Status of NOνA

NNN12 – Fermilab
October 4, 2012

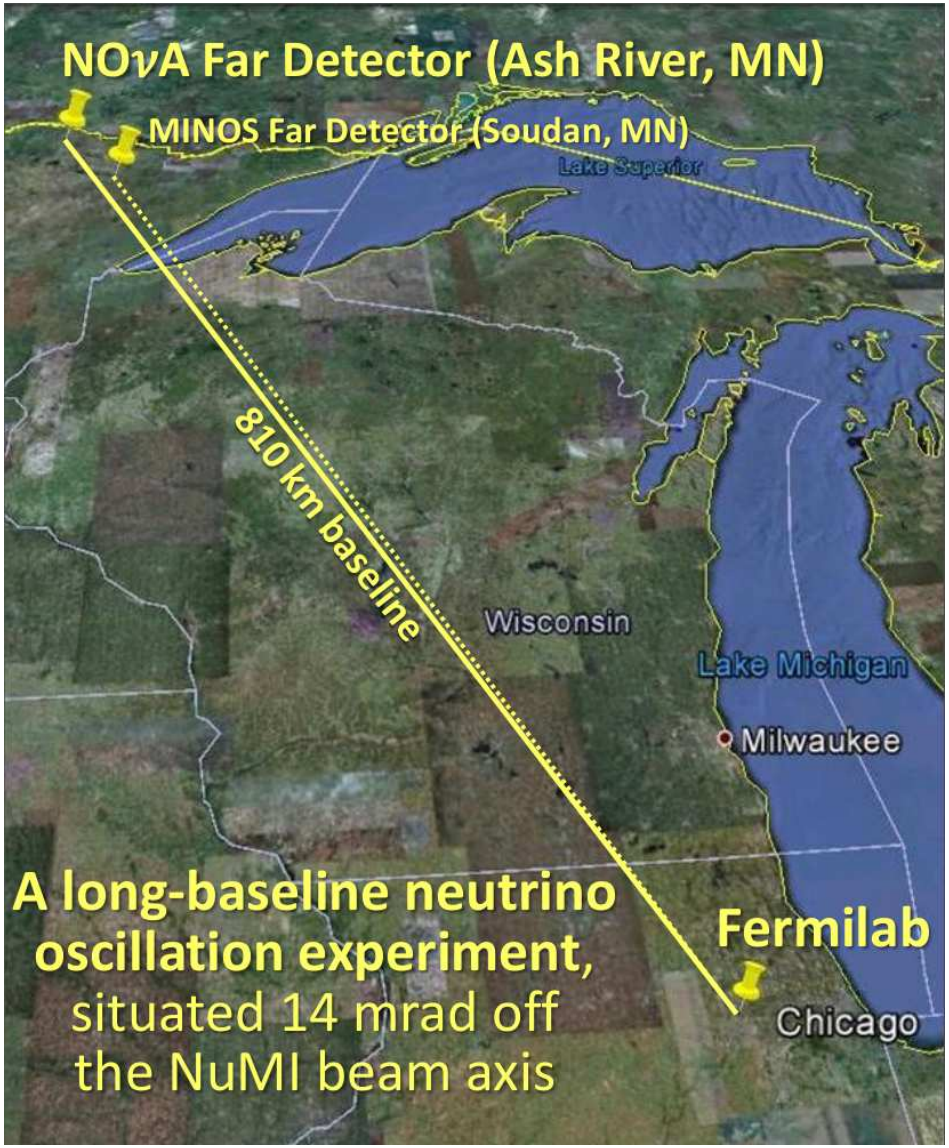
Christopher Backhouse
Caltech

for the NOνA Collaboration

Physics goals

$\nu_\mu \to \nu_e$

- Measure θ_{13} via ν_e appearance



Physics goals

$\nu_\mu \to \nu_e$

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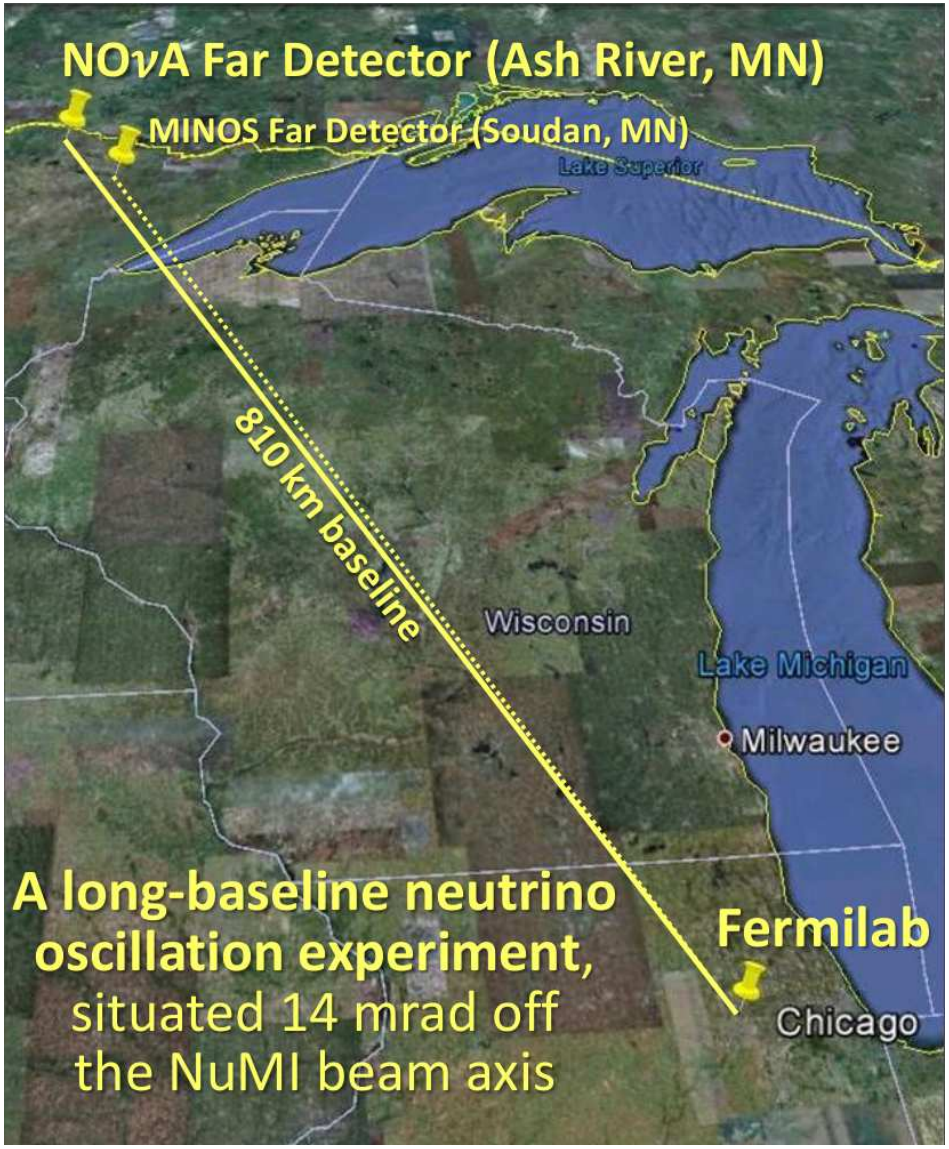
$\nu_\mu \to \nu_\mu$

- Precision measurements of $|\Delta m^2_{\text{atm}}|$ and θ_{23}
- Could exclude maximal mixing



Physics goals

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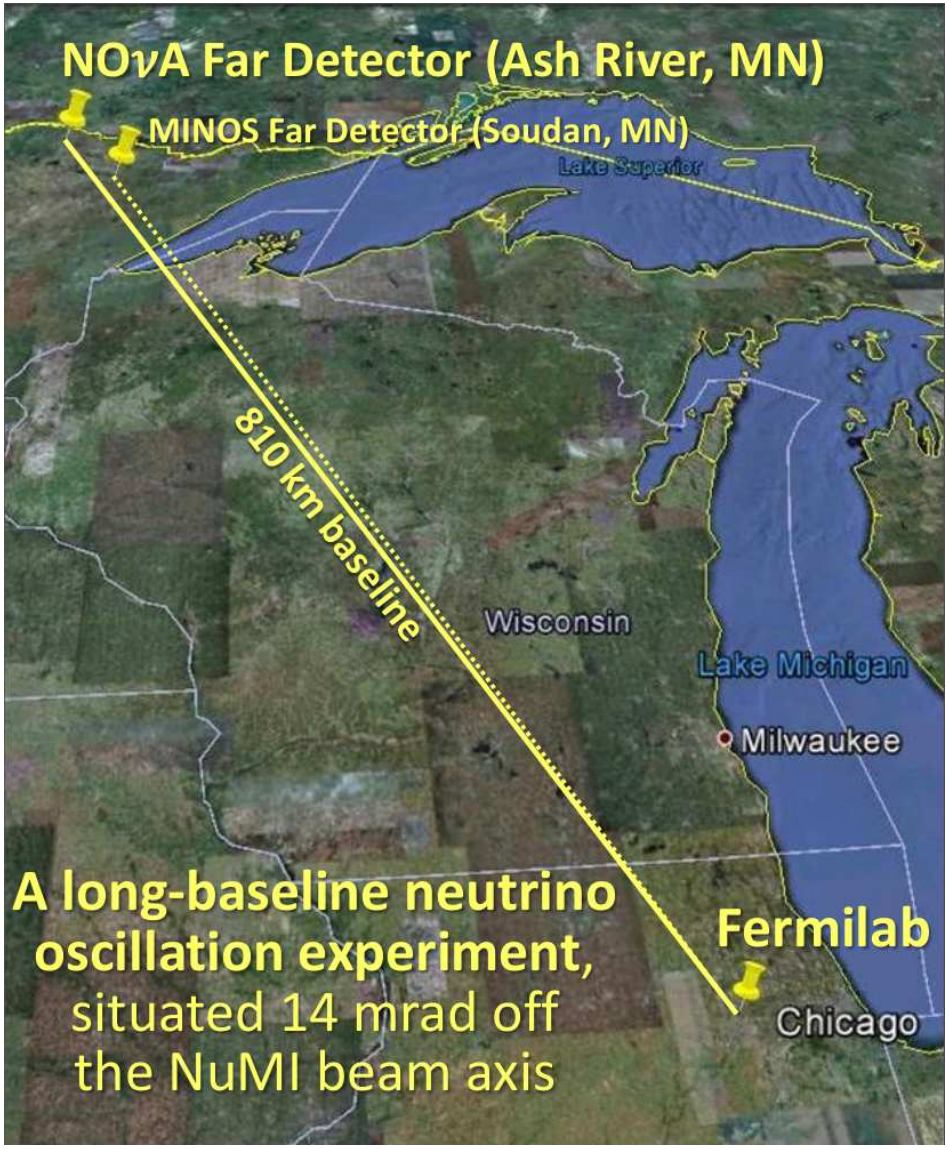

Physics goals

$\nu_\mu \to \nu_e$ **and** $\bar{\nu}_\mu \to \bar{\nu}_e$

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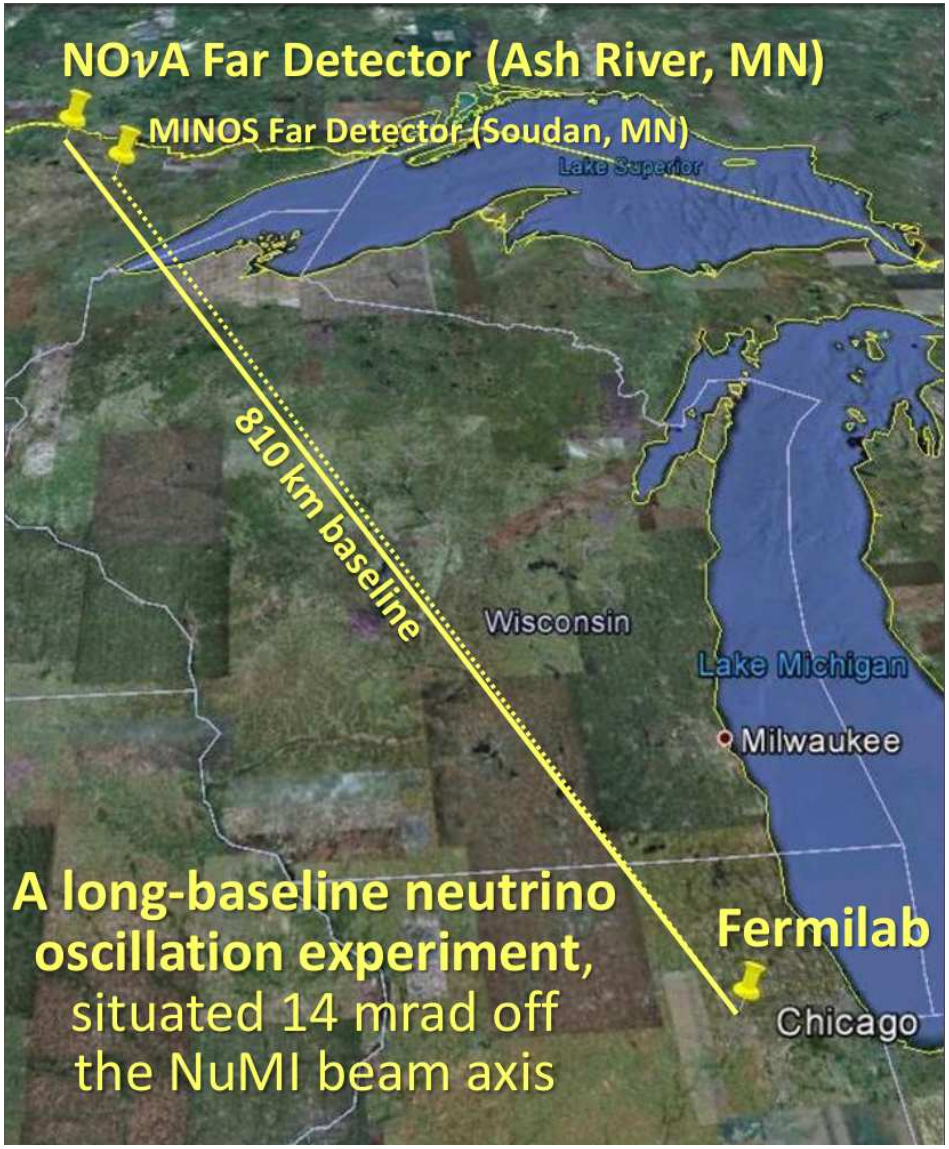

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$\nu_\mu \to \nu_e$ **and** $\bar{\nu}_\mu \to \bar{\nu}_e$

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- Search for $\delta_{CP} \neq 0$

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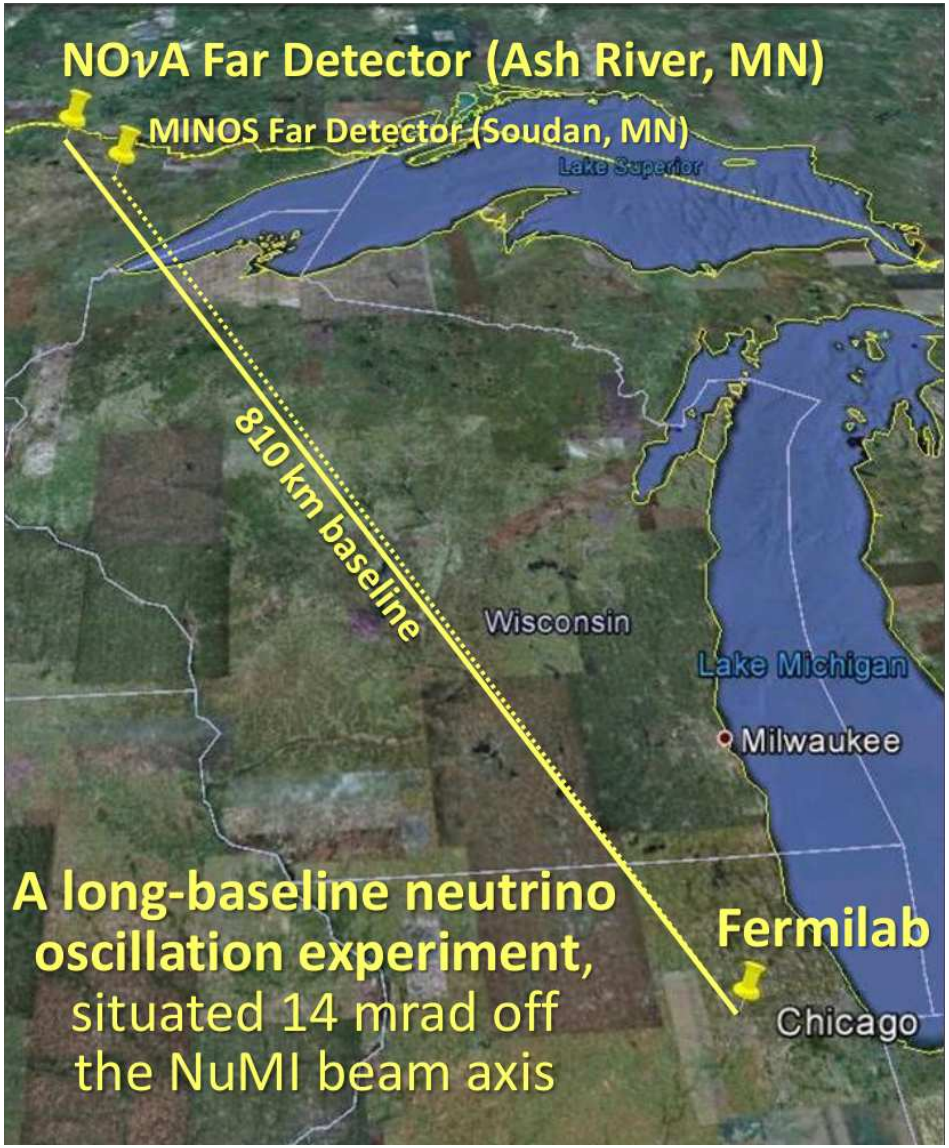

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$\nu_\mu \to \nu_\mu$ and $\bar{\nu}_\mu \to \bar{\nu}_\mu$

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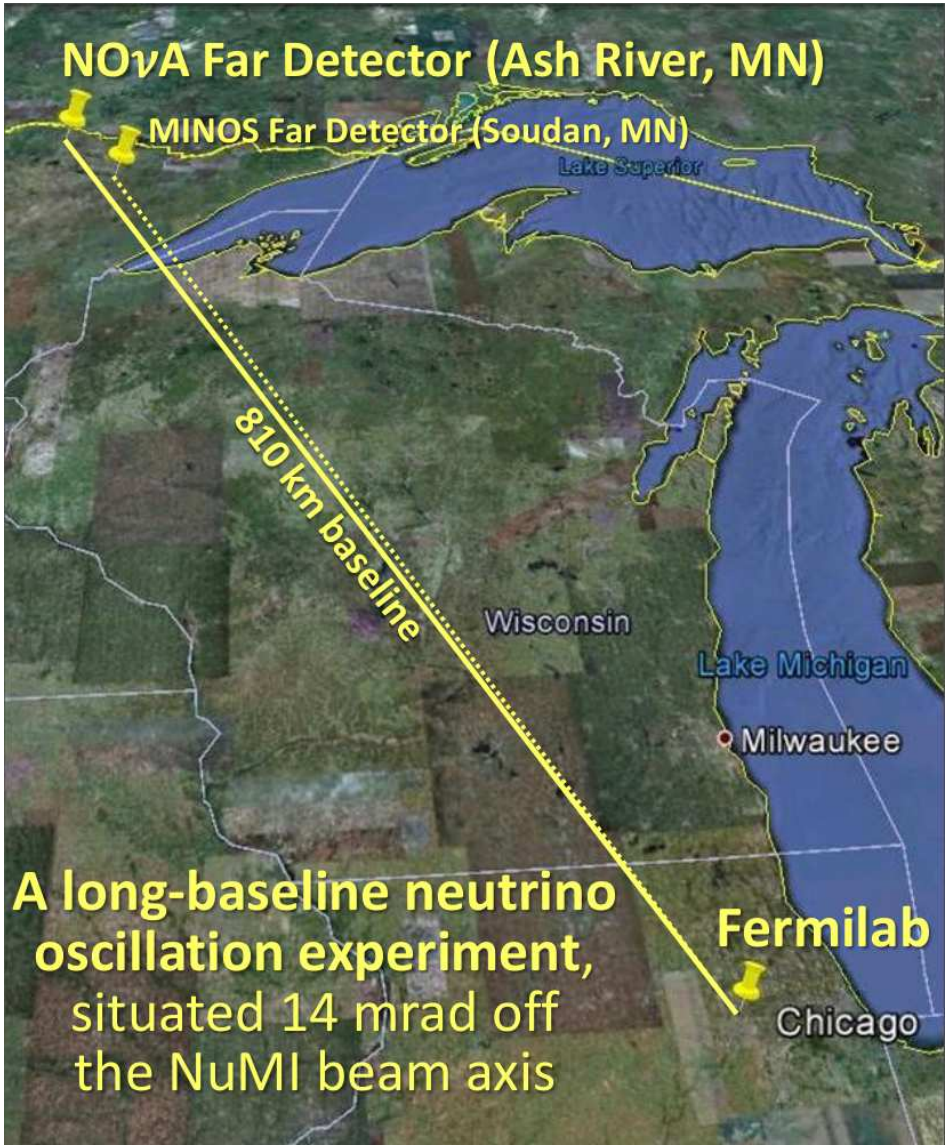
And...

