

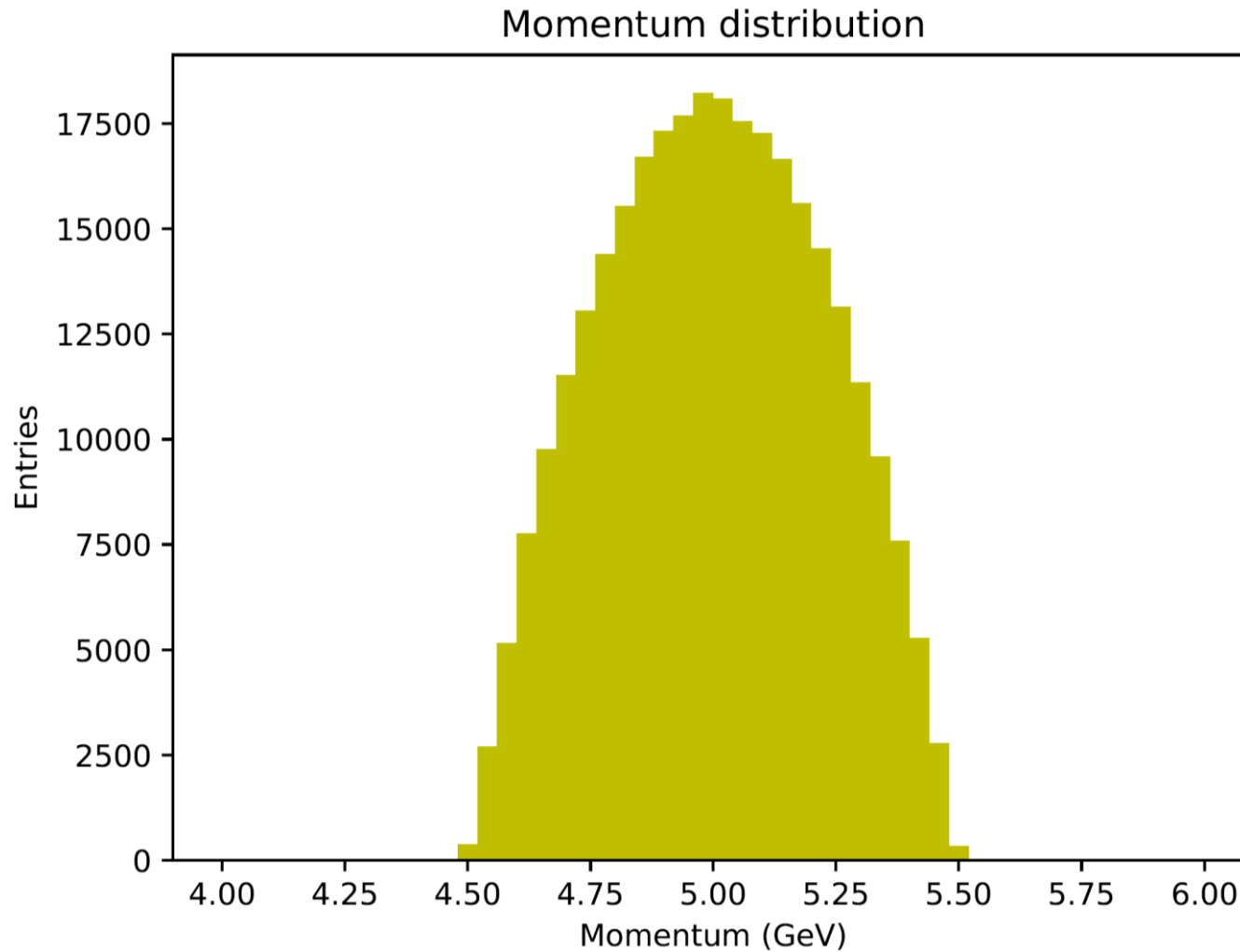
Simulating the nuSTORM Transfer Line with nuSIM

Marvin Pfaff

Motivation

- To understand the time structure and beam characteristics at the proposed nuSTORM detector, it is important to properly propagate the beam structure from the SPS on target through the whole nuSTORM set-up
- A simulation framework, that is simplified through effective parametrizations, has been developed to allow first event rate studies while detailed beam simulations with design of beam optics are carried out
- A multi-stage/interface approach allows the inclusion of more detailed simulation data as these get available
- The nuSIM transfer line class contains a *first simple propagation of beam characteristics from target to injection*
- For this, the following steps were taken:
 1. Pion distributions @ target generated
 - a) Momentum distribution
 - b) Transverse phase space distributions
 - c) Time distribution
 2. Pion decay taken into account
 3. Pions propagated to entrance of production straight

Momentum Distribution @ Target

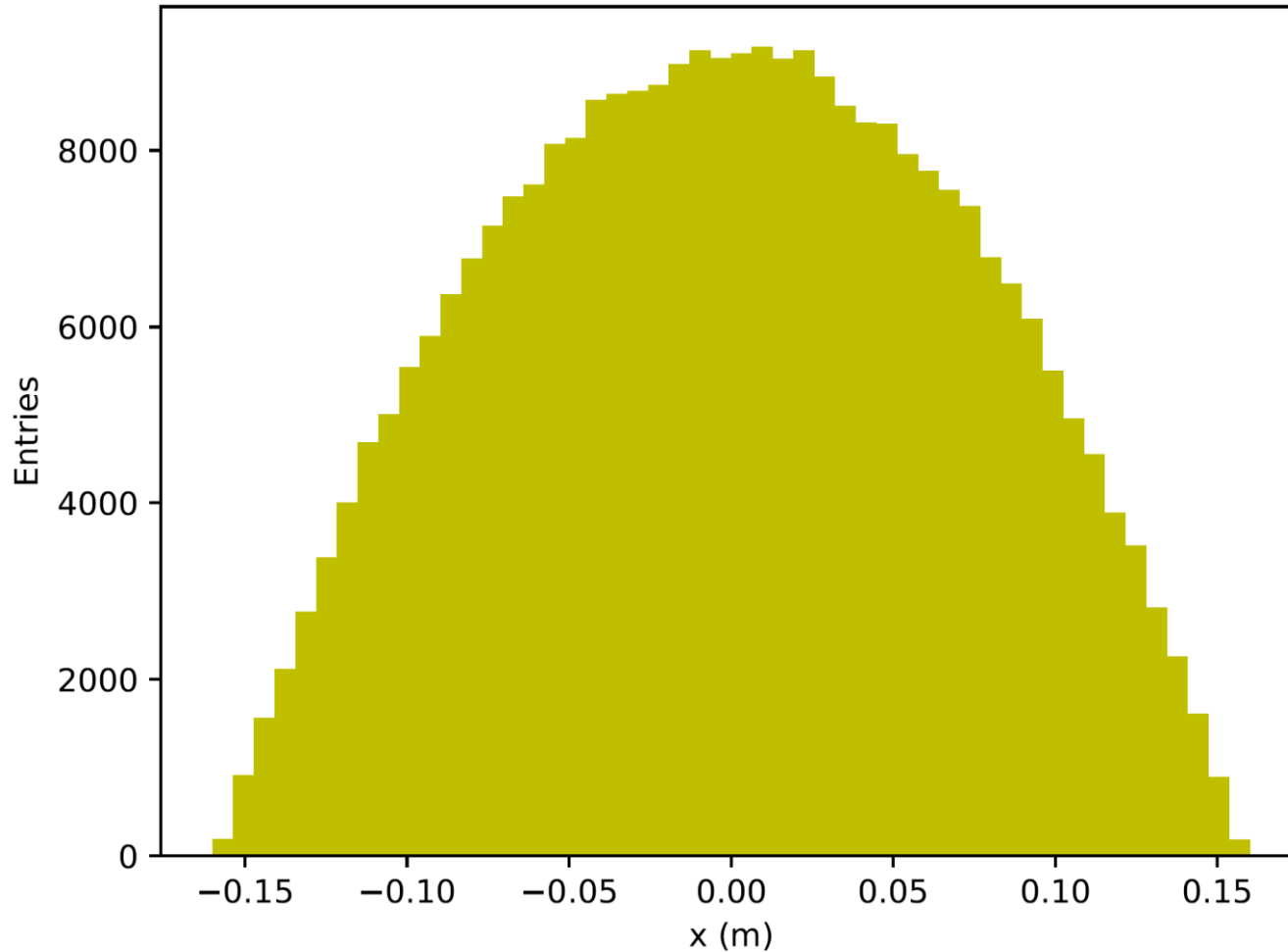


Momentum distribution @ target ($s = -50.0$ m):

