DUNE Sensitivity to Solar Oscillations

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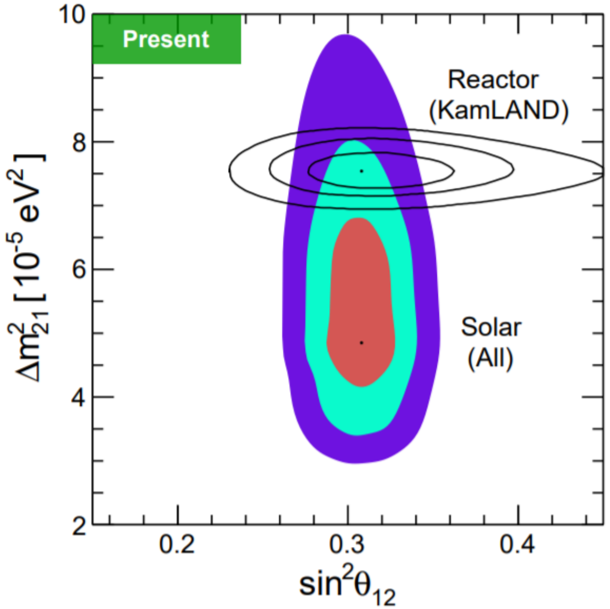
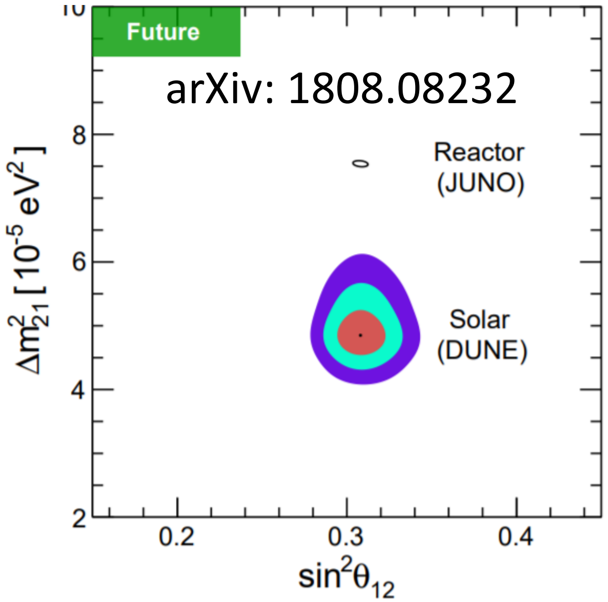
DUNE Capability for Solar Neutrino Oscillations

- The flux of ^{8}B neutrinos will yield an enormous number of ν_e CC interactions in DUNE
  - Great energy resolution for detailed $P_{ee}(E_\nu)$ studies
  - Studying this survival probability tests the standard neutrino mixing parameters $\sin^2\theta_{12}$ and Δm^2_{21}

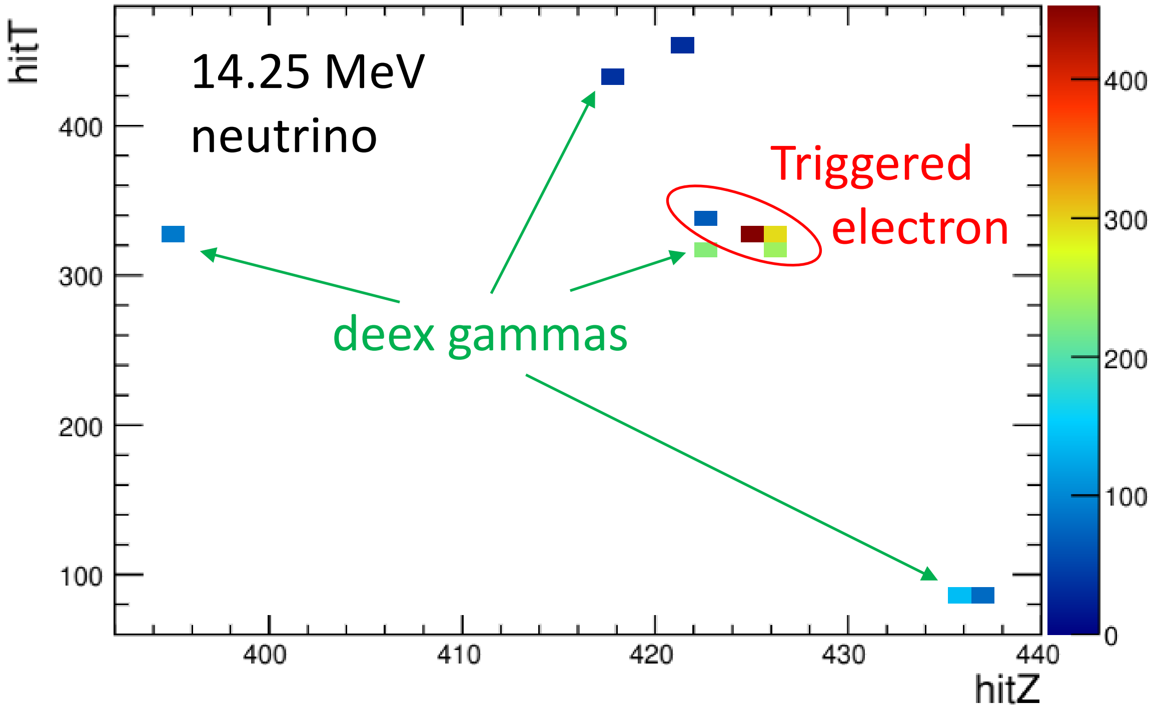


- Also, opportunities for studying fundamental neutrino properties
  - Current tensions in Δm^2_{21} between reactor and solar data could be pushed to a 5+σ discrepancy
- DUNE basically only experiment that has potential to (*first*) measure φ(hep) – testing stellar models



Low-E Neutrino Topology (ν_e CC)

- $\nu_e + {}^{40}Ar \rightarrow e^- + {}^{40}K$ channel is sensitive to $\varphi(\nu_e)$
  - Scattering to the ground state is forbidden
  - So deex gammas accompany signal

