PMT only analysis by MEG LXe detector
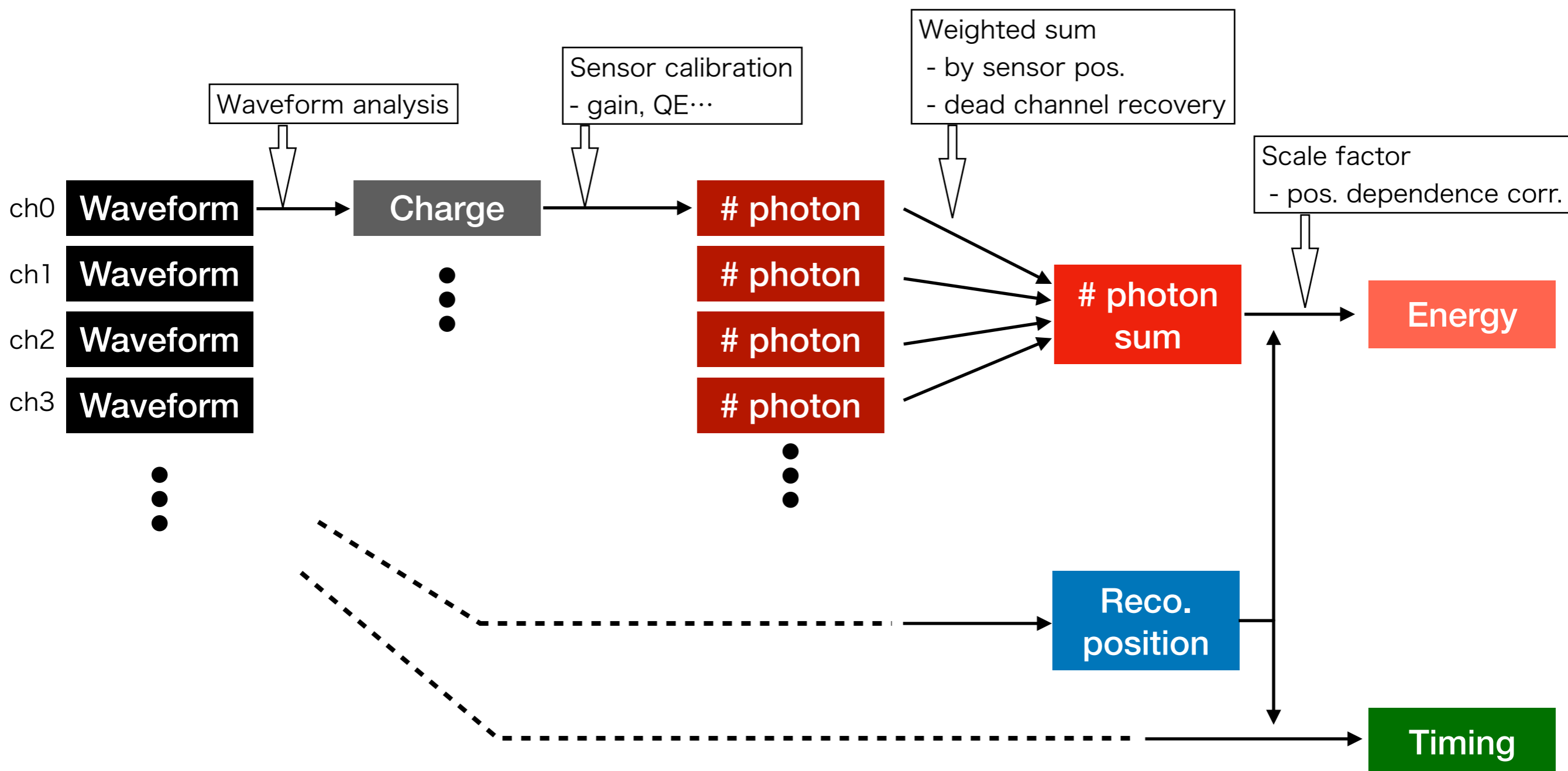
Note :

This study is very early stage…, the result is preliminary
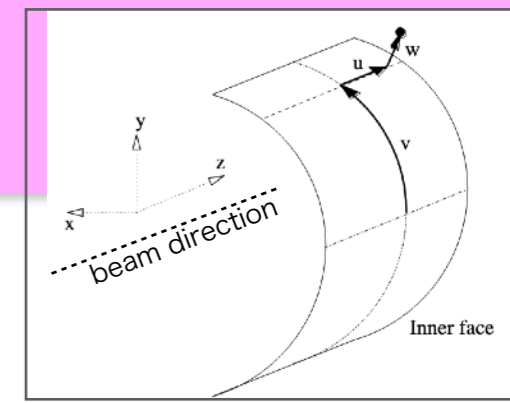
We'll study more based on this study

Sei Ban, 21st Jun. 2024

# Analysis schematic of the LXe detector

- Schematic of Analysis of the LXe detector
  - Finally, energy, position and timing of gamma-ray event are reconstructed
  - Pileup gamma-ray rejection is also applied in the LXe analysis

Weighted sum
 - by sensor pos.
 - dead channel recovery

Sensor calibration
- gain, QE···

Waveform analysis

Scale factor
 - pos. dependence corr.

ch0	Waveform	Charge	# photon	# photon sum	Energy
ch1	Waveform		# photon		
ch2	Waveform		# photon		
ch3	Waveform		# photon		

