WCsim and BONSAI reconstruction tool

T. Yano
Kobe University

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Motivation of this study

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- To study the capability of Hyper-Kamiokande at low energy with BONSAI.
  - BONSAI reconstruction algorithm have been used for SK low energy analysis.
  - ~ 3 MeV to a few tens MeV is the target range of BONSAI.

What is BONSAI?

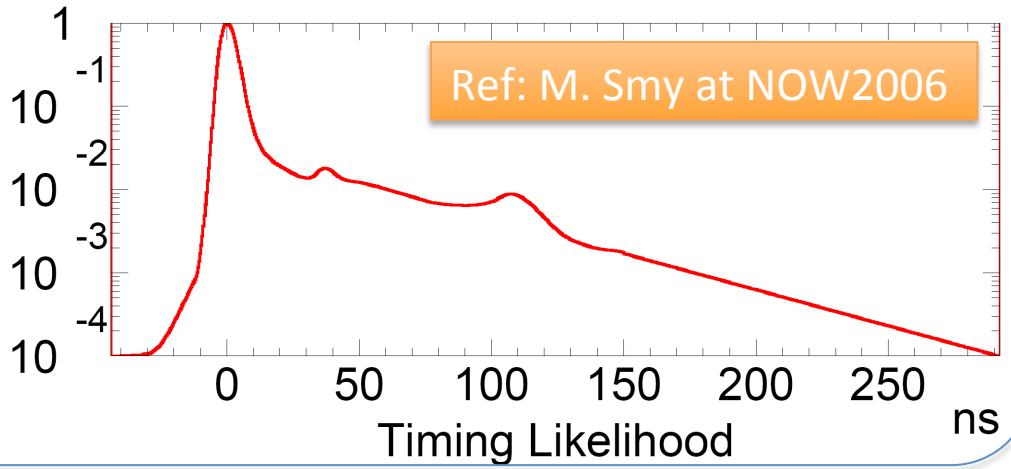
BONSAI :

- Low energy vertex reconstruction algorithm has been used for all SK period, including **SK-II**.
- Well-tested, reliable and **scalable**.

- Maximum Likelihood method
- Using PMT hit timing and charge information.

