Three Particle Elastic Scattering Experiment

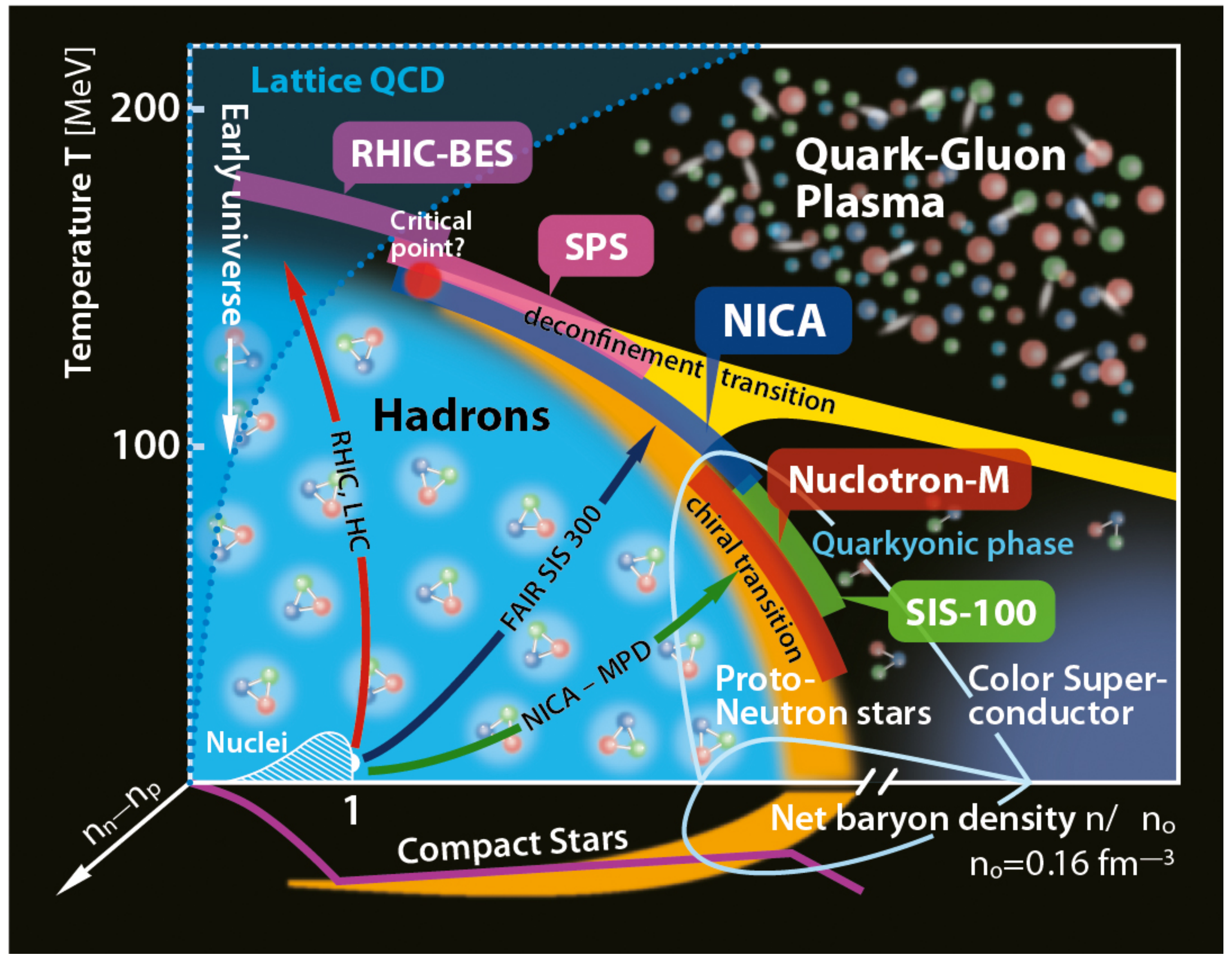
Toward new era of colliding experiment

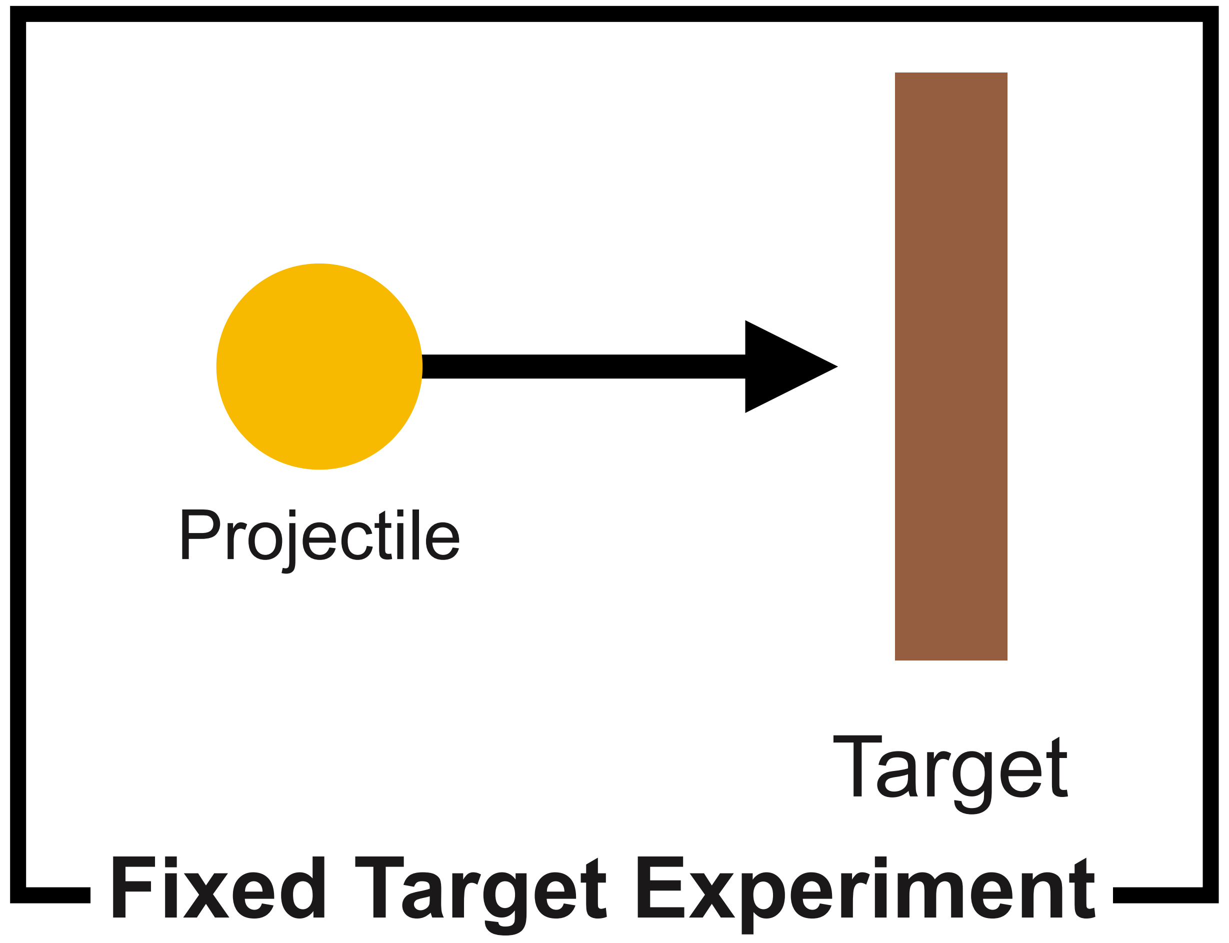
2021/1 PNU Workshop, 2021.02.25, MINJAE ISAAC KWON

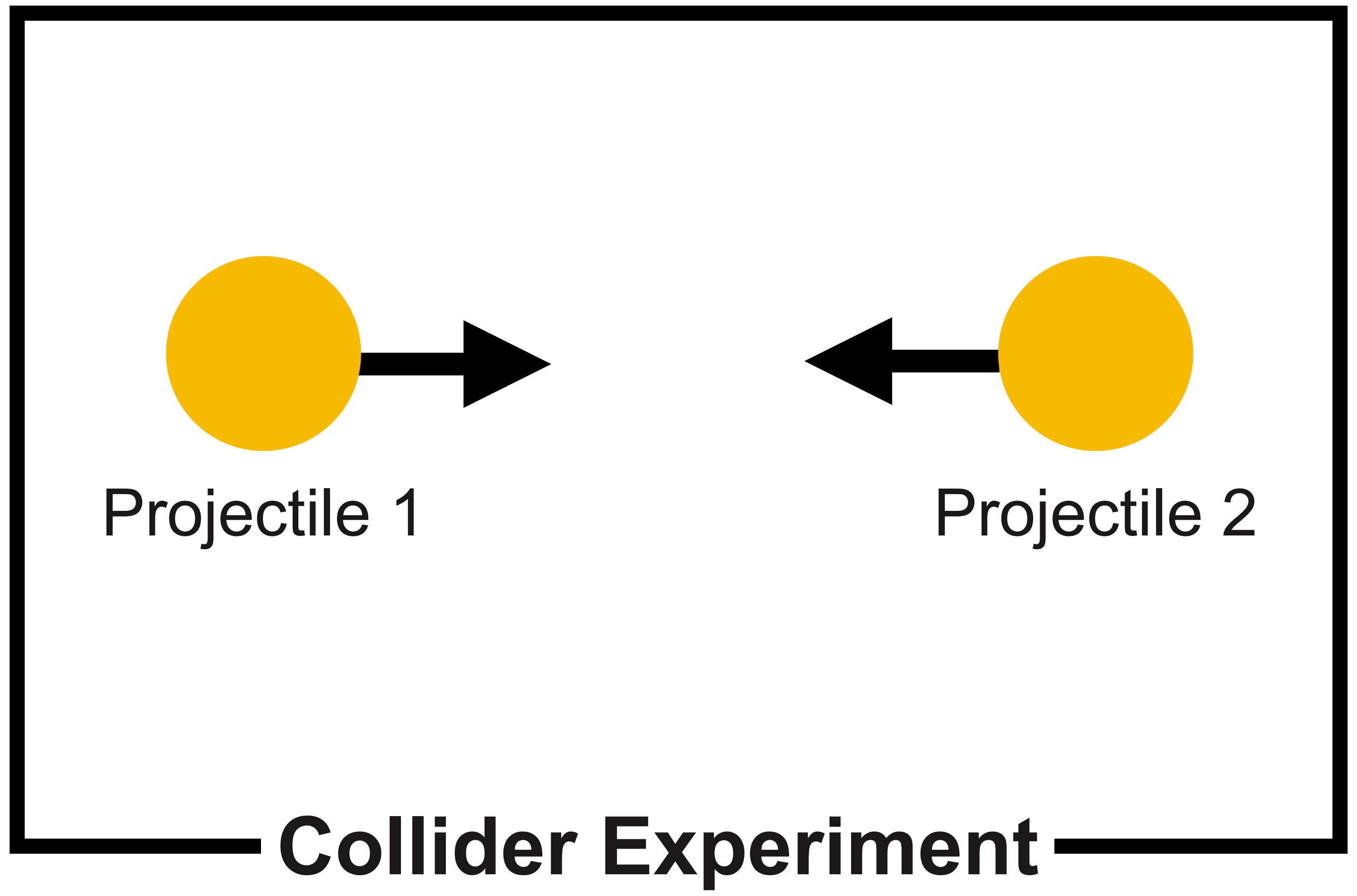
3 Particle Collision

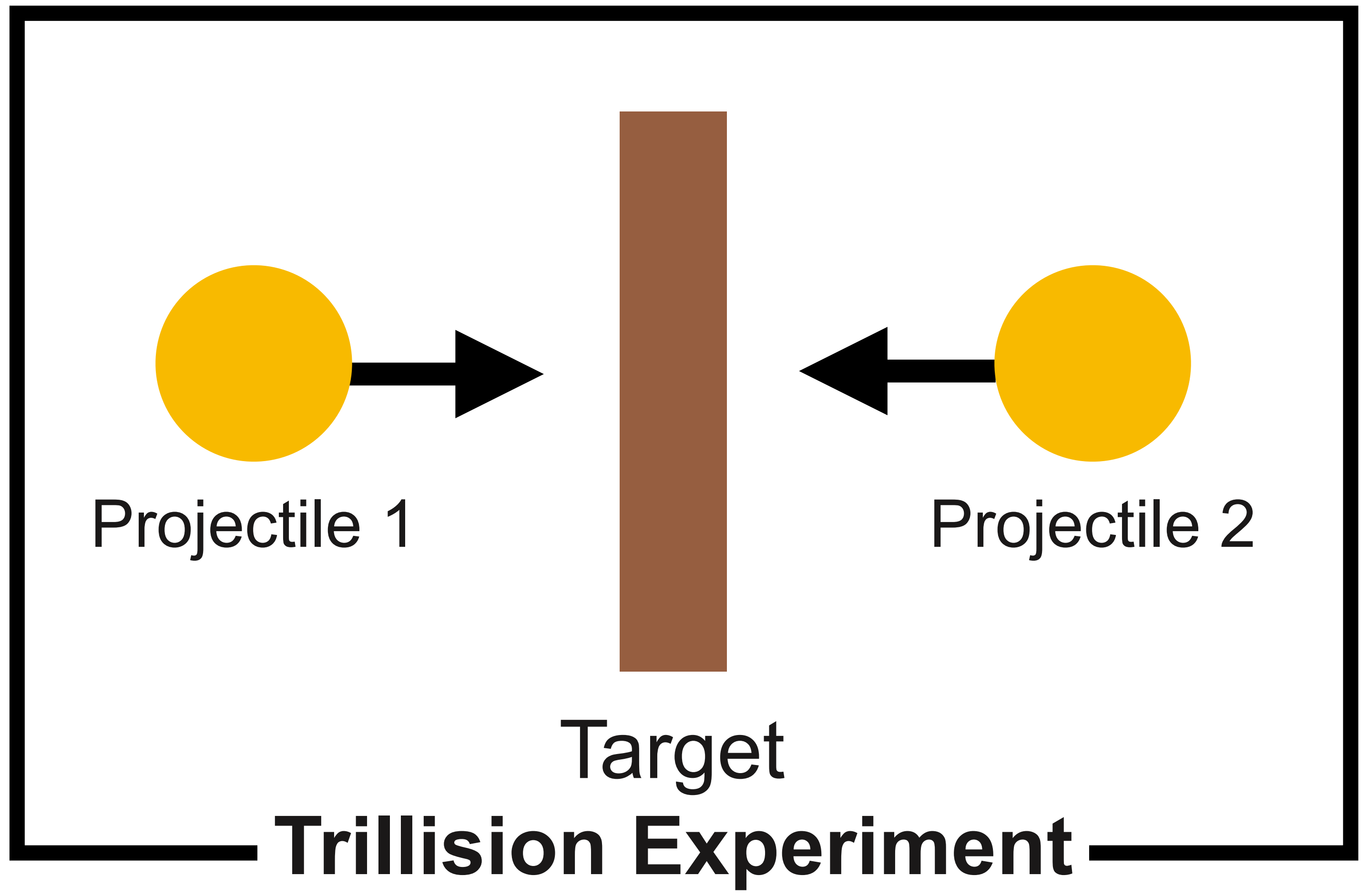
- *MORE DENSITY*: **Trillision Experiment** (3-body colliding)
- 2 particles and 1 target should be needed.
- ALITE is designed at run5-6 of ALICE.
  ALIce **T**arget **E**xperiment
- Firstly, 3 particle elastic scattering experiment **is on-going.**

QCD Phase Diagram









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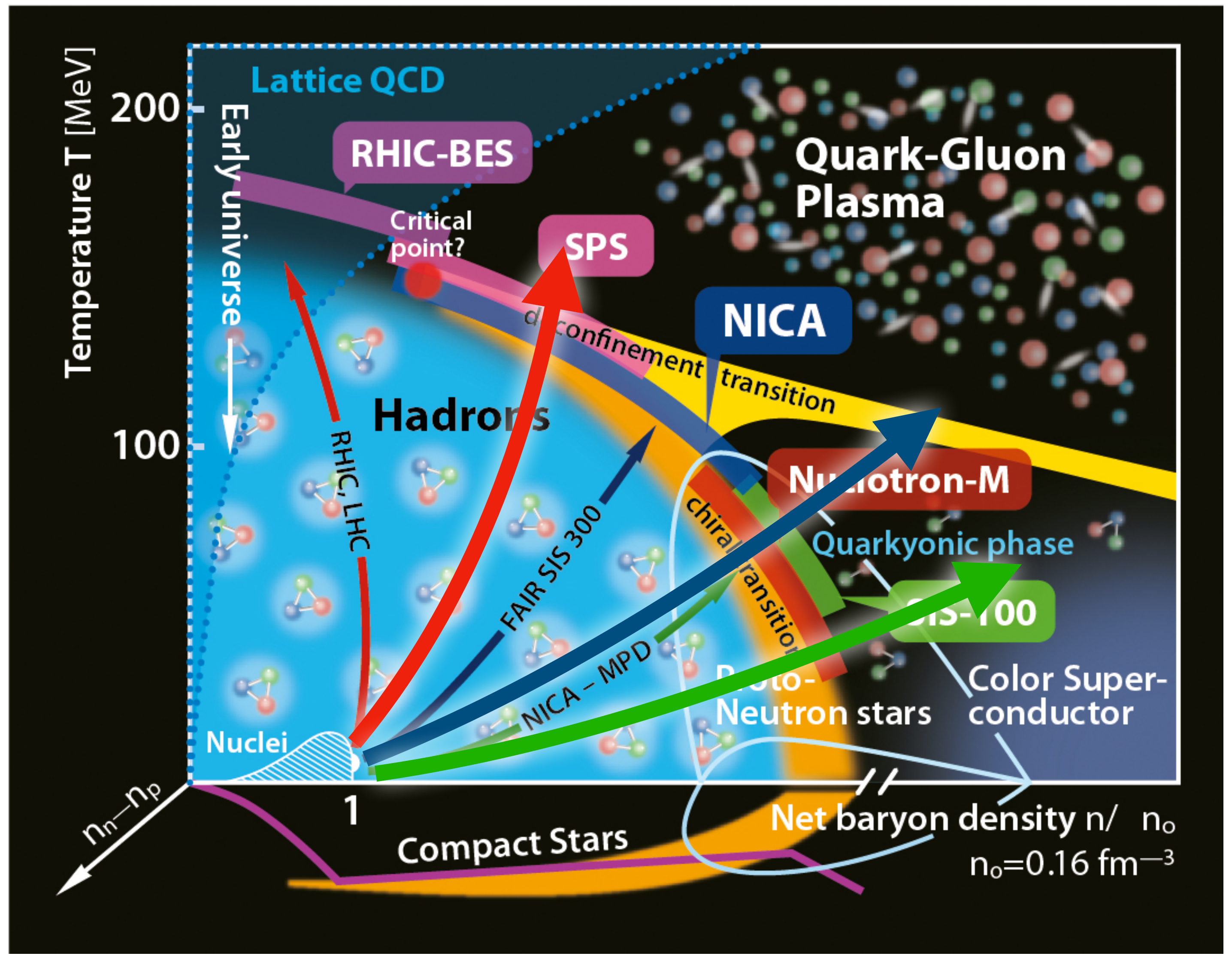
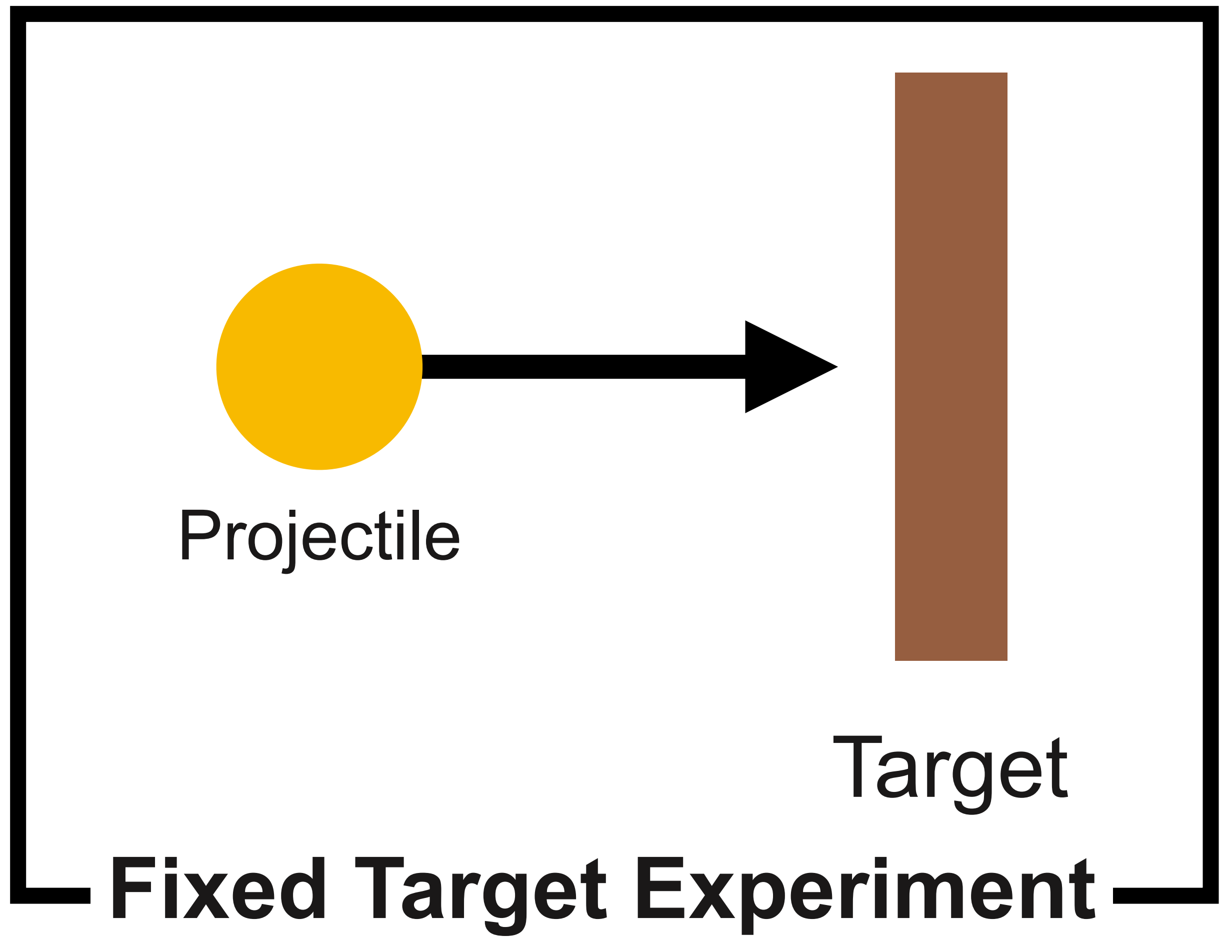
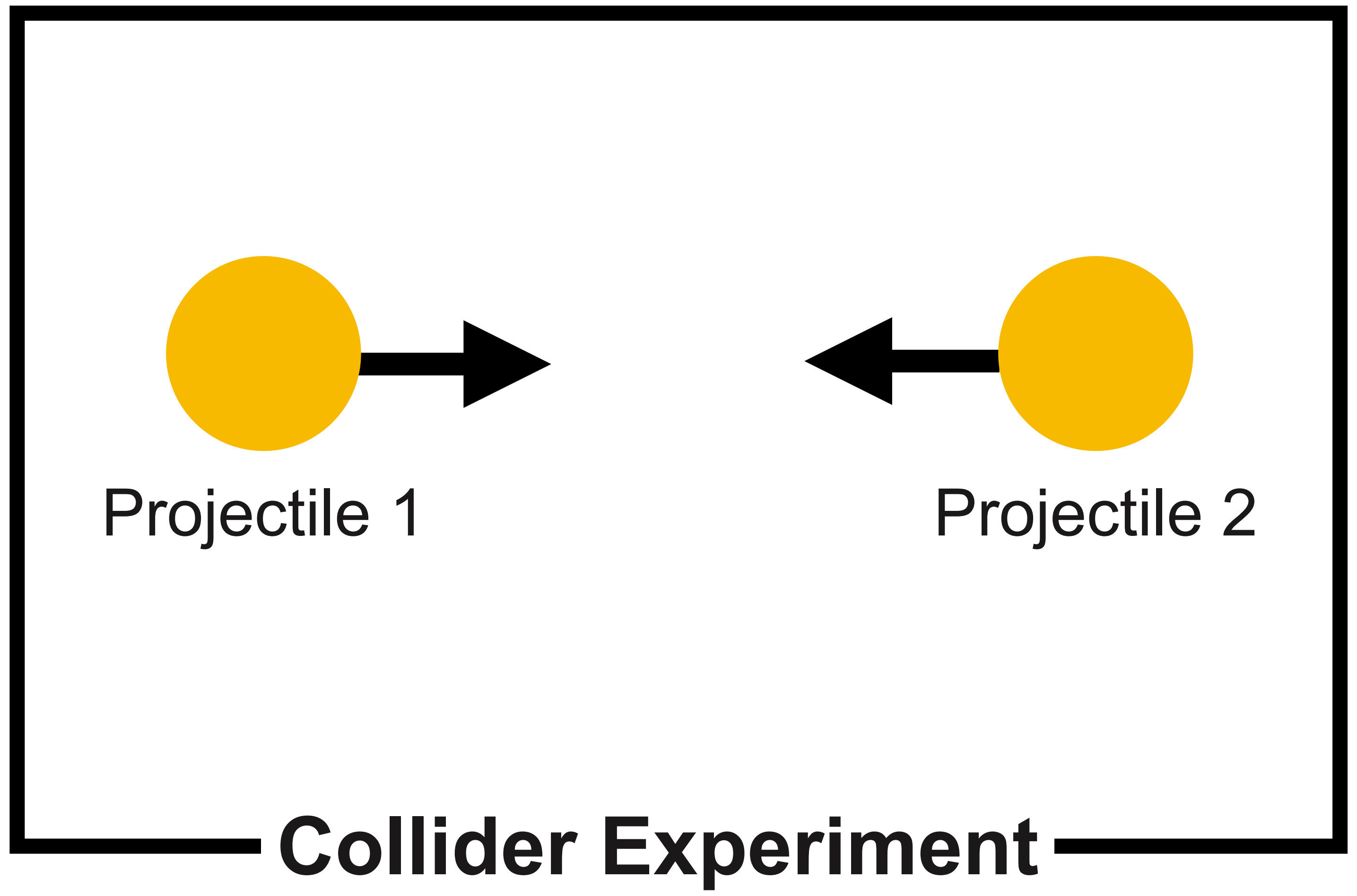
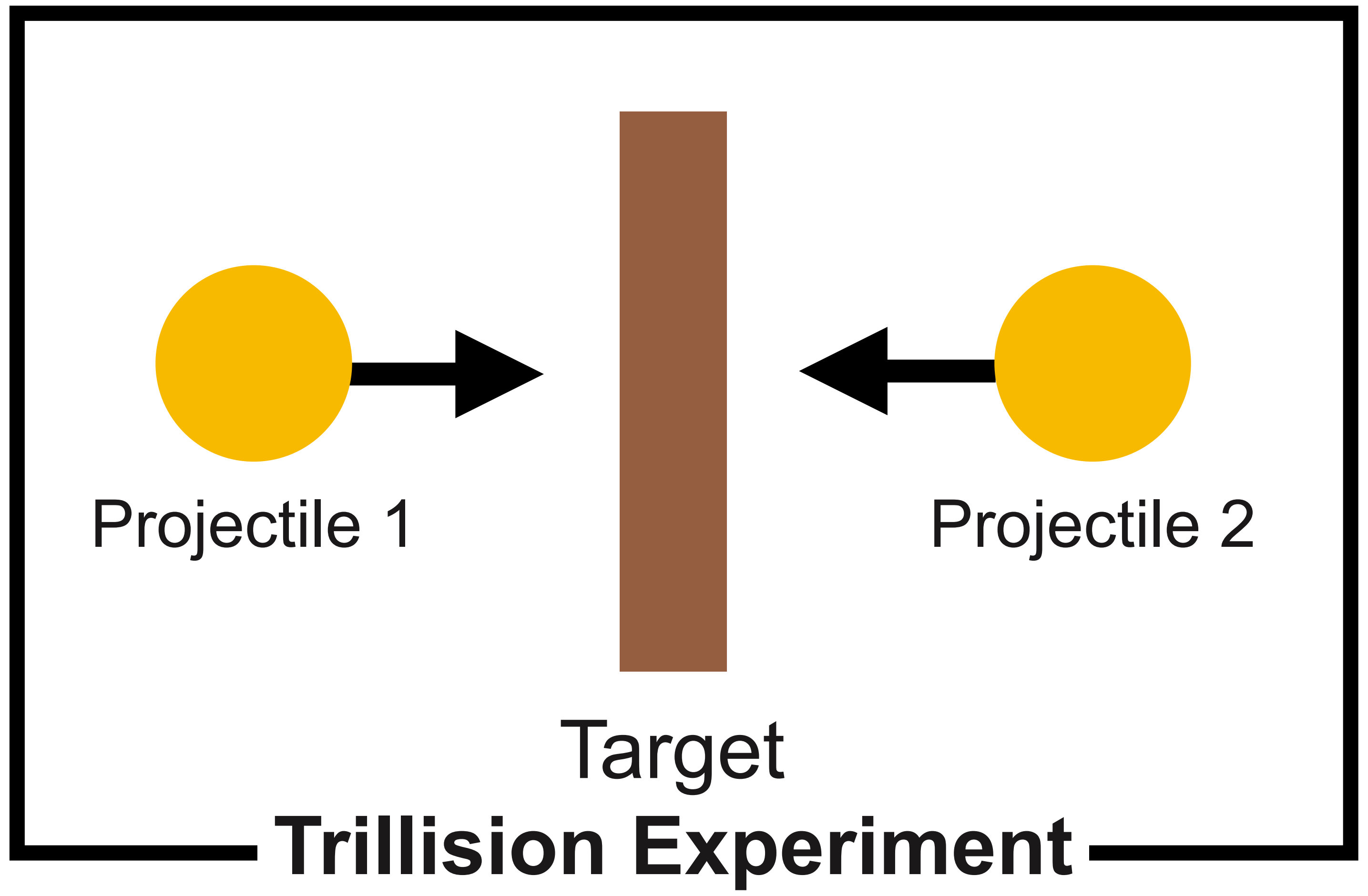


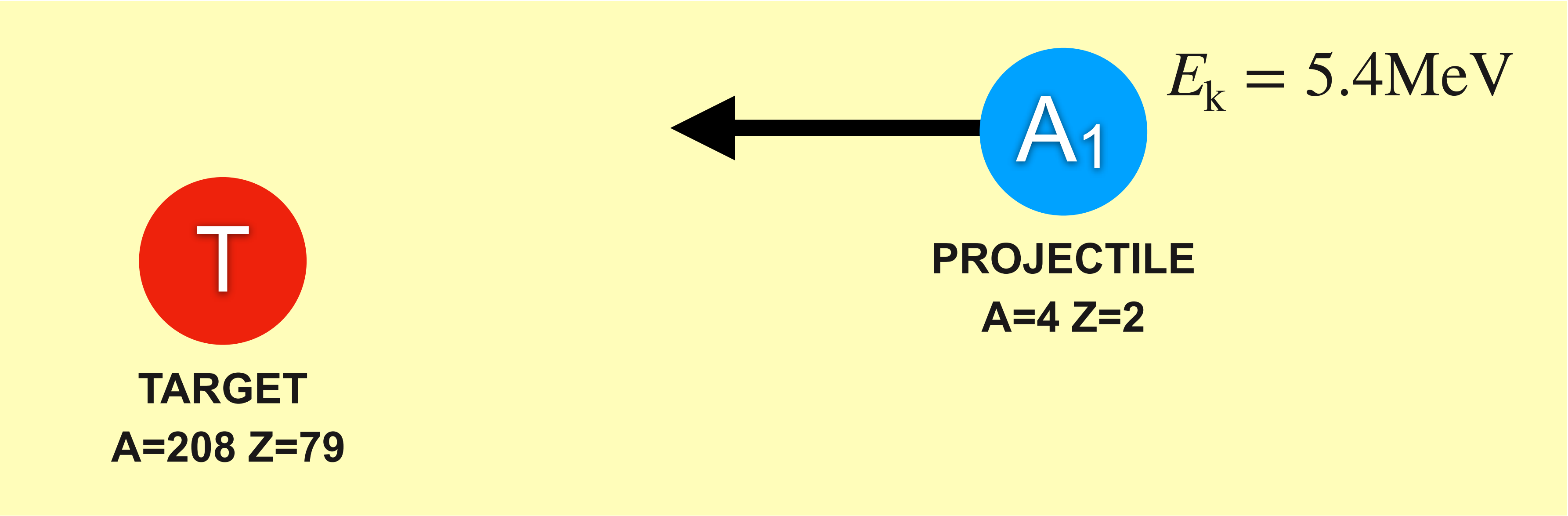






3 Particle Elastic Scattering

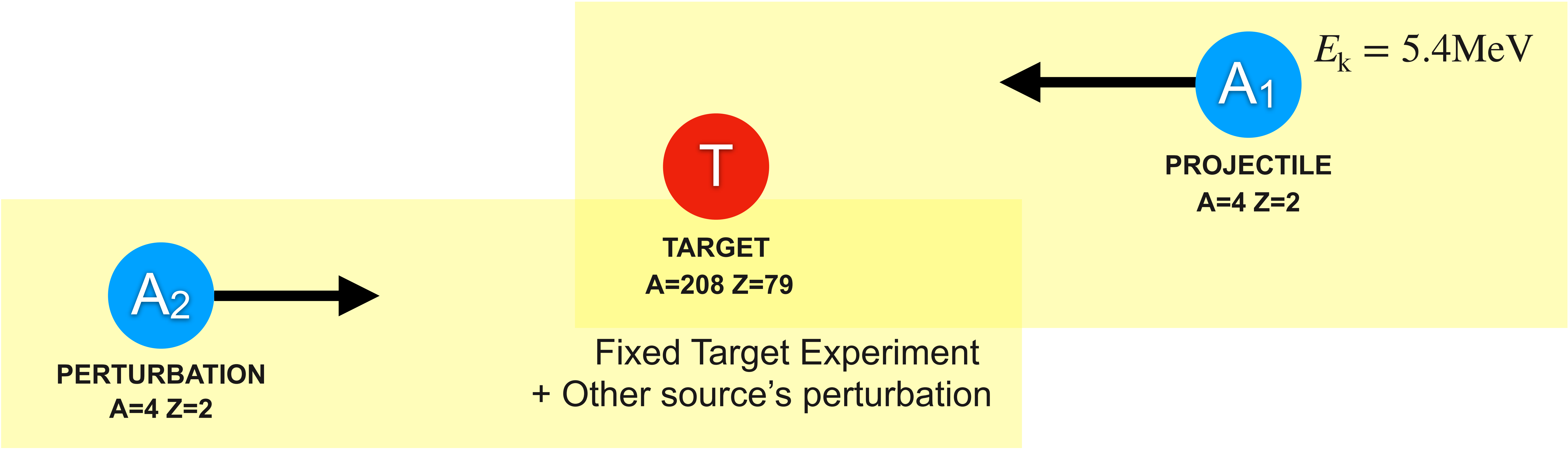
With perturbed scheme, For Background Rejection



Fixed Target Experiment

3 Particle Elastic Scattering

With perturbed scheme, For Background Rejection



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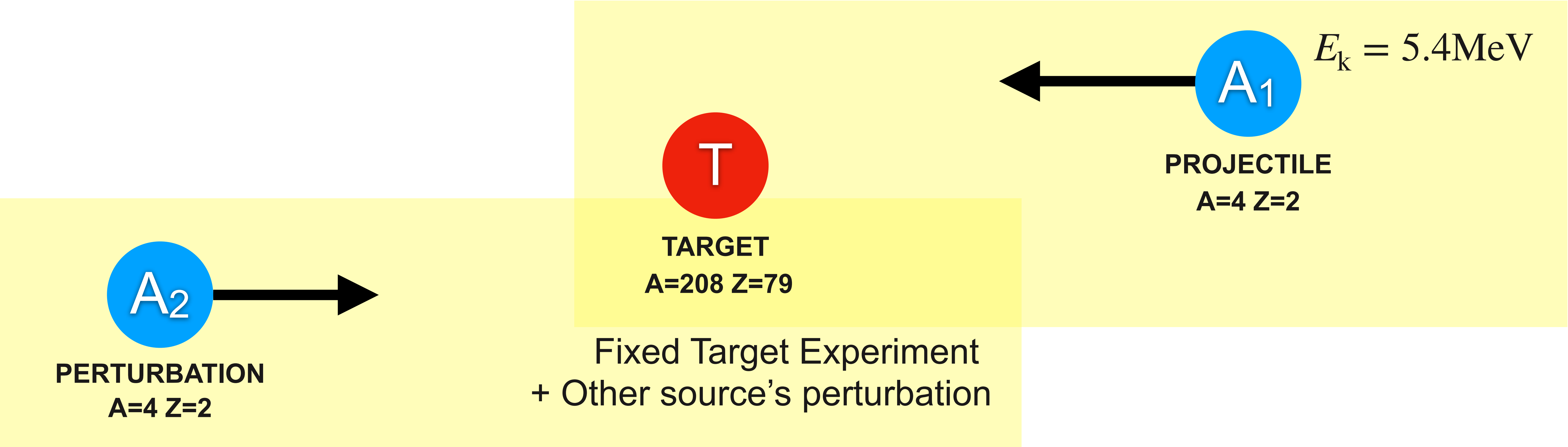

But, EVENT BY EVENT trajectory of particles cannot be measured.

