Simulation of the ionization cluster in space and update testing of TPC prototype

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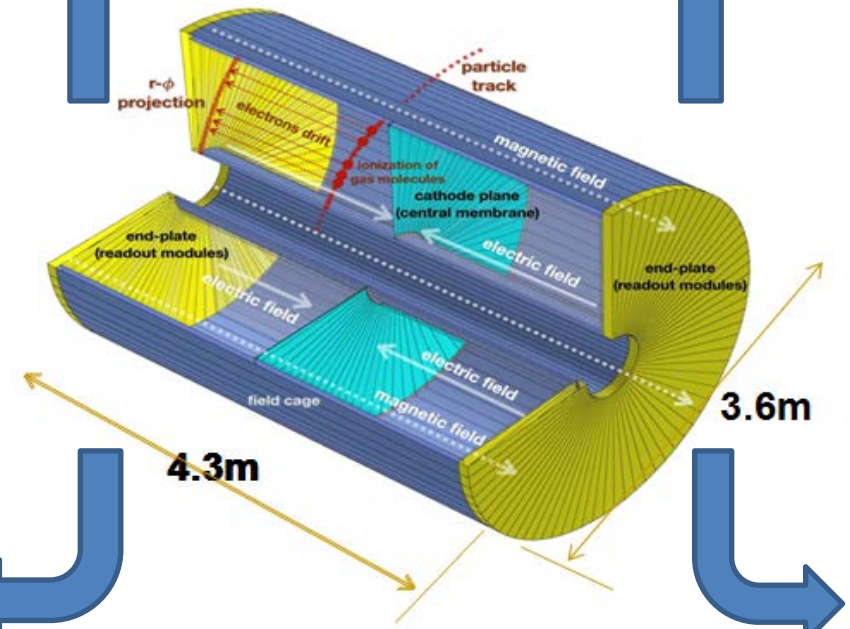
Content

- Motivation and physics requirements
- Simulation of the ionization cluster in space
- Update testing of TPC prototype
- Summary and plan

TPC – Physics requirements at CEPC

Pad readout TPC
- To meet Higgs physics
- 1mm×6mm of Pad
- TPC module
- TPC prototype with UV laser

TPC track technology for e+e- collider



Pixelated readout TPC
- To meet Z physics
- ~500μm of Pad
- TPC prototype with UV laser track
- dN/dx+dE/dx study

Ion back flow study
- Simulation of Ion Back flow
- Testing the UV light created the ion disk by photoelectric effect
- Experimental study

PID performance study
- Simulation of the ionization cluster in space
- PID studies of the different readout TPC prototype
- Experimental study

- Simulation of the ionization cluster in space

dE/dx and dN/dx

- **dN_{cl}/dx** resolution is potentially better than **dE/dx**.
- Cluster counting requires the high granularity readout methods in space determination.
- Cluster counting requires the fast electronics and sophisticated counting algorithms, or alternative readout methods in time determination.
- It has the potential of being dependent on some parameters – the primary ionization characteristics in the different mixture gases. (Gas pressure, mixed gases ratio, gas gain…)

$$\sigma \sim (\delta \cdot L)^{-0.5} \sim \sqrt{N_{cl}}$$

- In cluster-counting mode there is a clear statistical advantage, even taking into account a cluster identification efficiency.
- There is the potential of better resolution by at least a factor 2 (theoretically)
- The relativistic rise is flattened out by a strict primary cluster count

  → a hybrid approach (dE/dx + dN/dx) may be better suited long drift lengths (long. diffusion + attachment) tend to de-cluster the primary ionization.
- Potential source of systematics should be considered and R&D too.

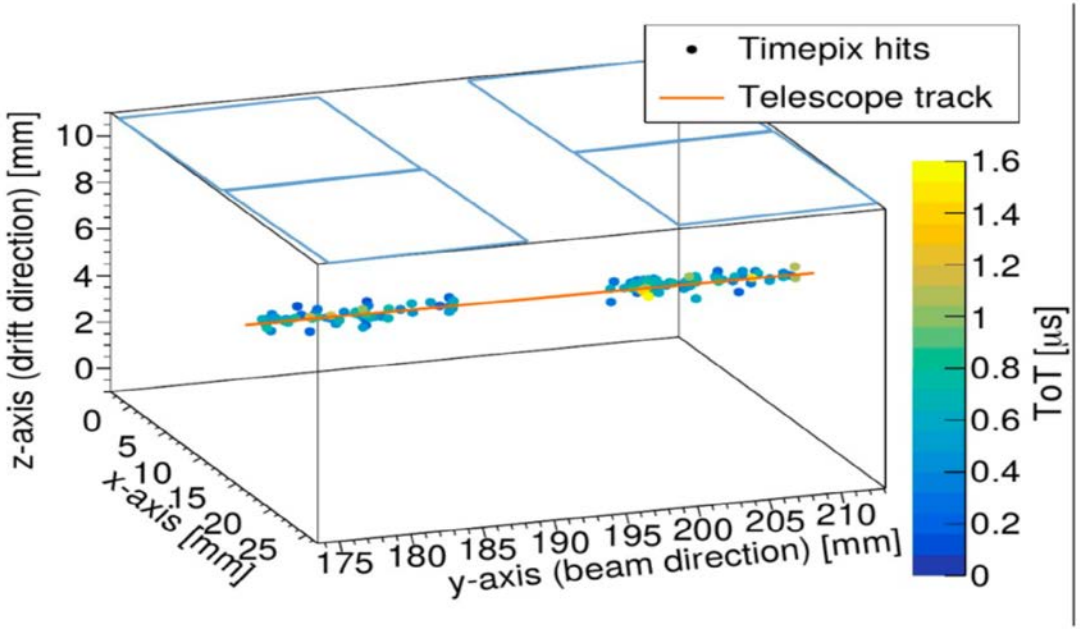
How to identify the clusters and achieve dN/dx using gaseous detector ?

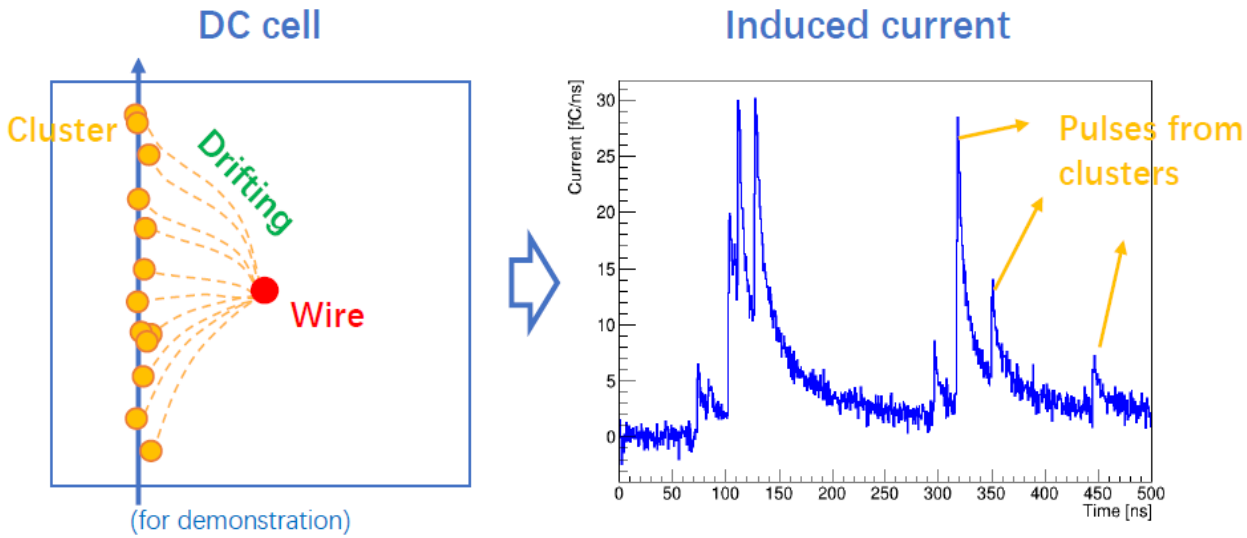
In Space

- Challenging of the low power consumption electronics (>40mV/fC needed at 2000 of gas gain)
- Pixelated readout - high granularity
- → the reasonable pixilation reveals the underlying cluster structure in 3D chamber

In Time

- Challenging of the fast-shaping electronics (~ ns needed)
- De-couple the charge collection from the cluster counting altogether
- → optical, with ~(sub)ns continuous readout sensors