$$\Delta t_i(\vec{x}) = t_i - \mathrm{tof}_i(\vec{x}) - t_0$$

$$L(\vec{x}, t_0) = \log\left(\prod \mathrm{pdf}(\Delta t_i(\vec{x}))\right)$$

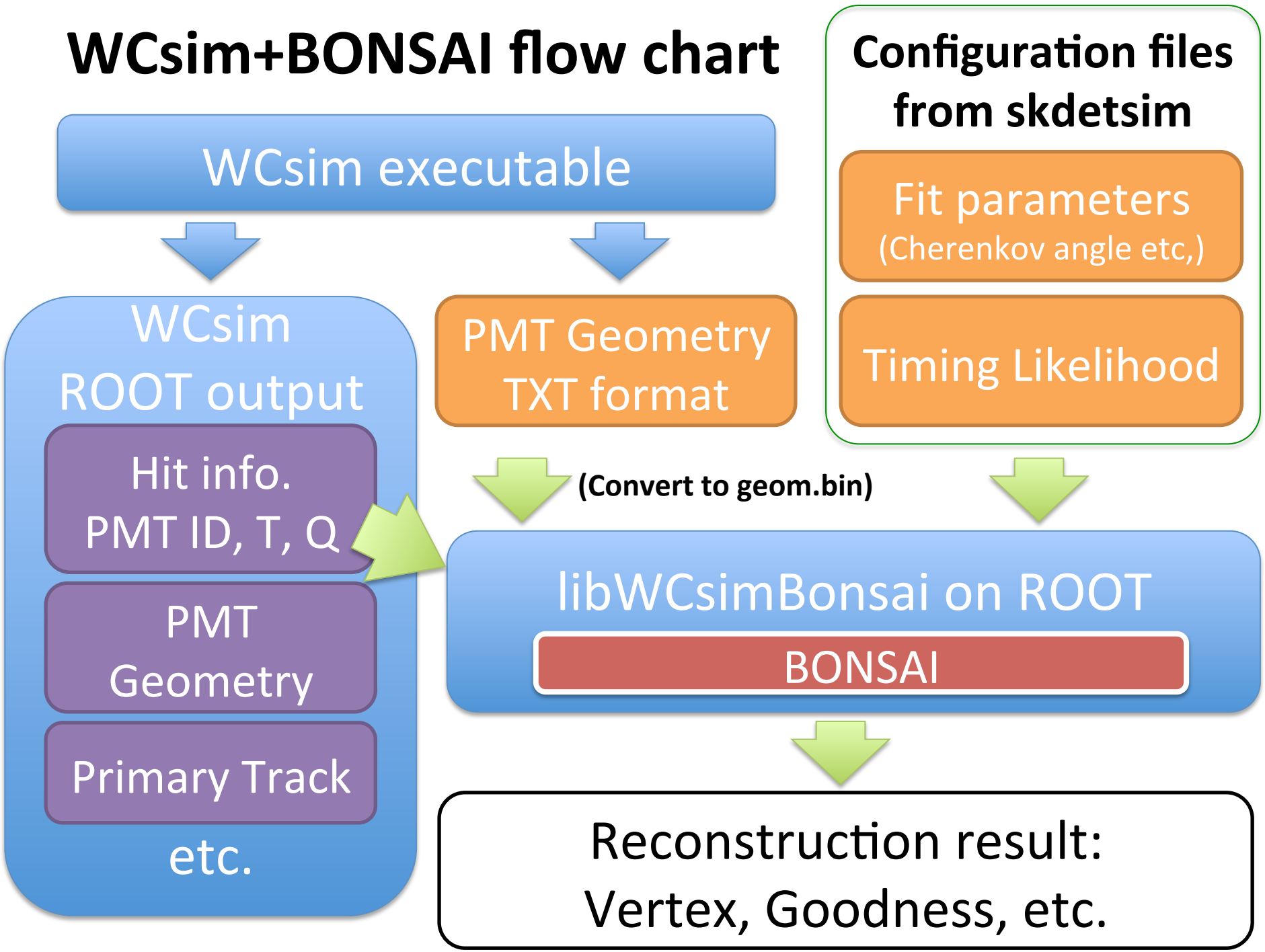


Status of Bonsai with WCsim

Status

- First version of bonsai-ROOT interface is made for WCsim ROOT output.
- This interface and original bonsai (coded in c++) are compiled into a shared library, which is readable from ROOT.
- Temporary, this interface is named “libWCSimBonsai”.

