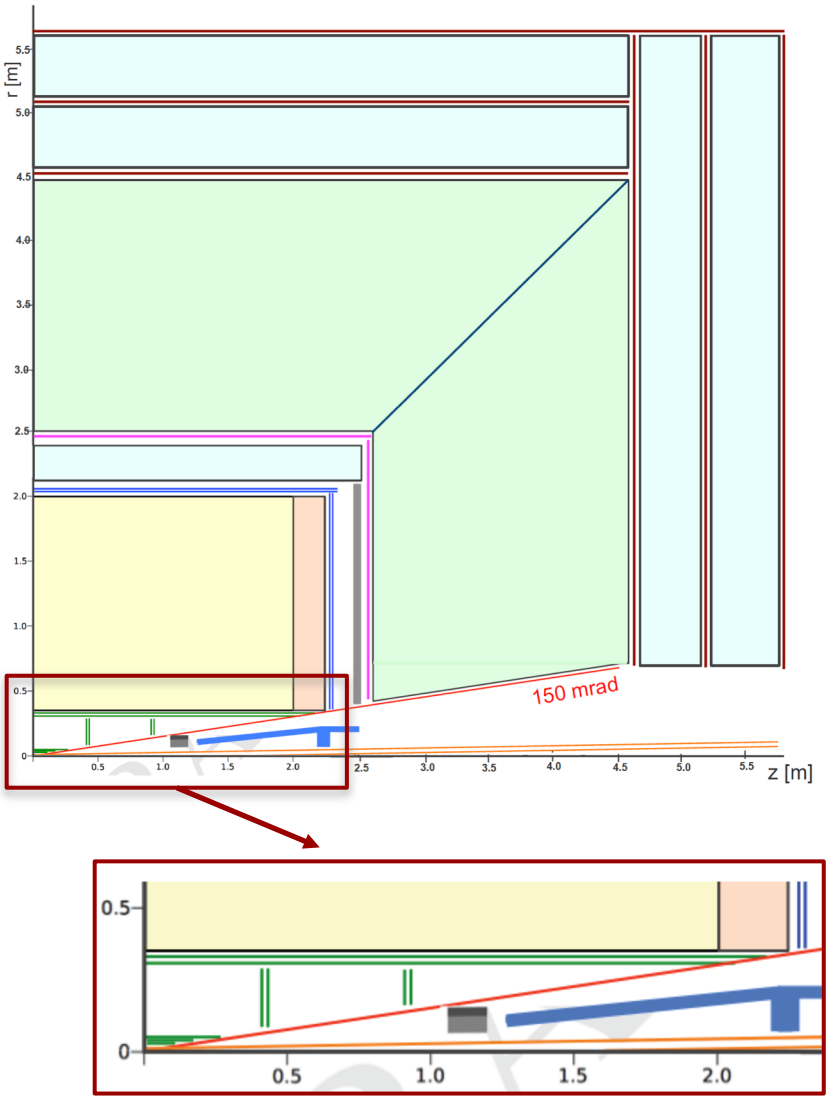
Combined test beam with IDEA

R. Santoro*
On behalf of a group of enthusiastic people (half of them PhD and post-doc)

* Università degli Studi dell'Insubria (COMO) and INFN (Milano)

IDEA - Layout

- Beam Pipe (≈1.5 cm radius)
- Vertex Detector (R ∈ [1.7; 34] cm)
- Drift Chamber (L = 400 cm, R ∈ [35; 200] cm)
- Outer Silicon Layer (strips)
- SC Coil (2T, ≈2.1m); 30 cm THIN! (0.74X_o; 0.16 λ @90°)
- Pre-shower (1-2 X_o)
- Dual Readout Calorimeter (2m, 7 λ)
- Yoke & Muon Chambers



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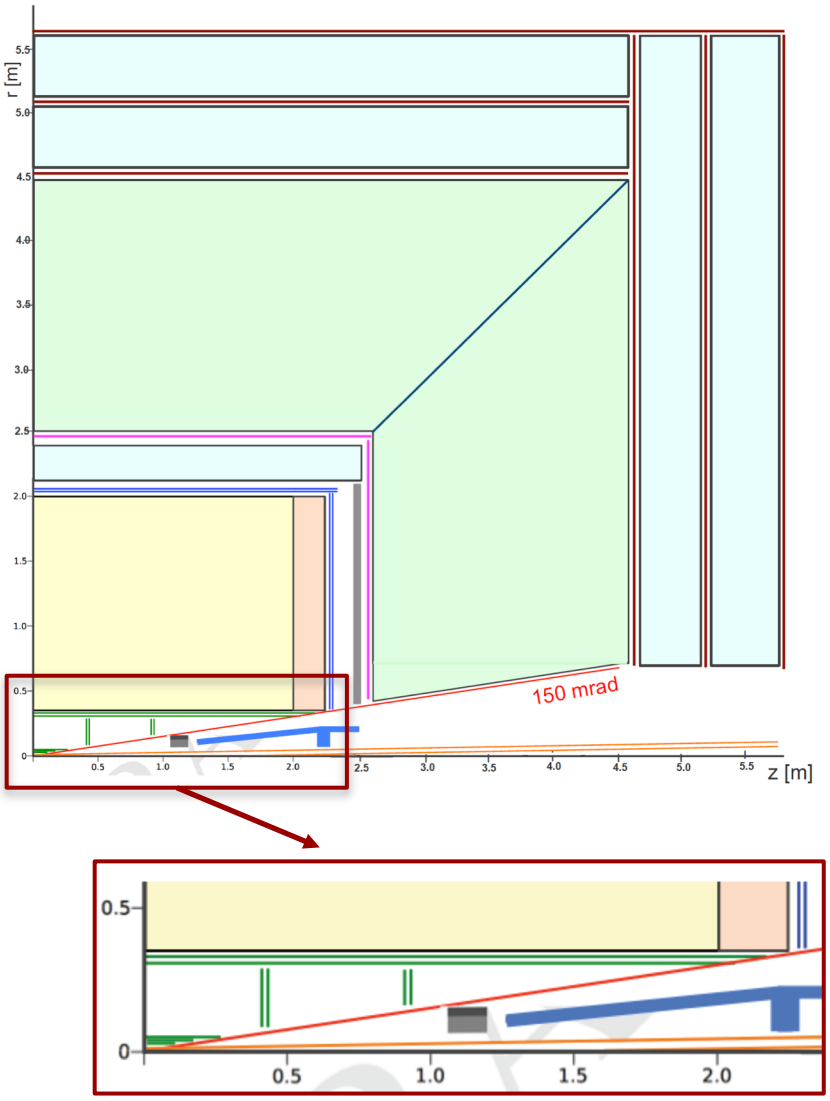
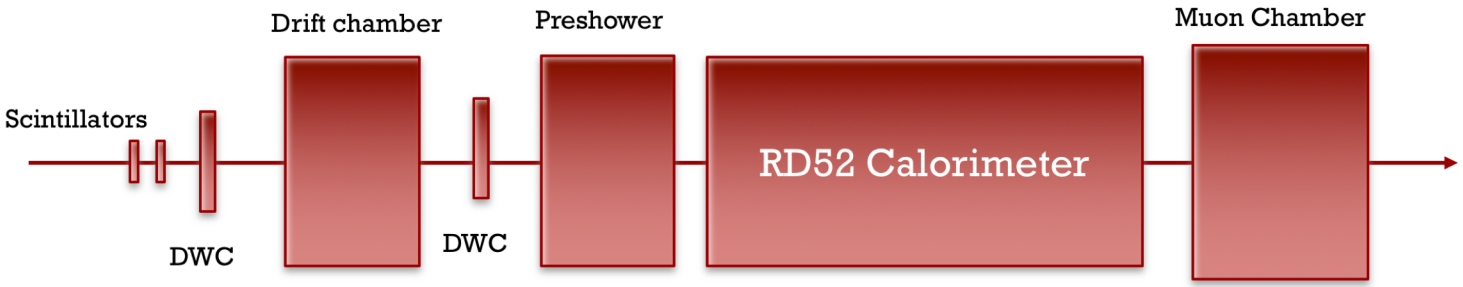


The test beam layout



- Trigger with 2 scintillators in coincidence + 1 veto
- 2 DWC (Delayed Wire Chamber)
- 2 CEDAR (Differential Cherenkov detector)

