New Developments with Microbulk Micromegas. Charge and Light Readout.

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OUTLINE

- Motivation
  - Microbulks for ββ0ν (and rare events) searches in a HP gas TPC
  - Relationship between them and the work presented here

1. MicroMegas with small gap
   - Gain and Energy Resolution Results
   - Outlook
2. New Concept: Charge and Light Amplification.

   → Using MicroMegas with deposit of CsI

   - First tests
   - First results measuring electroluminescence with microbulks
   - Outlook

Motivation

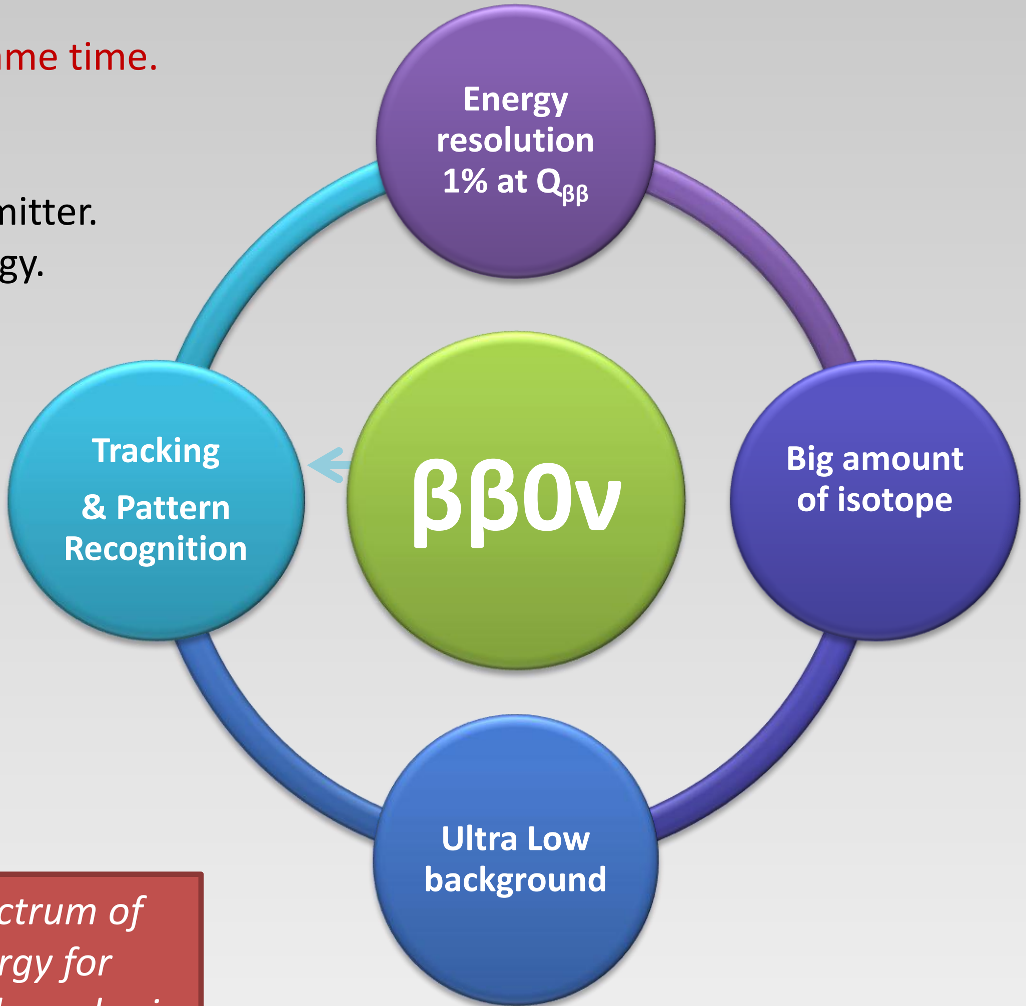
ββ0ν searches: from the experiments of oscillations we know that neutrinos (ν) have finite mass. But there are still open questions about them:

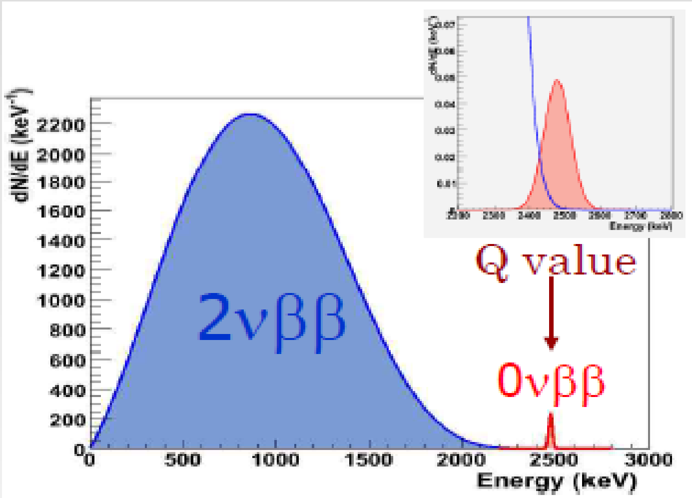
- ❑ Neutrino mass scale.
- ❑ Their nature. Dirac or Majorana.

  → ββ0ν can answer both questions at the same time.

Experimental Challenge

- Big amount of Mass: 100kg – 1 Ton of ββ emmitter.
- Excellent Energy Resolution ≈ **1%** at $Q_{\beta\beta}$ energy.
- Very Low Background. 10^{-4} c/keV/kg/y
  - Radiopure Materials.
  - Shielding.
  - Pattern Recognition.





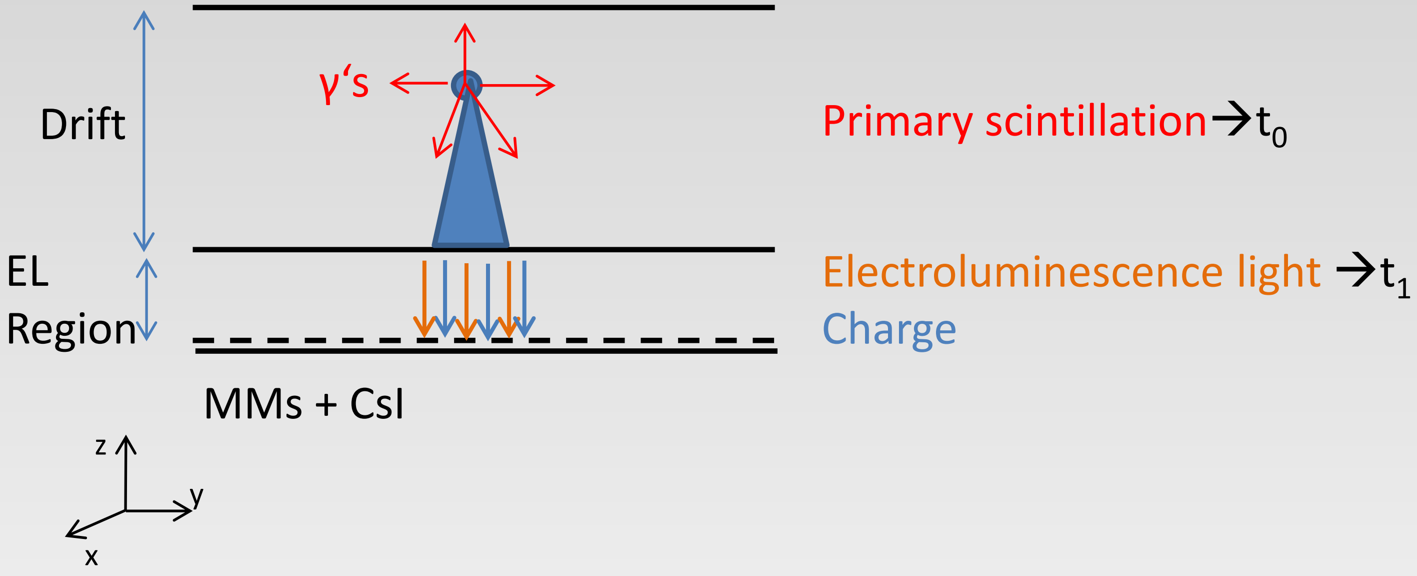
Spectrum of Energy for both modes in Xe-136.

Motivation

HP gas TPC

- We can go to higher masses of isotope
- Ionization/scintillation capabilities
- Tracking capabilities in gas
- Not only ββ0ν but also in DM experiments
- **Study of small gap Micromegas: they have better Energy Resolution at higher pressures**
- **New concept → MMs with CsI on mesh: Scintillation light will give us t_0 and also improves the gain and energy resolution of the microbulks**

Scintillation and t_0



$$z \propto t_0 - t_1$$

Motivation

HP gas TPC

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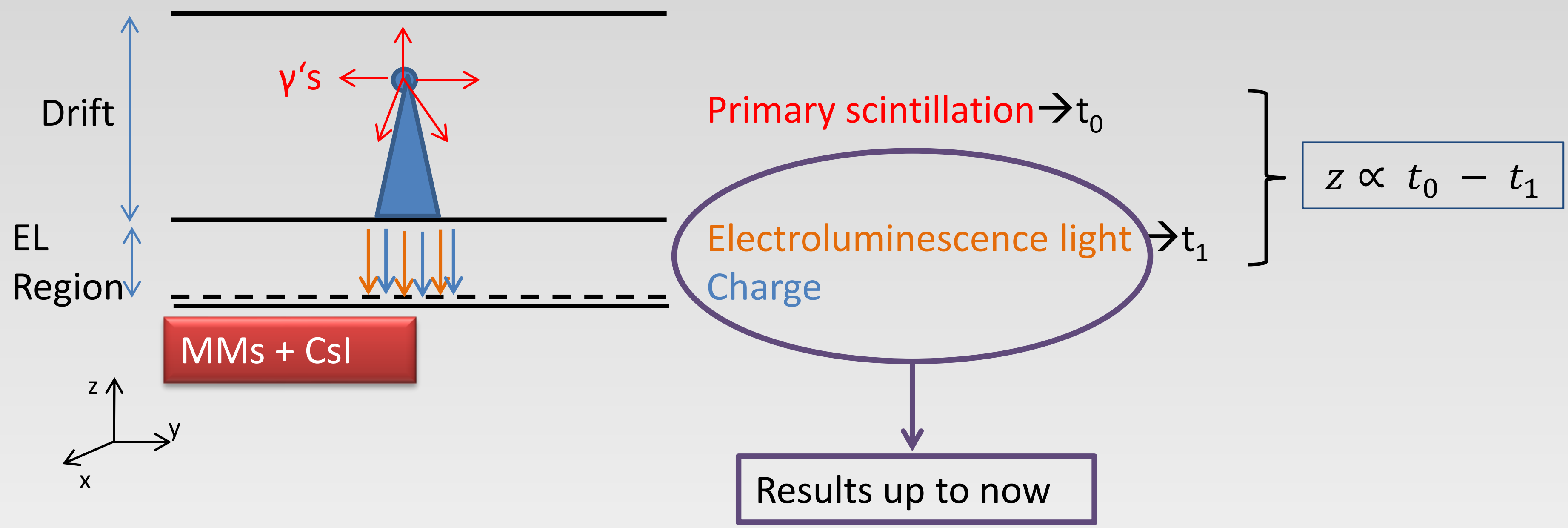
Scintillation and t_0

