WAGASCI-BabyMIND new Monte Carlo software

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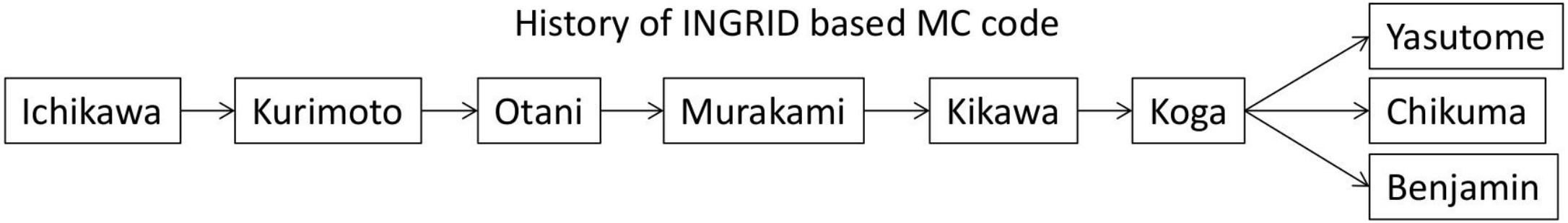
WAGASCI - BabyMIND Monte Carlo history

- It was developed starting from the INGRID Monte Carlo code
- There were three major problems with the previous version:
  1. It was designed **only for INGRID**
  2. Many people contributed to it **without any version control**
  3. The output is taylored towards the **INGRID cross-section analysis**



Problem 1 : it was designed only for INGRID

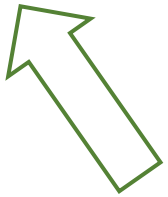
INGRID	WAGASCI-BabyMIND
No double readout	WallMRD and BabyMIND have **double readout**
Only horizontal, vertical and veto scintillators	WAGASCI has grid scintillators and YASU tracker has double scintillators (left - right)
Many variables are still called ingrid_<something>	
position of INGRID modules does not change very often	Position of WAGASCI detectors changed often and it is much more complex

Problem 2 : no version control

- Many people in different period of times contributed to the code
- Without a version control system, **it is difficult to understand who is doing what**
- Some code that is not used anymore is left there to rot
- Huge chunks of code are commented out for no apparent reason
- Some **constants are defined more than once** with different values

Problem 3 : output designed for INGRID analysis

- Many branches are useful only for INGRID analysis
- Some information useful for WAGASCI-BabyMIND is missing or difficult to read
- Michel electrons are not stored
- **Response of electronics and scintillators is fully implemented only for Proton Module**



