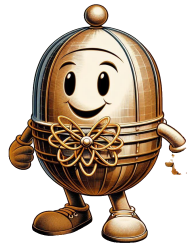
Detector Simulations

Computing subgroup mini-workshop

Stephan Meighen-Berger



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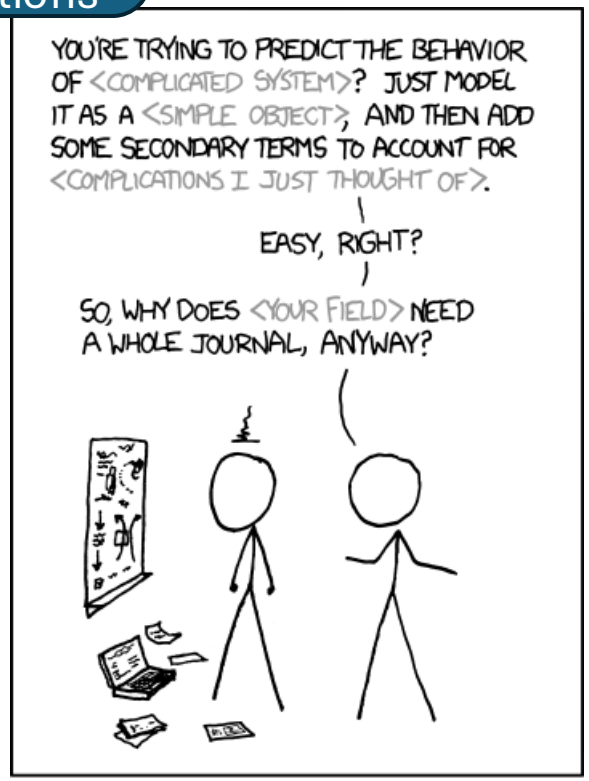
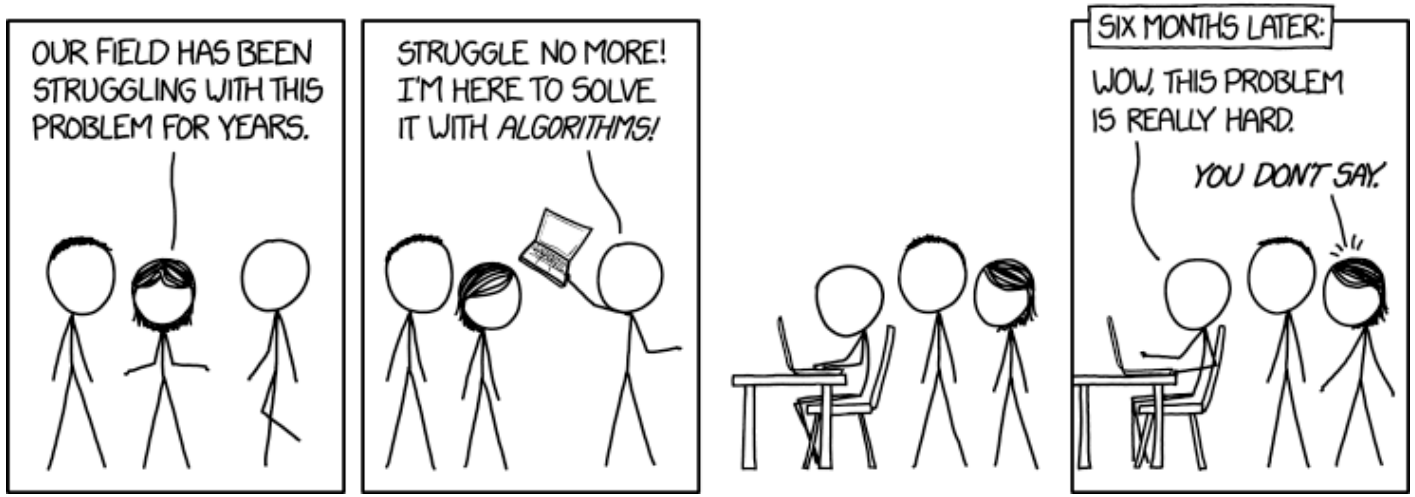
Let's start with a disclaimer

This is a phenomenologist telling you about detector simulations

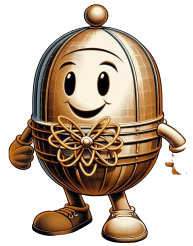


https://xkcd.com/793/



https://xkcd.com/1831/

But I'll do my best...



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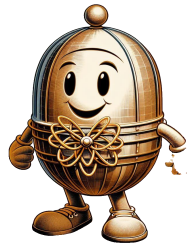
Before you get bored...

Document your code!!!!!!!!!!!!!



