Development of AT-TPC in Sejong University

2024.03.09 HIM meeting

Yechan Cheon

Contents

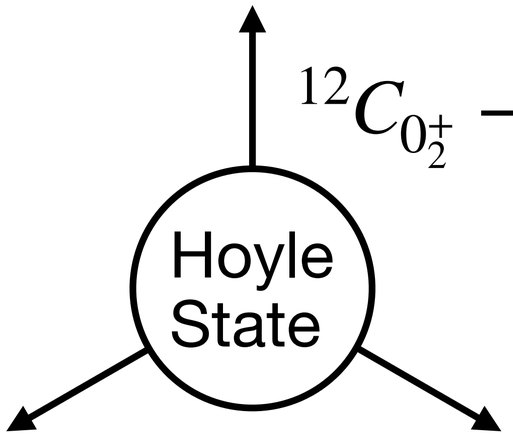
Introduction

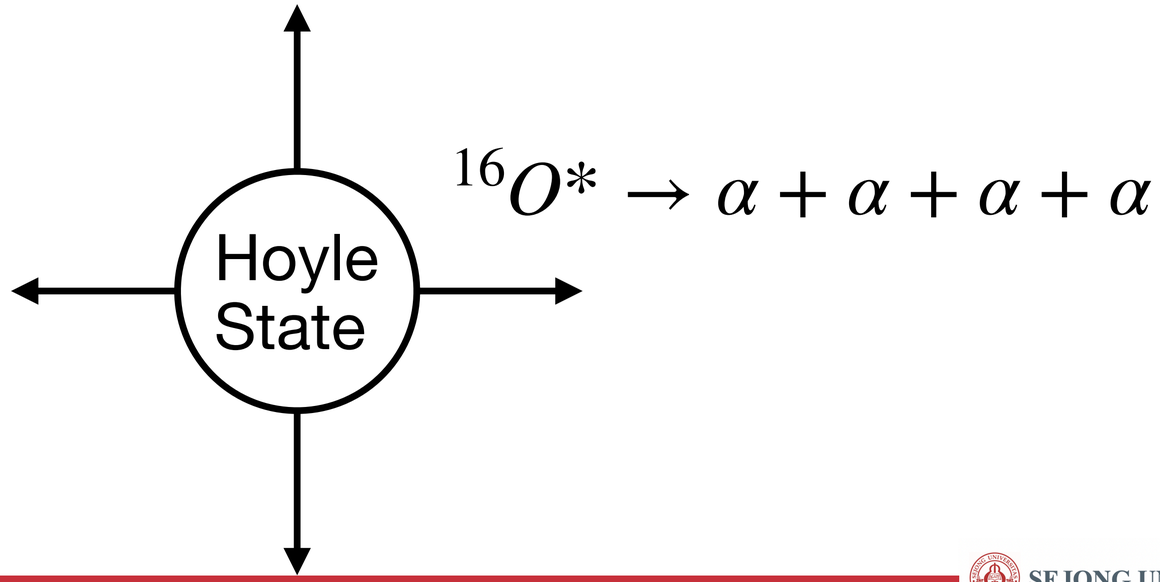
Hoyle state

One of excited state in α-conjugate nuclei,

It refers to the state where α particles are resonating within the nuclei.

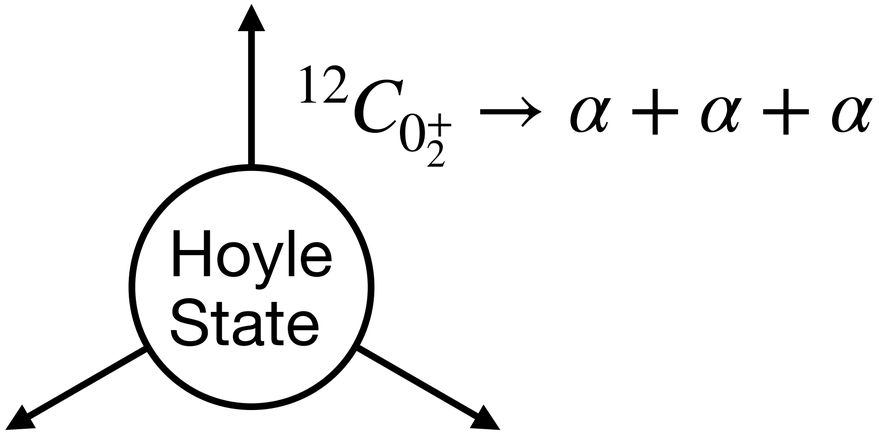
Hoyle state is evidently a alpha cluster state. Recently, there was many theoretical development which suggests it is in a Bose-Einstein condensate.
For example. THSR model in PRL 87, 192501 (2001).





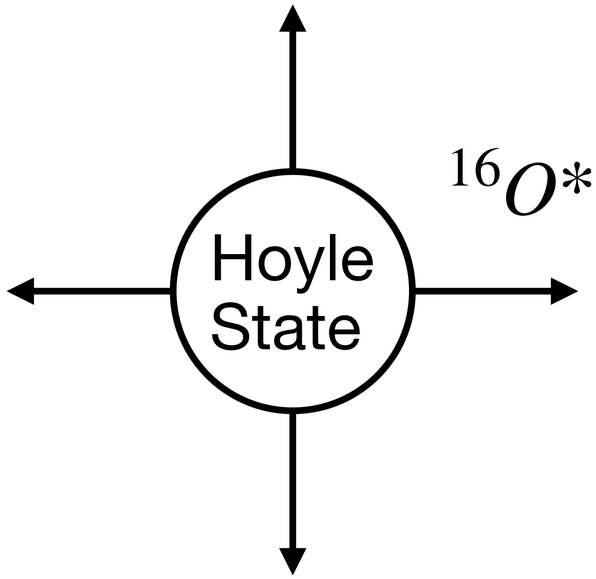
Introduction

Hoyle state



If this exists,

the symmetric 3α decay must exist,
however no one observed it due to
its decay rate is too low.
We aim to measure this.

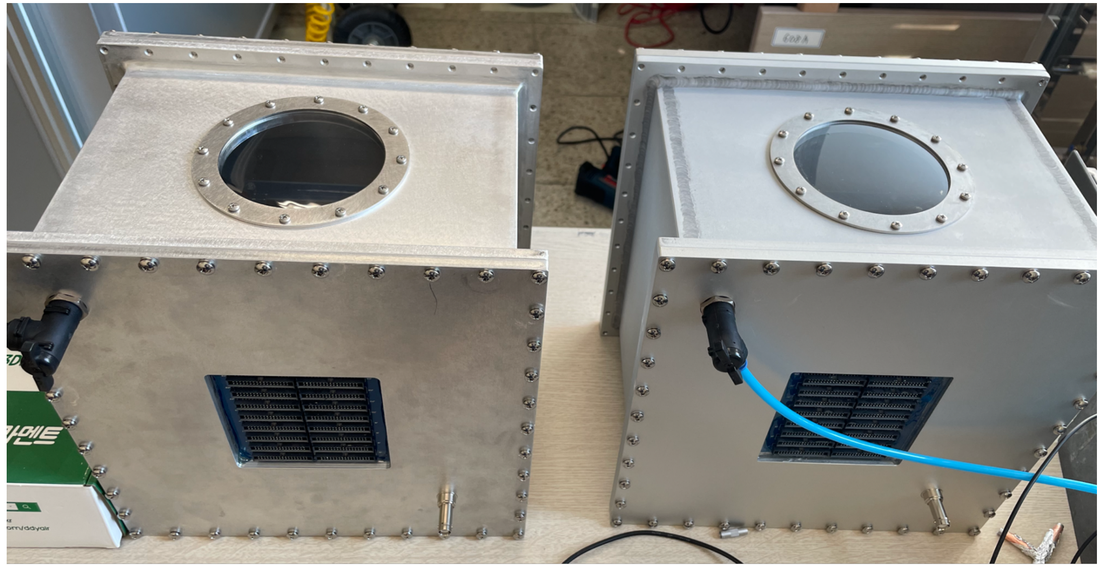


$^{16}O^* \rightarrow \alpha + \alpha + \alpha + \alpha$

We also try to measure α cluster in Oxygen,
It is never observed

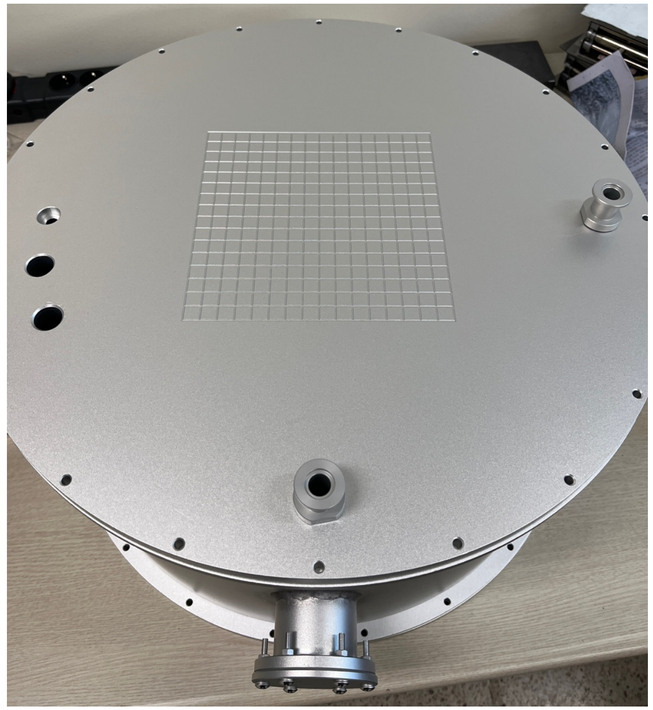
TPCs

Proto-type TPCs



In experiment at HIMAC
using prototype TPCs,
We successfully measured
$^{12}C(p, 2p)\ ^{11}B$

TPC-Drum (Working on)

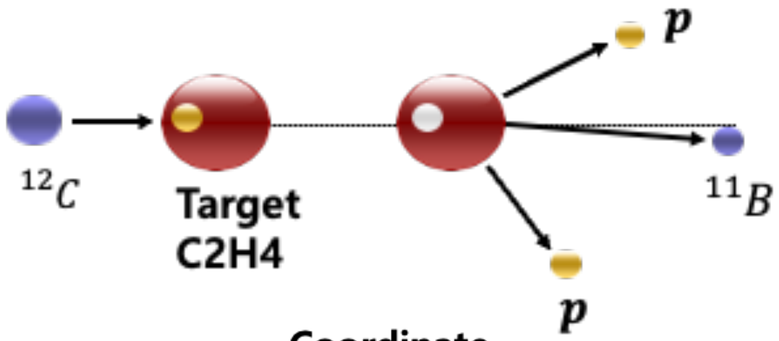


We proposed 20Ne + alpha collision
experiment at RAON this year.
The proposal is under PAC review.
If it is approved, we will do experiment
in early summer

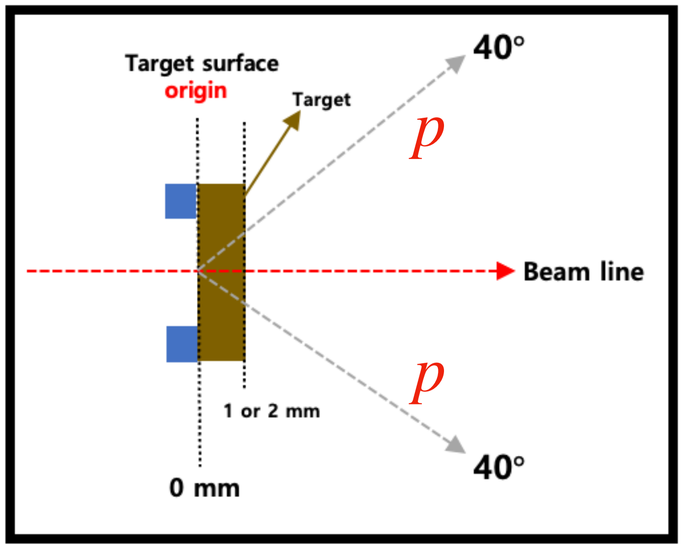
Experiment at HIMAC

p+p Quasi-Free scattering

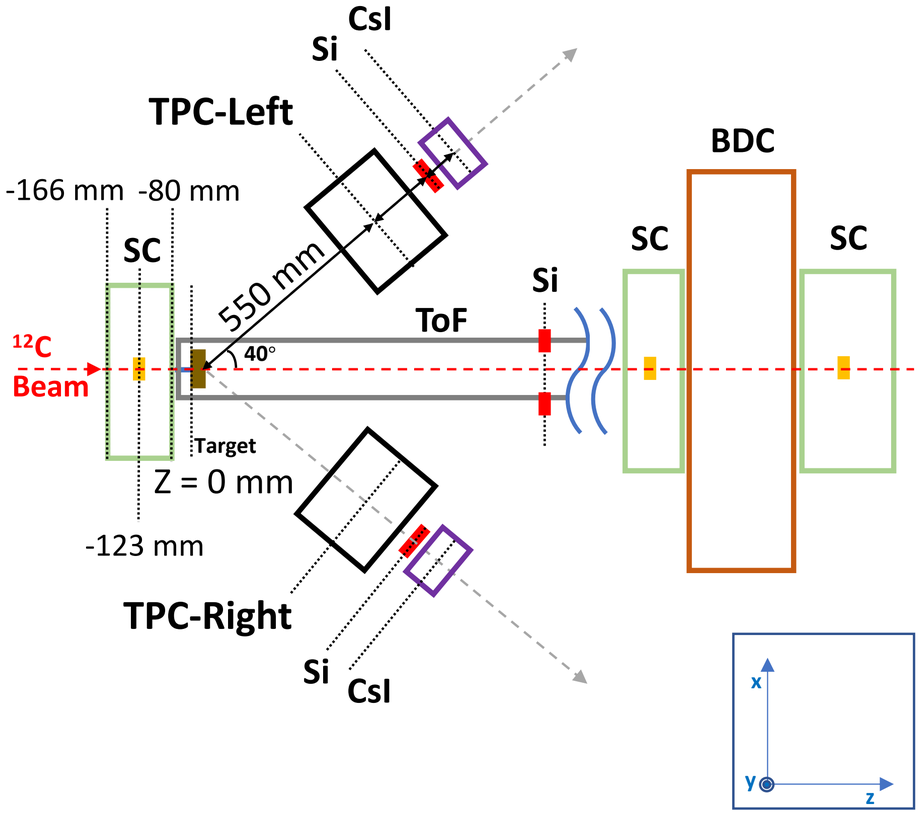
Measurement the cross section $^{12}C(p, 2p)\ ^{11}B$



