H1PEx
Heavy Ion Physics Experiment

KoALICE

Study on Reciprocal Scattering of Low Energy Alpha Source Using Silicon Pixel Detector

실리콘 픽셀 검출기를 이용한 저에너지 알파 선원의 상호 산란 연구

KoALICE National Workshop 2021, 2022.01.05, MINJAE ISAAC KWON

Ultra Short Summary of 2021

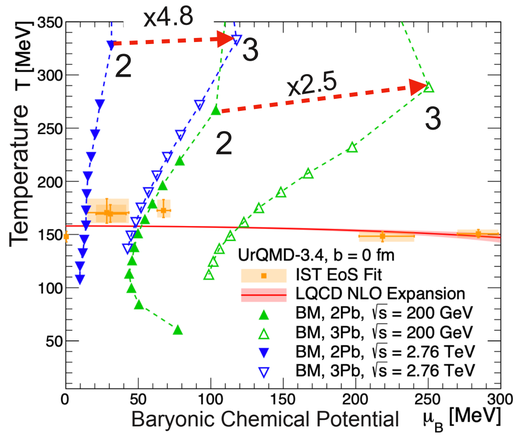
~~네 줄 요약~~

- Robust PID of α and γ particle from $^{241}\mathrm{Am}$
- Measure reciprocal scattering with 2 of $^{241}\mathrm{Am}$ sources.

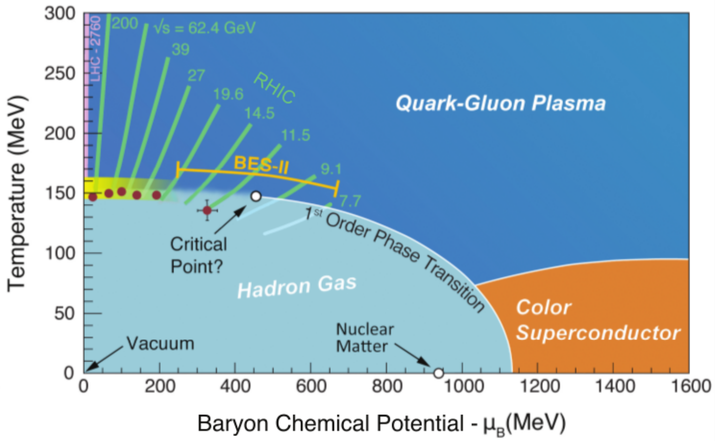
- On-call shift for ITS2 on ALICE-Commissioning 2021

- M.S Defense (15 Dec. 2021)
  Thesis Title: Study on Reciprocal Scattering of Low Energy Alpha Source Using Silicon Pixel Detector
  Referee: Prof.Dr. Sanghoon Lim, Prof.Dr. Minjung Kweon, Prof.Dr. In-Kwon Yoo

Tri- Nuclear Coliision



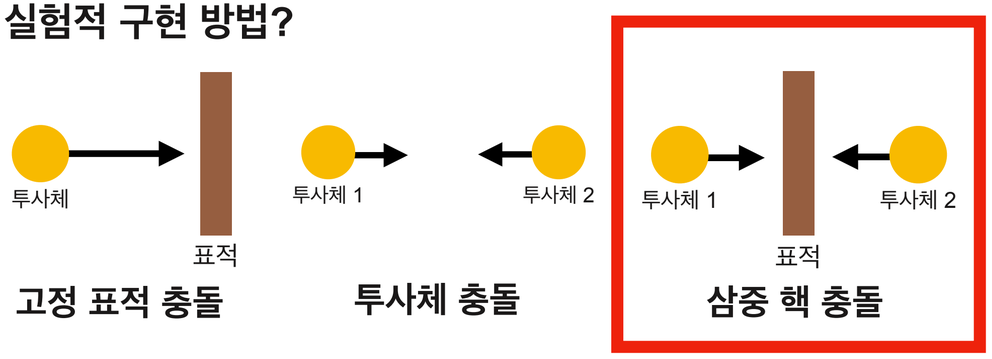
Comparison of Baryonic Chemical and temperature between 2 and 3 nuclear collisions[1] (Theory)



QCD Phase Diagram [2]

- New experimental scheme for nuclear colliding experiment.

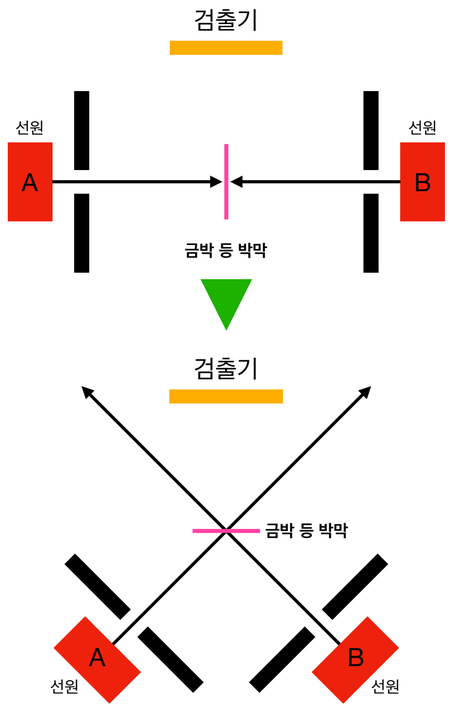
실험적 구현 방법?

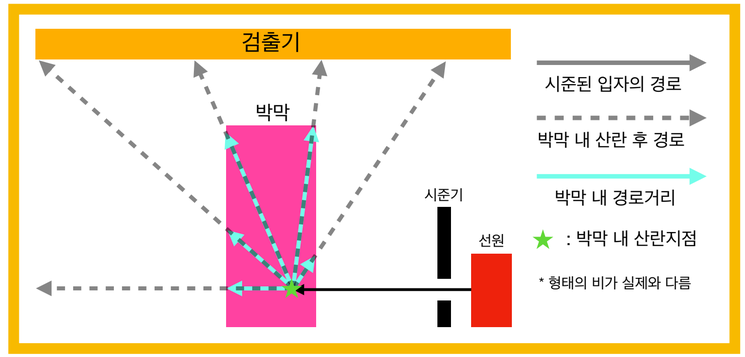


Elastic Scattering

- Experiment to prove observability
- Using low energy radioactive source
- Similar method with Geiger-Marsden Experiment.

Detail Scheme





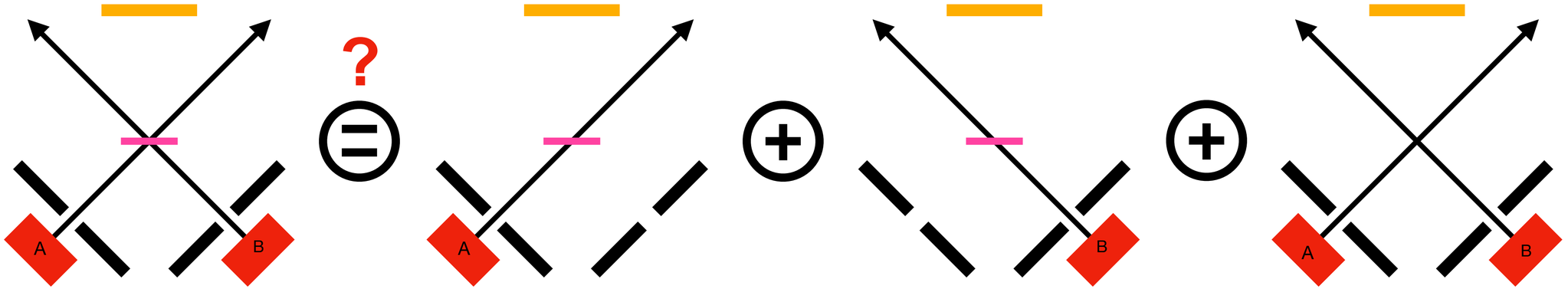
- Acceptance is dependent on scattering angle.
- Scattering Angle $\rightarrow 90°$, Acceptance $\searrow$

물질명	밀도 (g/cm^3)	투과범위 (mg/cm^2)	투과거리
공기(1기압)	1.20479×10^{-3}	4.990	4.142 cm
물	1.00	4.301	43.01 μm
실리콘	2.33	6.376	27.36 μm
금	19.32	18.06	9.34 μm

Penetration depth of 5.486MeV α particle in materials [3]

1) K. Bugaev and O. Vitiuk
2) USQCD
3) M. Berger, J. Coursey, M. Zucker, and J. Chang

3 Particle Elastic Scattering in REAL WORLD



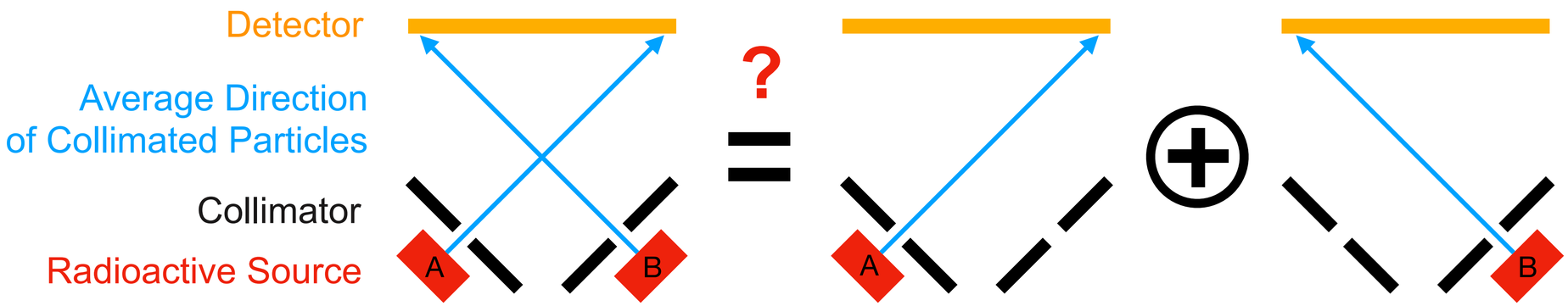
3 particle exp. A target exp. B target exp. Reciprocal exp.

: Detector : Thin film target : Thin film target

: Source : Particle Direction

Mesurement?
Hitmap of alpha particle

Reciprocal Scattering



- A part of three particle elastic scattering.
- Experiment of measurement of overlapping.

H1PEx
Heavy Ion Physics Experiment

Robust PID low E α and γ on SPD

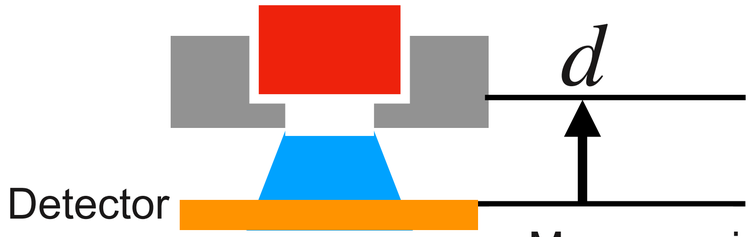
Motivation

- Measurement of characteristics of signal from $^{241}\mathrm{Am}$ is needed.

$$^{241}_{95}\mathrm{Am} \xrightarrow{432.2\ \mathrm{y}} \mathrm{Np} + \boxed{^{4}_{2}\alpha^{2+}} + \gamma$$

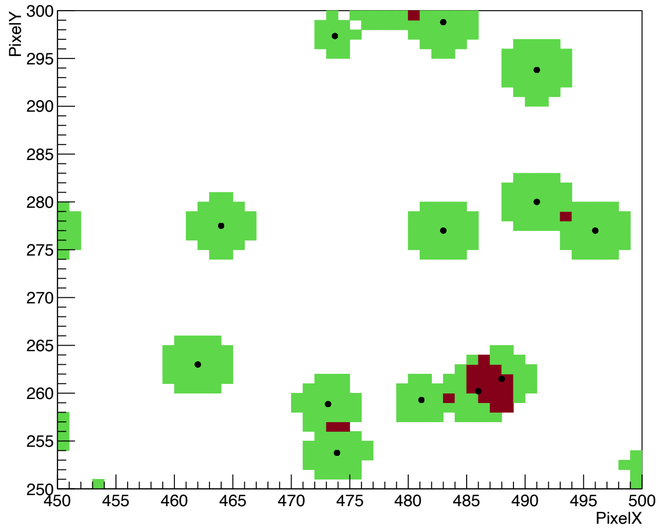
활용하는 알파 입자 감마 입자 (노이즈?)