Statistical Perturbation should be measured.

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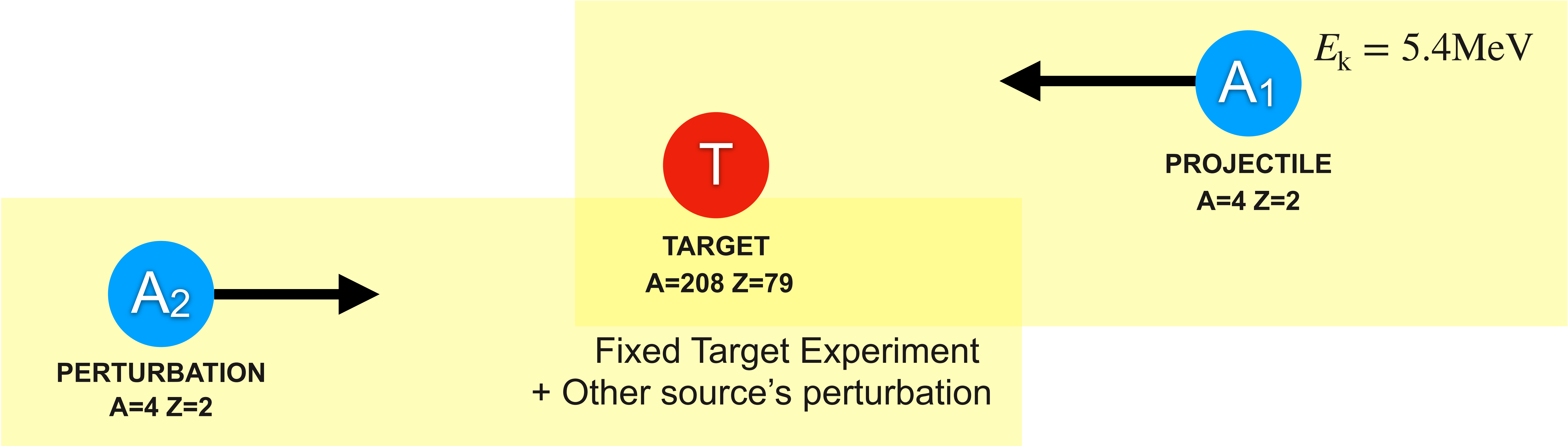

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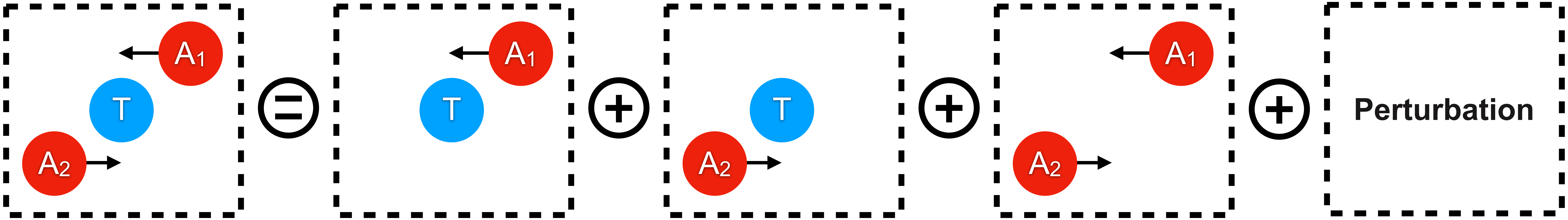
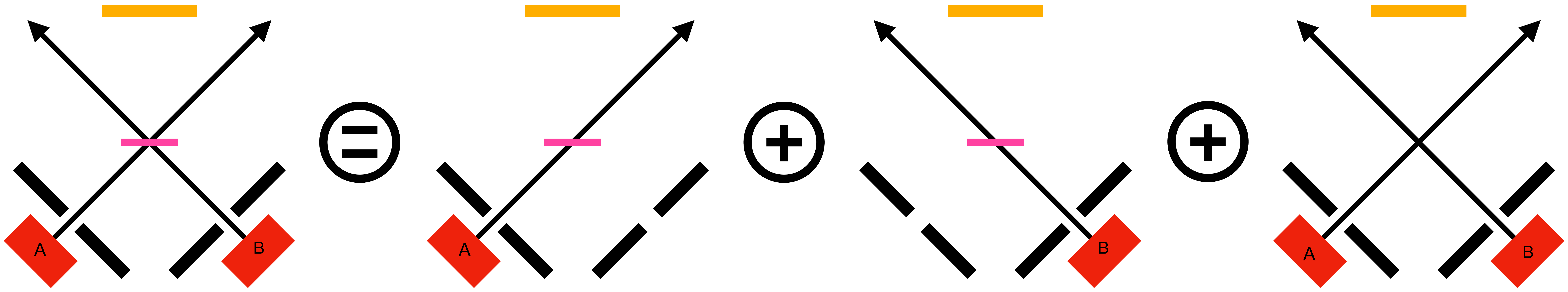


Triple Particle | 1 Source FTE (1) | 1 Source FTE (2) | 2 Source MTE

FTE: Fixed Target Experiment
MTE: Moving Target Experiment

3 Particle Elastic Scattering in REAL WORLD

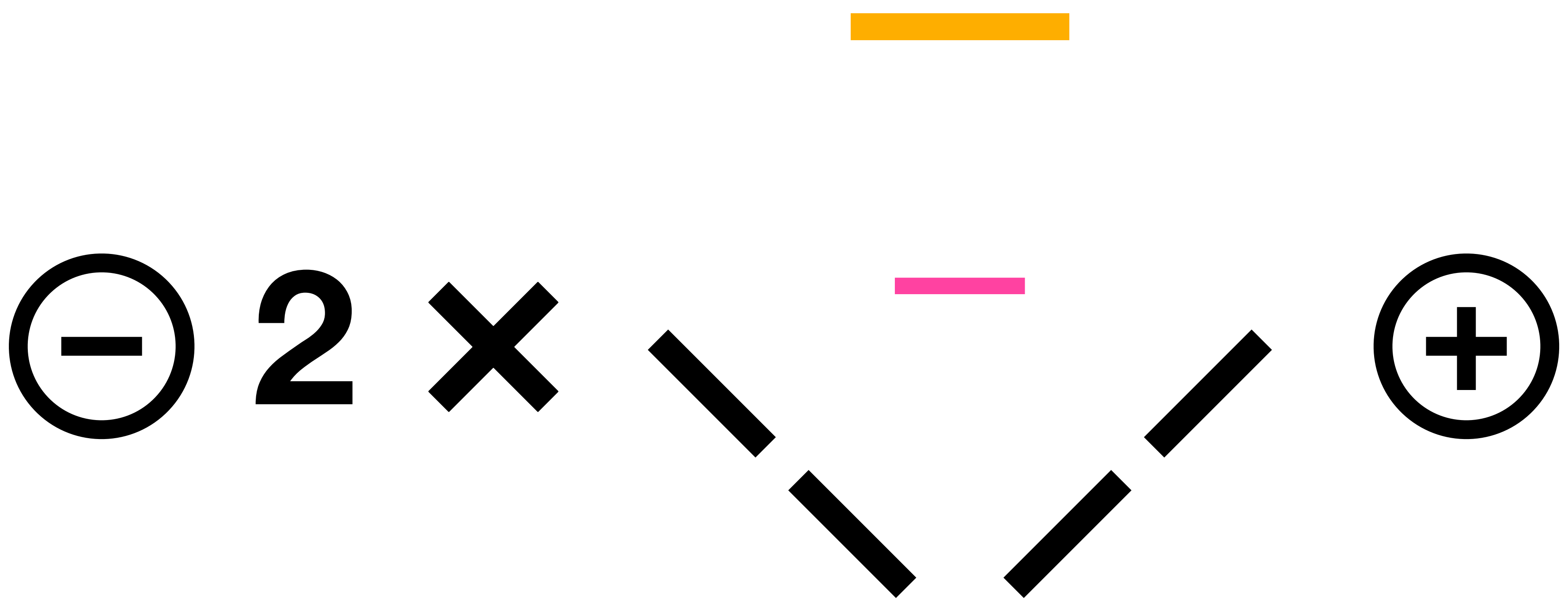


3중 충돌 실험 = A 표적 산란 실험 + B 표적 산란 실험 + 상호 산란 실험

: 검출기

: 박막 표적

측정하는 것
검출기에서의 입자 입사량

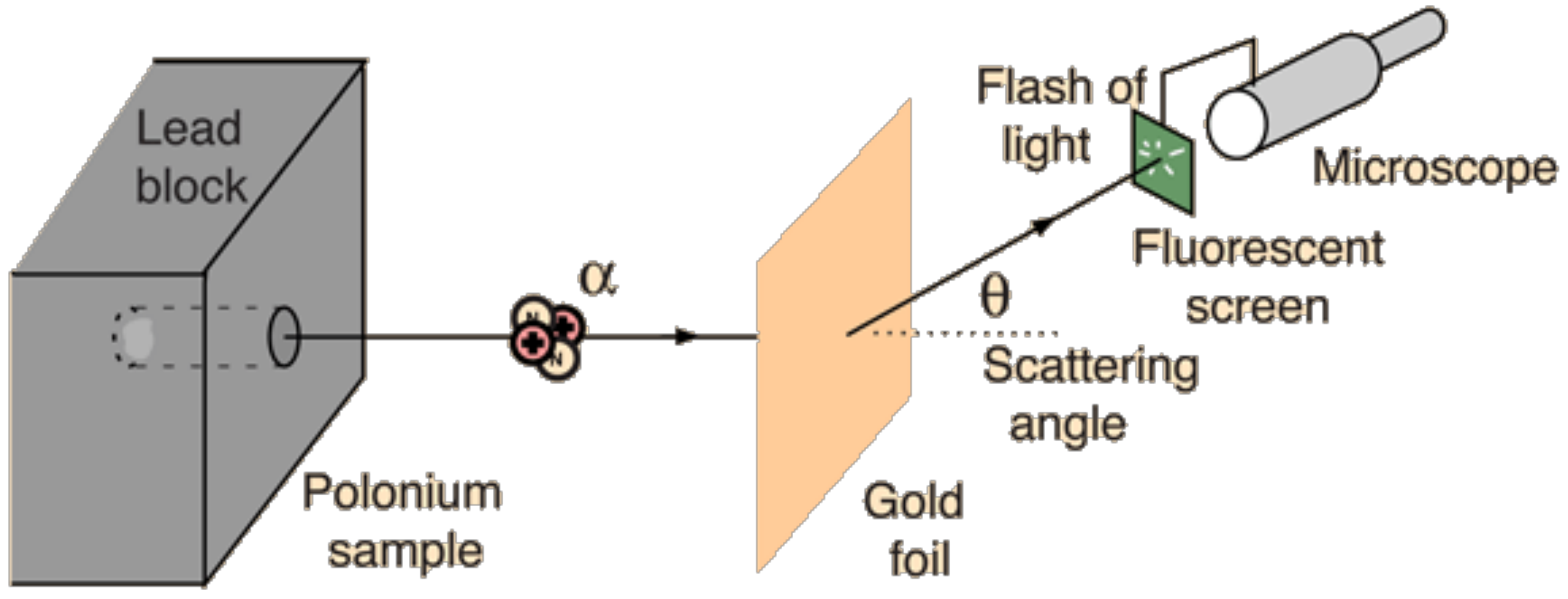


시간 독립 잡음

섭동 조건
= 0 ?

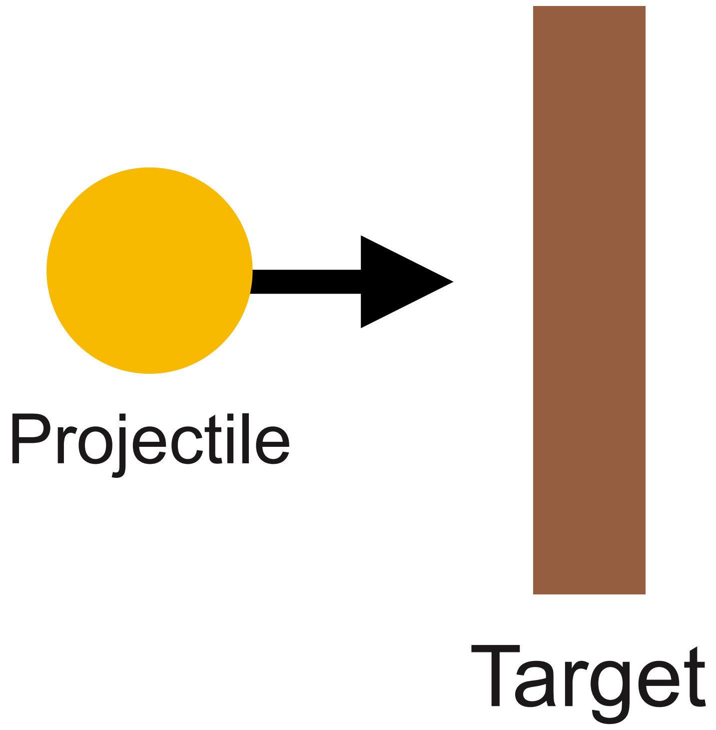
Elastic Scattering Experiment

Rutherford's experimental condition



Inspired from Rutherford Scattering …

Image is from hyperphysics
http://hyperphysics.phy-astr.gsu.edu/hbase/rutsca.html

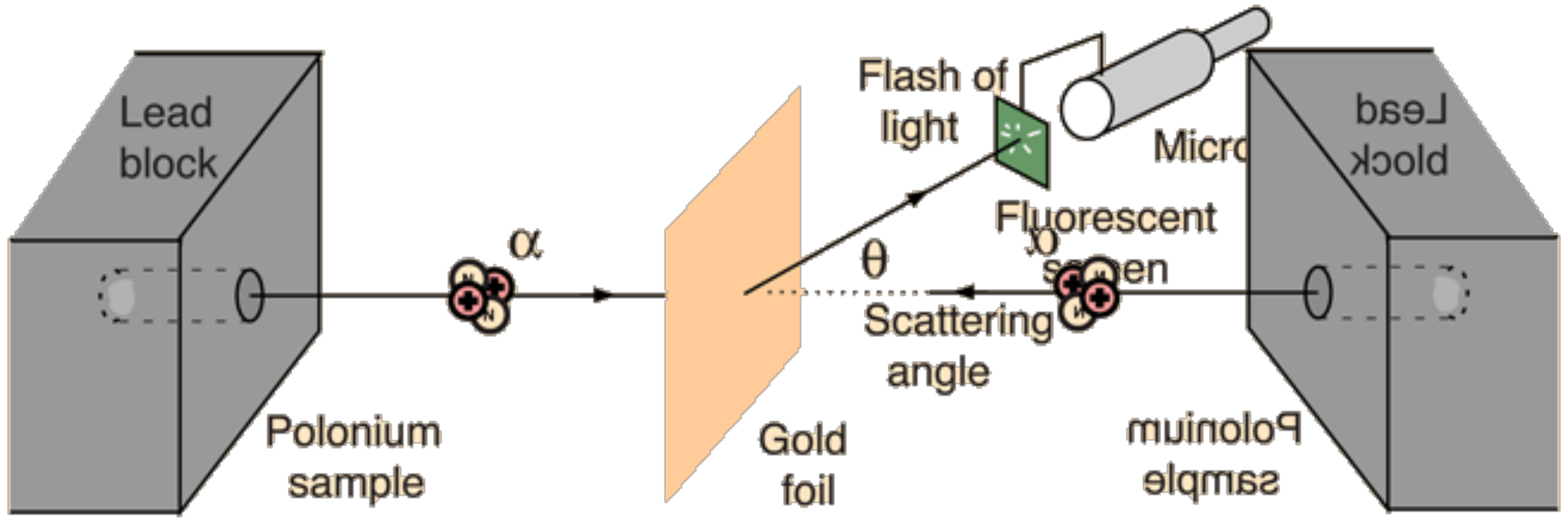


PNU's valid experimental condition

- Radiation Source
  - Am-241 Source **x 2**
    α-particle with $E_{\mathrm{k}} = 5.486\mathrm{MeV}$
- Detector
  - ALPIDE100 Detector
- Additional Environment
  - Vacuum Chamber

Elastic Scattering Experiment - more

Rutherford's experimental condition



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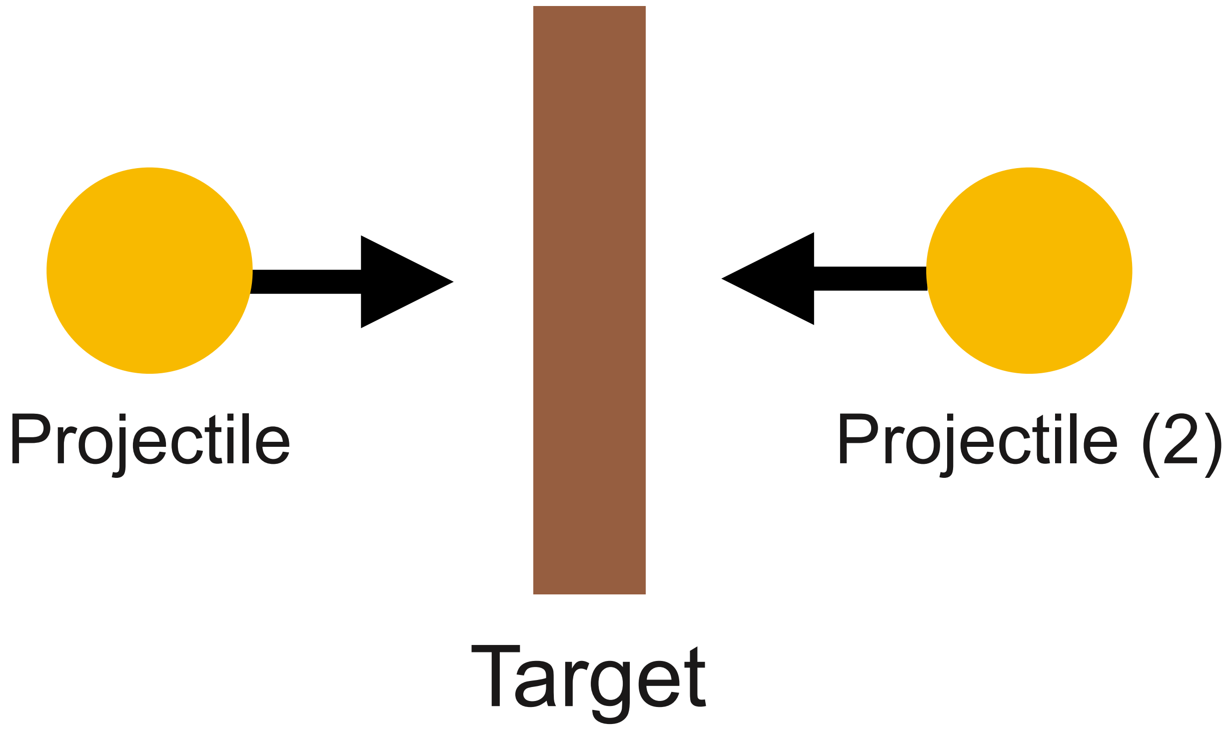

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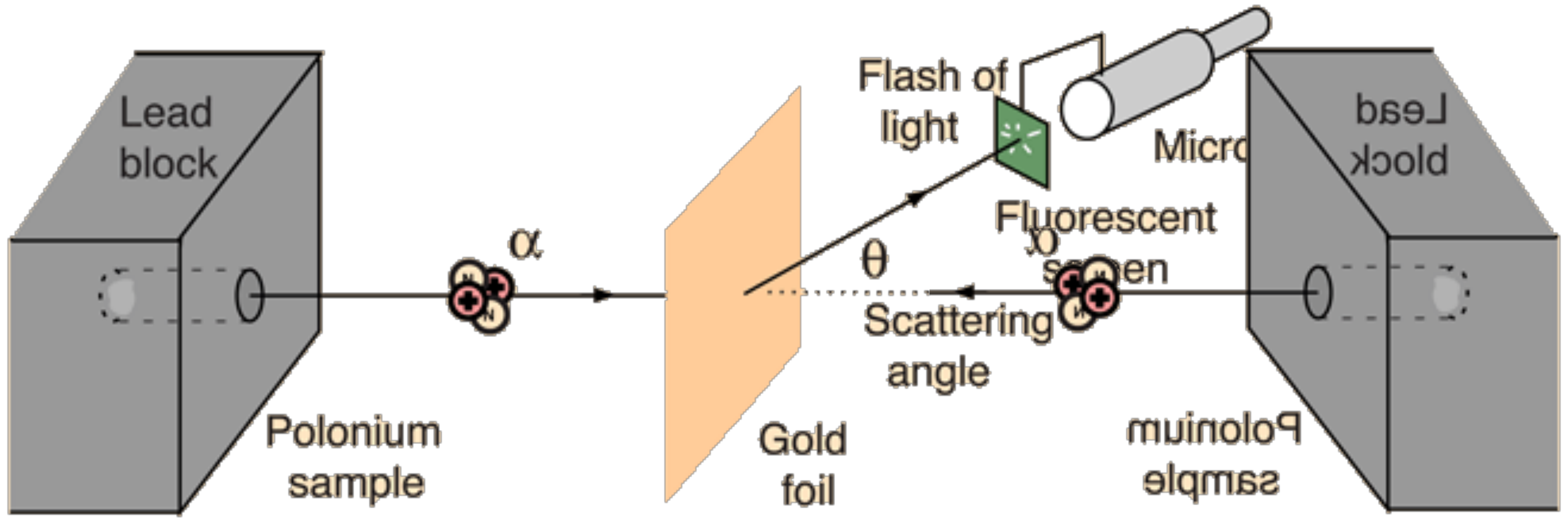

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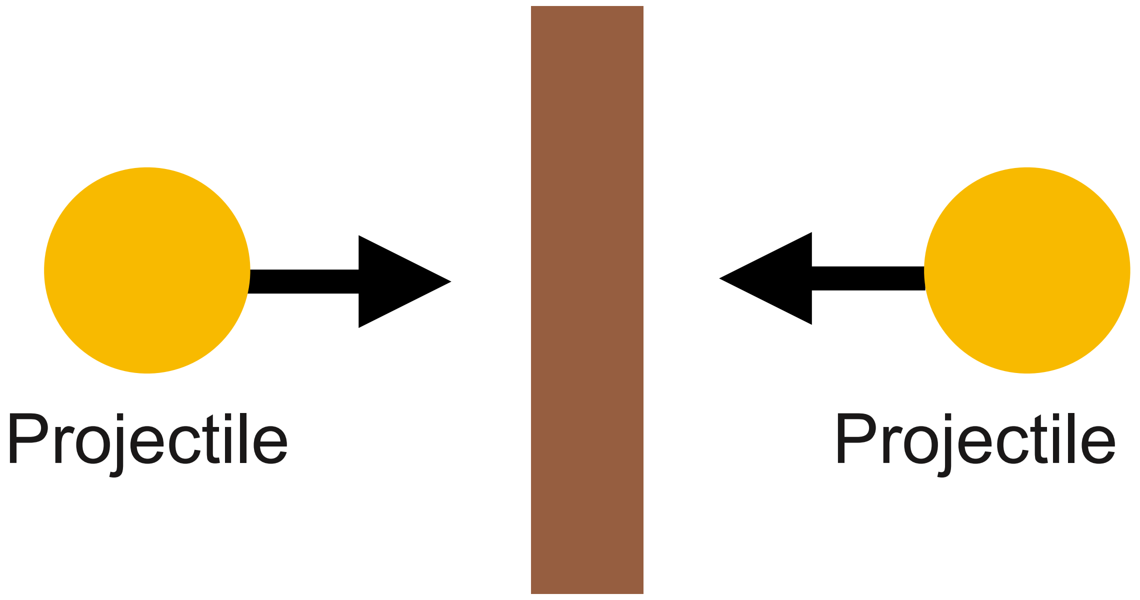

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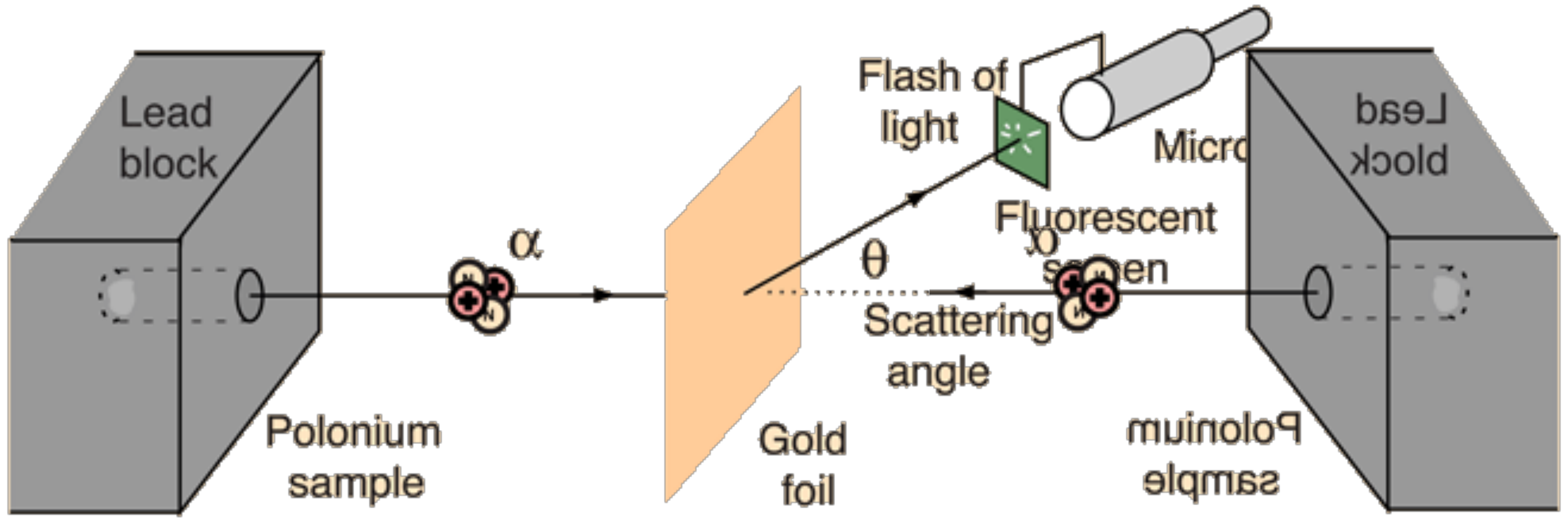

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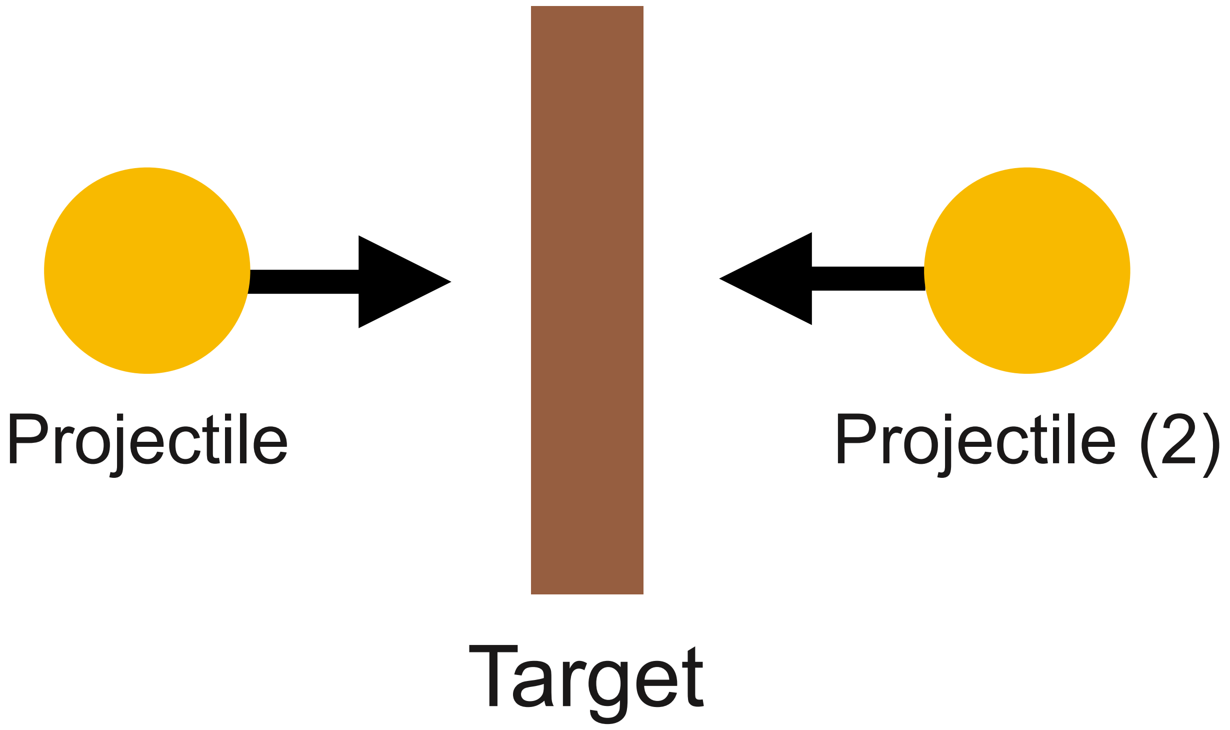