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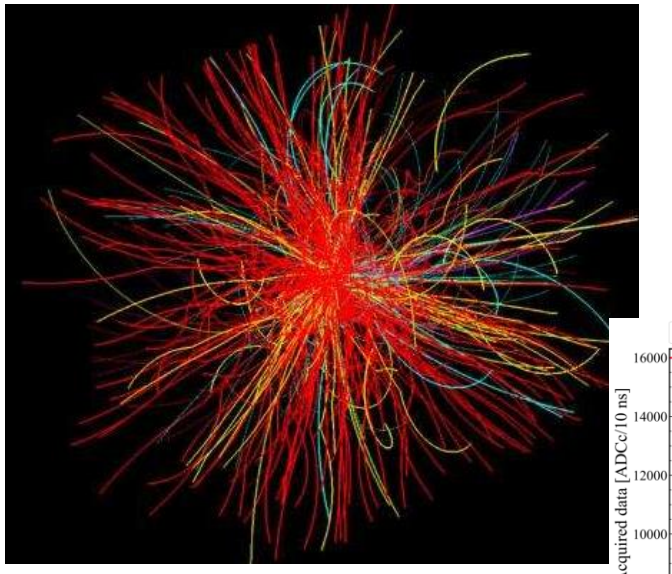
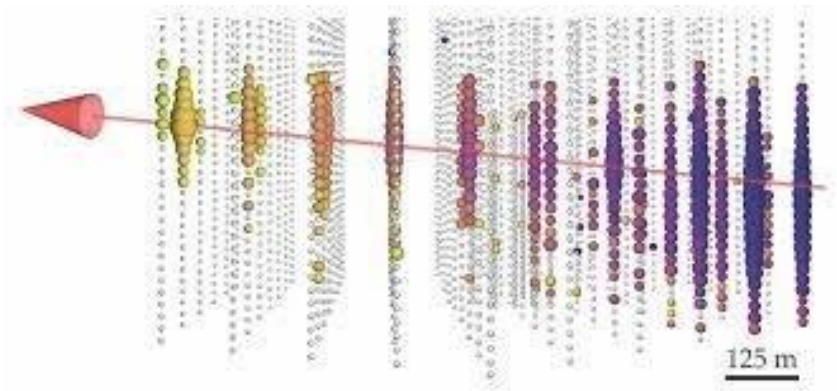
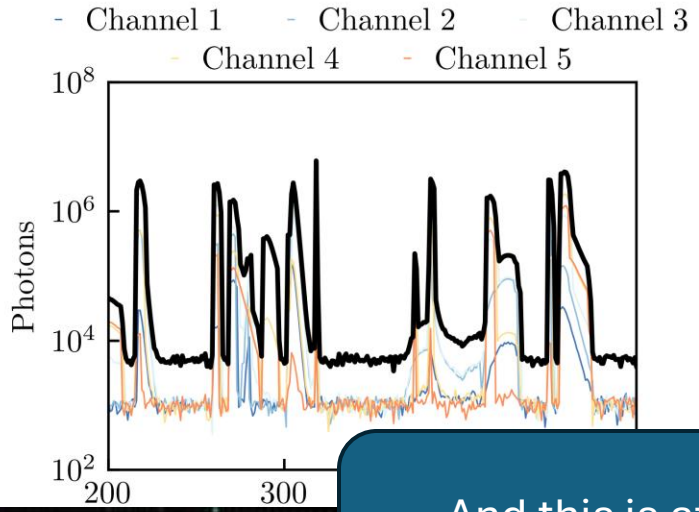
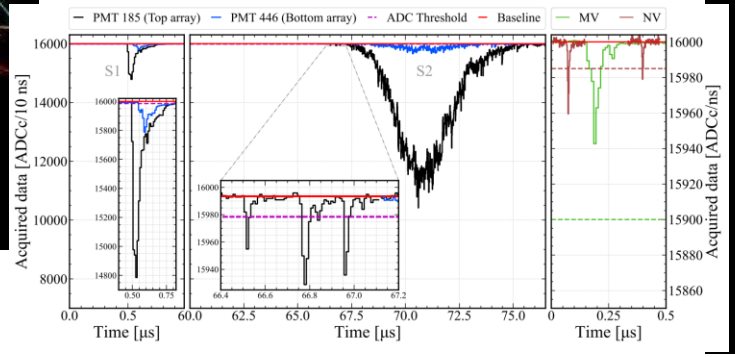
So you've built a detecor

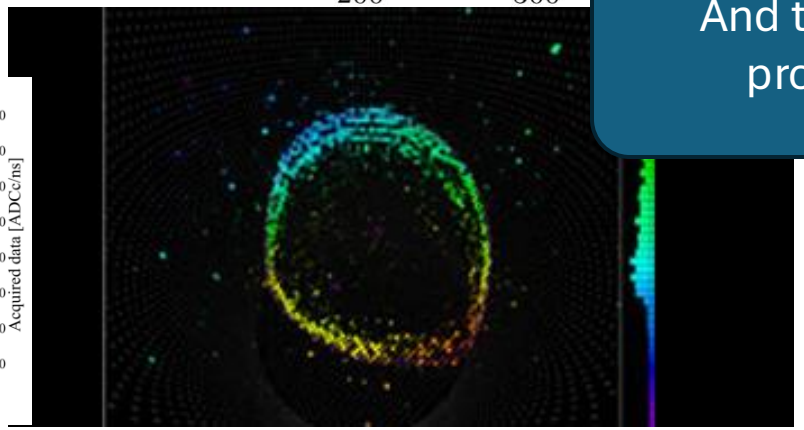
How do you understand what it is seeing?



