Update on the TAMBO Monte Carlo Simulation

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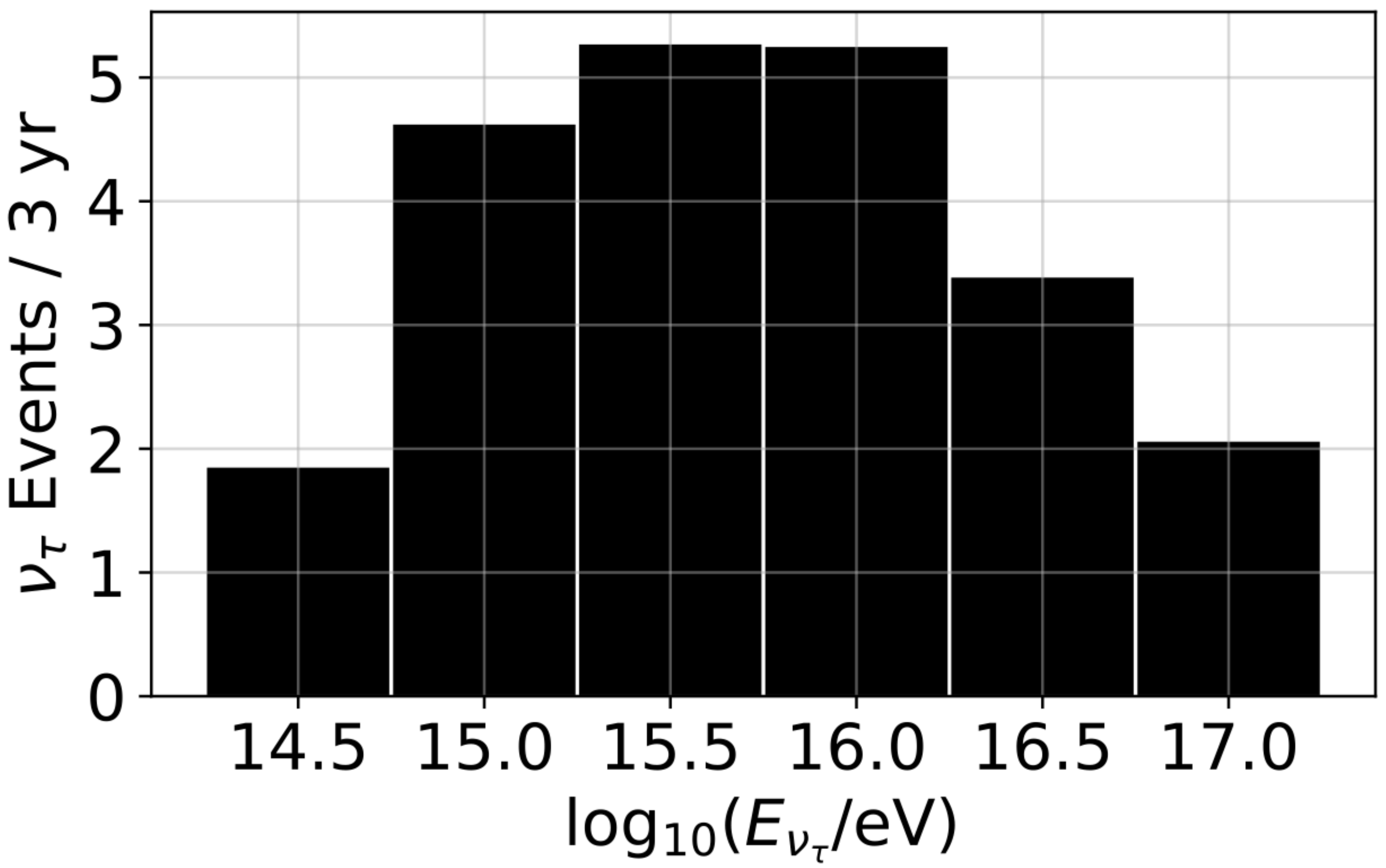
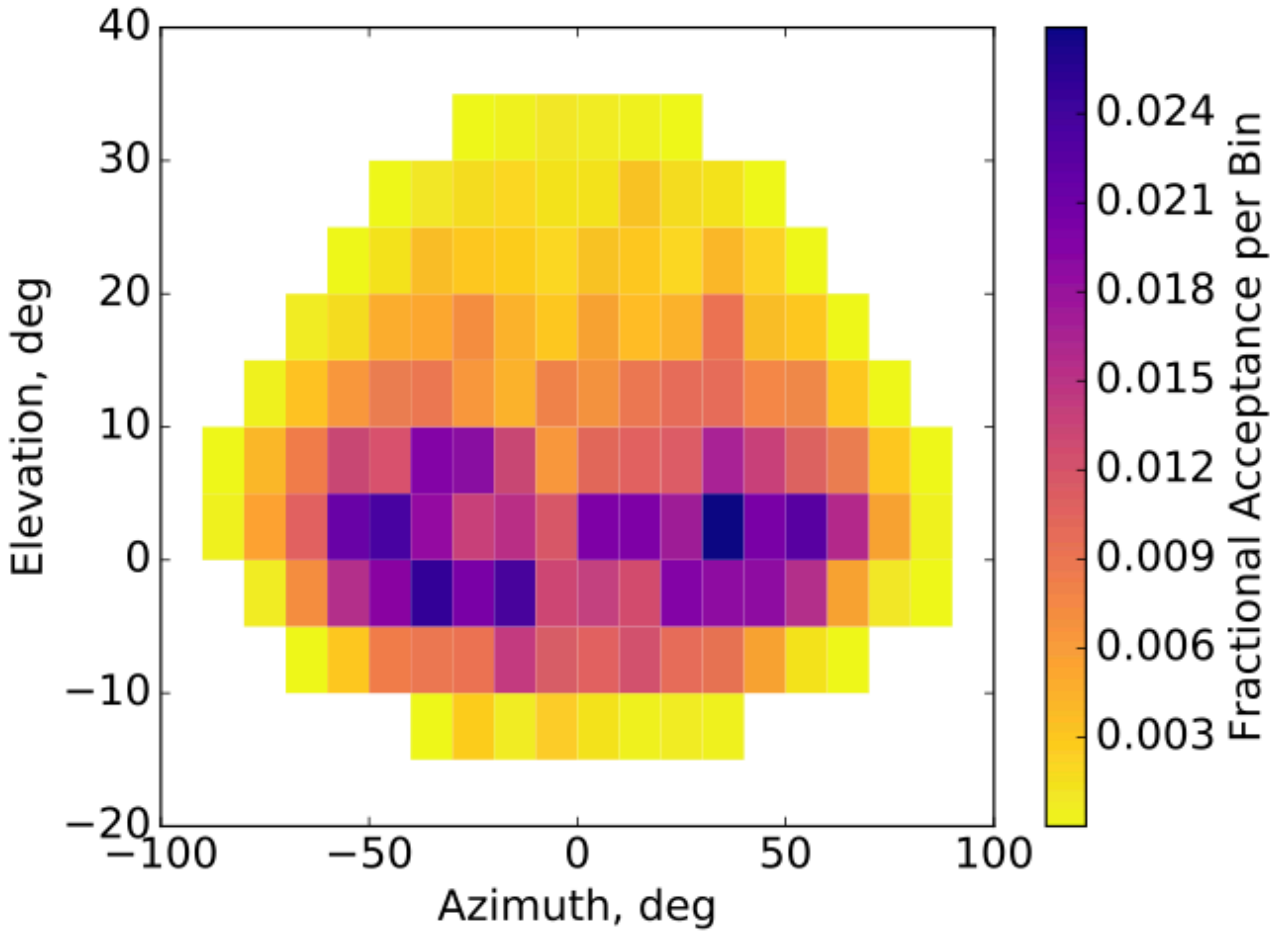
What we're after

