

# **THE PARTICLE PEERS**

THE SHAPE AND DEVELOPMENT OF AN ELECTROMAGNETIC SHOWER

# THE PARTICLE PEERS

Cecile Wiersema

Isabelle Koster

Abracha Koens

Ilja de Goede

Frederiek de Bruine

Janiek Weening

Kirsten Stadermann

Ad van den Berg



THE PARTICLE PEERS 28-10-2019

# THE PARTICLE PEERS

From the Praedinius Gymnasium, Groningen, NL



# CONTENTS

- ▶ Theory
- ▶ Research question
- ▶ Expectations
- ▶ Set-up
- ▶ Tungsten & Copper
- ▶ Data taking
- ▶ Analysis
- ▶ Discussion
- ▶ Next step

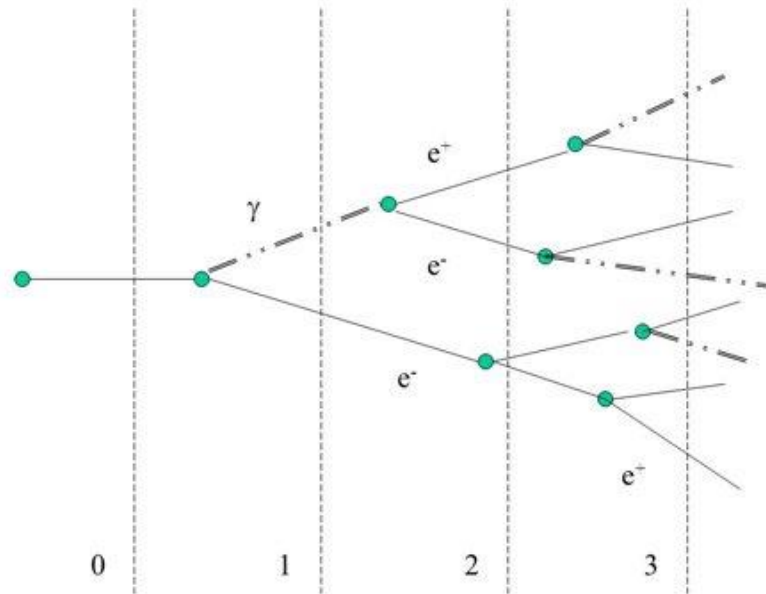


# STANDARD MODEL

## Standard Model of Elementary Particles

	three generations of matter (elementary fermions)			three generations of antimatter (elementary antifermions)			interactions / force carriers (elementary bosons)	
	I	II	III	I	II	III		
mass	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	$\approx 2.2 \text{ MeV}/c^2$	$\approx 1.28 \text{ GeV}/c^2$	$\approx 173.1 \text{ GeV}/c^2$	0	$\approx 124.97 \text{ GeV}/c^2$
charge	$\frac{2}{3}$	$\frac{2}{3}$	$\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	$-\frac{2}{3}$	0	0
spin	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	$\frac{1}{2}$	1	0
	<b>u</b> up	<b>c</b> charm	<b>t</b> top	<b><math>\bar{u}</math></b> antiup	<b><math>\bar{c}</math></b> anticharm	<b><math>\bar{t}</math></b> antitop	<b>g</b> gluon	<b>H</b> higgs
<b>QUARKS</b>	$\approx 4.7 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>d</b> down	$\approx 96 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>s</b> strange	$\approx 4.18 \text{ GeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$ <b>b</b> bottom	$\approx 4.7 \text{ MeV}/c^2$ $\frac{1}{3}$ $\frac{1}{2}$ <b><math>\bar{d}</math></b> antidown	$\approx 96 \text{ MeV}/c^2$ $\frac{1}{3}$ $\frac{1}{2}$ <b><math>\bar{s}</math></b> antistrange	$\approx 4.18 \text{ GeV}/c^2$ $\frac{1}{3}$ $\frac{1}{2}$ <b><math>\bar{b}</math></b> antibottom	0 0 1 <b><math>\gamma</math></b> photon	<b>GAUGE BOSONS VECTOR BOSONS</b>
	$\approx 0.511 \text{ MeV}/c^2$ -1 $\frac{1}{2}$ <b>e</b> electron	$\approx 105.66 \text{ MeV}/c^2$ -1 $\frac{1}{2}$ <b><math>\mu</math></b> muon	$\approx 1.7768 \text{ GeV}/c^2$ -1 $\frac{1}{2}$ <b><math>\tau</math></b> tau	$\approx 0.511 \text{ MeV}/c^2$ 1 $\frac{1}{2}$ <b><math>e^+</math></b> positron	$\approx 105.66 \text{ MeV}/c^2$ 1 $\frac{1}{2}$ <b><math>\bar{\mu}</math></b> antimuon	$\approx 1.7768 \text{ GeV}/c^2$ 1 $\frac{1}{2}$ <b><math>\bar{\tau}</math></b> antitau	0 1 <b>Z</b> Z <sup>0</sup> boson	
<b>LEPTONS</b>	$< 2.2 \text{ eV}/c^2$ 0 $\frac{1}{2}$ <b><math>\nu_e</math></b> electron neutrino	$< 0.17 \text{ MeV}/c^2$ 0 $\frac{1}{2}$ <b><math>\nu_\mu</math></b> muon neutrino	$< 18.2 \text{ MeV}/c^2$ 0 $\frac{1}{2}$ <b><math>\nu_\tau</math></b> tau neutrino	$< 2.2 \text{ eV}/c^2$ 0 $\frac{1}{2}$ <b><math>\bar{\nu}_e</math></b> electron antineutrino	$< 0.17 \text{ MeV}/c^2$ 0 $\frac{1}{2}$ <b><math>\bar{\nu}_\mu</math></b> muon antineutrino	$< 18.2 \text{ MeV}/c^2$ 0 $\frac{1}{2}$ <b><math>\bar{\nu}_\tau</math></b> tau antineutrino	1 1 <b><math>W^+</math></b> W <sup>+</sup> boson	
								<b>SCALAR BOSONS</b>

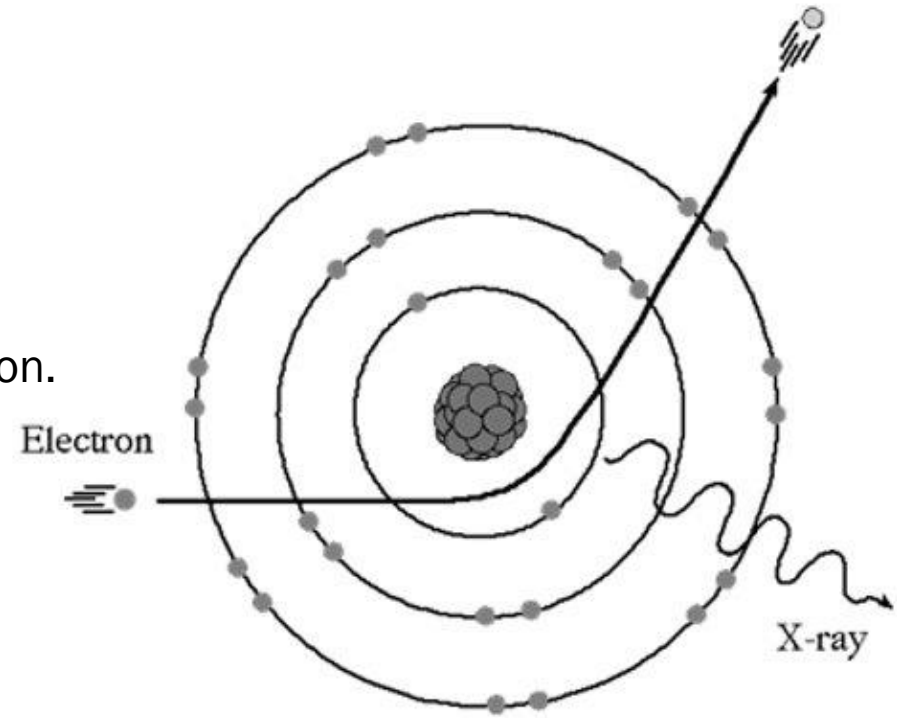
# ELECTROMAGNETIC SHOWER



- ▶ 3 types of particles involved:
  - Electrons e<sup>-</sup>
  - Positrons e<sup>+</sup>
  - Gamma rays (γ)
- ▶ 2 kinds of processes in the shower:
  - bremsstrahlung & pair production

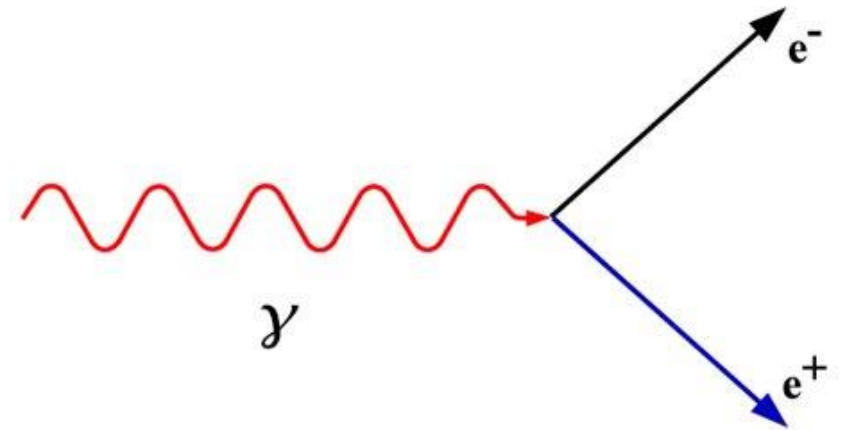
# BREMSSTRAHLUNG

- ▶ Electron or positron interacting with a nucleus  
-> emitting a photon
- ▶ When the electron or positron interacts closer with the nucleus, it will transfer more energy to the emitted photon.



