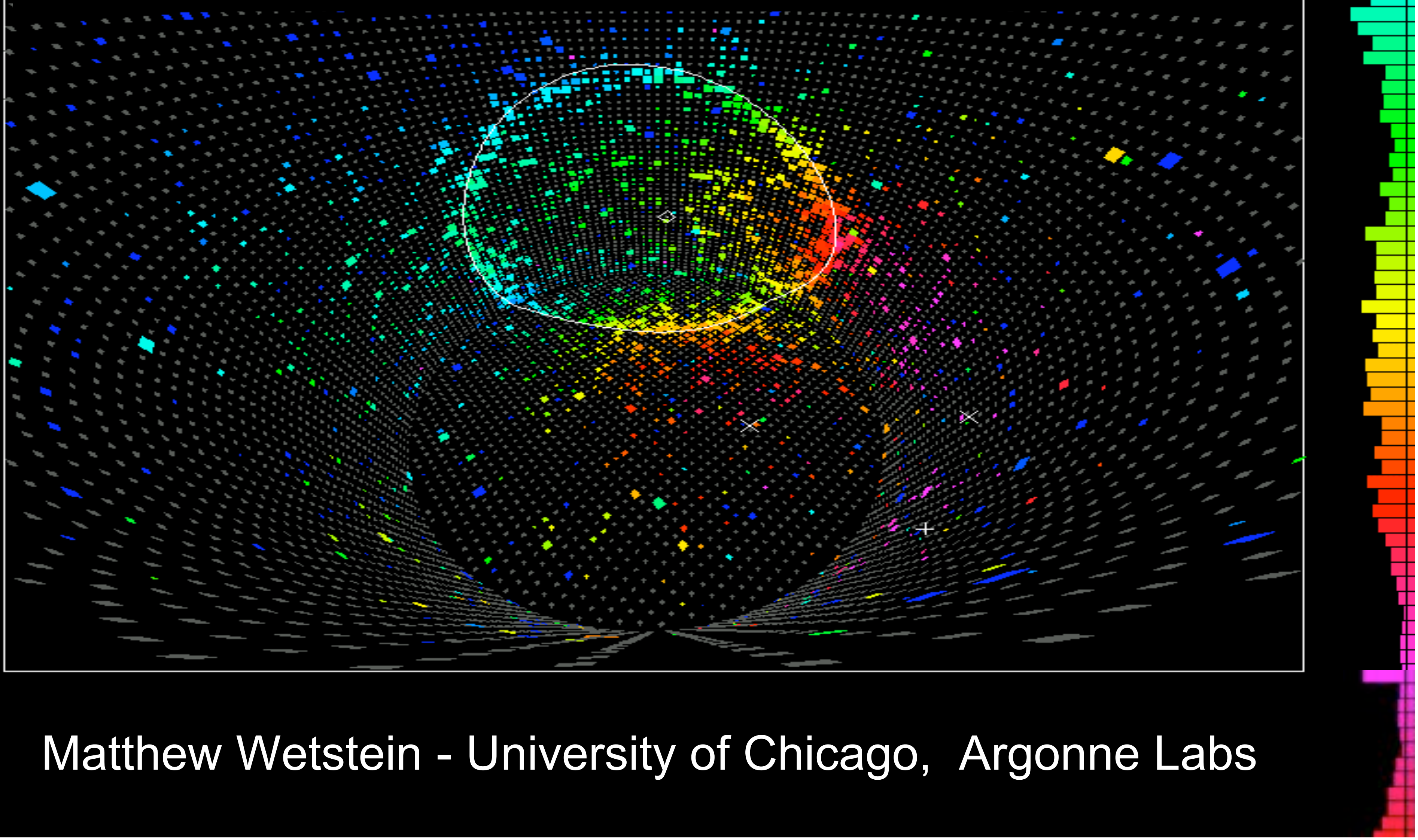
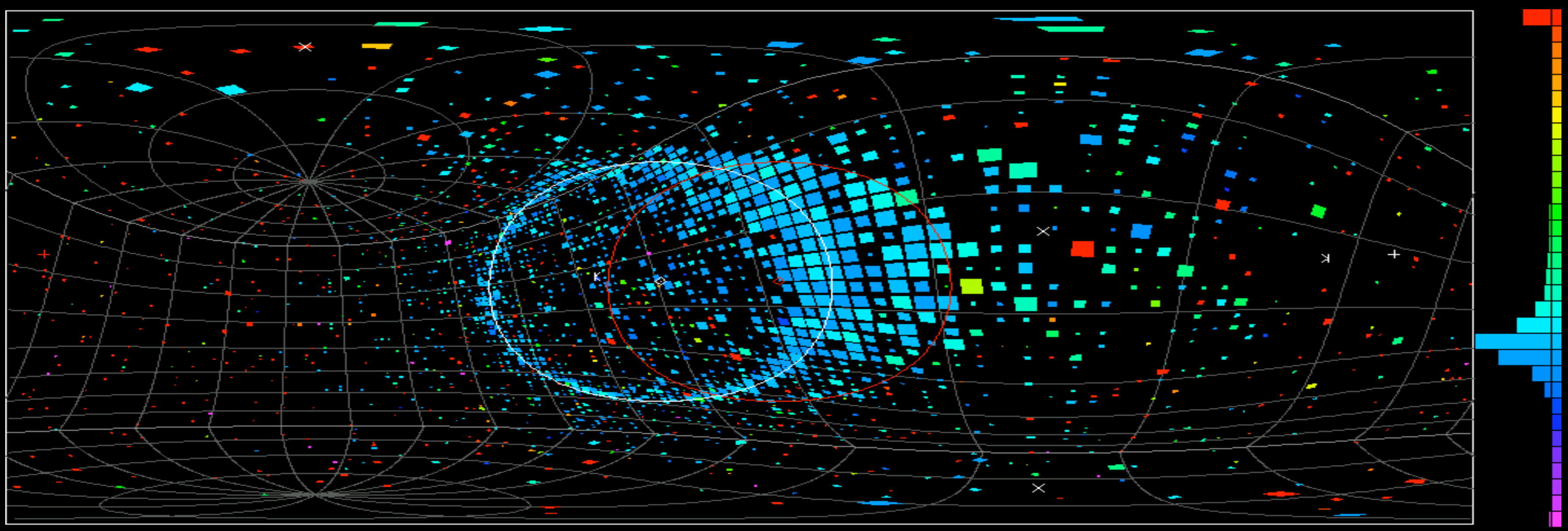
Time of Flight Simulations in Water Cherenkov Detectors



