TAO TDAQ and offline status

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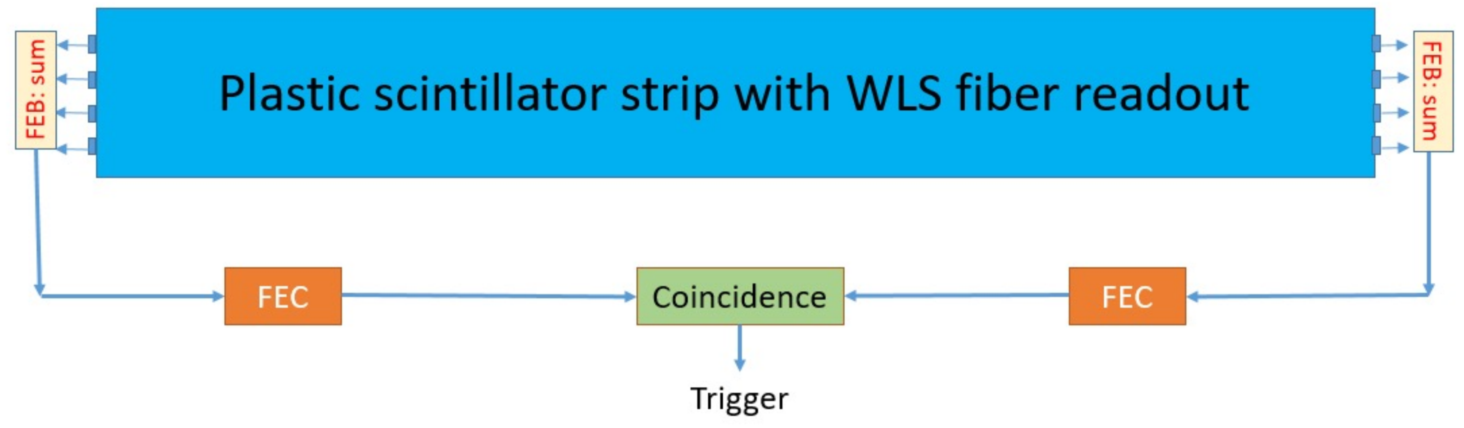
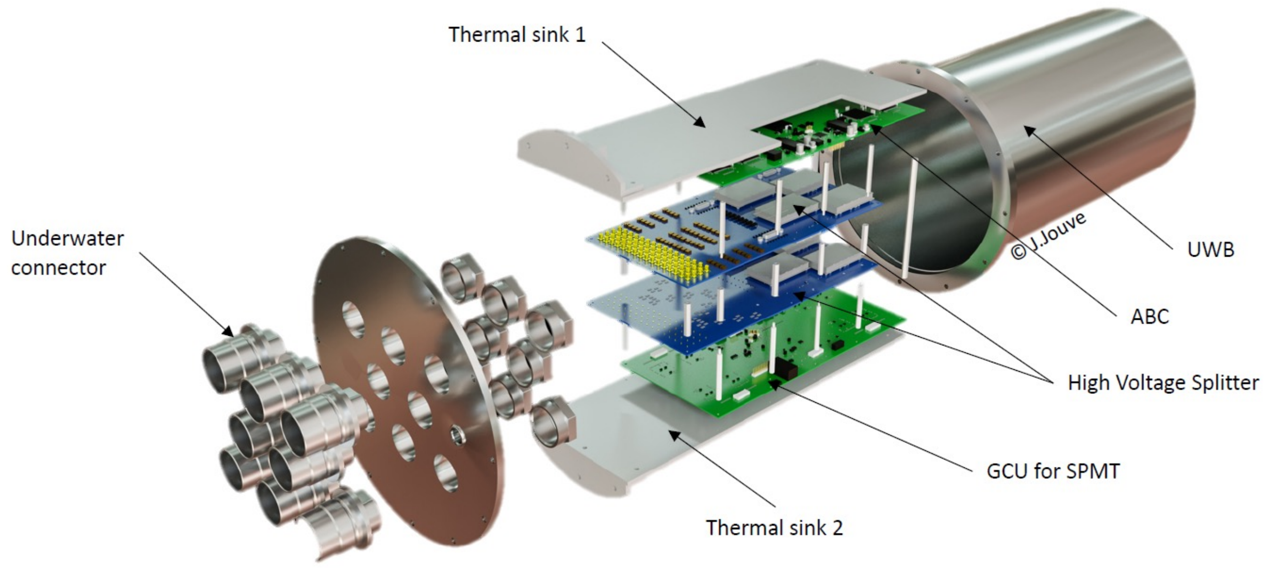
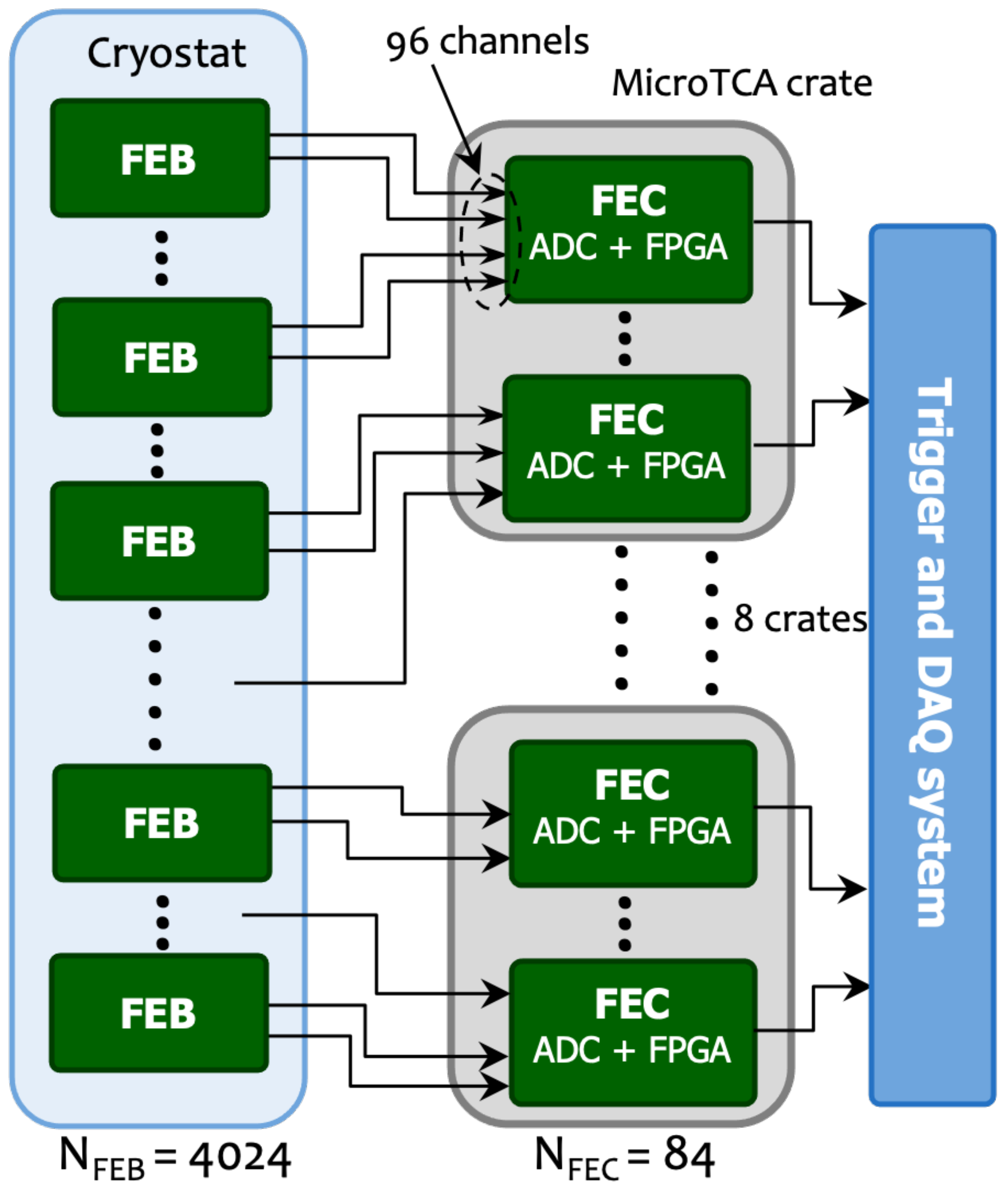
TAO TDAQ System