Old Concept: Electroluminescence
New technology: Microbulks + CsI



Motivation

STUDIES

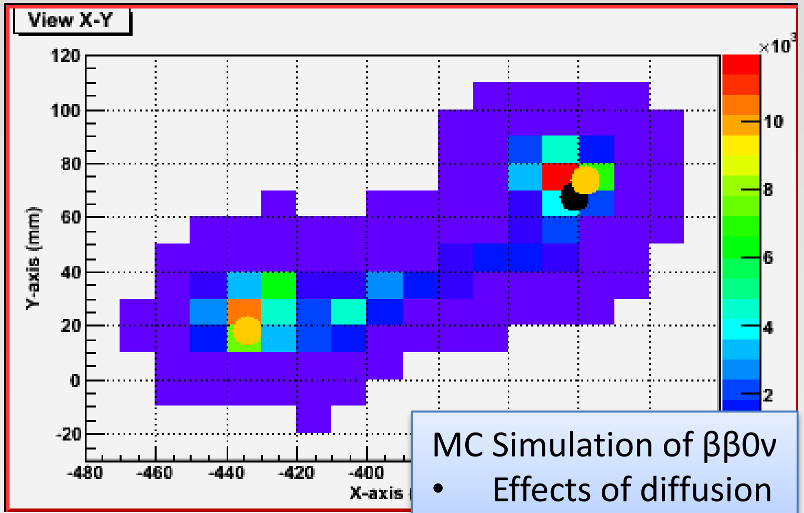
- **Unizar**
  - **Testing different Xe-mixtures**
  - **Testing Microbulks at High pressure Xe**
  - **Medium size prototype to register full e- tracks**
  - **Developing background models for a complet ββ0ν experiment and discrimination algorithms**

- **Saclay more focused on microbulk micromegas developments**
    - **25 μm and 12.5 μm gap micromegas were tested**
    - **Microbulk with CsI deposit in the mesh**
  - **…but also in gas-mixtures (see F.J.Iguaz talk)**
  - **Readout and High Voltage performance (electronics. feedthroughs….)**

- **Active collaboration between both institutes**

Topology of ββ0ν signal in a High Pressure **TPC** with Xe at 10bar:

Long track with two high energy deposits at the ends.



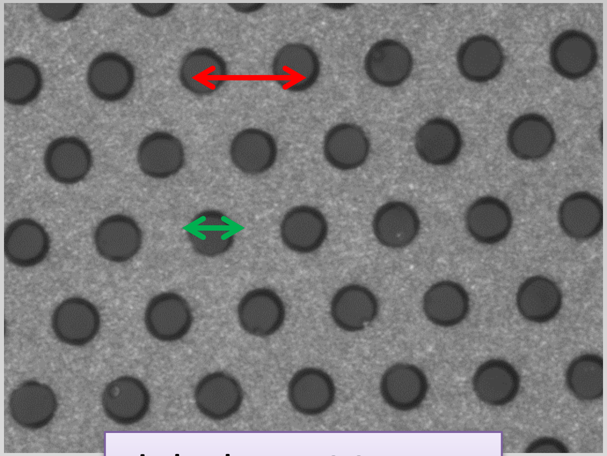
MC Simulation of ββ0ν
- Effects of diffusion and pixelization.

Microbulk Micromegas Small Gap

- Microbulk Micromegas of **25 μm** and **12.5 μm gap** were manufactured at CERN and tested in CEA/Saclay.
- With different geometries for the **holes** and **pitch**

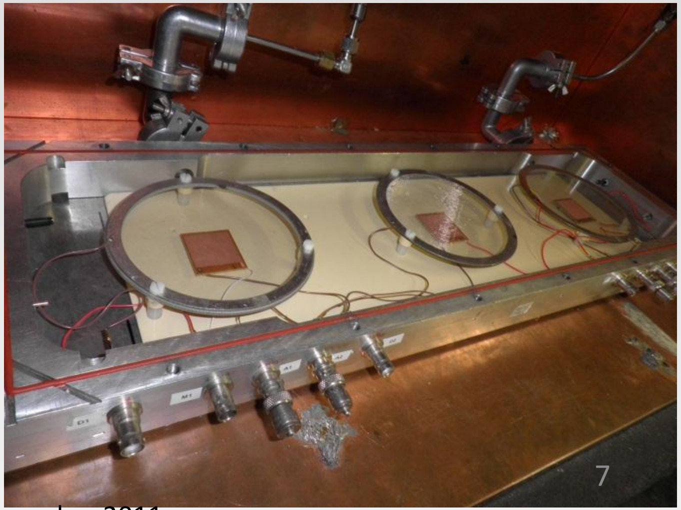
Gap	Hole	Pitch
12.5	15	50
12.5	20	65
12.5	25	80
12.5	30	100

Gap	Hole	Pitch
25	15	50
25	20	65
25	25	80
25	30	100



Φ holes = 20 μm
Pitch of 65 μm

- Tested in same setup that explained in F.J.Iguaz's talk
- P = 1 bar
- Ar-Iso 5% and 10%
- Fe-55 peak of 5.9 keV

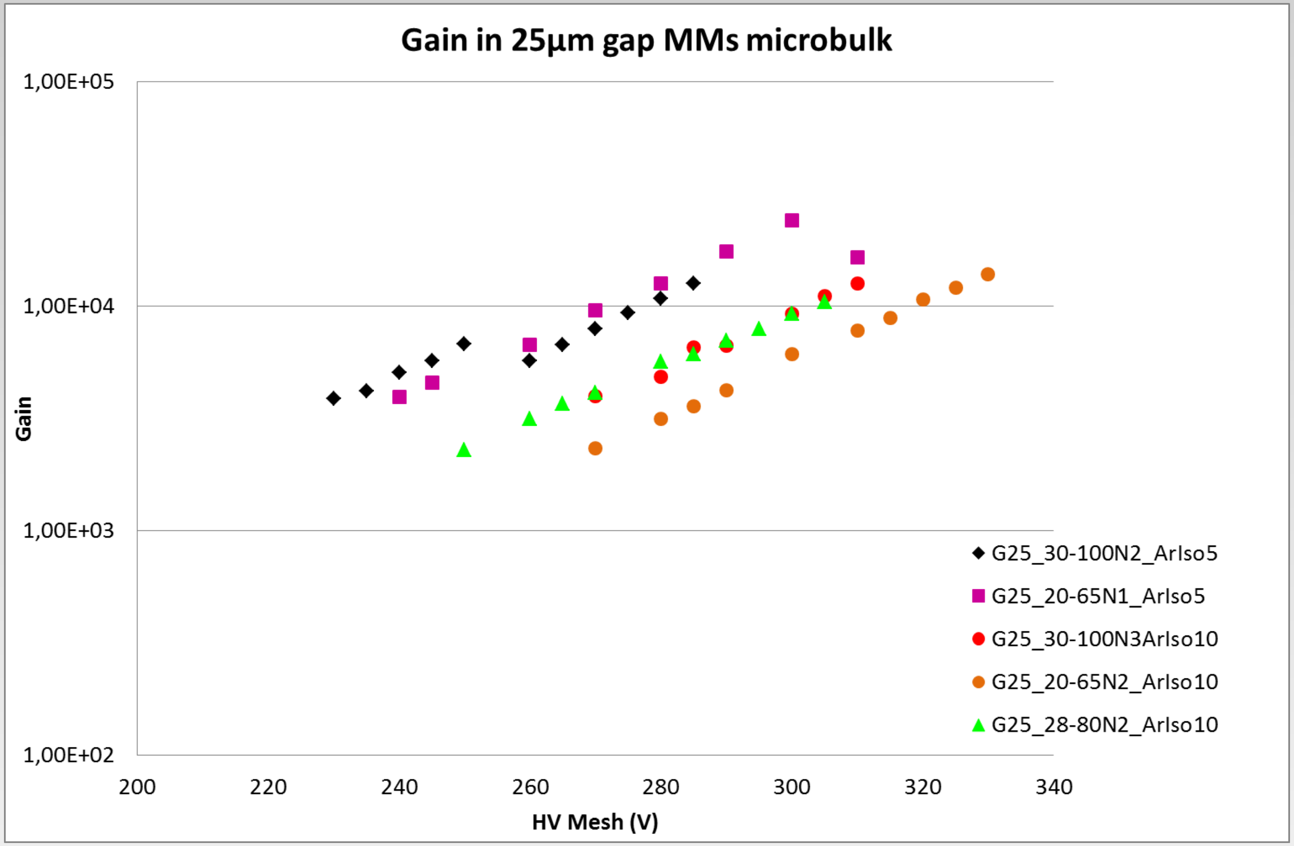


Microbulk Micromegas Small Gap → Results

25 µm gap

ArIso5%		
Geom	HV Mesh	Gain
20-65N1	300	2.41E+04
30-100N2	285	1.26E+04

ArIso10%		
Geom	HV Mesh	Gain
20-65N1	350	3.74E+04
20-65N2	330	1.39E+04
30-100N3	310	1.26E+04



