Imperial College
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nuSTORM Beamline Optics Results

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Motivations & Overview

- nuSTORM will produce a beam of known flavour and energy
- A 100 GeV proton beam hits a target producing particles of various energies
- The pion transport line uses quadrupoles and dipoles to differentiate particles and their respective momenta
- The pions pass through an OCS to combine with circulating muons in the storage ring
- Pions decay in the production straight to produce muons and if their dynamical and physical acceptances are within the accepted range, they continue circulating

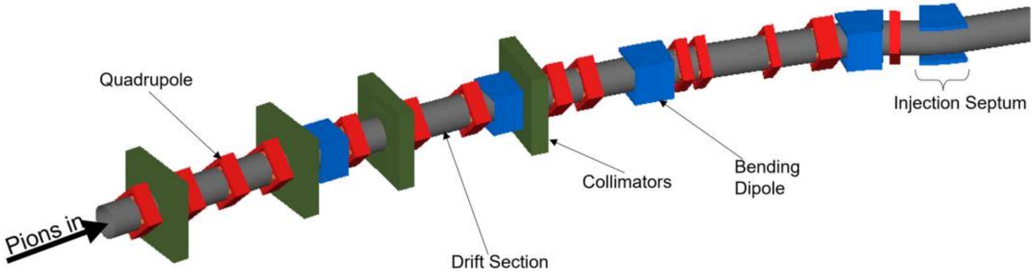


Fig 1 – A visualisation of the π transport line with labelled components

Beamline Optics and Simulations

- By using BDSIM, a Geant4-based particle tracking tool, we were able to design the optics of the facility
- Here we have $\beta_{x,y}$ and $D_{x,y}$ of the beam, made by sending an ideal stylised beam to reduce uncertainties
- By being able to visualise the Optics of the beam we were able to see and correct bugs
- This does not mean that our beam is complete yet

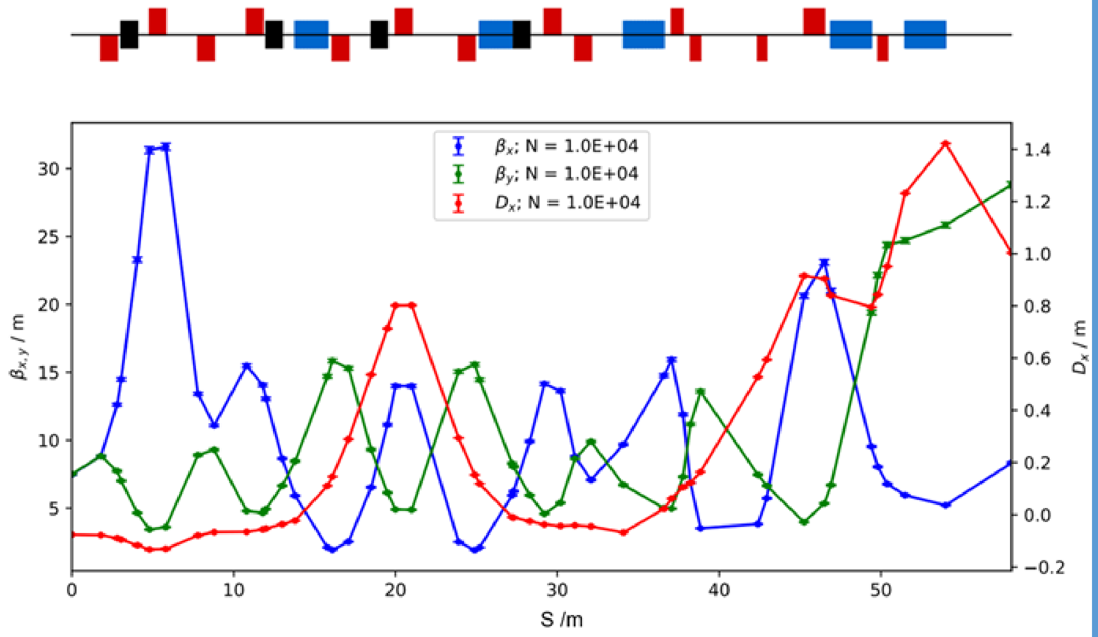


Fig 2 – The β and Dispersion of the π transport line

Orbital Combination System

- nuSTORM is a hybrid facility, using FODO cells and Fixed Field Alternating gradient (FFA) magnets
- The OCS is an FFA combined function magnet that combines pions and muons incoming from different positions and with different momenta
- No Geant4 toolkit as of yet can accurately simulate the magnetic fields of an FFA combined function magnet
- We've had to create our on field maps for the OCS FFA

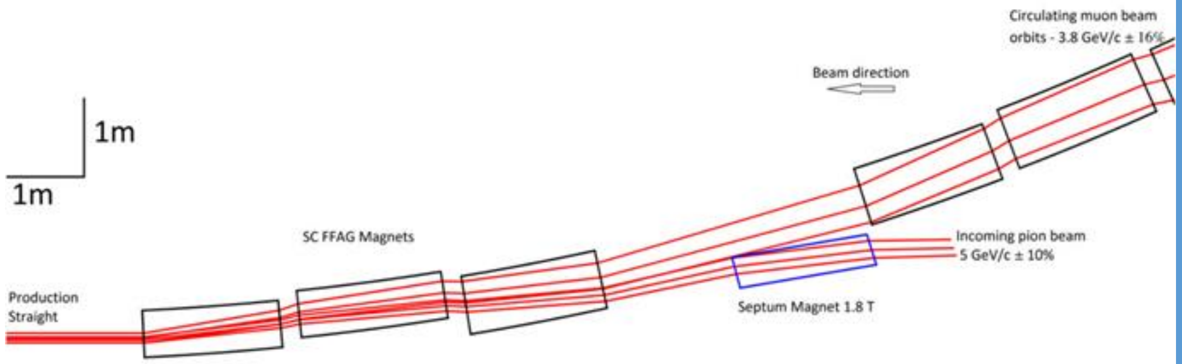
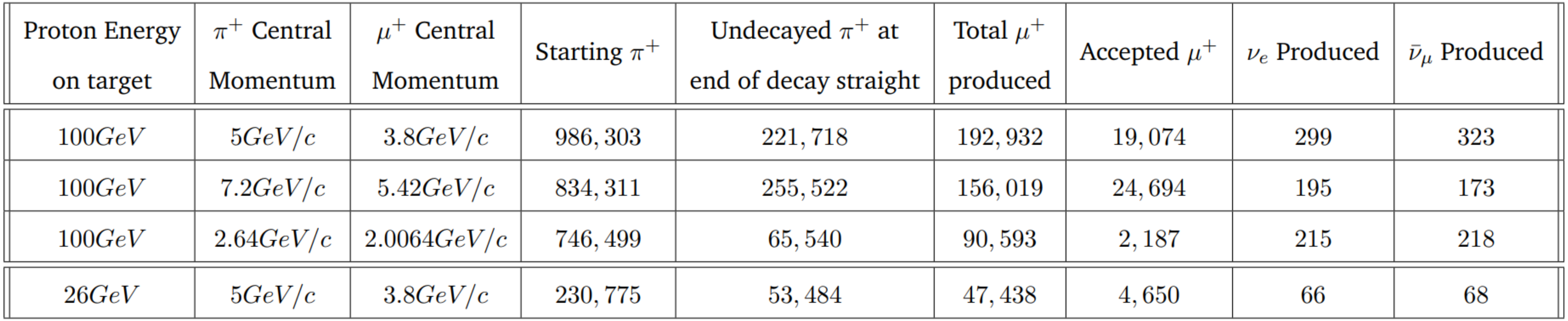


Fig 3 – A diagram showing how the OCS Magnets work. Beams are going right to left

Final Test Runs



Proton Energy on target	π^+ Central Momentum	μ^+ Central Momentum	Starting π^+	Undecayed π^+ at end of decay straight	Total μ^+ produced	Accepted μ^+	ν_e Produced	$\bar{\nu}_\mu$ Produced
$100GeV$	$5GeV/c$	$3.8GeV/c$	$986,303$	$221,718$	$192,932$	$19,074$	299	323
$100GeV$	$7.2GeV/c$	$5.42GeV/c$	$834,311$	$255,522$	$156,019$	$24,694$	195	173
$100GeV$	$2.64GeV/c$	$2.0064GeV/c$	$746,499$	$65,540$	$90,593$	$2,187$	215	218
$26GeV$	$5GeV/c$	$3.8GeV/c$	$230,775$	$53,484$	$47,438$	$4,650$	66	68

Thank You

Questions?

OCS Field Maps

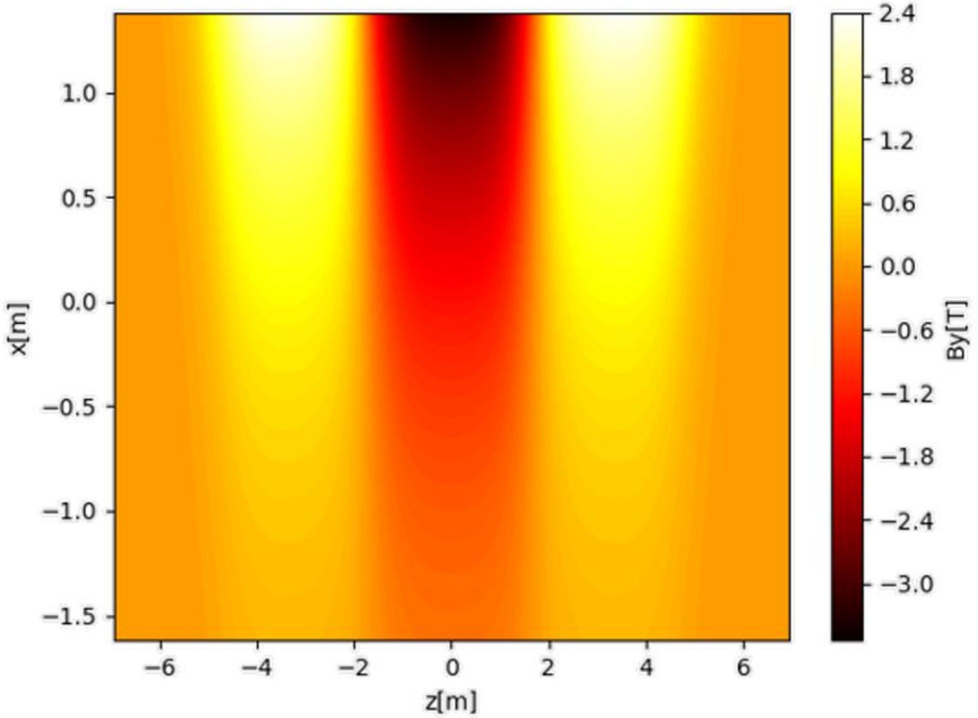


Fig 4 – A diagram showing how the OCS Magnets work. Beams are going right to left

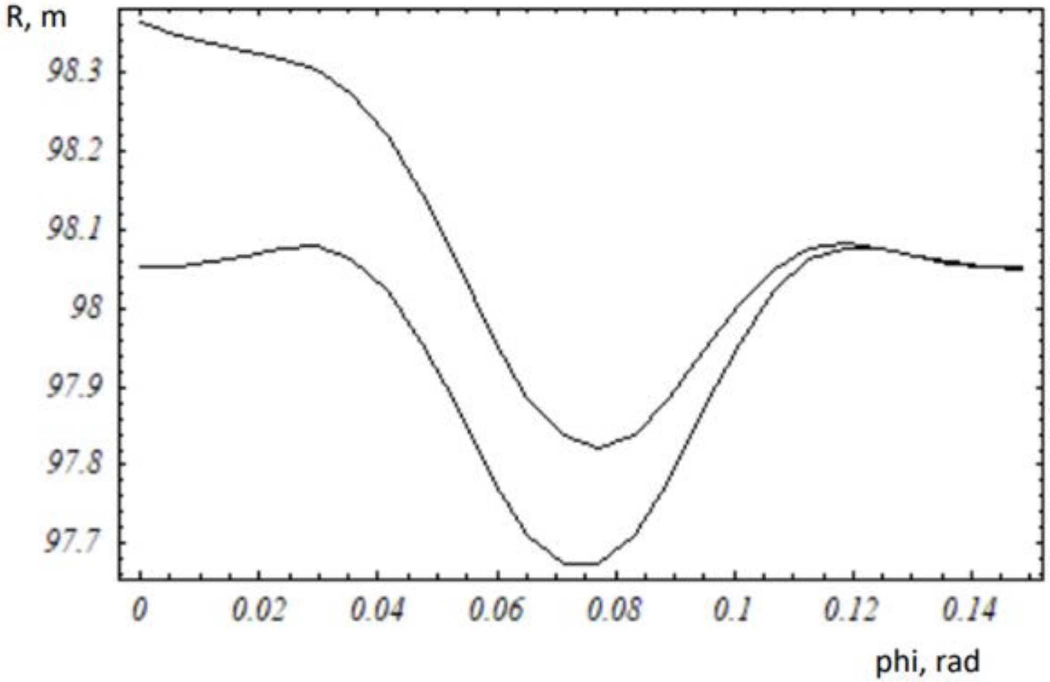


Fig 5 – A diagram showing how the OCS Magnets work. Beams are going right to left

