Proportional Counter array (PCa) —— a new concept and its realization

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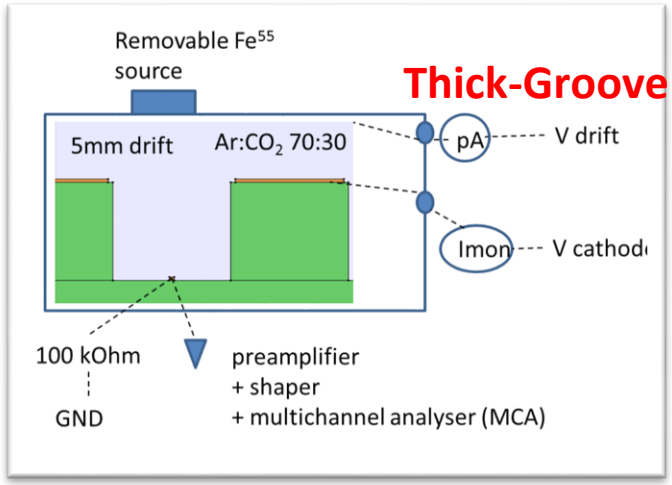
MPGD2022

Outline

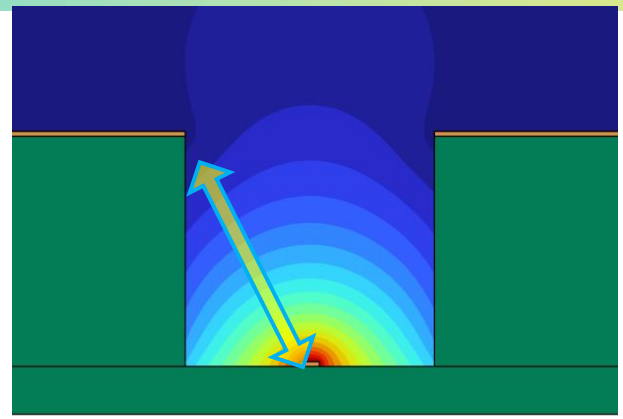
- A new structure : PCa
- Fabrication and test of PCa prototypes
- Summary
- Outlook

A new structure : PCa

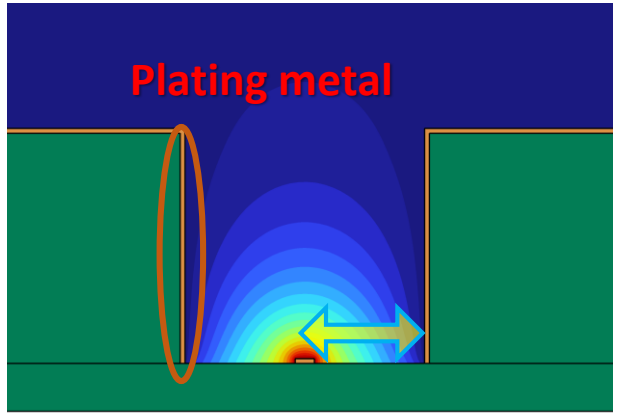
Inspiring idea



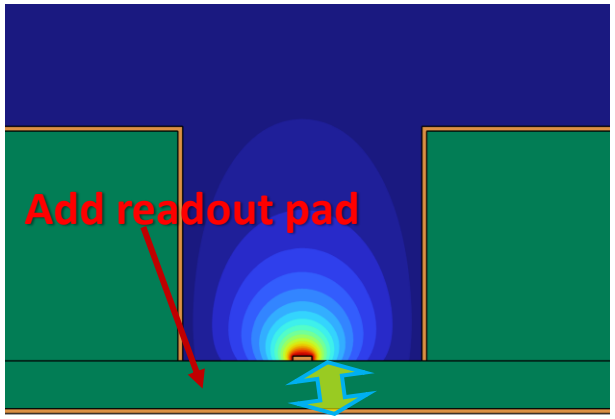
S.Franchino, 15th RD51 Collaboration Meeting CERN,18th March 2015



Thick-Groove (anode +HV)



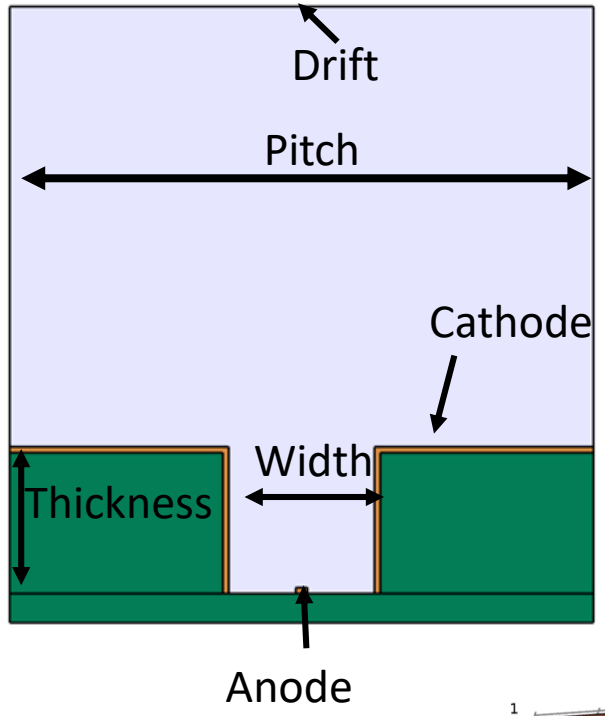
Plating metal on the wall to increase the gain



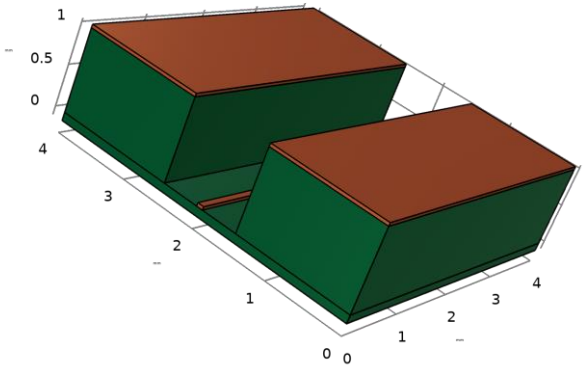
Add readout pad to increase the gain further

Simulation of gas amplification

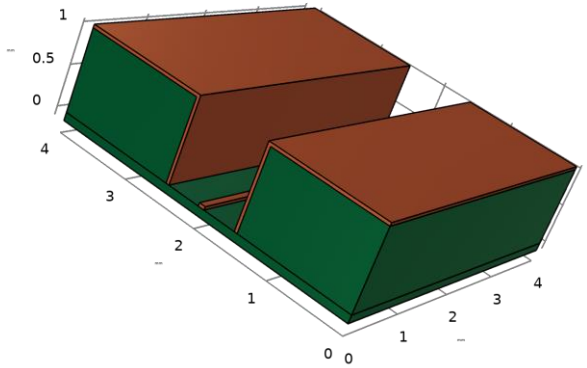
Drift : 0V
Cathode : 0V
Anode : 800V
(Readout pad: 0V)
Gas: Argon:iC4H10 = 95:5



P=**4mm**
T=**1mm**
W=1mm
Anode = 80um

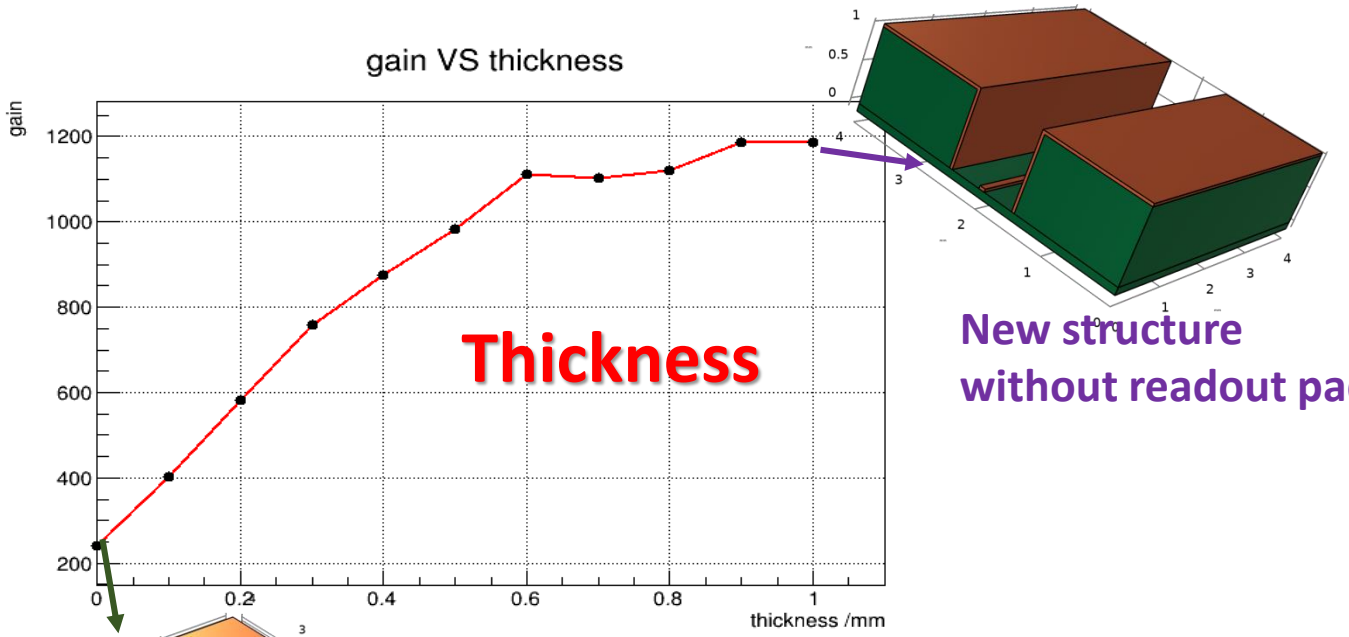


Thick-Groove
Gain: **~181**

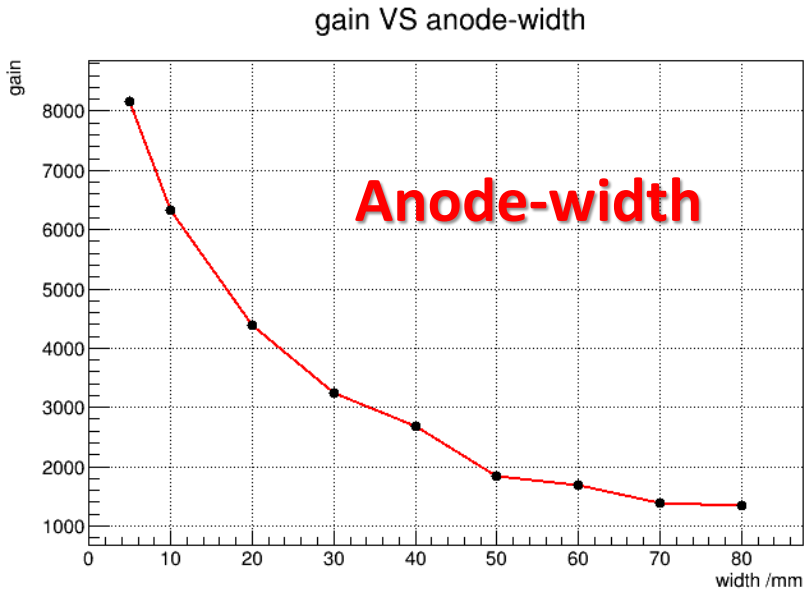


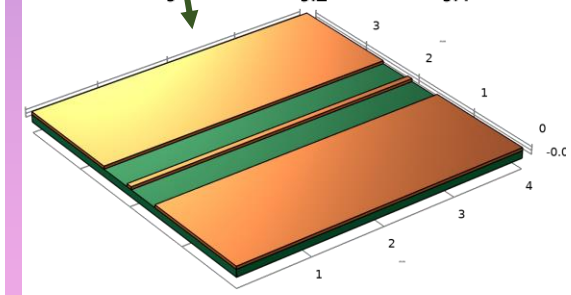
New structure
Gain: **~1354**

Gain .VS. thickness/anode-width



New structure
without readout pad

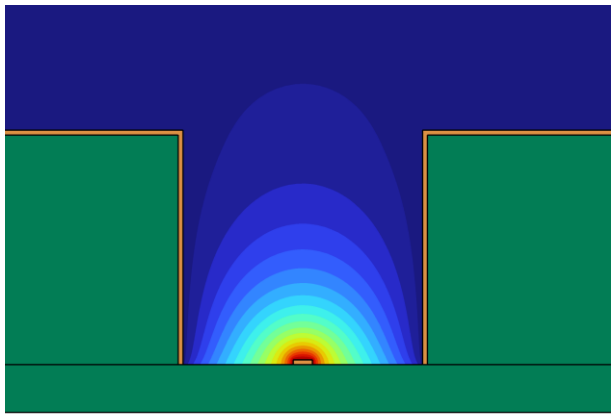




MSGC-like

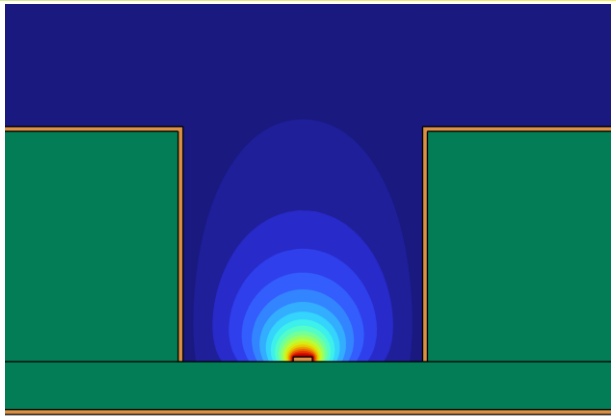
New structure without readout pad:
D/C/A :0/0/800
Gas: Argon:iC4H10 = 95:5

