Update of T2K sensitivity study

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2km meeting

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Update from last meeting

1. ✓ We included 19 out of 20 systematic errors
2. ✓ Systematic uncertainty of the nuclear effect doesn't work with current 2km MC sets (talk later)
3. Testing critical values 90% CL=2.71, 4.61 or … (See Maxim's talk at the last meeting) → decided to use Feldman and Cousins method
4. Generate Fij at every point of chi2 map of 30×30 grid
5. ✓ Make pull term and ε/σ plots

Systematic errors included

- We included 19 out of 20 systematic errors so far.

Neutrino flux

(C) Event selection

T2K related errors

a. ✓ Fiducial volume
b. ✓ Energy scale
c. ✓ Polfit
d. Beam related νe intrinsic BG

Event reconstruction

a. ✓ 1-ring/multi-ring separation
b. ✓ Particle ID (single-ring, multi-ring)

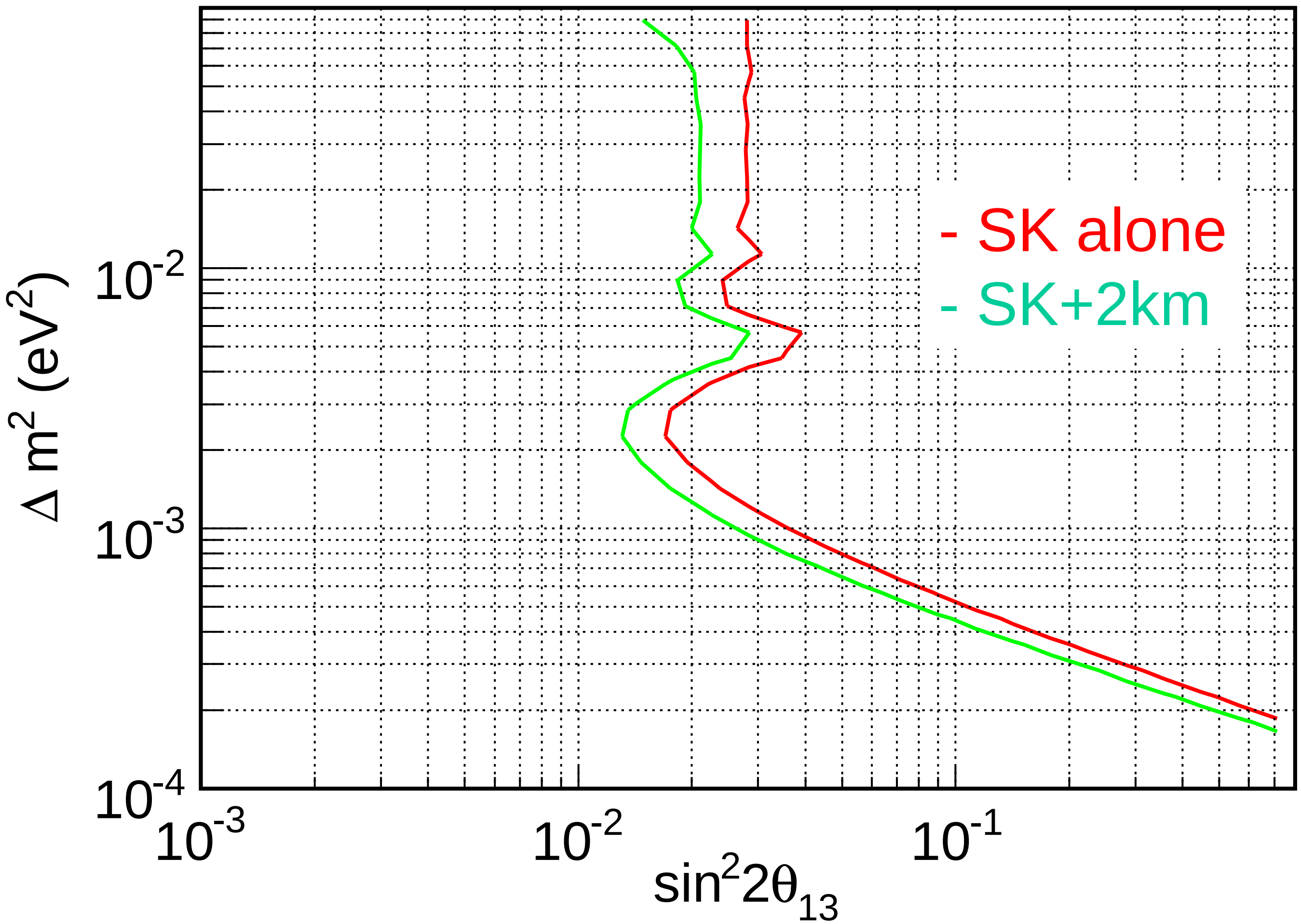
Neutrino interaction

M_A in quasi-elastic and single-pi
Quasi elastic scattering (model dependence)
Quasi elastic scattering (cross section)
single-pion production (cross section)
multi-pion production (model dependence)
multi-pion production (cross section)
coherent pion production (cross section)
NC/CC ratio
Nuclear effect in ^{16}O → Not yet

✓ SK&2km independent
✓ Shared errors between SK&2km

Preliminary Sensitive curve

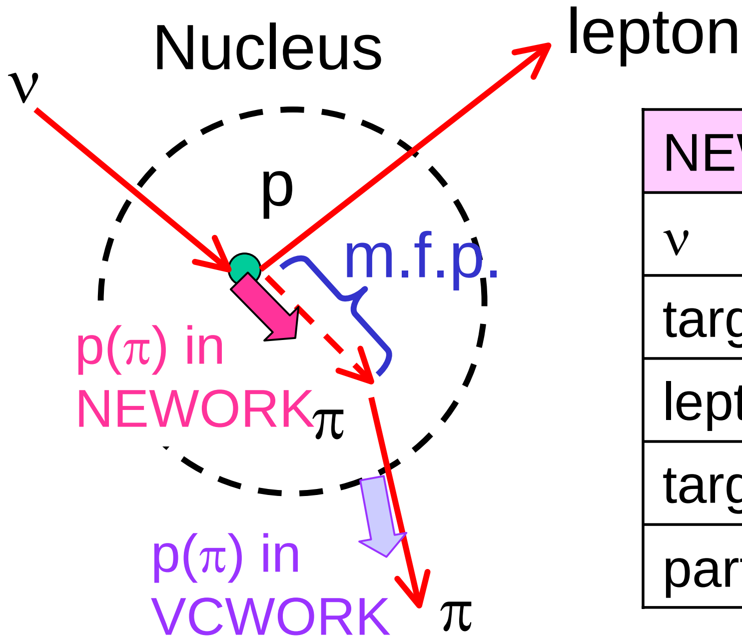
- 90% CL cut at 4.61 → F & C method not yet applied
- We are still studying a proper way to include F&C with systematics
