

A 3D architectural rendering of the Hyper-Kamiokande detector, showing its large cylindrical structure with a blue mesh interior, situated underground. The title text is overlaid on a dark horizontal band.

# Task 3.5 Hyper-Kamiokande Simulation

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### Deliverable:

**Simulation data analysis with the final photosensor configuration**

*Continue with the development of a realistic design of the experiment in the simulation as well as analysing the simulated data and focusing on implementing its calibration systems in the simulation and the analysis of the simulated data*

### Pieces of software to do this:

- ✱ **Current packages based on Geant-4 physics, PMT & electronics simulation:**
  - **WCSim**
  - **GHOST**
- ✱ **Triggering using TriggerAp & SNTriggerApp**

### WCSim

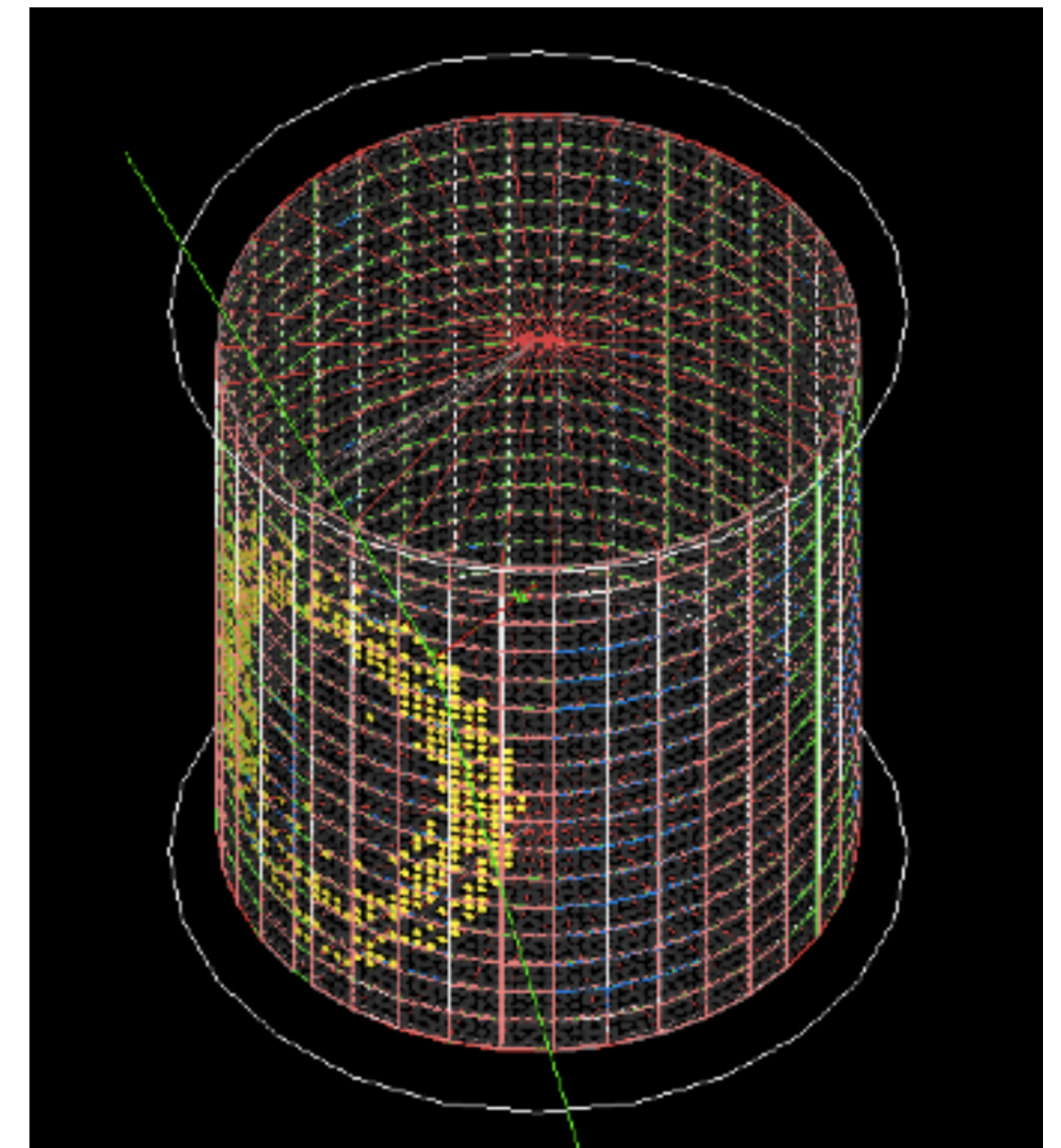
**An open-sourced, Geant4-based simulation code for water Cherenkov detectors**

