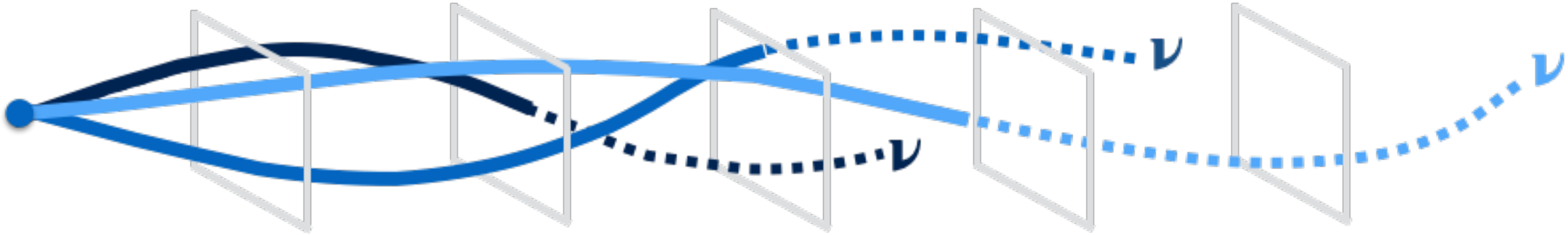


Precision Timing and Synchronization: Intensity Frontier needs/challenges

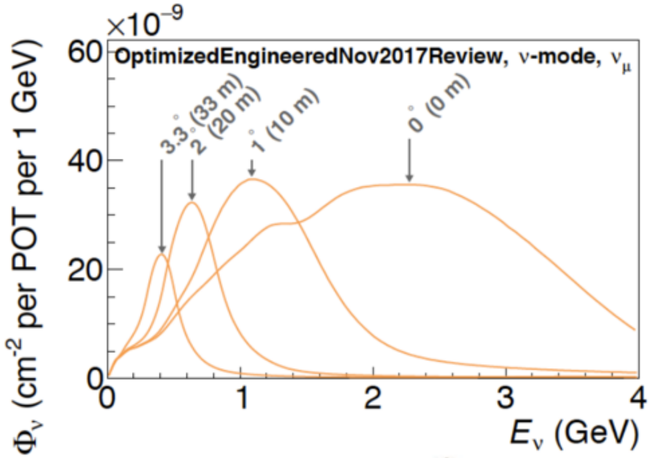
Jonathan Eisch and Matthew Wetstein
Iowa State University

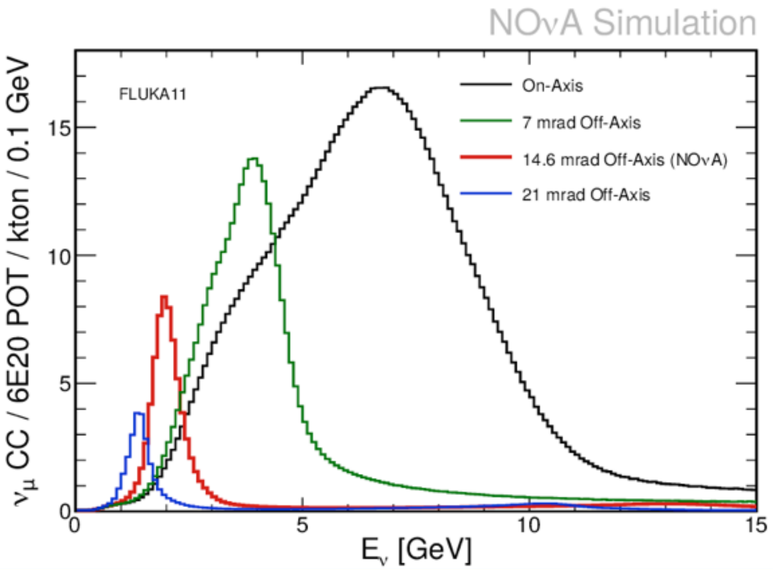
DOE Basic Research Needs Study
December 3, 2019