# PAIR PRODUCTION

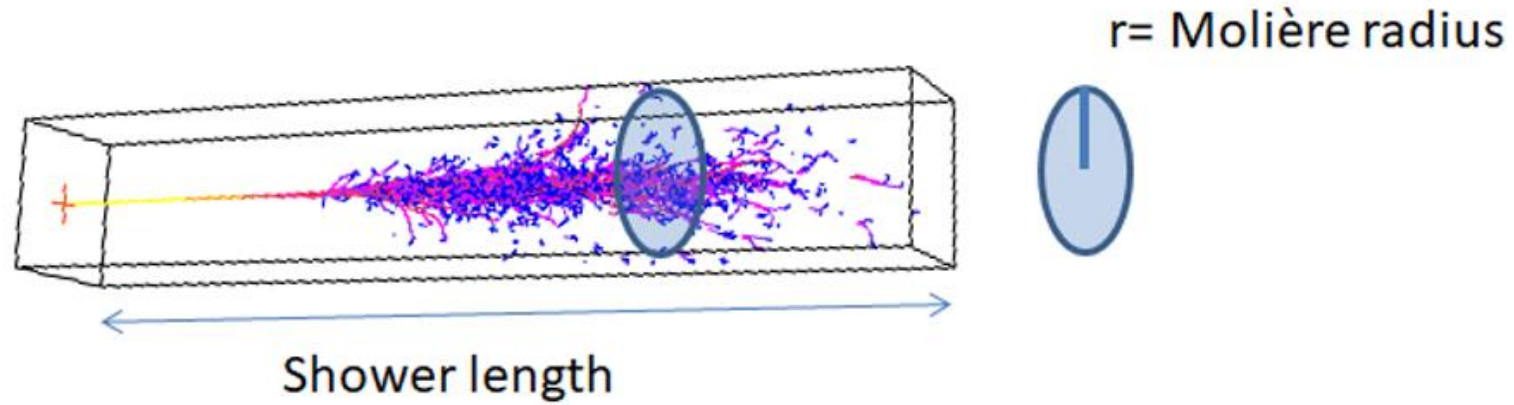
- ▶ A photon interacting with a nucleus -> creating an electron and positron pair
- ▶ The created electron and positron will have the same energy





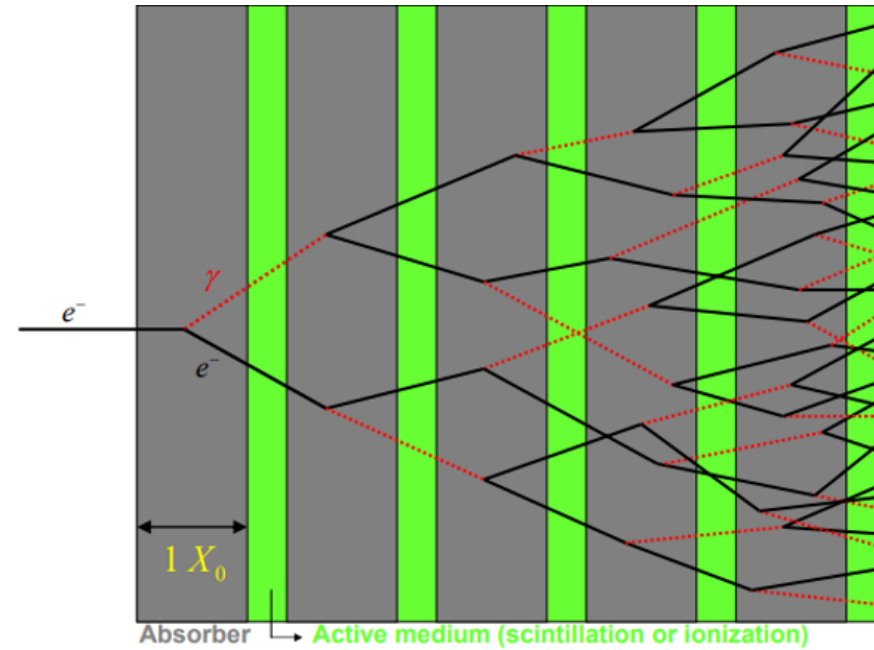
# SHOWER SHAPE

- ▶ Molière radius
- ▶ Shower length



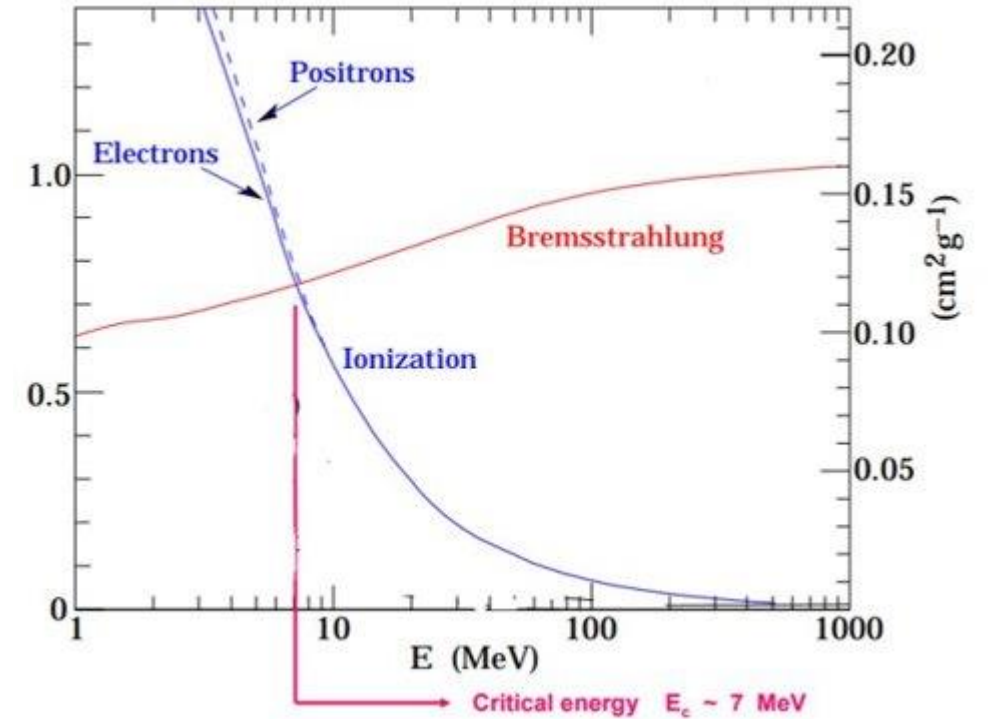
# RADIATION LENGTH -> SHOWER LENGTH

- ▶ The radiation length ( $X_0$ ) is the length which is necessary for one pair production
- ▶ The shower length is the length of the entire particle shower