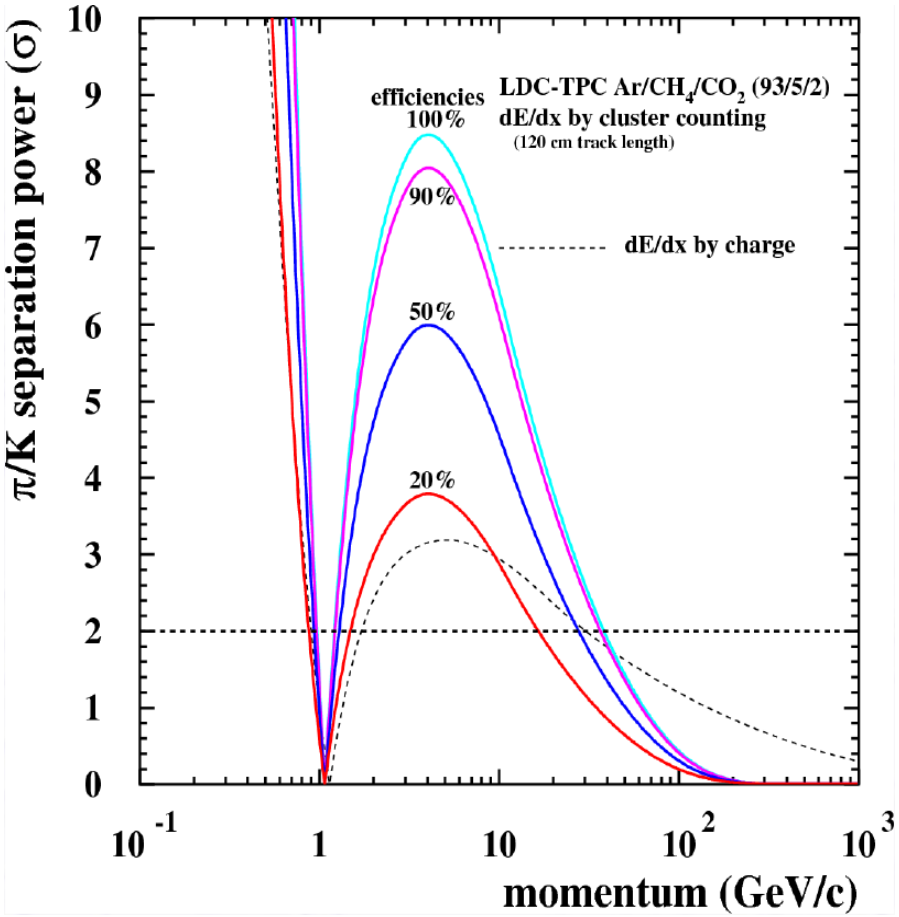
High granularity for improved PID in TPC

- For traditional dE/dx detection, the charge summation can be expected using the gravity method.
- In most experimental study from small to large TPC
  - L and N are correlated.
  - Constant L and changing granularity G = N/L

$$\frac{\sigma_{dE/dx}}{\langle \mu_{dE/dx} \rangle} \propto L^{-0.45} G^{-0.13}$$

- If pad size is at the level of cluster distances of primary ionization
  - i.e. ~ 300-500 μm in Ar-based
  - Cluster counting becomes effective

- PID improvement
  - The potential of better resolution by at least a factor 2



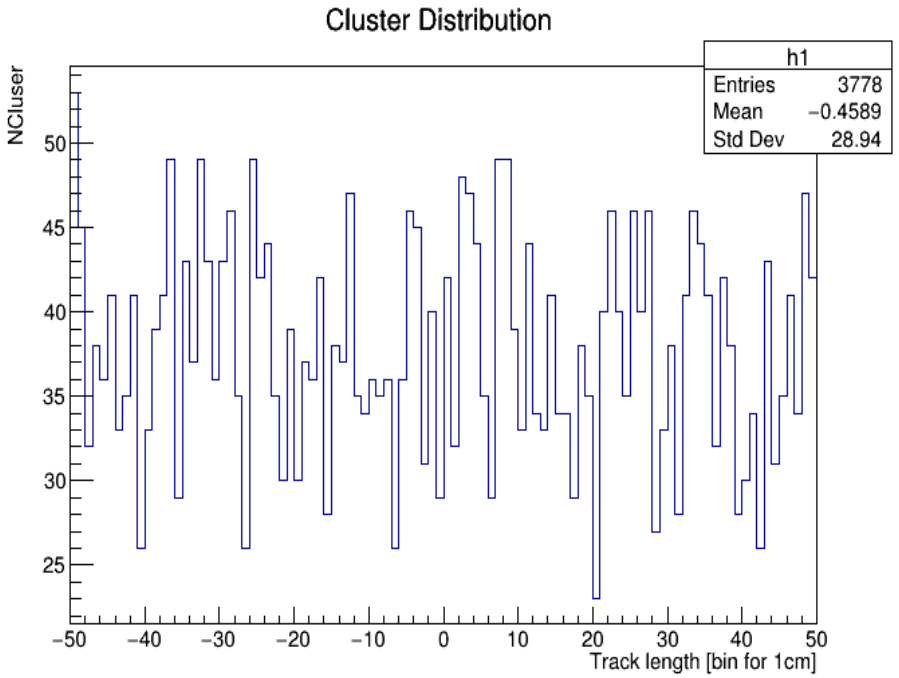
Hauschildt
http://ific.uv.es/~ilc/ECFA-GDE2006/0

Simulation setup

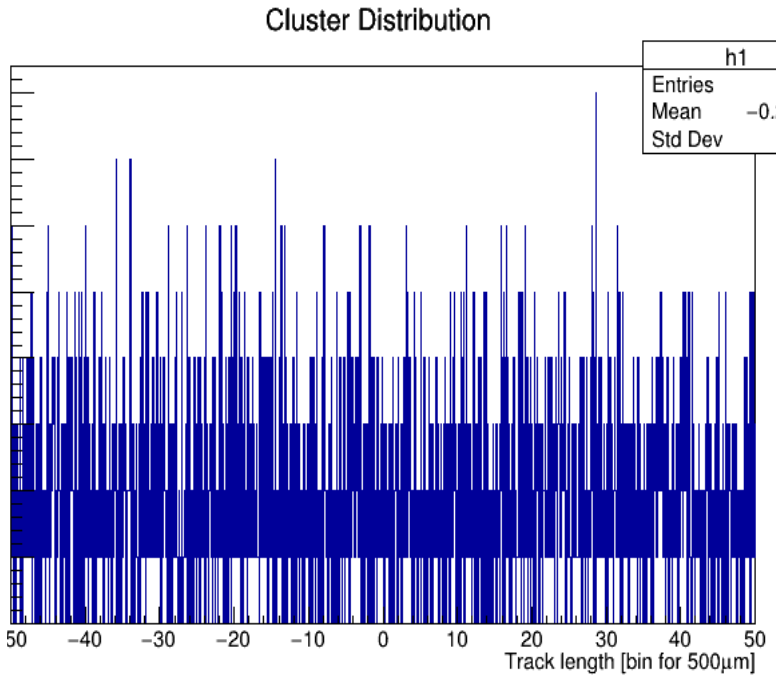
- Garfiled++ software package.
- Detailed simulation at the level of individual electrons from the ionization process
- For ionization a parameterized HEED simulation is used (Geant was insufficient)
- Some different mixture gases for TPC
    - 90% Ar, 10% CO2
    - 95% Ar, 5% iC4H10
    - T2K gas: 95% Ar, 3% CF4, 2% iC4H10
- E and B field for TPC
    - the electric field (~200V/cm and more, to reach to the saturation drift velocity)
    - the magnetic field (from 0 Tesla to 3Teslsa)
    - Angle of theta considered too.
- Ionization Particle of Muon, Pion and Kion with the different energy scanning (MeV/c to GeV/c)

