Finding Particles In MATHUSLA Using Timing Information

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What is a Particle?

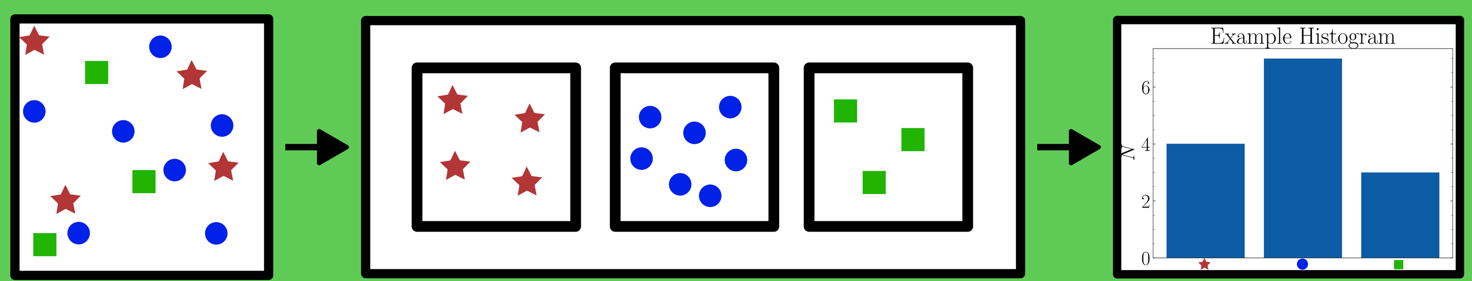
- Particles are the most fundemental building blocks of the universe
- Examples include Protons and Electrons
- Some important properties of particles are their mass and charge

What is MATHUSLA?

- MATHUSLA is a large proposed particle detector
- Our UVic team is currently building a prototype detector
- MATHUSLA is specialized to detect a certain type of particle that is a missing link in current particle physics knowledge

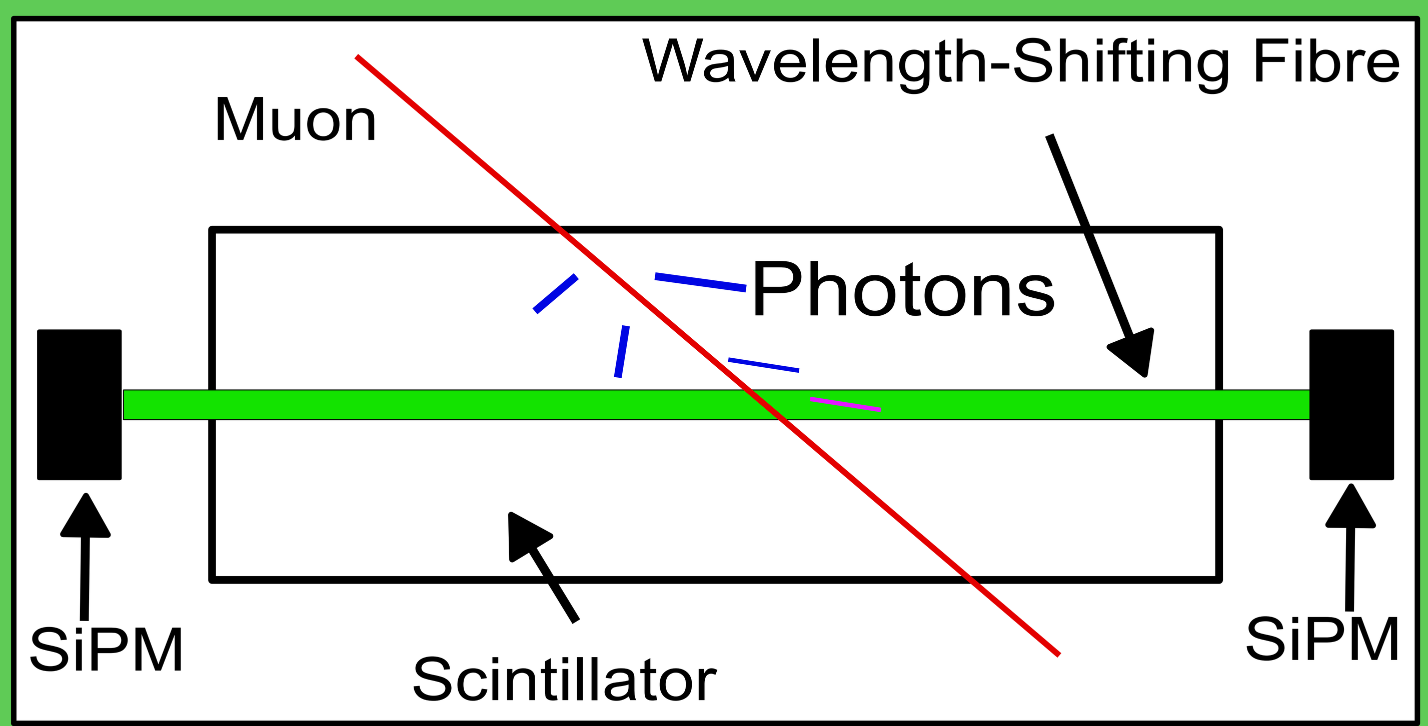
What is Measurement?

