The NOνA Experiment
Status and Outlook

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on behalf of the NOνA Collaboration

XXV International Conference on Neutrino Physics and Astrophysics

June 2012

NOνA

A broad physics scope

Using $\nu_\mu \to \nu_e$, $\bar{\nu}_\mu \to \bar{\nu}_e$ …

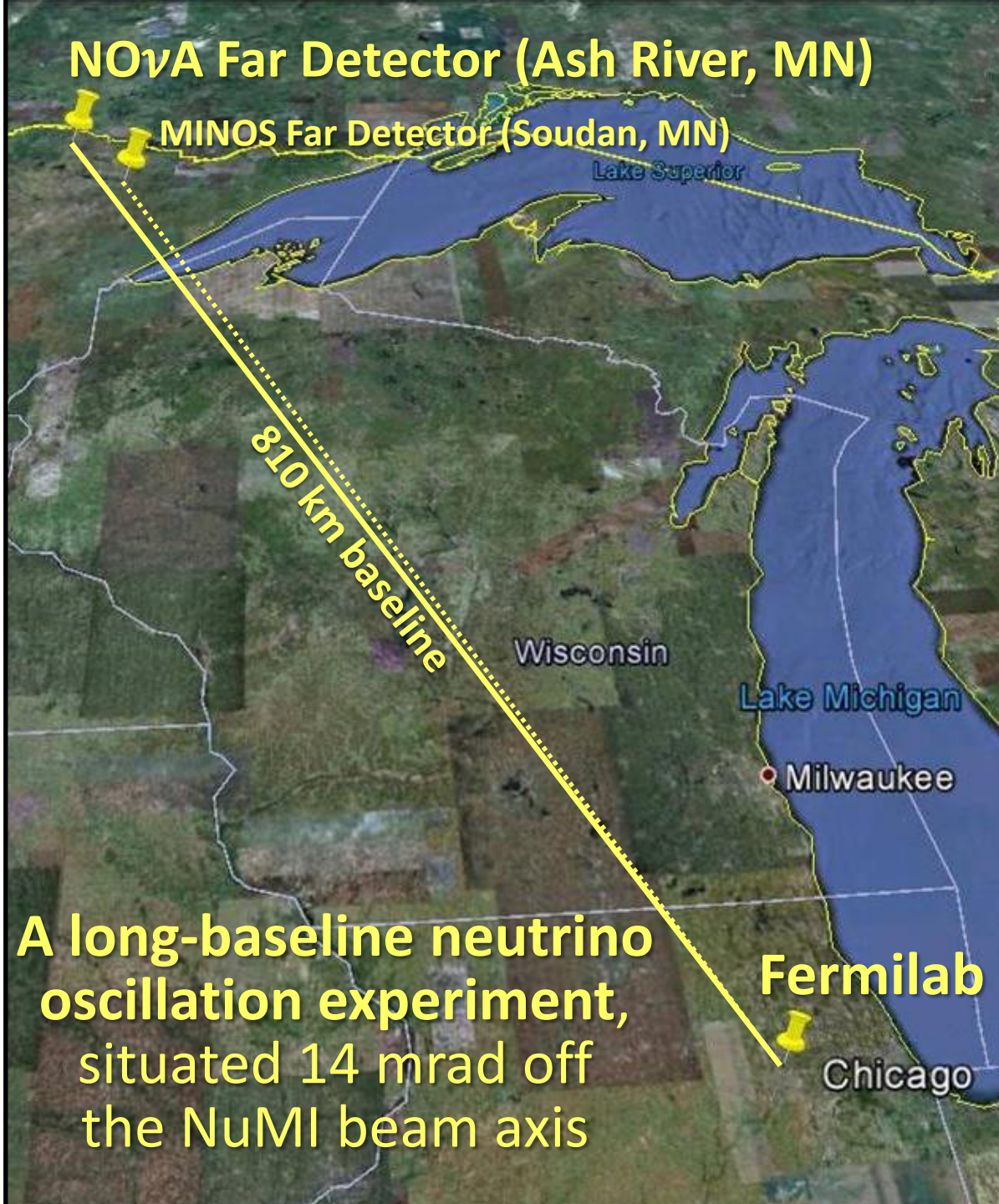
- **Measure θ_{13}** via ν_e appearance
- Determine the **ν mass hierarchy**
- Search for **ν CP violation**
- Determine the **θ_{23} octant**

Using $\nu_\mu \to \nu_\mu$, $\bar{\nu}_\mu \to \bar{\nu}_\mu$ …

- **Atmospheric parameters:** precision measurements of θ_{23}, $|\Delta m^2_{\text{atm}}|$. (*Exclude $\theta_{23}=\pi/4$?*)
- **Over-constrain** the atmos. sector (*four oscillation channels!*)

Also …

- Neutrino cross sections at the NOνA Near Detector
- Sterile neutrinos
- Supernova neutrinos
- Other exotica



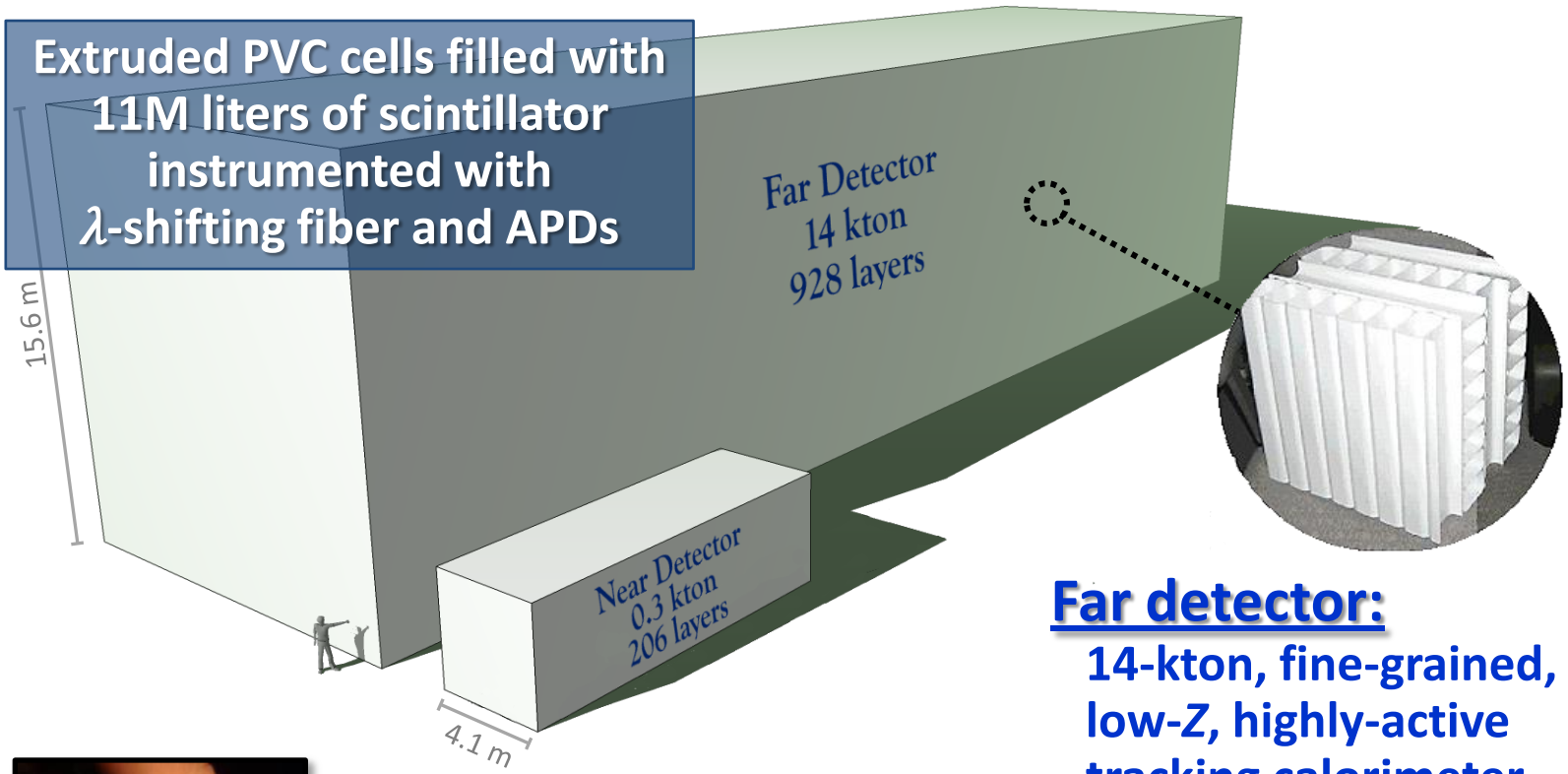
NOvA Collaboration

150+ scientists and engineers from 25 institutions, 5 countries

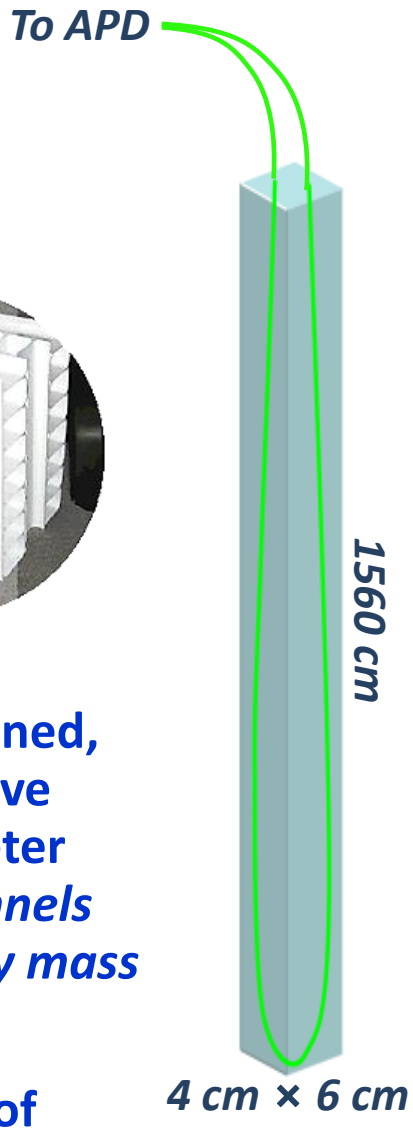
ANL / Athens / Caltech / Institute of Physics ASCR / Charles University / FNAL / Harvard
India Universities Consortium / Indiana / Iowa State / Lebedev / Michigan State
Minnesota, Crookston / Minnesota, Duluth / Minnesota, Twin Cities / INR Moscow / South Carolina
SMU / Stanford / Tennessee / Texas, Austin / Tufts / Virginia / WSU / William & Mary

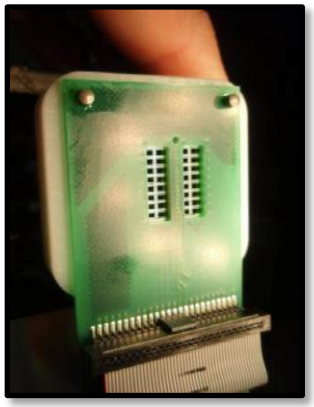
NOνA Detectors

Extruded PVC cells filled with 11M liters of scintillator instrumented with λ-shifting fiber and APDs



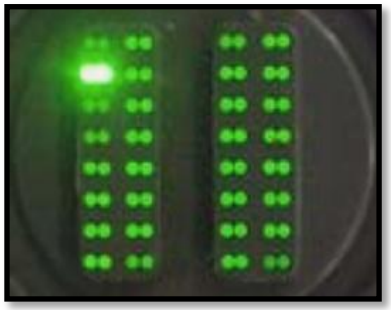
A NOνA cell





32-pixel APD

Fiber pairs from 32 cells



Far detector:

14-kton, fine-grained, low-*Z*, highly-active tracking calorimeter

→ *360,000 channels*

→ *77% active by mass*

Near detector:

