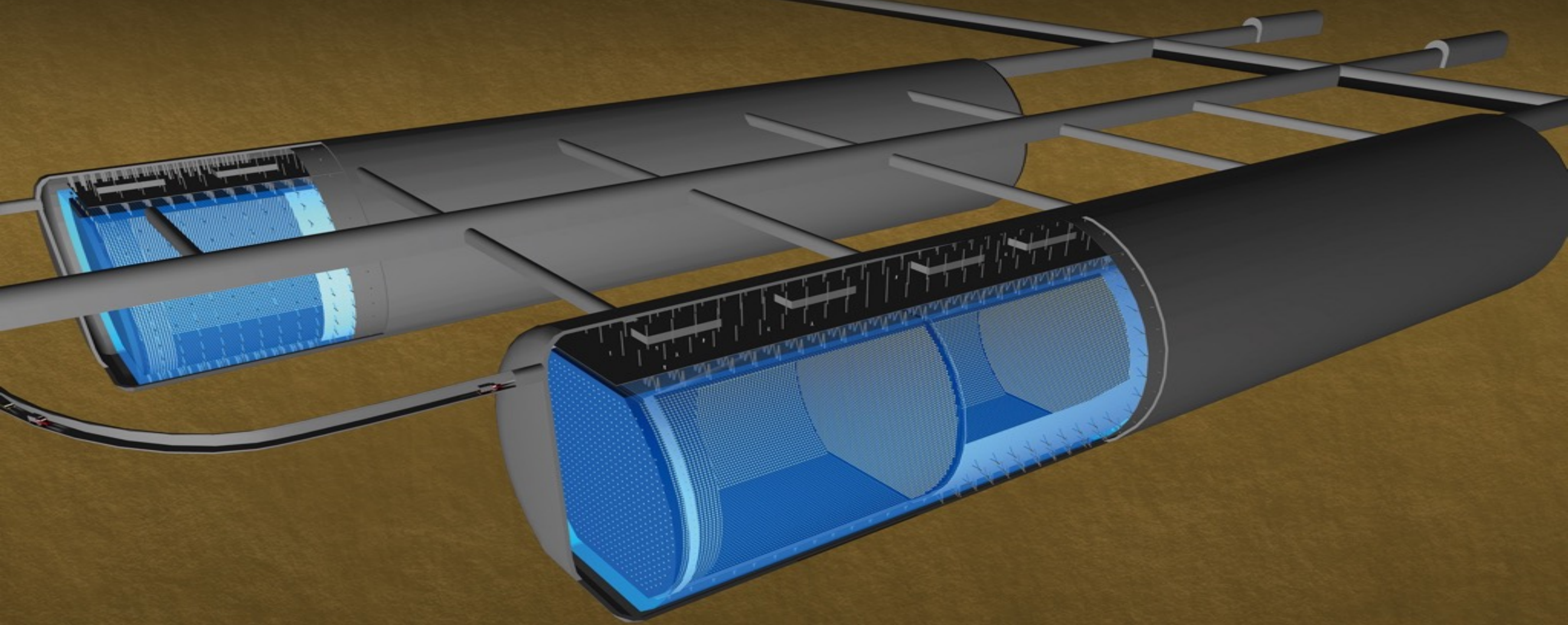
Hyper-K

present status and R&D for the next decade



David Hadley
University of Warwick

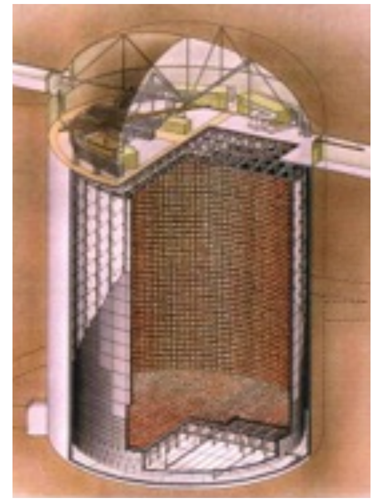
29th May 2015

Kamiokande Detectors

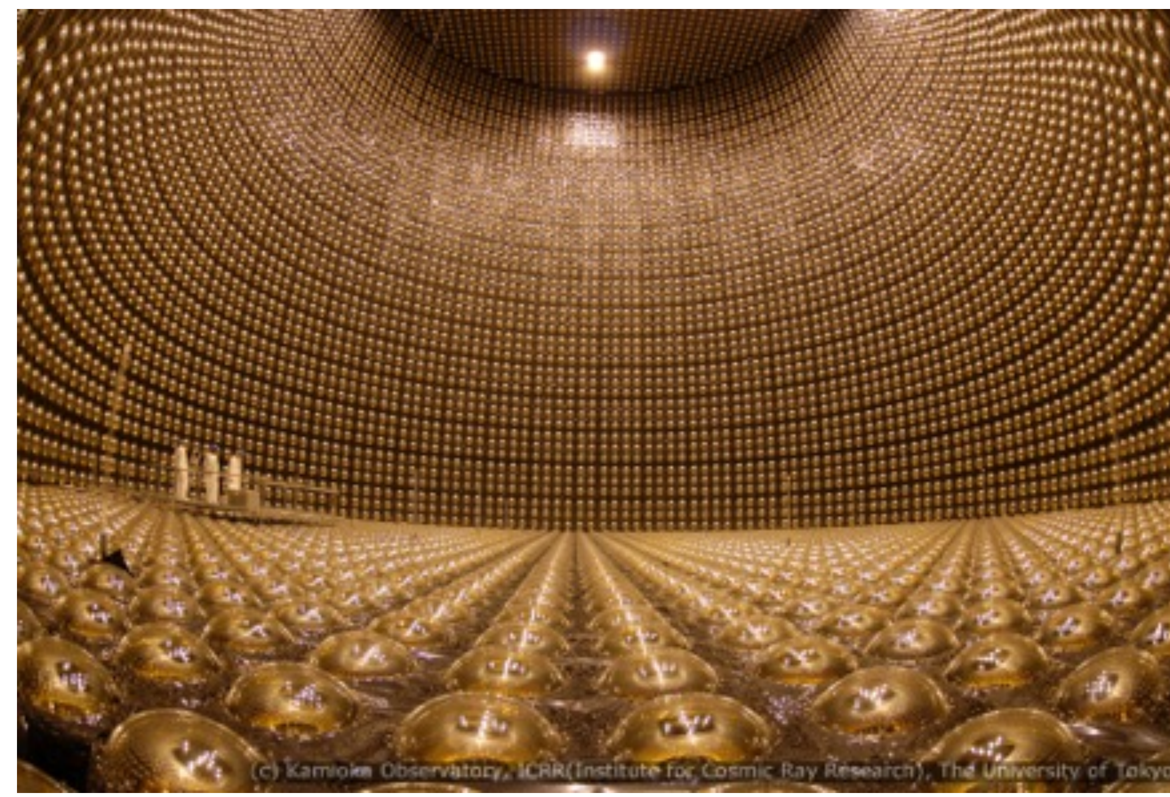
Kamiokande
680 tonne
fiducial mass
(1983)

Kamiokande Detectors

Kamiokande
680 tonne
fiducial mass
(1983)

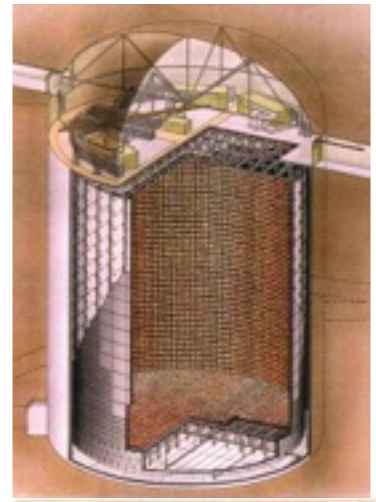


Super-Kamiokande
22.5kt fiducial mass
(33x Kamiokande)
(1996)



Kamiokande Detectors

Kamiokande
680 tonne
fiducial mass
(1983)



Super-Kamiokande
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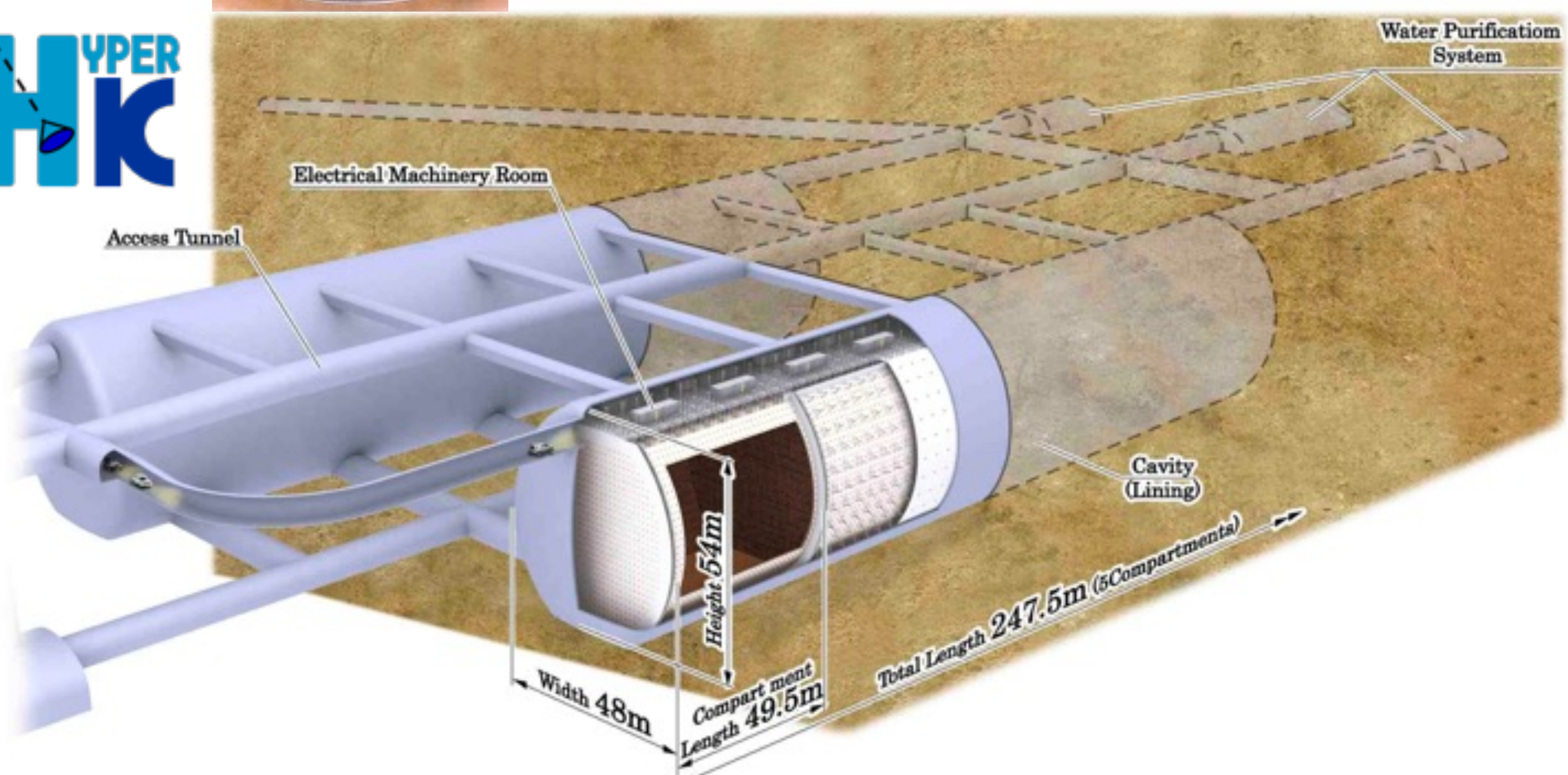
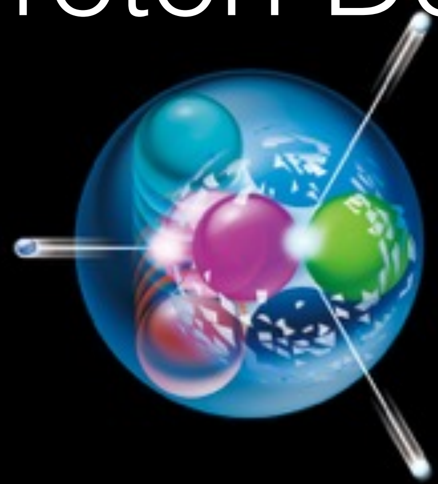
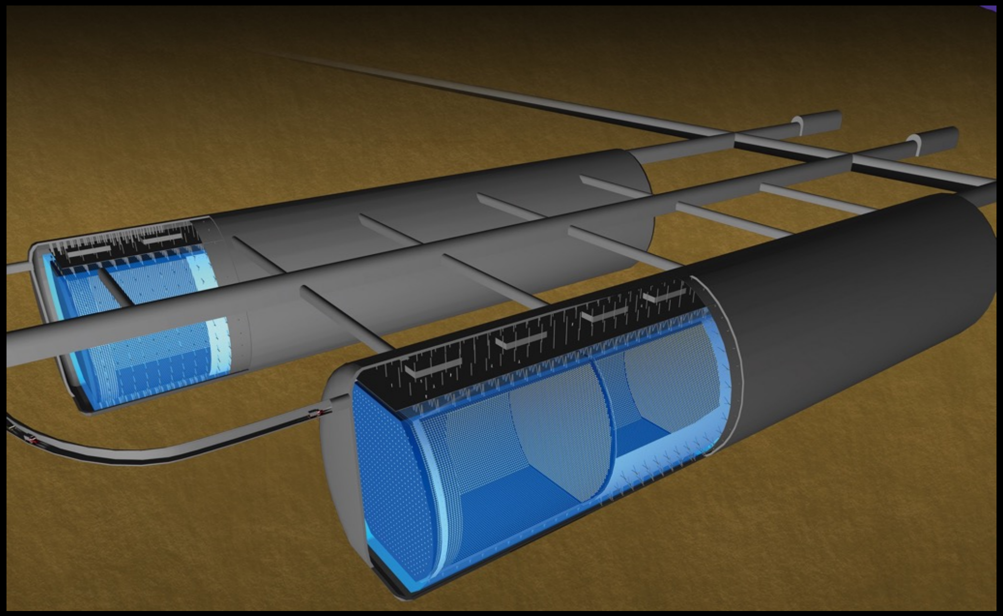


Megaton scale Water Cherenkov detector
x25 larger fiducial volume than Super-K.
(202X)

Physics at Hyper-K

Proton Decay

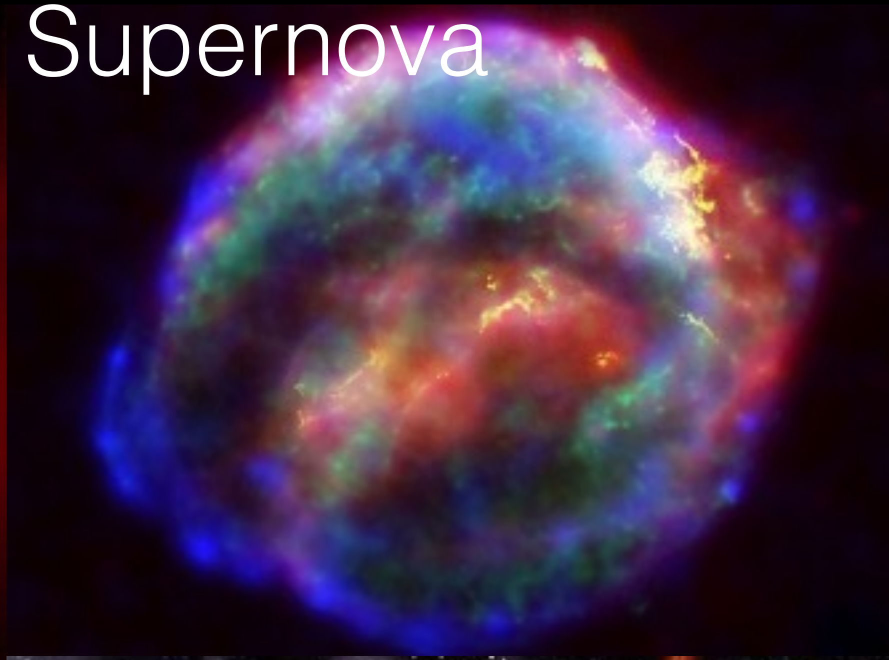




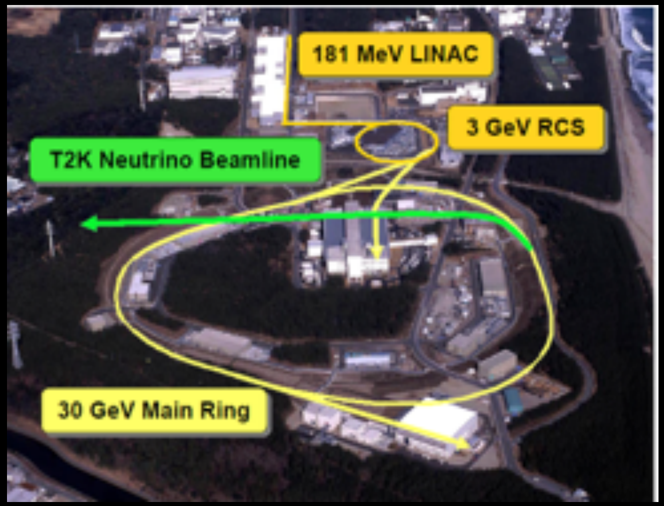
Neutrinos

Solar

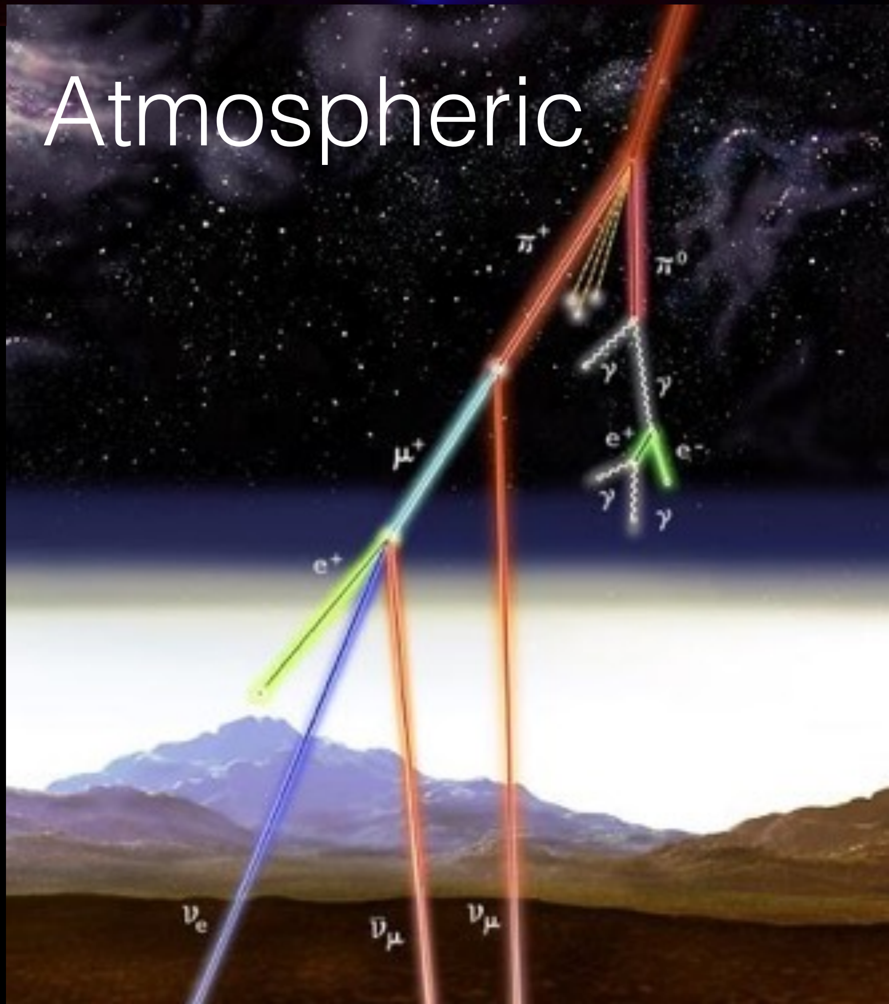
Supernova



Accelerator



Atmospheric



Broad physics programme.

