Status of
Micromegas Central Tracker

Outlines

- Detector layout
- Gas mixture
  - Requirements
  - Simulation
  - Experimental results
- Signal simulation
- Mechanical prototype

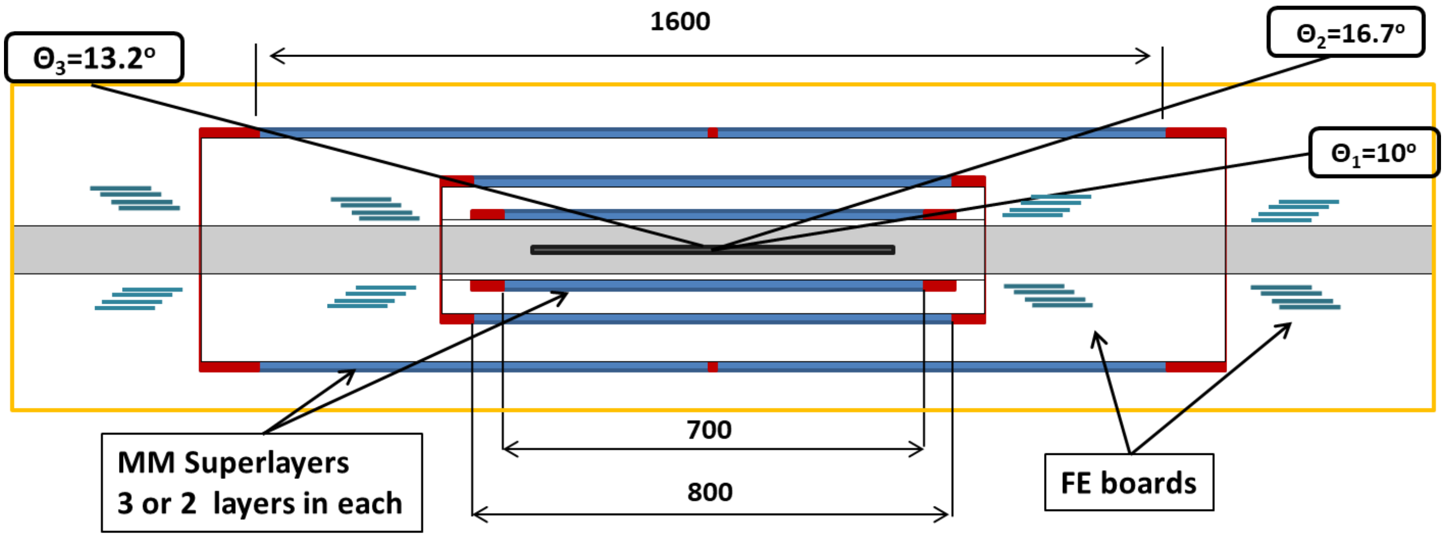
MCT Team:

- Koviazina Natalia
  - Garfield simulation, data analysis
- Luashko Igor
  - Experimental measurements, prototype assembling
- Gongadze Alexy
  - Production, material, general help
- Dedovich Dmitry

Micromegas Central Tracker

- “Temporary” detector, will be replaced by Si tracker in 2-3 years of operation
  - Cheap and simple in operation
  - Should provide fast results. Years of calibration and reconstruction turning is not acceptable

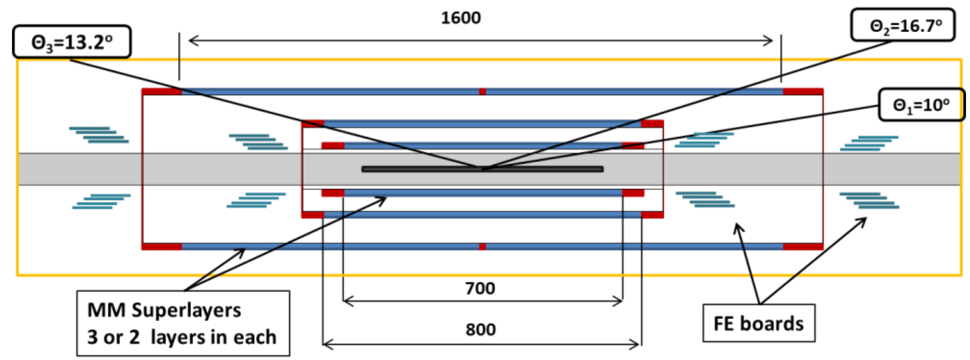
MCT layout



- 7 layers organized in 3 multilayer
- ~15K electronic channels (118 FE boards)
- Too big..

MCT layout

- Outer multilayers do not improve momentum resolution, but needed as background environment for inner layers is unknown



- Event rate & track multiplicity :
  - E=27GeV , full luminosity : 3MHz event rate
    - MB event : <N=9.9>; $N_{5\%}$=20+
    - Hard QCD events: <N=14>; $N_{5\%}$=22+
  - E=10GeV, 10% of full luminosity: 300 kHz event rate
    - MB event : <N=5.8>; $N_{5\%}$=10+
    - Hard events: <N=7.1>; $N_{5\%}$=11
- Detector occupancy and hit rate are strongly depends on Lorentz angle

Inner layer occupancy & hit rate

No background and noise

θ_L	1 event occupancy, %	1 event occupancy, 5% high multiplicity	Strip hit rate, kHz	
45	**7,3**	**12**	**22**	Standard HV settings

Inner layer occupancy & hit rate

θ_L	1 event occupancy, %	1 event occupancy, 5% high multiplicity	Strip hit rate, kHz	
45	**7,3**	**12**	**22**	Standard HV settings
15	**3.1**	**5.1**	**9.1**	L=80cm
10	**1.9**	**3.1**	**5.6**	L=80cm

Inner layer occupancy & hit rate

θ_L	1 event occupancy, %	1 event occupancy, 5% high multiplicity	Strip hit rate, kHz	
45	**7,3**	**12**	**22**	Standard HV settings
15	**3.1**	**5.1**	**9.1**	L=80cm
10	**1.9**	**3.1**	**5.6**	L=80cm
10	**<1**	**1.6**	**2.8**	L=2x40cm

Alternative layout

- **3 or 4 layers as close to beam pipe as possible, divided into 2 parts in Z direction (2x40cm)**
- **gas mix &HV setting providing Lorentz angle within 15^o**
  - ~10 safety factor for acceptable hit rate
  - 1/2 number of channels (44-60 boards instead of 118).
  - Smaller power dissipation and required space
  - Smaller RO PCB size, no problem with ordering, may be produced with integrated cable
  - Simple and reliable hit reconstruction with charge weighting
  - Slightly better momentum resolution
  - Smaller strip capacity => lower noise
  - 10-12 mm dead area along central line (junction)

What gas characteristics are important to MCT

High stable gas gain	Triggerless operation is vulnerable to noise : no time coincidence suppression
Lorentz angle	Numbers of active strips in hit cluster N_{cl}. Detector occupancy. Coordinate accuracy. Signal amplitude on strip $A \sim 1/N_{cl}$.
Ion mobility	Single-cluster signal length; main contribution to total signal length. Affect charge collection and event overlap probabilities
Electron drift speed In conversation gap	Max drift time => event time window; Contribute total signal length. Affect charge collection and event overlap probabilities

We need

- Stable operation with gas gain G~10^4 (and expect G~2-5x10^4 as best results for test chambers)
- Lorents angle θ_L within 10^o-15^o
  - Higher amplitude on strip
  - Reasonable occupancy
  - Simple hit reconstruction with charge centroid method and better accuracy
- Maximum drift time ~120ns => drift speed above 2.5 cm/ns
- Total signal length good within 300 ns to work with FE shaping time 100-200 ns