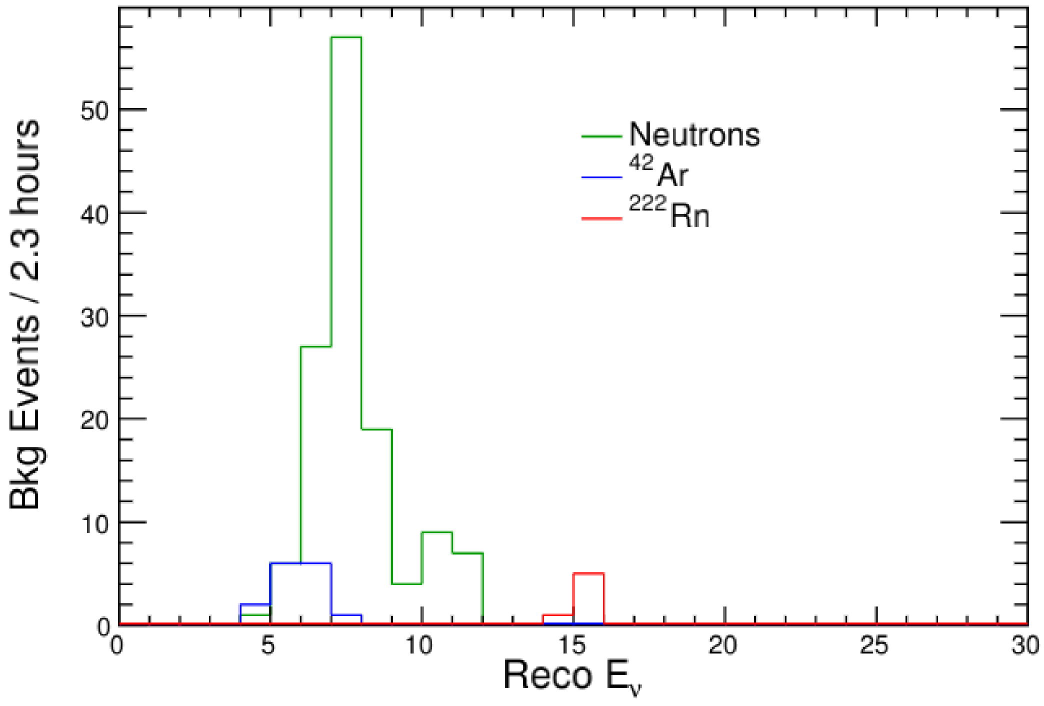


- Event topology is simple enough that matching ambiguities between wire views are rare
  - Electron and gamma reconstruction is straightforward

Solar Neutrino Backgrounds

- Running our radiological simulation in LArSoft identifies four distinct processes contributing to background

- ^{42}Ar decay
  - All activity sub-threshold
- ^{40}Ar(n,γ)
  - Will have experience with captures from neutron calibration
- ^{36}Ar(n,γ)
- ^{40}Ar(α,γ)
  - Rare, but high-energy



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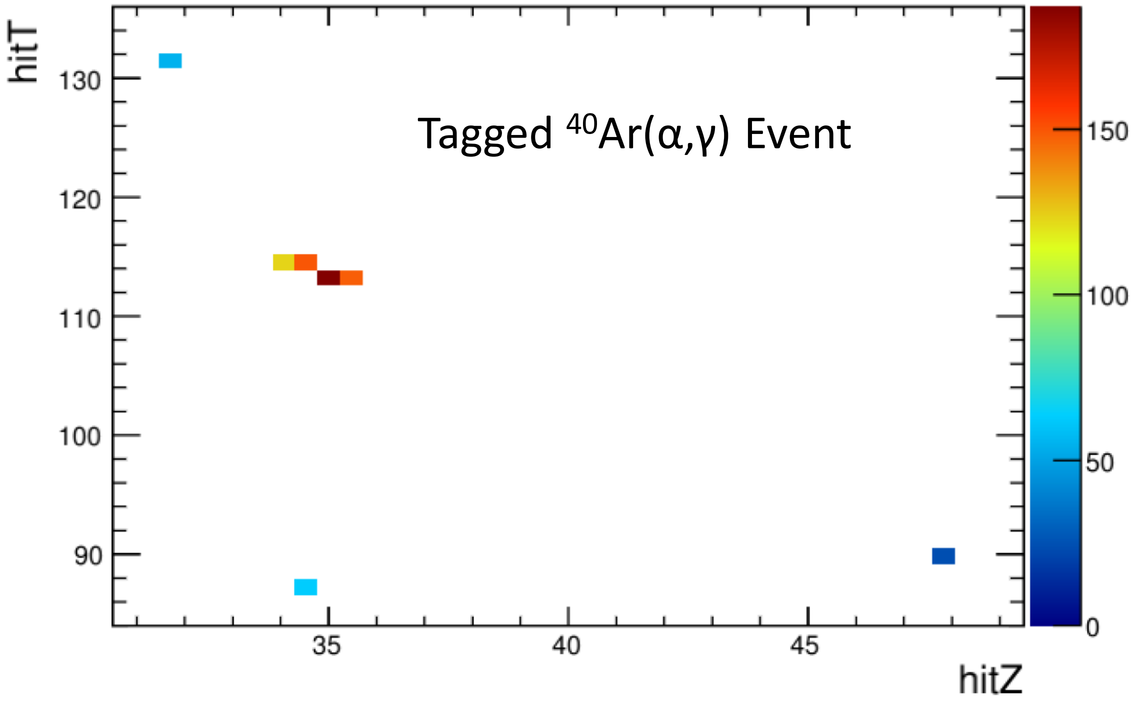
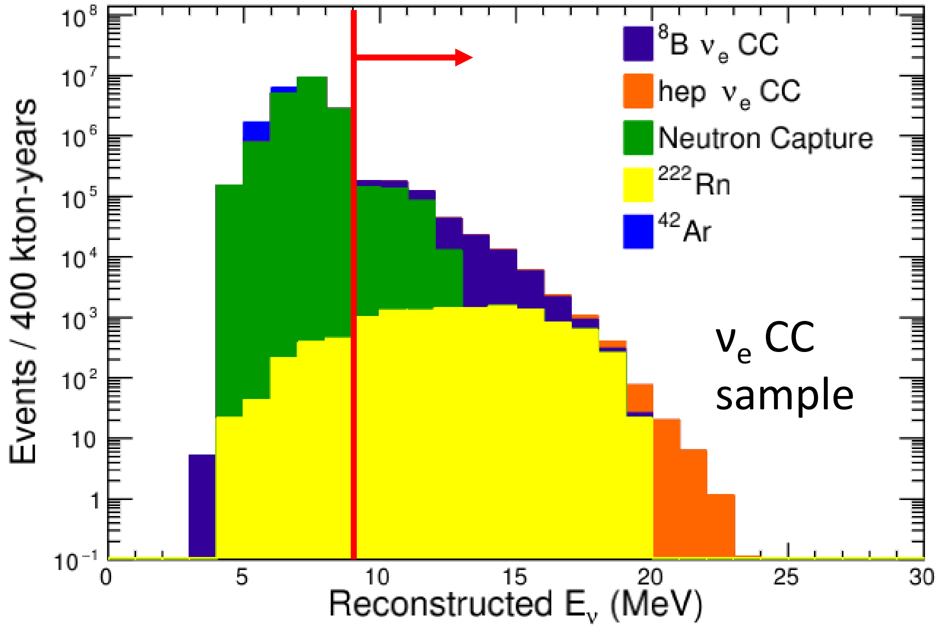