This is the only thing left to do

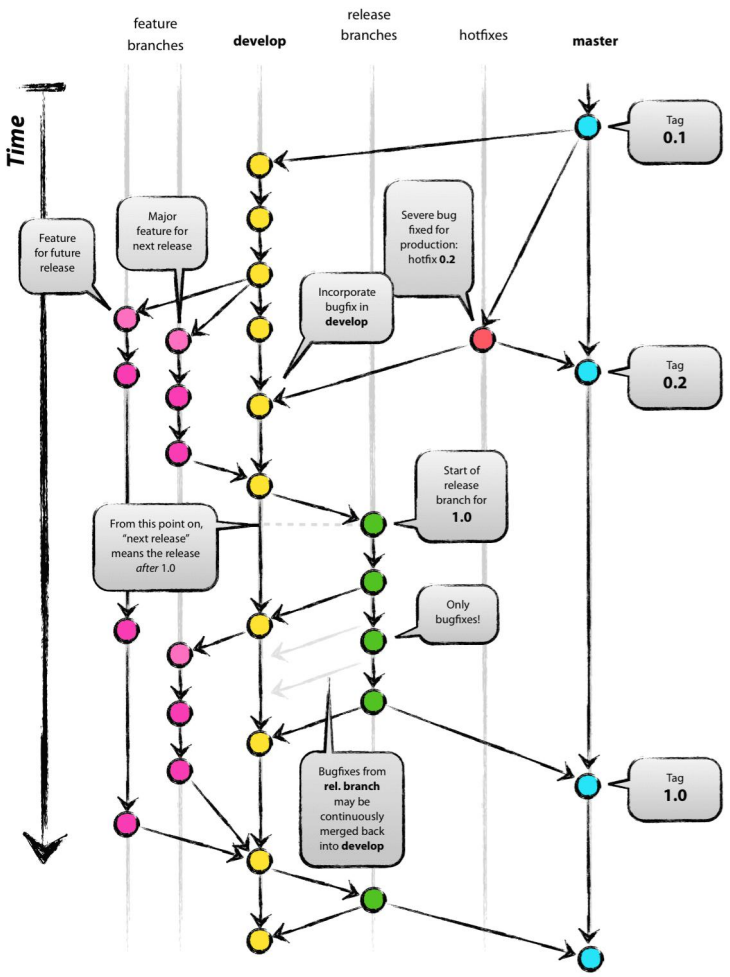
Solution 1 : new data format

HITS	TRACKS	VERTICES
can accomodate double readout	tracks can cross many subdetectors	can be not only primary vertex, **but secondary vertices too**
It is assumed the detectors are already calibrated	Initial and final information is recorded	**Each spill can contain many events (primary vertices)**
is compatible with all WAGASCI subdetectors	can record primary particles and secondary particles	

More about the new data format later

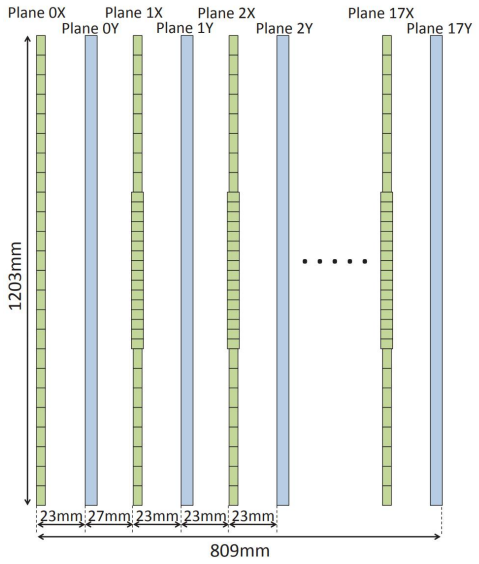
Solution 2 : version control system

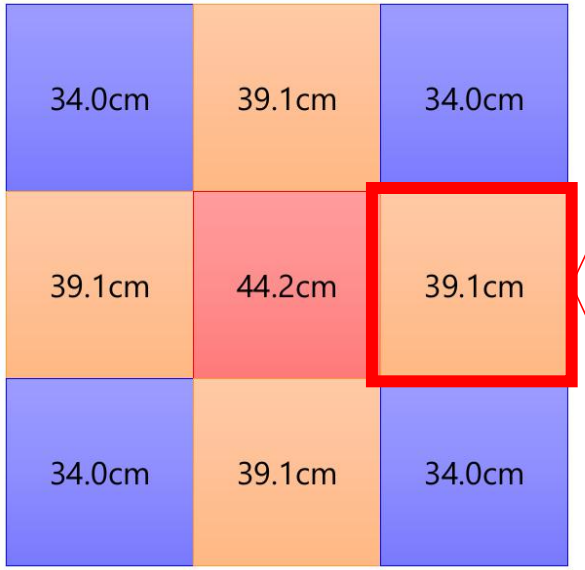
- All code is hosted on WAGASCI-BabyMIND **GitLab**
- A proper **git branching model** is exploited (Vincent Driessen model)
- A **version number** is used to tag all versions (current is v0.1.0)
- Everybody is getting used to git and I see a lot of improvement

