Study the Spectrometer Straw Tracker in SHiP project with straw tube sagging

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Background

CERN uses particle accelerator to study the high energy physics

LHC (The Large Hadron Collider)

- Largest particle accelerator

SPS (The Super Proton Synchrotron)

- Old particle accelerator used
- now used to increase the energy of the beam before injected to LHC

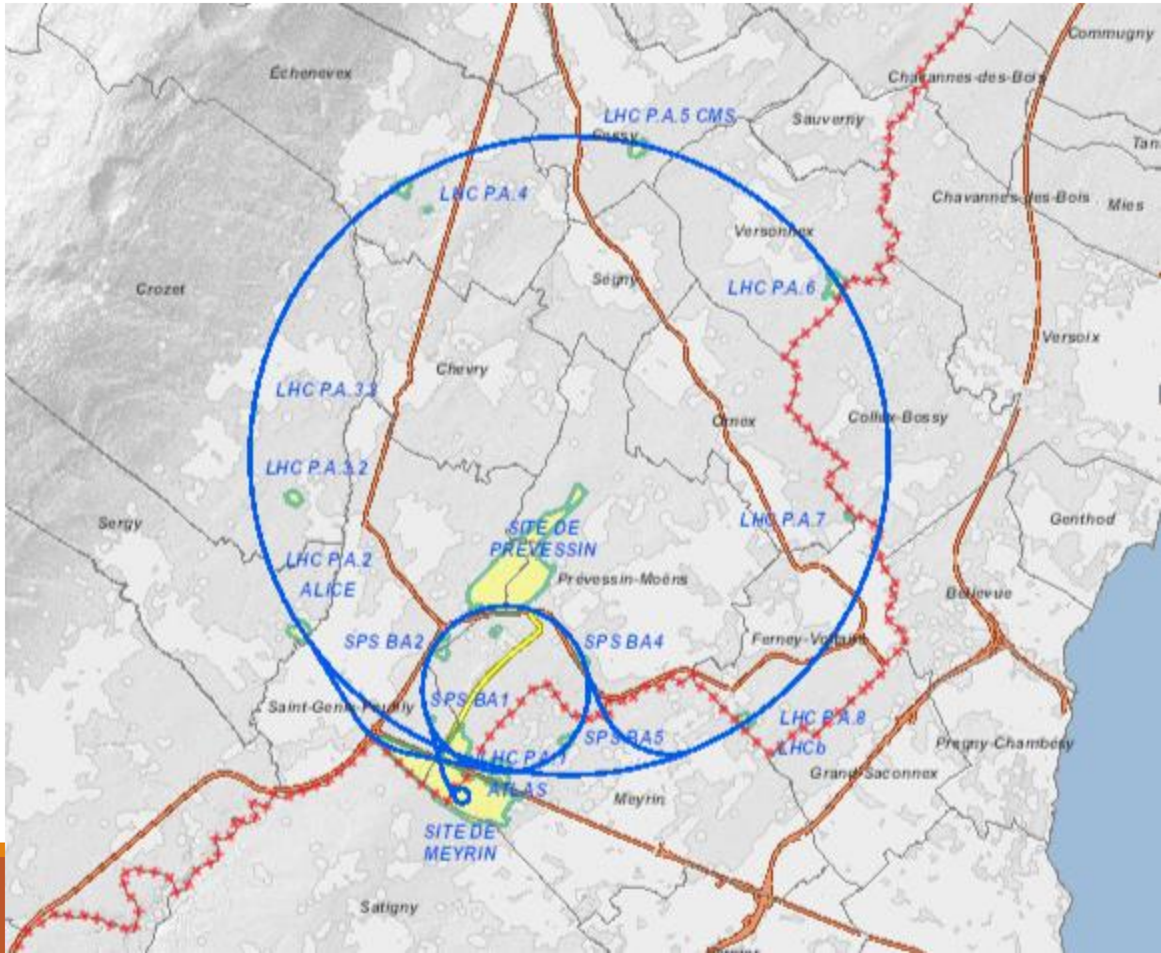


Fig. 1: map of LHC from https://maps.cern.ch/

Introduction

SHiP = Search for Hidden Particle

- A proposed fixed target facility at SPS

From http://ship.web.cern.ch/ship/

FairShip

- A developing software package for SHiP
- Open source on Github
- Base on FairROOT
- This work is base on FairShip

SHiP Setup

Optimization is in progress

Sketch:

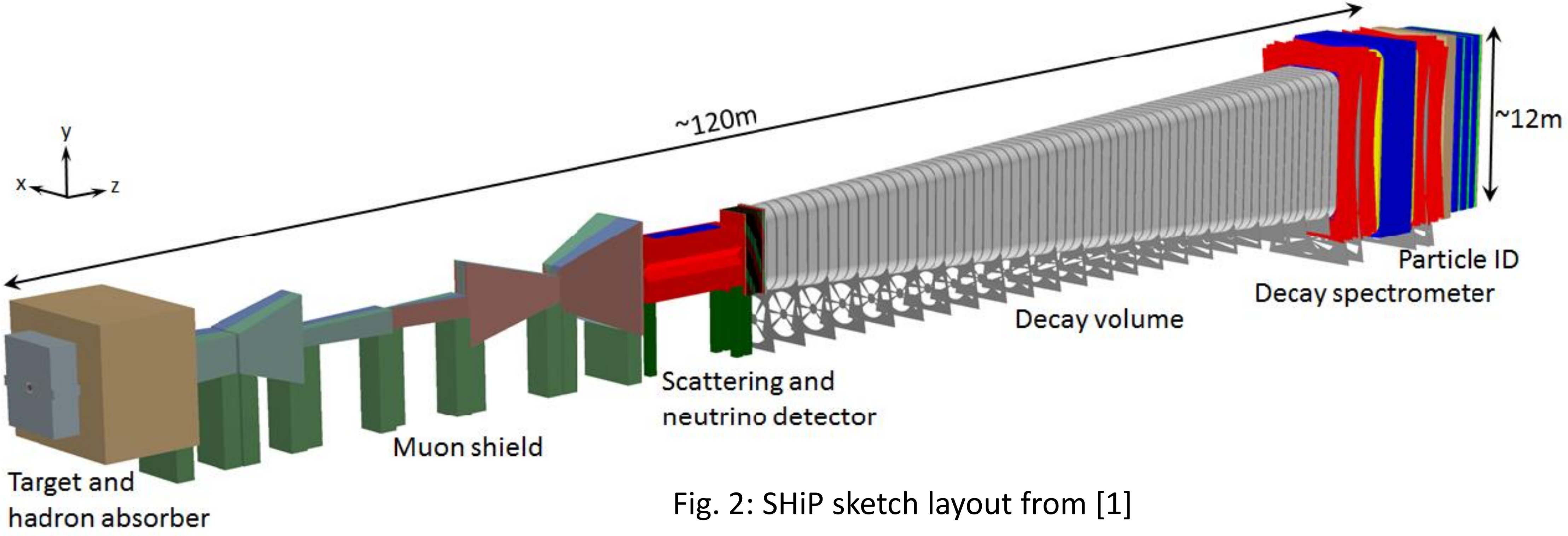


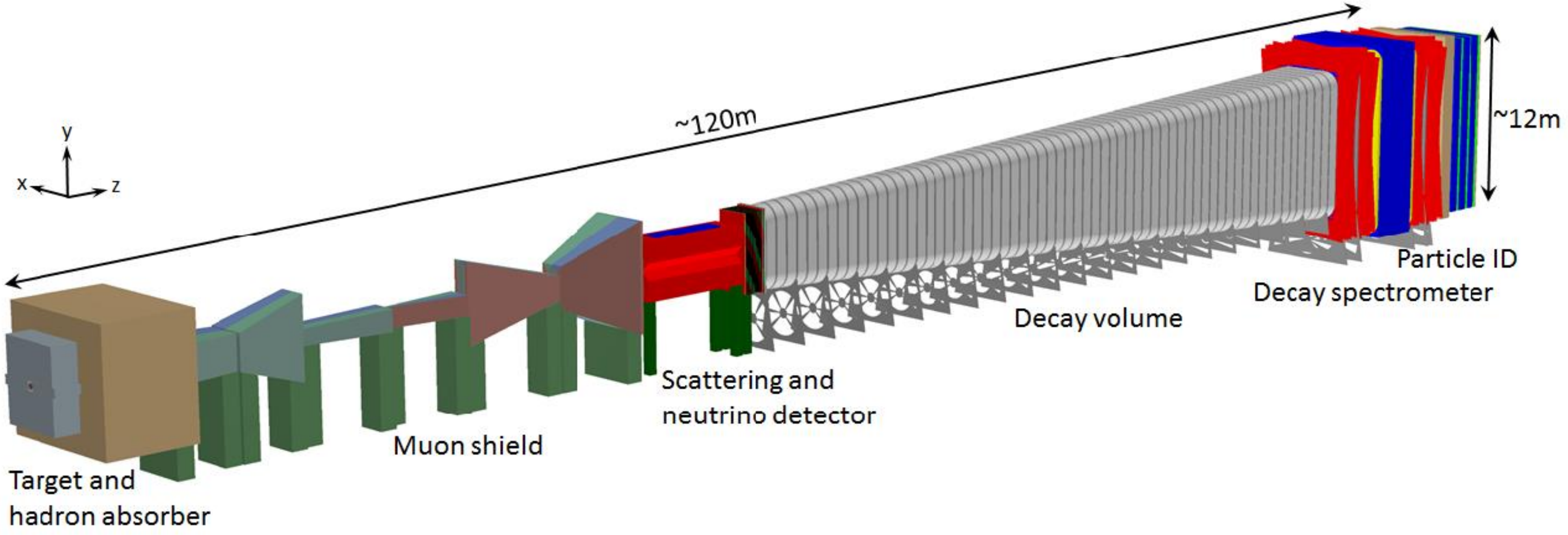
Fig. 2: SHiP sketch layout from [1]