Matthew Wetstein - University of Chicago, Argonne Labs

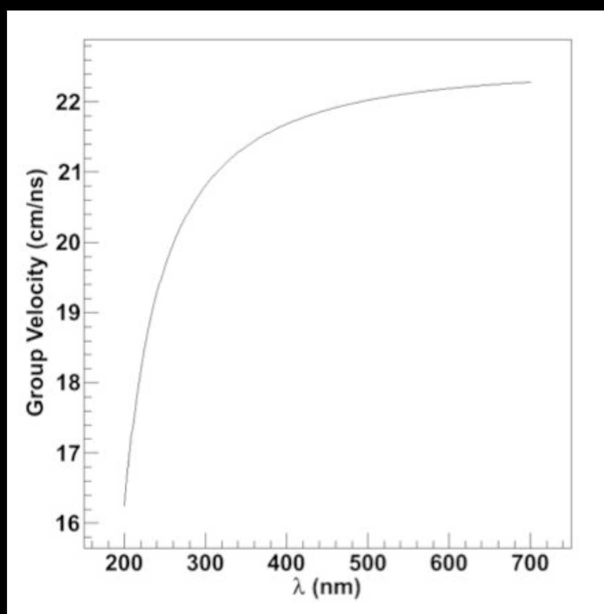
Goals of This Talk

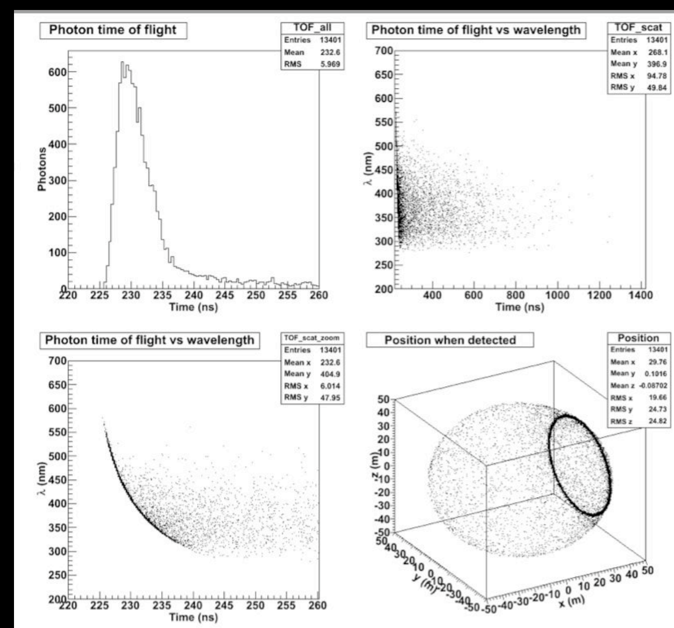
- Discuss some of the skills and capabilities we've developed for simulations of WC detectors at DUSEL.
- Look at the potential for using precision timing information to improve background rejection in large WC detectors.



What We Have I

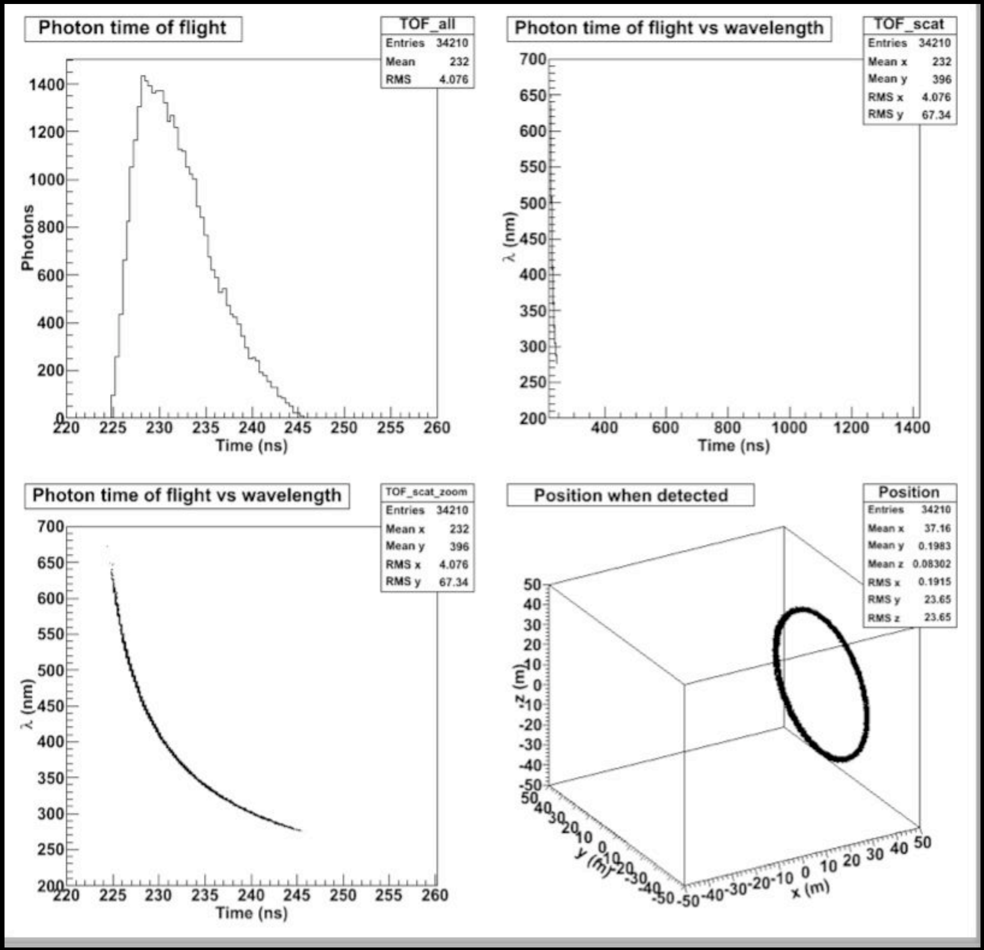
- Parameterized model for propagation of optical photons in water, developed by John Felde (UC Davis). Models frequency dependant dispersion, scattering and absorbtion of optical photons in a spherical water detector.





