Welcome to the Nikhef KM3NeT Outing

Why an outing?

- Take the time to listen to your colleagues
- Critical (but constructive) reflection
- Where are we going as a group? What can we do better?
- Relax…

Format:

- Talks, but save time for discussion
- Sports. If weather permits: canoe to Dalfsen, starting 16:00, return 19:00 by taxi
- Dinner, drinks.

Thursday 31 May 2018

Introduction (11:00-11:30)

- Presenters: JONG, Paul de

Talk (11:30-12:00)

- Presenters: BRUIJN, Ronald

Talk (12:00-12:30)

- Presenters: SAMTLEBEN, Dorothea

Talk (12:30-13:00)

- Presenters: STRANDBERG, Bruno

Lunch (13:00-14:00)

Talk (14:00-14:30)

- Presenters: NAUTA, Lodewijk

Talk (14:30-15:00)

- Presenters: SENECA, Jordan

Talk (15:00-15:30)

- Presenters: BRAAT, Pieter

Sports, drinks, dinner (15:30-21:00)

Friday 01 June 2018

Talk (09:00-09:30)

- Presenters: BUIS, Ernst-Jan

Talk (09:30-10:00)

- Presenters: VAN DEN ENDE, Rosa

Talk (10:00-10:30)

- Presenters: HEIJBOER, Aart

Talk (10:30-11:00)

- Presenters: DE WAARDT, Lieselotte

Coffee Break (11:00-11:30)

Talk (11:30-12:00)

- Presenters: GARCIA SOTO, Alfonso

Talk (12:00-12:30)

- Presenters: MELIS, Karel

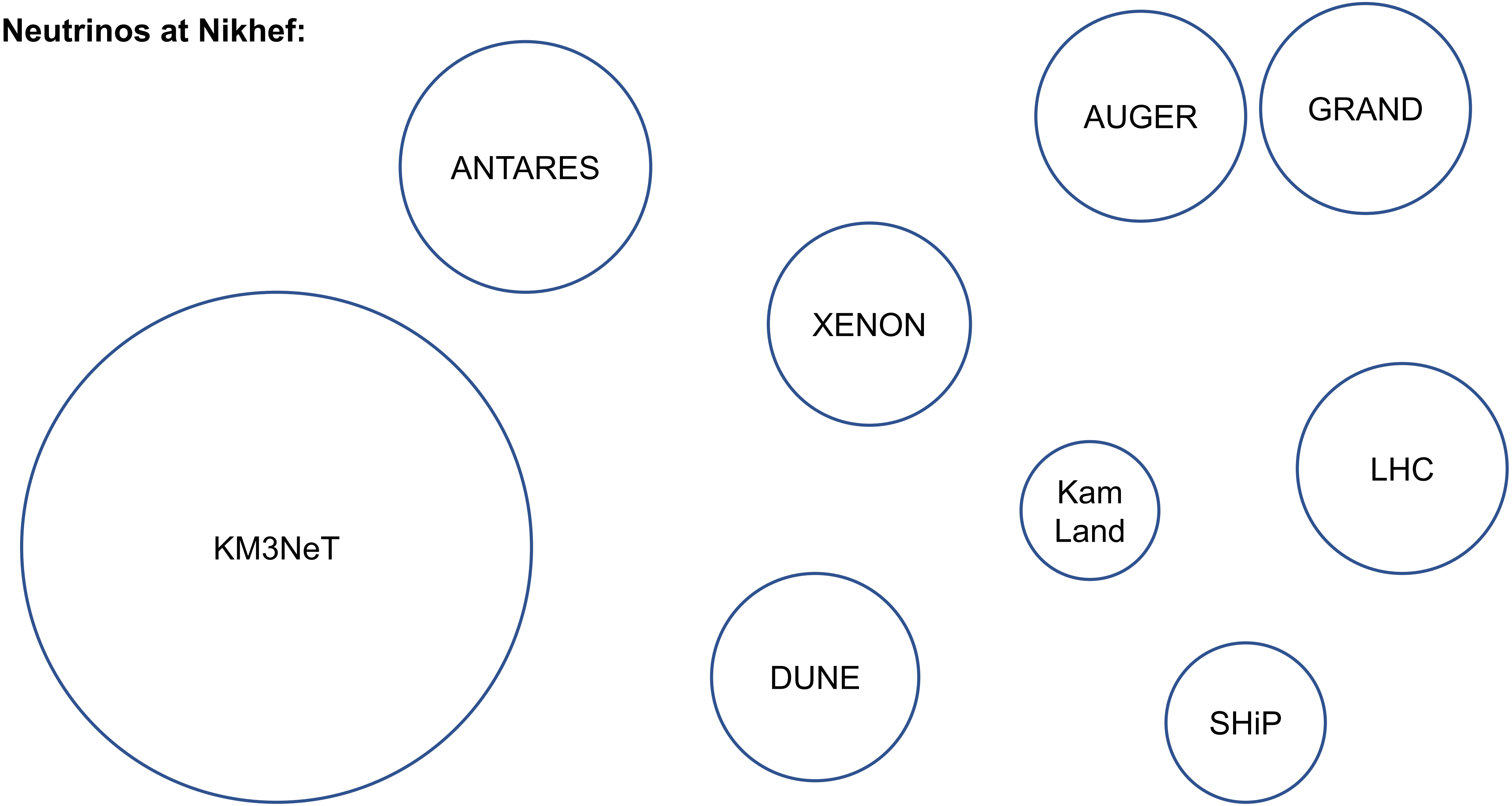
Talk (12:30-13:00)

- Presenters: POST, Maarten

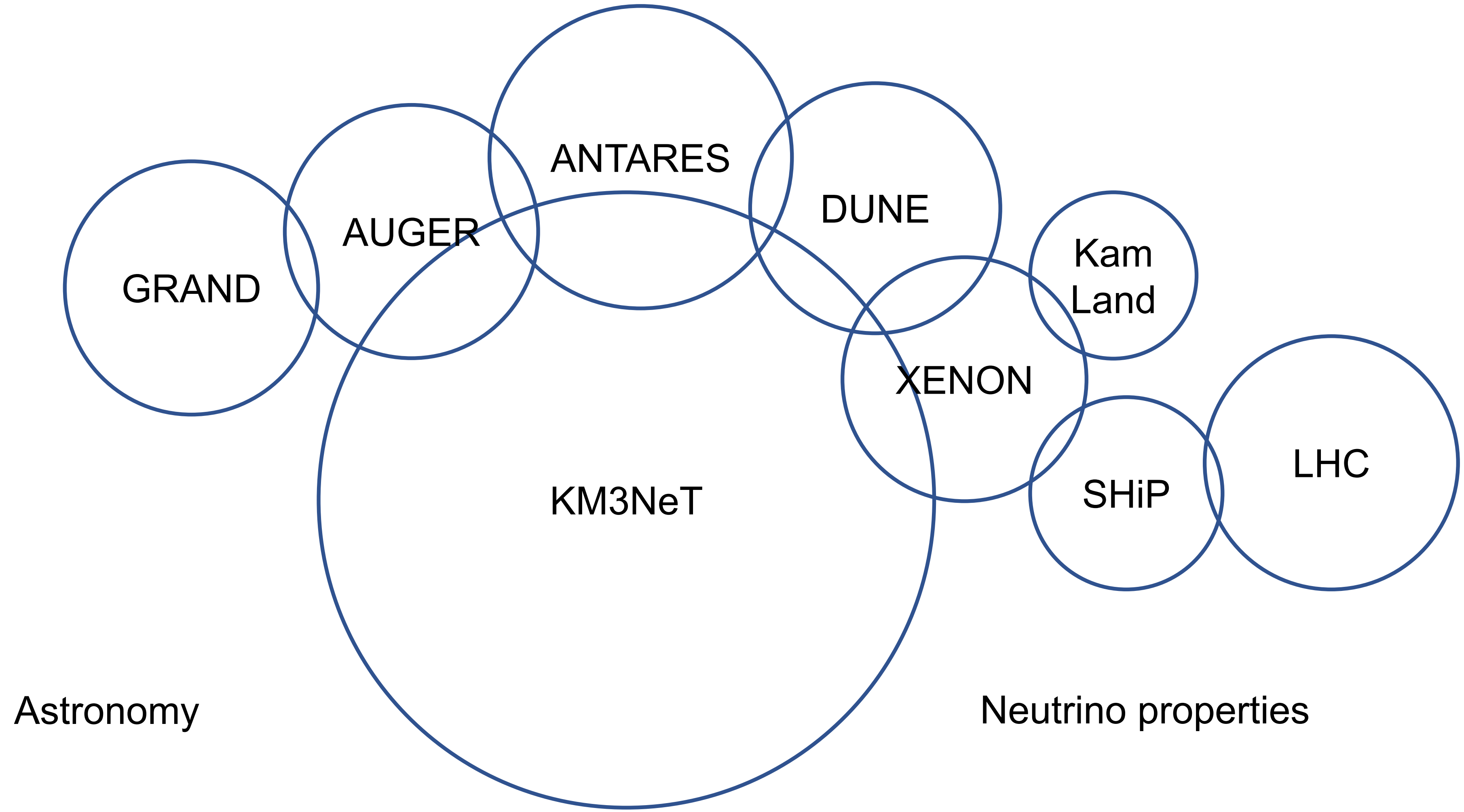
Lunch (13:00-14:00)