Selection only selects backgrounds that are topologically similar to our signal

Predicted Event Sample



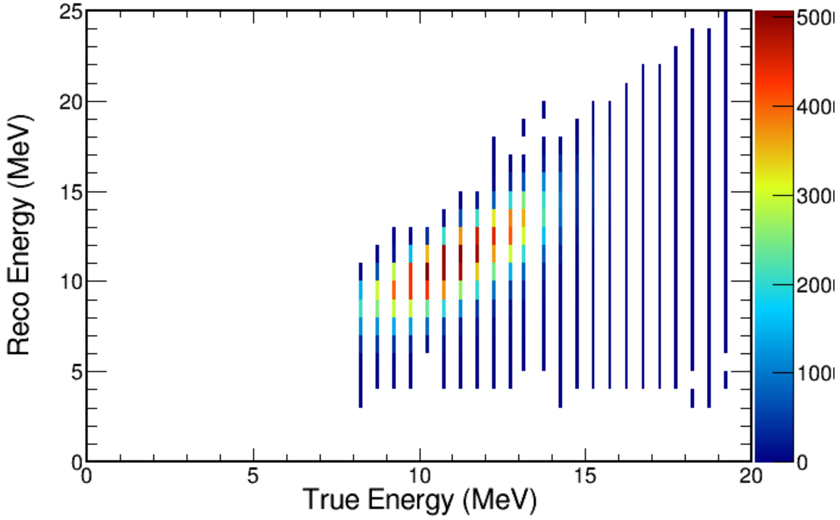
- ❑ Clearly visible sample of neutrinos above a certain energy threshold
  - 9 MeV threshold unless neutron bkg can be significantly reduced
- ❑ ^{222}Rn background will always be in sample and influences resolution of φ(hep)
  - Need to understand cross section, energy dependence, and shower topology
- ❑ Neutron capture important at low energies, but ought to be well understood with calibration source

Fitting for Oscillation Sensitivity

- The survival probability for solar neutrinos depend on E_ν and nadir angle
- Our prediction in each bin is determined by convolving

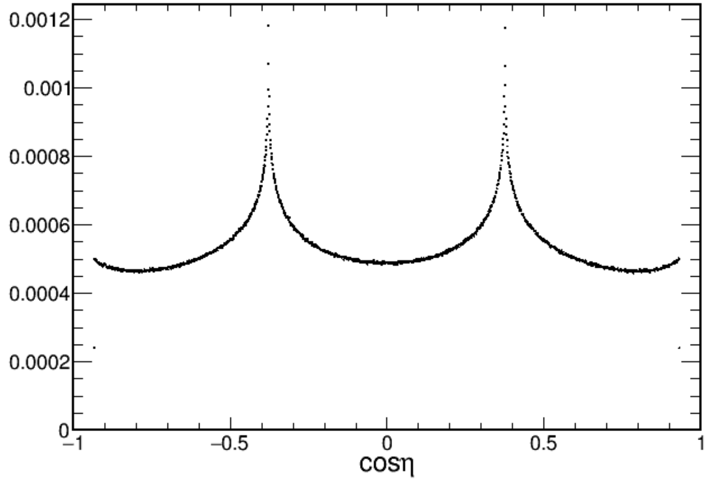
$$N(E_r,\eta) = \int_0^\infty dE_t \int_{\eta_0}^{\eta_1} d\hat{\eta} \times P(E_r|E_t) \times P(\hat{\eta}) \times p_s(E_t,\hat{\eta})$$

