

ND280 upgrade towards ND280++

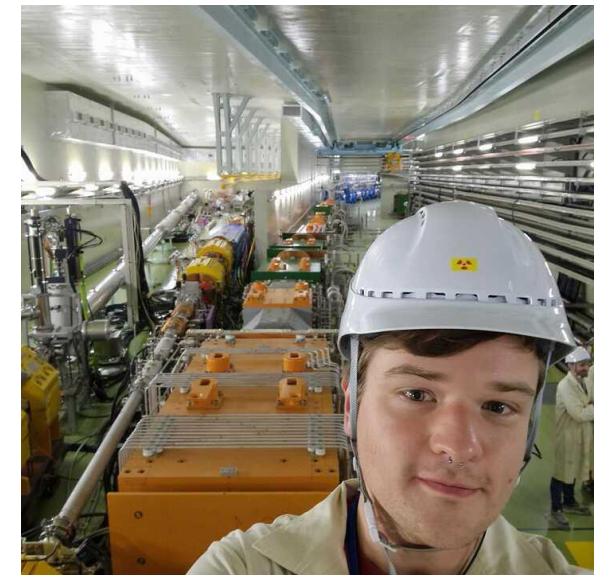
Ewan Miller

IFAE

30/09/2024



Institut de Física
d'Altes Energies



- Present Day

ND280 in T2K Oscillation analysis

- Near Future

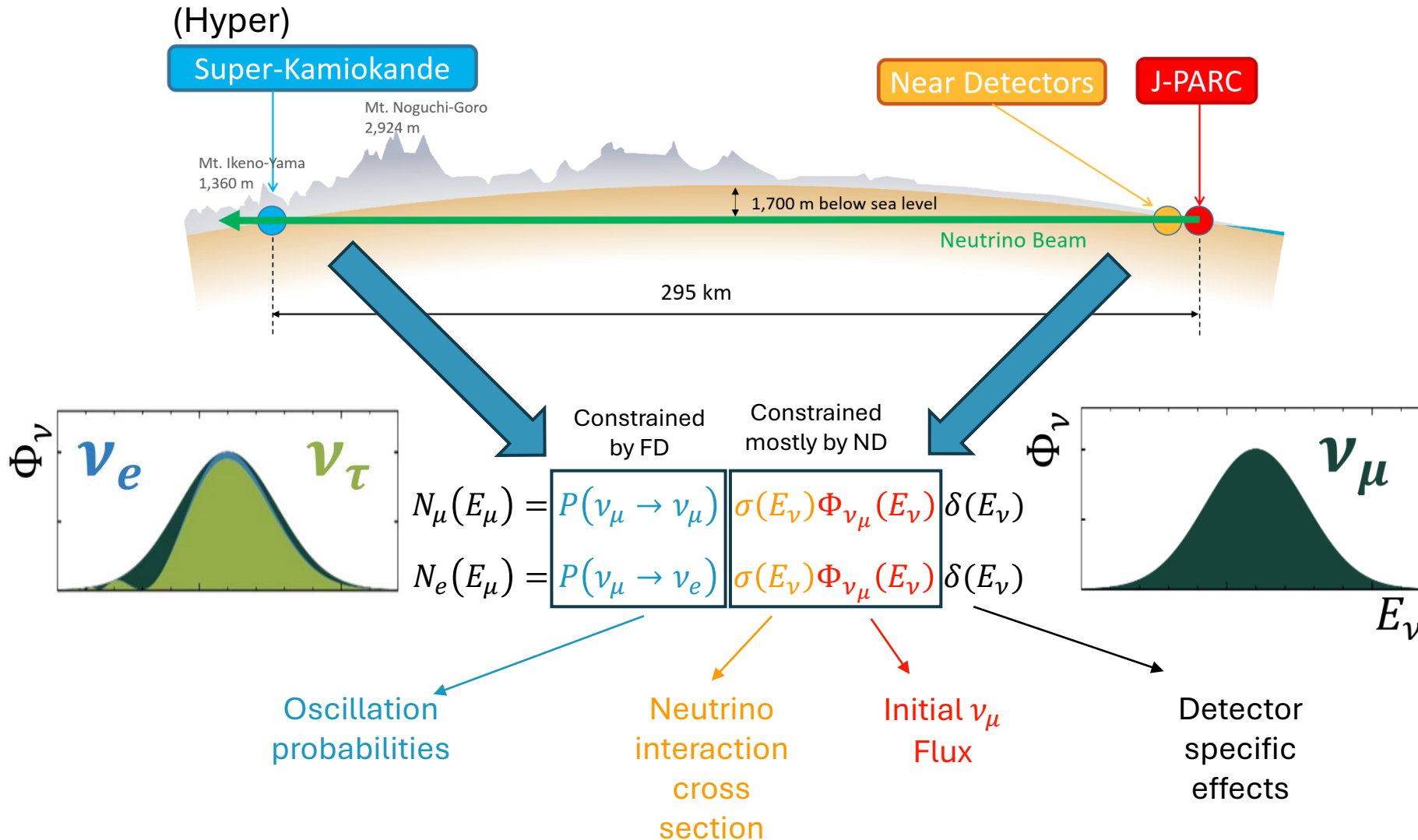
ND280 in Hyper-K Oscillation analysis

- Far Future

ND280++

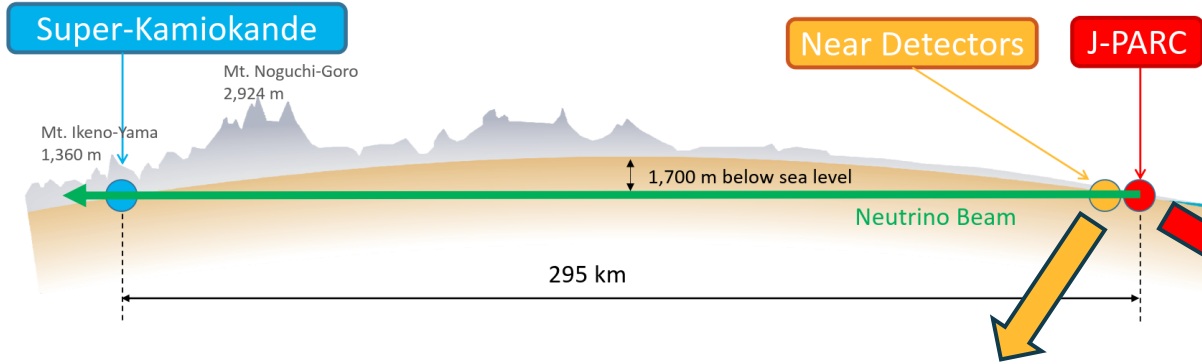
T2K Oscillation Analysis Overview

T2K Oscillation Analysis

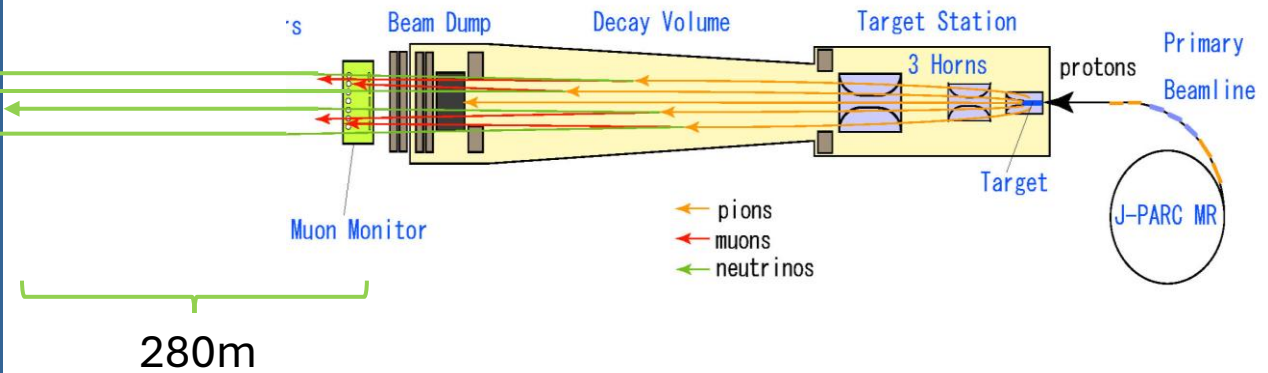
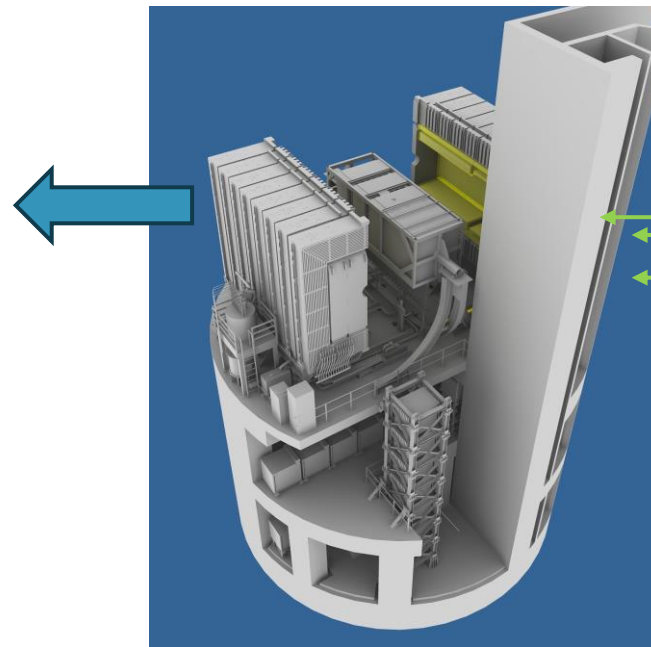
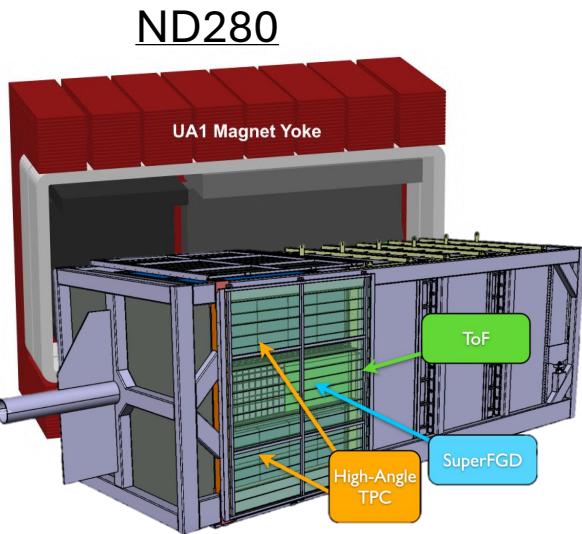


- Neutrino beam produced at J-PARC
- Characterised by near detectors
- Travels to far detector
- Measured again to extract osc parameters

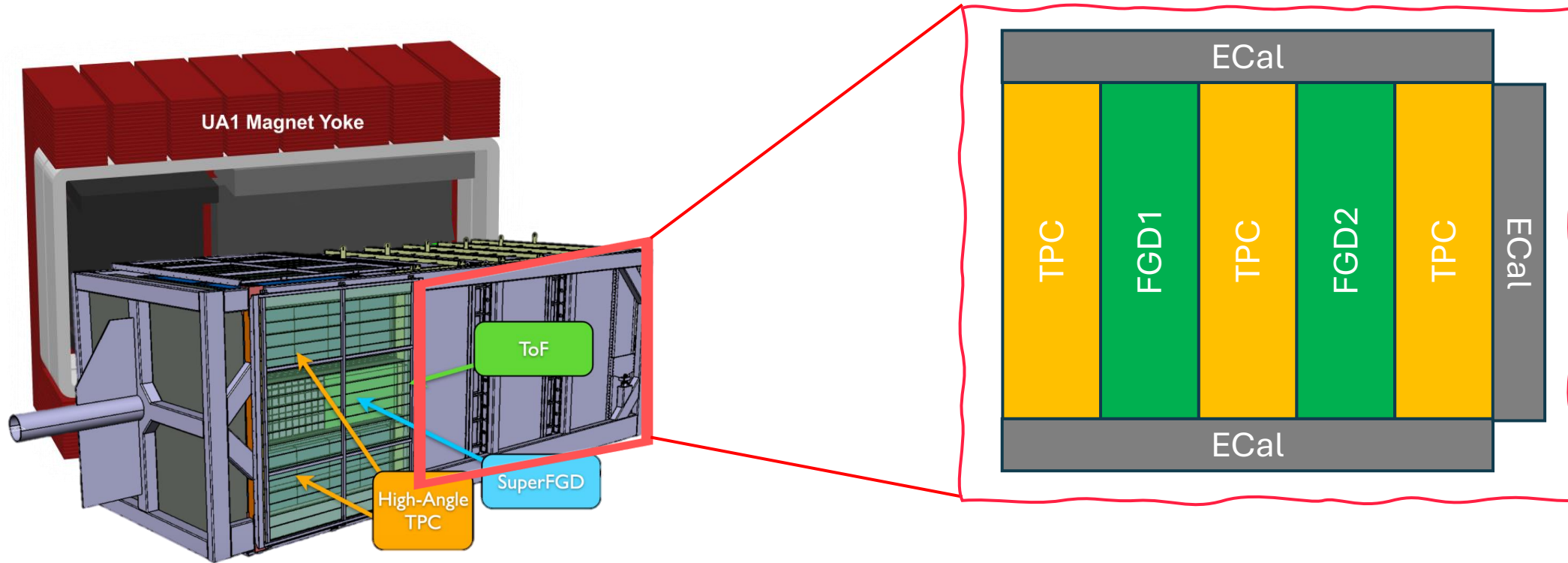
T2K Oscillation Analysis



- ND280 sits in the near detector pit 280 metres downstream of the neutrino beam target