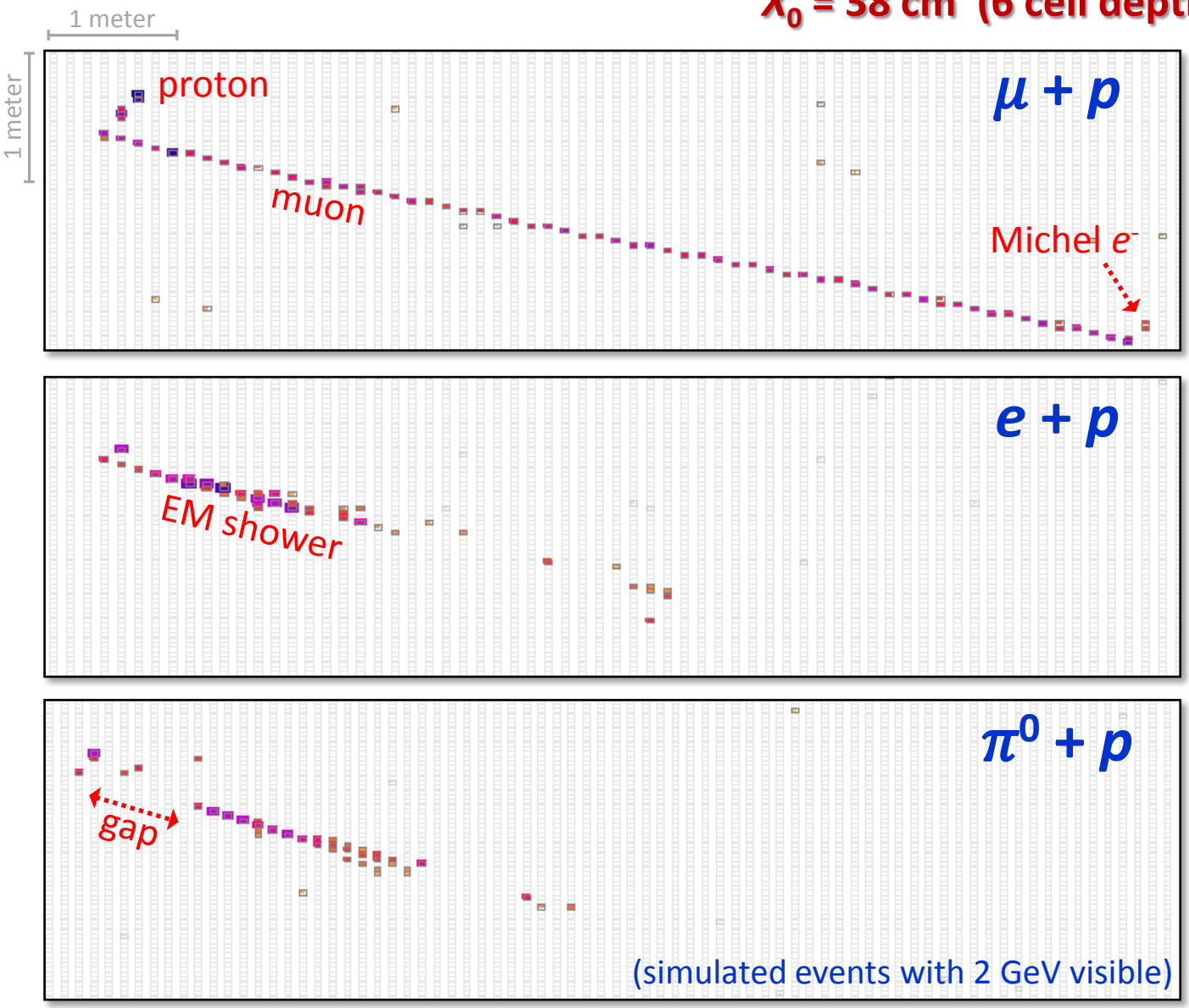
0.3-kton version of the same

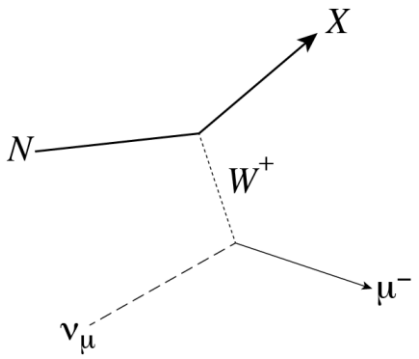
→ *18,000 channels*

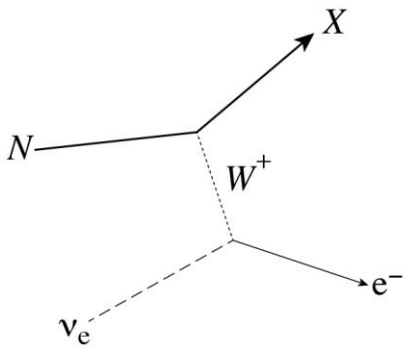
Events in NOνA

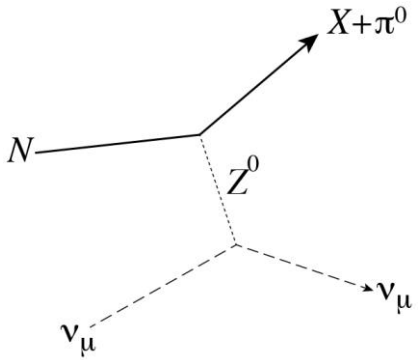
Superb spatial granularity for a detector of this scale

X_0 = 38 cm (6 cell depths, 10 cell widths)



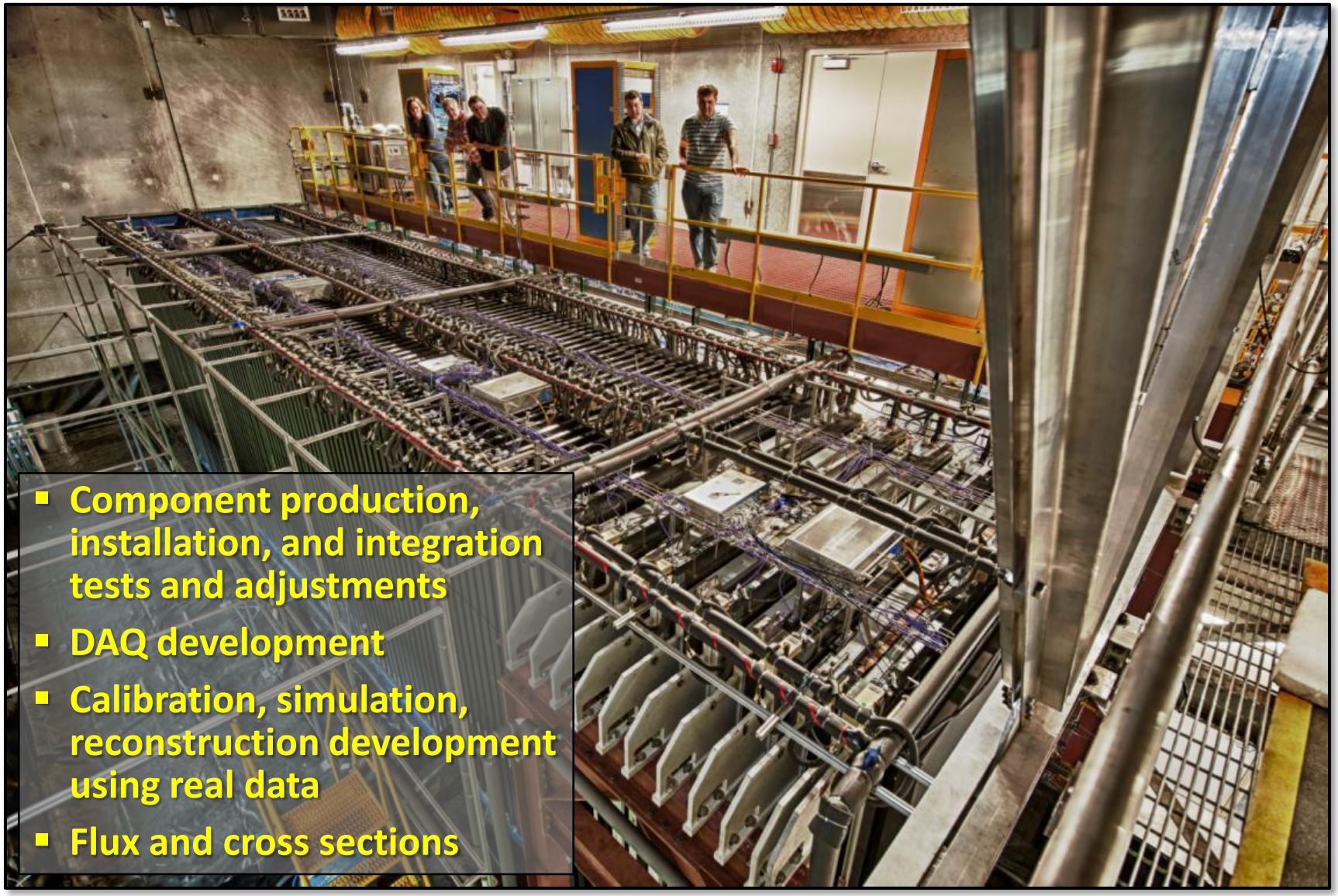






Prototype Near Detector

"NDOS"
(Near Detector on Surface)

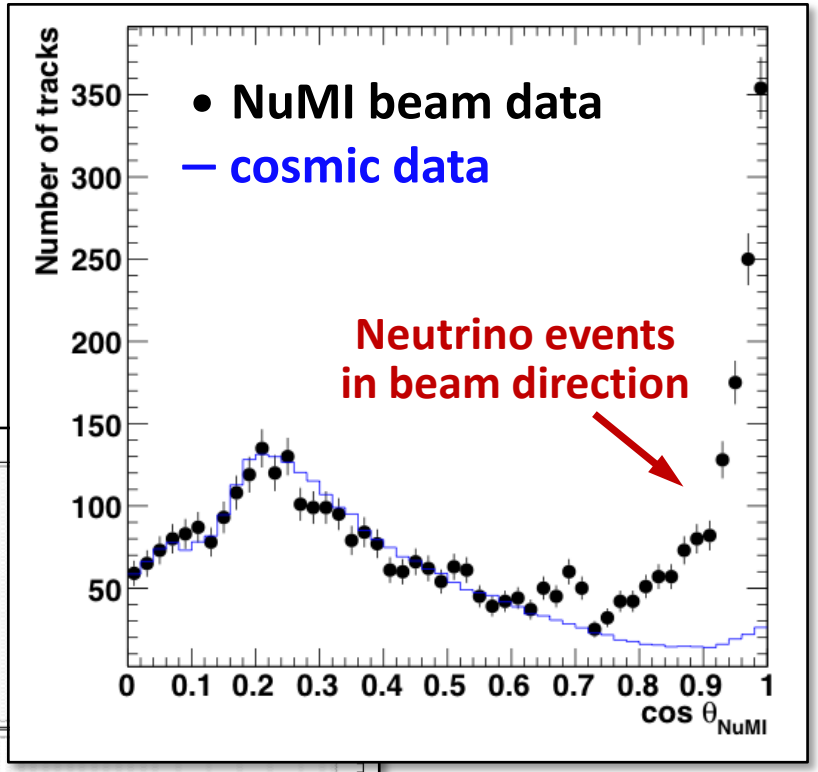


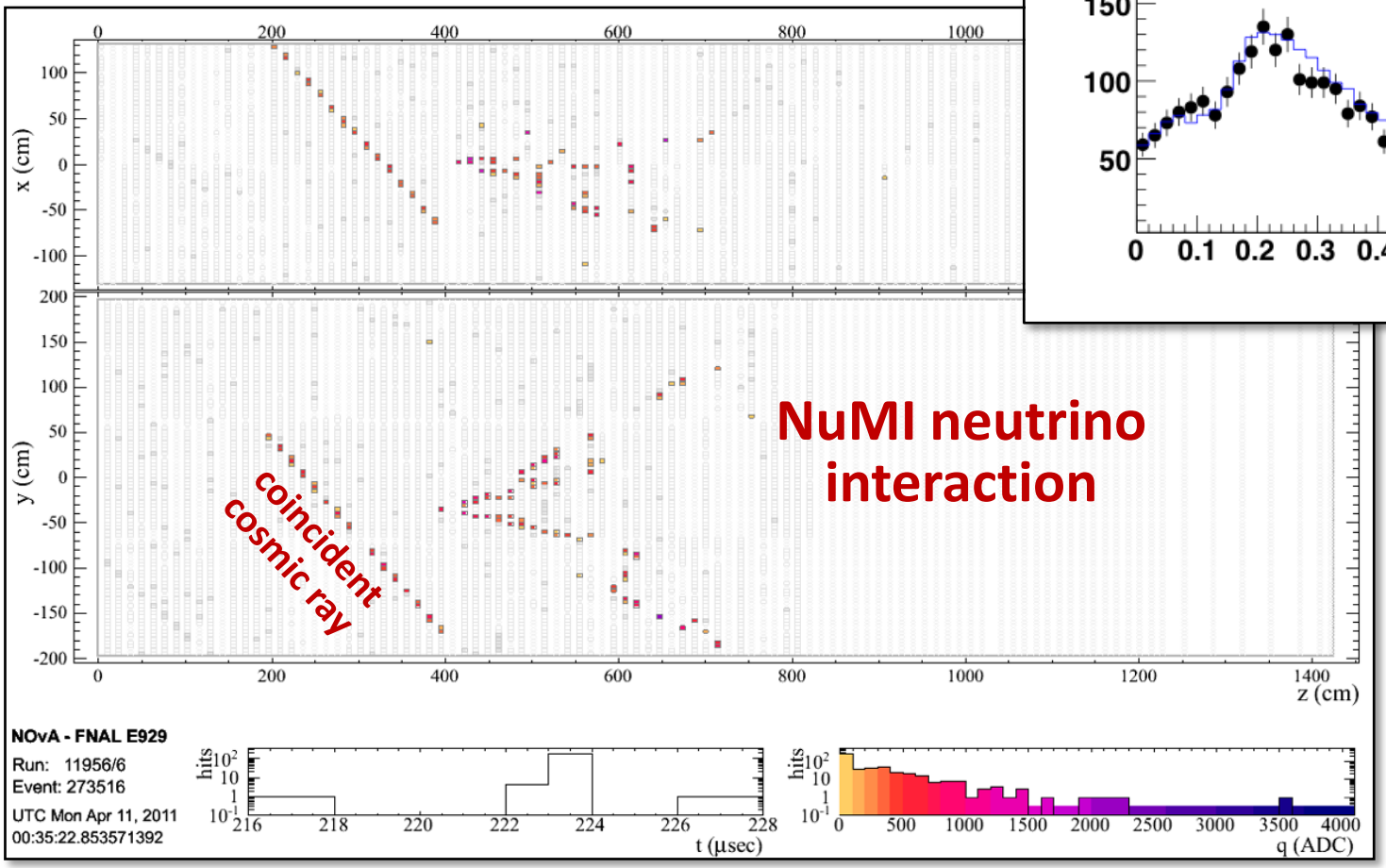
- Component production, installation, and integration tests and adjustments
- DAQ development
- Calibration, simulation, reconstruction development using real data
- Flux and cross sections

