Juno and CHIPS

PK

Location

Completed first test in feb 2016

Started operating in 2014

Juno

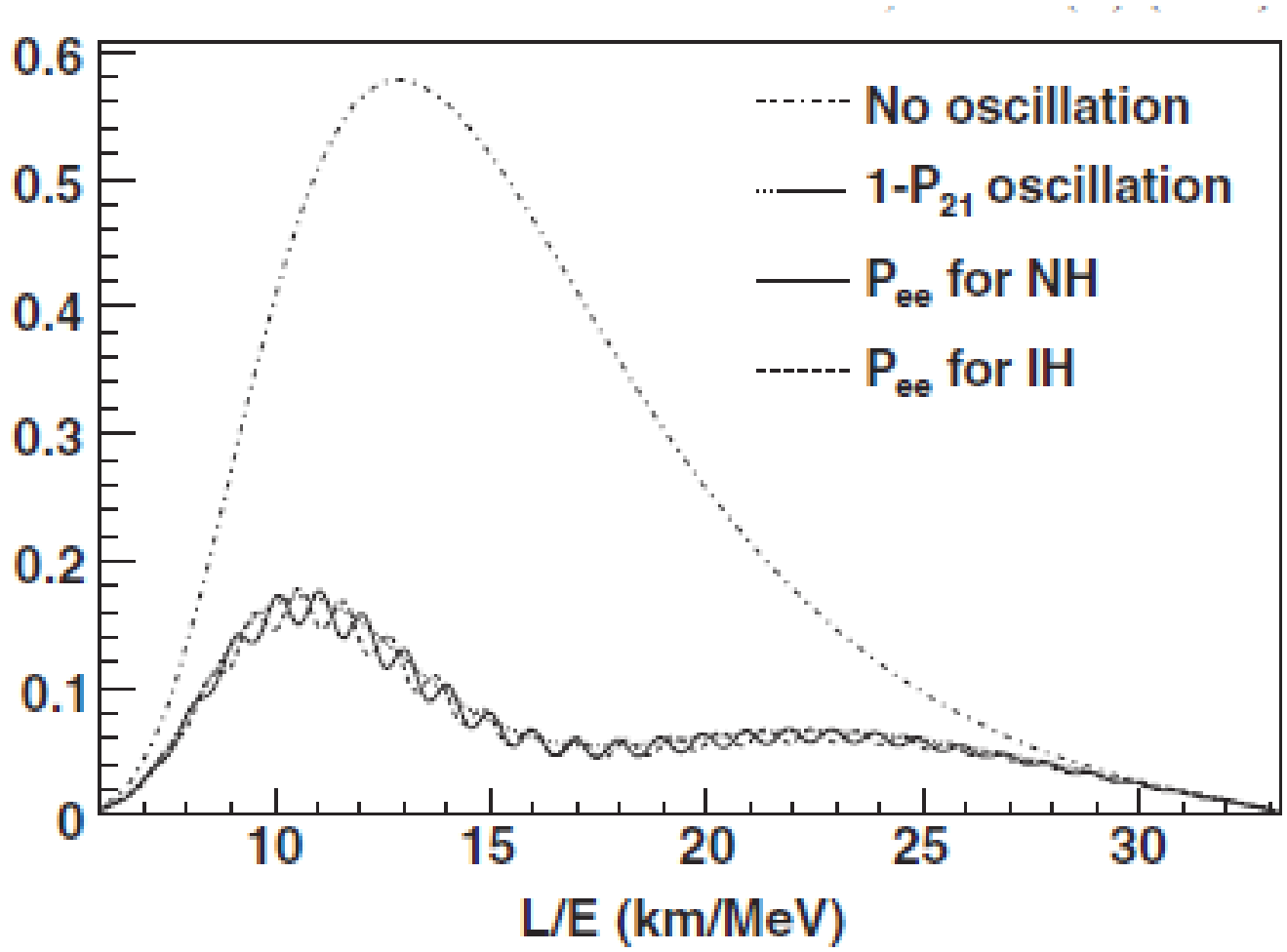
- Detector to measure the Mass Hierarchy
- Uses reactor neutrinos
- 60 km distance
- Looks for disappearance
- Fast and slow oscillations

