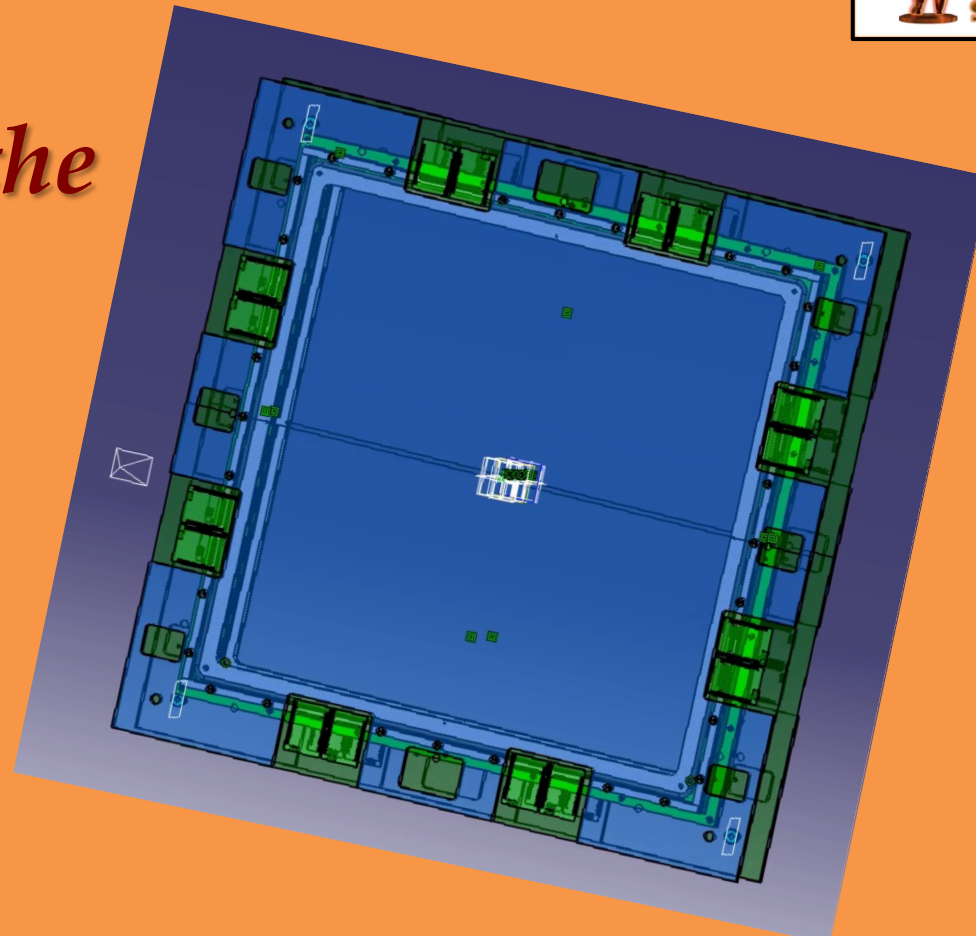
A MM tracker for the PADME upgrade



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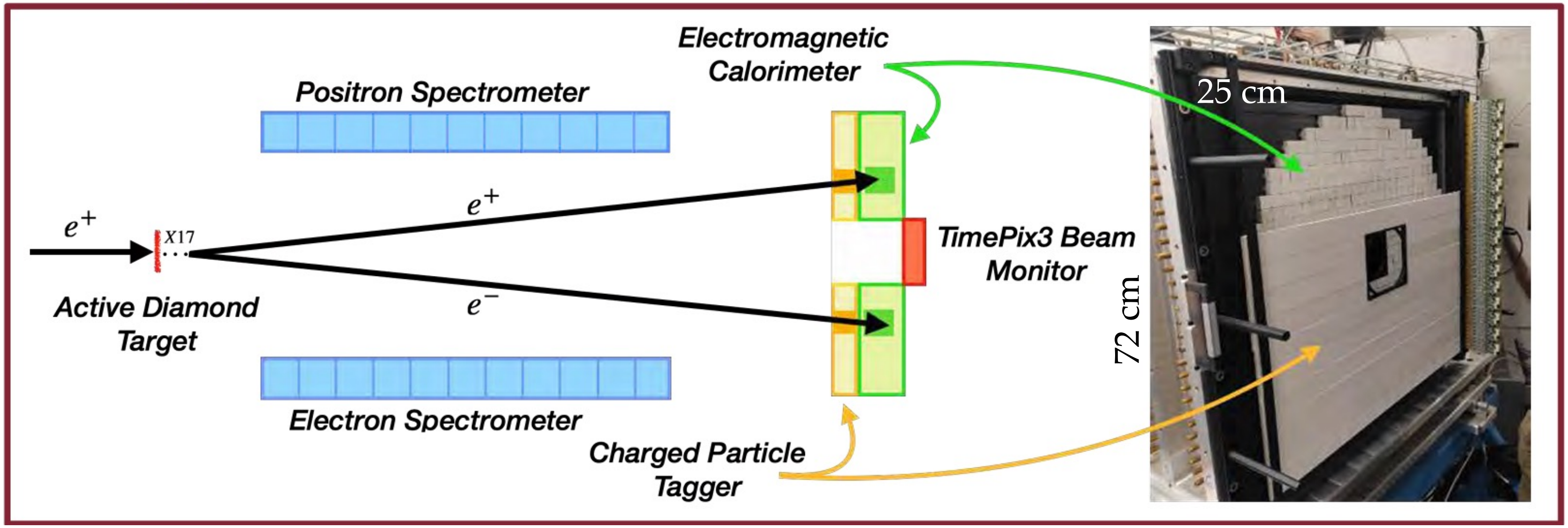
88 cm

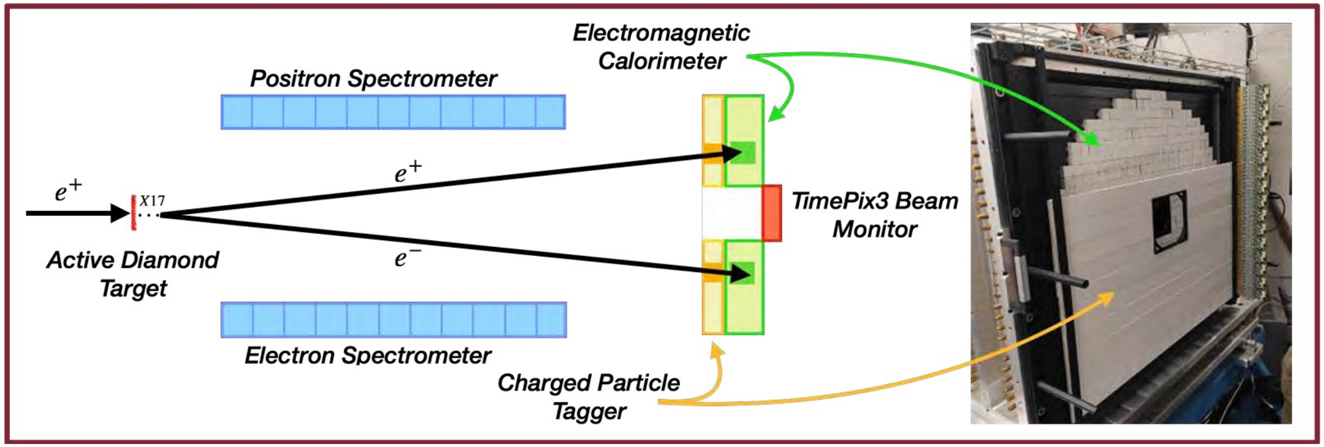


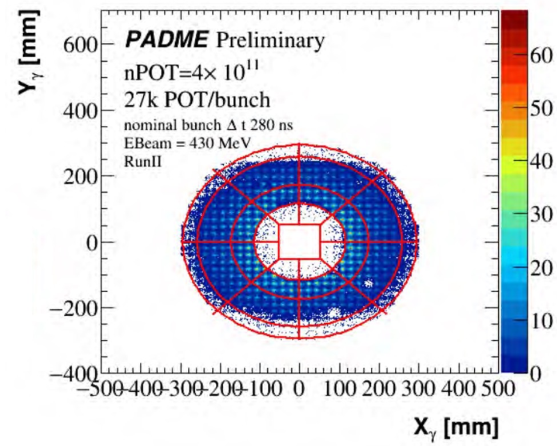
PADME:

- goal: exploit the ratio of the number of e+e- final state events to the number of annihilations to a photon pair (exploit a region in which the X^{17} can show up)
- run conditions: at the BTF at LNF, positron bunches with 3000 particles directed onto the PADME active diamond target, with up to 5 10^{11} POT

For PADME Run4 need a statistics increase (higher beam intensity) and a precise identification of the e+e- and photon-photon final states.
For this reason, a tracker is needed upstream of the electromagnetic calorimeter capable to run in high intensity conditon: a TPC MM tracker (MPGD, low material budget, high segmentation, good resolution in the transverse directions and tracking capabilities.)

