On the impact of the trigger on the CCSN signal event rates

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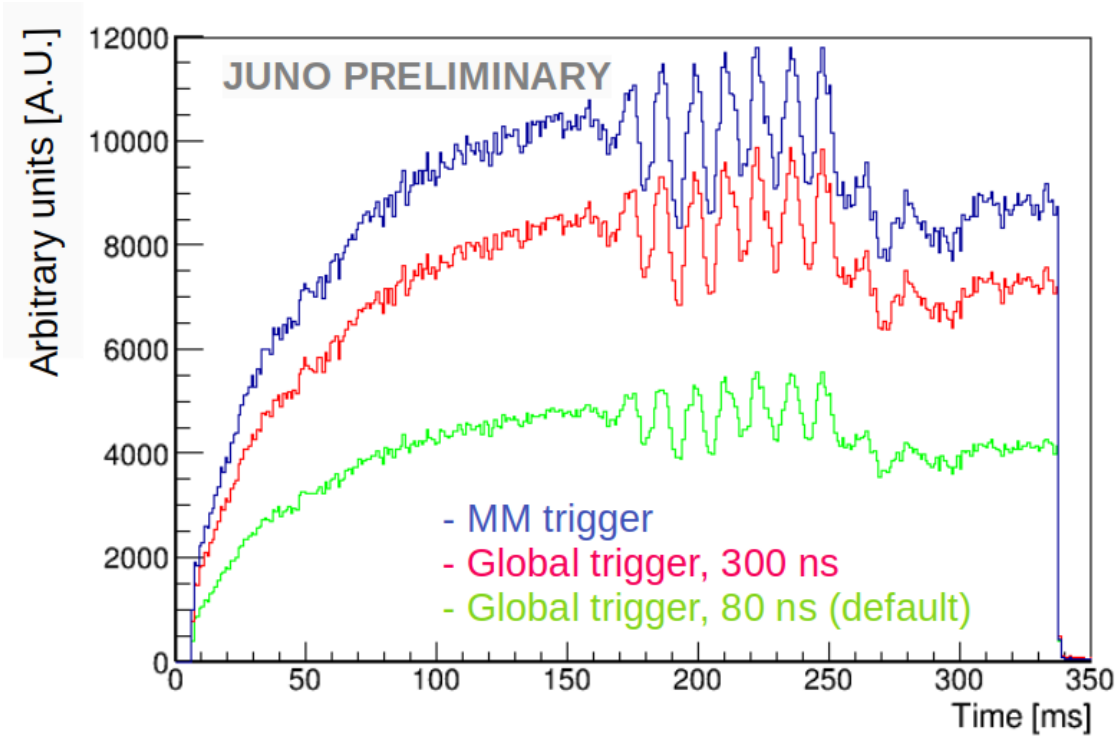
Detected neutrino lightcurve in JUNO:

- No interaction channel (flavor) classification
- No selection, all triggered events used for higher statistics (with global JUNO trigger for now)
- The effect(s) that we want to study are independent of the interaction channel
- We would aim at an almost real-time lightcurve analysis, reconstruction would take long
- Event trigger time from elecsim used to build the lightcurve

Reminder...