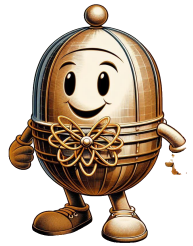








And this is after processing



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What do we want? I

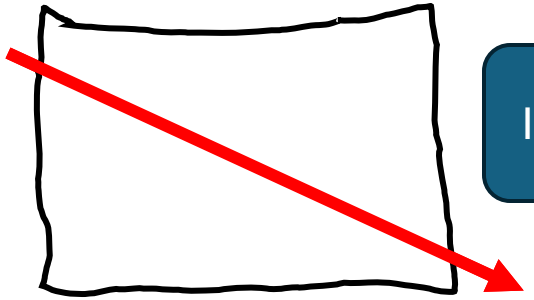
Example IceCube

A simulation (chain) that can re-create what we see in our detector(s)

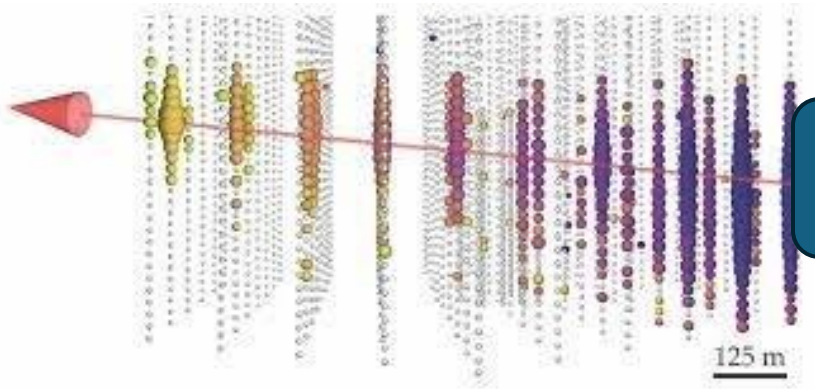
Should be a bit better than this

Volume Detectors

$$N_{\text{Events}} = N_t \Delta t \Phi \sigma$$



Instead of this

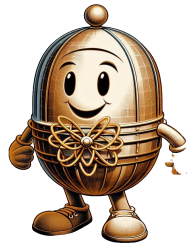


Something like this

Colliders $\frac{\mathrm{d}R}{\mathrm{d}t} = \mathcal{L}\sigma_{p\to\text{Sig}}$

Acronym Finding excercise

Focus Here on Neutrinos



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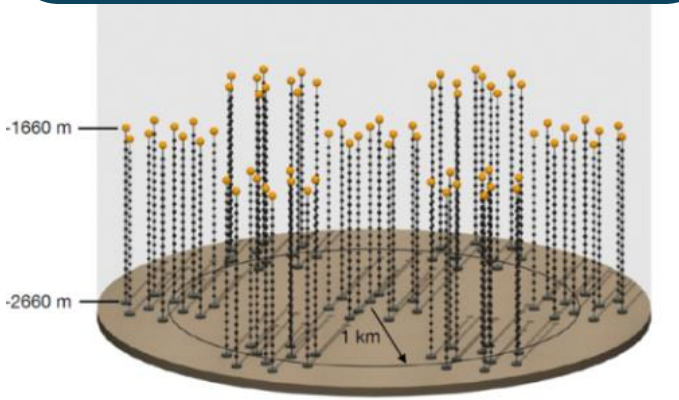
What do we want? II

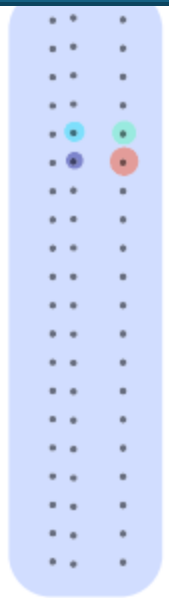
Plug in:
- Model

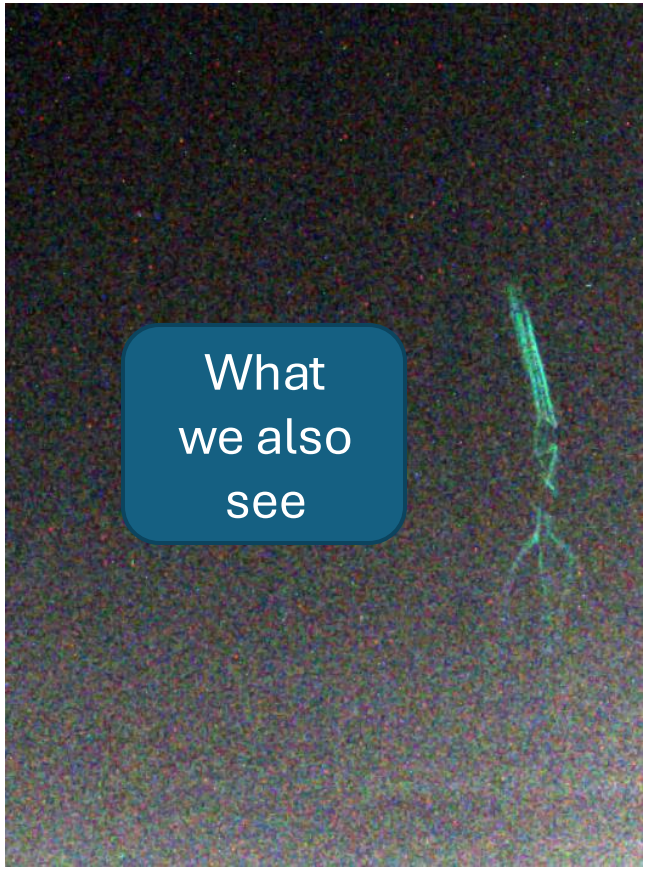
- What does your detector even measure?
  - (Not as easy as it sounds)