Physics at Hyper-K

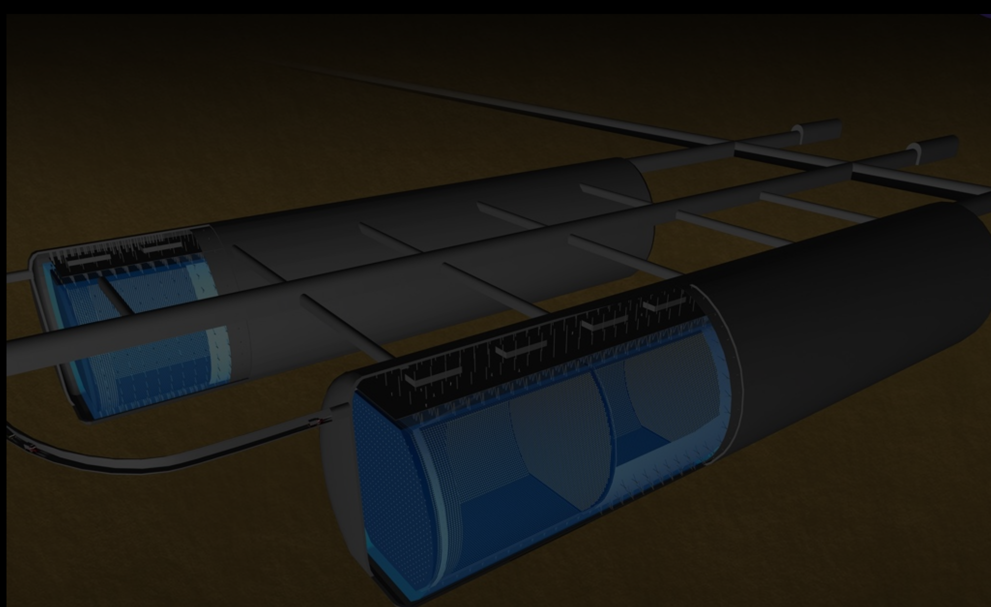
Proton Decay

$p \rightarrow e^+ + \pi^0$

$>1.3\times10^{35}$ years 90% CL

$p \rightarrow \bar{\nu} + K^+$

$>3.2\times10^{34}$ years 90% CL



Neutrinos

Solar

Supernova

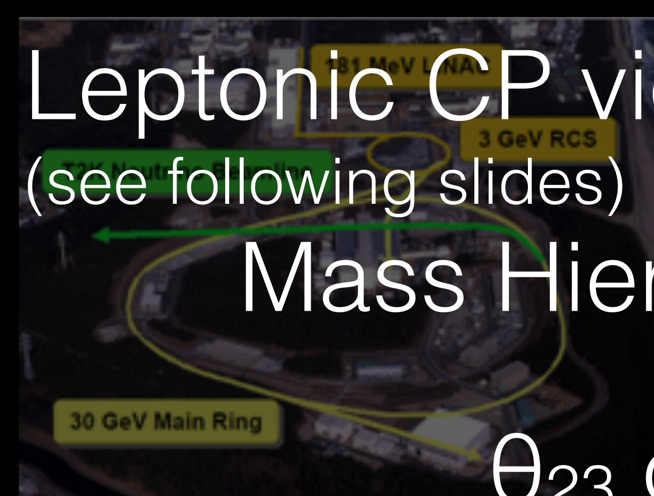
SN ~200,000 @ 10kPC

SN ~30-50 @ M31

200 solar ν per day

Indirect dark matter search

Accelerator



Atmospheric

Leptonic CP violation

(see following slides)

Mass Hierarchy determination

$>3\sigma$

θ_{23} octant determination

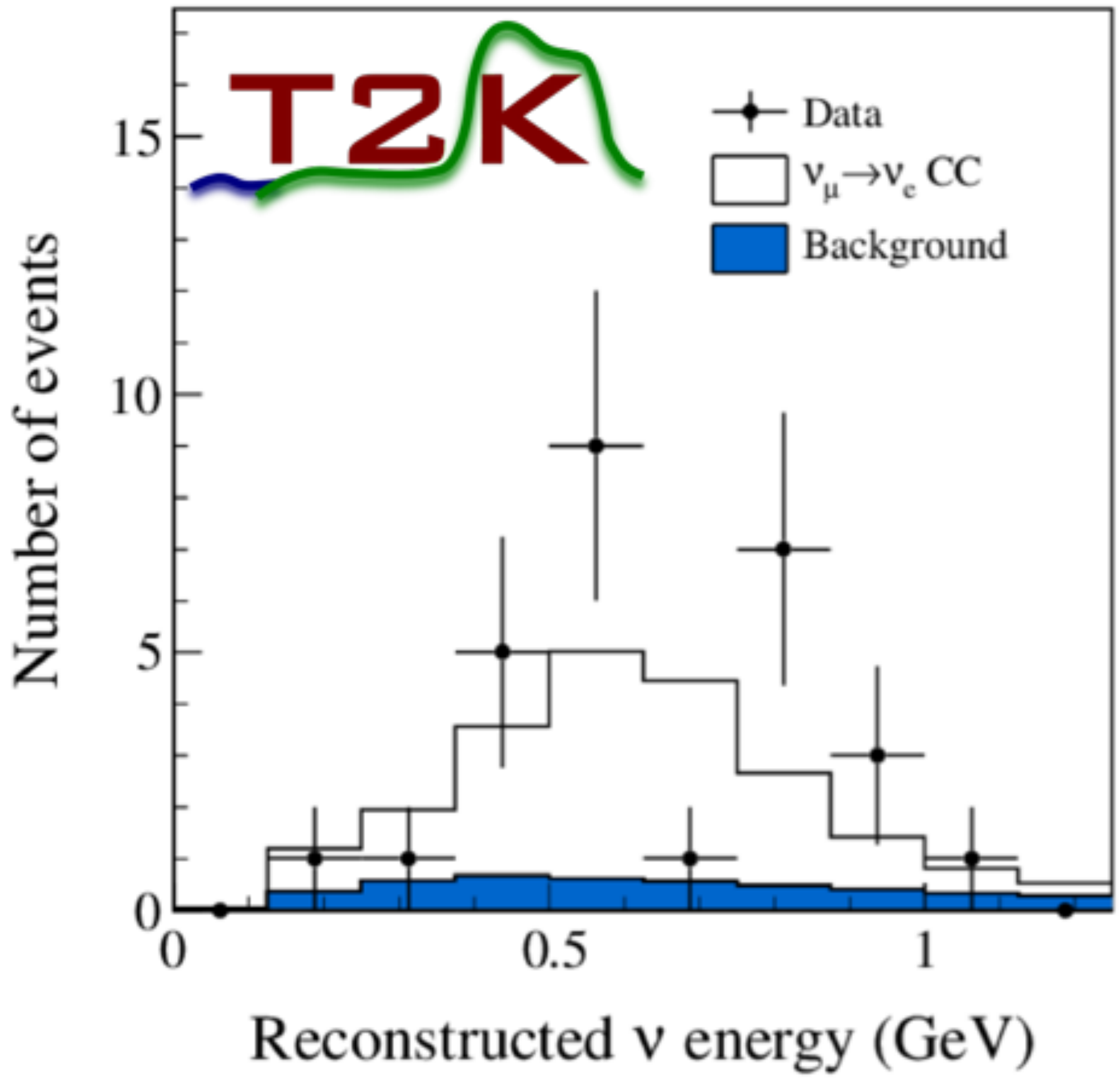
3σ for $\sin^2\theta_{23} > 0.56$ or $\sin^2\theta_{23} < 0.46$

Broad physics programme.

Leptonic CP Violation

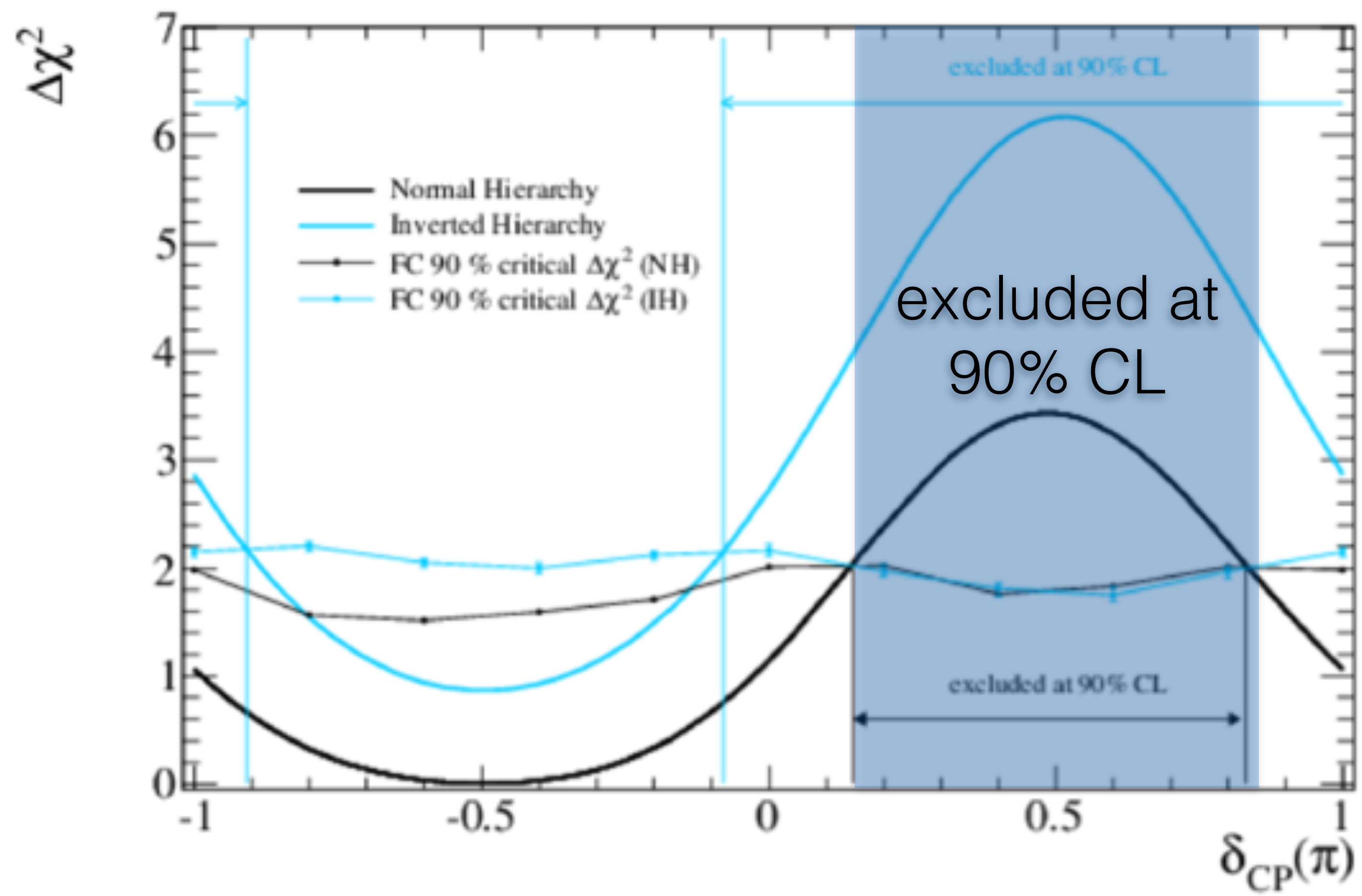
ν_e appearance established

28 events observed (4.3 expected background)



effect is large, opens the way to leptonic CP violation δ_{CP}.

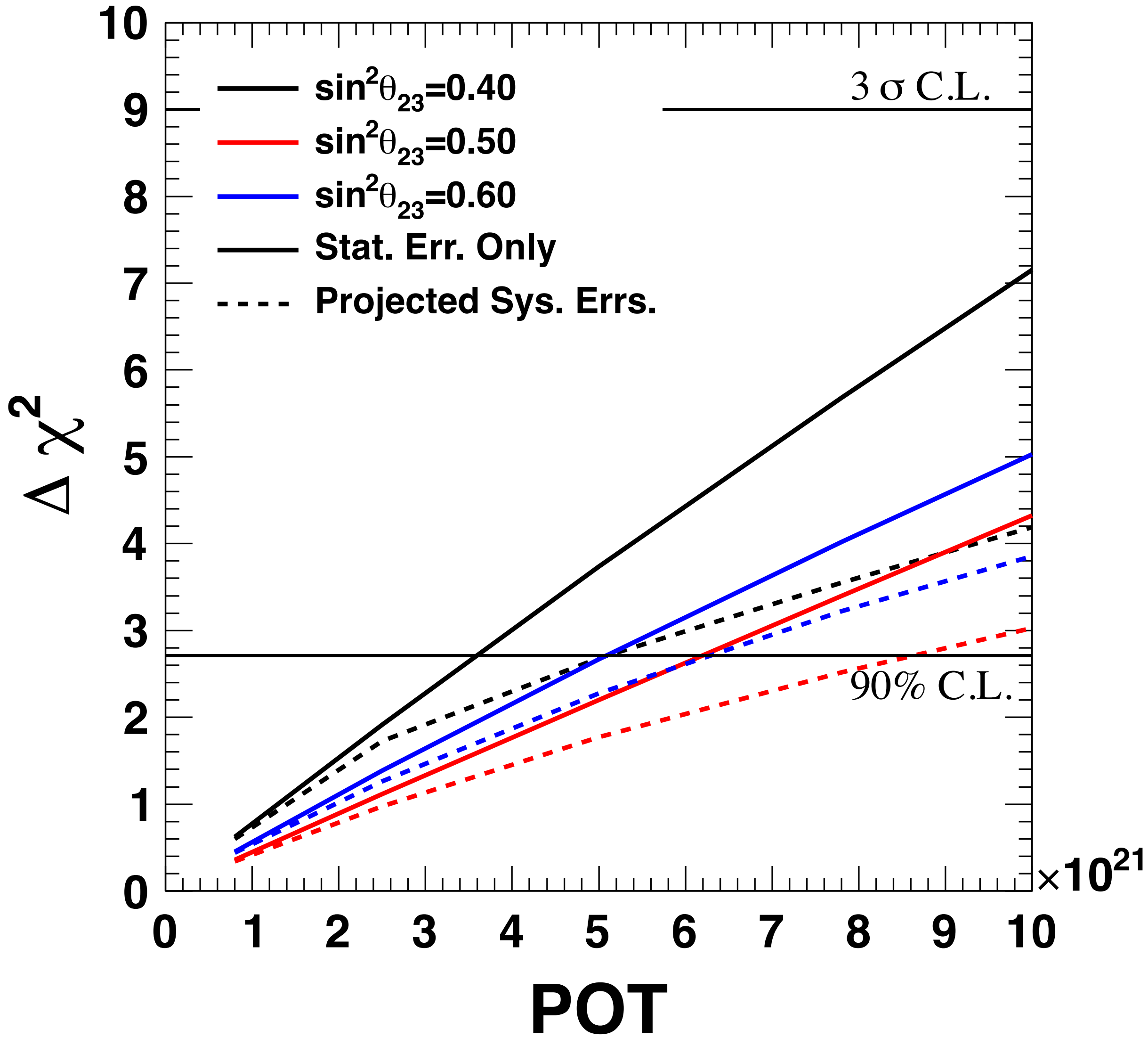
arXiv:1502.01550 [hep-ex]



T2K + reactor experiments
First constraints on δ_{CP}

Leptonic CP Violation

arXiv:1409.7469 [hep-ex]



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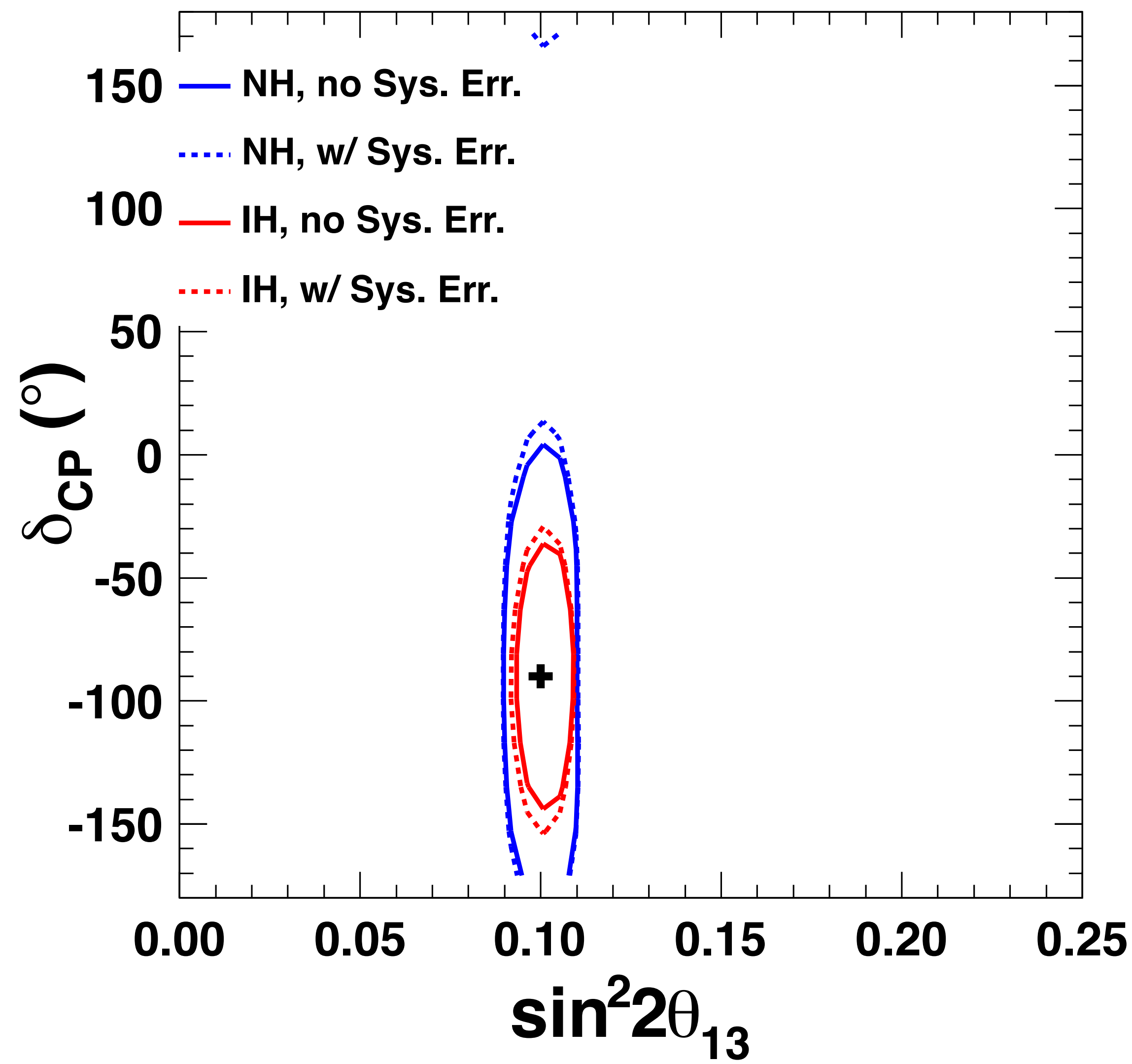


~2.5σ projected significance if *maximal CP violation*.

to firmly establish CP violation we will need **Hyper-K**!

THE UNIVERSITY OF WARWICK

Why Water Cherenkov?