Coordinate



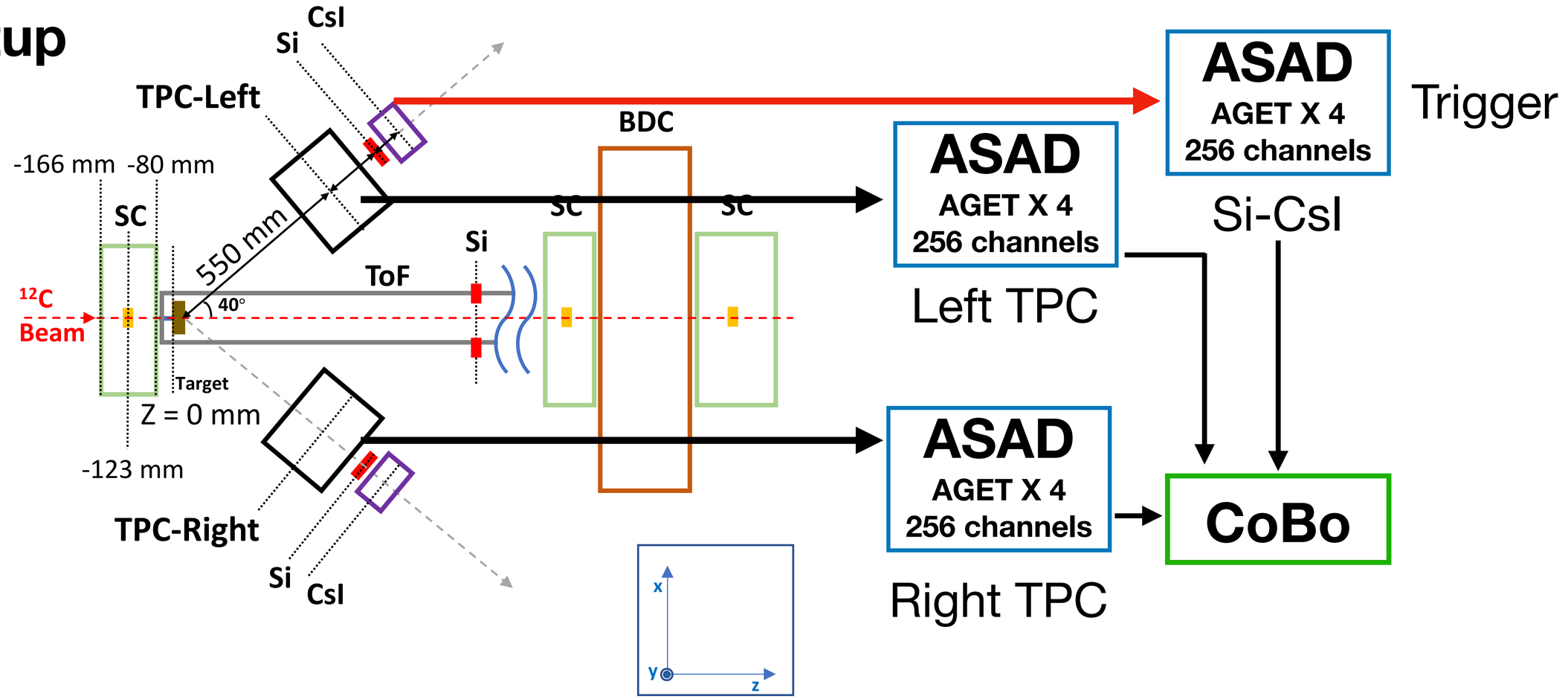
Geometry



Beam : Carbon 200MeV/u,
beam intensity ~10^6/fill

Experiment at HIMAC

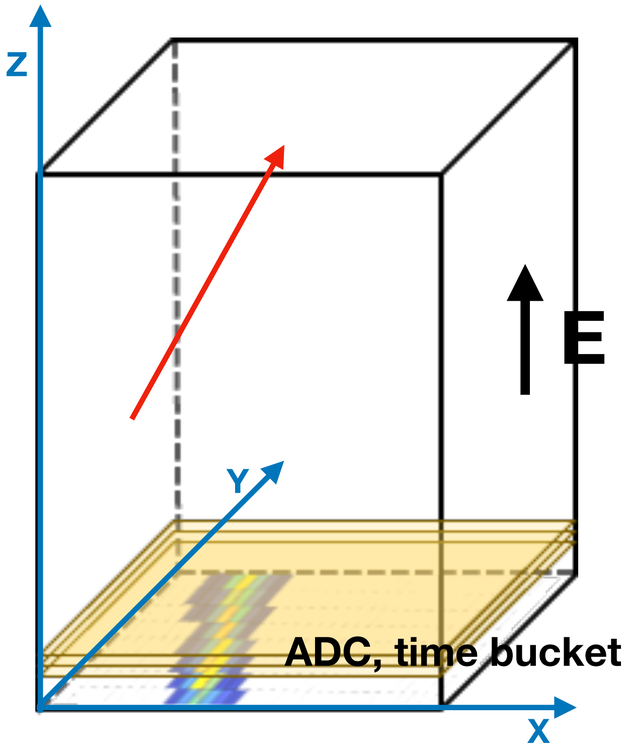
DAQ setup



Data taking for TPCs and Si-CsIs using 4 Asad

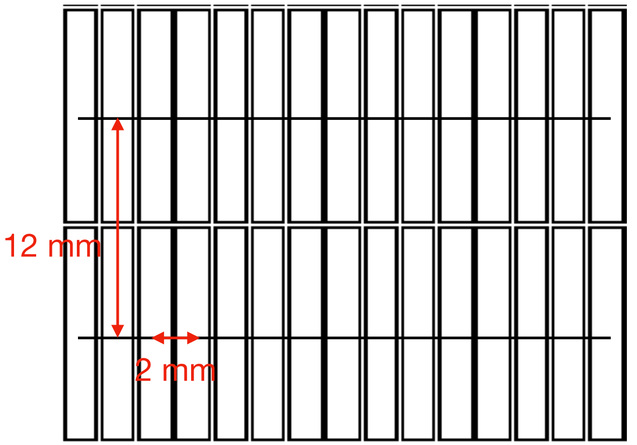
They are triggered using the SC in the upstream and each CsIs

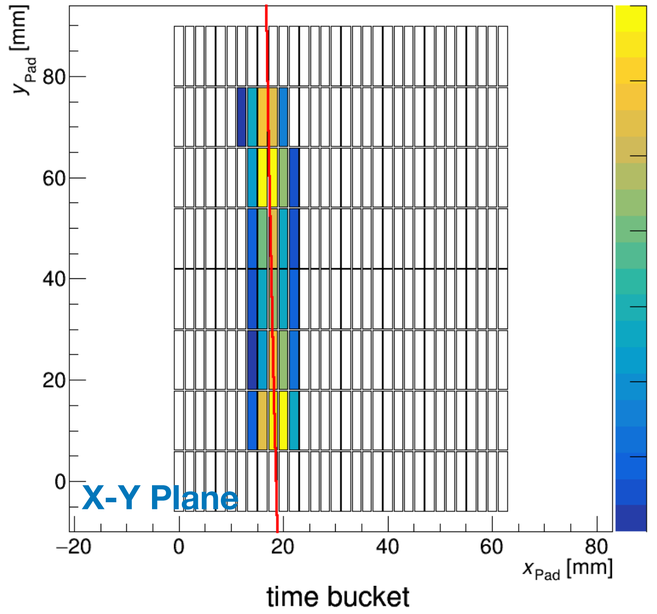
Proto-type TPC

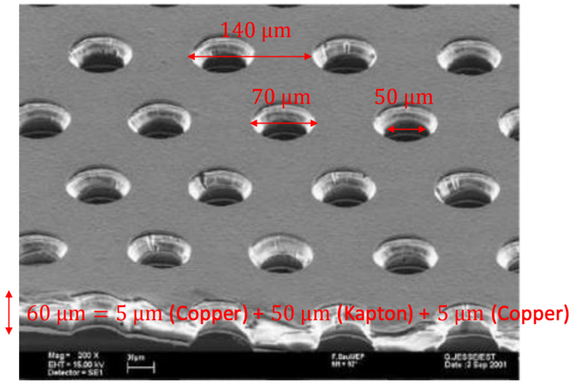


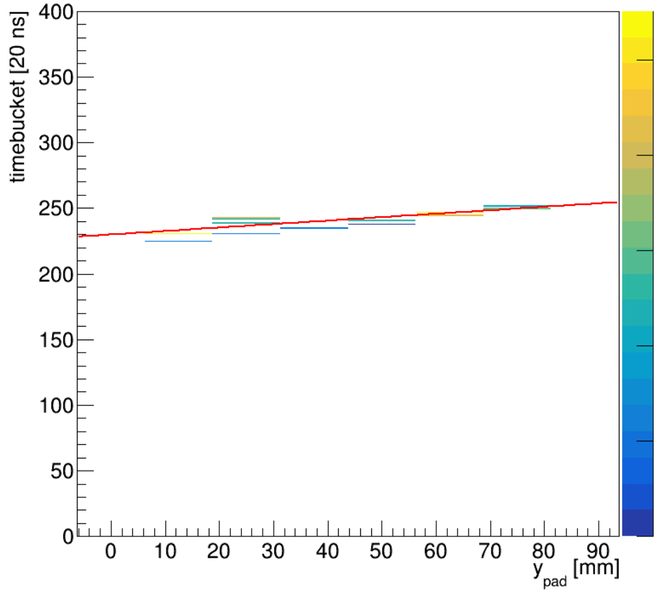
Row 32 Column 8
channel 256

Pad Height 11.9 mm
Pad Weight 1.9 mm
Pad Gap 0.1 mm









Active Area : 64 x 96 x 150 mm

Target Gas : P10 (Ar 90% + CH_4 10%)