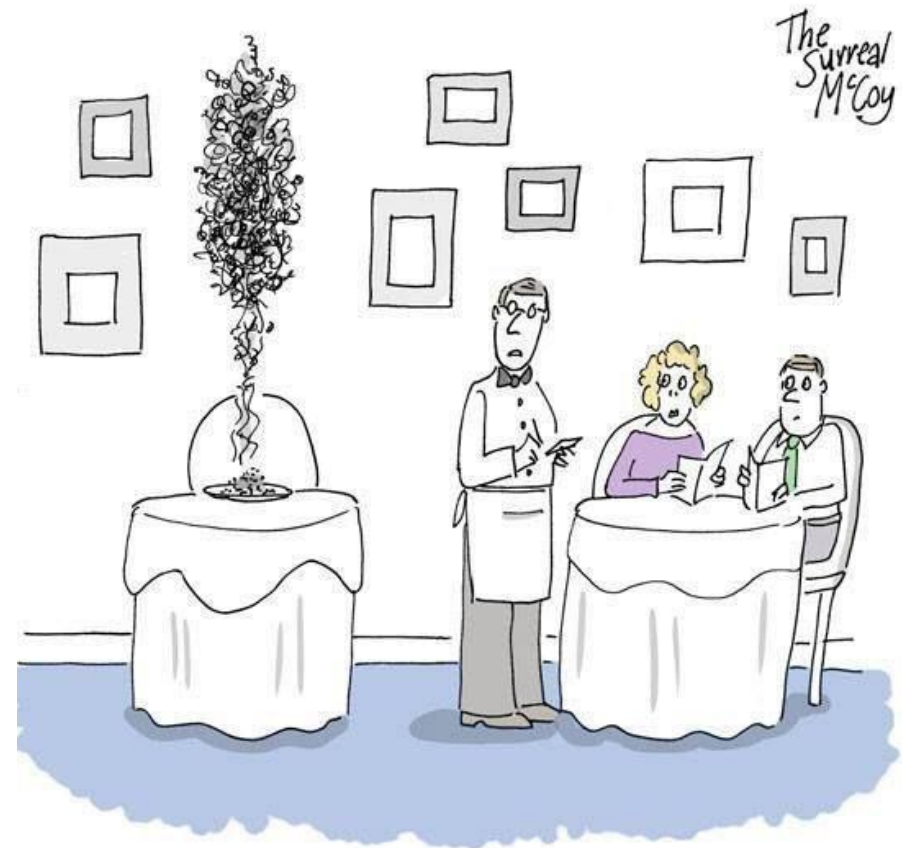
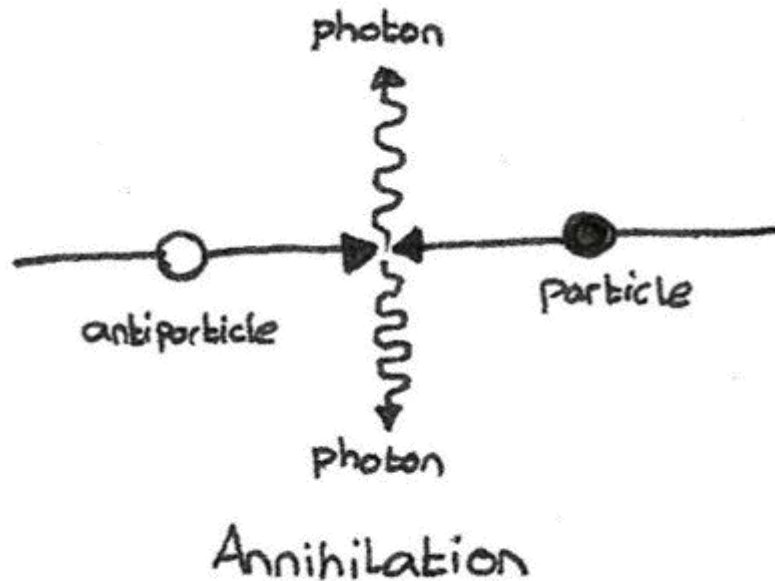
# CRITICAL ENERGY

- ▶ The critical energy ( $E_{\text{crit}}$ ) is the energy at which the chance of bremsstrahlung (thus pair production) is equal to ionization.



# ANNIHILATION

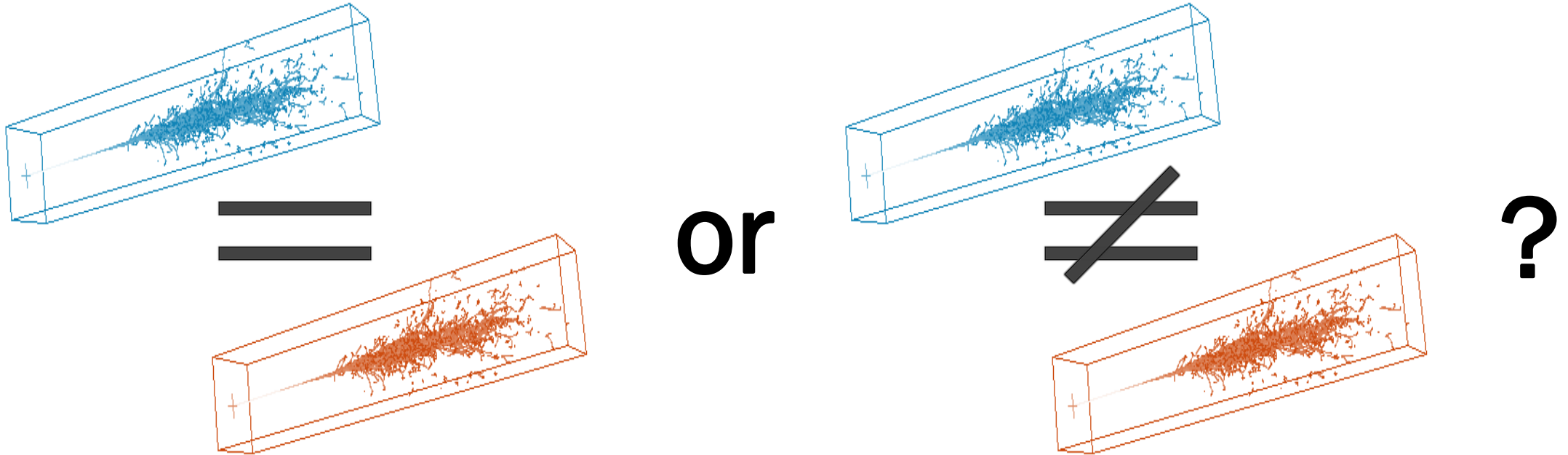
- ▶ Electron + positron  $\rightarrow$  two photons
- ▶ Might cause difference between the showers



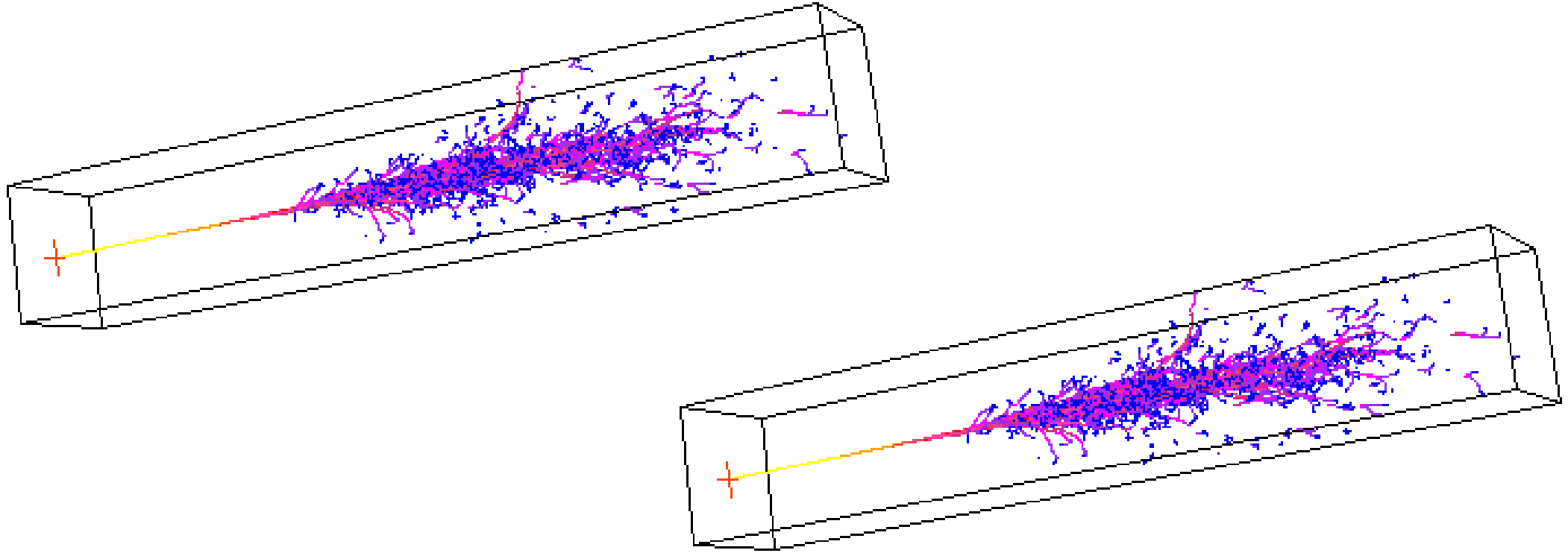
"It is my understanding that the gentleman ordered both the pasta and the antipasta."