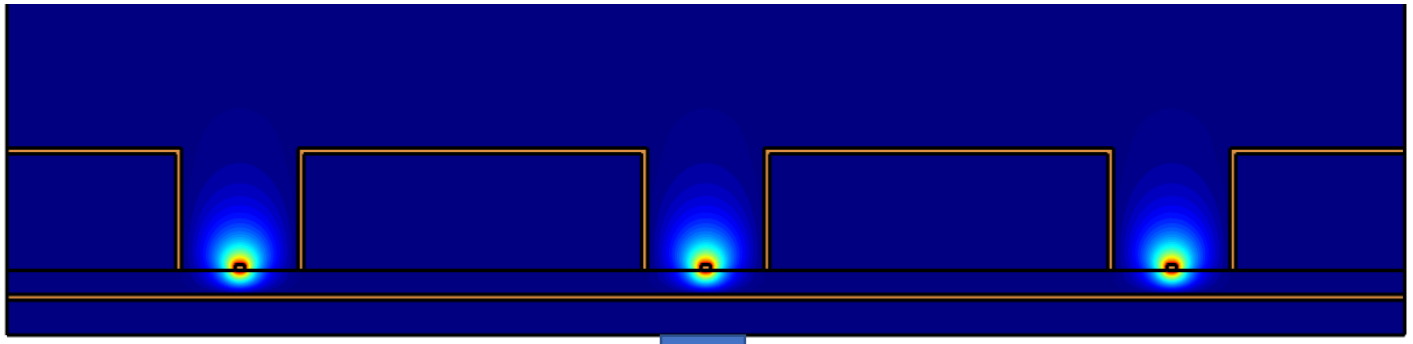
PCa with readout pad



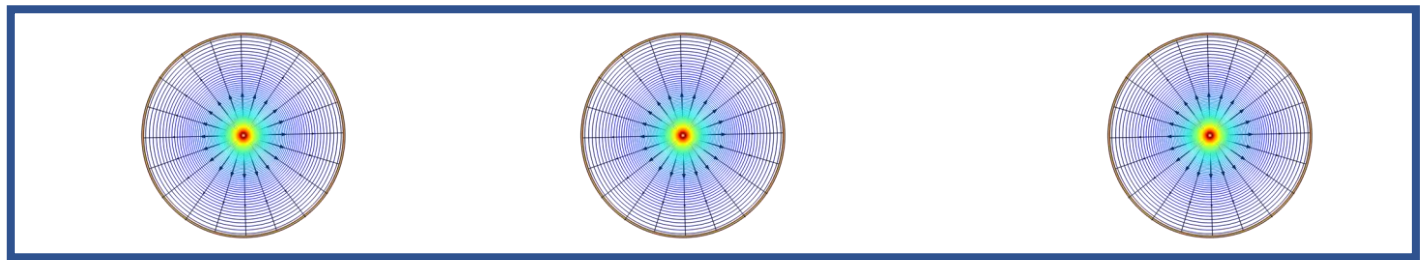
Add the readout

Gain :
~1354 → ~14231





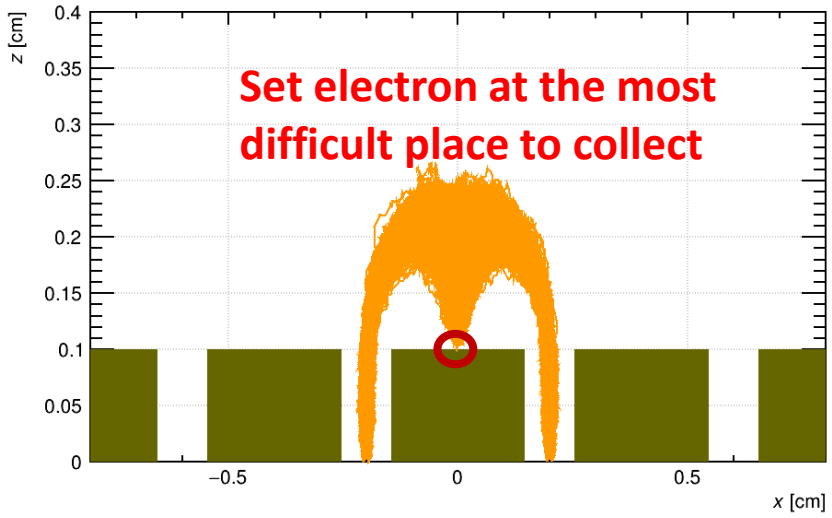
In each groove the metal wall and the read-pad surround the anode, around which the electric field is analogous to a proportional counter



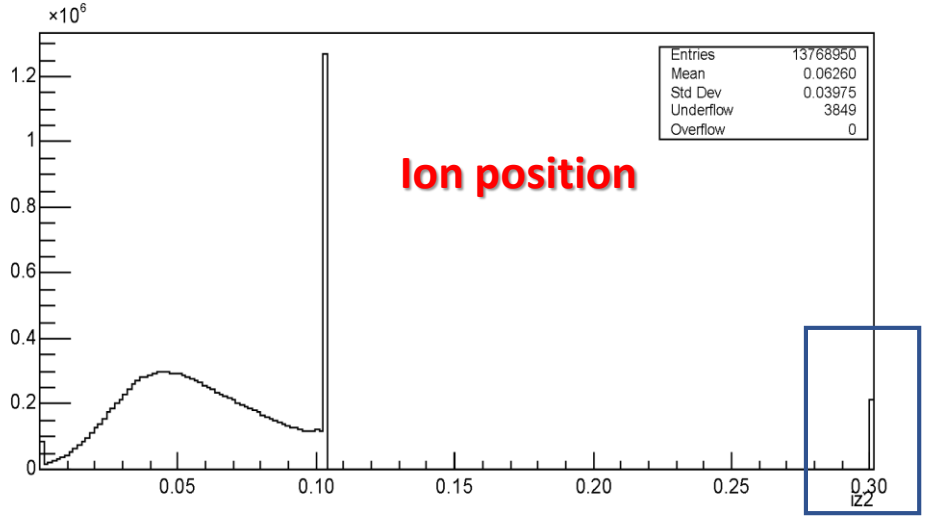
Proportional Counter array

PCa

IBF and collection efficiency of PCa



Voltage setup：
Drift (D): 0V
Cathode(C) : 0V
Anode (A): 800V
GAS: Ar:iC4H10 =95:5

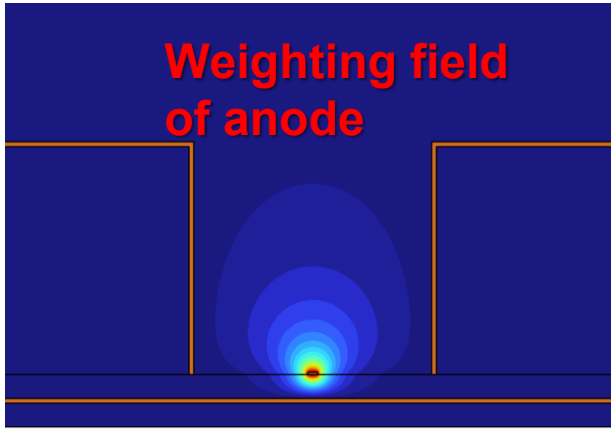


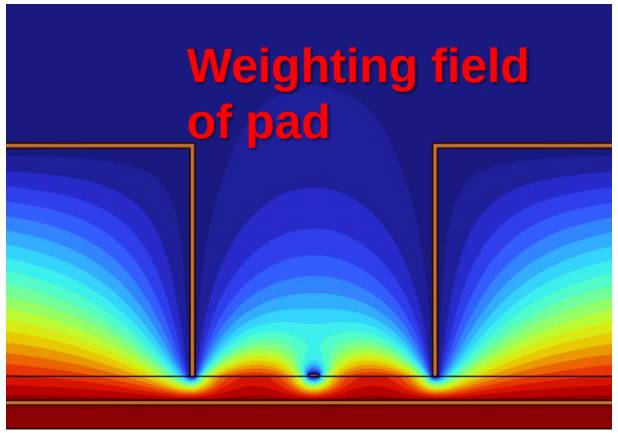
Set the initial electrons 1um above the cathode surface center
Collection efficiency： **98.75%**

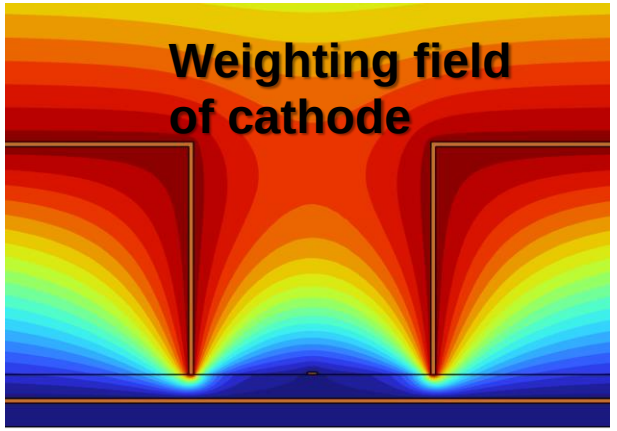
IBF （1000 initial electrons）：
drift： **1.5% ion feedback**

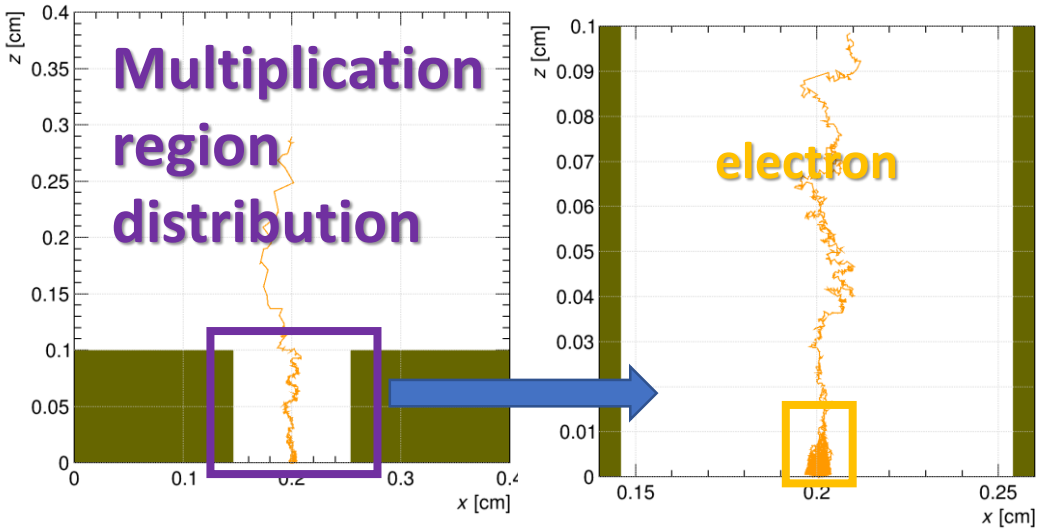
The voltage model:
D/C/A = 0/0/HV for high collection efficiency

