ND280 Upgrade Status

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CEA/IRFU/DPhP
04/04/2025
Jennifer2 - Pisa

Introduction

- Apologize for those present at Jennifer3 kick-off meeting
- Nothing really new since January…
- Tasks covered
  - Task 2.1: Construction and Commissioning of Near Detector ND280 Completion of ND280 upgrade
  - Task 2.2: Construction and Commissioning of Super FGD
- Deliverables:
  - D2.1 : Paper on the upgraded ND280 [48]
    Publication describing constuction and commissioning of the upgraded ND280

	WP2 - introduction *IFAE*	*Claudio Giganti* 17:10 - 17:25
	ND280 upgrade performances and plans *IFAE*	*David Henaff et al.* 17:25 - 17:50
18:00	**Status of T2K OA and plans for integration of ND280 upgrade** *IFAE*	*Andrea Longhin* 17:50 - 18:15
11:00	**Introduction** *131, INFN and University of Pisa*	*Emilio Radicioni* 11:00 - 11:10
	HA-TPC and sFGD construction and commissioning *131, INFN and University of Pisa*	*David Henafl* 11:10 - 11:35
	T2K Analysis *131, INFN and University of Pisa*	*Andrea Longhin* 11:35 - 12:00

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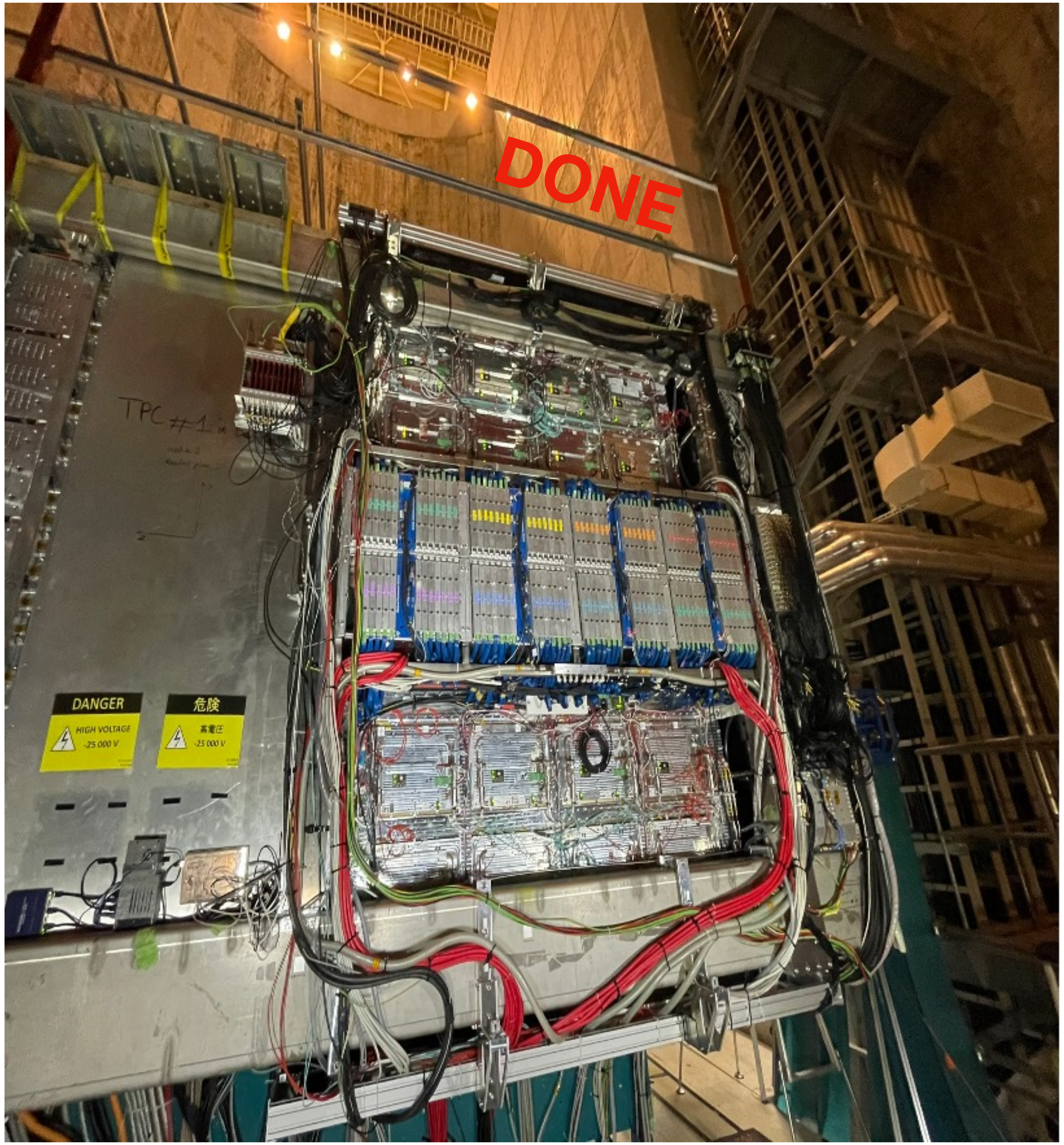
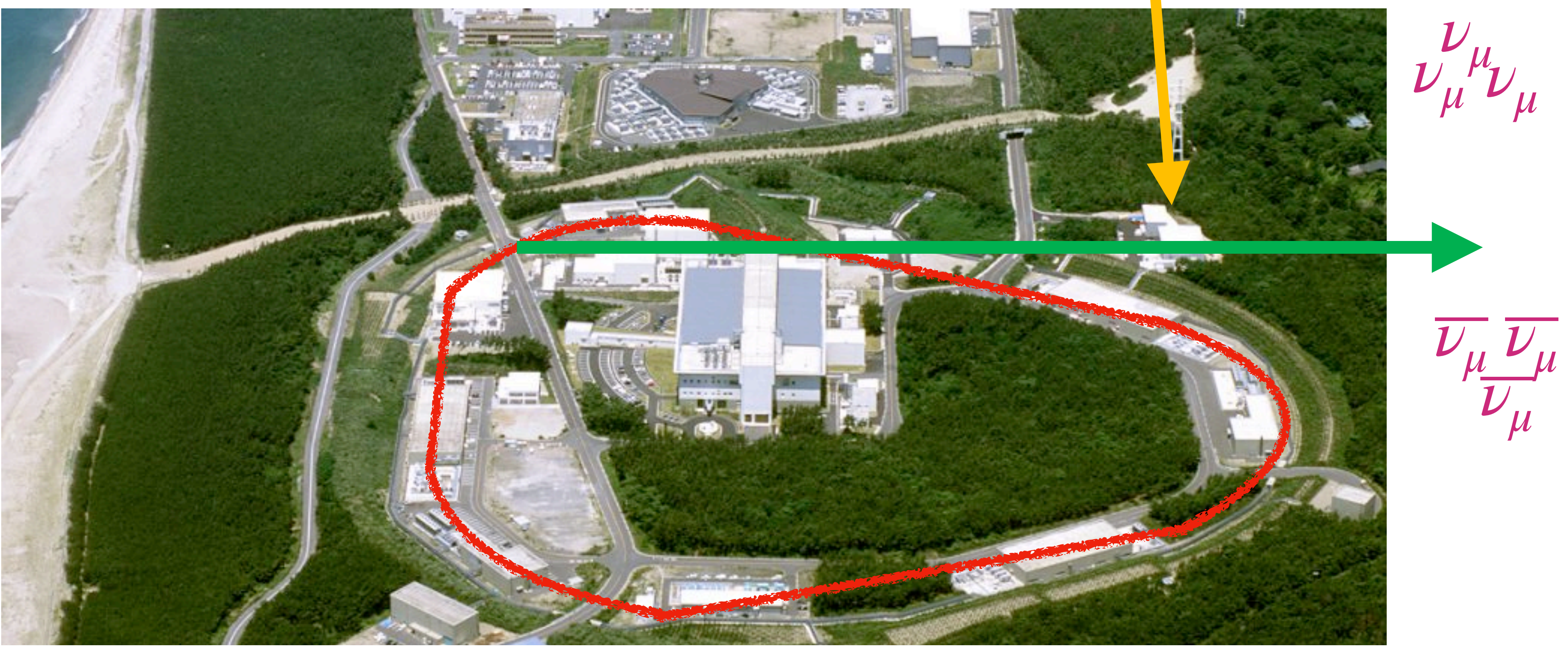
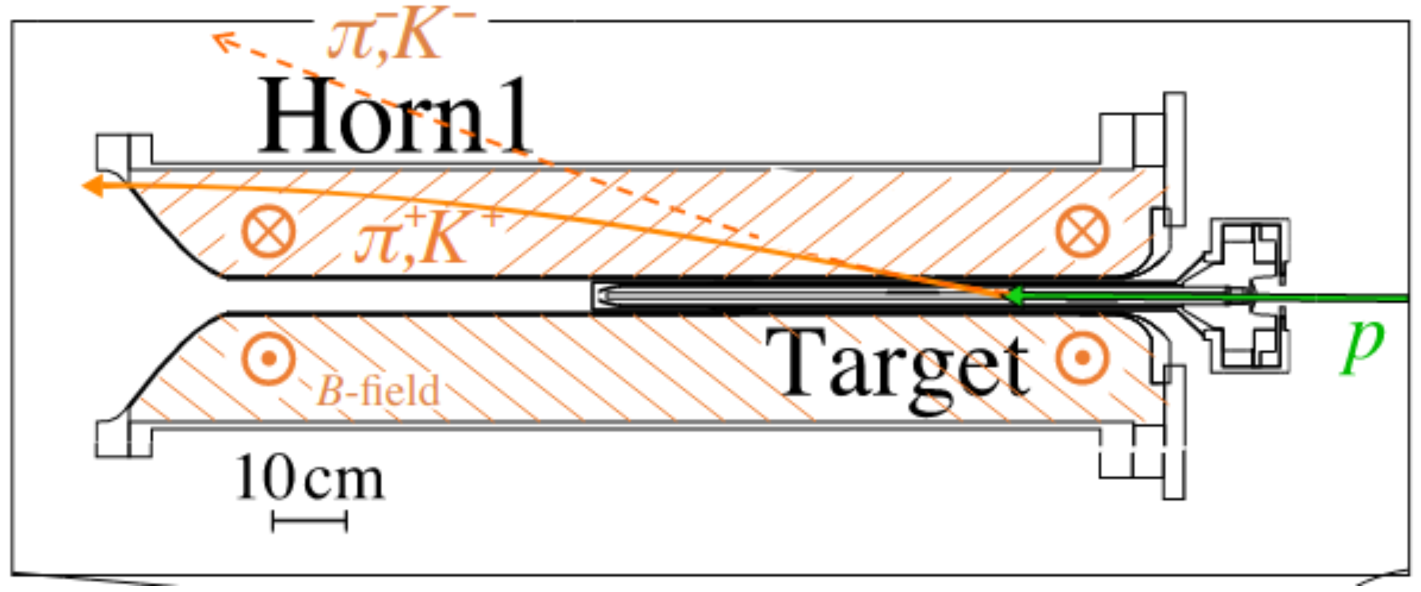