# RESEARCH QUESTION

- ▶ Is there a difference in the shape and development of an electromagnetic shower created by electrons and an electromagnetic shower created by positrons?

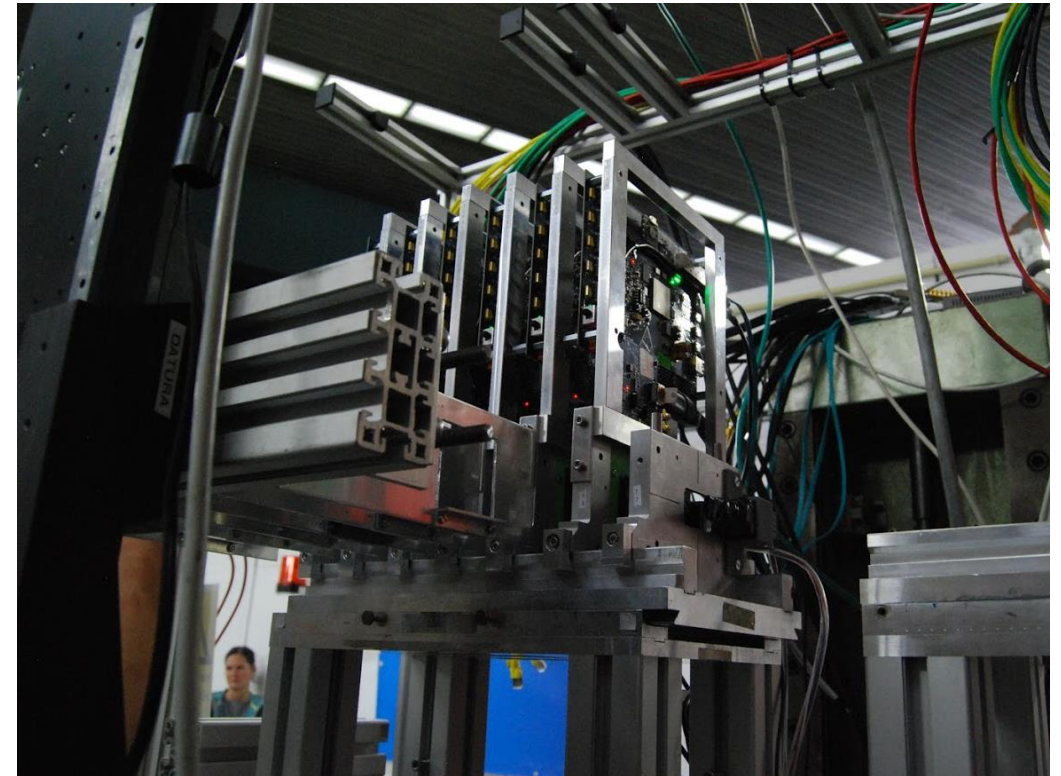
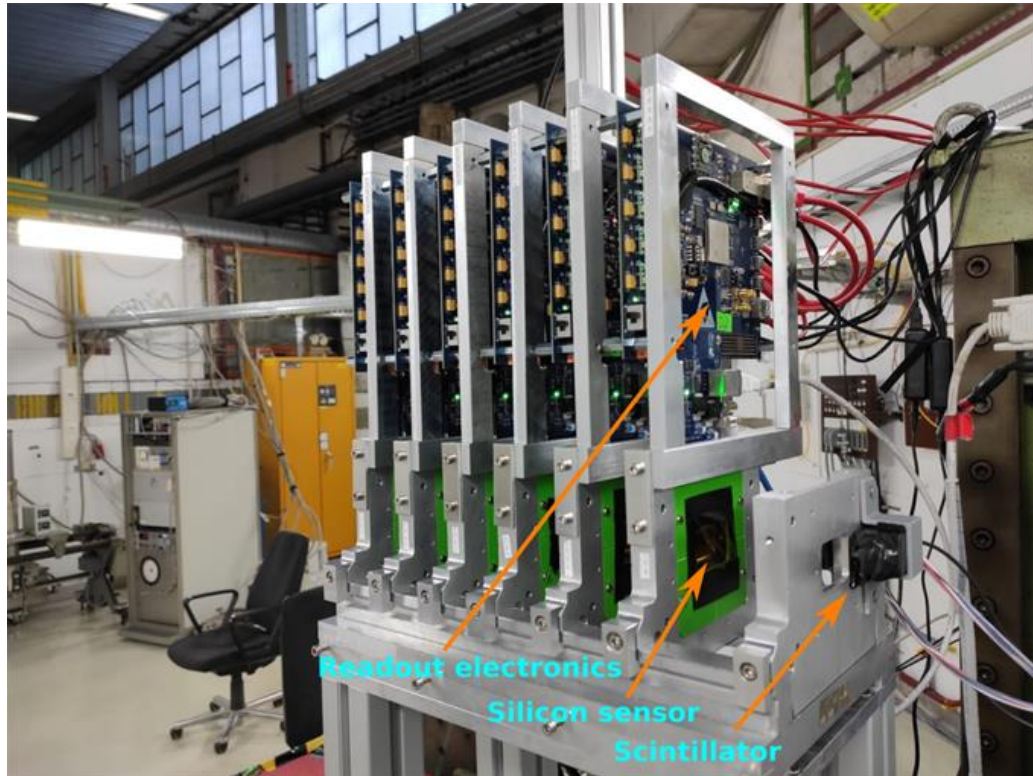


# EXPECTATIONS

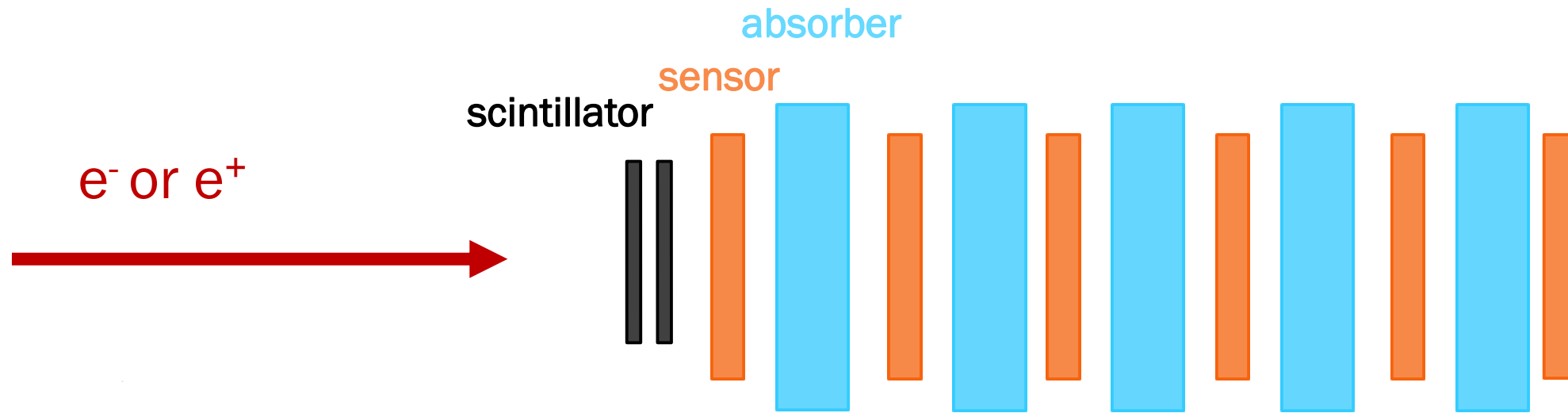


# SET-UP

Beam telescope



# THE SET-UP





# TUNGSTEN

- ▶ High density of  $19.28 \text{ g/cm}^3$
- ▶ Molière radius =  $0,9327 \text{ cm}$
- ▶ Radiation length =  $0,3534 \text{ cm}$
- ▶ Shower length     $1 \text{ GeV} = \text{ca. } 2,45 \text{ cm}$                        $6,3 \text{ GeV} = \text{ca. } 3,38 \text{ cm}$