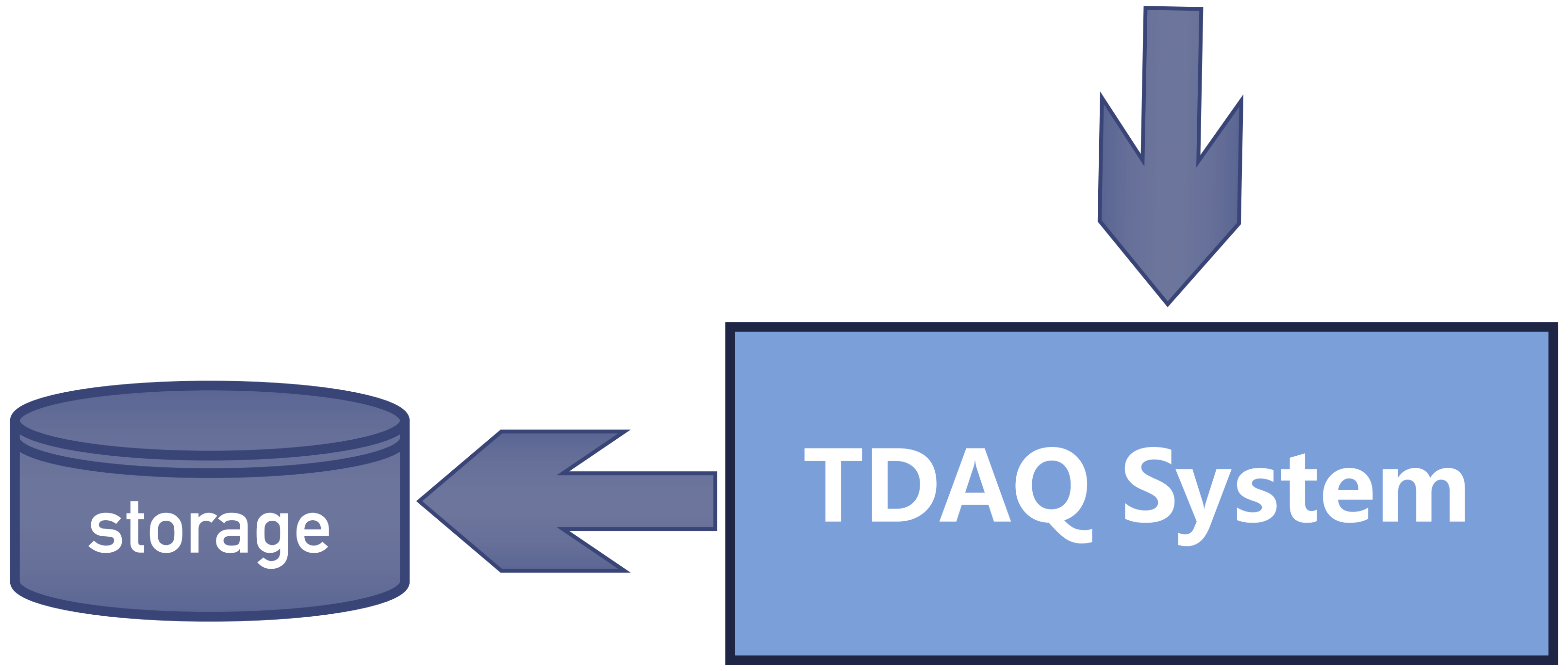
Top Veto



Water Tank

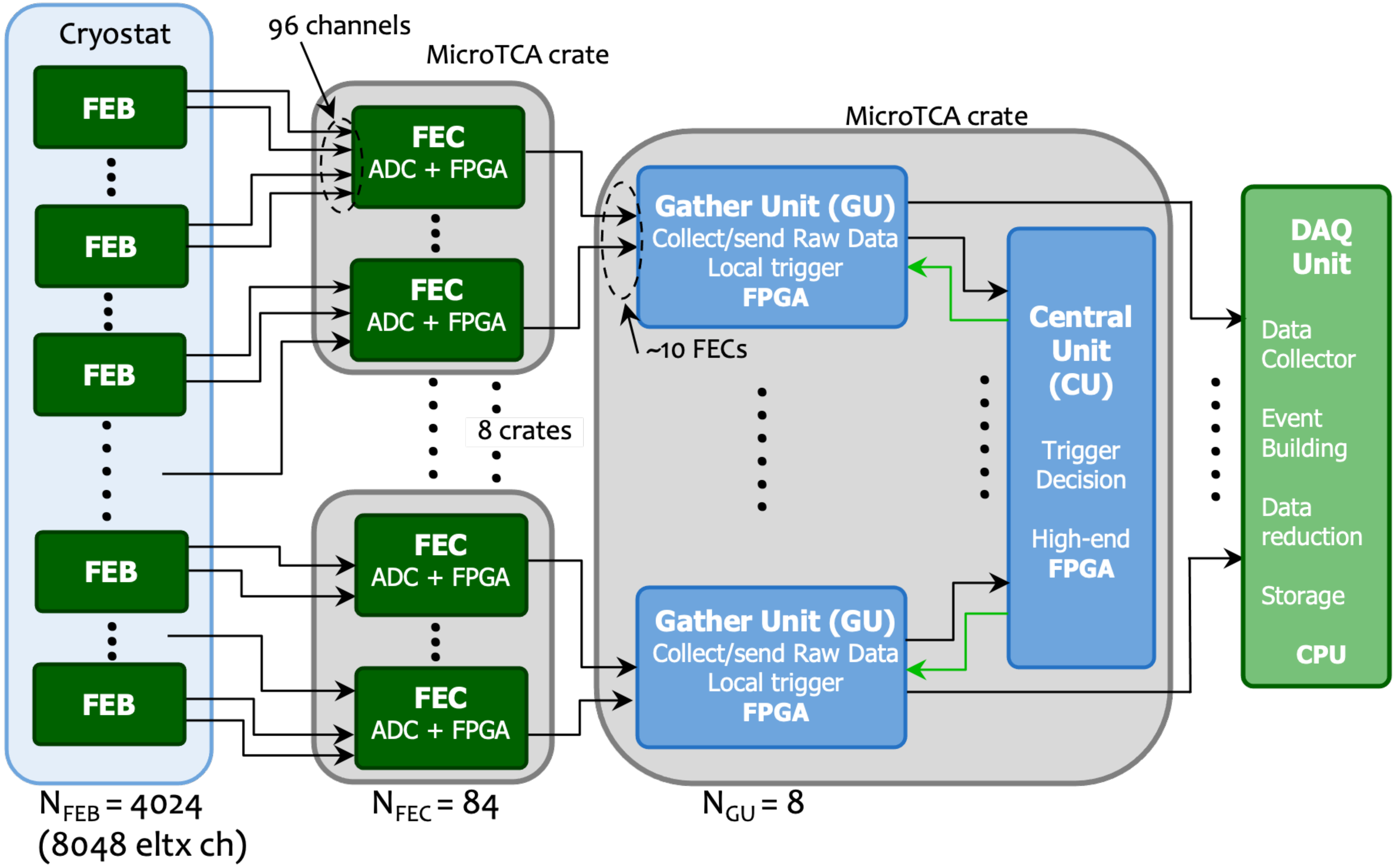


CD



- **Readout** the **~70Gbps** raw data from the 3 individual detectors' electronics system (mostly CD)
- **Suppress** the total data bandwidth **to < 100Mbps** before save to disk
- **Full efficiency** ($\varepsilon \sim 1$) for $\bar{\nu}_e$ IBD events

TDAQ Architecture



8 GU boards

- collects data from the 84 FECs (~10 FEC per GU);
- store data in DDR
- Compute local Nhit → CU
- Receive CU trigger → pack data and send to CU
- 1FEC→GU ~1 Gbps

1 CU

- Receives local Nhit → compute global Nhit and trigger decision
- Send trigger to the GUs
- Receives data from 8 GU, build event, send to DAQ
- 1GU→CU ~690 Mbps
- Could perform topological "on the fly" tagging

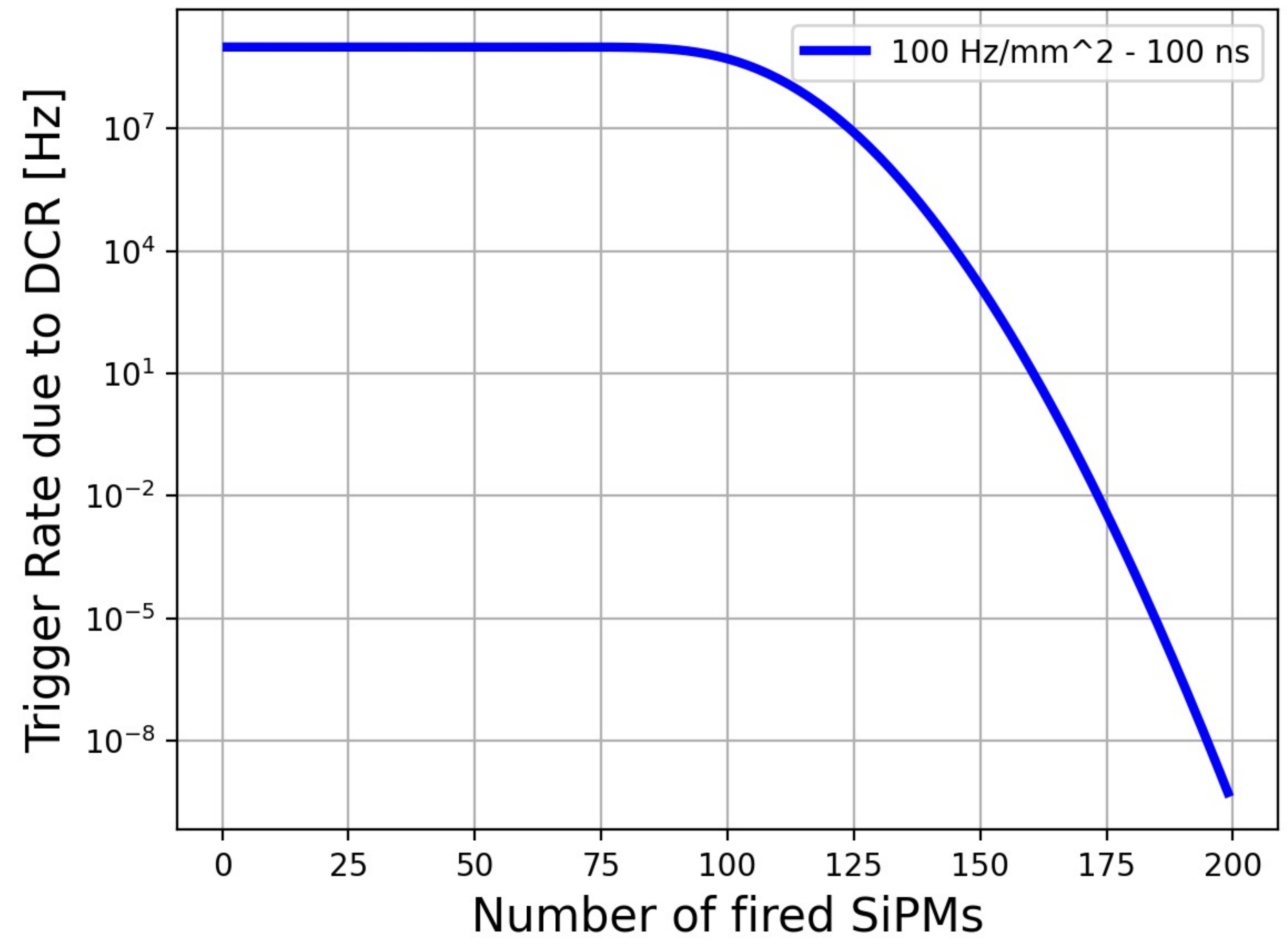
DAQ Unit (MU)

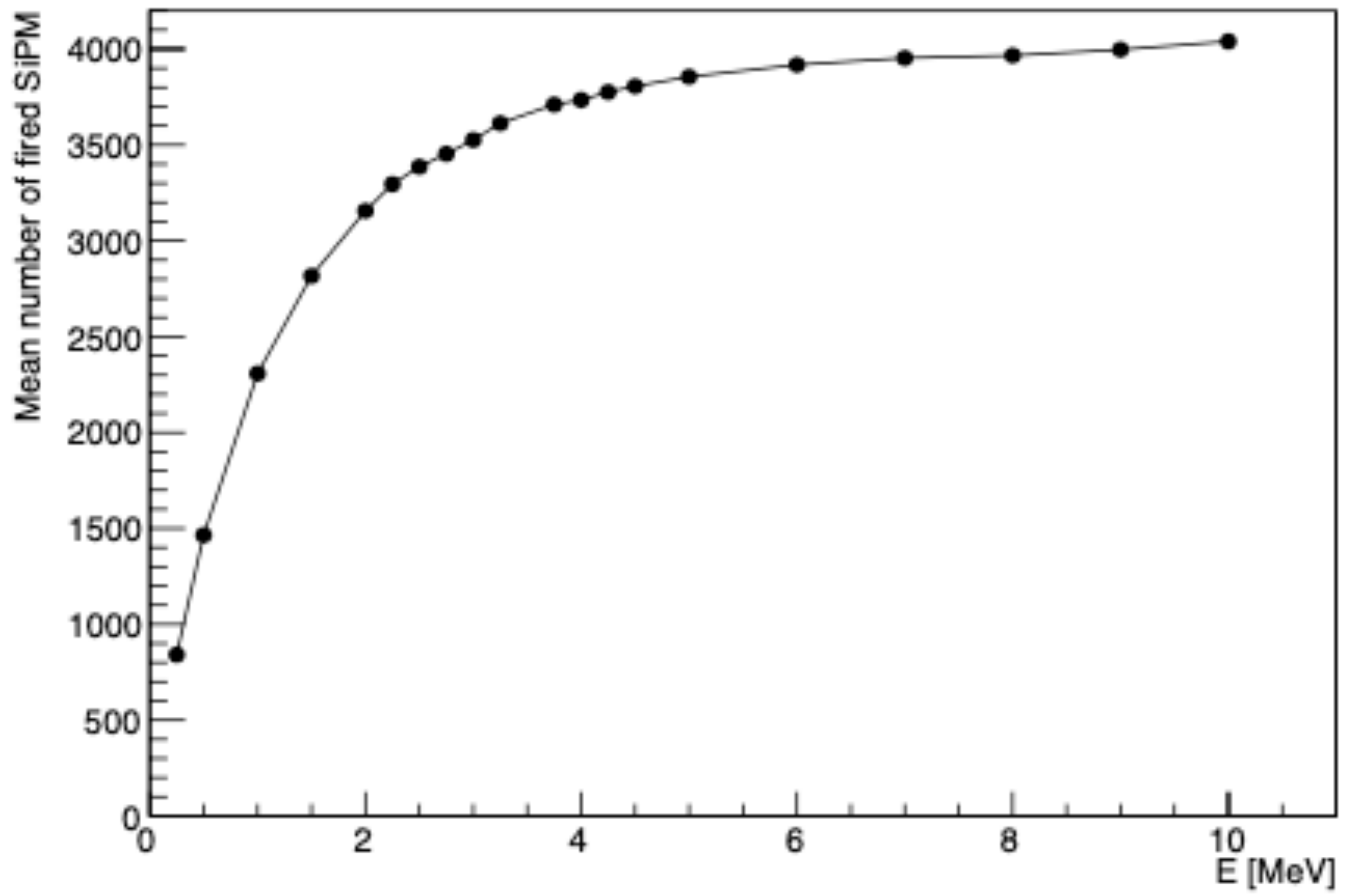
- Collects triggered events (and data stream from WT)
- performs data reduction and stores data

