Study of Accidental Activity at the Front Barrel of the KOTO Detector

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Introduction

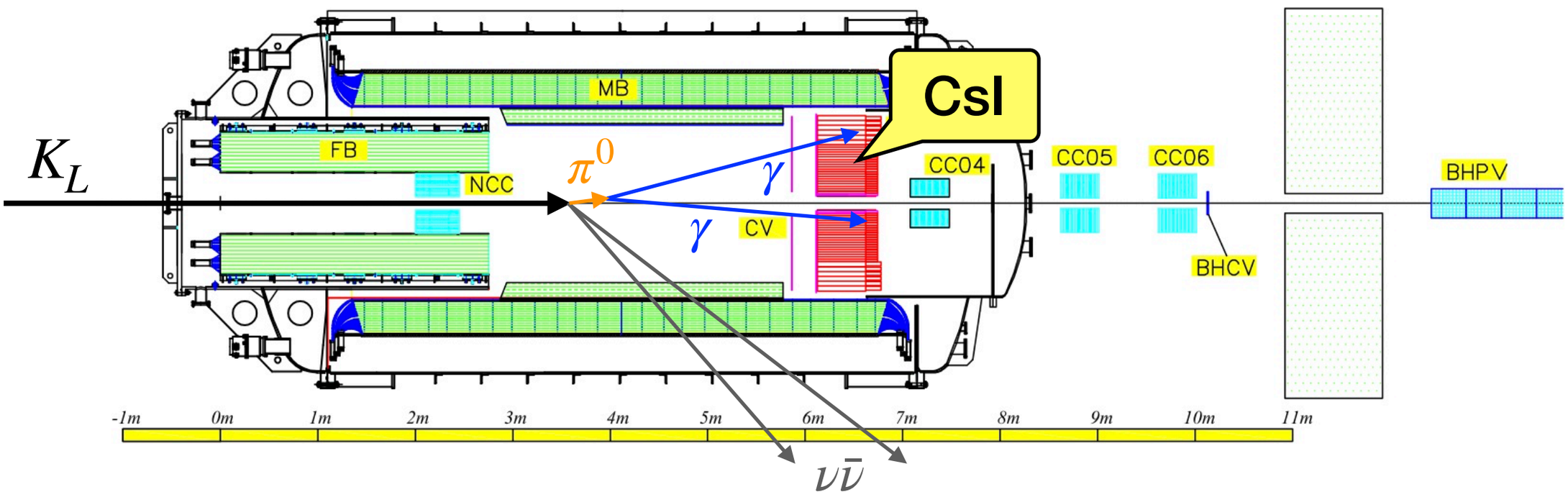
The KOTO experiment

Purpose : To observe the decay $K_L \to \pi^0 \nu\bar{\nu}$.

Signal : 2 photons + “nothing”

➥ detected at the CsI calorimeter

➥ other veto detectors make sure of no extra hits

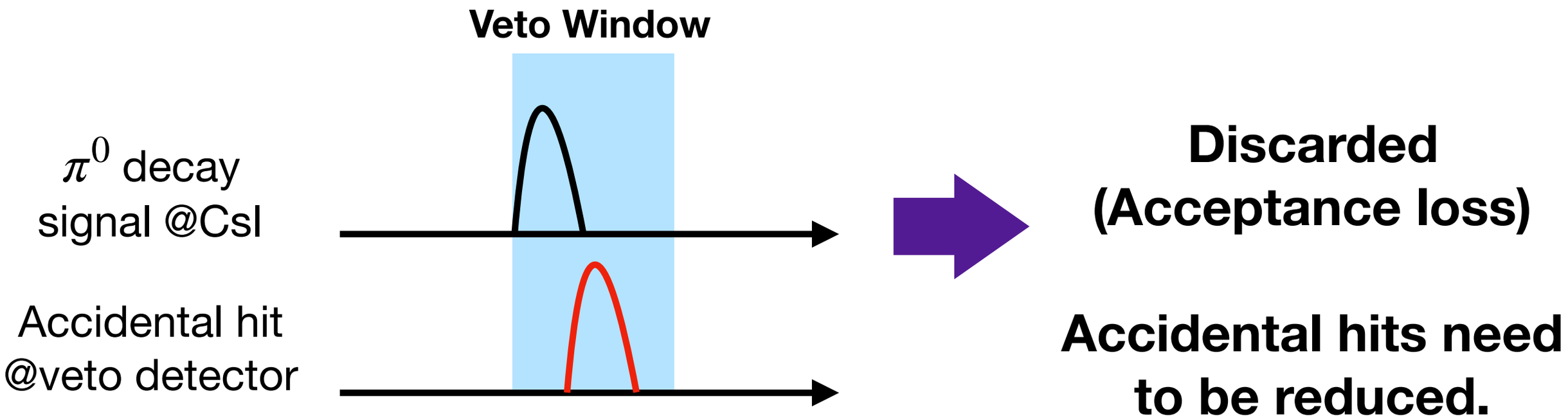


Accidental Signal Loss

Accidental hits on veto detectors coincident with the π^0 decay could cause signal loss.

Major sources…

- Other K_L decay
- Neutron from the J-PARC primary beam line



Purpose of This Study

- To understand accidental activities at the Front Barrel of the KOTO detector.

- To calculate accidental hit rates by using data taken in 2019.

- To check consistency of accidental hit rates between physics-triggered data and TMON-triggerd data.

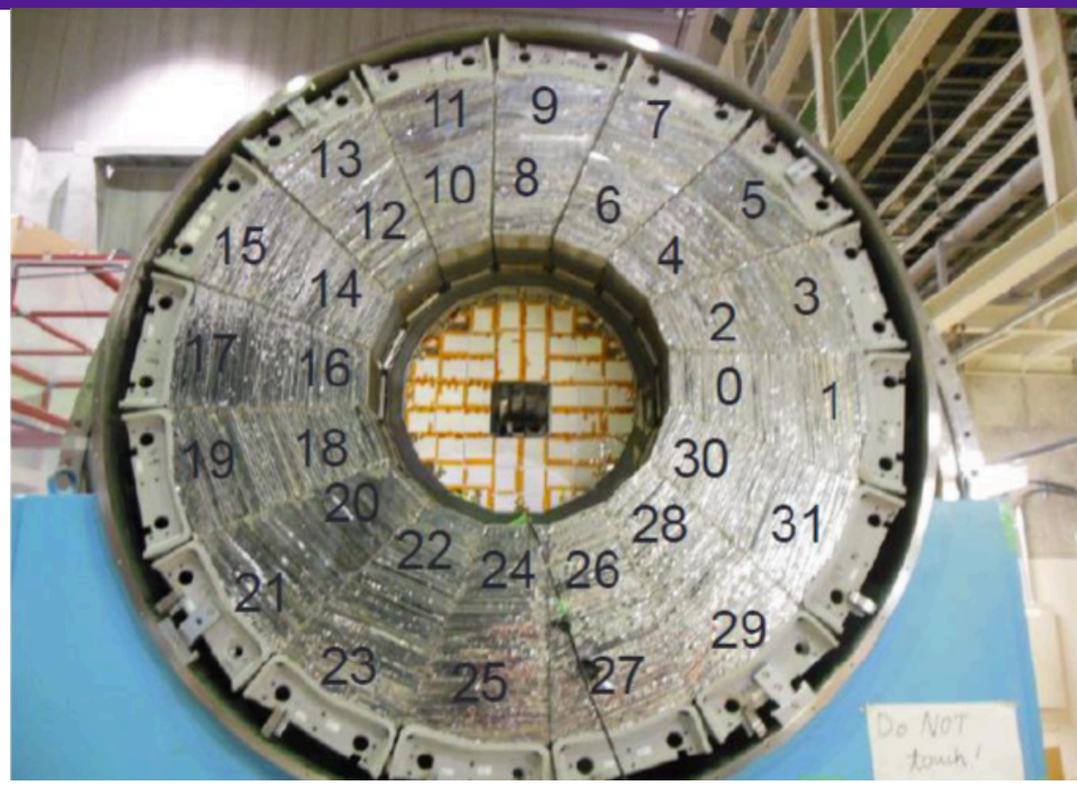
  Physics trigger…trigger to collect $K_L \to \pi^0 \nu \bar{\nu}$ data

