Opportunities using existing facilities

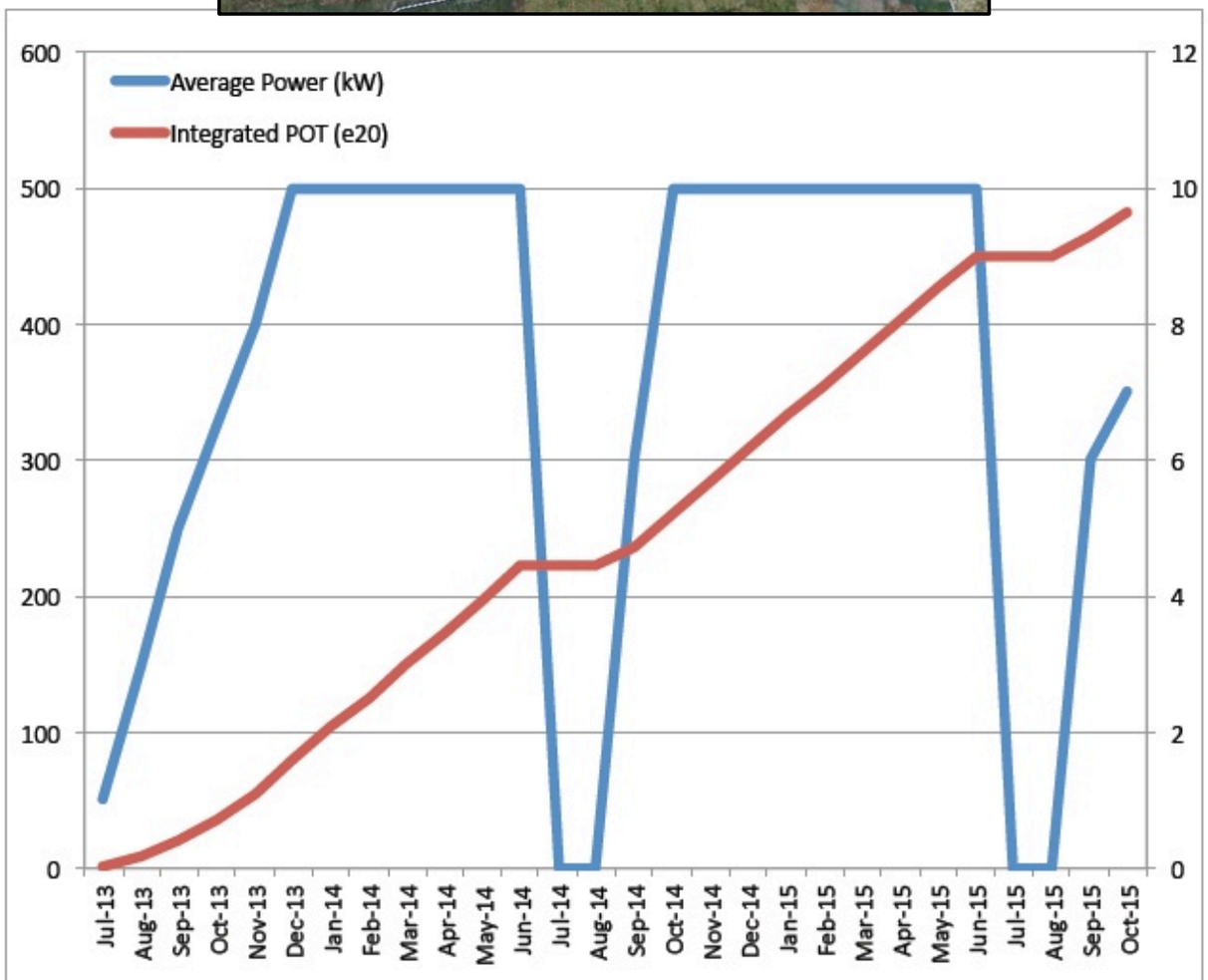
Mark Messier
Indiana University

CSS 2013
August 2, 2013

NuMI Neutrino Beam

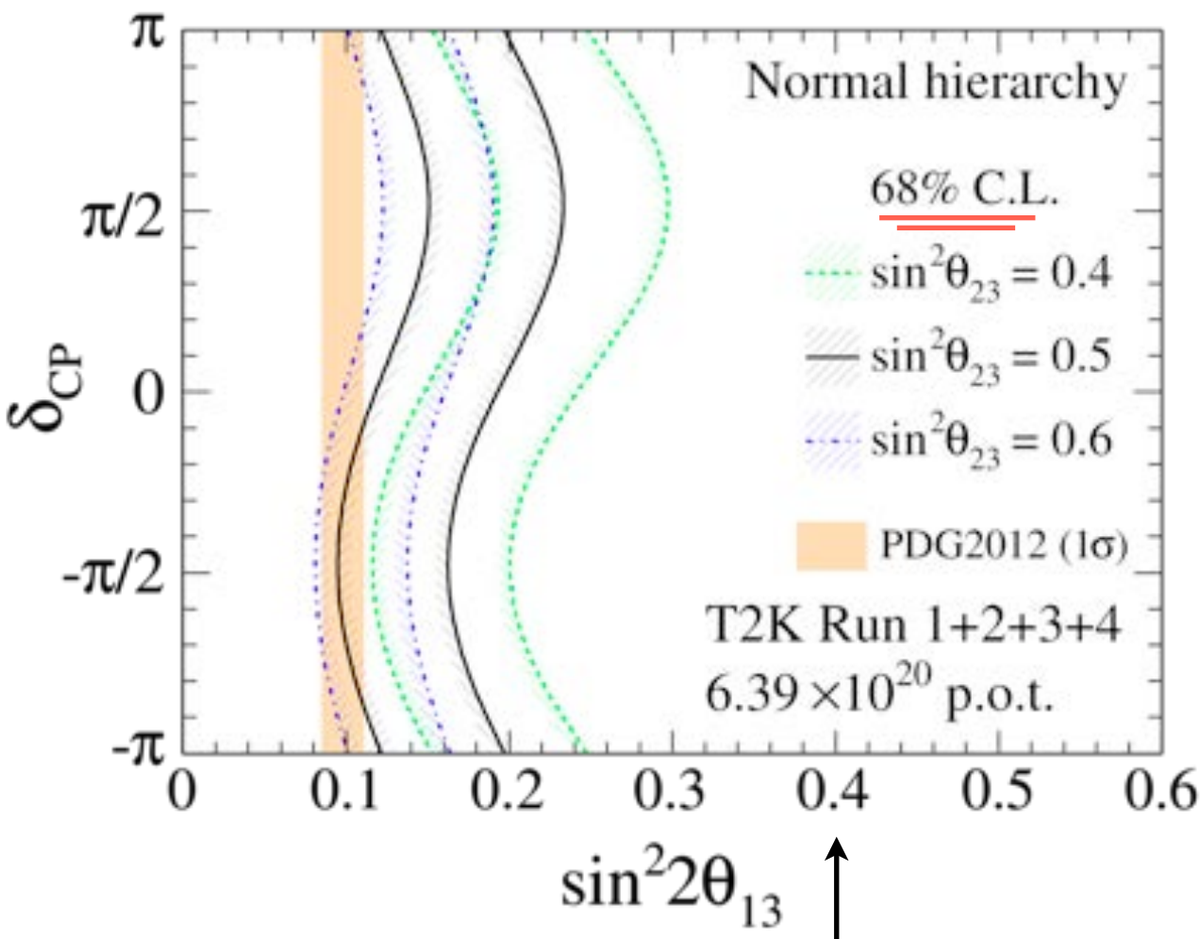
Ready, set, go!