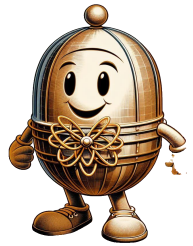
P-ONE is a new ocean based neutrino detector



What we expected to see in the pathfinder experiments







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What do we want? II

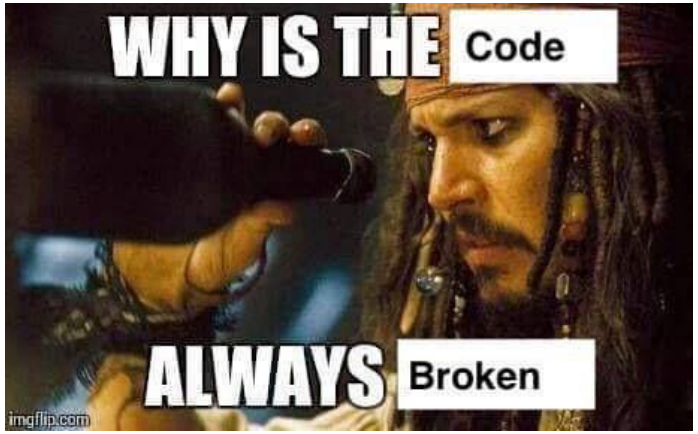
Plug in:
- Model

Physics Magic

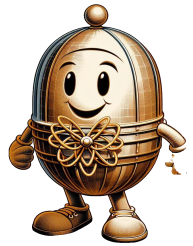
- What does your detector even measure?

Physicist's Code

1. Injection
2. Propagation
3. Response



Would be nice if this is easy to use...



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What do we want? II

Plug in:
- Model

Physics Magic

Some "usable" data

Why do experiments feel the need to create their own formats?

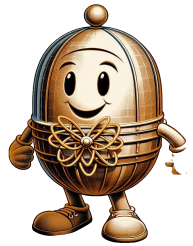
- What does your detector even measure?

Truth + Measurement

Physicist's Code

1. Injection
2. Propagation
3. Response

Would be nice if this is easy to use...



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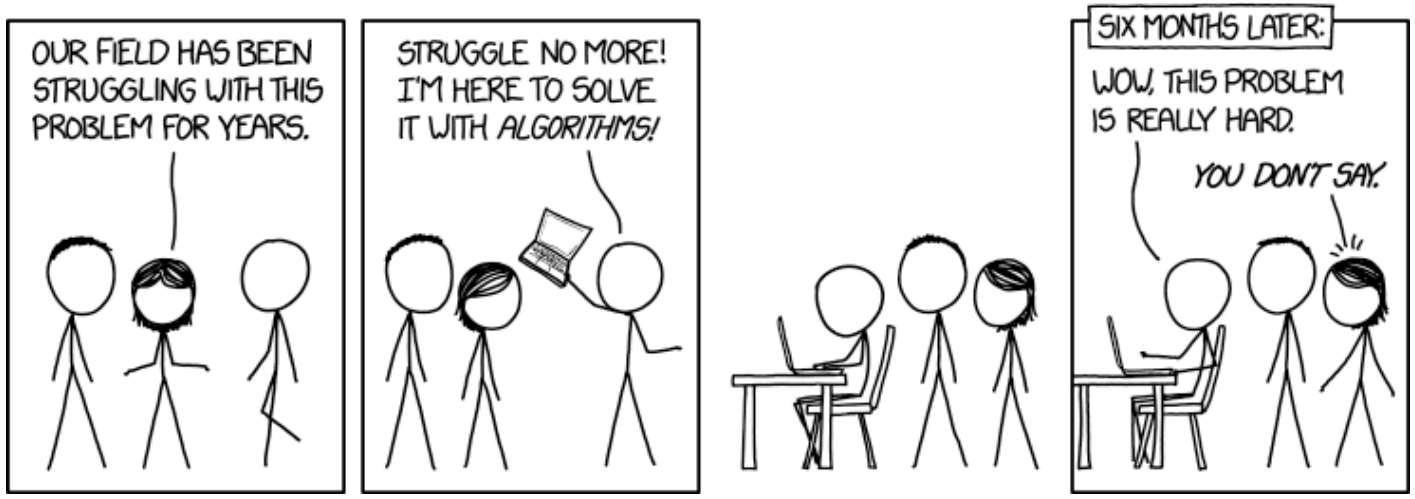
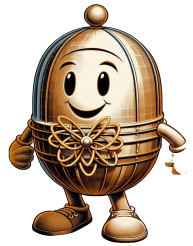
What do we want? III

