Pileup rejection in Run 8 data

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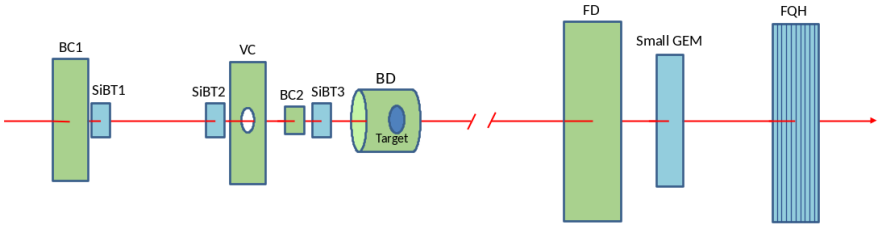
Aim

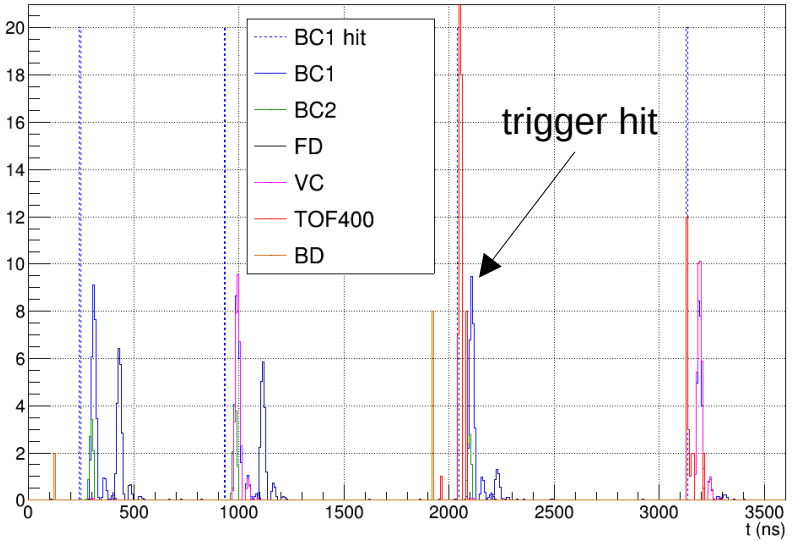
- Study frequency and effect of
  - Close pileup (narrow window around mean trigger time)
  - Distant pileup
- Develop a BmnRoot task providing the information about pileup events (distance to closest hits in BC1, probability of second interaction, etc.)
- Data: Xe+CsI @ 3.8A GeV (production 12.24)

Report on close pileup at previous CM

Analysis procedure

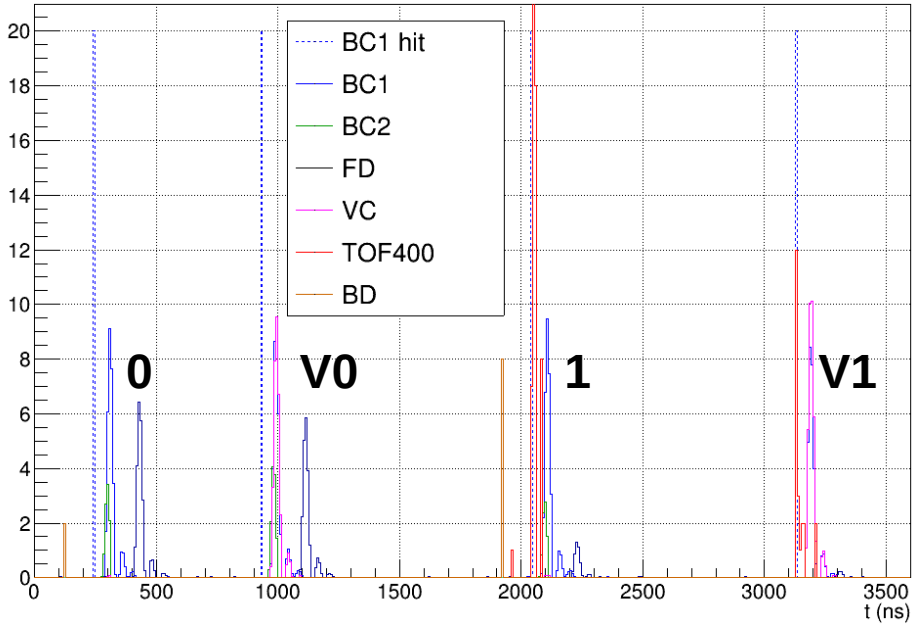
- Define run-by-run trigger hit window
- Define run-by-run time windows for peak search in VC, BC2 and FD (relative to BC1 hit time)
- Collect run-by-run distributions of single VC, BC2 peaks and FD peaks outside of the trigger window (mostly Xe)





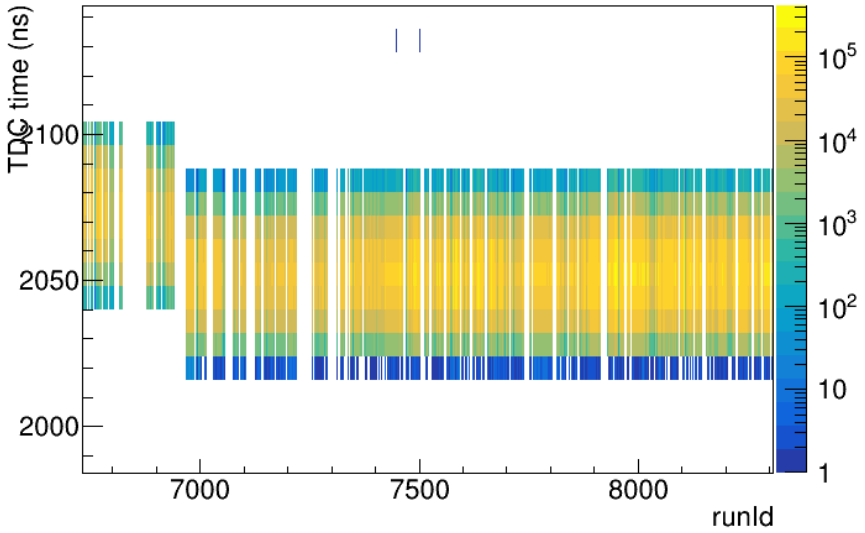
Analysis procedure

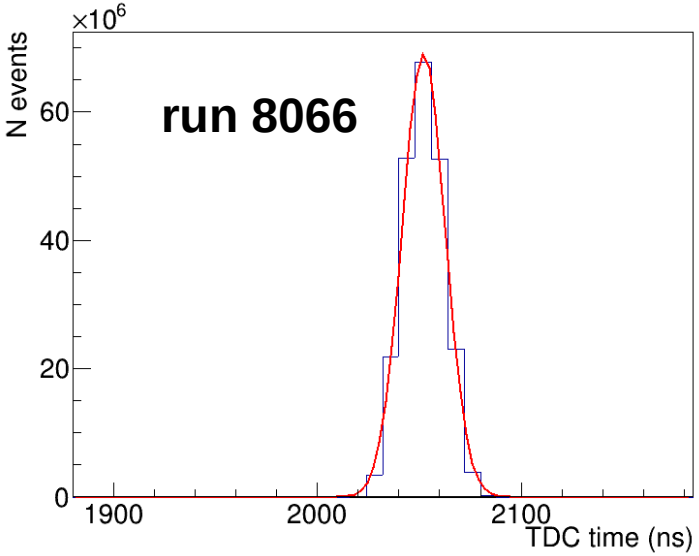
- For every hit in BC1S define the type based on corresponding peaks in VC, BC2 and FD:
  - No interaction (**0**) – high FD
  - Interaction (**1**) – low FD
  - No interaction + veto (**V0**) – high FD + high VC or low BC2
  - Interaction + veto (**V1**) – high FD + high VC or low BC2



- Estimate the effect of pileup on digitized and reconstructed data from “fast” (TOF400, TOF700) and “slow” (SILICON, GEM) detectors