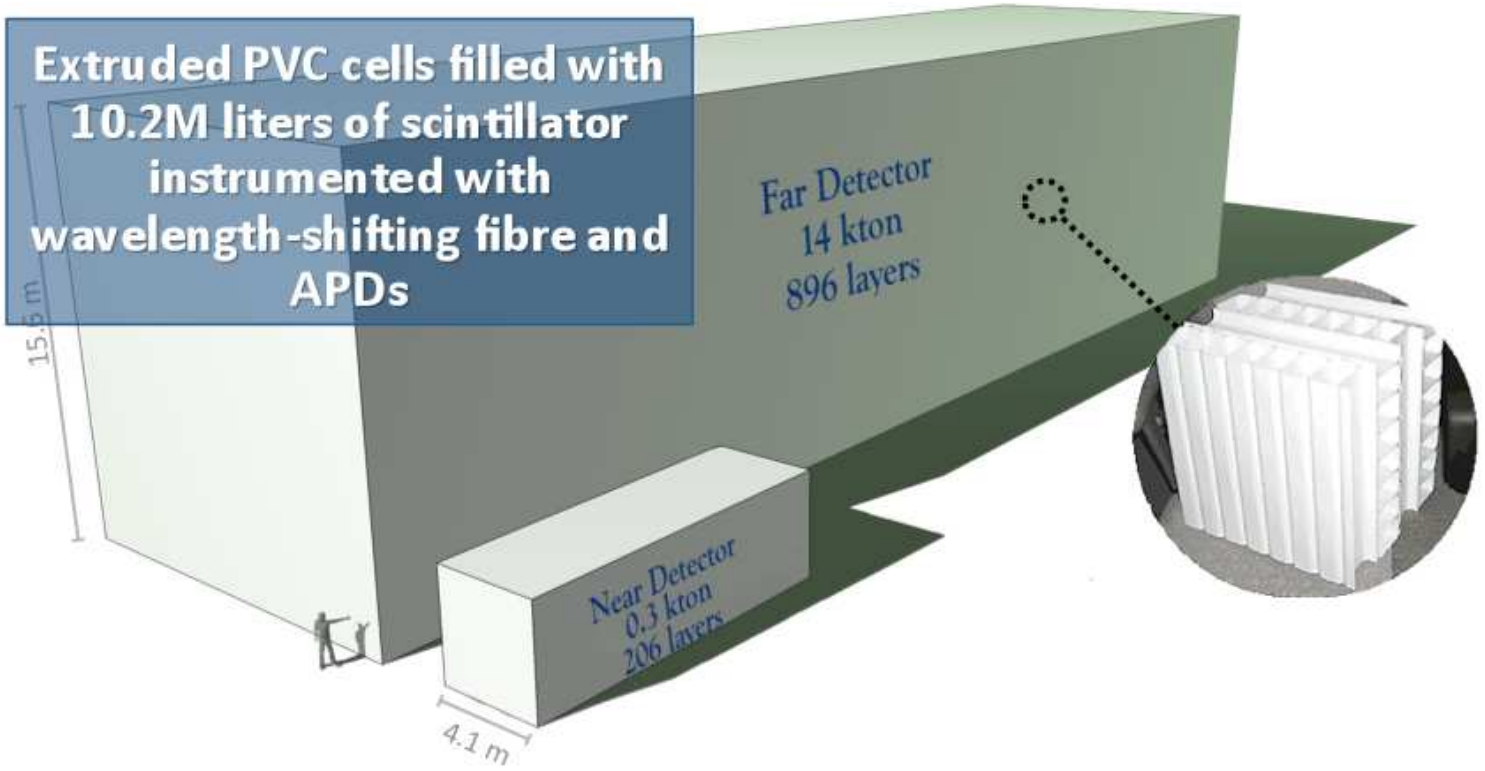
- Cross-sections from the ND
- Steriles, supernovae, exotica

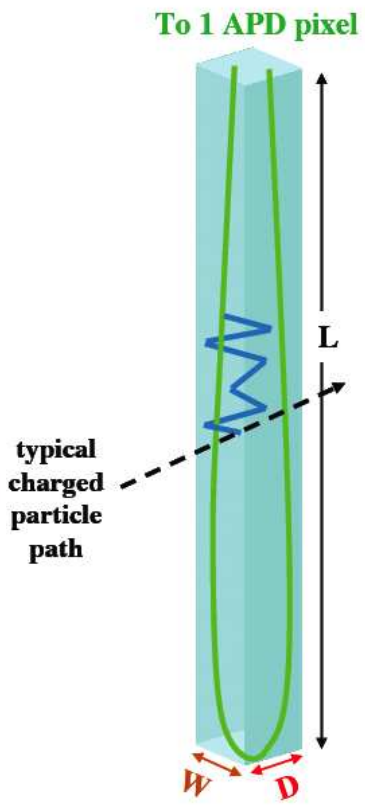


The NOνA Collaboration

$\sim$200 scientists and engineers from $\sim$30 institutions

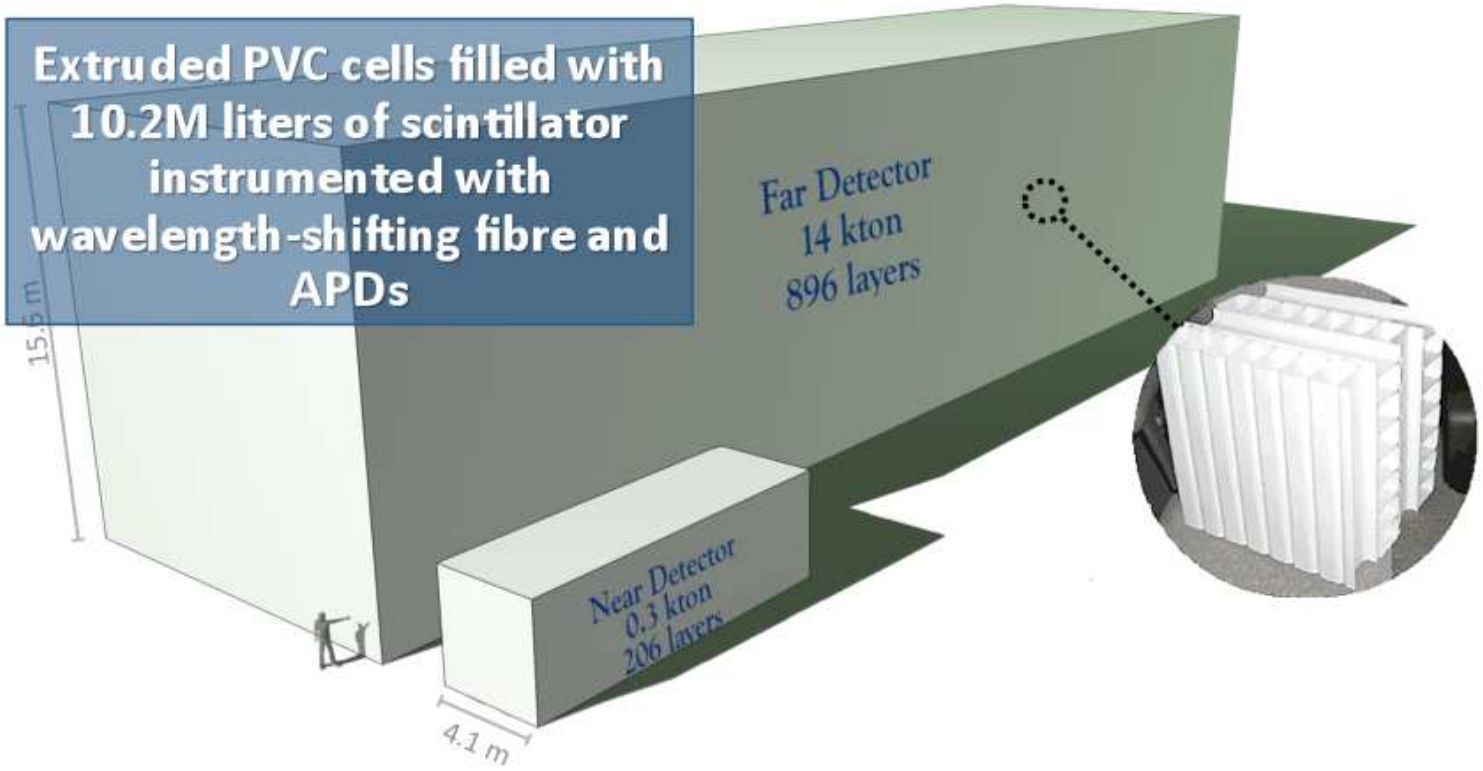
Detector technology

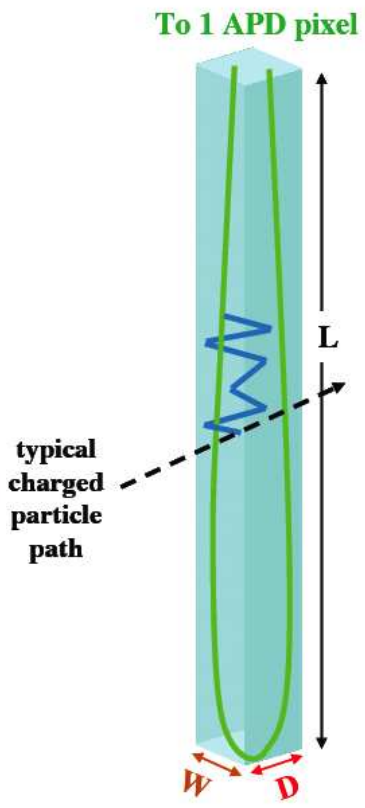




- Fine-grained low-Z, highly active, tracking calorimeter
- 64% liquid scintillator by mass
- WLS fibres looped in 4x6cm cells of PVC extrusion
- Each to one of 32 pixels of Hamamatsu APD
- $\sim$85% quantum eff. Gain $\sim$100$\times$. Cooled to -15°C

Detector technology





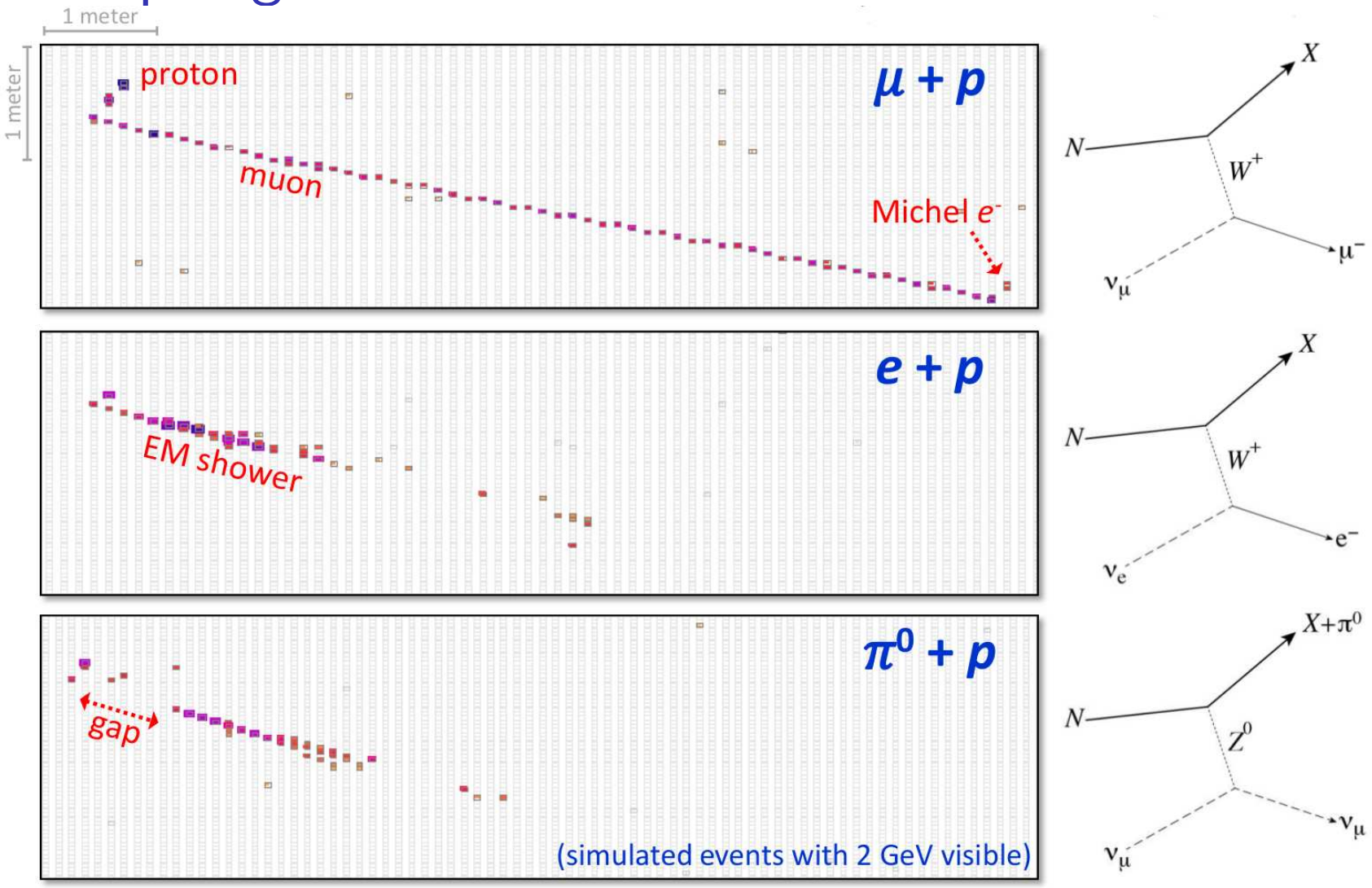
Far Detector

- 14 kton
- 344,000 channels

Near Detector

- 0.3 kton
- 18,000 channels

Event topologies

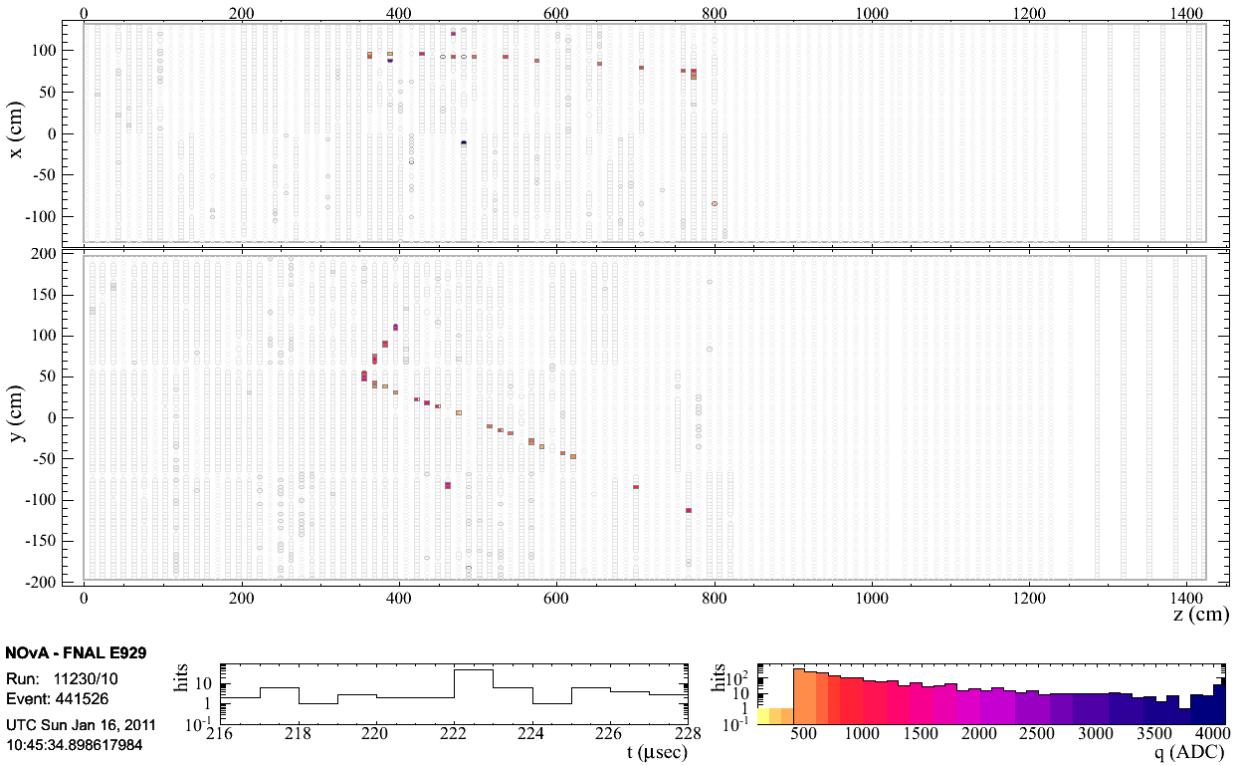


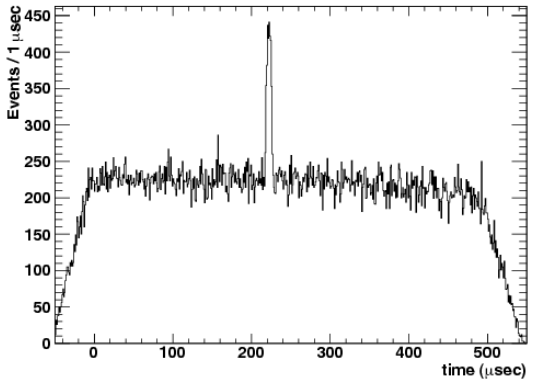
- Very good granularity, especially considering scale
- $X_0 = 38$cm (6 cell depths, 10 cell widths)

