Study of Cosmic-Ray Induced Background for COMET

Weichao Yao
久野研·山中研合同年末発表会
2017/12/28

Outline

- Introduce to CLFV in COMET, and the background study.
- Cosmic-rays study and method
- The simulation about cosmic-rays
- The efficiency of cosmic-rays simulation
- Summary

Lepton Flavor Violation

In particle physics, Lagrangian has many terms appearing in the Standard Model (features the global symmetry group). Here consider the term associated with the conservation of baryon number B and the three lepton number L, as the following:

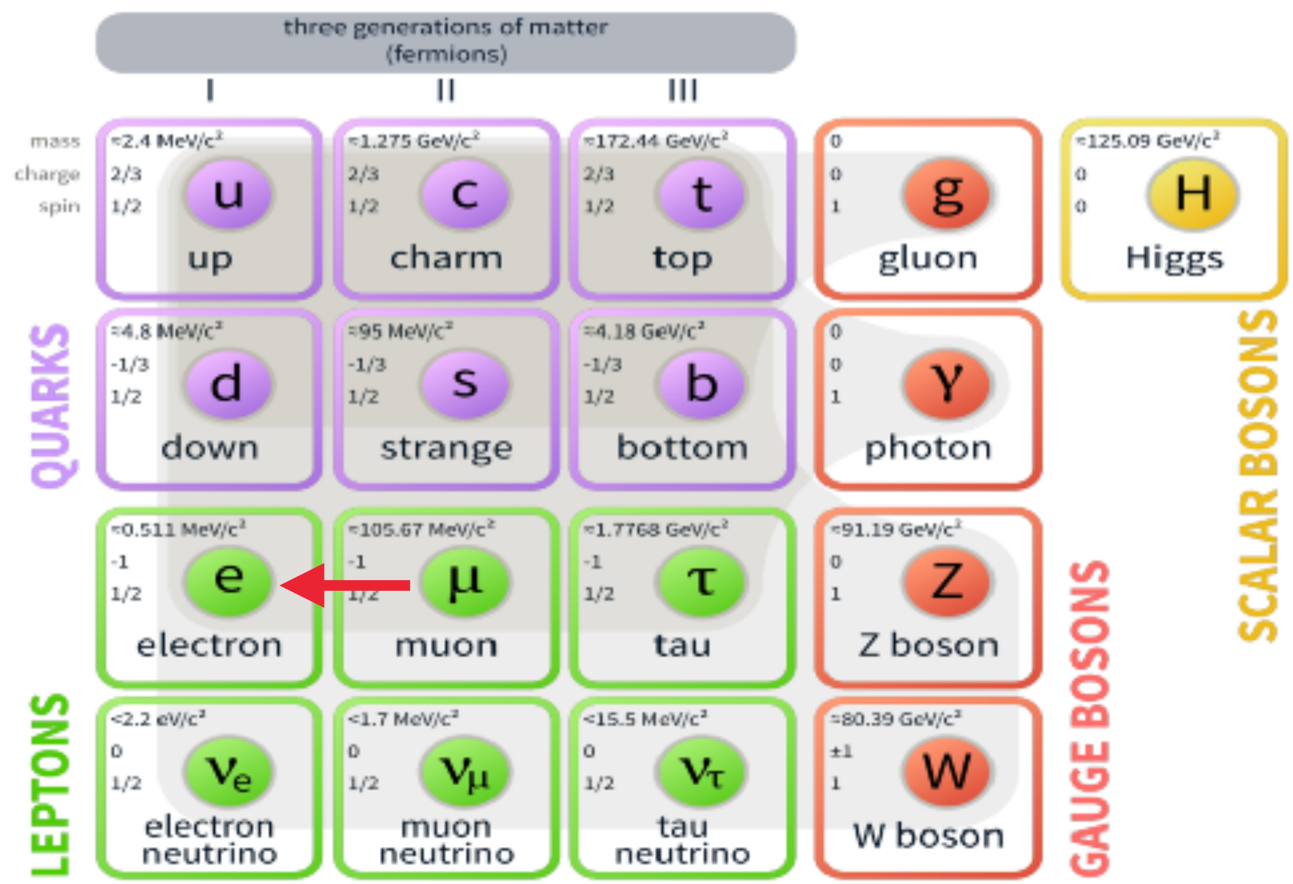
$$U(1)_B \times U(1)_{L_e} \times U(1)_{L_\mu} \times U(1)_{L_\tau}$$

$$\downarrow \quad L = L_\tau + L_\mu + L_e$$

$$U(1)_{B+L} \times U(1)_{B-L} \times U(1)_{L_\mu - L_\tau} \times U(1)_{L_\tau + L_\mu - 2L_e}$$

broken

not conserved



The SM with non-zero neutrino masses and mixing would induce that

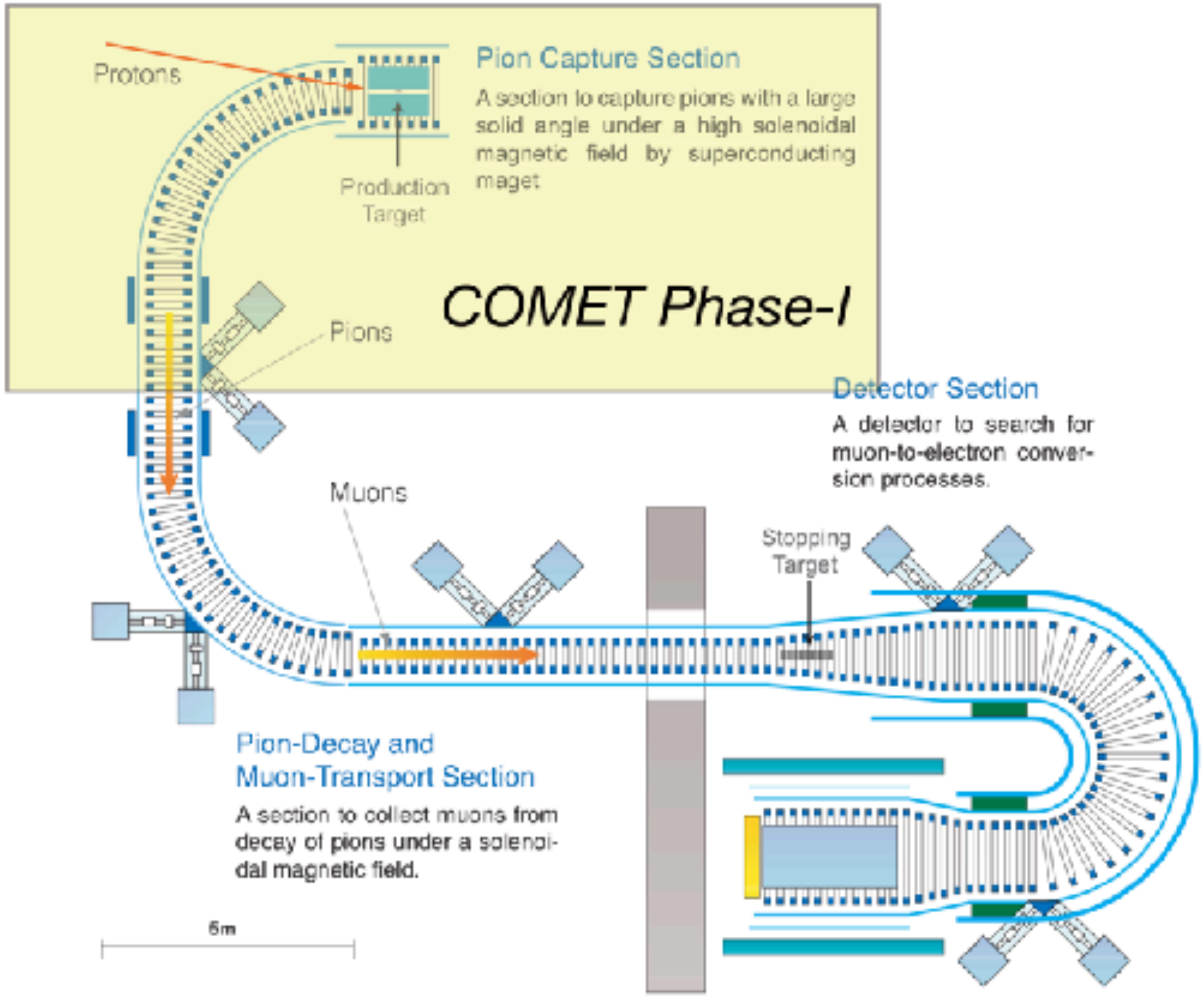
$$\frac{\Gamma(\ell_\alpha \to \ell_\beta \gamma)}{\Gamma(\ell_\alpha \to \ell_\beta \nu_\alpha \bar{\nu}_\beta)} \simeq \frac{3\alpha_{\rm EM}}{32\pi} \left| \sum_{j=2,3} U_{\alpha j} \frac{\Delta m^2_{j1}}{M_W^2} U^\dagger_{j\beta} \right|^2$$

The value is smaller than 10^{-54}

The any observation of CLFV would imply physics beyond the SM. Now more experiment focus on rare decays rather than collider signatures, such as COMET, Mu2e, MEG-II…

COMET experiment

- Research purpose:
- μ-e conversion: Coherent neutrinoless transition of moon to electron in a muonic atom
- The signal sensitivity:
- Phase-I: 3.1×10^{-15} (100 times better than the current experimental limit)
- Phase-II: 2.7×10^{-17}.



