Imperial College London

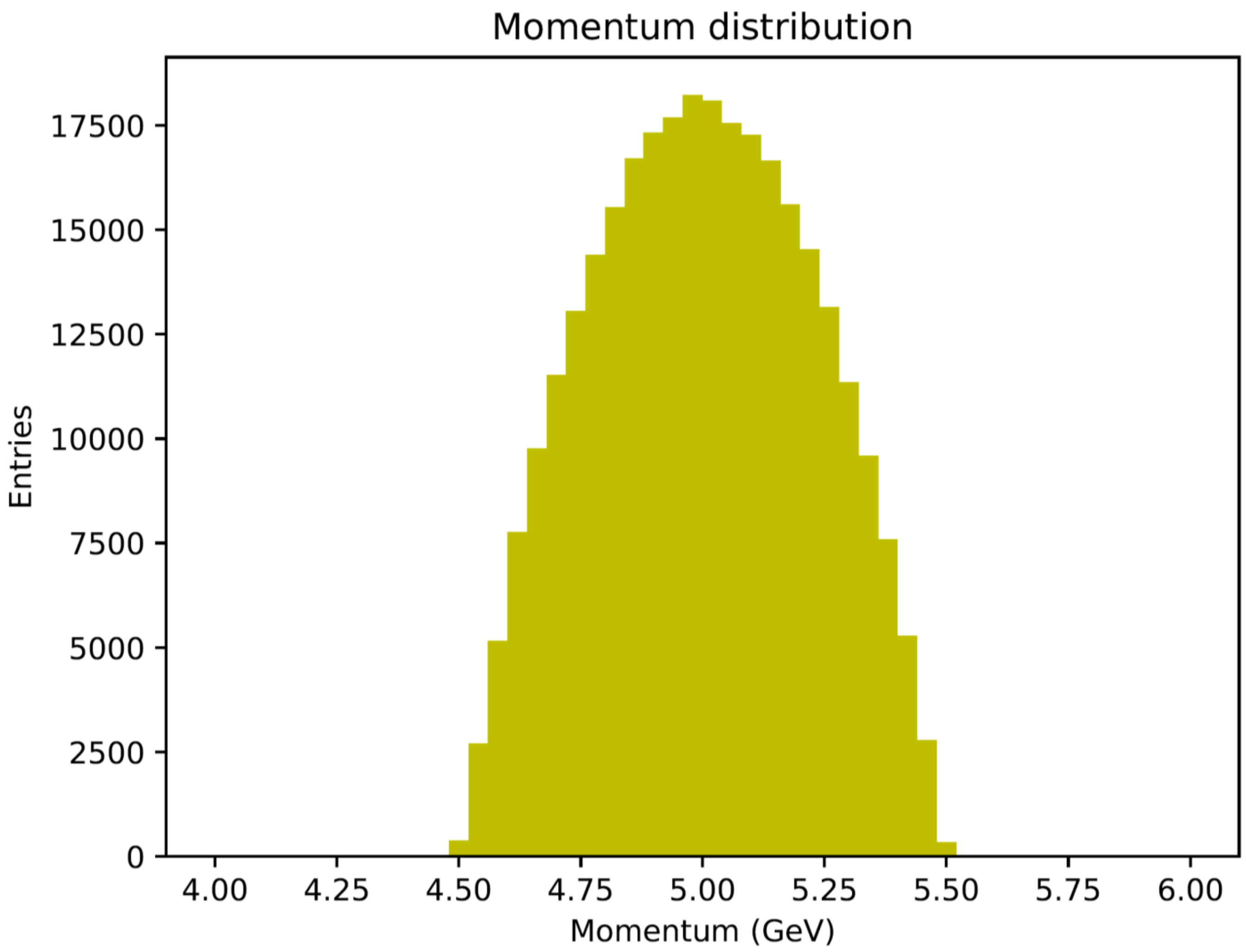
Simulating the nuSTORM Transfer Line with nuSIM

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 caried 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