  TMON trigger…trigger to reproduce accidental hits

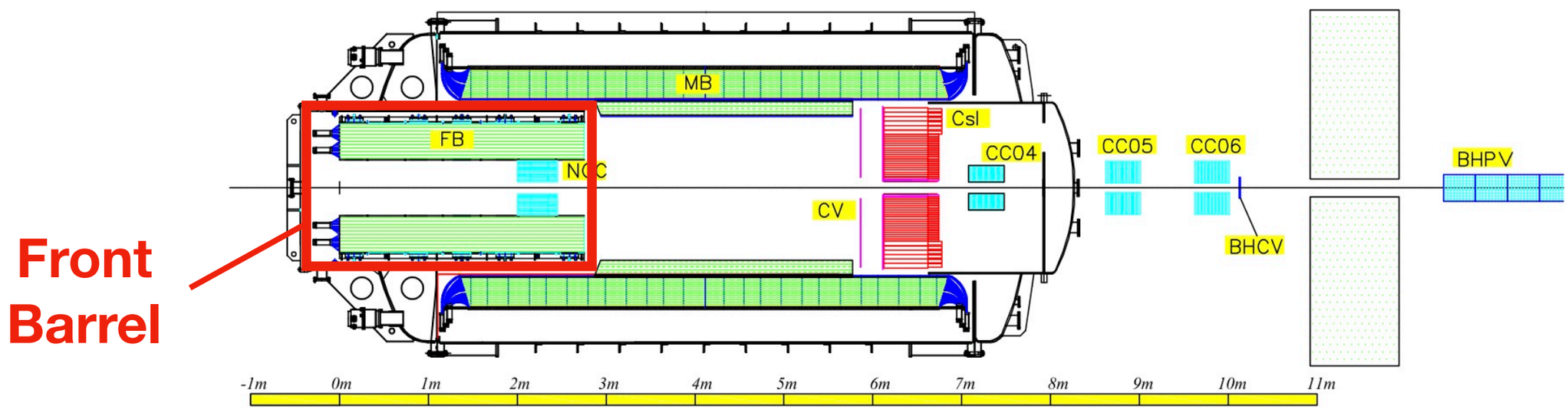
Front Barrel

- Sandwich of lead & plastic scintillators
- 2.75m long
- Sampled by125MHz FADC
- 16 modules
- 32 readout channels

(inner/outer layers are read separately)



View from the downstream side

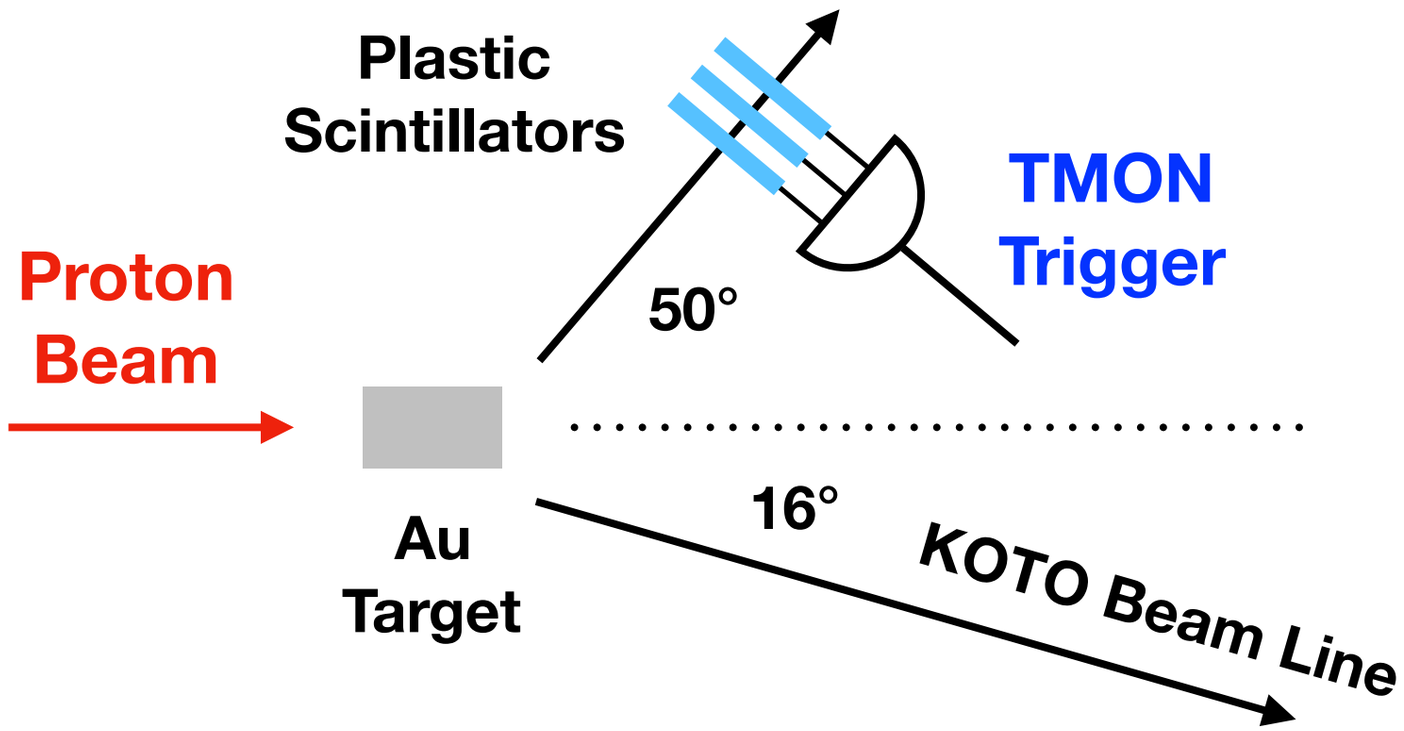


TMON Trigger

TMON trigger is…

A random trigger generated from the signals of the **Target Monitor**. The rate is proportional to the beam intensity.

We use this trigger to reproduce accidental activities and overlay the waveforms on generated waveforms in simulation.

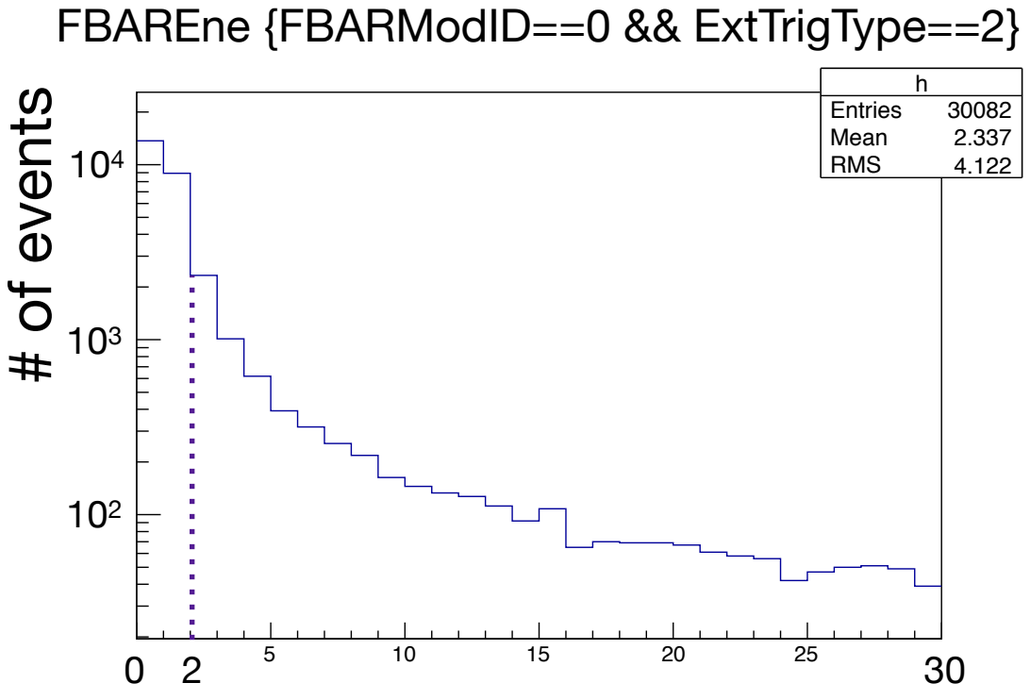


Energy Distribution

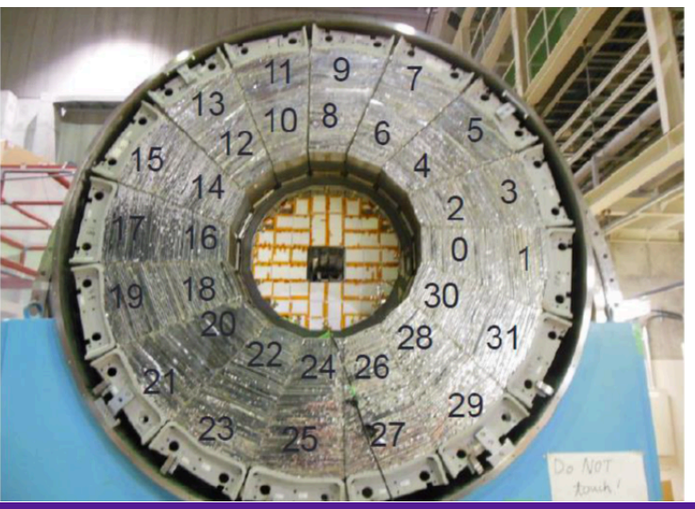
TMON data

Energy is distributed up to ~600 MeV.

Now, set the energy threshold to 2 MeV.