Events in NDOS

***Neutrino* and *cosmic ray* samples at NDOS**

- **Develop commissioning, calibration, reconstruction, and analysis tools**

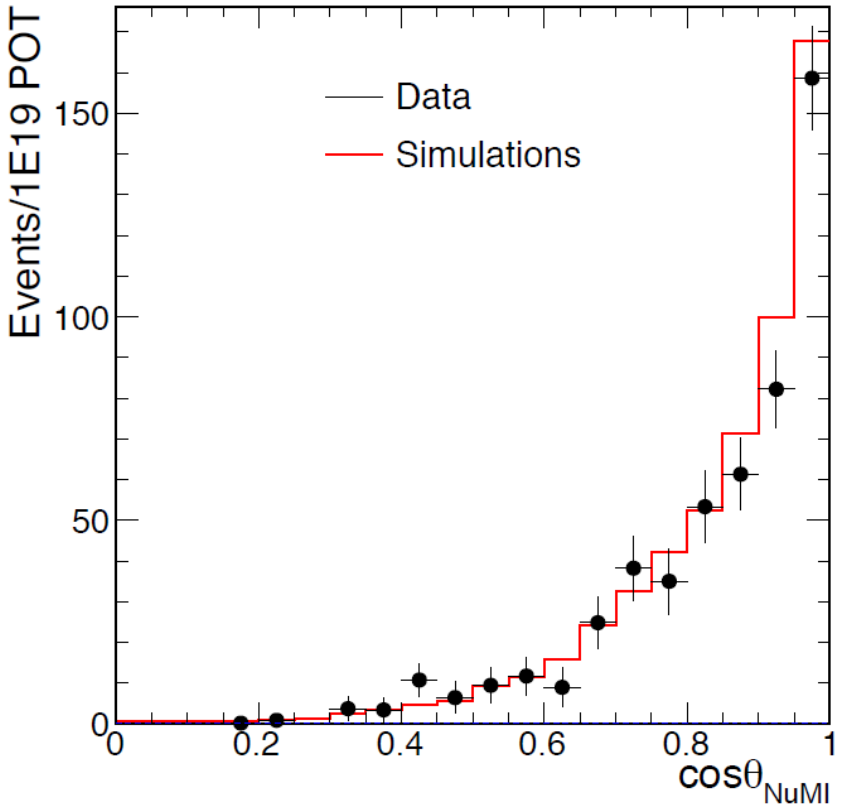


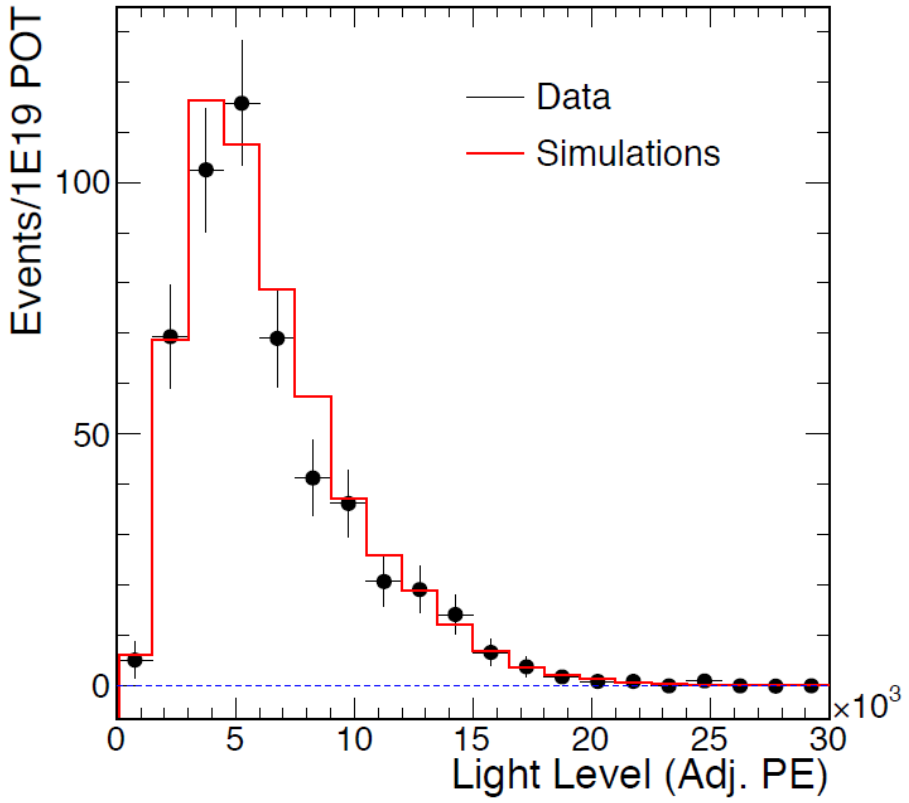


Neutrino event distributions

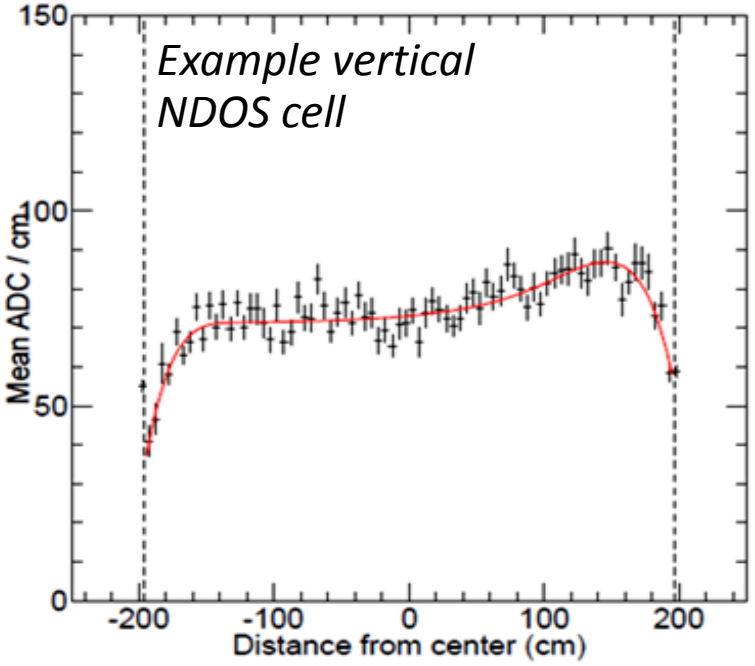
NuMI neutrino events at NDOS

- **Two example distributions:** *angle of primary track w.r.t. the neutrino beam*, **and** *total visible energy [in photoelectrons]*
- **Our Monte Carlo simulation agrees well with observations**



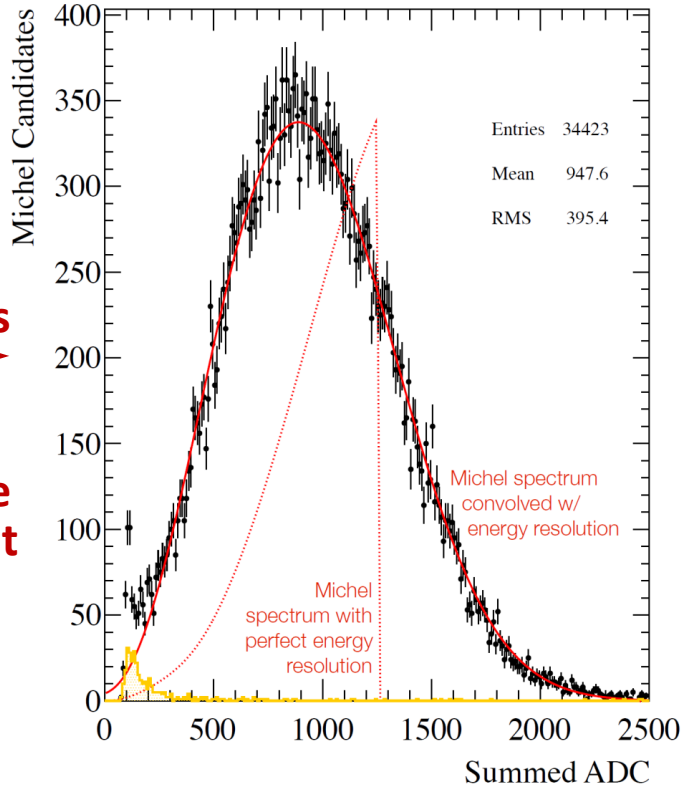


Detector calibrations

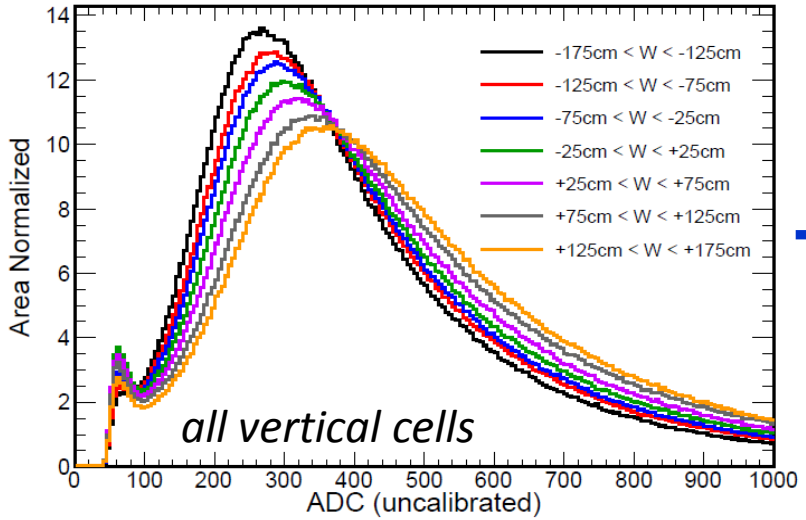


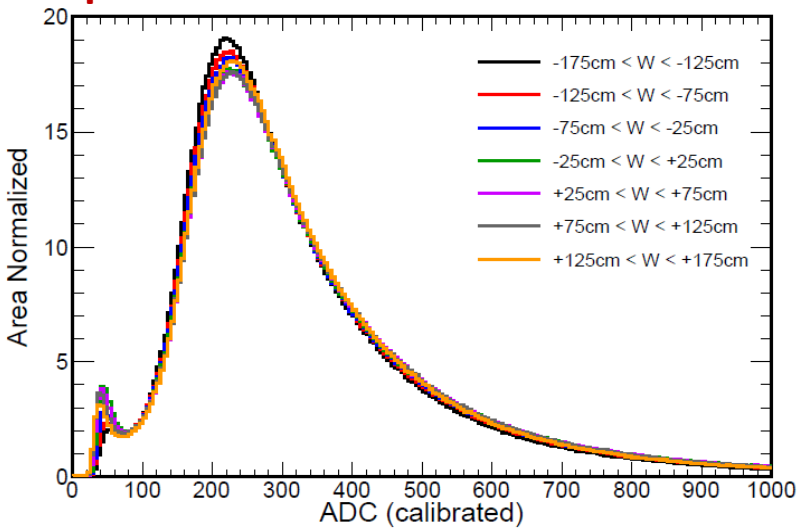
Position dependence of cell response (light attenuation, etc.)

