

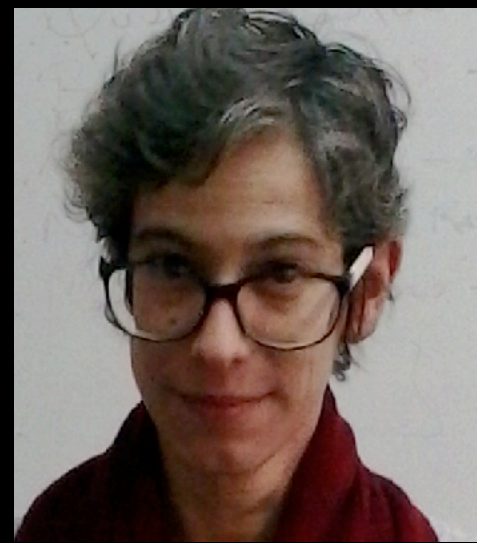
NEUTRINO PHYSICS

JOSÉ MANEIRA
FOR THE LIP
NEUTRINO PHYSICS GROUP

LIP ADVISORY COMMITTEE MEETING
LIP LISBOA, APRIL 27, 2026



Senior Researchers



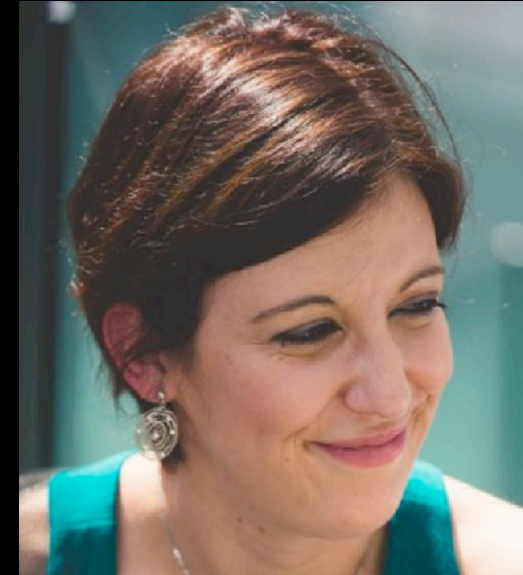
Sofia
Andringa



Fernando
Barão



Nuno
Barros



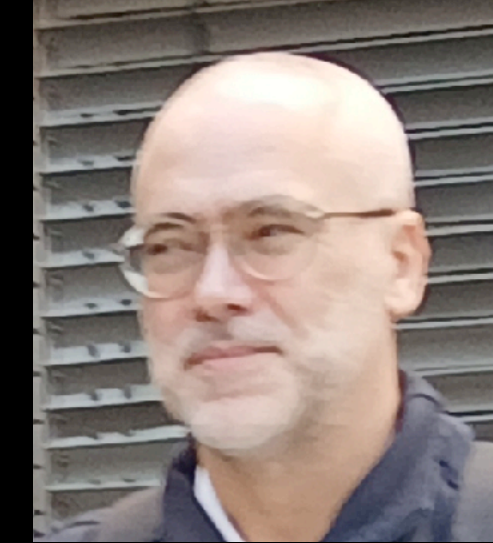
Valentina
Lozza



Amélia
Maio



José
Maneira



Francisco
Neves

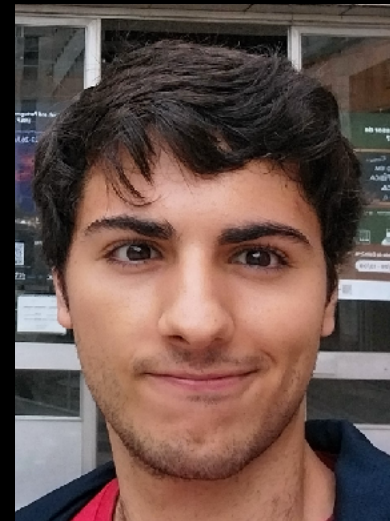


Vladimir
Solovov



Cristóvão
Vilela

Students



Manuel
Abreu



Tomás
Baltazar



Wallison
Campanelli



Joan
Kladnik



Beymar
Quenallata



Joana
Vences

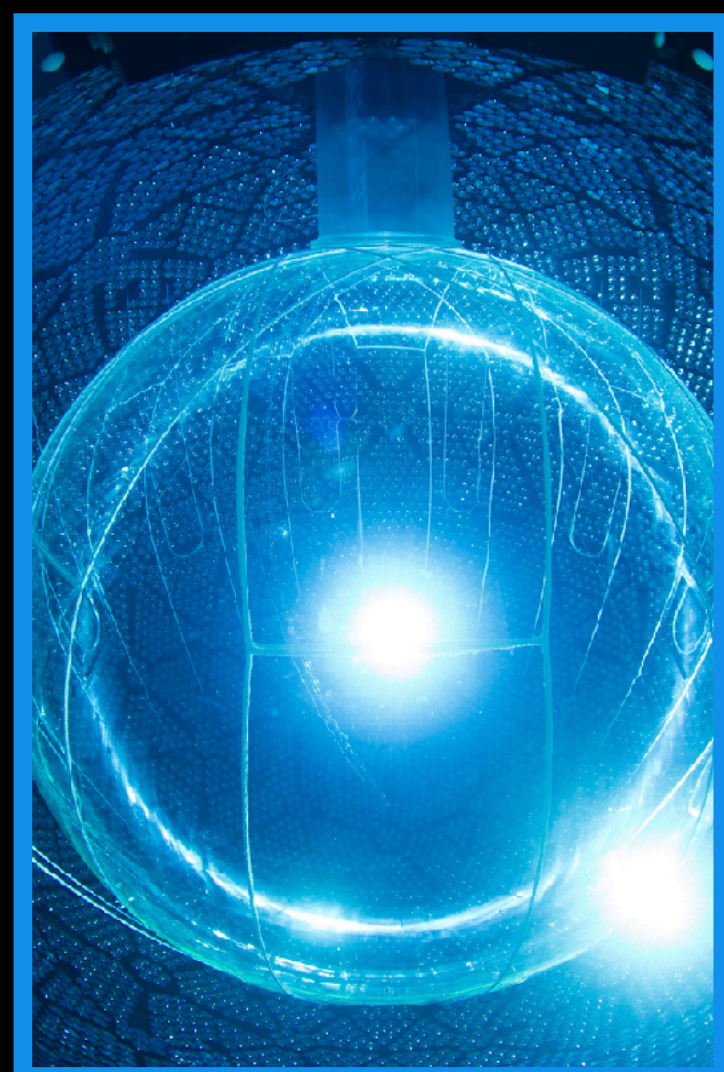
- Group structure
 - We are present in the Lisbon and Coimbra nodes, and participate in SNO+ and DUNE
 - Group PI: JM
- Funding:
 - None since January 2026
 - PTDC2023 application failed
 - PTDC2025 submitted 2 applications
 - Joined a MSCA Staff Exchange prop., for DUNE (follow-up of SENSE)
- Students
 - Three ongoing PhD grants, just applied for more
- Coordination responsibilities SNO+
 - VL: Analysis Coordinator, Backgrounds group
 - SA: Antineutrino Physics group
 - JM: Double-beta decay group, Source Review Committee, Executive Committee
- Coordination responsibilities DUNE
 - JM: Calibration and Cryogenic Instrumentation consortium, Executive Board
 - NB: DAQ and Computing liaison of CALCI consortium