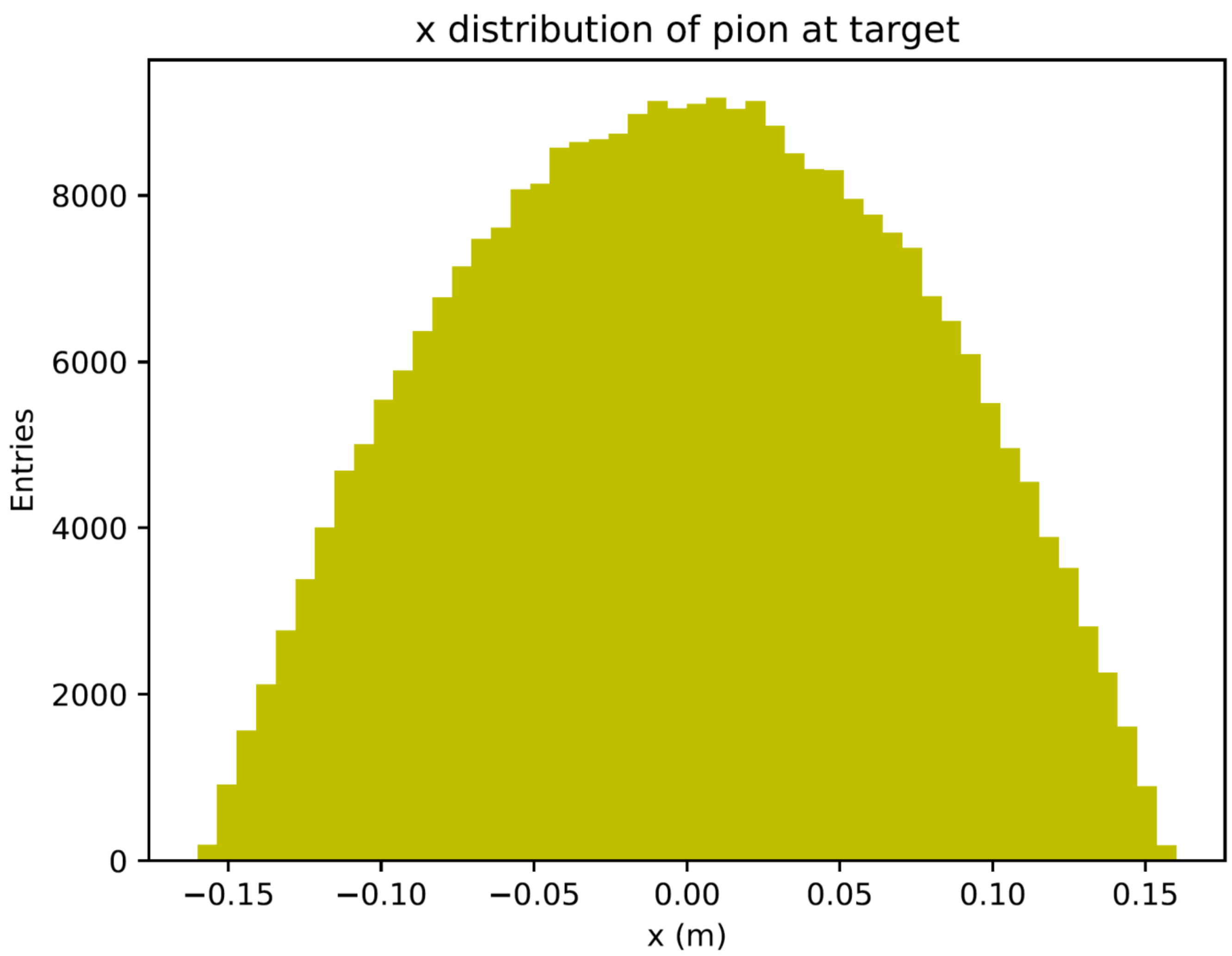
Momentum Distribution @ Target



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

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

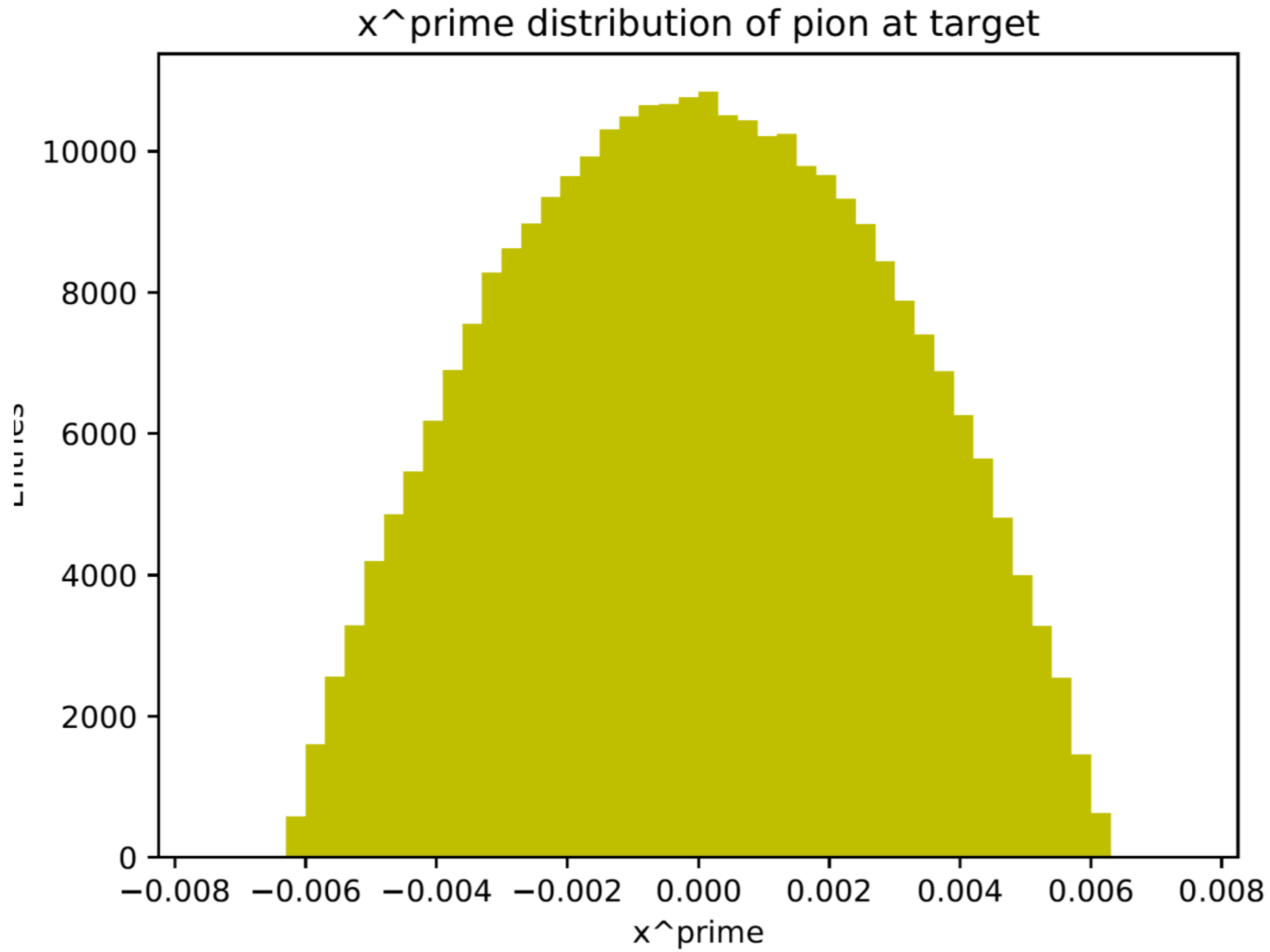
x Distribution @ Target



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

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