Pion Energy for different Horn Currents

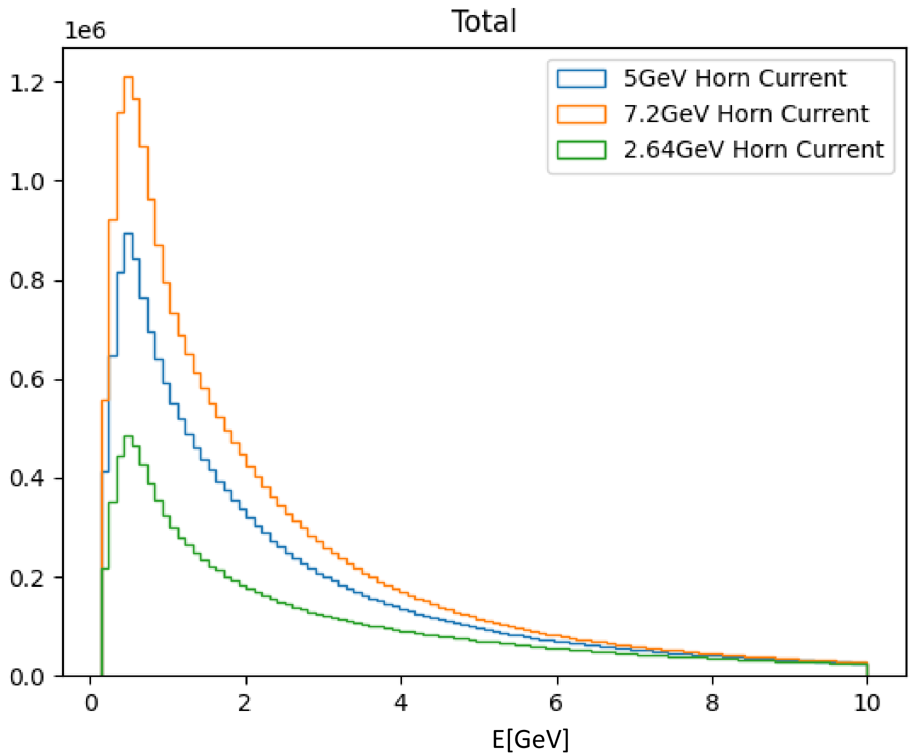


Fig 6 – The Energy Spectrum for the Horn Currents tailored to the muons Momenta seen above

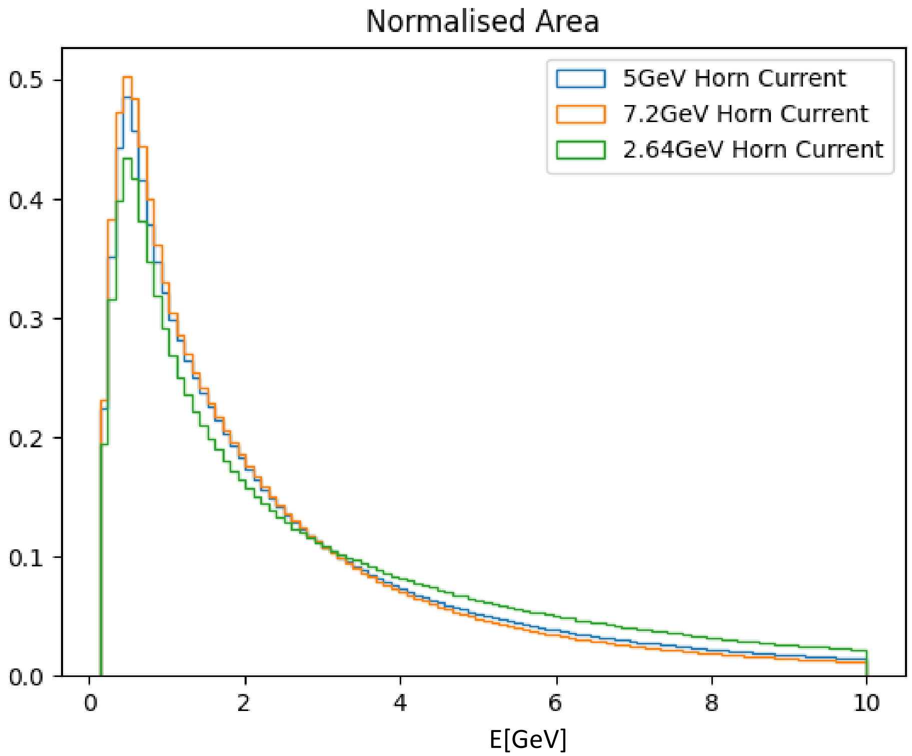


Fig 7 – The same Energy Spectrum but with normalised area to see the shape of graphs

Muon Cuts

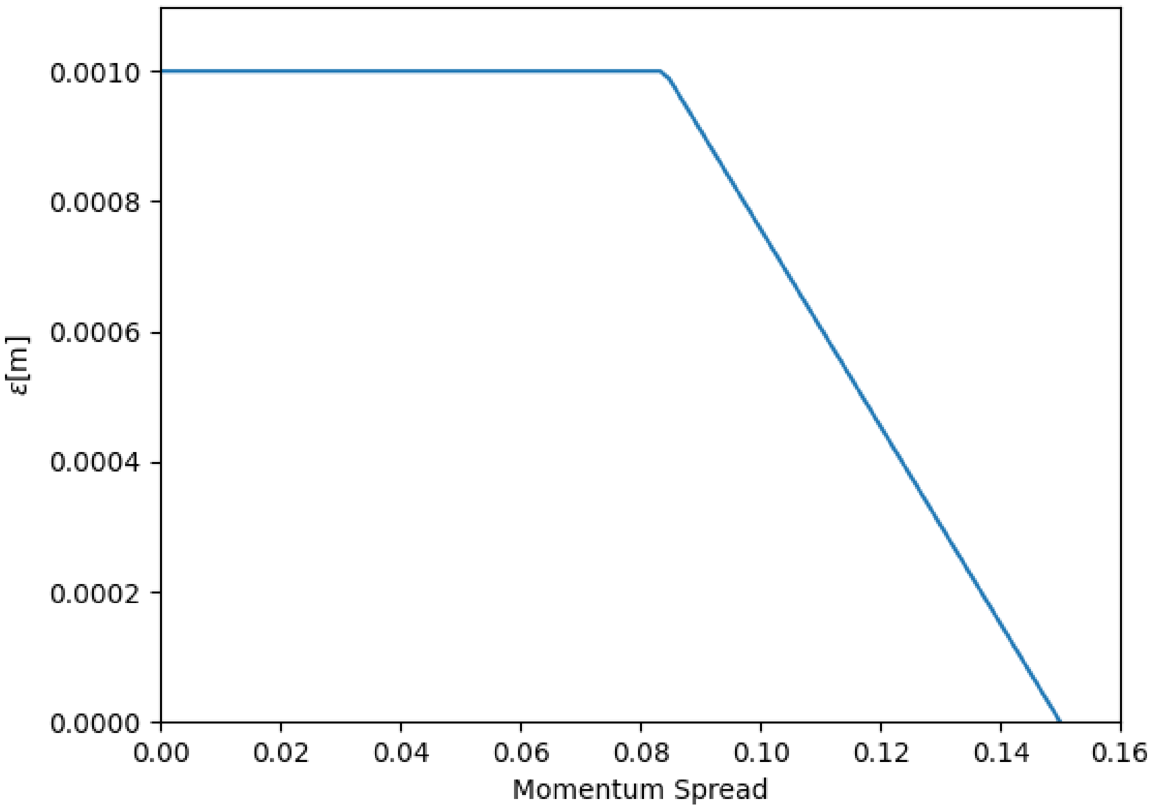


Fig 8 – The relationship between the Emittance and the Momentum Spread so we can make the muon cuts

- $\frac{x^2}{\beta_x^q} + \beta_x^q \left(\frac{p_x}{p_z}\right)^2 \leq \epsilon$
- $\frac{y^2}{\beta_y^q} + \beta_y^q \left(\frac{p_y}{p_z}\right)^2 \leq \epsilon$

- $\beta_x^q = 19.98m$
- $\beta_y^q = 22.96m$

Mirror OCS Muon Energies

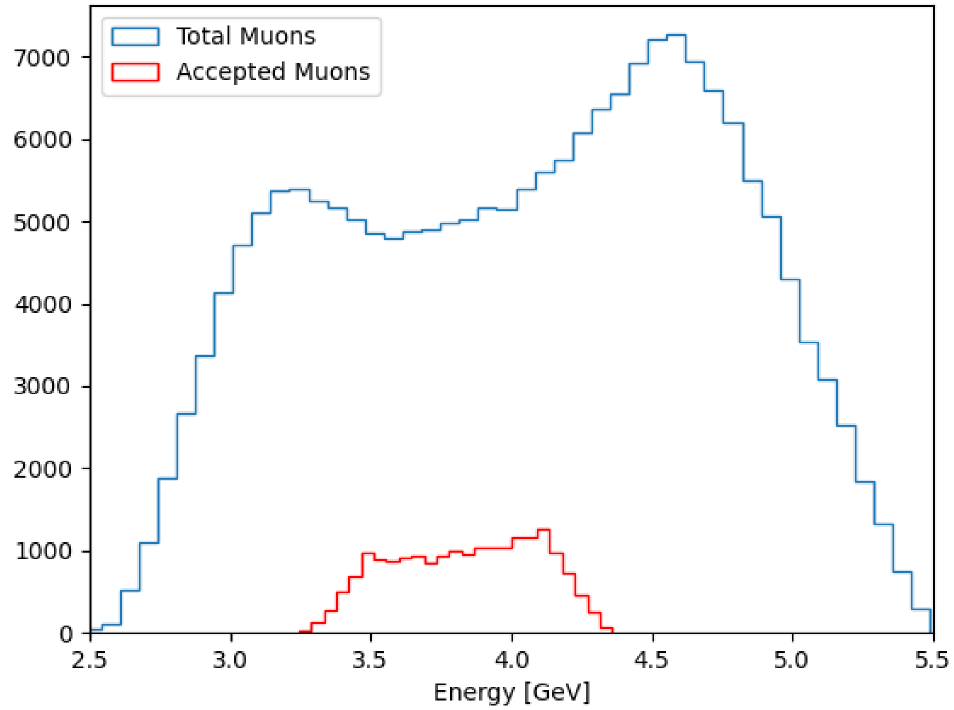


Fig 9 – The Energy Spectrum for the Total Muons and the Accepted Muons for a 5GeV/c Reference Pion Momenta

- Because we still do not have a working 3-D OCS field map we have to make the muon cuts artificially
- The muon energies for all muons measured at the end of the decay straight we then plotted in histograms
- The two distinct peaks exist because of forward and backward decay

Muon Energies Cont.