- Parabolic distribution
- 5 GeV central momentum
- 10% momentum spread

x Distribution @ Target

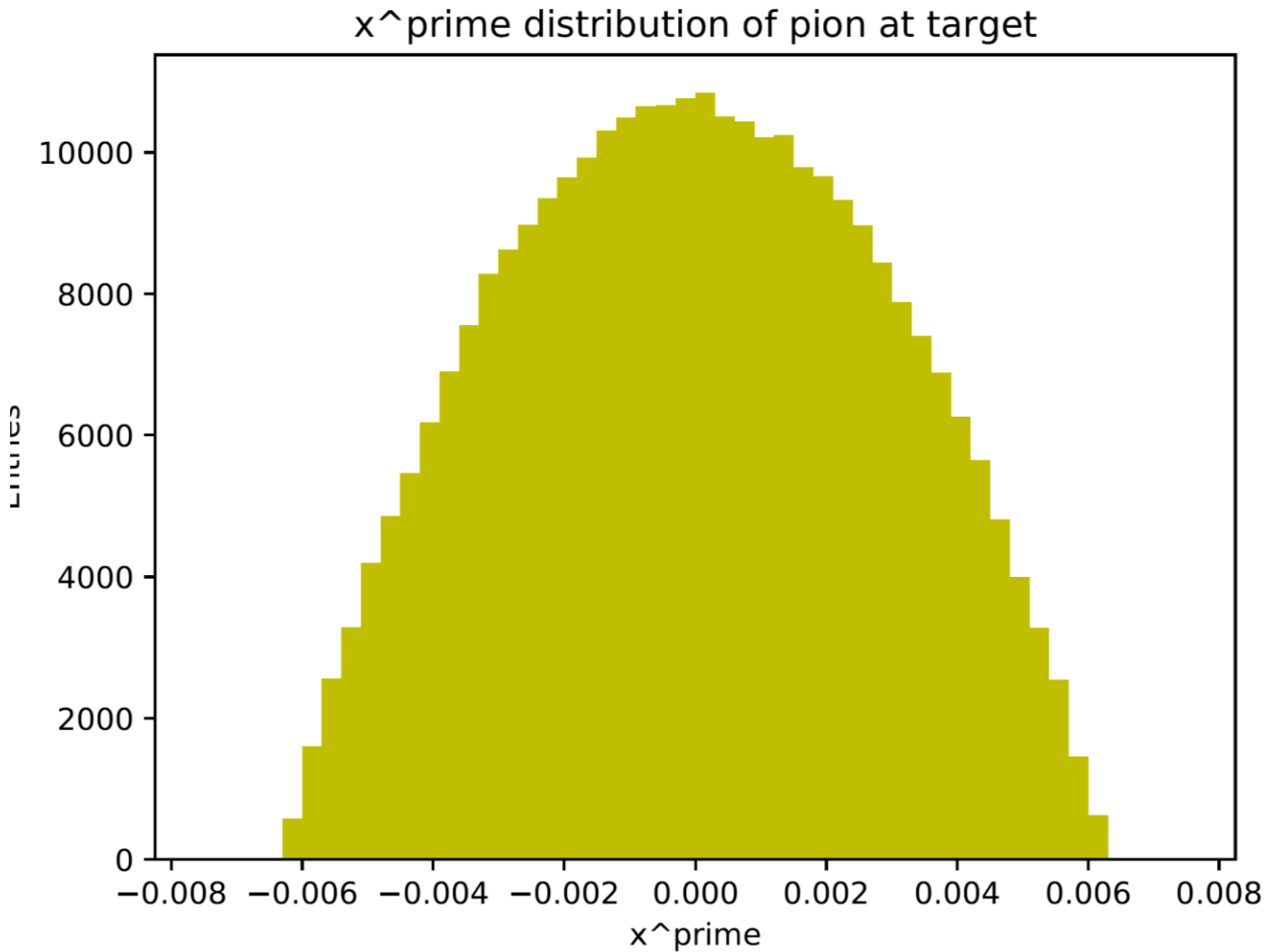
x distribution of pion at target



x distribution @ target (s = -50.0 m):

- Parabolic distribution
- Centered around 0 m
- Transverse (2D) acceptance: 1 pi mm rad
- Transverse beta function: 25,000 mm

x' Distribution @ Target

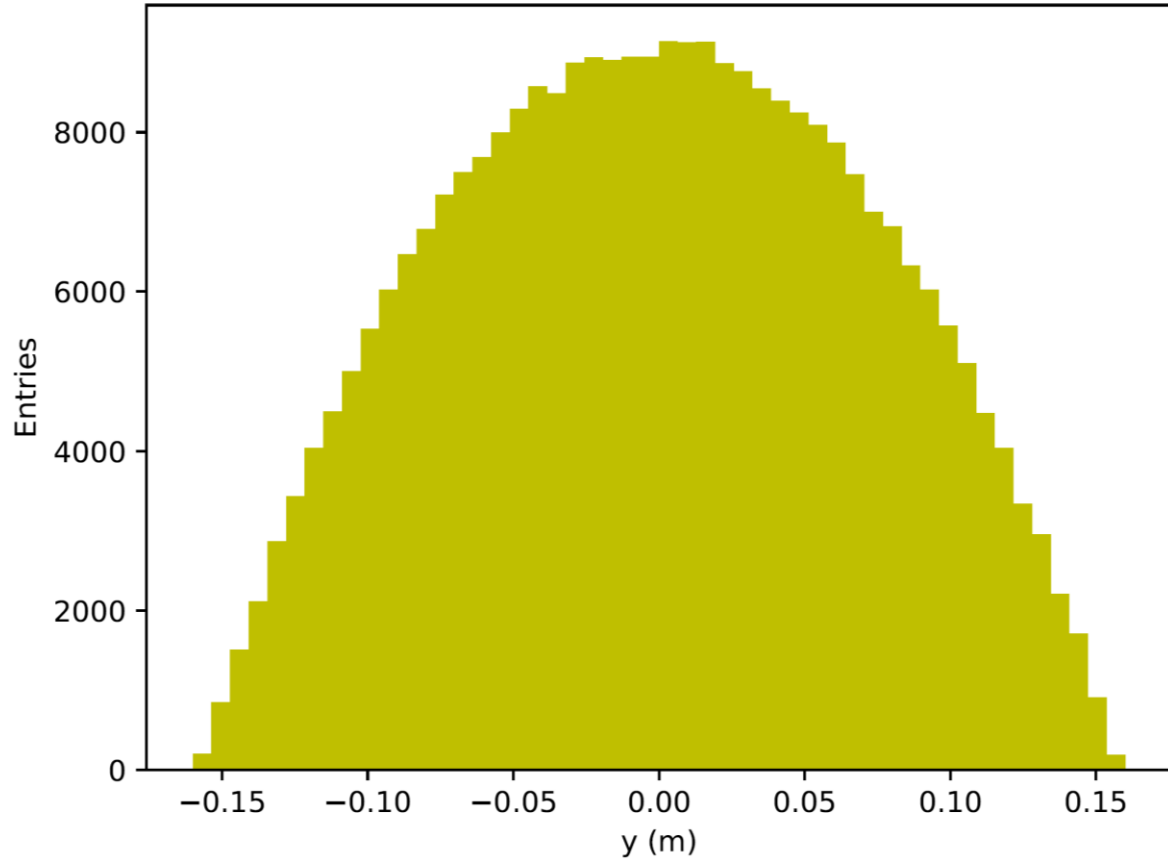


x' distribution @ target ($s = -50.0$ m):