Reco. position

Timing

Energy Calibration using 17.6 MeV Gamma

- Non-uniformity correction
    - using 17.6 MeV gamma-ray events to obtain correction table for non-uniformity during run time
    - First, the correction factor for 1-D (for u, v, w each) is calculated
    - Then, 2-D correction table (u,v plane) is calculated
    - Finally further correction for depth is applied with 3x8 uv sections
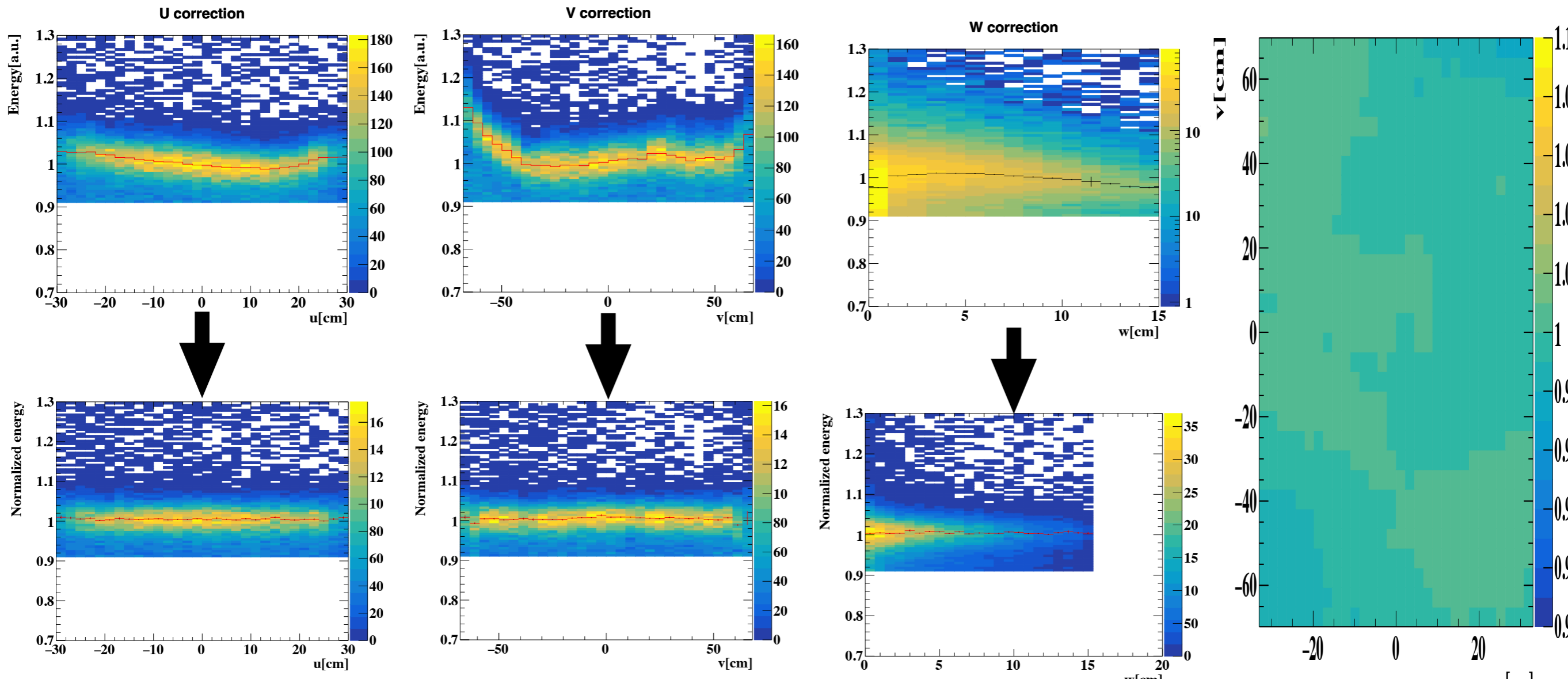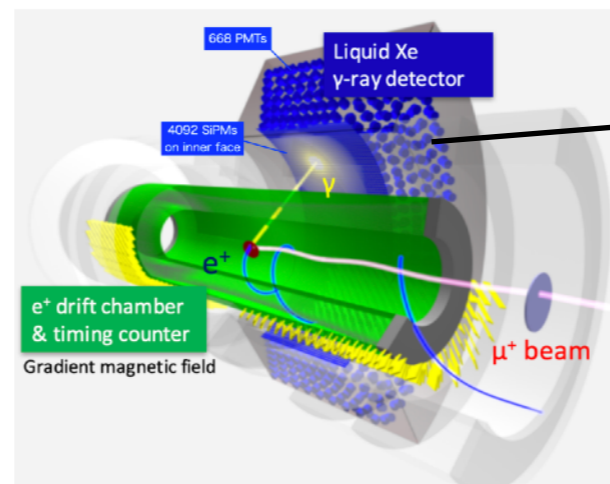
PMT only analysis (XEC)

Energy resolution study with only PMTs

- Purpose : Estimate the performance of CALO prototype (LXe option)
    - it doesn't have photo-sensors on the entrance face, and has PMTs on the other faces
    - To mimic the prototype, only PMTs are set to active in the XEC analysis

- Dataset : CEX (in 2022) : 55 MeV gamma-ray (and CW run : 17.6 MeV gamma-ray)

- Procedure :
    - Optimize "face factor (FF)" without using inner face (FF of the inner face is fixed to zero)
    - Then, if needed, optimize weight of each sensor for the energy resolution to be minimum

