NEW DATA MEMBERS FOR RECOB::OPHIT

LArSoft Coordination Meeting

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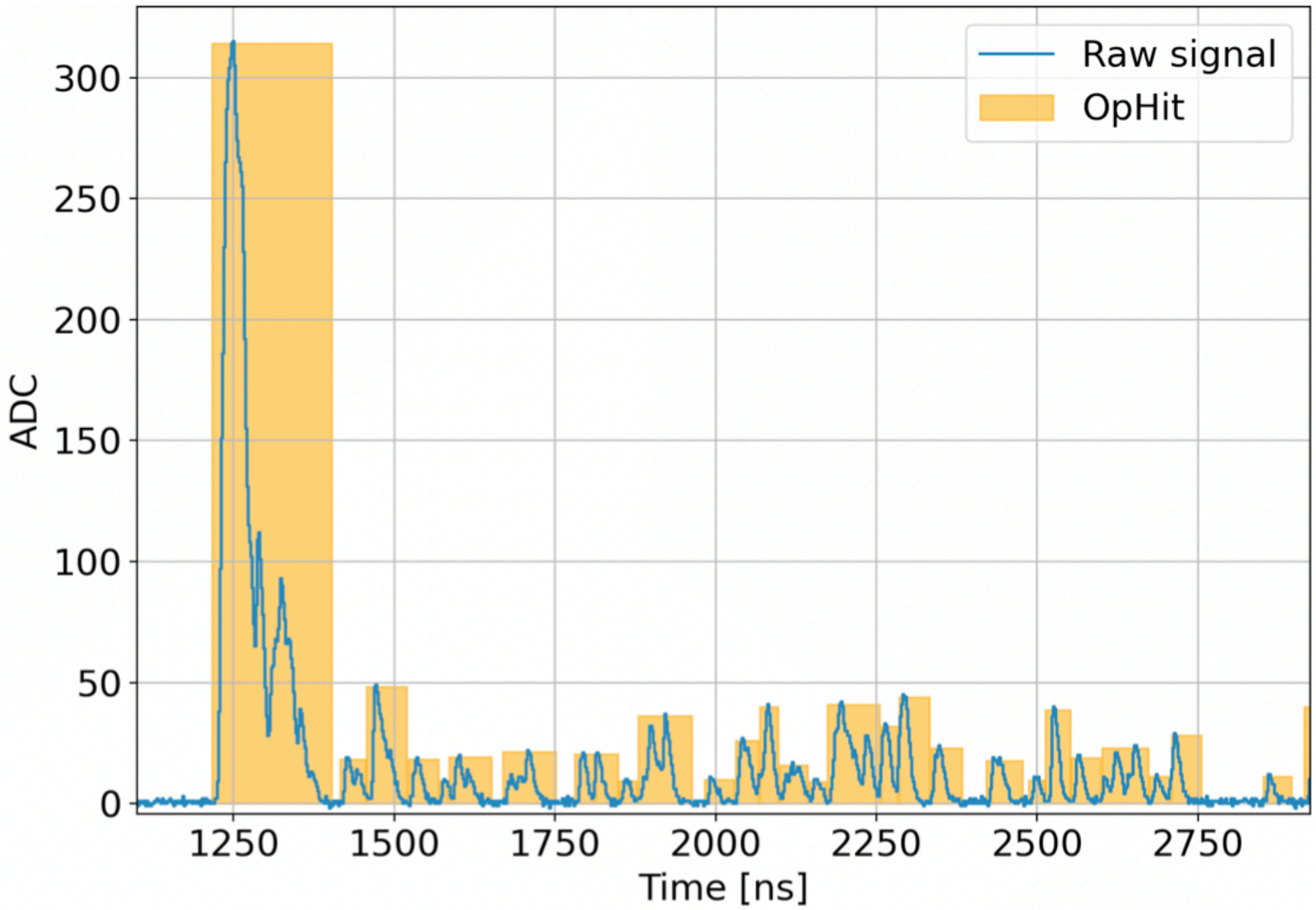
INTRODUCTION

- Standard reconstruction chain for a photon detector (PD):

