DUNE ND
Physics motivation

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3D TPC discussion
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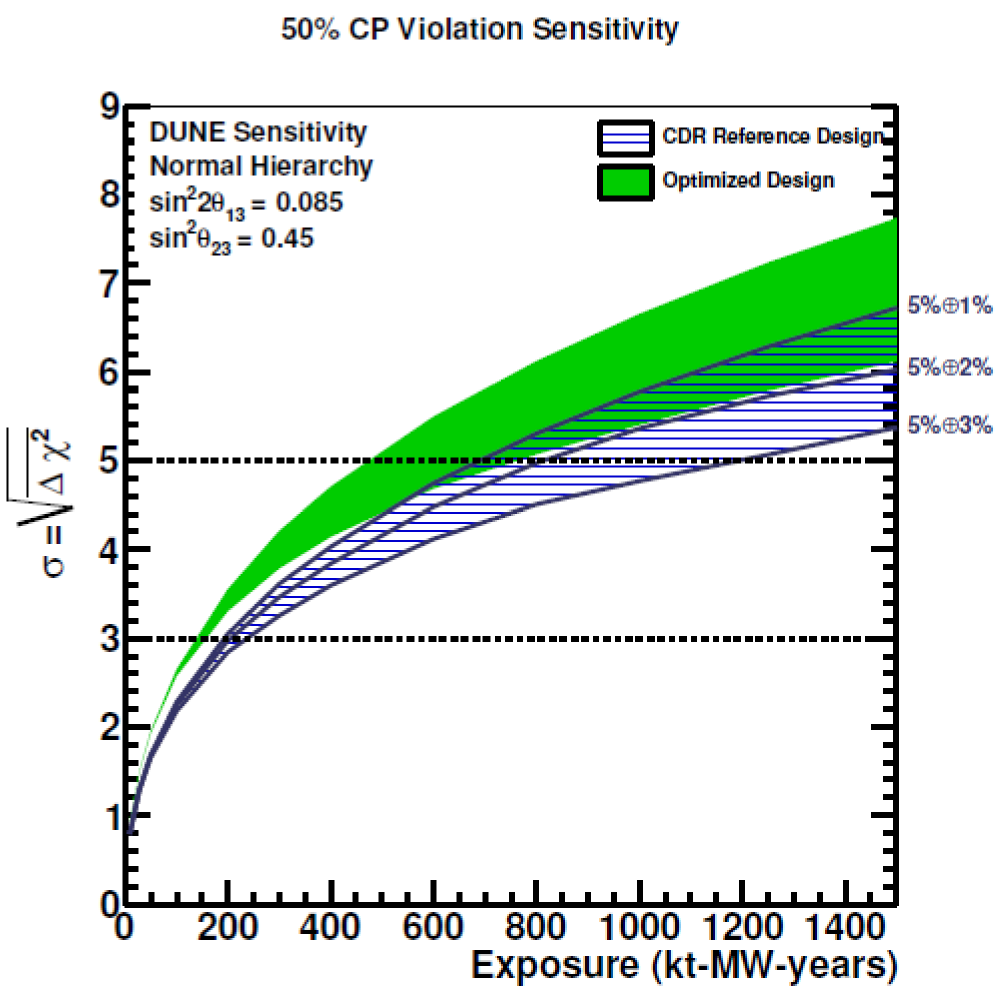
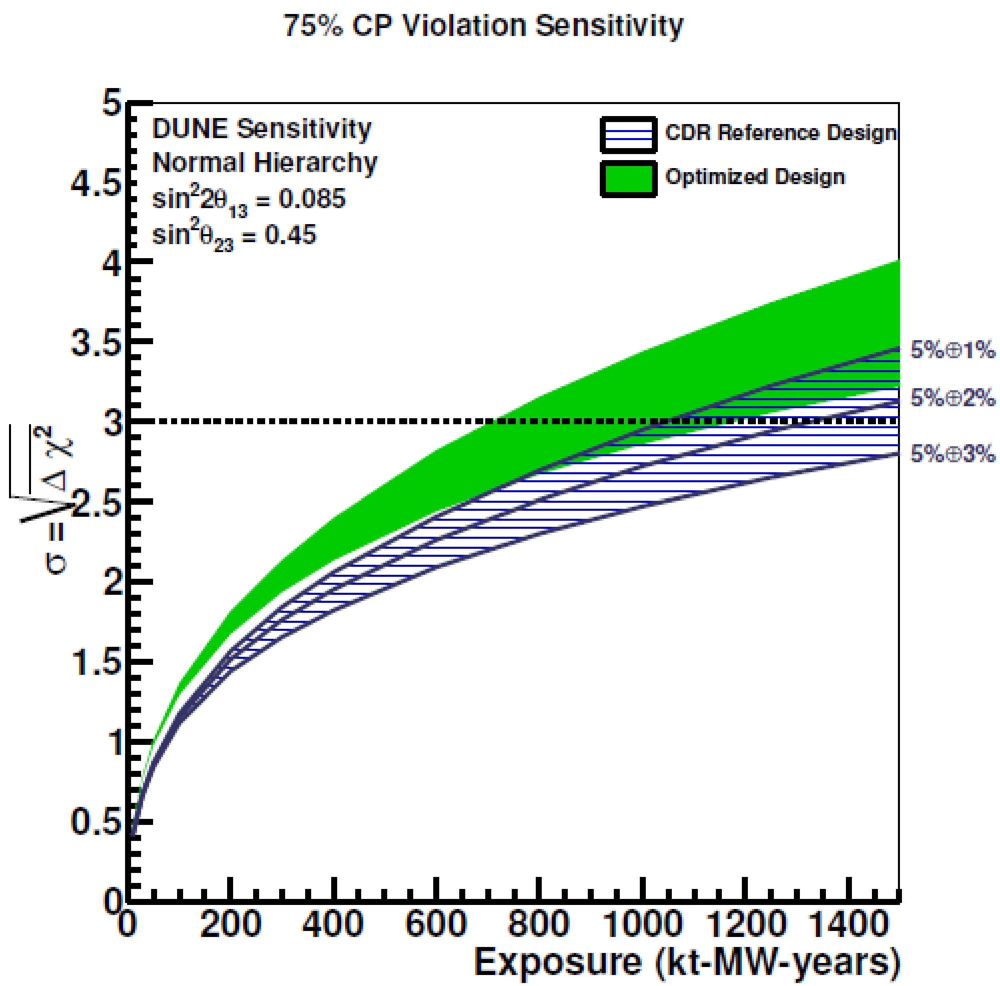
DUNE error budget