Challenging

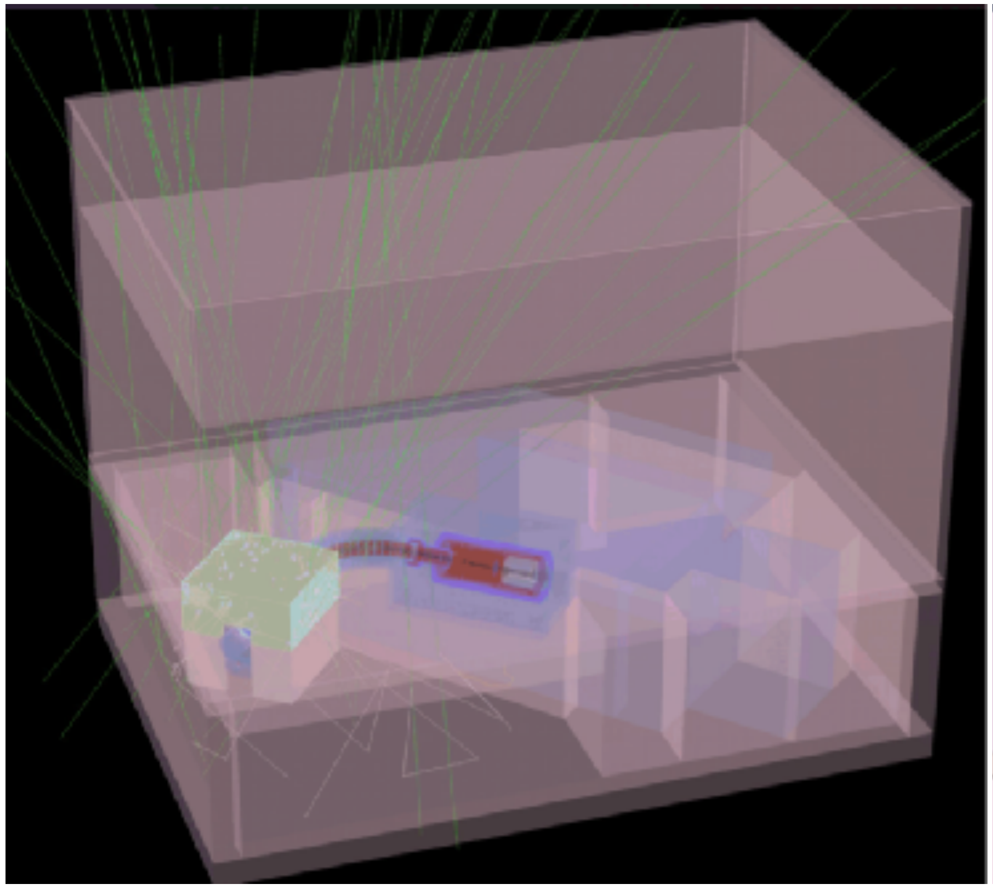
In order to realize the high single event sensitivity (SES), the different source of background should be strictly limited. The Cosmic-ray is one of the most impact. This work is to simulate the process of the cosmic-rays induced background, and based on the results, providing feasible solution.

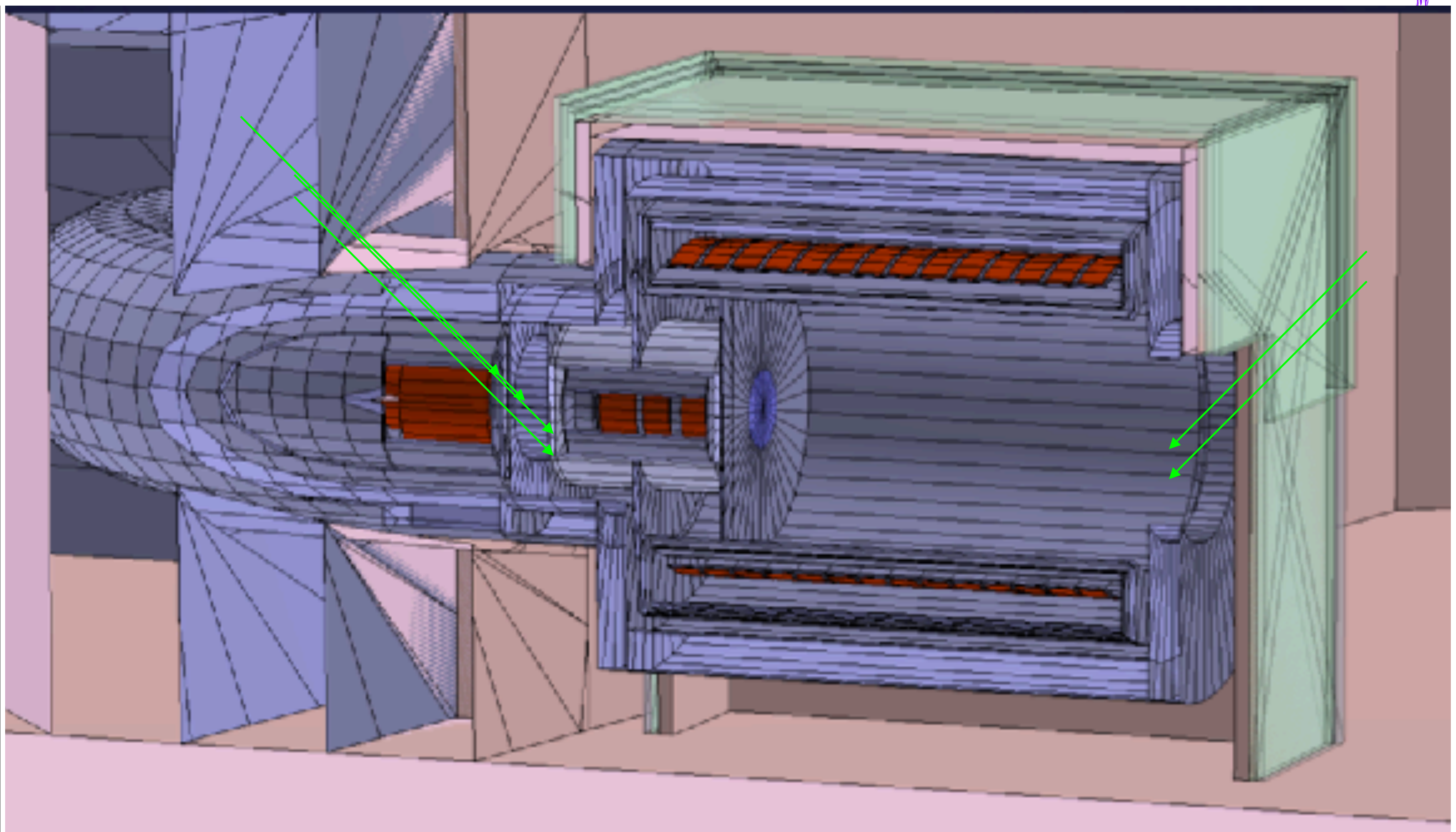
Type	Background	Estimated events
Physics	Muon decay in orbit	0.01
	Radiative muon capture	0.0019
	Neutron emission after muon capture	< 0.001
	Charged particle emission after muon capture	< 0.001
Prompt Beam	* Beam electrons	
	* Muon decay in flight	
	* Pion decay in flight	
	* Other beam particles	
	All (*) Combined	≤ 0.0038
	Radiative pion capture	0.0028
	Neutrons	$\sim 10^{-9}$
Delayed Beam	Beam electrons	~ 0
	Muon decay in flight	~ 0
	Pion decay in flight	~ 0
	Radiative pion capture	~ 0
	Anti-proton induced backgrounds	0.0012
Others	Cosmic rays†	< 0.01
Total		0.032

† This estimate is currently limited by computing resources.