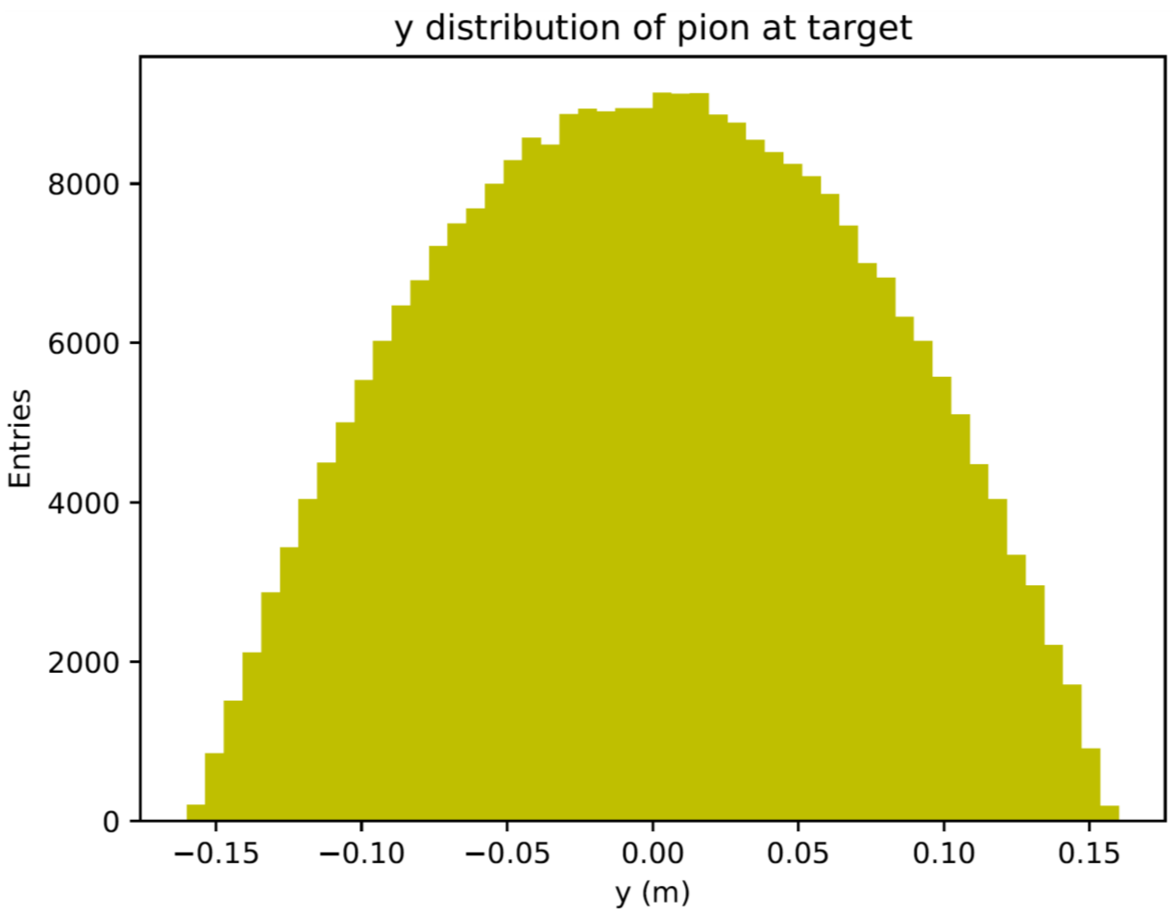
x‘ Distribution @ Target

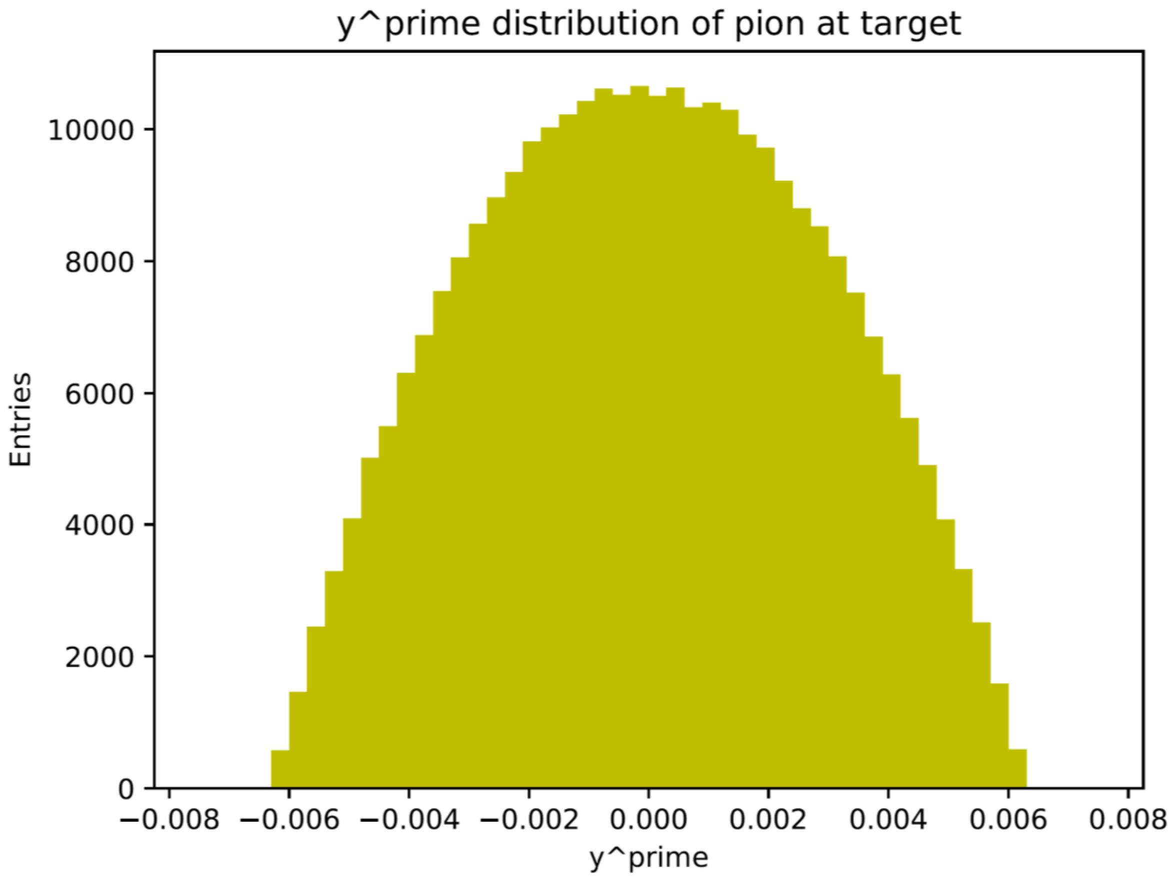


x‘ distribution @ target (s = -50.0 m):

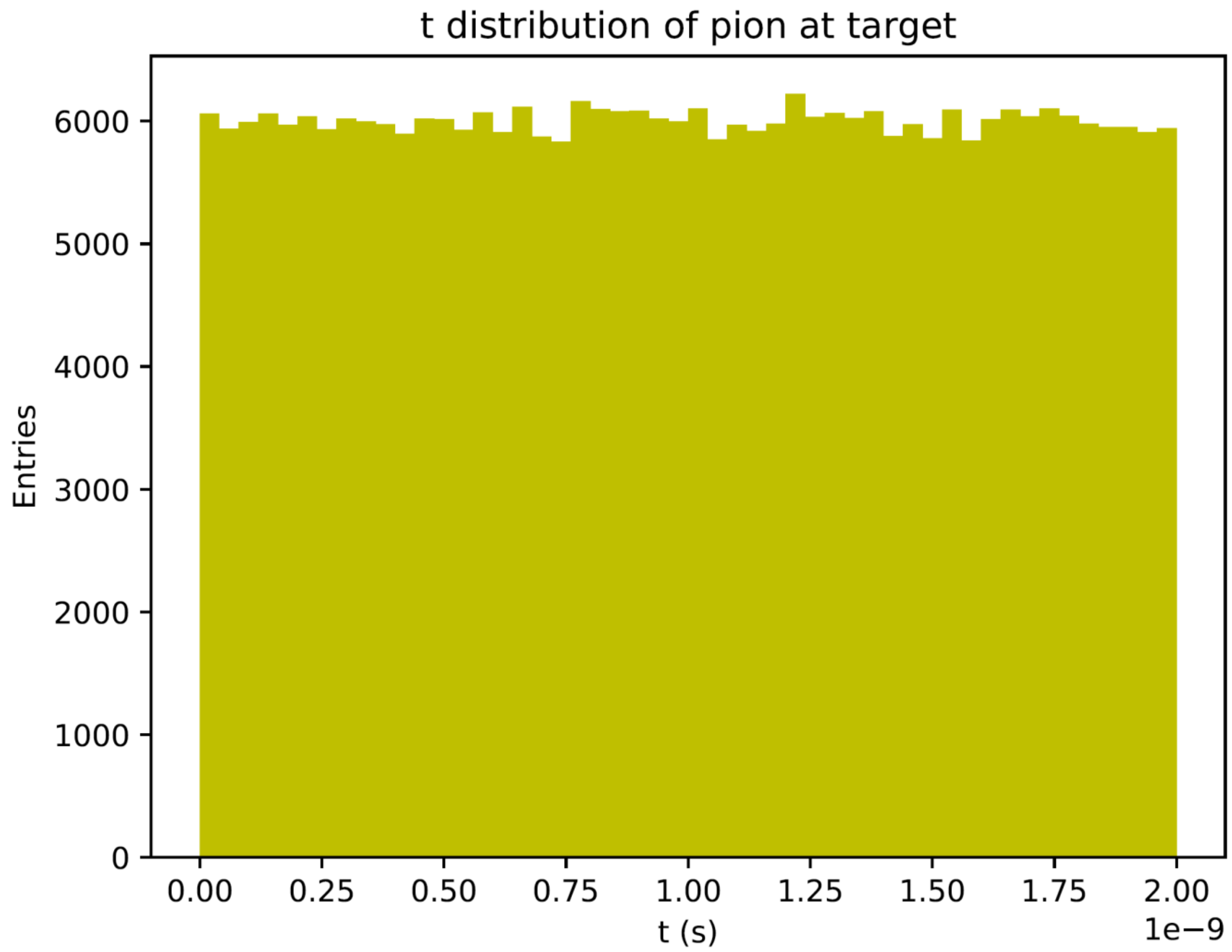
- Parabolic distribution
- Centered around 0 m
- Transverse (2D) acceptance: 1 pi mm rad
- Transverse beta function: 25,000 mm