True rates



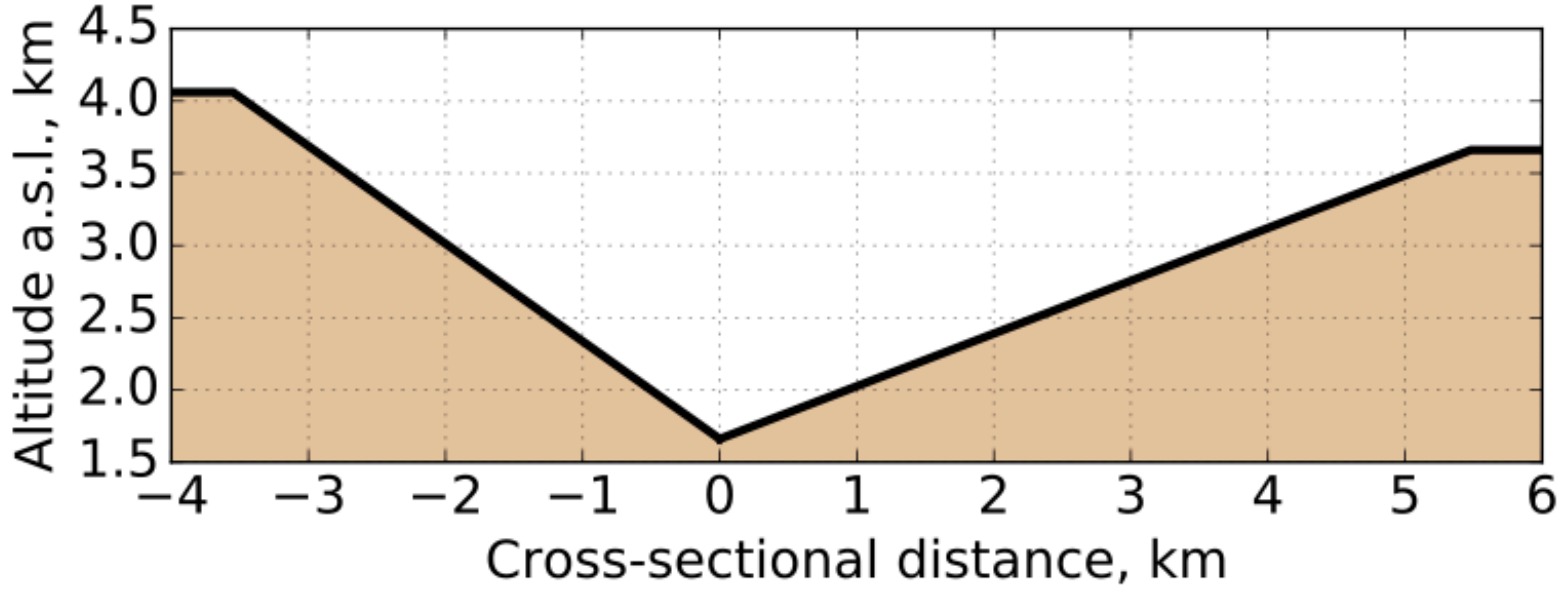
Total number of events in 3 years: Total number of events expected by extrapolating the high-energy flux measured by IceCube. Reproduced from DOI:10.1086/423124