GEM Layer : 2 mm

GEM Thinkness : 60 μm

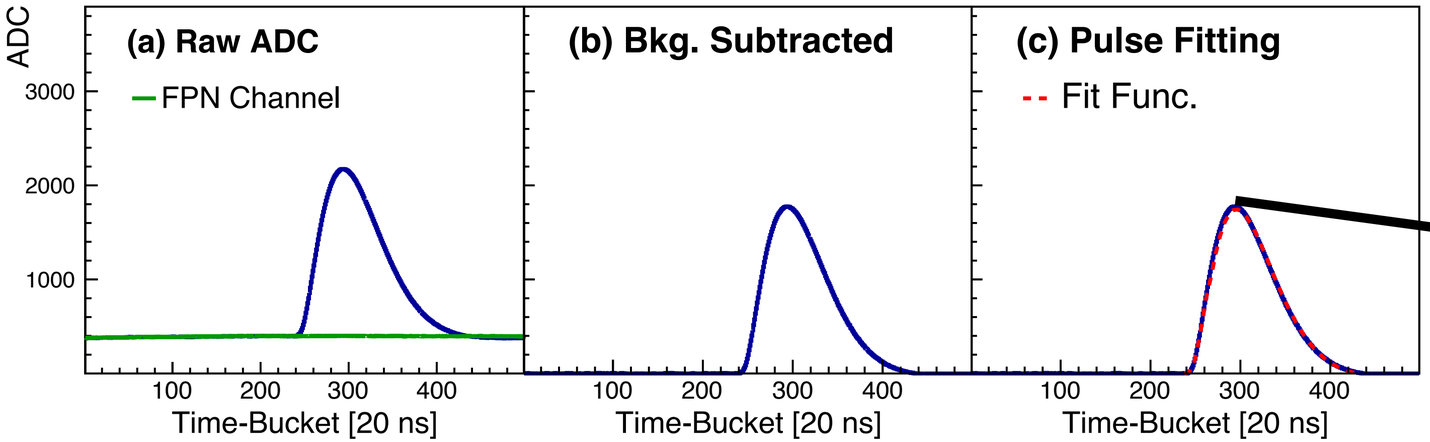
Triple GEM

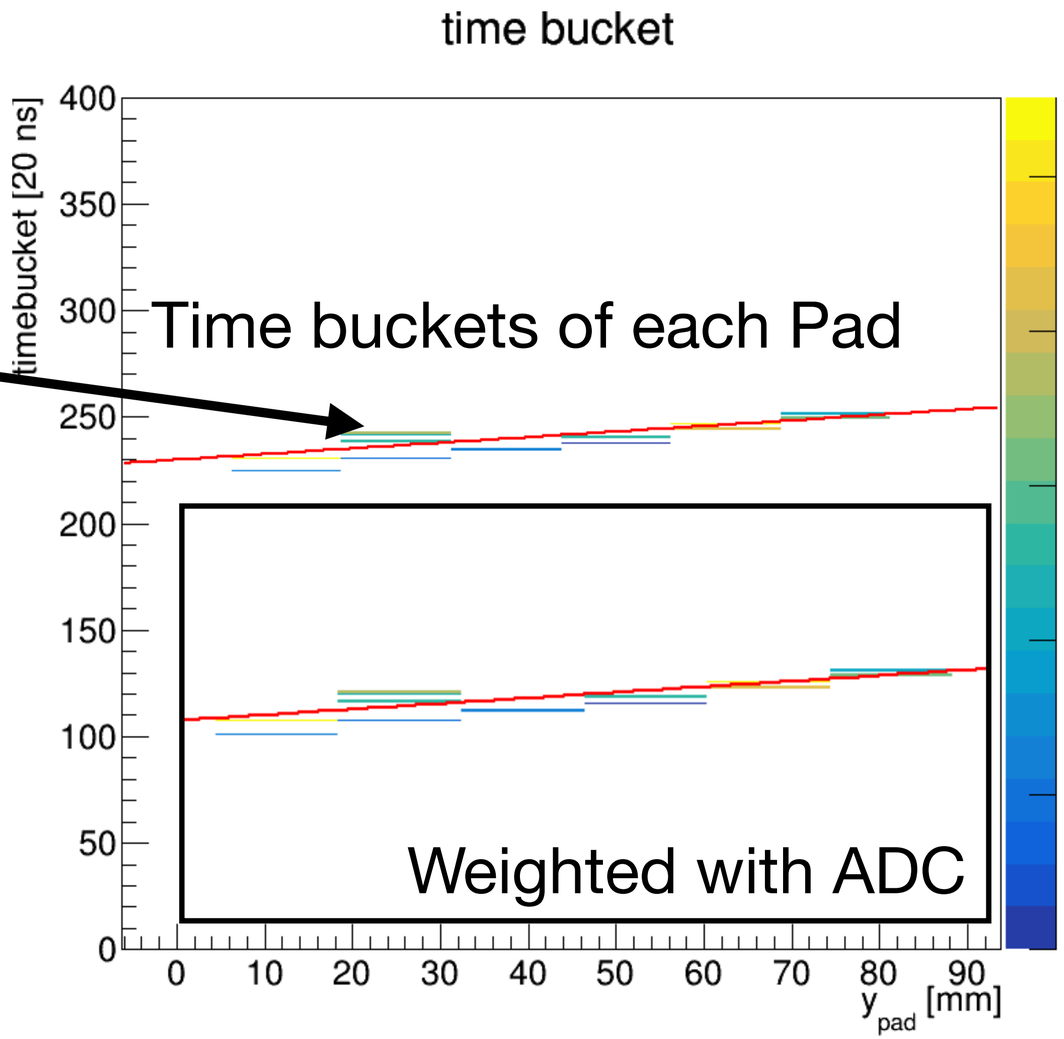
$\Delta V_{GEM} = 350V$

Active Area = 100 x 100 mm

Reconstruction

Pulse extraction & Fitting



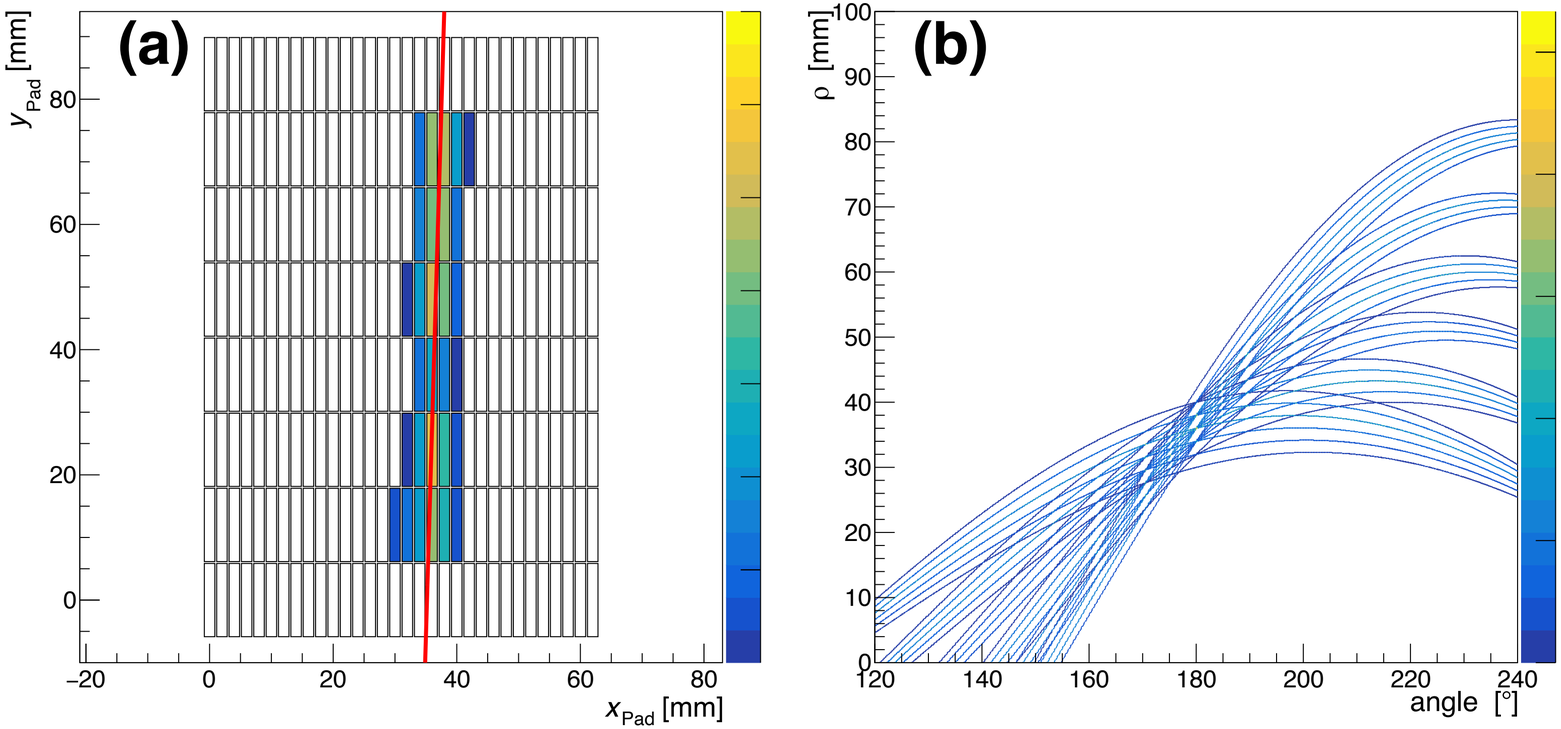


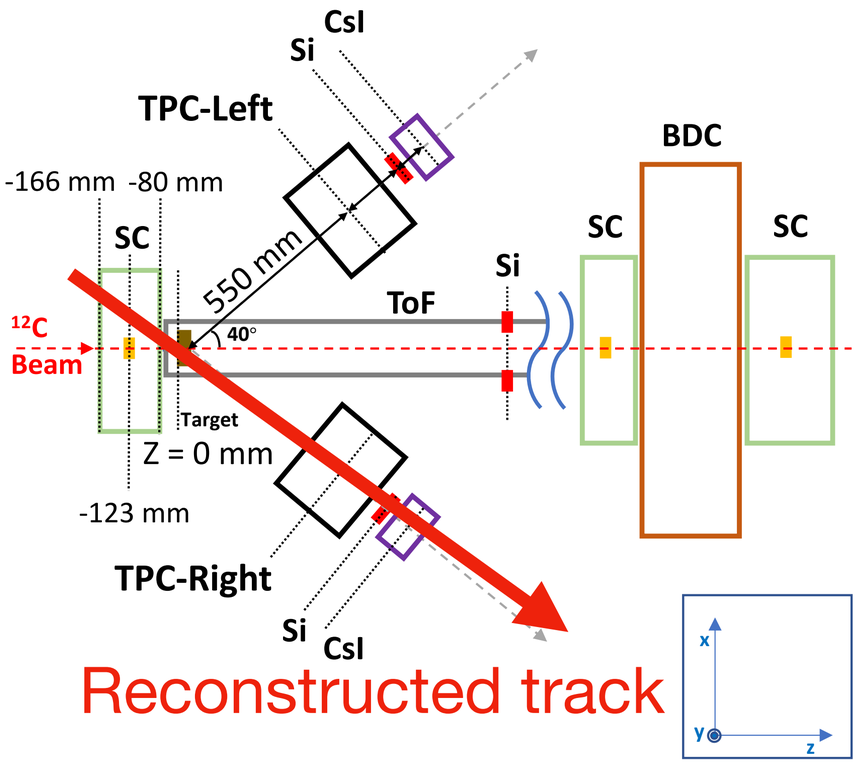
The background of ADC can be subtracted with information from Fixed Pattern Noise channel

We made the template of all of signal shapes, and signals were fitted with the template

Reconstruction

Tracking algorithm

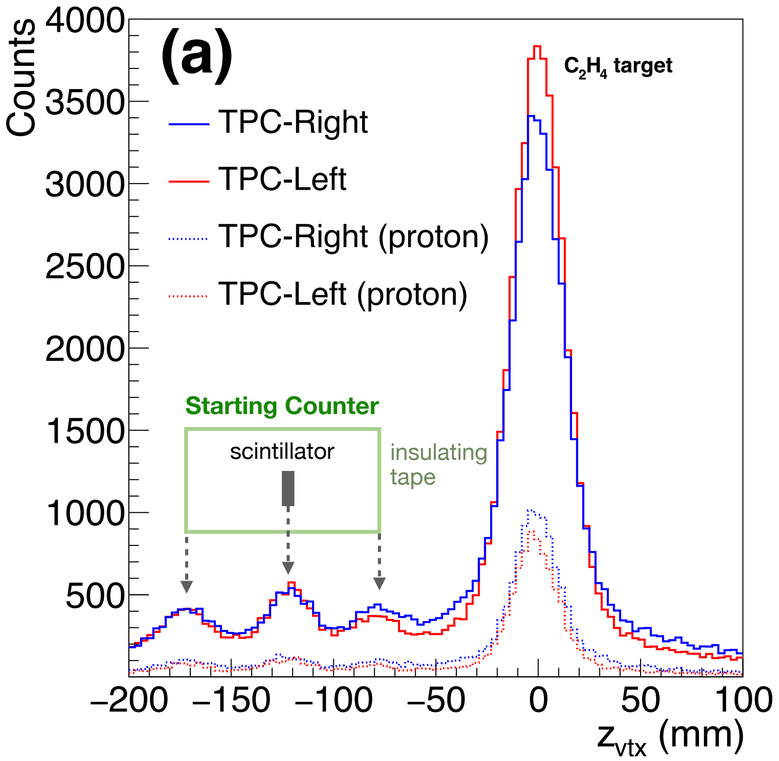


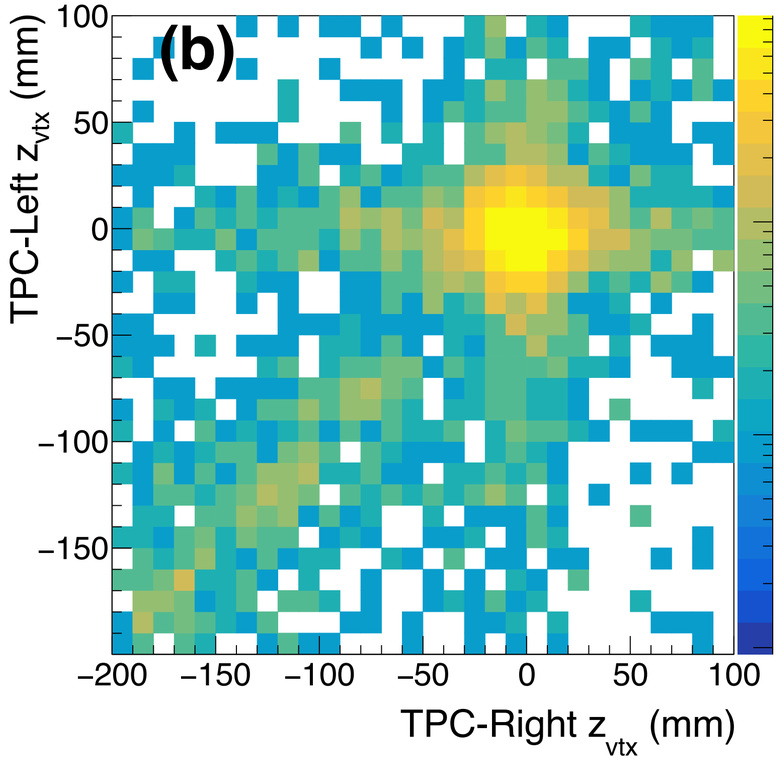


Hough transform maps each TPC hits
to curve in the space of the intercept and the angle

Reconstruction

Drift velocity & target vertex





$Z = (t_0 - t_{off}) \times v_d$

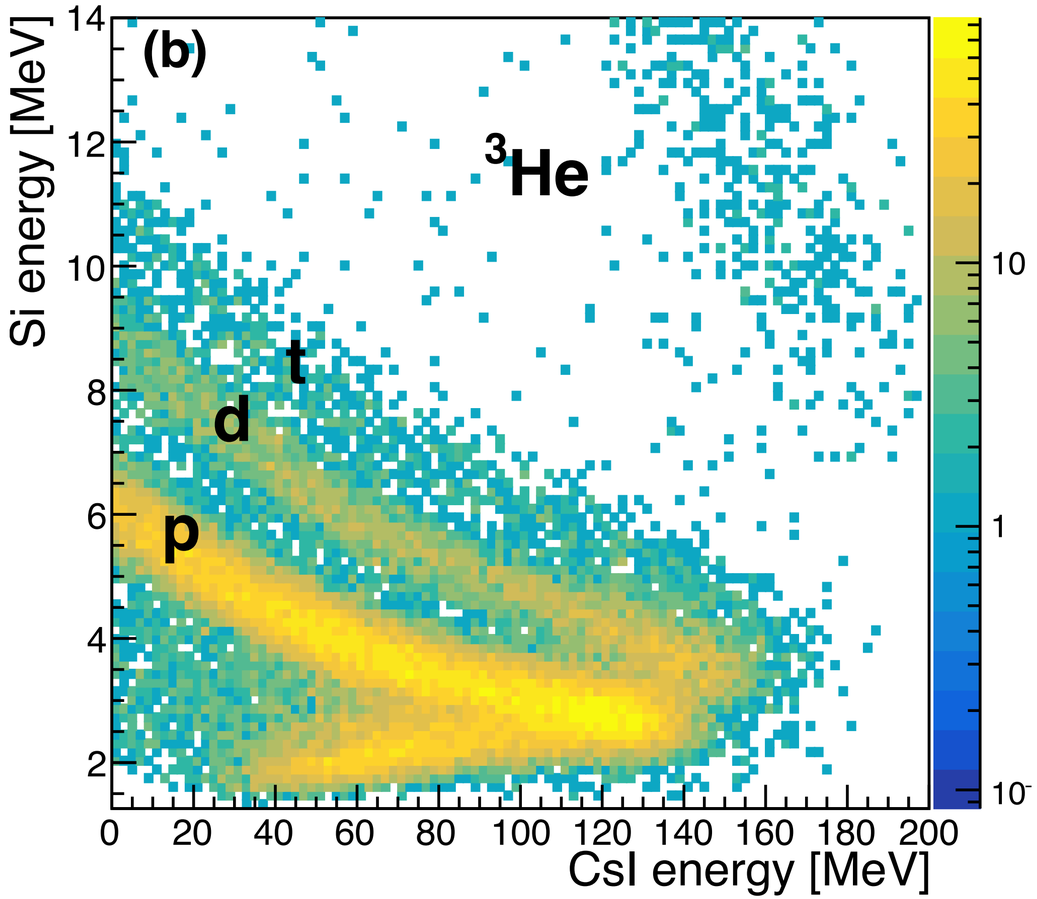
$$v_D = 5.6 \pm 0.1 cm/\mu s$$

We fixed t_{off} by matching the reconstructed vertex position (z_{vtx}) to the target position (z=0) in the lab frame

We extract v_d using the distance between target and the SC

Reconstruction

PID using Si-CsI



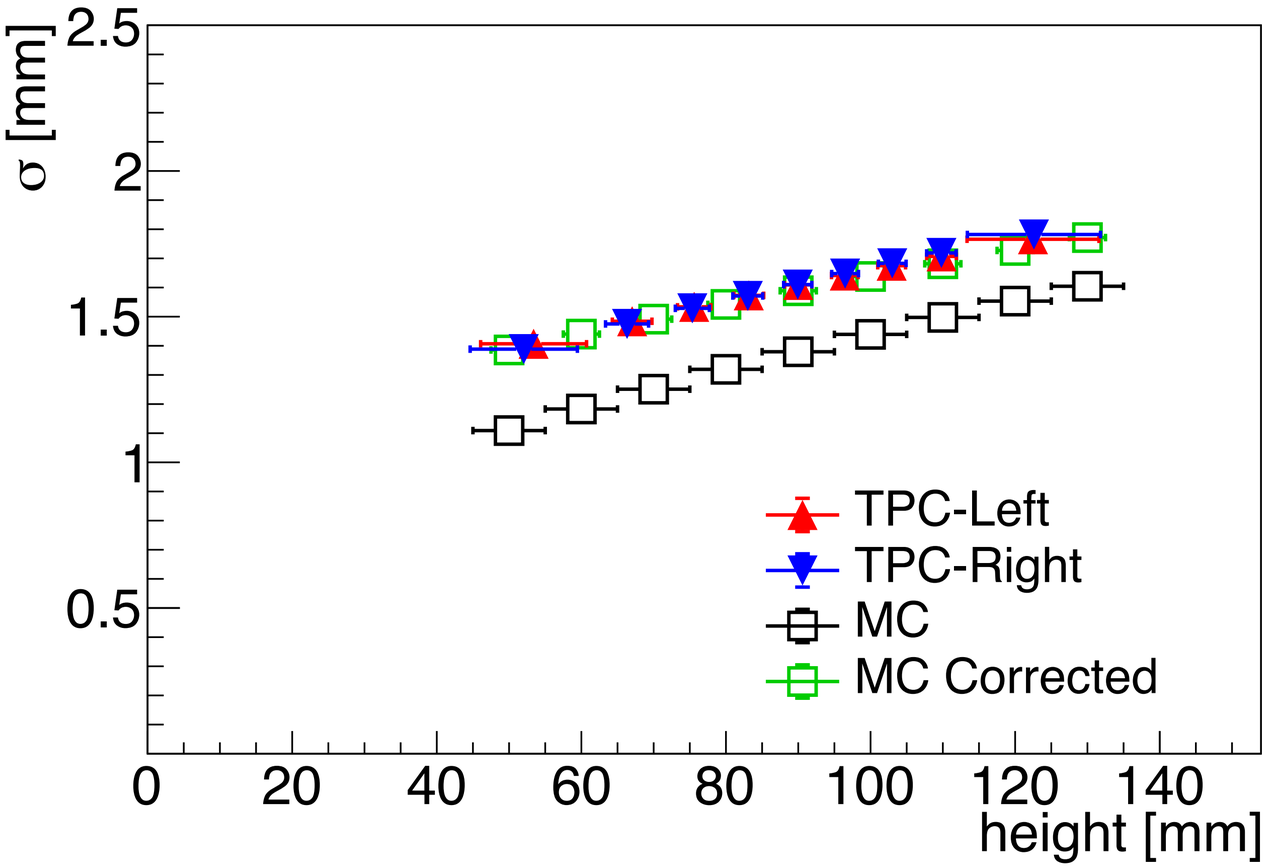
PID relies on the correlation
of energy measured in Si (ΔE) and CsI (E)

If we use Si and CsI, it shows differences
of response of each particles

calibration runs using a 100 MeV proton beam
were conducted.

