PDS and stability studies

ProtoDUNE DRA light

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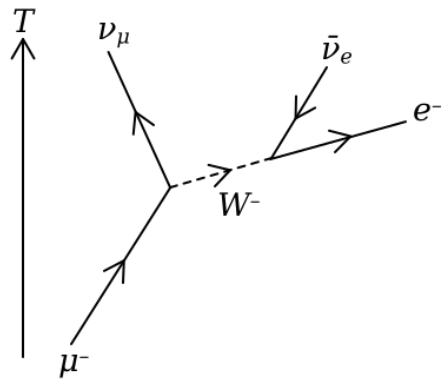
Summary.

Objective: Analysis of the NP04 runs performed with only PDS data.

- Cosmic Ray Analyses:
  - Stopping Muons
- Light Analyses:
  - Pulse Shape Discrimination
  - Light Rate - PDS stability

Cosmic Ray: Stopping muons

Cosmic muons with energy lower than ~1.2 GeV should decay inside NP04*.



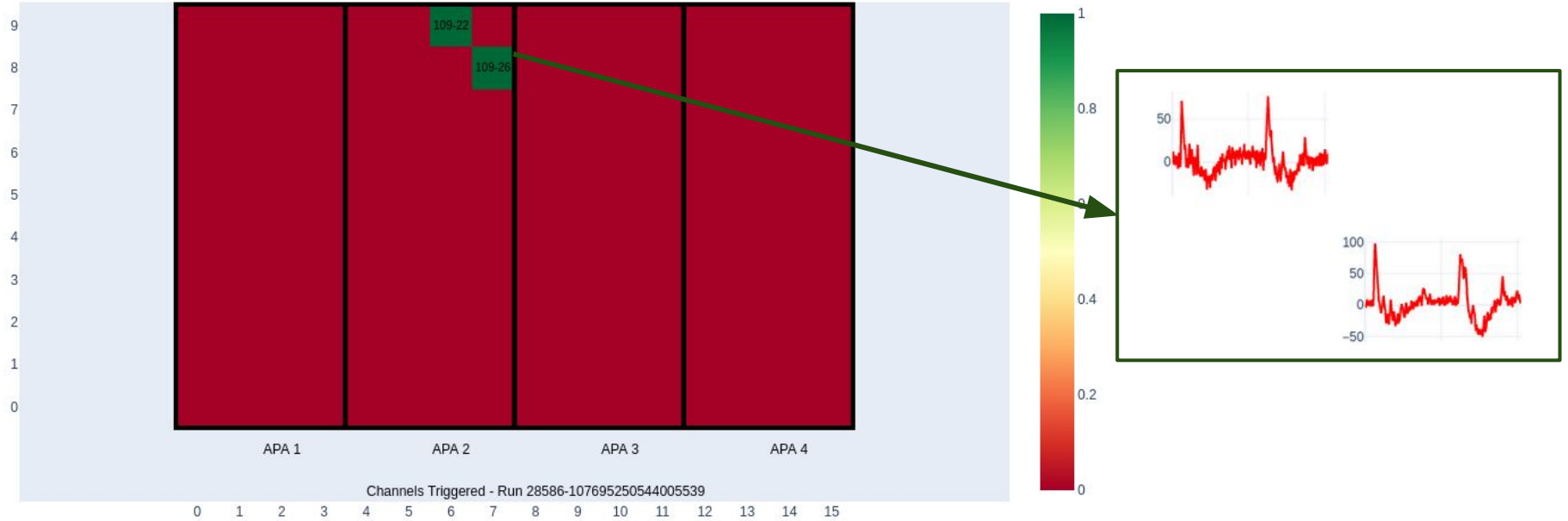
Candidates selection:

- Coincident events in different channels (same timestamp);
- The event in each channel should have, at least two peaks in 1024 ticks;
- Different conditions were applied to select the events according with the prominence of the peaks, but the amplitude of the main peak should be always greater than 50 ADCs;
    - Prominence conditions: 50 ADCs and half of the amplitude of the main peak.