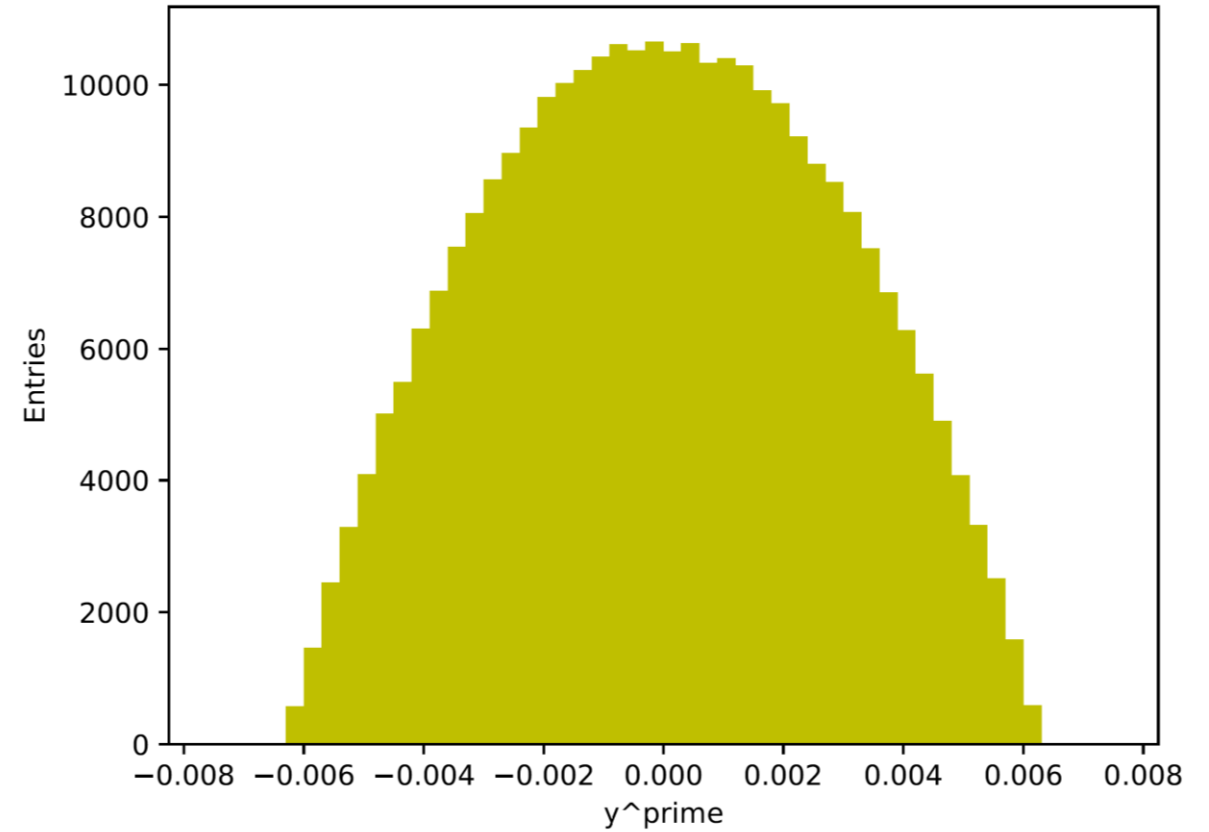
- Parabolic distribution
- Centered around 0 m
- Transverse (2D) acceptance: 1π mm rad
- Transverse beta function: 25,000 mm