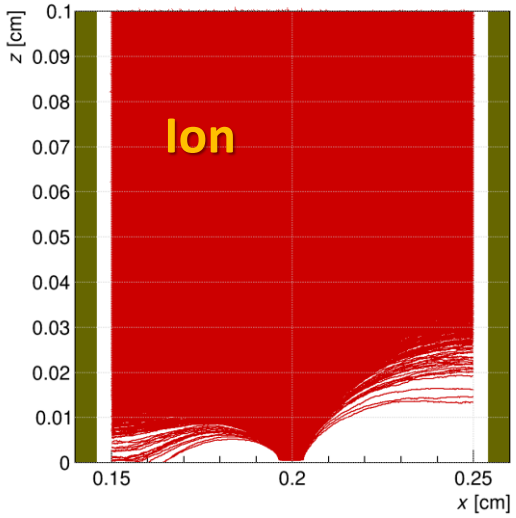
Signal and Weighting fields

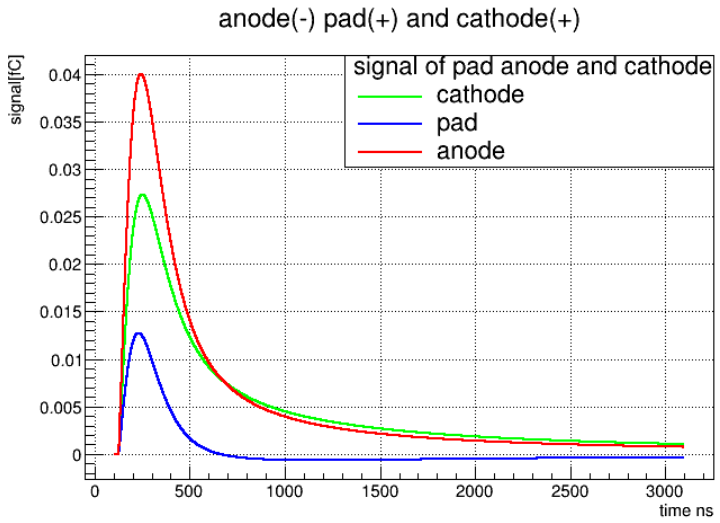




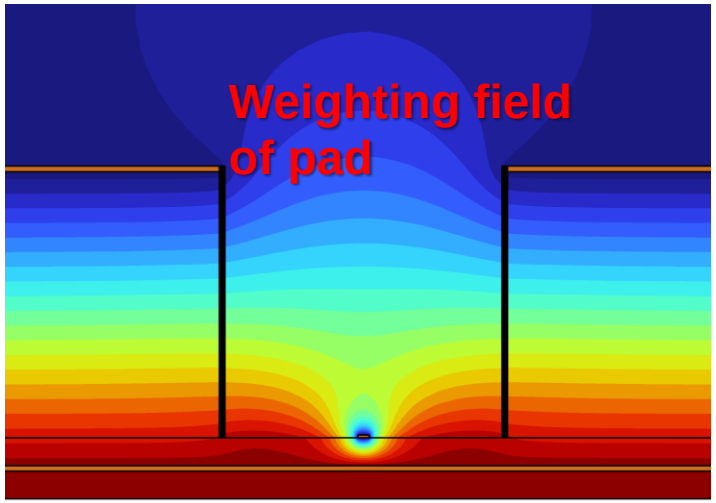


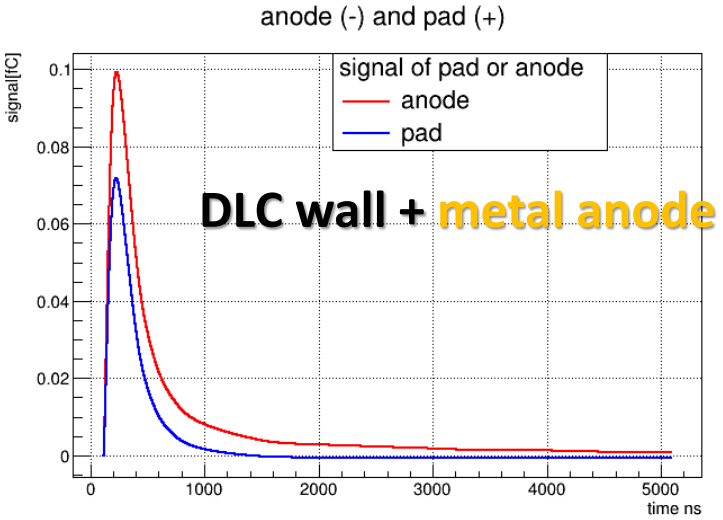


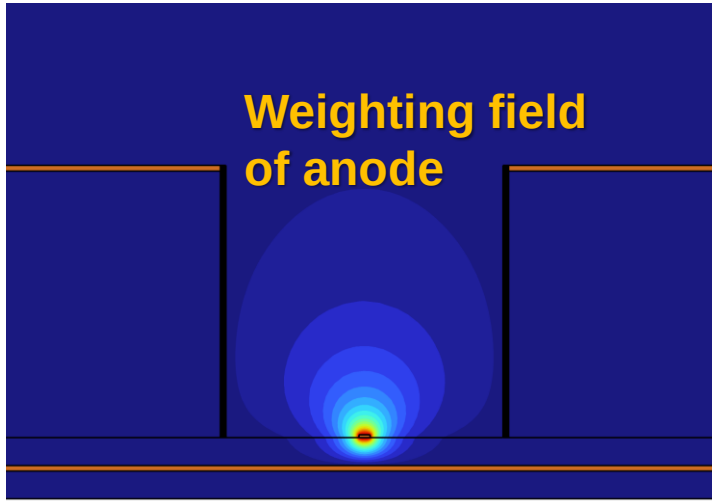


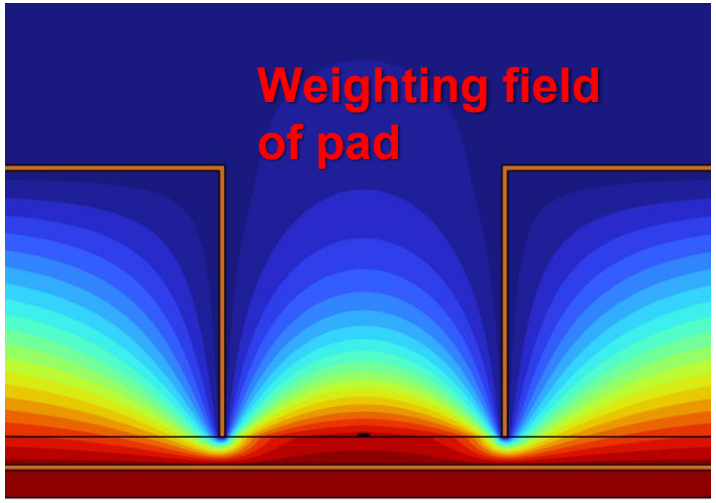


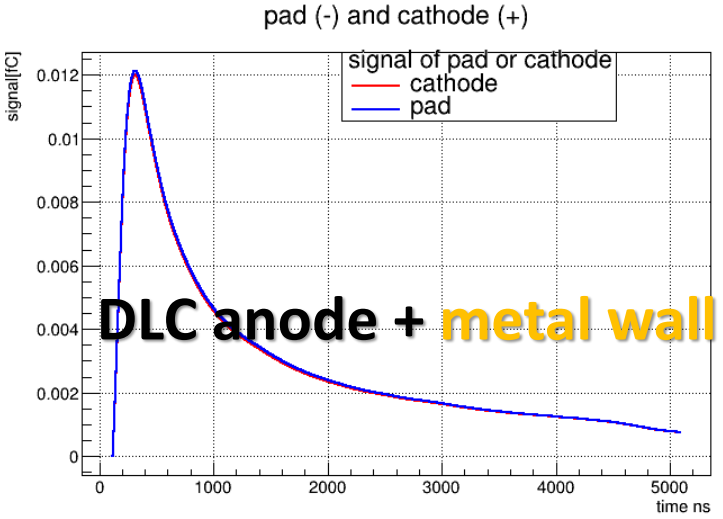
Weighting field of resistive electrodes

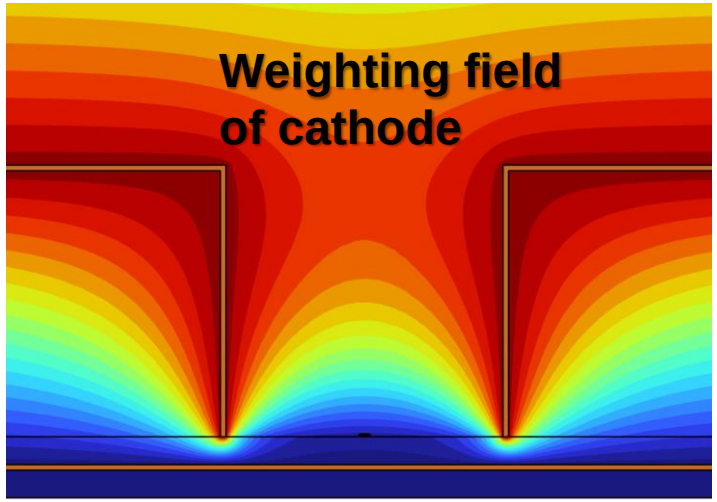












Fabrication and test of PCa prototypes

Manufacture of PCa

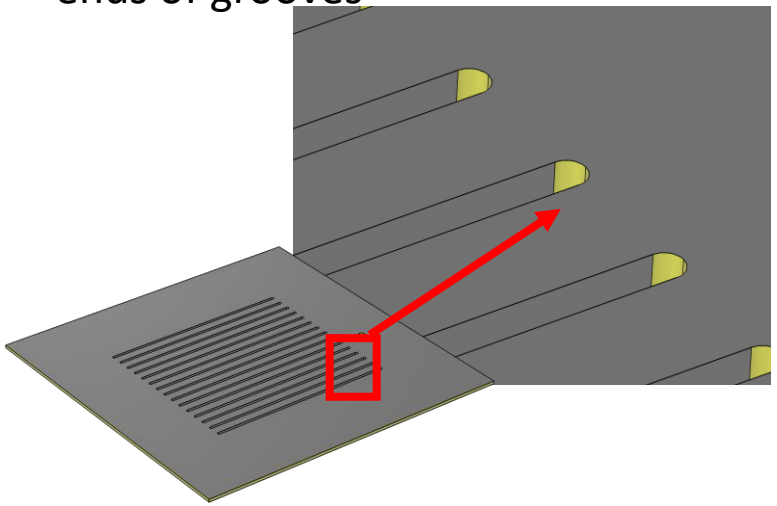
①. Copper thickness reduction

②. Grooves milling

③. Copper plating on the wall

④. Tin deposition on copper

⑤. Mill out the metal at both ends of grooves

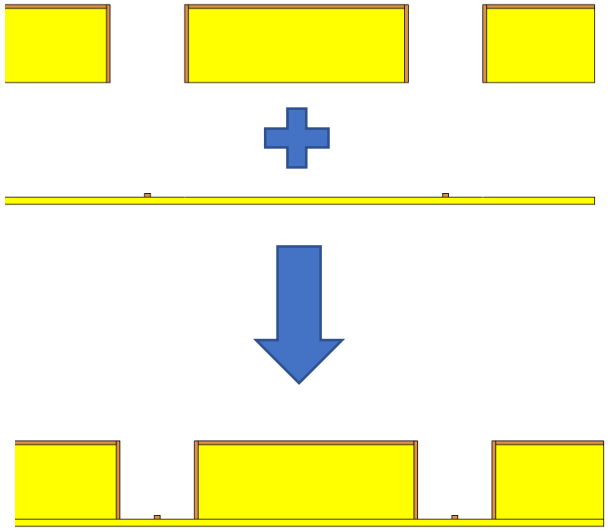


Advantages:

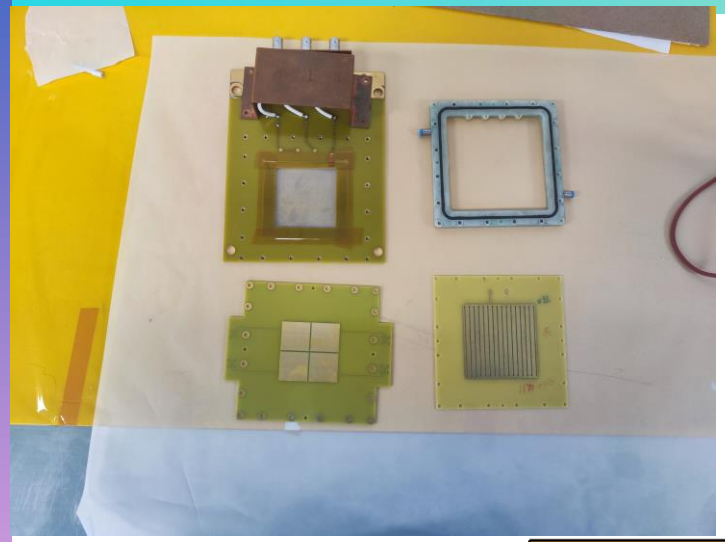
- **Could be readily fabricated by the standard PCB technique**
- **Low cost**
- **Good potential of scaling up**

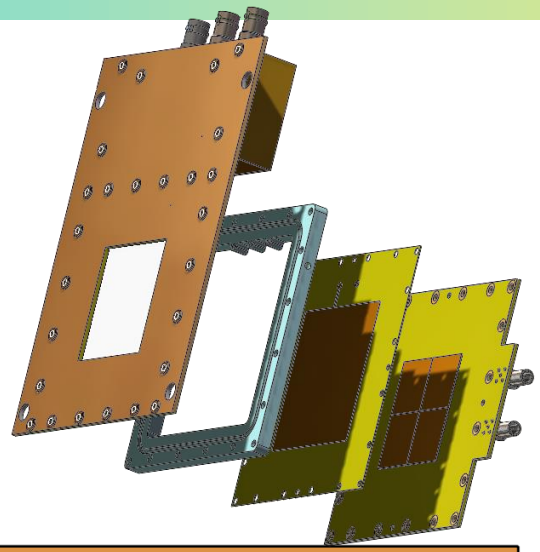
⑥. Tin etching and gold deposition

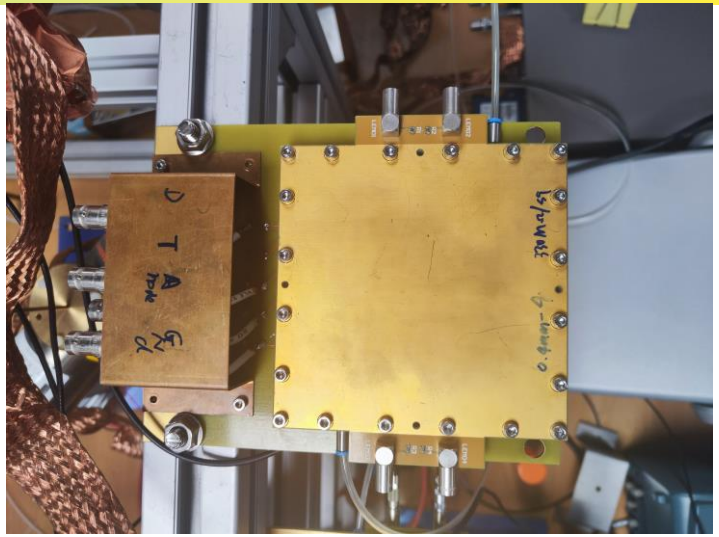
⑦. Vacuum lamination with anode plate

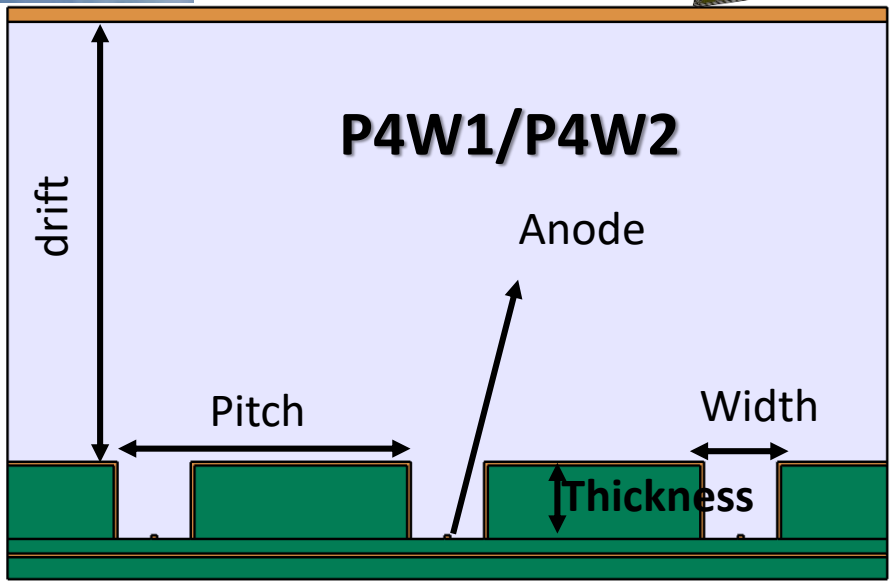


Prototype assembly (PCB version)