Single BC1S hit time

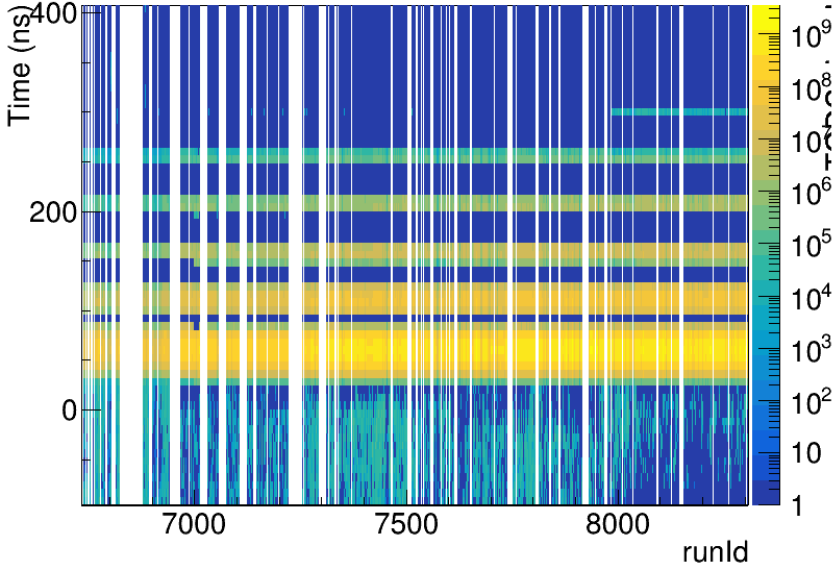


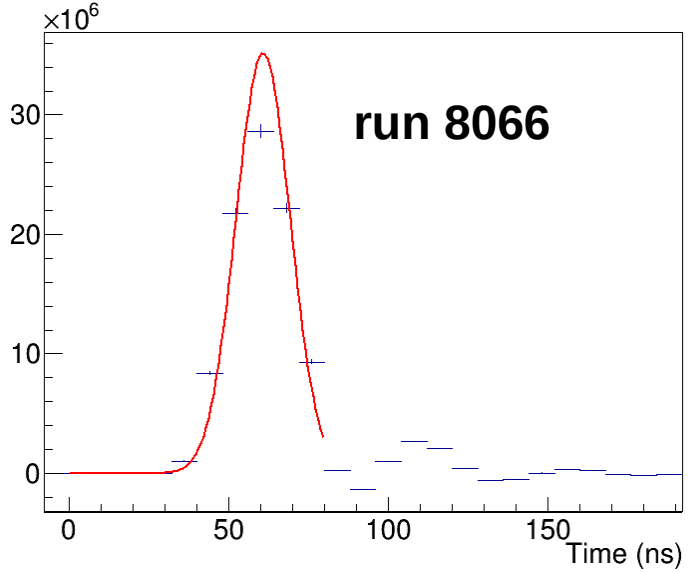


Class **1** hit closest to mean is considered to be the trigger one

Signal shape relative to single BC1S hit time

VCS

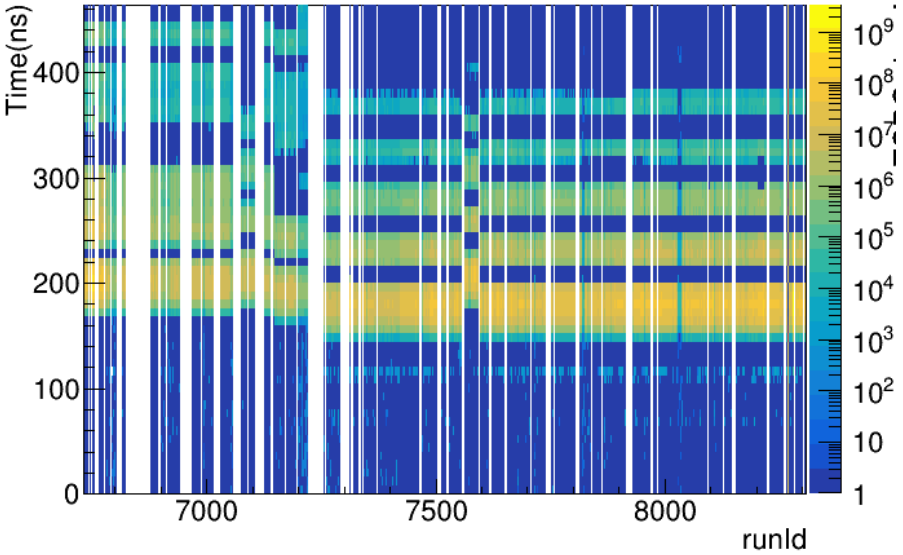


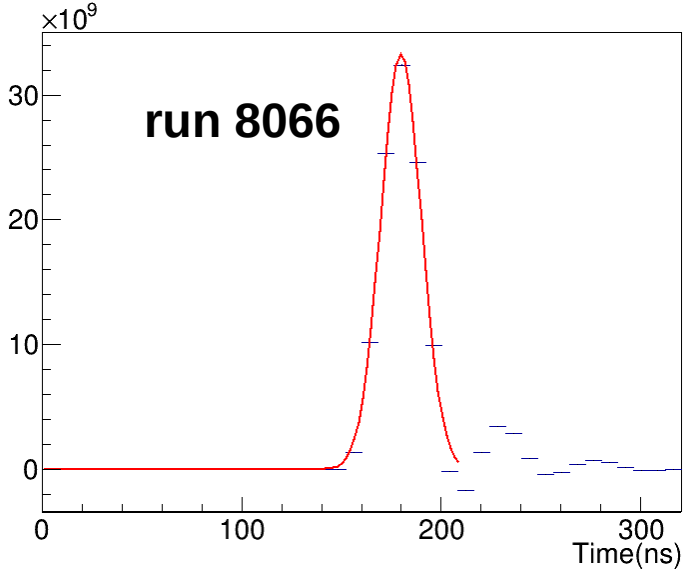


Peak is collected in mean +/- 2 sigma time from BC1S hit time

Signal shape relative to single BC1S hit time

FD

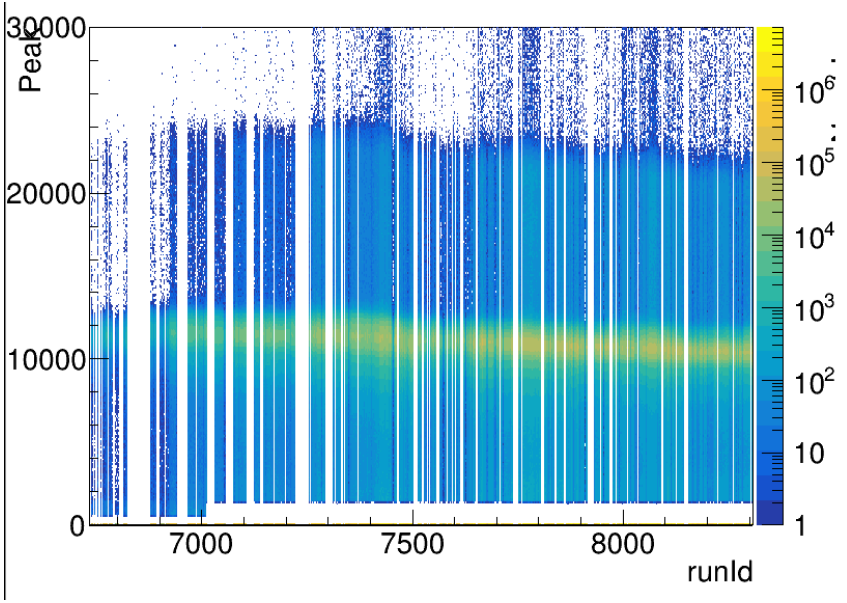


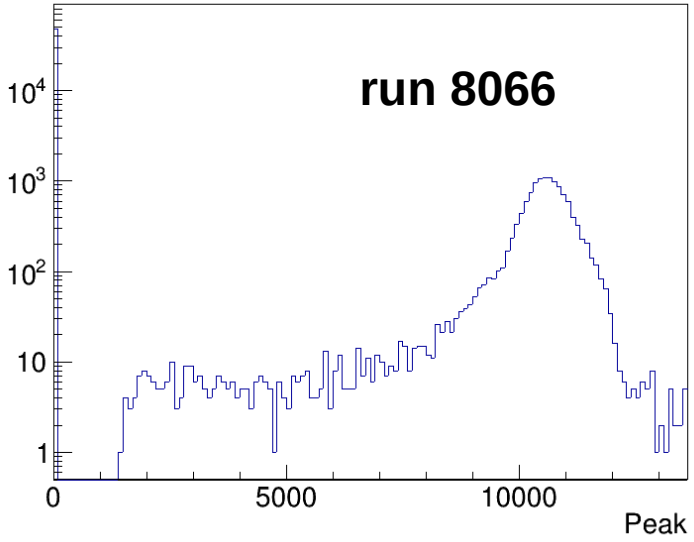


Peak is collected in mean +/- 2 sigma time from BC1S hit time

Peak distributions

VCS

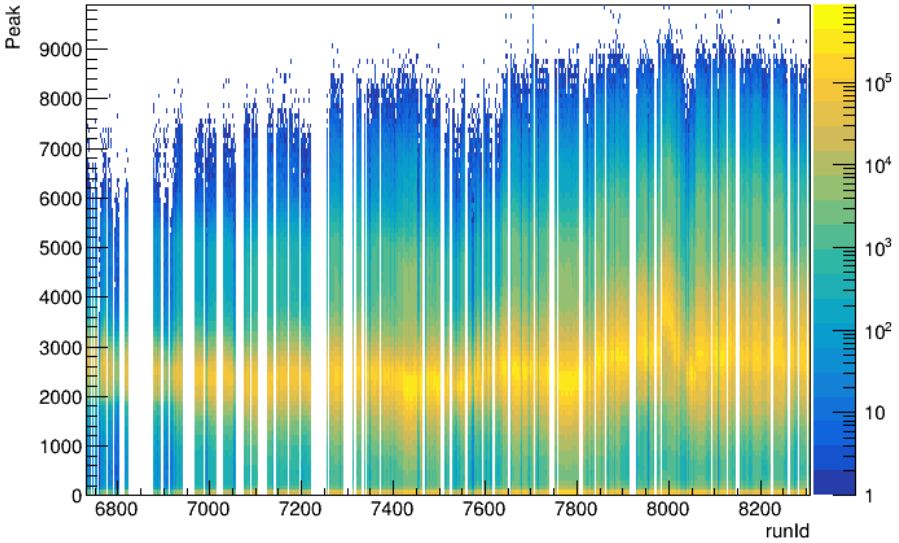


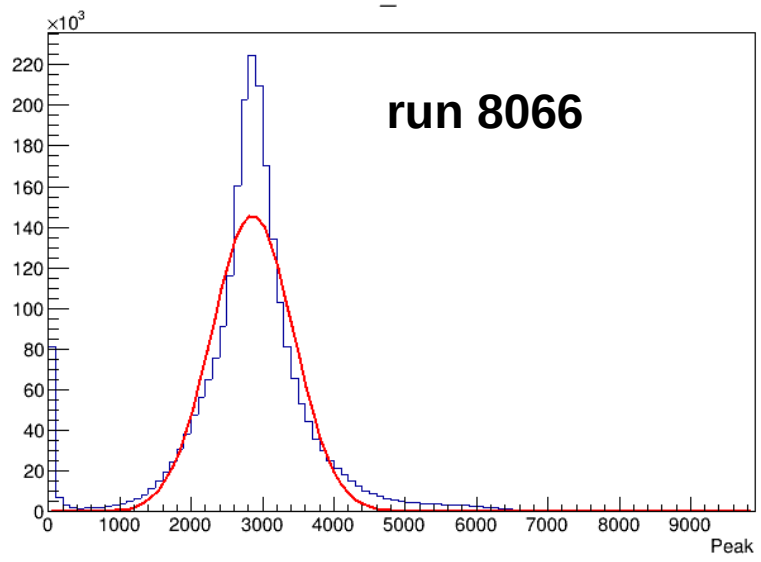