y & y' Distributions @ Target

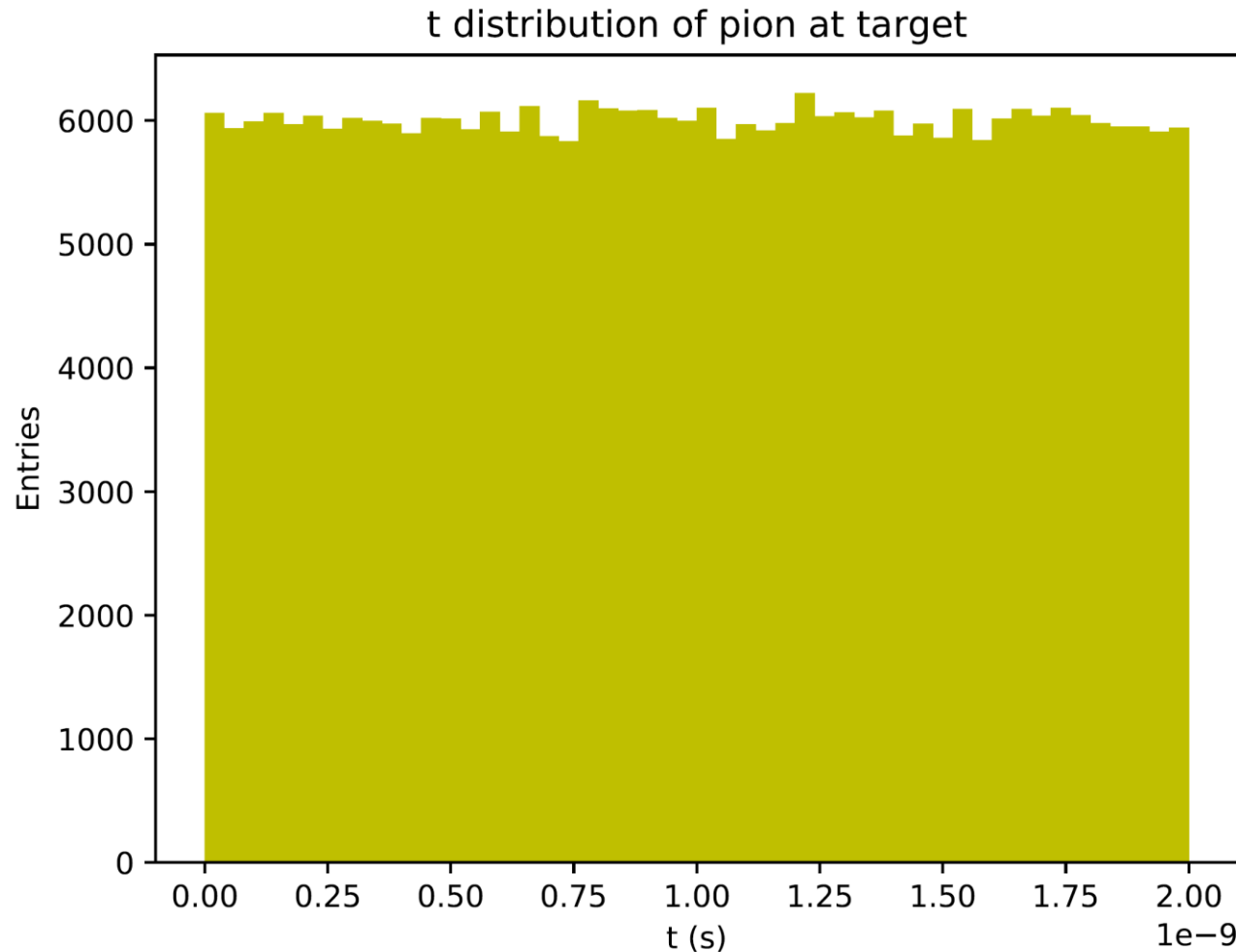
y distribution of pion at target



y' distribution of pion at target



Time Distribution @ Target

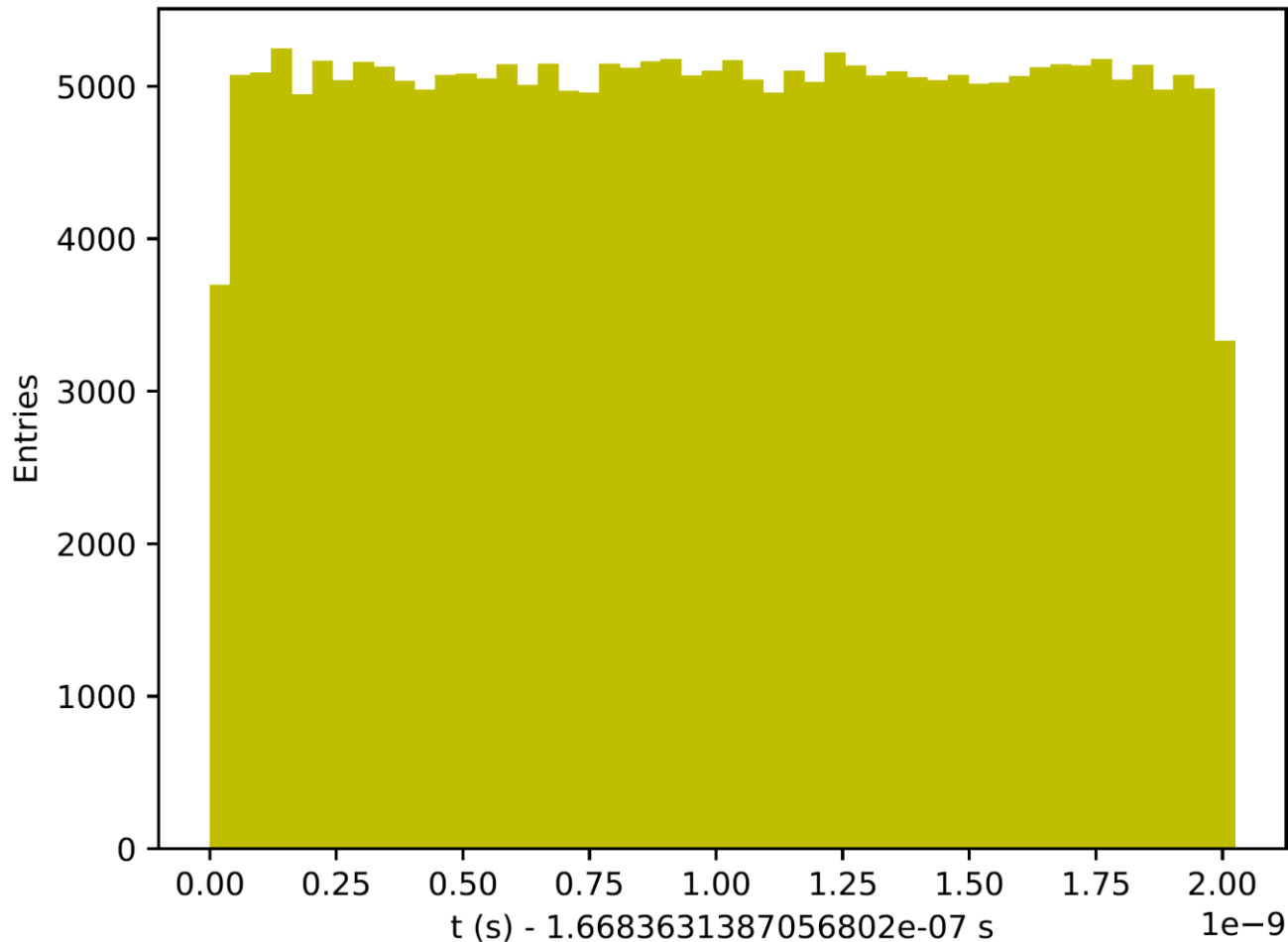


Time distribution @ target ($s = -50.0$ m):

- Uniform distribution
- 2 ns bunch length

Time Distribution @ Decay Straight Entrance

t distribution of pion at production straight entrance

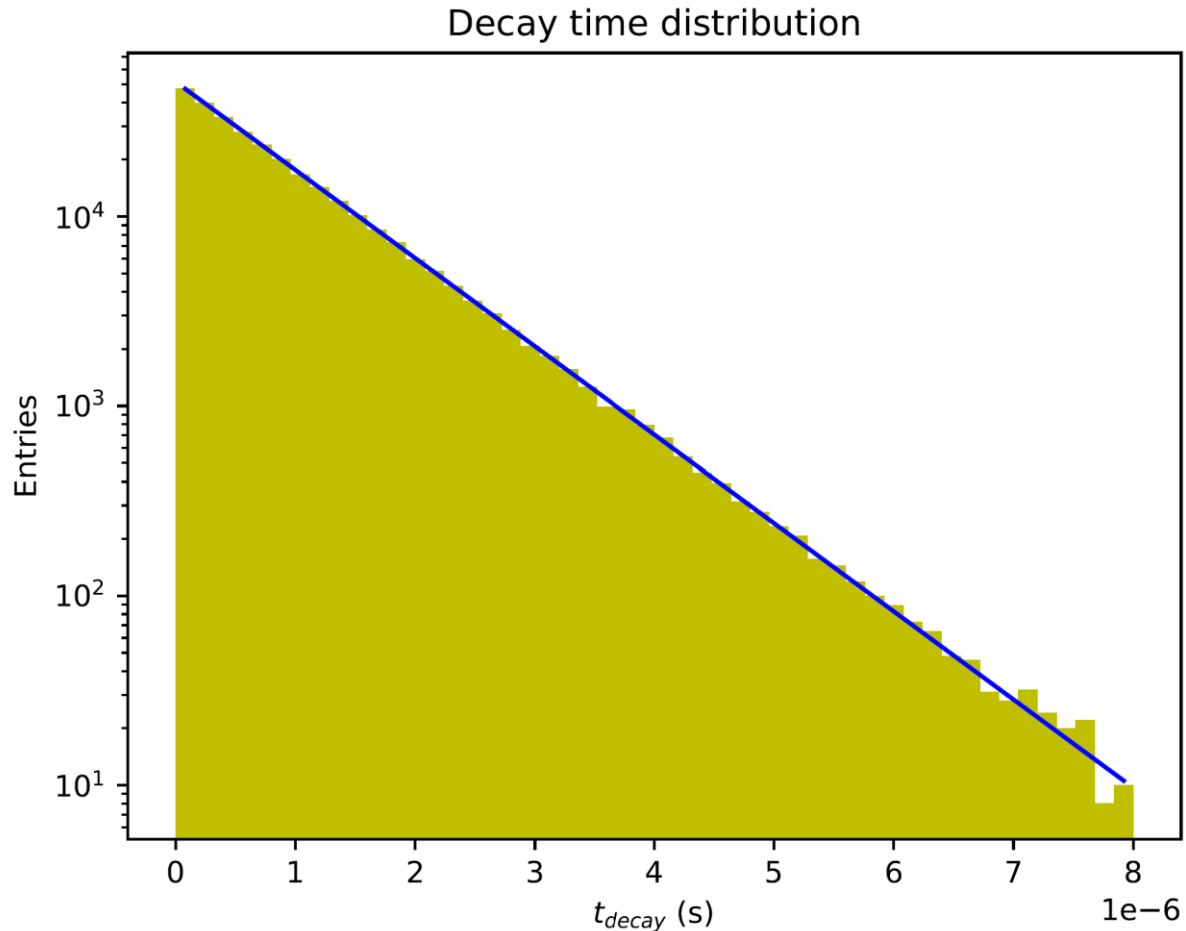


Time distribution @ Decay straight entrance
(s = 0 m):

- Approx. 16 % of pions have decayed
- Time of propagation: $\Delta t_{prop} \approx 165$ ns
- Bunch length: $\Delta t_{bunch} \approx 2.010$ ns

→ Bunch length increased by approx. 0.5%

Pion Decay – Decay Times



PDF:

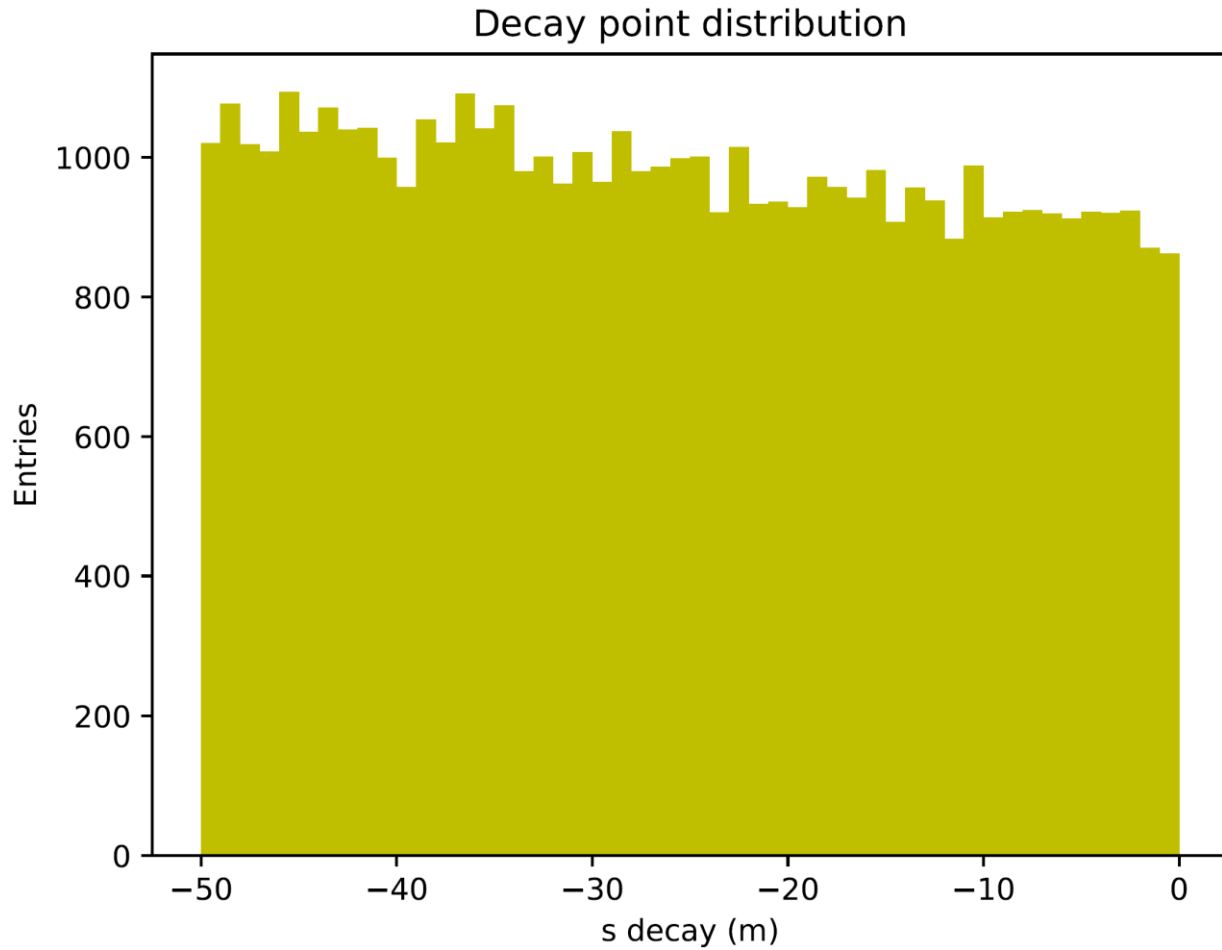
$$f(p) = N_0 \times \exp\left(-\frac{t}{\gamma \cdot \tau}\right)$$

