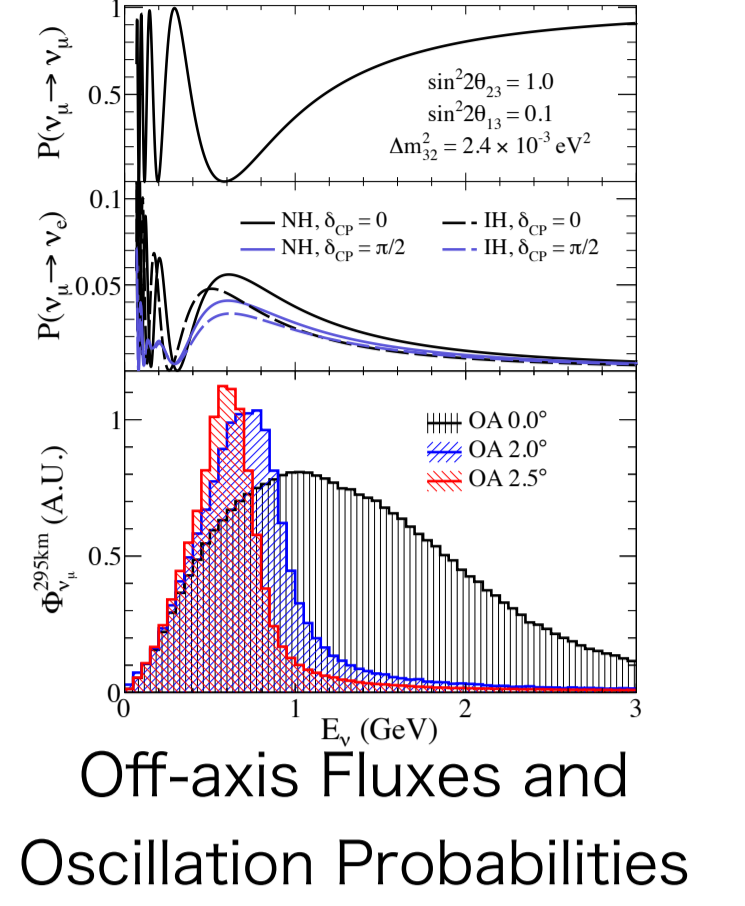
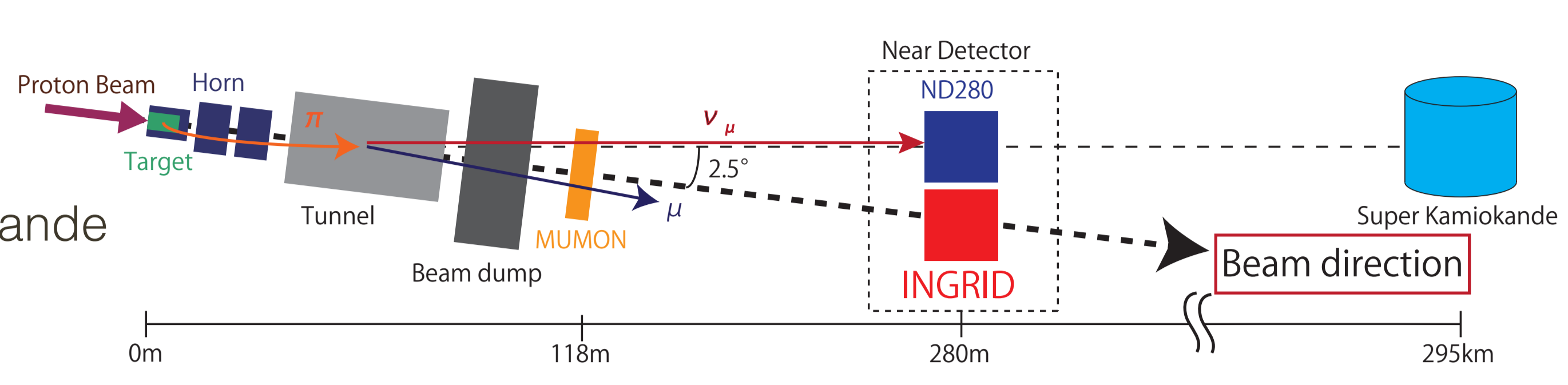