Detector response

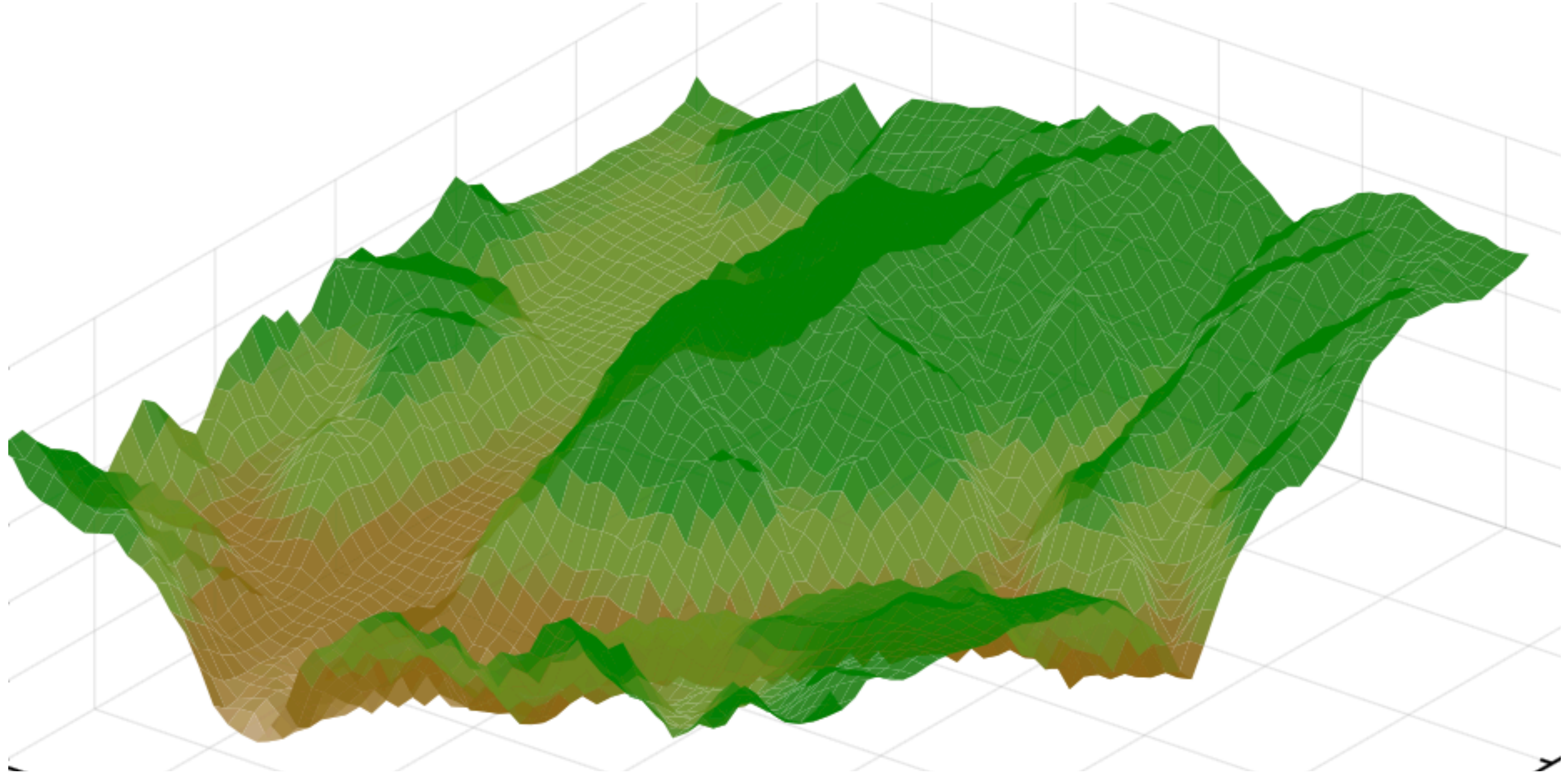


Fractional acceptance of events as a function of arrival direction: Reproduced from DOI:10.1086/423124

Moving past the first pass

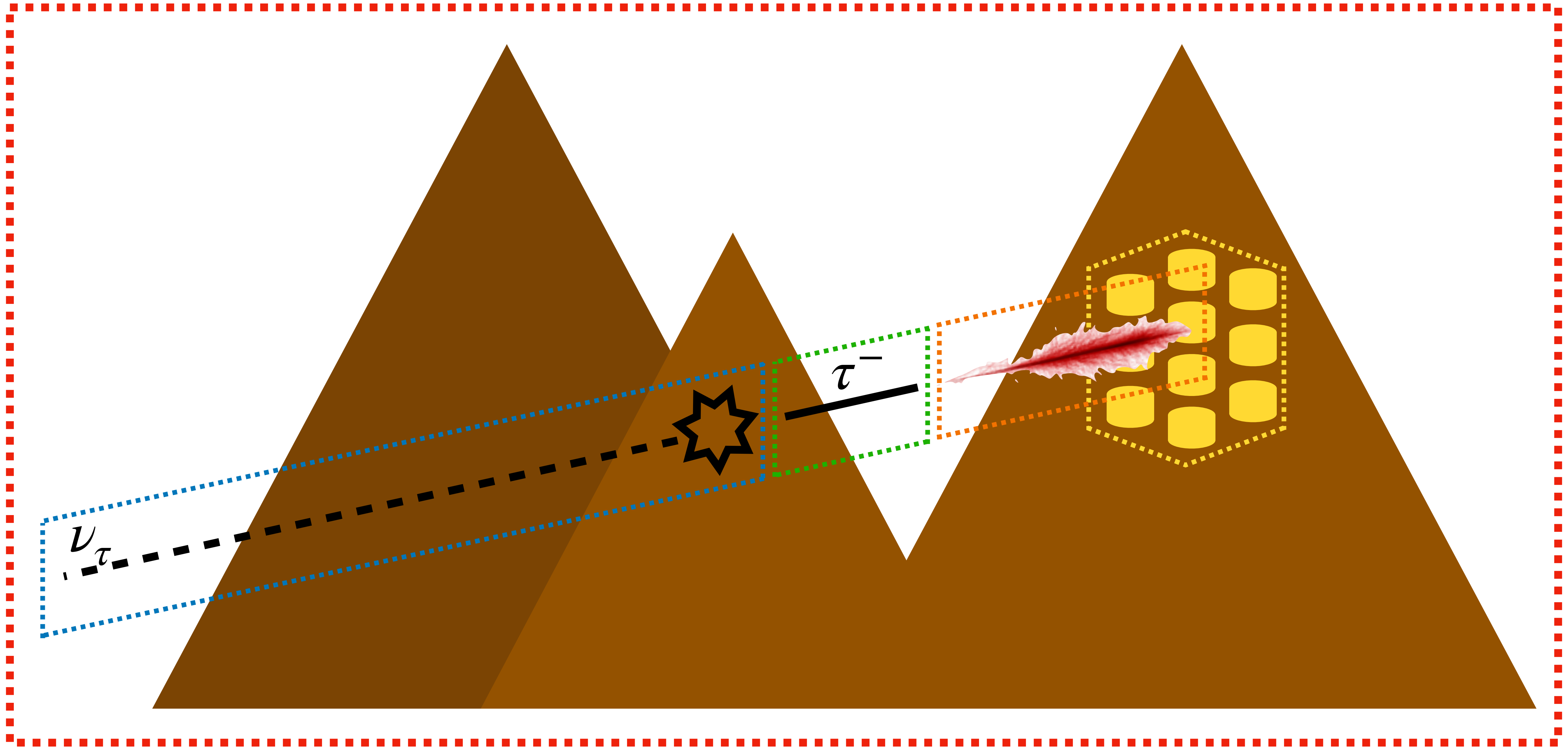


- Simplified geometry
- No treatment of $\tau^{\pm}$ energy losses
- Approximation of air-shower physics



- Realistic
- Full treatment of $\tau^{\pm}$ energy losses
- (Less) approximation of air-shower physics. Eventually few simulation

Monte Carlo Simulation: an overview



Initial neutrino injection: Select initial neutrino properties, *i.e.* energy, direction, interaction vertex, *etc.*