By COMET TDR

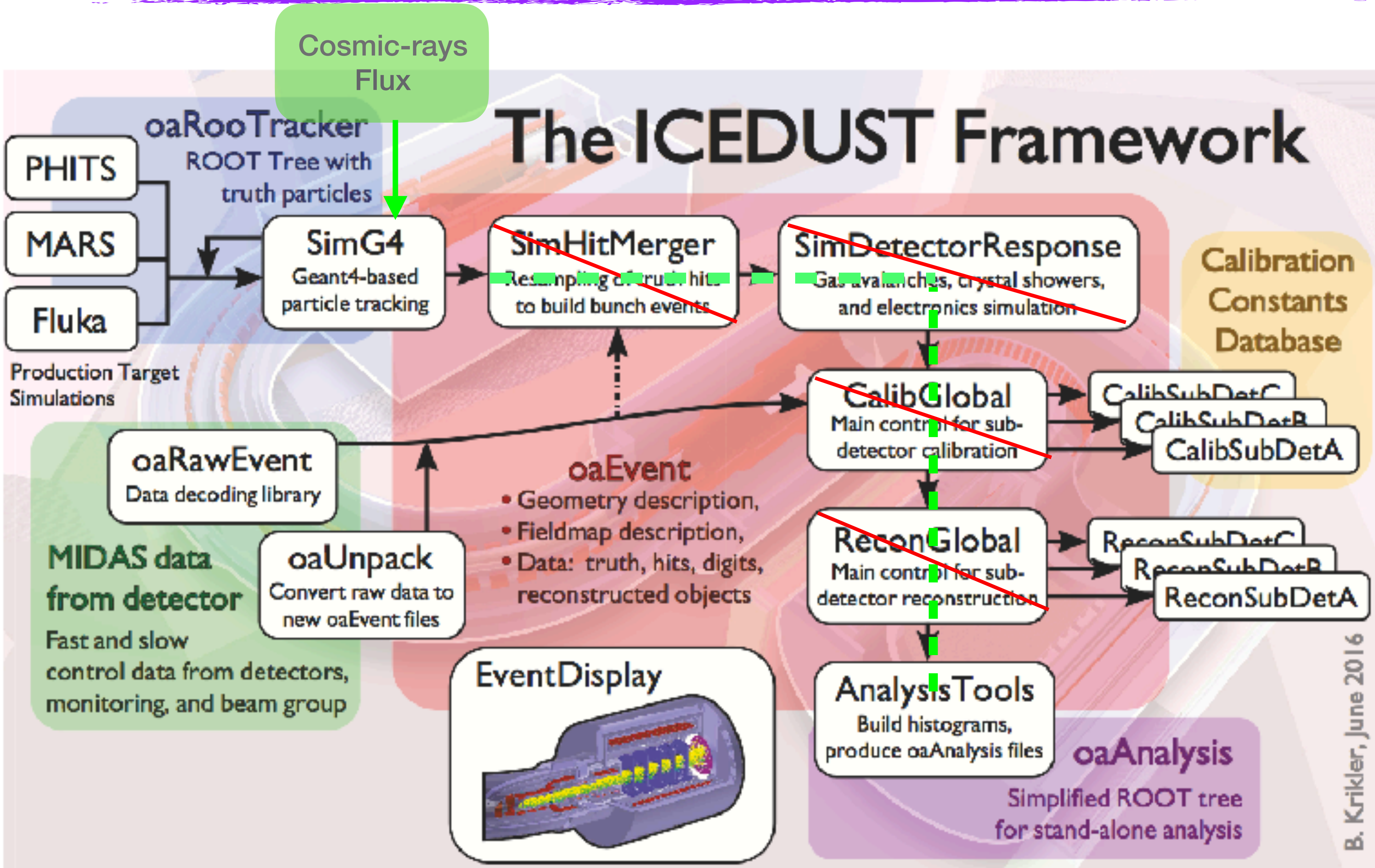
Cosmic-rays





Display that cosmic-ray pass through the experiment hall . There are two situation: 1. cosmic-rays produced at the whole experimental hall; 2. cosmic-rays produced in the focused area on the bridge solenoid. The cosmic-rays veto has been designed, based on the preliminary simulation, which could effectively reject the impact of the cosmic-rays. The further simulation also need to do.

Method



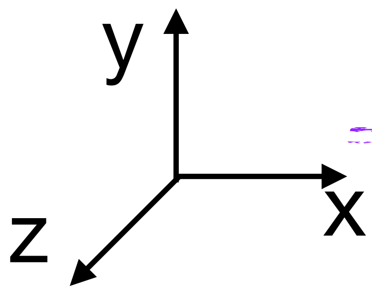
The main program: C++, python

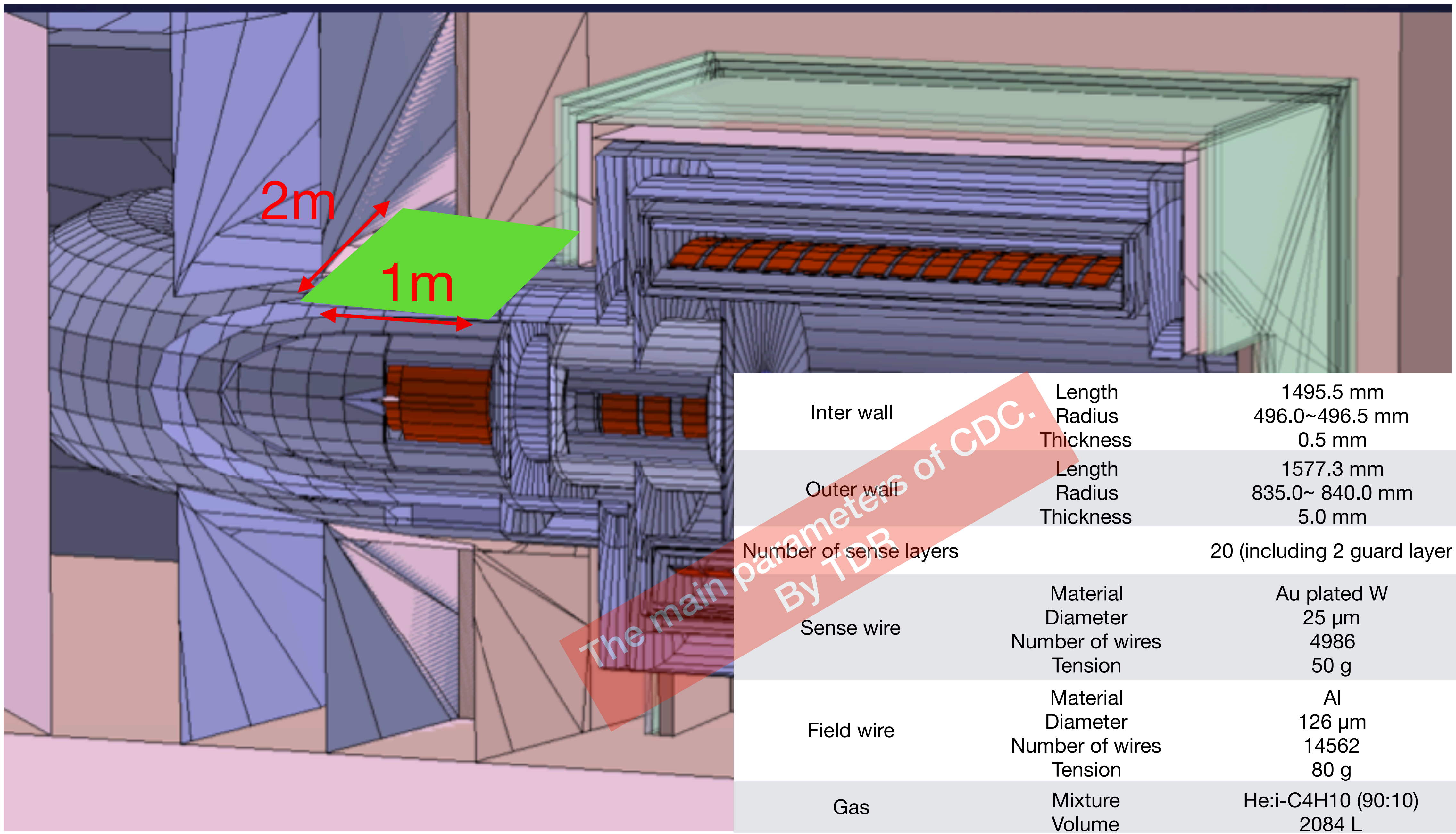
What has be done

In COMET, cosmic-rays veto already has been designed and discussed with high efficiency of 10^{-4} (will be improved in the future) , but which could not cover all the area. Cosmic-rays can pass through these areas or generate the secondary particles enter into the CyDet, which might create fake signal (≃104MeV electron).

Here using the ICEDUST to simulate the cosmic-ray induced background. The vertical flux of cosmic muons are based on a CERN data source, which contains 23 million $\mu^{\pm}$ events. The primary particle, which were used to simulate, were generated at a 2m×1m plane