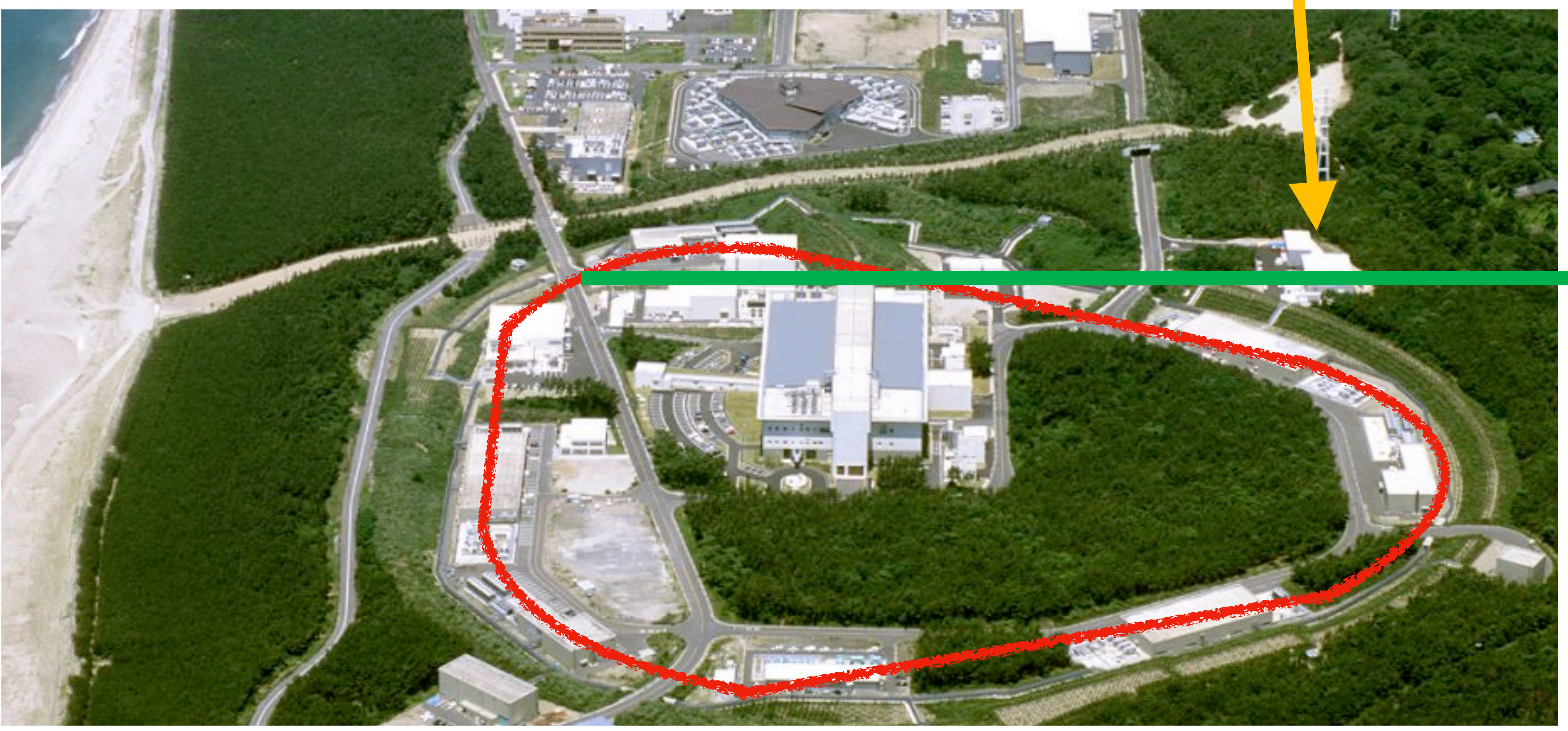
T2K experiment

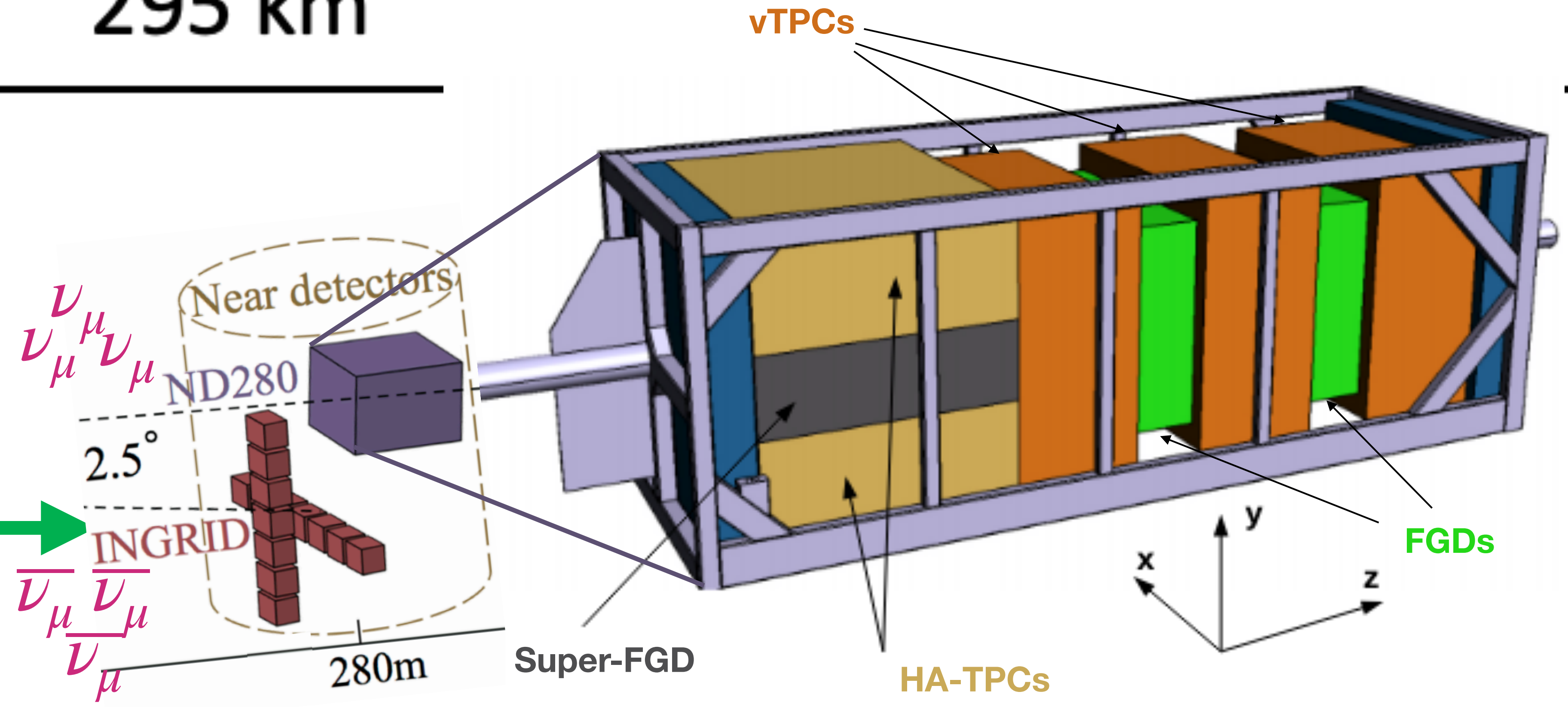




- **Beam:** 30 GeV protons on a graphite target, producing Kaons and Pions

T2K experiment



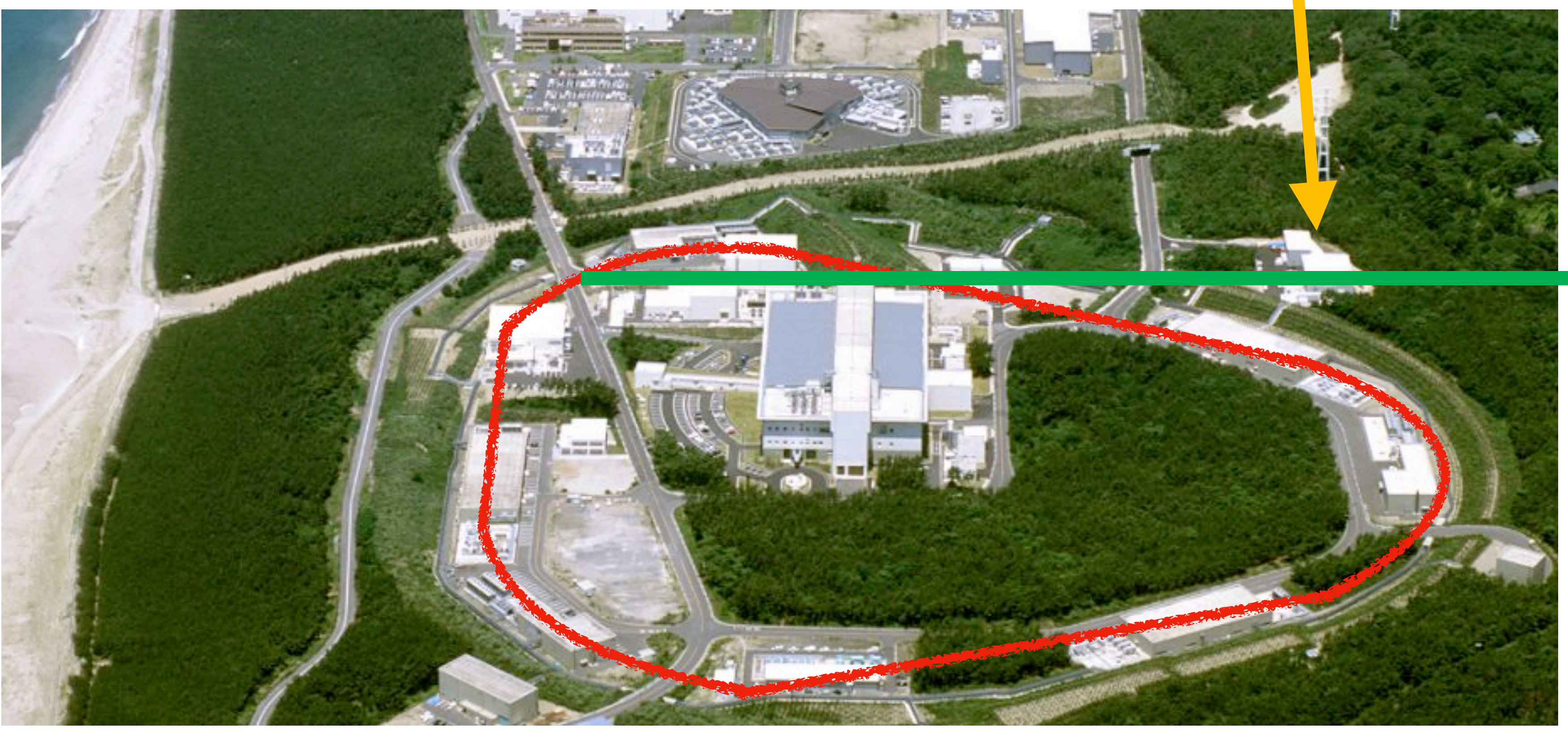


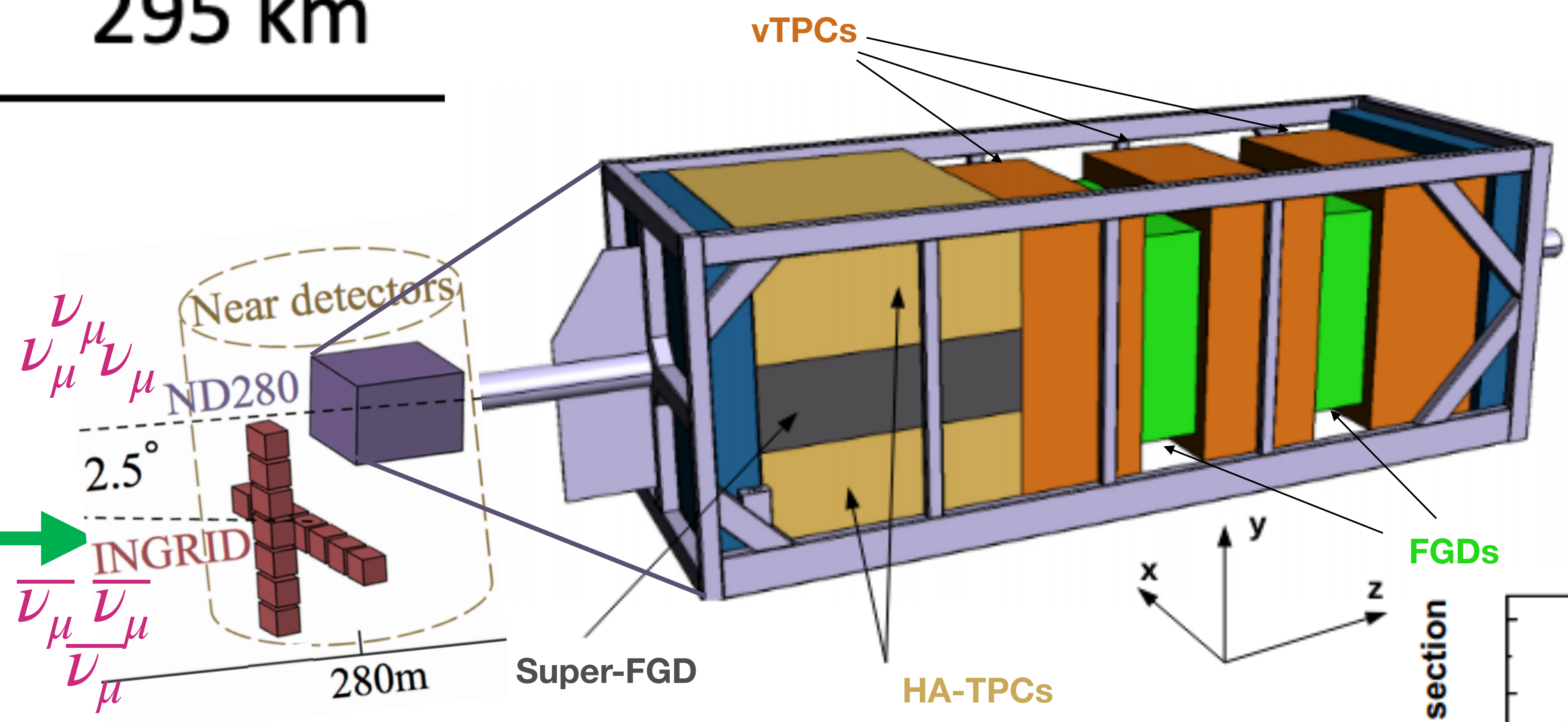
- **Beam:** 30 GeV protons on a graphite target, producing Kaons and Pions

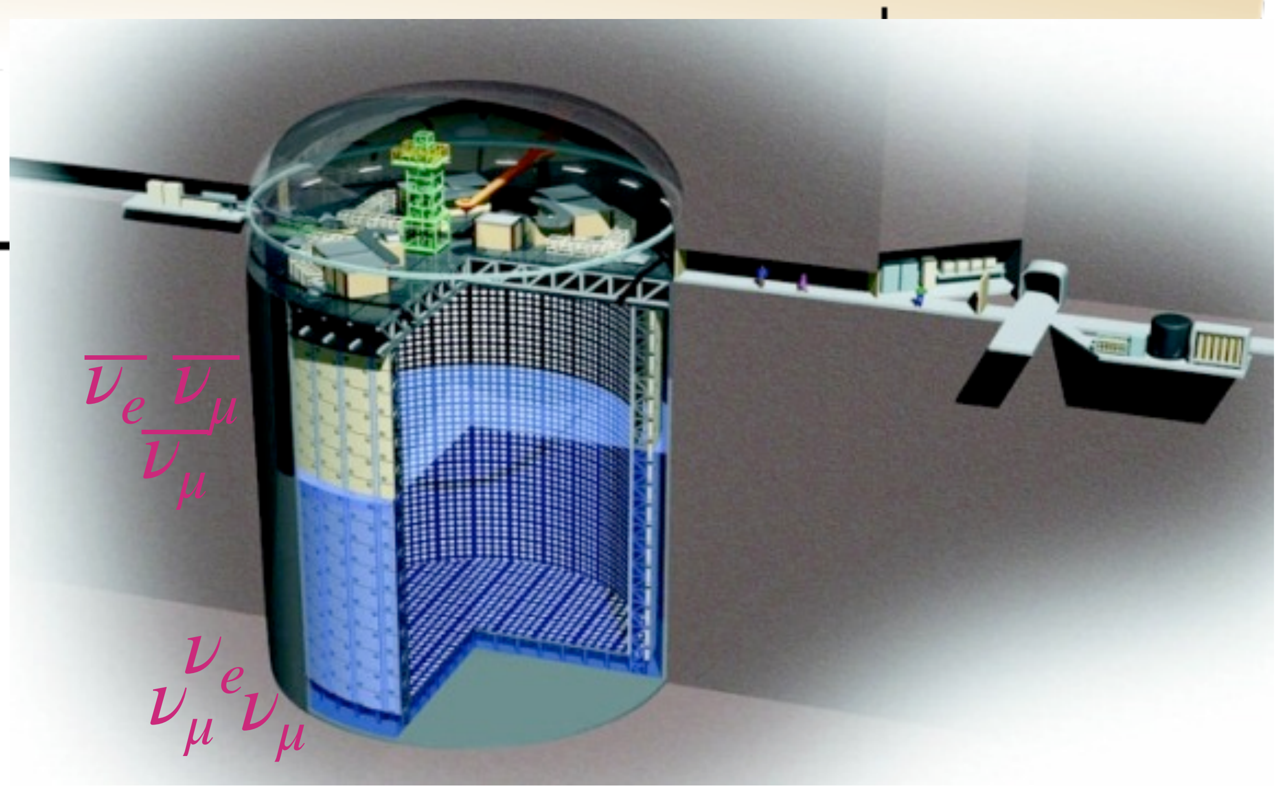
- **ND site:** *on and off axis detectors:*
  - Beam monitoring
  - Tune flux & interaction models predictions for OA
  - ν cross-sections
  - Magnetized 0.2T
  - Upgraded ND280 completed

T2K experiment

$$N_{\nu_\beta}(E_\nu^{reco}) = P_{\nu_\mu \to P_{\nu_\beta}}(E_\nu^{true})\Phi(E_\nu^{true})\sigma(E_\nu^{true})\epsilon(E_\nu^{true})S(E_\nu^{true}, E_\nu^{reco})$$







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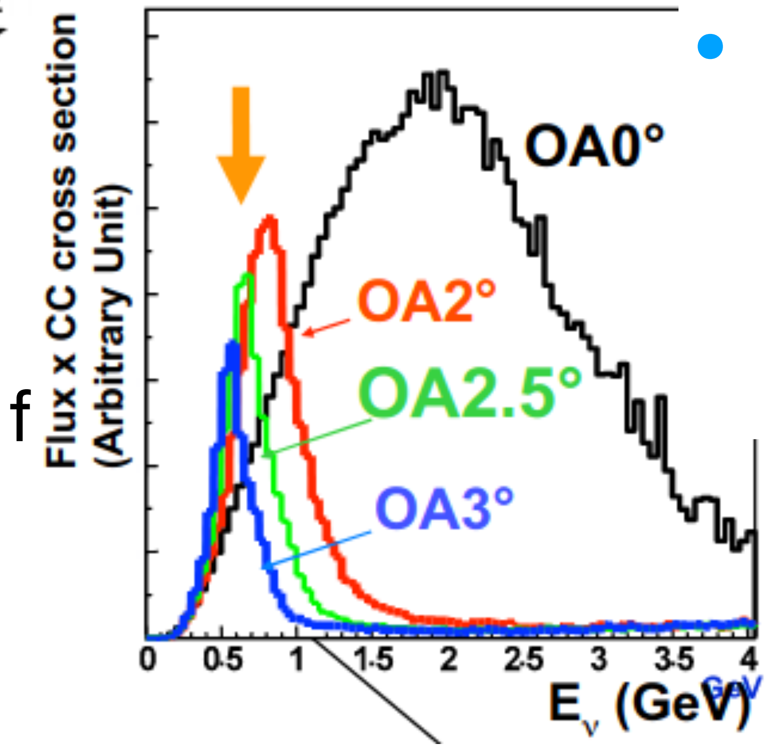
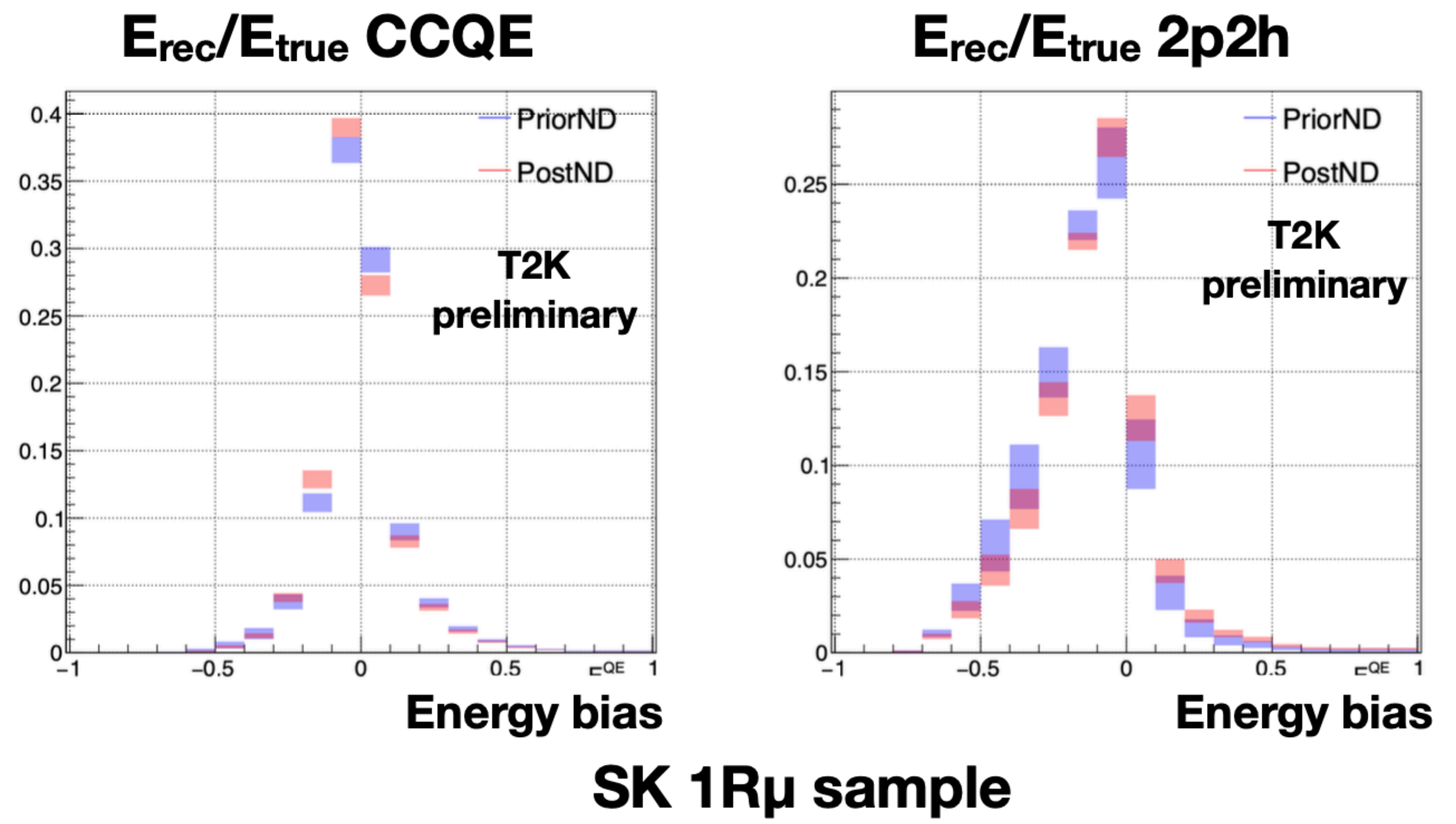


- **FD site:**
  - Super-Kamiokande
  - 50kton water Cherenkov detector

Why doing an upgrade?

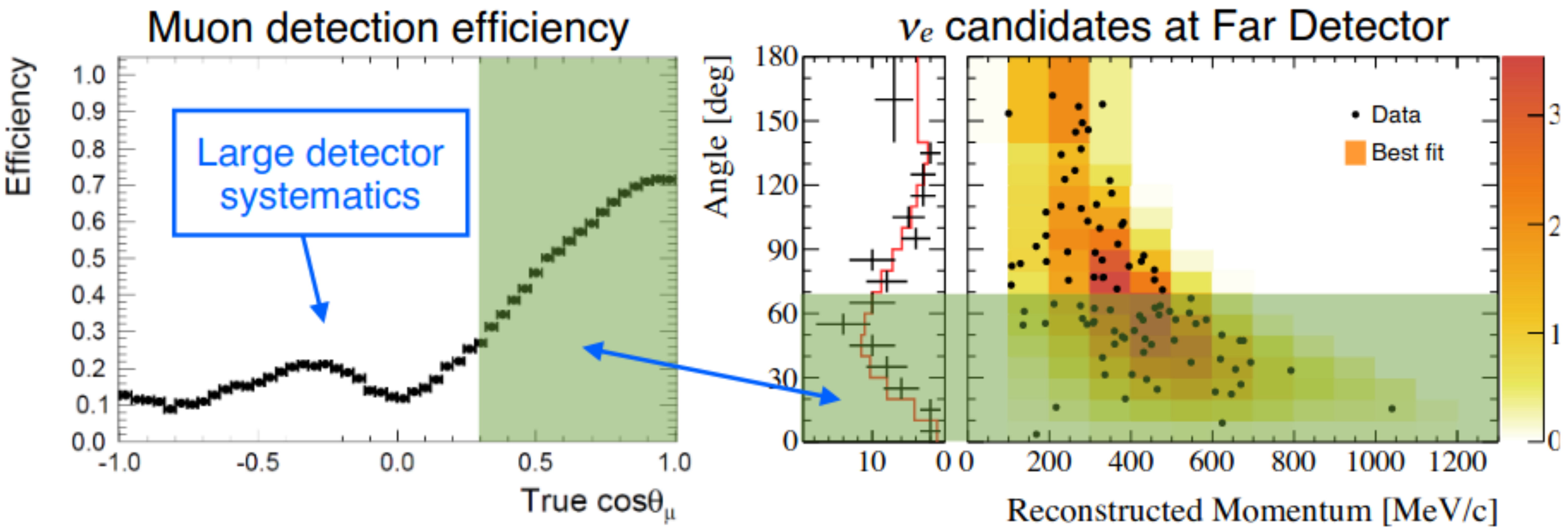
Neutrino oscillation

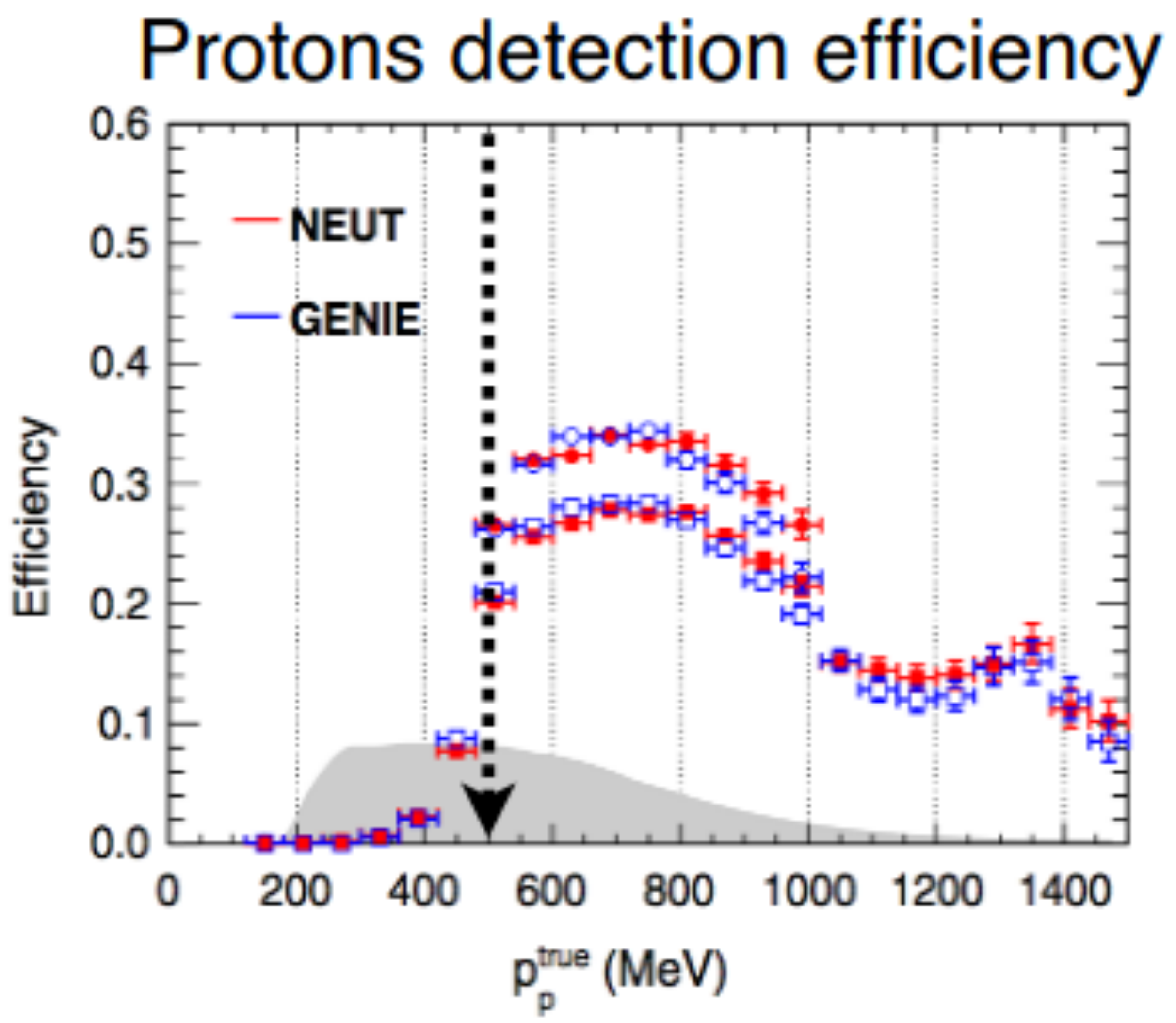
- Measure the neutrino energy is non trivial
- And could have large impact on oscillation parameters