- Face factor
    - Factors for weighted sum of #photon determined for each face according to the hit position in (u,v)
        - i.e.) same value is used for all sensors on certain face
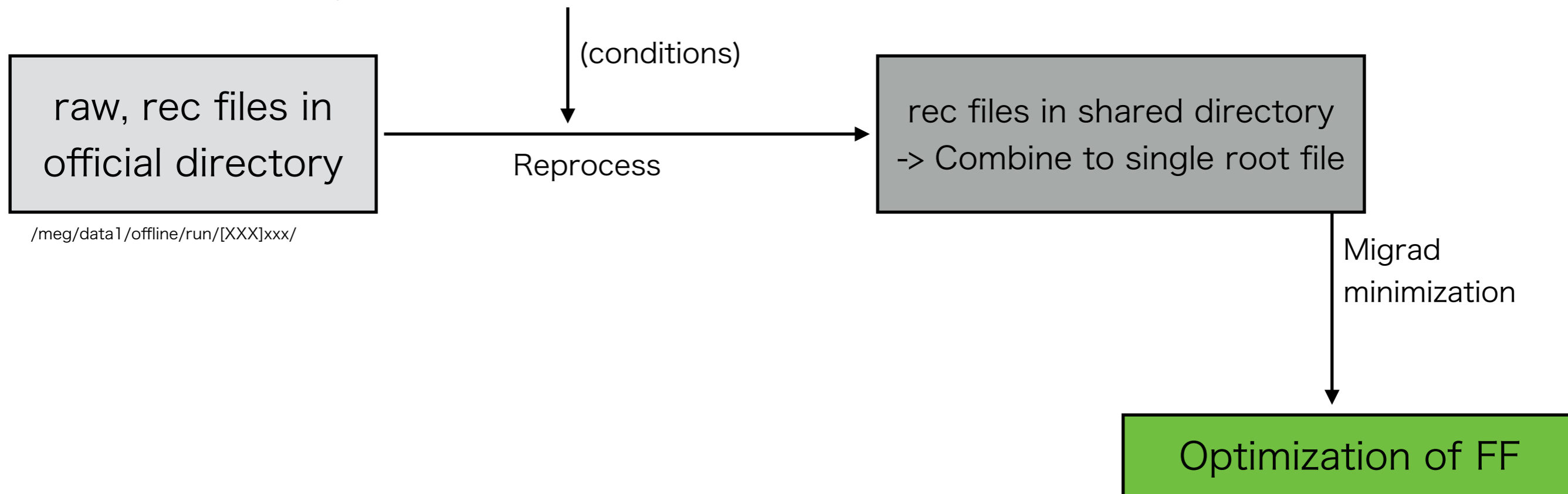   - e.g.) if reconstructed position is (u,v)=(-10, 20) -> 0.65 is used for all sensors on upstream face


upstream face

~0.65
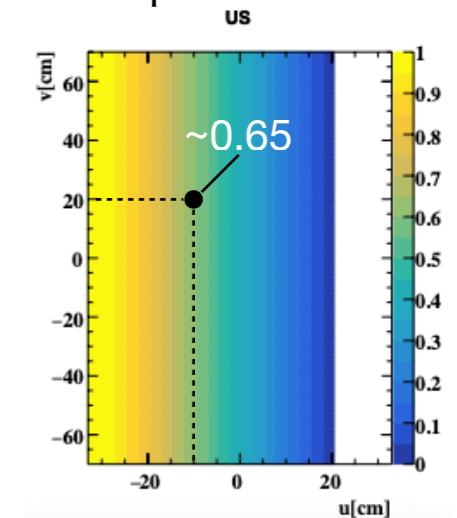
PMT only analysis (XEC) / FF optimization

- Face factor optimization using CEX 2022
    - input file path : /meg/data1/offline/run/[:::]xxx/
    - using ordinal offline_second_raw.xml
        - XECconf=2212 : (Re-)finalized gain, QE histories
            - Gain/CTAPHistoryDB .id=2205, QEHistoryDB .id=2210
   - XECEnergyRec=15 : flat FF, DCR ON (solid angle method)

(conditions)

raw, rec files in official directory

/meg/data1/offline/run/[XXX]xxx/

Reprocess →

rec files in shared directory -> Combine to single root file

Migrad minimization

Optimization of FF

- Optimization of FF by Migrad minimization
    - minimize : $\sqrt{\ } \Sigma (N_{pho} - N_{pho,\ target})^2$ /entries
    - with FF on Inner face = 0
        - in event selection of 55 MeV, inner face are used
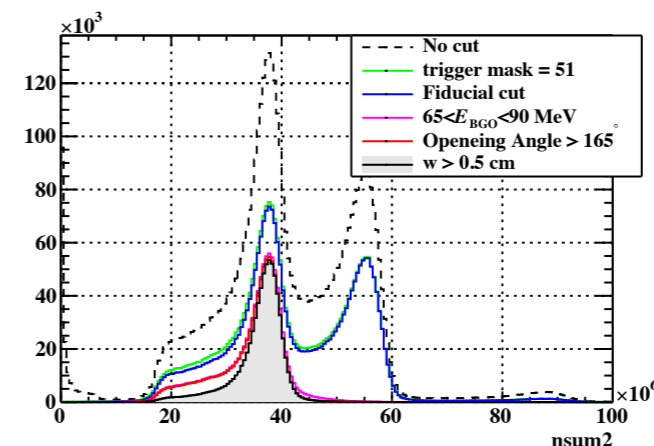
Face factor optimization