Michel electrons



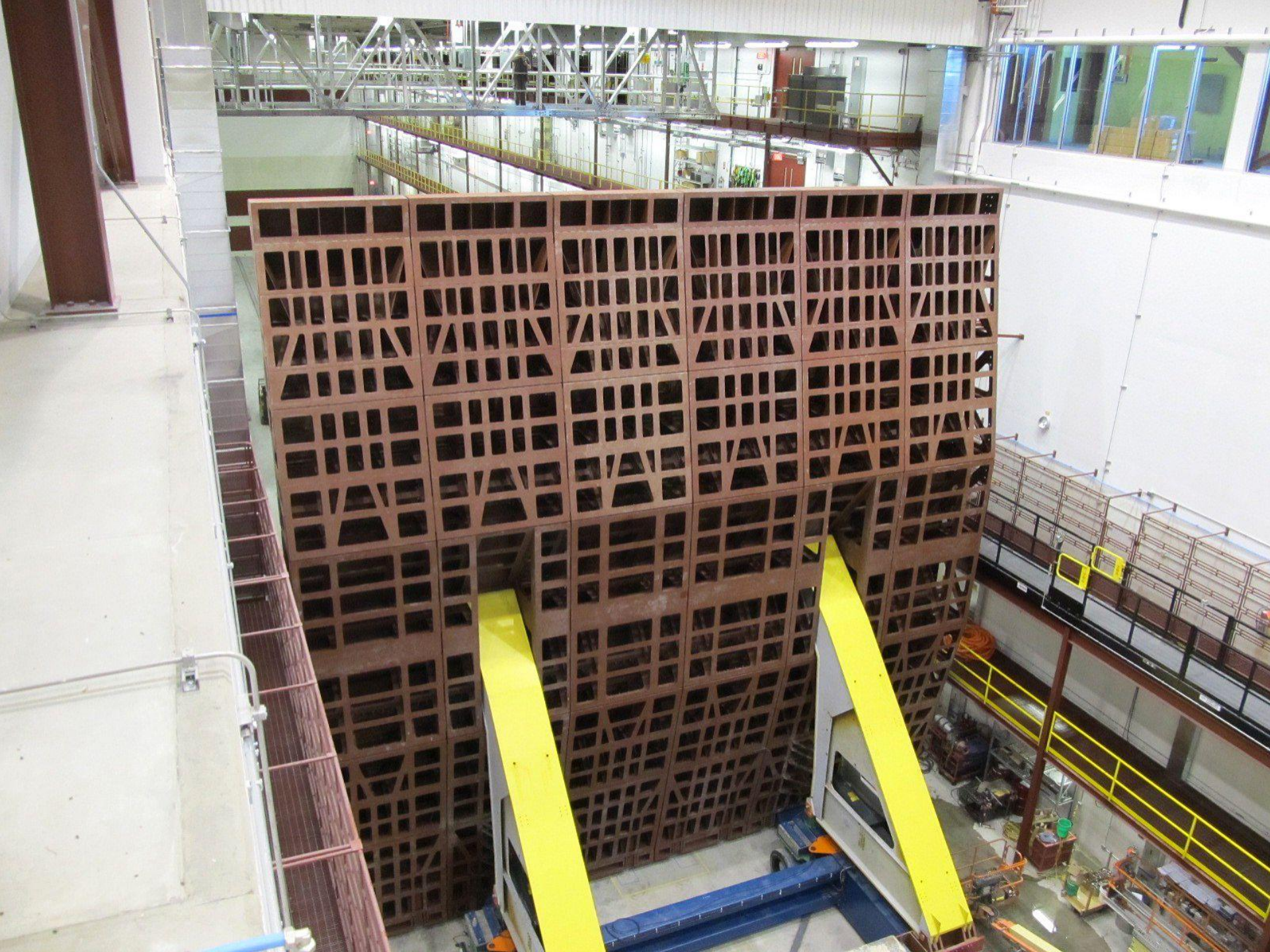
Corrected cell response





Far Detector Building – Complete

Inside the Hall (looking south) before the block pivoter. And then…



Assembly status

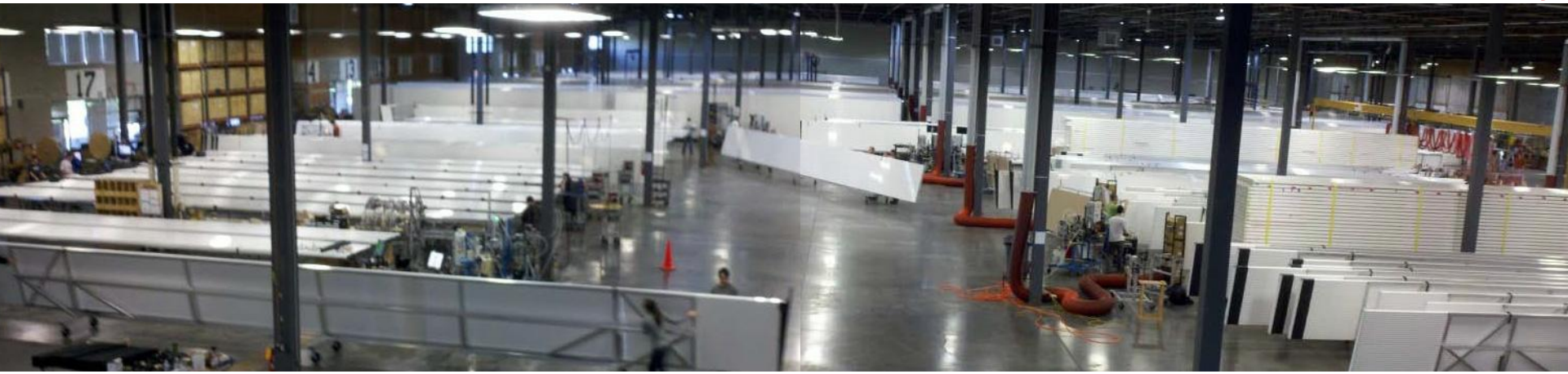
- **Pivoter essentially complete**
  (a few reinforcement plates to be added; final flatness shimming)
- **Bookend, lifters, leak testers ready**
- **1st block assembly to begin this month!**

Near Detector

- **ND cavern excavation and assembly to proceed in parallel at Fermilab**
- **Changing to (96 cell) × (96 cell) design**
  - *NDOS is 64×96*
  - *Improved ND event containment*

Lifting fixture and adhesive dispenser

NOνA module factory



Accelerator and NuMI Upgrades

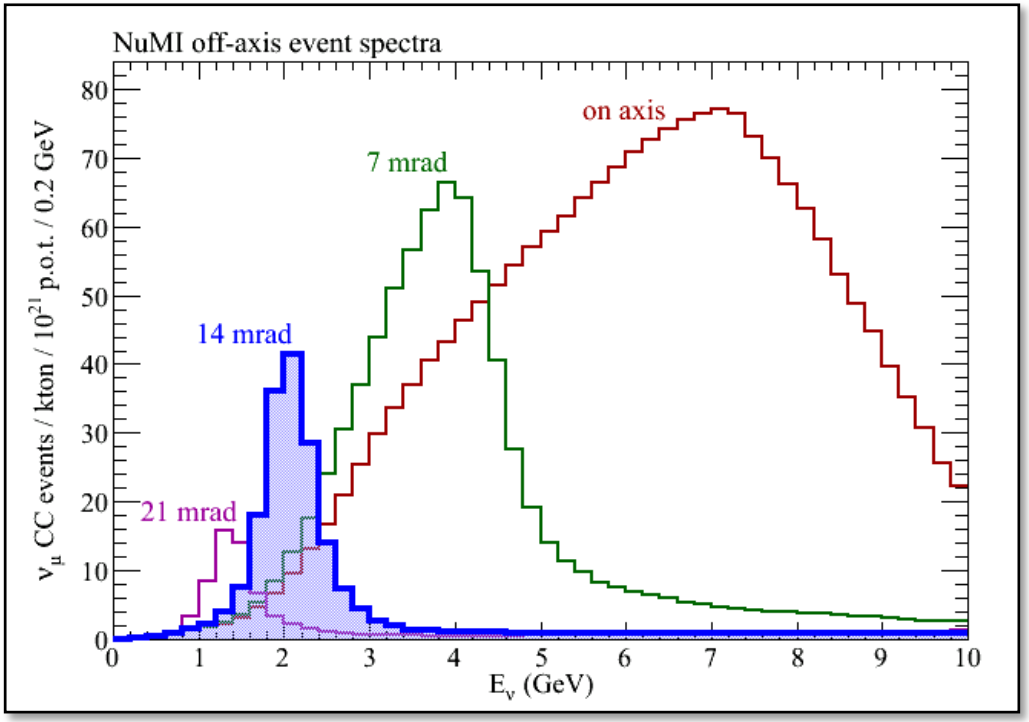
Taking the NuMI source from ~350 kW to 700 kW

- **Year-long accelerator shutdown underway (since May 1)**
- **Turn Recycler from antiproton to proton ring**
  injection & extraction lines, associated kickers & instrumentation, 53 MHz RF
- **Shorten Main Injector cycle from 2.2 seconds to 1.33 seconds**
  RF upgrades, power supply upgrades
- **Overhaul of NuMI target station for 700 kW running**

Beam to return May 2013.
Six month ramp-up to 700 kW.

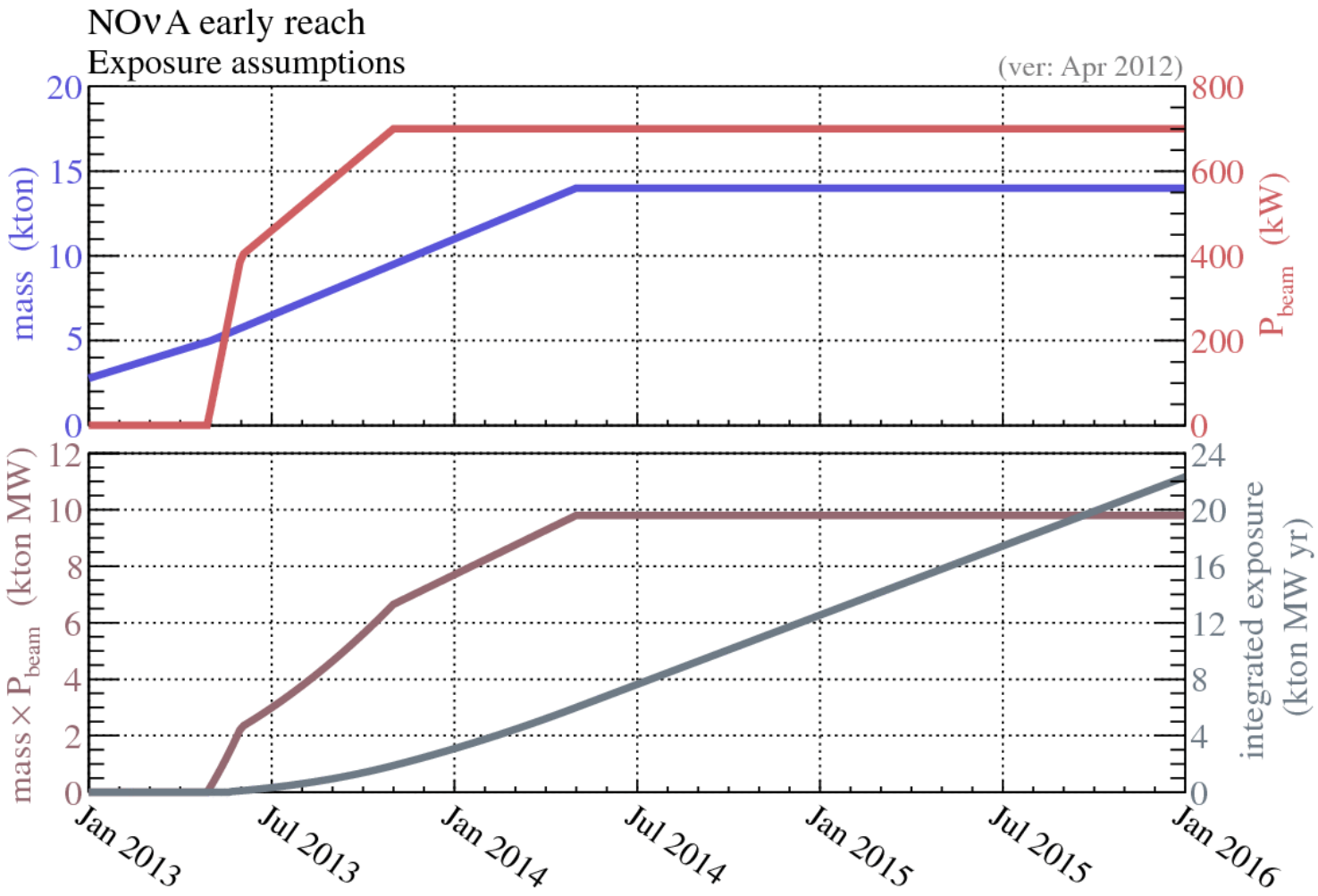
Event rate vs. E_ν at various angles relative to the NuMI beam axis →