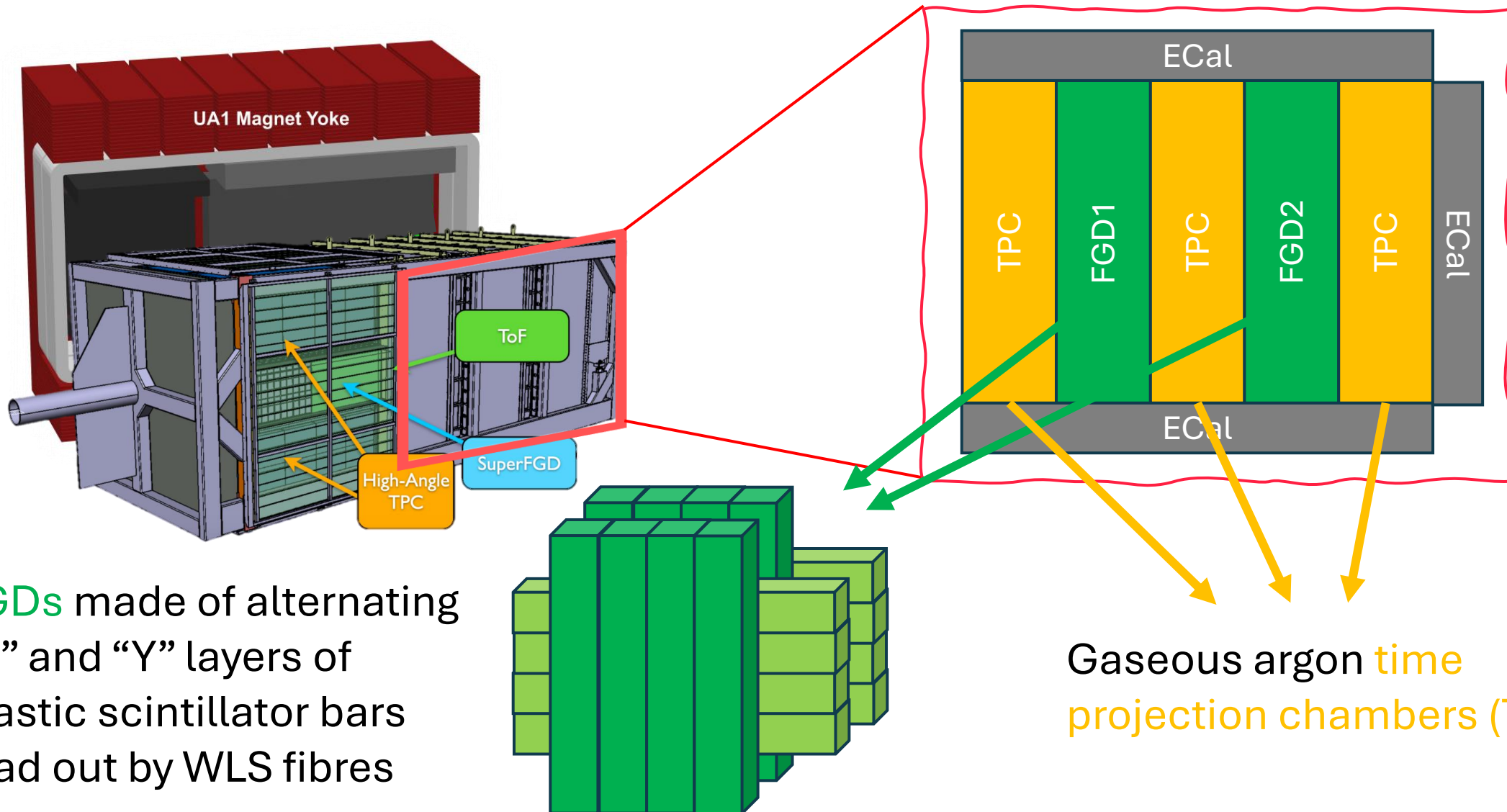


ND280 Detector - Downstream Tracker



“ND280 classic”
tracker
region

ND280 Detector - Upgrade Tracker

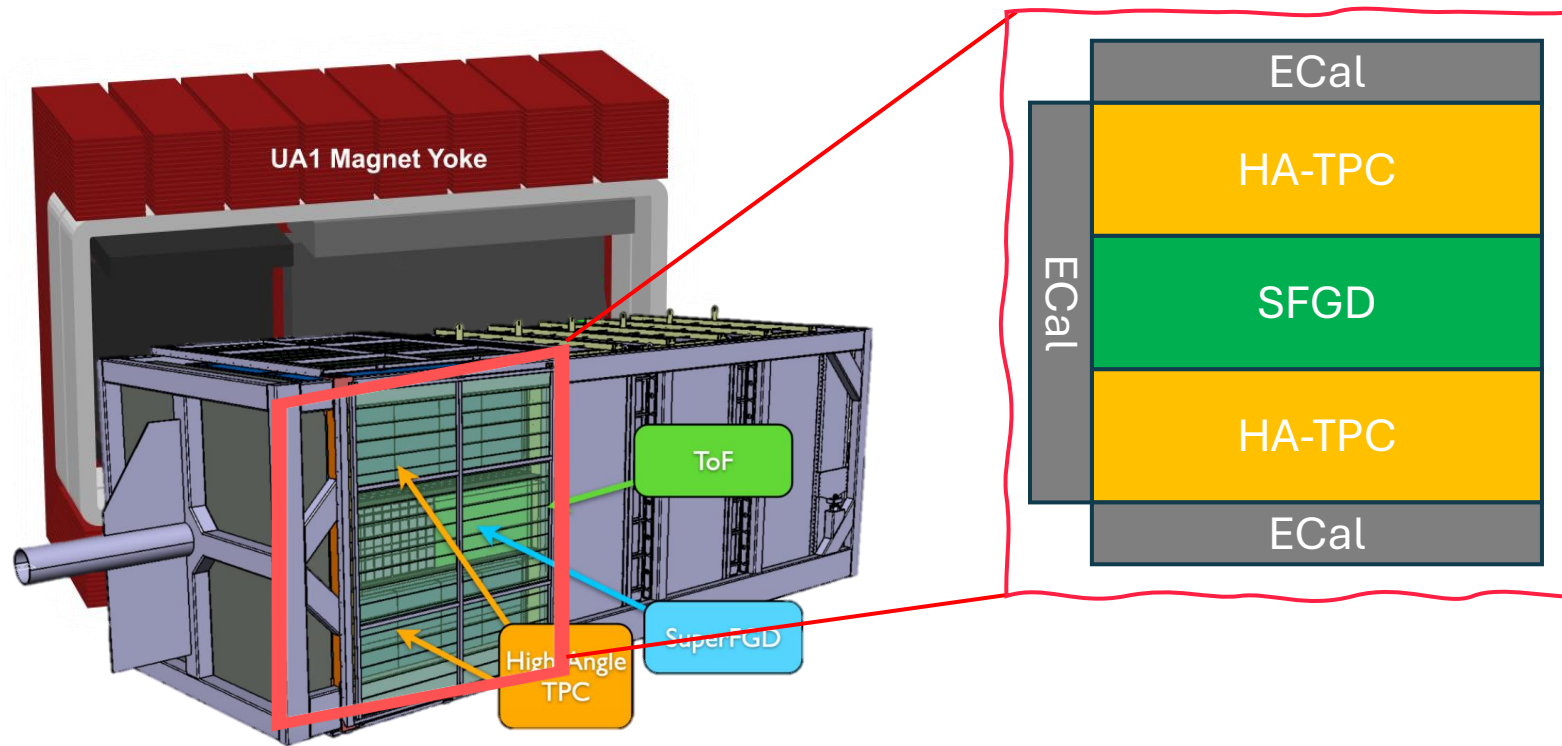


“ND280 classic” tracker region

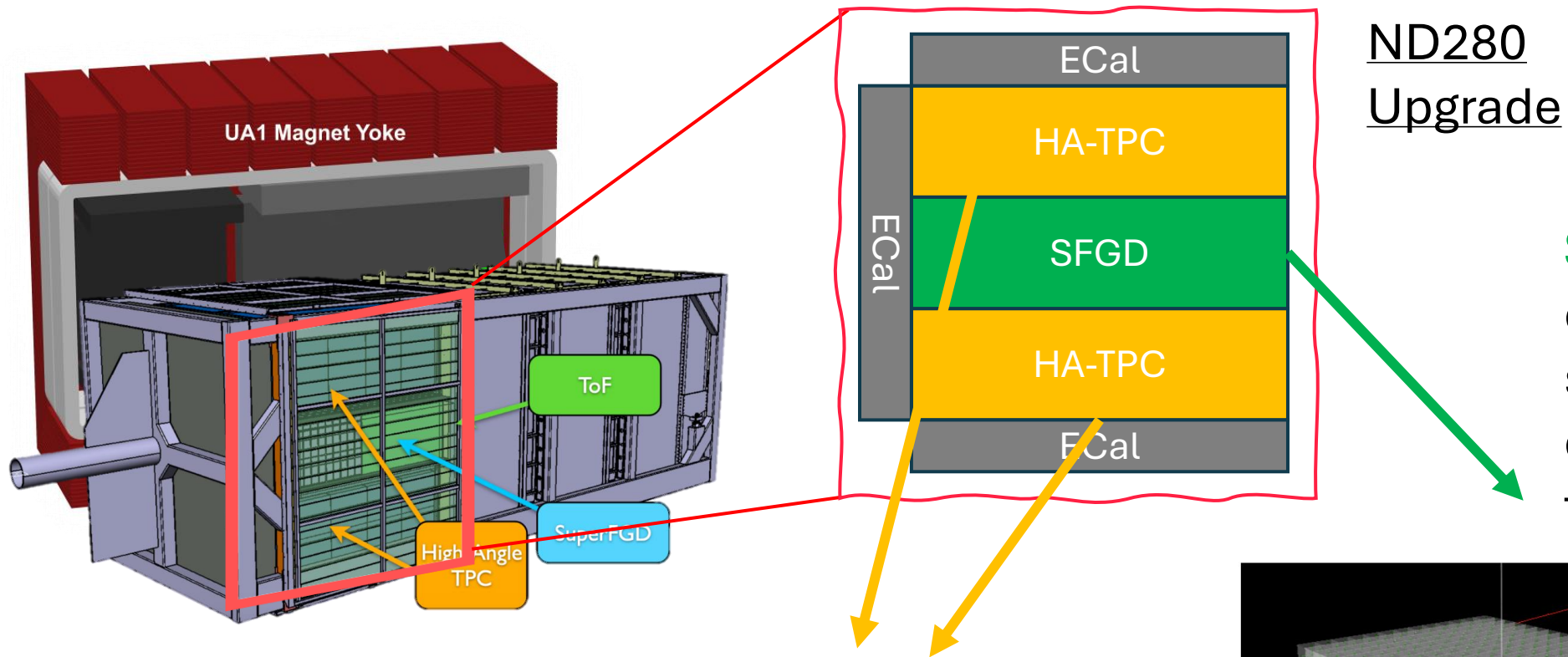
FGDs made of alternating “X” and “Y” layers of plastic scintillator bars read out by WLS fibres

Gaseous argon time projection chambers (TPCs)