Staff Meeting (14:00-15:00)

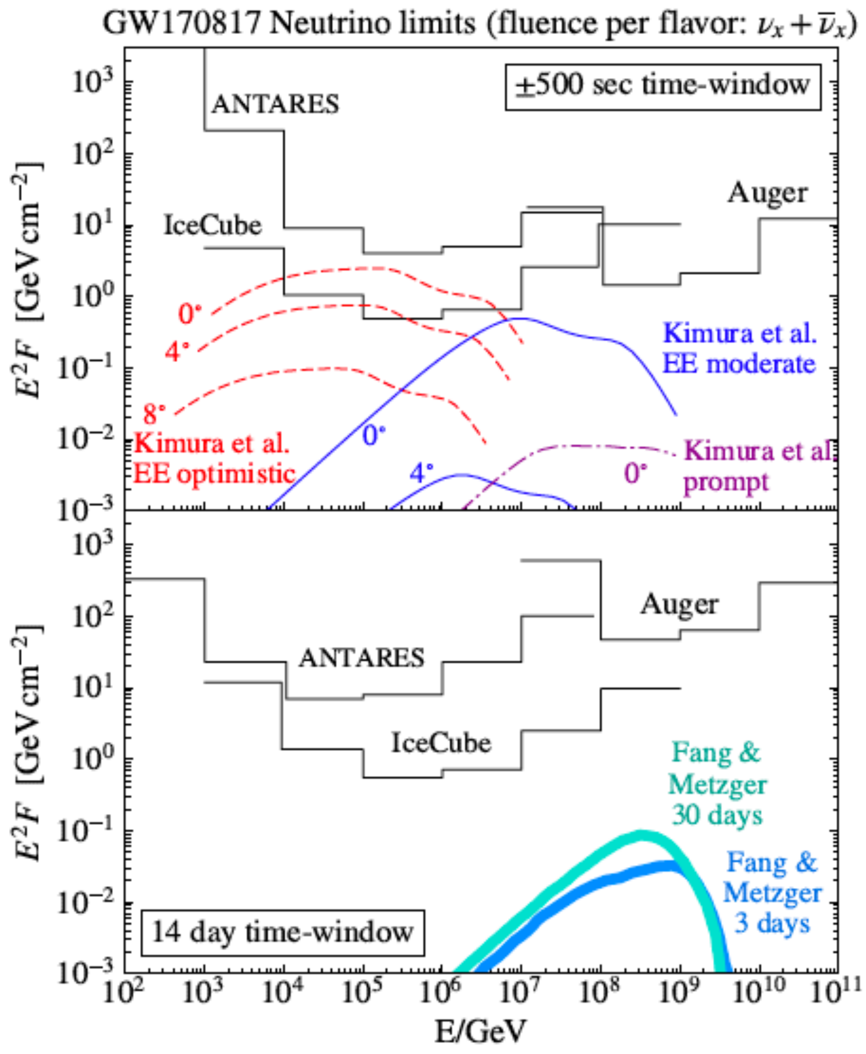
Neutrinos at Nikhef:



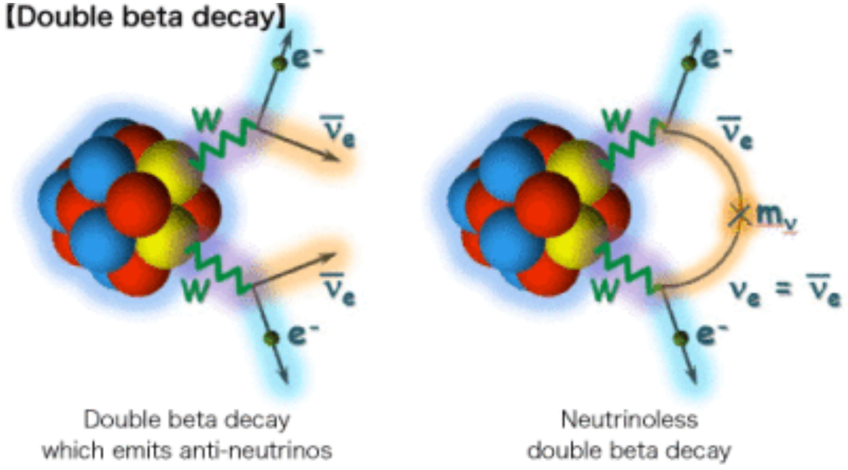
Neutrinos at Nikhef:

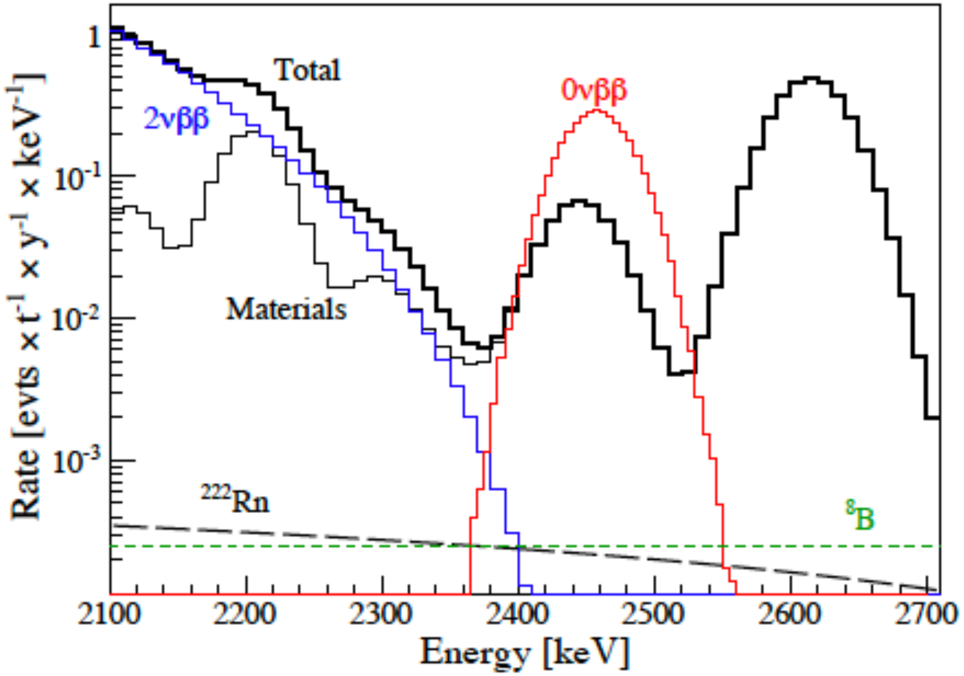


AUGER, GRAND: air showers from ultra-high energy neutrinos
(KM3NeT: acoustic detection)