MARLEY + LArSoft sim of ν_e CC interactions



X

Function parameterized by DUNE's latitude



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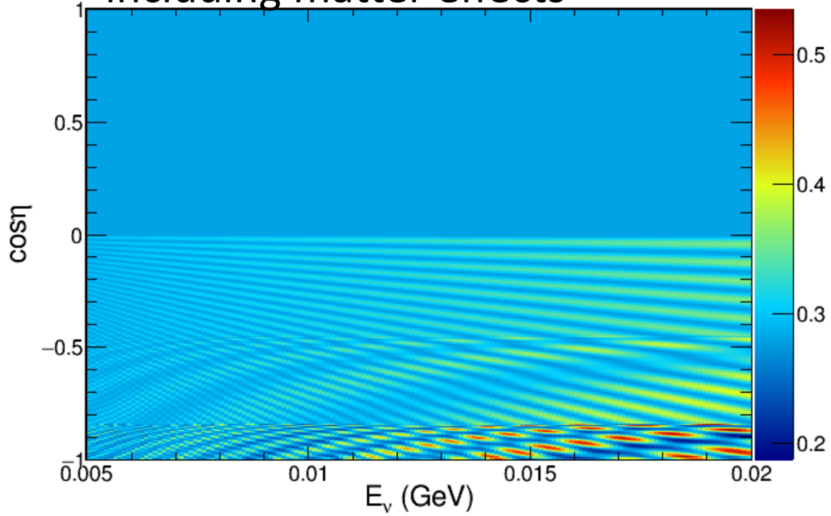
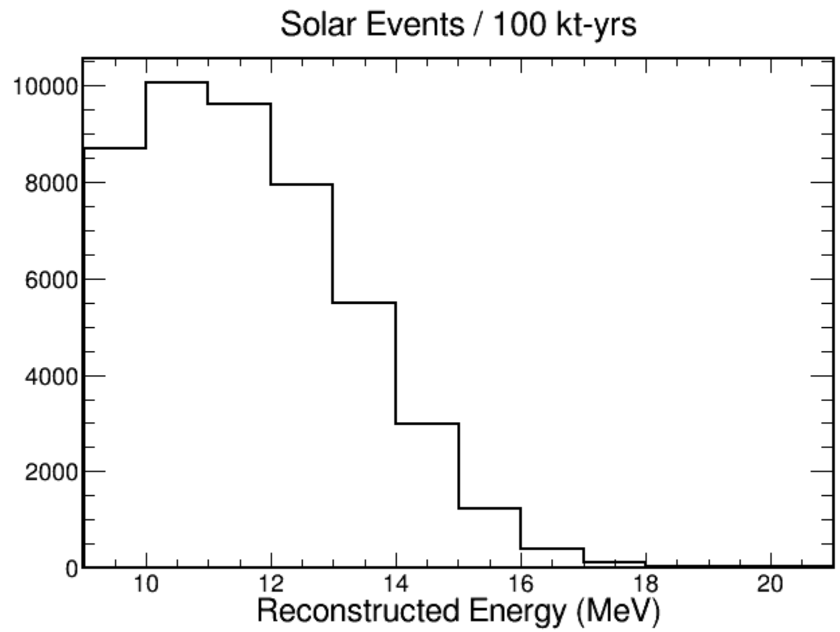
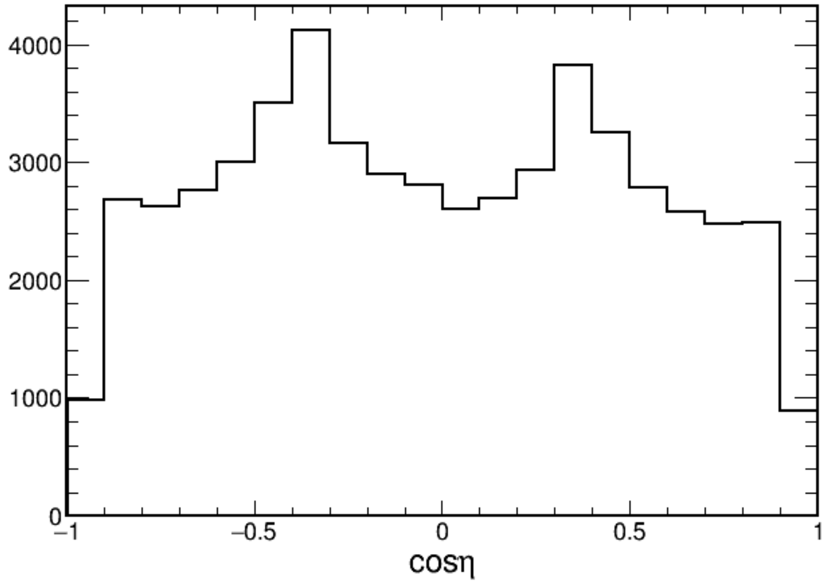
Survival probability, including matter effects