$$P_{ee}(L/E) = 1 - P_{21} - P_{31} - P_{32},$$

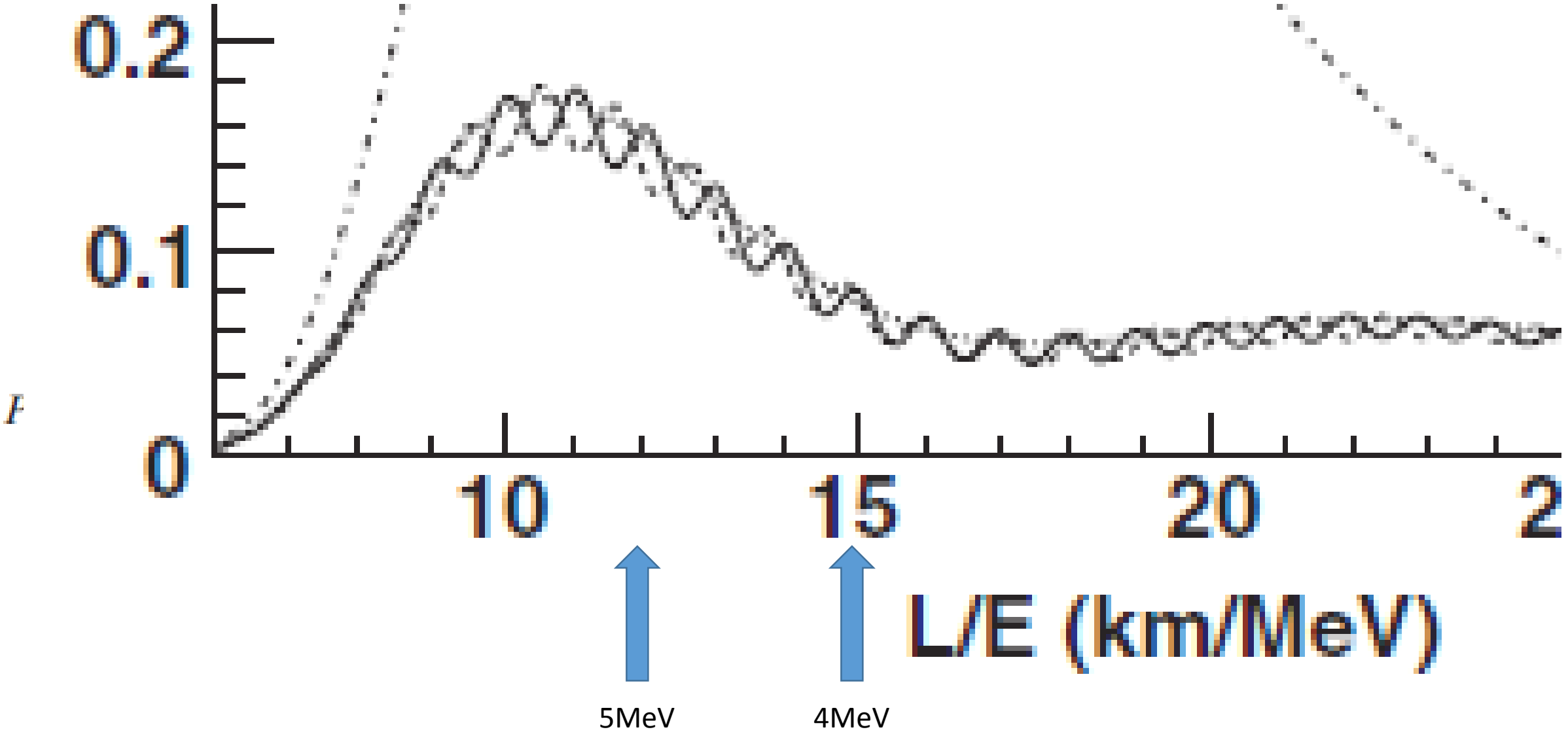
$$P_{21} = \cos^4(\theta_{13})\sin^2(2\theta_{12})\sin^2(\Delta_{21}),$$