Performance

Diffusion



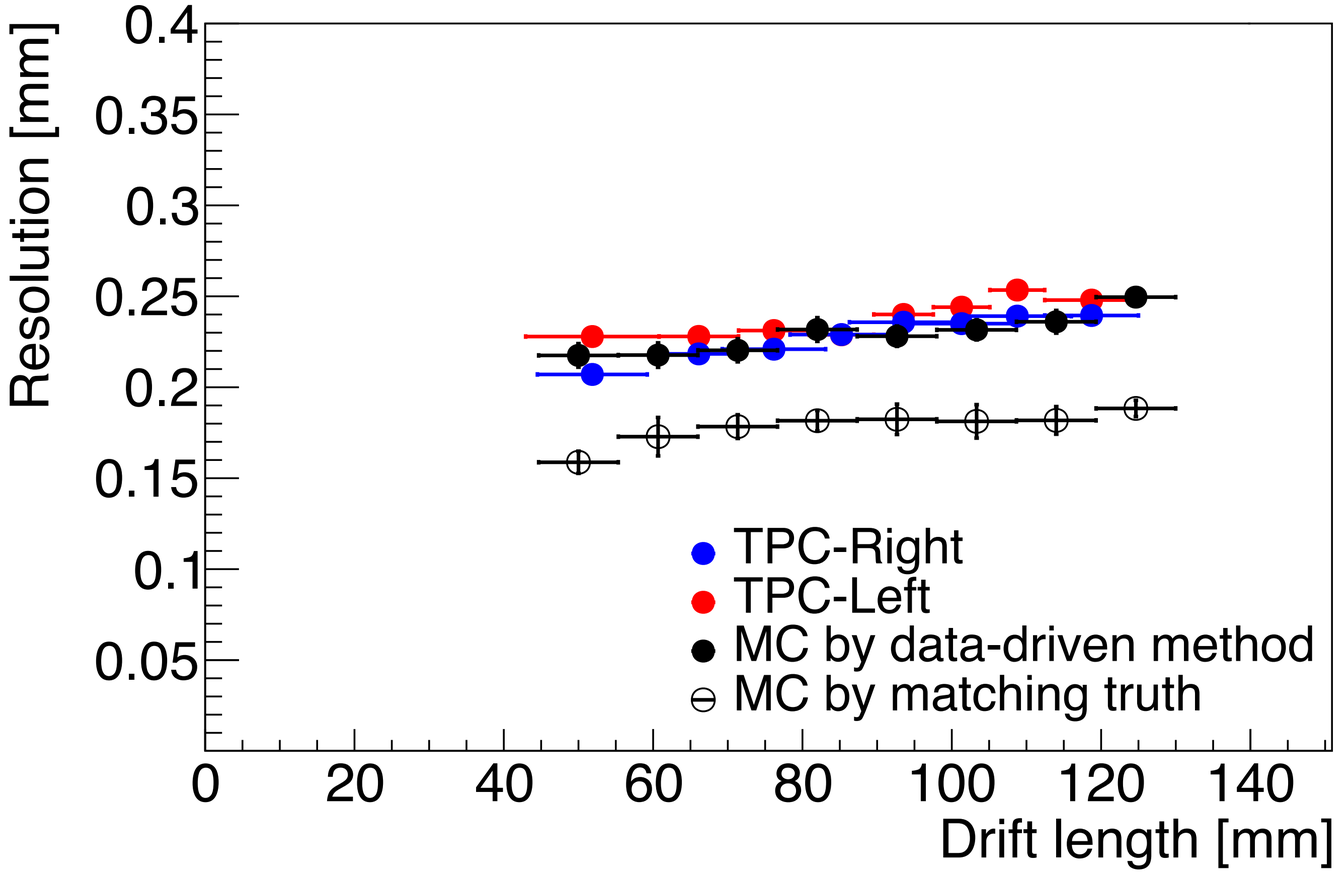
The diffusion of electrons leaves hits of 3-5 pad per layer

The result for Left and Right TPC agree very well with each other

In MC, It can consider only the diffusion effects from GEM and Gas
Hence, by comparing data and MC, we can understand unknown effects.

Performance

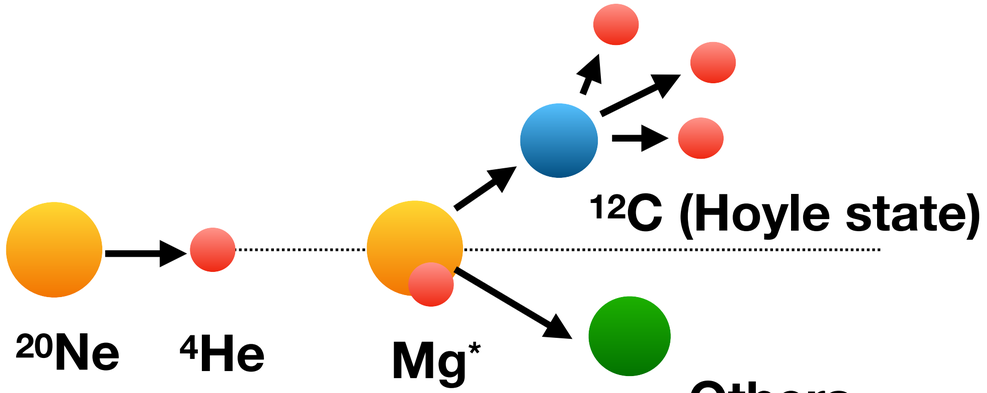
Tracking resolution

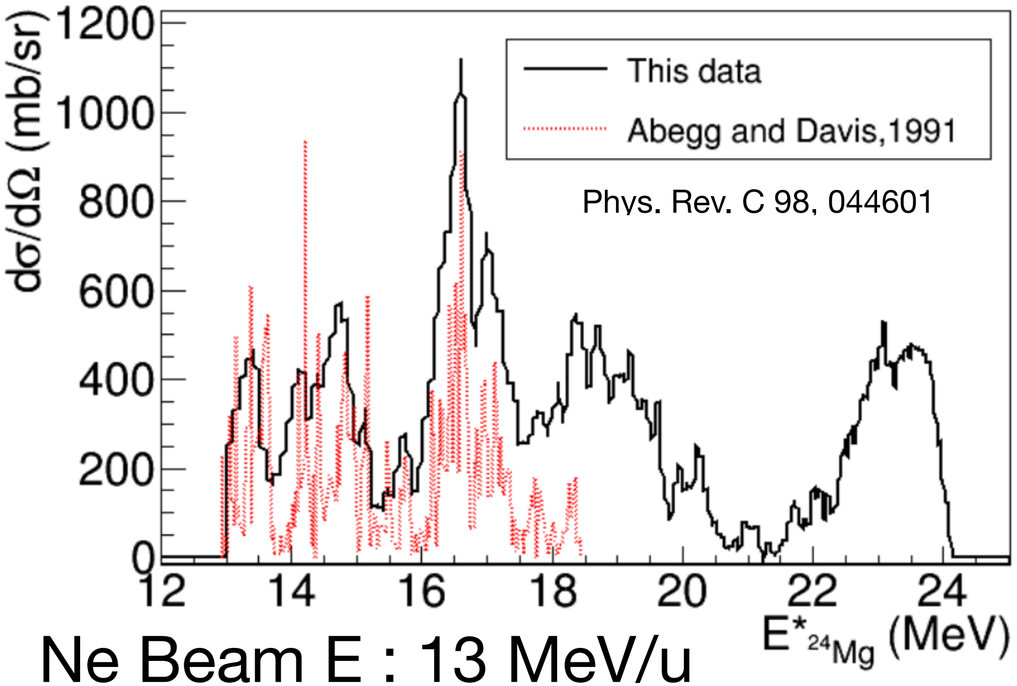


Particle positions are determined for each row of the matrix and calculating the ADC-weighted mean

Deviations between the reconstructed and reference positions followed a Gaussian distribution, with resolutions ranging from 210 μm to 250 μm, depending on drift length.

Observable





Ne Beam E : 13 MeV/u

Decay channels

Target

Ne + He -> 12C + 3α(Hoyle)

Background

Ne + He -> 12C + 12C -> 12C + 8Be + α

-> 12C + 3α

Ne + He -> 16O + 8Be (2α)

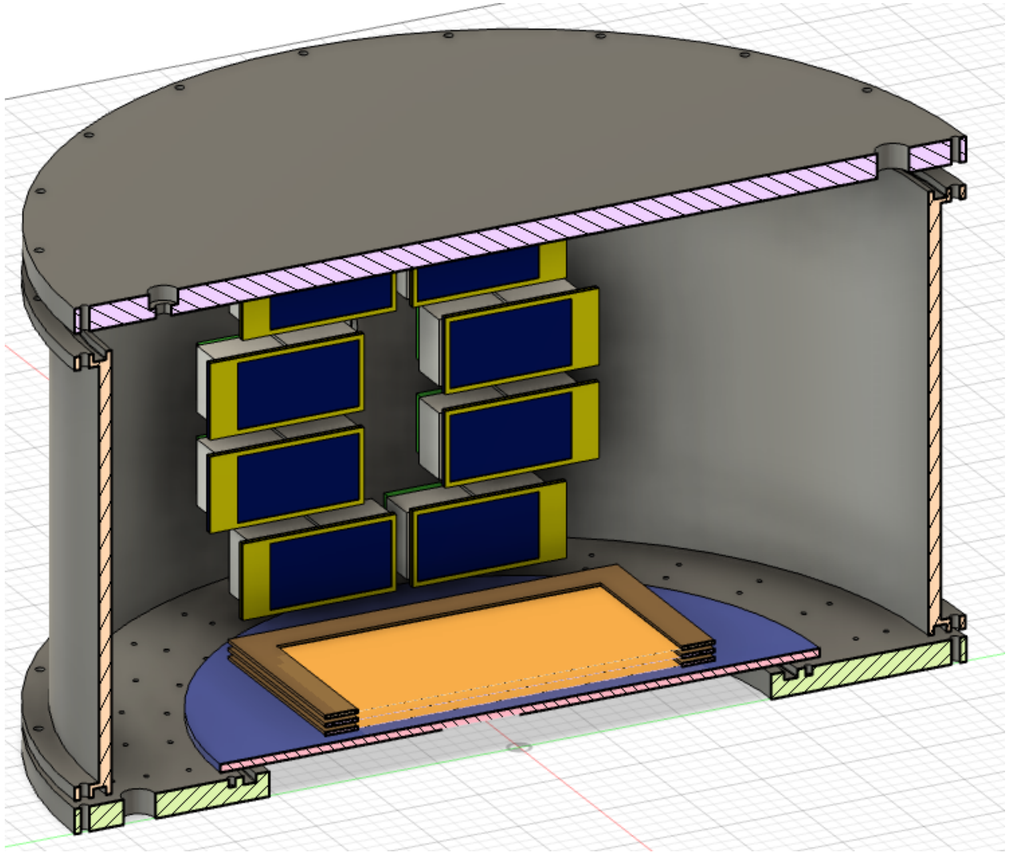
Ne + He -> 20Ne + α

=> every backgrounds were generated in NPTool MC

Decay channel	α+^{20}Ne	p+^{23}Na	^{12}C+^{12}C	^{8}Be+^{16}O
E_{th} [MeV]	9.31	11.69	13.93	14.14

TPC-Drum design

This AT-TPC is EXCLUSIVELY developed for experiment at RAON



AT-TPC

Active Area : 74 x 144 x 200 mm

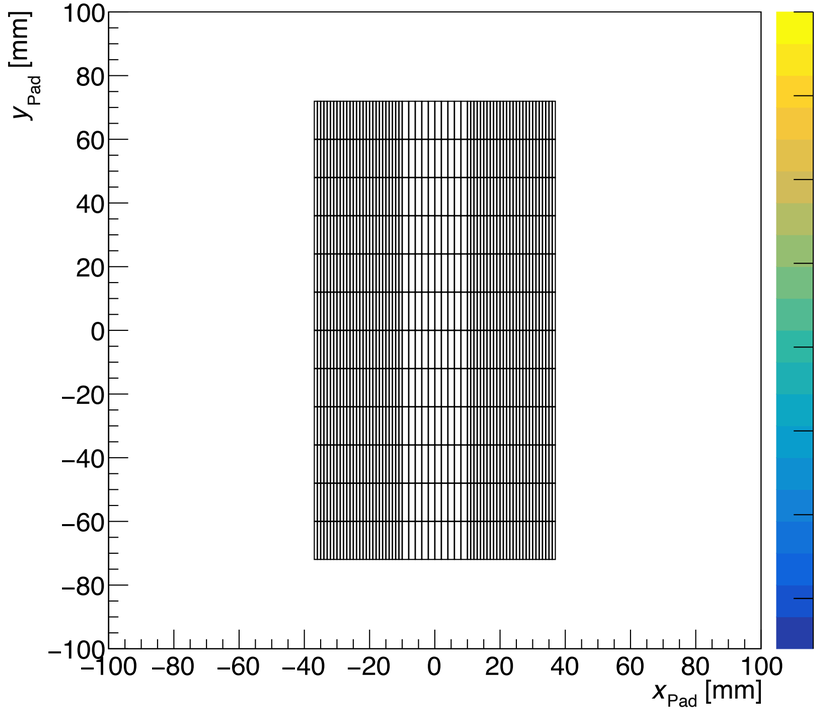
Target Gas : He + CO_2 mixture (He 90% + CO_2 10%)

GET electronics

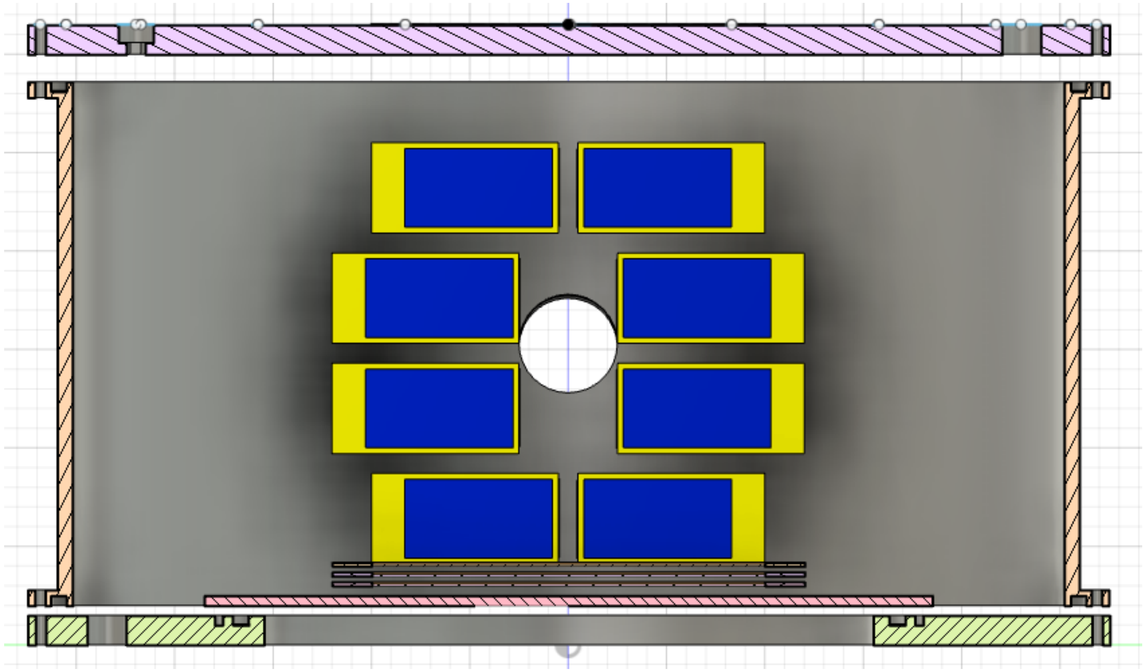
Row 64 Column 12
channel 768

Pad1
Pad Height 11.9 mm
Pad Weight 1.9 mm
Pad Gap 0.1 mm

Pad2
Pad Height 11.9 mm
Pad Weight 0.9 mm
Pad Gap 0.1 mm



TPC-Drum design



Si-CsI

Si-Active Area : 75 x 40.3 mm x 8

CsI-Active Area : 40 x 40.3 mm x 16

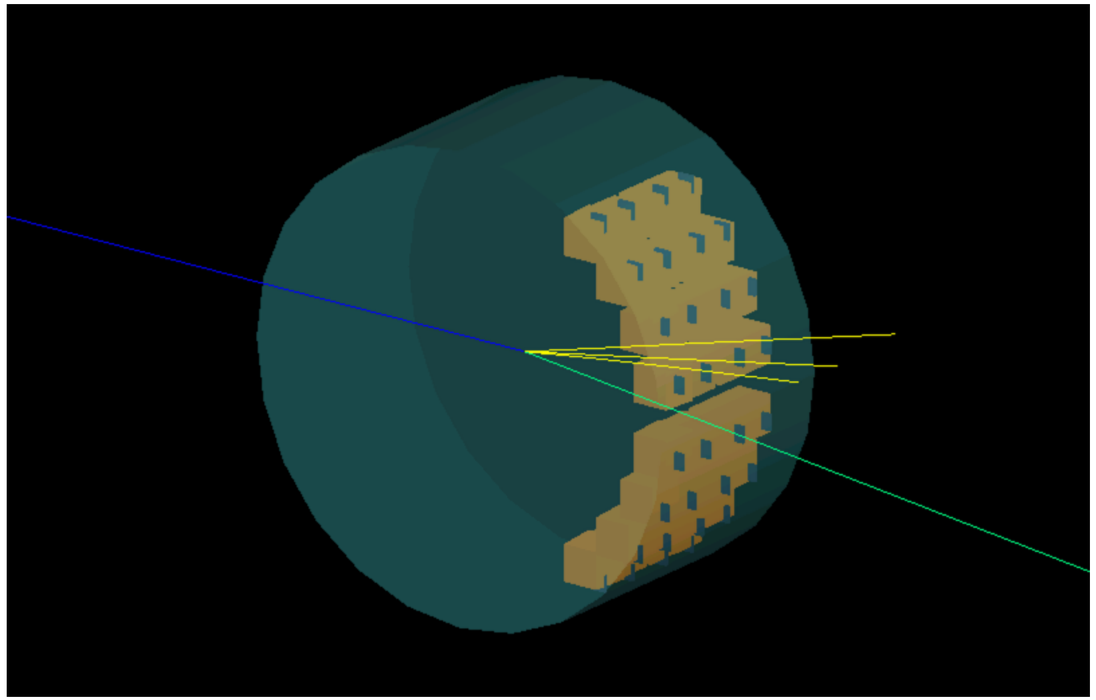
GET electronics

NPTool MC provided more realistic decay kinematics
and we located position of Si-CsI array to optimize α acceptance