ND280 Detector - Upgrade Tracker



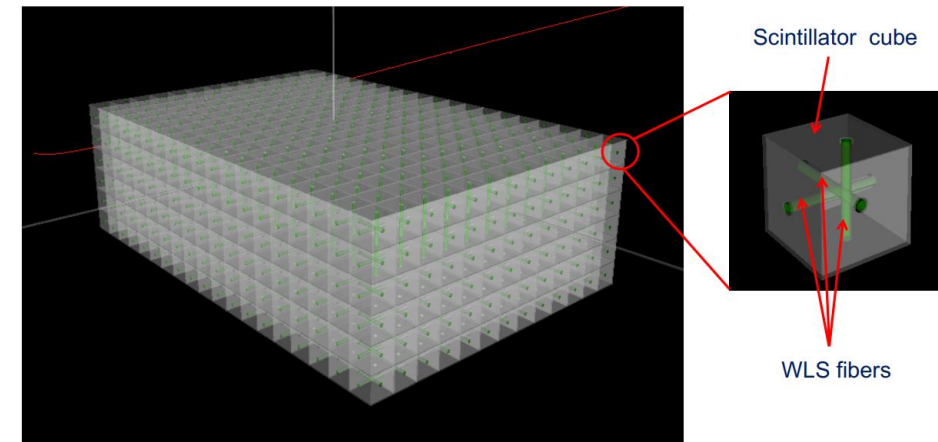
ND280 Detector - Upgrade Tracker



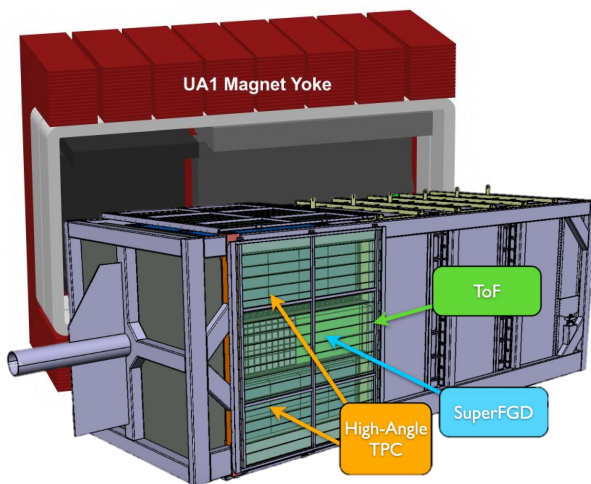
ND280
Upgrade

Super FGD made out of 1cm^3 plastic scintillator read out in 3d by WLS fibres

Gaseous argon High Angle TPCs give information about high angle events



ND280 Detector - SFGD Assembly



(i) Support system assembly



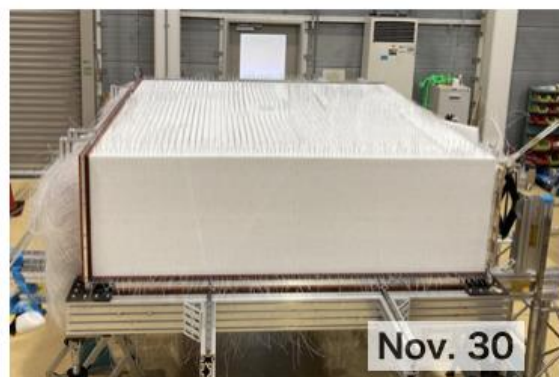
(ii) First cube layer assembly



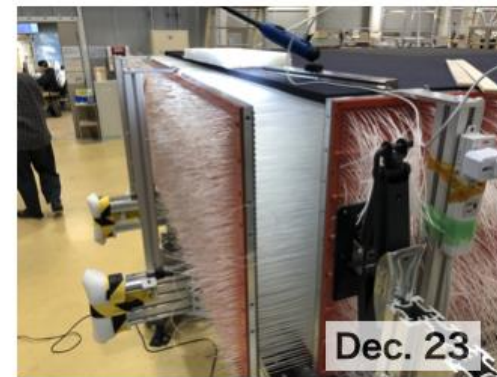
(iii) All 56 layers assembled



(iv) Stop panels removed



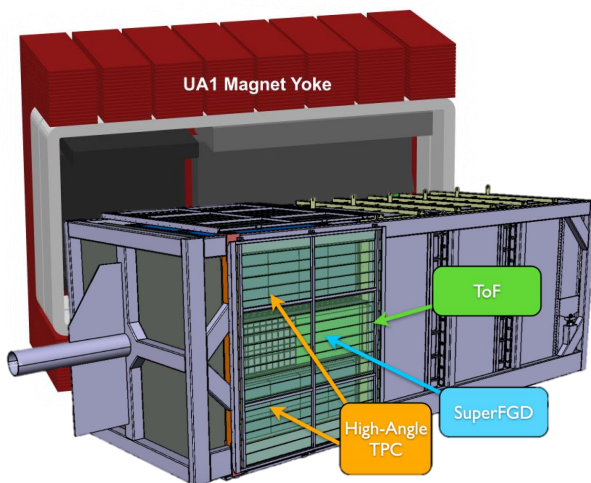
(v) Box closure



(vi) Transfer to new support



ND280 Detector - SFGD Assembly



(vii) Horizontal fibers assembly



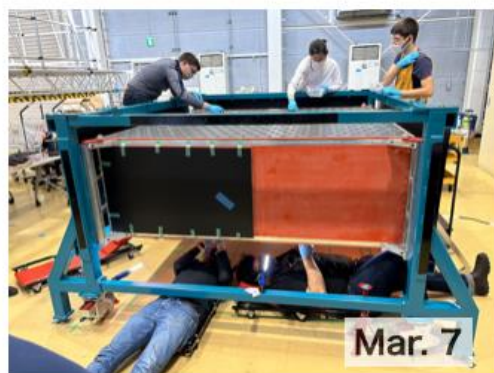
(viii) Wall MPPCs assembly



(ix) Vertical fibers assembly



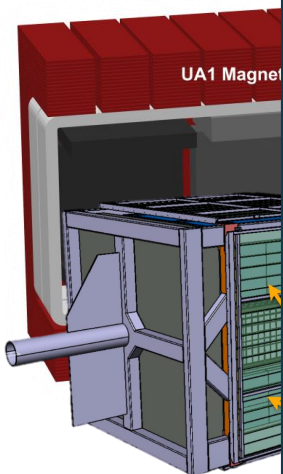
(x) Top MPPCs assembly



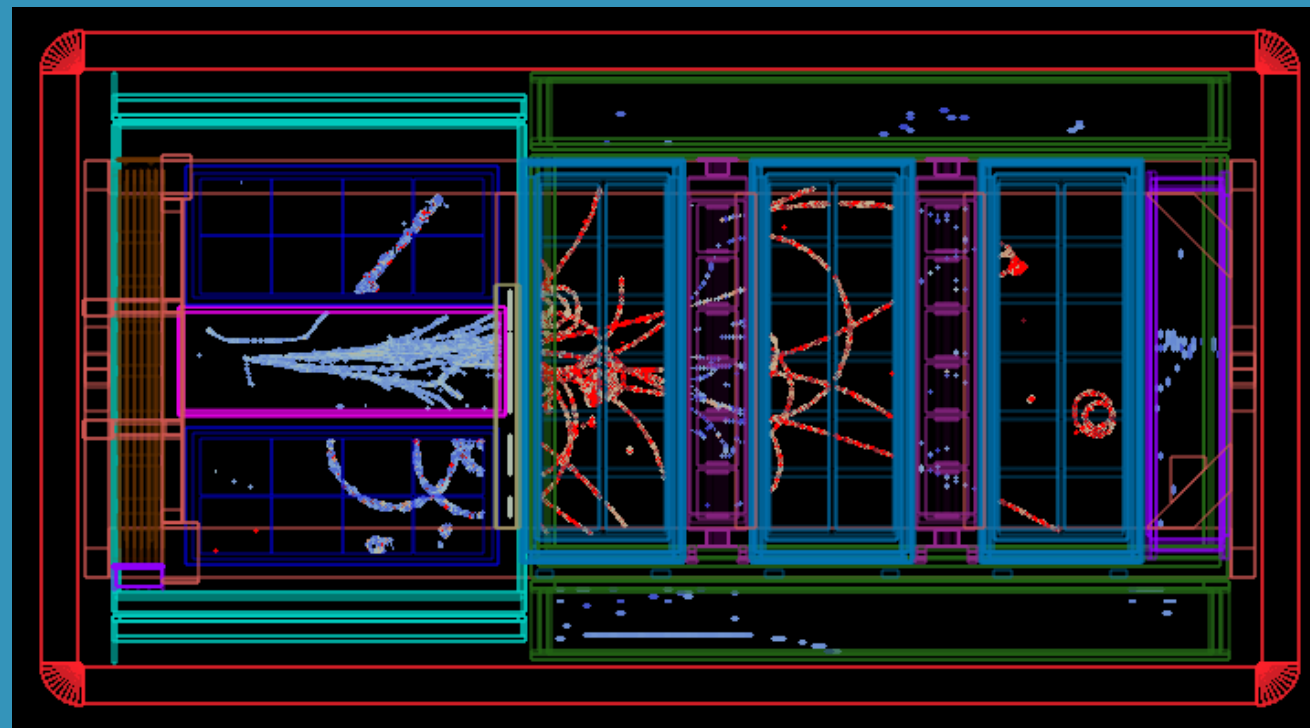
(xi) LED calib. modules assembly (xii) Light barrier/cables assembly



ND280 Detector - SFGD Assembly



Upgrade is now fully installed and has
been taking data!