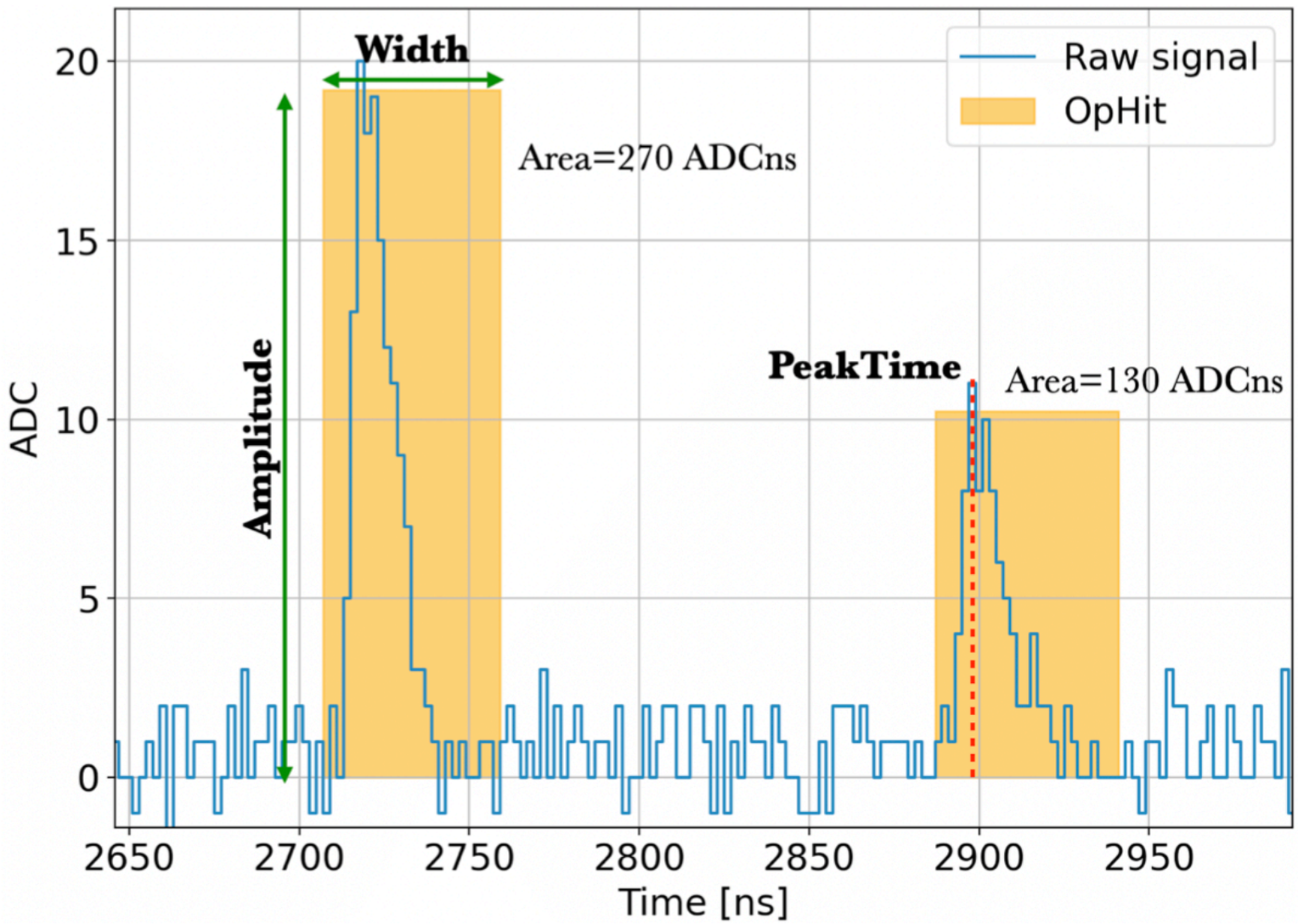


- Input: raw::**OpDetWaveform**
  - Baseline restoration
  - Pulse finder
- Output: recob::**OpHit**
  - PeakTime
  - Photoelectrons (PE)

- OpHits in time coincidence among different PDs: recob::**OpFlash**
  - Provides an absolute t_0 measurement