Primary cluster profile along the drift length

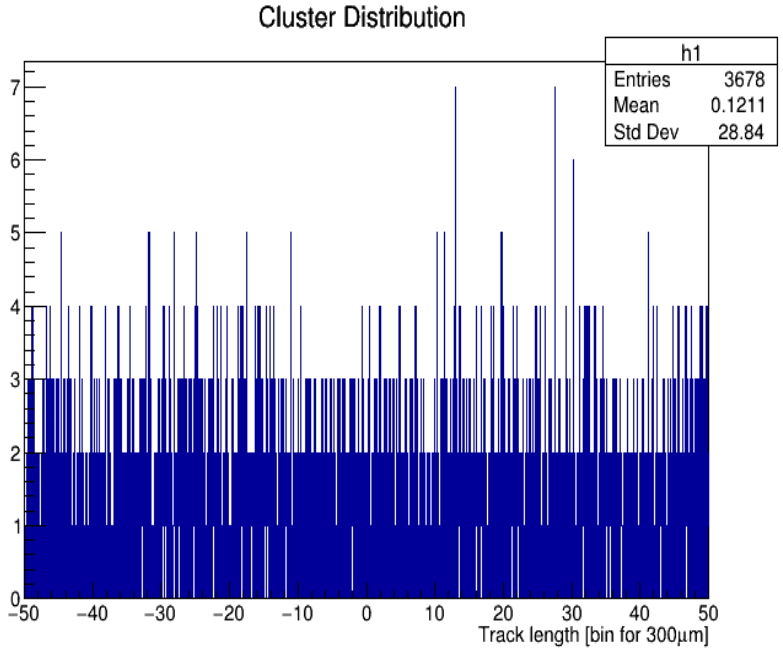
- Drift length: 1m
- Operation gas: **T2K gas**
- Running 10000 events using Garfiled++
- Simulation result show that the primary cluster profile along the drift length



Bin: per 10mm



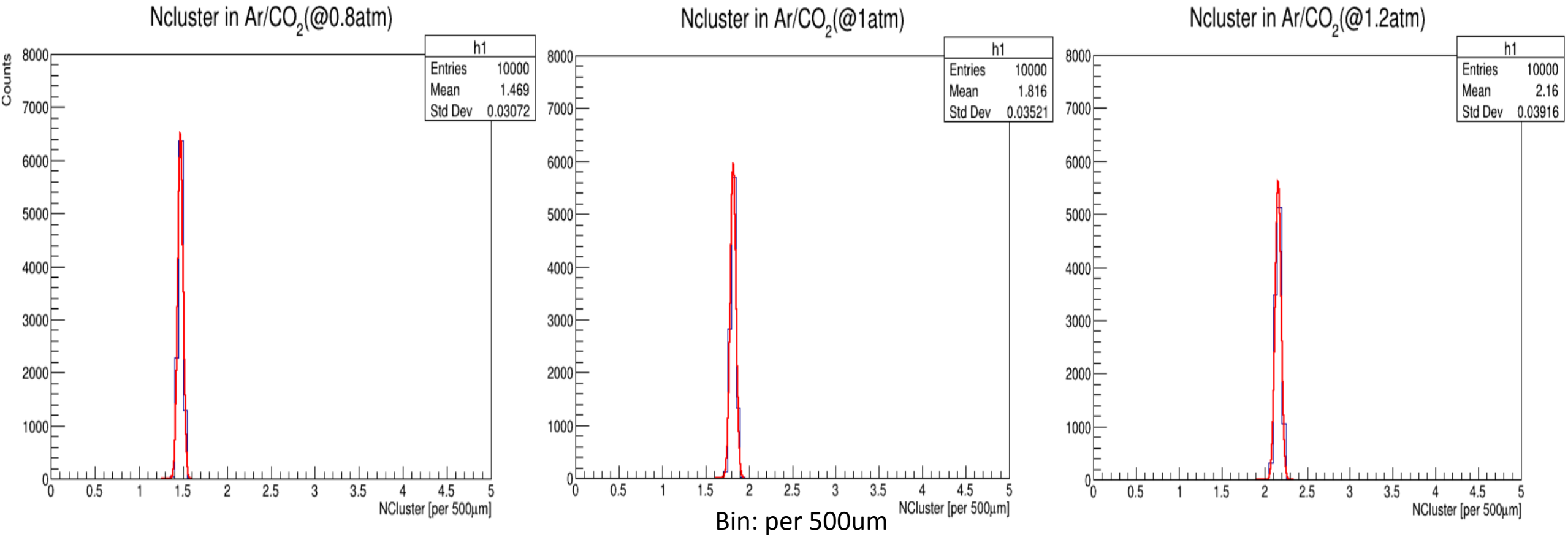
Bin: per 500um



Bin: per 300um

Primary cluster profile using **Ar/CO2=90/10** gas at the different pressure

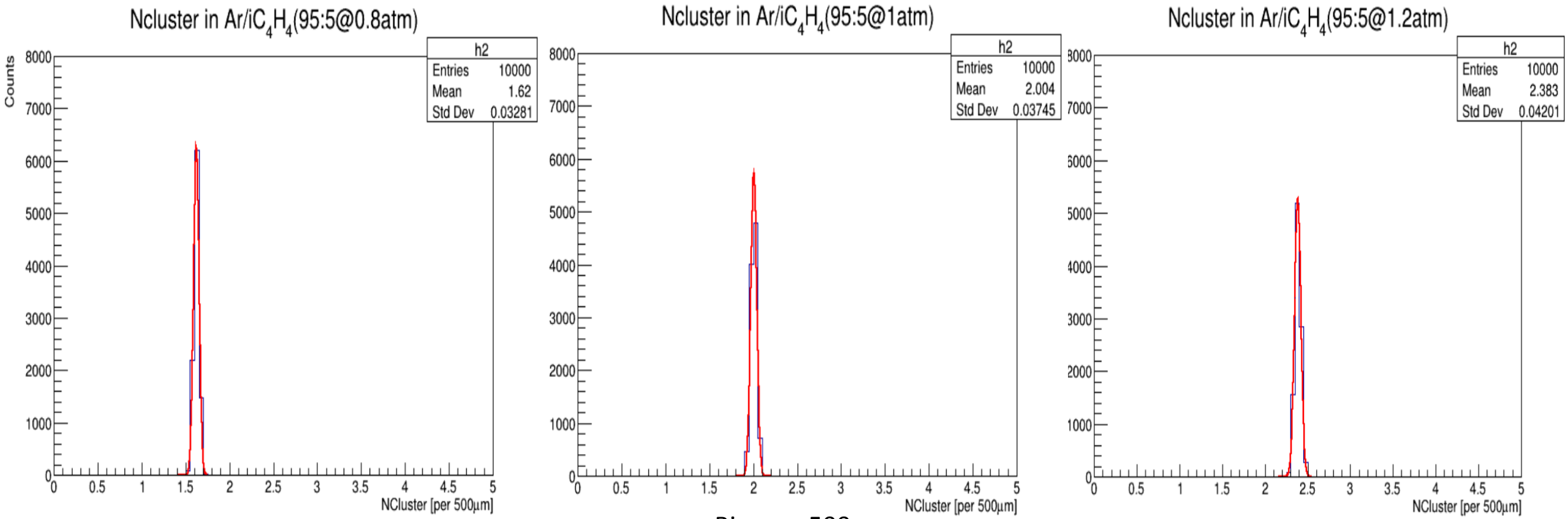
- Simulation result of the primary cluster using Ar/CO2=90/10 gas
- Mean of N_cluster: **0.8atm: 1.47 / 1.0atm 1.81/ 1.2atm 2.16**
- Changed ±0.5 atm operation gas pressure, the cluster will be smaller/bigger about **20%**



Bin: per 500um

Primary cluster profile using **Ar/iC4H10=95/5** gas at the different pressure

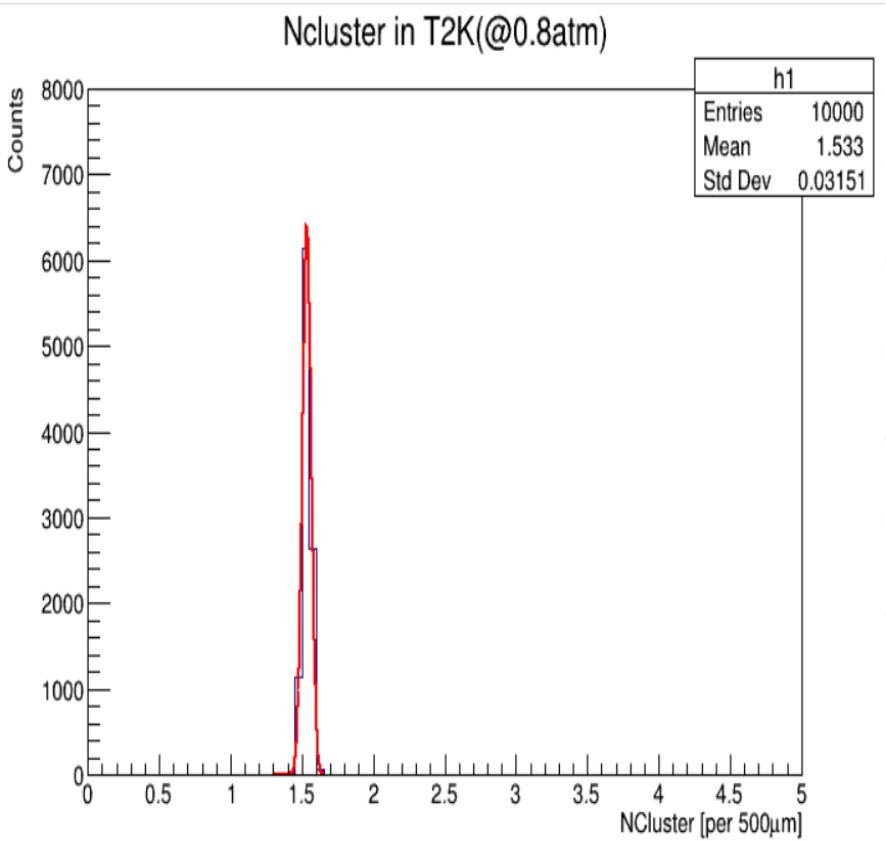
- Simulation result of the primary cluster using Ar/iC4H10=95/5 gas
- Mean of N_cluster: **0.8atm: 1.62 / 1.0atm 2.00/ 1.2atm 2.38**
- Changed ±0.5 atm operation gas pressure, the cluster will be smaller/bigger about **20%**