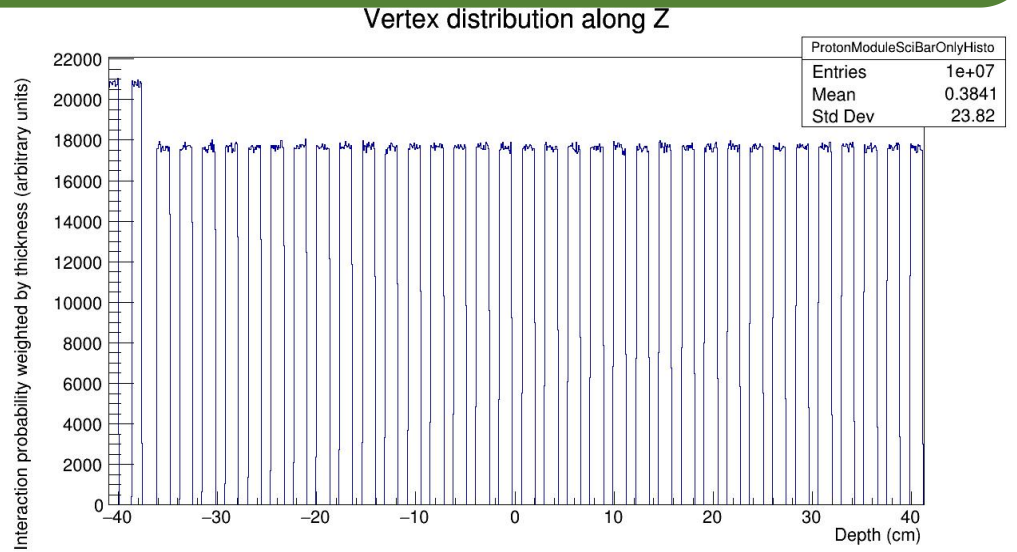


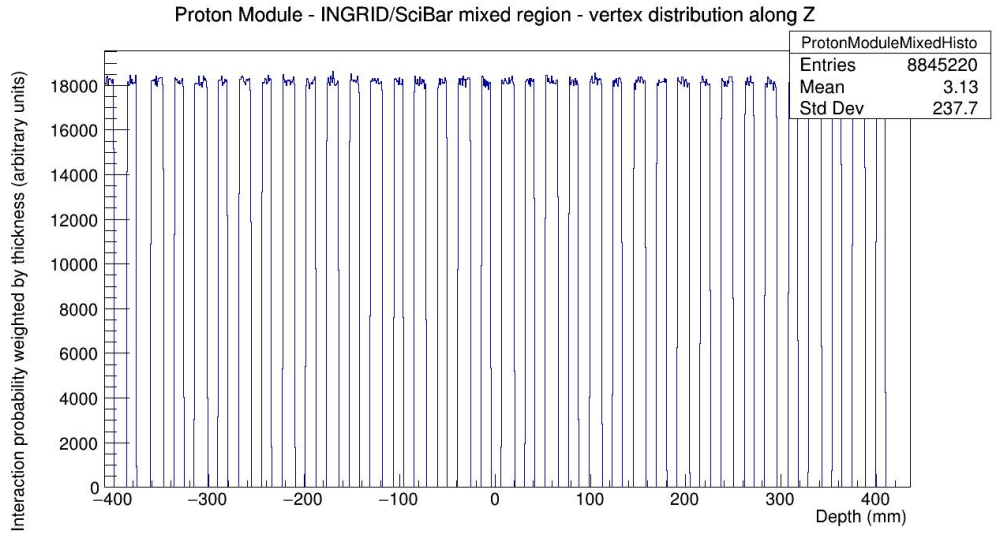
Solution 3 : WAGASCI-BabyMIND analysis

- Fixed some bugs in the vertex Z position of Proton Module
- Probability of vertex in the front VETO planes was higher than the other planes



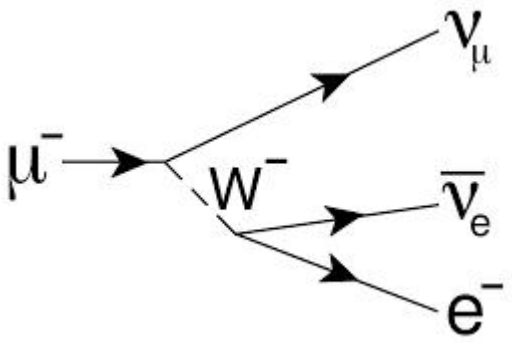






Solution 3 : WAGASCI-BabyMIND analysis

- **Michel electrons** are found and recorded
- The decay of the muon into neutrinos and Michel electron must be **checked manually** (Geant4 does not provide a function like “give me Michel electron”)
- All decay products are looked for (muon neutrino, electron neutrino and Michel electron) and checked
- The **invariant mass** of the decay is checked for consistency (up to 5%)



and the relative decay for **μ+**

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:

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

Solution 3 : WAGASCI-BabyMIND analysis

- **Response of Proton Module is fully implemented**
- **Response of WAGASCI scintillator is implemented. Response of WAGASCI electronics is partially implemented**
- **Response of WallMRD is partially implemented**
- **Response of BabyMIND is partially implemented**

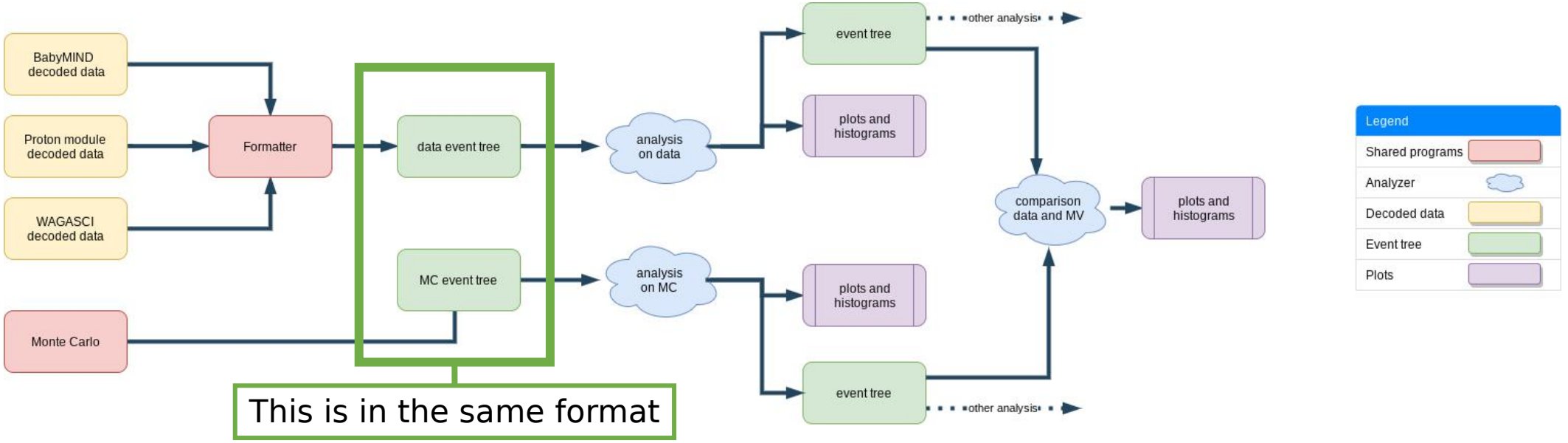
This needs to be done in the near future