OPHIT DATA PRODUCT

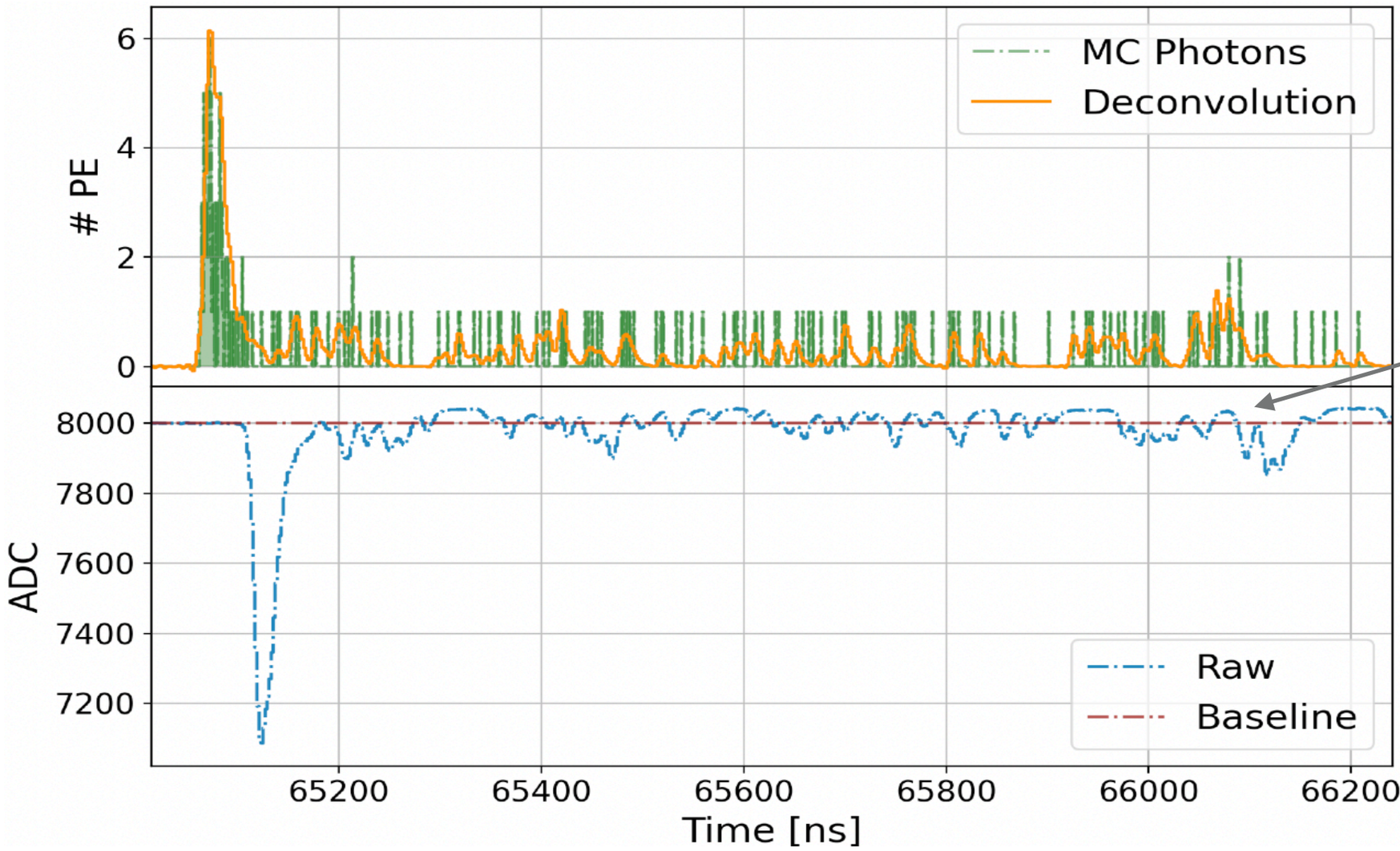
- OpHit data members:
  - Calorimetric: #PE
  - Timing: currently we only save the time slot in which the **waveform reaches its maximum value** (PeakTime)



int	**OpChannel** () const
double	**PeakTimeAbs** () const
double	**PeakTime** () const
unsigned short	**Frame** () const
double	**Width** () const
double	**Area** () const
double	**Amplitude** () const
double	**PE** () const
double	**FastToTotal** () const