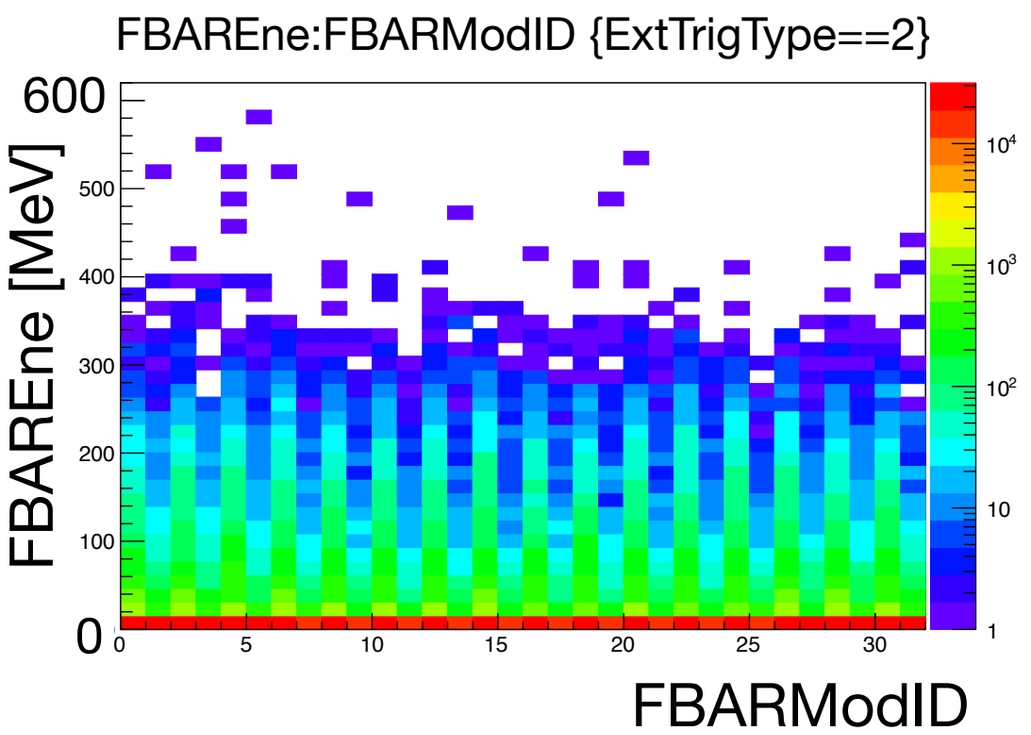
➤ **Consider only events with FBAREne > 2 MeV.**



Higher counts in inner channels

Lower counts in outer channels

→

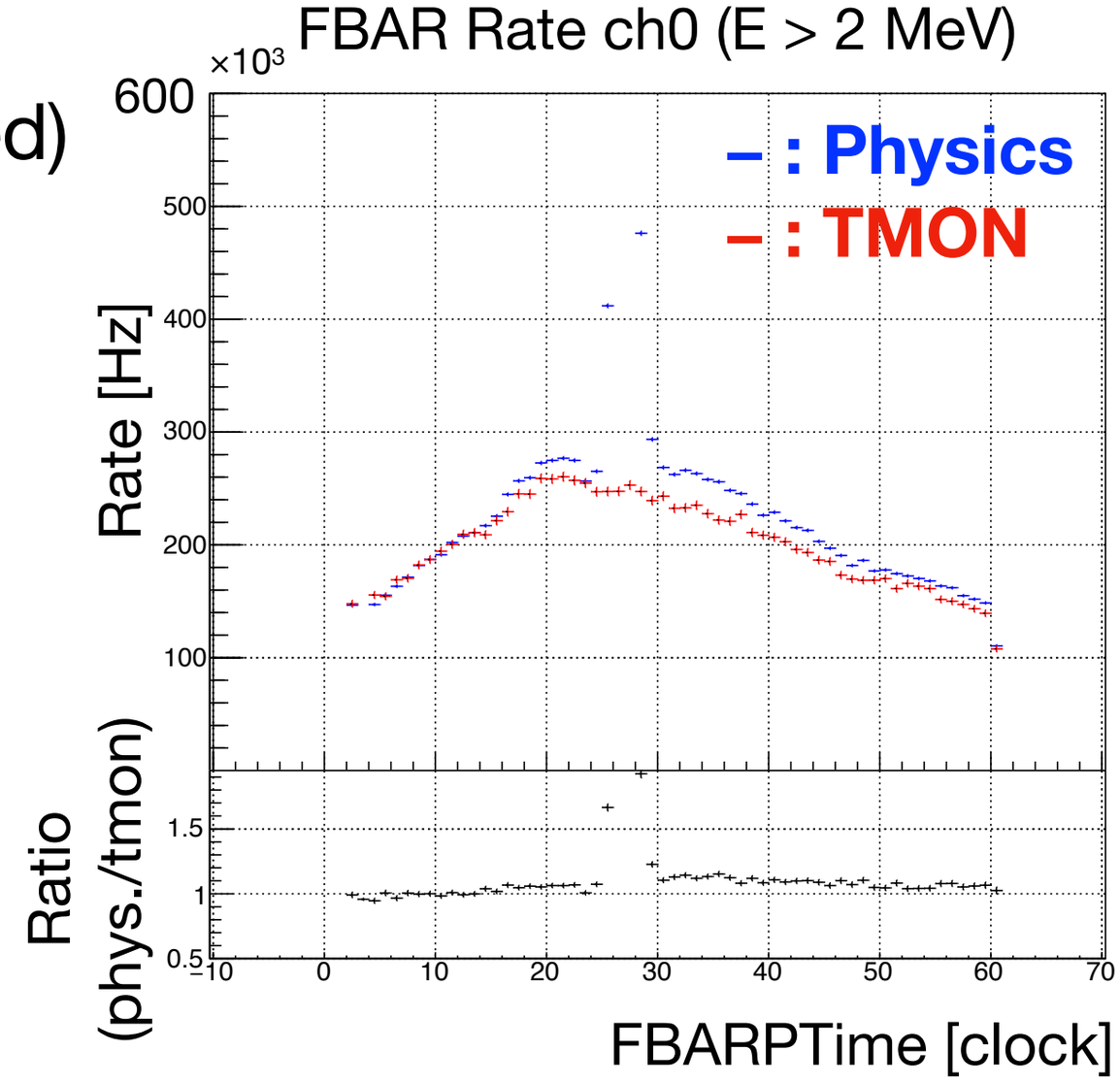


Comparison between Phys. & TMON data

Rate[Hz] per bin(= 1clock=8ns)

Rate = #events / (ΔT×#triggered)

(ΔT = 1clock = 8ns)