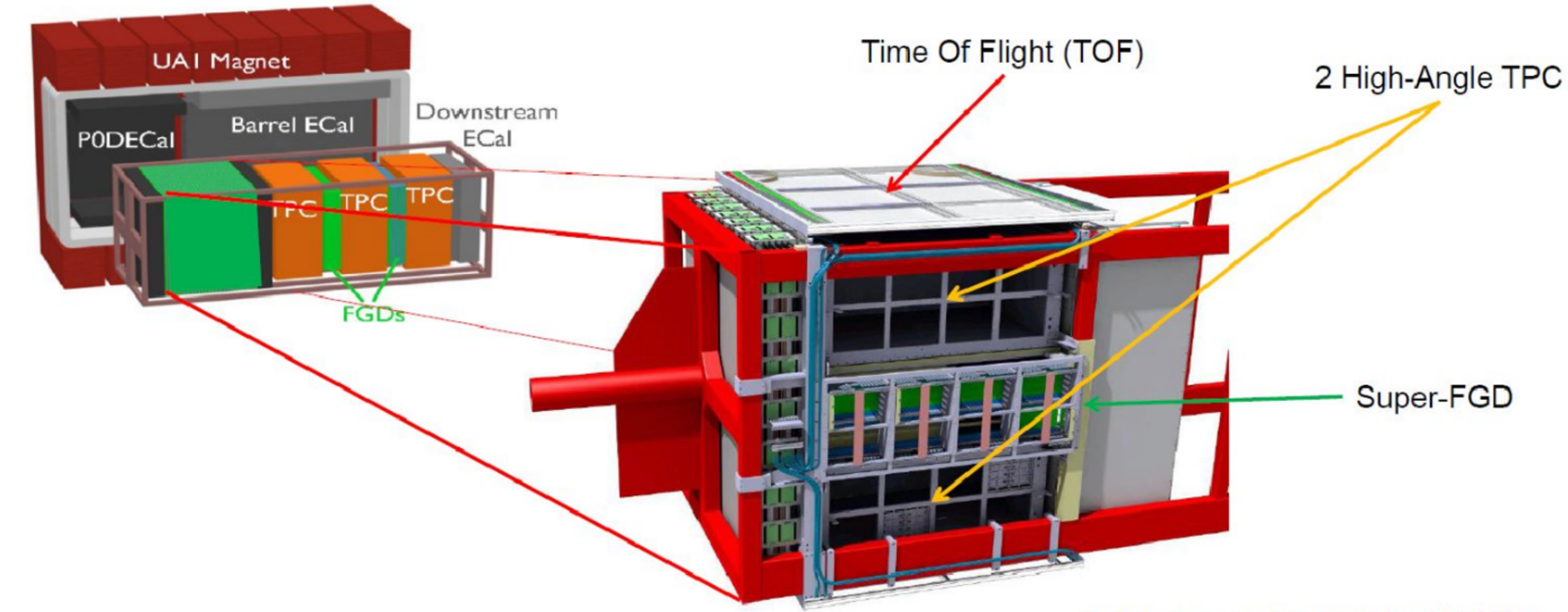
Limitations

- Old ND280 mainly a forward detector while SK is 4pi (high-angle and backward tracks not well reconstructed)
- Hadronic part of interactions only **partially** reconstructed because of proton threshold
  - Loss of information -> need to rely on neutrino-nucleus model to construct the neutrino energy from final state lepton





ND280 Upgraded



Technical Design Report: arXiv:1901.03750

ND280 upgrade installation timeline

T2K

September 2023

- Installation of most upgraded detectors:
  - Bottom HATPC
  - SuperFGD (partially equipped)
  - TOF downstream, bottom and top panels

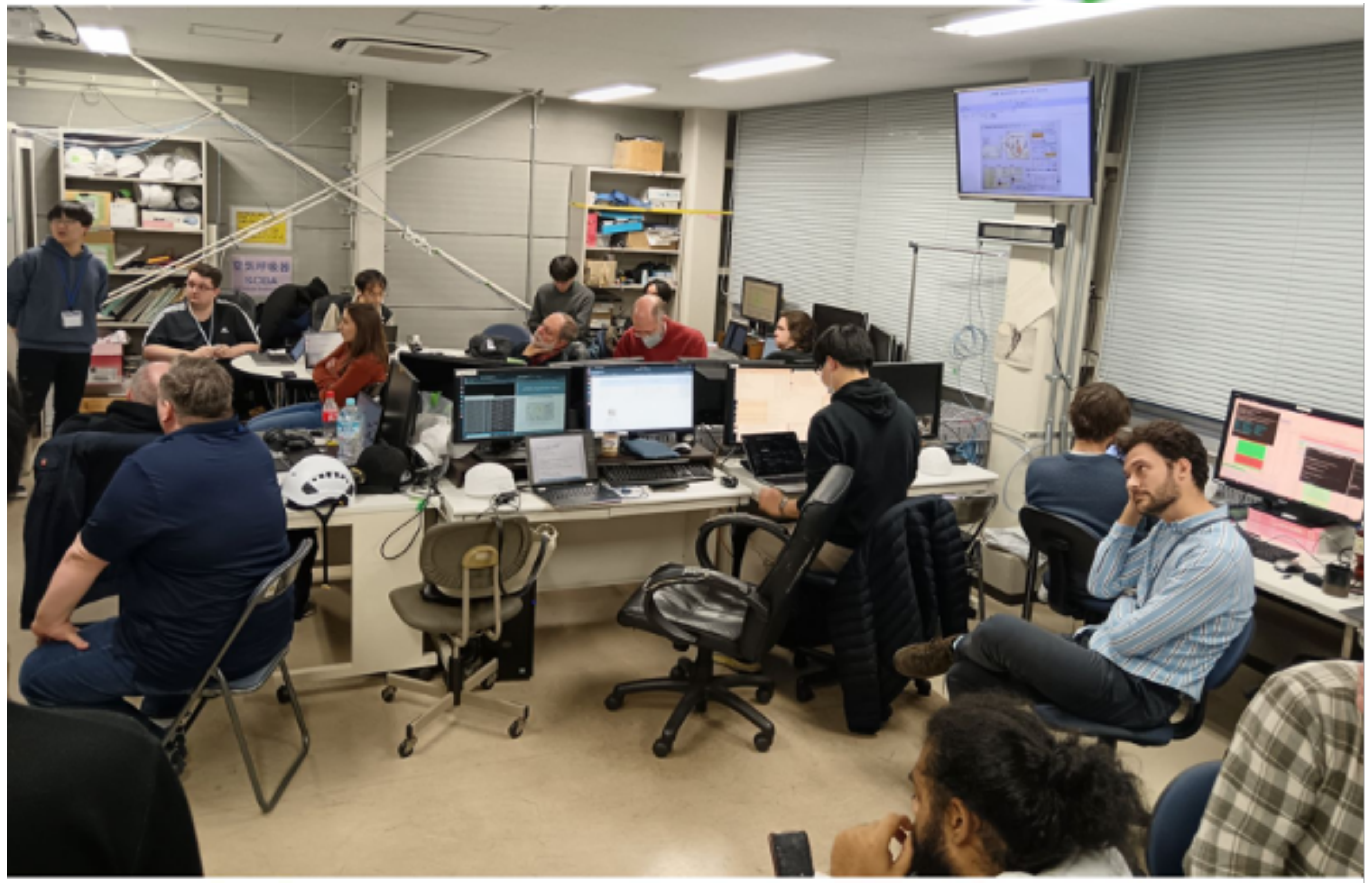
=> Already integrated and first beam taken in Dec 2023

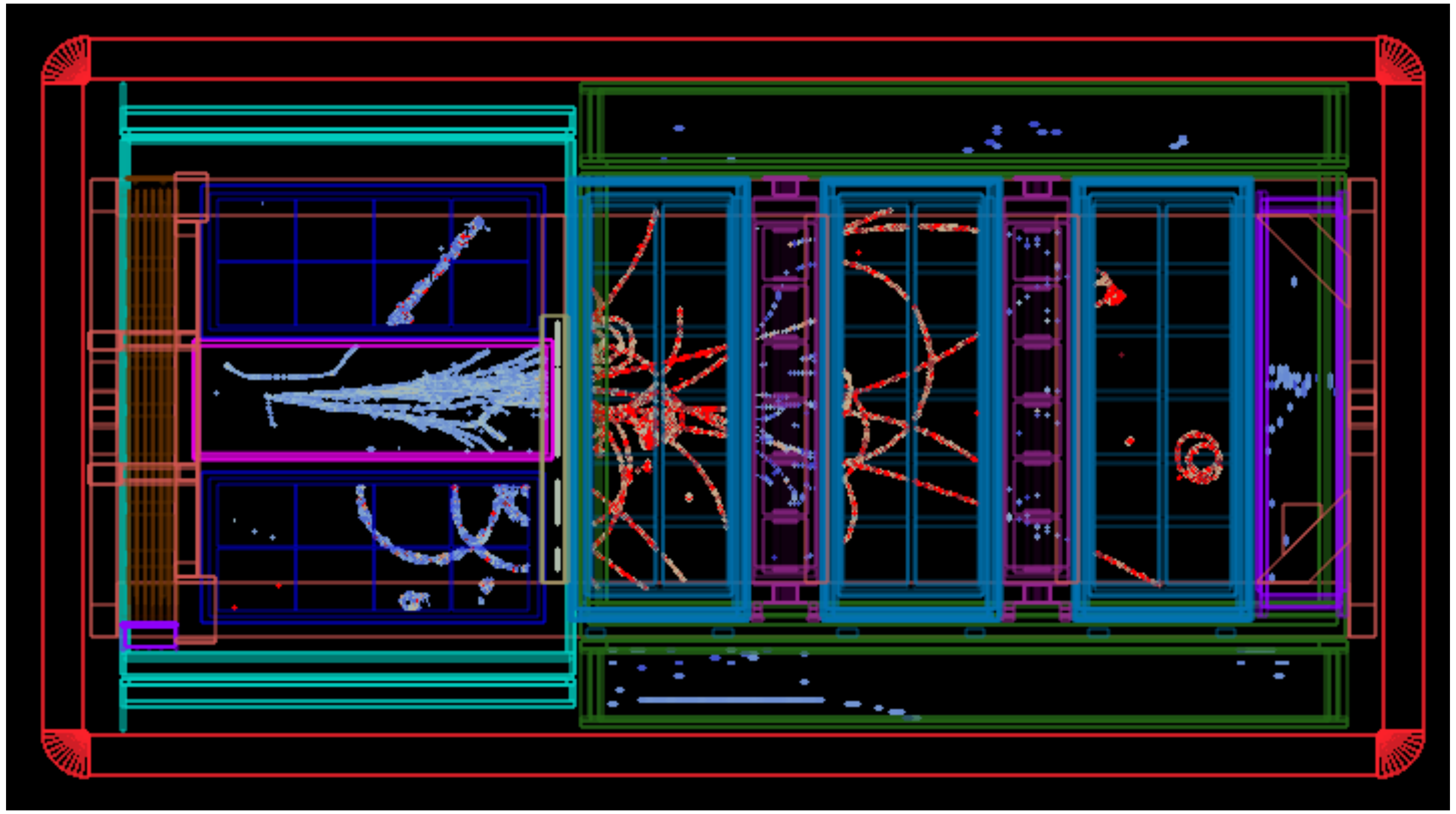
April 2024

- Installation of Top HATPC
- SFGD fully equipped with its electronic
- Installation of remaining TOF panels

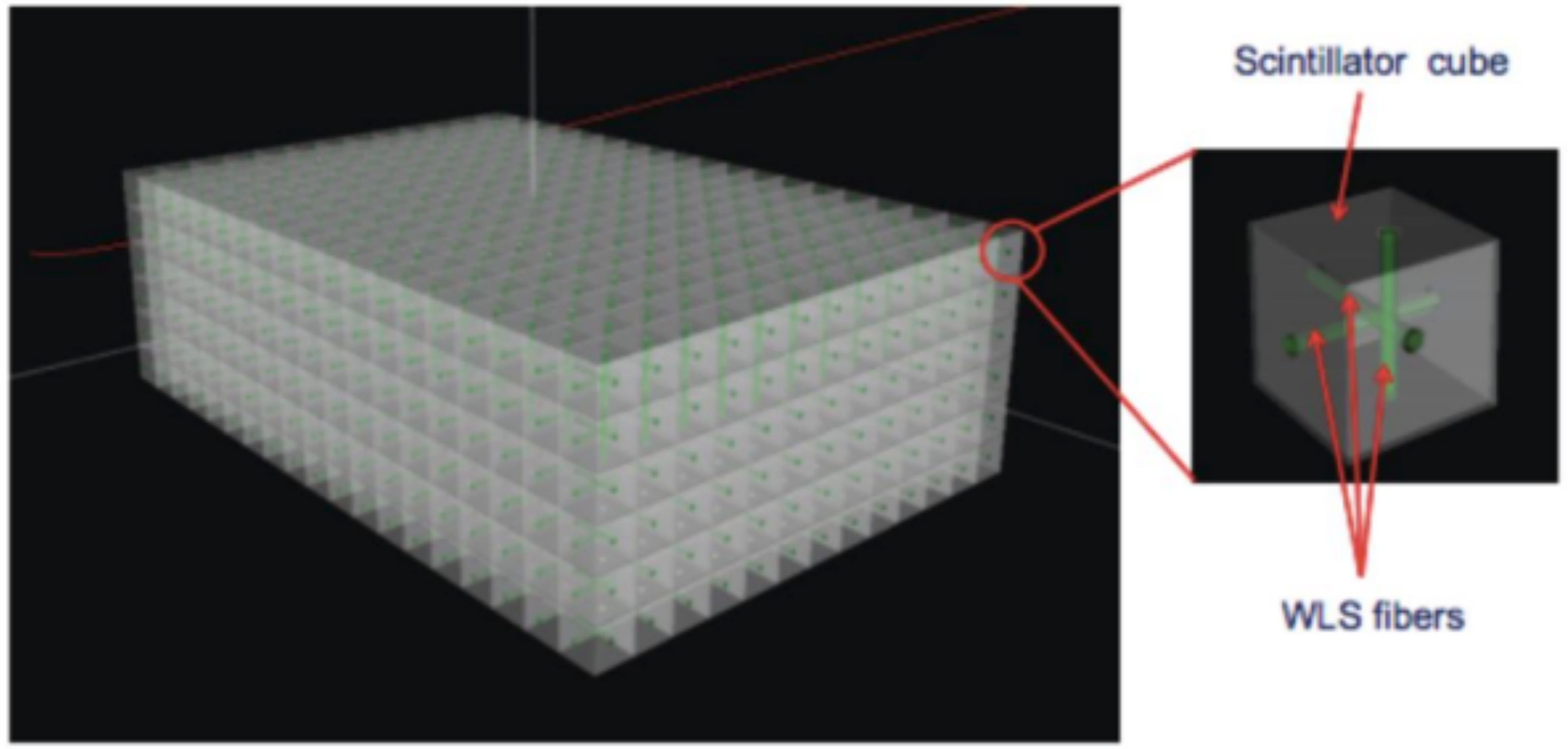
=> All detectors online for June 2024 beam run

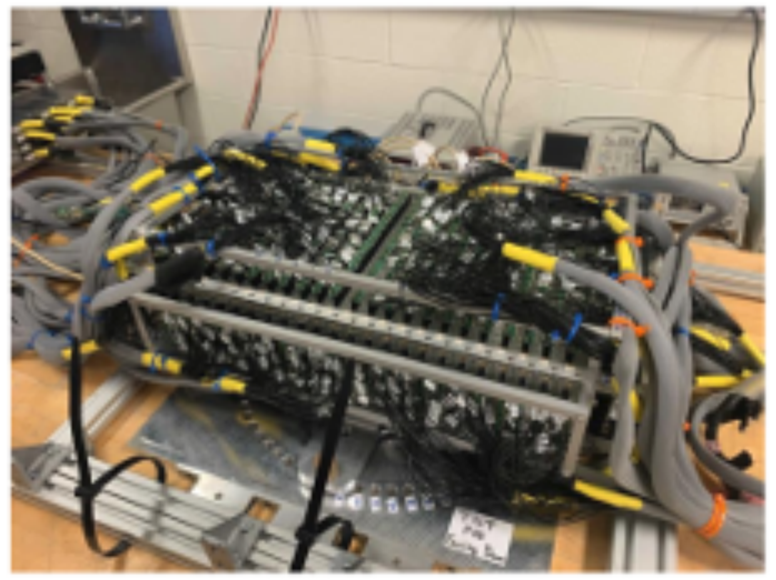
Smooth installation thanks to high presence of Jennifer2 people on-site!

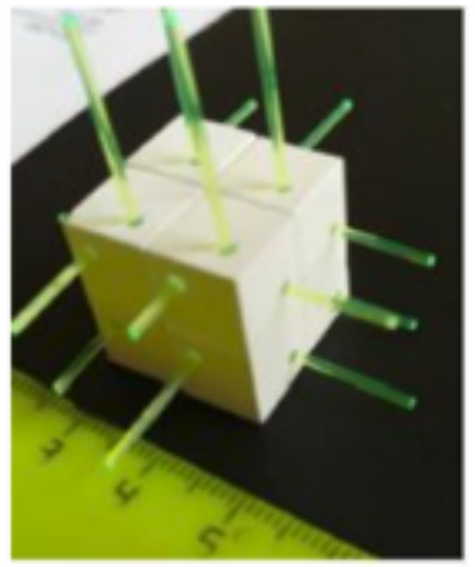


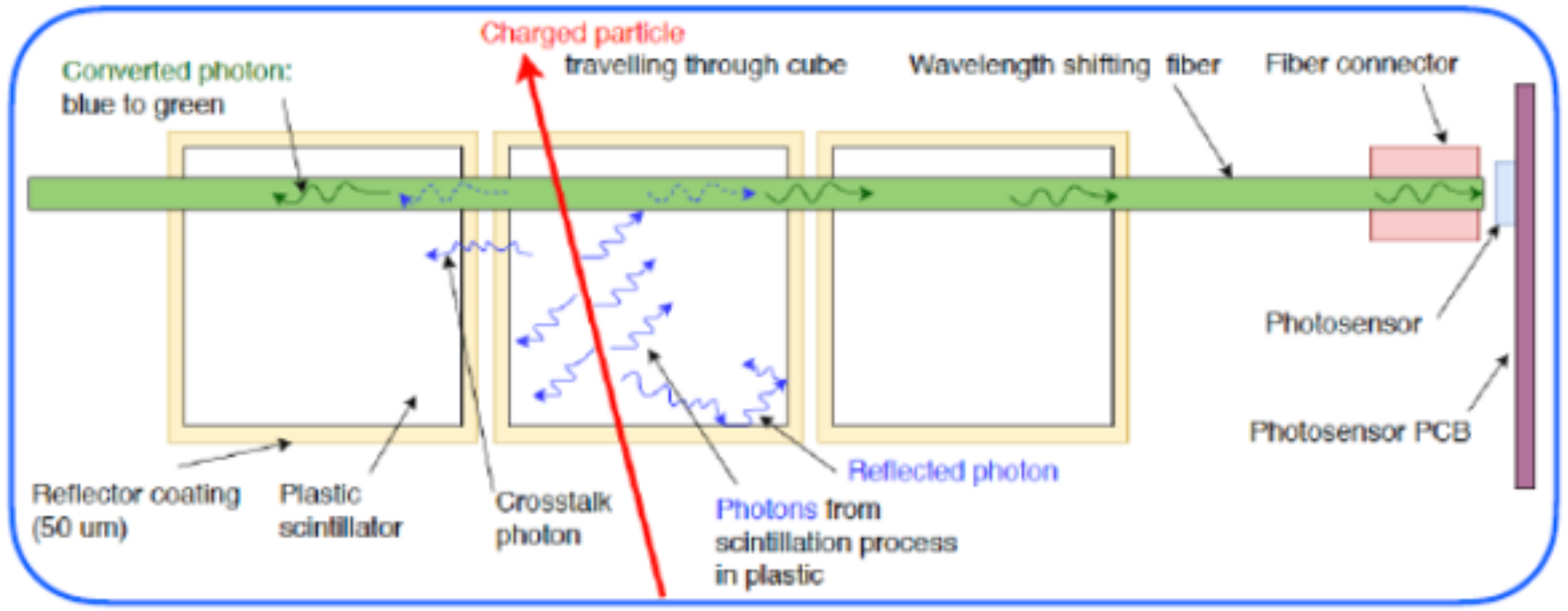


SuperFGD concept and installation









1x1x1 cm^3 cubes
Polystyrene scintillator
1.5% paraterphenyl
0.01% POPOP
Chemical etched reflector
WLS fiber Kuraray Y11
2-clad (⌀=1mm)

Main characteristics

- Highly segmented target made of 2 millions cubes of plastic scintillators
- Readout by a 3D array of fibres
  - Precise location of primary vertex
  - Lower threshold for protons and neutrons