Scalability

Water is cheap, non-toxic, liquid at room temperature

we already know how to build big water WC detectors

Proven technology

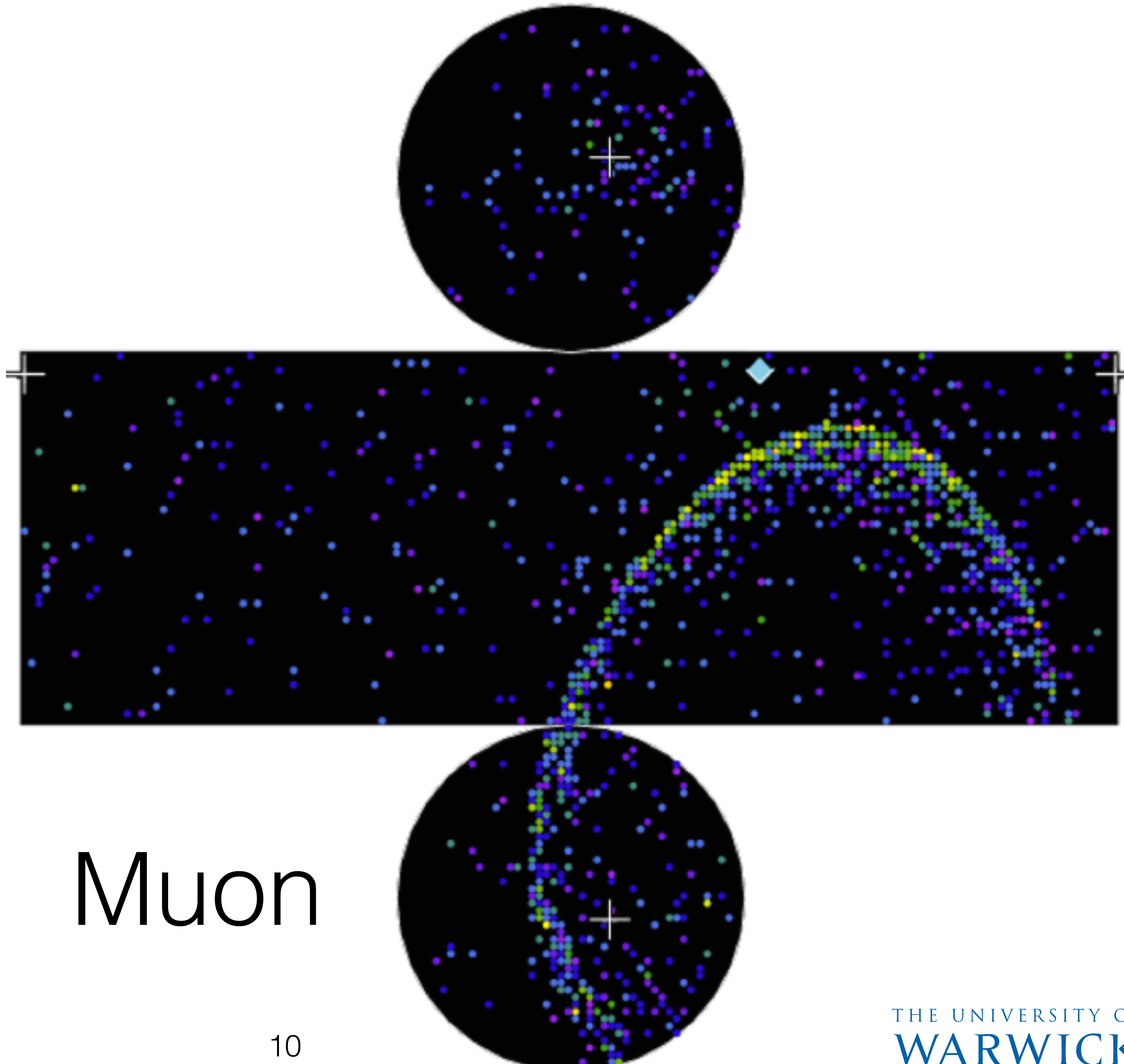
many years of experience from Super-K

low risk

Excellent performance

based on real Super-K and T2K performance

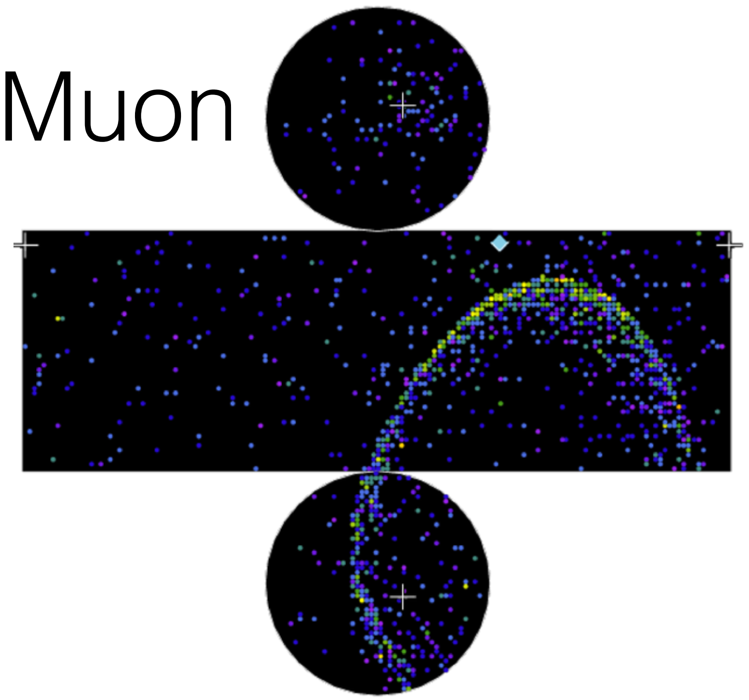
Water Cherenkov Technique

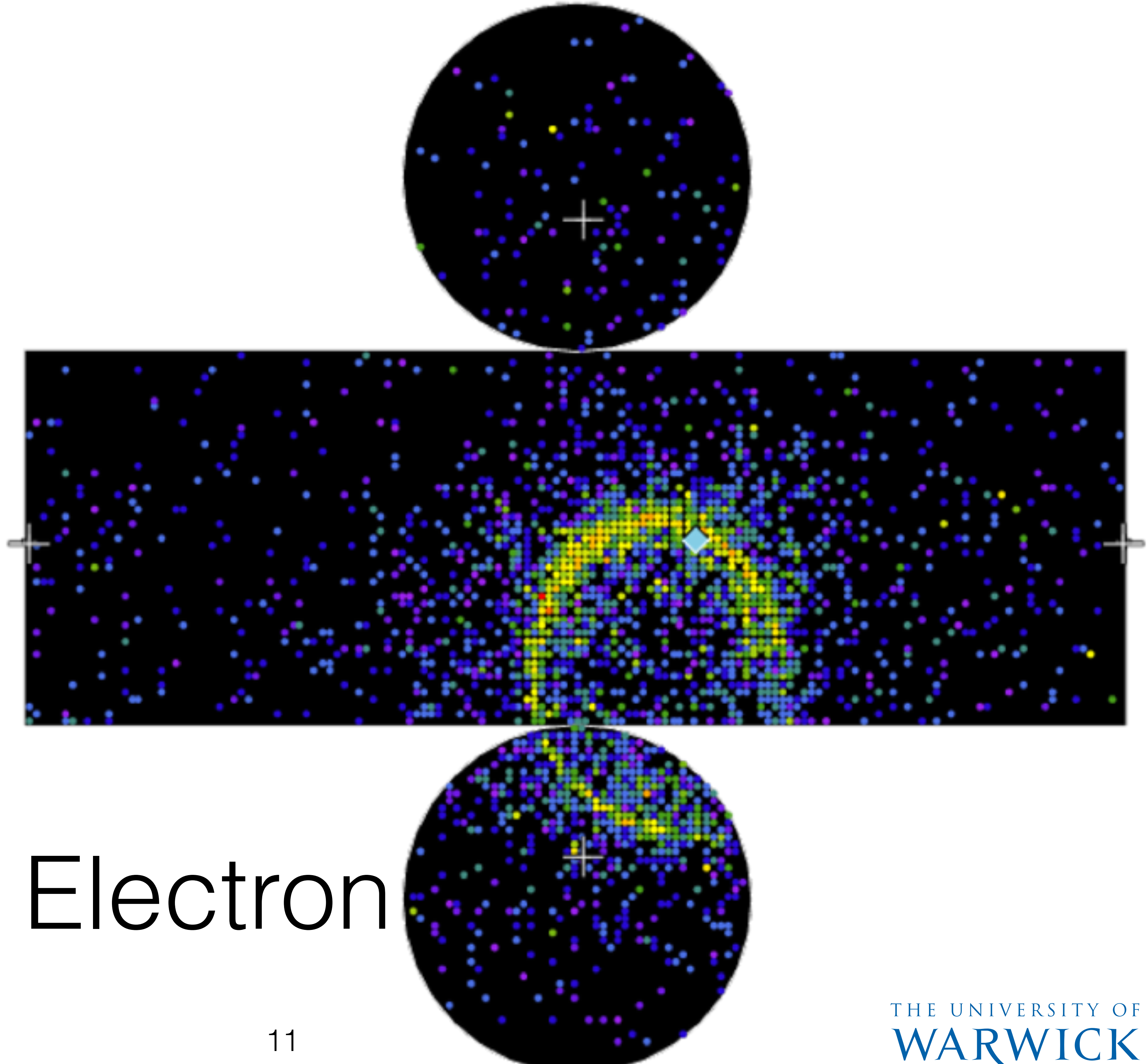


Muon

Water Cherenkov Technique

Muon

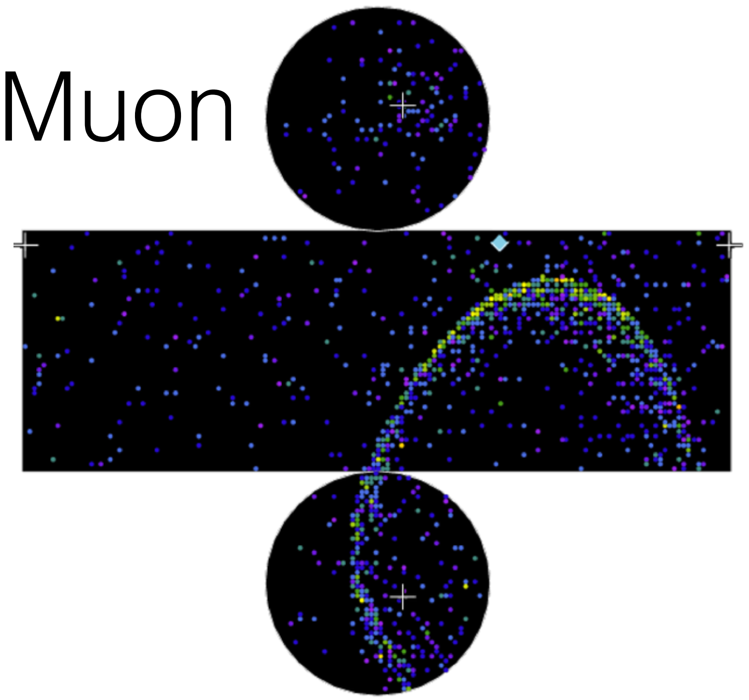




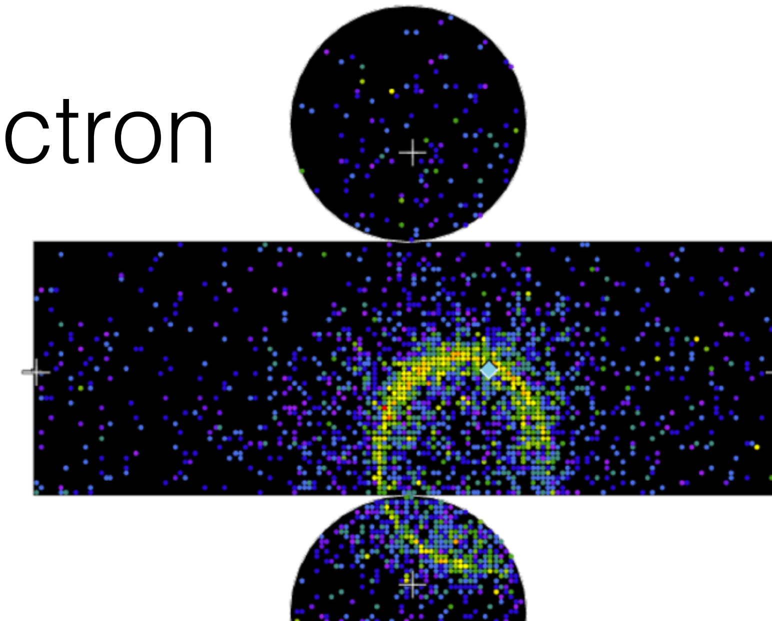
Electron

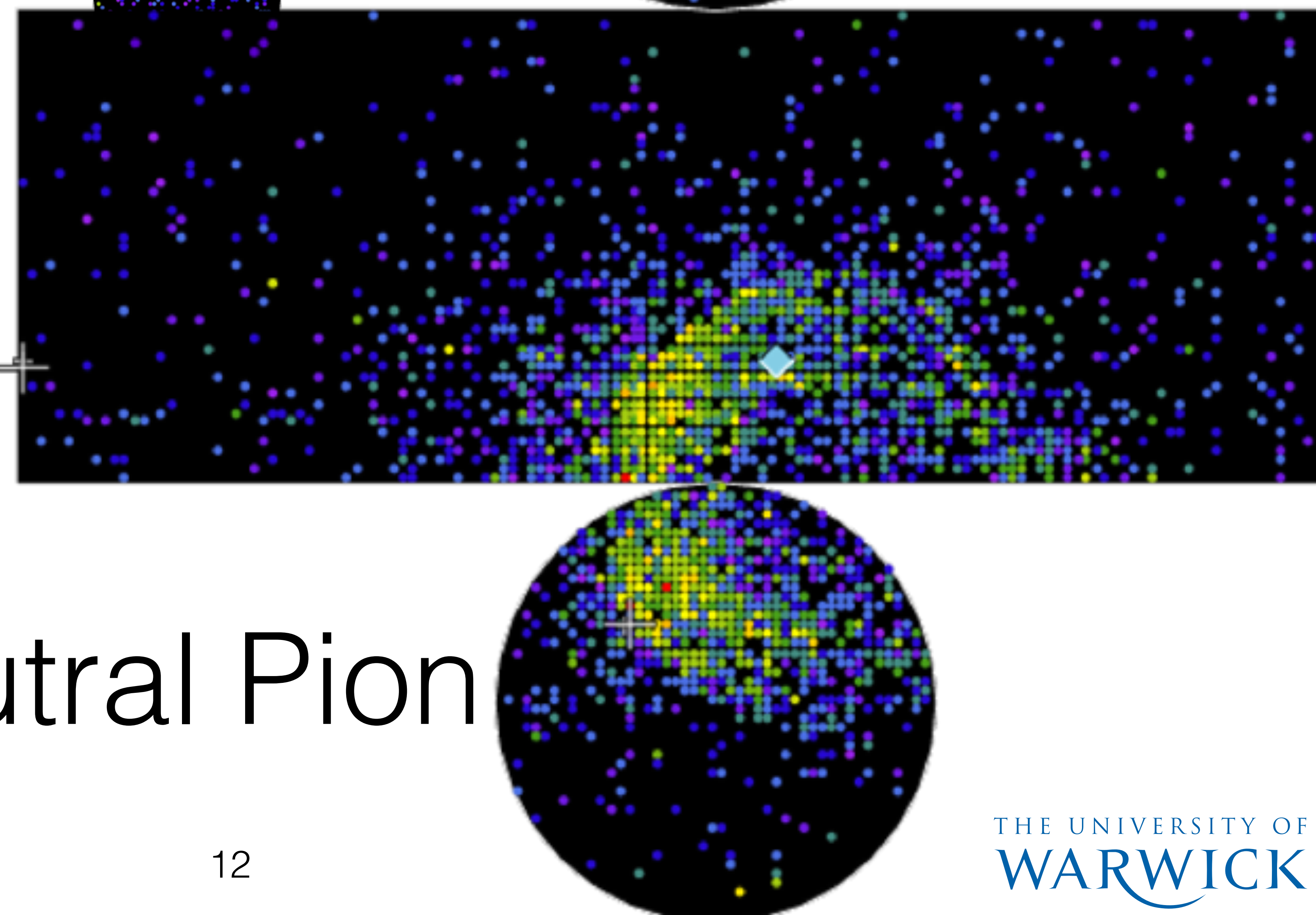
Water Cherenkov Technique

Muon



Electron

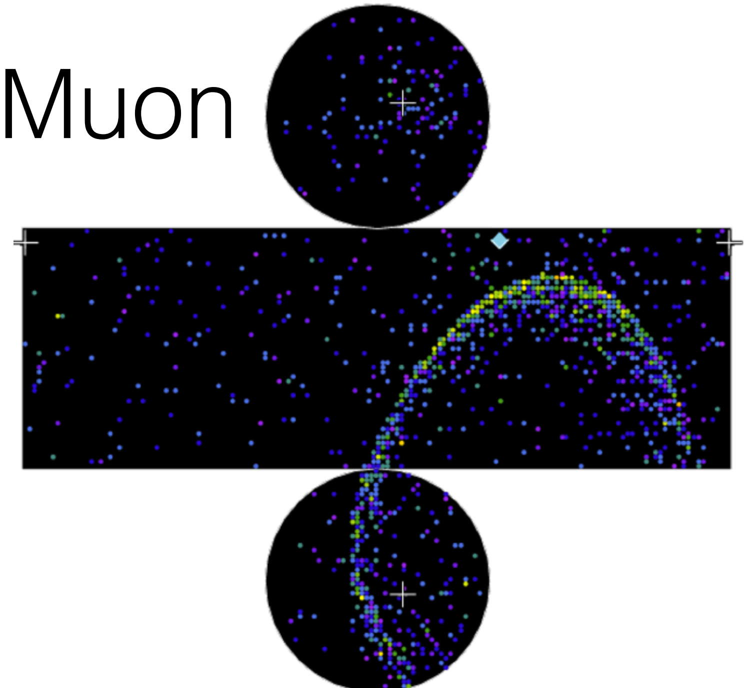




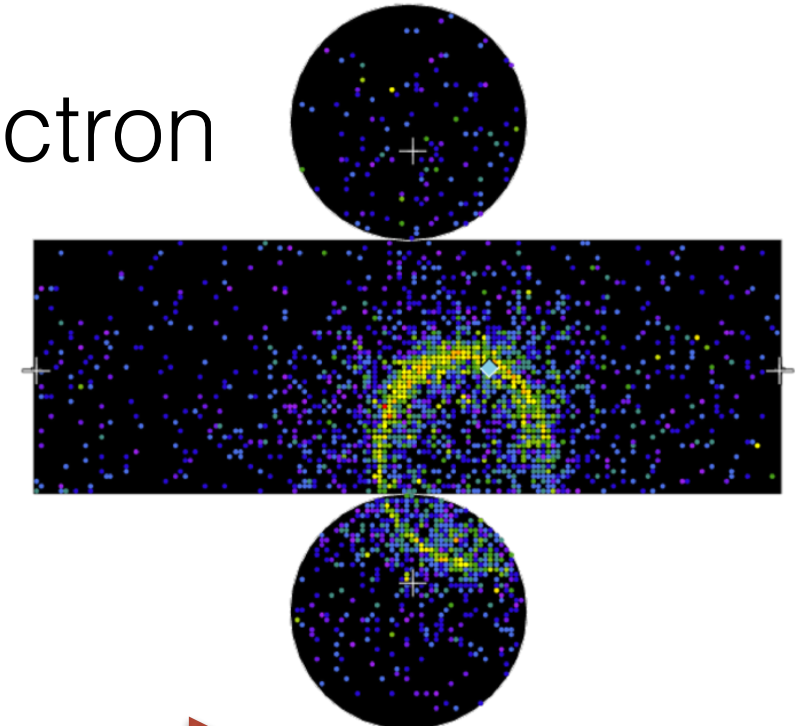
Neutral Pion

Water Cherenkov Technique

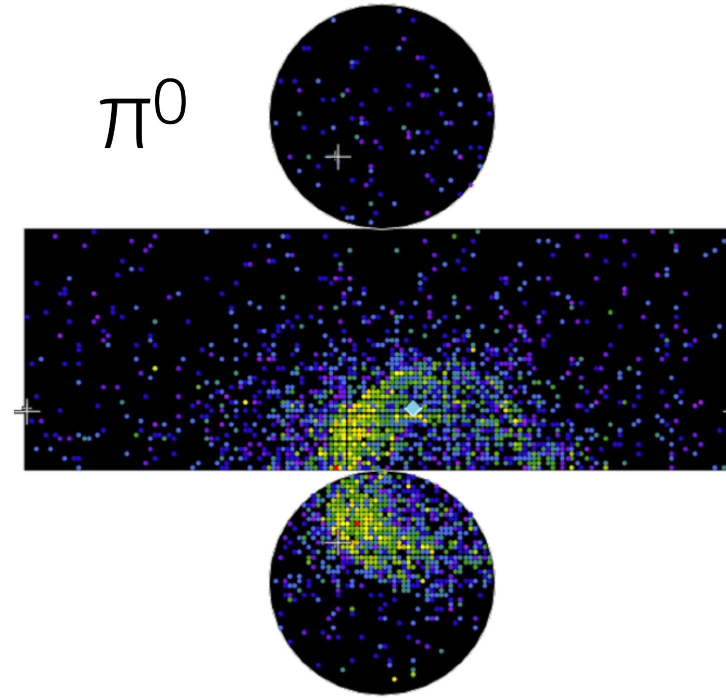
Muon

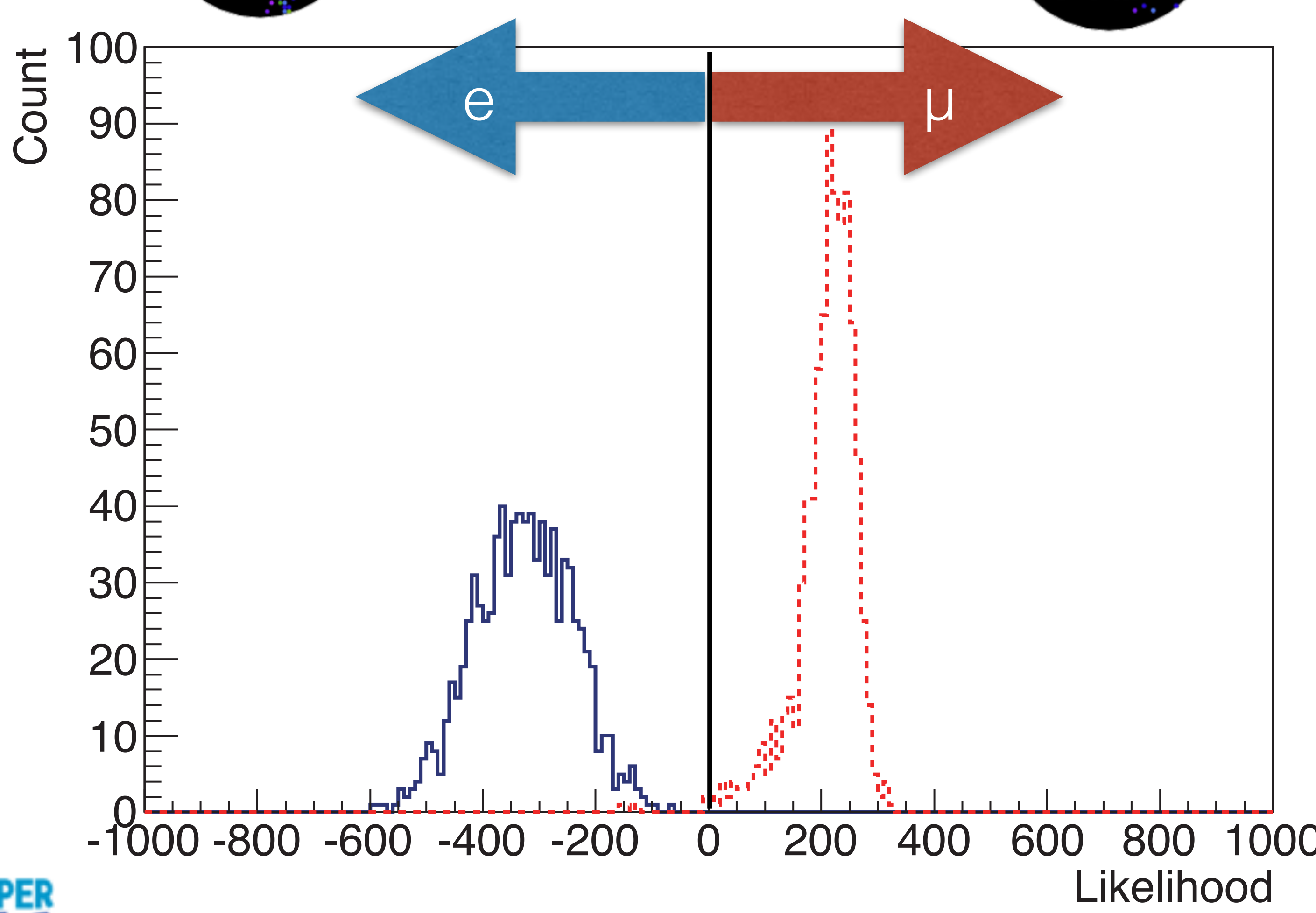


Electron



π^0

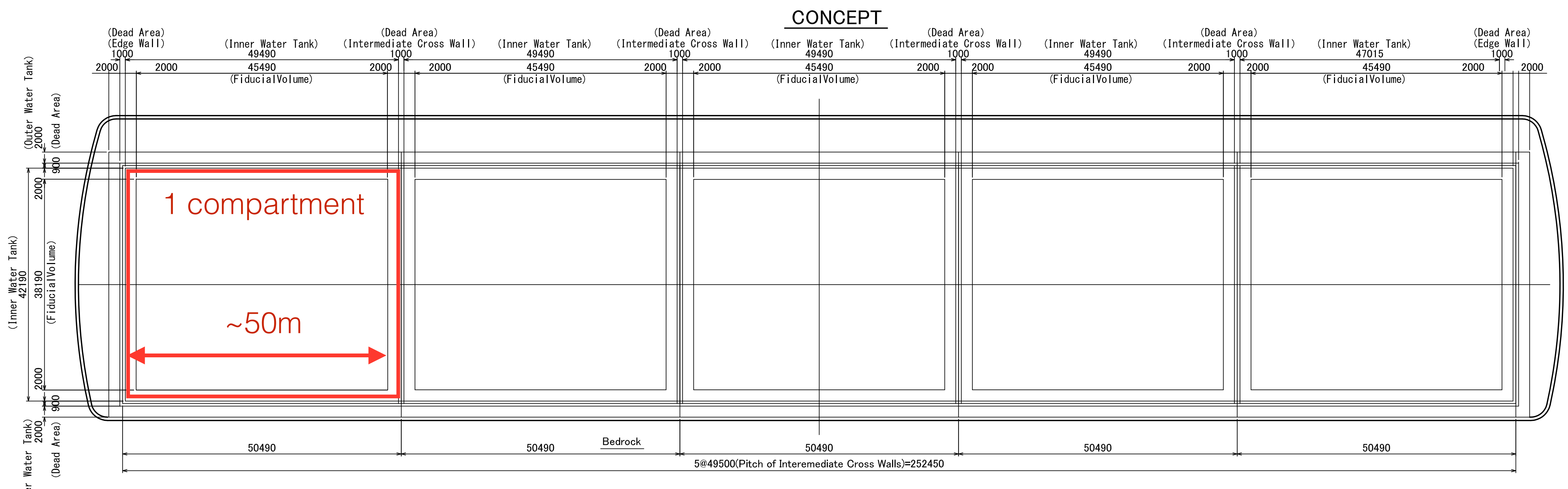


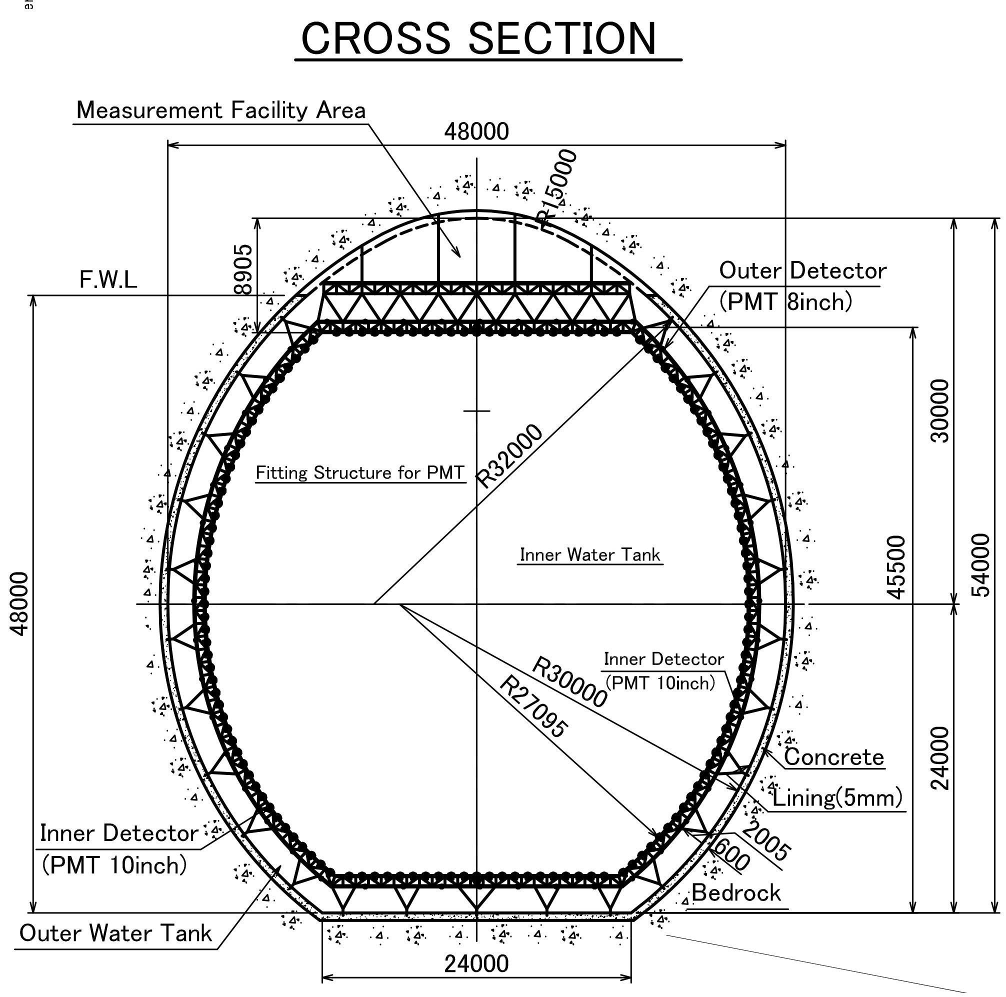


Excellent PID performance

Accelerator ν_e background is dominated by irreducible intrinsic ν_e.