y & y‘ Distributions @ Target





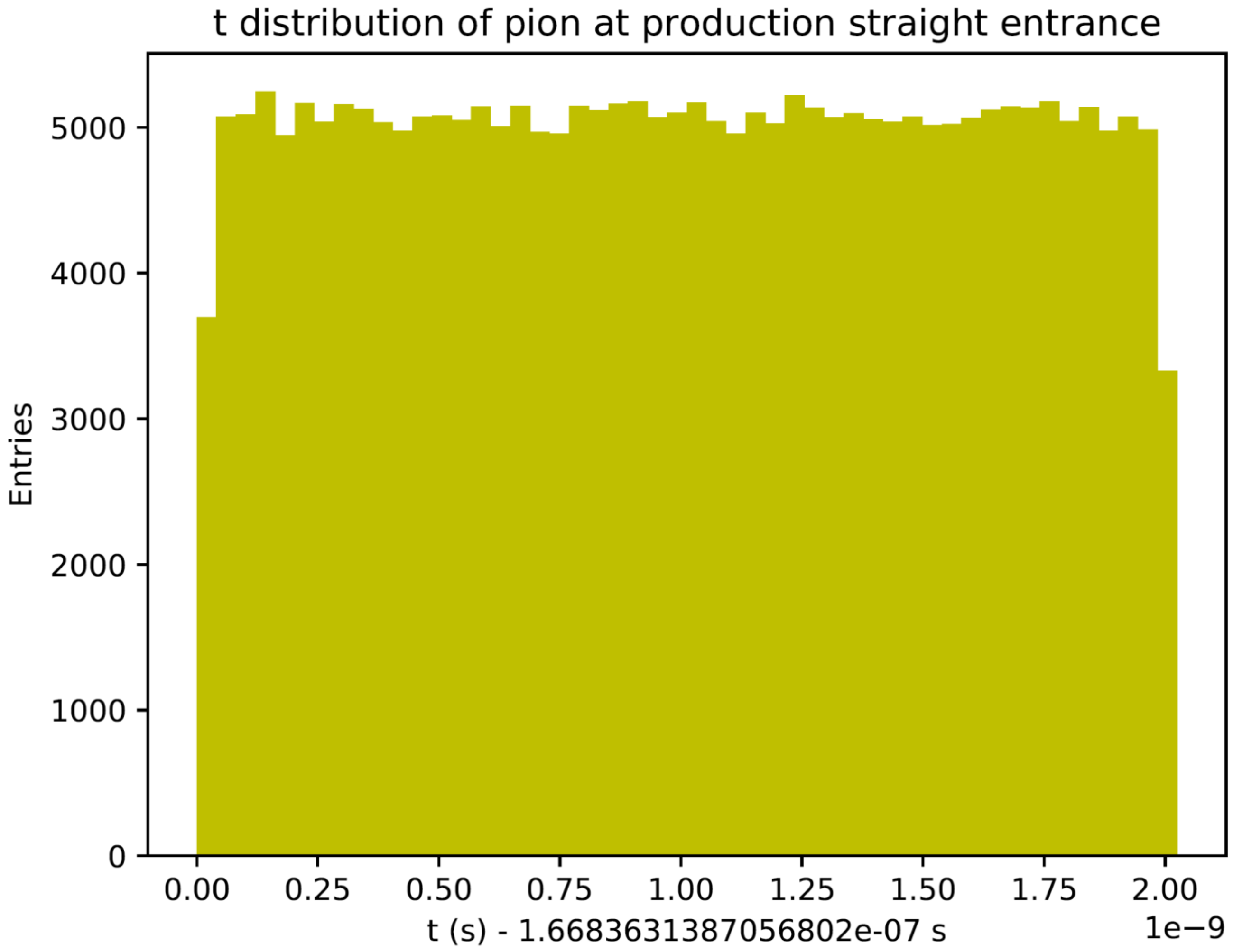
Time Distribution @ Target



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

- Uniform distribution
- 2 ns bunch length

Time Distribution @ Decay Straight Entrance

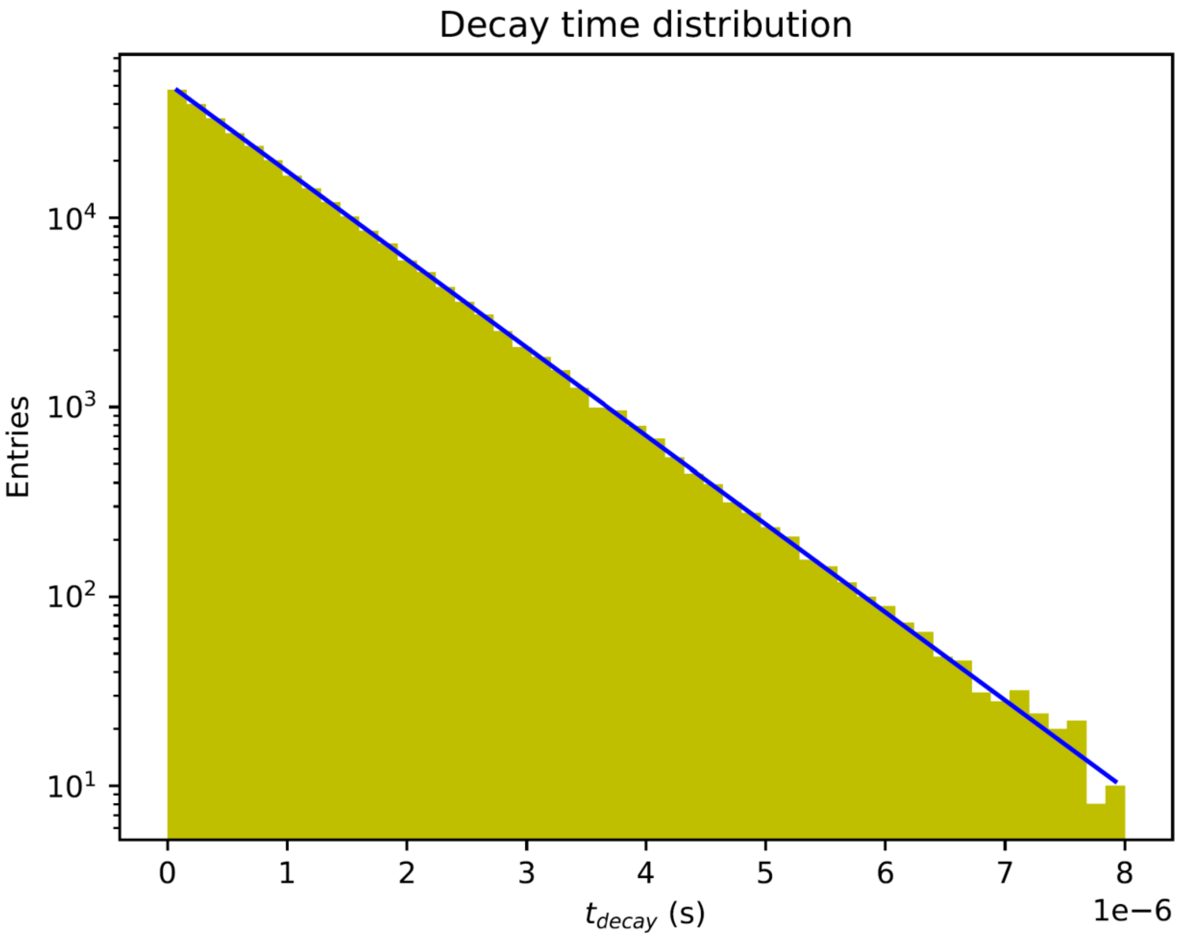


Time distribution @ Decay straight entrance (s = 0 m):

- Approx. 16 % of pions have decayed
- Time of propagation: $\Delta t_{prop} \approx 165$ ns
- Bunch length: $\Delta t_{bunch} \approx 2.02$ ns

→ Bunch length increased by approx. 1%

Pion Decay – Decay Times



PDF:

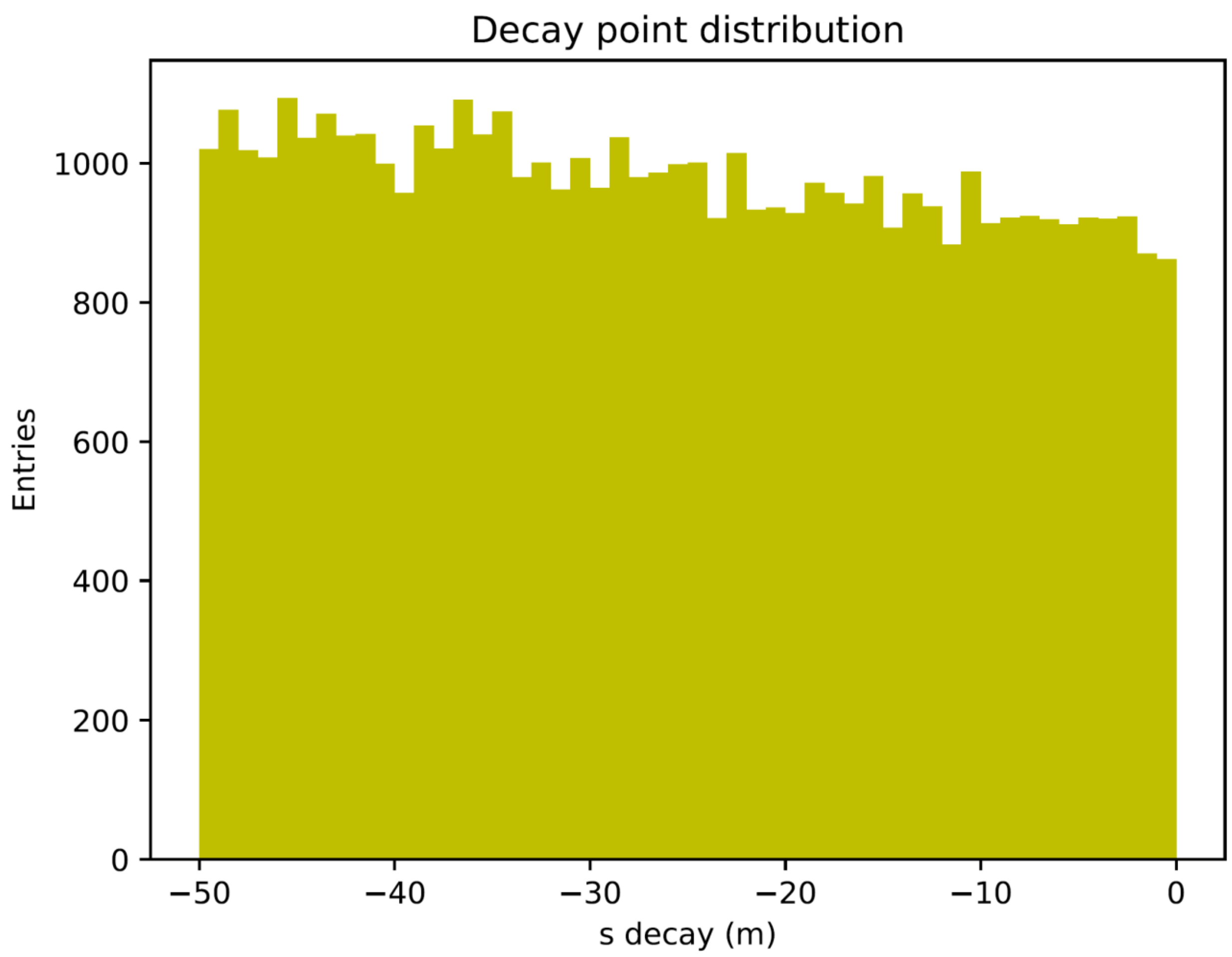
$$f(p) = N_0 \times \exp\left(-\frac{t}{\gamma \cdot \tau}\right)$$