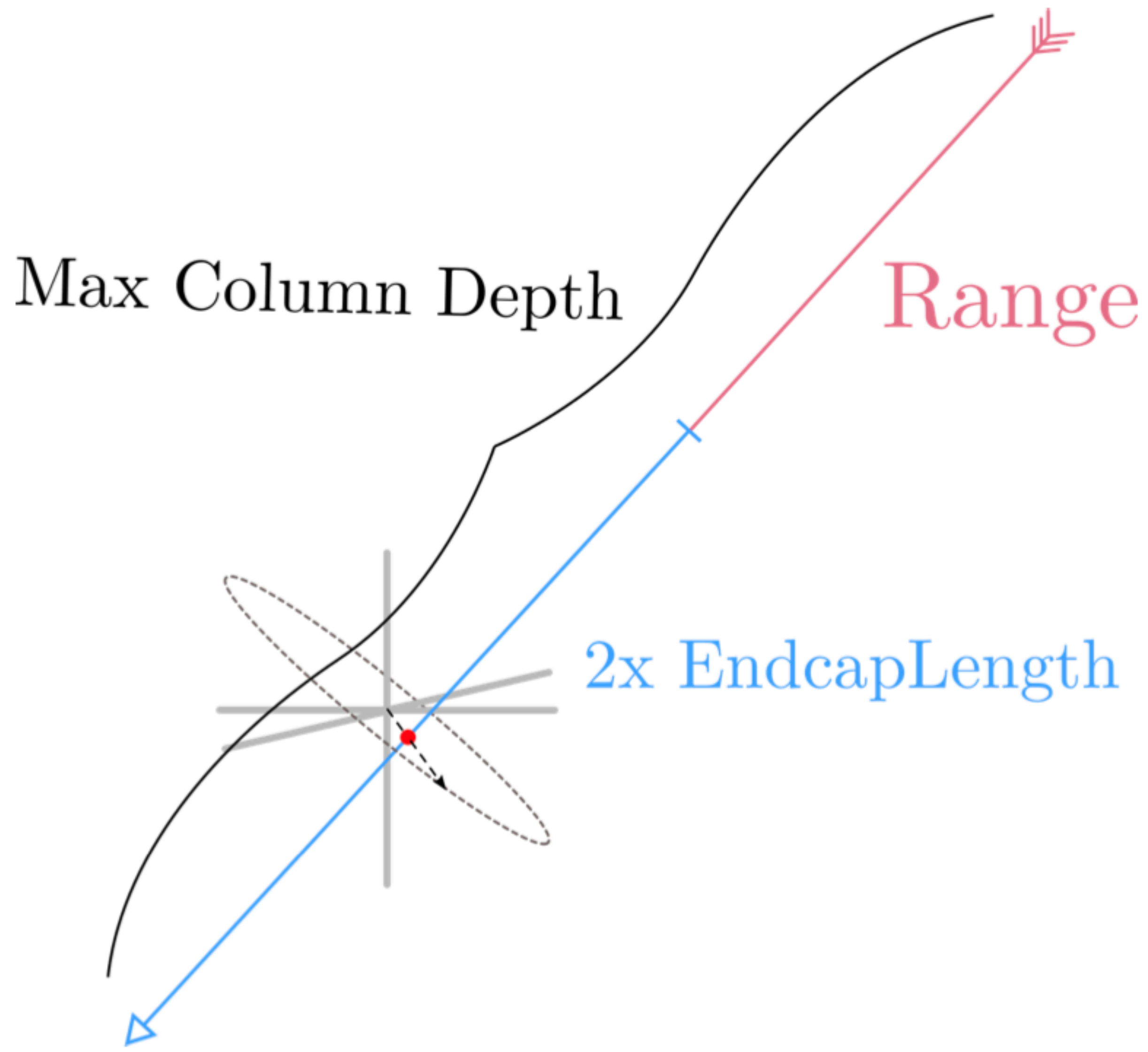
Charged lepton propagation: Propagate outgoing charged lepton, accounting for energy losses and decay, to find decay point

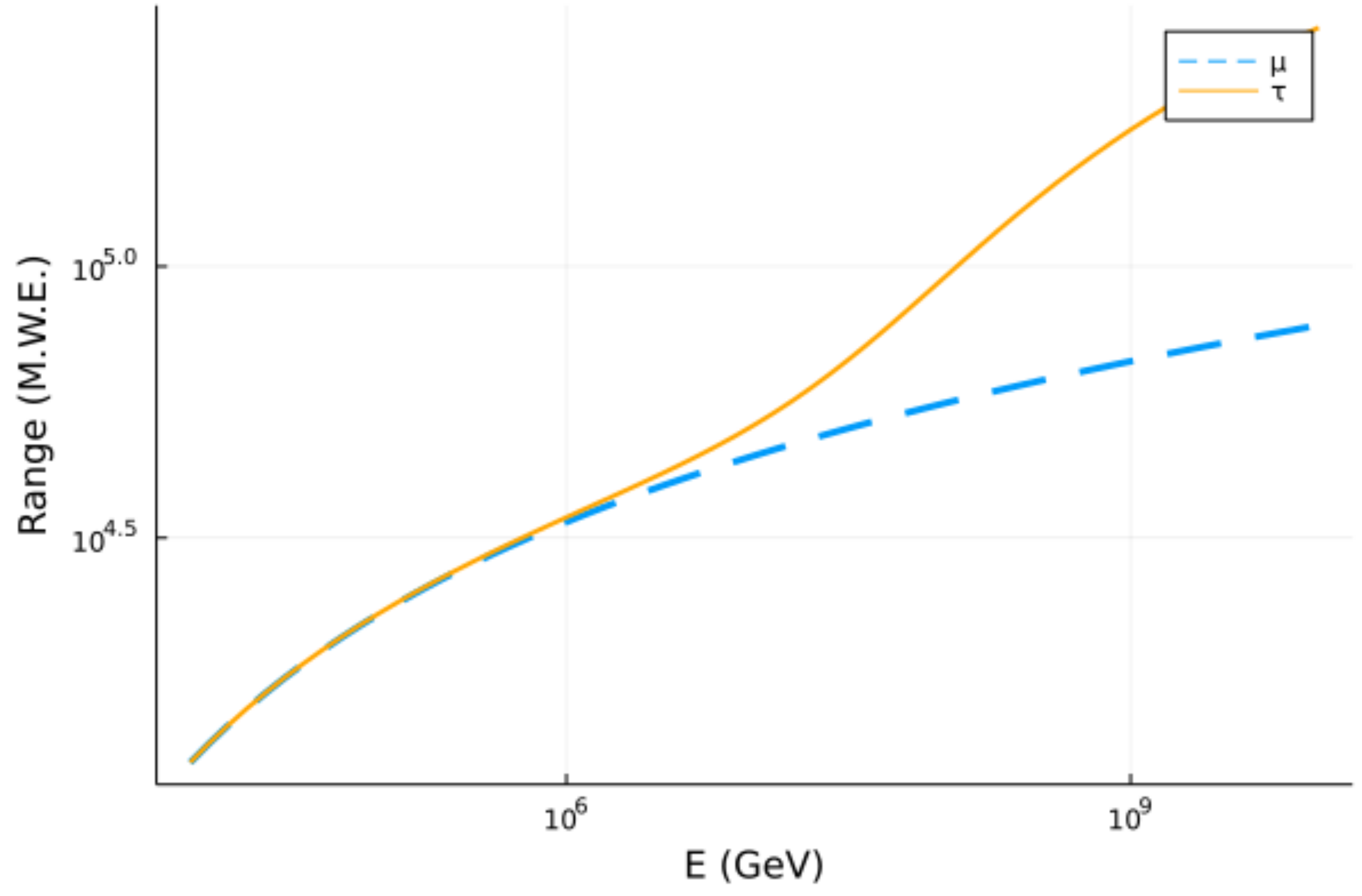
Air-shower simulation: Model shower development from lepton decay