- SNO+ highlights 2025
 - Scintillator phase calibrations
 - Results and papers
 - New results in solar and reactor neutrinos in scintillator phase
 - World's first measurement of solar neutrino interaction on ^{13}C
- DUNE highlights 2025
 - Installation, operation of laser calibration system at ProtoDUNE-VD, CERN
 - Analysis of ProtoDUNE-HD data
 - Finalizing design for Far Detector calibration system, production started
- Conferences, etc (both)
 - talk at Weak Interactions and Neutrinos (Sussex)
 - talk at Workshop on hybrid Cherenkov/Scintillation detectors (Philadelphia)

SNO+ TIMELINE AND PLANS



2017 2018 2019 2020 2021 2022 2023 2024 2025 2026



Water phase

best inv. nucleon decay limits; first reactor ν in water

Partial fill phase

solar ν directionality
reactor ν in LS



Scintillator phase

reactor ν : meas. of Δm_{12}^2 ;
first solar CC on ^{13}C
low energy ^8B solar ν

SNO+ ANALYSIS COORDINATOR:
VALENTINA LOZZA

2026 2027 2028 2029 2030 2031 2032

Repairs

Fill 0.5% Te

0.5% data

Fill 1.5% Te

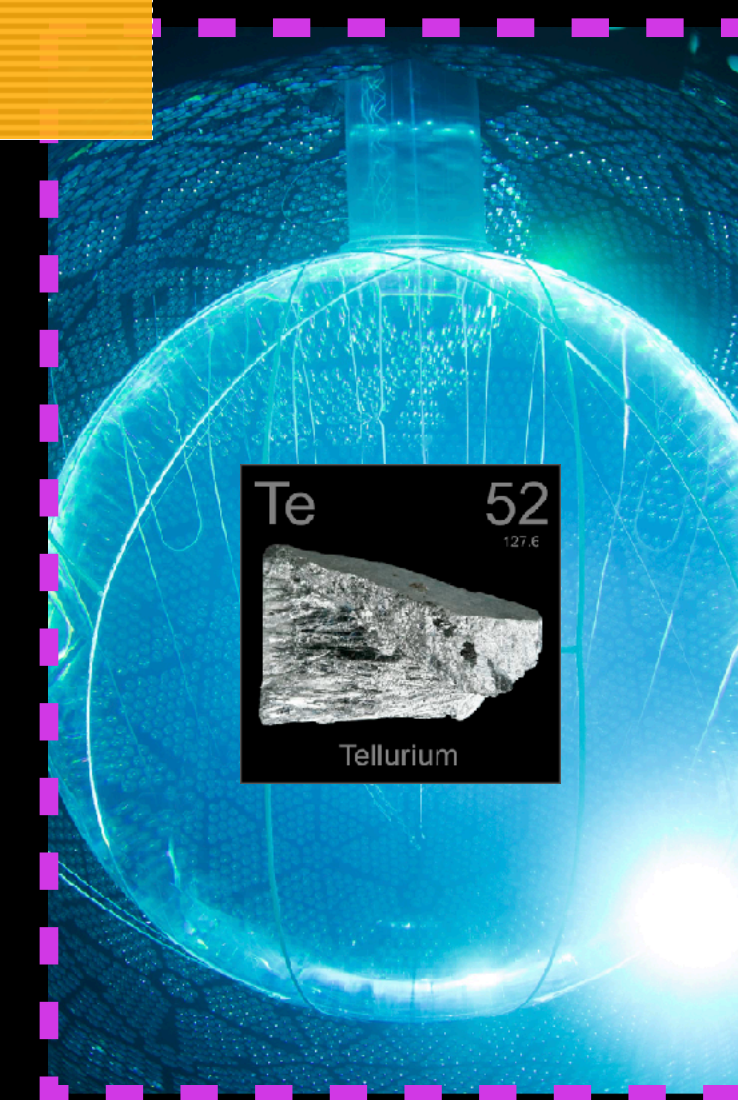
1.5% data

Acrylic Vessel Repairs

leak in AV, height identified, lowering water now to repair, autumn restart

Tellurium-loaded phase:

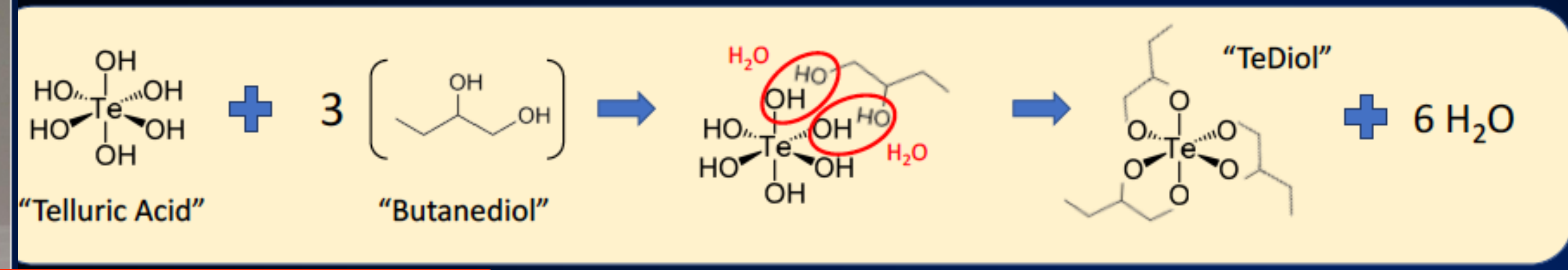
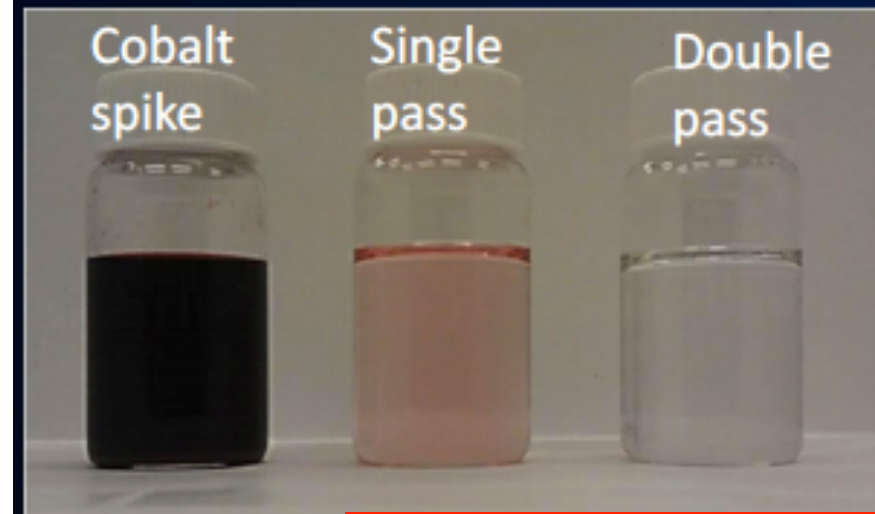
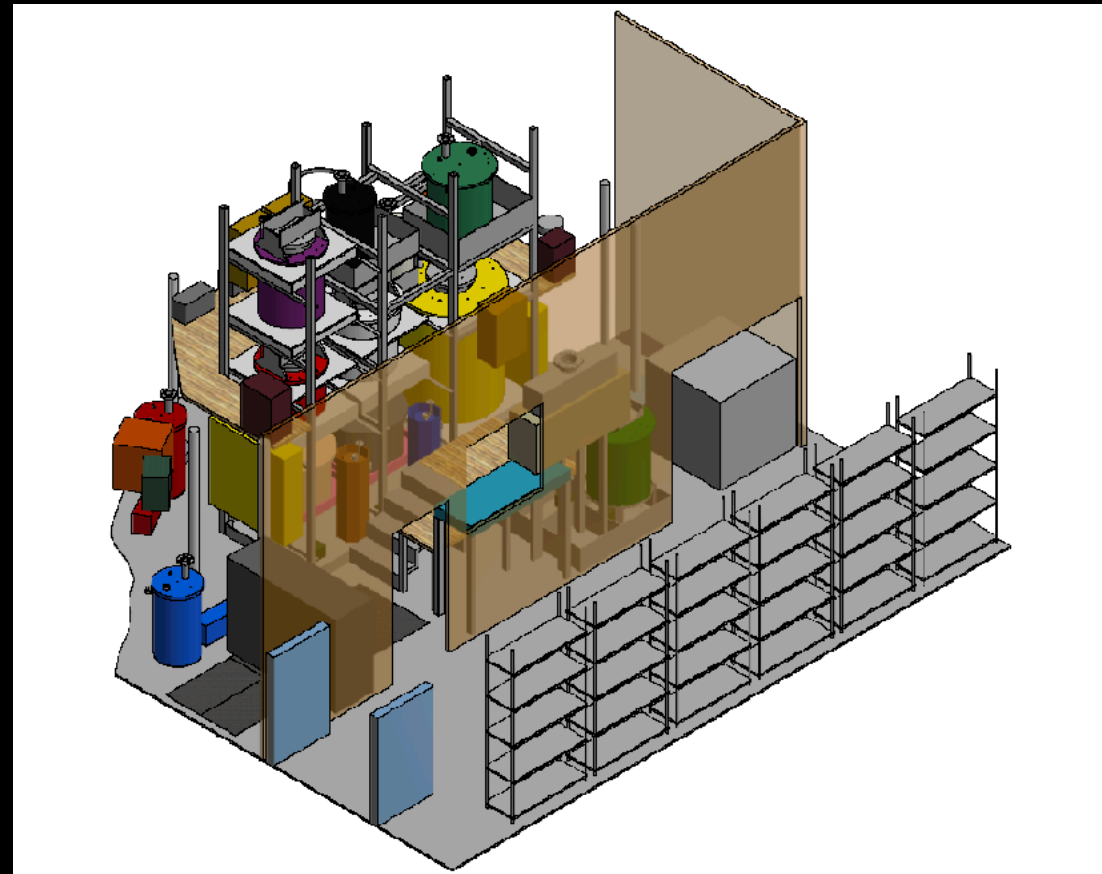
0.5%: best sensitivity to ^{130}Te $0\nu\beta\beta$ (2×10^{26} yr in 3 yrs). Submitted proposal for 1.5% loading



