FRAMEWORK FOR PRODUCING A NEW ATM-NU SAMPLE

Pierre Granger

APC

WISH LIST FOR NEW SAMPLE

1. **Production scheme included in the official DUNE LArSoft**
   - use as much as possible same design-logic as in beam-setup

2. **Flux implementation is flexible; generation such that**
   - sample usable out of the box, w/ default parameters for physics studies, but also to allow
   - easy reweighting to facilitate parameter changes

3. **Normalization to a desired kt-year is possible**
4. **Contains 3 flavors**
5. **Un-oscillated**
   - Easy: don’t oscillate

WISH LIST FOR NEW SAMPLE

1. **Production scheme included in the official DUNE LArSoft**
    - use as much as possible same design-logic as in beam-setup

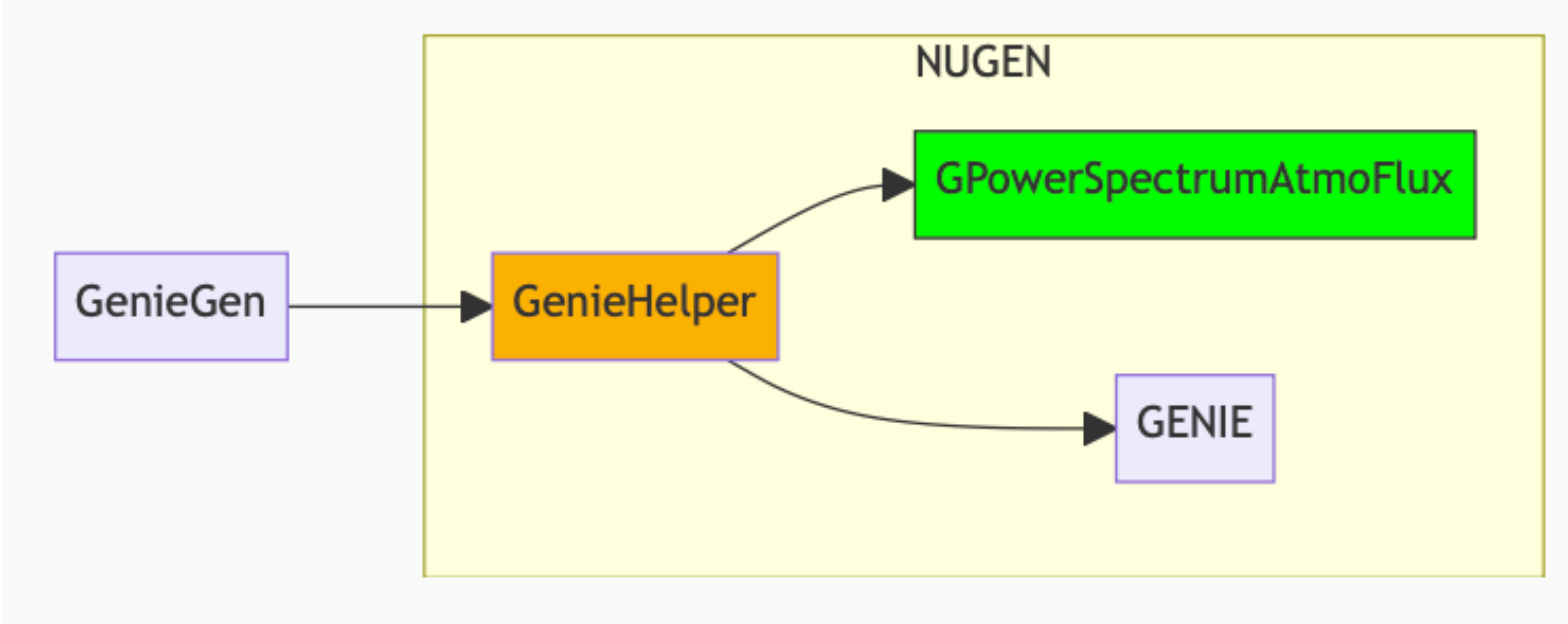
2. **Flux implementation is flexible; generation such that**
    - sample usable out of the box, w/ default parameters for physics studies, but also to allow
    - easy reweighting to facilitate parameter changes

3. **Normalization to a desired kt-year is possible**
4. **Contains 3 flavors**
5. **Un-oscillated**
    - Easy: don't oscillate