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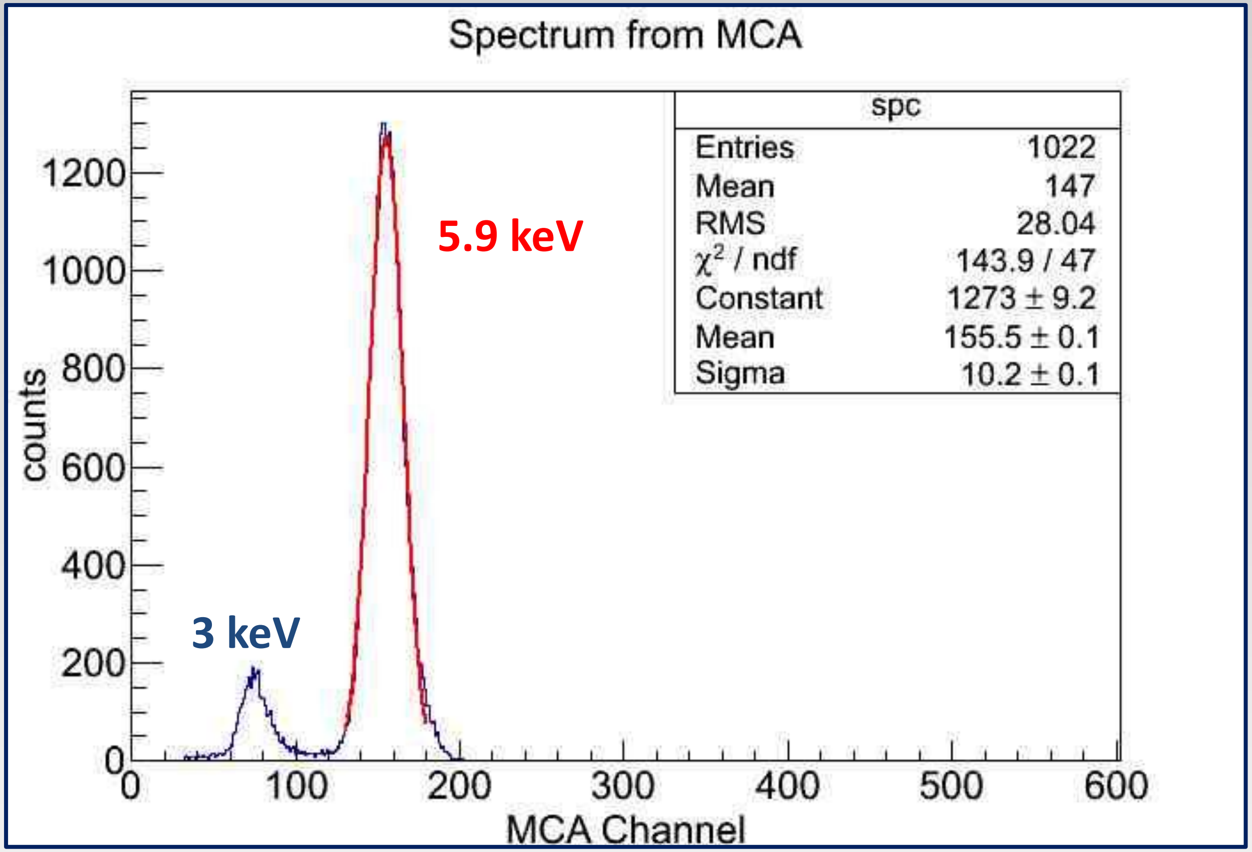


Better E Resolution achieved

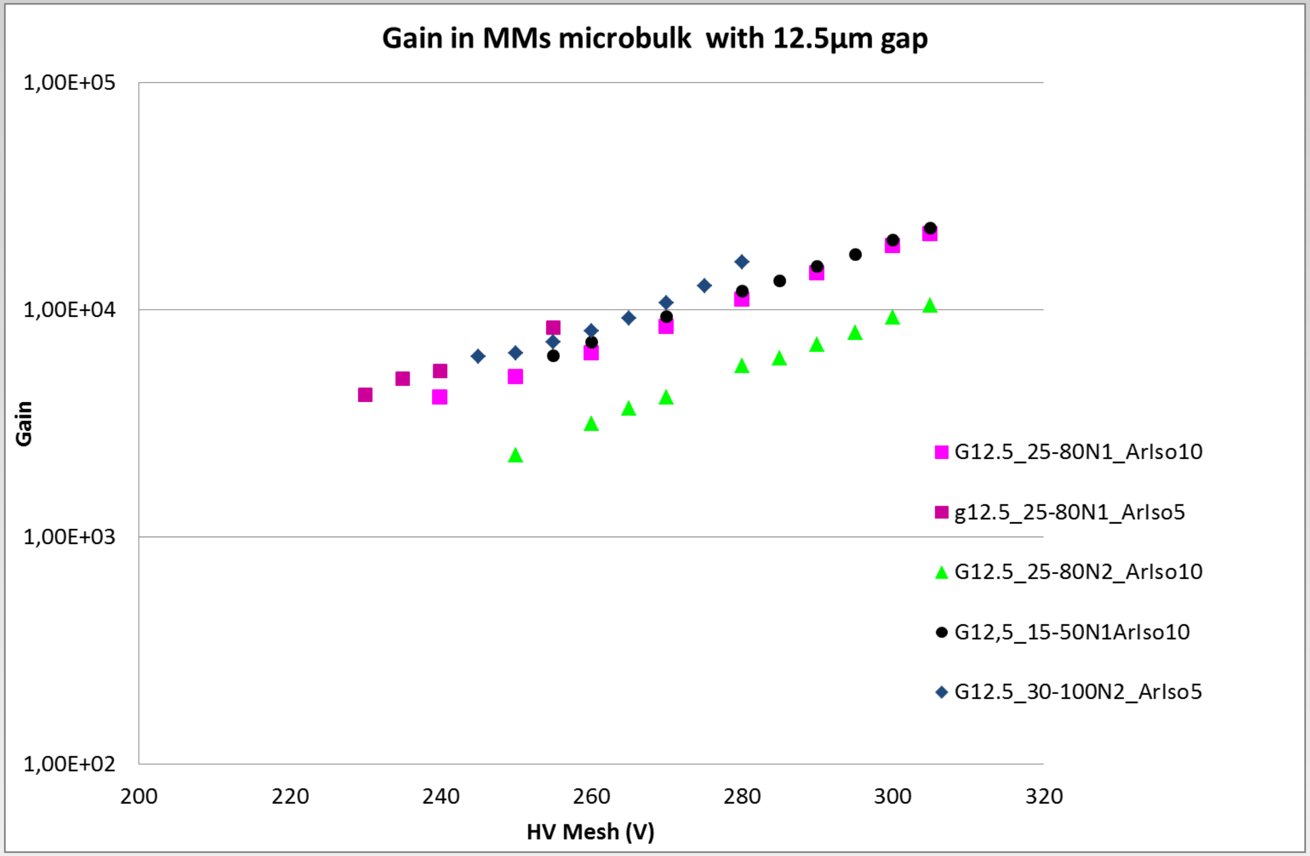
15% @ 5.9 keV in **Ar-Iso10%** with geometry 20-65

Microbulk Micromegas Small Gap → Results

12.5 µm gap

ArIso5%		
Geom	HV Mesh	Gain
25-80N1	255	8.35E+03
30-100N2	280	1.62E+04

ArIso10%		
Geom	HV Mesh	Gain
15-50N1	305	2.28E+04
25-80N1	305	2.15E+04
25-80N2	305	1.04E+04
30-100N2	325	3.46E+04



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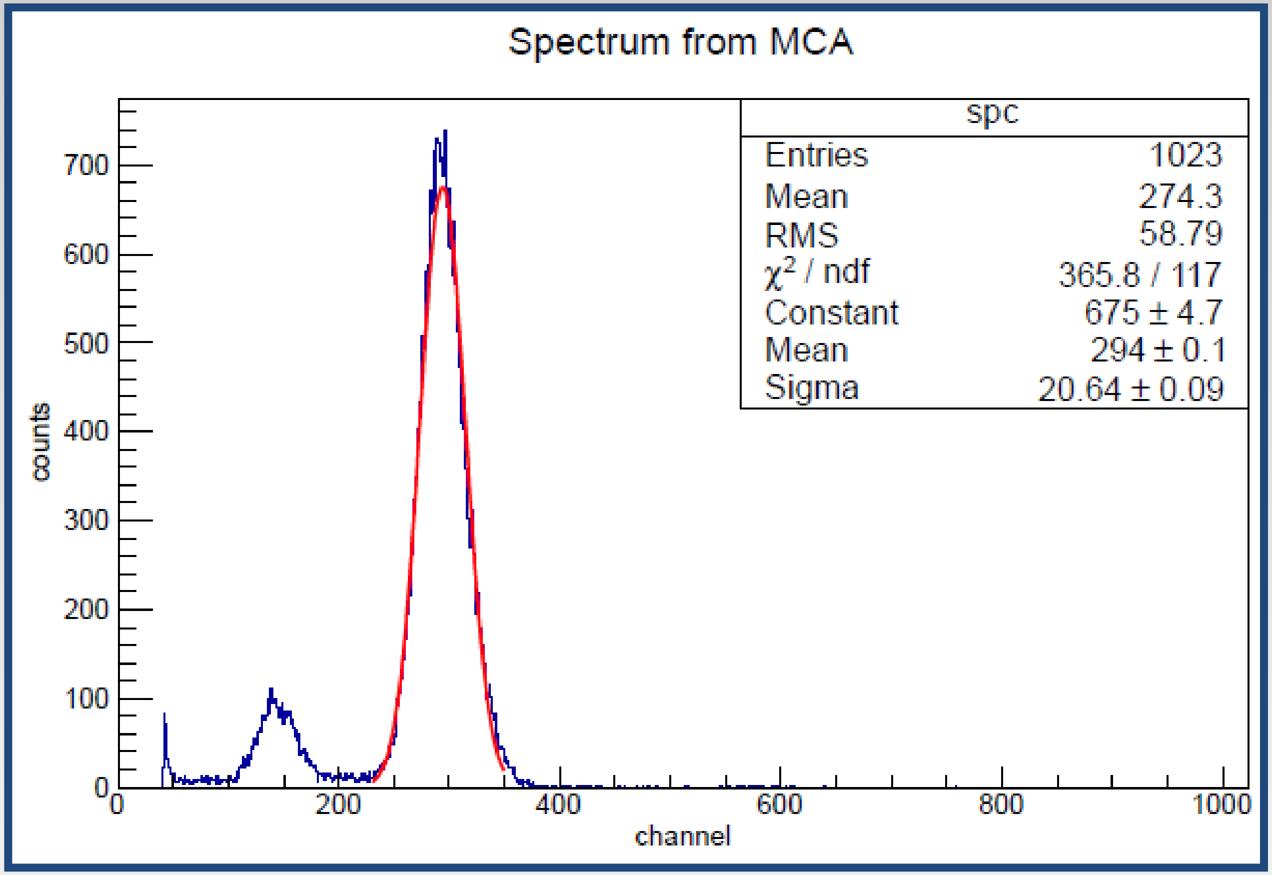