Geometry

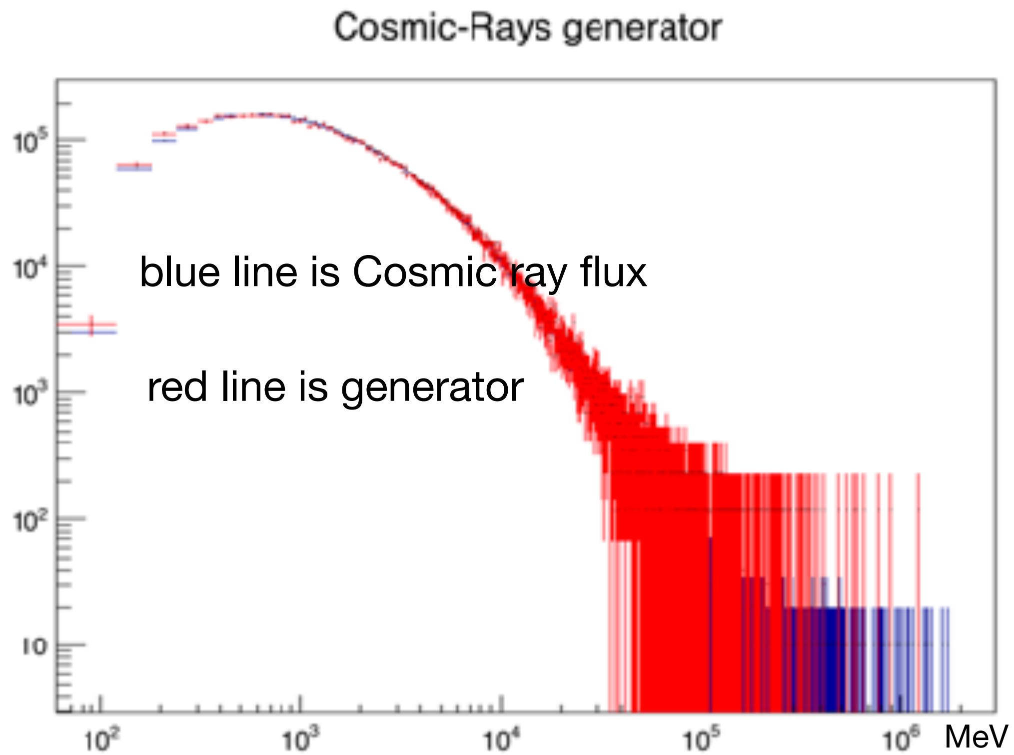


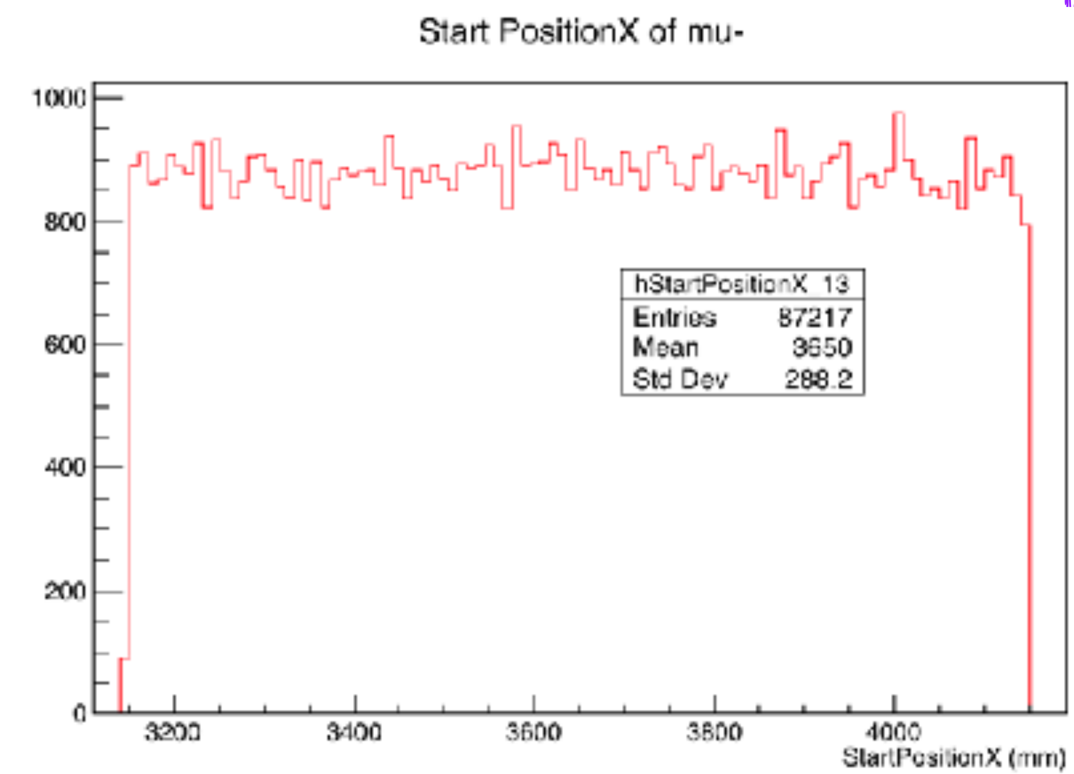


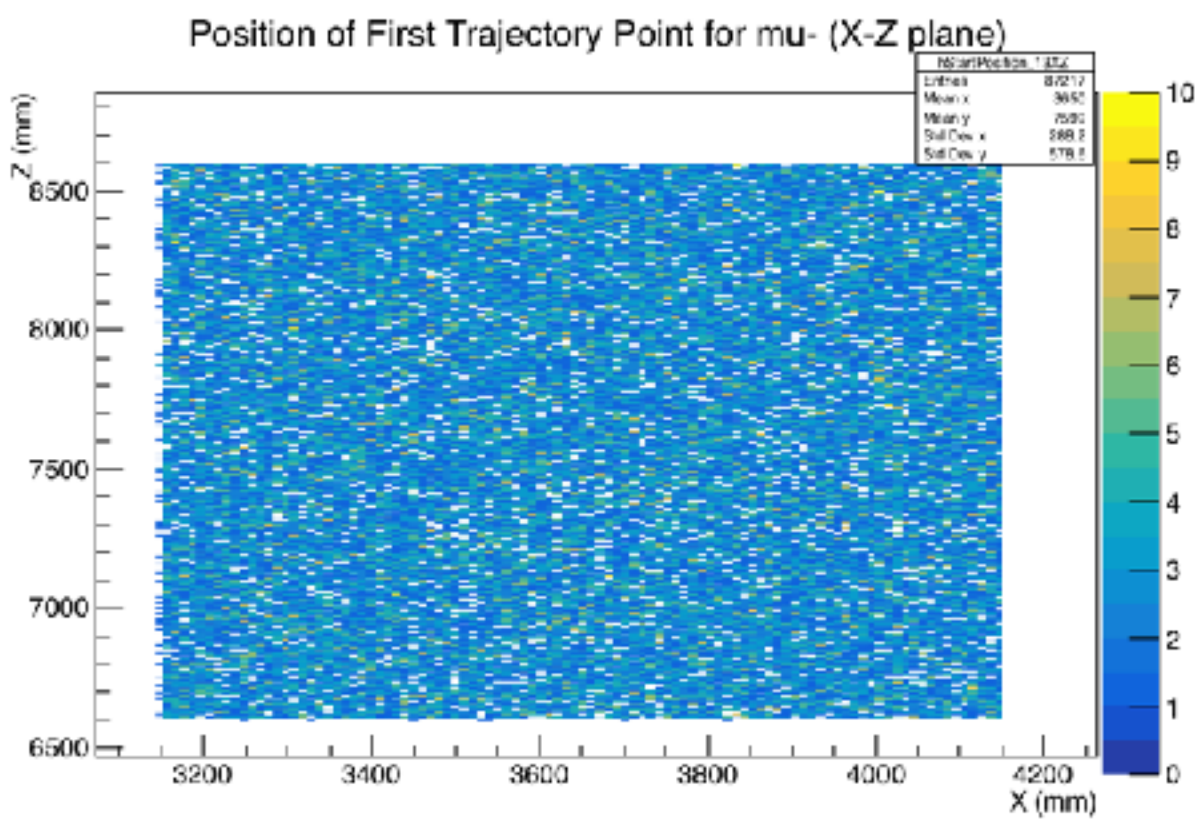
The main parameters of CDC.
By TDR

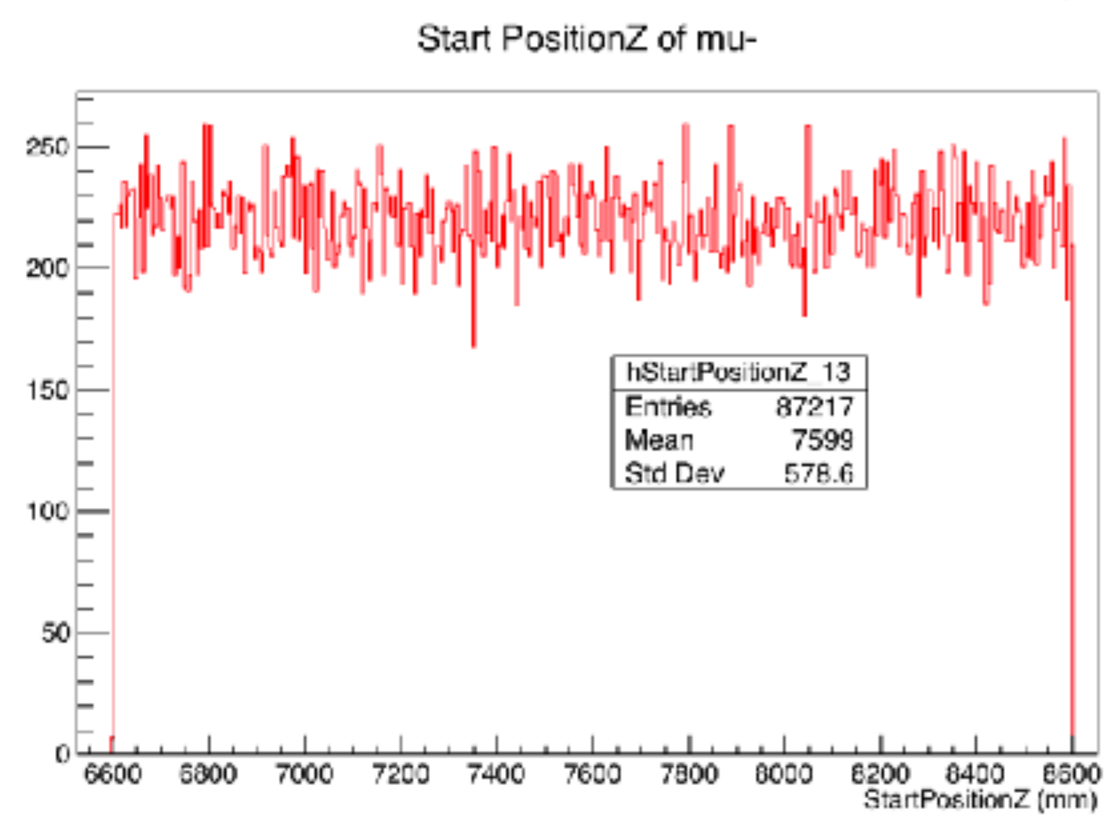
Inter wall	Length Radius Thickness	1495.5 mm 496.0~496.5 mm 0.5 mm
Outer wall	Length Radius Thickness	1577.3 mm 835.0~ 840.0 mm 5.0 mm
Number of sense layers		20 (including 2 guard layer
Sense wire	Material Diameter Number of wires Tension	Au plated W 25 μm 4986 50 g
Field wire	Material Diameter Number of wires Tension	Al 126 μm 14562 80 g
Gas	Mixture Volume	He:i-C4H10 (90:10) 2084 L