- Particles are far to small to see with our eyes
- We need special camera-like devices to observe them
- Lots of particle physics measurements are more related to counting compared to traditional measurements (i.e. length with a ruler)
- Particles are binned by type, then the bin sizes are compared



Detector Technology

- Scintillating materials release photons (light) when charged particles pass through them
- Some photons are absorbed by a wavelength shifting fibre (WSF)
- Light travels down the WSF to a Silicon Photomultiplier (SiPM)
- The SiPM converts the light signal to an electric current
- This current is recorded by our computer along with the time it was recieved (very important)
- The recorded information is a hit and a collection of hits is an event



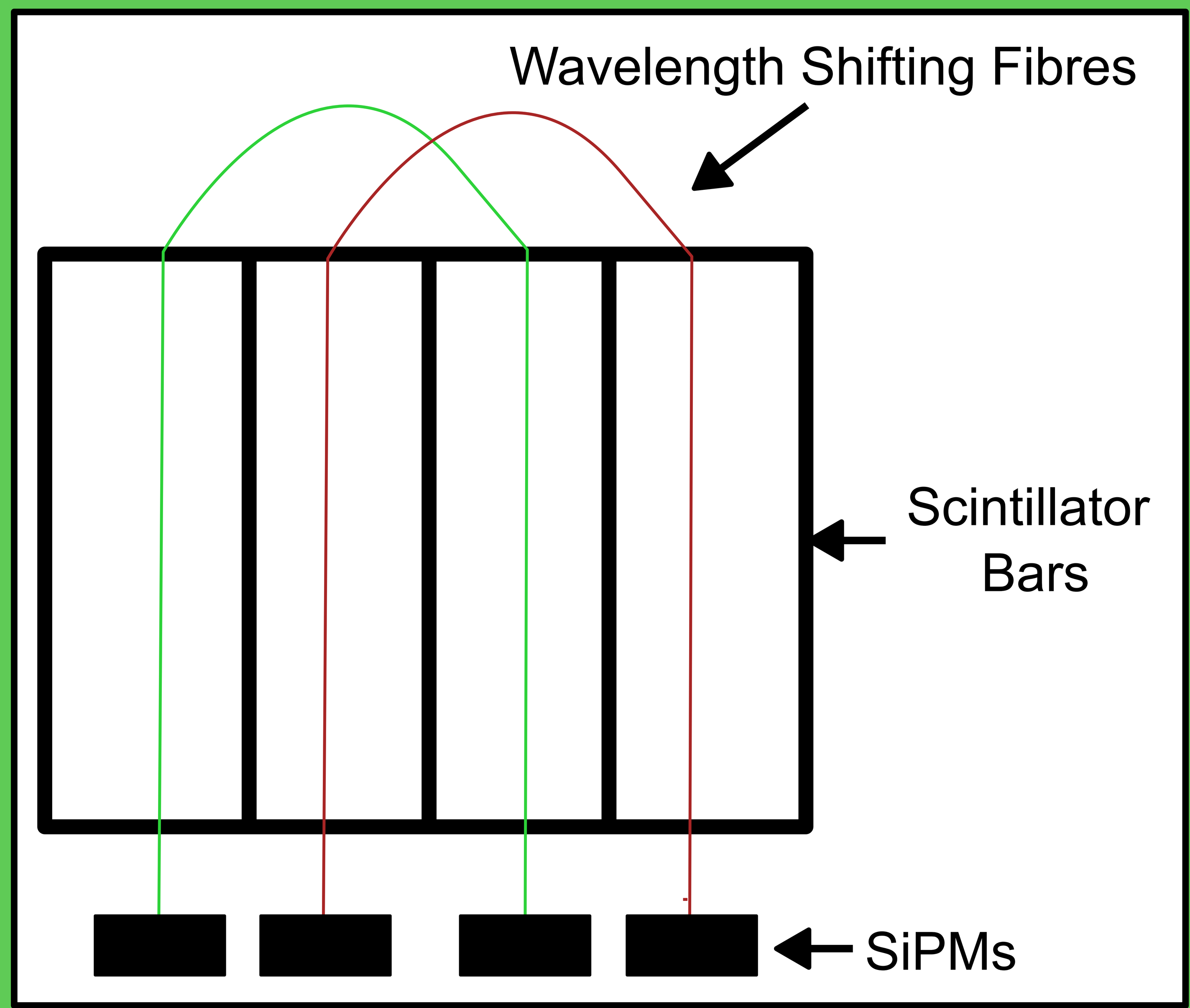
Locating in 1D

- Three pieces of information are required to measure the particle's location down WSF
  - Speed of light in the WSF (v)
  - The time between SiPM measurements (Δt)
  - The total length of the WSF (L)
- Displacement from one end calculated using constant velocity motion

$$x = \frac{1}{2}(L - v\Delta t)$$

Locating in 2D

- For our design, two bars share a WSF
- Red or Green path identified by which SiPM pair fires
- Use same technique from above to locate path displacement
- Note that 4 bars was used as an example, but the true layers have between 12 and 16 bars