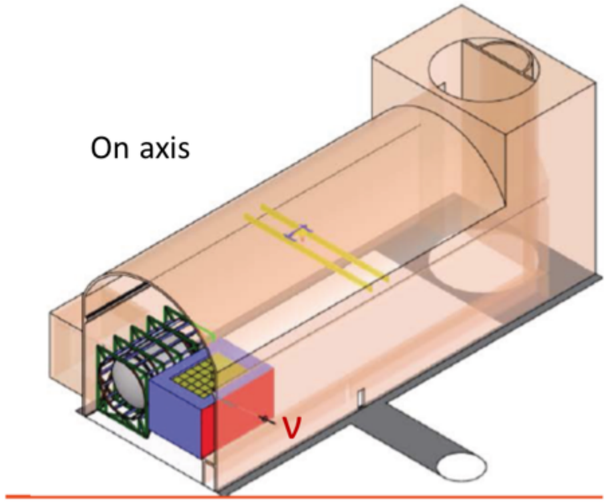
Motivation: Sub-selecting neutrinos

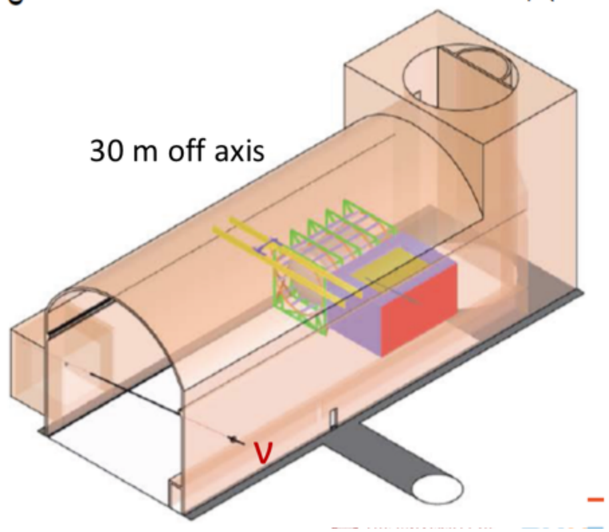
- The DUNE near detector will be able to slide off axis, to sample different energies from the neutrino beam.
- The NOvA far detector was built off axis to optimize the neutrino energy spectrum at the cost of flux.