$$P_{31} = \cos^2(\theta_{12})\sin^2(2\theta_{13})\sin^2(\Delta_{31}),$$

$$P_{32} = \sin^2(\theta_{12})\sin^2(2\theta_{13})\sin^2(\Delta_{32}).$$

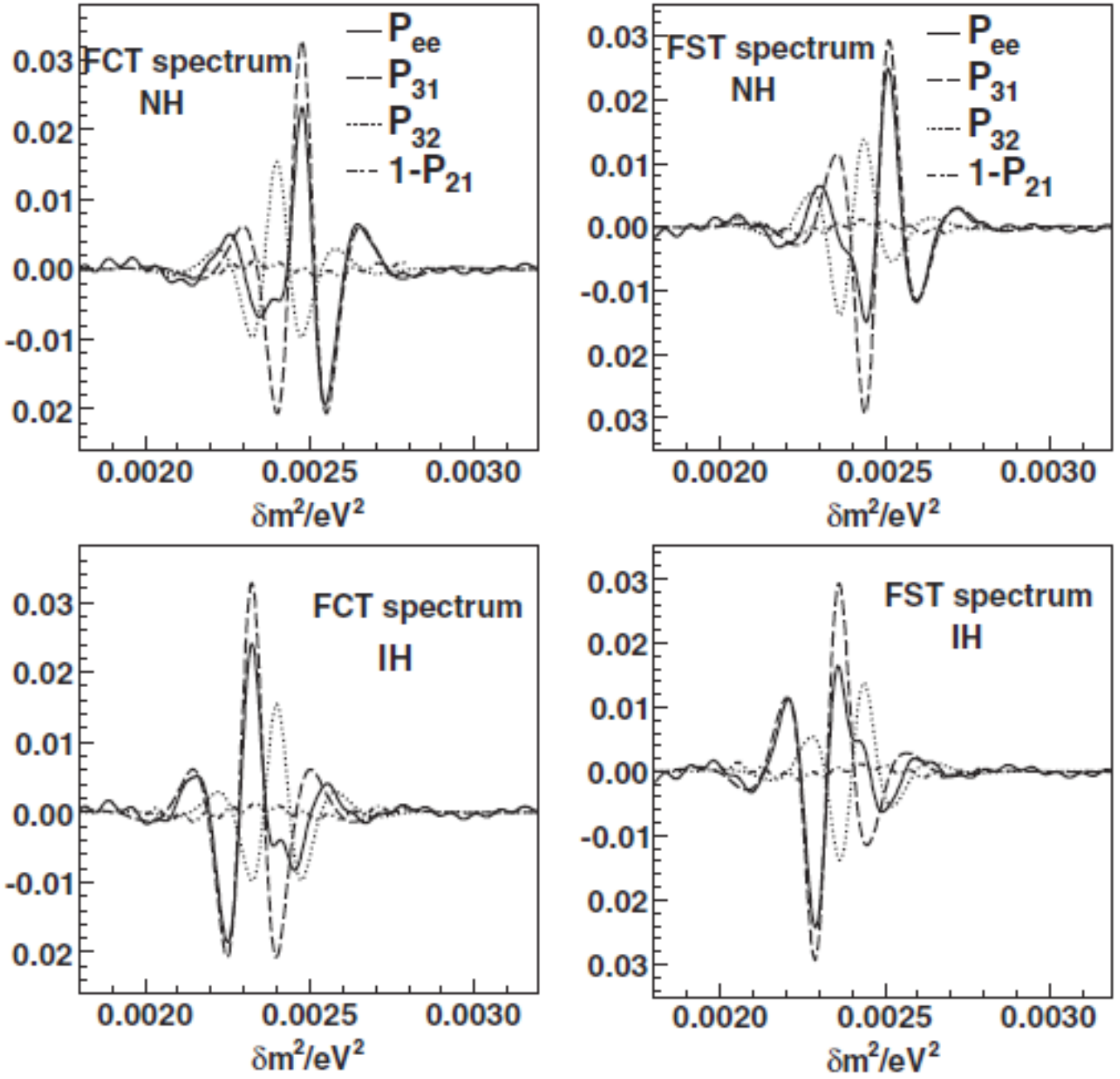


Juno



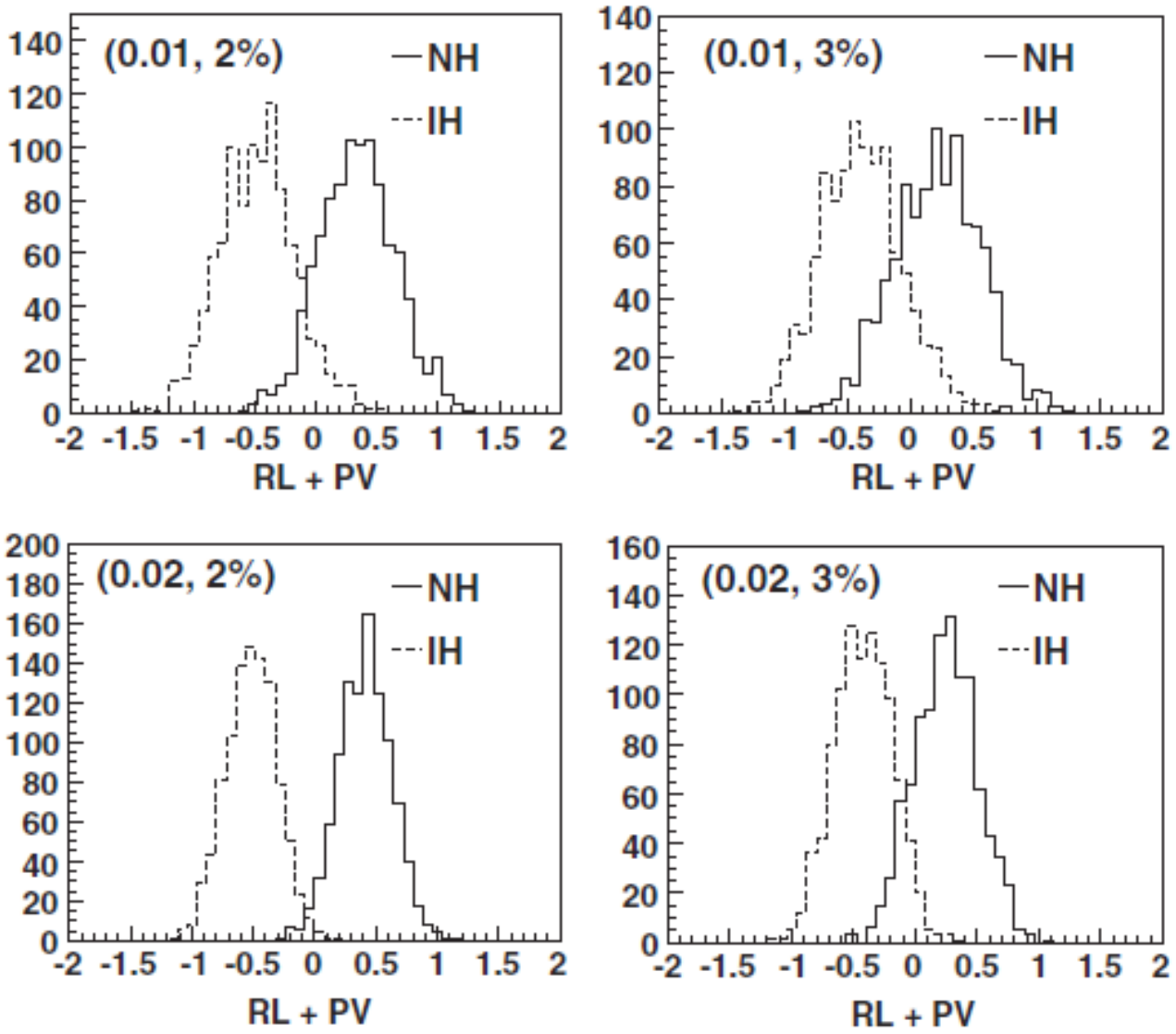
Very low energy

- NH and IH are equal at about 3 MeV
- Have a slightly different wavelength for IH and NH
- Requires about 2-3% energy resolution to be able to separate the two
- Use Fourier analysis with cosine and sine weighted integrals



