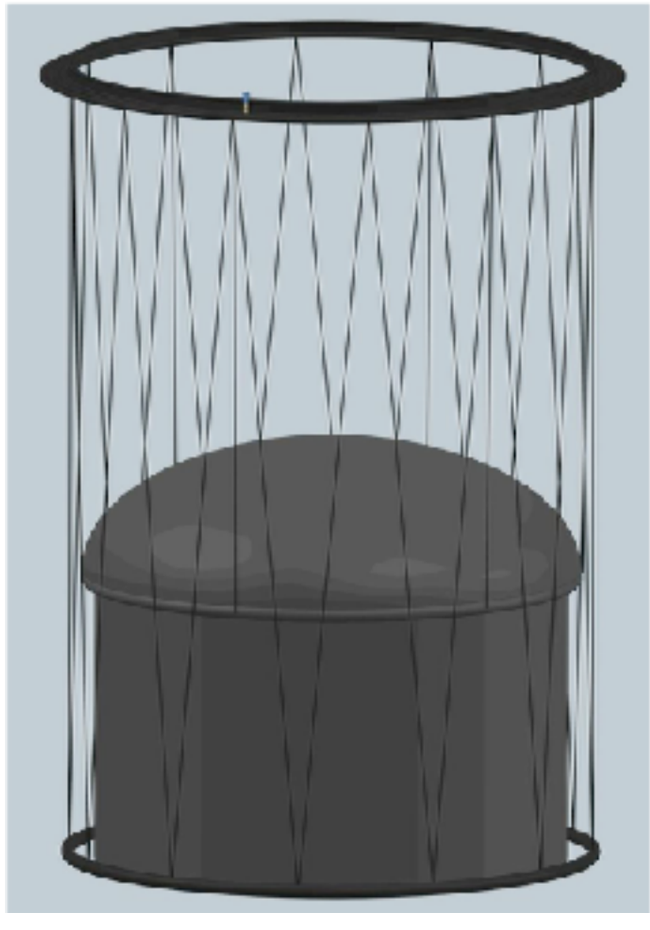
Something New and Risky

CHIPS

CHIPS : Cherenkov Detectors in Mine PitS

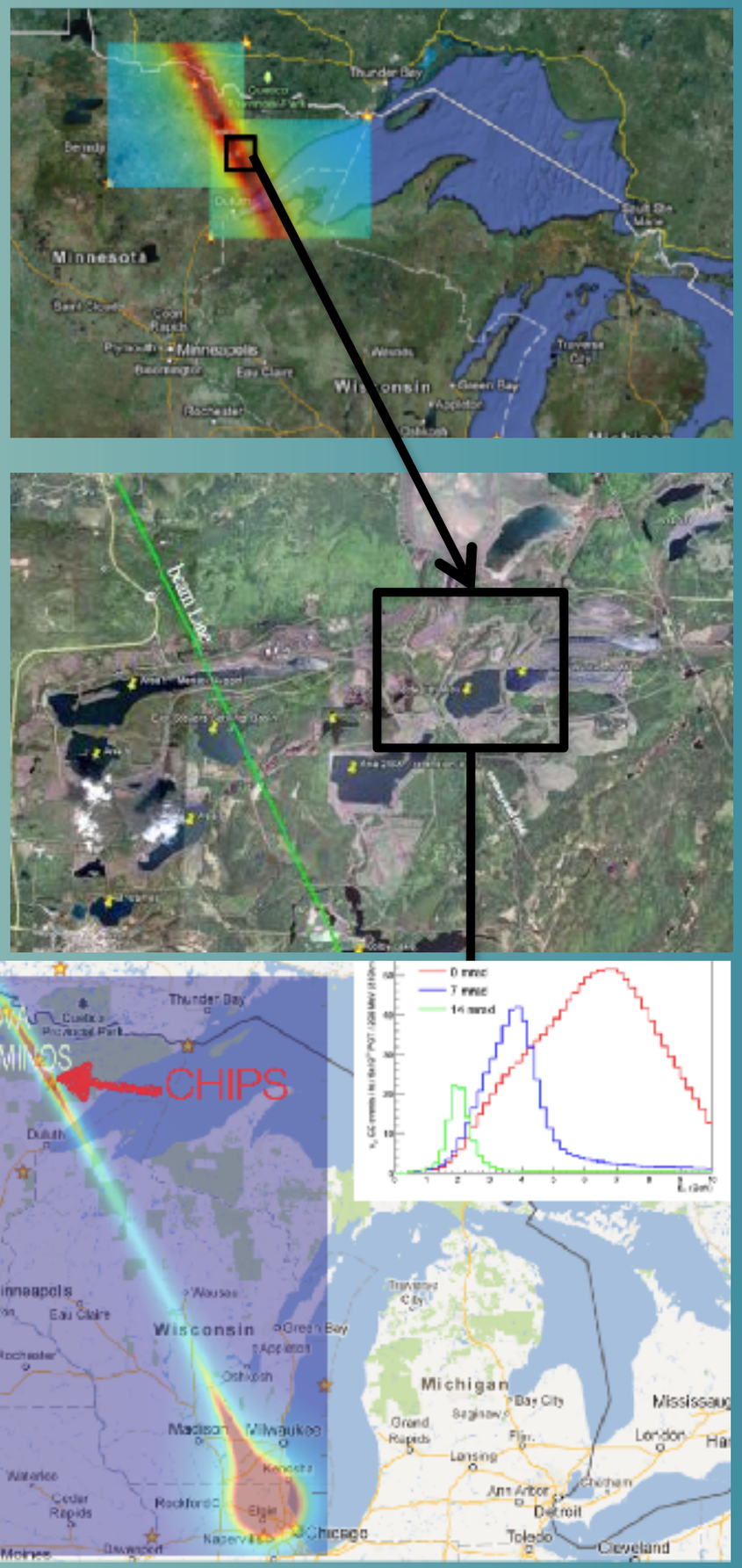
- The CHIPS goal is to prove that a water Cherenkov detector can do oscillation physics for a fraction of the cost of present neutrino detectors, and also to contribute to constraining δ_{CP} using NuMI neutrinos in the short term
  - ➡ to $200k/kt (presently $2-10M/kt water, $10-20M/kt Liquid Ar
  - ➡ These prices include location/infrastructure etc
- CHIPS will be submerged in a flooded mine pit in the path of the NuMI beam