Detector response: Simulate internal hardware to model what we will see

Event weighting: Remove unphysical remnants from selection of initial neutrino properties

Initial Neutrino Injection





Charged Lepton Propagation

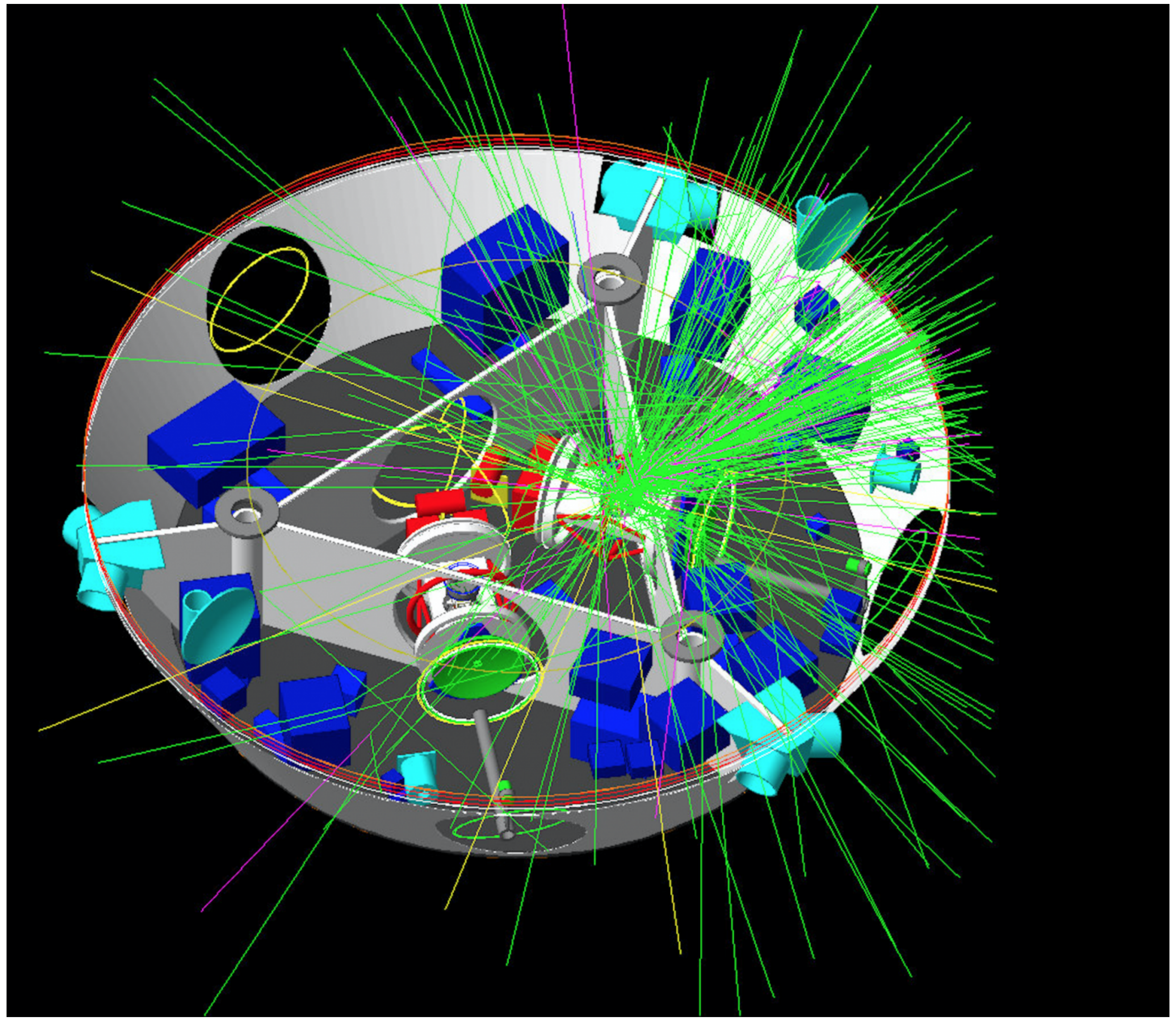
- PROPOSAL is a Monte Carlo framework for propagating charged leptons and gamma rays
- Most up-to-date cross sections and for interaction and decay
- C++ and Python interfaces. Sometimes can be installed with `pip`

Air-Shower Simulation

- CORSIKA is a MC-based software for calculating air-shower
- FORTRAN-based code, c++ hopefully coming soon
- Currently working on an approximation that treats the mountain as a plane
- We will need to simulate a large CORSIKA library for a fully accurate simulation

Detector Response

- Geant4 is a toolkit for simulating the passage of particles through matter
- Detailed treatment of internal detector geometries
- Reference for LHC experiments
- C++ interface



Event Weighting

$$\frac{1}{w_{\text{gen}}} = N_{\text{gen}} \frac{1}{\Omega_{\text{gen}} A_{\text{gen}}} \times \frac{\rho_{\text{gen}}(\ell)}{X_{\text{gen}}} \times \frac{1}{\sigma_{\text{tot}}(E)} \frac{\partial \sigma}{\partial y}(E, y) \times \frac{\Phi_{\text{gen}}(E)}{\int \Phi_{\text{gen}}\, \mathrm{d}E}$$

$$w_{\text{phys}} = \sum_{\{\text{gen}\}} \underbrace{\left(\frac{X_{\text{phys}} N_A}{M_{\text{target}}} \times \frac{\rho_{\text{phys}}(\ell)}{X^{\text{col}}_{\text{phys}}} \times \frac{\partial \sigma}{\partial y} \times \boxed{\Phi_{\text{phys}}(E, \theta)} \right)}_{\text{physical distribution}} \times w_{\text{gen}}$$

- We generate according to a distribution which may not be physical
- For example, we may sample event uniformly on a sphere but attenuation makes the unlikely
- Remove "unphysicalness" reweighting by removing generation dependence
- Also allows simulation to be applied to different fluxes, cross section models, *etc*.