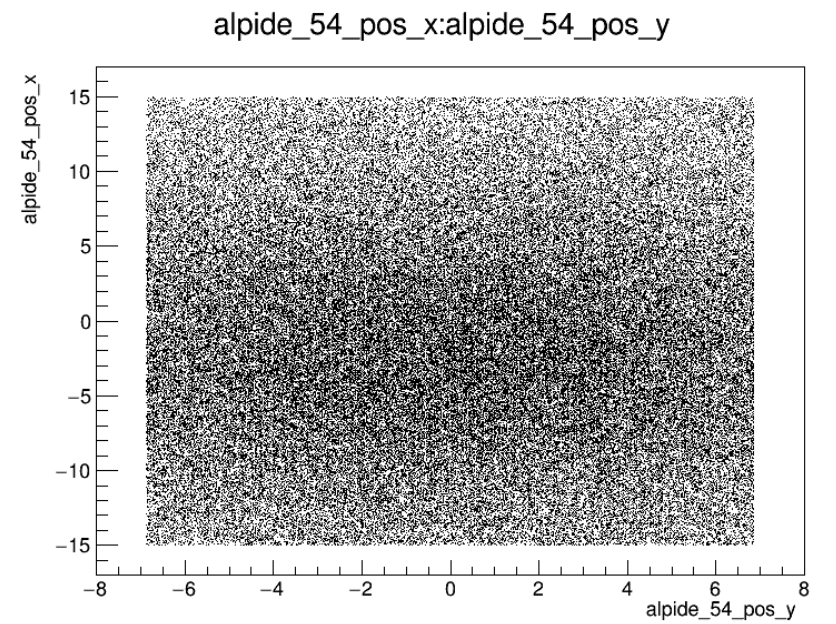
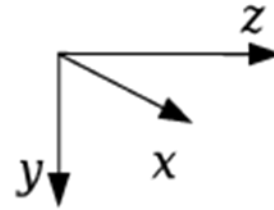
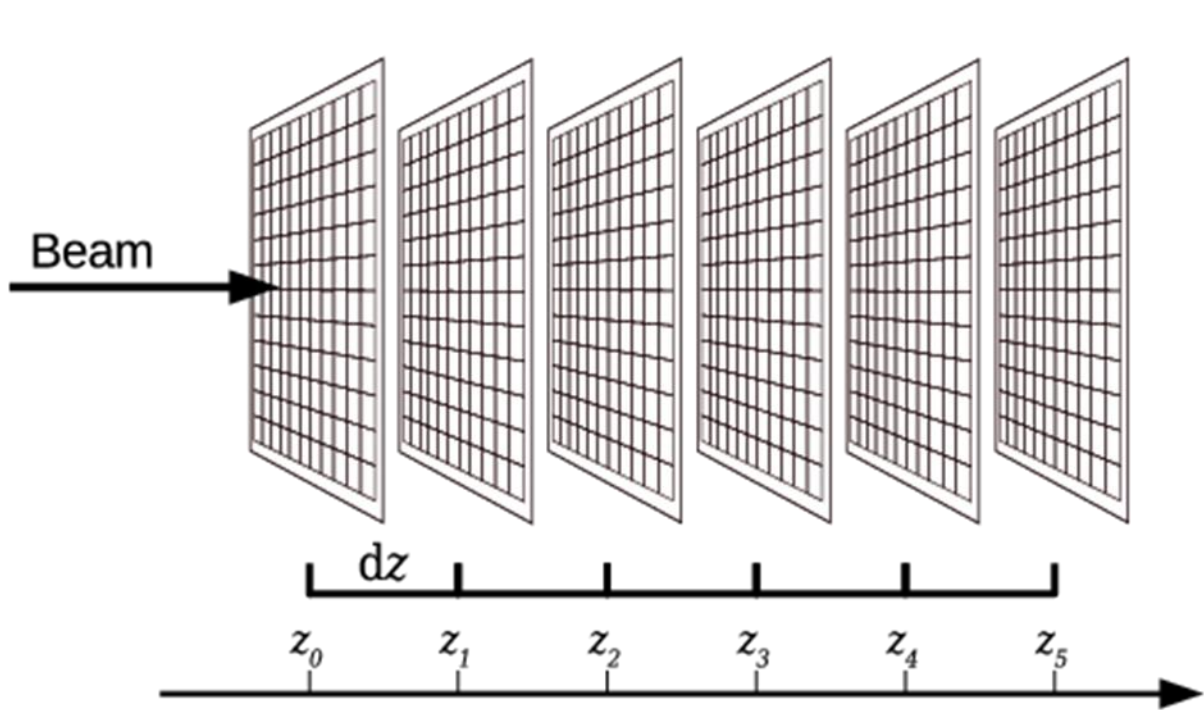


# COPPER

- ▶ High density of 8,96 g/cm<sup>3</sup>
- ▶ Molière radius = 1,598 cm
- ▶ Radiation length = 1,436 cm



# DATA TAKING



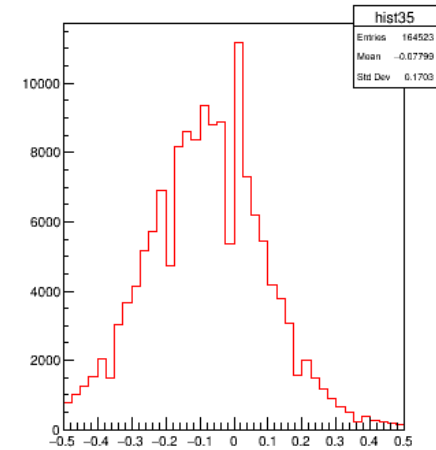
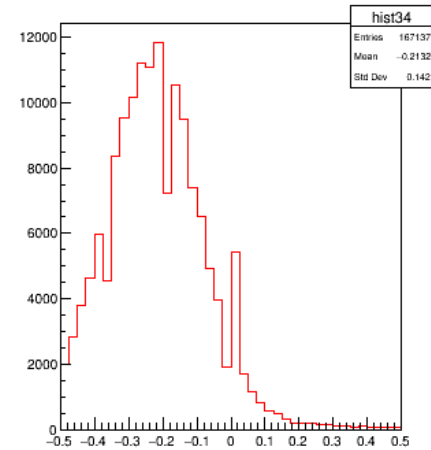
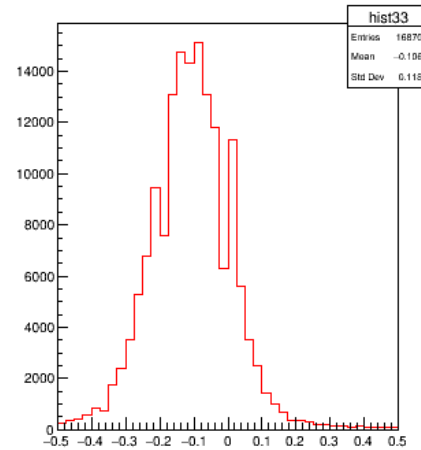
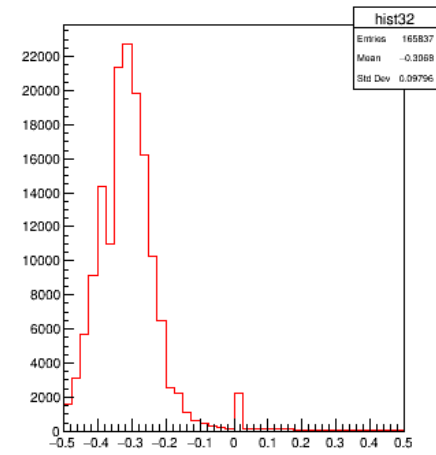
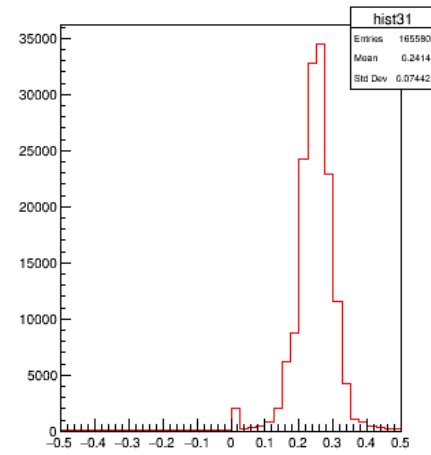
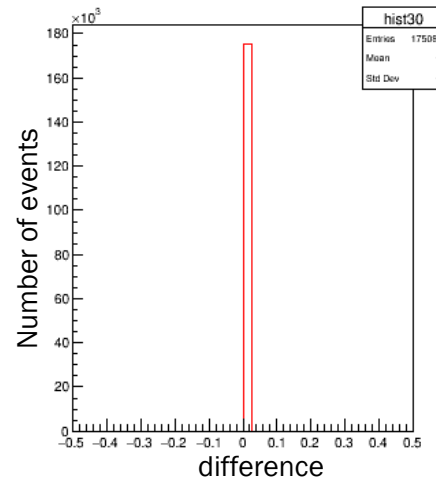
# DATA TAKING