25m



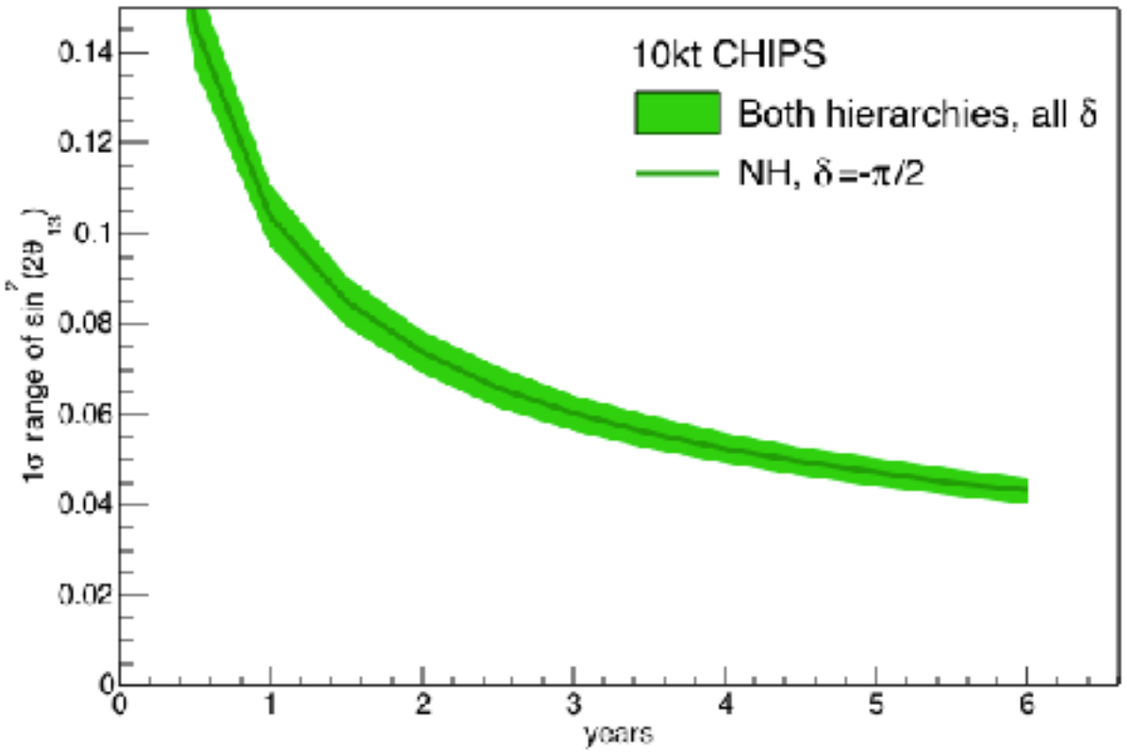
CHIPS : Location

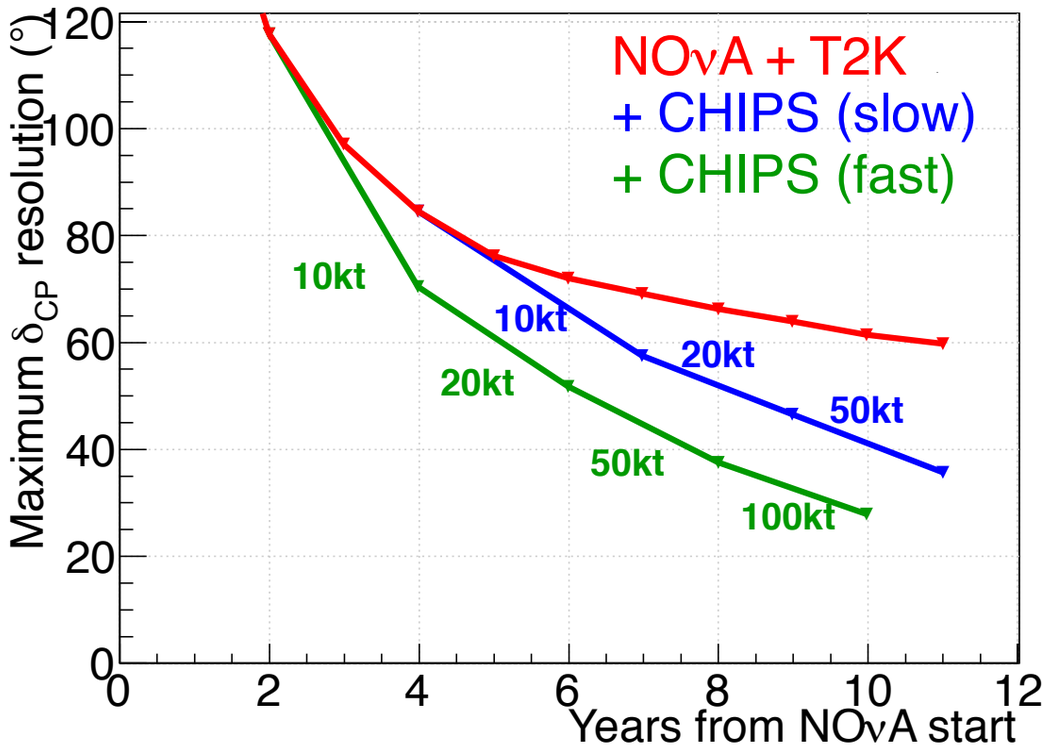
- Deep lake or body of water on mining site: Wentworth 2W
  - 60m depth, cosmic overburden (later)
- High energy neutrino beam
- At 7mrad off axis
  - Between signal and background extremes
- CHIPS-M (mini) prototyped in 2014 and 2015