SHiP experiment

Target: collision take place

High energy collision

=> hidden sector particle may be generated

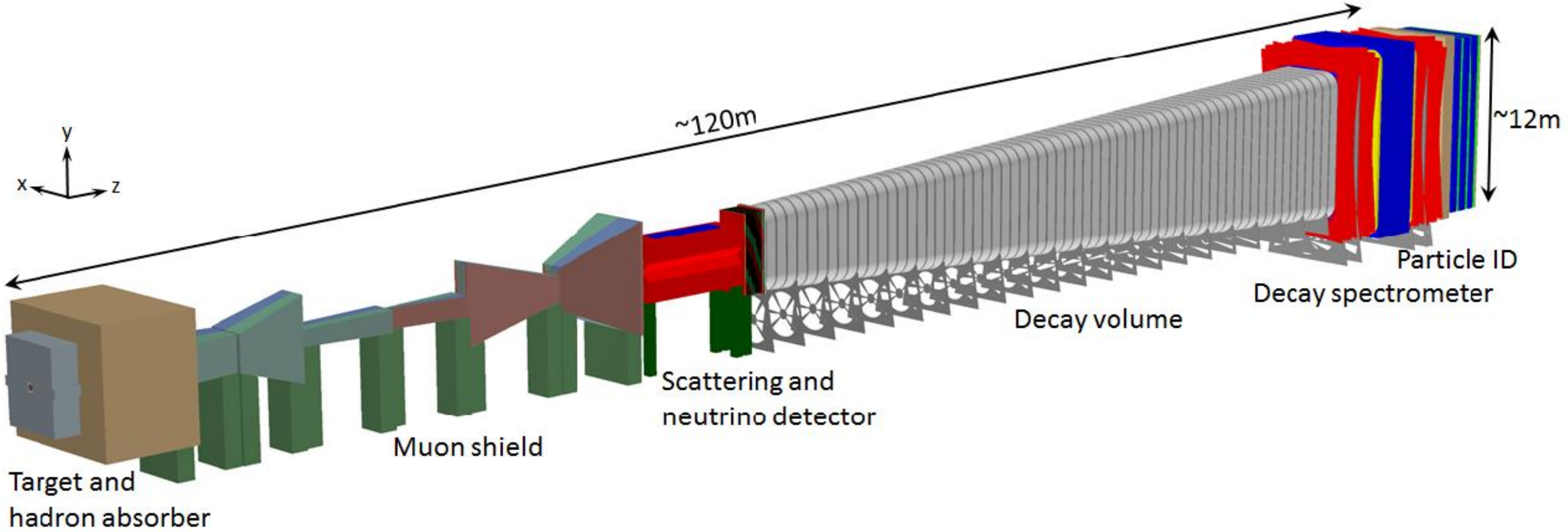


SHiP experiment

Hadron absorber: remove hadron produced

Muon shield: remove muon produced

Also treat with neutrino

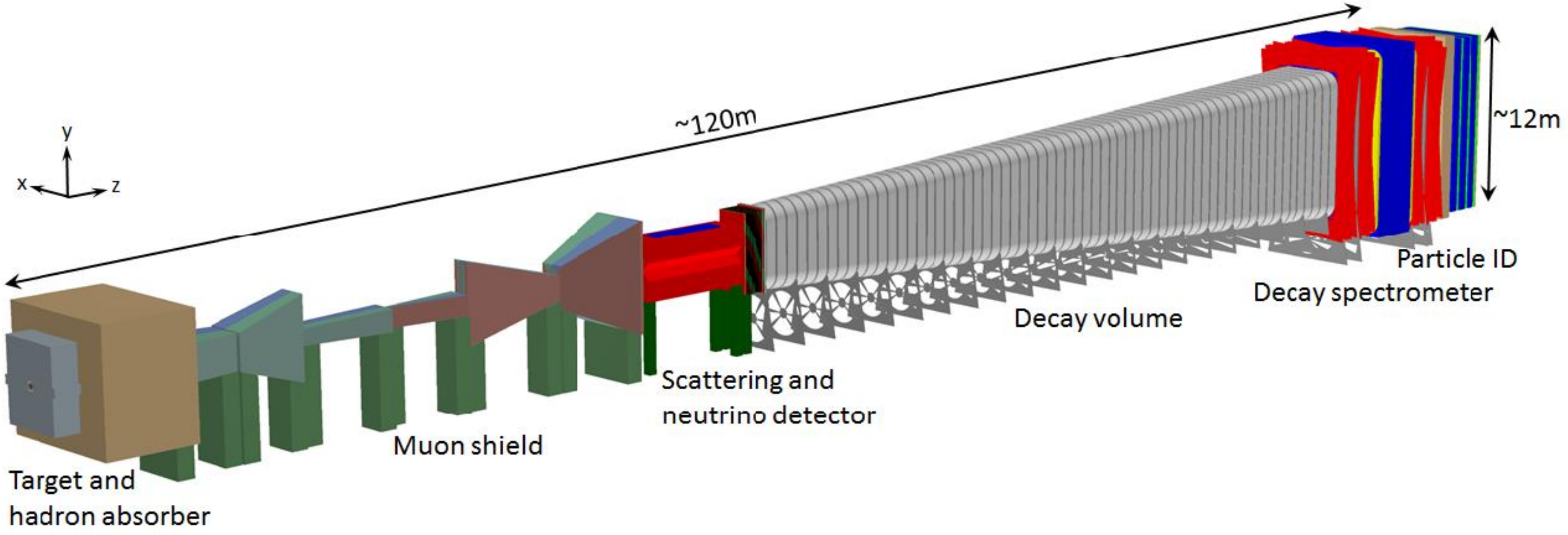


SHiP experiment

Only hidden particle left in decay volume

Decay volume is large

Allow the hidden particle to decay

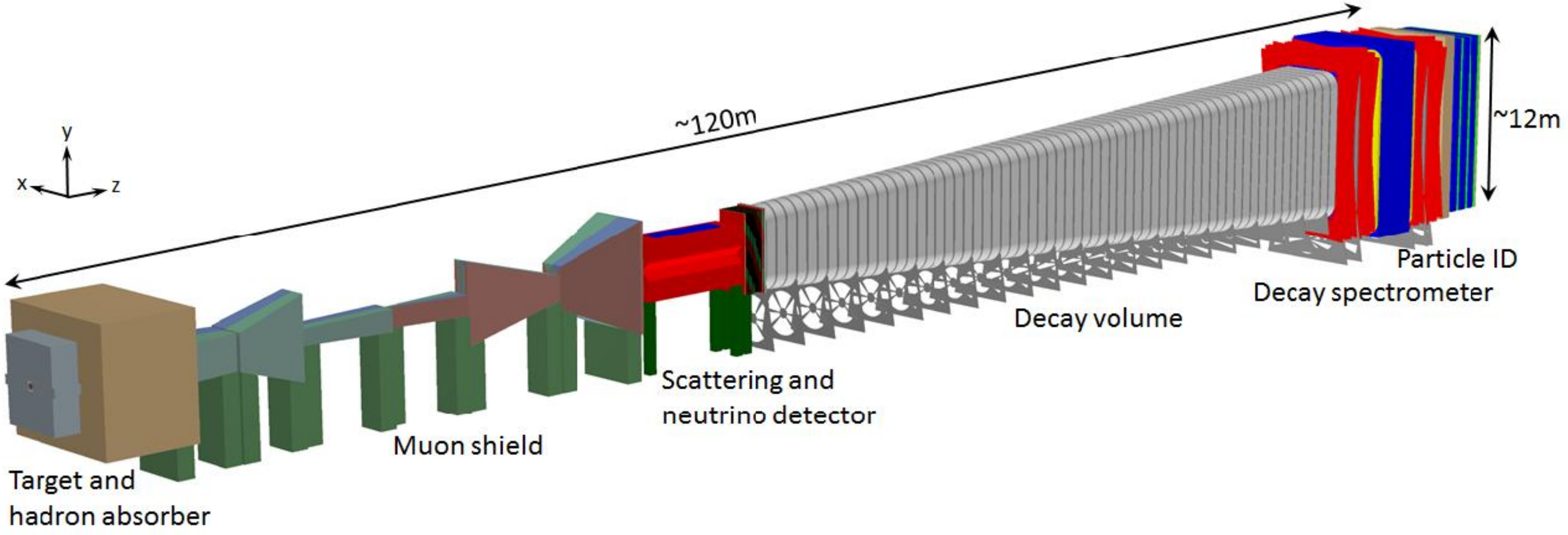


SHiP experiment

In many models beyond Standard Model,

Final product will include charged Standard Model particle [2]

e.g. charged meson, electron, muon

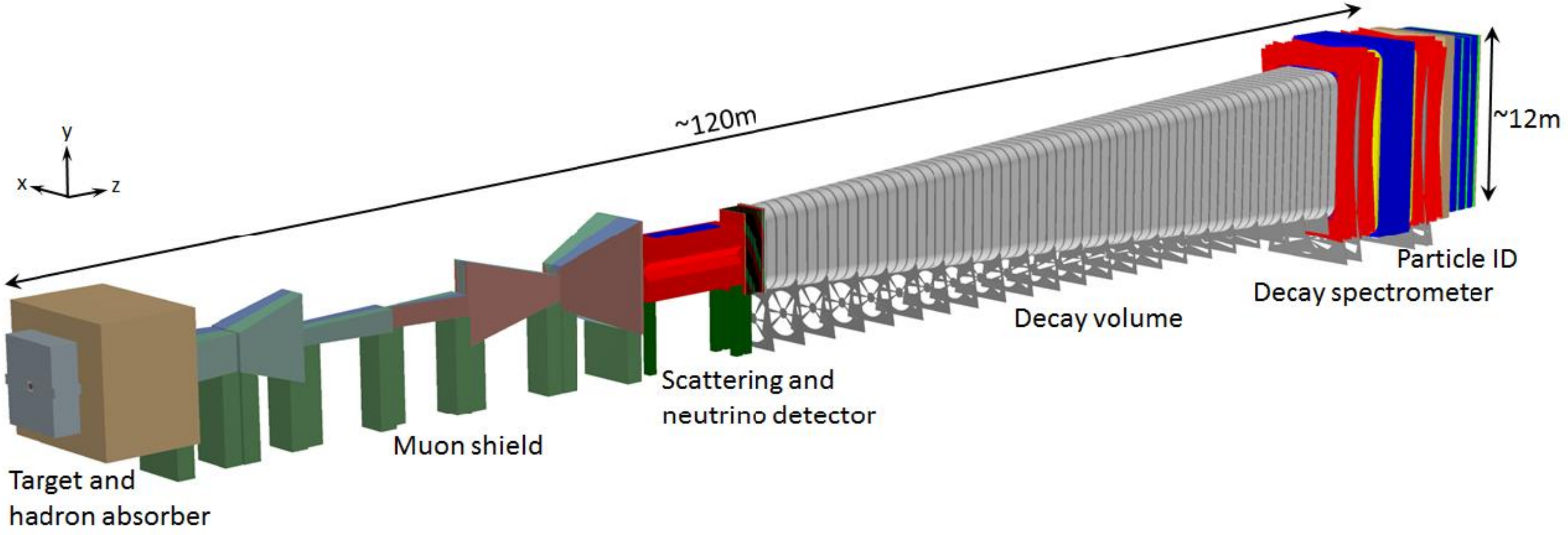


SHiP experiment

Spectrometer: Spectrometer Straw Tracker(SST)