Exp. is done in 2020!



Measure pixel hitmaps in different distance d

Analysis



1. Clustering
2. Measure characteristics of each cluster
3. Get Statistics!

Cluster Characteristics?

- **Size**
- Position
- Eccentricity
- …

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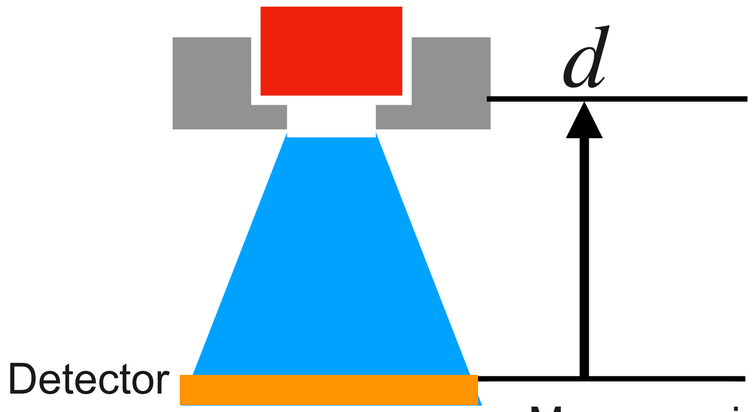

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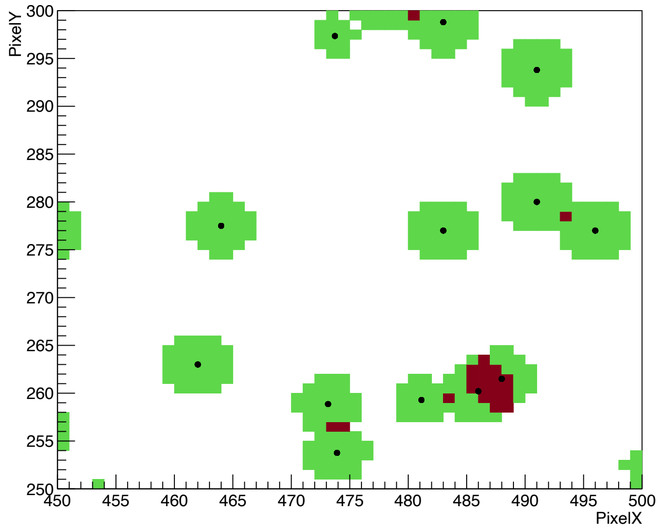

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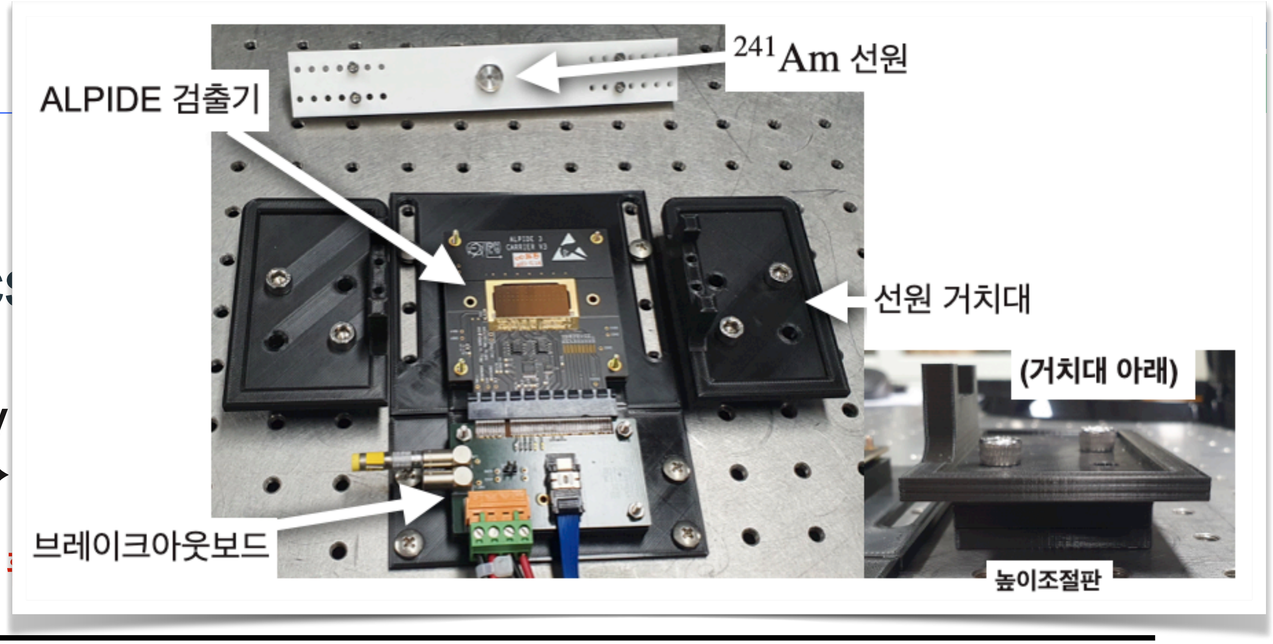

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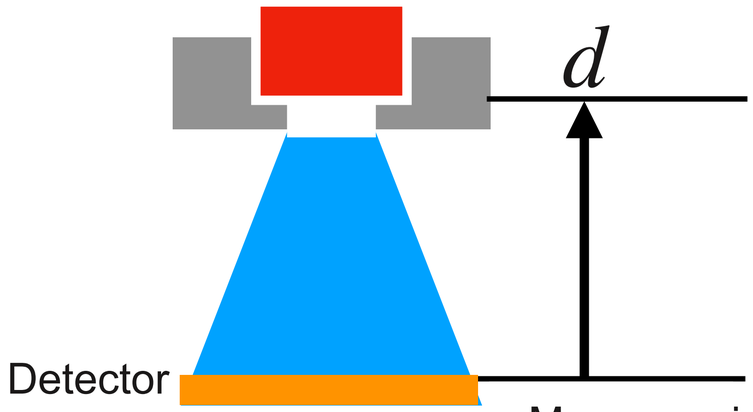

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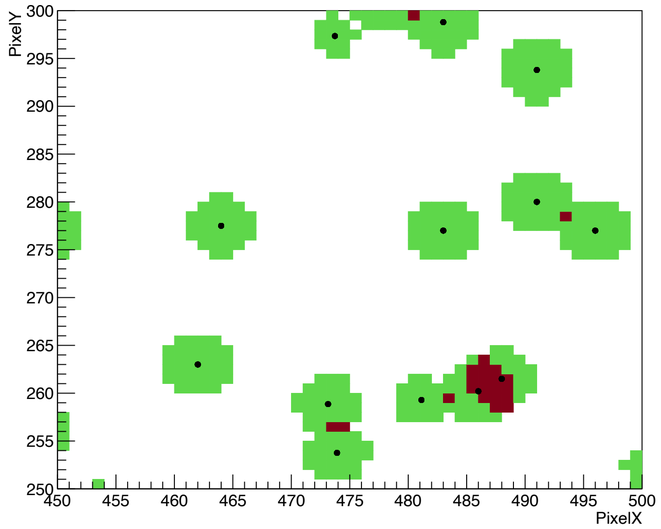

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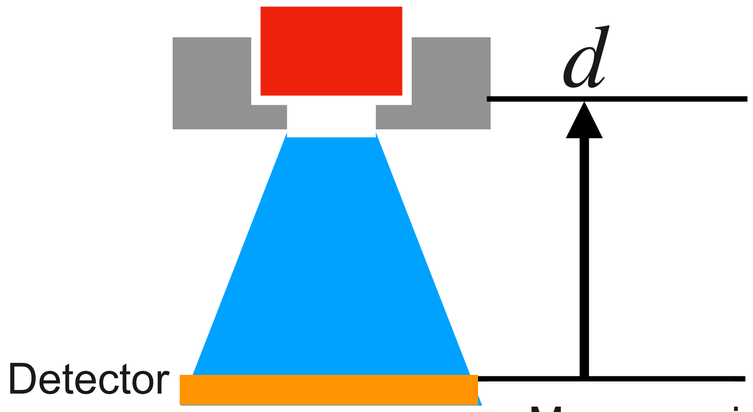

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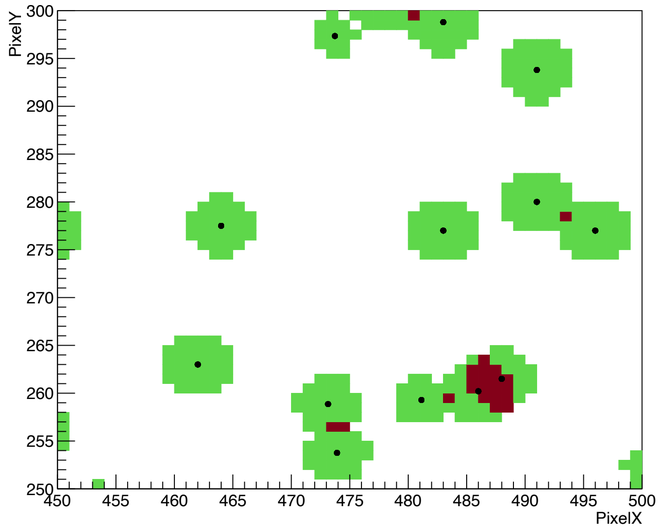

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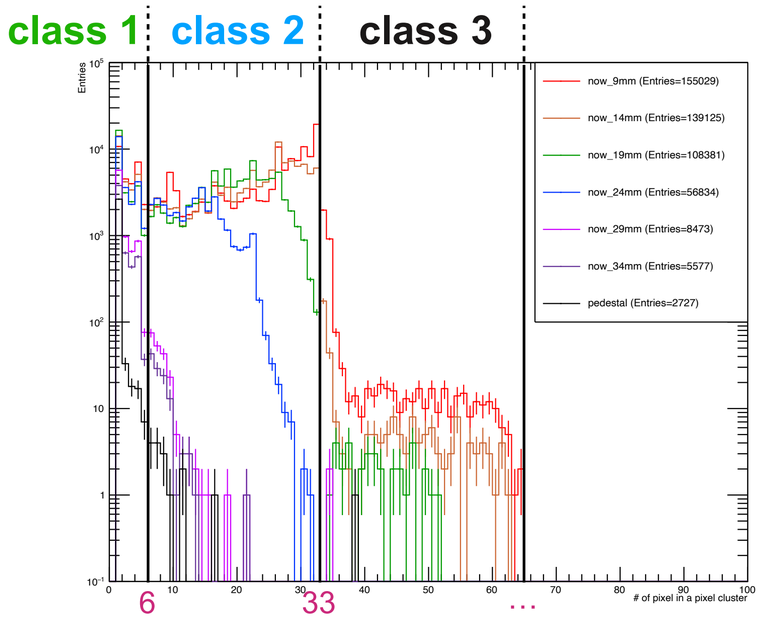
Result

class 1

class 2

class 3



Histogram of # of Pixels in a cluster

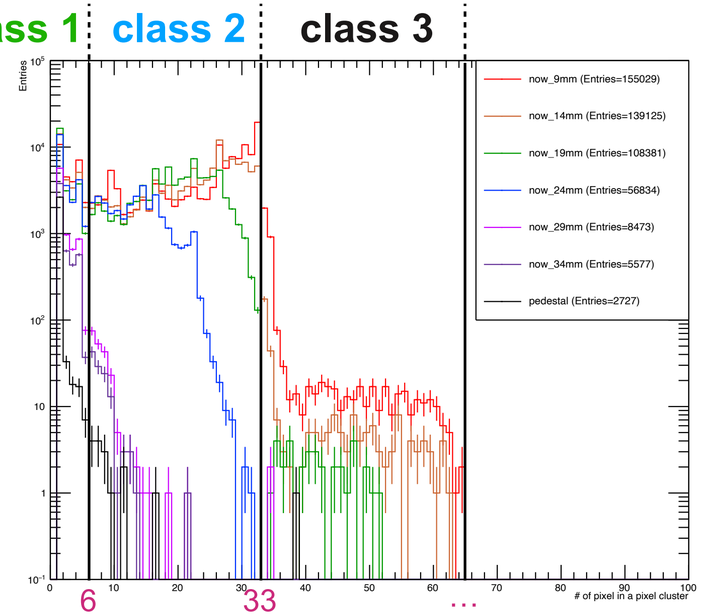
(Each color: different distance d)

1) Minjae Kwon. (2021). Isaac-Kwon/qupid

Result

class 1

class 2



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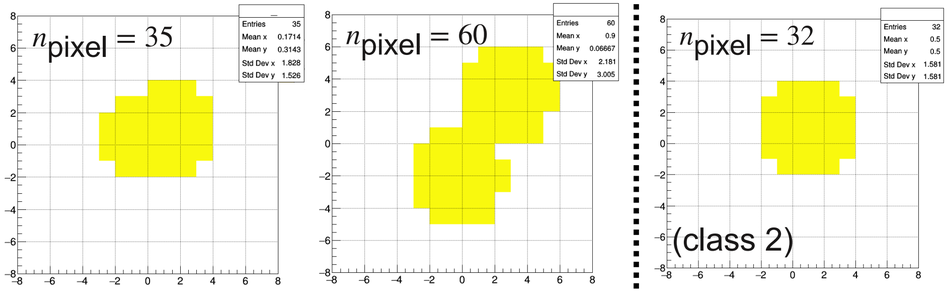


Unsymmetrical Clusters

→ 2 or more cluster generated nearby.