The T2K experiment

- Long-baseline neutrino oscillation experiment
- The J-PARC neutrino beam
- The near detector at J-PARC and far detector, Super-Kamiokande
- Super-K off-axis angle are 2.5 degrees
 - Neutrino energy is optimized for neutrino oscillations
 - **Any shift in beam direction must be within 1 [mrad] of the nominal direction**

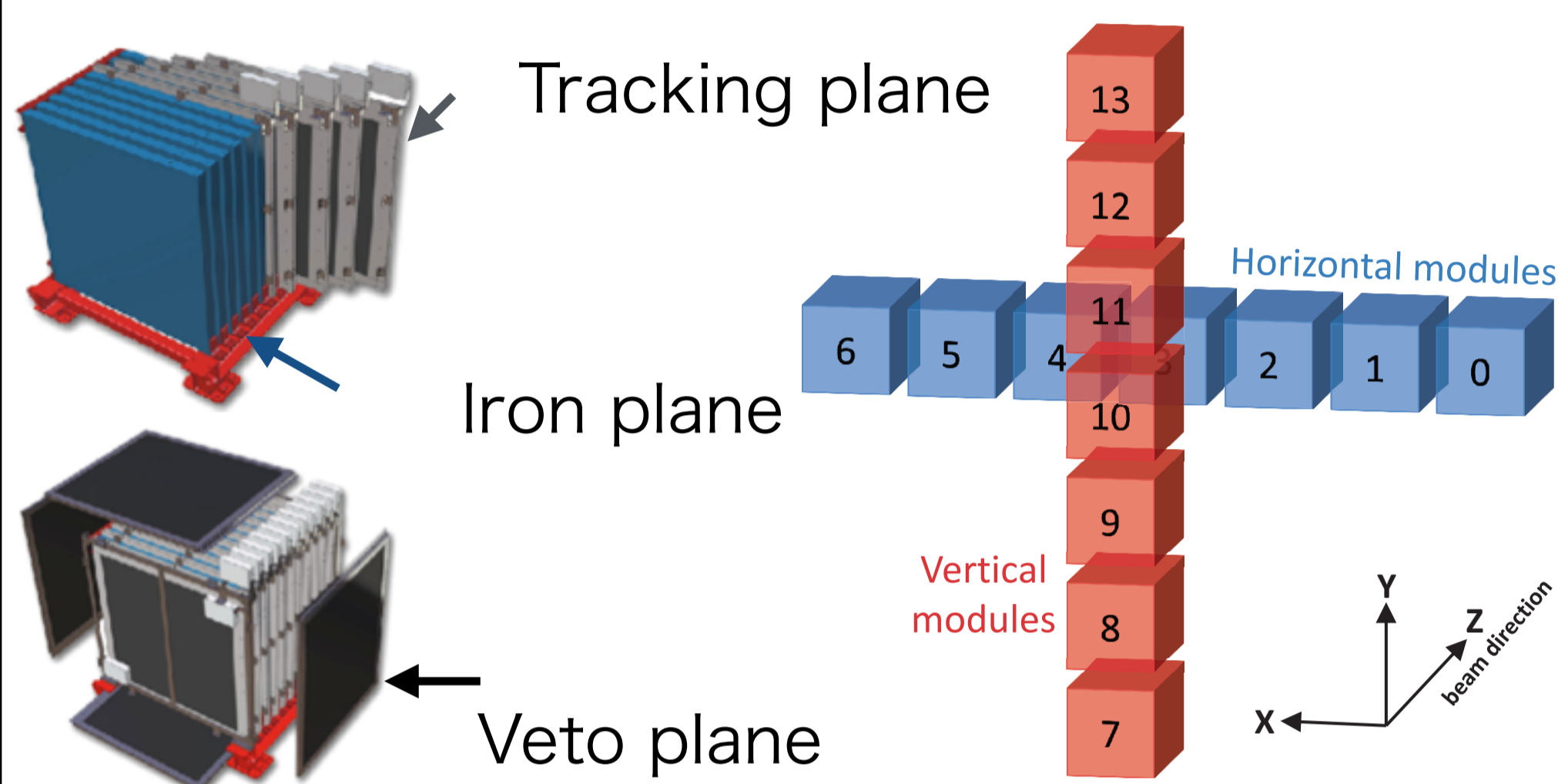


Measurement of δ_{CP}

δ_{CP} is CP violating phase of the neutrino matrix

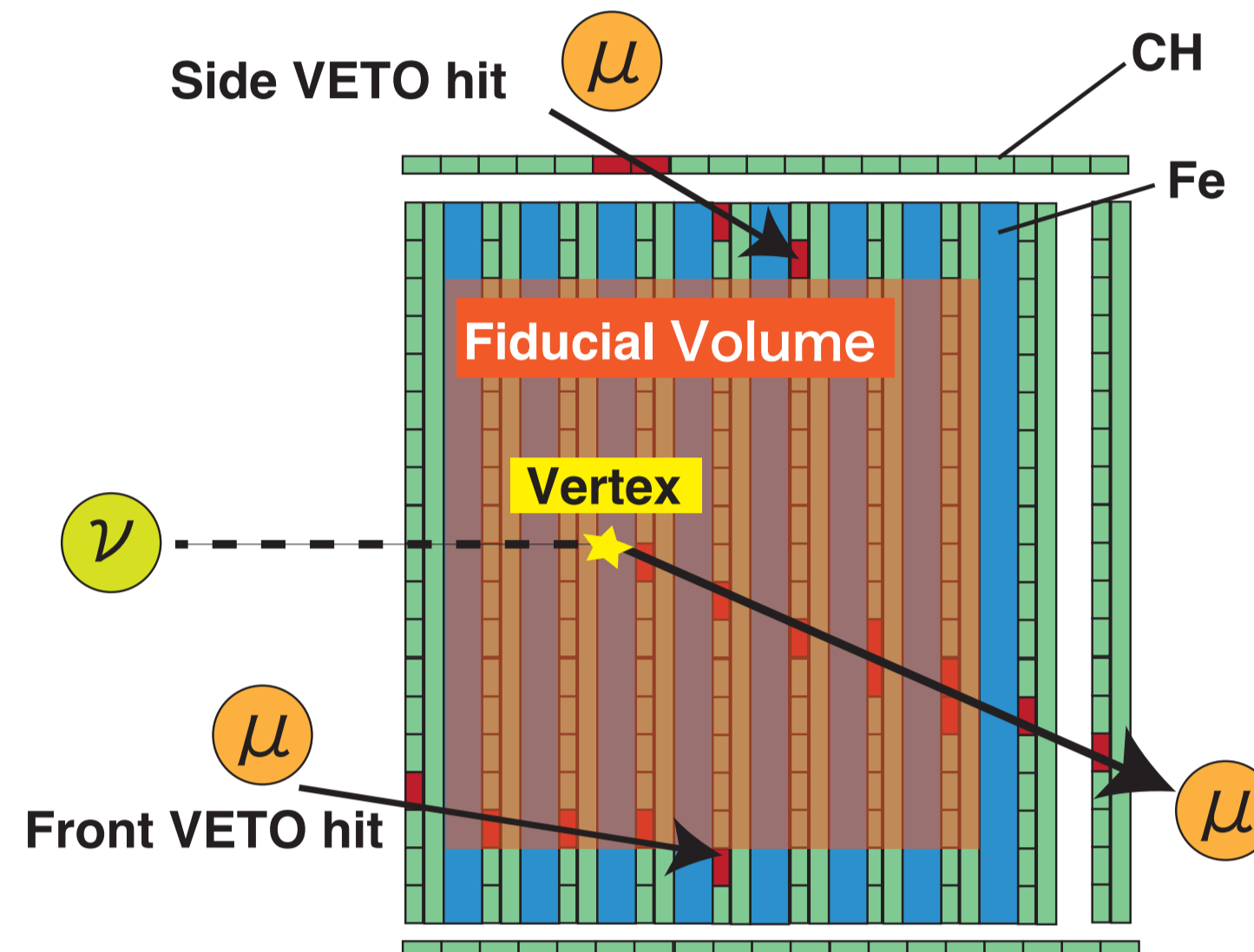
Anti-neutrino beam data taking started in June 2014