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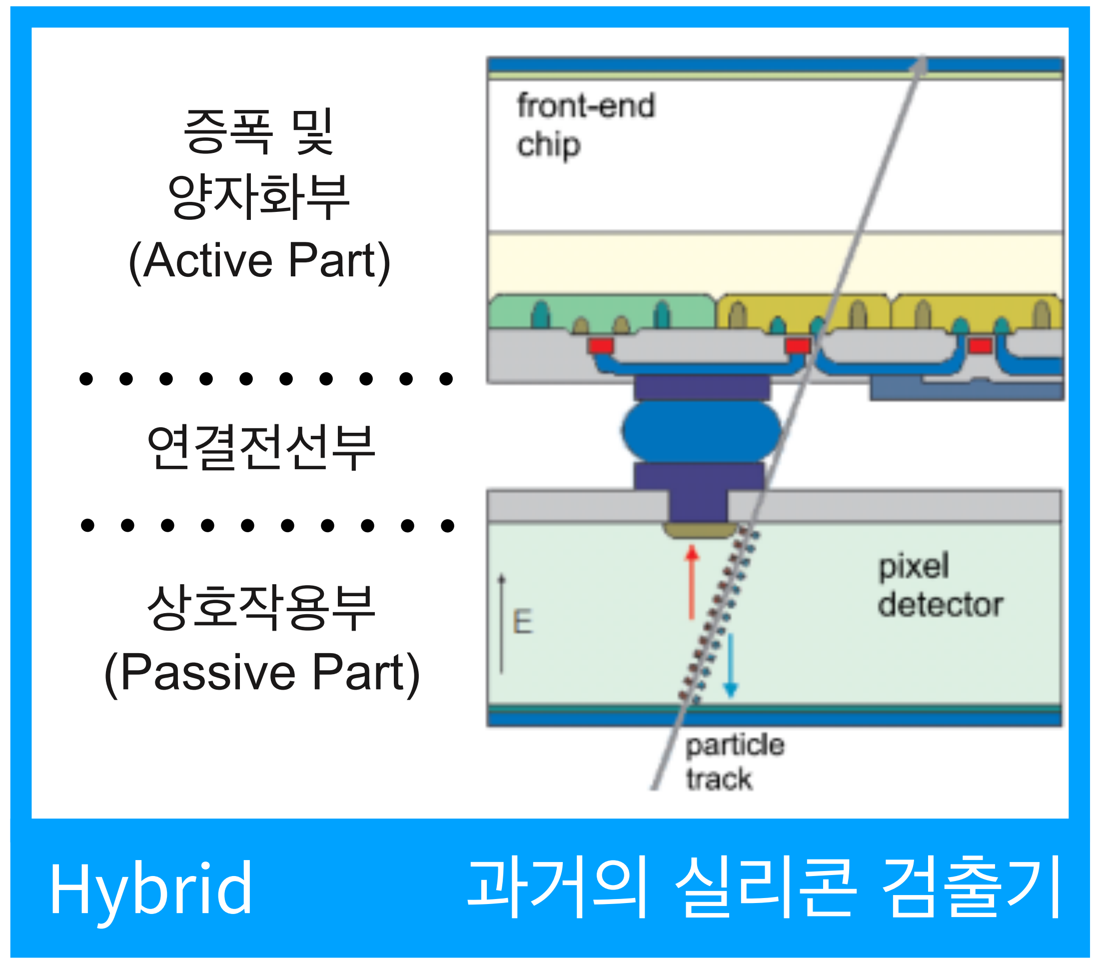
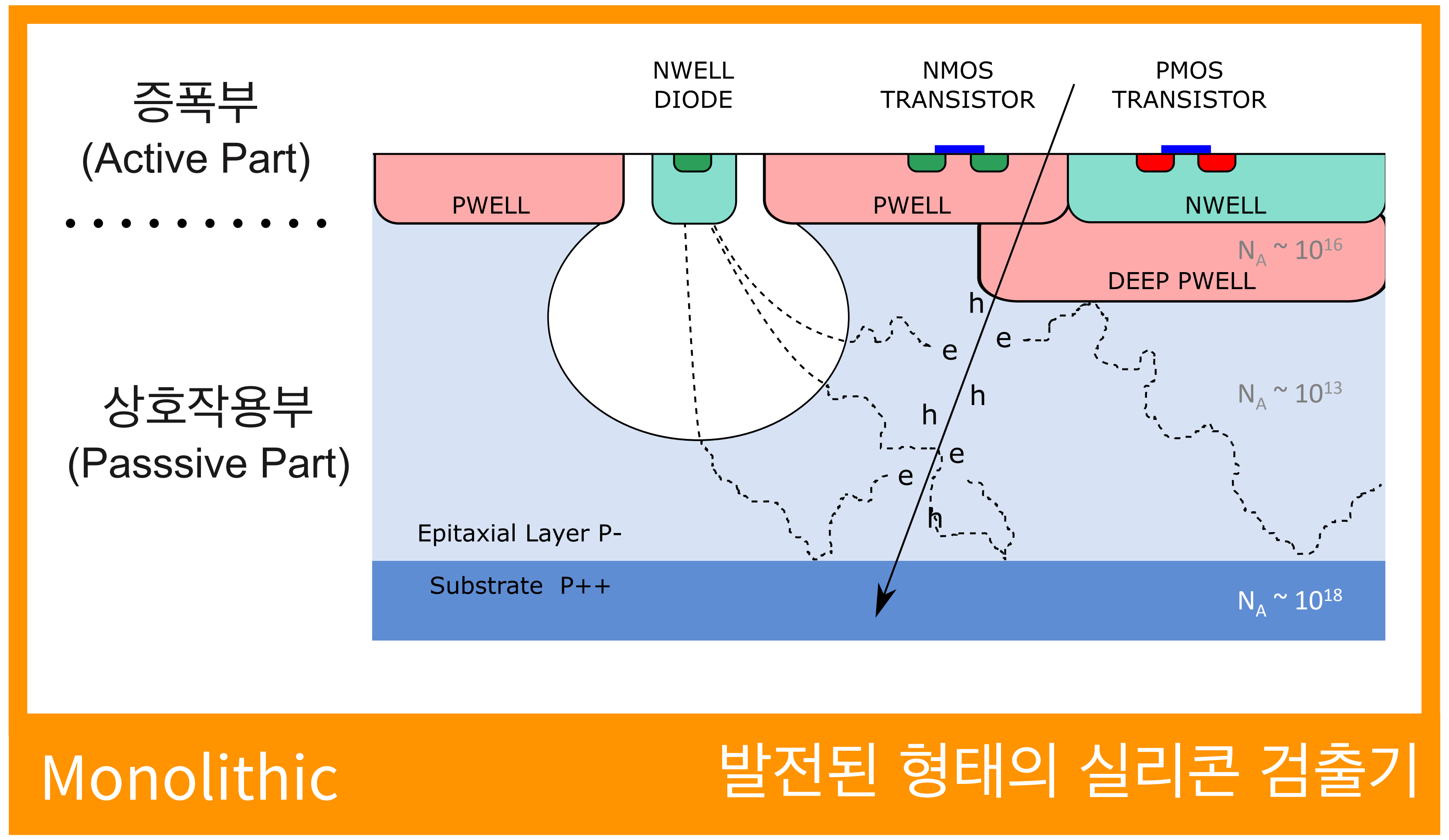
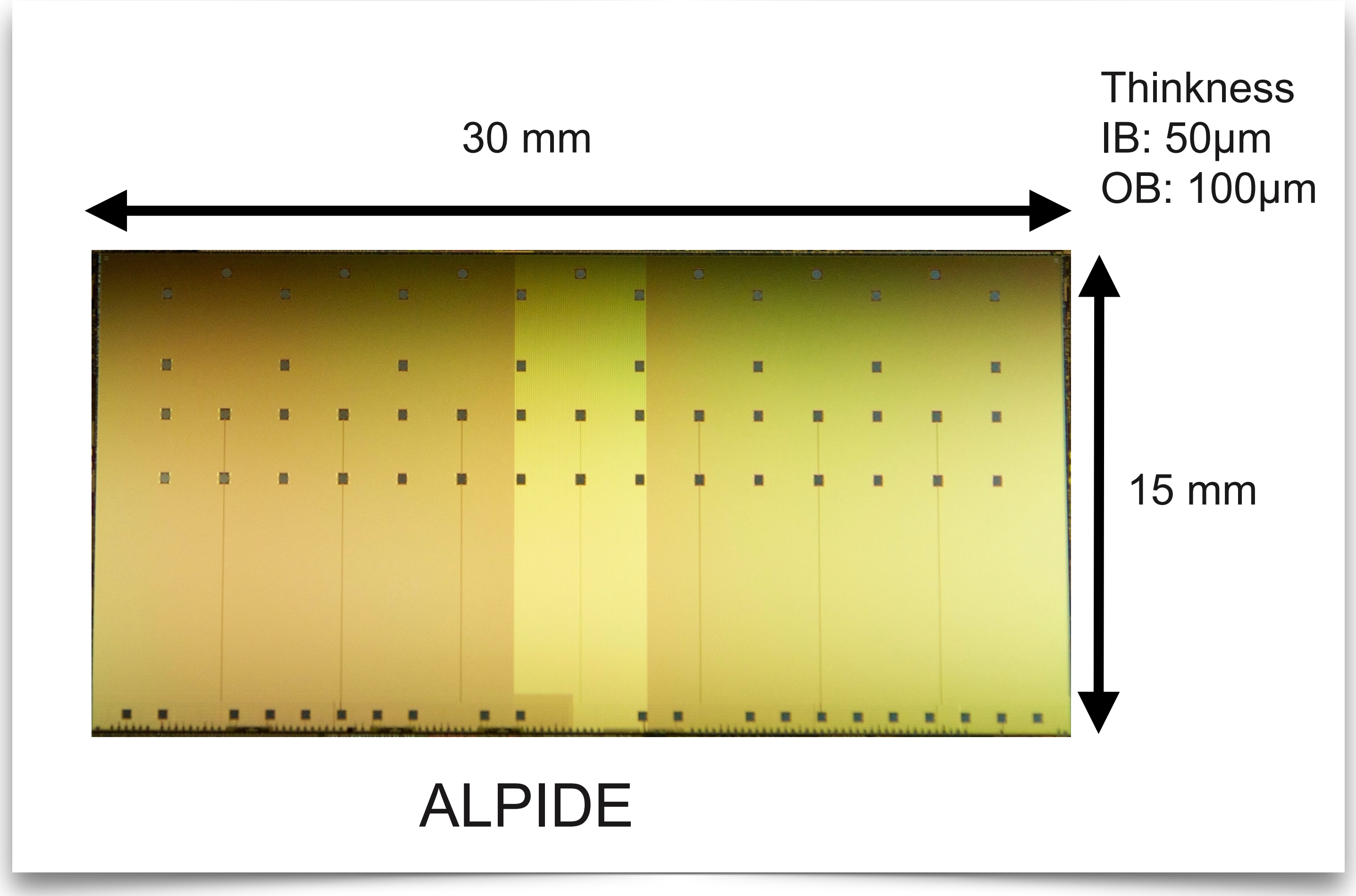
ALPIDE

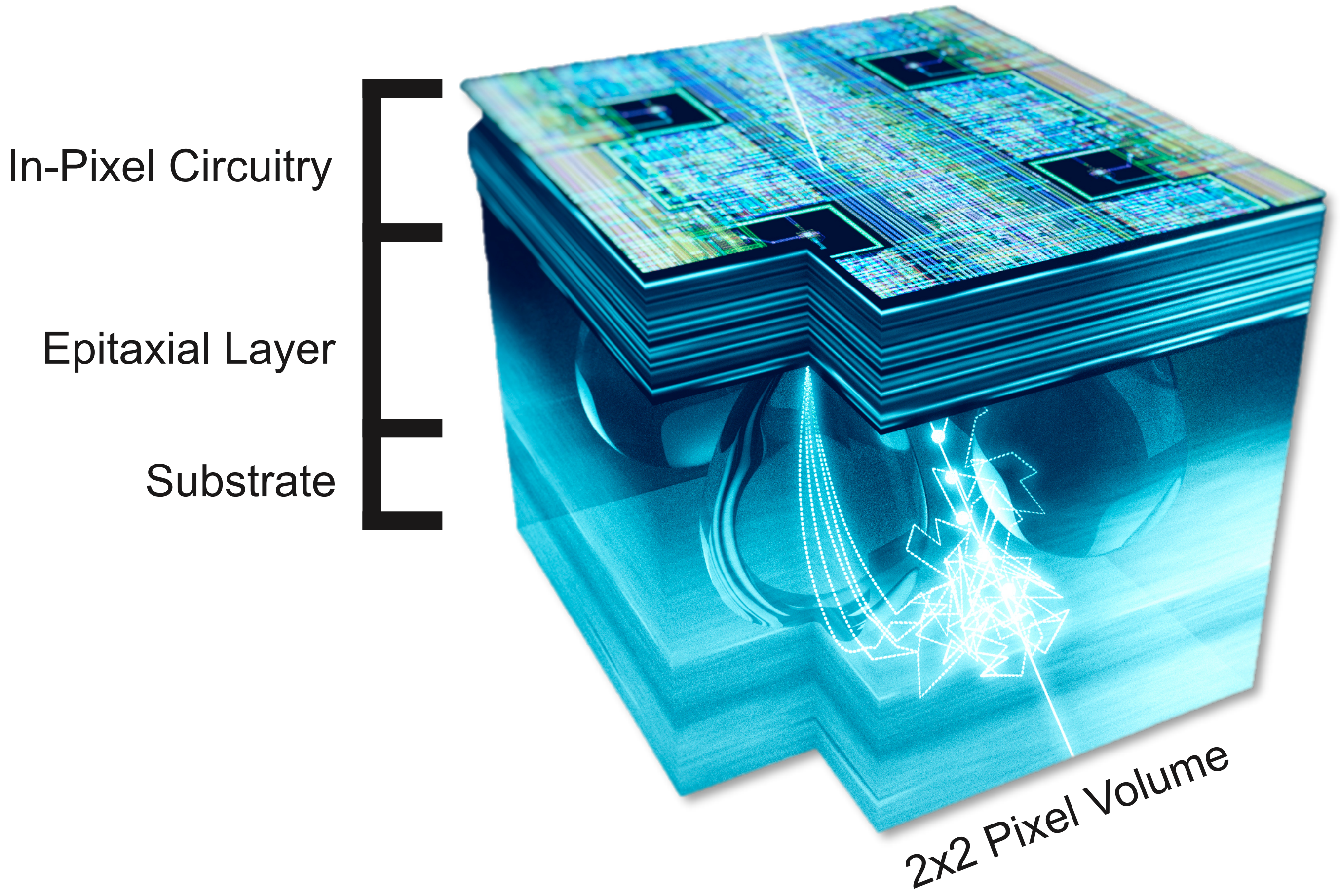
ALICE PIxel DEtector





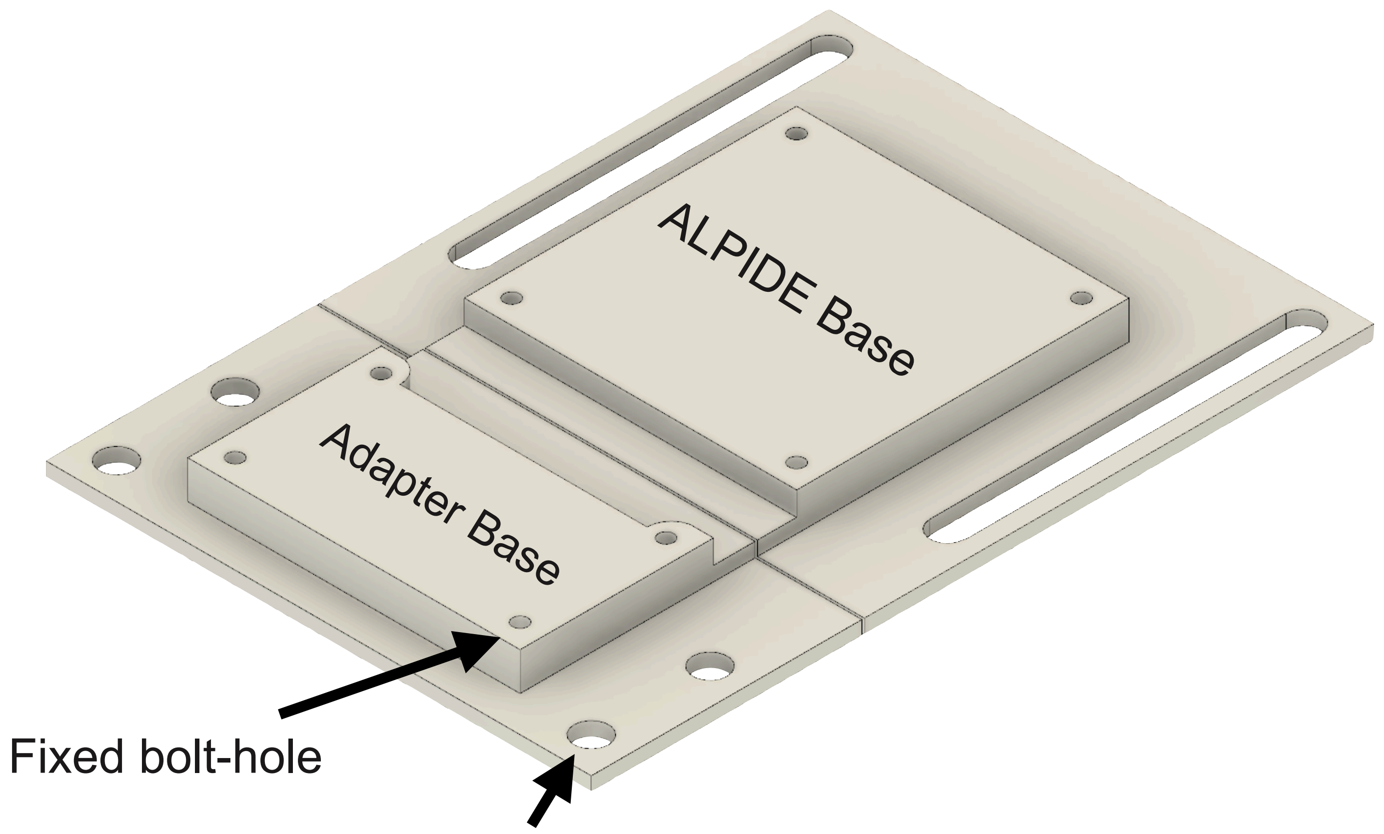


- 단일 활성 픽셀 센서 기술 (Monolithic Active Pixel Sensor)
  - 픽셀 내에서 스스로 증폭 과정을 거칠 수 있는 기술
- 검출기 내에서 신호 후가공 및 양자화가 모두 가능하도록 내부 프로세서 탑재
  - DAC, ADC 모두 내부에서 자체 해결 가능.
  - 별도의 전선이나 연결부가 없어서, 물질량을 매우 줄일 수 있음.
- 180nm CMOS (**C**omplementary **M**etal-**O**xide **S**emiconductor) 공정
- 29.24 μm × 26.88 μm 픽셀이 1024 × 512 개 있음.
- ALICE 를 위해서 만들어짐. 이후 MPD (NICA) 와 sPHENIX (RHIC) 등에서 활용 계획.



Experimental Setup (Particle Detection Test)

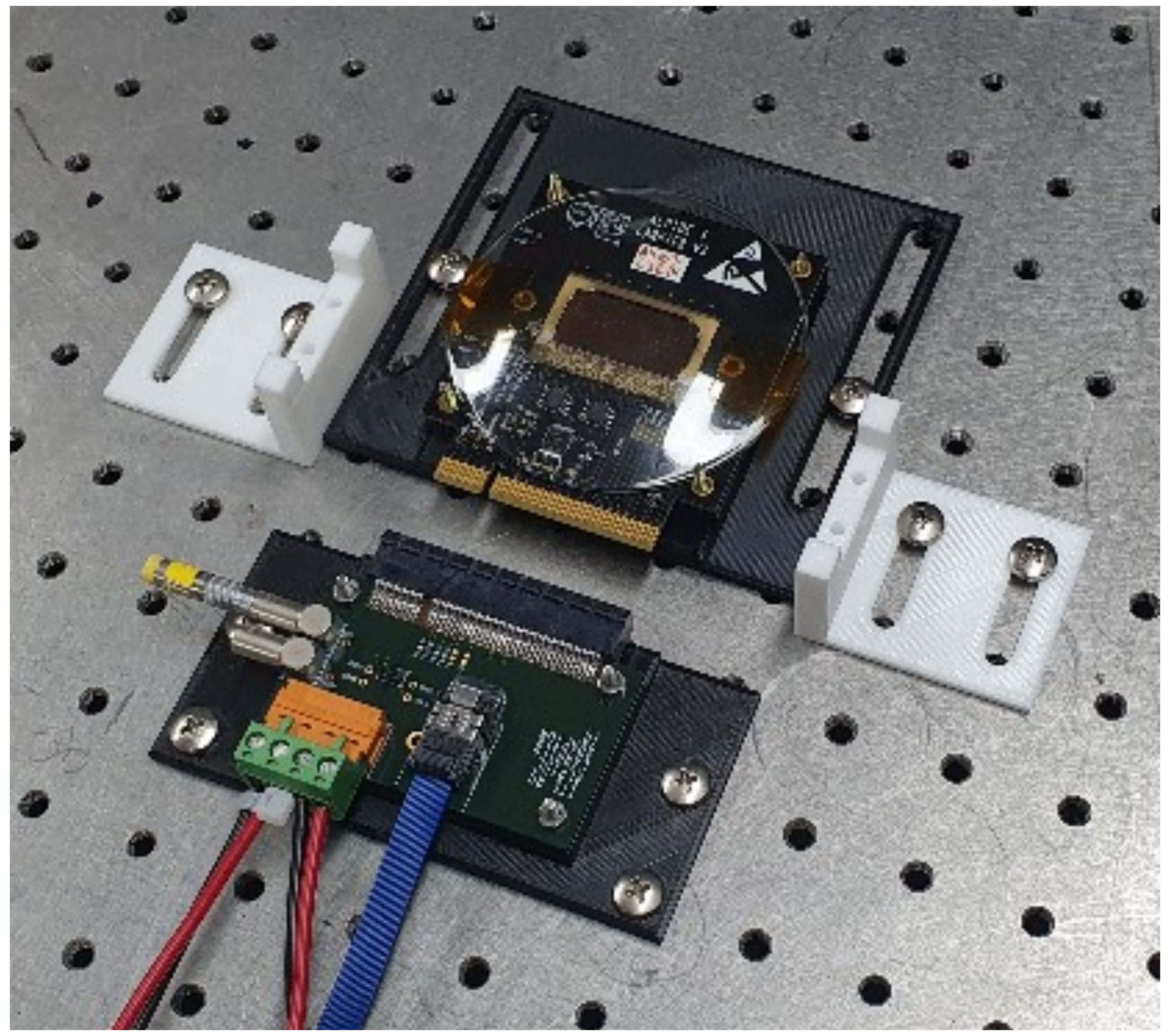
3D Modeling

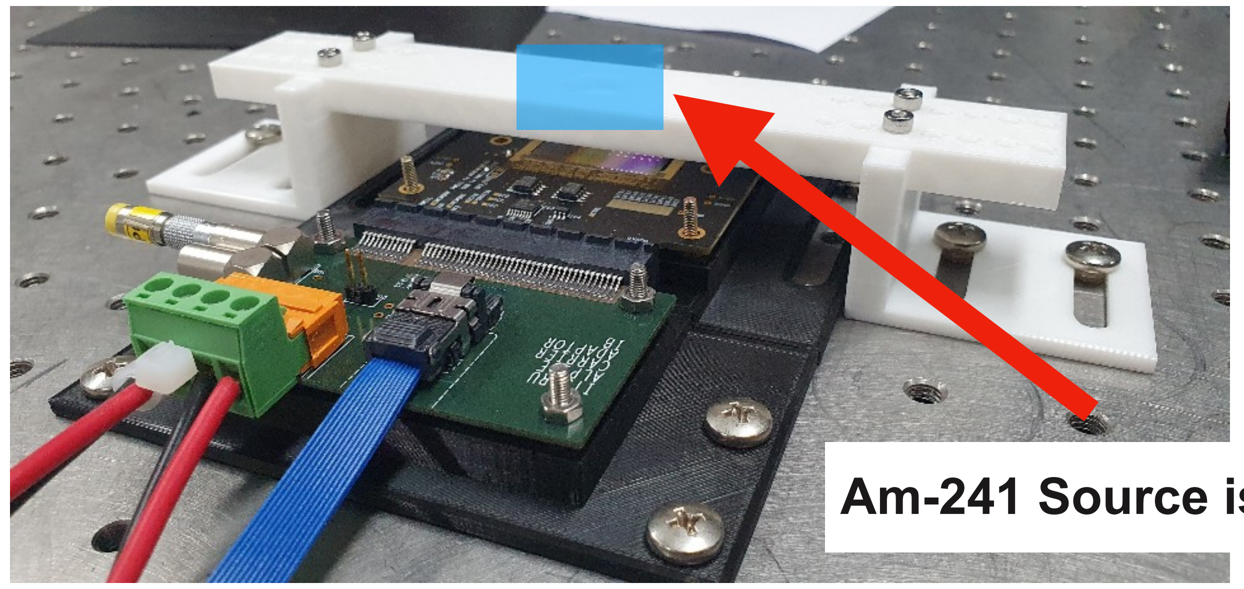


Optical Breadboard bolt-hole

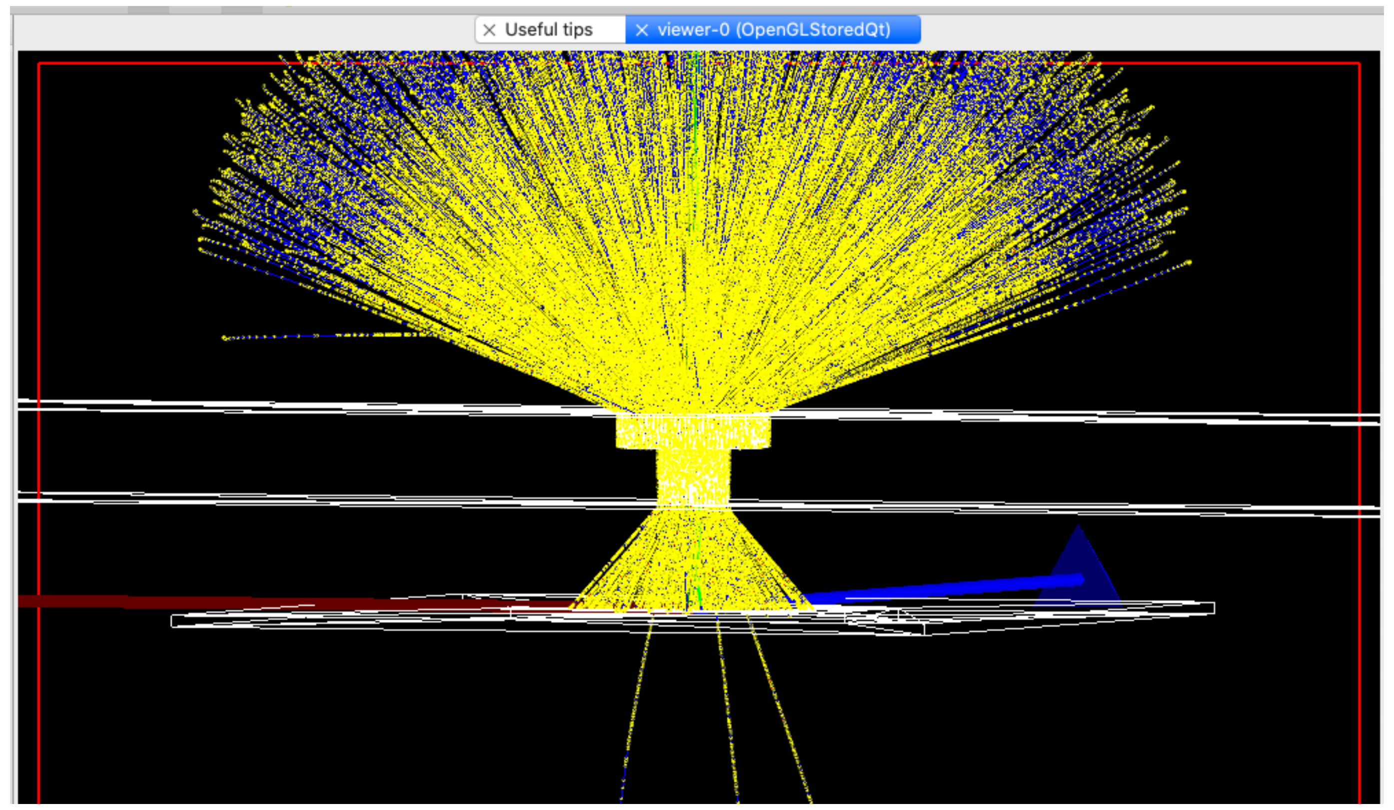
Material: PLA (Polylactic Acid)
Manufacturer: HIPEx (made by 3D printer)
Manufacturing Methode: FDM

In Real Word





GEANT4



PLA is also good collimator for L.E. alpha particle!
(GEANT4 Simulation with PLA source stand)

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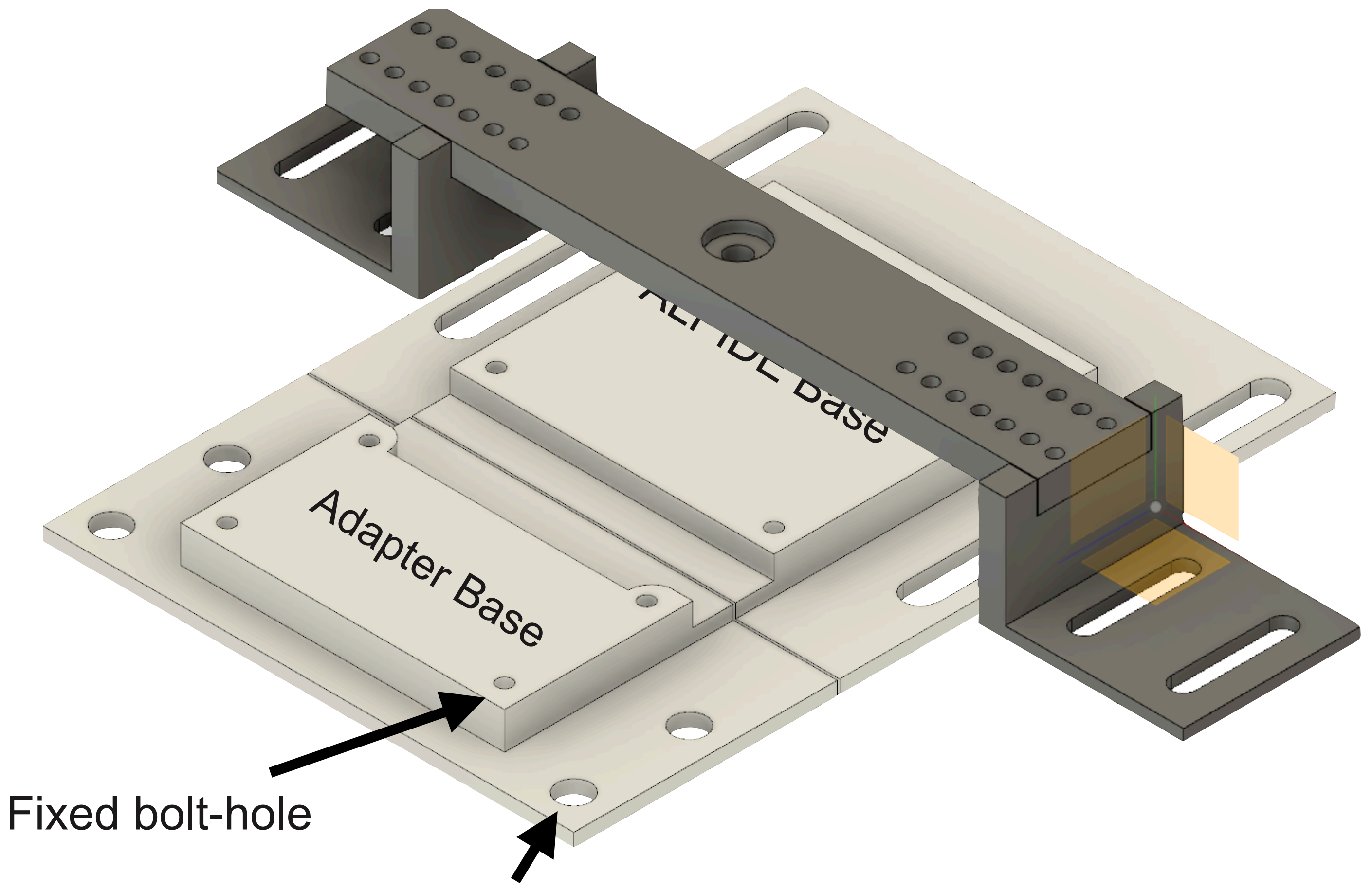

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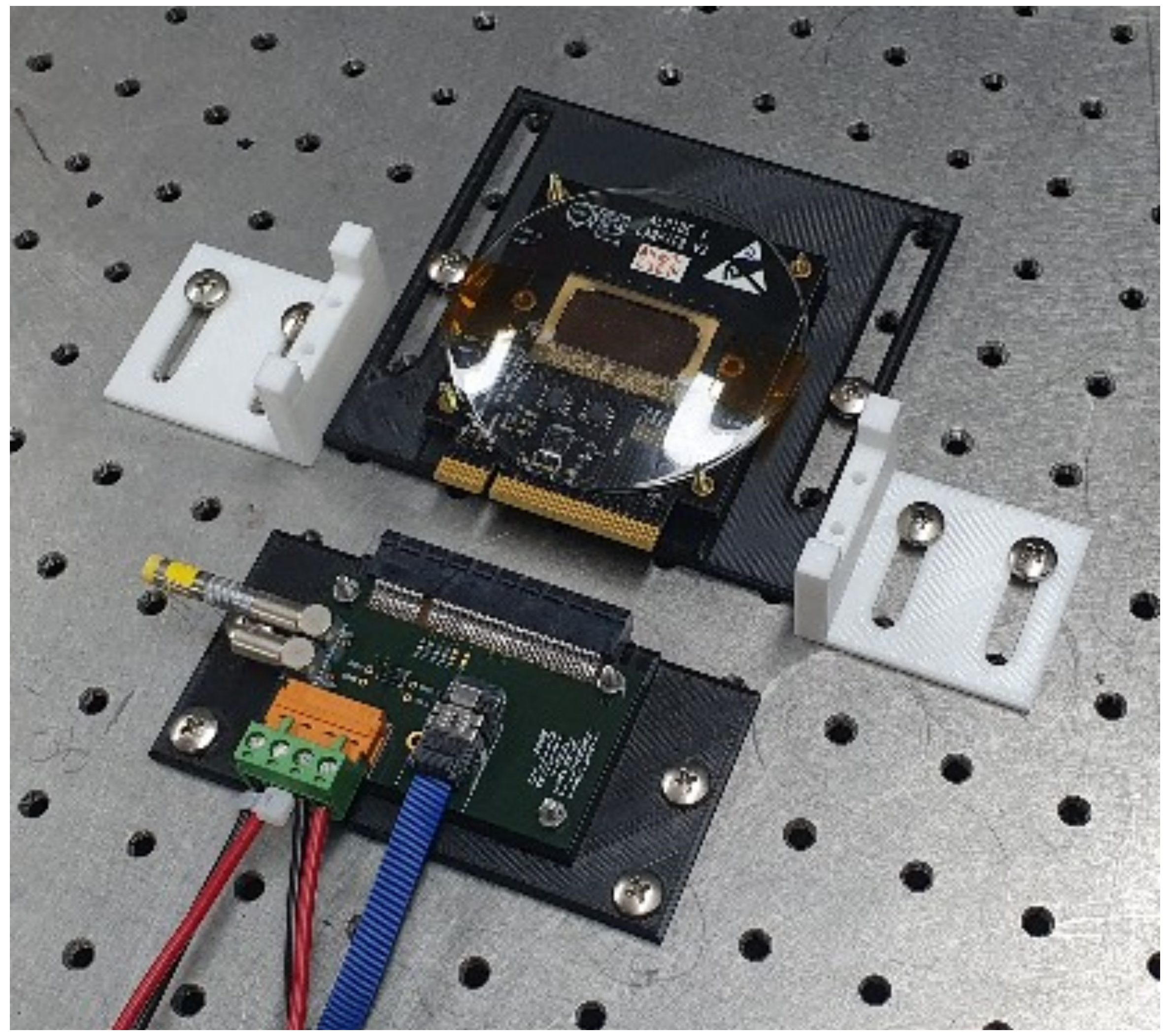