Better E Resolution achieved

16% @ 5.9 keV in **Ar-Iso10%** with geometry 30-100

Microbulk Micromegas Small Gap → Conclusions

Conclusions

- Gains higher than 10^4 with both gaps
- The best energy resolution ~16% with both gaps in Ar-Iso 10%
- Higger gains achieved and better Energy Resolution in Ar-Iso 10%

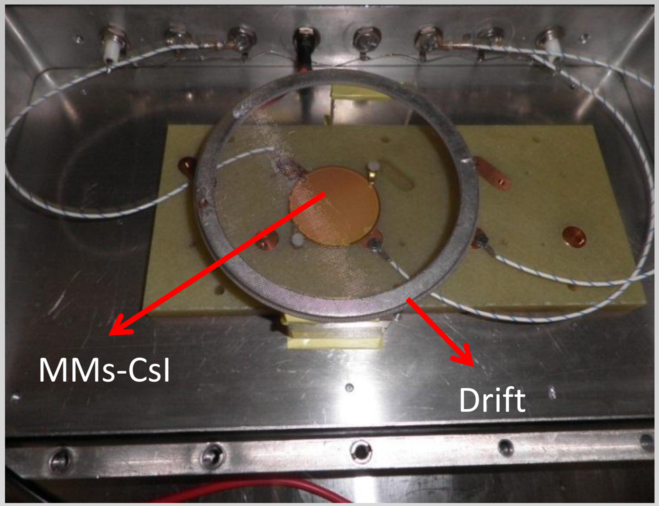
Outlook

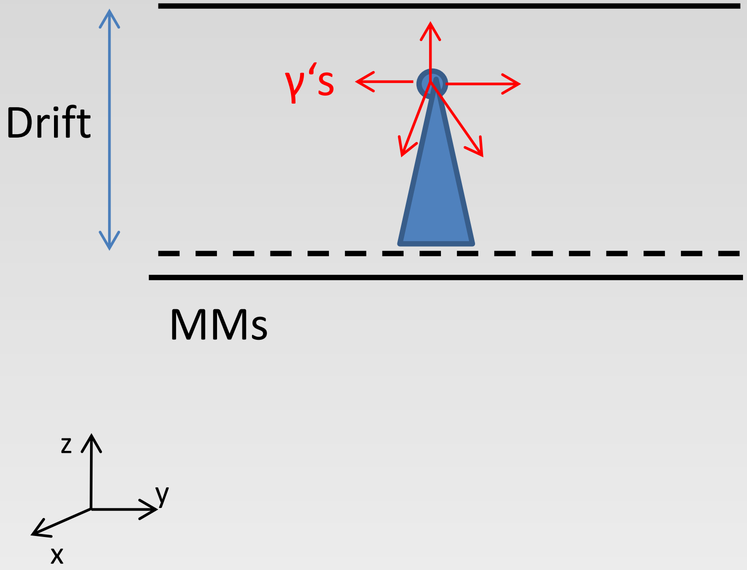
- A new bunch of micromegas with this gaps are being produced reducing some manufacturing problems observed in first bunch → better results expected
- They will be tested as soon as they will be ready
- Test them in other gas mixtures
- Also at high pressure to compare their performance

New Concept: Light and Charge Amplification →Microbulk Micromegas with CsI

Microbulk Micromegas with CsI deposit in the mesh:

- Gap 50 µm; pitch 100 µm. holes diam. 30 µm
- Deposit of CsI by thermal evaporation (CERN): 300 nm thick





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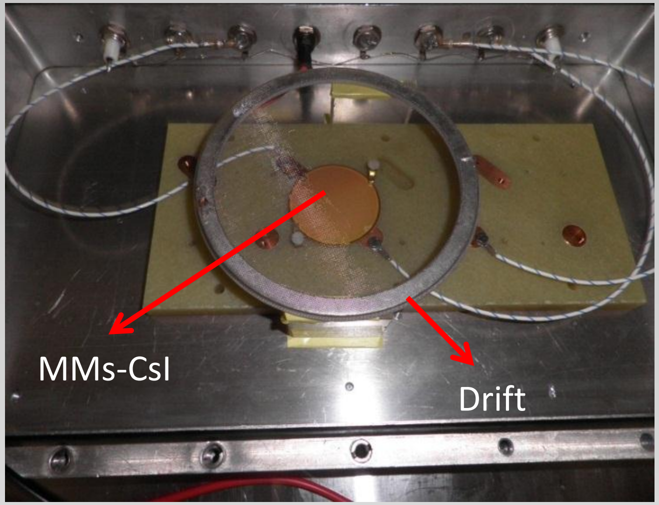
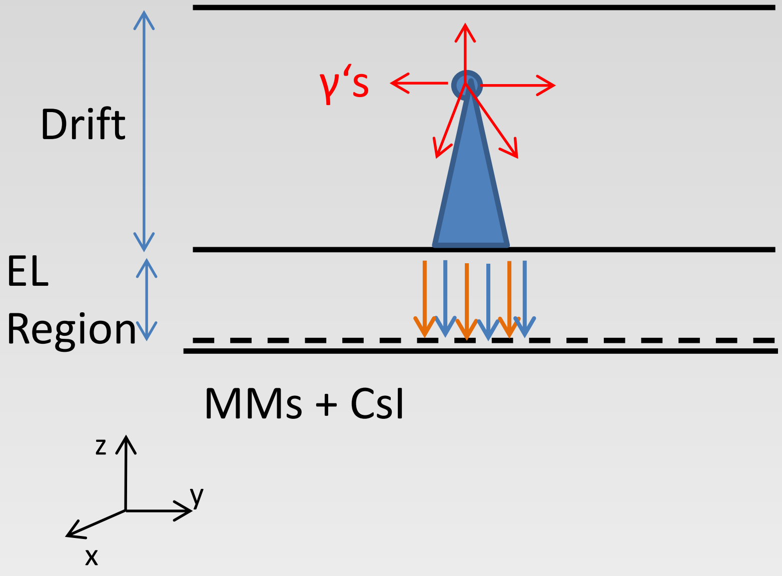




With MMs not only EL light will be detected but also charge → Higher gains observed!

Microbulk Micromegas with CsI

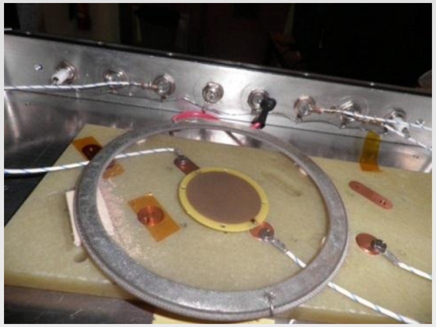
Experimental setup

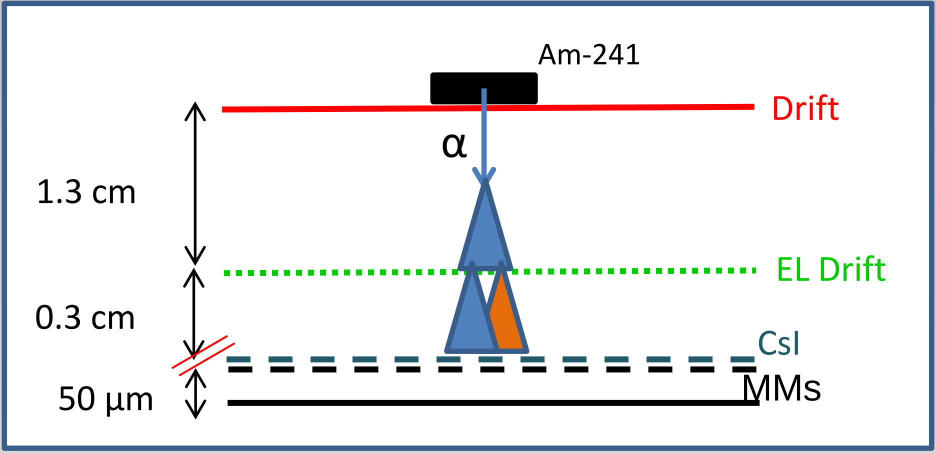
- ✓ 2 drifts
  - ✓ EL region at 0.3 cm from MMs (~ 80% transparent)
    - $\vec{E}$ up to 3.7 kV/cm
  - ✓ Drift region at 1.6 cm
    - $\vec{E}$ up to 1.2 kV/cm
- ✓ P = 1 bar
- ✓ Pure Ar

But

✗ Poor quality of gas

✗ CsI maybe damaged after few re-opens of chamber. QE decreased.





Physics of the EL light process

- α from the ^{241}Am ionize Ar atom producing e-'s
- The e- enters in the scintillation region and excite an Ar atom which emits a photon of 126 nm
- This photon produces photoelectric effect in the CsI deposit on the mesh and the resulting e- enters through the mesh → avalanche → signal recorded.

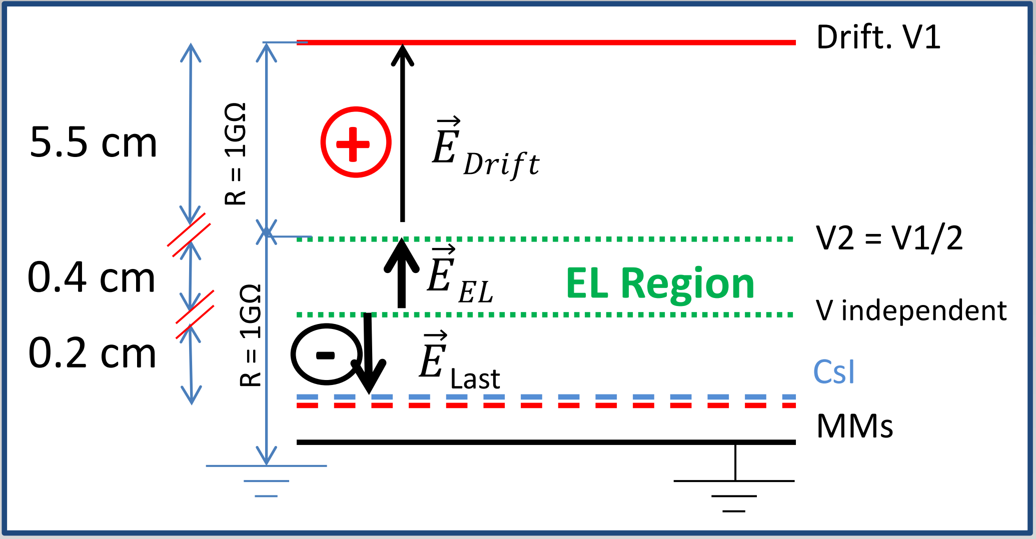
Even on this setup a little effect due to the scintillation of the Ar looks to appear!!

