WAGASCI - Baby MIND - NINJA meeting
Wednesday, September 23, 2020

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Agenda

- WAGASCI experiment introduction
- Acquired POT history before data quality cut
- Acquired POT history after data quality cut
- List of hardware problems
- Spill number problem and its solution
- Calibration challenges
- Gain and dark noise history
- WAGASCI run database and BSD database
- New Monte Carlo software
- New data format
- Plans for the future

WAGASCI / Baby MIND experiment

Current Physics goal

Aim to measure the double differential cross-section on CC0π0p samples at ~10% precision for each bin with the H2O and CH target

Reduce the systematic error on cross-section on the far detector by a better understanding of neutrino interaction models.

Target Detectors

2 X WAGASCI

interaction target : **H2O (80%)** + CH (20%)
directly detectable particles : μ, π, p, e

Proton Module

interaction target : CH (100%)
directly detectable particles : μ, π, p, e

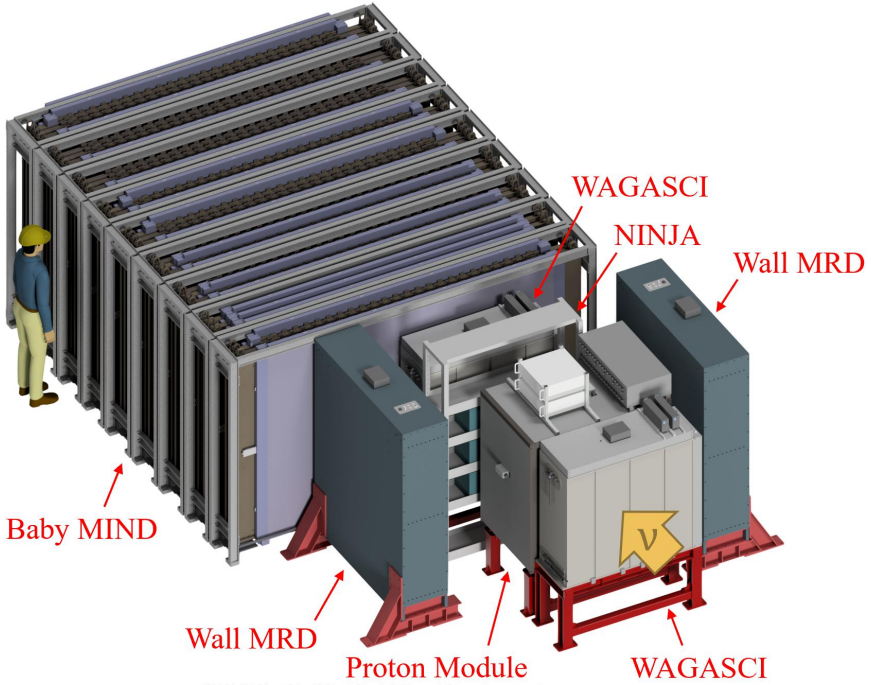
Muon range detectors

2 x Wall MRD (iron + scintillator)

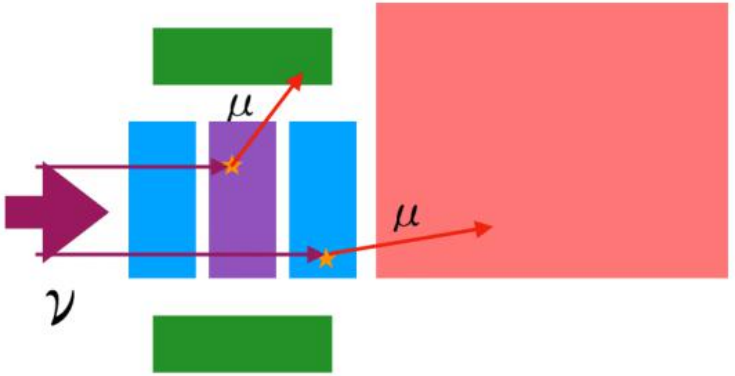
directly detectable particles : mainly μ

Baby MIND (magnetized iron + scintillators)

directly detectable particles : mainly μ



WAGASCI detectors

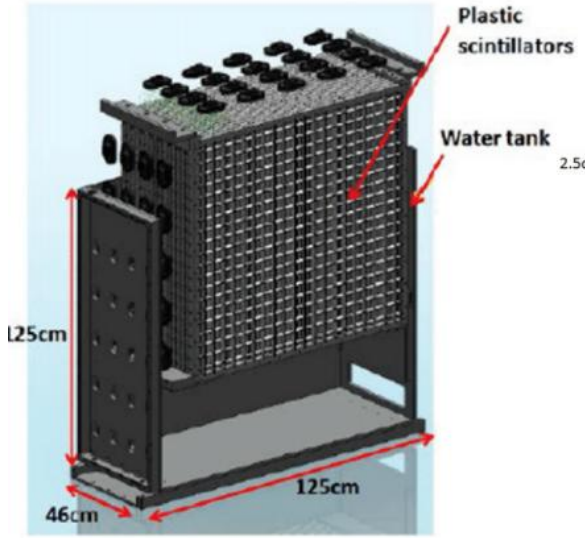


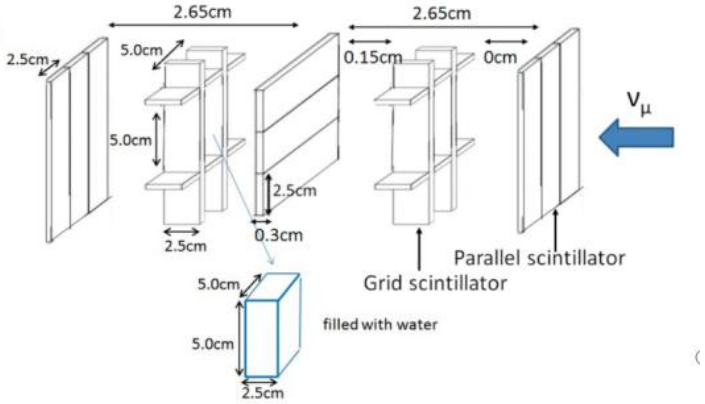
Top view

Target detectors

WAGASCI

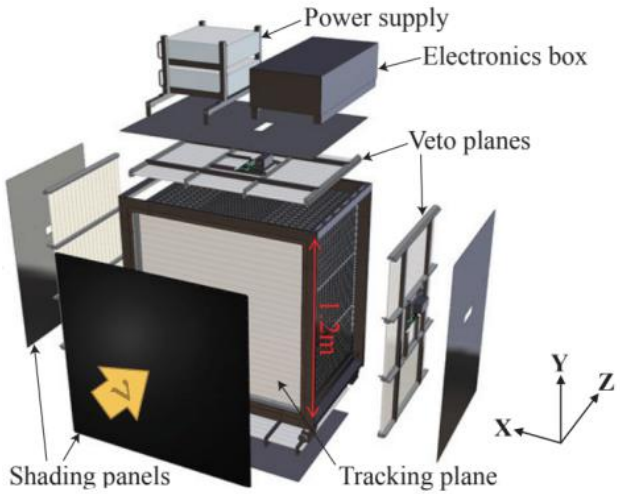
- 4π full angular acceptance
- Main target is 500kg of water (passive target)
- Readout system: scintillator, WLS fiber, MPPC
- Grid-like structure