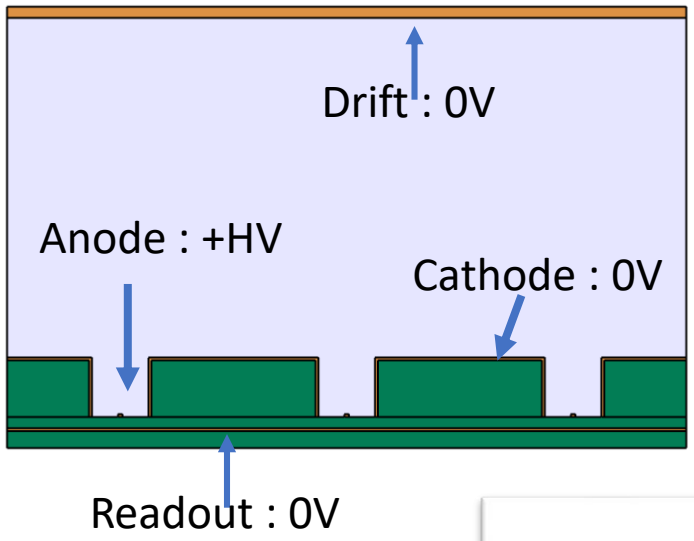




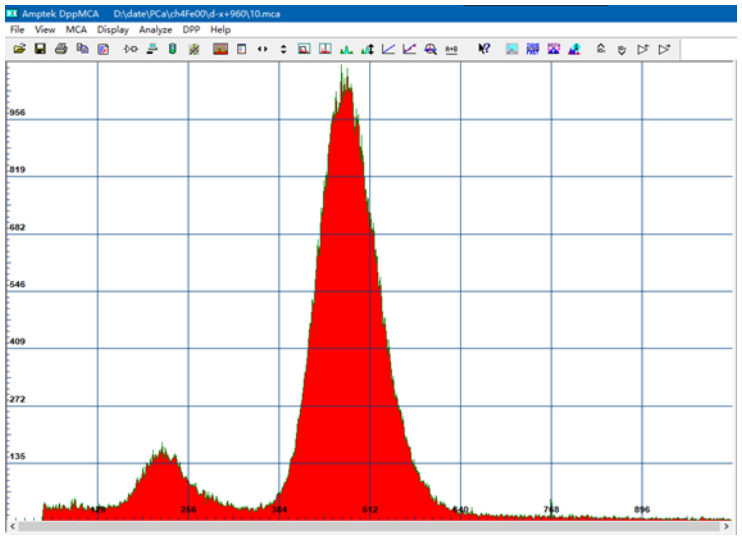


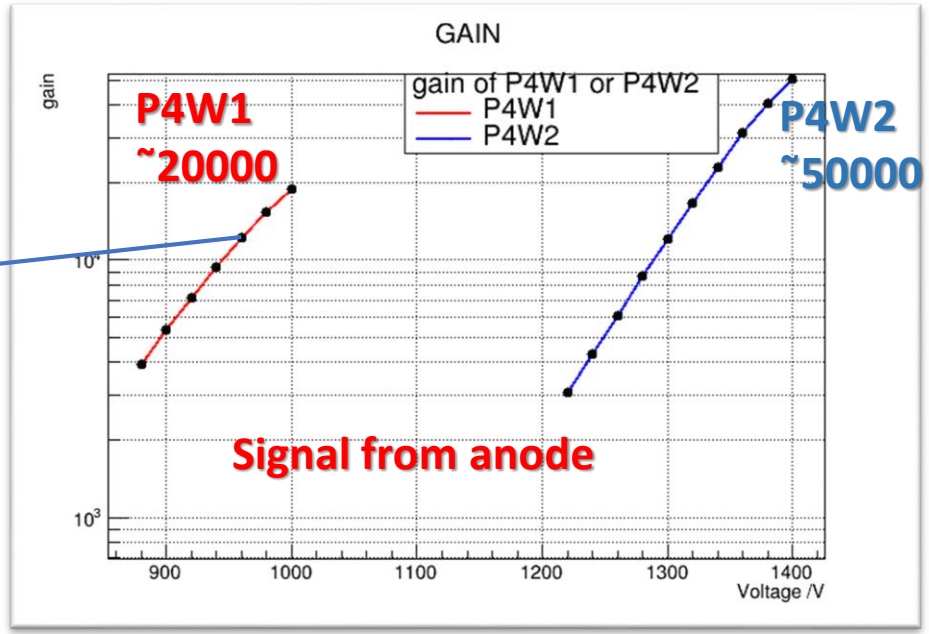
Main frame:
Drift = 6mm
Pitch = 4mm
Thickness = 1mm
Groove width = 1mm/2mm
Anode = 0.08mm

Gain test

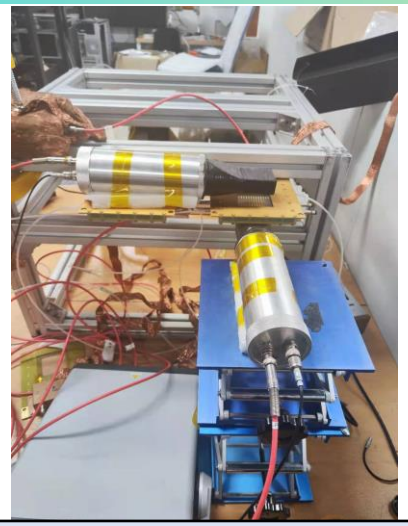


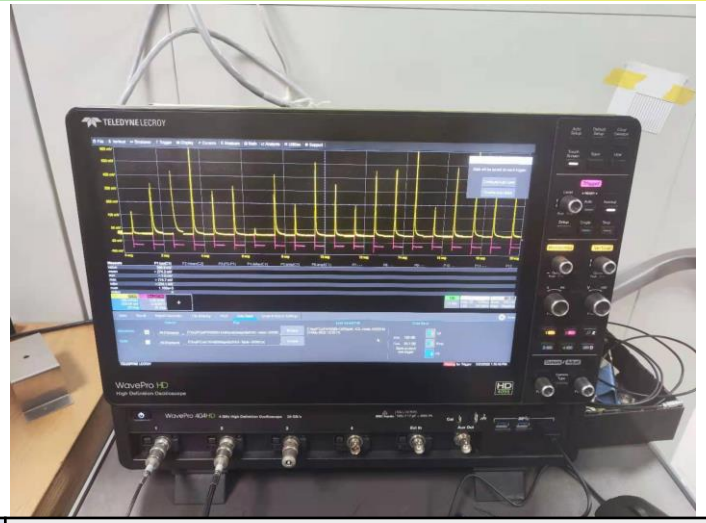
Gas :
Argon/CH4 : 95/5
Voltage :
D/C/A : 0/0/+HV
Source :
Fe55





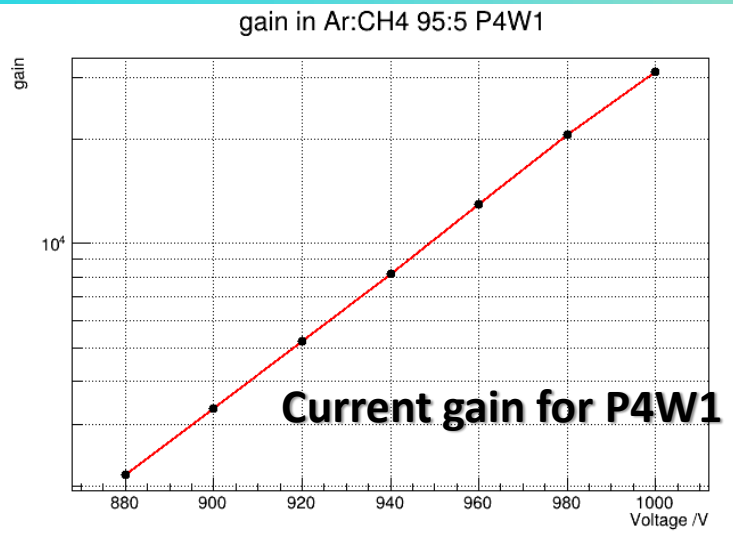
Detection efficiency of cosmic ray

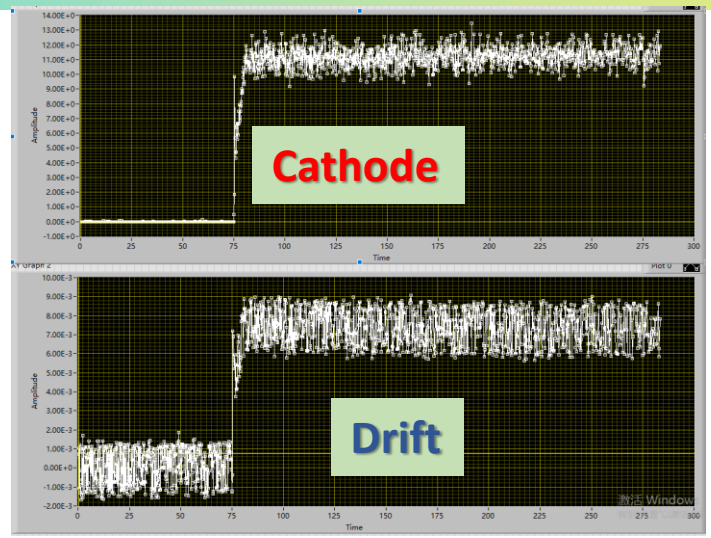


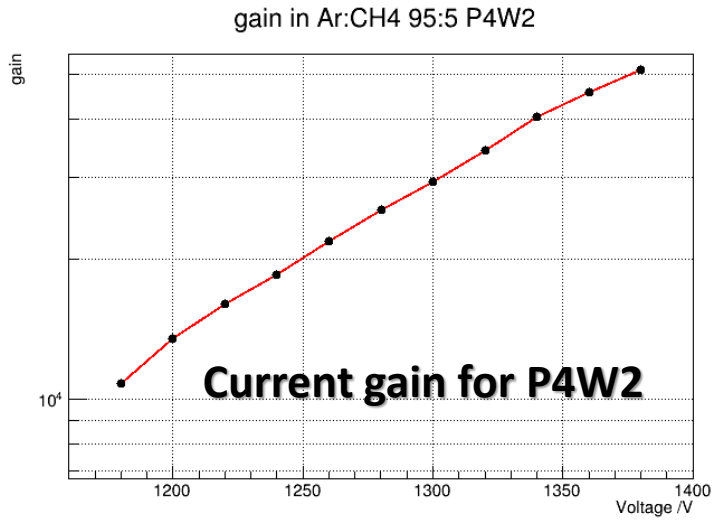


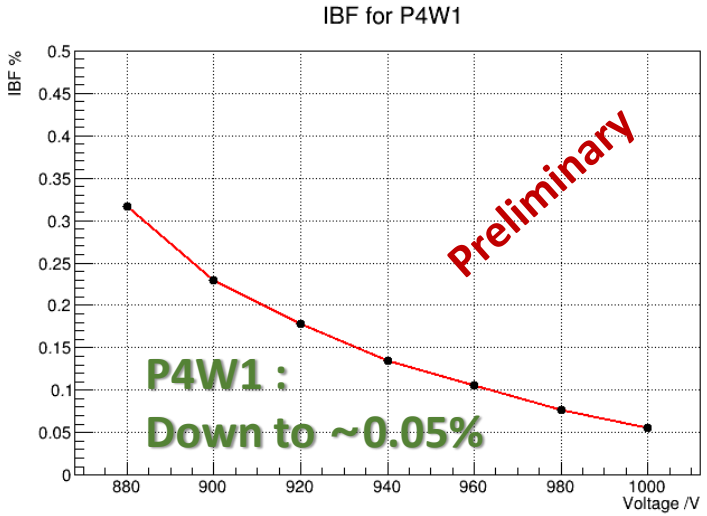
	P4W1			P4W2			
Gain	~10000			~25000			~5000
Readout	Anode			Anode			Pad
Voltage (D/C/A)	0/0/960	-10/0/960	-100/0/960	0/0/1340	-10/0/1340	-100/0/1340	0/0/1340
Ratio	97.10%	98.17%	90.22%	96.73%	97.56%	97.17%	95.92%

