# INGRID beam monitoring

# Contents

- Problem : double-count of noise effect on Data and MC
- Problem : neutrino event loss due to pileup

# Double count of noise effect

## Process for MC

Generate Detector MC w/o BG and noise hits

↓

Add noise hits on MC

↓

Neutrino event selection

↓

**# of expectation**

## Process for Data

Neutrino event selection

↓

Correct Iron mass diff.

Correct event loss due to noise hits (by MC)

Remove BG remaining contamination

↓

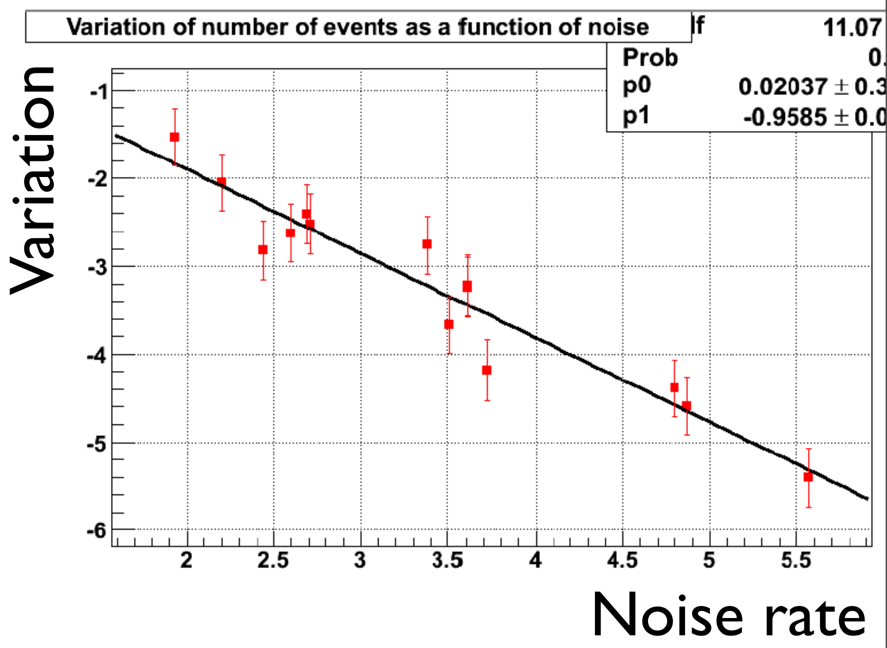
**# of observation**

**# of expectation** ⟷ **# of observation**

Noise treatment inconsistent b/w Data and MC

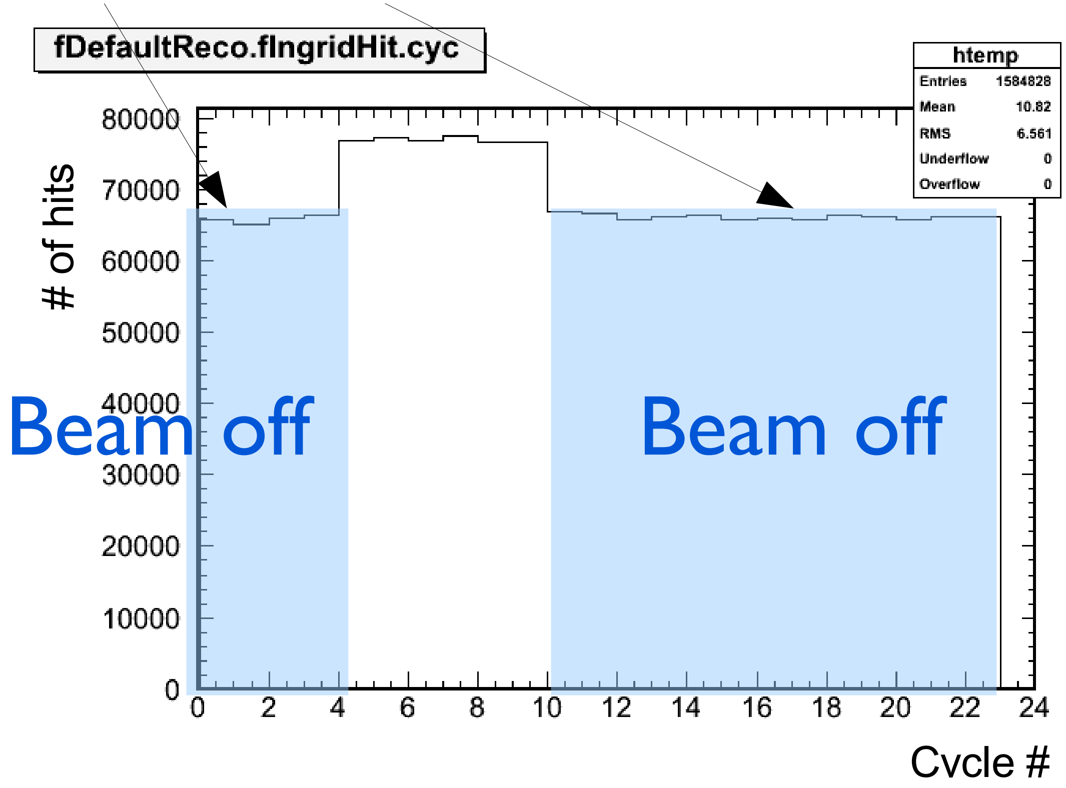
# Noise correction for MC

1. Measure some noise properties in no beam period
2. Reproduce the noise properties by MC
3. Calculate variation of MC # of expectation between w/ noise and w/o noise each module
    1. Get the correlation b/w variation of MC expectation vs. noise rate
4. Calculate the correction factors for MC expectation from the result of fitting.
5. Calculate noise rate (currently every MR Run) and do correction



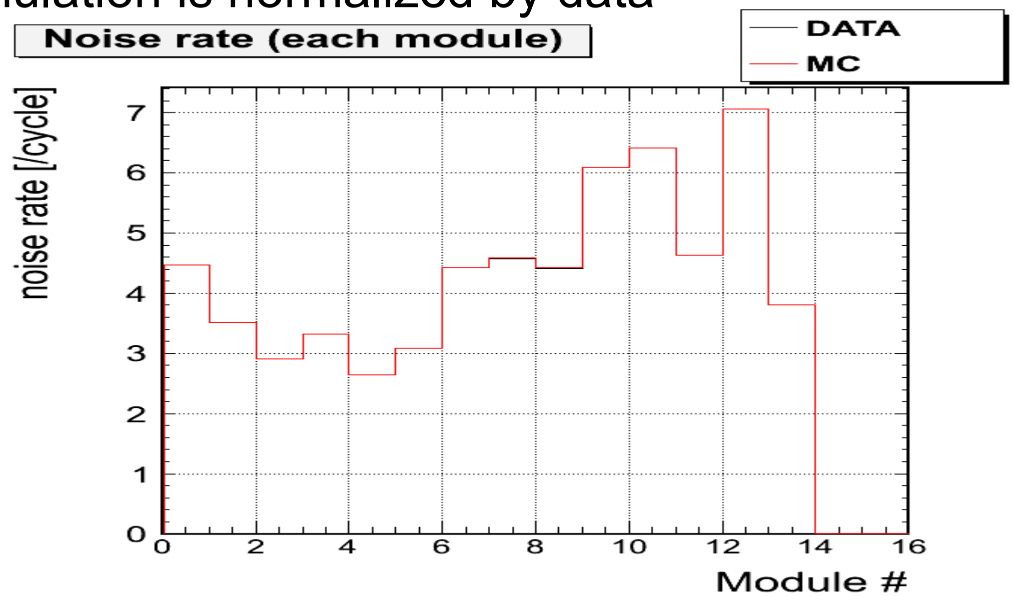
# MPPC noise properties

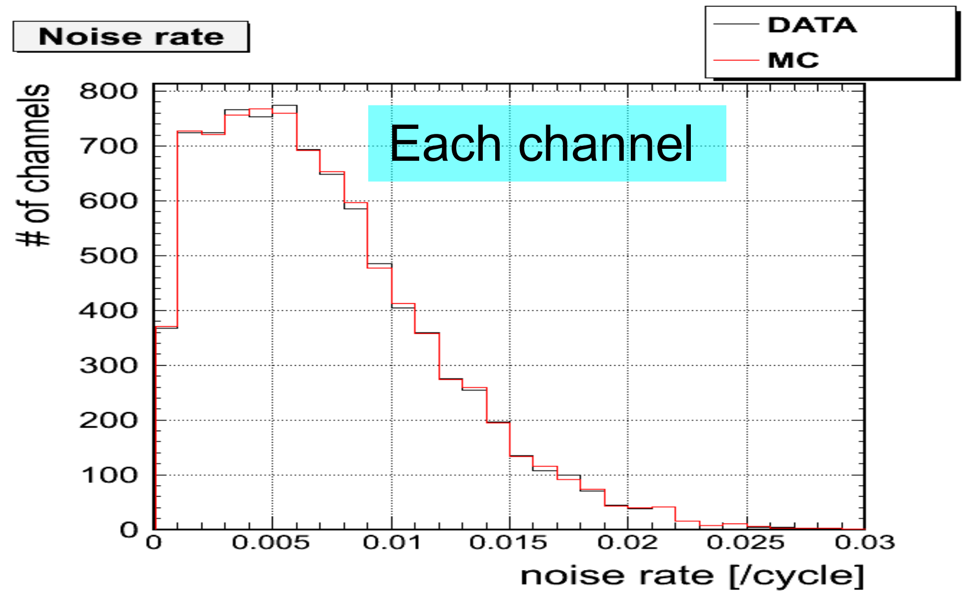
- Noise
  - is hits on beam off cycles
  - is hits on cycles which have no time cluster events
- Measured noise property
  - Noise rate / cycle for each channel
  - Light yield (LY) and TDC distribution of each module
- Reproduce these noise property by MC