Peak less than 500 is considered as absense of veto signal

Peak distributions

BC2

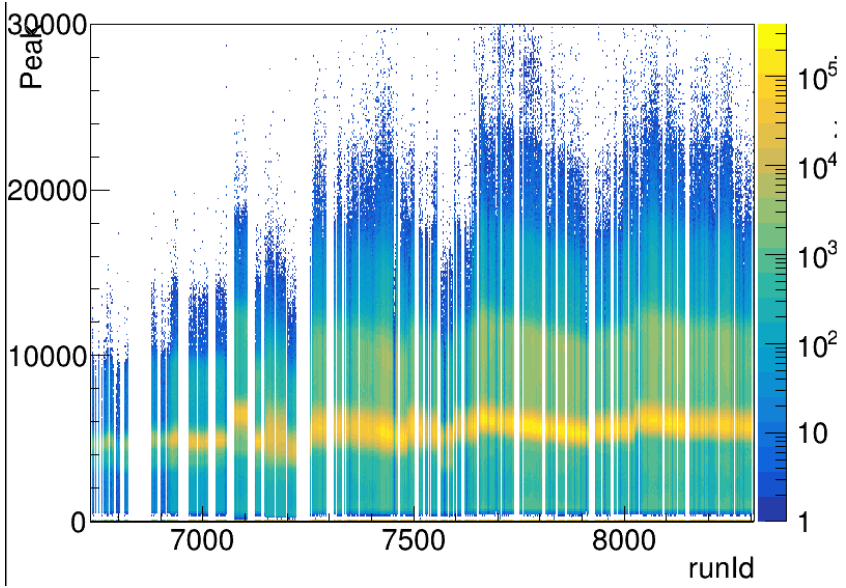


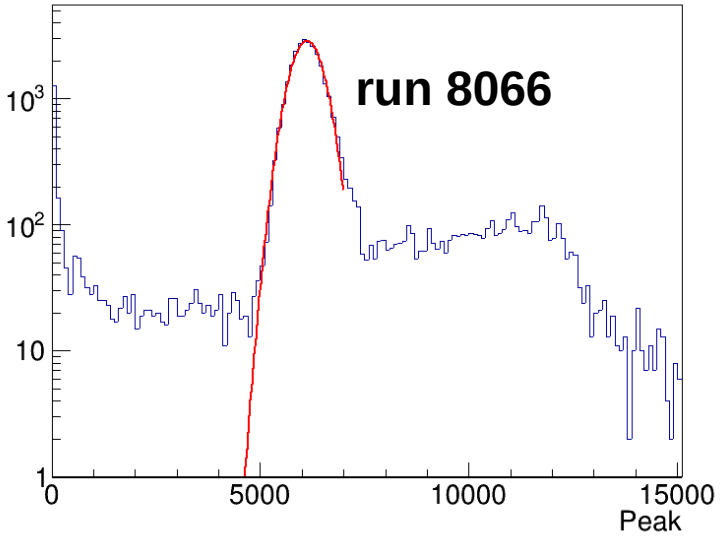


Veto if peak is less than mean - 3 sigma

Peak distributions

FD (non-trigger hits)

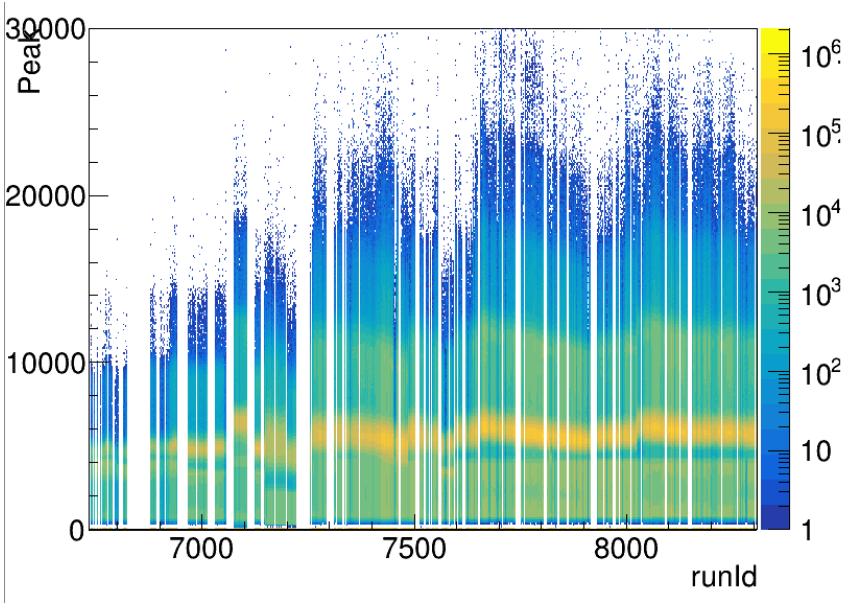


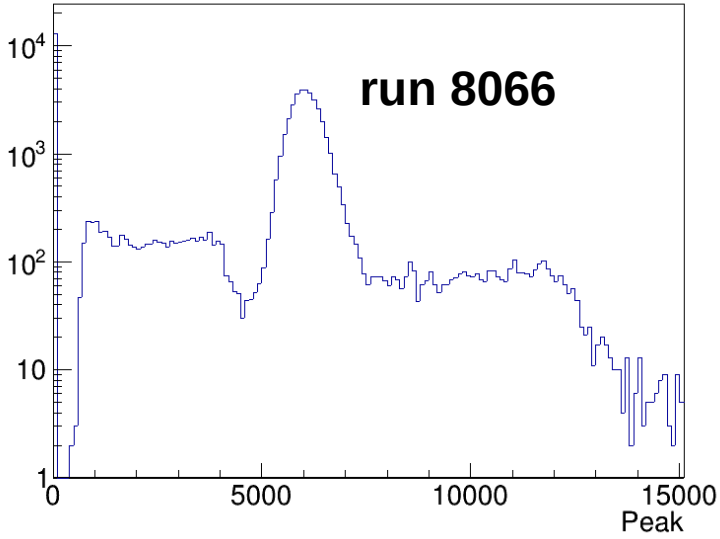


Interaction if peak is less than mean - 3 sigma

Peak distributions

FD (all hits)

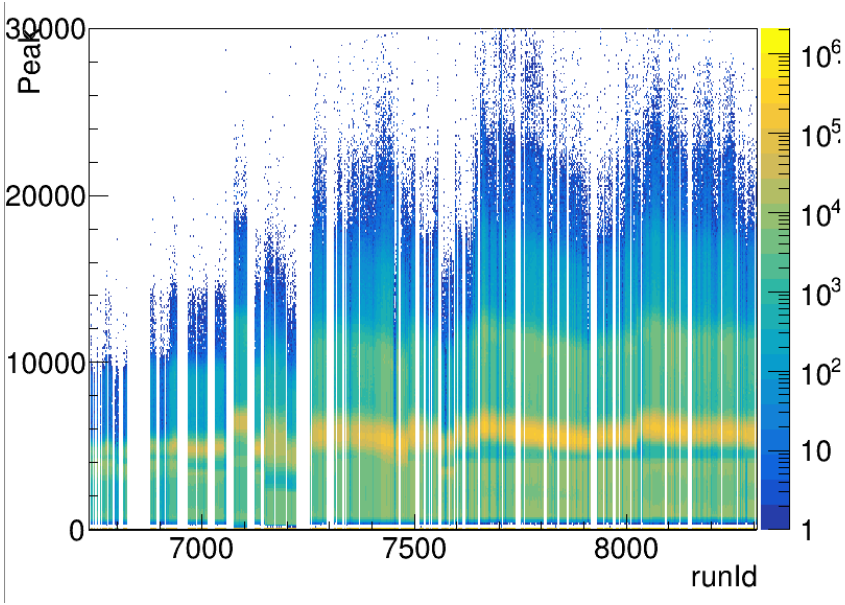


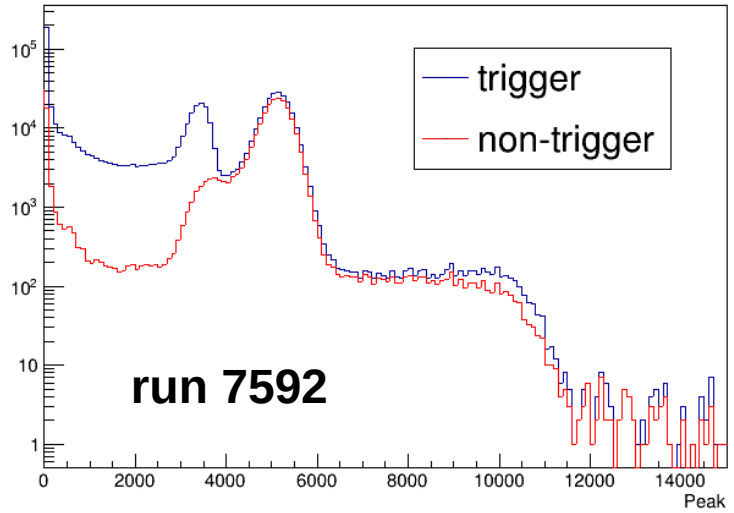


Interaction if peak is less than mean - 3 sigma

Peak distributions

FD (runs before 7596)





Additional peak at interation region

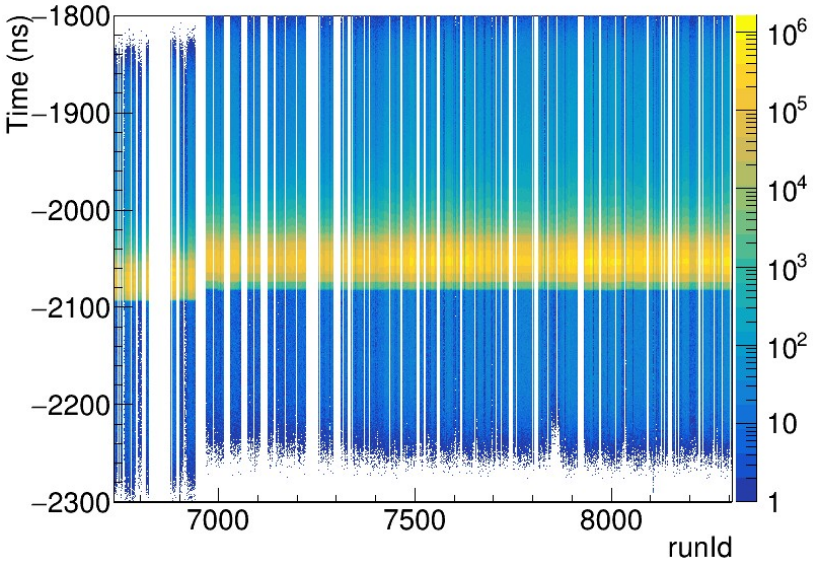
Effect of pileup at digitized data level