Current gain and IBF





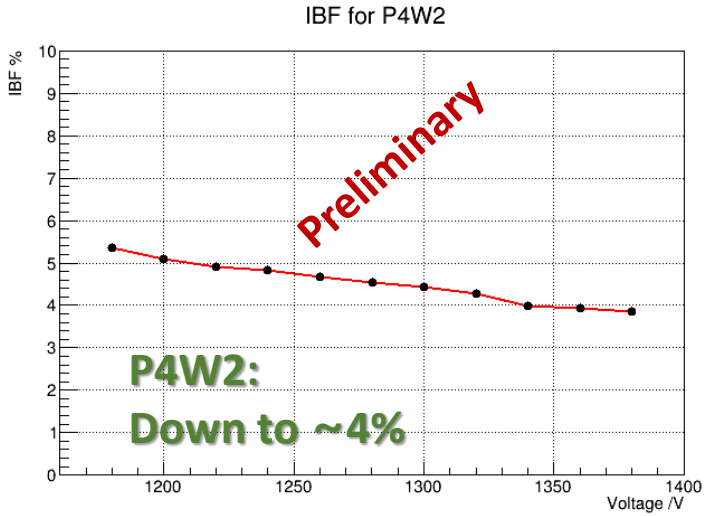




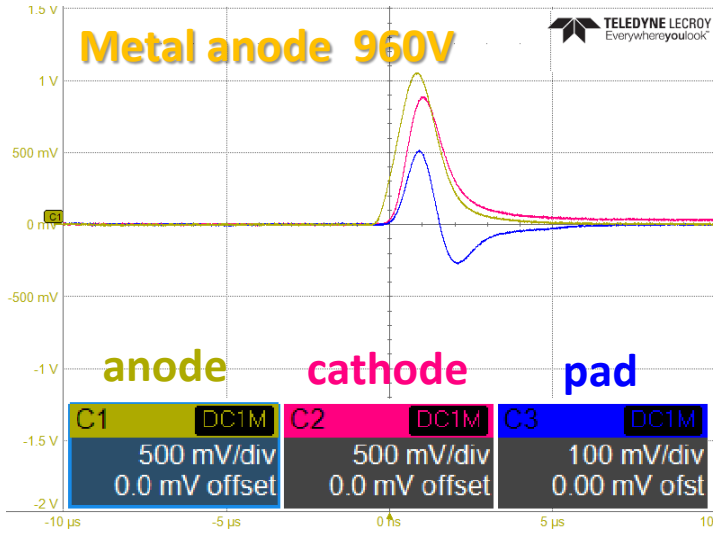
Rate~15000Hz

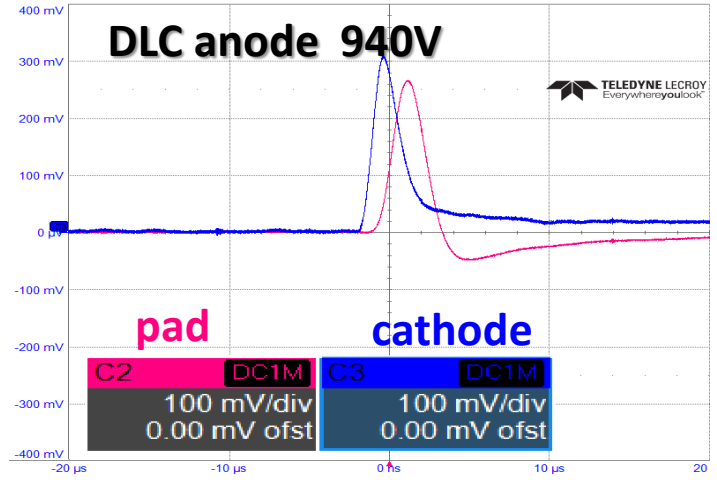
Voltage:
D/C/A : 0/0/+HV

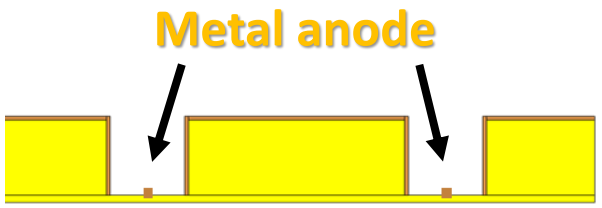
IBF = Id/(Id+Ic)



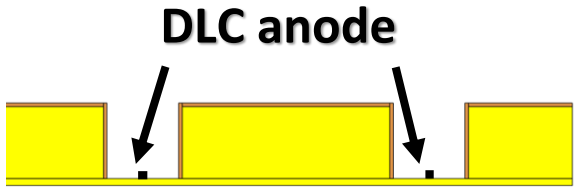
PCa with resistive electrode

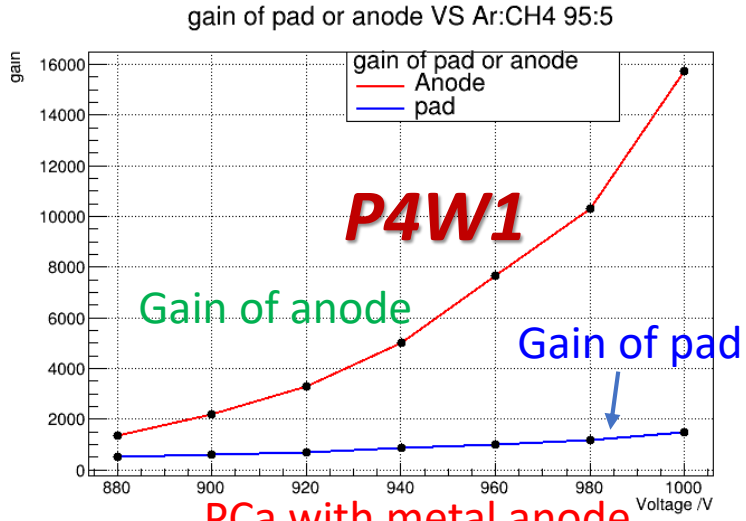




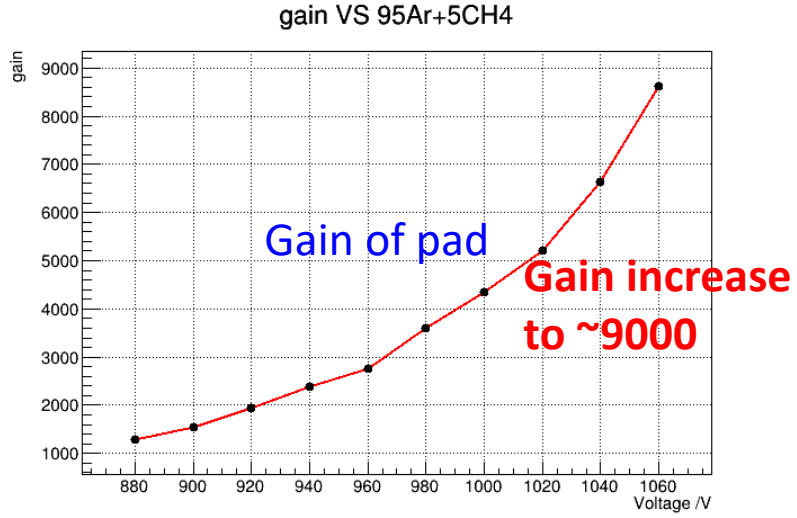


Using DLC anode can increase the magnitude of signal from the pad





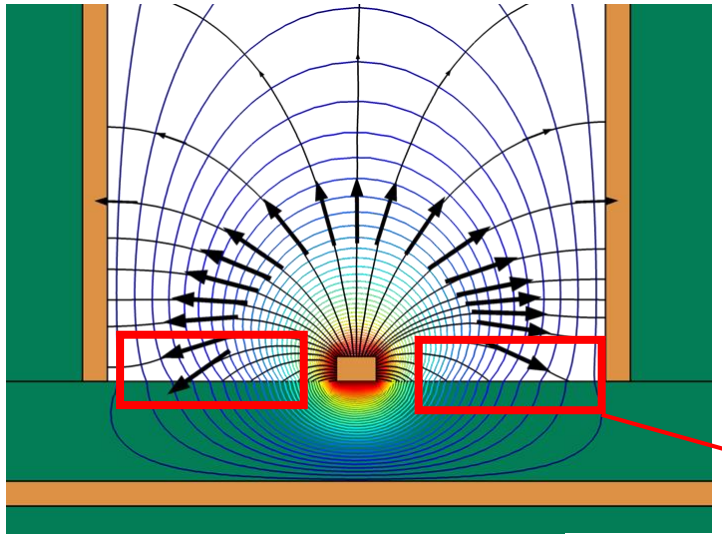
PCa with metal anode

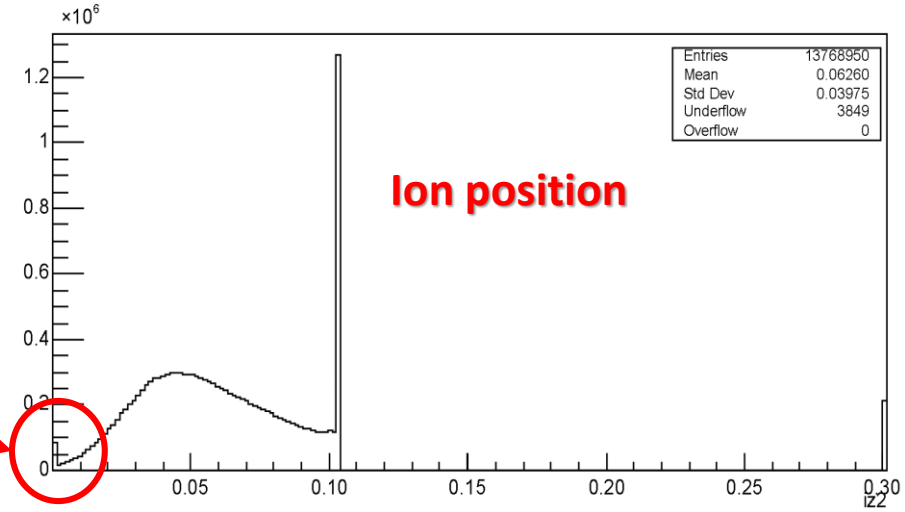


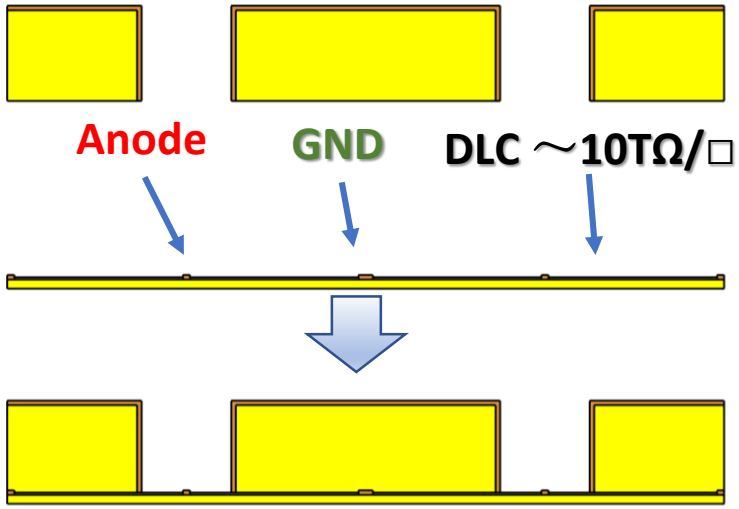
PCa with DLC anode

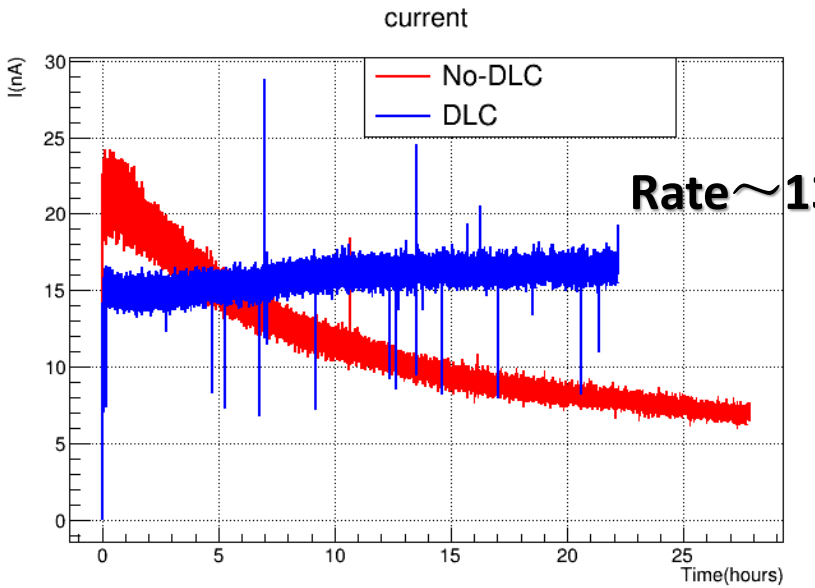
Remove charging-up effect by DLC

Less of ions accumulated around the anode ,there is a long-term charging-up. Coating High resistivity DLC will solve it.