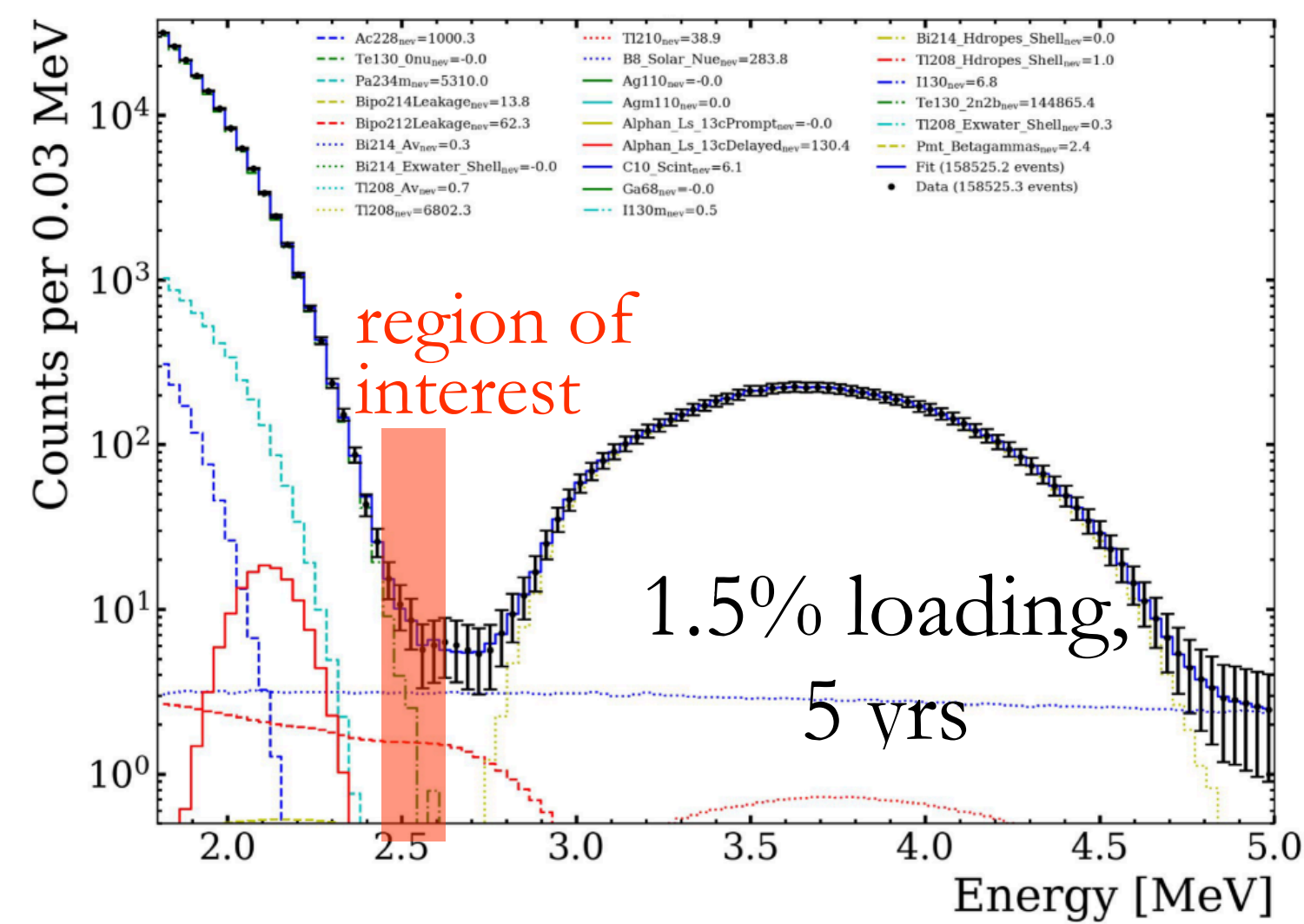
SNO+ WITH TELLURIUM

DOUBLE BETA DECAY
GROUP LEADER: JM

LIQUID SCINTILLATOR LOADING TECHNIQUE:
HIGH ISOTOPE MASS, LOW BACKGROUNDS

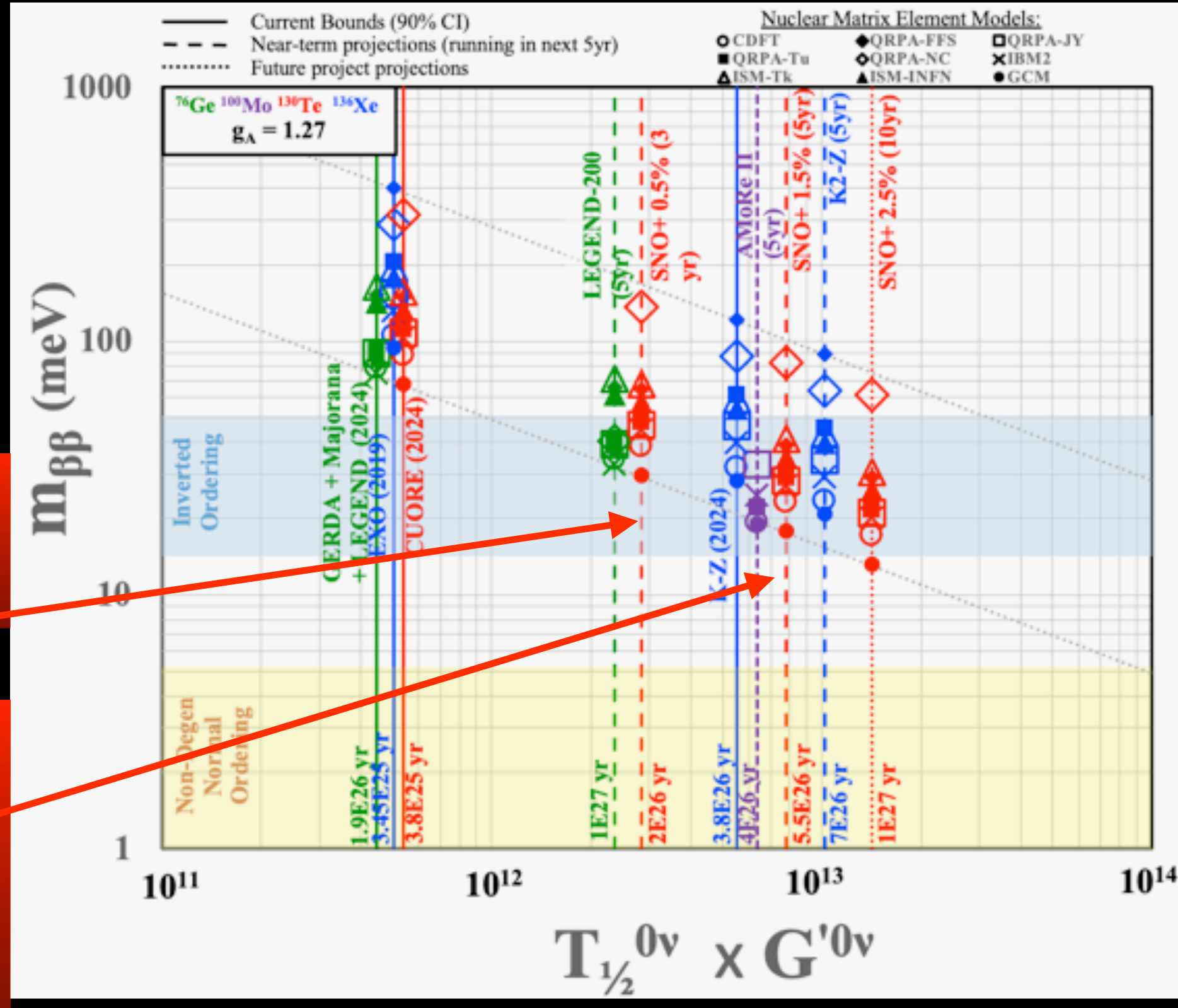


