# Development of Muon Spin Imaging

***<u>Soshi Ishitani</u>***

*Department of Physics, the University of Osaka, Japan*

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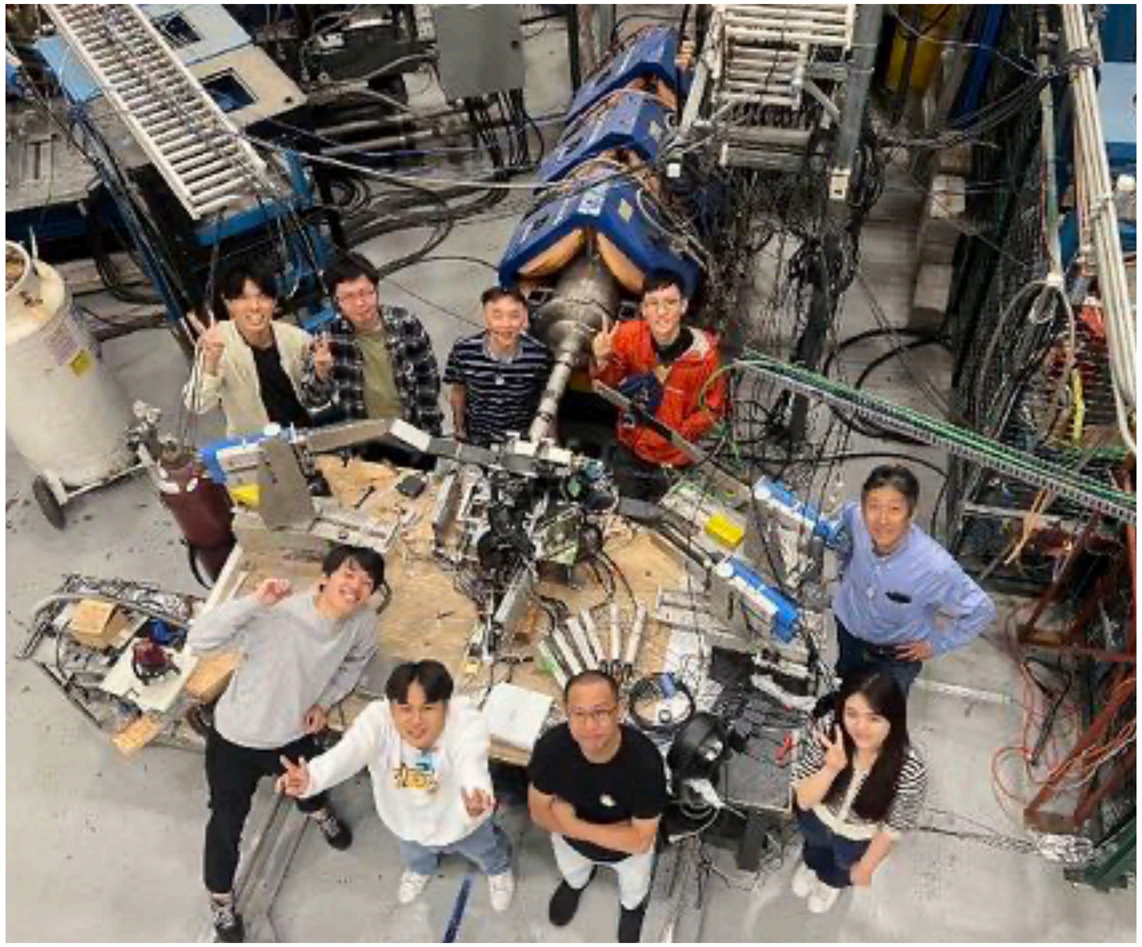
# Collaborator


**Collaborators** :

S. Ishitani[B,J], K. Kojima[A,I], M. Mihara[B,I], A. Sato[B], G. Takayama[B], K. Yasuda[B], T.Sugisaki[B], Y. Kimura[B,I], R.Taguchi[B], M. Fukutome[B], S. Shimizu[B], R. Imai[B], S. Ide[B], K. Shimizu[C], M. Kamon[C], M. Fukushima[C], Y. Mizoi[D], K.Horie[B], A. Koda[E], S. Kanda[E], W. Sato[E], D. Nishimura[G], M. Tanaka[F,I], R. Yasuda[H], M. Fukuda[B]


**Affiliation :**

[A]CMMS, TRIUMF, [B]Dept. Phys., Osaka U., [C]KYOKUGEN, Osaka U., [D]OECU, [E]KEK, [F]Kanazawa U., [G]Kyushu U., [H]Tokyo City Univ., [I]Tokyo Noko Univ., [J]Open-it