SuperFGD concept and installation

On-surface tests

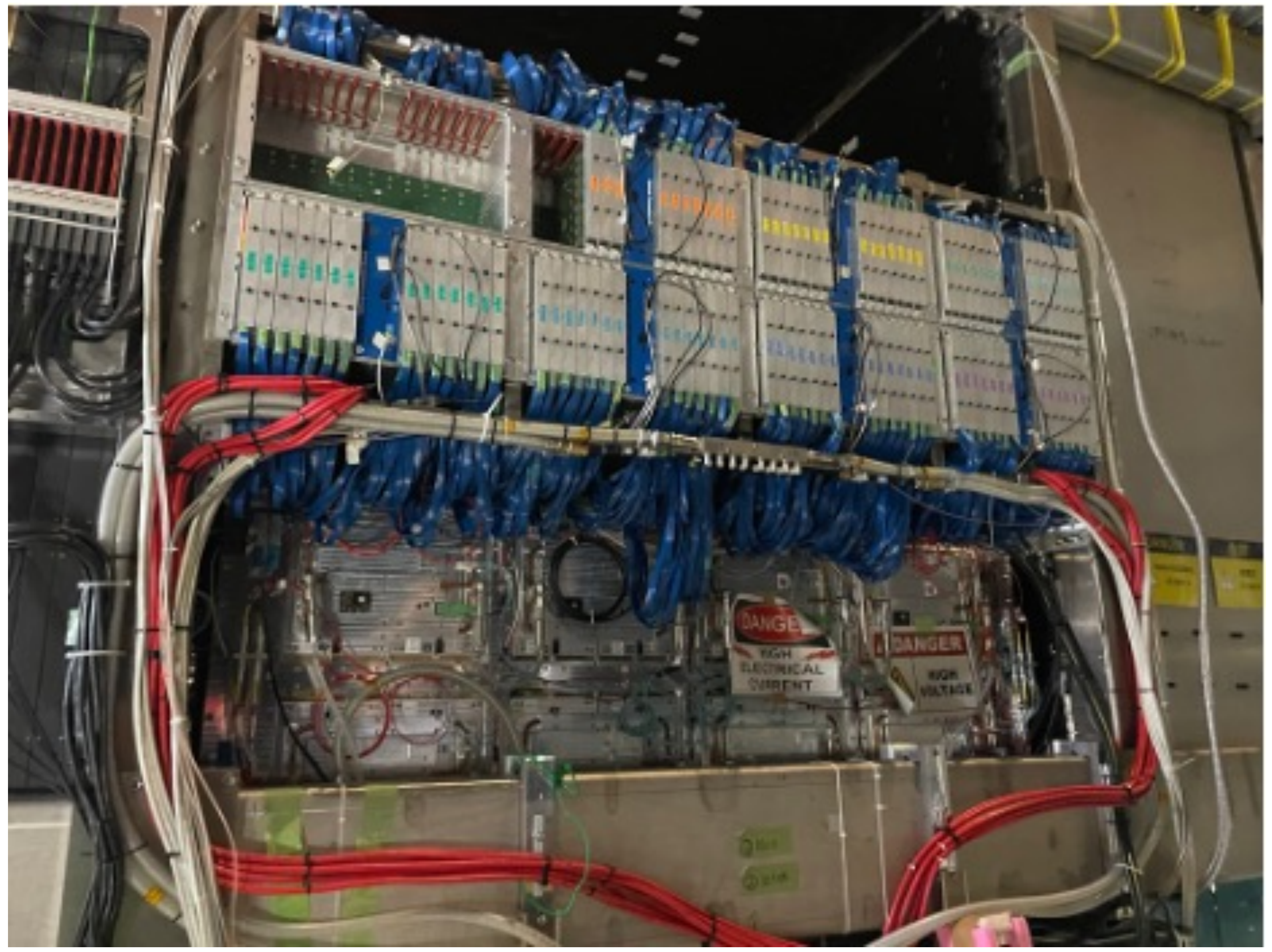
- Tested and qualified before installation

Installation in basket

- 12th October 2023

Cabling and commissioning

- Cabled and tested with TOF cosmic trigger before December beam



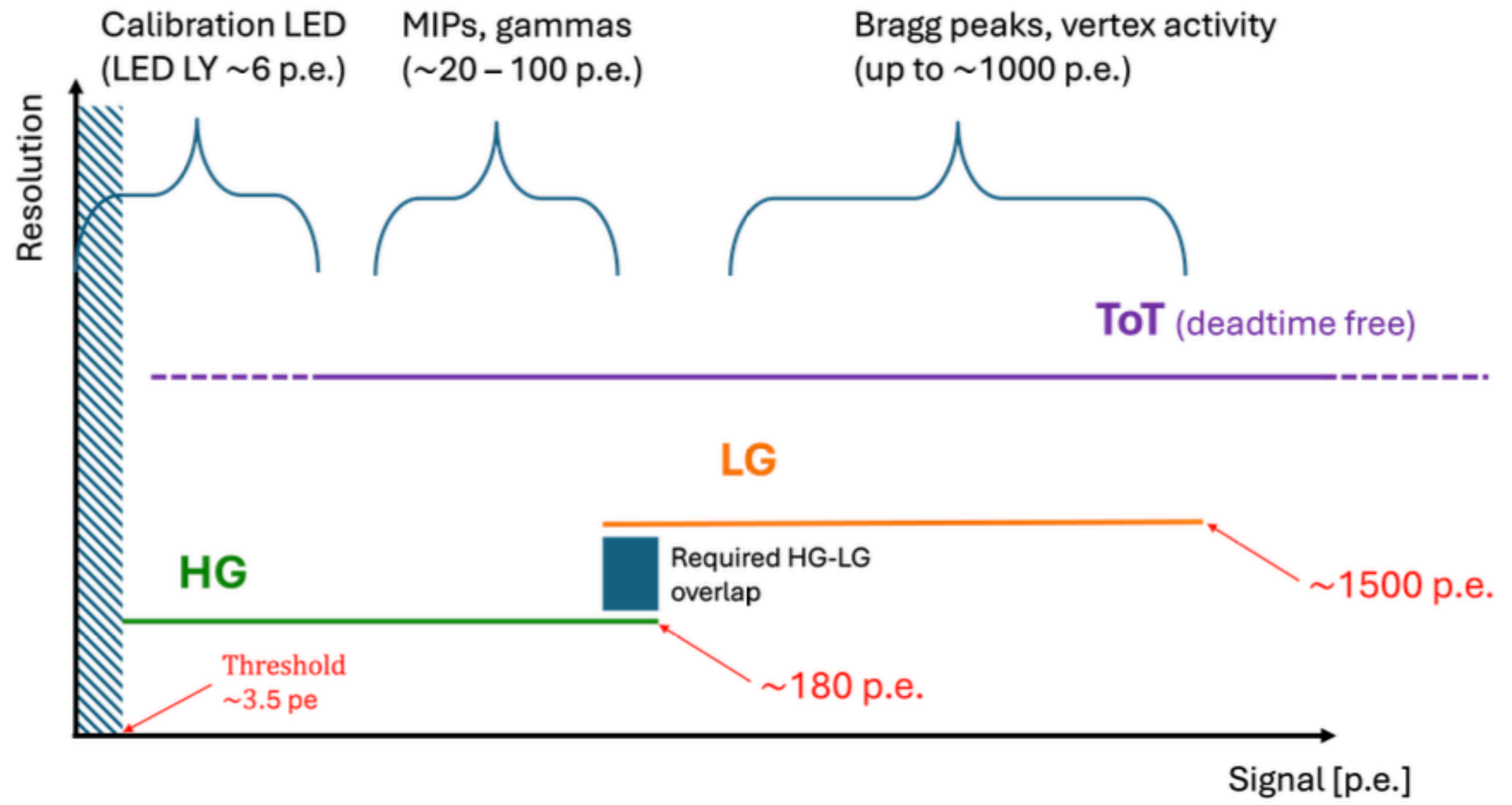
Important presence of Jennifer groups

SuperFGD calibration

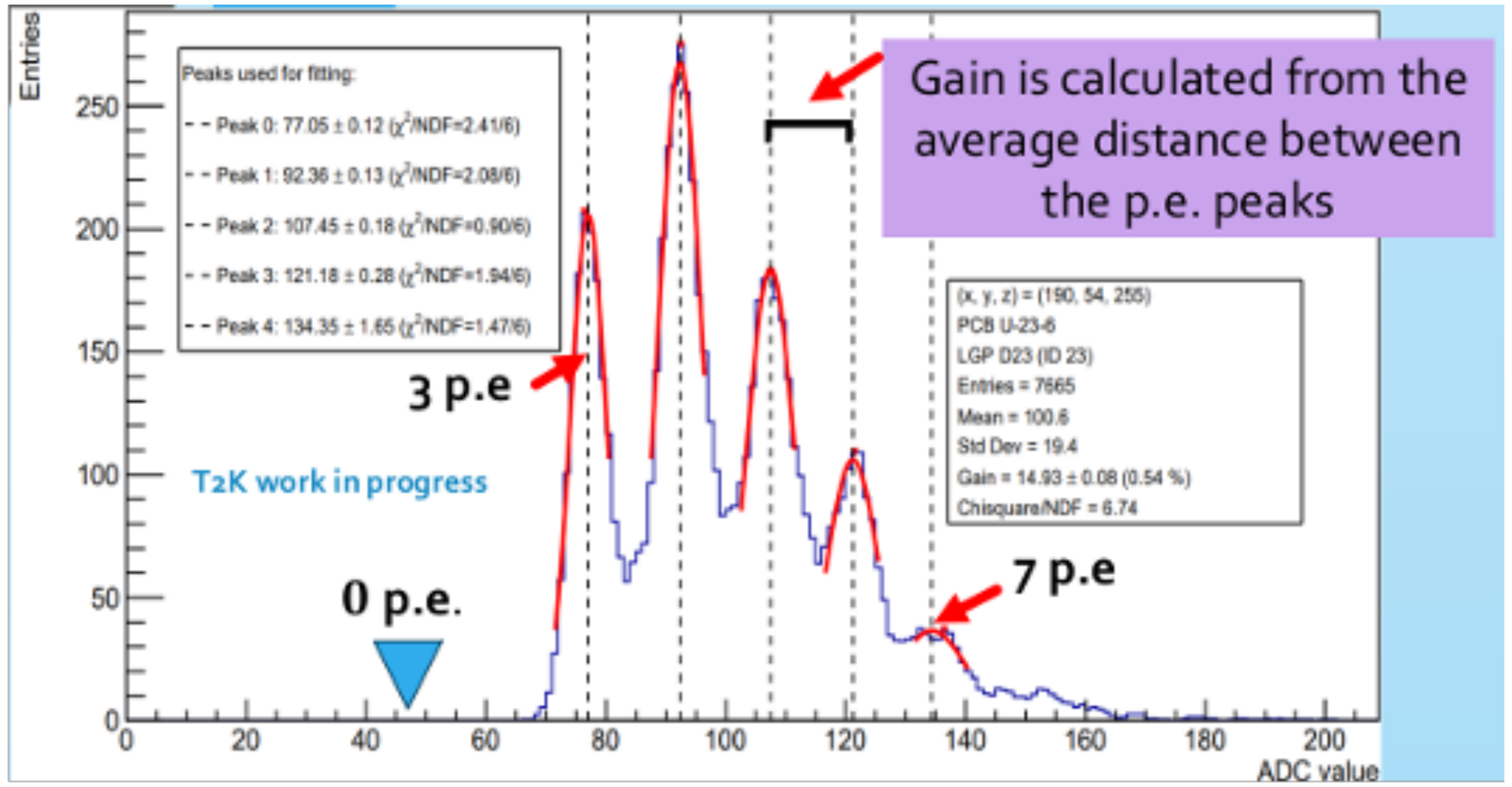
Detector response: Low and high gain readout

- Signal digitized by CITIROC (Omega lab. Ecole Polytechnique)
- Low and high gain signals (2x 12-bits ADC)

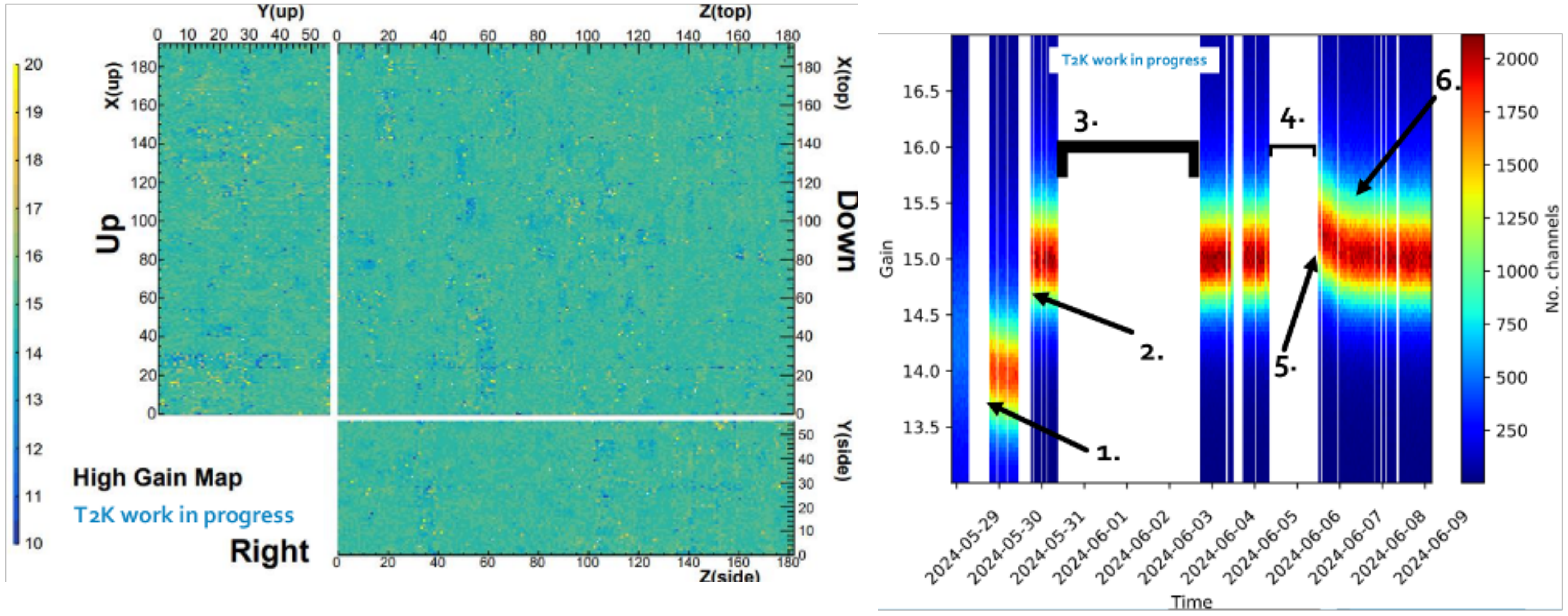
  => Full coverage of high dynamic range



