

Progress status report :

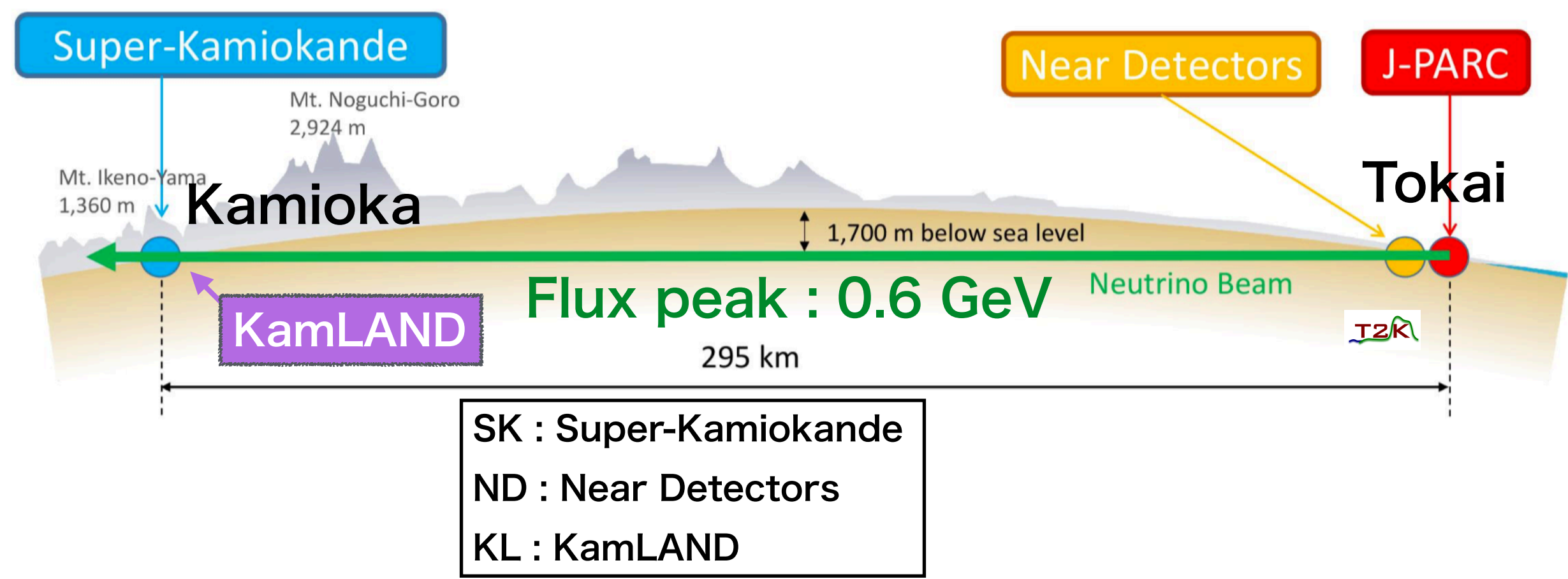
Study on neutrino interaction using T2K beam at KamLAND



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T2K and KamLAND



Flavor (interaction)

$$\begin{pmatrix} |\nu_e\rangle \\ |\nu_\mu\rangle \\ |\nu_\tau\rangle \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{i\delta_{CP}} \\ 0 & 1 & 0 \\ -s_{13}e^{-i\delta_{CP}} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} |\nu_1\rangle \\ |\nu_2\rangle \\ |\nu_3\rangle \end{pmatrix}$$

