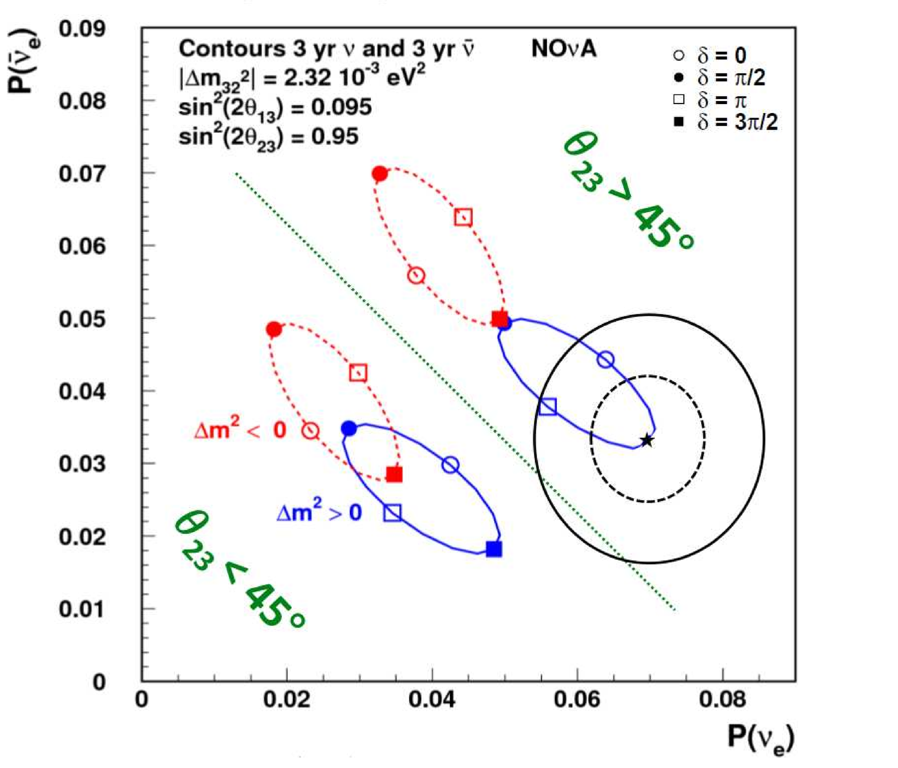
The NOνA electron neutrino appearance analysis

Christopher Backhouse for the NOνA collaboration

Caltech

Introduction



- NOνA makes measurements of $P(\nu_\mu \to \nu_e)$ and $P(\bar\nu_\mu \to \bar\nu_e)$

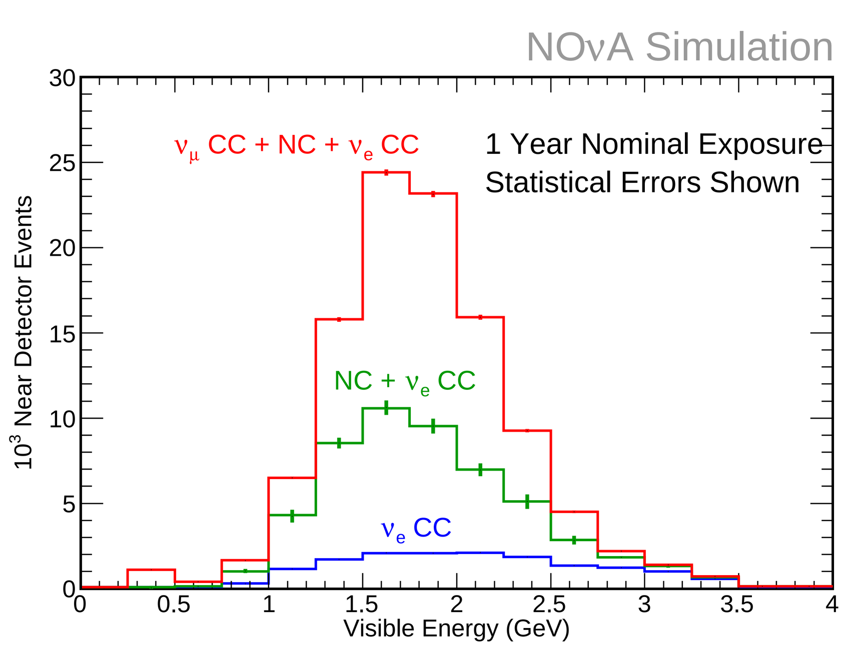
Experiment design:

- **Off-axis** beam, sharp 2GeV peak
- **Long baseline** (810km)
- Large (14kt) Far Detector (FD)
- **Neutrino** or **antineutrino** beam

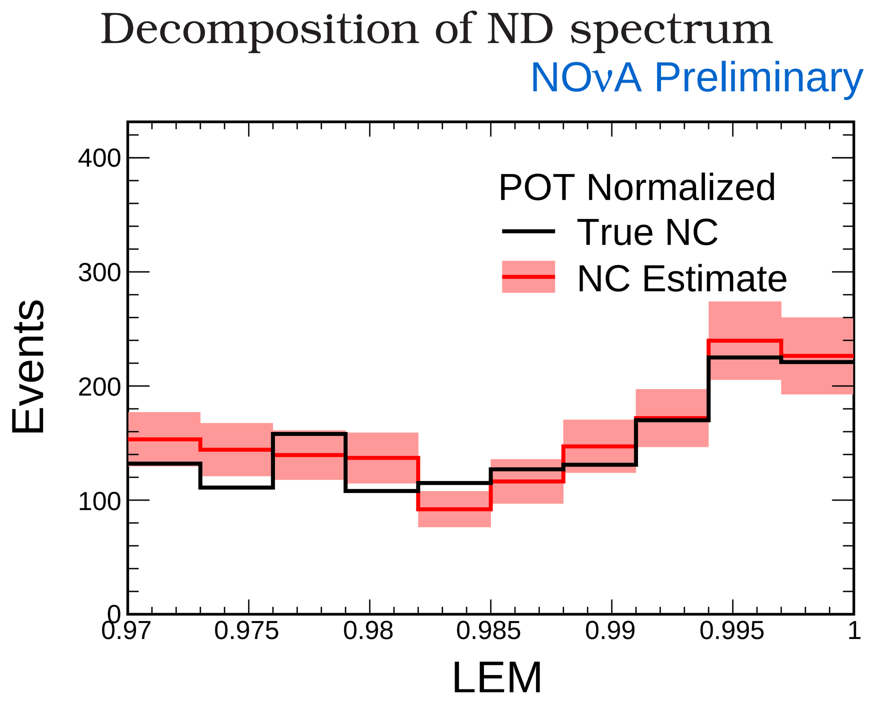
Sensitive to:

- neutrino **mass hierarchy**
- θ_{23} **octant**
- $\mathcal{CP}$**-violation**

Decomposition and Extrapolation



Decomposition of ND spectrum



MRCC estimate of NC background

- **Near Detector** (ND), smaller FD
- 300ton, 1km from target
- Robustness to **cross-section**, **flux**, **detector** uncertainties
- **Decompose** into components: ν_μ CC, NC, beam ν_e
- **Extrapolate** components to Far Detector (*L. Suter poster*)
- Cancels common systematics
- Have two decomposition methods