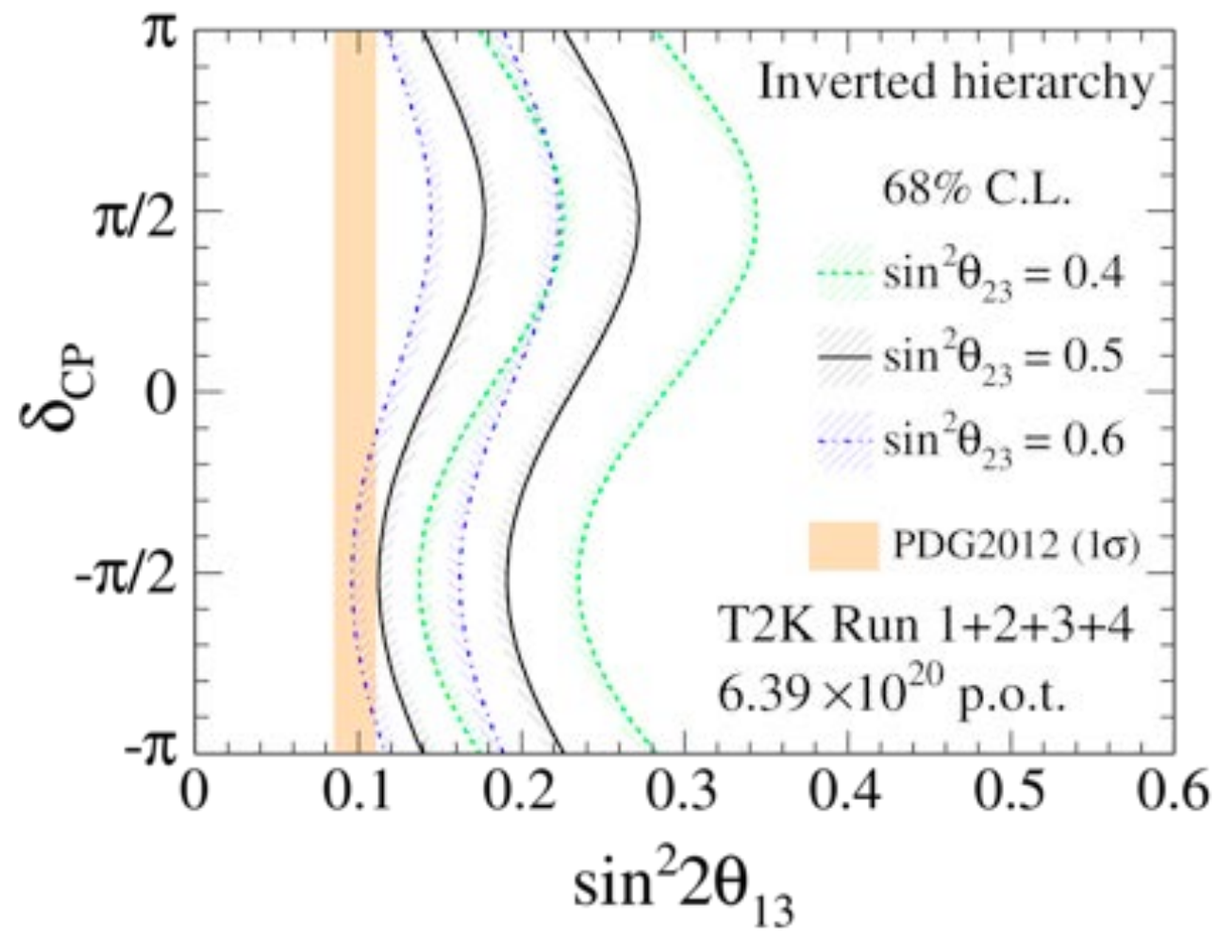
- The project to upgrade the Main Injector and NuMI for 700 kW operation is now complete.
- This will make NuMI the hottest neutrino beam on the planet
- Commissioning is underway. On Wednesday the MI ramped all the way to 120 GeV.
- Expect routine neutrino running by about September 1st
- MINOS+ and MINERvA ready for beam
- NOvA has 2 kt of detector being commissioned. More to follow soon.

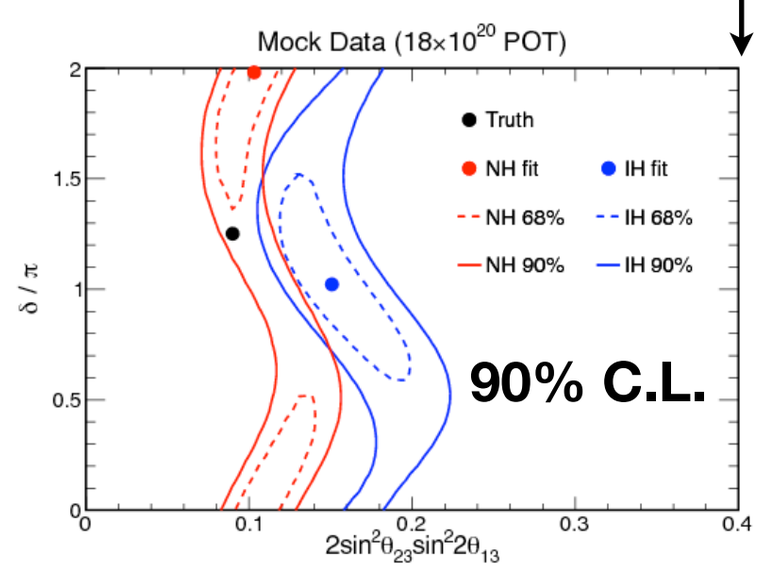


The decade ahead will be very exciting

Recent T2K results compared to reactors (Daya Bay + Reno + Double CHOOZ)







NOvA *projections for 3 years of neutrino running*

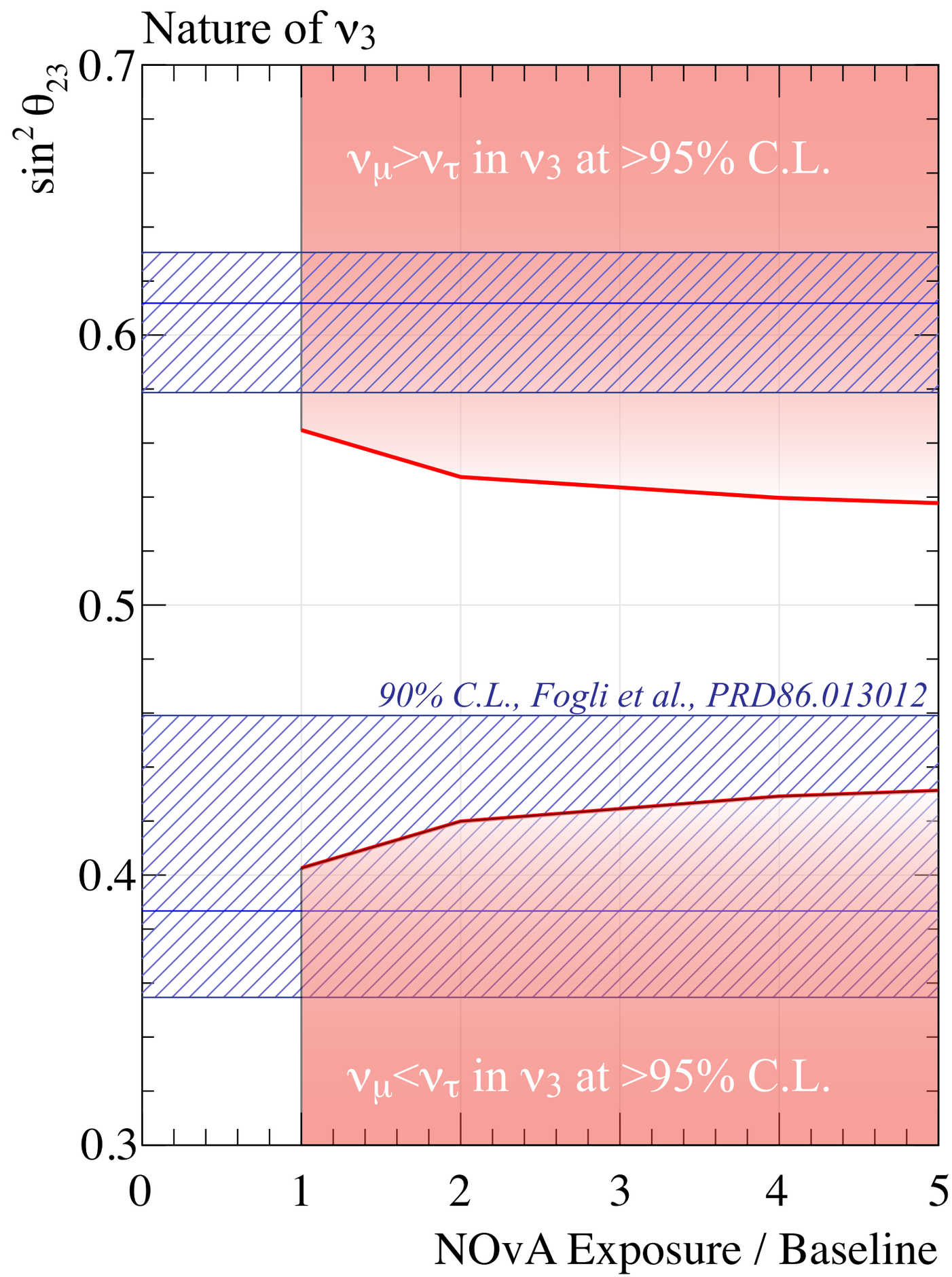
This is potentially great news for the future NOvA and LBNE program.
Q: What can we do to advance the LBNE program while exploiting the opportunities nature and the NuMI beam present us?