- Open source
- Easy to install
- Easy to run
- Easy to use output

A quick call-back



https://xkcd.com/1831/



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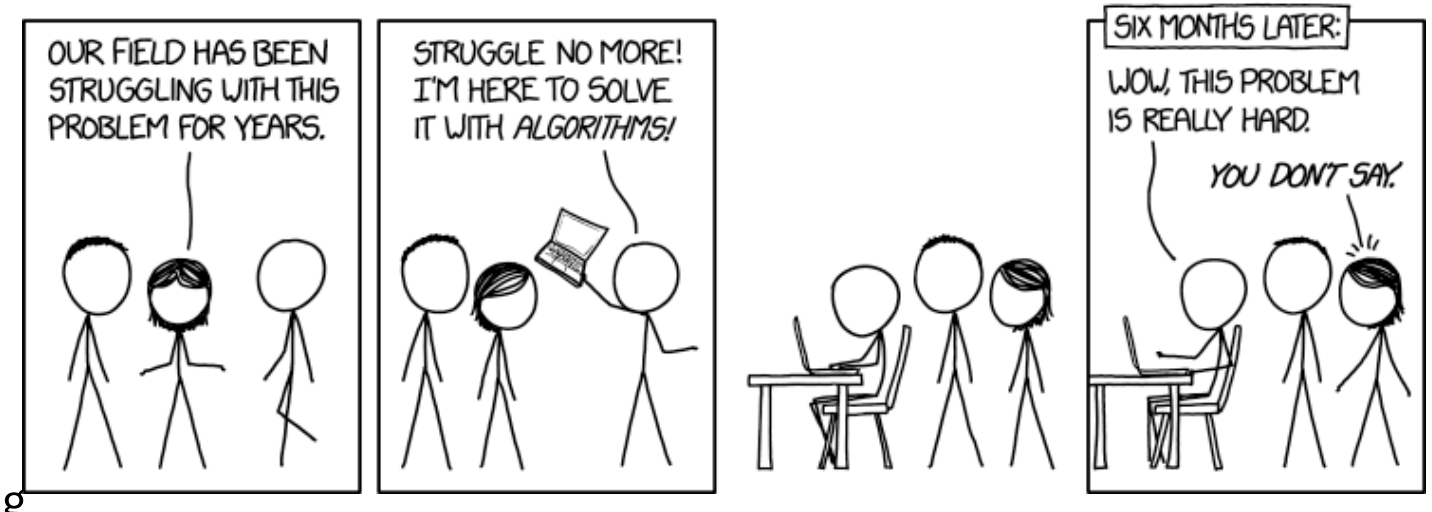
The problems

- Open source
  - Your collaboration will have a problem with this
- Easy to install
  - Your dependencies will have a word with you
- Easy to run
  - It might be easy for you, but your users will NOT agree
- Easy to use output
  - There's always going to be something missing



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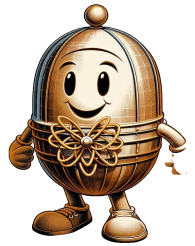

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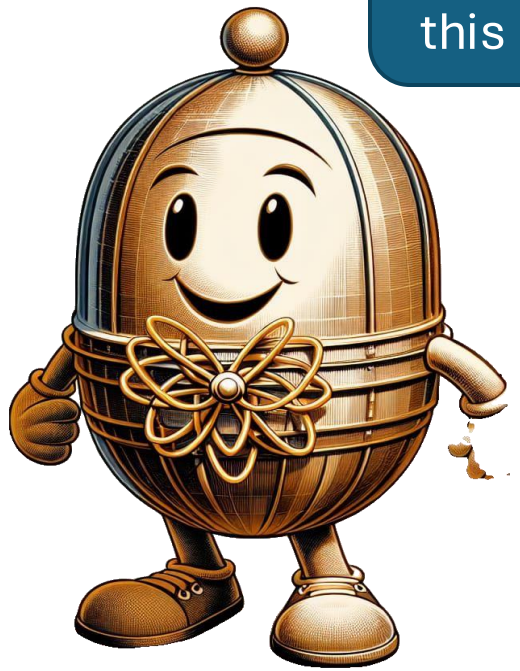
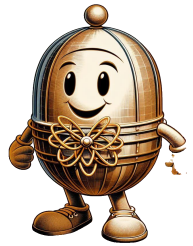
Before you start I

- The most important thing:

Think of a fantastic name and logo

Still need a name for this little guy





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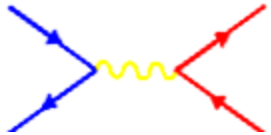
Before you start II