NOνA : 14 mrad
→ *spectrum peaks sharply at 2 GeV*



NOνA Exposure in Early Running

Evolution of detector mass and beam power…



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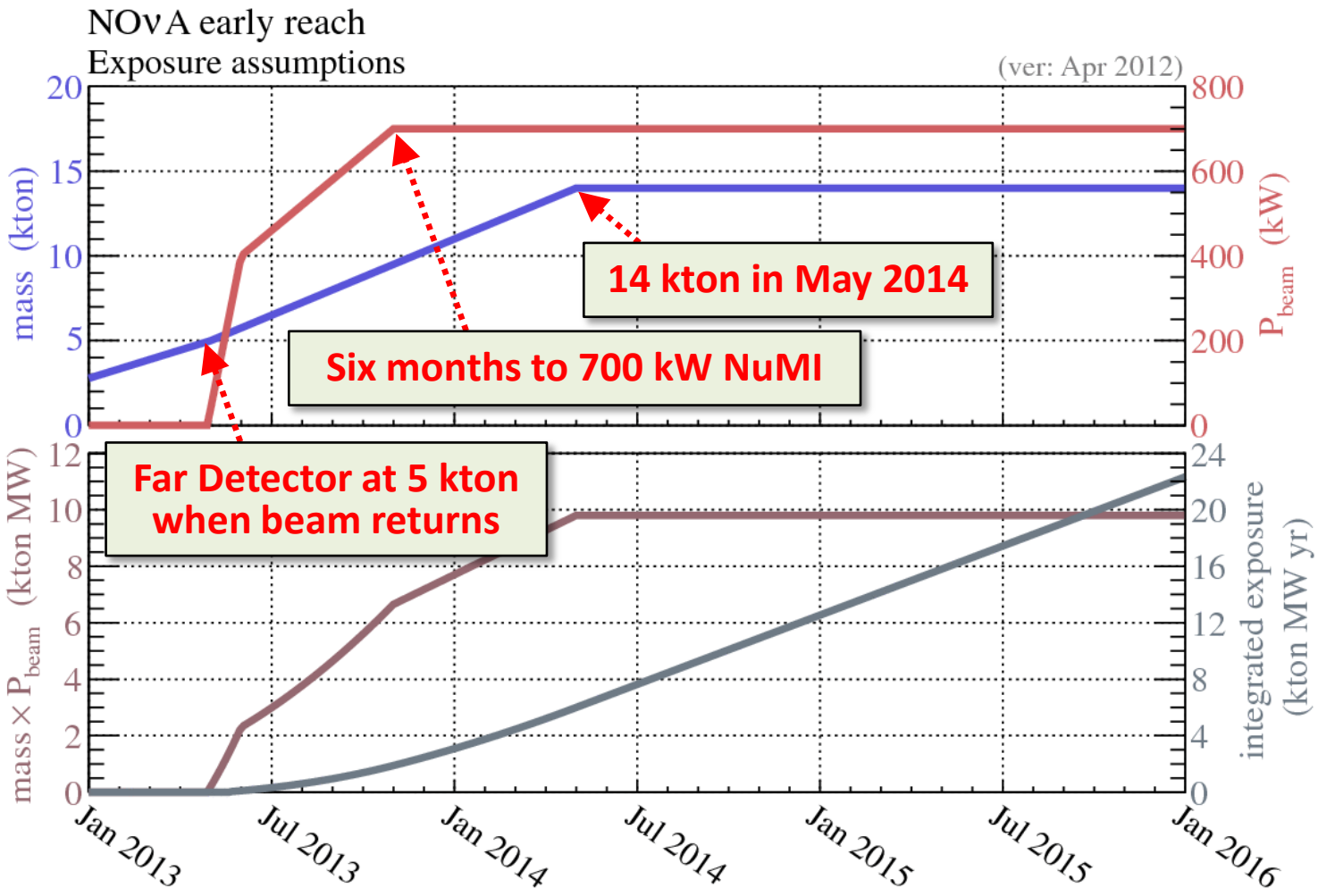
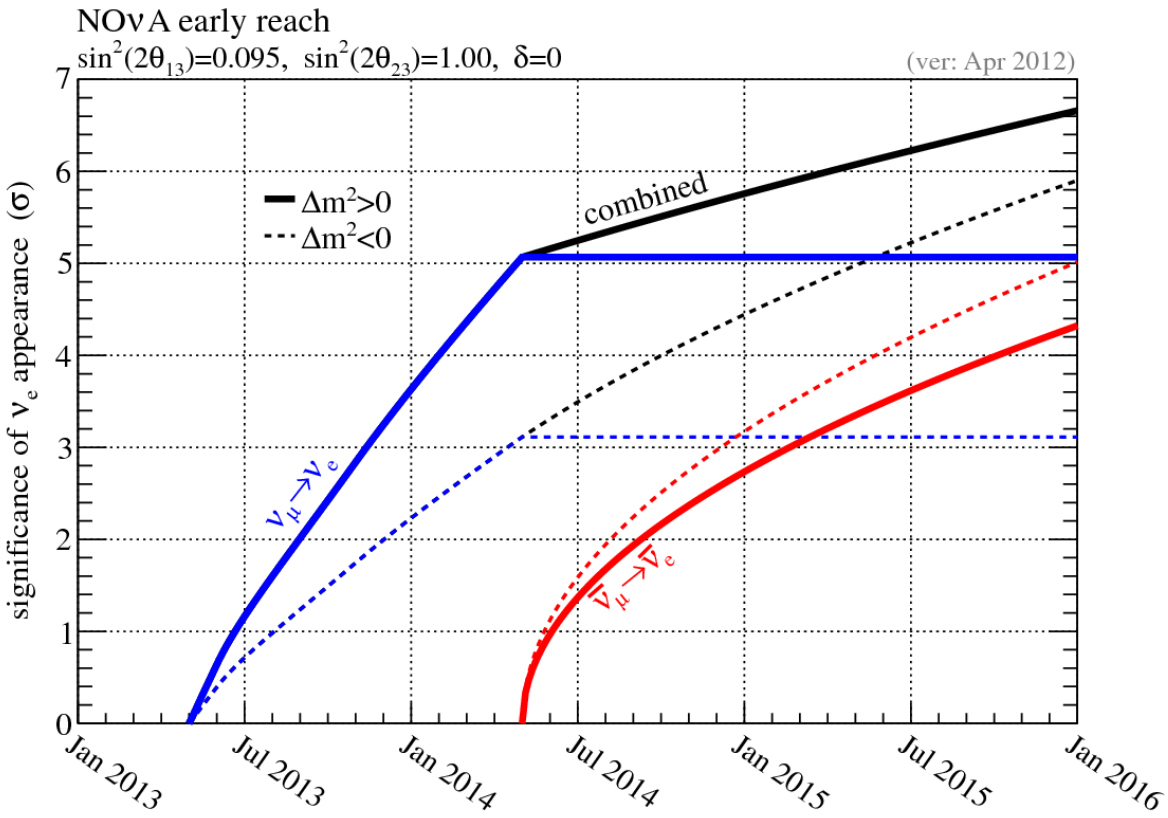


Early Reach

Will start with ν running

- **Can switch to $\overline{\nu}_\mu$ any time, optimizing the run plan based on our or others' results**
- **5σ observation of $\nu_\mu \rightarrow \nu_e$ in first year if NH**
  (even with partial detector and beam commissioning!)



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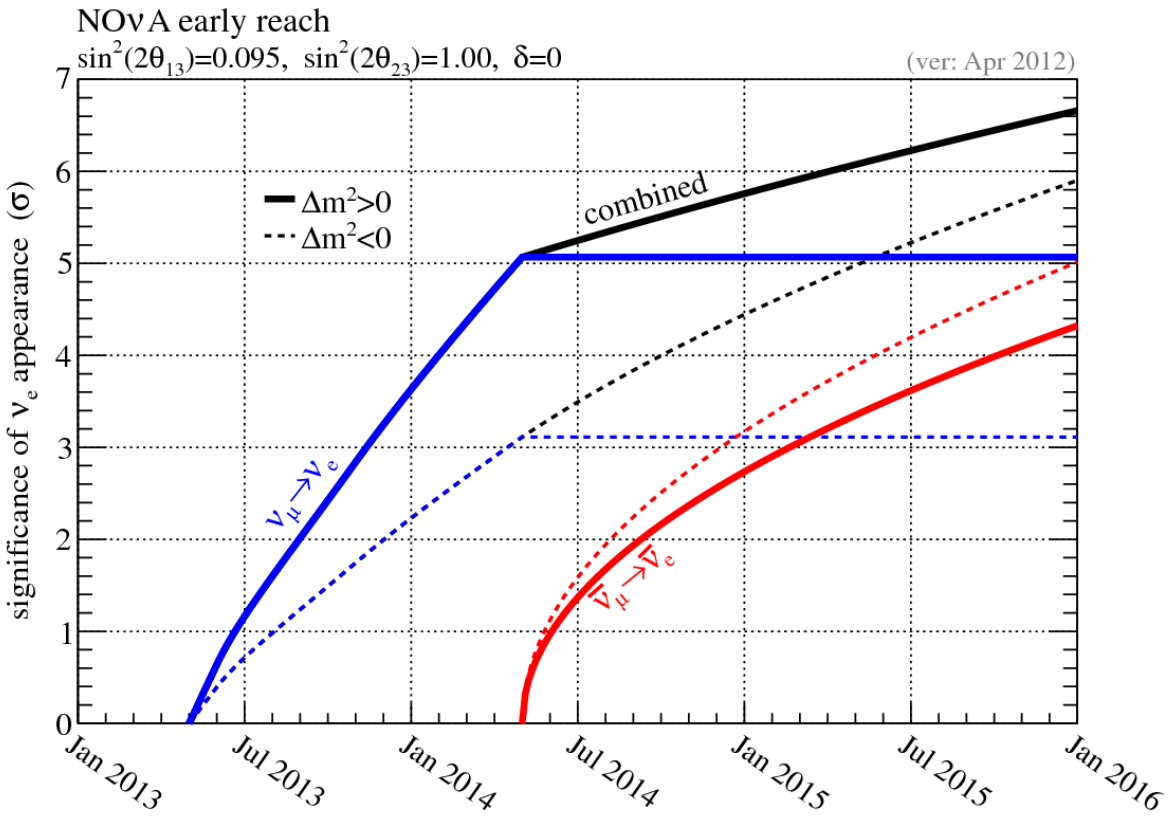


And beyond...

Nominal run plan: 3 yr (ν) + 3 yr ($\bar{\nu}$) (with 6×10^{20} p.o.t./year)

- In this talk: using *earlier analysis methods*, but including new θ_{13} knowledge
  - ⇨ Taking $\sin^2(2\theta_{13}) = 0.095$
- Representative event counts for $\nu_\mu \rightarrow \nu_e$ analysis →
  - ⇨ *These depend greatly on the specific oscillation parameters*
- Signal efficiency: 45%
  NC fake rate: 0.1%

3 yr + 3 yr

beam =	ν	$\bar{\nu}$
NC	19	10
ν_μ CC	5	<1
ν_e CC	8	5
tot. BG	32	15
$\nu_\mu \rightarrow \nu_e$	68	32

NOνA measurement principle

NOνA will measure:

$P(\nu_\mu \rightarrow \nu_e)$ at 2 GeV

and

$P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ at 2 GeV

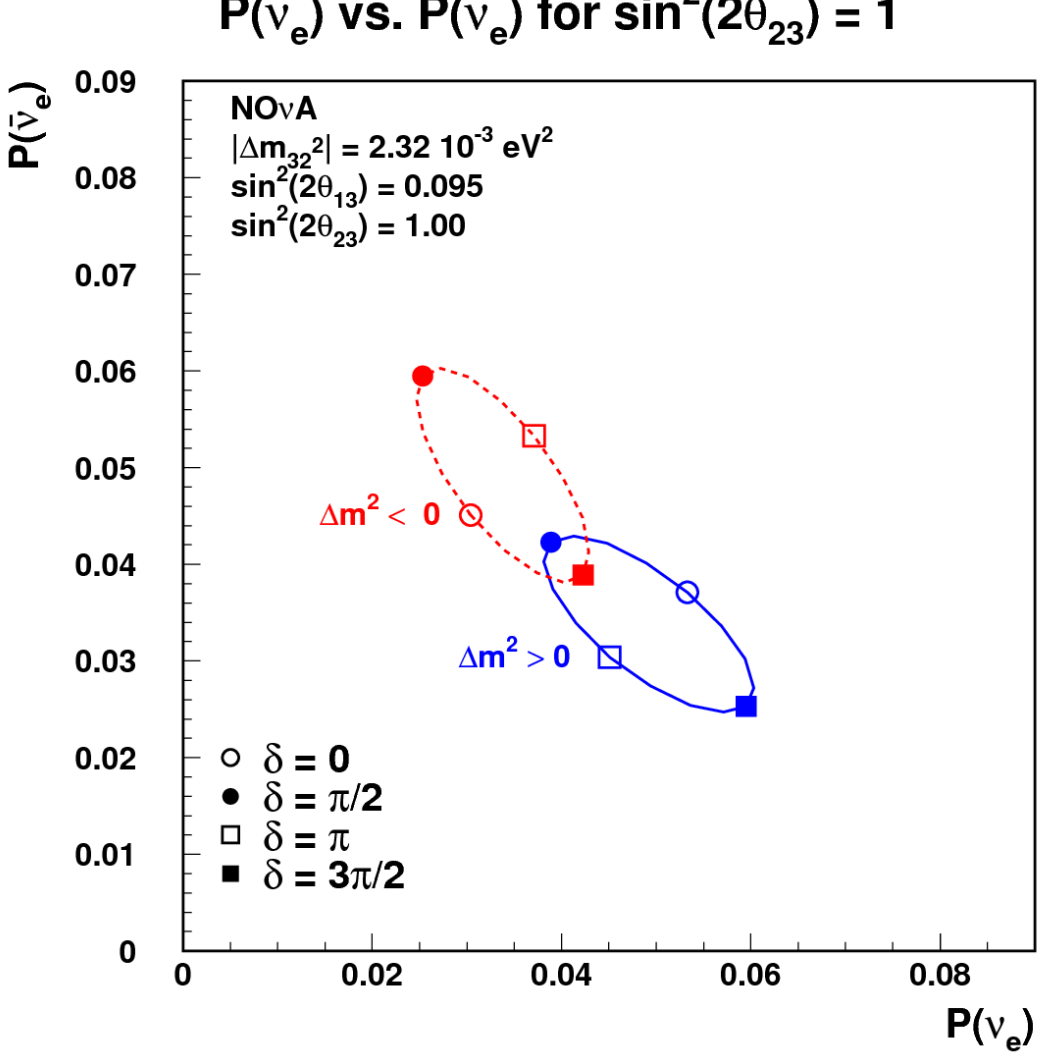
These depend *in different ways* on the CP phase δ and on sign(Δm^2) .

At right, these appearance probabilities are plotted as:

$P(\bar{\nu}_e)$ vs. $P(\nu_e)$

for all δ and both hierarchies

[*assuming:* $\sin^2(2\theta_{13})=0.095$, $\sin^2(2\theta_{23})=1$]



(This sketch ignores available spectral information.)

