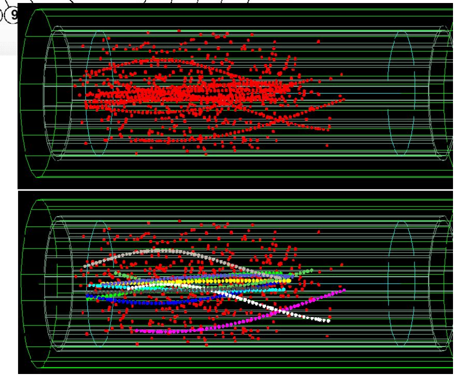
Attività 2024 → 2025

- **Sviluppo di un prototipo di TPC con readout ottico da utilizzare per il monitoraggio dei muoni al dimostratore del muon collider (DRD1-WP4/WP8)**



From MICE proposal





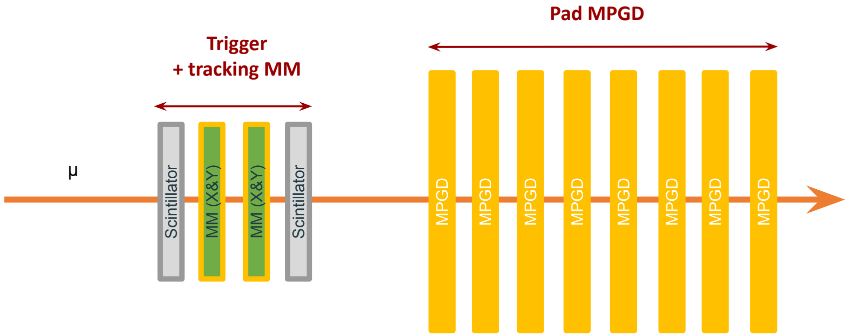
  - Differentemente da quanto proposto per MICE, si vuole sfruttare l'ultima generazione di readout ottici (TimePix4 or similar) per avere una TPC con una struttura più leggera in grado di tollerare una più alta densità di tracce e tale da migliorare la ricostruzione multitraccia e la reiezione del fondo.

  - Studi sulle miscele di gas saranno necessari.

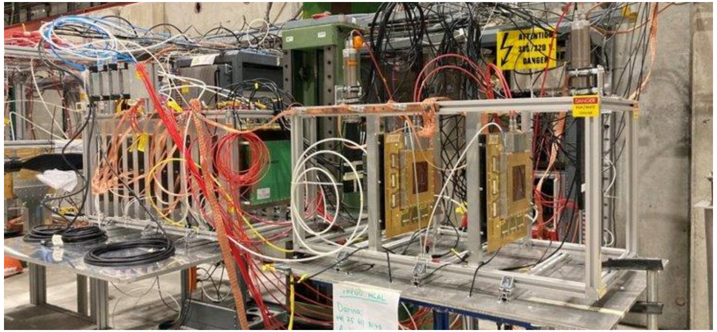
  - Al momento e' in corso il rinnovo del laboratorio:
    - realizzazione e installazione del nuovo sistema di gas utilizzabile fino a pressioni di 10 bar [DRD1 (WP4,WP8)
    - acquisto di HV supply per voltaggi fino a 100 kV

  - Si conta di portare a Bari una field-cage standard gia' esistente

MPGDHCAL: SPS test beam



Test beam setup at SPS



Readout layers operated in **test beam at SPS** (July 2023):

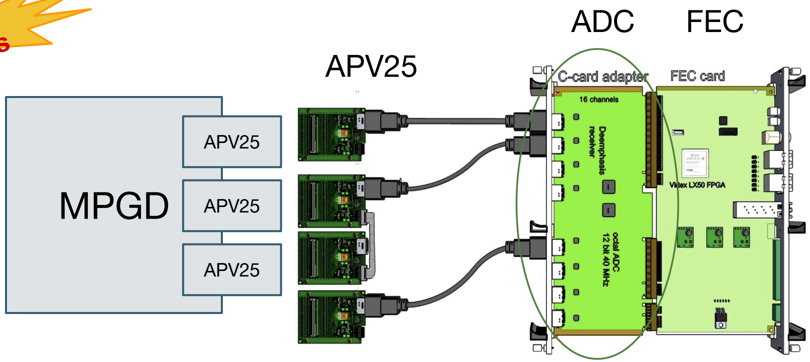
- Tracking: 2 MicroMegas (256 μm-strip)
- Under test: 12 MPGD prototypes

  Gas: **$Ar:CO_2:C_4H_{10}$** (MicroMegas & RPWELL), **$Ar:CO_2:CF_4$** (μ-RWELL)
- Particle: O(100) GeV/c **muons**

No absorbers

Readout **electronics**:

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



Readout electronics based on the APV25 SRS

Goal: **validating** the readout detectors **with MIPs** and **compare** the three **technologies**

MPGDHCAL: SPS test beam

Test beam **analysis workflow**:

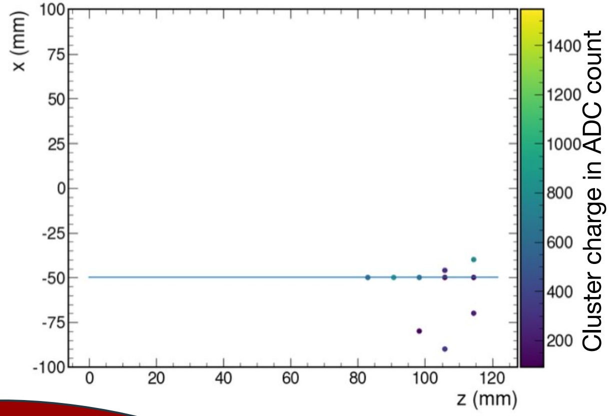
- **Tracking detectors unused** in reconstruction for the moment (high noise → possible to recover the tracker offline, currently ongoing). **Tracks built using MPGDs** under test (5 out of 6 at a time)

Track residuals:

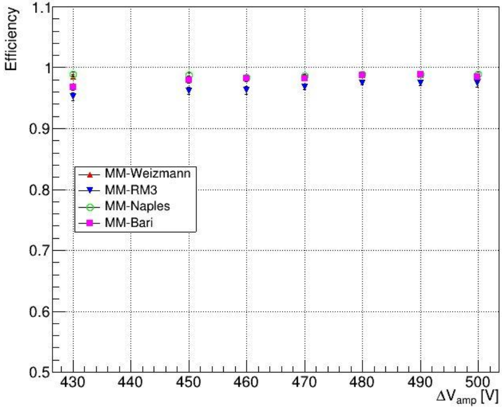
- Observed high probability of **cross-talk** between pads *due to routing of readout vias from pads to front-end*
- Patched **offline** by clustering pads based on charge sharing fraction

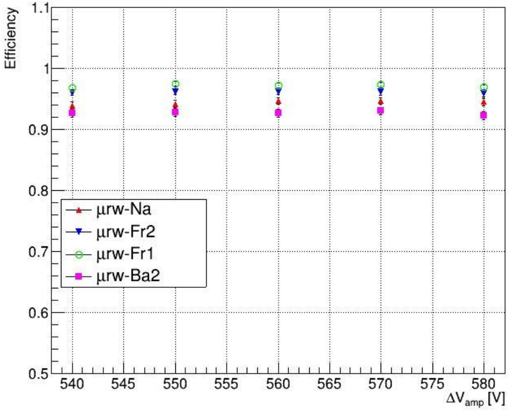
High average **efficiency** (detectors always operated at plateau)

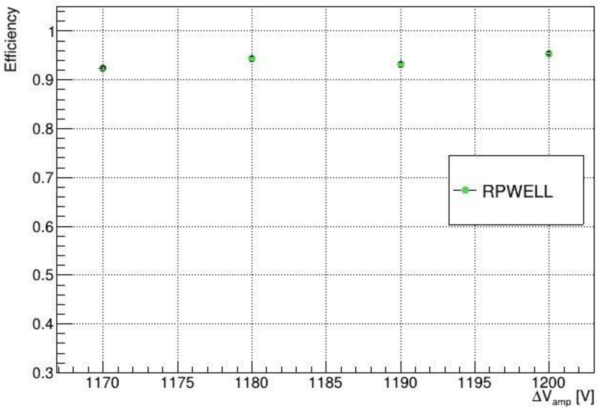
Track reconstructed using 4 detectors out of 5



Preliminary







MPGDHCAL: SPS test beam

Preliminary

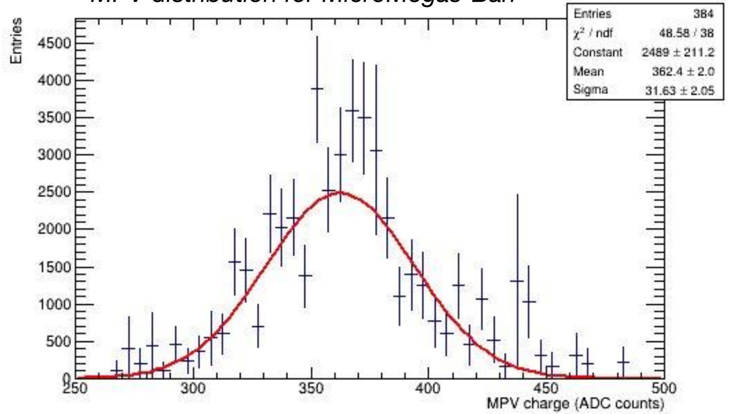
Gain uniformity

Response uniformity measured using clusters matching muon tracks

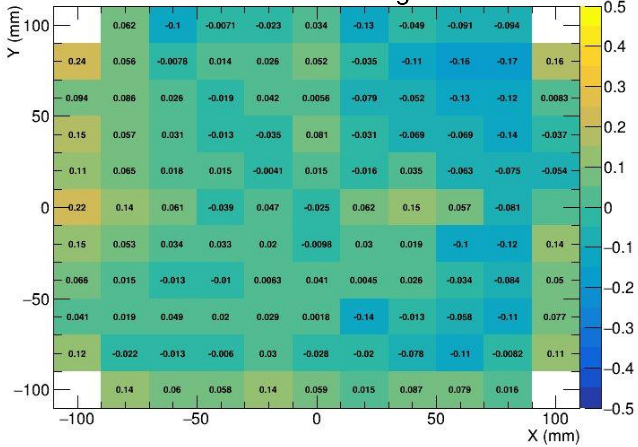
- Good uniformity for **MicroMegas** (~10%)
- Regions of non-uniformity observed on some **μ-RWELLs** → under investigation in lab
- Slightly worse uniformity for **RPWELL**

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	$(11.3 \pm 1.0)\ \%$
μrw-Fr2	$(16.2 \pm 1.7)\%$
μrw-Fr1	$(16.3 \pm 1.1)\%$