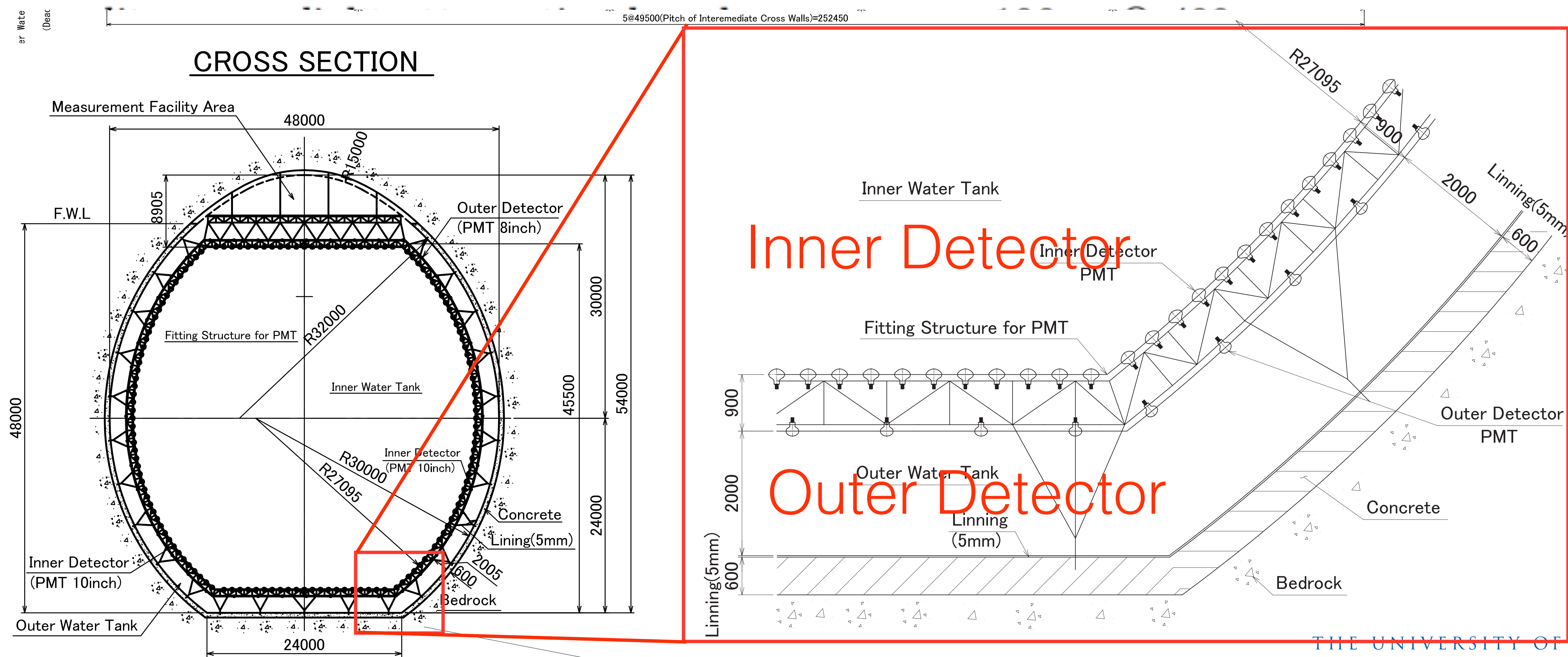
Hyper-K (in detail)





Hyper-K (in detail)

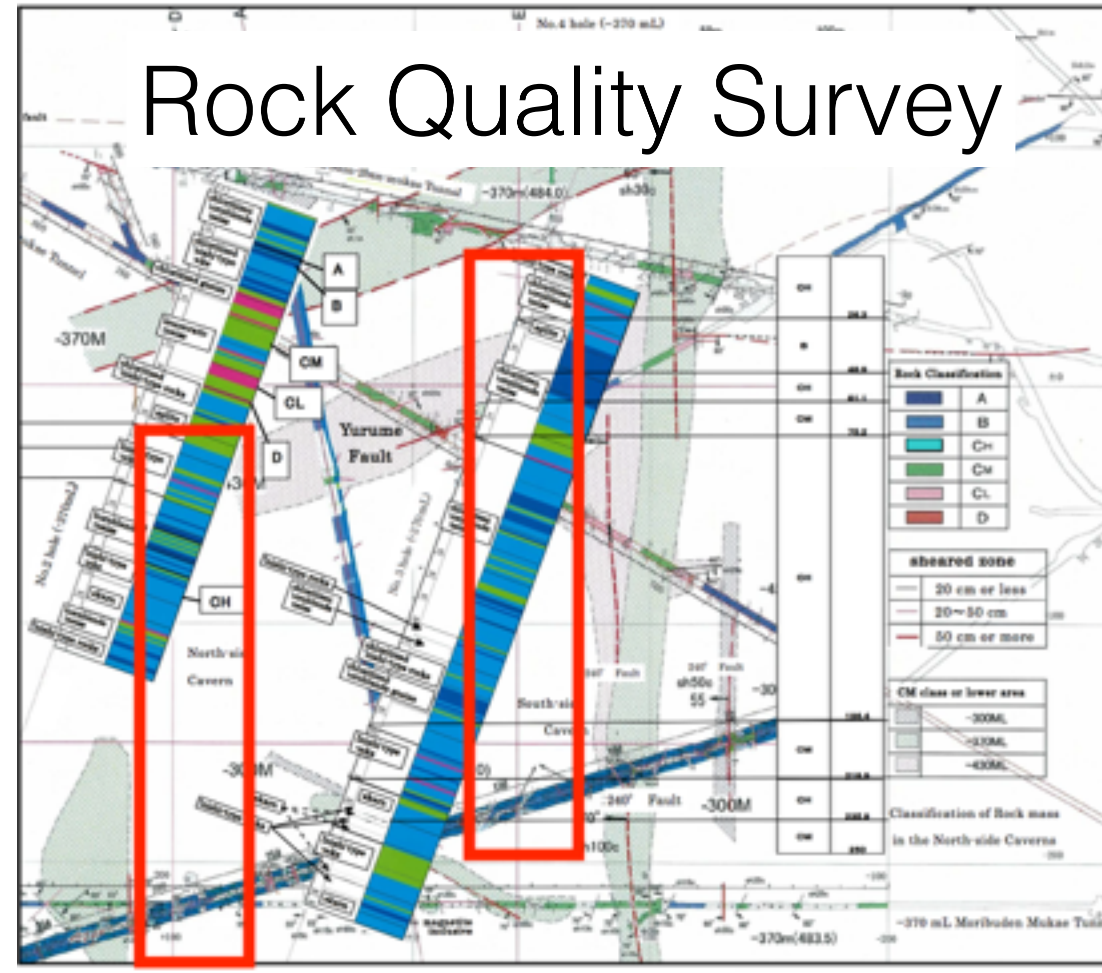
Detector geometry	Total Water Mass	0.99 Megaton
	Inner Detector (Fiducial) Mass	0.74 (0.56) Megaton
	Outer Detector Mass	0.2 Megaton
Photo-sensors	Inner detector	99,000 20-inch ϕ PMTs
		20% photo-coverage
	Outer detector	25,000 8-inch ϕ PMTs



Detector Site

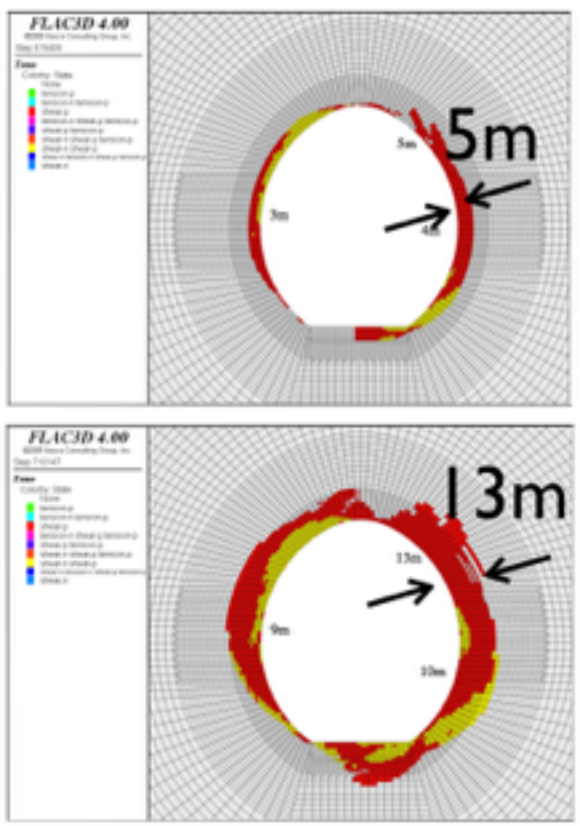
Candidate site: Tochibura Mine
680m rock overburden
1750m water equivalent (cf SK 2700m)

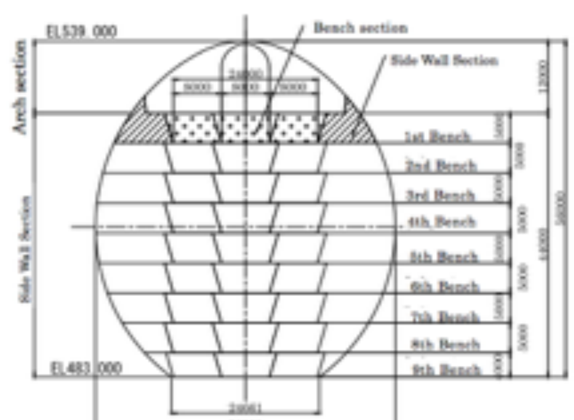
Hyper-K can be constructed with
existing techniques.