General Idea for the MM tracker



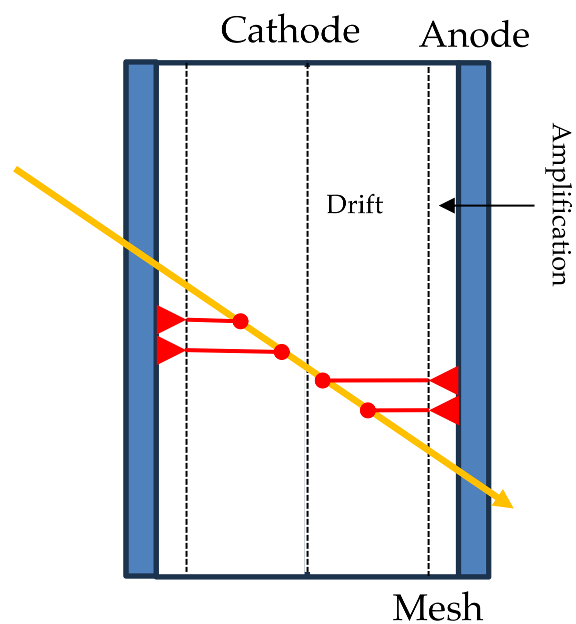


General idea:

- need a light detector capable for tracking (material budget: few%X_0)
- use a TPC based on MM technology (drift gap of 5cm)

DAQ:

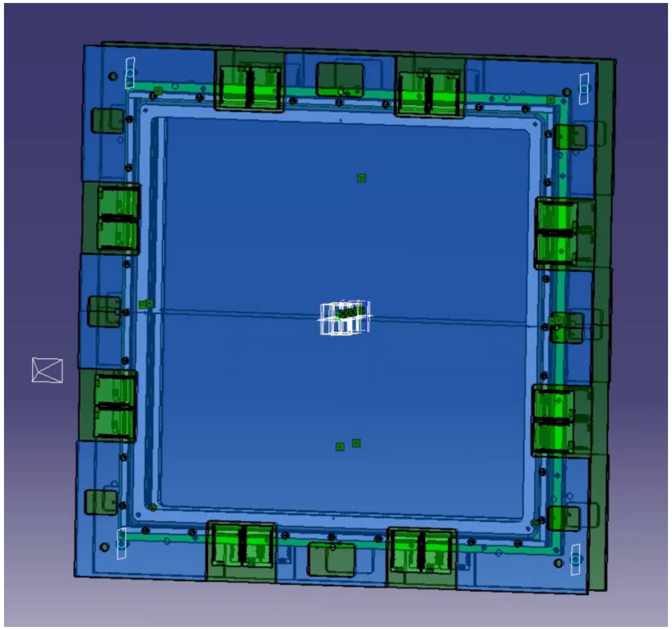
- APV based -> acquisition window of ~700ns
- Fast gas mixture Ar:CF4:Iso (88:10:2)

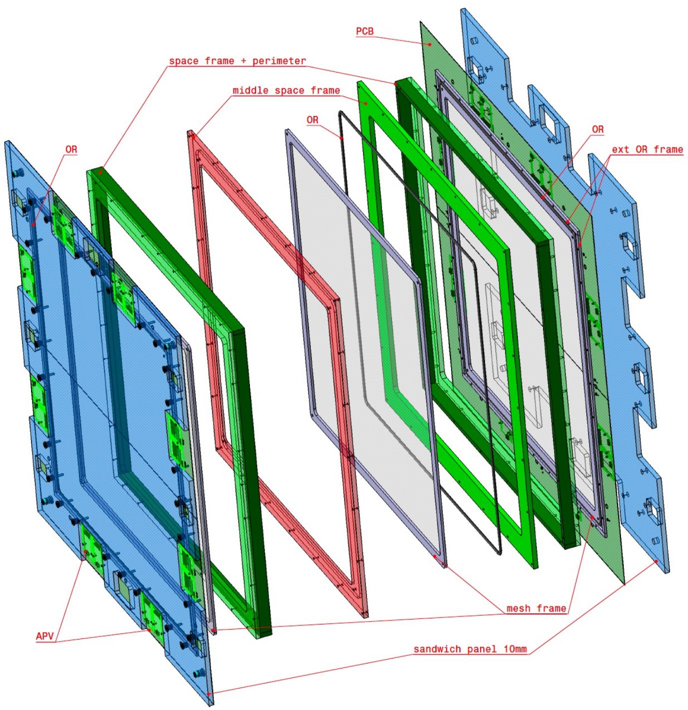


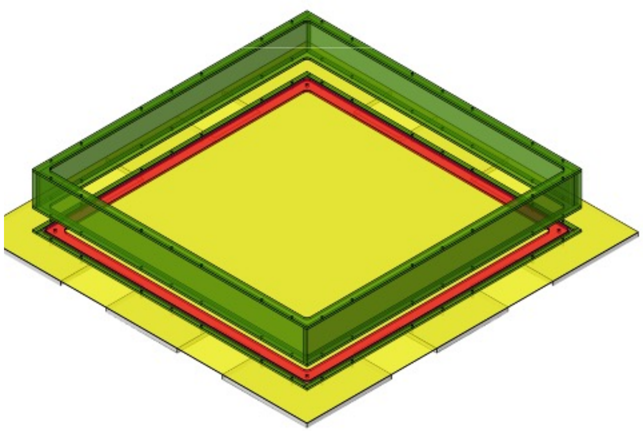
Detector scheme

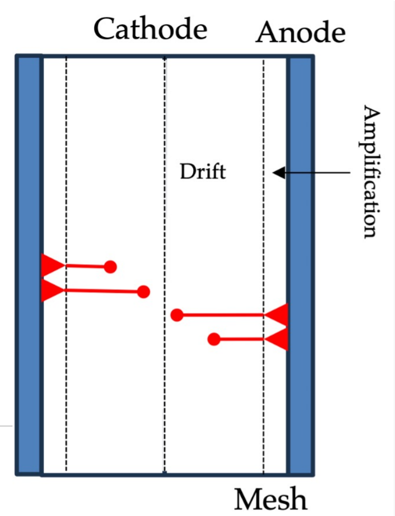
The padMMe detector:

- 65 cm x 65 cm
- TPC operation with 2 RO planes (2 views per plane)
- a central drift cathode (a stainless steel mesh)
- single gas gap 10 cm long
- gas mixture based on Ar : CF4 : Iso = 88 : 10 : 2 to optimize the drift velocity, so that the signals can be read using an APV-based frontend









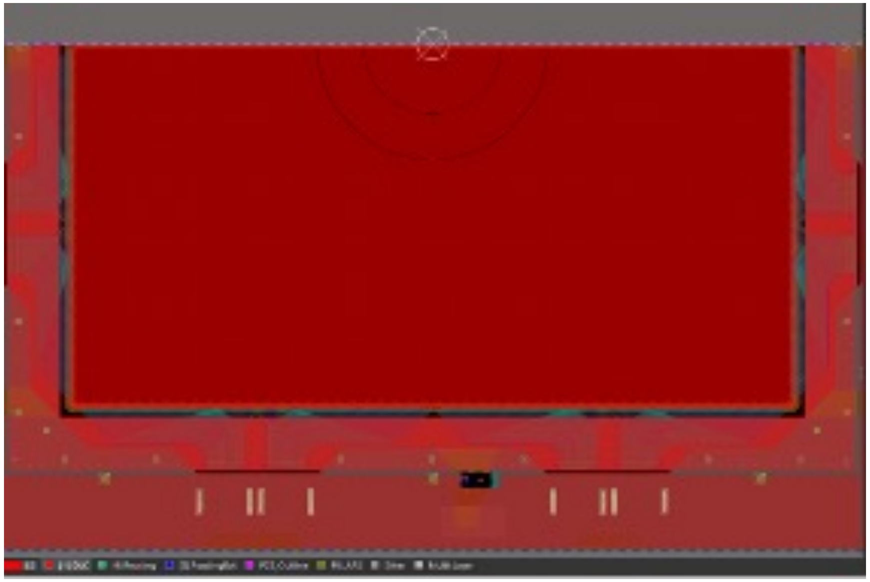
HV distribution

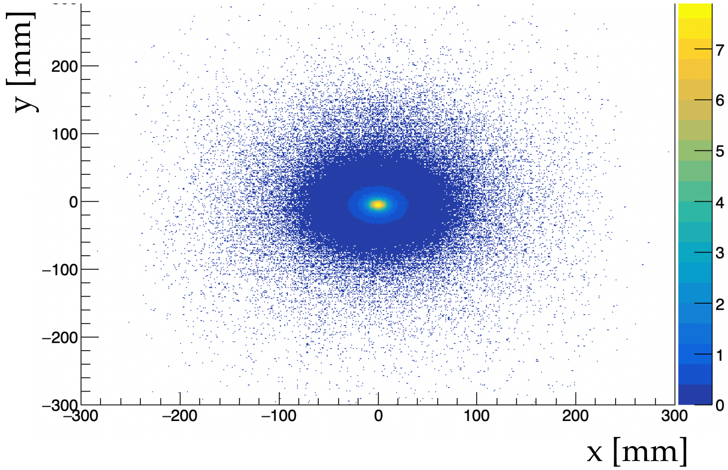
To cope with the high particle flux in the central region, the resistive circuit has been designed to allow for 3 different regions in HV (gain).