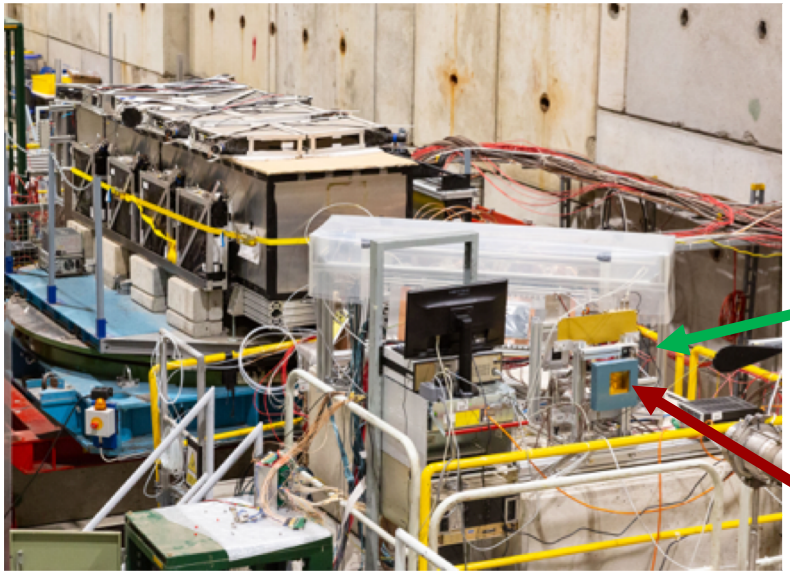
Beam instrumentation

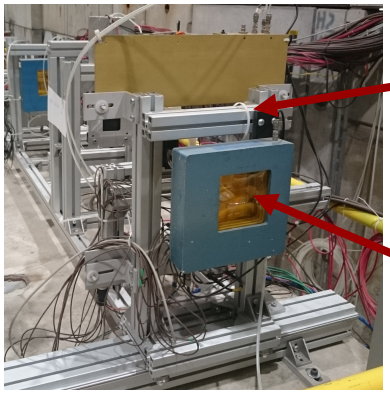
- Drift Chamber Prototype
- Preshower:
  - 2 layers of GEM + the converter
- Different Dual Readout prototypes
  - RD52 calorimeter with PMT readout
  - RD52 calorimeter with staggered fibers
  - Small calorimeter module with SiPM readout
- Muon chamber: 1 layer GEM + 2 layers μRWell

The test beam goal

- Combined measurements: data taking with all detectors
  - Particle Identification with:
    - Drift Chamber Prototype (p, π, k) using dE/dx VS cluster counting
    - Preshower + Dual Readout Calorimeters (e, π, μ)
    - μRWell (e, μ)
  - Preshower optimization studies
  - Tracking qualification
- Calorimeter R&D: standalone program
  - Qualification of a RD52 calorimeter with staggered fibers
  - Qualification of a small calorimeter module readout with SiPM

The real setup





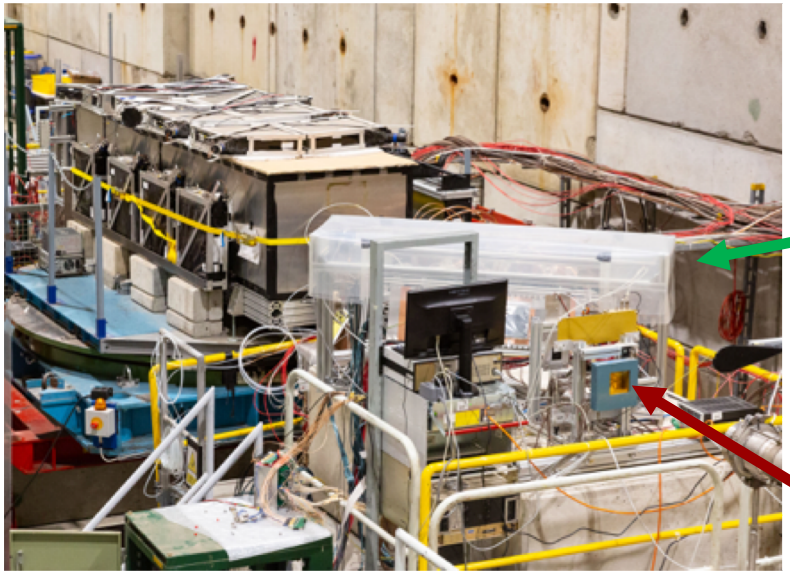
Trigger

DWC

Beam line

The real setup

See Grancagnolo's Talk
Parallel session: Gas Detector

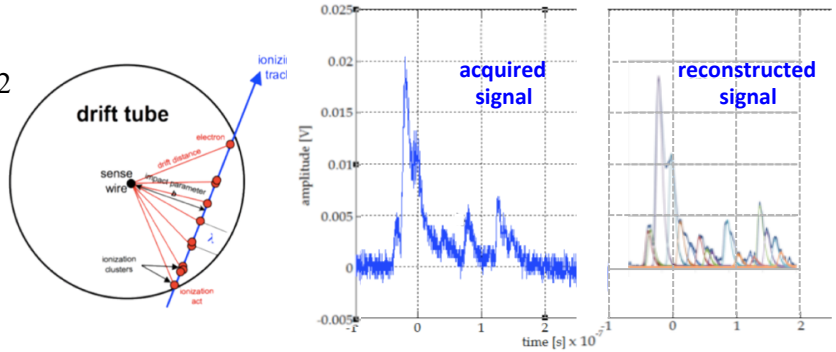


Beam line

Drift Chamber prototype

- 144 channels: 12 layers X 12 cells, 1X1 cm^2 drift cells
- 5 field sense instrumented with MEG2 front-end
- readout with
  - DRS4 (32 channels)
  - Discriminator + TDC 96 channels

Tracking



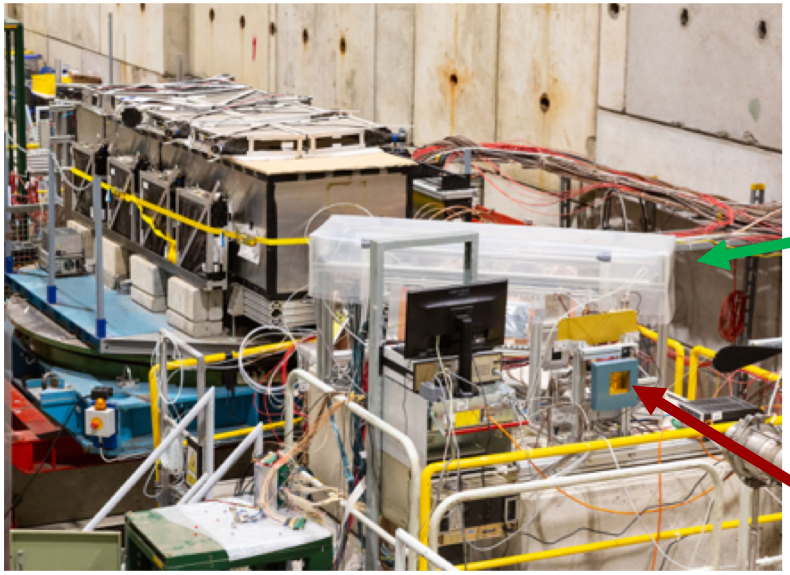
Measured resolution for the MEGII prototype:

$\sigma_{xy} \approx 100\ \mu m$

$\sigma_{z} \approx 1000\ \mu m$

The real setup

See Grancagnolo's Talk
Parallel session: Gas Detector



Drift Chamber prototype

Particle Identification

Cluster counting for improved particle identification:

based on the truncated mean method dE/dX replacing the ANALOG information with a DIGITAL one: namely the number of ionisation clusters per unit length

$$\frac{\sigma_{dE/dx}}{(dE/dx)} = 0.41 \cdot n^{-0.43} \cdot \left(L_{track}[m] \cdot P[atm]\right)^{-0.32}$$

Walenta parameterization (1980)