- N_0 : number of entries in first bin
- t : time of particle decay in nuSTORM frame
- τ : particle lifetime
- γ : particle gamma factor (fitted)

$$\rightarrow \gamma \approx 36$$

$$\rightarrow E_0 \approx 5.0 \text{ GeV}$$

Pion Decay – Decay Point

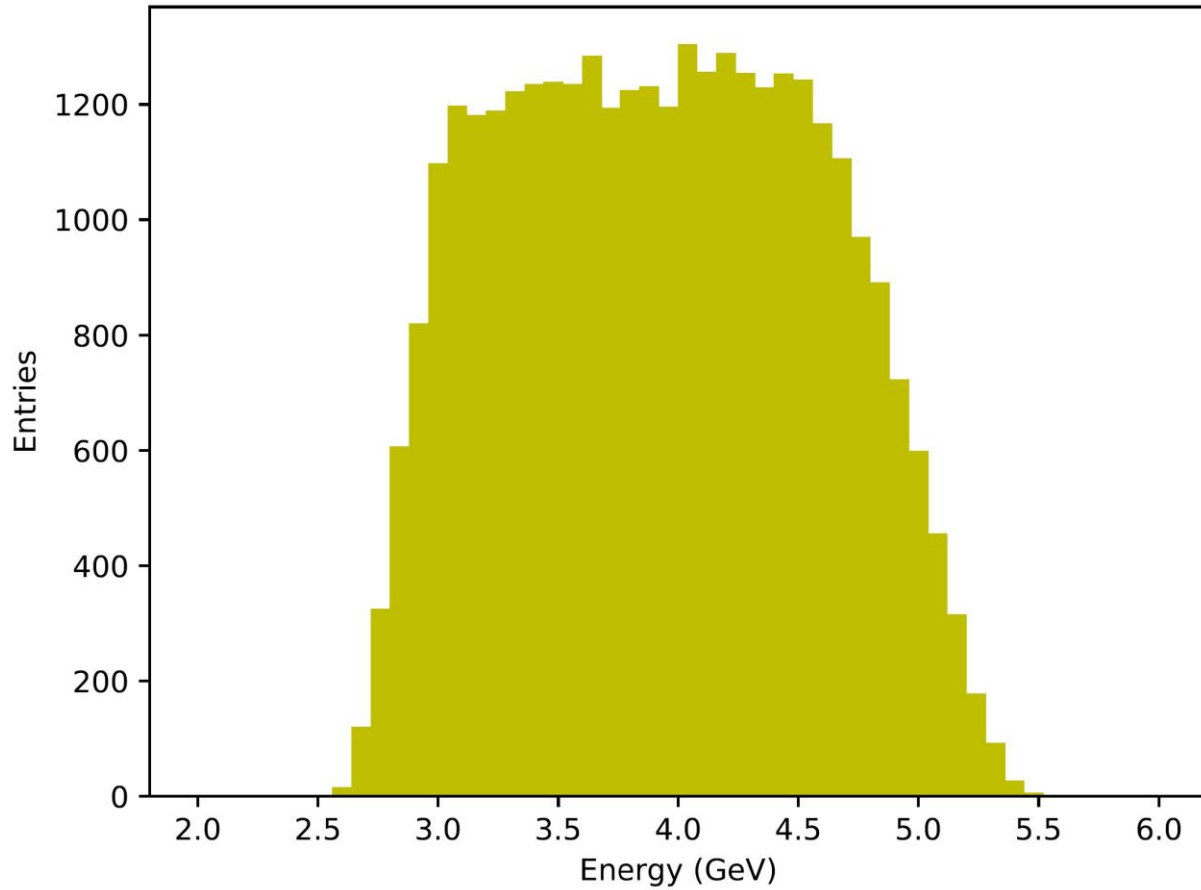


Spatial distribution of pion decays in transfer line:

$$s_i = z_i = v_i \cdot t_{dec,i}$$

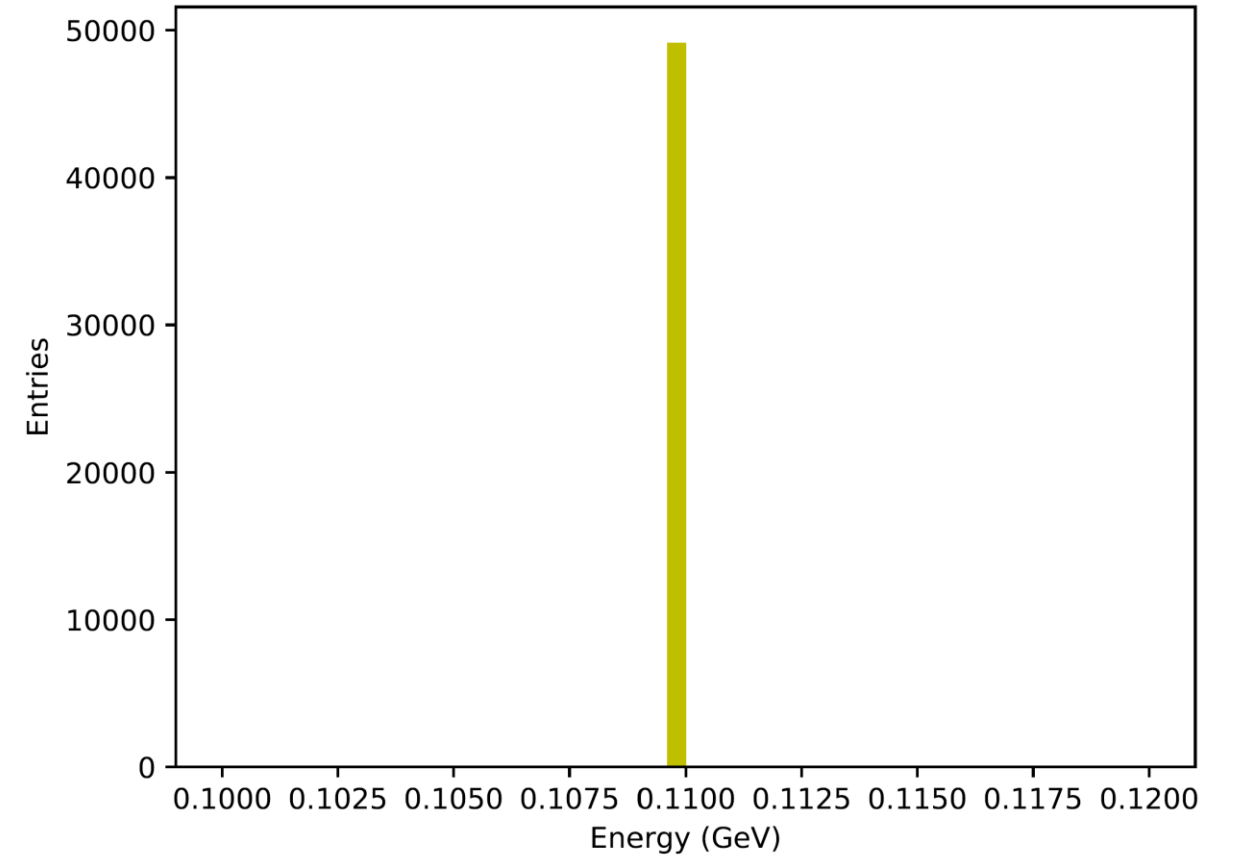
Pion Decay – Muon Energy

Energy distribution of muon at production point



nuSTORM frame

Energy distribution of muon at production point in pion restframe

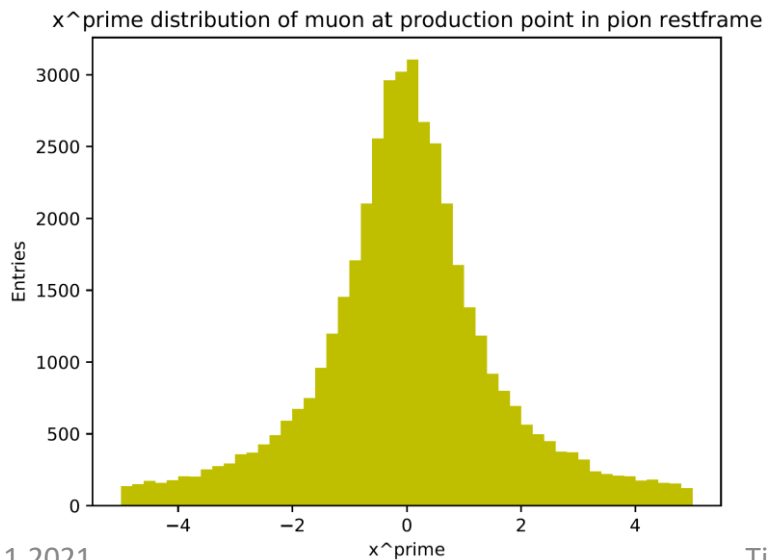
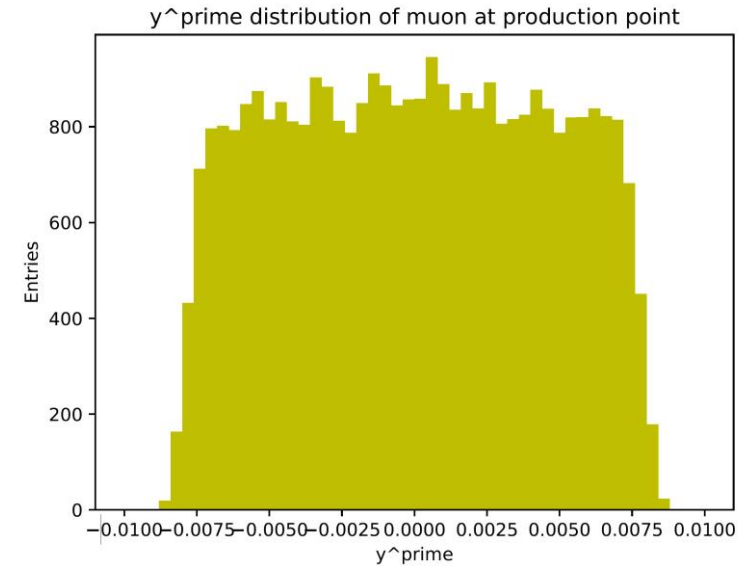