Calibration of LG with LED injection

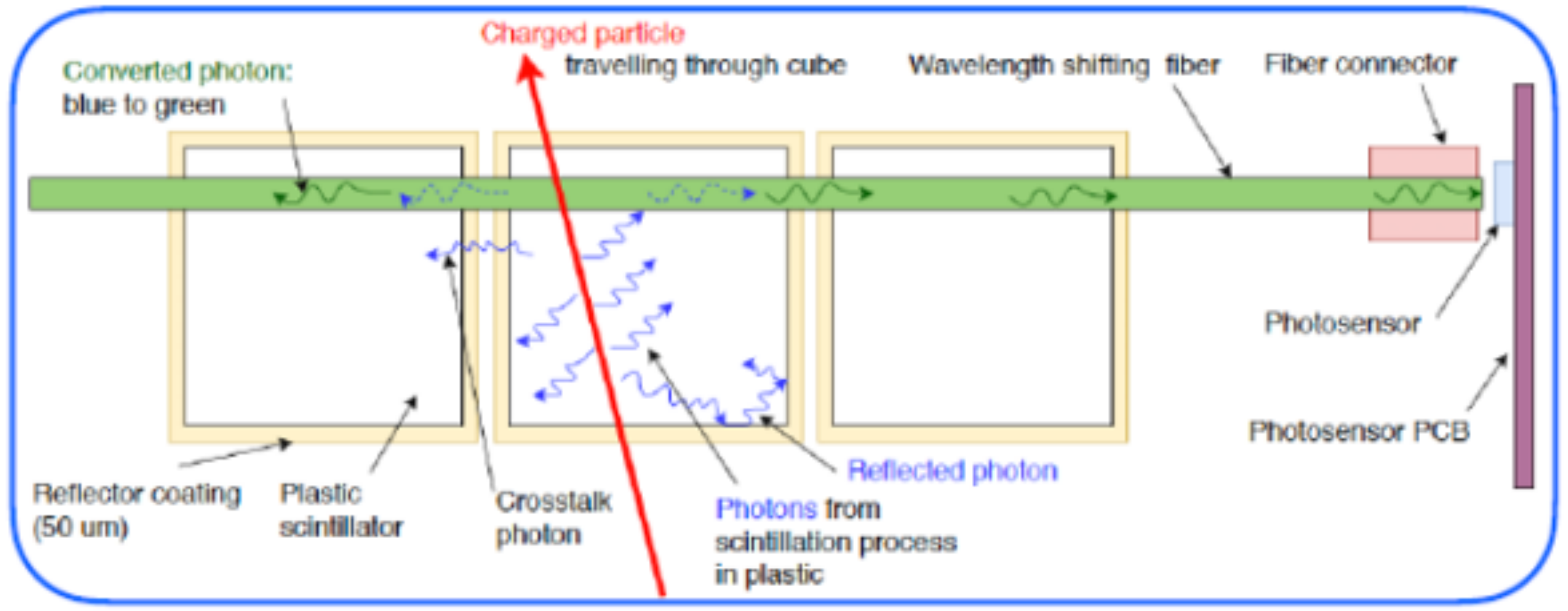


Calibration of HG with cosmic



From D. Sgalaberna's CERN seminar: here

SuperFGD



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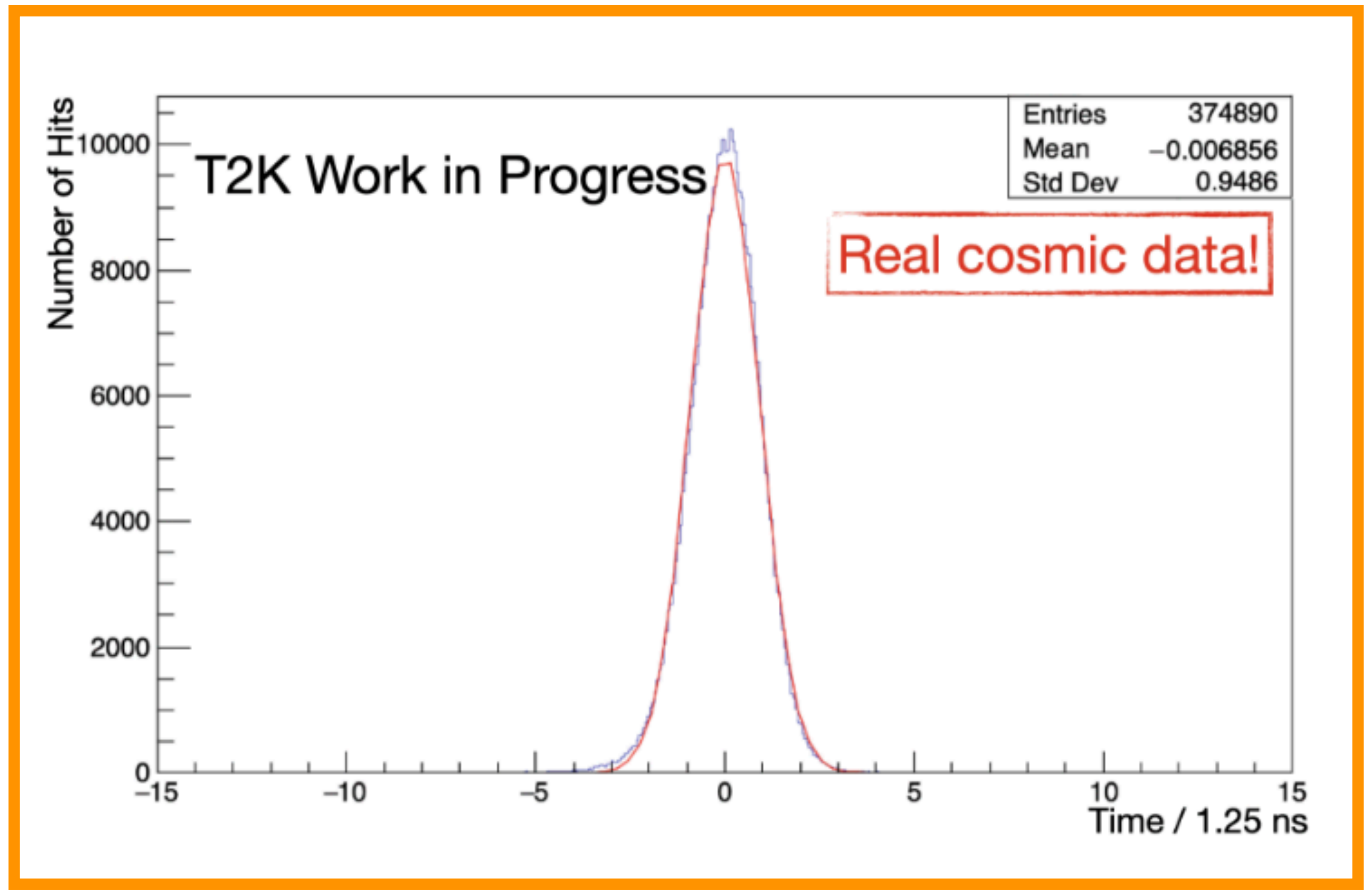
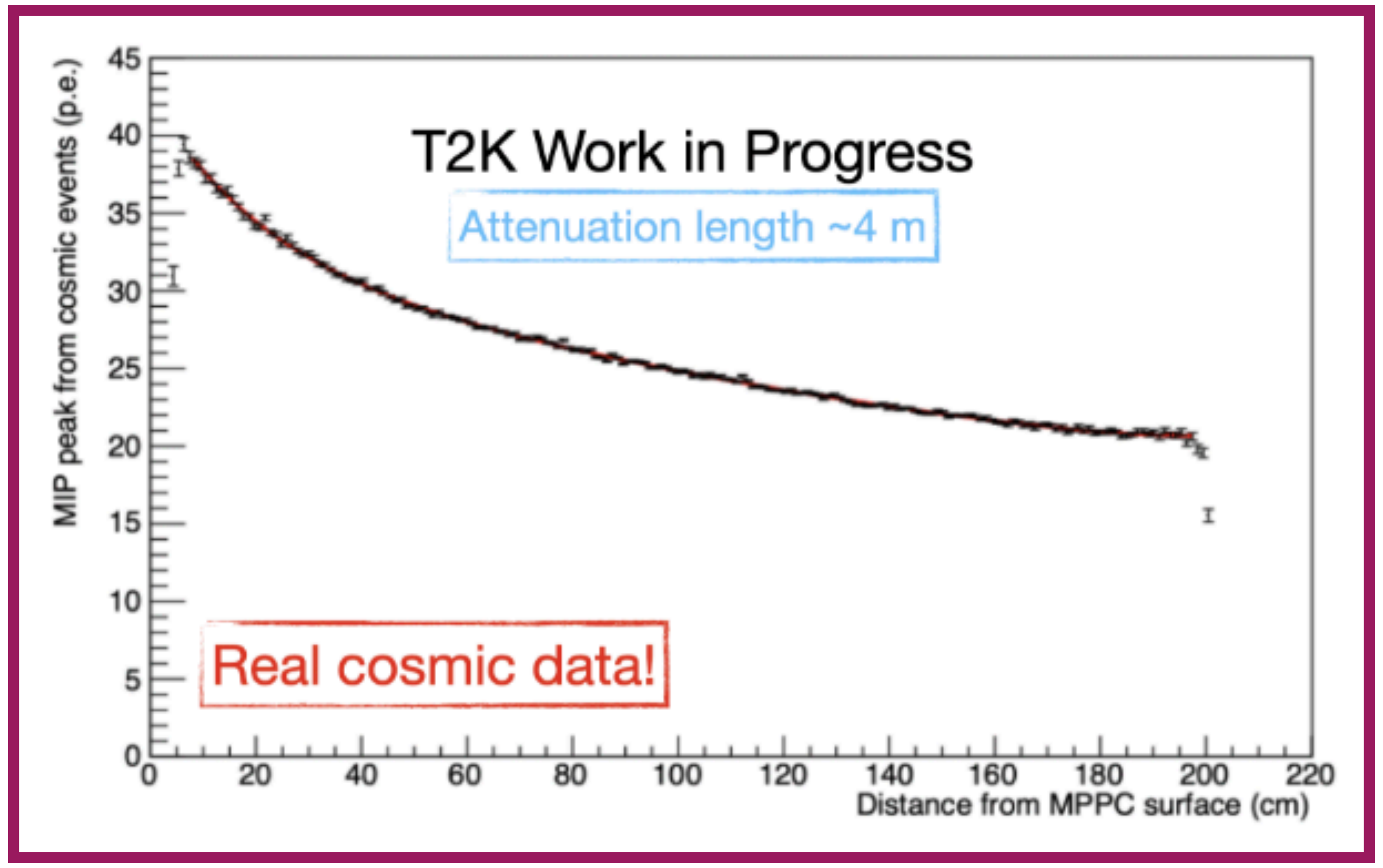
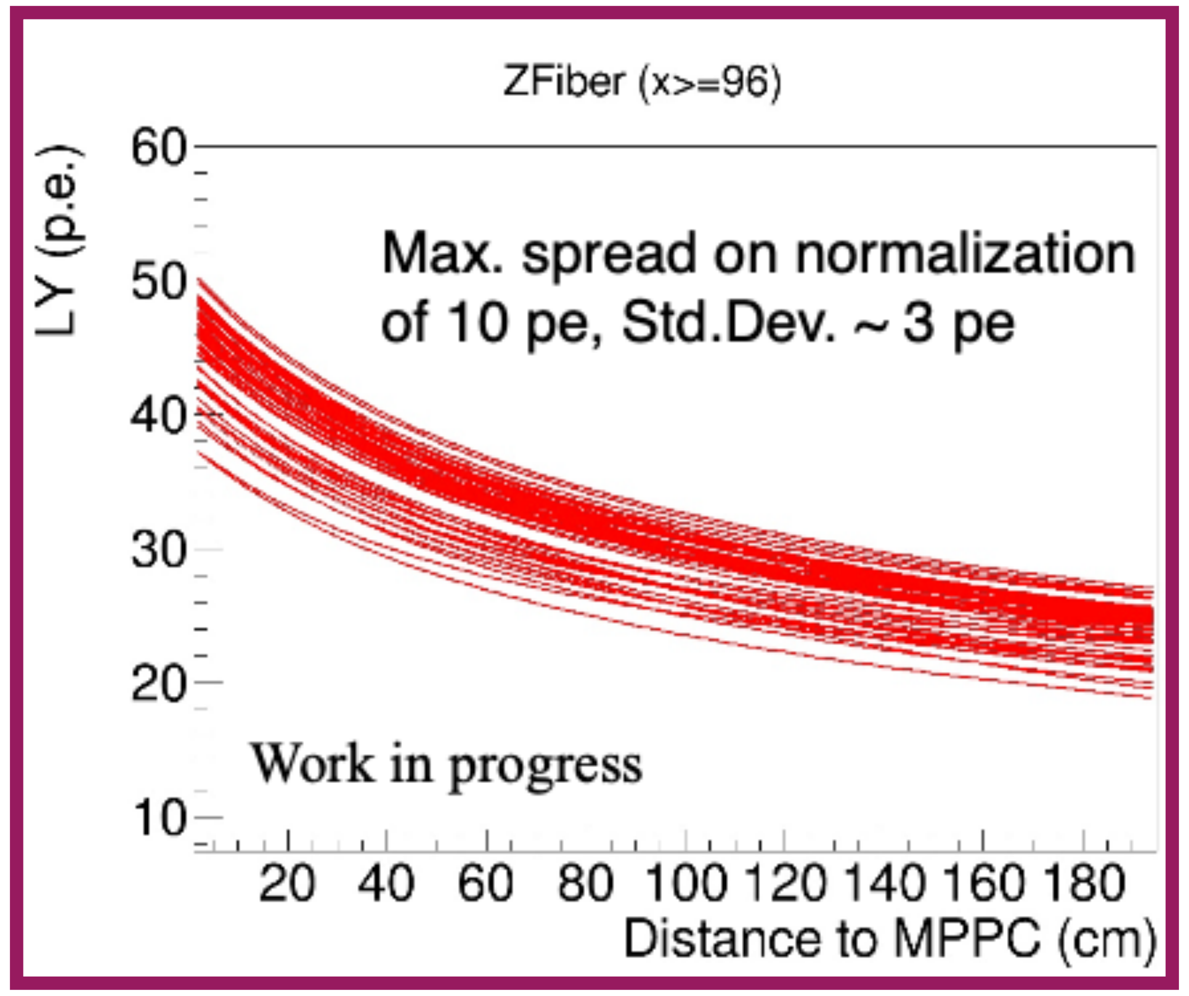
Performances

- **Time**: Time shift between (x,y,z) channels crossed by same tracks
  - **~1.2 ns time resolution** per channel

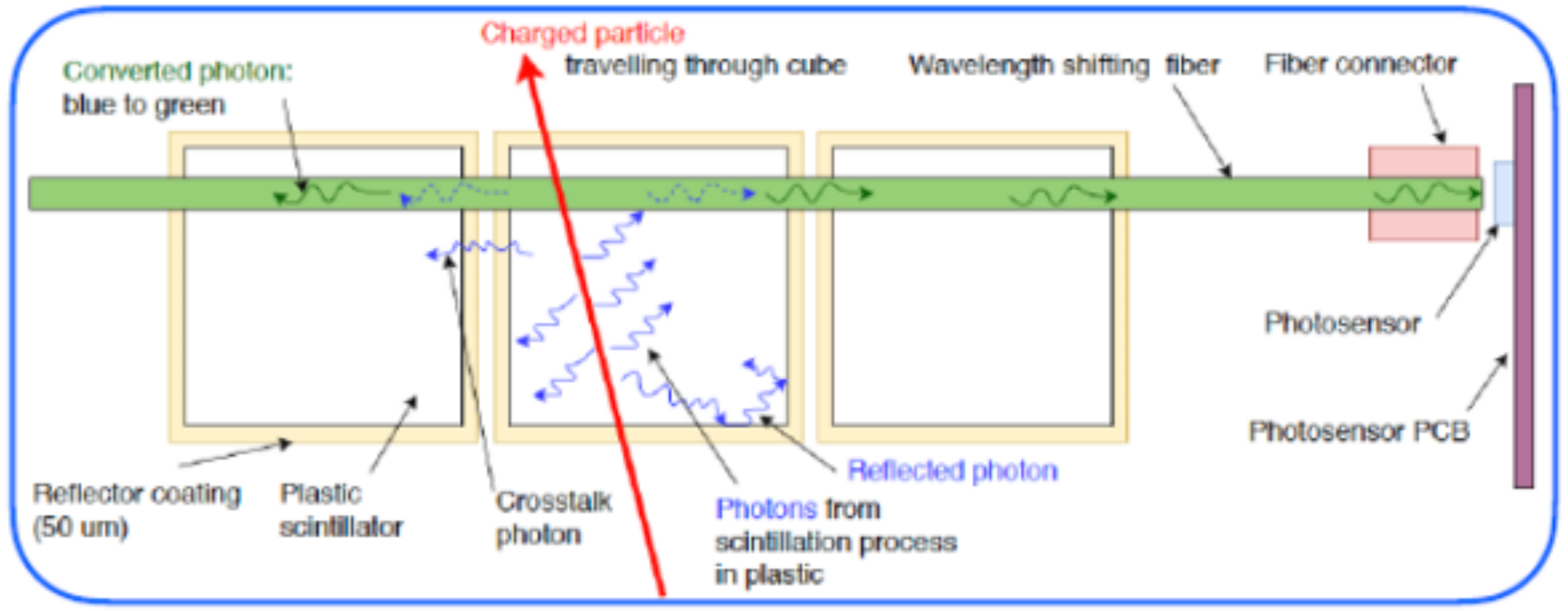
- **Light Yield**: Measurement of the ~55k attenuation length with cosmic
  - Consistent with expectations







SuperFGD



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T2K

Performances

- **Time**: Time shift between (x,y,z) channels crossed by same tracks
  - **~1.2 ns time resolution** per channel
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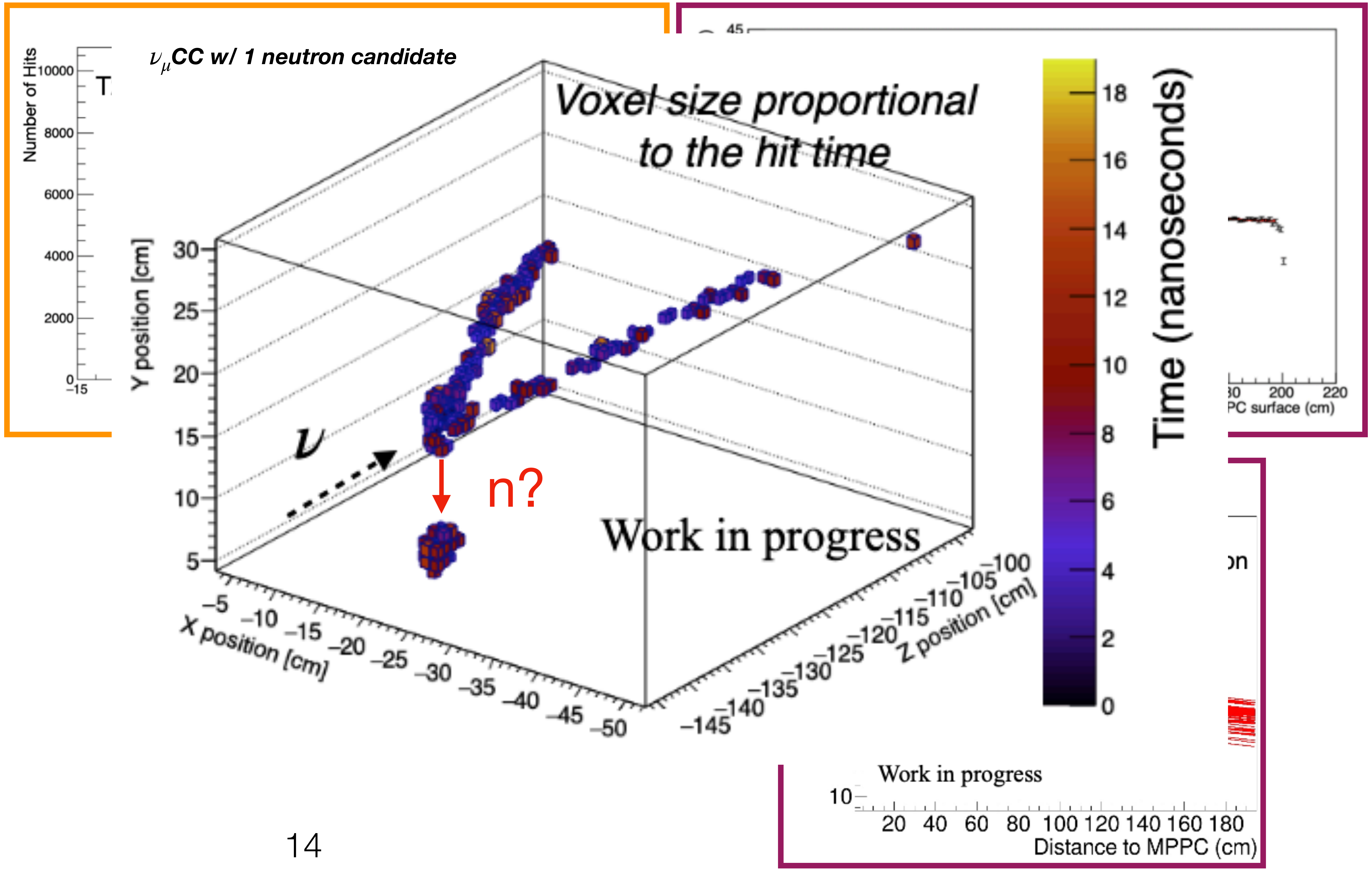
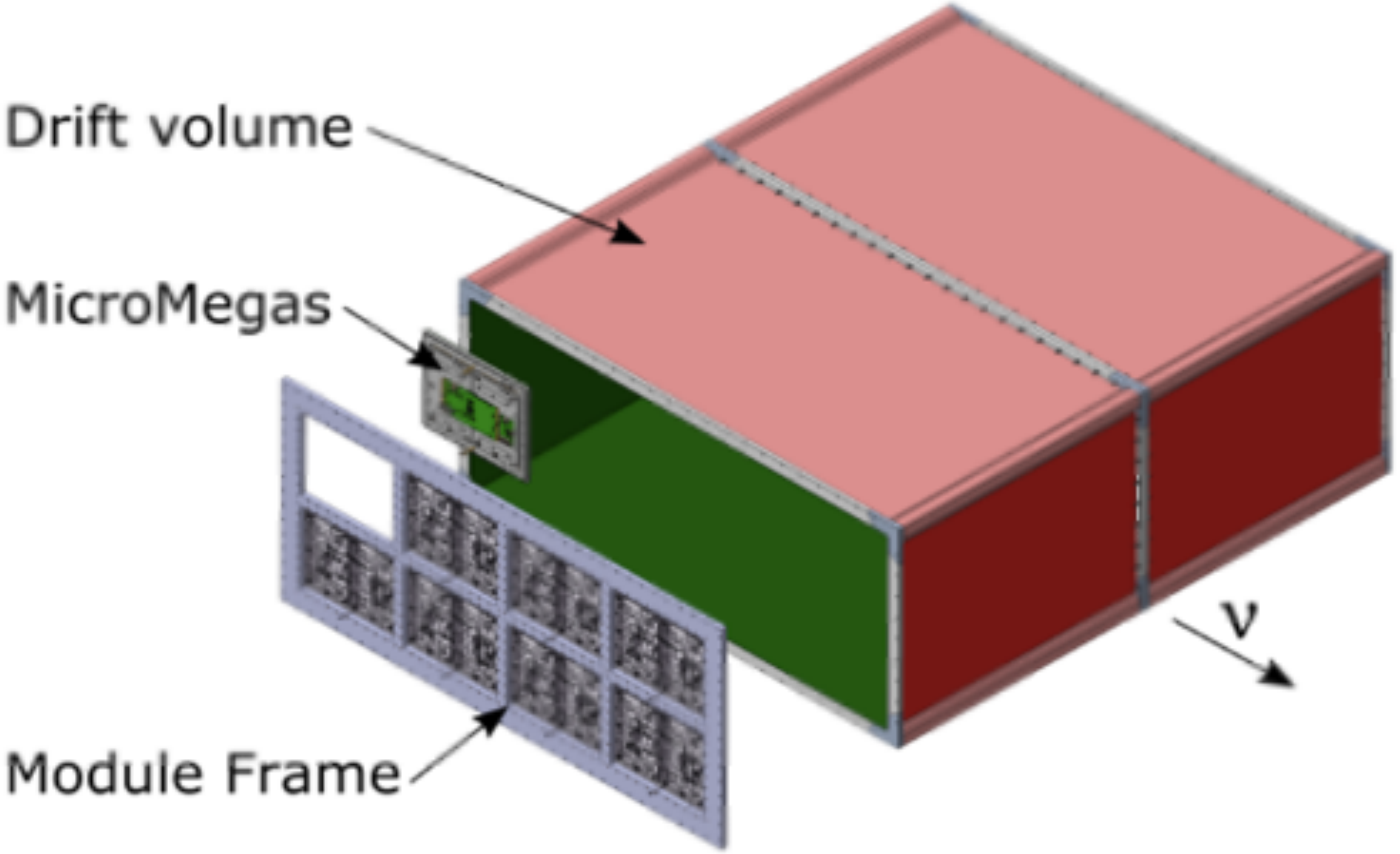
  - Consistent with expectations
- **Allow to see hadrons!**



HATPC concept

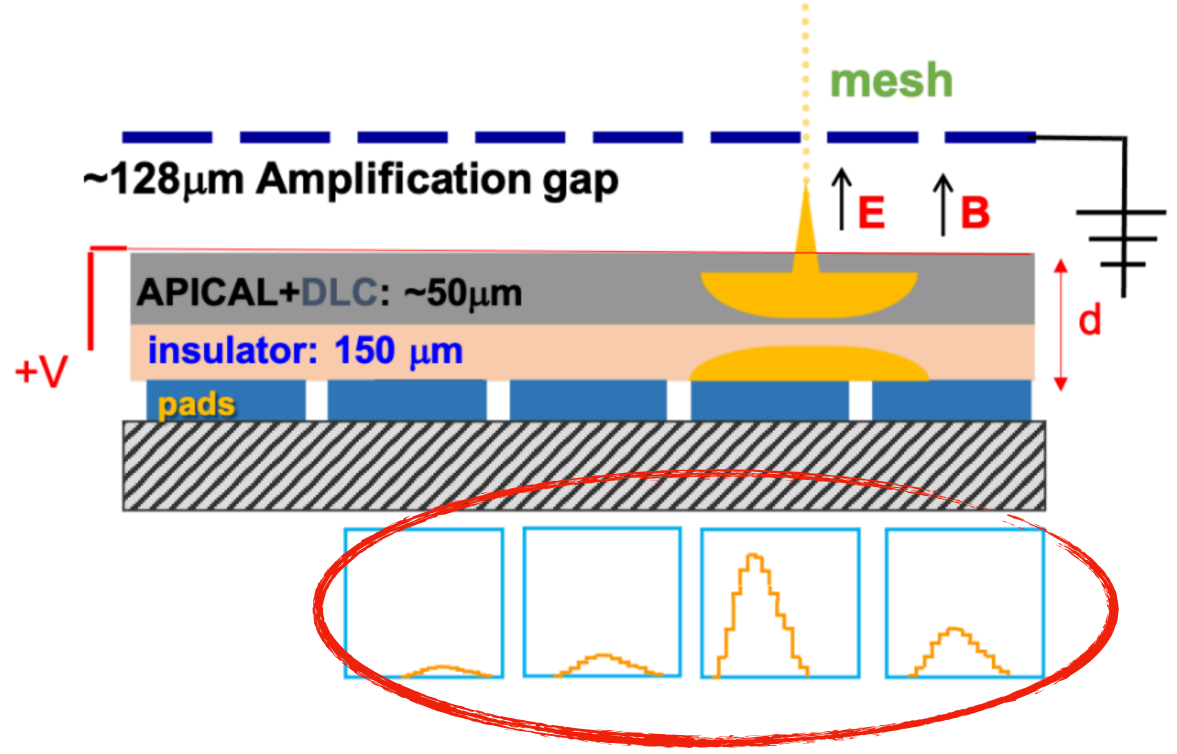


Atmospheric pressure TPC

- Gas: T2K mixture (95 Ar - 3 CF4 - 2 isoC4H10)
- New gas system -> contaminants better than 10ppm
- Drift length 1m
  - Central cathode @ 27kV
- Low material budget
  - Thin wall thanks to composite materials

Encapsulated Resistive Anode Micromegas (ERAM)

- Benefits from ILC TPC & RD51 (now DRD1)
- Bulk micromegas with a resistive layer (DLC) for **charge spreading**
  - Improves spatial resolution for same pads density
  - Reduce sparks rate -> Electronic protection
- Mesh at ground -> Improves E field homogeneity