- ▶ Set-up 1:
  - 14 mm of Tungsten
- ▶ Set-up 2:
  - 4 mm of Tungsten
- ▶ Set-up 3:
  - 2 mm of Tungsten
- ▶ Set-up 4:
  - 9 mm of Tungsten
- ▶ Set-up 5:
  - 40 mm of Copper



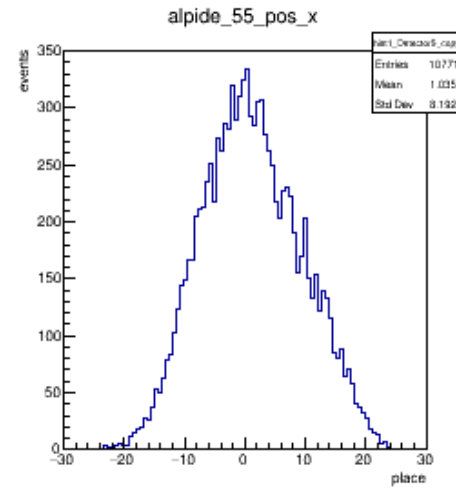
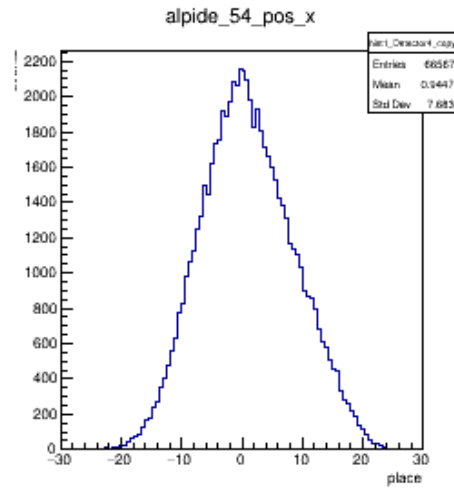
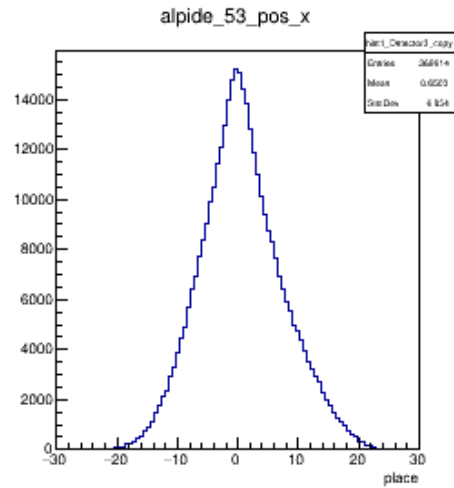
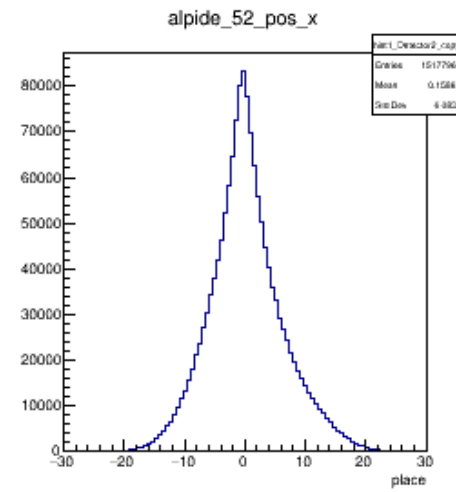
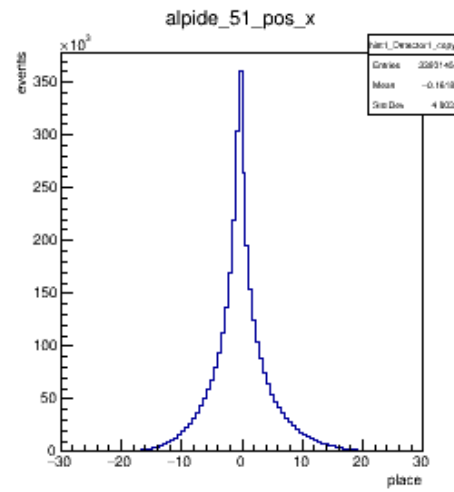
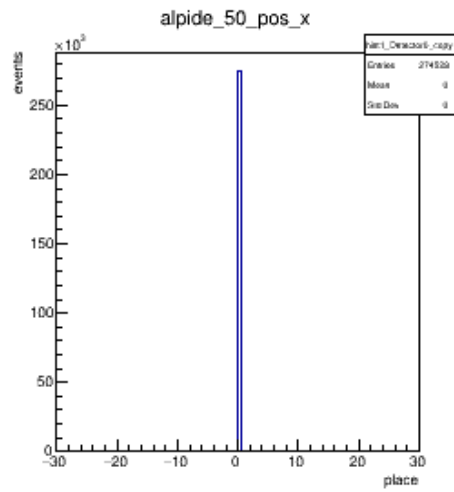
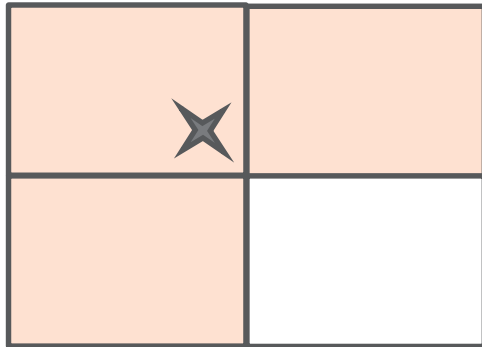
# ANALYSIS

- ▶ Alignment
- ▶ Clusters
- ▶ Molière radius
- ▶ Number of clusters
- ▶ 3D model



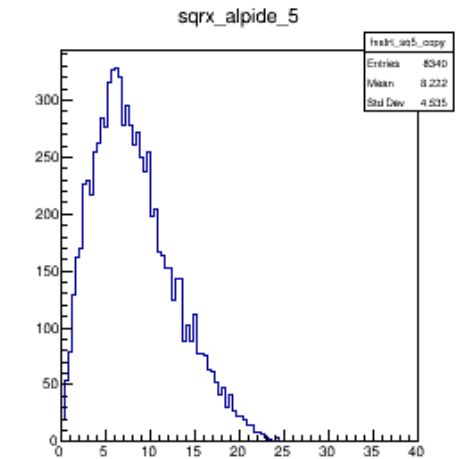
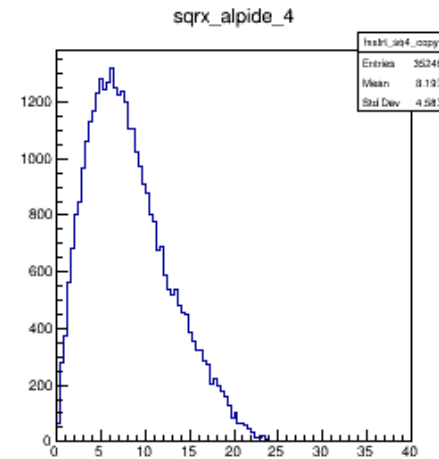
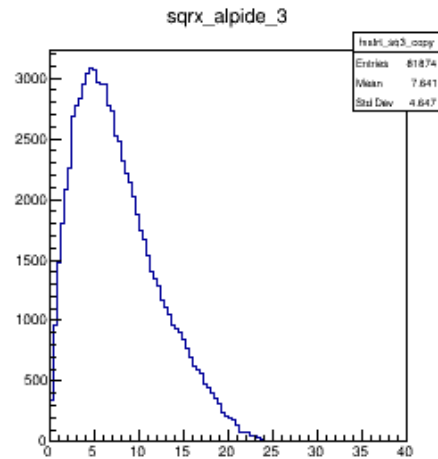
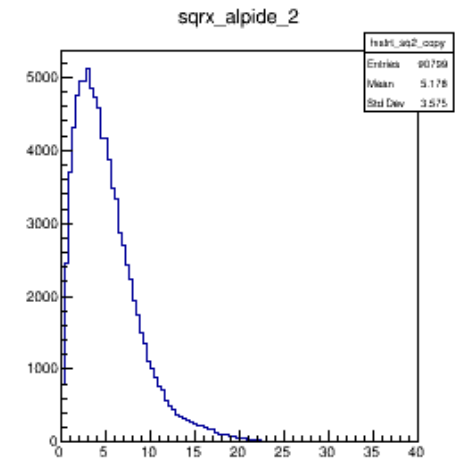
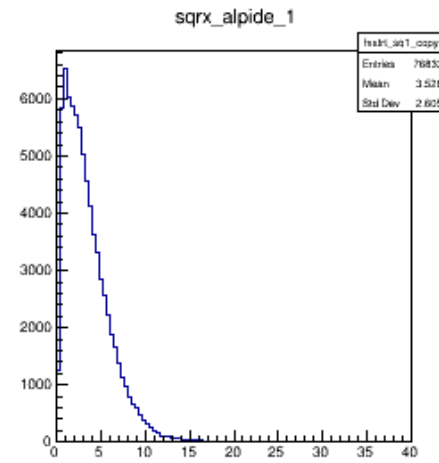
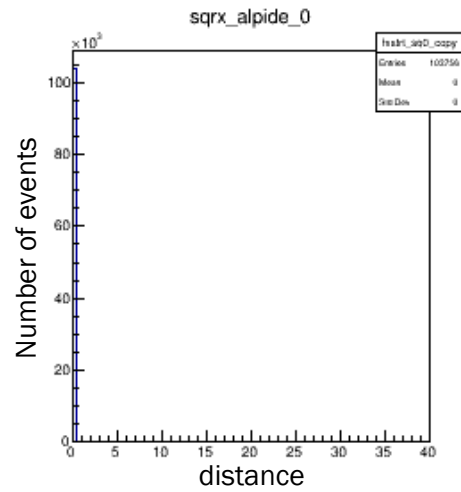
# ANALYSIS