- How to calculate (optimize) face factor :
  - (u,v) is divided to 6×16
  - For certain segment (e.g. segment with red square), $\Sigma F_i \times \#Ph_i$ (i=0,1,2,3,4,5) distribution is drawn
  - Factors : F_i (i=0,···,5) are optimized for the s.t.d. to be smallest (for resolution to be best)
    - TMinuit is used for minimization (optimization)
      - minuit ->mnexcm("MIGRAD", arglist, 1, ierflg);
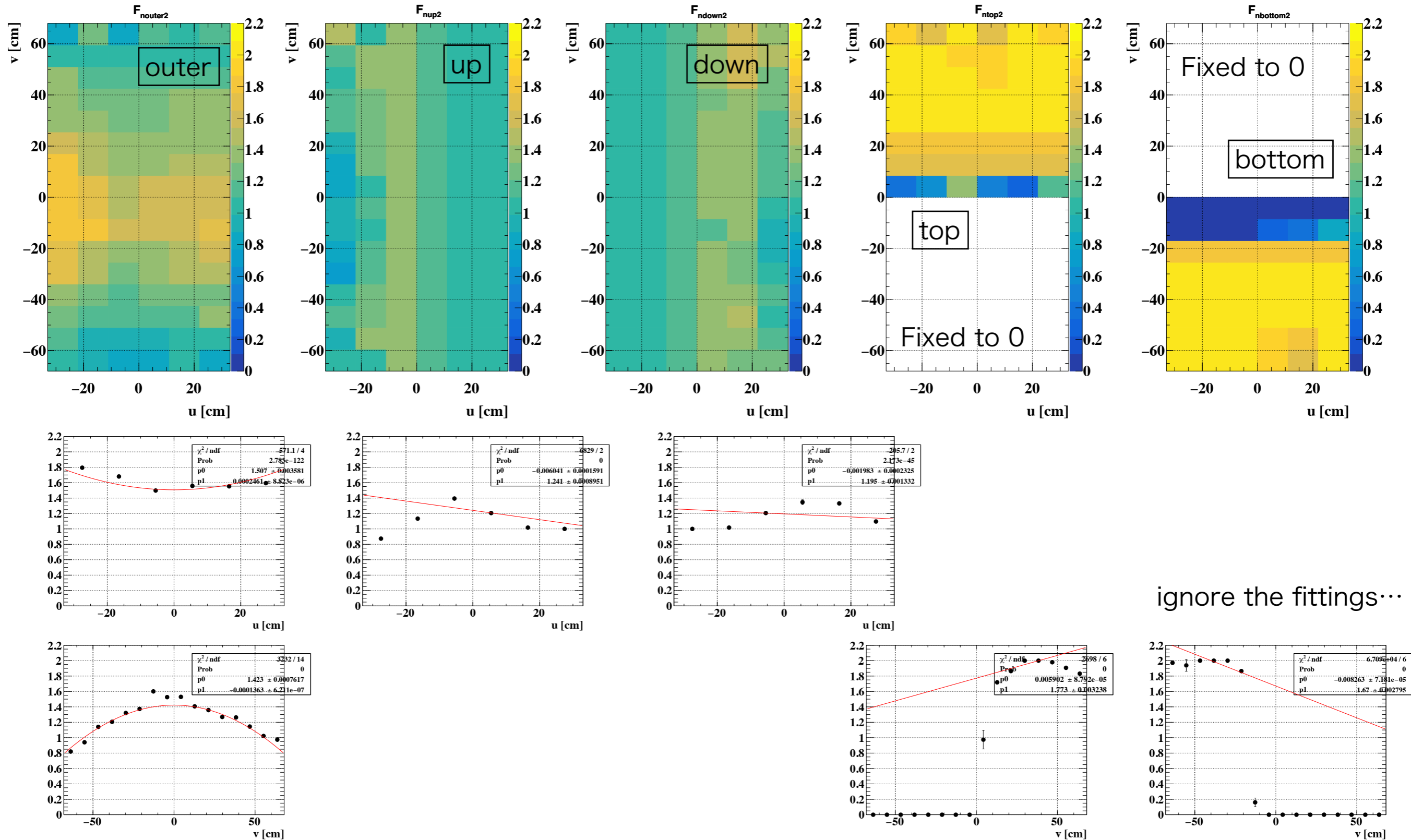   - for top (bottom), F_i is set to 0 when v<0 (v>0)