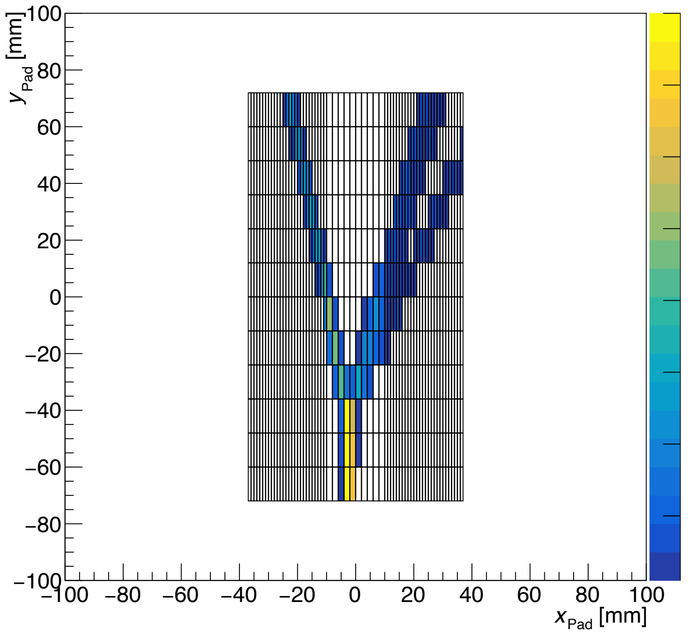
CsI will be used for PID and Trigger system

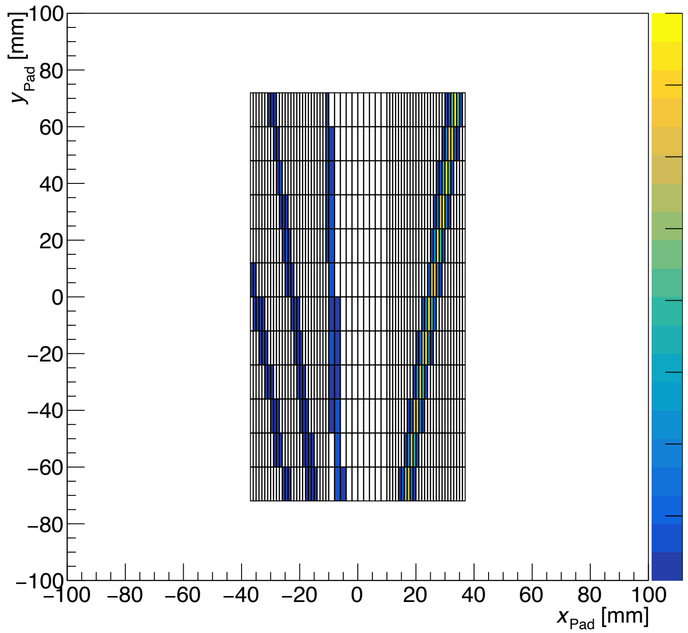
Simulation

NPTool



Ne + He -> 12C + 3α(Hoyle)



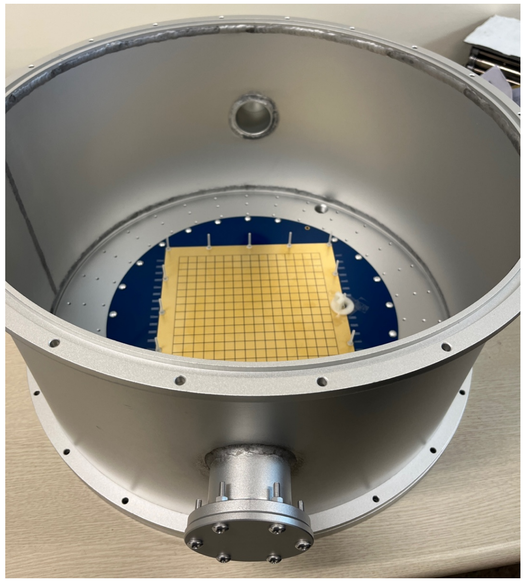


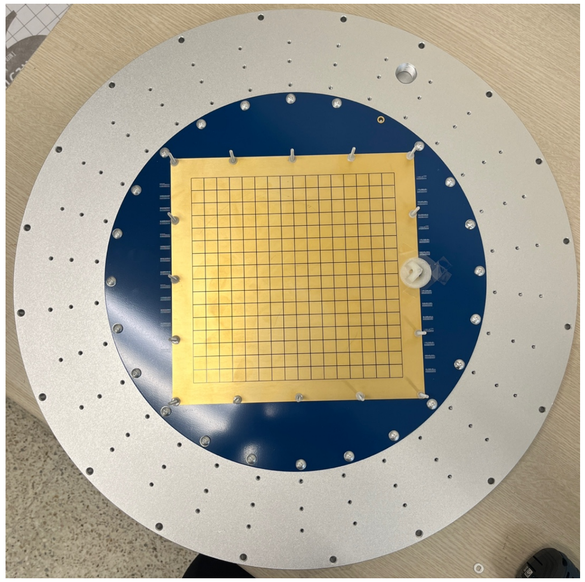
Events are generated by NPTool

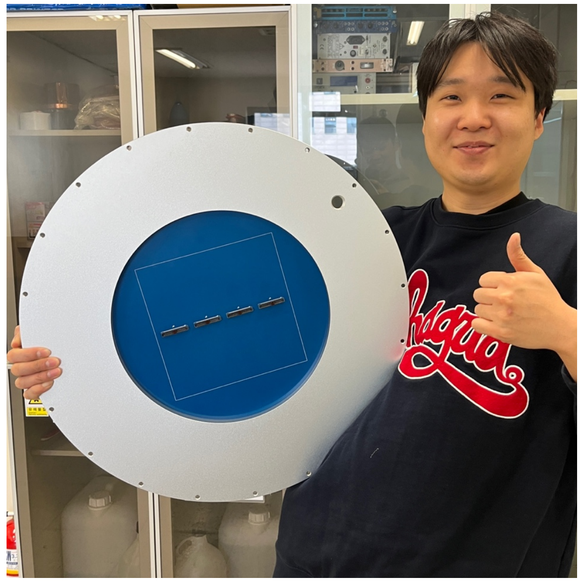
Detector response by Geant4 and Garfield++

We also developed the multi-track finding alogorithm using the Hough transform

Detector status







Type1 (GEM test)

Assembling TPC-Drum (working on)

Conduct GEM Gain analysis using
Fe-55 source (~end of March)

Type2 (for Experiment at RAON)

Auxiliary component, such as supporter and field cage, will be 3d printed (working on)

Requesting the production
of readout Pad (768 ch) (working on)

Gas system is ready

Summary

We check the performance and utility of the prototype TPC
though experiment at HIMAC

Characteristics of the prototype LAMPS TPC for low-energy nuclear collisions at RAON

Yechan Cheon[a,b], Seunghwan Lee[a,b], Deuk Soon Ahn[c], Jung Keun Ahn[d,b], Joonsuk Bae[g], Yunseul Bae[h], Jeongsu Bok[e], Sung Wook Choi[d,b], Seungkyung Do[d,b], Cheong Heo[h], Byungsik Hong[d,b], Jangyong Huh[c], Jaein Hwang[d,b], Seonggeun Hwang[a,b], Youngseub Jang[d,b], Byungmin Kang[d,b], Aram Kim[d,b], Beomkyu Kim[g], Chong Kim[e], Eun-Joo Kim[j], Giyeong Kim[f,b], Hyunchul Kim[h], Jiseok Kim[d,b], Jiyoung Kim[f,d,b], Shinhyung Kim[d,b], Yongsun Kim[a,b], Young Jin Kim[i], Yongjun Kim[e], MinJung Kweon[f,b], Cheong Soo Lee[i], Hyo Sang Lee[i], Jaehwan Lee[d,b], Jong-Won Lee[d,b], Jung Woo Lee[c], Junseok Lee[d,b], Haein Lee[d,b], Hyungjun Lee[g], Seoung Hun Lee[f,b], Sungjune Lee[d,b], Sanghoon Lim[e], Dong Ho Moon[h], Seon Ho Nam[d,b], Jeonghyeok Park[d,b], (The LAMPS Collaboration)

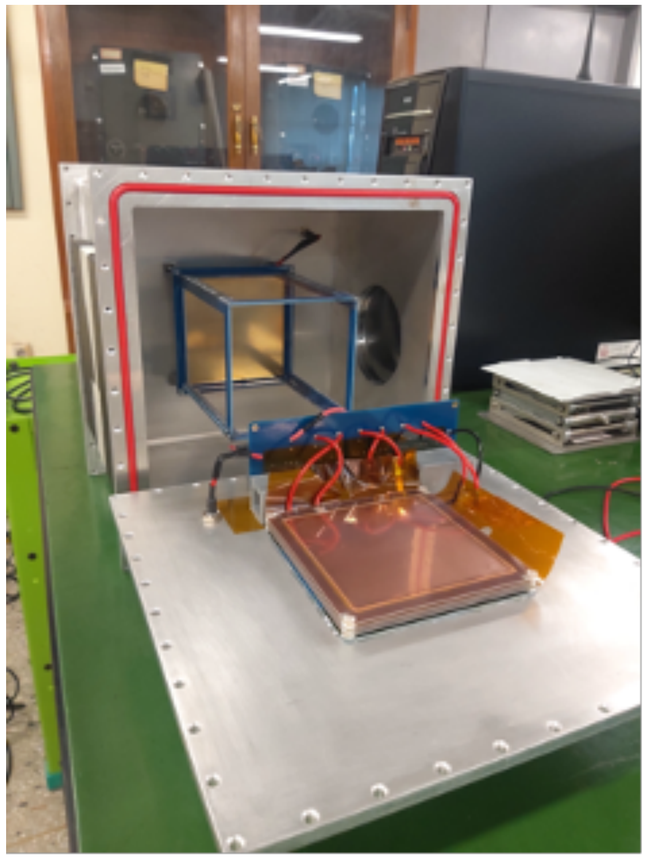
We are preparing the second paper with a more physics-oriented content

The newly designed TPC-Drum, for the RAON experiment,
is expected to be completed by mid-April and operational by mid-May

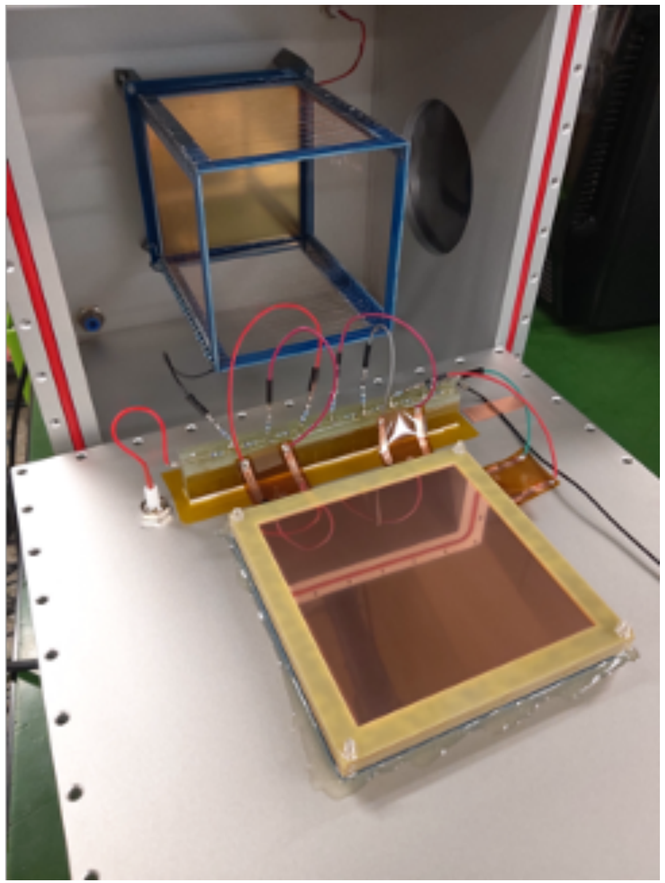
Our group has extensive experience with TPCs, and based on this experience, we are confident that we will deliver good results in the upcoming experiment as well.

Back ups

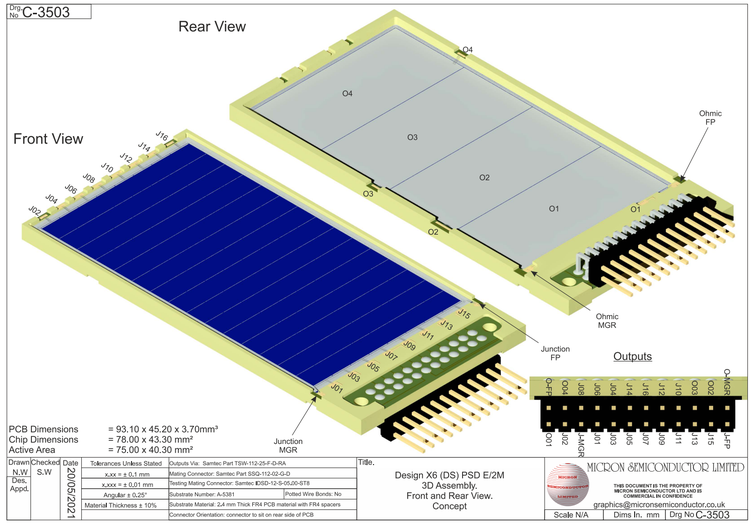
Right wing

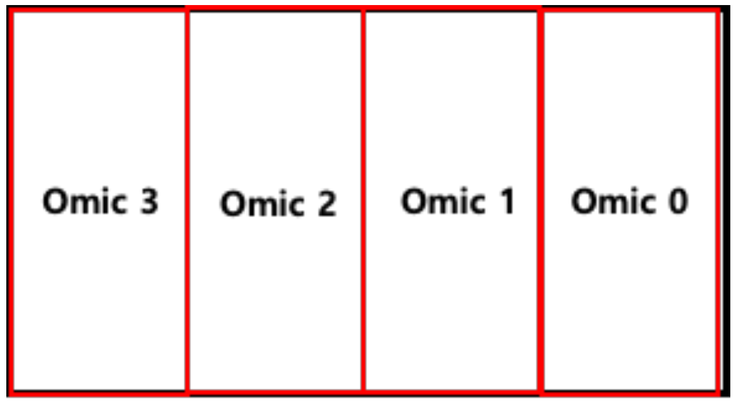


Left wing

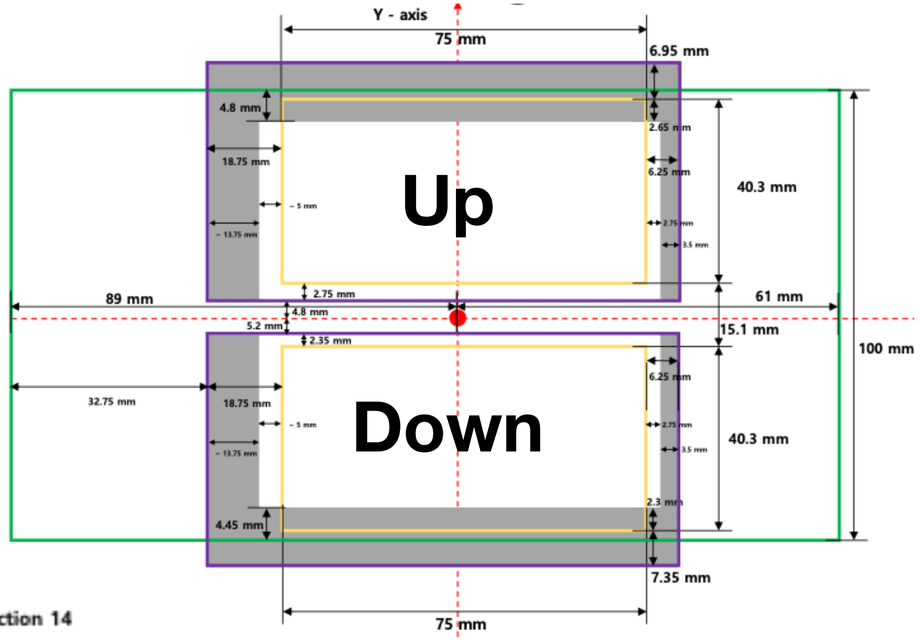


Si Geometry





Rear view (Omic-side)