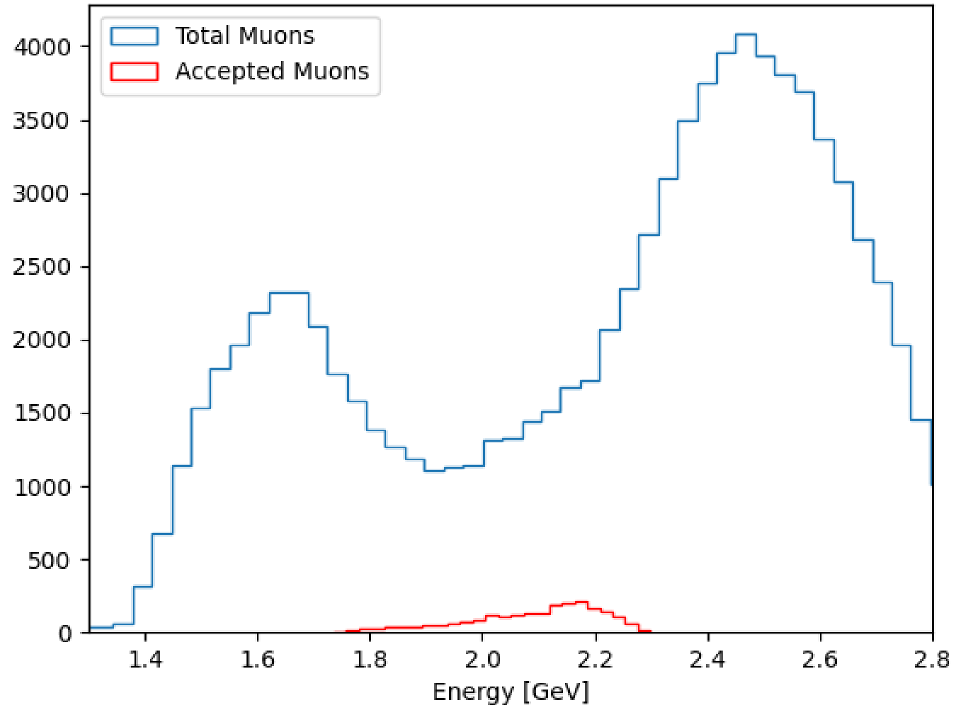


Fig 10 – The Energy Histogram for the Total Muons and the Accepted Muons for a 2.64GeV/c Reference Pion Momenta

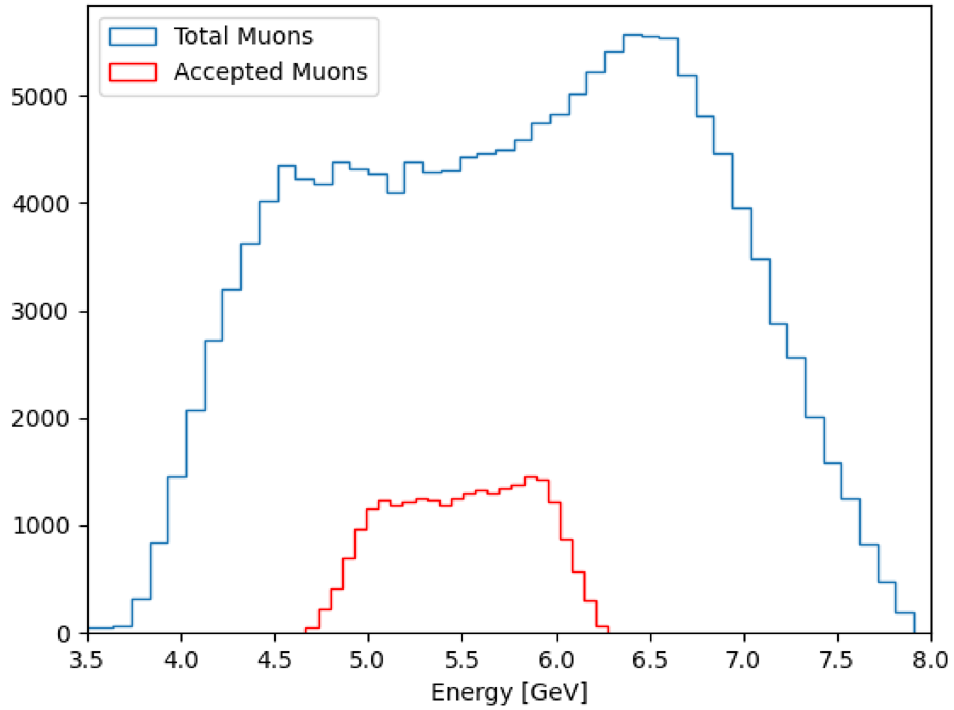


Fig 11 – The Energy Histogram for the Total Muons and the Accepted Muons for a 7.2GeV/c Reference Pion Momenta

Mirror OCS Position of Muons

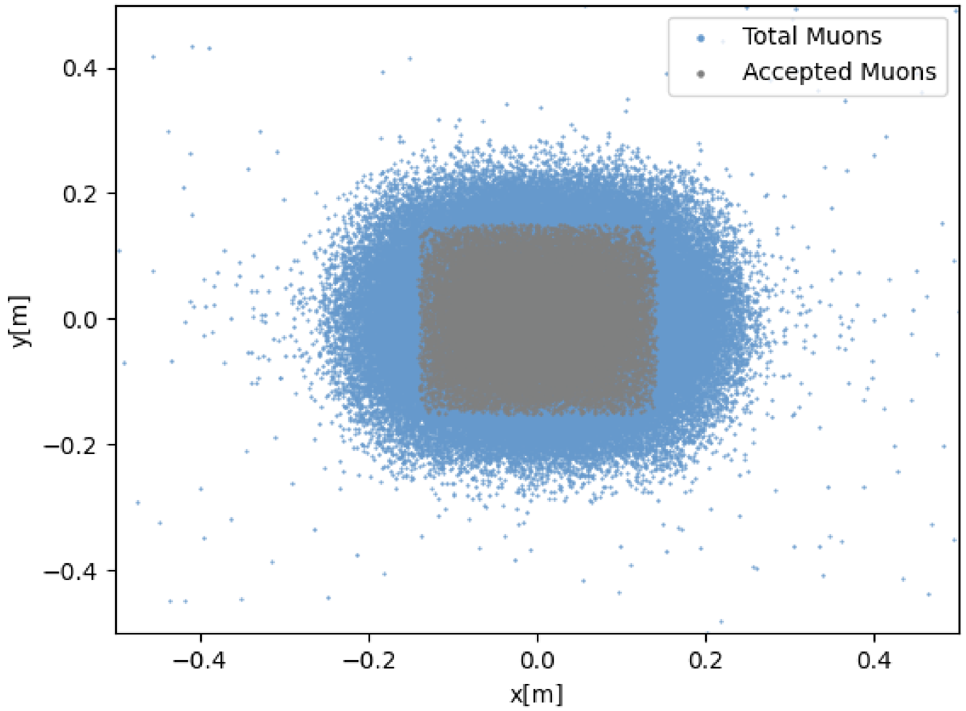


Fig 12 – The Position of the muons and the accepted muons for a 5GeV/c Reference Pion Momenta

- The position of the particle beam is then taken right at the end of the decay straight
- The accepted muons form a square shape in the center due to the way we make cuts to the muons
- Its important that we are making cuts before the muons pass through the OCS

Muon Position cont.

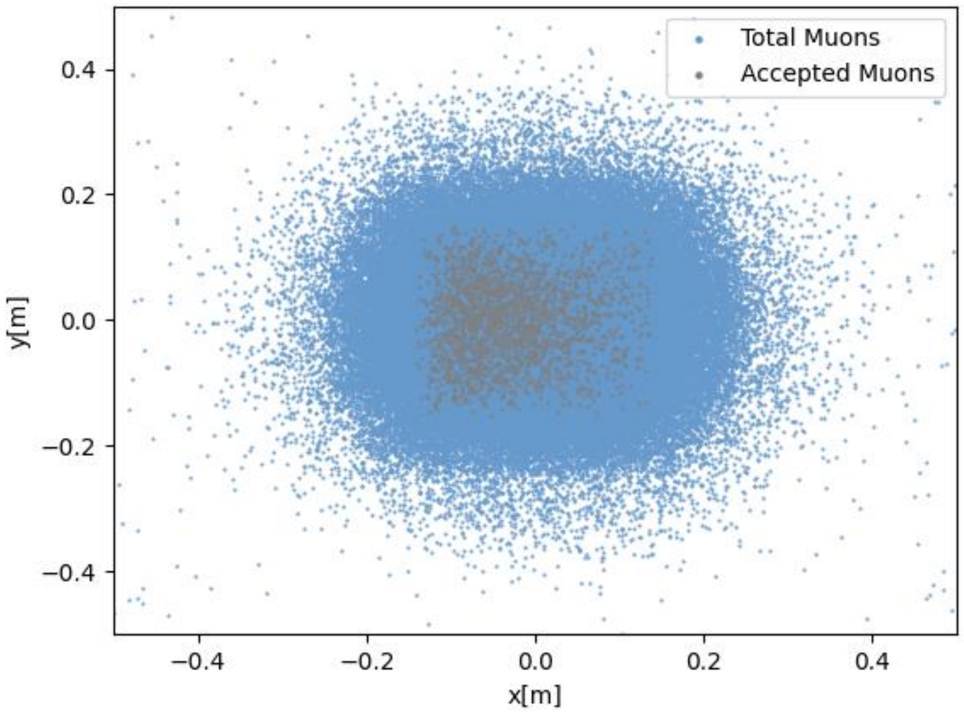


Fig 13 – The Position of the muons and the accepted muons for a 2.64GeV/c Reference Pion Momenta

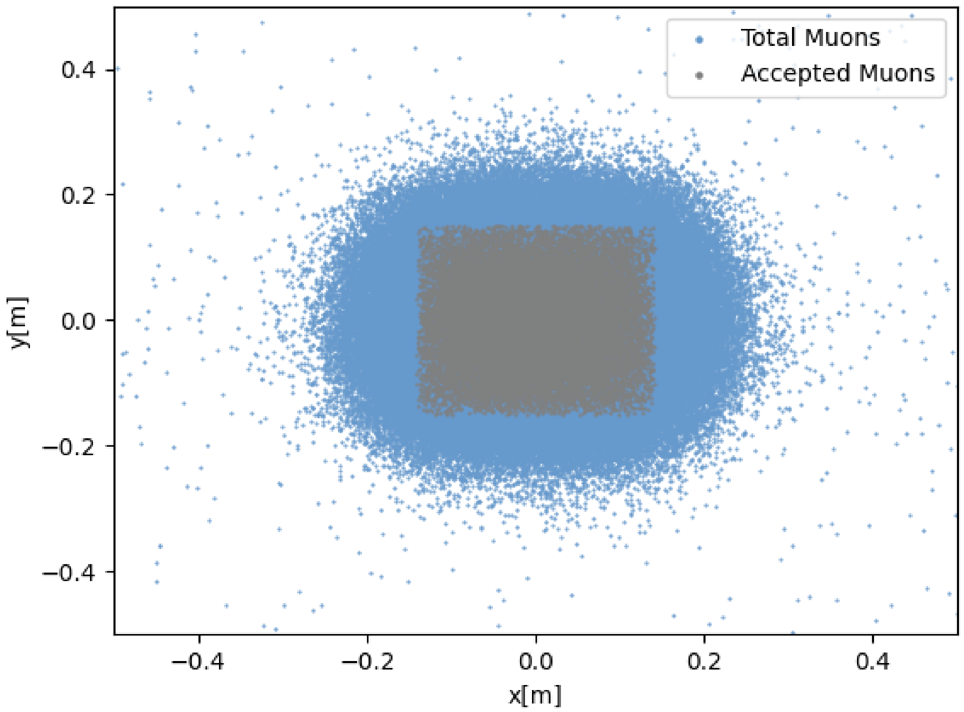
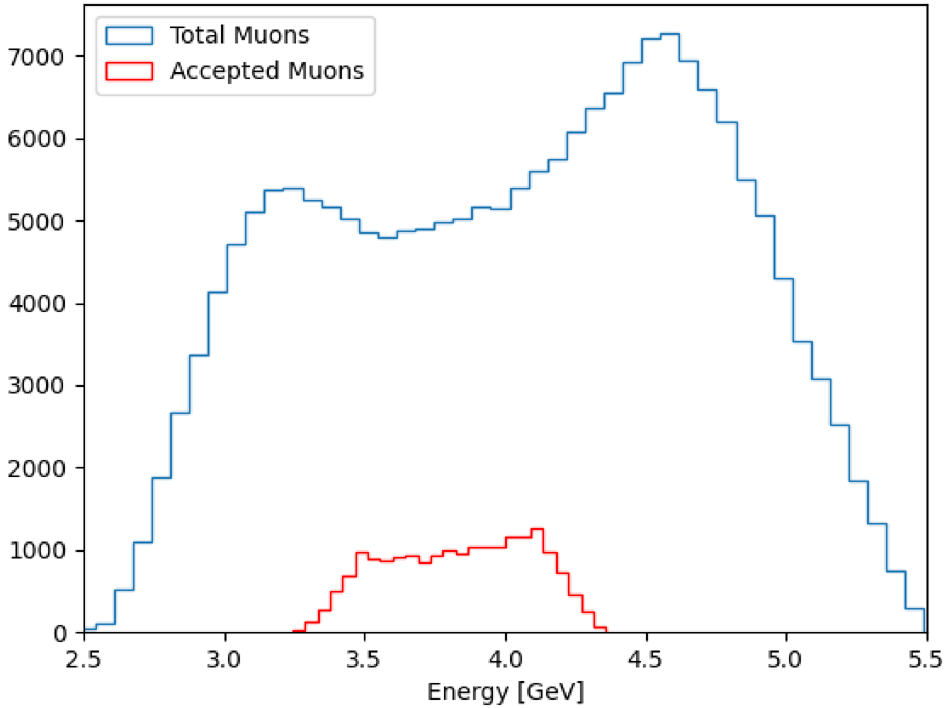
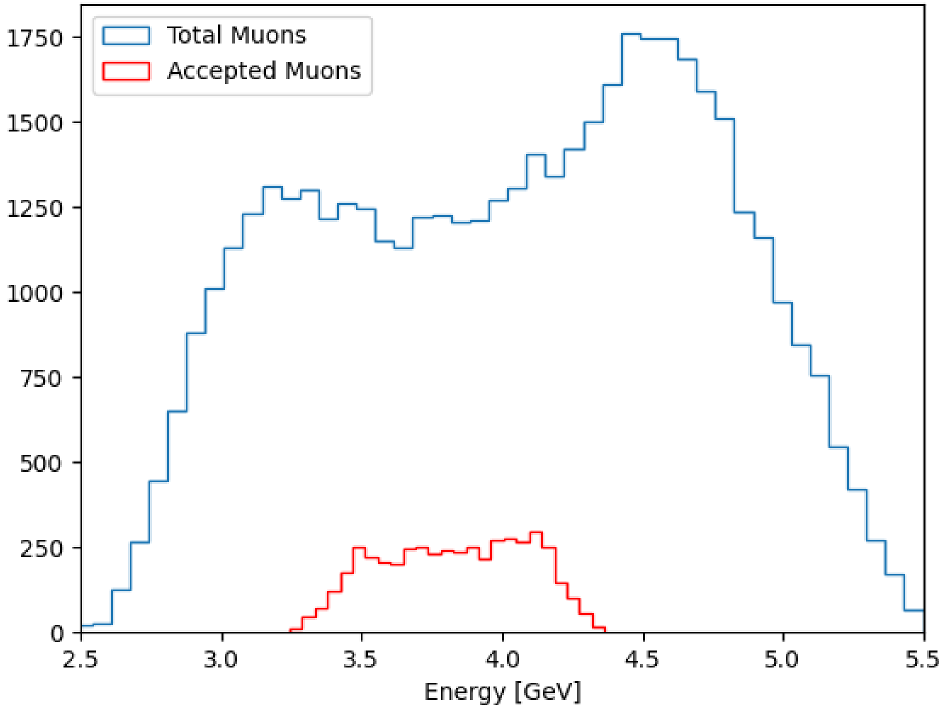