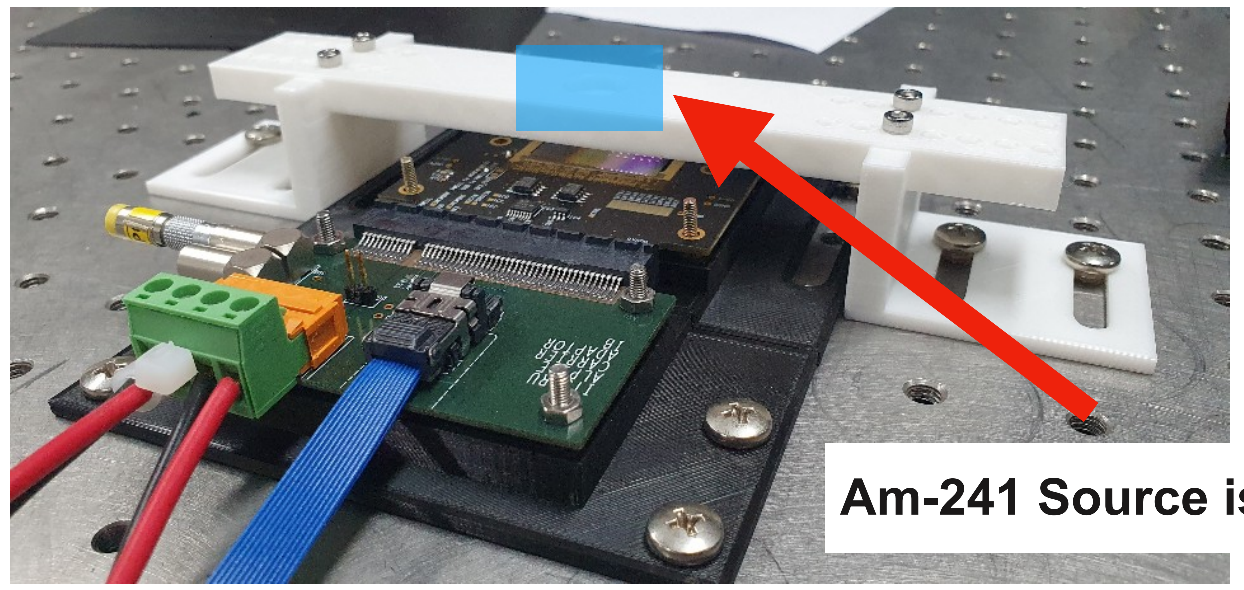

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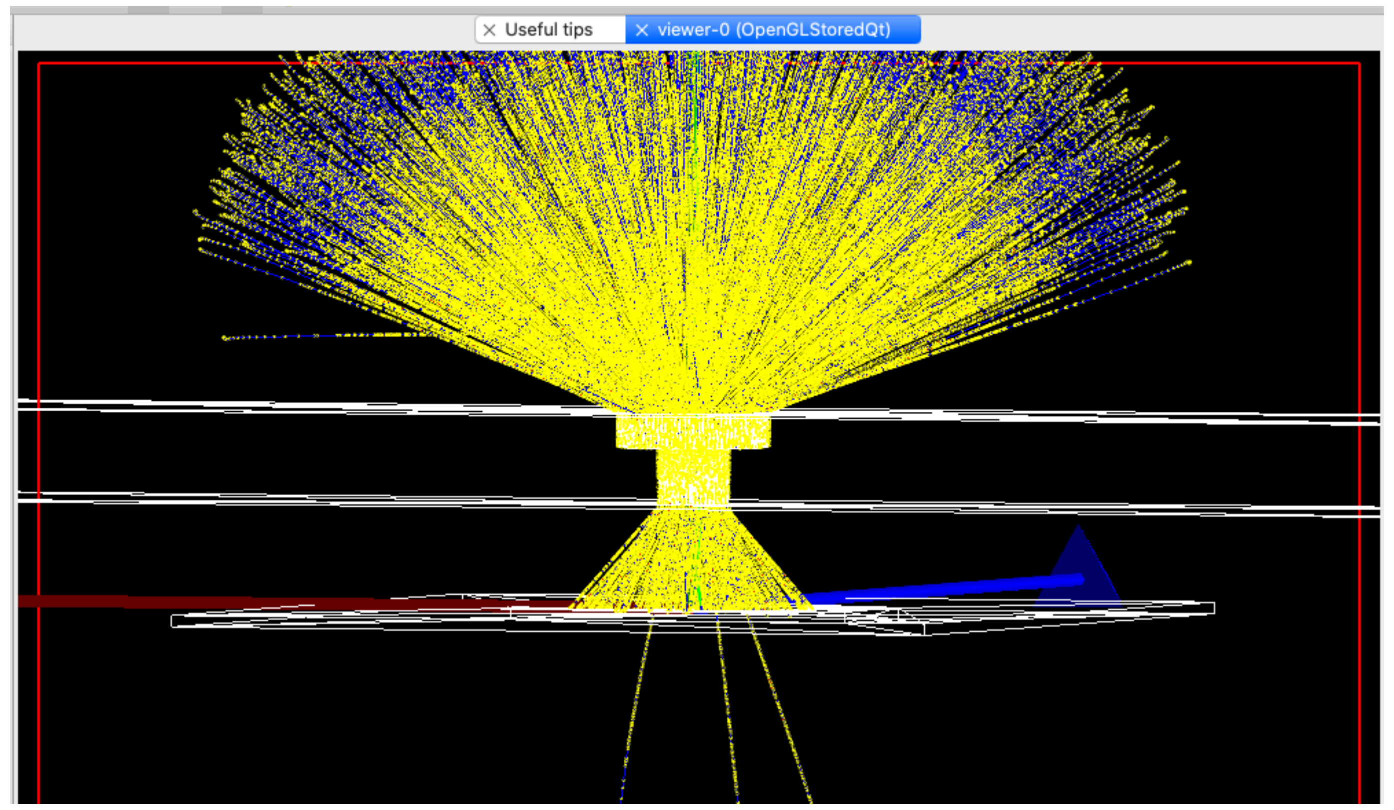

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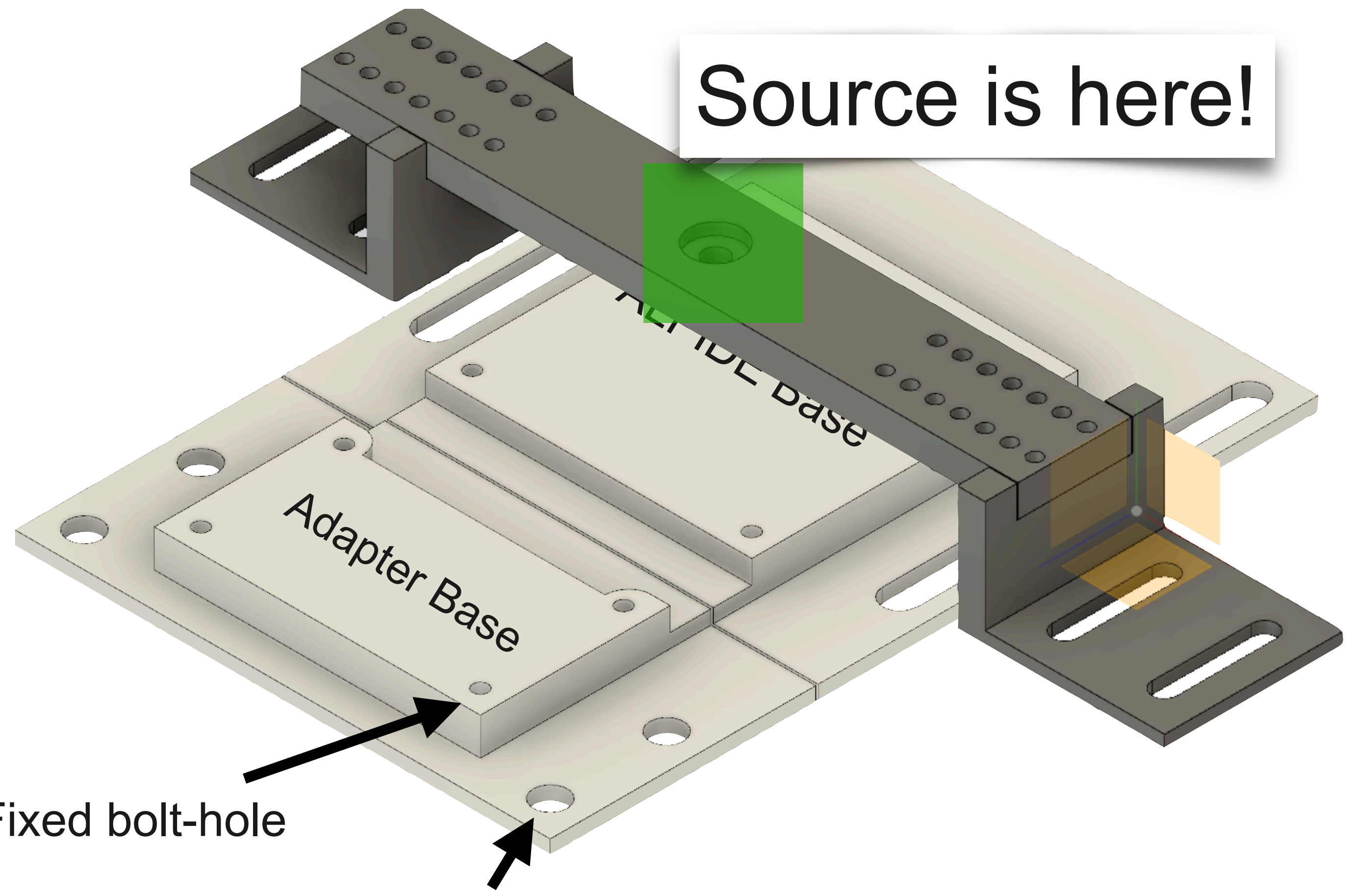

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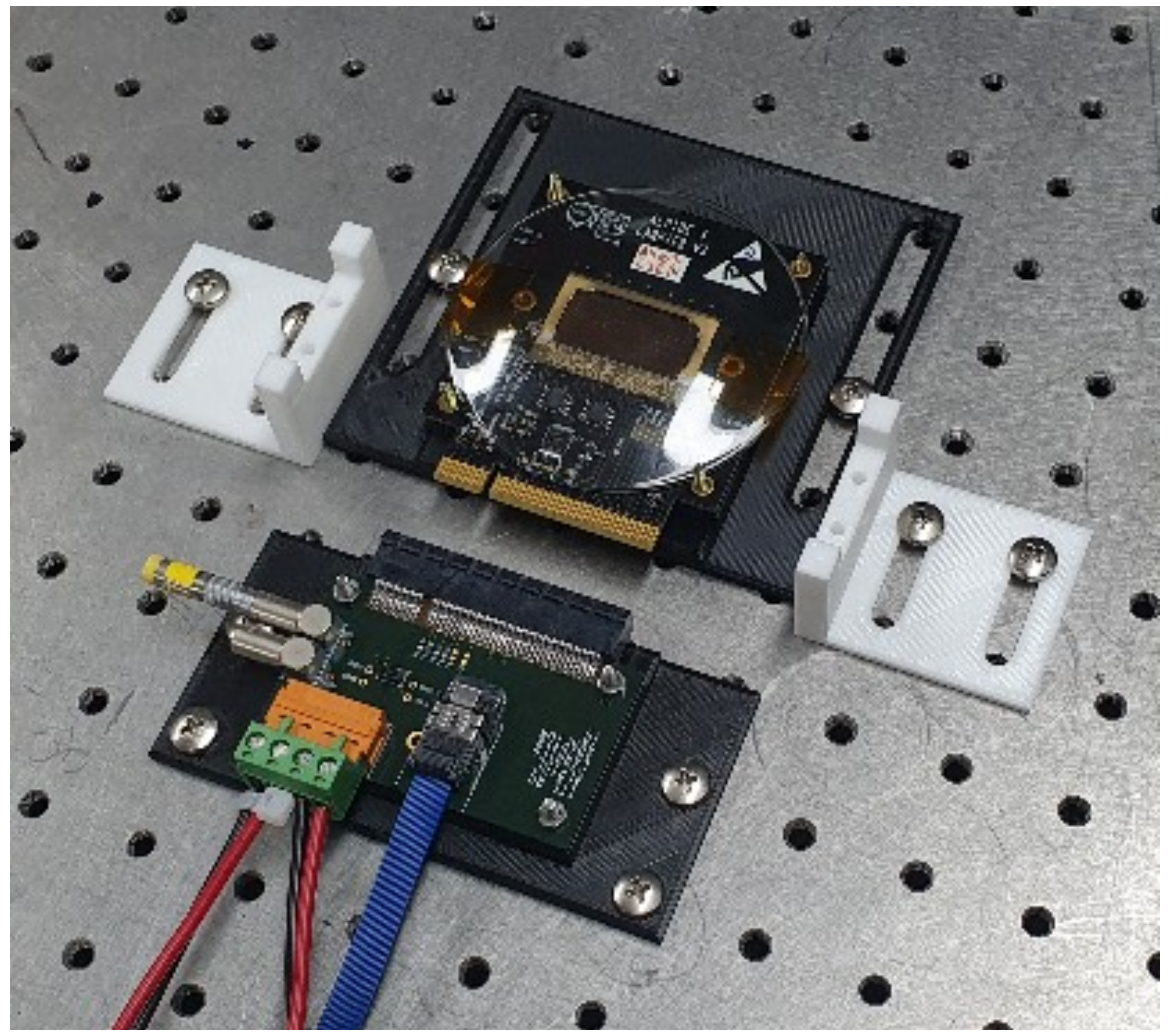

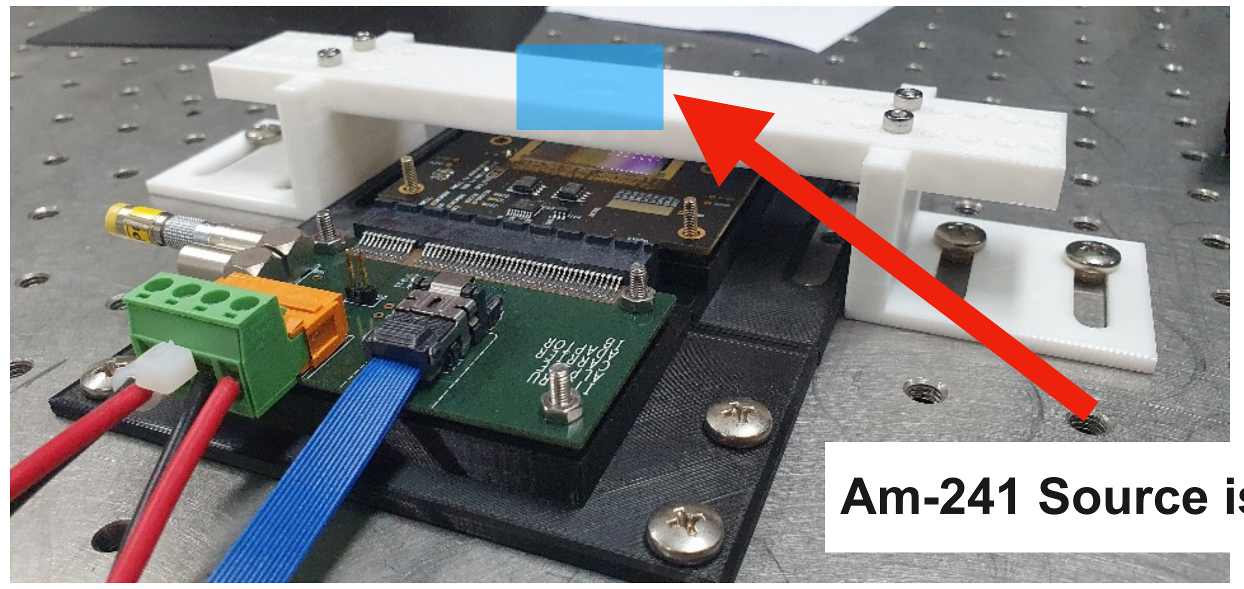

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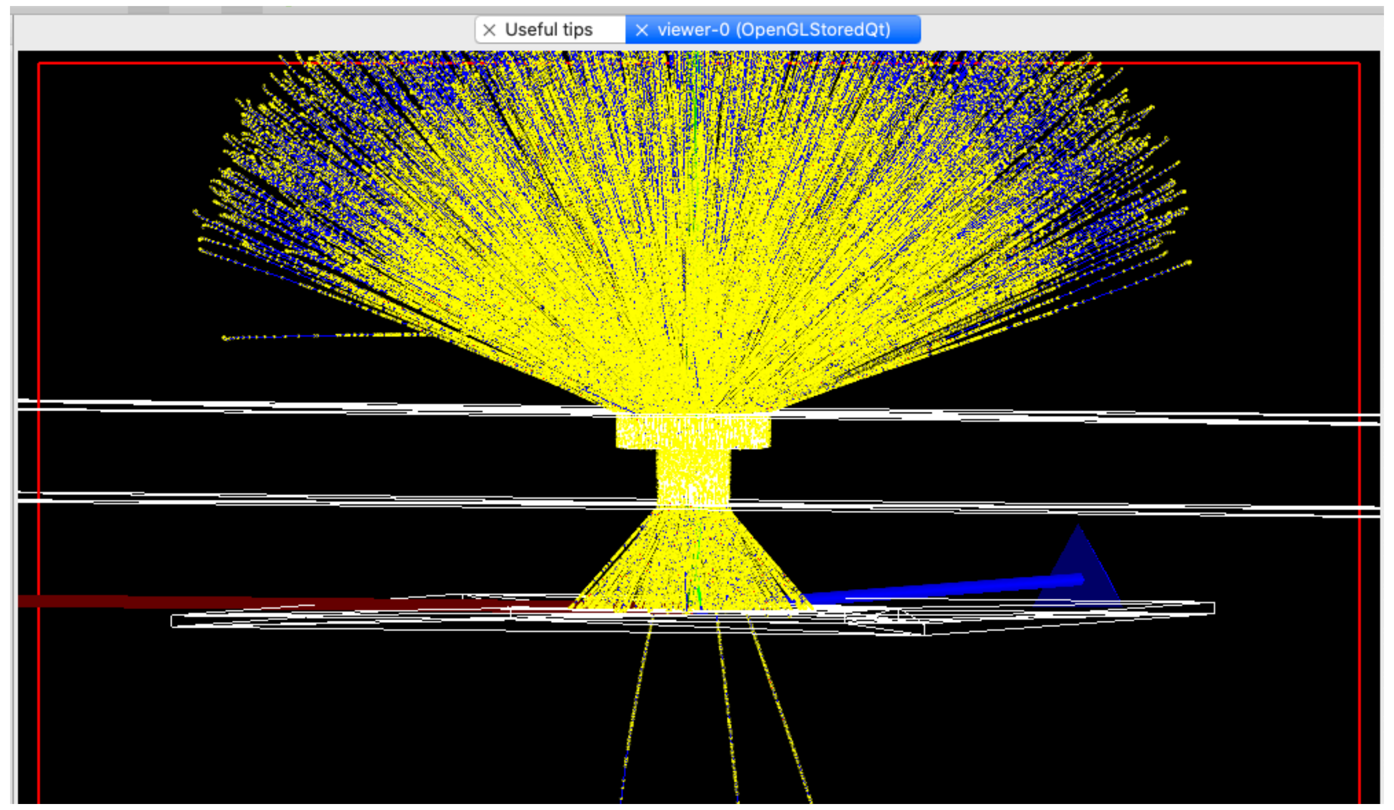

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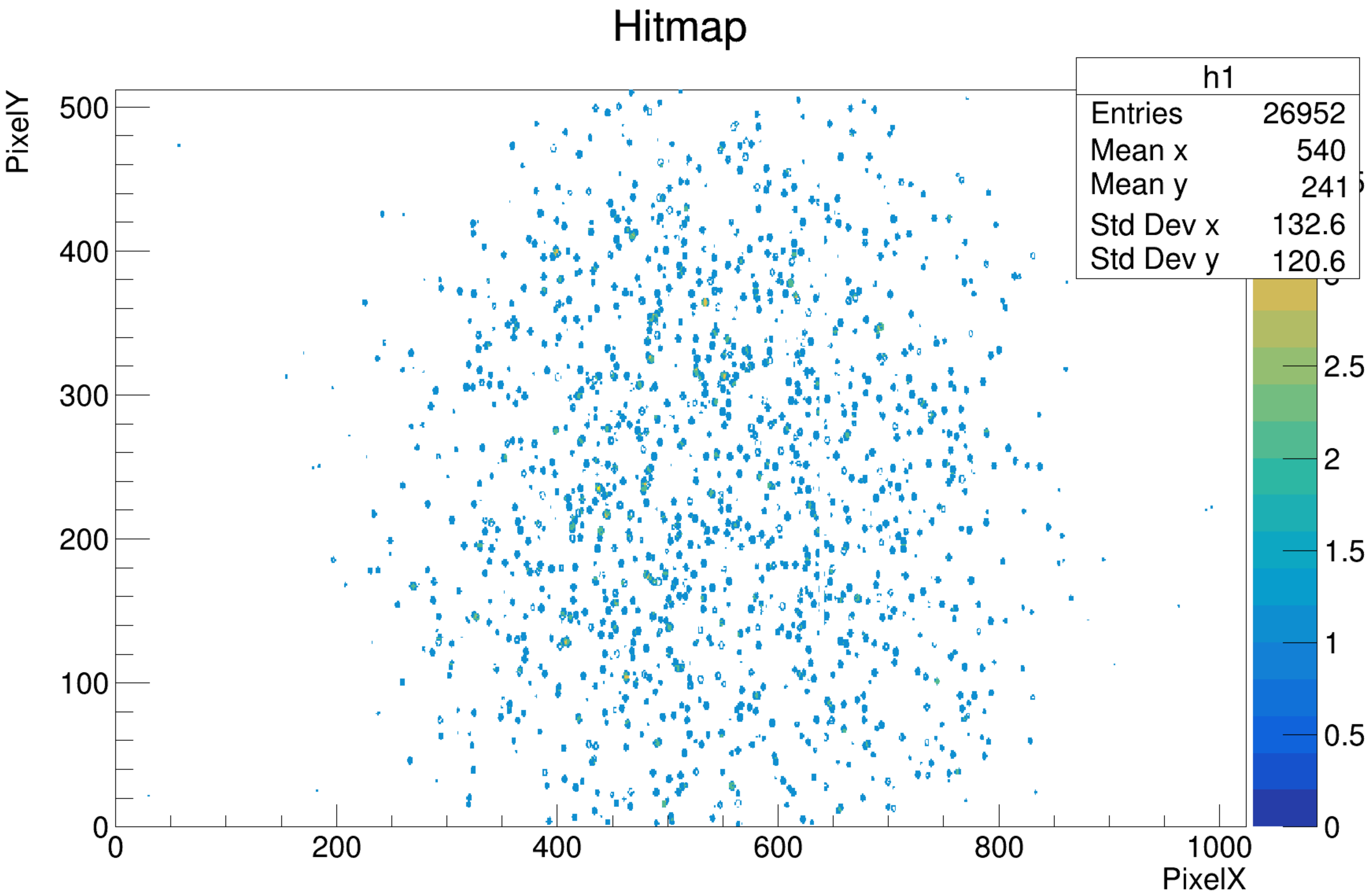
Hitmap In Basics

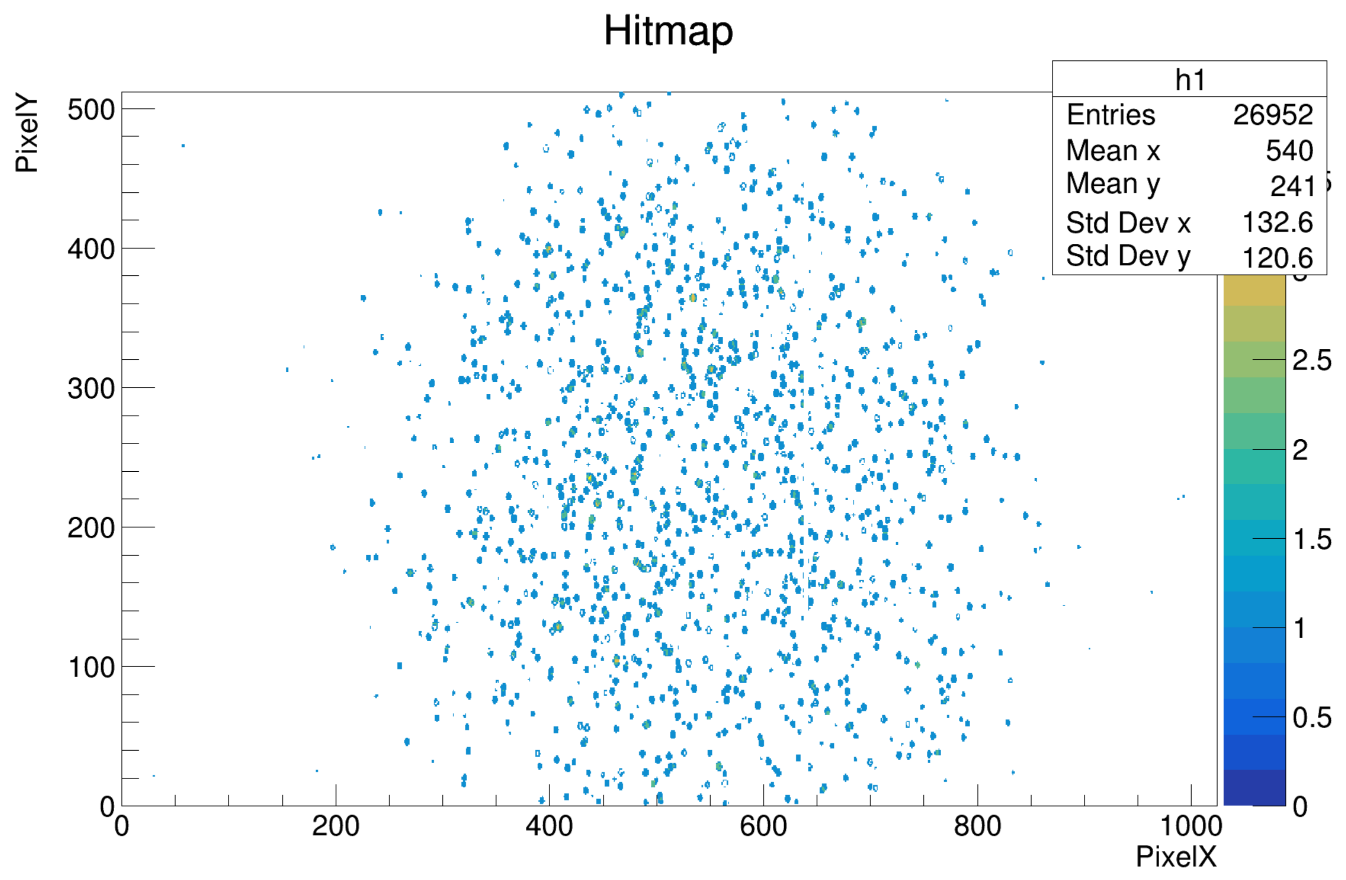


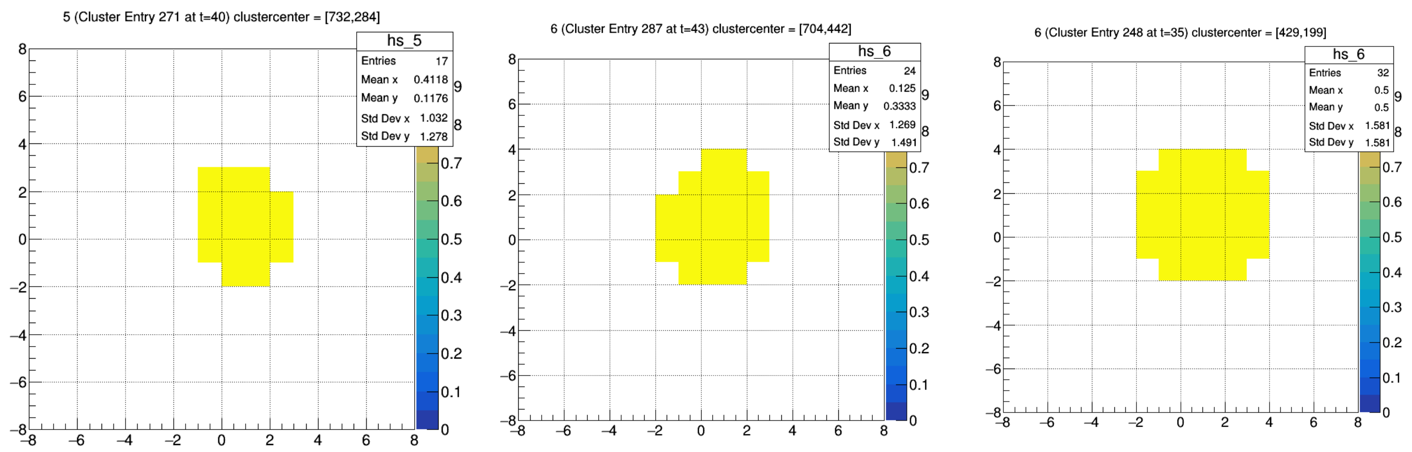
ALPIDE with low-energy alpha particle

Objective : To know response of ALPIDE about α particle $E_{\mathrm{k}} = 5.4\mathrm{MeV}$ to use for next measurement.