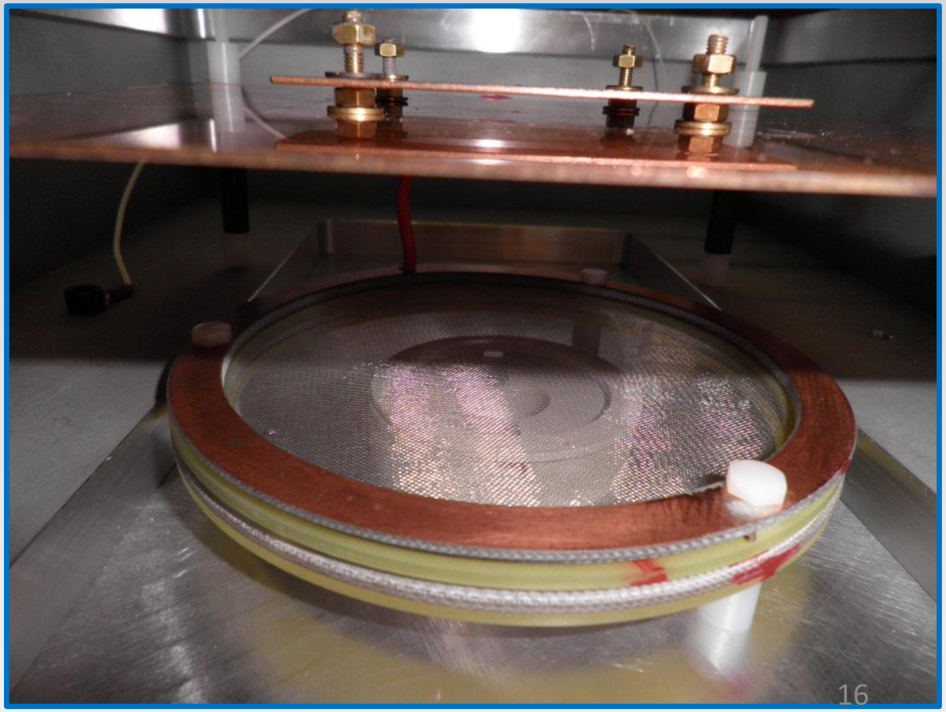
Microbulk Micromegas with CsI

NEW SETUP - IMPROVEMENTS

To be sure that we were producing the Ar scintillation:

- ✓ New chamber (vacuum of 10^{-4} mbar)
- ✓ Ar high purity (6.0)
  - ✓ < 0.2 ppm O_2
  - ✓ Total impurities <1ppm
- ✓ Annealing process in the MMs
  - ✓ 58h in Ne flux at 60ºC
- ✓ Installation of 3 drifts to be able to revert the field before the MMs and stop the charge





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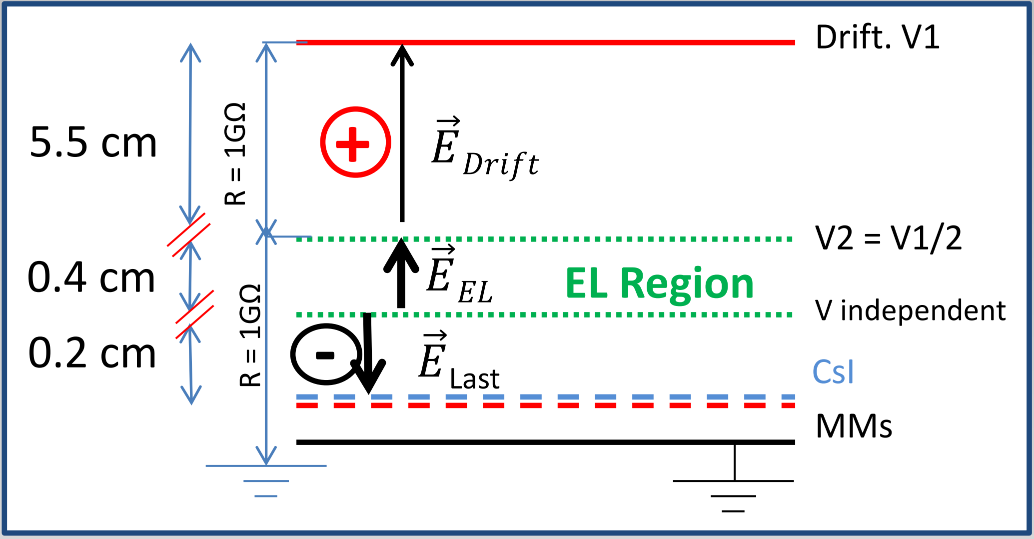


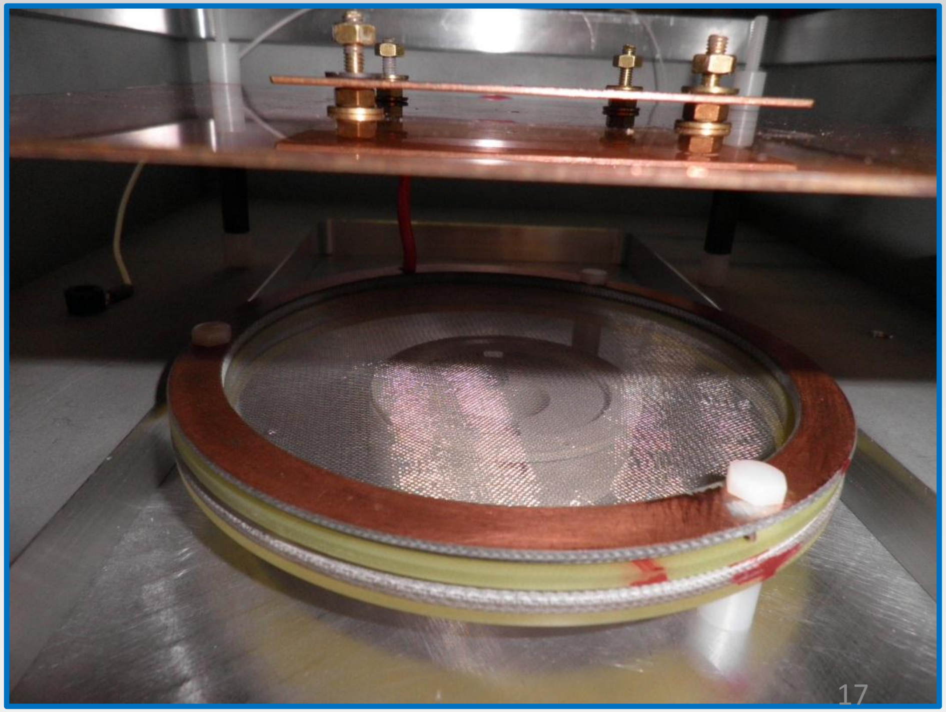
If we **revert the field in last region**

→ it stop the e-'s produced in the EL region

→only gammas from scintillation will pass

→ They will interact with the CsI producing e-s

→ and they will leave energy in the MMs

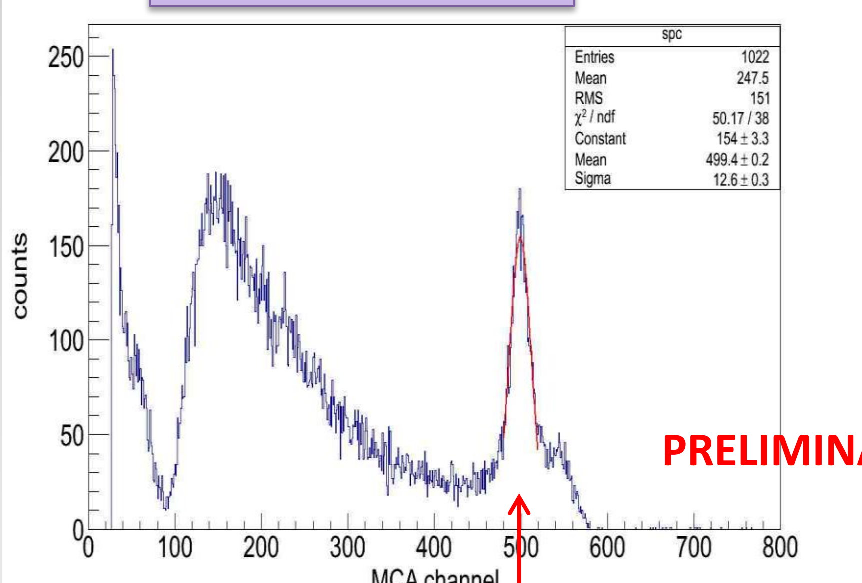


Microbulk Micromegas with CsI – RESULTS

Scintillation light and charge

- Two different configurations: first with all fields drifting the e-'s to the MMs and the second with the last electric field inverted to stop the charges.

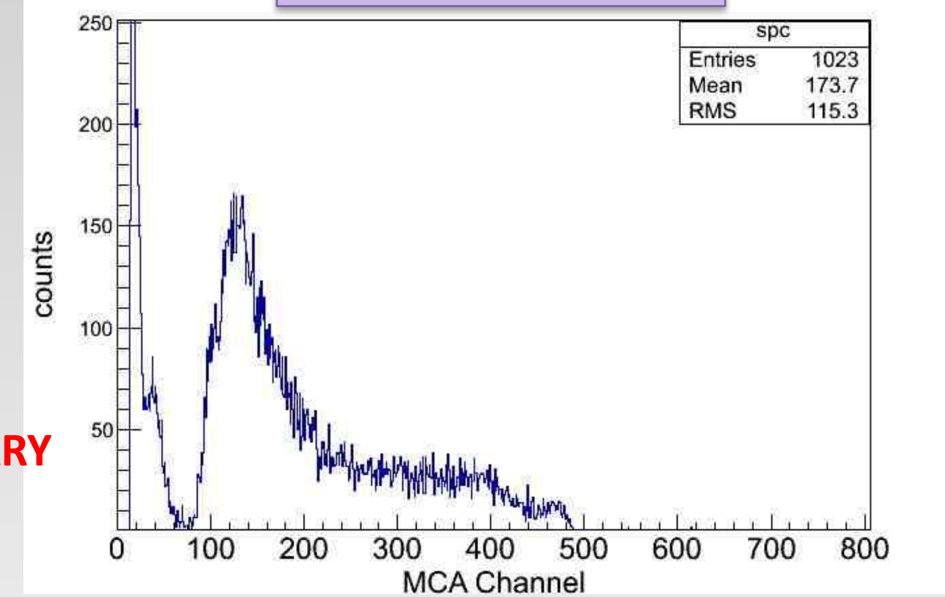
$\vec{E}_{drift}$ = 0.32 kV/cm
$\vec{E}_{EL}$ = 1.37 kV/cm
$\vec{E}_{Last}$ = 4.69 kV/cm



PRELIMINARY

Alpha
5.5 MeV

$\vec{E}_{drift}$ = 0.35 kV/cm
$\vec{E}_{EL}$ = 4.84 kV/cm
$\boldsymbol{\vec{E}_{Last}}$ = **-1.24 kV/cm**



Charge stopped!
We only see the light!