INGRID



- INGRID **on-axis** near detector consists of 14 identical modules
- Located at 280m downstream of the target
- A INGRID module has a sandwich structure made of **the iron plates and the scintillator trackers**.
- **Measuring neutrino beam direction, profile and event rate.**

Event selection

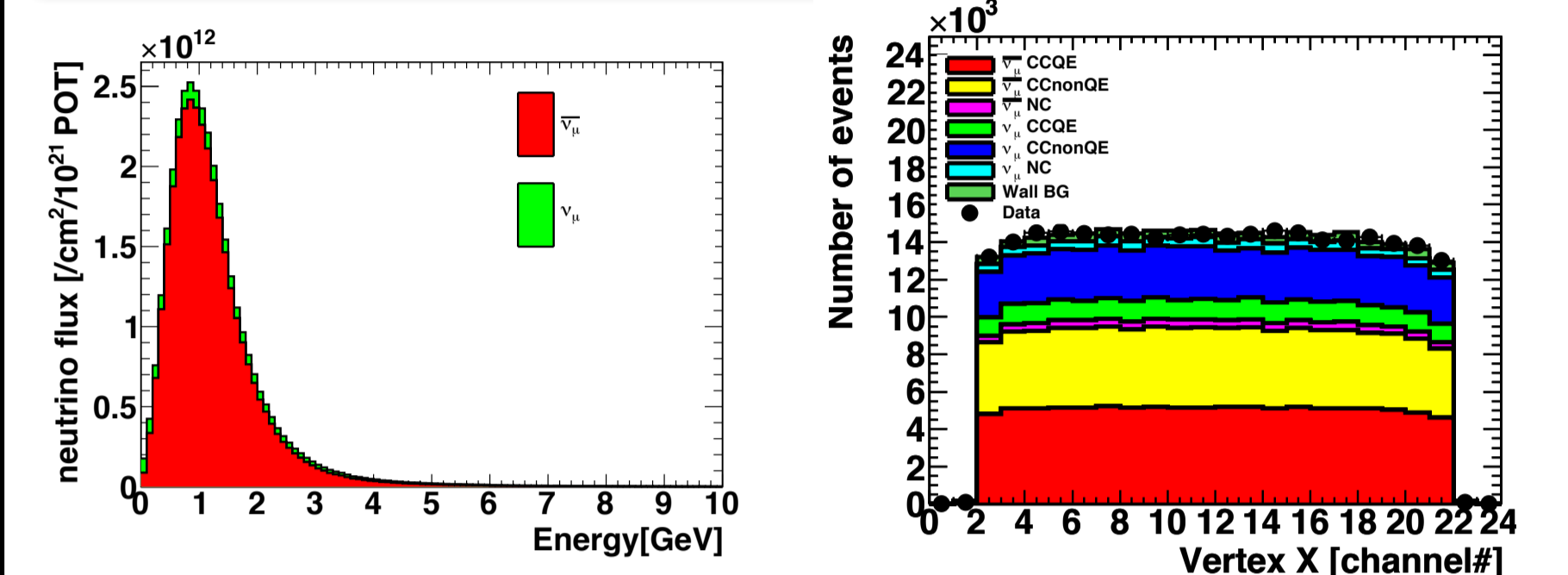


1. Time clustering
2. Active plane cut
3. Track reconstruction
4. Vertexing
5. Beam timing cut
6. VETO cut
7. Fiducial volume cut