Distribution of cosmic-rays generated





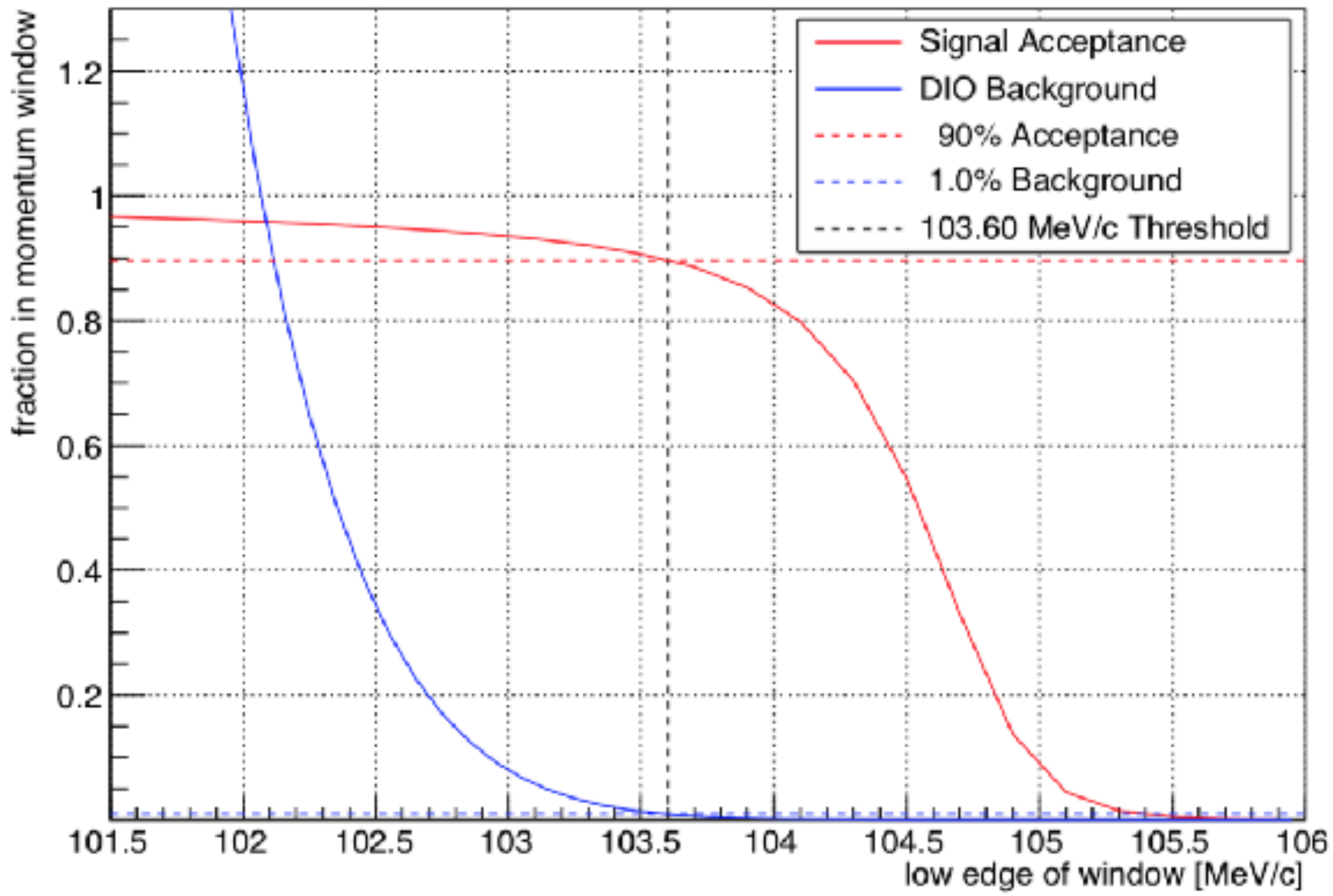




Momentum threshold by TDR

For muon intrinsic physics, the fate of the bound μ^- is dominated by two (Standard Model) allowed processed: muon decays in orbit (DIO), and nuclear muon capture (NMC)

Momentum window can be used to reduce contaminations from background events such as DIO electron



The vertical scale is integrated fractions μ-e conversion signals, it is normalized so represent one event at a branching ratio of $B(\mu N \rightarrow eN)=3.1\times10^{-15}$. the momentum window is set to be 103.6MeV/c ~106.0 MeV

Events selected

- For candidate tracks, Several requirements are satisfied.

	single turn tracks	multiple-turn tracks	single + multiple
Geometrical	0.16	0.10	0.26
NL5	0.78	0.98	
NHIT + NDF30 + χ^2 + CL3	0.91	0.73	
total	0.11	0.072	0.18

- NHIT: at least one whole turn in the CDC to be fitted is required
- NDF30: number of degree of freedom greater than 30
- CL3: hits in more than 3 consecutive layers at both entrances and exit of tracks
- normalized χ2(statistical measure) less than two (χ2)

For event selection, other requirements are shown

Item	Value	Setting
Momentum window	0.90	103.6 MeV/c <P<106 MeV/c
Timing window	0.3	700ns<t<1170ns

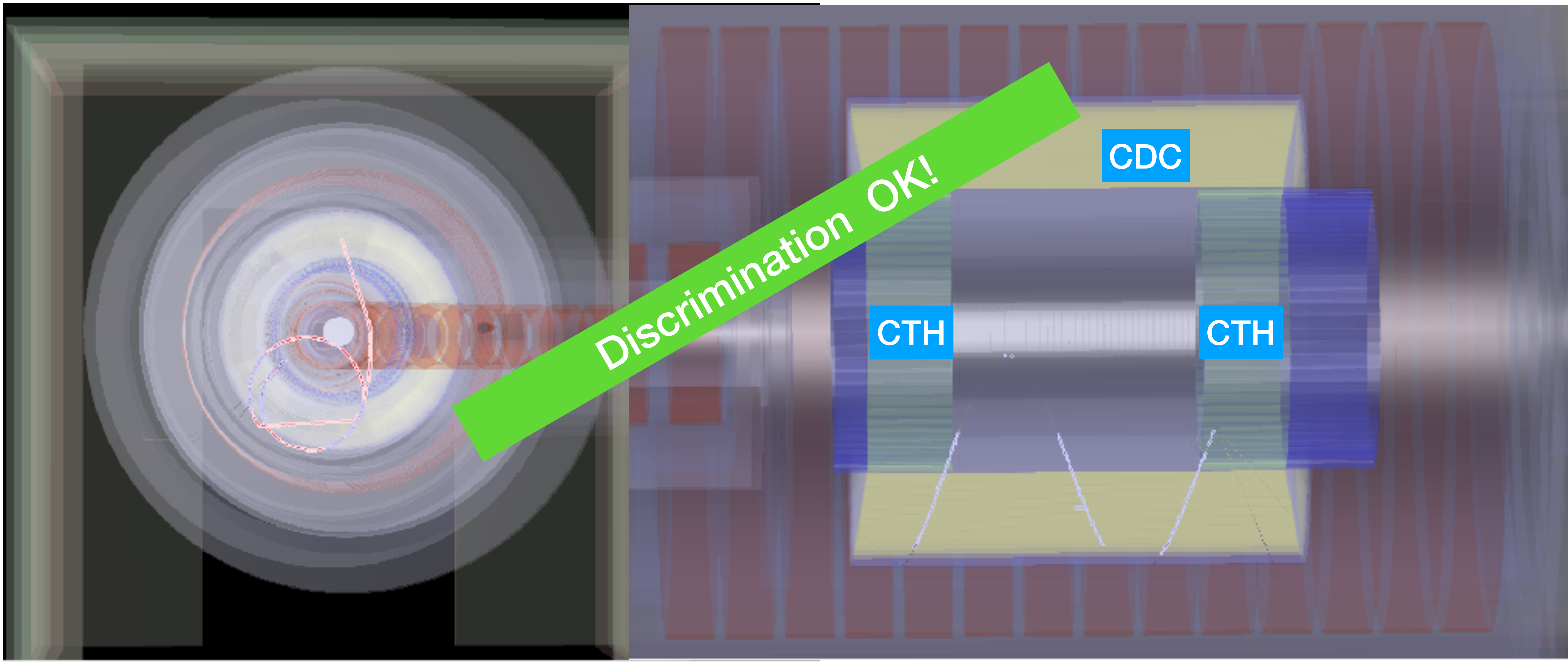
Run 13.6 million events (10 hours)

There are 9 electrons of 83~120 MeV/c reach CDC and CTH. One of them has momentum close the threshold.