Slide from E. Blucher, Sep 2019 DUNE collab meeting



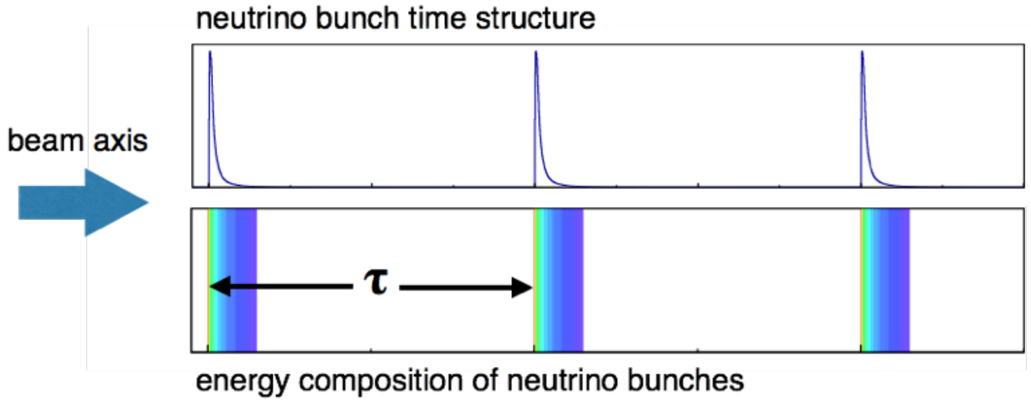


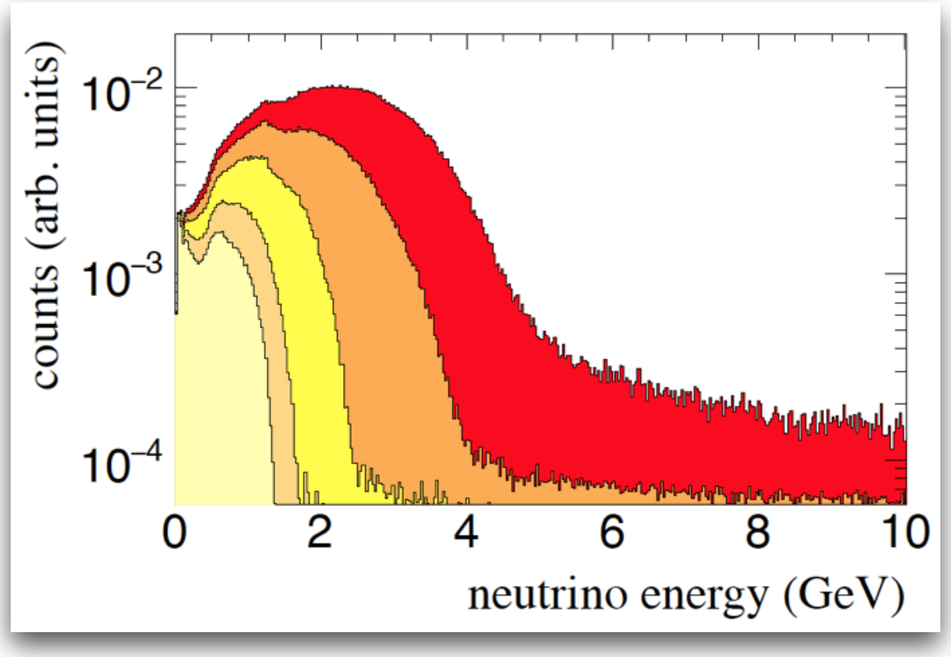




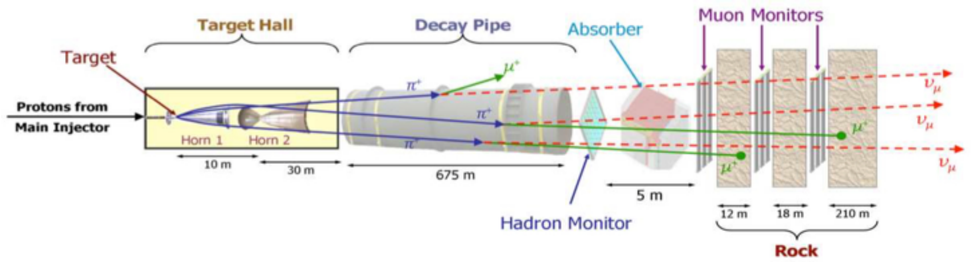
Thoughts on Timing

- These thoughts based on:
- Energy and Flavor Discrimination Using Precision Time Structure in On-Axis Neutrino Beams
  - PHYS REV D 100, 032008 (2019)
  - https://arxiv.org/abs/1904.01611
- Workshop on Precision Time Structure in On-Axis Neutrino Beams (Fermilab Nov. 2-3)
  - https://indico.fnal.gov/event/21409/