WCsim+BONSAI flow chart



WCsim + BONSAI demonstration

WCsim : Super-K Mode

No. of PMTs : 11146

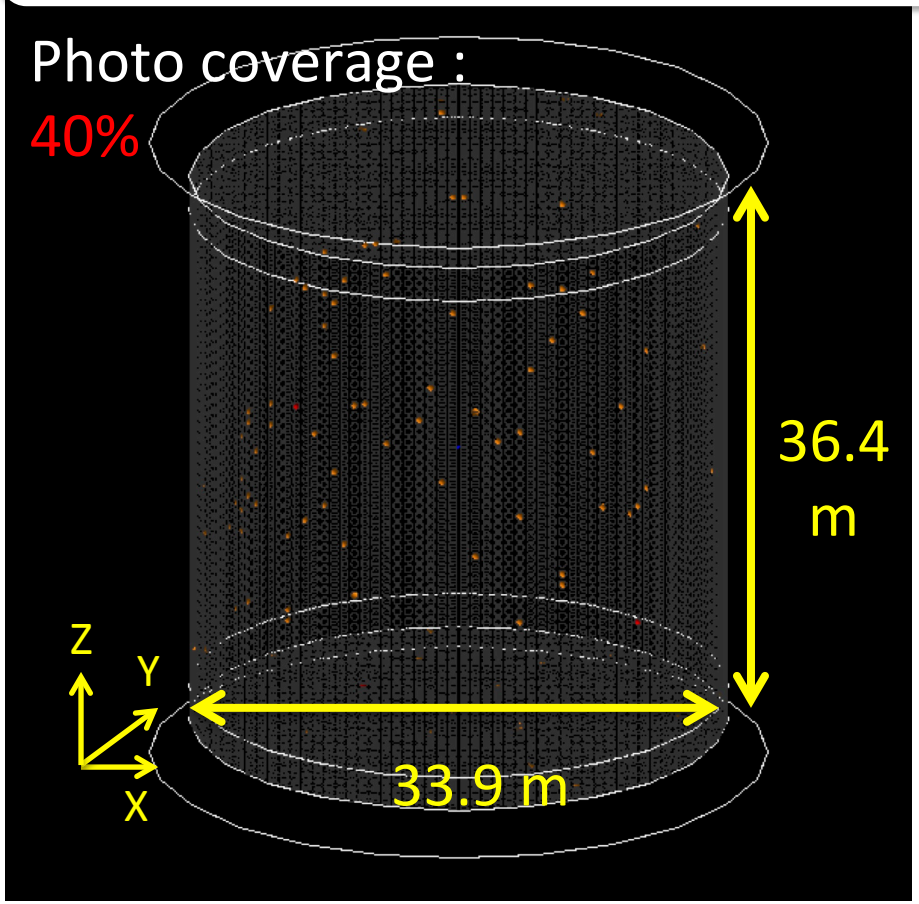
ID : 11146, OD : 0 (for SK mode)