Neutrino detection efficiency is 66%

mainly charged current interaction events

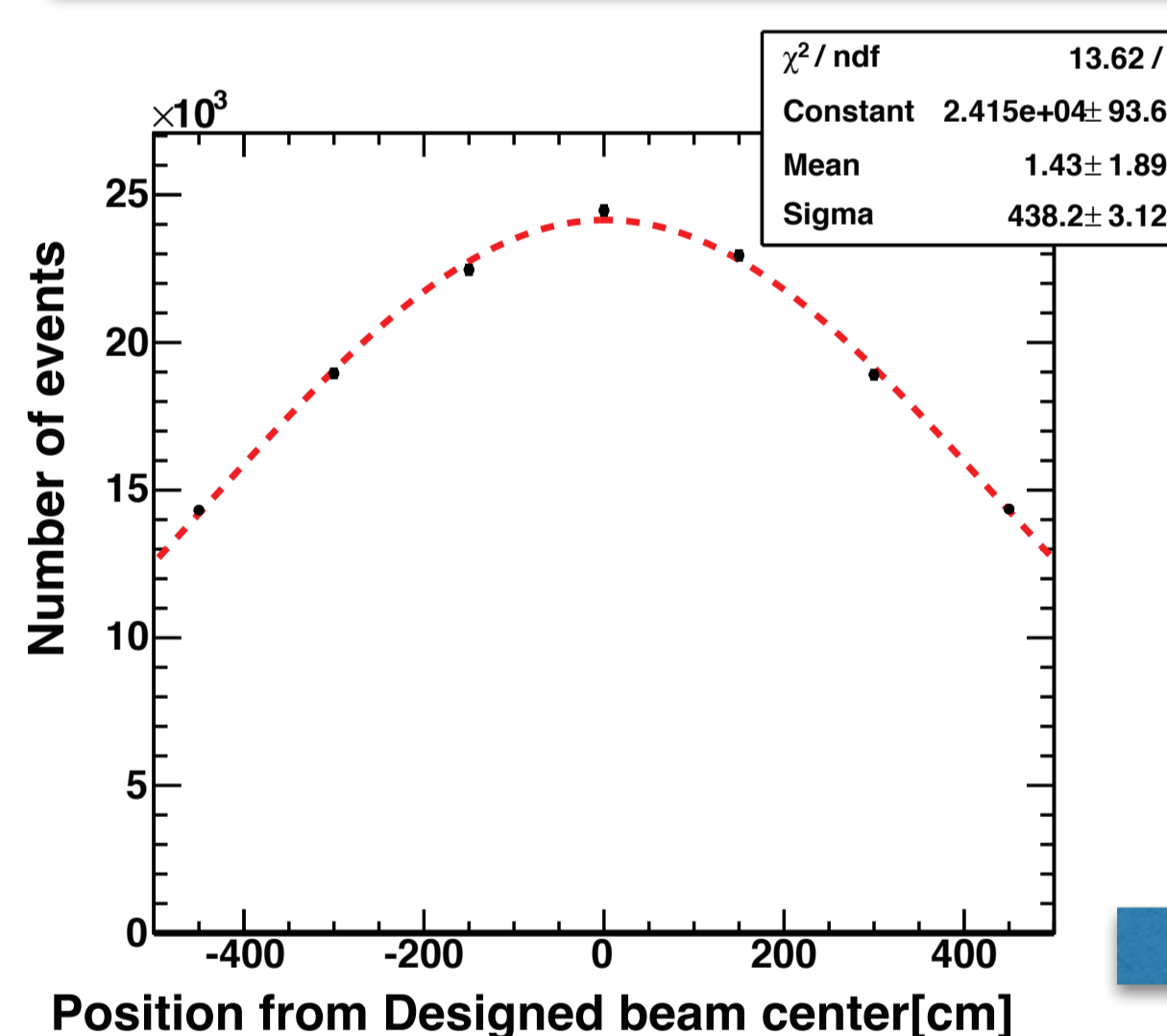
Flux and events



Neutrino flux at INGRID Vertex X distribution after event selection

- Neutrino energy is around 1GeV
- $\bar{\nu}_\mu$ cross section is about three times smaller than ν_μ cross section
 - After event selection, number of $\bar{\nu}_\mu/\nu_\mu = 2.2$
- After event selection, # of events are corrected for event pileup, dead channel and background effects.