Other improvements

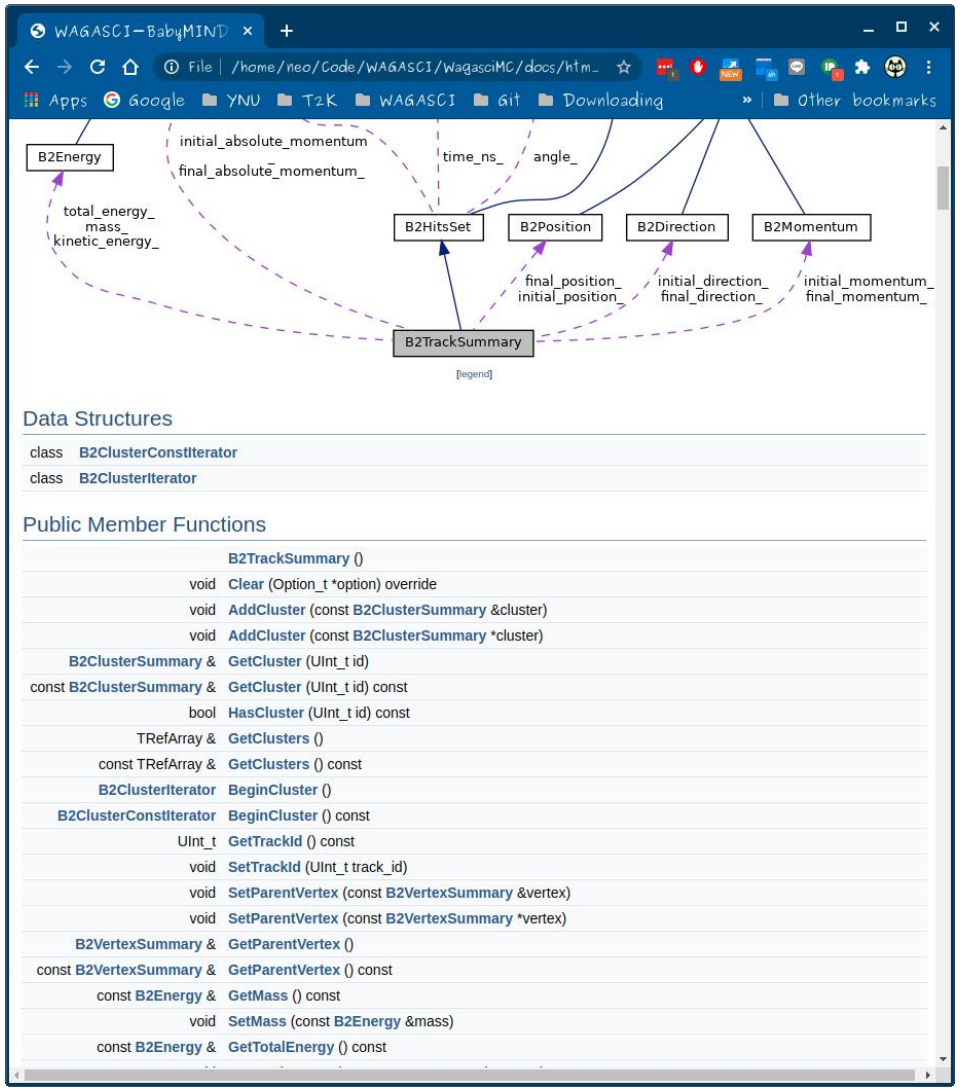
1. **No more CERNLIB dependency** (input is ROOT file from NEUT)
2. No more path hard-coding
3. All constants defined in one place
4. **All physical variables are expressed in consistent units**
   - Length in **mm**
   - Time in **ns**
   - Energy/momentum/mass in **MeV**
5. Configuration can be changed using the CLI and **configuration INI file**

New data format

- It contains all the info about **hits, vertices, cluster of hits, tracks, beam**
- It can be used for **any kind of analysis** in WAGASCI-BabyMIND
- It comes with a **library** that makes it easy to access and modify
- It tries to reduce the amount of redundancy



New data format



Data Structures

class B2ClusterConstIterator

class B2ClusterIterator

Public Member Functions

	B2TrackSummary ()
void	Clear (Option_t *option) override
void	AddCluster (const B2ClusterSummary &cluster)
void	AddCluster (const B2ClusterSummary *cluster)
B2ClusterSummary &	GetCluster (UInt_t id)
const B2ClusterSummary &	GetCluster (UInt_t id) const
bool	HasCluster (UInt_t id) const
TRefArray &	GetClusters ()
const TRefArray &	GetClusters () const
B2ClusterIterator	BeginCluster ()
B2ClusterConstIterator	BeginCluster () const
UInt_t	GetTrackId () const
void	SetTrackId (UInt_t track_id)
void	SetParentVertex (const B2VertexSummary &vertex)
void	SetParentVertex (const B2VertexSummary *vertex)
B2VertexSummary &	GetParentVertex ()
const B2VertexSummary &	GetParentVertex () const
const B2Energy &	GetMass () const
void	SetMass (const B2Energy &mass)
const B2Energy &	GetTotalEnergy () const