1) Minjae Kwon. (2021). Isaac-Kwon/qupid

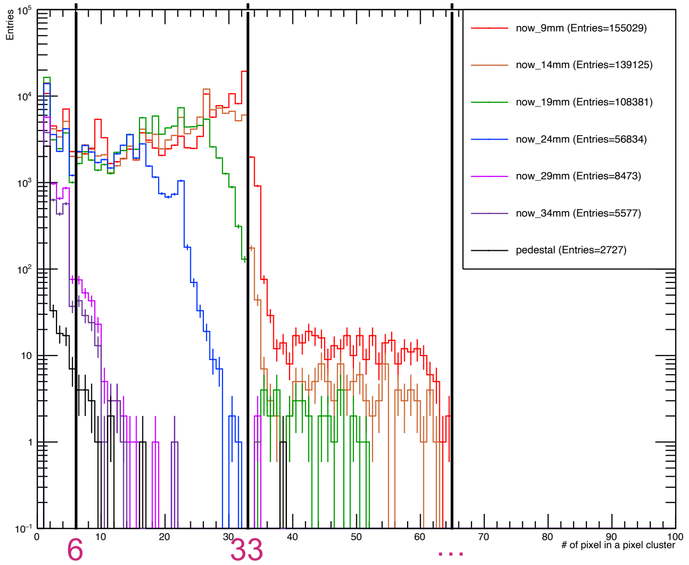
Result

class 1

No shape different but entries
→ No effect on char. of signals

class 2

class 1 | class 2 | class 3



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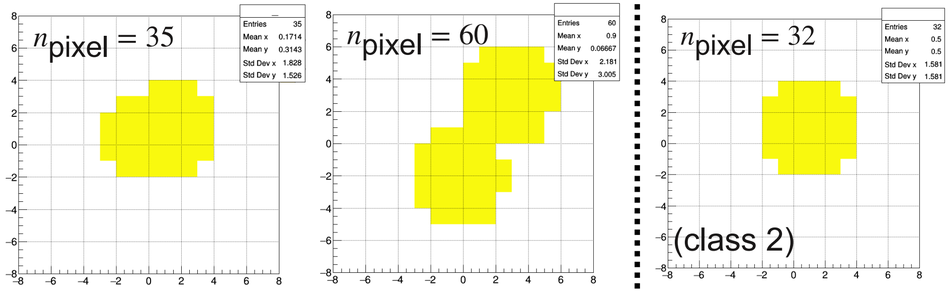

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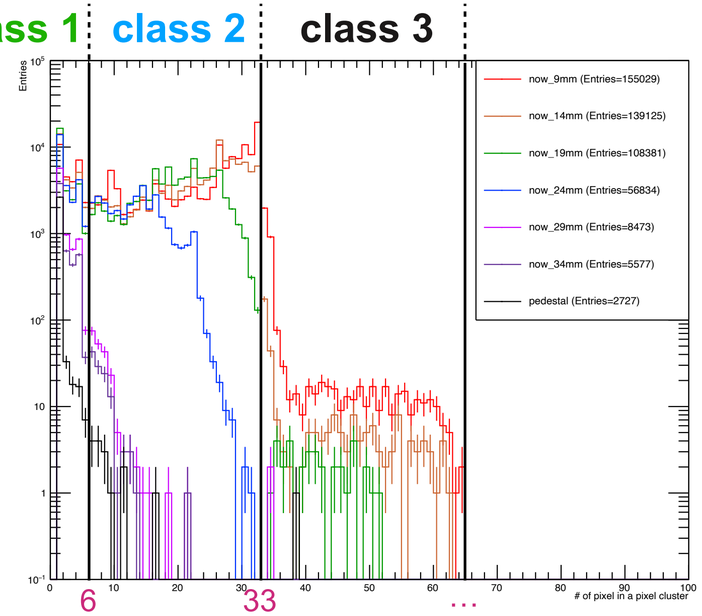

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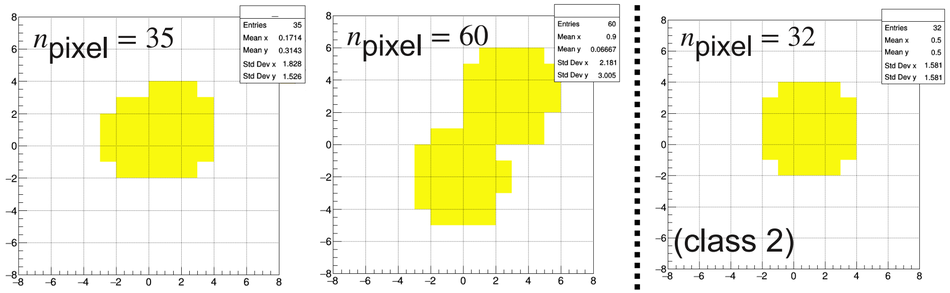

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(γ: almost no material interaction)

$$^{241}_{95}\mathrm{Am} \xrightarrow{432.2\ \mathrm{y}} {}^{237}_{93}\mathrm{Np} + {}^{4}_{2}\alpha^{2+} + \gamma$$

class 2

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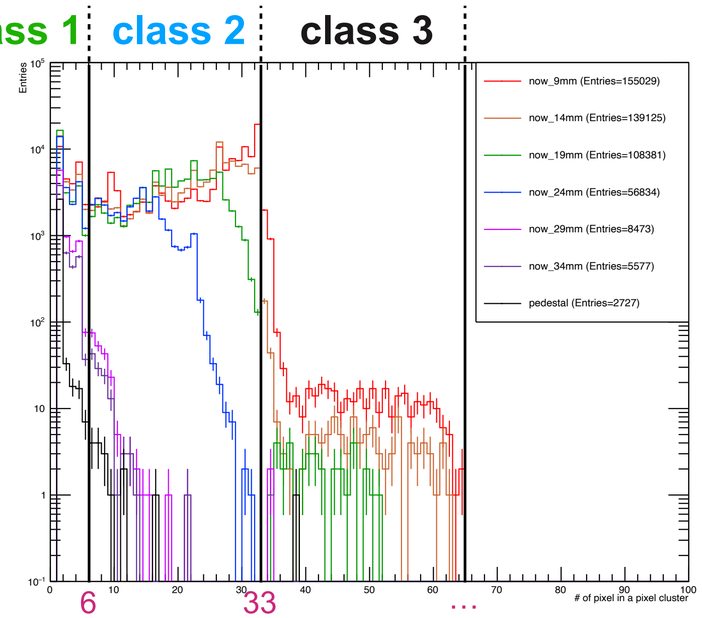
→ Effect on char. of signals exists

(α: Lots of material interaction)



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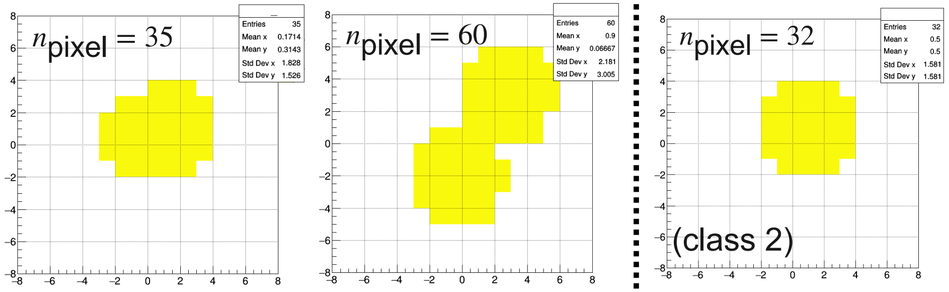

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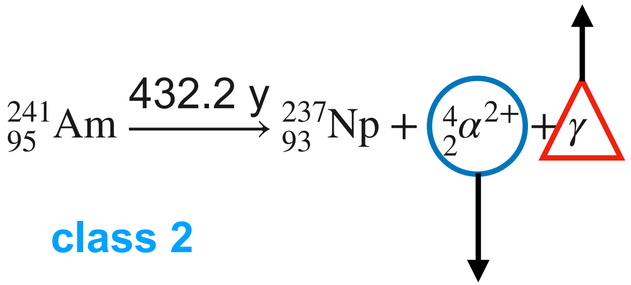

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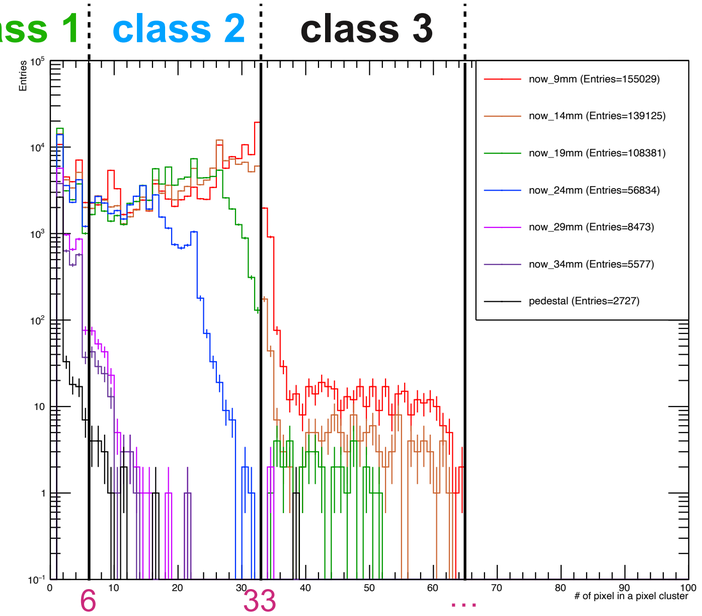
(α: Lots of material interaction)

α and γ can be identified with size of cluster!