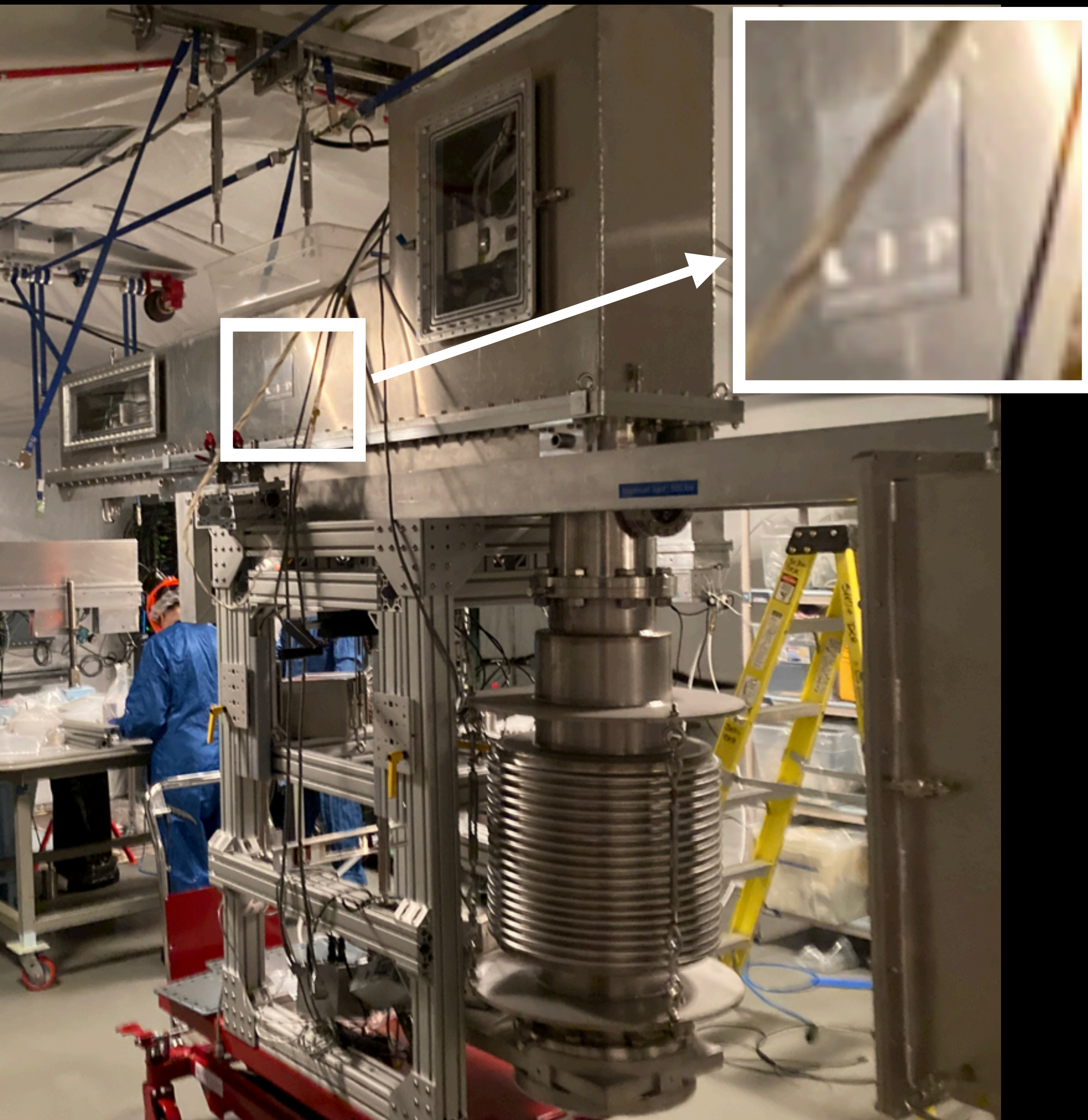
SNO+ DEVELOPED
TECHNIQUES FOR
TELLURIUM PURIFICATION
AND LOADING



0.5% LOADING: BEST ^{130}Te
SENSITIVITY

1.5% LOADING: WINDOW OF
OPPORTUNITY FOR BEST
SENSITIVITY, ANY ISOTOPE
(BEFORE "TON-SCALE")