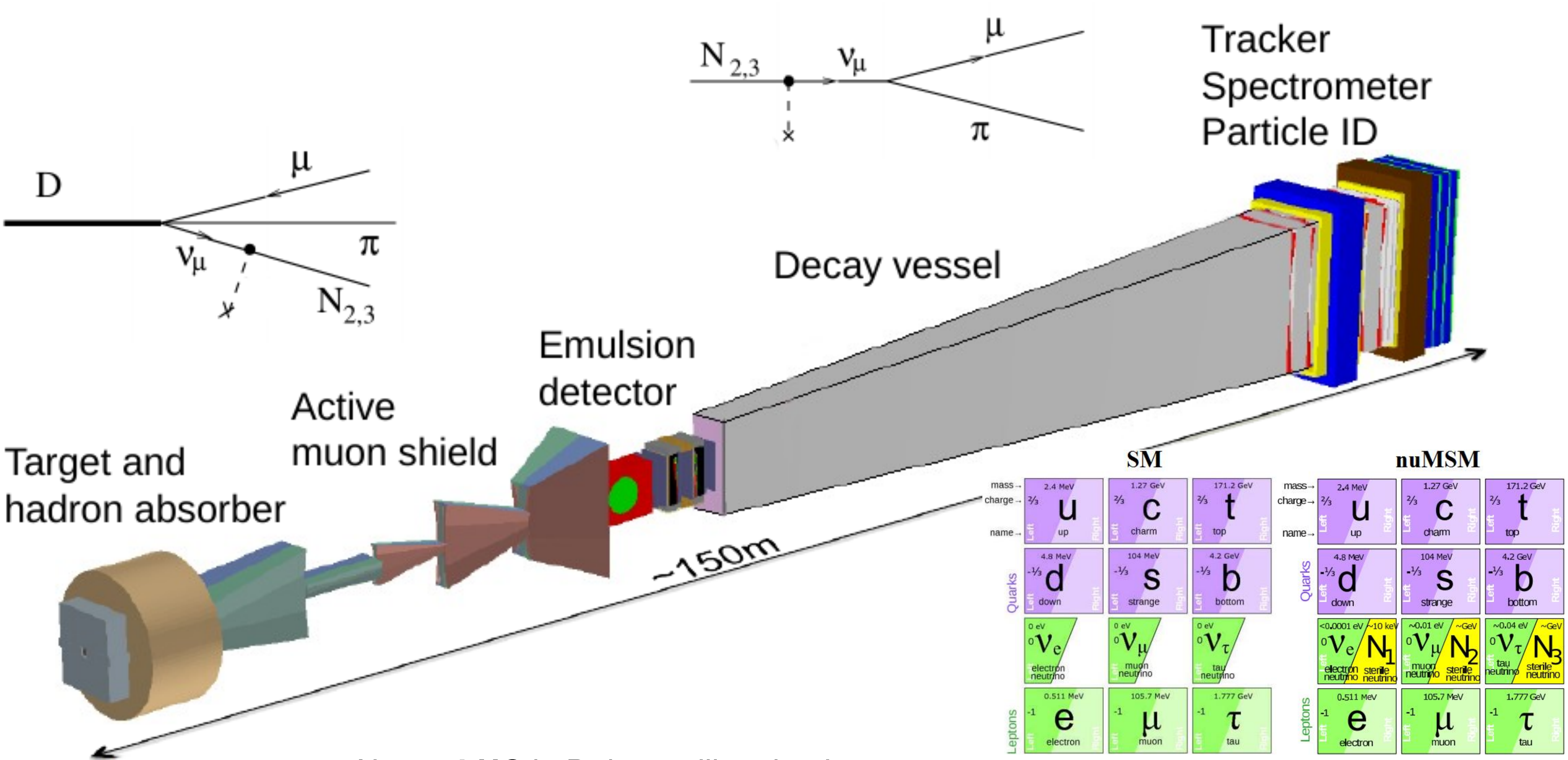
XENON: sterile neutrinos
neutrino-less double beta decay
supernova neutrinos





KamLand: neutrino oscillations (terminated)
neutrino-less double beta decay (KamLand-Zen)

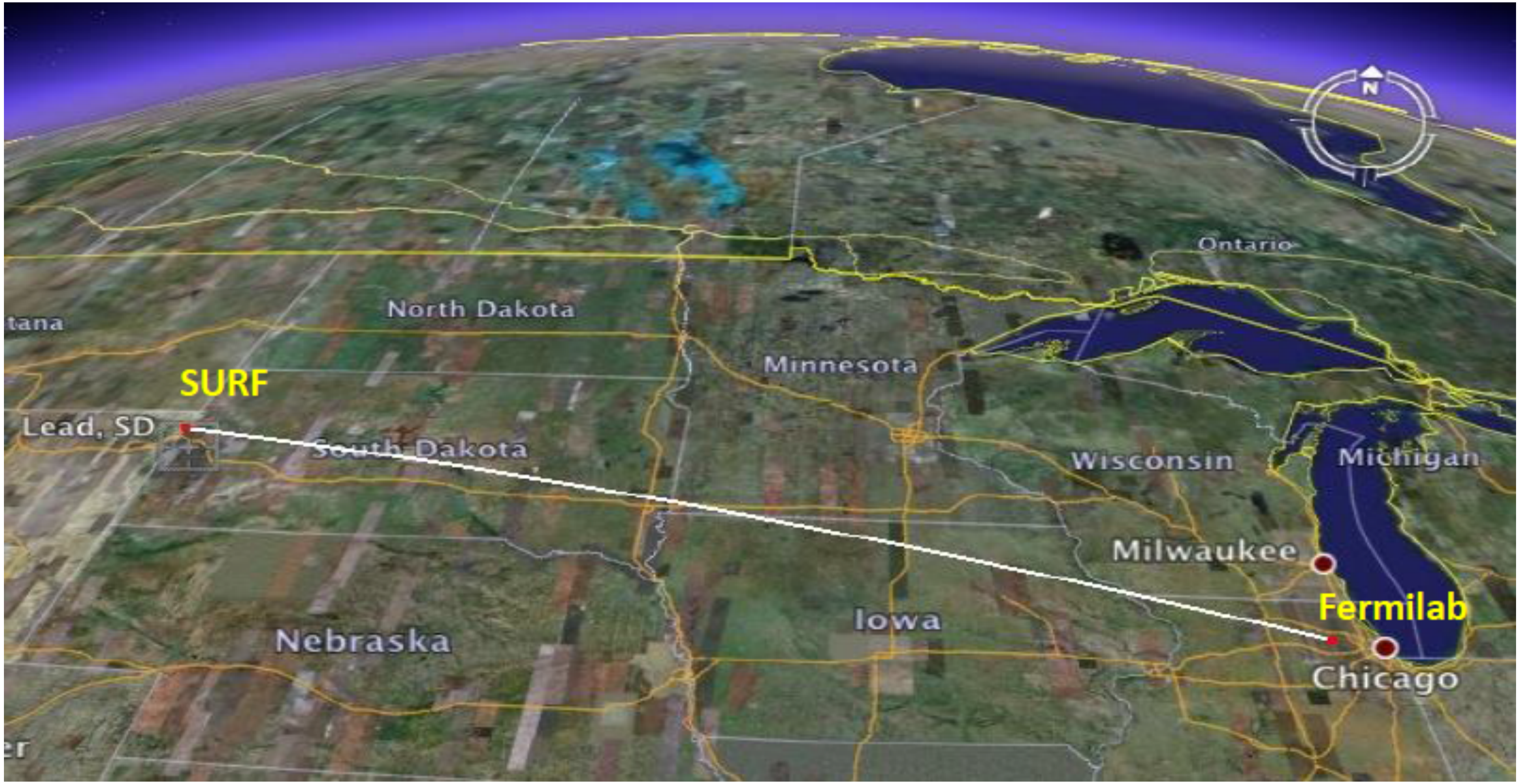
SHiP (Search for Hidden Particles)