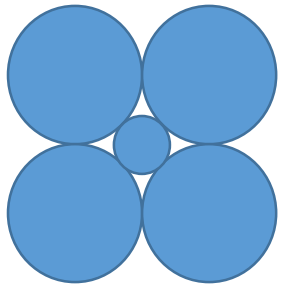
sensitivity

- Depending on the resolution and the value of $\sin^2\vartheta_{13}$

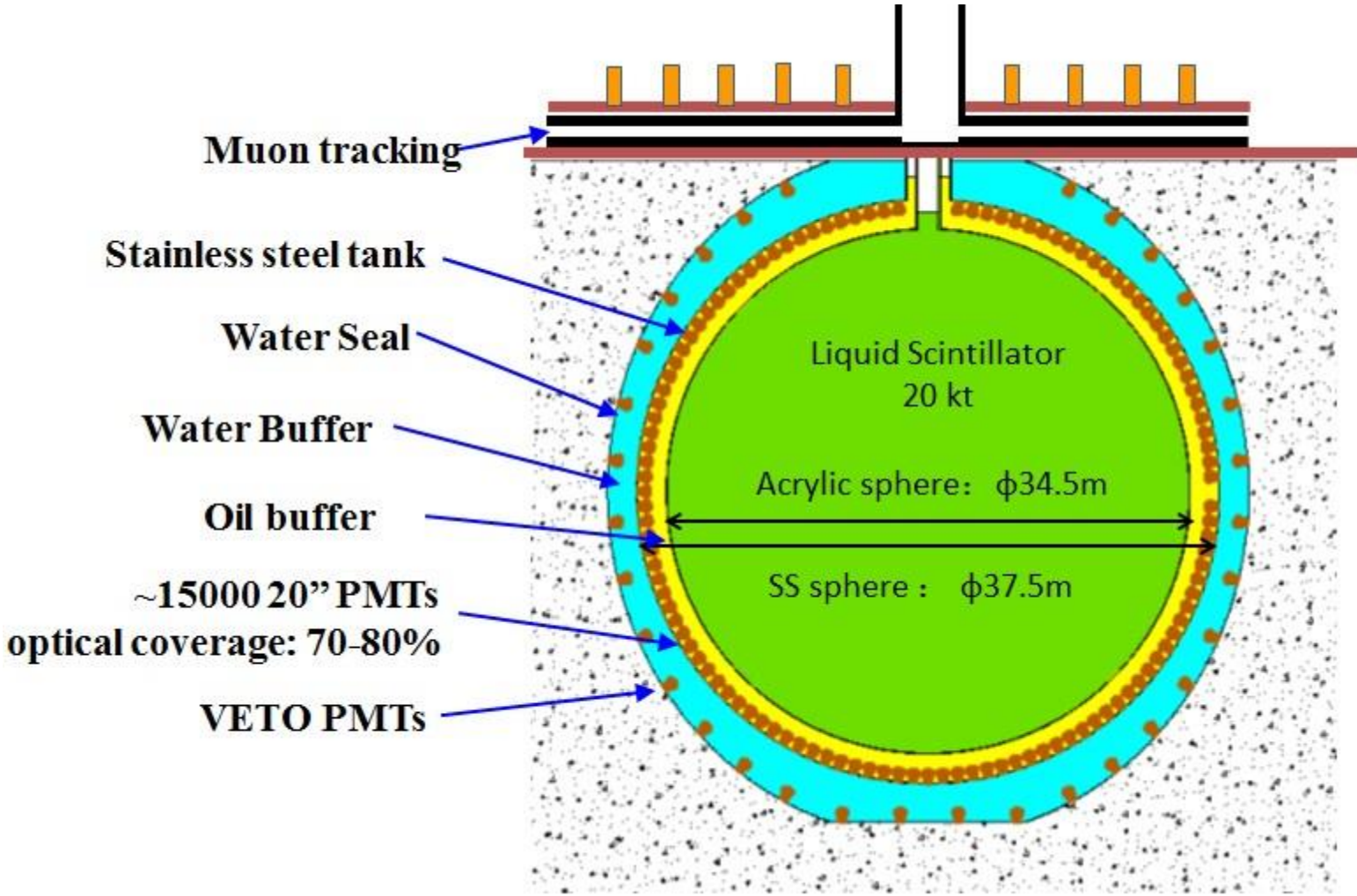


Detector

- 20 kTonne of liquid scintillator
- 15000 50 cm PMTs
- 70-80% coverage
- Want to go even higher



Add 15000 3” pmts



Timescale

- Start in 2020
- 3-4 σ after 5 years
- Independent of CP or Mass effect

- Supernovae
- Geo neutrinos
- Solar neutrinos
- Nucleon decay
- Sterile neutrinos ??