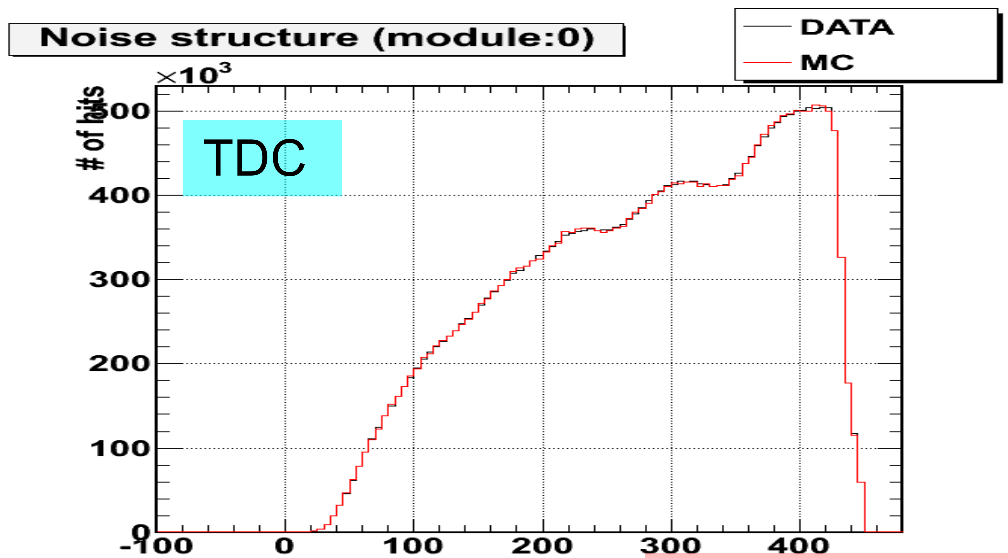


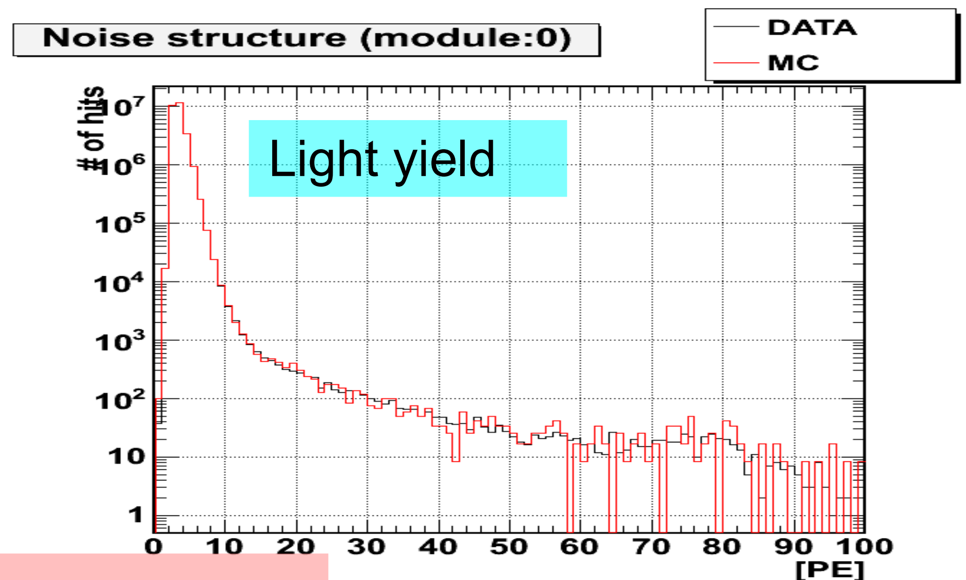
# Comparison between data and simulation（Run33）

*simulation is normalized by data



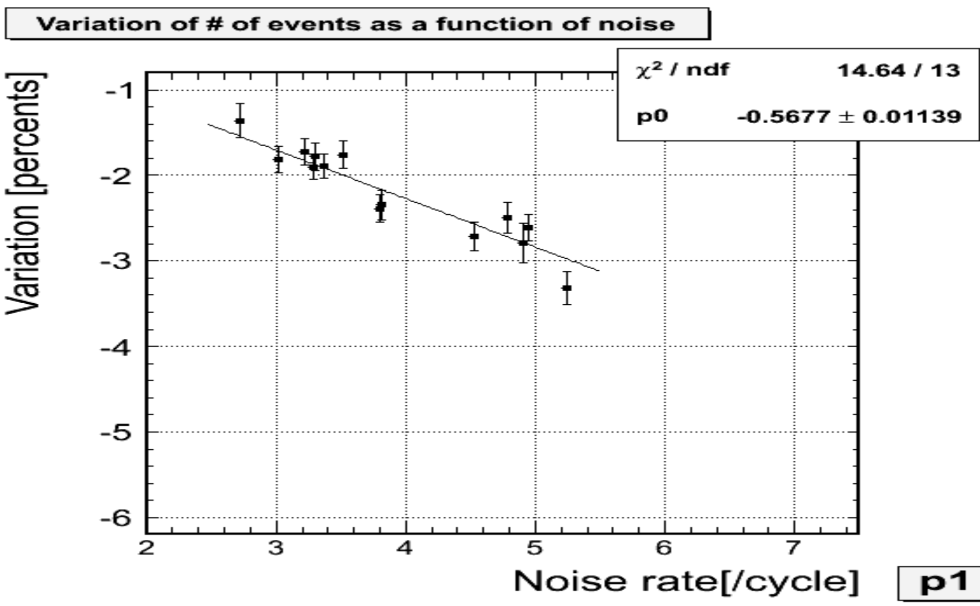



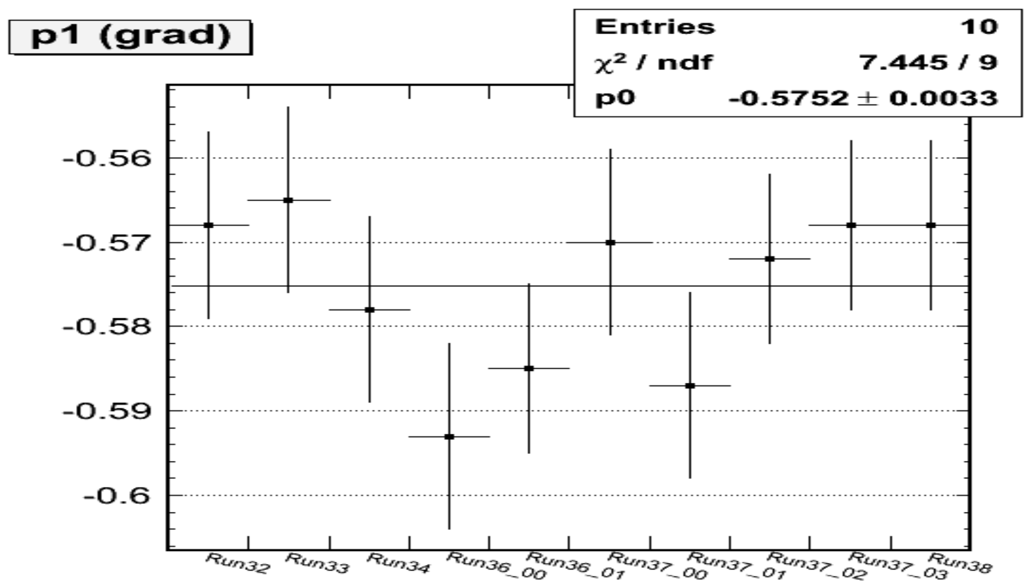

Good agreement

# Variation of MC expectation from noise

- Appropriate neutrino event selection for MC w/ and w/o noise MC and calculate variation b/w two.