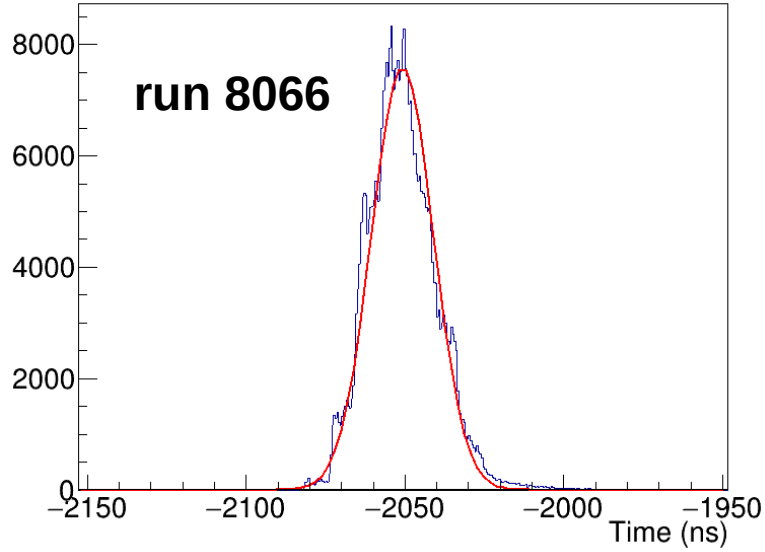
- Choose events with 2 hits in BC1 (runs 7596-8304)
- Define trigger hit as closest interaction to mean time for single BC1 events.
- For different event types plot mean number of digits/hits/tracks as a function of distance from additional to trigger hit for:
  - “Fast” detectors (TOF400, TOF700)*.
  - “Slow” detectors (SILICON, GEM)
- Compare the values with those for events with single hit in BC1.

* TOF digits and hits are counted in a defined (run-by-run) window relative to BC1 hit time

Digit time distributions

TOF700

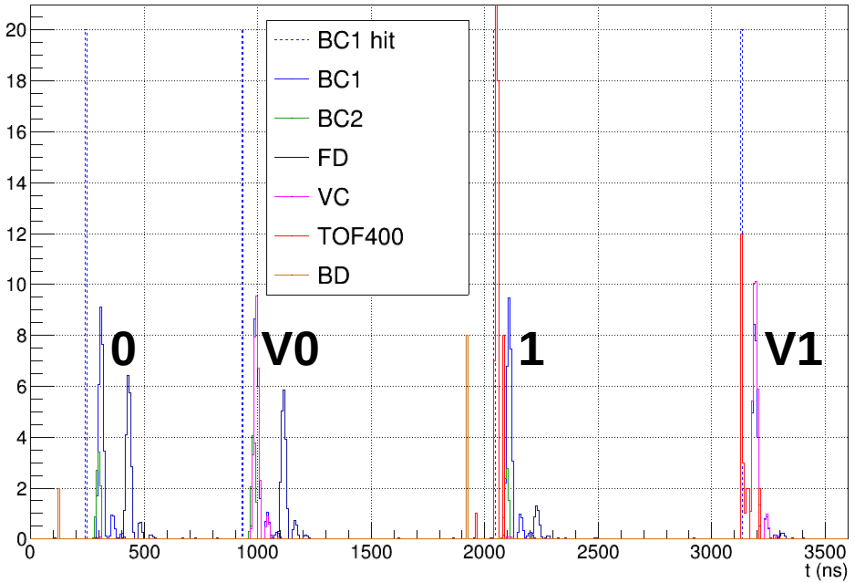




TOF digits and hits are collected in mean +/- 3 sigma time from trigger hit

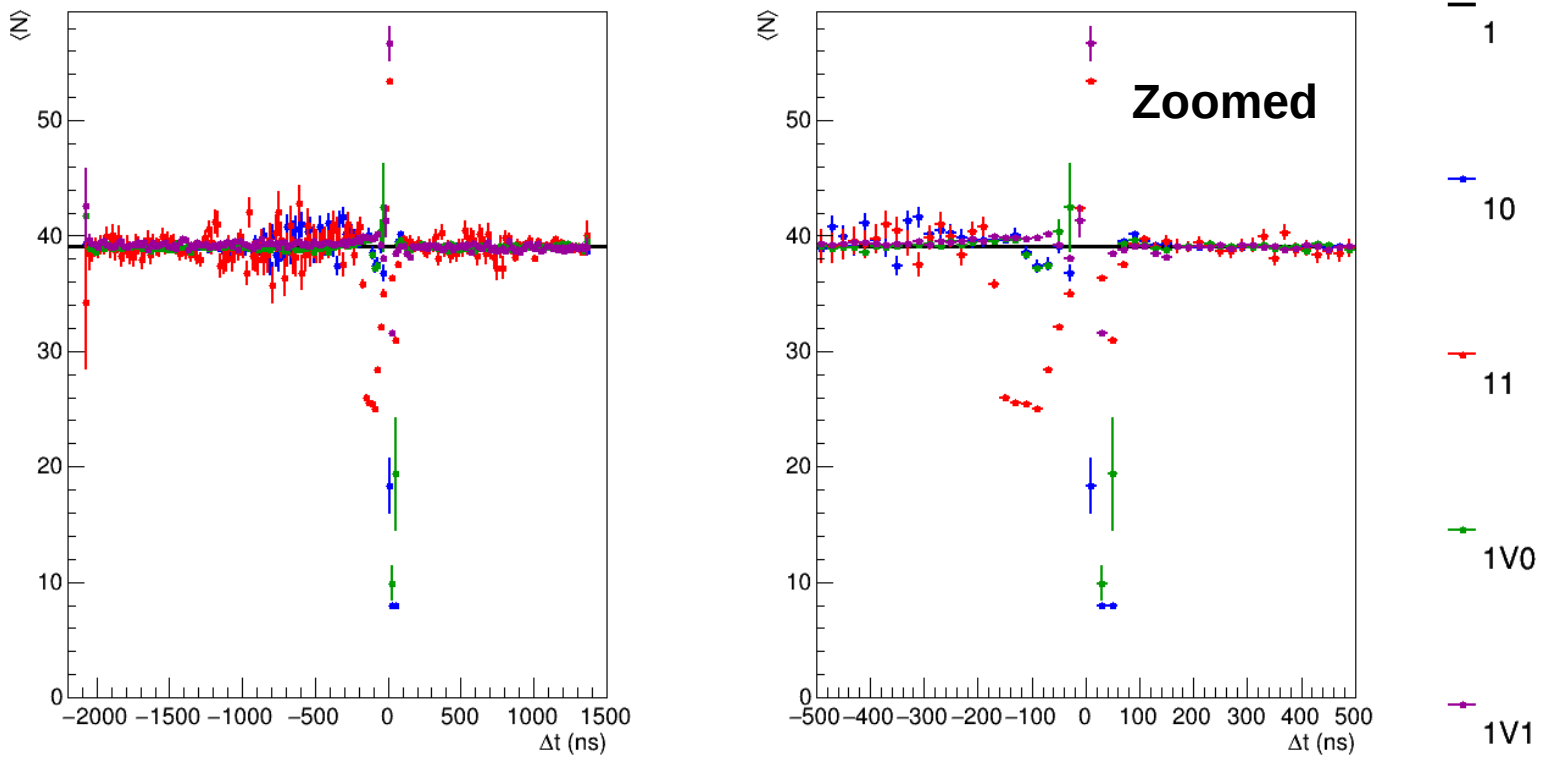
BC1 hit and event types

- BC1 hit type is defined based on corresponding peaks in VC, BC2 and FD:
  - No interaction (**0**) – high FD
  - Interaction (**1**) – low FD
  - No interaction + veto (**V0**) – high FD + high VC or low BC2
  - Interaction + veto (**V1**) – high FD + high VC or low BC2