**\* User can define a detector configuration by choosing:**

- ☒ **Detector geometry: Super-K, Hyper-K Far Detector, IWCD, WCTE**
- ☒ **PMT type: Super-K 50 cm, Hyper-K 50 cm, mPMT 8 cm, OD 8 cm, ...**
- ☒ **Electronics: SKI**
- ☒ **Simple triggers: NHits, pass all**

**\* Run particles in the detector using either:**

- ☒ **Input from neutrino interaction generators**
- ☒ **or using Geant4 particle generation**

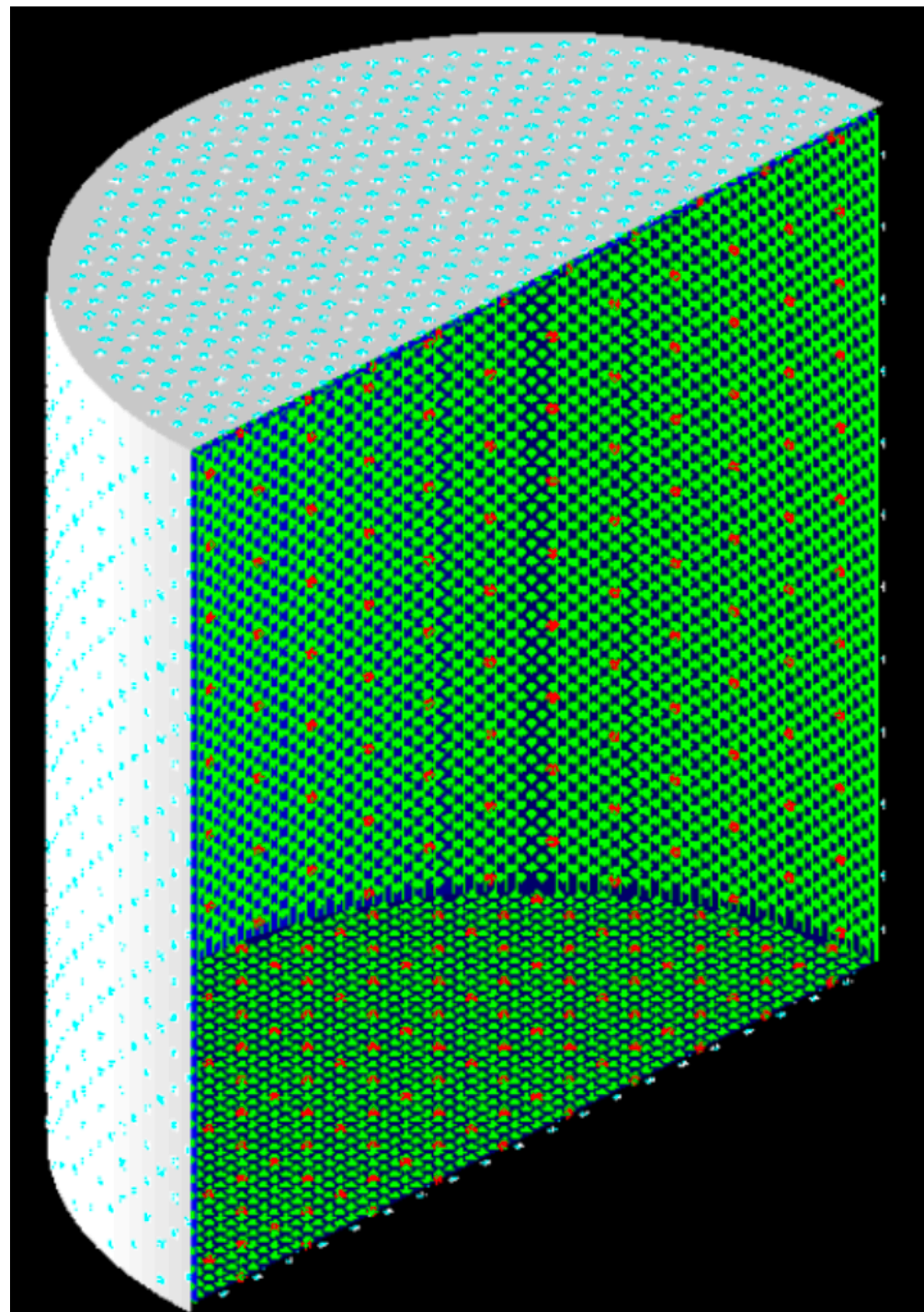




## WCSim - Far Detector

Realistic implementation based on integration drawings

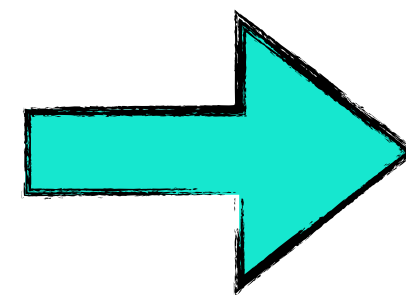
PMTs placed in realistic positions



\* 50 cm PMTs

\* mPMTs

\* OD



Recent changes:

- \* WCSimRootEvent memory leak fixed
- \* Changes to **IWCD** & **WCTE geometries**
- \* Option to constrain to 1 digit per PMT in NoTrigger trigger
- \* Found bug in OD facing direction
- \* Fixed it and making new tag, and used for MC production
- \* **Documentation/printout** improvements
- \* + **multiple minor improvements**