| | All planes |
|---|---|
| | p1 |
| Run32 | -0.568 +/- 0.011 |
| Run33 | -0.565 +/- 0.011 |
| Run34 | -0.578 +/- 0.011 |
| Run36_00 | -0.593 +/- 0.011 |
| Run36_01 | -0.585 +/- 0.010 |
| Run37_00 | -0.570 +/- 0.011 |
| Run37_01 | -0.587 +/- 0.011 |
| Run37_02 | -0.572 +/- 0.010 |
| Run37_03 | -0.568 +/- 0.010 |
| Run38 | -0.568 +/- 0.010 |

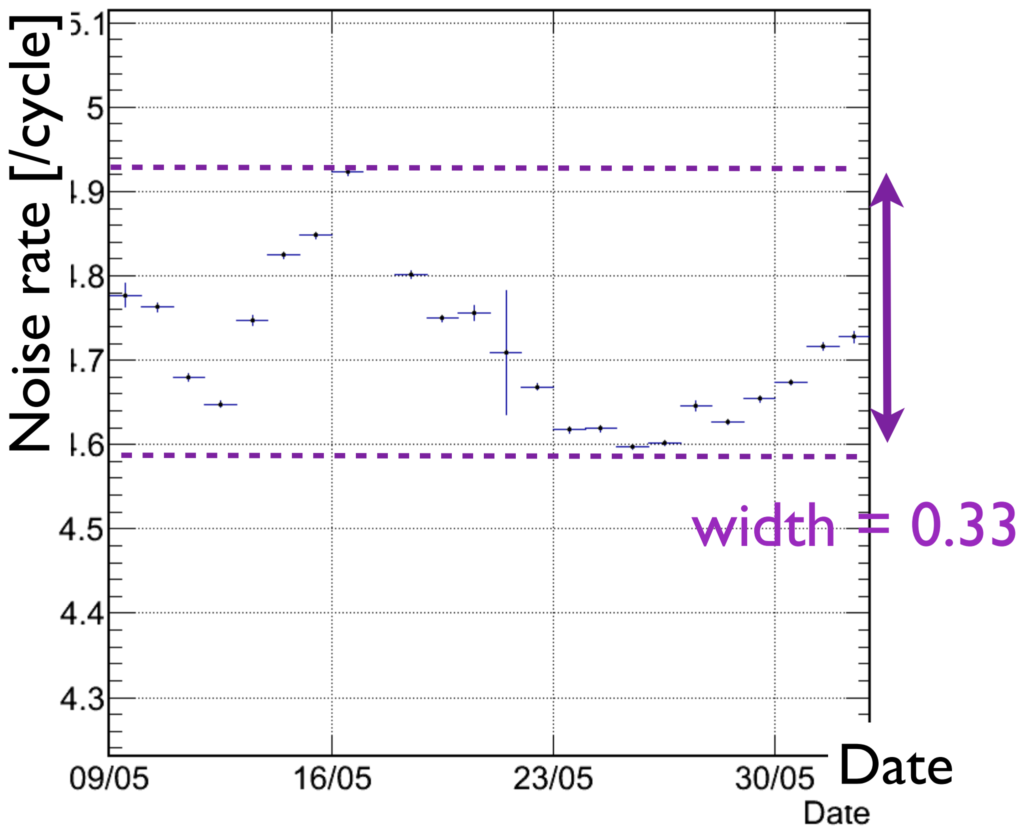



Calc. correction factor by this result

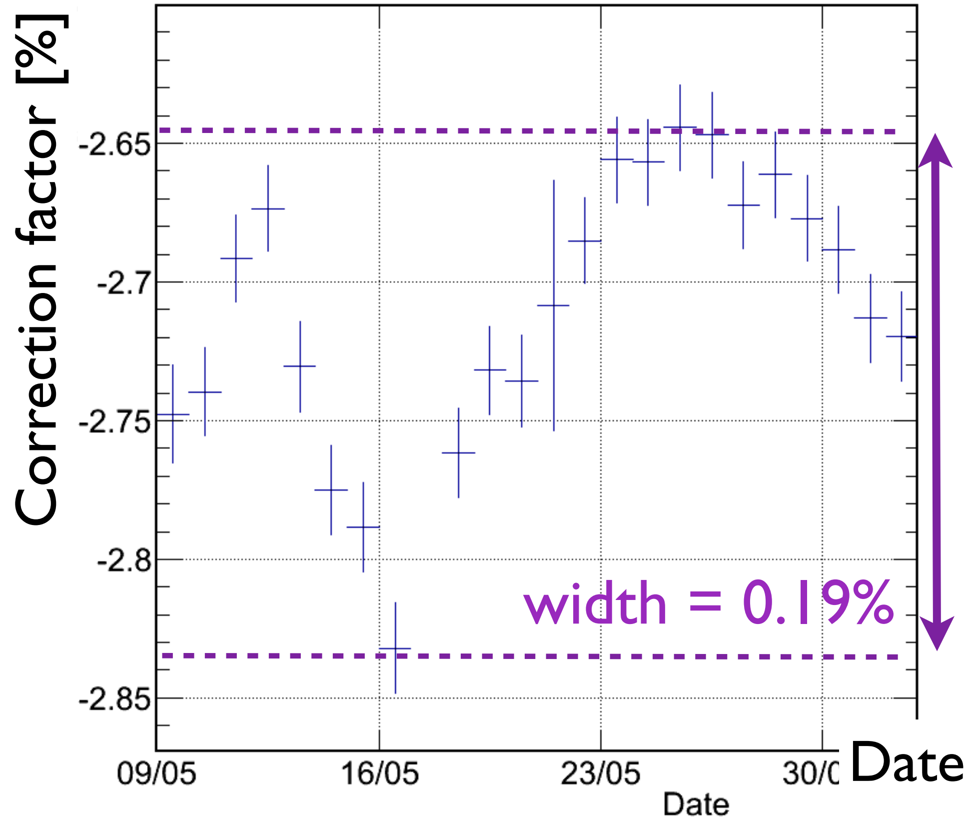
# Correction factor

Calc. noise correction factor every day (ex. MR Run33)

Noise rate of module#0




Correction factor for module#0

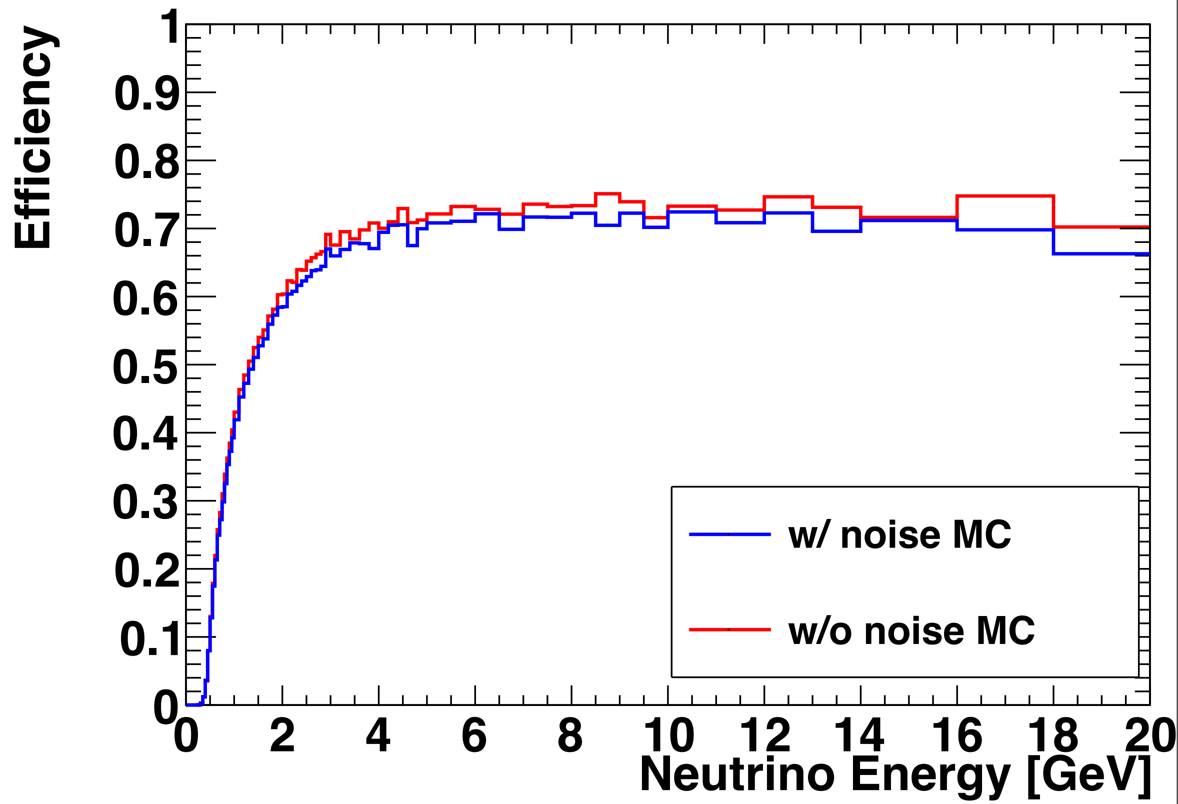



Fluctuation is small → Estimate correction factor every MR Run

# MC expectation w/o noise

- Again, generate INGRID Standard MC just w/o used noise MC
  - Currently, only for numu neutrino.
- Small difference of selection efficiency b/w w/ and w/o noise MC