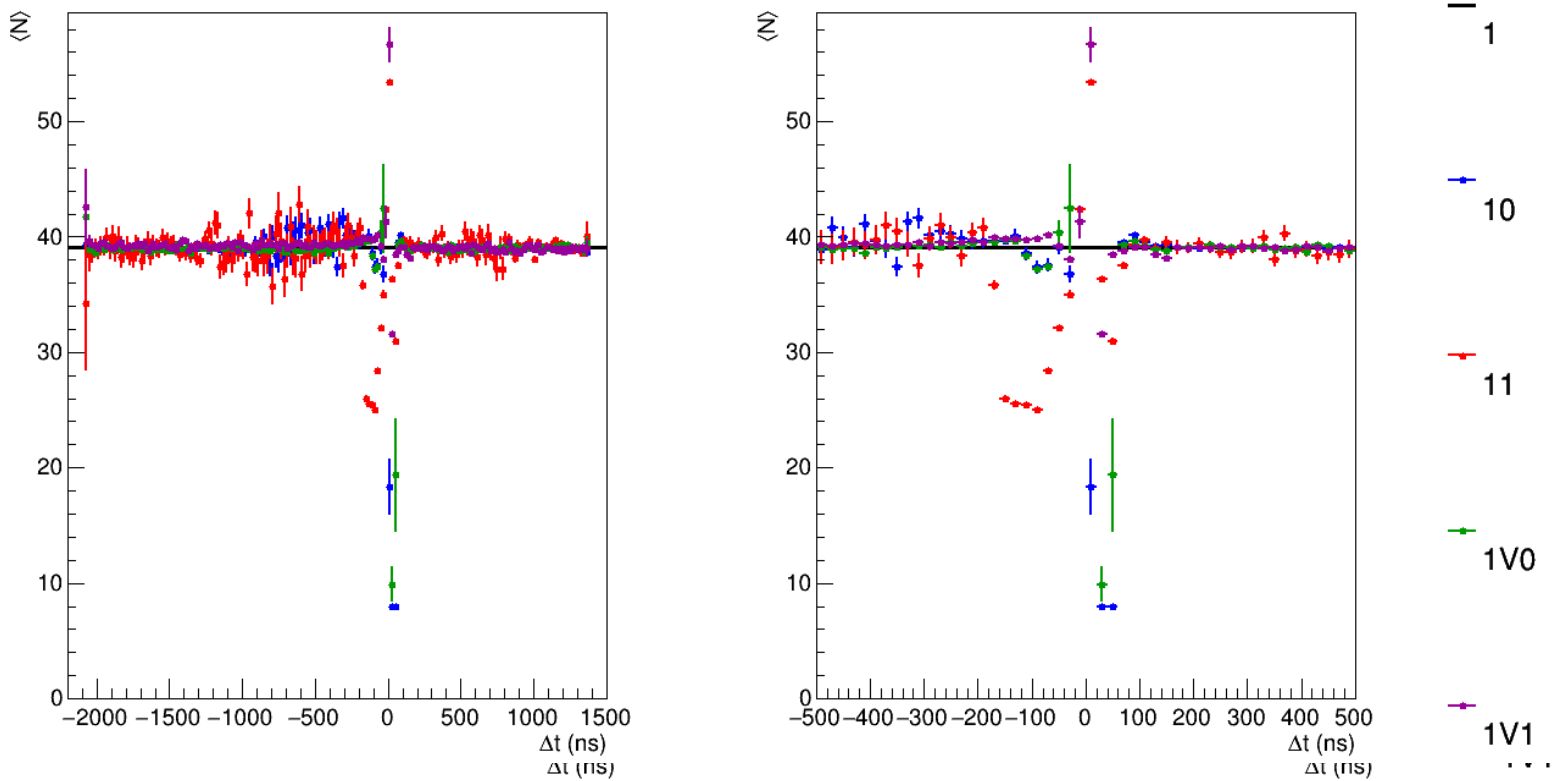
- Events with 1 hit in BC1 are assigned its type
- Events with 2 hits in BC1 are assigned a type based on type of trigger and additional hits (e.g. **1V0**).

Effect on TOF 400 digits



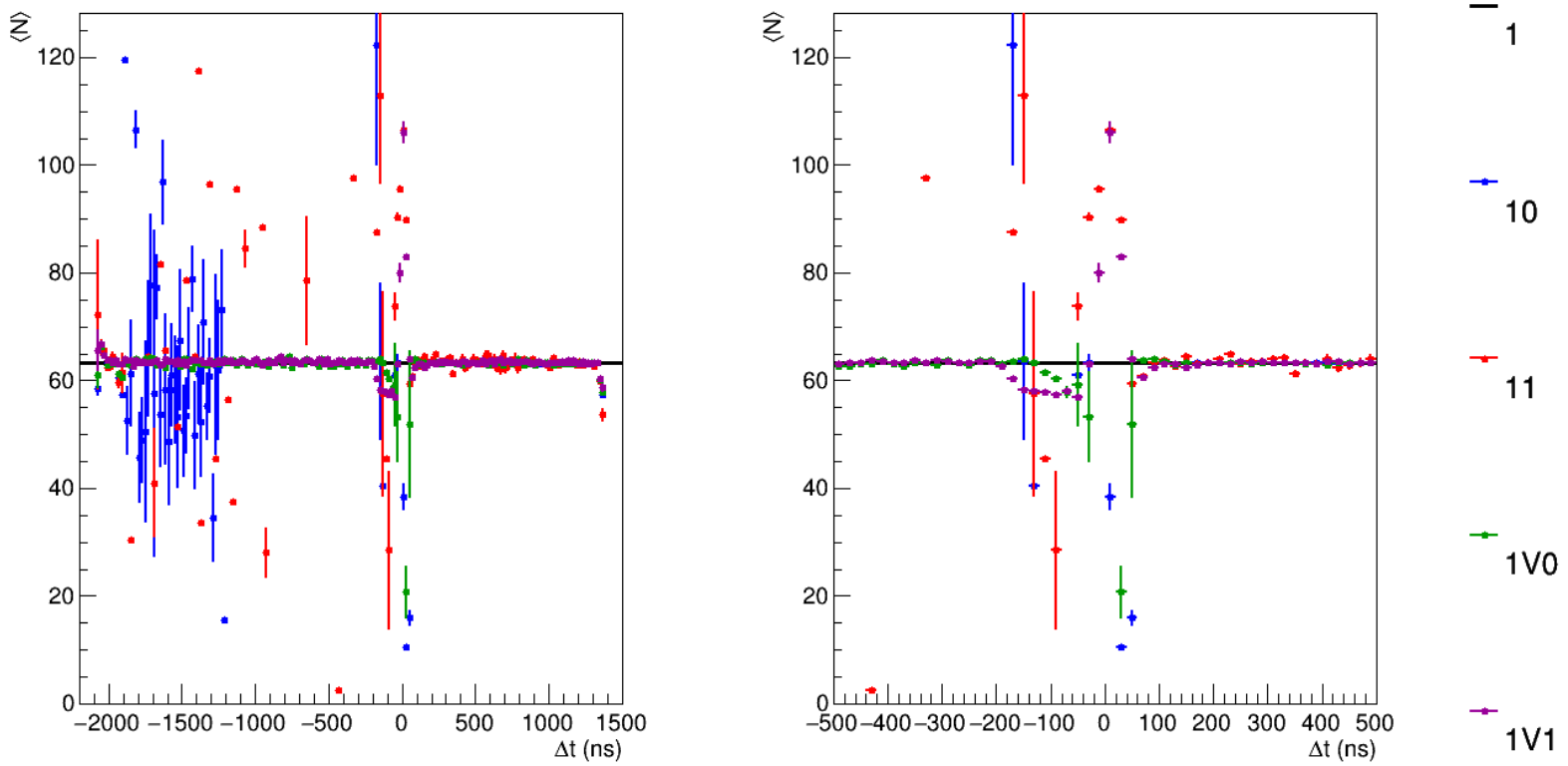
Significant effect at ~100 ns from trigger hit even without additional interaction

Effect on TOF 400 hits



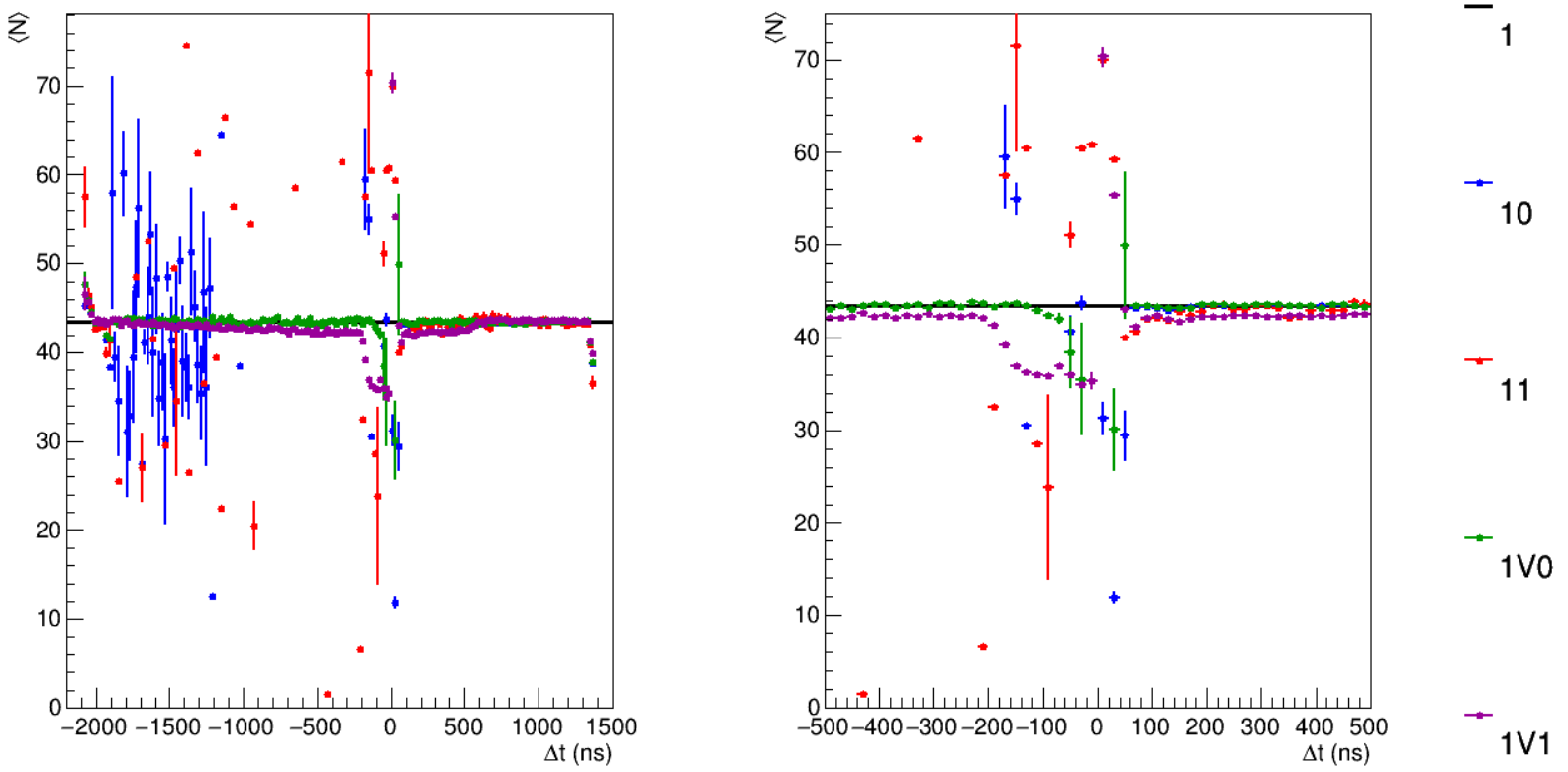
Significant effect at ~200 ns from trigger hit even without additional interaction