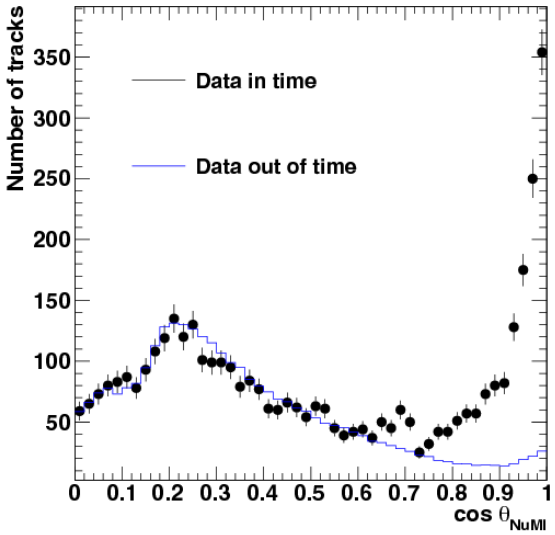
Near Detector prototype (NDOS)

- Operating since April 2011
- Test component production and integration
- DAQ development
- Calibration, simulation, reconstruction development with real data

Near Detector prototype (NDOS)







- We have collected a large number of neutrino events from the NuMI and Booster beams

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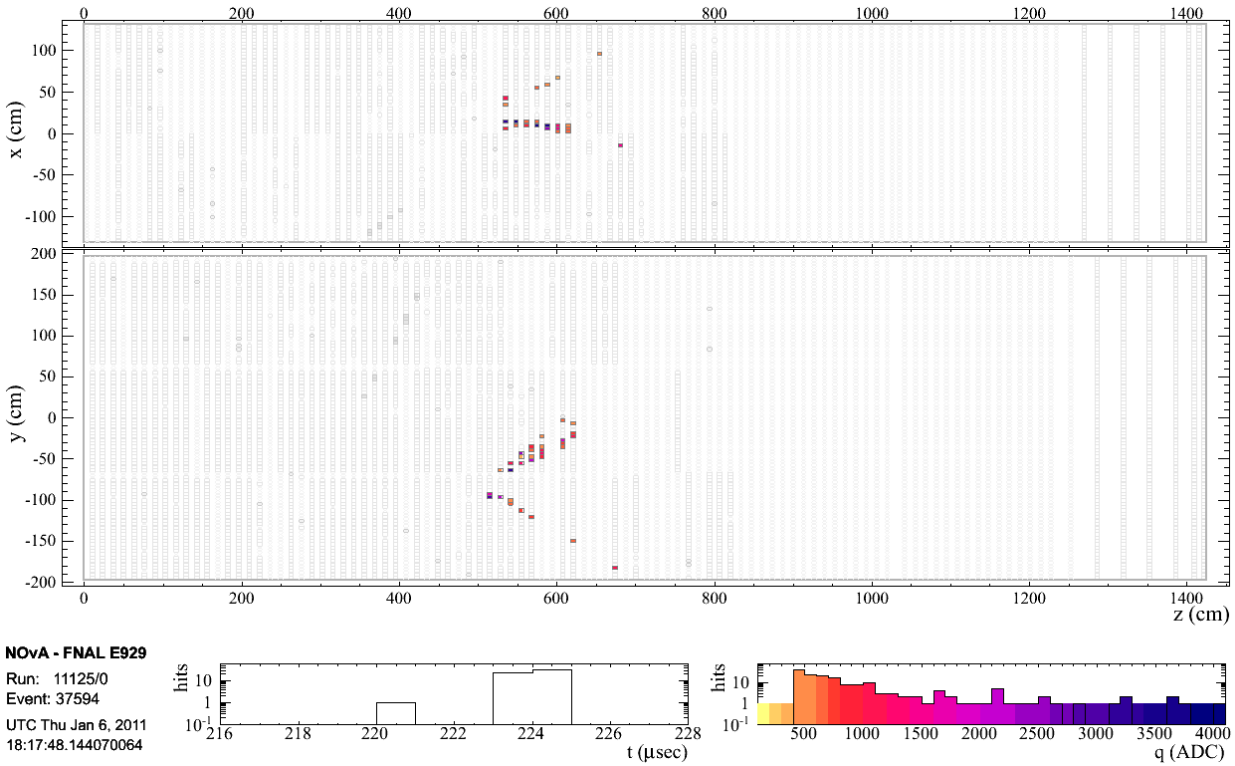

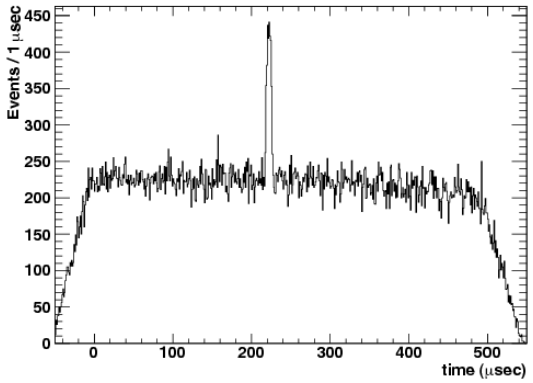

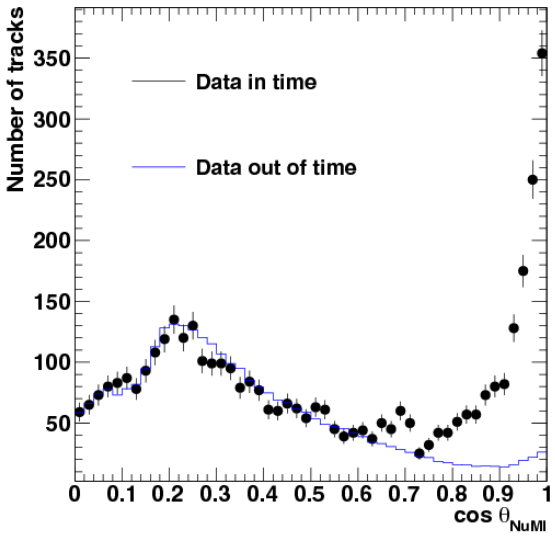

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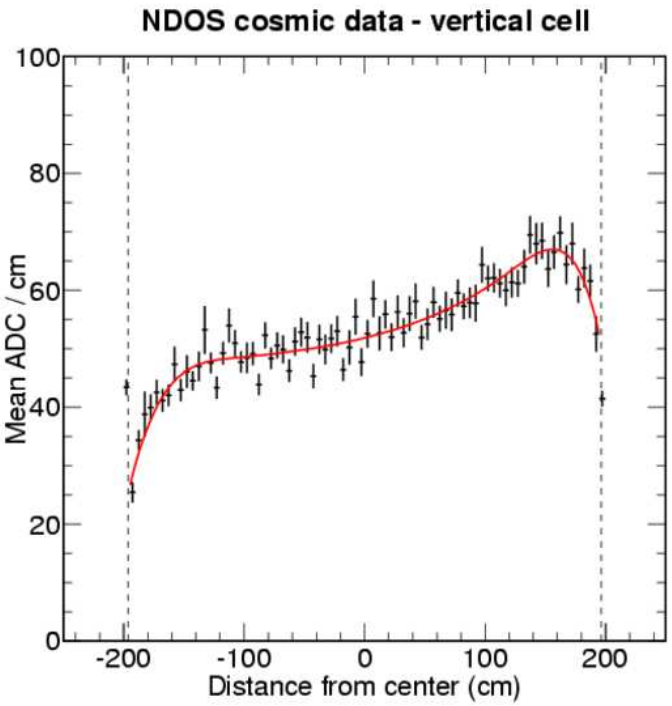
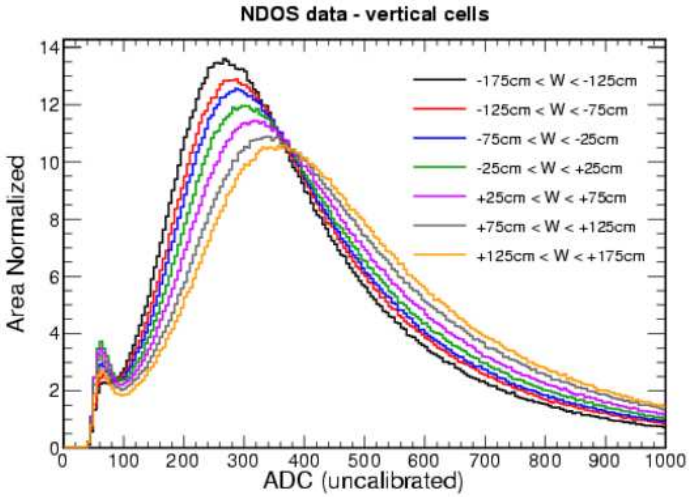
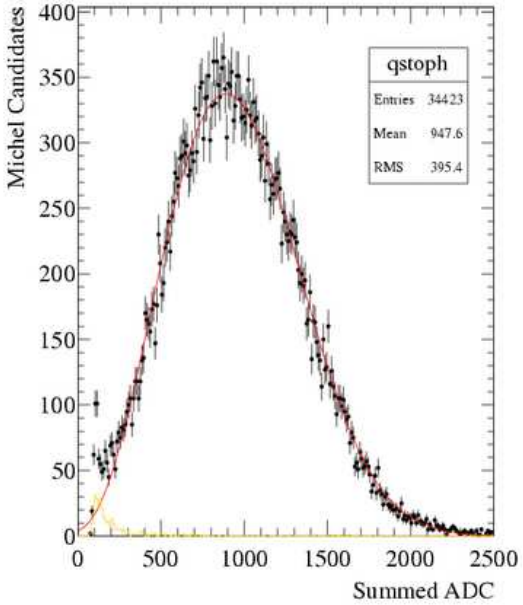
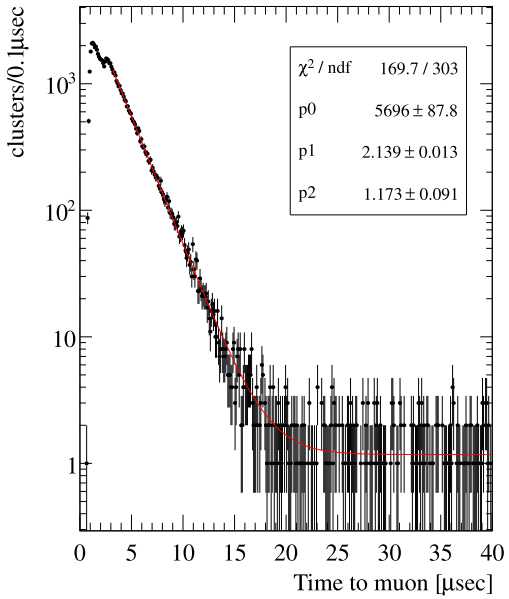
Calibration





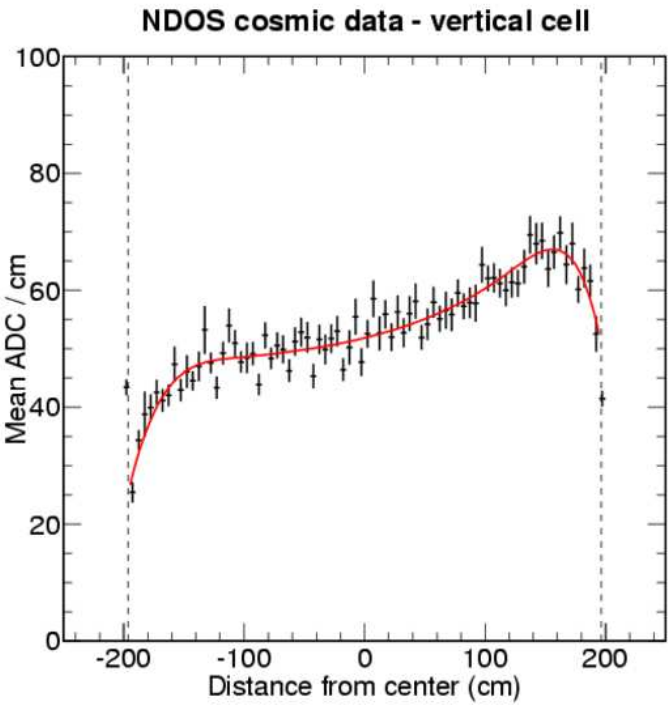


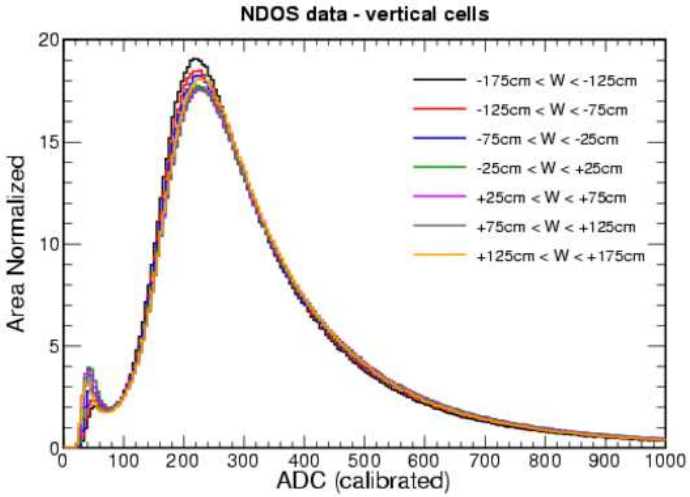


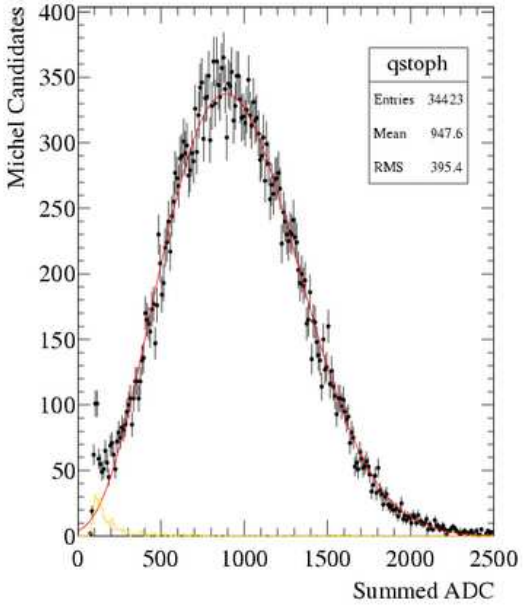
- Use cosmic muons to measure attenuation and light-level in situ
- #15 Enrique Arrieta Diaz "Calibration and Reconstruction in the NOvA Detectors"

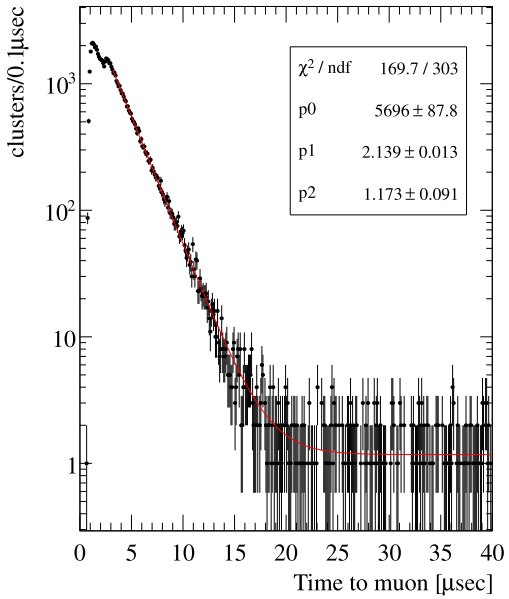
- Large sample of Michel electrons from stopping muons
- Study low-energy modelling