Neutrino selection efficiency of νμ in FV (CC+NC)



# Difference of MC expectation

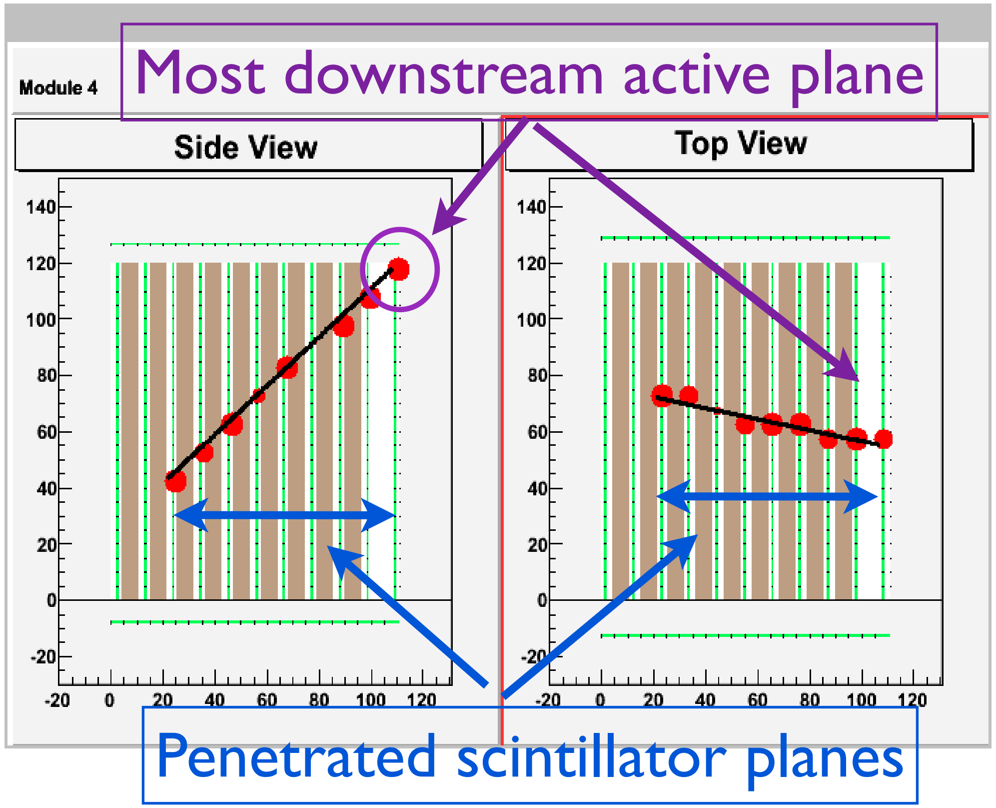
Expected # of events in 14 standard modules
(include **only numu**)

| unit:[/$10^{21}$POT] | Nexp (w/ noise MC) | Nexp (w/o noise MC) | (w/o noise) / (w/ noise) |
|---|---|---|---|
| 10d-v2 (Run I proton beam.) | **1.427E+07** | **1.467E+07** | **1.028** |
| 10d-v3.1 (Run I&II proton beam) | **1.464E+07** | **1.506E+07** | **1.028** |
| 11a-v2 | **1.504E+07** | **1.546E+07** | **1.028** |

**MC expectation (for numu) increase by 2.8%**
Also check this effect on numu-bar by generating MC w/o noise MC.

# Pileup problem

- At current INGRID tracking, select only one track at more than two tracks in same module in same bunch.
    - Track selection is depend on the most downstream plane# (MD#) and penetrated tracking planes (=track length)
        - Select the track with larger MD# and longer length

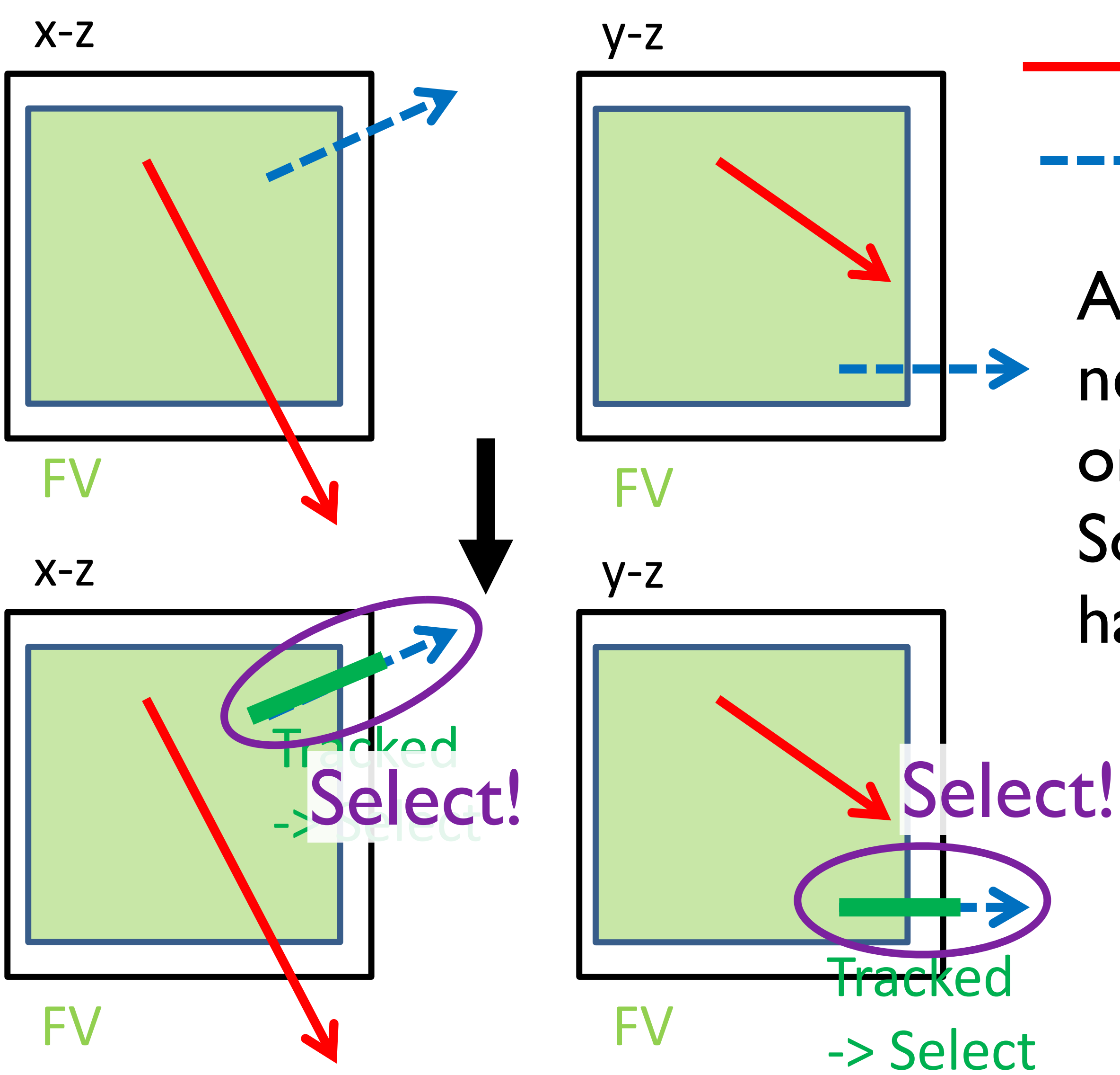



- At high power beam, possible to miss track of neutrino event → neutrino event lost (pileup problem) → Want to estimate the effect