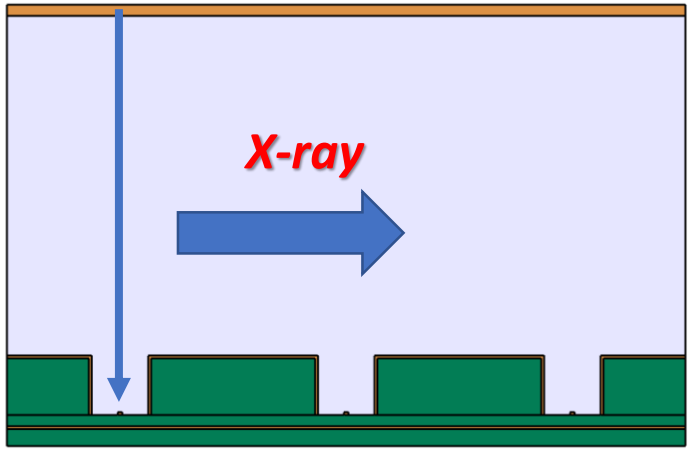




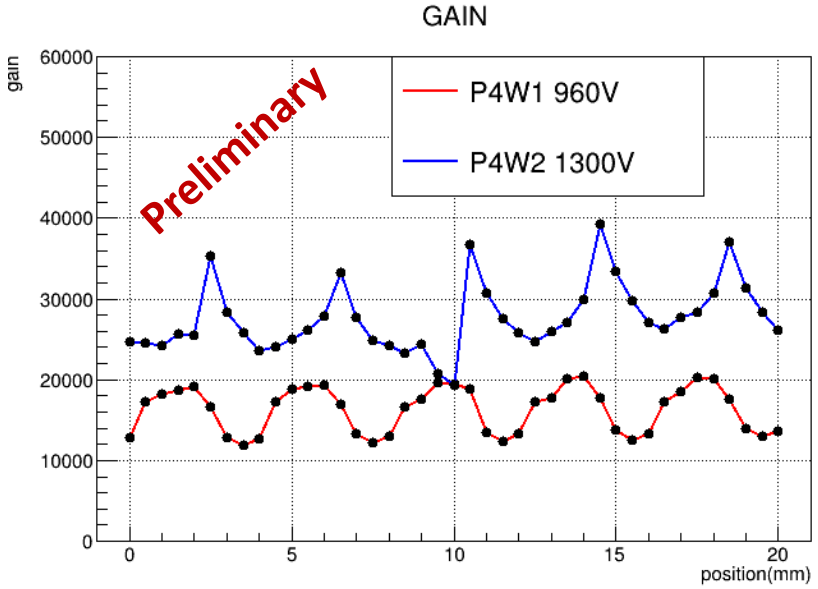
Rate～13MHz

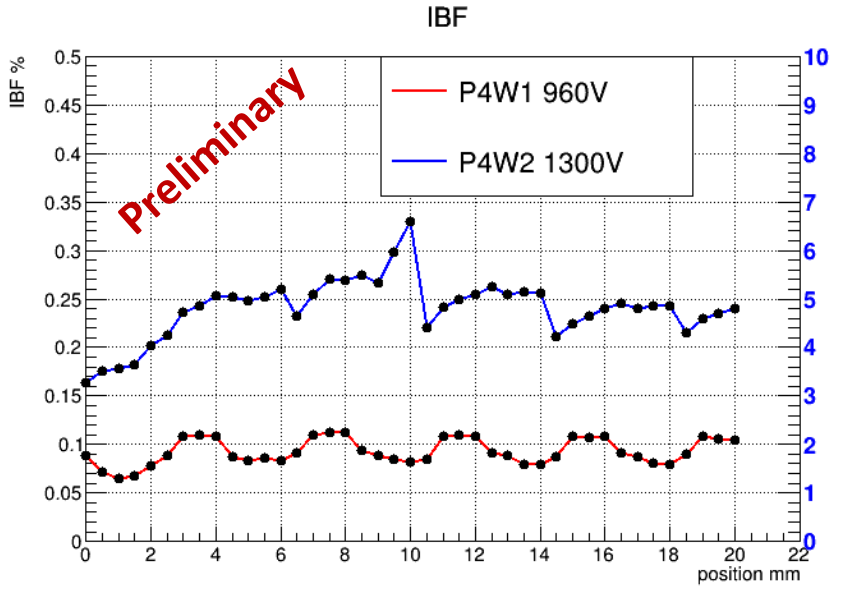
Gain and IBF uniformity

Step= 0.5mm
Point= 41
Rate ~15000Hz



- **The gain changes periodically with position, not understood yet.**
- **We will try to reduce the pitch to improve it.**



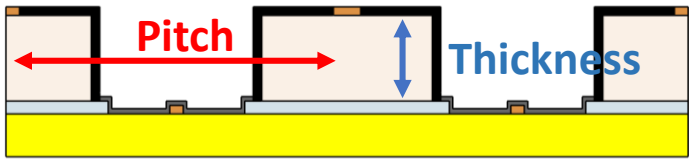


Summary

- We have developed a new structure: PCa (Proportional Counter array)
- Simple structure, easy fabrication by the standard PCB technique
- High gain(can be increase further), high efficiency and low IBF
- Good potential of scaling up (PCB version)
- With DLC we can increase the signal of pad , and remove charging-up effect
- The gain uniformity needs more study.

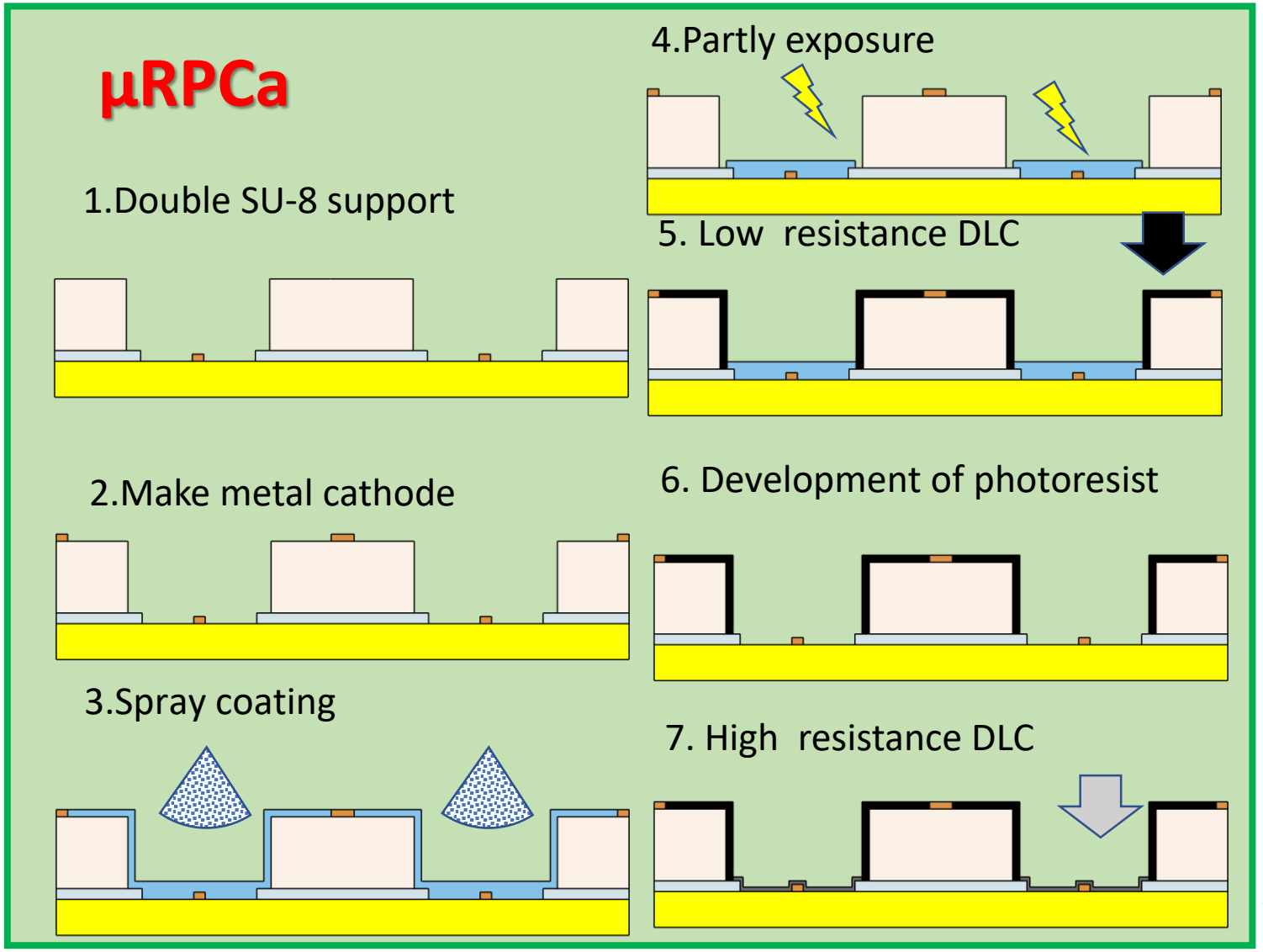
Outlook 1

- To reduce the pitch of the grooves may get better uniformity
- The PCB version cannot produce amplification structures with smaller pitch due to the mechanical strength
- Try to produce µRPCa by nano techniques