What We Have I

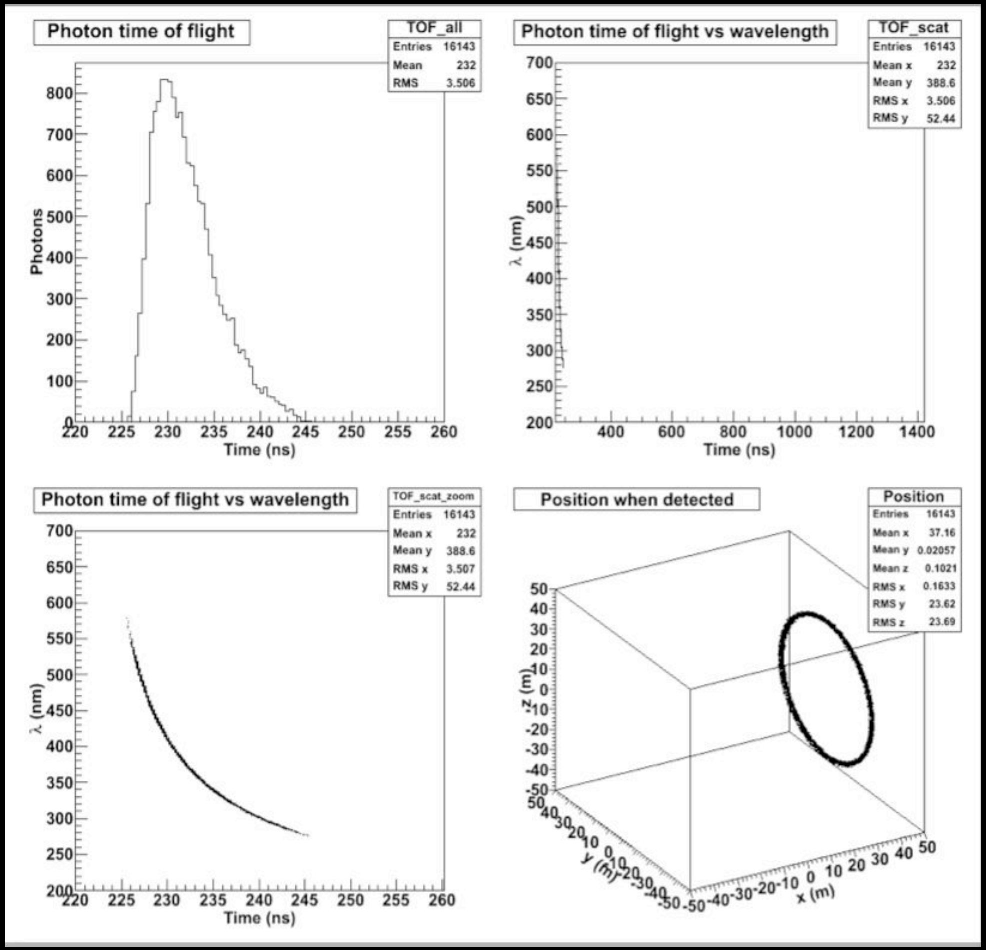
- Dispersion



Courtesy of John Felde (UC Davis)

What We Have I

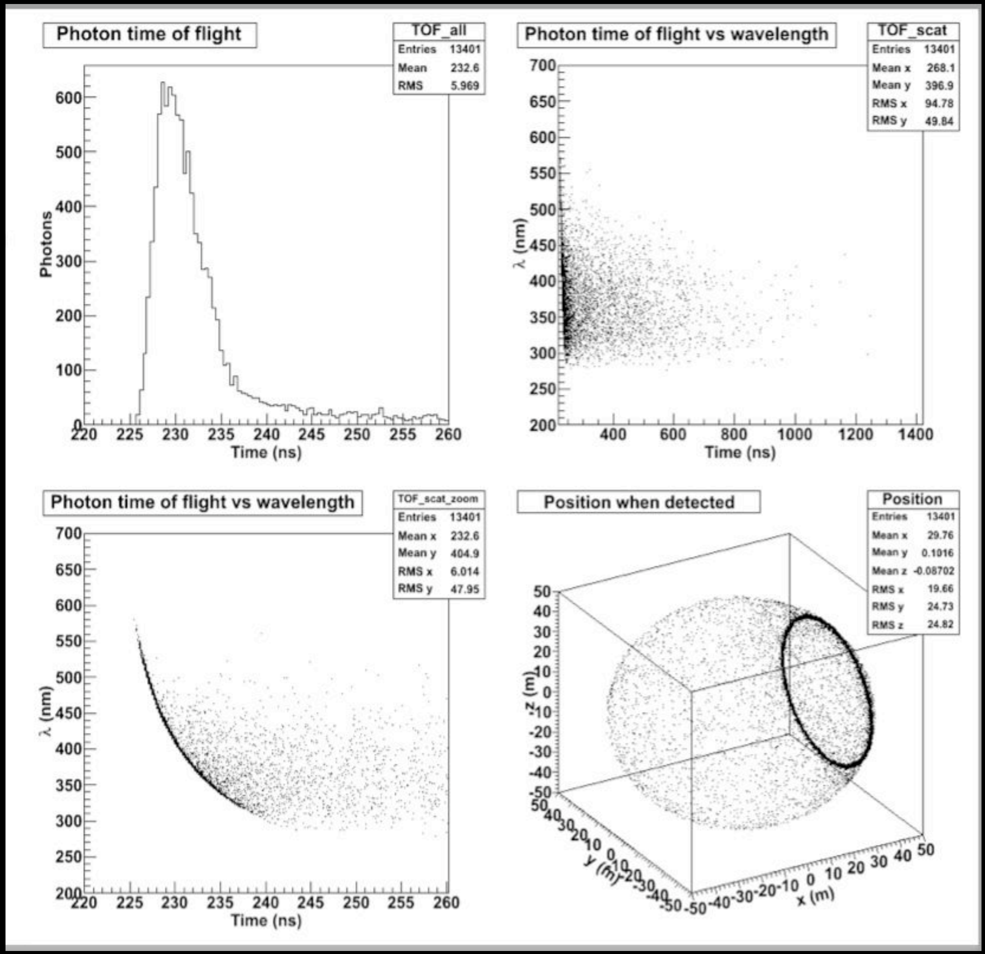
- Dispersion
- Absorption



Courtesy of John Felde (UC Davis)