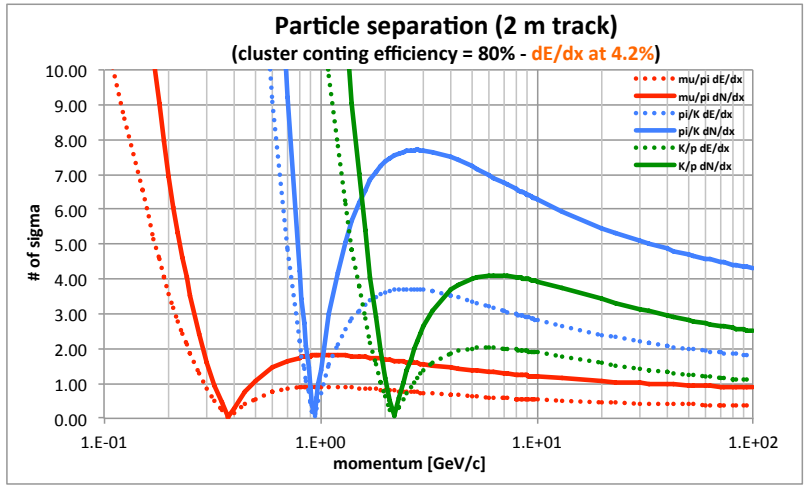
dE/dx

vs

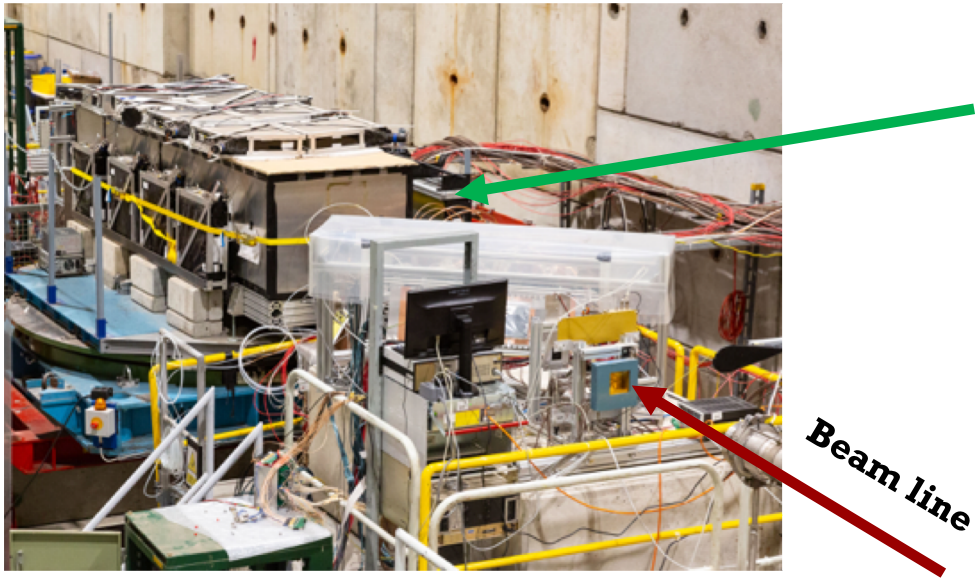
$$\frac{\sigma_{dN_{cl}/dx}}{(dN_{cl}/dx)} = \left(\delta_{cl} \cdot L_{track}\right)^{-1/2}$$

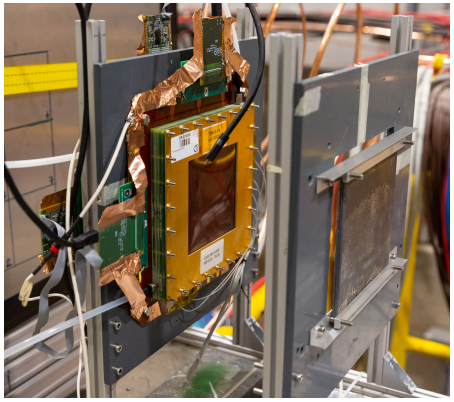
Poisson distribution

dN_{cl}/dx



The real setup





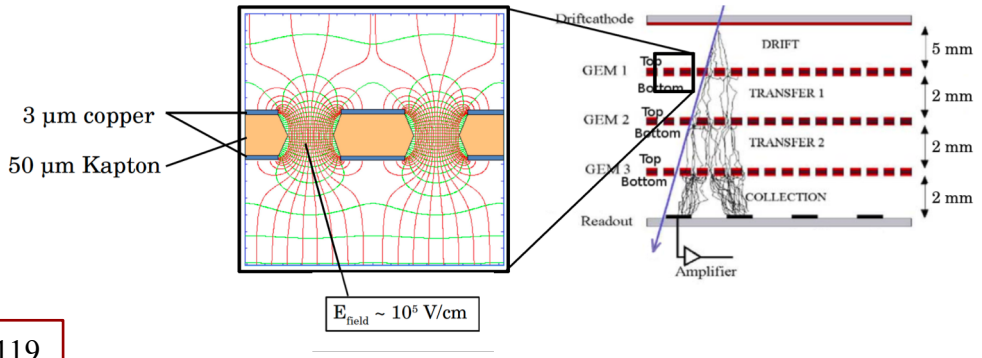
Preshower: 2 triple GEM chambers 10 x 10 cm² with different material (1-2.5 X_0) in front

128 strips, 800 µm pitch

GAS mixture: $Ar/CO_2/CF_4$ (45/15/40)

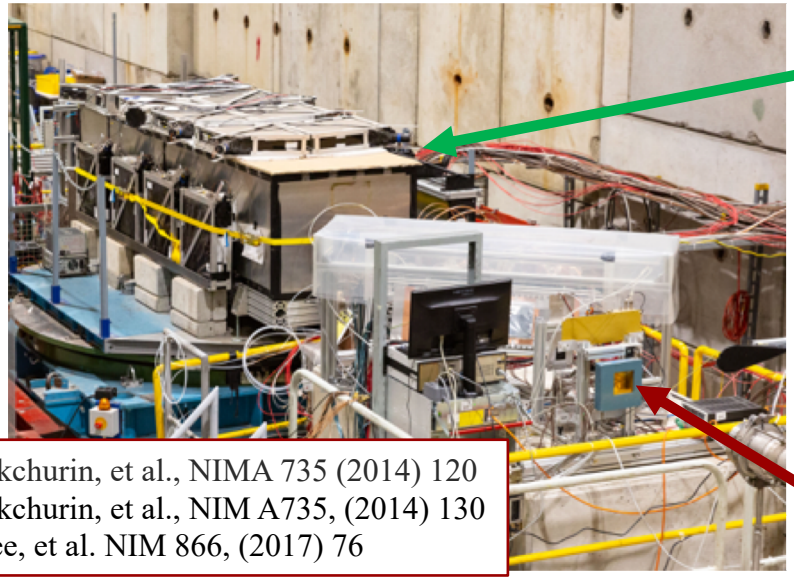
Planar prototypes of triple GEM have already been tested on a muon/pion beam @ H4CERN.

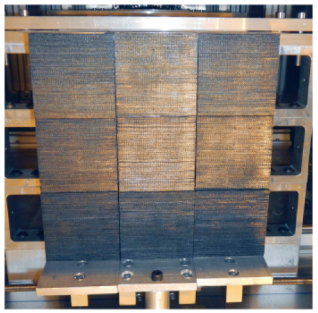
- The plateau efficiency has been measured to be ~97% at a gain of ~ 6000
- resolution better than 100 μm with average cluster size larger than 2
- Performances have been measured with different geometries, gas mixtures and electric fields.



S. Marcello et al., Int.J.Mod.Phys.Conf.Ser. 48 (2018) 1860119

The real setup





Dual Readout Calorimeter RD52 Module

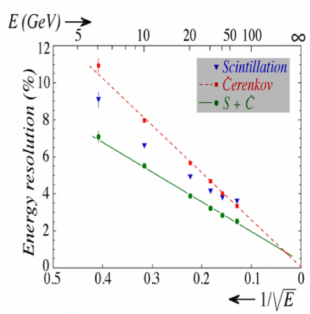
9 lead modules 9.3 x 9.3 x 250 cm3

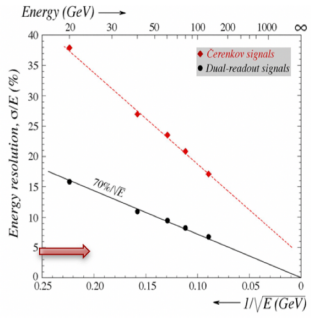
Sampling fraction 5.0 %

N. Akchurin, et al., NIMA 735 (2014) 120
N. Akchurin, et al., NIM A735, (2014) 130
S. Lee, et al. NIM 866, (2017) 76

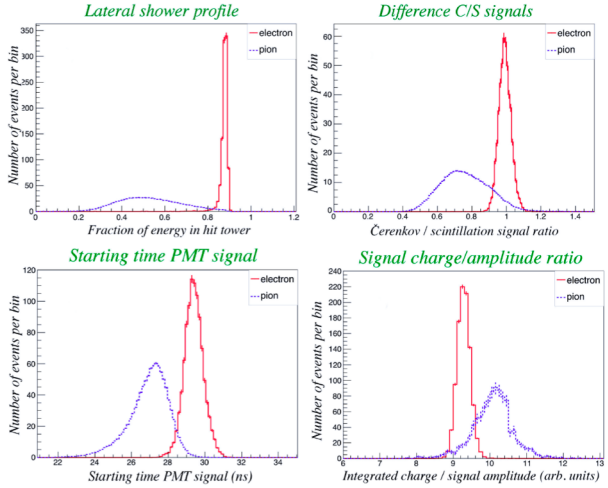
Energy Resolution

Em resolution: $\frac{11\%}{\sqrt{E}} + 1\%$ Had resolution: $\frac{70\%}{\sqrt{E}}$ Leakage dominated → From simulation in 4-π geometry $\frac{34\%}{\sqrt{E}}$