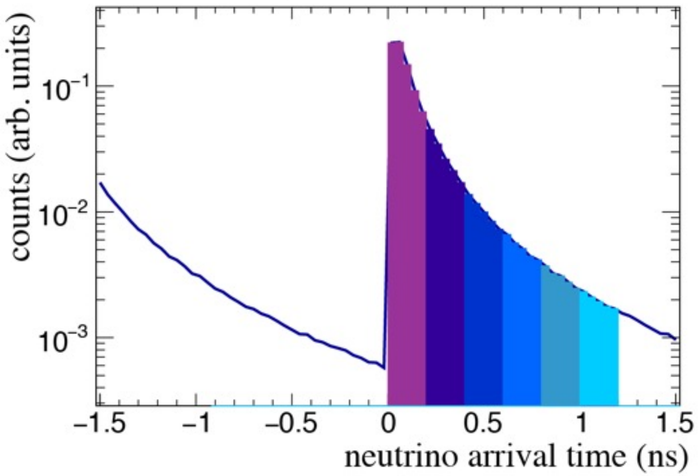


Basic Timing Concept

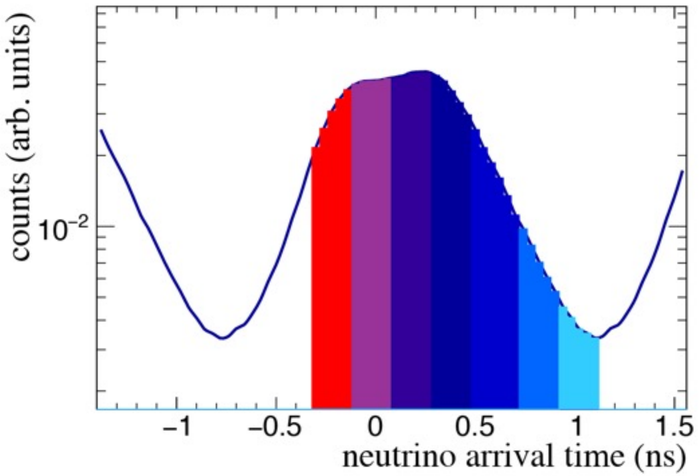


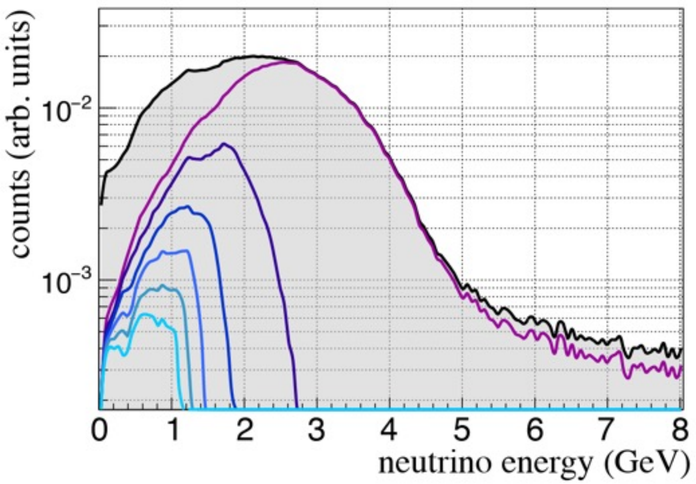
- Precision timing can be used to measure the arrival time of neutrinos with respect to the rest of the bunch
- Later neutrinos tend to have lower energies due to the correlation between neutrino energy and the velocity of the parent hadron
- This allows one to select different flux spectra based on timing
- All of these fluxes co-exist within a single on-axis detector

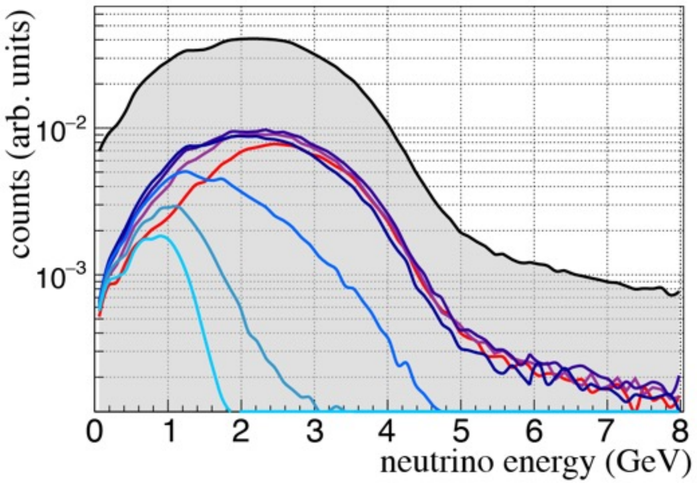
All protons instantaneous (unrealistic)