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

→ $\gamma \approx 36$

→ $\mathrm{E}_0 \approx 5.0$ GeV

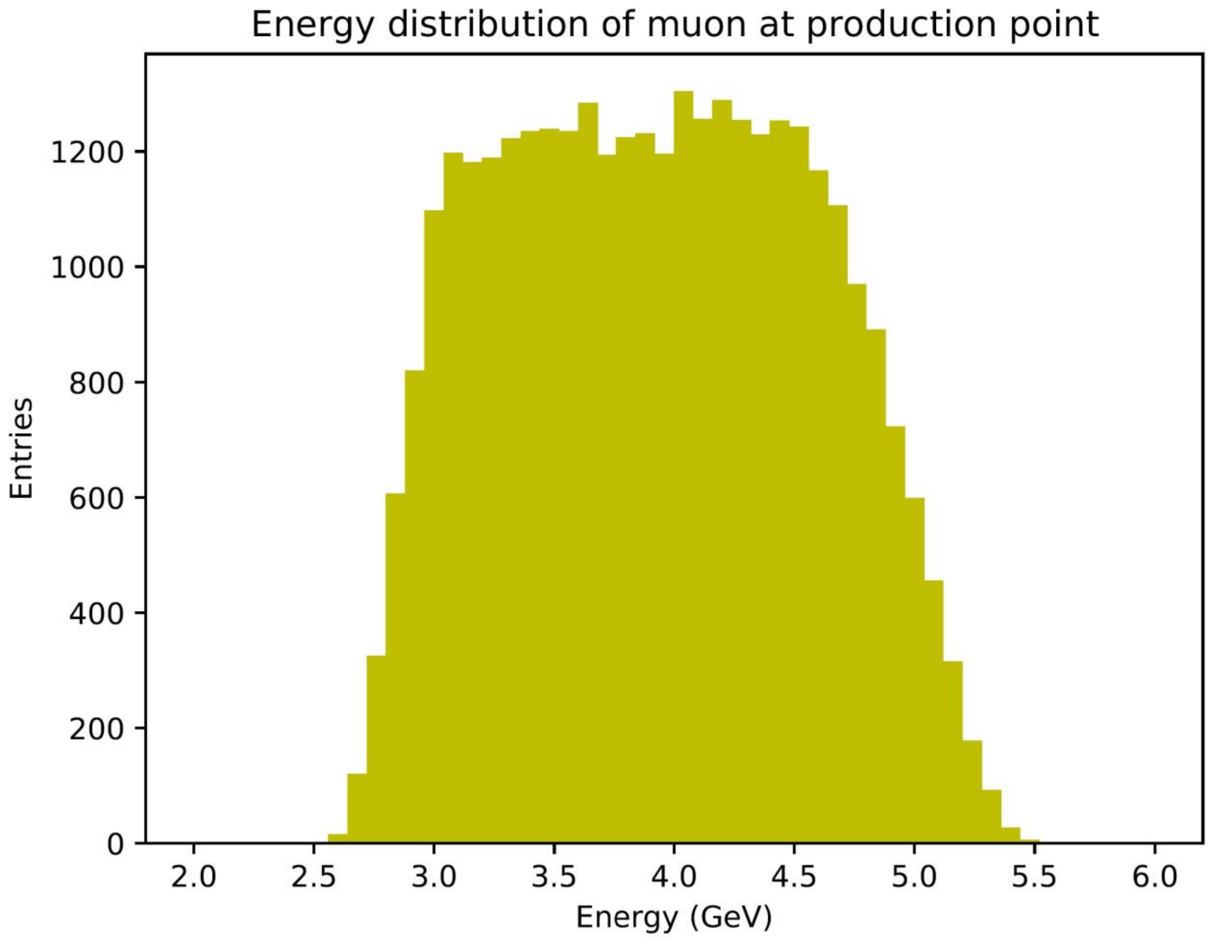
Pion Decay – Decay Point



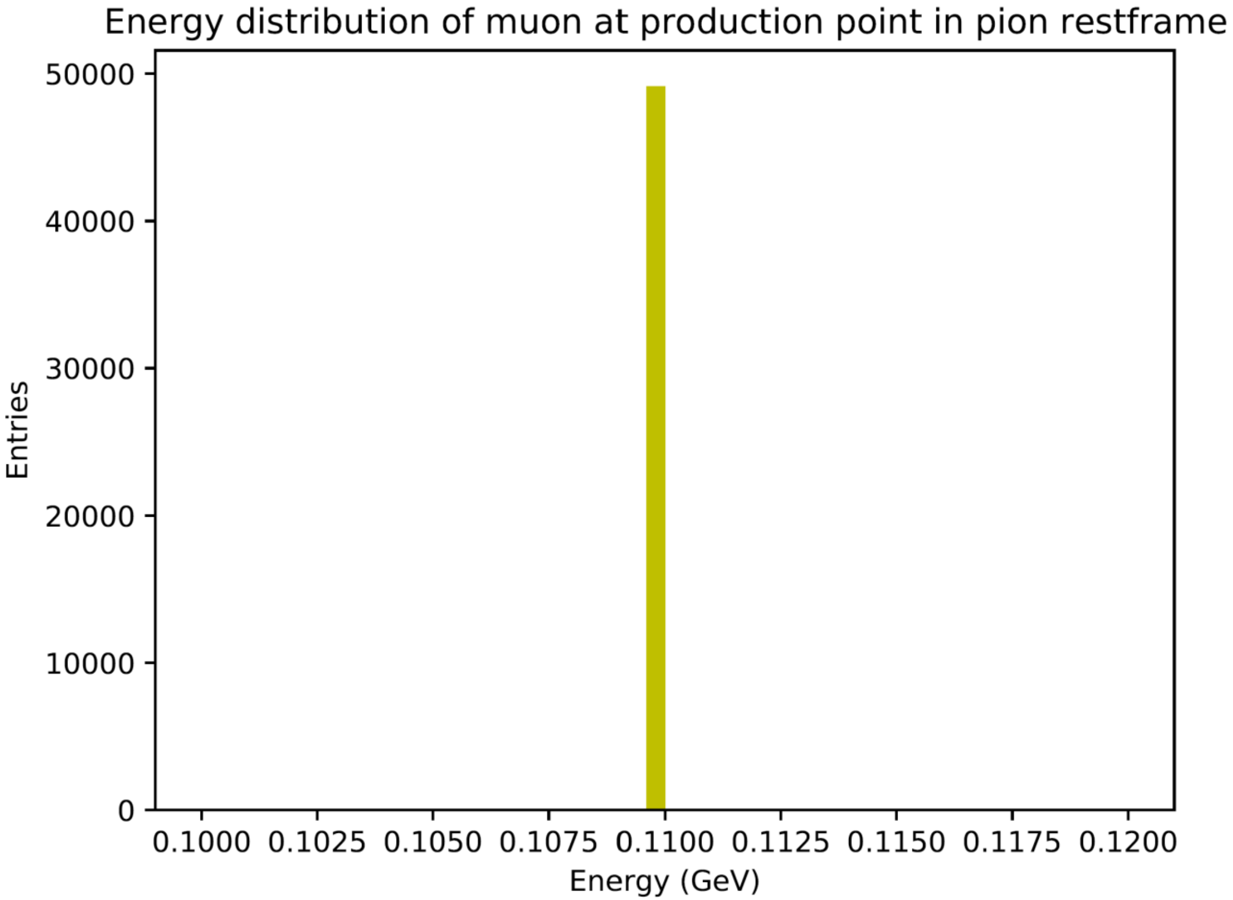
Spatial distribution of pion decays in transfer line:

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

Pion Decay – Muon Energy



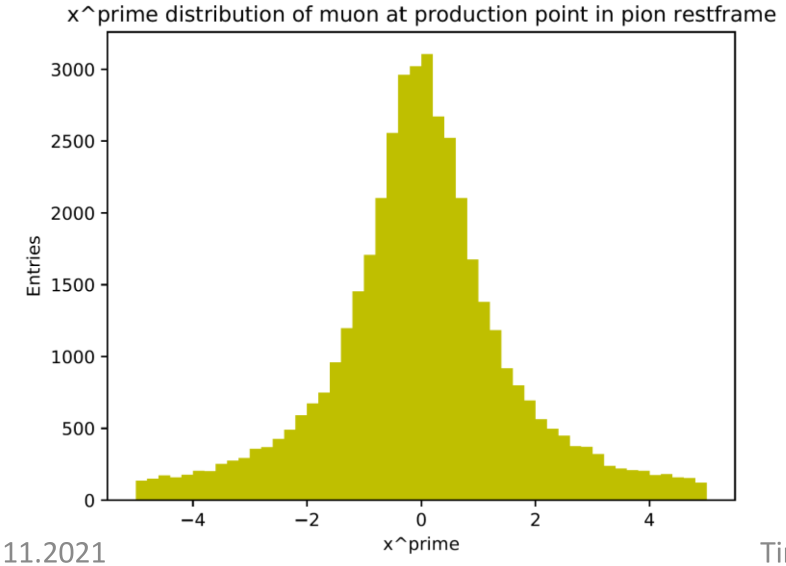
nuSTORM frame



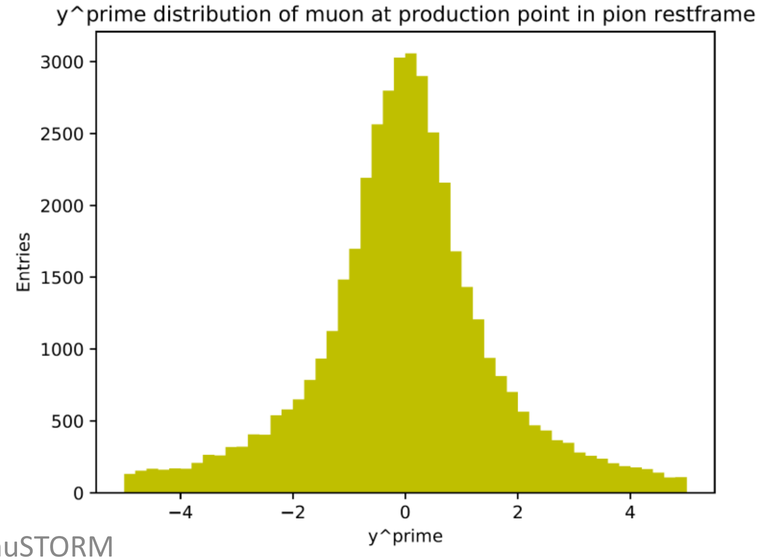
pion rest frame

Pion Decay – Muon x‘ & y‘ Distributions

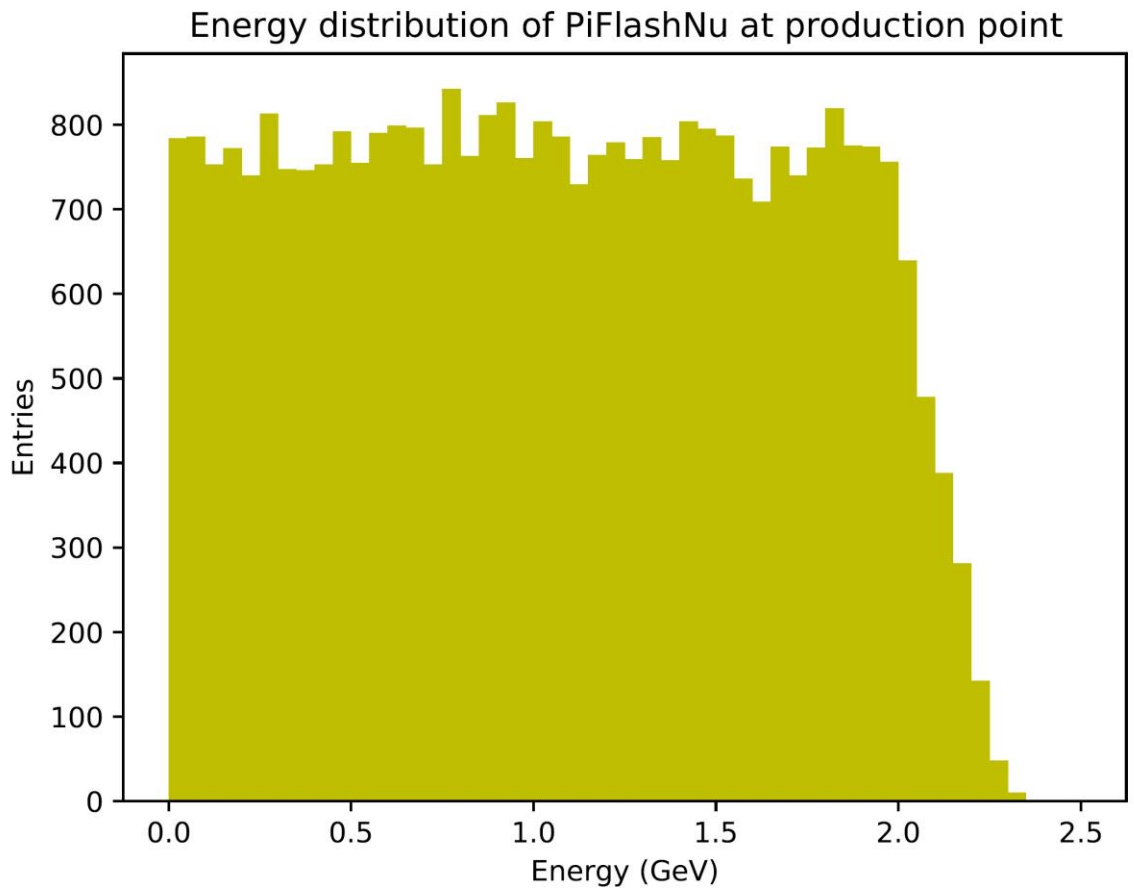
nuSTORM frame



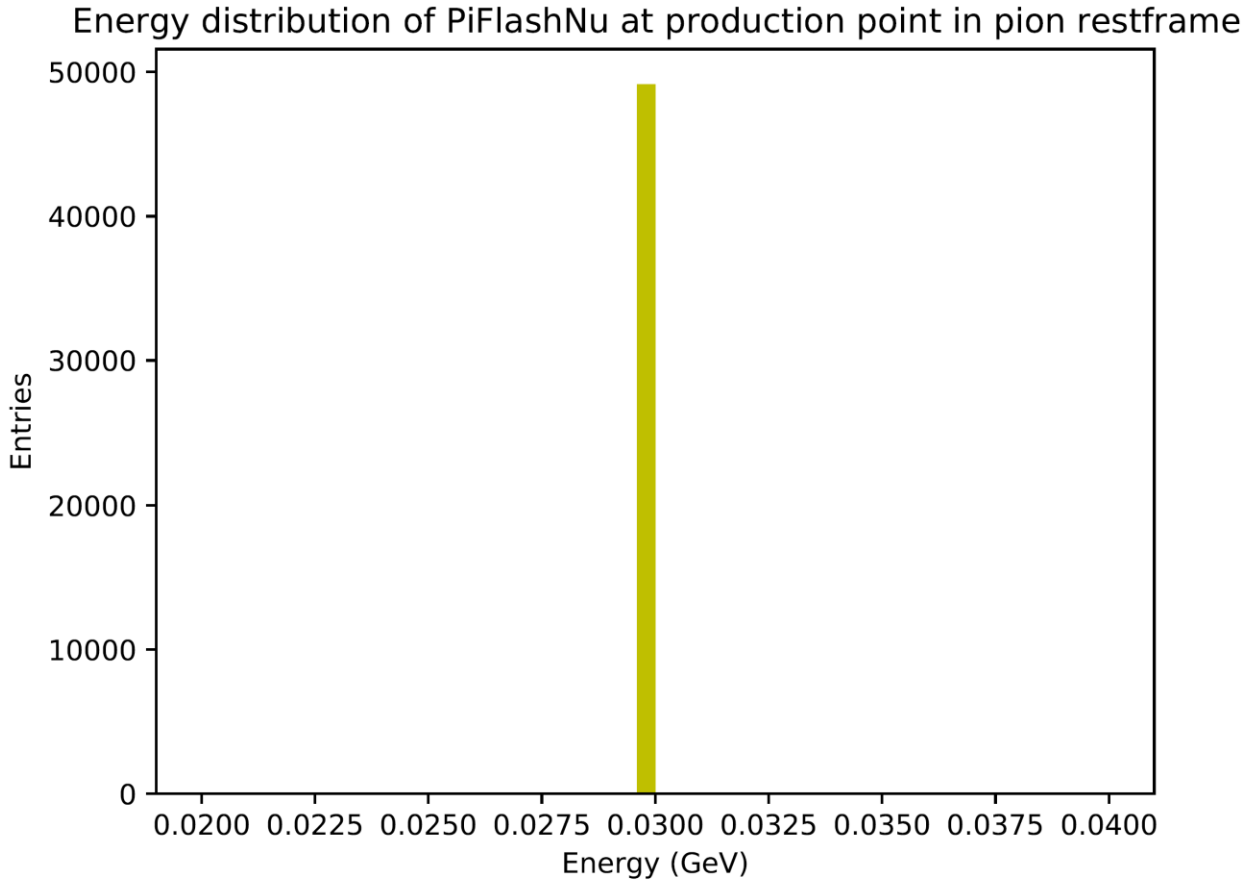
pion rest frame



Pion Decay – Neutrino Energy

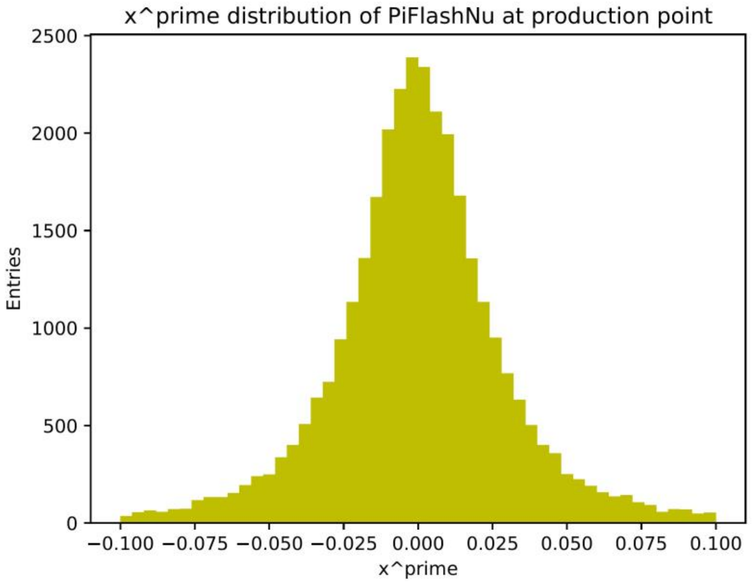


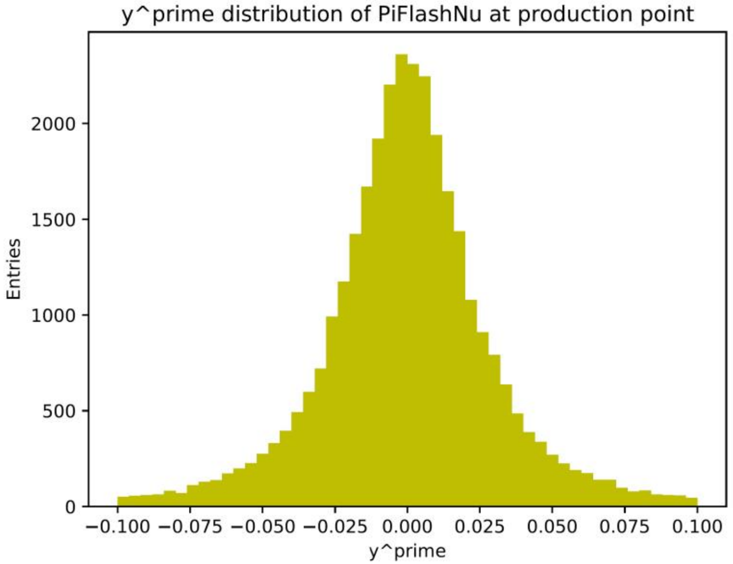
nuSTORM frame



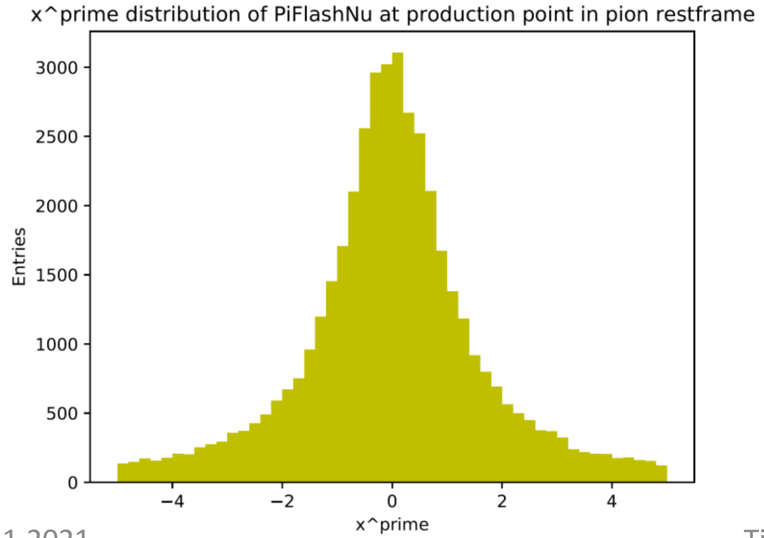