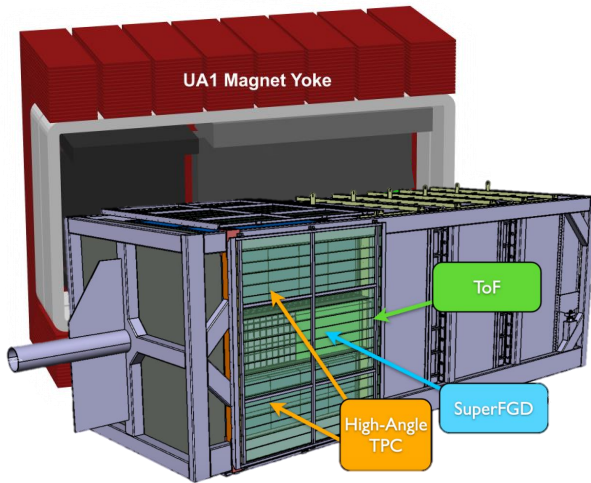
s assembly



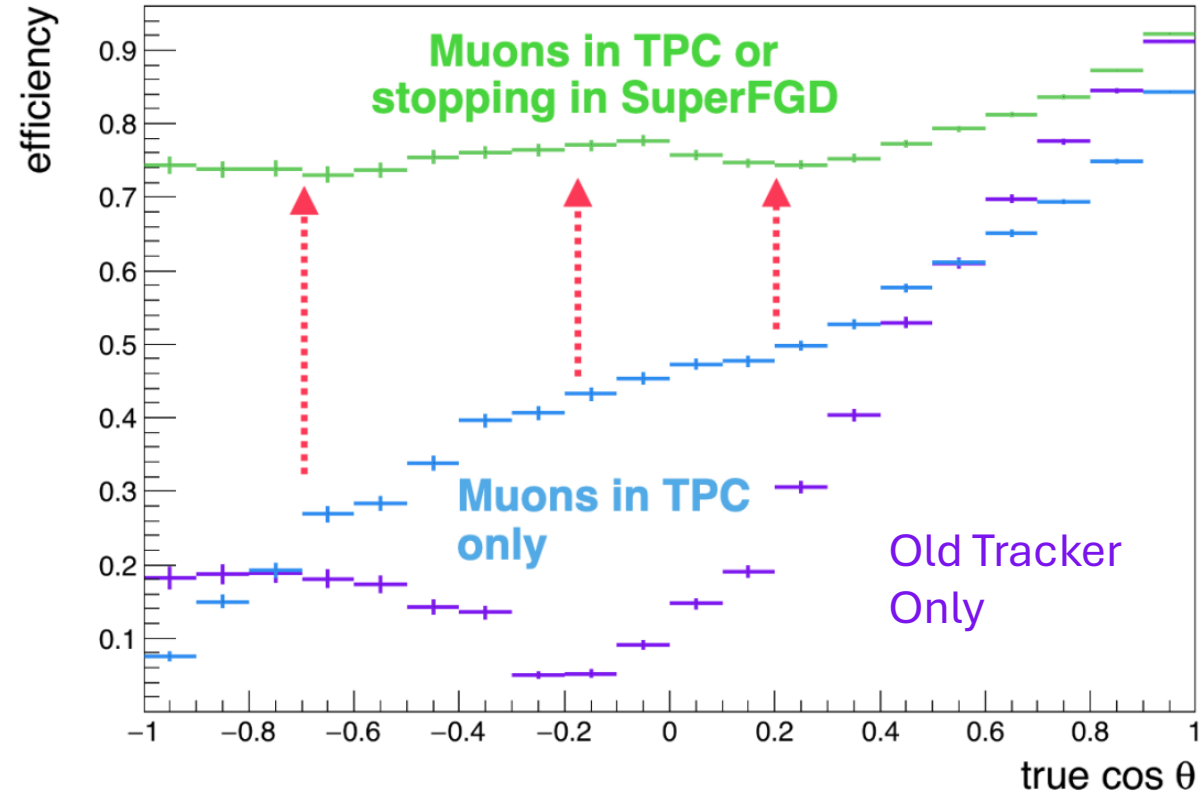
cables assembly



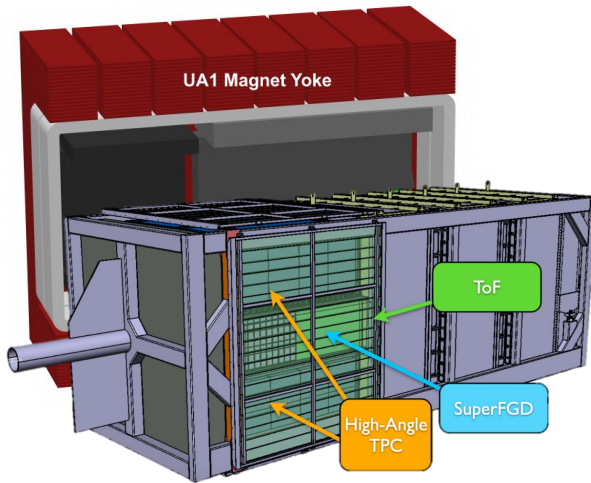
ND280 Detector - Upgrade Performance



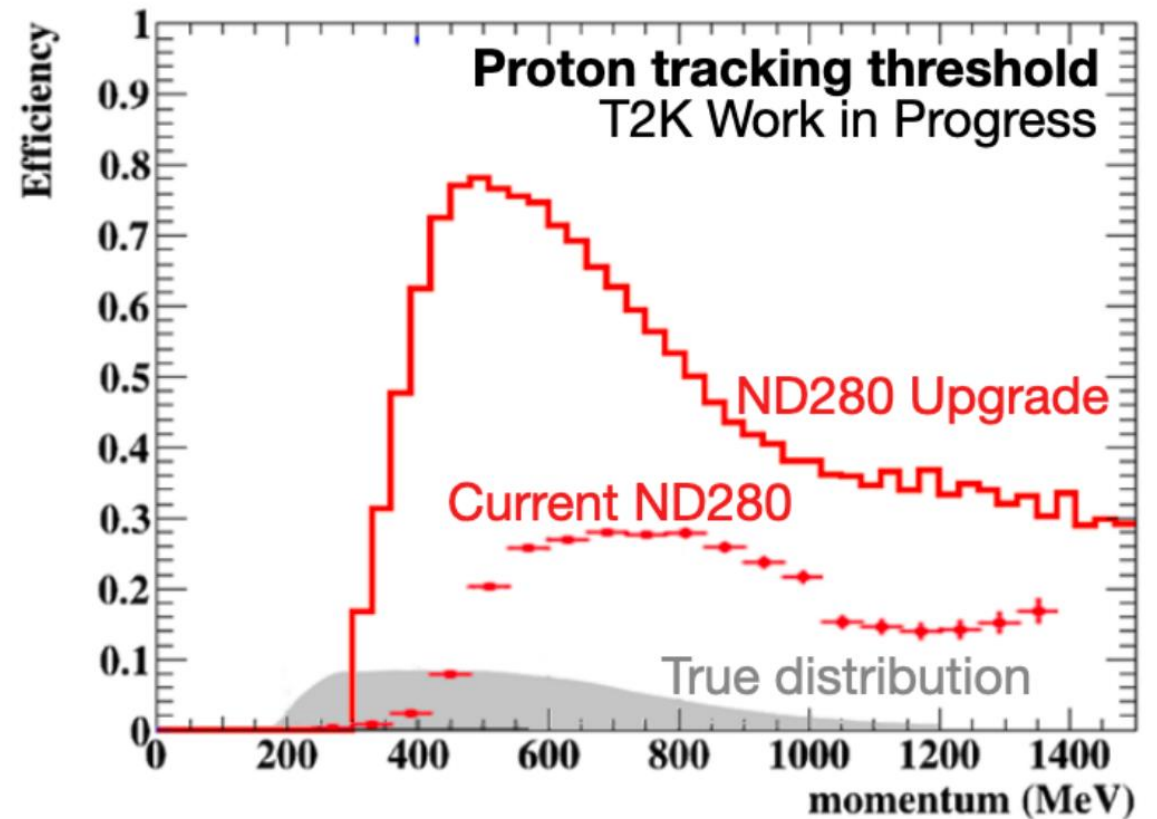
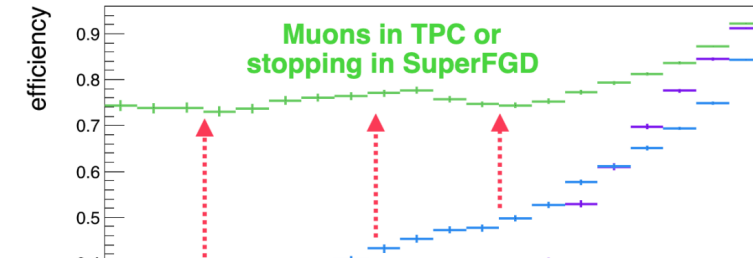
- Greatly improved efficiency, particularly for high angle muons



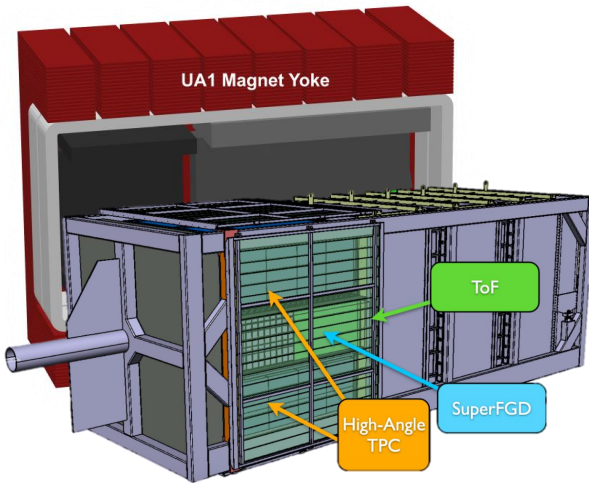
ND280 Detector - Upgrade Performance



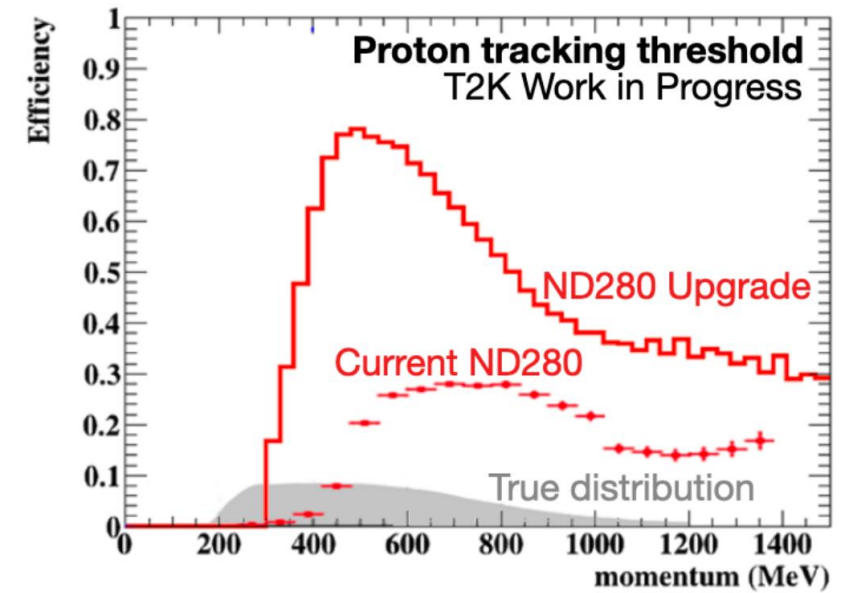
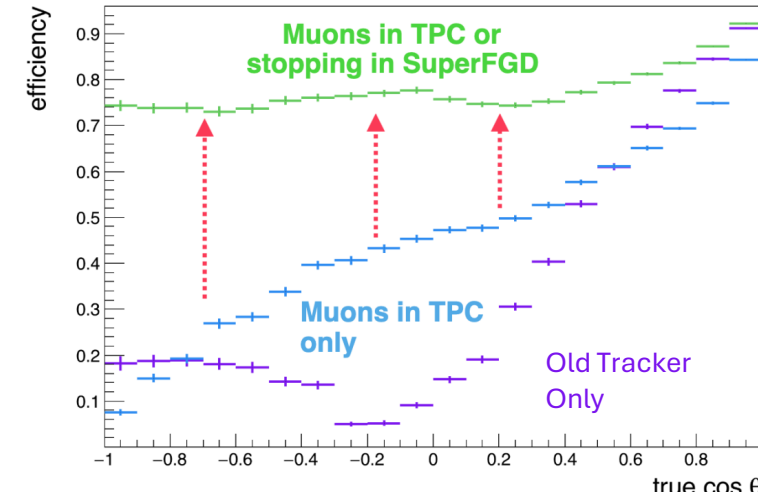
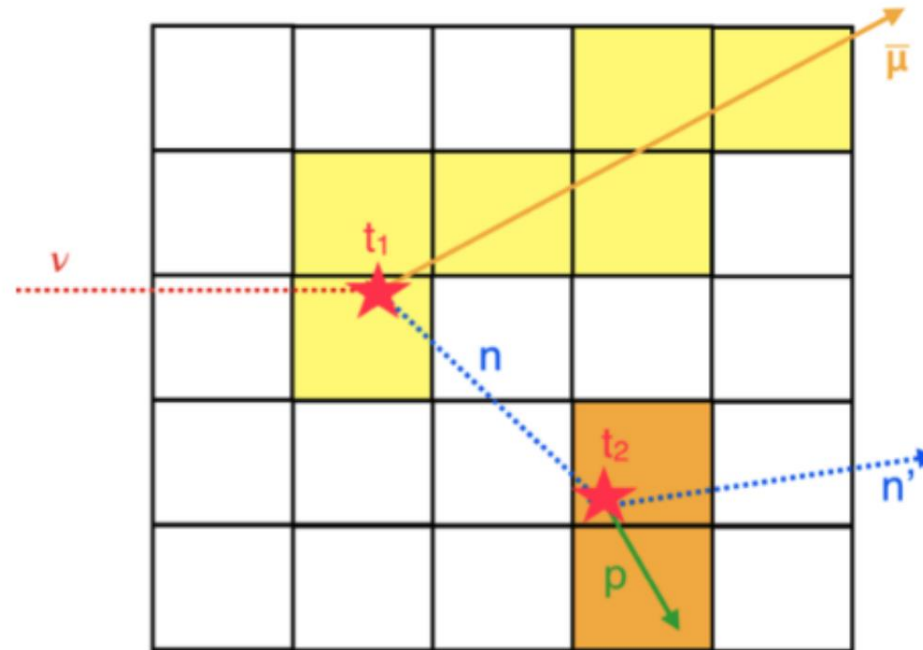
- Reduced threshold for proton tagging



ND280 Detector - Upgrade Performance



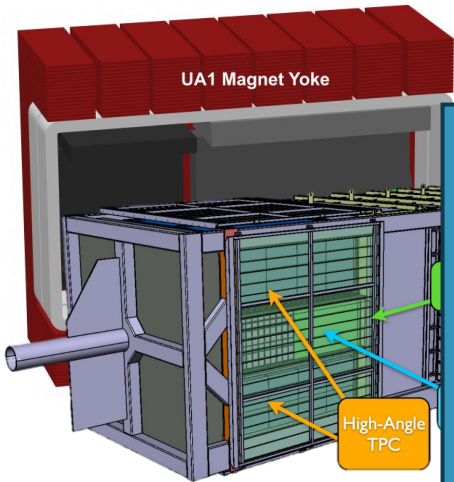
- Possibility of tagging neutrons and reconstructing kinematics



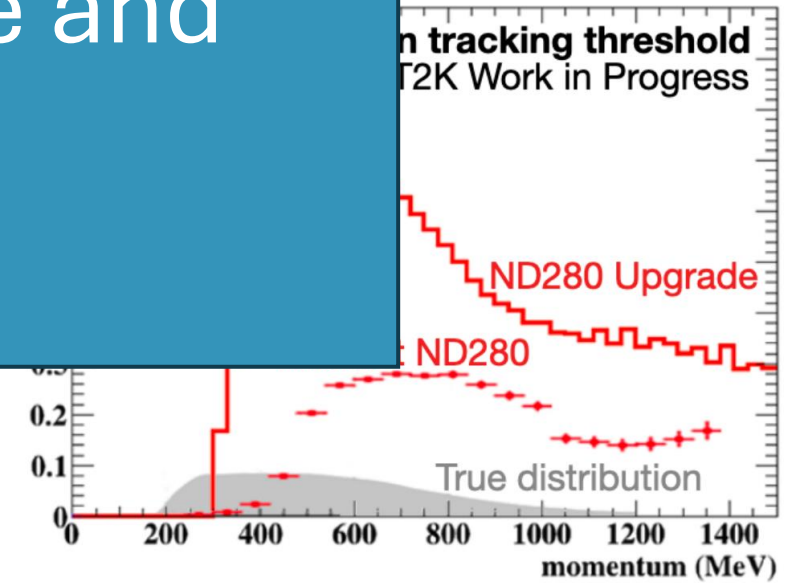
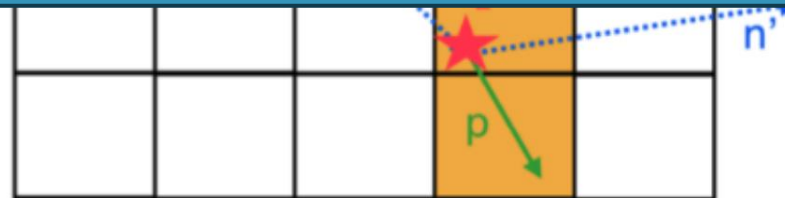
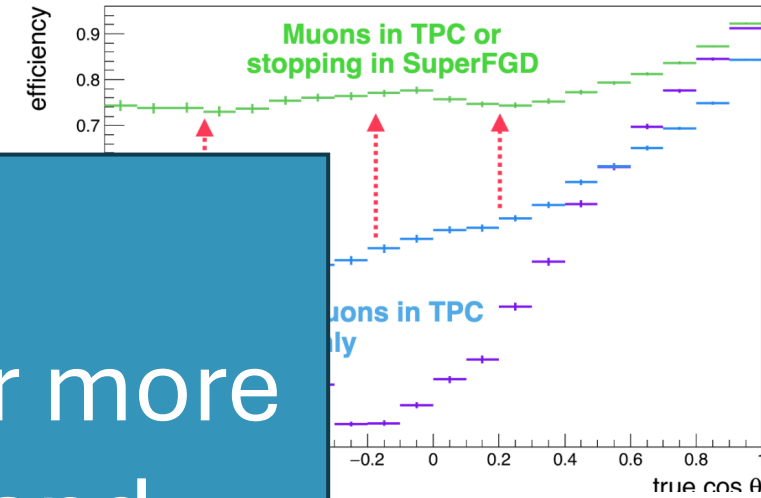
ND280 Detector - Upgrade Performance



- Possibility of tagging



See Pilars talk tomorrow for more details on performance and physics!