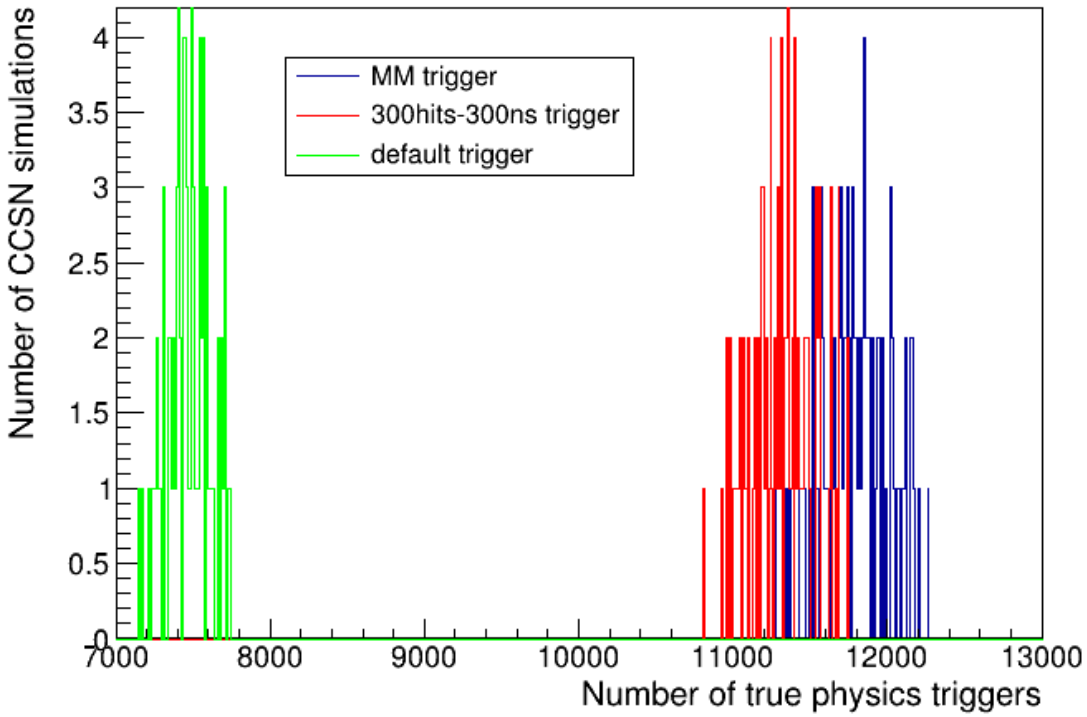
In previous meetings...
$\rightarrow$ different final triggered rates for CCSN events with the different triggers shown



Questions raised during review for Neutrino2022 / JUNO EU meeting:

- Is the increase in the rates with the MM trigger due to more ν-p ES events?
- Then, where does the difference between default and new global setup rates comes from?

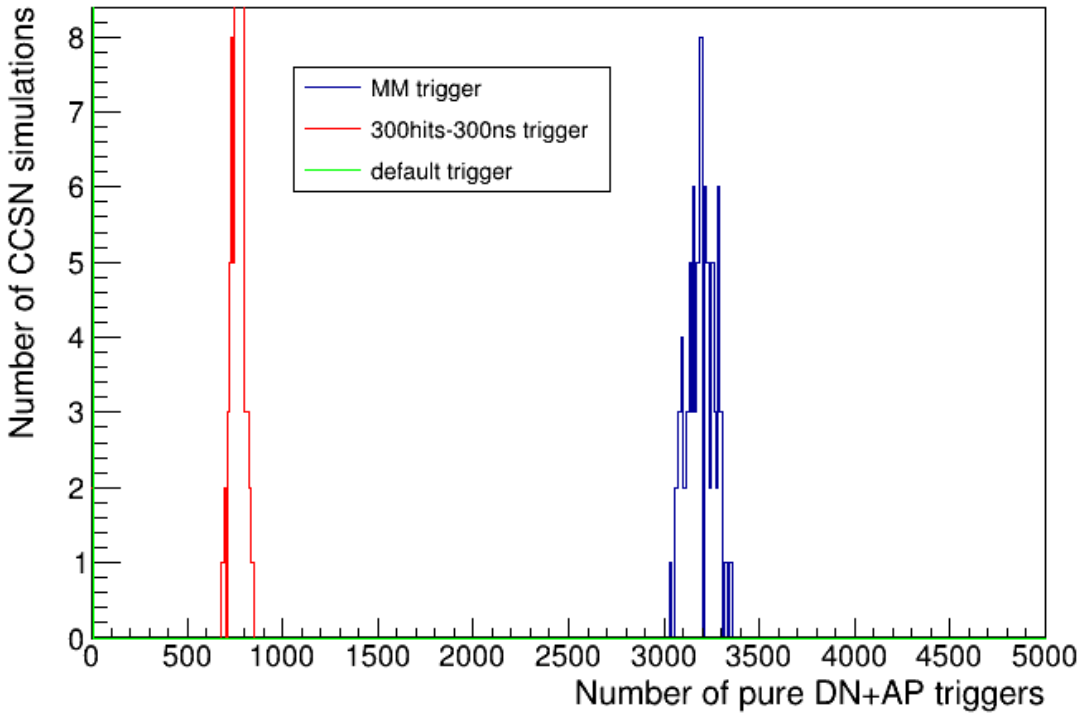
First check: compare number of TRUE physics (CCSN) triggered events



Conclusion:

- The number of total TRUE signal events increases almost the same with MM trigger OR with "new" global trigger setup with respect to "default"

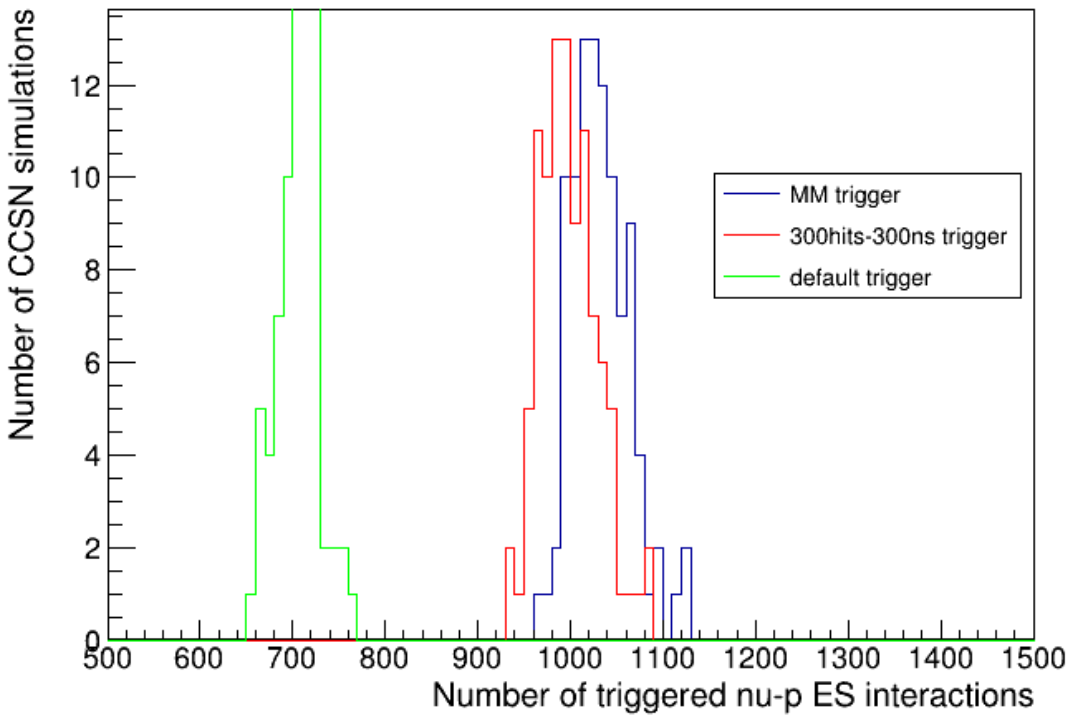
Second check: compare number of pure DN+AP triggered events (zero true physics nhits)



Conclusion:

- The difference between the two global trigger setups comes from an increase of signal AND of DN+AP events, dominated by signal increase
- With default trigger, negligible number of DN+AP triggers, not anymore with new global setup and MM triggers

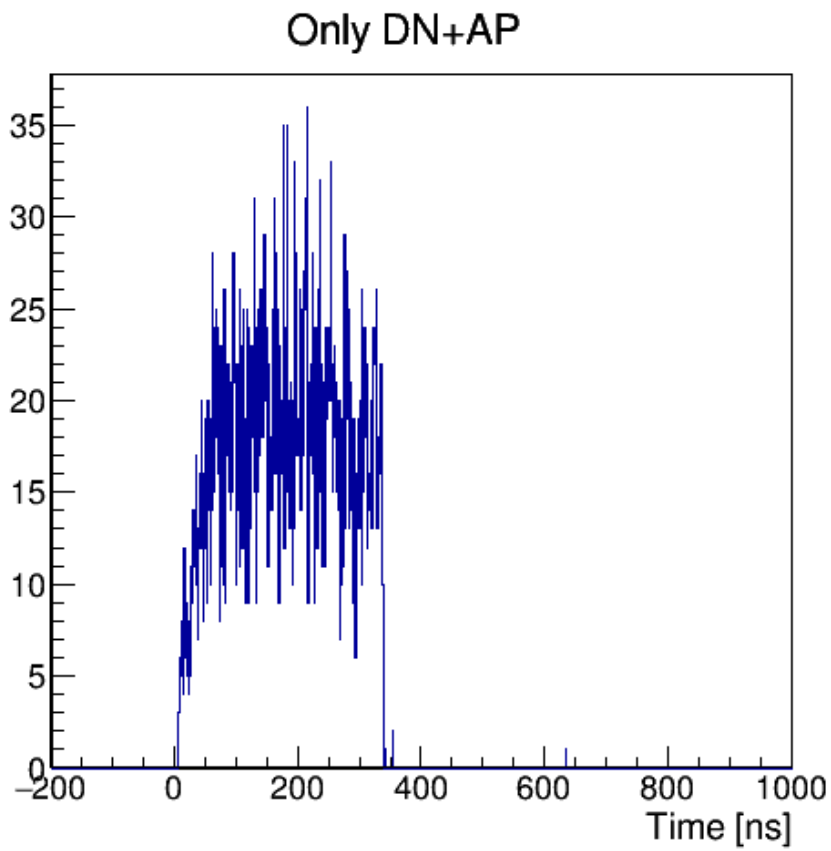
Second check: compare number of ν-p ES triggered events