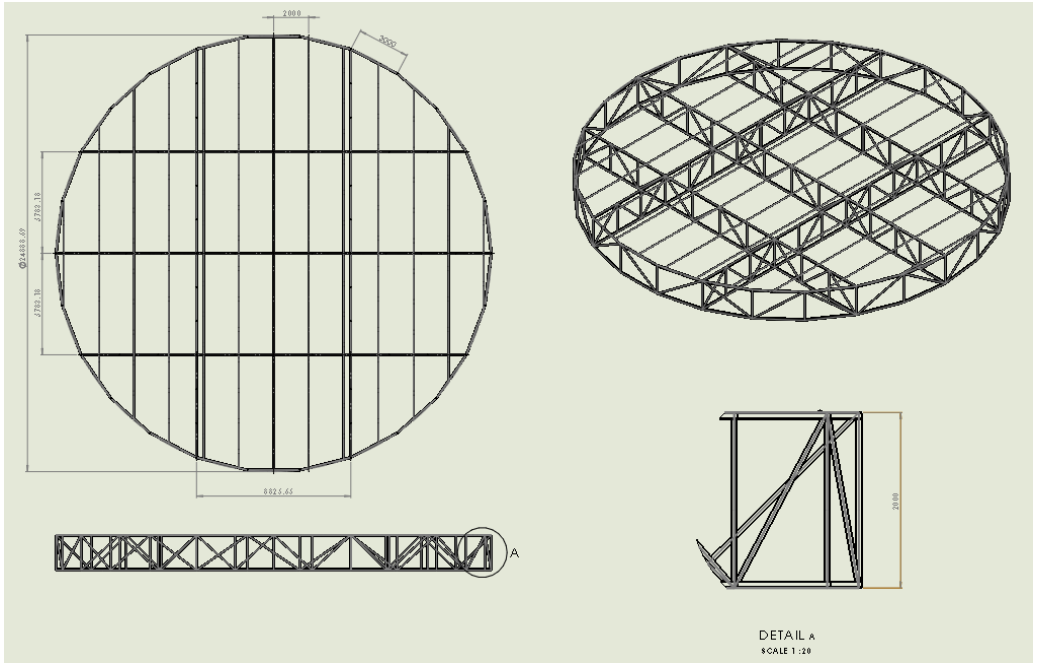
CHIPS

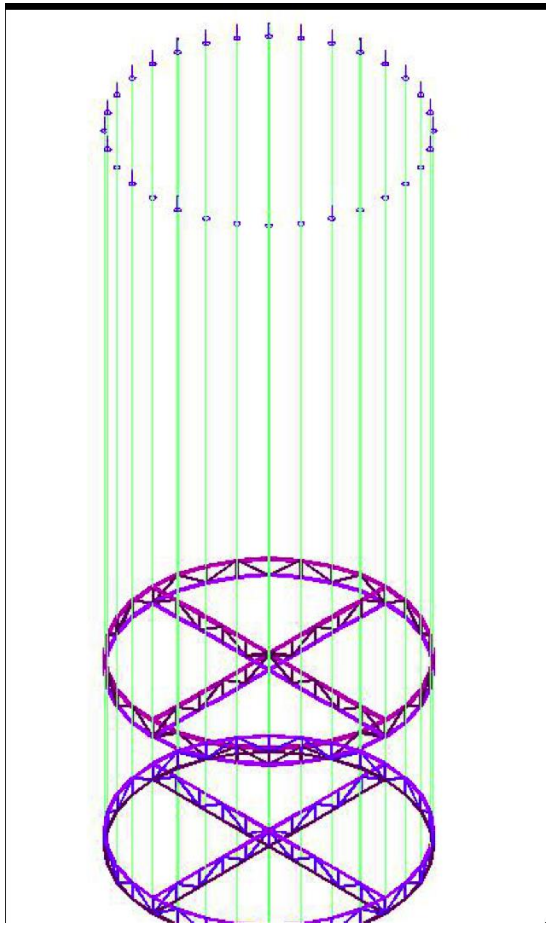
- Water Cherenkov
- In the NuMI neutrino beam (700kW)
- 7 mrad off axis
- “surface detector”
- Initial size 10 – 15 kTonne
- Time schedule:
  - 5 kTonne in beam Q3-2018
  - 10 –15 kTonne in beam Q3-2019

Pilot project for cheap CP violation detector

- No excavation
- Concentrate on neutrino beam only
  - Don’t worry about cosmic background too much
  - No proton decay or supernovas in our galaxy
- Use small PMTs distributed finely evenly over cylinder walls
  - Provides much better granularity
  - Need much less photocathode coverage
  - Typically 6% coverage is more than sufficient for 3” tubes
  - For 10” or bigger 20% is minimum
- Cost goal is 200 k$/kTonne (hyperK ~3M$/kTonne and DUNE ~25M$/kTonne)

Design





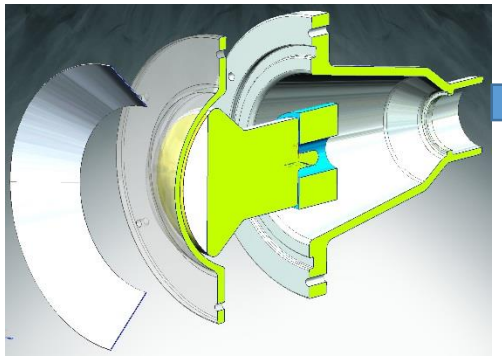
Two spaceframes 20-30 m apart connected by ropes (Dyneema – KM3NeT)
Sunk to 60 m depth

Instrumented around the walls and endcap. Plus extra veto layer on top.