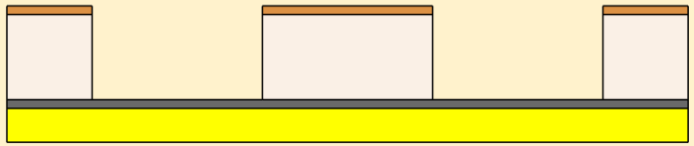
Pitch: 4mm →~200µm

Thickness : 1mm →~ 50µm

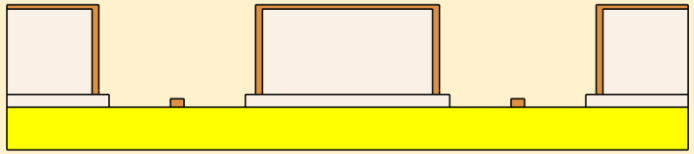


Outlook 2

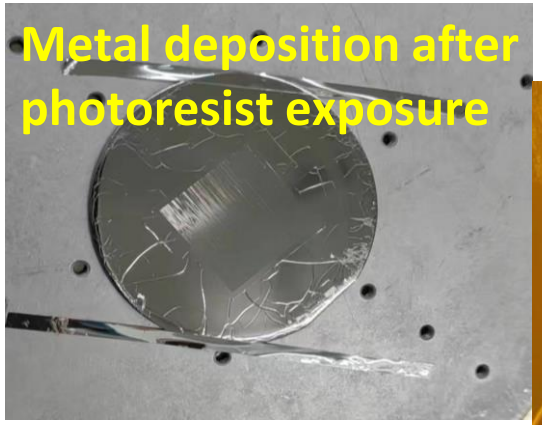
µRGroove



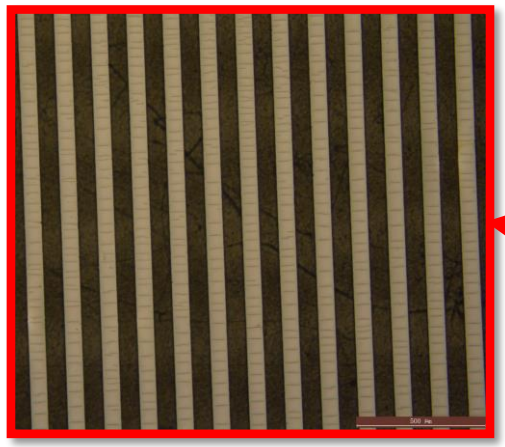
µPCa

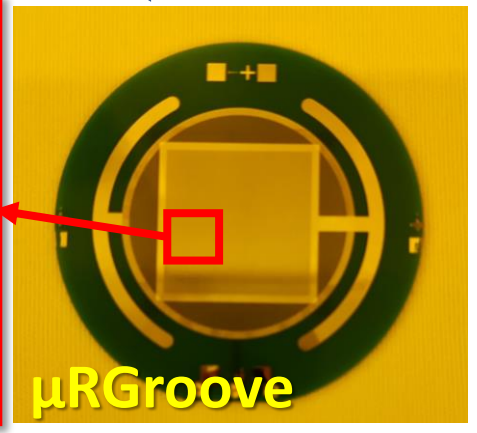


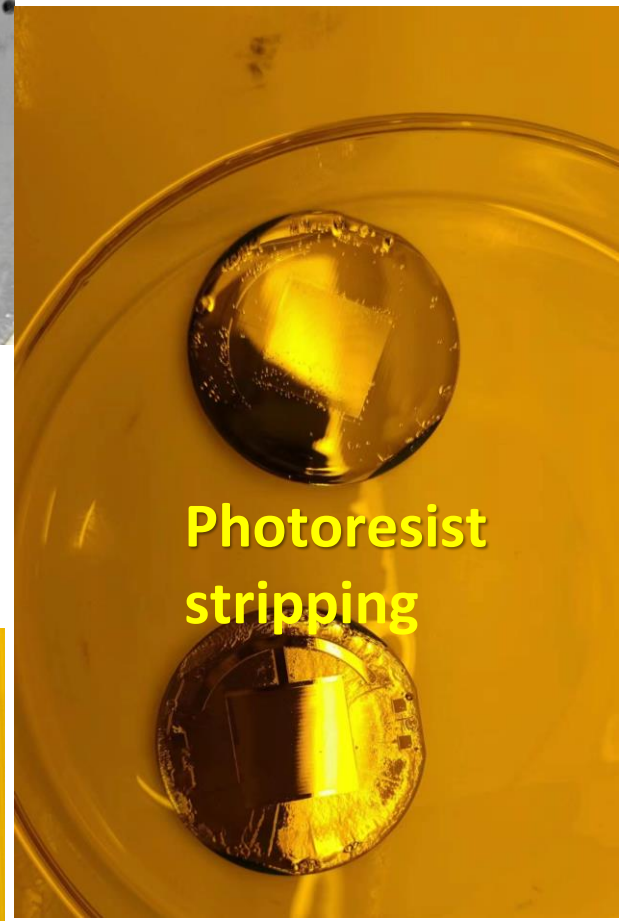
µRPCa



µRGroove is ongoing

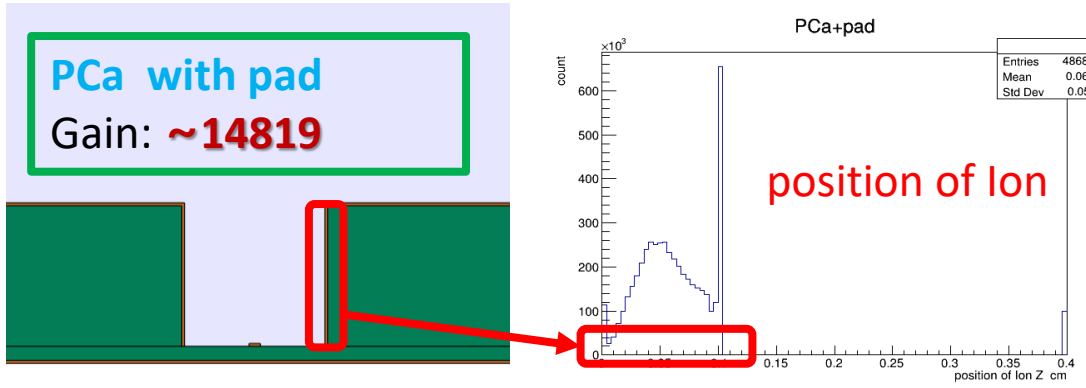


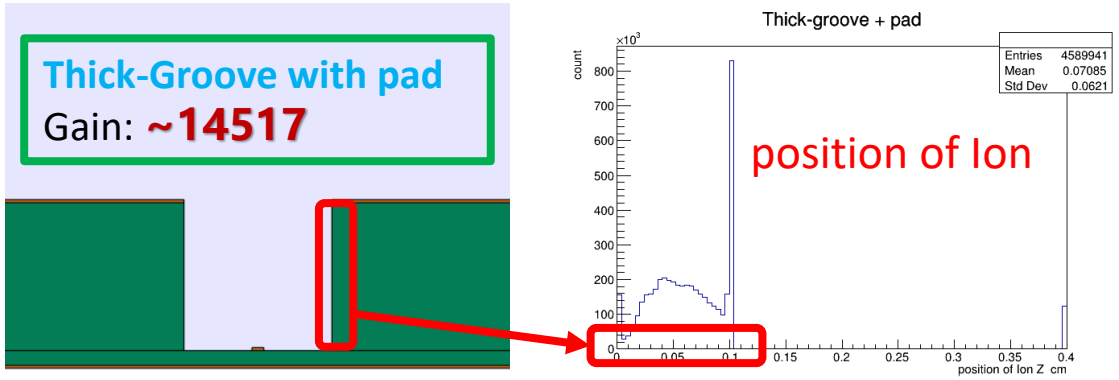


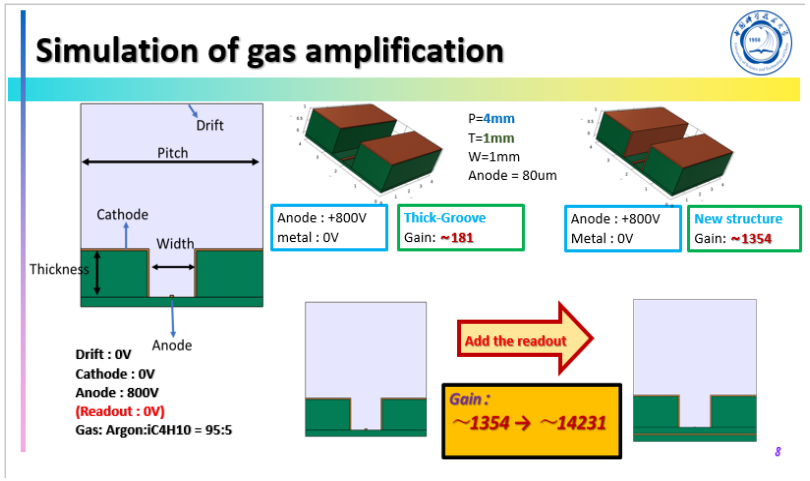


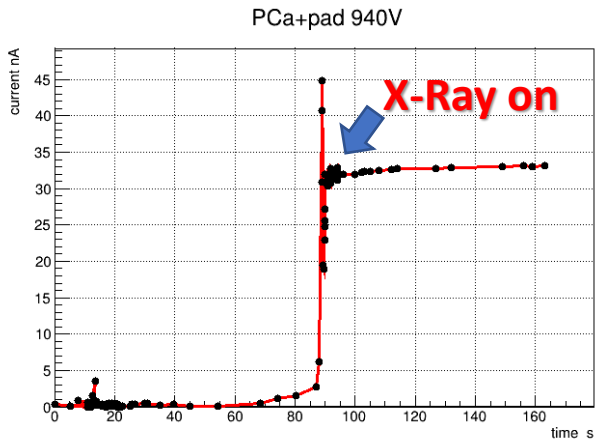
Backup

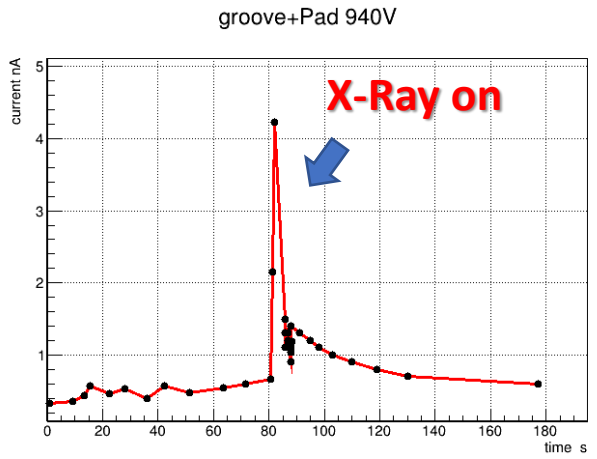
Add readout pad position of Ion









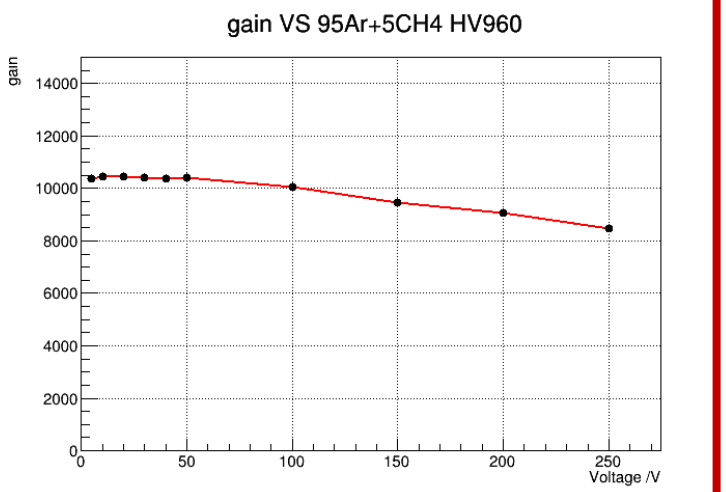


RD51 Collaboration Meeting 13-17 June 2022 , Tian Xiangqi, Preliminary results of the Proportional Counters array (PCa)

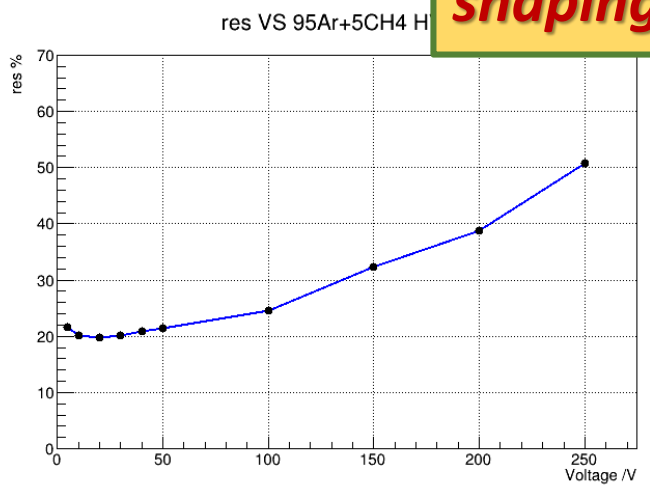
PCa anode current gain

Thick-groove anode current gain

Energy spectrum .VS. drift field(P4W1)