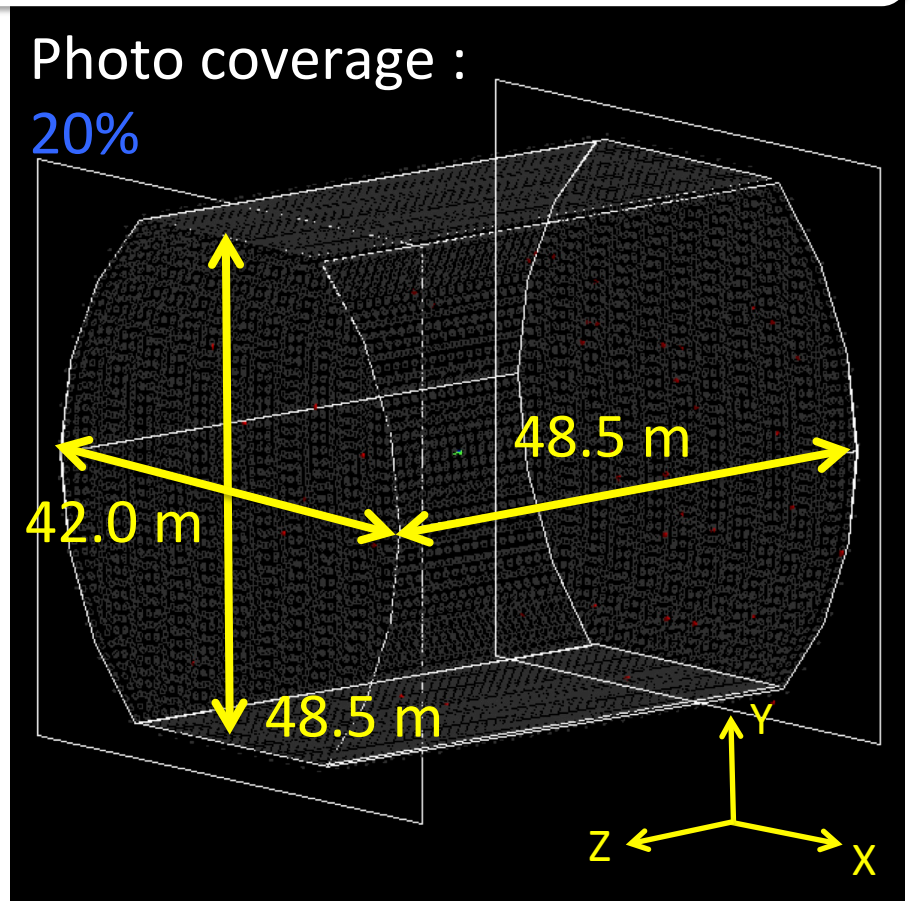
WCsim : Hyper-K Mode

No. of PMTs : 11995

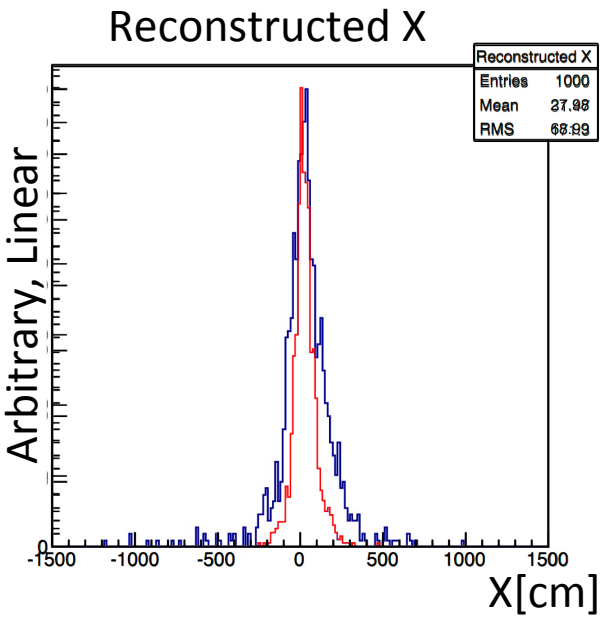
ID : 9870, OD : 2125

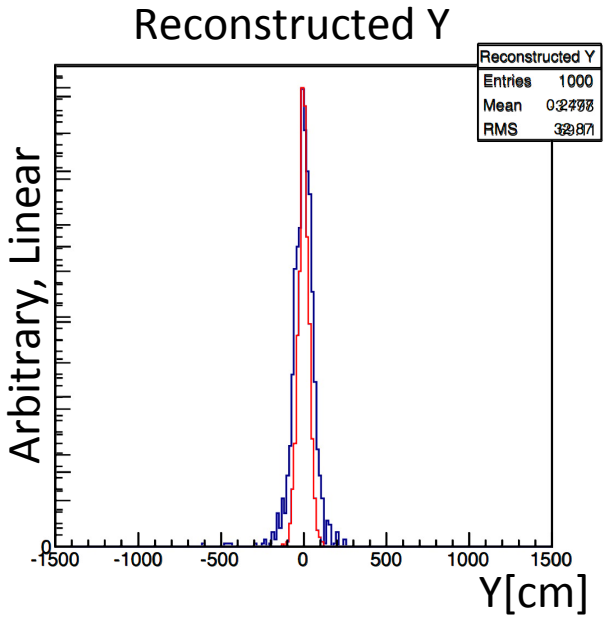
1000 shots of 3 – 30 MeV electron. Pos: (0,0,0), Dir: (1,0,0)