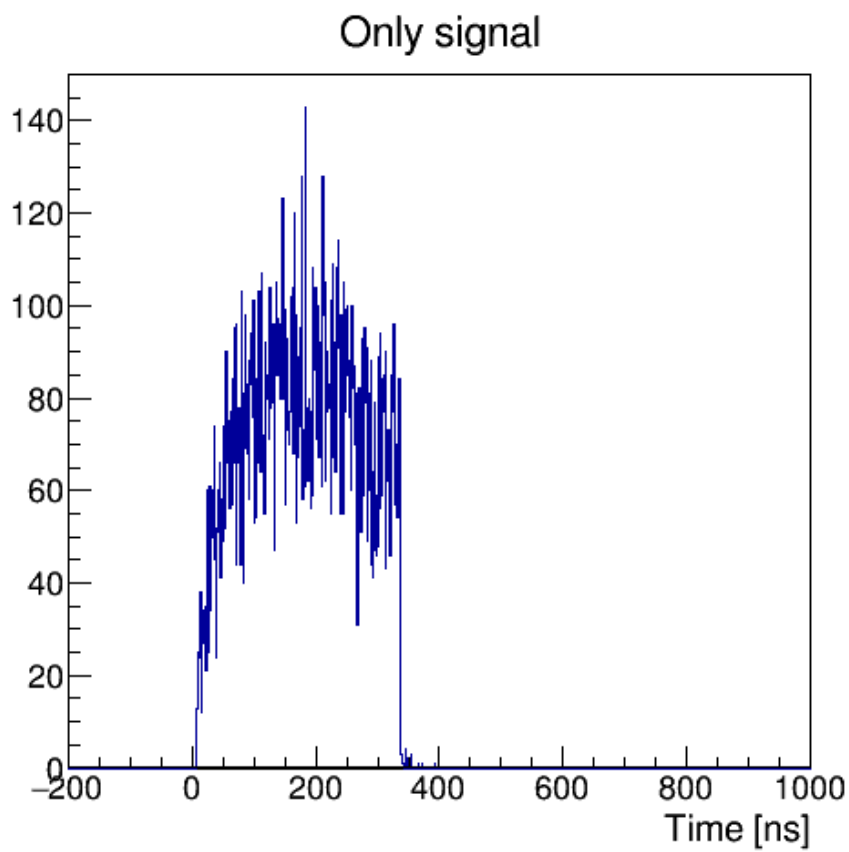


Conclusion:

- The number of triggered ν-p ES signal events is almost the same with MM trigger OR with "new" global trigger setup
  $\rightarrow$ longuer global trigger window allows to trigger DN+lowE signal events as the lower E threshold of the MM trigger
- The number of triggered ν-p ES signal events does not account for the total trigger signal rate increase

What is the time distribution of AP+DN events?