Effect on TOF 700 digits



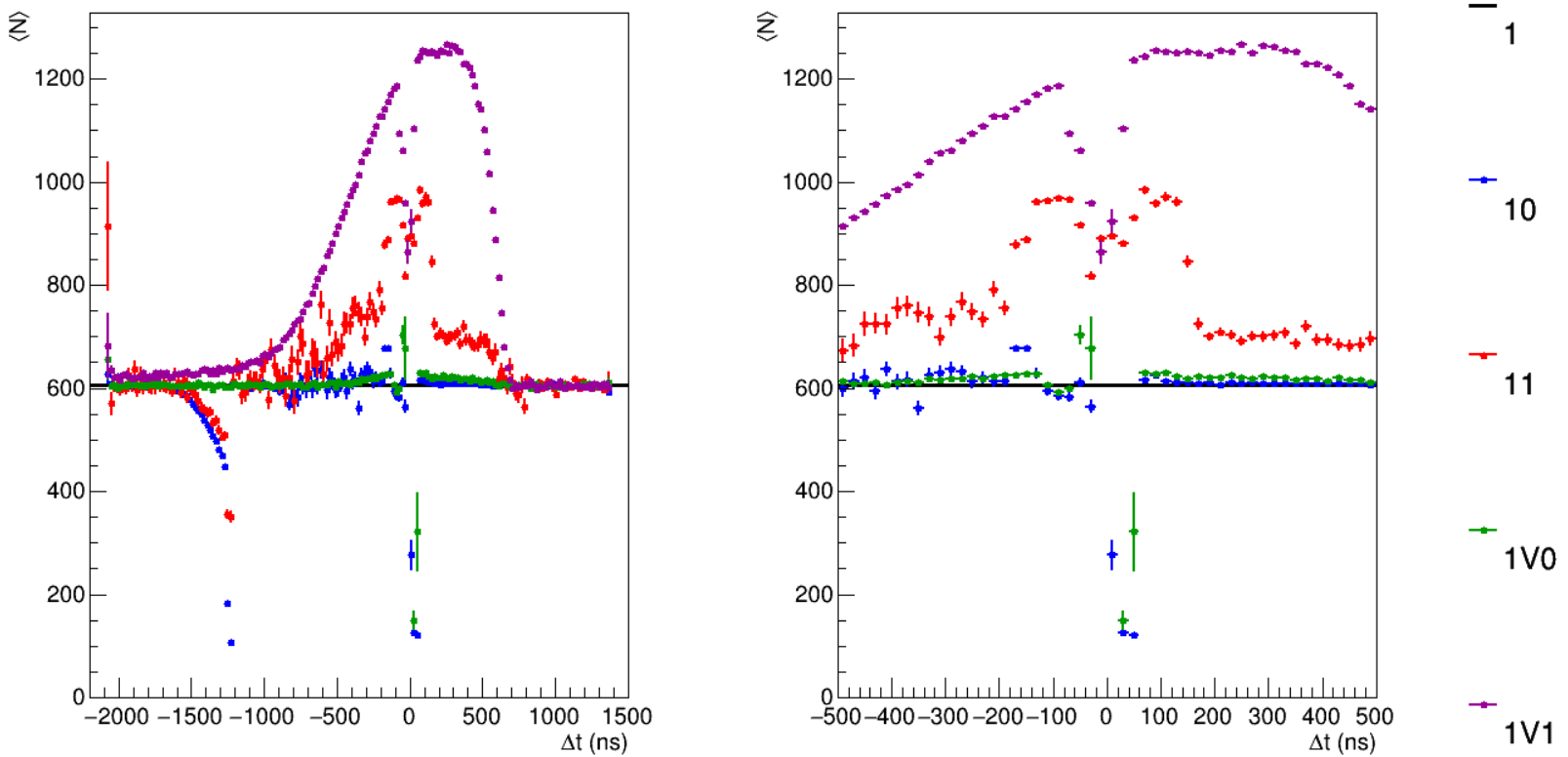
Significant effect at ~200 ns from trigger hit even without additional interaction

Effect on TOF 700 hits



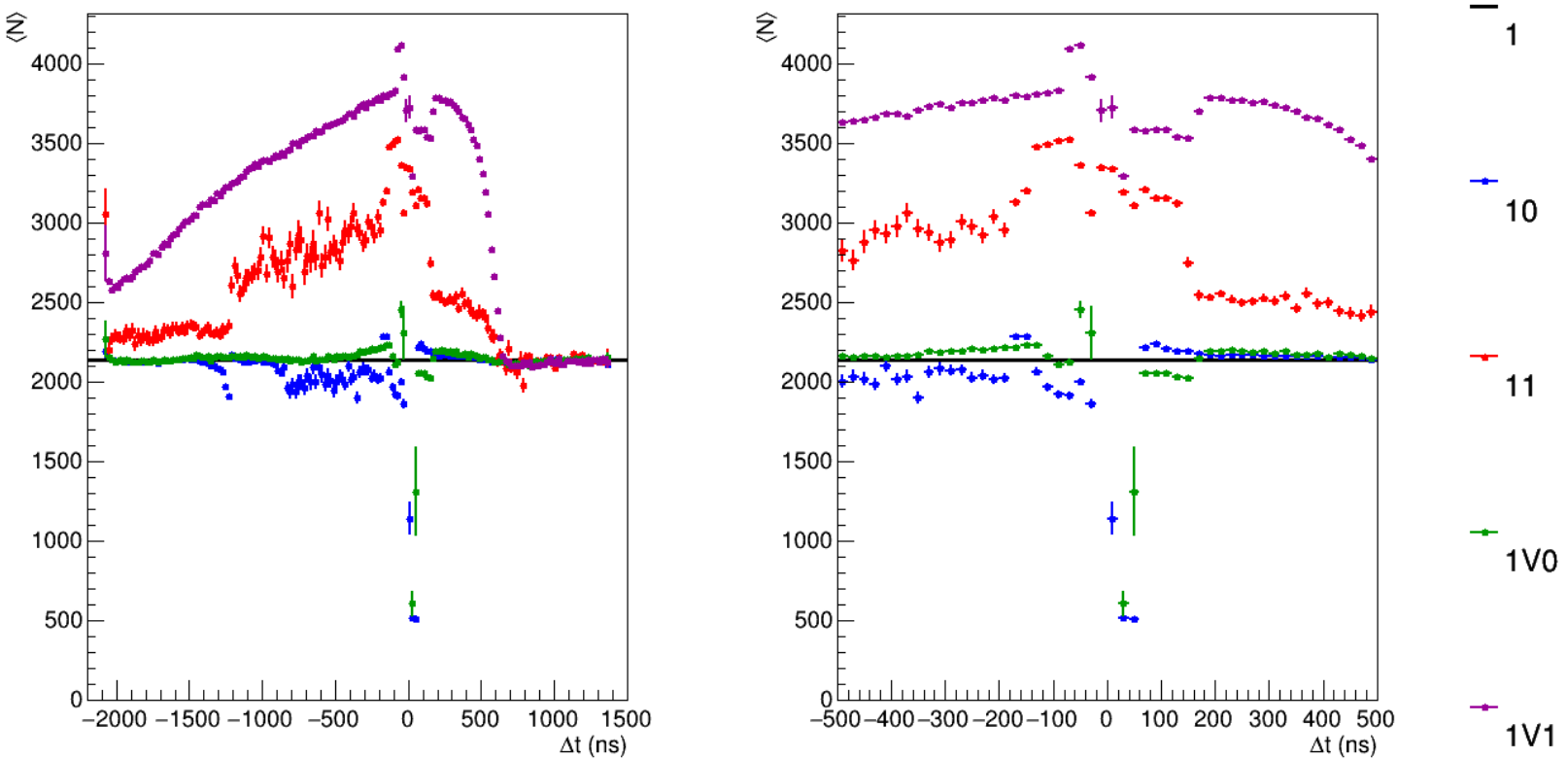
Significant effect at ~200 ns from trigger hit even without additional interaction

Effect on SILICON digits



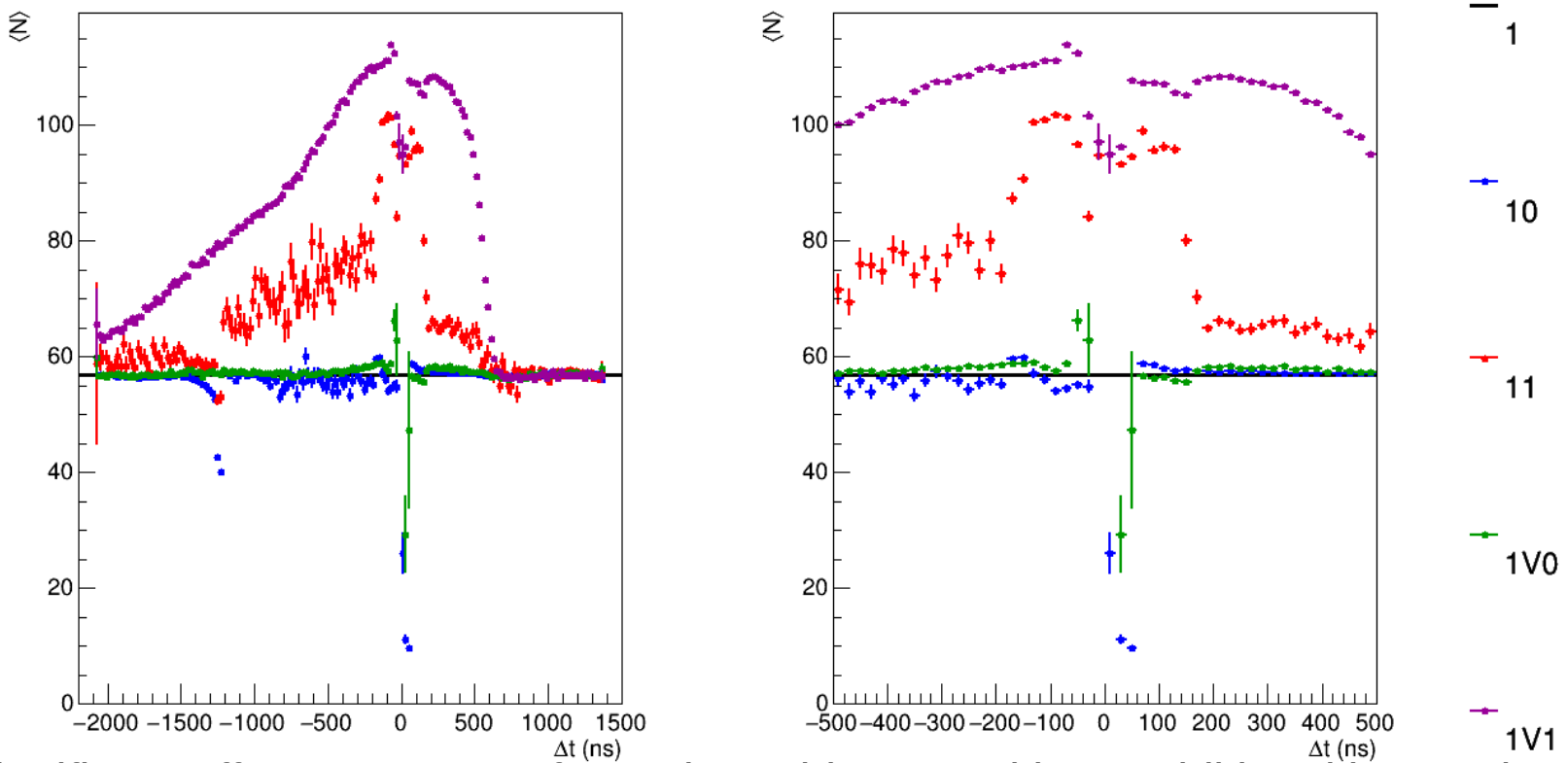
- Significant effect at ~100 ns from trigger hit even without additional interaction
- Significant long-range effect in case of additional interaction, esp. off-target