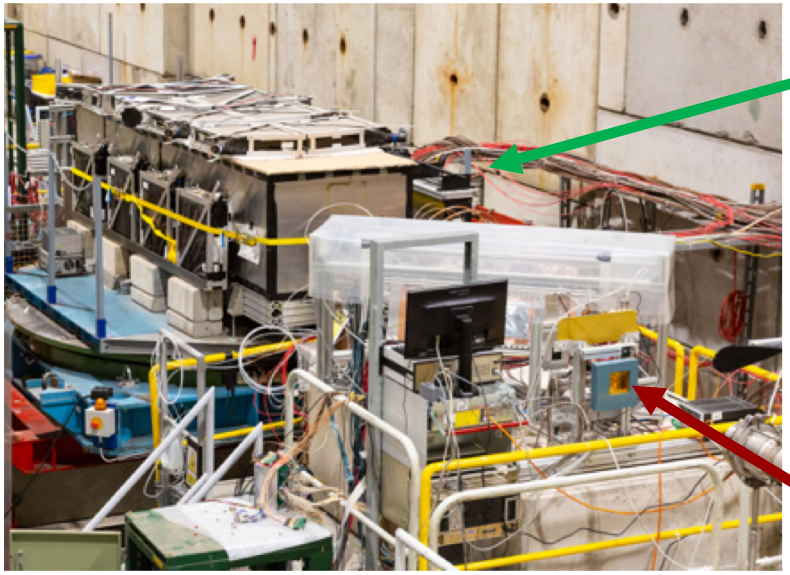
Particle Identification:



Electron hadron identification efficiency ≈ 99.8%

The real setup

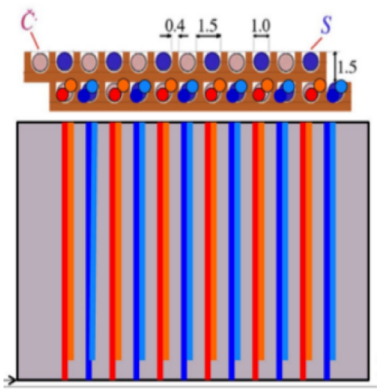
See Pezzotti's Talk
Parallel Session: Calorimetry – 2

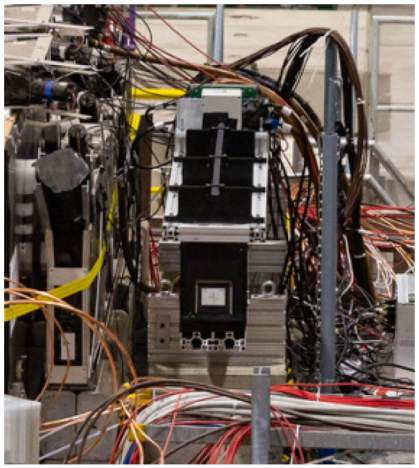


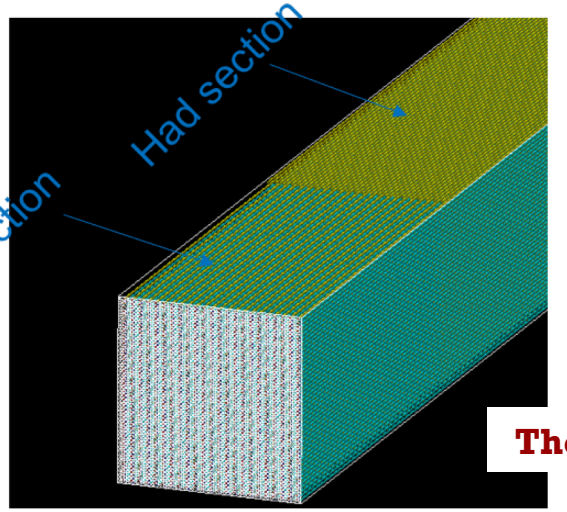
Beam line

Calorimeter R&D program

Standalone runs







Dual Readout Calorimeter Module with staggered fibres: longitudinal segmentation

1 lead modules 9.3 x 9.3 x 250 cm3

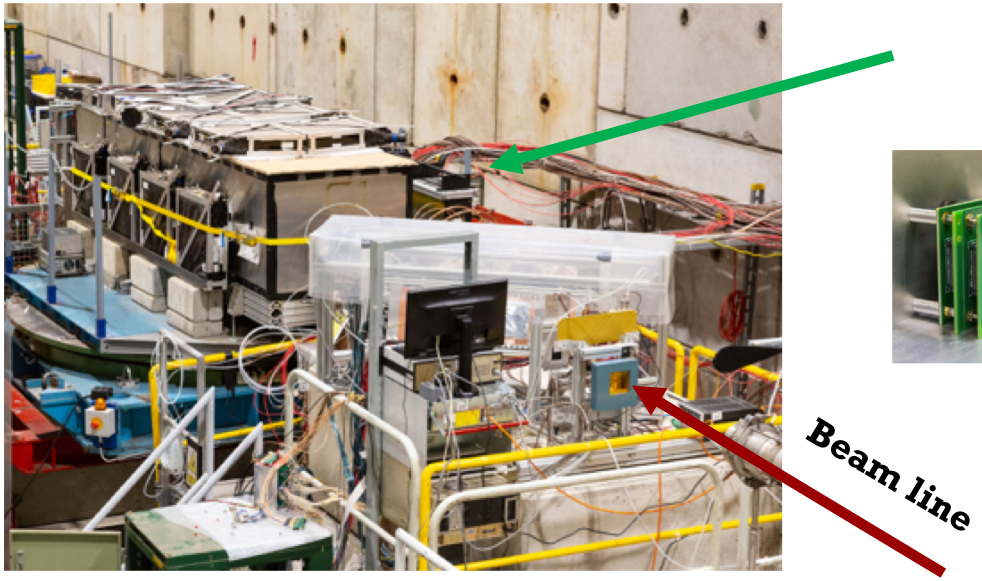
Sampling fraction 5.0 %

All fibres (long a short) are readout with PMTs

The 1st time on beam

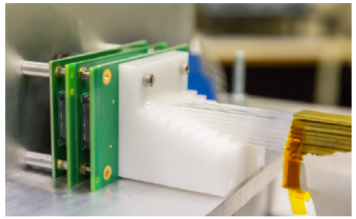
The real setup

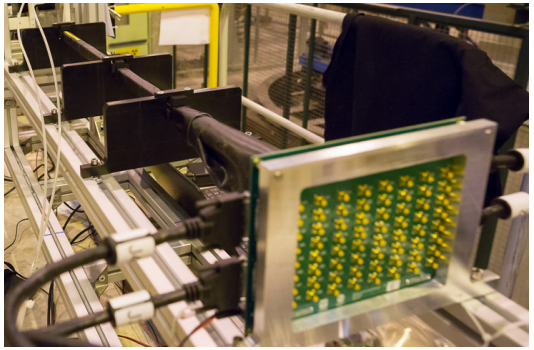
See Pezzotti's Talk
Parallel Session: Calorimetry – 2



Calorimeter R&D program

Standalone runs

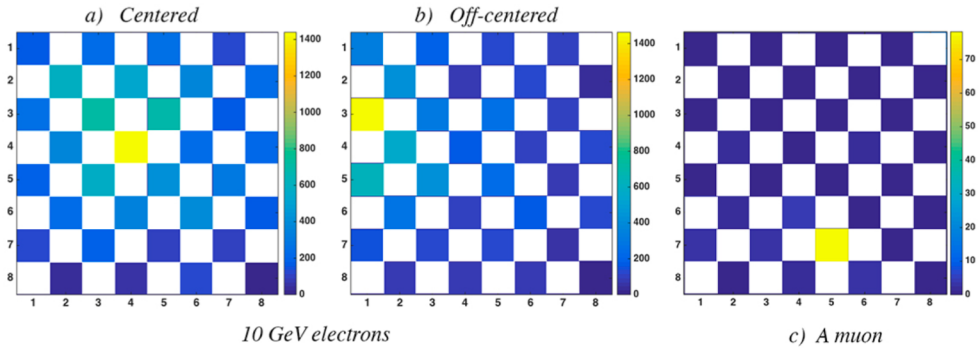




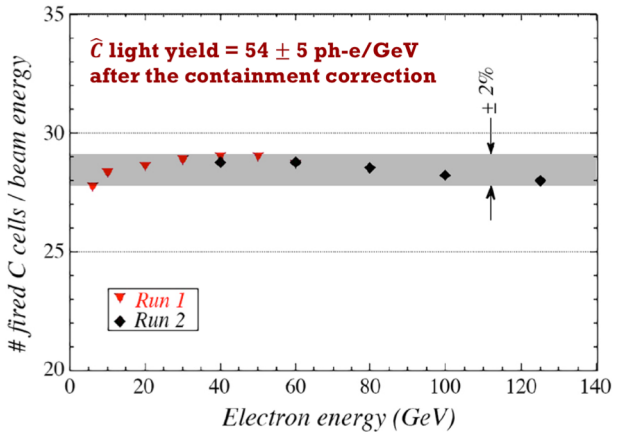
Dual Readout Calorimeter Module
readout with SiPM

