# Measurement of CC inclusive cross-section on Iron in a few GeV neutrino beam at the T2K

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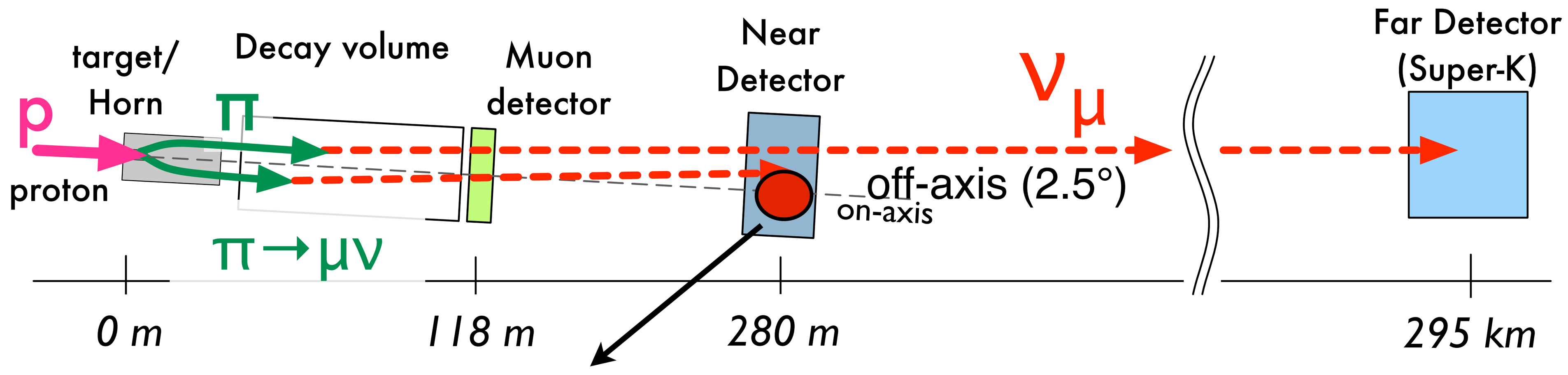
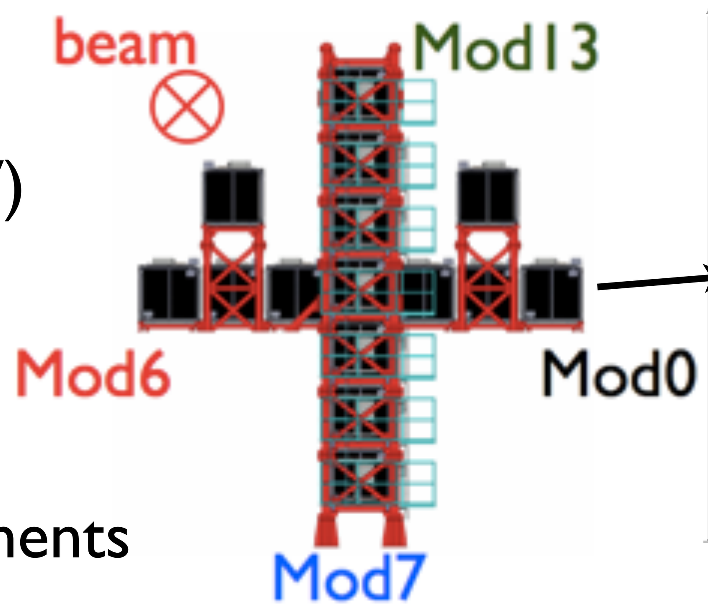
## Abstract

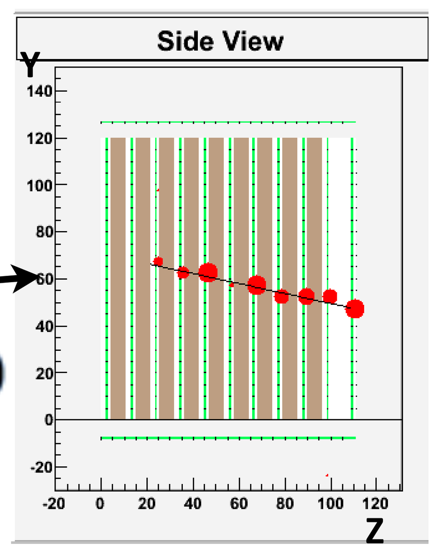
In T2K, INGRID is on-axis neutrino beam monitor which composes with 14 identical neutrino detecting modules. The method of the cross-section measurement by INGRID is to take advantage of the difference of flux at each modules. The energy spectrum of the neutrino flux at each modules is expected to be different only in the 1 GeV to 3GeV range from the simulation. By the toy MC with statistical error, the uncertainty of the cross-section in this region is found to become about 4%.