- mean #ph. for each face

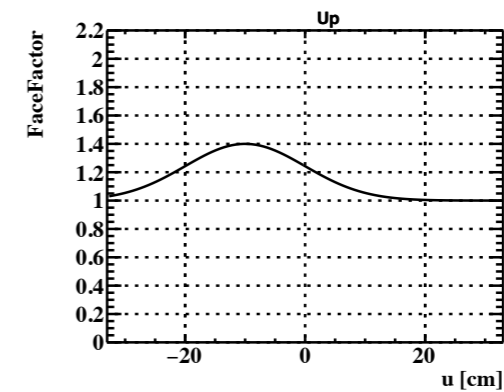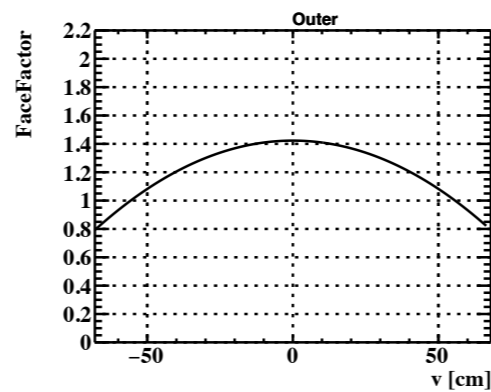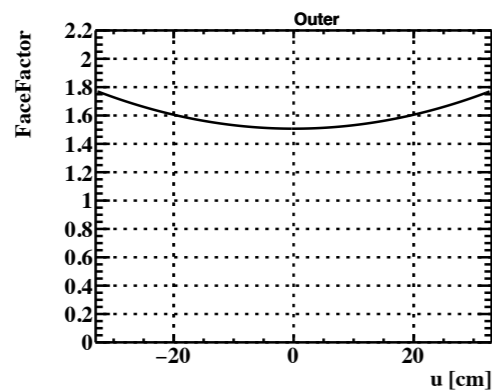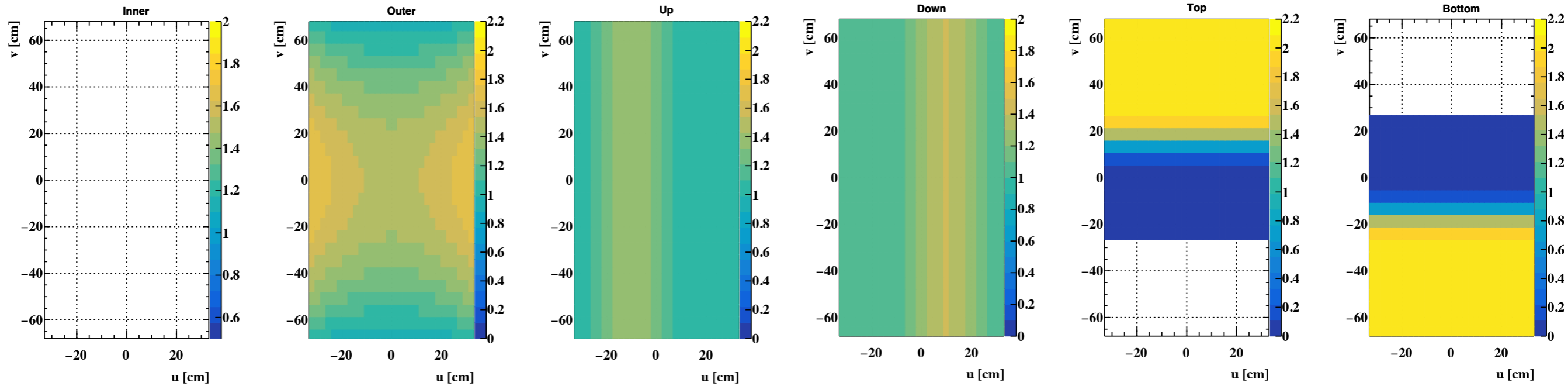- weighted sum
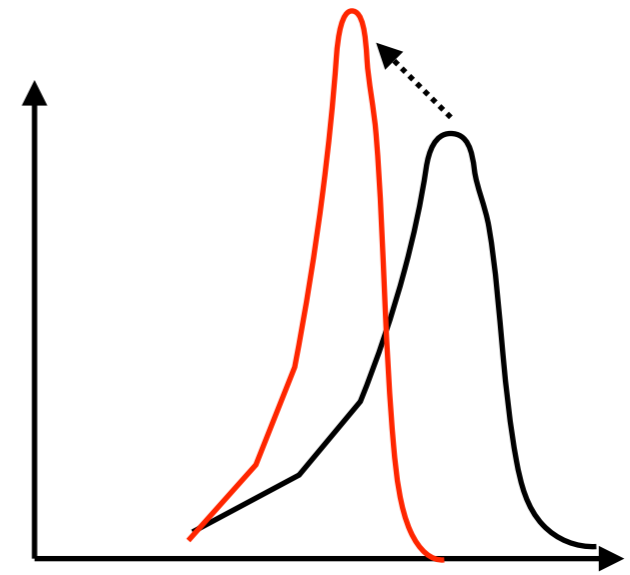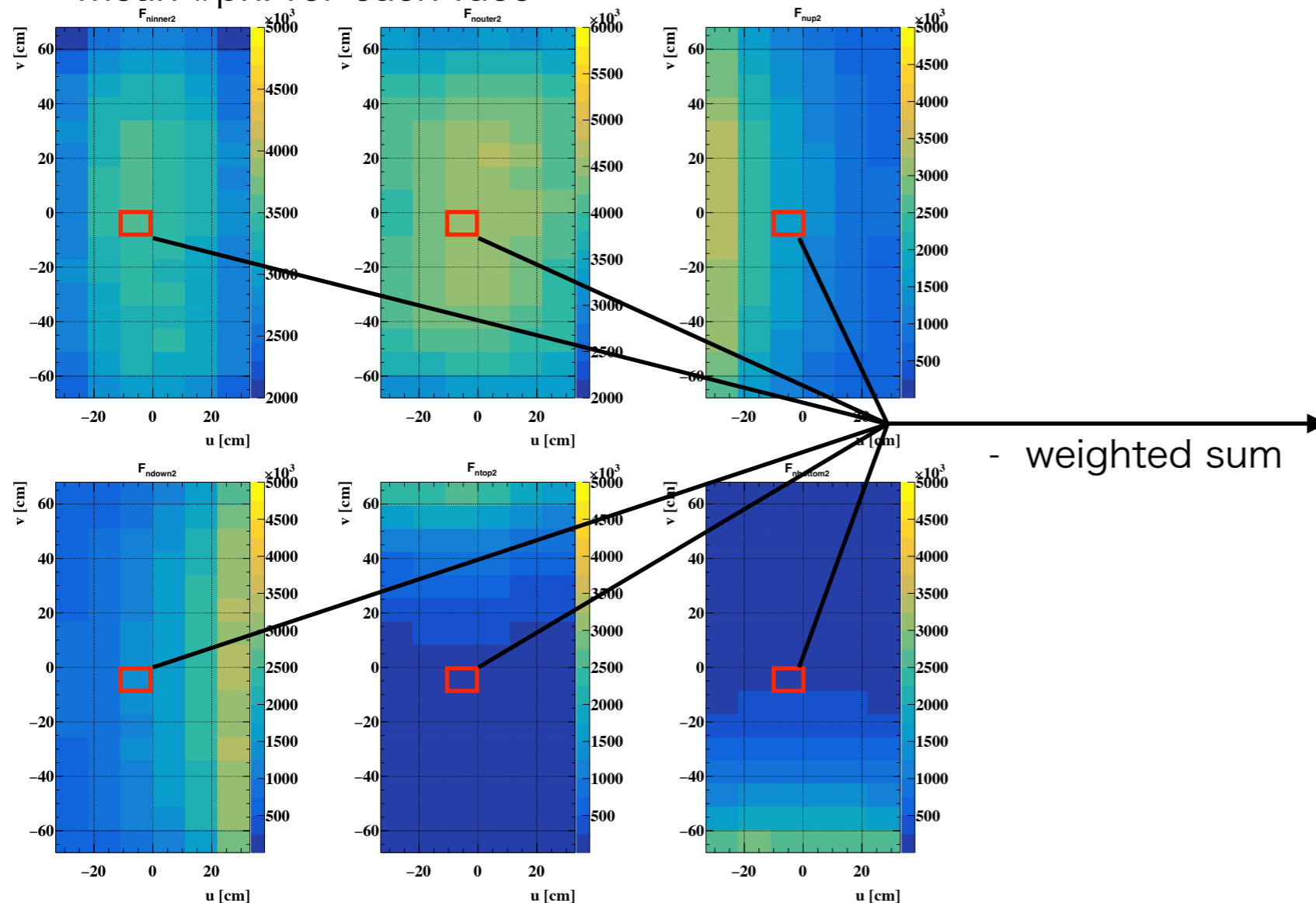
- weights (F_i) optimization