* Considering a vertical muon with stopping power about 2 MeV/cm in liquid argon .

Cosmic Ray: Stopping muons

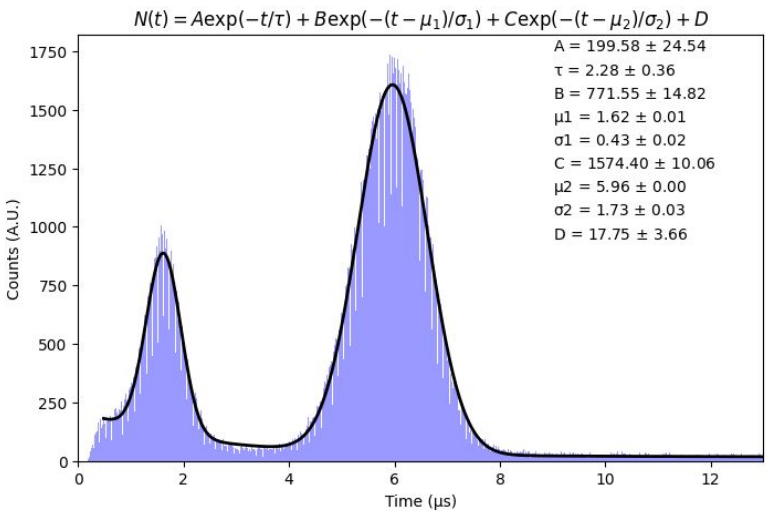
Example of a candidates - run 28586:



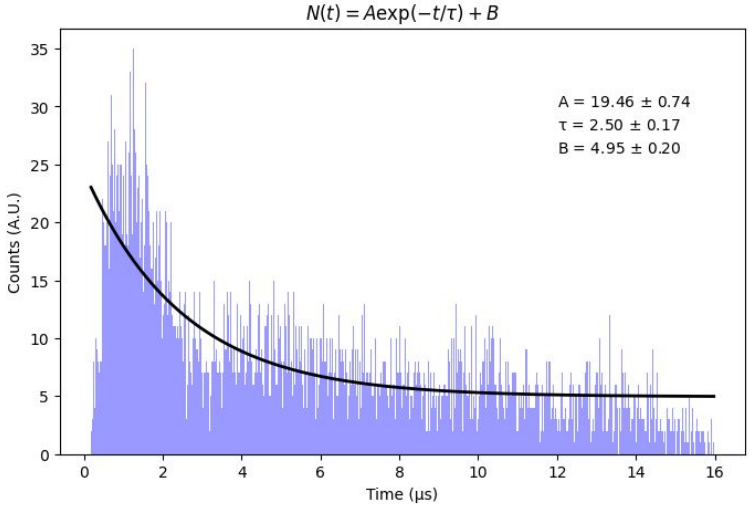
Cosmic Ray: Stopping muons

Preliminary Results:

Prominence: 50

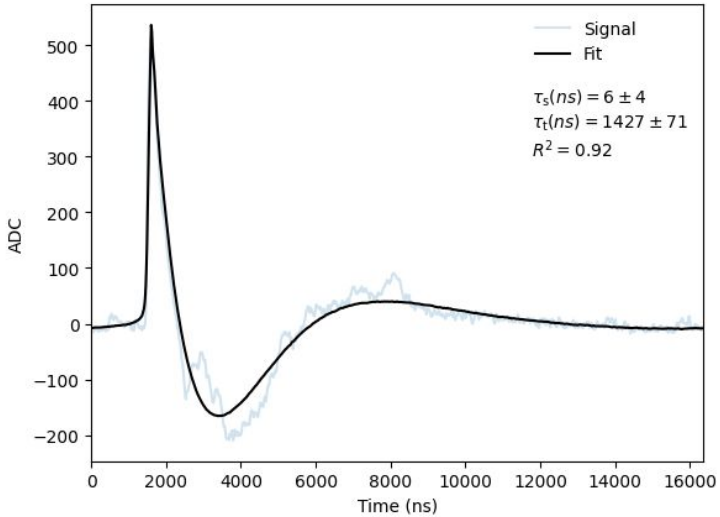


Prominence: Half of the main peak

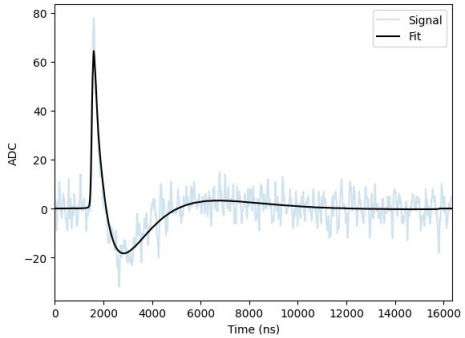


Light Analyses

The scintillation light information is being calculated by convolving the SPE template and the scintillation profile:



However some unknown light source with just the fast component was observed in many runs:




```
A_s = 4.232853250913637 +- 0.8063134274721051
A_t = 4.35289253242026e-15 +- 0.0025821639528243122
tau_s_guess = 6.455716237181523 +- 5.481077525188305
tau_t_guess = 1764.6839415691134 +- 0.0
offset = 0.04204609509411753 +- 0.03300249680956852
 R² = 0.7835647085670956
```

Apparently, there is a correlation between the rate of those signals and the SiPM type.

Light Analyses: Unknown Signals

APA3

Module	Channels	SiPM	WLS	Rate (Hz)
1	1, 3, 4, 6	FBK	ELJ	368 ± 46
2	36, 24, 33, 31	HPK	ELJ	144 ± 21
3	0, 2, 5, 7	FBK	G2P	686 ± 100
4	37, 35, 32, 30	HPK	ELJ	146 ± 19
5	41, 43, 44, 46	HPK	G2P	228 ± 45
6	16, 14, 13, 11	FBK	G2P	961 ± 145
7	10, 12, 15, 17	FBK	ELJ	422 ± 46
8	26, 24, 23, 21	FBK	G2P	515 ± 87
9	40, 42, 45, 47	HPK	G2P	99 ± 27
10	27, 25, 22, 20	FBK	G2P	751 ± 113

FBK + G2P > FBK + ELJ

HPK + G2P ~ HPK + ELJ

ELJ + FBK > ELJ + HPK

G2P + FBK > G2P + HPK

FBK produces more unkonwn signals

APA4

Module	Channels	SiPM	WLS	Rate (Hz)
1	0, 2, 5, 7	HPK	G2P	223 ± 48
2	6, 4, 3, 1	HPK	G2P	301 ± 57
3	10, 12, 15, 17	HPK	ELJ	153 ± 13
4	16, 14, 13	HPK	ELJ	181 ± 83
5	0, 2, 5, 7	FBK	G2P	- ± -
6	27, 25, 22, 20	HPK	G2P	- ± -
7	21, 23, 24, 26	HPK	ELJ	397 ± 90
8	37, 35, 32, 30	HPK	ELJ	254 ± 55
9	31, 33, 34, 36	HPK	G2P	254 ± 49
10	47, 45, 42, 40	HPK	G2P	213 ± 44

HPK + G2P ~ HPK + ELJ

Light Analyses: Pulse Shape Discrimination

Method:

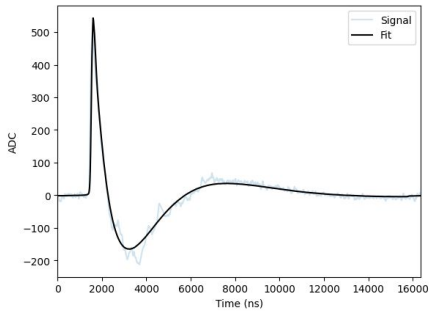
- Apply the convolution;
- Remove the unknown signals;
- Compute the ratio between the number from photons the fast and the slow components (If / Is).