Adding detector mass at NOvA's Ash River site

Octant reach

NOvA's baseline exposure is

- 700 kW
- 14 ktons
- 6 years split evenly between neutrinos and antineutrinos



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Adding detector mass at NOvA's Ash River site

Hierarchy reach

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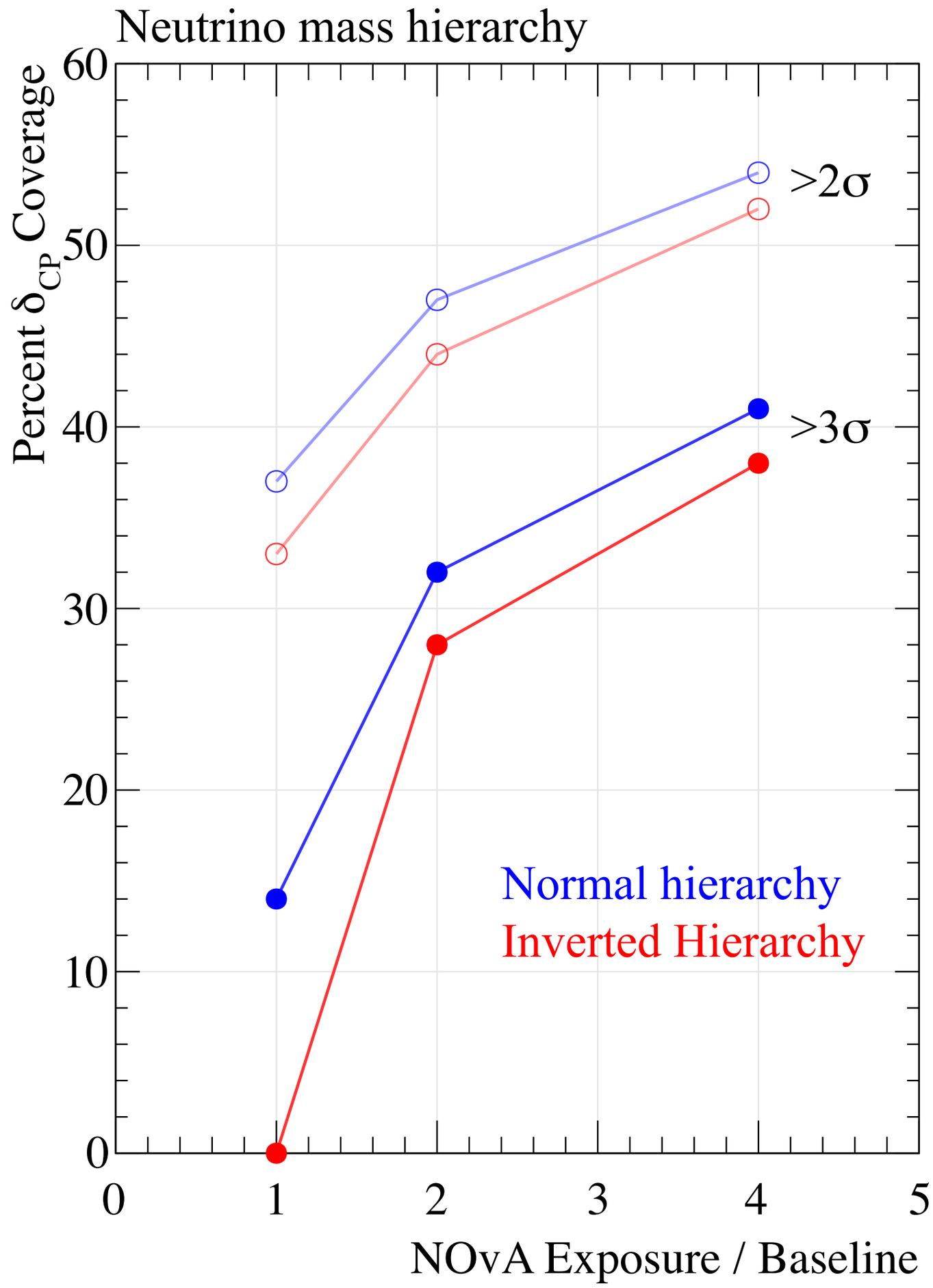

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Adding detector mass at NOvA's Ash River site

CPV reach

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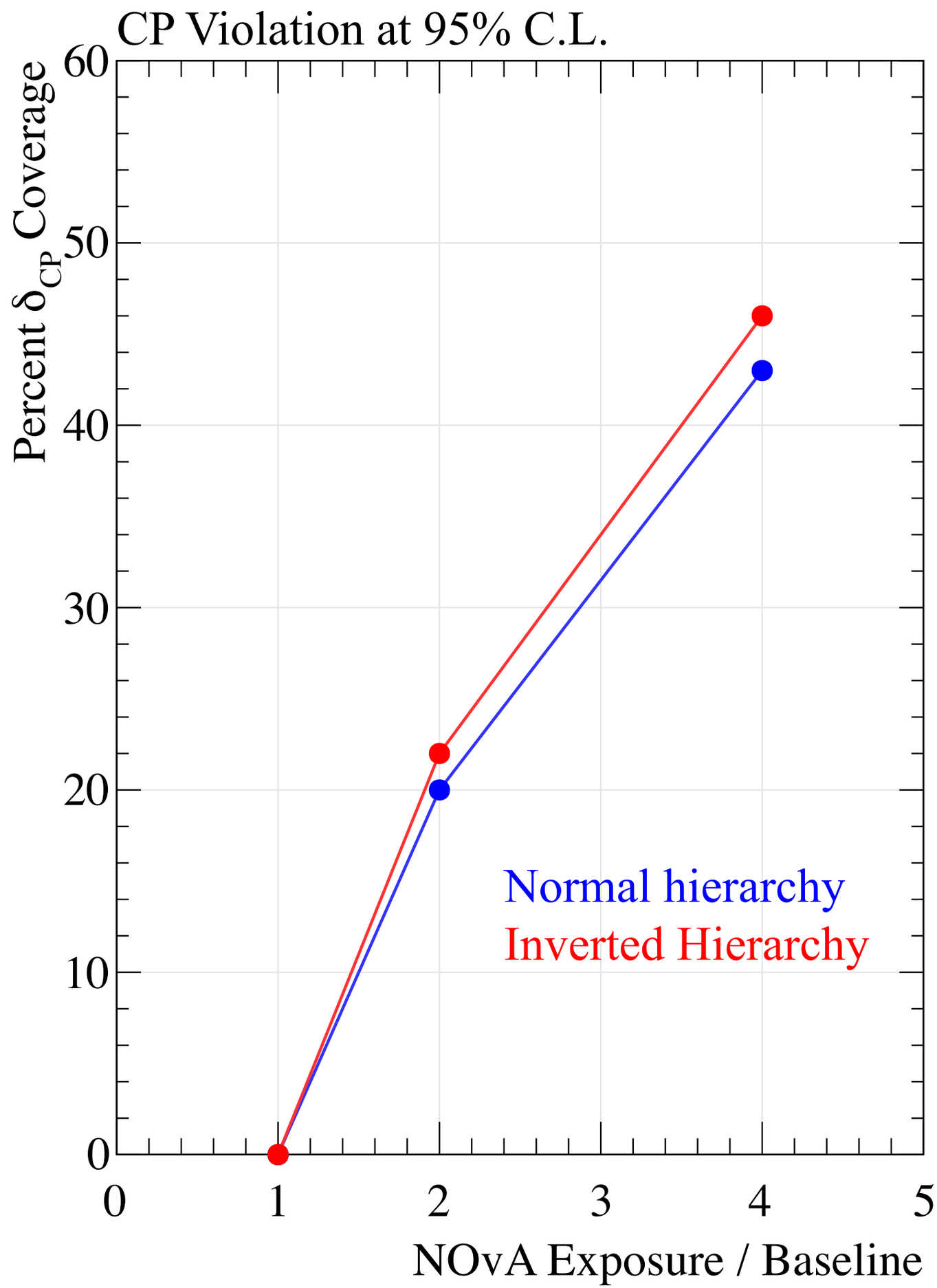