1 brass module 1.2 x 1.2 x 112 cm3

Event Display

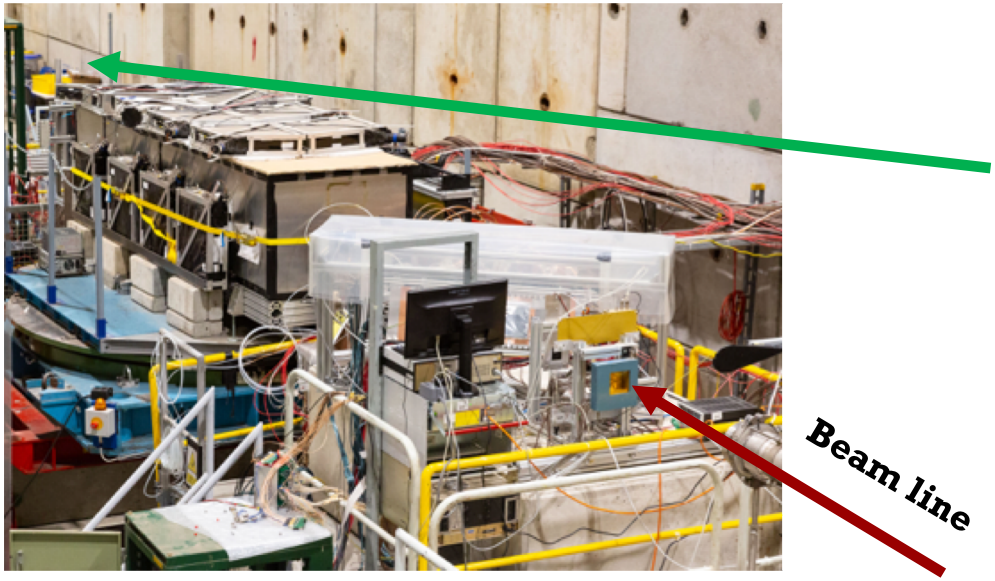


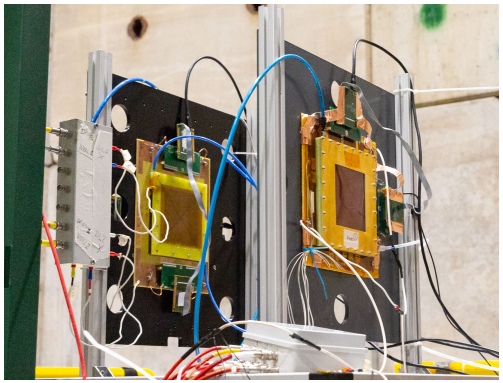
M. Antonello, et al, NIM-A 899 (2018) 52



The real setup

See G Mezzadri's talk and Giacomelli and Borgonovi contribution to the Pelnary Poster Session





Muon detector with μR-Well

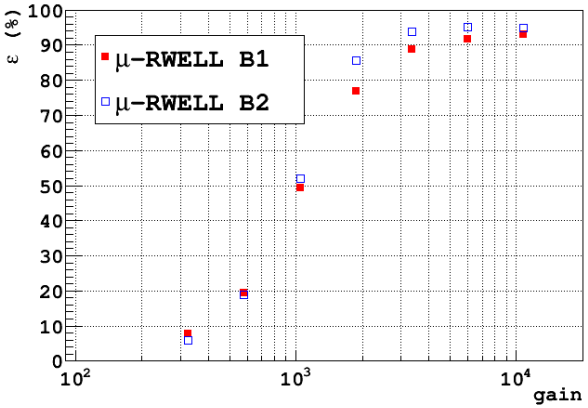
chambers 10x10 cm^2

256 strips, 400 µm pitch

GAS mixture: Ar/CO_2/CF_4 (45/15/40)

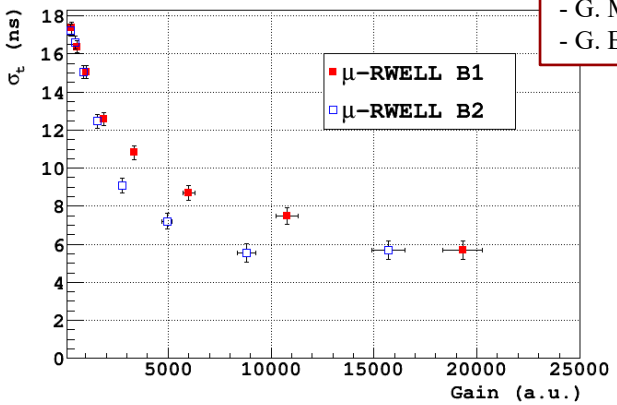
Tracking efficiency

above **97%** at gain of about 3000



Time Resolution

5.7 ns at the optimal gain



- G. Bencivenni et al., JINST 12 (2017) no.06, C06027
- G. Morello et al., PoS BORMIO 2017 (2017)
- G. Bencivenni et al., NIM A 886 (2018) 36

Test beam condition

- 1 week beam time at SPS CERN (H8-line)
- Different beam condition
  - Muon beams
  - Electrons at different energies (10 – 60 GeV)
  - Hadrons at different energies (50 – 60 GeV)
- Trigger based on the coincidence from scintillators
  - Particle identification can be also performed with external detectors (preshower and muon counter) for cross reference
- 3 different DaQ systems and Qas running in parallel
  - Central (trigger, calorimeters, CEDAR and leakage detectors, installed around the calorimeter to measure the energy leakage)
  - Preshower and muon chamber
  - Drift chamber

Phase I: Calibration and commissioning (≈ 2 days)

- 80 GeV Secondary beam (pions + ≈ 5% electrons)
  - RD52 calorimeter: equalization runs
    - Beam centered in each Tower (36 runs)
  - Muon chamber and Preshower
    - Integration test and commissioning
  - Drift Chamber calibration runs:
    - Integration test and HV scan

Phase II: combined program (≈ 2.5 days)

- μ beam
  - Alignments for all detectors
- Electron Beam (20 GeV)
  - Rd-52 calorimeter
    - Performance study with different converter thickness (1 – 2.5 X_0)
  - Drift Chamber
    - Tracking performances at different HV
- Hadron beam at two energies (50, 60 GeV)
  - Drift Chamber
    - Tracking performance
    - PID: even if this energy is not optimal, we guess it may be useful for:
      - Algorithm comparison
      - Comparison with simulation and parametrization
  - RD52 Calorimeter
    - Performance study with hadrons

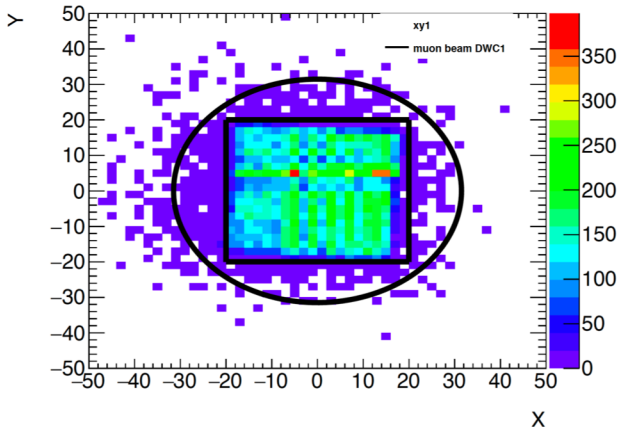
Phase III: standalone program (≈ 2 days)

- Dual readout calorimeter prototype module with staggered fibres readout by PMTs (1 day)
  - Response equalization and calibration
    - 20 GeV Electron beam for the long fibres (beam centered in each tower)
    - 60 GeV π beams for the short fibres (beam centered in each tower)
  - Long runs with the detector centered in the beam
    - 20 GeV electrons
    - 60 GeV π beams
- Dual readout calorimeter prototype module readout by SiPM (1 day)
  - Energy Scan with electrons beams (10, 20, 30, 40 GeV): Ph-e / Gev measurement