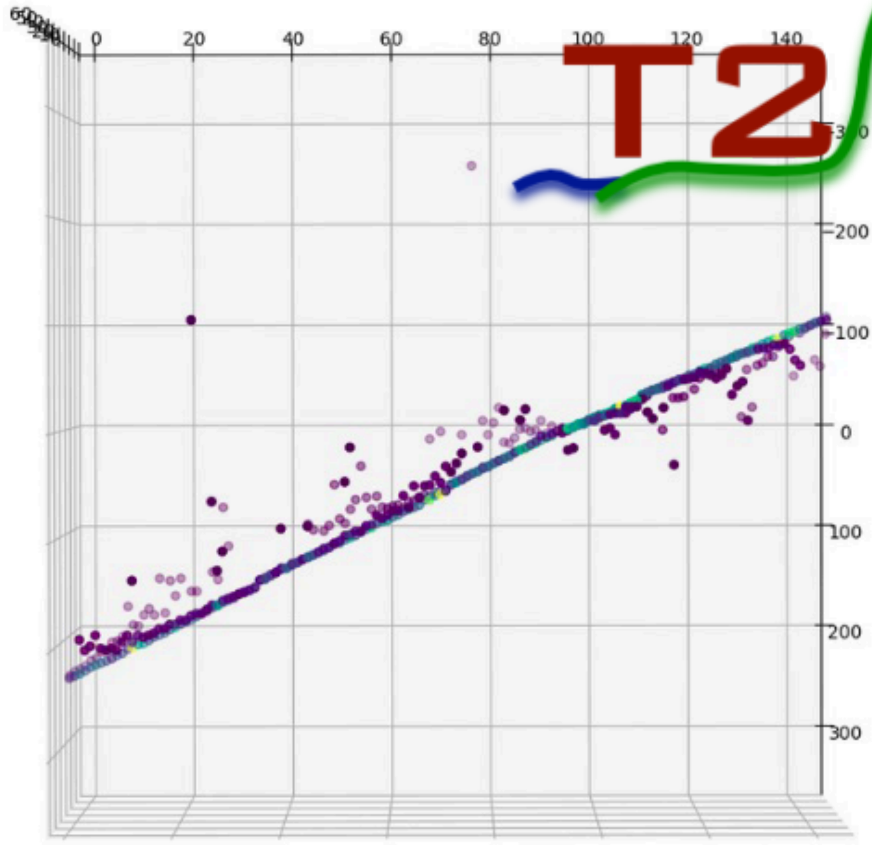
From S. Levorato CERN Seminar: here

HATPC installation

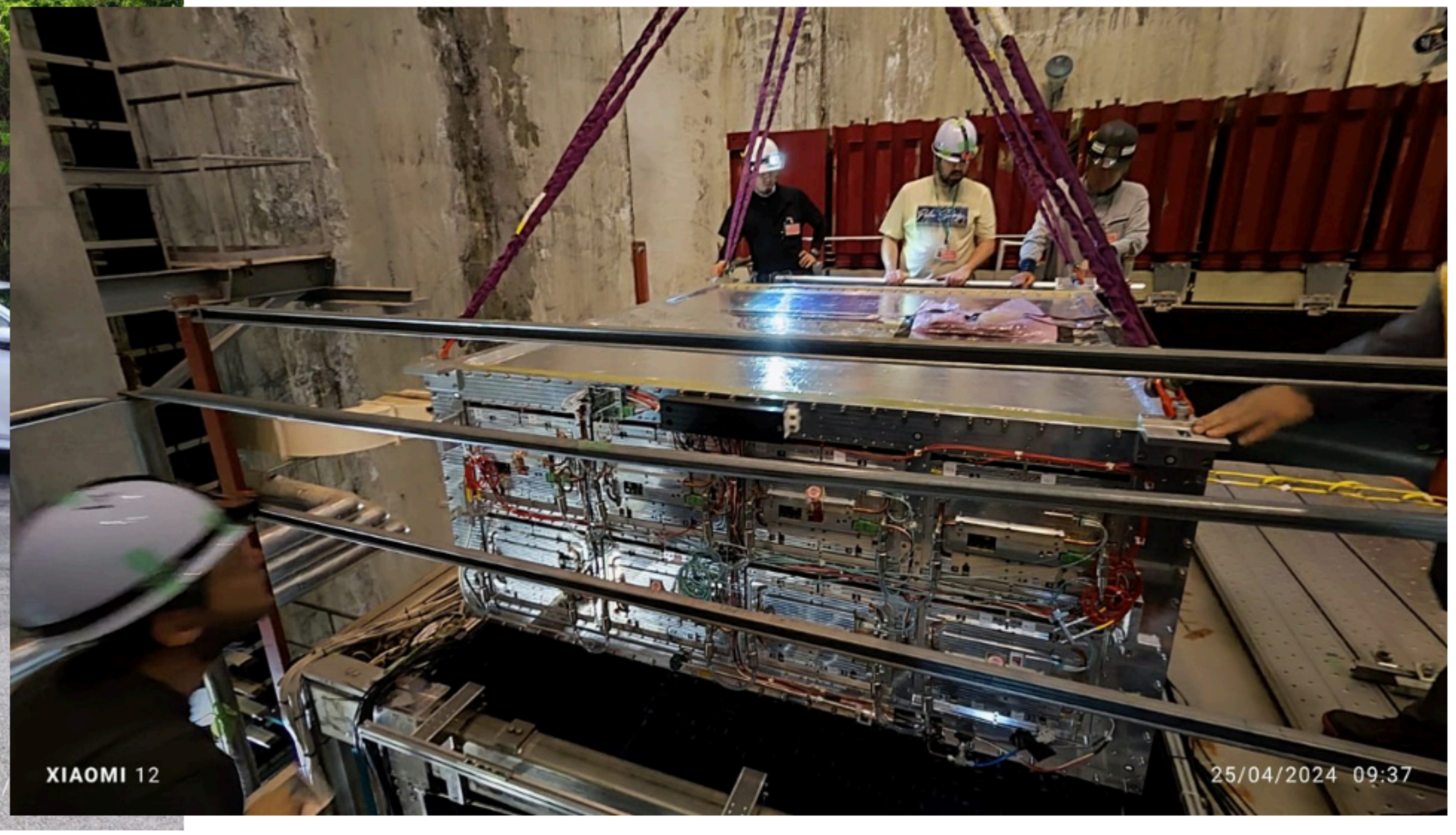
25th August: Delivery at JPARC

6-7th September: Installation

6-7th September: Installation



11th October: First cosmic track



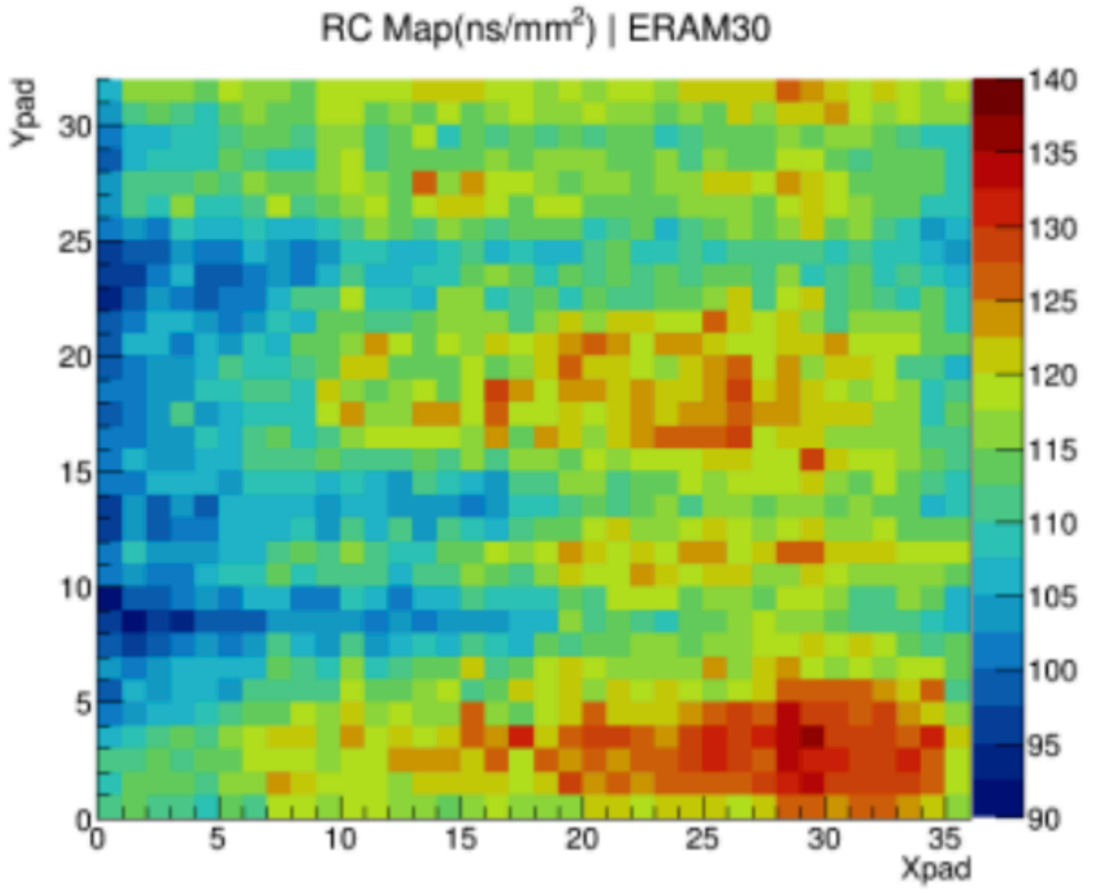
Important presence of Jennifer groups

25th April: Installation of tHATPC after top TOF removal

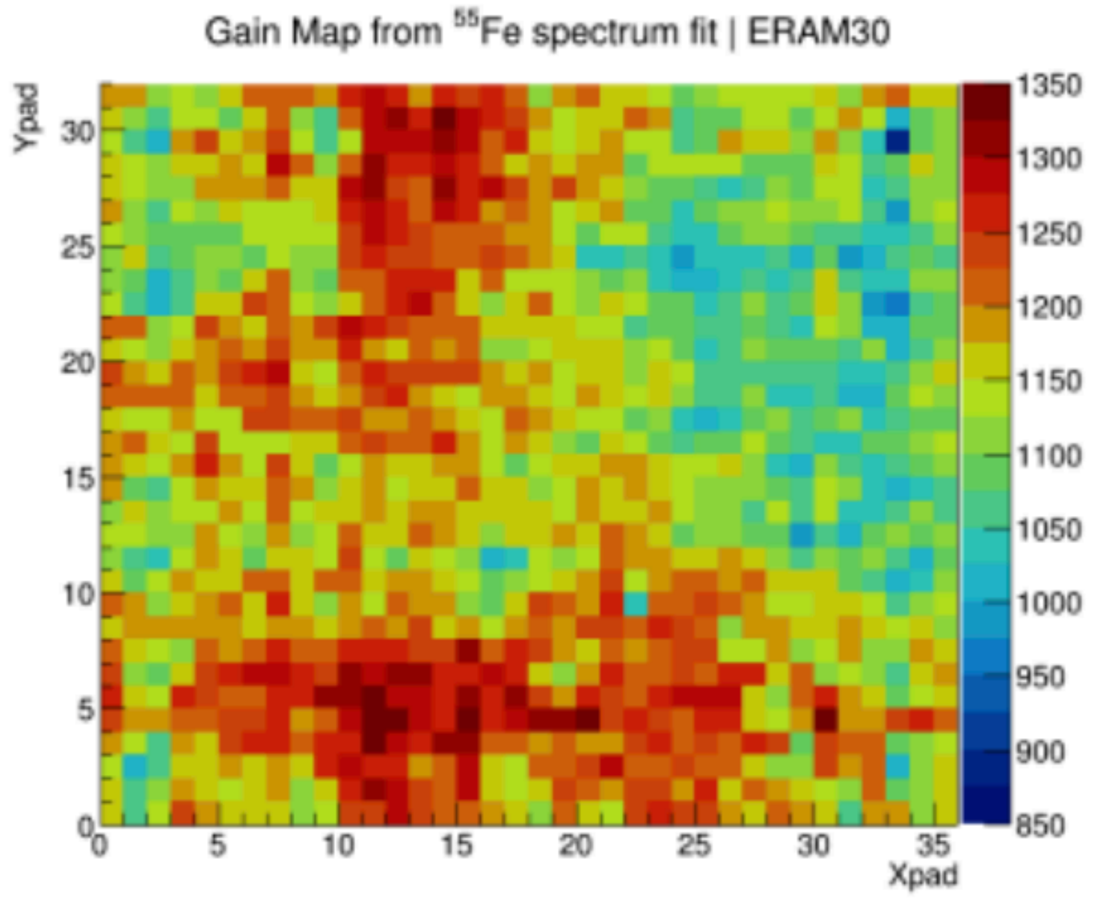
HATPC characterisation

Extensive characterization @ CERN

- Each modules was characterized using a 55-Fe source to extract:
  - Gain, RC => Used as input of reconstruction to homogenized detector response



RC map of ERAM30

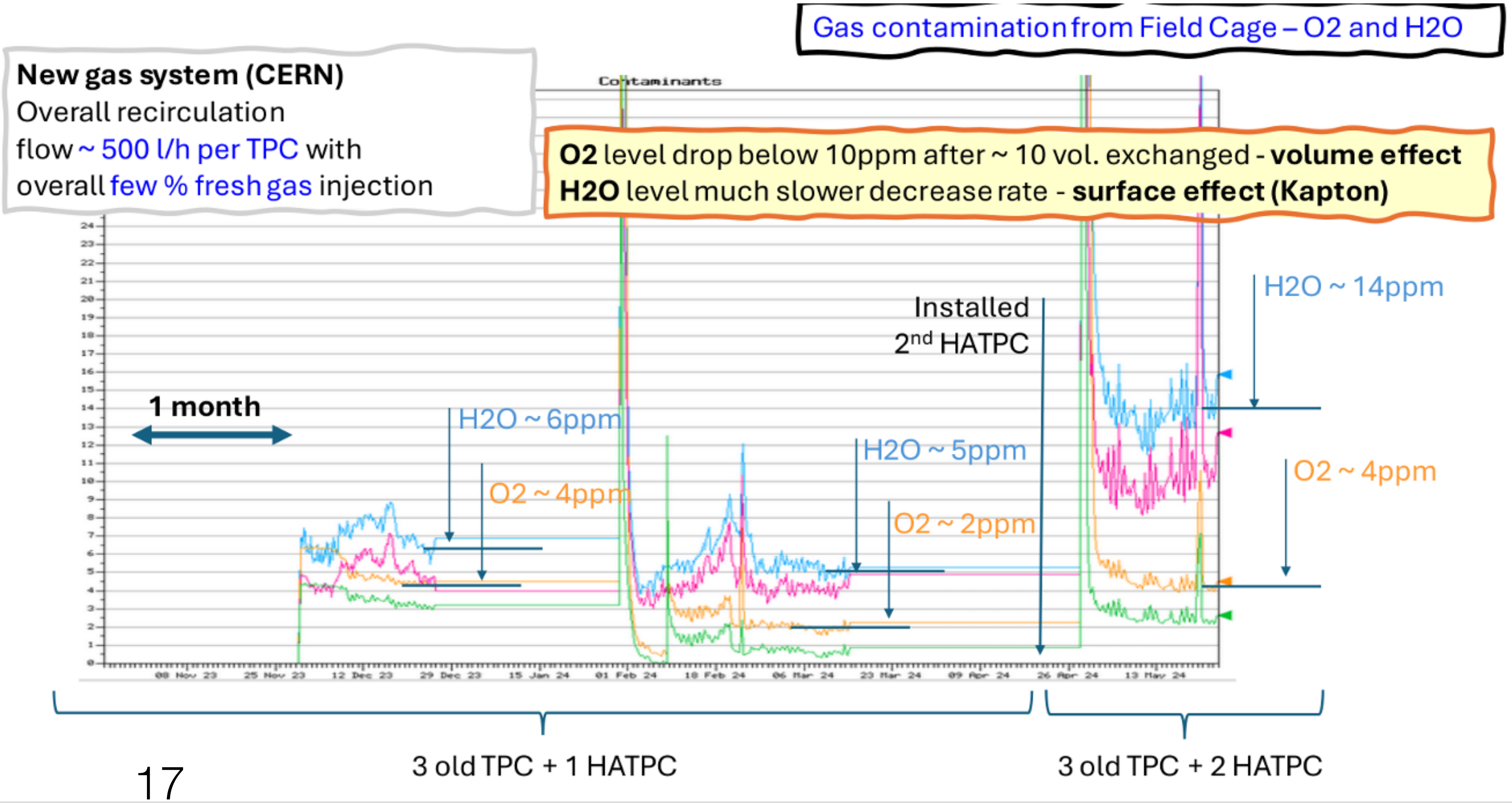


Gain map of ERAM30

Gas system monitoring

- New gas system has been installed @ JPARC
  - Connections to chambers few days after installation, thanks to constant on-site supports from Jennifer groups

- **Reach ~ 10ppm level of contaminants**, constantly monitored to precisely correct detector response time evolution



HATPC performances

Performances on-site

- Using sand muons from beam to study detector response
- Reach expected performances:
  - **Spatial resolution ~ 600um**
  - **Energy resolution < 10% for dE/dx**

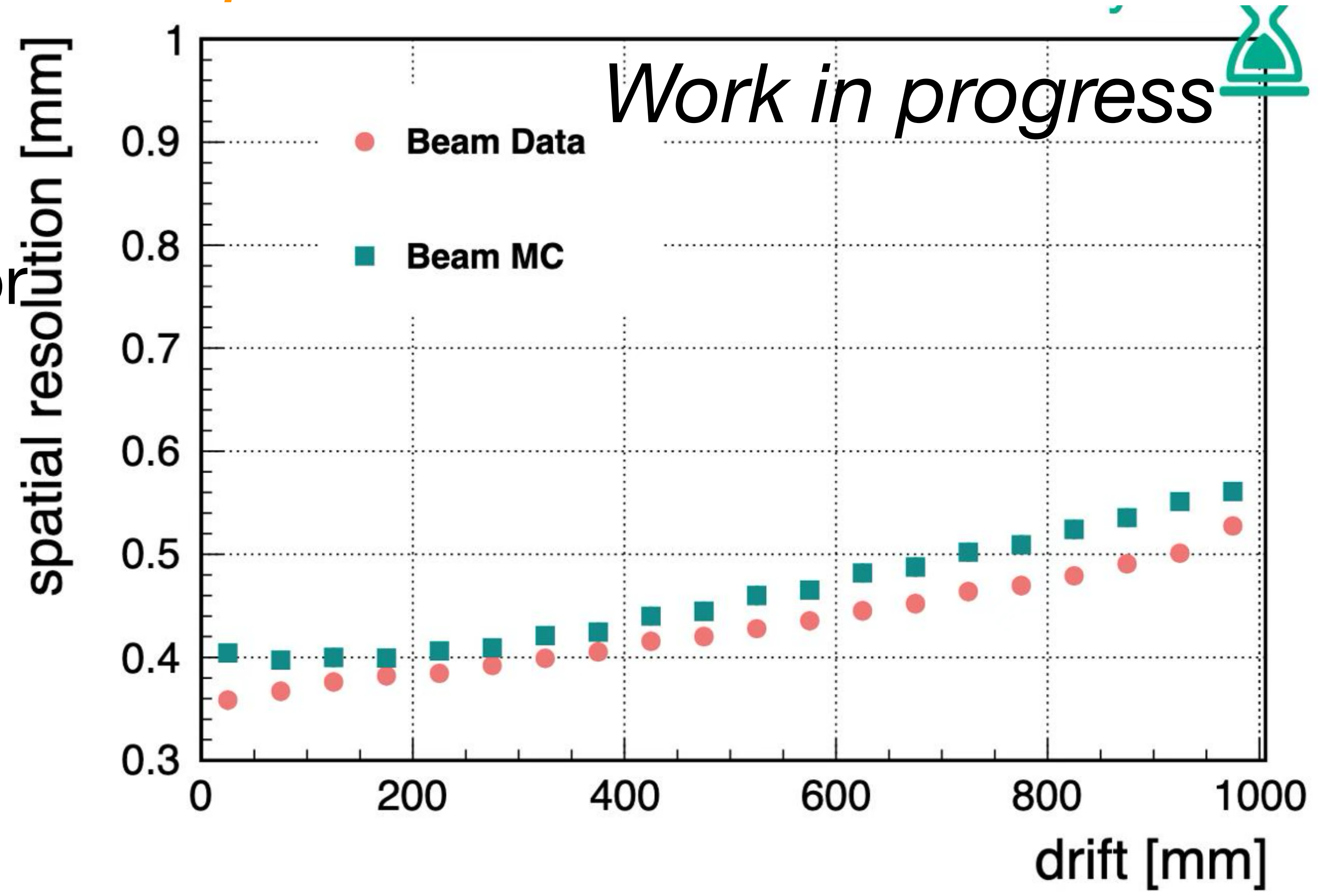
E field distortion

- Discovered distortion near cathode
- HAT geometry fully implemented to COMSOL
  - Already implemented in reconstruction and simulation