1. SCHEME INCLUDED IN LARSOFT

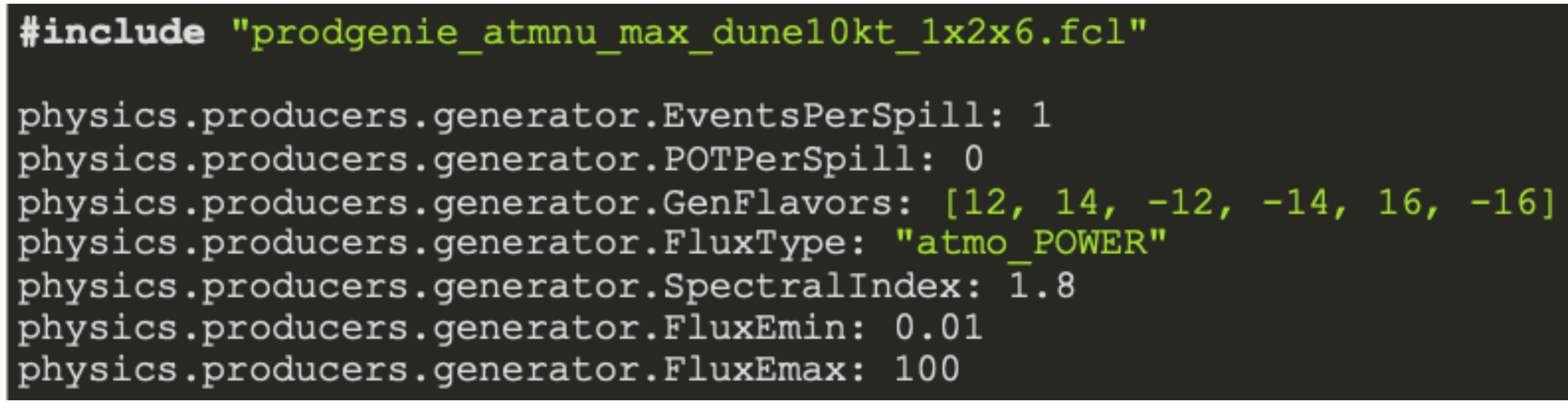
Guiding principles for the choices made

- Use available LArSoft machinery: in NUGEN



- All NUGEN changes: **https://gitlab.in2p3.fr/pgranger/nugen**

- Easy configuration: w/ FCL



```
#include "prodgenie_atmnu_max_dune10kt_1x2x6.fcl"

physics.producers.generator.EventsPerSpill: 1
physics.producers.generator.POTPerSpill: 0
physics.producers.generator.GenFlavors: [12, 14, -12, -14, 16, -16]
physics.producers.generator.FluxType: "atmo_POWER"
physics.producers.generator.SpectralIndex: 1.8
physics.producers.generator.FluxEmin: 0.01
physics.producers.generator.FluxEmax: 100
```

- Flavors
- flux type
- energy ranges
- spectral index

- **Next step (after OK from HE-WG):** ask to merge this into a nugen/LarSoft release

1. SCHEME INCLUDED IN LARSOFT

- **In addition: mismatch between DUNE geometry and atm-fluxes coord. syst**
  - The new production scheme is using a correction which exists already in LArSoft:
    - a rotation is applied to the geom. before passing it to GENIE, to fix the mismatch

```
dune_fd_atmo_flux_rotation_precise: {
   # the details of this rotation are explained in `dune_fd_genie_atmo`;
   # the imparted rotation is phi = 1.414 rad (81.016 degrees)
   # from southward direction counterclockwise
   # (and rounded to 4 significant digits).
   FluxRotCfg: "newxyz"
   FluxRotValues: [
      +0.9877, -0.1564, +0.0000,   # new x axis in old coordinates: be nice and fix thi
ngs (ends up the same)
      +0.0000, +0.0000, +1.0000,   # new y axis in old coordinates: vertical
      -0.1564, -0.9877, +0.0000    # new z axis in old coordinates: away from Batavia,
IL
      ]

} # dune_fd_atmo_flux_rotation_precise
```

WISH LIST FOR NEW SAMPLE

1. **Production scheme included in the official DUNE LArSoft**
   - use as much as possible same design-logic as in beam-setup

2. **Flux implementation is flexible; generation such that**
   - sample usable out of the box, w/ default parameters for physics studies, but also to allow
   - easy reweighting to facilitate parameter changes

3. **Normalization to a desired kt-year is possible**

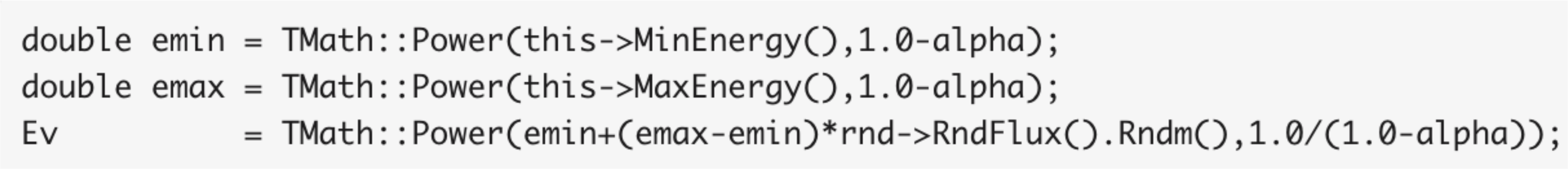
4. **Contains 3 flavors**

5. **Un-oscillated**
   - Easy: don’t oscillate

2. FLUX IMPLEMENTATION

- **Step 1: events are generated isotropic, according to a power-low in energy**

  - power-low function: (alpha is the spectral index)