CDC: The Cylindrical Drift Chamber
CTH: The CyDet trigger hodoscopes

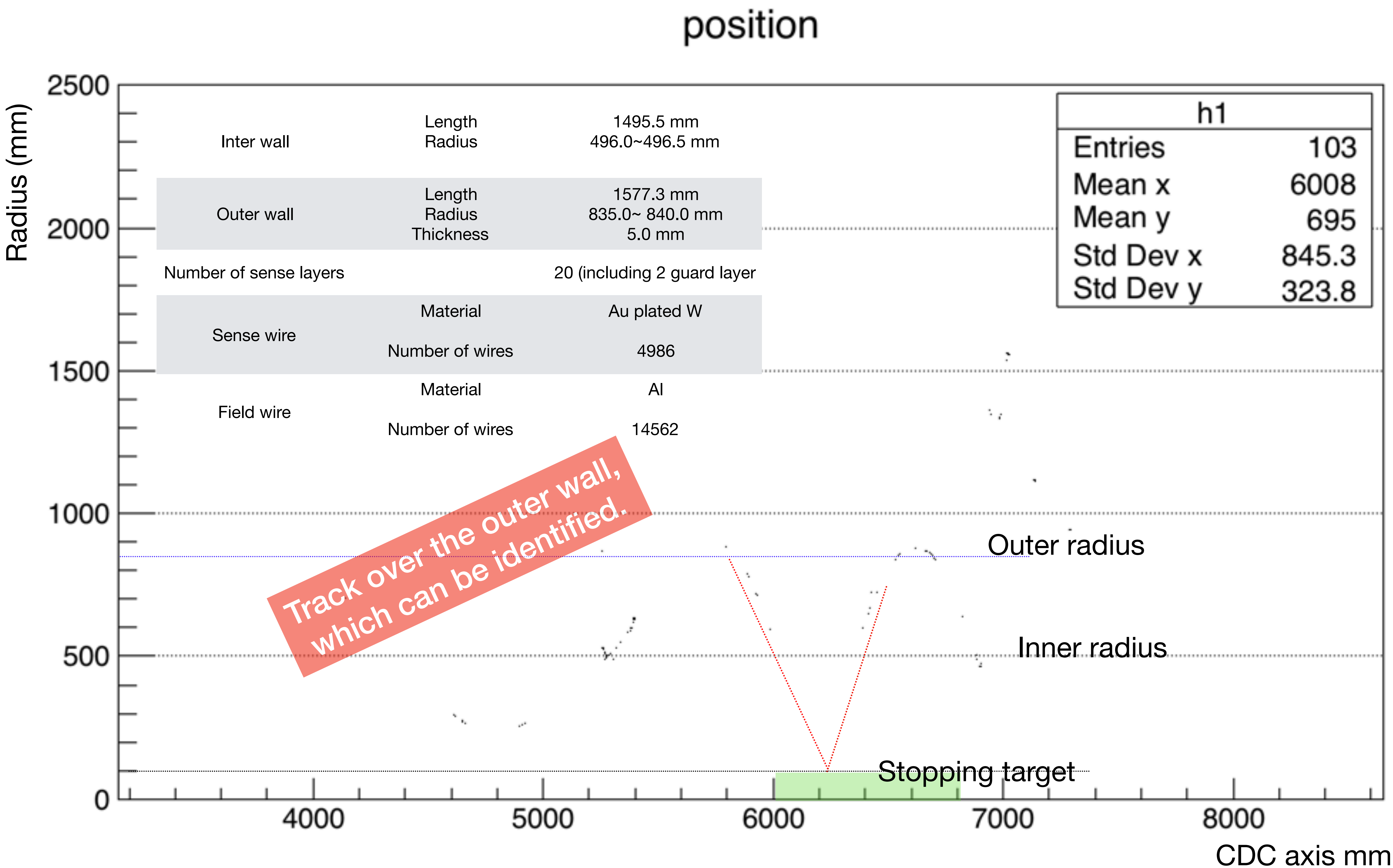
	Event_ID reach CDC and CTH	PID	Momentum
0	8472	mu	
1	148413	e	89 MeV/c
2	34886	mu	
3	170740	e	107 MeV/c
4	179903	211	
5	150328	e+	112 MeV/c
6	160539	e	92 MeV/c
7	86159	mu	
8	106089	mu	
9	141634	e	83 MeV/c
10	190365	mu+	105 MeV @CTH
11	164513	mu+	
12	114091	mu	
13	169365	mu+	
14	22534	e	96 MeV/c
15	27497	mu+	
16	107621	mu	
17	111083	e+	95 MeV/c
18	125759	mu+	
19	3494	e	116 MeV/c
20	195342	e	120 MeV/c

#190365 muon 127MeV@CDC, 105MeV@CTH



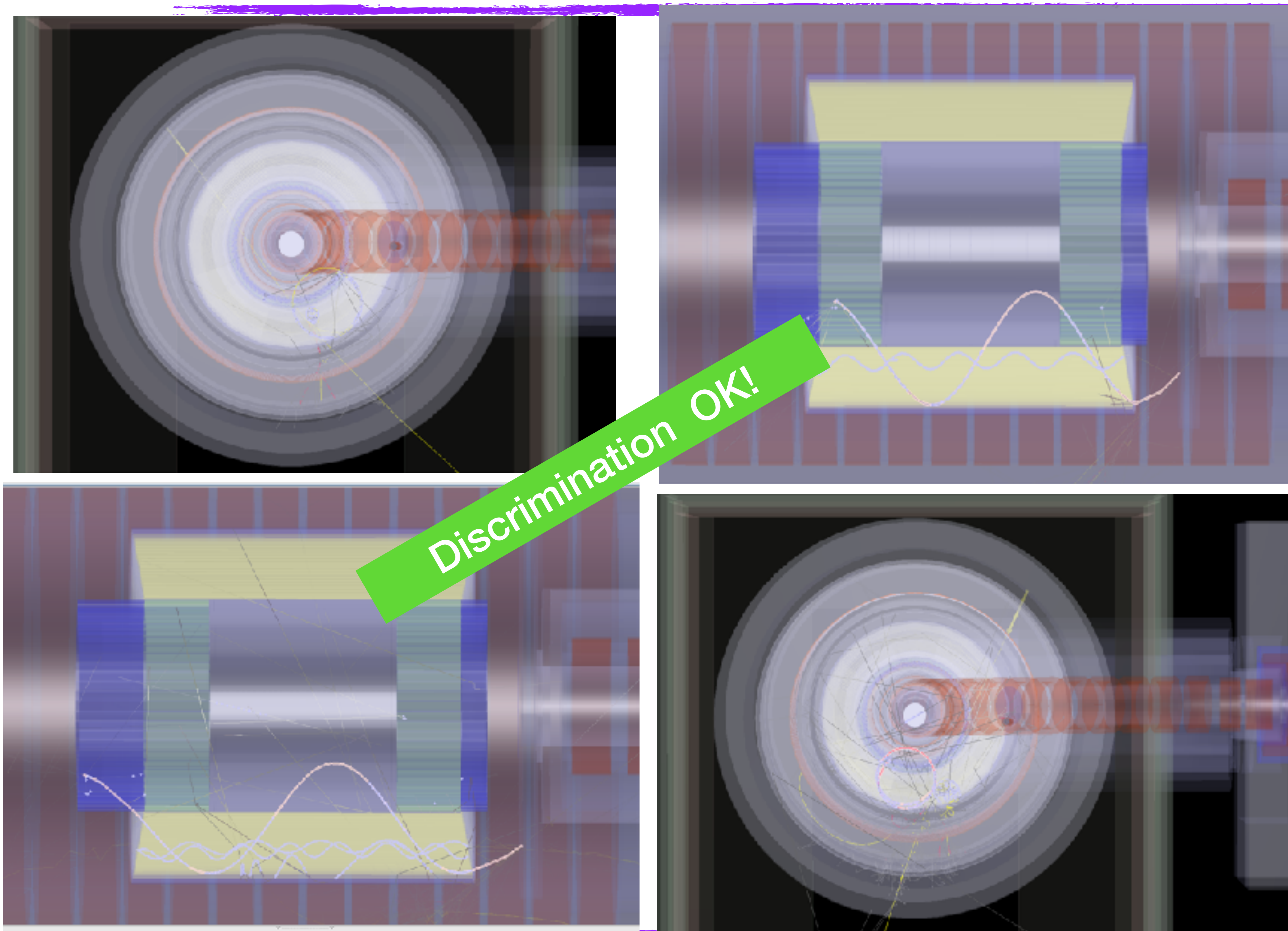
- Note: Cosmic-ray muon enter the detector, and could be misidentified as an electron

Track check

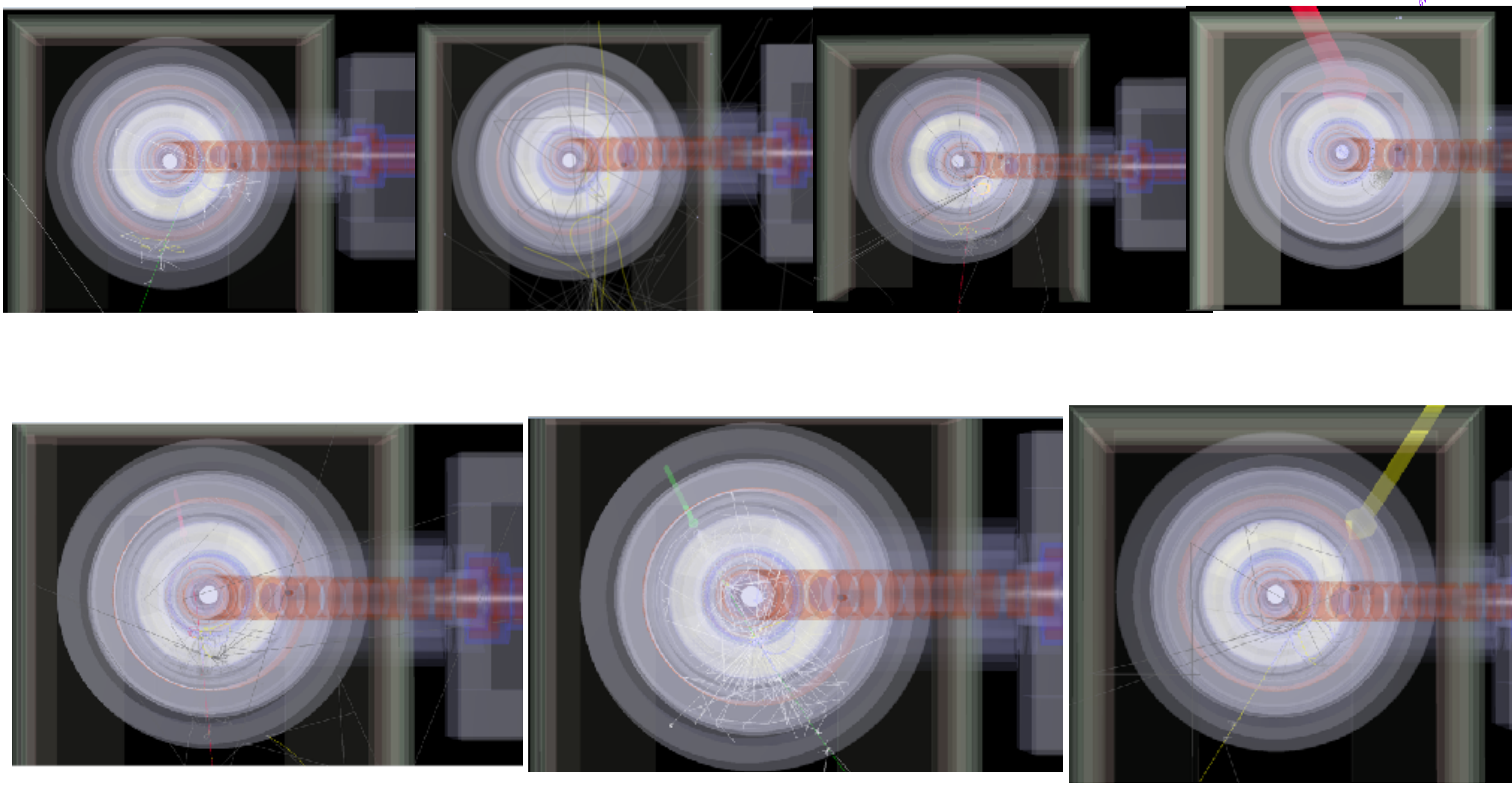


Inter wall	Length Radius	1495.5 mm 496.0~496.5 mm
Outer wall	Length Radius Thickness	1577.3 mm 835.0~ 840.0 mm 5.0 mm
Number of sense layers		20 (including 2 guard layer
Sense wire	Material Number of wires	Au plated W 4986
Field wire	Material Number of wires	Al 14562