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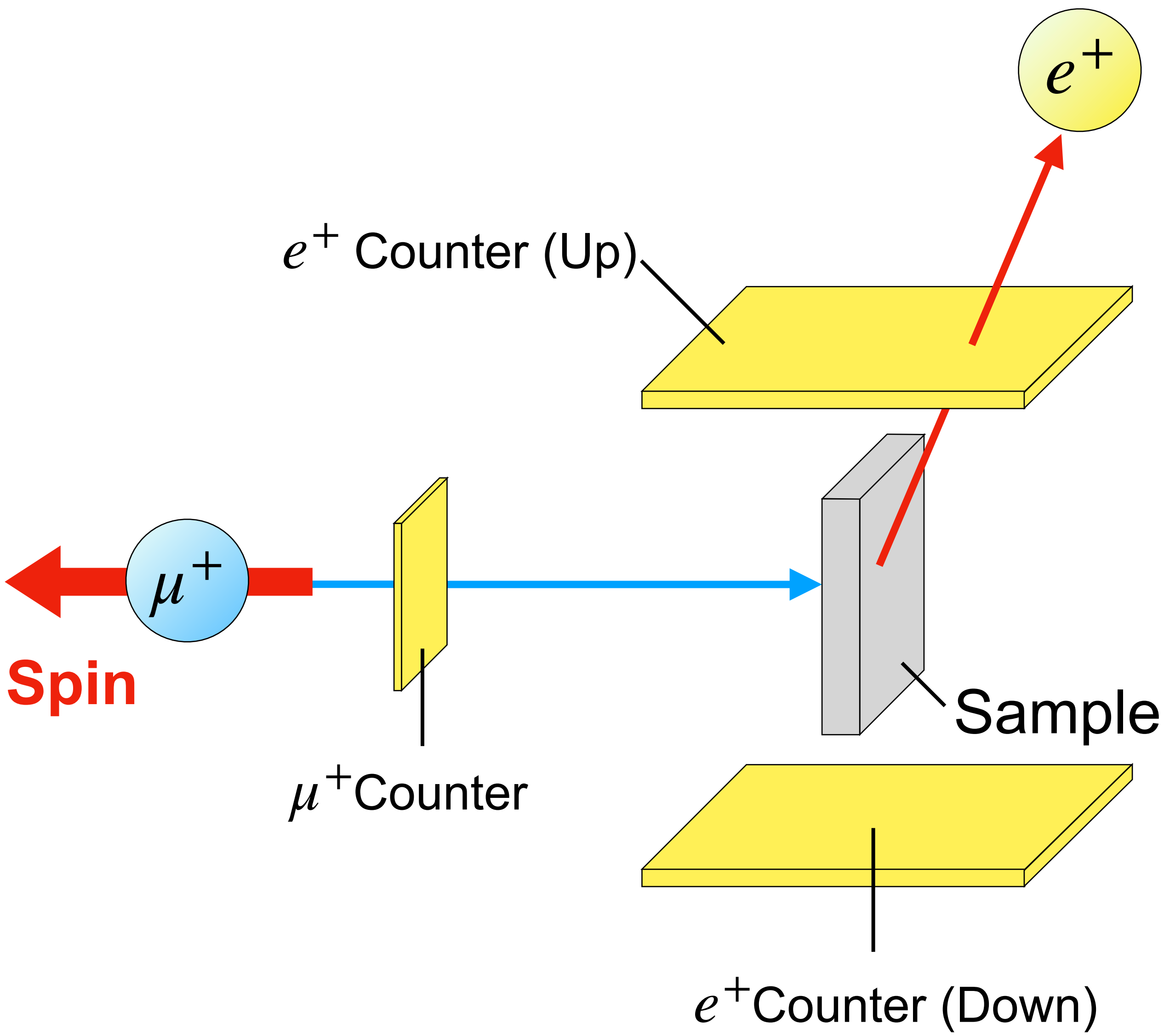
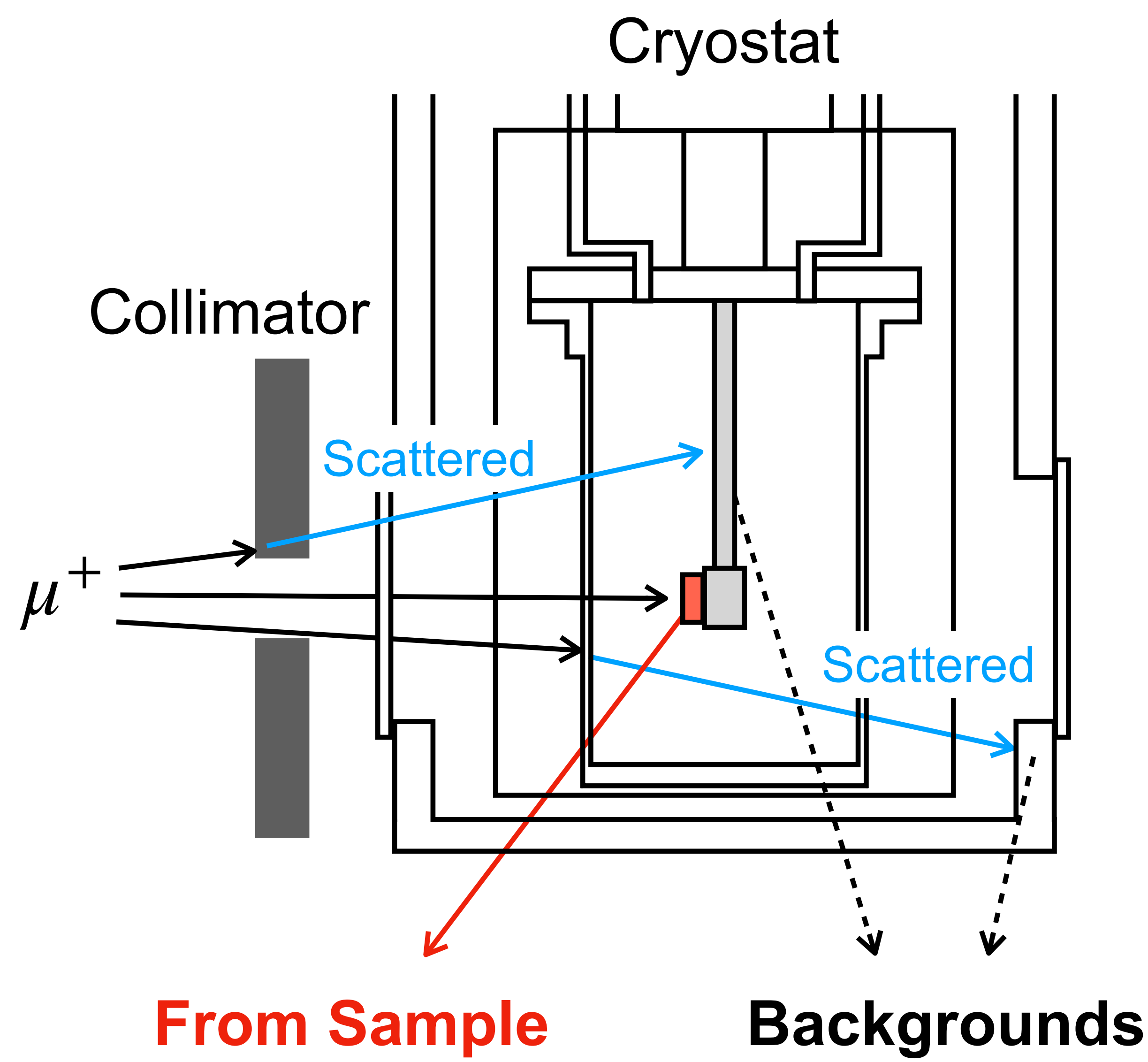
# Contents

# Challenges of Conventional μSR

- **Conventional DC μSR**




- **μSR for Small Sample**

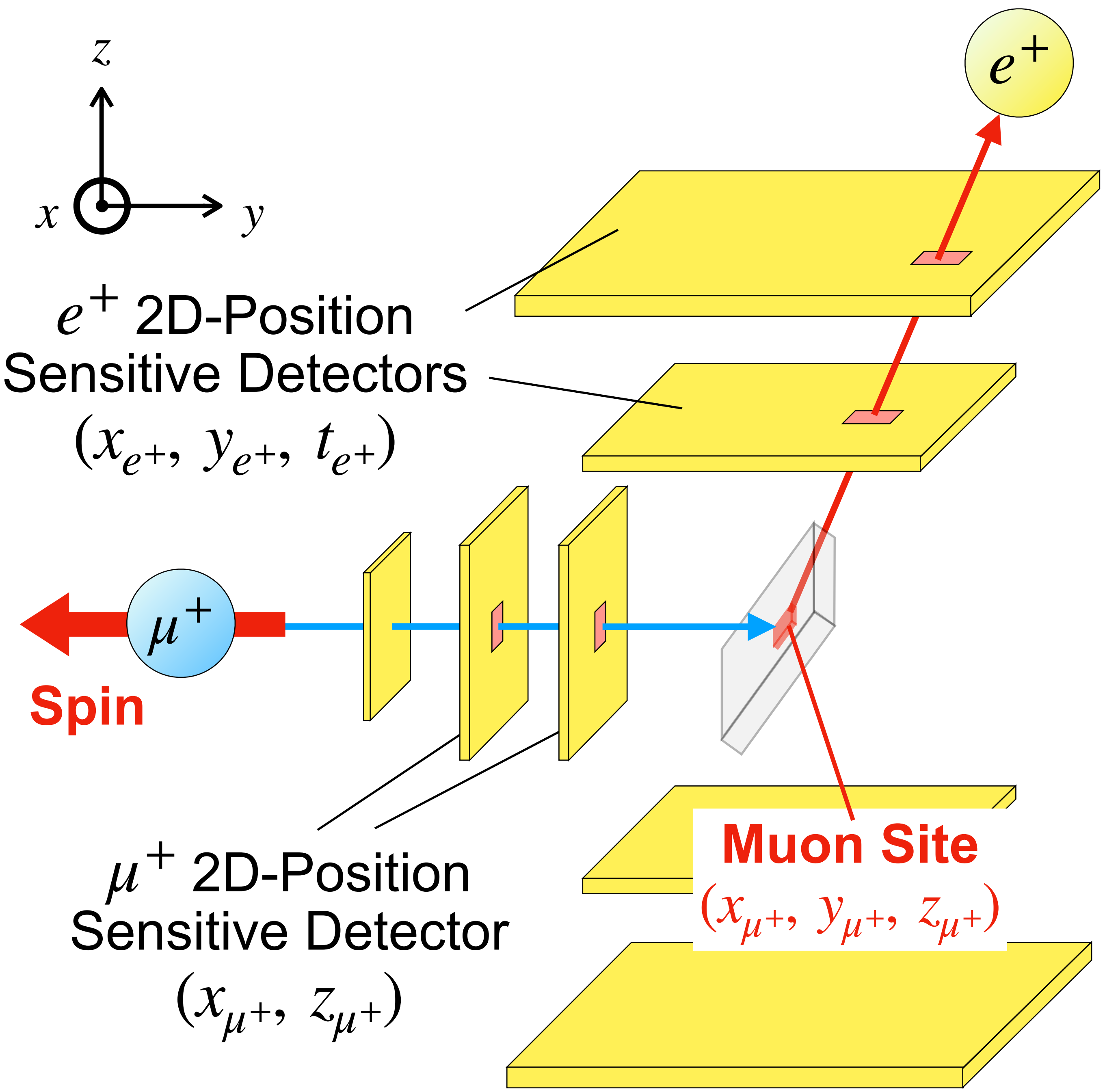



Beam Size >> Sample Size → Many Backgrounds

→ **Difficult for small sample** (size $< 4 \times 4\ \mathrm{mm}^2$ )