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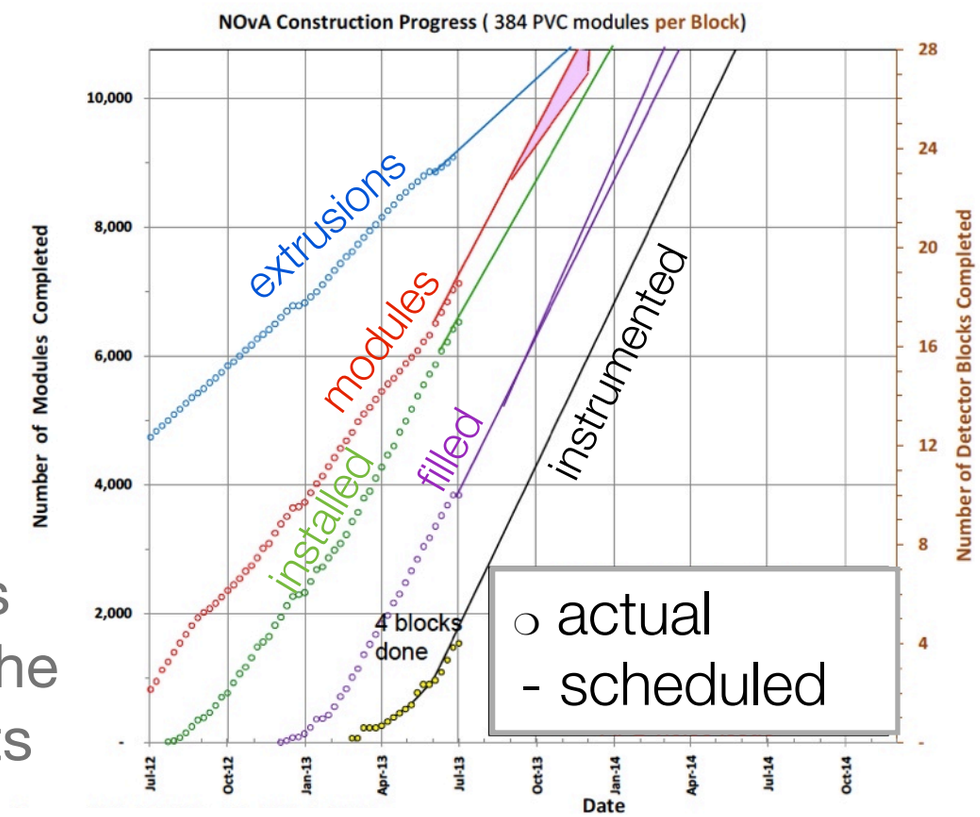
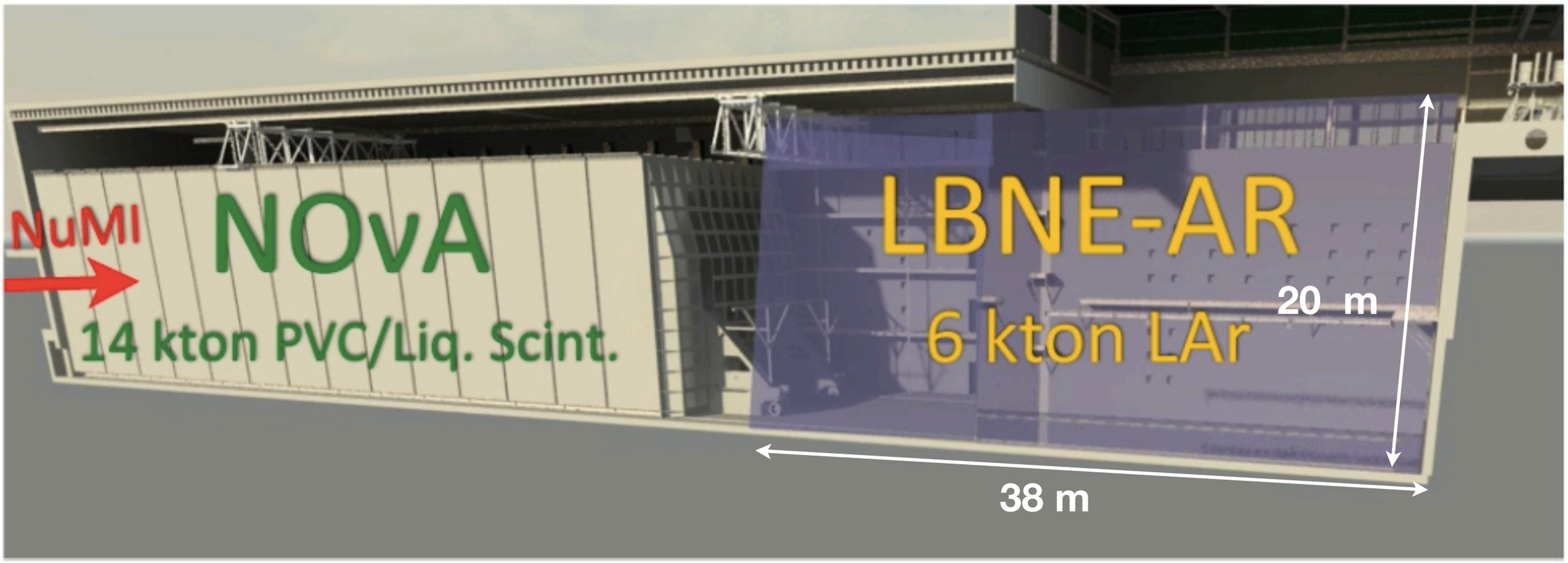
NOvA, LAr@Ash River, CHIPS

- The most straight forward way to extend the NuMI reach is to build more **NOvA**.
  - The detector hall is sized for 18 kt and we have funds to build 14 kt. NOvA construction is proceeding very well and costs are known.
  - Including all the start-up and R&D costs, NOvA costs about $9M/kt. But if we keep the factories going, this cost is reduced to $6M/kt. Building the modules and filling and instrumenting later, costs ~$2M/kt.
  - A decision on this would need to be made fast as NOvA construction will begin ramping down early next year.



- A second way, **LAr@Ash River**, would be to fill empty space in the NOvA hall with a large liquid argon detector
- A third way is **CHIPS** which would build a large water Cherenkov detector in an abandoned mine pit at a new location

“LBNE at Ash River” aka “RADAR”

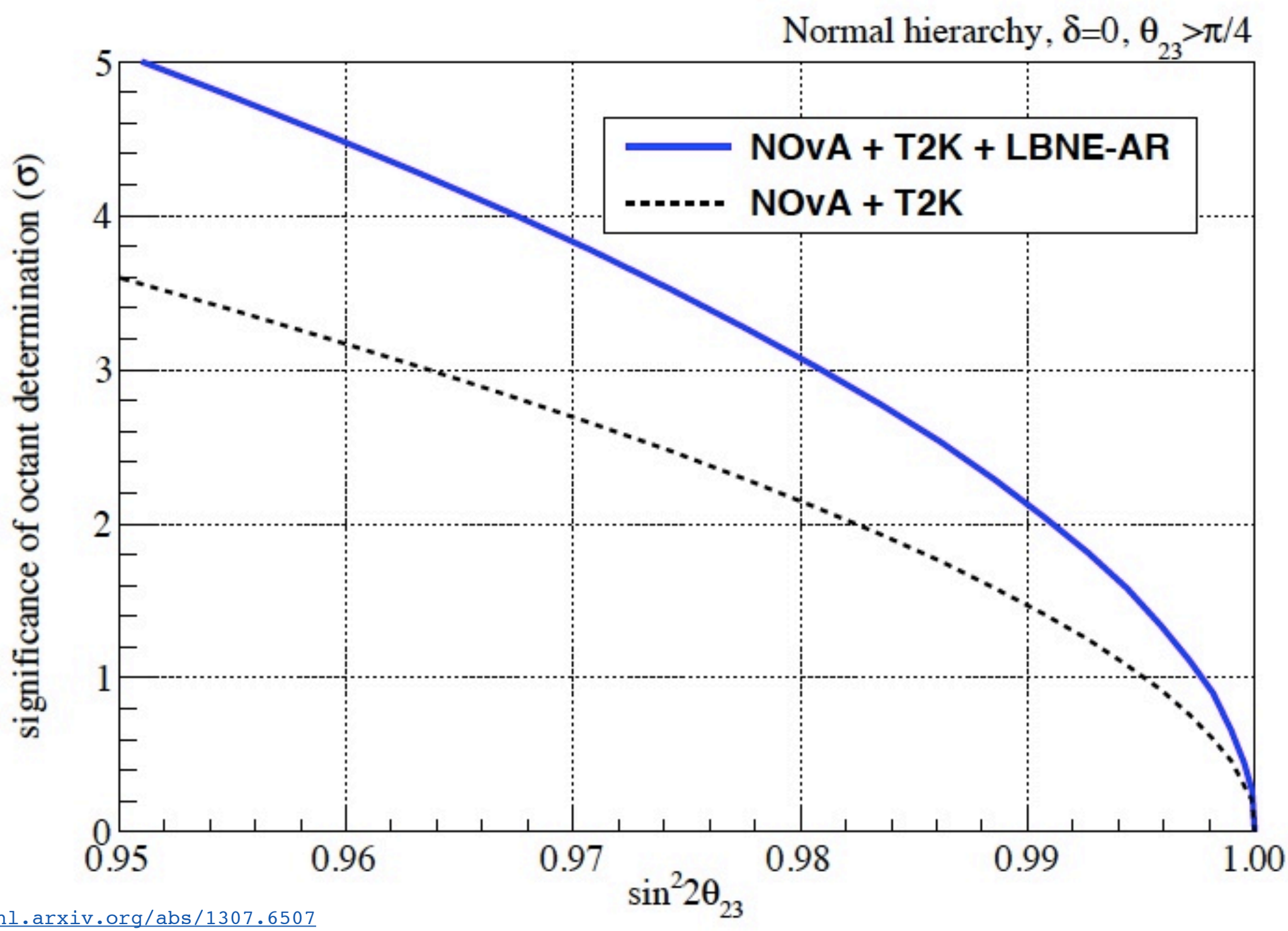


- 5 years to construction
- Estimated cost $108M
- Of this potentially $46M could be applied directly to LBNE

http://lanl.arxiv.org/abs/1307.6507

LBNE-AR
Octant reach

NuMI = 700 kW in medium energy tune
NOvA = 14 kt x 10 years
RADAR = 5.6 kt x 5 years
T2K = 6 year proposed run