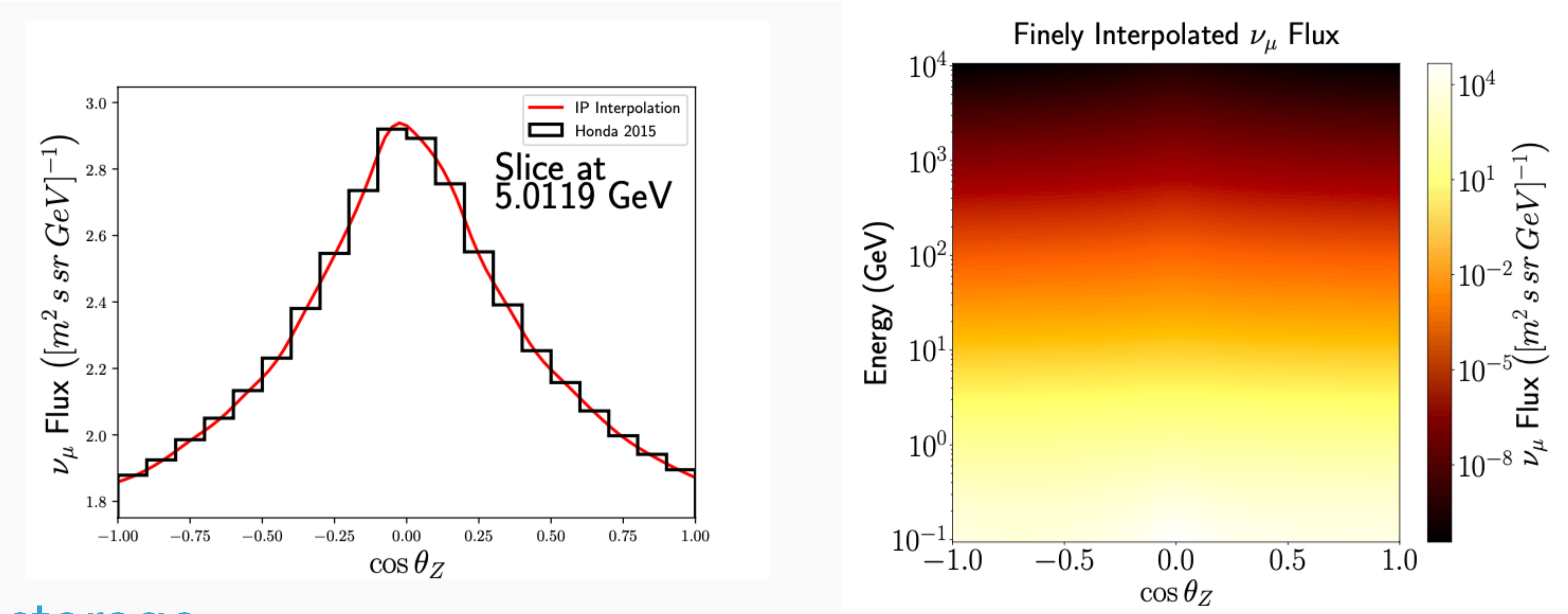
```
double emin = TMath::Power(this->MinEnergy(),1.0-alpha);
double emax = TMath::Power(this->MaxEnergy(),1.0-alpha);
Ev          = TMath::Power(emin+(emax-emin)*rnd->RndFlux().Rndm(),1.0/(1.0-alpha));
```

  - spectral index:
    - **default value=1.8**
    - stored in **MCTruth.GeneratorInfo()**

2. FLUX IMPLEMENTATION

- **Step 2: events are weighted according to a specific flux**
  - **default flux: Honda (max/min)**