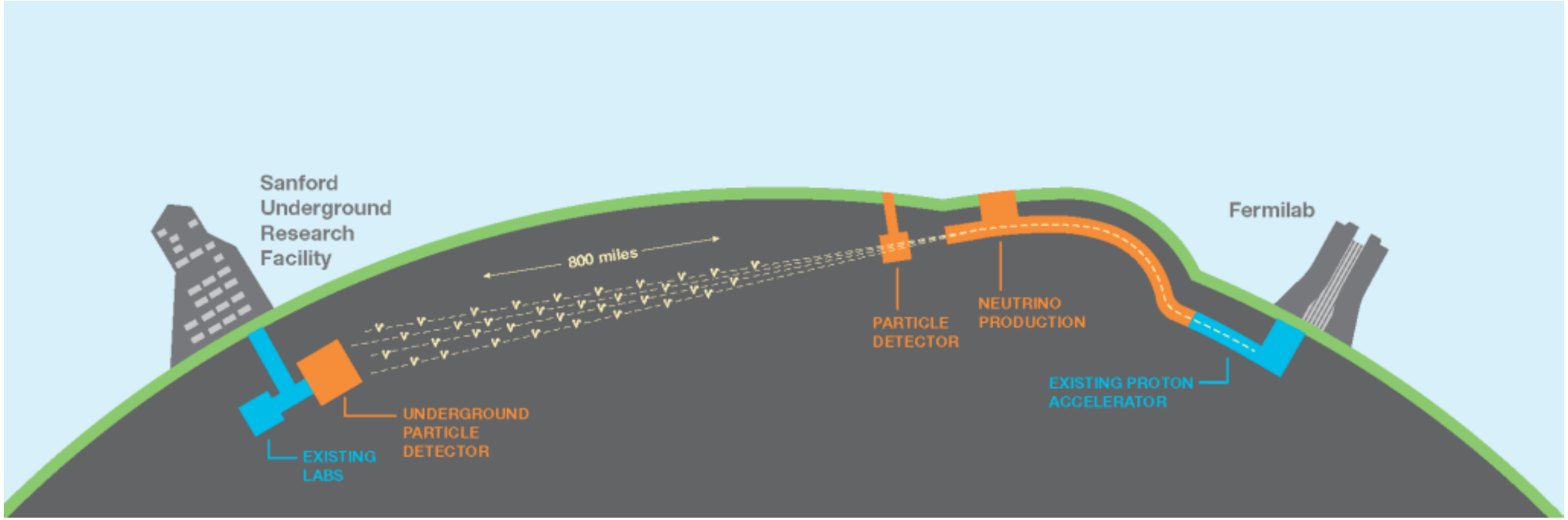


Also at **LHC** in B decay, like-sign leptons

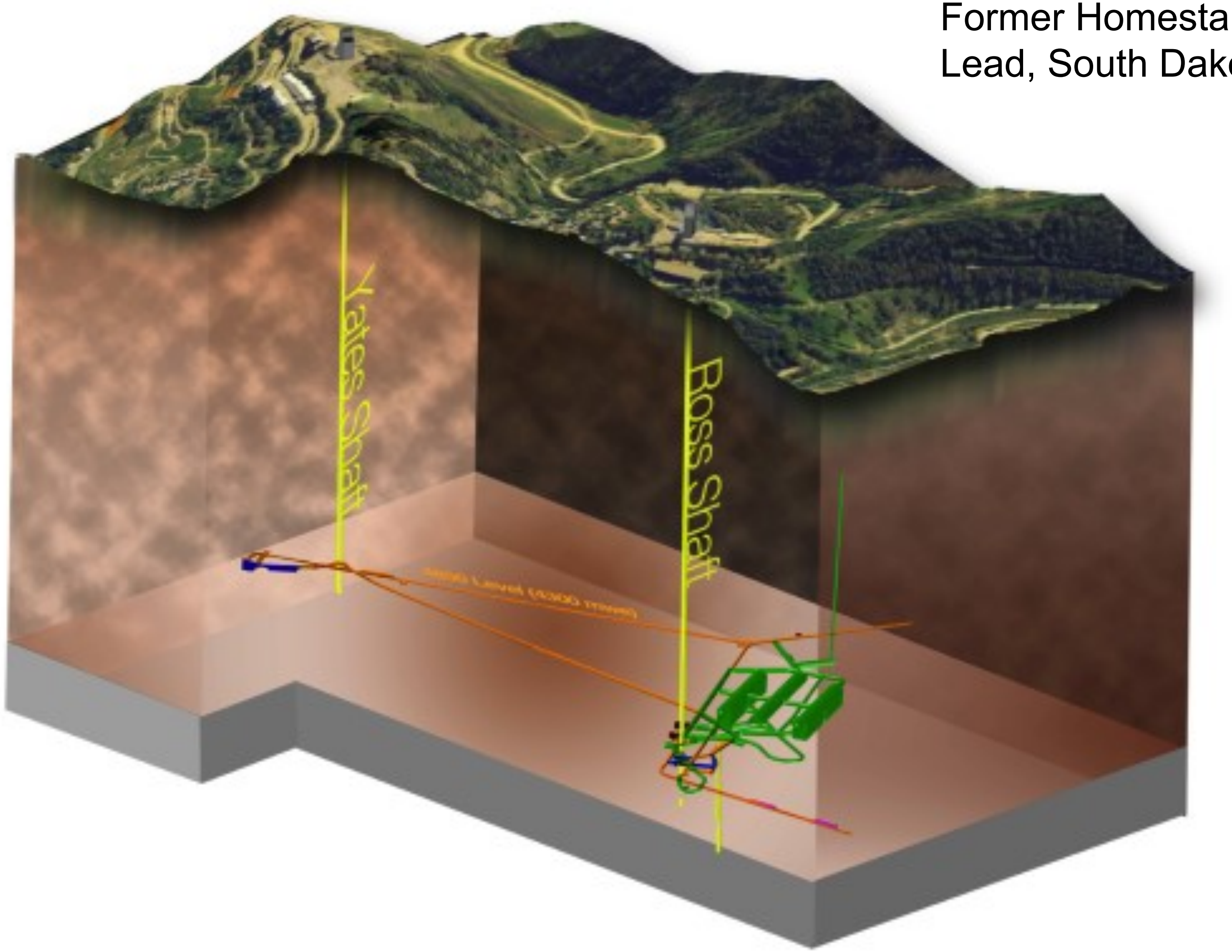
LBNF-DUNE

(Long Baseline Neutrino Facility / Deep Underground Neutrino Experiment)




Sanford Underground Research Facility
800 miles
PARTICLE DETECTOR
NEUTRINO PRODUCTION
Fermilab
EXISTING PROTON ACCELERATOR
UNDERGROUND PARTICLE DETECTOR
EXISTING LABS

Former Homestake mine
Lead, South Dakota



The Standard 3-Flavour Paradigm

★ **Unitary PNMS matrix ⇨ mixing described by:**

- three "Euler angles": $(\theta_{12},\ \theta_{13},\ \theta_{23})$
- and one complex phase: δ

$$U_{\mathrm{PMNS}} = \begin{pmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & c_{23} & s_{23} \\ 0 & -s_{23} & c_{23} \end{pmatrix} \begin{pmatrix} c_{13} & 0 & s_{13}e^{-i\delta} \\ 0 & 1 & 0 \\ -s_{13}e^{i\delta} & 0 & c_{13} \end{pmatrix} \begin{pmatrix} c_{12} & s_{12} & 0 \\ -s_{12} & c_{12} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

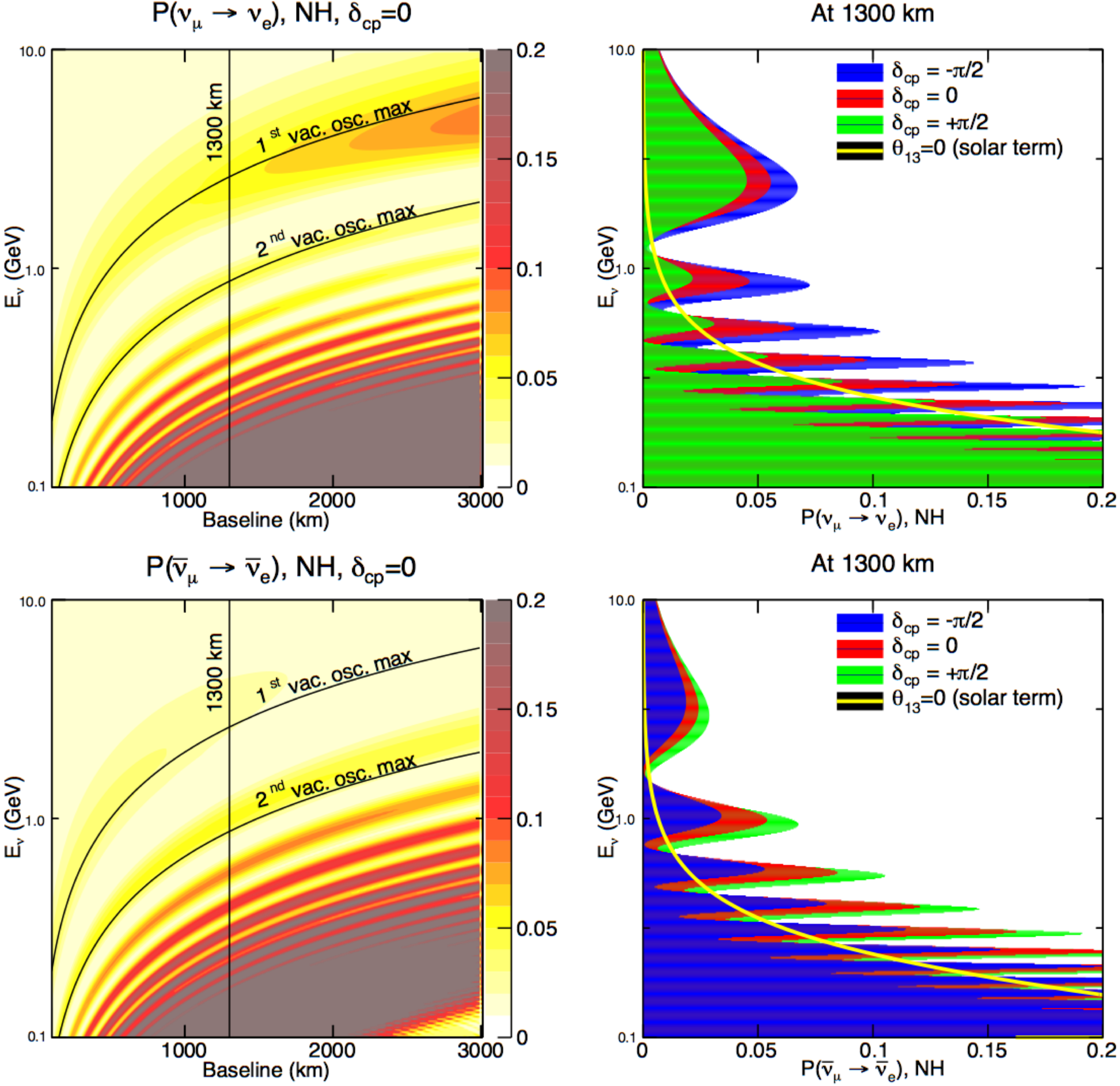
with $s_{ij} = \sin\theta_{ij}\ ;\ c_{ij} = \cos\theta_{ij}$