- From CDR, assumed uncertainty on ν_e appearance signal
  - 5% fully-correlated with ν_μ and ν_e
  - 2% uncorrelated
- The fully-correlated part turns out to not matter at all – you can put 10% and it changes nothing

DUNE error budget



- We might never get 75% CP violation sensitivity at 3σ if that systematic inflates from 2% to 3%
- The 2% is rate only
- All rate+shape systematics must have smaller total effect than 2% overall rate uncertainty

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Far detector measurement

Detector response matrix

Neutrino flux

CC cross section

$$\frac{dN}{dE_{reco}} = \frac{\mathbf{D}(E_\nu^{true}, E_\nu^{reco})\Phi(E_{true})\sigma(E_{true})}{\epsilon(E_{true})}$$

Observed spectrum

Detector acceptance * reconstruction efficiency

Near detector differences

Different containment

Different solid angle, oscillations

Different neutrino flavor

$$\frac{dN}{dE_{reco}} = \frac{\mathbf{D}(E_{\nu}^{true}, E_{\nu}^{reco})\Phi(E_{true})\sigma(E_{true})}{\epsilon(E_{true})}$$

Observed spectrum

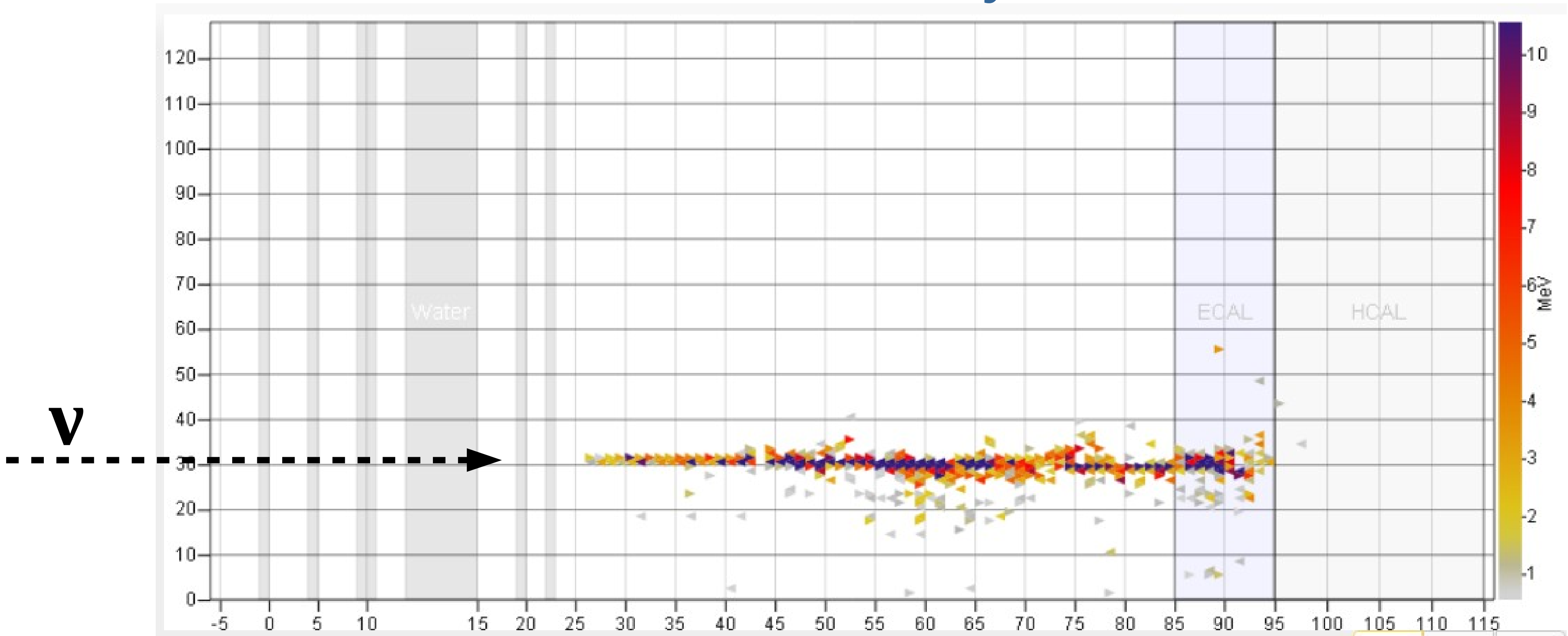
Smaller ND, different containment, different readout technology