What We Have I

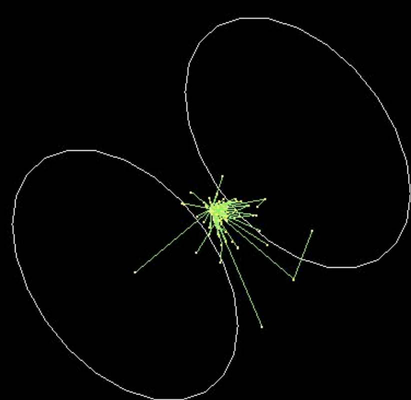
- Dispersion
- Absorption
- Scattering

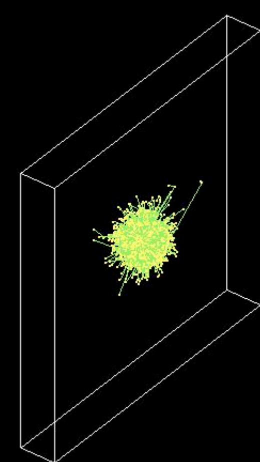


Courtesy of John Felde (UC Davis)

What We Have II

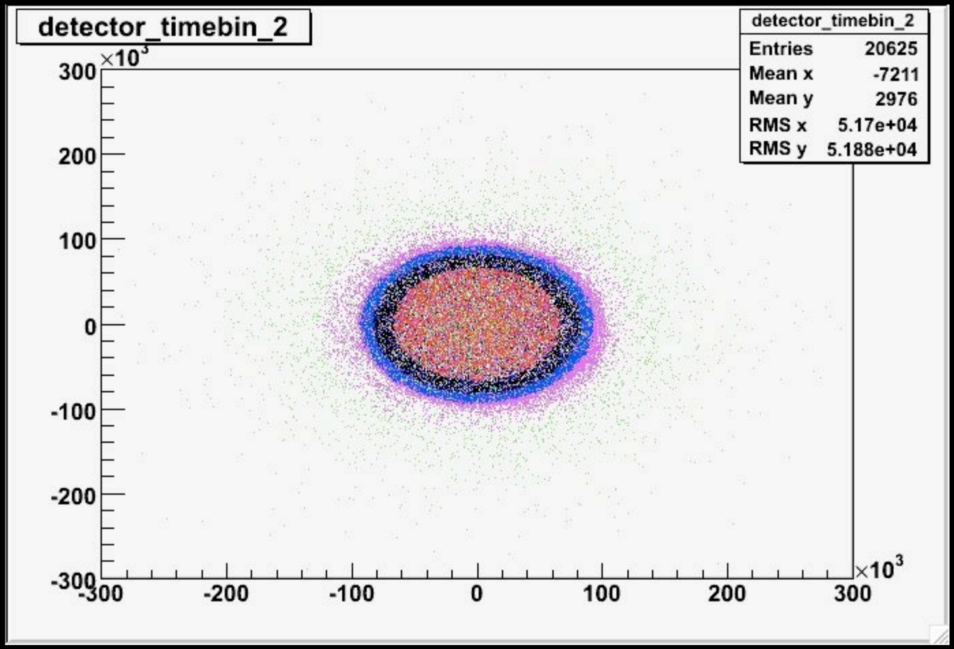
- A basic GEANT-based WC model for propagating charged particles in water.
- Simulates showering, ionization, and …, as well as optical physics
- We can turn these effects on and off and vary detector geometry and properties.



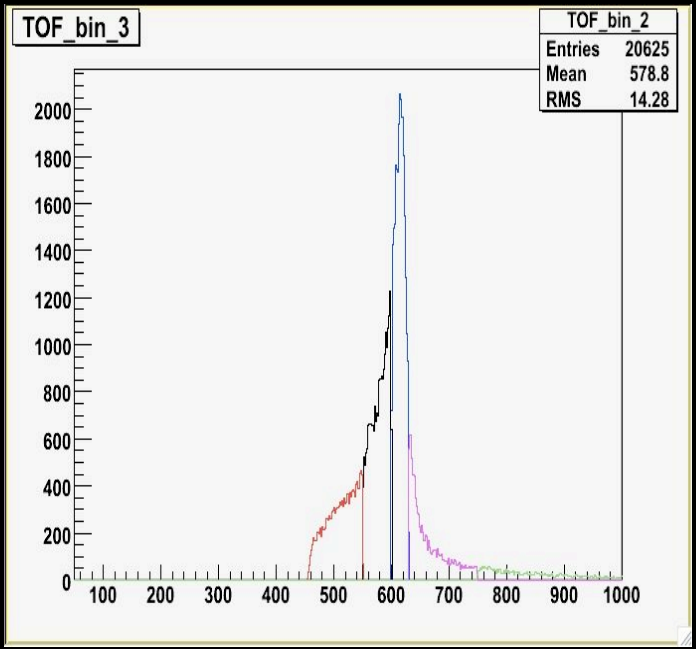


What We Have II

- We can extract initial and final states of the photons that hit our detector and make interesting plots…