Front view (Junction-side)

Si Channel:

Omit-side = 4
Junction-side = 16

Si active area:

75 x 40.3 mm

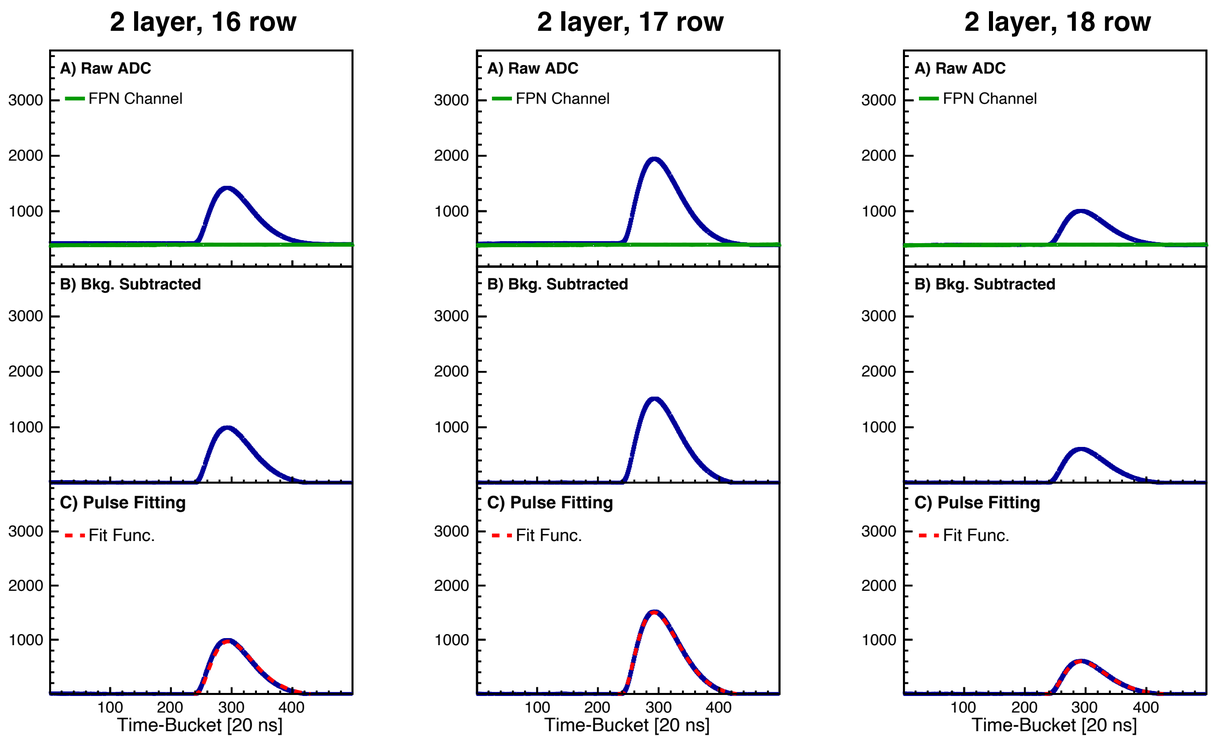
AT-TPC active area

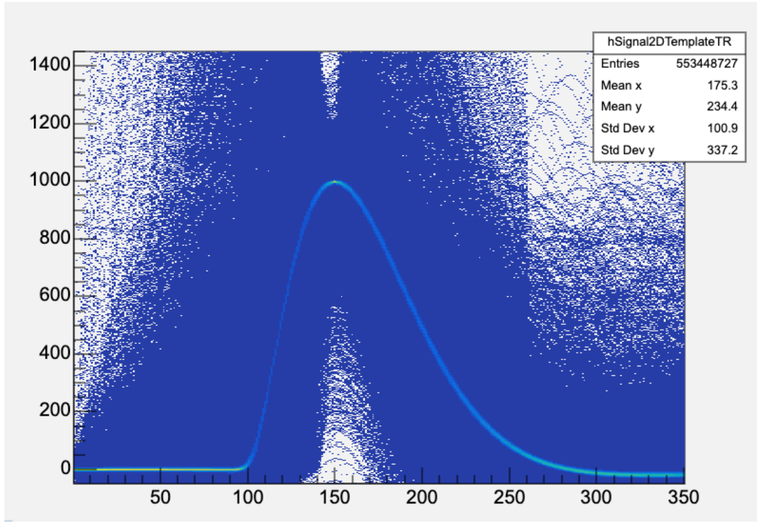
Si active area

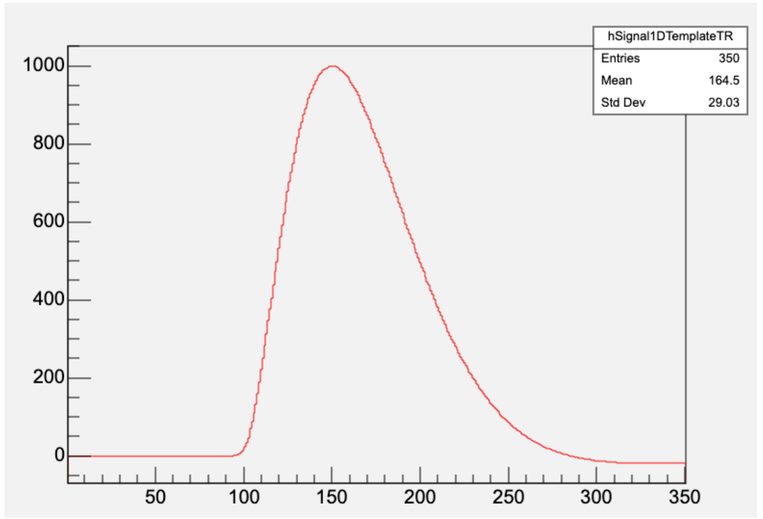
Frame shadow area (CsI-Si)

CsI active area

Time Bucket Fitting method





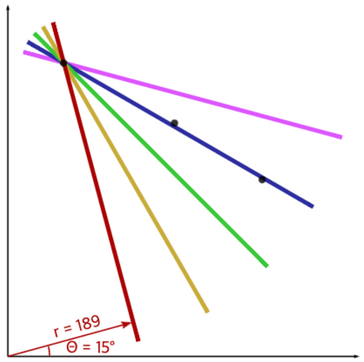


1. Background subtract with FPN Channel
2. Fitting with the template

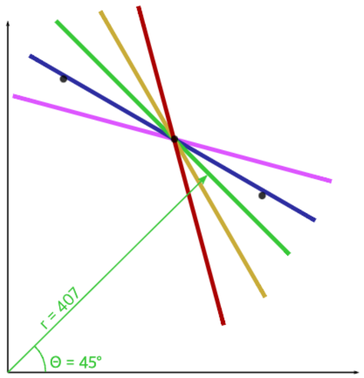
The Peak of distribution of the time-bucket is decided as time-bucket each pad.

Data Analysis

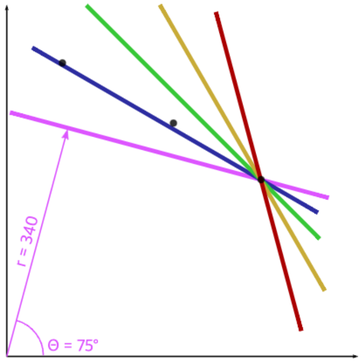
AT-TPC tracking Algorithm - Hough transform



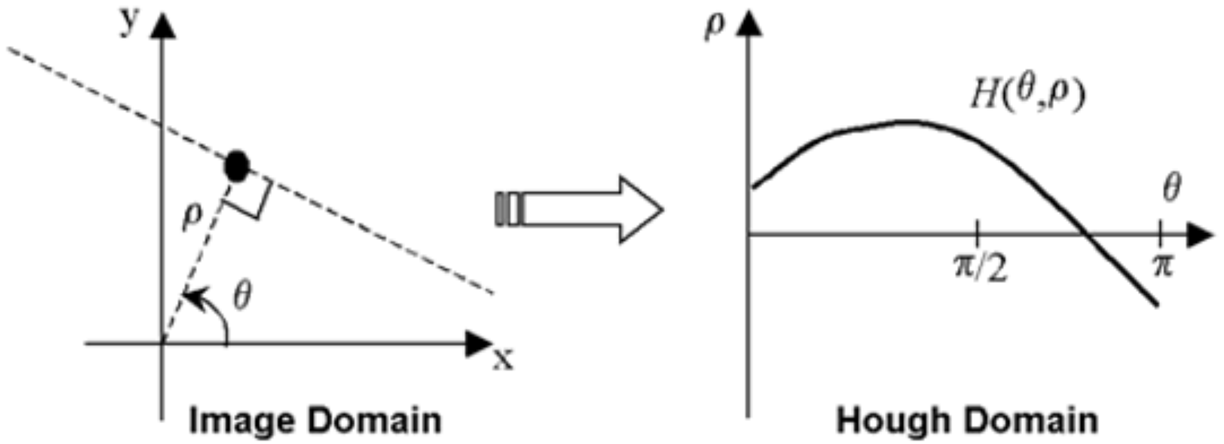
Θ	r
15	189.0
30	282.0
45	355.7
60	407.3
75	429.4