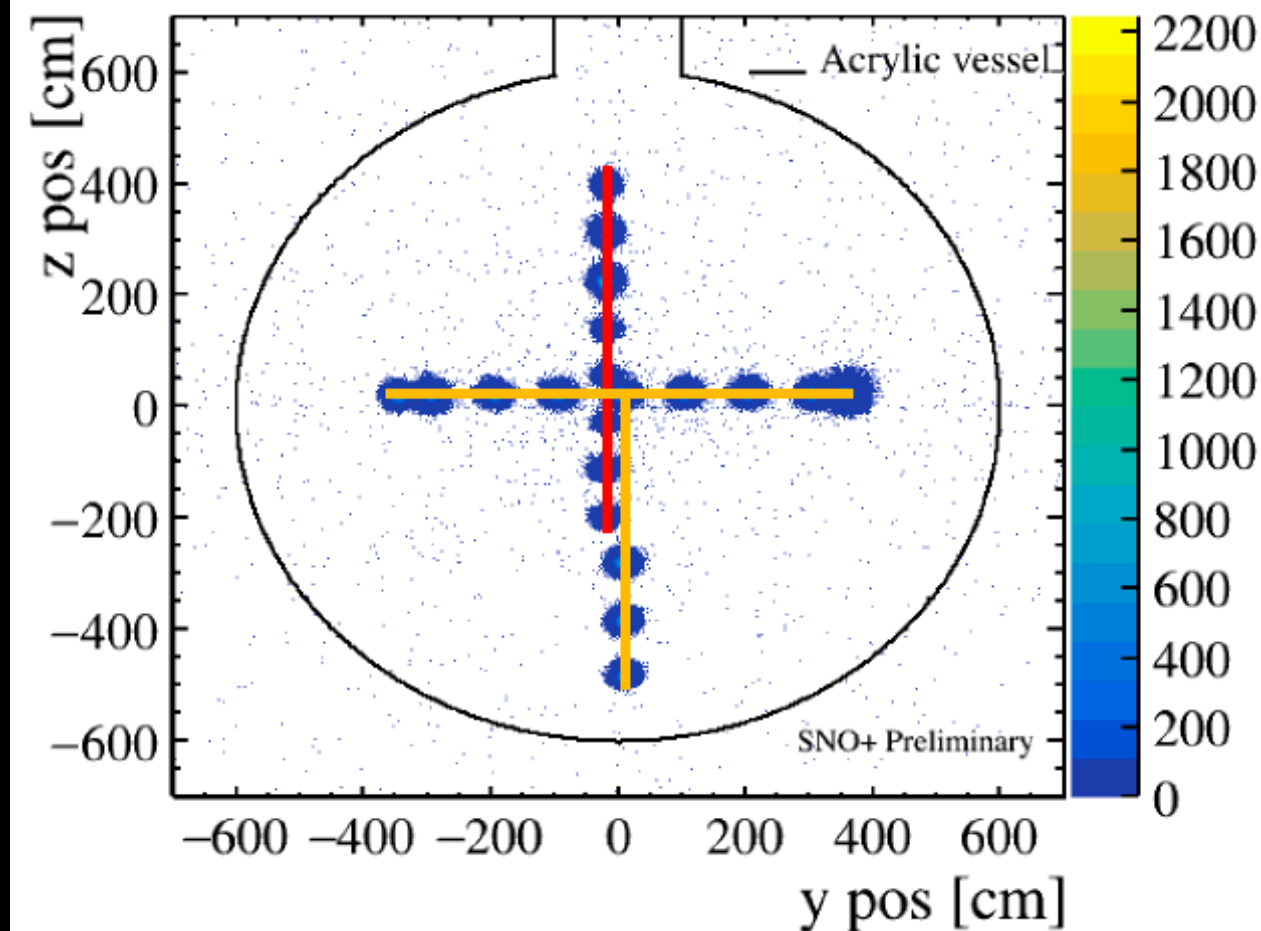
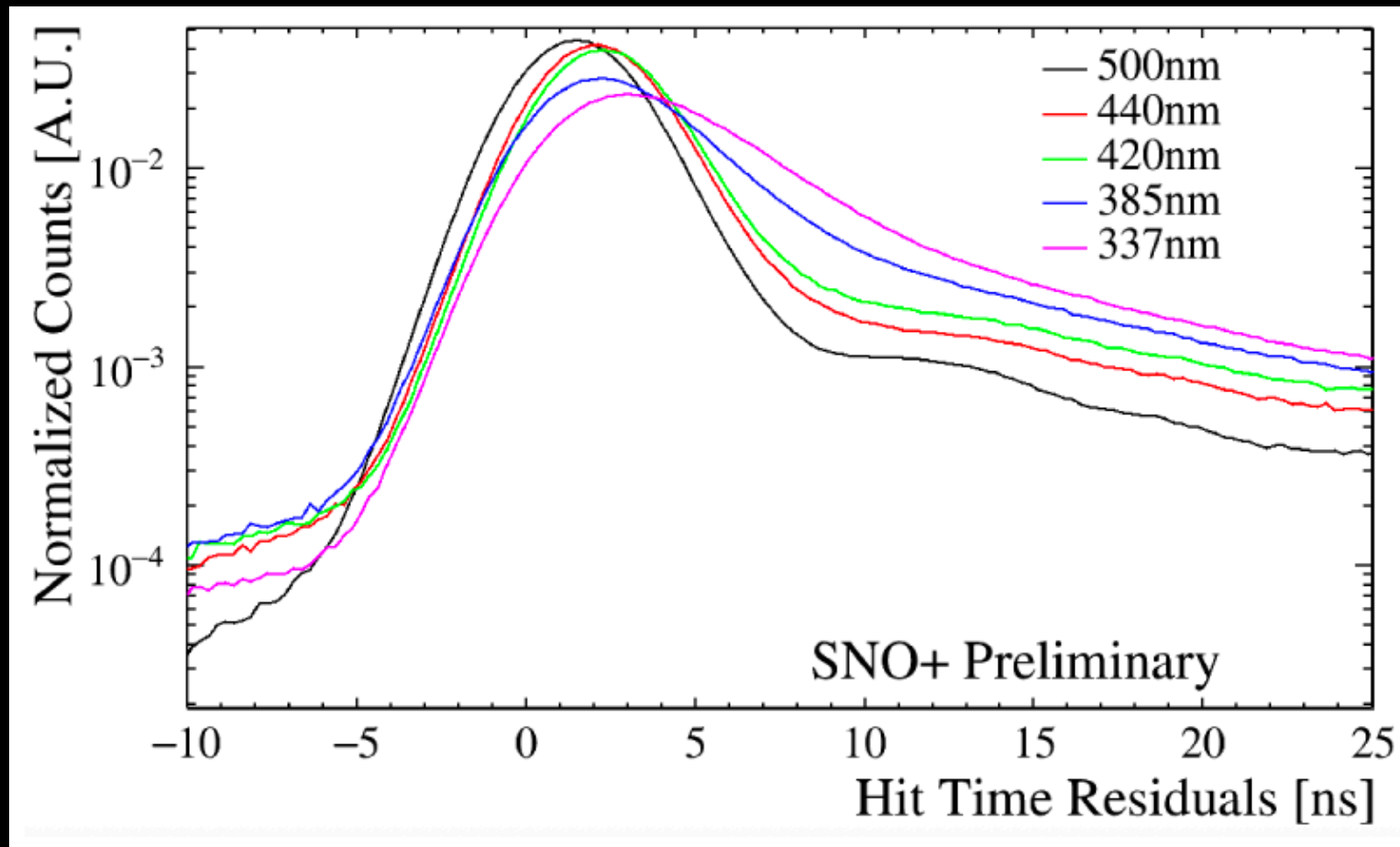
- Extensive review leading to scintillator phase calibrations
- deployment hardware and two sources: laserball and AmBe (neutron) source
- all aspects of design, fabrication, cleaning and deployment procedures: numerous changes
- successful deployment and data taking in summer 2025
- no contamination introduced!