Calibration









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Near Detector underground

- Work started on cavern excavation
- Possible access March 2013

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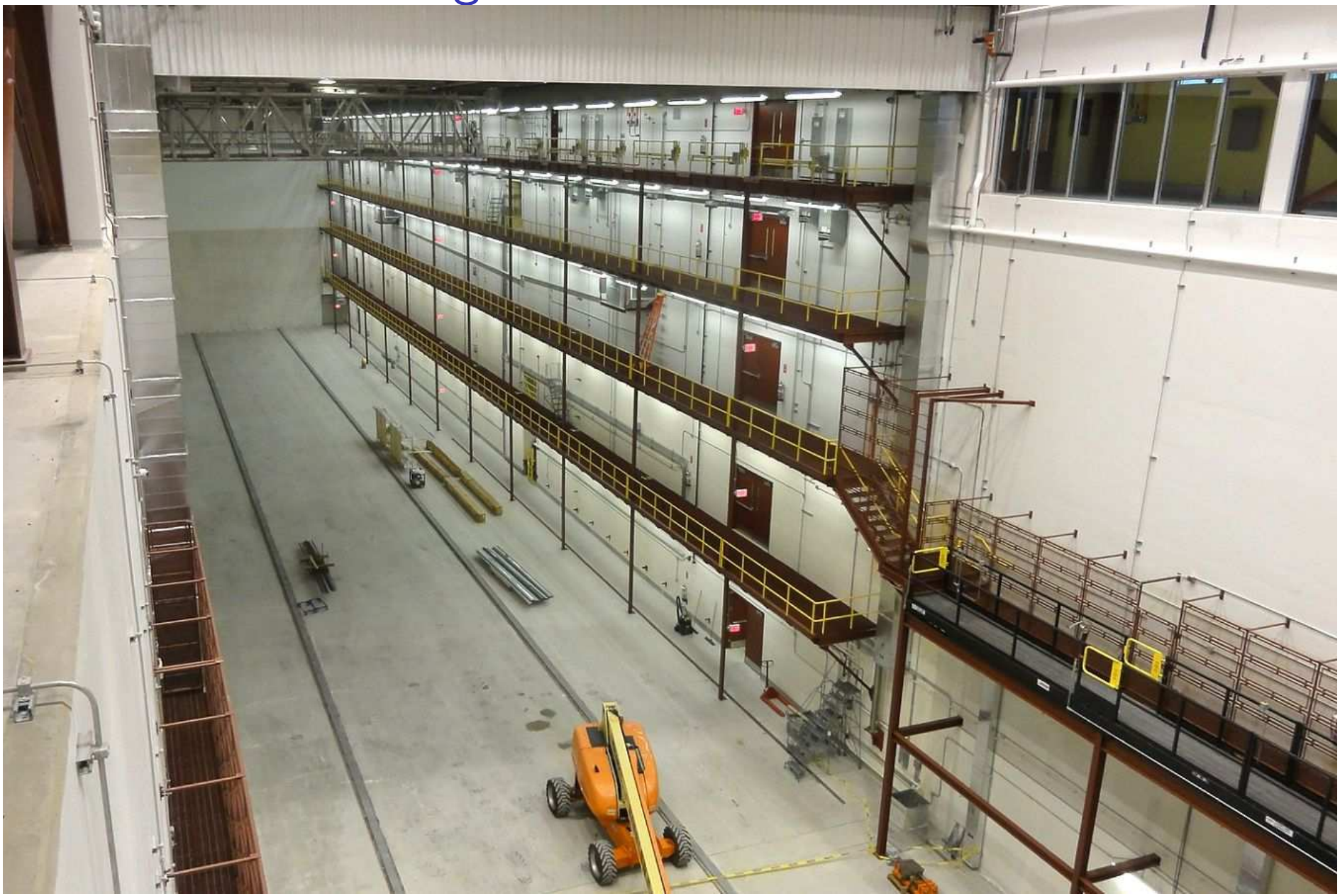
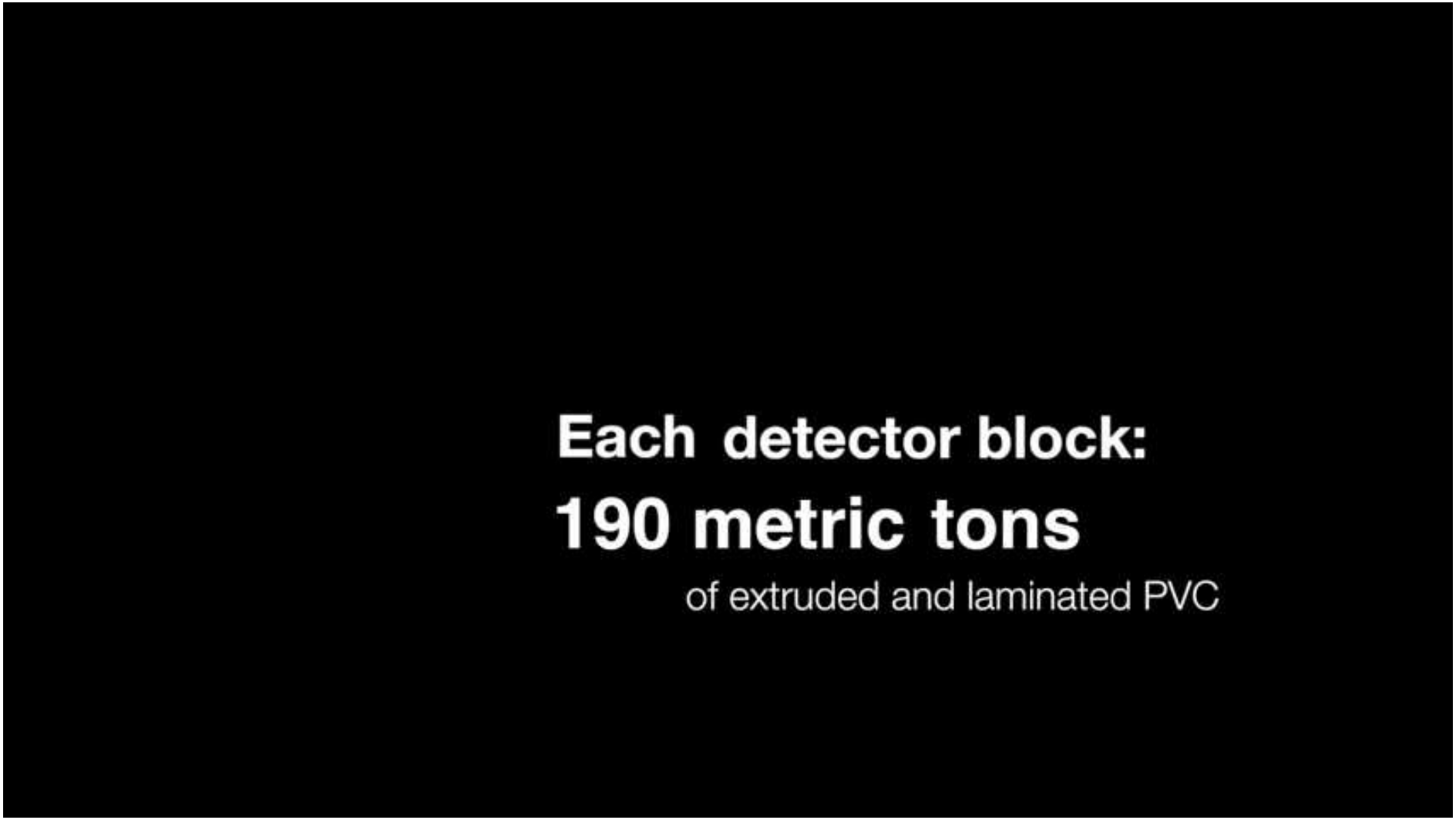
Far Detector building



First Far Detector block



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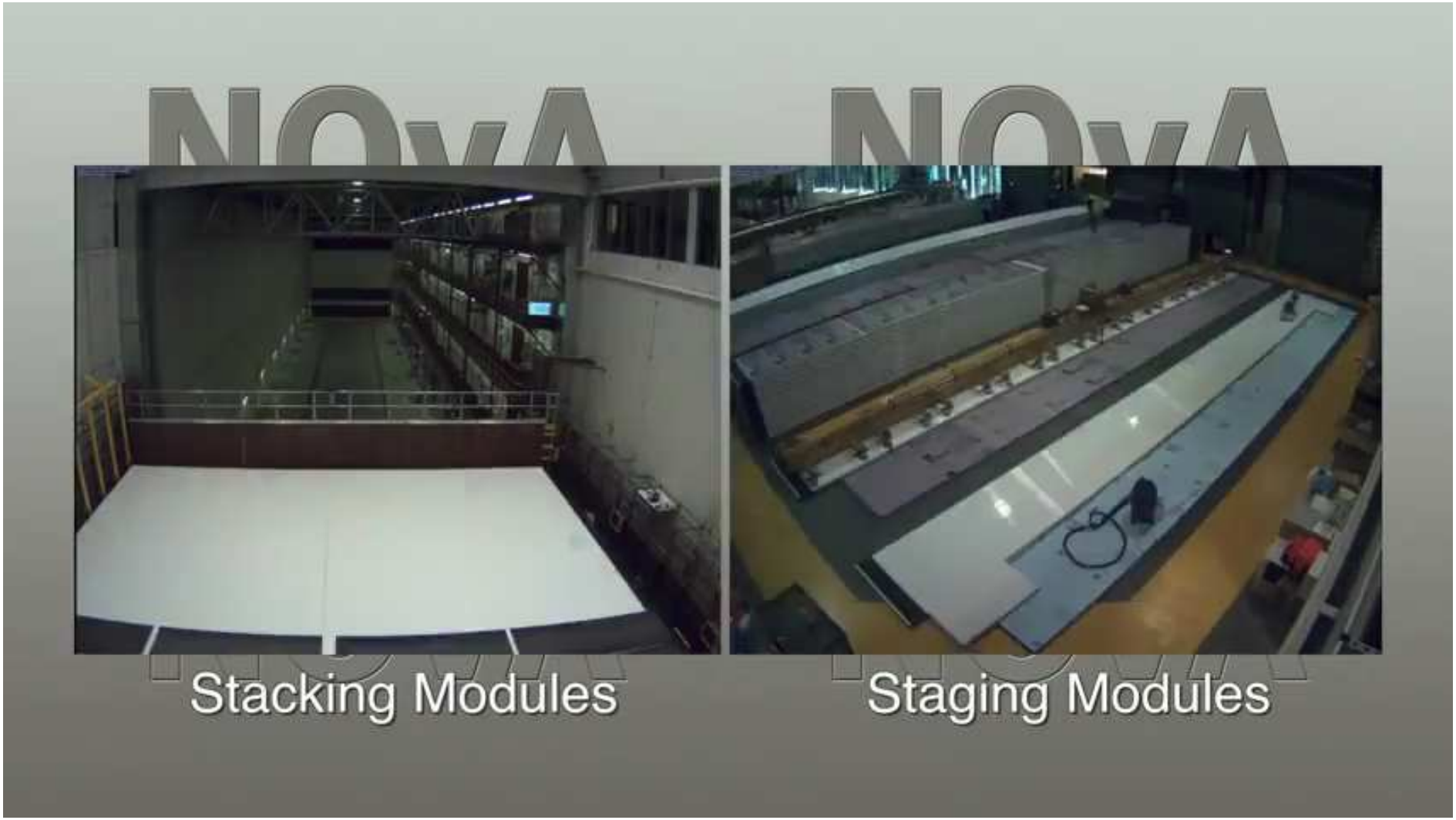

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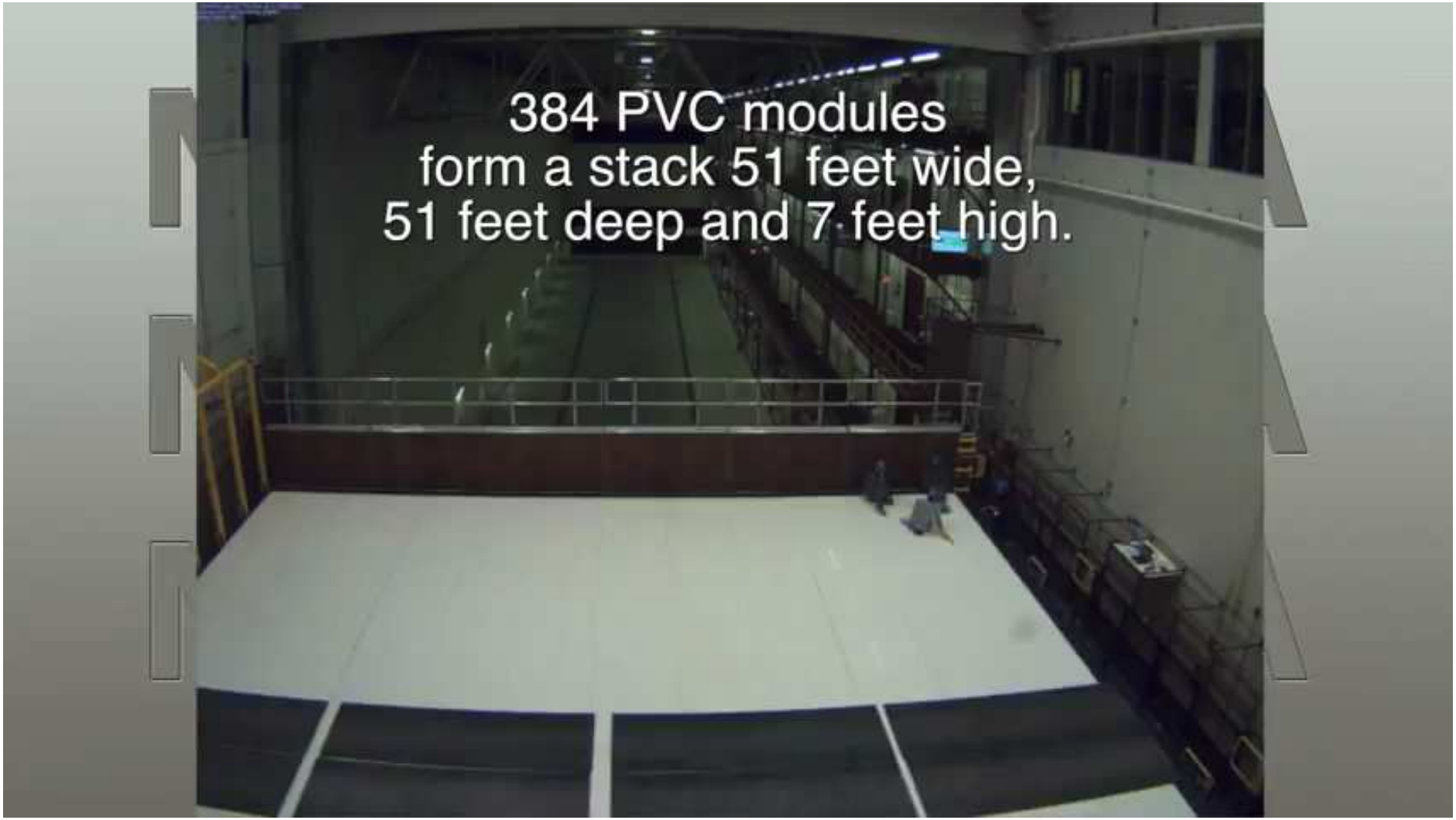

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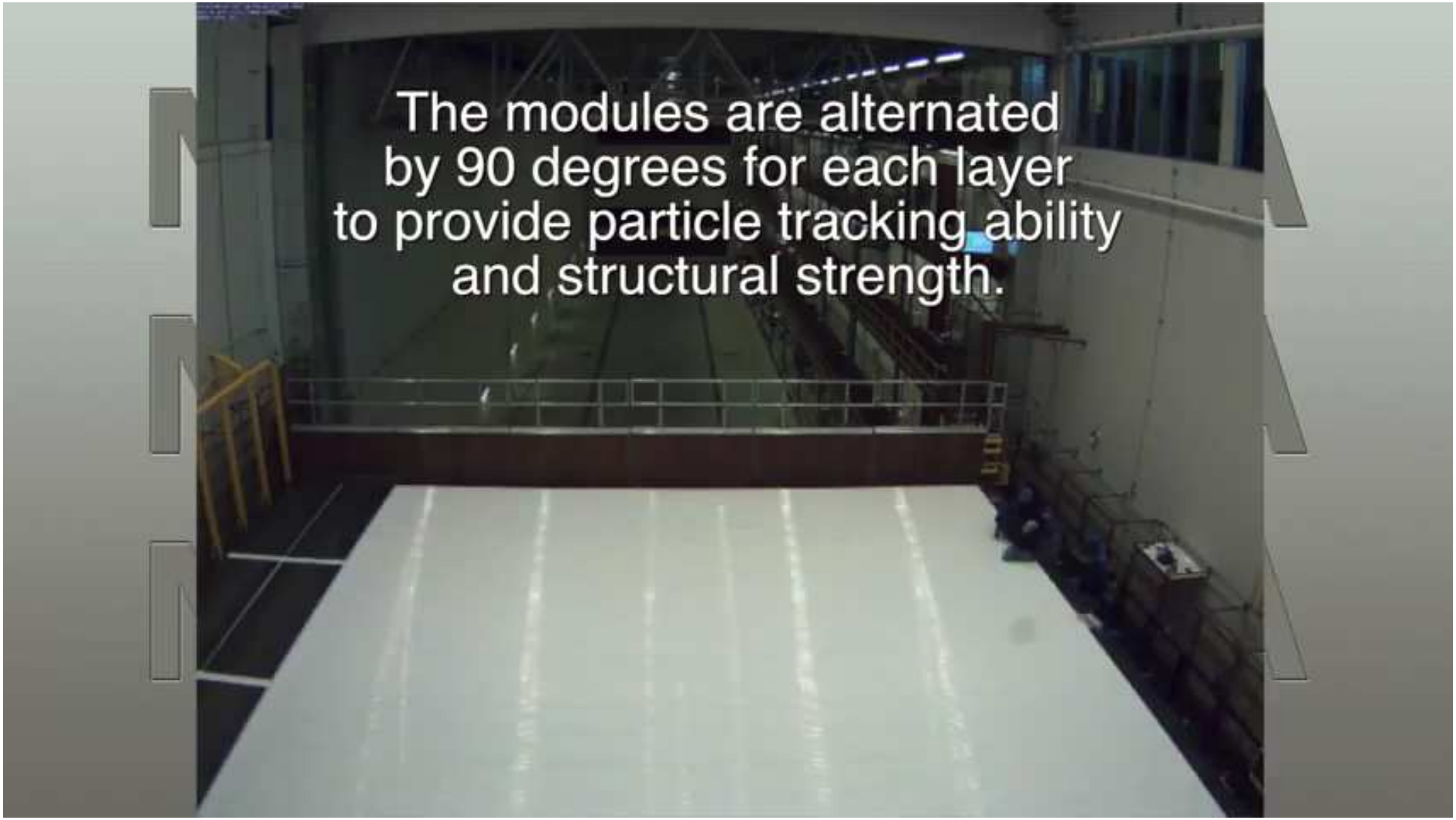

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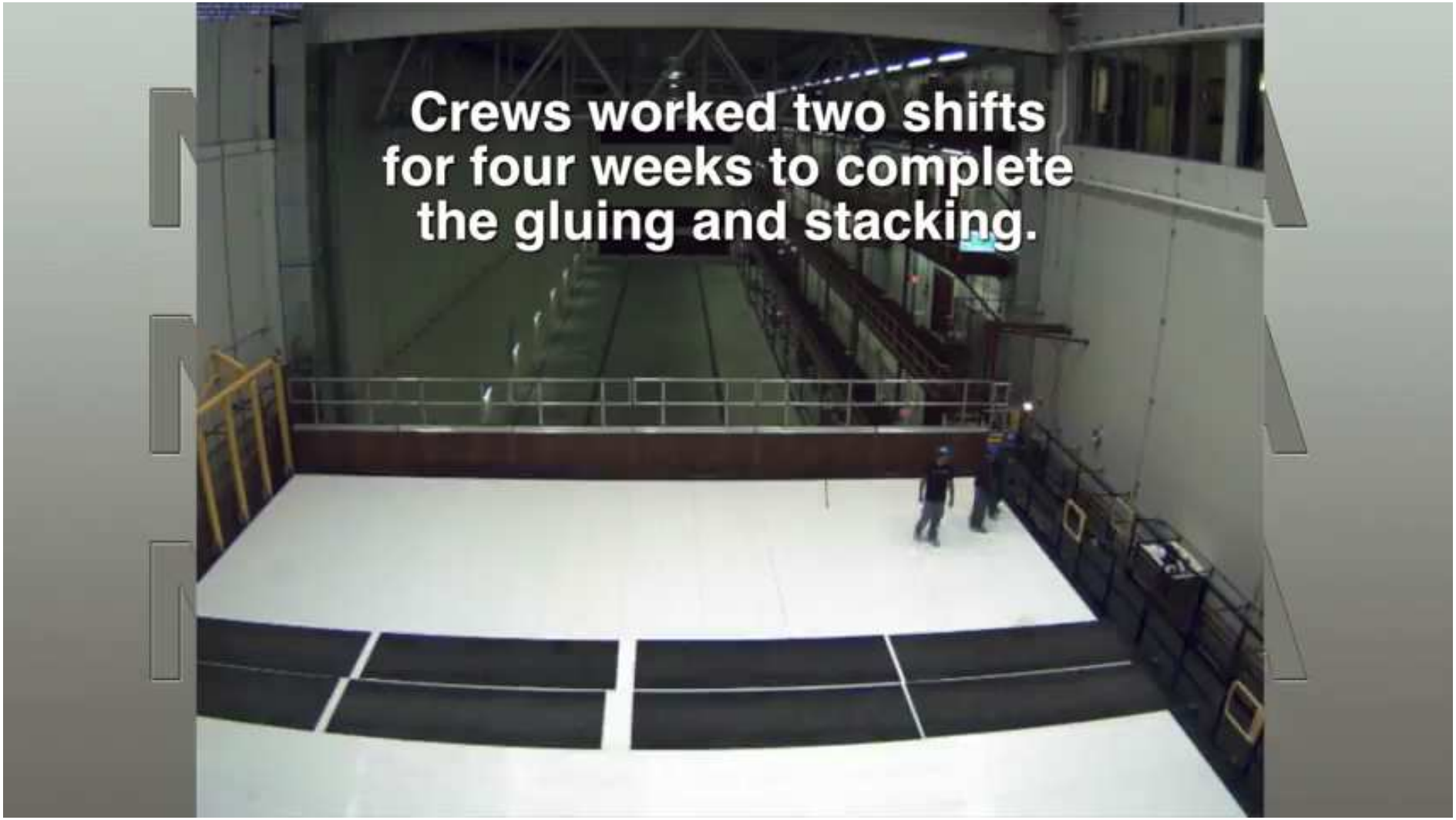