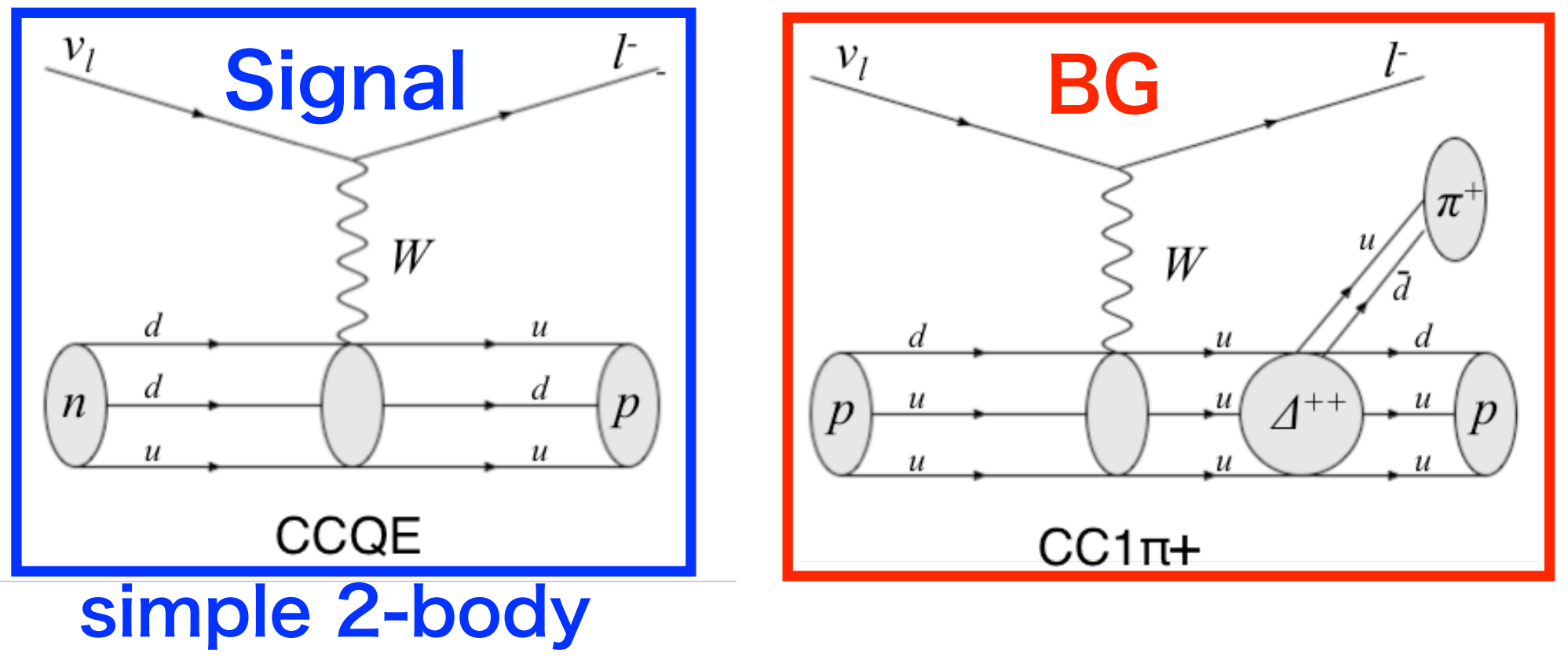
Mass (propagation)