SOURCE REVIEW COMMITTEE
MEMBERS: JOSÉ MANEIRA
(CHAIR), VALENTINA LOZZA

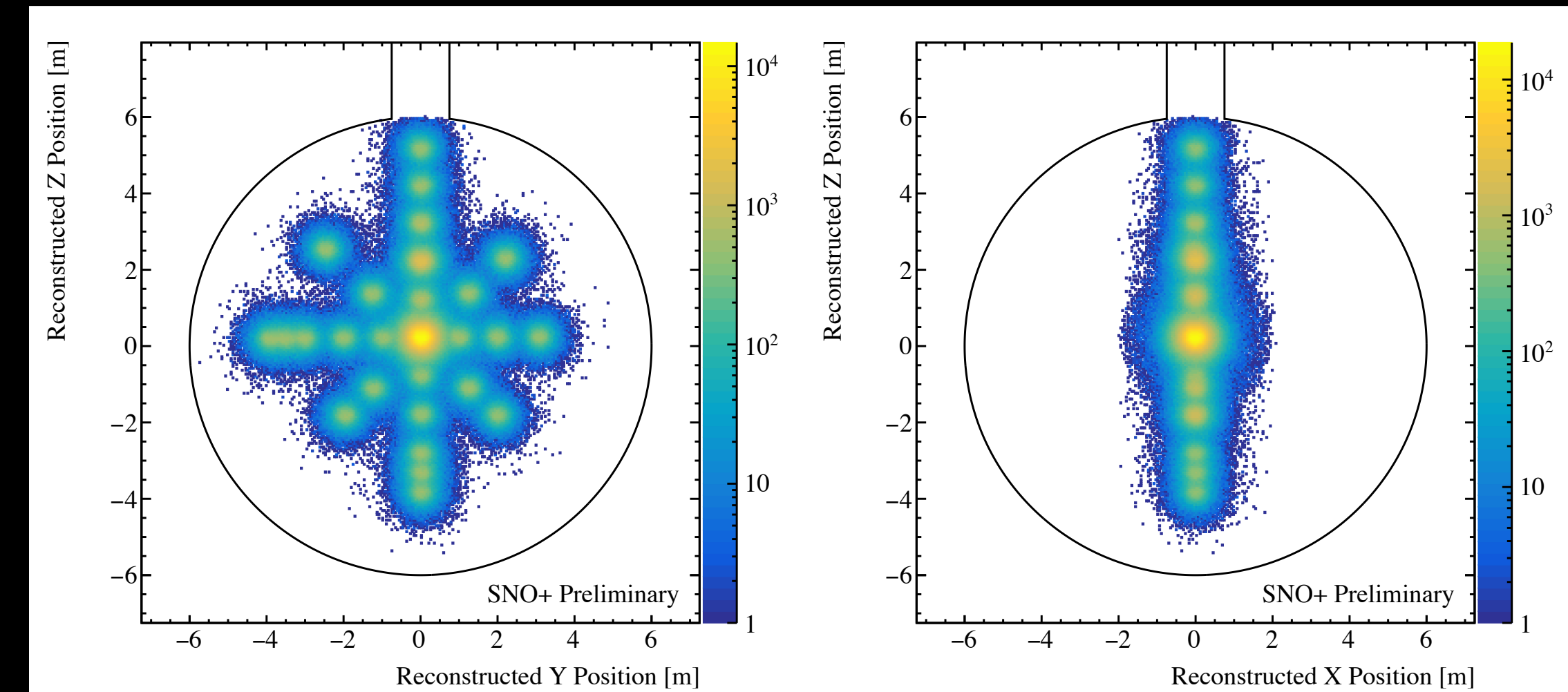
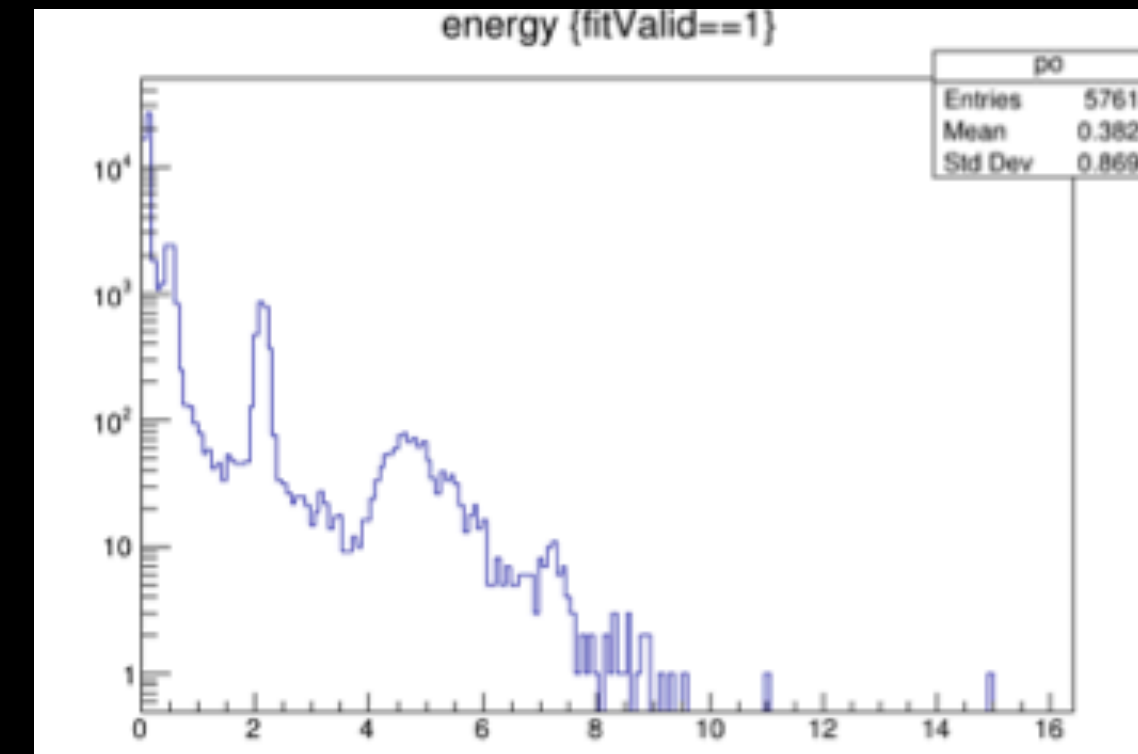
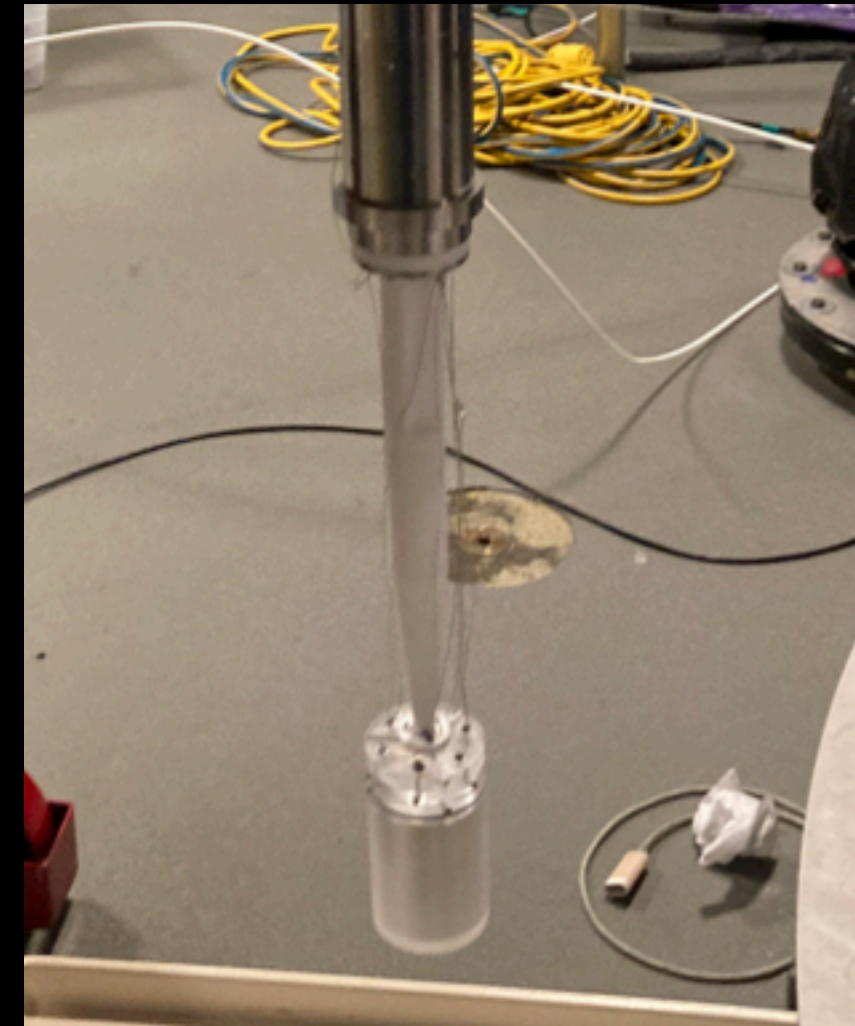
SCINTILLATOR PHASE CALIBRATIONS