Label for each event case

- NuFV = Remain after FV cut = neutrino event candidate
- NuOV = Reject w/ FV cut
- BG = Reject w/ Upstream VETO cut

# Pileup-1 : NuFV & NuFV




Track (NuFV)

Track (NuFV)

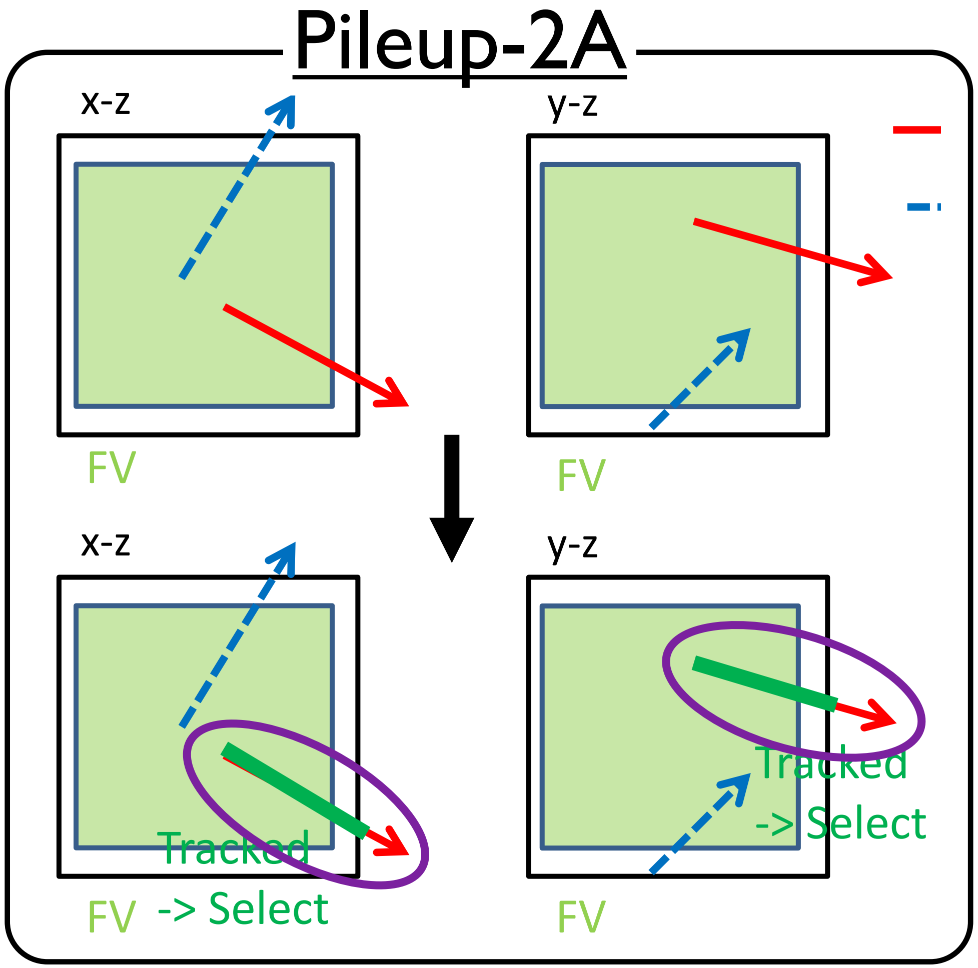
At current MC, generate neutrino events one-by-one.
So event pileup always not happen.

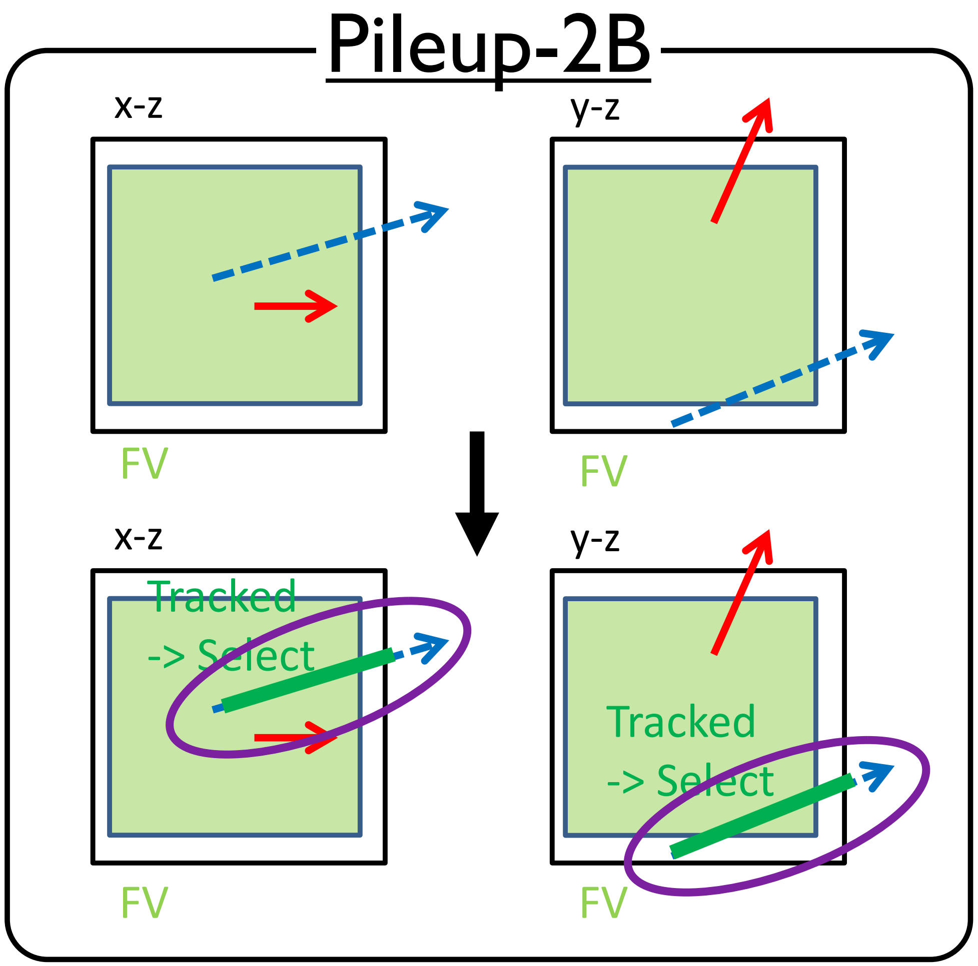
Data : 1 events
MC : 2 events

→ 1 event loss

# Pileup-2 : NuFV & NuOV

Track (NuFV)
Track (NuOV)