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LBNE-AR

Mass hierarchy reach

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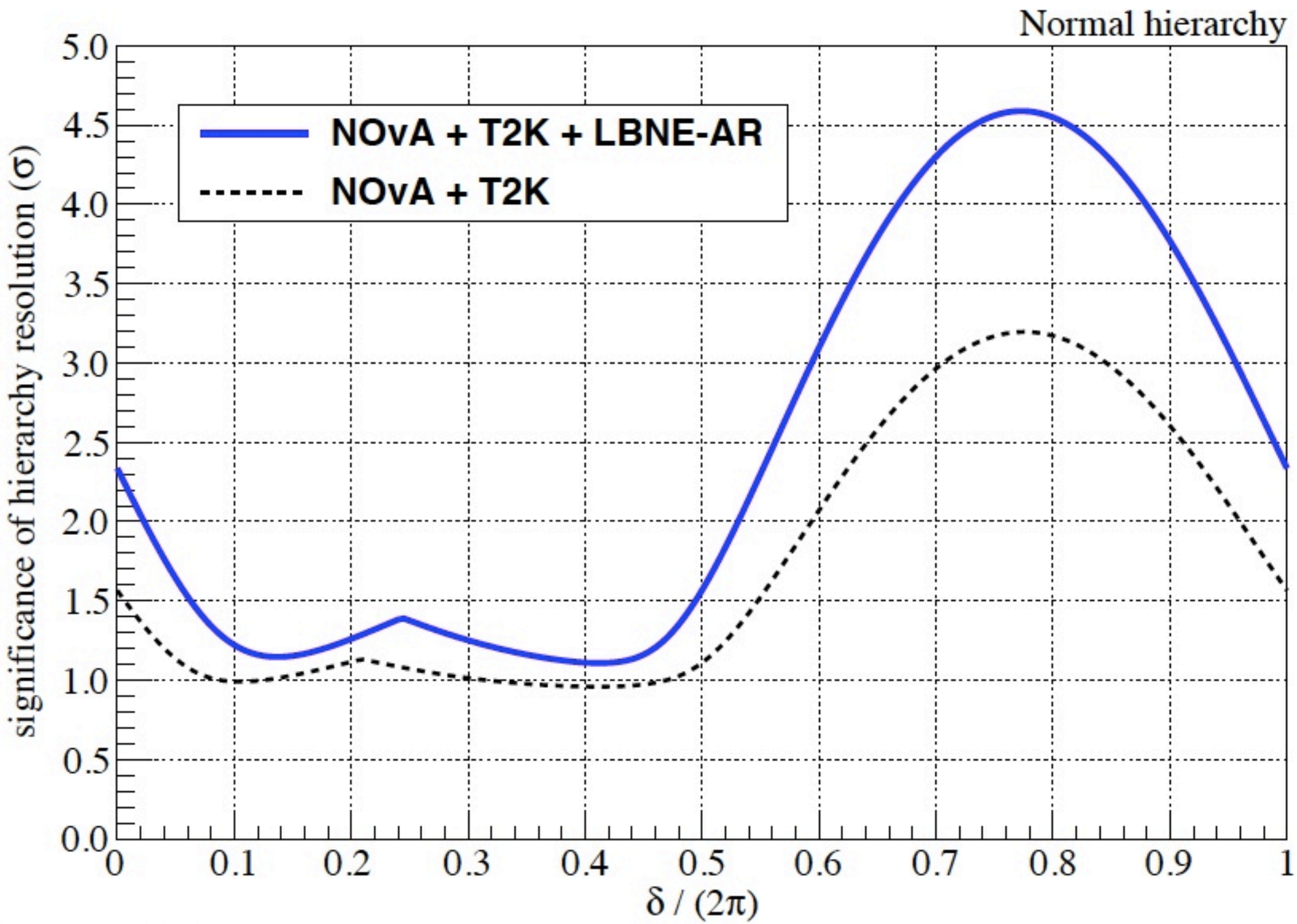

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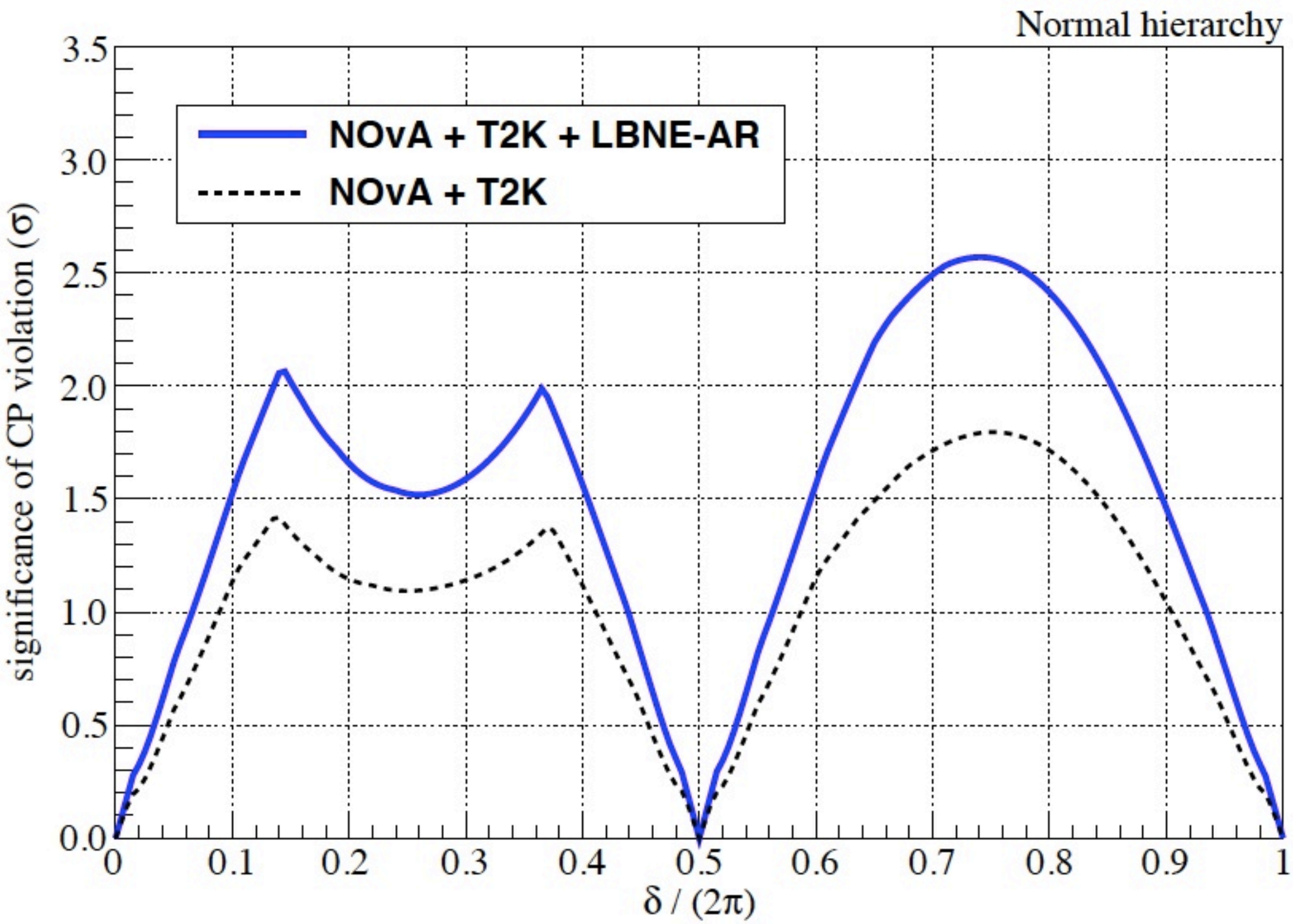

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LBNE-AR

- LBNE-AR physics reach does not compete with “next generation” LBNE. It builds on and extends the current program physics reach.

- LBNE-AR may prove useful to further the LBNE-Homestake program:

  - **As detector R&D**. If constructing LBNE-AR results in a 10% savings for construction at the Homestake site, LBNE-AR could pay for itself.

  - **As a focal point** for establishing collaboration and working relationships, especially for foreign collaborators

  - **As as training ground** for building and maintaining expertise with this new technology to support LBNE design, construction, and operation, over the long term.

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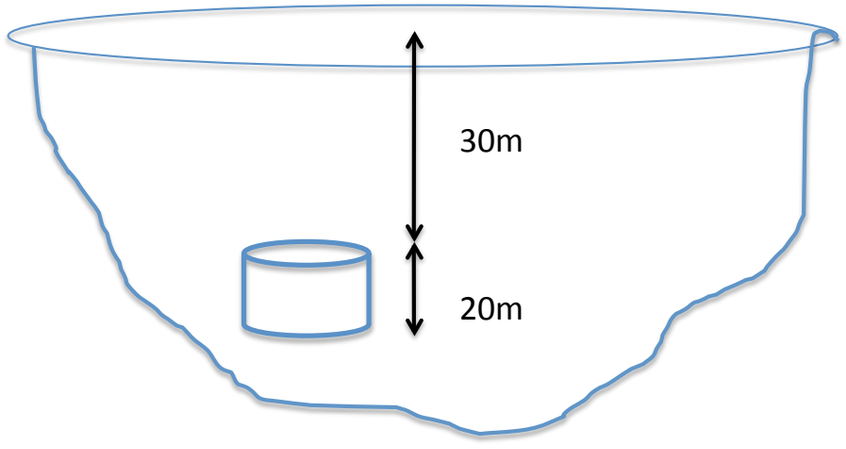
CHIPS