PMT only analysis (XEC) / FF optimization

- Face factor optimization using CEX 2022
  - Optimized FF (6x16 segmentations)

ignore the fittings…

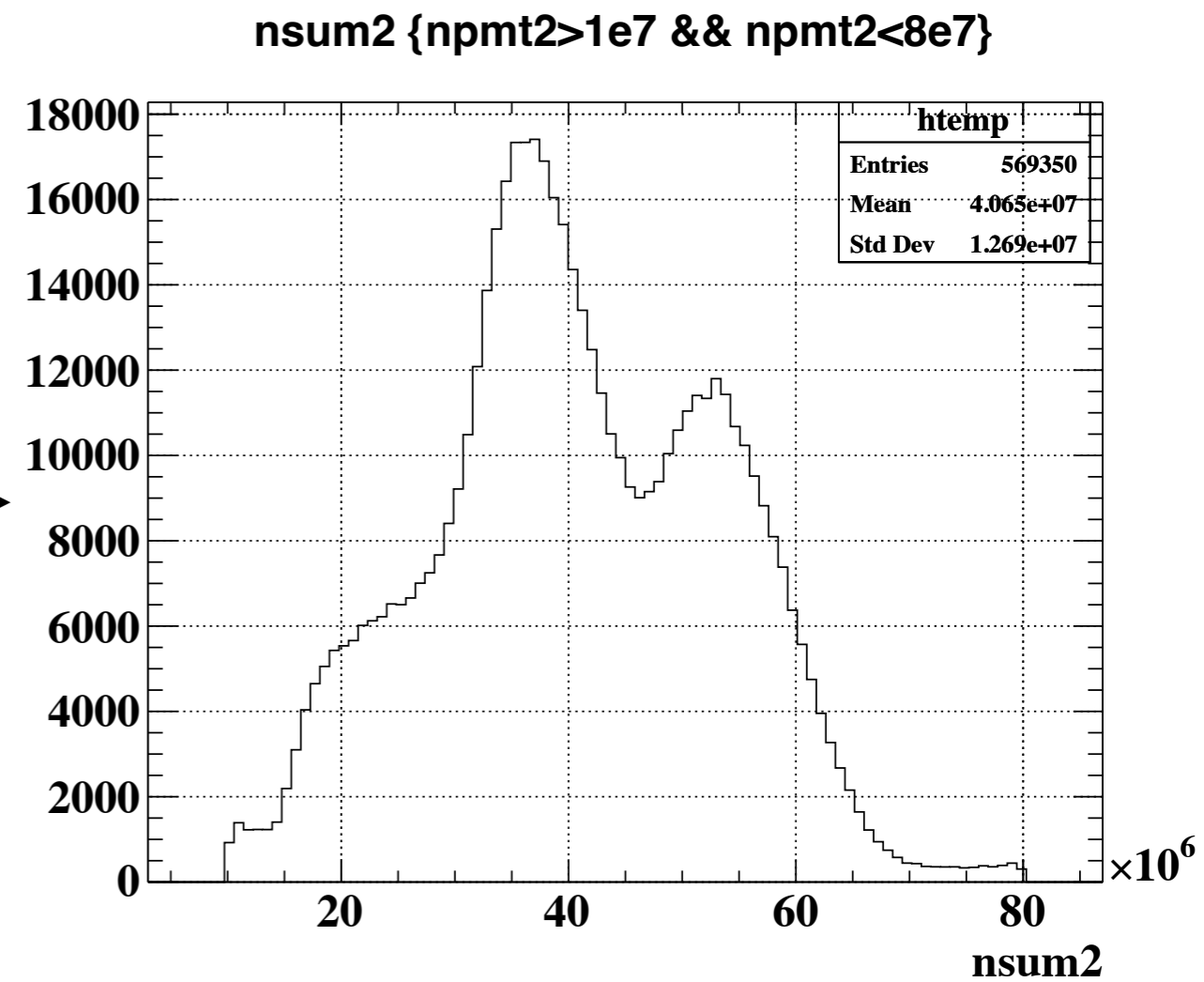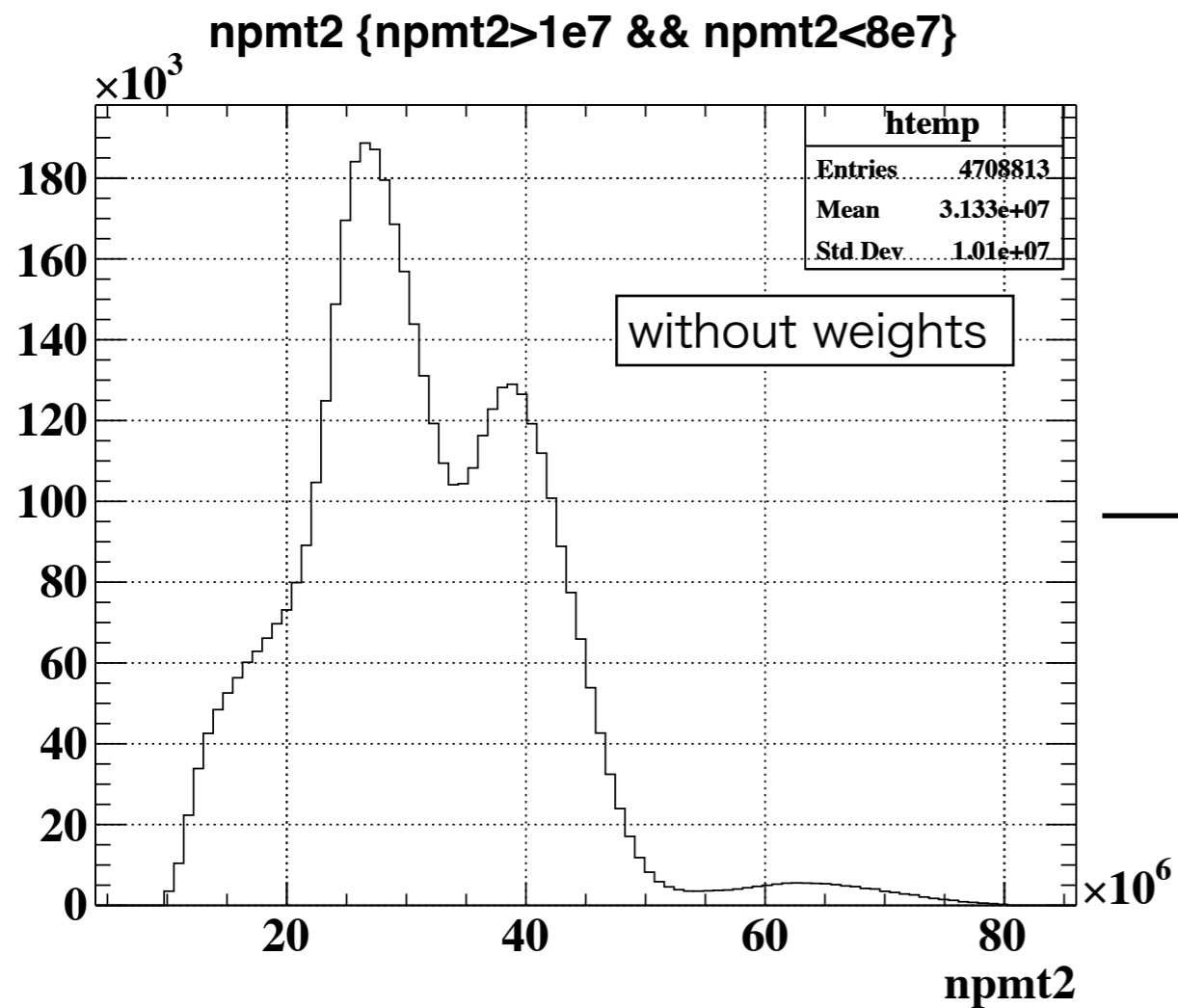# PMT only analysis (XEC) / FF optimization