Measure the charged particle trajectory and momentum

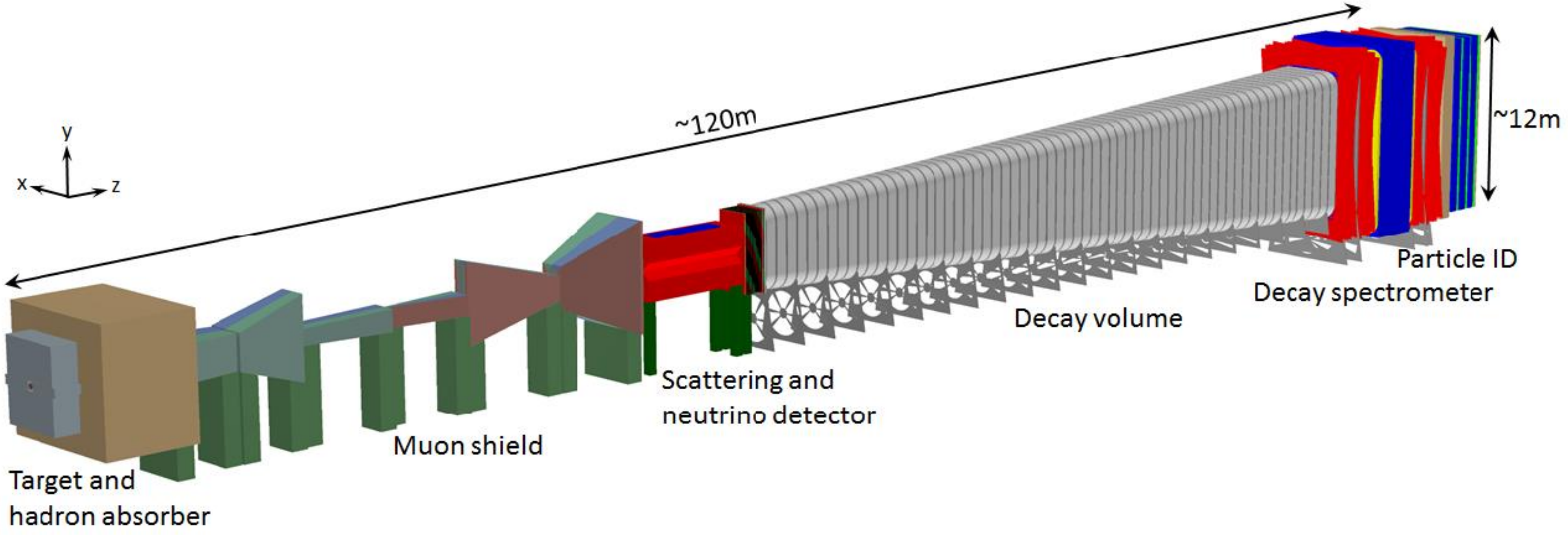
The focus of my work



SHiP experiment

Particle identification detector(ID):

To identify the type of particle



Spectrometer Straw Tracker

Why measure the trajectory and momentum?