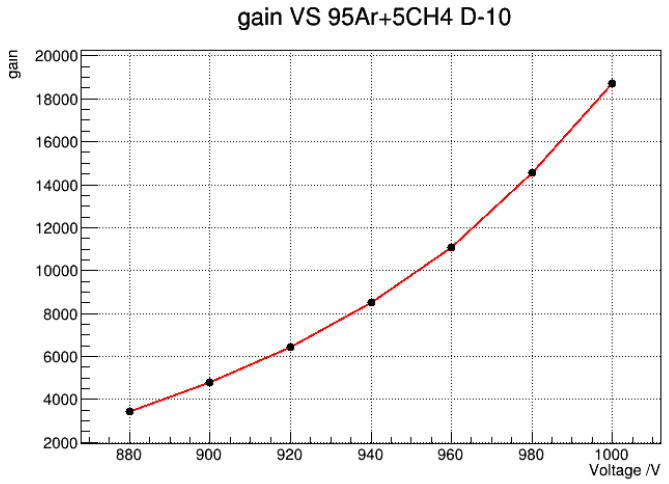


HV=-960V

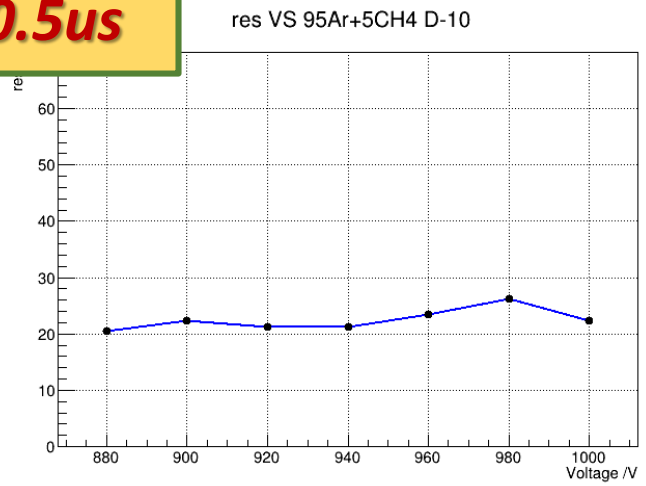


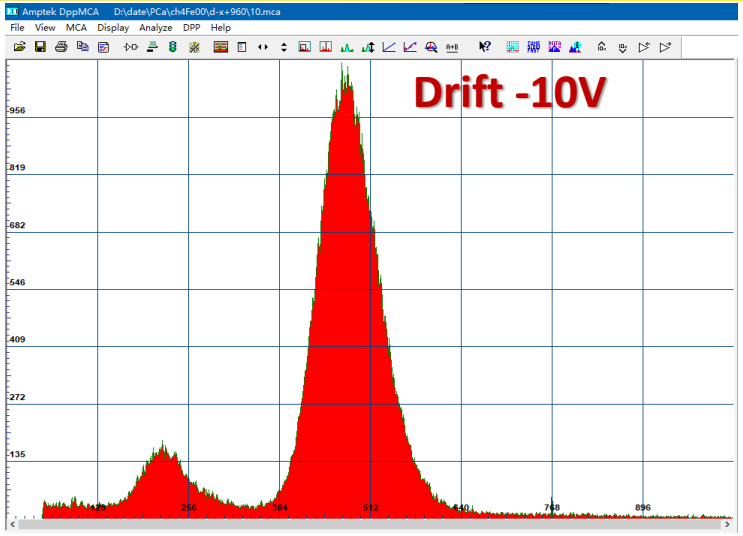
D-C-A ~ -LV-0+HV

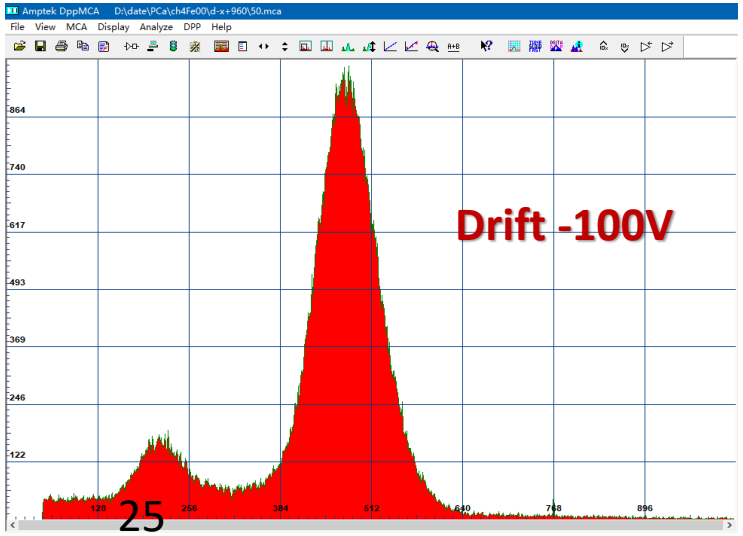
shaping time 0.5us



LV = -10V

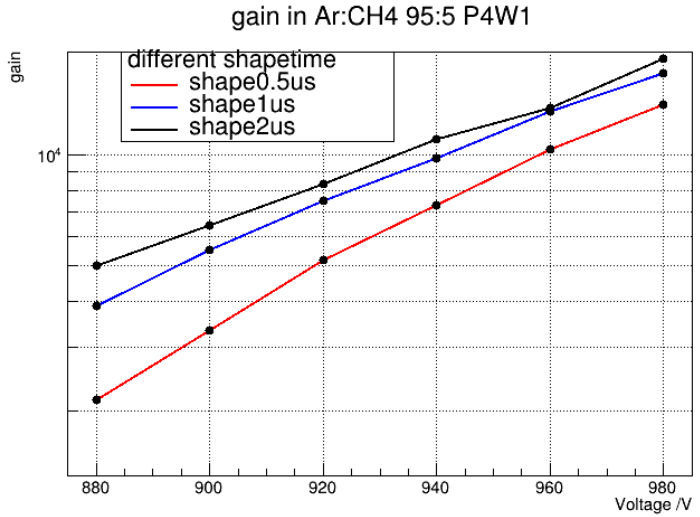


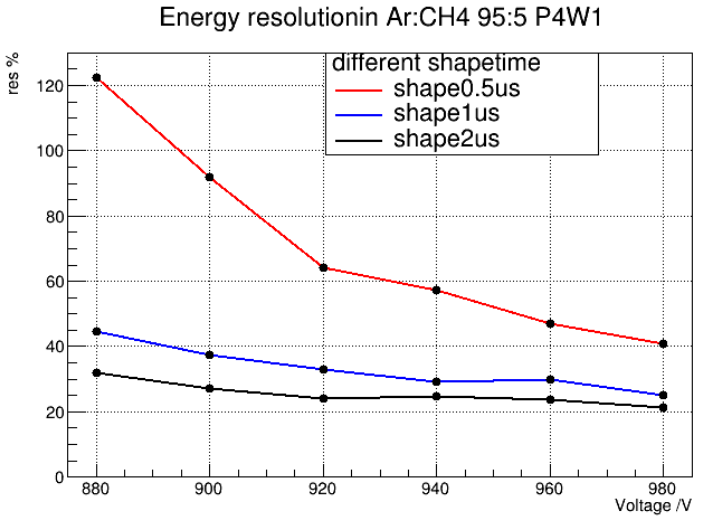




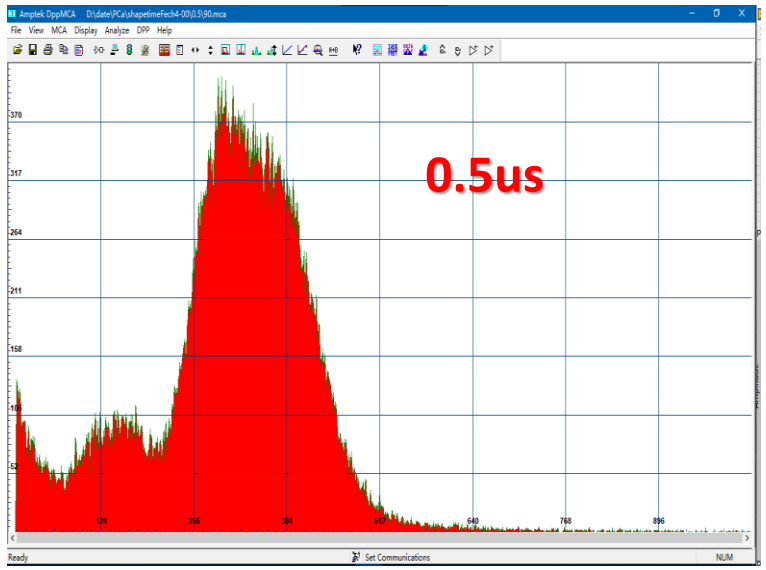
25

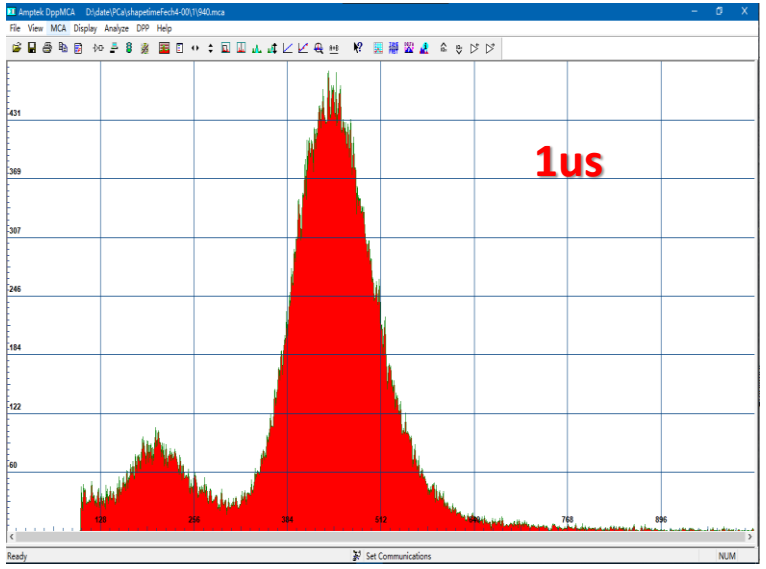
Energy spectrum .VS. Shaping time (P4W1)

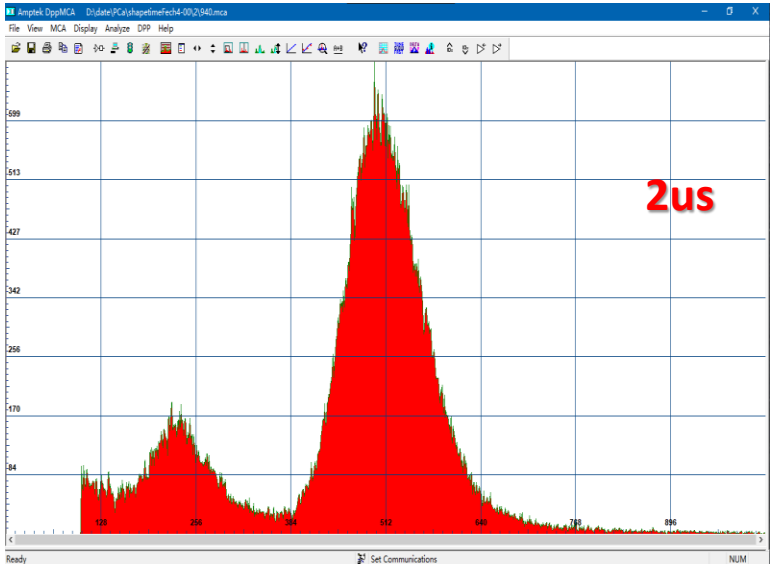


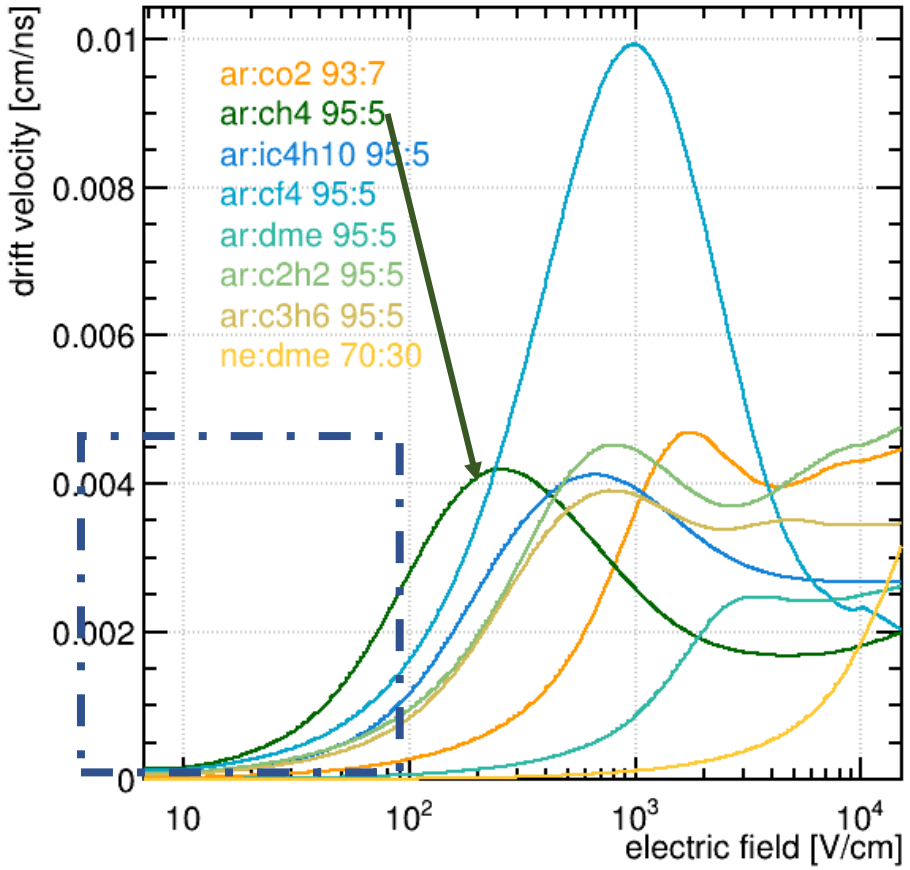


Gas : Argon : CH4 = 95:5
Voltage : Drift = 0V
Cathode = 0V Anode = +HV

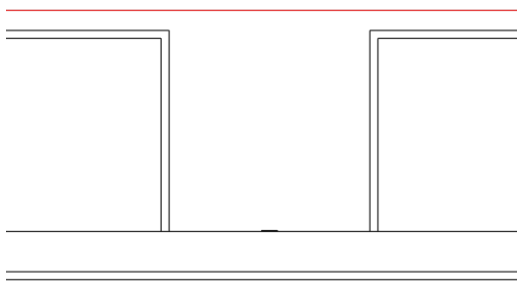




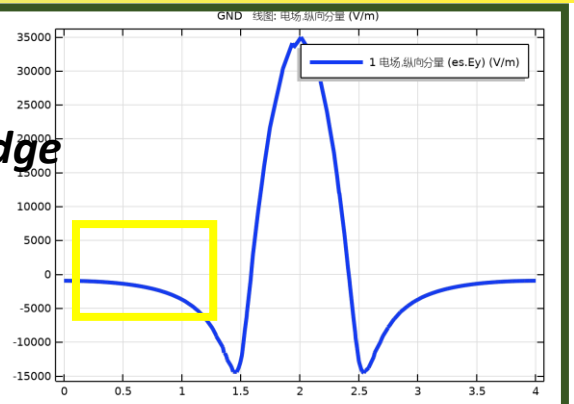




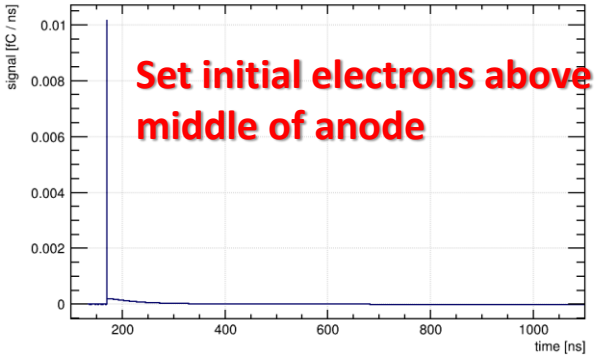
Simulation several gas mixture Drift velocity find Argon with CH4 is the fastest



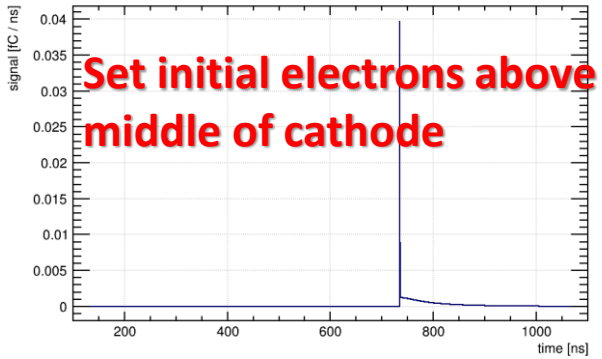
Drift field is so weak in the edge the groove



***Finite element calculate* Drift field**



Set initial electrons above middle of anode



Set initial electrons above middle of cathode

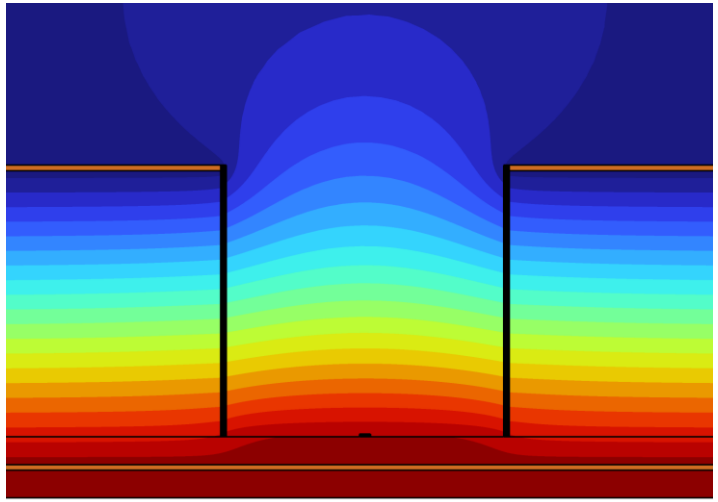
Using Gatfield++ simulation the signal arrival time

Changing test conditions(using CH4):

Change the signal forming time of the amplifier

change the drift field (-drift or +Cathode)

Wight of field for DLC wall and anode



Less coverage area than DLC anode + metal wall .
For the signal of ion the gain will be reduce