CPV parameter



- ▶ Measure δ_{CP} (CP violation phase)
- ▶ Indication of CP violation by 2σ

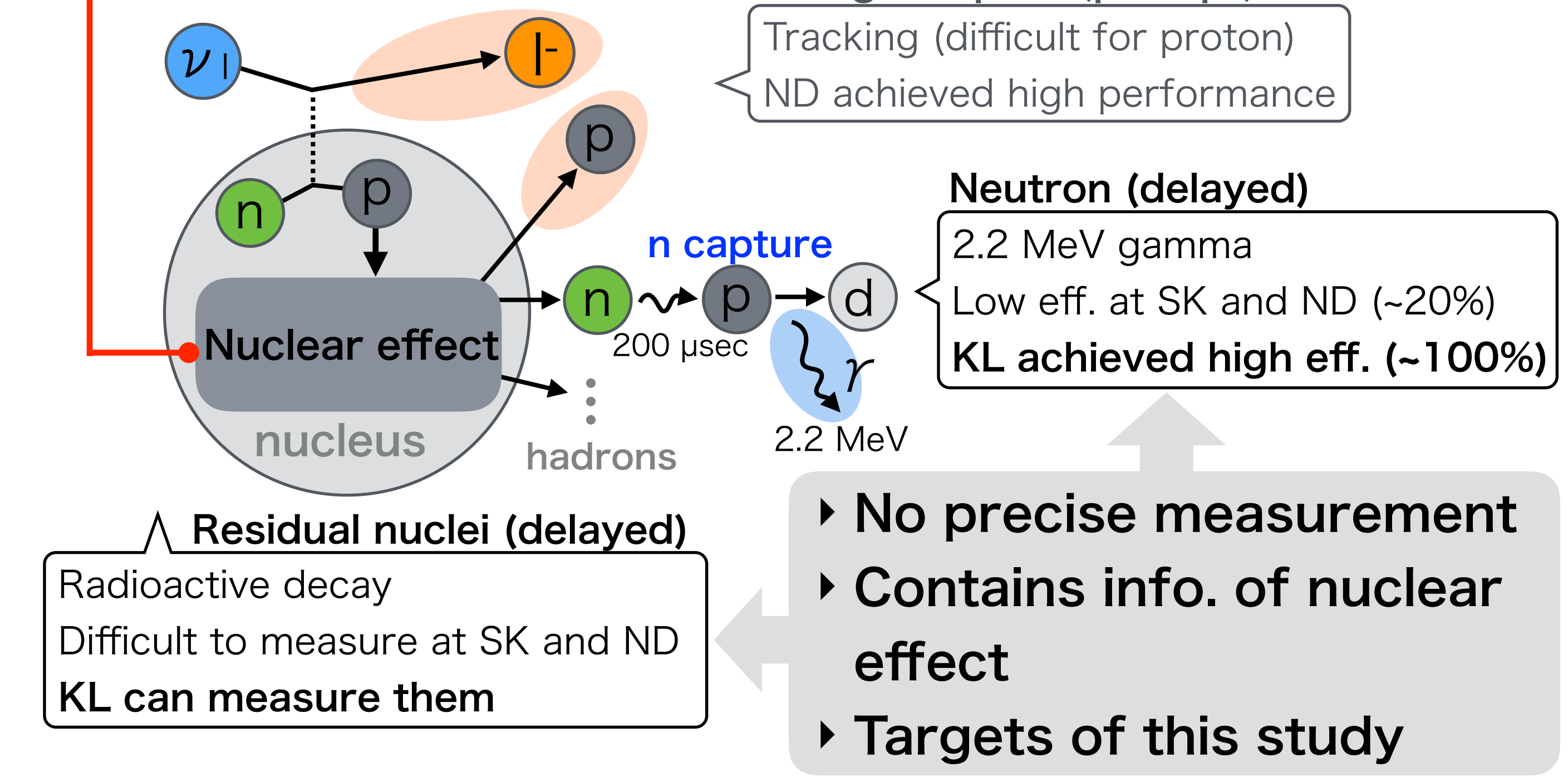
Largest systematic error :
neutrino-nucleus (νN) interaction



Improper nuclear effect leads miss E_ν recon.

- ▶ Categorized as CCQE if we loss π (absorbed in nucleus, etc)

Large uncertainty



Studies so far



- ▶ Data analysis and MC simulation study were performed
 - Measured osc. parameters & indication of improper ν -N model
 - Newly find unexpected excess in low energy region

Measured osc. parameter

$$\Delta m_{32}^2 = 2.55^{+1.60}_{-0.75} \times 10^{-3} \text{ eV}^2$$

$$\sin^2 \theta_{23} = 0.36^{+0.41}_{-0.13}$$

▶ MiniBooNE observed excess in low energy region
 - BG underestimation? Unknown interaction?
 Sterile ν ?