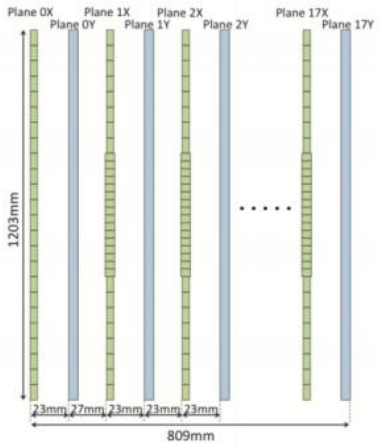




Proton Module

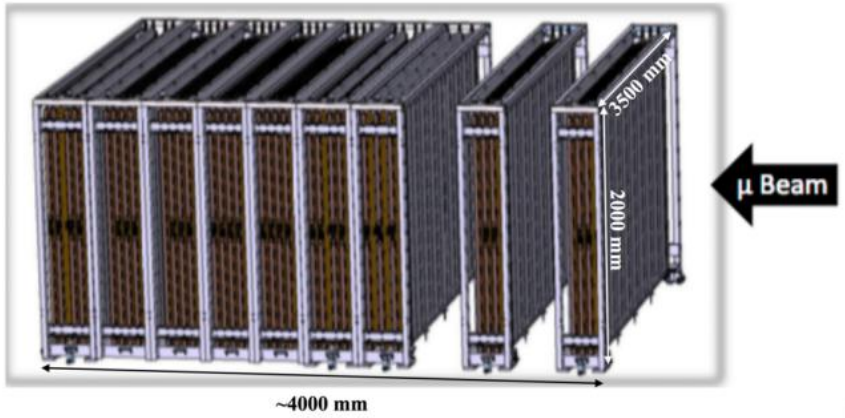
- forward acceptance
- fully active scintillator target (556 kg CH)
- Readout system: scintillator, WLS fiber, MPPC





Muon range detectors

WallMRD



Baby MIND

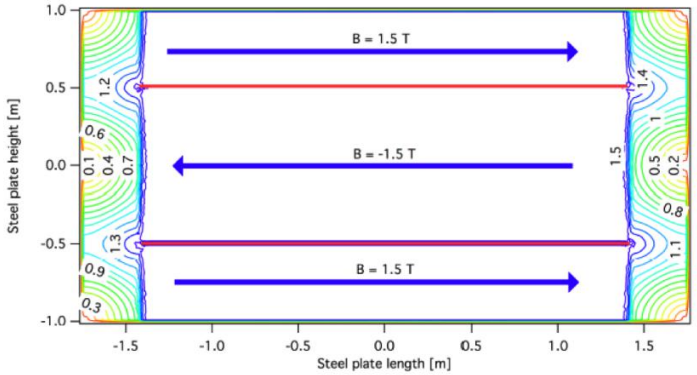
Wall MRD

- Sandwich-structure of iron planes and scintillator tracking planes
- Readout system: scintillator, WLS fiber MPPC
- **Detect side going muons**
- Measure momentum by range

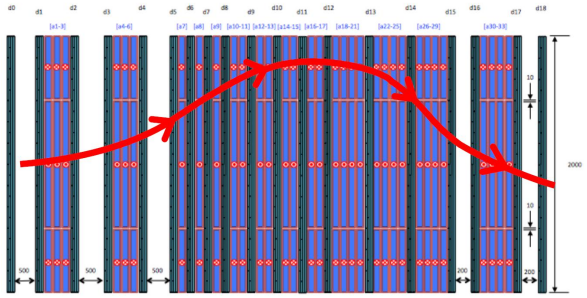
Baby MIND

- Iron-core magnet modules and scintillator tracking planes
- Readout system: scintillator, WLS fiber, MPPC
- Detect forward going muons
- **Measure momentum by range and curvature**
- **Non uniform magnetic field to keep particles inside tracking region**

Baby MIND magnetic field front view



Baby MIND magnetic field side view

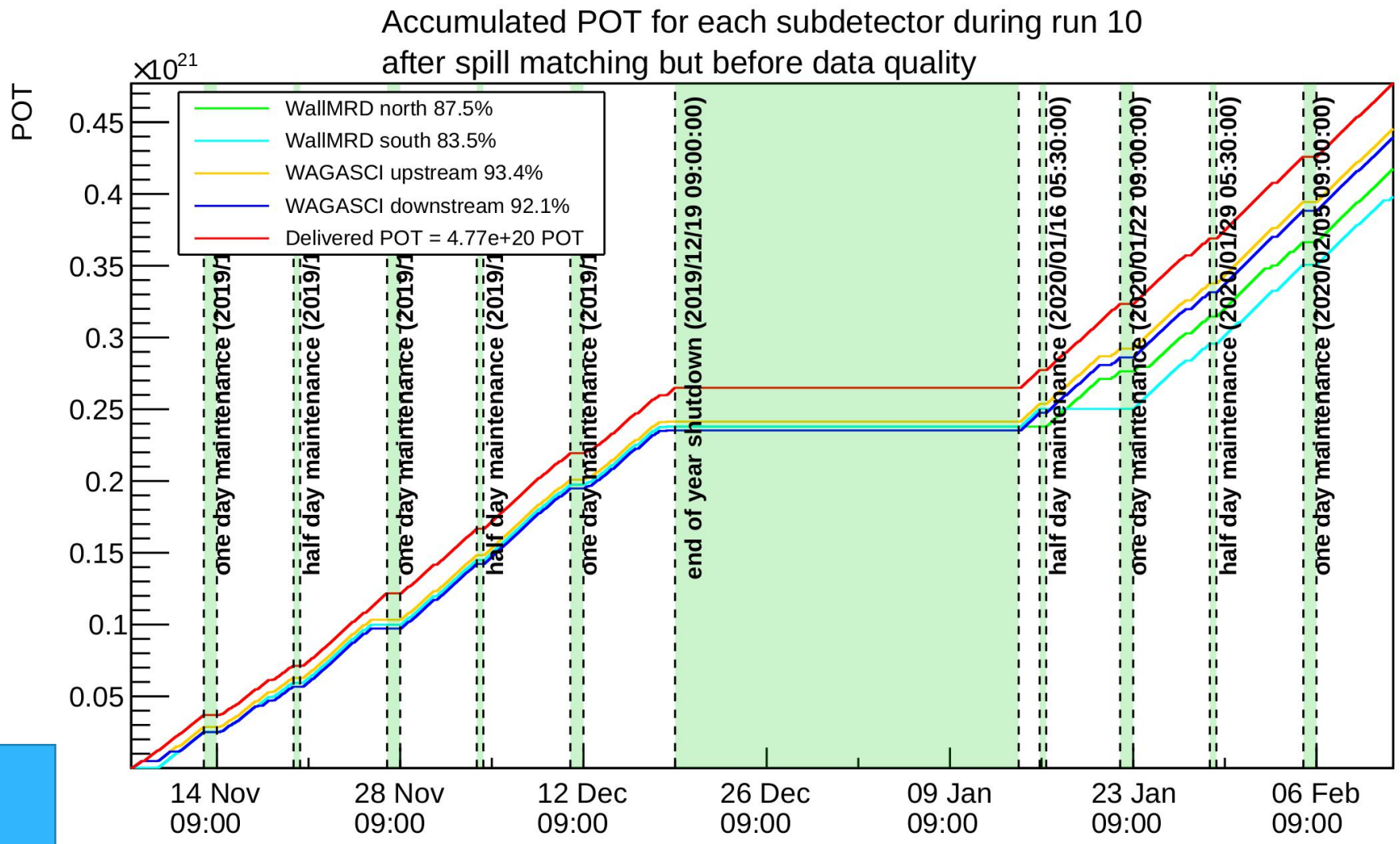


Acquired POT before data quality cut

Problems that affect the acquired POT on the right:

- Shutdown due to hardware work and maintenance
- Human error (DAQ misconfiguration)
- Failure of power supply
- Cable failures

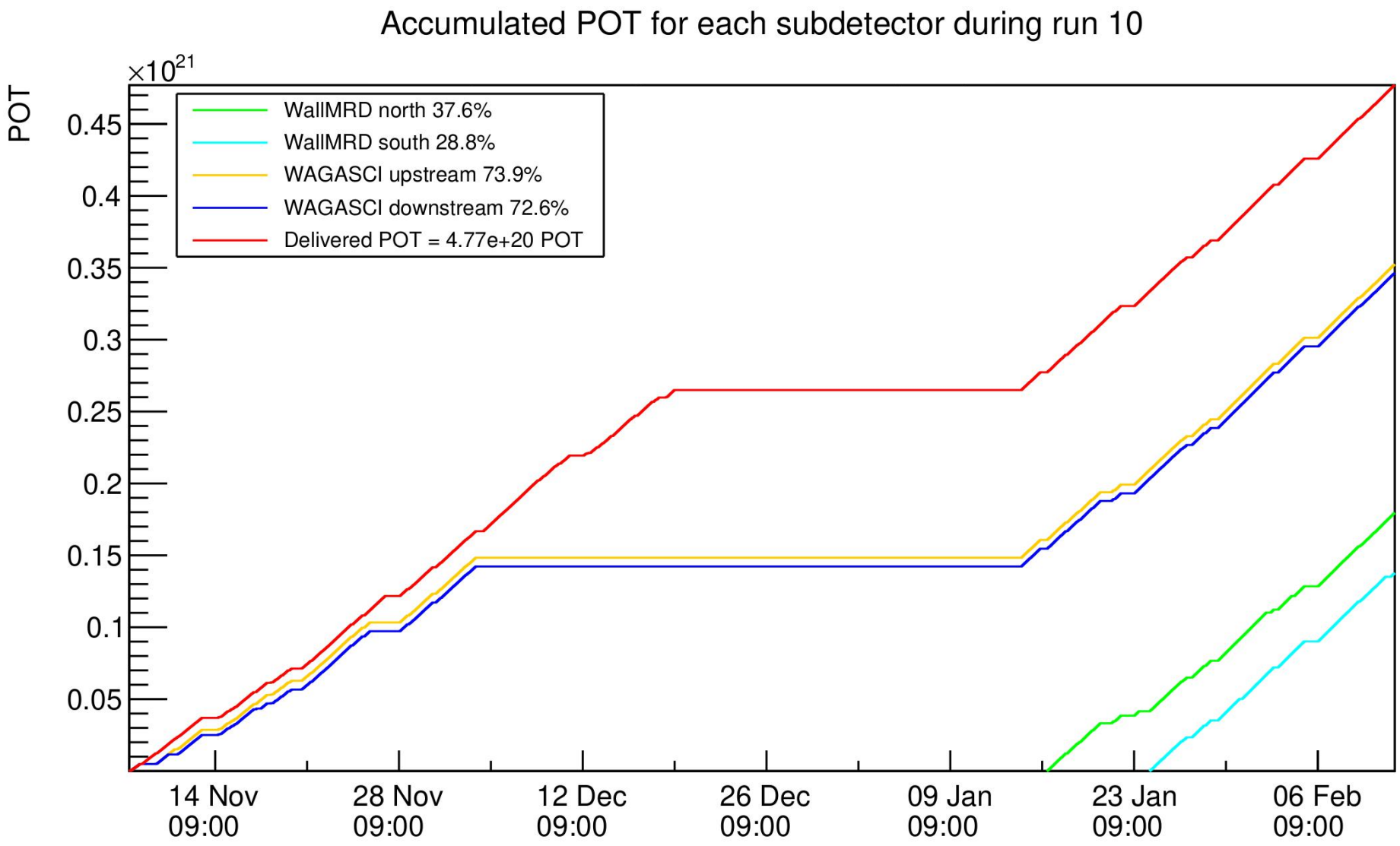
T2K run 10:
Nov 2019 ~ Feb 2020



Acquired POT after data quality cut

Problems that affect the acquired POT on the right:

- **FPGA bug** that corrupts the raw data
- Hardware problem in the frontend boards that corrupts the **ASIC configuration**
- Hardware problem in the frontend boards that picks up **electromagnetic interference** from the environment