- ▶ Alignment
- ▶ Clusters
- ▶ “Molière radius
- ▶ Number of clusters
- ▶ 3D model



# ANALYSIS

- ▶ Alignment
- ▶ Clusters
- ▶ Molière radius
- ▶ Number of clusters
- ▶ 3D model

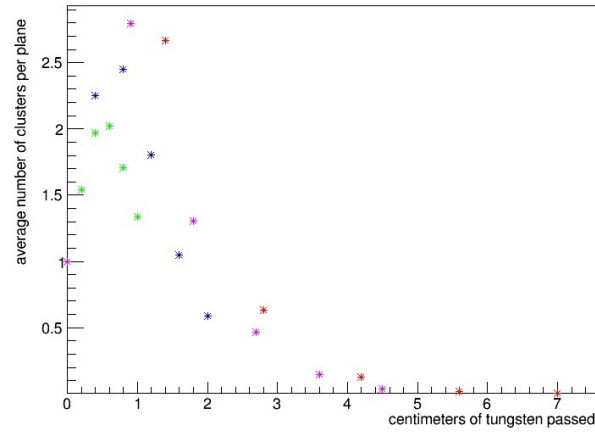


# ANALYSIS

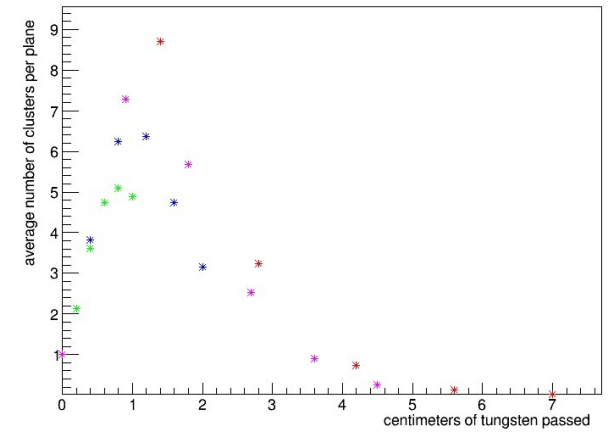
- ▶ Alignment
- ▶ Clusters
- ▶ Molière radius
- ▶ Number of clusters
- ▶ 3D model

Green 2mm  
Blue 4mm  
Pink 9mm  
Red 14mm

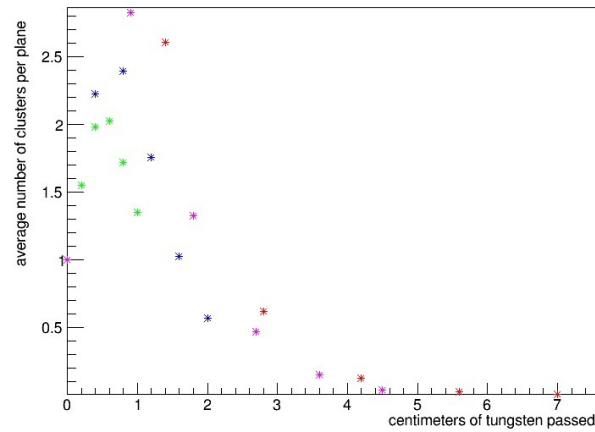
0.5 GeV electrons



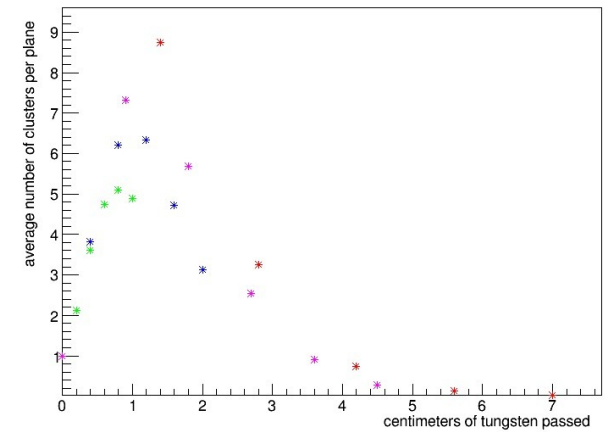
2 GeV electrons



0.5 GeV positrons



2 GeV positrons



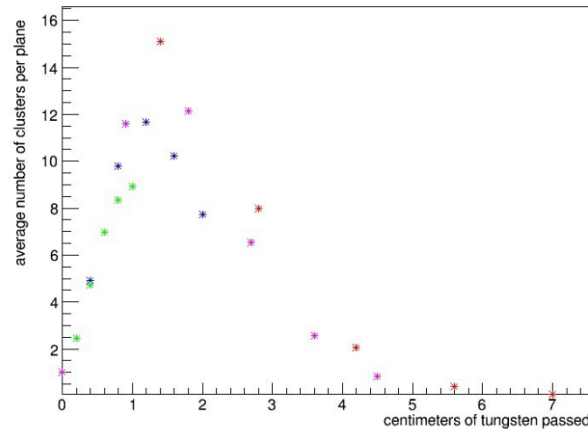


# ANALYSIS

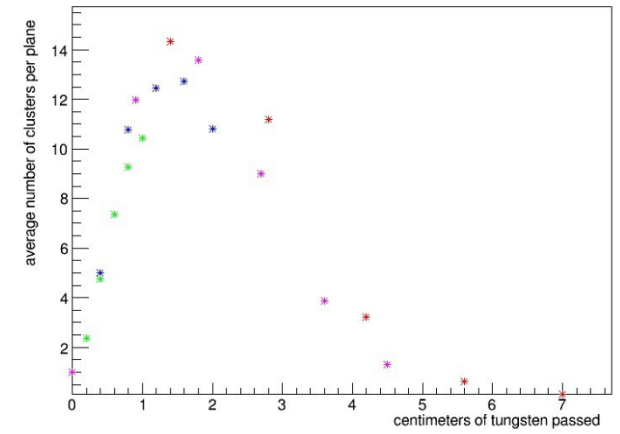
- ▶ Alignment
- ▶ Clusters
- ▶ Molière radius
- ▶ Number of clusters
- ▶ 3D model