CD event rates

Signal	Mean energy	Event rate
Reactor IBD	~4 MeV	4000/day
Radioactivity background	~1.5 MeV	150 Hz
Muons [0.7, 20] MeV	~4 MeV	36 Hz
Muons >20 MeV	~235 MeV	296 Hz
Cosmogenic background [0.7, 20] MeV	~7 MeV	20 Hz
Cosmogenic background >20 MeV	~37 MeV	20 Hz
SiPM dark counts	-	1 GHz

A simple **global majority logic** can be used to suppress the DCR down to ~0
(example: ~1Hz with a majority of ~170 fired SiPM tiles)
with no effect on the signal efficiency





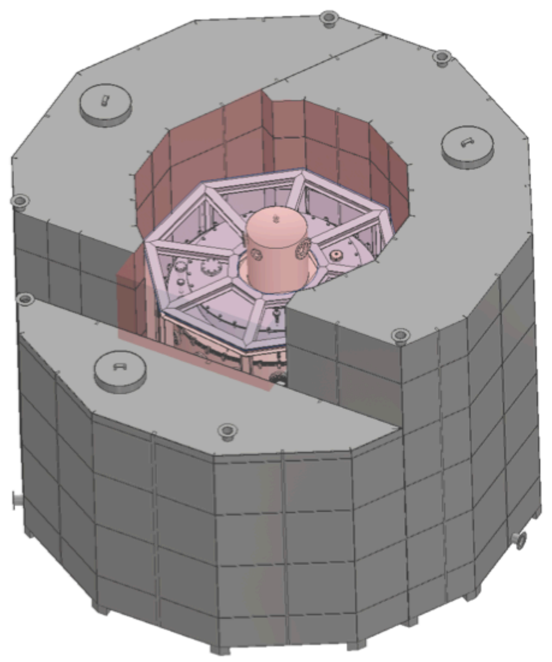
CD Data troughput

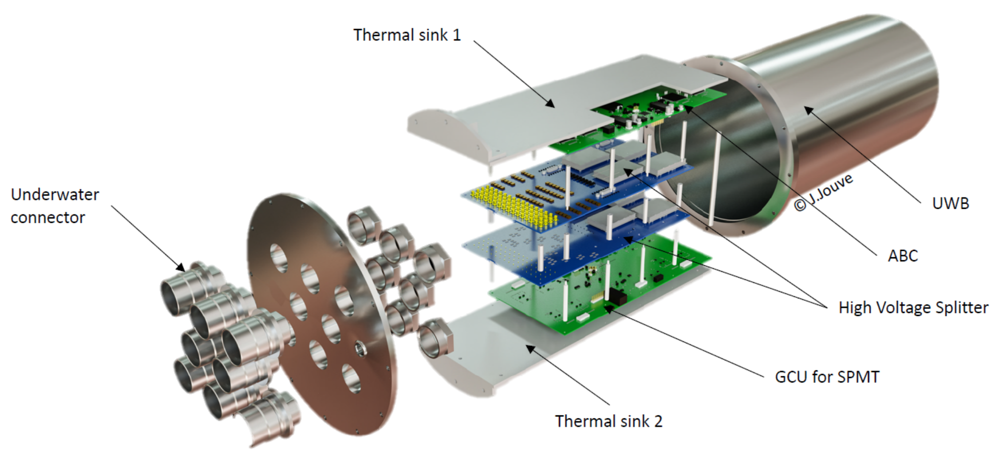
- One FEB per SiPM tile: 2 ch/tile
- ~8048 Channels
- 64 bits/channel: 16 bits charge (Npe) + 32 bits timestamp + 16 bits ch ID

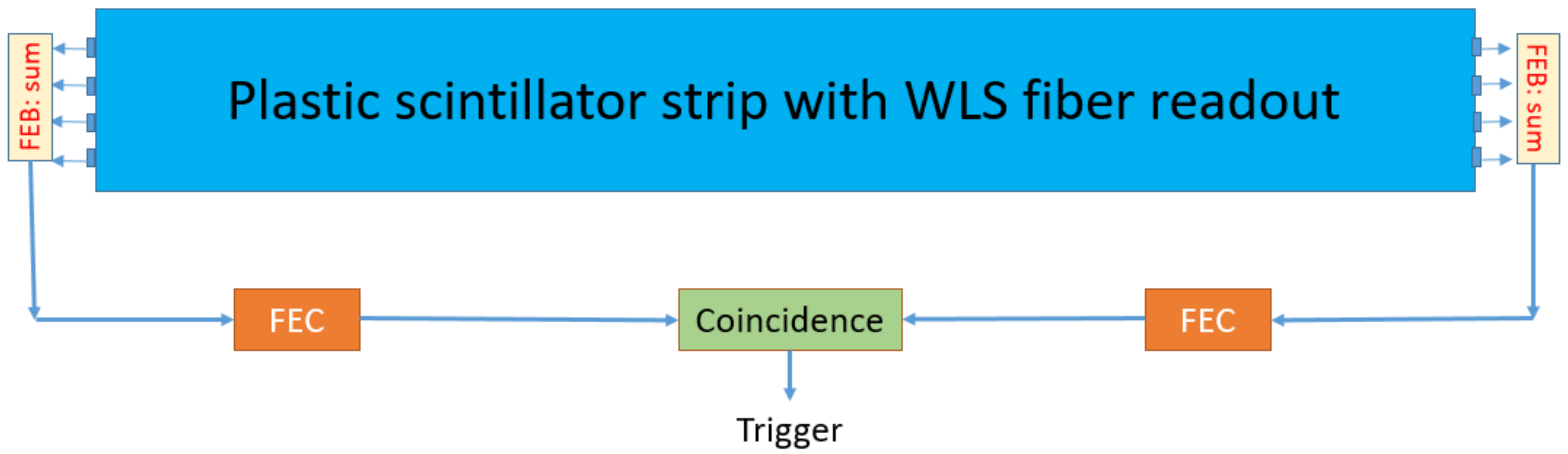
Signal	Event rate (Trigger input)	Event rate (output)	Data rate trigger input (Mbps)	Data rate trigger output (Mbps)
Reactor IBD	4000/day	4000/day	-	-
Radioactivity background	150 Hz	150 Hz	77	77
Muons [0.7, 20] MeV	36 Hz	36 Hz	19	19
Muons >20 MeV	296 Hz	296 Hz	152-304[c]	152-304[c]
Cosmogenic background [0.7,20] MeV	20 Hz	20 Hz	10	10
Cosmogenic background >20 MeV	20 Hz	20 Hz	10-20[c]	10-20[c]
SiPM dark counts	1 GHz[b]	~0	$64 \cdot 10^3$	-
TOTAL			**$64 \cdot 10^3$**	**240-400 [a]**

- Challenging input rates
- The output data rate has to be < 100 Mbps: compression needed
- a) we can implement a logic to reduce data size for large energy events at FEC level; also, a local FEC logic can be implemented to reduce DCR hits rate to the TDAQ

Veto: water tanks + top tracker







- ~300 HZC 3" PMTs in 3 standalone water tanks (1.2 m thickness) JUNO 3" PMT electronics
- DCR/PMT: ~3.1kHz Muon rate: 0.8kHz, 1.4kHz, 1.6kHz (total 3.1kHz)

Trigger: DAQ online trigger (same as JUNO) :

- PMT self firing with threshold (configurable)
- Trigger default: 5 PMT hits in 300 ns (configurable)
- DAQ readout all the raw data to server and implement online trigger and event building of each tank.

Data throughput:

- Data size: Time stamp + Q + T : ~9 Bytes/hit
- DCR: 8.4MB/s (~67 Mbps)
- Muons: 3.1MB/s (~25 Mbps)
- 8.4MB/s (DCR) + 3.1MB/s (Muons) = ~13MB/s (~100 Mbps) @ DAQ input;
- ~3 MB/s (Muons) after trigger @ DAQ output ~1 MB/s (~8 Mbps) with data suppression

- Plastic Scintillator + Fibers with double side SiPM Read Out
- 4 cross layers, ~4x4 m^2: 2cm(thickness)*2m(length)*20cm(width) strips

→~160 "strips" -> 320 electronics channels

- 8 * 3x3mm^2 SiPMs per strip (Sum 4 SiPMs at the same end)

- DCR: ~50kHz/mm^2 @25°C
- Muons: rate: ~32Hz/Strip (0.2m*2m*80Hz/m^2); >20p.e./Muon

Trigger:

1) coincidence of the two ends of a strip (L1)
   - DCR two side coincidence in 100 ns:
     - @ 4.5 p.e. thr: ~0.02 Hz ; @ 10.5 p.e. thr: ~0 Hz
   - Event rate after L1: <35 Hz (with ~32Hz/strip from muons)
2) triggered events in the TDAQ chain as for the CD

Data throughput:

- Data size: Time stamp + Q + T : ~12 Bytes/hit

→Data throughput: 35Hz Hit/strip * 2 FEC/strip * 160 strips * 12 Bytes/Hit → 0.13 MB/s (~1 Mbps)