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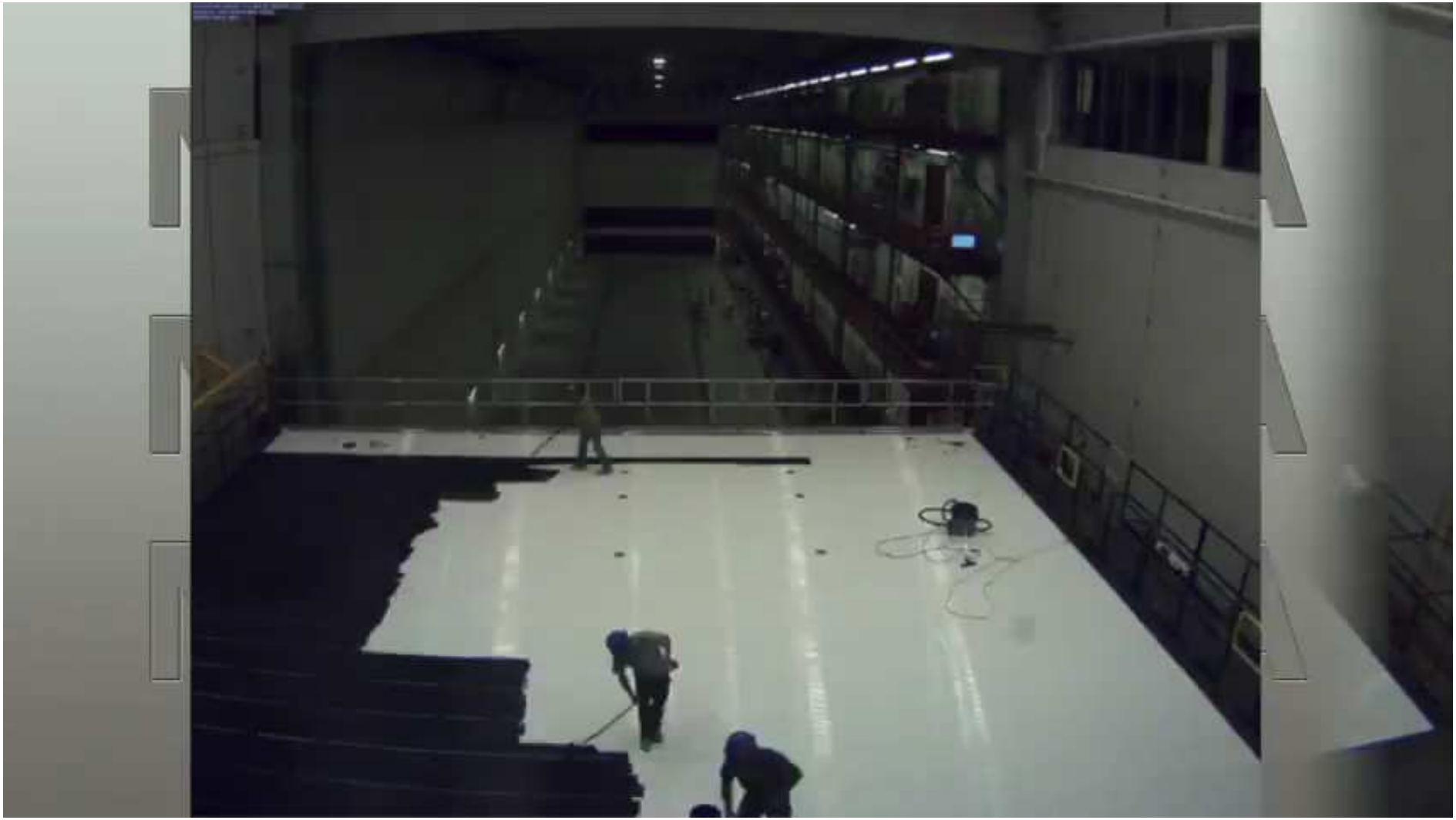

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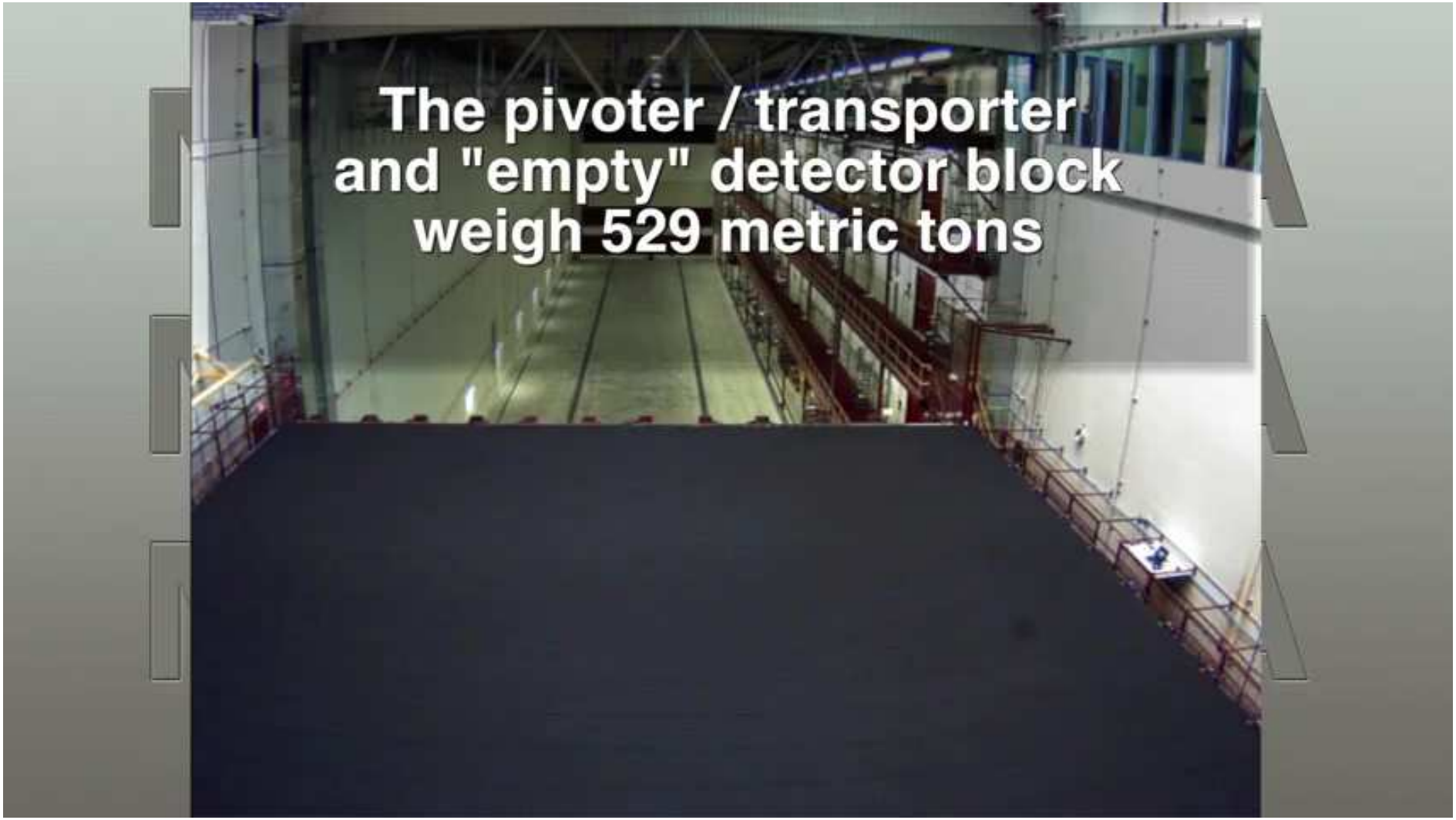

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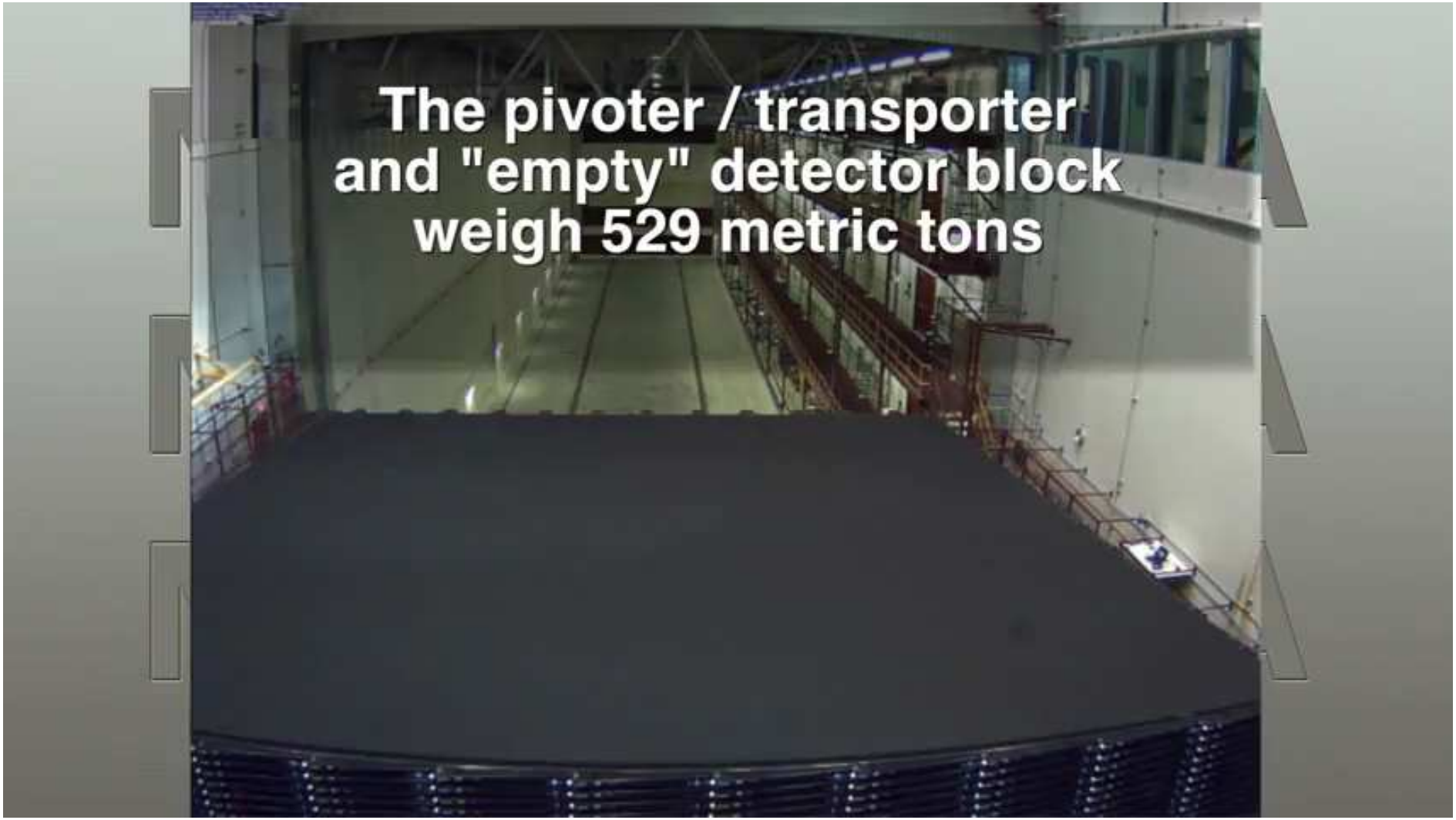

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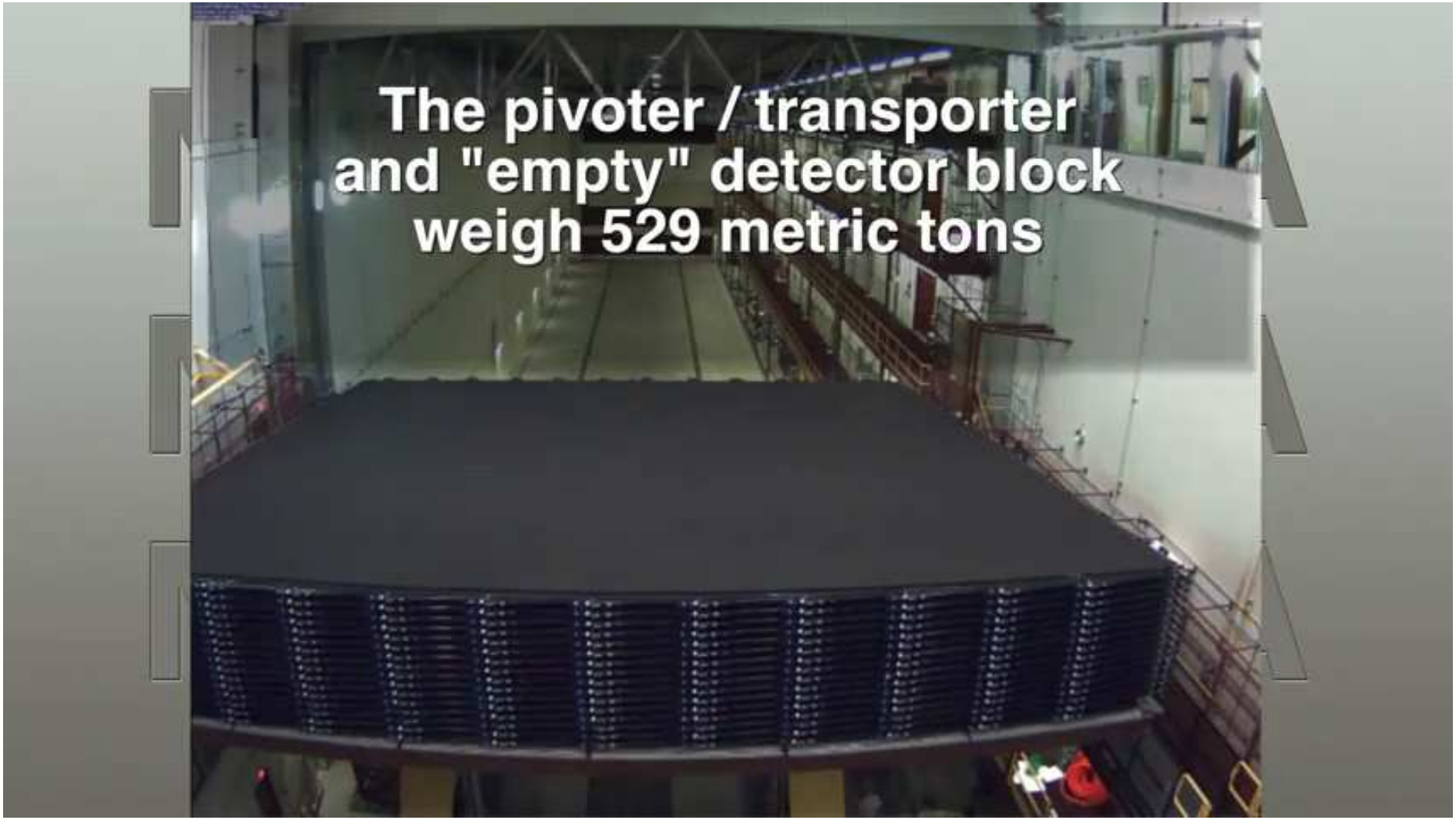

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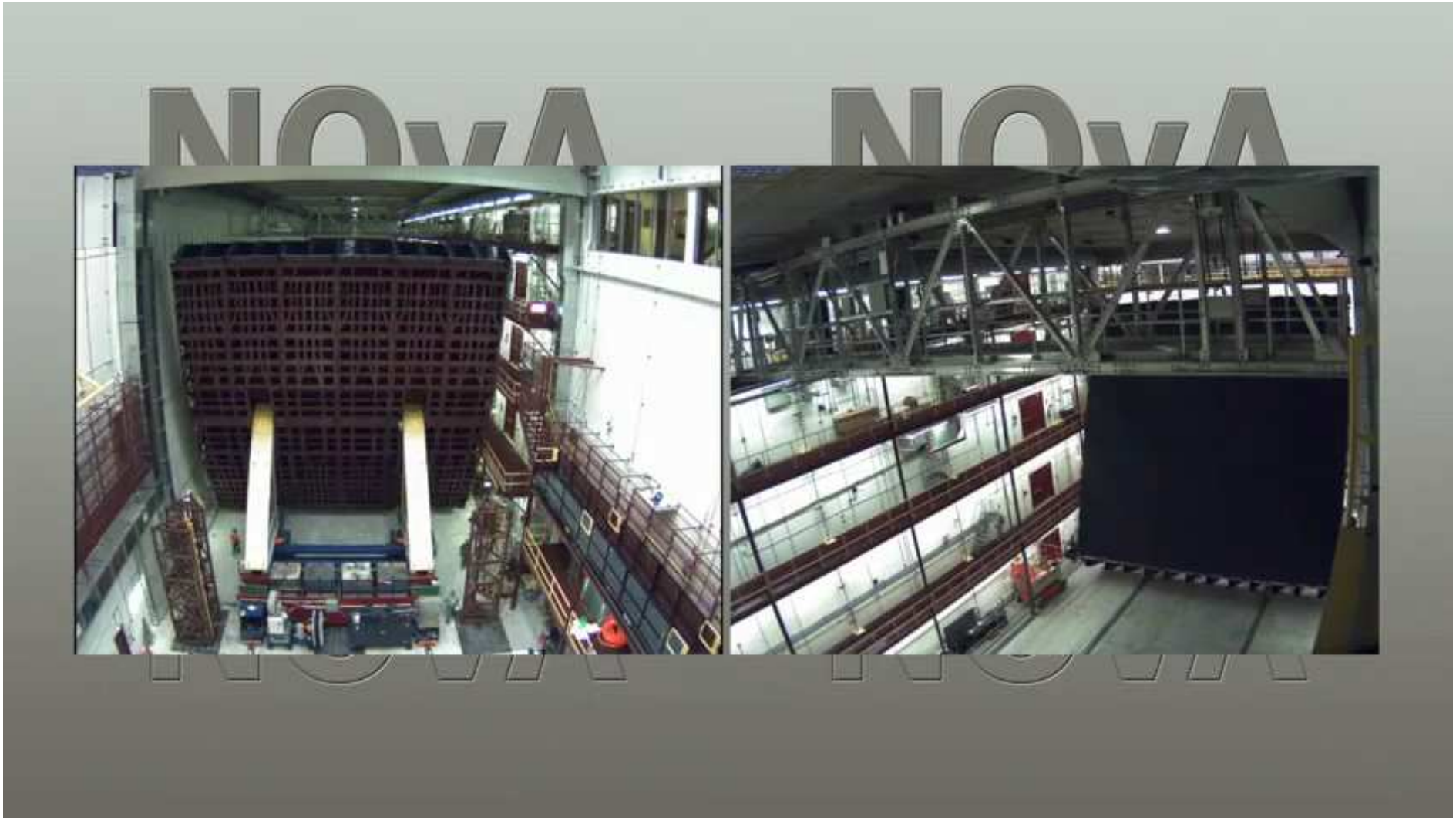