# *Muon Spin Imaging*

## • Position Sensitive μSR



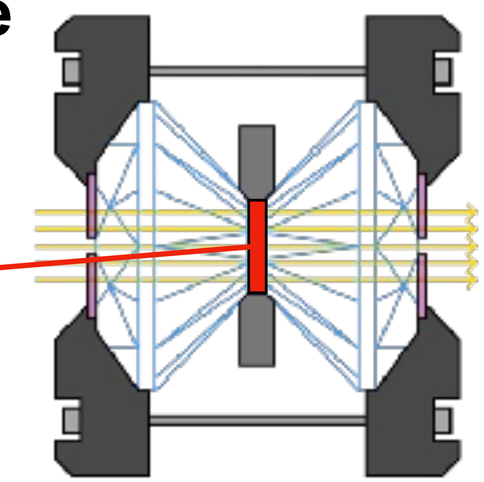

## • What will be realized?

### μSR for small sample

e.g.) High Pressure μSR

Pressure : 100–200 GPa
Sample Size : 100–250 μm

**Background Removal**



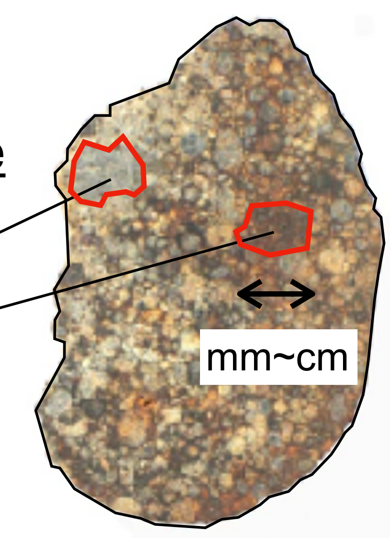
Diamond Anvil Cell

### μSR 3D imaging

e.g.) Mixture with microstructure

Chondrule
- Non-magnetic
- Magnetic

**Component Analysis**




Chondrite Meteoride

# Contents

# Experiment Status

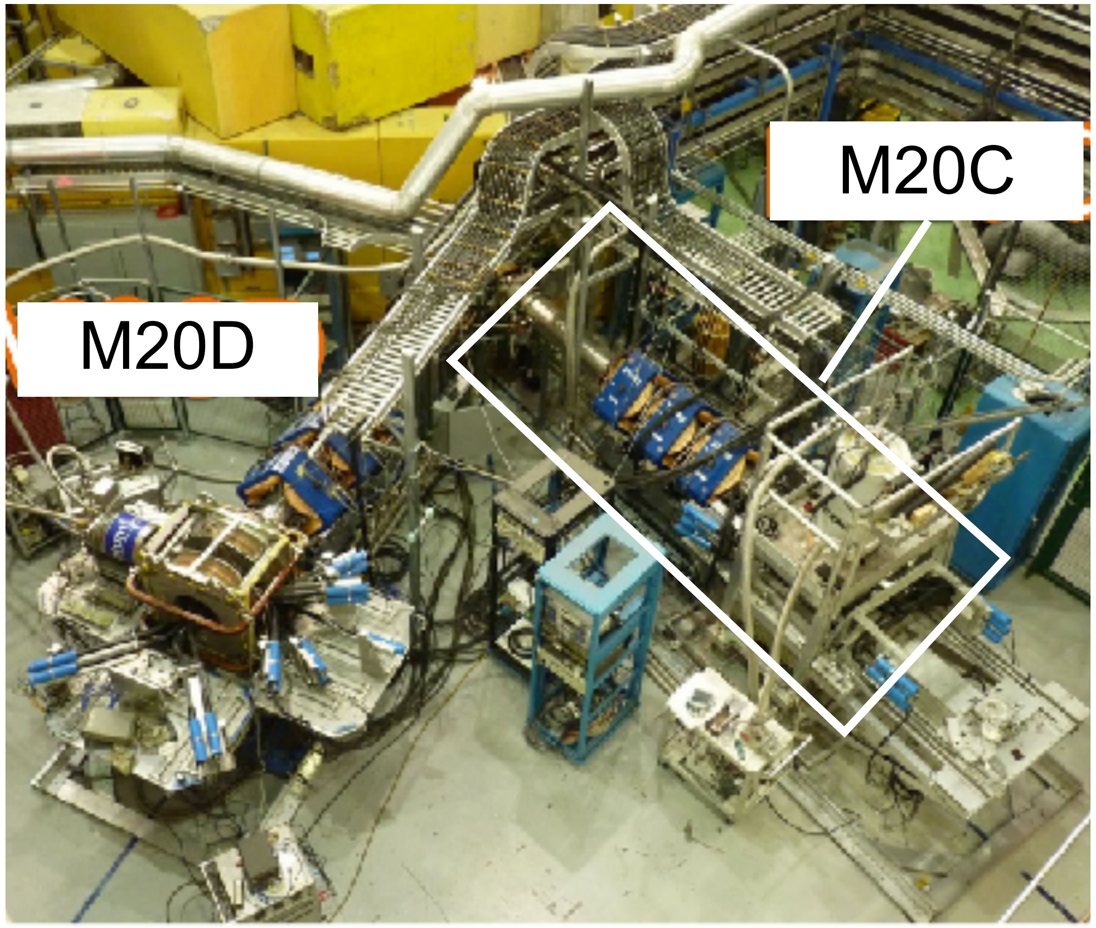
## TRIUMF M20C Performance

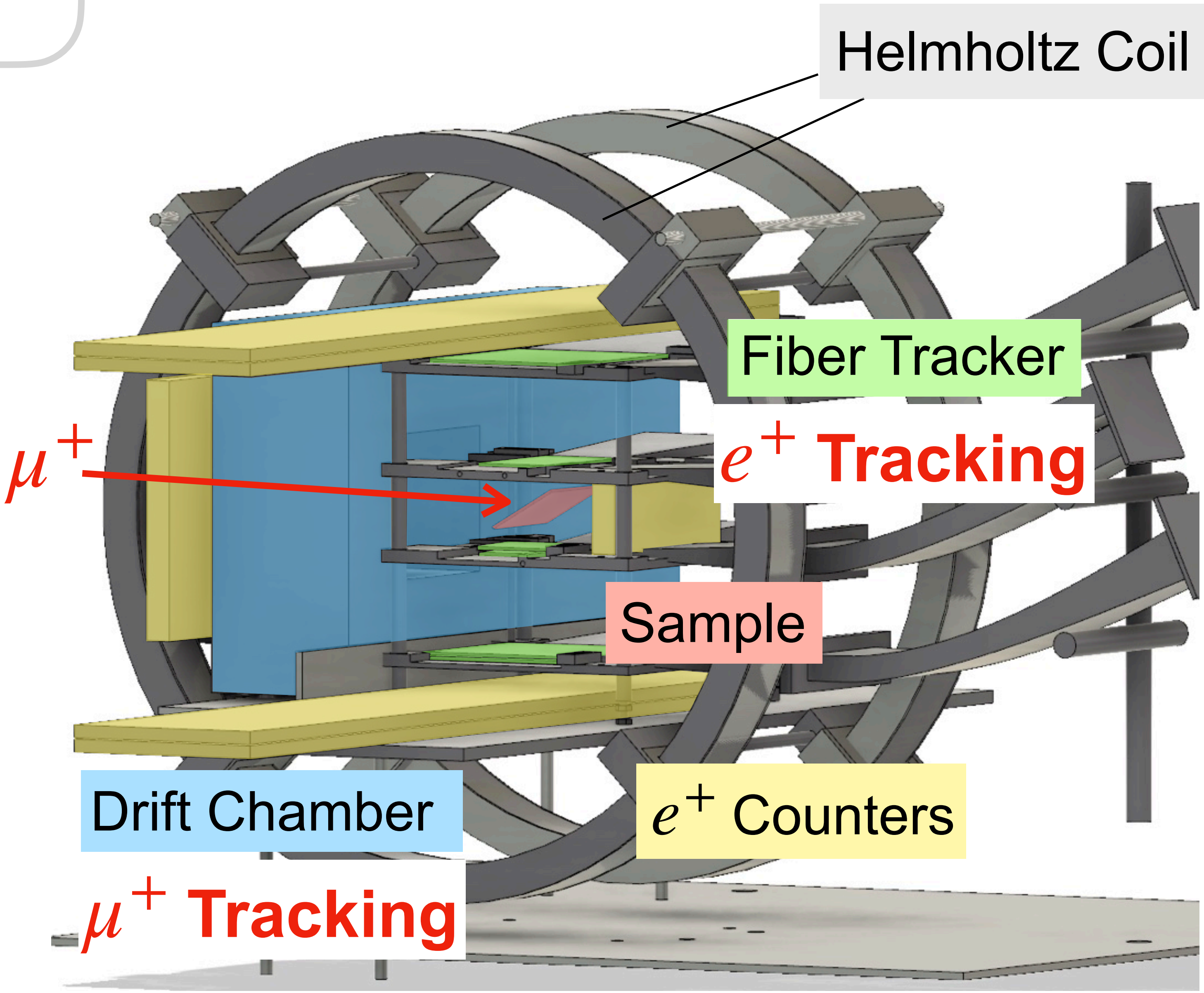
- **Continuous Surface $\mu^+$ beam**
- Max Beam Intensity : 70k cps