Water Cherenkov in Mine Pits

- CHIPS is an R&D program to investigate techniques to reduce the detector costs to roughly $100k/kt that is deemed necessary to consider mega-ton scale detectors
- Concept is to use industrial techniques used by fisheries industry to construct a floating platform supporting a WC detector at 30 m depth in a lake
- PMTs deployed using the floating deployment techniques developed for LBNE WC design
- Harkens back to ideas like GRANDE and DUMAND
- Estimate cost is $1M/kt x 100 kt = $100M
- Reuse: Get started in NuMI beam and relocate to LBNE



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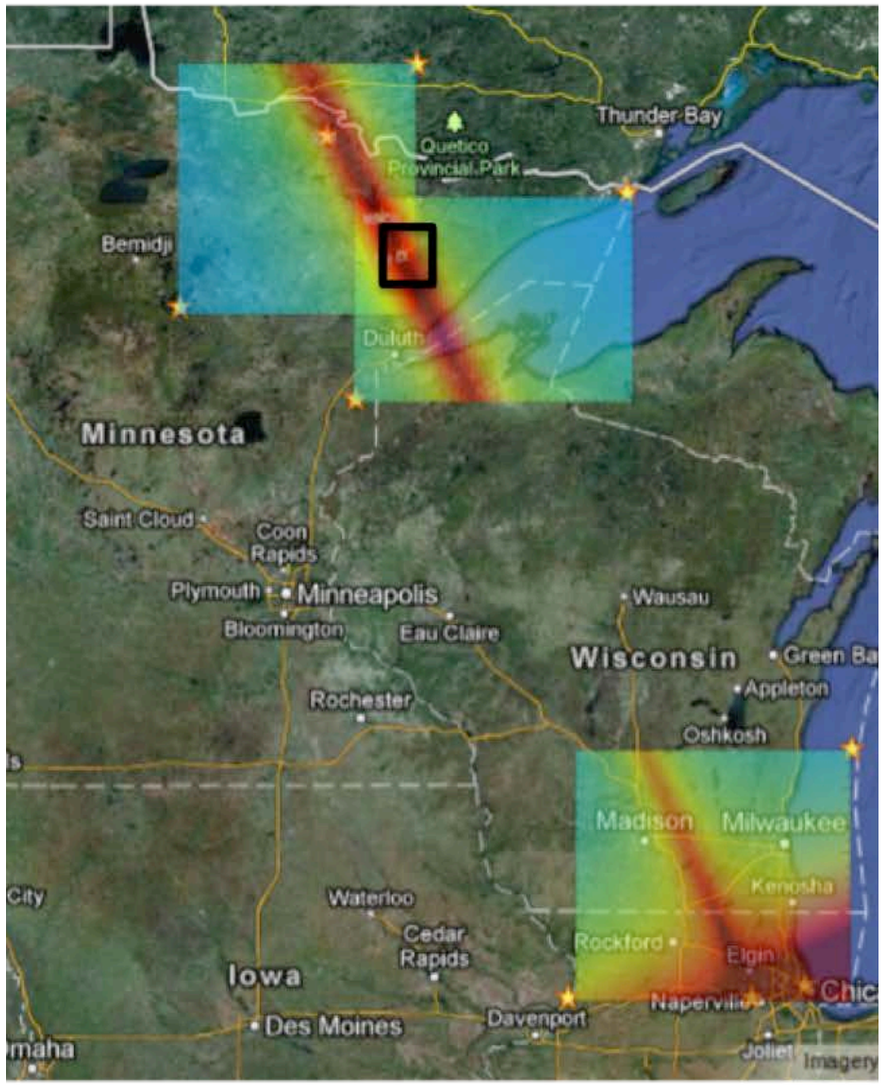
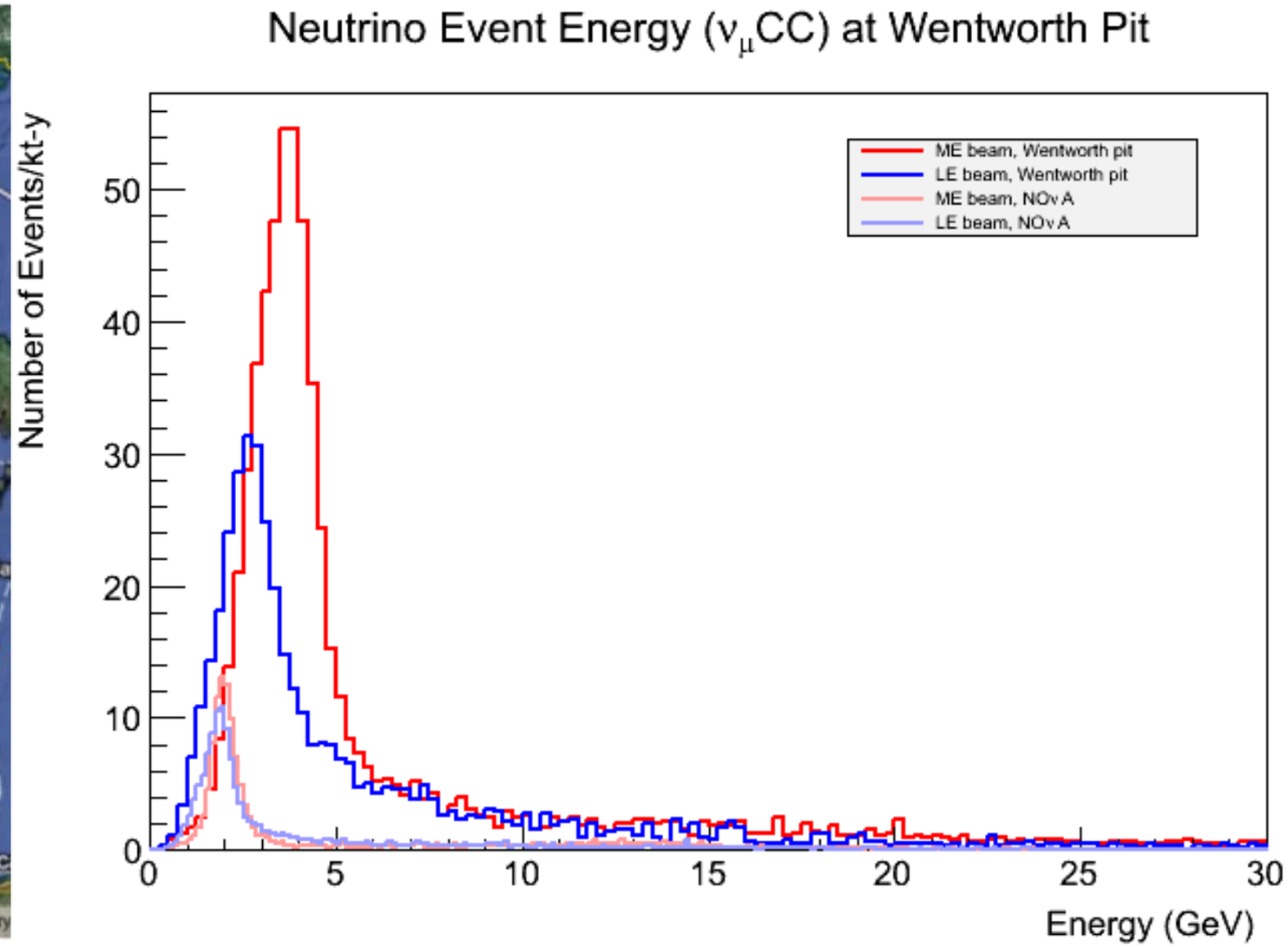
CHIPS site