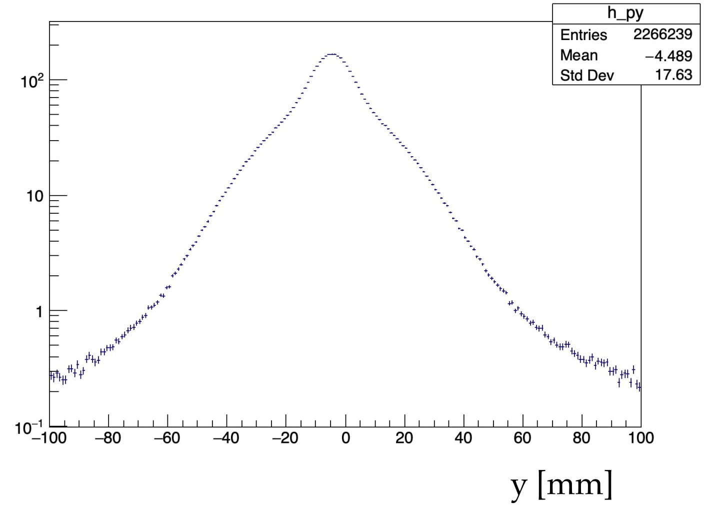
GEANT4 simulation have been performed to study the expected occupancy.

3 HV regions: central region (beam, ±60mm), corona (occupancy lower by a factor 100, external radius 100mm), peripheral (further lower occupancy, elsewhere)

With relative gains set as 0.001 : 0.01 : 1.





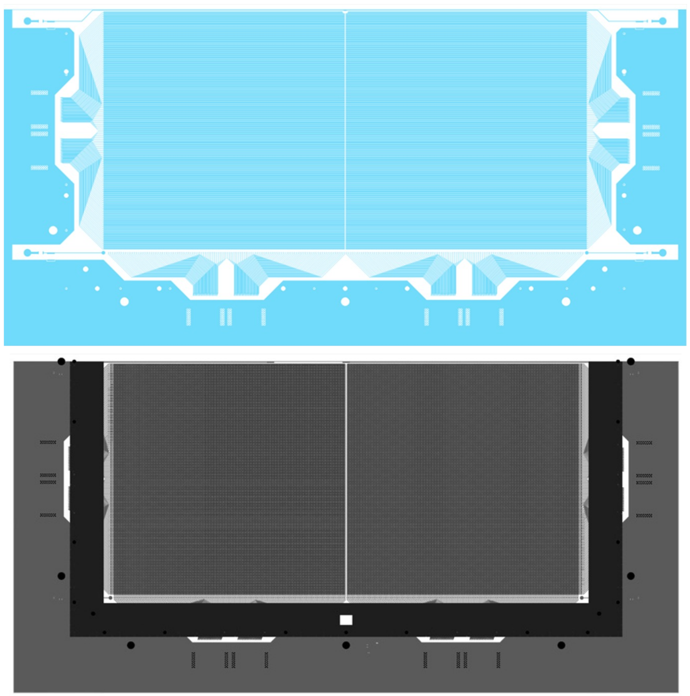


2 different RO pcbs

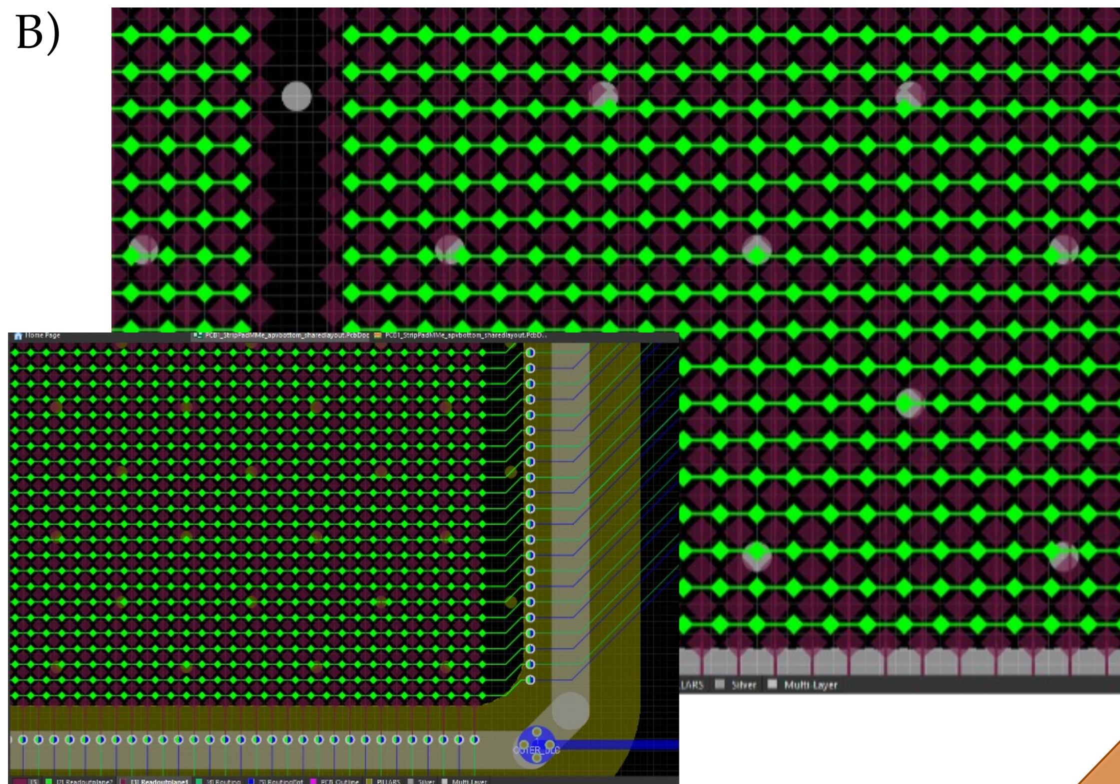
2 detectors will be built:

- A) 1 with well known technology: strips along 2 RO views, capacitively coupled, pitch 1.1mm. Expected resolution on the hidden RO ~1mm
- B) 1 with new technology: based on rhomboic-shaped strips, pitch 1.1 mm.
  Green and purple are the 2 RO planes (50 μm apart), capacitive coupling towards the resistive layer isequalized by scaling the rhomboid areas. The overlap between the 2 coord is minimized to reduce the signals induced. Expected resolution on the hidden RO ~300um

A)



B)



Gas mixture

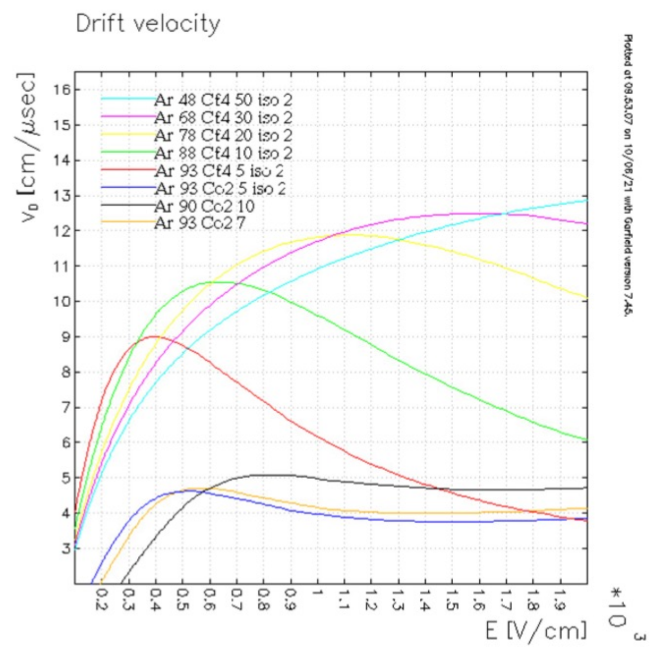
Gas mixture: 88Ar: $10CF_4$: 2Iso

Detector design:

- 5 cm for the drift gap
- HV granularity: ad hoc depending on the simulated occupancy
- for a 5 cm drift gap -> (Ar:CF4:Iso 88:10:2)

  -> v_d=10 cm/us   con HV=3000V -> 500ns drift time
- APV 128 ch -> acquisition window

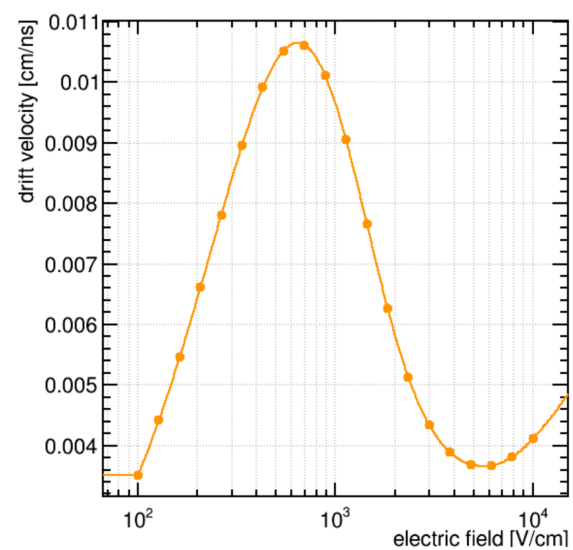
  675ns (27x25ns)



Garfield simulation for a planar gap

of 5 cm drift gap

-> gas mixture tested during test beam at BTF



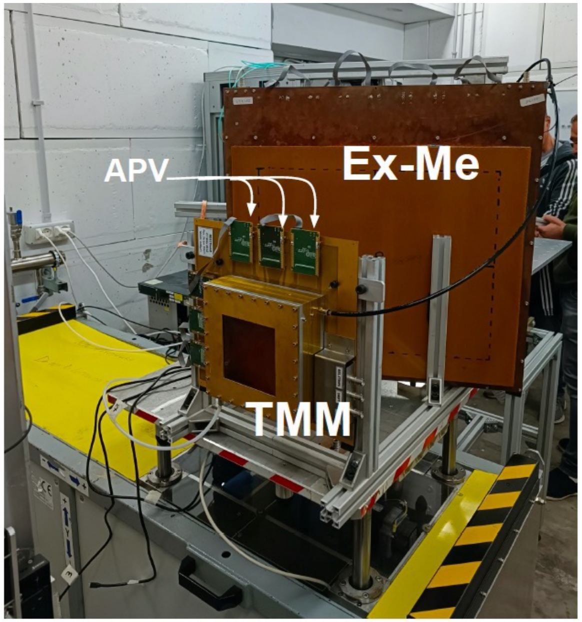
Test beam in 11/23 and 05/24 at BTF (LNF)

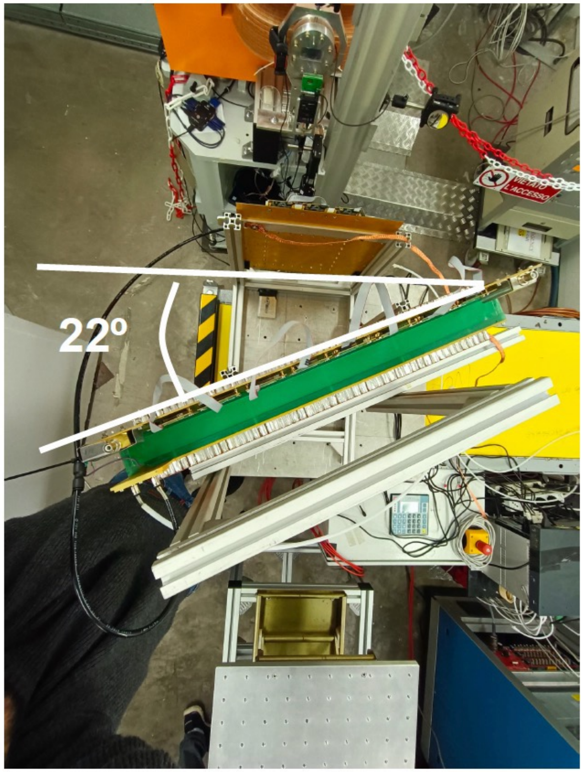
Same setup, 2 chambers: TMM 5cm drift gap 10x10cm^2 + ExMeMM 5cm drift gap (40x50 cm^2)

- Ar:CF4:Iso (88:10:2)
- Ex-Me chamber tilted by 22°
- Very narrow O(mm) positron beam
- Electronics: APV
- HV settings (nominal):

TMM Amp: 460 V, Drift: 3 kV

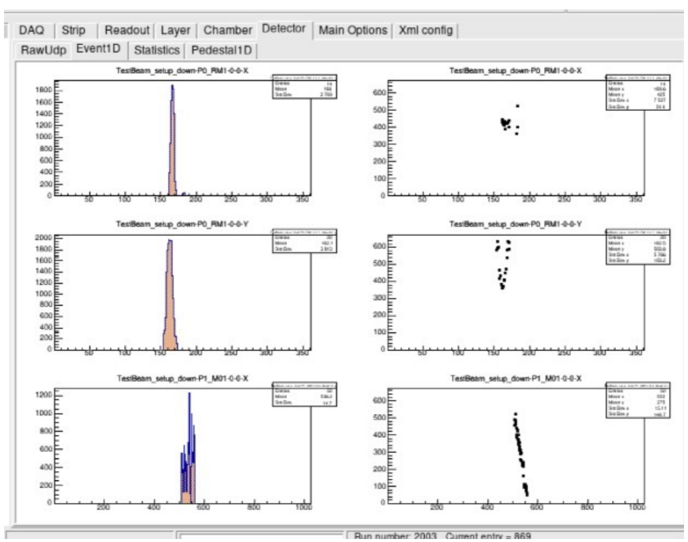
Ex-Me Amp: 490 V, Drift: 3 kV

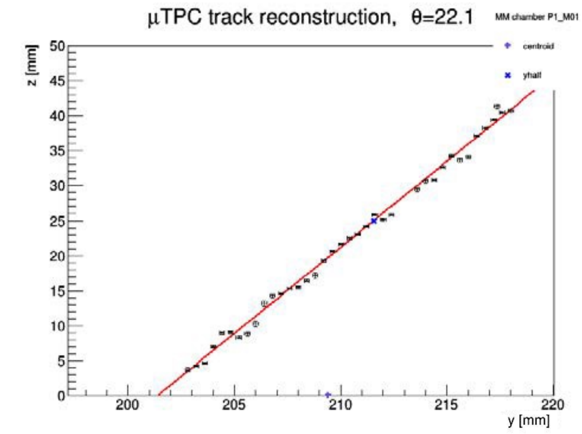


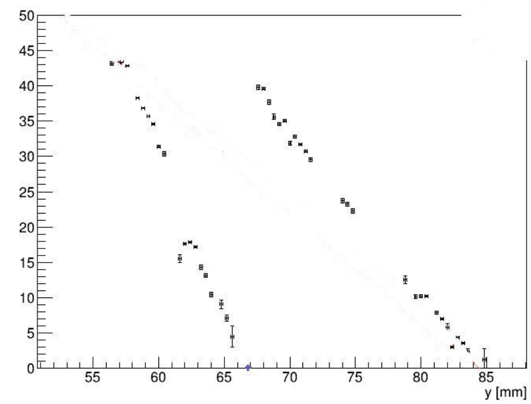


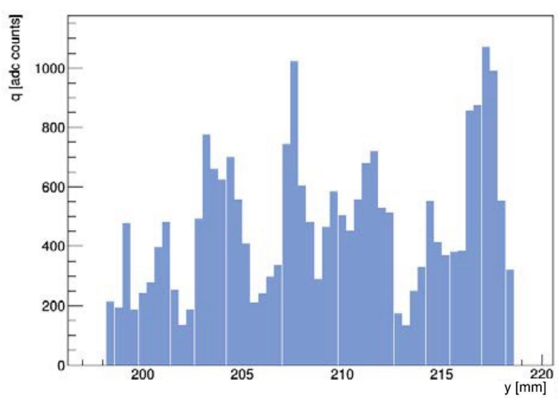
Aims for the test beam: TPC operation to be proved, resolution on the z coordinate estimation, drift and HV scans to define the operation nominal conditions