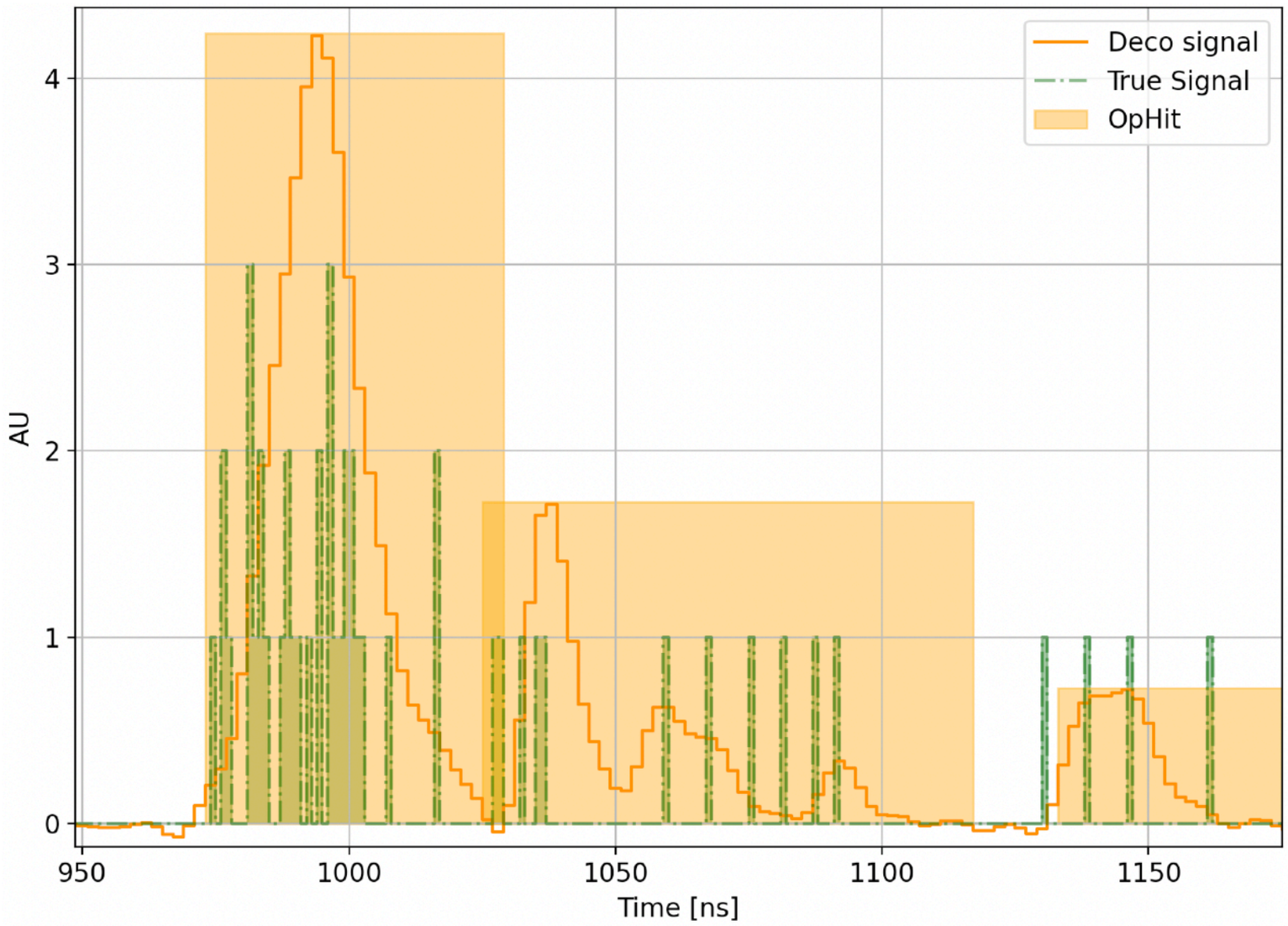
SBND CASE

- AC coupled readouts→SBND light waveforms are bipolar
  - Overshoot makes PD output charge estimation challenging
- SBND has been working on a **deconvolution-based signal processing** (both PMTs and XARAPUCAs)
  - Deconvolution applied before OpHit finder
- Topic already introduced in the LArSoft coordination meeting by R.Álvarez ("New data product proposal: recob::OpWaveform")