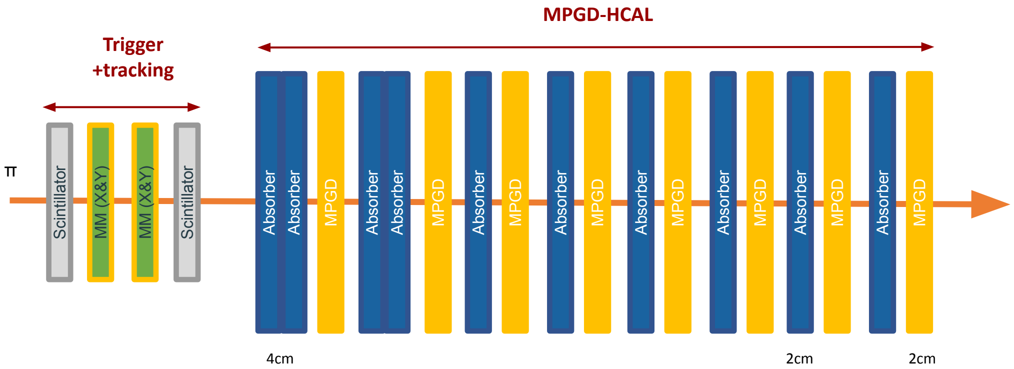
MPV distribution for MicroMegas-Bari

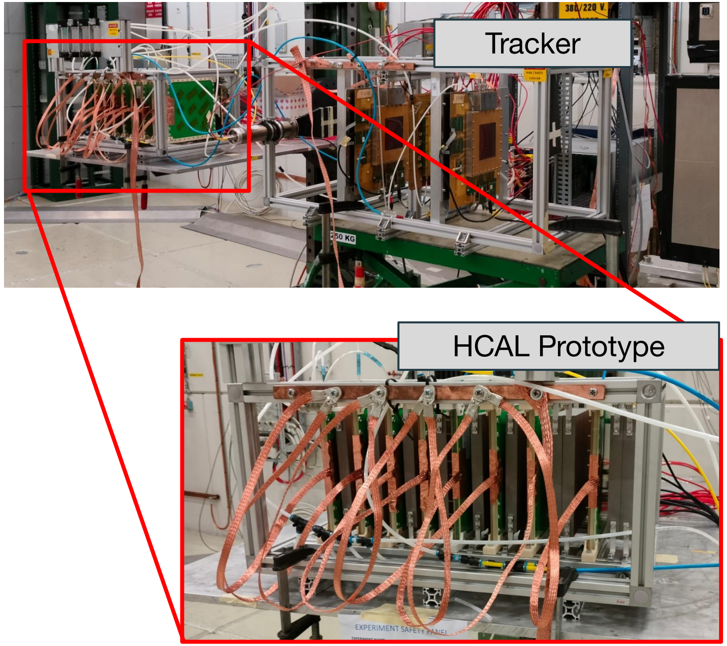


2D-MPV variation for MicroMegas-Bari



MPGDHCAL: prototype at PS test beam





Test beam at PS with calorimeter prototype (August-September 2023):

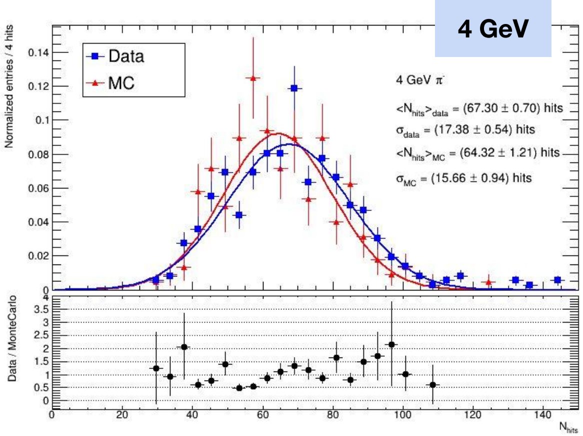
- Goal: **measuring** the energy resolution of a 1 λ calorimeter prototype with 1-10 GeV pions beam
- Developed **G4 simulation** for the **small prototype**, including a **digitization algorithm** to account for charge-sharing among adjacent pads and detector efficiency
- **Issue:** problematic electronics for the first 2 MPGD layers → taken into account for data/MC comparison

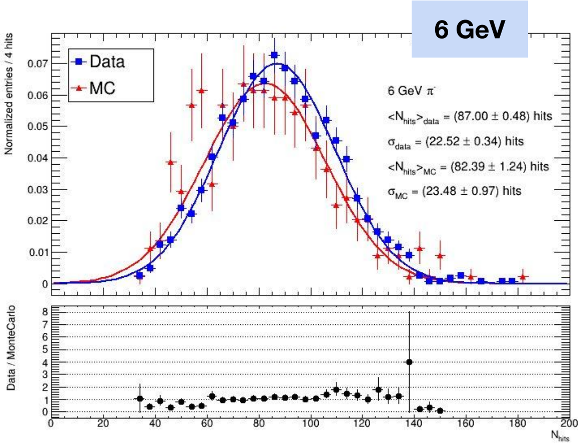
MPGDHCAL: prototype at PS test beam

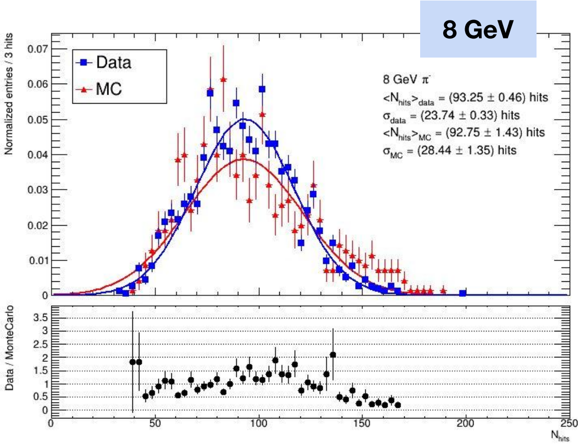
Event selection: events where pions start showering from the third layer

Preliminary

Number of hits distributions for MC and data at different pion energies







- **Good data/MC comparison**
- Ongoing studies to fully exploit all the data collected