MRCC method

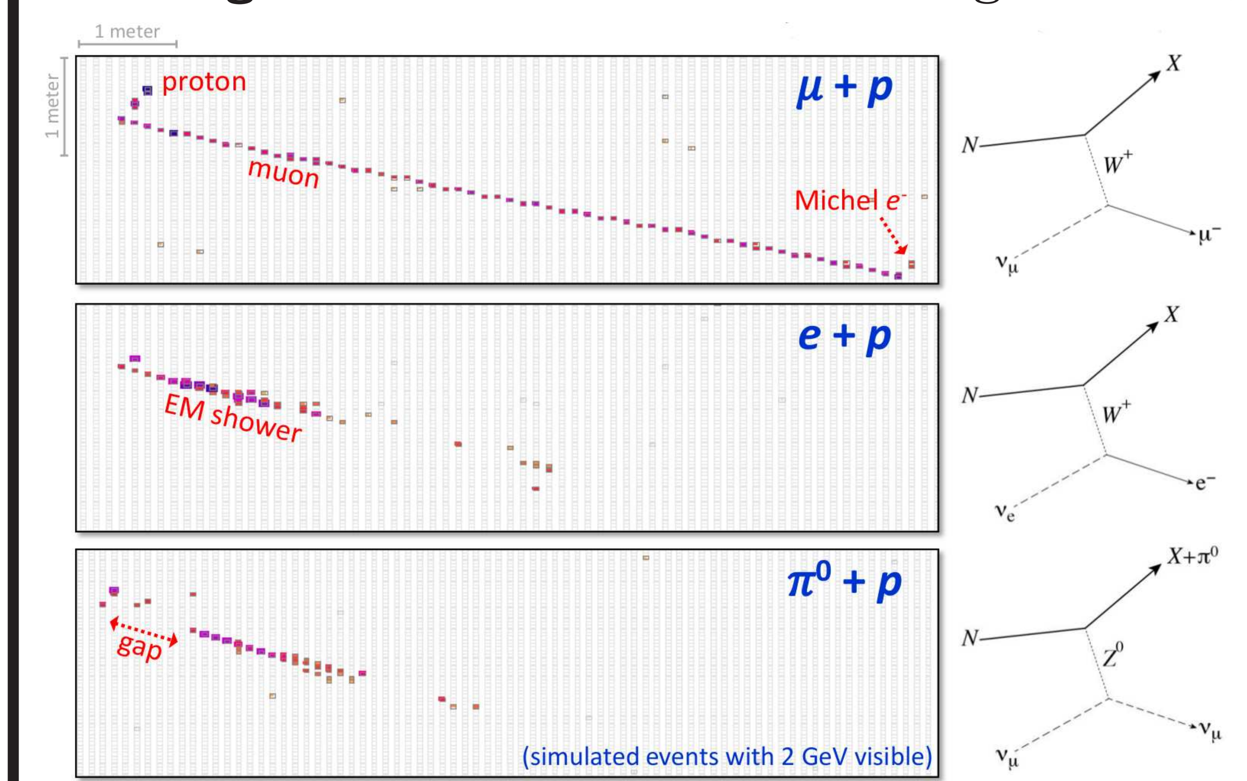
- Remove muon from ν_μ CC events
- Apply ν_e PID in data and MC
- $N_{NC}^{decomp} = \frac{N_{MRCC}^{data}}{N_{MRCC}^{sim}} N_{NC}^{sim}$

Michel method

- Count Michel electron candidates in ν_e-selected events
- Scale MC templates for ν_μ CC, NC, beam ν_e to match

Event selection

- **Fine-grained** detector: radiation length 38cm (10 cell widths)