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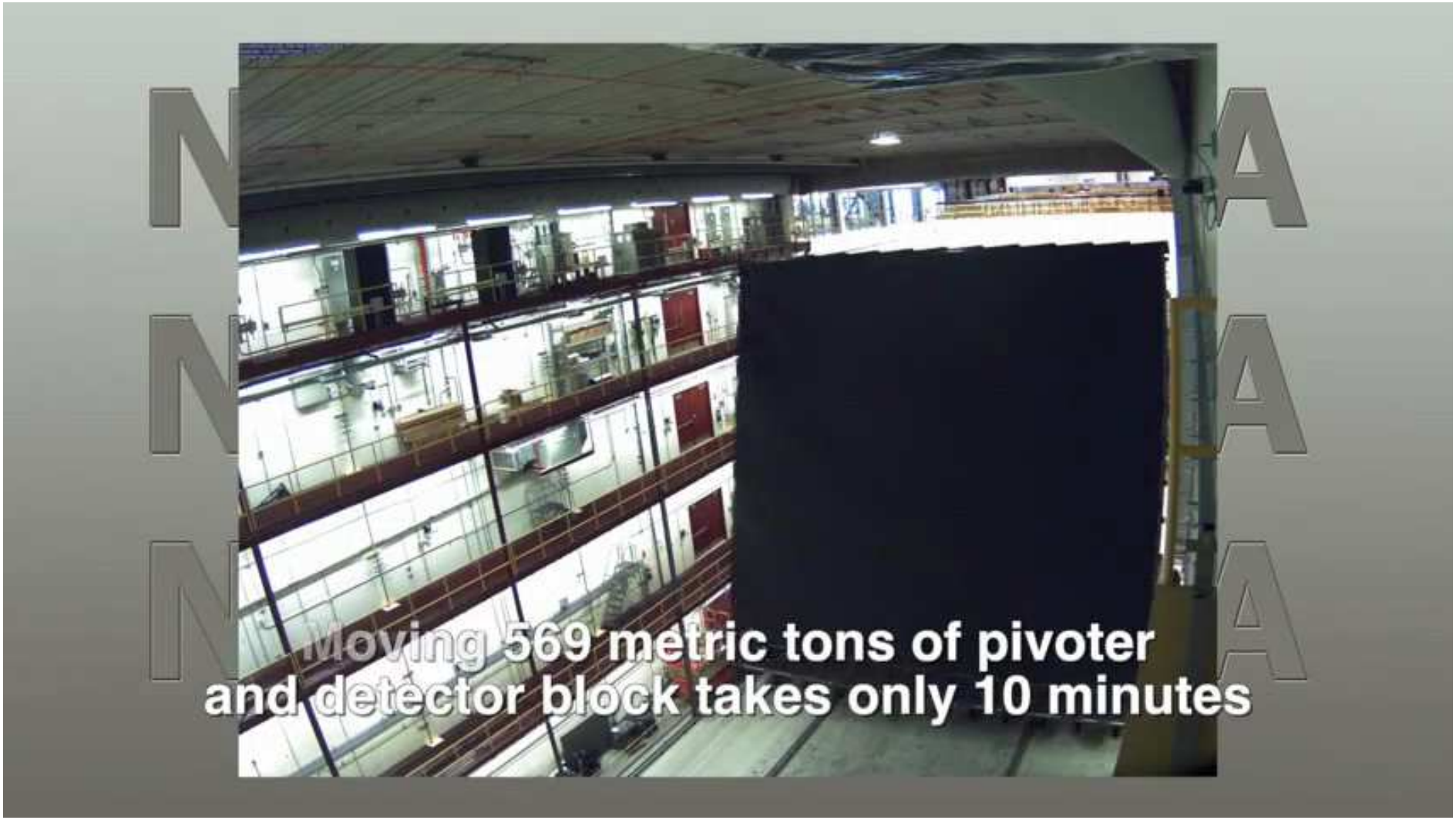

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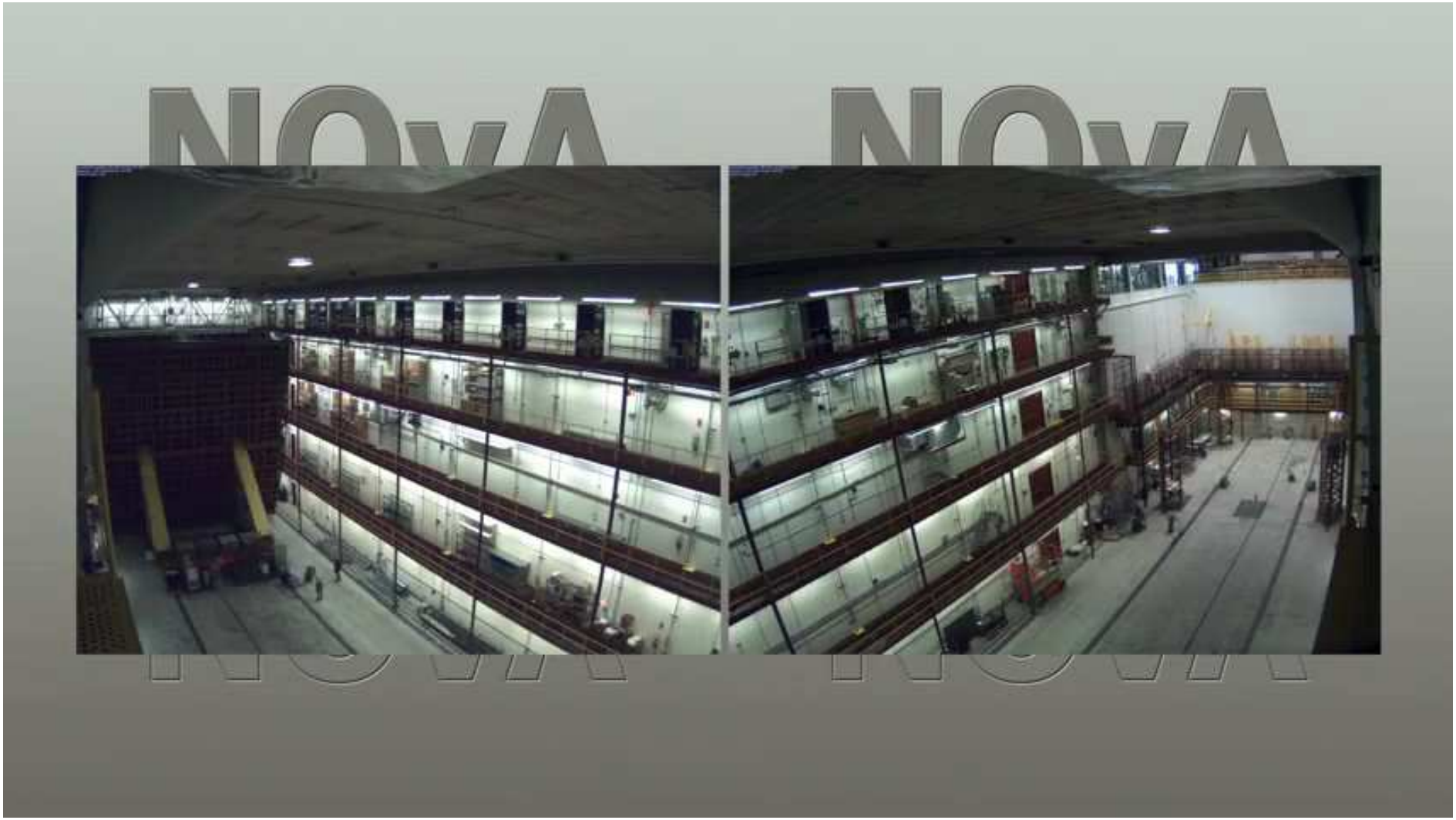

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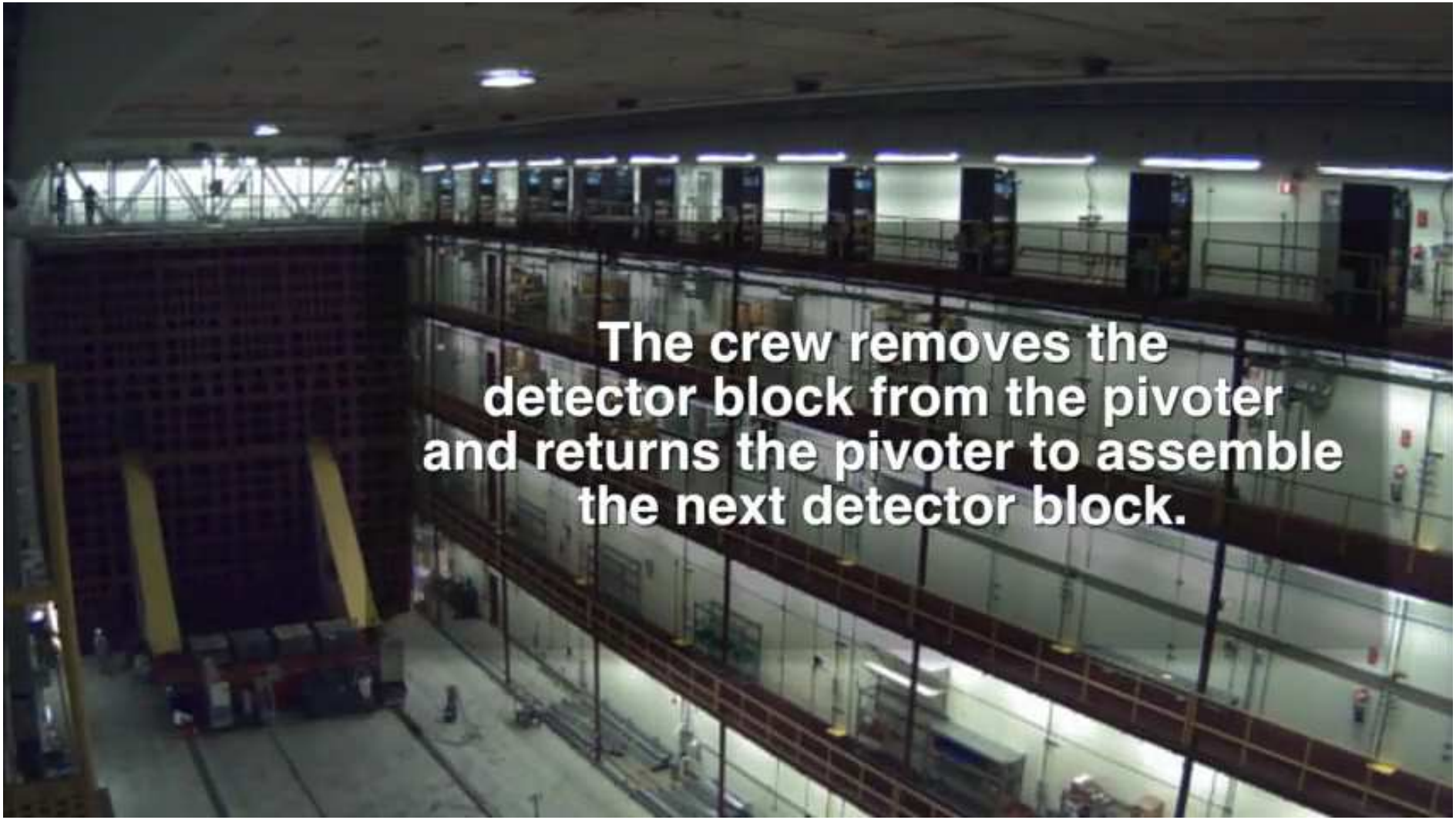

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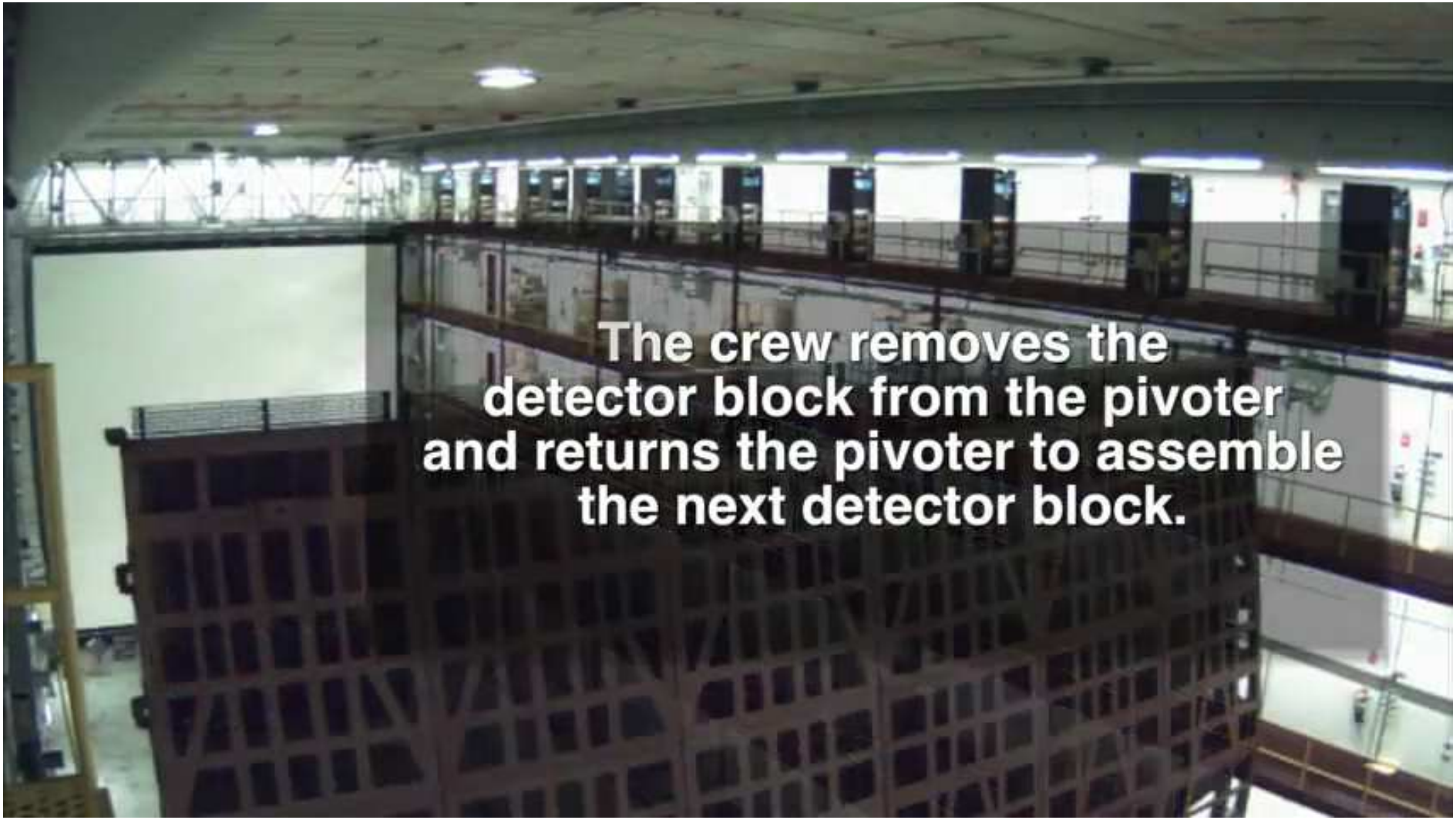

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#14 Mathew Meuther "NOvA Construction Status"

First Far Detector block

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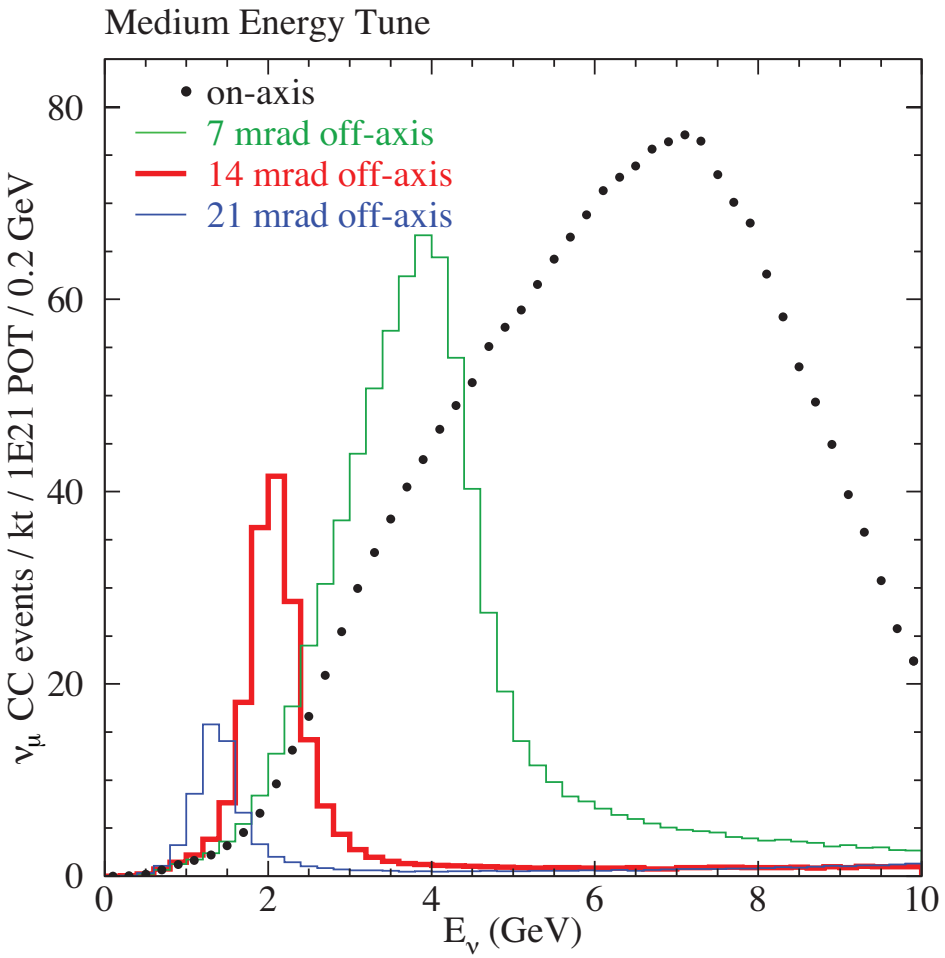
First Far Detector block

One down, 27 to go!