MPGDHCAL: full simulation studies

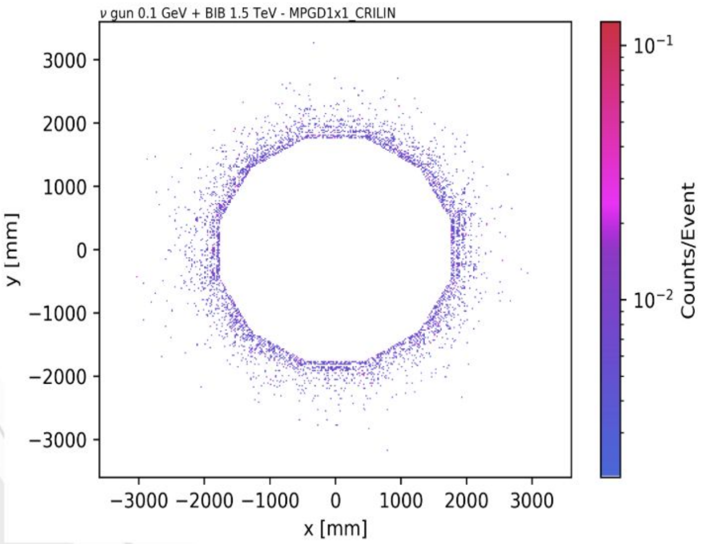
Preliminary

BIB CHARACTERIZATION

SIMULATED HITS IN MPGD 1X1 CM² HCAL BARREL

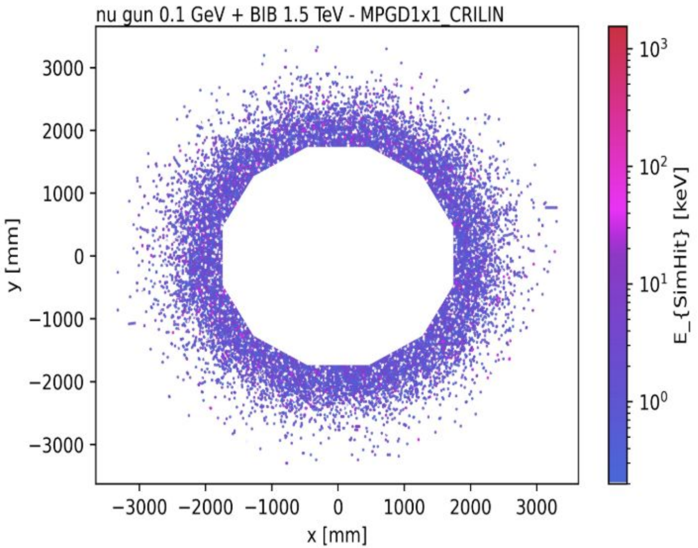
DISTRIBUTION IN X-Y

- Uniform distribution of BIB SimHits on each layer
- BIB contained within the first 20 Layers



ENERGY IN X-Y

- Uniform distribution in plane x-y of the energy deposits of BIB SimHits
- Mean enegy deposits of ~ 4 keV



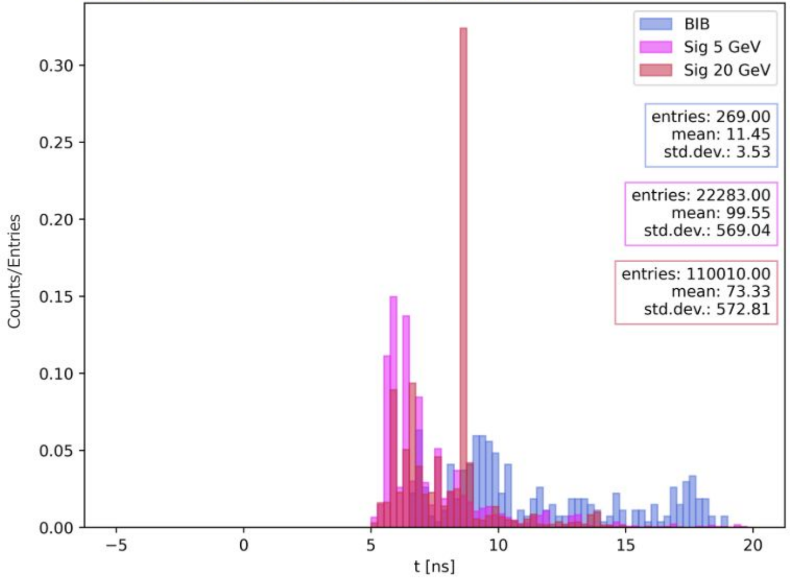
MPGDHCAL: full simulation studies

ARRIVAL TIME DISTRIBUTION

SIMULATED HITS IN MPGD 1X1 CM^2 HCAL BARREL

Preliminary

SIGNAL AND BIB SEPARATELY



- Most of the signal SimHit have arrival times between **5 and 10 ns**

  Assuming relativistic pions, the average time of flight to reach the first layer (~ 1.7 m from IP) is around 6 ns

- Overflow events with t > 20 ns are unexpected, they may derive from bugs in the simulation step
- **BIB** SimHit **time** distribution is **uniform** in the range from about **7 to 20 ns**

→ A **cut on t > 10** should exclude half of the BIB SimHit while neglecting a small fraction of signal

MPGDHCAL: richieste/piani

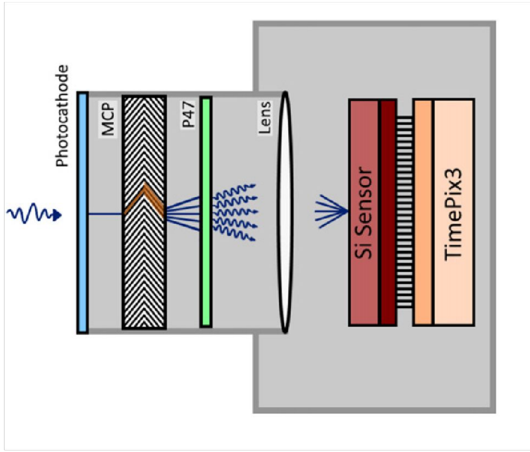
- **2024:**
  - **struttura meccanica:** si stima un costo di circa 5-6k; nel preventivo di spesa dello scorso anno ci si aspettava un costo di 2k in totale e si vuole chiedere un rabbocco di 4k per coprire la differenza [DRD6-WP2]. Questo permetterebbe di acquistare tutto il materiale necessario quest'anno e di procedere con la lavorazione in officina meccanica il prossimo.
- **2025:**
  - **Camere 50x50cm2:** l'offerta ricevuta dall'MPT workshop del CERN per il design e la produzione delle camere 50x50cm2 si è rivelata elevata:
    - MicroMegas x 2: 32.3 CHF
    - μRWELL x 2: 28.7 CHF
    - Vorremmo coprire con il prin 2 μRWELL ed una MicroMegas
    - Richiesta di 17k per l'acquisto di una MicroMegas [DRD1-WP5]
  - **Gas:**
    - Richiesta di 1k per l'acquisto del gas (Ar:CO2:Iso e/o Ar:CO2:CF4) [DRD1-WP5]
  - **Struttura meccanica:**
    - Richiesta di 1k per la spedizione della struttura da Bari al CERN [DRD6-WP2]

MPGDHCAL: richieste/piani

- **2025:**
  - **Missioni per test beam e loro preparazione:** richiesta di 23k [DRD1-WP5/DRD1-WP2] 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
    - test al gdd per una prima caratterizzazione delle camere (4 settimane)
  - **Missioni:**
    - ~3k da metabolismo
    - ~11k per meeting/conferenze

HPTPC: richieste/piani

YEAR	Item	Cost (Keuro)	Total/Year	Comment
2024	HV (100KV)	21	21	DRD1-WP8
2025	Image Intensifier	22	33	DRD1-WP8/WP4
	Obiettivo fotografico	5		
	2 piani di Thick GEM (30 cm)	4		
	Gas	1		
	Trasporto	1		
2026	TimePiX4	50 (?)	50(?)	DRD1-WP8/WP4
Tot.			**102**	



- Come per il 2024, le richieste 2025 riguardano solo la parte non pressurizzata della TPC. In particolare, ci concentriamo sulla parte relativa all 'Image Intensifier' (sulla sinistra nel disegno schematico).
- Oltre all'Image intensifier medesimo, questa parte include 2 piani di thick gem (30 cm di diametro) ed un obiettivo fotografico.
- Si aggiungono anche le richieste su acquisto di gas ed il trasporto della field cage.
- Richiesta complessiva di 33k
- In attesa di poter acquistare un TIMEPIX nel 2026, si è deciso di farsi prestare un TIMEPIX da un Gruppo di colleghi con cui collaboriamo.