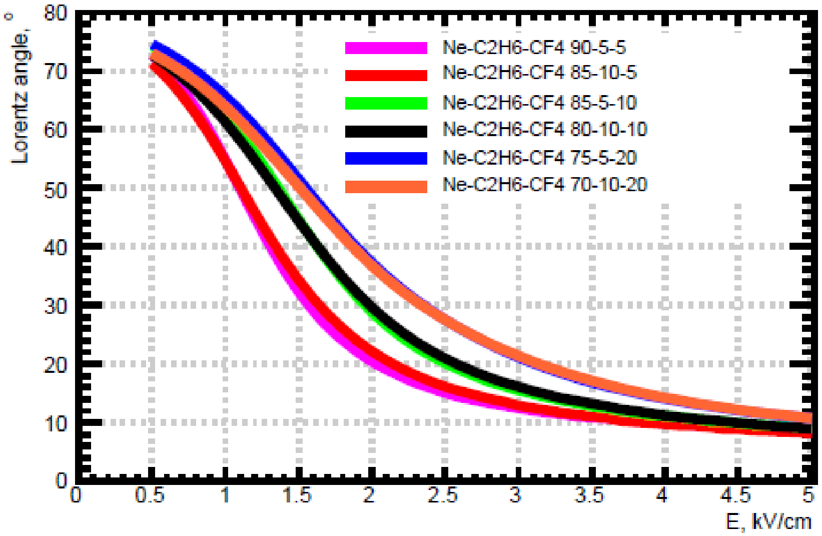
Overview of gas mixtures for MM

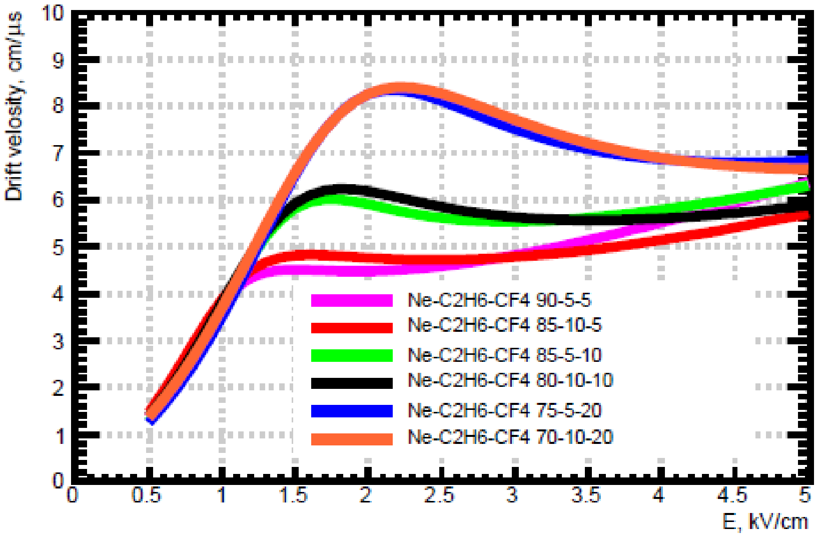
- **Compas** : no magnetic field
  - Ne-C_2H_6-CF_4 (80%-10%-10%)
- **ATLAS : B=0.3T**
  - Ar-CO_2 (93%-7%)
  - Ar-CO_2-iC_4H_{10} (93%-5%-2%)
- **CLAS12 : B=5T** (!!)
  - Ar-iC_4H_{10} (90-10) +very high drift field
- **New gas?**
  - Ar-CO_2-iC_4H_{10} with high CO_2 fraction (~70%)

Overview of gas mixtures for MM:

$Ne\text{-}C_2H_6\text{-}CF_4$ 80-10-10 (COMPASS)

Garfiels simulation



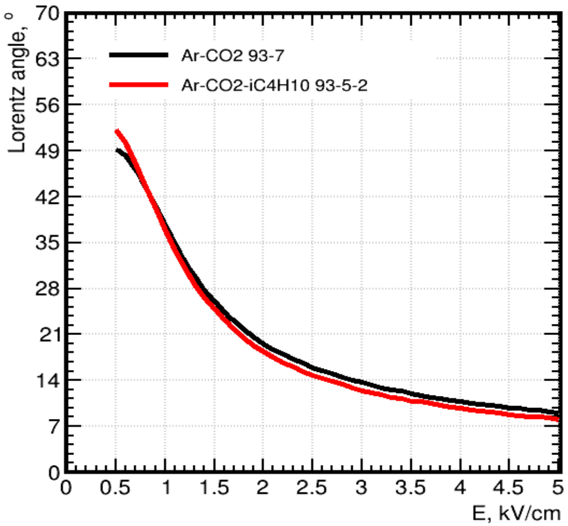


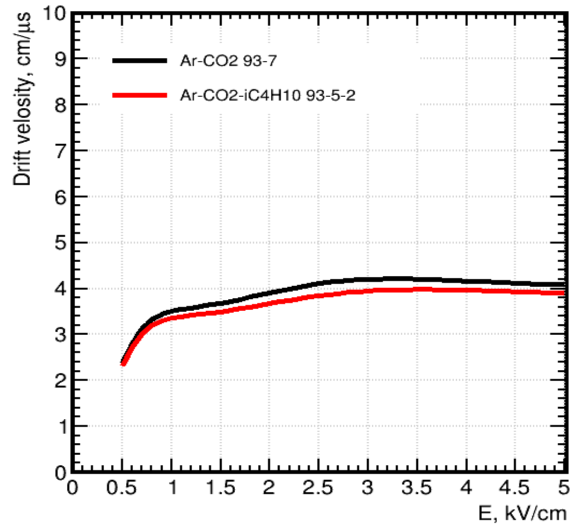
- \+ Low discharge rate
- \- Very high θ_L for “standard” working point
- \- Low primary ionisation

Overview of gas mixtures for MM:

$Ar\text{-}CO_2(7\%)$, $ArCO_2(5\%)iC_4H_{10}(2\%)$. ATLAS, NA64

Garfiels simulation



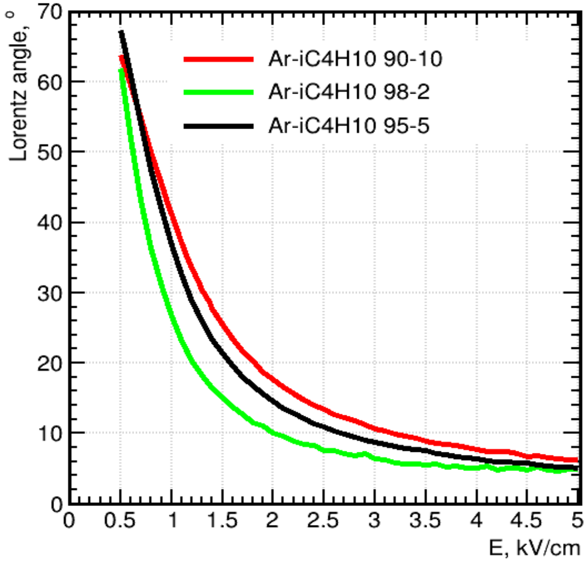


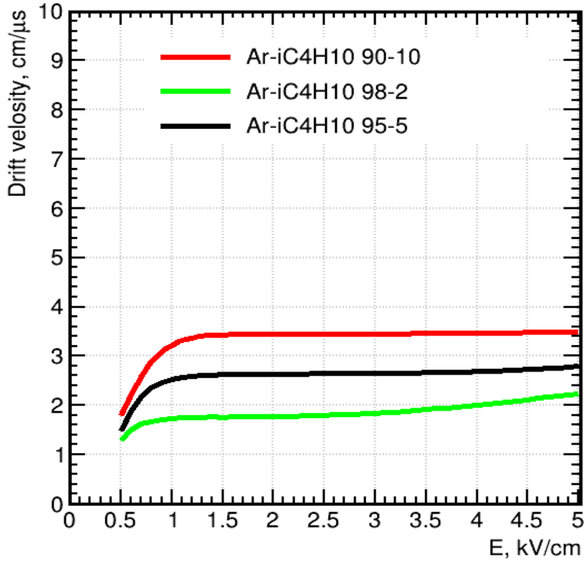
- Problem with high-voltage stability for ArCO2(7%)
- High θ_L, $E_{drift} \cong 3\ kV/cm$ is needed to have reasonable θ_L

Overview of gas mixtures for MM:

Ar-iC_4H_{10} 90-10% (CLAS12)

Garfiels simulation





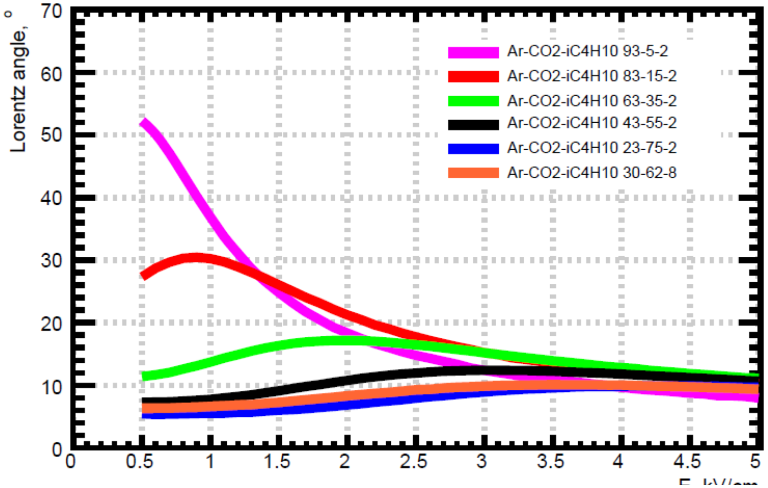
- 8 kV/cm drift field is used by CLAS12 to reduce θ_L to acceptable value by the cost of ~40% amplitude lost.
- Stable operation at $G>10^4$
- For B=1T and E_{drift}=3 kV/cm θ_L~11°
- Flamable