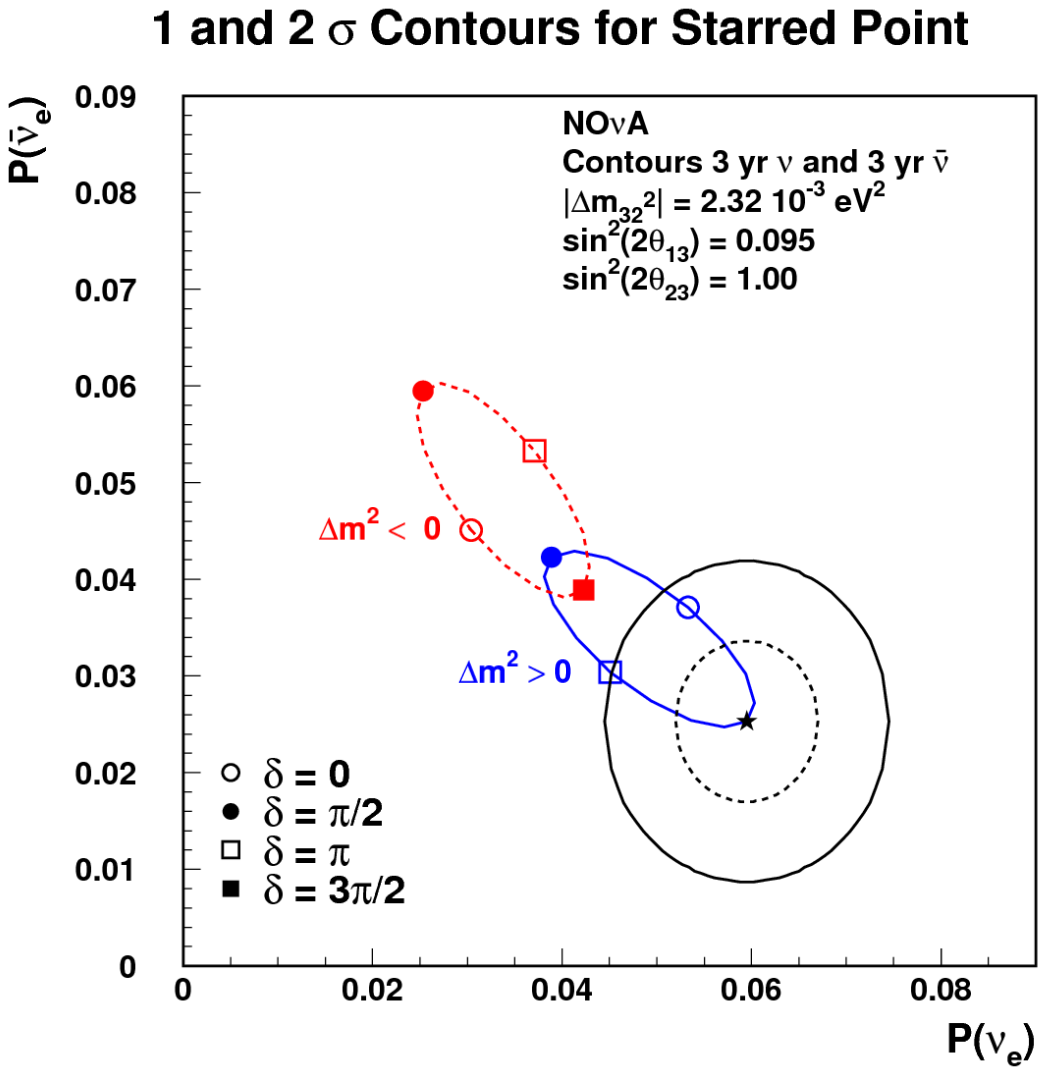
NOνA measurement principle

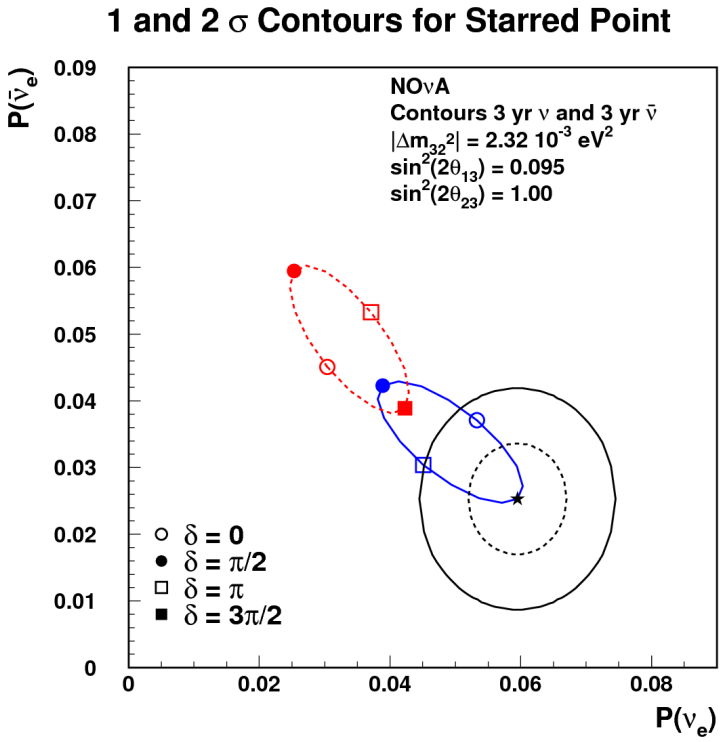
Example NOνA result…

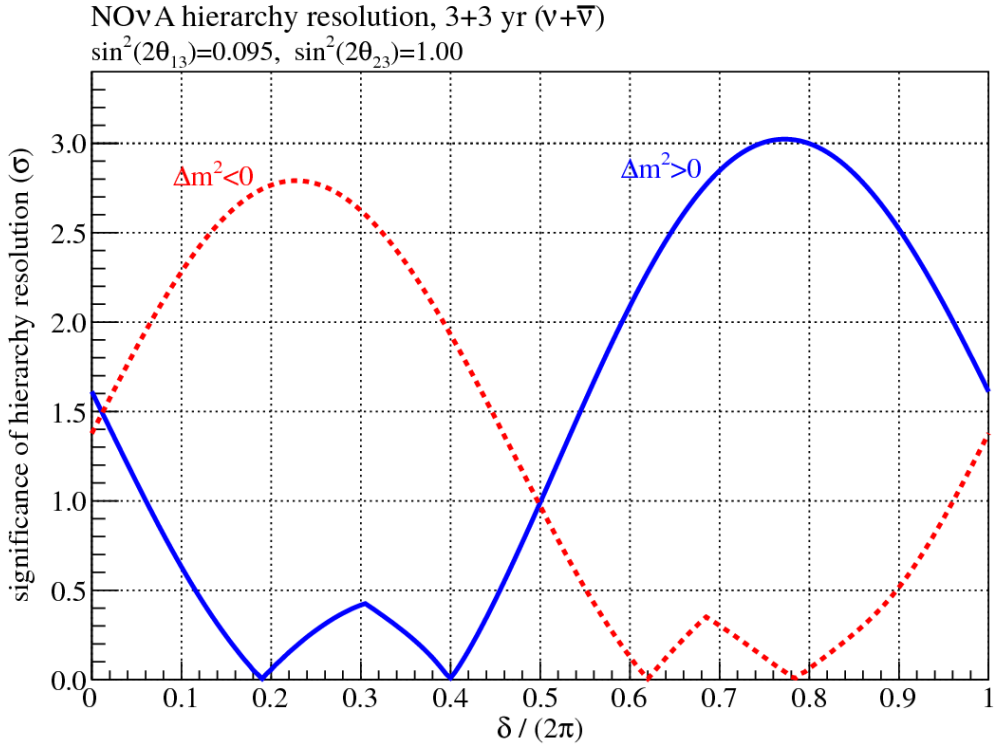
Our data will yield allowed regions in $P(\bar{\nu}_e)$ vs. $P(\nu_e)$ space

(3 yr + 3 yr possibility shown)

Here, all inverted hierarchy scenarios are excluded at >2σ.



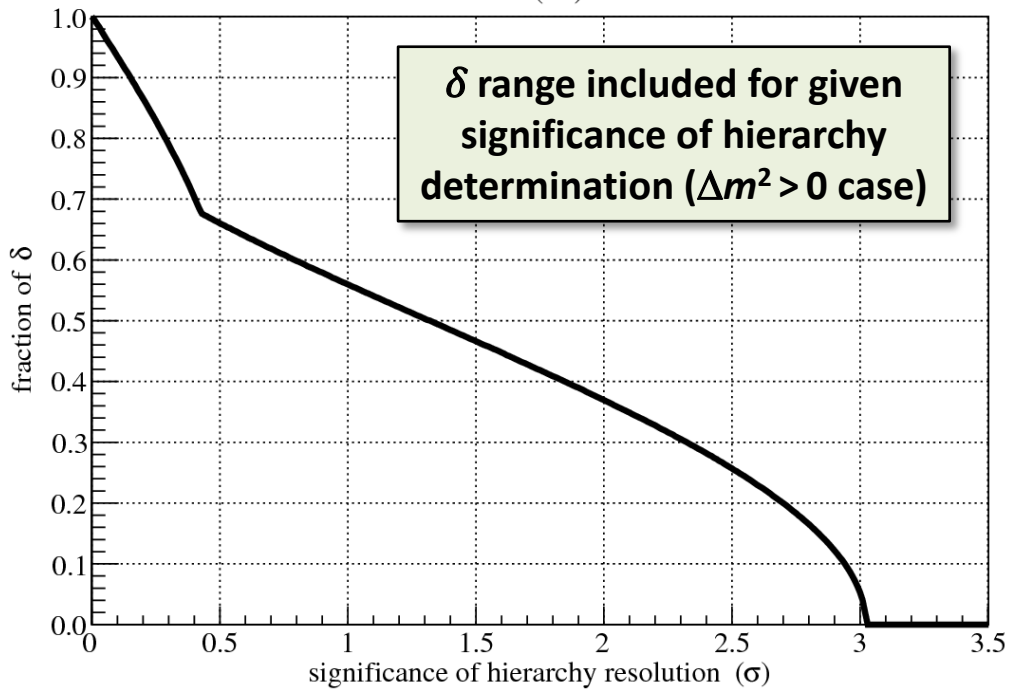




Hierarchy determination

[still with: $\sin^2(2\theta_{13})=0.095$, $\sin^2(2\theta_{23})=1$]

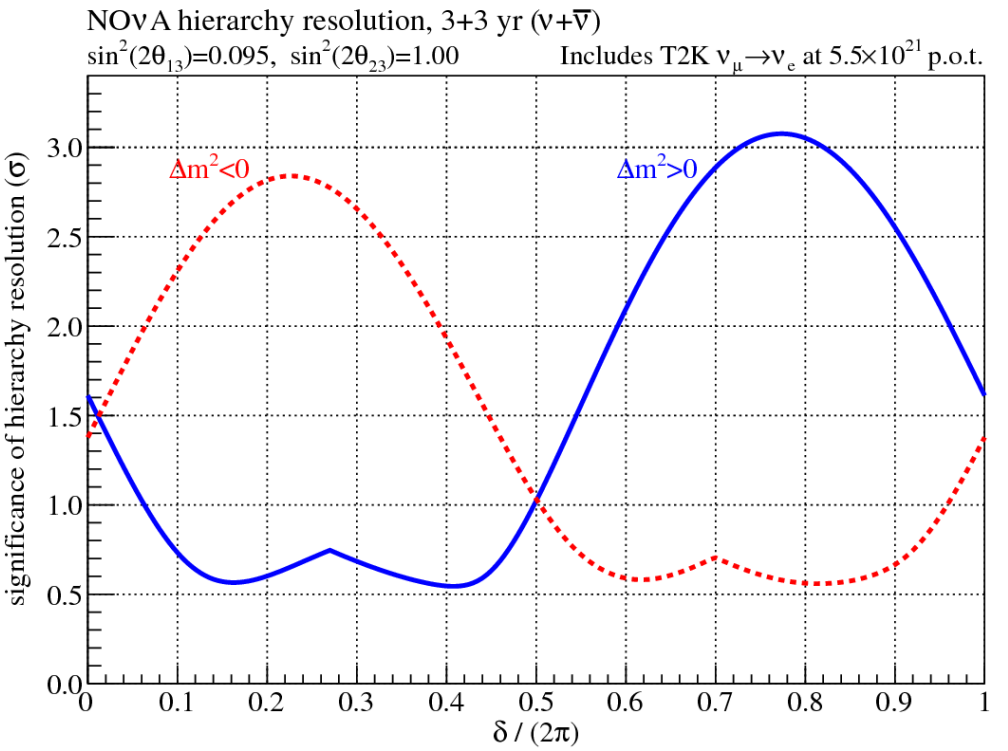
…in a more general form

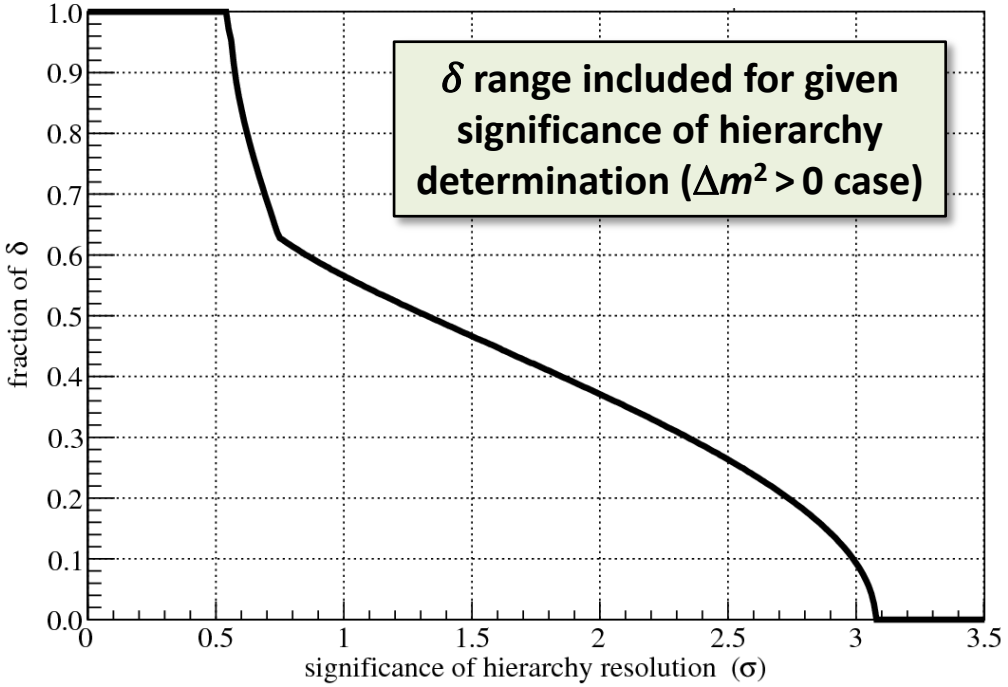


Including T2K information

In T2K, $P(\nu_\mu \rightarrow \nu_e)$ has δ dependence but comparatively little hierarchy dependence (shorter baseline).