- Nsys = 18 out of 19



Systematic errors for Nuclear effect

- π's from neutrino interactions will interact inside of the ^{16}O nucleus. There are three possible types of interactions:
  1. Inelastic scattering
  2. Charge exchange
  3. Absorption
- Cross sections of these processes are determined by the calculated mean free path of each interaction
- These interactions are taken care by the NEUT program and saved into NEWORK bank
- NEUT output fed to the Geant4 simulation and saved into VCWORK bank

NEWORK and VCWORK banks



@interaction

NEWORK	
ν	…
target	…
lepton	…
target	…
particle (π)	p(π)=0.8

Leave nucleus

VCWORK	
ν	…
target	…
lepton	…
target	…
particle (π)	p(π)=1.2

Checking p(π) between NEWORK and VCWORK, and determine whether there was a nuclear effect → No simple flag!

Is p(π) different? (Inelastic scattering)
Is π missing? (Absorption)
Is π charge different? (Charge exchange)

If the mode is single π, but PDFcode(π)=200000, then this event is π less delta resonance decay

Problem of current Nuclear effect code

- SK Atmpd nuclear effect checking code relies on the order of particle in NEWORK and VCWORK banks. SK uses Geant3 as the detector simulator
- 2km detector simulator, Geant4, screwed up the particle order in the banks, and there is nothing to indicate whether or not a nuclear effect happened
- Testing new nuclear effect flags in the ATMPD SK code
- In future, 2km MC can access to this flag