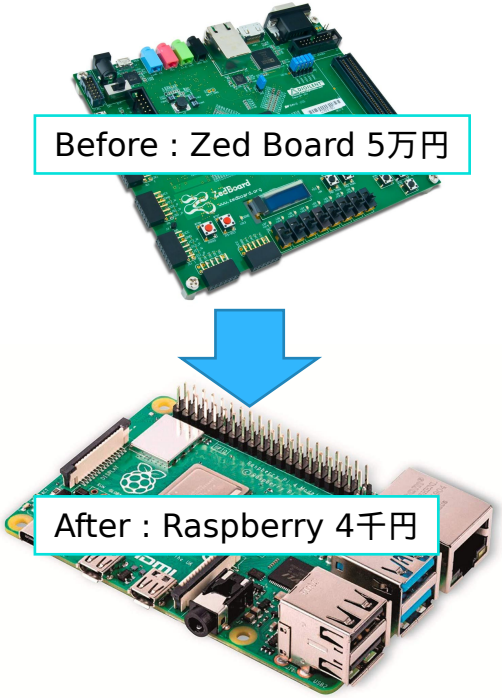


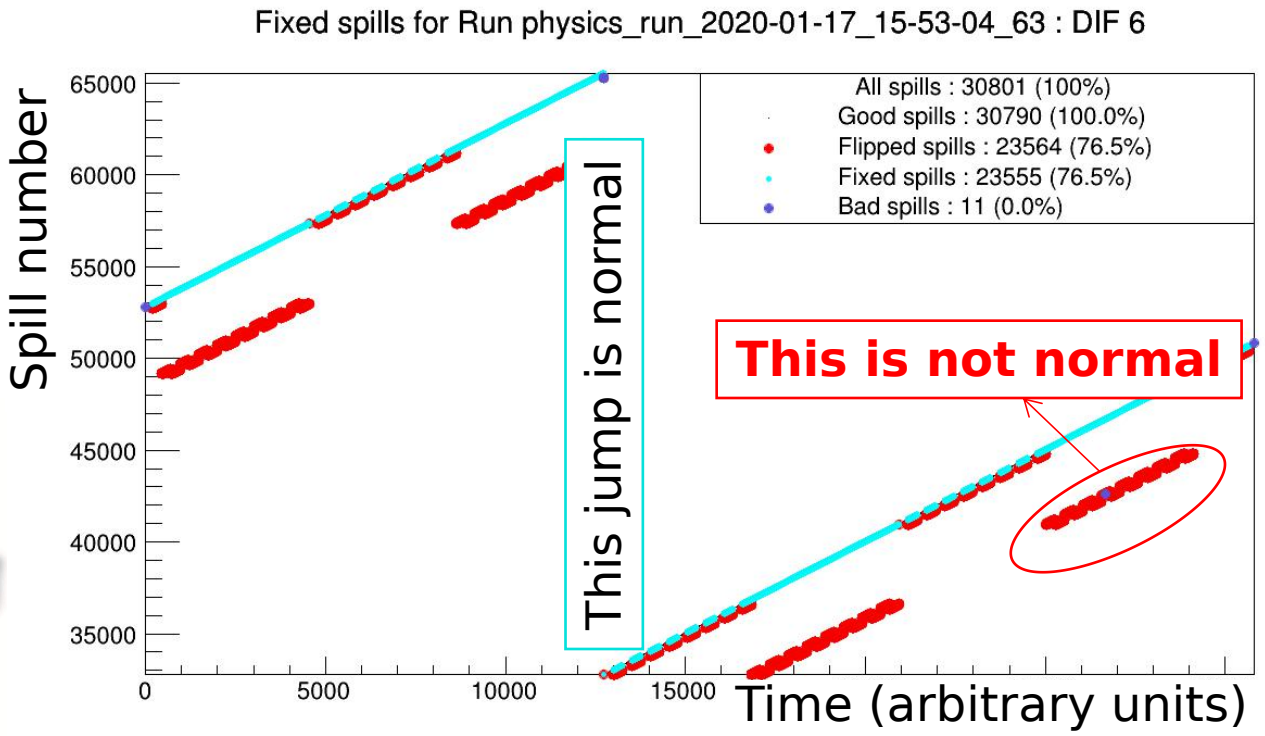
List of hardware problems and their solution

	Problem	Effect	Solution
✓	WallMRD frontend electronics picks up electromagnetic noise from the environment	Many hits in WallMRD due to noise (even with high threshold). Signal is partially lost. 2/3 of data is affected.	Add decoupling capacitors on frontend boards (during the Physics run)
✗	Data corruption due to bug in FPGA firmware	In total 3 days of run time are lost	Add online monitor to check for corruption (in the future)
✓	Fine time information is wrong because of bug in FPGA firmware	No fine time information. No information on track direction. This year data is not affected.	Solved last year by updating the DIF firmware.
✗	Bug in FPGA firmware makes the electronics configuration step fail	It takes many tries to load the configuration. A power cycle may be needed.	Installed a remote power switch to power cycle electronics from CR
✓	FPGA bug in spill number converter	Spill number is correctly recorded for 2 weeks	Spill number recovery by software analysis. New spill number converter
✗	Hardware bug inside the frontend SPIROC2D ASIC threshold comparator	Threshold is applied on the undershoot of the signal and it is not applied correctly	Use the new SPIROC2E ASIC (most probably it is not going to happen)

Spill number converter problem and its solution

Because of COVID19 pandemic I developed the RPI converter at home





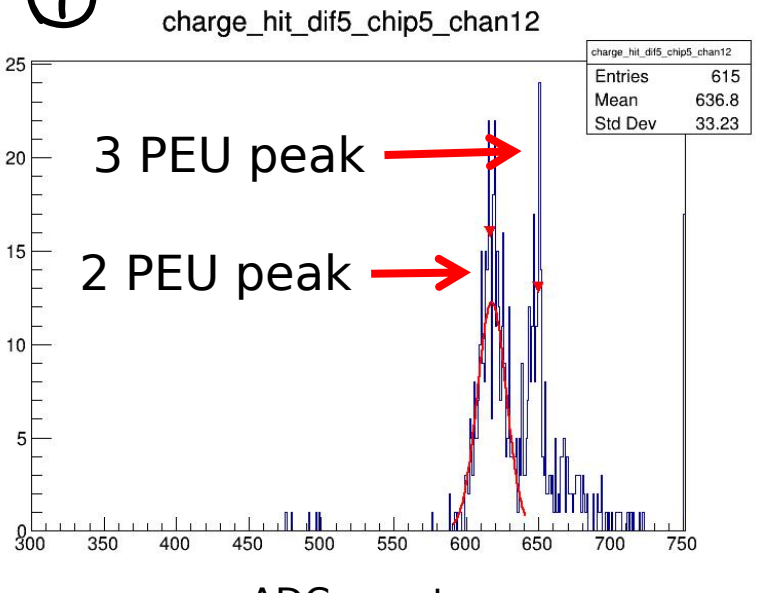
Next year data: New spill number converter based on Raspberry Pi

BIT FLIP PROBLEM	BIT FREEZE PROBLEM
Sometimes a bit flips: 0 → 1 or 1→0	The 8th bit and 12th bit stay always down (are always zero)
The flip is temporary (affects on one spill)	This problem is not temporary (affects all the spills)
The flip is random (but there are many bit flipped during spill number reset	This problem affects only runs 58 to 78 (2020 January 14 to January 22)

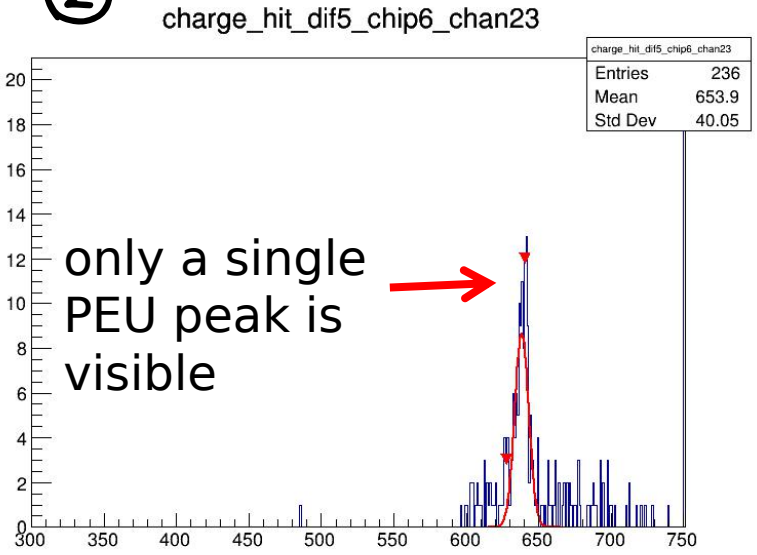
This year data: spill number recovery by software analysis