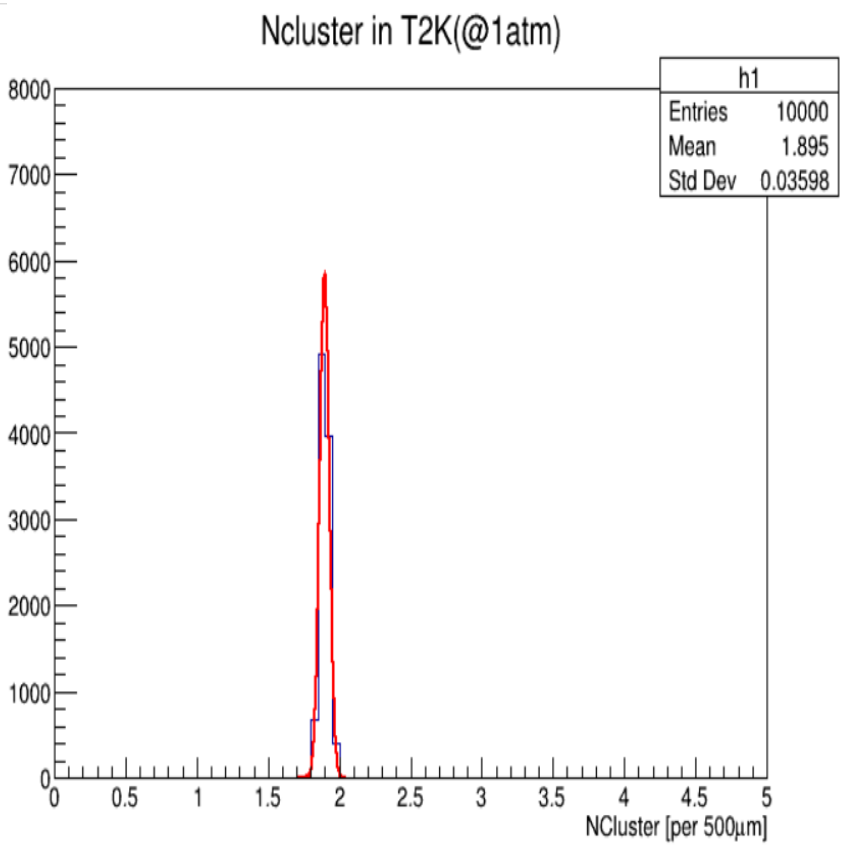


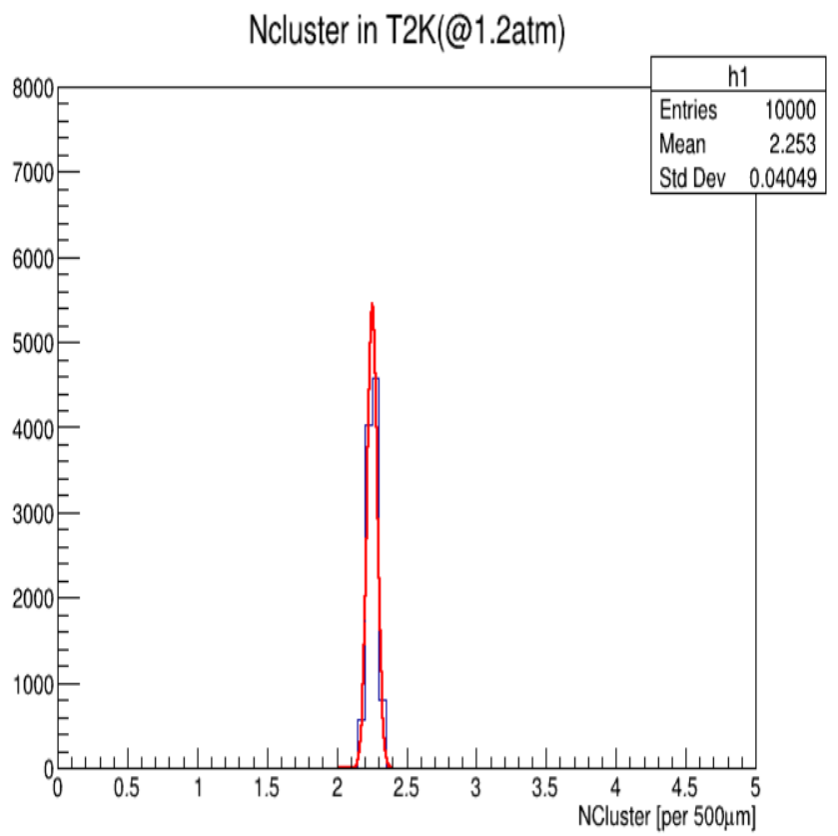
Bin: per 500um

Primary cluster profile using **T2K** gas at the different pressure

- Simulation result of the primary cluster using T2K gas
- Mean of N_cluster: **0.8atm: 1.53 / 1.0atm 1.89/ 1.2atm 2.25**
- Changed ±0.5 atm operation gas pressure, the cluster will be smaller/bigger about **20%**