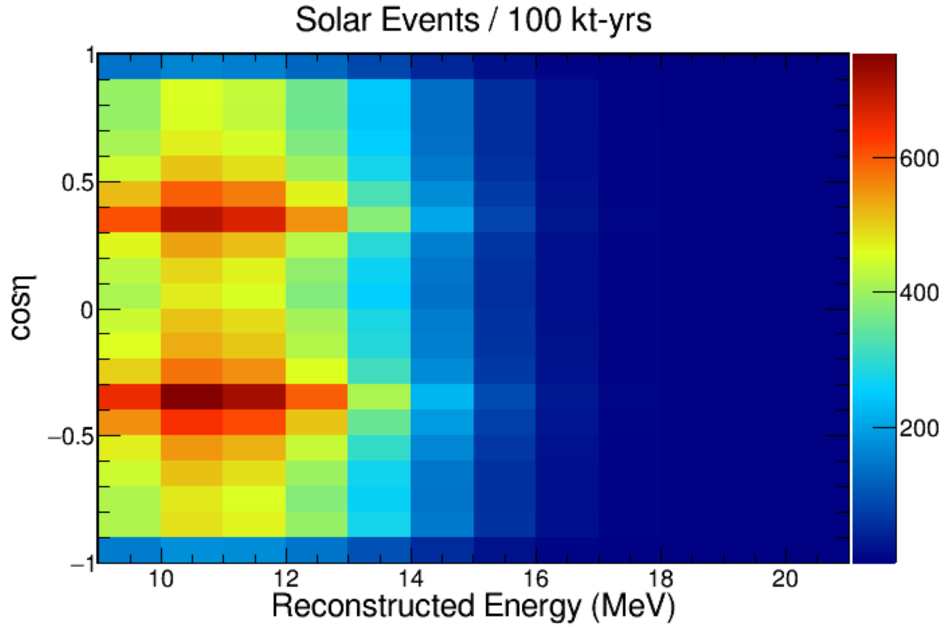


Signal Prediction

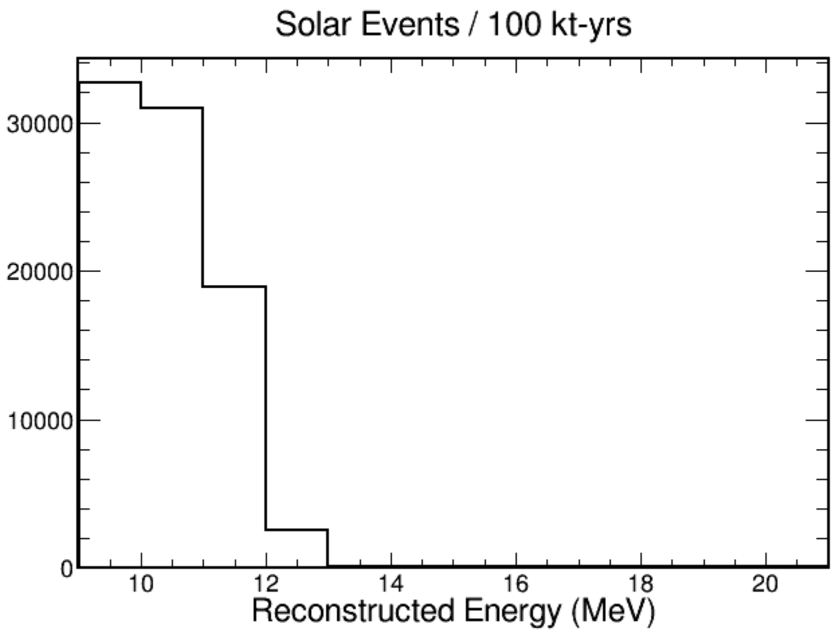
- Day/night asymmetry clearly visible in the η distribution