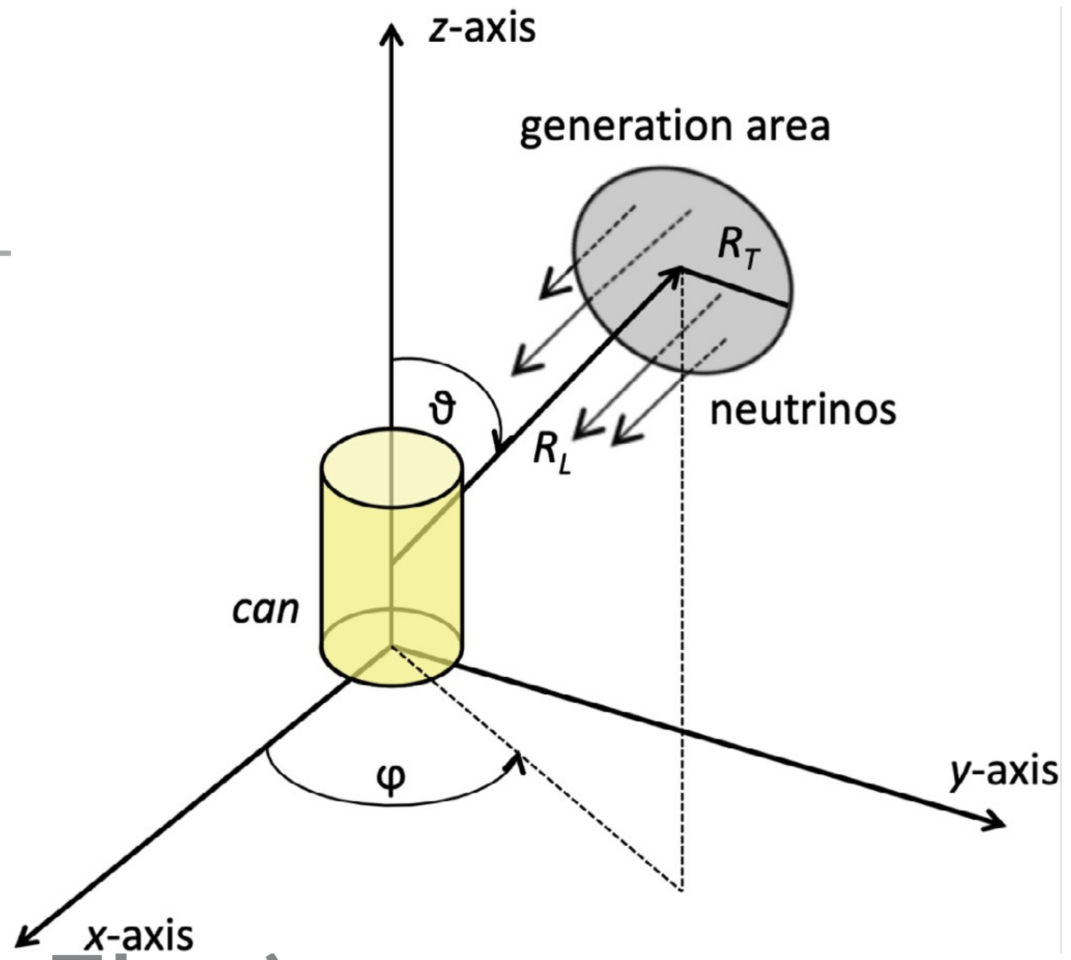
- **Honda flux is binned**
  - an interpolation has to be used to generate event weights (***w***$_{\textbf{honda}}$)
  - implemented: IceCube "Integral preserving" interpolation (arXiv:1803.05390)
    - # bins used: 1000 (E) x 200 (cos theta) ––– oversampling of 10
    - files location: /dune/app/users/pgranger/atmospherics/test power spectrum/fluxes/
      - honda_2d_homestake_2015_{nue, nuebar, numu, numubar}.root
      - solar maximum fluxes
  - this finely-binned flux is linearly interpolated during event generation



Generated with the Icecube PISA code for Homestake site.

- **Next step (after OK from HE-WG):** these flux files to be put in cvmfs-dune storage

GENERATION SCHEME IN 1 SLIDE



- **Genie:**
  - 1) Defines a generation area:
    - a circle of Rt
    - at a distance Rd from the detector center
  - 2) Generates a neutrino according to flux driver (GPowerSpectrumAtmFlux):
    - power spectrum
  - 3) Weights the event w/ the provided flux: W_{honda}
  - 4) Keeps or discards the event according to path-length & x-sec for that neutrino
  - 5) Computes the partial genie weight, used later/analysis_level, for final normalization
    - **W_{genie} partial weight stored in GenieEventRecord.Weight**
    - $$W_{\text{genie}} = W_{\text{honda}} \cdot I_E \cdot I_\theta \cdot A_{\text{gen}} \cdot E_\nu^X \cdot P_{\text{scale}}$$

Applied in GPowerSpectrumAtmoFlux

- I_E: energy phase space factor
- I_θ: angular phase space factor
- A_{gen}: area of gen surface
- E_ν^X: reciprocal of the gen spectrum