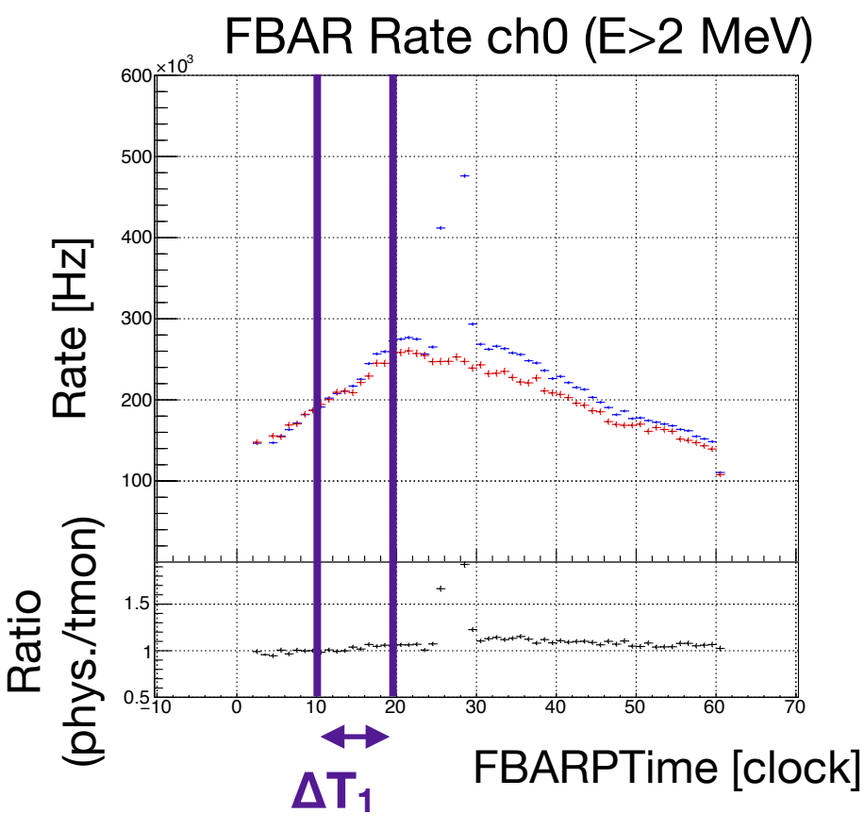
Earlier timing region

-> consistent

Later timing region

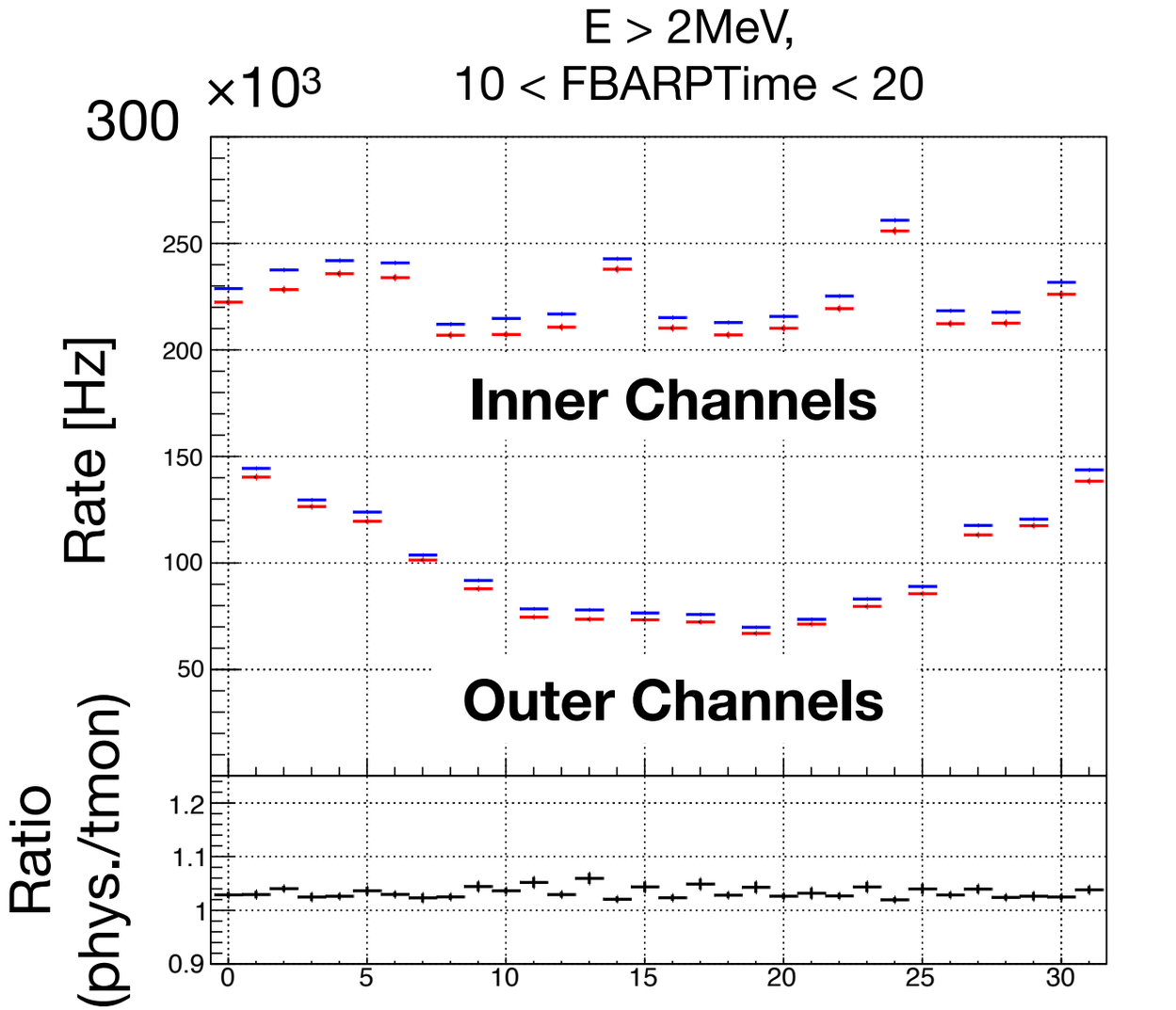
-> subtle discrepancy exists

Rates in 10 - 20 clock timing



– : Physics

– : TMON

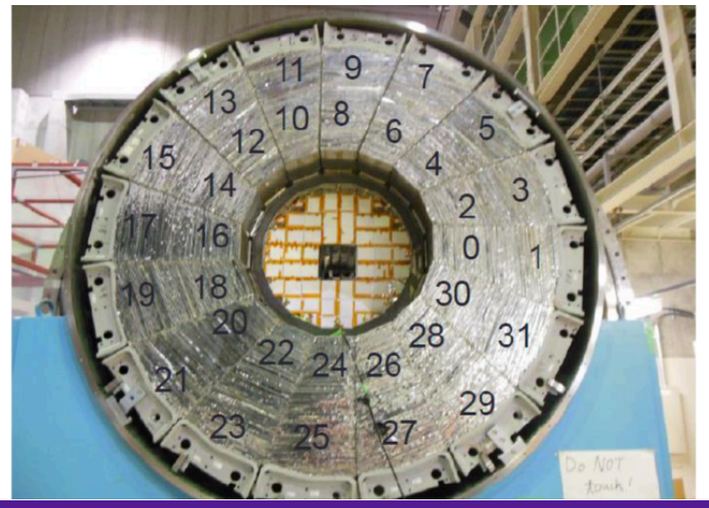


Energy Threshold : 2MeV

Rate = #events/(ΔT×#triggered)
ΔT = ΔT_1

Ratio = Phys./TMON
= 1 ~ 1.1

→ Good agreement



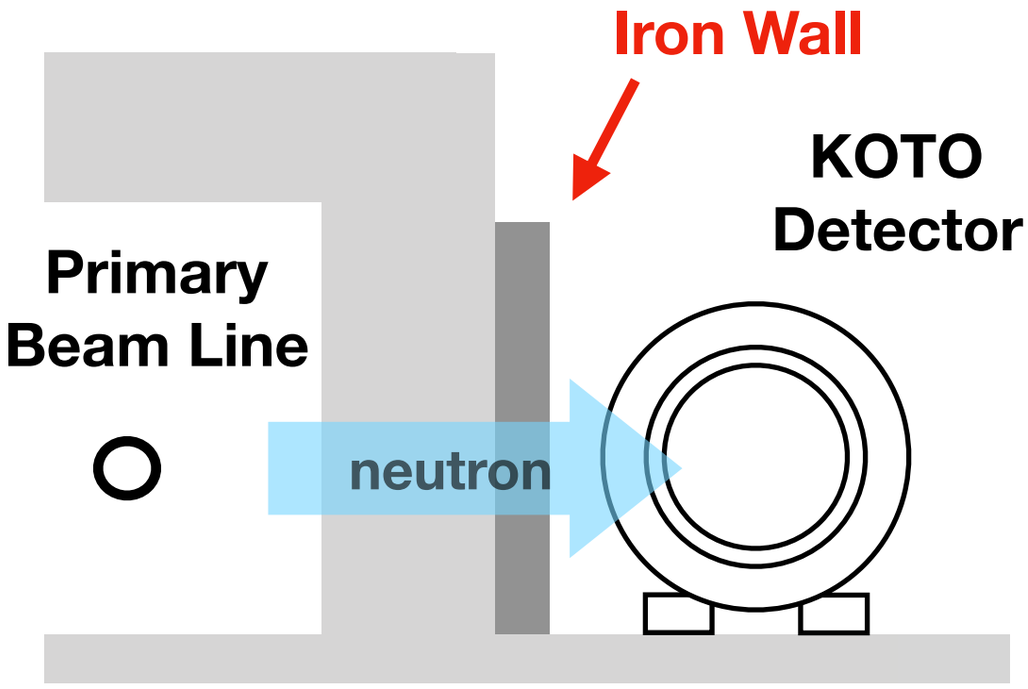
→

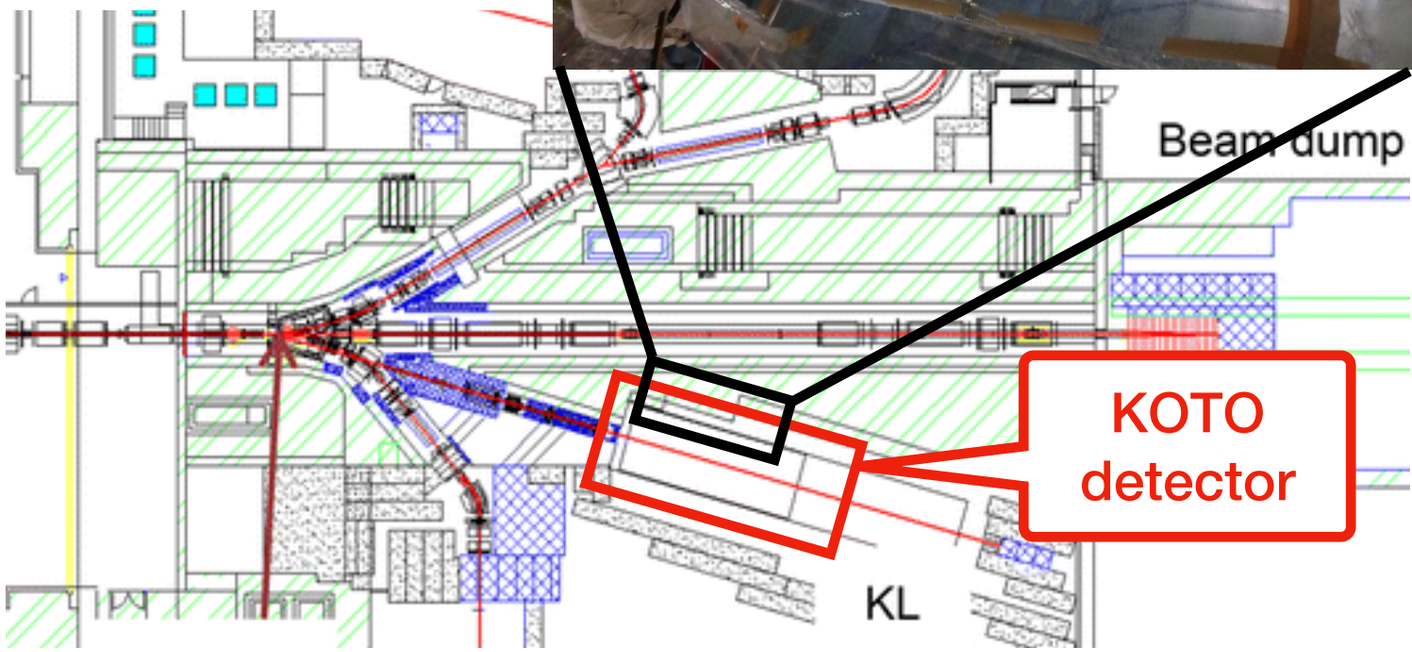
Primary beam line side

How we will reduce accidental hits

Accidental activities by neutrons coming from the J-PARC primary beam line

To reduce the neutron flux, we installed a 33cm-thick iron wall.