Anagrafica

Preliminare

PERSONA	ATTIVITA'		TOT (incl synergies)
	IMCC	MuCol	%FTE
Ali Muhammad	2		30
Catanesi Gabriella	2		0
Colaleo Anna	2		10
Creanza Donato Maria	2		10
Fiore Luigi	2		0
Longo Luigi	2		20
Magaletti Lorenzo	2		10
Maggi Marcello	2		10
Marjeka Ilirjan	2		20
Pellecchia Antonello	2		20
Radicioni Emilio	2		10
Stamerra Anna	2		30
Venditti Rosamaria	2		30
Verwilligen Piet	2		15
Zaza Angela	2		30
			245

Tot FTE: 2.45

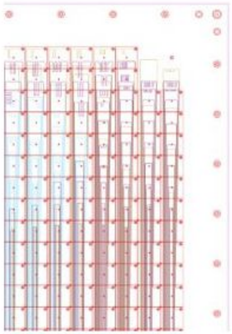
Richieste di servizi di sezione

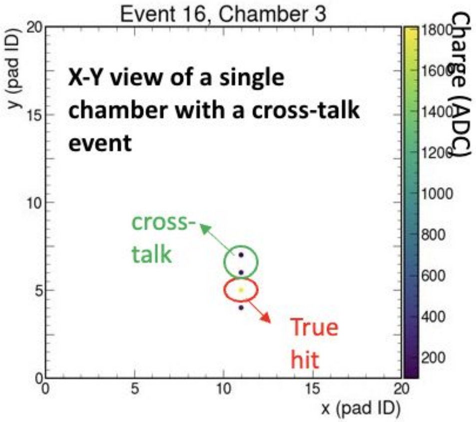
Servizio	MP	Motivazione	Stato
Progettazione Meccanica	0.5	• Possibile update della struttura meccanica contente 8 camere 20x20cm2 e 4 camere 50x50cm2;	Richiesta sottomessa
Officina meccanica	2	• Costruzione della struttura meccanica contente 8 camere 20x20cm2 e 4 camere 50x50cm2;	Richiesta sottomessa
Servizio elettronico	1	• Supporto per la lettura dei layer attivi (basati su tecnologia MPGD) del prototipo di un calorimetro adronico per un futuro esperimento al Muon Collider con FATIC3	Richiesta sottomessa

Backup

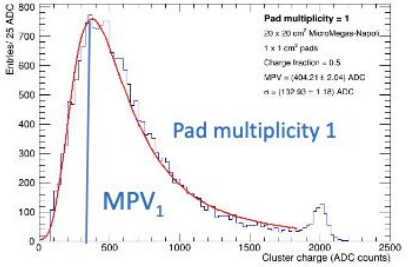
Cluster reconstruction

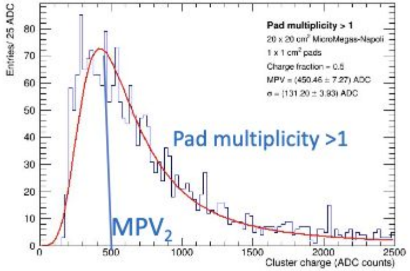
Preliminary

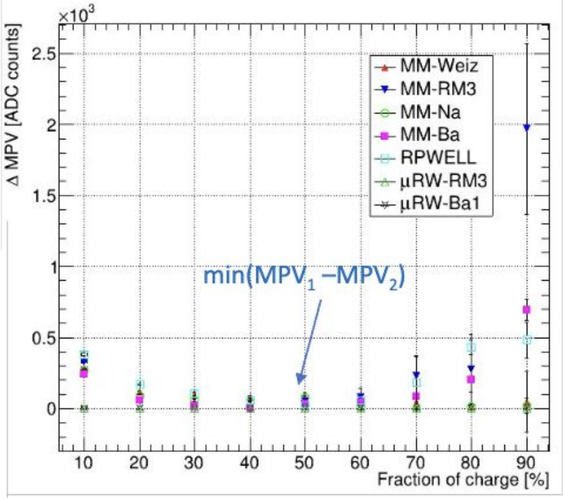




High probability of **cross-talk** effect observed among adjacent pads due to routing of the vias connecting pads to the connectors