Applied in GENIEHelper

- Pscale : GENIE interaction prob. scale

WISH LIST FOR NEW SAMPLE

1. **Production scheme included in the official DUNE LArSoft**
    - use as much as possible same design-logic as in beam-setup

2. **Flux implementation is flexible; generation such that**
    - sample usable out of the box, w/ default parameters for physics studies, but also to allow
    - easy reweighting to facilitate parameter changes

3. **Normalization to a desired kt-year is possible**
4. **Contains 3 flavors**
5. **Un-oscillated**
    - Easy: don’t oscillate

3. NORMALIZATION: AT ANALYSIS LEVEL

$$W_{\mathrm{total}} = W_{\mathrm{genie}} \cdot \frac{N_\nu}{N_{\mathrm{Tot}}} \cdot P_{\mathrm{Earth}}(E, \cos\theta)$$

W_{genie}: stored in GenieEventRecord.Weight

Stored for each subRun in sumdata::POTSummary

- N_{tot}: total number of simualted neutrinos
- N_ν : number of generated neutrino flavors
- same setup as in beam-ana

$P_{\mathrm{Earth}}(E, \cos\theta)$

- transmission prob. through Earth
- earth density profile model dependent see [here]

WISH LIST FOR NEW SAMPLE

1. **Production scheme included in the official DUNE LArSoft**
   - use as much as possible same design-logic as in beam-setup

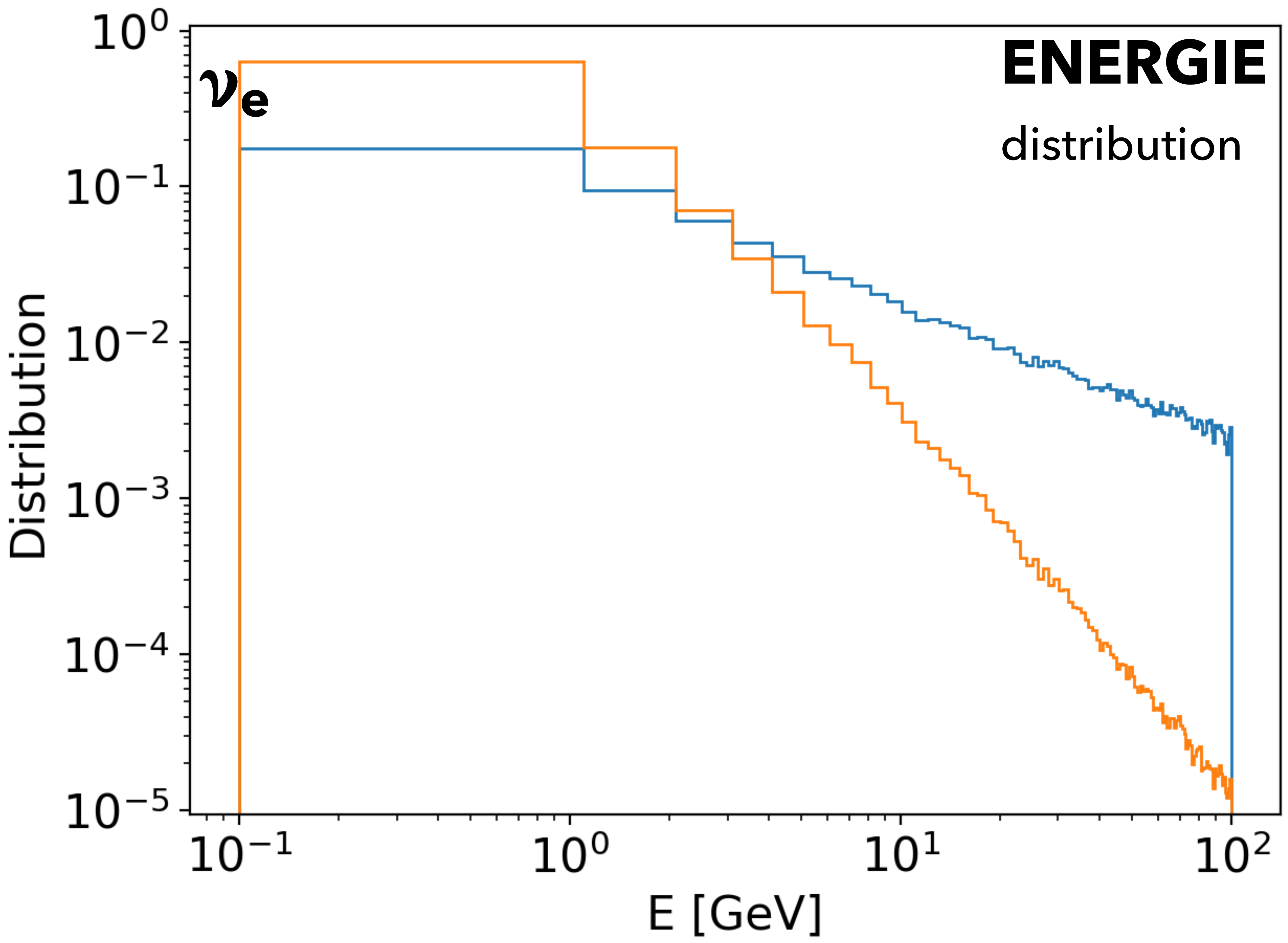
2. **Flux implementation is flexible; generation such that**
   - sample usable out of the box, w/ default parameters for physics studies, but also to allow
   - easy reweighting to facilitate parameter changes