Fig 14 – The Position of the muons and the accepted muons for a 7.2GeV/c Reference Pion Momenta

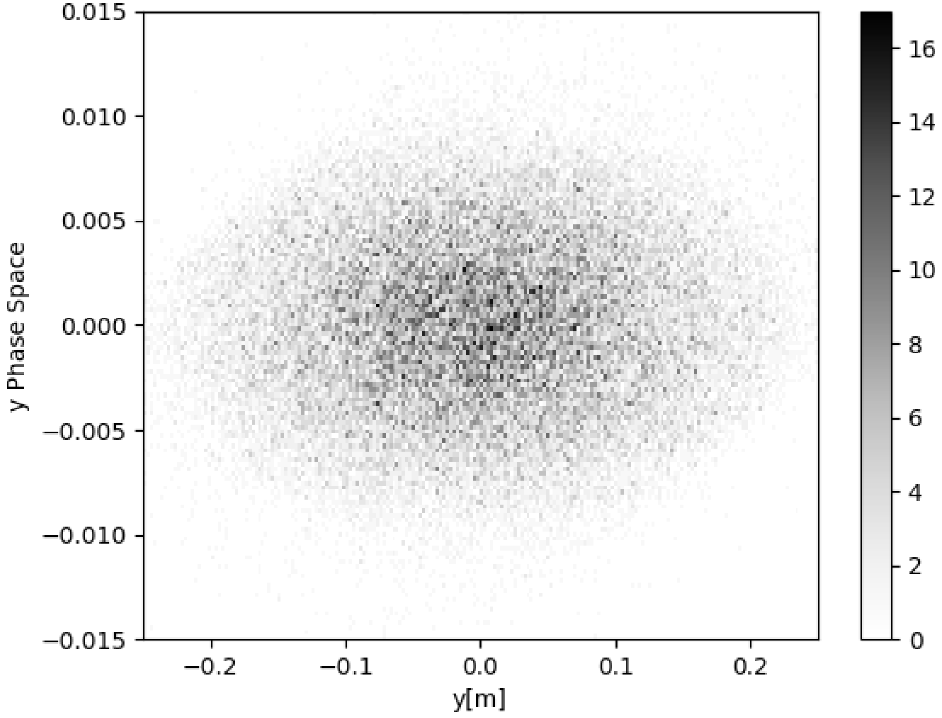
SPS vs PS

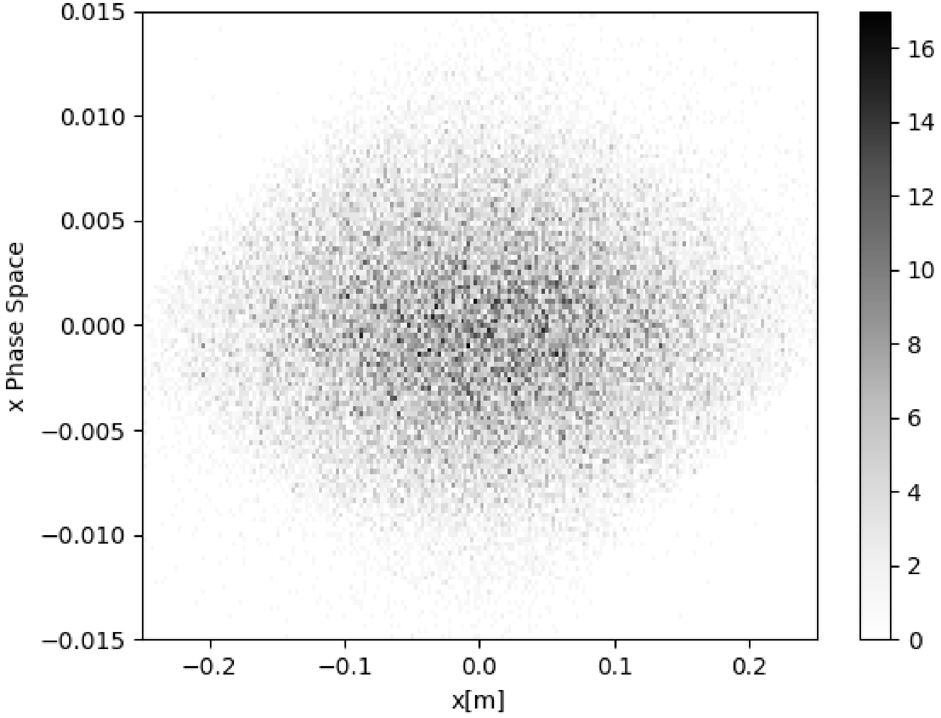
SPS vs PS Muon Energy Range



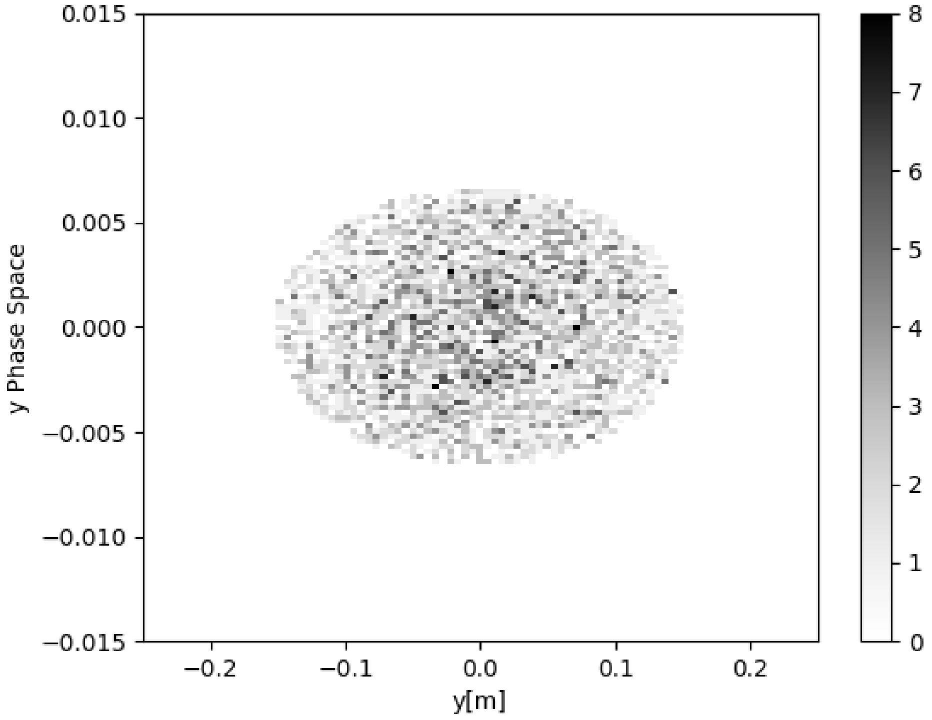


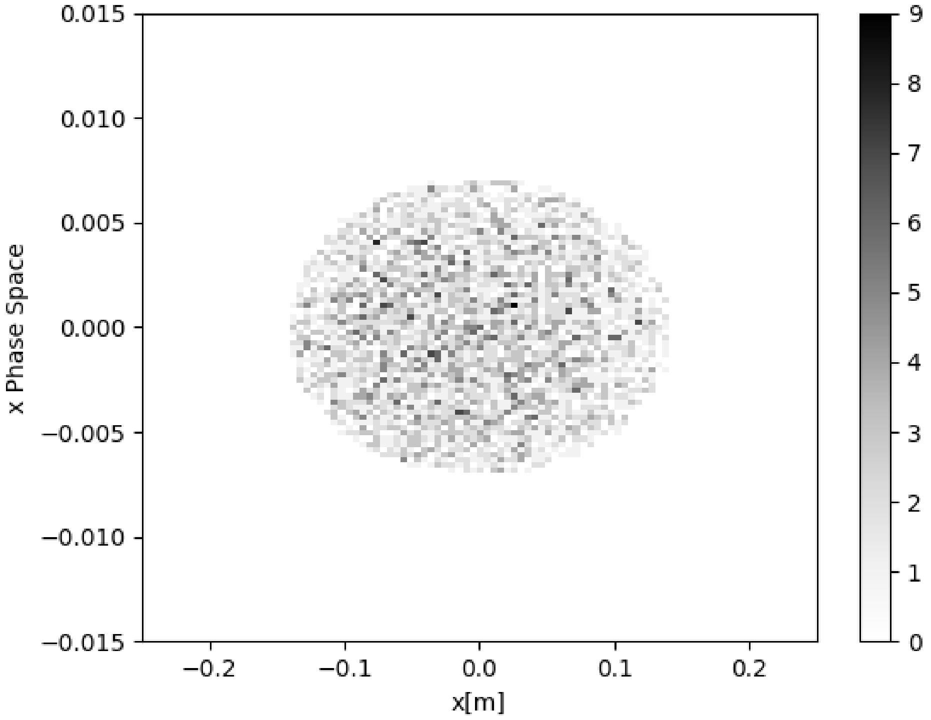
Total Muons PS Phase Space





Accepted Muons PS Phase Space





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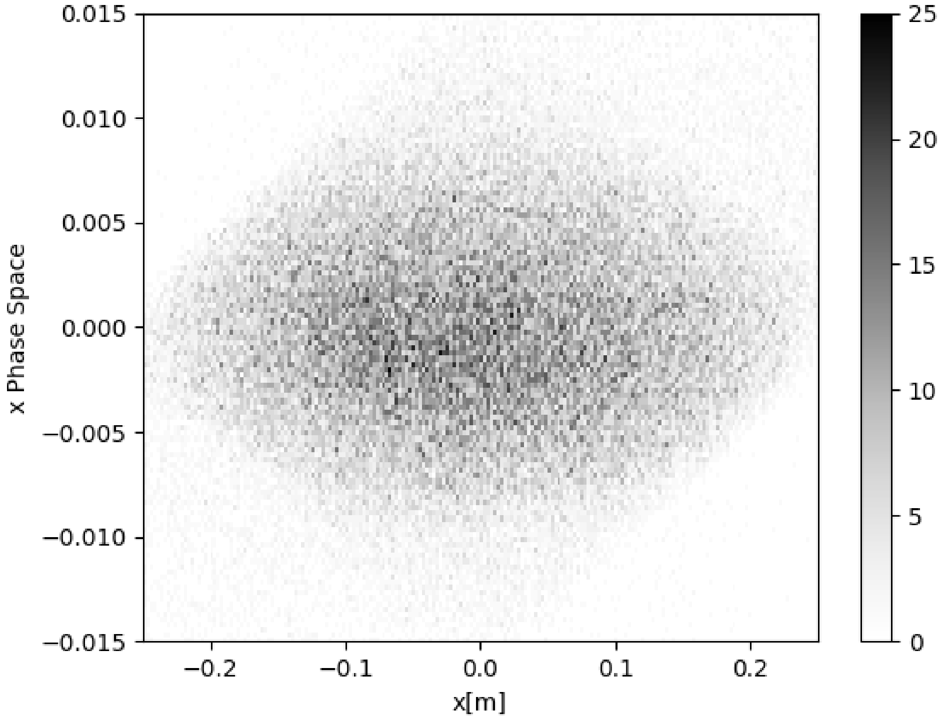
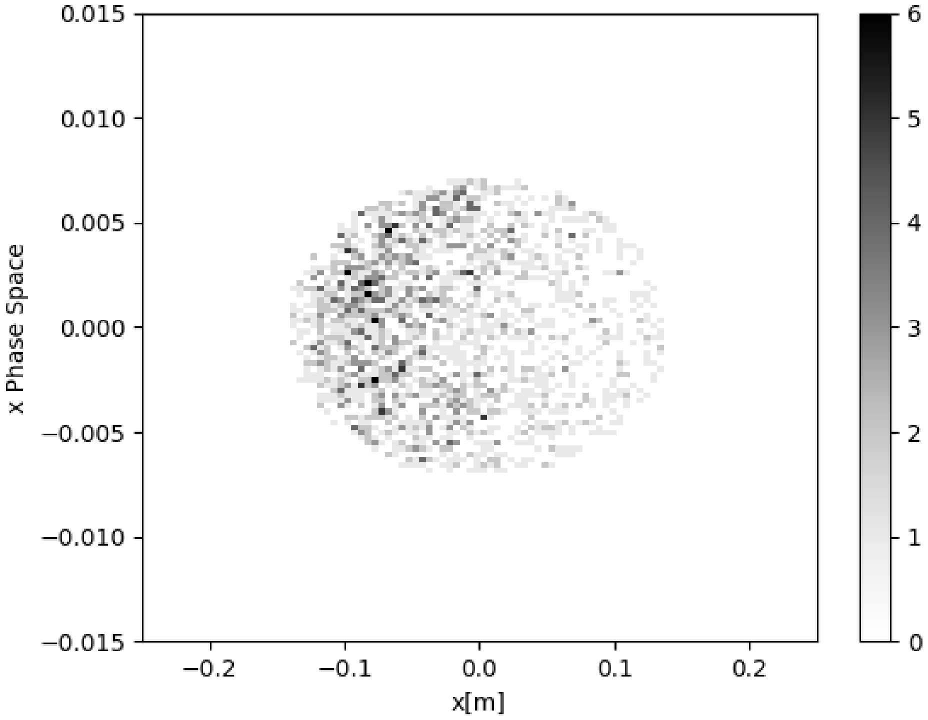
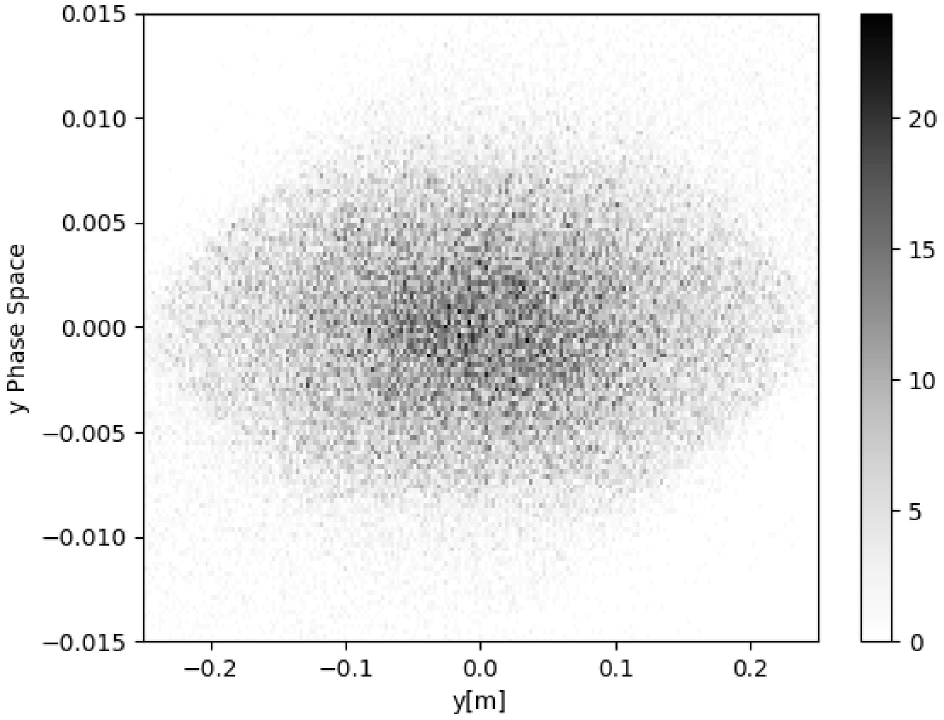
More Results