Large charge deposit (CCSN events Eav∼20 MeV) is accompanied by afterpulses
→ DN+AP events (simulation) follow the same time distribution as signal events
→ Signal and "background" are time correlated → noise keeps signal features

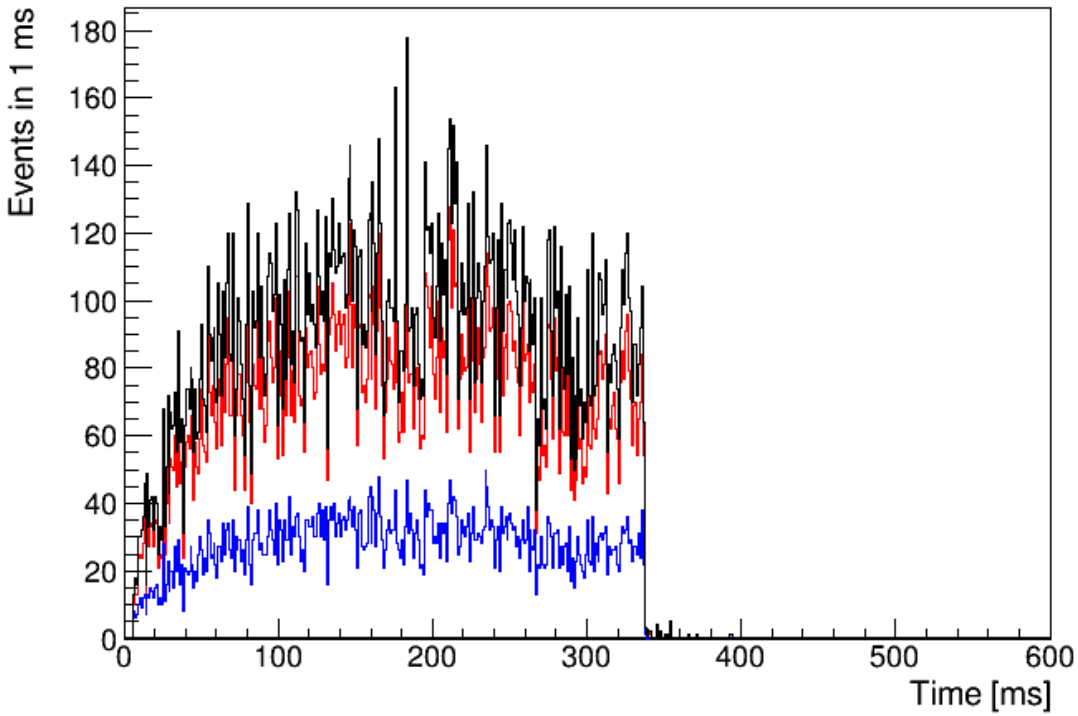
Conclusion:

- One single neutrino event is counted twise in the 1ms time bin when triggers a DN+AP event. This double counting increases the sensitivity.
- This is also happening for SN IBD events: promt+delay signal double count, as there is no event selection

All triggers

Triggers with true physics hits

Triggers removing double counting



True neutrino events VS triggered events

Table: Comparison of the total number of events

True neutrino interactions (generated events)	Triggered events with signal, no double counting	Triggered events (all)
∼14.300	∼9.400	∼30.000

- Without selection: ∼ twice the true number of neutrinos
- After 100% eff selection, ∼34% of the events are lost (not triggered)

Scan over events:

We can clearly see that indeed events are truly lost:

```
root [13] eventindex->Scan()
*****************************************************************************************
*    Row   * Instance * eventid.e * nevents.n *      tags * filenames *   entries *     nhits *
*****************************************************************************************
*        0 *        0 *         0 *         1 *        SN * /pnfs/iih *         3 *       242 *
*        1 *        0 *         1 *         1 *        SN * /pnfs/iih *         4 *     28253 *
*        2 *        0 *         2 *         1 *        SN * /pnfs/iih *         4 *        72 *
*        3 *        0 *         3 *         1 *        SN * /pnfs/iih *         5 *        28 *
*        4 *        0 *         4 *         0 *           *           *         * *         * *
*        5 *        0 *         5 *         1 *        SN * /pnfs/iih *         4 *      3363 *
*        6 *        0 *         6 *         1 *        SN * /pnfs/iih *         6 *       325 *
*        7 *        0 *         7 *         1 *        SN * /pnfs/iih *         7 *       400 *
*        8 *        0 *         8 *         1 *        SN * /pnfs/iih *        11 *     26159 *
*        9 *        0 *         9 *         1 *        SN * /pnfs/iih *        11 *        49 *
*       10 *        0 *        10 *         0 *           *           *         * *         * *
*       11 *        0 *        11 *         0 *           *           *         * *         * *
*       12 *        0 *        12 *         1 *        SN * /pnfs/iih *        12 *       248 *
*       13 *        0 *        13 *         1 *        SN * /pnfs/iih *        17 *      1492 *
*       14 *        0 *        14 *         1 *        SN * /pnfs/iih *        28 *     17619 *
*       15 *        0 *        15 *         1 *        SN * /pnfs/iih *        28 *        37 *
*       16 *        0 *        16 *         0 *           *           *         * *         * *
*       17 *        0 *        17 *         1 *        SN * /pnfs/iih *        28 *      3370 *
*       18 *        0 *        18 *         1 *        SN * /pnfs/iih *        36 *     19385 *
*       19 *        0 *        19 *         1 *        SN * /pnfs/iih *        36 *        37 *
*       20 *        0 *        20 *         0 *           *           *         * *         * *
*       21 *        0 *        21 *         1 *        SN * /pnfs/iih *        38 *       104 *
*       22 *        0 *        22 *         1 *        SN * /pnfs/iih *        39 *       115 *
*       23 *        0 *        23 *         1 *        SN * /pnfs/iih *        40 *     18207 *
*       24 *        0 *        24 *         1 *        SN * /pnfs/iih *        40 *        28 *
```