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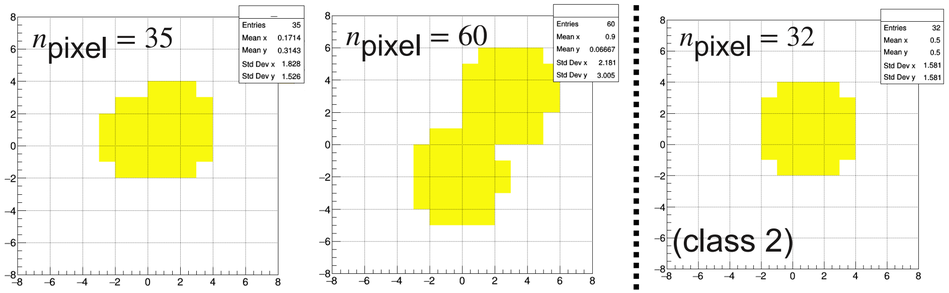

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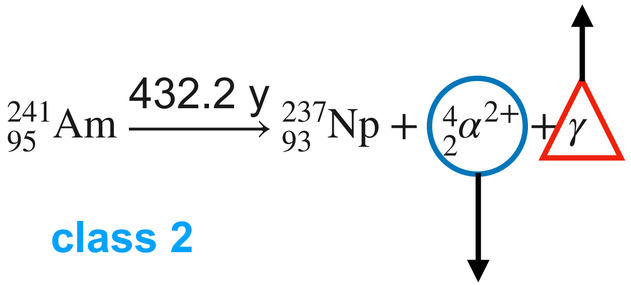

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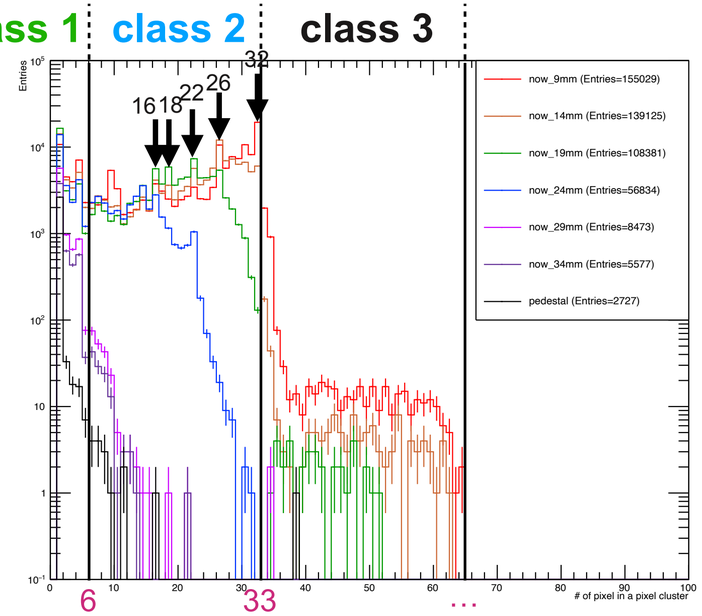

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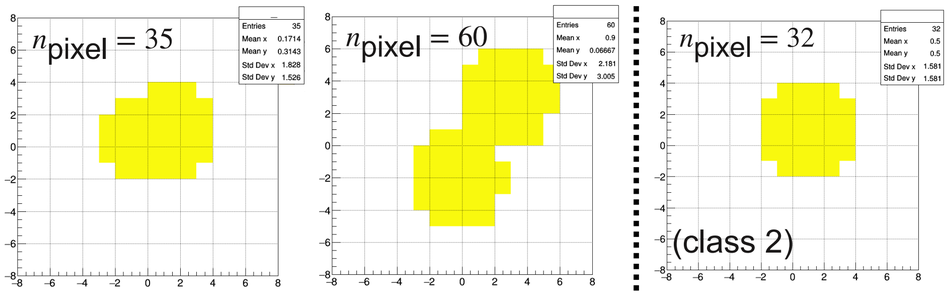

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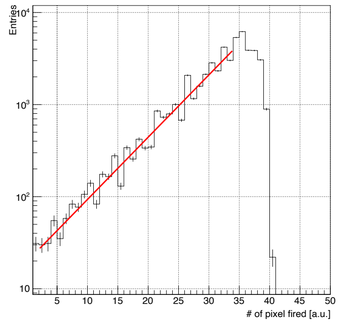
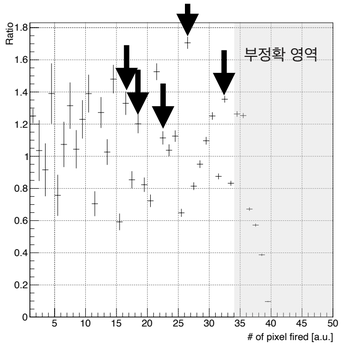
Shape

Toy model simulation[1)]



Data / simulation ratio



Signal on pixel geometry is simulated.
It can explain local maxima.

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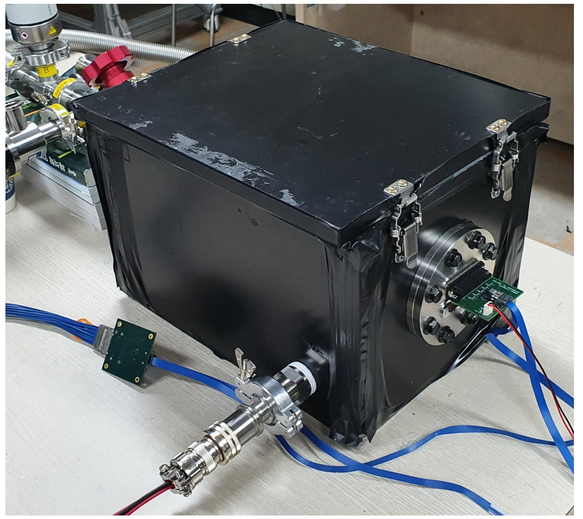
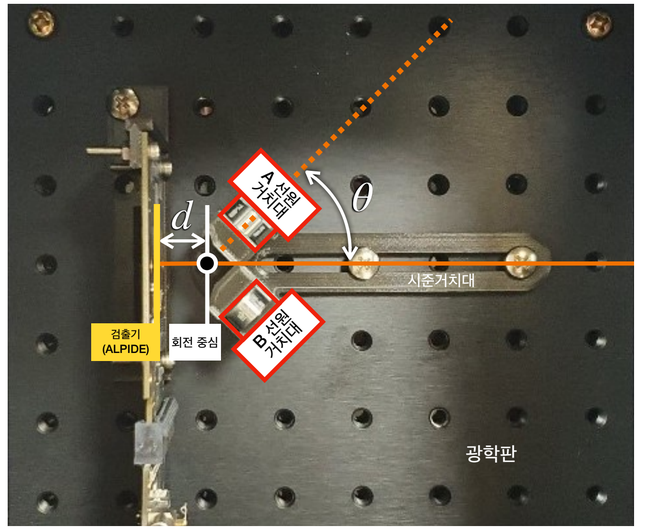
Measurement of reciprocal scattering with 2 of $^{241}\mathrm{Am}$ sources.

Constructing Experiment

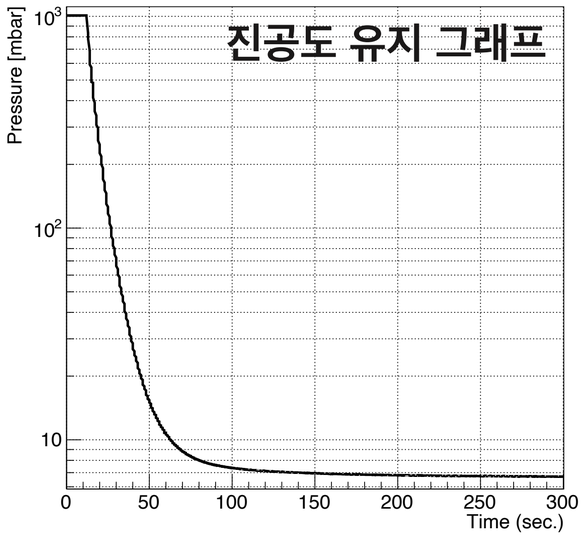
- Vacuum chambre
  - To prevent interaction with air for α
  - 1013mbar → 7mbar in 5 min.
  - Includes data, power Feedthoughes.
- Collimating Stand
  - 2 Sources can be attached with 45 deg of interfering angle
  - Each parts of stand are named as "A", "B"
  - Can be rotated on the interaction center
  - d : Distance from interaction center to detector
- Experiment Monitoring System
  - Remote control and monitoring
  - Operating on TMUX

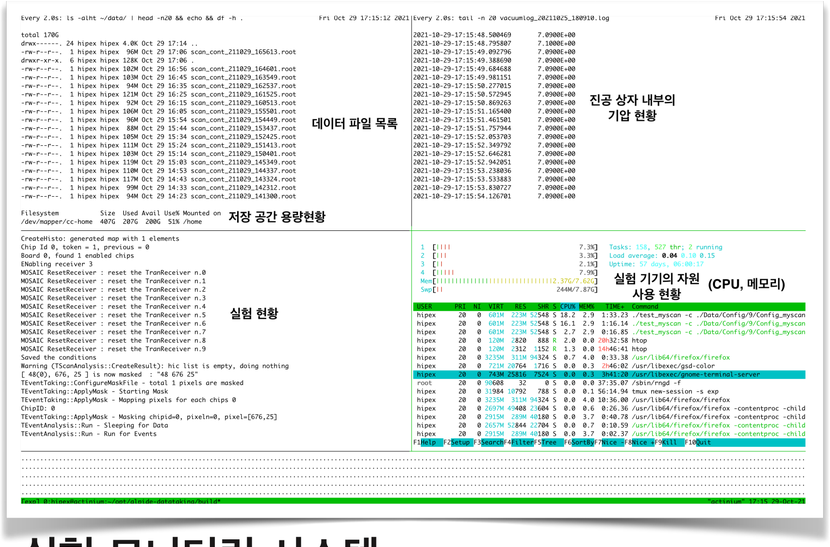


진공 상자



실험 구조





실험 모니터링 시스템

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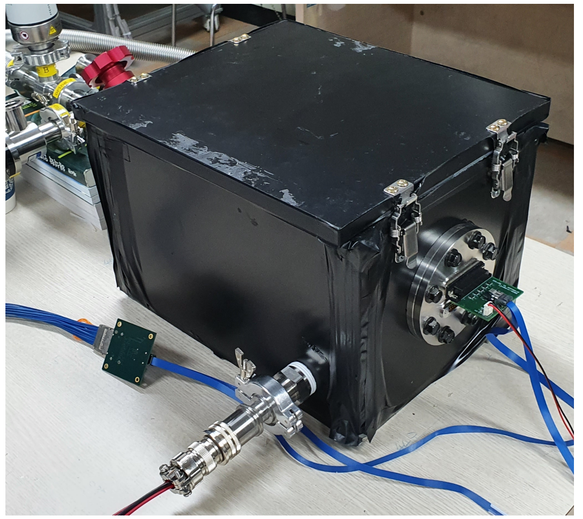

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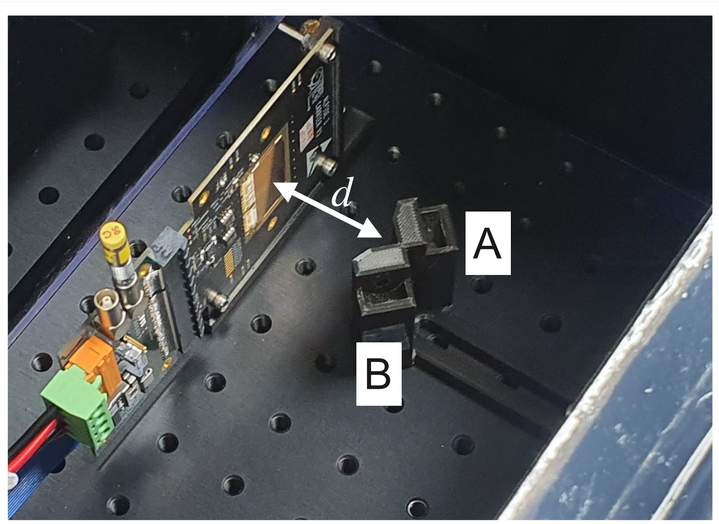
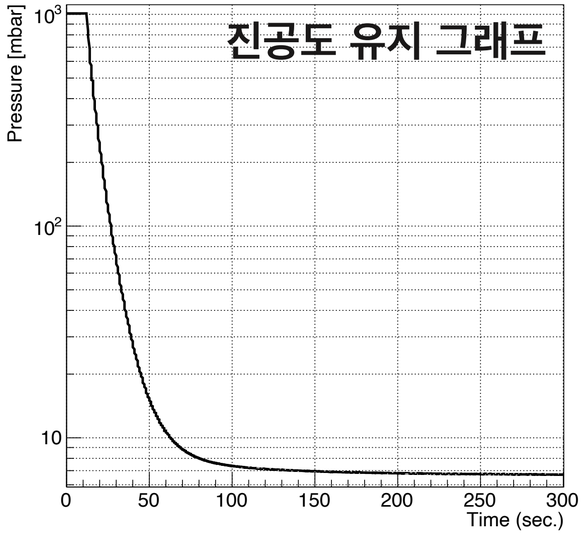
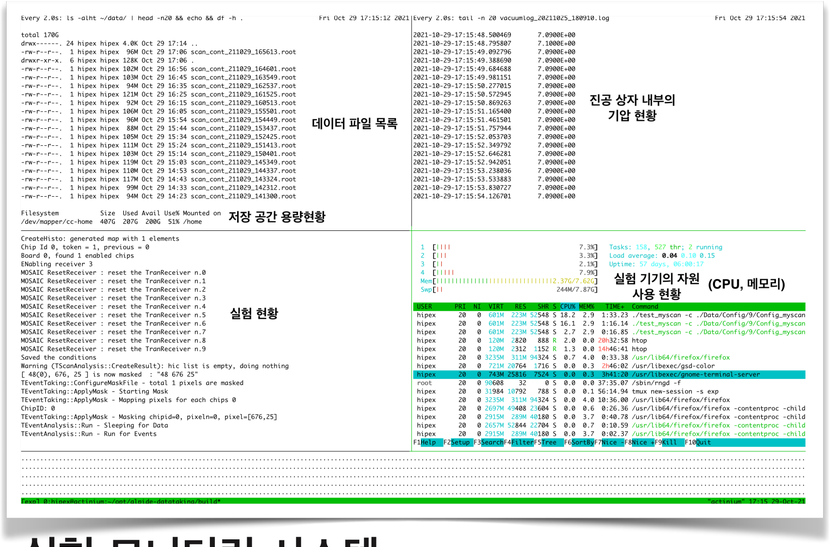