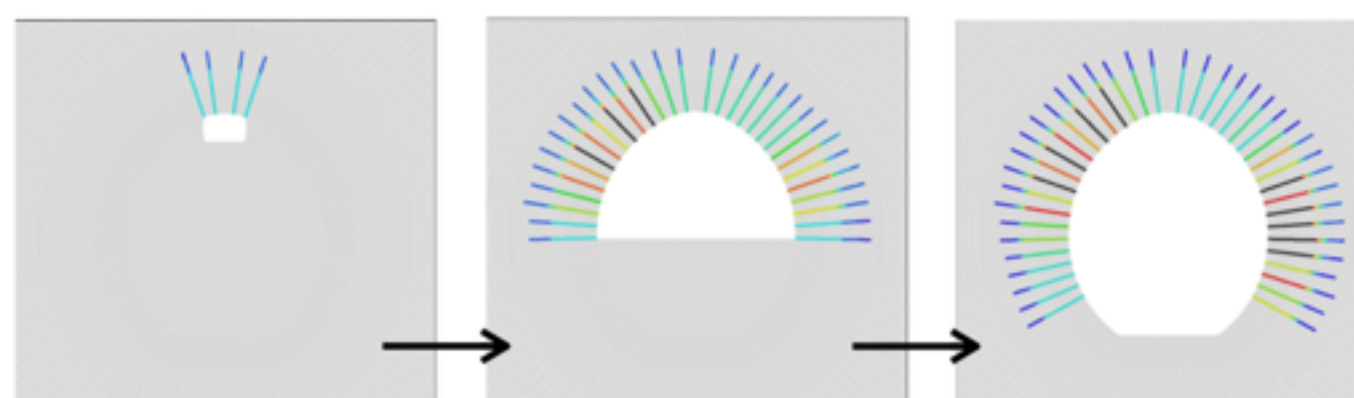
Rock Quality Survey

Alternative site (Mozumi)
also under investigation



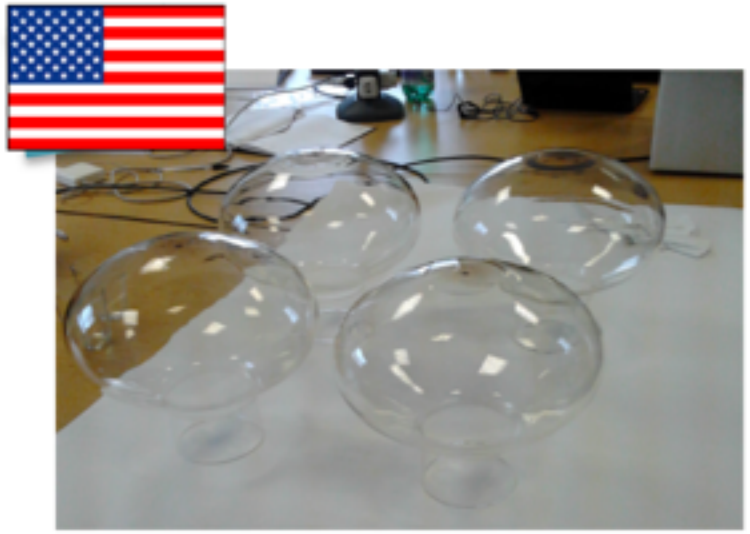


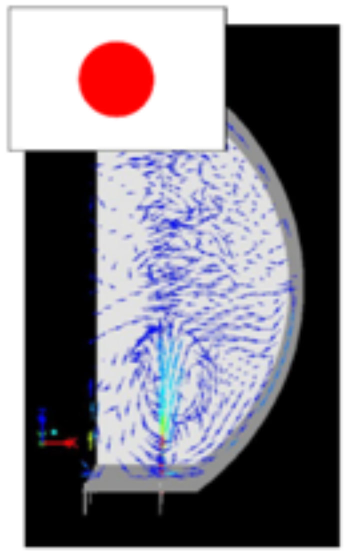
Stability Analysis

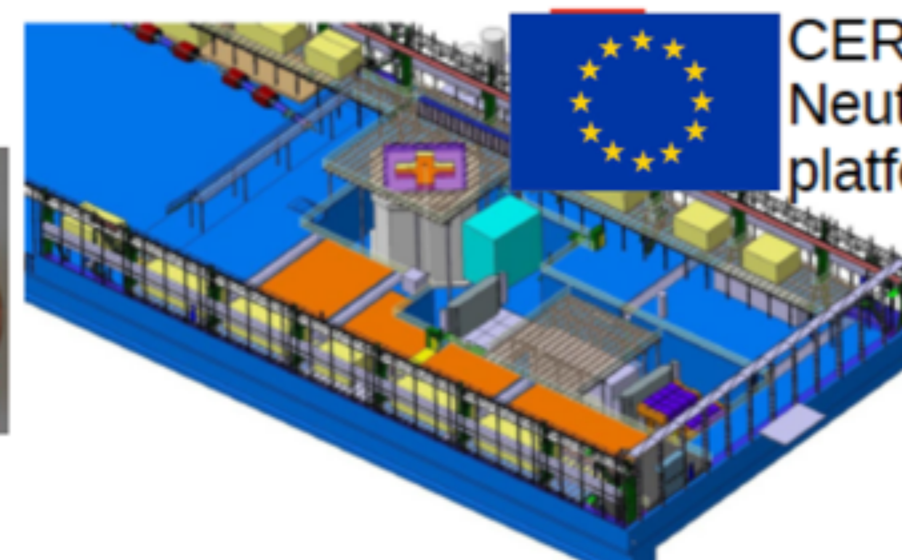


Cavern Excavation and Support

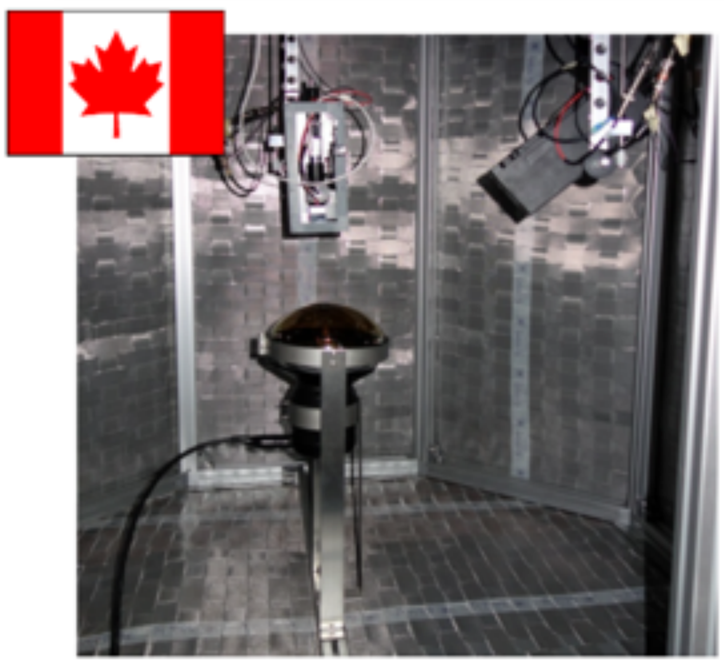
Worldwide R&D

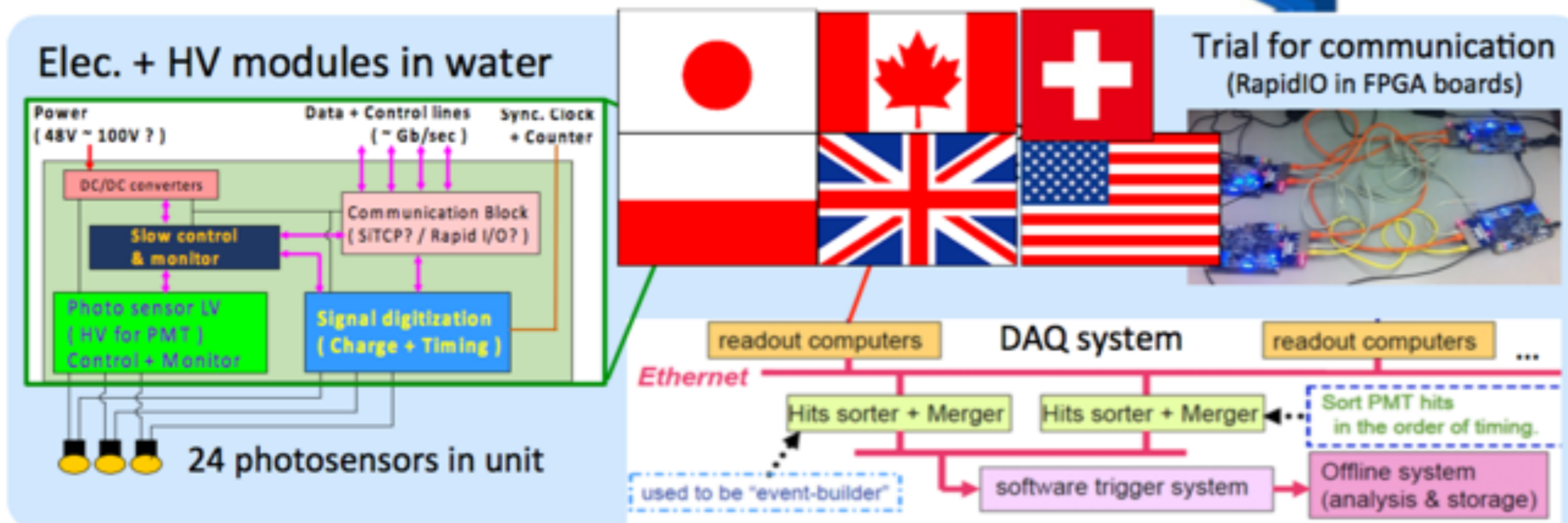


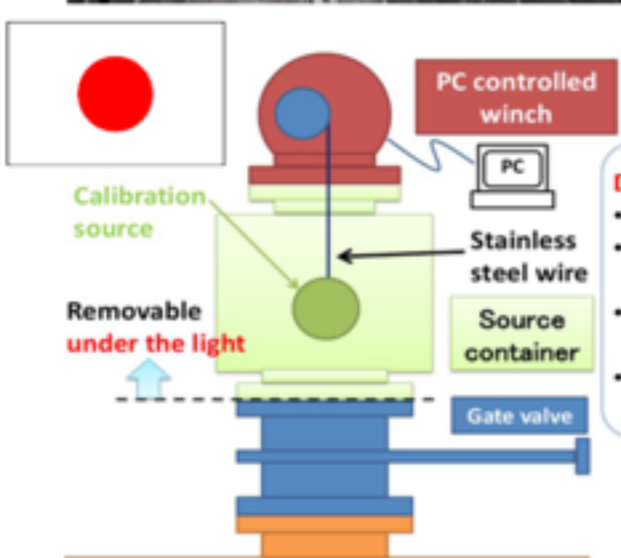




CERN
Neutrino
platform

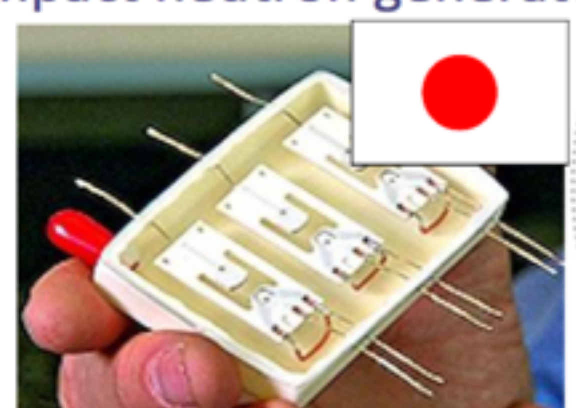


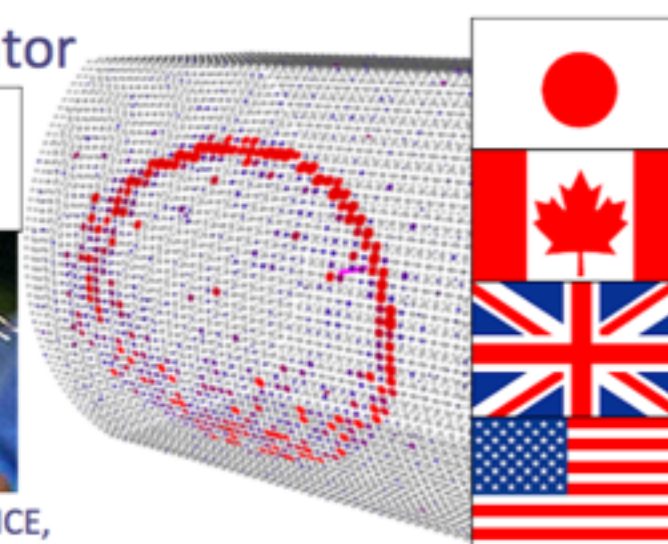




LED

Compact neutron generator





IEEE TRANSACTIONS ON PLASMA SCIENCE,
VOL. 40, NO. 9, SEPTEMBER 2012

Photo Sensors

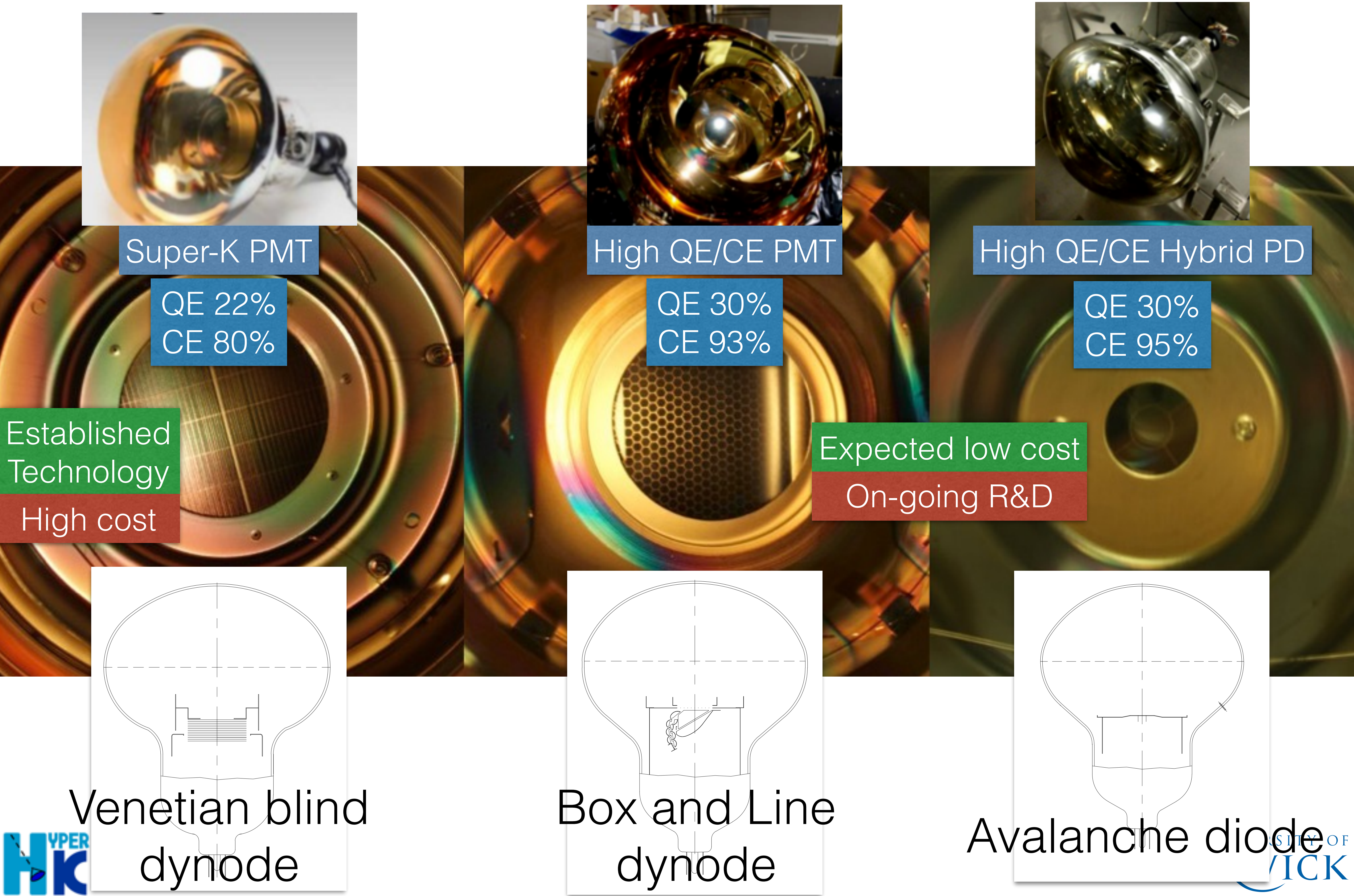
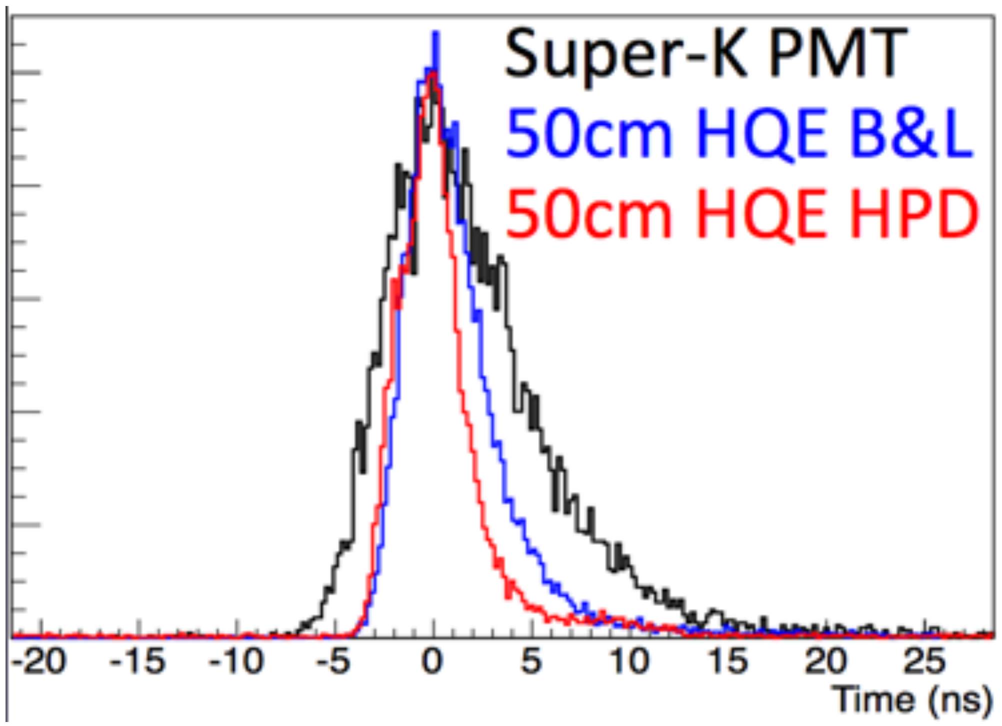
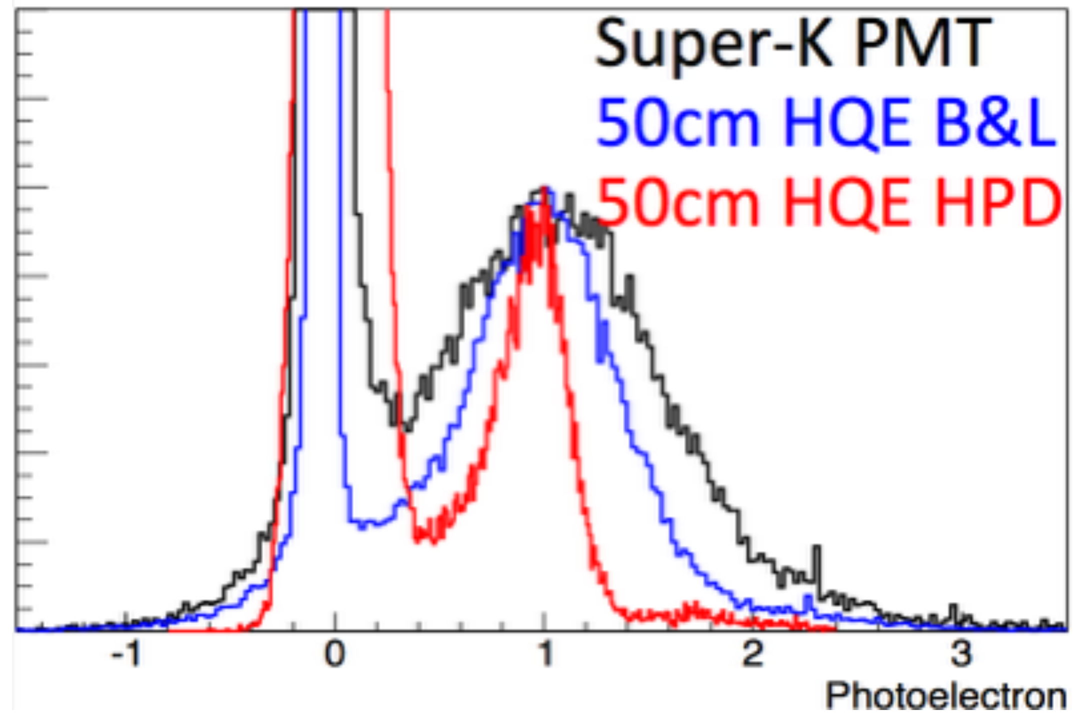


Photo Sensors

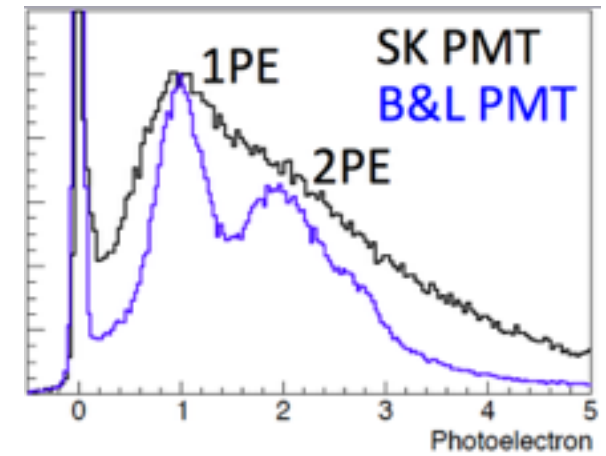
Time Resolution

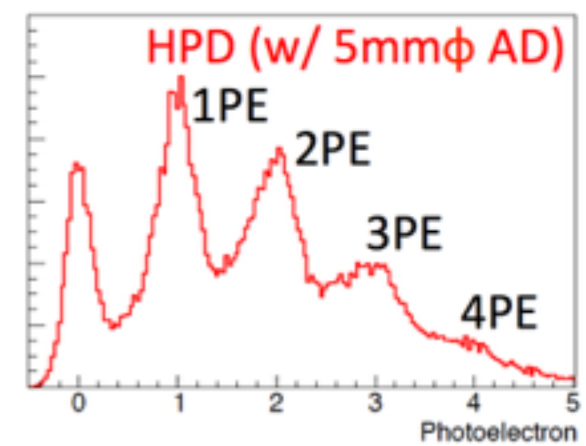


1p.e. charge distribution



Multi-p.e. charge distribution





	SK PMT	B&L PMT	50cm HPD (20cm)
1PE T resolution σ (ns)	2.1	1.1	1.4 (1.1)
FWHM (ns)	7.3	4.1	3.4 (3.3)
1PE Q resolution σ/mean	53%	35%	16% (12%)
Peak-to-Valley ratio	2.2	4.3	3.9 (5.2)

Near Detector Development

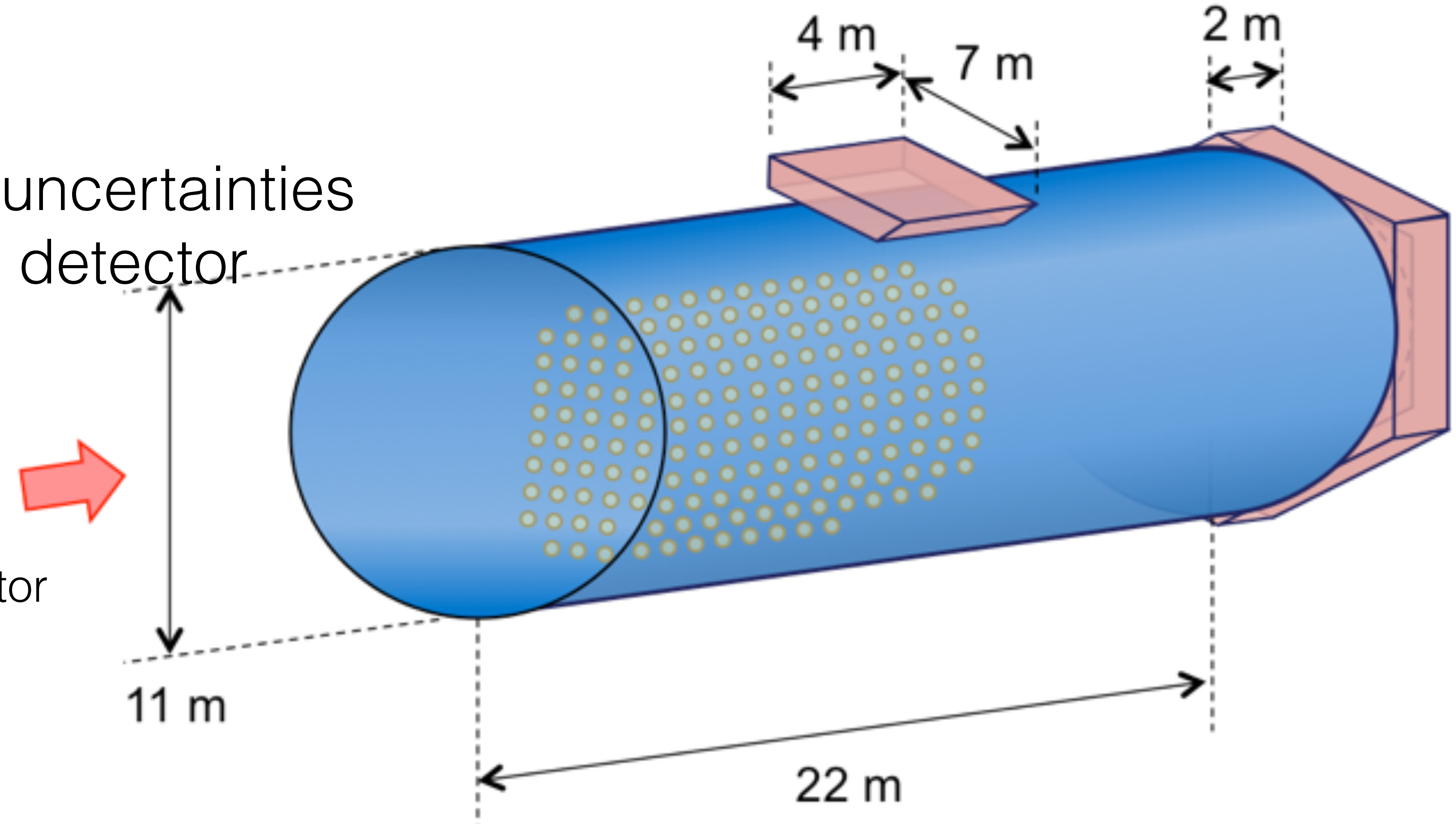
New Intermediate Water Cherenkov Detectors

TITUS Detector

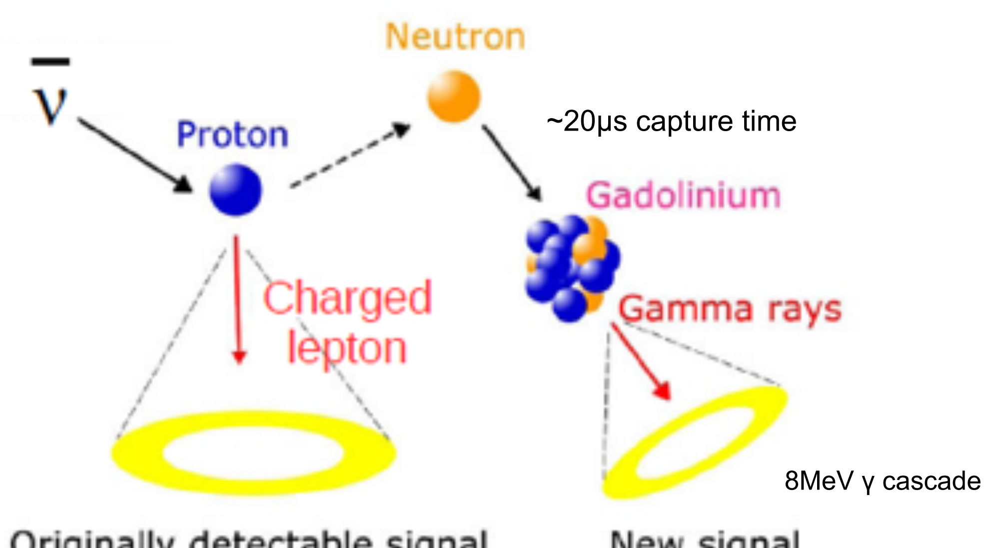
Maximise cancellation of uncertainties between near and far detector

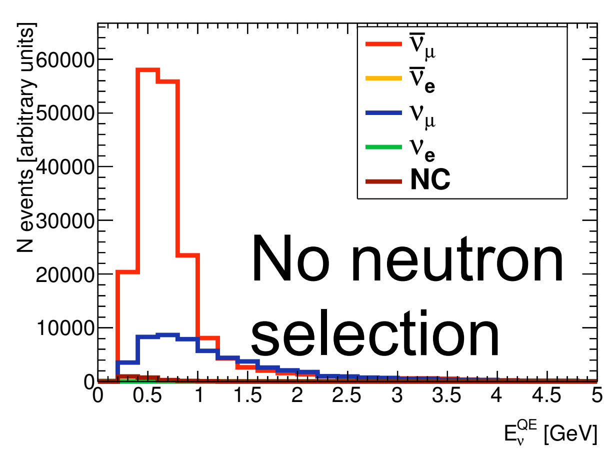
Identical target nucleus and detector technologies

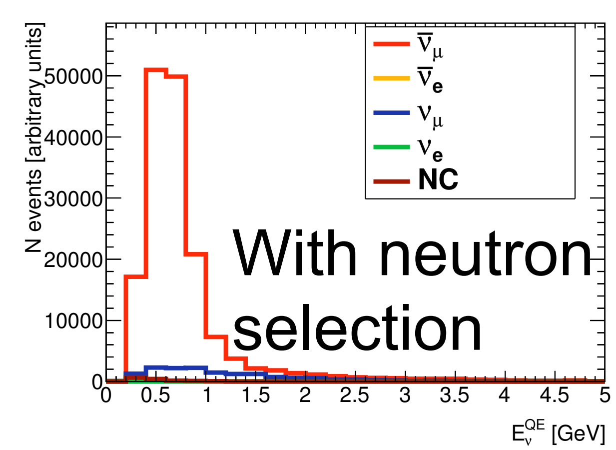
~2 km from beam source match the flux at the far detector