General procedure of position independent, sourced measurement for radiation characteristic study

Experiment: Taking data in sourced measurement ▶ **Clustering**: Cluster pixels in a event ▶ **Analysis**: Analyze the characteristics of clusters





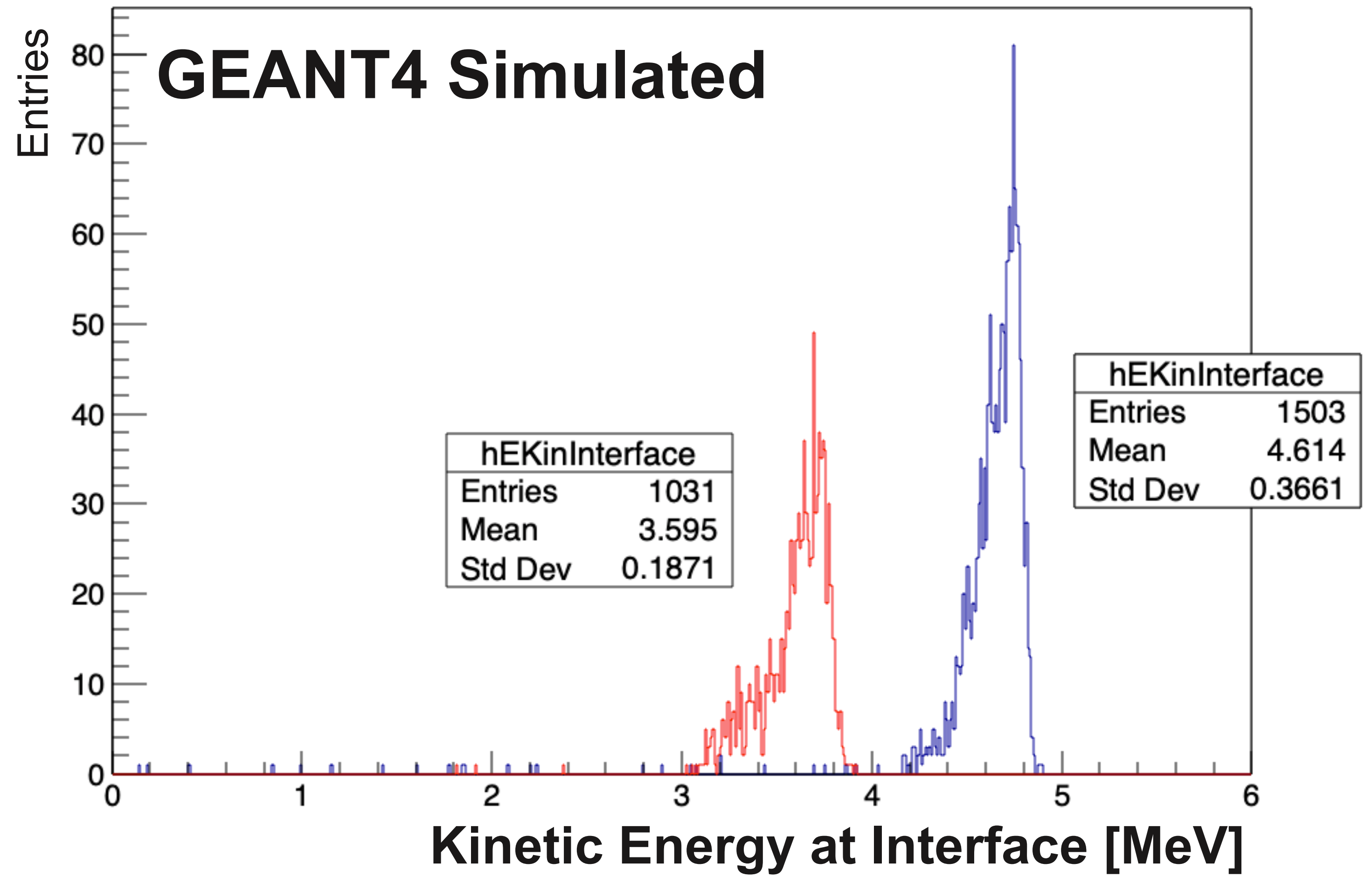
Group pixels nearby

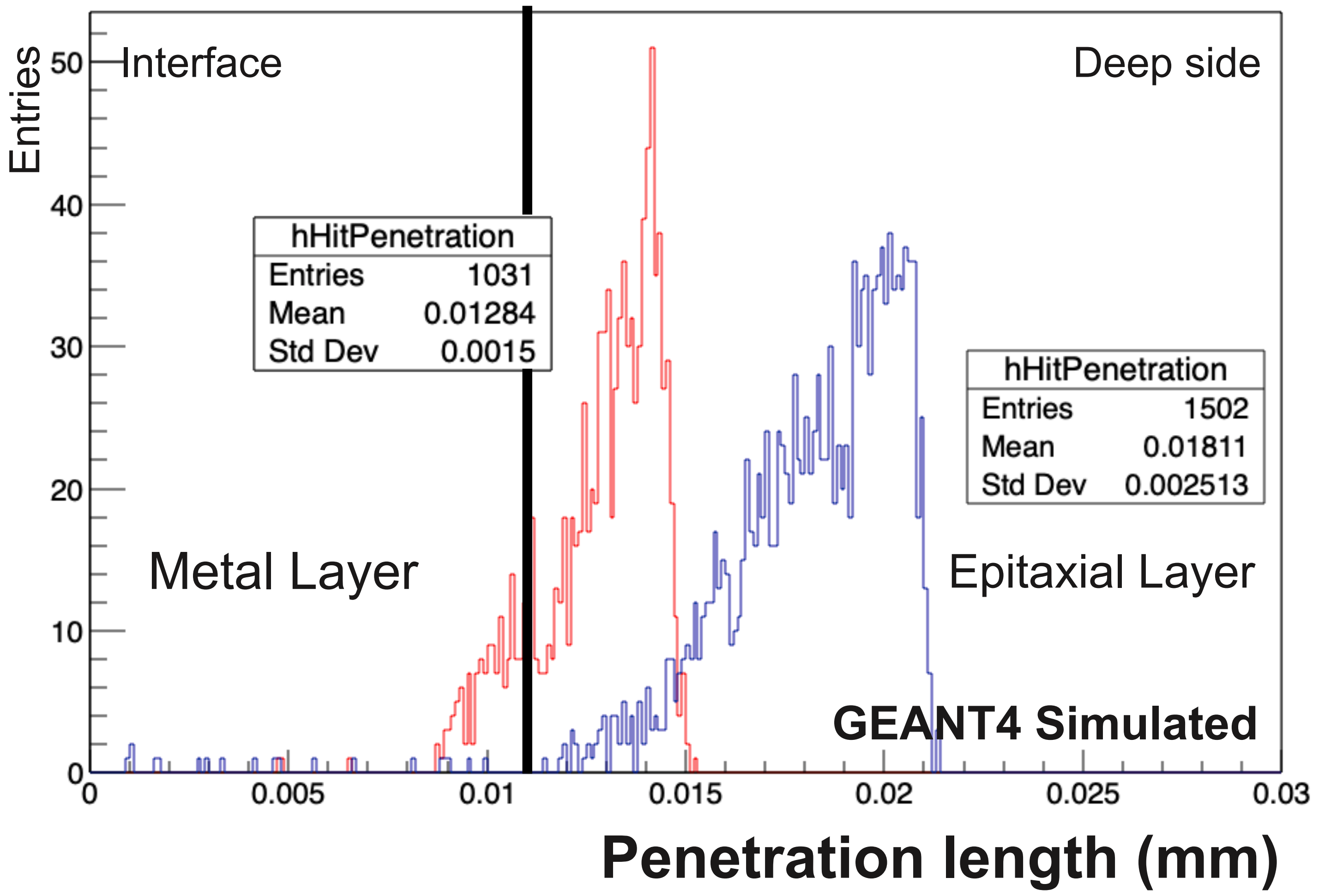
Characteristics of components…

- N pixel in a cluster
- N cluster in specific time duration
- N cluster in a timeframe
- Shape of cluster

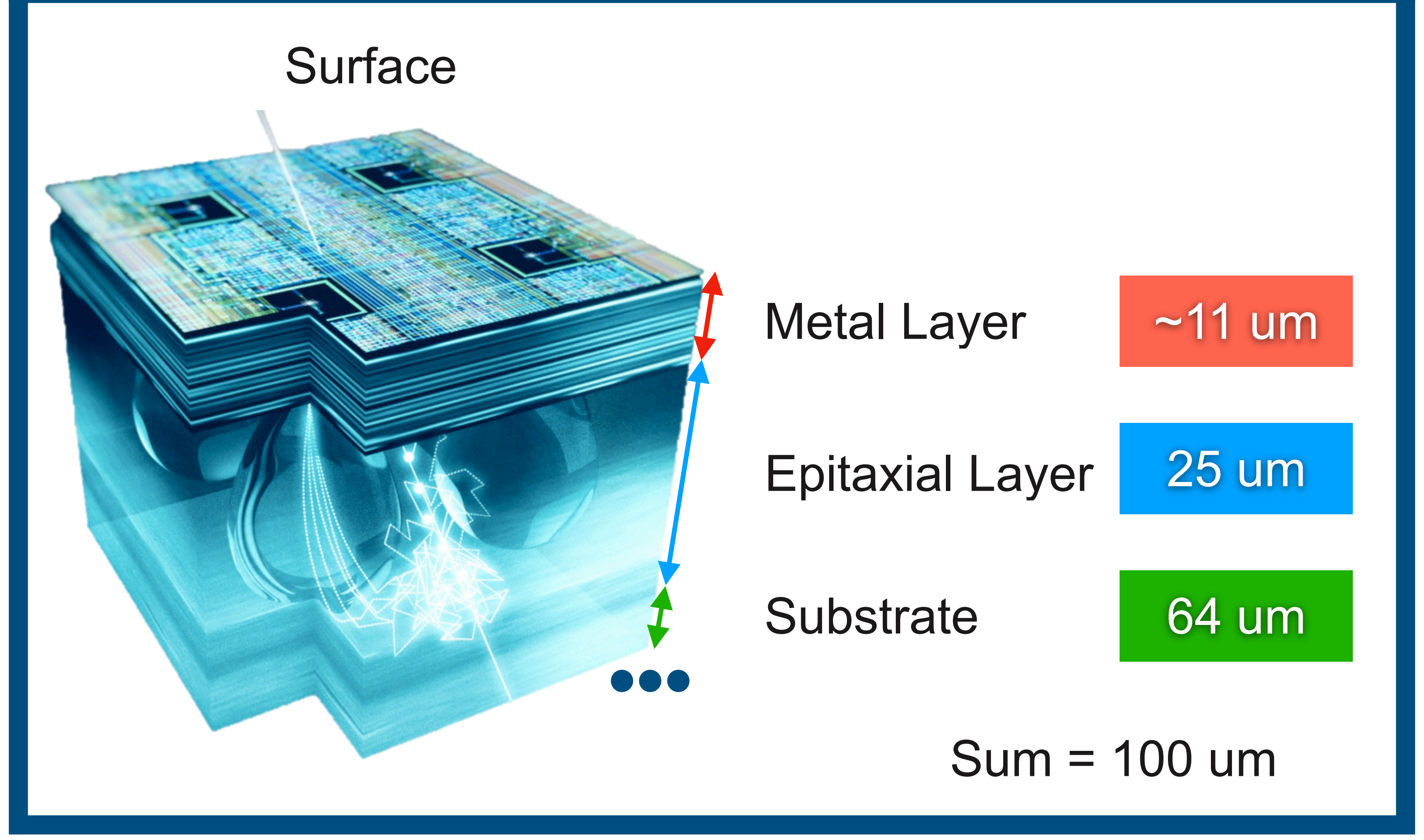
ETC…

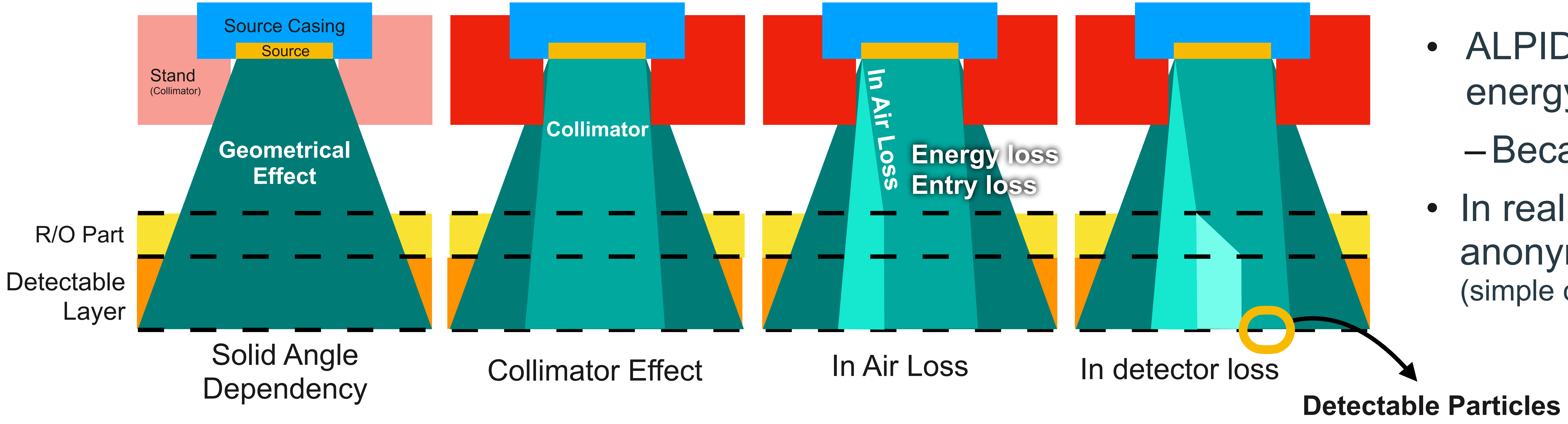
On chip penetration length dependency





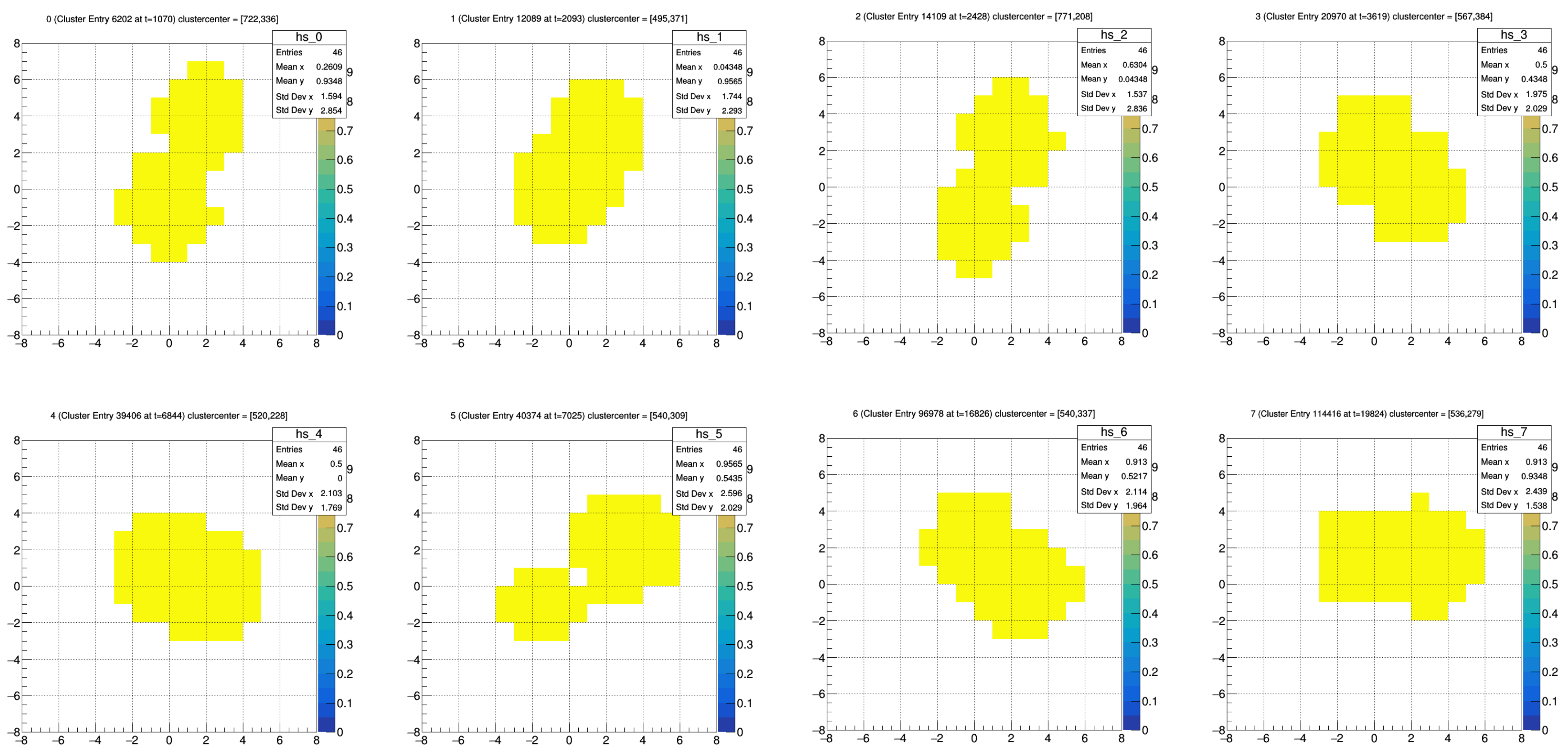
ALPIDE's depth information





- ALPIDE can detect α particle with energy dependent efficiency.
  - Because of R/O part layer.
- In real experiment data, anonymous loss part existed.
  (simple calculation is in backup; 16p, 17p)

Double Particle Cluster



- 2 Particle is detected, very closely, in same timeframe
- Should be separated.
  - Into 2 particle's 2 positions
  - OR remove in statistics.
- How to recognize?
  - Machine Learning…
    - Thanks to Hyunji Lim!
  - But large dataset needed…

Massive Generation Model Is Needed!

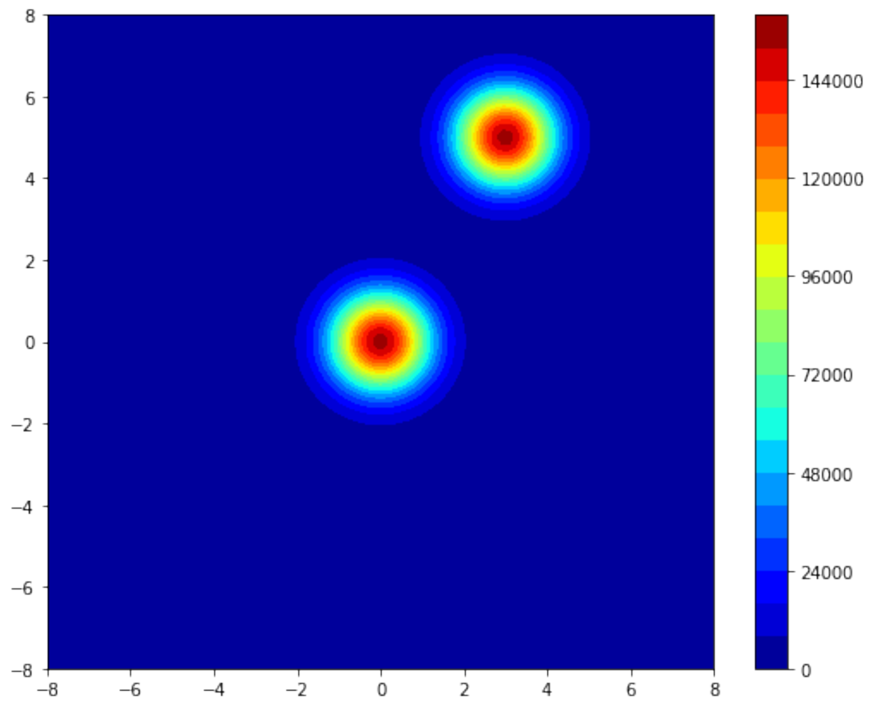
Qupid model

***Qu**asi-Signal Generation Model for **Pi**xelized **D**etector*

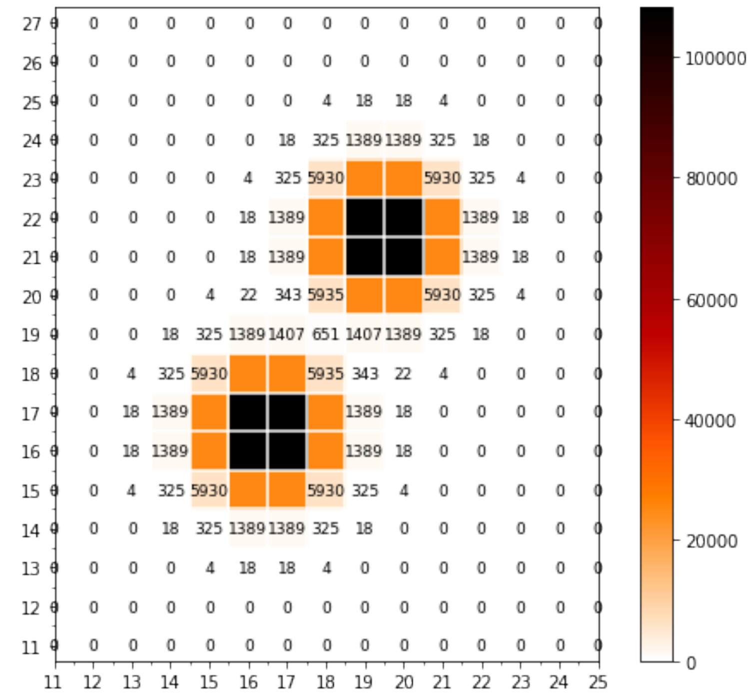
Objective
Fired pixel cluster shape generation to use for machine learning

- Based on Python3 (numpy, scipy)
- Procedure
  - Define signal amplitude distribution function (ADF) on detector plane
  - Calculate signal in pixel with integrating ADF with for each pixel.
  - Find pixel which has signal over threshold.

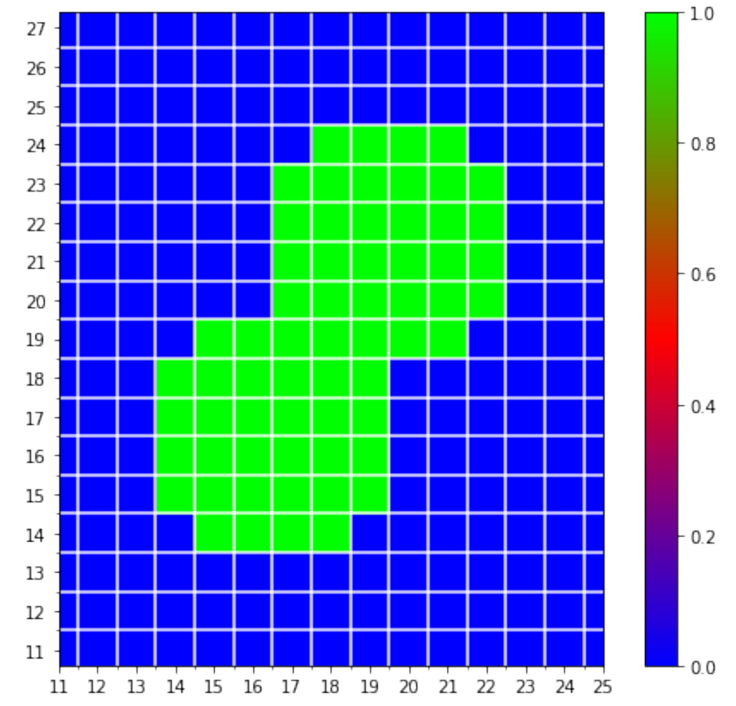
Github Repository: https://github.com/Isaac-Kwon/qupid
Documentation : https://isaac-kwon.github.io/qupid



Analogue Signal Distribution



Digital Signal Distribution (Integrated Signal)



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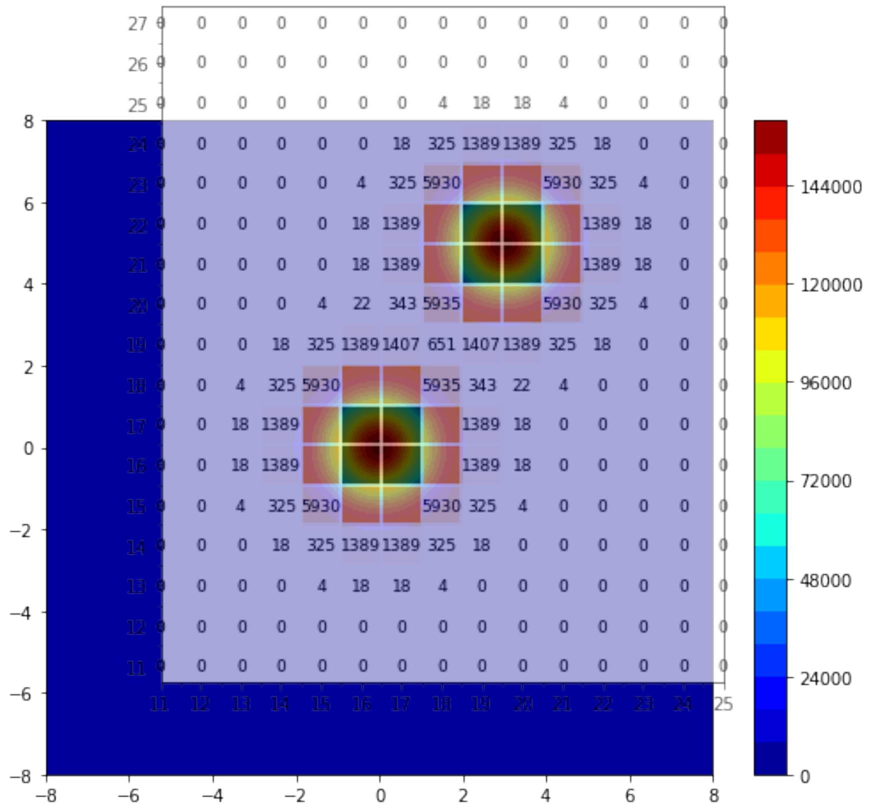

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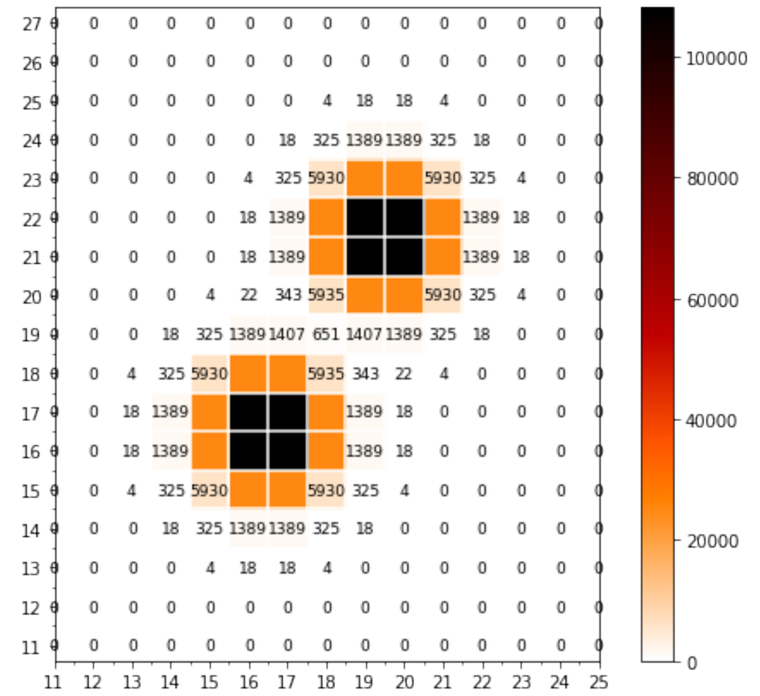

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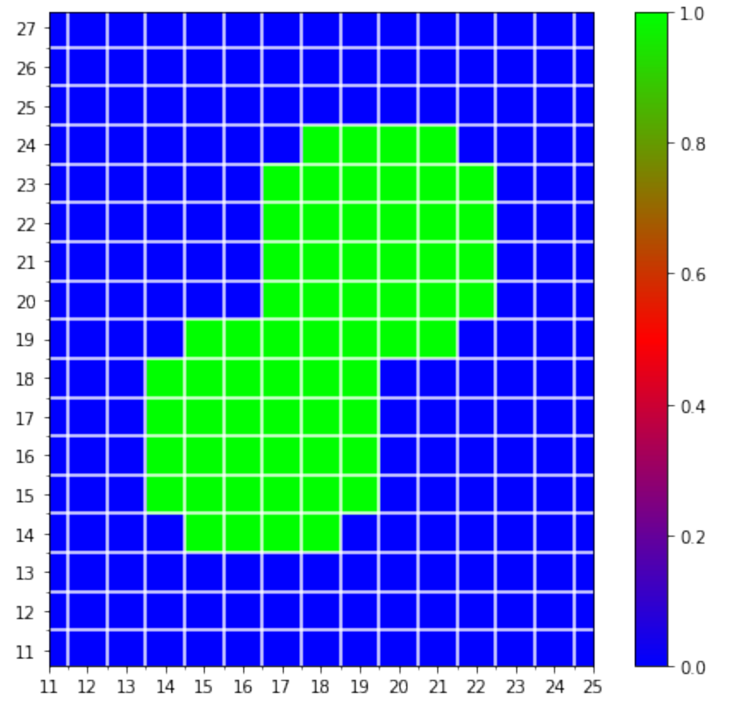

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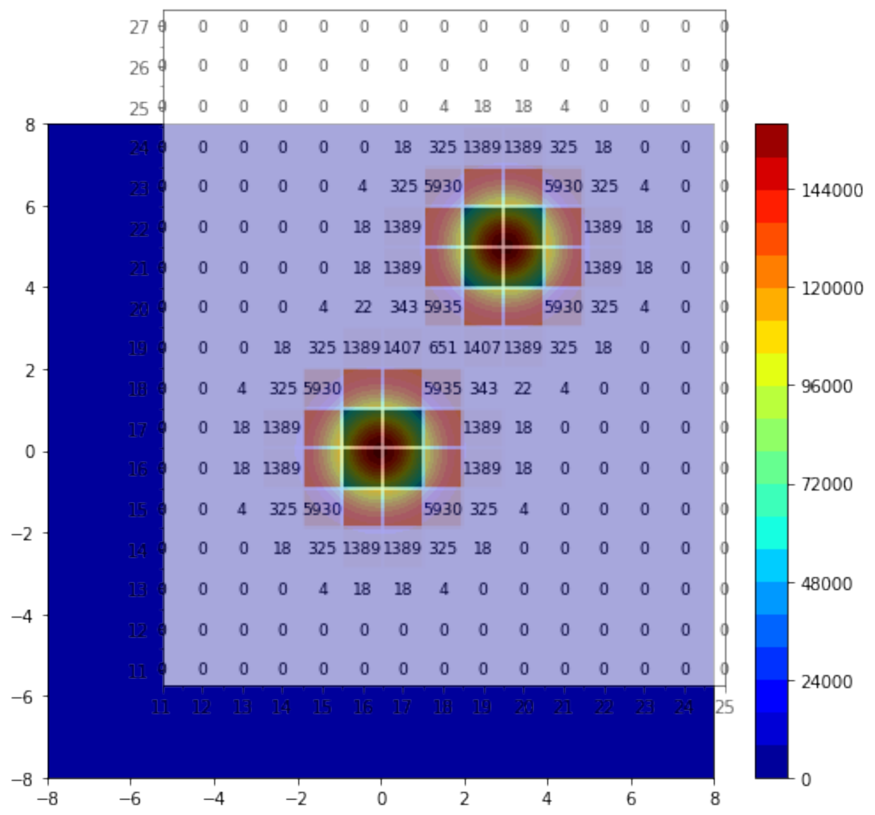
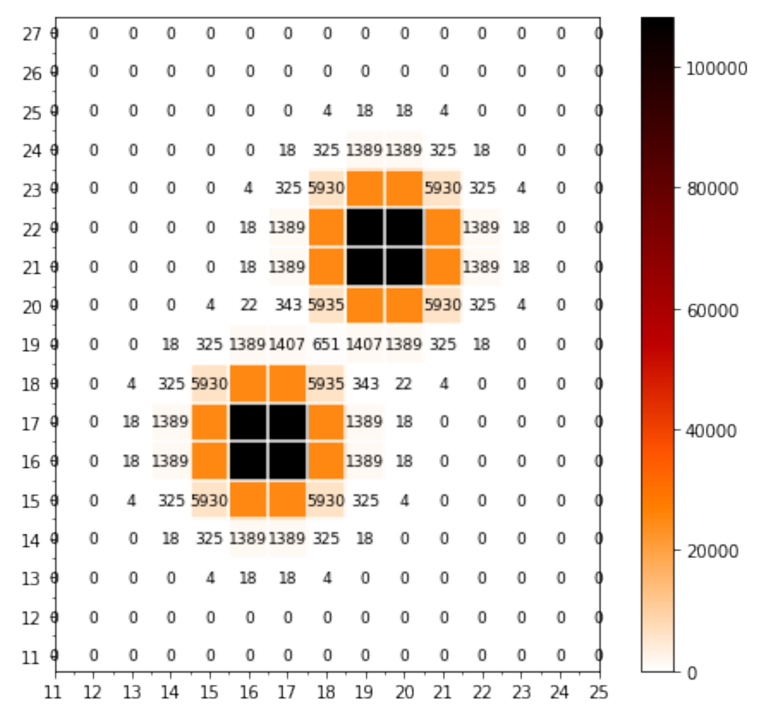
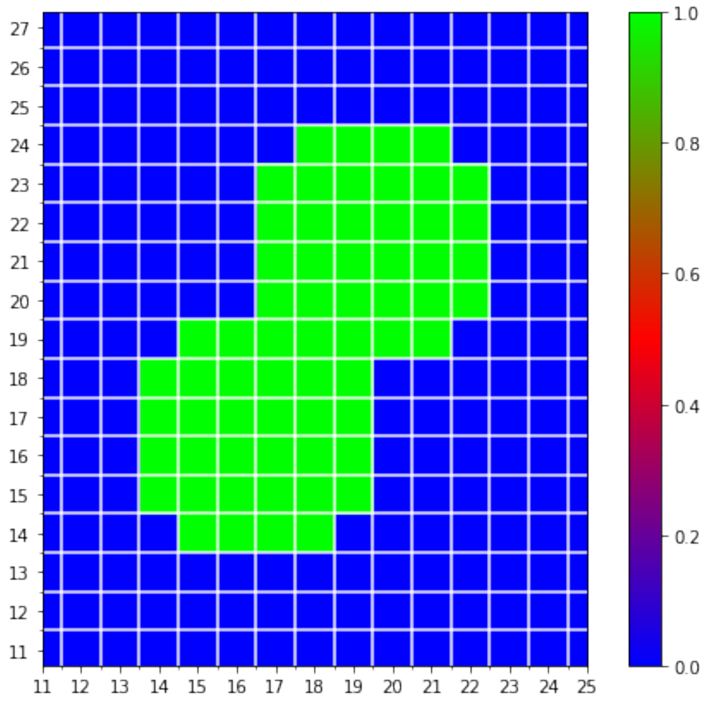


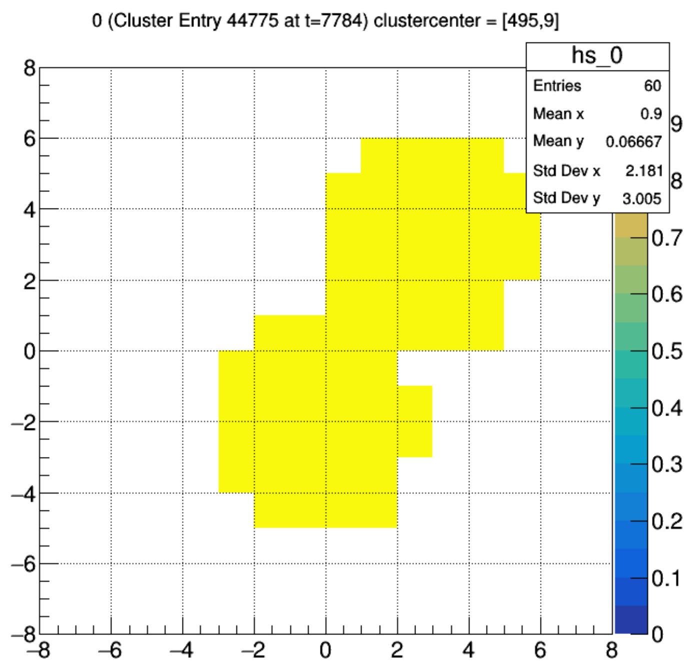
Analogue Signal Distribution



Digital Signal Distribution (Integrated Signal)