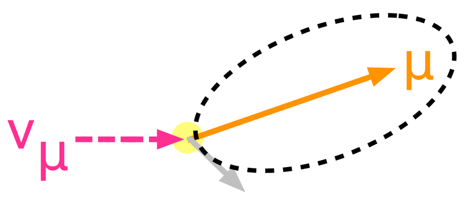

## T2K experiment, INGRID


**ν Beam Monitor : INGRID**



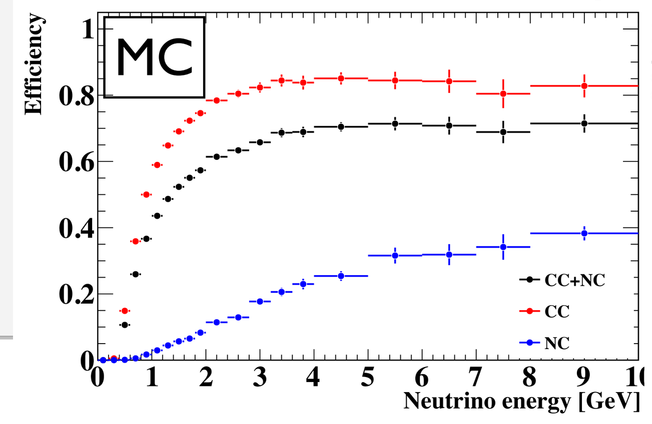



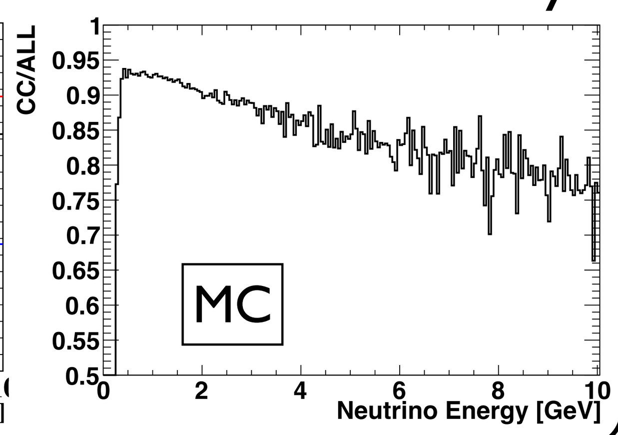

Select 1 μ-like track in FV

MC:NEUT5.0.6+GEANT4

ν Selection Efficiency




CC inclusive Purity




Feature

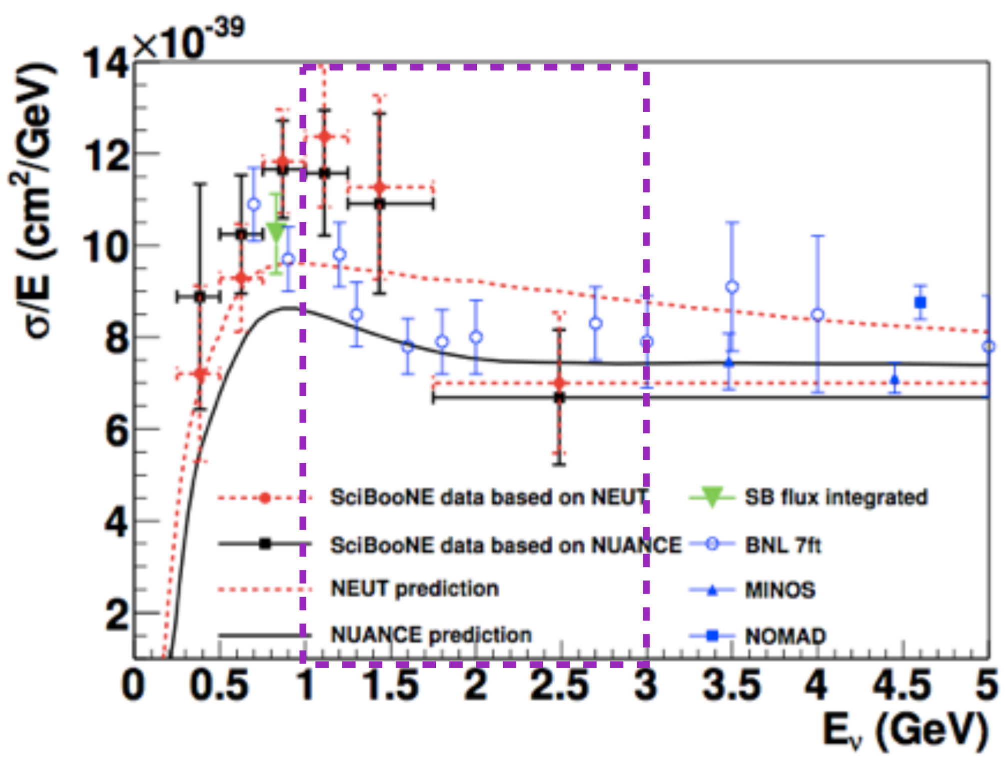