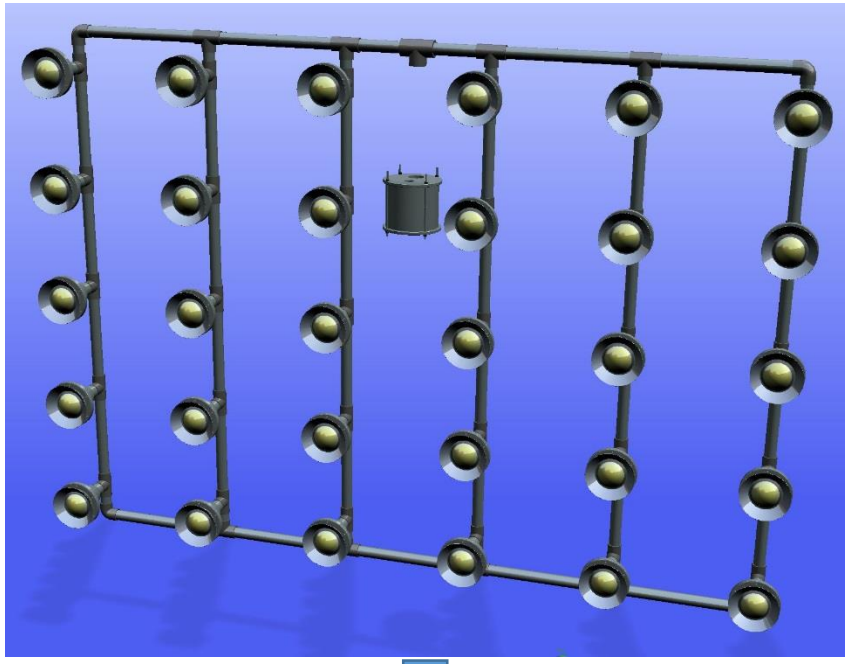
Diameter about 25 m.

Contained in PVC roofing material (fiber loaded) ie light tight plastic bag.

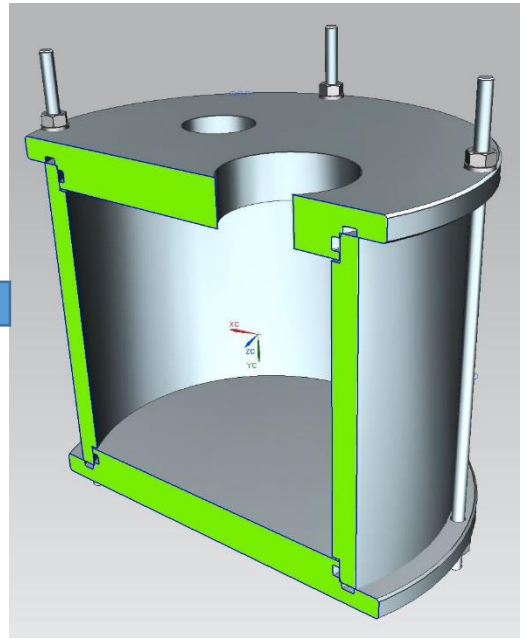
Design



Custom unit:
Plexiglass front
Mirror
PVC back



Planes with PMTs
High pressure PVC
Cat5 cabling



Electronics container

Total Price for 10 kTonne is 1.6M€
200k€ more for another 5kTonne

Institutes

- UCL
- University of Texas
- University of Minnesota
- University of Wisconsin
- Nikhef

- Total investment money
  - 1.2 M€ from ERC grant
  - 0.2 k€ for mechanics
  - 0.4 k€ for travel etc