Beam profile and systematic error

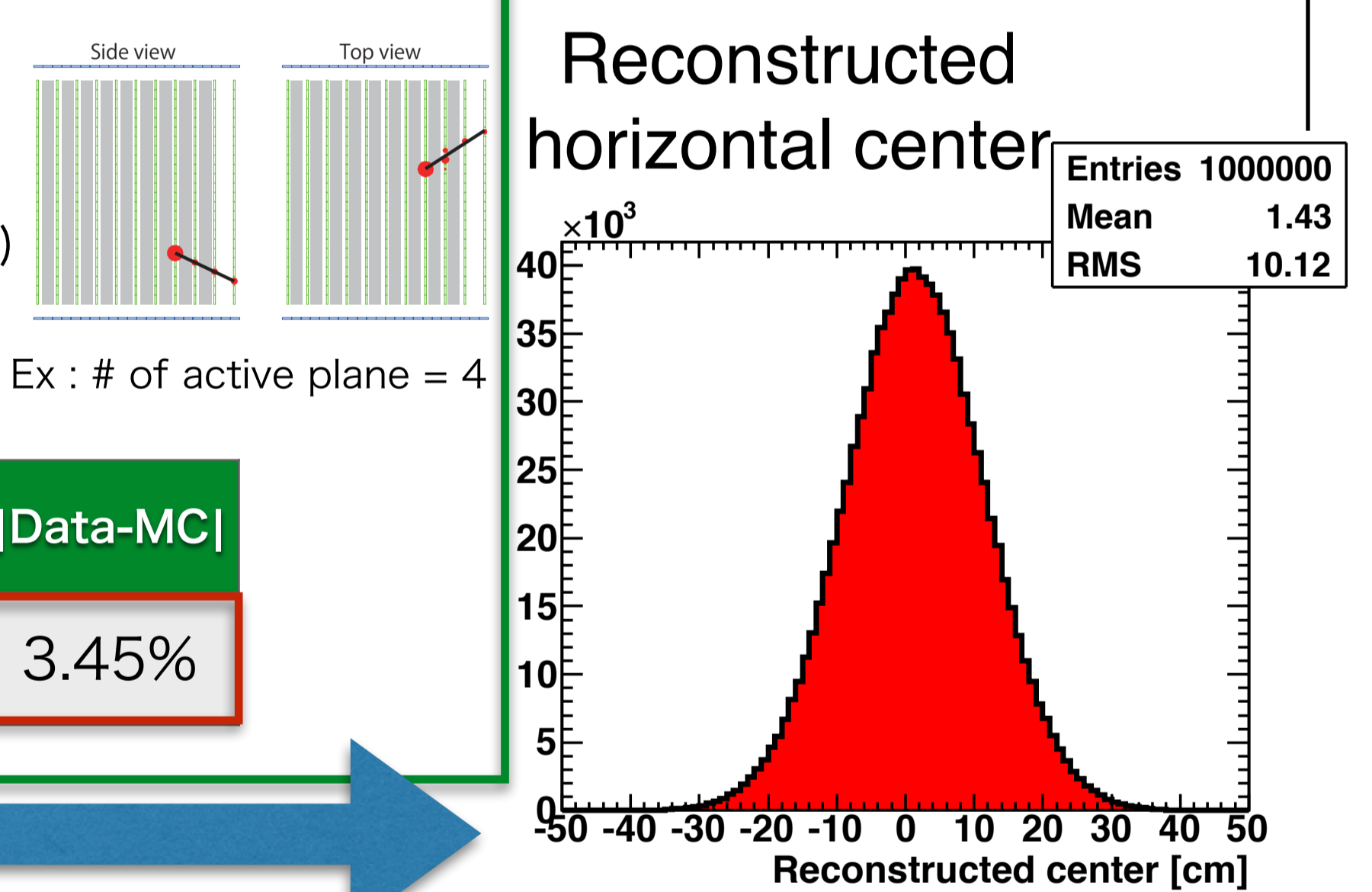


- Systematic error item
 - Background
 - Track reconstruction efficiency
 - VETO cut
 - Fiducial volume cut
 - etc
- Total : **4.08%**

Track reconstruction efficiency is largest error : 3.45%