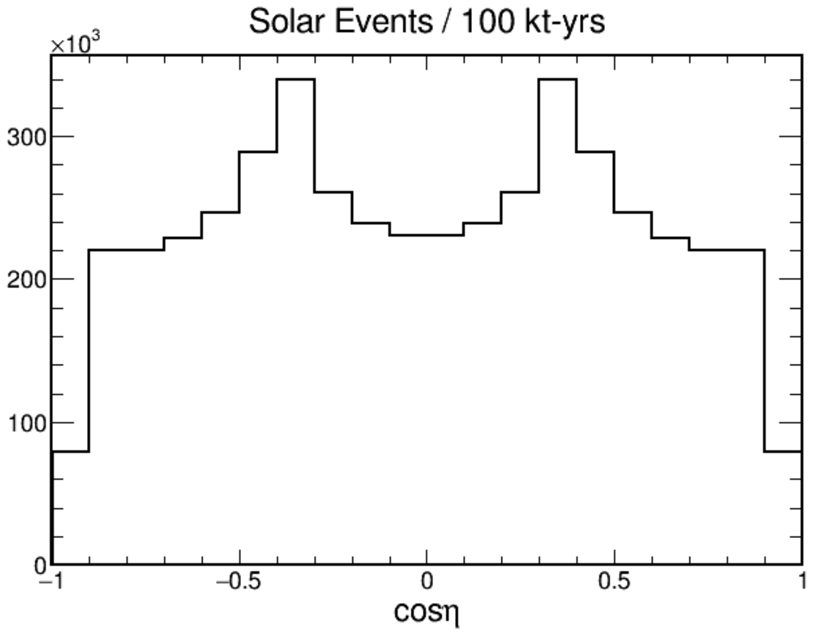


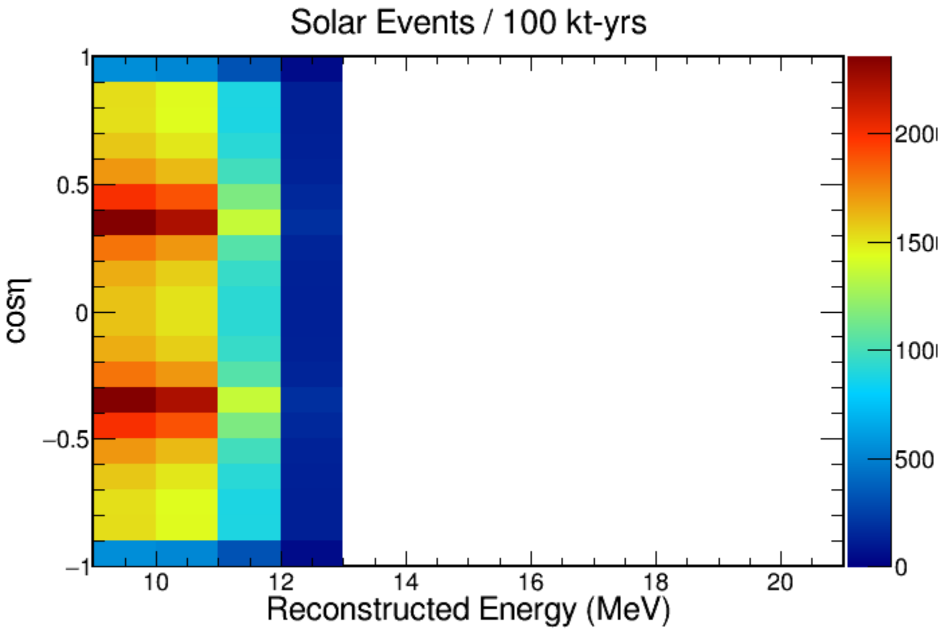




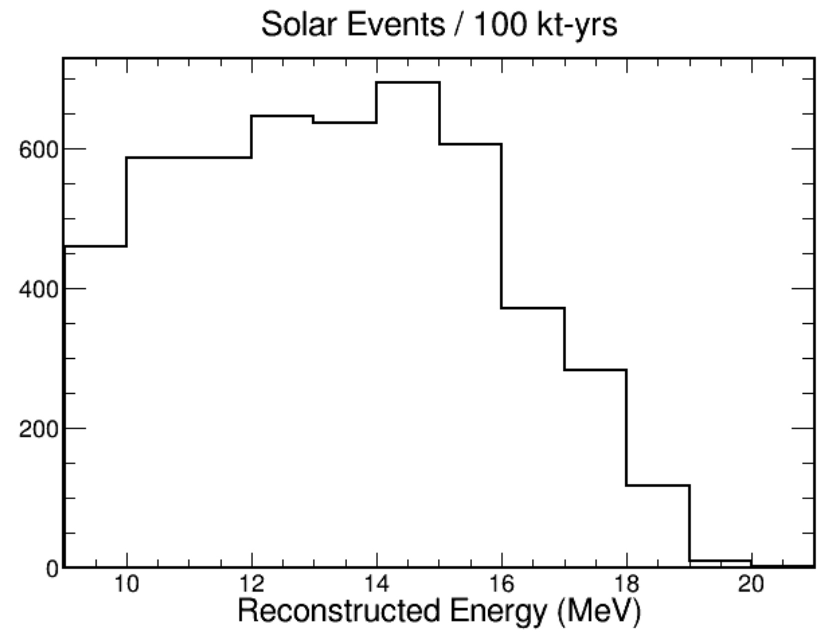
Neutron Prediction

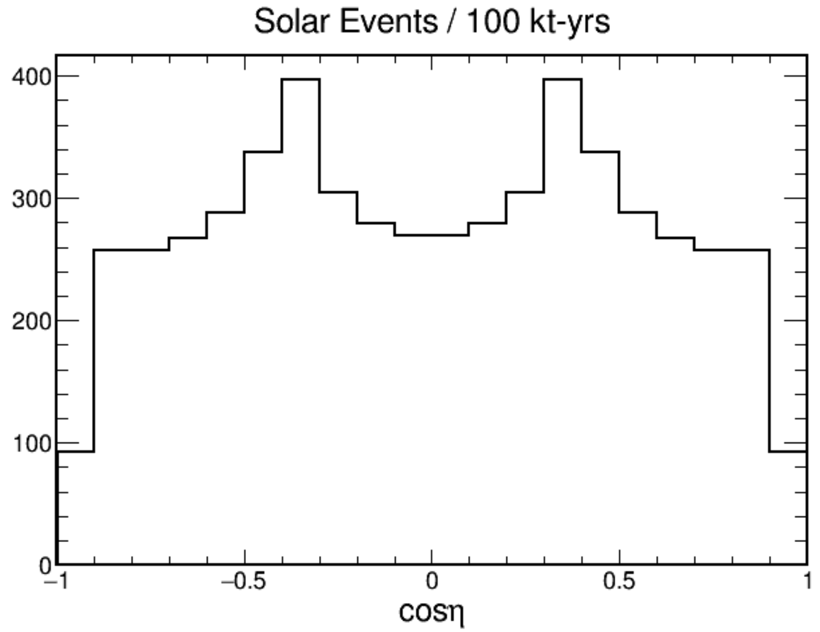


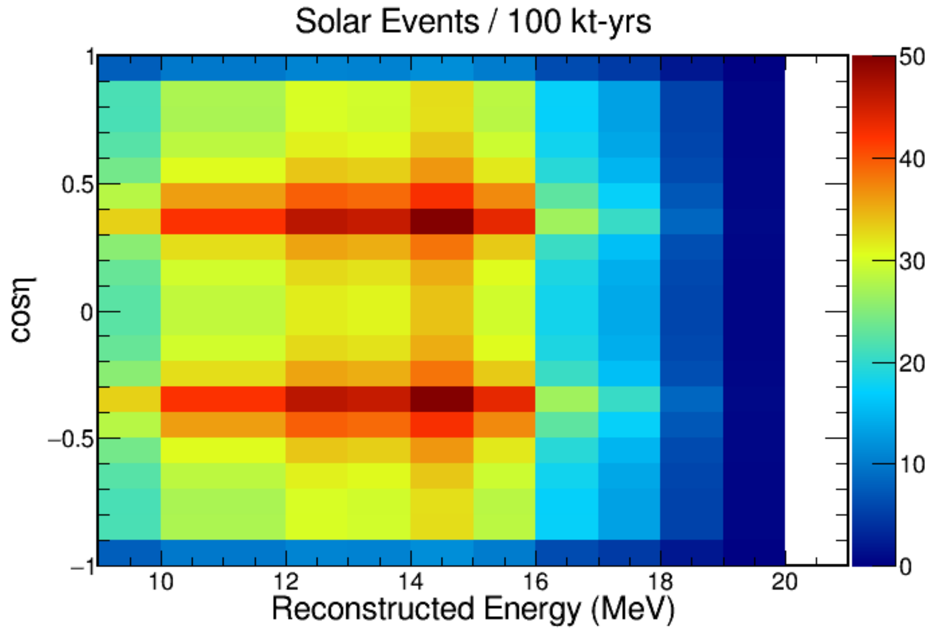




Radon Prediction

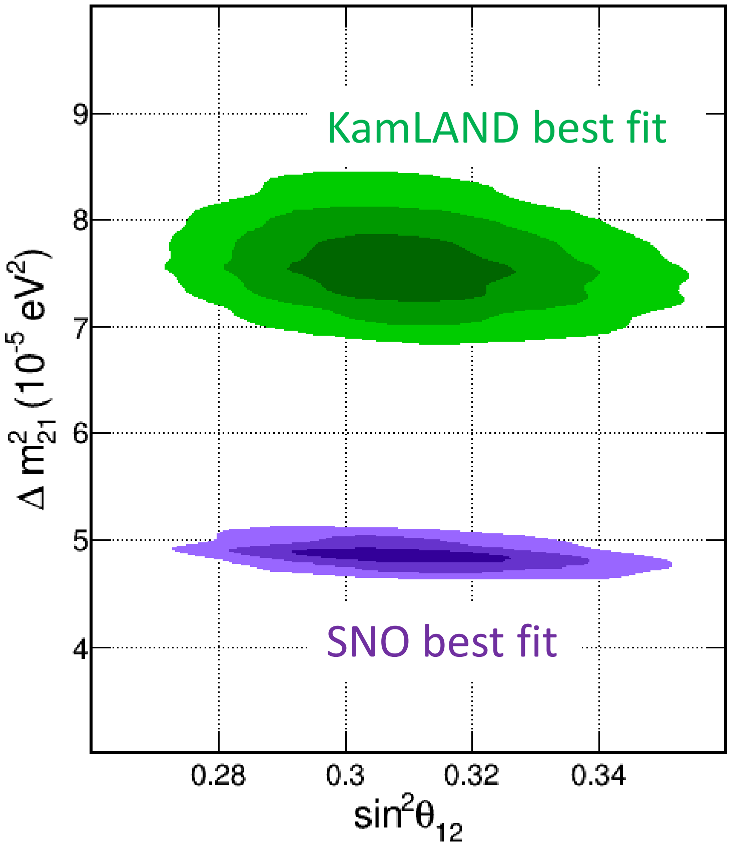






Sensitivity to Oscillation Parameters

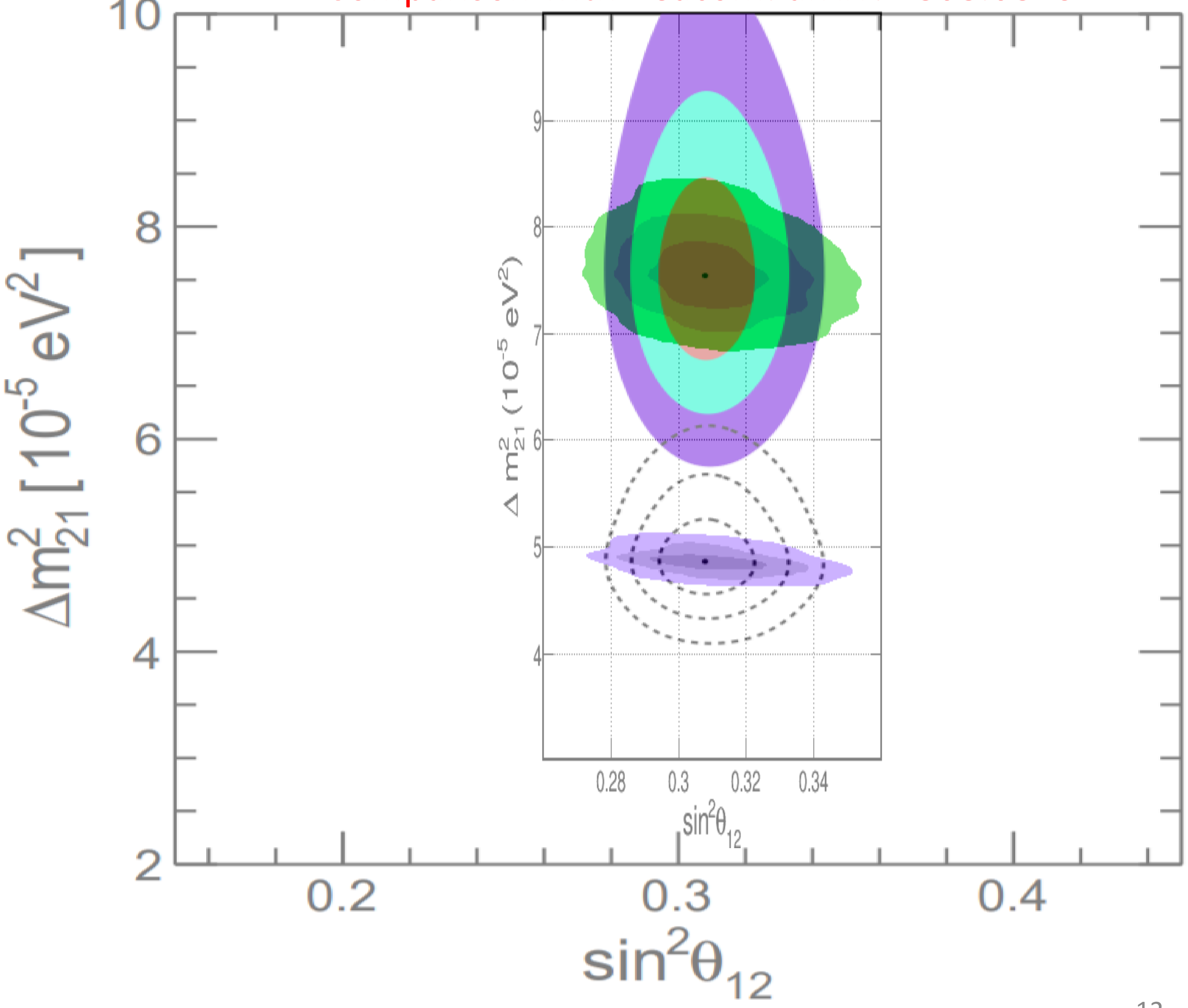
- Calculated the Asimov sensitivity to parameter space with the ν_e CC sample
  - Using 400 kt-yr
- Can't disambiguate $\sin^2\theta_{12}$ and $\varphi(^8B)$ with single sample
  - Instead bring in 4% prior uncertainty on solar flux (SNO) and let the signal float within that uncertainty
- Reasonable normalization uncertainty on backgrounds, but no accounting for their shape
- Fake-data studies show >5σ tension between KamLAND and SNO best fits even if our background levels are 100x what's expected



Comparison with Theoretical Sensitivity Predictions

- Our sensitivity to Δm^2_{21} is quite strong compared to theorists' predictions
- Adding η as a fitting variable ends up giving us a great sensitivity boost
  - All the little ripples in osc prob collectively pull the fits
- Can push current tension between SNO/SK and KamLAND up to 10σ