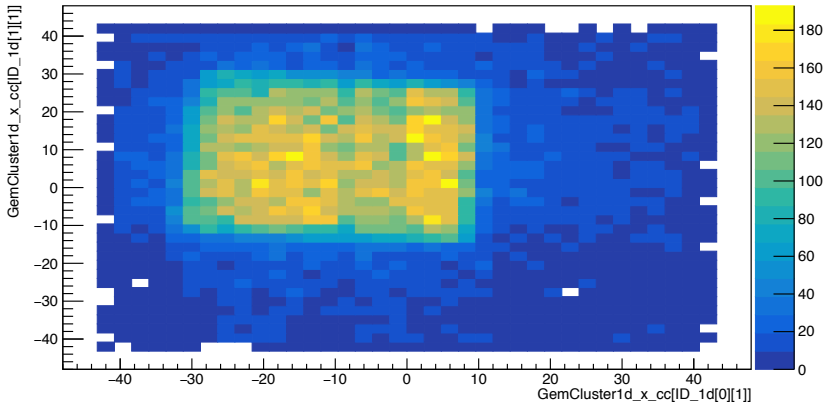
Preliminary plots

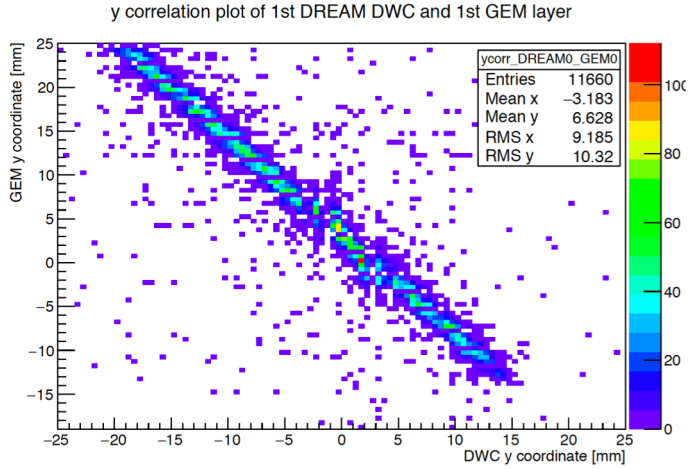
Beam profile with muon Beam:
Trigger with 2 scintillators in coincidence and no veto

Delayed Wire Chamber



Preshower: GEM



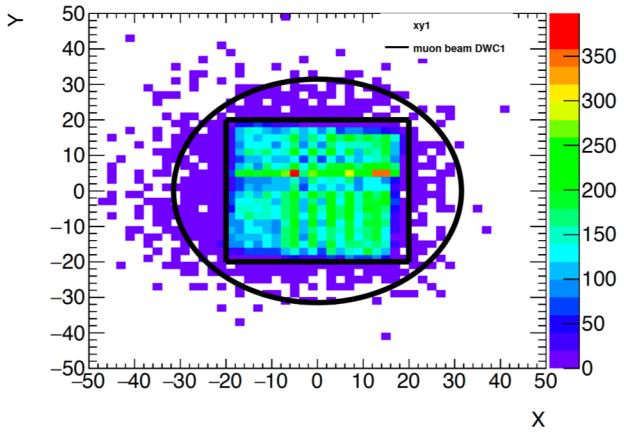


Correlation plots between the 1st DWC layer and the 1st GEM layer (2 different DaQ systems)

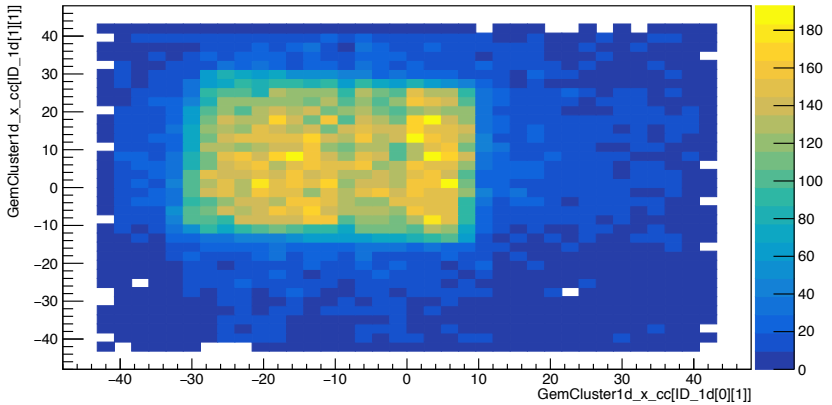
Preliminary plots

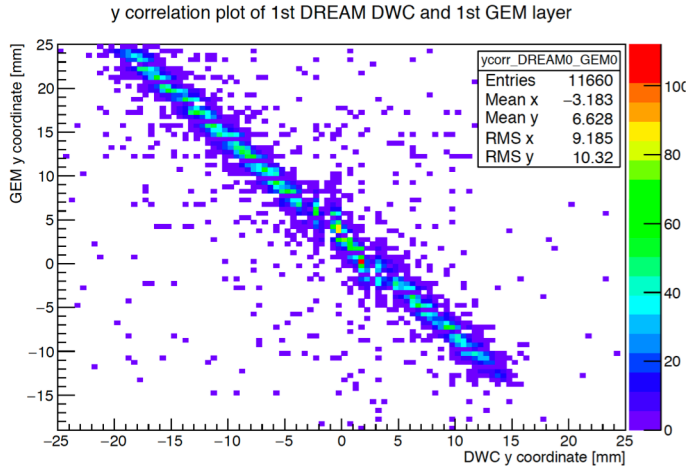
Beam profile with muon Beam:
Trigger with 2 scintillators in coincidence and no veto