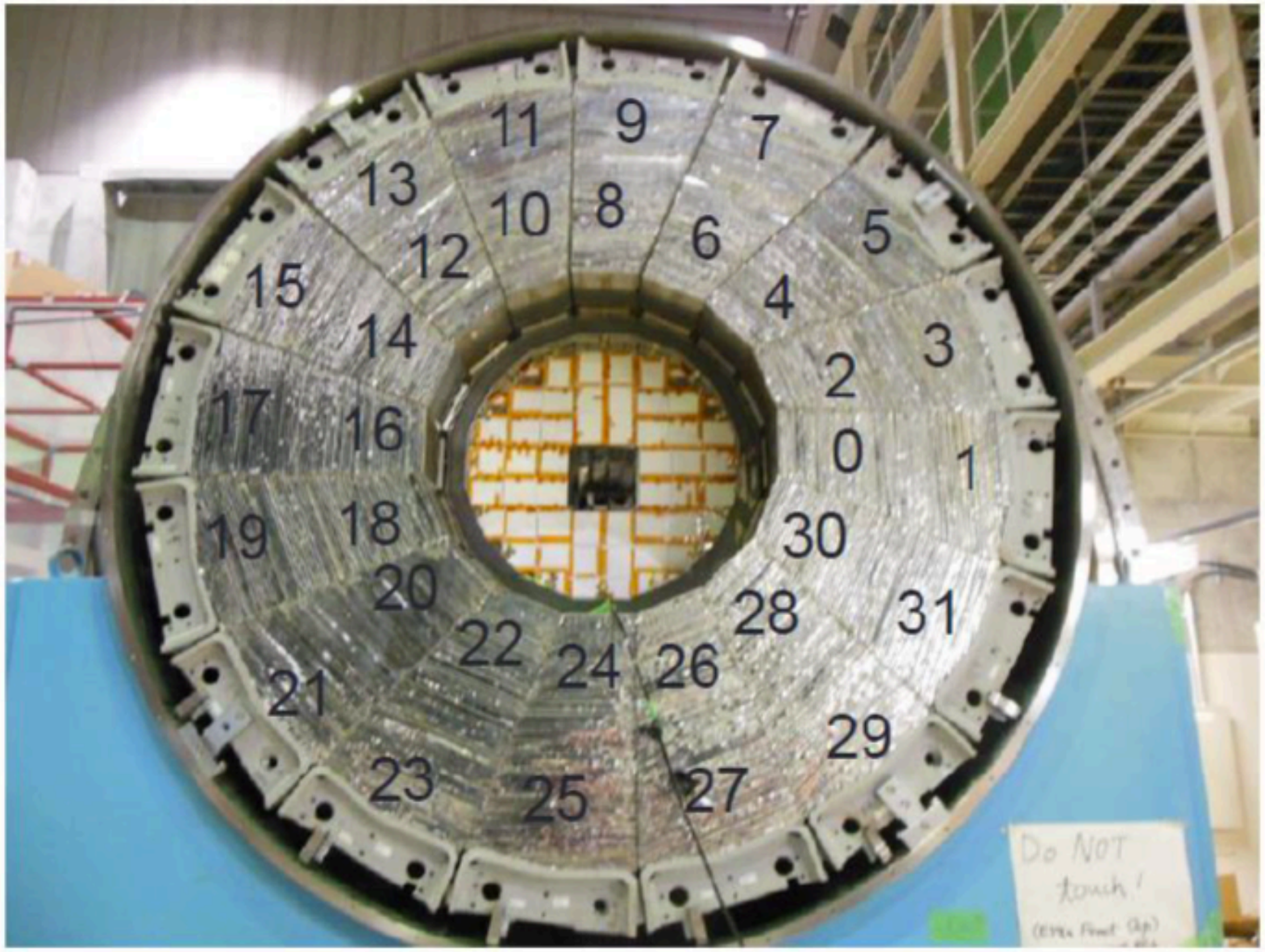


Summary / To do

- Confirmed consistency of accidental counting rates in physics/TMON data.
- To reduce neutrons from the primary beam line, we installed an iron wall and will check the reduction effect.

Backup

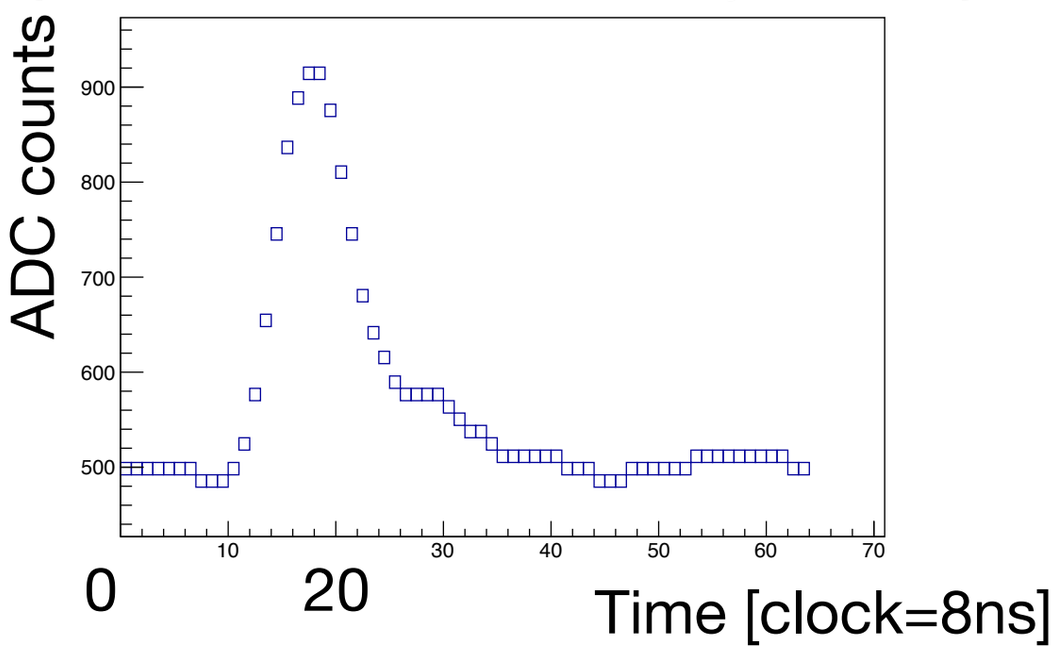
Detector



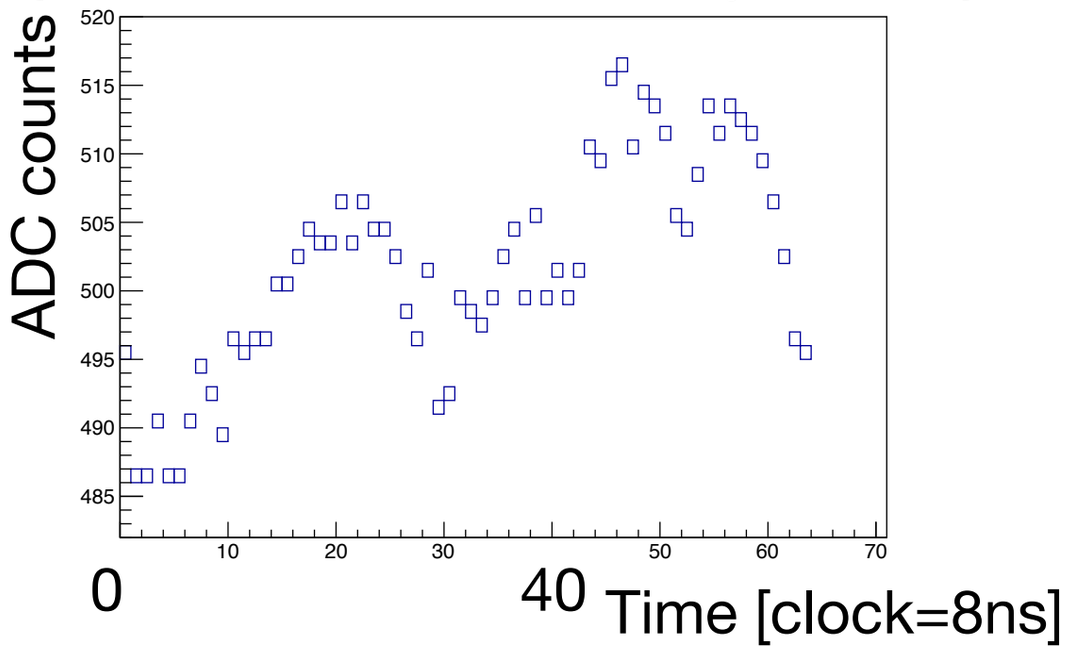
View from the downstream side

Waveforms at the Front Barrel

Waveform Examples



Physics-triggerd event
Energy : 13.8 [MeV]
Time : 17.7 [clock=8ns]



TMON-triggerd event
Energy : 3.1 [MeV]
Time : 47.3 [clock=8ns]

Consider an energy threshold and timing distributions.