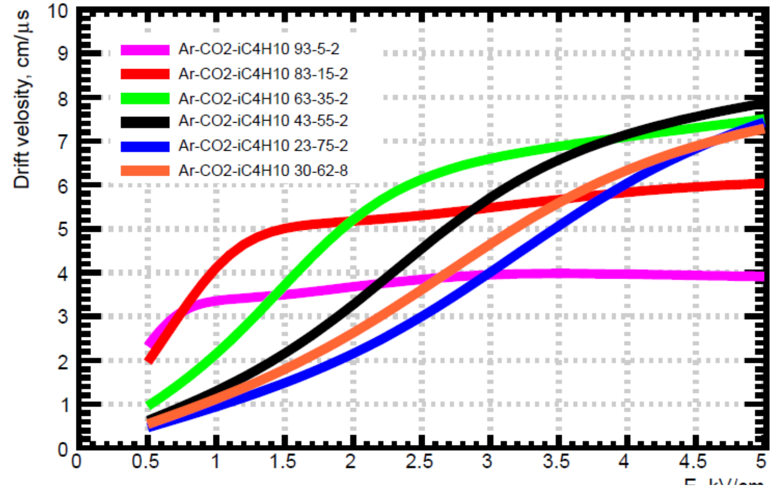
- Good and reliable candidate

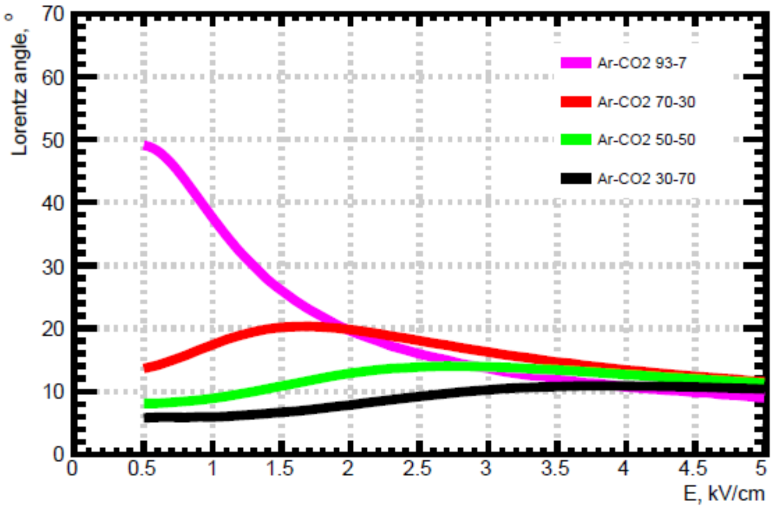
Overview of gas mixtures for MM:

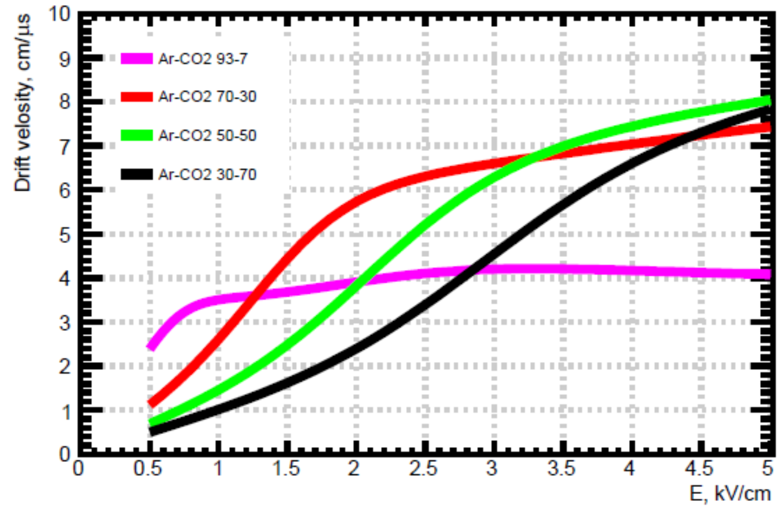
Ar-CO_2 and Ar-CO_2-iC_4H_{10} with high CO_2 fraction (~70%)

Garfiels simulation



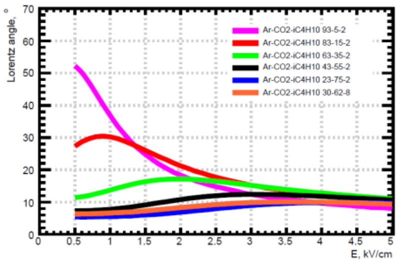


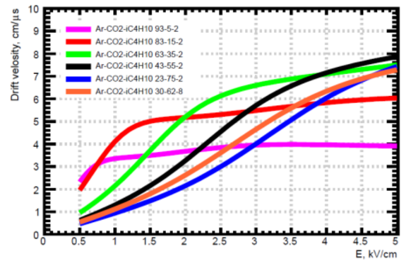


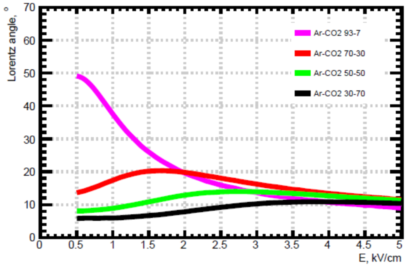


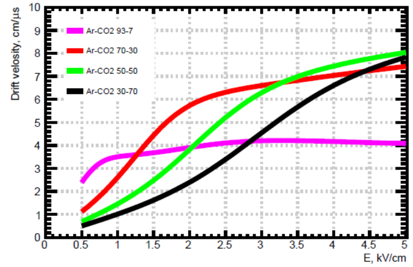
Overview of gas mixtures for MM:

Ar-CO_2 and Ar-CO_2-iC_4H_{10} with high CO_2 fraction (~70%)









- Very low Lorentz angle
- Slow in weak field. E_{drift} 2-2.5 kV/cm is needed ho have ~100 ns maximum electron drift time
- Was never used for MM. maximum achievable gain must be checked

Experimental study of Ar-CO2 mixtures with high CO2 fraction

- Ar-CO_2 mixtures with CO_2 fraction 30%, 50%, 70 % and Ar-CO2-iC_4H10(91%-7%-2%) was tested

- Gas gain vs amplification voltage and charge collection efficiency vs drift field dependencies were measured

- Signal length was estimated

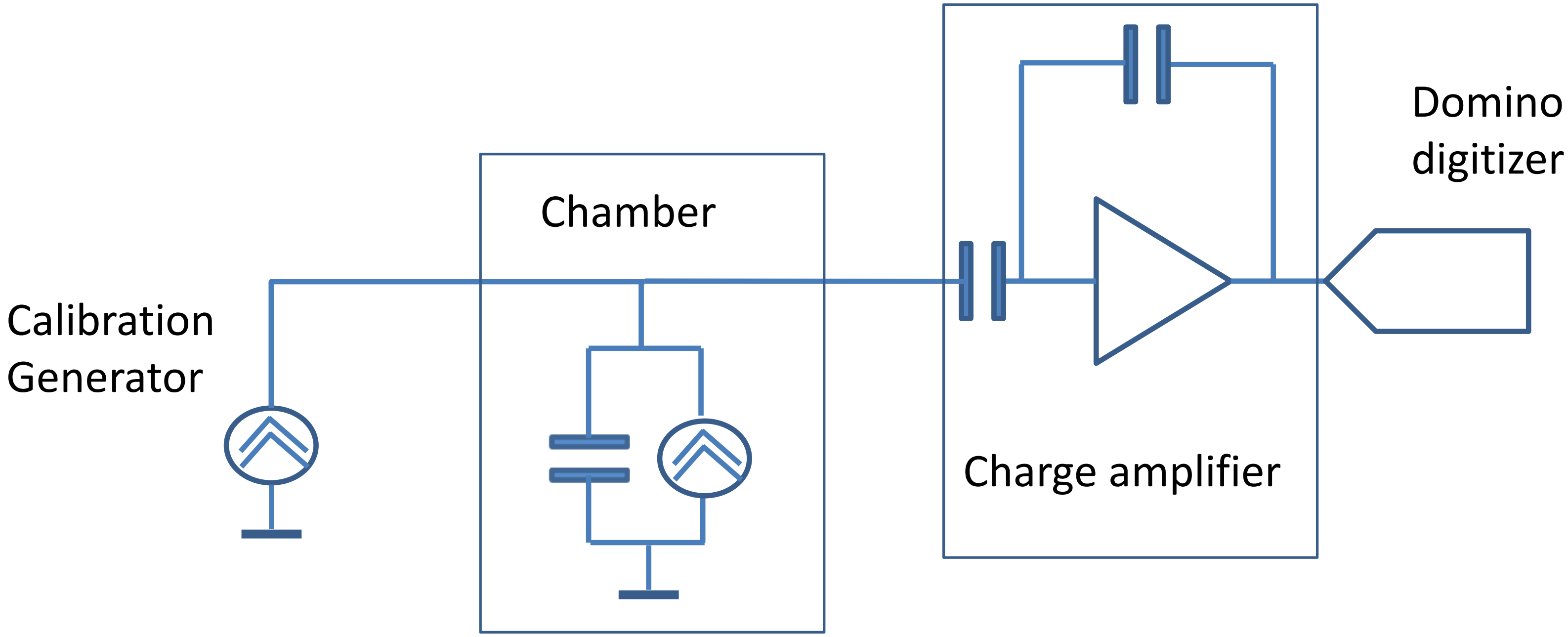
Experimental setup

- MM prototype with DLC resistive layer
  - 10x10 cm^2 active area
  - 128um amplification gap , 5 mm drift gap
  - All strips connected to single charge amplifier