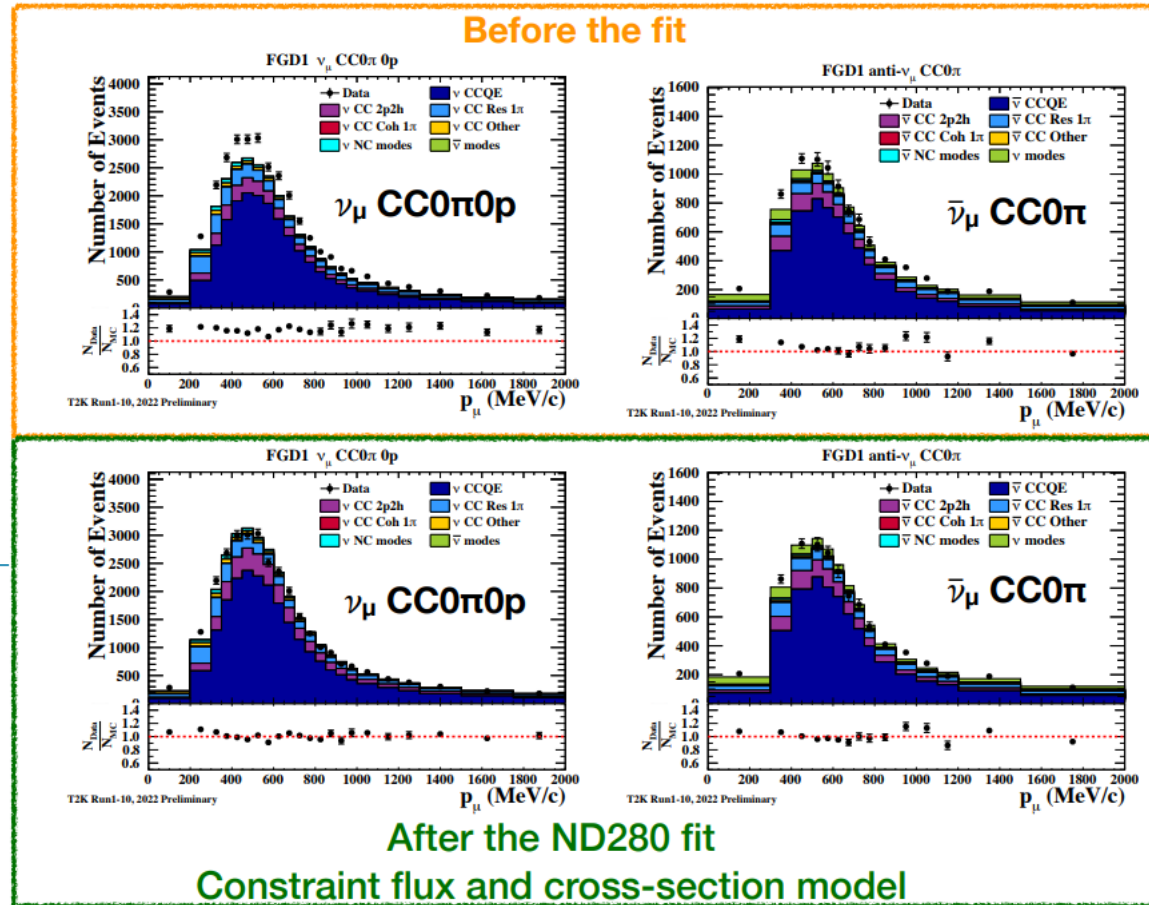
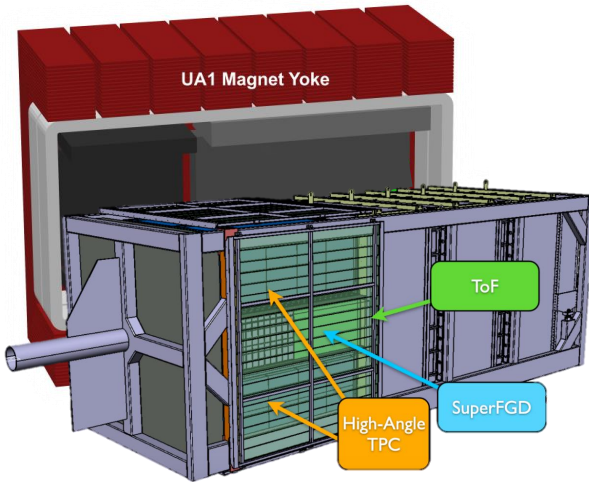


T2K Oscillation Analysis

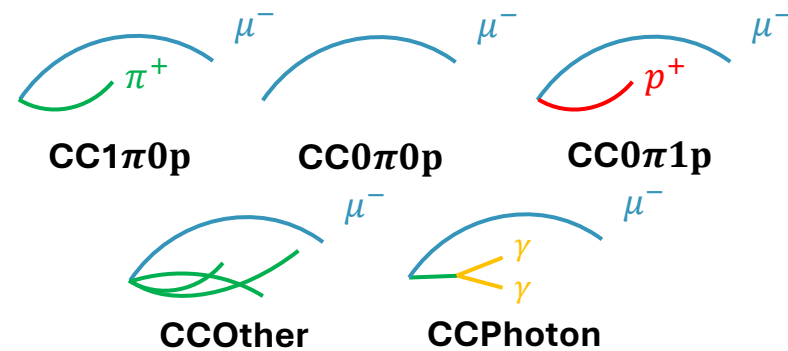
- ND280 Part



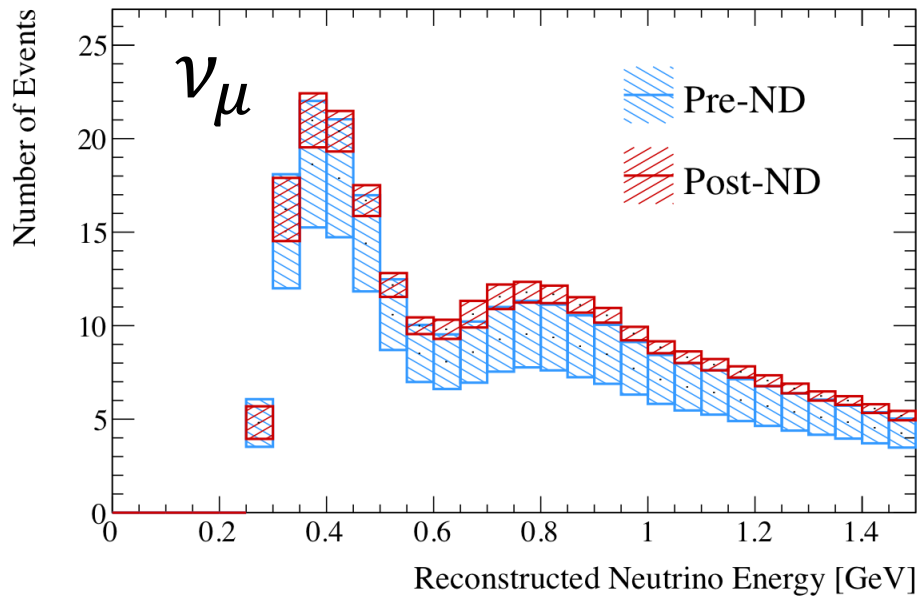
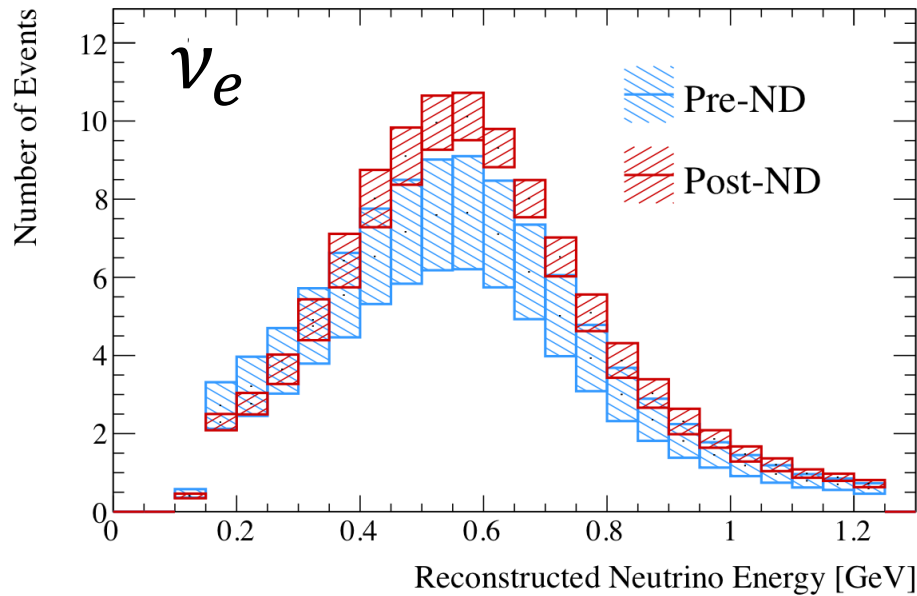
ND280



- Split events depending on final state particles
- Build distributions of muon kinematics
- Tune cross section & flux model parameters to fit data



T2K Oscillation Analysis - Model Constraints



- Greatly reduce uncertainties on event rates at far detector:

$$\nu_\mu: \sim 17\% \rightarrow \sim 3\%$$

$$\nu_e: \sim 17\% \rightarrow \sim 5\%$$

- Tuned model gets propagated to far detector
- Greatly reduces uncertainties on event rates
- Crucial to provide world leading oscillation measurements

ND280 In Hyper-K

ND280 in Hyper-K



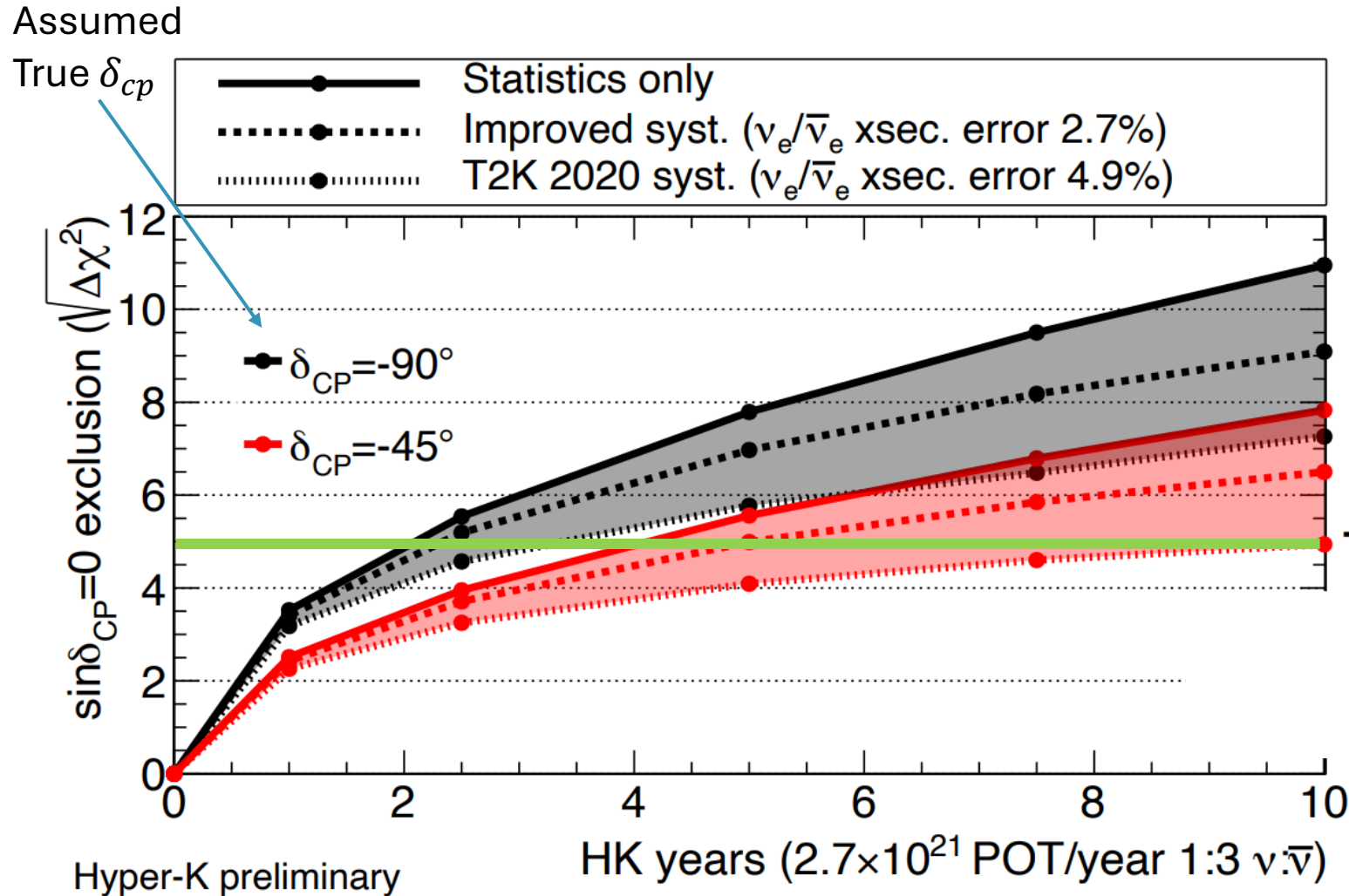
- Hyper-K will have **much** higher statistics than Super-K
- More statistics => systematic uncertainties become much more important