- Don't do everything yourself
  - Use the standard codes
- No matter how good, it has to be usable

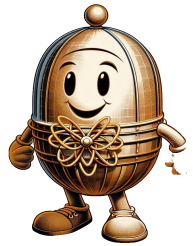


The MadGraph5

PYTHIA 8.3

Let's work with an example

This setup works for most detectors



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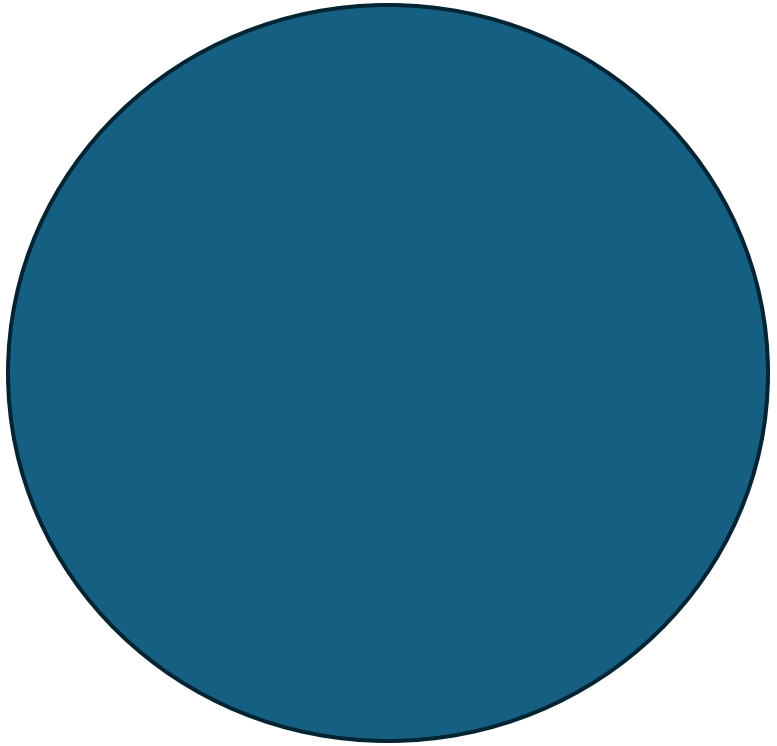
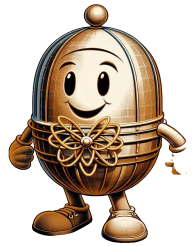
- An atmospheric neutrino detector
- Assume it's spherical
- Filled with water
- 100% PMT coverage on the outer wall



We'll (hopefully) get to that



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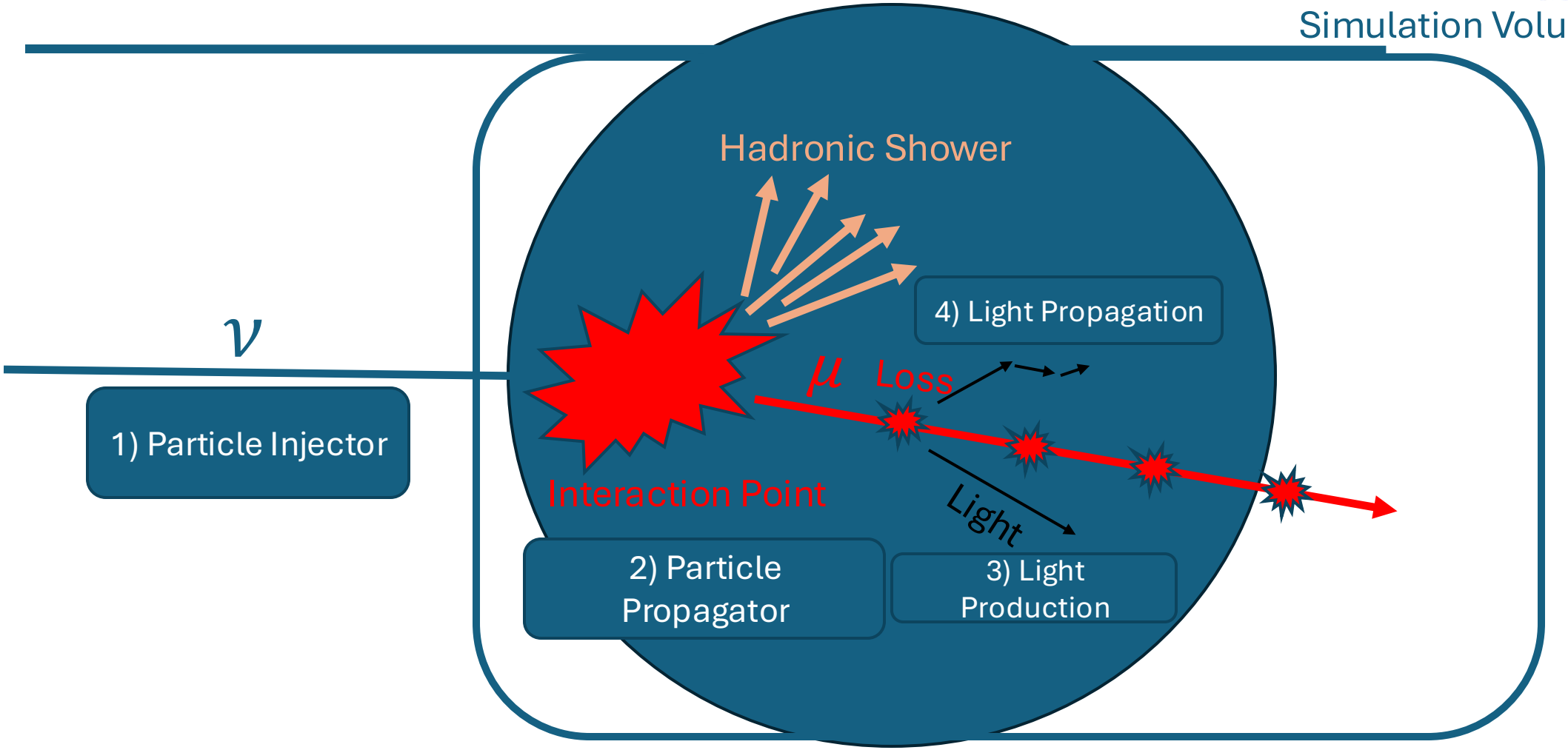
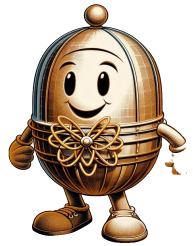
What do we need?