ND needs

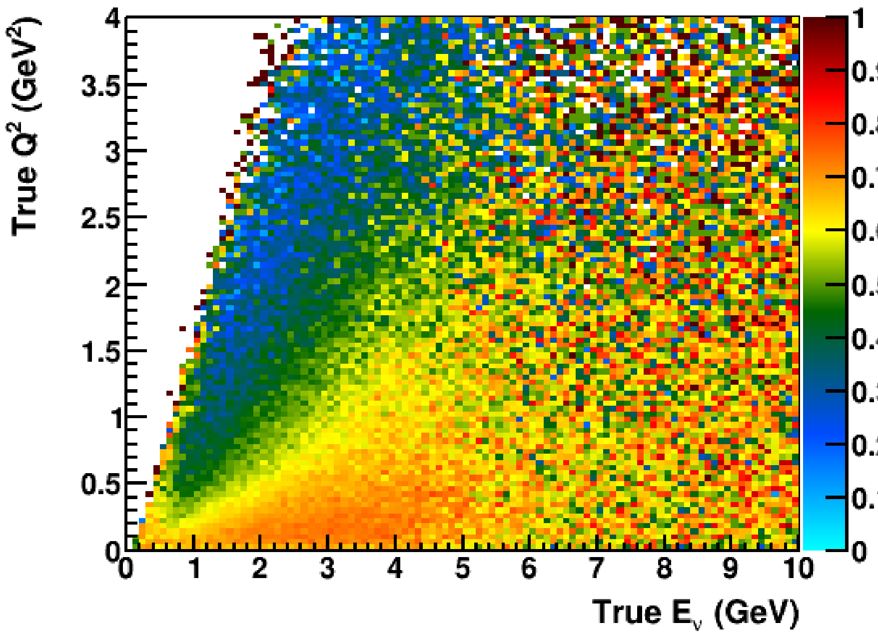
- Argon target to measure $\Phi\sigma$
- Direct flux measurement via processes with known cross section
  - ν+e elastic scattering (known absolute cross section)
  - Low-ν CC scattering (~known shape in neutrino energy)
- Coverage of same phase space as far detector for CC interactions, and good containment of hadrons
- Ability to measure background processes (NC π^0 production, intrinsic ν_e flux)
- Ability to function in high-intensity environment
  - At 2MW beam power, 0.2 interactions per ton per beam spill

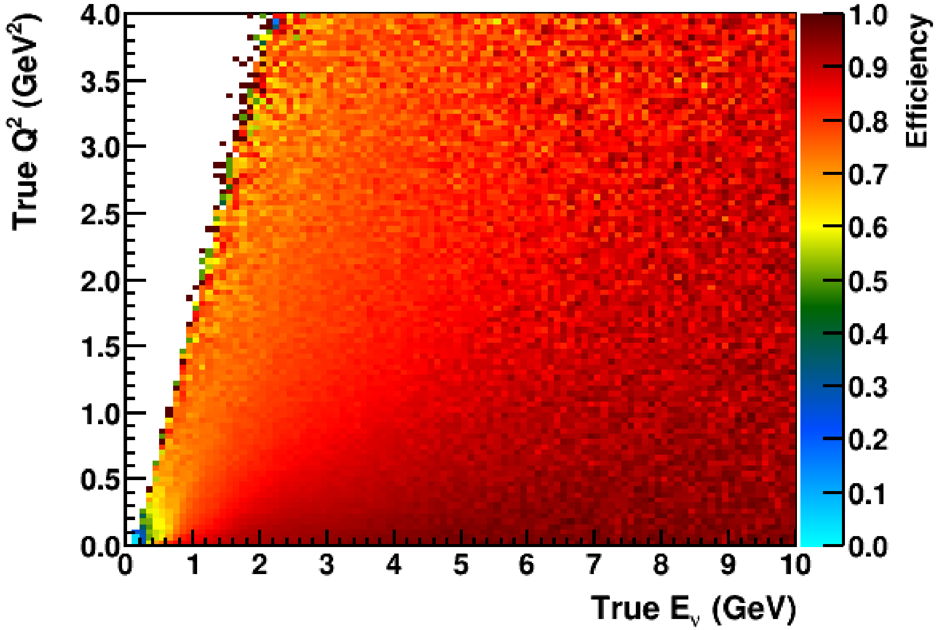
Direct flux measurements

- ν+e elastic scattering: angular resolution ~ 5-7 mrad
- Low-ν method: Muon energy scale bias < 1%, ability to detect neutrons at modest efficiency