Estimator

- Use a Poisson likelihood ratio estimator, including :
  - SK 1 ring e-like sample, Eν, 10 bins
  - SK 2 ring e-like sample, invariant mass, 28 bins
  - 2km 1 ring e-like sample, Eν, 20 bins
  - 2km 2 ring e-like sample, invariant mass, 28 bins

  → 86 bins in total

$$\chi^2 = \sum_{n=1}^{86}\left[2\left\{N^n_{exp}\left(1+\sum_{i=1}^{45} f_i^n\cdot\epsilon_i\right)-N^n_{obs}\right\} +2N^n_{obs}\ln\left(\frac{N^n_{obs}}{N^n_{exp}\left(1+\sum_{i=1}^{45} f_i^n\cdot\epsilon_i\right)}\right)\right] + \sum_{i=1}^{43}\left(\frac{\epsilon_i}{\sigma_i}\right)^2$$

Pull term

ϵ/σ term

- See Phys. Rev. D 66, 053010 (2002)

Pull term

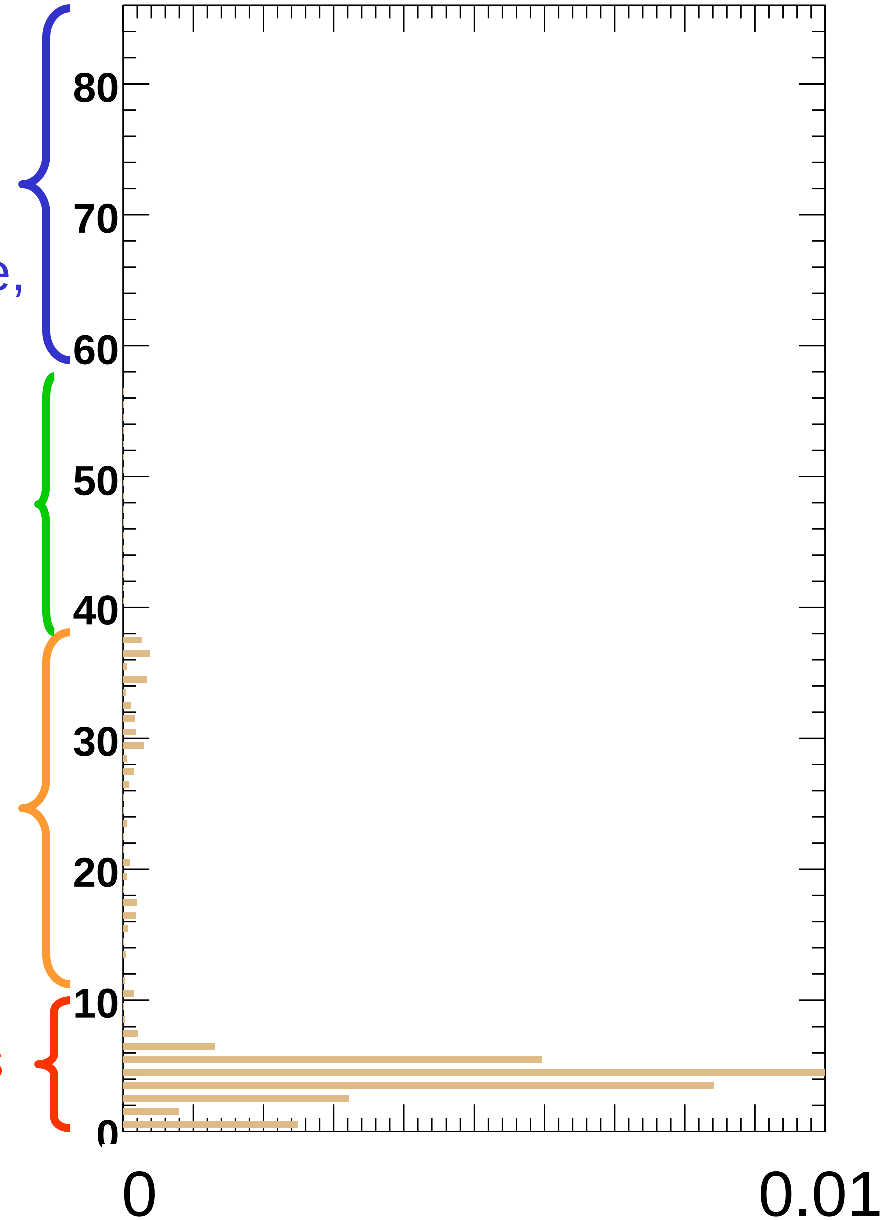
This histogram tells which sub-sample is good agreement with expectation