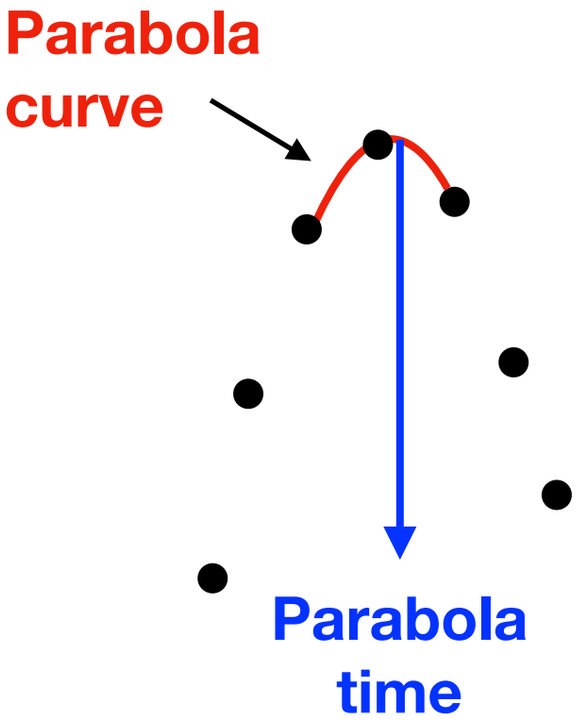
Time Distribution

Take the moving average -> make waveforms smoother

Calculate a parabolic curve using three samples around the peak.

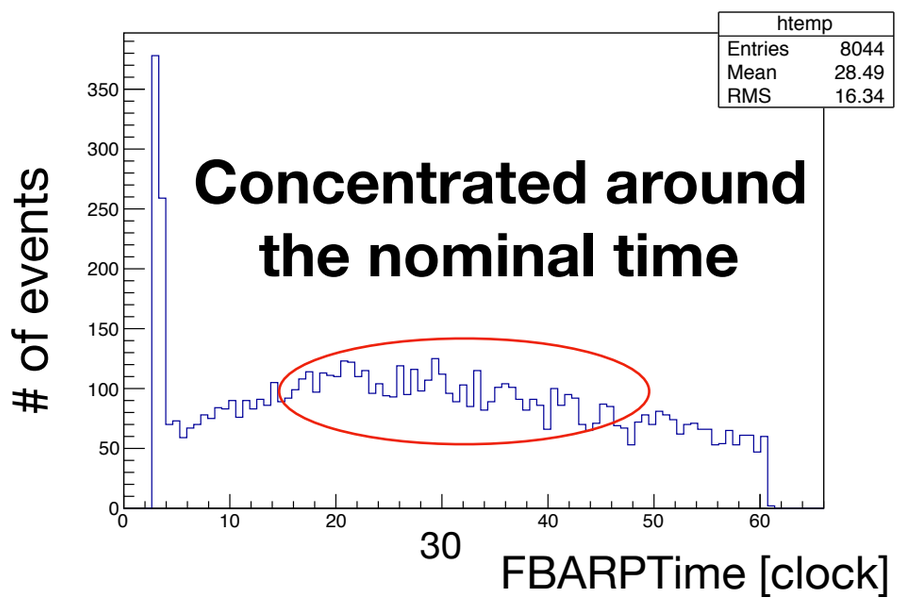
The parabola time closer to the **nominal time** (~31 clocks) for the Front Barrel is selected.

➤ **Tend to have a structure like a broad hill.**



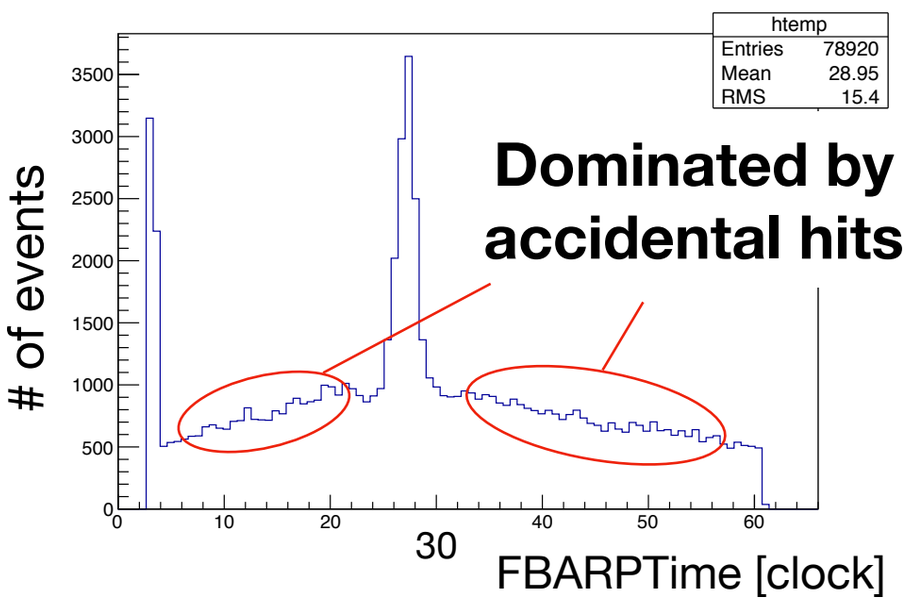
TMON

FABRPTime {FBARModID==0 && FBAREne>2 && FBARPTime>-10 && (ScaledTrigBit&0x1)==0x1}