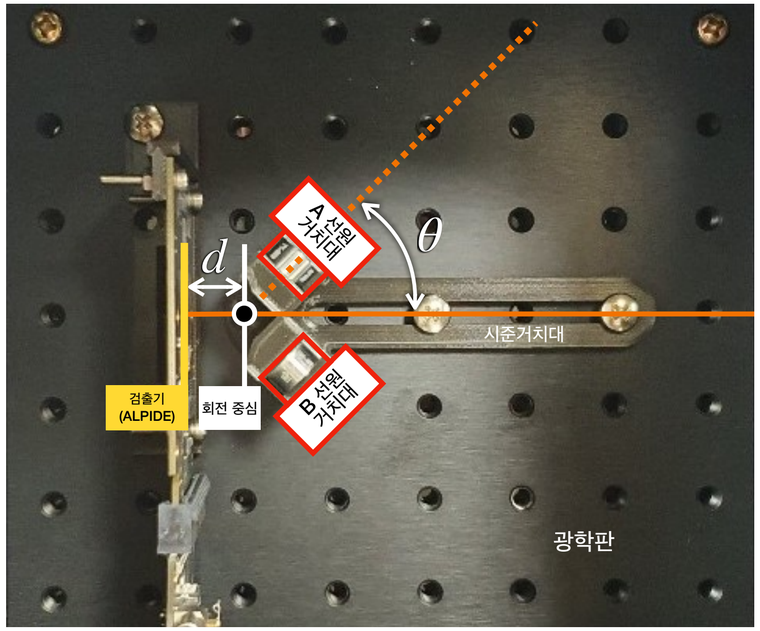
실험 구조



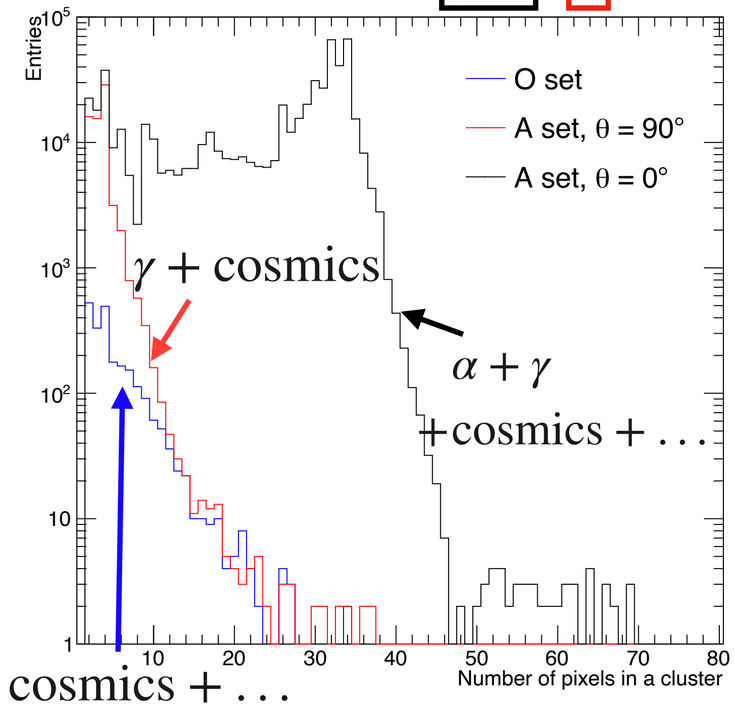


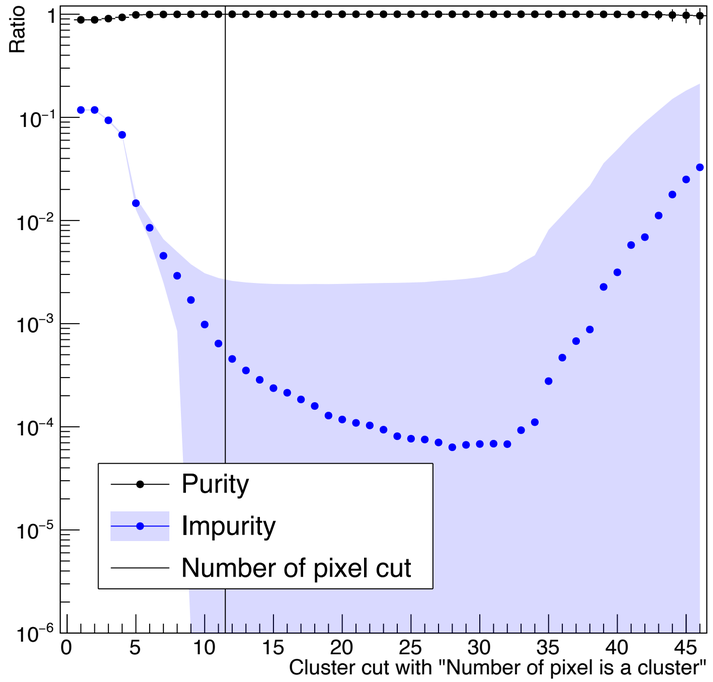
실험 모니터링 시스템

Pre-exp.) Noise ID



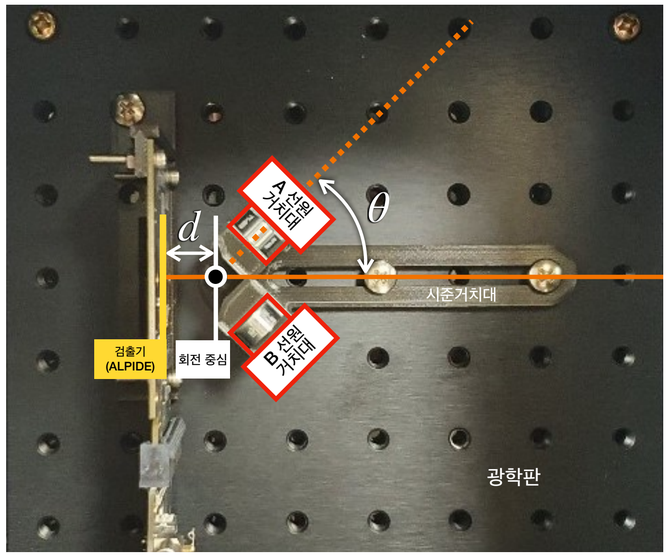
$$^{241}_{95}\mathrm{Am} \rightarrow {}^{237}_{93}\mathrm{Np} + {}^{4}_{2}\alpha^{2+} + \gamma$$





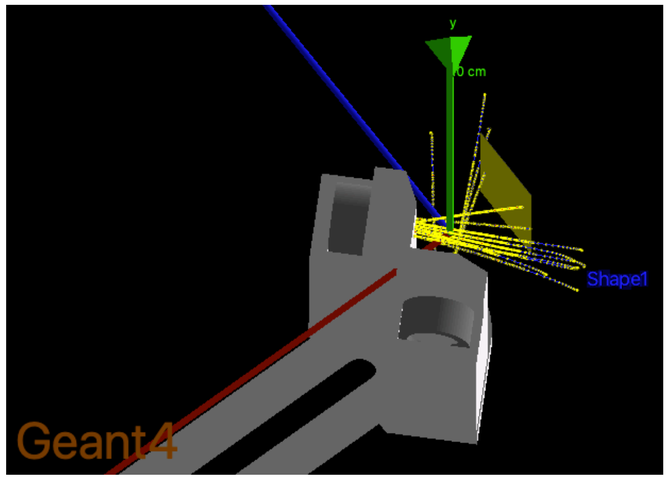
- Noise rather than α : γ, Cosmics
- $n_{\mathrm{pixel}} > 9$: Purity's uncertainty includes **0**
- Set the n-pixel cut to take α: $n_{\mathrm{pixel}} > 11$

Main exp.) Is there different on distance d about recip. scattering?



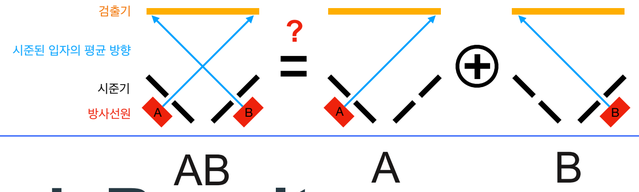
Real World

- $d = 7\text{mm}, 12.4\text{mm}, 17.0\text{mm}$
- Experiments are done with A, A and B, B source.
  - Never re-attach source!
- 1 Experiment = 6 hrs.



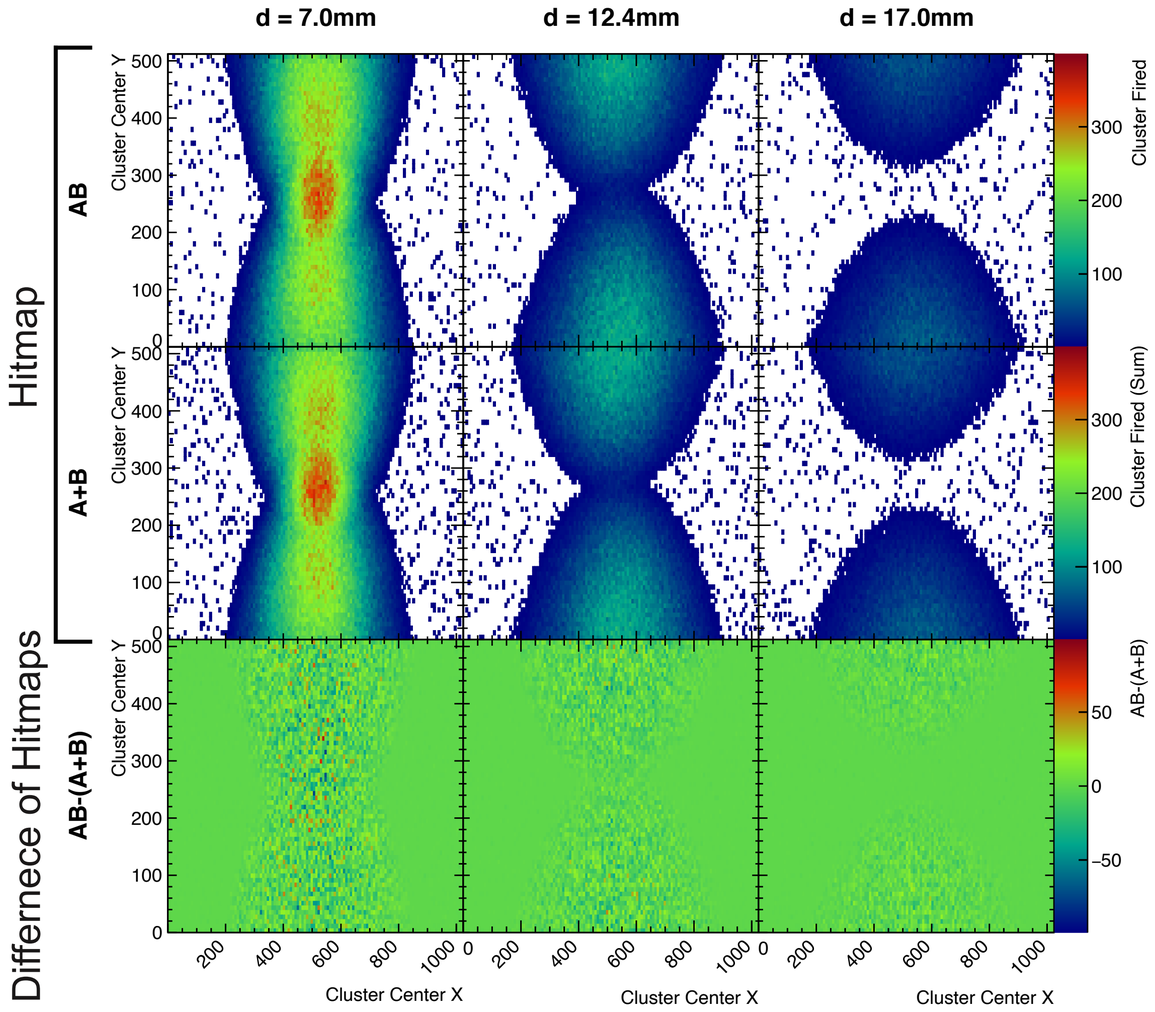
GEANT4 World

- **No interaction between α particles**
  - The interference can be watched by comparison.
- Same geometrical, source conditions
- Done with equivalent number of particles on time on real world