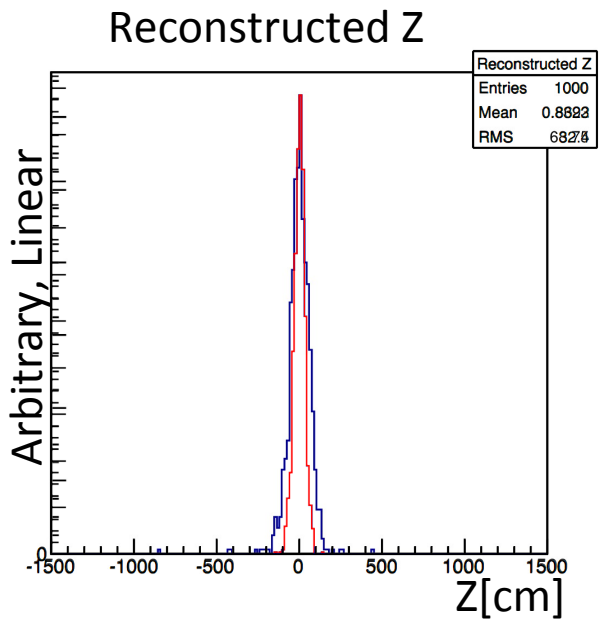


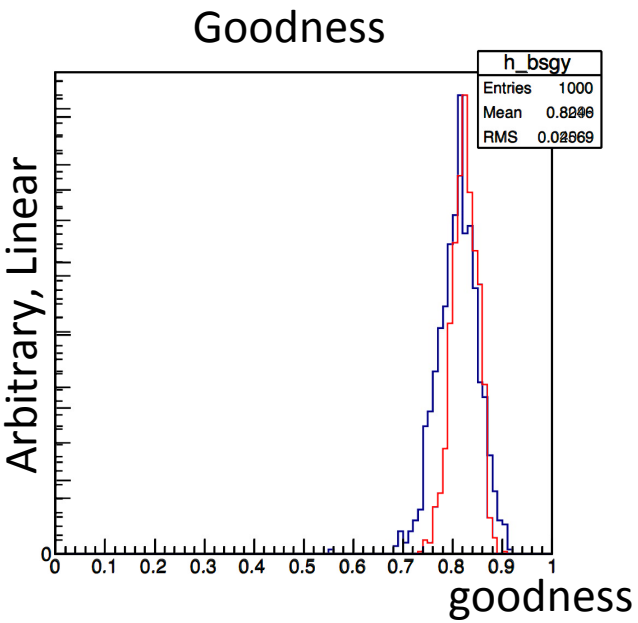


Reconstruction Result









Example figures

Red : WCsim Super-K mode

Blue : WCsim Hyper-K mode

Source particle : **electron**

Source energy : **11 MeV**

Source position : **(0,0,0)**

Source direction: **(1,0,0)**

Dark rate : **5.8 kHz**

Bonsai works well with WCsim and root. It successfully reconstructs events.

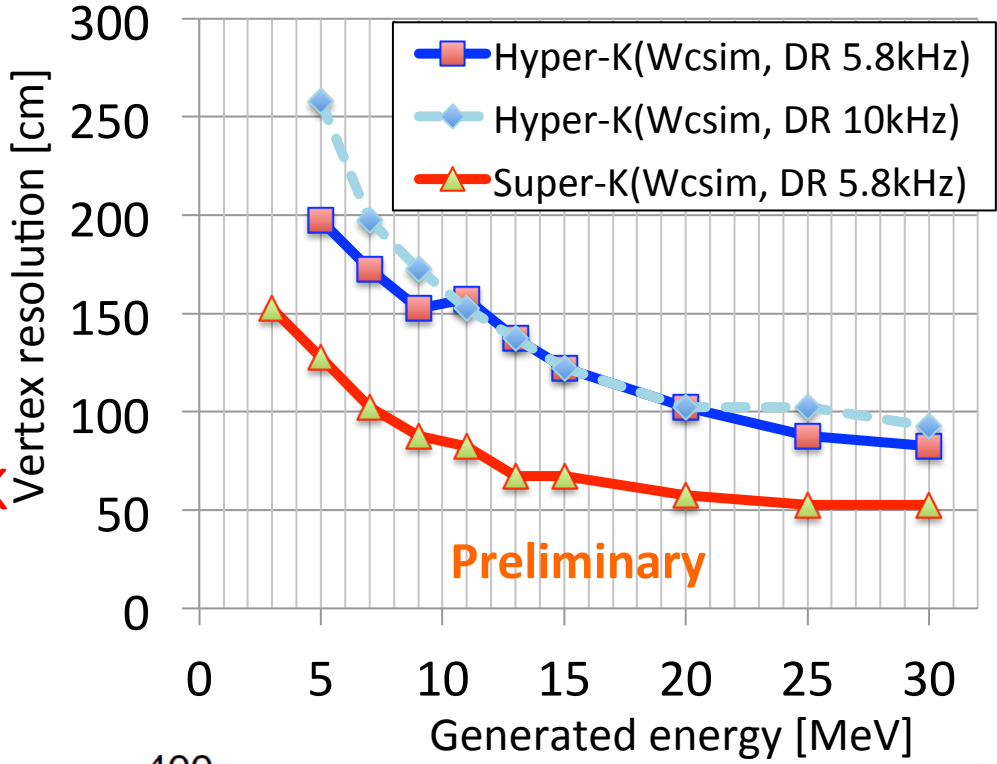
The vertex resolution of Hyper-K mode is worse than Super-K mode, as expected.