Online calibration challenges for WAGASCI and WallMRD

①



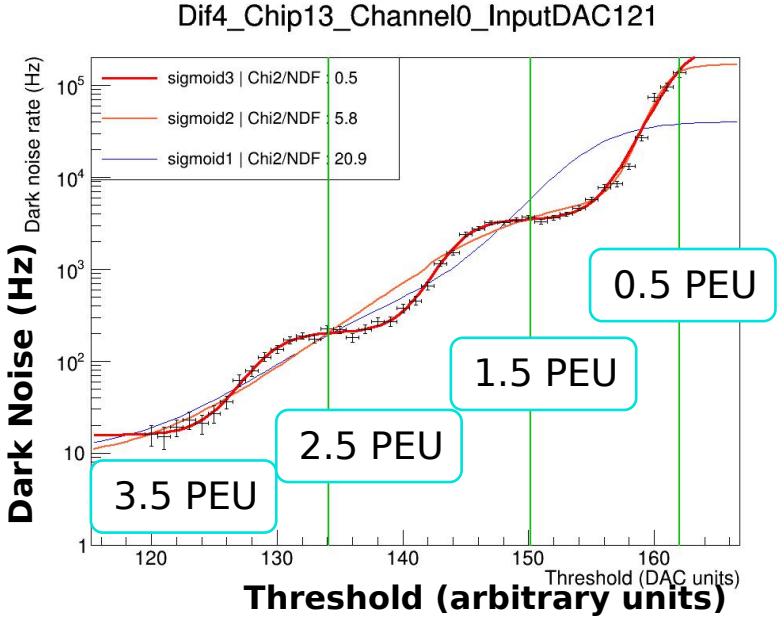
②

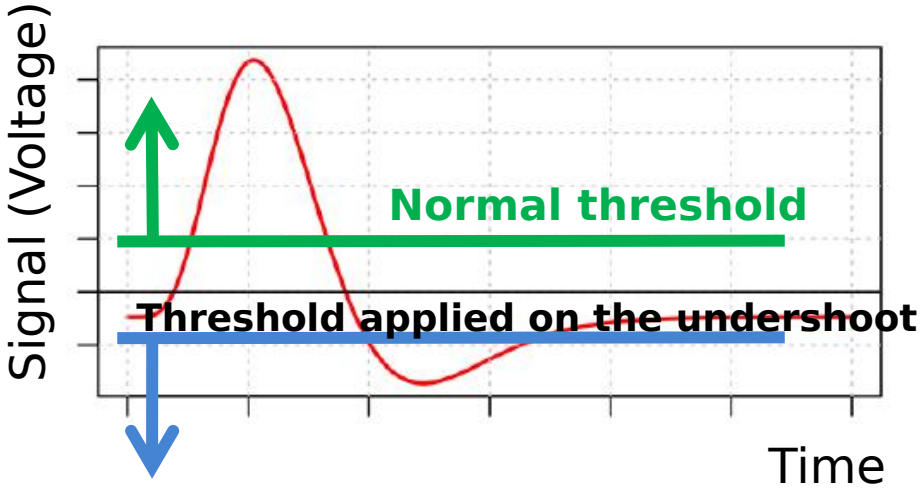


charge distribution

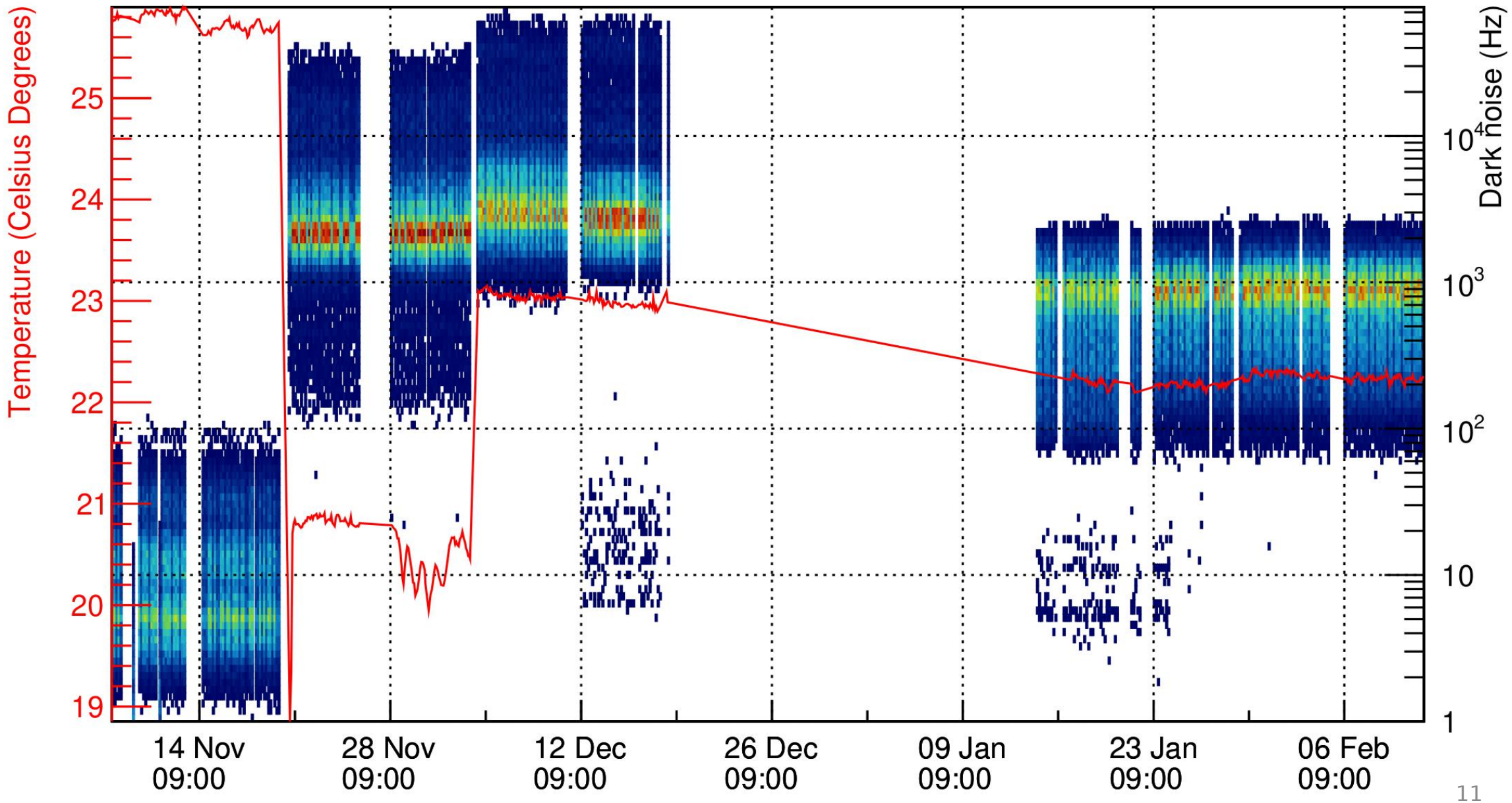
- The gain calibration of WAGASCI detector was never properly done until now
- Because of an **hardware problem in the threshold comparator circuit** the threshold is applied on the undershoot of the signal
- Dark noise of new generation MPPC is very low (very few hits at 2.5 PEU threshold)
- Sometimes **only one peak** is seen in the charge distribution
- Gain must be calculated using the pedestal and guessing the PEU number of the peak