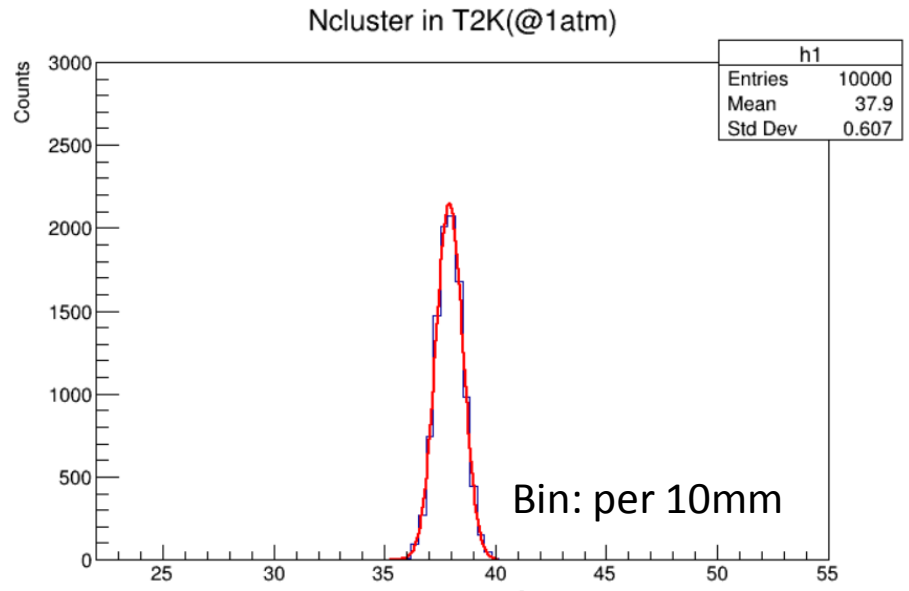


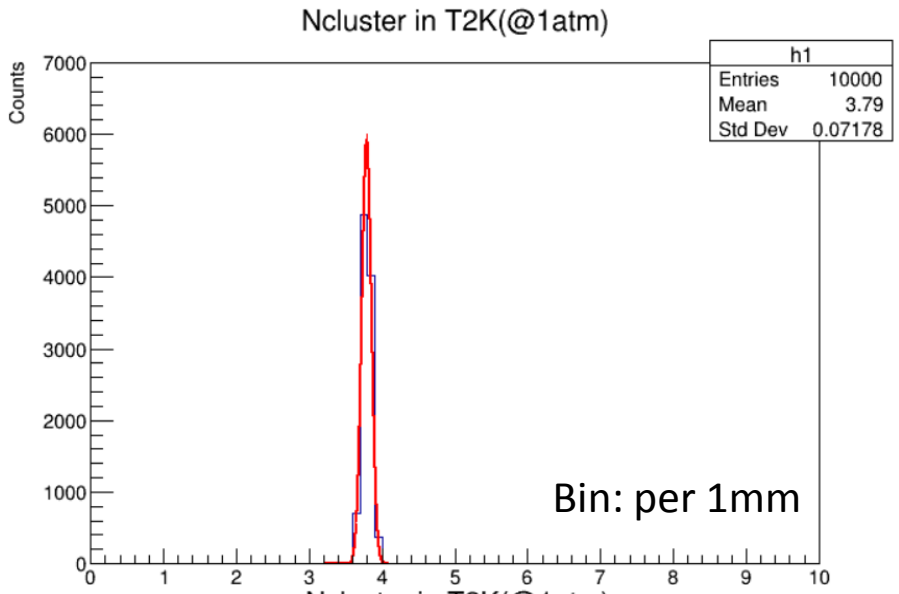


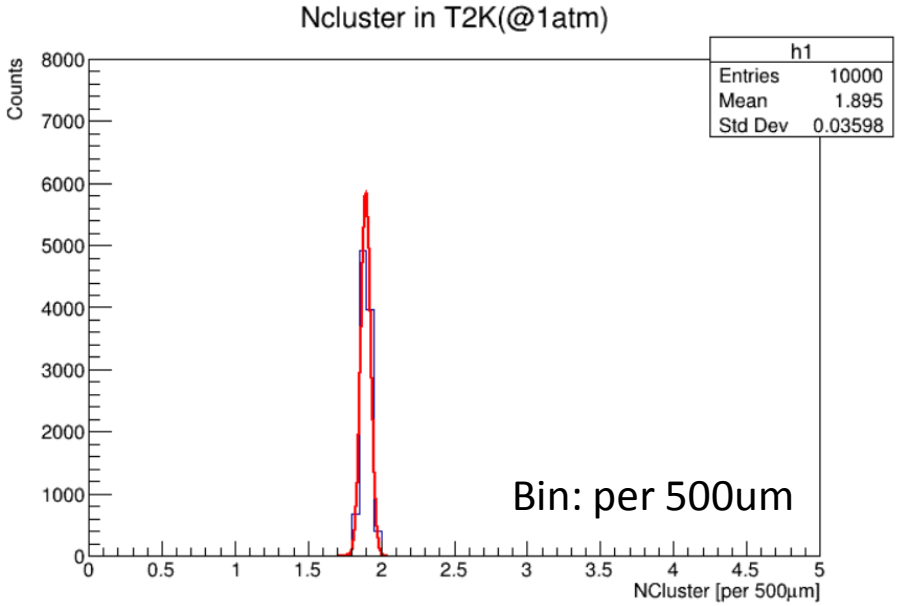
Bin: per 500um

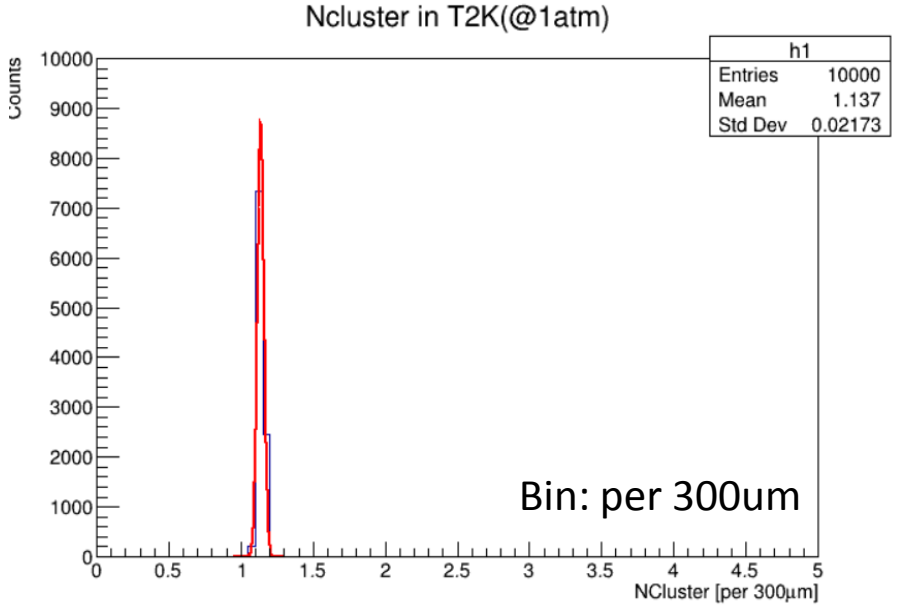
Standard deviation of the primary cluster distribution in T2K gas

- Simulation result of the primary cluster using T2K gas at 1atm
- Standard deviation of the primary cluster distribution will be changed from 0.8 to 0.02 (bin from 10mm to 300um)
- For 300um-500um, the standard deviation of the primary cluster distribution can keep in the same level.