- Face factor optimization using CEX 2022
    - Optimized FF : Formalization
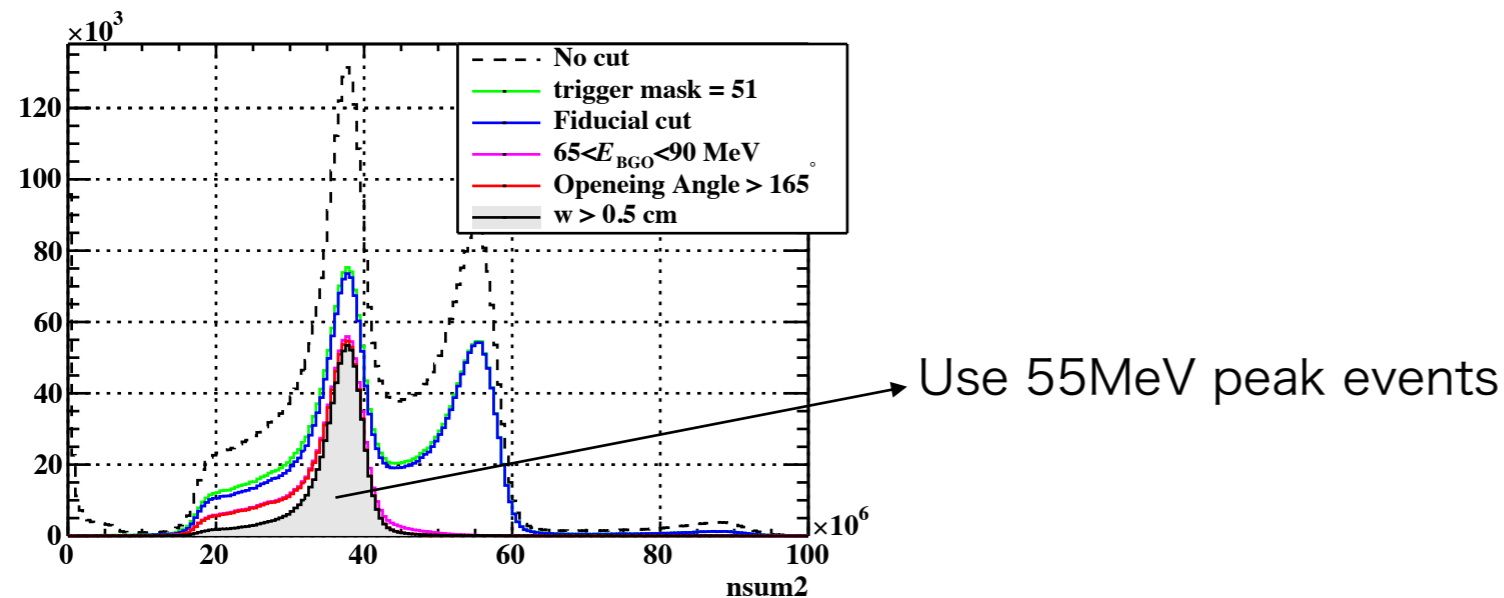