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- More statistics => systematic uncertainties become much more important
- Two different scenarios have been considered:
 - **T2K 2020**: Current (ish) model (constrained with “ND280-classic”)
 - **Improved**: Estimated constraints from ND280 upgrade and IWCD

Total percentage error on sample event rates:

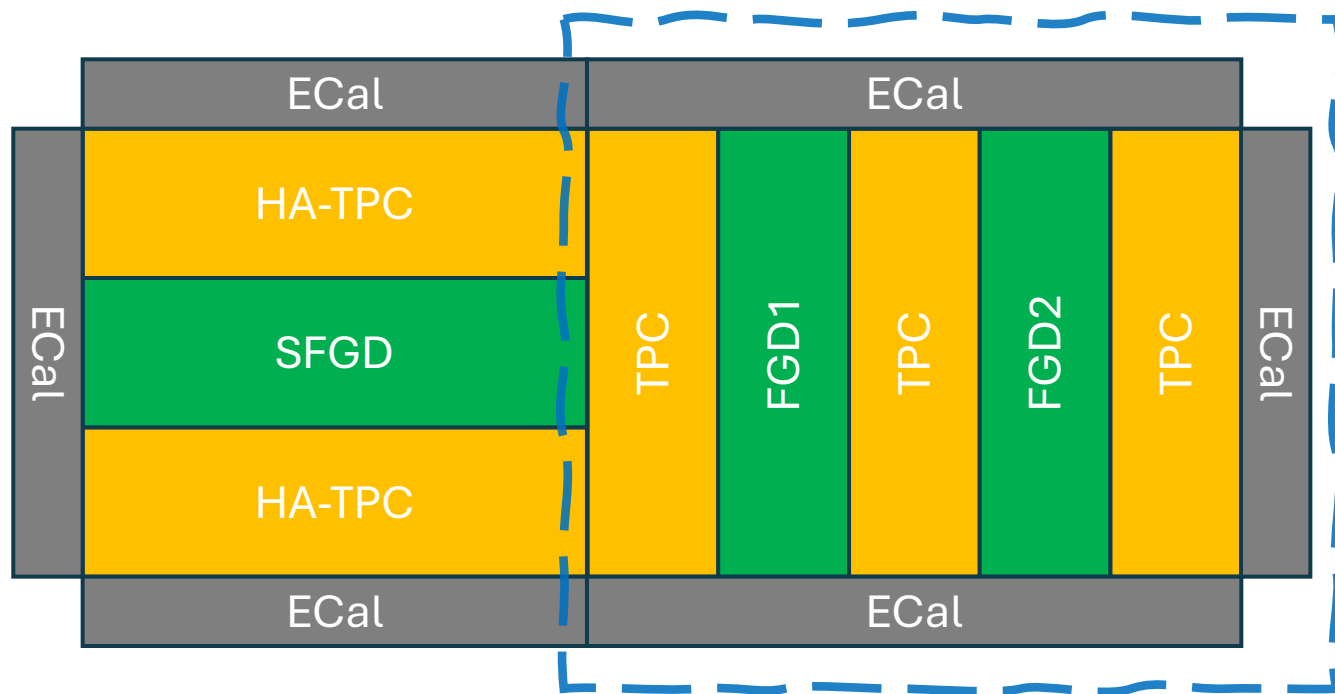
Error model	μ -like		e-like			
	ν -mode	$\bar{\nu}$ -mode	ν -mode 0 d.e.	$\bar{\nu}$ -mode 0 d.e.	ν -mode 1 d.e.	$\nu/\bar{\nu}$ modes 0 d.e.
T2K 2020	3.0%	4.0%	4.7%	5.9%	14.1%	4.6%
Improved	1.2%	1.1%	2.1%	2.2%	5.2%	2.0%

ND280 in Hyper-K

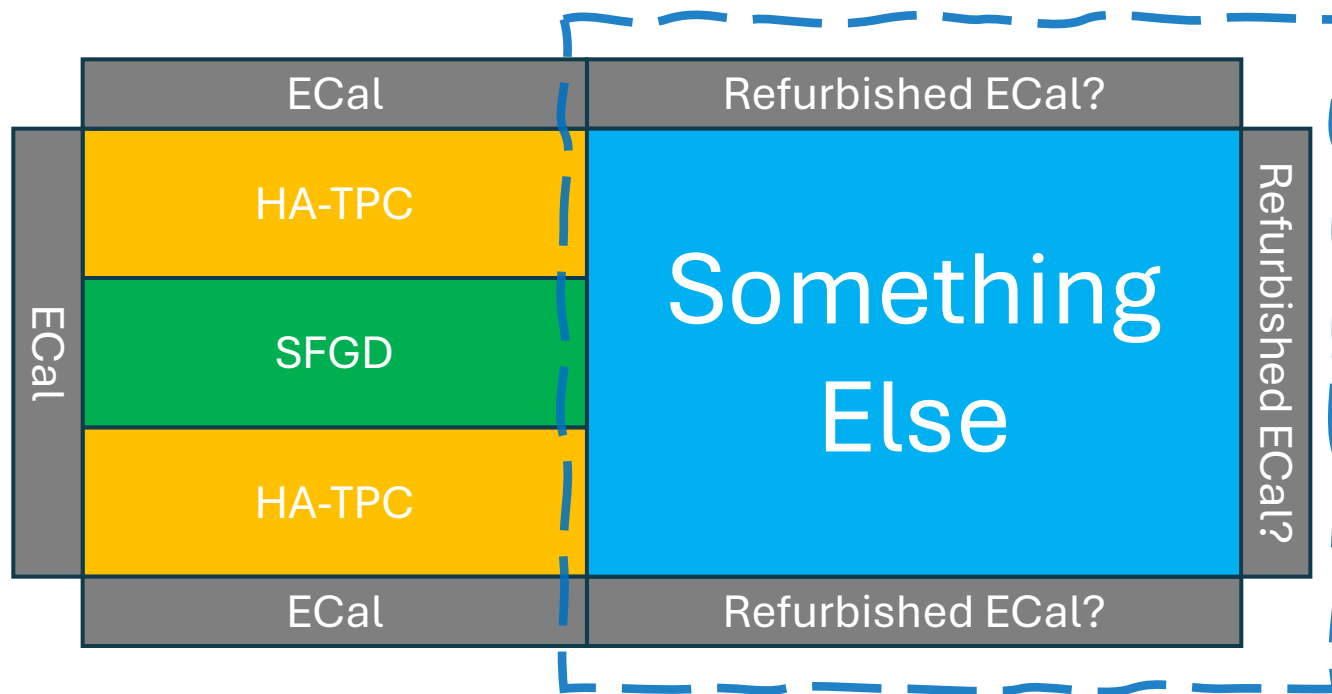


- Studies done on ability to exclude cp conservation
- Time to reach goal of 5σ can be drastically reduced by improved systematics

ND280++



- Idea is to upgrade remaining un-upgraded part of ND280



- Idea is to upgrade remaining un-upgraded part of ND280
- Potentially refurbish ecals
- Replace tracker region with some new detector/set of detectors
- This was the focus of the final day of the last T2K CERN workshop

Physics goal of ND280++

- Measure $\sigma(\nu_e)$ vs $\sigma(\nu_\mu)$ and $\sigma(\nu_e)$ vs $\sigma(\bar{\nu}_e)$ precisely
 - ⇒ need 3D granularity (possibly very fine), large mass, good calorimetry, and low threshold (<0.5 GeV), hadronic part (studies of C vs O)
- Measure interactions in water (ν_μ and $\bar{\nu}_\mu$)
 - ⇒ need 3D granularity, large H₂O/CH content ratio, detailed hadronic part
- Reconstruct neutrons and reconstruct kinetic energy w/ time of flight (2p2h, direct $\bar{\nu}_\mu$ flux measurement, axial mass)
 - ⇒ need 3D granularity, high hydrogen content, fully active, large mass, fast
- Reconstruct detailed hadronic part (e.g. protons below 300 MeV/c, vertex act.)
 - ⇒ need very fine granularity
- What about Neutral Currents (break the degeneracy in IWCD-PRISM analysis, important NC1pi+)
 - ⇒ need 3D granularity, large mass, at least...

- Taken from Davides [discussion slides](#) from HK part of CERN ND280++ workshop

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- Strong theme of high granularity with 3D reconstruction

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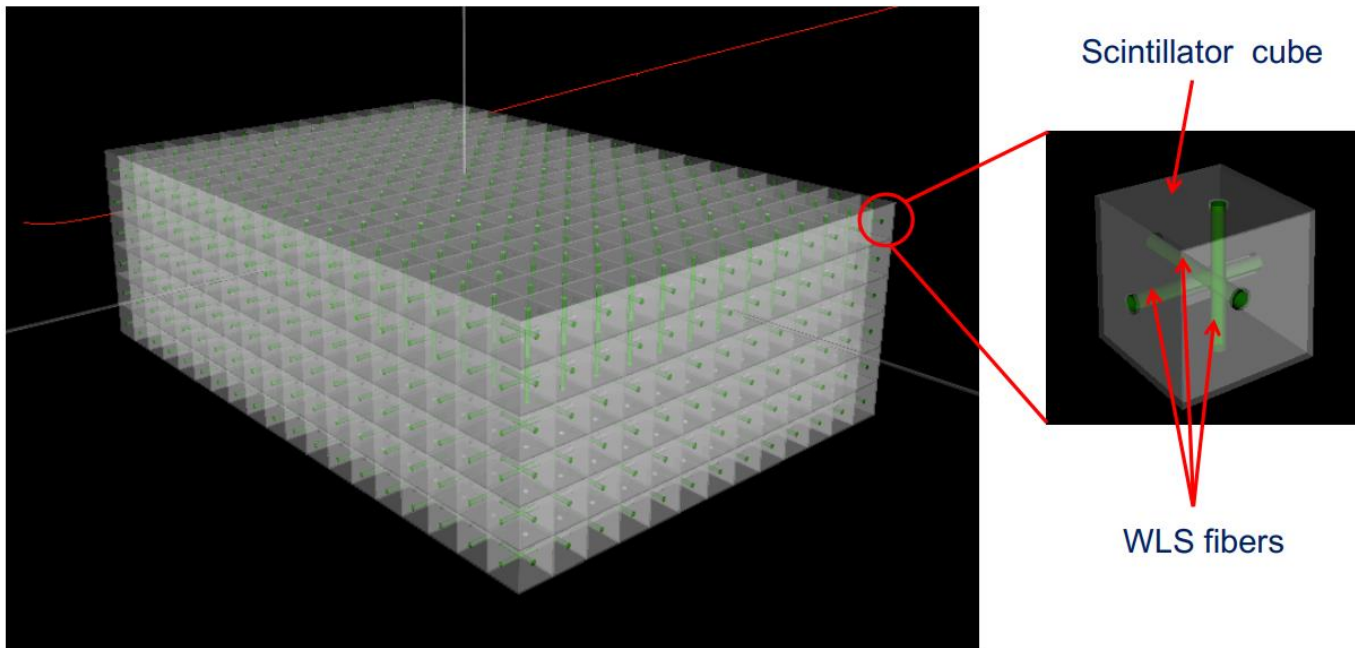
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- Strong theme of high granularity with 3D reconstruction
- Also large mass with high H/ H₂O content