2km 2 ring e-like sample, invariant mass, 28 bins

2km 1 ring e-like sample, Eν, 20 bins

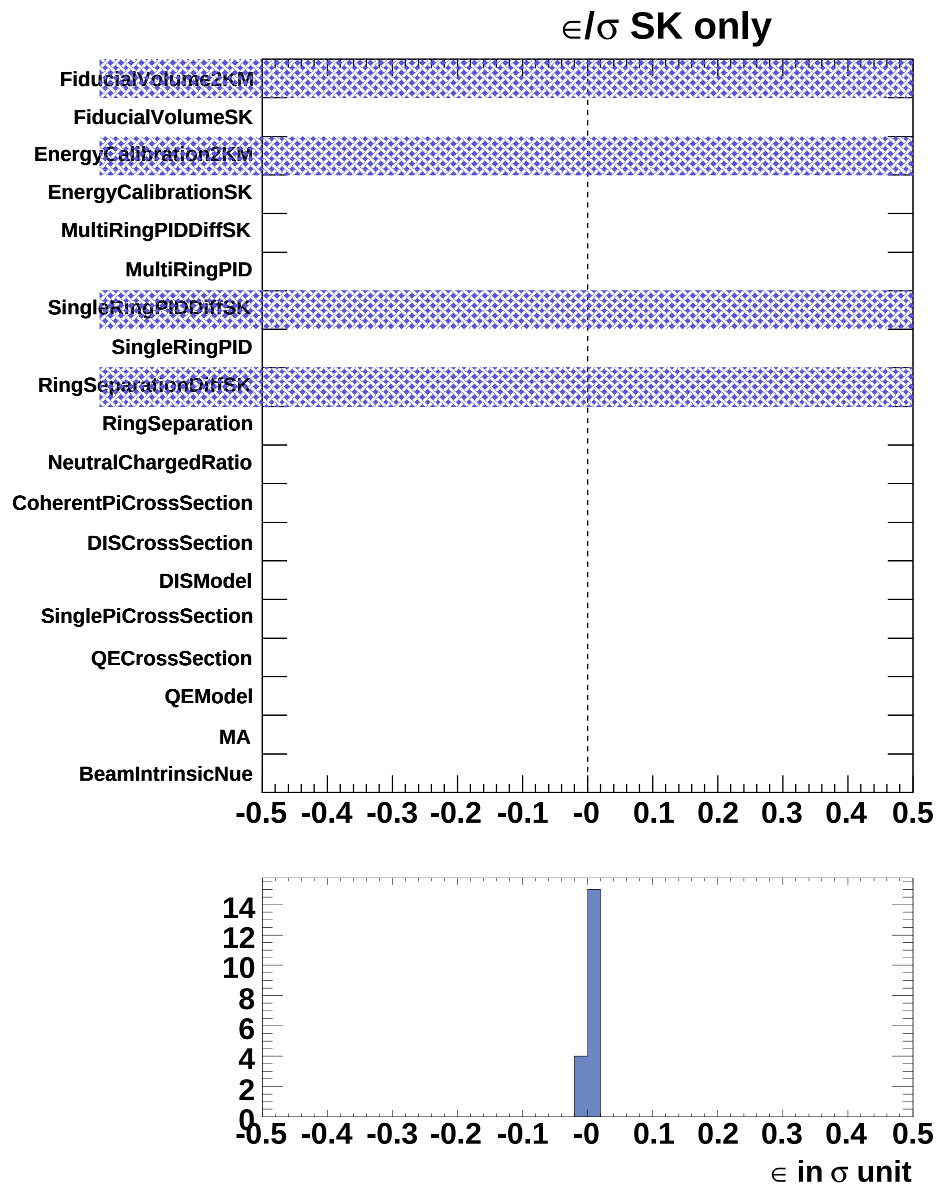
SK 2 ring e-like sample, invariant mass, 28 bins