$$\text{Reconstruction efficiency} = \frac{\text{\# of events (success 2D reconstruction)}}{\text{\# of events (\# of active plane} \geq 3)}$$

	Data	MC	Data-MC
Reconstruction efficiency	97.46%	94.01%	3.45%



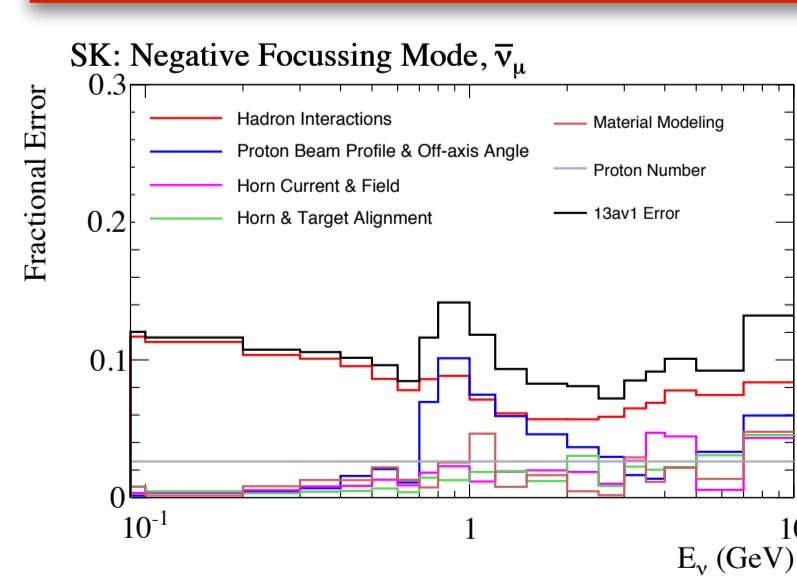
RMS is systematic error of direction. (10.1cm)