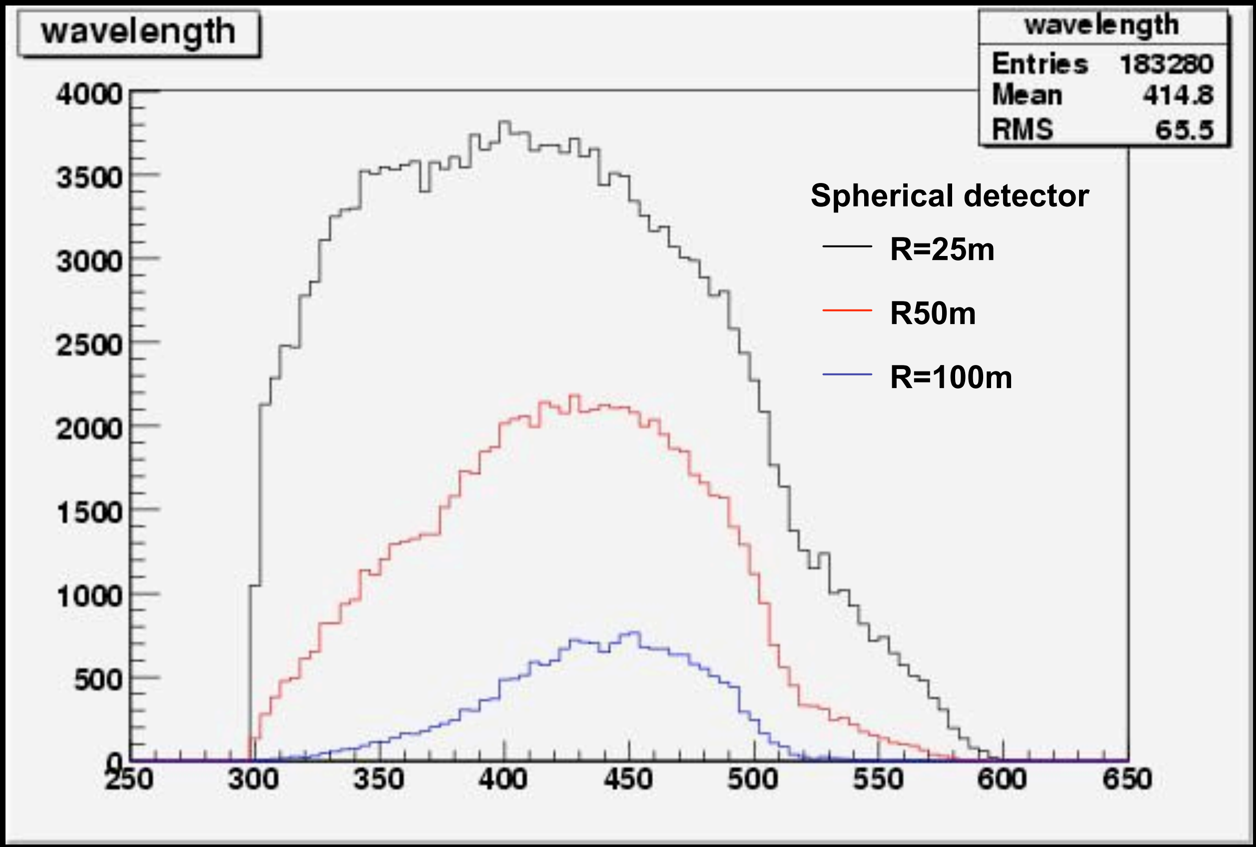
Cherenkov Ring from a 1 GeV Gamma



TOF for a 1 GeV Gamma

("flat wall" detector)