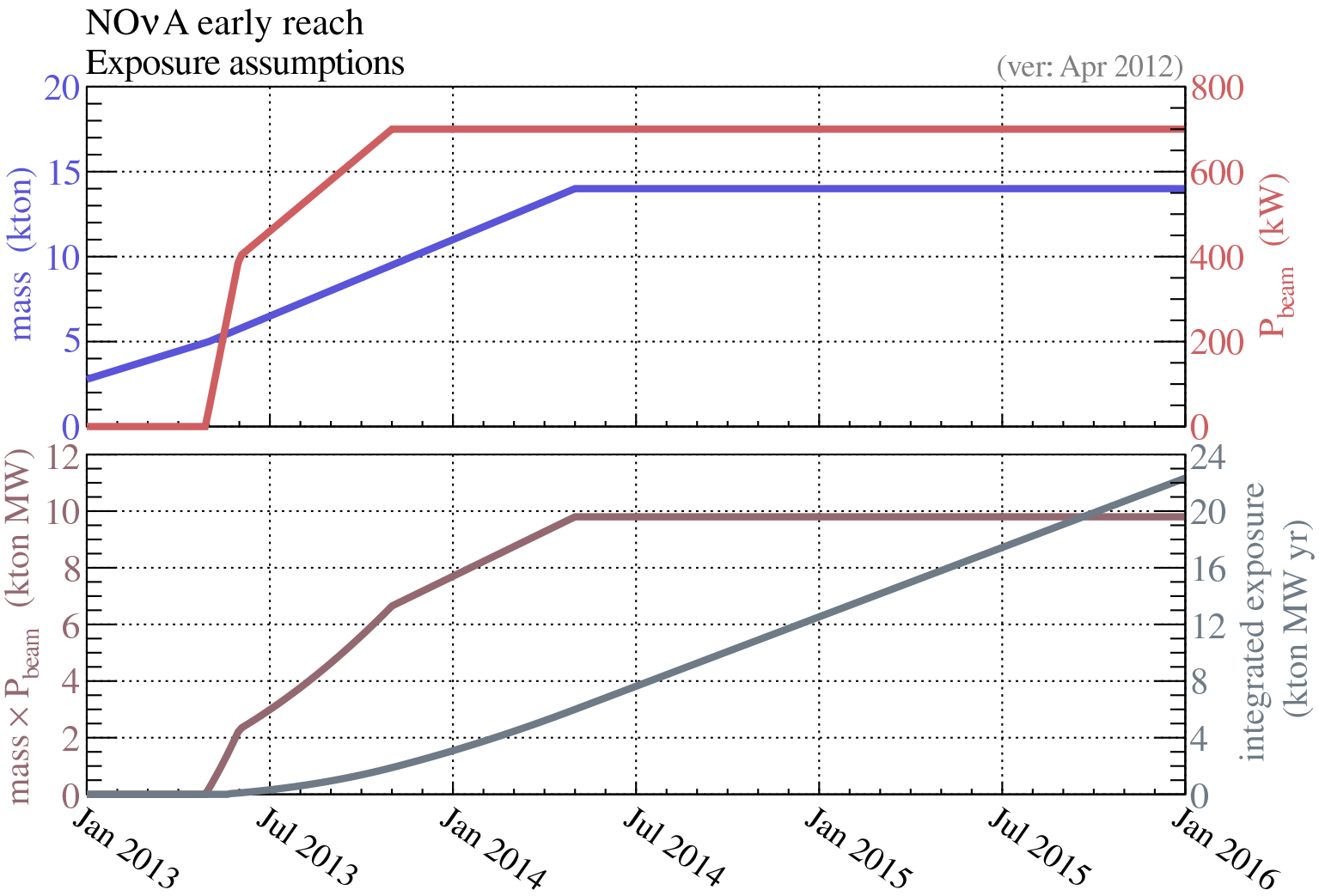
Accelerator and NuMI upgrades

- NuMI being upgraded from 350kW to 700kW
- 1-year shutdown, began May 1
- Convert Recycler to protons from antiprotons
- Shorten Main Injector cycle 2.2s→1.33s
- Overhaul of NuMI target station
- Beam returns May 2013
- 6-9 month ramp-up to full power



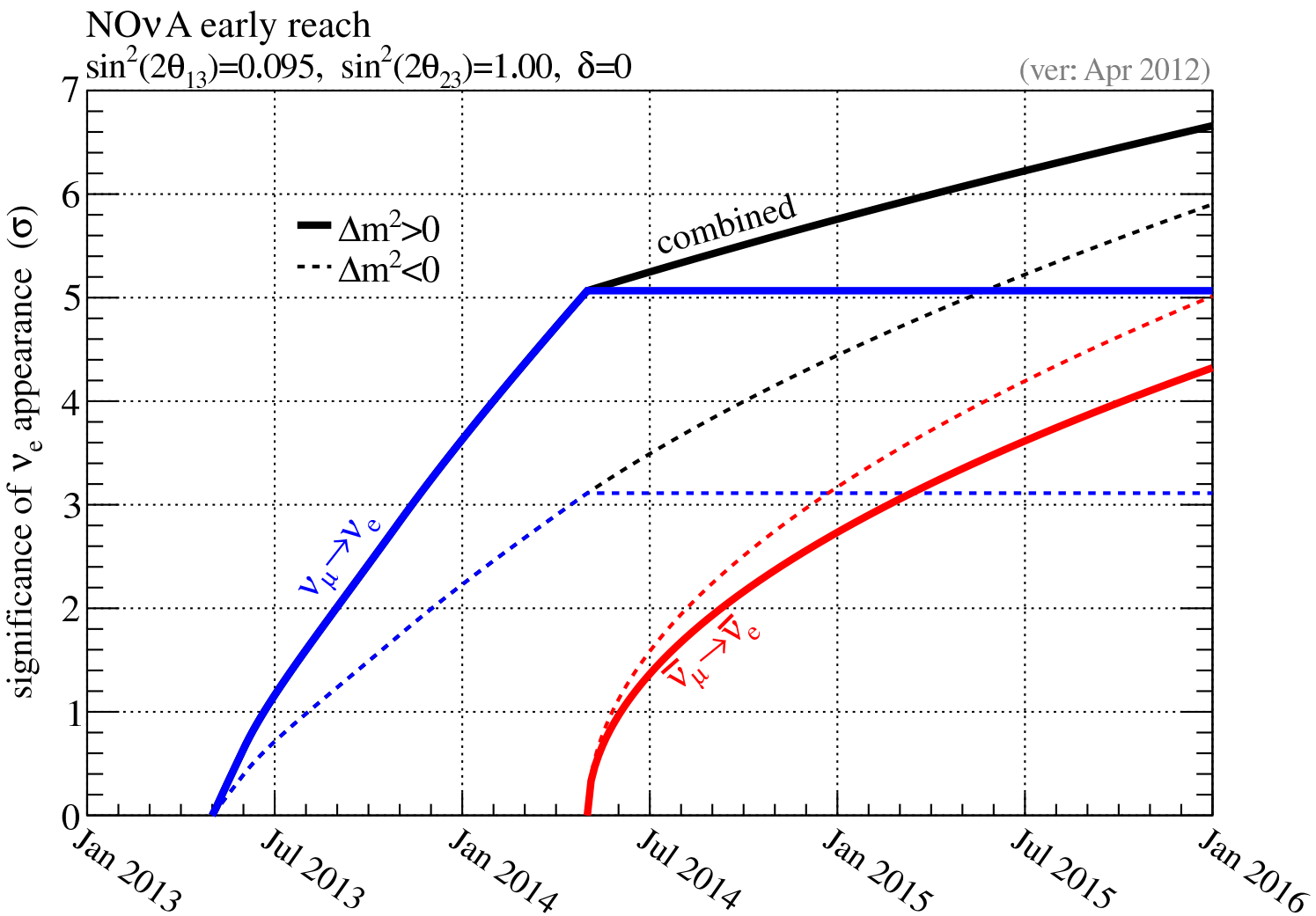
14mrad off-axis beam peaks sharply at 2GeV

Exposure assumptions and early reach



- 5kton when beam returns. 700kW in six months. 14kton in May 2014

Exposure assumptions and early reach



- 5σ observation of ν_e appearance within first year (assumes NH, $\delta = 0$)
- With detector still under construction and beam commissioning

Sensitivities

- Assuming 3 years ν-mode + 3 years $\bar{\nu}$-mode @ 6×10^{20} POT/yr
- Start in neutrino mode
- Can switch to antineutrinos at any time based on our or others' results

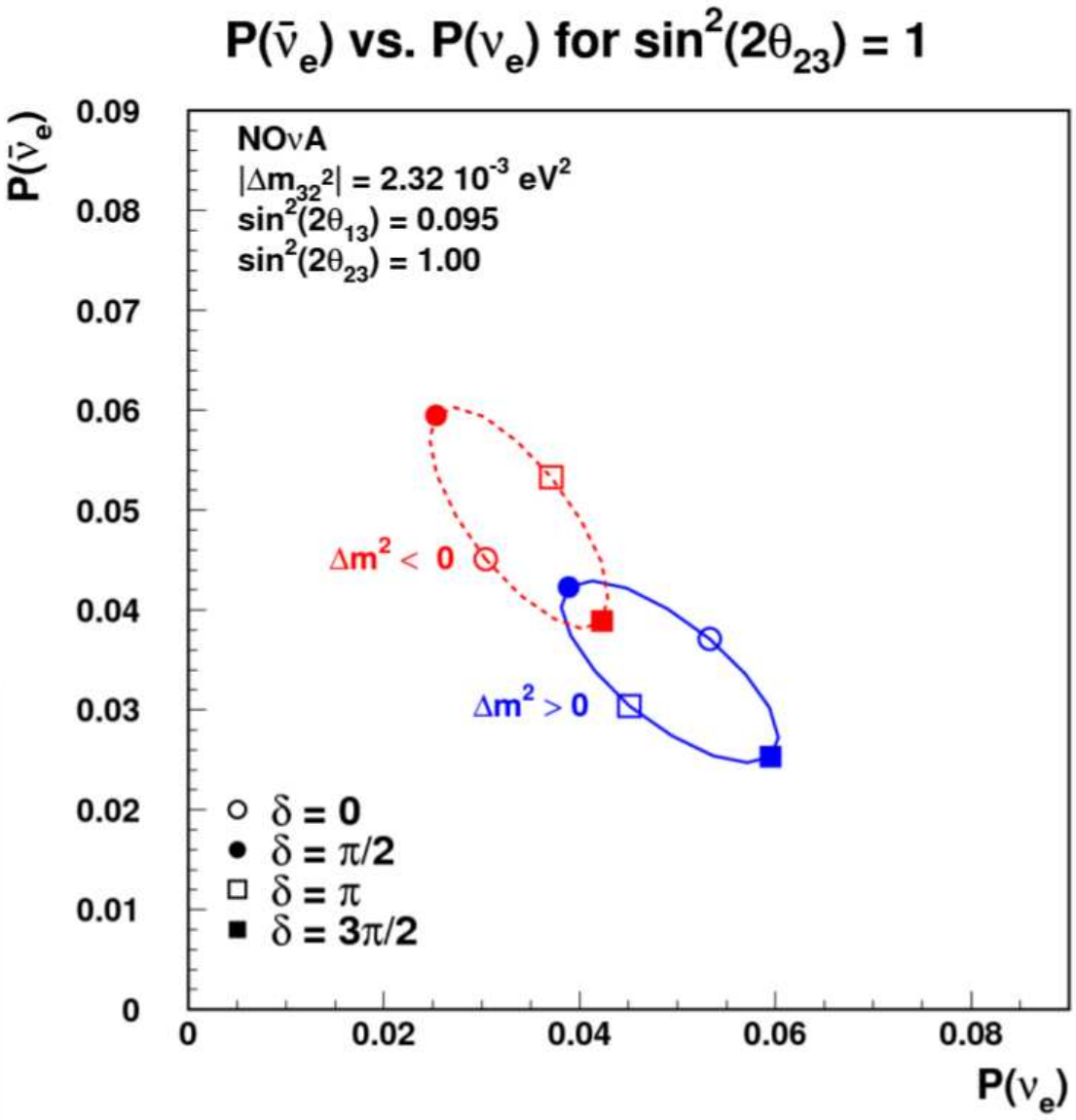
- Take $\sin^2 2\theta_{13} = 0.095$

- Representative event counts for $\nu_\mu \to \nu_e$ analysis
- Vary dependending on specific oscillation parameters

	ν	$\bar{\nu}$
NC	19	10
ν_μ CC	5	<1
ν_e CC	8	5
tot bkg	32	15
$\nu_\mu \to \nu_e$	68	32

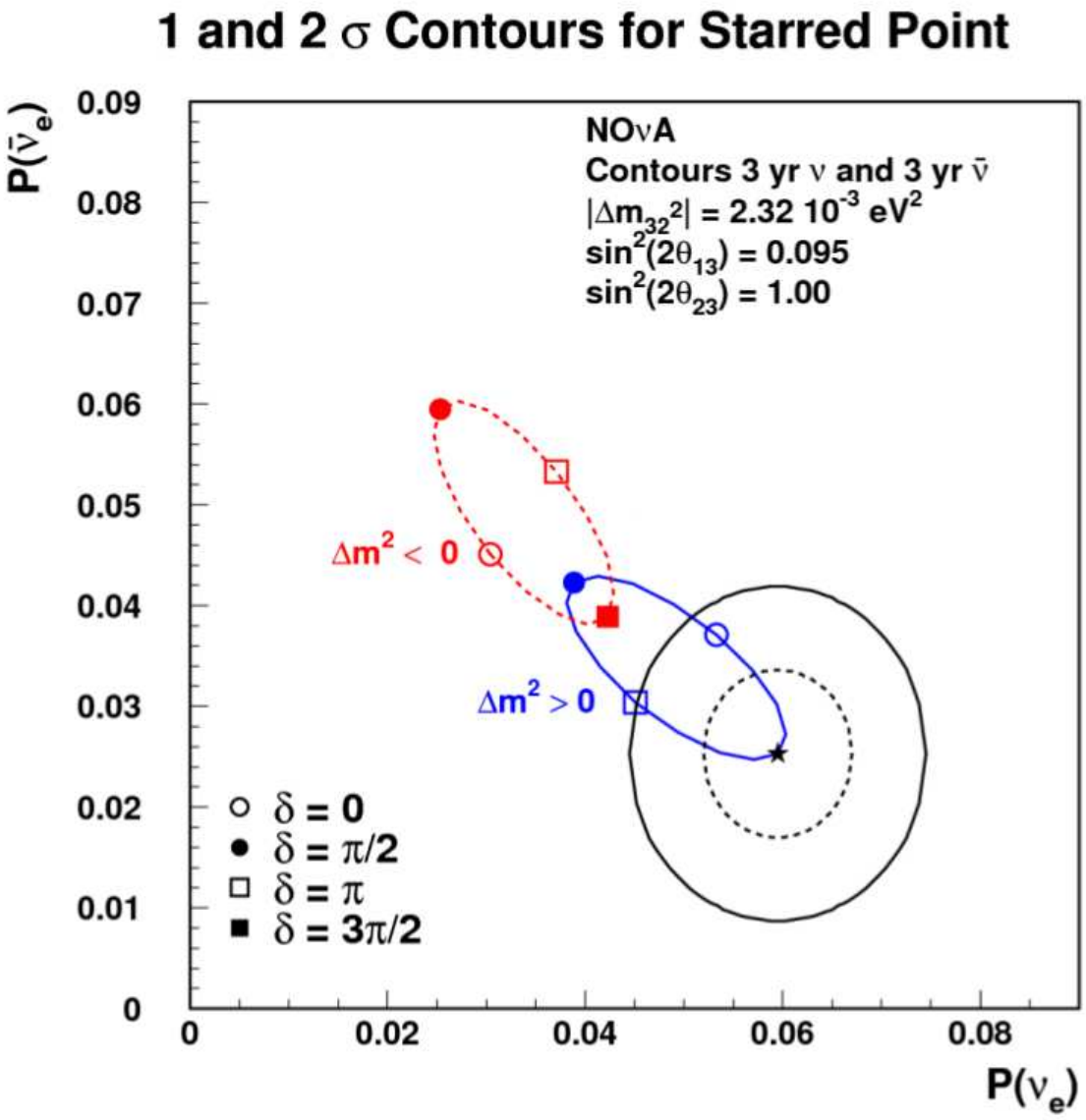
Principle of the ν_e measurement

- To first order, NOνA measures $P(\nu_\mu \to \nu_e)$ and $P(\bar{\nu}_\mu \to \bar{\nu}_e)$ evaluated at 2GeV
- These depend differently on sign(Δm^2) and δ_{CP}
- #16 Gavin Davies "Neutrino Physics with the NOvA Detectors"

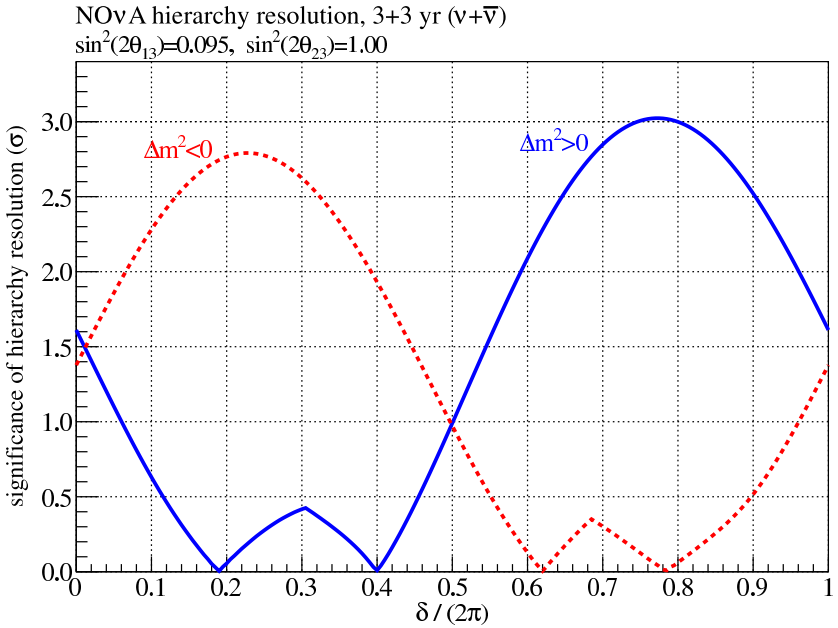


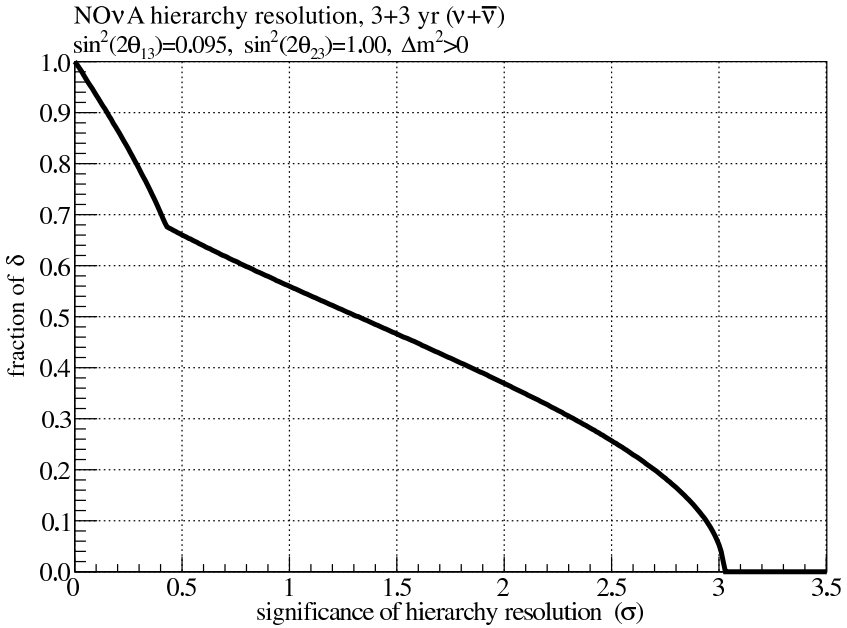
Principle of the ν_e measurement

- Measurements give an allowed region in this space
- In this case all inverted hierarchy scenarios are excluded at $>2\sigma$
- #16 Gavin Davies "Neutrino Physics with the NOvA Detectors"