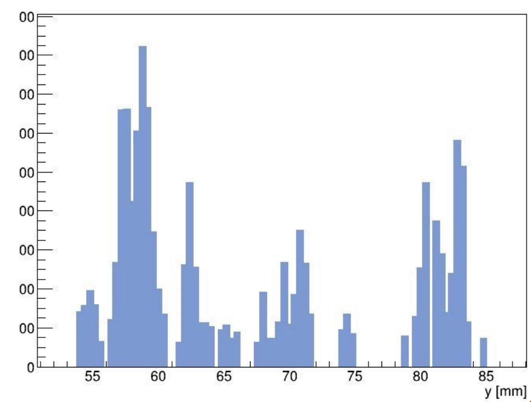
Few event displays and reconstructed tracks:







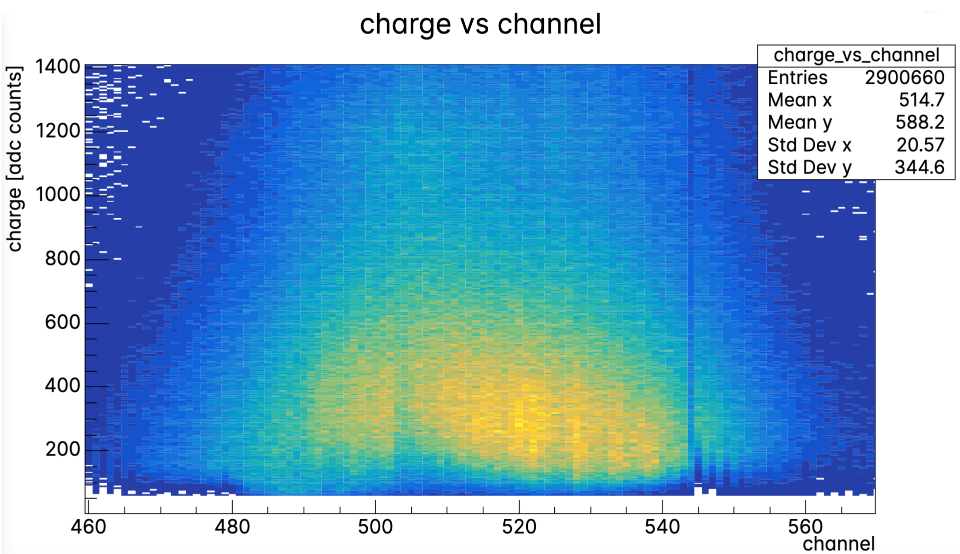




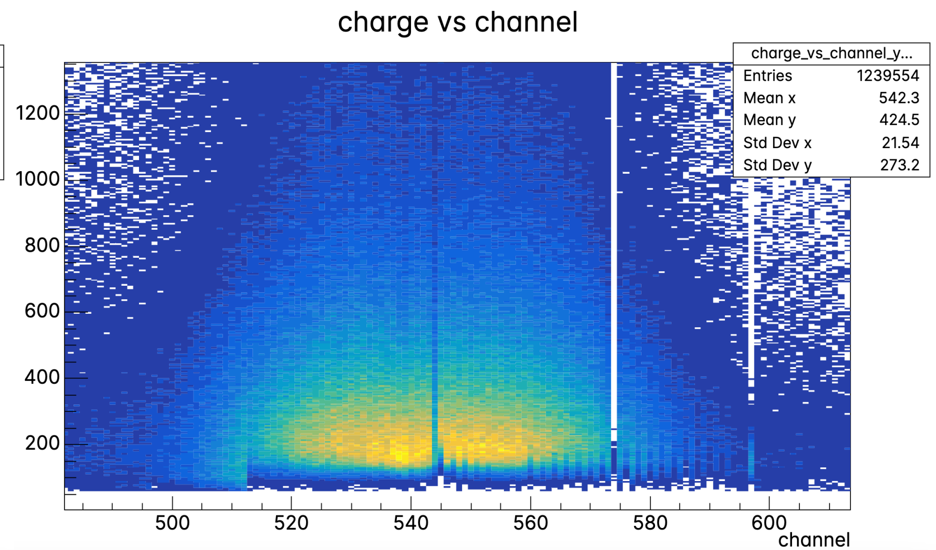
Test beam results

Same conditions for the 2 test beams but -> from the occupancy we can clearly spot that 1 APV was not working well and in the 2nd test beam the beam was more centered on it (big number of holes in the cluster and less hits per track)

Nov test beam



May test beam



Nov Run: drift scan results + z resolution
May Run: HV scan results (hit and cluster efficiency)

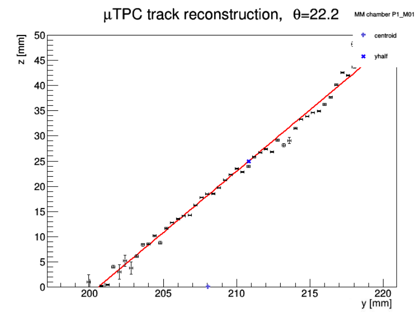
Of course analysis cuts have been adapted to cope with the bad APV.

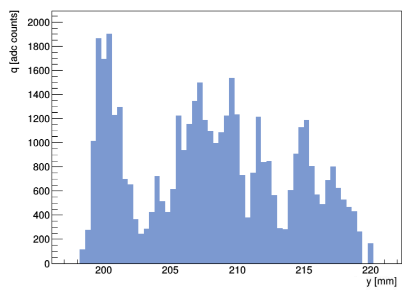
Test beam results

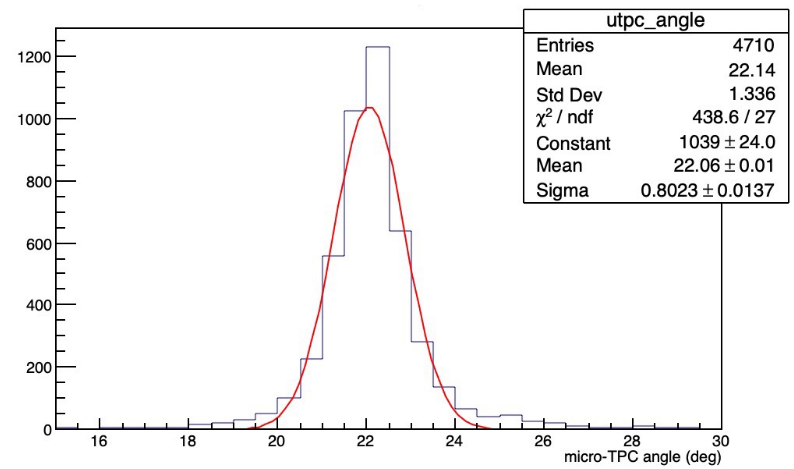
Nov test beam

TPC reconstruction working very well

- All muon ionizations reconstructed in the 5 cm gap
- TPC reconstructed track angle 22.06 ± 0.80°