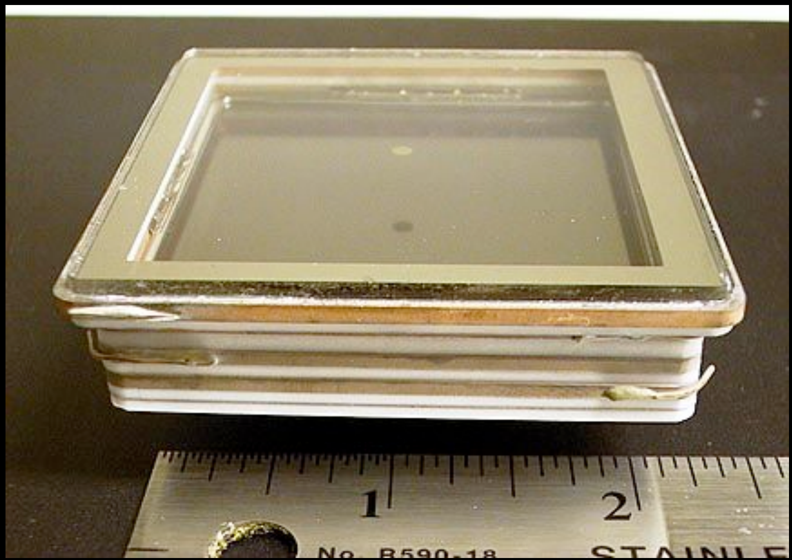
What We Have II

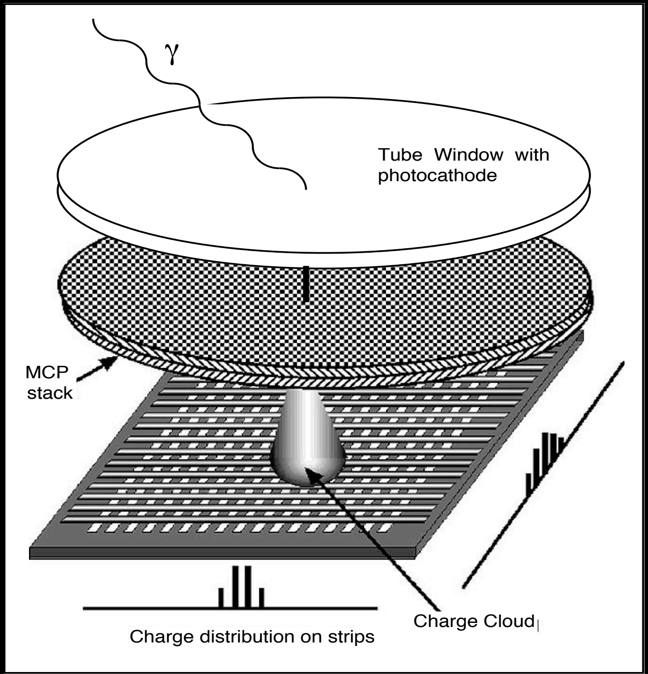


Wavelengths of Cherenkov photons from a 200 MeV Muon

Fast Timing

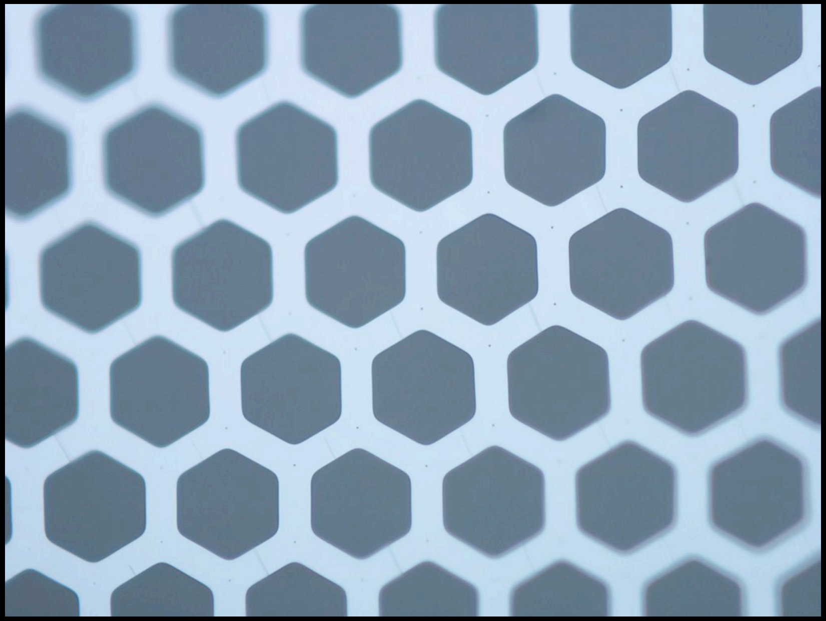
- New Detector R&D Project
  - Collaboration between U of Chicago, 4 Divisions at Argonne, and several other Universities
  - Goal: provide cheap, large-area photo-detectors, with precision time resolution [O(1)-O(100) psec, depending on the application].
- Based on Micro Channel Plate (MCP) technology





Fast Timing

- MCP's are traditionally expensive. Dynode pore-structures micro-machined out of ceramics.
- Our strategy:
  - Use cheap, batch methods to produce pore-structure (glass filters, Anodized Aluminum Oxide)
  - Use ALD to coat the pores with the appropriate semi-conductor materials.
  - Build into large-area plates with fast, custom front-end electronics.