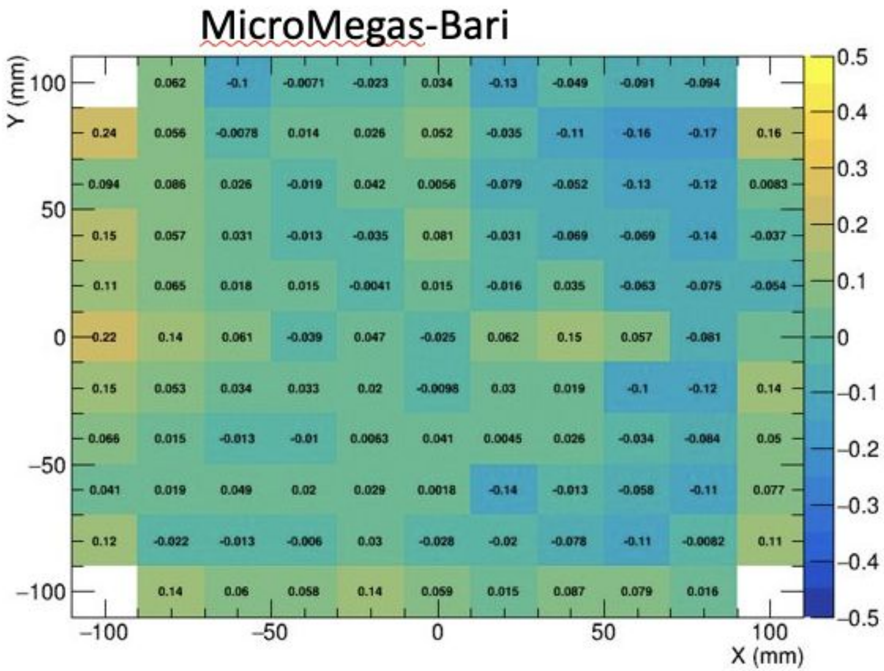


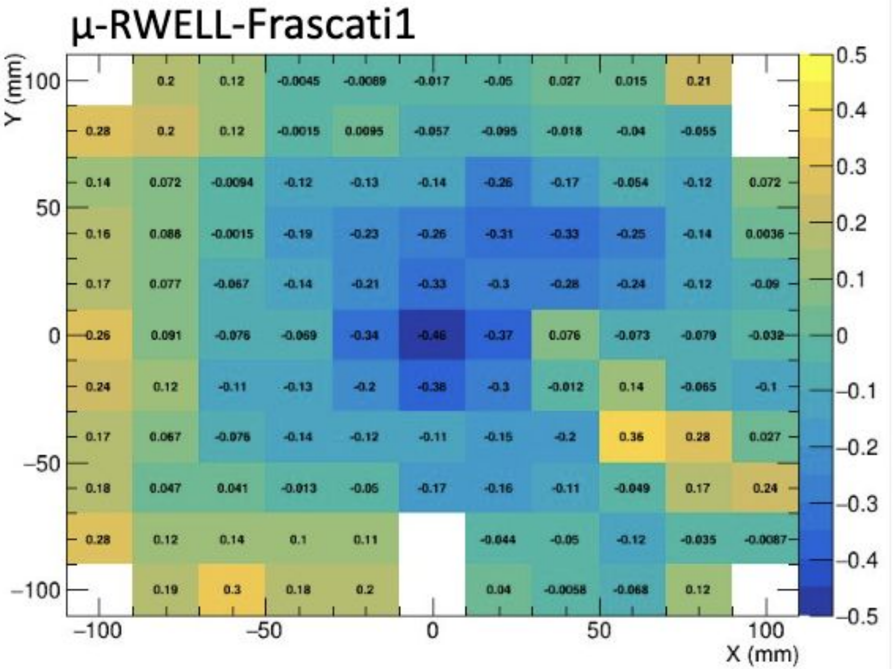
Developed ad-hoc **clustering algorithm** based on charge sharing criterium

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

Response uniformity

Preliminary

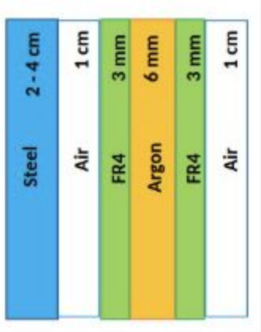




G4 simulation: small prototype

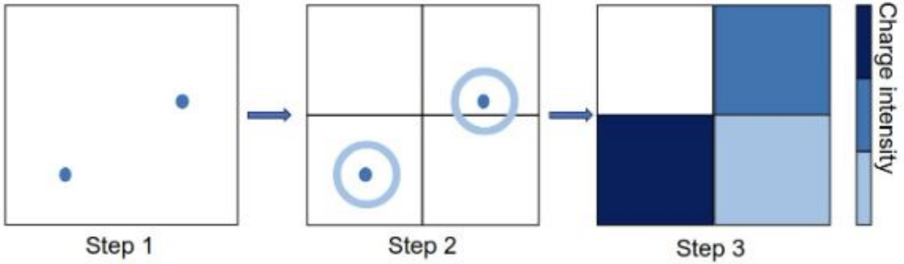
Preliminary

- 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)

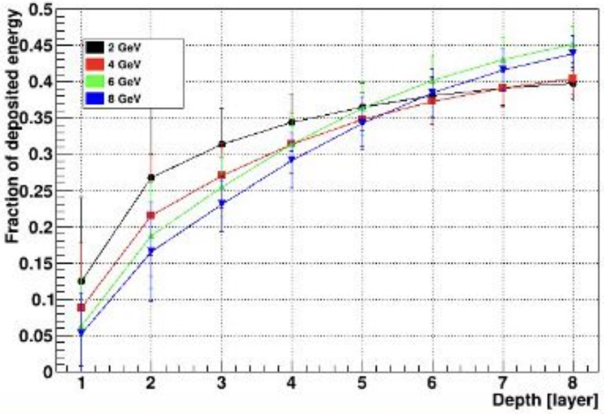


- **Digitization algorithm** implemented to account for charge-sharing among adjacent pads and detector efficiency

Digitization algorithm



Shower containment



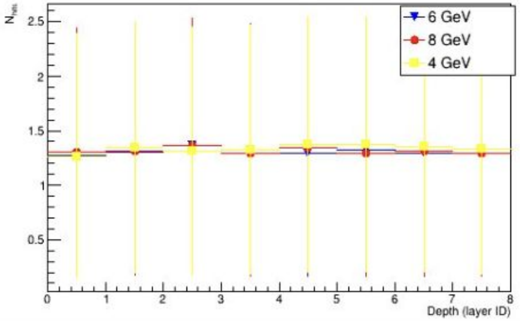
PS data / G4Sim prototype - event selection

Preliminary

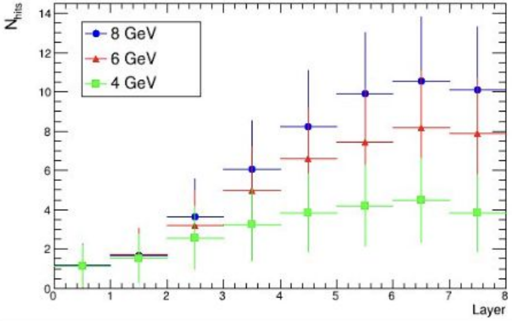
Event **selection criteria** supported by **simulation** using MC truth