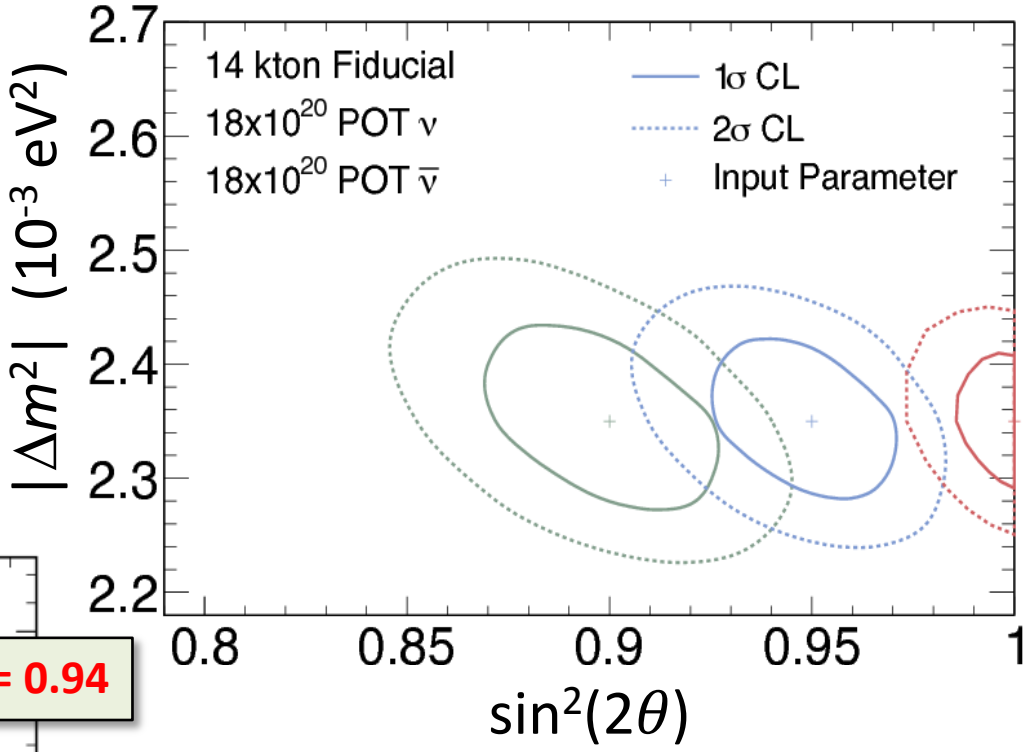
When CPv and matter effects cancel in NOνA, the NOνA + T2K combination helps.

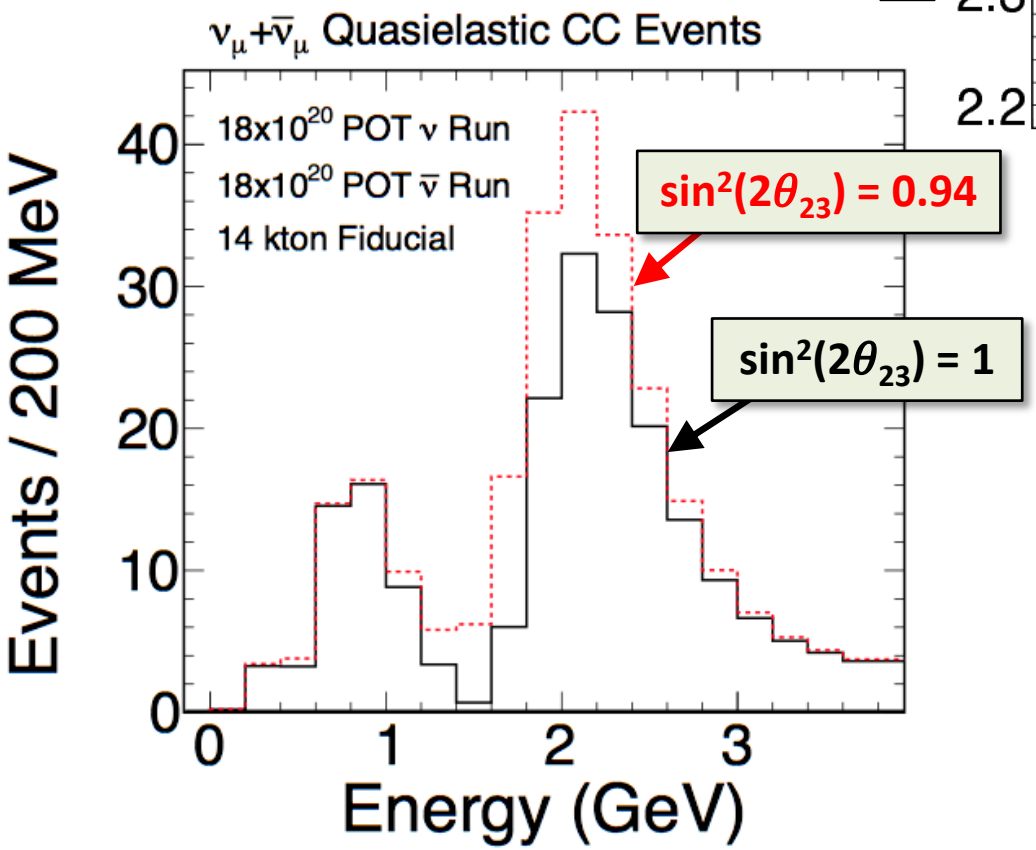




$\sin^2(2\theta_{23}) \neq 1$?

Example NOνA contours for three test points →





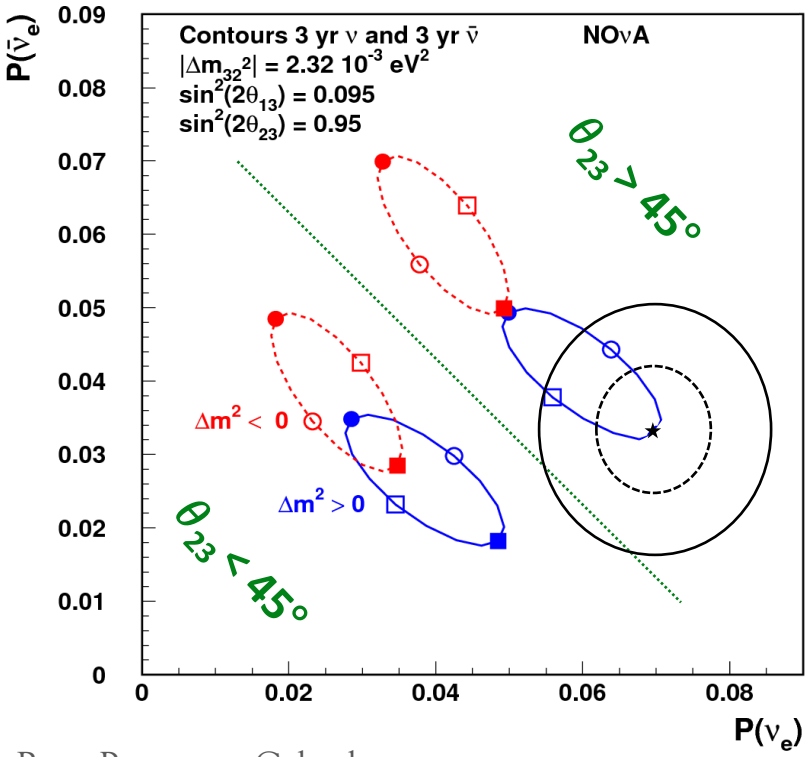
4% energy resolution for the QE sample.

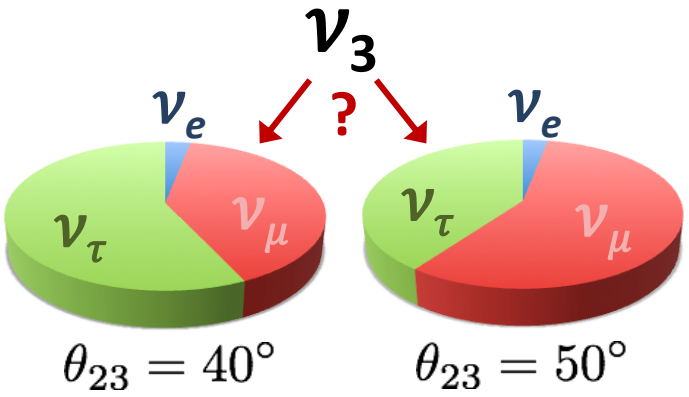
Inclusive ν_μ CC sample should be background-free