- Charge amplifier, 7ns front, 100 us decay time (an ideal integrator for our conditions)

- Output signal was digitized with DOMINO digitizer, sampling rate 0.7 GS/sec , 1024 point/event . Signal shape was analyzed to extract amplitude and time information.

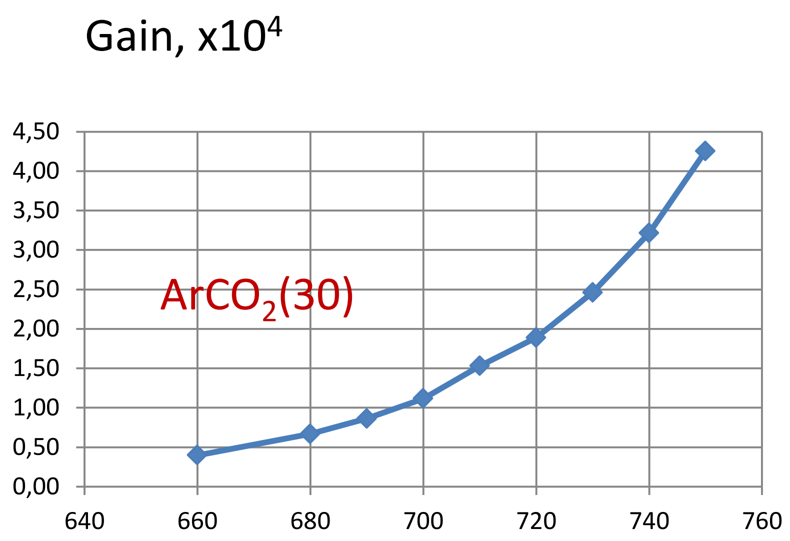
Experimental Setup

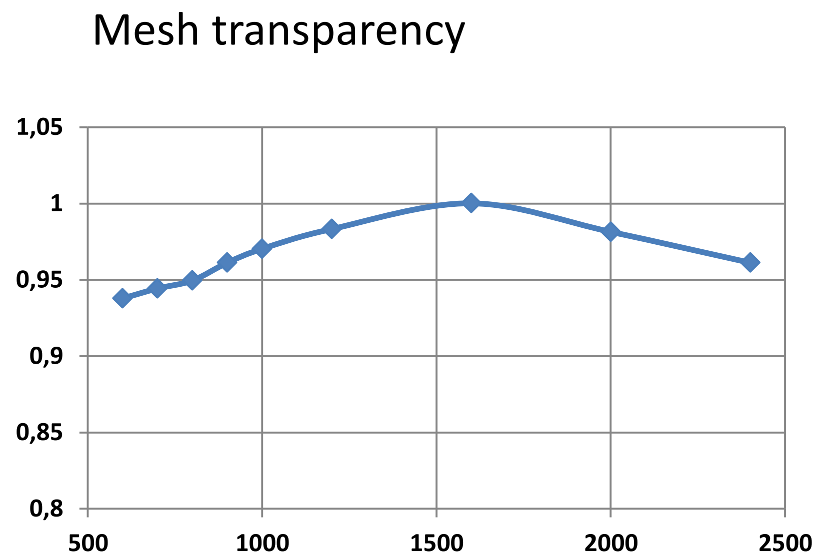


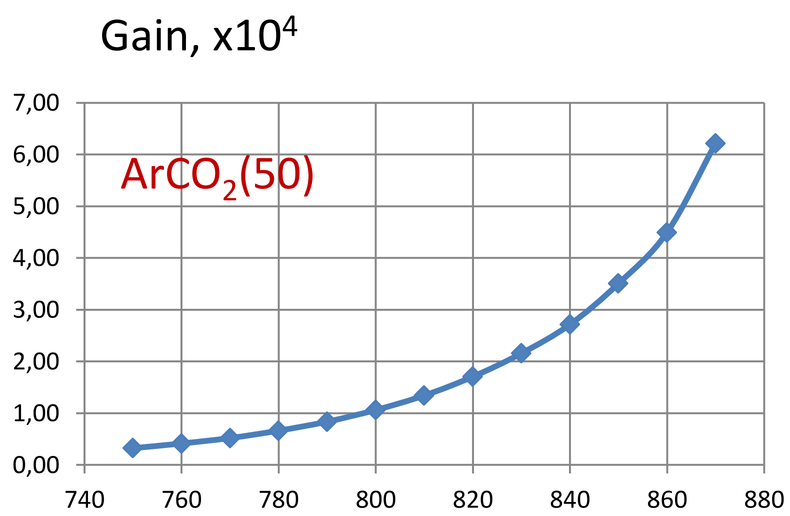
- Full amplitude with Fe^{55} source (known primary ionization) was used to measure $G \times \varepsilon$ for set of amplification and drift voltages

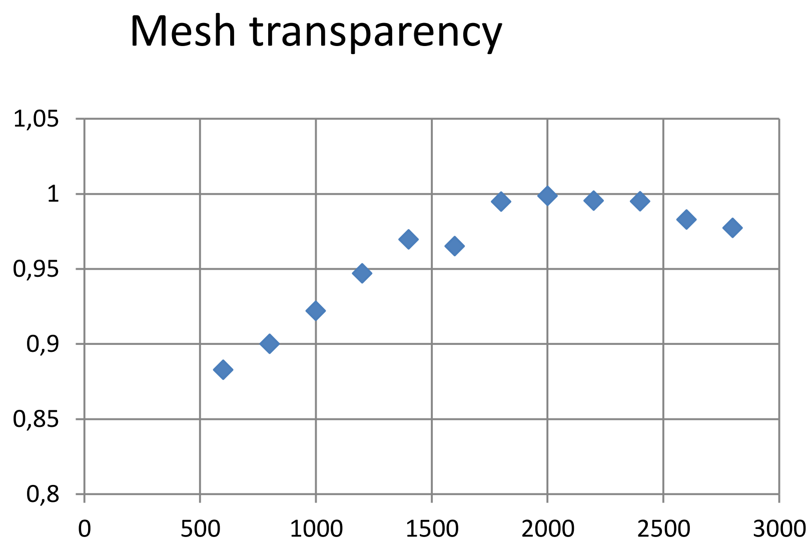
- Front of output signal is an integral of raw signal from MM => front length was used to estimate signal length for single primary cluster (Fe55 source) and MIP-like event (with cosmic trigger)