Microbulk Micromegas with CsI – RESULTS

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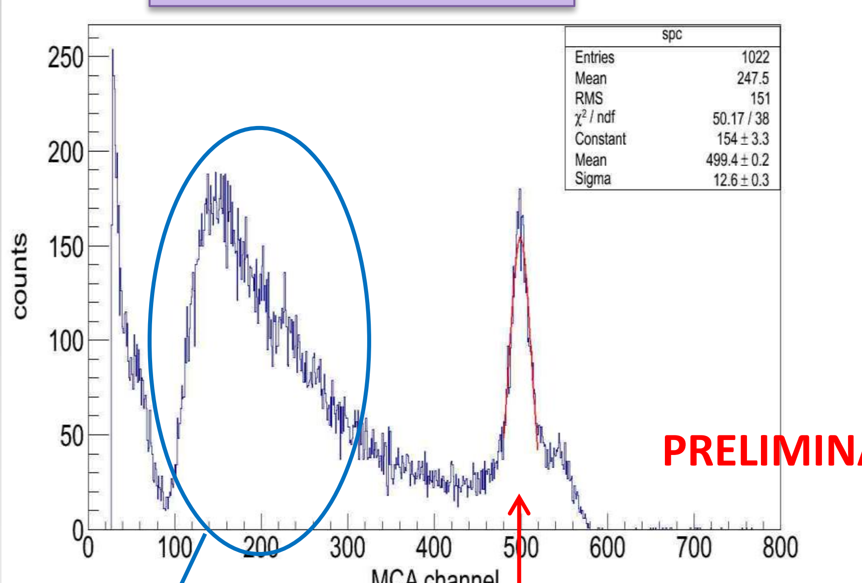

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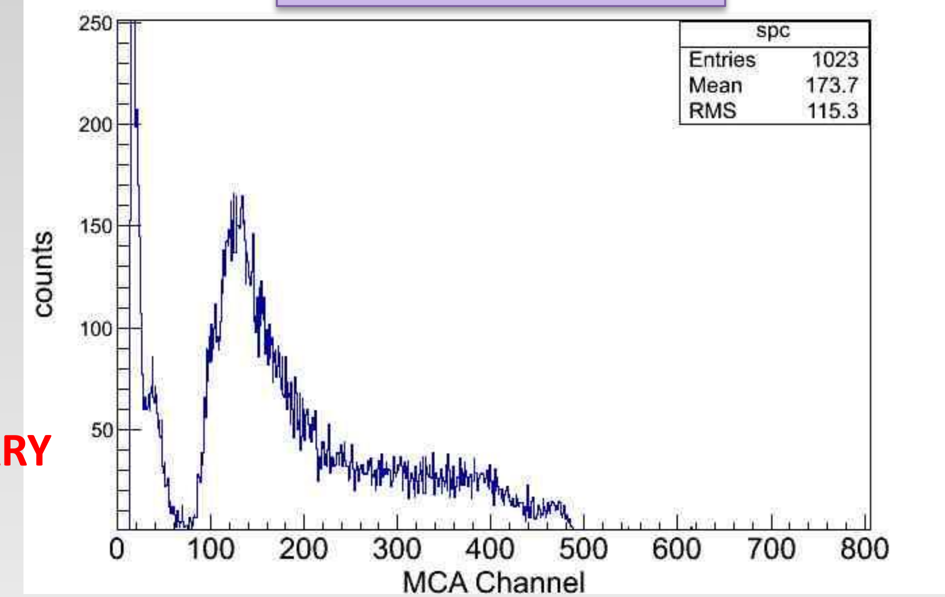


Bad recollection of light

Alpha 5.5 MeV

Charge stopped!
We only see the light!

Microbulk Micromegas with CsI – RESULTS

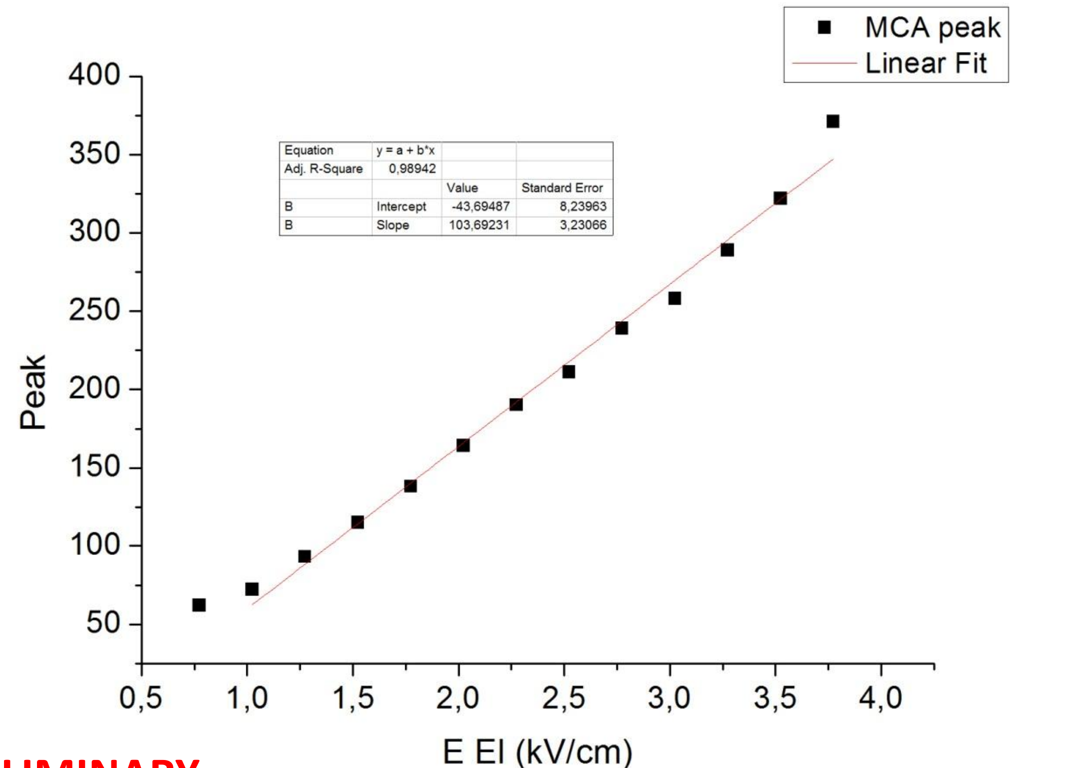
Evolution of the signal with the Electroluminescence field

- Mesh gain constant
- Drift and electroluminescence field changed

$\vec{E}_{Last}$ = 0.45 kV/cm

$\vec{E}_{Amp}$ = 50 kV/cm

EEL(kV/cm)	Edrift(kV/cm)	Signal
0.78	0.12	62
1.03	0.14	72
1.28	0.15	93
1.53	0.17	115
1.78	0.19	138
2.03	0.21	164
2.28	0.23	190
2.53	0.25	211
2.78	0.26	239
3.03	0.28	258
3.28	0.30	289
3.53	0.32	322
3.78	0.34	371



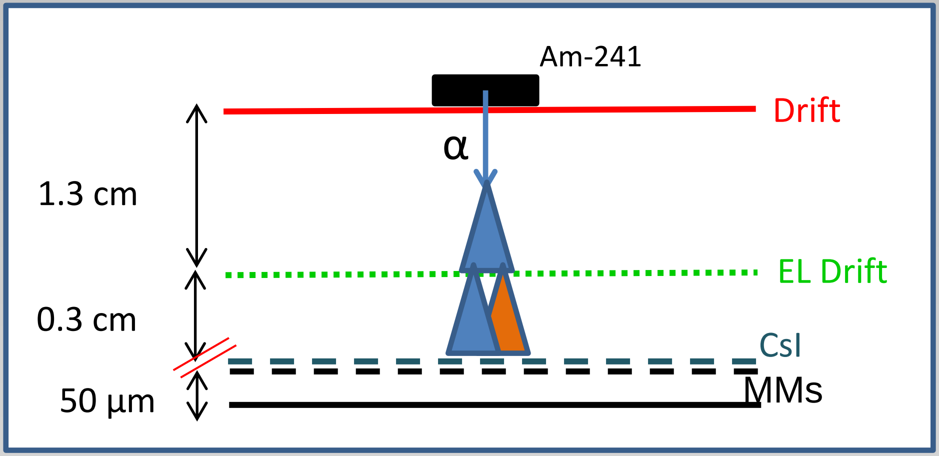
PRELIMINARY

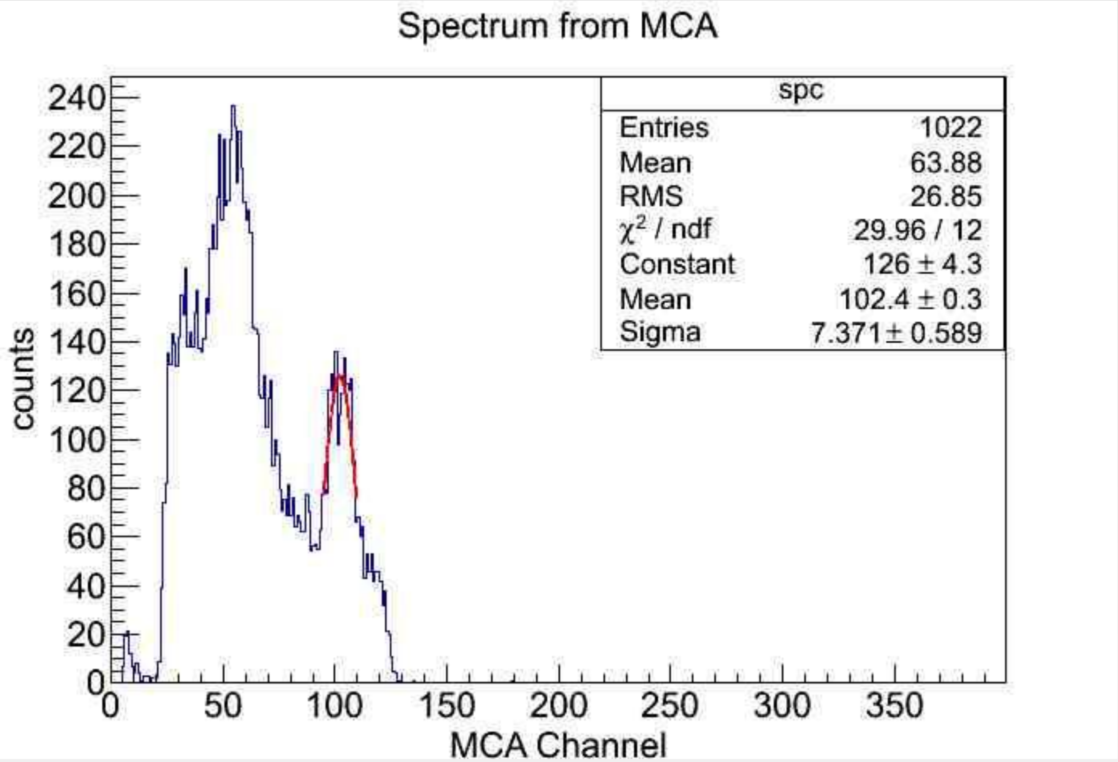
Scintillation light has a linear dependency with electric field, as shown!!