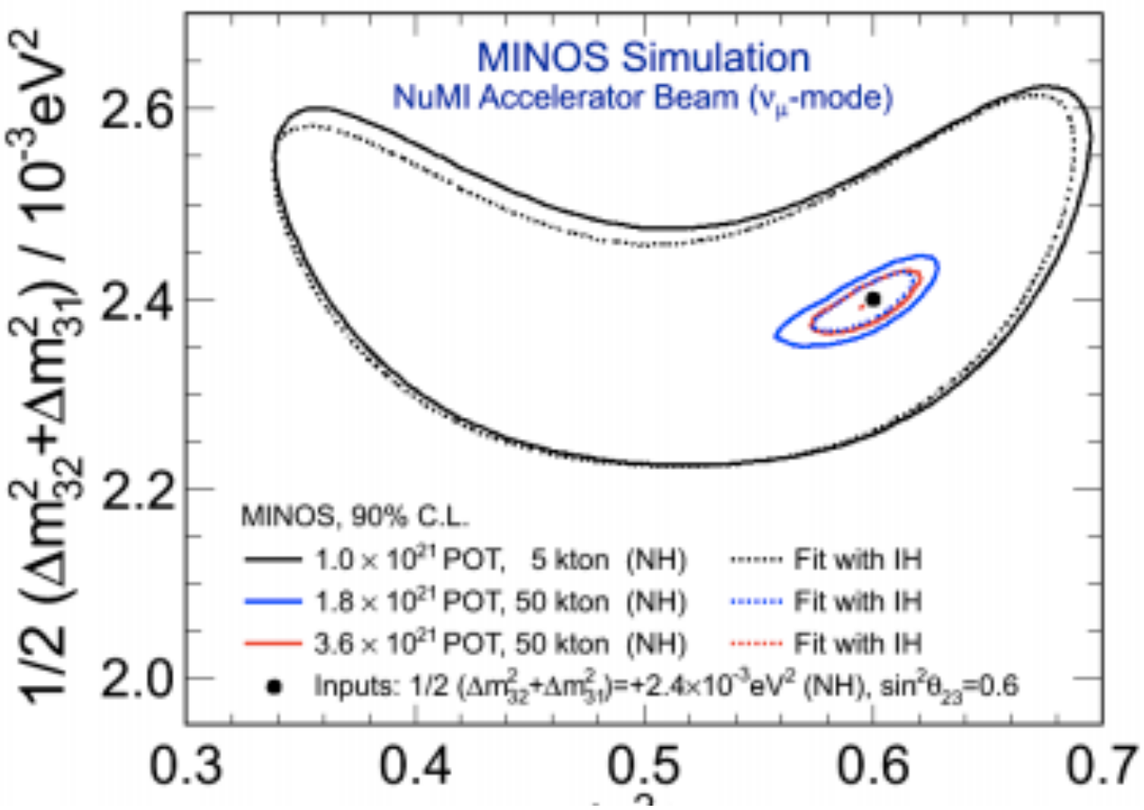


CHIPS Physics Goals

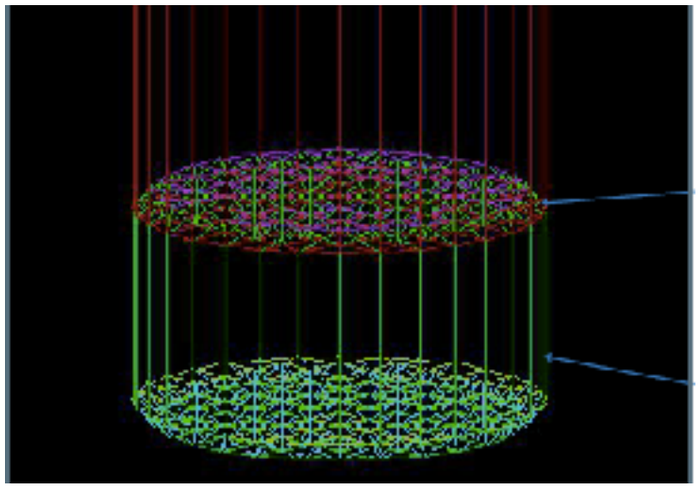
- Improve global knowledge
  - Measurement of θ_{13}
  - Measurement of θ_{23}
  - Contribution to δ_{cp} knowledge
- These plots assume old SK like reconstruction ability..
  - Key will be to grow beyond 5kt!
  - If proof-of-principle succeeds, this may be possible

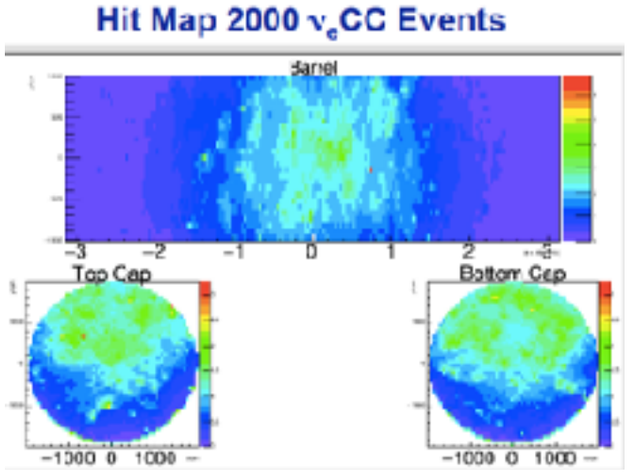


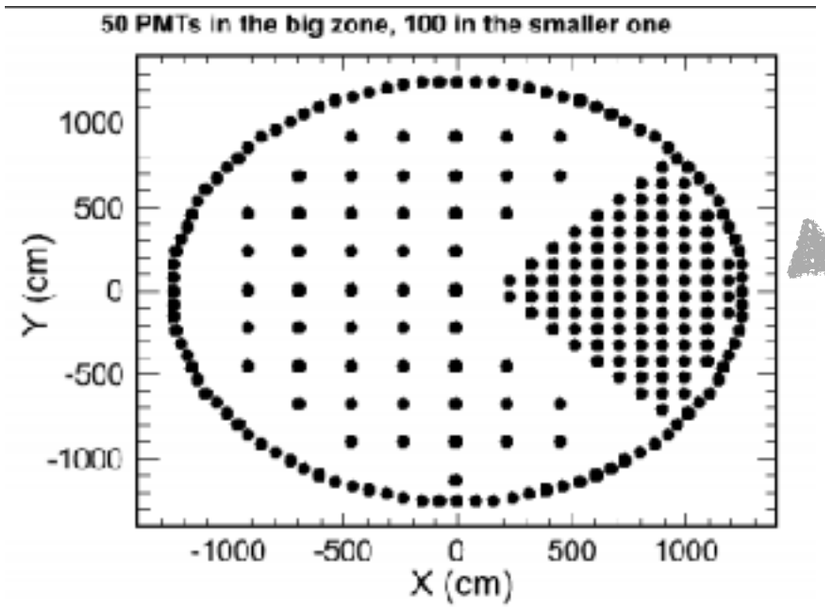




5 Steps to (cheap as) CHIPS





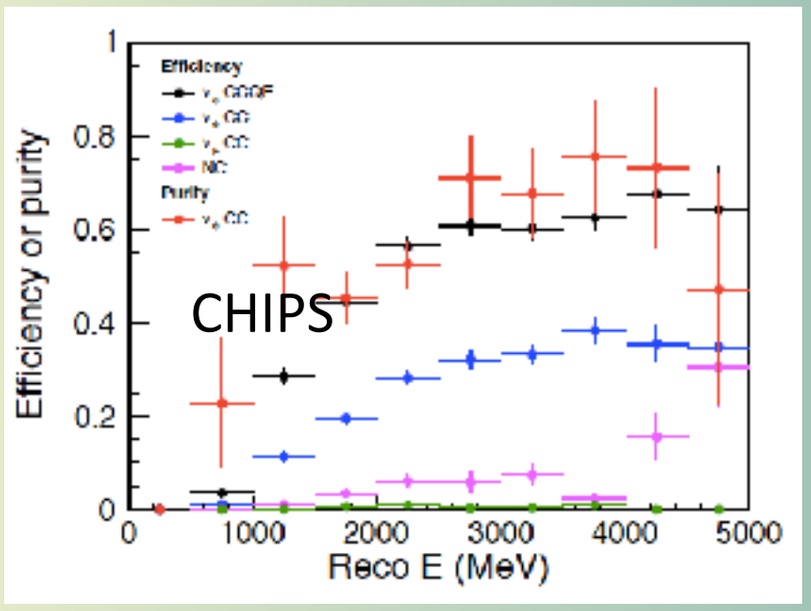


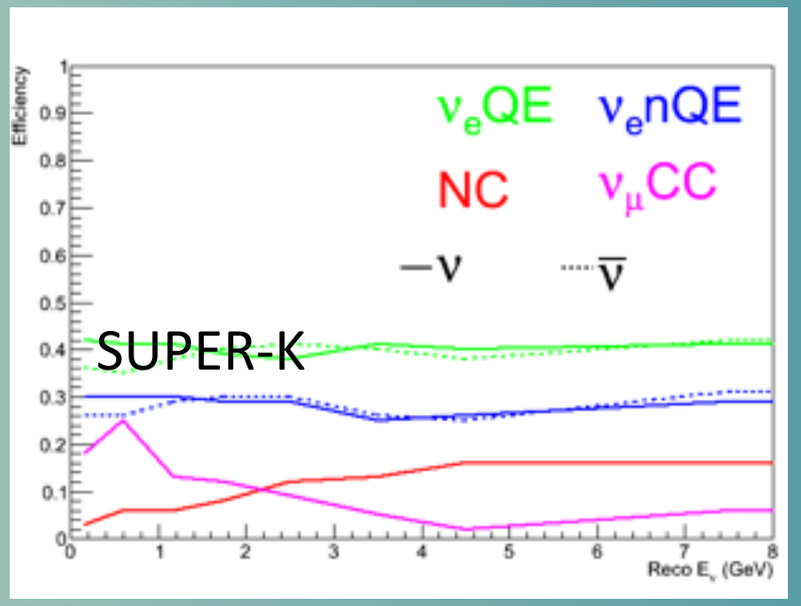
1) **Location**
   sunk in a flooded mine pit in the path of the NuMI neutrino beam, will make use of the water for cosmic overburden and mechanical support;
2) **Structure design**
   will allow it to grow in size with time but with no financial penalty beyond the instrumentation costs
3) **PMT choice and layout**
   3” PMT’s good position and time resolution and beam optimized layout
4) **Electronics**
   will make use of ubiquitous mobile phone and communications technology and already developed KM3Net Solutions
5) **Simple water purification plant**
   will use straightforward filtering to maintain water clarity.