★ **If** $\delta \neq \{0, \pi\}$ then SM leptonic sector ⇨ CP violation (CPV)

- CPV effects $\propto \sin\theta_{13}$
- **now know that θ_{13} is relatively large**

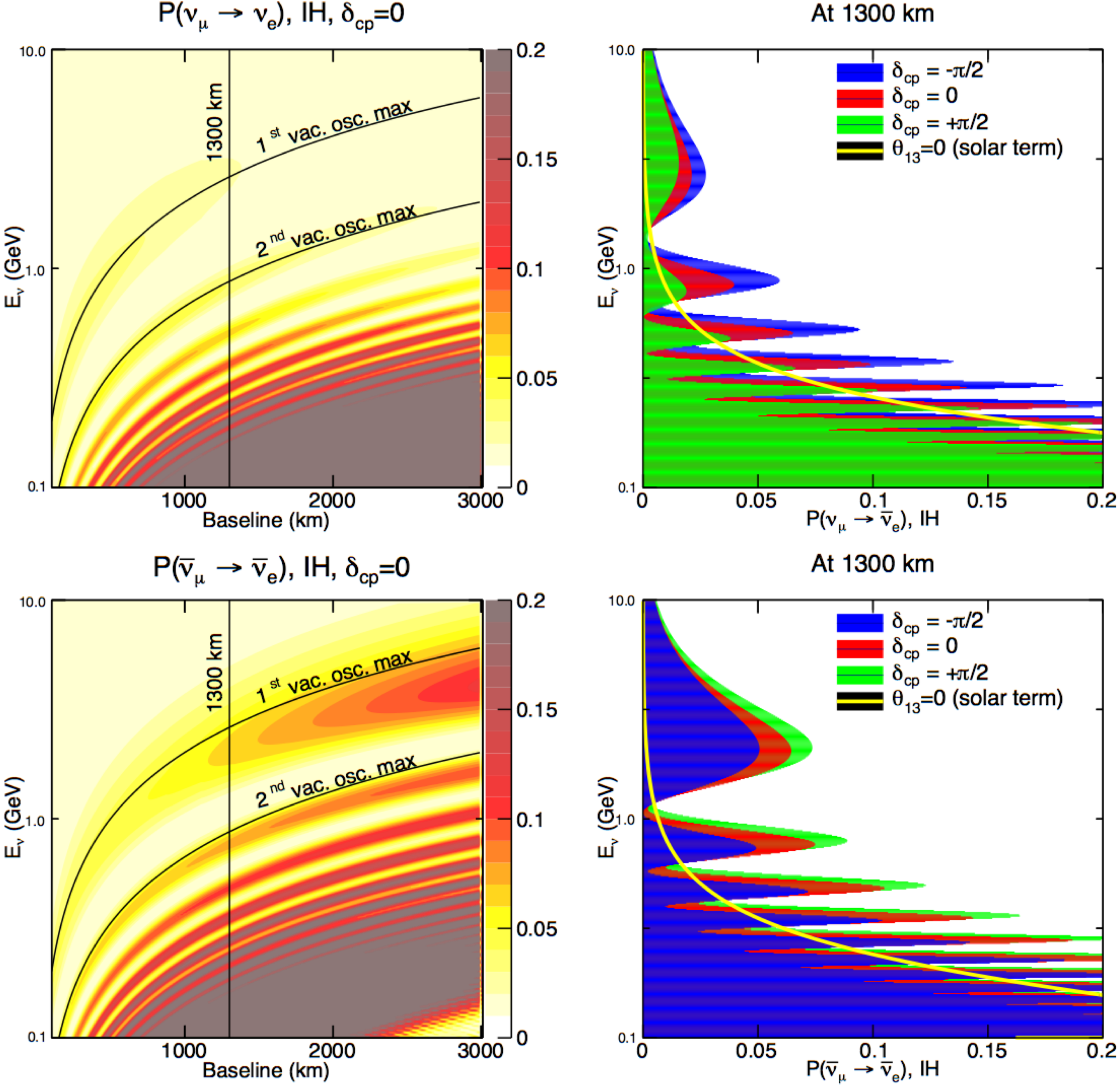
⇨ **CPV is observable with conventional ν beams**

⇨ **LBNF/DUNE**
Hyper-Kamiokande



P(νμ → νe), NH, δcp=0
1300 km
1st vac. osc. max
2nd vac. osc. max
Eν (GeV)
Baseline (km)
At 1300 km
δcp = -π/2
δcp = 0
δcp = +π/2
θ13=0 (solar term)
P(νμ → νe), NH
P(ν̄μ → ν̄e), NH, δcp=0
P(ν̄μ → ν̄e), NH