→ **for parasite Exp. : 8–25k cps**

## Experimental Setup

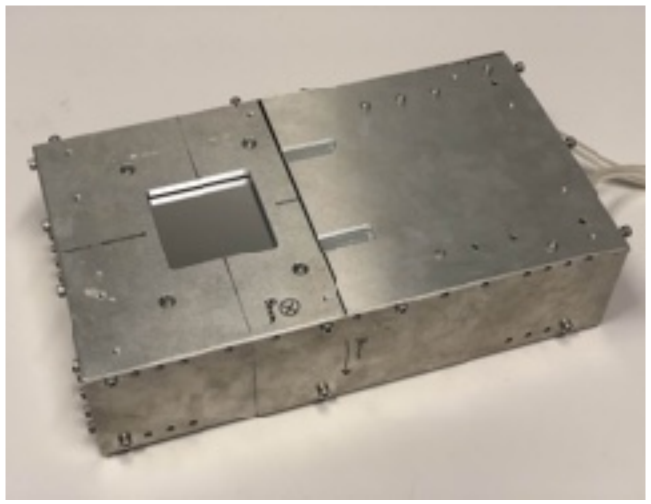
- No Cryostat → Room temperature
- Magnetic Field : ZF / TF (<10G)



# Position Sensitive Detectors

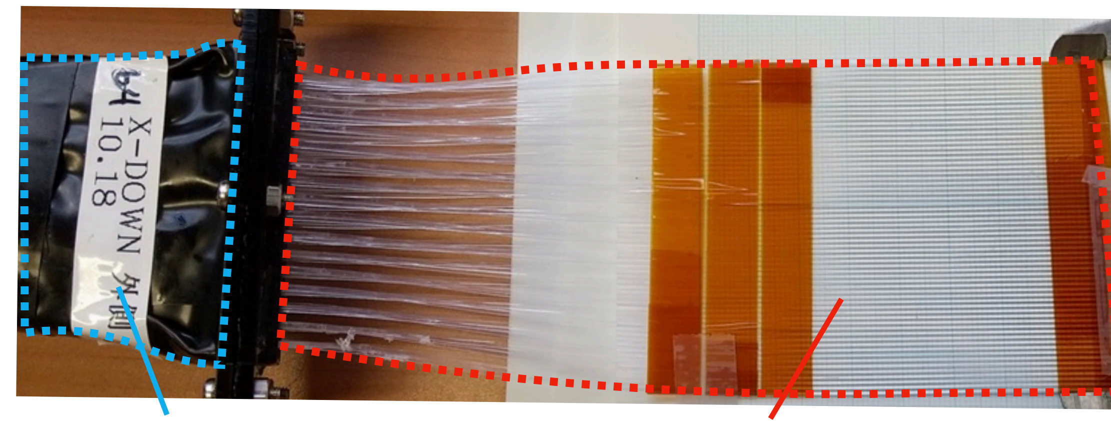
## Drift Chamber : $\mu^+$



- ✓ Surface $\mu^+$ beam : $\beta \sim 0.28$

  → thin detector to avoid stopping inside = Gas Detector
- ✓ High Resolution : $\sigma_{\mathrm{DC}}^{\mathrm{intrinsic}} \sim 0.1\ \mathrm{mm}$
- ✓ Layer : x, y each 3 layer
- ✓ High Efficiency : $\varepsilon \sim 95\ \%$
- ✓ Tracking Efficiency : $\varepsilon^6 \sim 80\ \%$

## Fiber Tracker : $e^+$



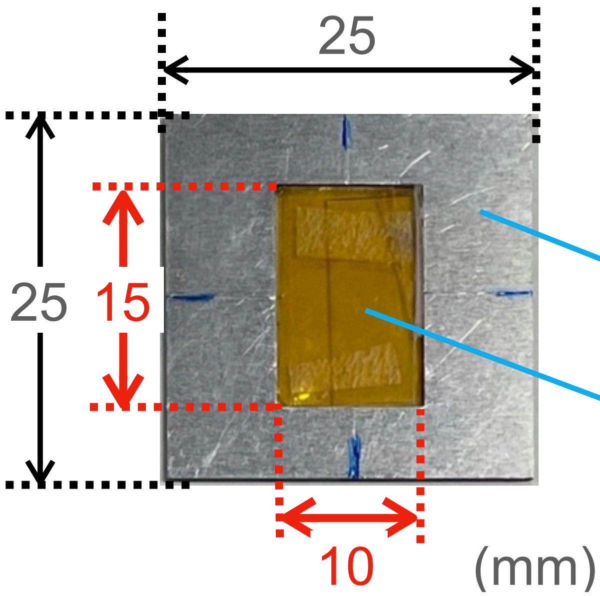

Optical Fiber Scintillation Fiber

- ✓ Decay $e^+$: $\beta \sim 0.99$

  → thick detector to detect with high efficiency = Plastic Scintillator
- ✓ Good Resolution : $\sigma_{\mathrm{Fiber}}^{\mathrm{intrinsic}} \sim 0.7\ \mathrm{mm}$
- ✓ Layer : x, y each 2 layer
- ✓ Low Efficiency : $\varepsilon \sim 40\ \%$
- ✓ Tracking Efficiency : $\varepsilon^4 \sim 0.02\ \%$