Reconstruction

Table 1. The resolutions of various reconstructed parameters from single ring electron (muon) track fits to a sample of CCQE ν_e (ν_μ) interactions with energies following those expected from the NuMI beam.

Sample	Geometry	Reconstruction Resolution			
		Position (cm)	Time (ns)	Direction (°)	Energy (MeV)
CCQE ν_e	10 inch, 10%	35	0.9	2.1	208
	3 inch, 10%	35	0.84	1.9	210
	3 inch, 6%	38	0.89	2.1	211
CCQE ν_μ	10 inch, 10%	47	1.35	2.6	113
	3 inch, 10%	44	1.14	2.7	110
	3 inch, 6%	51	1.28	3.0	113

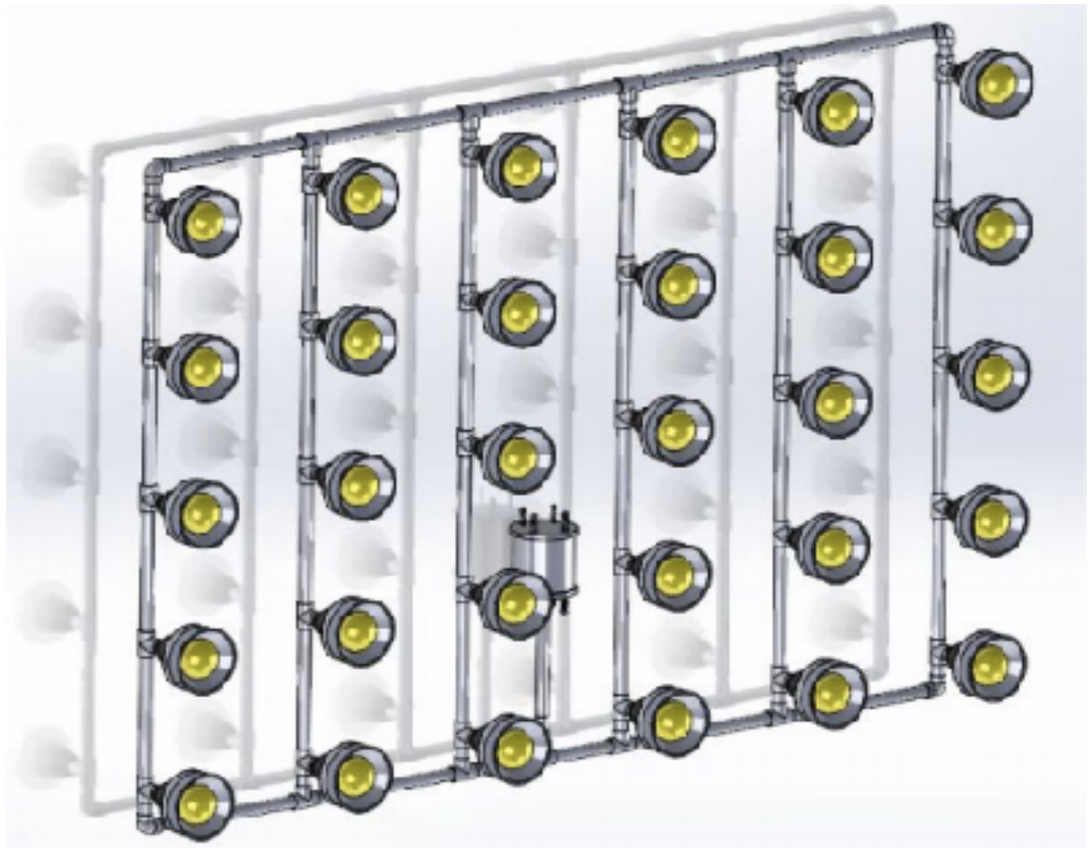


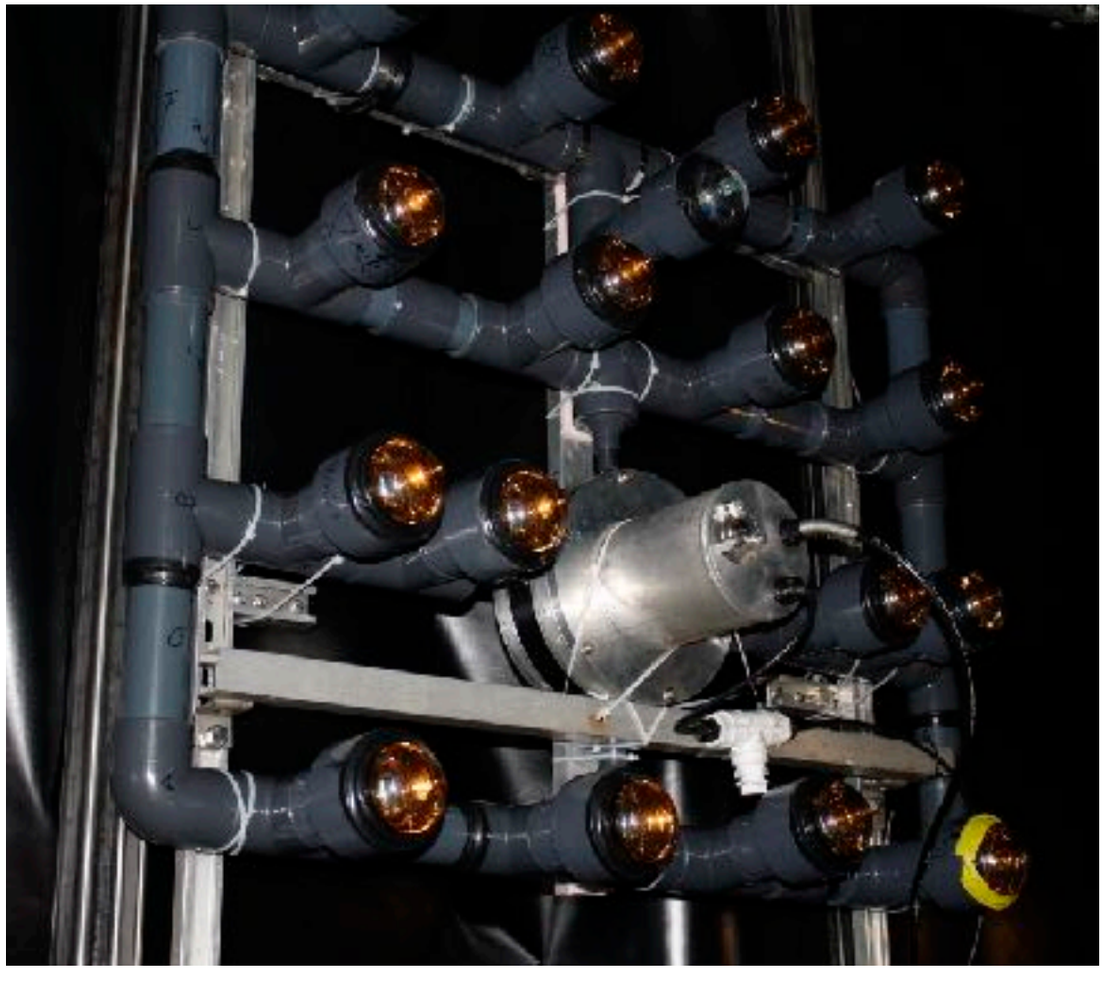


- Originally based on MiniBOONE approach, several innovations from that point (time)
- Neural Nets, Fourier transform analysis and even deep learning all being studied
- Pretty good basic bottom line so far, more improvements on the way