Comparison with Beacom: arXiv: 1808.08232

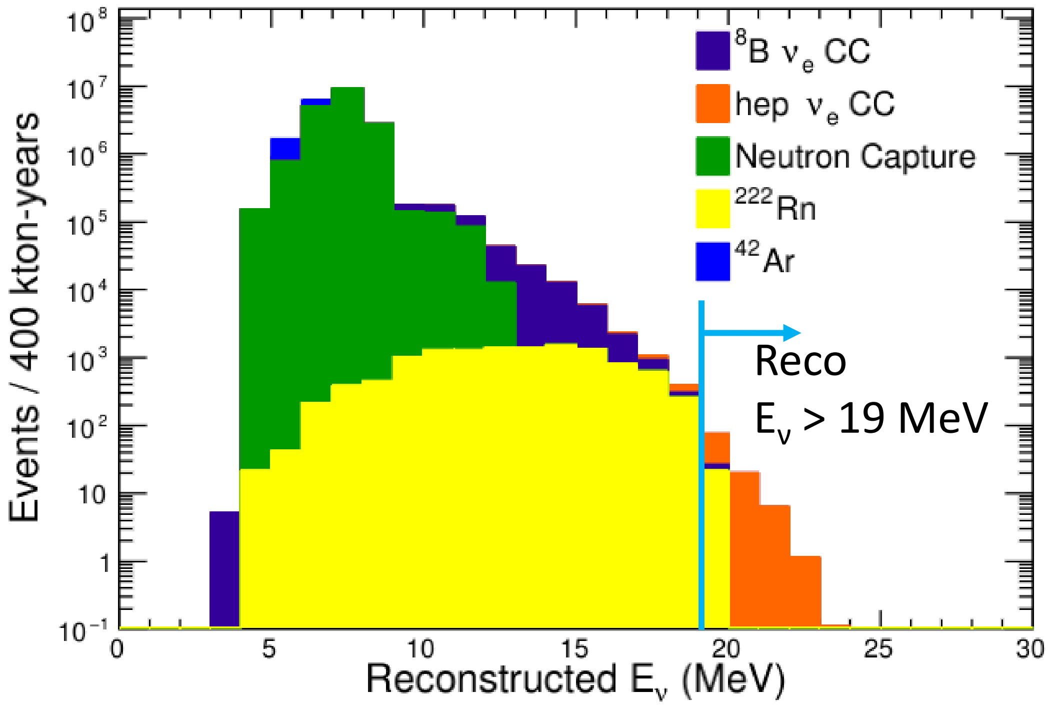


Summary

- We estimate we can measure Δm^2_{21} to $\approx$1% with realistic simulation of signal and radiological background
- Can push SNO/SK and KamLAND tension up to 10σ
- Huge boost in sensitivity from fitting sample in both E_ν and η from wiggles in solar survival probability due to matter effects

Backup

New Astrophysics: Resolving φ(hep)



- The hep flux is the hottest flux predicted by the SSM but has never been observed
  - φ(hep) ~ 10^{-3} x $\varphi(^8B)$, but, its flux extends to ≈19 MeV
- DUNE is ideal experiment for discovering this flux with its good energy resolution at the several kton scale

DUNE Sensitivity to Measuring φ(hep)

- Unfortunately, tied to ^{222}Rn concentration in the cryostat
  - $^{40}Ar(\alpha,\gamma)$ reaction dominates the background
  - For nominal sim, ^{222}Rn concentration gives 10 mBq/kg and is relatively conservative

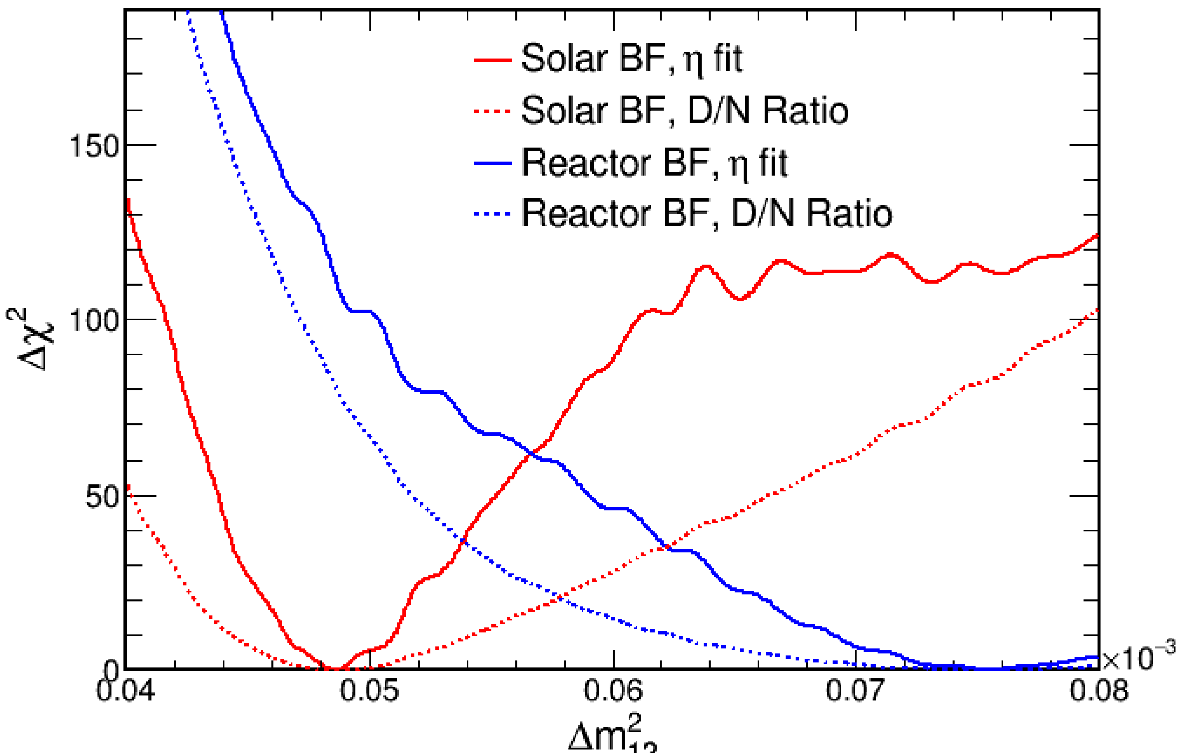
	0.1x	0.3x	1x	3x	10x	100x
$s/\sqrt{b}$	31.4	27.0	19.6	12.5	7.2	2.3
res	11.8%	12.0%	12.5%	13.9%	18.0%	44.6%

- At the nominal rate, we'd expect 5σ evidence at 2.6 x 10kt-yrs
  - 12.7 hep neutrinos on a background of 6.4
  - Could give an interesting paper early in experiment's run

- But need better understanding of $^{40}Ar(\alpha,\gamma)$ before measurement possible

Benefits of Fitting in η

- Beacom paper determined Δm^2_{21} using the total day/night asymmetry
  - We can do such a fit, and can show explicitly benefit of the η-fit
  - Sensitivity to push KamLAND/SNO+SK tension to >10σ in Δm^2_{21} resolution



- Fitting in η decreases sizes of contours by a factor of 2-4

	Solar		Reactor	
	η-fit	Day/Night	η-fit	Day/Night
1σ	0.7%	2.8%	1.5%	6.0%
2σ	2.0%	5.5%	4.7%	11.3%
3σ	4.0%	8.1%	8.0%	16.5%

Great sensitivity!
About 1% resolution of mass splitting from wiggle pulls.