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

MIP-like events - simulation

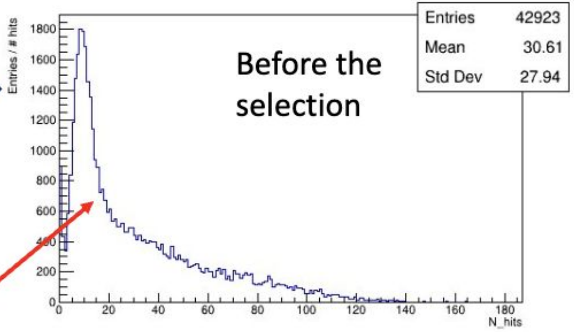


Shower events - simulation



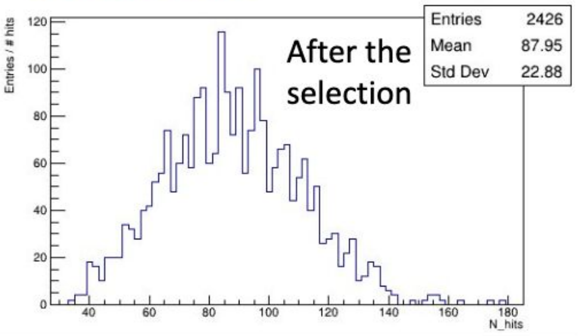
Distribution of the **number of hits** in all active layer from the **experimental data**

Number of hits for all events



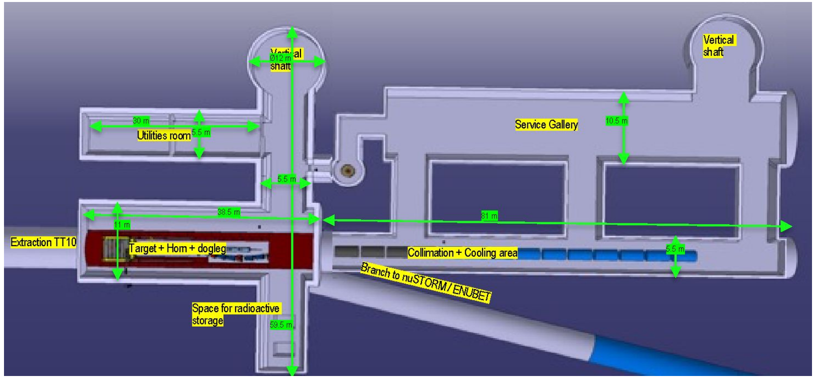
Peak at ~ 10 hits
-> MIP-like events

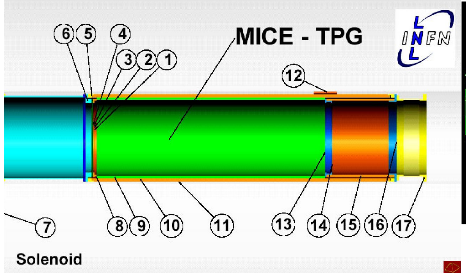
Number of hits for showers event



The Demonstrator will produce a large number of muons/neutrinos of few hundred MeV or less

A TPC can be used as tracker for the detection of muons in the cooling sector and/or as active target to detect neutrinos.





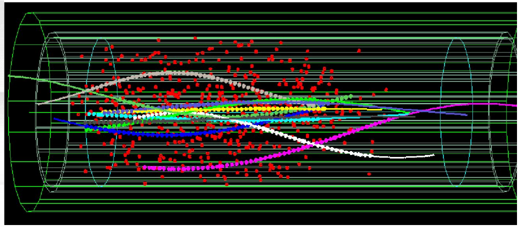
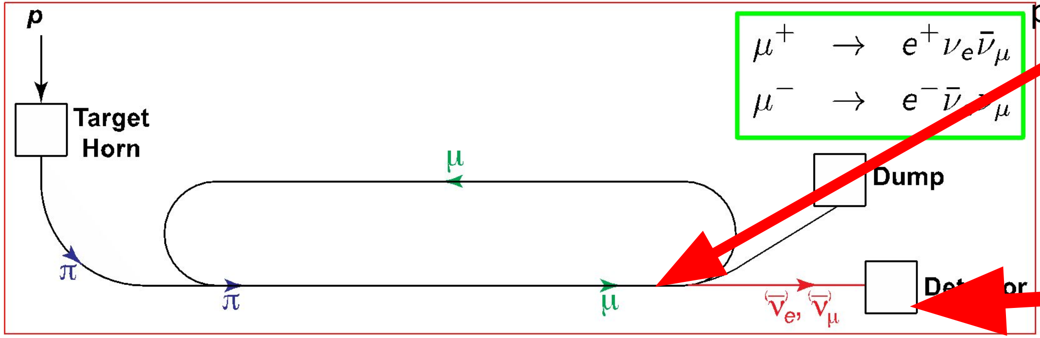
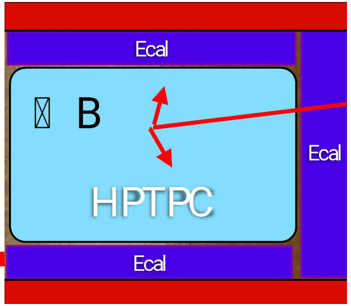


Figure 8.7: top: simulated track and noise hits in the TPG; middle: highlighted hits are those assigned by the pattern recognition to belong to the same track; bottom: track fitted on the selected hits.

From MICE proposal

a unique facility for neutrino physics and muon-collider test bed





Concept for a neutrino X-sec measurement

Why a TPC as muons monitor in the cooling sector

- It was already an option in the MICE proposal (MICE-TPG)
- 3D reconstruction capabilities
- Very low material budget (gem foils + gas (He+CH4))
- low background
- excellent track resolution
- Working principle already proved and tested in 2005

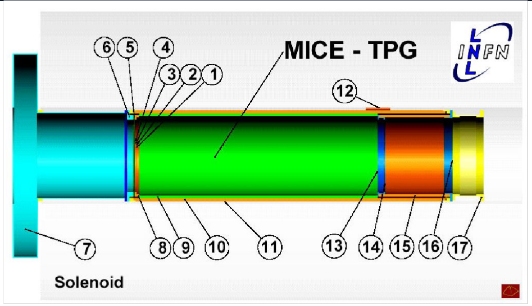
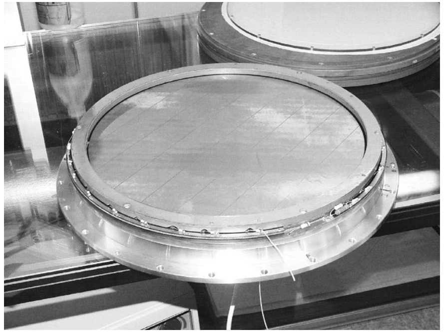
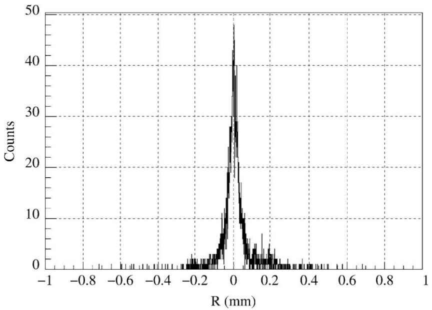