ν_μ charged current

- Easy to reject muon track

ν_e signal

- Electron shower

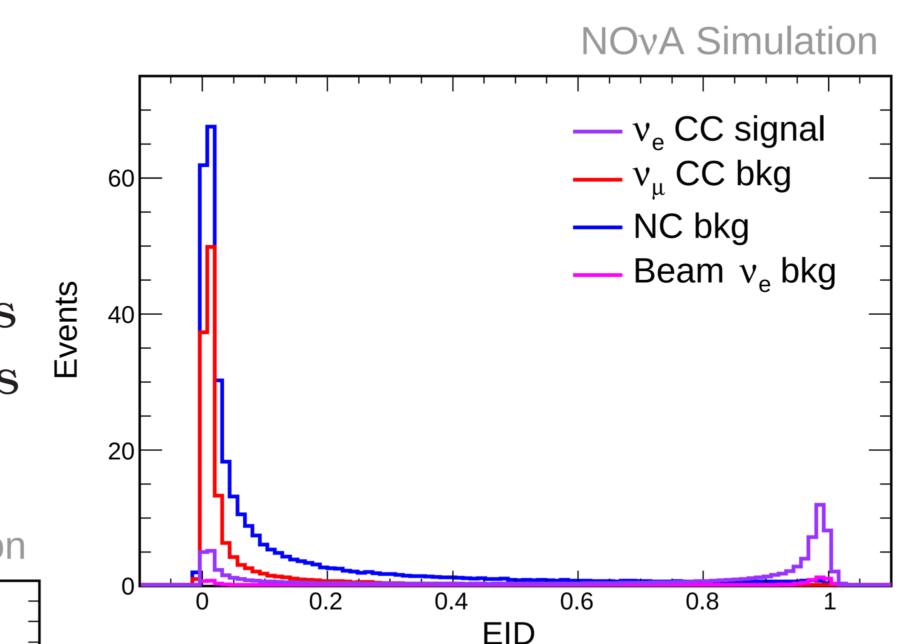
Neutral current

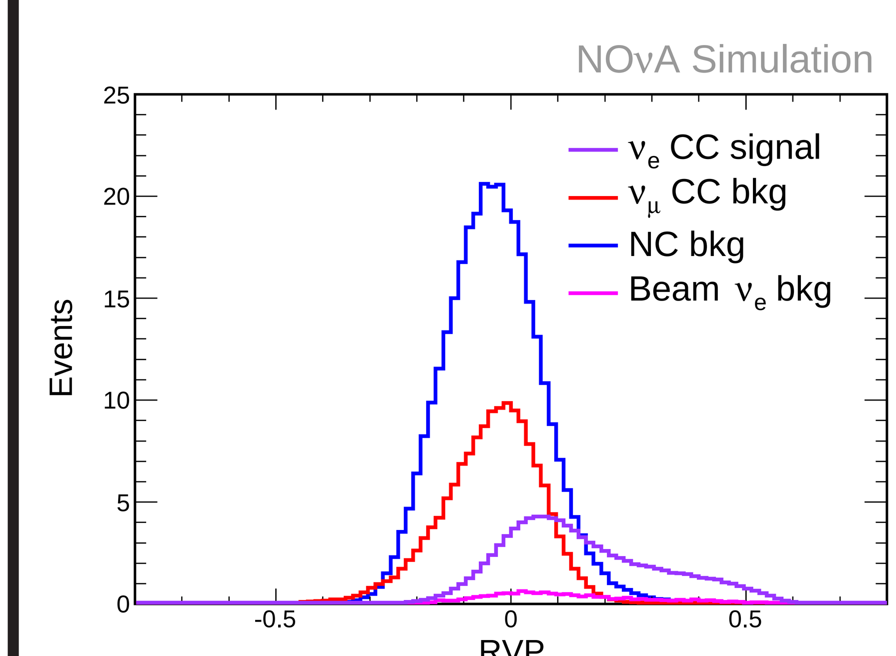
- $\pi^0 \to \gamma\gamma$ fakes electron shower
- Conv. length 50cm

- Three ν_e **selection** algorithms developed: **EID, RVP, LEM**

EID

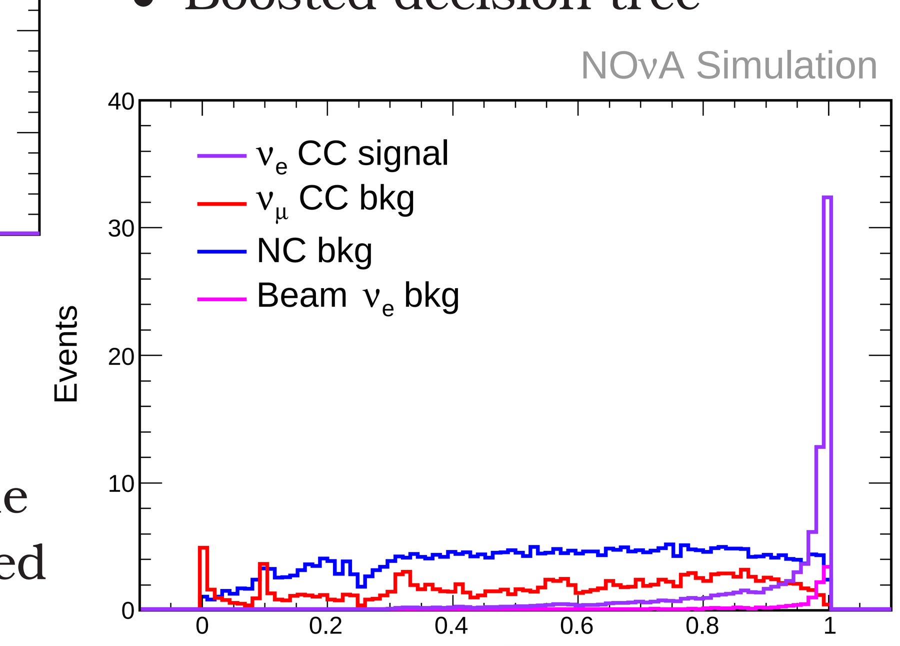
- Use prong reconstruction (*M. Baird poster*)
- Long. and trans. dE/dx profiles
- $\log \mathcal{L}$ of each particle hypothesis
- Feed into neural network