CHIPS detector planes

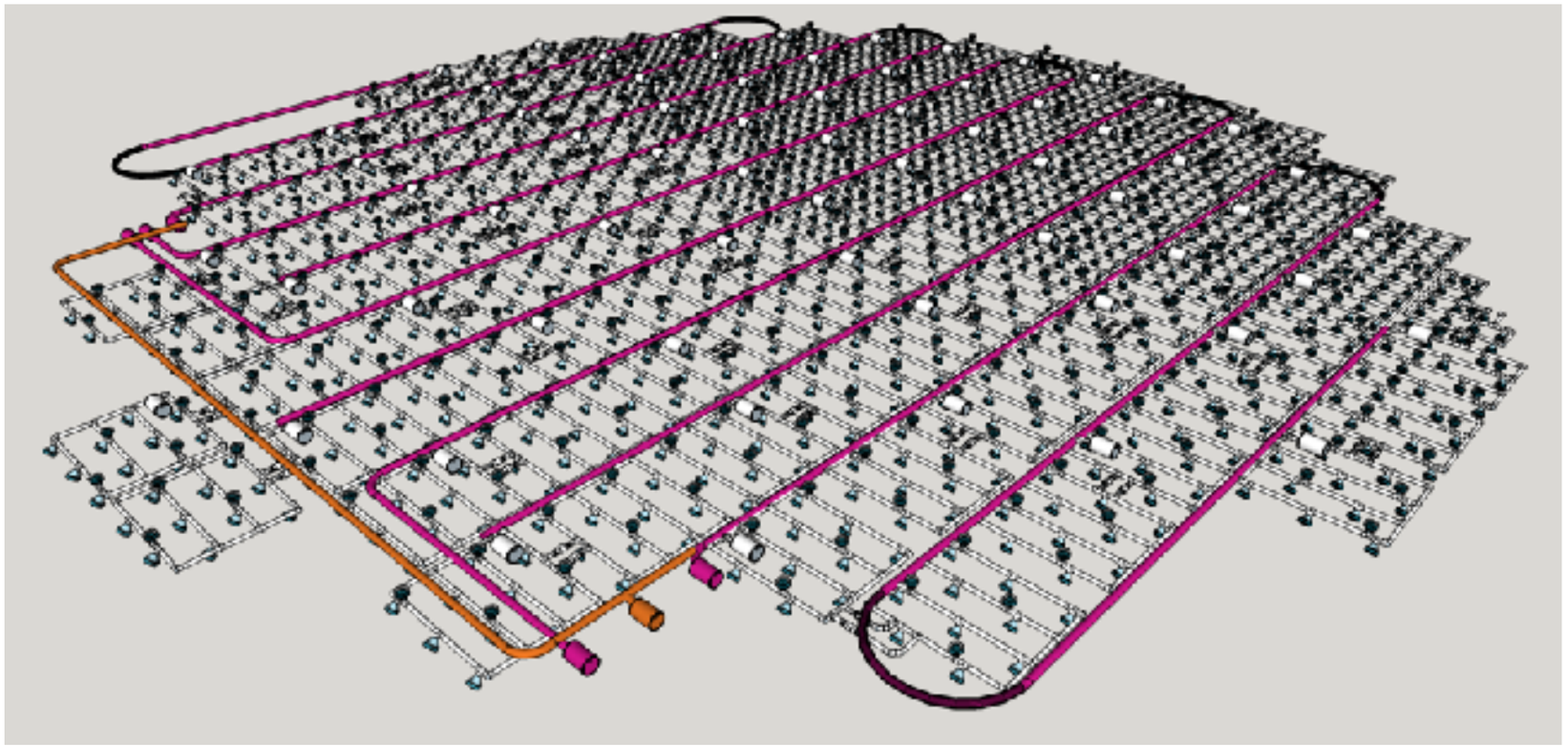
- CHIPS-M design will be carried forward
- Layout will involve high and low density planes
- A big part of the instrumentation will just implement KM3Net technology
  - New 3" PMTs at 6% coverage in front and end caps, and 4% coverage back end cap region
- Low density wall planes will be made with NEMO-III 3" PMTs and Madison electronics.
  - Old 3" PMTs at 4% coverage in back