Wentworth Pit, MN. 7 mrad off-axis L = 712 km





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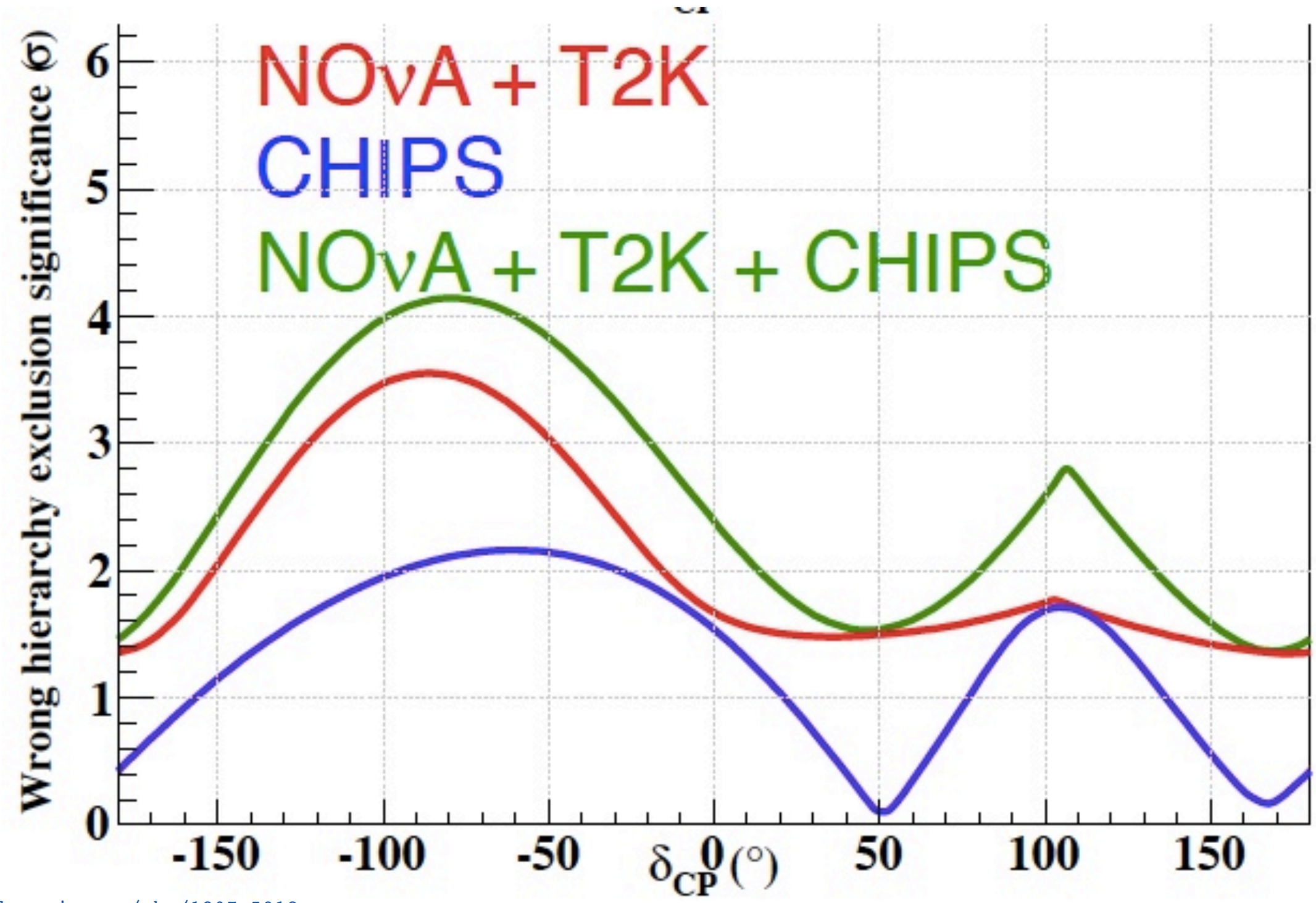
CHIPS 100 kt reach in NuMI

Mass Hierarchy

NOνA + T2K

CHIPS

NOνA+T2K+CHIPS



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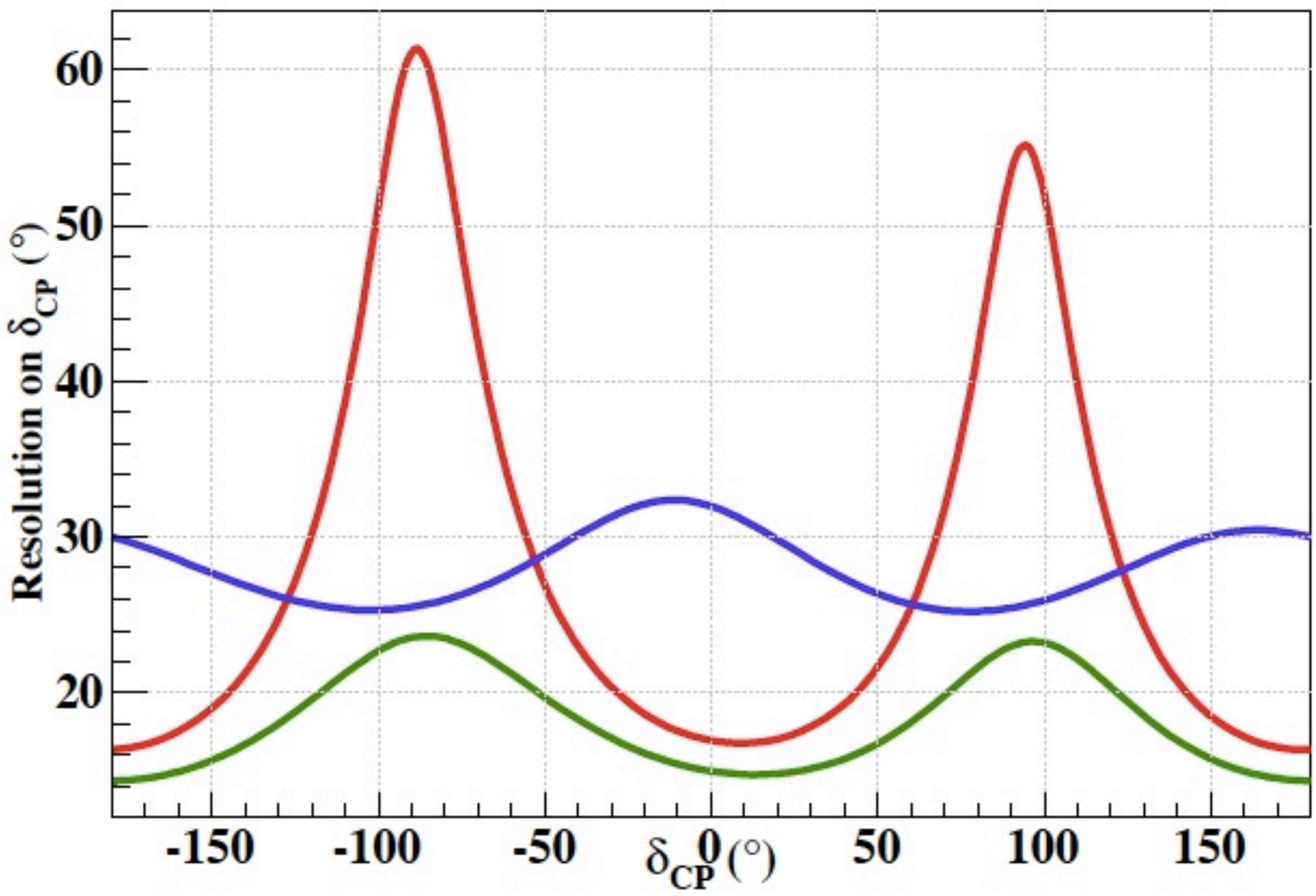
CHIPS 100 kt reach in NuMI

CPV



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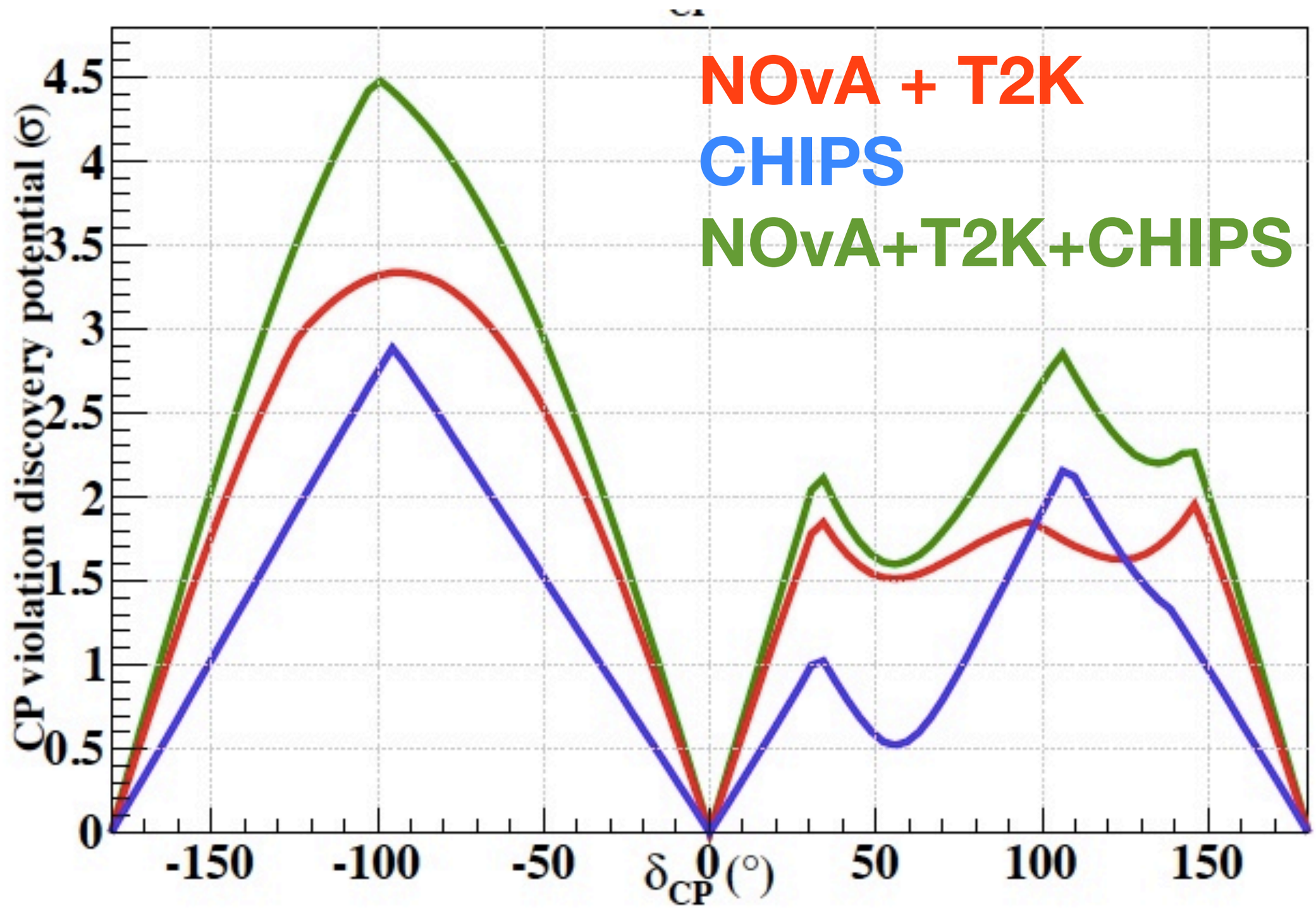