pion rest frame

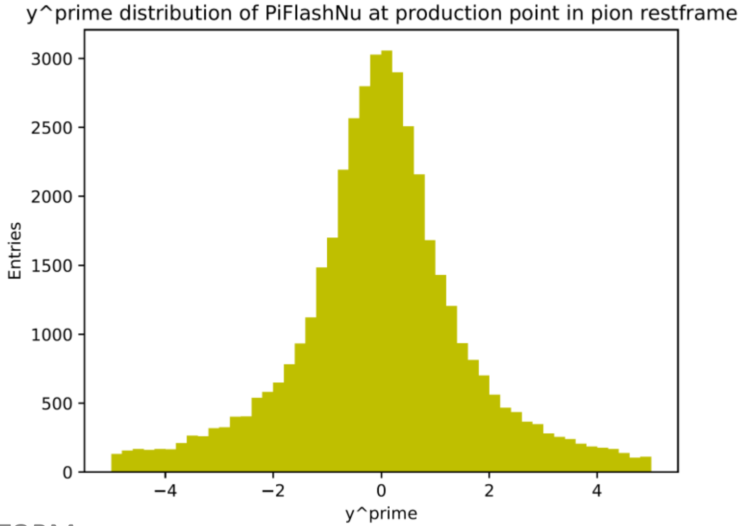
Pion Decay – Neutrino x‘ & y‘ Distributions





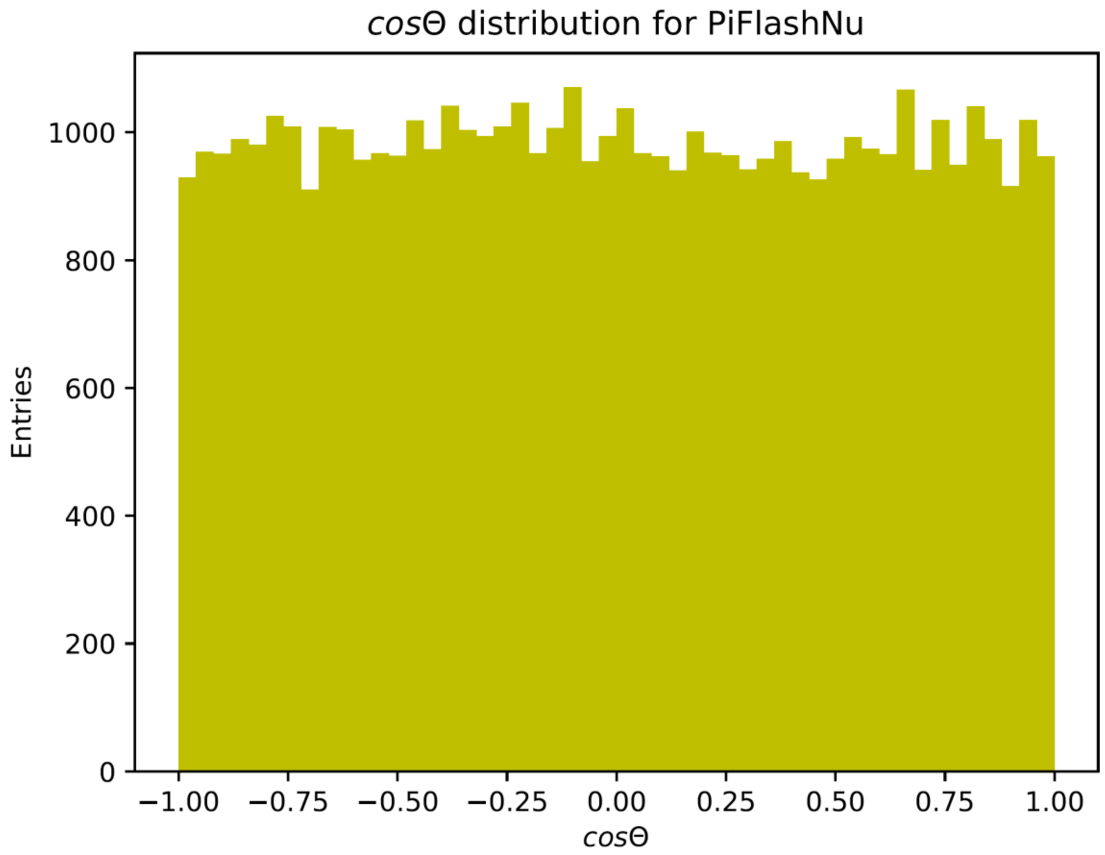
nuSTORM frame

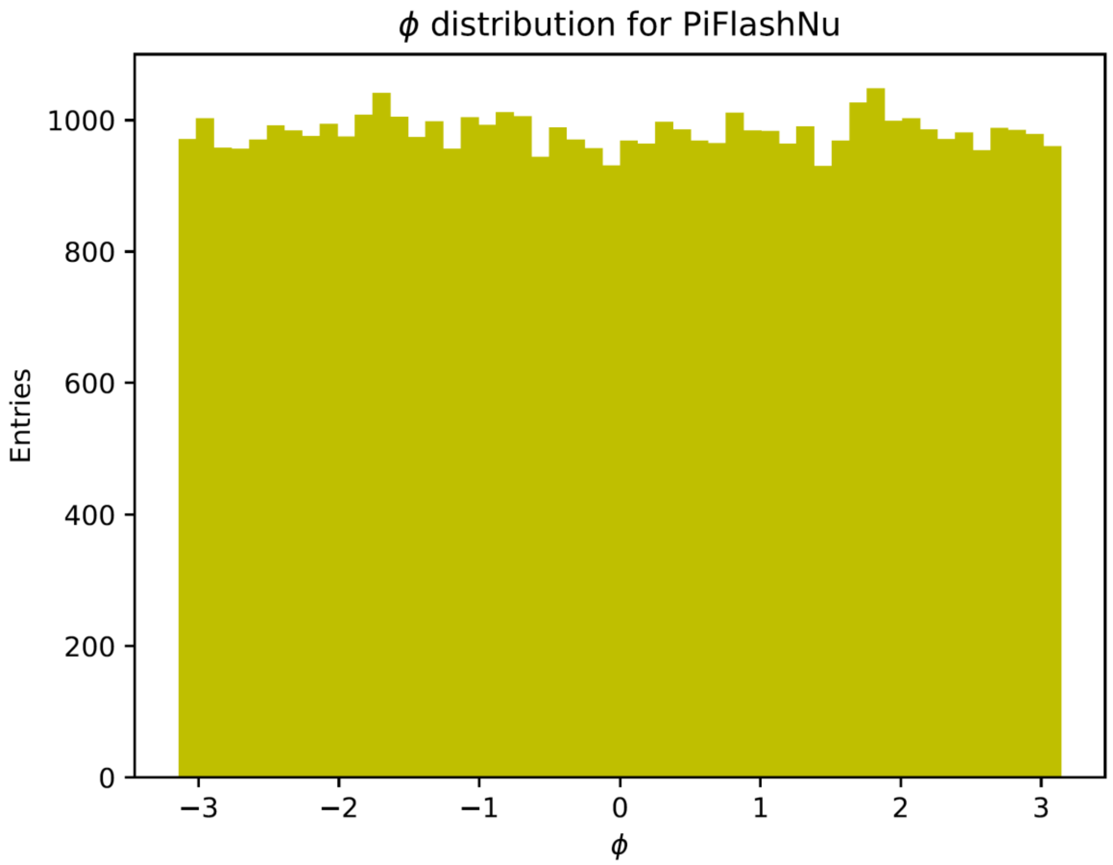




pion rest frame

Pion Decay – Neutrino cosΘ & 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 caried 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. 1% ($\Delta t_{bunch} \approx 2.000$ ns → $\Delta t_{bunch} \approx 2.02$ 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)