nuSIM: parameters for first simulation of neutrino spectra

P. Kyberd and K. Long

1 Simulation of nuSTORM production straight

A rudimentary simulation of nuSTORM has been created in python. The simulation is based on the design presented in [1]. To initiate consideration of detector systems and sensitivities the following parameters have been adopted for the storage ring, the production straight and the muon-beam optics:

- Total ircumference: 616 m
- Length of production straight: 180 m
- Stored muon momentum (p_μ) range: $1 \leq p_\mu \leq 6$ GeV
- Momentum acceptance: $\pm 15\%$
  - Simulate a parabolic momentum distribution with limits $\pm 15\%$
- Transverse acceptance: $1\,\pi$ mm rad
- Transverse beta function (in both transverse coordinates: 25000 mm

The transverse beta function is taken as "representative" of the production straight. It is assumed that $\alpha = 0$, and that the emittance, ϵ, (acceptance) and beta are momentum independent. The width of the transverse phase space is obtained using:

$$\begin{aligned} x_i &= \sqrt{\epsilon\beta} \quad ; \quad \text{and} \\ x_i' &= \sqrt{\frac{\epsilon}{\beta}} \quad ; \end{aligned}$$

where x_i refers to both transverse coordinates (x and y).

2 Neutrino flux interface specification

The data is held in root files. The TTree is divided into 3 branches: runInfo; beam; and flux.

runInfo is filled once at the beginning of the run and contains information about the run.

At present that is the data format version and the run number. The run number should correspond to the number in the name of the file.

beam is filled once per event.

The muon beam comes down the nuStorm straight. The co-ordinate system has its origin at the beginning of the straight. z is the distance down the straight along the machine axis. y is the vertical distance from the machine axis and x is the horizontal distance completing a right handed co-ordinate system (x is to the left as you stand looking down the beam).

Values of px, py, pz and E are stored for the parent muon and the decay electron, ν_e, and ν_μ.

Decay contains the values relevant to the muon at the decay point. The x, y, and z co-ordinates in the system defined above are stored. The angle in the x plane px/pz (x'), and the angle in the y plane (y'). The distance travelled by the muon measured along its trajectory s, at present that is just equal to z. The

time of the decay. This is not stored at present. The values of the x, y, x' and y' and E_μ are distributed to reflect the energy spread, the β and the emittance of the beam. The model for a particular run can be found by looking in the file which contains the description of the simulation conditions for each run.

flux is filled once per event.

The neutrinos from the decay are projected forward until they intersect with a plane at right angles to the machine axis and 50 m beyond the end of the production straight. The x, y position at which the neutrino intersects the plane is recorded together with the momentum components and the total energy of the neutrino.

3 Data format: version 2.6

Branch: sub-branch	Variable	Type	Description
runInfo:information	runNumber	Integer	Run Number
	Version	Float	Version number of the data format
	FluxPlaneW	Float	Unused
	FluxPlaneH	Float	Unused
	PZ	Float	Unused
	DetectW	Float	Unused
	DetectH	Float	Unused
	DetectD	Float	Unused
	DetectZ	Float	Unused
	Emit	Char	Unused
beam:muon	px	Float	muon momentum in x (horizontal plane)
	py	Float	muon momentum in y (vertical plane)
	pz	Float	muon momentum in z (nuStorm machine axis)
	E	Float	muon Energy
beam:decay	s	Float	Decay distance along the particle trajectory.
	x	Float	x at the decay point, horizontal. Beam centre as origin
	y	Float	y at the decay point, vertical. Beam centre as origin
	z	Float	Decay point from the start of the beam straight as origin
	xp	Float	px/pz at the decay point
	yp	Float	py/pz at the decay point
	t	Float	time of the decay - not filled currently

Branch: sub-branch	Variable	Type	Description
beam:electron	px	Float	electron momentum in x (horizontal plane)
	py	Float	electron momentum in y (vertical plane)
	pz	Float	electron momentum in z (nuStorm machine axis)
	E	Float	electron Energy
beam:ν_μ	px	Float	ν_μ momentum in x (horizontal plane)
	py	Float	ν_μ momentum in y (vertical plane)
	pz	Float	ν_μ momentum in z (nuStorm machine axis)
	E	Float	ν_μ Energy
beam:ν_e	px	Float	ν_e momentum in x (horizontal plane)
	py	Float	ν_e momentum in y (vertical plane)
	pz	Float	ν_e momentum in z (nuStorm machine axis)
	E	Float	ν_e Energy
flux:ν_e	ex	Float	x position of intersection of $\nu_e$with flux plane
	ey	Float	y position of intersection of $\nu_e$with flux plane
	epx	Float	px for the ν_e at the flux plane
	epy	Float	py for the ν_e at the flux plane
	epz	Float	pz for the ν_e at the flux plane
	eE	Float	Energy for the ν_e at the flux plane
flux:ν_μ	ex	Float	x position of intersection of $\nu_\mu$with flux plane
	ey	Float	y position of intersection of $\nu_\mu$with flux plane
	epx	Float	px for the ν_μ at the flux plane
	epy	Float	py for the ν_μ at the flux plane
	epz	Float	pz for the ν_μ at the flux plane
	eE	Float	Energy for the ν_μ at the flux plane

References

[1] C. Ahdida, R. Appleby, W. Bartmann, J. Bauche, M. Calviani, J. Gall, S. Gilardoni, B. Goddard, C. Hessler, P. Huber, I. Efthymiopoulos, J. Lagrange, M. Lamont, K. Long, J. Osborne, J. Pasternak, F. Soler, S. Tygier, and F. Velotti, "nuSTORM at CERN: Feasibility Study," Tech. Rep. CERN-PBC-REPORT-2019-003, CERN, Geneva, Oct, 2020. `http://cds.cern.ch/record/2654649`.