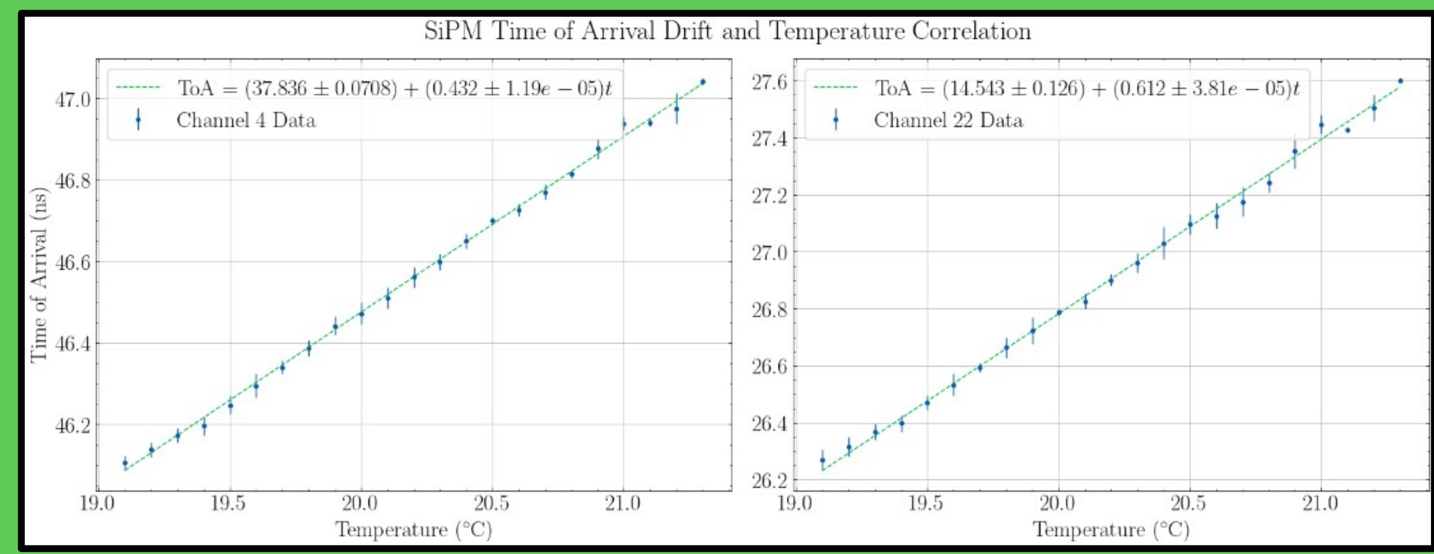


Locating in 3D

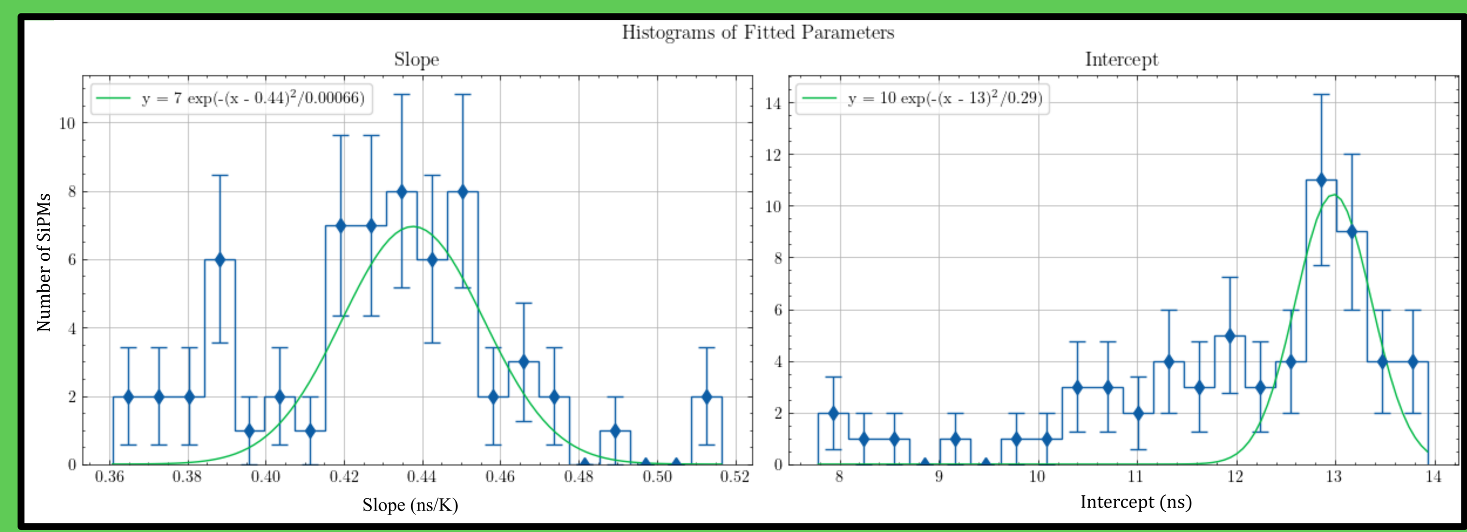
- The detector consists of four 2D layers shown above
- The detector has 64 SiPM inputs
- By matching hits in different layers we can reconstruct particle trajectories

Temperature Dependence of Data

- SiPMs are sensitive to ambient temperature
- Time of Arrival measurements were made with a laser pulser at a fixed position
- Plotting the mean Time of Arrival against the ambient temperature during the run reveals a linear relationship
- The fit parameters are dependent on the SiPM (slope of the line)



- Next, we characterize how the temperature correction varies for all 64 SiPM inputs on the array
- The plot below is a histogram of the slope and intercept fitting parameters for each channel
- The uncertainties on each bin are statistical symmetric Poisson uncertainties
- The overlayed curve shows the data is not normally distributed



Key Take Aways

- Particles are the fundemental building blocks of the universe
- We need to find creative ways to measure them that don't rely on sight
- With very limited information we can still locate charged particles
- The effects of temperature are non-neglegible, but manageable

Acknowledgements

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