Neutron Capture on Gd







THE UNIVERSITY OF WARWICK

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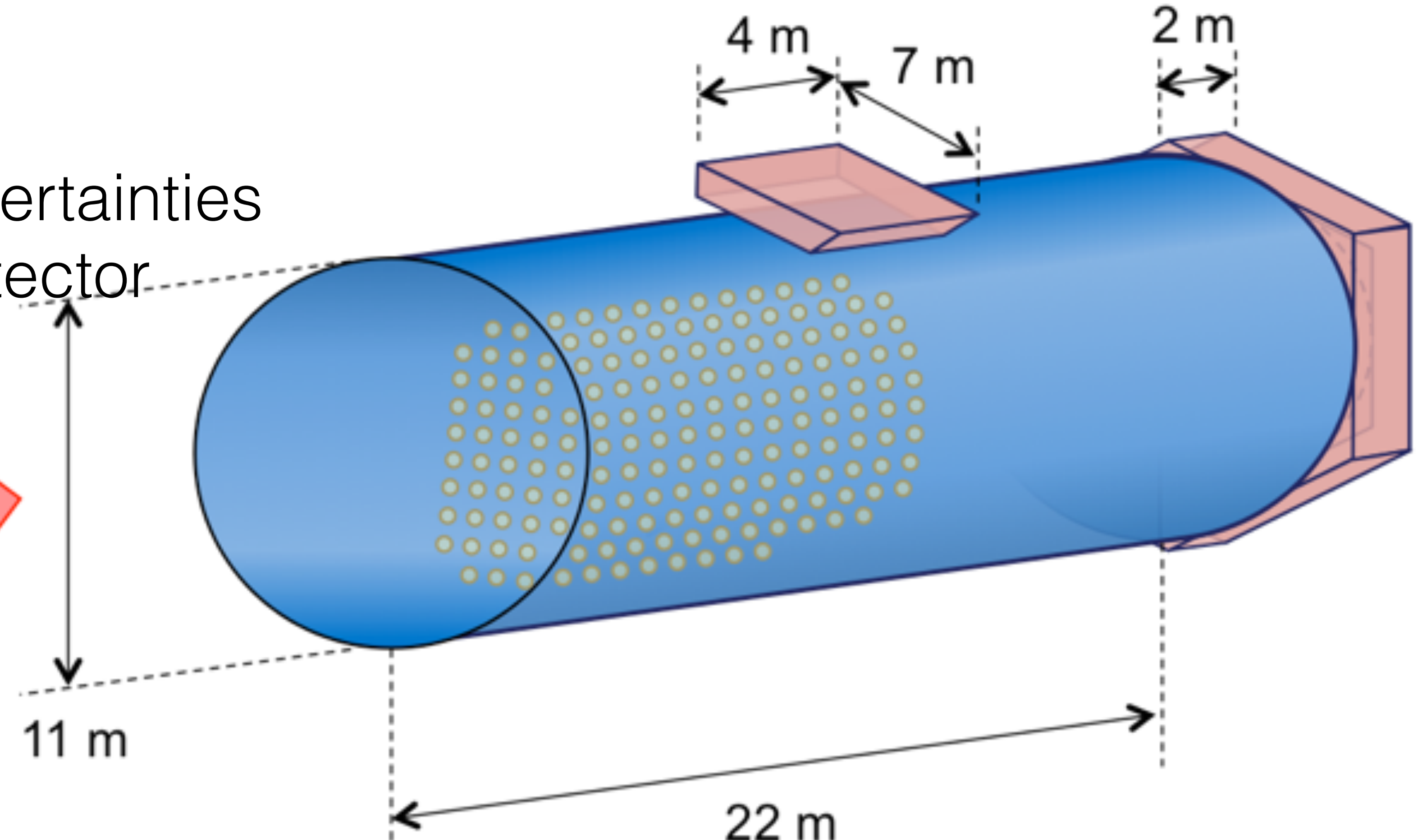
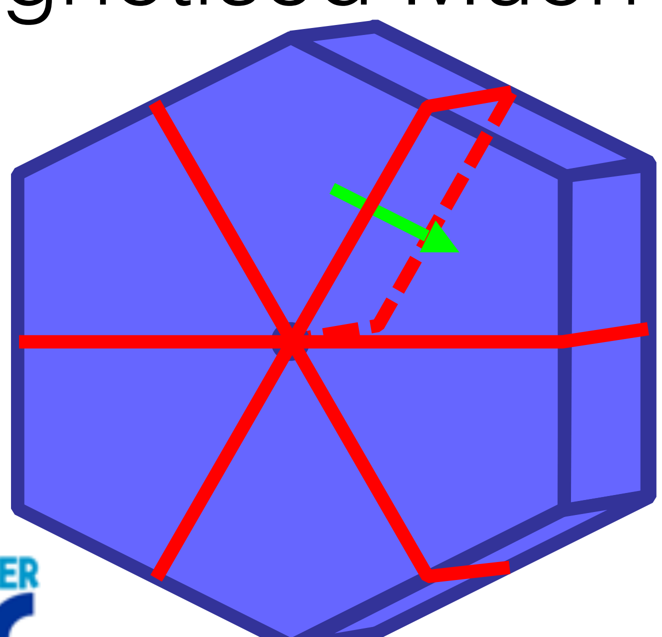
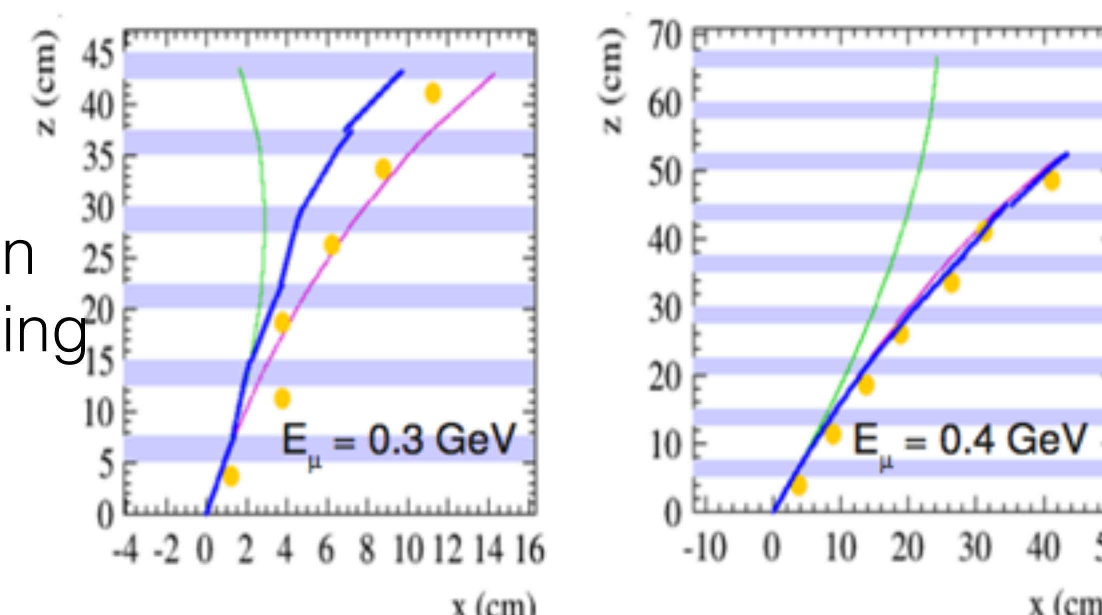


Magnetised Muon Range Detector



Measure momentum of escaping muons.

In-situ cross-check of sign selection with neutron tagging method.



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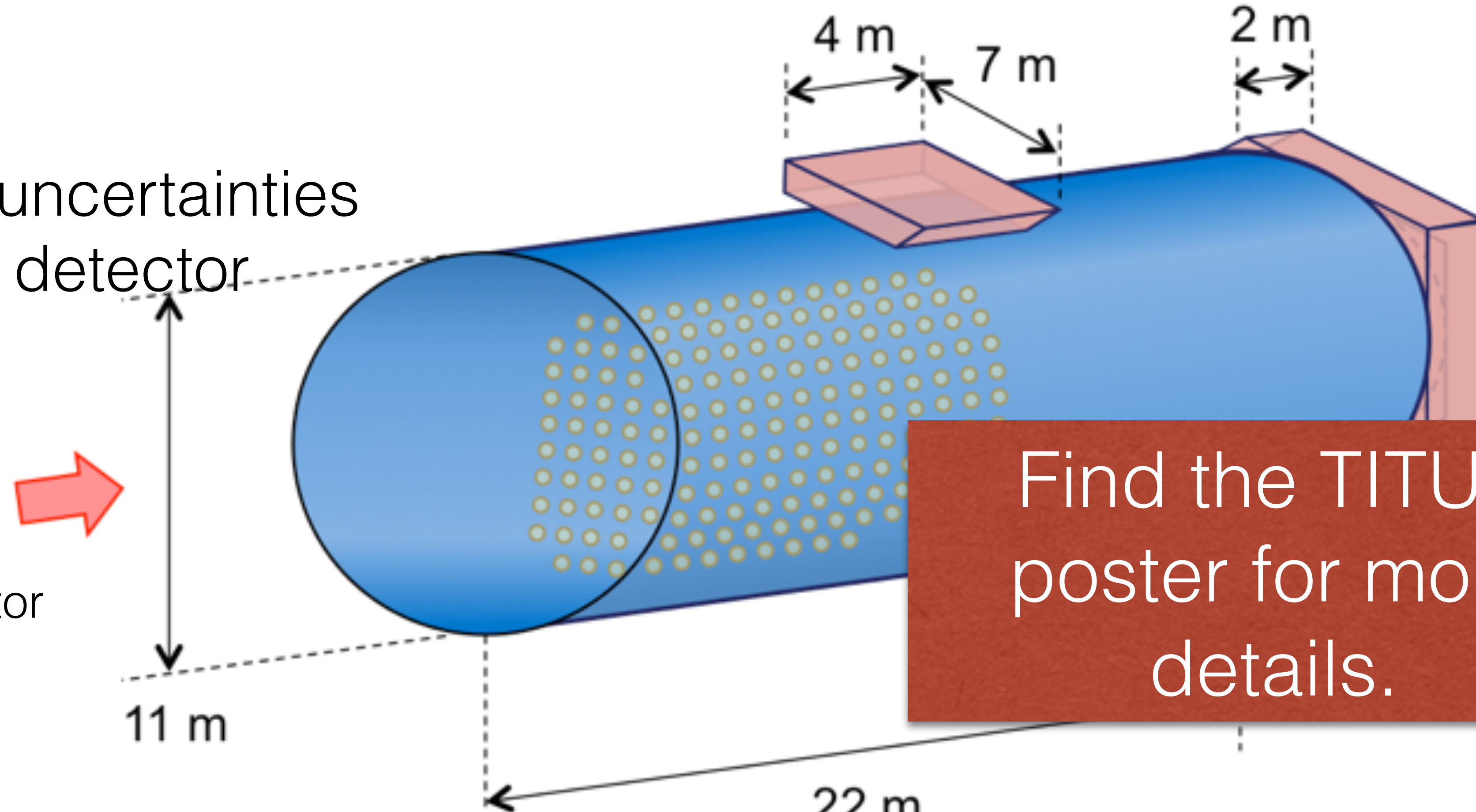
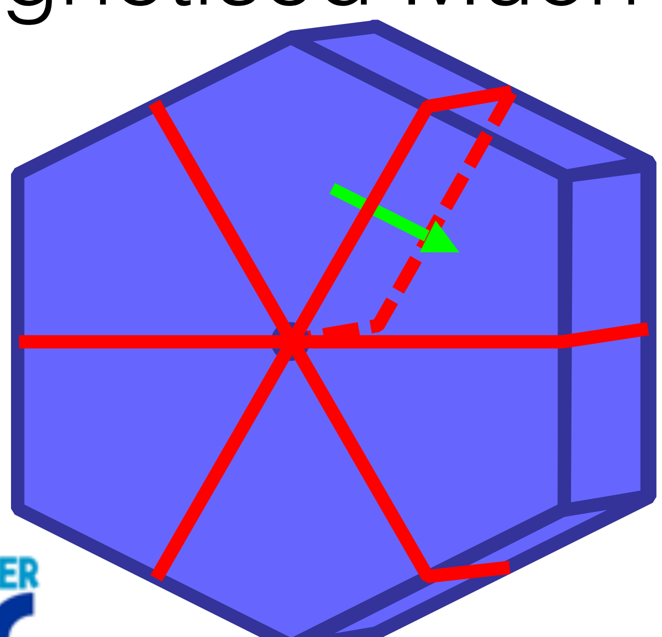


Find the TITUS poster for more details.

Magnetised Muon Range Detector



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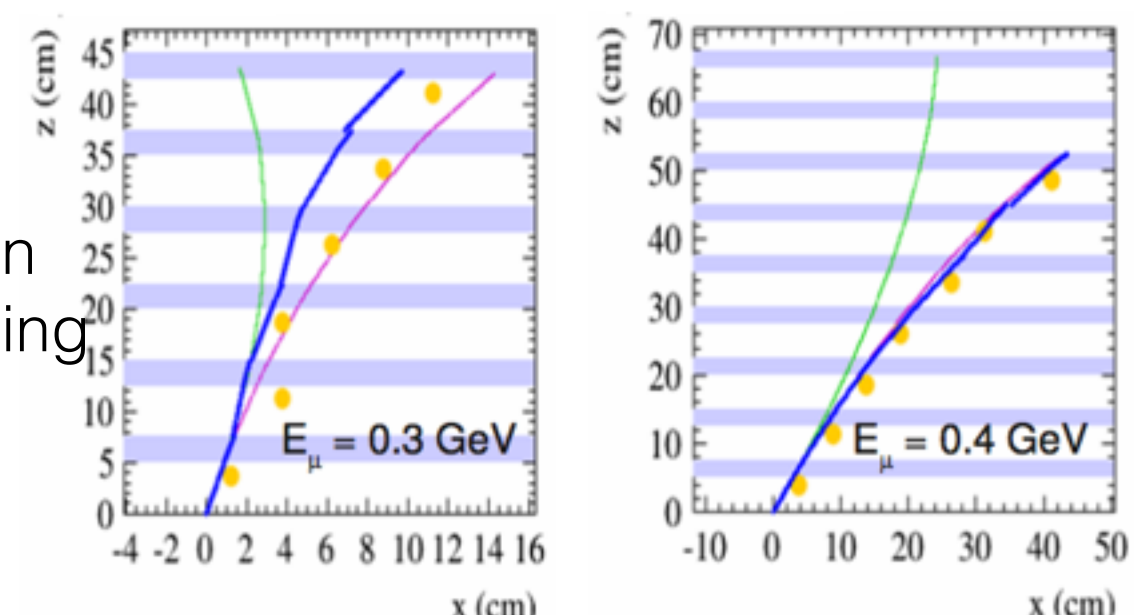


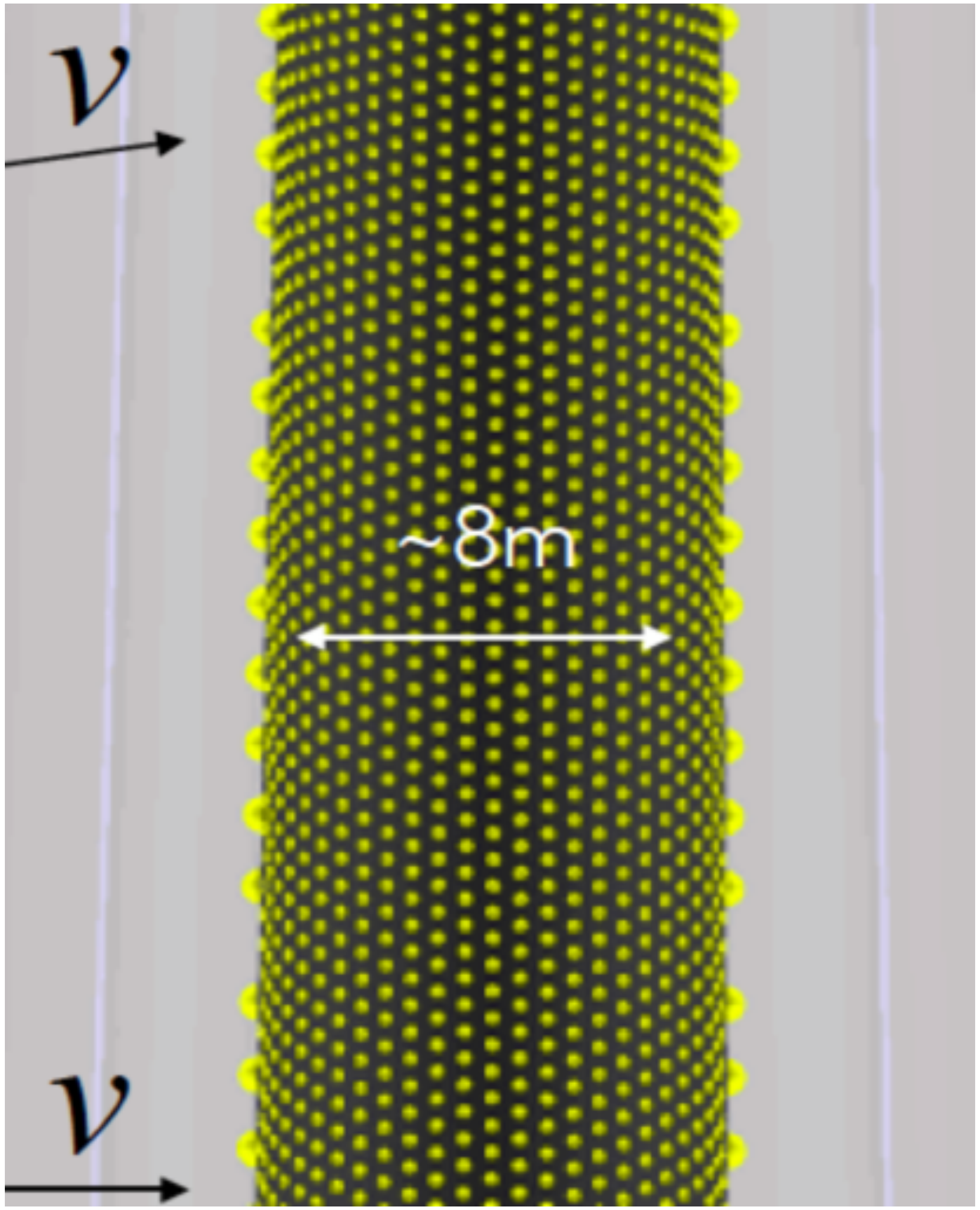
Near Detector Development

New Intermediate Water Cherenkov Detectors

nuPRISM Detector

arXiv:1412.3086 [hep-ex]

Instrumented vertical water column
Samples a wide range of off-axis angles



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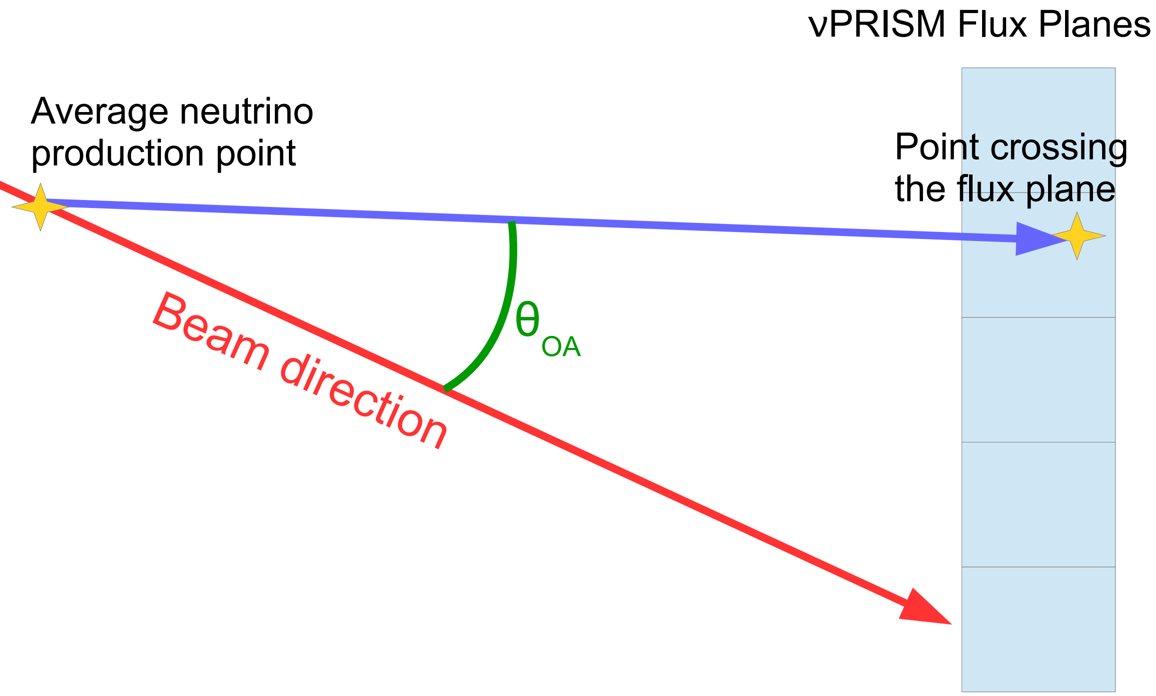

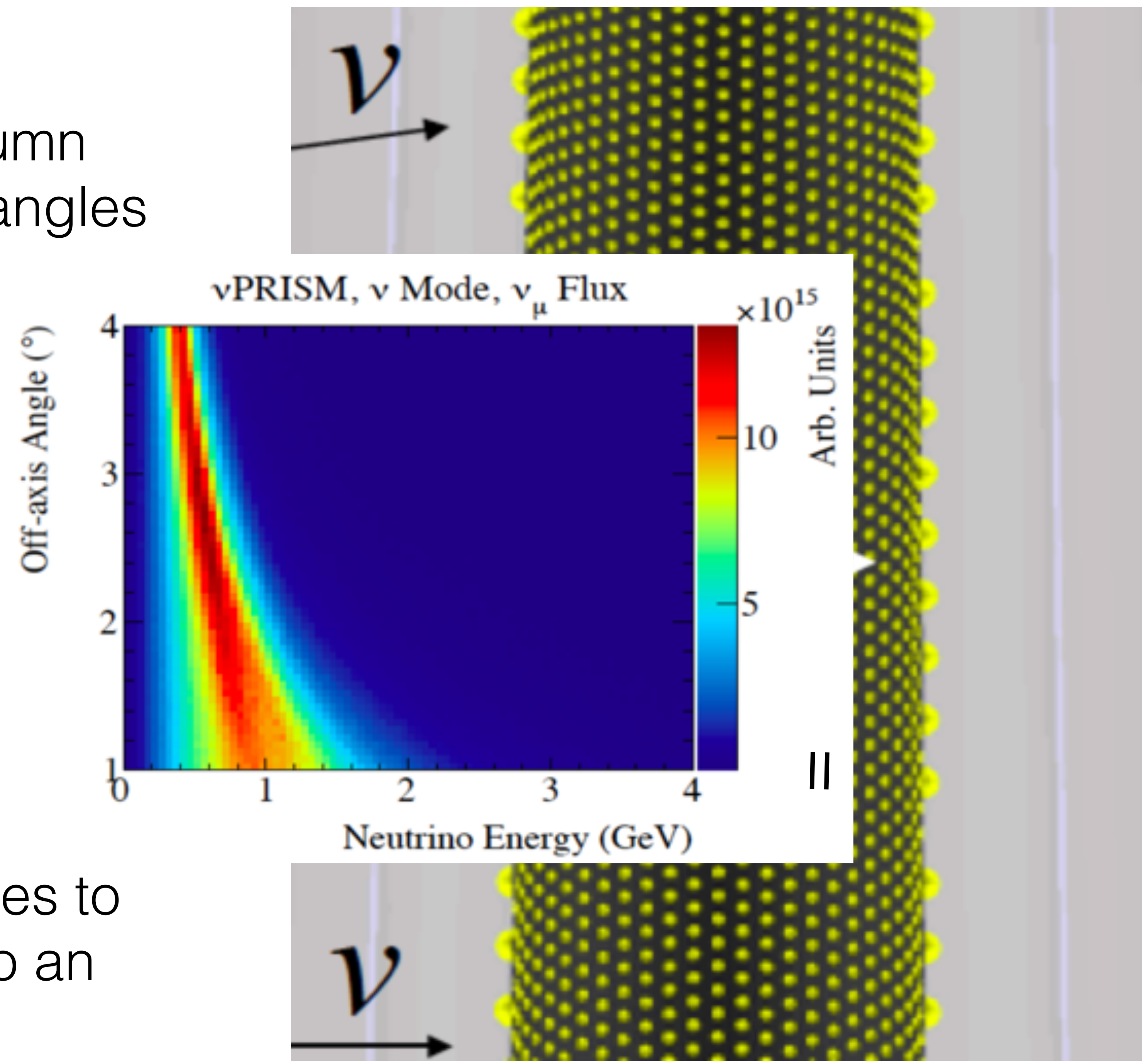

Combine data from different angles to build a dataset corresponding to an arbitrary flux.