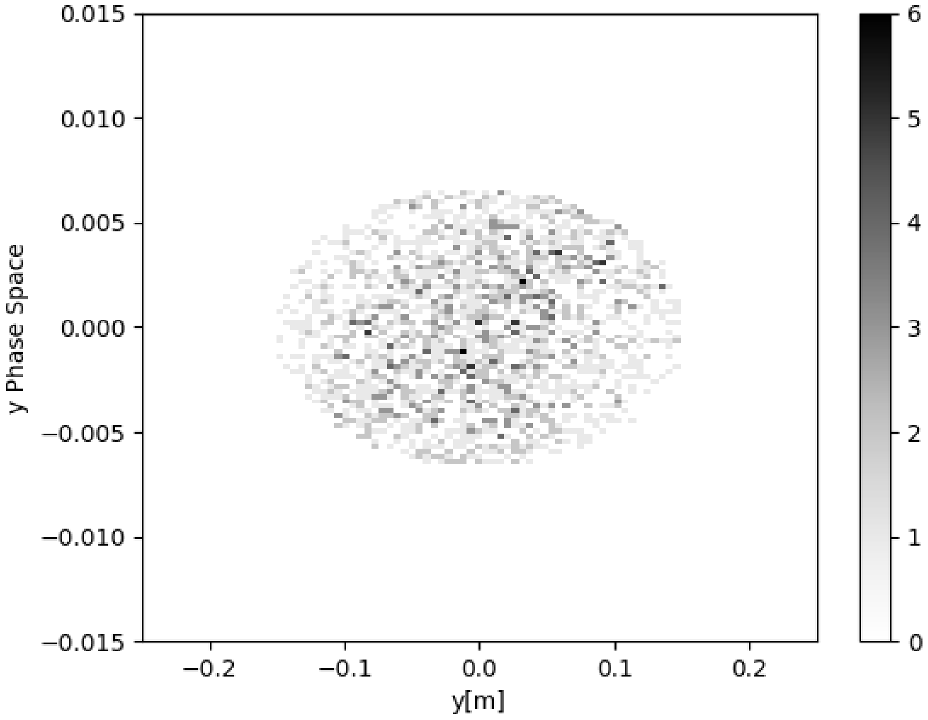
x-Phase Space 2.64GeV



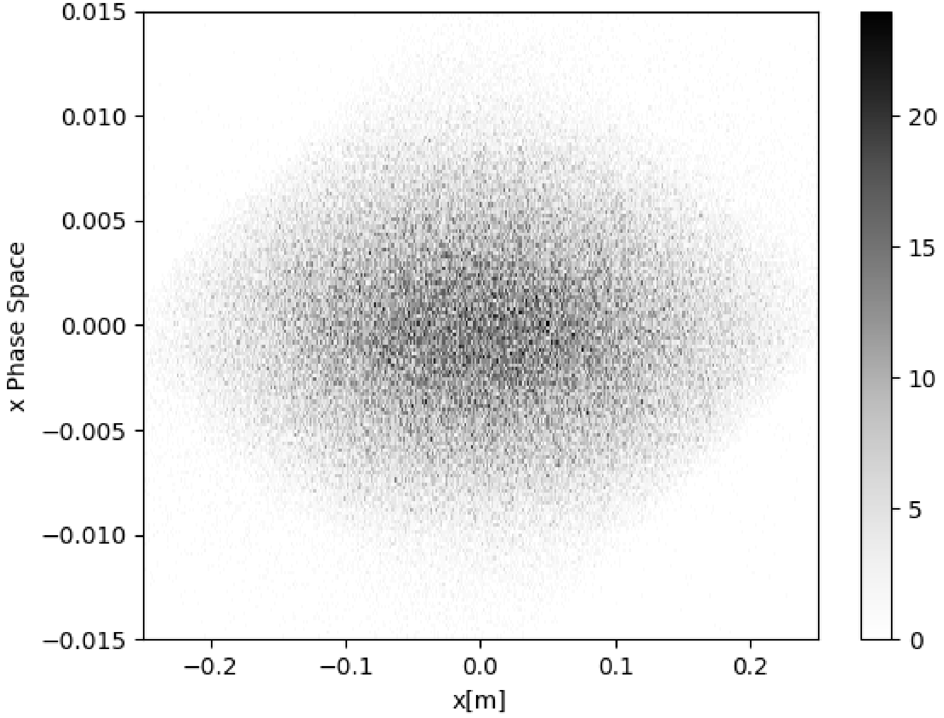


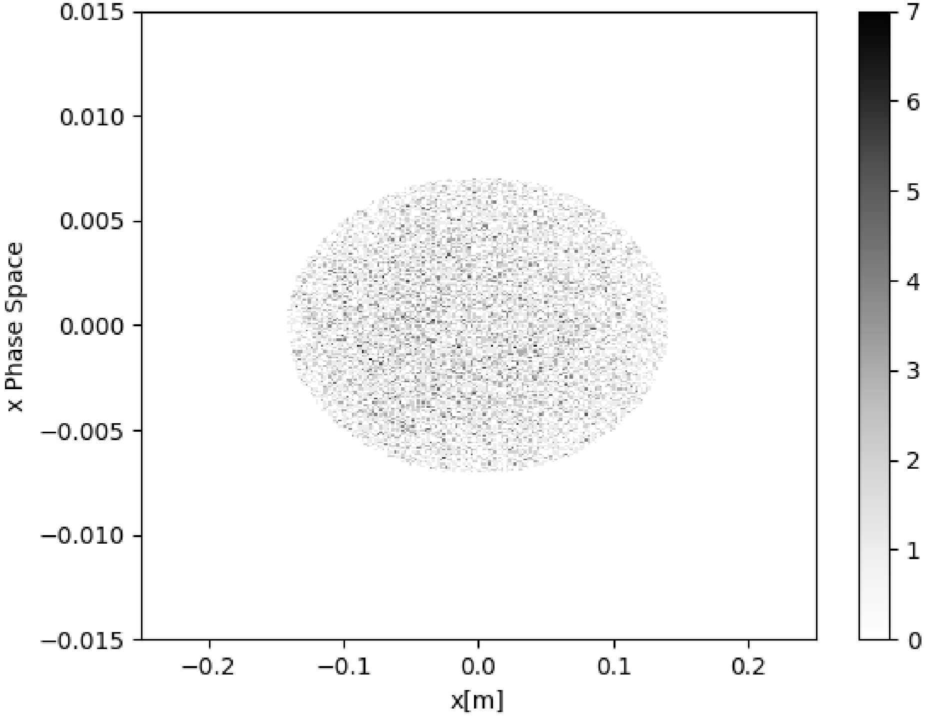
y-Phase Space 2.64GeV



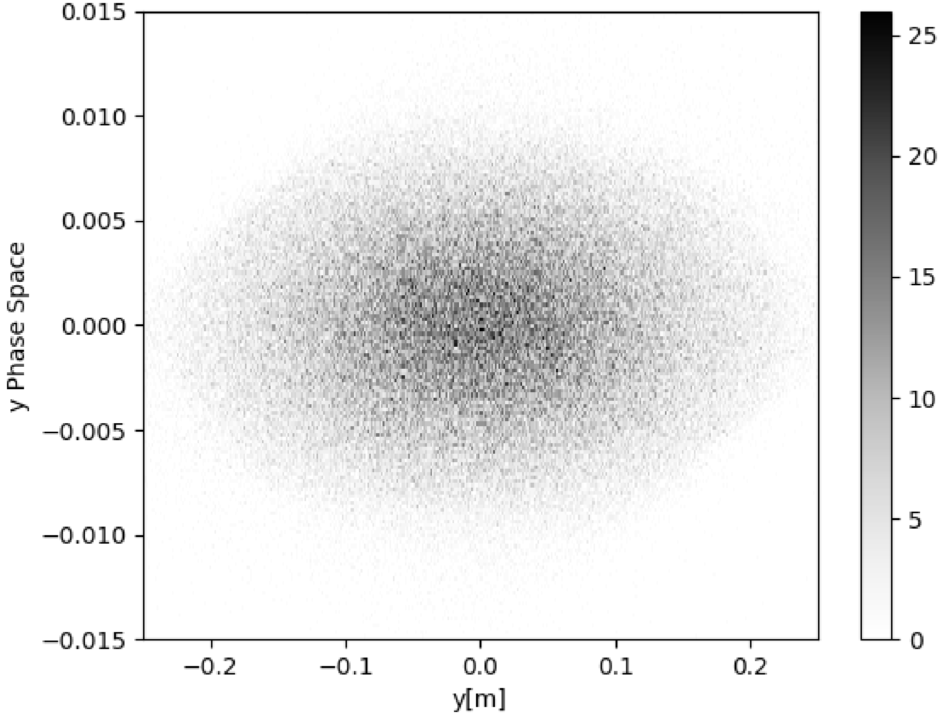


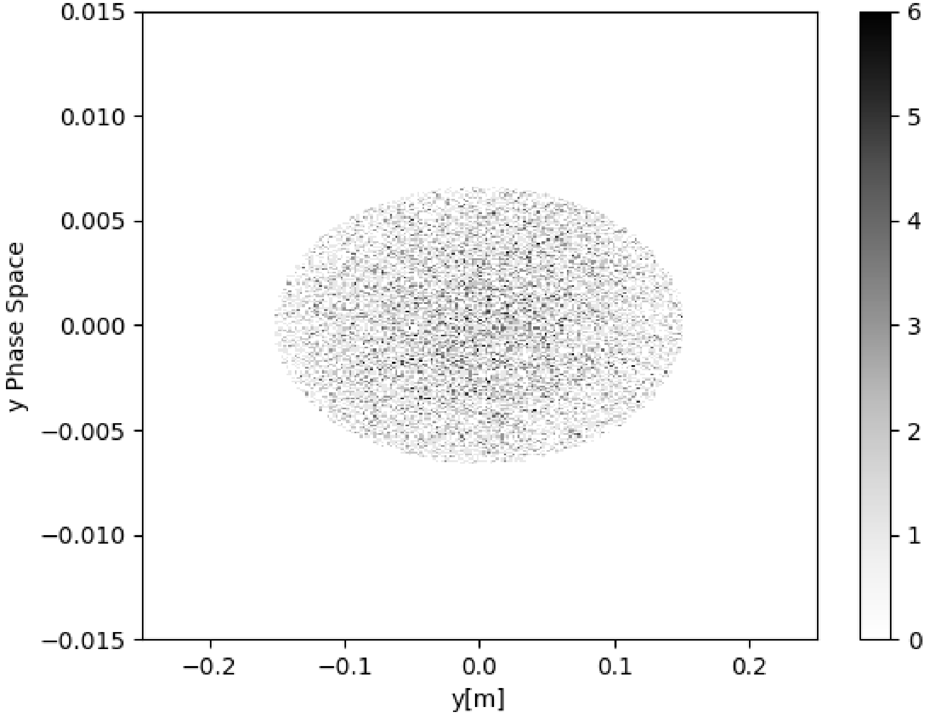
x-Phase Space 5GeV



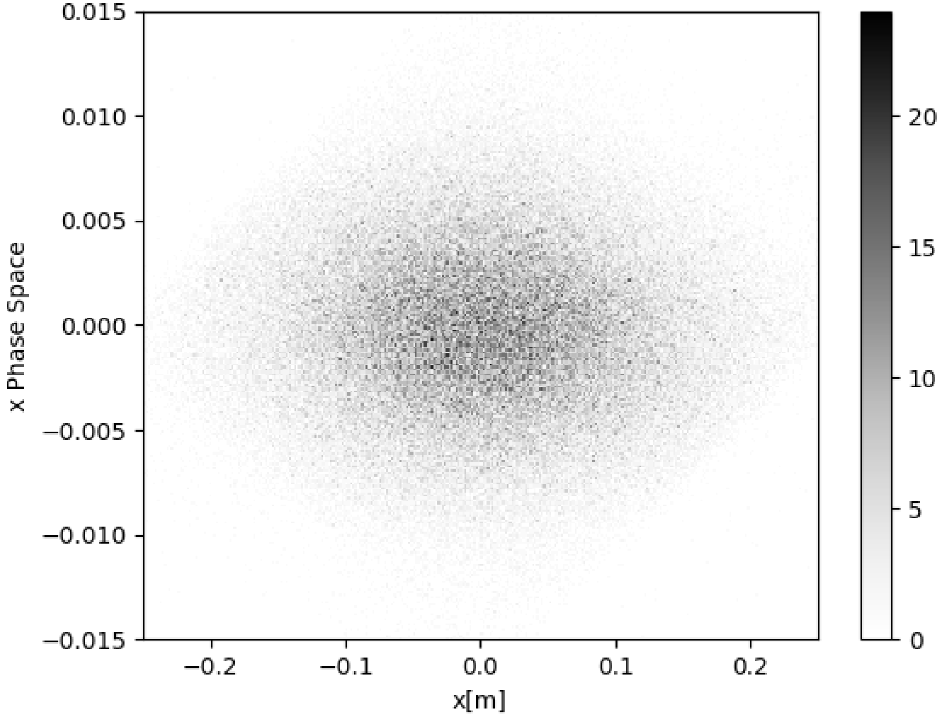


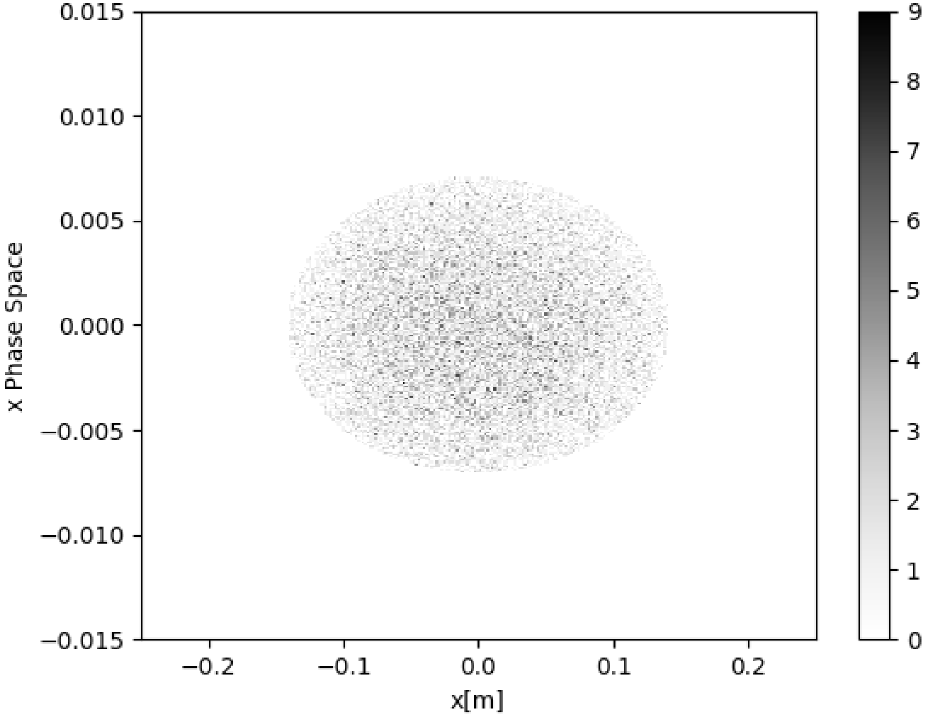