pion rest frame

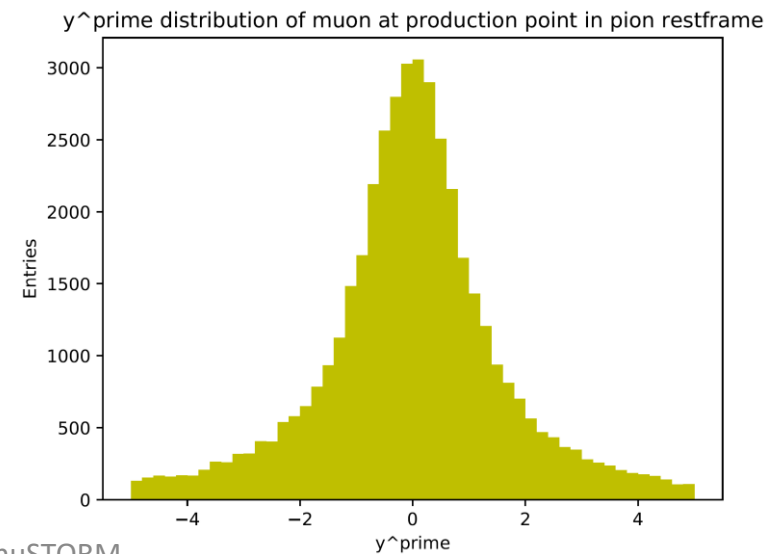
Pion Decay – Muon x' & y' Distributions



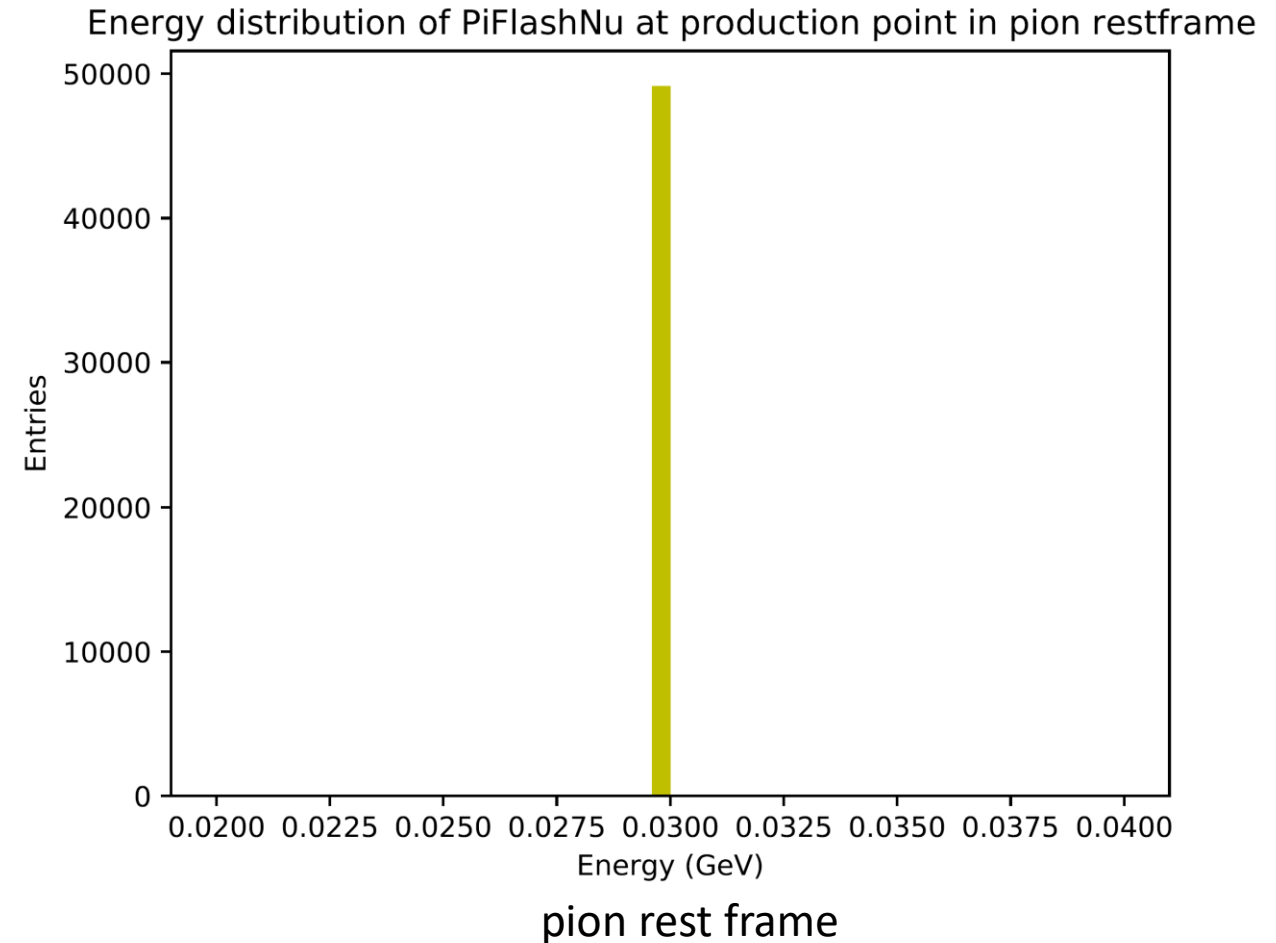
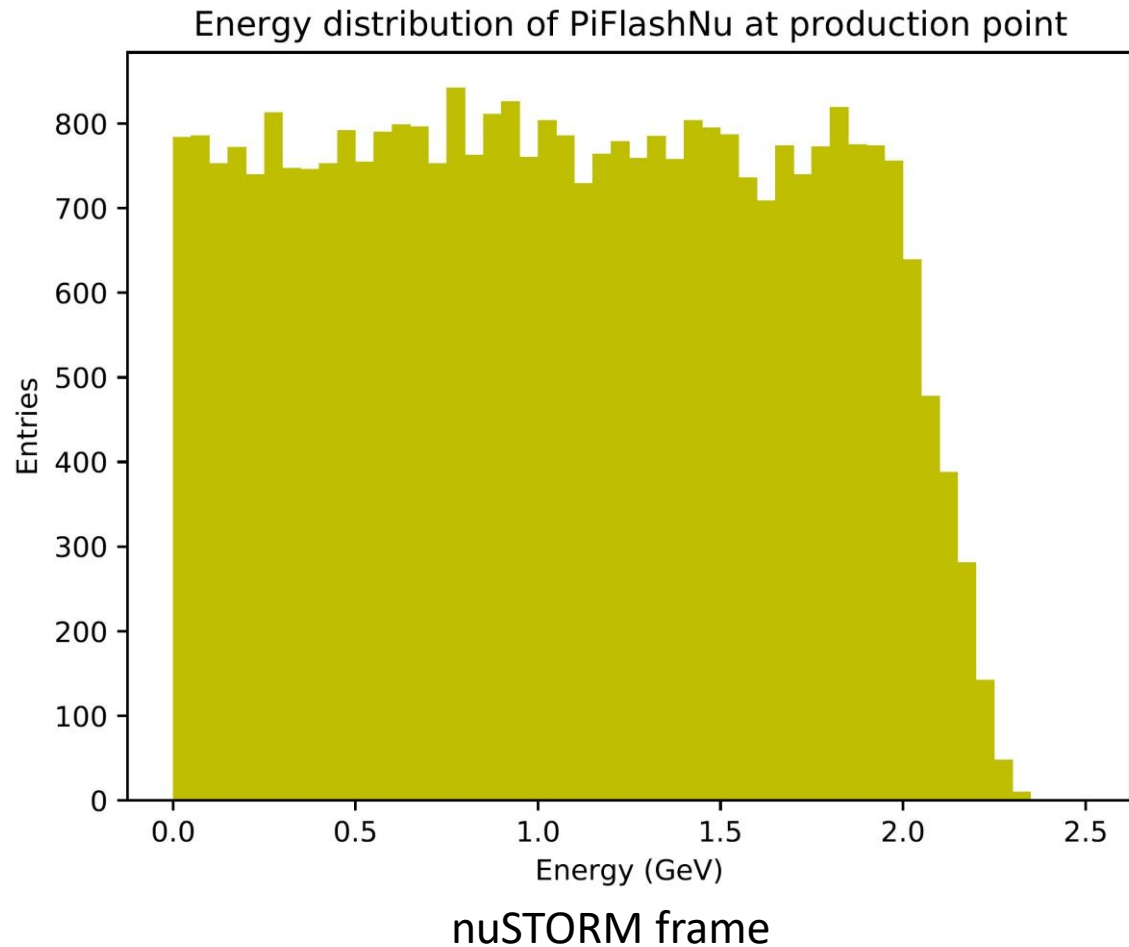
nuSTORM frame



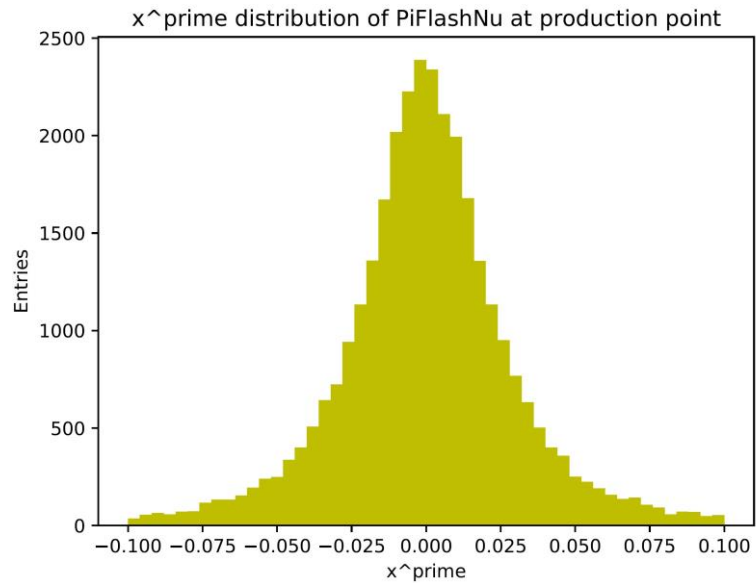
pion rest frame



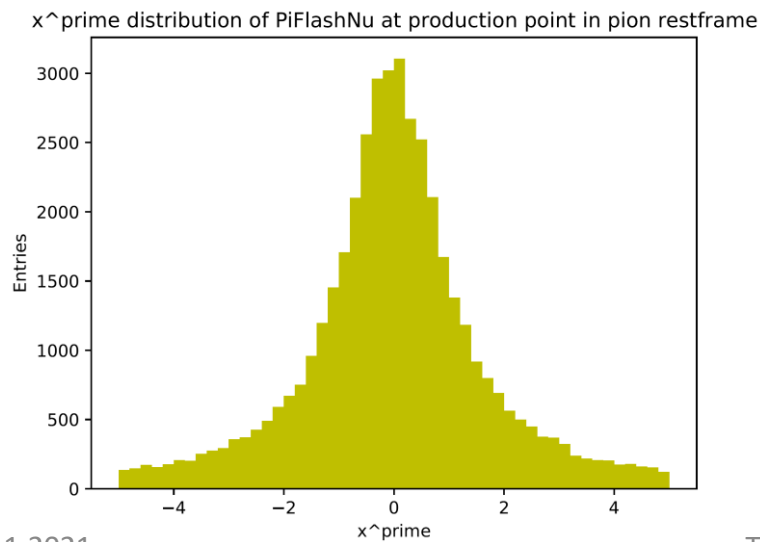
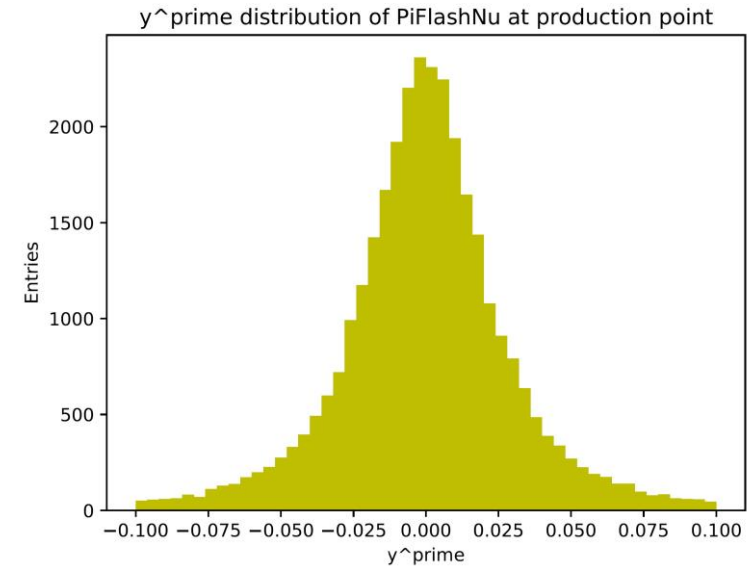
Pion Decay – Neutrino Energy