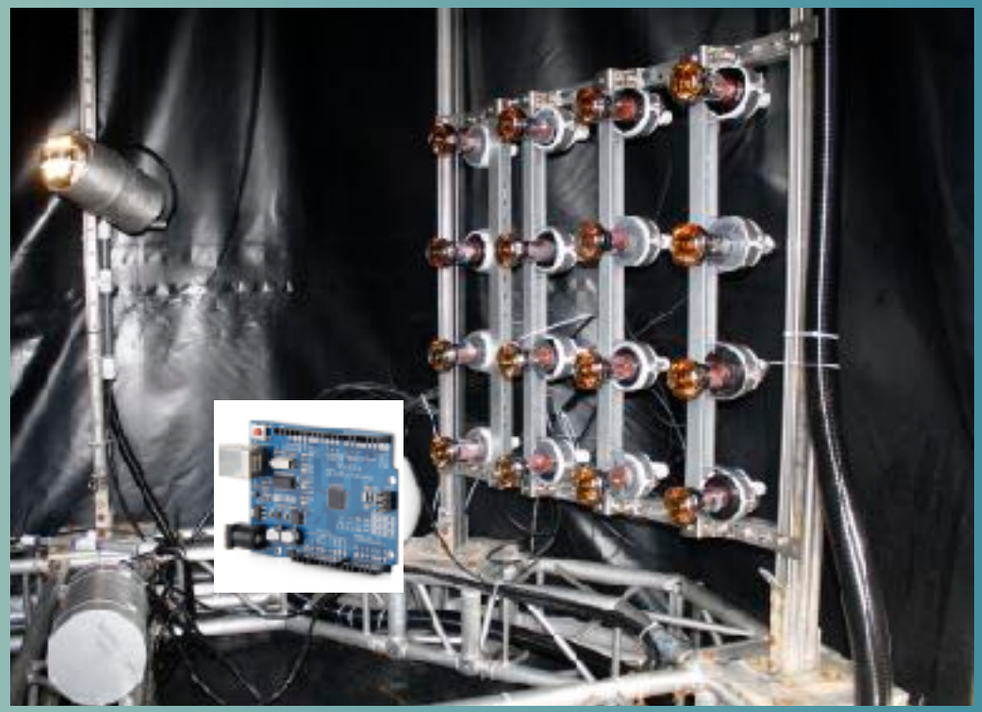
CHIPS detector planes

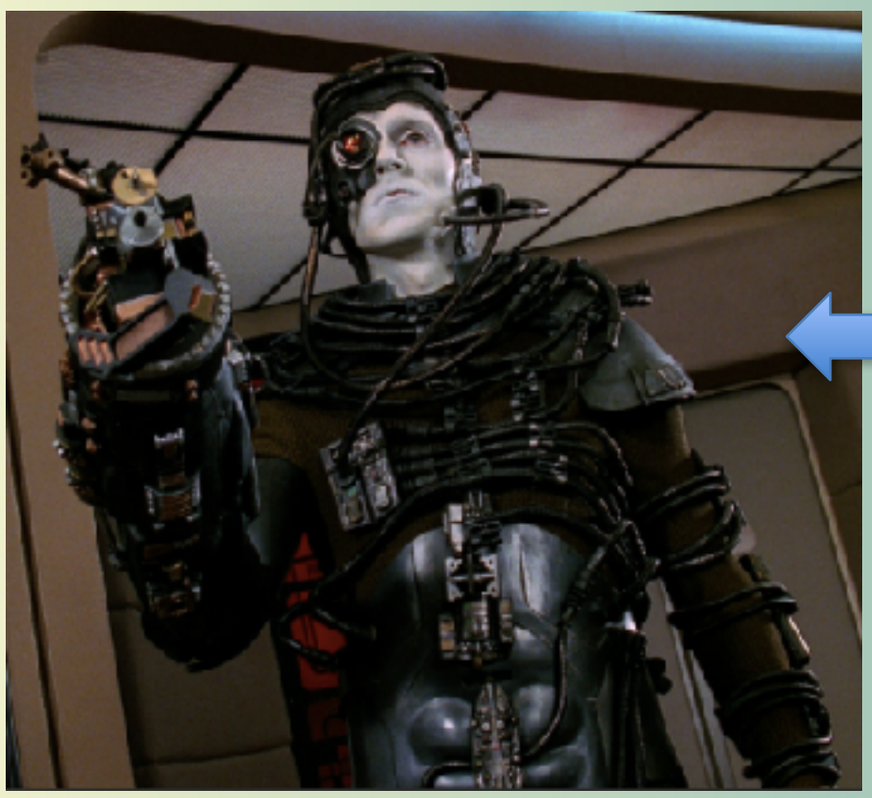
- CHIPS-M design will be carried forward
- Layout will involve high and low density planes
- A big part of the instrumentation will just implement KM3Net technology
  - New 3" PMTs at 4% coverage in front and end caps, and 3% coverage back end cap region
- Low density wall planes will be made with NEMO-III 3" PMTs and Madison electronics.
  - Old 3" PMTs at 2% coverage in back



4. Electronics: iPHONE and ARM

- We are riding a revolutionary wave in development
- $20 for a BBB to collect signals and transmit to Ethernet
- Reduce cost to minimum
- Microprocessors on each PMT provide ToT and receive clock from WR system