y-Phase Space 5GeV



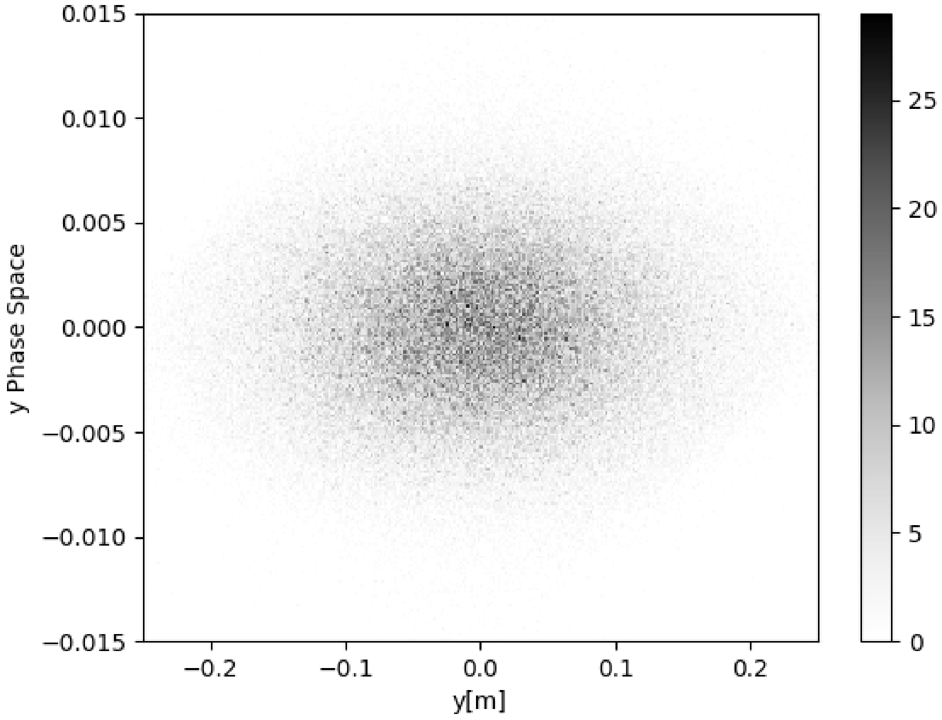


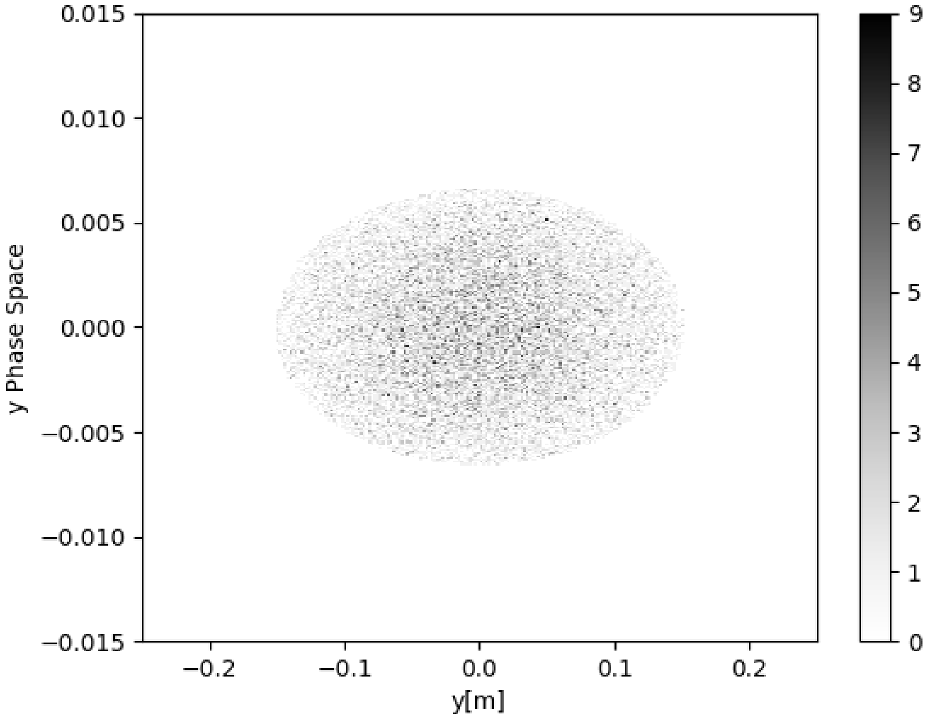
x-Phase Space 7.2GeV



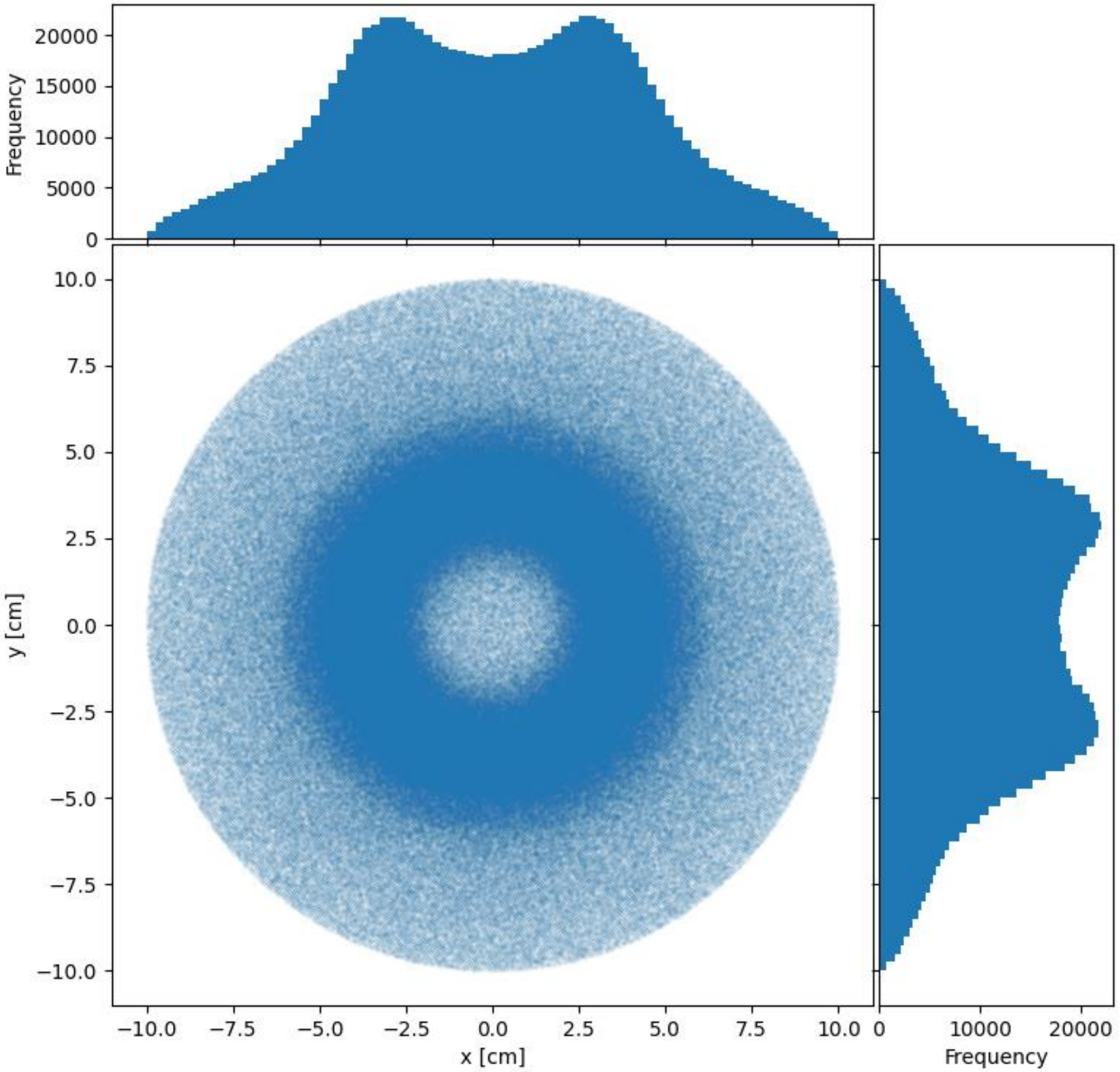


y-Phase Space 7.2GeV

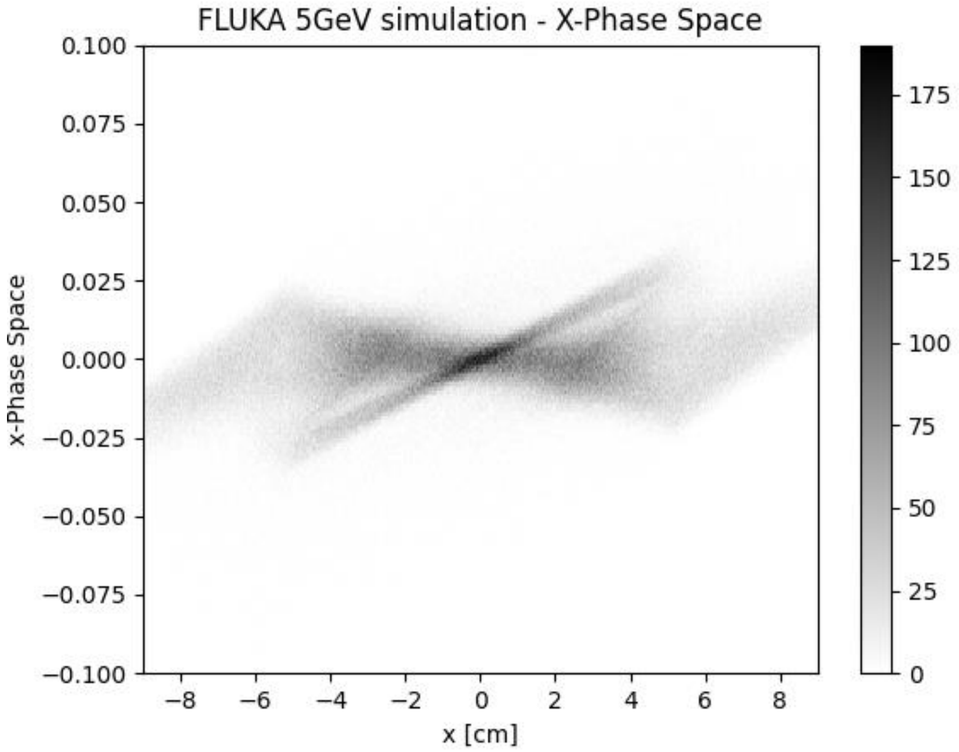


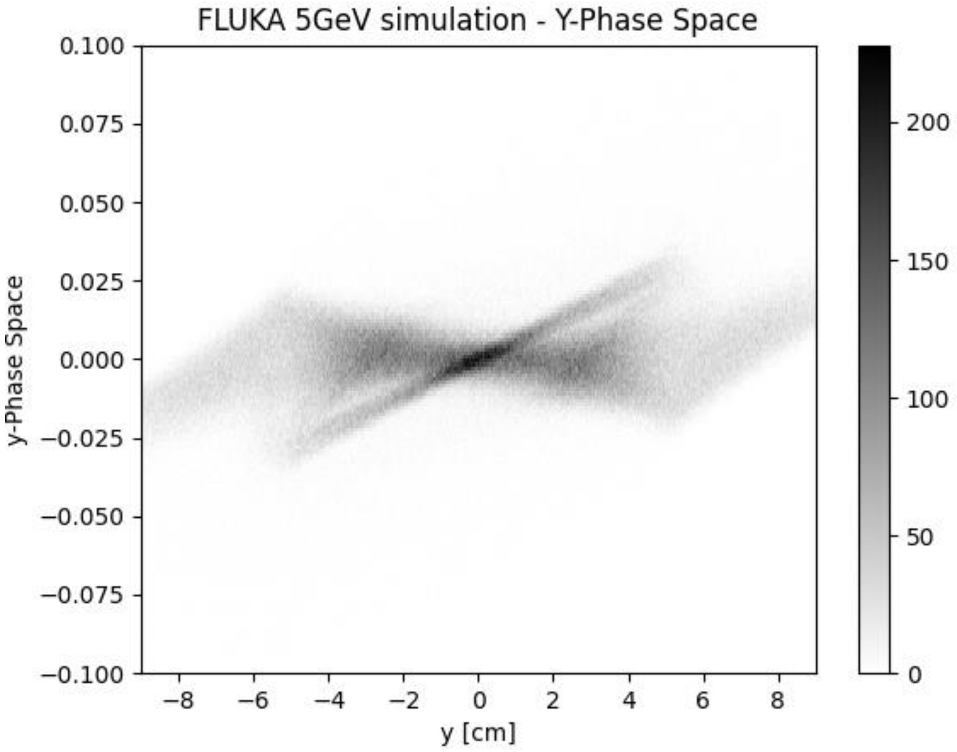


Pion Beam Position

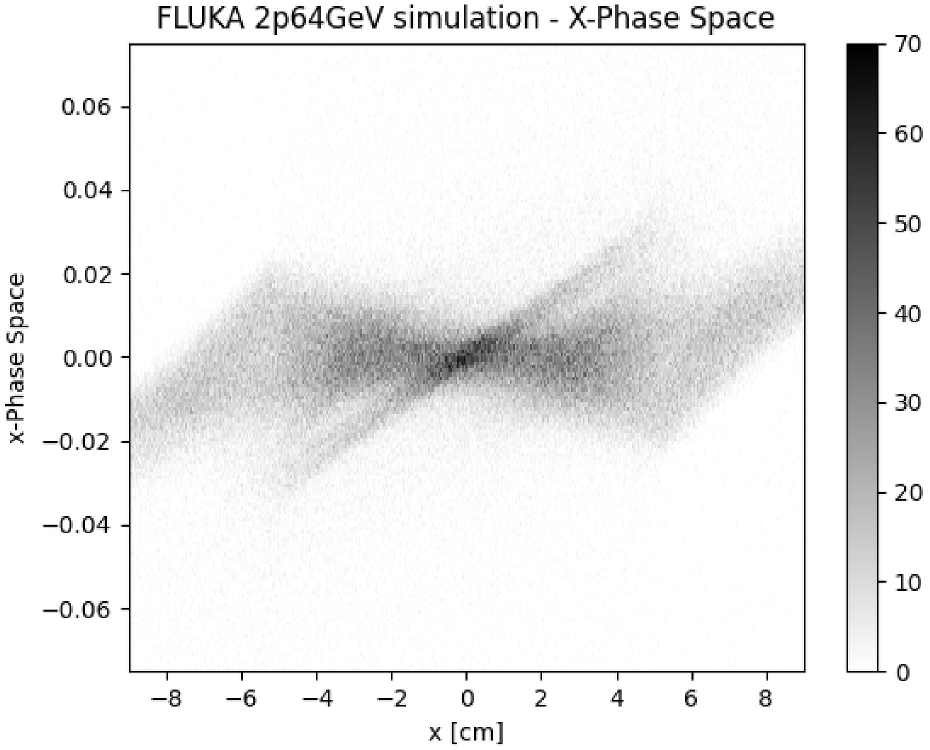