Gas gain and mesh transparency

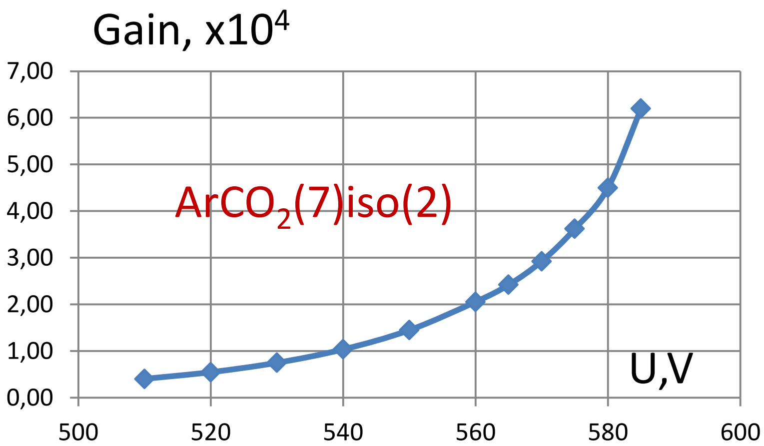


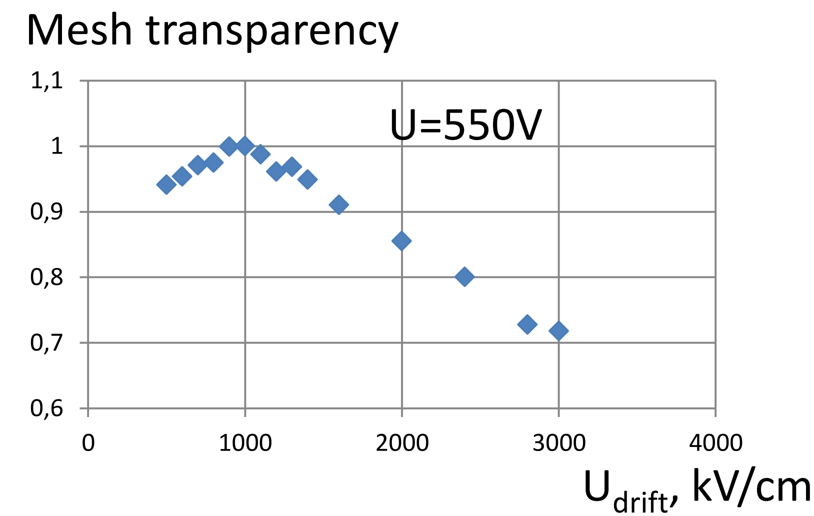


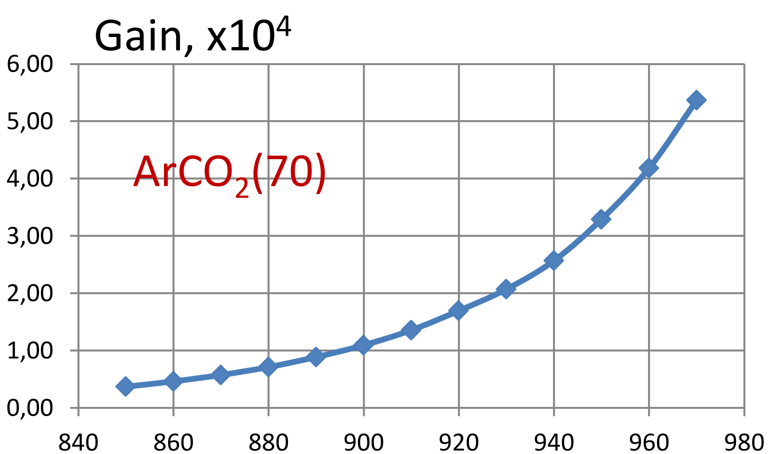


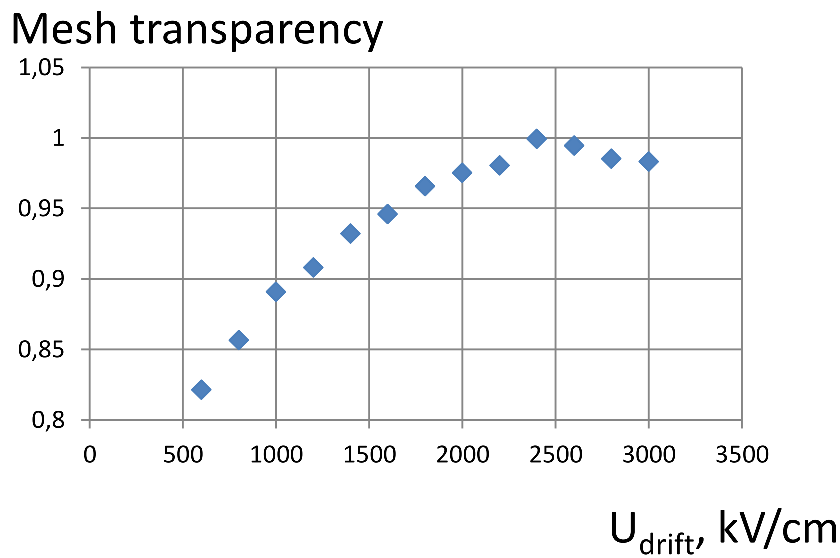


Gas gain and mesh transparency





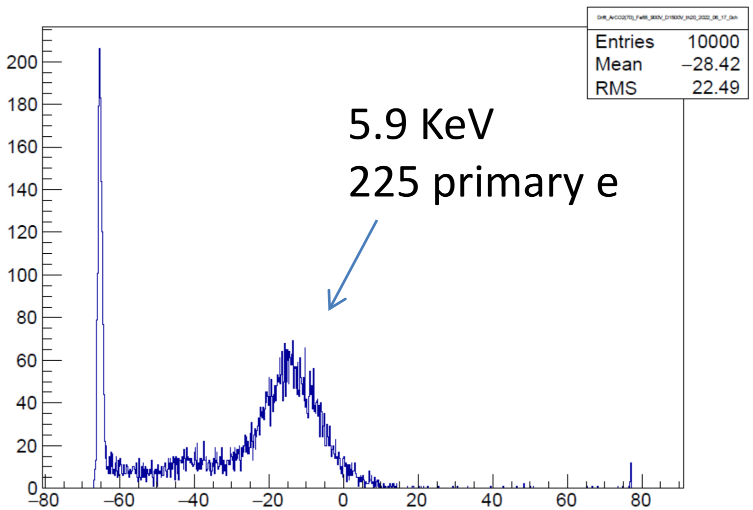


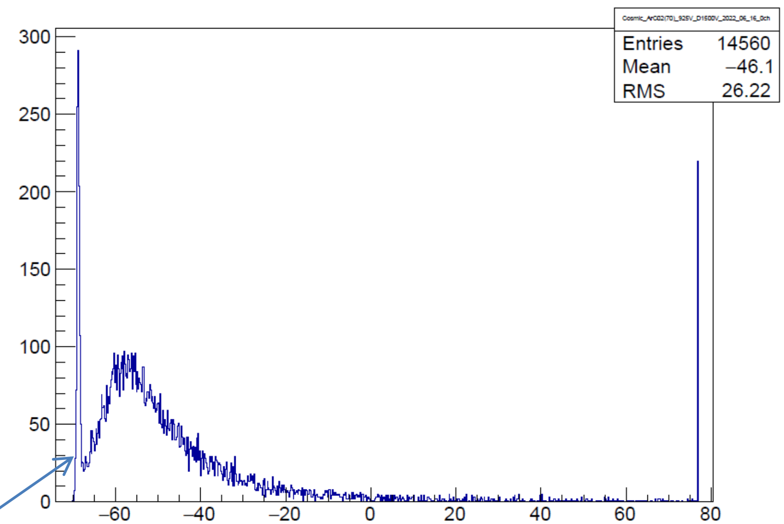


Amplitude measurement

Fe ^{55} , self-triggering
$ArCO_2(70)$
Uampl=900V
Edrift= 3 kV/cm

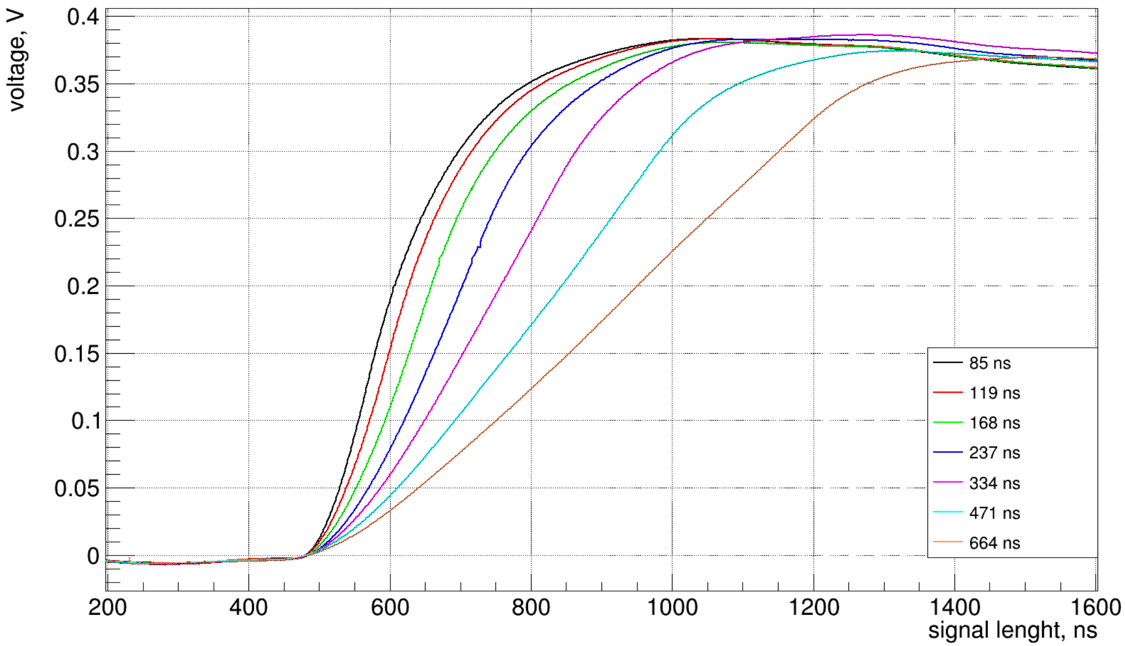
Cosmic, external trigger
$ArCO_2(70)$
Uampl=925V
Edrift= 3 kV/cm