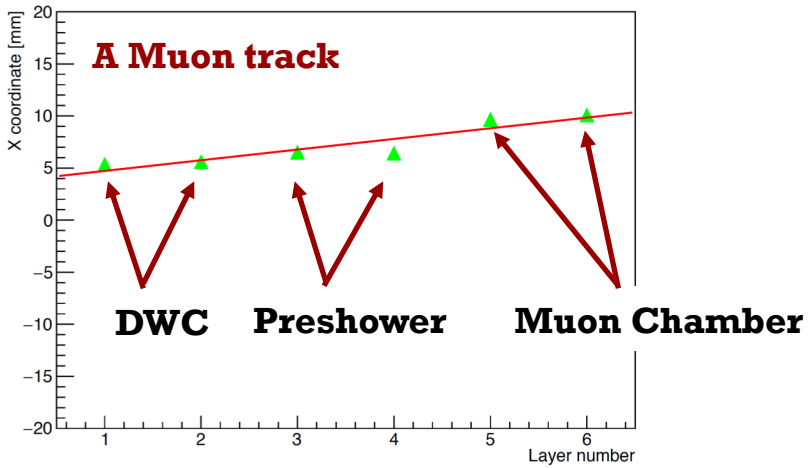
Delayed Wire Chamber



Preshower: GEM



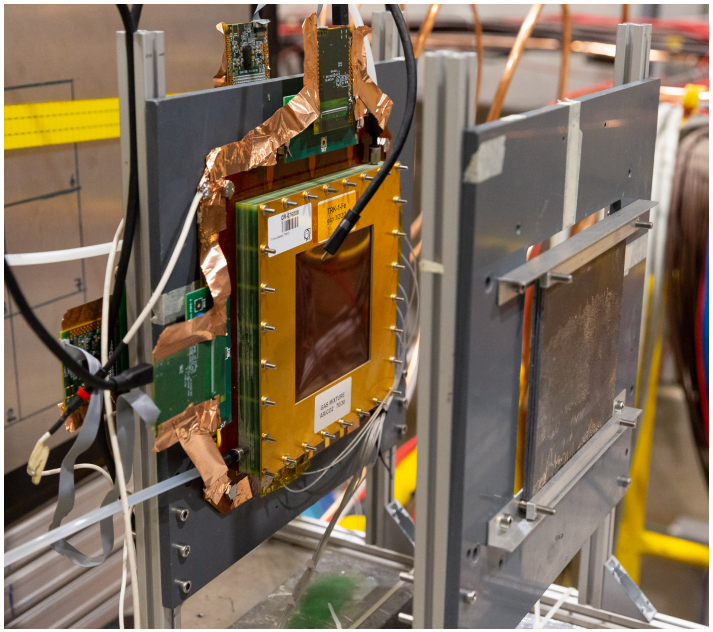


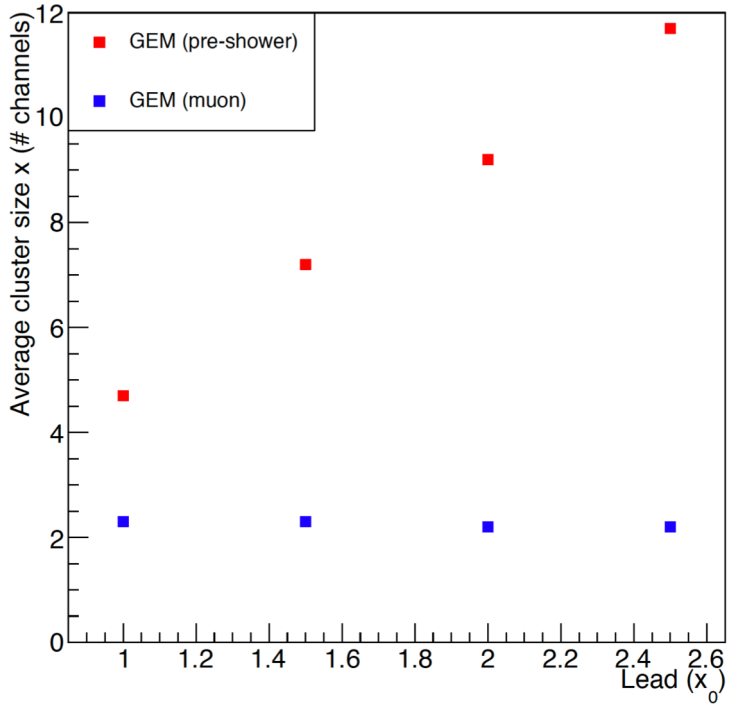


Preliminary plots

20 GeV Electron beam (with muon contamination)

The impact of the material (up to 2.5 X_0) placed in front of the GEM



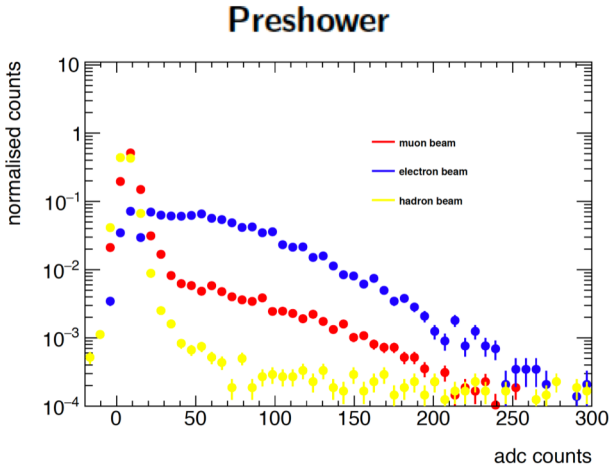


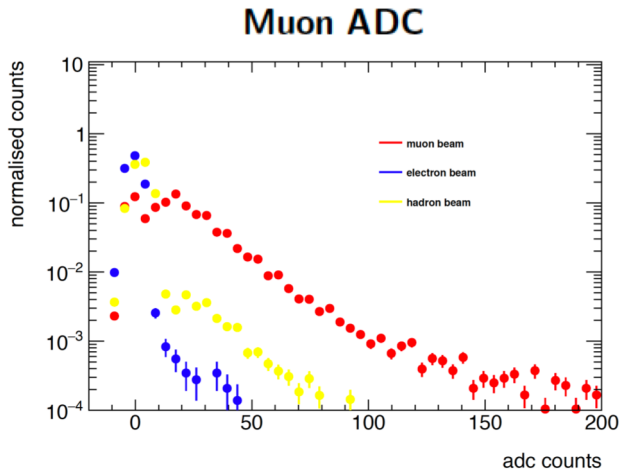
Preliminary plots: particle selection

Different beam compositions used for this test

Composition	Run No.	Energy
Electron	12709	20
Muon	12686	40
Hadron	12802	60

Signals measured in the preshower (scintillator + converter) and in the muon counter (large scintillator) used as cross reference detectors for particle identification





Possible cuts

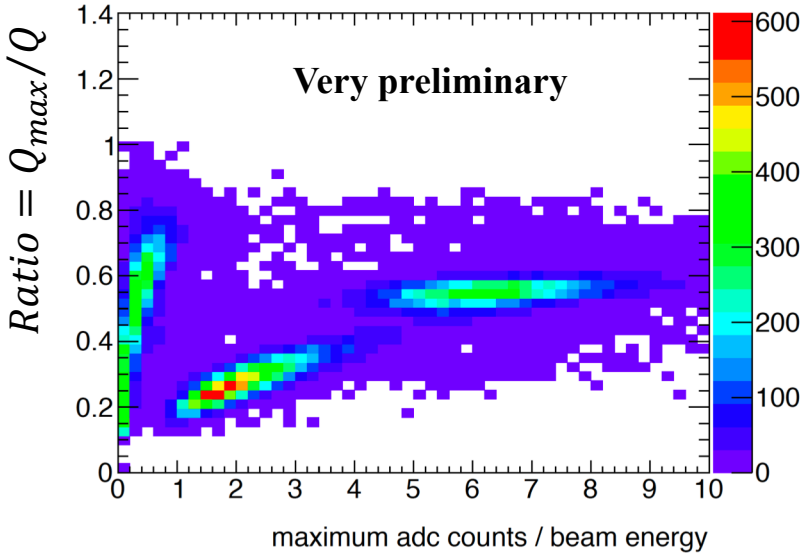
	preshower	muon ADC
electron	> 20	< 8
muon	< 20	> 10
pion	< 20	< 5

Preliminary plots: particle selection

Different beam compositions used for this test

Composition	Run No.	Energy
Electron	12709	20
Muon	12686	40
Hadron	12802	60

Signals in the RD52 calorimeter:
response not yet equalized



$$Ratio = Q_{max}/Q$$

Q_{max}= adc count measured in the tower with the larger signal

Q= sum of the 10 adc counts in the towers with larger signals

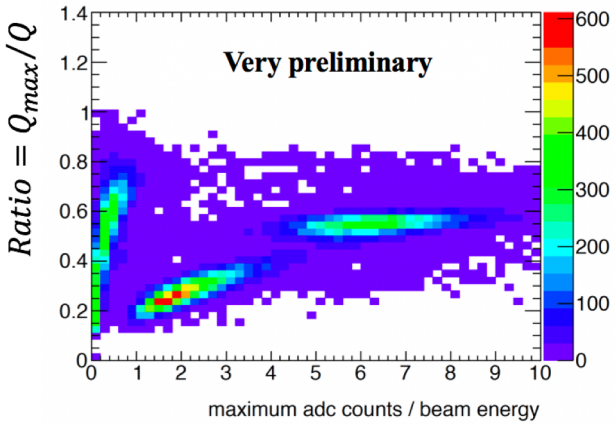
Preliminary plots: particle selection

Different beam compositions used for this test

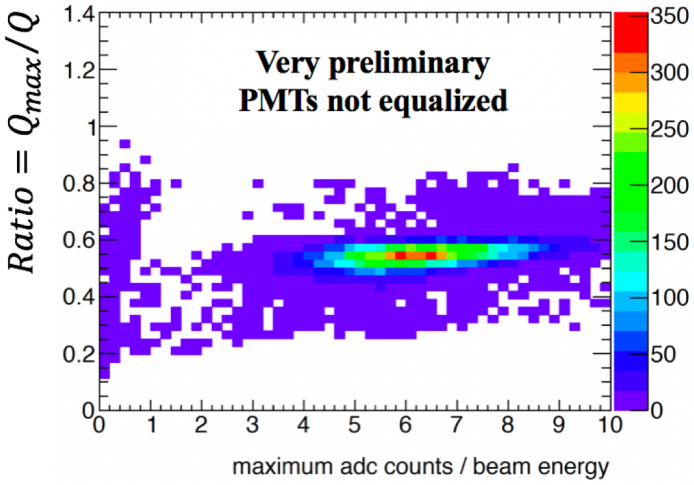
Composition	Run No.	Energy
Electron	12709	20
Muon	12686	40
Hadron	12802	60