TAURUNNER

Python-based package for simulating ν_τ propagation: Uses MC approach to propagate tau neutrinos including previously neglected

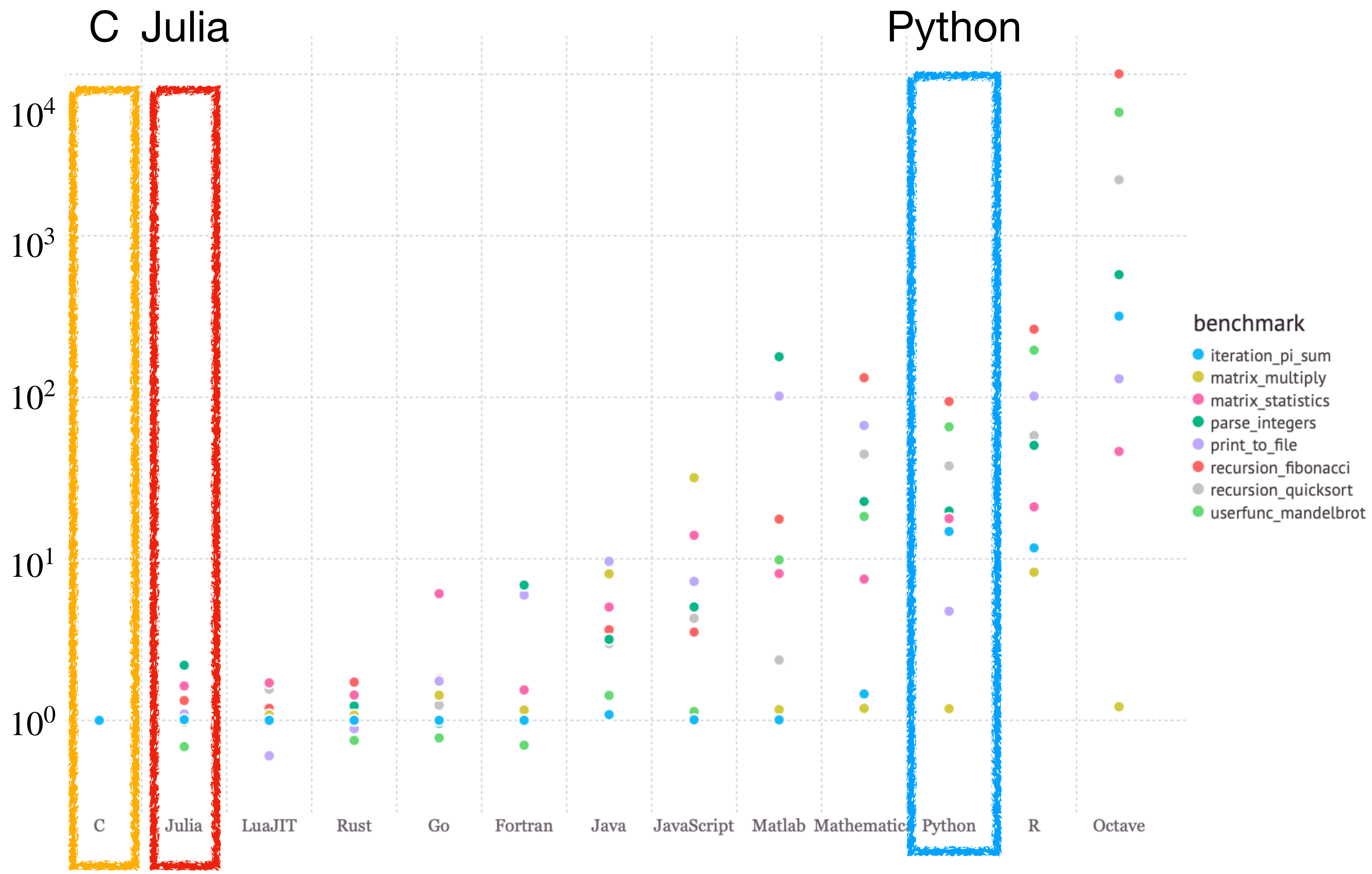
Python, C++, FORTRAN

Which one should we use ?

- None of them :-)
- Currently being designed in the Julia language
- Initial injection is purely in Julia, and most other things rely on Julia-based interface to other codes