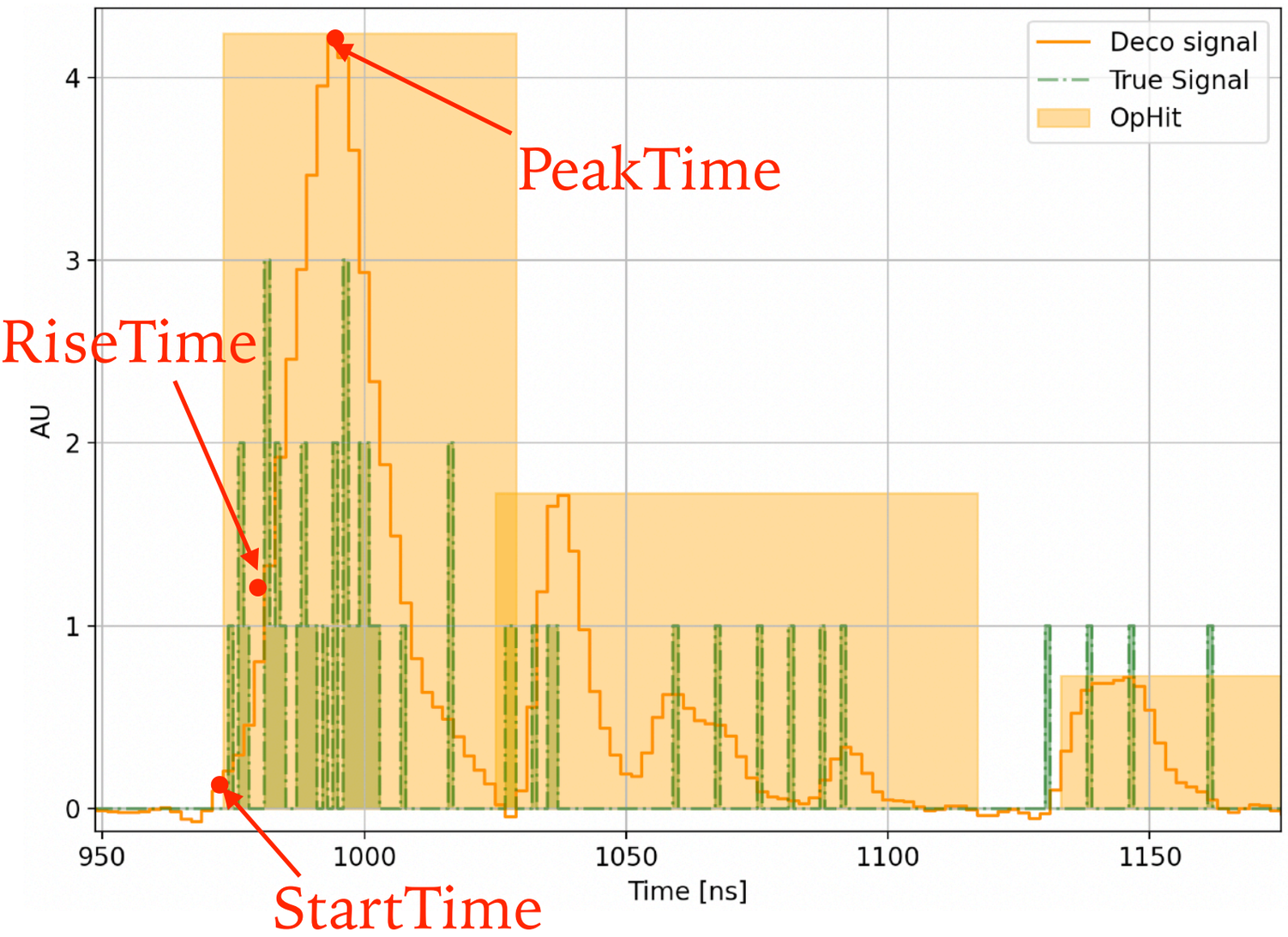
T0 MEASUREMENT

- Main application of the light signals in LAr thus far: **absolute t_0 measurement**
- However, the OpHit PeakTime does not represent well the **arrival time of the first photon** to the photon detector



- Particularly relevant for multiple PE signals (the <u>prompt light</u>)
- The shift depends on:
  - #PE
  - Signal shape

NEW DATA MEMBERS



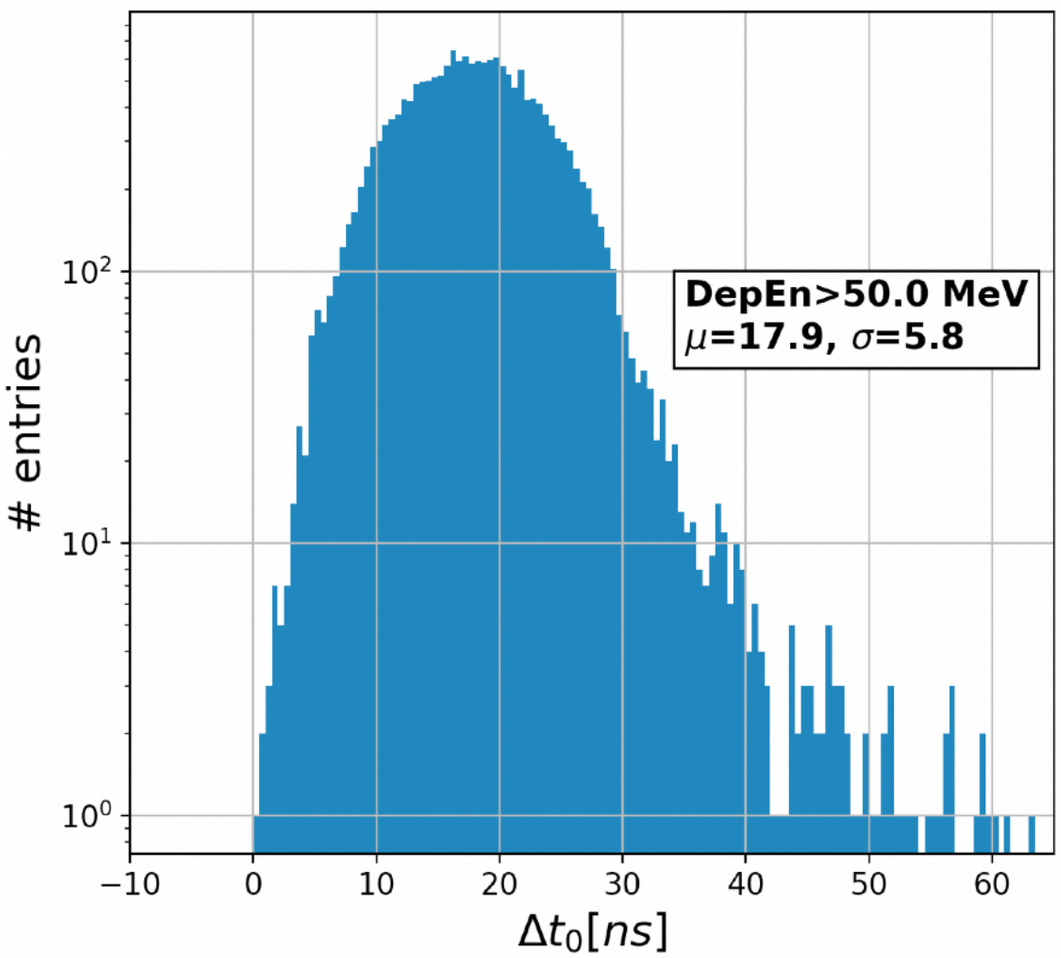
- New data members proposal:
  - **StartTime**
  - **RiseTime**
- Deconvolution introduces additional smearing:
  - OpHit start time would underestimate the t_0: rise time required

- The PeakTime can still be useful for different analysis:
  - Performs better (after deconvolution) for single PE OpHits
  - Scintillation signal time profile (PID)