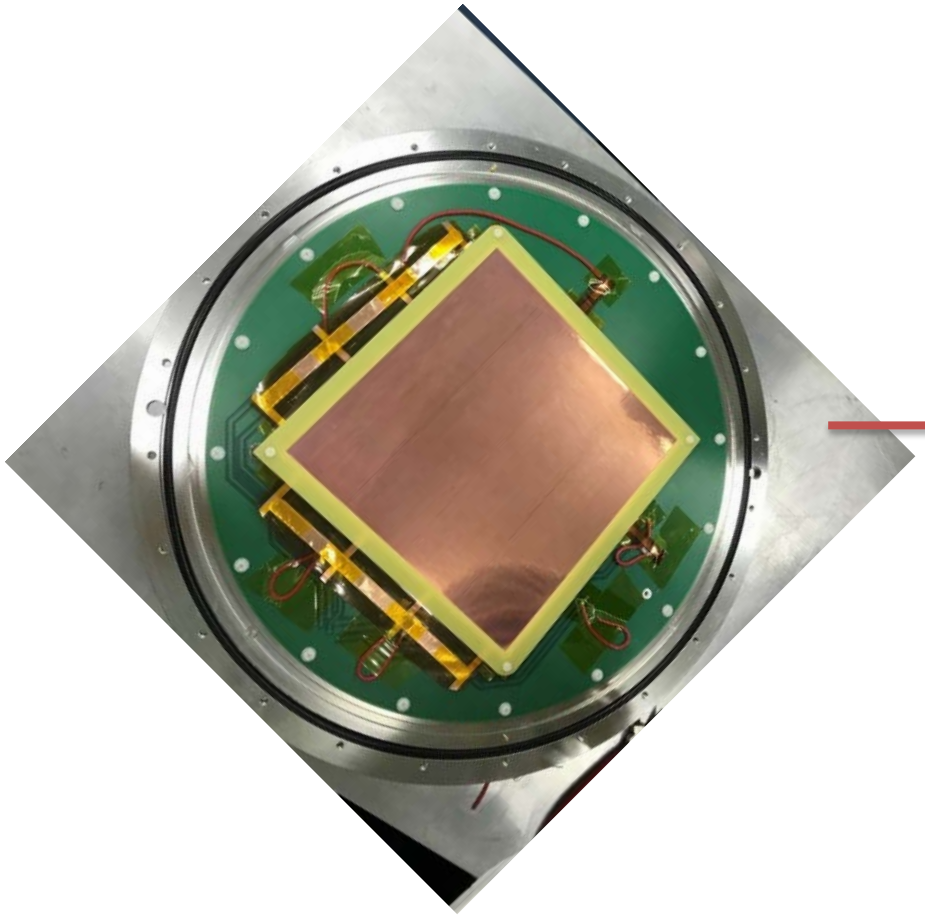
Simulation results

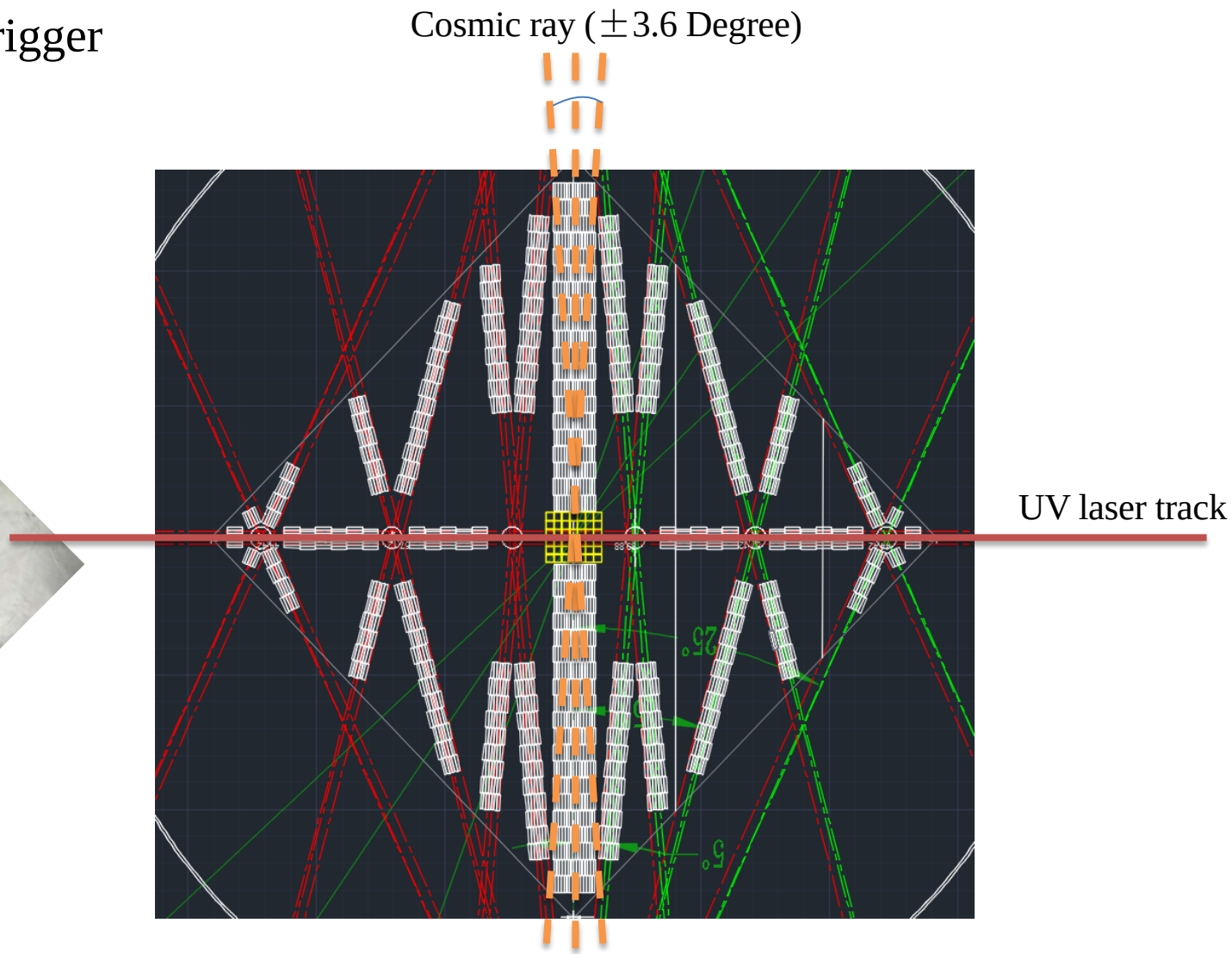
- The codes successfully simulated the primary cluster using the different operation mixture gases.
- Simulation result show that the primary cluster profile along the drift length, and it could meet the pixelated readout TPC detector if the pad size will be kept in the rang of 300um – 500um.
- Simulation result show that the number of the primary cluster under the different gas pressure, and it could be optimized and meet the requirements of the pixelated readout TPC detector if the MPGD readout will run at the low gain.
- More performance of the cluster along the drift in the T2K gas are ongoing…

- Update testing of TPC prototype

TPC detector with UV laser/55Fe/Cosmic ray

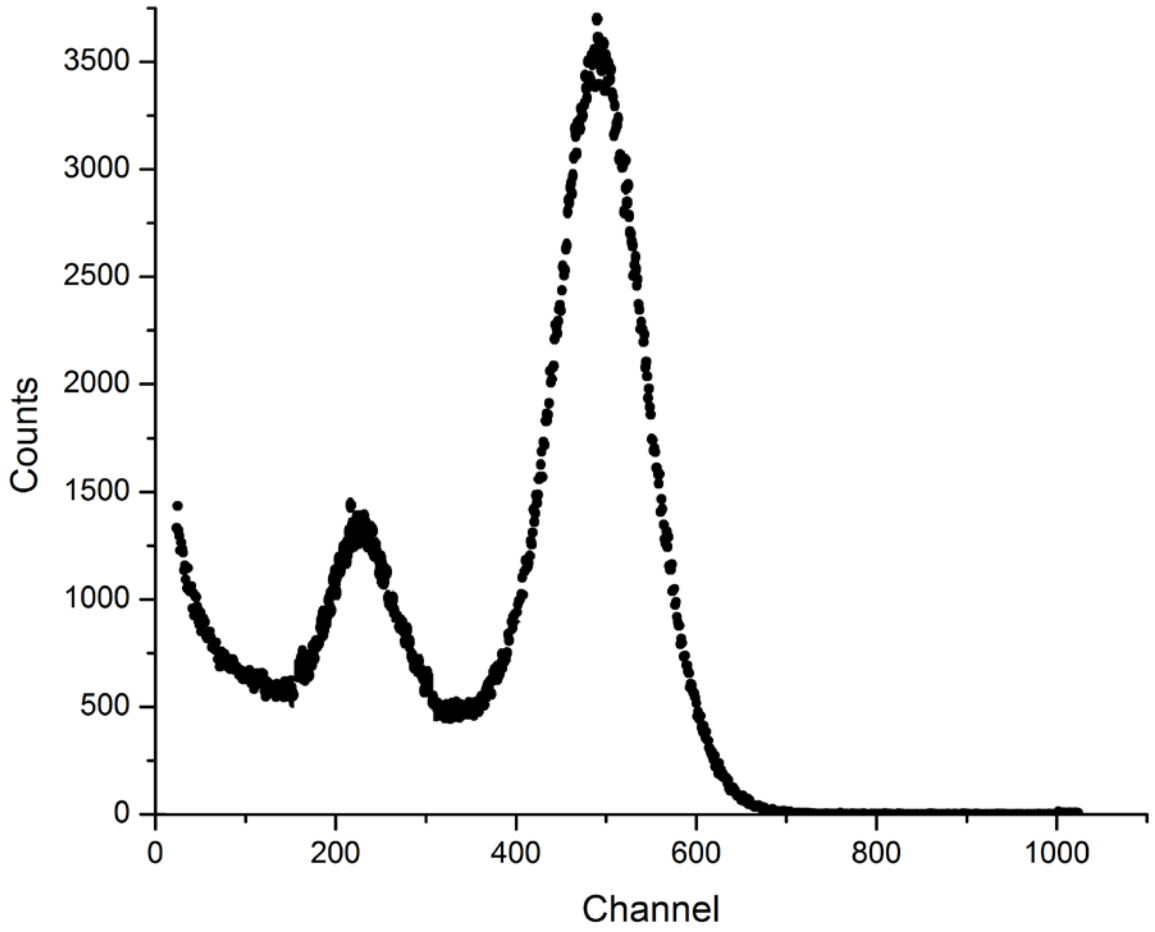
- TPC detector prototype can study the UV laser track, ^{55}Fe radiation source and the cosmic ray.
- Self-trigger, only UV with the external trigger