Fired Pixel Distribution

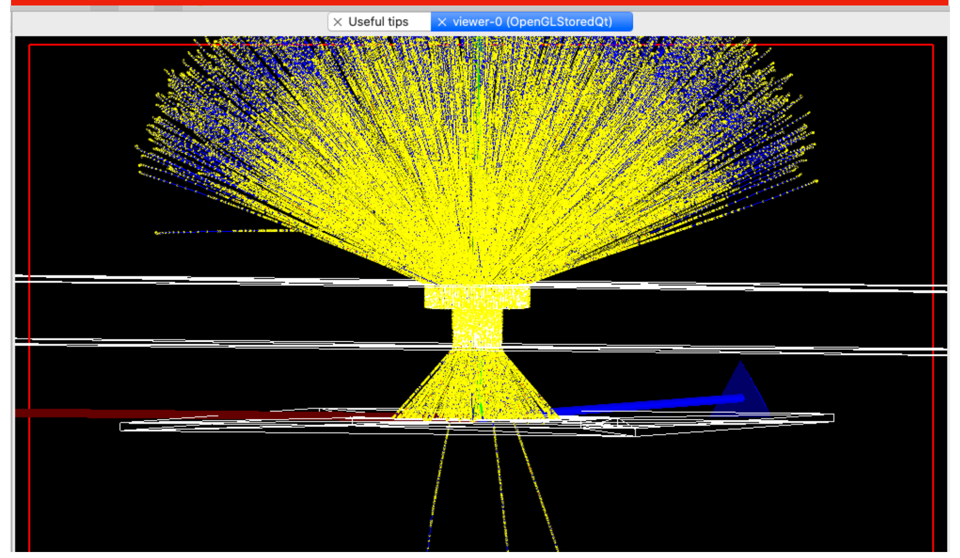


One of cluster in real data

Model vs Reality

실제와 모델이 맞아야 모델이지

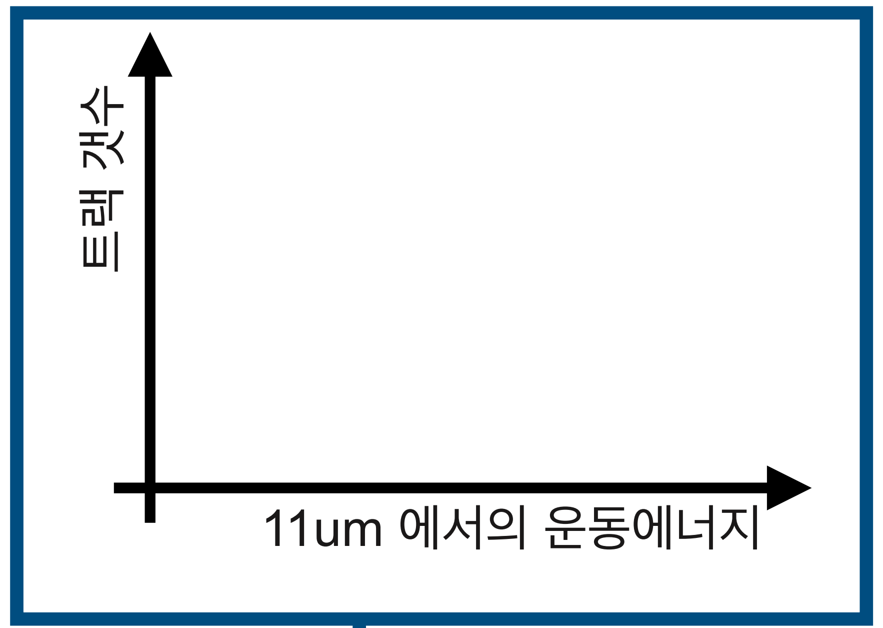
GEANT4



실리콘 내 깊이 별 Energy Loss

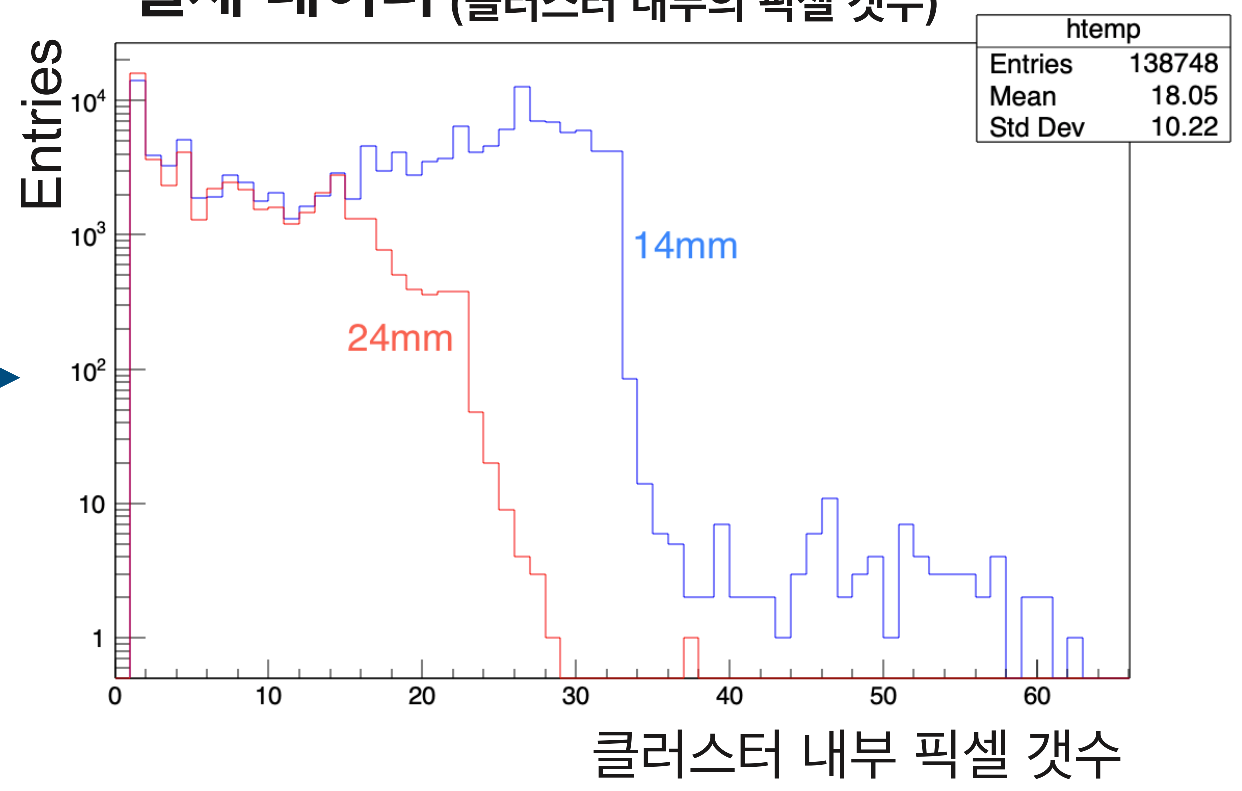
$$\frac{dE_{\text{Loss}}}{dz} \longrightarrow \boxed{\int_{11um}^{\text{Lost}} dE_{\text{Loss}}}$$

입자별 시그널 크기 분포

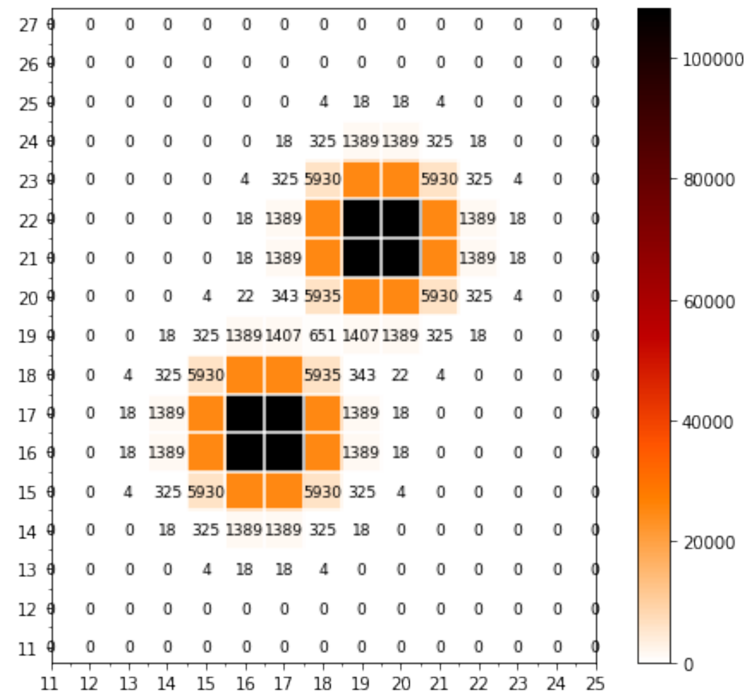


?

실제 데이터 (클러스터 내부의 픽셀 갯수)

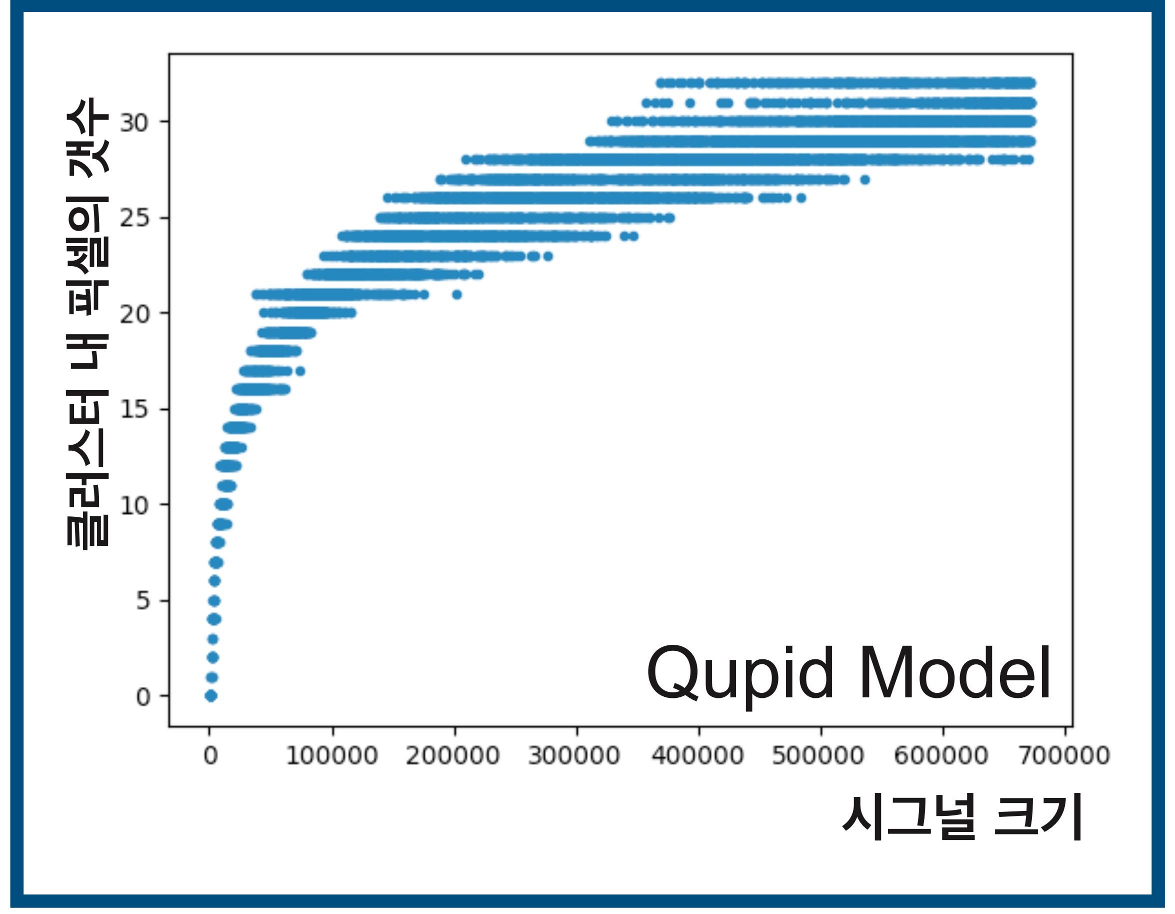


Qupid



무작위
- Signal 크기
- 위치

에서 시그널 분포 형성



재현 예정………

Summary & Outlook

- Base study for 3 particle elastic scattering experiment is on-going
  - ALPIDE has energy dependent detection efficiency.
    - Cross-check experiment will be done.
  - Double cluster finder is now developing.

- Concept of Experimental Geometry for real experiment is designed.
  - For background rejection, additional experiment needed.

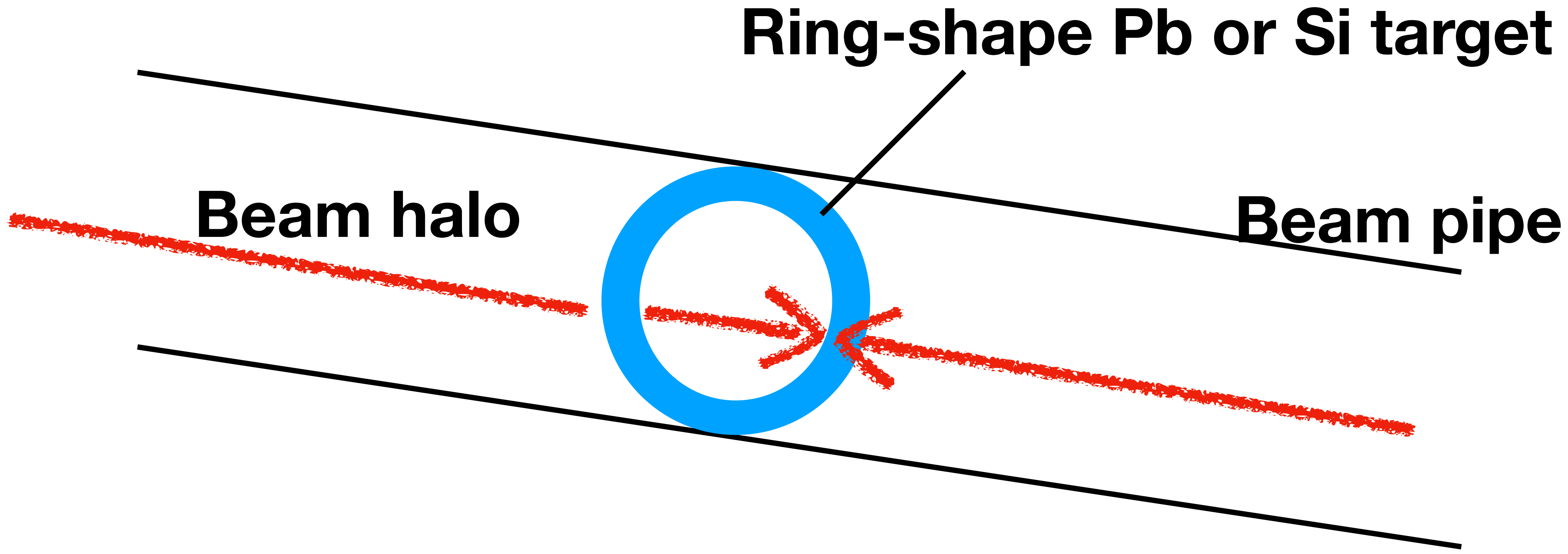
- Further experiment, analysis will be designed and done.


¡Thank You!
부산대학교
PUSAN NATIONAL UNIVERSITY
1946
koALICE National Workshop 2020, 16JAN2021, MINJAE ISAAC KWON

ALITE in RUN4

KoALICE2030

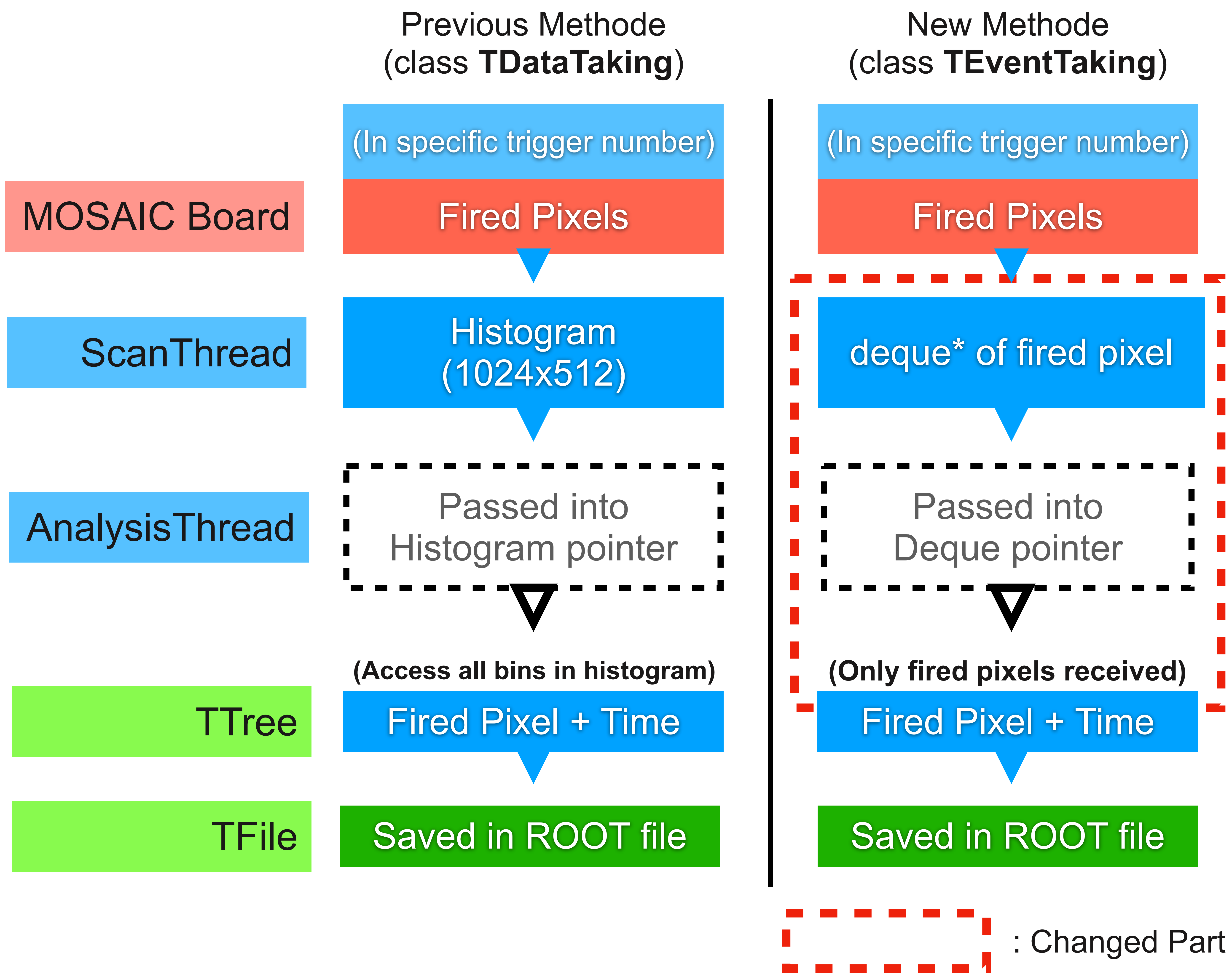
KoALICE



$\sqrt{s_{NN}}$ = 60 .. 75 GeV

- ALI Target Experiment
  - A short period of Target (Test) Experiment (in RUN5-6 with ALICEs)
  - Higher Interaction rate at (little) lower $\sqrt{s_{NN}}$
  - Closer IP
  - Trillision (3 nuclei collision) event?
- Silicon R&D + Production for ALICEs in RUN5-6
  - ITS3 + 7 tracking barrel layers +
  - (Active Target Experiment at SPS)
- Exploring QCD diagram with Charm

Development of NEW Data-taking methode with new-alpide-software



- **Solving memory problem**
  - Previous: Make histogram in every timeframe (1 hist = ~ 4MB)
  - Generally, 1pix - 400 pix / 1 timeframe
    1pix = ~20 byte → Not whole histogram needed.
  - Modify class to save **fired pixel only.**

- **Solving time budget problem**
  - Previous: Whole bins in histogram are parsed.
    - Unnecessary bins are parsed.
    - Analyzing, writing time > trigger time
      - Data is stacked → Memory getting full.
  - Modify class passing **fired pixel only.**
    - **Not needed to parsing whole bin.**
    - Now: Analyzing, writing time ≪ trigger time (~10times)

* deque : Double-Ended Queue.
can be thought as "list"

Developed Programs for This Project

- new-alpide-software (forked)
  - Datataking software for ALPIDE
    https://gitlab.cern.ch/mkwon/new-alpide-software
- RooParticle
  - (Numerical) Particle Scattering Simulator with ROOT
    https://github.com/Isaac-Kwon/RooParticle
- QUPID
  - ***Qu***asi-Signal Generation Model for ***Pi***xelized ***D***etector
    https://github.com/Isaac-Kwon/QUPID, https://isaac-kwon.github.io/QUPID

Objectives

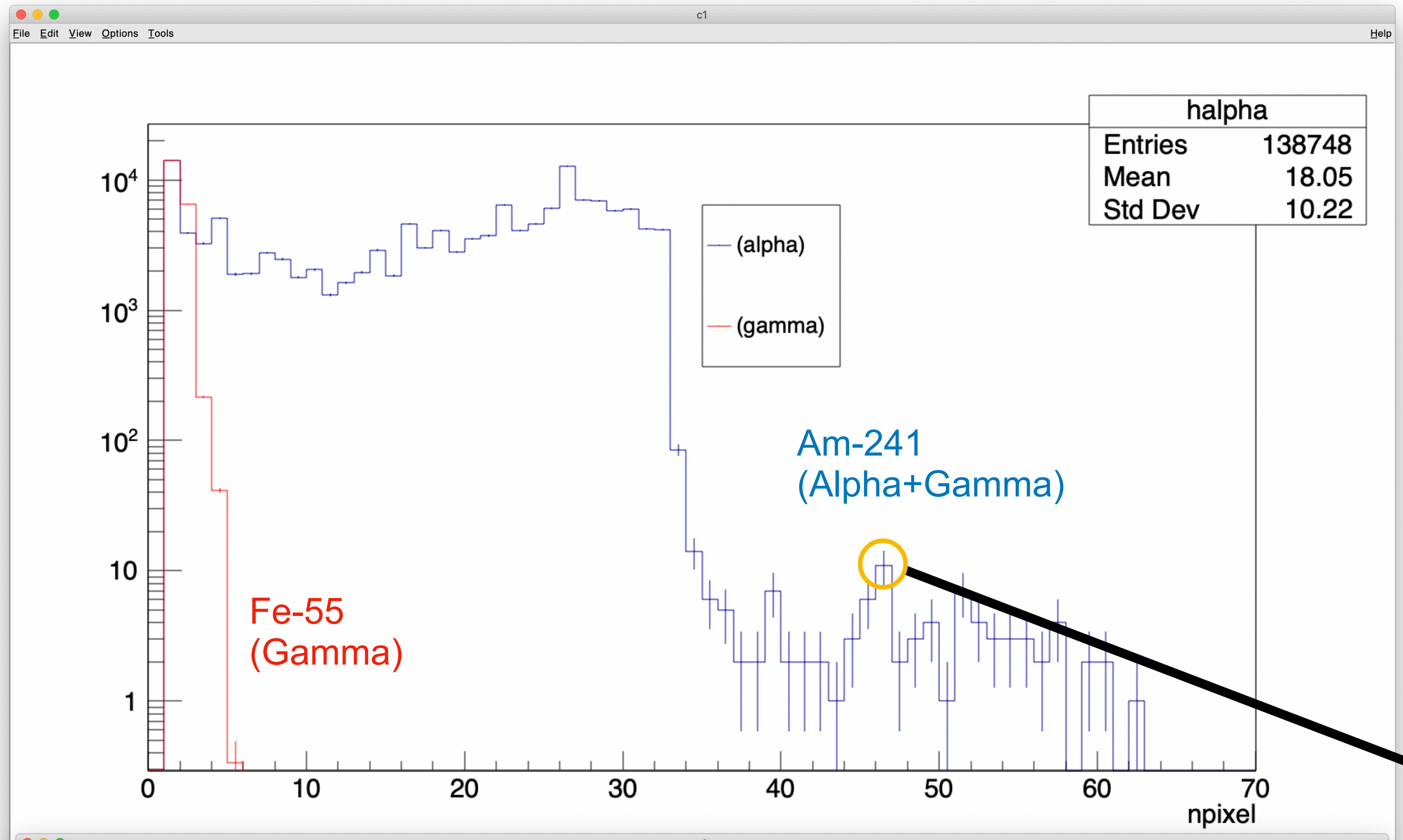
Realtime datataking

Simulate particles' trajectory with interacting forces

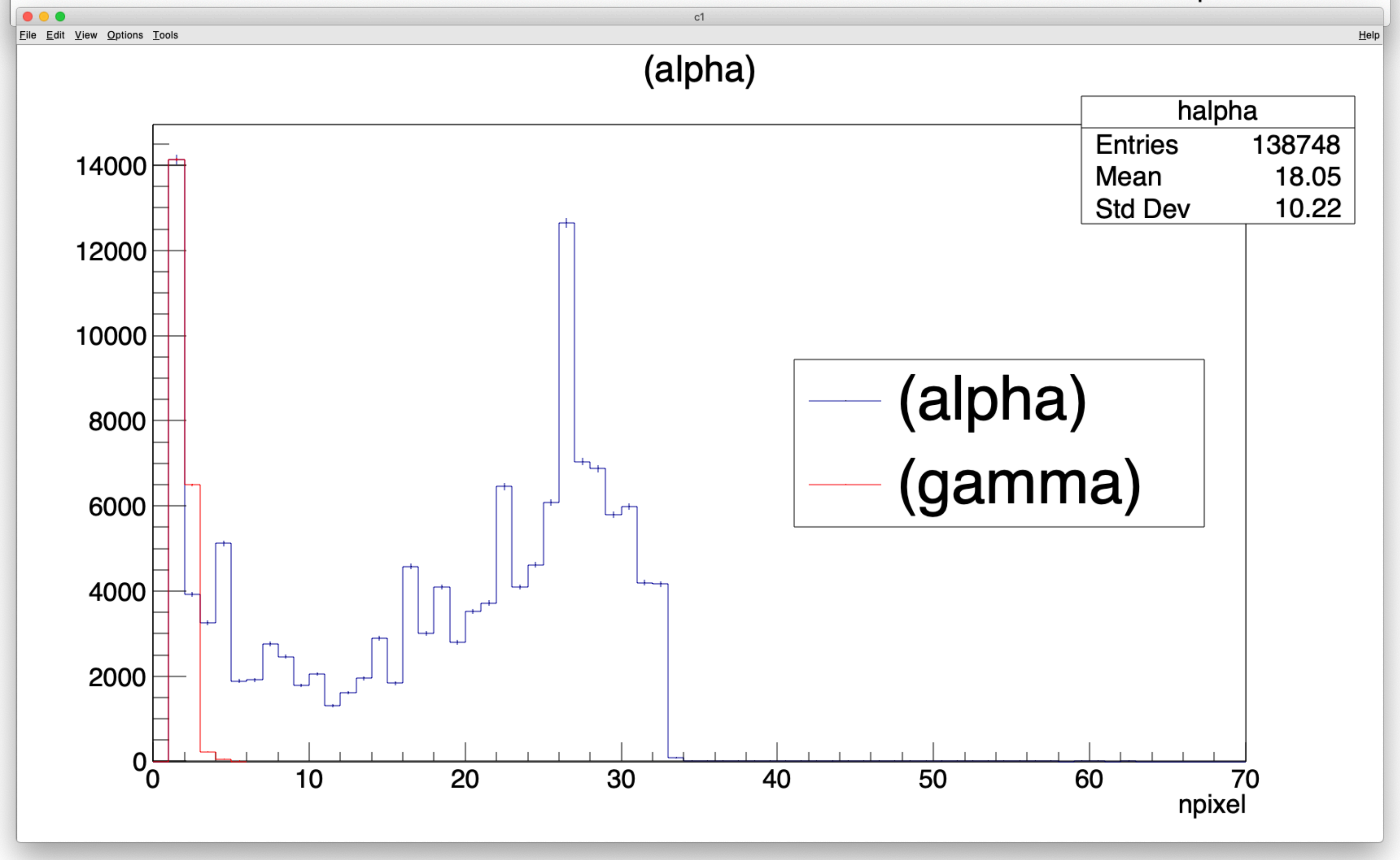
N (n>1) particle cluster data generation

Am-241 실험의 클러스터 크기 vs Fe-55 실험의 클러스터 크기? (l=14mm)

로그스케일



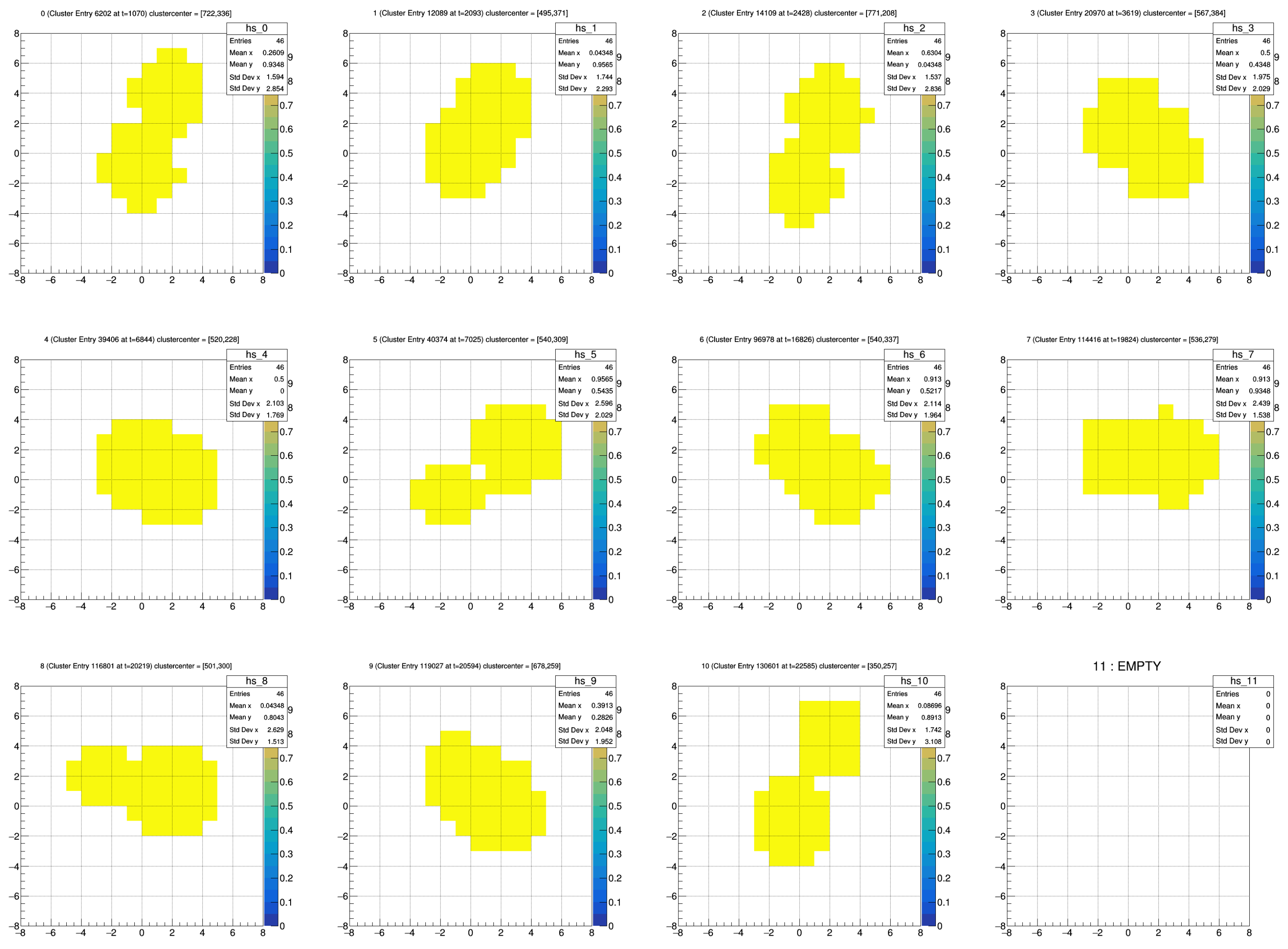
리니어스케일



npixel = 1 기준으로 맞춰짐. (Fe-55 히스토그램을 스케일링함)

- 작은 크기의 클러스터가 (거의 전부가) Fe-55 에 의해 설명되지 않음.
- 근데, 매우 큰 클러스터들은 도대체 뭘까?