• Using the toyMC

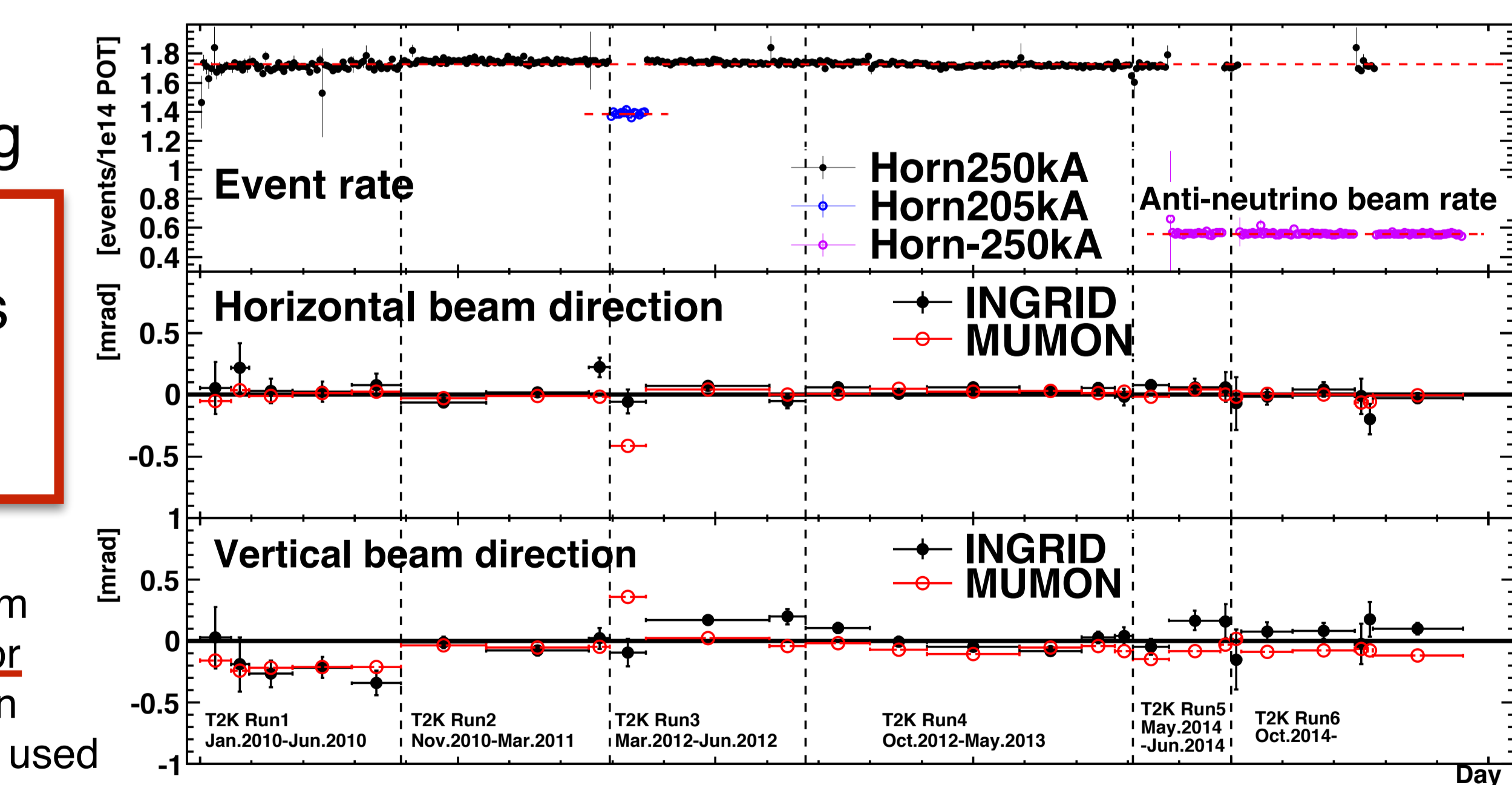
• The number of events at each module is varied with 4.08%

Result

- Event rate is stable for data taking
- The shift in beam direction is smaller than 1 [mrad] and meets the physics requirements in each run period



- $\bar{\nu}_\mu$ flux error
- Blue line is proton beam profile and off-axis error
- INGRID beam direction measurement result is used to estimate flux error.



Event rate and beam direction using all data until April

anti-neutrino beam measurement result

Run period	T2K Run5	T2K Run6(until March)
Event rate [events/10 ¹⁴ POT]	0.562±0.001(stat.)	0.5591±0.0004(stat.)
Horizontal beam angle [mrad]	0.050±0.067(stat.)±0.357(syst.)	0.010±0.028(stat.)±0.363(syst.)
Vertical beam angle [mrad]	0.155±0.076(stat.)±0.427(syst.)	0.102±0.031(stat.)±0.423(syst.)

Conclusion

- T2K experiment succeeded in generating anti-neutrino beam
- Any shift in beam direction must be within 1 [mrad] of the nominal direction
- Measured event rate and beam profile using INGRID detector
- Beam direction systematic error is 4.08%
- INGRID detector recorded 3.63×10^{20} POT
- Event rate is 0.56 Events/10¹⁴POT
 - Rate is stable for data taking
- The shift in beam direction is within 1 [mrad] and meets the T2K physics requirements.