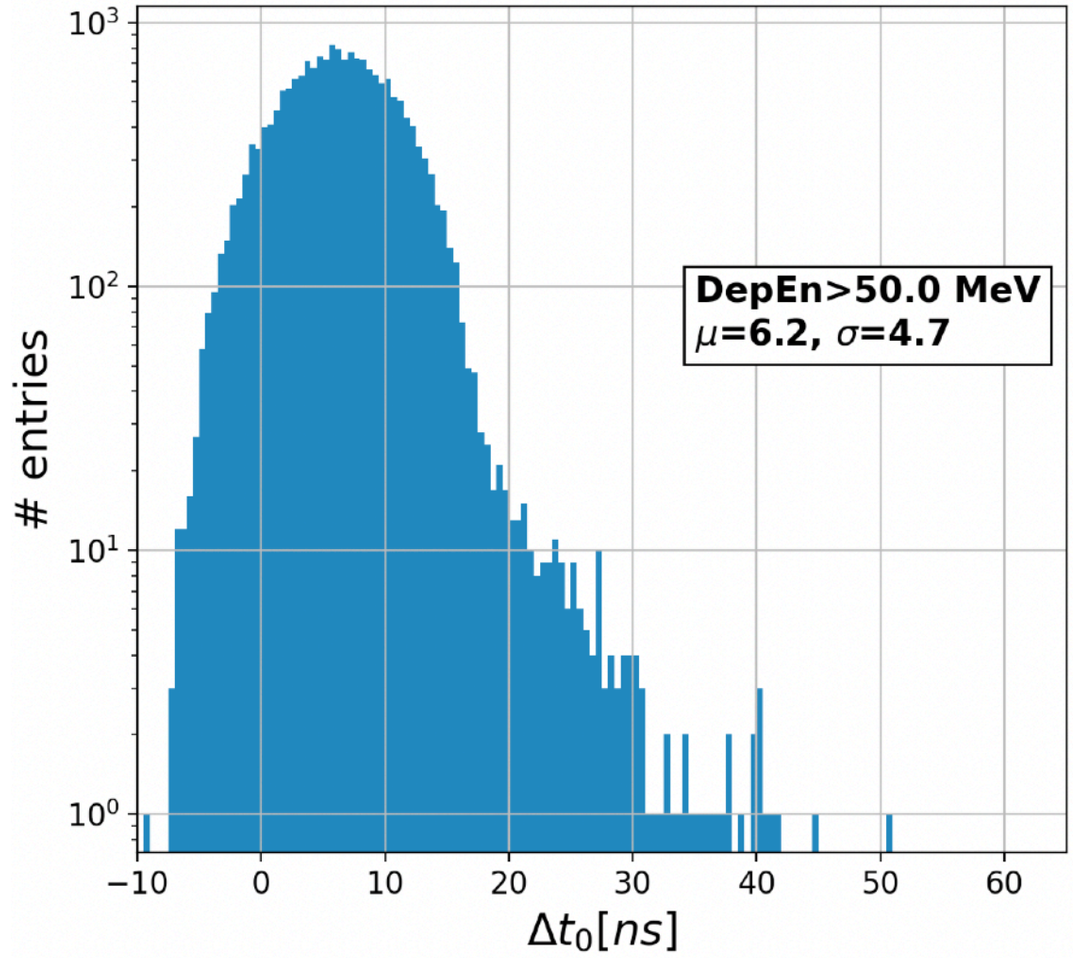
IMPROVED RESOLUTION

- Rise time approach + deconvolution tested in SBND (details in tech note SBN-doc-26422-v1):
- Time resolution for 20k ν events at OpFlash level ($\Delta t_0 = t_{OpFlash} - t_\nu$)
  - Reduces bias by 60%
  - Improves resolution by ~1 ns (~15%)