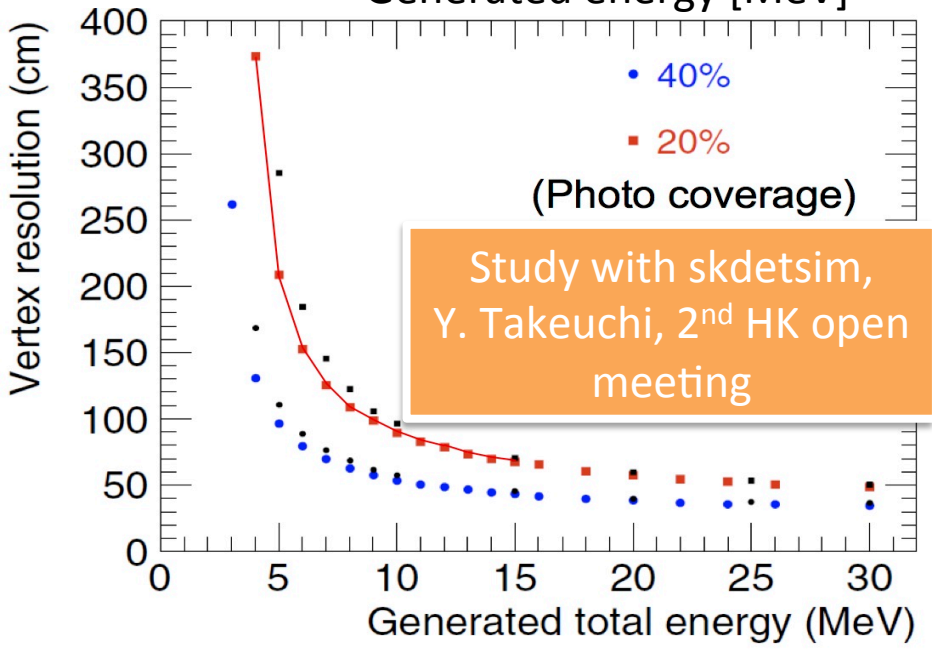
Vertex resolutions

Three-dimensional Vertex resolution of WCsim HK and WCsim SK are compared.