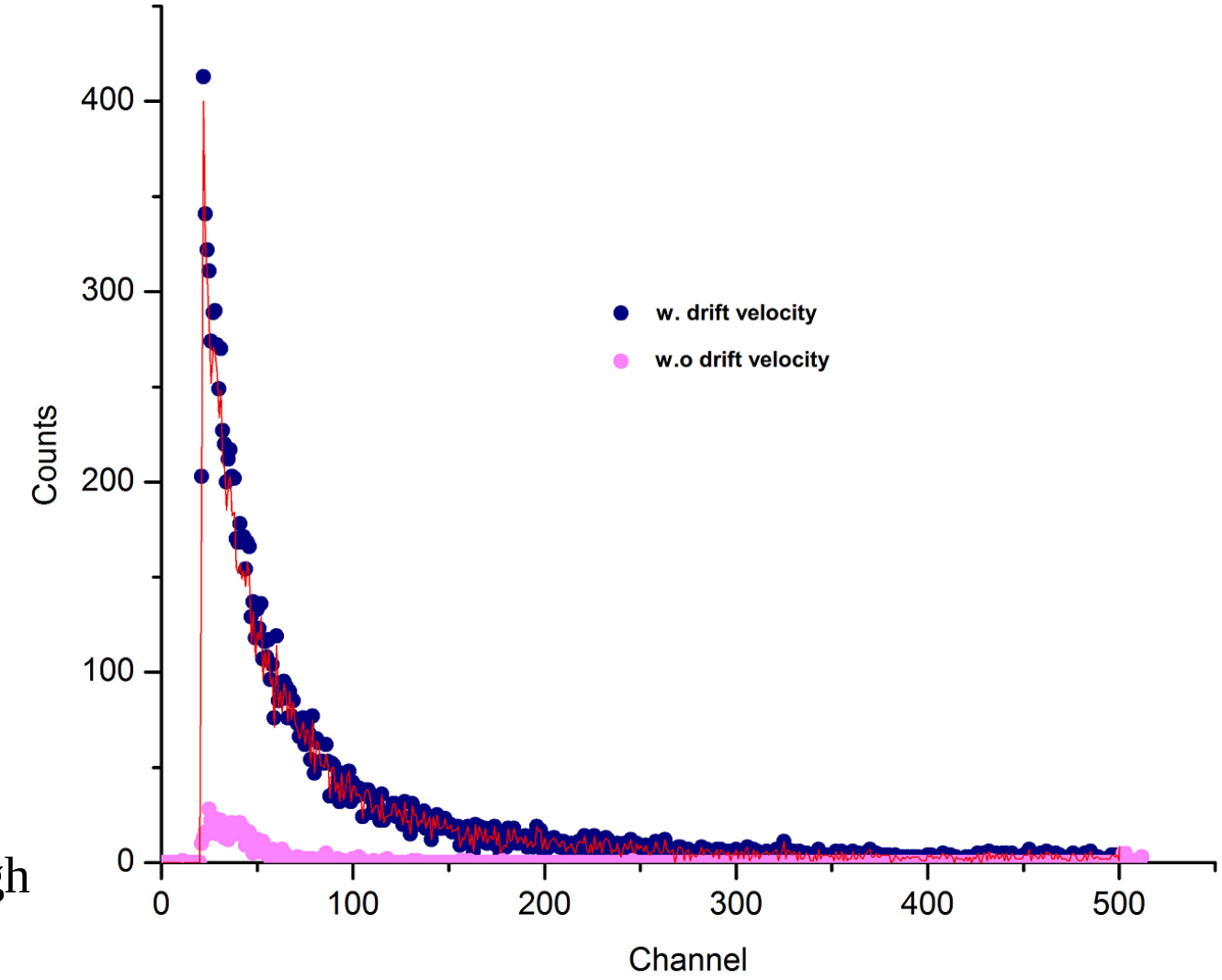
TPC detector with 55Fe

- TPC detector prototype can study using ^{55}Fe radiation source
- 5.9keV X-ray
- Operation gas: T2K
- Only using 7 adjacent readout pads
- TPC prototype was checked after one year development
  - 55Fe X-ray spectrum profile is very good
  - Gain just shift -2% than one year before.



TPC detector with Cosmic ray

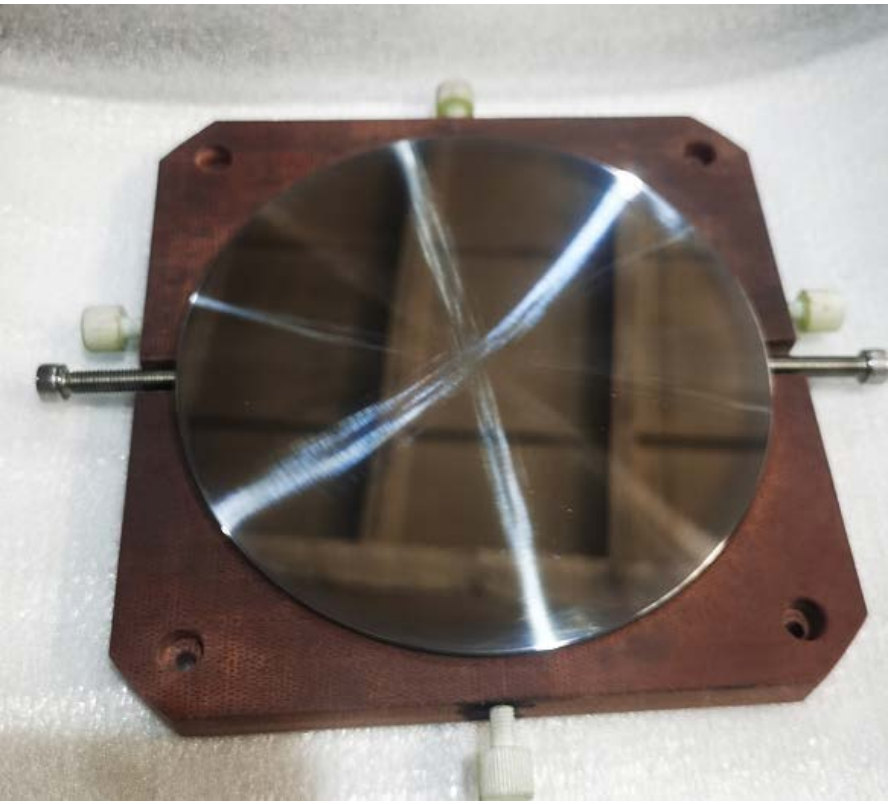
- TPC detector prototype can study using the cosmic ray.
- Operation gas: T2K
- All middle adjacent readout pads
- TPC prototype was studied after 55Fe testing
  - Taken one month data
  - Trigger rate: 0.32Hz in ± 3.6 degree
- The Landau distribution of the cosmic ray's energy spectrum was successfully obtained, but the dE/dx analyzed is so difficult without enough data statistics.

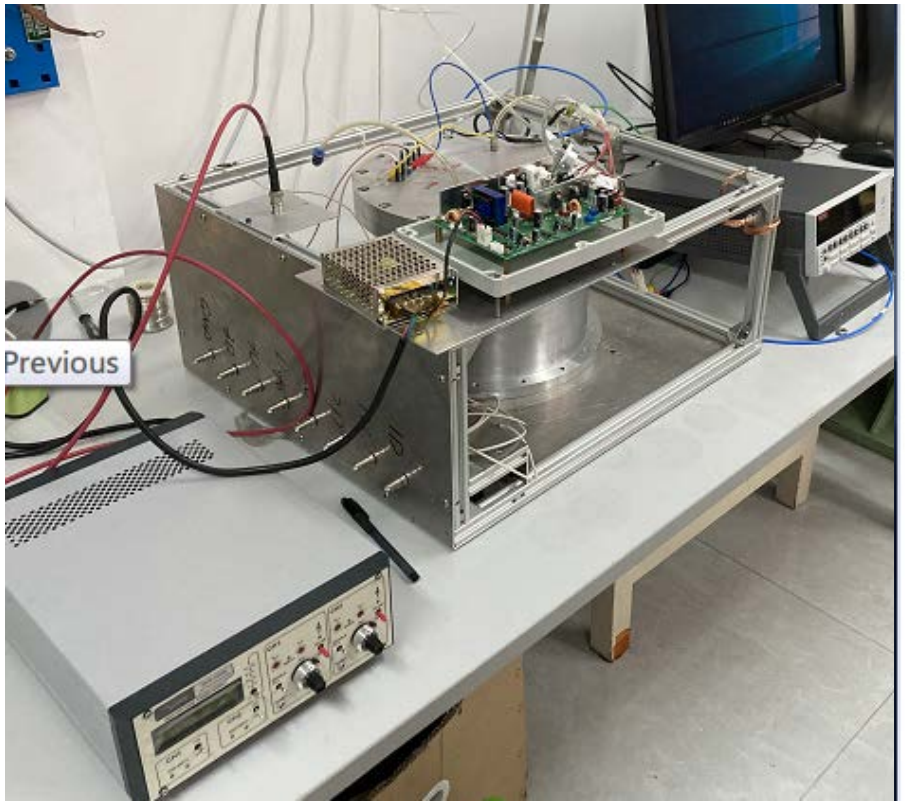


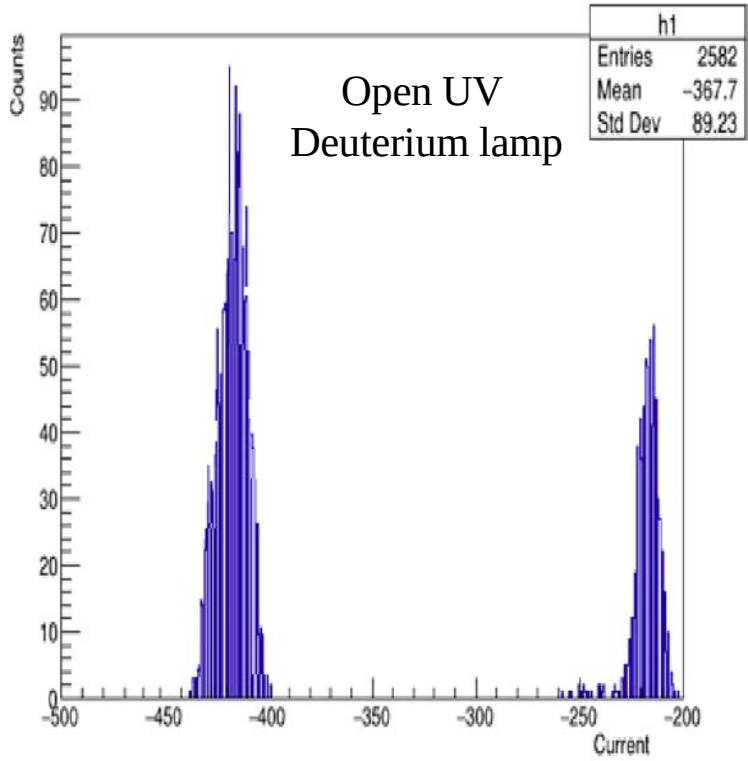
Testing the UV light created the ion disk by photoelectric effect