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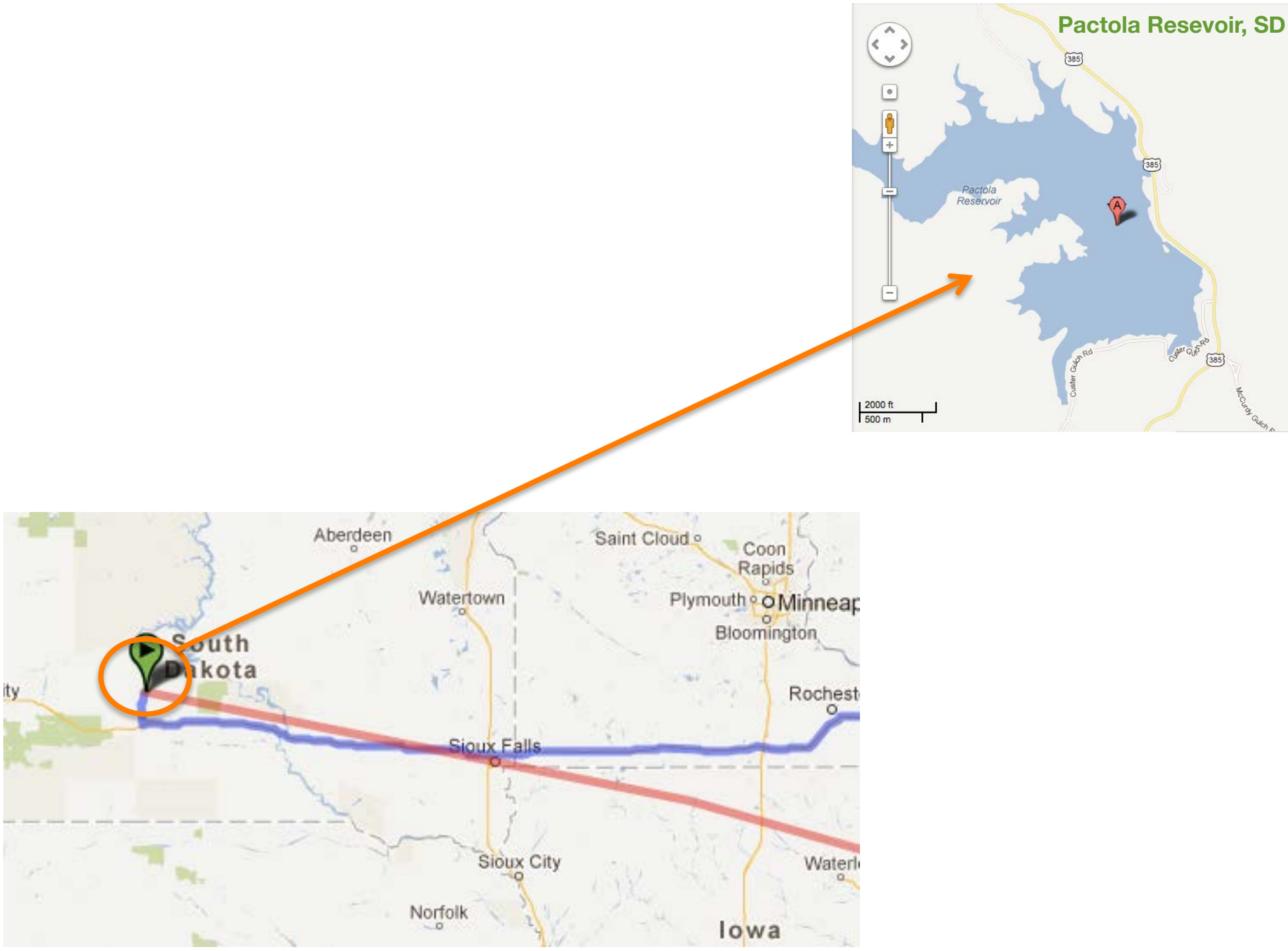
CHIPS in LBNE



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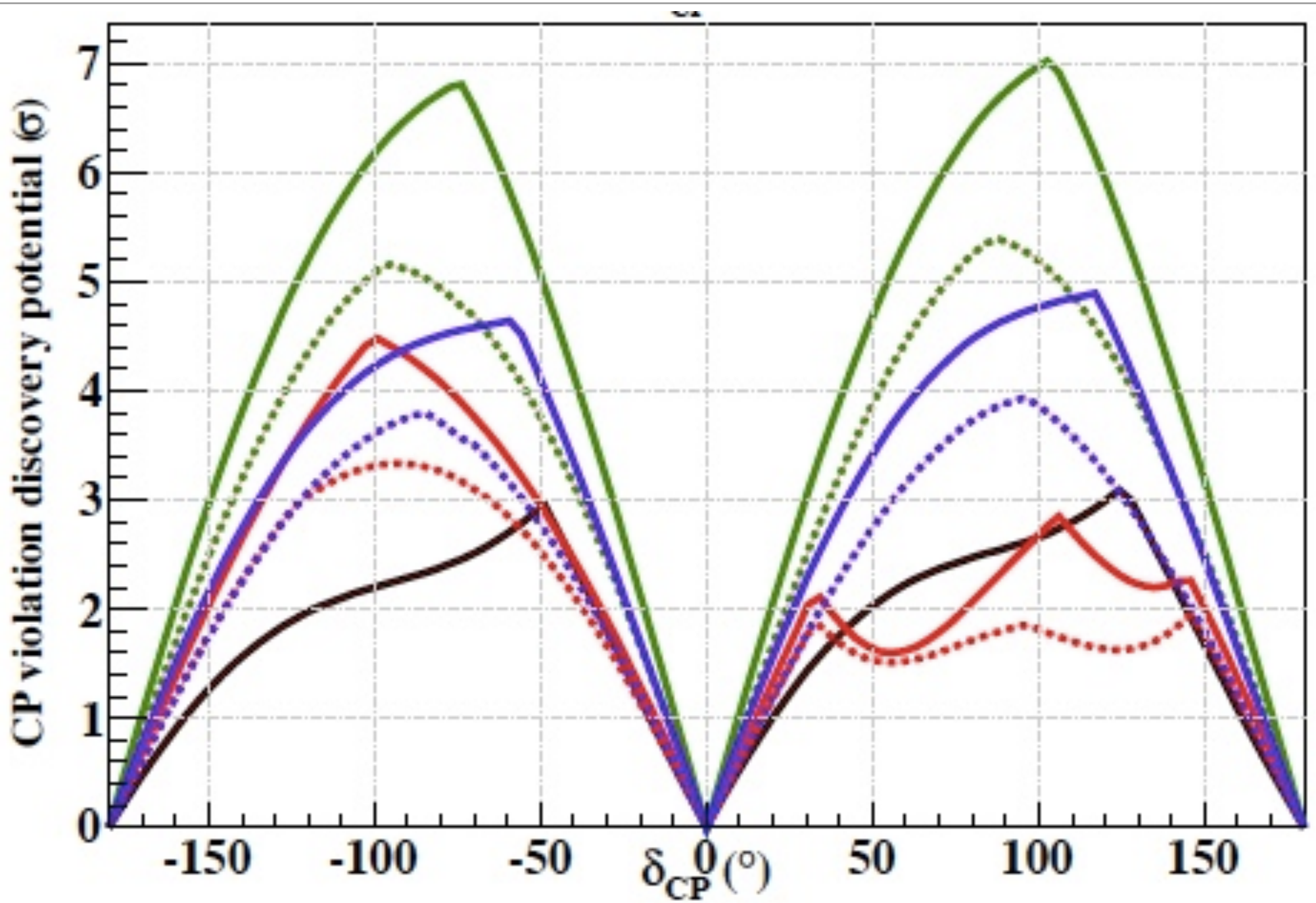
CHIPS in LBNE

CPV



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Other opportunities using existing facilities at Fermilab site

- **LAr1** - Short baseline neutrino oscillation search using booster and NuMI beams. LOI presented to Fermilab PAC.

- **NOvA-2 km -** Short baseline neutrino oscillation search using a new off-axis detector in the NuMI line at L = 2 km. Presented at workshops.

- **SciNOvA** - Neutrino cross-sections, esp. QE and NC cross-sections, in 2 GeV narrow-band beam using a new fine-grained detector in front of the NOvA near detector. LOI presented to Fermilab PAC.