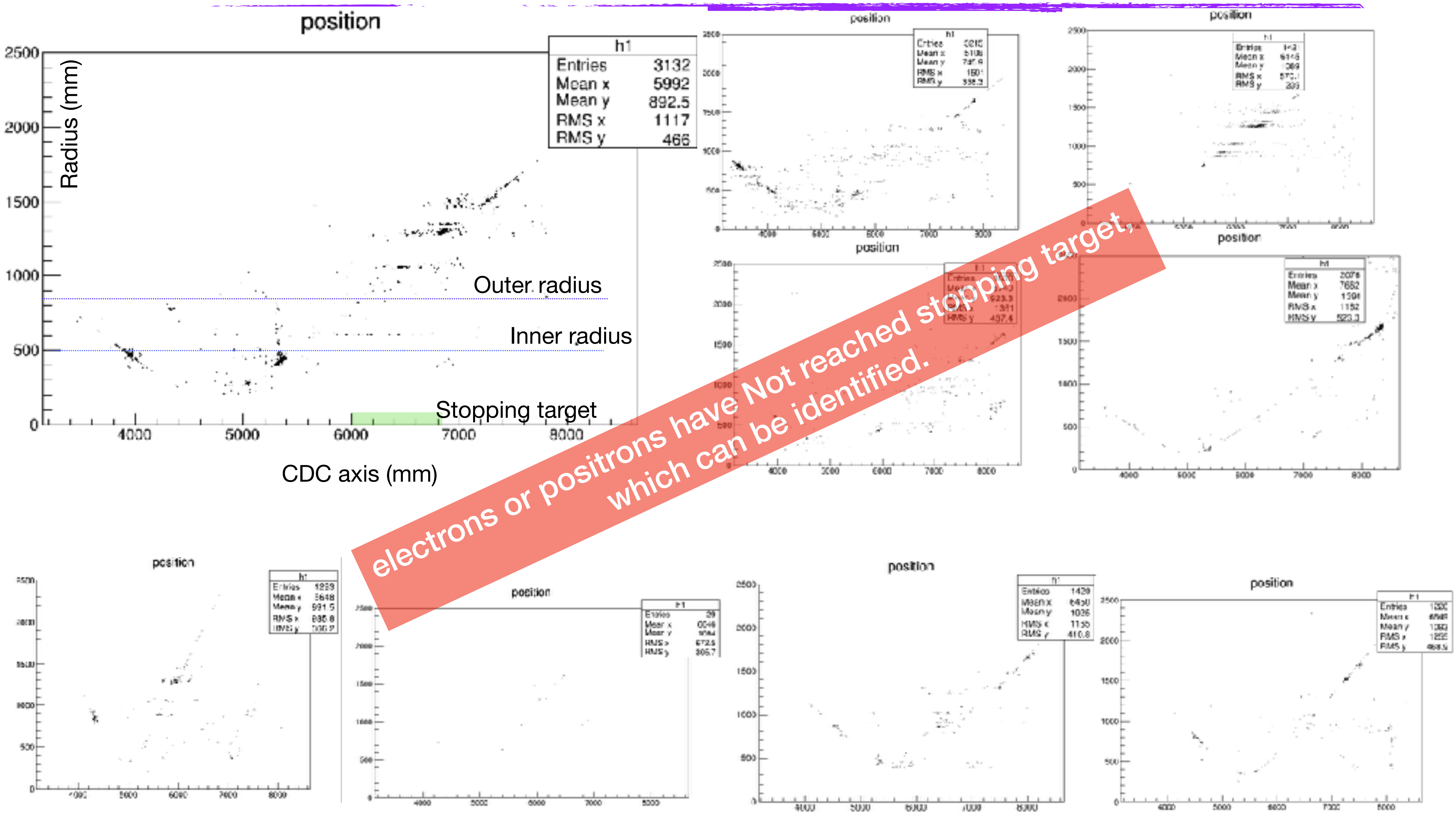
#22534 and #111083 electrons



Other electrons, No impact



Electrons Track check

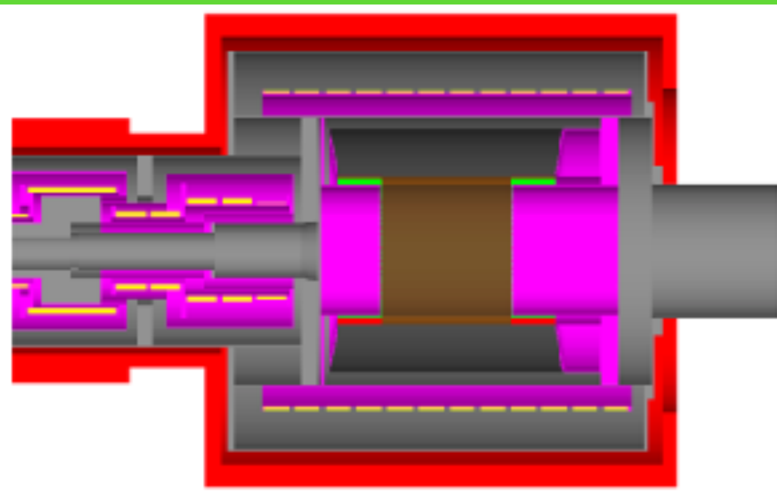


electrons or positrons have Not reached stopping target, which can be identified.

Cosmic-rays induced background

Based on current simulation, about 13.6 million $\mu^{\pm}$ events were generated over a 1m×2m plane. Among this sample, there were 20 events containing close 100 MeV electrons and muons, which could be identified (the electrons and positrons have not reached stopping target and over outer wall of the CDC, the muon's track over outer wall of the CDC) , but it is just corresponding to about 10 hours (for COMET Phase-I will be running about 146 days)