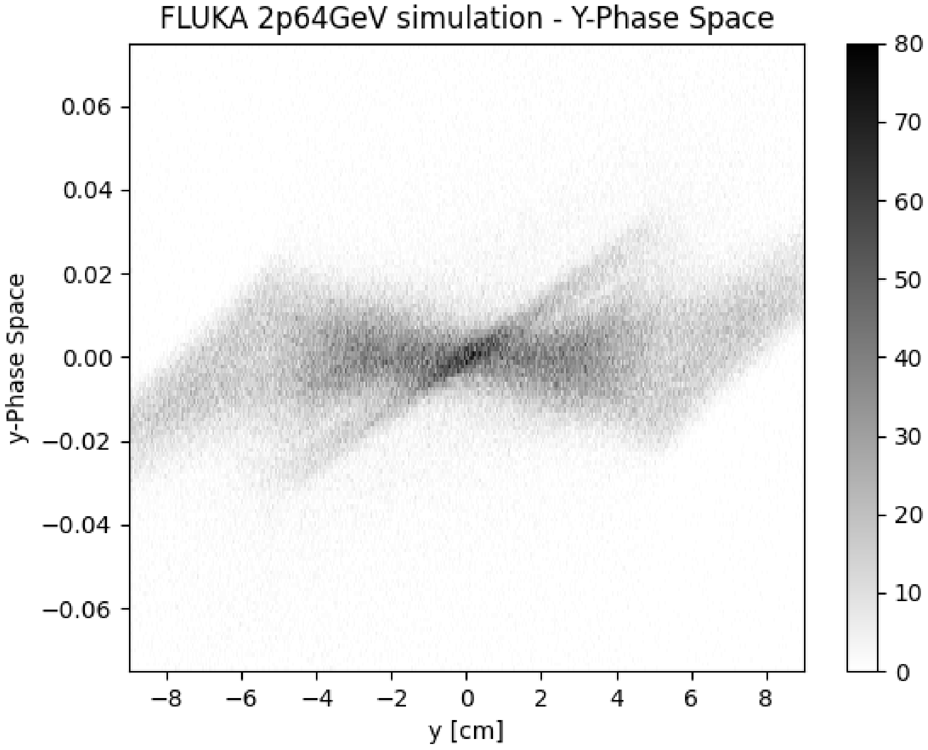
Pion Phase Spaces 5GeV



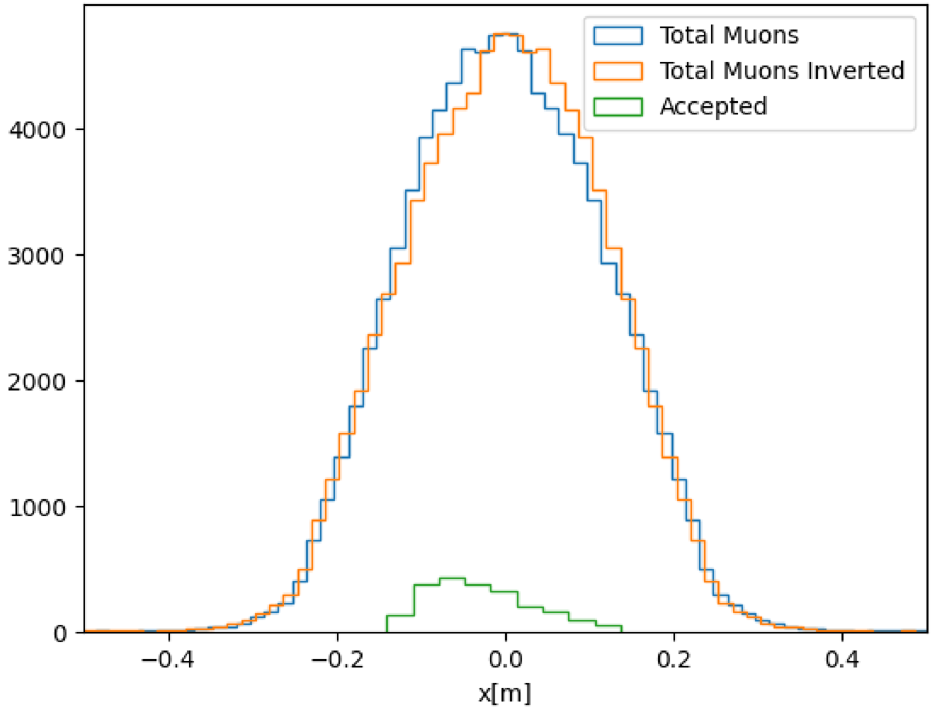


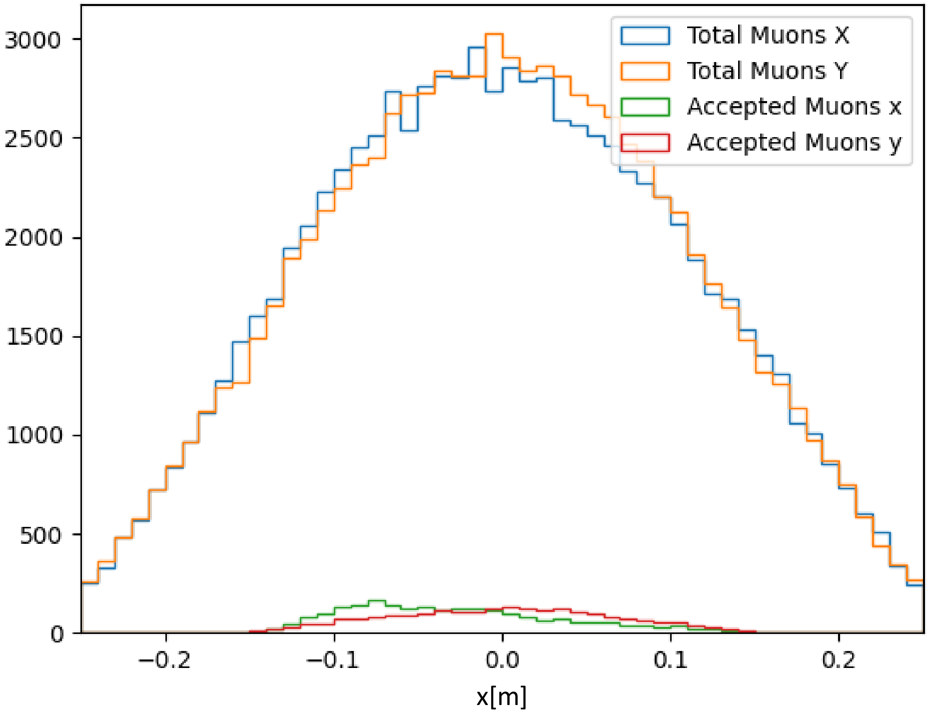
Pion Phase Space 2.64GeV


FLUKA 2p64GeV simulation - X-Phase Space

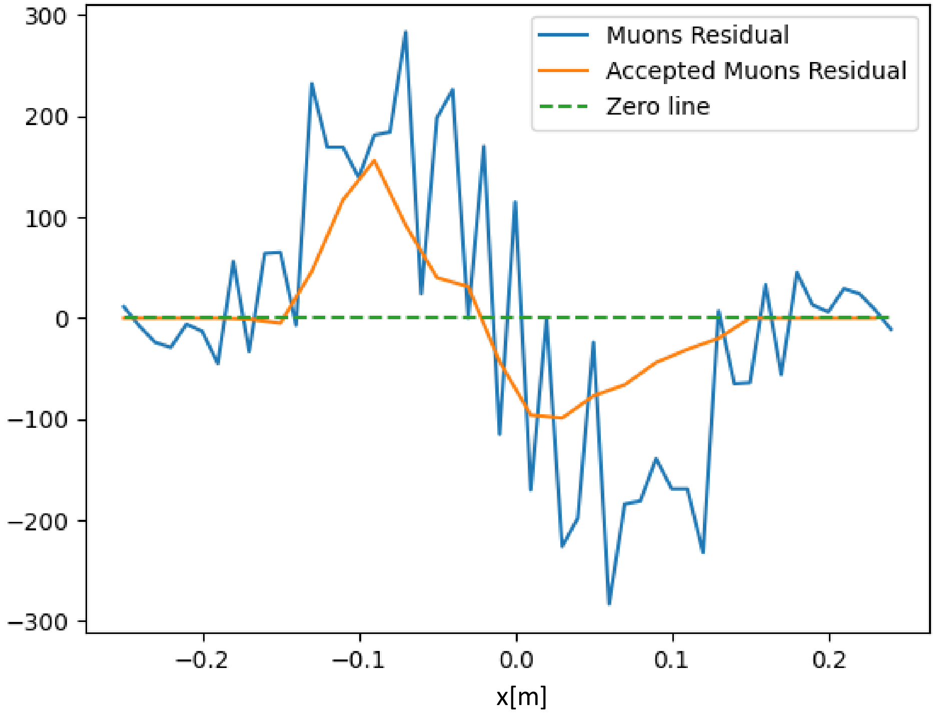

FLUKA 2p64GeV simulation - Y-Phase Space

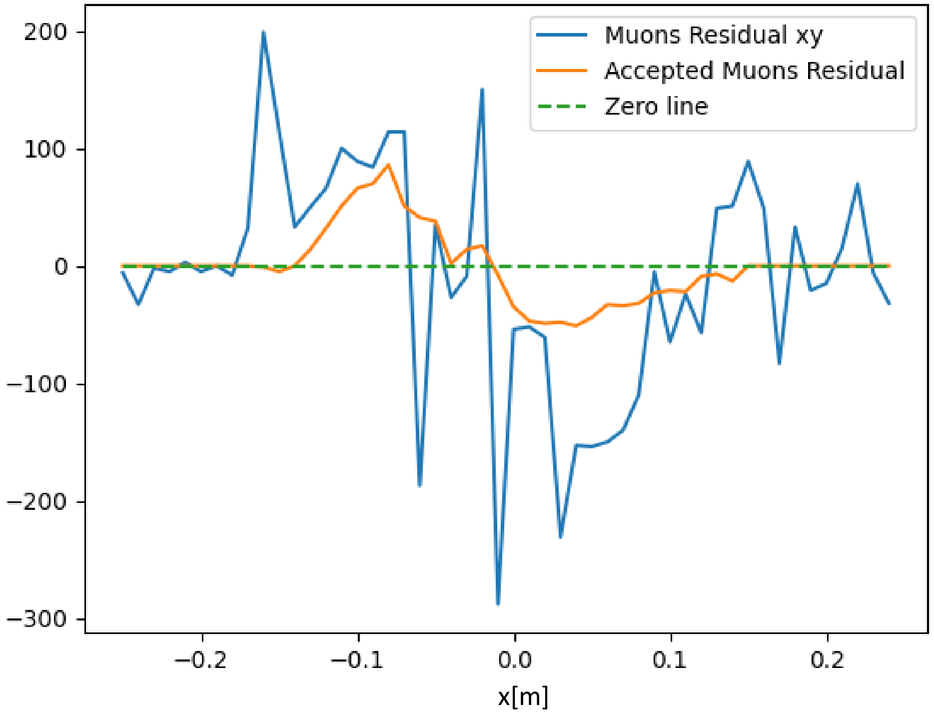
Left sided Conundrum





Residual