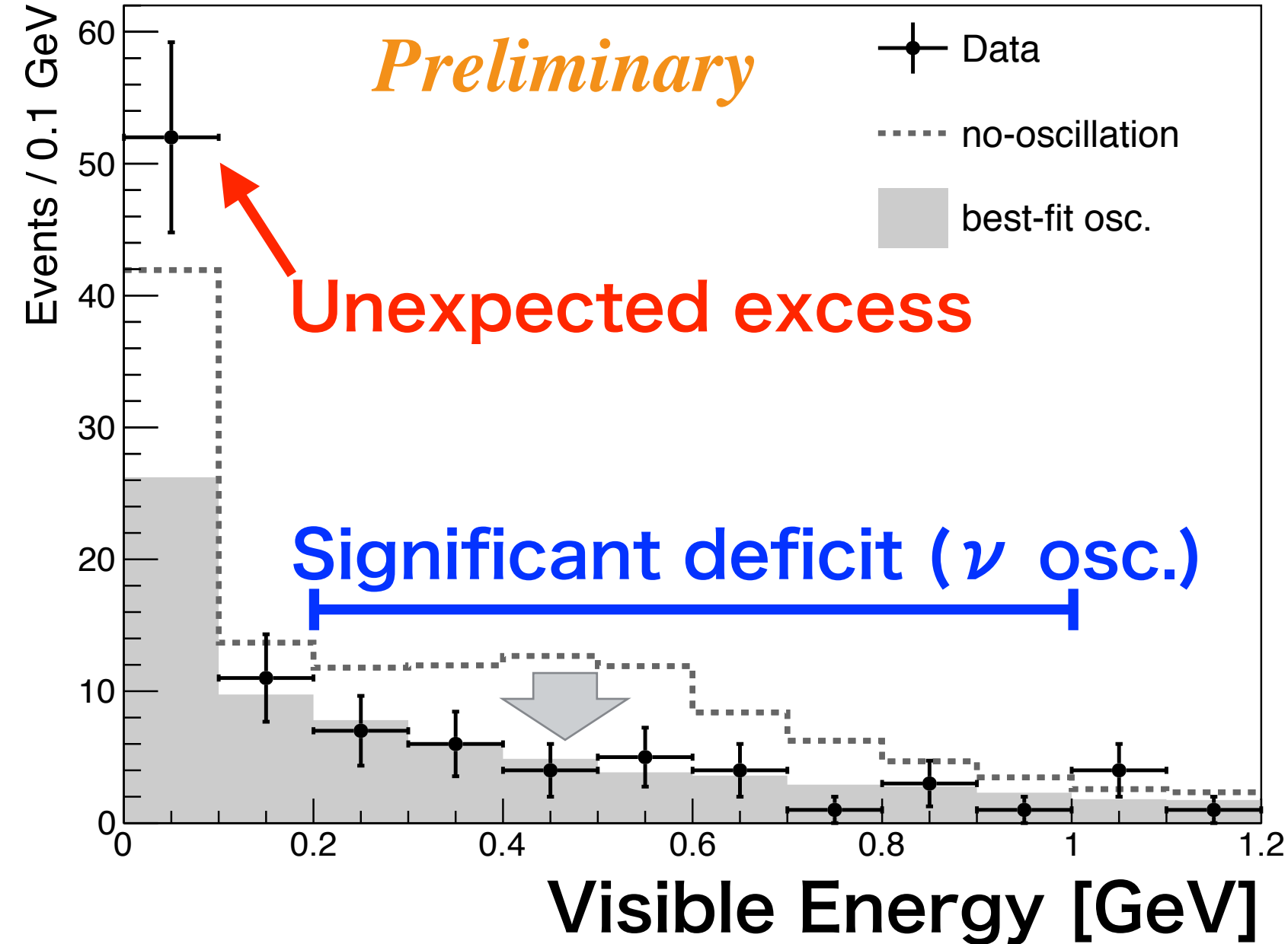
Needs consistency check !