Total TDAQ data throughput

	CD	Water Tank	Top Veto
Readout electronics	TAO SiPM electronics	JUNO 3-inch PMT electronics	TAO SiPM electronics
RAW data throughput (Mbps)	~70×10^3 [a]	~100	~1 [b]
Data throughput at DAQ input (Mbps)	<100 [c]	~100 [d]	~1

global majority (Nhit trigger) needed to suppress DCR

[a] DCR is the largest contribution, here with DCR=100 Hz/mm^2

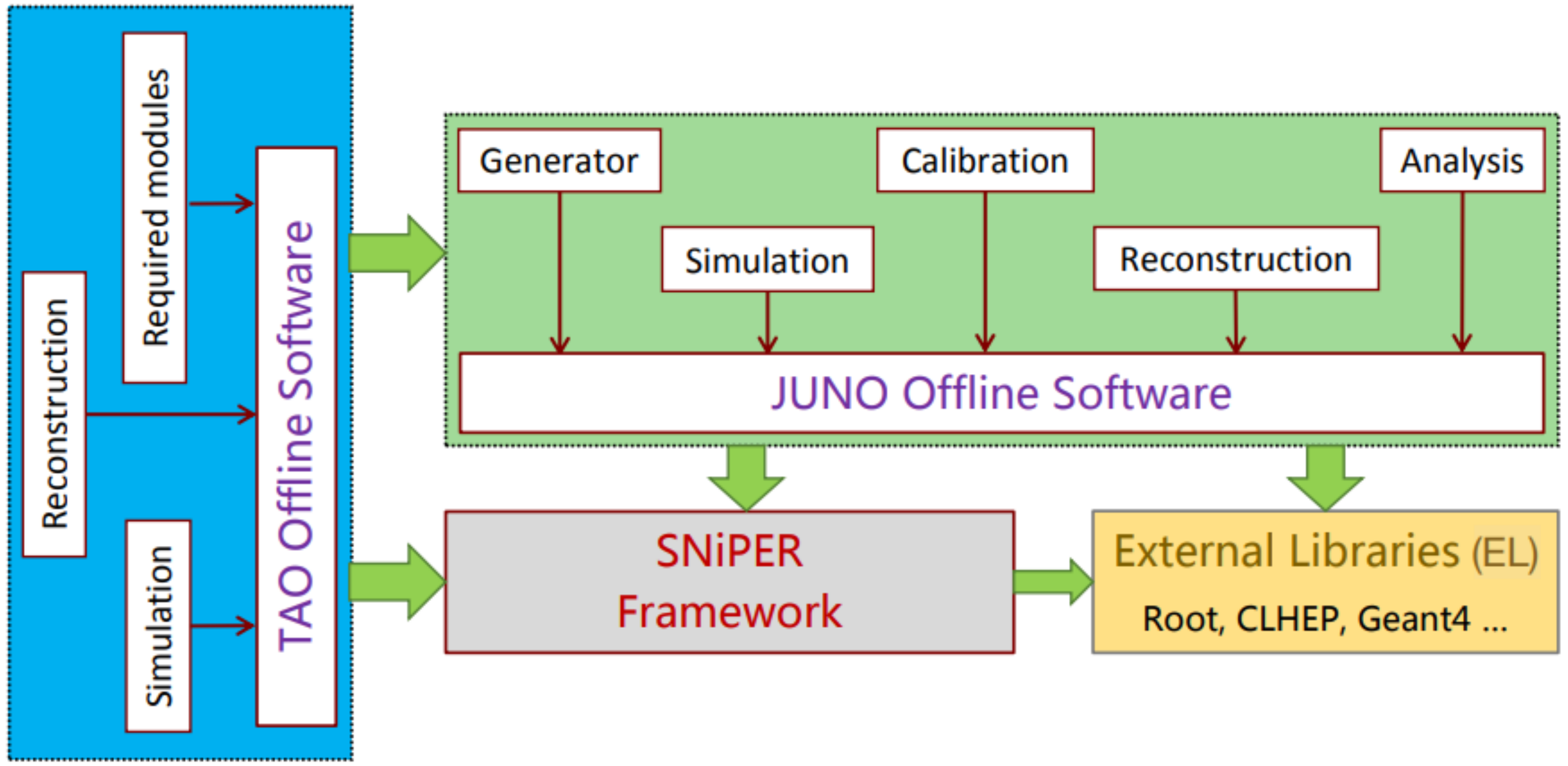
[b] after the coincidence of both ends of each PS strip

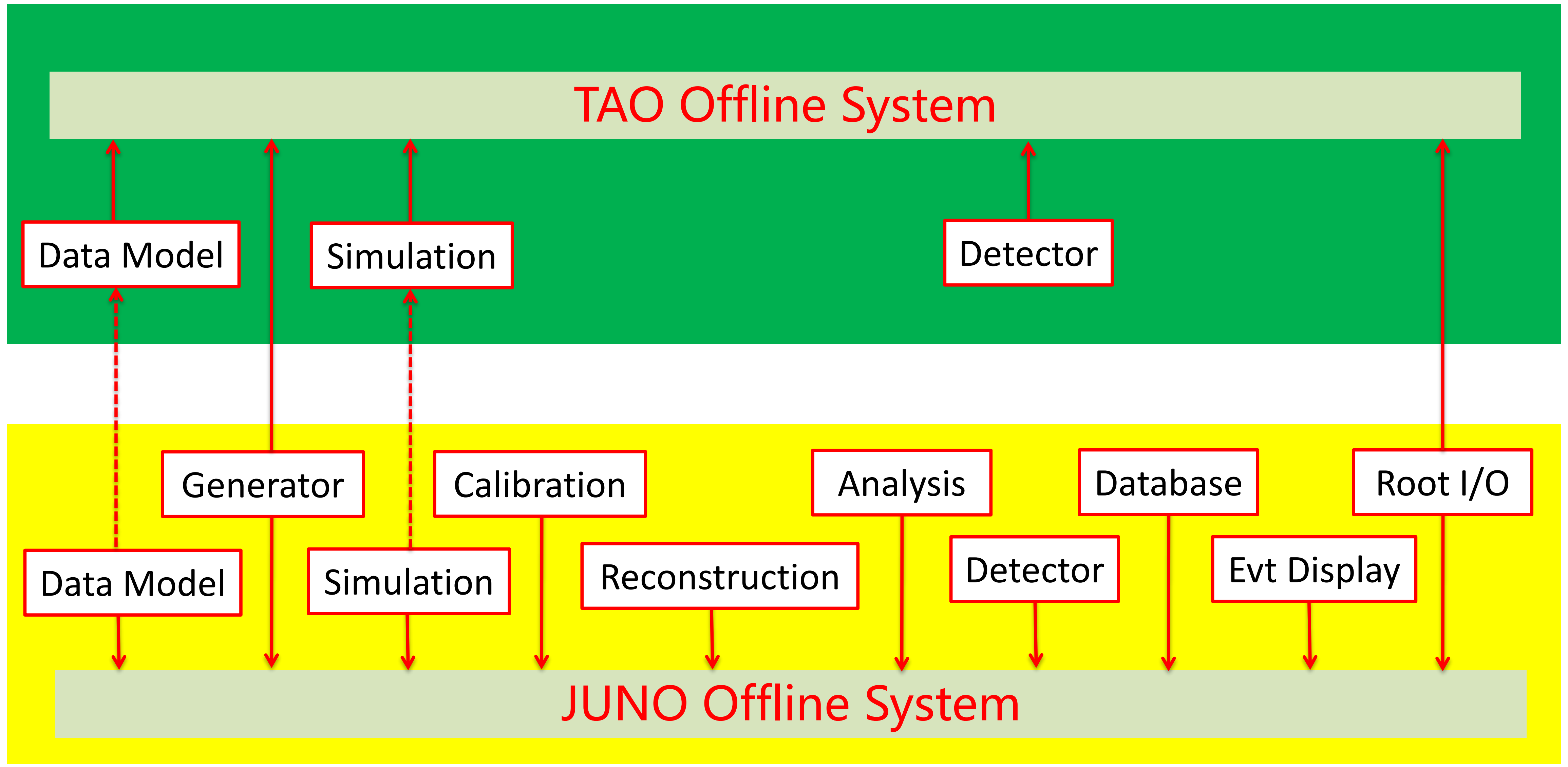
[c] actually 240-400 Mbps; to be reduced to <100 Mbps with some compression

[d] to be reduced at <10 Mbps with SW trigger and data suppression

TAO Offline software status

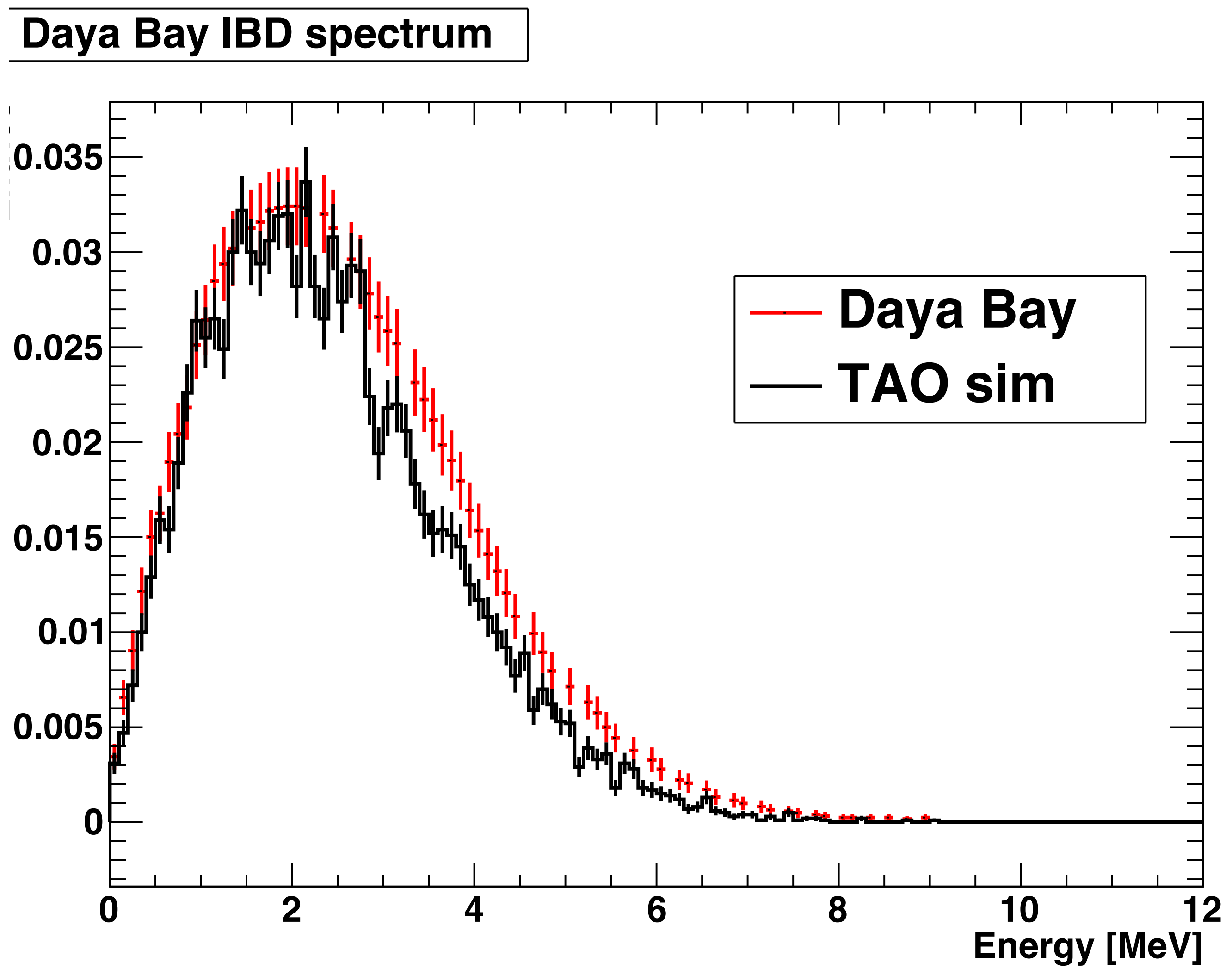
- You can find a working version at
  - https://juno.ihep.ac.cn/svn/tao_offline/trunk
  - DetSim
- Documentation and a brief manual for the first run can be found at
  - https://juno.ihep.ac.cn/mediawiki/index.php/TAO
- Please inform us if you want to use it and report any bug or malfunction