RVP

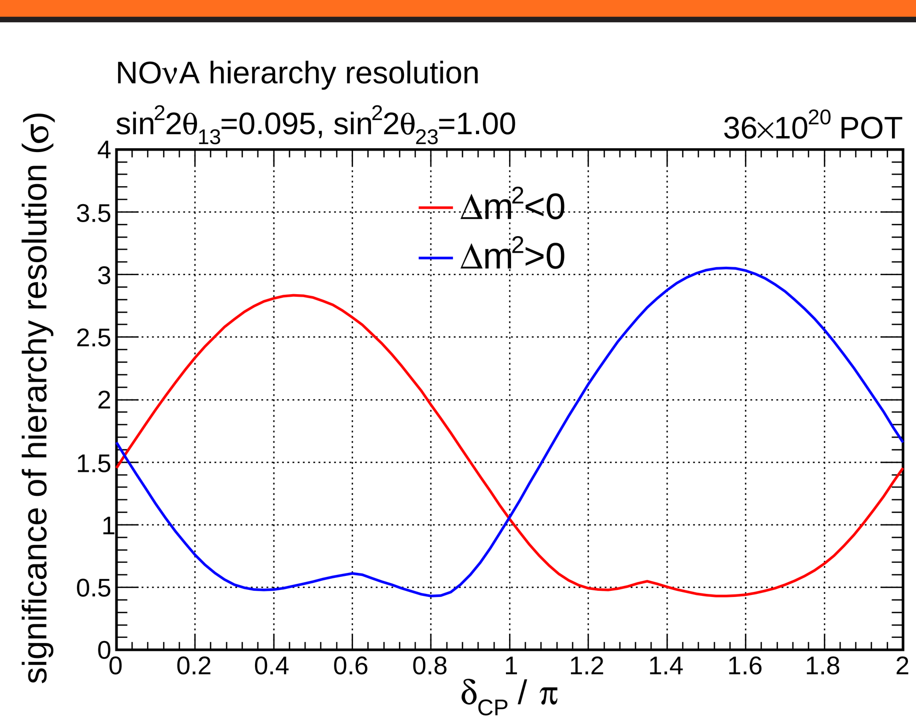
- Simple event quantities
- Boosted decision tree



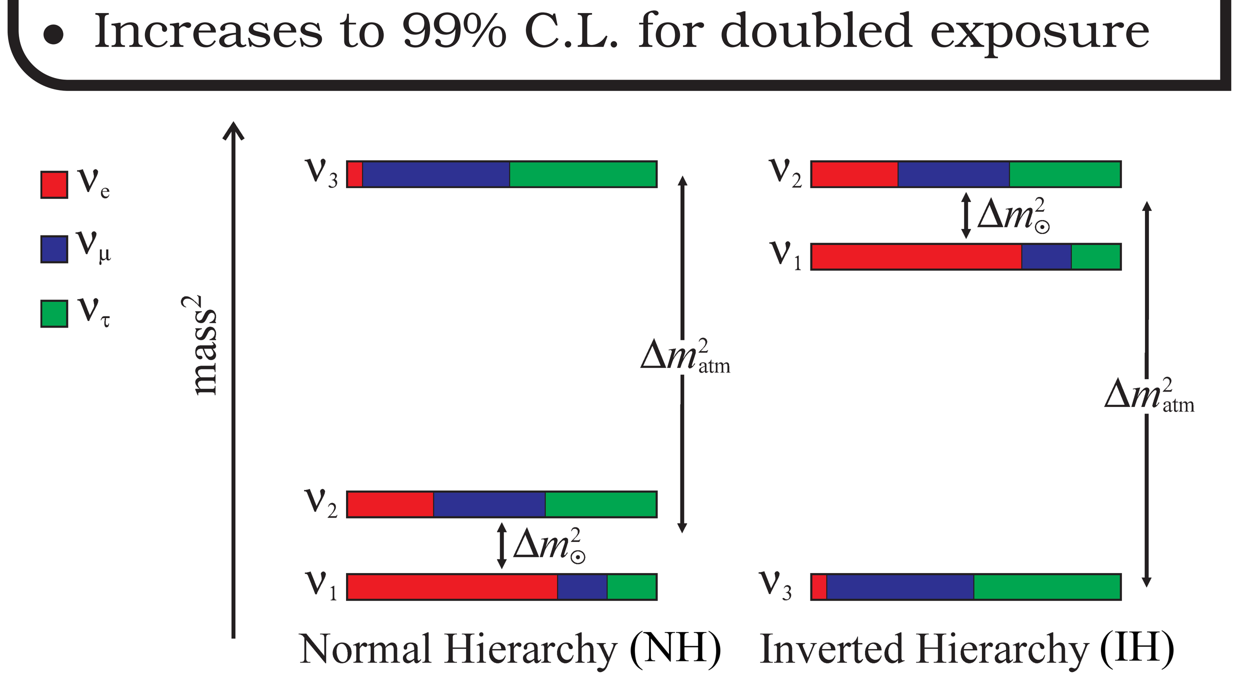
LEM

- Compare to large MC library
- Match via electrostatic analogue
- Use properties of best-matched events