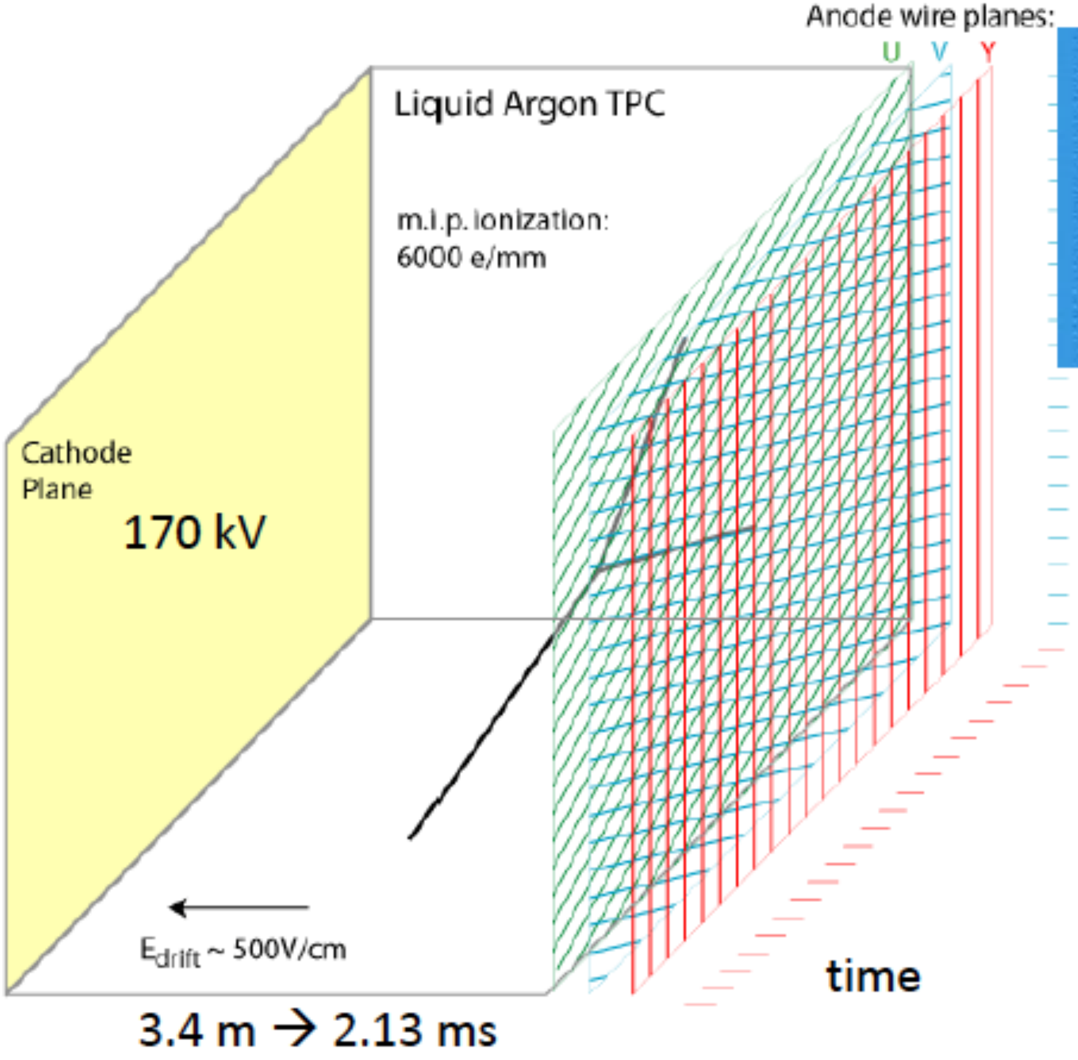
NH



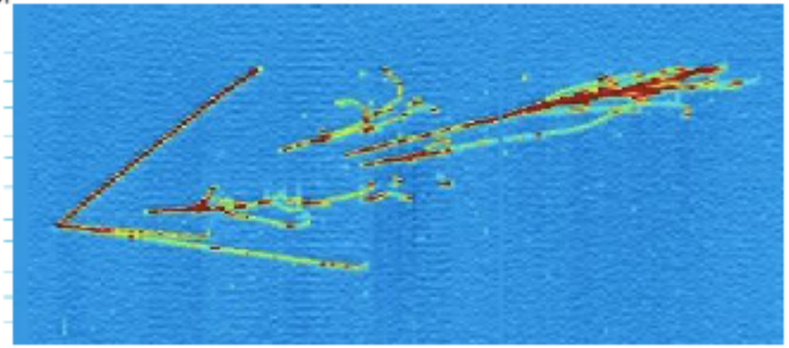
P(νμ → νe), IH, δcp=0
At 1300 km
1300 km
1st vac. osc. max
2nd vac. osc. max
Eν (GeV)
Baseline (km)
δcp = -π/2
δcp = 0
δcp = +π/2
θ13=0 (solar term)
P(νμ → ν̄e), IH
P(ν̄μ → ν̄e), IH, δcp=0
P(ν̄μ → ν̄e), IH

IH

Time Projection Chamber (TPC)



ArgoNeuT

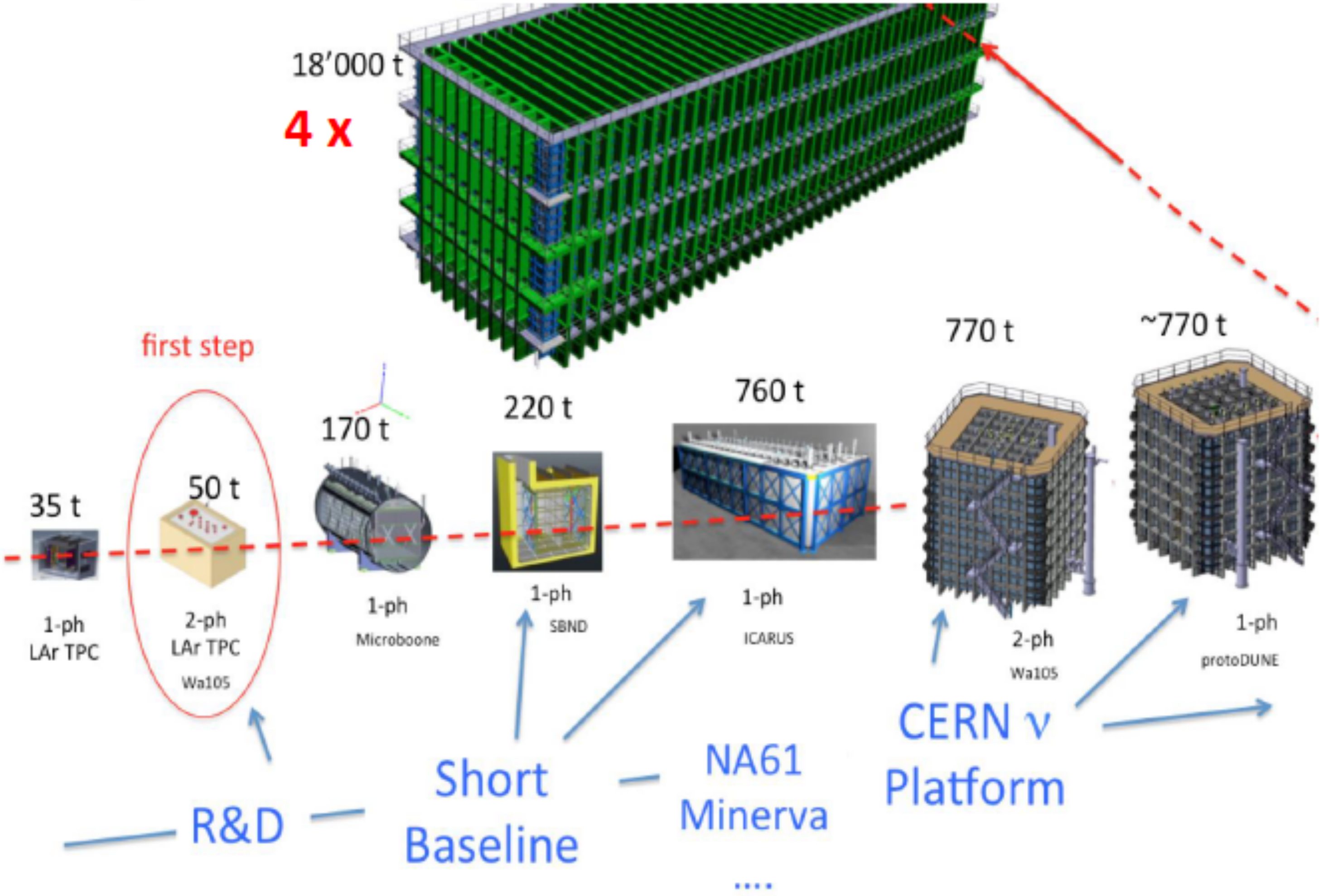


- "Bubble chamber" like imaging capabilities (few mm resolution).
- Excellent energy measurement.
- Excellent e-γ separation.
- Particle identification through dE/dx, range,..
- Timing through scintillation light

single-phase readout

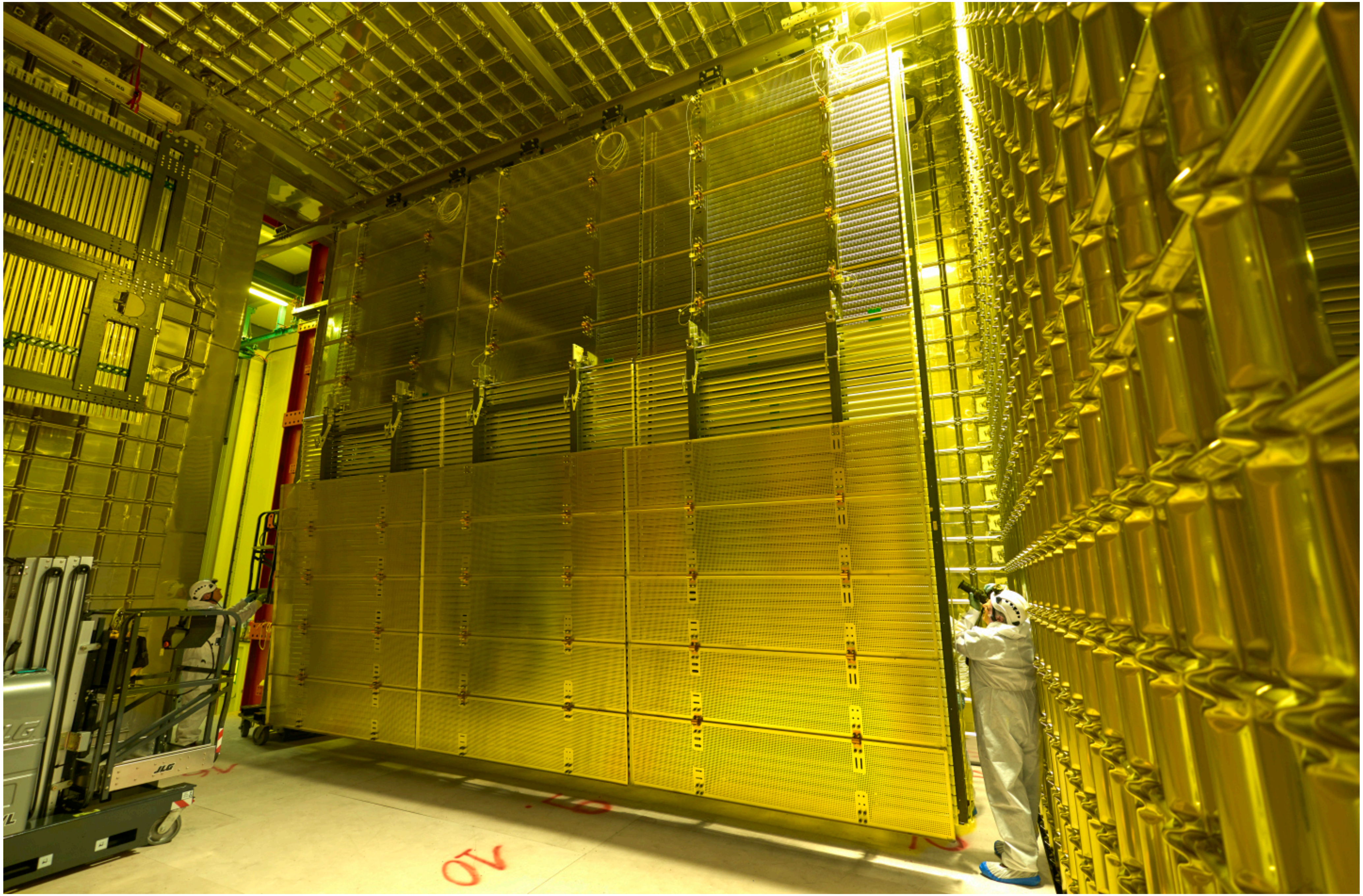
Step by step (LAr TPCs)