Default



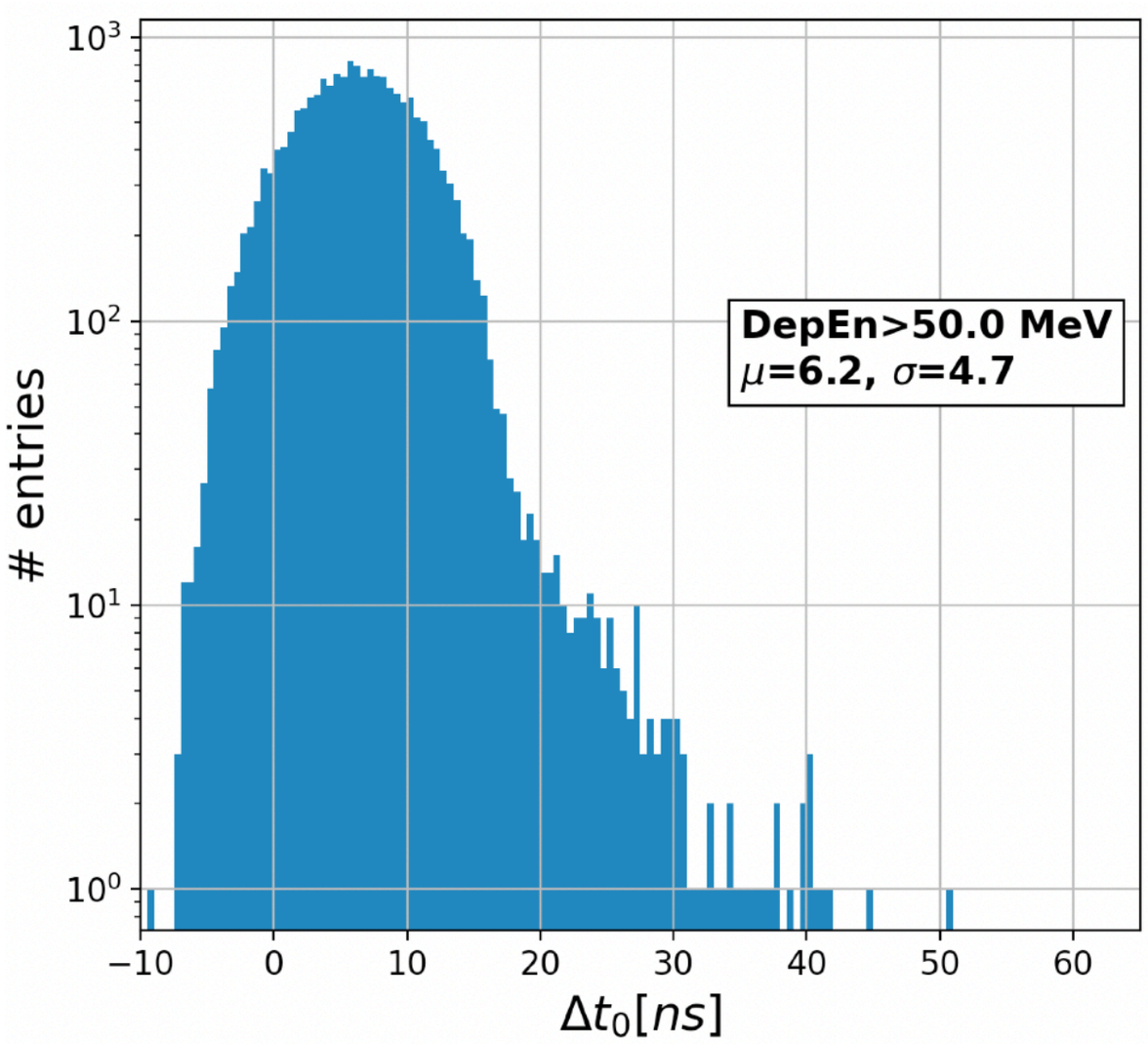
w RiseTime correction



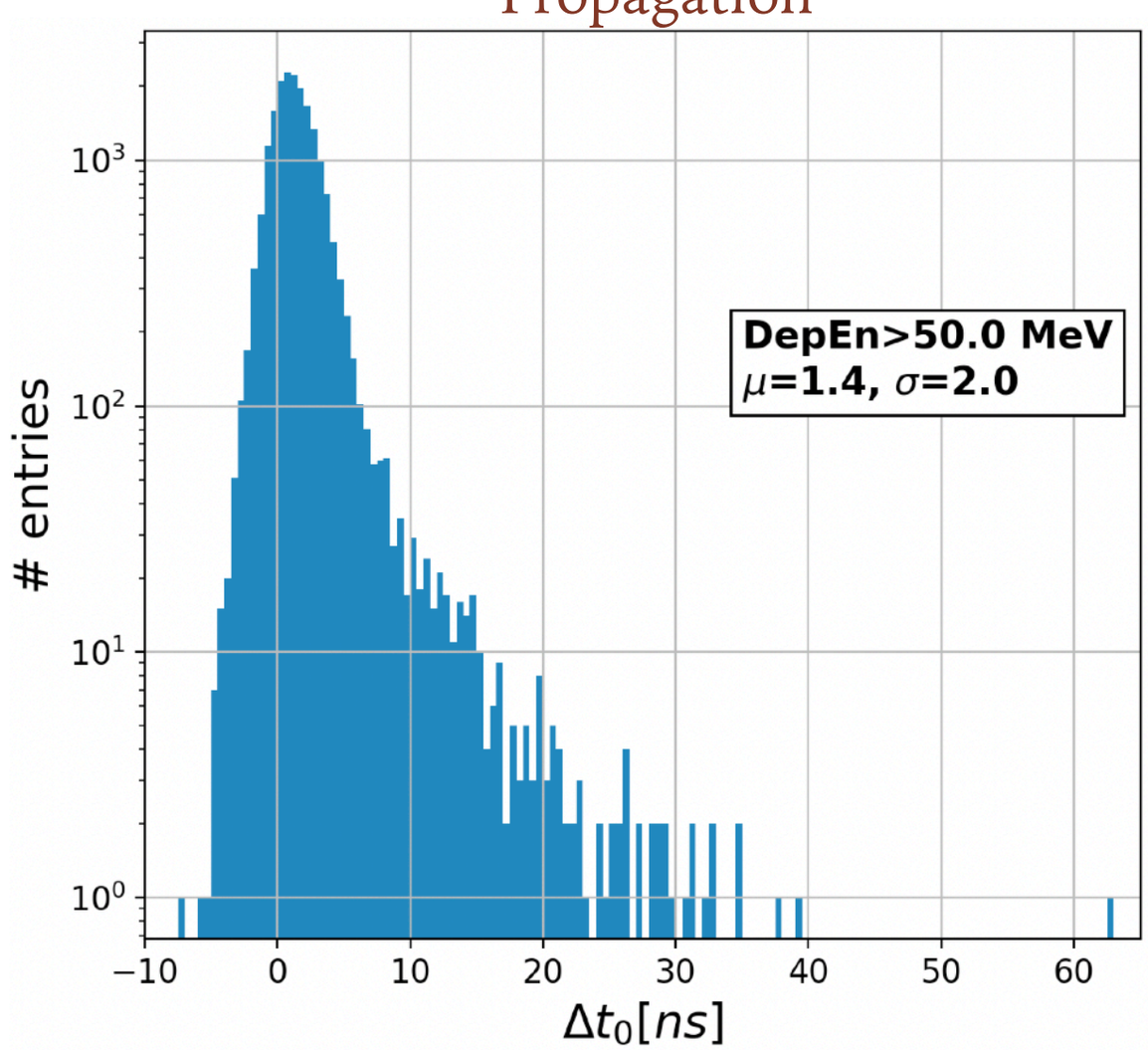
IMPROVED RESOLUTION

- A resolution **~2 ns** can be achieved **in combination with other reconstruction upgrades**:
  - At OpFlash level
  - Light propagation time
- Enables resolving the beam inner bucket structure: more efficient triggers

w Rise Time



w RiseTime+OpFlash+Light Propagation



PROPOSAL

- Feature branch feature/fnicolas_newophit (SBN fork)
- lardataobj/RecoBase/OpHit.h

4 new data members

```
25  private:
26
27        int                 fOpChannel;
28        unsigned short      fFrame;
29        double              fPeakTime;
30        double              fPeakTimeAbs;
31        double              fStartTime;
32        double              fStartTimeAbs;
33        double              fRiseTime;
34        double              fRiseTimeAbs;
35        double              fWidth;
36        double              fArea;
37        double              fAmplitude;
38        double              fPE;
39        double              fFastToTotal;
```

```
68        // Get Methods
69        int                 OpChannel()         const;
70        double              PeakTimeAbs()       const;
71        double              PeakTime()          const;
72        double              StartTime()          const;
73        double              StartTimeAbs()          const;
74        double              RiseTime()          const;
75        double              RiseTimeAbs()          const;
76        unsigned short      Frame()             const;
77        double              Width()             const;
78        double              Area()              const;
79        double              Amplitude()         const;
80        double              PE()                const;
81        double              FastToTotal()       const;
82        friend bool         operator <  (const OpHit & a, const OpHit & b);
```

2 constructors

```
42    public:
43
44        OpHit(int opchannel,
45              double peaktime,
46              double peaktimeabs,
47              double starttime,
48              double starttimeabs,
49              double risetime,
50              double risetimeabs,
51              unsigned short frame,
52              double width,
53              double area,
54              double peakheight,
55              double pe,
56              double fasttototal);
57
58        OpHit(int opchannel,
59              double peaktime,