- Green 2mm
- Blue 4mm
- Pink 9mm
- Red 14mm

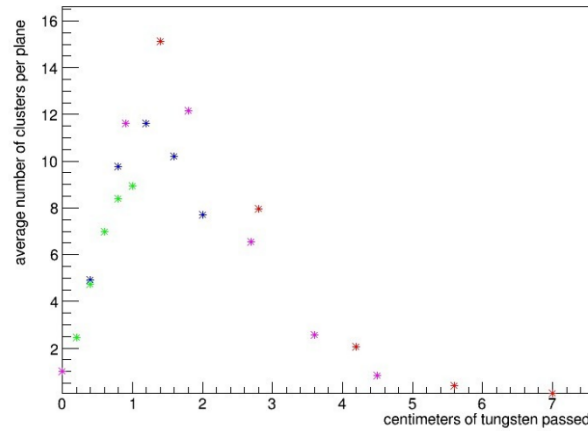
4 GeV electrons



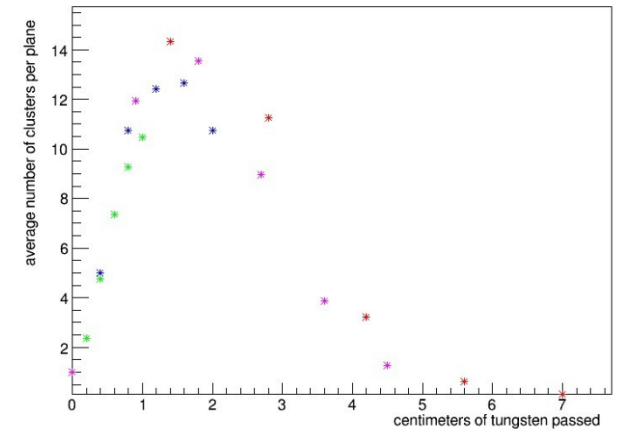
6 GeV electrons



4 GeV positrons

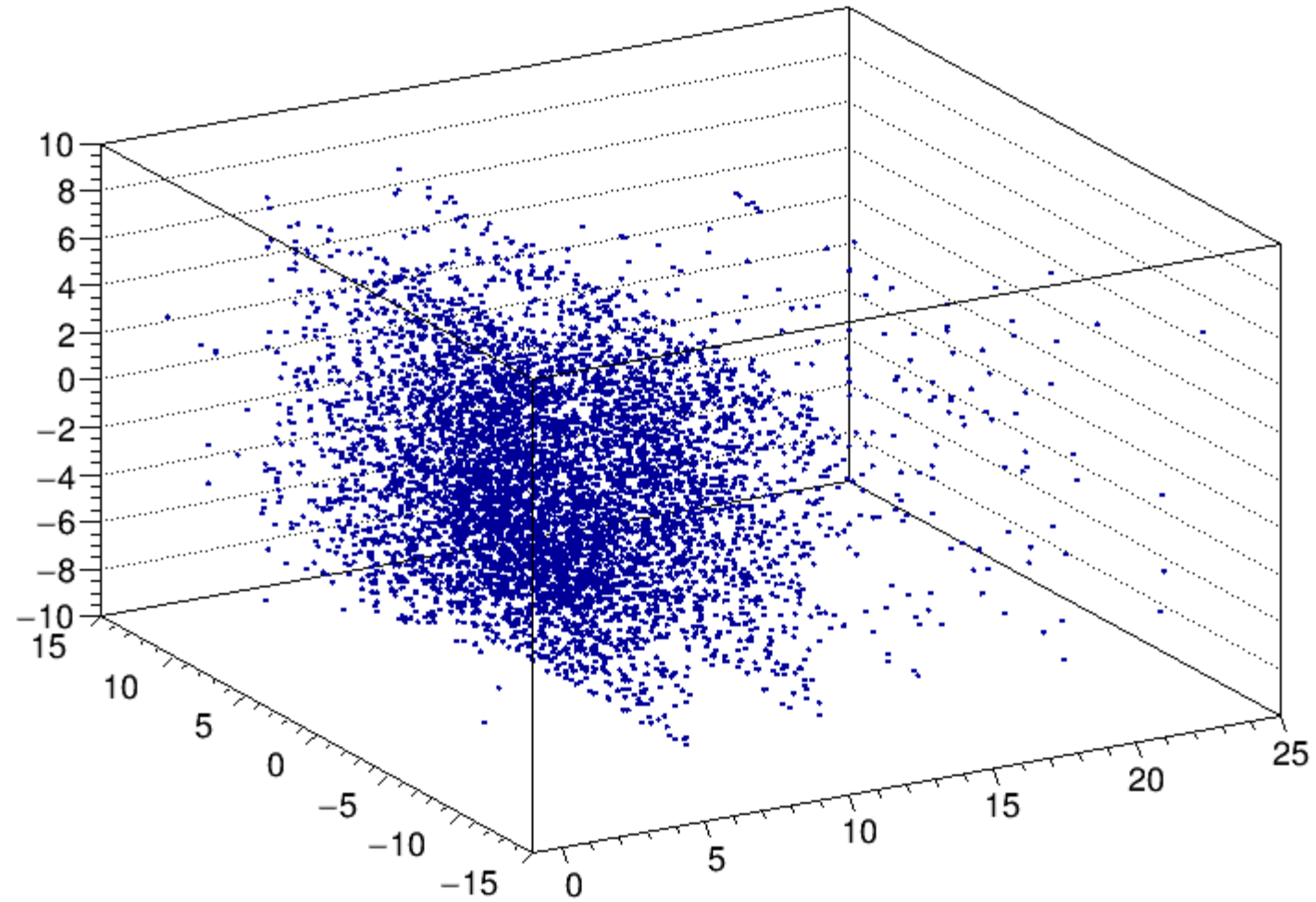


6 GeV positrons



# ANALYSIS

- ▶ Alignment
- ▶ Clusters
- ▶ Molière radius
- ▶ Number of clusters
- ▶ 3D model



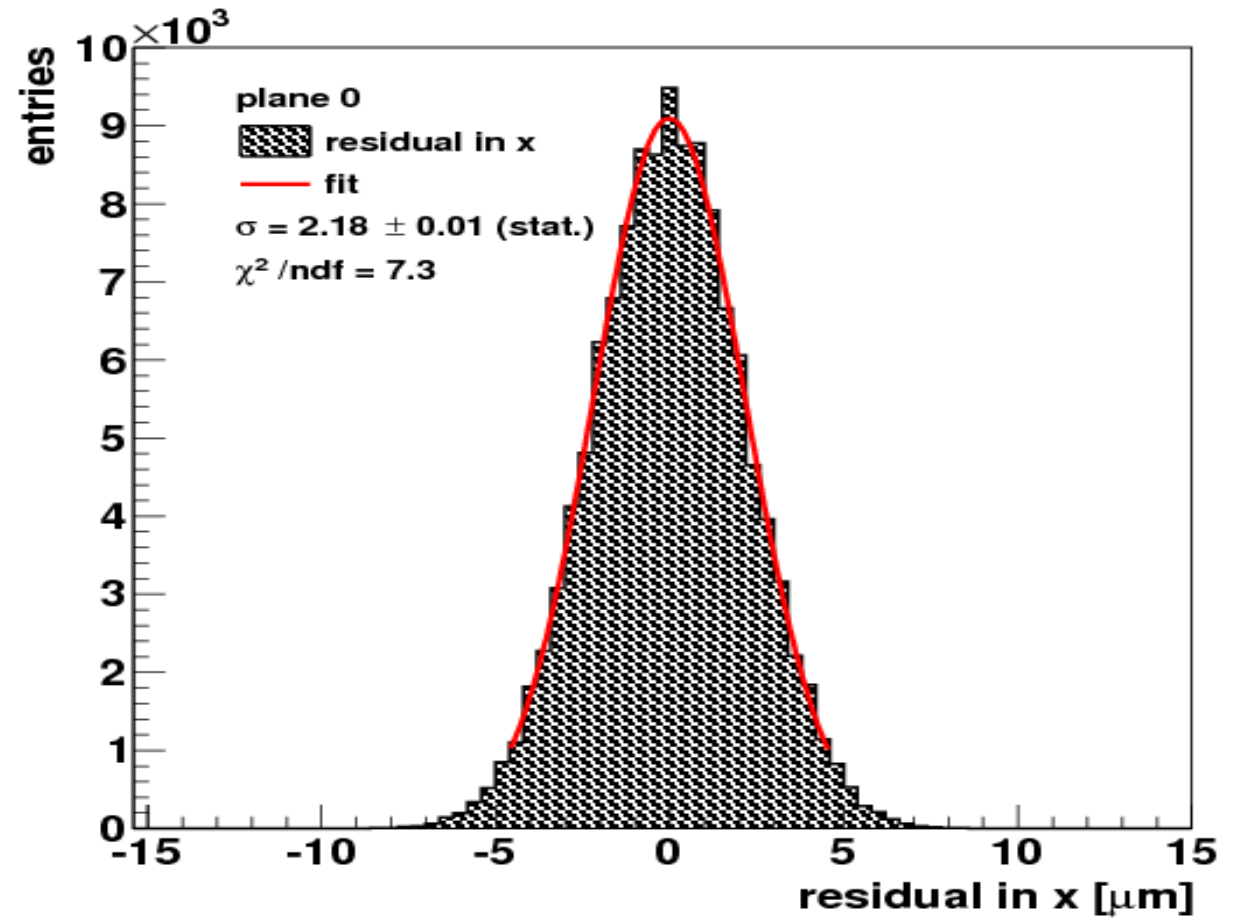
# DISCUSSION

- ▶ Detector size
- ▶ Scattering
- ▶ Amount of events
- ▶ Antimatter as absorber



# NEXT STEP

- ▶ Further analysing of our data
- ▶ Fitting
- ▶ Tracking
- ▶ Comparing
- ▶ Conclusion



# QUESTIONS?