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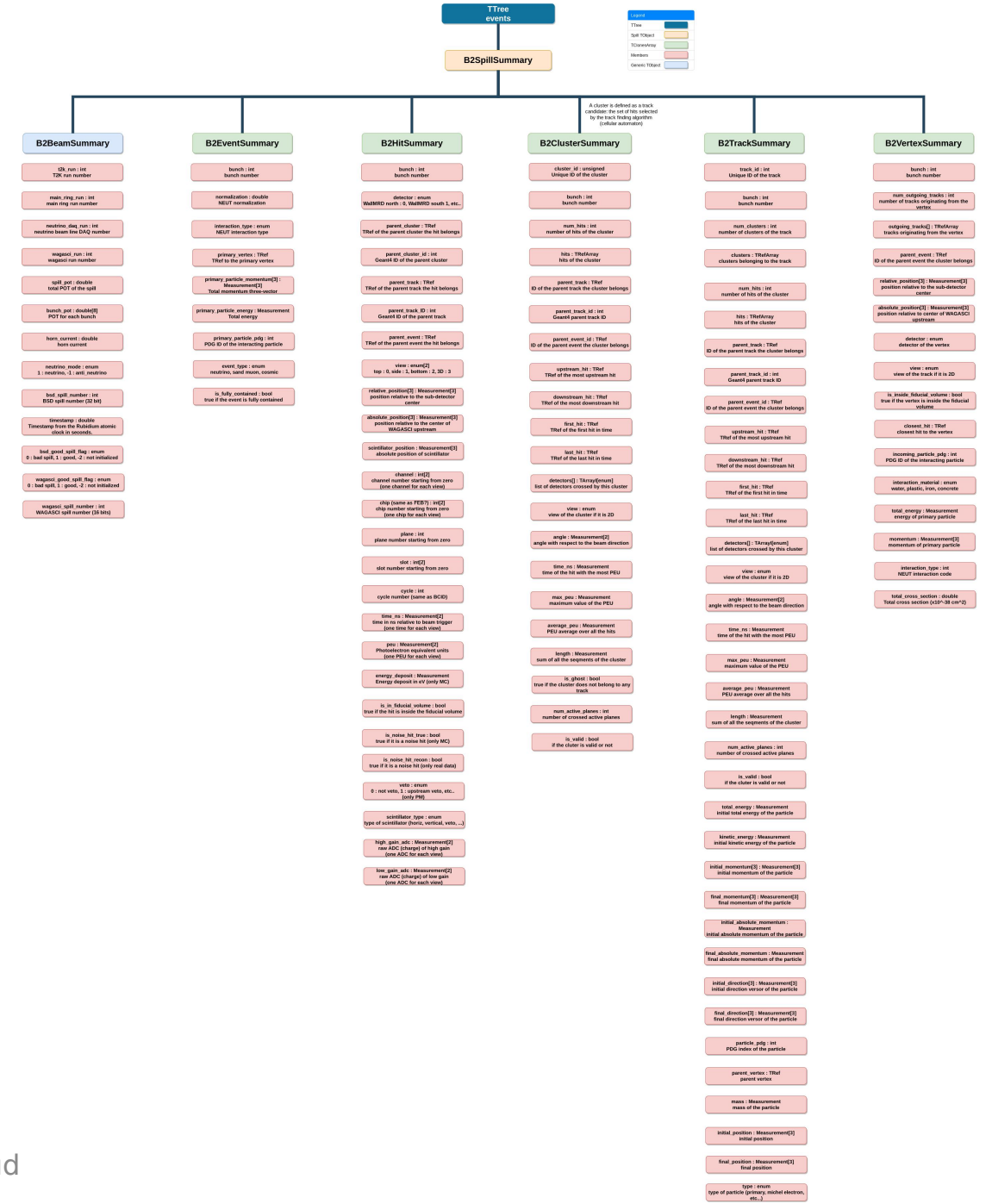

Pintaud

New configuration file

```
# General
gui=false
command=
neutrino-interaction-settings=WagasciDownstream
water-settings=WgupInWgdownIn
neutrino-flavor-settings=MuonNeutrino
magnetic-field=true

# IO
output-file-path=data/output.root
input-file-path=data/input.root

# GEOMETRY
geometry-dir-path=data/geometry

# Log
debug-level=info
log-file-path=data/log/B2MC.log
```

- Every option can be configured both in the configuration file and CLI
- The CLI has priority over the configuration file
- A default configuration file is created the first time the program is run

Backup slides