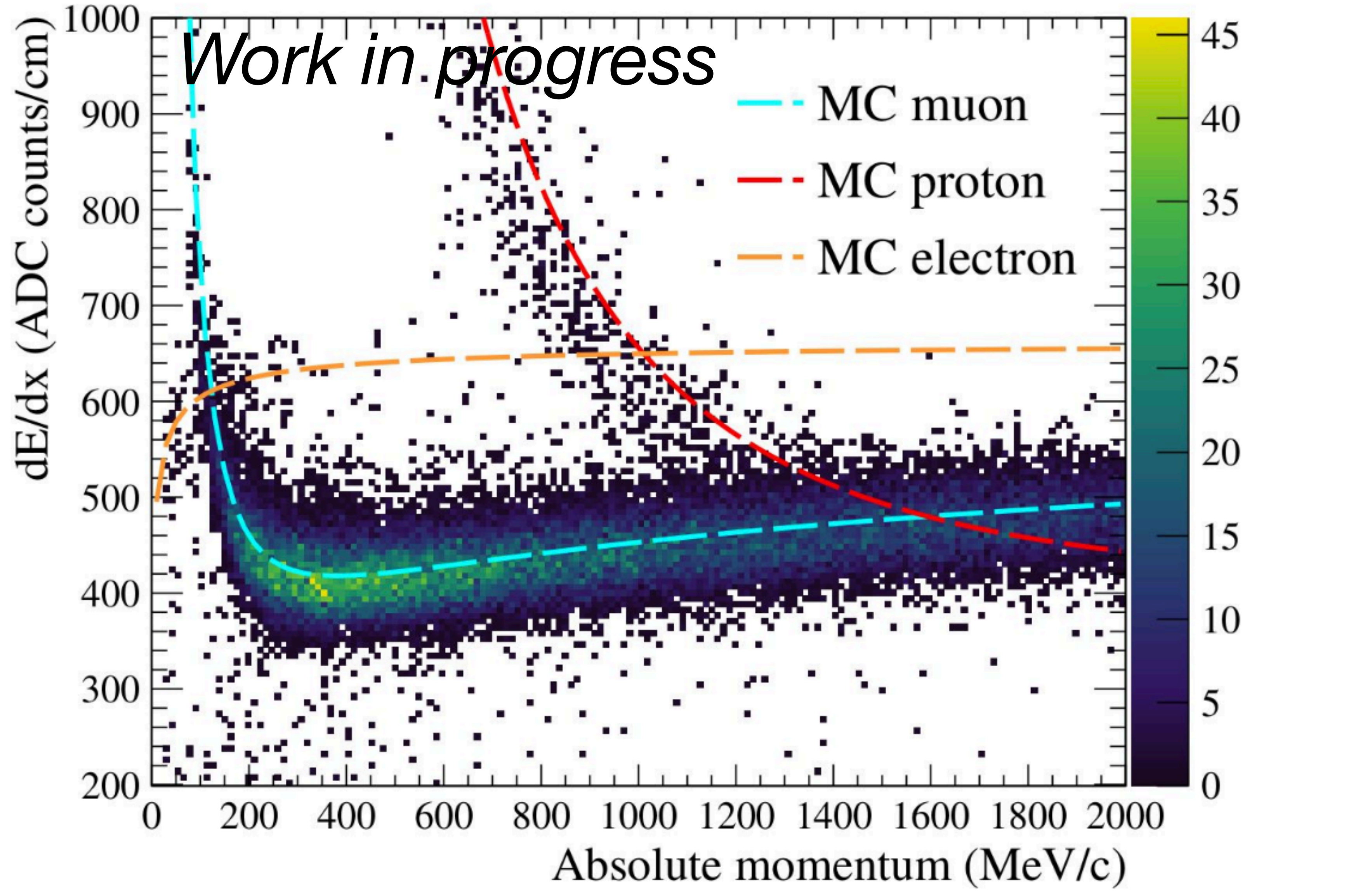
Improvements

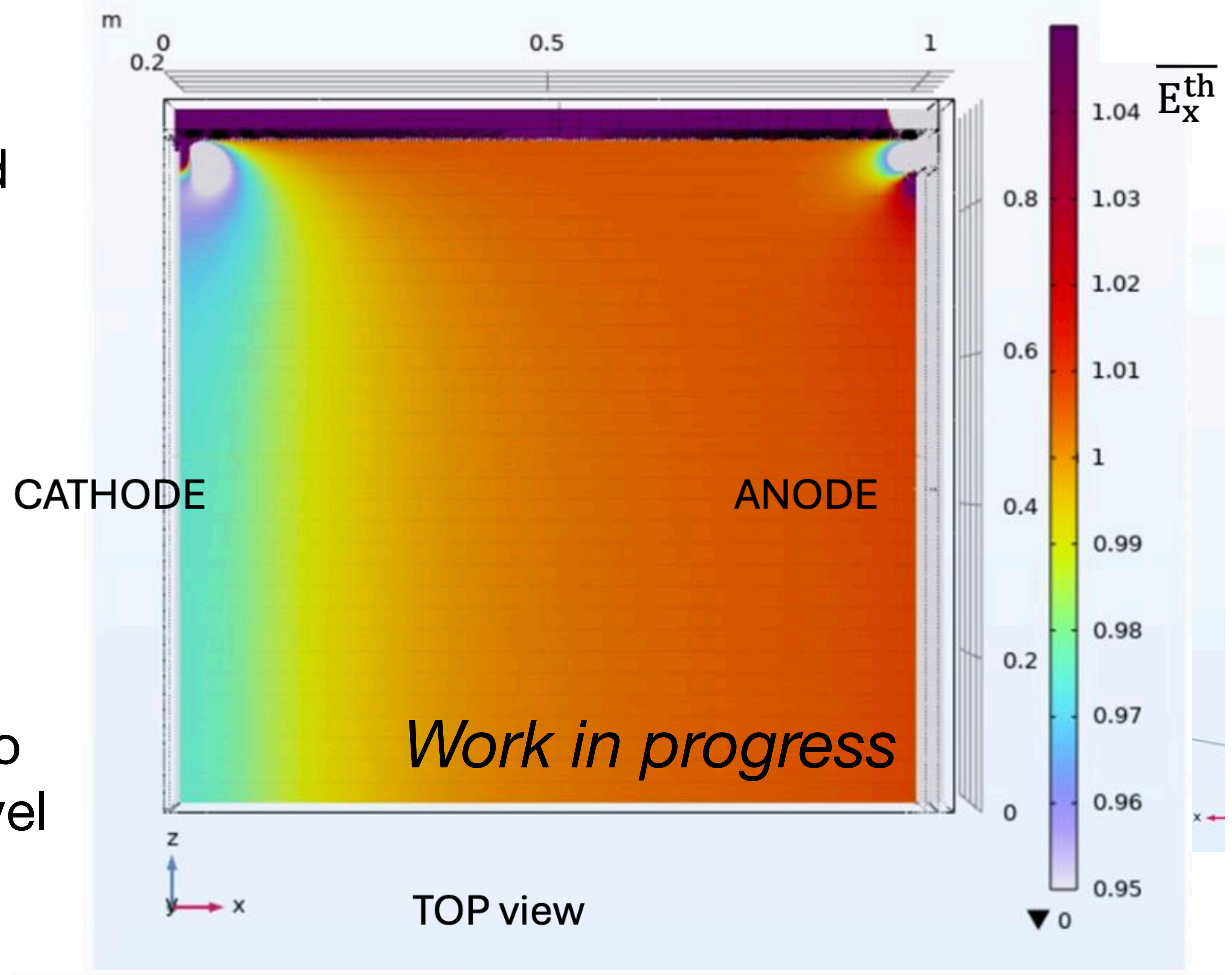
- Currently using cluster based track reconstruction
  - Get full advantage of spreading by doing a global fit
- Noise has been studied and a model derived to get better data/MC agreement @ waveform level

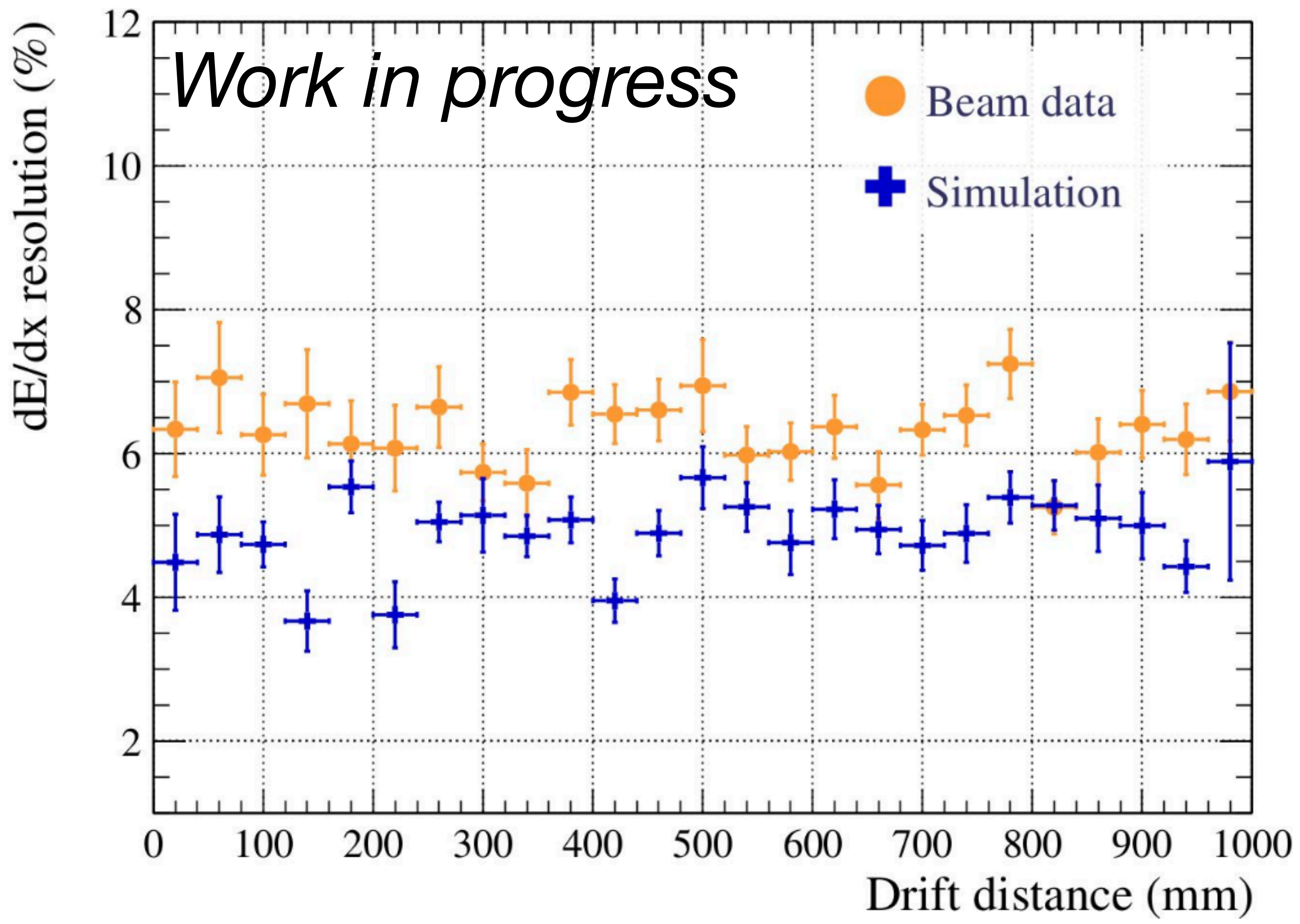
Spatial resolution data/MC



dE/dx resolution







TOF concept and installation

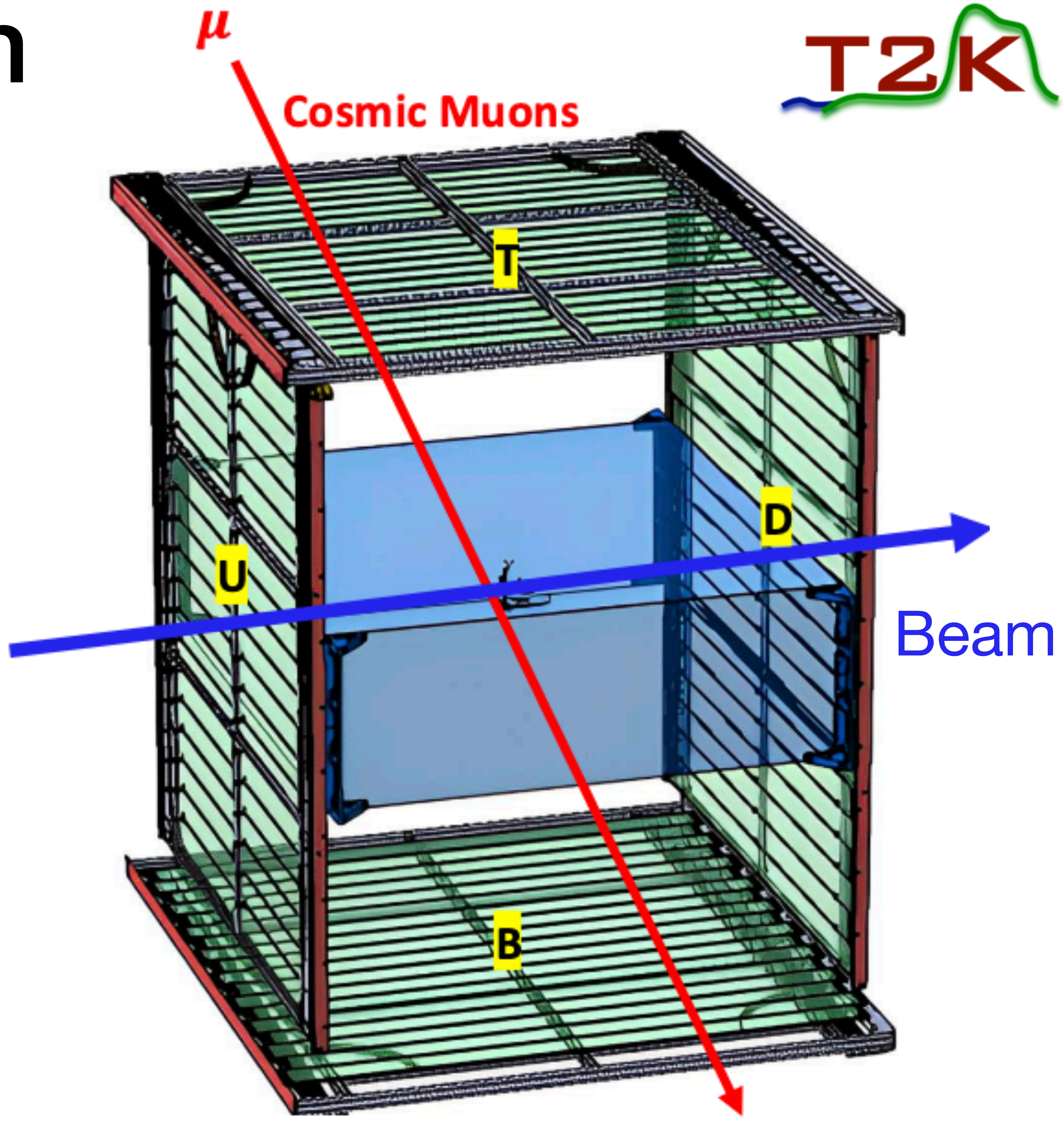
TOF modules

- Composed of 20 plastic scintillator bars arranged in a plane with a total active area of 5.4 m^2
- Readout on both ends by SiPM arrays

TOF goals

- PID using time-of-light
- Tags background from out-of-fiducial volume
- Provide T0 to HATPCs
- Improve SFGD neutron time-of-light measurement
- Beam and SAND muons monitoring

In addition has provided cosmic triggers to upgrade detectors

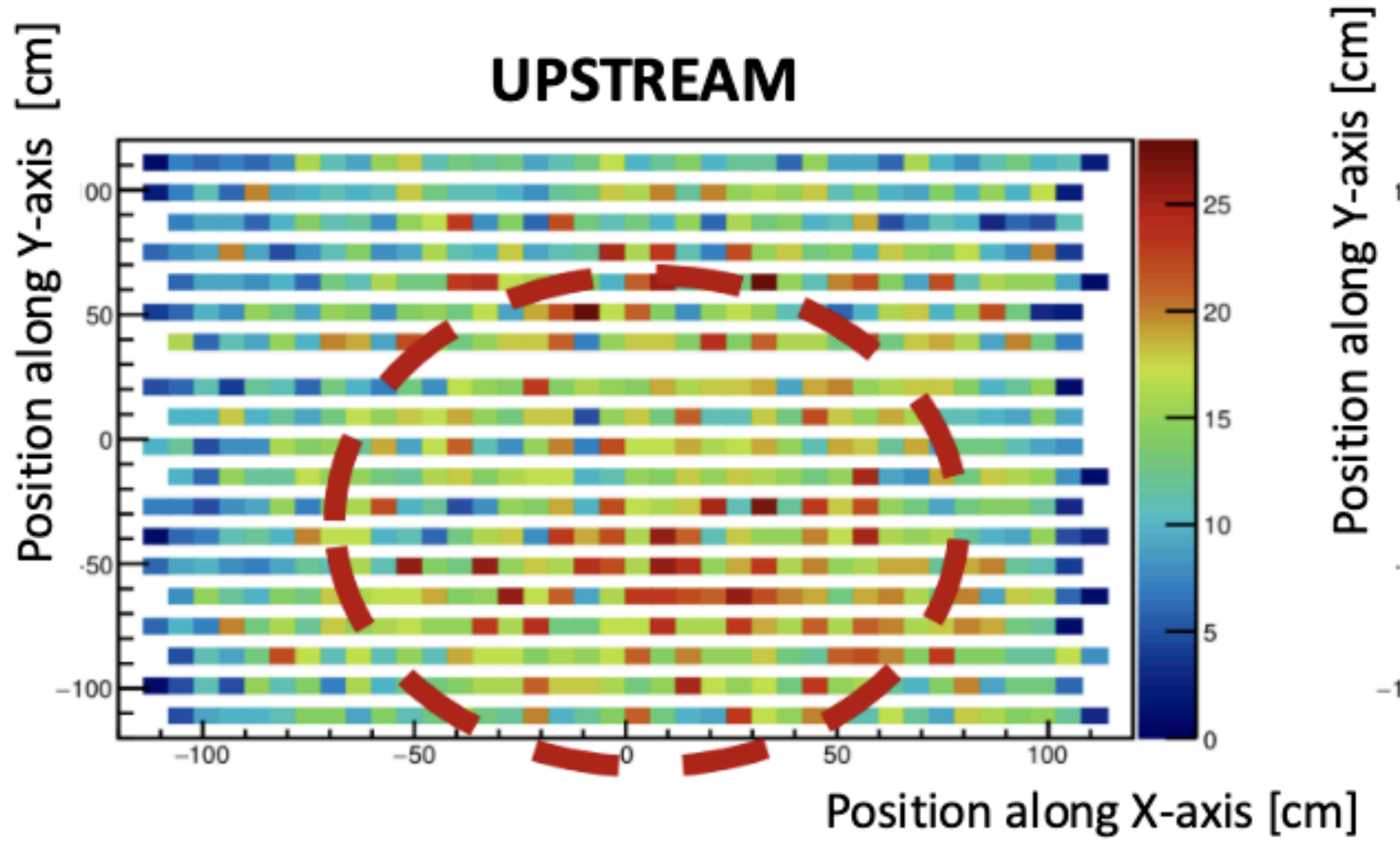


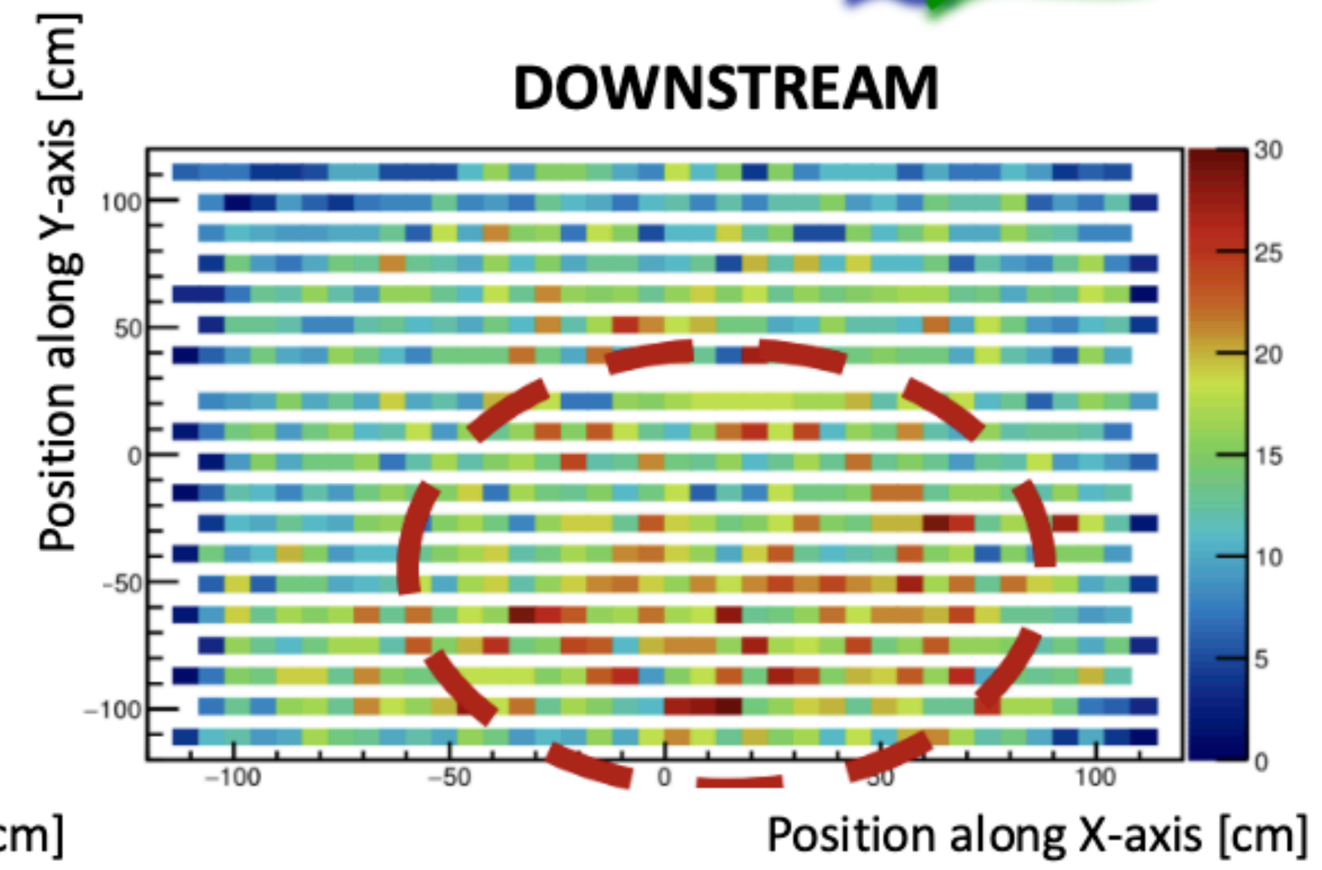
Plus 2 hidden side panels for a 4pi coverage of detectors