60              double peaktimeabs,
61              unsigned short frame,
62              double width,
63              double area,
64              double peakheight,
65              double pe,
66              double fasttototal);
```

PROPOSAL

- lardataobj/RecoBase/OpHit.cxx

```
64    //---------------------------------------------------------------------
65    OpHit::OpHit(int opchannel,
66           double peaktime,
67           double peaktimeabs,
68           unsigned short frame,
69           double width,
70           double area,
71           double amplitude,
72           double pe,
73           double fasttototal)
74        : OpHit{
75            opchannel, peaktime, peaktimeabs,
76            DefaultTime, DefaultTime, DefaultTime, DefaultTime,
77            frame, width, area, amplitude, pe, fasttototal
78          }
79        {}
```

```
33    //---------------------------------------------------------------------
34    OpHit::OpHit(int opchannel,
35                 double peaktime,
36                 double peaktimeabs,
37                 double starttime,
38                 double starttimeabs,
39                 double risetime,
40                 double risetimeabs,
41                 unsigned short frame,
42                 double width,
43                 double area,
44                 double amplitude,
45                 double pe,
46                 double fasttototal)
47       : fOpChannel     (opchannel     )
48       , fFrame         (frame         )
49       , fPeakTime      (peaktime      )
50       , fPeakTimeAbs   (peaktimeabs   )
51       , fStartTime     (starttime     )
52       , fStartTimeAbs  (starttimeabs  )
53       , fRiseTime      (risetime      )
54       , fRiseTimeAbs   (risetimeabs   )
55       , fWidth         (width         )
56       , fArea          (area          )
57       , fAmplitude     (amplitude     )
58       , fPE            (pe            )
59       , fFastToTotal   (fasttototal   )
60    {
61
62    }
```

```
static constexpr double DefaultTime = std::numeric_limits<double>::max();
```

SUMMARY

- SBND has a unique Photon Detection System:
  - A resolution ~2 ns can be achieved
  - We need to save additional information in the OpHit product
- The light information that is usually stored in the artroot events is very limited
  - *e.g.* waveforms typically drop for large scale productions
  - It can be also useful for other LAr experiments to store more details about the timing of the light pulses