Figure 8.5: MICE-TPG upstream detector. Muon beam enters from the left. 1: GEM-1 foil; 2: GEM-2 foil; 3: GEM-3 foil; 4: hexaboard; 5: Board (for hexaboard support, gas seal and signal connectors); 6: readout flange; 7: front-end electronics support and EM shield; 8: field cage termination; 9: field cage; 10: TPG isolating container; 11: TPG peripheral grounded shield; 12: HV inlet for drift electric field; 13: HV thin metallized foil cathode; 14: HV thin metallized foil gas seal; 15: HV foil support (insulating tube); 16: grounded thin foil seal; 17: TPG–LH2-absorber integration connection flange (schematic).



hexaboard + gem foils ready to be inserted in the fieldcage



Intrinsic pad plane resolution for X-ray events FWHM ~ 40 µm

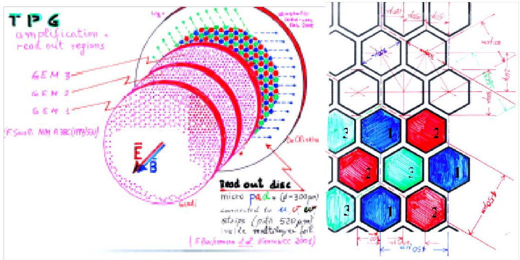
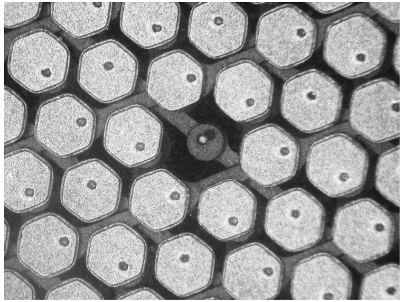


Figure 8.6: TPG readout: left: the 3 GEM foils provide amplification onto the hexaboard. Right: the hexaboard with one third of the pads (blue) connected in strips at 30°, one third at 150° (red), and one third at 90° (green).



Magnified view with pad removed with a scalpel.

Why a TPC as muons monitor in the cooling sector

- Today great improvements (and simplification) can be obtained by using the last generation of optical readouts in place of the hexagonal board+GEM proposed in 2003
- It still requires studies to find the optimal gas mixture

We propose to realize a prototype of TPC with optical readout (TimePix4 or similar) to be used as muon monitor for the demonstrator

A size of 50 length and 30cm diameter was already imagined for MICE. It could today be equipped with a more modern an optical readout.
Such a device would be lighter and tolerate a higher track density w.r.t. what was proposed 20 years ago, enhancing the advantage of multi tracks reconstruction and optimal background rejection

the development of this device is highly synergic with the development of a TPC as active target and both fit very well the **DRD1,W8/W4 Program**

This application requires non-pressurized operation

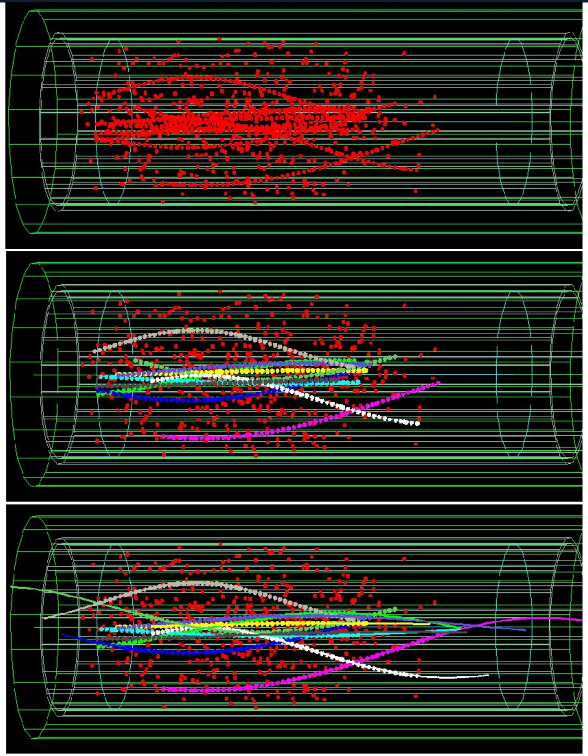
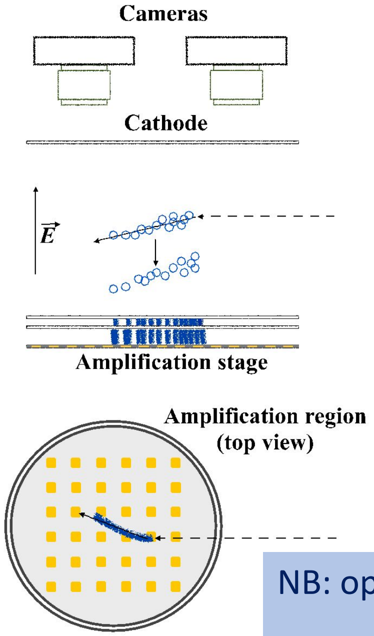


Figure 8.7: top: simulated track and noise hits in the TPG; middle: highlighted hits are those assigned by the pattern recognition to belong to the same track; bottom: track fitted on the selected hits

HPTPC with optical readout (a "great" improvement)



- Primary ionisations in the drift region are guided to the amplification region by an electric field
- Amplification produces electrons and photons
- Cameras image the amplification region and record a 2D projection of the electroluminescence photon
- Highly segmented readout (~ 100 × 100 μm^2) at low cost per pixel possible

Current CCD cameras do not allow to access the longitudinal coordinate due to their slow readout speed
The goal is to combine optical and charge readout Full 3D tracking information (since the longitudinal coordinate can be reconstructed from charge signals) (TimePix or SIPM array)

NB: optical readout is also of great interest for for the beam instrumentation case:
1) reduction of the budget material along the beam line
2) readout optimization low gas amplification factor high density of tracks