Effect on GEM digits



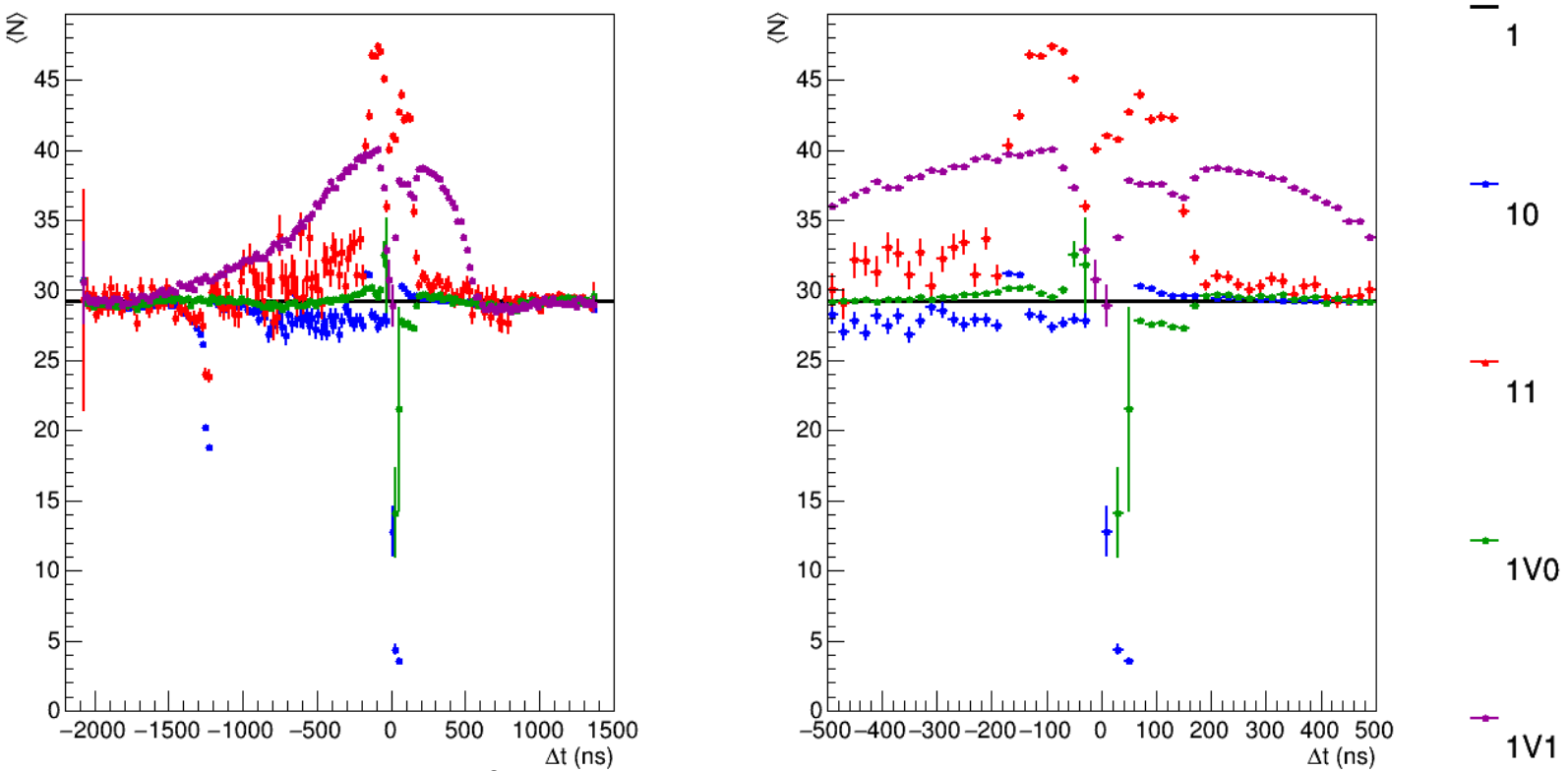
- Significant effect at ~200 ns from trigger hit even without additional interaction
- Significant long-range effect in case of additional interaction, esp. off-target

Effect on tracks



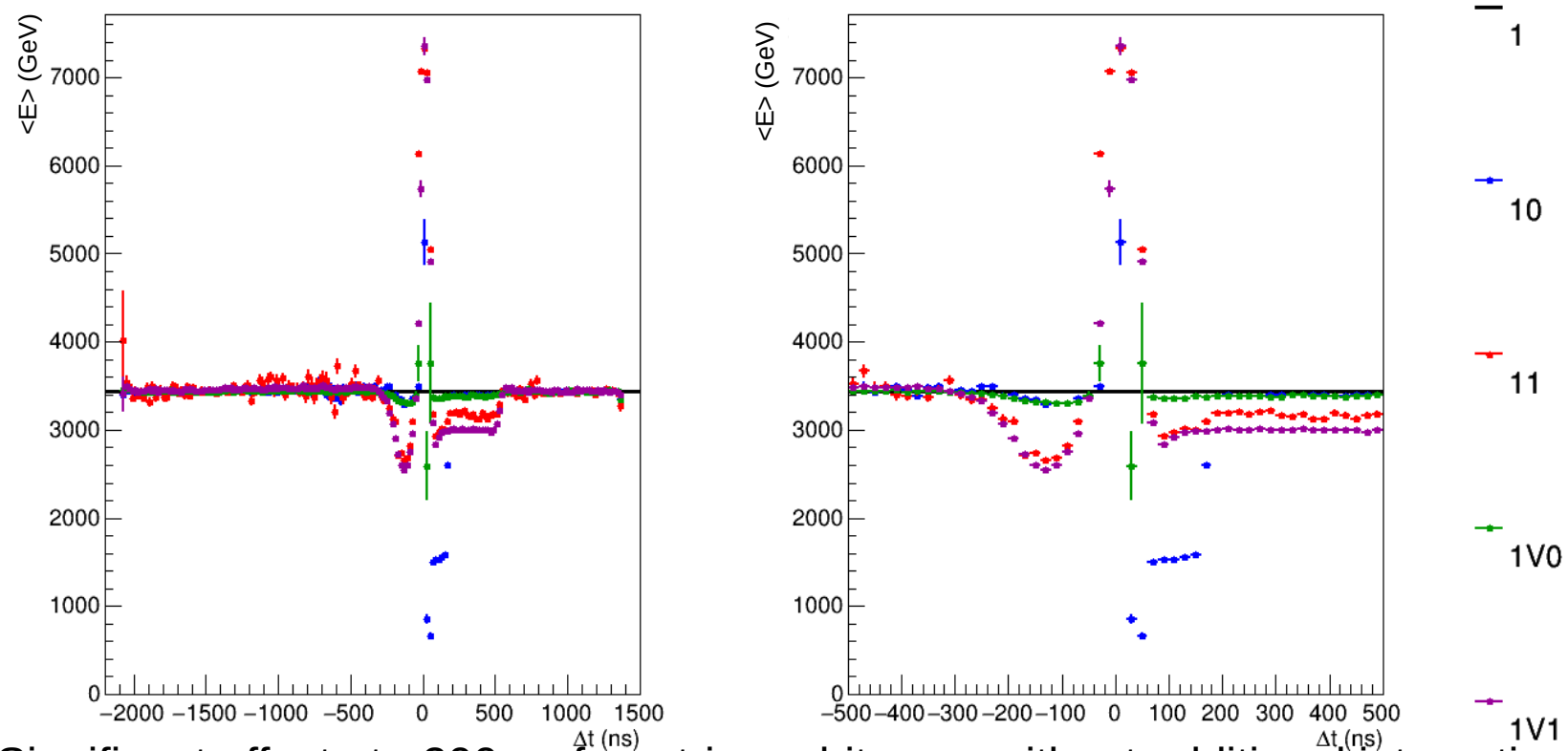
- Significant effect at ~200 ns from trigger hit even without additional interaction
- Significant long-range effect in case of additional interaction

Effect on selected tracks



- Track selection: >4 hits, χ^2/NDF<5, DCA < 5 cm
- Long-range effect is less for **1V1** pronounced but still significant

Effect on FHCal



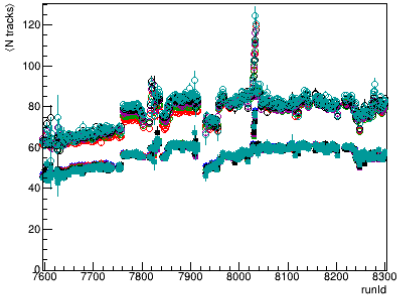
- Significant effect at ~200 ns from trigger hit even without additional interaction
- Long-range effect up to ~600 ns