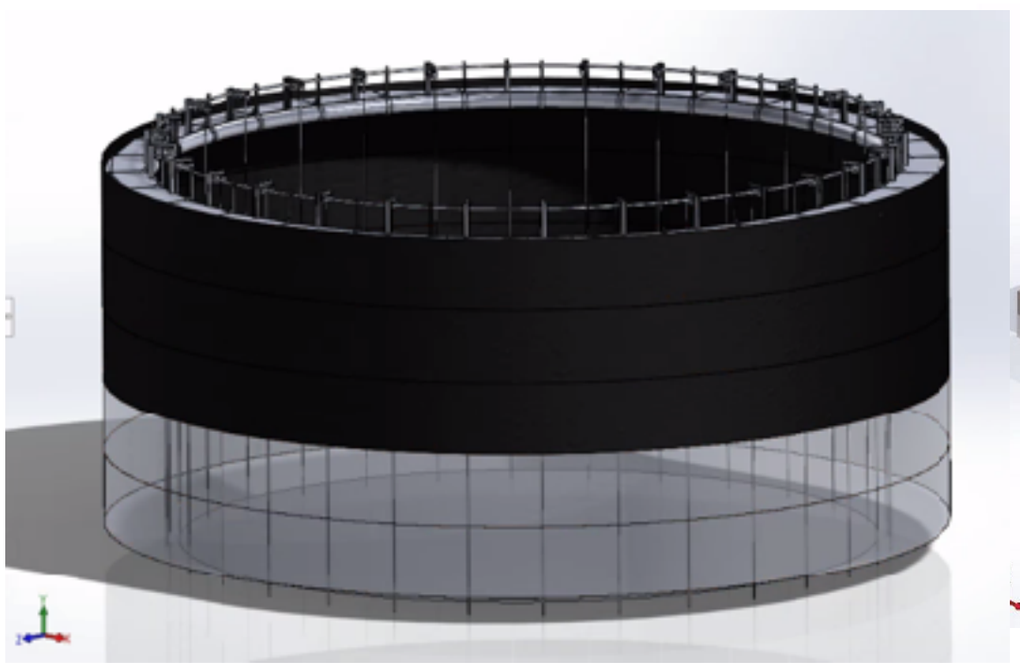


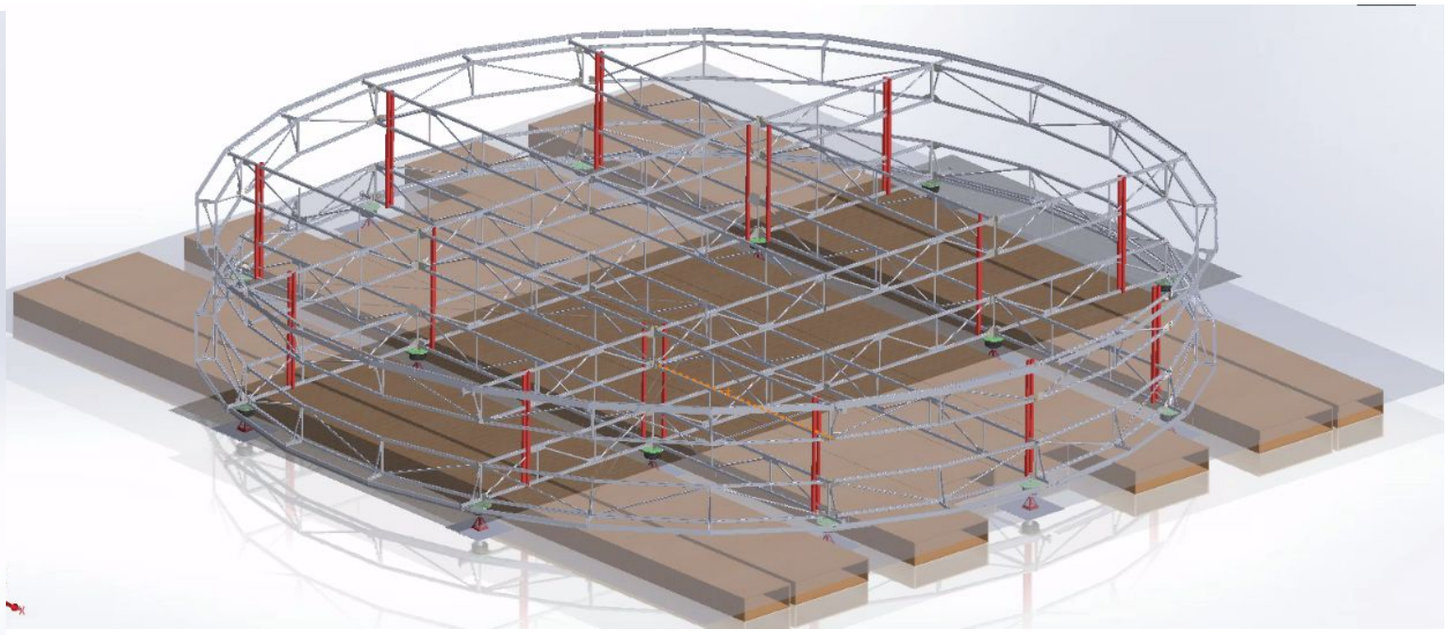


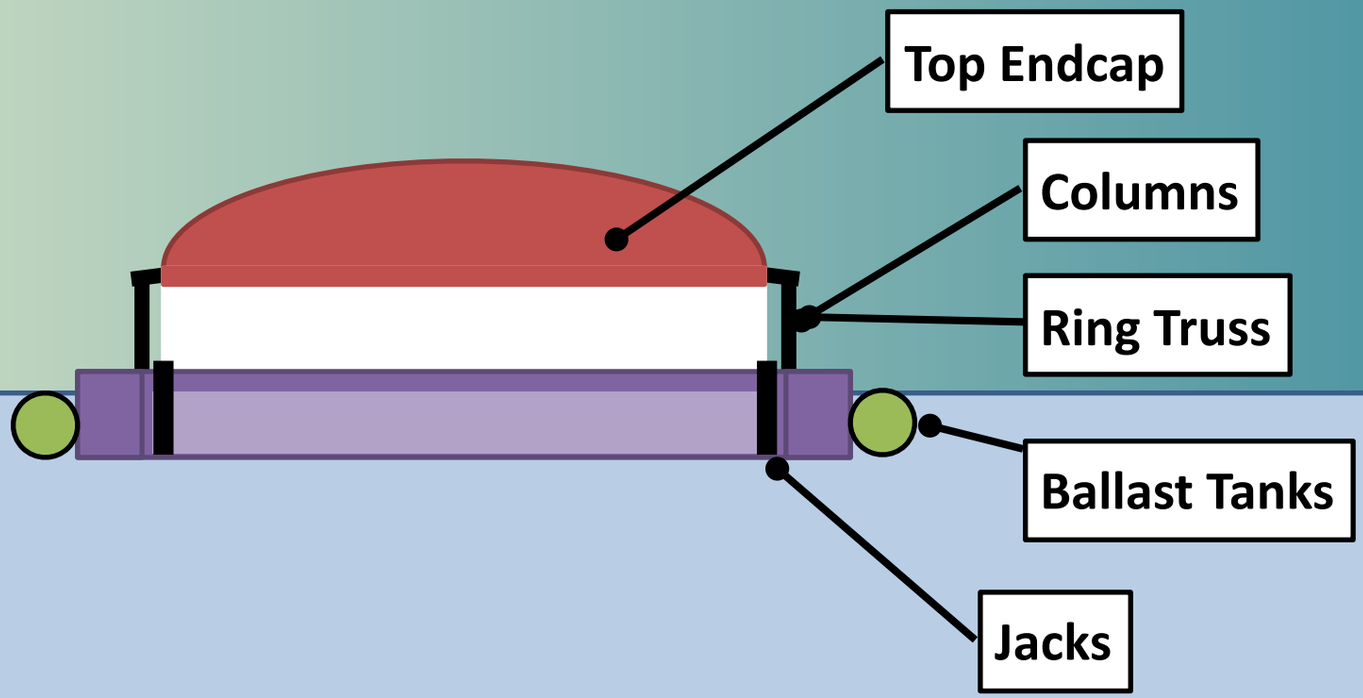
- Side comment: Industrially available ASICs in version 100 (ish): home grown electronics is typically in version 2-5the combination of cheap processors such as Raspberry Pi, BeagleBone and Arduino combined with the WWW means progress goes incredibly fast as solutions are known instantaneously
- Developers are like the Borg: and **resistance is futile..**

CHIPS Deployment

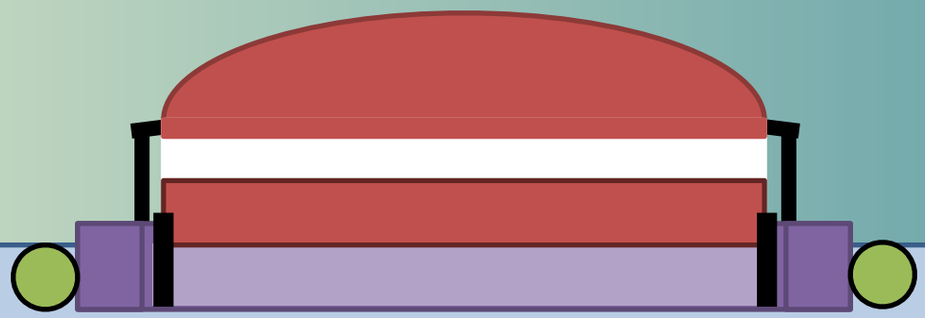
Coffer Dam technology can prepare area for building







- Domed roof self-supporting in air
- Supported by circumferential columns
- Columns supported by floating ring truss equipped with ballast tanks
- Entire assembly built next to shore with crane support
- Floating ring truss provides work surface
- Temporary curtain around circumference to keep inside of detector clean
- Dome’s roof could be equipped with a radial crane

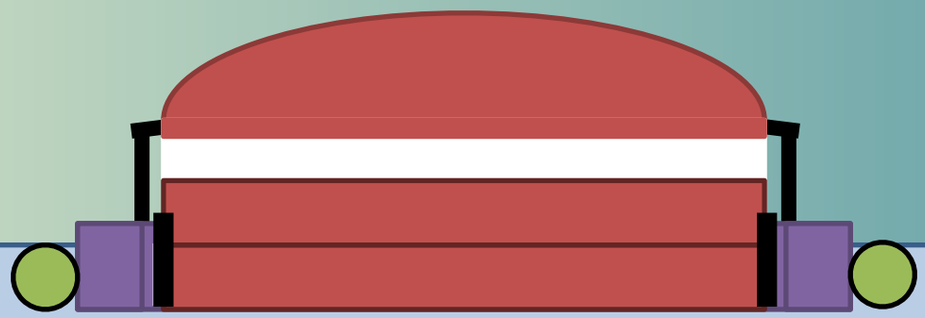


Assembly sequence on water

1. Build floor and first wall layer. The wall layer also attaches to the floating ring jacks.

Assembly sequence on water

1. Build floor and first wall layer. The wall layer also attaches to the floating ring.
2. First wall layer “climbs” down the floating ring into the water as it is filled.



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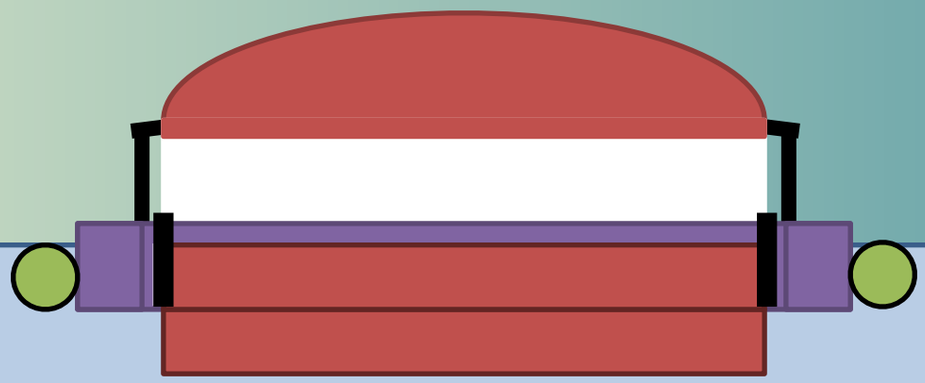
3. Build second wall layer.