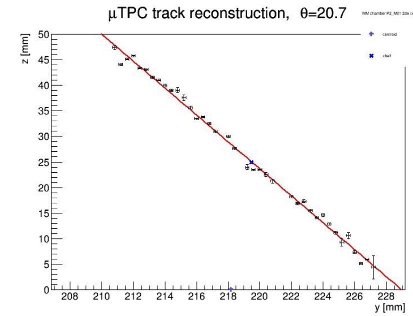


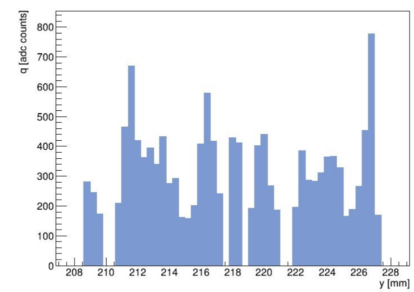


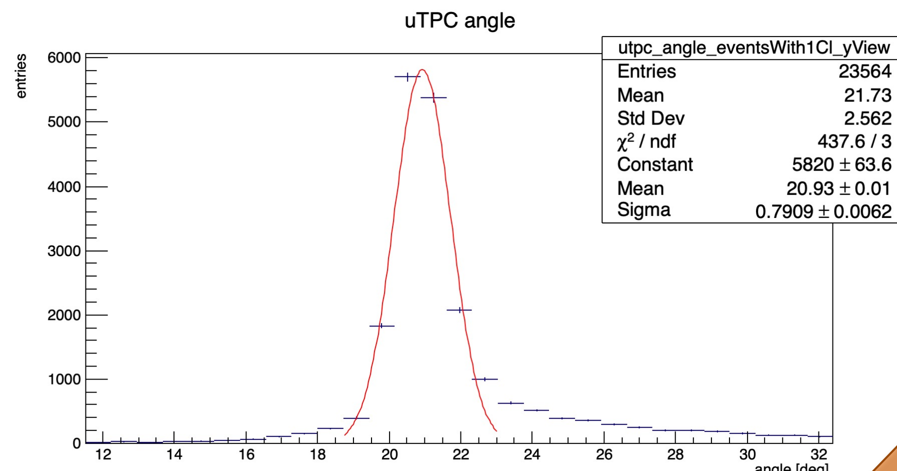
May test beam

TPC reconstructed track angle 20.93 ± 0.79°

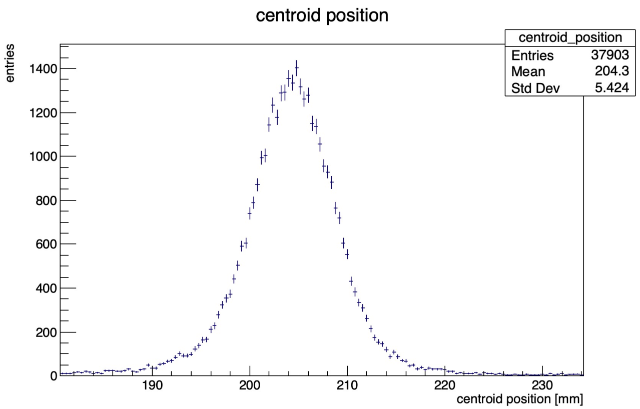
N.B. descending slope is due to the reversed coord syst



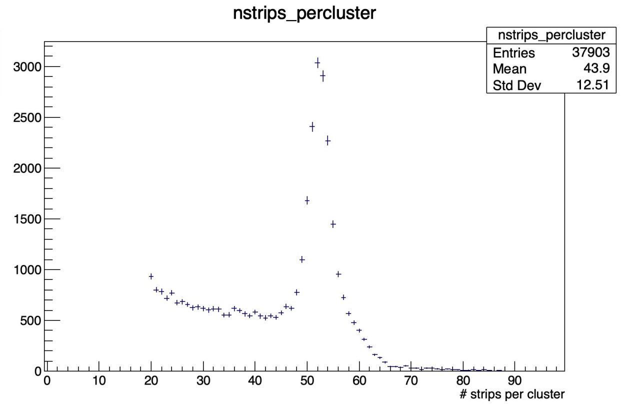




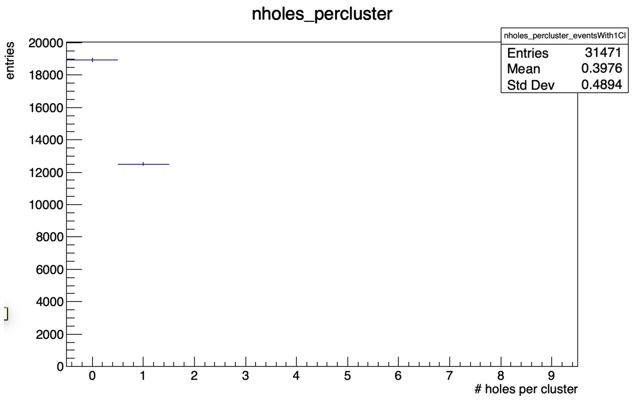
Nov test beam



Mean 204 mm

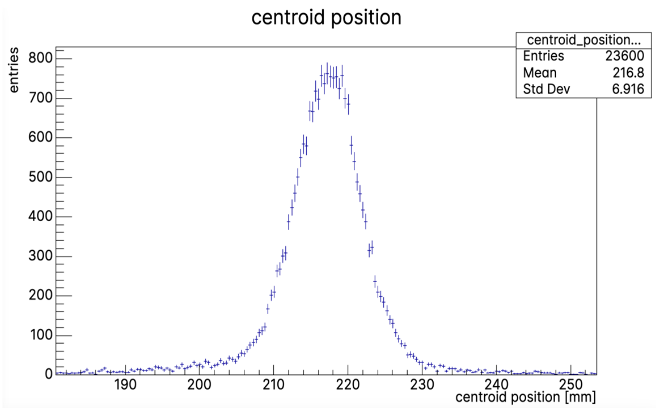


Peaked over 50

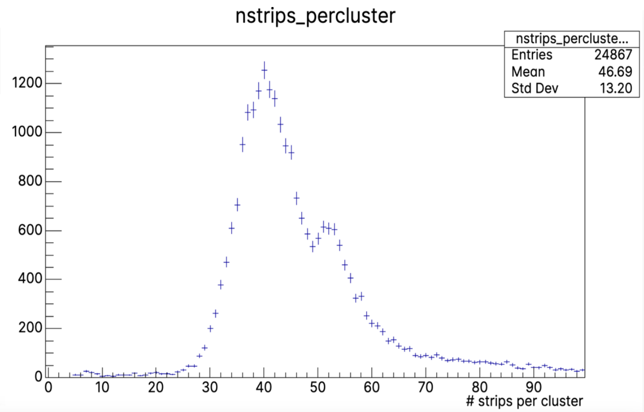


Max 1

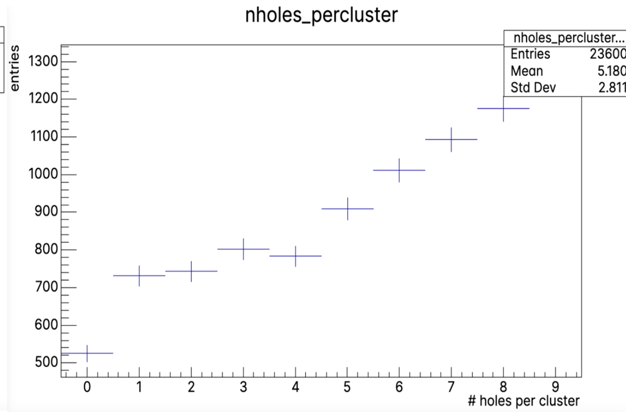
May test beam



Mean 217 mm



Overall reduced number of strips per cluster



Huge number of holes

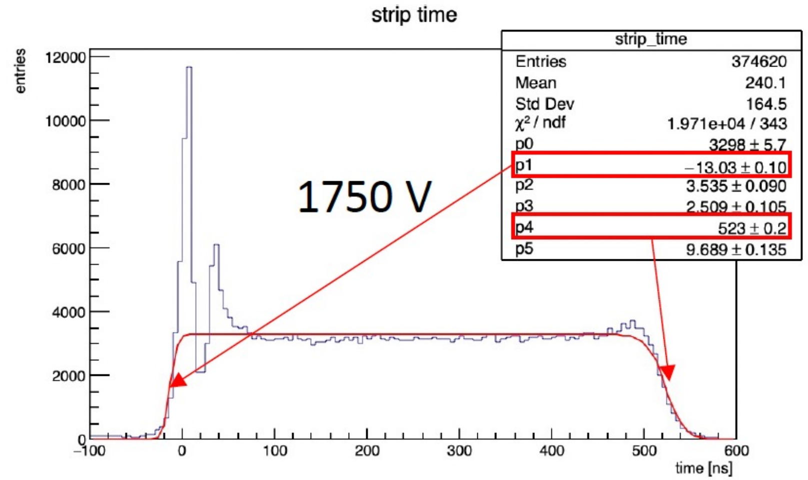
Test beam results

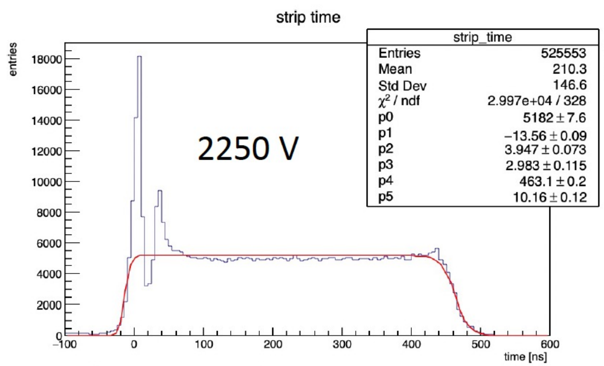
Nov test beam

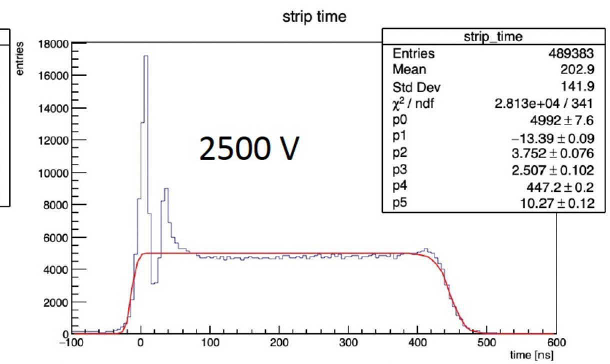
Drift voltage scan from 1750 V to 4000 V