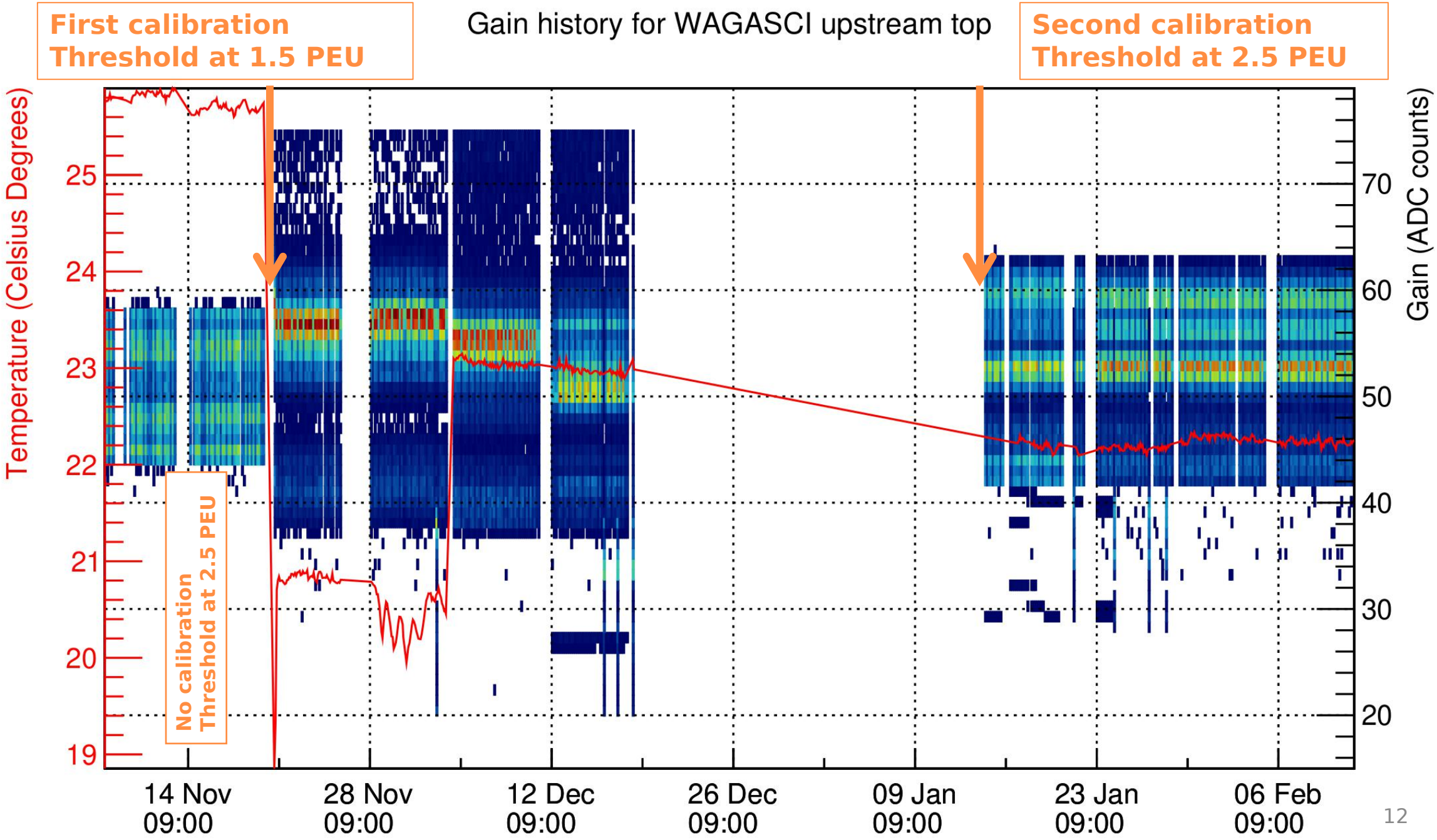
S-curve calibration



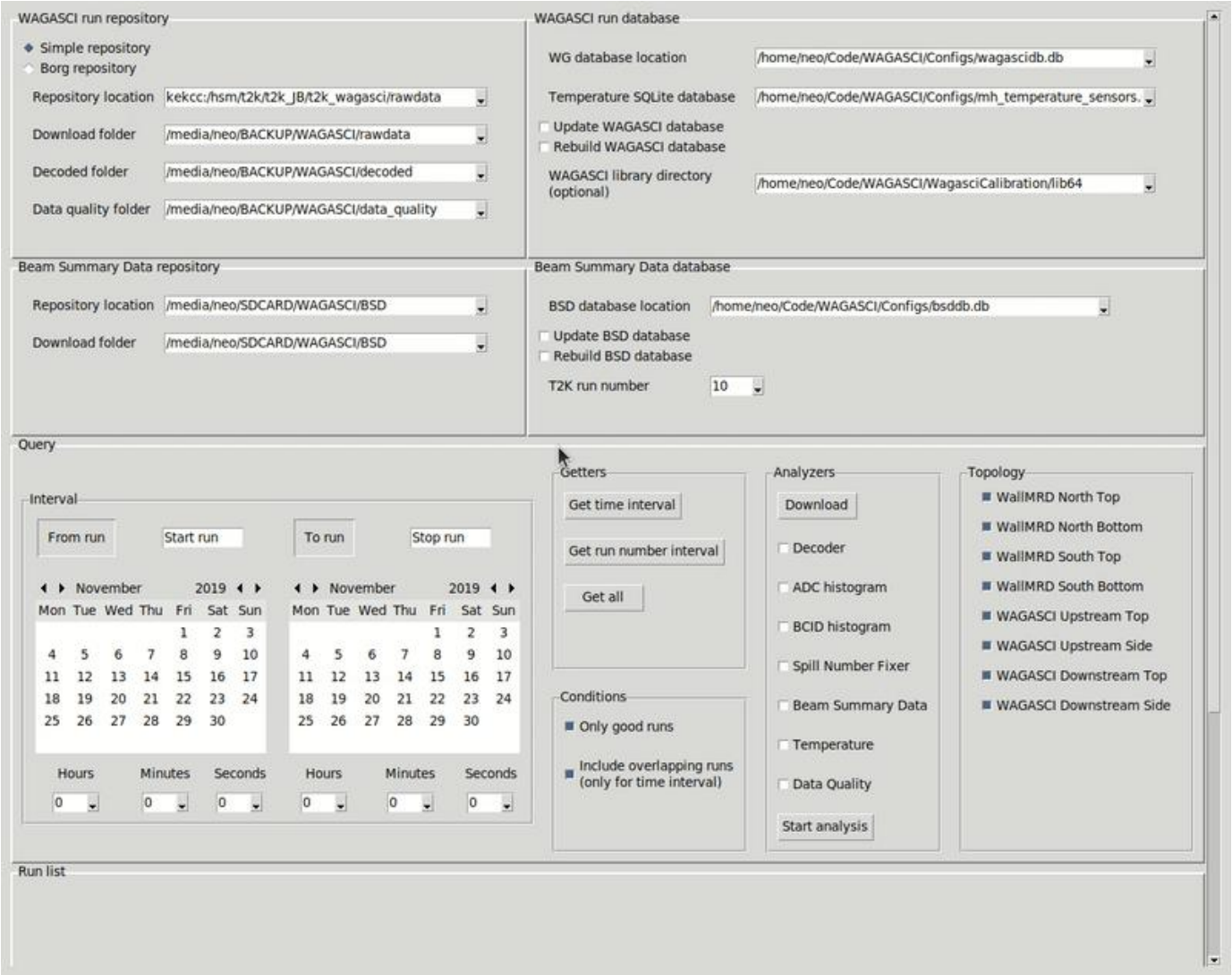


Dark noise history for WAGASCI upstream top




First calibration
Threshold at 1.5 PEU
Gain history for WAGASCI upstream top
Second calibration
Threshold at 2.5 PEU
Temperature (Celsius Degrees)
Gain (ADC counts)
No calibration
Threshold at 2.5 PEU
19
20
21
22
23
24
25
20
30
40
50
60
70
14 Nov 09:00
28 Nov 09:00
12 Dec 09:00
26 Dec 09:00
09 Jan 09:00
23 Jan 09:00
06 Feb 09:00

Automated run database and data quality checks



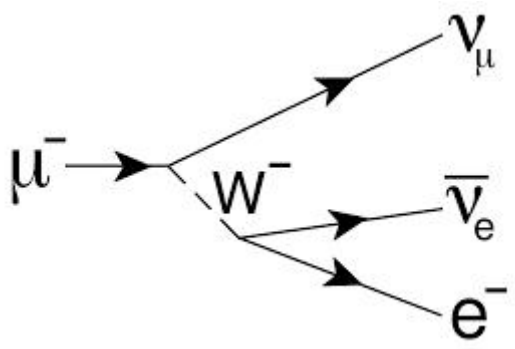
- **Perform automatic or semi-automatic data quality checks (ADC and TDC histograms, gain and dark noise history plots)**
- **A shifter with minimal training should be able to operate it**
- All functions must be accessible both from the **GUI** (graphical user interface) and from the **CLI** (command line interface)
- **Linux is fully supported** (MacOS support is partial)
- It can download all databases and data from remote repository if needed