Data : 1 events
MC : 1 events

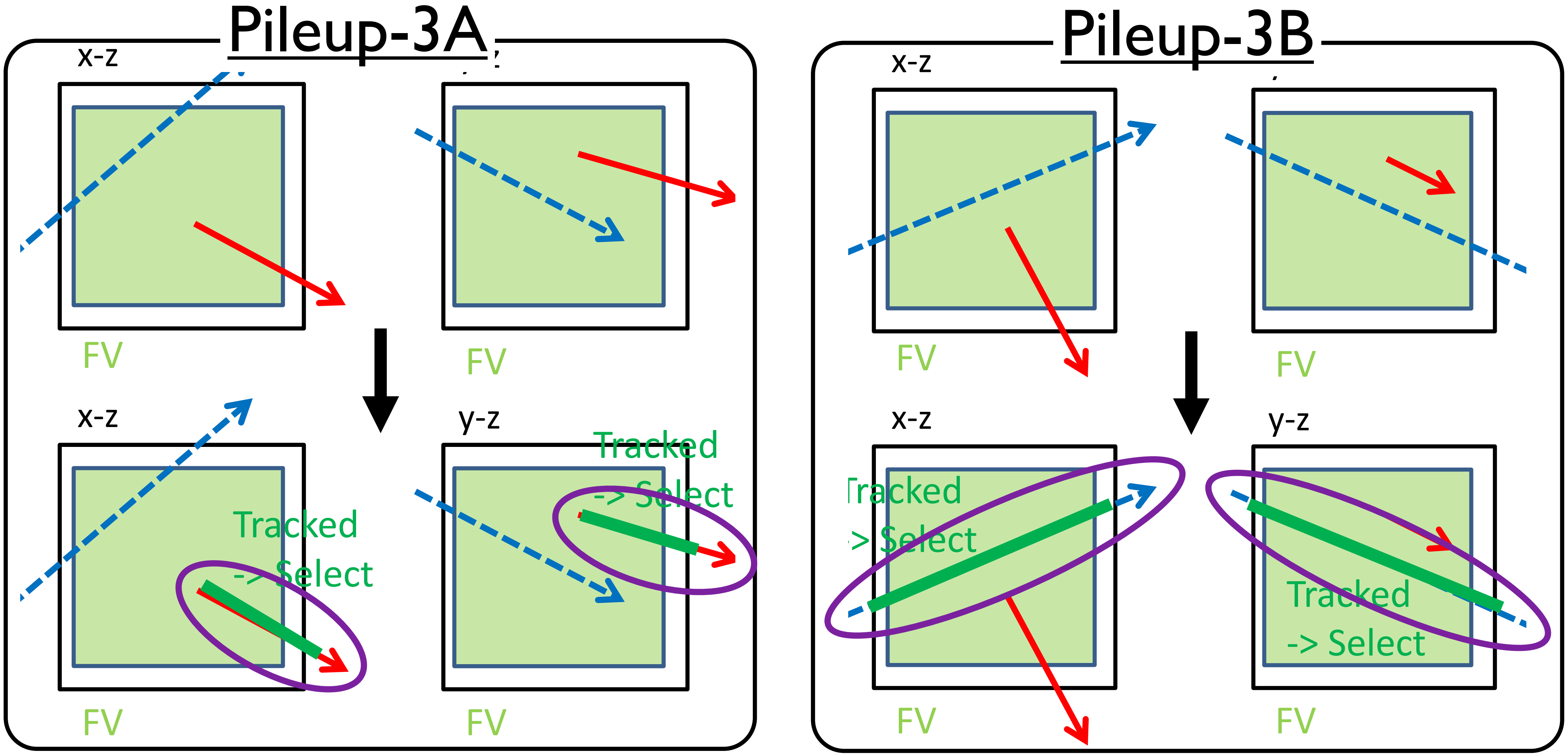
No loss

Data : 0 events
MC : 1 events

1 event loss

# Pileup-3 : NuFV & BG

Track (NuFV)
Track (BG)




Data : 1events
MC : 1 events

No loss

Data : 0 events
MC : 1 events

1 event loss

# Probability of Pileup event loss

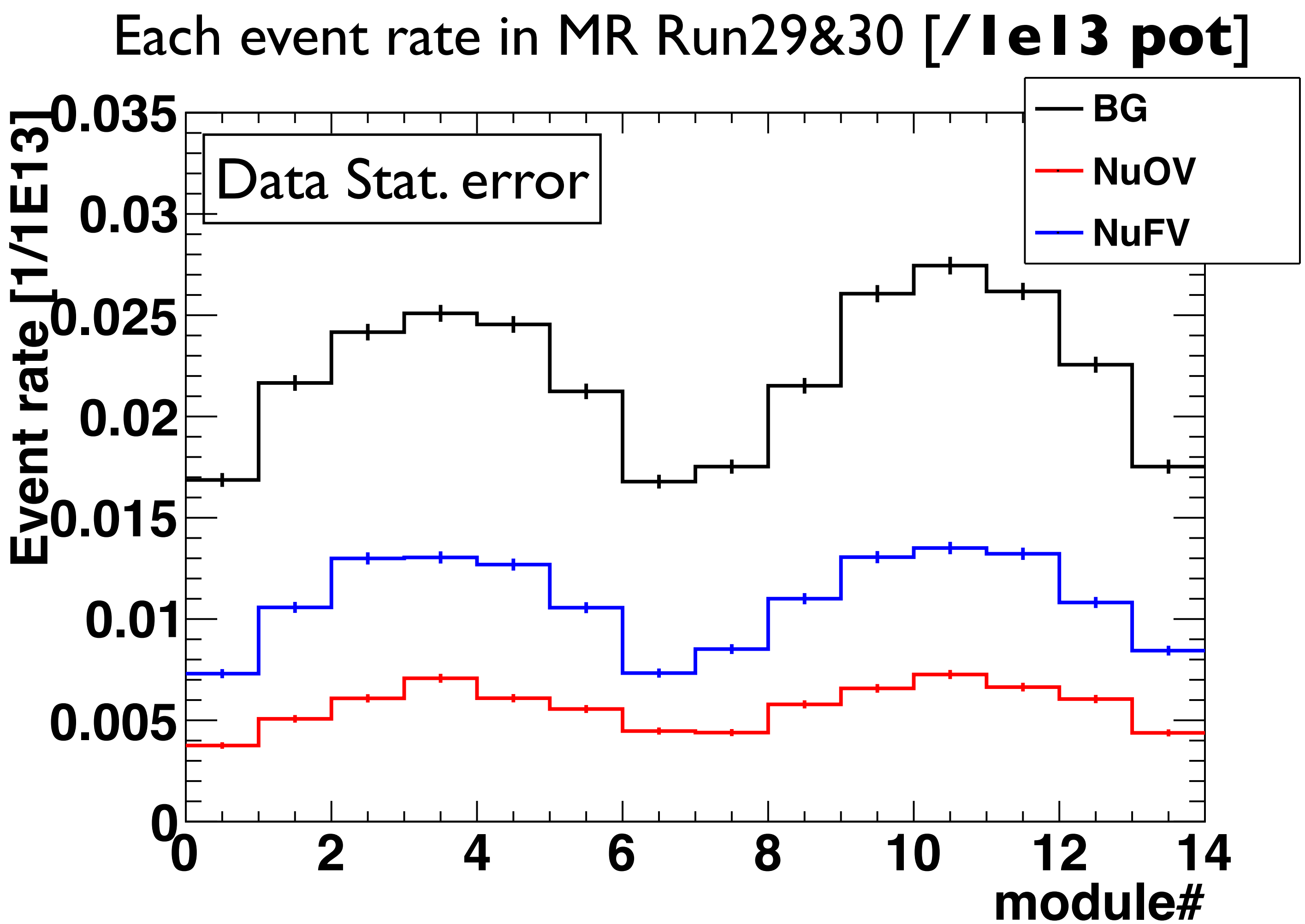
Rate of event loss due to Pileup when 1 NuFV happen
= Rate(pileup-1) + Rate(pileup-2B) + Rate(pileup-3B)

**Conditional Probability of event loss**
= Event loss rate / NuFV rate
= Rate(NuFV) + Rate(NuOV) x Prob(pileup-2B) + Rate(BG) x Prob(pileup-3B) [ppb]

→ Each event rates estimated from data.
→ Probability of whether 2A or 2B is selected in Pileup-2. (also for Pileup-3) estimated by toy MC with PDF from data.

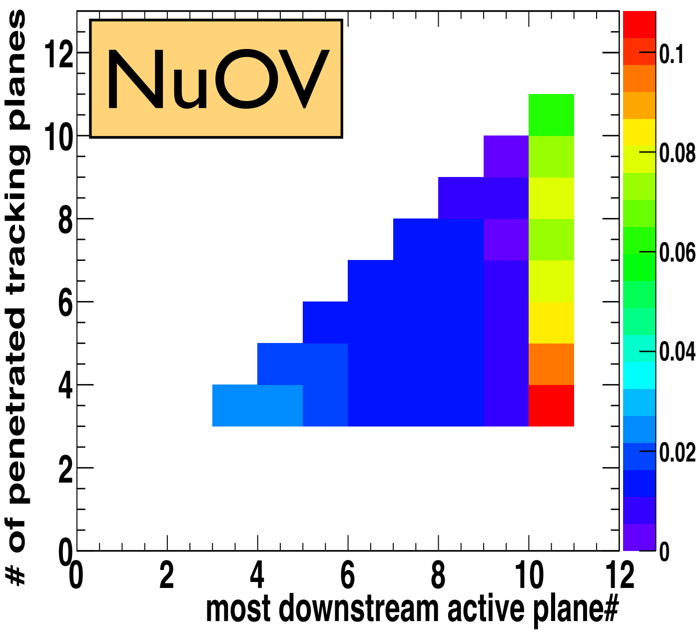
# Each event rate (Data)