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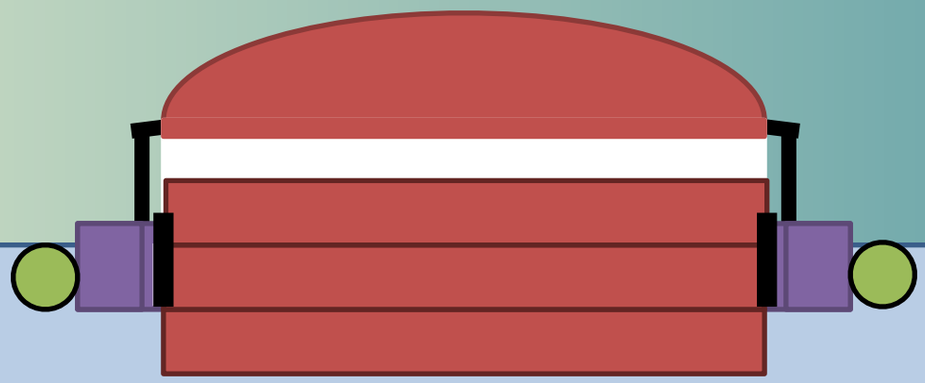
4. As layers are added the floor and wall assembly successively climbs down.



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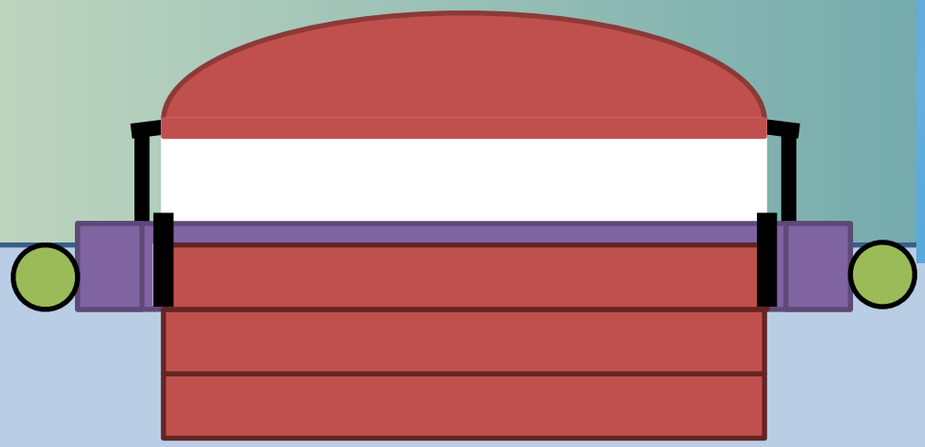

Similar to how a tower crane assembles itself

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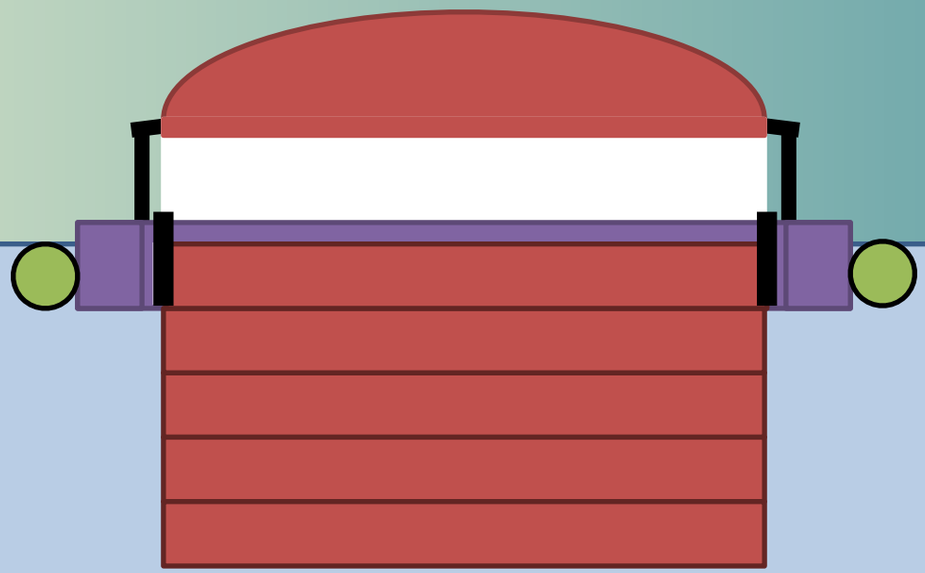

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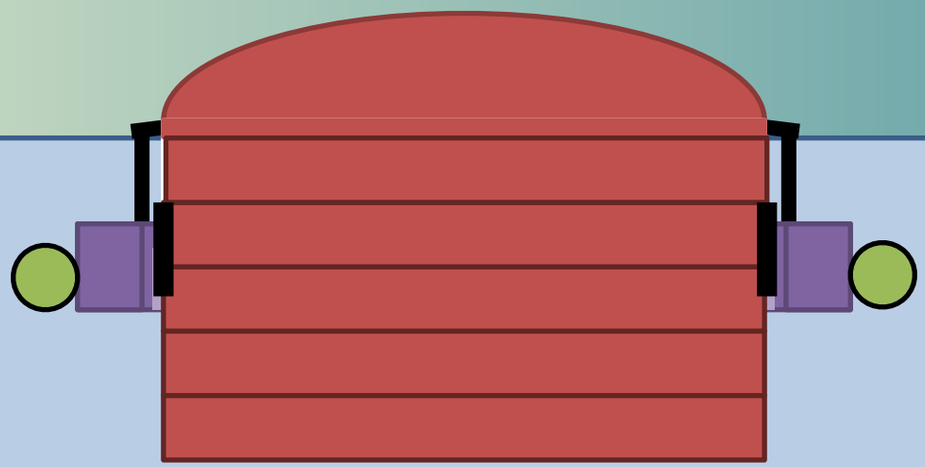

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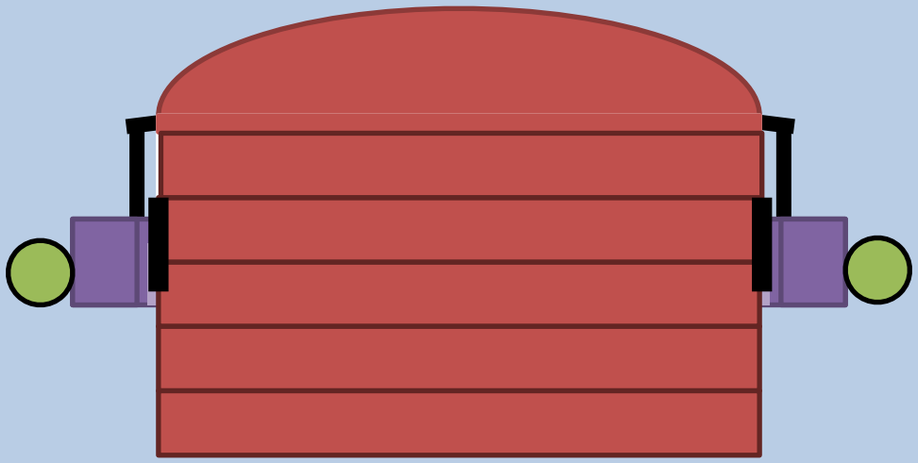
4. As layers are added the floor and wall assembly successively climbs down.
5. After all wall layers are assembled, ballasts are adjusted and the ring and top climb down the wall. A seal is made at the perimeter seam.



(Lowering)

Additional comments

- The ring truss may also be used for rigging and mooring.

CHIPS schedule

- Detector plane factories being set up now in Madison and Minneapolis
- 5 kilotons will be deployed next summer (2018)
- Hopefully data taking will start before end of 2018
- If successful,
  - ➡ we could expand the detector for $200k/kiloton in NuMI
  - ➡ we could propose a new larger detector for deployment in LBNE
    - If the PMTs don't get flooded :-)…