CRV cover bridge solenoid and detector solenoid

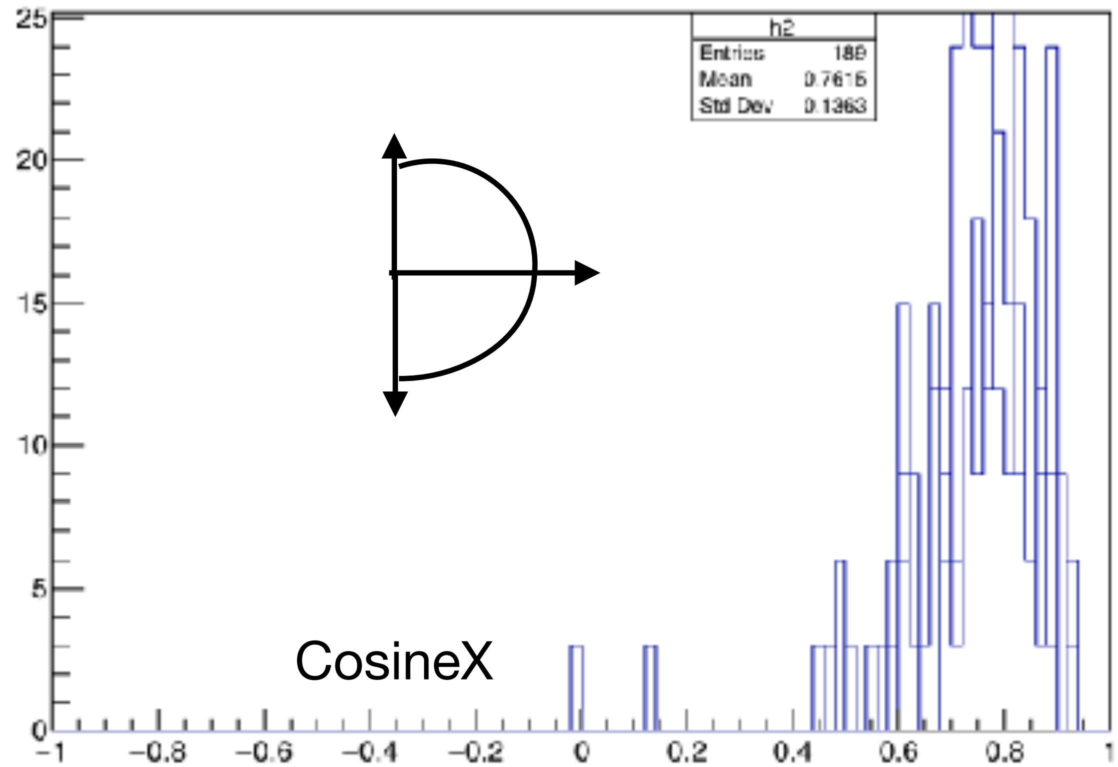


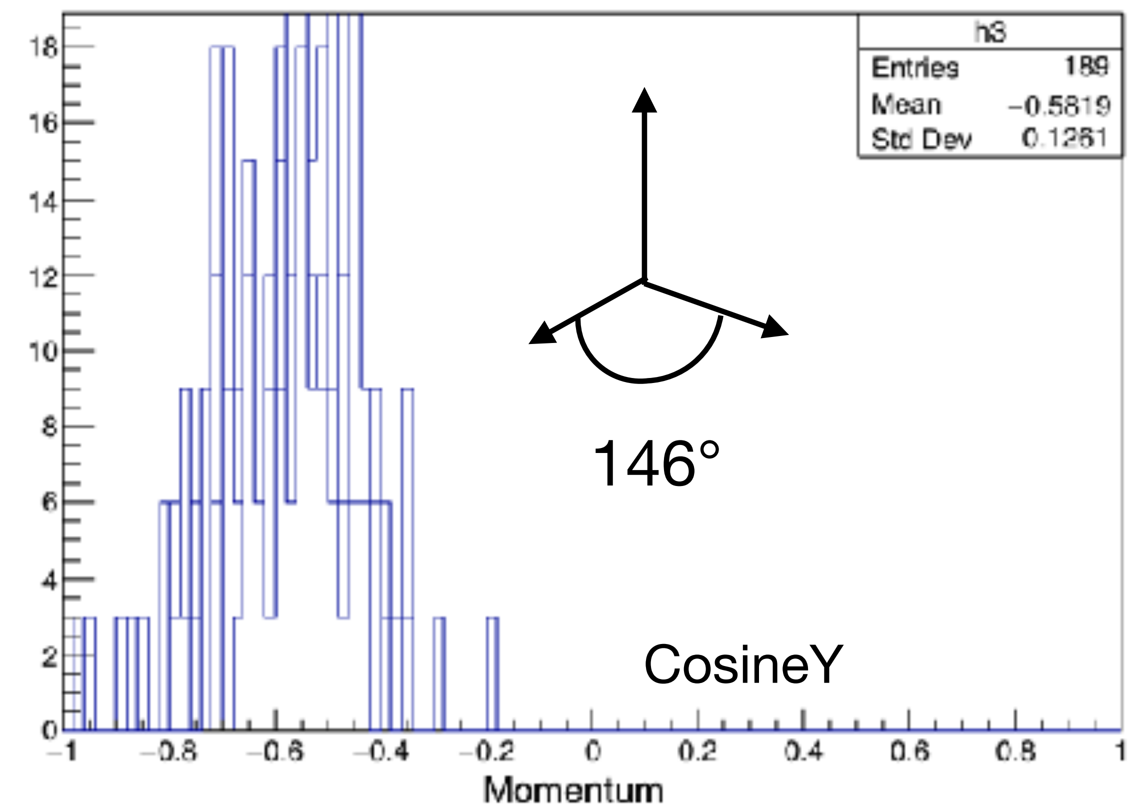
To veto and eliminate cosmic-ray induced background, the Cosmic Ray Veto (CRV) system will be installed. The CRV will work with high efficiency of 10^{-4}.Further study will be continue, there are two processes need to research: 1. Running enough events to gain the estimation of contamination from Cosmic-rays. 2. Discrimination efficiency of fake signal based on the track selected method;

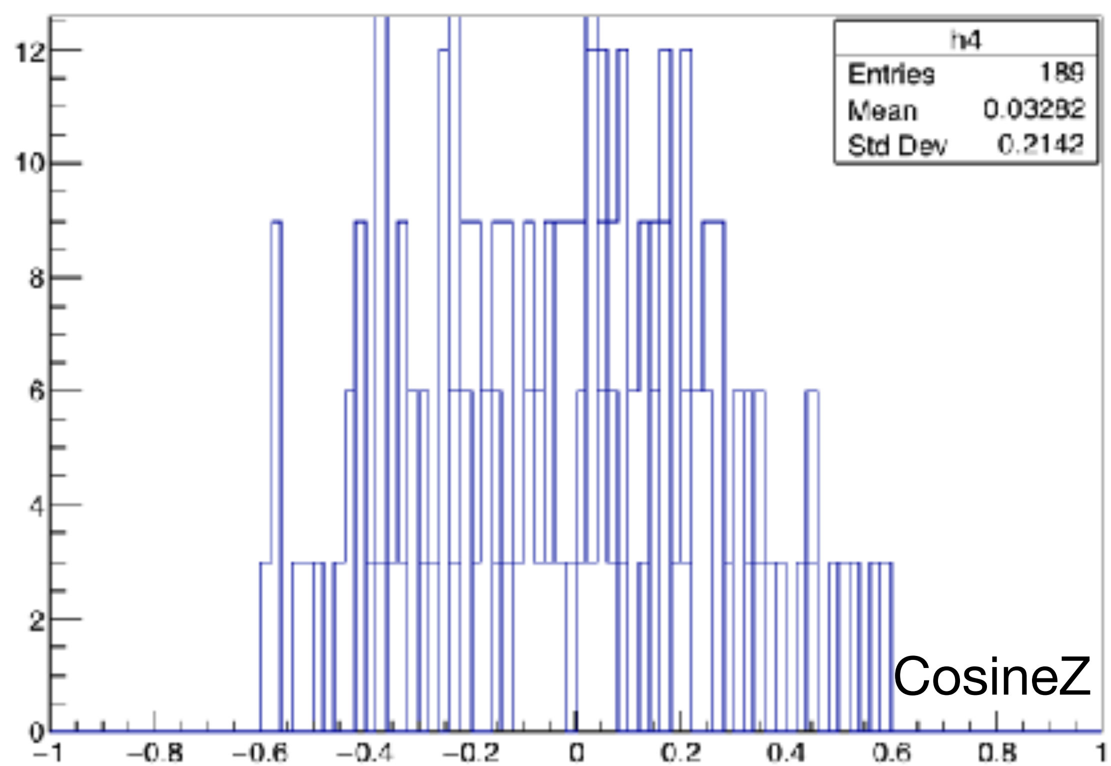
Simulation efficiency

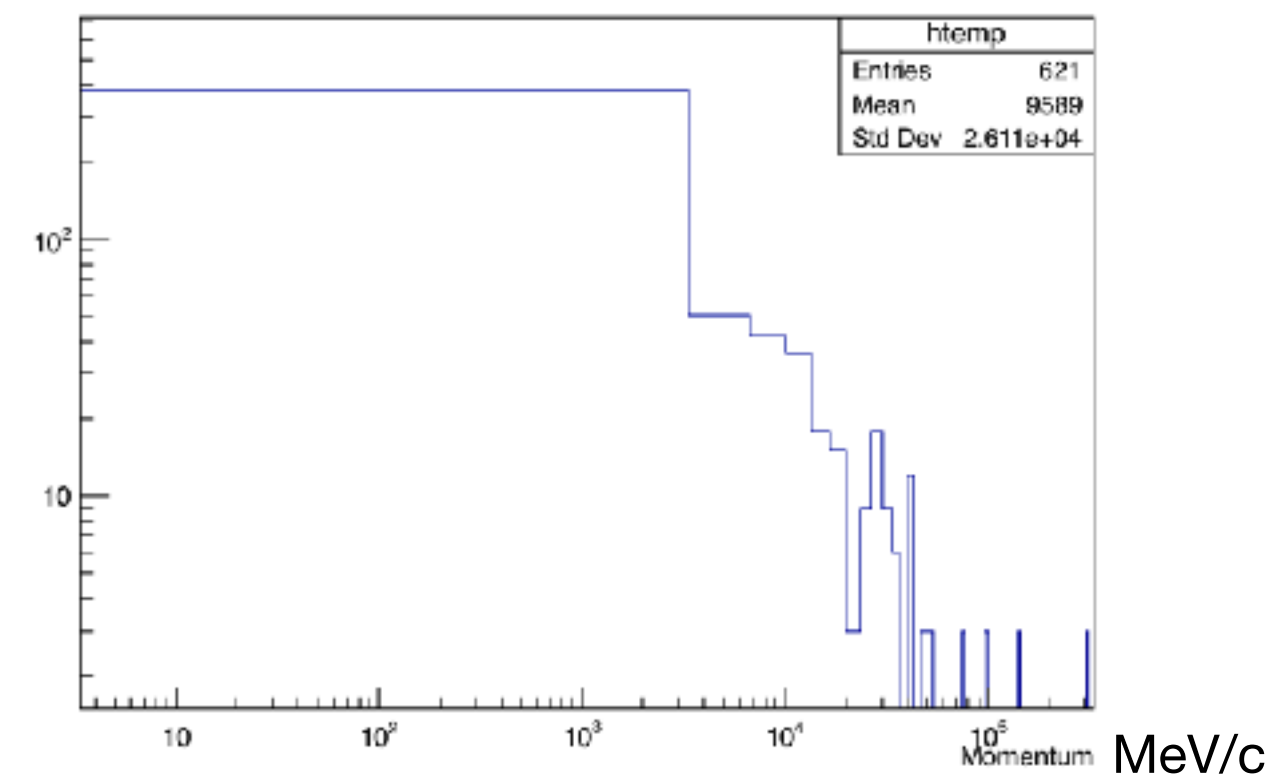
The estimate of cosmic-rays require huge computing resource, so improving the efficiency is very important.

select the primary particles









Summary

- The COMET experiment is promising to find cLFV
- Using ICEDUST to simulate the cosmic-rays to estimate the events
- Cosmic-rays are one of the most important source of backgrounds. Based on current study, some events closing threshold have been found, even though which could be identified. So the simulation of more cosmic-rays should be done (at lest triple running-time of COMET experiment).The simulation efficiency have been considered,.
- Research proposal
  - There are two situation: 1.noting be found (lucky); 2.find a few fake signals
  - 1. Designing CRV coving the serious areas
  - 2. Using track finding to estimate the fake signal

Thank you for your attention!