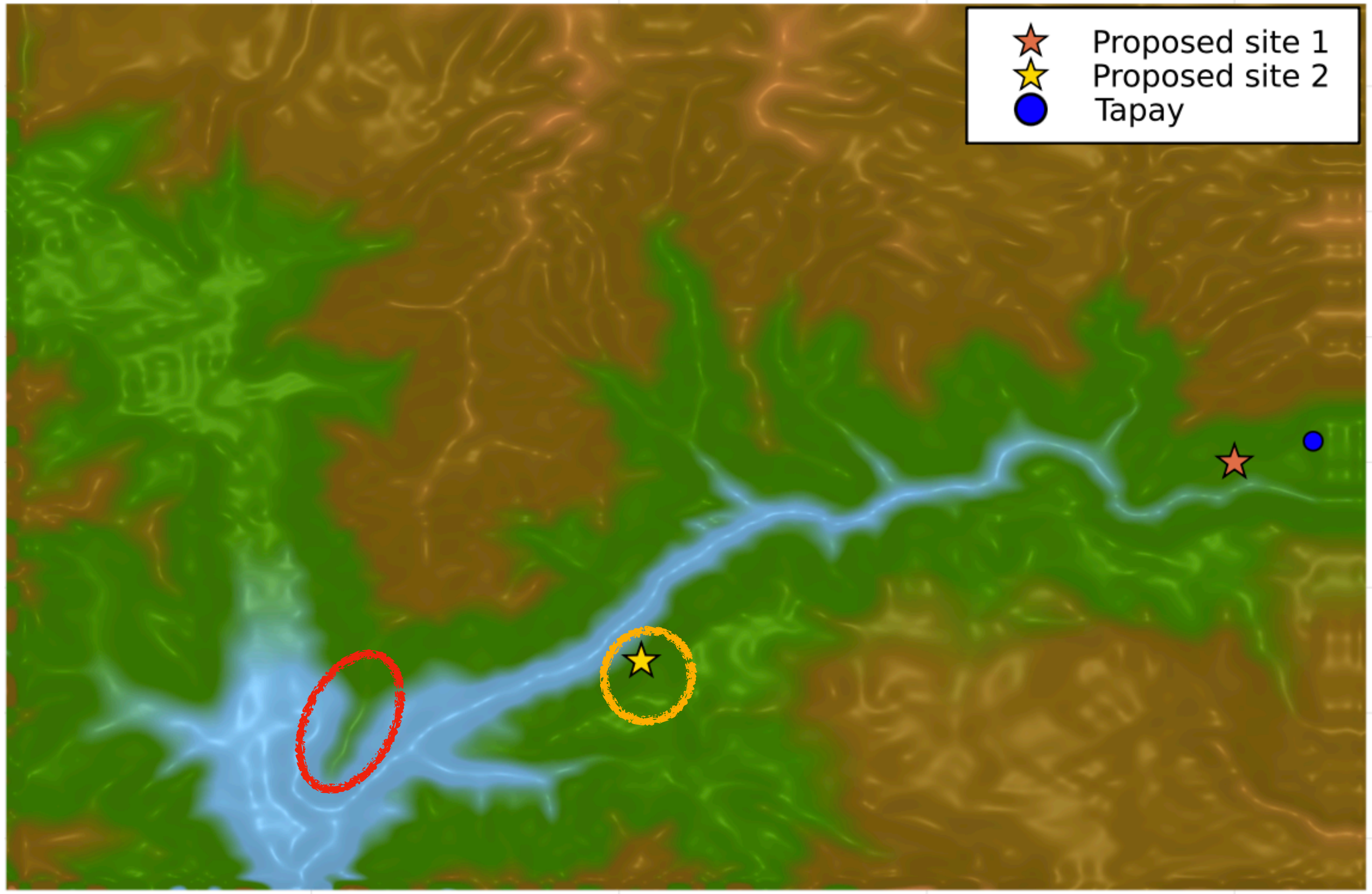
Julia Language

- Relatively new language optimized for data analysis
- JIT compilation allows for a nice combination of interactive coding and speed
- Can be used as scripts, in a REPL, or in Jupyter notebooks

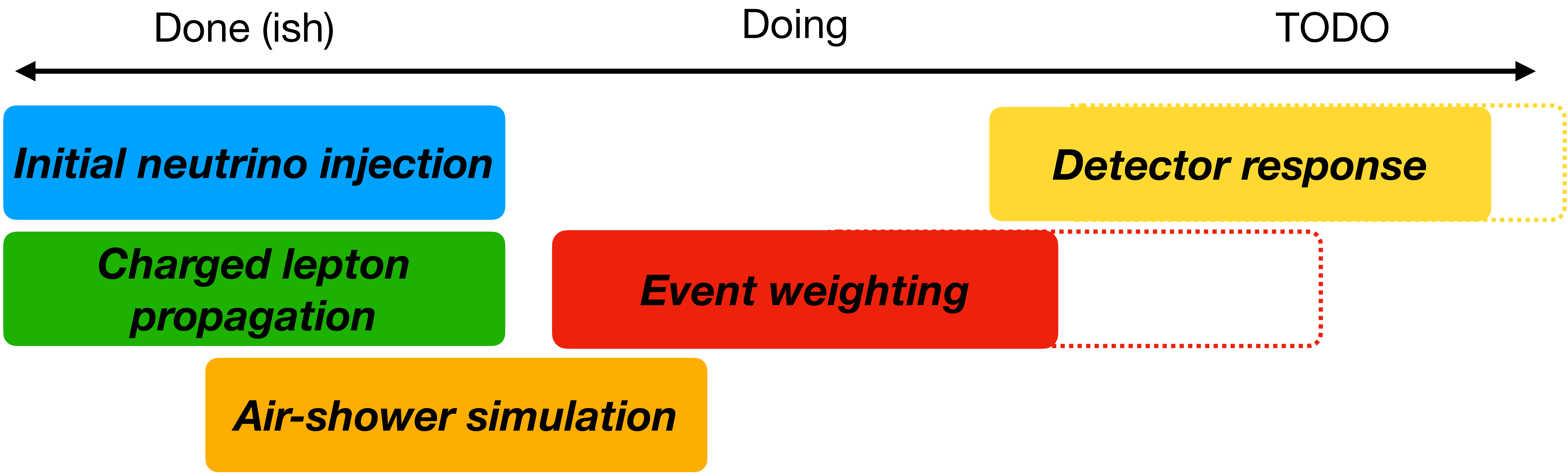


Timing comparison for various languages: Timing comparisons on a variety of benchmarks normalized to their time in C. Note, compile time is not included for Julia

Where do we stand ?