Proposed pileup rejection

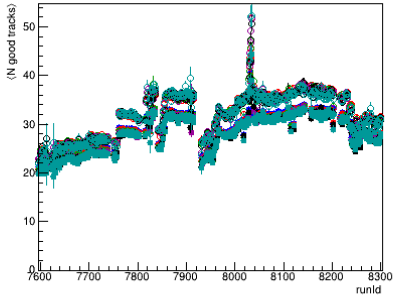
- Interaction associated with the trigger hit in BC1S (**1**)
- No additional **0** hit from -40 to 80 ns
- No **V0** hit from -60 to 160 ns
- No **1** hit from -200 to 200 ns
- No **V1** hit from -1500 to 500 ns

Effect on reconstructed data (multi-hit events)

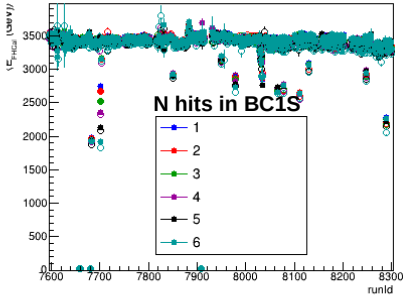
N tracks

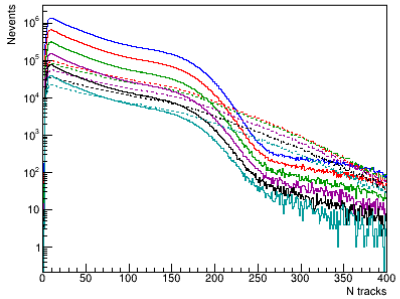


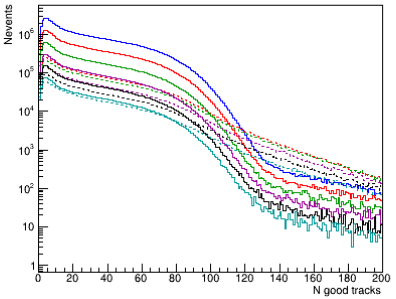
N good tracks

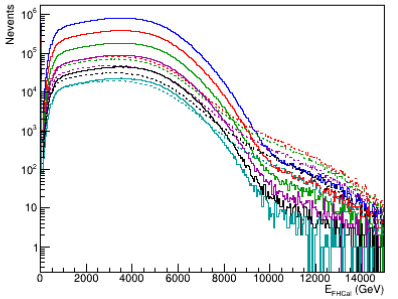


E_{FHCal} (GeV)



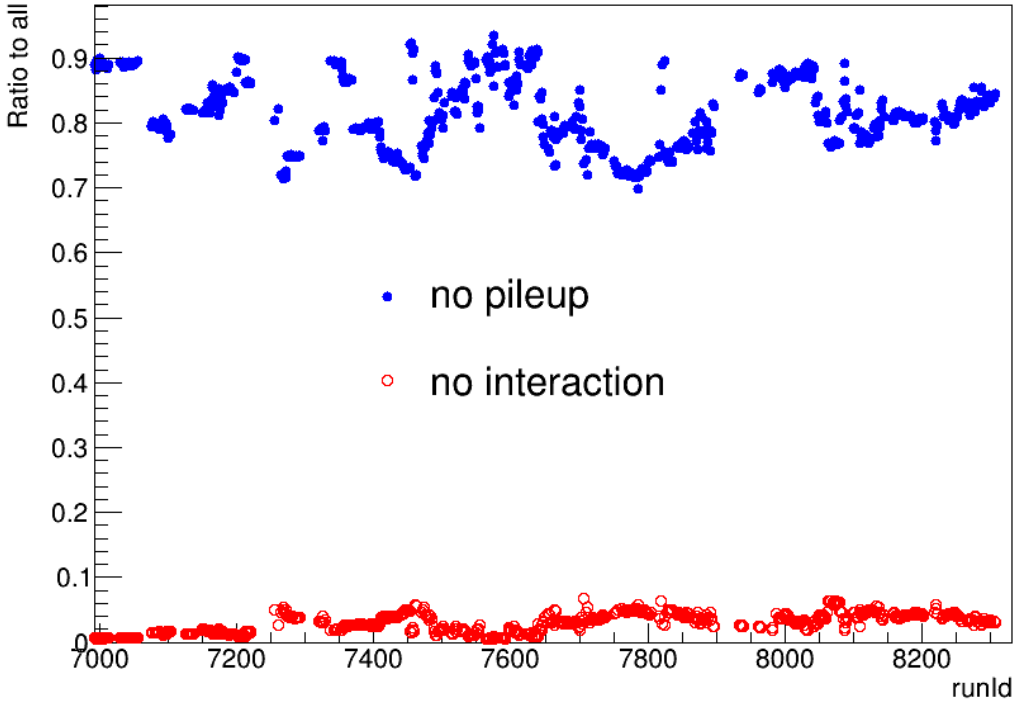






- Events w/o pileup (filled markers) are in agreement with single BC1S events
- Pileup events (empty markers) agree with one another

Share of non-pileup events (CCT2)



- Selection: CCT2, > 1 tracks at primary vertex
- Up to ~80% of non-pileup events for the CCT2 trigger

BmnRoot task for event classification

- Collects run-by-run distributions to obtain needed constants
- Based on run-by-run constants calculates peaks and defines classes of BC1 hits in event
- Provides time distances (positive and negative) from trigger to the closest hits of selected class
- Creates additional branch with variables:
  - Index of trigger hit in BC1
  - For every hit in BC1
    - Hit class
    - Time distance to trigger hit
    - Corresponding VC, BC2 and FD peak values
    - Number and amplitude sum of BD digits
    - Number of TOF400 and TOF700 digits

HOWTO

In the analysis macro (to use with current production):

```
#before the analysis task
auto eventSelector = new BmnEventSelector();
eventSelector->SetRunId(run_number);
eventSelector->SetInputFileName("$VMCWORKDIR/input/eventSelector_calib_run8.root");
fRunAna->AddTask(eventSelector);
```

In the analysis code:

```
#include “BmnEventSelector.h”
```

```
#in Init() function:
auto hitInfo = (BmnBC1hitInfo*)ioman -> GetObject(“BmnBC1hitInfo”);
#in Exec() function:
auto dt0=hitInfo -> GetClosestBC1hitsDt(BmnEventClass::k0);
auto dtV0=hitInfo -> GetClosestBC1hitsDt(BmnEventClass::kV0);
auto dt1=hitInfo -> GetClosestBC1hitsDt(BmnEventClass::k1);
auto dtV1=hitInfo -> GetClosestBC1hitsDt(BmnEventClass::kV1);
if(dt0.at(0)>-40 || dt0.at(1)<80) continue;
if(dtV0.at(0)>-60 || dtV0.at(1)<160) continue;
if(dt1.at(0)>-200 || dt1.at(1)<200) continue;
if(dt0.at(0)>-1500 || dt0.at(1)<500) continue;
```

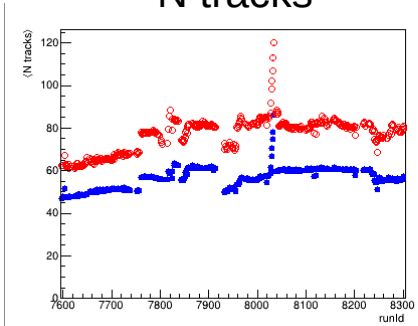
Summary

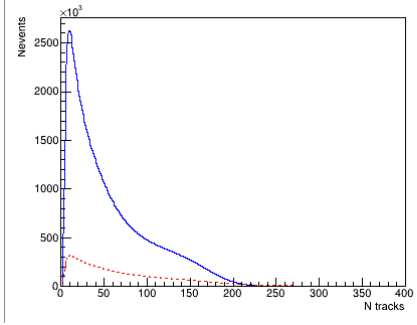
- BmnRoot task for classification of pileup events has been developed and tested.
  - may be used “on the fly” and available with current production
- Significant effect on digitized and reconstructed data of additional hit in BC1 without interaction at ~200 ns from trigger
- Short-range effect on “fast” detectors in case of additional interaction
- Long-range effect on “slow” detectors in case of additional interaction.
  Still part of muli-hit events may be used.

BACKUP

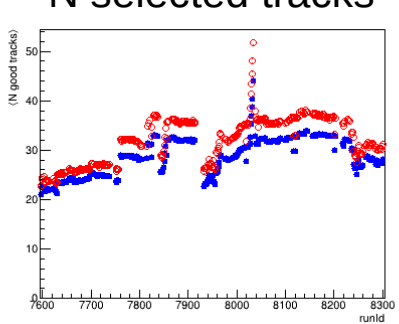
Effect on reconstructed data (multi-hit events)

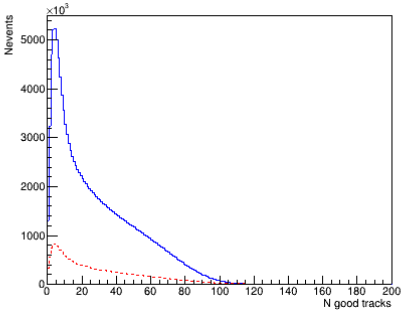
N tracks



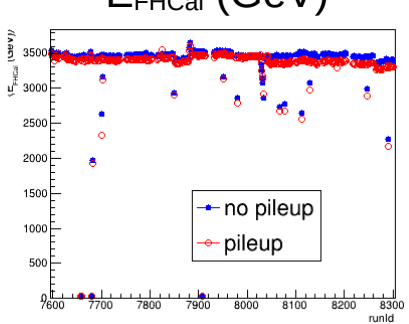


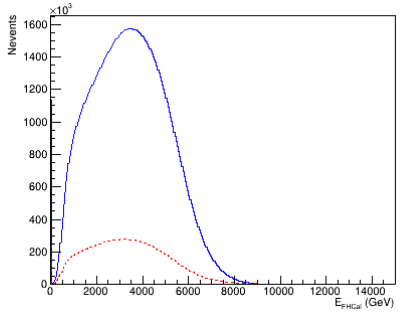
N selected tracks





E_{FHCal} (GeV)





- Significant effect on number of reconstructed tracks
- Little effect on FHCal energy