(some of the) Possible technologies

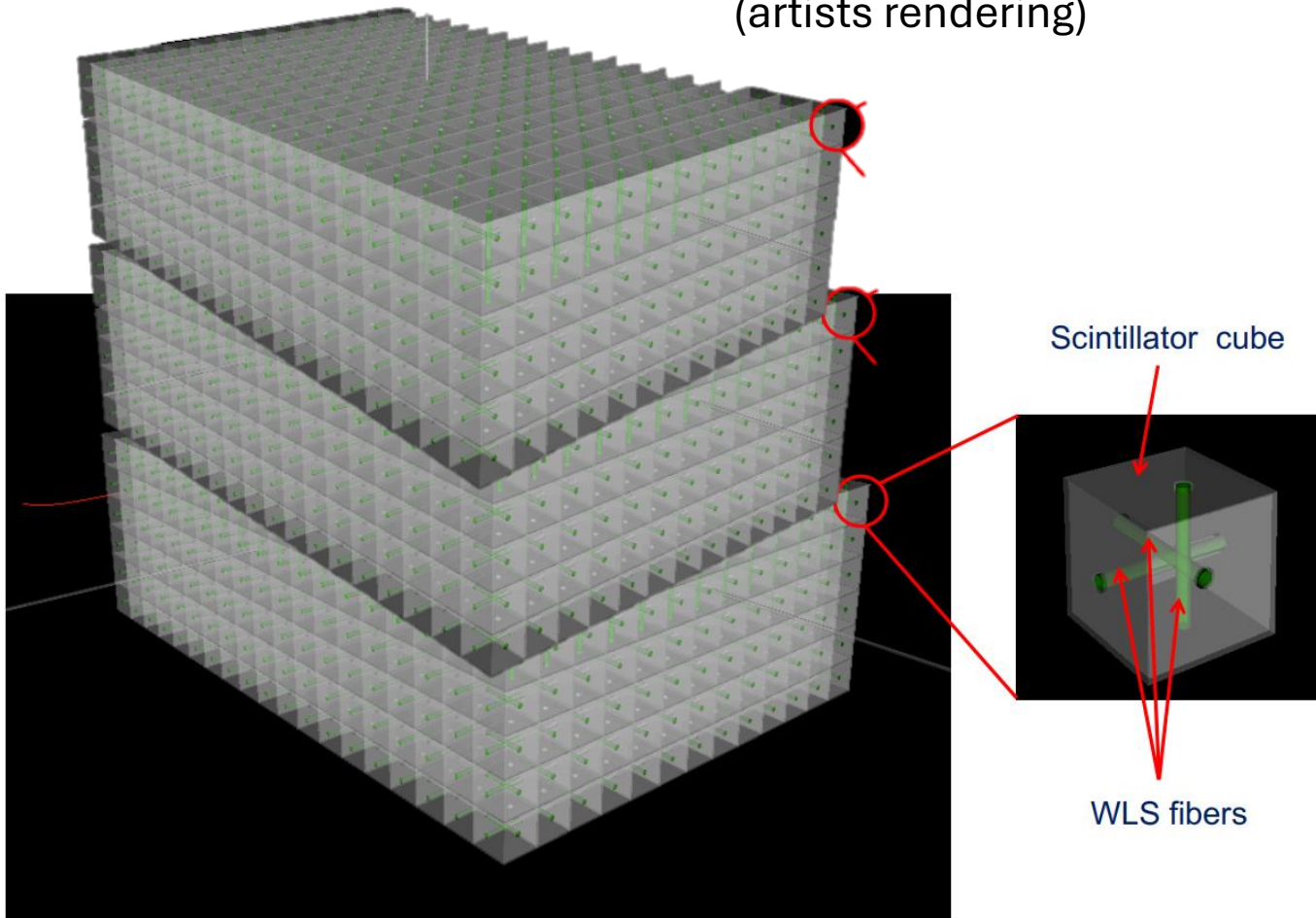
Hyper FGD (HFGD)

- Same concept as the super FGD
- 1cm plastic scintillator cubes read out by WLS fibres



Hyper FGD (HFGD)

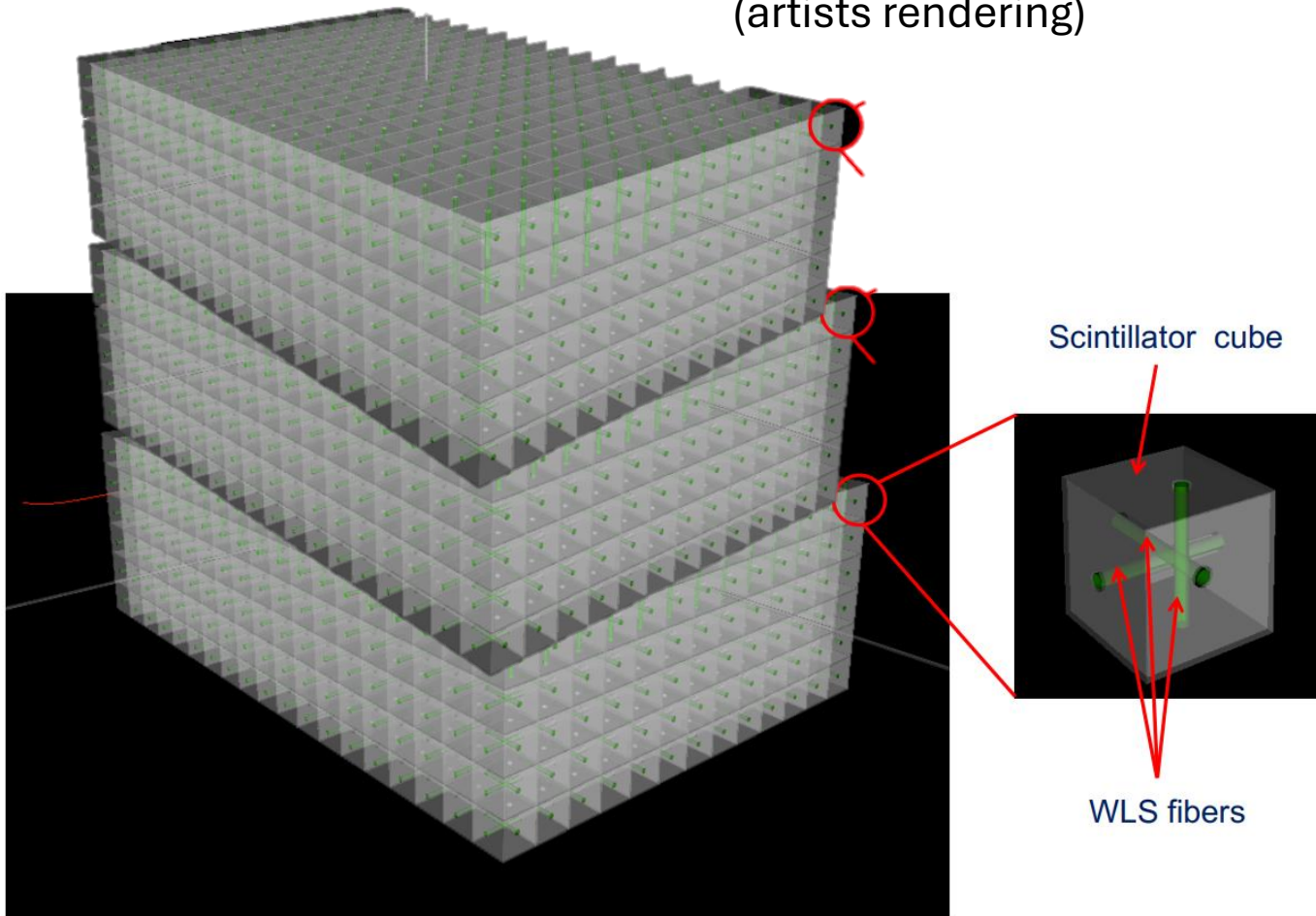
(artists rendering)



- Same concept as the super FGD
- 1cm plastic scintillator cubes read out by WLS fibres
- But More!!!

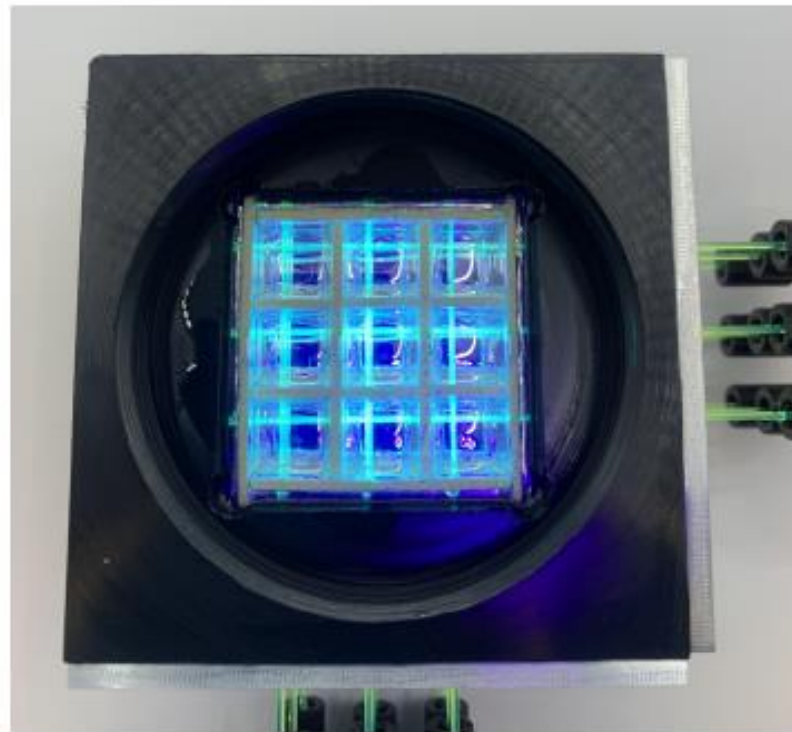
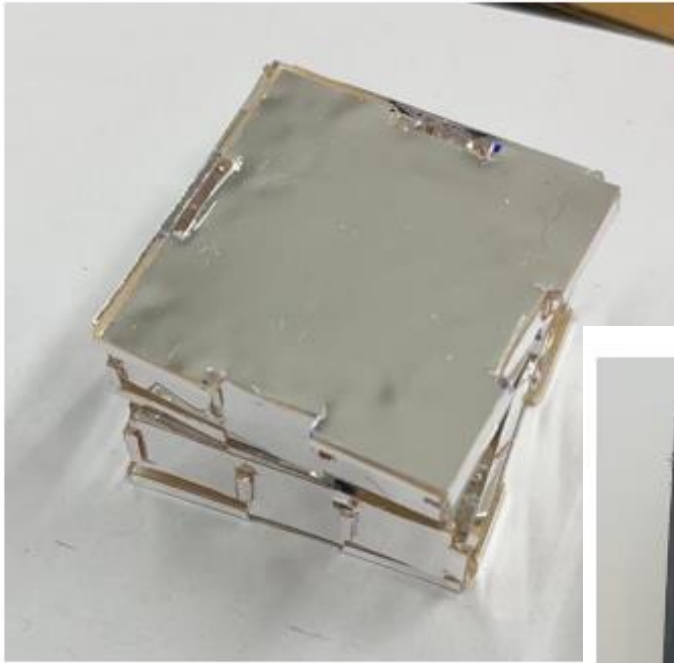
Hyper FGD (HFGD)

(artists rendering)



- Same concept as the super FGD
- 1cm plastic scintillator cubes read out by WLS fibres
- But More!!!
- + Technology is now mature and tested in SFGD
- - Installation for SFGD was very difficult – for HFGD.... Best not to think about

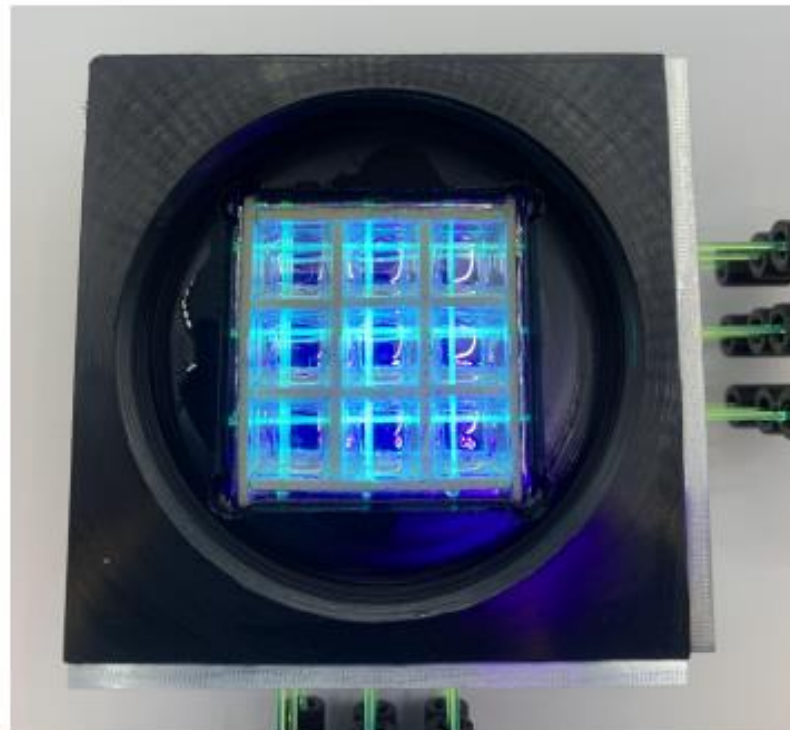
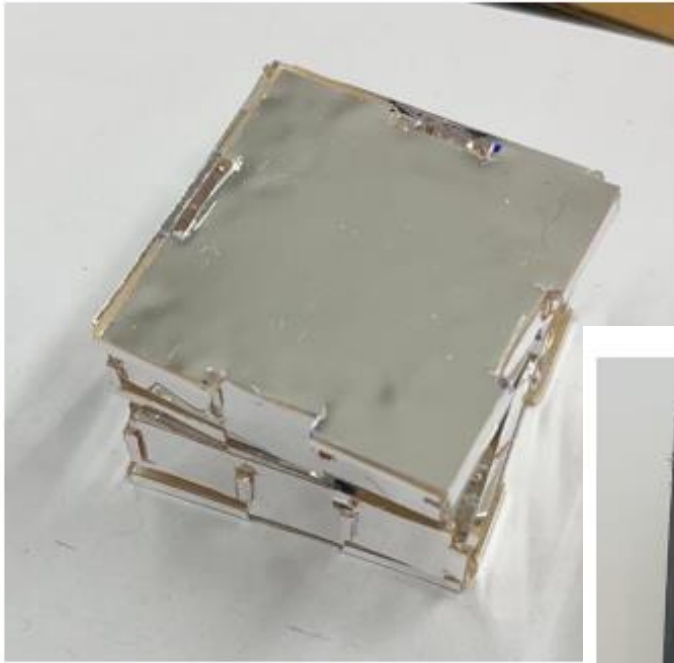
Segmented WBLS