– 2입자 클러스터였네…



입자수 예상 과정

14mm 실험과 24mm 실험, 두 실험의 교차검증과정

	particle	Incident	14mm	24mm
GEANT4	α	**200k**	12070 $\equiv \alpha_{14}$	7809 $\equiv \alpha_{24}$
	γ	1,000k 1/5 scaling	22431 $\equiv \gamma_{14}$	10085 $\equiv \gamma_{24}$
실험	$\alpha + \gamma$	?	138748 $\equiv T_{14}$	50377 $\equiv T_{24}$
			$T_{14} = \alpha_{exp,14} + \gamma_{exp,14}$	$T_{24} = \alpha_{exp,24} + \gamma_{exp,24}$

시간에 대한 조정변수 **입사 비율 계산**

$$A_n(\alpha_n + \gamma_n) = T_n = \alpha_{exp,n} + \gamma_{exp,n} \text{ [for } n = 14,\ 24]$$

14mm 관련

$$\boxed{A_{14} = 4.02156}$$

$$\rightarrow \alpha_{exp,14} = T_{14}\frac{\alpha_{14}}{\alpha_{14} + \gamma_{14}} = 48540.3$$

$$\rightarrow \gamma_{exp,14} = T_{14}\frac{\gamma_{14}}{\alpha_{14} + \gamma_{14}} = 90207.7$$

$$\longleftarrow \not\approx \longrightarrow$$

24mm 관련

$$\boxed{A_{24} = 2.8153}$$

$$\rightarrow \alpha_{exp,24} = T_{24}\frac{\alpha_{24}}{\alpha_{24} + \gamma_{24}} = 21984.7$$

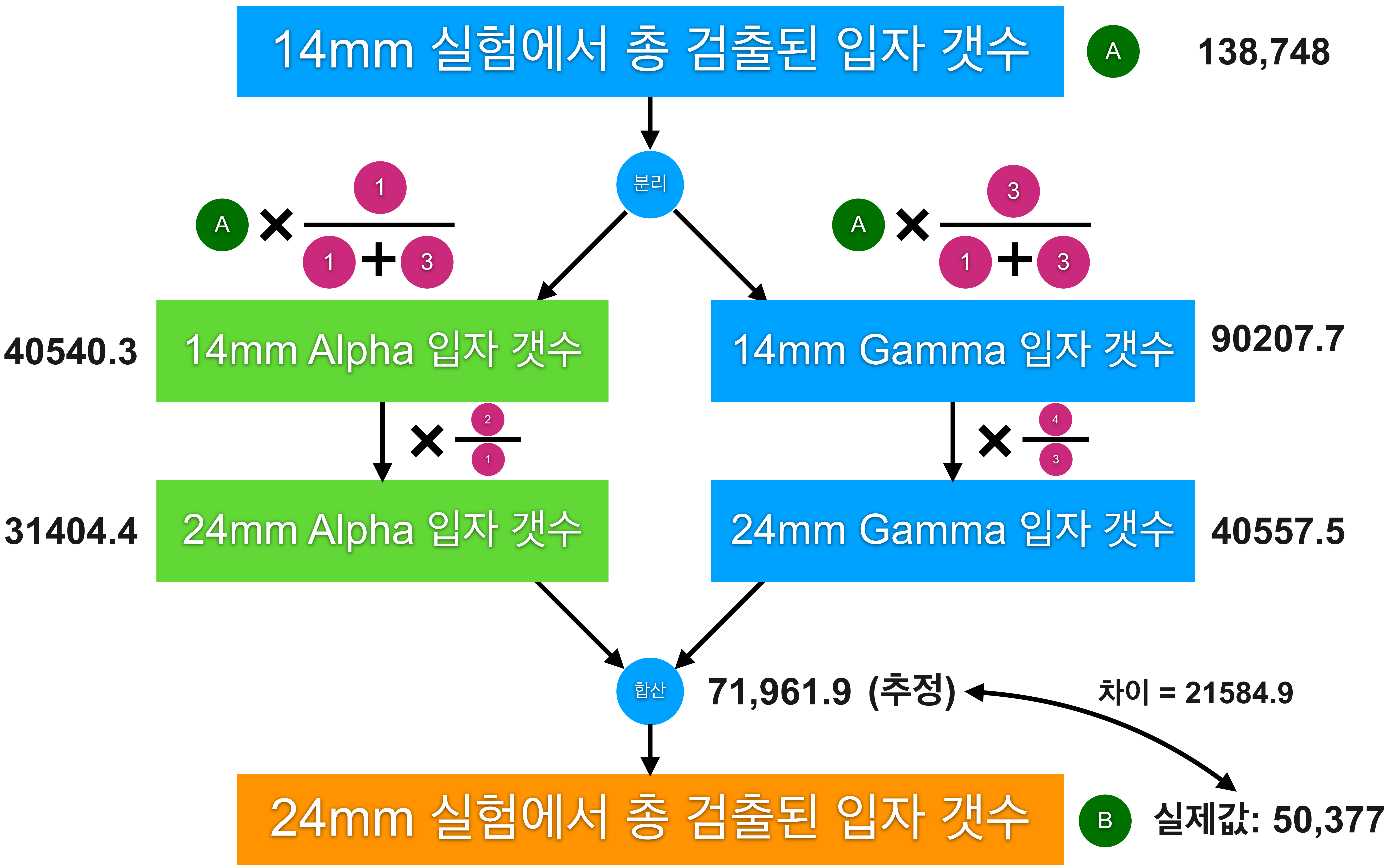
$$\rightarrow \gamma_{exp,24} = T_{24}\frac{\gamma_{24}}{\alpha_{24} + \gamma_{24}} = 28392.3$$

현재까지 진행한 실험/시뮬레이션

- Am-241 실험 (α, γ 가 섞임)
  - 14mm
  - 24mm
- Am-241 실험과 동일한 기하구조의 GEANT4 실험
  - 14mm α
  - 24mm α
  - 14mm γ
  - 24mm γ

입자수 예상 과정 v2

두 실험의 교차검증과정



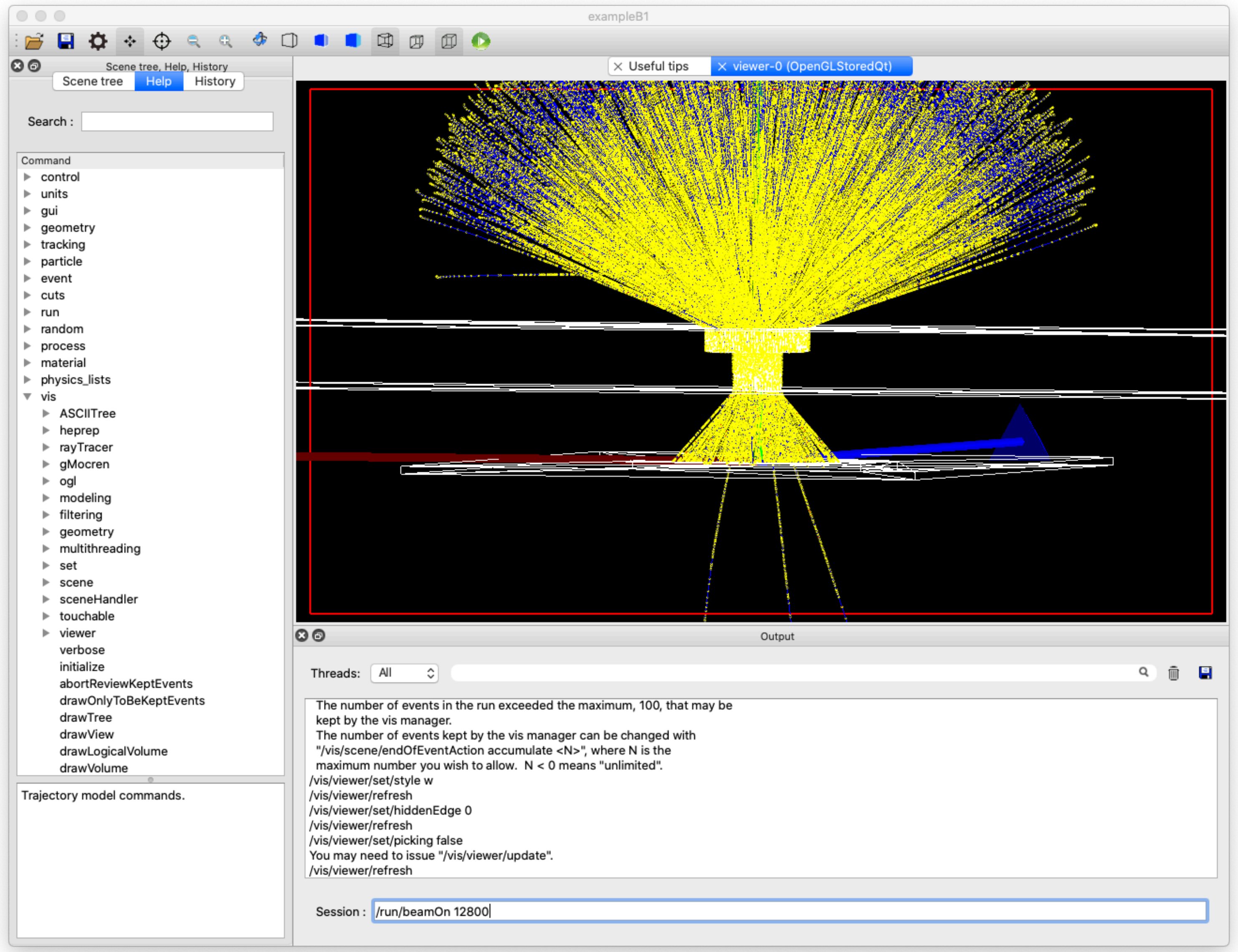
현재까지 진행한 실험/시뮬레이션

- Am-241 실험 (α, γ 가 섞임)
  - 14mm A
  - 24mm B
- Am-241 실험과 동일한 기하구조의 GEANT4 실험
  - 14mm α 1
  - 24mm α 2
  - 14mm γ 3
  - 24mm γ 4

알파의 검출기 내 손실이 원인인가?

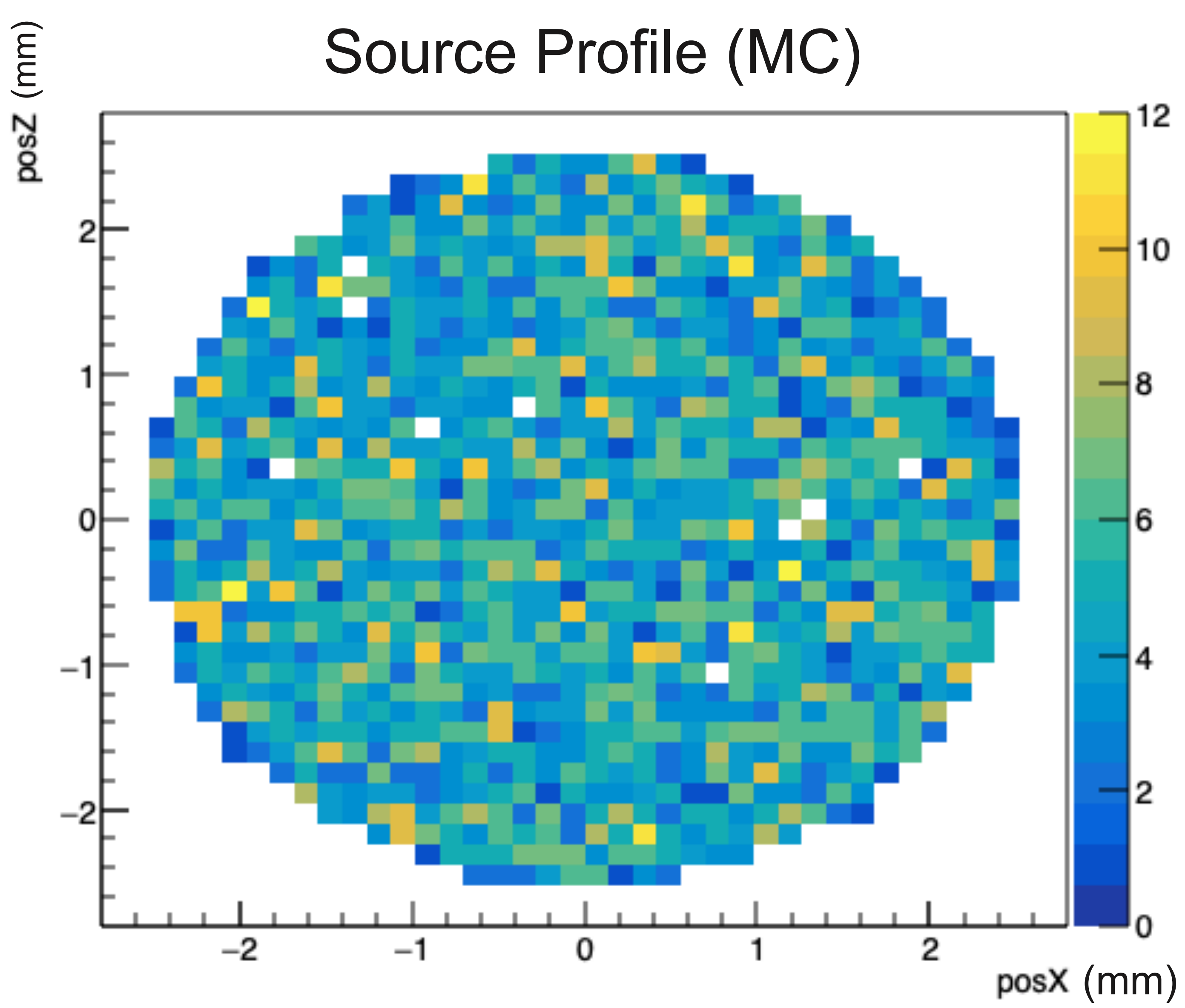
31404.4-21584.9 = 9820.4

31.27% 만 생존?

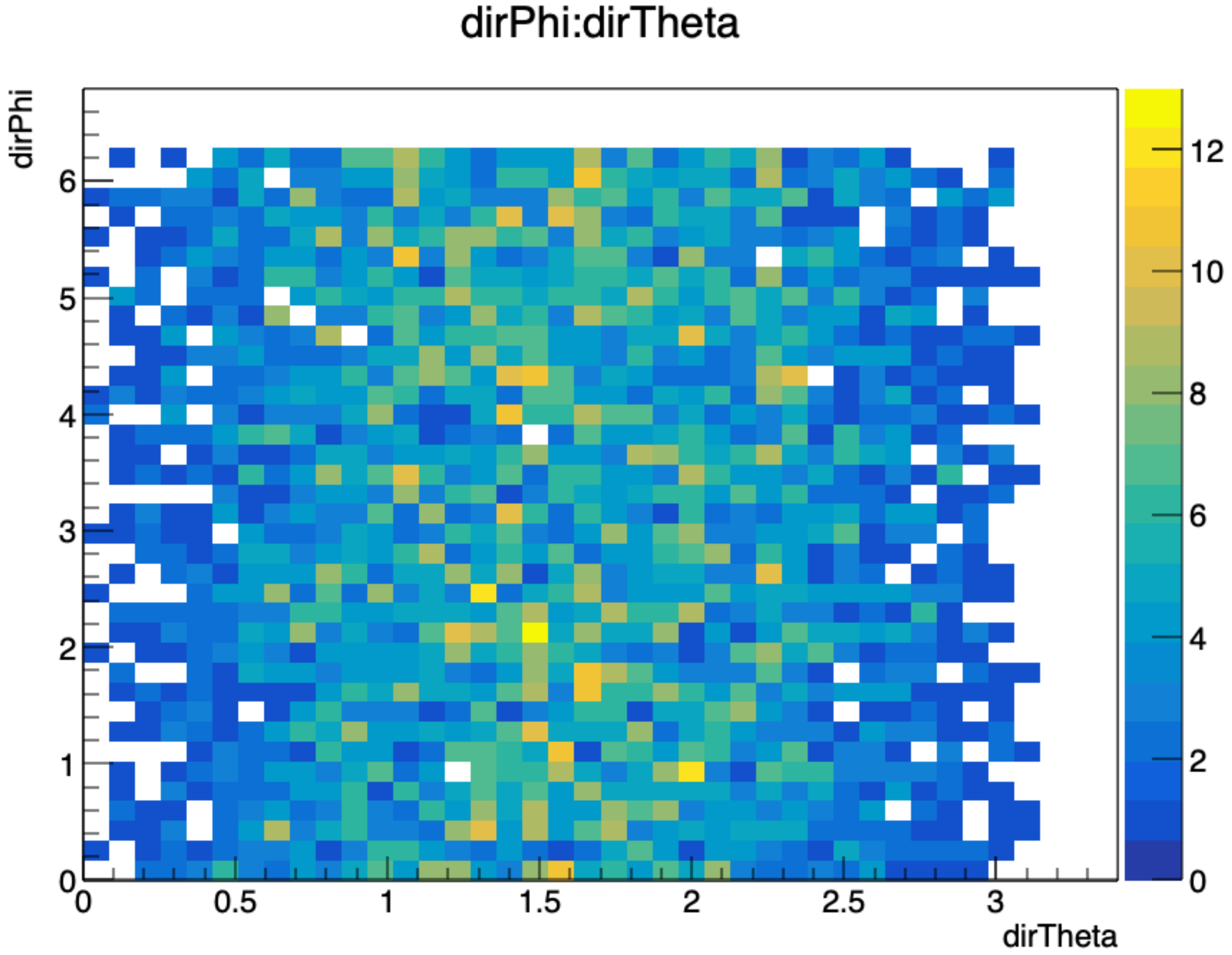


GEANT4 에 의해 형성된 알파 입자의 궤적

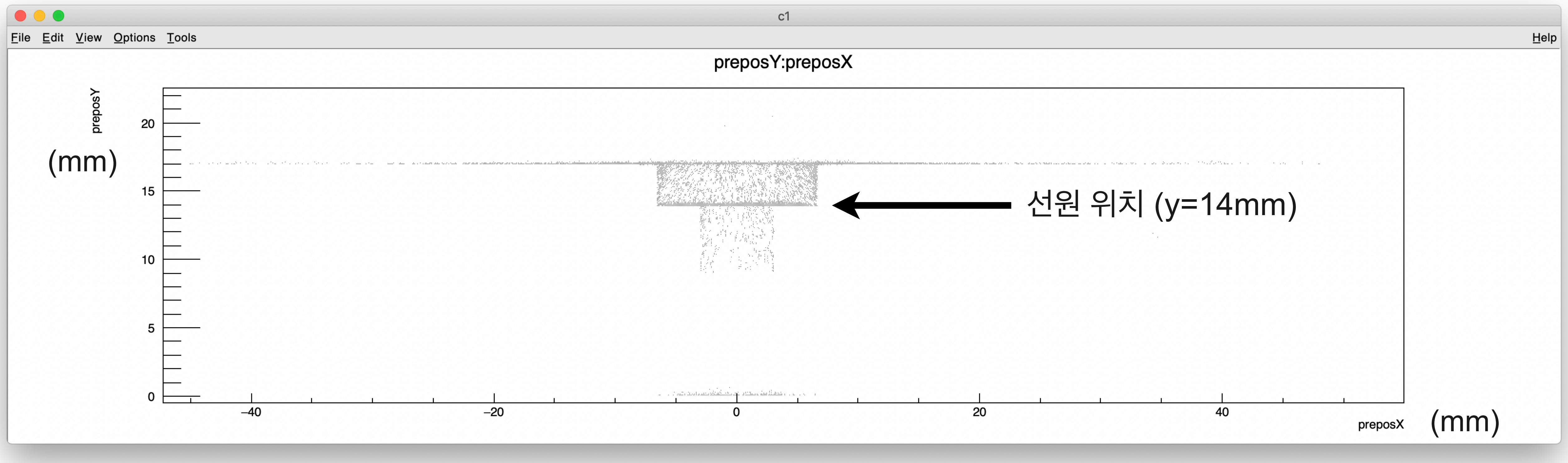
(생성 위치)



(생성 방향)

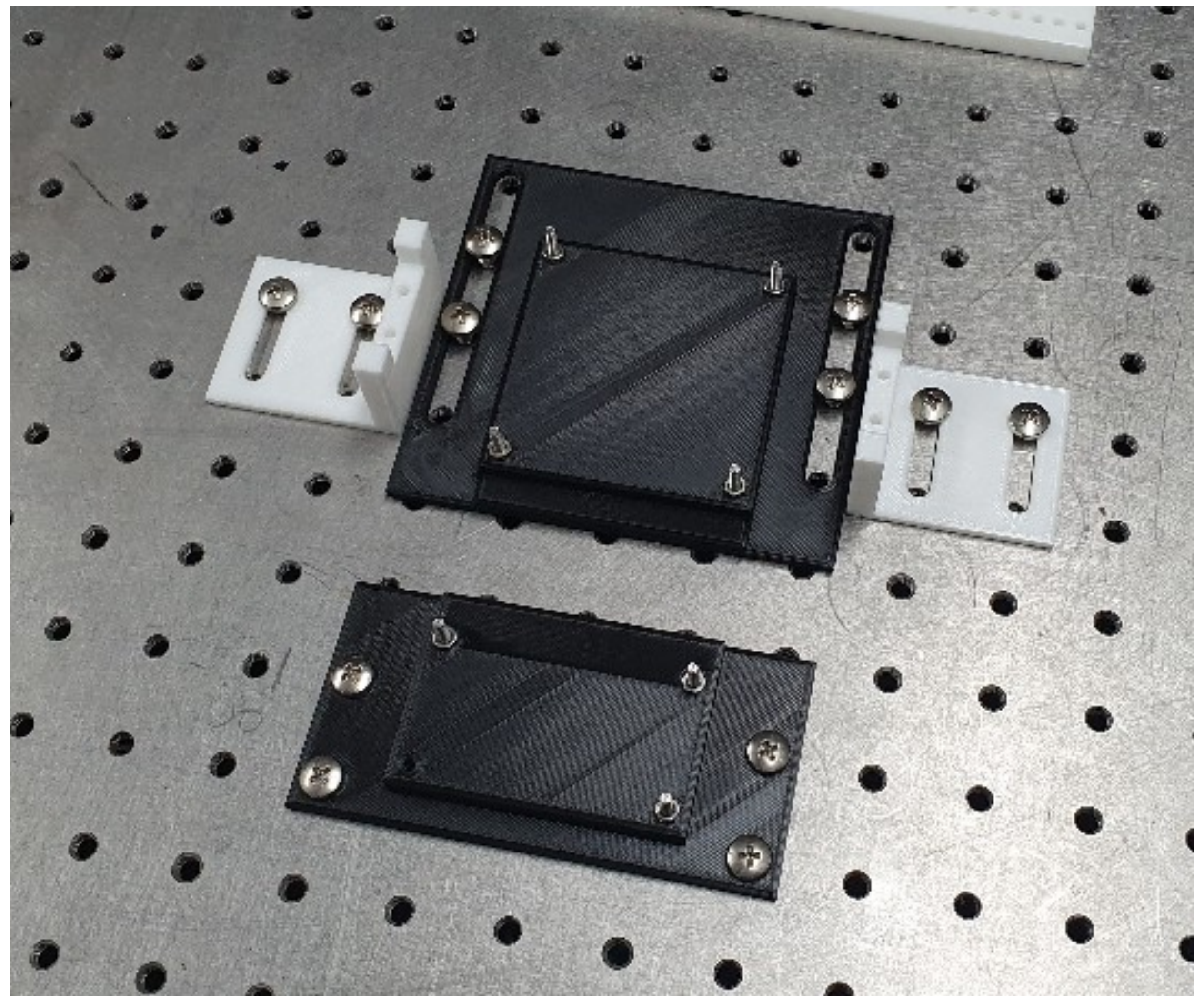


에너지를 잃은 지점의 분포 (공기는 제외)

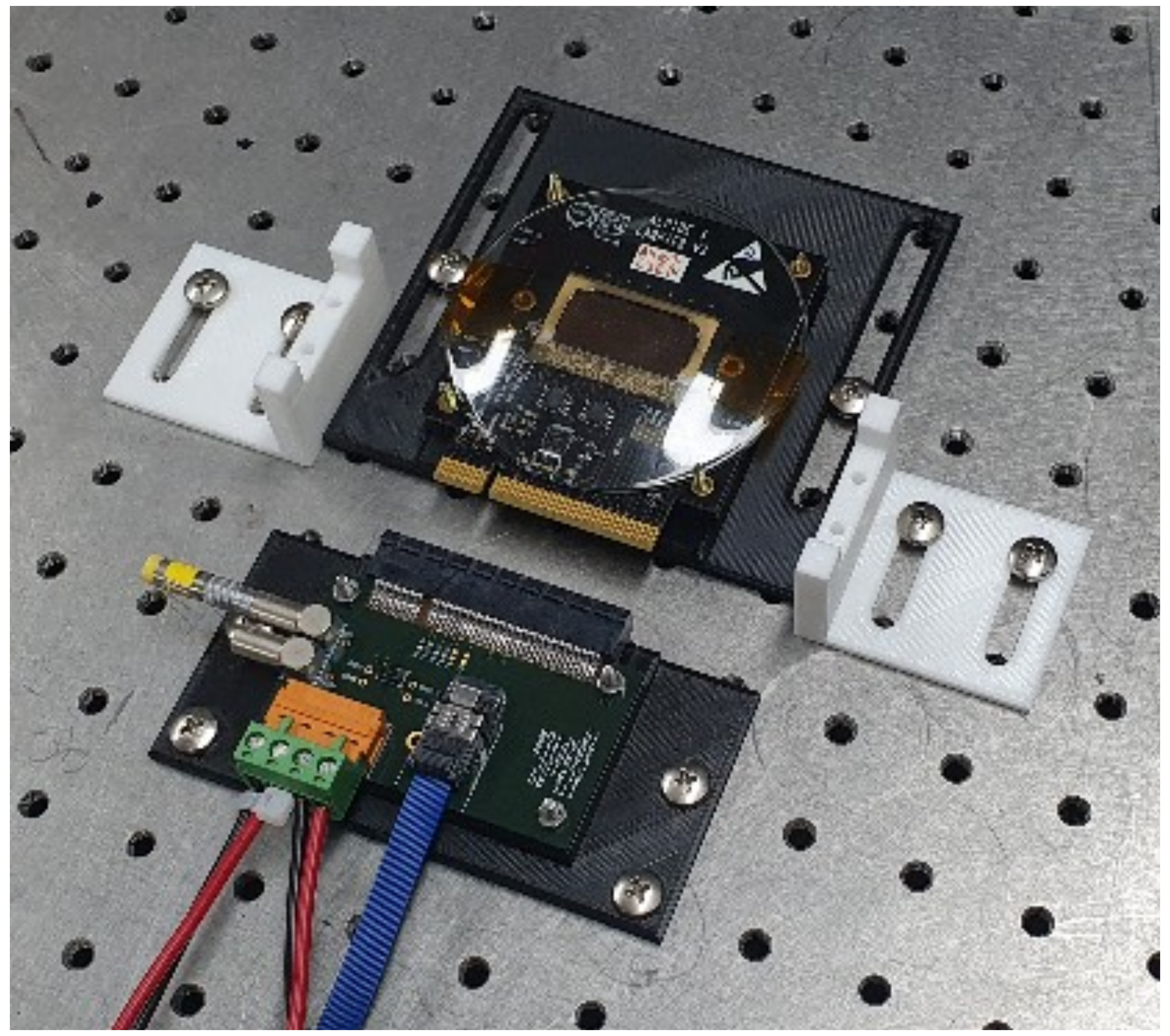


실험 구성 (실제)

실험 셋업 과정

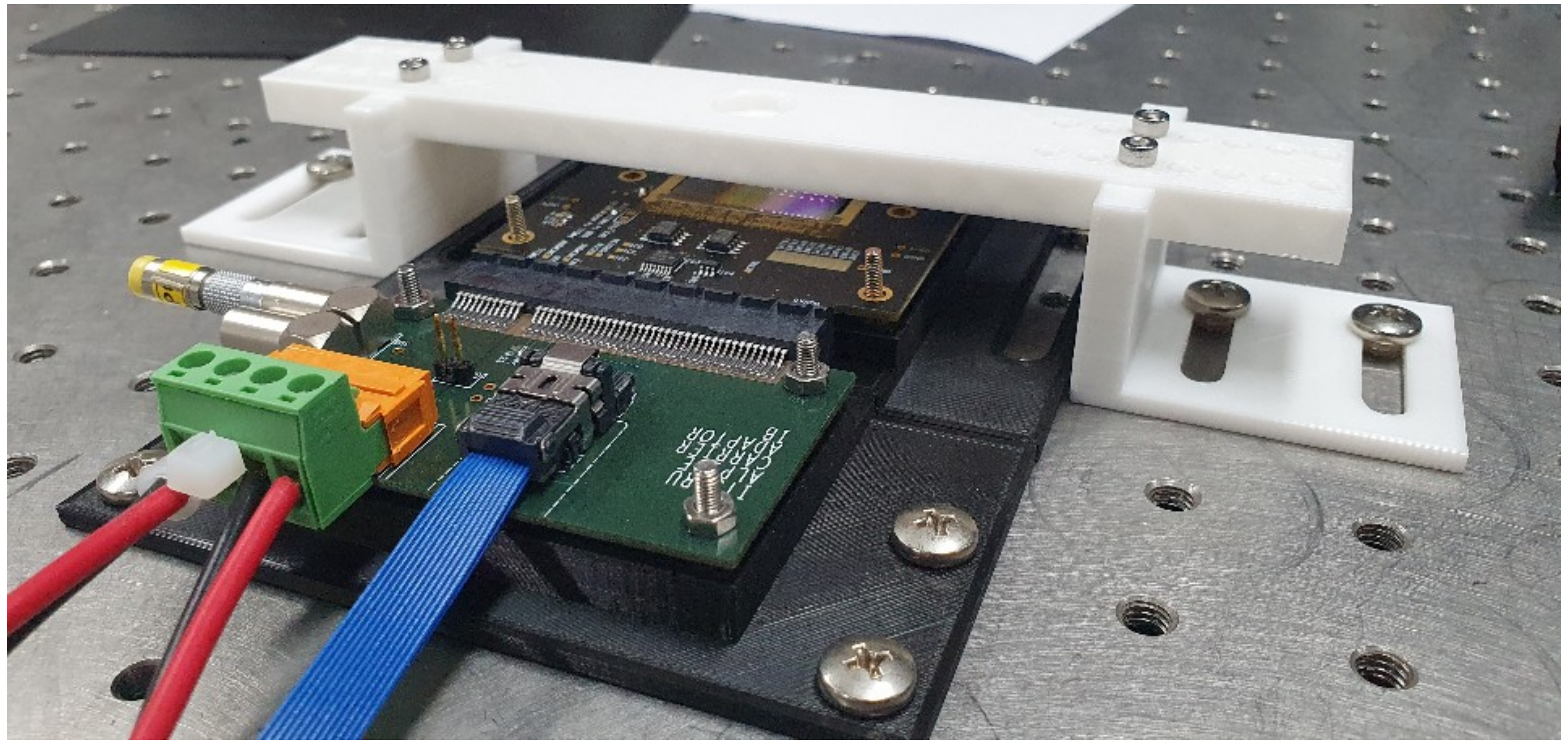


베이스



ALPIDE + 어댑터 올린 후

(어댑터 베이스를 잘못 맞춰서 한칸 옮겼음)

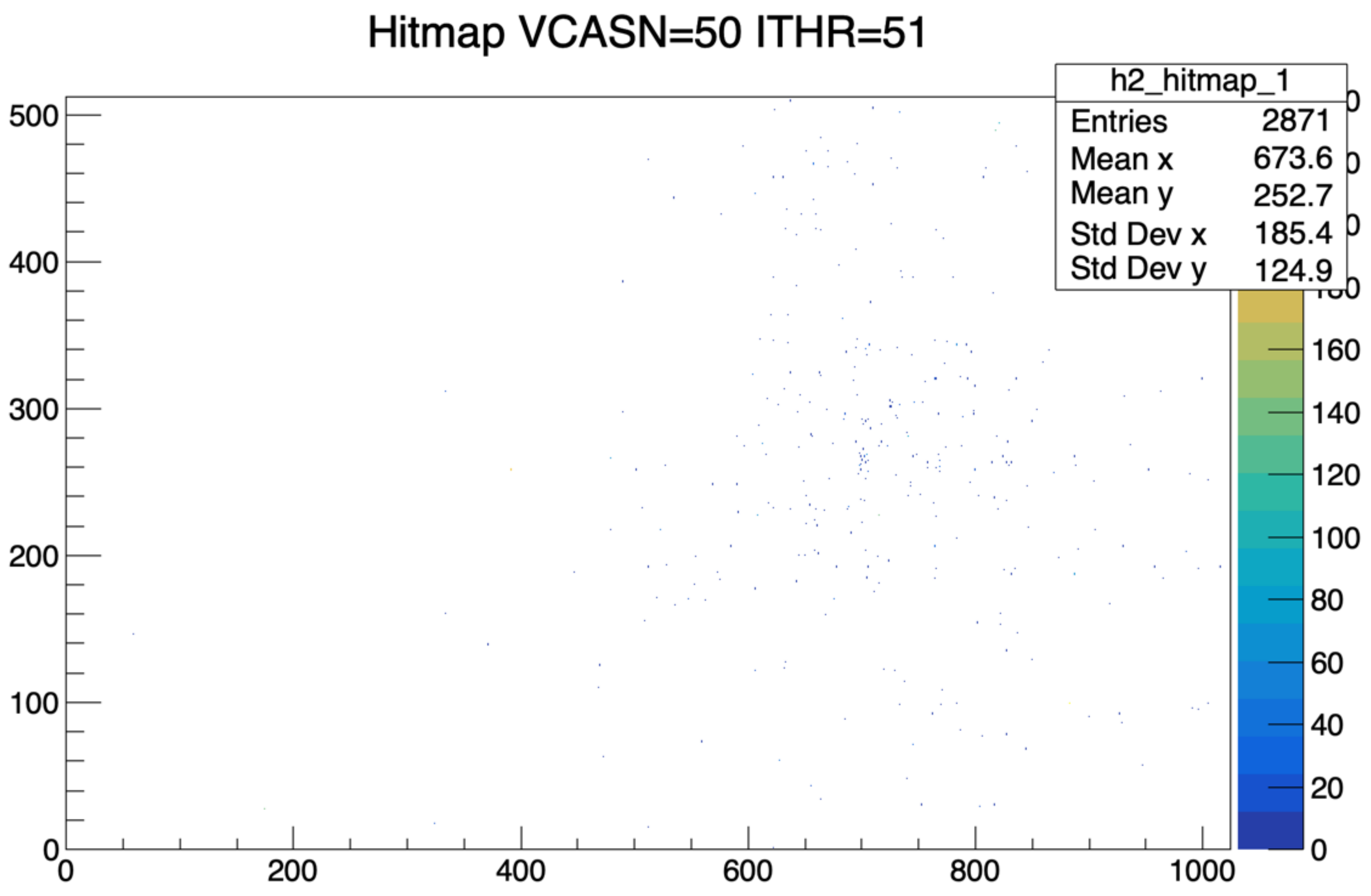


소스가 올라갈 브릿지를 올리고 고정

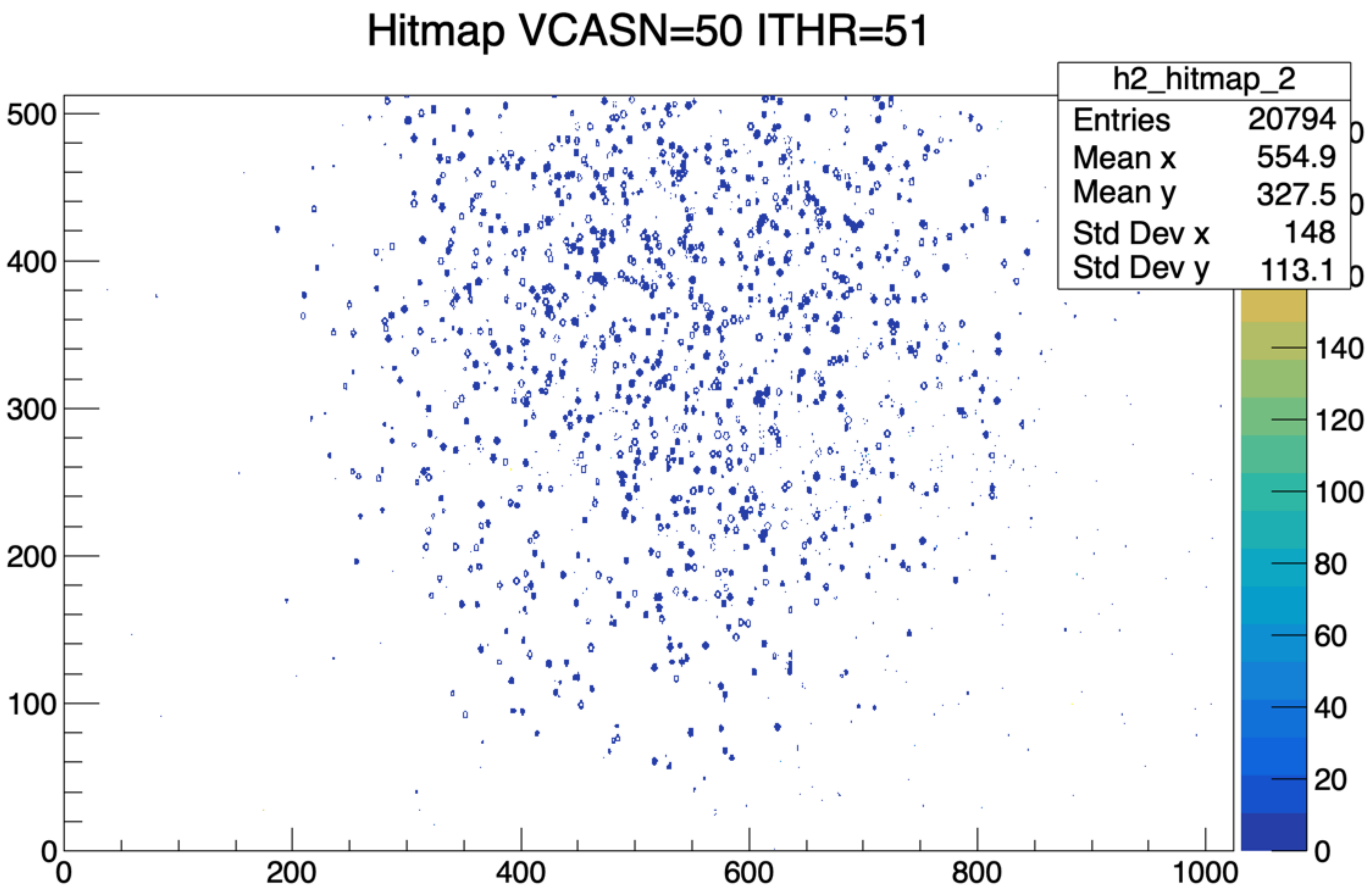
(ALPIDE 로부터 유리를 먼저 제거했음. 생략된 장면.)