- First application of off-axis ν beam
- Highest intensity proton beam (30GeV, 750kW)

Physic Goal

- Discovery of νe appearance
- Precise measurement of νμ disappearance
- Study of many neutrino cross-section measuements

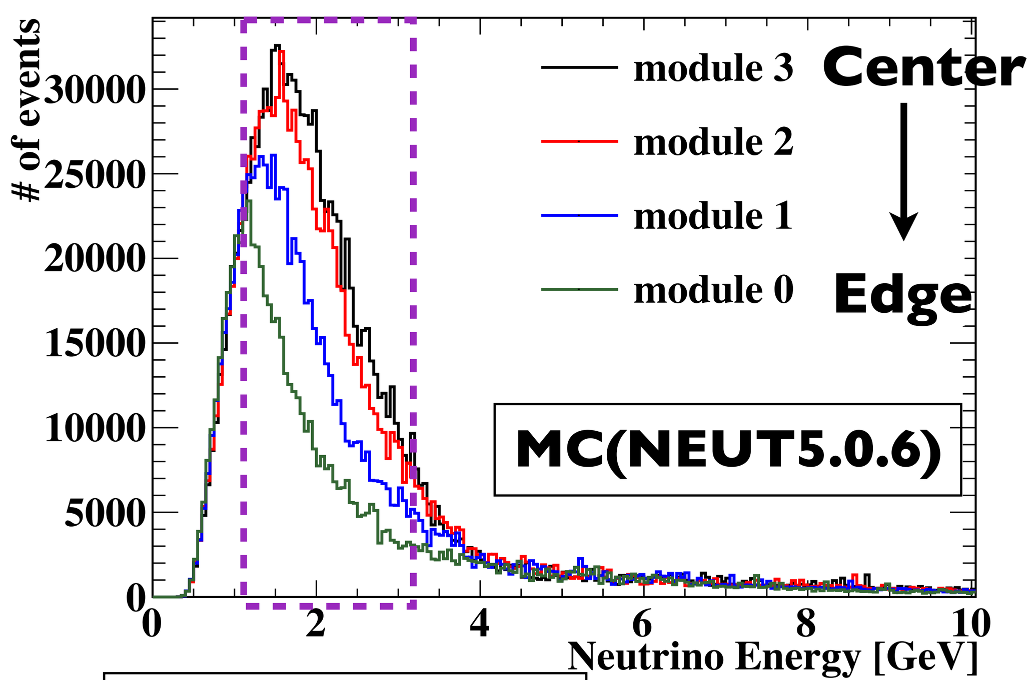
## Motivation of CC inclusive cross-section measurement at INGRID