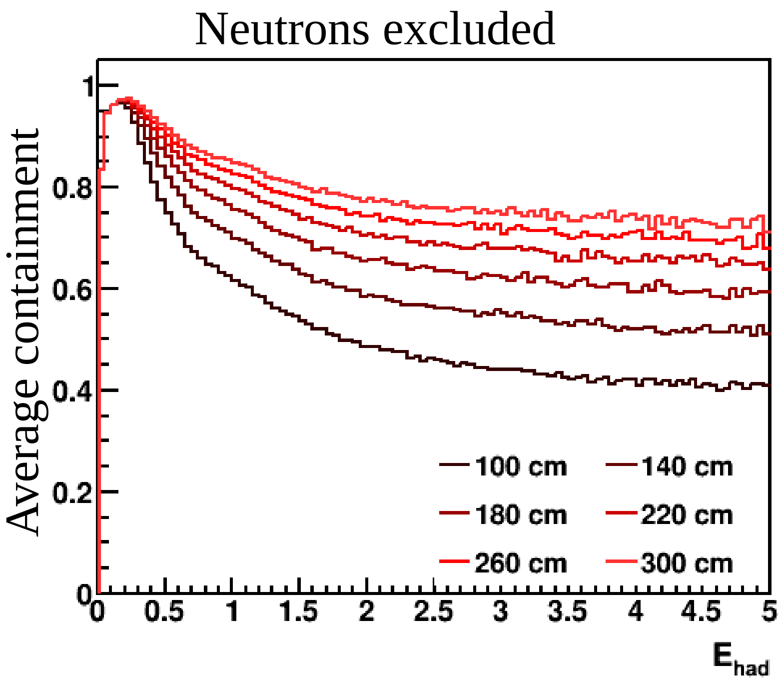
Good acceptance

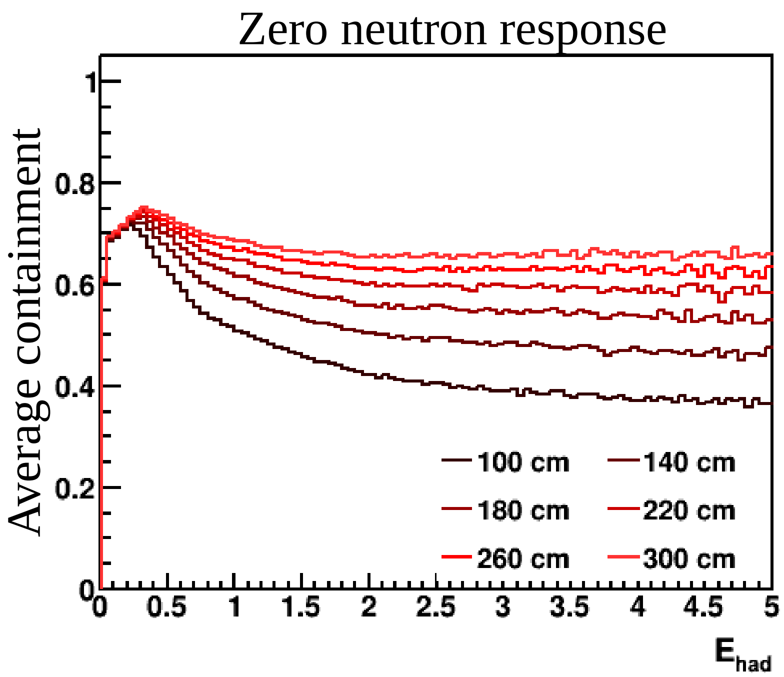




- Left: 3m x 3m x 3m LAr with no magnetic field, muon acceptance only for forward events
- Right: FGT with magnetic field, ~4π acceptance

Containment





- LAr cubic detector, with 40cm between F.V. and detector edge
- 30-ton detector is big enough

Pile-up

- At 2 MW beam power:
  - 0.2 interactions per spill per ton = 1 per 4 m^3 LAr
  - 2 rock muons per spill per m^2 (at 10m from rock)
- Rough estimate per spill for ~30ton detector:
  - 5 neutrino interactions in detector
  - Products of ~5-10 interactions entering detector
  - 8 through-going rock particles
- More rough estimating: ~30 charged tracks + neutrals you must be able to associated to specific interactions
- My opinion: for DUNE's physics needs this is possible only with a sophisticated fully-3D reconstruction