$$I(t) = I_f(t) + I_s(t) = A \cdot e^{-\frac{t}{\tau_f}} + B \cdot e^{-\frac{t}{\tau_s}}$$

Particle	τ_f (nsec)	τ_s (nsec)	I_f/I_s	Reference
Electrons	6.3 ± 0.2	1020 ± 60	0.083	[62]
	4.6	1540	0.26	[63]
	4.18 ± 0.2	1000 ± 95		[64]
		1110 ± 50		[65]
	$\mathbf{6 \pm 2}$	$\mathbf{1590 \pm 100}$	**0.3**	[66]
α	~ 5	1200 ± 100		[62]
	4.4	1100	3.3	[63]
	$\mathbf{7.1 \pm 1.0}$	$\mathbf{1660 \pm 100}$	**1.3**	[66]
Fission Fragments	$\mathbf{6.8 \pm 1.0}$	$\mathbf{1550 \pm 100}$	**3**	[66]

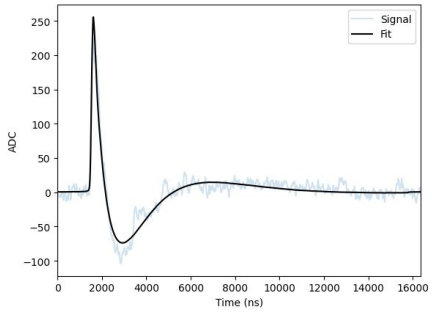
SEGRETO, E. . Analysis and Simulation of events with scintillation light emission from the ICARUS T600 LAr detector., 2006

Signals on run 28094:



MIP

```
A_s = 33.85000858641664 +- 3.6072224517636164
A_t = 0.45738547261489015 +- 0.020006662084654903
tau_s_guess = 6.005913587281838 +- 3.3062333581248993
tau_t_guess = 1240.765688947452 +- 79.64702640697277
offset = -0.07245344008418289 +- 0.14080963997570914
 R² = 0.9498676921269975
Is/It = 0.3582331076888849 +- 0.20278531047474027
N photons = 770.8084275423367 +- 122.22056198009781
```



ALPHA (?)

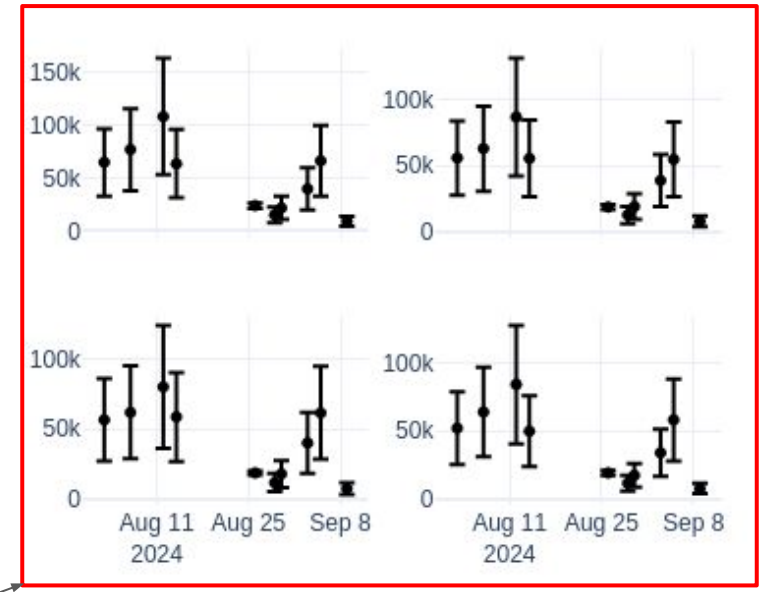
```
A_s = 12.056794321848725 +- 0.9823662610176888
A_t = 0.0549556083354102 +- 0.013286036639796545
tau_s_guess = 14.999999972119975 +- 2.3176600350705576
tau_t_guess = 1000.000000000539 +- 307.0091987260561
offset = 0.4428077117705384 +- 0.07281708972398743
 R² = 0.927468916547693
Is/It = 3.2908727602048797 +- 1.4086108692006793
N photons = 235.80752282702696 +- 38.1988978753648
```