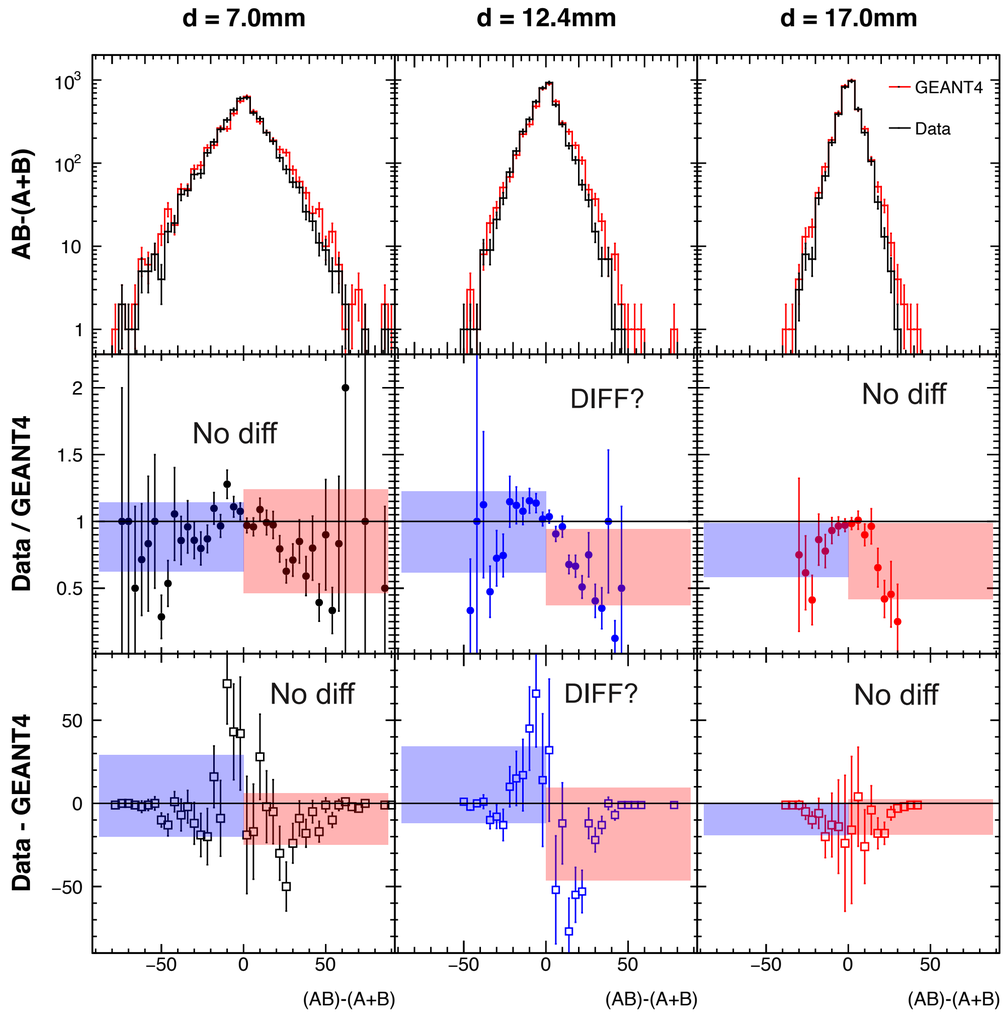


Analysis Method, Result

Red: Mean Value in Positive Range
Blue: Mean Value in Negative Range

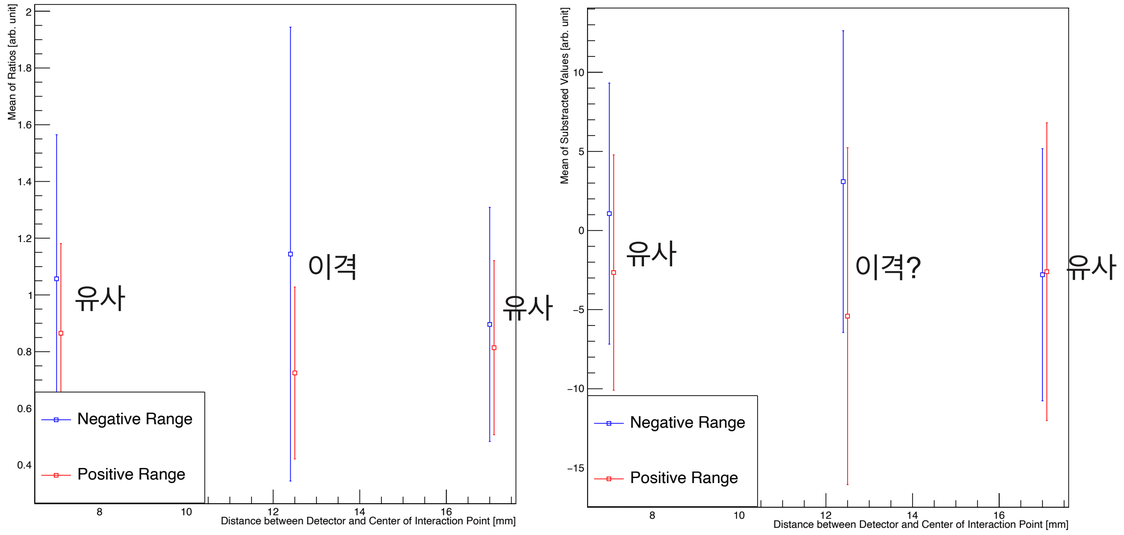


Difference of Entries in each bins



The part, AB is less than A+B and larger than A+B

Result / Possibility



수집된 클러스터의 갯수 일람

d(mm)	A	B	A+B	AB
7.0	310000 ± 600	285700 ± 500	595700 ± 800	591600 ± 800
12.4	107300 ± 300	118500 ± 300	225800 ± 500	220500 ± 500
17.0	34900 ± 200	45900 ± 200	80800 ± 300	81300 ± 300

d(mm)	AB-(A+B)	(AB-(A+B))/AB
7.0	-4200 ± 1100	-0.0070 ± 0.0018
12.4	-5400 ± 700	-0.024 ± 0.003
17.0	500 ± 400	0.006 ± 0.005

- **If, # of AB's incident particle is less than A or B(With any other reasons)?**
  - **Same effect!**
- Analysis about systematic uncertainty?

Summary & Outlook

- PID for low energy α particle **with SPD(ALPIDE)** is done
- The first reciprocal scattering using 2 of $^{241}\mathrm{Am}$ is done
- The result is compared with GEANT4 which doesn't have reciprocal effect.

- The experiment is done in distance $d = 7\mathrm{mm}, 12.4\mathrm{mm}, 17.0\mathrm{mm}$
  - In case of $d = 12.4\mathrm{mm}$, the result is different with other d.
  - It can be from lack of incident of particles because of other reasons.
  - Analysis about systematic uncertainty is needed.

Reference

1. K. Bugaev and O. Vitiuk, “Triple nuclear collisions – a new method to explore the matter properties under new extreme conditions”, Online Strangeness in Quark Matter Conference 2021. New York, NY, May, 2021. https://indico.cern.ch/event/985652/contributions/4302192/.
2. USQCD, https://www.usqcd.org/extreme.html
3. M. Berger, J. Coursey, M. Zucker, and J. Chang, “Estar, pstar, and astar: Computer programs for calculating stopping-power and range tables for electrons, protons, and helium ions (version 1.2.3). [online]”,. http://physics.nist.gov/Star. Last Updated at July 2017, Accessed at 20 October 2021. Originally published as: Berger, M.J., NISTIR 4999, National Institute of Standards and Technology, Gaithersburg, MD (1993).
4. M. Kwon, “Isaac-kwon/qupid”, Sept., 2021. https://doi.org/10.5281/zenodo.5519749.
5. S. Agostinelli, J. Allison, K. Amako, J. Apostolakis, H. Araujo and et al. “Geant4—a simulation toolkit”, Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment 506 no. 3, (2003) 250–303. https://www.sciencedirect.com/science/article/pii/S0168900203013688.
6. C. M. Poole, I. Cornelius, J. V. Trapp, and C. M. Langton, “A cad interface for geant4”, Australasian Physical & Engineering Sciences in Medicine 35 no. 3, (2012) 329–334. https://doi.org/10.1007/s13246-012-0159-8.

Thank You!

Ultra Short Summary of Years

2020

- Development frameworks for data-taking and analysis are done.
  - Source measurement with $^{241}\mathrm{Am}$ on ALPIDE.
- Concept for elastic low-energy scattering is designed.

2021

- Robust PID of α and γ particle from $^{241}\mathrm{Am}$
- Measure reciprocal scattering with 2 of $^{241}\mathrm{Am}$ sources.
- On-call shift for ITS2 on ALICE-Commissioning 2021

Qupid model

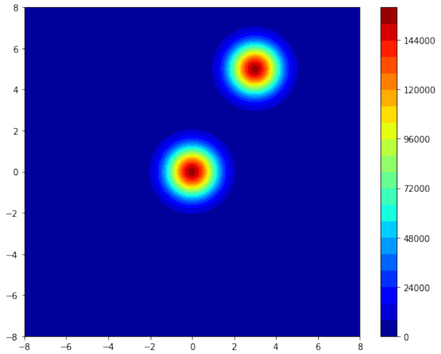
Quasi-Signal Generation Model for ***Pi***xelized ***D***etector

Objective
Fired pixel cluster shape generation to use for machine learning

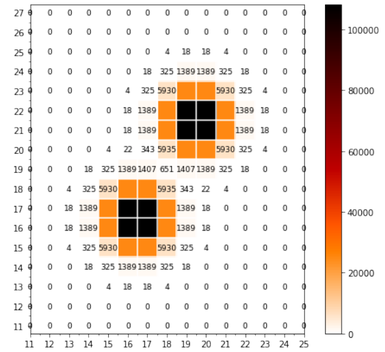
- Based on Python3 (numpy, scipy)
- Procedure
  - Define signal amplitude distribution function (ADF) on detector plane
  - Calculate signal in pixel with integrating ADF with for each pixel.
  - Find pixel which has signal over threshold.