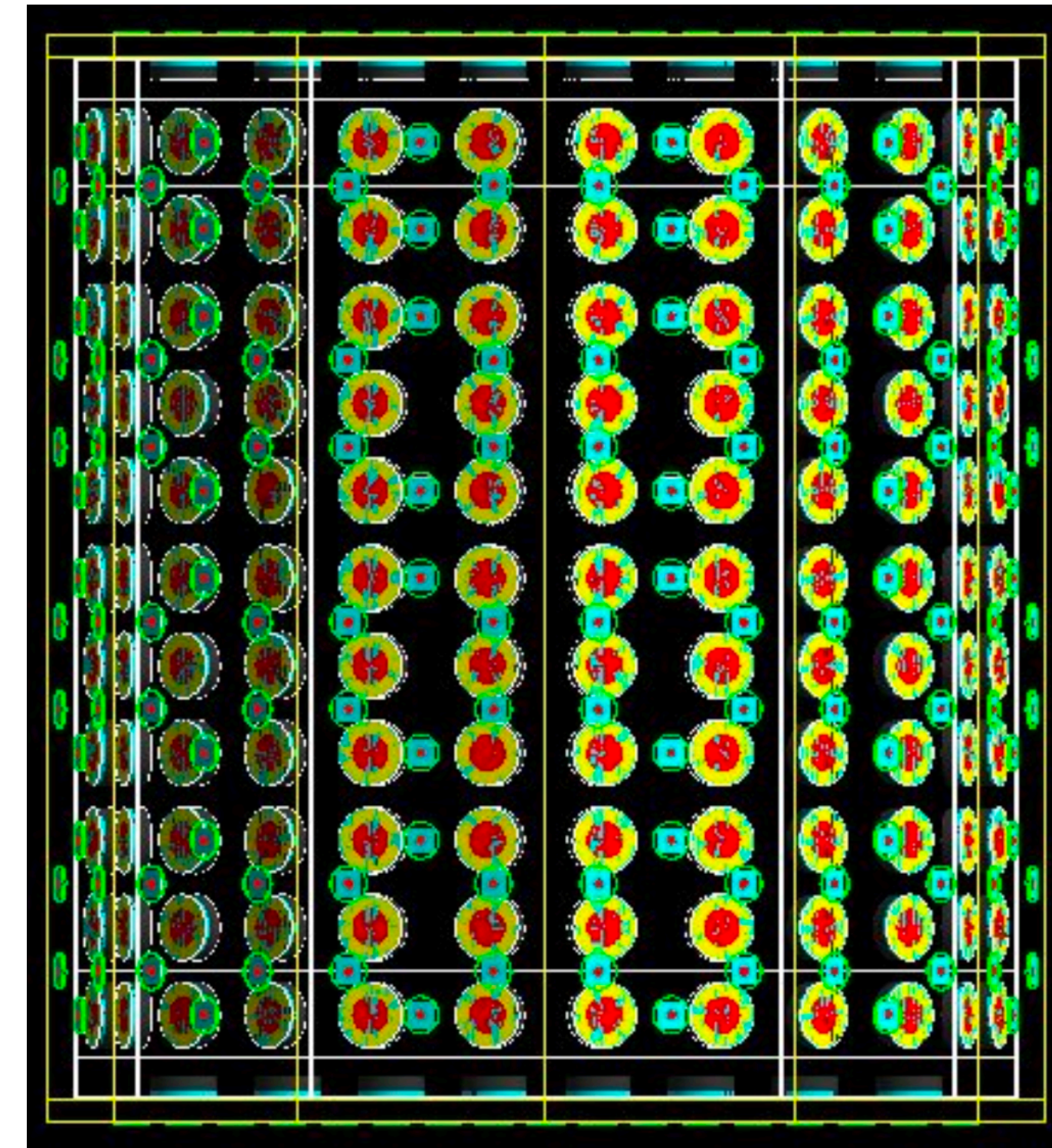


### WCSim - IWCD

**Latest IWCD geometry in WCSim:**

**Realistic implementation based on integration drawings**

- ✱ Tank size
- ✱ Number of mPMTs
- ✱ Number of OD PMTs
- ✱ OD water thickness



# GHOST

### \* WCSim is

- Not very modular = hard to develop
- Uses old C++11 standard
- Uses old Geant4 v10.3.3 [October 2017]
- Single threaded = inefficient
- New features have been added in inconsistent ways
- Not tuned to data (or other MC) for a few years

### \* Enter GHOST

- Geant4 H<sub>2</sub>O Simulation Tool



**GHOST structure was designed**

\* **v1 = WCSim restructured**

\* **v2 = simulation improved**

# GHOST

- ❑ Migrate to **GHOST v1** (restructure of WCSim code): finish restructure by end of April
- ❑ Tool/class status
  - **Have:** generator, physics list, actions (stacking, stepping, tracking, event, run)
  - *In progress:* PMT simulation
  - *Todo:* geometry, electronics simulation, other data storage classes
- ❑ DataModel class status
  - **Implemented:** track, geometry, event linkage
  - *Todo:* hit related classes (Deposit, DarkNoise, Trace, Hit), vertex



## TriggerApp + SNTriggerAPP

TriggerApp can act on both data & MC: will run **online** in **DAQ** & **offline** with **MC** using the same code

- \* Less maintenance; fewer mistakes
- ☑ **TriggerApp** takes as **input all PMT hits**, to perform 3 jobs
  - \* Triggering, including dedicated low-energy algorithms
  - \* Online reconstruction
  - \* If a very high trigger rate is seen, switch DAQ to SN readout mode (all data saved, alerts sent)