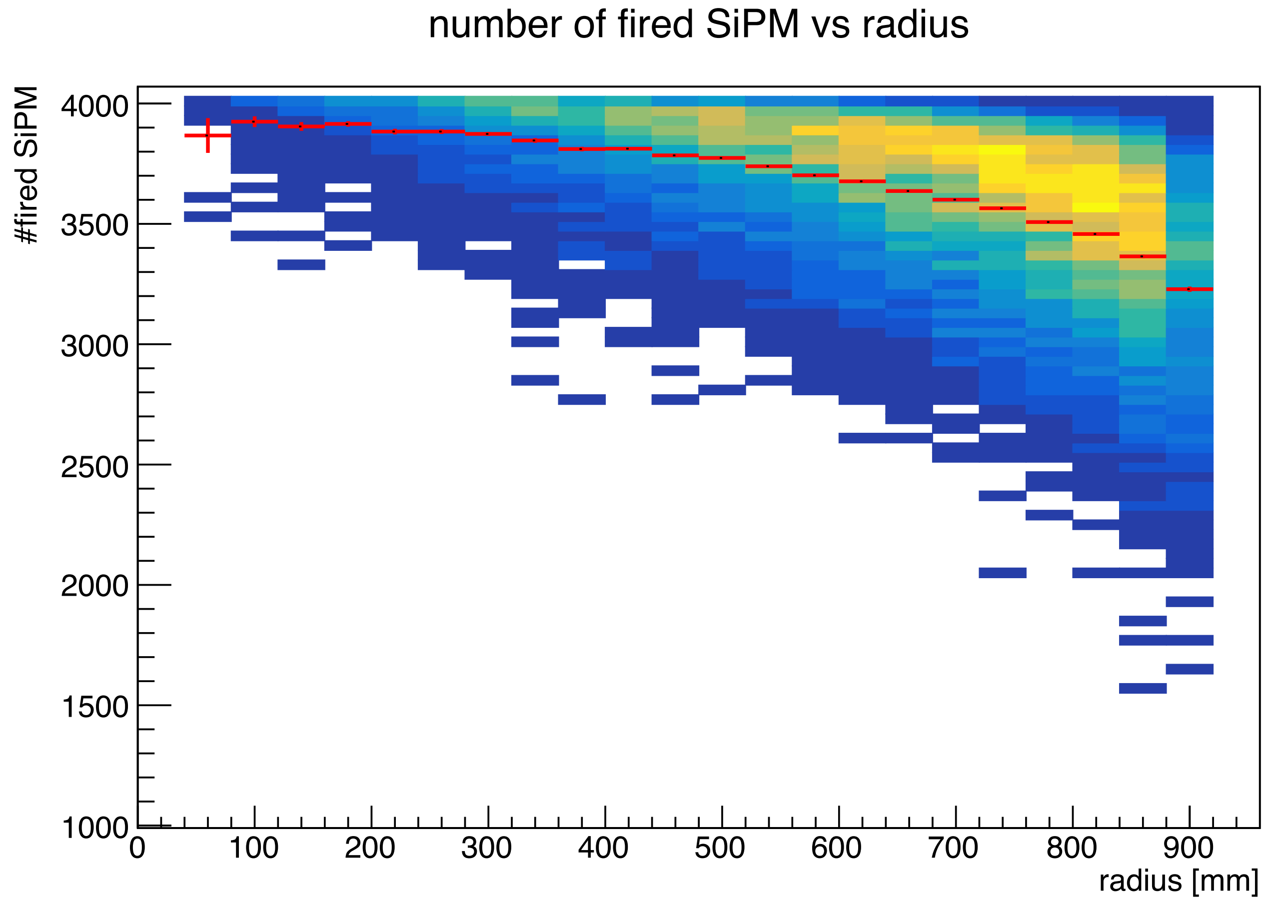


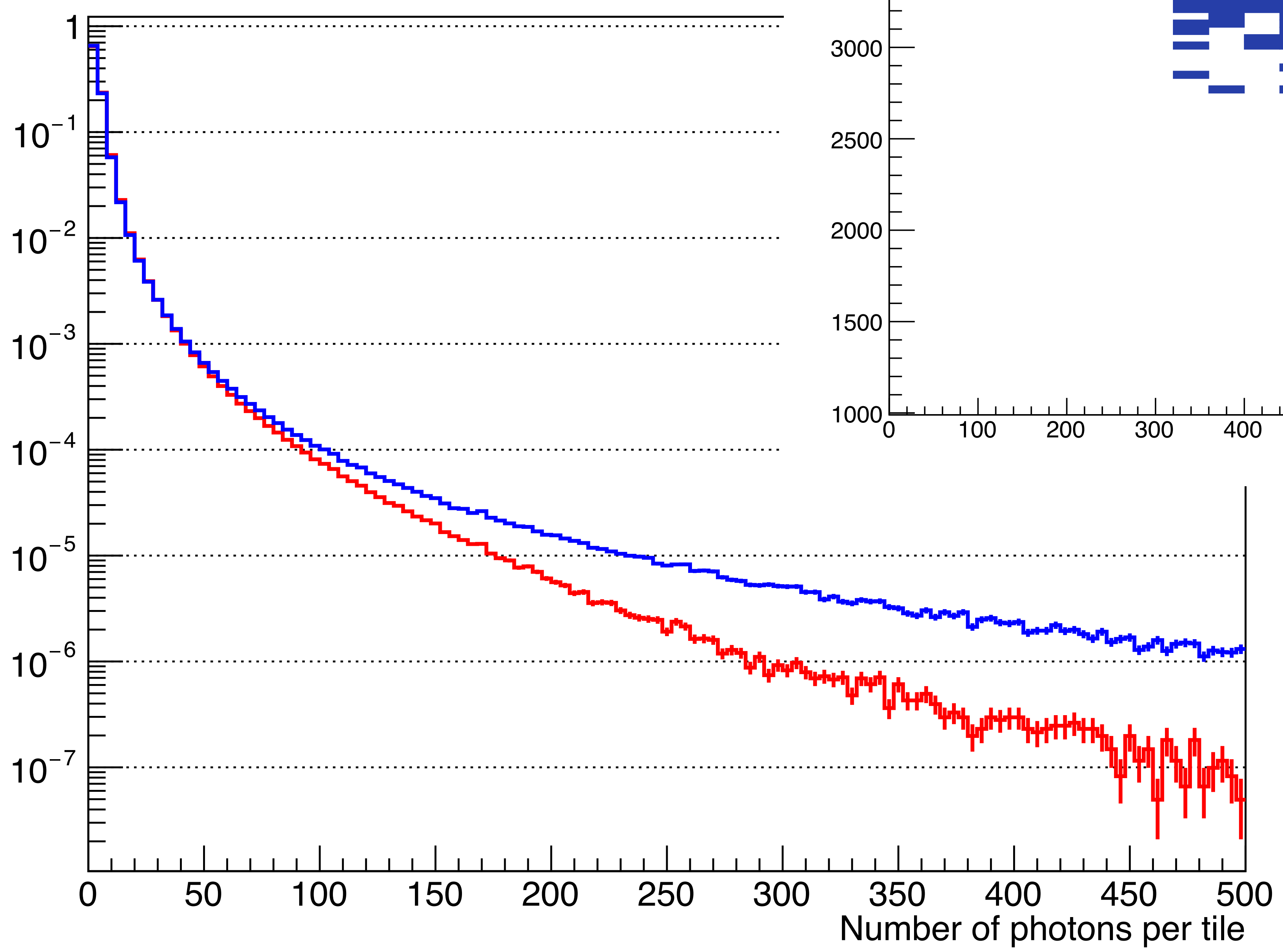


IBD data production

- About 3M IBD events corresponding to ~2 years of data taking
- Stored @CNAF, planned to be available on the JUNO dci for the whole TAO group (thanks to Giuseppe and Agnese)
- Simulation is pretty time consuming (~12 hours for 10k evts) and requires a lot of storage: about 16 GB for 10k events —> ~5 TB for the whole dataset
- Detsim only