Not directly measure the hidden particle

Reconstruct the decay vertex

Help to filter out the background

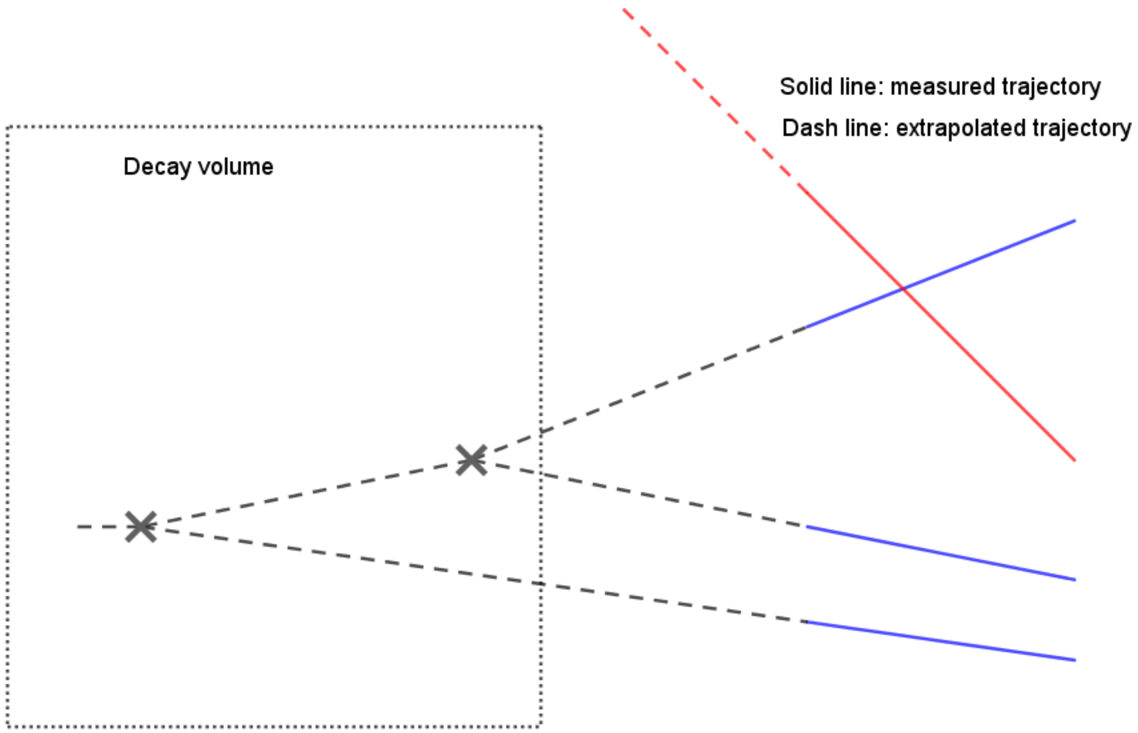


Fig. 3: Illustration of the trajectory

Spectrometer Straw Tracker

Search for the vertex of two trajectory

Considered the time interval

Find the possible decay mode

Found the trajectory before decay

Repeat…

Not originate in decay volume

=> background/scattering

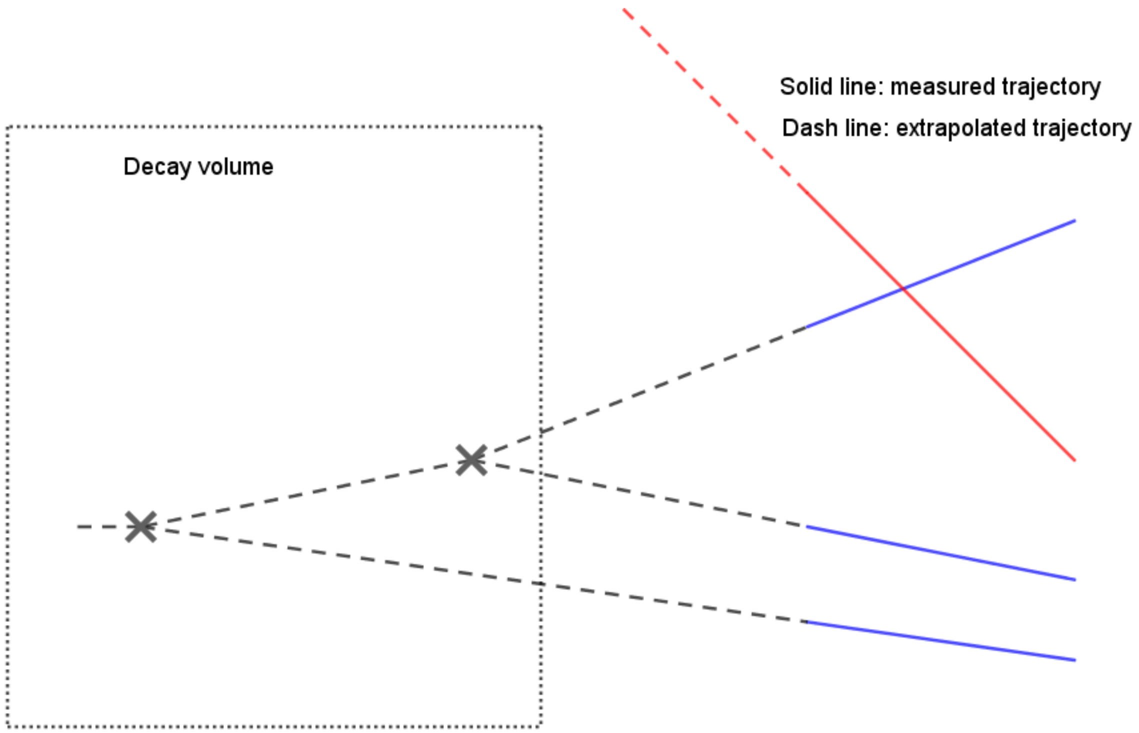


Fig. 3: Illustration of the trajectory

Straw tubes

A key component to measure the trajectory of charged particle

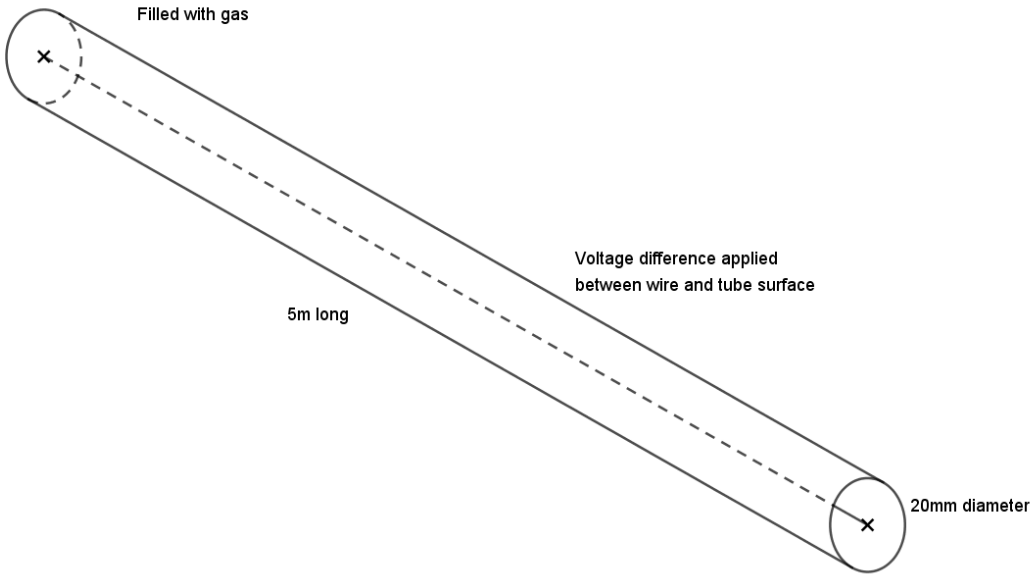
A long straight tube with very small diameter

- 5m long, 20mm diameter in the updated version

A wire centered in the tube

Filled with gas

Voltage applied



Signal from Straw tubes

High energy charged particle penetrated the tube ionizes the gas

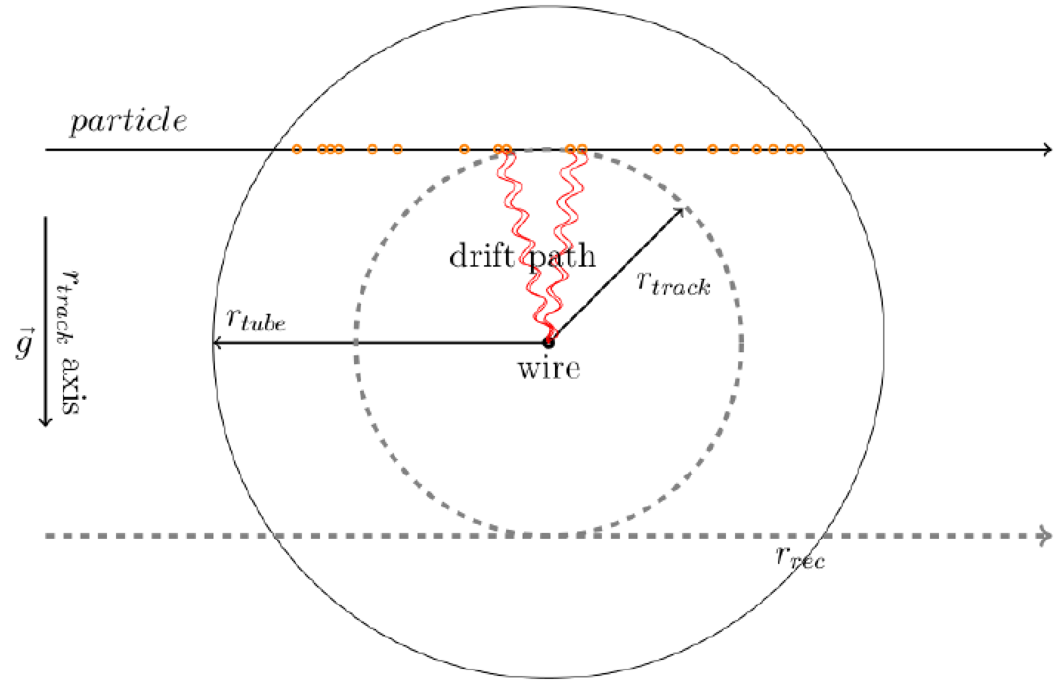
Charge carrier produced (not the penetrated one)