Hitmap

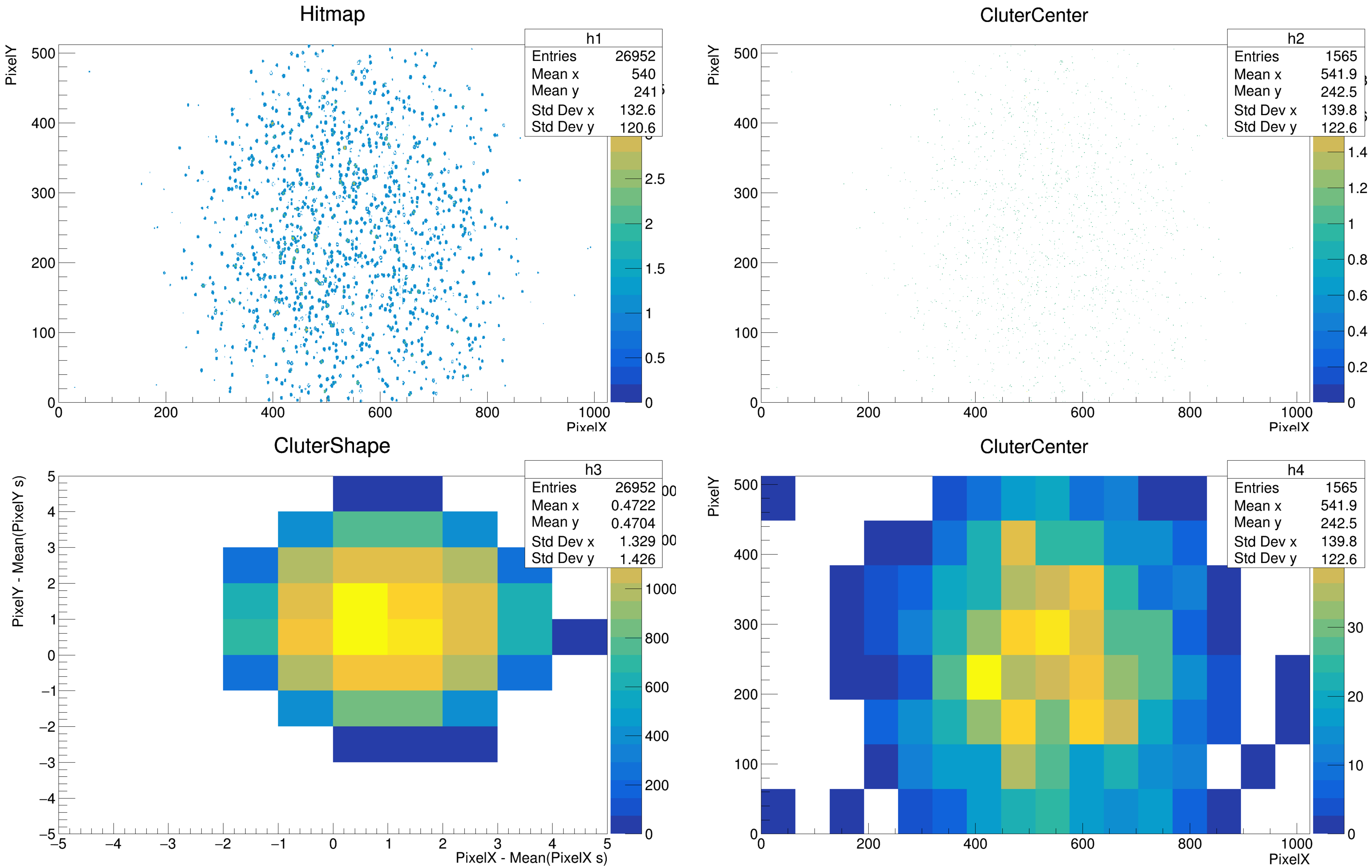
Pedestal



With Am-241

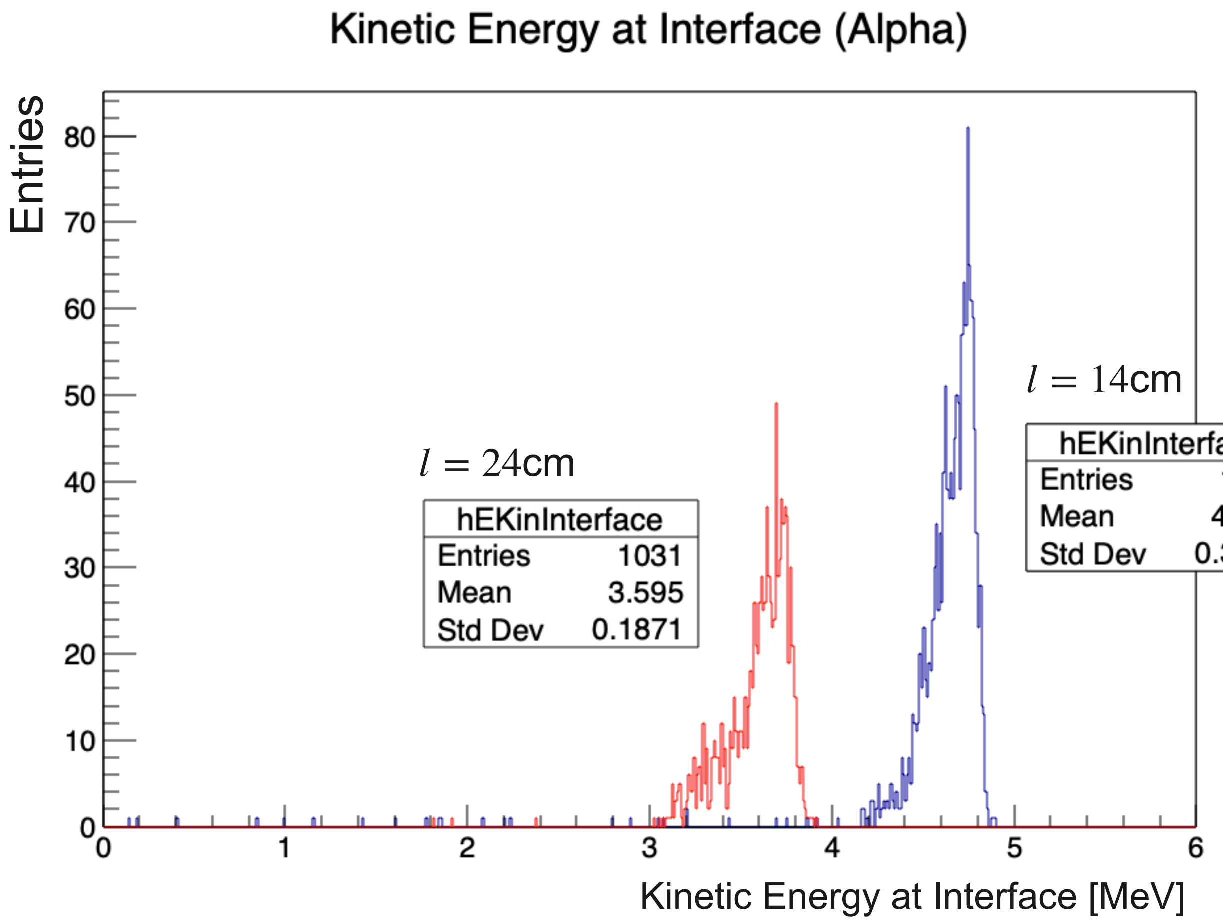


Clustering\


Hitmap
h1
Entries 26952
Mean x 540
Mean y 241
Std Dev x 132.6
Std Dev y 120.6
PixelY
PixelX
CluterCenter
h2
Entries 1565
Mean x 541.9
Mean y 242.5
Std Dev x 139.8
Std Dev y 122.6
CluterShape
h3
Entries 26952
Mean x 0.4722
Mean y 0.4704
Std Dev x 1.329
Std Dev y 1.426
PixelY - Mean(PixelY s)
PixelX - Mean(PixelX s)
CluterCenter
h4
Entries 1565
Mean x 541.9
Mean y 242.5
Std Dev x 139.8
Std Dev y 122.6

그래서 뭐가 문제일까?

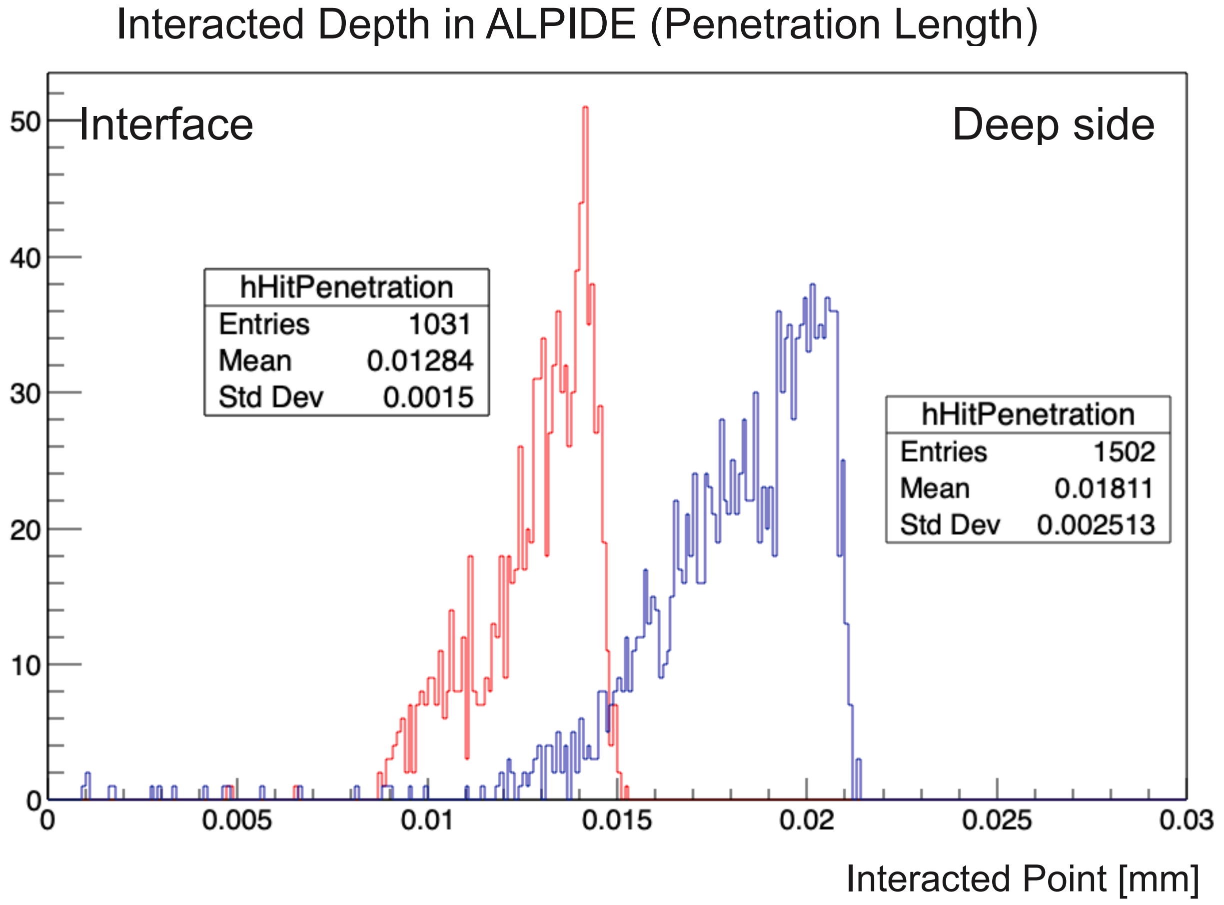
24mm 에서 특히 덜 나오는 것 같은 이유? (GEANT4 시뮬레이션)



검출기 표면에서의 알파 입자의 운동에너지

운동에너지가 부족한걸까?

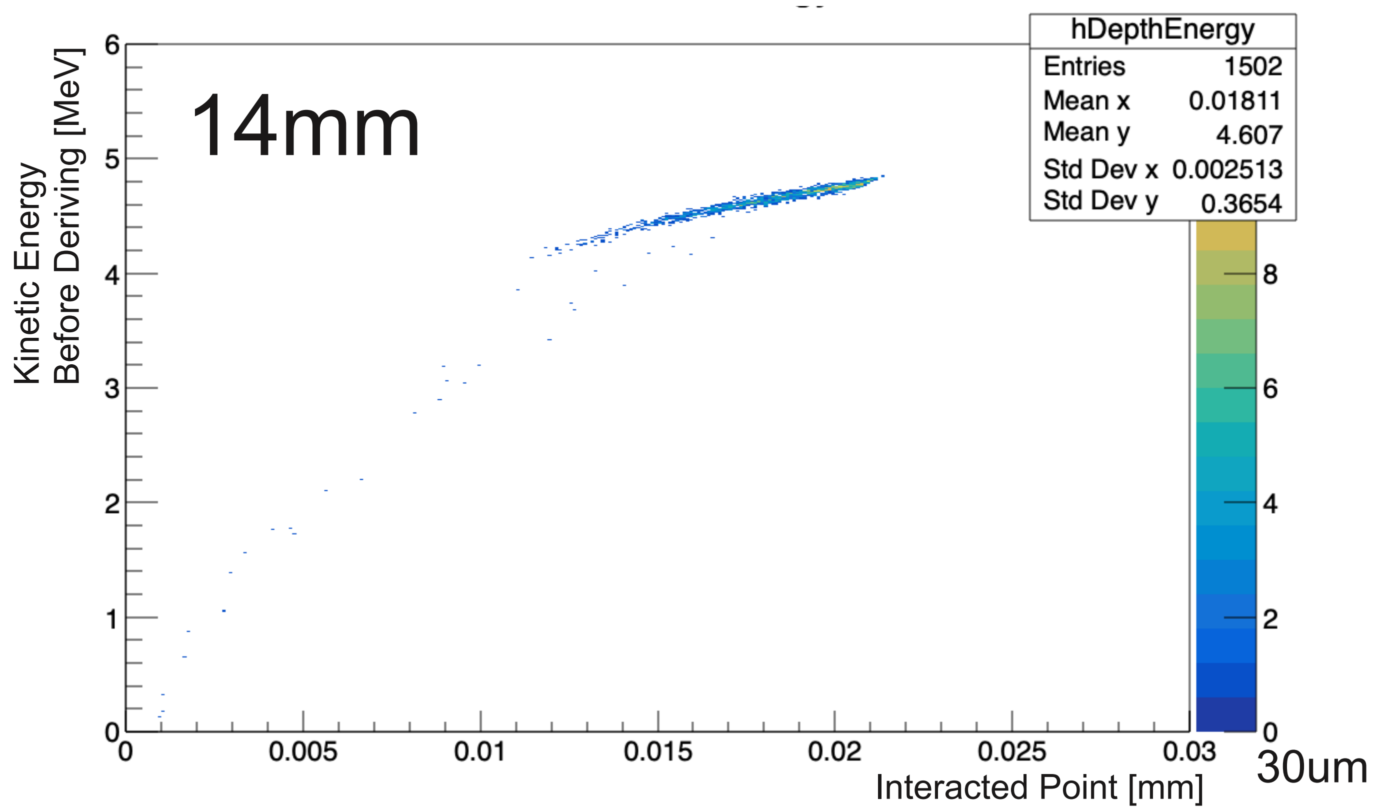
600개가 빠지려면… 3.5MeV 에서 끊어야.
(Threshold 기준 (250e 정도) 으로 2.038MeV 정도면 감지되어야 함.)

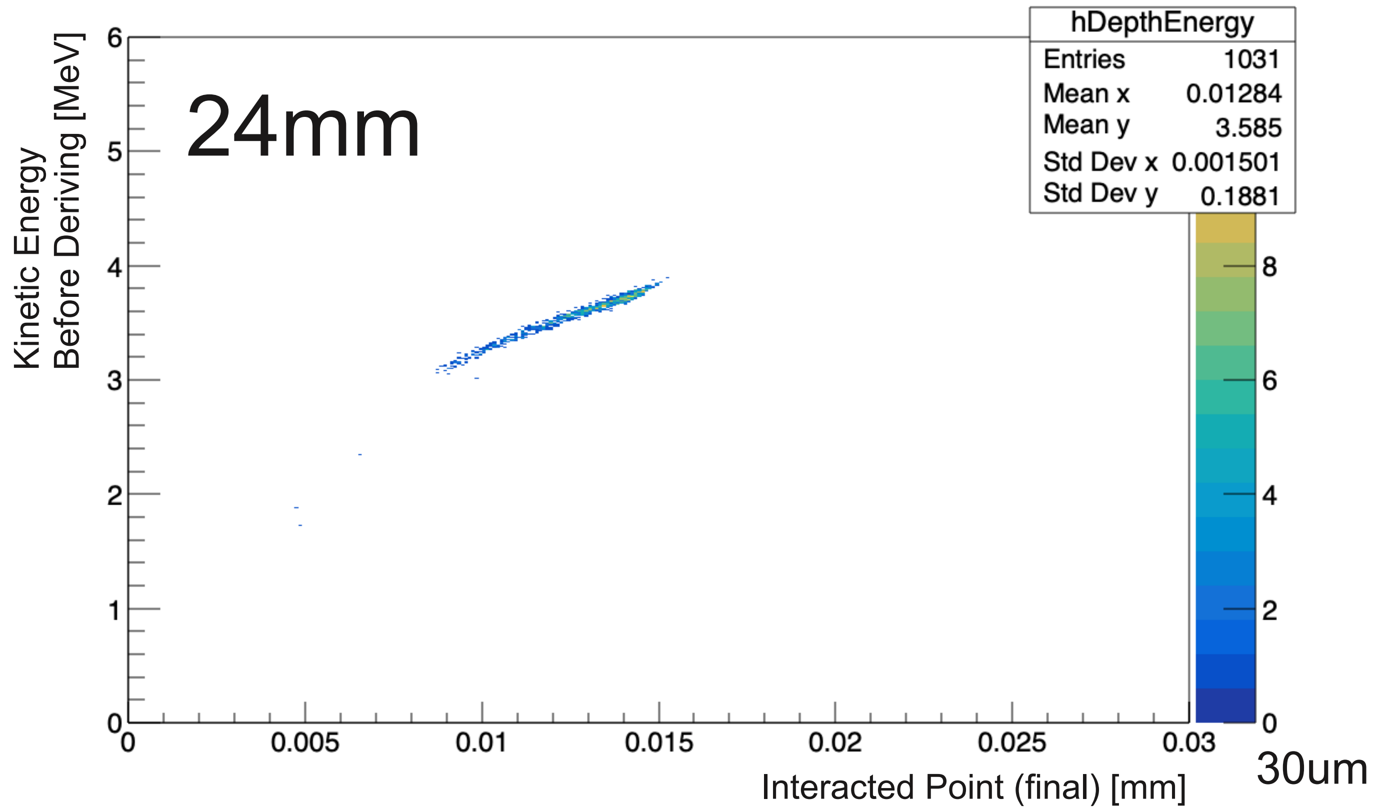


검출기 안에서 Interaction 하는 포인트들

그래서 검출기의 Epitaxial Layer 까지 못간걸까?

11um 정도 뚫으면 됐댔는데…





Epitaxial Layer까지 갔는데
운동에너지가 부족해서 시그널에 안들어왔나?

종합하면… 아직 잘 모르겠음.
다만, 시뮬레이션 스텝이 실리콘에서 한번밖에 없어서,
정확도에 영향이 있어보임. → **분석이 더 필요한 이유.**

11 um 이후부터 잃어버리는 에너지가 2 MeV보다 커야할 것.

그래서 뭐가 문제일까?

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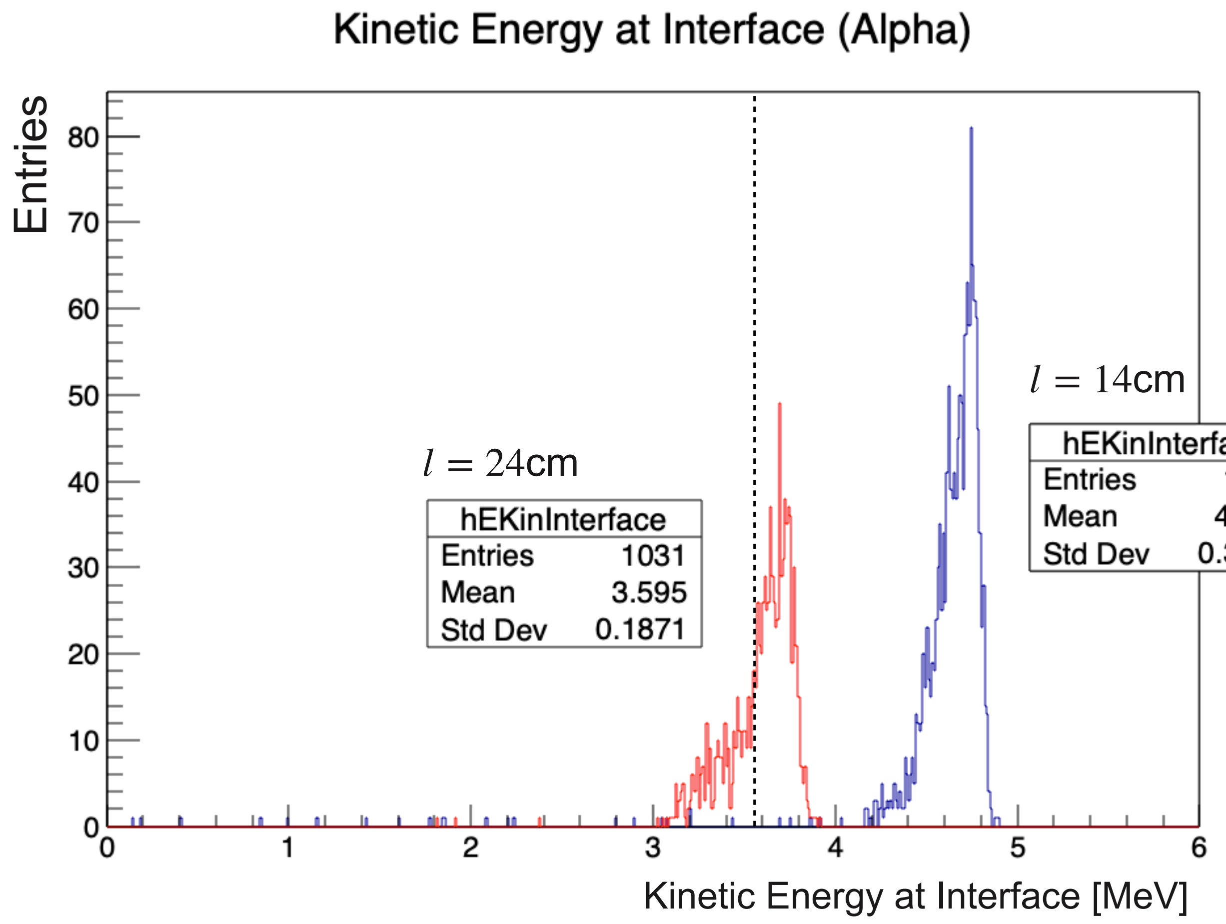

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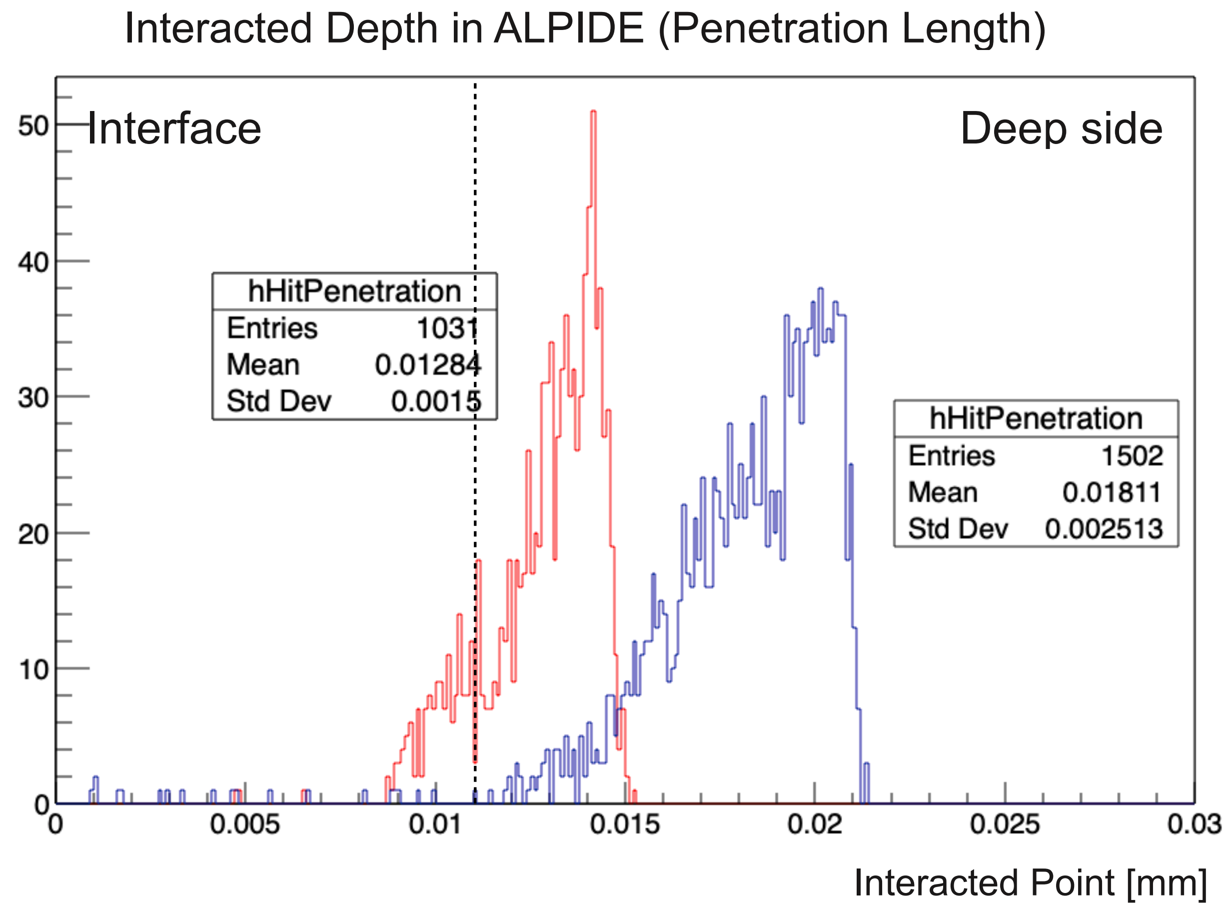

검출기 안에서 Interaction 하는 포인트들

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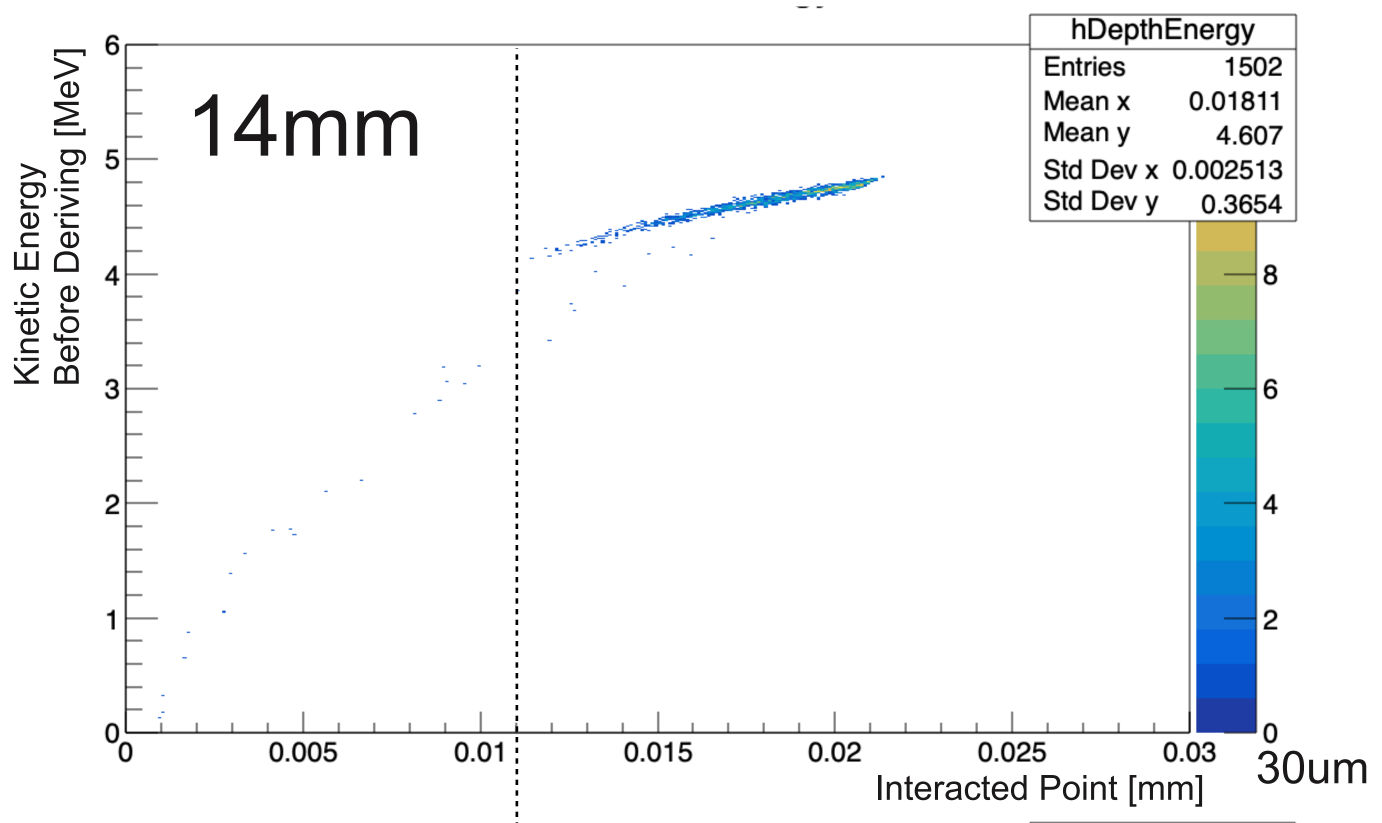

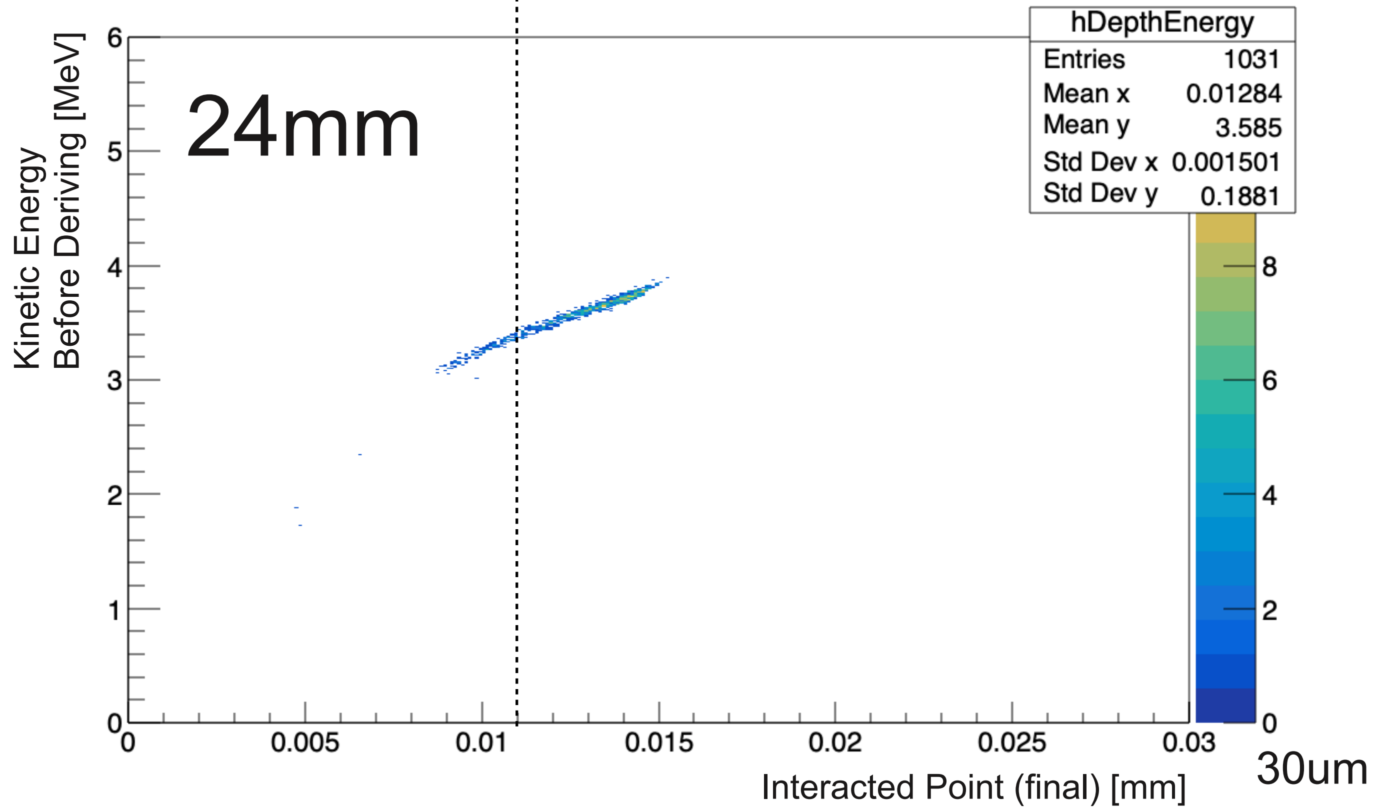

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