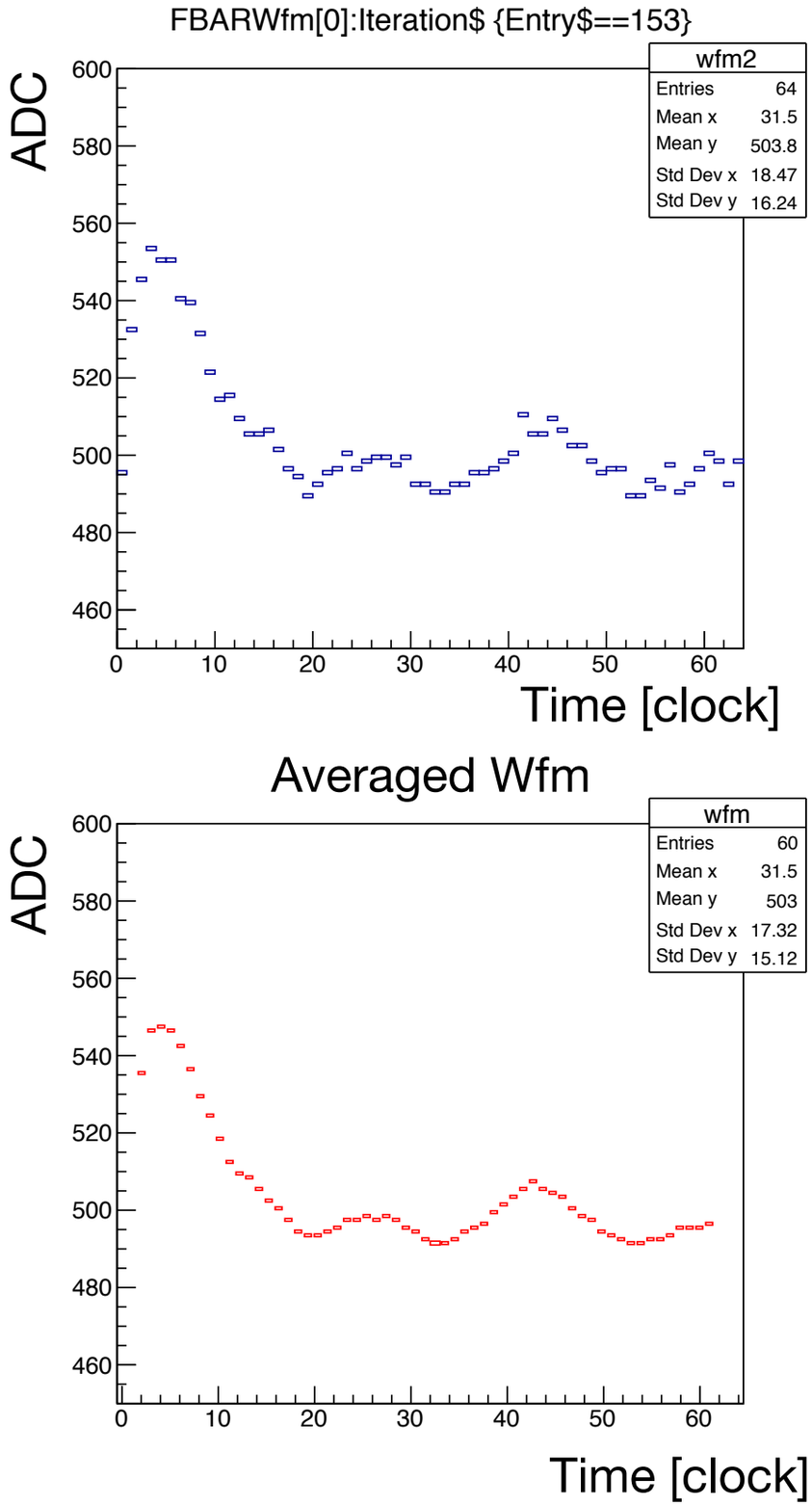


Physics

FABRPTime {FBARModID==0 && FBAREne>2 && FBARPTime>-10 && ExtTrigType==2}



Moving Average



Calculation Code

```
//Pedestal and PeakTime need to be calculated in advance
static Int_t n_sample_average = 5;//must be odd number
Int_t n_sample_oneside = (n_sample_average-1)/2;

ptime = -9999;

Float_t averaged_wfm[k_nSamples]={0};
for (Int_t i_sample=n_sample_oneside; i_sample<k_nSamples-n_sample_oneside; i_sample++) {
  averaged_wfm[i_sample] = TMath::Mean(n_sample_average, &data[i_sample-n_sample_oneside] );
}
```

/sw/koto/e14ana/release/v4.01.10/AnalysisLibrary/UserProjects/E14ProdLibrary/E14ProdDstConv/src/E14CrateData125MHz.cc

Take the average of five consecutive samples.

Make waveforms smoother and mitigate local fluctuations.

Parabola Interpolation Method

FB — rshirais@aau01:~ — ssh -Y rshirais@sshcc1.kek.jp — 120×37

```
void E14CrateData125MHz::CalcParabolaTime(const short *data,
                                          const float pedestal,
                                          const float nominal_time,
                                          const float threshold,
                                          const float t0,
                                          float &ptime)
{
  //Pedestal and PeakTime need to be calculated in advance
  static Int_t n_sample_average = 5;//must be odd number
  Int_t n_sample_oneside = (n_sample_average-1)/2;

  ptime = -9999;

  Float_t averaged_wfm[k_nSamples]={0};
  for (Int_t i_sample=n_sample_oneside; i_sample<k_nSamples-n_sample_oneside; i_sample++) {
    averaged_wfm[i_sample] = TMath::Mean(n_sample_average, &data[i_sample-n_sample_oneside] );
  }

  Float_t best_peak_time = -1;
  for (Int_t i_sample=n_sample_oneside; i_sample<k_nSamples-n_sample_oneside-1; i_sample++) {
    if (averaged_wfm[i_sample]>threshold+pedestal
        && averaged_wfm[i_sample-1]<averaged_wfm[i_sample]
        && averaged_wfm[i_sample]>=averaged_wfm[i_sample+1]) {
      Float_t tmp_ptime
        = i_sample - 1 + ( 3*averaged_wfm[i_sample-1]-4*averaged_wfm[i_sample]+averaged_wfm[i_sample+1] )
        /( 2*(averaged_wfm[i_sample-1]-2*averaged_wfm[i_sample]+averaged_wfm[i_sample+1]) );
      Float_t tmp_ptime_addt0 = tmp_ptime + t0;
      if ((best_peak_time<0) || ( TMath::Abs(tmp_ptime_addt0-nominal_time)<TMath::Abs(best_peak_time-nominal_time) ))
{

        ptime = tmp_ptime;
        best_peak_time = tmp_ptime_addt0;
      }
    }
  }
}
:
```