Microbulk Micromegas with CsI – RESULTS

Now, we are sure we are seeing the scintillation. We install again the setup with just ***two drifts*** but…

- ✓ In the new chamber
- ✓ Using Ar of high quality





Microbulk Micromegas with CsI – RESULTS

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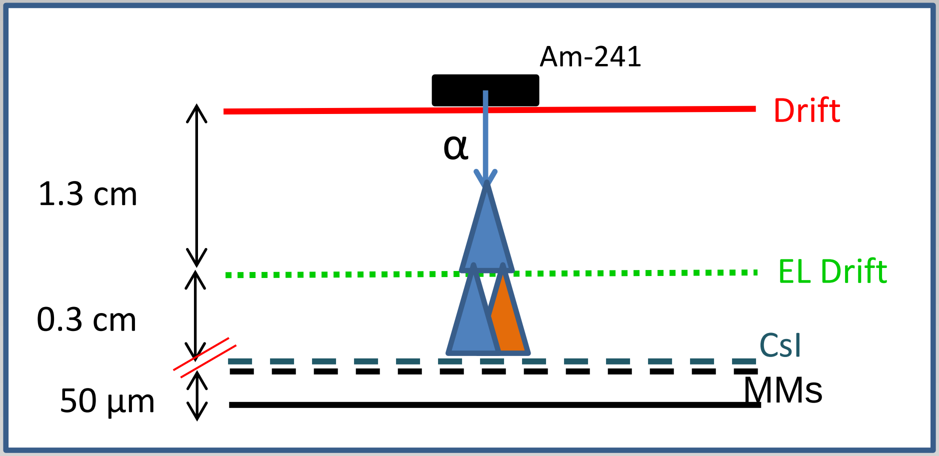
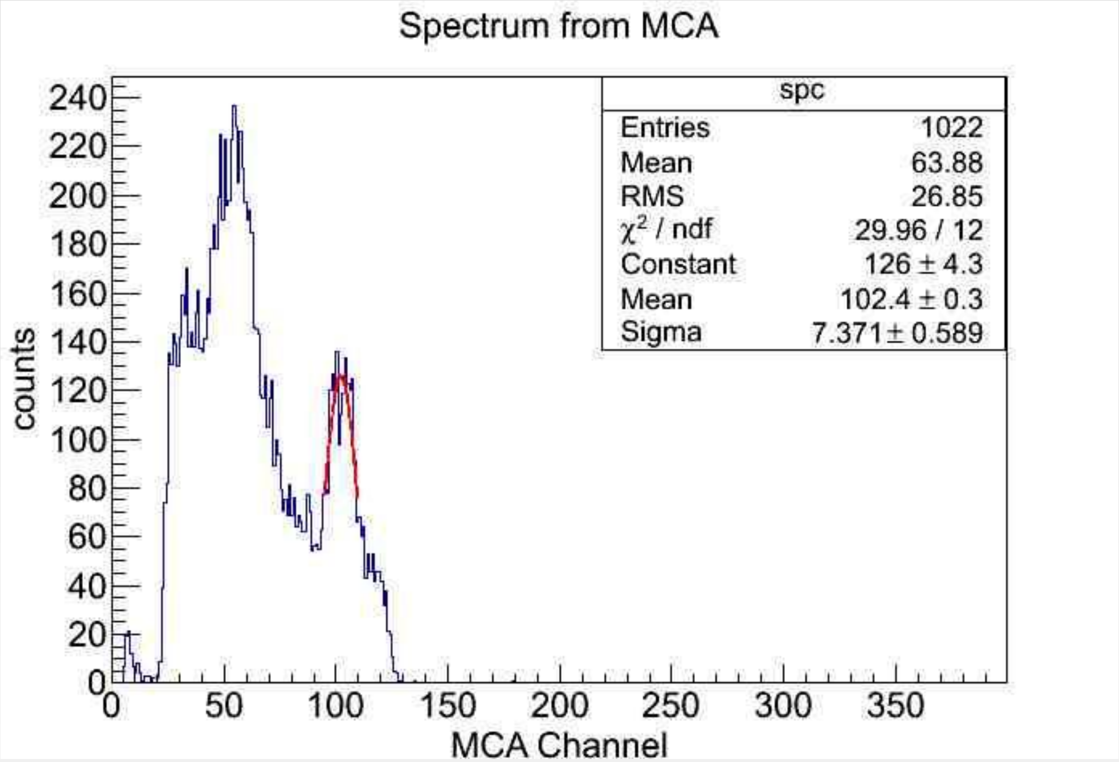
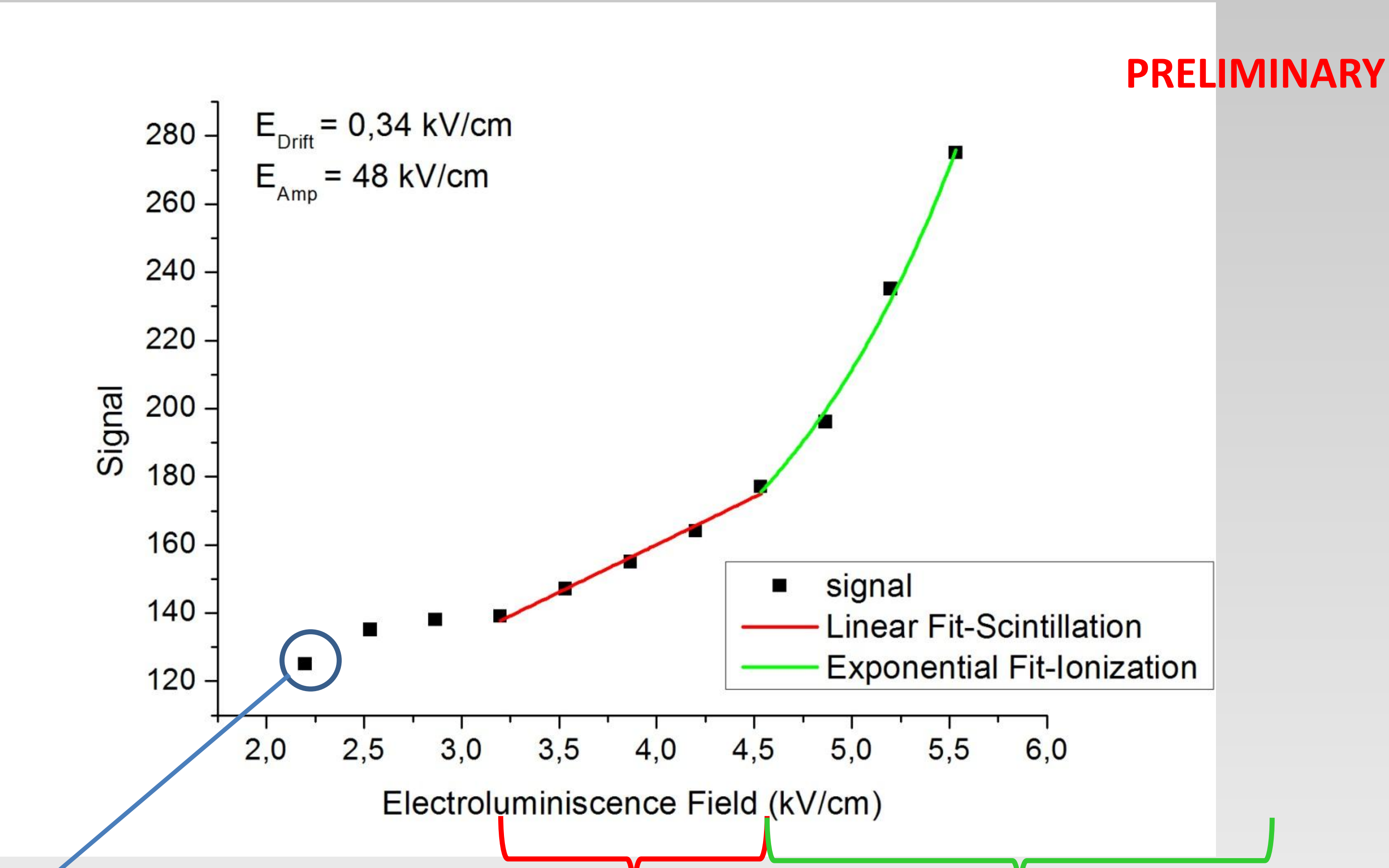
→Higher Gains observed!!!