Muons Residual
Accepted Muons Residual
Zero line
300
200
100
0
−100
−200
−300
−0.2
−0.1
0.0
0.1
0.2
x[m]


Muons Residual xy
Accepted Muons Residual
Zero line
200
100
0
−100
−200
−300
−0.2
−0.1
0.0
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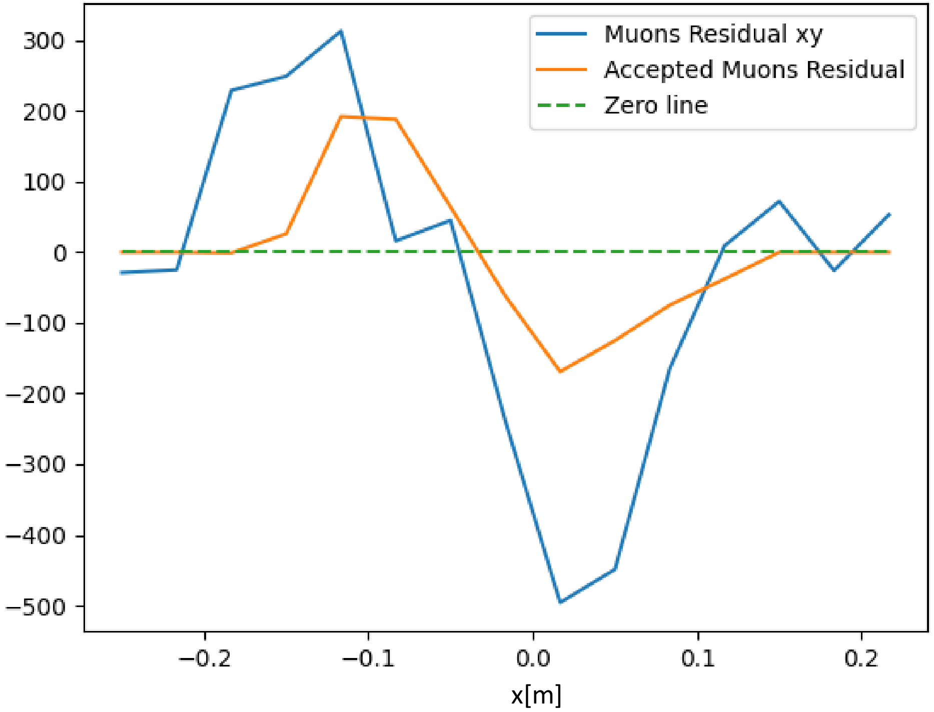
0.2
x[m]

Larger Bin Size



Different Mom Spread for 5 & 2.64GeV/c