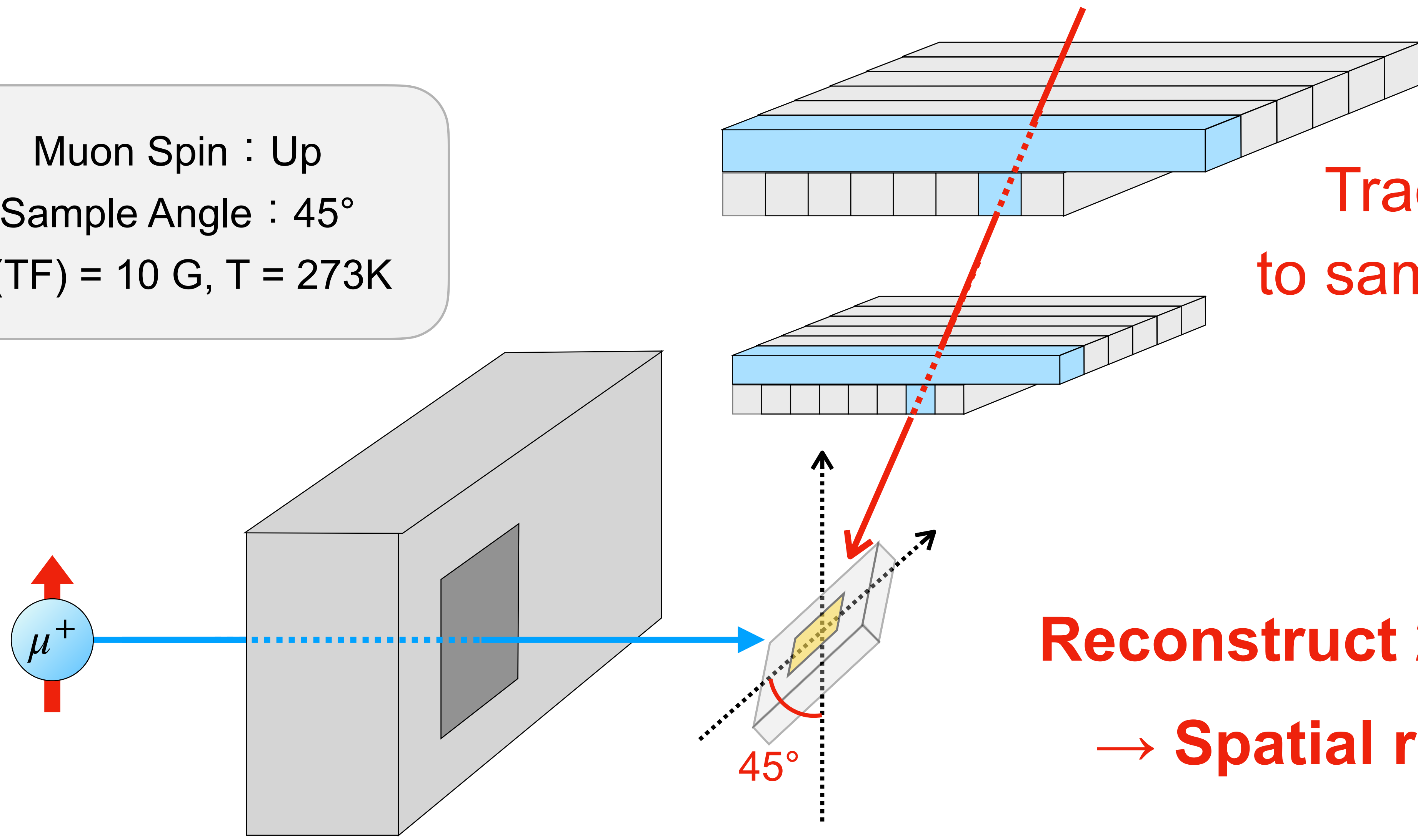
# Contents

# 2D Imaging Test with Al / $Al_2O_3$ Sample




| Sample | | State | TF Spectra |
|---|---|---|---|
| Metal | Al | $\mu^+$ | Slow Rotation (T = 7.38 μs/10 G) |
| Insulator | $Al_2O_3$ | $\mu^+e^-$ | Rapid Rotation (T = 0.074 μs/10 G) |

Muon Spin : Up
Sample Angle : 45°
B(TF) = 10 G, T = 273K



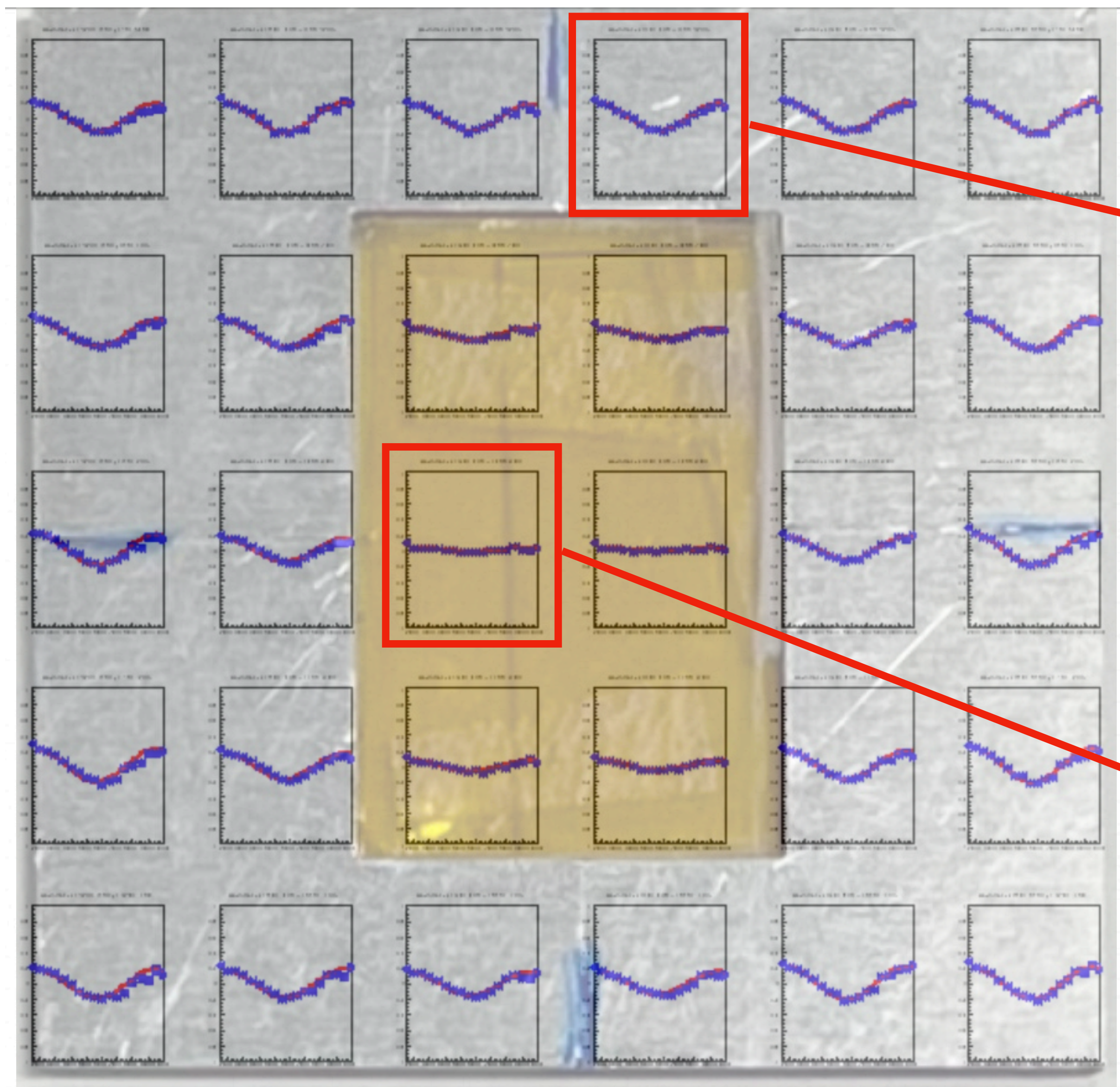

Track back to sample plane

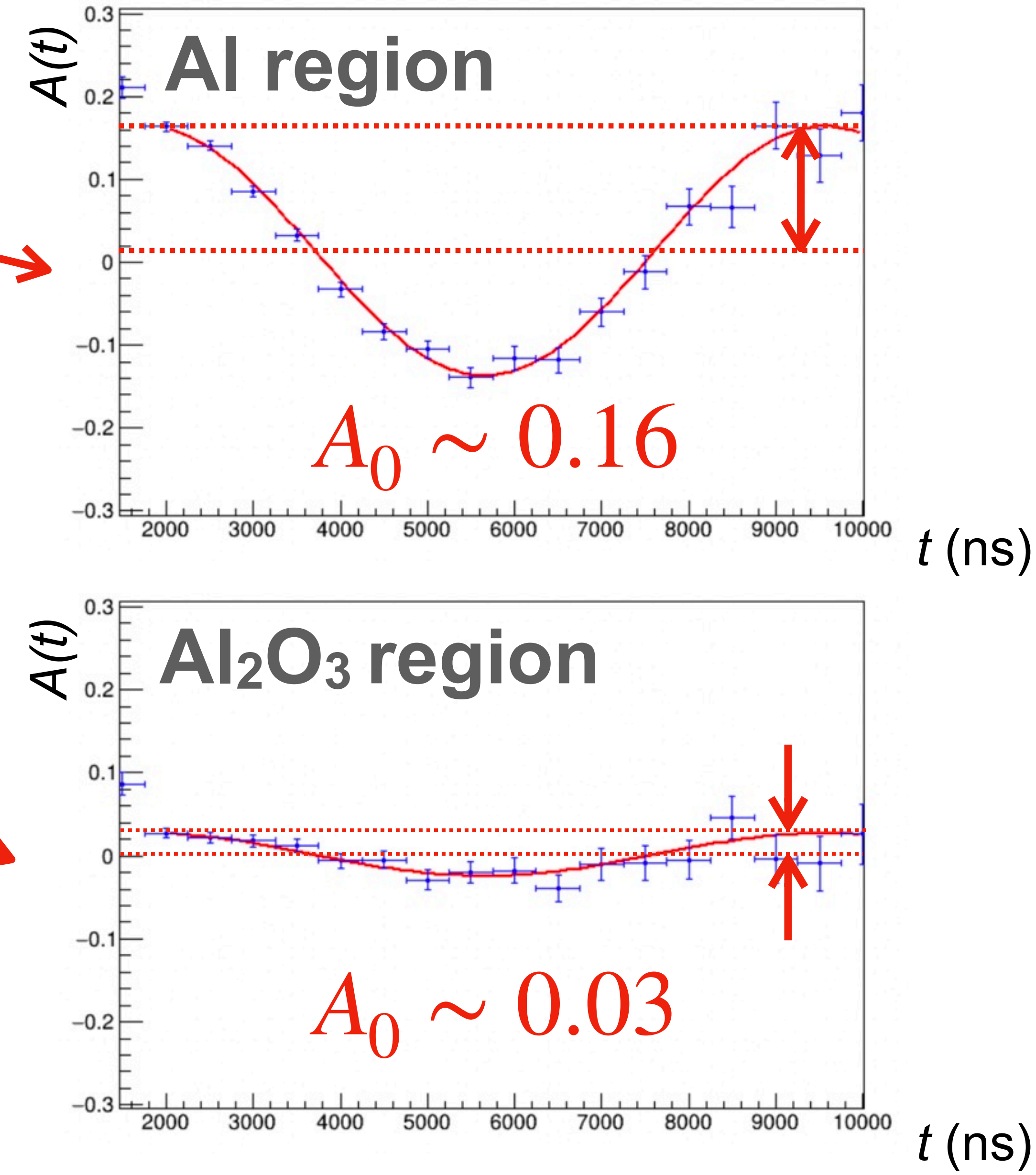
**Reconstruct 2D imaging**
**→ Spatial resolution**