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

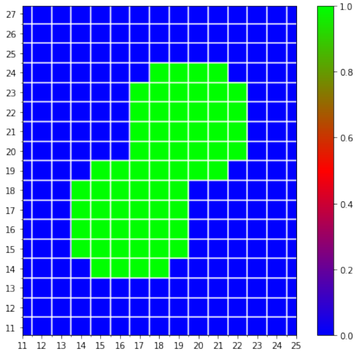
Now Generation is on-going…



Analogue Signal Distribution



Digital Signal Distribution (Integrated Signal)



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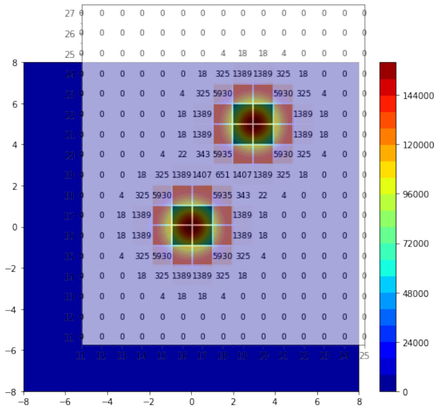

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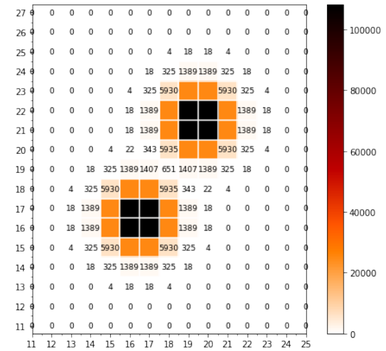

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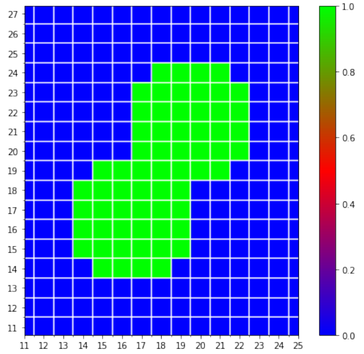

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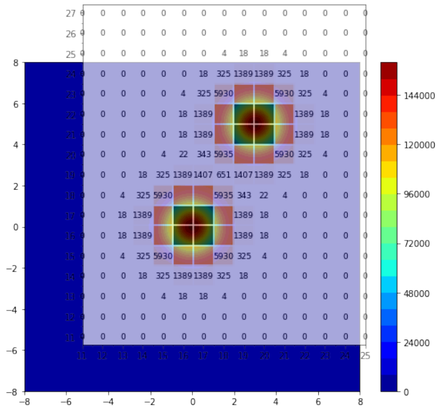

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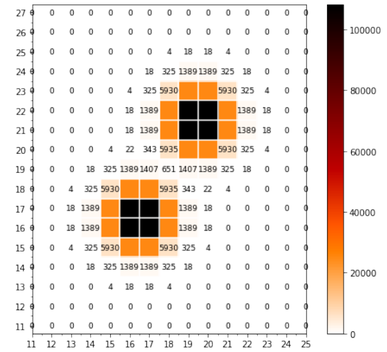

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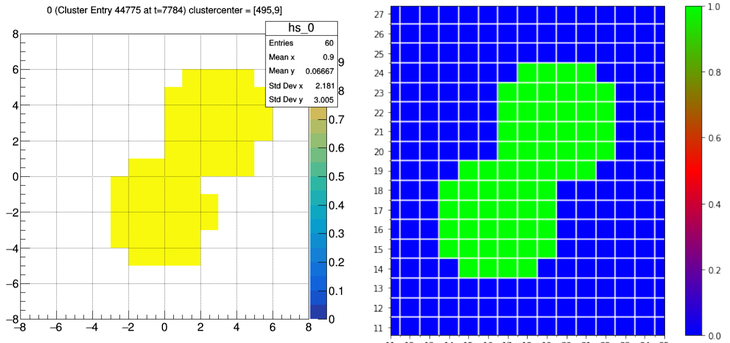
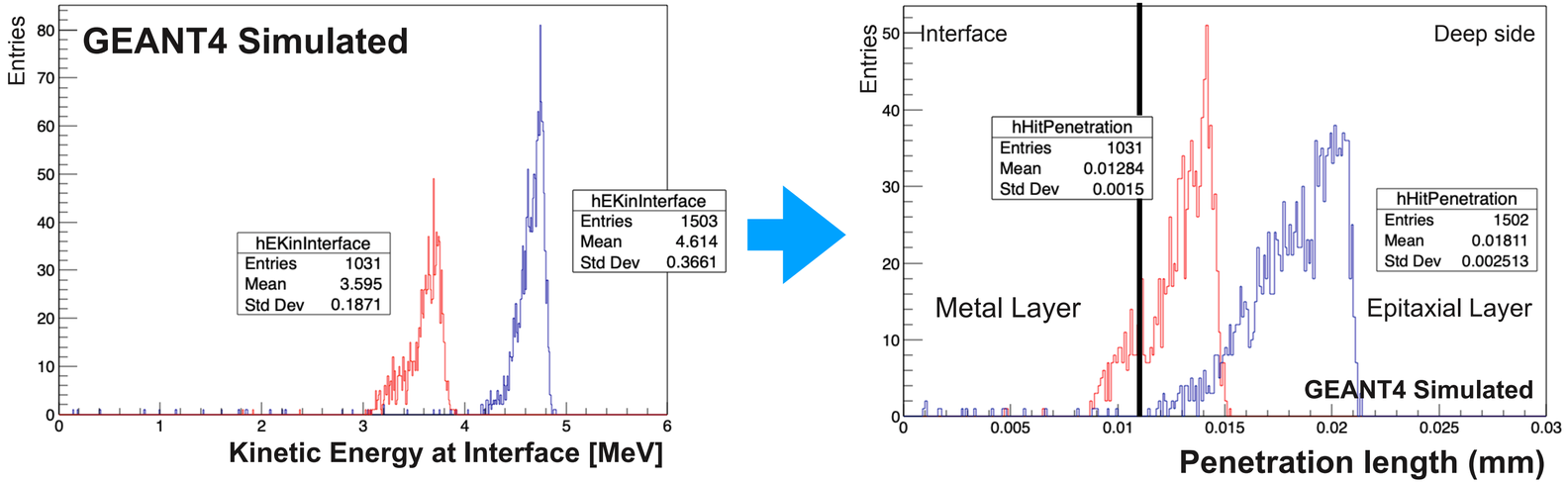


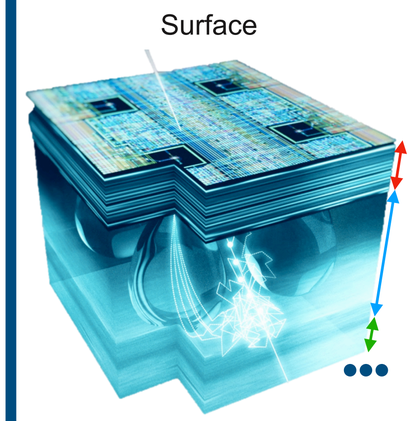
Fired Pixel Distribution

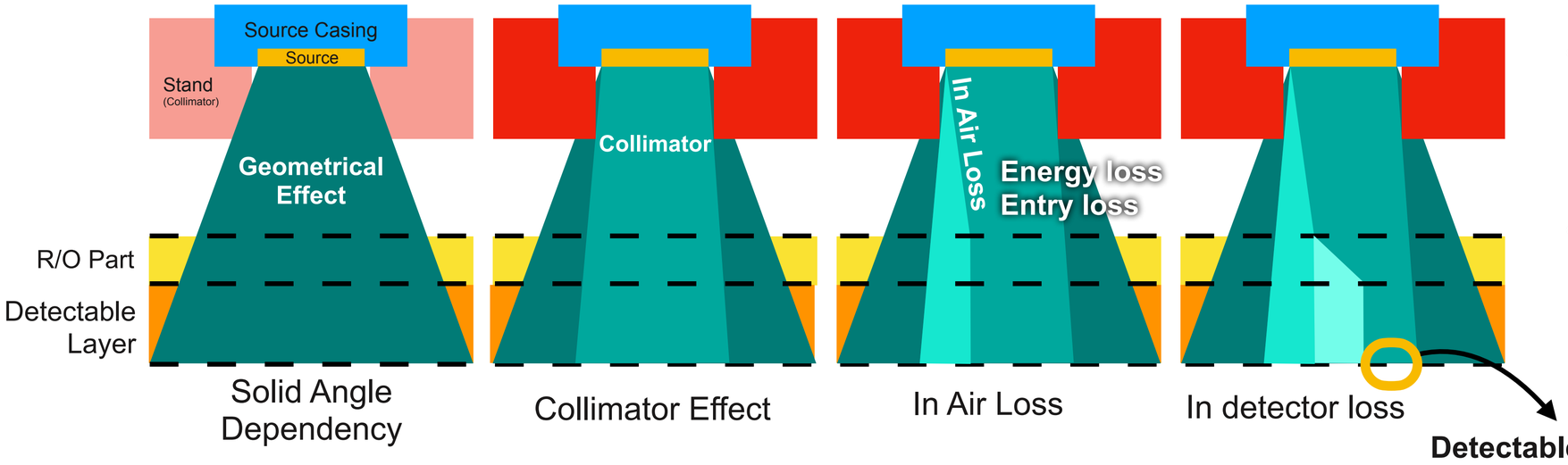
One of cluster in real data

On chip penetration length dependency



ALPIDE's depth information

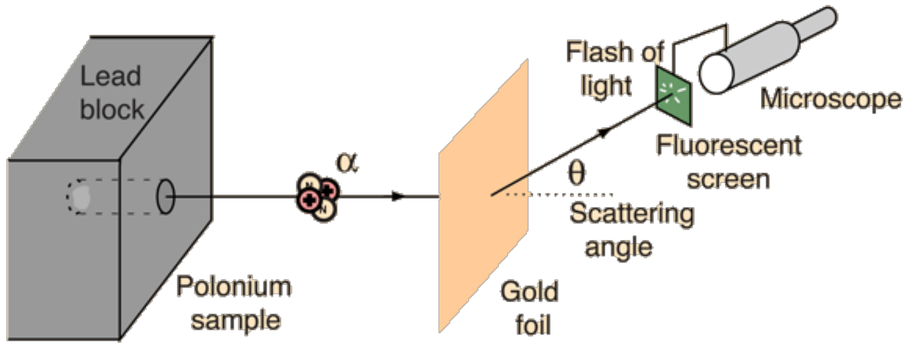




- ALPIDE can detect α particle with energy dependent efficiency.
  - Because of R/O part layer.
- In real experiment data, anonymous loss part existed.
  (simple calculation is in backup; 16p, 17p)

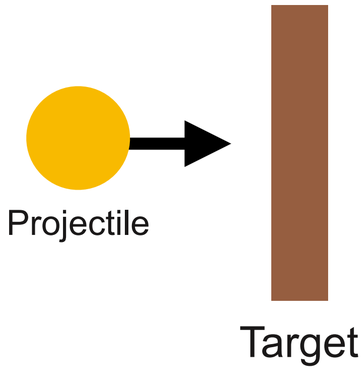
Elastic Scattering Experiment - more

Rutherford's experimental condition



Inspired from Rutherford Scattering …

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

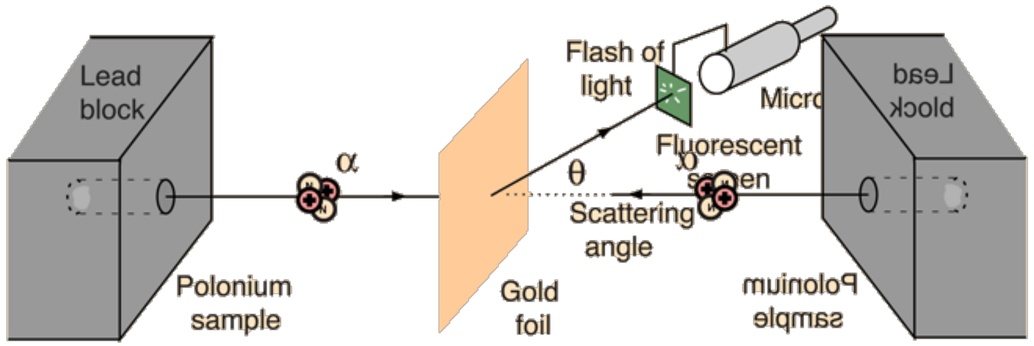


PNU's valid experimental condition

- 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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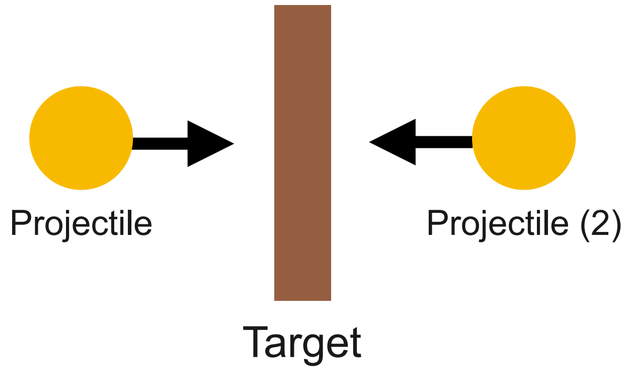