Laserball source and data



AmBe source and data

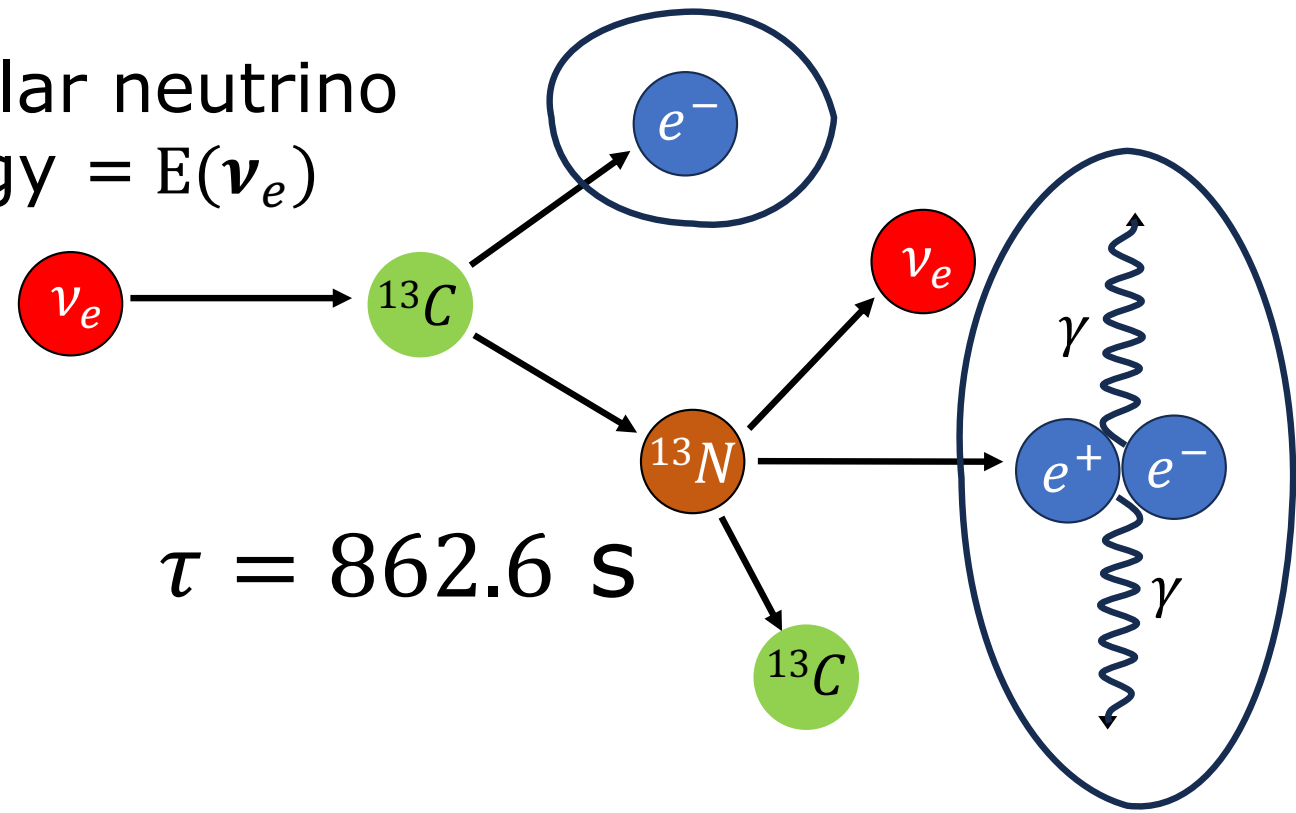


FIRST SOLAR NUS ON C-13

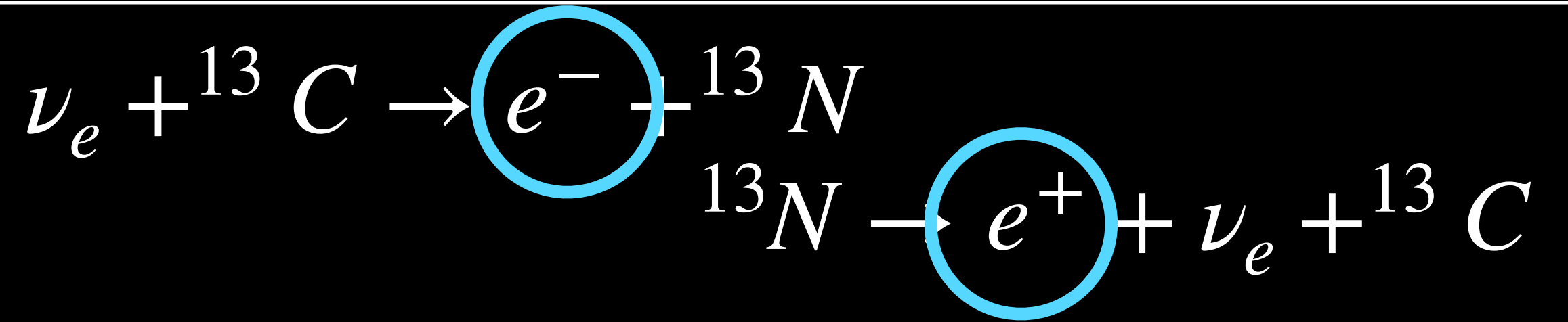


Prompt e^- energy = $E(\nu_e) - 2.2 \text{ MeV}$

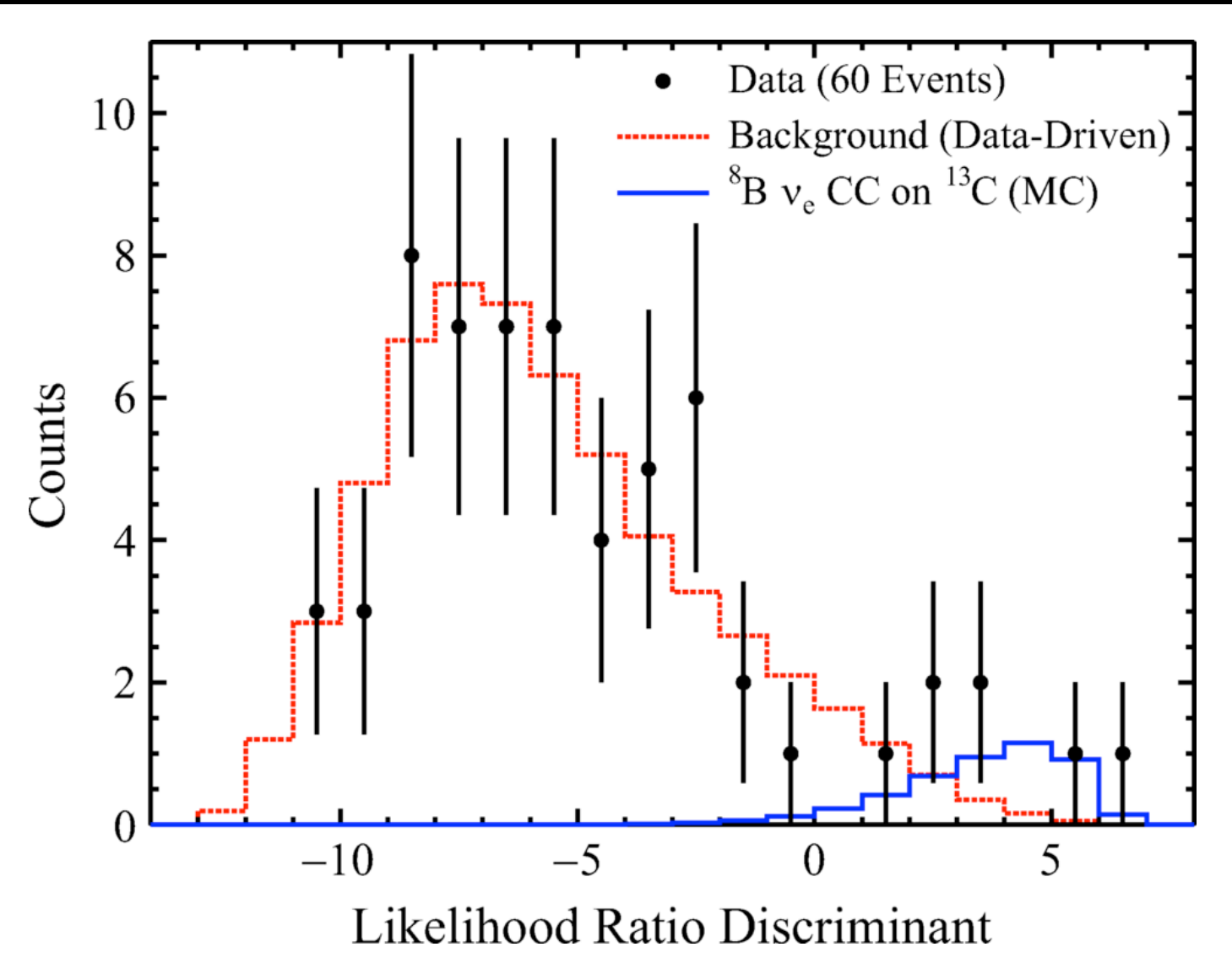
^8B solar neutrino energy = $E(\nu_e)$



Delayed e^+ annihilation [1.01, 2.20] MeV