- ☑ **SNTriggerApp** takes as **input all reconstructed triggers**, to perform 3 jobs
  - \* Triggering of astronomical sources (SN burst, preSN)
  - \* Direction reconstruction of astronomical sources
  - \* If trigger created, switch DAQ to SN readout mode (all data saved, alerts sent)



☑ **SNTriggerApp** features were implemented in **TriggerApp v1**. Now writing them in new SNTriggerApp package

- Using new ToolFramework multi-threading features

☑ **Status**

- 👤 **Data structures setup**
- 👤 **Tool/toolchain structure setup ongoing (offline file I/O tools, dummy tools)**
- 👤 **Development occurring on gitlab**

☑ **Plans**

- 👤 **Migrate TriggerApp v1 SN tools to new SNTriggerApp package**
- 👤 **Implementation of novel tools, collaborating with other groups (e.g. SNCast)**
- 👤 **Setup CI with HK-Validation package**

# Summary

- \* **Using same software for Hyper-K's far detector & IWCD**
  - More efficient coding by just doing it once
  - Allows consistent models, systematics, etc
- \* **WCSim** development: **v1.12.20** is latest release of WCSim
  - New release with FD OD PMT orientation bug fix coming soon
- \* **GHOST** is being developed as the replacement for WCSim
  - Migrating to GHOST v1: better structure for future developments ongoing
  - v2 will bring many simulation improvements



# Summary

- \* Development of **TriggerApp** & **SNTriggerApp** ongoing
- \* TriggerApp development: **v2.1.1** latest release of TriggerApp
  - New TriggerApp release with 3 triggers & low-E recon soon
  - First release of SNTriggerApp will come afterwards

# THANK YOU!