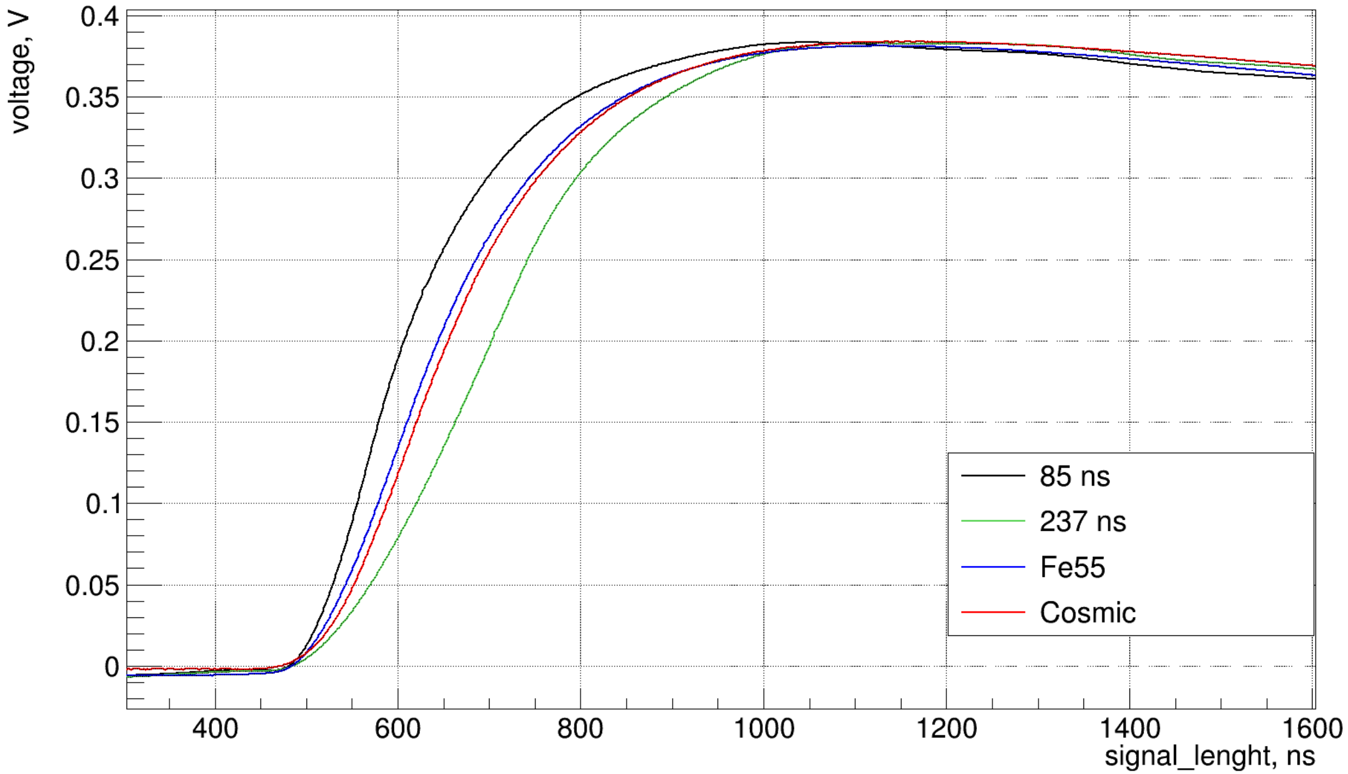
Internal amplifier noise is ~8000 e due to high detector capacitance

Time measurement : calibration



- With chamber connected due to high detector capacity (C~1nf) and non-zero amplifier input impedance system have additional transition time ~100ns
- For measurements averaged detector signal was compared with calibration signal

MM signal length measurement



- Red: averaged signal (~50000 events) for Cosmic run with ArCO2(70%) gas. U=925V, G~1.8×10^4, Edrift=3kV/cm
- Blue :averaged signal for Fe^{55} run (single cluster signal) U=900V
- Response to 85ns(black) and 237 ns(green) is given for comparisson.
- Estimated signal length is within 200 ns

Signal length: calculations and measurements

Gas	U_{ampl}	E_{drift}, V/cm	τ_{1e} Calc., ns	τ_{drift} Calc., ns	τ_{MIP} Meas., ns	Lorentz Angle
Ar-CO_2(7%)-iC_4H_{10}(2%)	550	800(3000)	~160	140	<200	35(13)
Ar-CO_2(30%)	740	2400	140	82	<200	18
Ar-CO_2(50%)	830	2800	141	83	<200	14
Ar-CO_2(70%)	925	3000(2500)	142	113	<200	11(<10)

- Electron drift time is based on GARFIELD v_{drift} data
- Ion mobility is calculated using Blanc’s Law and data for pure argon and carbon dioxide
- CO_2 is much slower then argon, but higher working voltage compensate it

Results

- Ar-CO_2 and Ar-CO_2-iC_4H_{10}(2%) gas mixtures with high CO_2 fraction look very promising as MM working gas. It combine good HV stability (in this particular case ☹) , good timings and very low Lorentz angle

- Clear downback is very high working voltage, what may cause surface discharge

- We believe, operation with low Lorentz angle (special mixture + high drift field) is more realistic then “standard” setting and μ-TPC mode

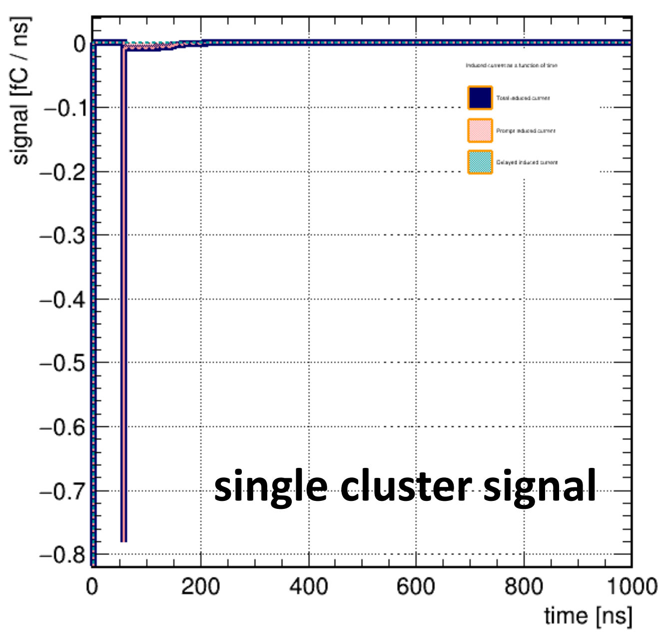
Gas test:
Problems and future plans

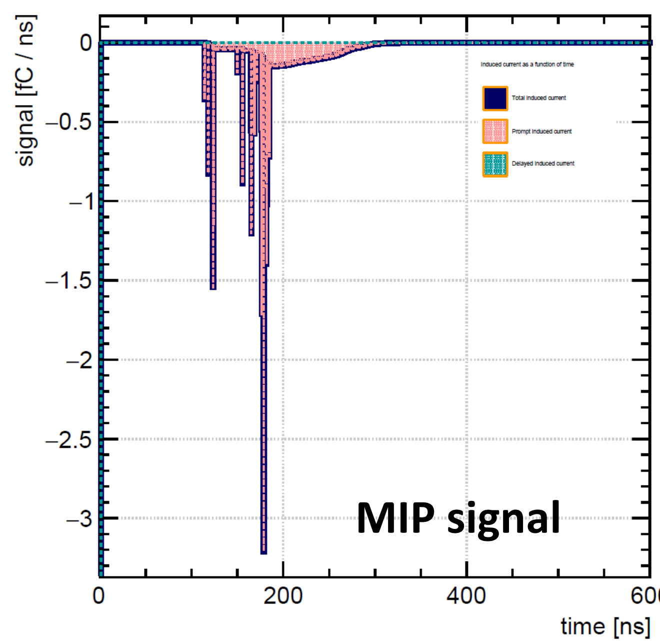
- Prototype was damaged during intervention, and can not be used for further tests

- New pre-mixed Ar-CO_2-iC_4H_{10} gases is delivered, test will be continued with new chamber.