- Similar concept but with fixed segmented cell structure filled with water based liquid scintillator (WBLS)

[Link to talk](#)

Segmented WBLS



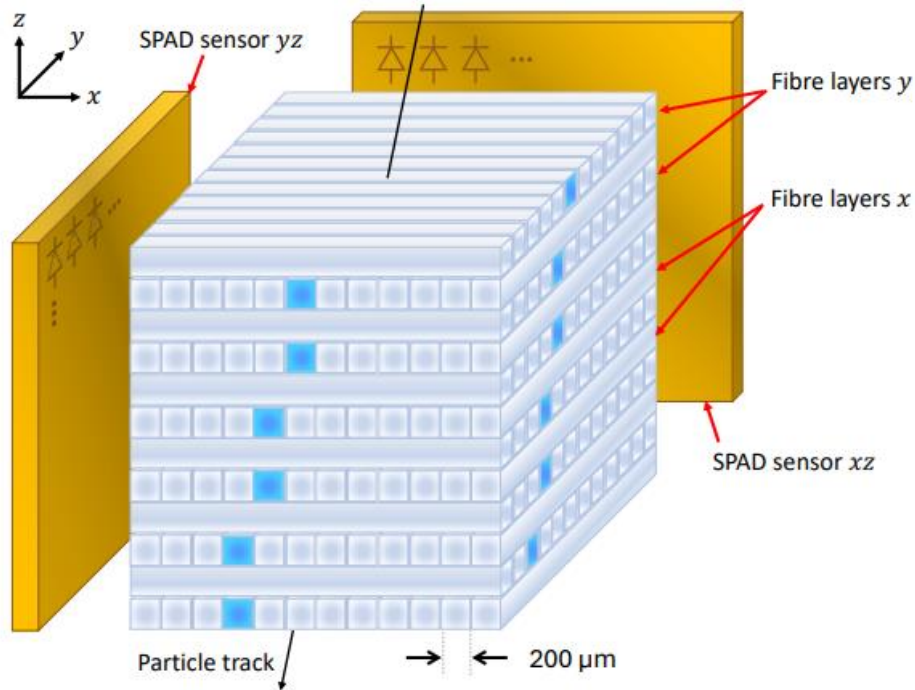
- Similar concept but with fixed segmented cell structure filled with water based liquid scintillator (WBLS)
- Same target as HK
- Similar spatial resolution as SFGD
- Being developed and prototyped at ETH

[Link to talk](#)

Scintillating Fibres (SciFi)



Motivation: Fine-grain 3D particle tracking



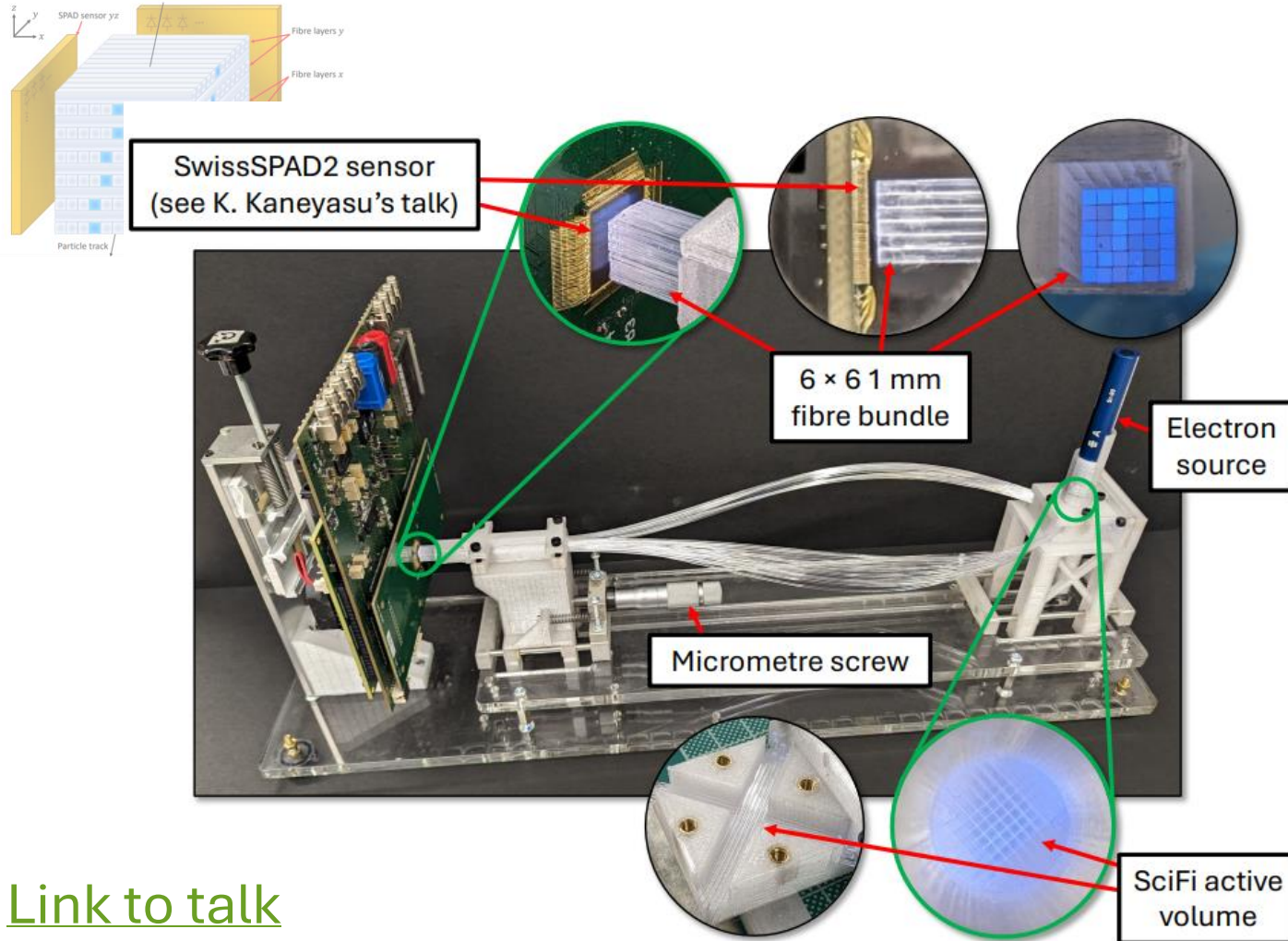
- Based on similar concept to existing FGDs in ND280

[Link to talk](#)

Scintillating Fibres (SciFi)



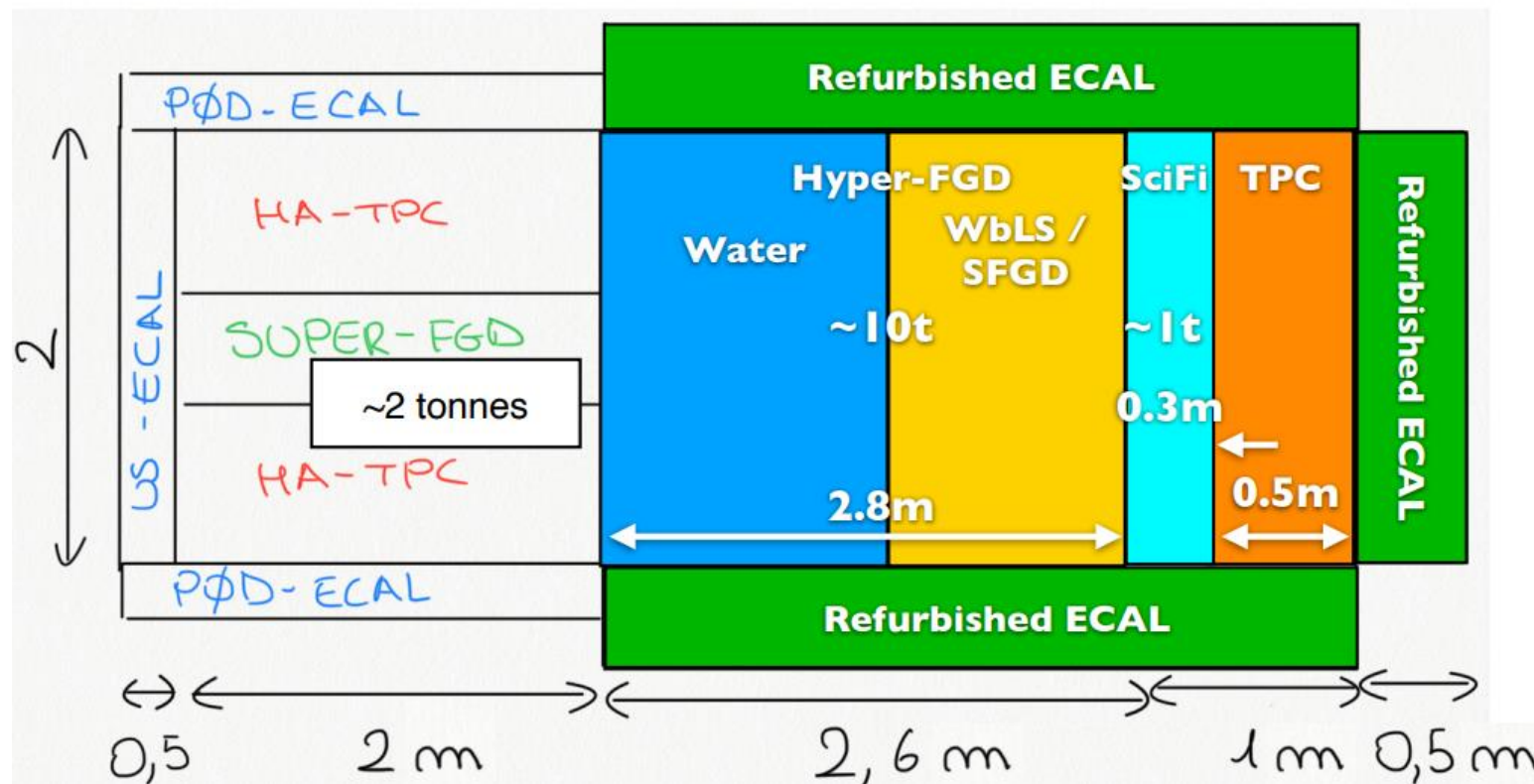
Motivation: Fine-grain 3D particle tracking



[Link to talk](#)

- Based on similar concept to existing FGDs in ND280
- Just on a very different scale
- Sub-mm thickness fibres giving incredible spatial resolution
- Being worked on at ETH – in early prototype stages

ND280 ++ Baseline

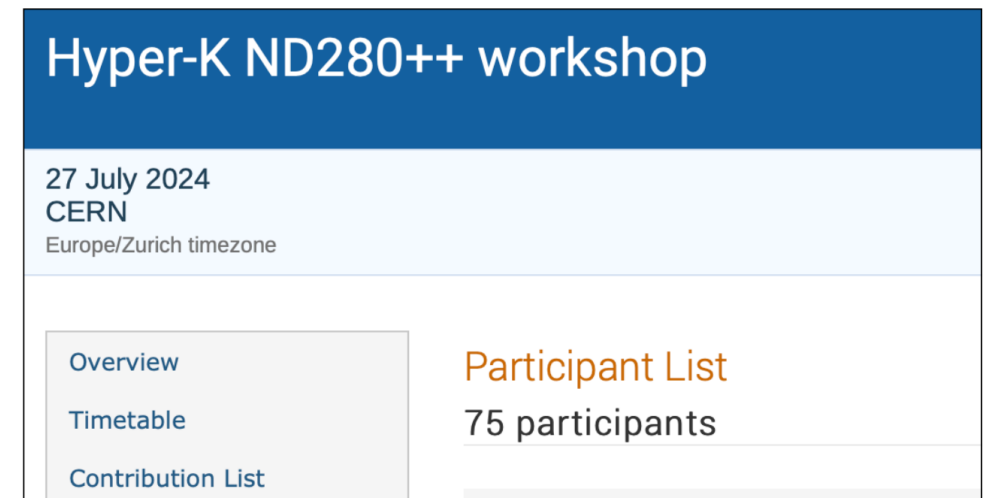


- (very) rough proposal of baseline design
- Taken from Davides [discussion slides](#) from HK part of CERN ND280++ workshop

Summary

- ND280 plays a crucial role in constraining the cross section and flux uncertainties for T2K
- For Hyper-K this will be even more important, given the greatly reduced systematic uncertainties – there will be nowhere left to hide!

- ND280 plays a crucial role in constraining the cross section and flux uncertainties for T2K
- For Hyper-K this will be even more important, given the greatly reduced statistical uncertainties – there will be nowhere left to hide!
- Lots of excitement and interest about ND280++
- Great deal of R&D ongoing into possible new technologies



Hyper-K ND280++ workshop

27 July 2024
CERN
Europe/Zurich timezone

Overview
Timetable
Contribution List

Participant List
75 participants

Thanks for listening!