Voltage applied

=> drift to the tube surface or wire

=> signal is obtained

Fig. 4: Cross section of straw tube from [2]



Signal from Straw tubes

Potential gradient is large near the wire

When charge carrier is close to the wire

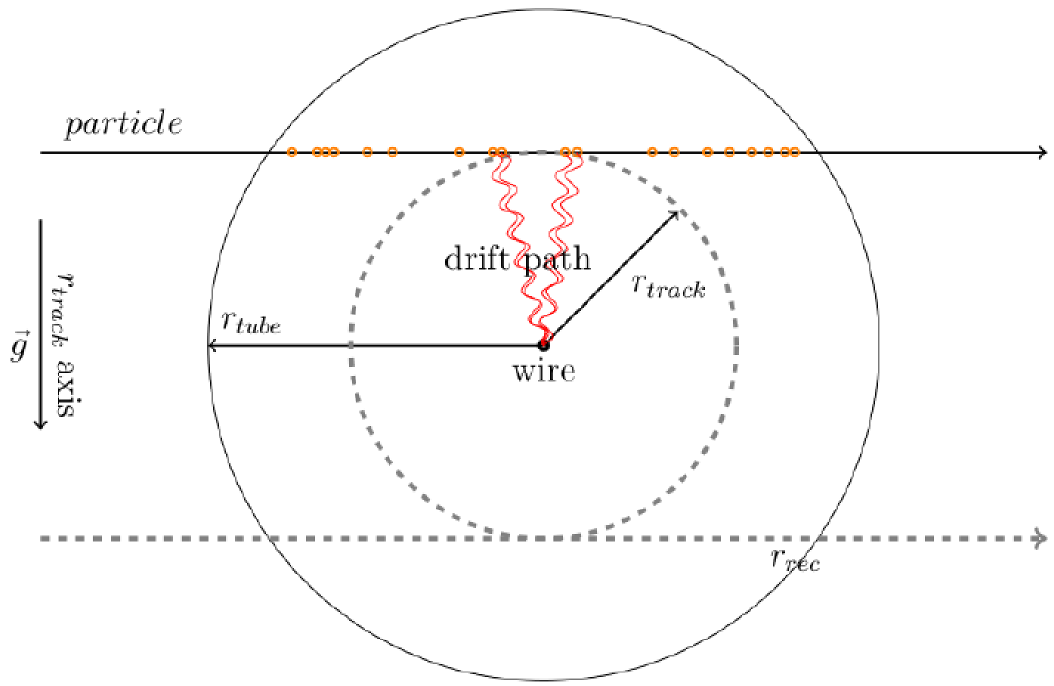
=> gain a lot of energy

=> ionized the gas again

=> repeat the process

=> amplification of the signal

Fig. 4: Cross section of straw tube from [2]



Reconstruct trajectory

SST consist arrays of straw tubes

Some views are tilted with a small angle

Which tube is hit, with the tilted angle

How long is the time interval

Etc…

Reconstruct the trajectory

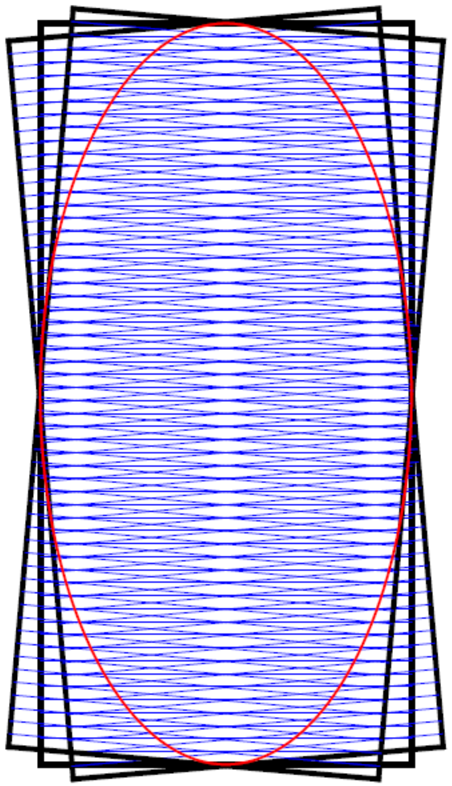


Fig. 5: Array of straw tubes from [3]

Reconstruct momentum

Two station of SST before magnet

Two station of SST after magnet

Charged particle under magnetic field

=> curved trajectory

=> reconstruct the momentum

Straw tube Sagging

Here is the problem comes

Long & thin tube subjected to different external force

E.g. Gravity, EM…

Expected not ideal

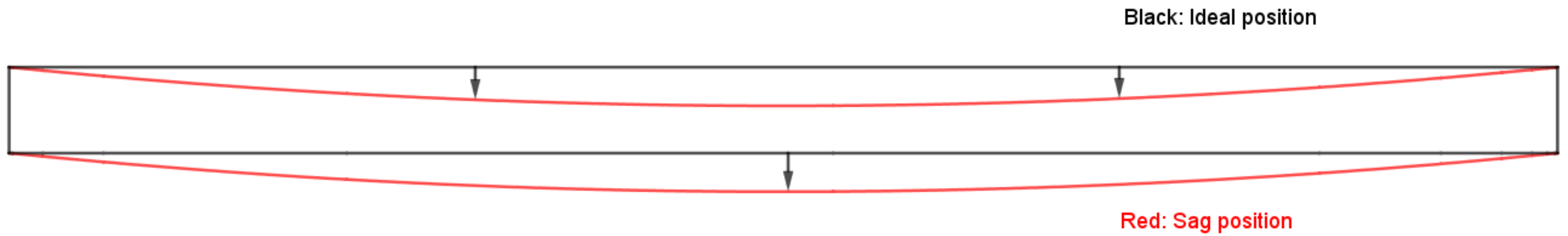


Fig. 6: Sketch of sagging

Straw tube Sagging

Difference:

1. Actual position is shifted

2. No cylindrical symmetry for the straw tube
   - => complicated configuration of the electric field in the tube*
   - => affect the drift time

Fig. 6: Sketch of sagging

*investigating by other member

Straw tube Sagging

The influence due to this effect shall be studied

Expect the performance is degraded

Two Case:

All straw tubes have same sagging

Straw tubes may have different sagging

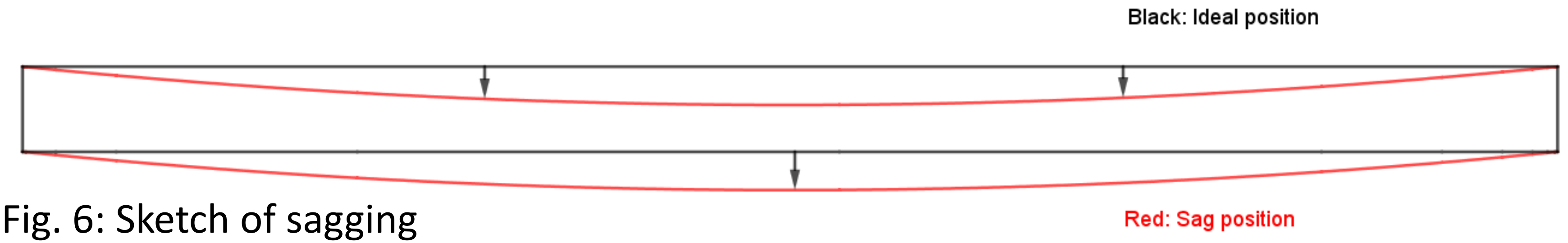


Fig. 6: Sketch of sagging

Implementation

Sagging is implemented in FairShip

The exact sagging profile is not obtained

FairShip will base on ideal case

Only simulated signal will be pre-processing

Base on sagging

Implementation

Sagging profile is unknown

Assume a parabolic profile

- Simple
- Maximize at the middle
- Fixed for two ends

Case 1: same maximum sagging for all

Case 2: a uniform distribution for the maximum sagging

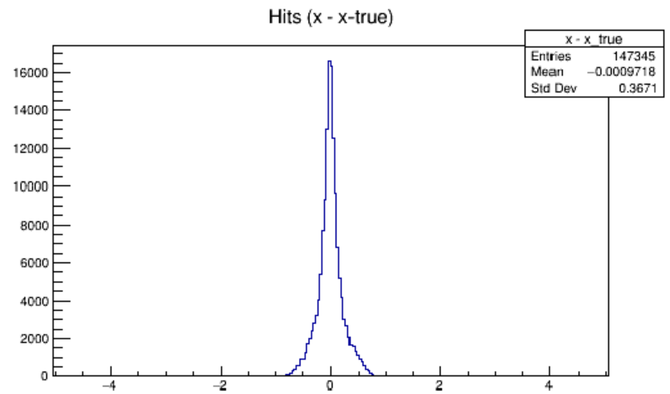
Result: x coordinate

sagging makes the result degraded

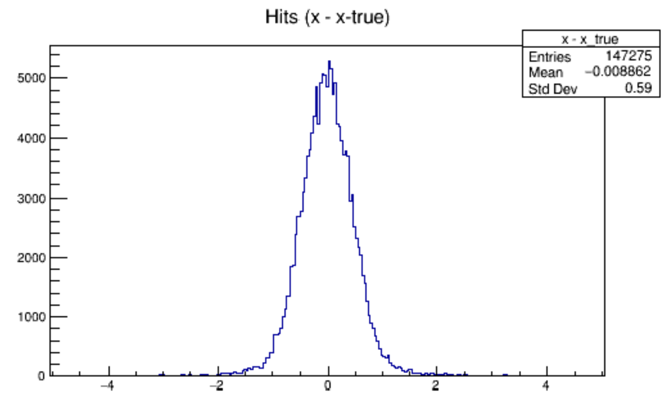
Case with distribution get worse

Even smaller average sag

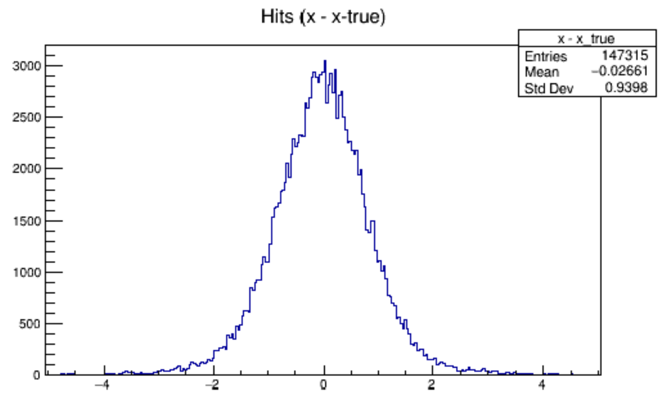
Even all have less sagging



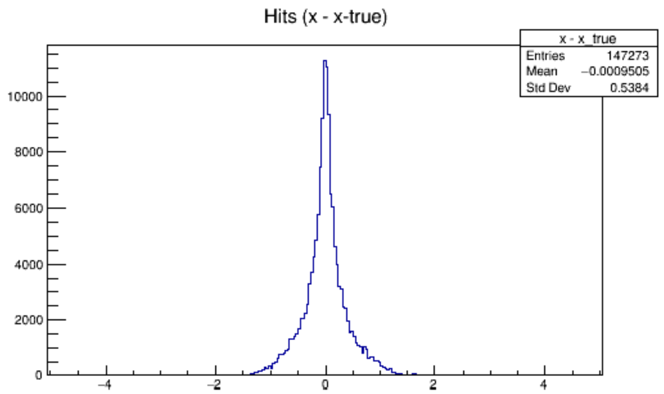
(a) 4mm maximum sagging



(b) 3-5mm maximum sagging



(c) 2-6mm maximum sagging



(d) 7mm maximum sagging

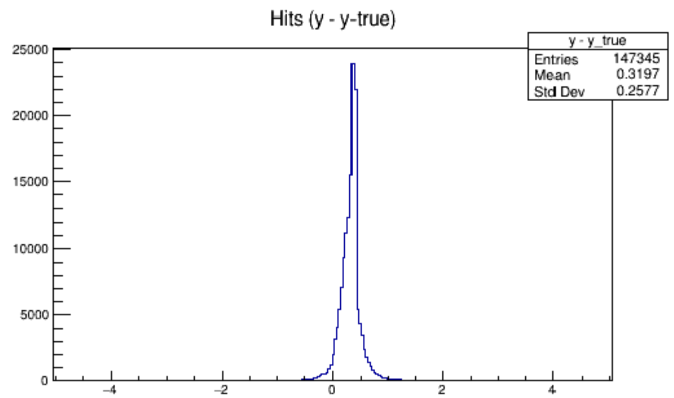
All plots in Result are from the report

Result: y coordinate

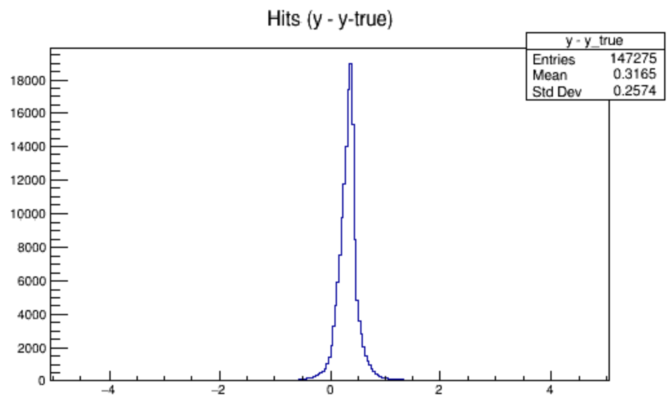
sagging makes the result worse

A shift

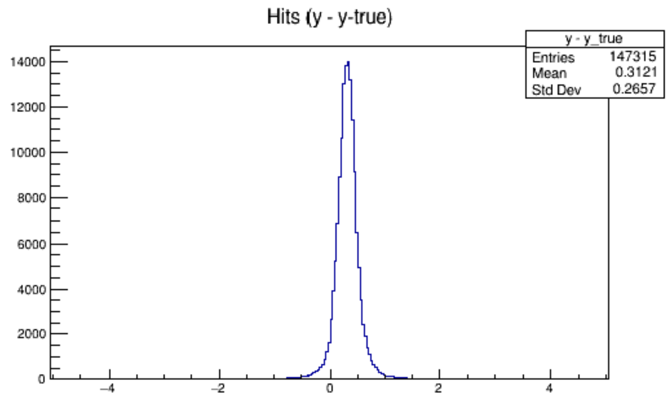
Distribution makes more smeared



(a) 4mm maximum sagging



(b) 3-5mm maximum sagging



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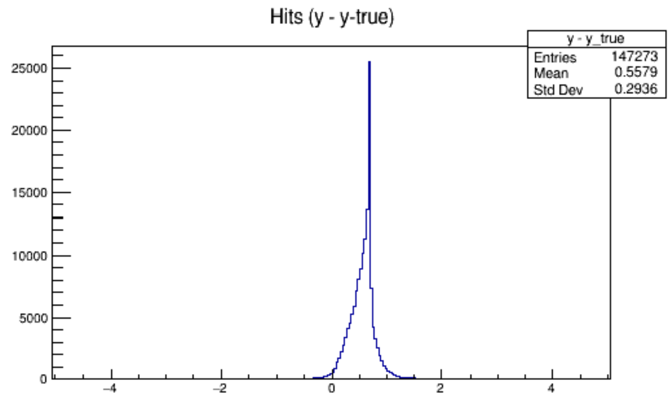