Moving Average

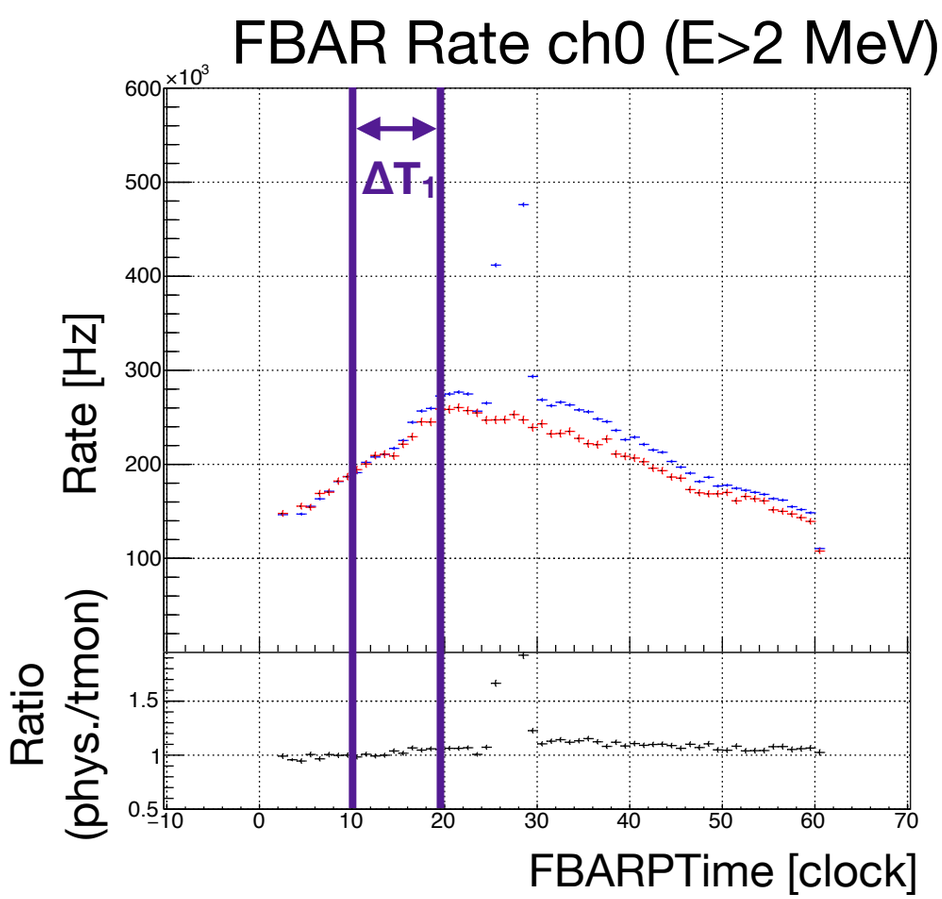
Peak Search

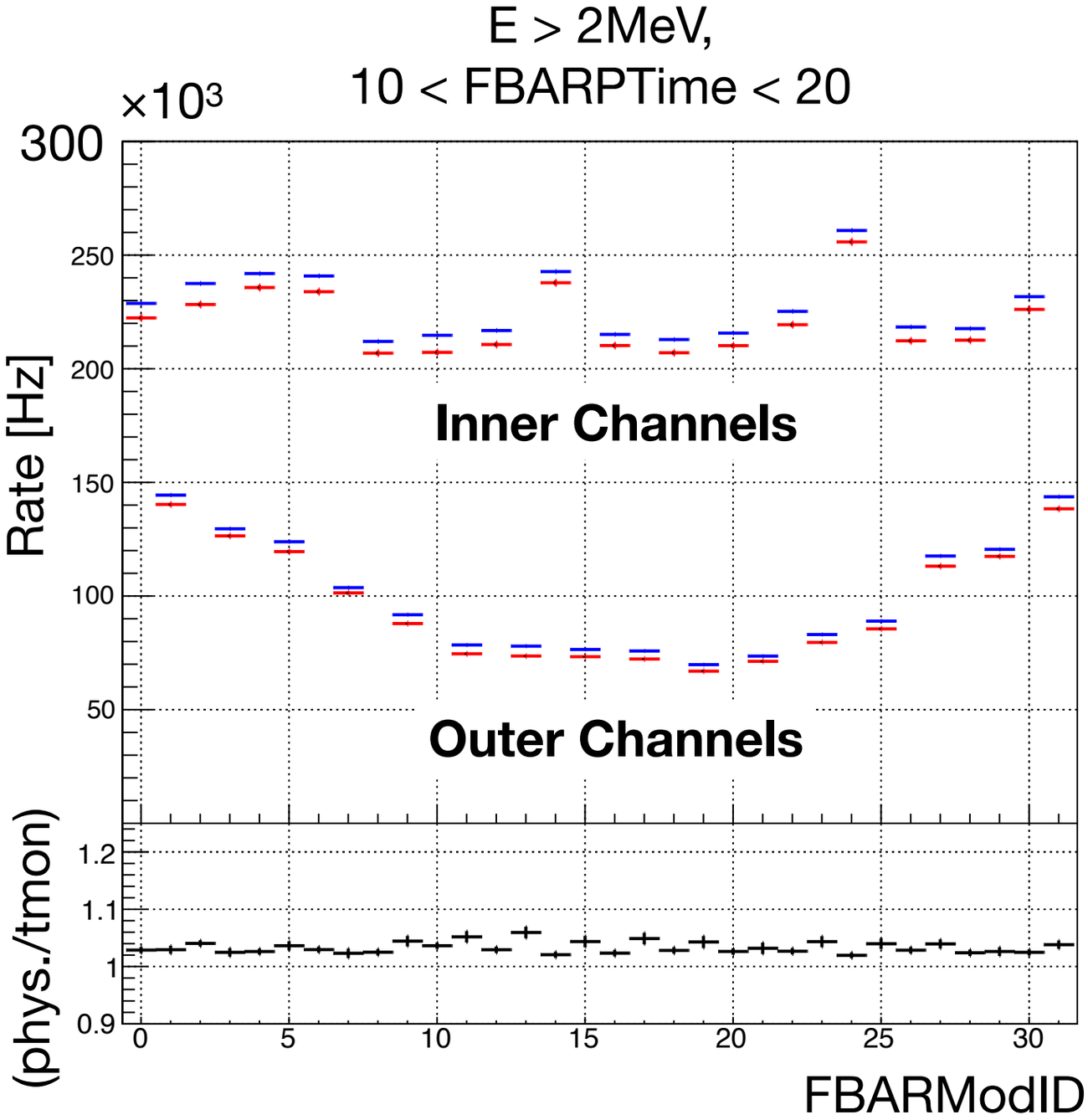
ptime

Nominal Time Condition

Calculation of ptime

Rates in 10 - 20 clock timing





Energy Threshold
FBAREne > 2MeV

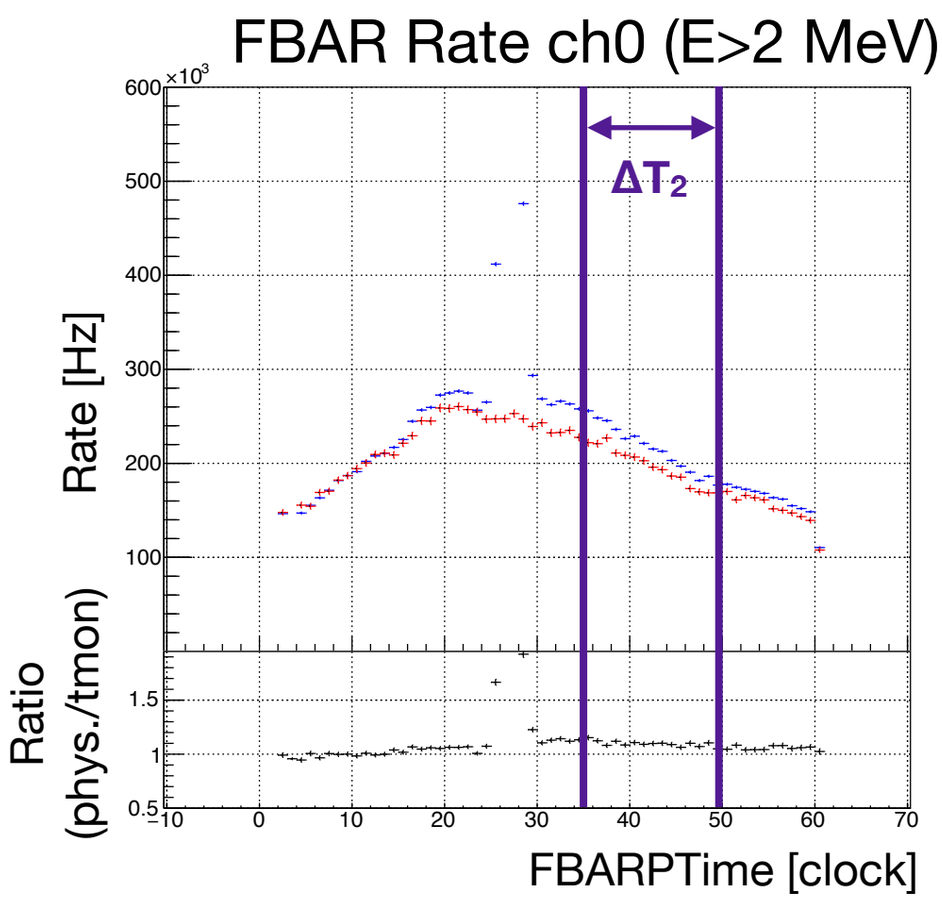
Rate = #events/(ΔT×#triggered)
ΔT = ΔT_1

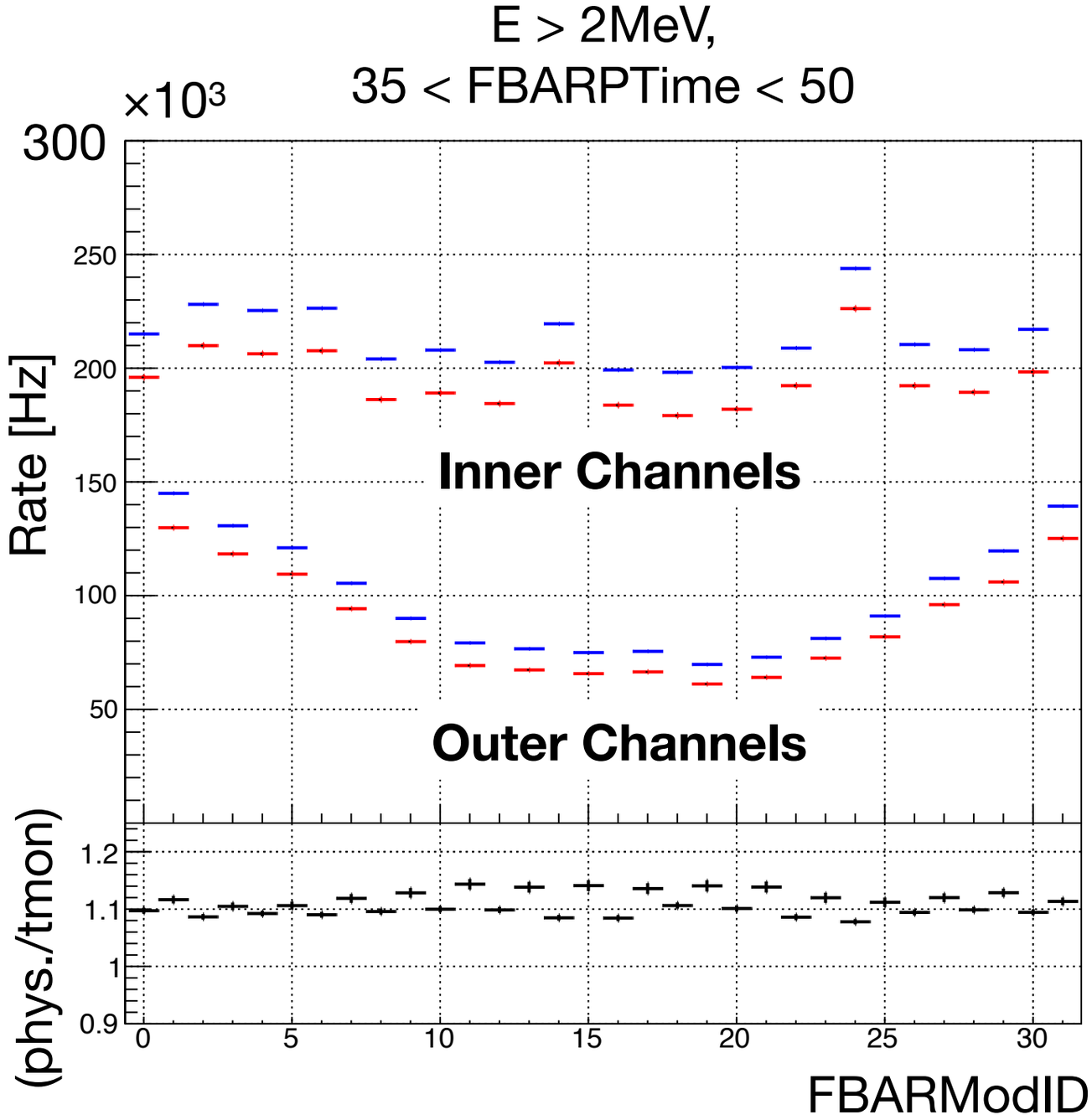
Ratio = Phys./TMON
= 1 ~ 1.1

→ Good agreement

– : Physics
– : TMON

Rates in 35 - 50 clock timing





Energy Threshold
FBAREne > 2MeV

Rate = #events/(ΔT×#triggered)
ΔT = ΔT_2

Ratio = Phys./TMON
= 1.1 ~ 1.2

→ A little bit worse than earlier timing

– : Physics

– : TMON