Signal simulation

- Simplified MM description in Garfield is ready (mesh as a row of wires, no resistive layers), signal simulation is available

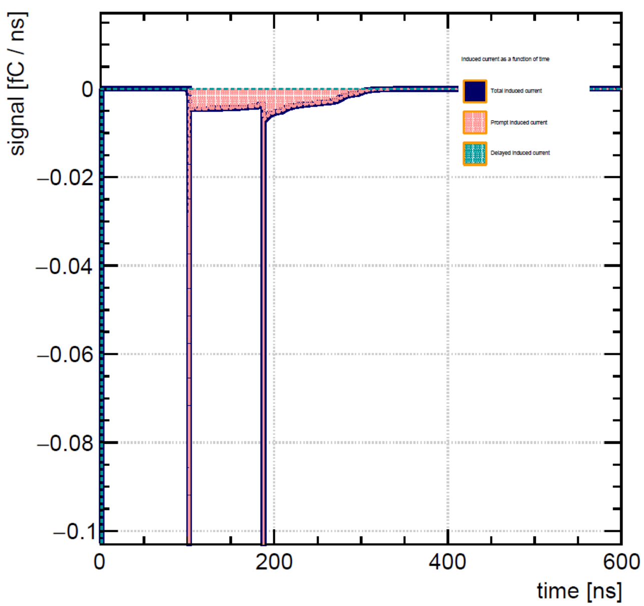




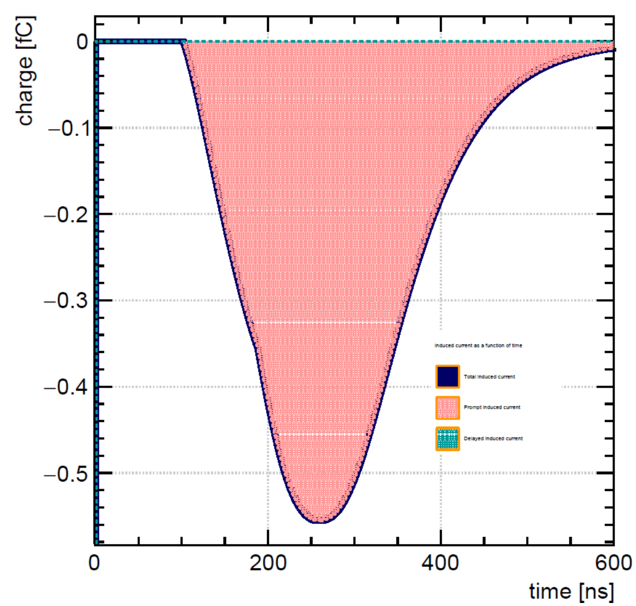
Ion component provide ~88% of total signal

Signal simulation:
Charge collection vs shaping time

- Charge collection efficiency was studied for two cases:
  - 1 cluster(best possible variant)
  - 2 cluster, 1st was placed near cathode, 2d near mesh (worst possible case)



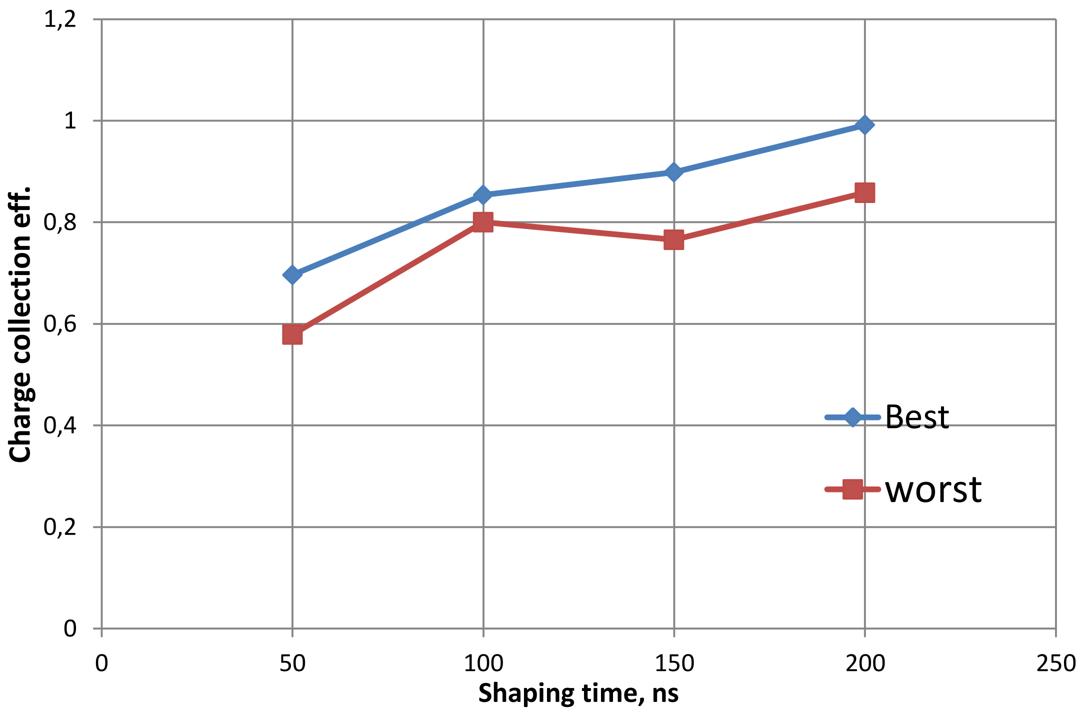
Raw 2-custer signal



2-custer signal convoluted with amplifier transfer function

Signal simulation:
Charge collection vs shaping time

- Charge collection efficiency was studied for two cases:
  - 1 cluster(best possible variant)
  - 2 cluster, 1st was placed near cathode, 2d near mesh (worst possible case)
- 1st order unipolar shaper



Signal simulation:
next steps

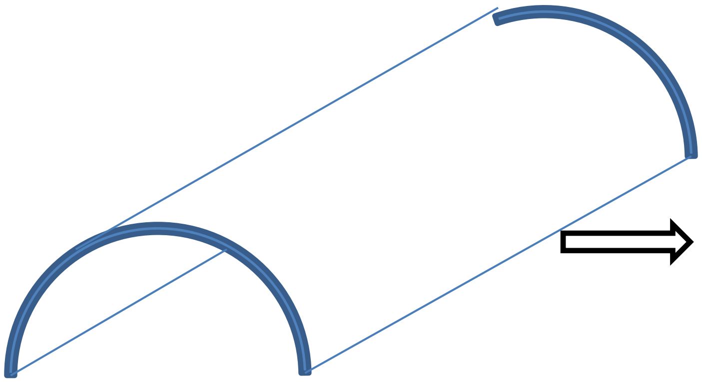
- Signal simulation with realistic transfer function
- Add resistive layer to simulation for correct charge smearing
- Study space resolution vs strip pitch

Mechanical prototype

- We are forced to develop assembling procedure from scratch, and we plan to glue several simple mechanical prototype to check procedure variants and find hidden traps …
- 1st mechanical prototype was glued in September (raw FR4, no strips, no mesh, commercial carbon fiber longbeams, 3D-printer end-face arcs) and tested for geometry