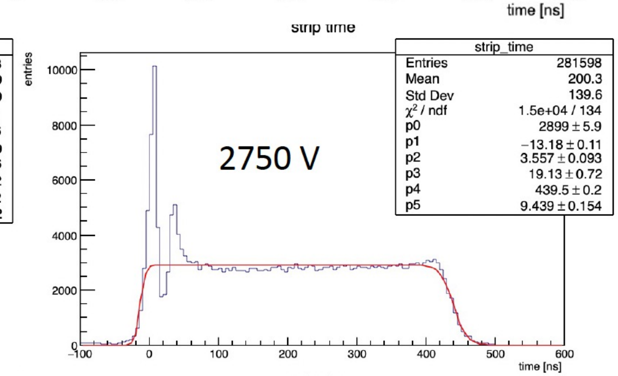
- Drift velocity measured from double-Fermi-Dirac fit on strip times distribution

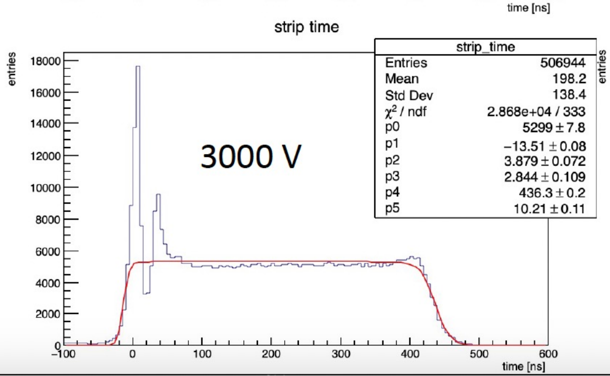
$$v_{drift} = \frac{5.0128\ cm}{p4 - p1}$$

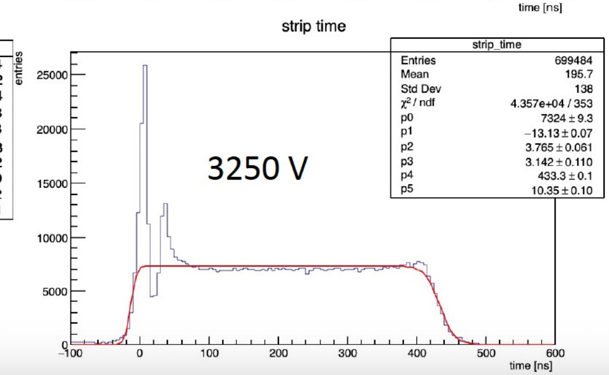


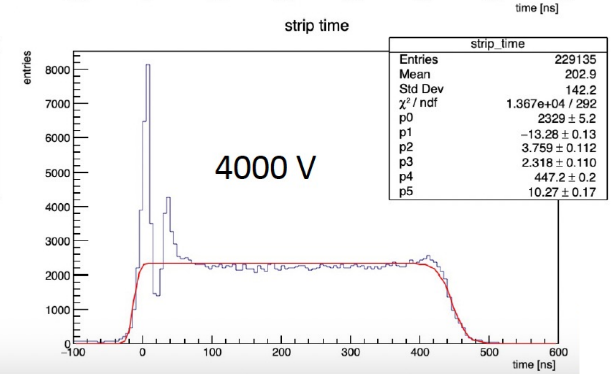








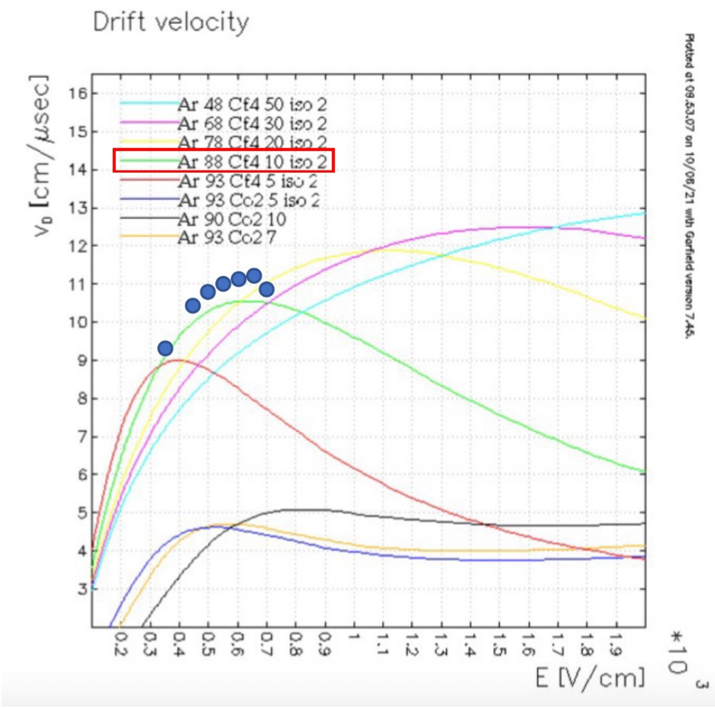


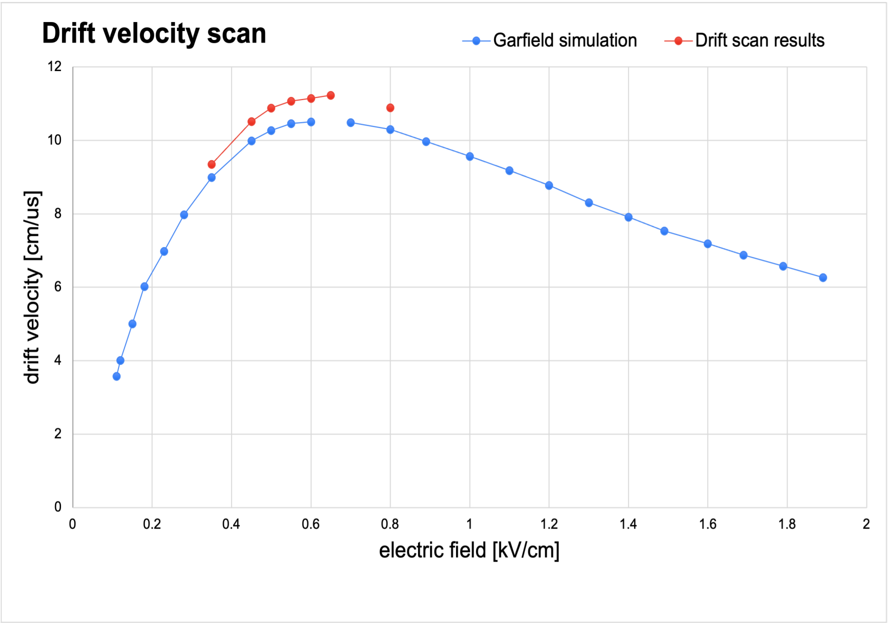


Drift voltage scan from 1750 V to 4000 V

- Drift velocity measured from double-Fermi-Dirac fit on strip times distribution