Θ	r
15	318.5
30	376.8
45	407.3
60	409.8
75	385.3



Θ	r
15	419.0
30	443.6
45	438.4
60	402.9
75	340.1



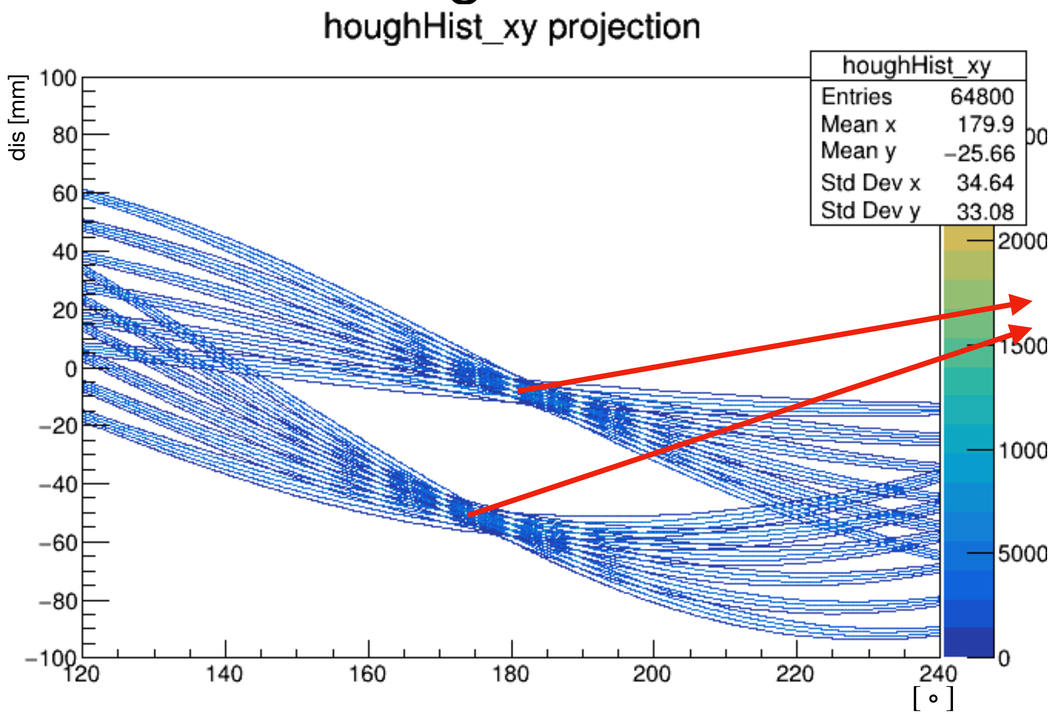
$$\rho = x\cos\theta + y\sin\theta$$

1. Transforms over all possible angle ranges for a single point
2. Repeat the same transformation for another point

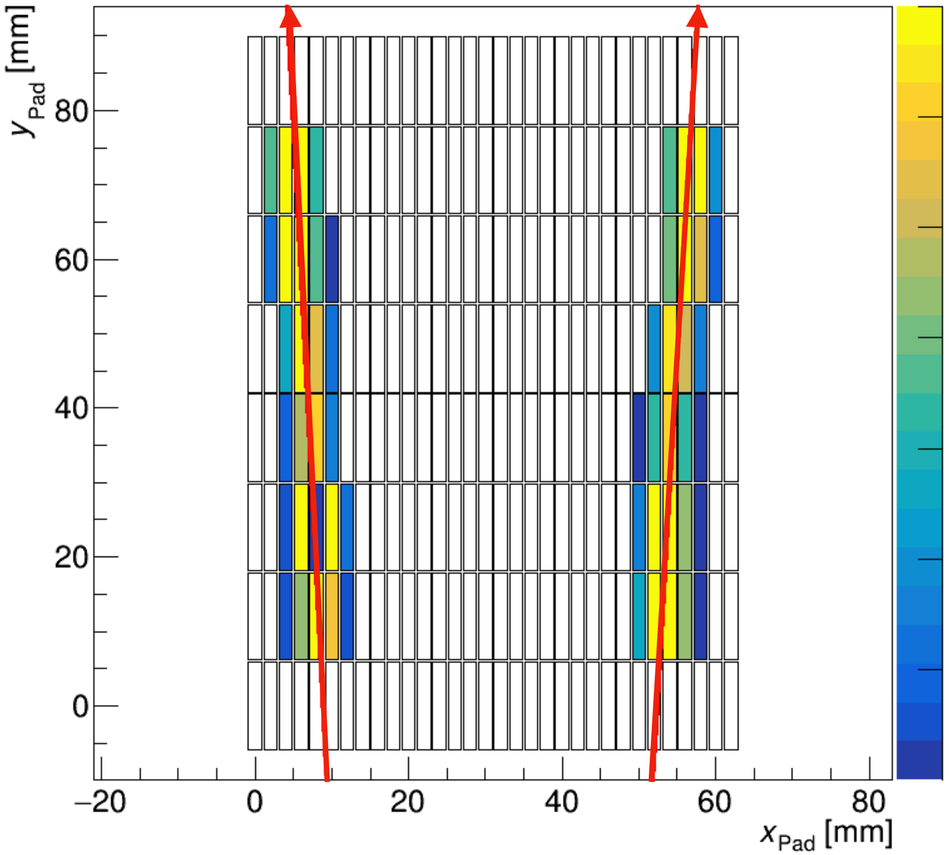
Data Analysis

AT-TPC tracking Algorithm - Hough transform

Method of Hough transform has advantage to specify multi-tracks



This is the regions where the hit has conditions to create a straight track

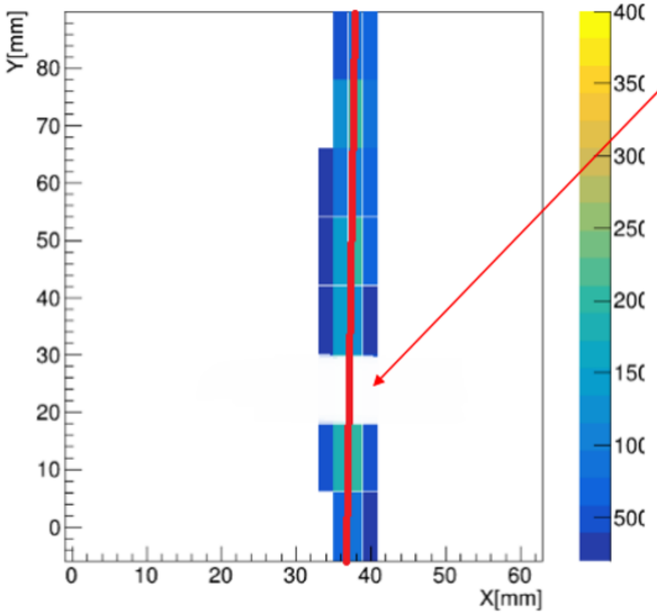


dis = origin point to center of pad

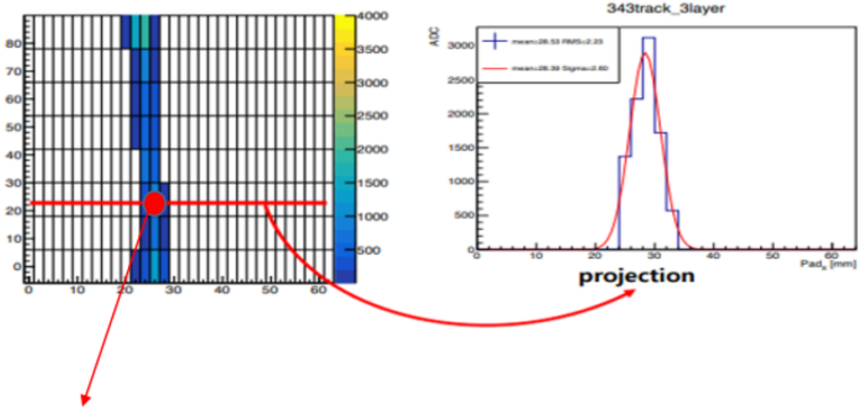
each Pad weighted with ADC

Event-Driven method

MC simulation & cluster fitting method different

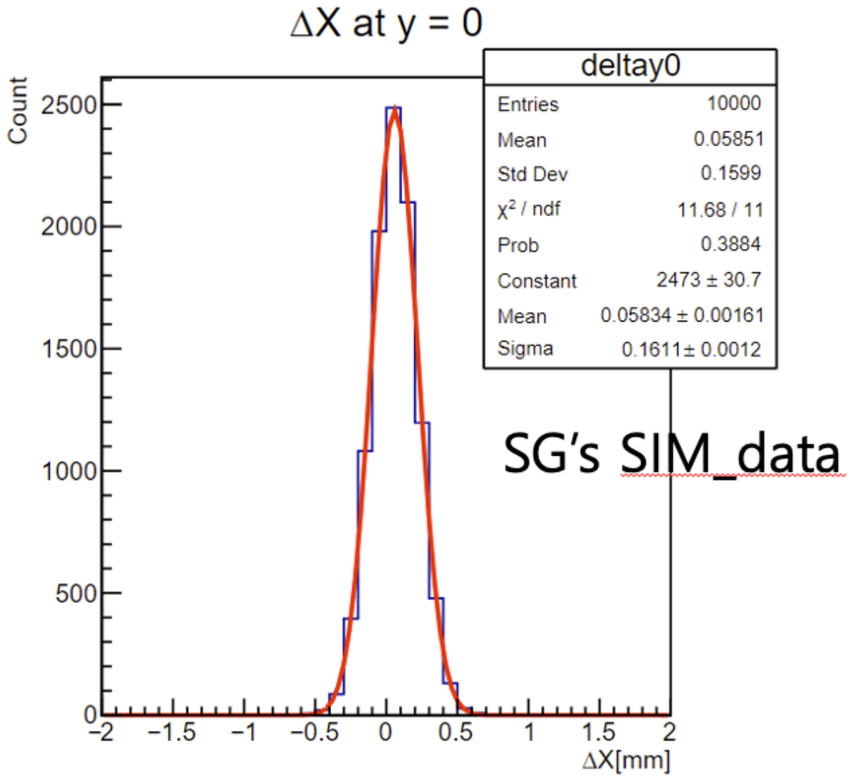


Hough-transform without one layer -> X_{hough}



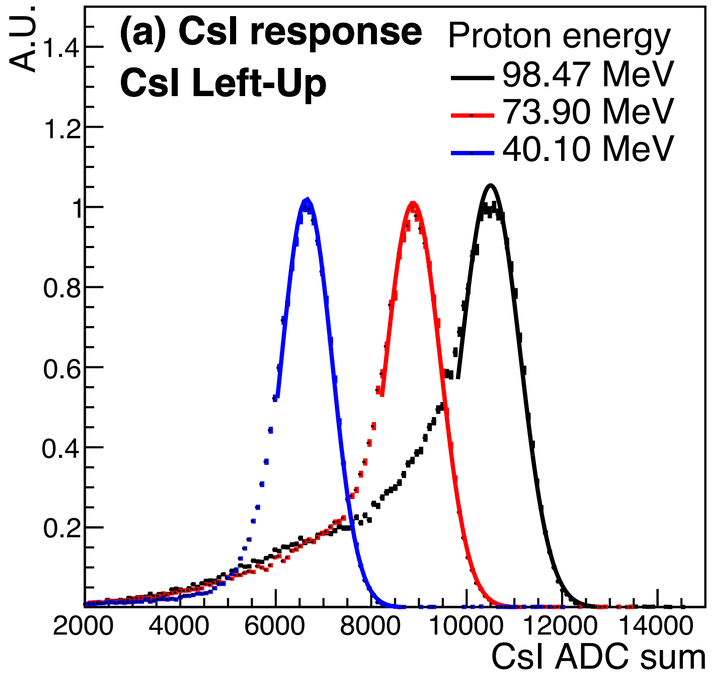
Estimate middle-point with Gaussian fitting -> X_{pad}

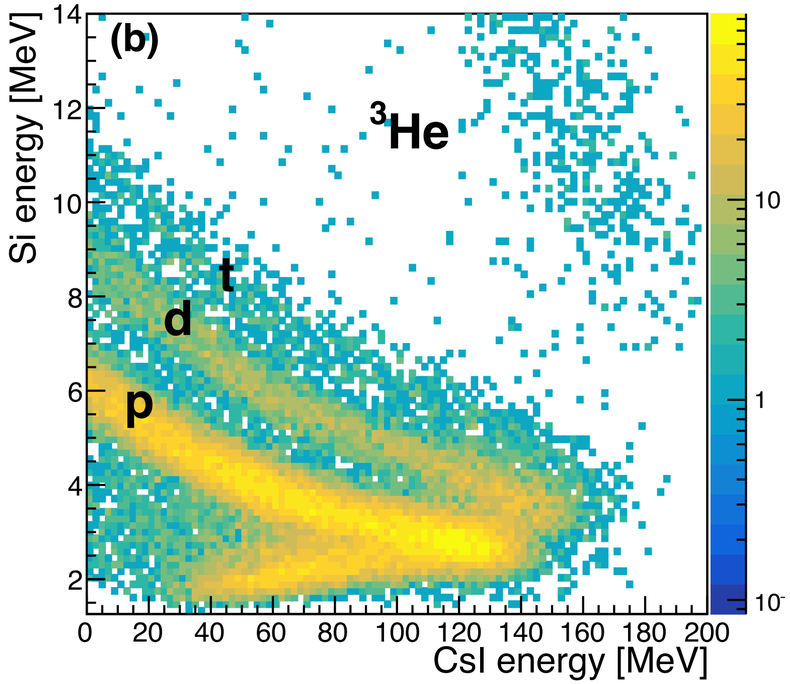
$$\Delta X = X_{pad} - X_{houg}$$



PID using Si-CsI

Calibration



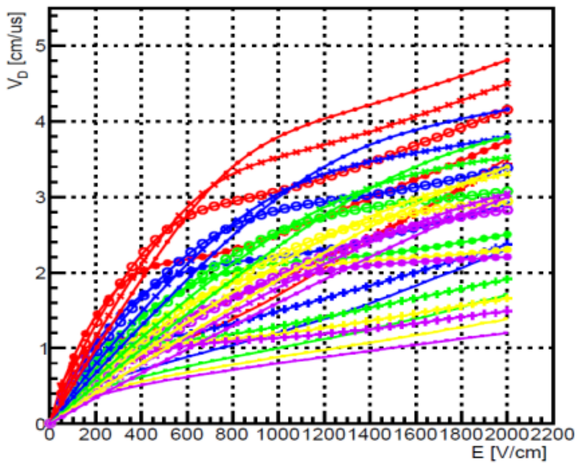


We calibrate the energy in Si and CsI with MC result,
The calibration proceeded by comparing the ADC values from the data with simulation results conducted under the same conditions