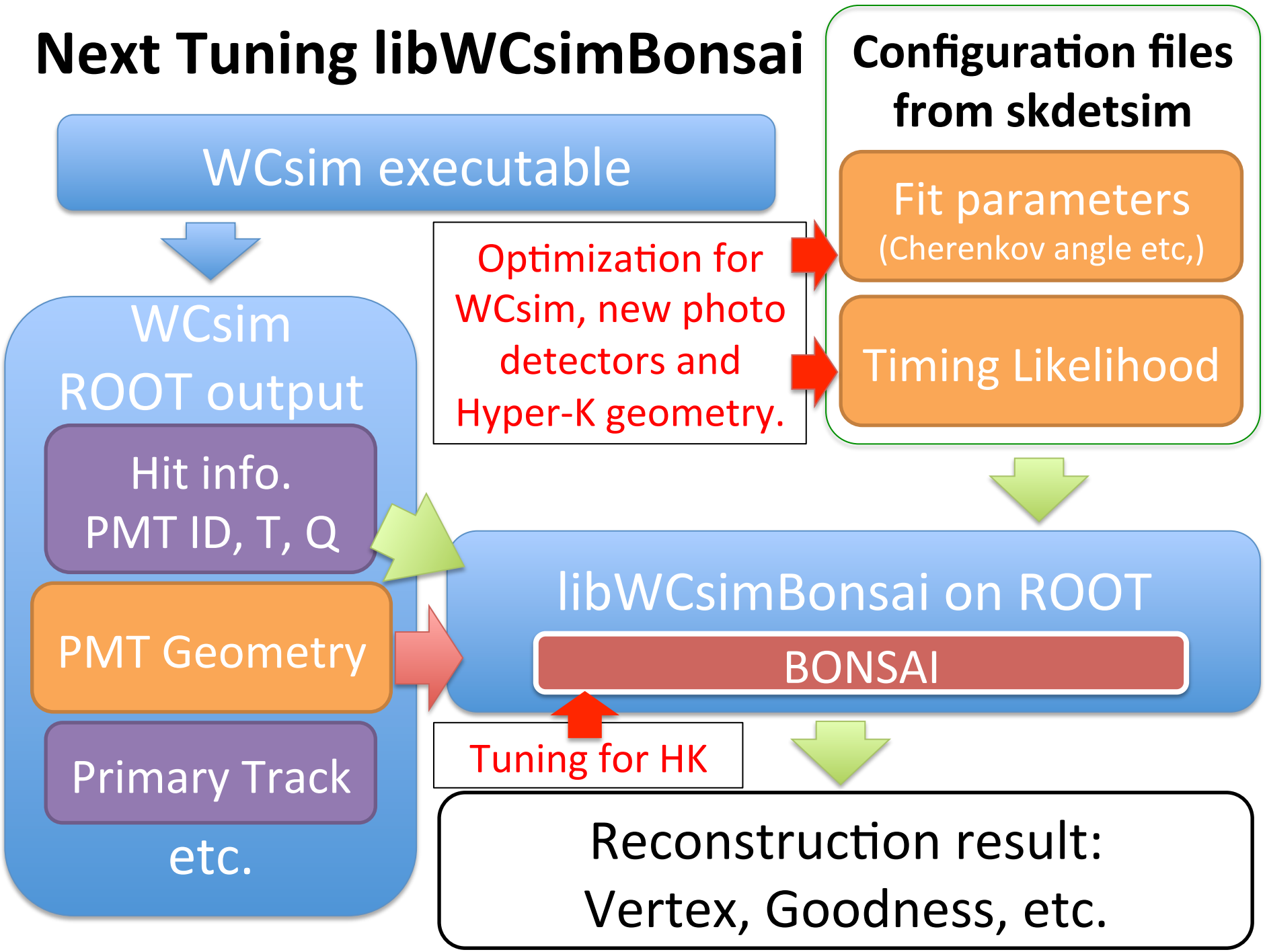
The vertex resolution of WCsim SK and WCsim HK with BONSAI are ~50% larger than skdetsim ones. The relation between vertex resolution and energy is similar for these cases.

The vertex resolution and other characteristics of one Hyper-K compartment is expected to be similar to SK-II. We need more tuning for further studies.