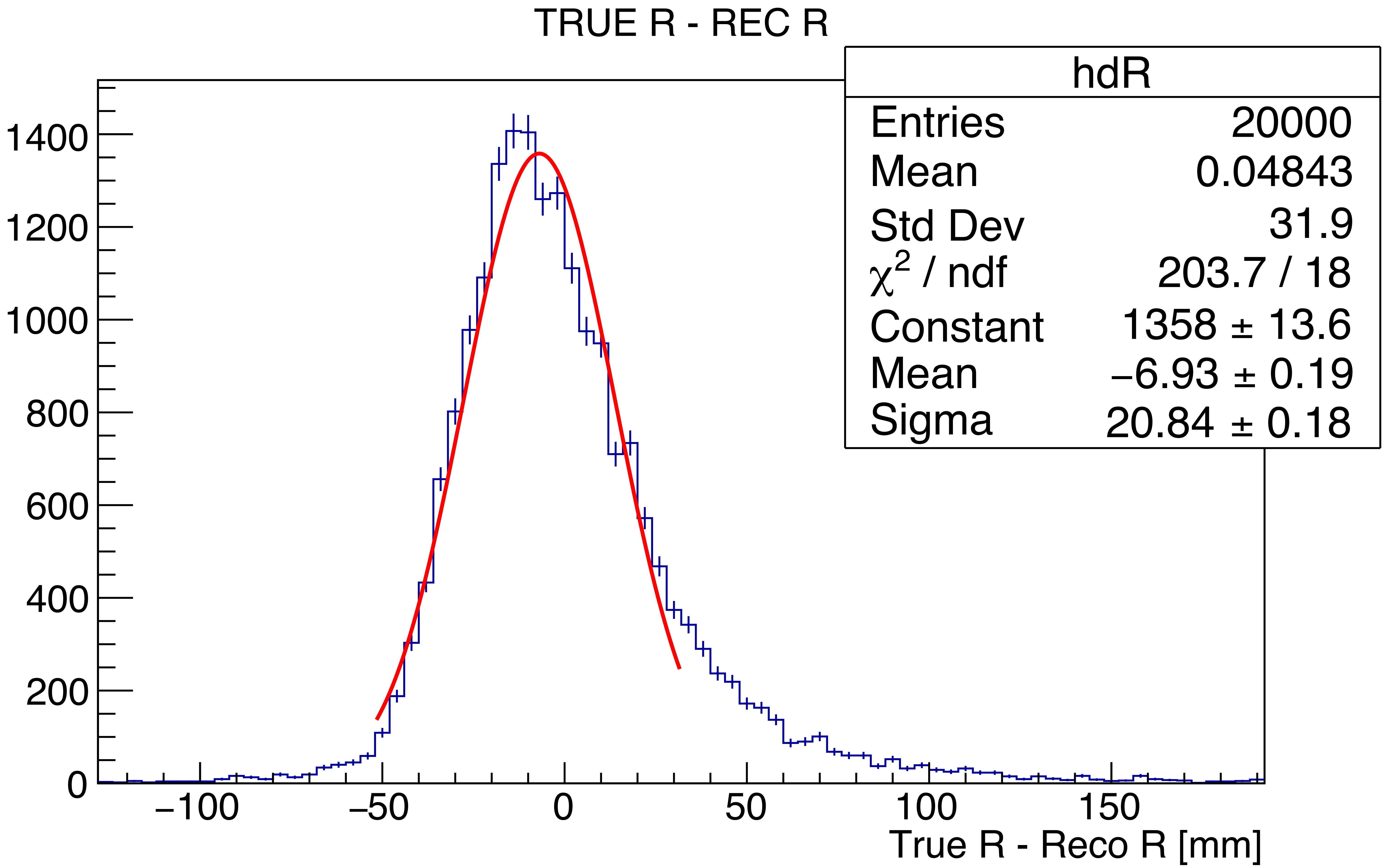


Vertex resolution

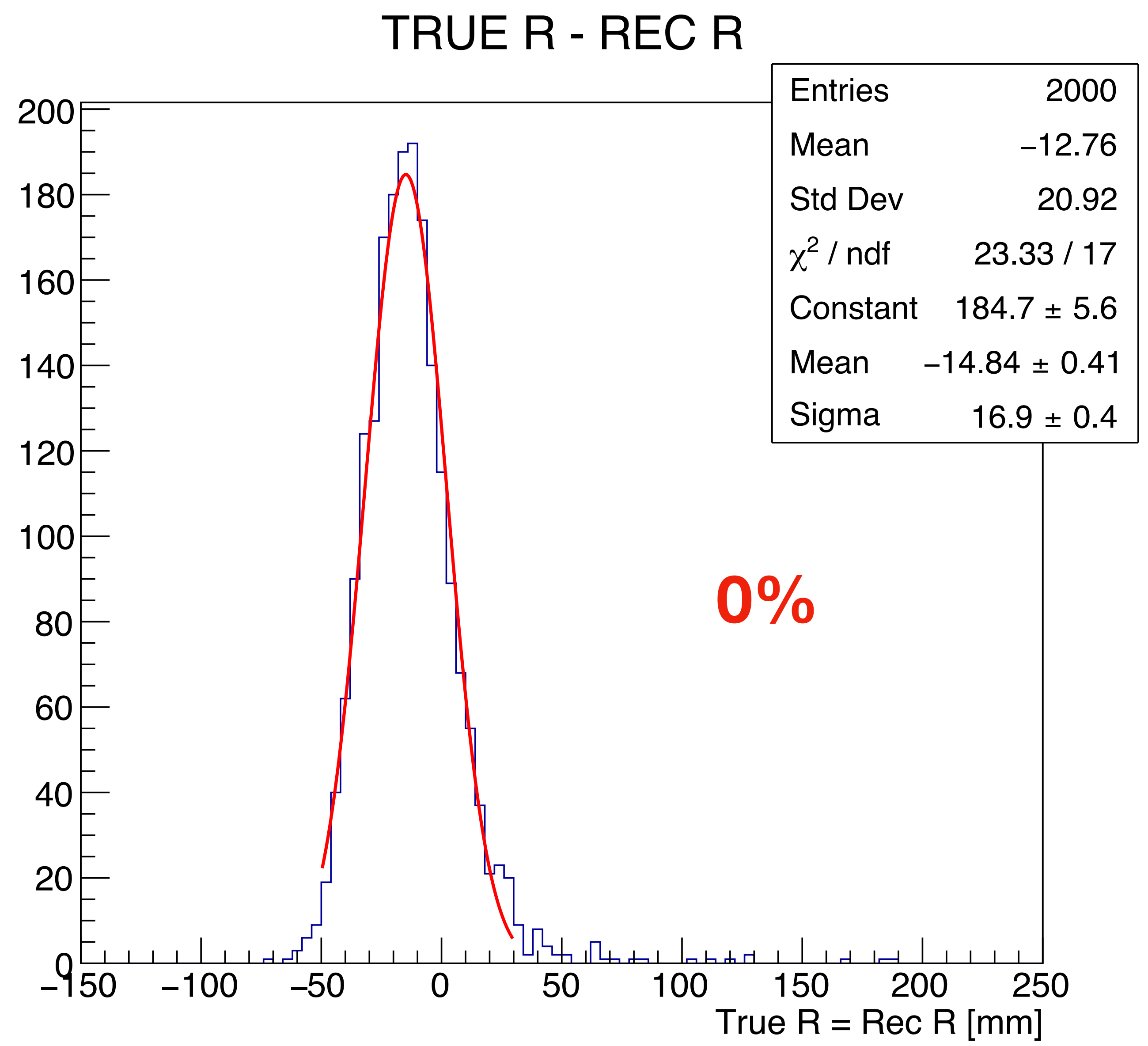
See also Hangkun talk DocDB 7893

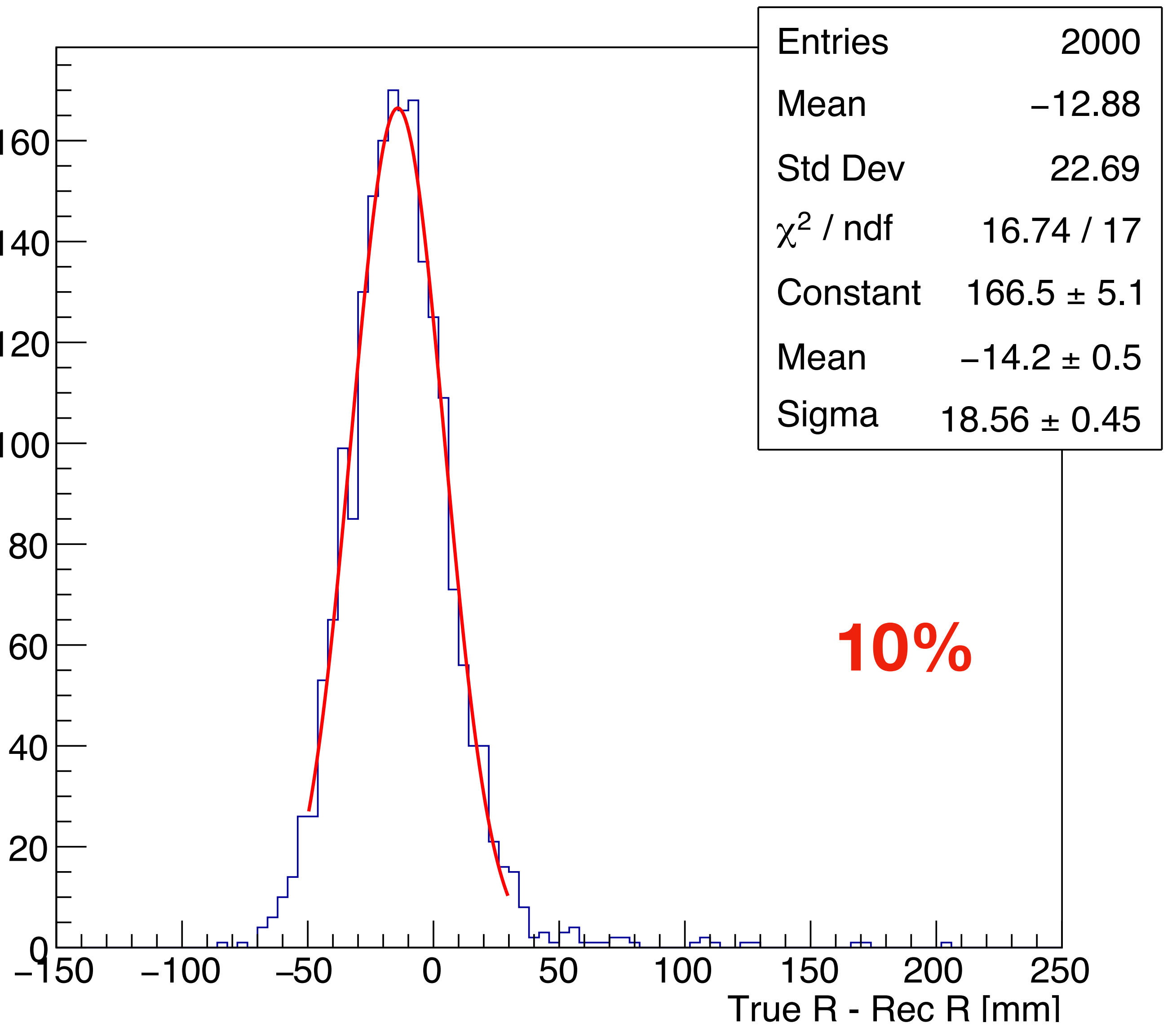
- IBD randomly distributed in the GdLS volume
- Vertex resolution few cm without fiducialization

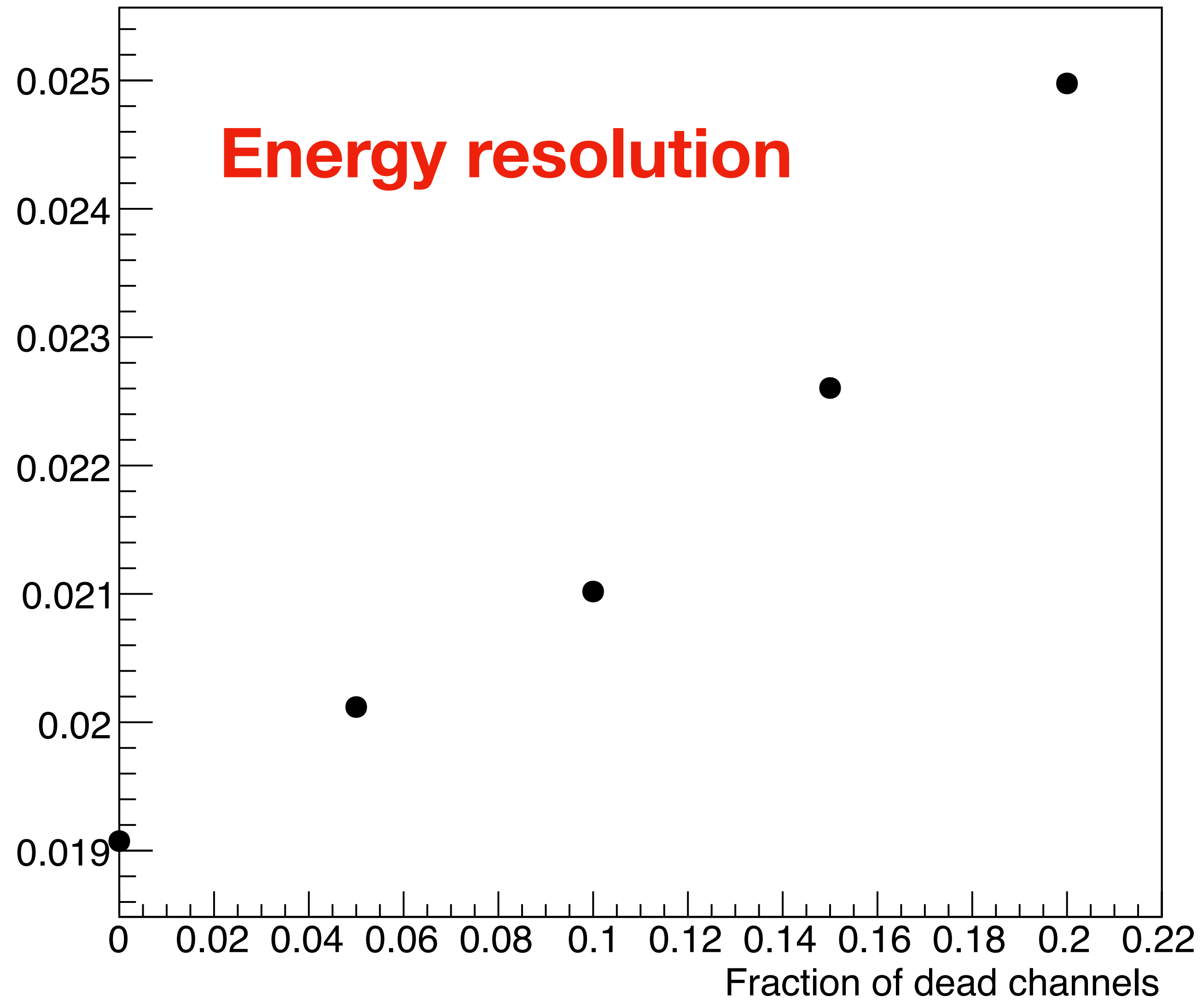
$$\bar{\mathbf{x}} = \frac{\sum_{i=1}^{N} q_i \times \mathbf{r_i}}{\sum_{i=1}^{N} q_i}$$