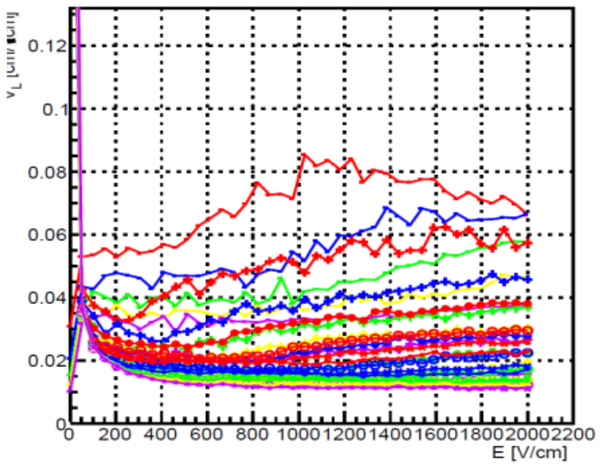
TPC-Drum

Gas study

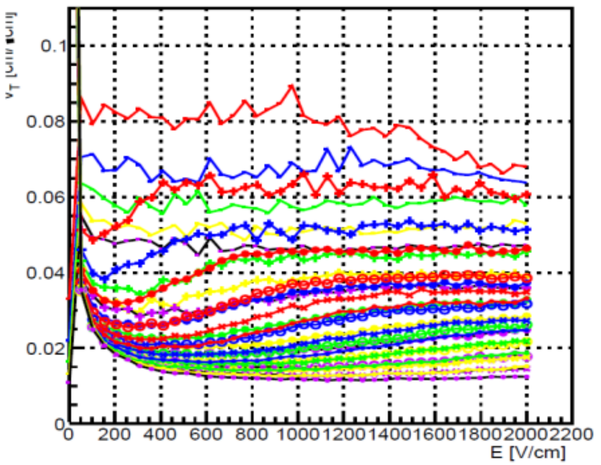
Drift velocity in drift



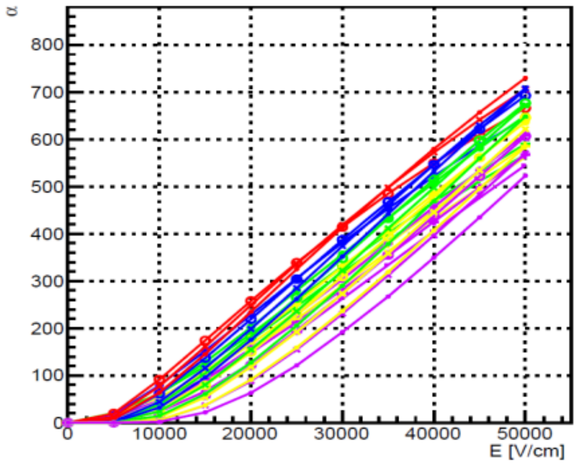
Longitude diffusion in drift



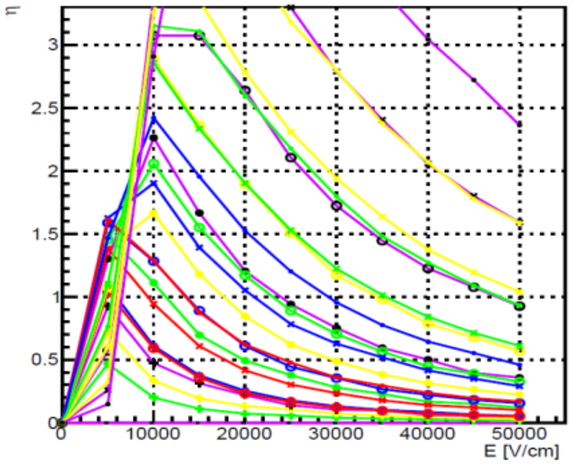
Transverse diffusion in drift

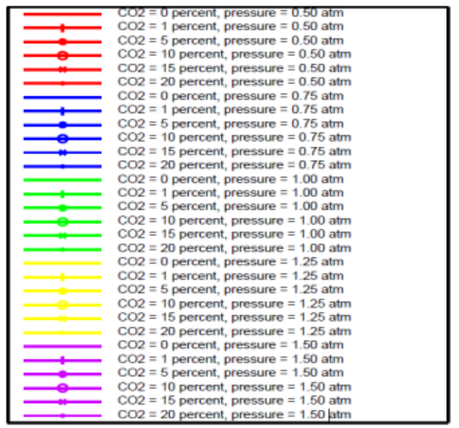


Townsend coefficient in GEM



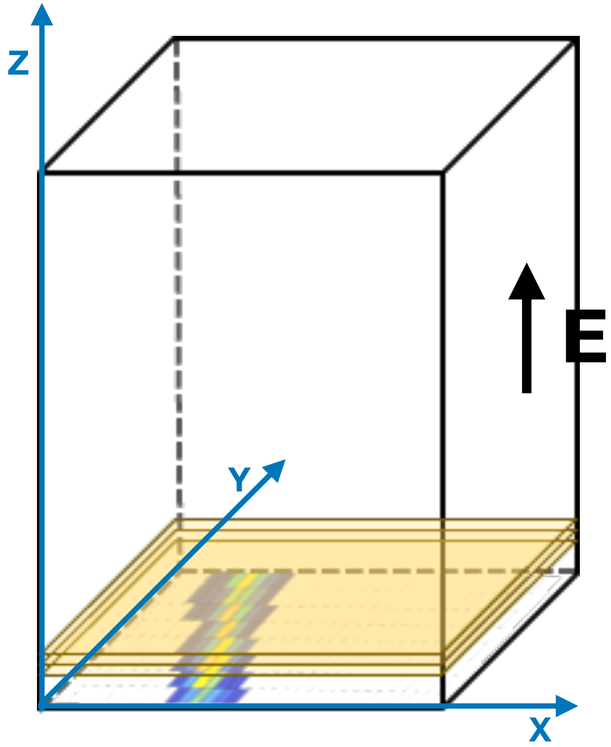
Attachment coefficient in GEM





Gas study

Drift velocity in TPC-Drum



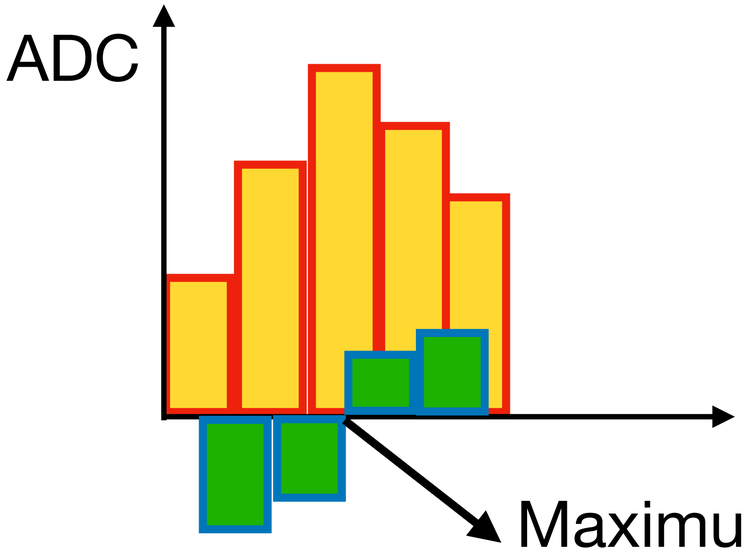
Height of Field cage = 20 cm

700 ~ 800 V/cm electric field -> drift velocity = ~ 2 cm/μs

20cm / 2 cm/μs = 10 μs

Available size of 1tb (20 ns) X total 500 tb = 10 μs

Tracking

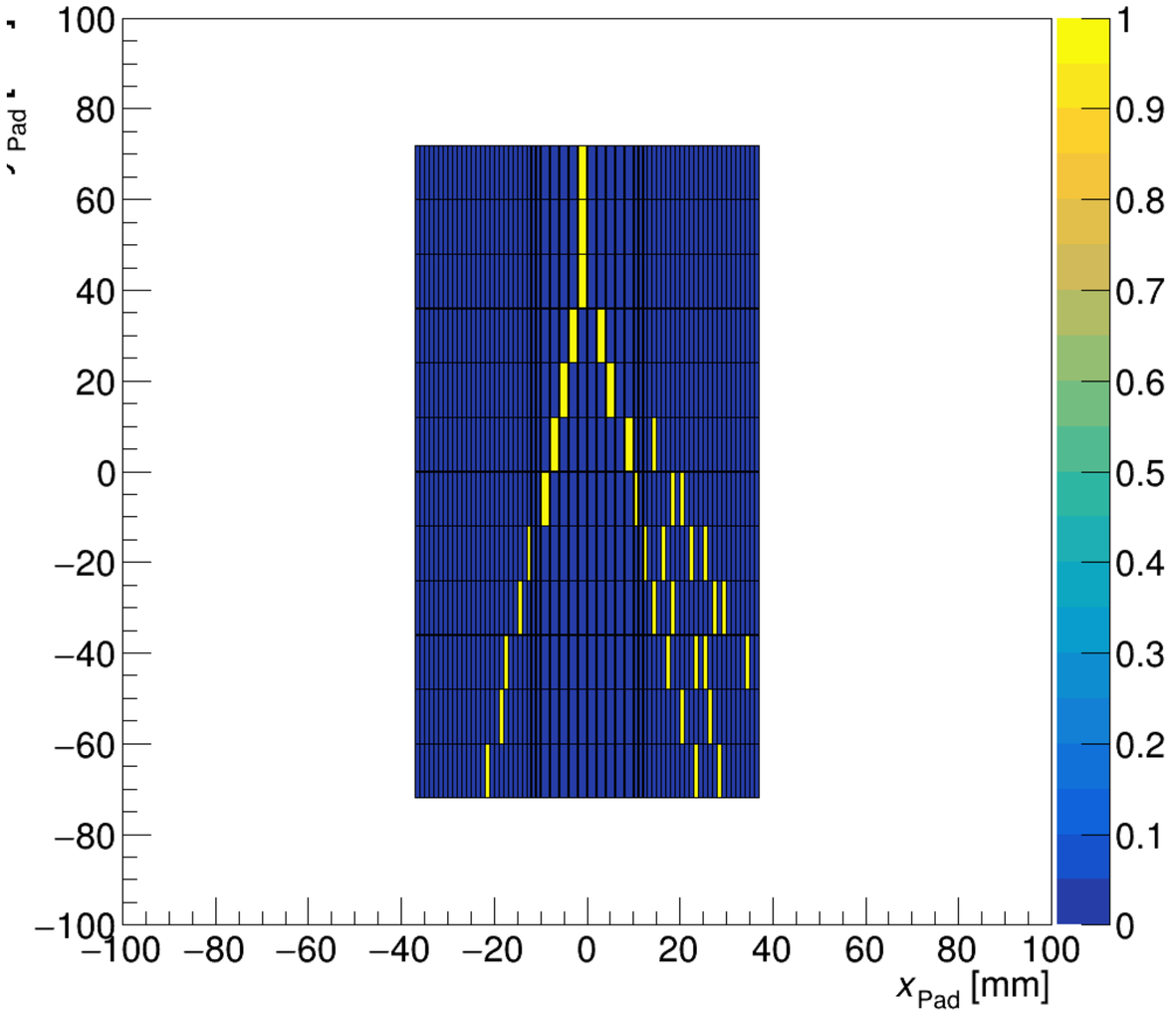


Maximum value (Peak)

-> 1

Others -> 0

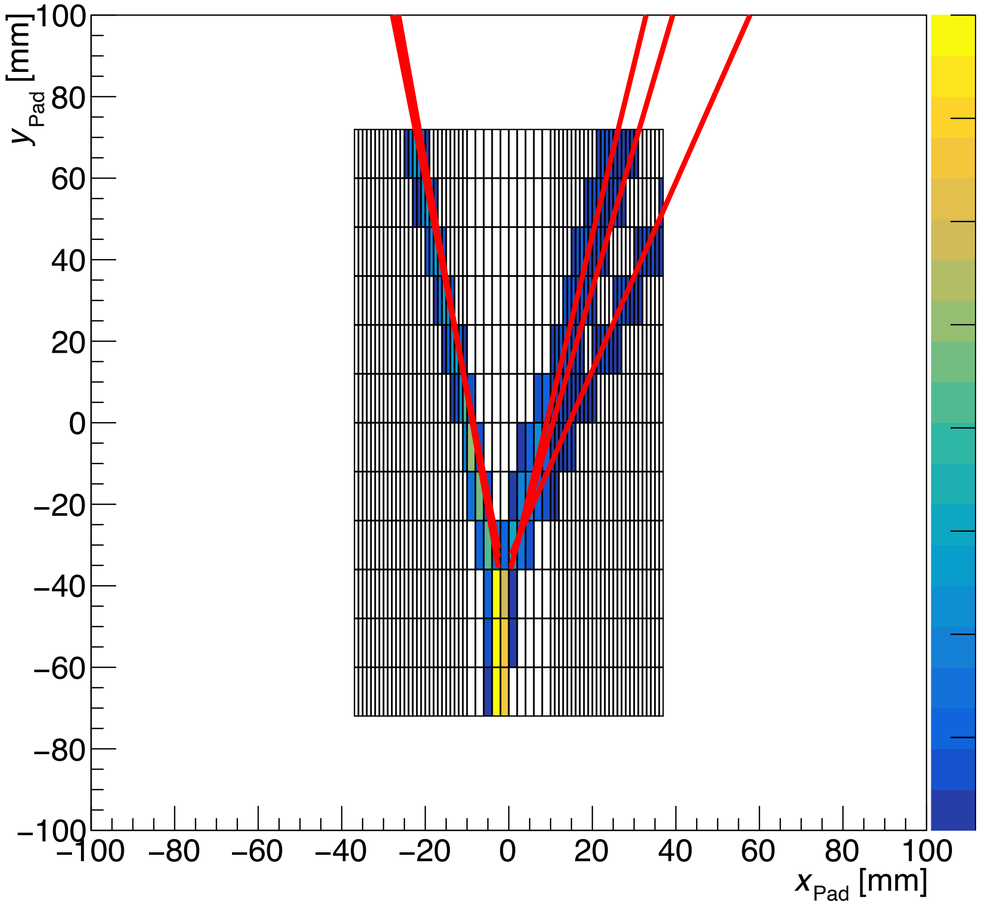
Different of ADC
{row and (row-1)}

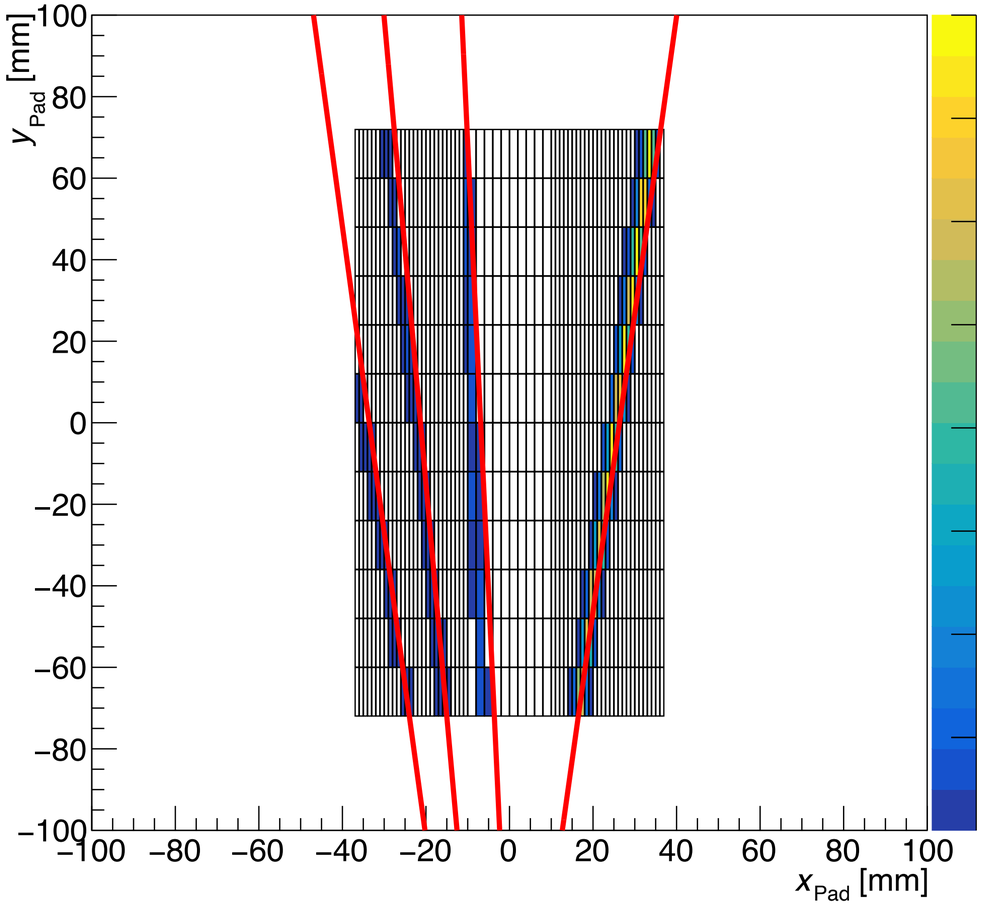


It provided the local maximum ADC on pads

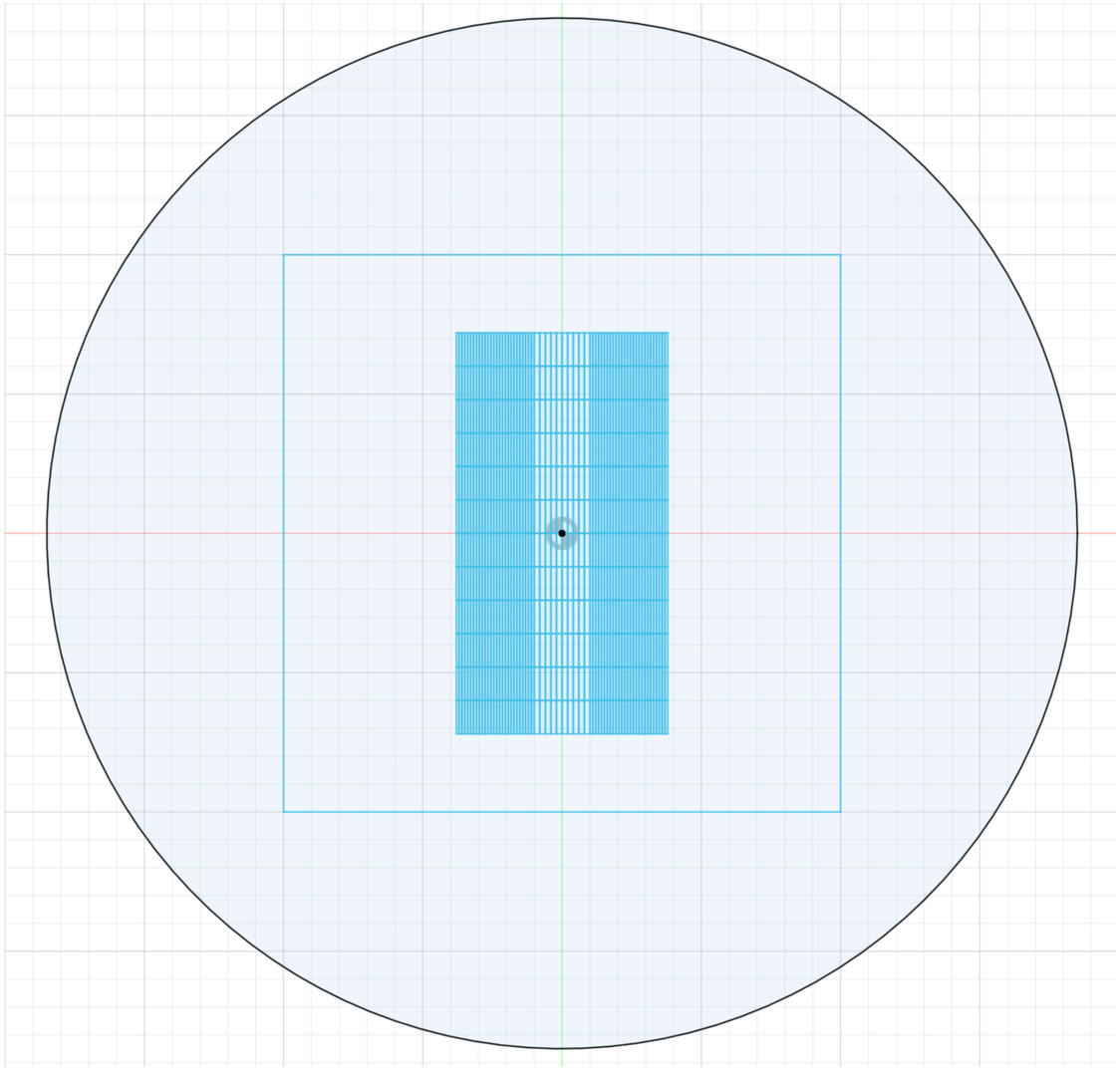
We can use this information to determine how many tracks are present in each layer.

Tracking

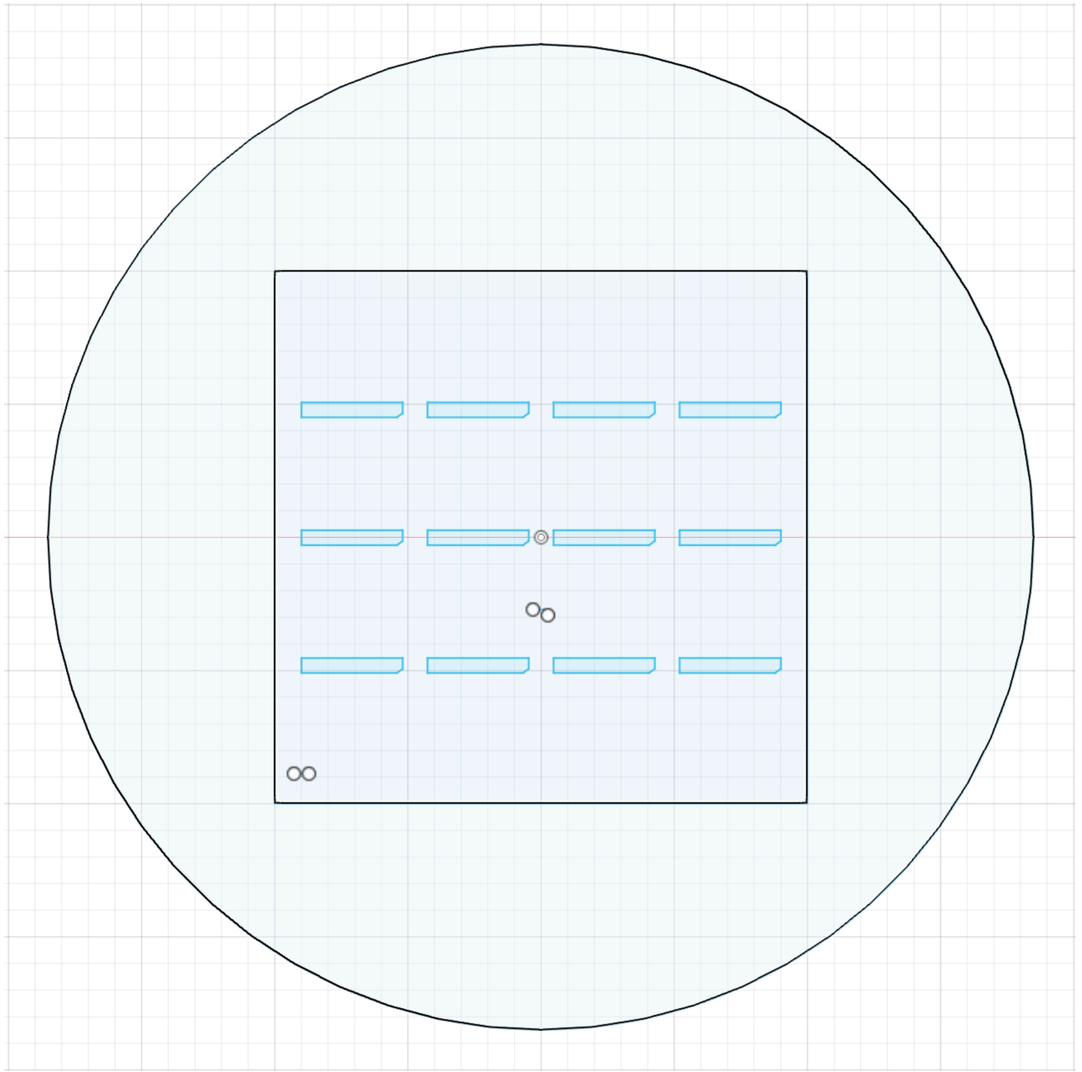




We can distinguish tracks that are closely aligned with local-maximum finding method



앞



뒤