Next Tuning libWCsimBonsai

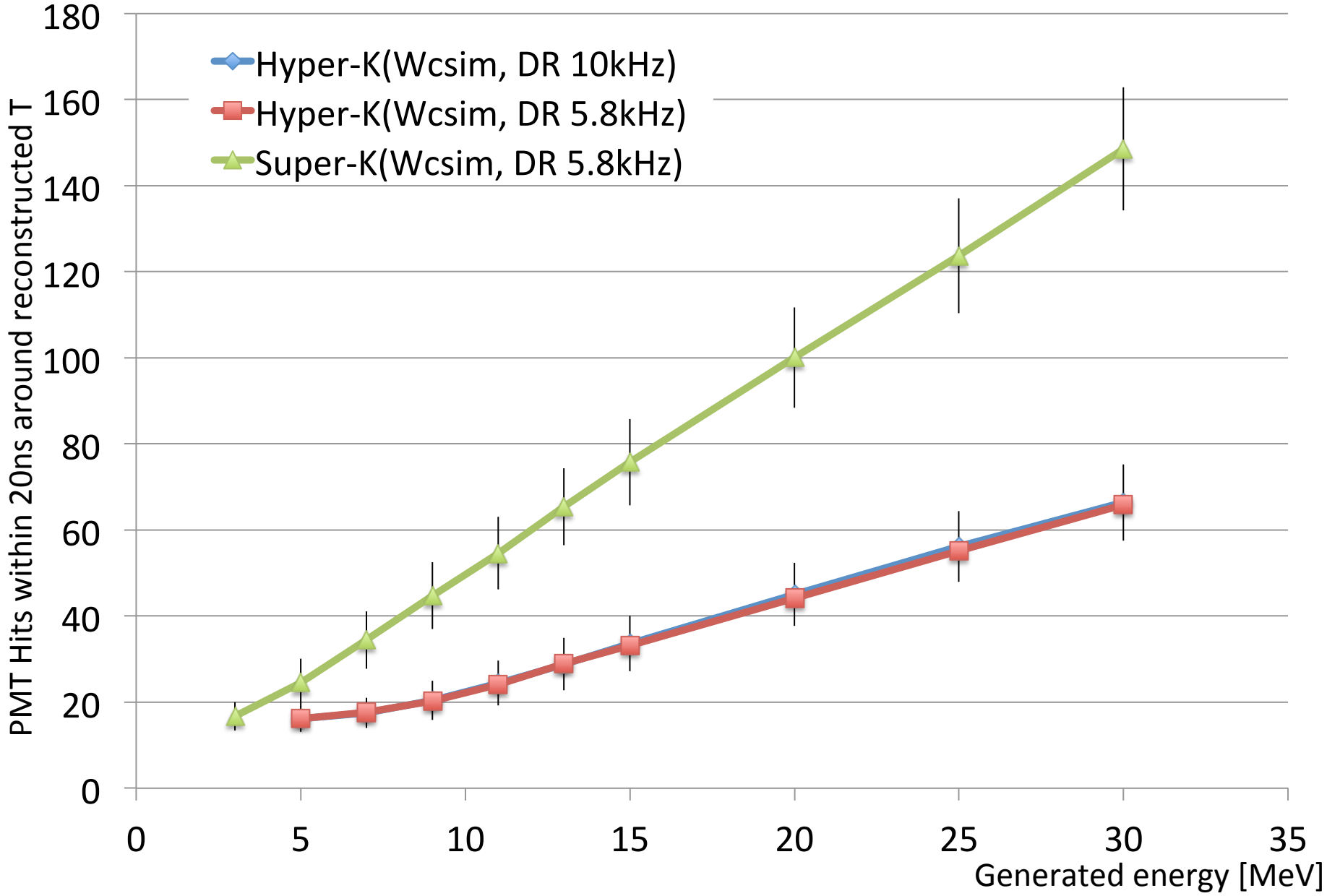


Summary and Discussion

- **First version of BONSAI-ROOT interface is made for Hyper-K low energy reconstruction.**
  - **"libWCSimBonsai"** ROOT library.
- libWCSimBonsai is tested with SK and HK mode of WCsim.
  - It is promising first attempt, but more tuning is needed for Hyper-K.

- For energy calculation, we need other libraries from SK software.
  - e.g. compensation for PMT occupancy, dark rate, effective PMT density, water transparency. They will be ported from SK software.
- The contribution of higher QE photo detector for low E and that of the detector design (e.g. partition size) will be studied.

Summary and Discussion



libWCSimBonsai

Implementation of libWCSimBonsai

- Because bonsai itself is written in C++, we can compile bonsai with rootcint. If we have a interface, we can use current bonsai with small modification.
- Parameters to be tuned:
    - PMT position (geom.bin. A small separated program to convert geofile.txt -> geom.bin is made.)
    - Fitting parameter (fit_param.dat. This file defines the angle of Cherenkov ring and the reconstruct position limit as distance from wall.)
    - Timing likelihood (like.bin. This defines the PDF for PMT detection time distribution of Cherenkov lights.)
    - Because fitting parameter and likelihood is based on physics, only PMT position is updated for WCsim currently.