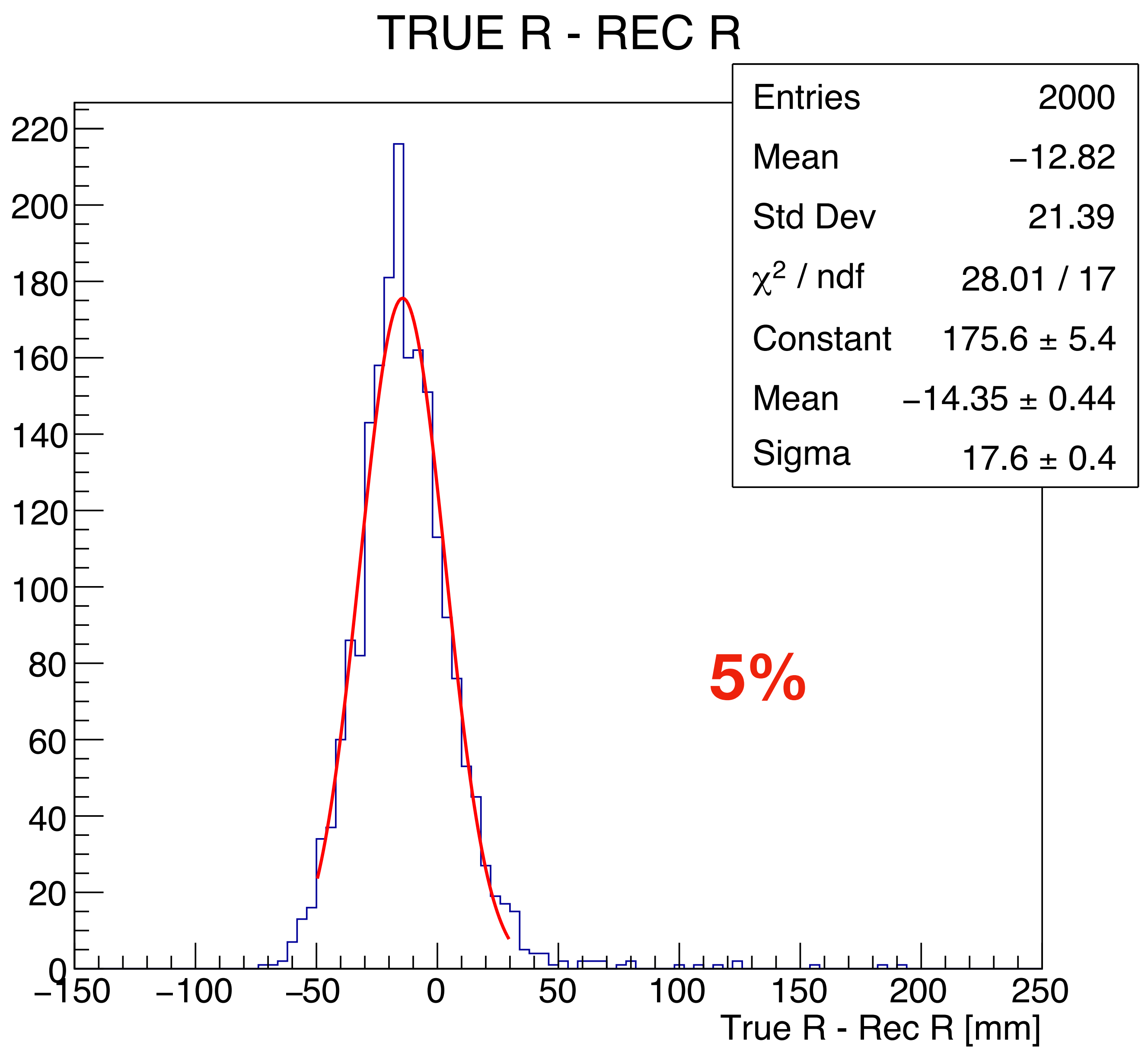


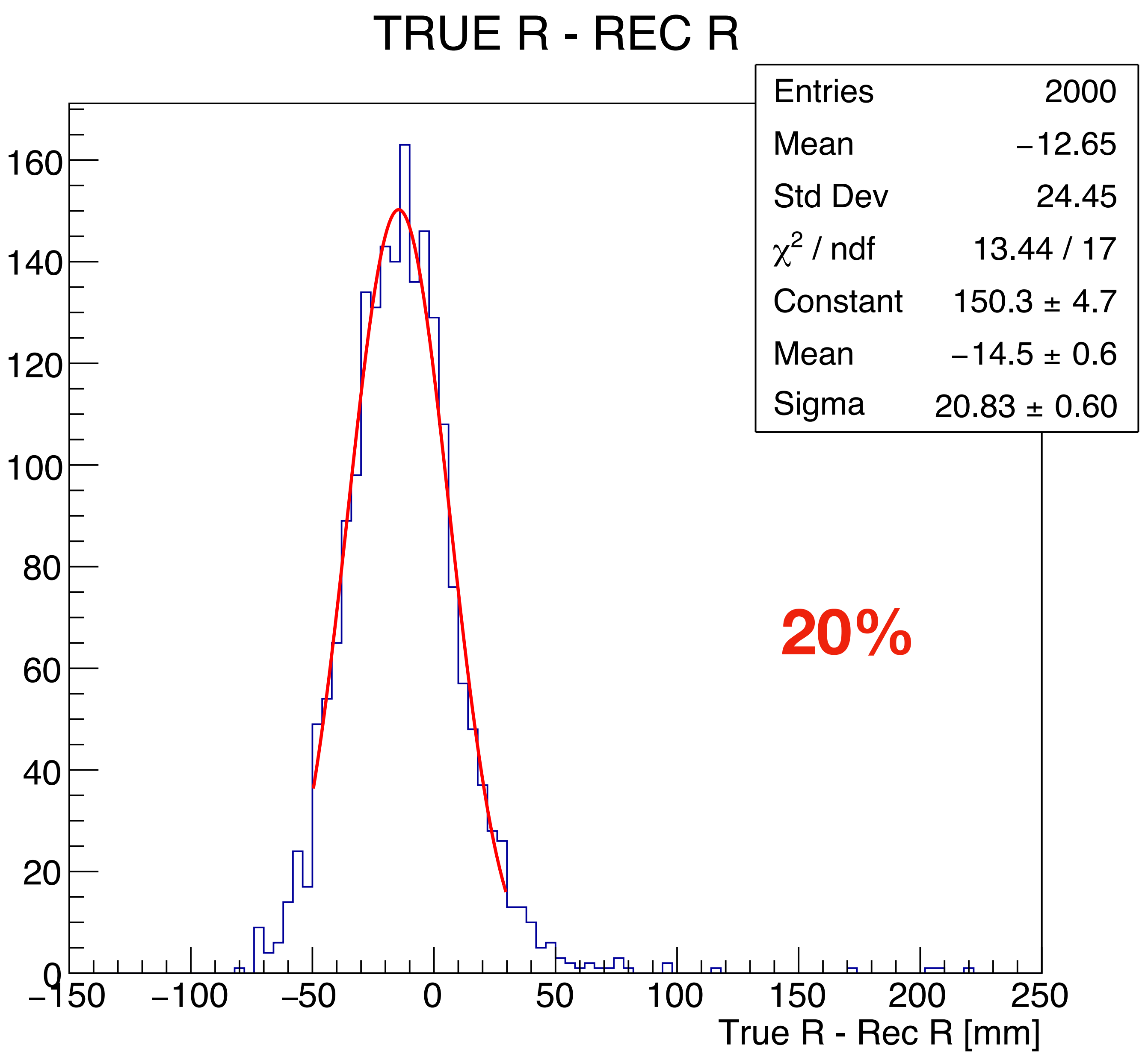
Impact of dead channels

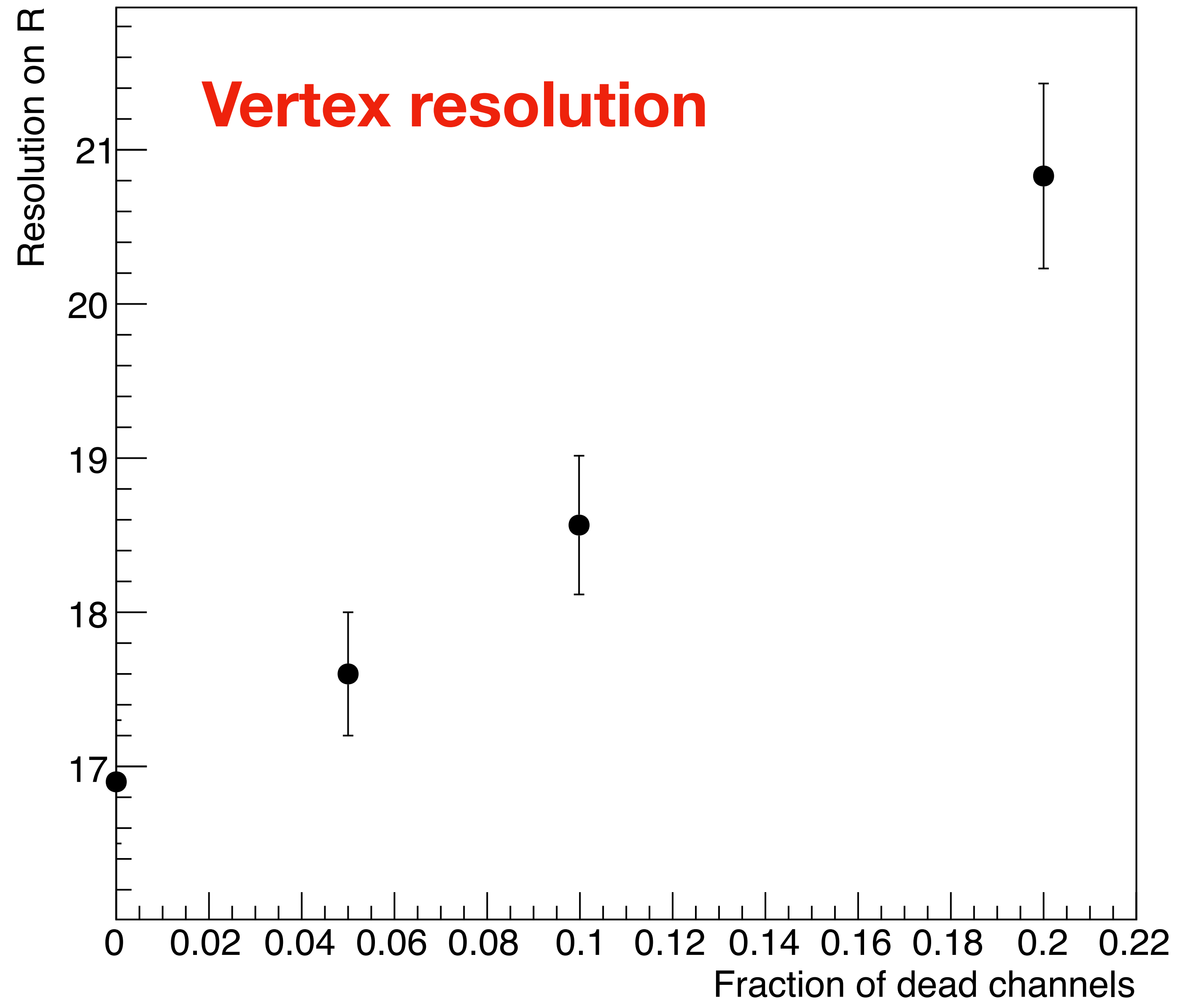








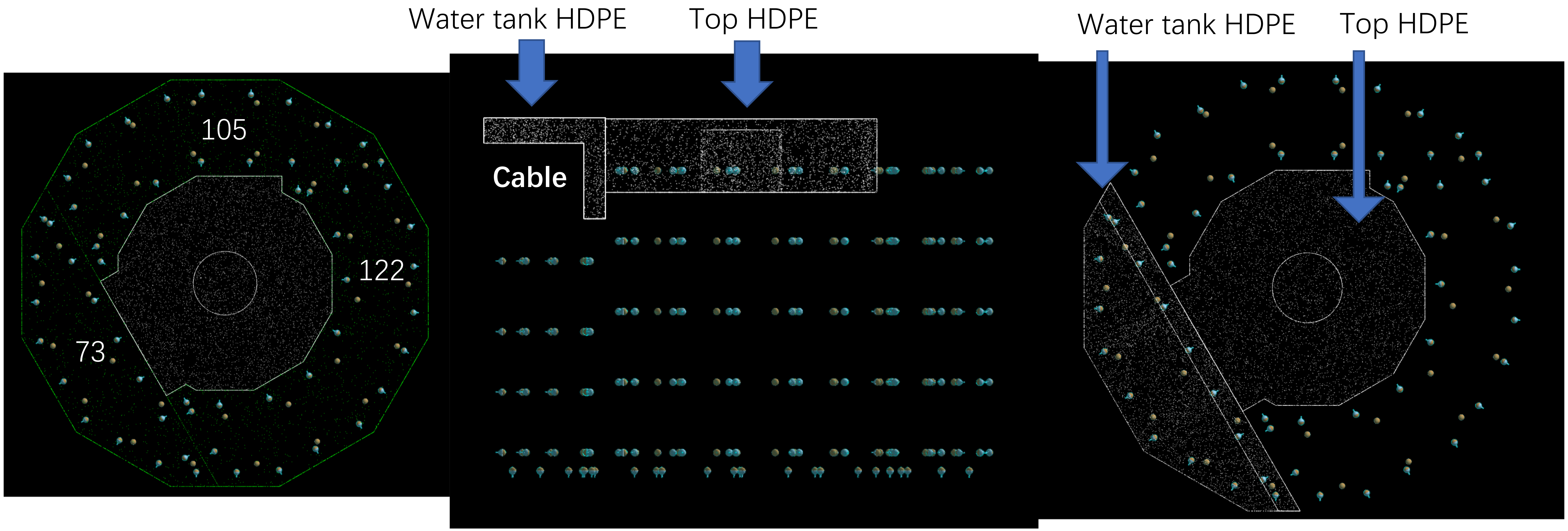




Veto simulation

See Ruhui's Talk Docdb 7884

Veto simulation: HDPE



PMT position is the same as engineer design.
Top HDPE is fit in with the inner water tank wall.
Water Tank (WT) HDPE is fit in with the gap between the cable tray & WT. 6

Veto simulation

See Ruhui's Talk Docdb 7884

	Muon rate
Sea level (0m)	200 Hz/m2
TAO location (-10m)	~80 Hz/m2

Efficiency and Rate of Veto

- For water tank, the default threshold is 5 PMT(~4 cm trackL) fired of each tank (300 ns)
  - Efficiency: 99.4%
- For PS, the default threshold is 1 MeV of single PS strip (floor efficiency ~97%), 3 layers fired out of 4
  - Efficiency: 98.4%

Event rate & Efficiency of Every Part of the Water Tank

Time window: 300 ns	WT 1	WT 2	WT 3	total
Muon trackL>0	826 Hz	1421 Hz	1600 Hz	3086 Hz
PMT hit>0	851 Hz	1449 Hz	1630 Hz	-
PMT hit>5	831 Hz	1423 Hz	1603 Hz	-
PMT hit>0&trackL>0	824 Hz	1419 Hz	1598 Hz	-
PMT hit>5&trackL>0	818 Hz	1409 Hz	1588 Hz	-
Efficiency of PMT hit>5	99.11%	99.15%	99.24%	99.36%
Mean fired PMT	65.1 (out of 73)	90.4 (out of 105)	102.6 (out of 122)	-

PS Muon Efficiency & Mimic Gamma Rate of Different Threshold

Threshold/MeV		0.8	1	1.2	1.4	1.6
Muon Efficiency	2/4	99.5%	99.4%	99.1%	98.6%	97.9%
	3/4	98.9%	98.4%	97.6%	96.4%	94.5%
	2/3	99.4%	99.1%	98.7%	98.0%	97.0%
Gamma Identified as muon /Hz	2/4	362.92	102.18	22.82	5.20	1.34
	3/4	0.67	0.17	0	0	0
	2/3	290.80	79.87	16.61	2.68	1.01

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Thanks to Yichen