- Support for KEKCC job system

New Monte Carlo simulation software for WAGASCI-BabyMIND

WAGASCI Monte Carlo is based on INGRID Monte Carlo

Issue 1	Issue 2	Issue 3
Simulation and detector response is fully implemented only for Proton Module (previously part of INGRID)	No version control until recently	Output is taylored towards the INGRID analyis

Solution 1	Solution 2	Solution 3
Fixed some bugs and search for Michel electron candidates	Proper version control with git	New data format ready for WAGASCI-BabyMIND analysis



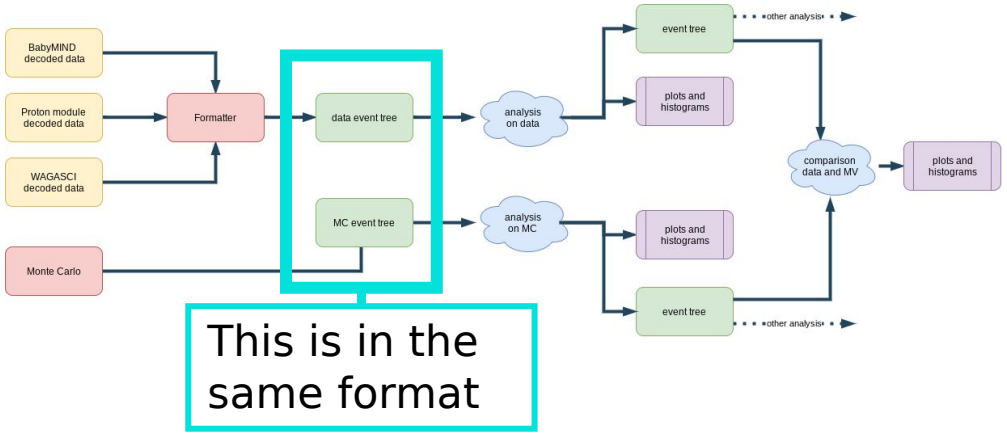
Muon decaying into Michel electron

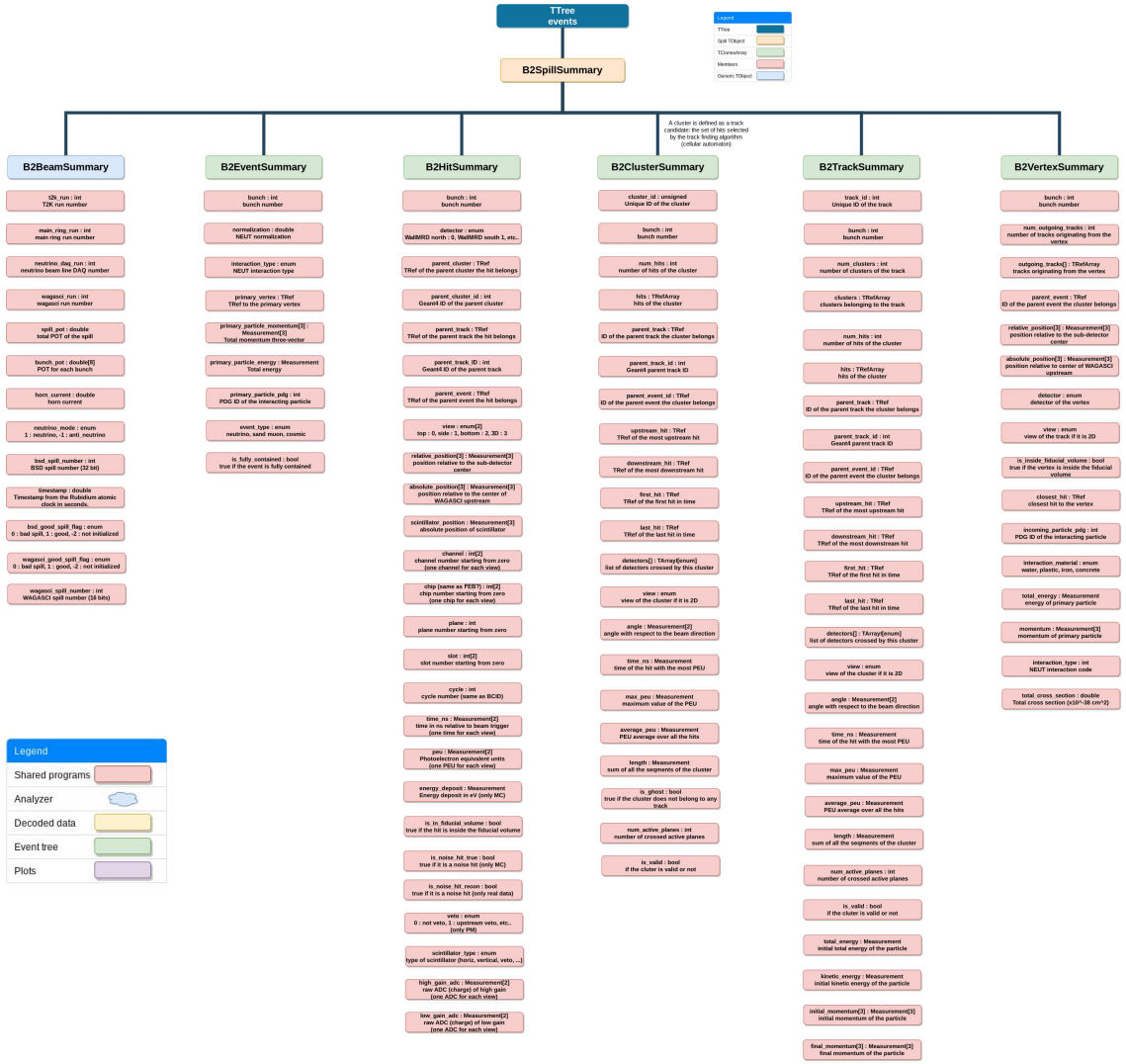
Since the invariant mass is determined from quantities which are conserved during a decay, **the invariant mass calculated using the energy and momentum of the decay products of a single particle is equal to the mass of the particle that decayed**. The mass of a system of particles can be calculated from the general formula:

$$(Wc^2)^2 = \left(\sum E\right)^2 - \left\|\sum \mathbf{p}c\right\|^2,$$

New data format for WAGASCI-PM-BabyMIND cross-section analysis

- Based on ROOT
- Container for **hits, tracks, vertices, events**, etc...
- **Same output for Monte Carlo and Physics data** (using converters) so that we can apply the same analysis to both MC and Physics data
- Comes with a **library** simple to use



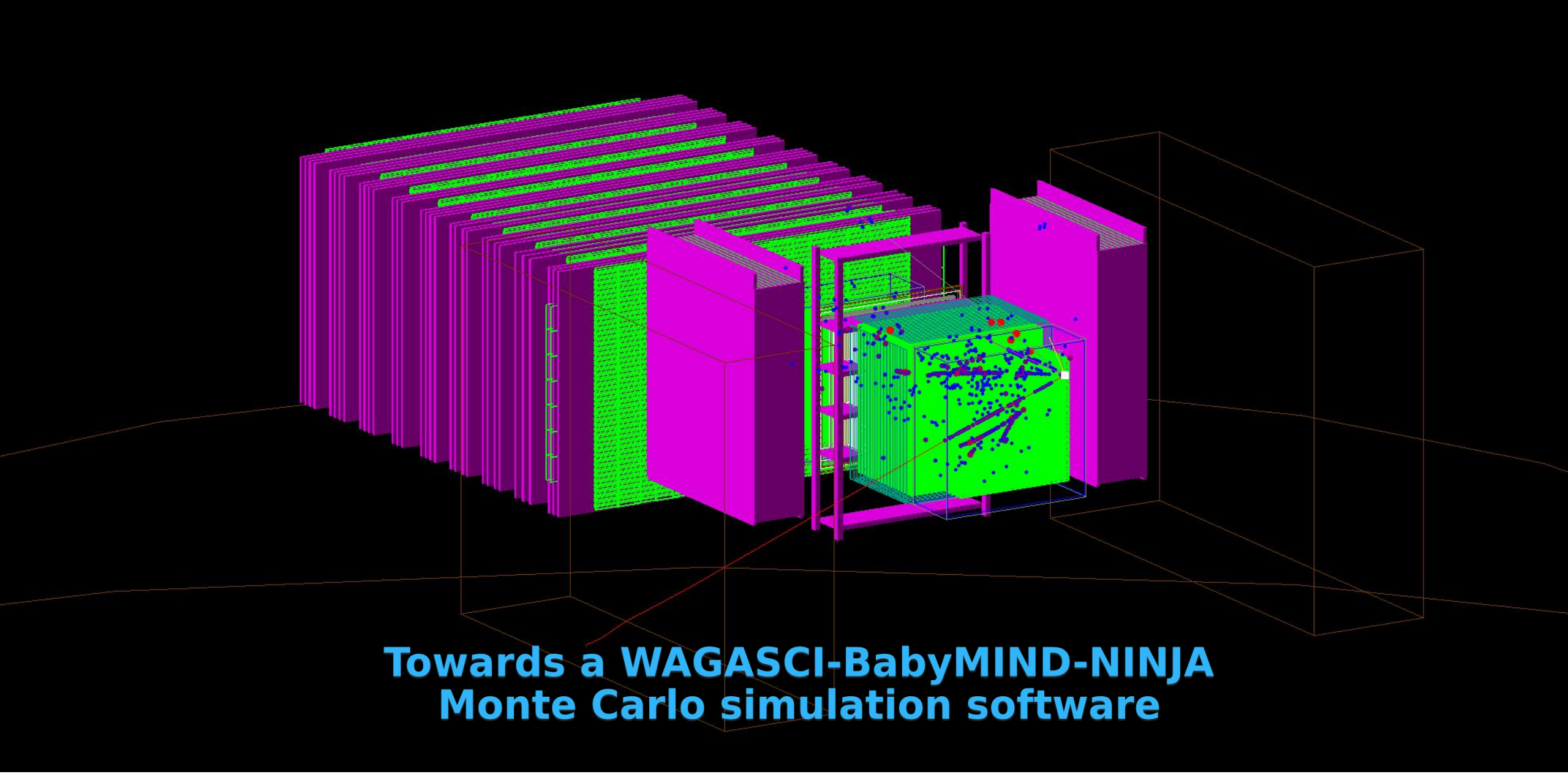


Plans for the future

HARDWARE
Properly do the TDC calibration of WAGASCI and WallMRD
Test and install the new spill number converter based on Raspberry Pi
Install fixed frontend electronics (only so called interface board) to fix the failed configuration problem
Improve the online monitor software
Improve the BabyMIND DAQ

before February 2021

ANALYSIS
Currently developing the converter from Physics data to new data format (1 week)
Add support for double readout scintillators in the Monte Carlo software (1 week)
Improve reconstruction code for WAGASCI module (1 month)
Improve scintillator, WLS fiber and electronics responce in the Monte Carlo software (2 weeks)
Start real cross-section analysis ...



Towards a WAGASCI-BabyMIND-NINJA Monte Carlo simulation software

TODO list

TODO	DONE
Detector responce (scintillator-fiber-MPPC-electronics responce) for all detectors is not complete	Geometrical description of WAGASCI and NINJA (thanks to Odagawa-kun)
All hits inside NINJA are not visualized (only hits in tracker are visualized)	Description of sensitive detectors for WAGASCI and NINJA (thanks to Odagawa-kun)
Write NINJA output TTree in a different file as WAGASCI (add configuration option)	
Merge NINJA MC and WAGASCI MC. Currently they are in different branches.	