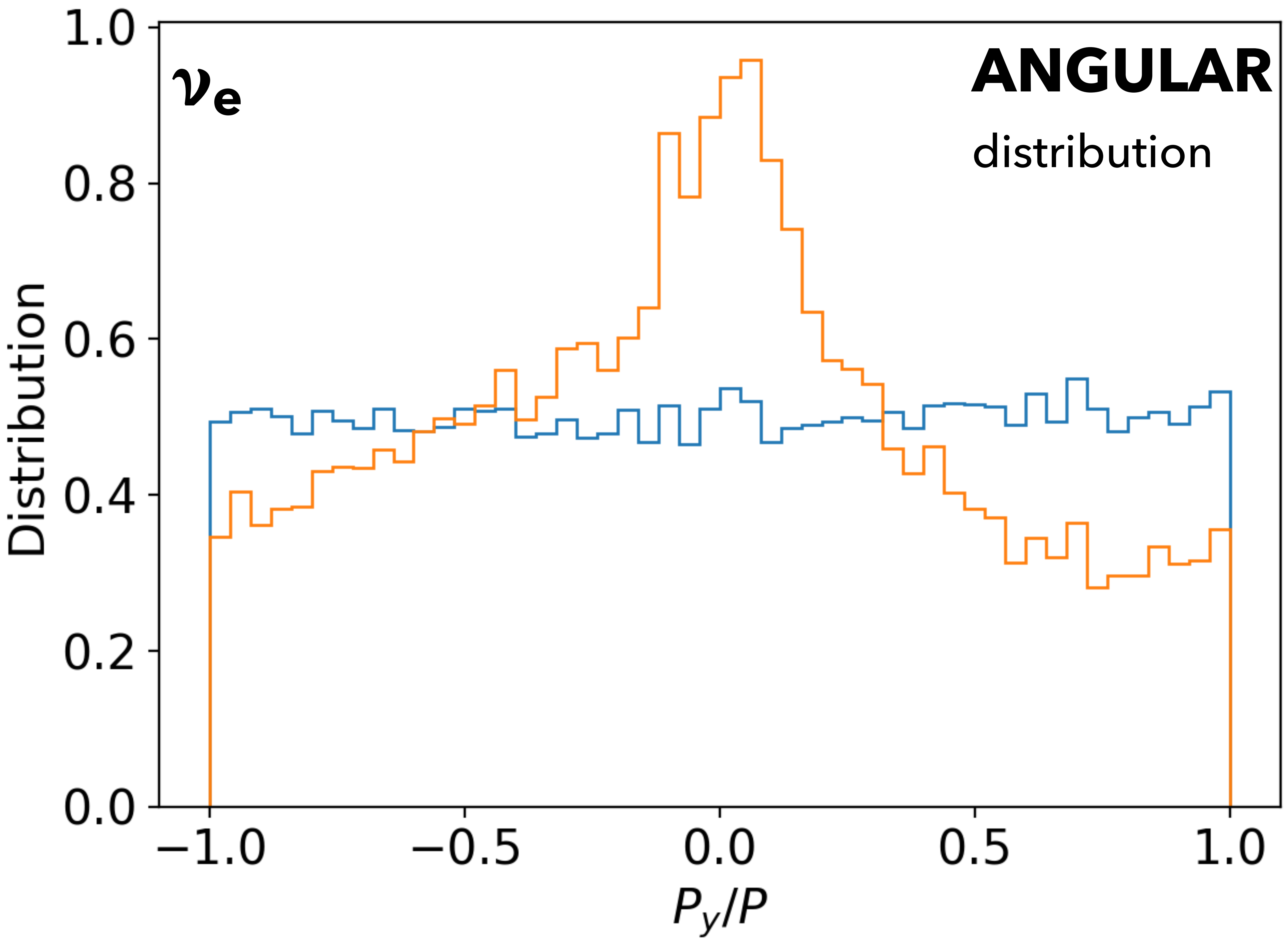
3. **Normalization to a desired kt-year is possible**
4. **Contains 3 flavors**
5. **Un-oscillated**
   - Easy: don’t oscillate