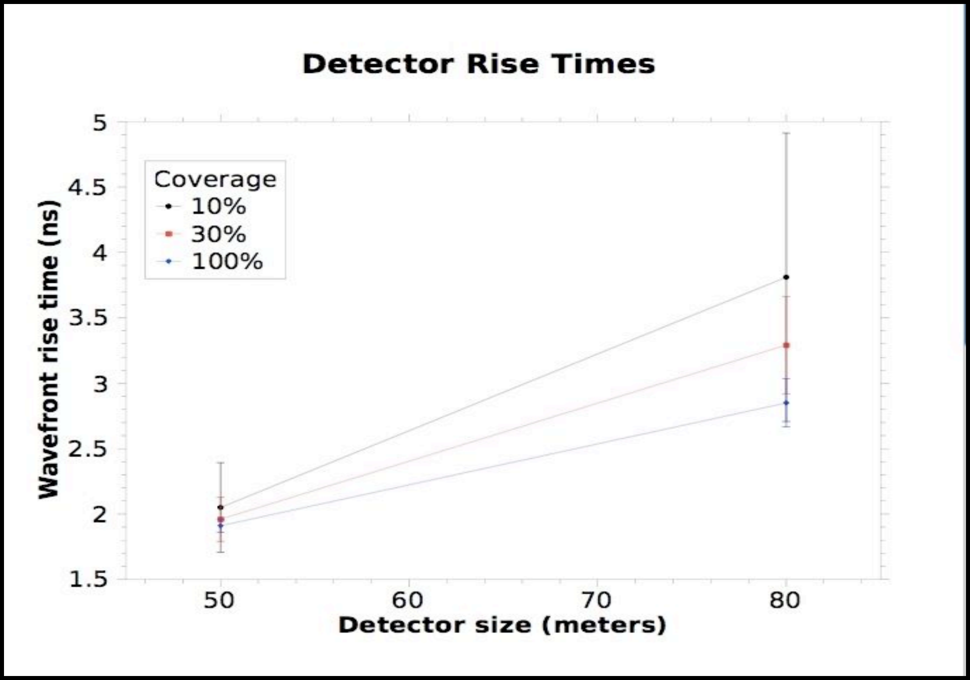


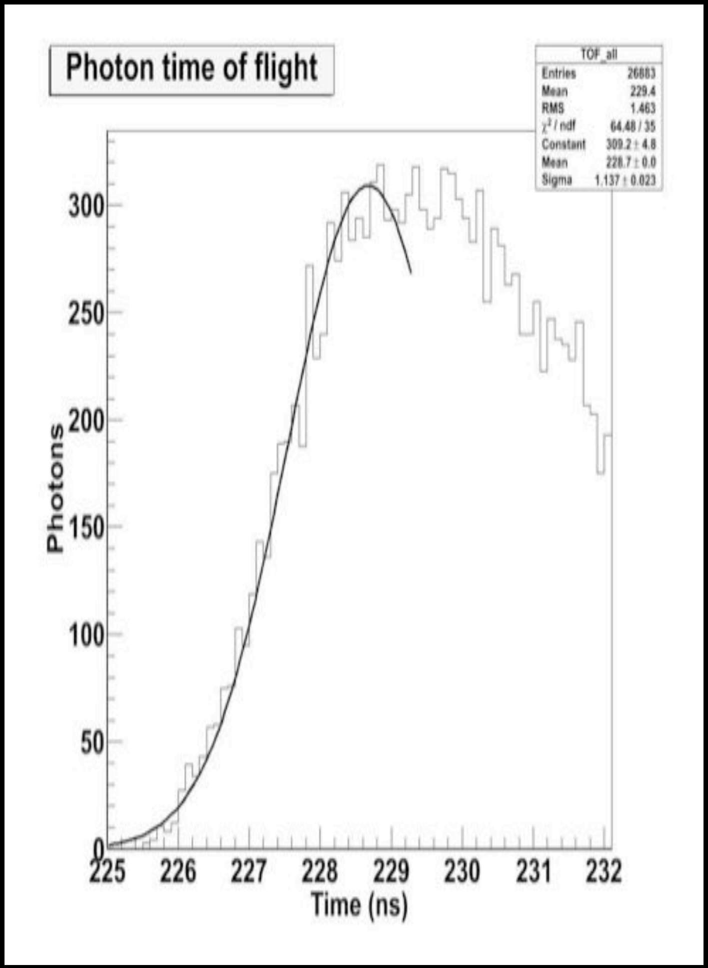
Fast Timing

- One goal is to lower the cost per unit area of photo detection
- But, even more exciting: what are the physics gains?
  - Better vertexing? π_0 background reduction?
  - 100% coverage?

Fast Timing

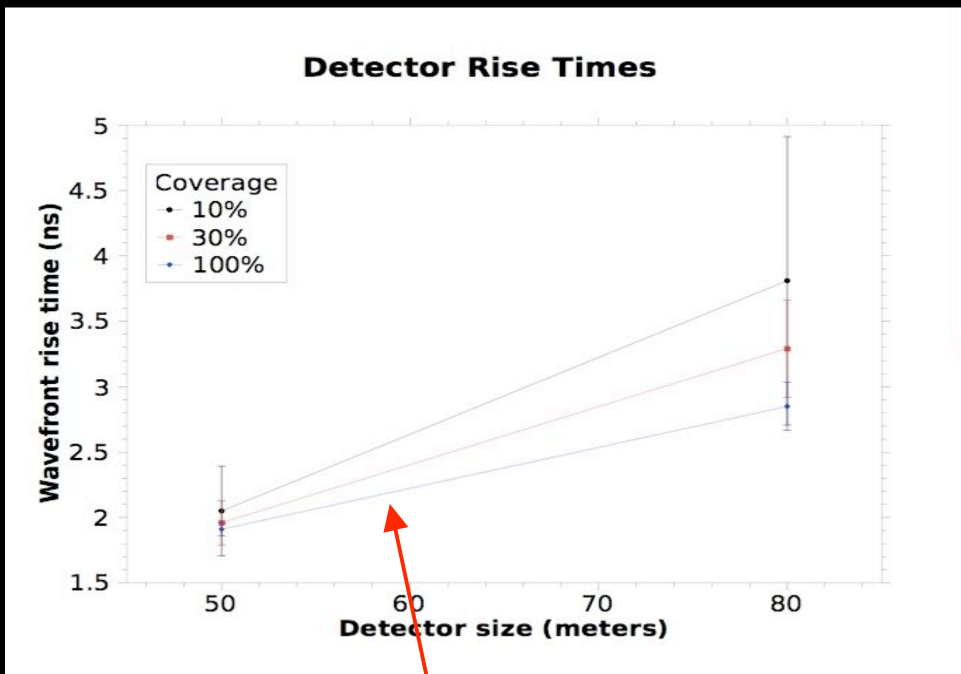
- A closer look at the dispersion of light in water…