$P(\nu_e) \propto \sin^2(\theta_{23})\sin^2(2\theta_{13})$

⇨ θ_{23} *octant sensitivity*

Expected NOνA contours for one example scenario at 3 yr + 3 yr





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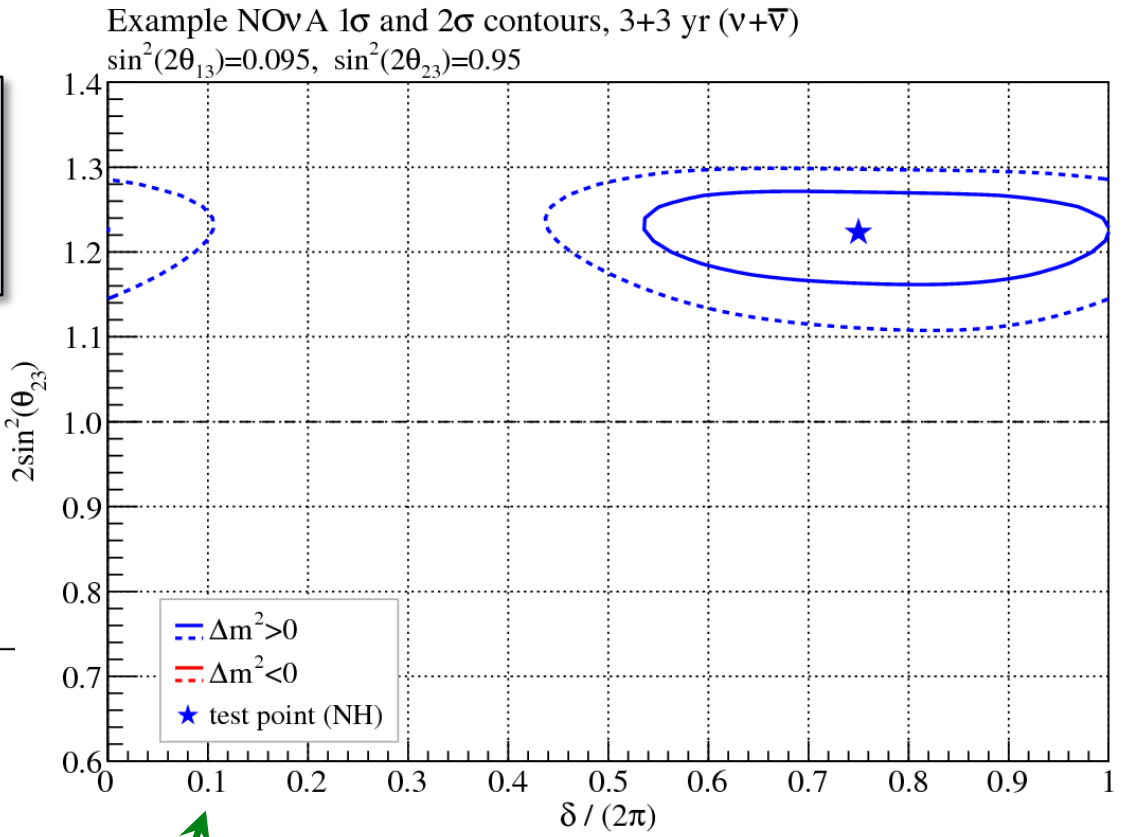
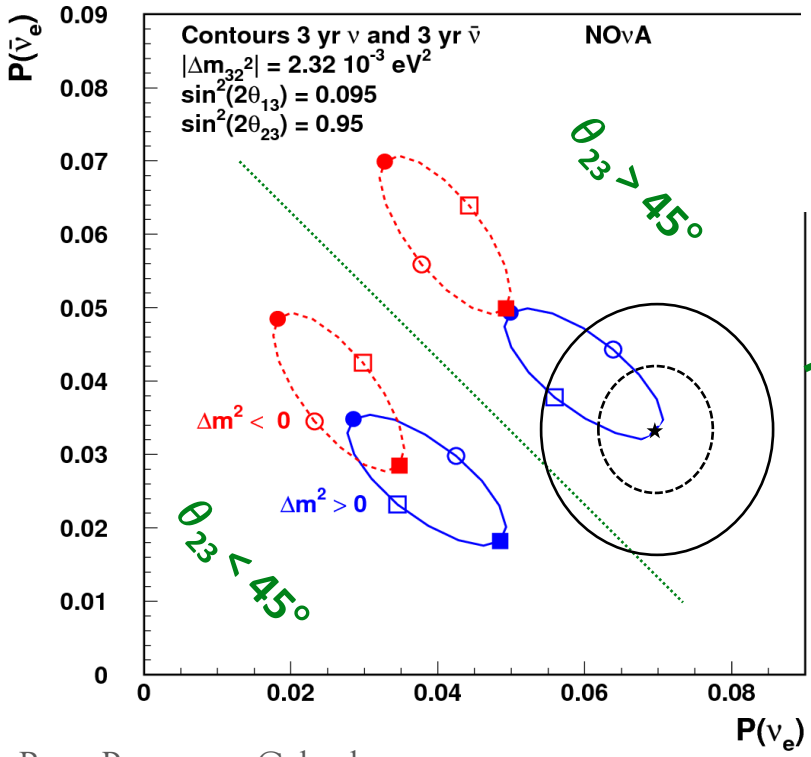
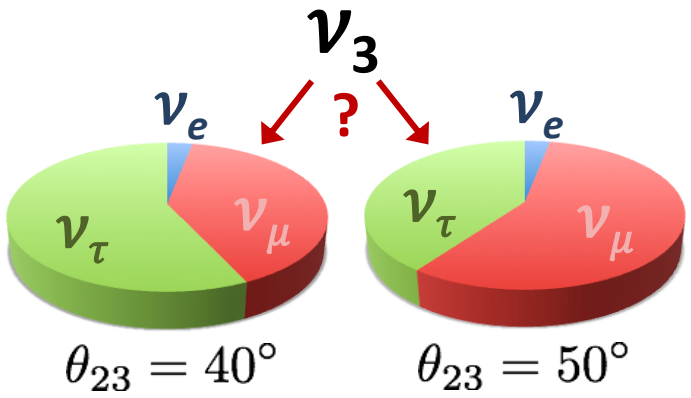


Expected NOνA contours for one example scenario at 3 yr + 3 yr



Simultaneous hierarchy, CP phase, and θ_{23} octant information from NOνA



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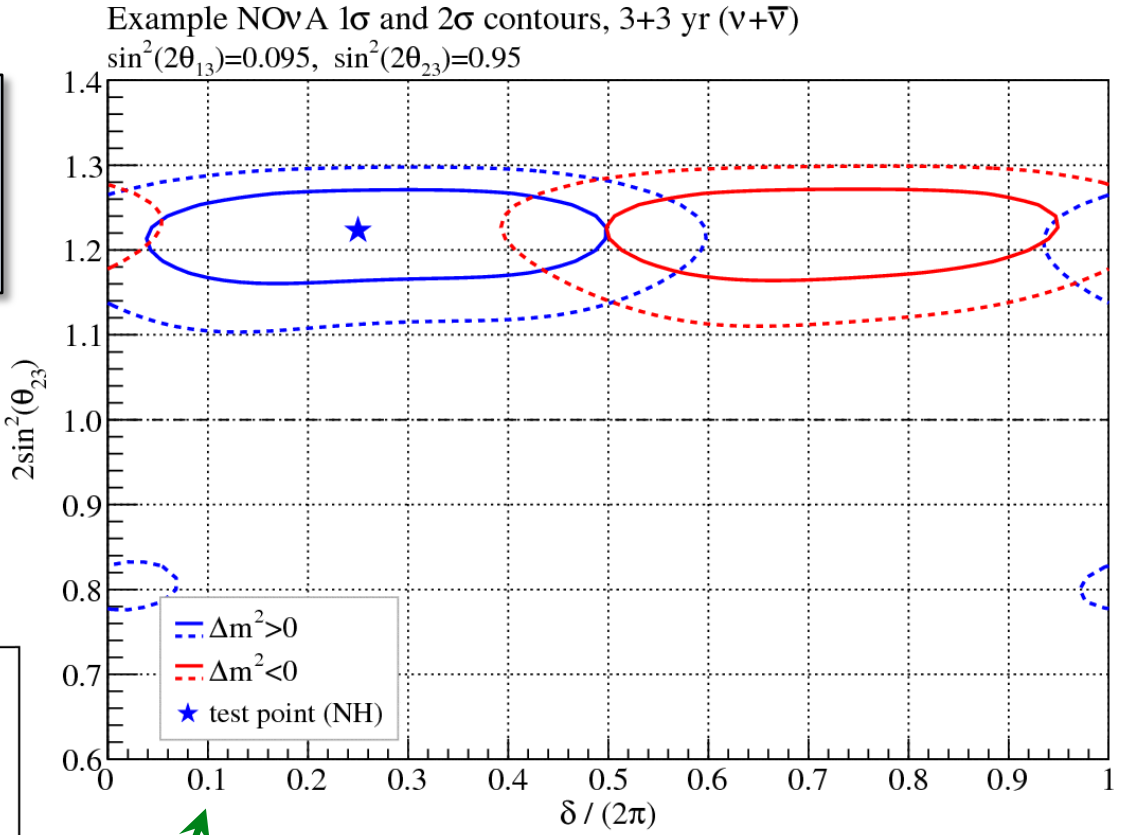

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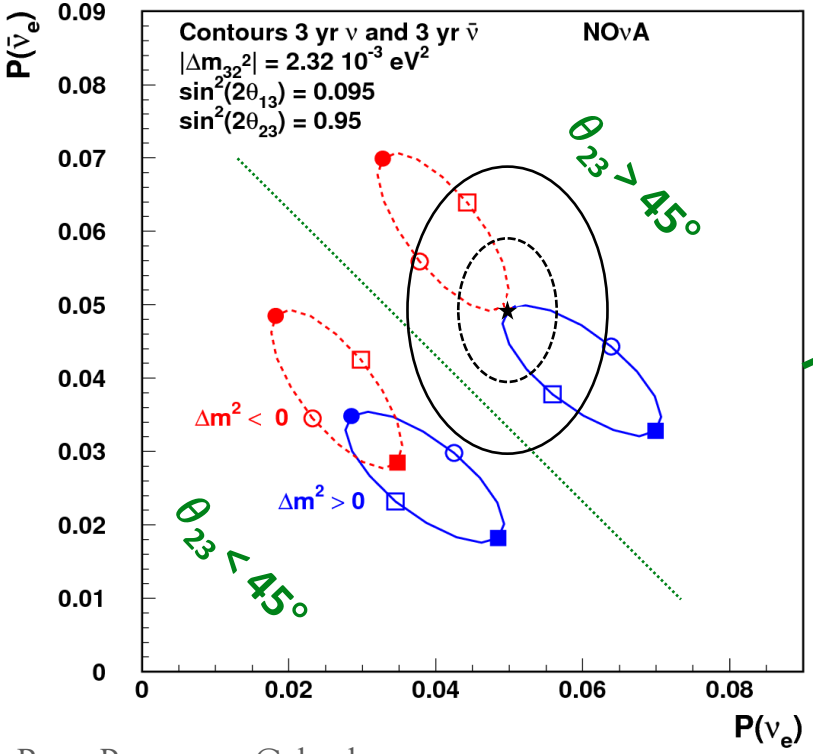
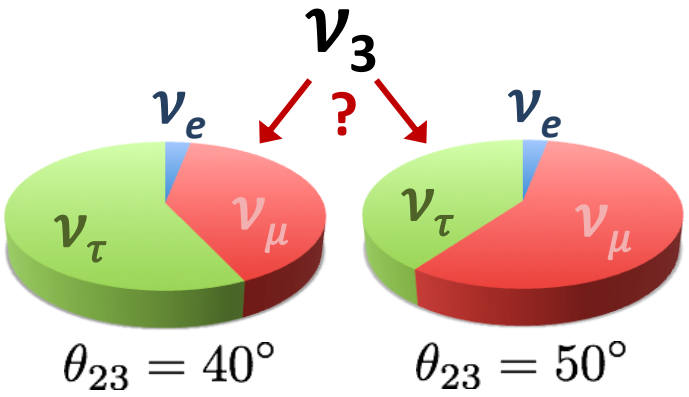
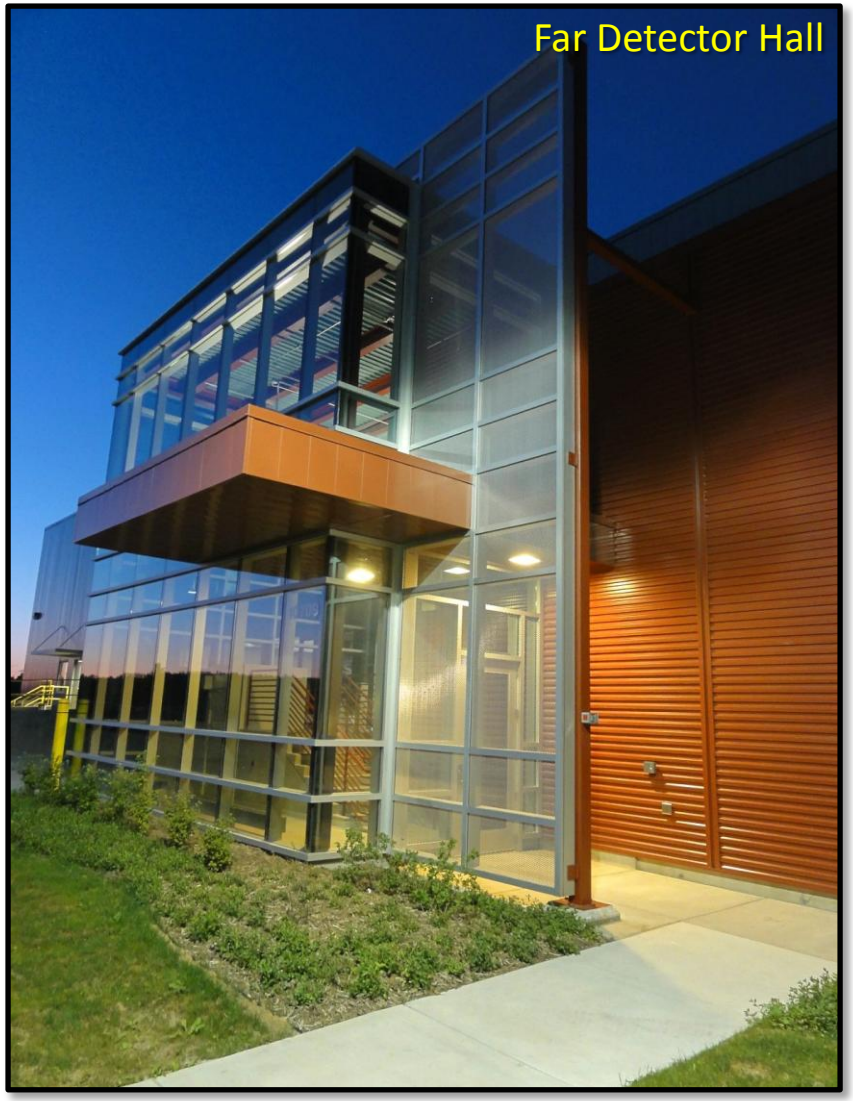


In "degenerate" cases, hierarchy and δ information is coupled. θ_{23} octant information is not.



Closing

- **NOνA FD assembly underway at Ash River!**
- **NuMI upgrades underway → 700 kW**
- **First neutrino events in the partial FD next Spring**
- **NDOS run:**
  - → *commissioning, cosmic ray, and neutrino data*
  - → *invaluable for assembly practice and analysis development*
- **Actively developing analyses for 1st FD data**
  - → *aiming to surpass the sensitivities shown in this talk*
- **The observed θ_{13} is great for NOνA program**
  - → *mass hierarchy, δ_{CP}, θ_{23}*
  - → *broad range of ν-sector measurements*



NOνA Posters			
	98-2	N. Mayer	*Status of the NOνA Experiment*
	99-3	R. Schroeter	*Neutrino Physics with the NOνA Experiment*
	178-1	E. Arrieta-Diaz	*Calibration and Reconstruction in the NOνA Detectors*