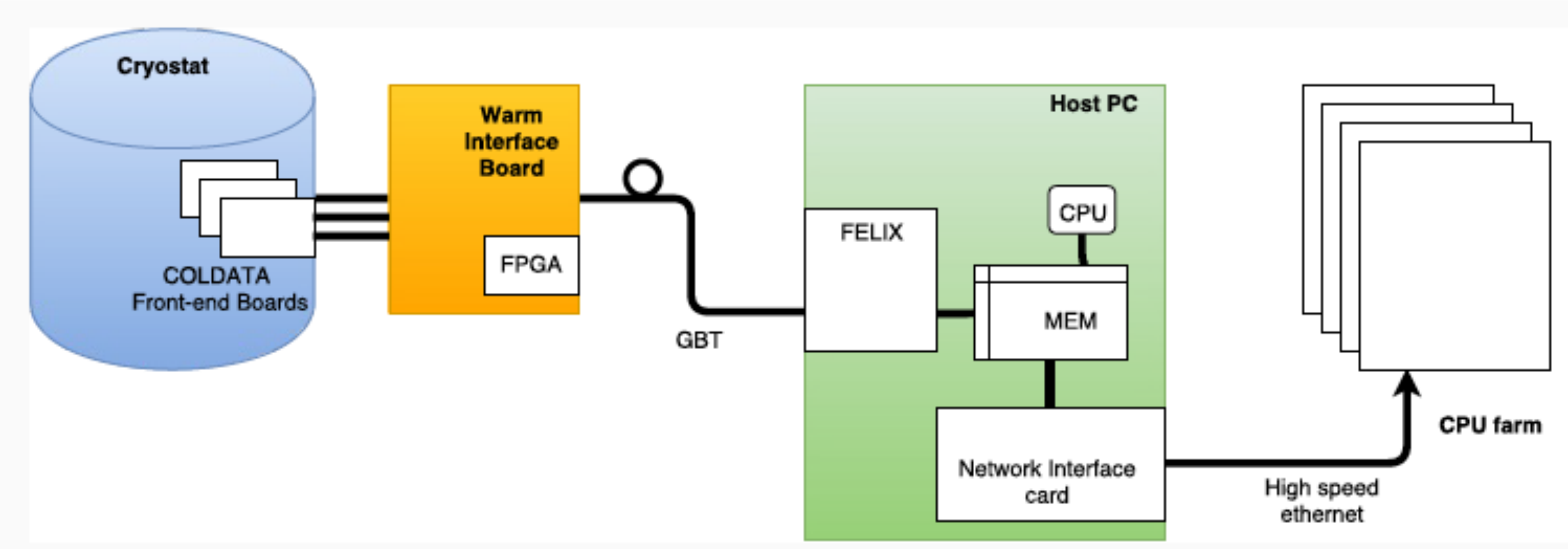
- .... the large scale is a big and new challenge



To succeed we need to proceed in steps (for cryostats, cryogenics and detectors)


YDAP
PPE184

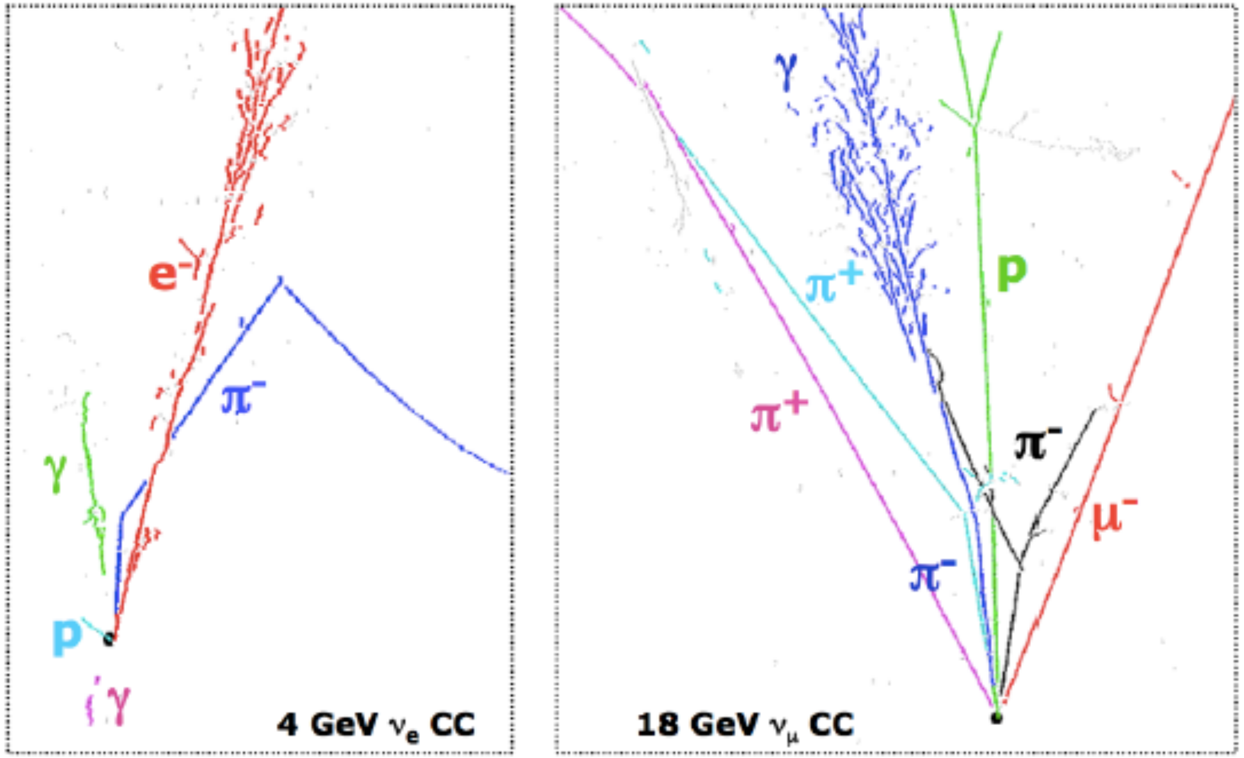

JLG



FELIX is being developed in ATLAS for the phase 1 (LS-2) upgrade, and afterwards
Get data in computer memory, COTS networking equipment downstream
Essentially on a PCI-e card in a host PC, equipped with a FPGA
Nikhef is one of the major developers in ATLAS

protoDUNE plan: at least APA read out with FELIX. Test setup in ATLAS test room.
PhD student Milo Vermeulen, staff Frank Filthaut, Patrick Decowski, Paul de Jong