(d) 7mm maximum sagging

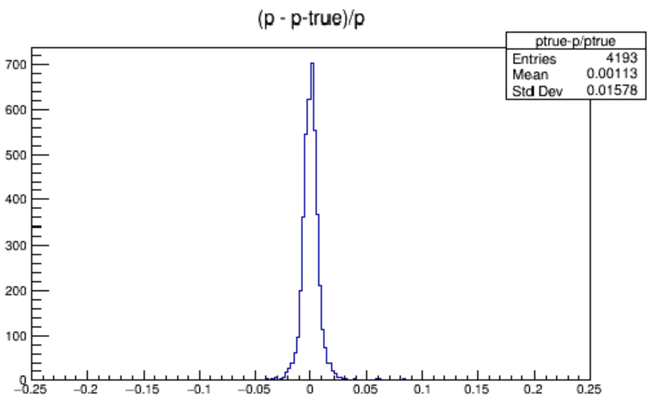
Result: momentum

No distribution

=> almost unchanged

With distribution

=>significantly worse



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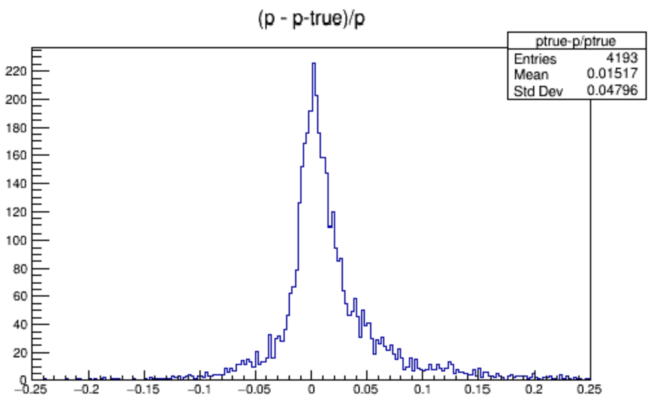
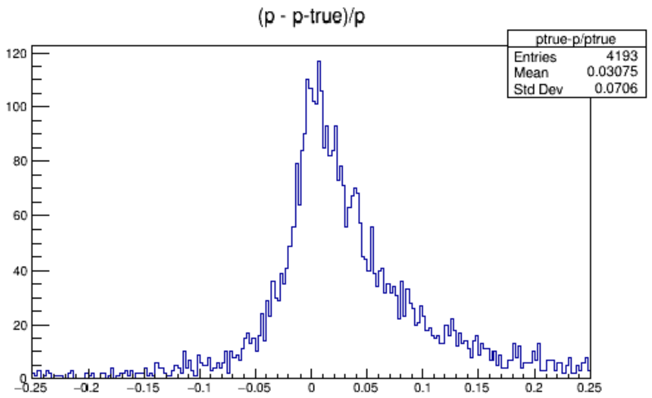


(b) 3-5mm maximum sagging



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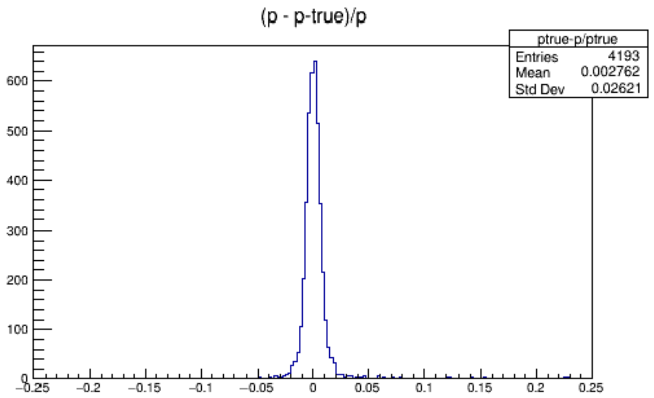

(d) 7mm maximum sagging

Result

Only include the position shift due to sagging

If consider the changed drift time

=> may cause poorer performance

Implemented sagging in FairShip

Others can study the influence on drift time base on the implement

Further

The sagging influence seems depends on x

Fitting quality get worse

Performance of difference algorithm to handle signal can be studied

Optimization with sagging can be studied

Modification on straw tubes?

- Shorter/thicker?
- Extra tension?

Reference

[1] The SHiP Collaboration, *SHiP Experiment - Progress Report*, CERN-SPSC-2019-010, SPSC-SR-248, 25 January 2019.

[2] I. Bereziuk , O. Bezshyyko and M. Ferro-Luzzi, *Initial design studies of the SHiP straw detector*, CERN-SHiP-NOTE-2015-001, 31 March 2015.

[3] The SHiP Collaboration, Technical Proposal. *An Experiment to Search for Hidden Particles (SHiP) at the SPS*, CERN-SPSC-2015-016, SPSC-P-350, 8 April 2015.

Q&A