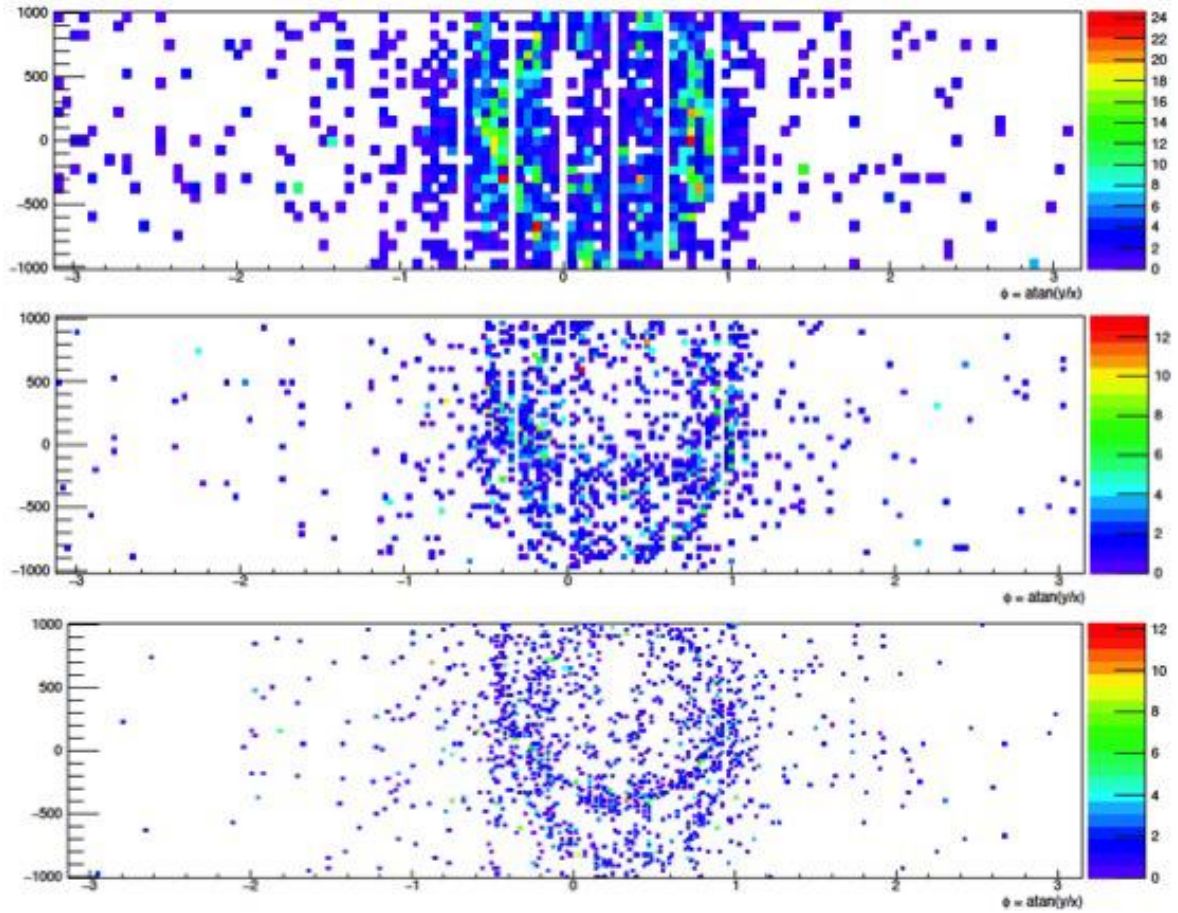
Advantage of small tubes

Main background NC(ν_μ) π^0 production
Separation of 1 and 2 Cherenkov rings

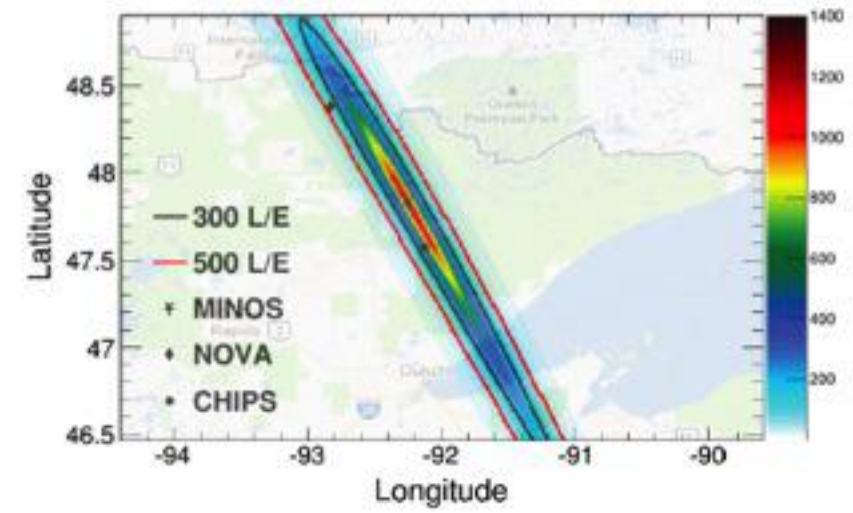
10” PMTs 10% coverage

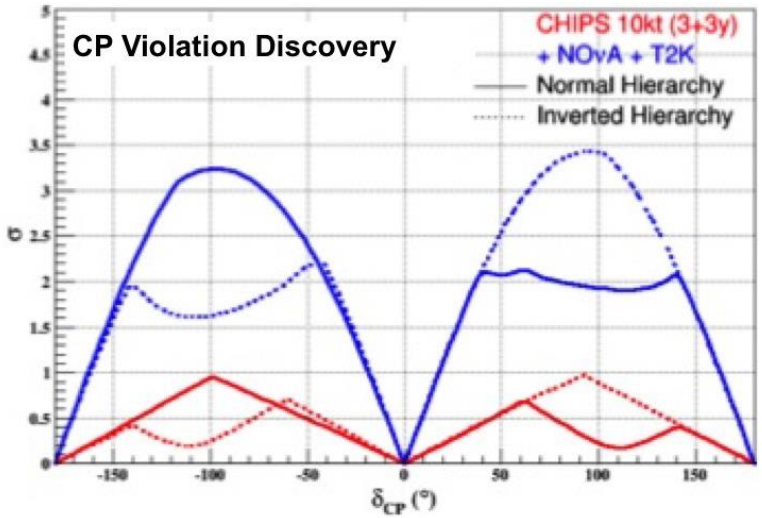
5” PMTs 10% coverage

3” PMTs 10% coverage



Physics potential



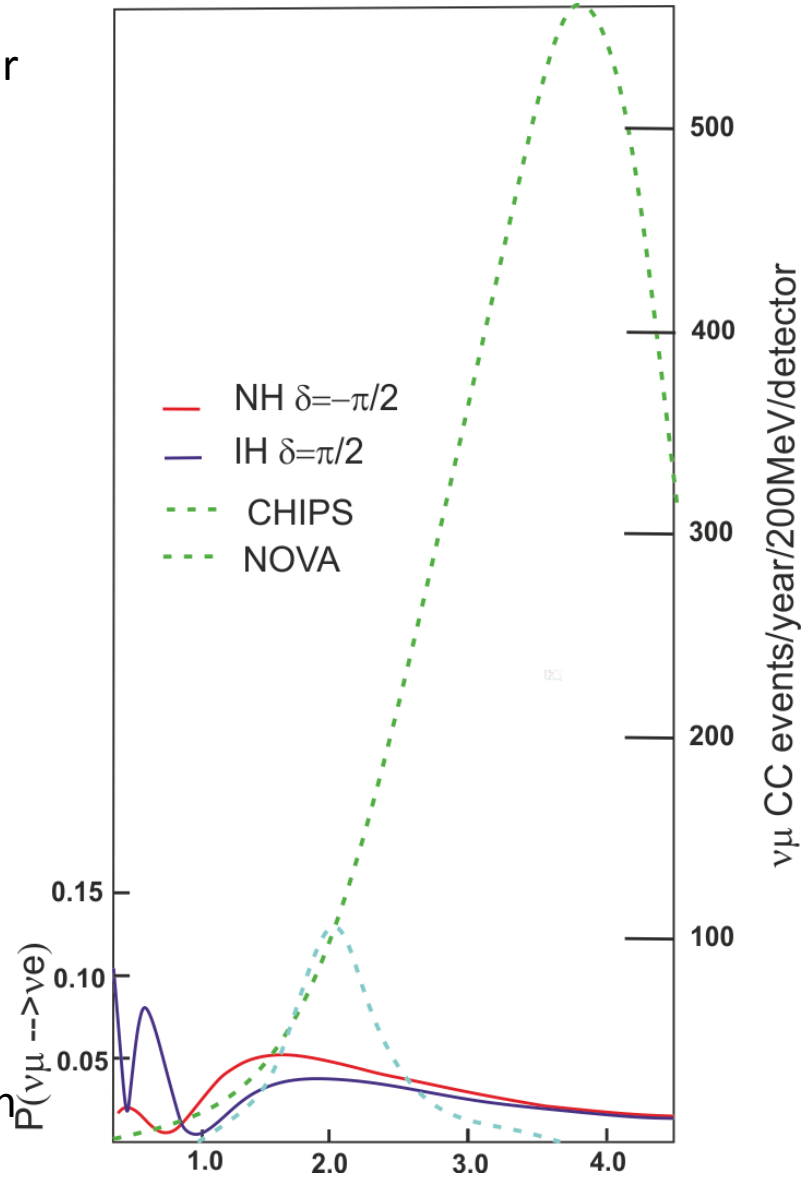


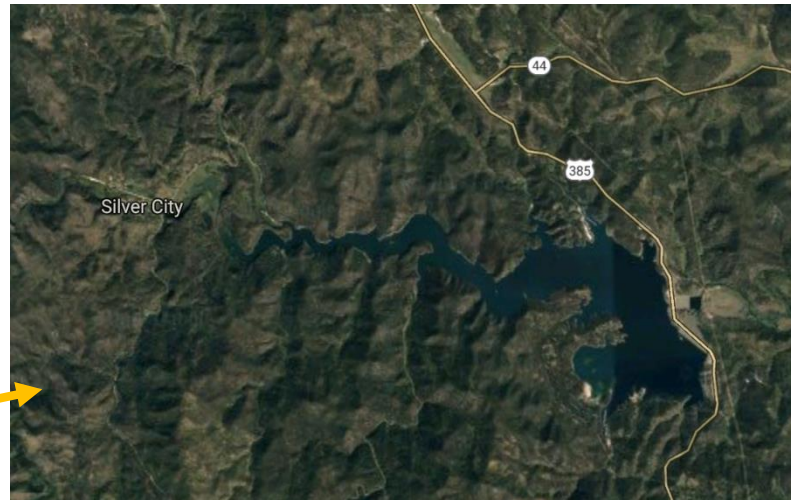
About 100 electron appearance events/year For best configuration Difference between CP states is about 4 events/year.

If successful for 1 year showing expected ne rate could extend detector to 100 kTonne for <10 M$. Together with Nova and T2K get 20 degree resolution

→ 1000 events/year
→ Difference 40/year

This could also be put in DUNE beamline.





20 mrad off axis
In Silver City rather than Deadwood

A similar sensitivity addition to DUNE for 1% of the cost

Sensitve to second oscillation