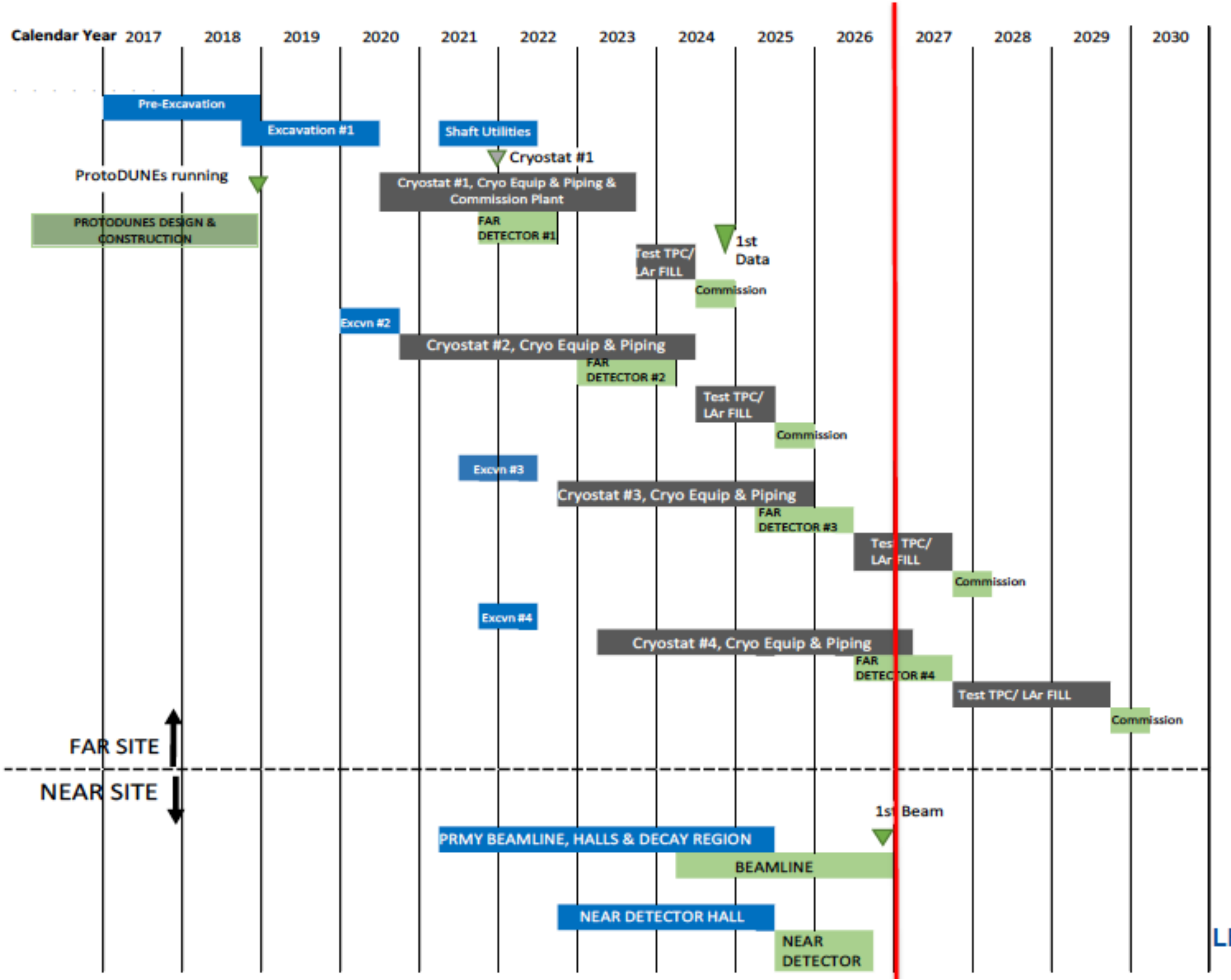
Another Challenge: Event Reconstruction



Highly complex event topologies that require sophisticated reconstruction algorithms.

Need to reconstruct tracks and showers, measure their energy and perform particle identification. Automatisation a major challenge.

LBNF/DUNE – Construction Summary



Assumptions in CDR

Particle type	Detection Threshold (KE)	Energy/Momentum Resolution	Angular Resolution
$\mu^{\pm}$	30 MeV	Contained track: track length Exiting track: 30%	1°
$\pi^{\pm}$	100 MeV	μ-like contained track: track length π-like contained track: 5% Showering or exiting: 30%	1°
$e^{\pm}/\gamma$	30 MeV	$2\% \oplus 15\%/\sqrt{E}$[GeV]	1°
p	50 MeV	p<400 MeV/c: 10% p>400 MeV/c: $5\% \oplus 30\%/\sqrt{E}$[GeV]	5°
n	50 MeV	$40\%/\sqrt{E}$[GeV]	5°
other	50 MeV	$5\% \oplus 30\%/\sqrt{E}$[GeV]	5°

Source of Uncertainty	MINOS ν_e	T2K ν_e	DUNE ν_e	Comments
Beam Flux after N/F extrapolation	0.3%	3.2%	2%	See "Flux Uncertainties" in Section 3.6.2
Interaction Model	2.7%	5.3%	$\sim 2\%$	See "Interaction Model Uncertainties" in Section 3.6.2
Energy scale (ν_μ)	3.5%	included above	(2%)	Included in 5% ν_μ sample normalization uncertainty in DUNE 3-flavor fit.
Energy scale (ν_e)	2.7%	2.5% includes all FD effects	2%	See "ν_e Energy-Scale Uncertainties" in Section3.6.2
Fiducial volume	2.4%	1%	1%	Larger detectors = smaller uncertainty.
Total	5.7%	6.8%	3.6 %	
Used in DUNE Sensitivity Calculations			$5\% \oplus 2\%$	Residual ν_e uncertainty: 2%

Conclusions

- Both ARCA and ORCA have close links with other experiments
- Neutrino forum needs reanimation…

On ArXiv this morning:

Observation of a Significant Excess of Electron-Like Events in the MiniBooNE Short-Baseline Neutrino Experiment

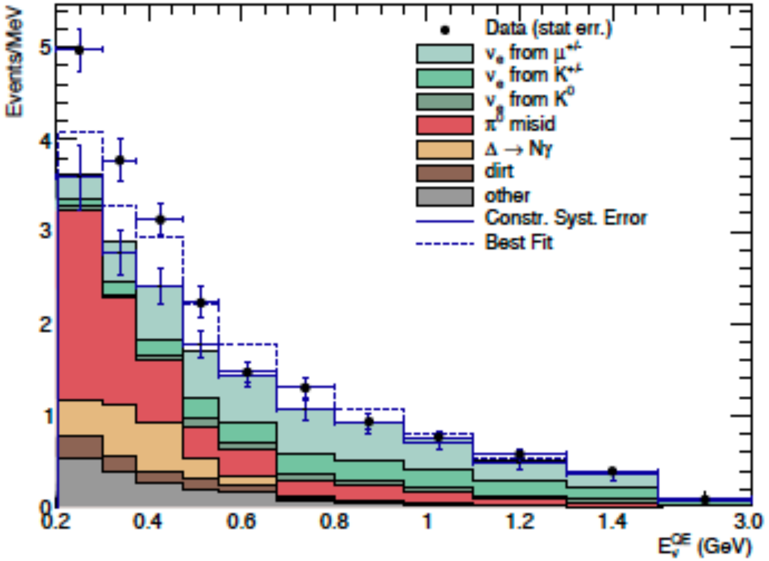


FIG. 1: The MiniBooNE neutrino mode E_ν^{QE} distributions, corresponding to the total 12.84×10^{20} POT data, for ν_e CCQE data (points with statistical errors) and background (histogram with systematic errors). The dashed curve shows the best fit to the neutrino-mode data assuming standard two-neutrino oscillations.

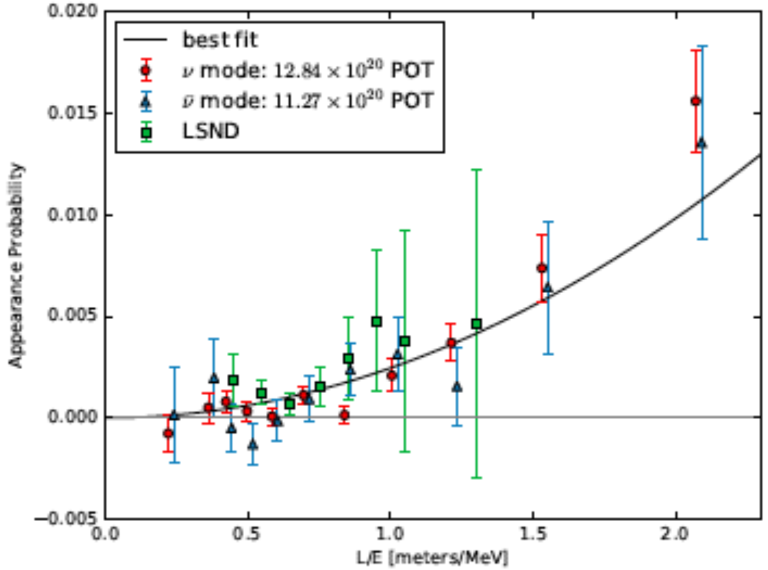


FIG. 3: A comparison between the L/E_ν^{QE} distributions for the MiniBooNE data excesses in neutrino mode (12.84×10^{20} POT) and antineutrino mode (11.27×10^{20} POT) to the L/E distribution from LSND [1]. The error bars show statistical uncertainties only. The solid curve shows the best fit to the LSND and MiniBooNE data assuming standard two-neutrino oscillations. The excess of MiniBooNE electron-neutrino candidate events is consistent with the LSND excess.