# Asymmetry Identification

Divide into small regions → Create Asymmetry

$$A(t) = A_0 \sin(\omega_\mu t + \phi_0)$$

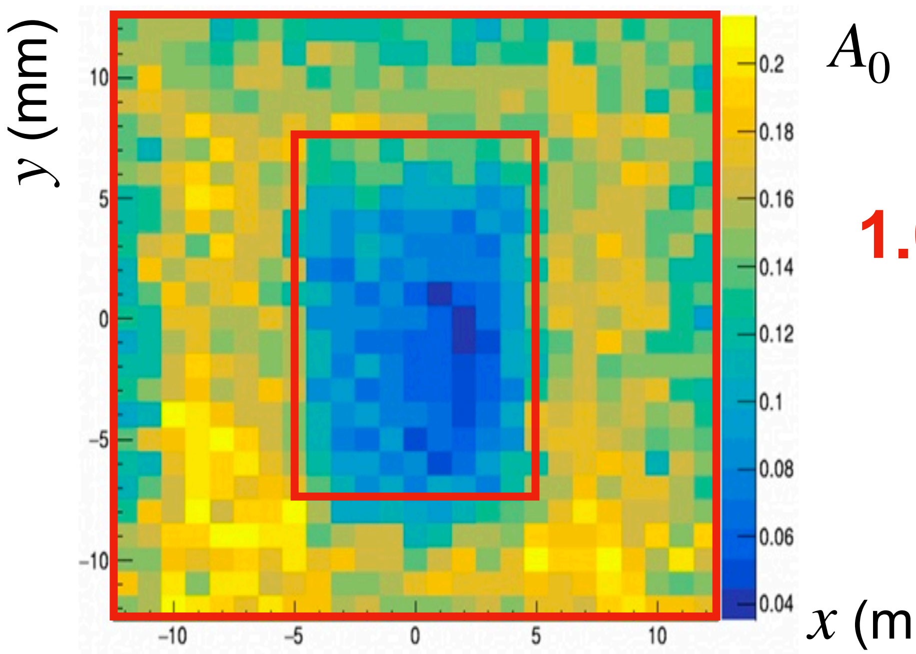




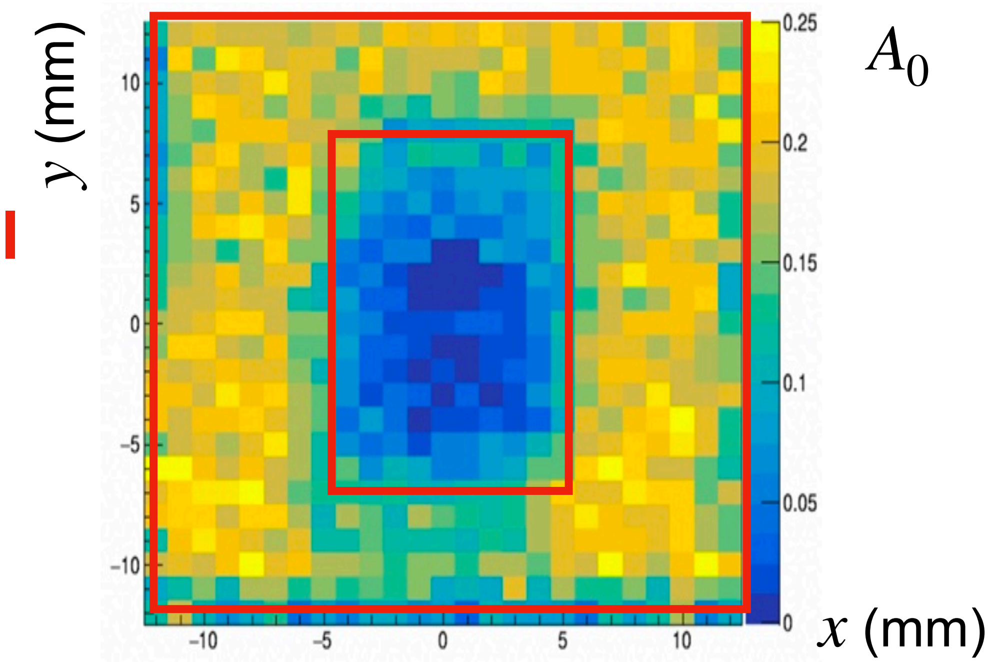

**$A_0$ is a good parameter of distinguish materials**

# Results : 2D imaging & Spatial Resolution

## Drift Chamber

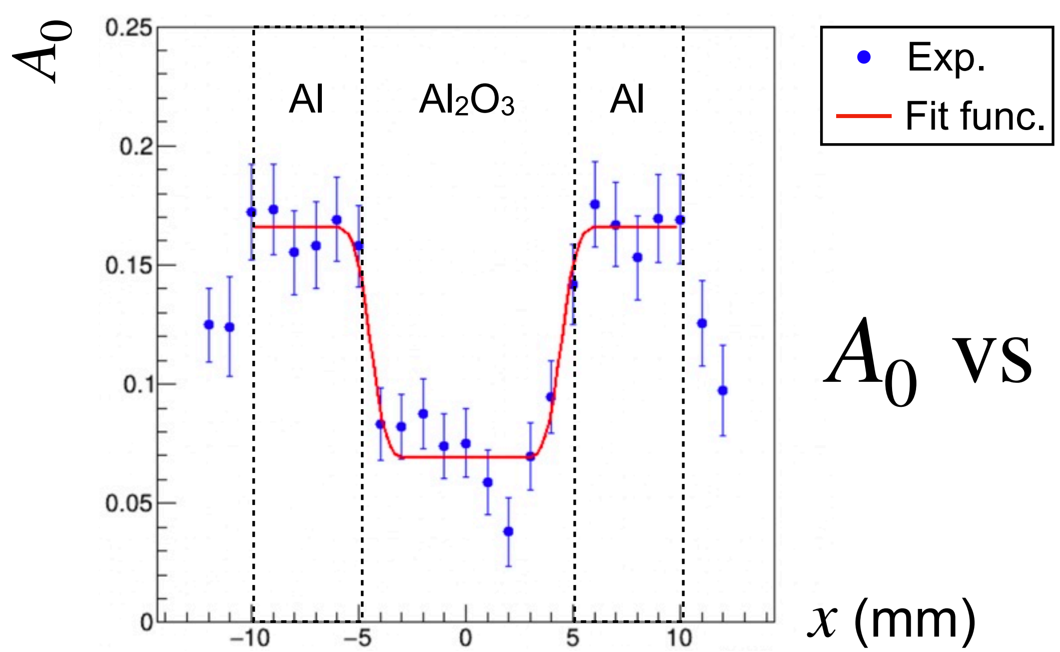



## Fiber Tracker

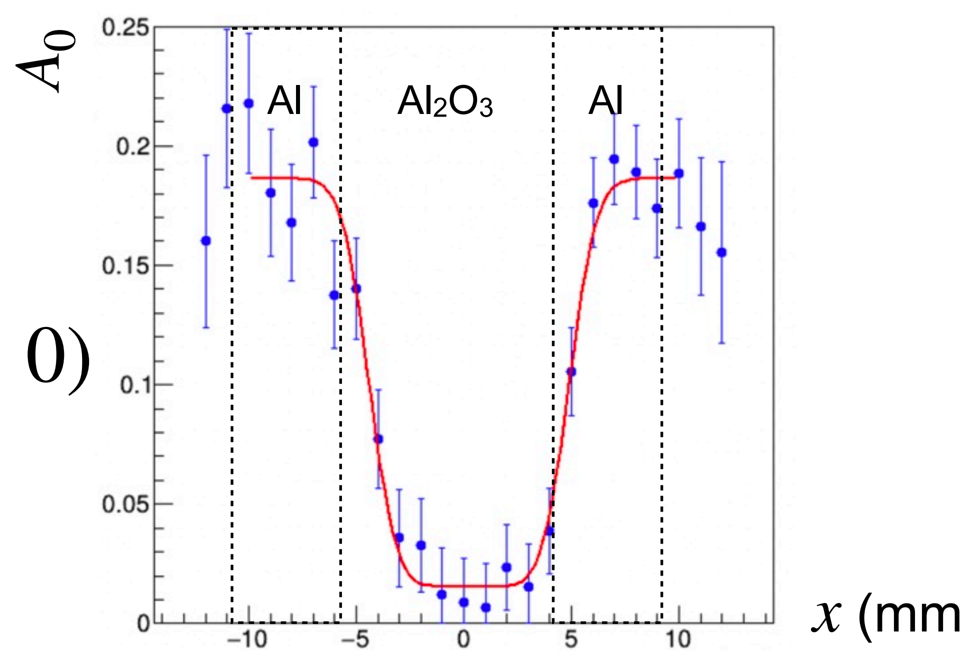



**1.0 mm² pixel**

**↓ Reproduce Calibrated Patterns ↓**




$A_0$ vs $x$ $(y = 0)$

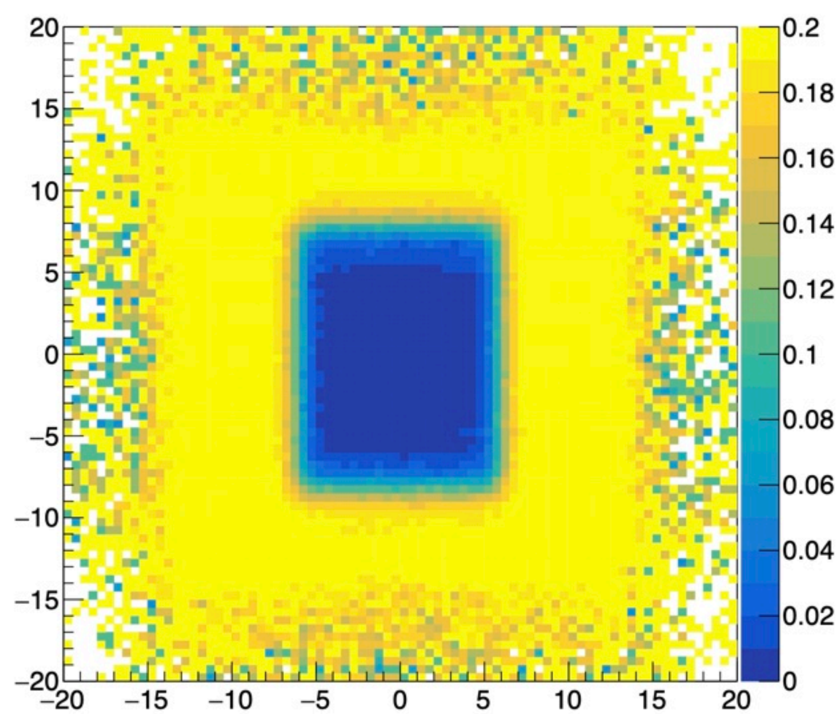


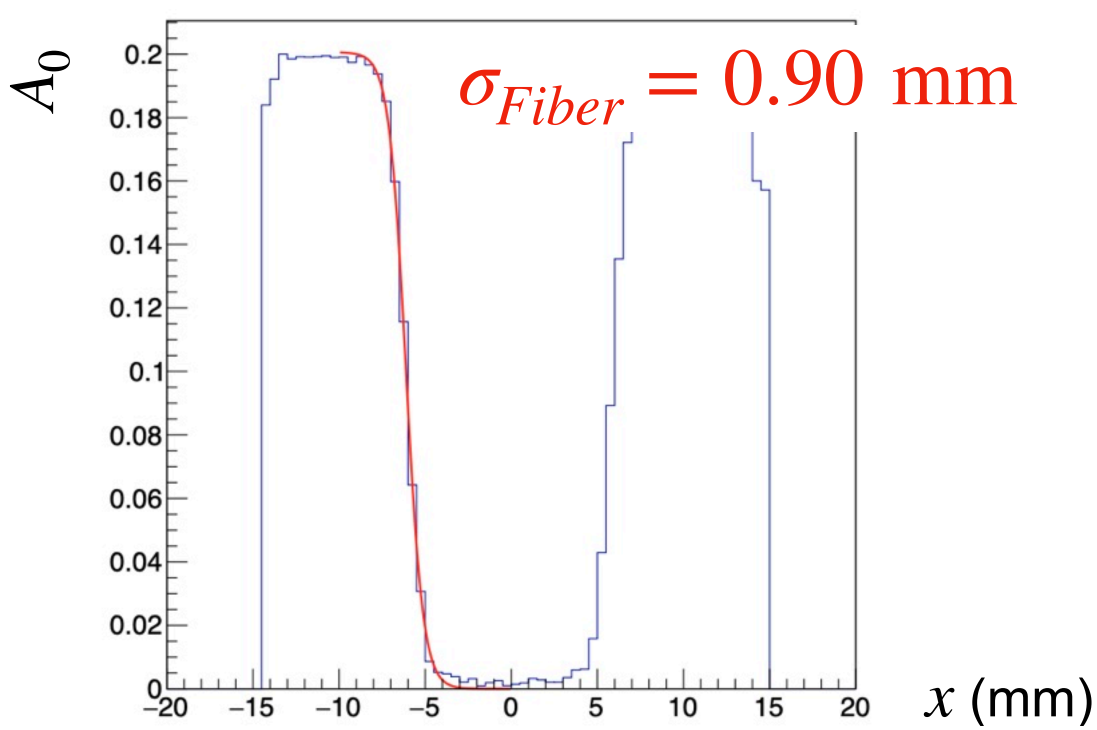

$$\sigma_{DC} = 0.6 \pm 0.2 \text{ mm}$$

$$\sigma_{Fiber} = 1.0 \pm 0.2 \text{ mm}$$

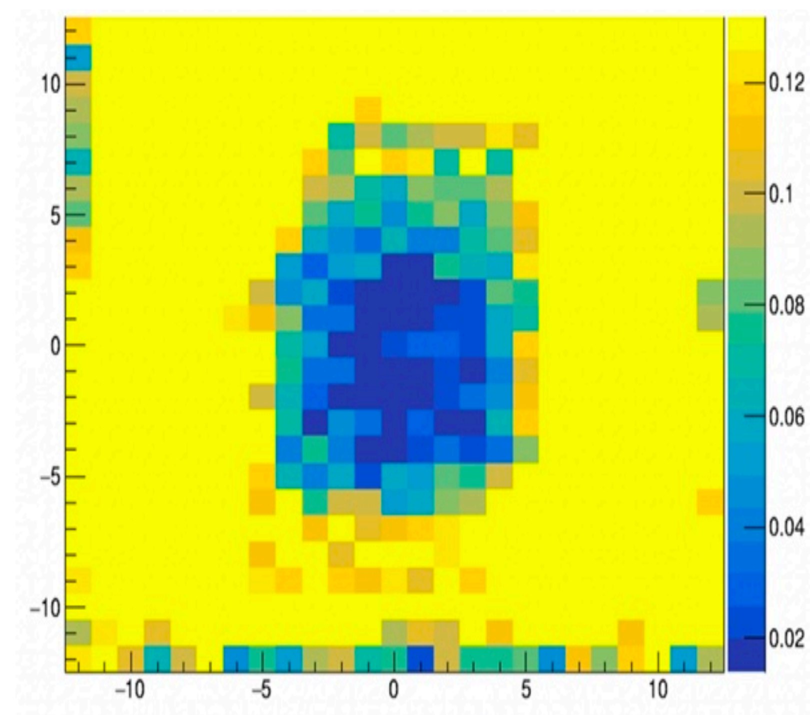