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This scheme works for most

Model → Injection → Propagation → Detector Response → Usable output*

Need an injection model

Need to define how neutrinos interact

How do secondaries produce light

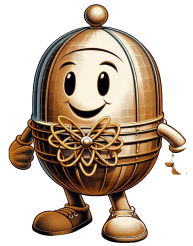
PMTs aren't perfect, clocks may not be in sync, DAQ etc.

No general rule for this*

Setting up an interface will encourage people use your code

This needs to be part of your code

*Use an established format. E.g.HDF5, Parquet, etc.



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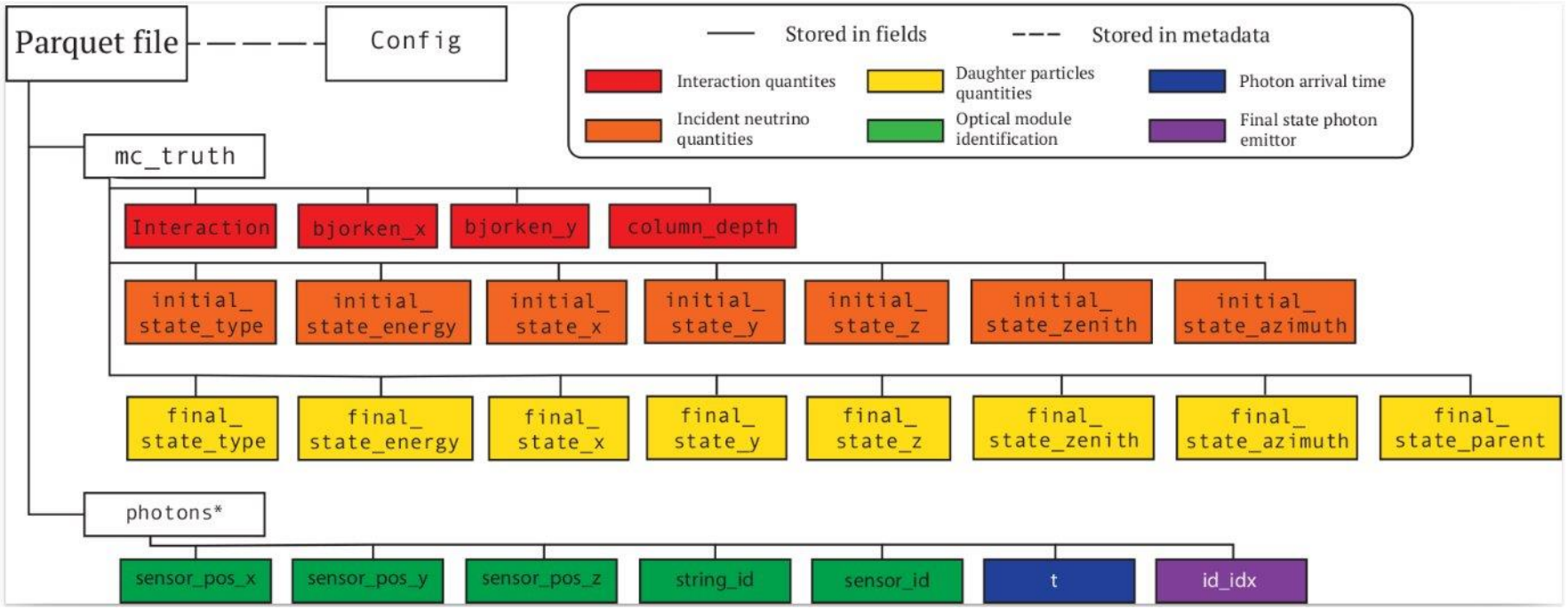
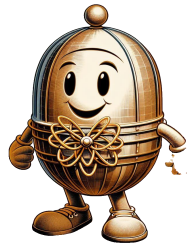
Output example