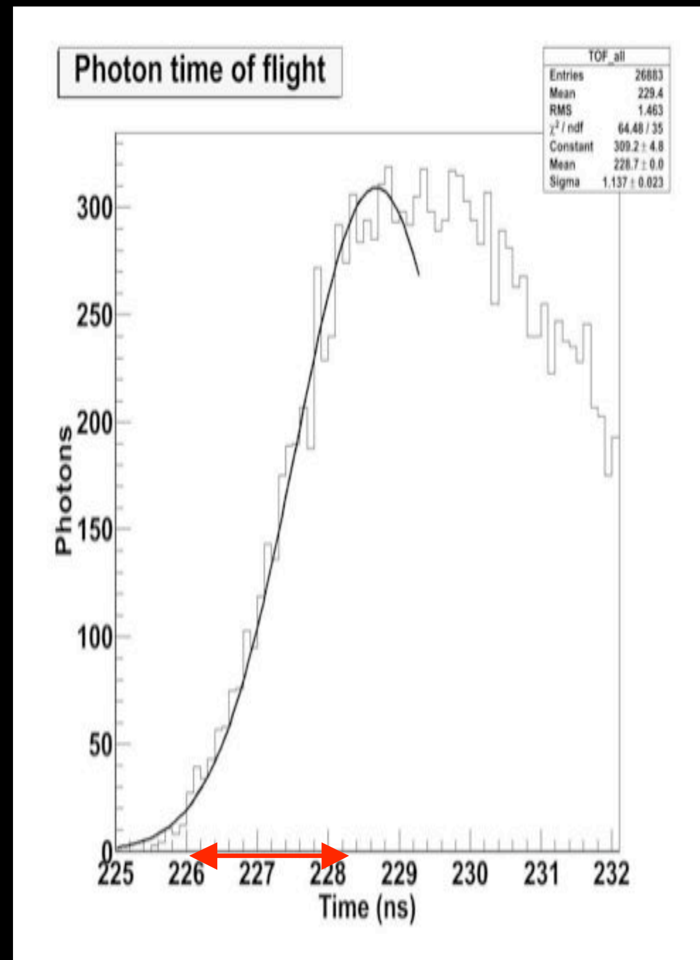




Fast Timing

- A closer look at the dispersion of light in water…





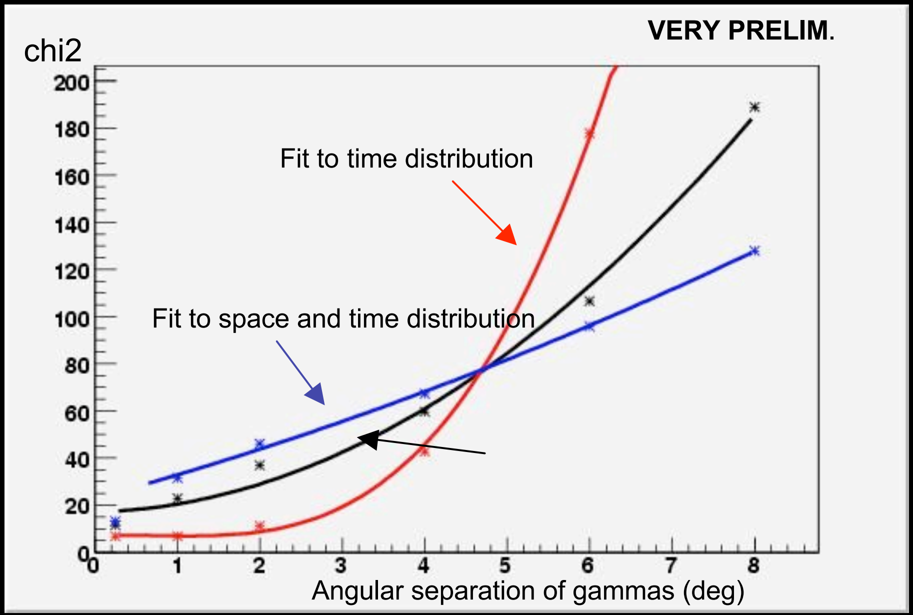
Rise times are comparable to typical PMT time resolution (2.2 nsec)! This means a typical WC cannot sample enough points on the leading edge to resolve the arrival time…

Fast Timing

- Toy models are good for directly studying dispersion effects…
- GEANT is good at simulating a complete shower, along with Cherenkov
- We can construct a simple model.
    - Compare events with two 500 MeV gammas, separated by a small angle, to a set of gammas with no angular separation.
    - Determine chi-sq per degree freedom as a function of angular separation, comparing
        - The spatial distribution only
        - The time distribution only
        - The distribution of collected photons in both time and space.
    - Do we gain additional information by including the timing?

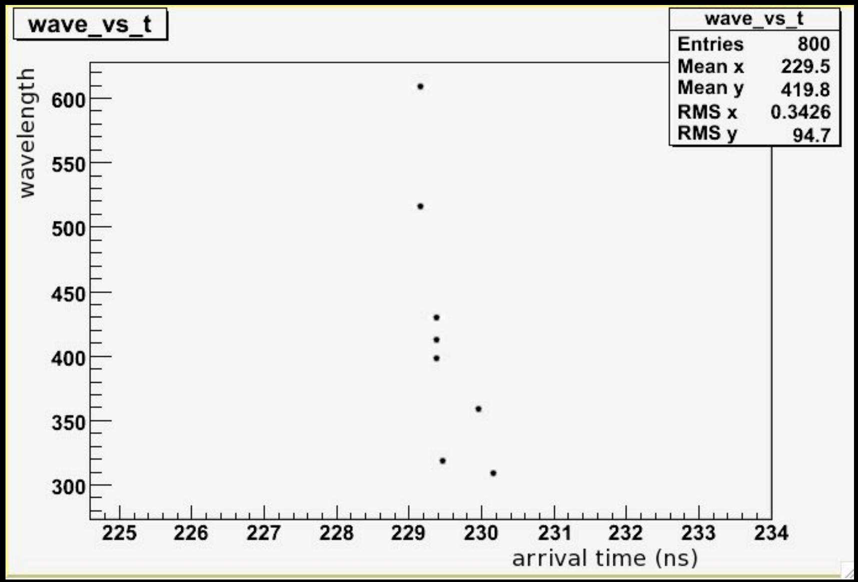
Fast Timing

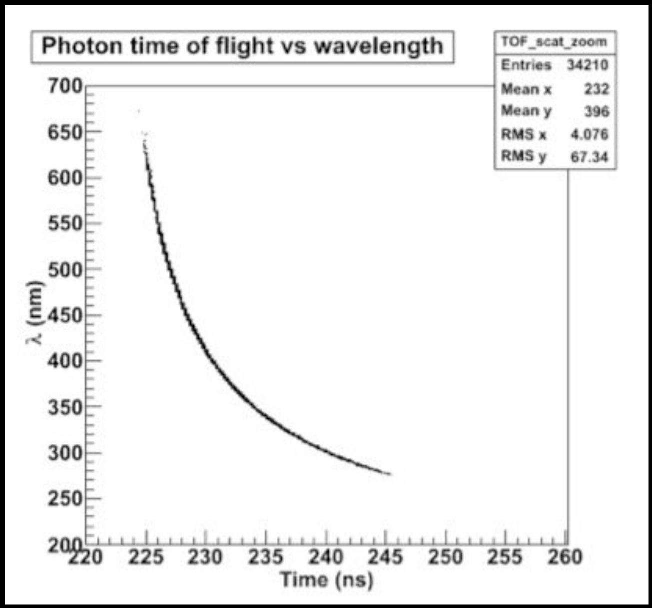
- Shoot 200, 500MeV double-gamma events normal to the center of a wall. Histogram positions and arrival times of the photons that make it.
- Compare with sets 200 events generated with two 500 MeV gammas with increasing angular separation.
- For each of these sets, perform a chi2 comparison between
  - The spatial distribution of hits
  - The distribution of arrival times
  - Both space and time information
- Does the timing information increase our sensitivity to angular separation.



Fast Timing

- Group velocity versus wavelength in GEANT…
- Problems with how GEANT approximates dn/dlogE





Improvements to Timing Study

- Use a cone finding Algorithm.
- Put granularity into the detector. What happens then?
- Put frequency dependence to the “detector response”
- Choose a more realistic detector geometry
- What about when the nominal signal is not normal to the detector surface?
- Maybe two 500 MeV pions separated by 5d can’t fake a 1GeV pion, but what about a 1.2 GeV pion?
- Need to do a weighted average of angular resolution integrated over the distribution of all possible pi0 decays in order to determine improvements to background rejection.
- Dispersion model in GEANT is not sufficient

Future Prospects

- There are reasons to believe that better time resolution can improve background rejection in WC detectors.
    - Rise time of Cherenkov light hitting the detector is smaller than the typical time-resolution of a PMT.
    - Not having access to fast-timing technology, certain questions did not need to be asked
- We now have some tools to answer this question
- Either way, we've taken some modest steps in developing skills that will be helpful in answering more general WC simulation questions.