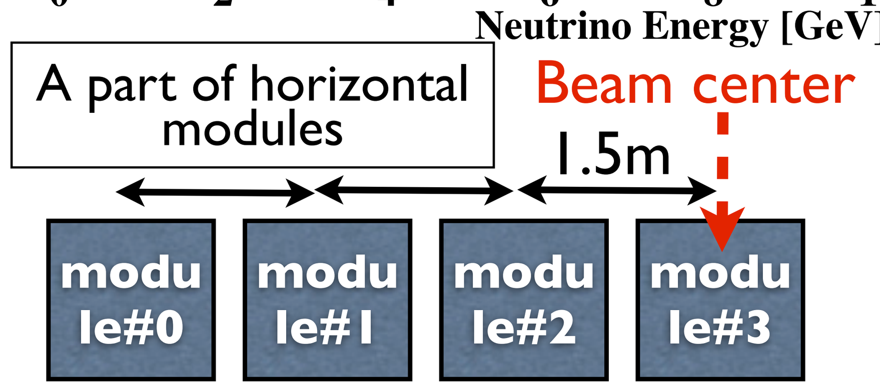
CC inclusive interaction cross sections




Discrepancy between models in 1~3 GeV region in the CC inclusive interaction cross section.

νμ Energy (after ν selection) @INGRID

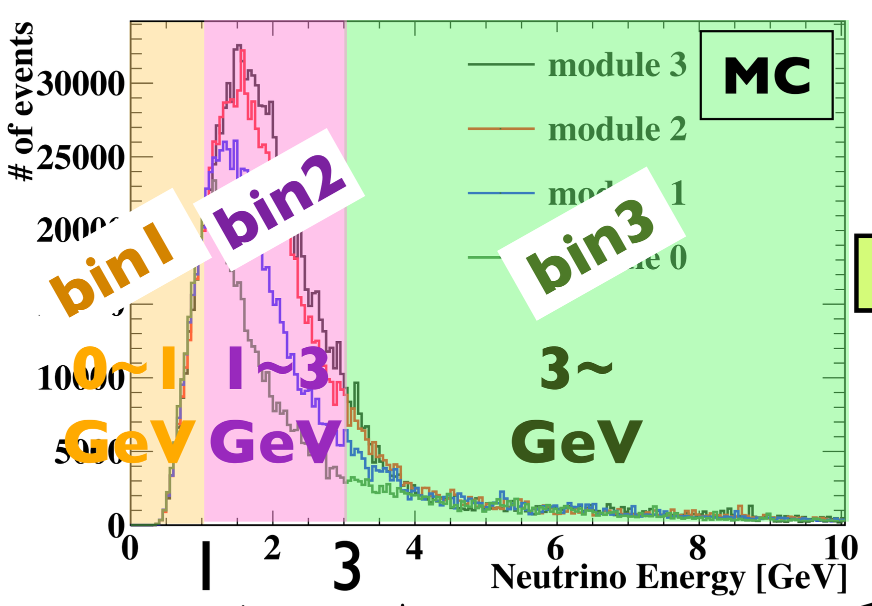


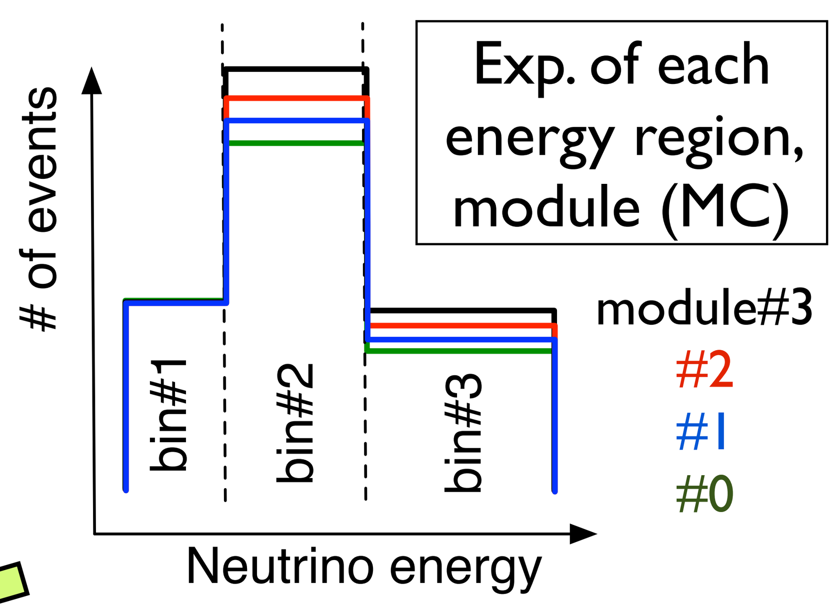




- T2K ν flux can be estimated more precisely than ν cross-section with the benefit of external hadron experiments (NA61,etc)
- ν energy distribution at INGRID is expected to be different at different modules.
  - Because each modules is set at different off-axis angle.
- Flux at each module is almost same for Enu<1GeV and Enu>4GeV, but different at 1<Enu<4GeV