Radioactivity background

General summary with fiducial volume

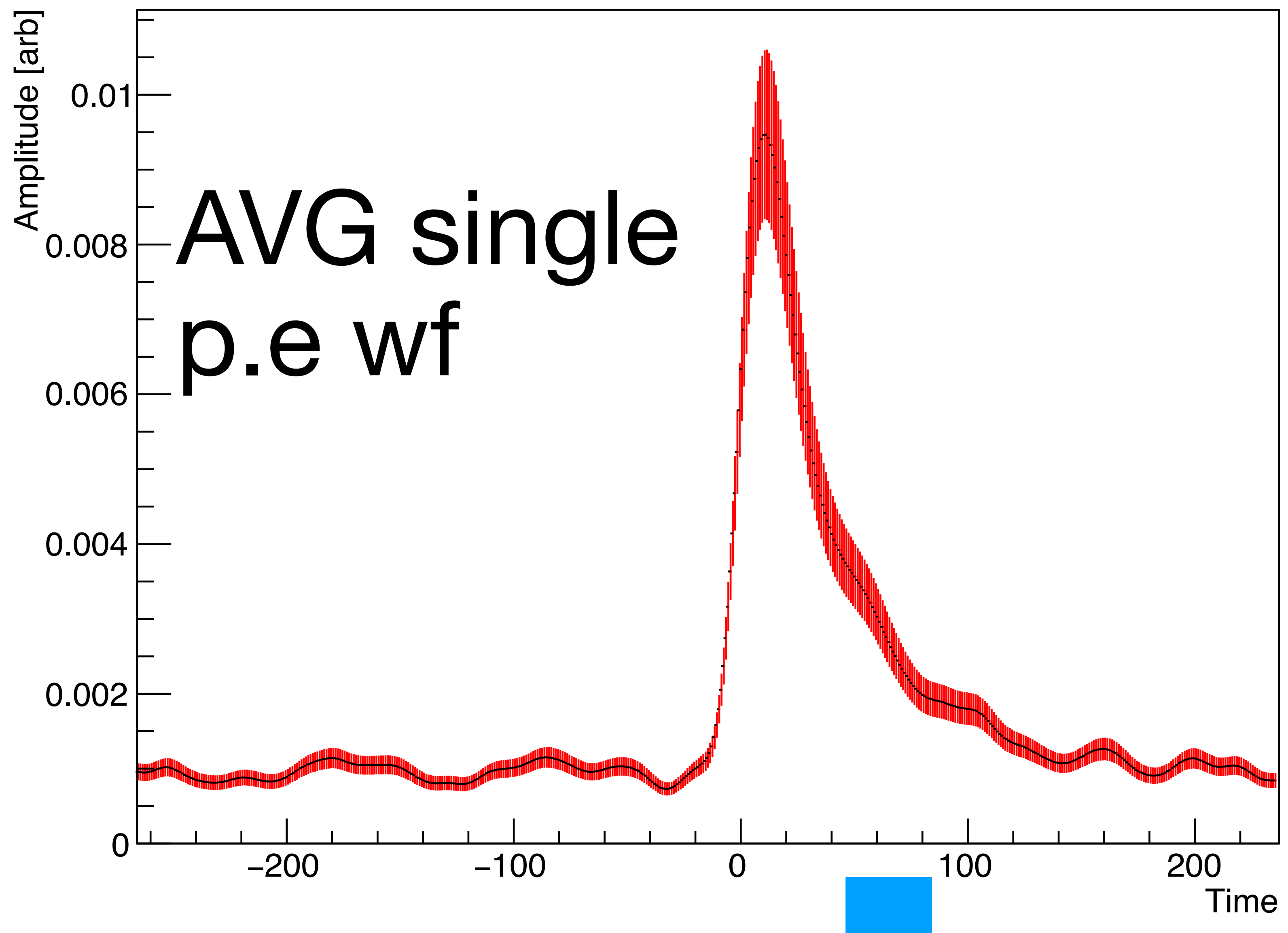
Material	Fiducial(Hz)	Total(Hz)	Rad. Ref.	C.L.
GdLS	0,9	2,0	YWQ	Upper limit
Acrylic Shell	0,001	0,004	ZJ	Upper limit
SiPM/FEB PCB	1,2	7,1	CGF	Upper limit
Copper Shell	2,5	13,0	XYG	Upper limit
Buffer LAB	0,009	0,039	YWG	Upper limit
SS Tank	2,0	7,4	XYG	Upper limit
HDPE	5,7	21,0	WZM	K40 Upper limit
Thermal Insu.	0,5	1,9	XYG	Upper limit
Water Shielding	0,1	0,4	JUNO	Upper limit
Water Tank	0,3	1,1	XYG	Upper limit
Lead Shielding	3,0	11,5	WZM	Upper limit
Concrete (50 cm)	23,7	87,8	YHF	Upper limit
Total	39,9	153,3		

Elecsim

- Discrete ElecSim is currently under development
- Many effects have to be taken into account: SiPM, TIA response, ADC Driver, ADCs…..
- A different approach: instead of defining a model for each component we use an effective simulation based on real SiPM data
- For each pulse a waveform is generated starting from a set of single p.e. waveforms sampled with the very same readout electronics
- Resulting waveform are processed with the same algorithm that will be implemented on the FEC firmware

DetSim (G4)

Photon collection + SiPM PDE



Waveform integration —> Q,t pair

Conclusions

- TDAQ in pretty good shape:
  - Solid architecture
  - Data throughput is under control
  - PDR in July 2021 (Success!!) - FDR expected in 2022

- Detector simulation works smoothly: rad. Background and veto performance studies are in a good shape
- First physics production: a lot of statistics
- Several items are still open (manpower is a always a big issue): Discrete Elecsim (work in progress), Background mixing, Reconstruction,Event display…