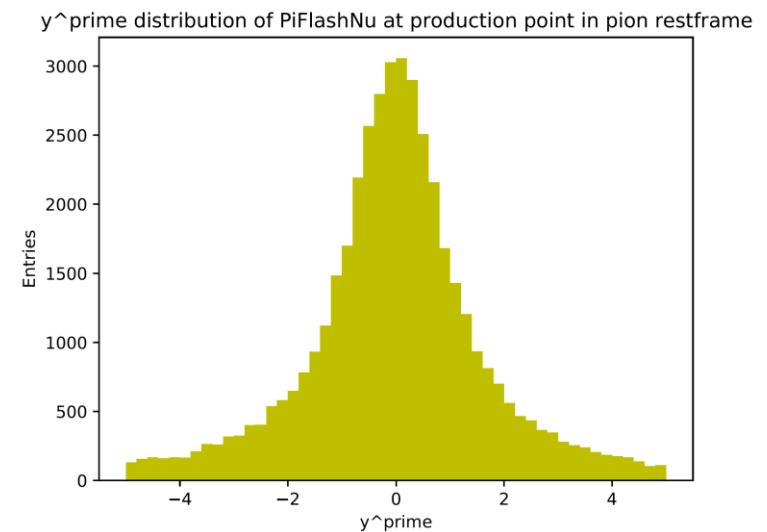
Pion Decay – Neutrino x' & y' Distributions



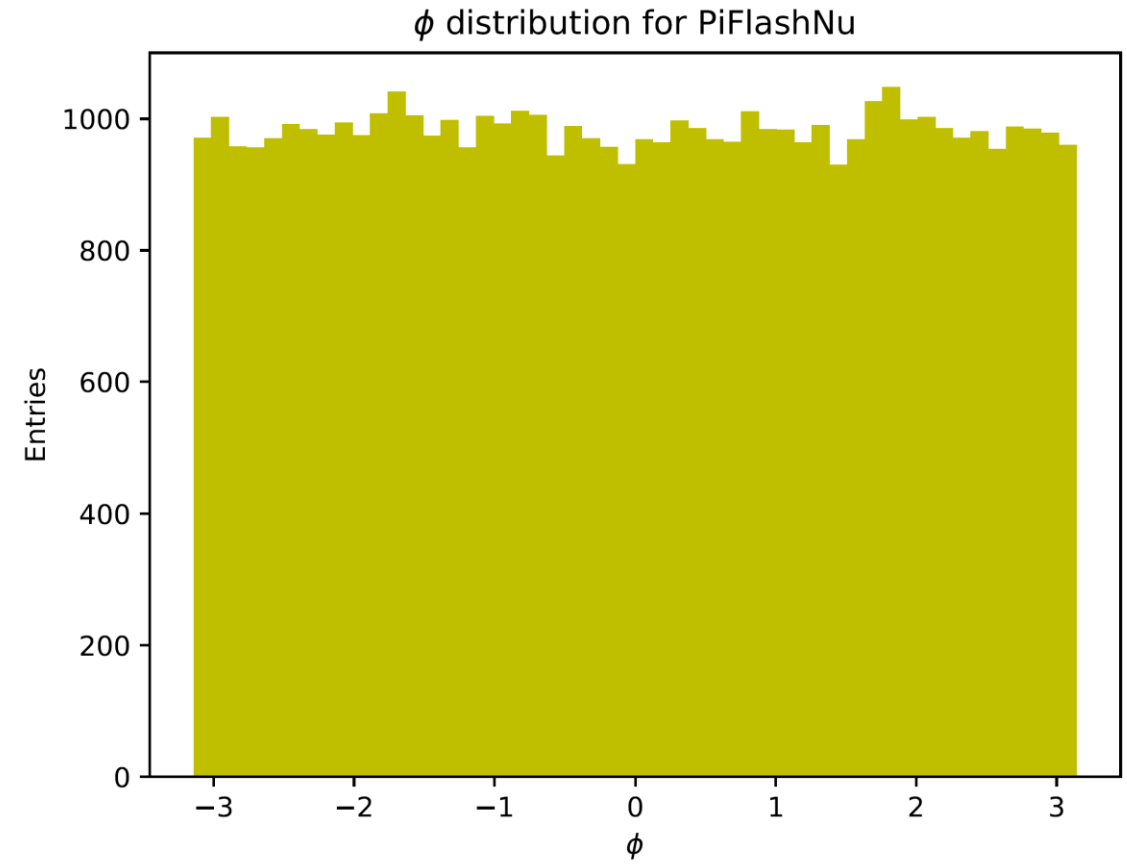
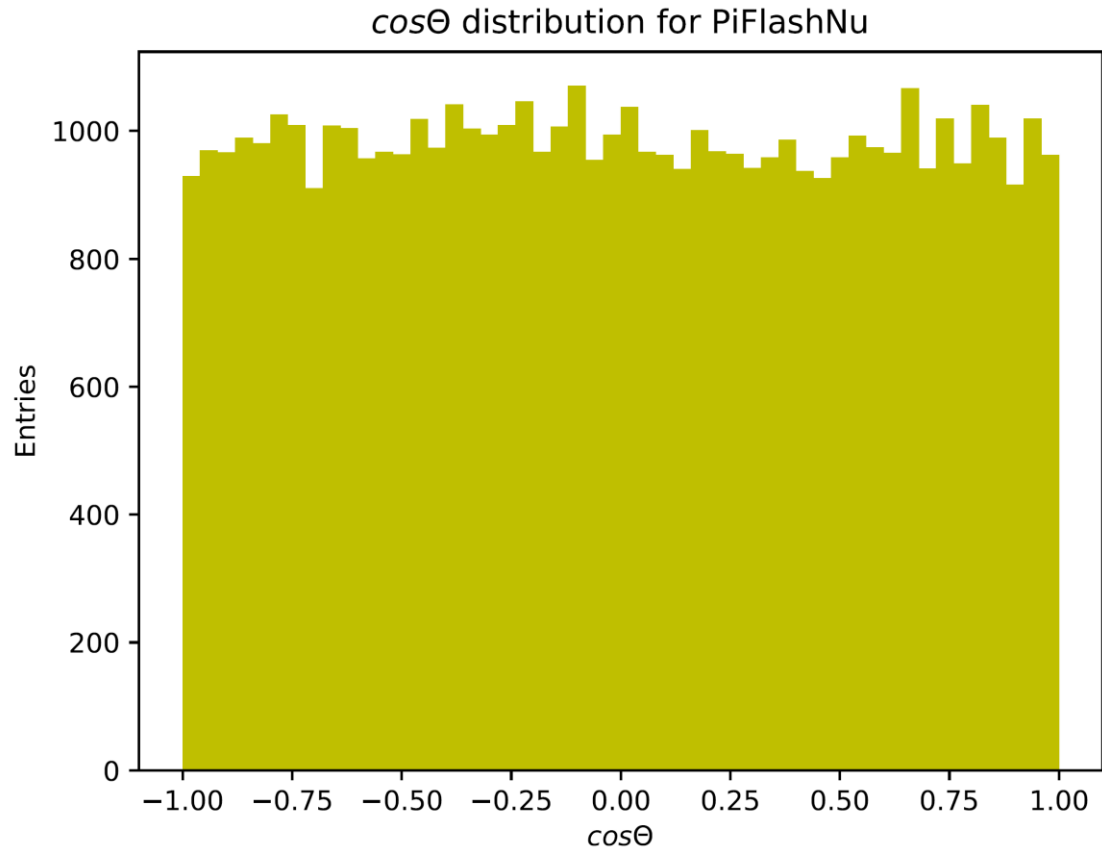
nuSTORM frame



pion rest frame



Pion Decay – Neutrino $\cos\theta$ & ϕ Distributions



$$\cos \theta = \frac{p_z}{|\vec{p}|}$$

→ Isotropic decay, as expected

$$\phi = \arctan \frac{p_y}{p_x}$$

Summary & Outlook

- To understand the time structure and beam characteristics at the proposed nuSTORM detector, it is important to properly propagate the beam structure from the SPS on target through the whole nuSTORM set-up
- A simulation framework, that is simplified through effective parametrizations, has been developed to allow first event rate studies while detailed beam simulations with design of beam optics are carried out
- A multi-stage/interface approach allows the inclusion of more detailed simulation data as these get available
- The nuSIM transfer line class contains a *first simple propagation of beam characteristics from target to injection* and timing characteristics studied:
 - Approx. 16% of pions have decayed
 - Particles need approx. 165 ns to propagate through transfer line
 - Bunch length increased by approx. 0.5% ($\Delta t_{bunch} \approx 2.000 \text{ ns} \rightarrow \Delta t_{bunch} \approx 2.010 \text{ ns}$)
 - Code works well (as shown by consistency checks)
- Next steps:
 1. Work out proper normalization
 2. Calculate neutrino flux at detector plane
 3. Work out neutrino event rates in detector (material: tbd)