Microbulk Micromegas with CsI – RESULTS

- With a constant drift field and a constant amplification field in the MMs we obtain a gain curve varying the electroluminescence field



We were NOT in the plateau of the MMs

From < 3kV/cm to 4.5 kV/cm→Only scintillation

> 4.5 kV/cm→Starts ionization

Microbulk Micromegas with CsI

Conclusions

- First tests with a microbulk micromegas with CsI deposit in the mesh
- Electroluminescence light clearly detected
- Gain curve: scintillation regime (linear dependency with electric field) and when the ionization starts (exponential dependency)
- Higher gains obtained with charge and light amplification

  → we are able to see the X-Rays in pure Ar

Outlook

- Improve the setup with a field cage to collect better the events
- Calibrations with an iron source → gammas from source already detected
- QE measurements at Ar wavelength
- Future tests in Xe and at high pressure
- First steps with a new device, an open field…

THANK YOU

Microbulk Micromegas wit CsI

First Tests with a *Microbulk with CsI*

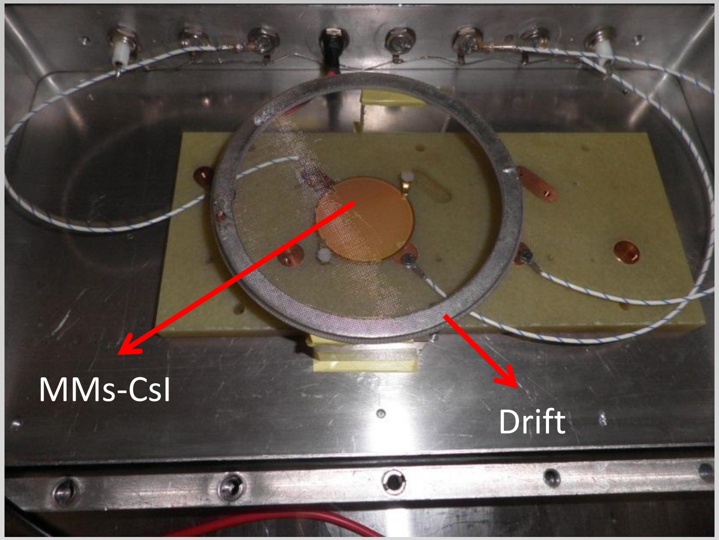
- Inside TPC Chamber
- Tested in Ar-Iso 5% and in pure Ar
- Constant flux 10 l/h
- P = 1 bar

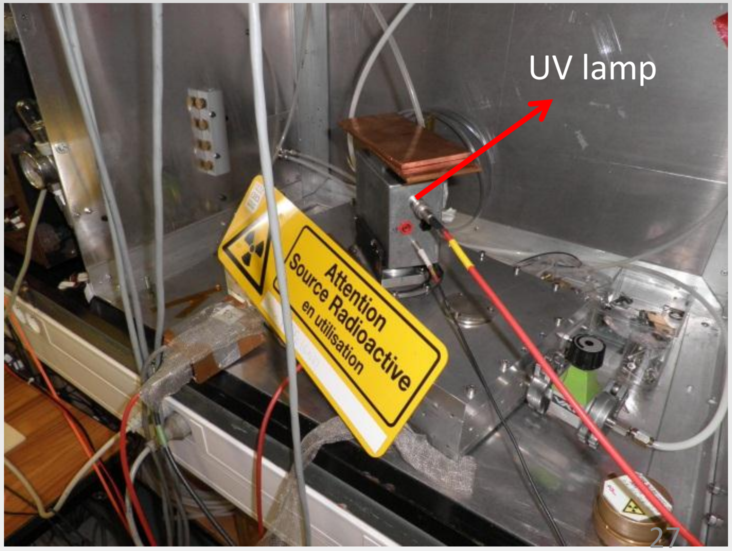
Signals obtained with:

- ✓ UV Lamp
- ✓ Am-241 with a piece of Cu to see its fluorescence (source situated directly in the drift)

✗ But just one drift at 2.5 cm (not EL region)

→ $\vec{E}$ up to 480 V/cm. not enough to EL





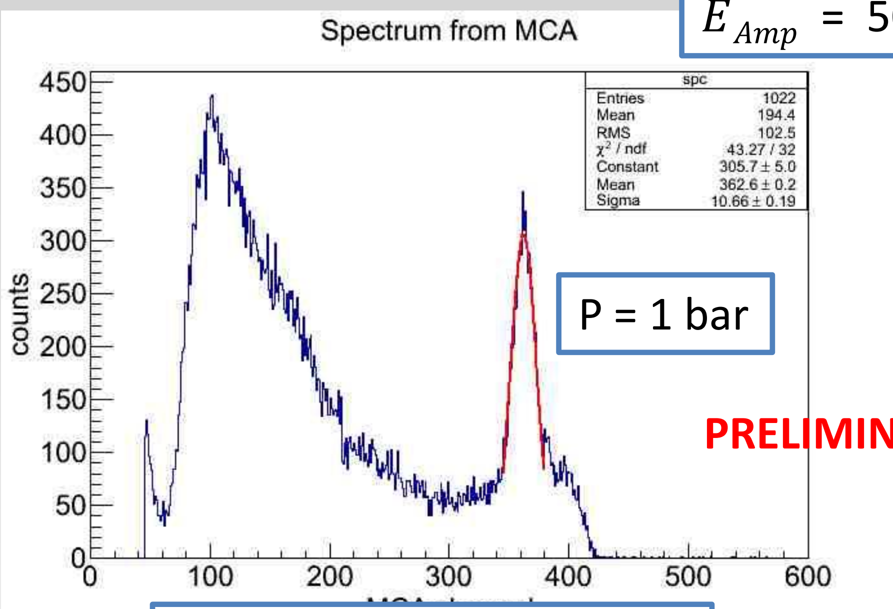
Microbulk Micromegas with CsI – RESULTS

t (min)	Peak
0	371
10	354
20	350
30	346
40	330

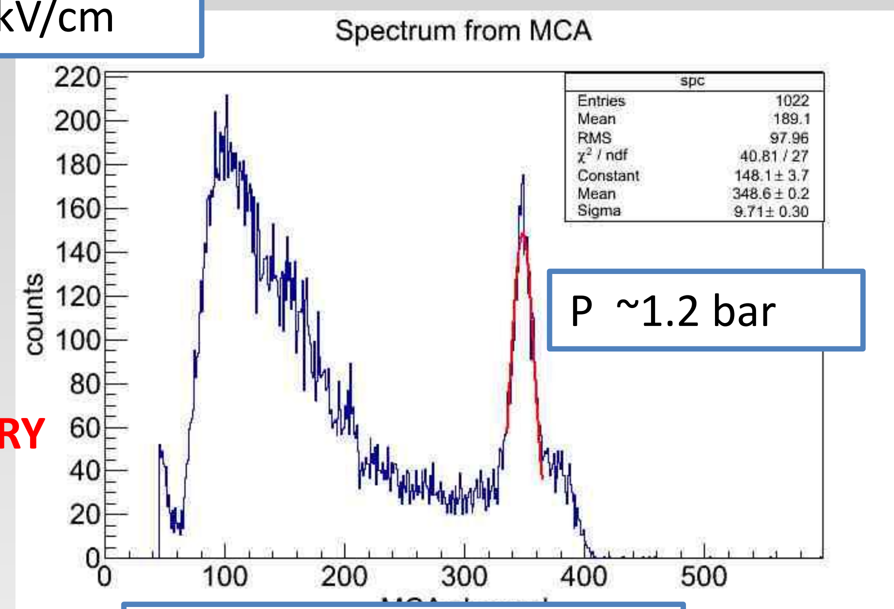
Evolution with pressure

- We increase the pressure inside chamber to explain distribution on the left
- Data taken each 10 min at same fields conditions

$\vec{E}_{drift}$ = 0.35 kV/cm
$\vec{E}_{EL}$ = 1.63 kV/cm
$\vec{E}_{Last}$ = 5.25 kV/cm
$\vec{E}_{Amp}$ = 50 kV/cm



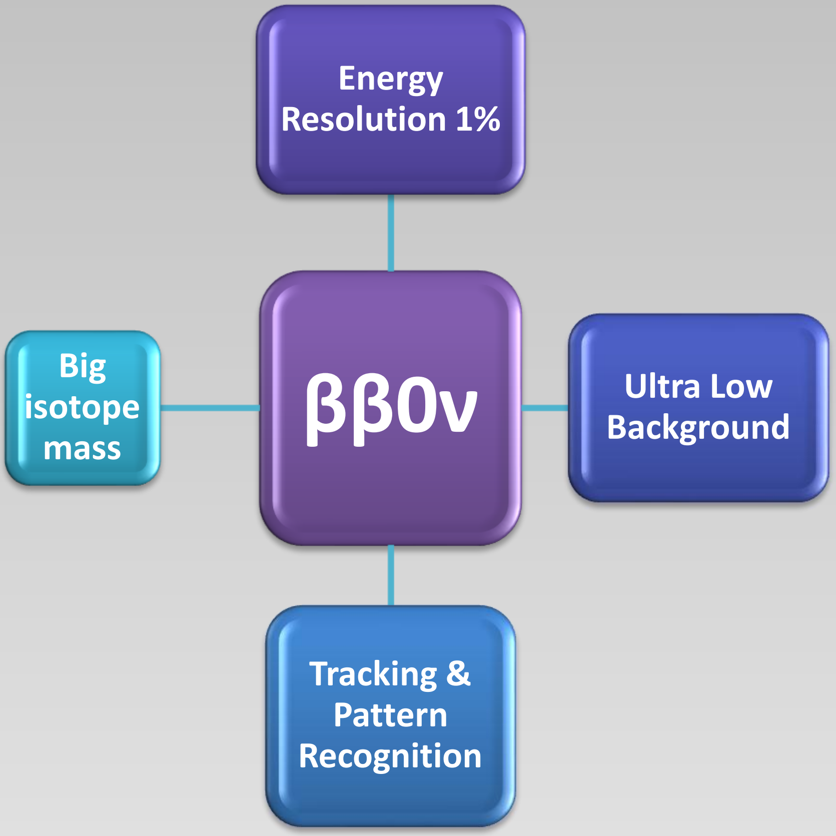
PRELIMINARY



Peak in channel 362
Energy Resolution = 7 %

Peak in channel 348
Energy Resolution = 6.5 %

Motivation


Energy Resolution 1%
Big isotope mass
ββ0ν
Ultra Low Background
Tracking & Pattern Recognition

New Concept: Light and Charge Amplification
→Microbulk Micromegas wit CsI

Microbulk Micromegas with CsI deposit in the mesh:

- Gap 50 μm; pitch 100 μm. holes diam. 30 μm
- Deposit of CsI by thermal evaporation (CERN): 300 nm thick

First Tests

- ➢ Inside TPC Chamber
- ➢ Tested in Ar-Iso 5% and in pure Ar
- ➢ Constant flux 10 l/h
- ➢ P = 1 bar

Signals obtained with:

- ✓ **UV Lamp** → its gammas excite the CsI producing a photoelectric effect that is measured in the MMs
- ✗ But just one drift at 2.5 cm (not EL region)

→ $\vec{E}$ up to 480 V/cm. not enough to EL