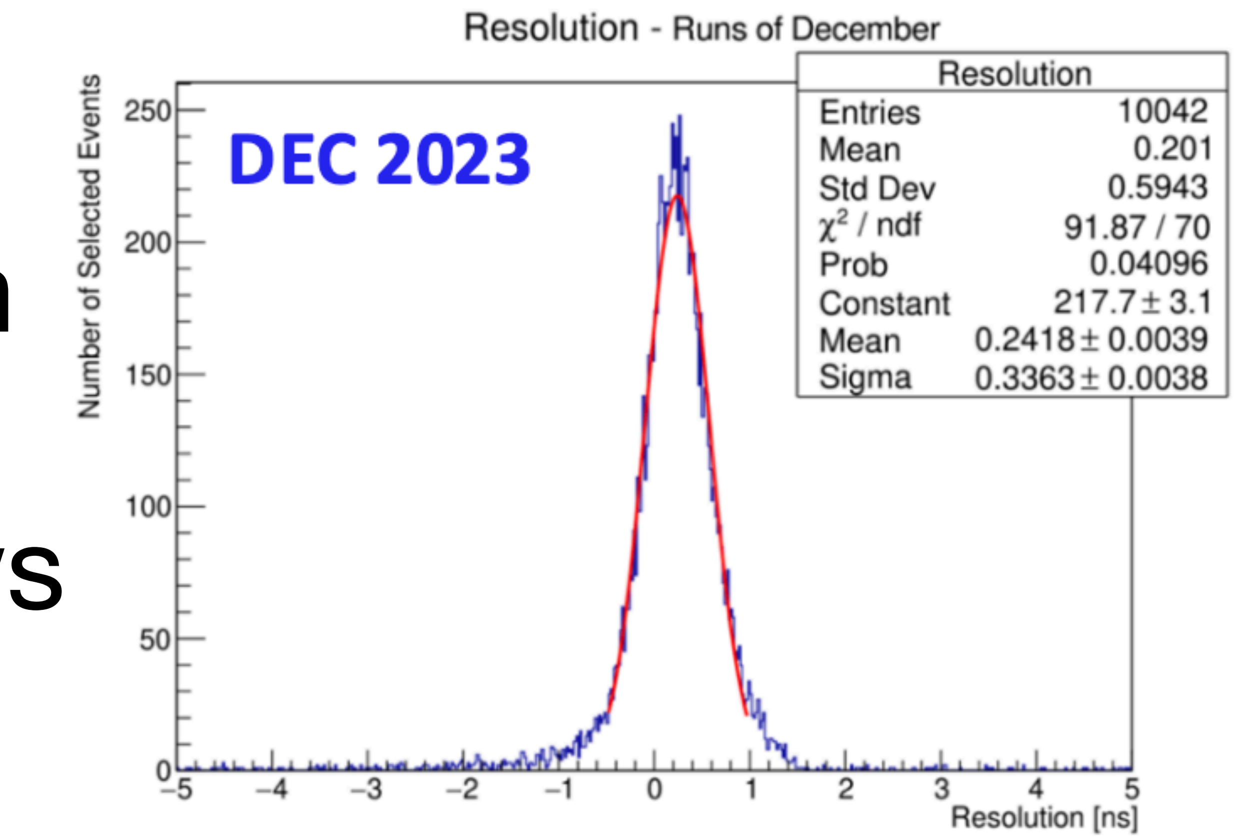
TOF performances

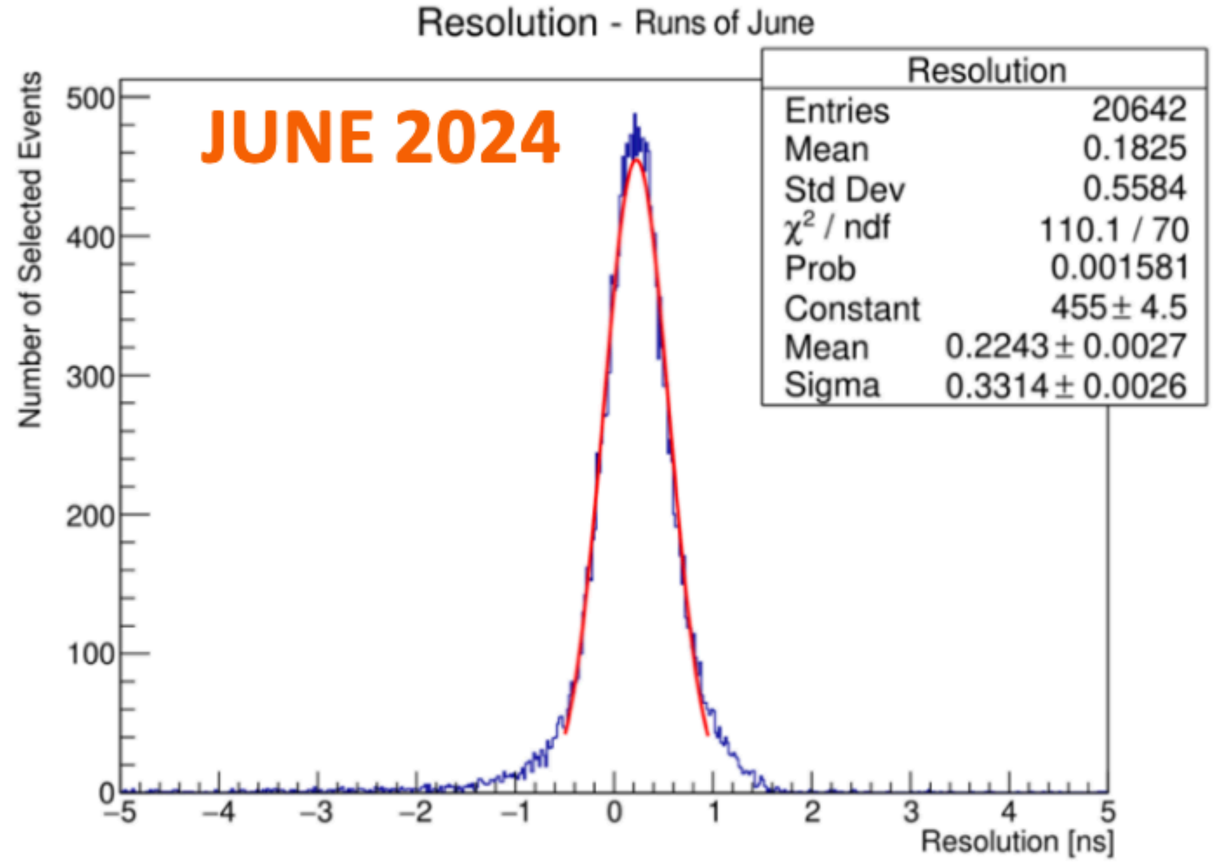
SAND muons selection

- Provide an ideal sand muons selection
- Well observed beam position
- Computed time resolution between upstream-downstream panels
  - **Reach a resolution of 330ps**



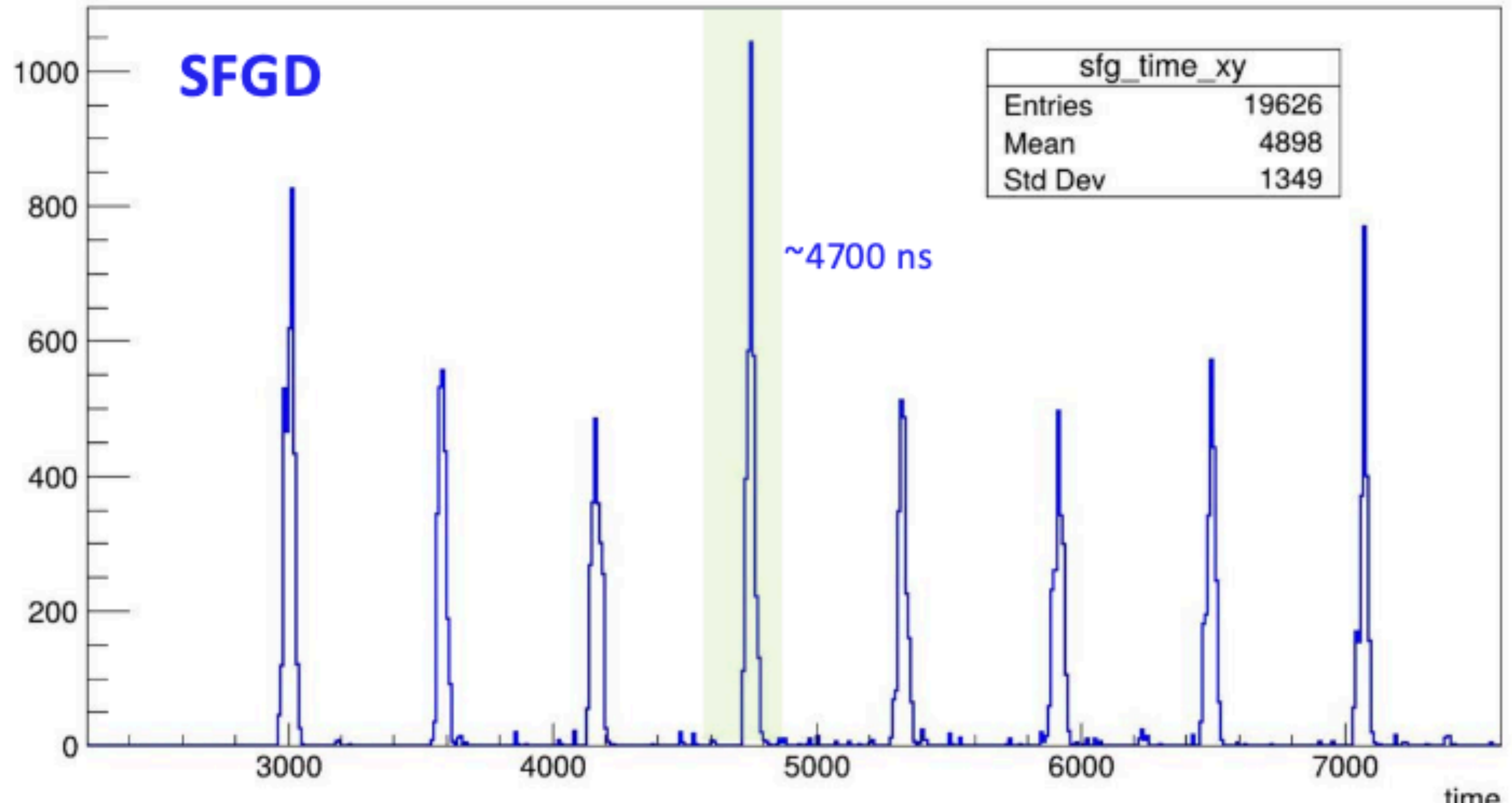


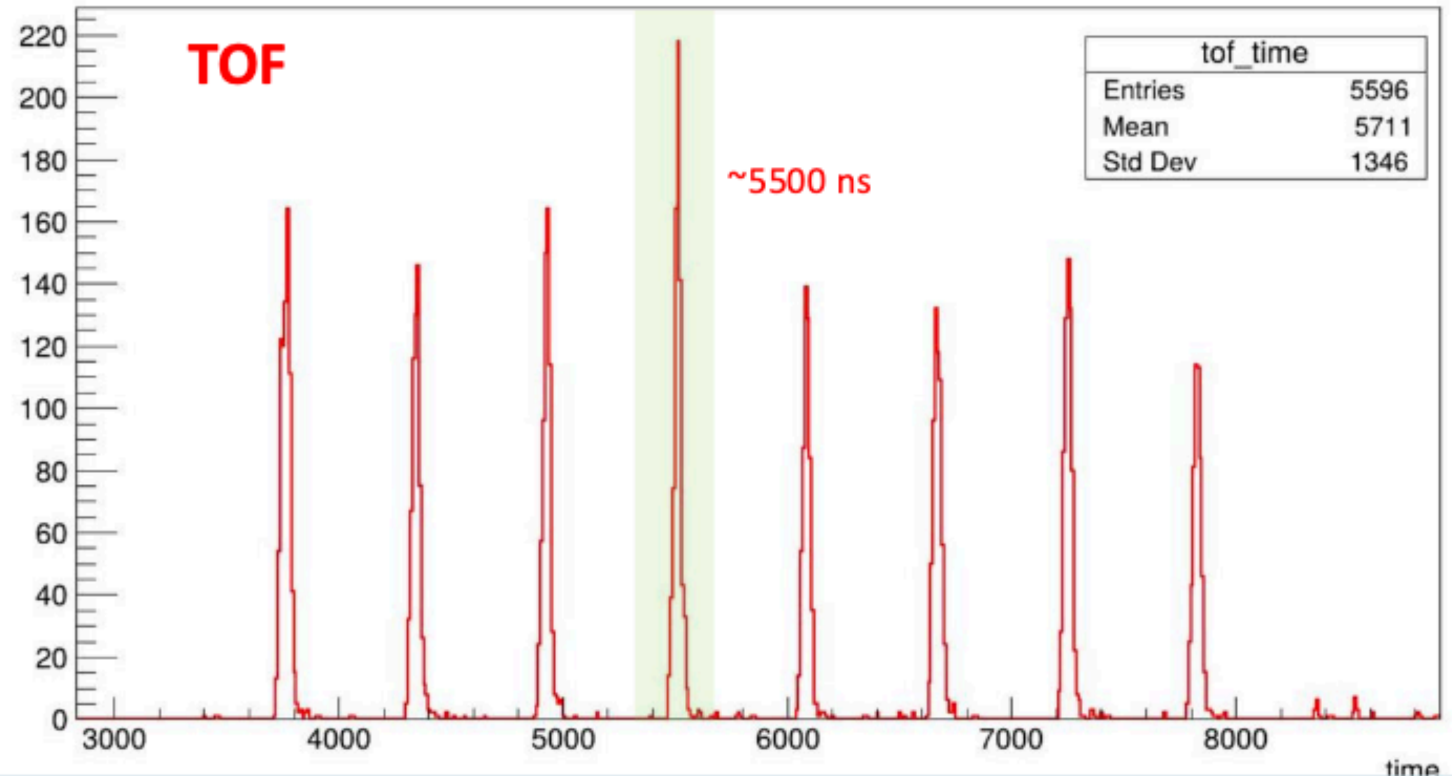




Beam time profile

- Provide time alignement X-check between sub-detectors
- Comparison with for example SFGD shows time offset





Towards global reconstruction

How to combine informations?

- Each sub detectors provides hits or tracks to global reconstruction
- Inter-detector tracking is made to create objects crossing several sub detectors
- Propagate, combine and merge local information to form global tracks

Systematic strategy

- Systematics will be studied at two levels:
  - Low-level: by detector groups,
  - High-level: by analyzers
- Presence of people involved in detector developments in each analysis groups for better communication

Conclusion

Upgrade installed

- The ND280 upgrade was completed in May, 2024 and ready for the June beam
- Upgrade detectors are very stable and detector developments runs are taken during beam off period
  - **Crucial support from Jennifer-2 project to have experts on-site!**

Detector calibration and performances

- Jennifer-2 groups were highly involved in the characterization of detector responses
- First performances were extracted and tools were developed for monitoring performance during data acquisition
  - Issues are investigating
- “Detector paper” are ongoing

Toward high-level analysis

- Also efforts have been put to include upgraded detector into high-level analysis software
  - Double cross-check detector performances and evaluation of systematics
  - Constant discussion between analysis and detector groups
- Prepare inputs for oscillation and cross-section measurements (See Andrea’s talk!)

Going further

- More sophisticated tools under developments
  - Use of CNN at different stages of the reconstruction (SFGD, HAT, global for example)
- **This works is key for HK era to better understand systematics (beam upgrade, HK..)**

A lot of interesting results to come!

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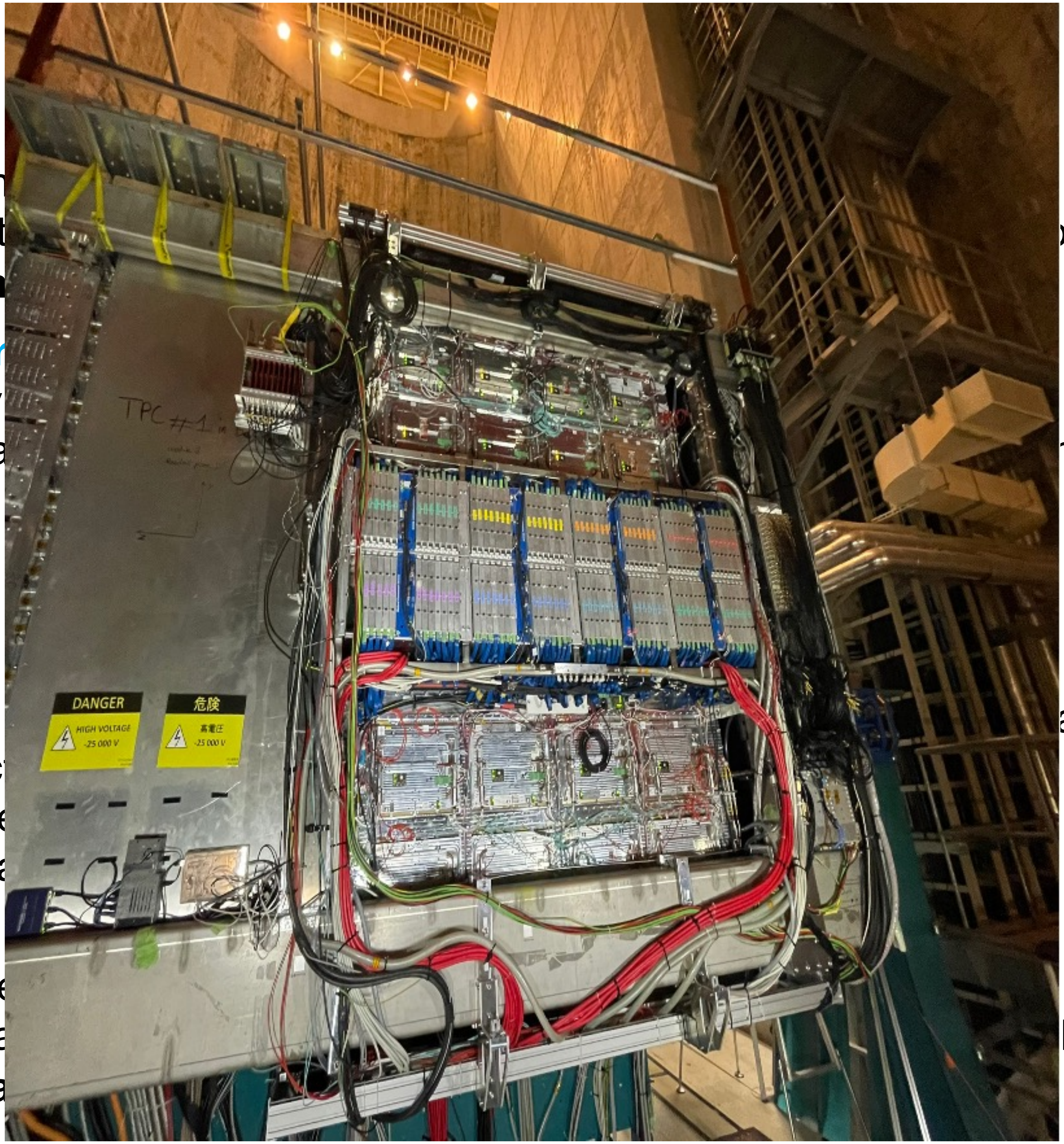

Thank you!