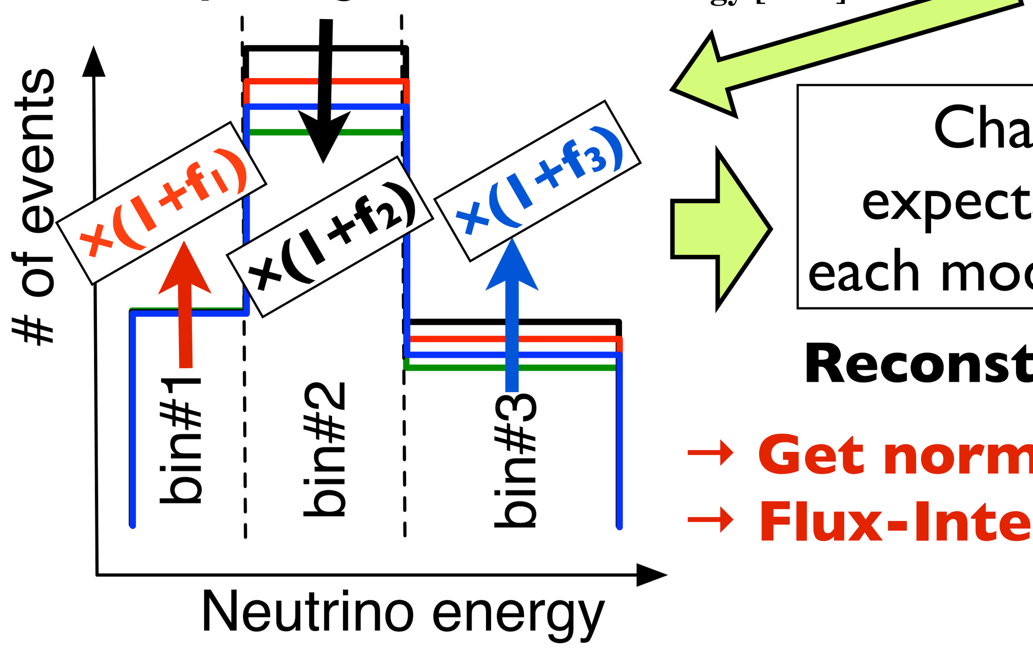
Measure the flux-integrated CC inclusive neutrino x-section at **1~3GeV** by using the flux difference among modules.

## Method of Cross-section Measurement by INGRID




Exp. of each energy region, module (MC)




Changed expectation of each module (MC) ⇔ Observation of each module (DATA)

**Reconstruct DATA with varied MC**

**→ Get norm. parameter of bin#2(f2)**

**→ Flux-Integrated cross-section in bin#2**

ν cross-section in Iron Calculation

$$\sigma^{CC}_{Fe}(bin\#i) = \text{Fit par. }(\#i) \times \frac{\text{MC exp. }(\#i) \times \text{CC purity }(\#i)}{\text{Flux}(\#i) \times \epsilon(\#i) \times \text{\# of target nucleon}}$$