Light Analyses: PDS Stability

- **Objective**: verify the effects of time on the PSD output based on the photon rate of different 1 GeV beam events.
- **Methods**:
  - Select the fragments of the HDF5 files that have just beam events by looking the TC (trigger candidates);
  - Apply the convolution and remove the unknown signal;
  - Integrate the scintillation profile to estimate the number of photons;
  - Compute the mean photon rate detection.
- For each run, only the 18 initial hdf5 files were selected.
- **Challenges**:
  - Many changes have been made to the PDS setup: BIAs, firmware modification, trigger…
  - Modifications on the DAQ triggering system: At the end of August, only pions triggered the DAQ system in 1 GeV events, unlike what happened before.

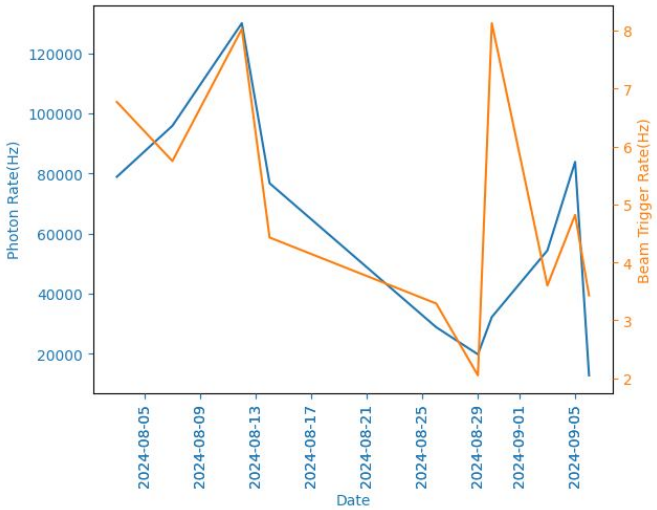
Light Analyses: PDS Stability

- Preliminary results with overestimated errors.

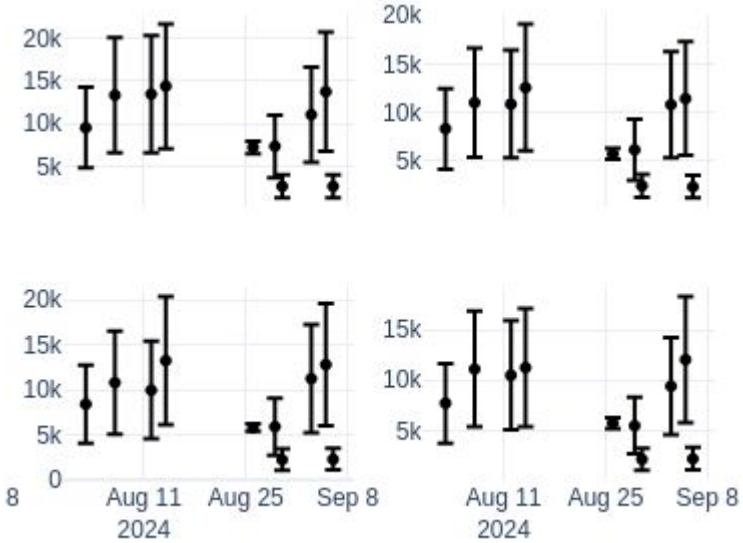


Light Analyses: PDS Stability

- Influence of the beam trigger rate (?):



- Normalizing for 1Hz beam rate:



Next Steps

- The TPC data must now be checked to validate the stopping muon results and make particle selection for the stability analysis.

- The script for the PSD has being upgraded and now runs with different energies will be analysed.