SK 1 ring e-like sample, Eν, 10 bins



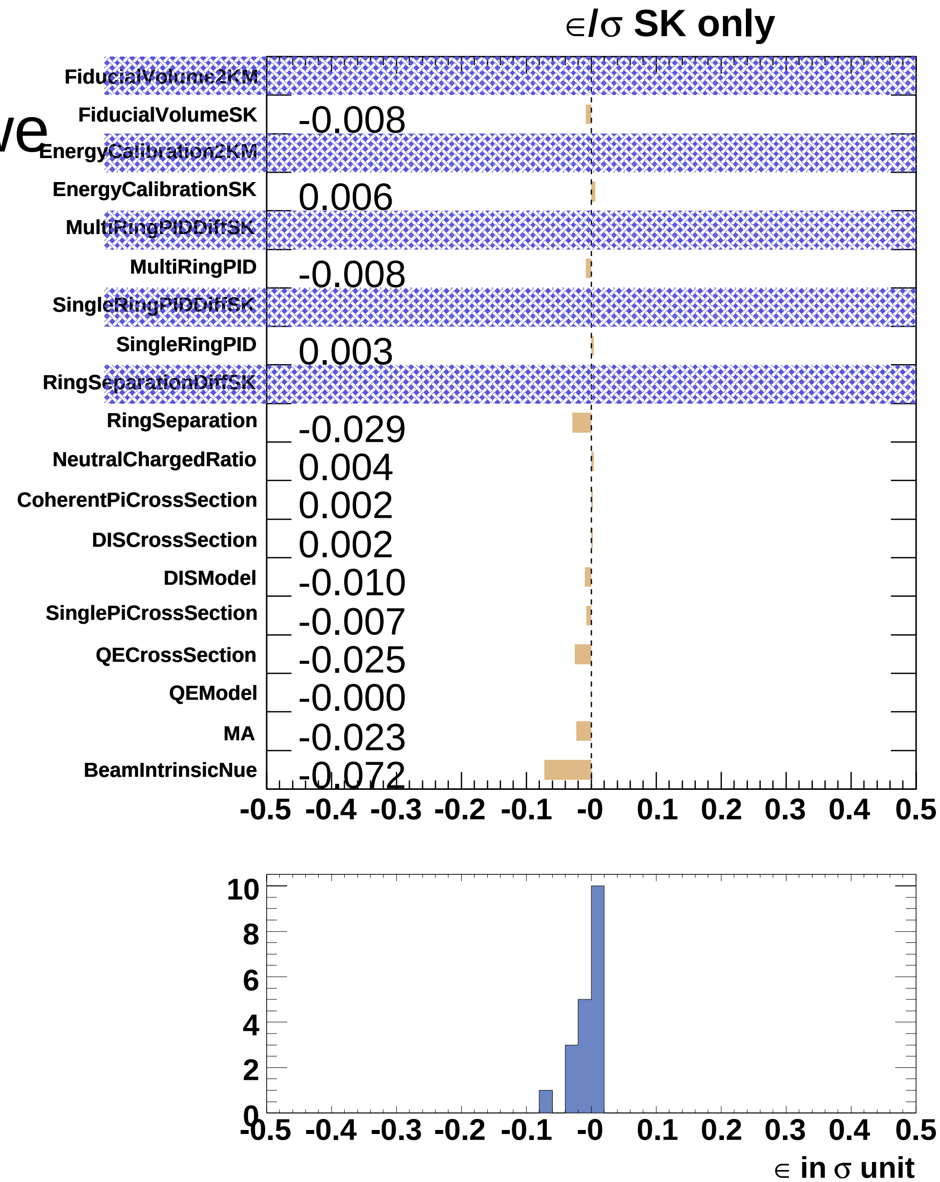
ε/σ term (1)

- If data and expected are generated at the same place, ε/σ goes to zero. Because data & expected histograms are exactly the same at the best fit point
- $(\sin^2 2\theta, \Delta m^2) = (0.017, 2.2e\text{-}3)$



ε/σ term (2)

- If data generated at $(\sin^2 2\theta, \Delta m^2)=(0, 2.5e\text{-}3)$, we see which systematic uncertainty has significant offset



Conclusion and plan

- We included 19 out of 20 systematic errors
- Made pull term and ε/σ plots

- Update sensitivity curve with systematic uncertainties with Feldman & Cousins method
- Throw fake data and see ε/σ term and pull term
- I will implement time scaled beam profile