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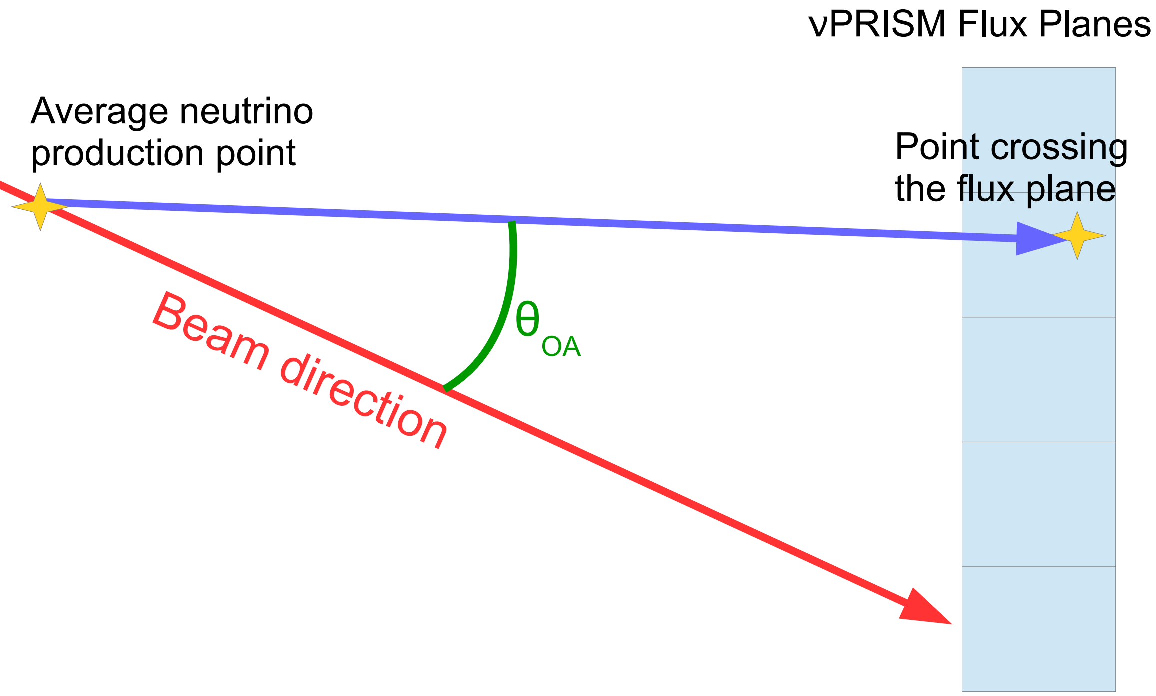
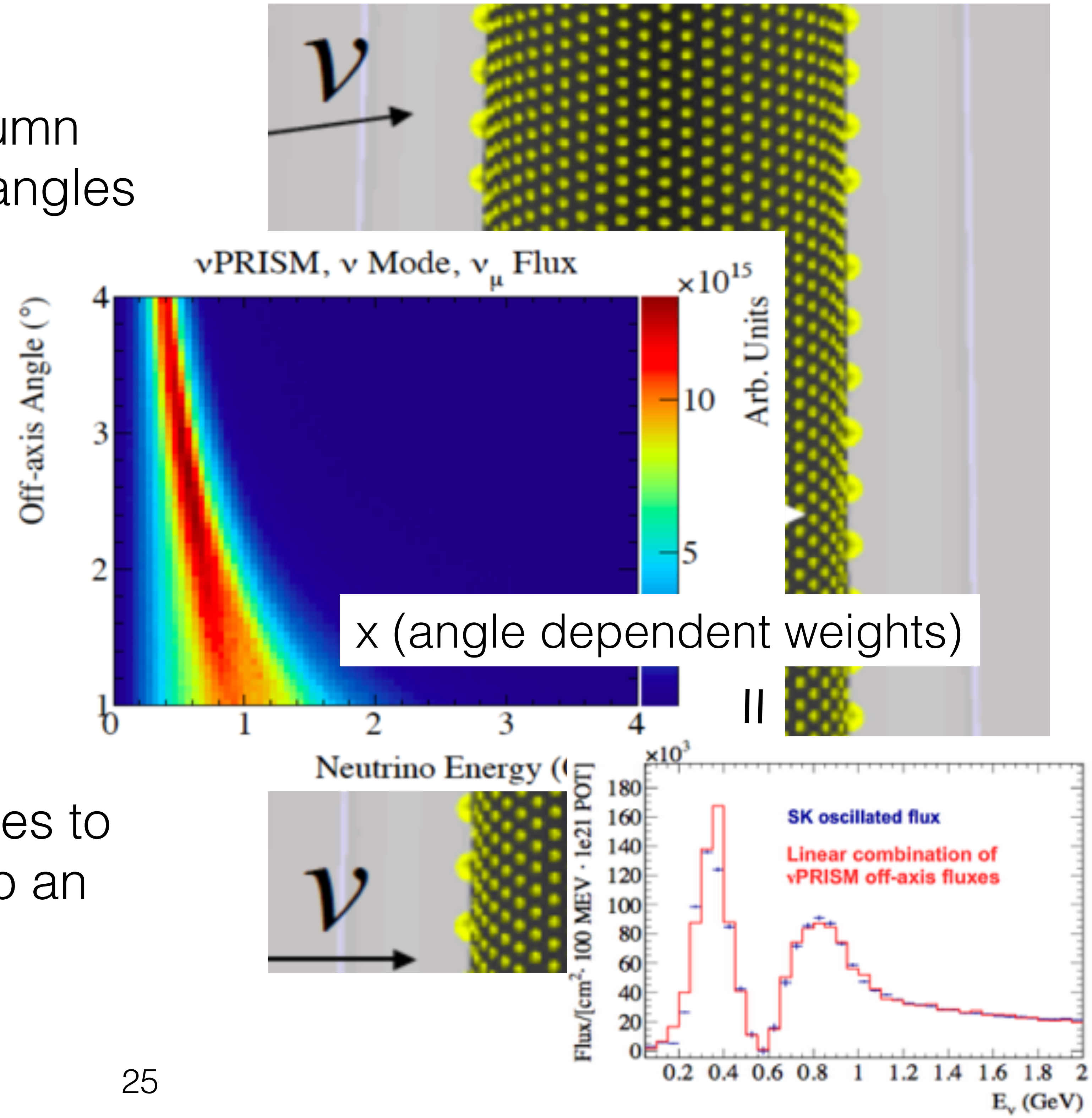
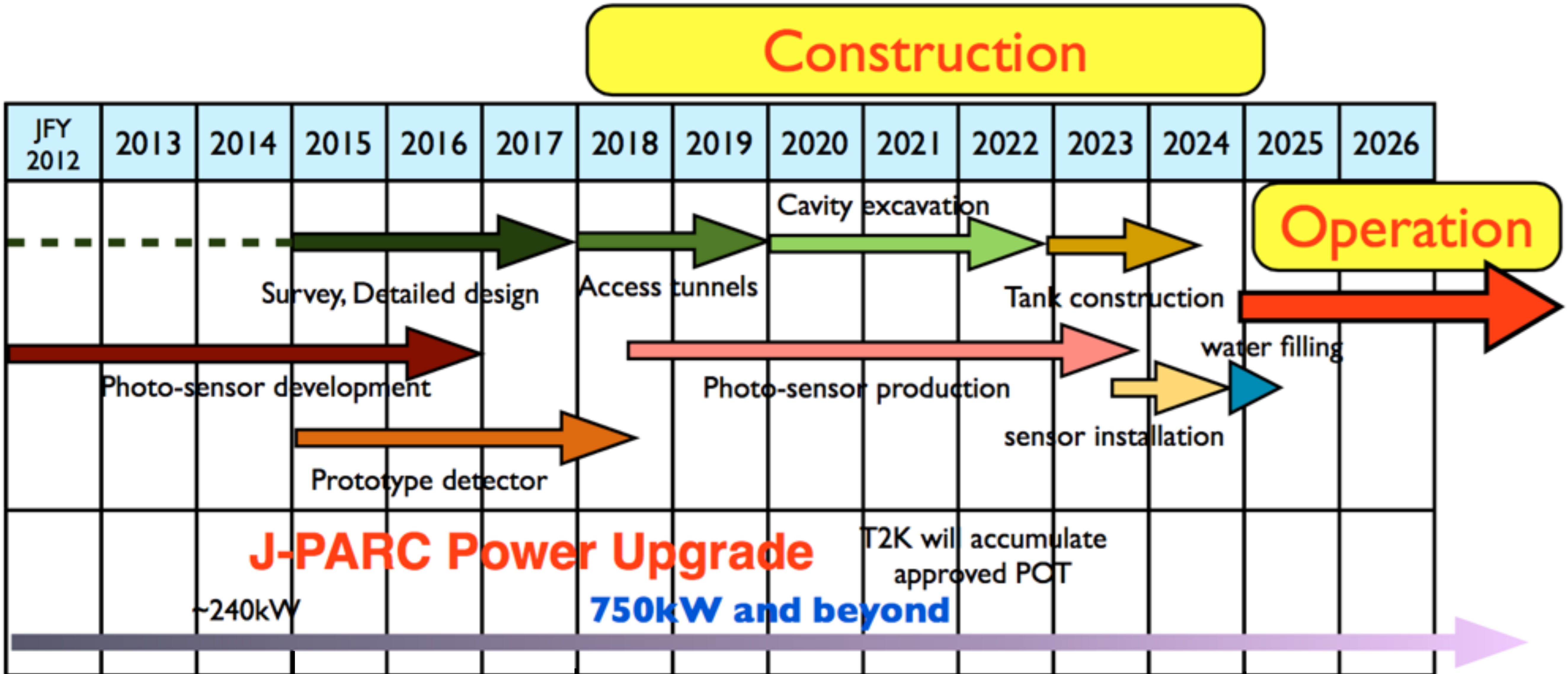




Combine data from different angles to build a dataset corresponding to an arbitrary flux.