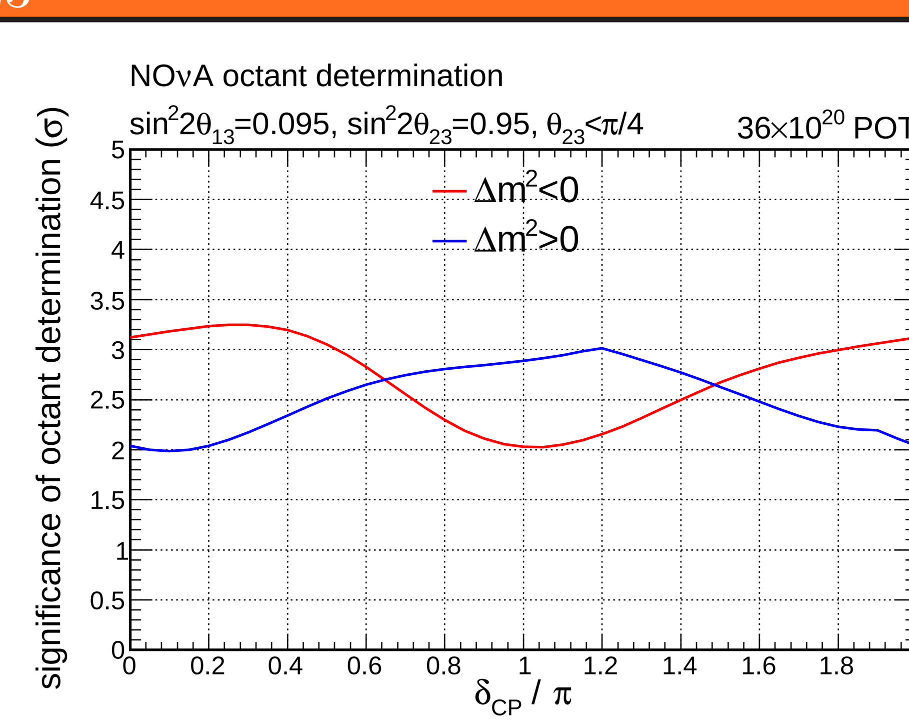
Mass hierarchy



- Is ν_3 heavier (**NH**) or lighter (**IH**) than ν_1/ν_2?
- Alters sign of matter effects
- Important for interpretation of $0\nu\beta\beta$ expts.
- **Large matter effects** ($\pm30\%$) from uniquely long baseline
- 95% C.L. determination for 1/3 of δ_{CP} values
- Increases to 99% C.L. for doubled exposure