Impact on the sensitivity, example of SASI

Table: Sensitivity comparing the different triggers and conditions at 9 kpc.

Trigger:	new global: sig	MM: sig	MM: sig+DN-AP	MM: sig+DN-AP+^{14}C
Method 1	2.2 σ	2.4 σ	2.8 σ	2.6 σ
Method 2	3.1 σ	3.3 σ	3.7 σ	3.5 σ

Conclusion:

- One cannot use all raw triggered events data without event selection
- "Double counting" was making our sensitvity "artifically" grow
- The loss of statistics after event selection will dramatically impact the sensitivity

Unordered triggered times? (issue #28)

Some trigger times come unordered:

```
1 trigger time:   6591872.0  (ns)
2 trigger time:   6611307.0  (ns)
3 trigger time:   6612457.0  (ns)
4 trigger time:   6614317.0  (ns)
5 trigger time:   6616011.0  (ns)
6 trigger time:   7276221.0  (ns)
7 trigger time:   6645537.0  (ns)
8 trigger time:   6727984.0  (ns)
9 trigger time:   6776377.0  (ns)
```

```
40 trigger time:   8500513.0  (ns)
41 trigger time:   8557448.0  (ns)
42 trigger time:   8558599.0  (ns)
43 trigger time:   8560247.0  (ns)
44 trigger time:   8561799.0  (ns)
45 trigger time:   8879877.0  (ns)
46 trigger time:   8659196.0  (ns)
47 trigger time:   50861272.0  (ns)
48 trigger time:   8994437.0  (ns)
49 trigger time:   9038894.0  (ns)
50 trigger time:   9040045.0  (ns)
```

Answer by experts: There is no ordering between sub-detectors (CD-WP-TT)
do they happen in other sub-detectors (not CD)?
But...
- In J21 I used to simulate this data set, WP/TT were yet not fully implemented
- I don't expect many MeV events interacting in CD to trigger also the WP
- I did not enable WP in my script configuration:

```
#Detsim...
python $JUNOTOP/offline/Examples/Tutorial/share/tut_detsim.py --evtmax=-1 --seed=${DETSEED} --output=${DETSIMFILE} --user-output=${USERDET} sn --input ${GENFILE} --relative-hittime

#Elecsim...
python $JUNOTOP/offline/Examples/Tutorial/share/tut_det2elec.py --evtmax=-1 --seed=${ELECSEED} --input=SN:${DETSIMFILE} --rate SN:1.0 --loop SN:0 --startidx SN:0 --enableSNMode
--output=${ELECFILE} --user-output=${USERELEC} --LpmtTrigger_alg MM-trigger
```

$\rightarrow$ Is this an issue?
Not able to access sub-detector info at elecsim (trigger) level in J21 files...

Conclusions/outlook:

- Significant number of triggers by DN+AP with MM and new global setup
- Still, MM trigger and new global trigger setup improve sensitivity for lightcurve studies (e.g. SASI, distance, etc)
- The signal increase with MM and new global setup triggers is not given by ν-p ES events only
- Removal of pure DN+AP (and of delayed IBDs) will decrease event statistics $\rightarrow$ impact on the lightcurve studies, reduces sensitivity
- WORK IN PROGRESS:
  event rates and sensitivity updates after event selection to:
  - Reject AP+DN events
  - Remove delayed IBD signals