15th Jun. 2024

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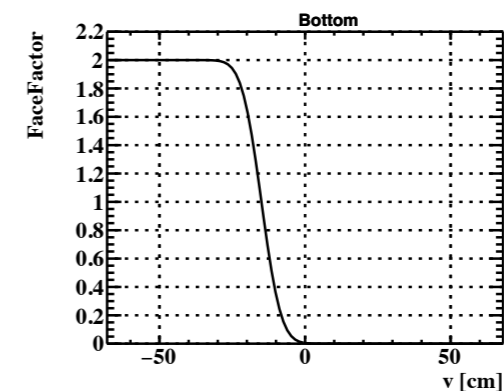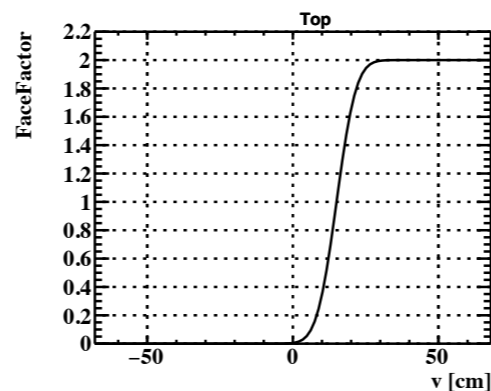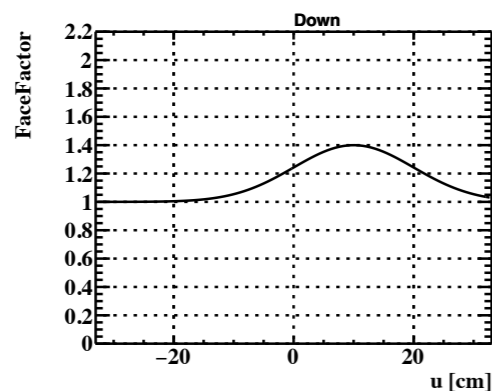
PMT only analysis (XEC) / FF optimization

- Face factor optimization using CEX 2022
    - Weighted sum of #photons by PMTs

- Significant resolution improvement is not seen…

PMT only analysis (XEC) / weight optimization

- In addition to the Face Factor optimization, weights for each PMT are also optimized
    - make the Loss minimize

Use 55MeV peak events

$N_{wsum} = \Sigma_i \ \#pho_i * w_i \quad (\ i : index \ of \ PMT)$

$Loss := \Sigma_{events} (N_{wsum} - N_{target})^2/N_{target}^{\ 2}$

⟶ $w_{i,j+1} = w_{i,j} - \lambda * \partial Loss/\partial w_{i,j}$

here, $w_{i,j}$: weight of i-th PMT (j-th iterated)

1/10 of dataset are used as test

Loss vs Iteration

- ○ **train**
- * **test**

PMT only analysis (XEC) / weight optimization

- In addition to the Face Factor optimization, weights for each PMT are also optimized
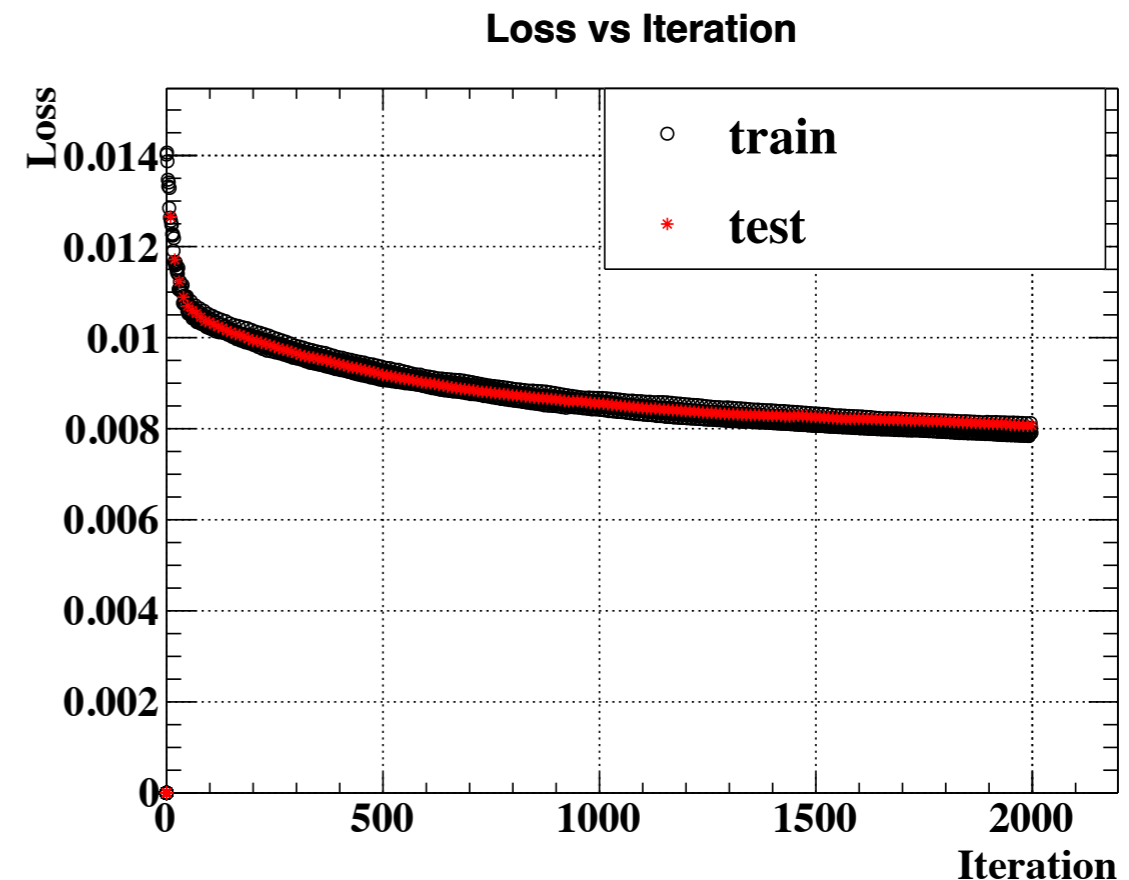   - make the Loss minimize