θ_{23} octant

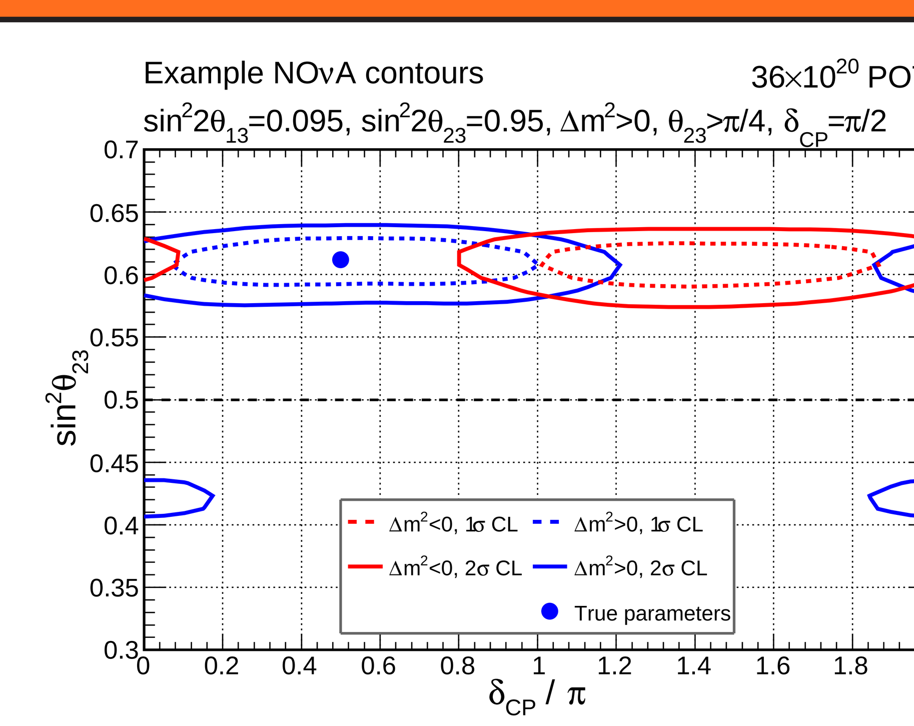


- If θ_{23} is **non-maximal**
- Is ν_3 more ν_μ ($\theta_{23} > 45°$) or more ν_τ ($\theta_{23} < 45°$)?
- ν_e appearance $\sim \sin^2\theta_{23}$, measures θ_{23}
- 95% C.L. determination for all δ_{CP}
- $3\sigma - 4.5\sigma$ for doubled exposure

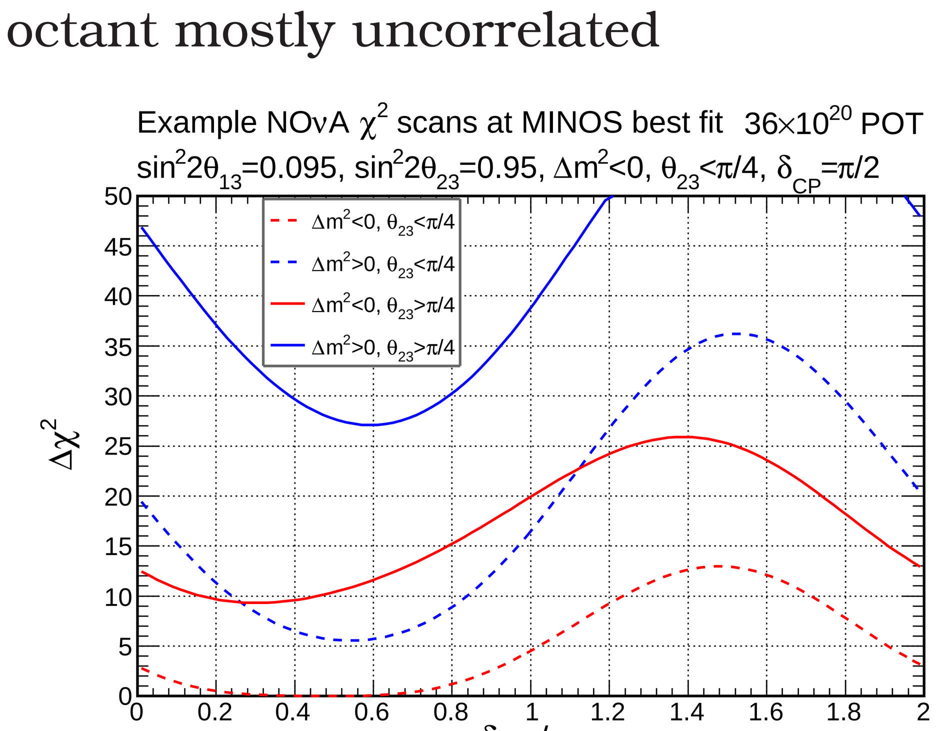
Assumptions

- 3 years ν + 3 years $\bar\nu$ ($2 \times 18 \times 10^{20}$ POT)
- $\sin^2 2\theta_{13} = 0.95$
- $\Delta m^2_{32} = 2.40 \times 10^{-3}$ eV^2
- $\sin^2 2\theta_{23} = 1.00$ or 0.95
- Assuming high efficiency cosmic ray rejection (*G. Davies, T. Xin, J. Bian poster*)
- Joint fit with NOνA ν_μ analysis (*K. Bays poster*) and reactor constraints

Contours



- In the degenerate case, NOνA narrows the mass hierarchy/$\mathcal{CP}$ phase space, with the θ_{23} octant mostly uncorrelated



- Could reject NH, upper octant at >5σ and favour correct hierarchy/octant at 95% C.L.