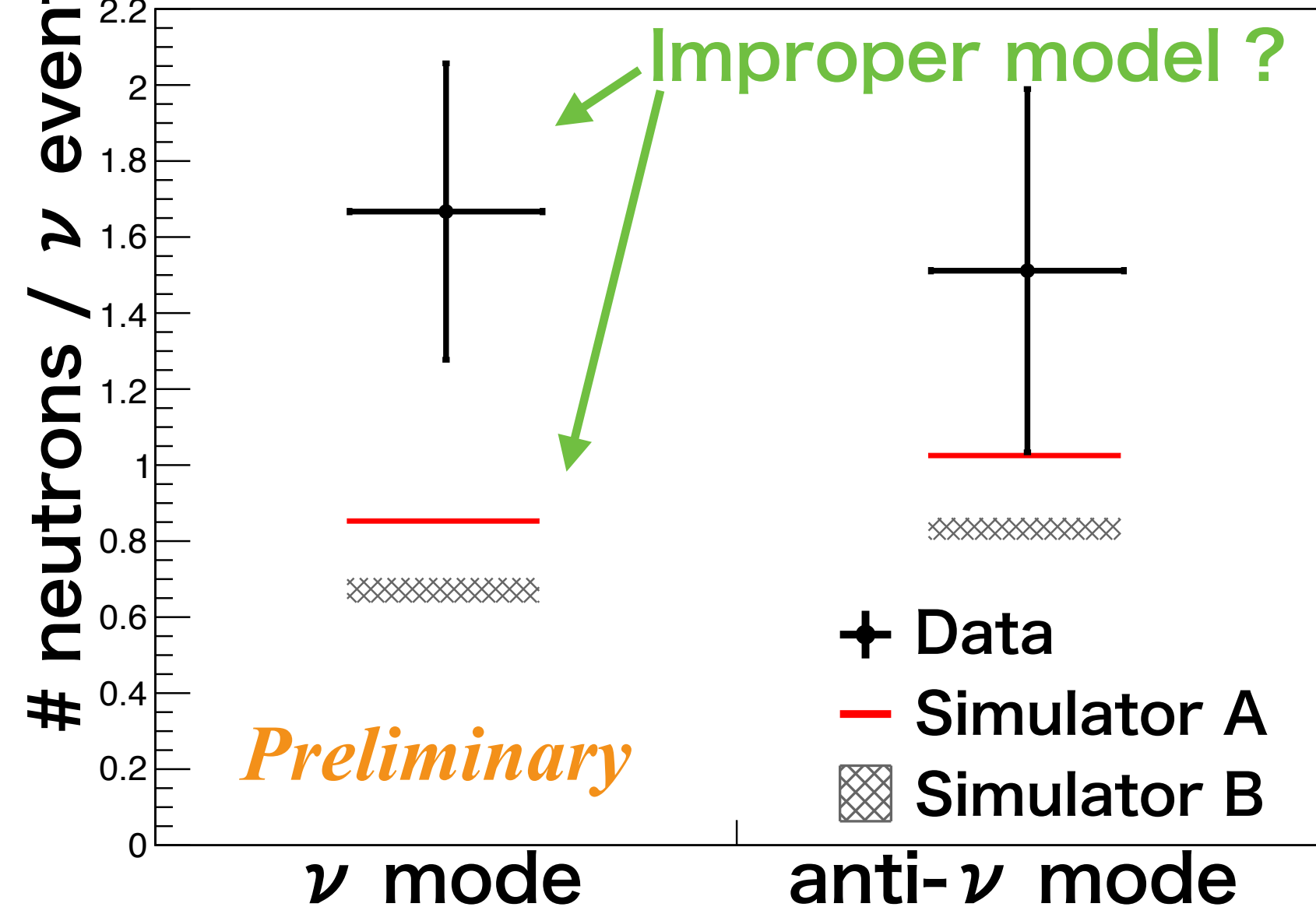
2 targets we have

- ▶ (1) ν -N model constraint
- ▶ (2) Understand excess in low E region

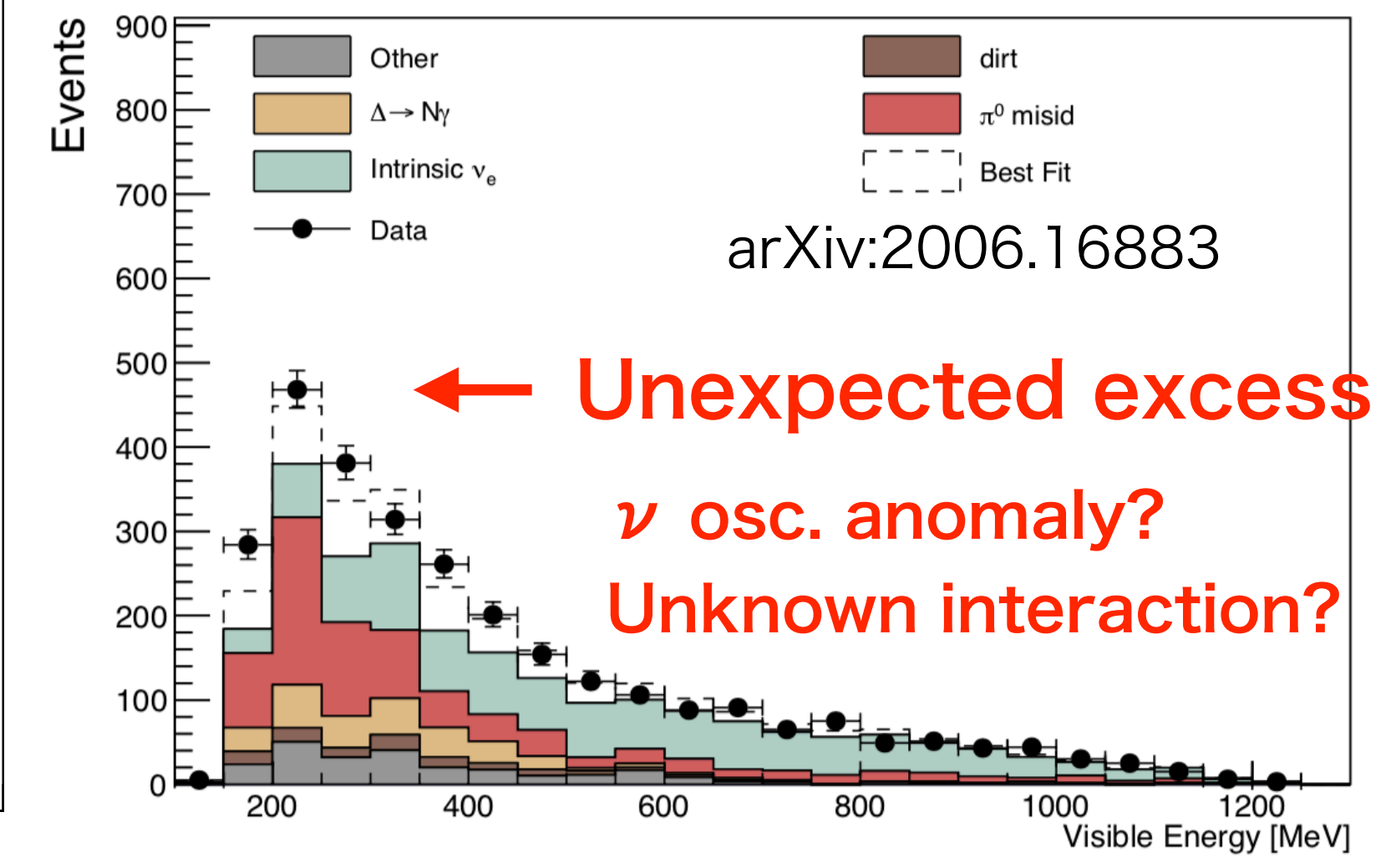
Energy spectrum of T2K events



Averaged number of neutron



MiniBooNE ν_e CCQE-like events

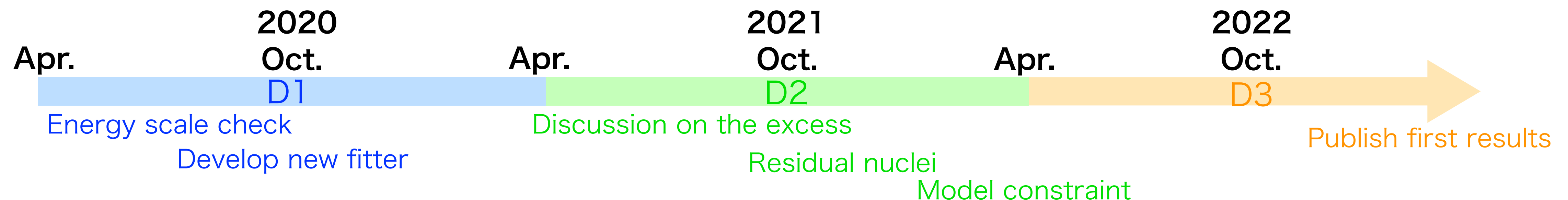


(1) ν -N model constraint

- ▶ Further analysis on neutron detection (efficiency estimation, selection optimization, etc)
- ▶ Residual nuclei decay tag.
- ▶ Develop new fitter to reconstruct charge lepton (start and end points of the track, PID)
- ▶ Fit data with several model parameters and find best-fit value

(2) Understand excess in low E region

- ▶ Energy scale check (Both of MC and data)
- ▶ Get detail info. of these events
 - e-like? μ -like ? inner ? outer ?
- ▶ Compare with MiniBooNE excess in low E region
 - Consistency check.





- ▶ **Supervisor : Kevin S. McFarland (University of Rochester)**

- T2K collaborator as a **neutrino interaction expert**

- ▶ **Purpose : Study on NCEL (Neutral Current Elastic scattering) model**

- Understand the model and that uncertainty there are in NCEL using NEUT

- Lean how to use NEUT more detail

- Discuss current constraint on the model and what kind of parameter we need to improve

- **Constrain with some measurements?**

NEUT ; ν interaction simulator

- **Detail contents are under discussion**

- ▶ With video meetings and e-mail staying in Sendai.

- ▶ I will submit an application document soon.

- ▶ I'm planning to start in this month.