Project Timeline



2025: Operation

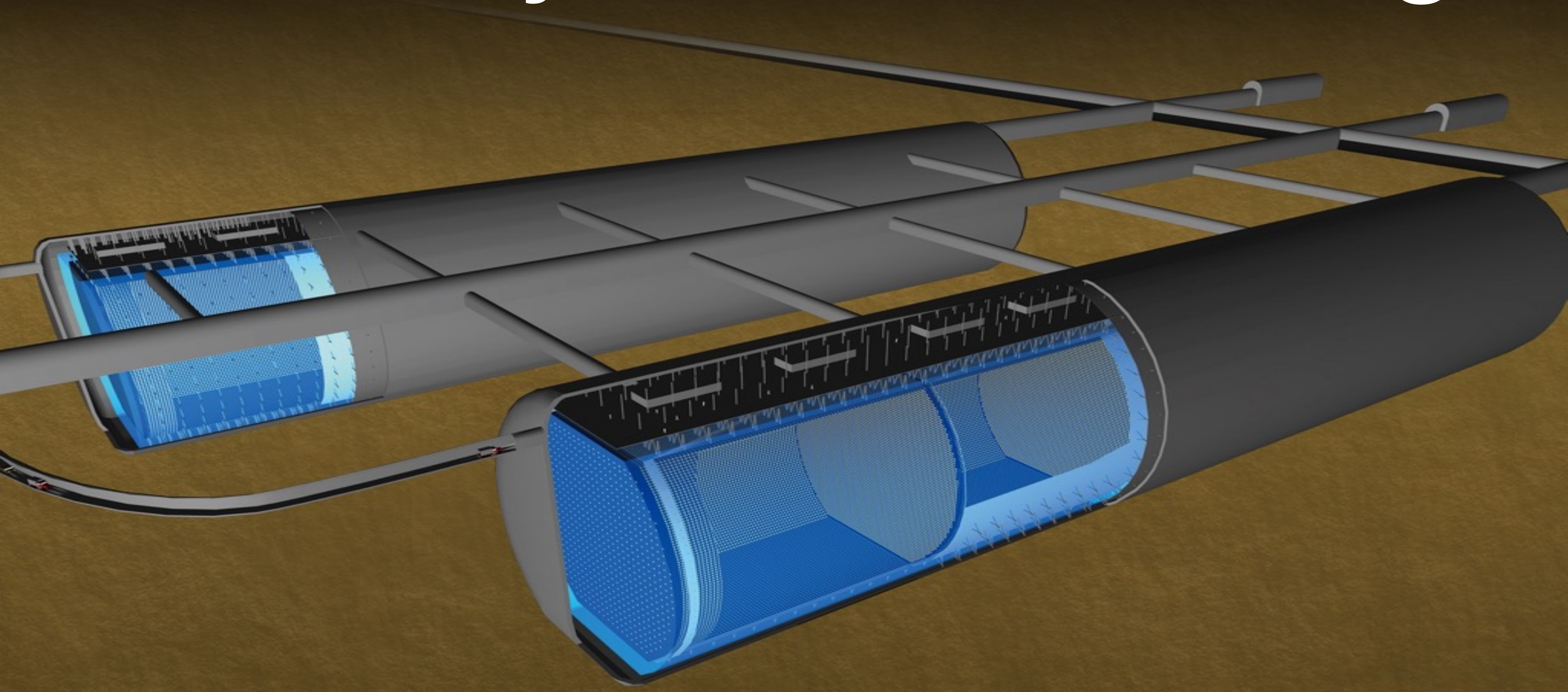
2018: Construction begins

2015: Design report

Hyper-K Collaboration

Growing international collaboration: 13 countries, ~230 people

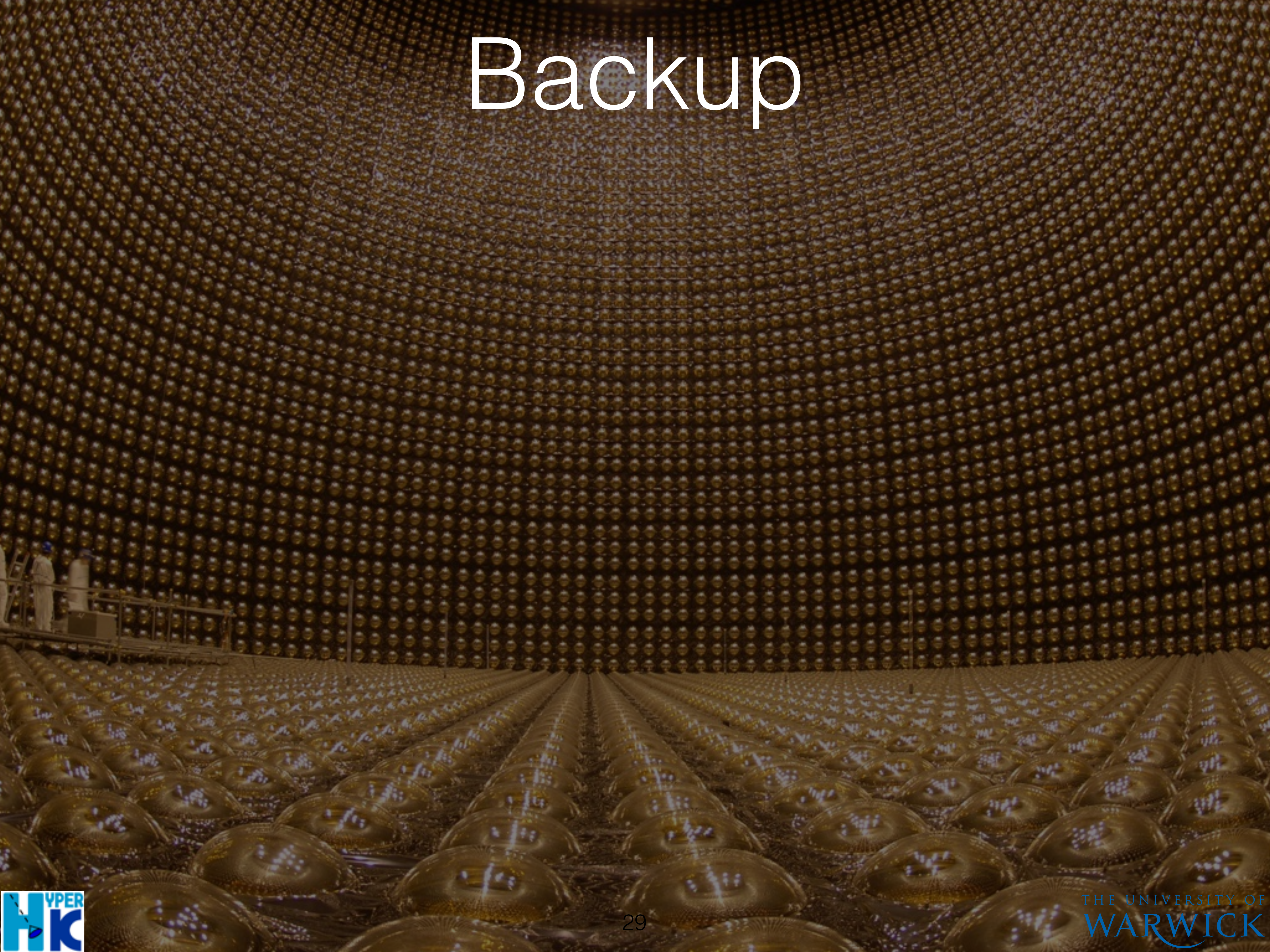
Thank you for listening



David Hadley
University of Warwick
29th May 2015

www.hyperk.org
arXiv:1502.05199
arXiv:1412.4673

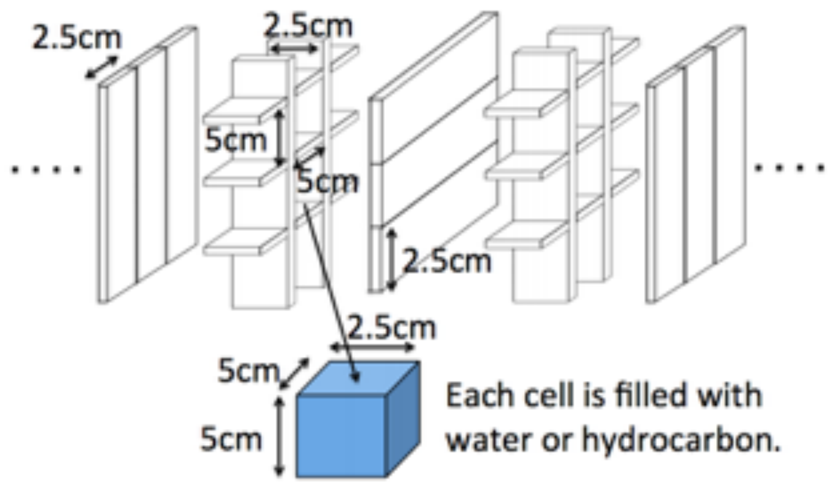
Backup

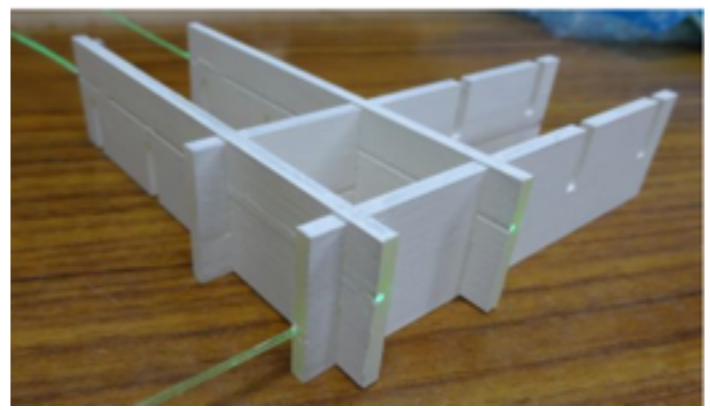


Near Detector Development

New/Upgraded Detectors in the Existing ND280 Complex

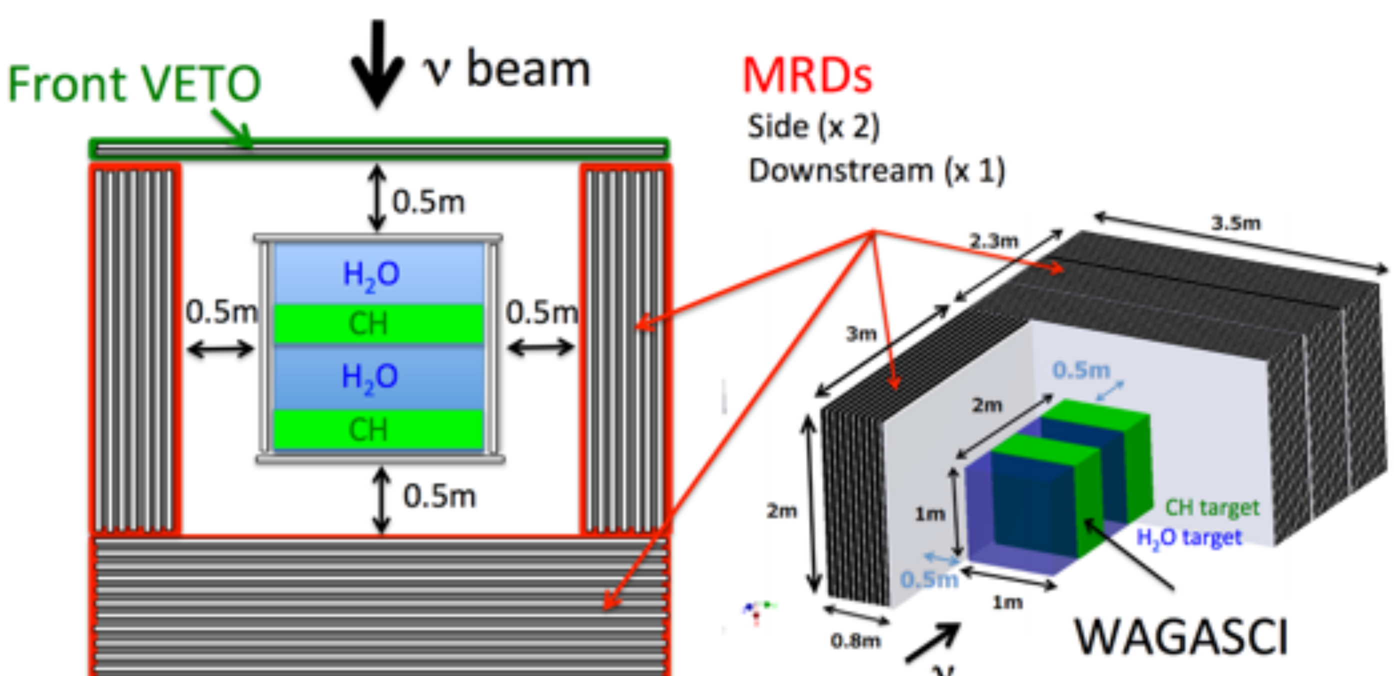
WAGASHI



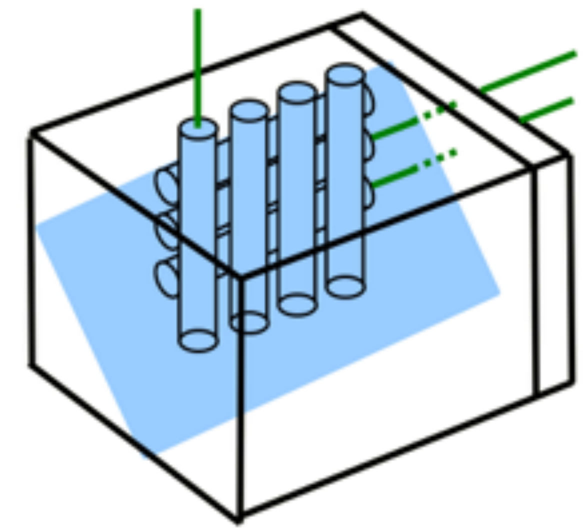


Water dominated target

4π acceptance



Water based liquid scintillator



An alternative approach is to improve knowledge of neutrino-nucleus interactions

e.g. High Pressure Gas TPC

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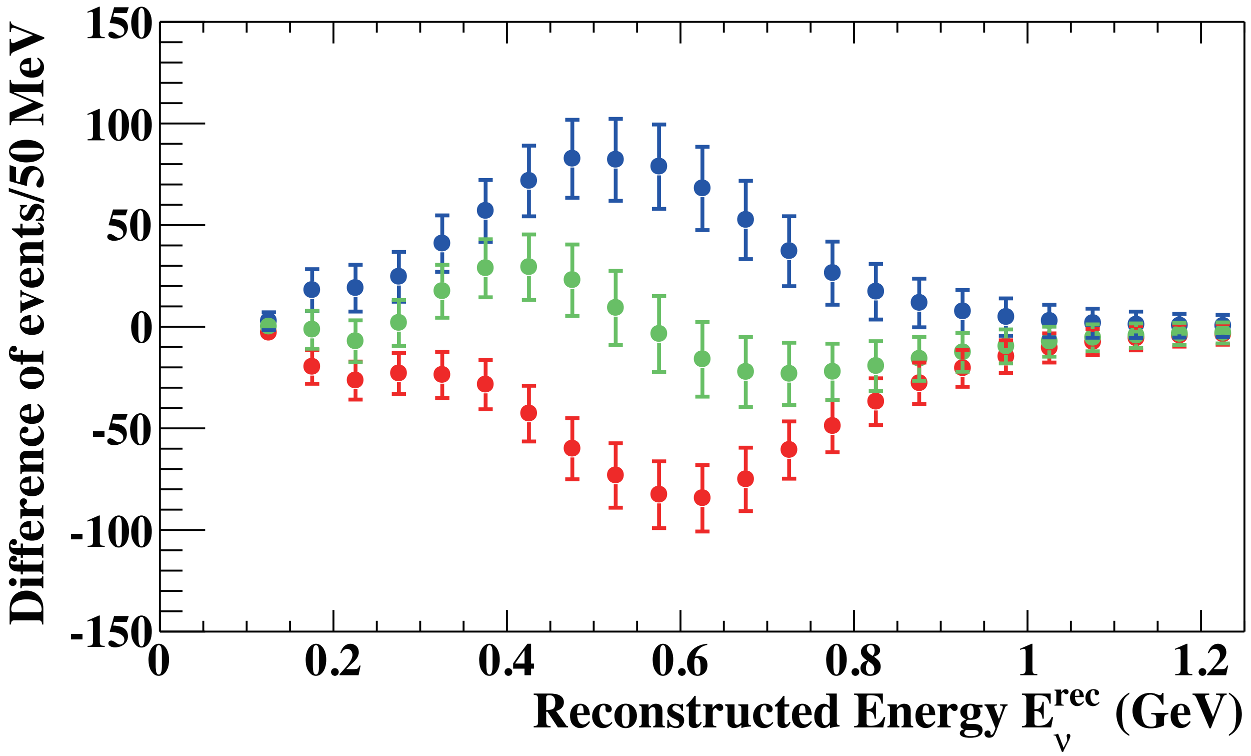
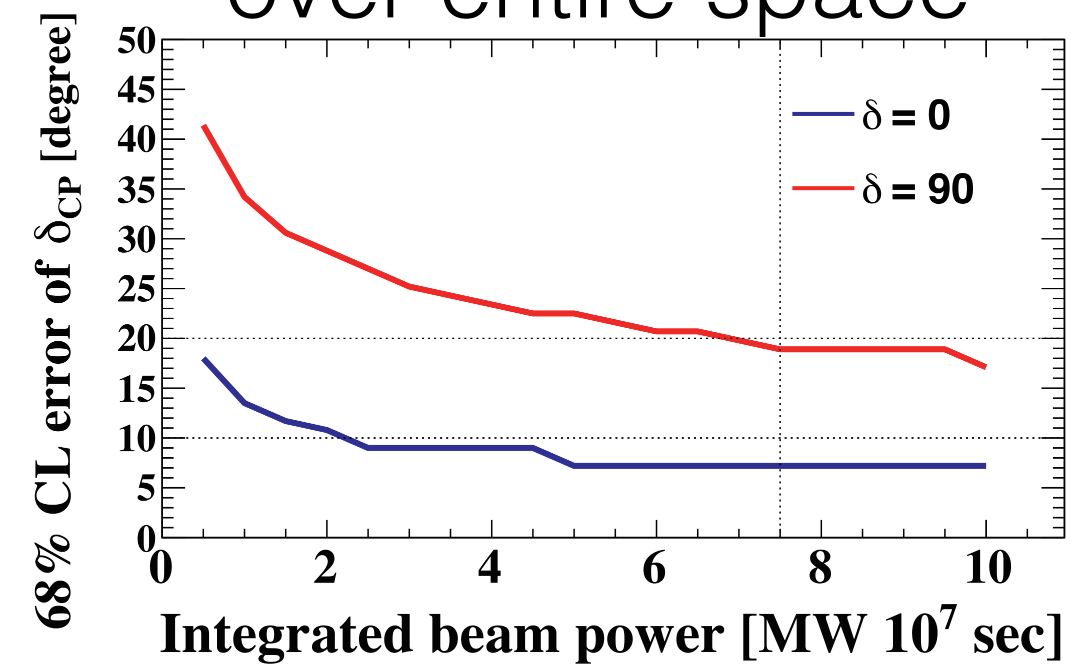
Leptonic CP Violation

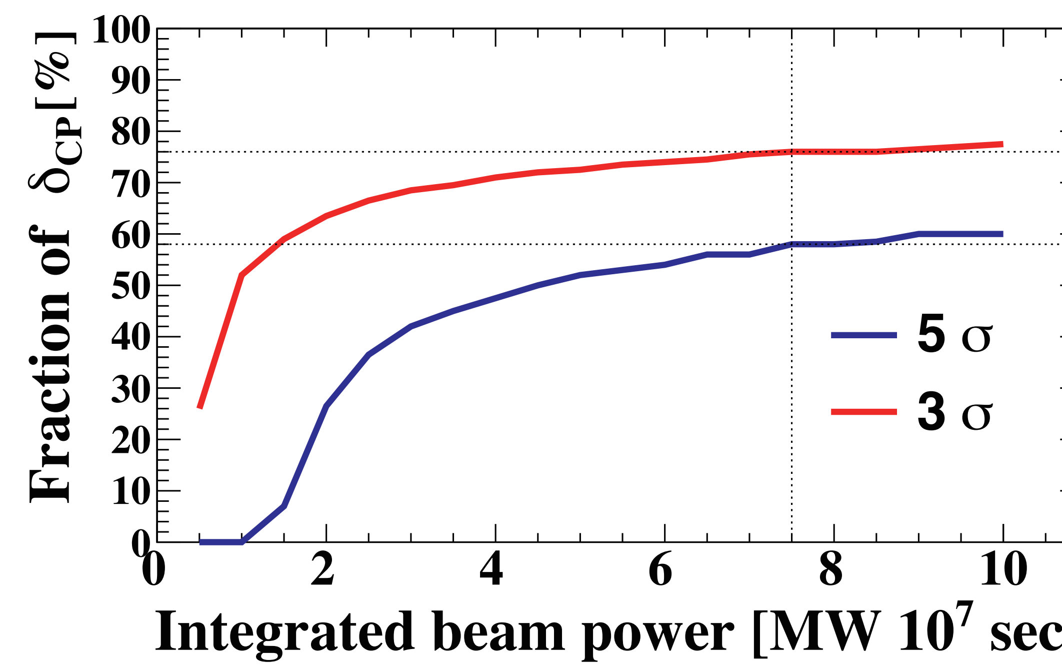
Measure δ_{CP} by comparing data with beam in ν-mode with anti-ν mode



CP violation can be established at 3σ (5σ) for 76% (58%) of δ_{CP} space.

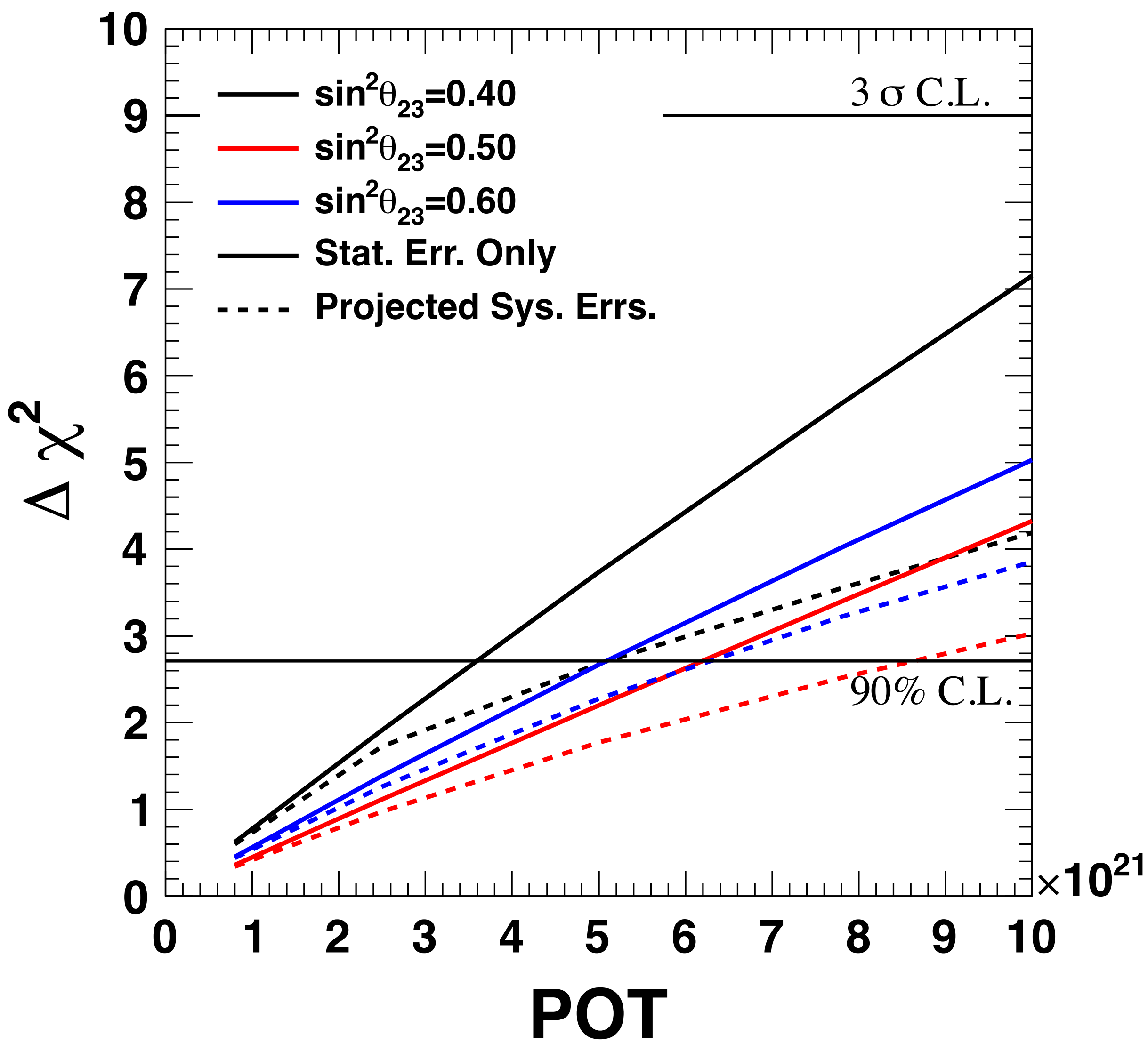
δ_{CP} measured to < 20° over entire space





Near Detector Development

arXiv:1409.7469 [hep-ex]

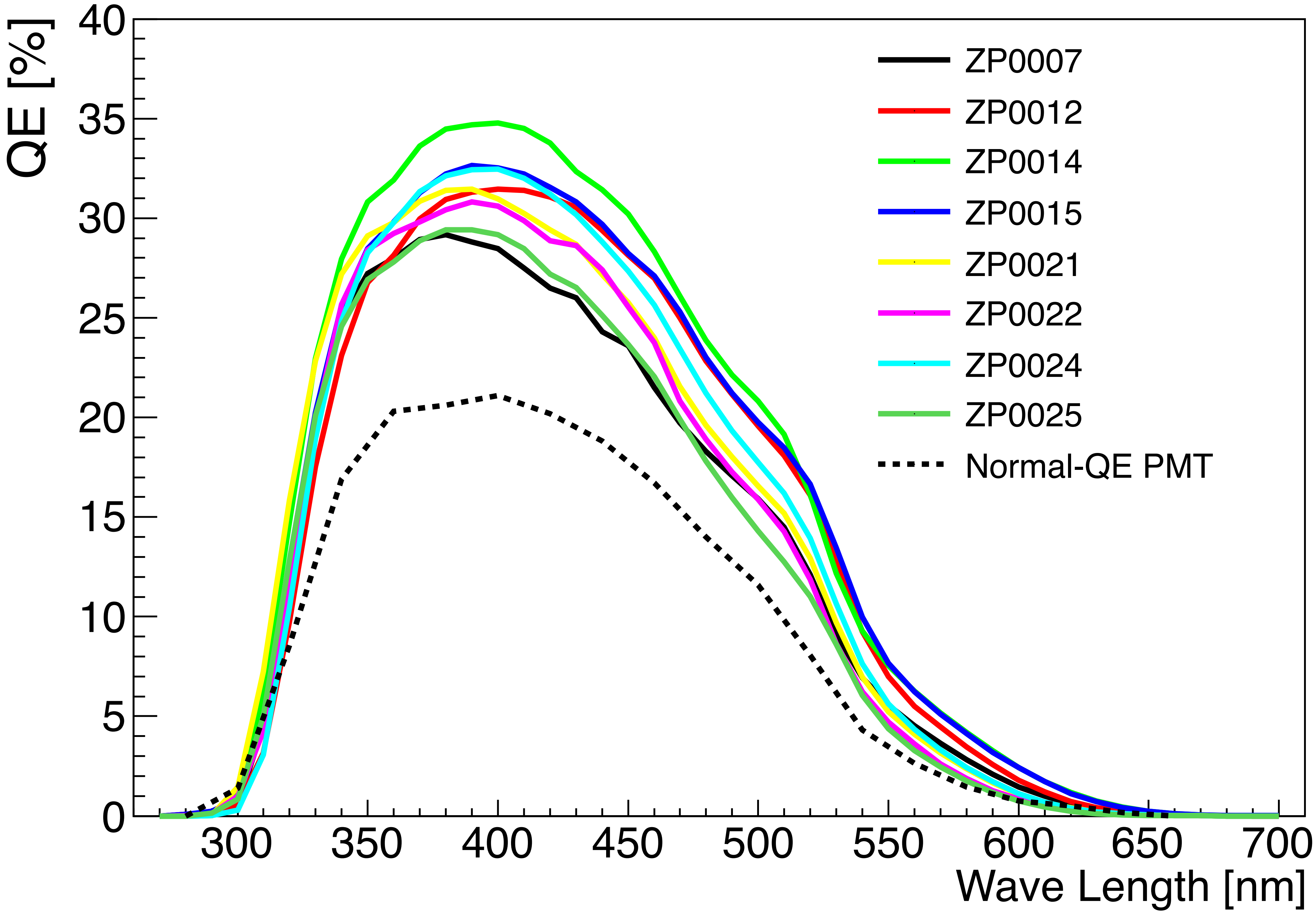


arXiv:1311.4750 [hep-ex]

Error source [%]	$\sin^2 2\theta_{13} = 0.1$
Beam flux and near detector	2.9
(w/o ND280 constraint)	(25.9)
Uncorrelated ν interaction	7.5
Far detector and FSI+SI+PN	3.5
Total	8.8

To fully exploit the Hyper-K accelerator neutrino statistics, upgraded near detectors will be needed.

Photo Sensors



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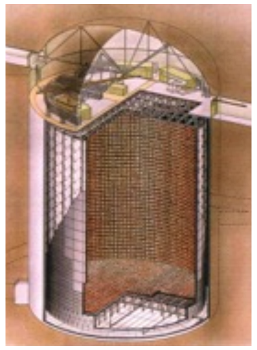
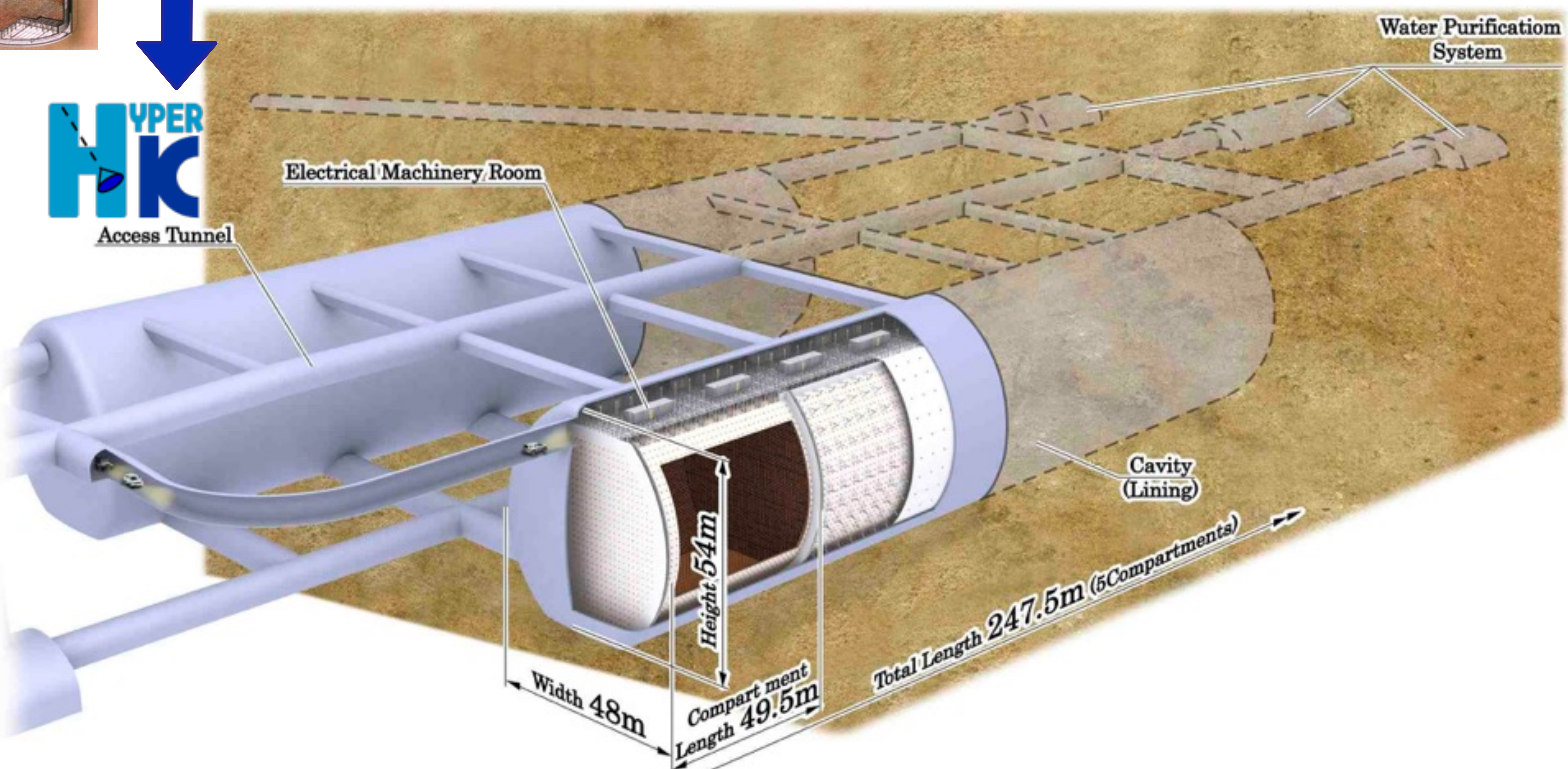
Hyper-K





Megaton scale Water Cherenkov detector
x25 larger fiducial volume than Super-K.