4. FLAVORS INCLUDED

- **Separate different oscillation channels into different files**
  - generate ν_α with ν_β flux with ν, $\beta \in$ {electron,μ, τ}
    - total output files: 12

THE SCHEME AT WORK



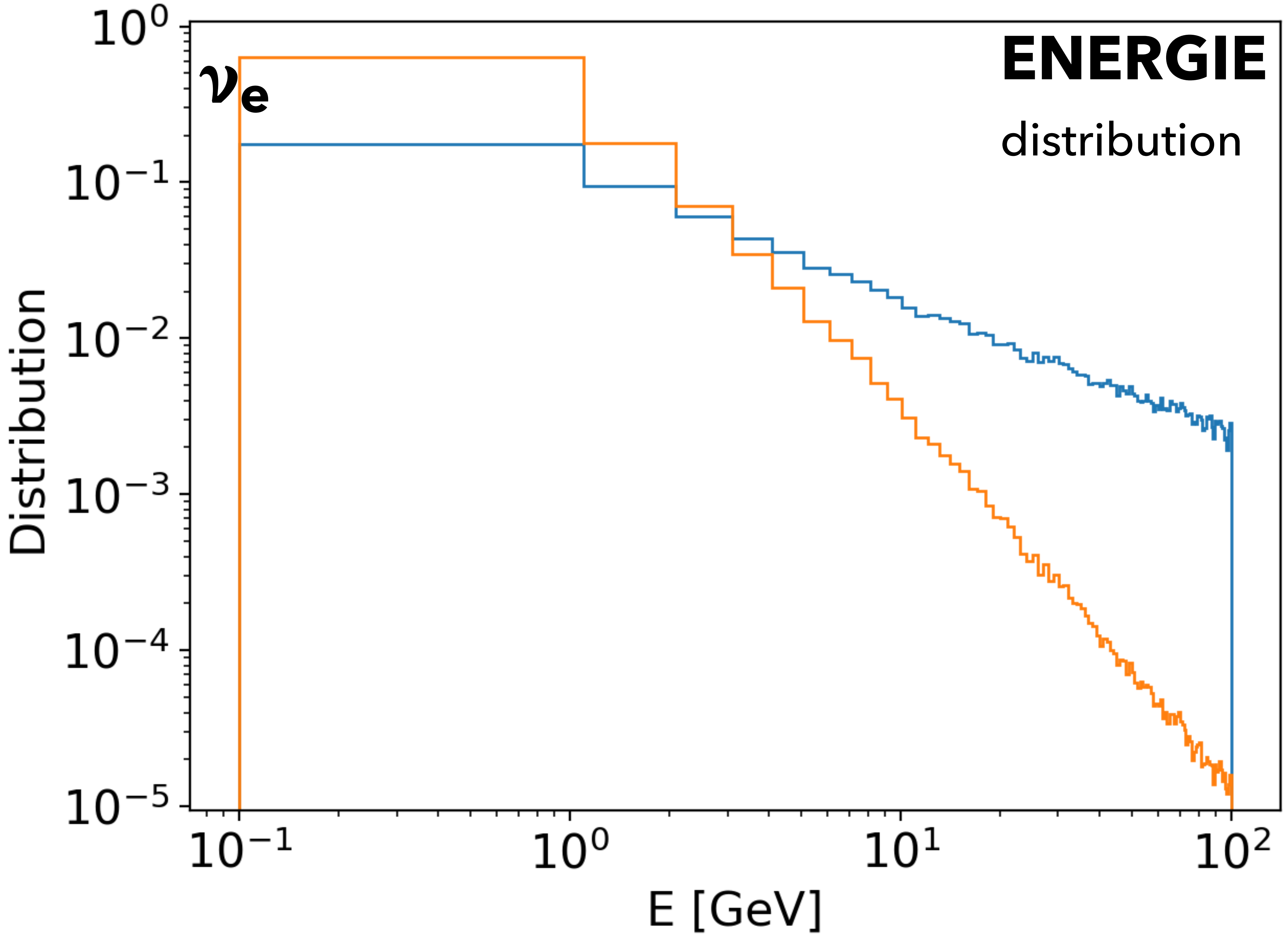


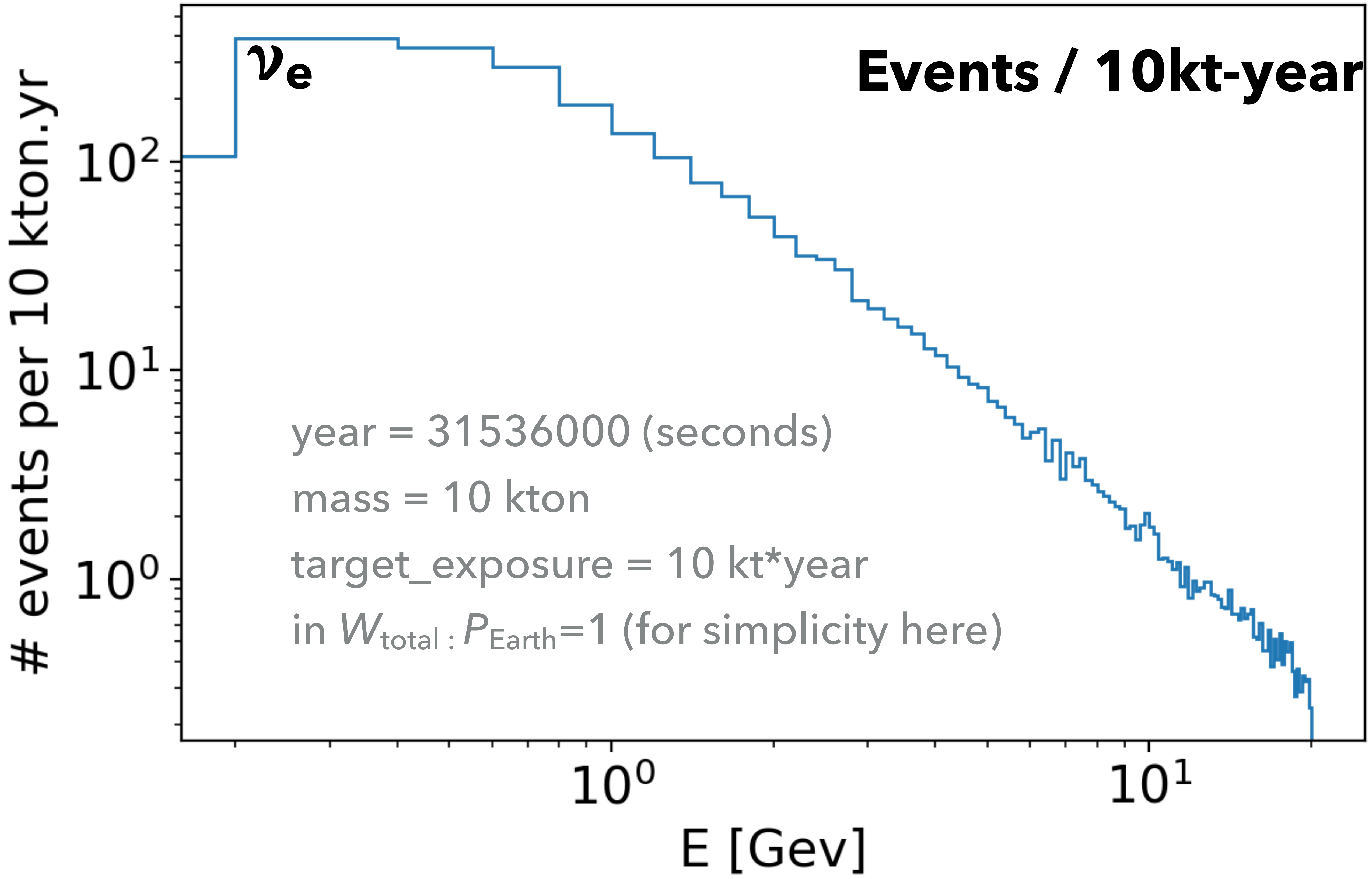
RAW distrib. (power-law)

WEIGHTED distrib. = RAW * W_{genie}

- **Note: no Pandora reco in these figures, just Genie generation**
  - test samples (generated ν_e with ν_e flux): /pnfs/dune/scratch/users/pgranger/test_sample/genie/

THE SCHEME AT WORK





year = 31536000 (seconds)

mass = 10 kton

target_exposure = 10 kt*year

in $W_{total\,:}$ P_{Earth}=1 (for simplicity here)

RAW distrib. (power-law)

WEIGHTED distrib. = RAW * W_{genie}

Normalized distrib =

RAW * W_{total} * year/target_exposure/ mass

- **Note: no Pandora reco in these figures, just Genie generation**

SUMMARY: CURRENT SCHEME

- **Contains 3 flavors** ✅

- **Normalization to a desired kt-year is possible**✅
- **Flux implementation is flexible** ✅

- **Production scheme included in the official DUNE LArSoft** ☑️
  - scheme is using existing infrastructure, and keeps in sync w/ the beam analysis setups
  - pending ok from HE WG: ready to proceed w/ contacting reco/sim conveners to start PRs.