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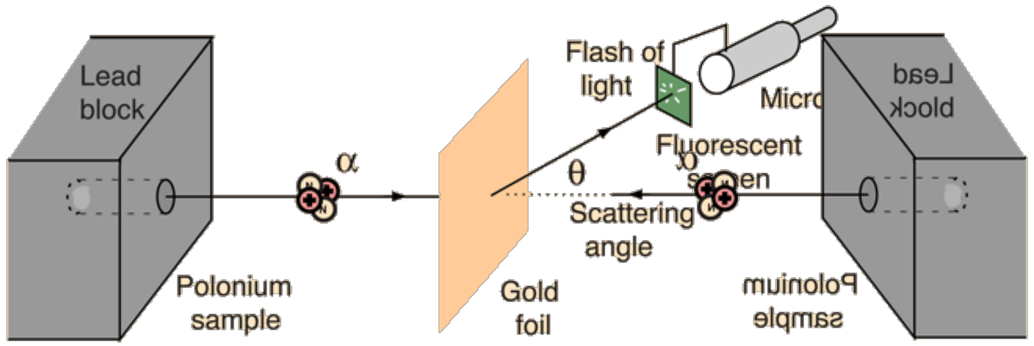

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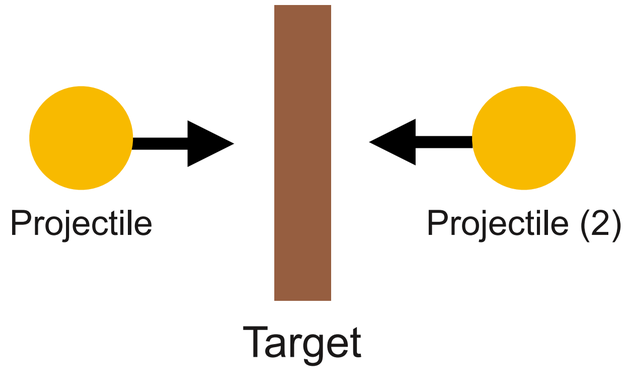

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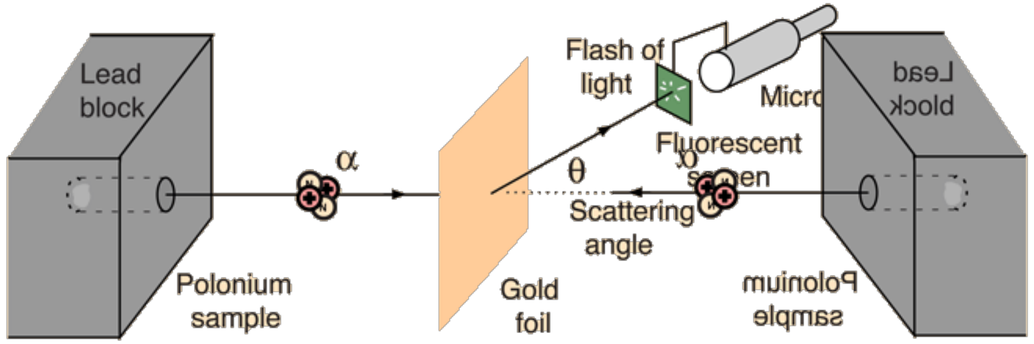

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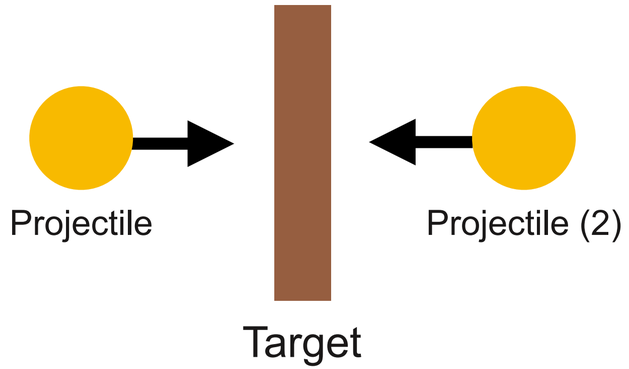

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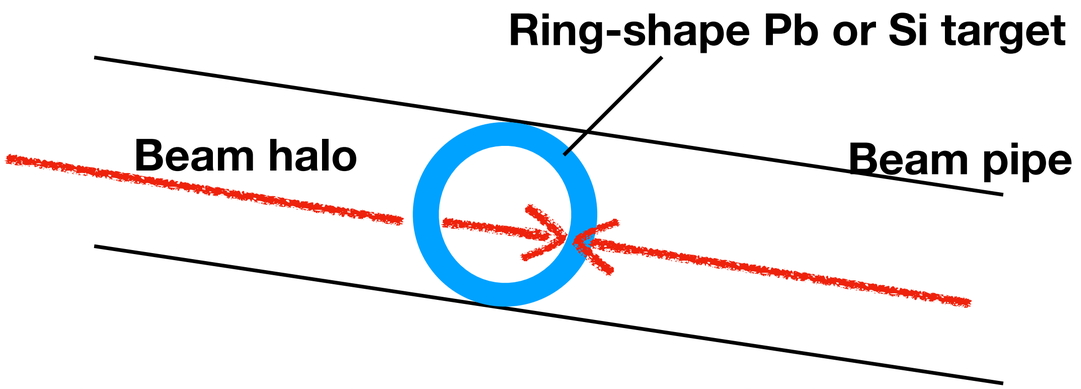
ALITE in RUN4

KoALICE2030

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



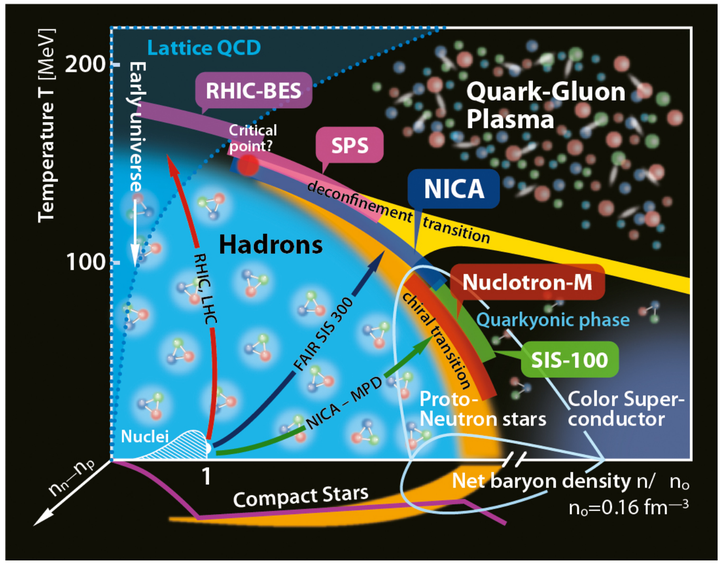
- ALI Target Experiment
  - A short period of Target (Test) Experiment (in RUN5-6 with ALICEs)
  - Higher Interaction rate at (little) lower $\sqrt{s_{NN}}$
  - Closer IP
  - Trillision (3 nuclei collision) event?
- Silicon R&D + Production for ALICEs in RUN5-6
  - ITS3 + 7 tracking barrel layers +
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

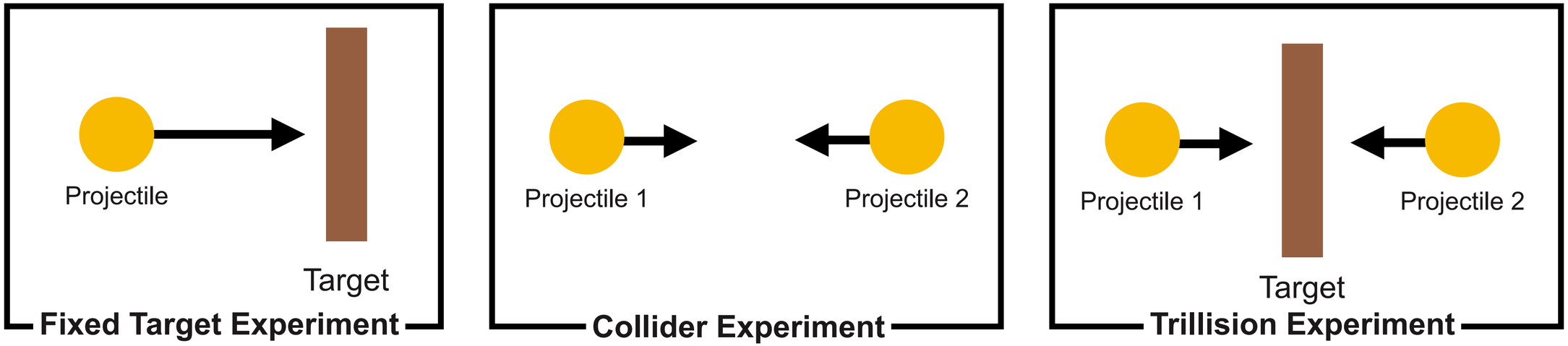
3 Particle Collision

- *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**xperiement

- Firstly, 3 particle elastic scattering experiment **is on-going.**

QCD Phase Diagram





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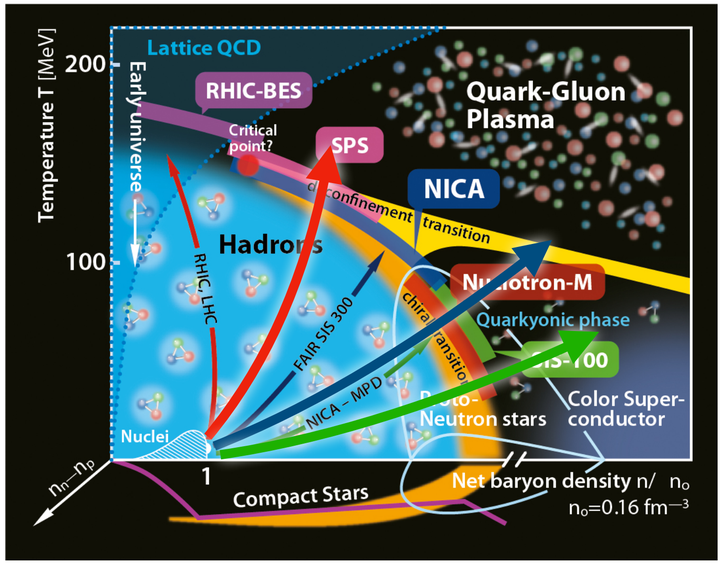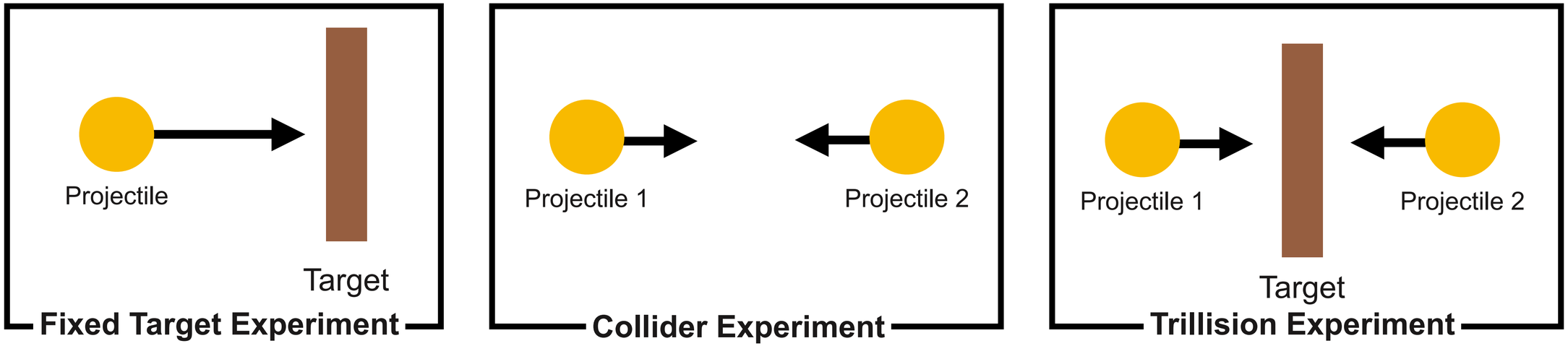
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