→Fitting error

→Estimate error with MC,DATA

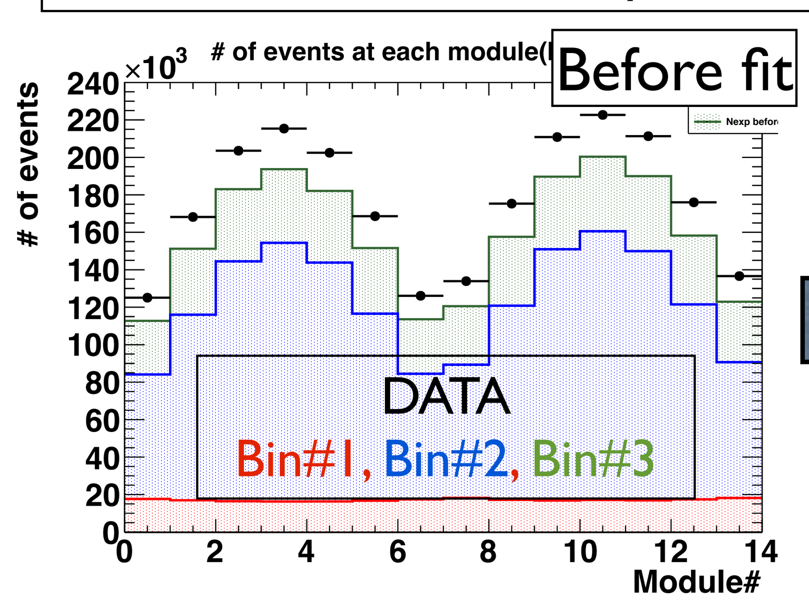
Fitting Demonstration by using toy MC

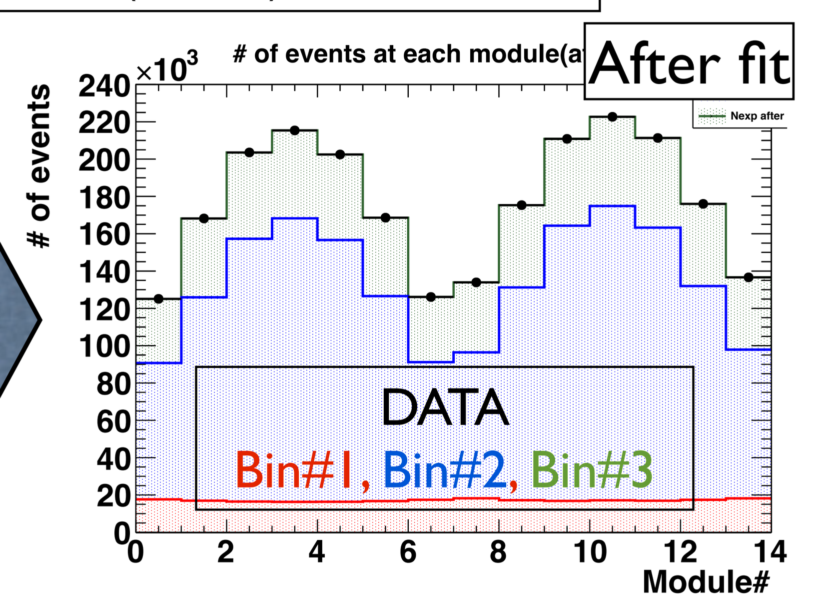
$$\chi^2 = \sum_m^{module} log(N_m^{MC}) + \frac{(N_m^{DATA}-N_m^{MC})^2}{N_m^{MC}} + \left(\frac{f_{det}}{\sigma_{det}}\right)^2$$

**stat. term** **syst. term**

$$N_m^{MC} = (1+f_{det})\sum_i^{E_{bin}} \int_i \phi_m(E)(1+f_i)\sigma(E)\epsilon(E)dE$$

$f_i$ = parameters of normalization (1+fi>0)
$f_{det}$ = nuisance parameter of common detector systematic error
$\sigma_{det}$ = common detector systematic error (~3.7%)




| | Input Toy | Fit center | Fit error |
|---|---|---|---|
| Bin#1 | x 1.0 | 1.000 | ±0.14 |
| Bin#2 | x 1.1 | 1.100 | +0.047/-0.044 |
| Bin#3 | x 1.2 | 1.200 | ±0.13 |

**Fitting OK → Consider other syst. error for fitting**