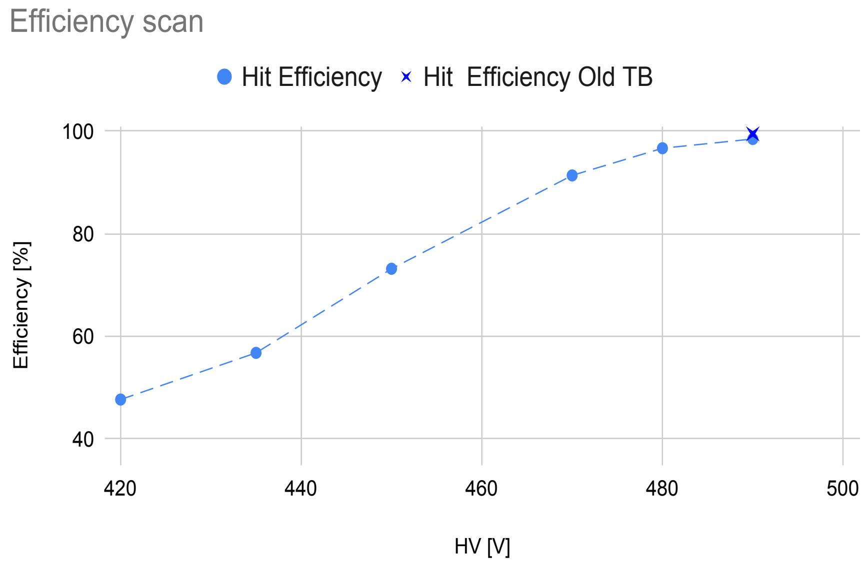
V_{drift} (V)	E_{drift} (V/cm)	Exp. v_{drift} (cm/μs)	Meas. v_{drift} (cm/μs)
1750	350	9.2	9.35
2250	450	10.0	10.52
2500	500	10.3	10.88
2750	550	10.5	11.07
3000	600	10.6	11.15
3250	650	10.5	11.23
4000	800	10.4	10.89

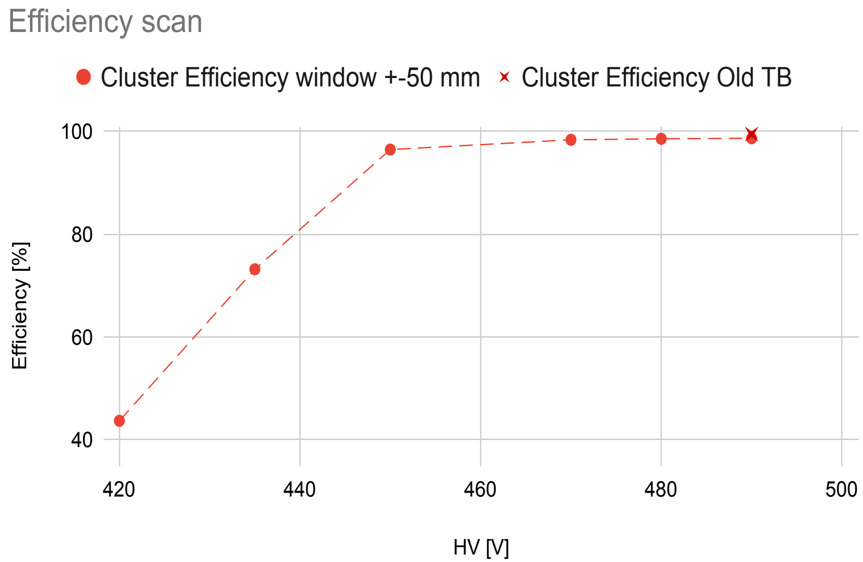




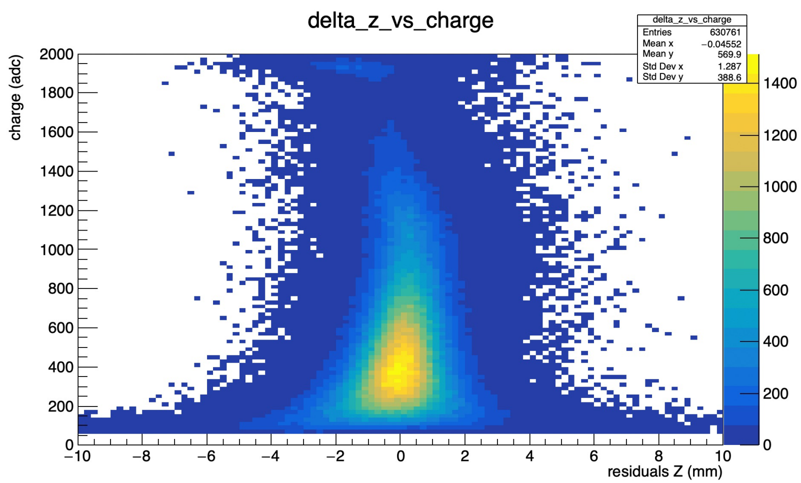
HV scan:

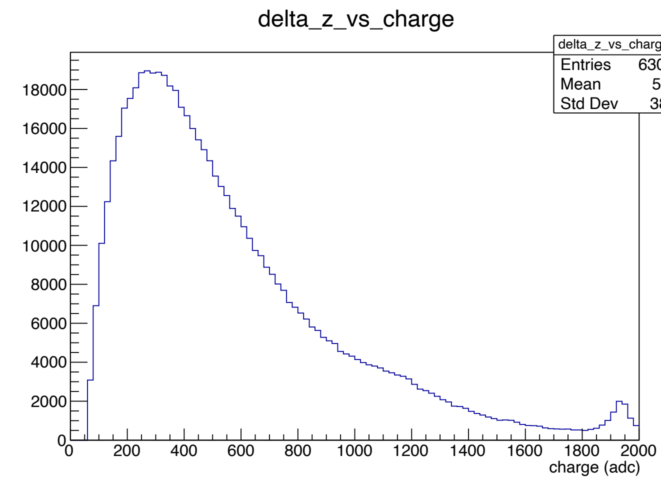
- to cope with the bad APV, we rely on the hit efficiency taking into account an average good strip within the good APV region and computing the efficiency of the strip when a reconstructed track is present (little bias but negligible)
- for the cluster efficiency of course cuts have been adapted to the present conditions: no cut on the max holes (was 1) and no cut on max consecutive holes (was 0) + window of ± 5cm (was ± 1cm) from the TMM reco position
- comparison with the nominal run from Nov test beam is reported (same cut conditions)





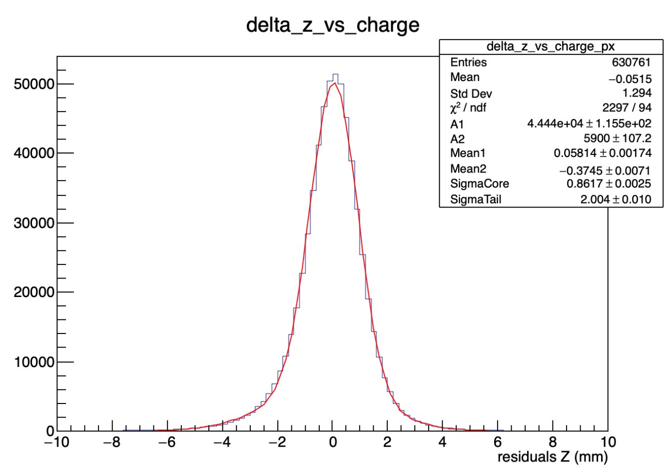
Δz and Δt obtained from the strip time measured (z measured via drift velocity) wrt the track fitted position (derived time).

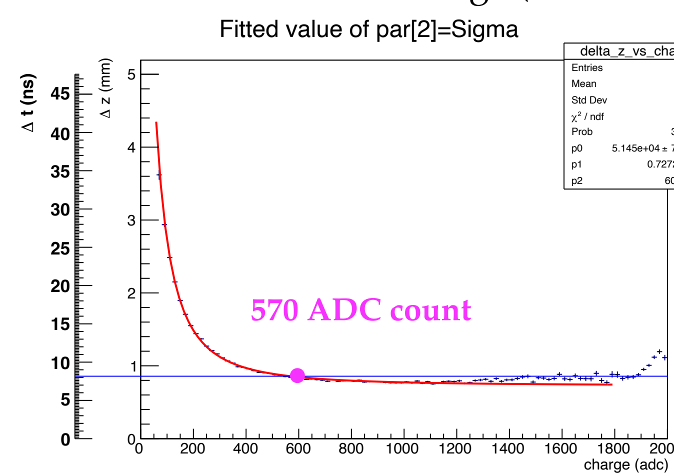




Z resolution obtained by fitting the Δz proj with a double gaussian (dependency on the strip charge included): 861.7 ± 2.5 um

Z resolution obtained by fitting the Δz for strip charge slices:
time resolution: 8ns at mean charge (570 ADC count)
z resolution: 840 um at mean charge (570 ADC count)





Conclusions

- A new MM detector has been designed to be installed inside PADME with tracking purposes
- TPC operation has been proved at 2 test beam at BTF In Frascati with very good results using refurbished detectors already available within the collaboration
- We tested the capability to reconstruct single tracks
- We achieved resolution of the z coordinate for each hit of 850um, well below 1 mm (PADME request) and corresponding to 8ns time resolution (at 570 ADC count, mean charge)
- 2 RO pcbs have been designed for this purpose and detectors are now under construction to be used for PADME Run4 (Jan25)