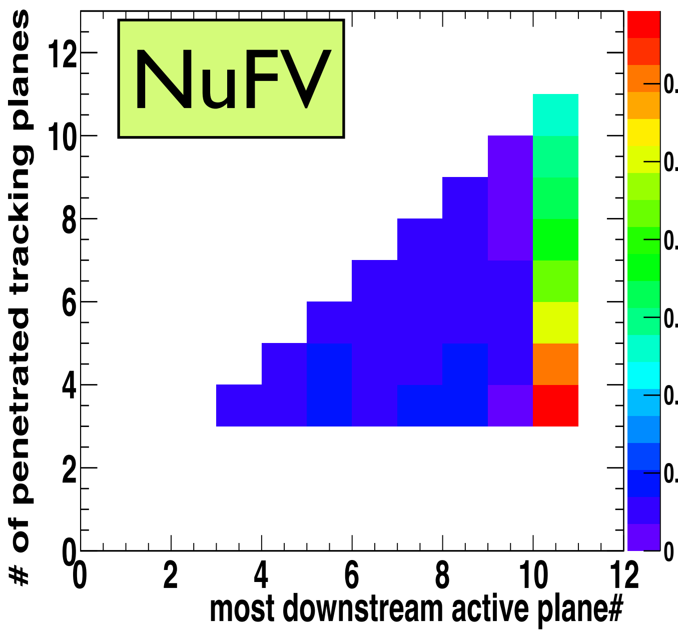
- Use data in MR Run29-30 to estimate each event rates
- Low beam power (~2e12 ppb)

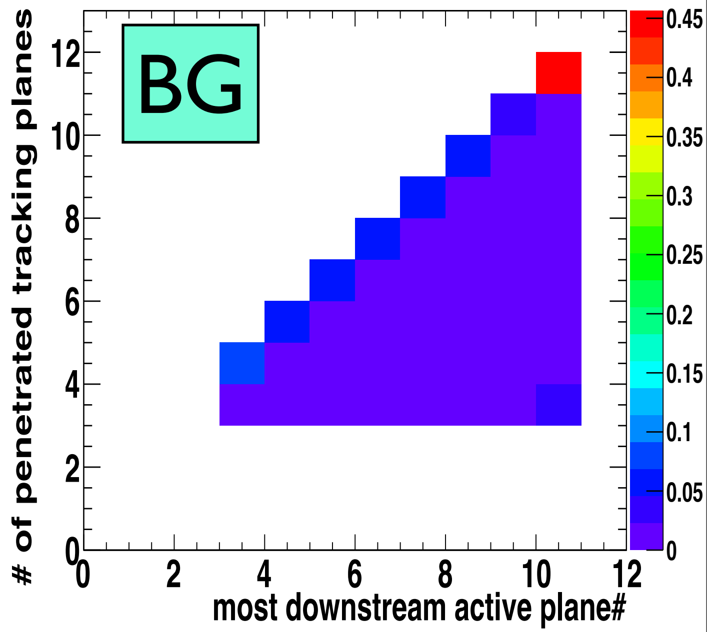


# Toy MC

Most dow <u>PDF of most downstream plane# vs track length (MR Run29-30)</u>




MD#, Track length ↔ MD#, Track length ↔ MD#, Track length

Compare
→ Count as 2A or 2B

Compare
→ Count as 2A or 2B

Make 1e6 toys → Calc. prob. of which event selected.

# Result of $10^6$ toy MC

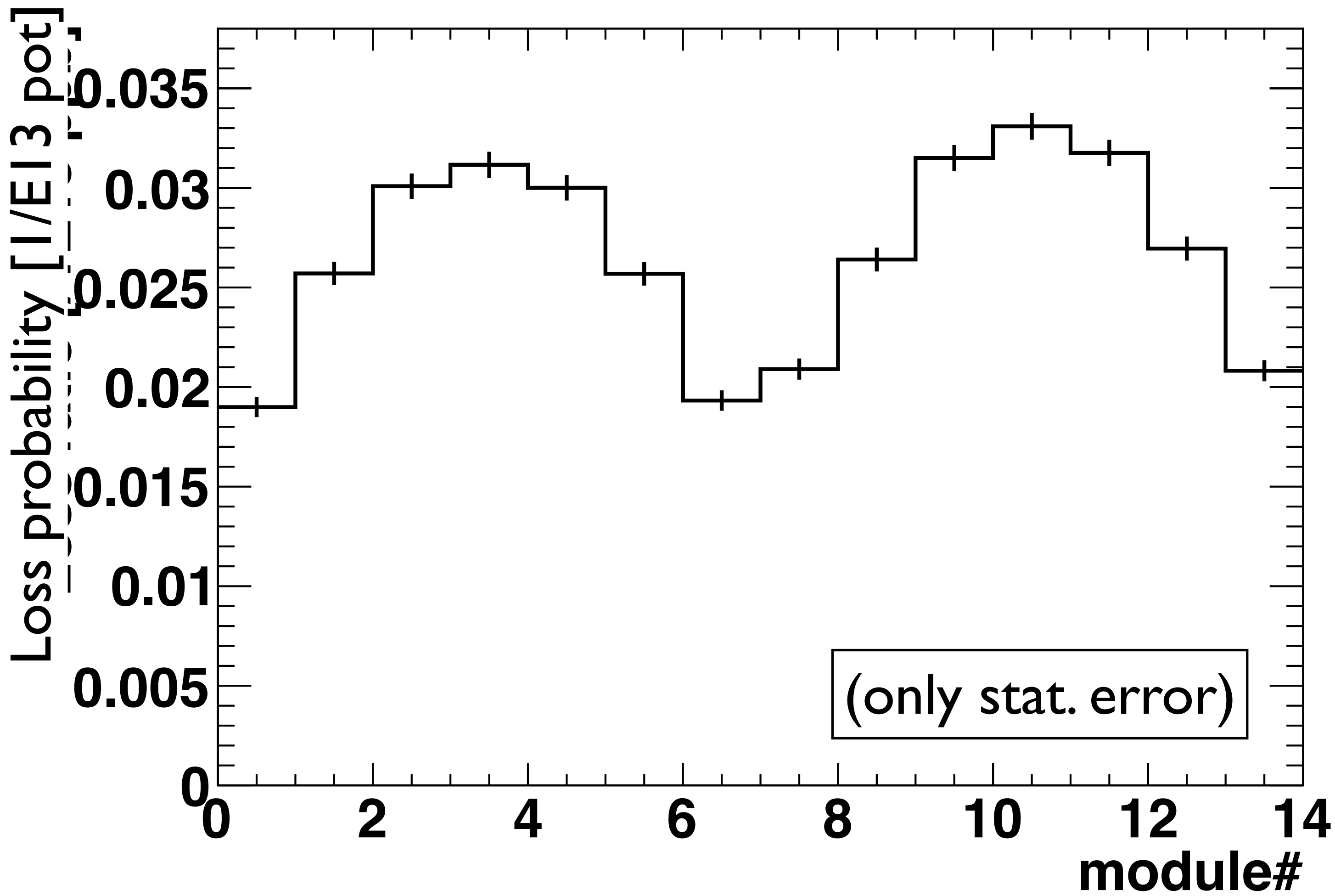
| Pileup 2 (NuFV & NuOV) | Probability |
| --- | --- |
| 2A (No loss) | 0.4758 |
| 2B (1event loss) | 0.4605 |
| Same MD# and Track length | 0.0637 |

| Pileup 3 (NuFV & BG) | Probability |
| --- | --- |
| 3A (No loss) | 0.4107 |
| 3B (1event loss) | 0.5773 |
| Same MD# and Track length | 0.0120 |

- Probability of "same MD# and track length" added on Prob-A and Prob-B fifty-fifty at this time.