# Discussion : Fiber Tracker Simulation

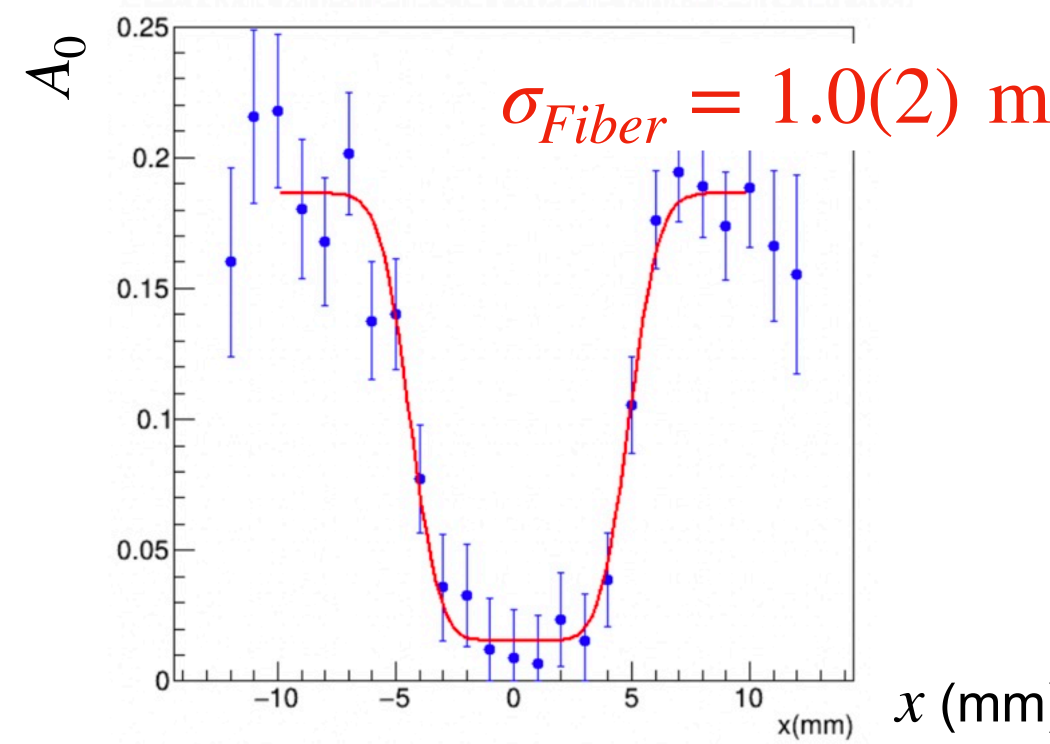
## Geant4 Simulation





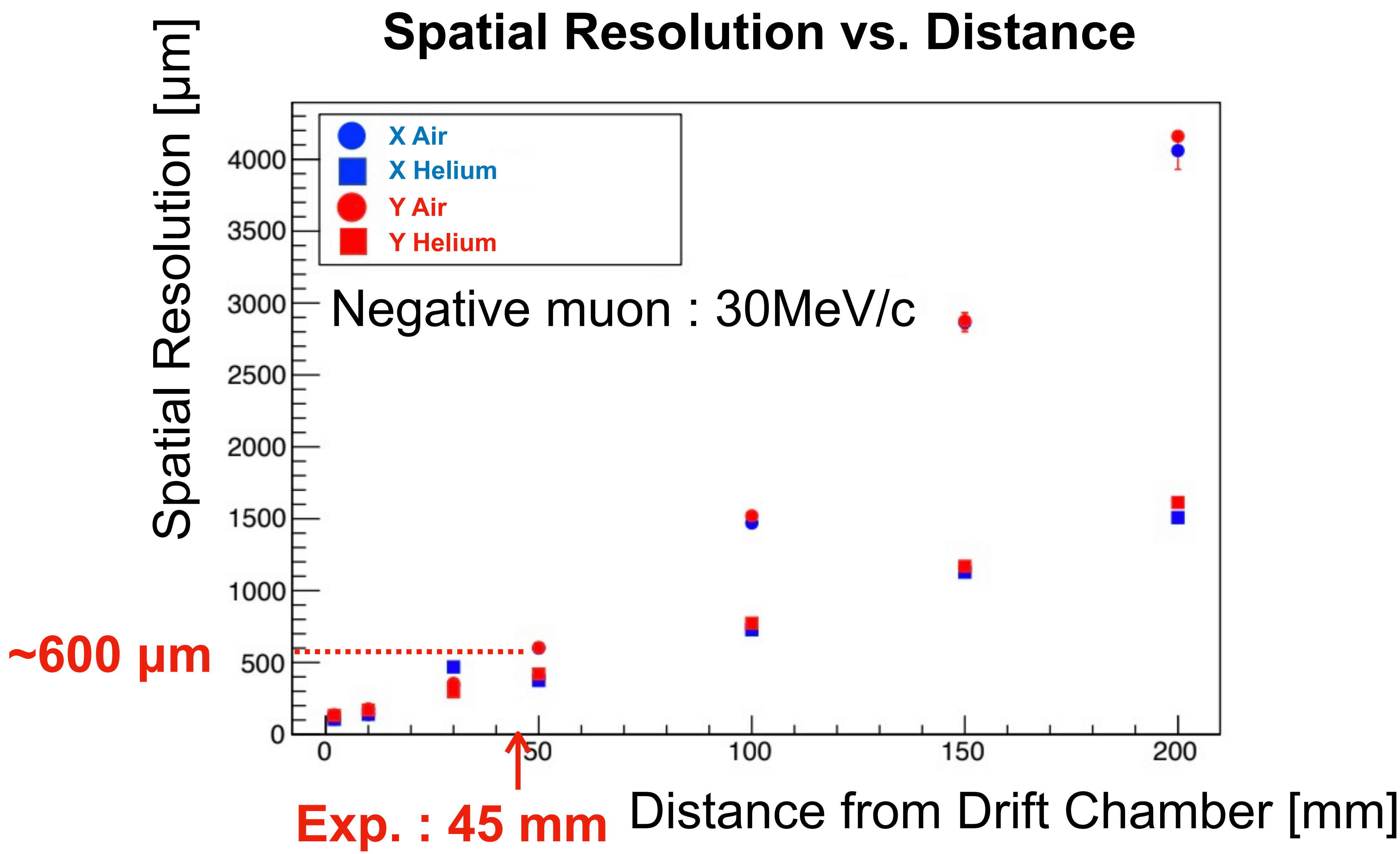

## Experiment






**Consistent with simulation**

# Discussion : Drift Chamber Simulation




**Experiment :** $\sigma_{DC} = 0.6(2)\ \mathrm{mm} \rightarrow$ **Consistent**

# Contents

# *Summary & Future work*

## Summary

1. Successfully performed 2D imaging using 1.0 mm² pixels with both the drift chamber and the fiber tracker, reproducing the known material distribution.
2. From the imaging results, the spatial resolution was estimated to be:

– Drift chamber: $\sigma_{\mathrm{DC}} = 0.6 \pm 0.2\ \mathrm{mm}$

– Fiber tracker: $\sigma_{\mathrm{Fiber}} = 1.0 \pm 0.2\ \mathrm{mm}$

## Future Work

- Improve resolution and efficiency of fiber tracker.
- Update toward standard μSR setup (e.g. : install cryostat).
- 3D imaging with $\mu^+ - e^+$ vertex reconstruction (in progress)
- μSR measurement on micro-sized sample
  - e.g. : Diamond Anvil Cell : size ~ 1.0mm

# Back Up

# Progress Steps

**STEP1**

**First Test**

- 2D imaging (known sample)
- Spatial resolution evaluation
- Exp. vs. Simulation

**STEP2**

**Update Setup**

- Install Cryostat
- Higher Spatial Resolution

**STEP3**

**Application test with known sample**

- 3D imaging
- Tiny sample μSR

**STEP4**

**Application to unknown sample**

- 2D/3D imaging
- Tiny sample μSR