	preshower	muon ADC
electron	> 20	< 8
muon	< 20	> 10
pion	< 20	< 5

Signals in the RD52 calorimeter:
response not yet equalized



applying preshower cut



Preliminary plots: particle selection

Different beam compositions used for this test

Composition	Run No.	Energy
Electron	12709	20
Muon	12686	40
Hadron	12802	60

	preshower	muon ADC
electron	> 20	< 8
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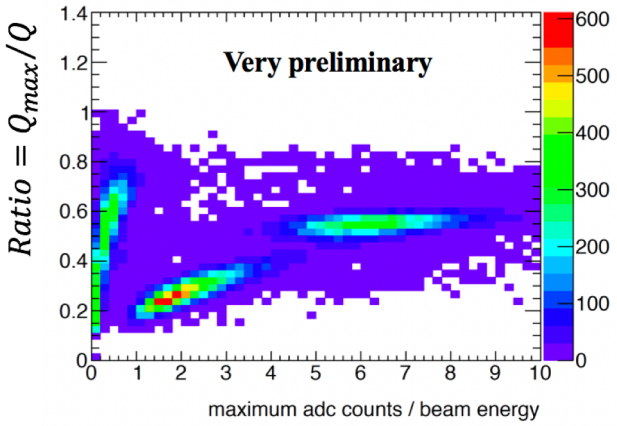
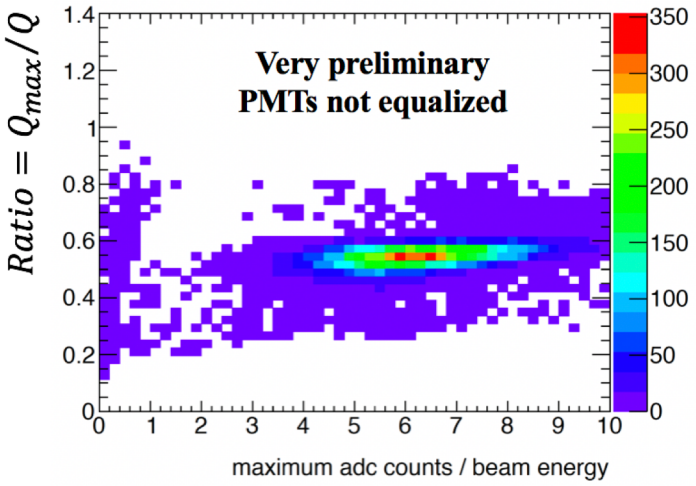
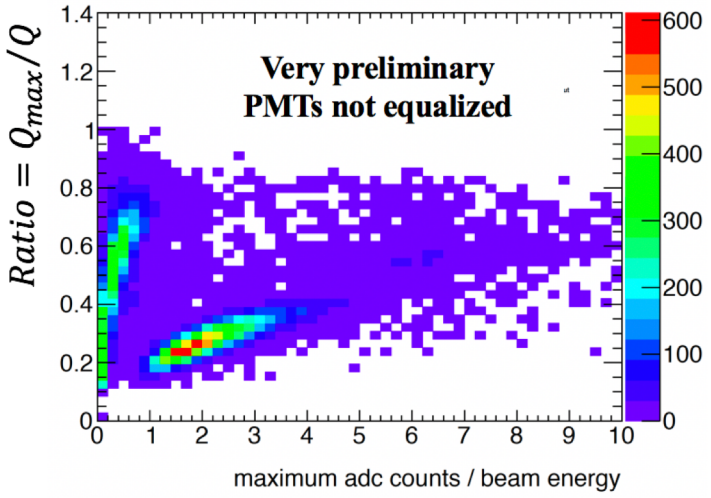
Signals in the RD52 calorimeter:
response not yet equalized



applying preshower cut



applying anti-preshower cut



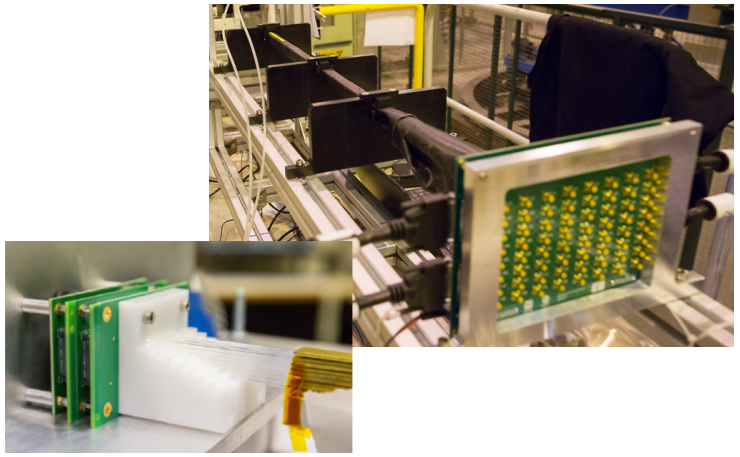
Summary

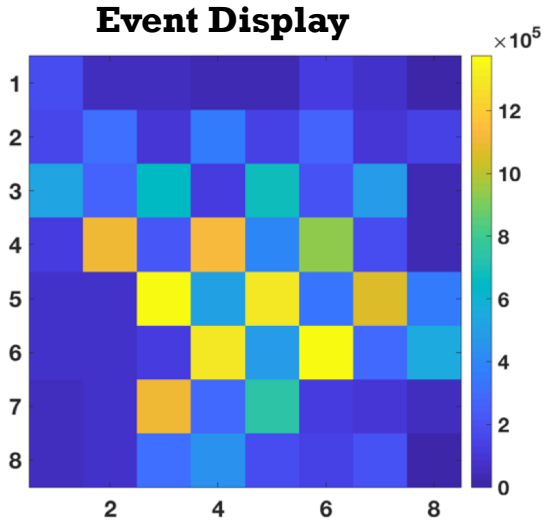
- Even if we defined a long program, we managed to collect a good set of data to study the combined detector performances
- The test beam data analysis is started and detailed studies will come soon providing updated input to the simulations
- We already achieved a good result: there is a growing interest around this test beam which started to enlarge and consolidate the "collaboration" (≈ 50% PhD and postdocs)

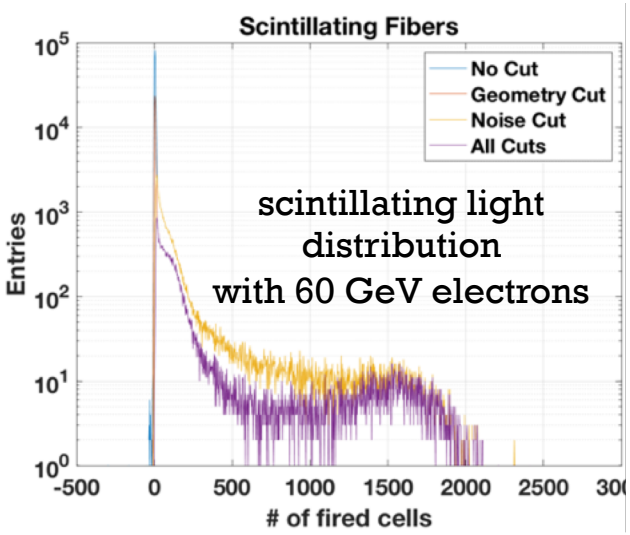
Backup

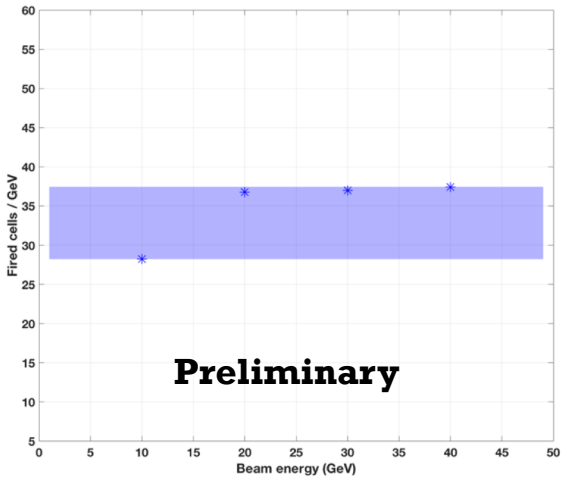
Standalone program (1 day)

- Dual readout calorimeter prototype module readout by SiPM (1 day)
  - Energy Scan with electrons beams (10, 20, 30, 40 GeV): Ph-e / Gev measurement









Preliminary plots: particle selection

Different beam compositions used for this test

Composition	Run No.	Energy
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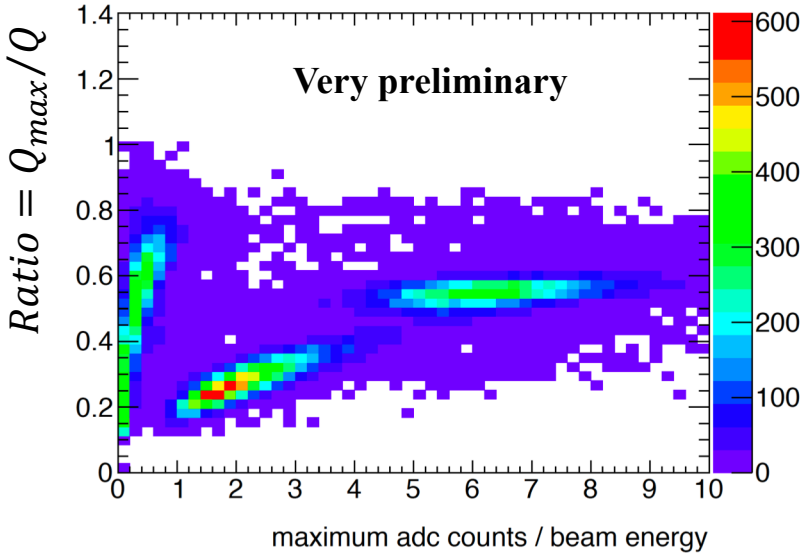
Tower numbering

1	2	3	4	5	6
7	8	9	10	11	12
13	14	15	16	17	18
19	20	21	22	23	24
25	26	27	28	29	30
31	32	33	34	35	36

Each Tower has 1 PMT for scintillating and 1 PMT for Cherenkov light detection

Signals in the RD52 calorimeter:
response not yet equalized



$$Ratio = Q_{max}/Q$$

Q_{max}= adc count measured in the tower with the larger signal

Q= sum of the 10 adc counts in the towers with larger signals