# Event loss probability at each module

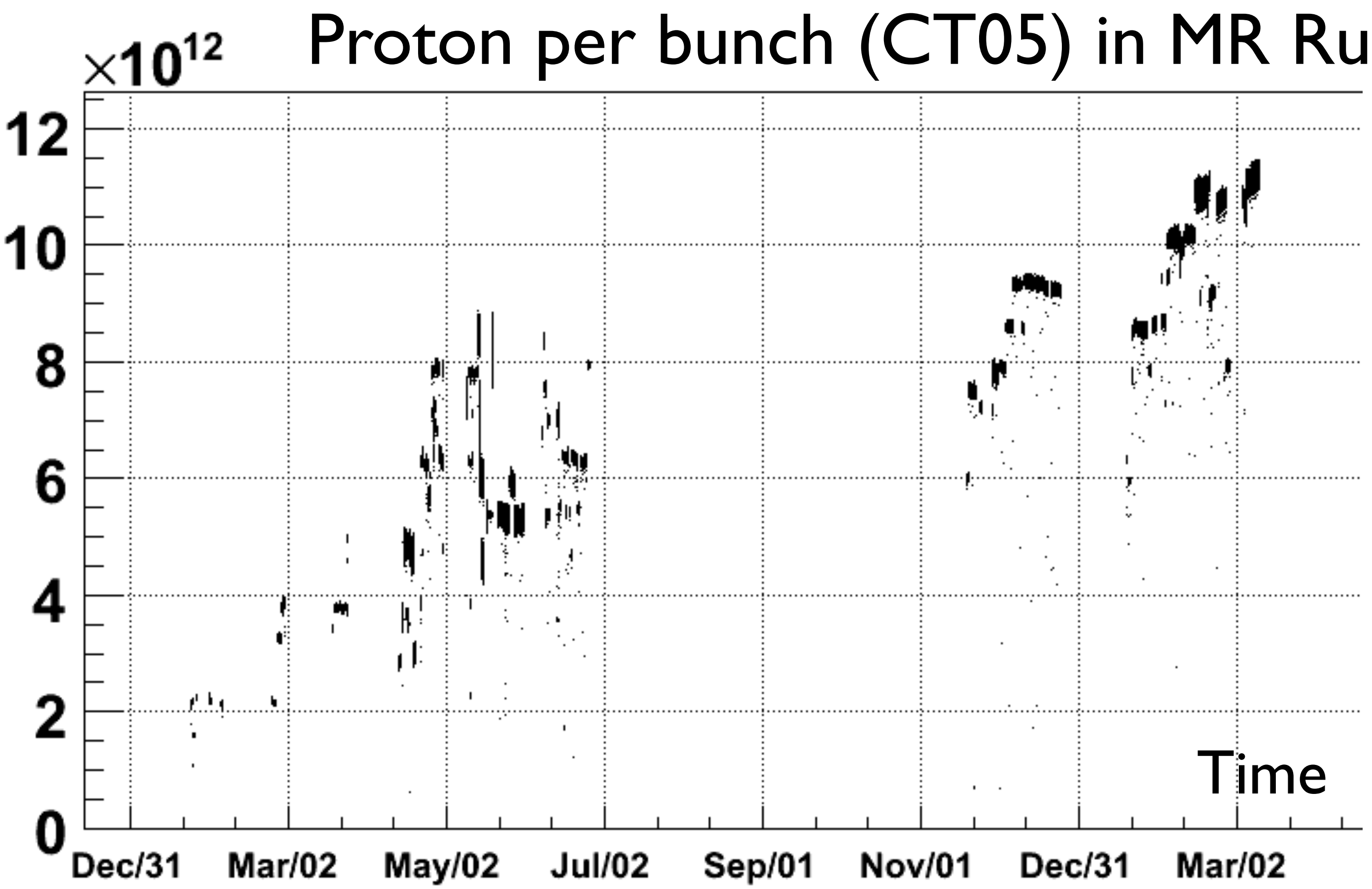
Probability of event loss when neutrino observed




Fractional Stat. error: 2~3%

Event loss probability: 2~3% [/1E13 pot]

# History of protons/bunch



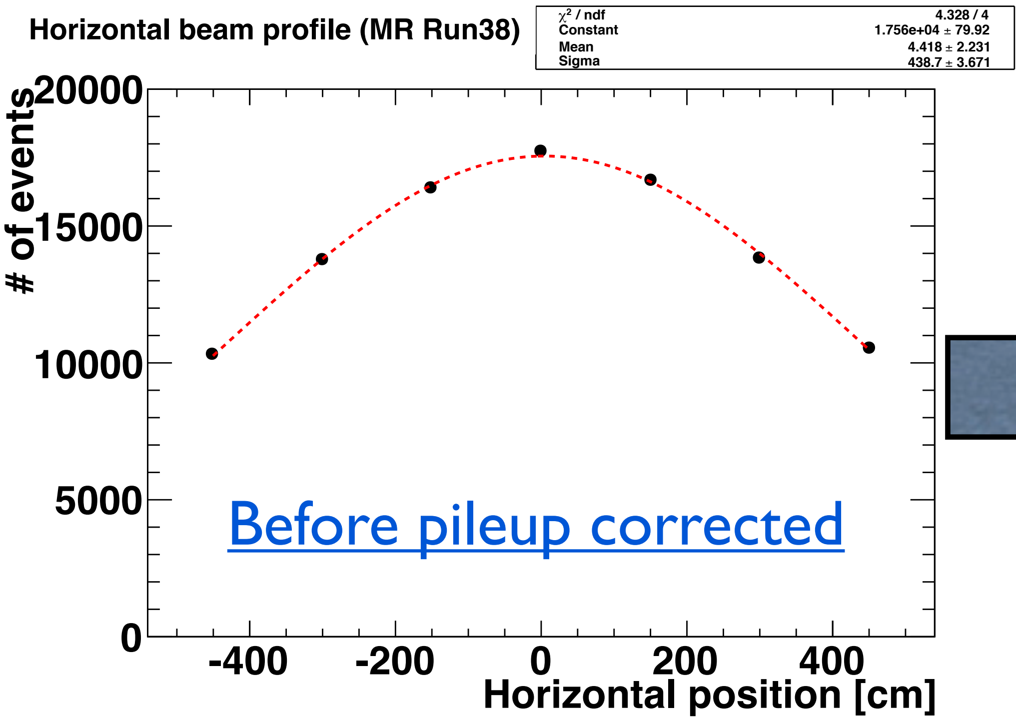

| MR Run | Avg. ppb |
|---|---|
| 29-30 | 2.57E+12 |
| 31 | 3.77E+12 |
| 32 | 5.30E+12 |
| 33 | 5.72E+12 |
| 34 | 6.22E+12 |
| 36 | 8.66E+12 |
| 37 | 9.57E+12 |
| 38 | 1.10E+13 |

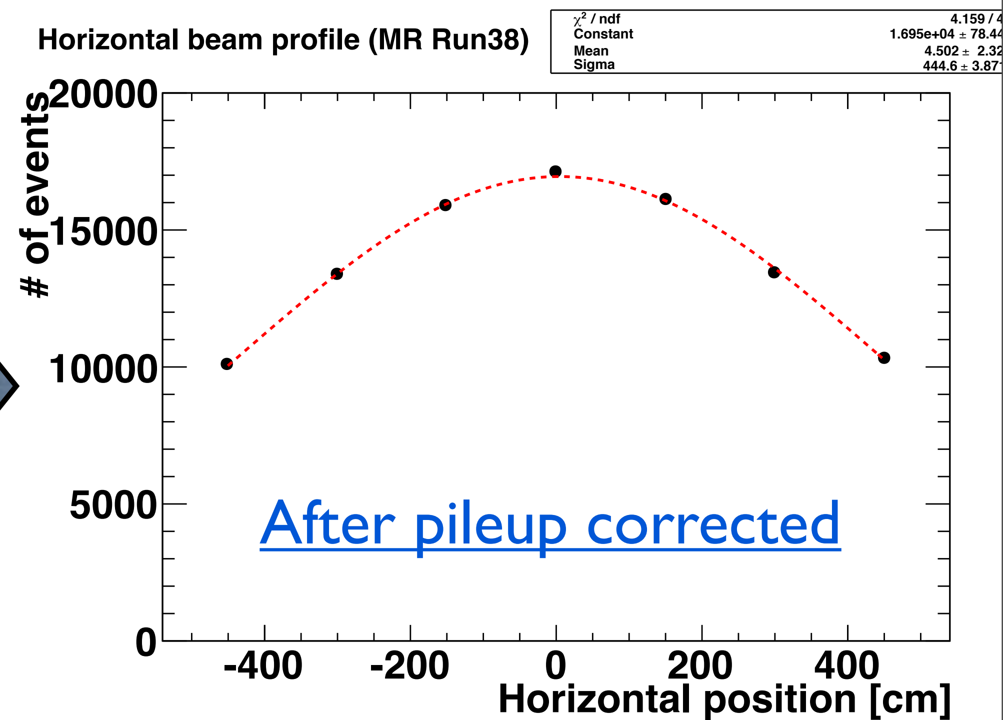
Average pileup probability at module#10 (assume pileup prob. increase linearly to ppb)

- MR Run29-30 : 0.85%
- MR Run38 : 3.6%

# Effect on beam profile

Ex) check the horizontal beam profile width in MR Run38




Center =4.5 ± 2.3
Width = 445 ± 4 cm

Center =4.4 ± 2.2
Width = 439 ± 4 cm

→ Width decrease by 1.4%

# Summary

- Check pileup effect by using the low intensity beam data and toy MC
- Probability of event loss due to pileup = 3.3% [/1e13 pot] (module#10)
- In March 2011, beam power reach to145kW ~ 1.1e13 ppb
  - 3.6% event loss (assume linearity of pileup loss to ppb) → Not negligible.
- Plan to estimate the correction factor spill-by-spill for observed neutrino event by using this results
- For details, Kikawa-san estimate this pile-up effect bunch-by-bunch by using Detector MC