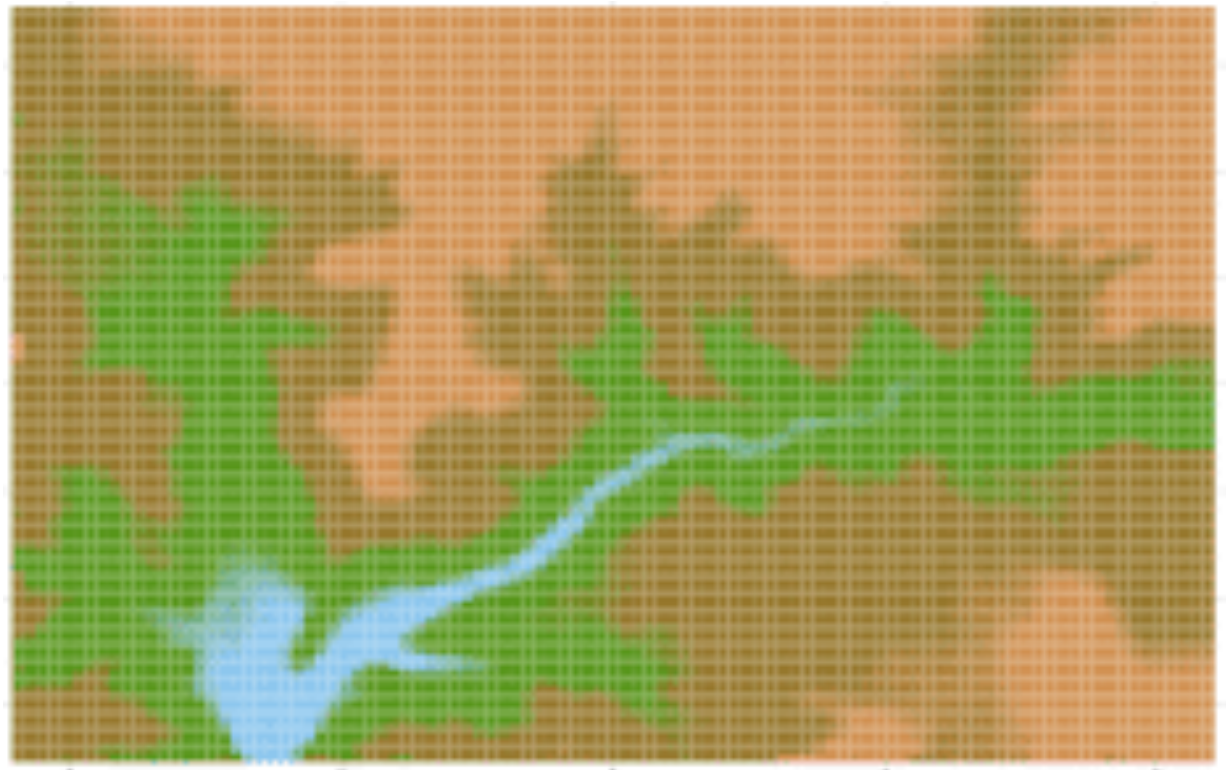


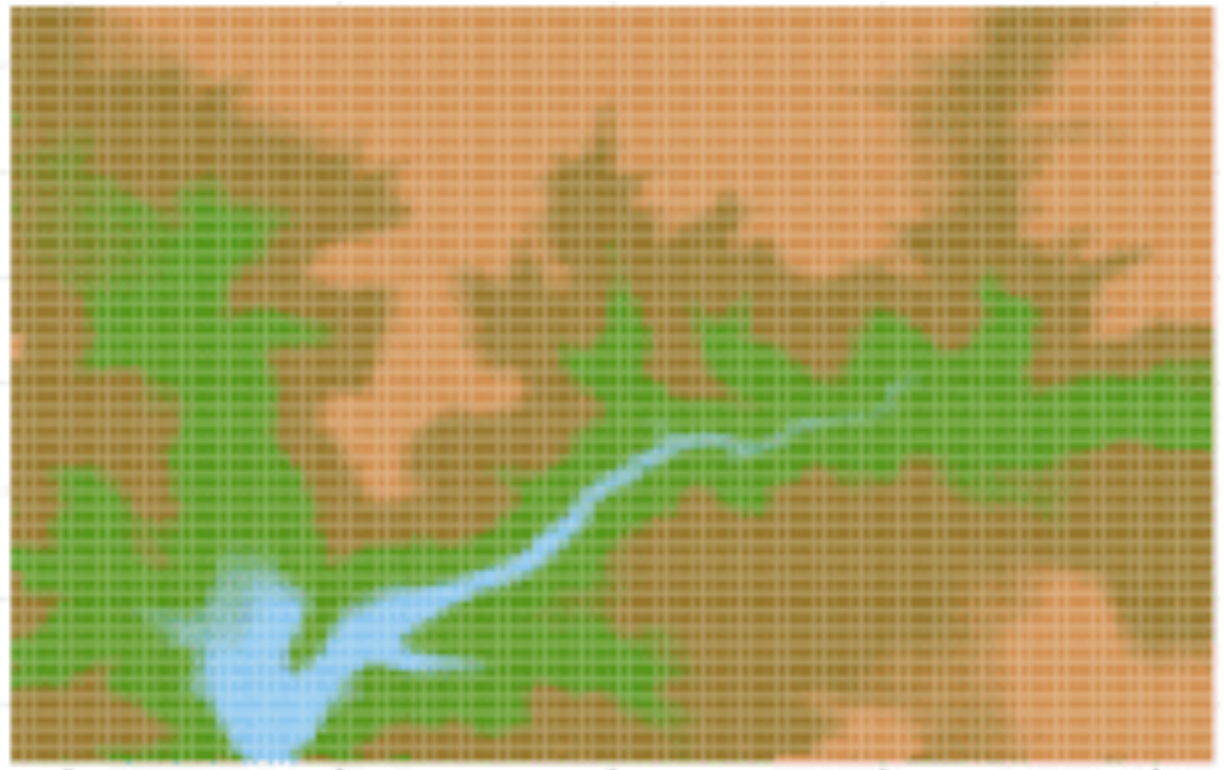
Where do we stand ?

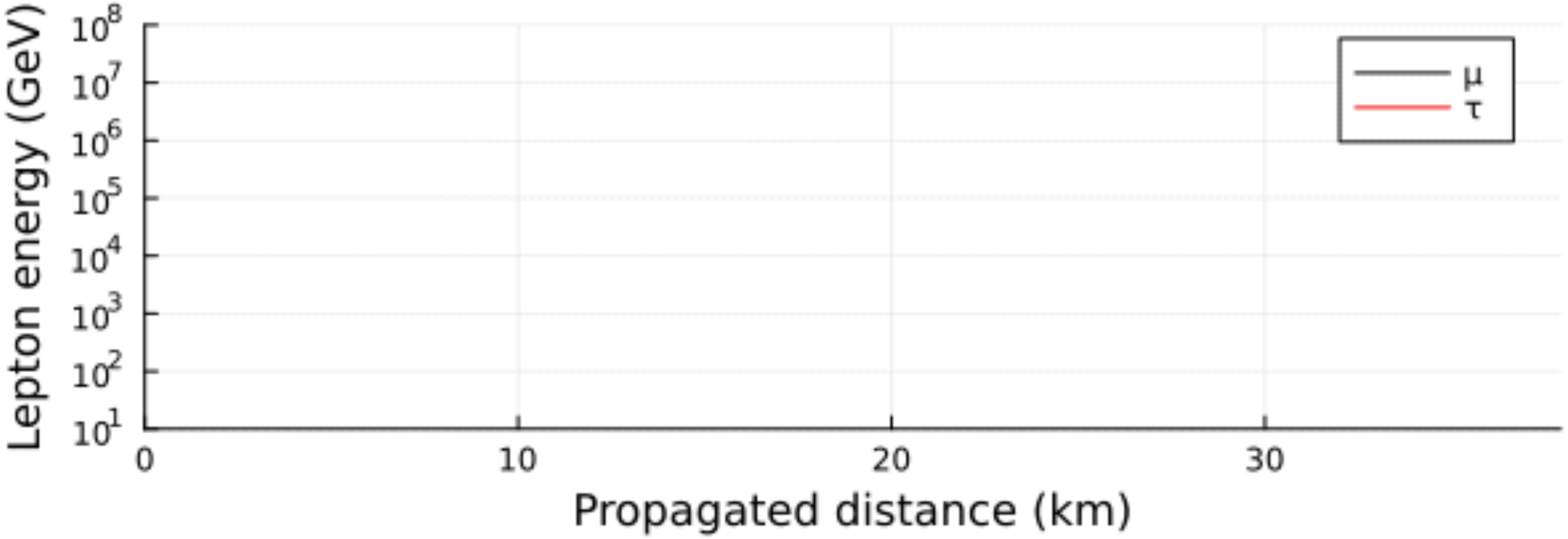


- If we can finish the air-shower simulation, we can do a first round of simulation
- This will allow us to assess detector needs, optimize configurations, and determine feasibility of sites

A GIF for the End :-)







We would love your help !

- We are close to pushing past a major milestone and producing realistic simulation at a site of interest
- Beyond this, we will need to hone and perfect the particle physics and detector simulations
- Plenty to do. Code needs to be tested, bugs needs to be found, and large simulation needs to be run
- All skill levels welcome and no familiarity with Julia necessary :-)