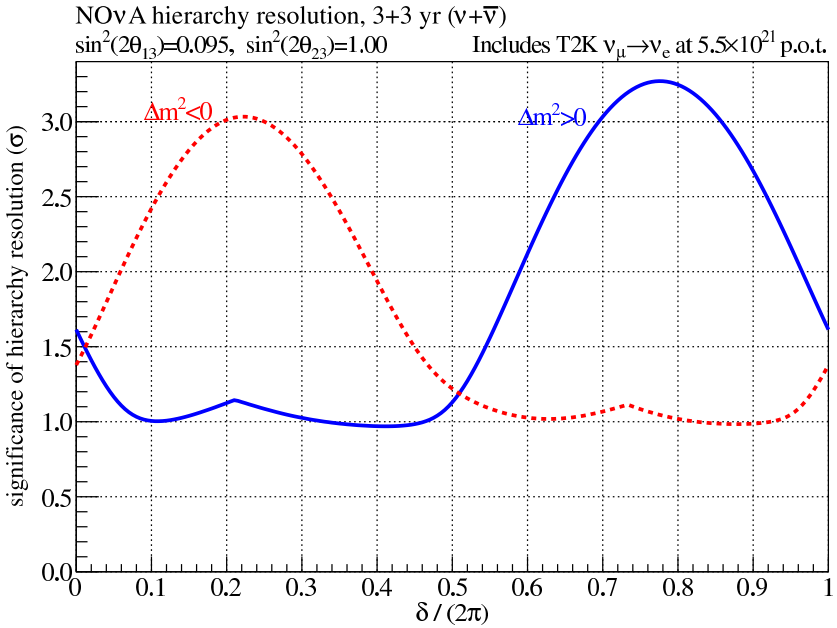
Significance to resolve hierarchy

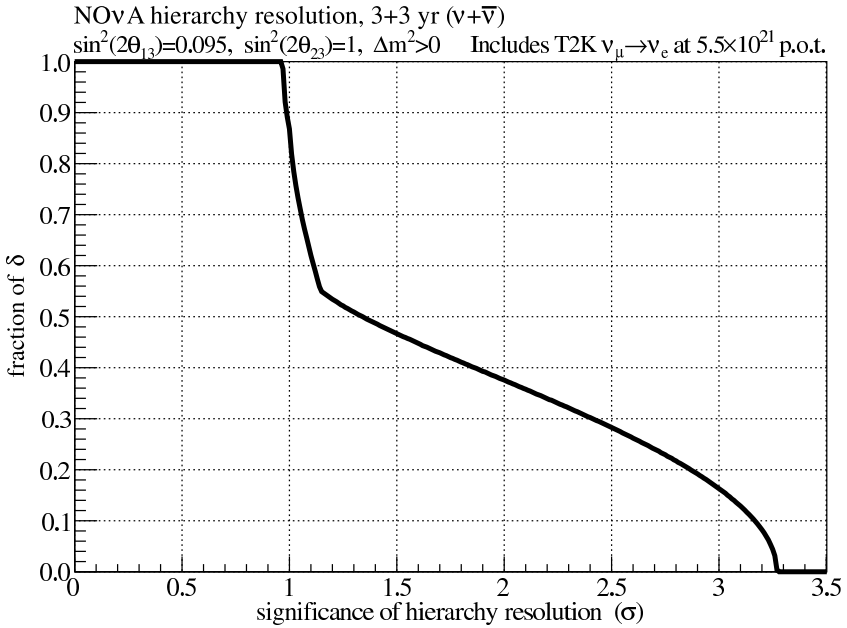




- For favourable values of δ we can measure the hierarchy at high significance
- There also exist degenerate scenarios

Significance to resolve hierarchy

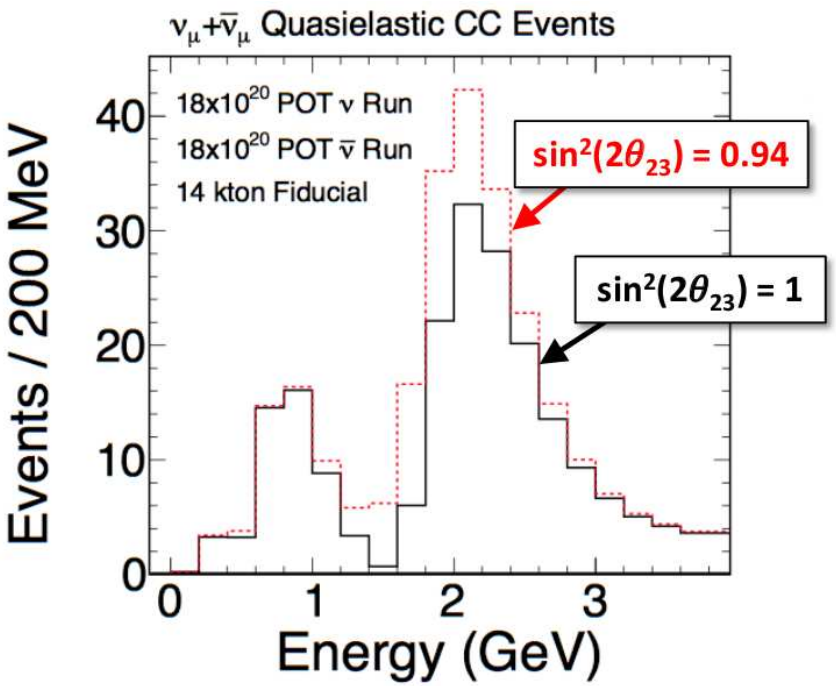


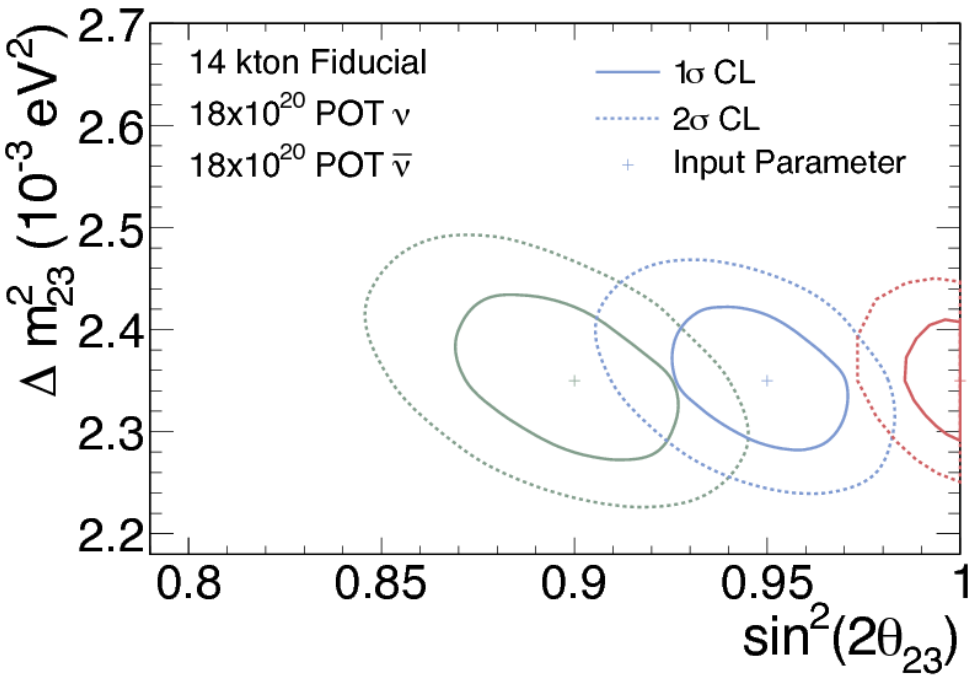


- For favourable values of δ we can measure the hierarchy at high significance
- There also exist degenerate scenarios

- Matter effects have a much smaller impact on T2K
- Help to break the degeneracies

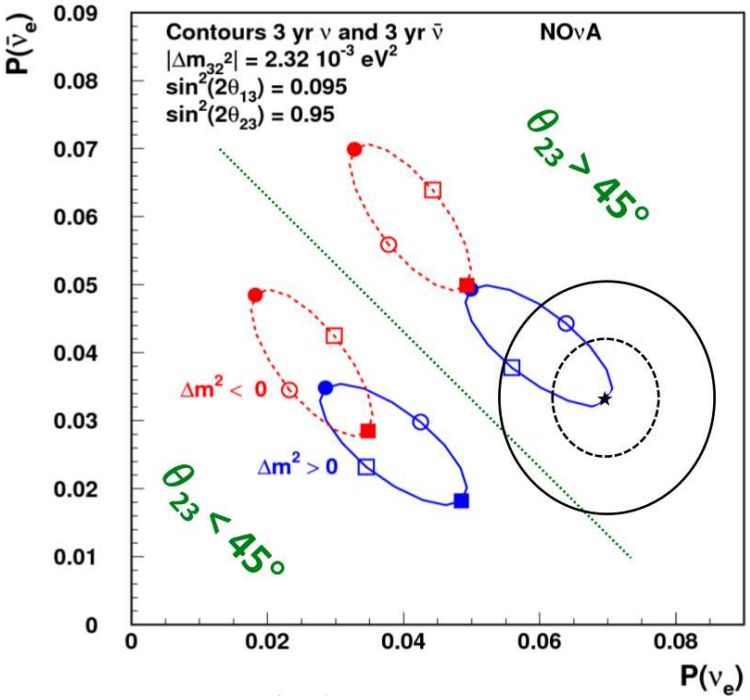
ν_μ analysis





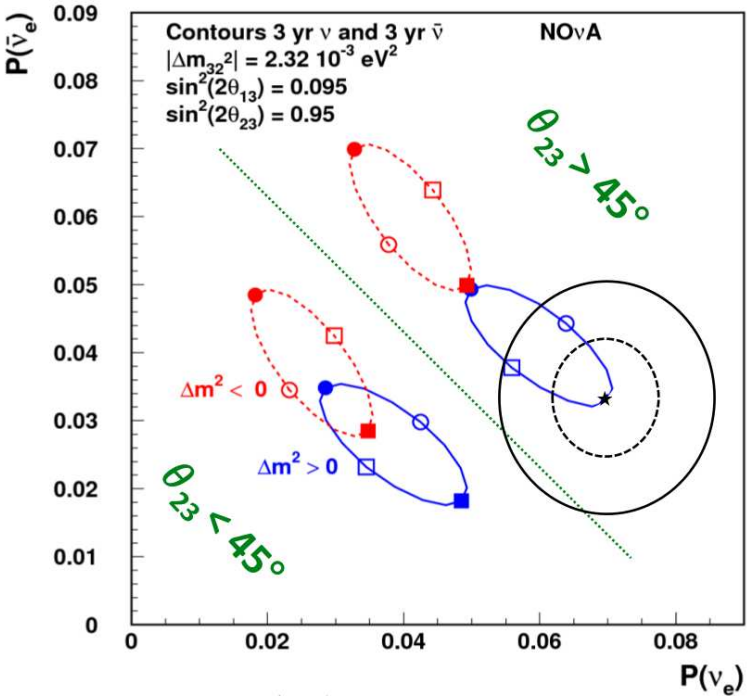
- Current constraints on $\sin^2 2\theta_{23} \gtrsim 0.9$
- NOνA can distinguish these cases from maximal mixing

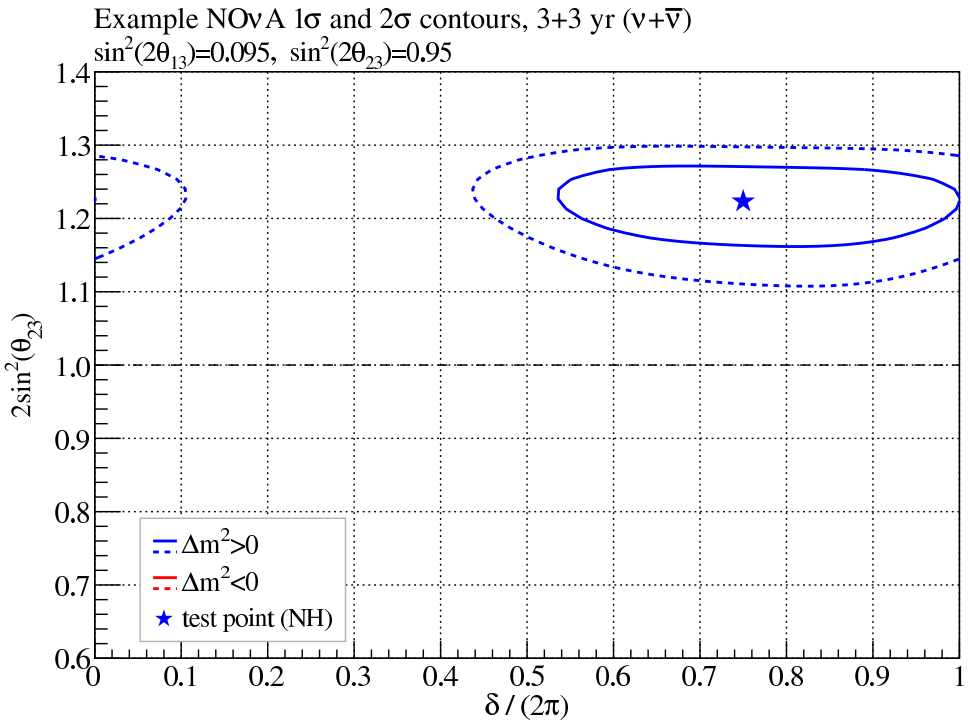
Determining the octant of θ_{23}



- If it turns out $\theta_{23} \neq 45°$, is it bigger or smaller?
- Affects ν_e probabilities. In same sense, contrasting with hierarchy and δ_{CP}'s opposite sense

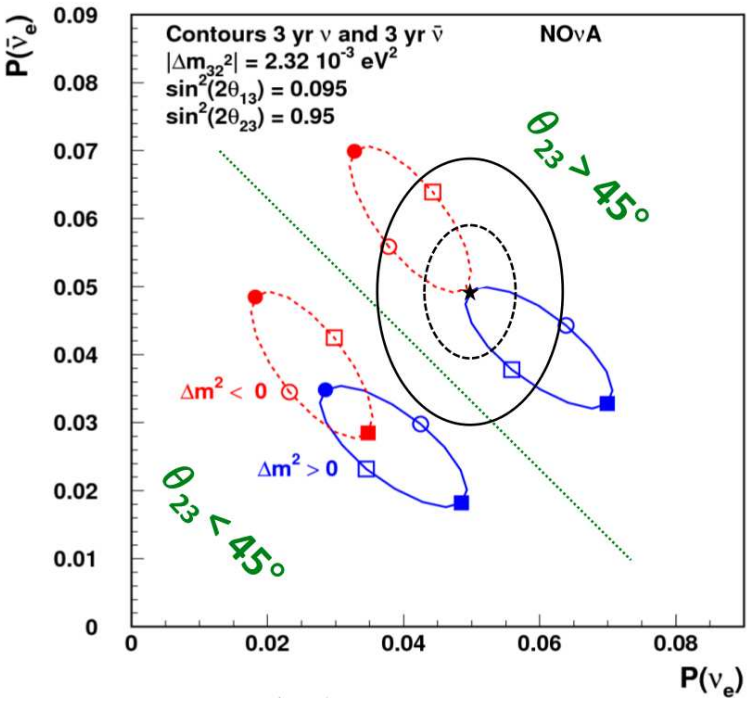
Determining the octant of θ_{23}

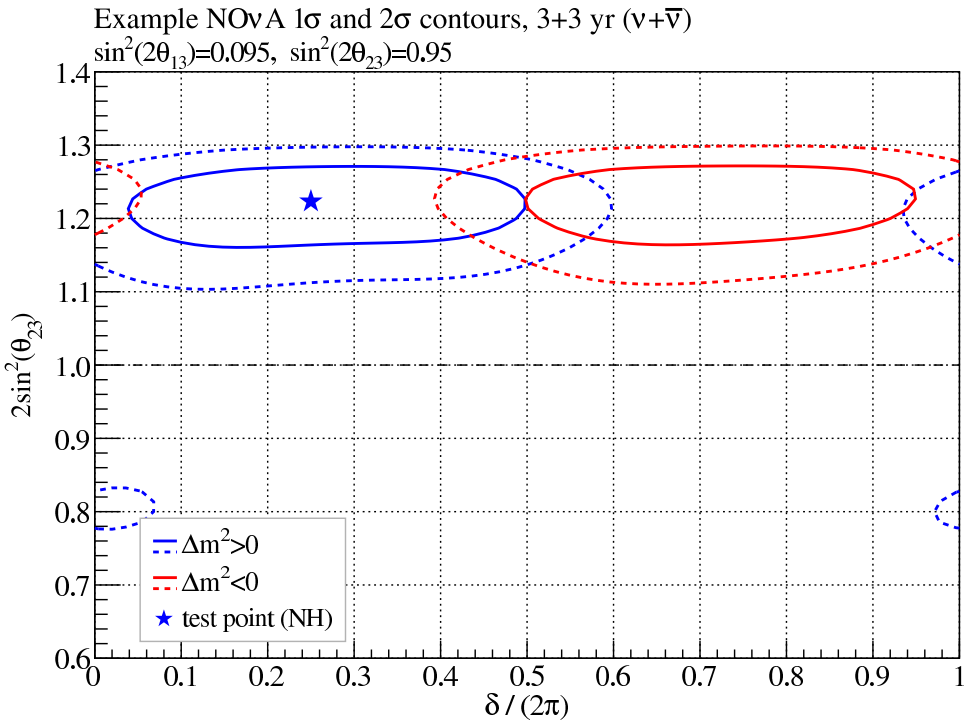




- If it turns out $\theta_{23} \neq 45°$, is it bigger or smaller?
- Affects ν_e probabilities. In same sense, contrasting with hierarchy and δ_{CP}'s opposite sense
- Here we determine hierarchy and octant ($>2\sigma$) and rule out half of δ_{CP} space (at 2σ)

Determining the octant of θ_{23}





- If it turns out $\theta_{23} \neq 45°$, is it bigger or smaller?
- Affects ν_e probabilities. In same sense, contrasting with hierarchy and δ_{CP}'s opposite sense
- In a degenerate case hierarchy and δ information are coupled, octant is not

Conclusion

- Gained experience with NDOS operation
- First FD block!
- NuMI upgrade in progress
- First neutrino events in partial FD next Spring

- Large $\theta_{13} \rightarrow$ sensitivity to hierarchy, δ_{CP}, and θ_{23} octant
- Developing analyses for first data

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EXIT