Example from a neutrino telescope simulation

This only deals with photon hits! Your output will probably be far more complicated





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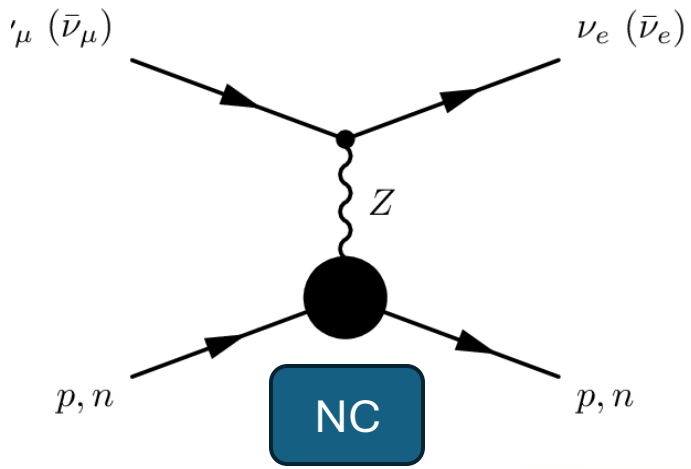
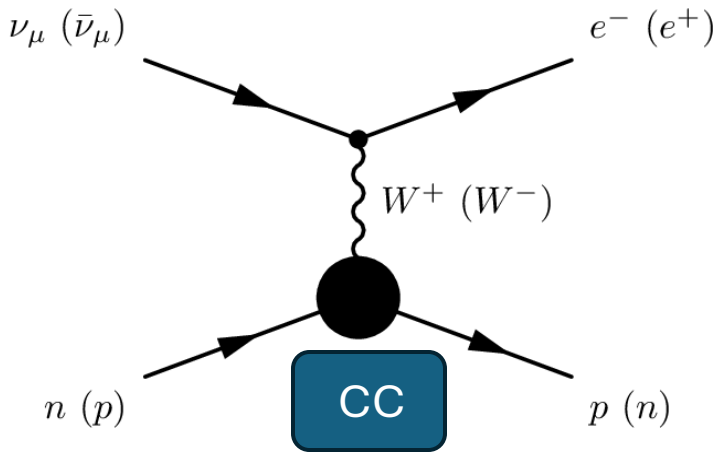
Everyone's busy

Let's define the problem

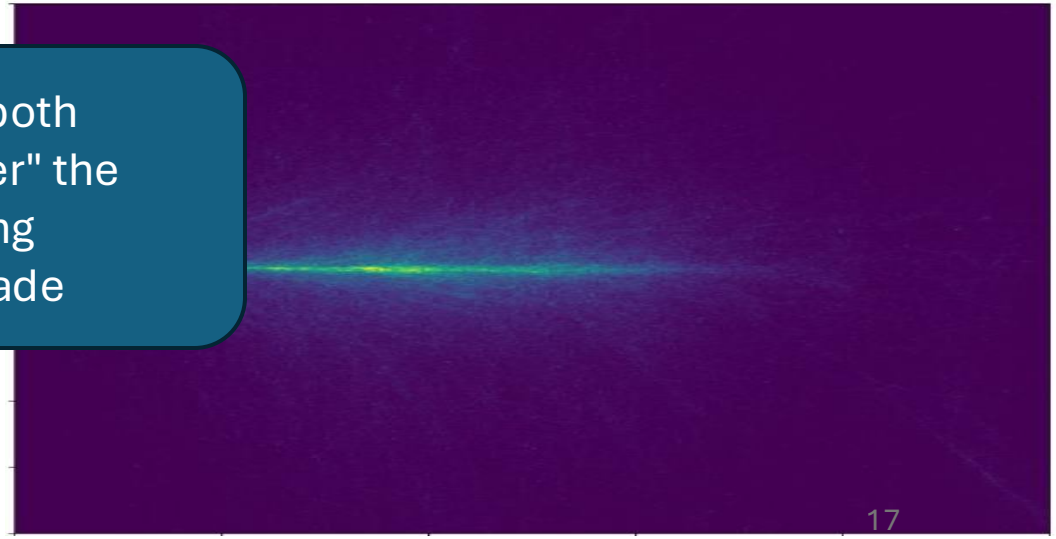
We want to construct an approximate simulation of CC and NC events in a water sphere

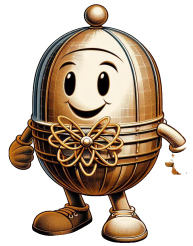
We want to use the different signals to discriminate between electron-neutrino CC events and NC events





At high energies both interactions "shatter" the nucleon creating a hadronic cascade





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Let's get to it

Example time

If the CDM GitHub doesn't work

https://github.com/MeighenBergerS/cdm_detector_example