UV light created the ion disk

- Ions will fill in the drift chamber of TPC to mimic the ions distortion
- Metal mesh polishing Aluminum's surface: 600/800/1000/1200/2000 LPI (**Done)**
- Experimental testing of the current at GEM foil (Ongoing, **>100nA** level)

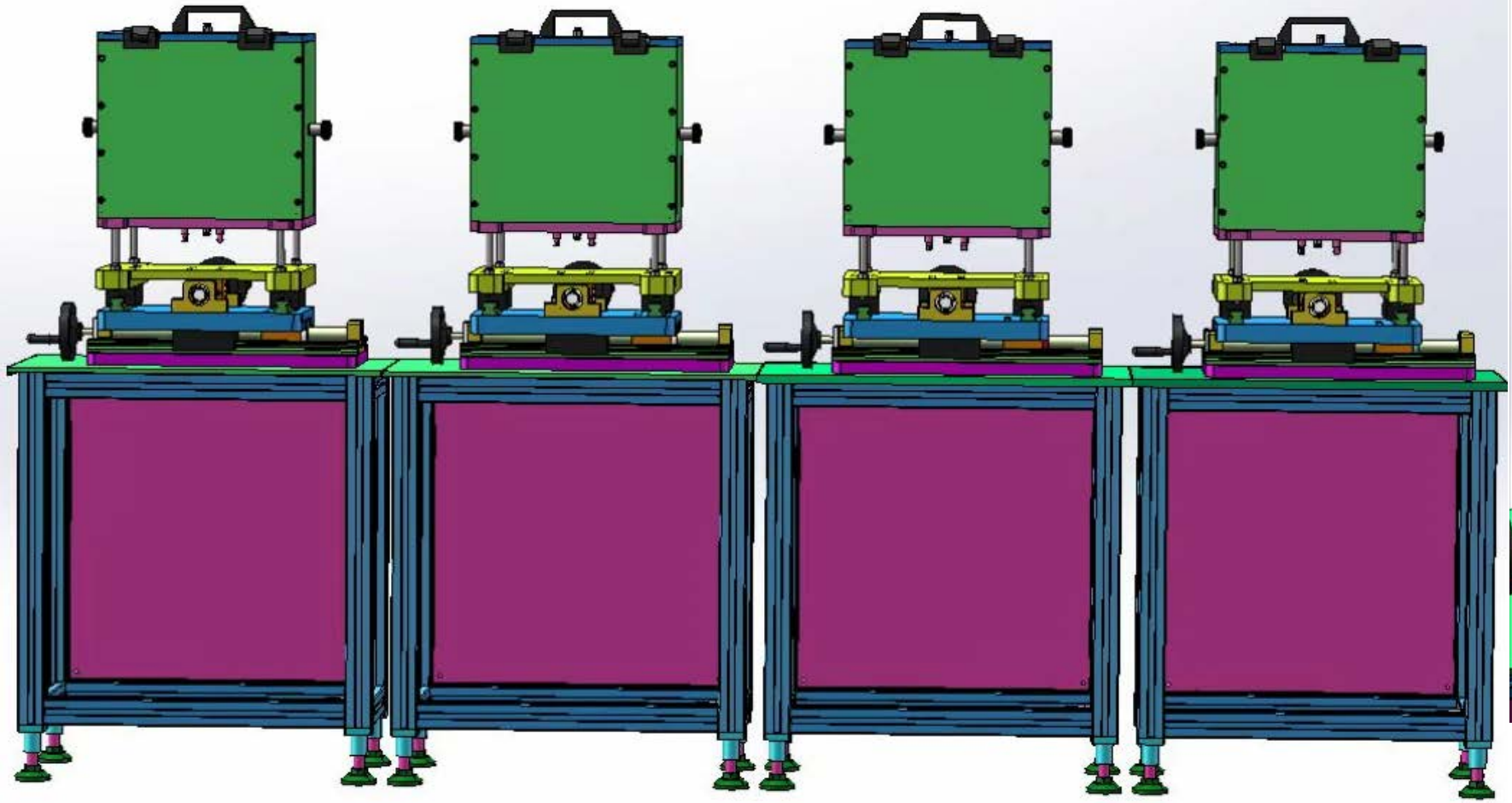


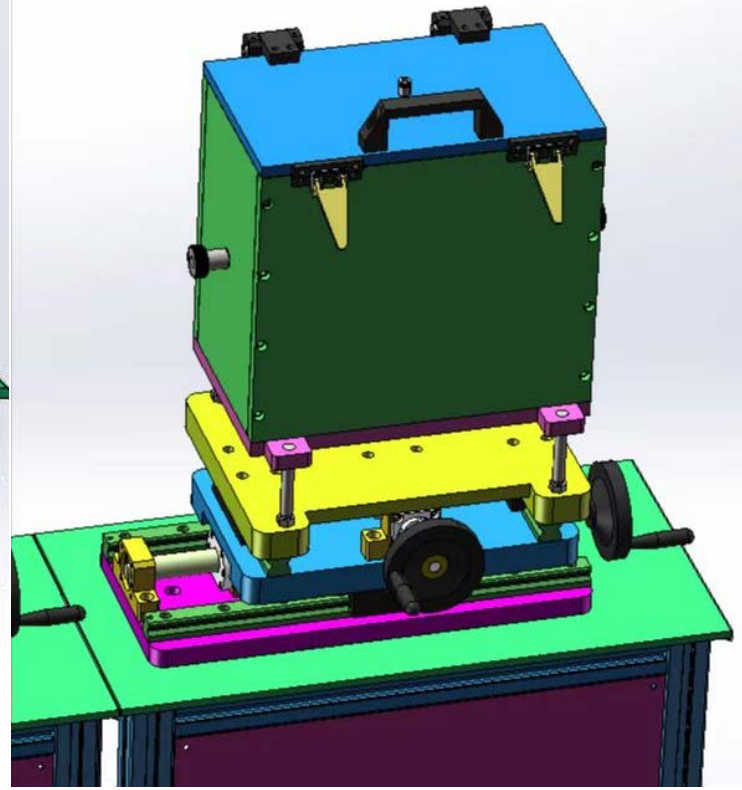




New TPC prototype design and optimization (v0 -> v1)

- Study some new parameters complemented previous circular TPC
- Cascaded TPC detectors to test dE/dx and IBF distortion
- Single TPC detector to test under 1.0T beam test in DESY
- New FEE ASIC chip wafer production submitted **on 20, June** (500um pixelated based, Tsinghua)





Summary and plan

First ECFA WORKSHOP.

on e+e- Higgs/EW/Top Factories, October 5-7, 2022, in Hamburg

https://indico.desy.de/event/33640/

- The simulation is starting to study the primary cluster using the different operation mixture gases, the different operation gas pressure and optimization.
    - Some preliminary results obtained at IHEP.
    - LCTPC setup a separate task working to study the cluster counting algorithms
        - TPC potential extending to e+e- collider (abstract from Huirong)
- TPC detector prototype was studied using the UV laser track, ^{55}Fe radiation source and the cosmic ray.
    - TPC prototype was checked after one year development (Good performance!)
    - Landau distribution of the cosmic ray's energy spectrum was analyzed.
- To meet high luminosity of Z pole run, the testing the UV light created the ion disk by photoelectric effect, and the experimental results show the reasonable current to study.
    - Created the enough ions in the drift chamber
    - Mimic the ion distortion and calibrate by UV track, cosmic events.

Many thanks!