Smeared by 270ps bunch + 100ps detector



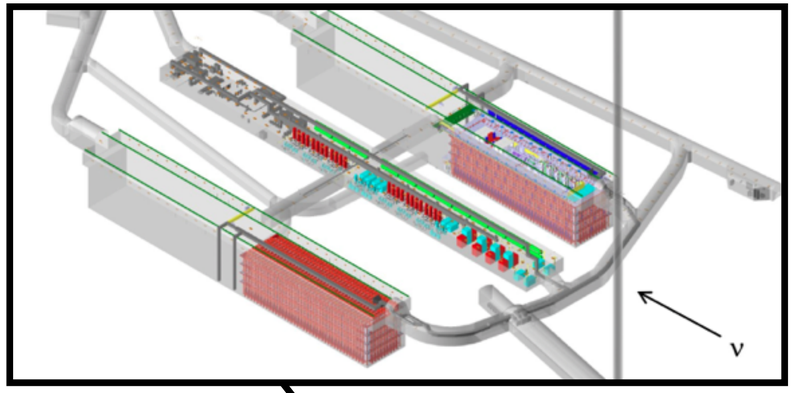


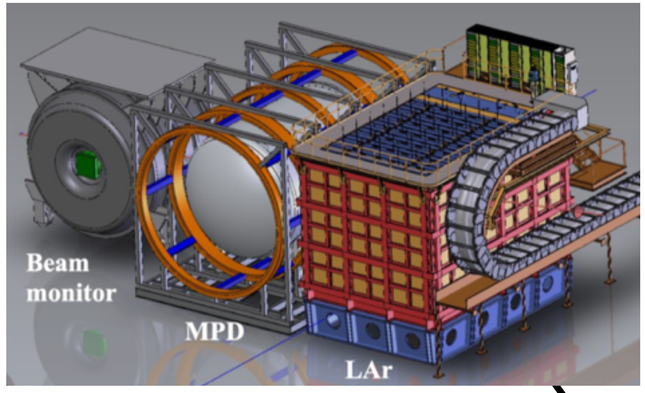


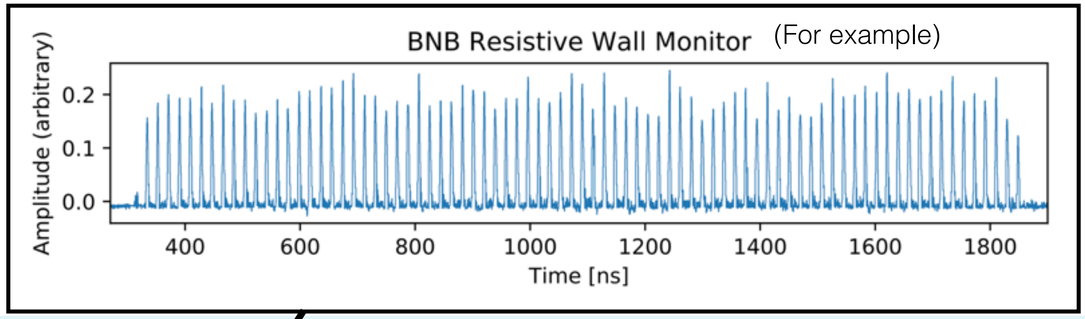
Detector synchronization

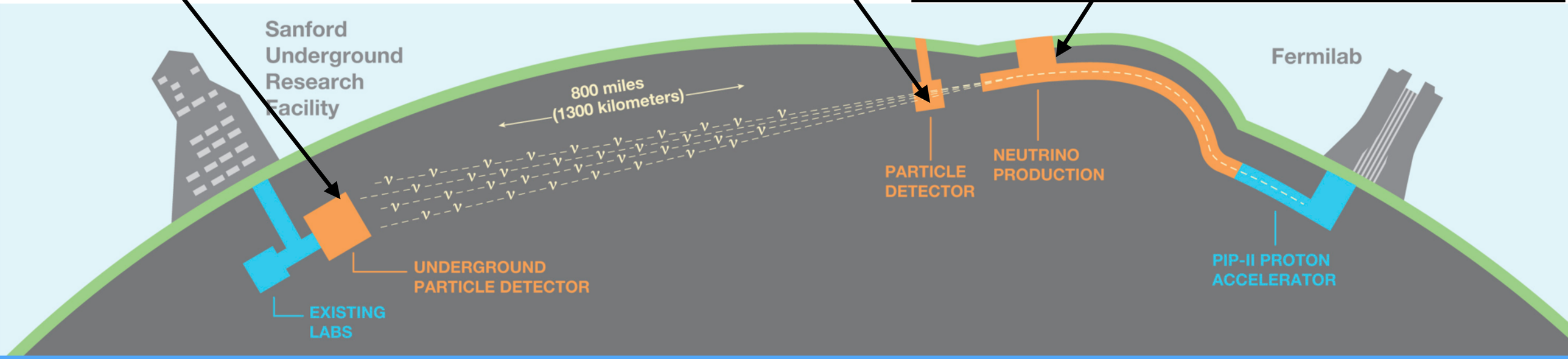
Far Detector ⟷ 1300km ⟷ Near Detector ⟷ <1km ⟷ Neutrino beam

(Tougher) (Easyish)









Challenges

- Scale:
  - Long-baseline Neutrino experiments are *relatively* large and homogeneous.
  - Liquid Argon TPC's are natively ambitious about time to ~ms
  - Direct Optical Cherenkov light can be used for timing, but requires large area detectors and high-resolution in time and position
- Precision:
  - <100ps timing requires better than 3cm track resolution.
  - 1300 km far detector difficult to synchronize to <100ps.
    - Possible to synchronize stable clocks offline using GPS Geodetic Time transfer
- Budget:
  - Most existing detectors are optimized for ~ns time resolution, <100ps requires order of magnitude more channels.
  - Jitter due to temperature, cables, discriminator etc. starts to become important.
    - Need local digitizing, reduction and synchronizing at the detector.