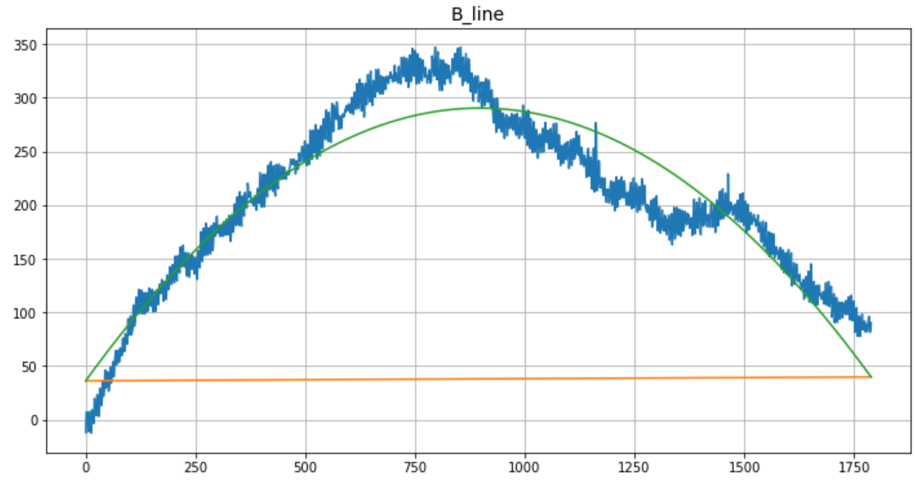
Mechanical prototype

Geometry check: “readout”(inner) plane



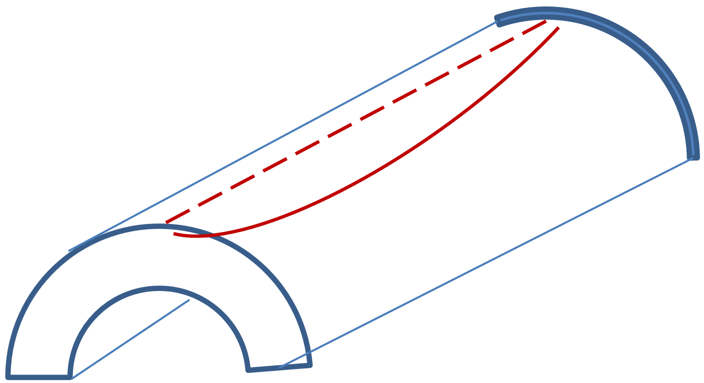
[“Barrel-like”] Deformation due to limited longbeam regidity

Maximum deformation is about 300μ. Acceptable

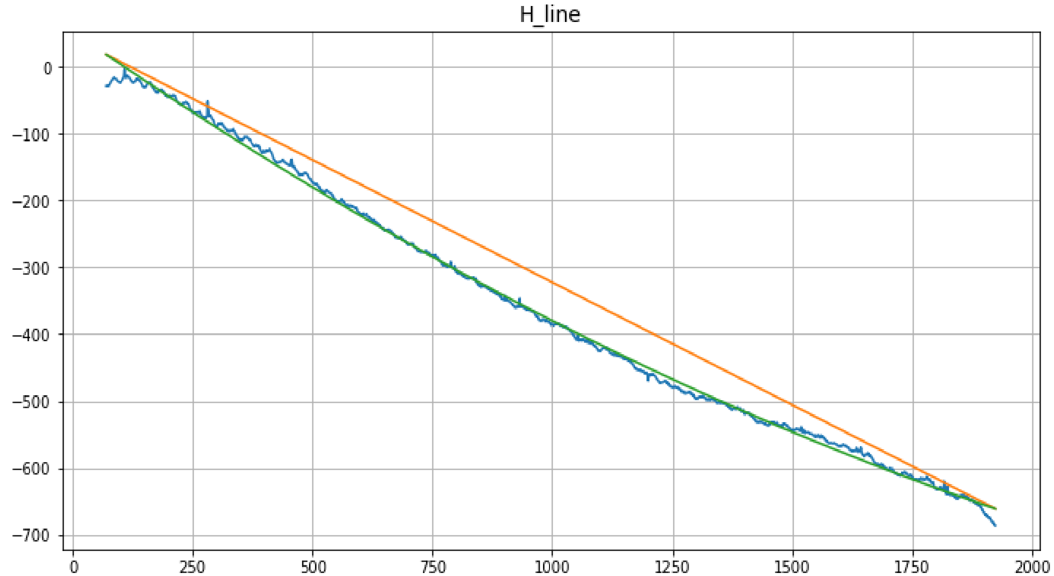


Mechanical prototype

Geometry check: “cathode”(outer) plane



Saddle-like deformation of top line (affect drift gap) ~ 100 μ



Maximum variations of drift gap <200μ, equivalent to 7.5% variation of drift field. Acceptable

Mechanical prototype
Next step:

- Several more step 0 prototype with different material (FR4, kapton)

- Prototypes with mesh stretched

- “minimal functionality” prototype with simple but working RO pcb

MCT status : problem

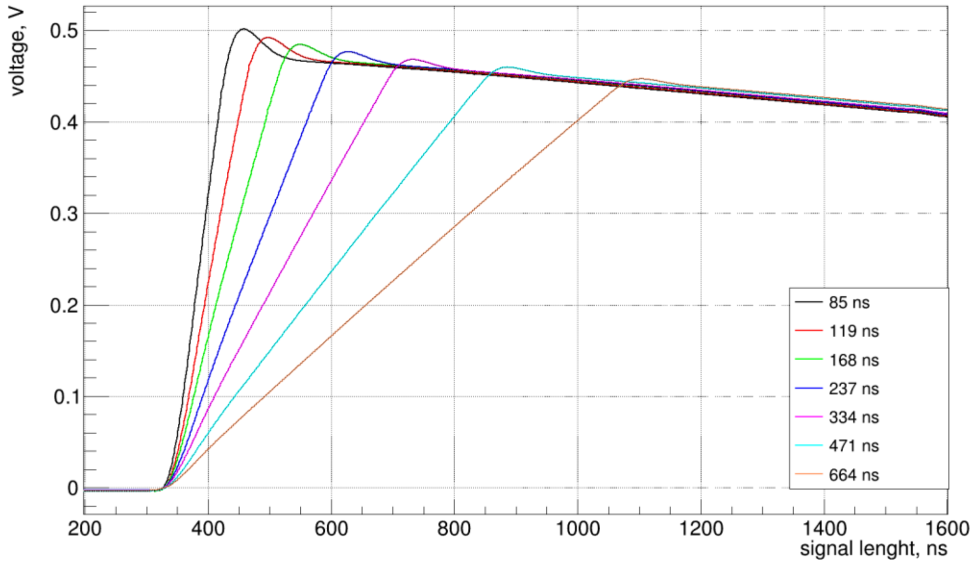
- **This moment we can’t order proper mesh**

MCT : Summary

- We are forced to develop detector and assembling procedure almost from scratch
- Test program is started, fist results is obtained
- The main problem is availability of raw material

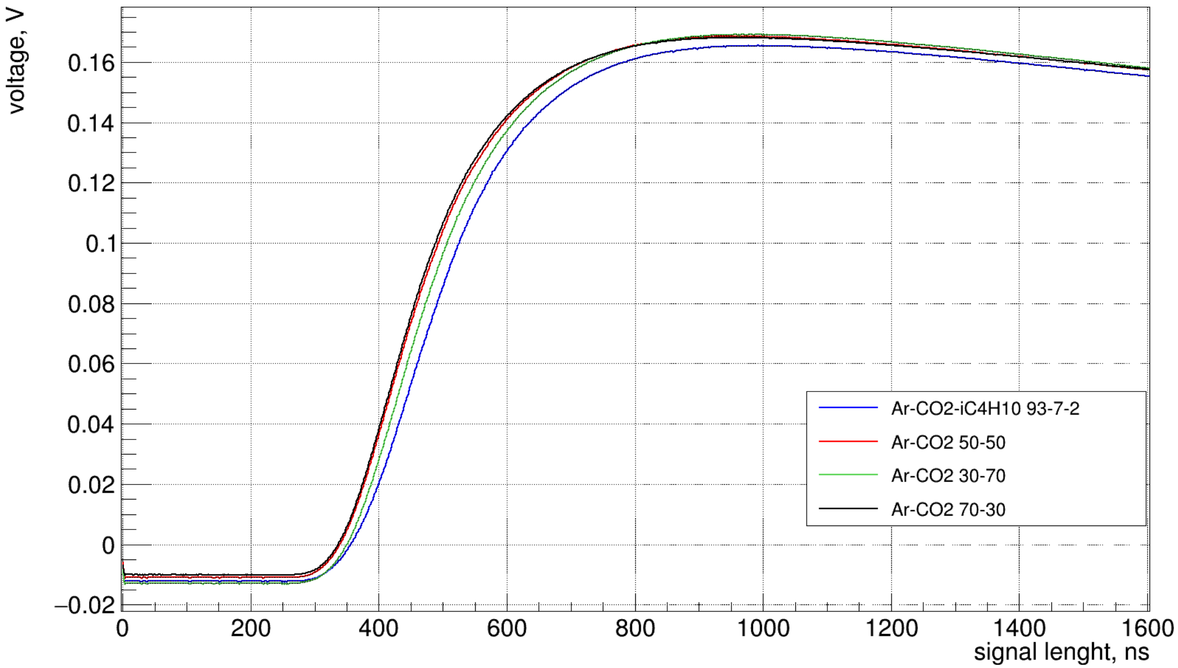
BACKUP SLIDES

Time measurement : calibration



- Rectangular signal of different length was sent to amplifier input. Input signal length vary from 60 ns to 664 ns; total charge was Q=350fQ in all case
- Single-cluster signal from MM is very close to rectangular shape due to uniform field in amplification gap

MM signal length measurement



- Comparison of MIP-like averaged signal for different gas mixtures