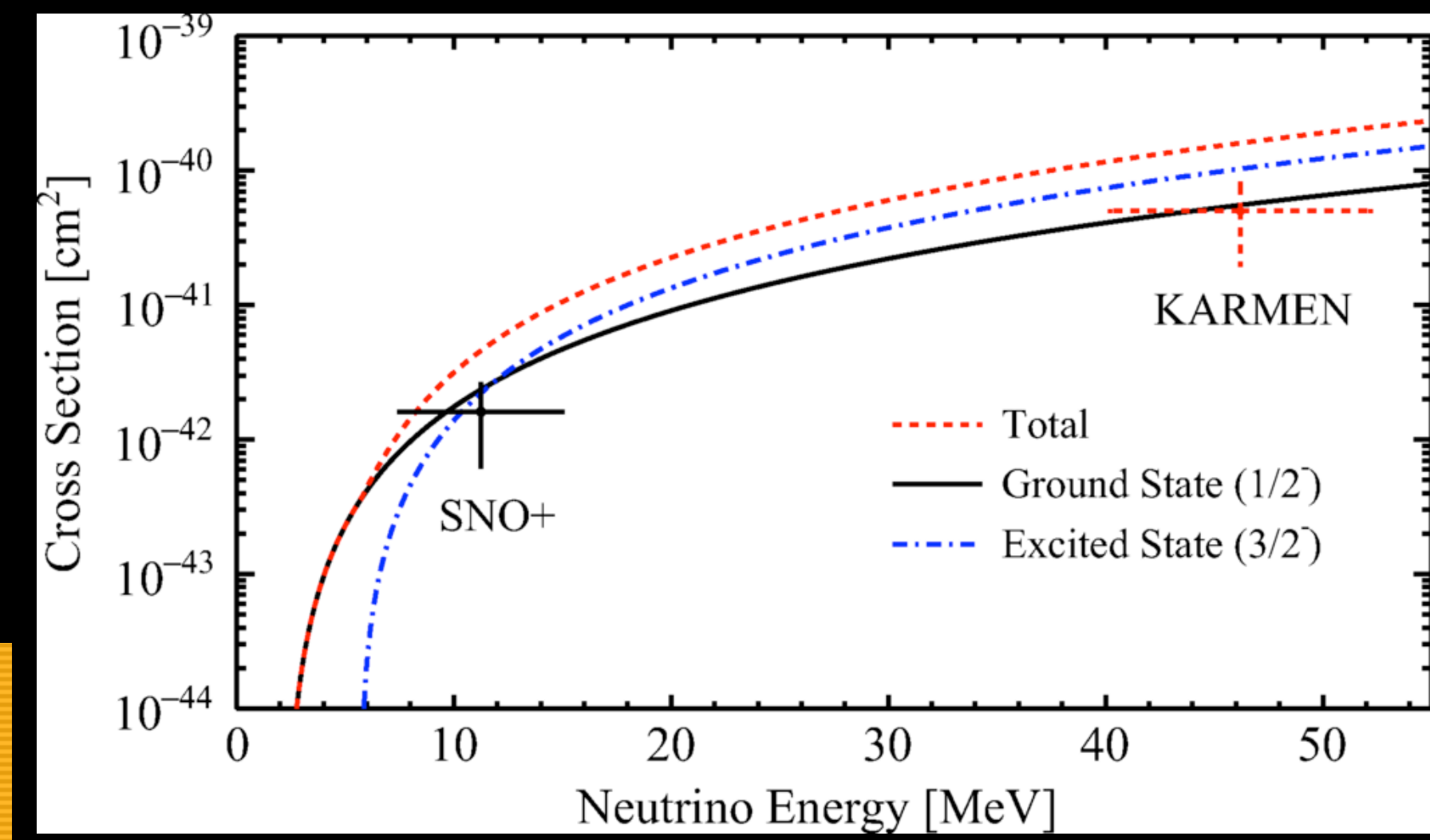


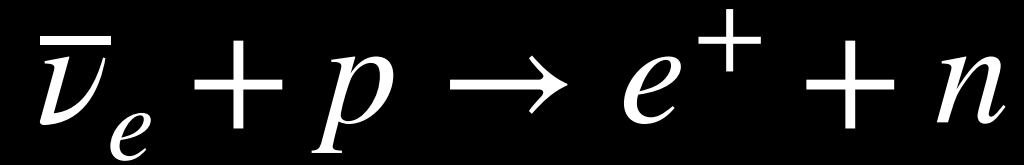
- C-13 has only 1.1% abundance, but cross section $\sim 12\times$ higher than ES at ^8B ν energies
- 10 min half-life of N-13 \rightarrow possible only due to low backgrounds



- Observed 5.6 events vs 4.7 expected in 231 days
- First observation of low energy neutrinos on Carbon-13

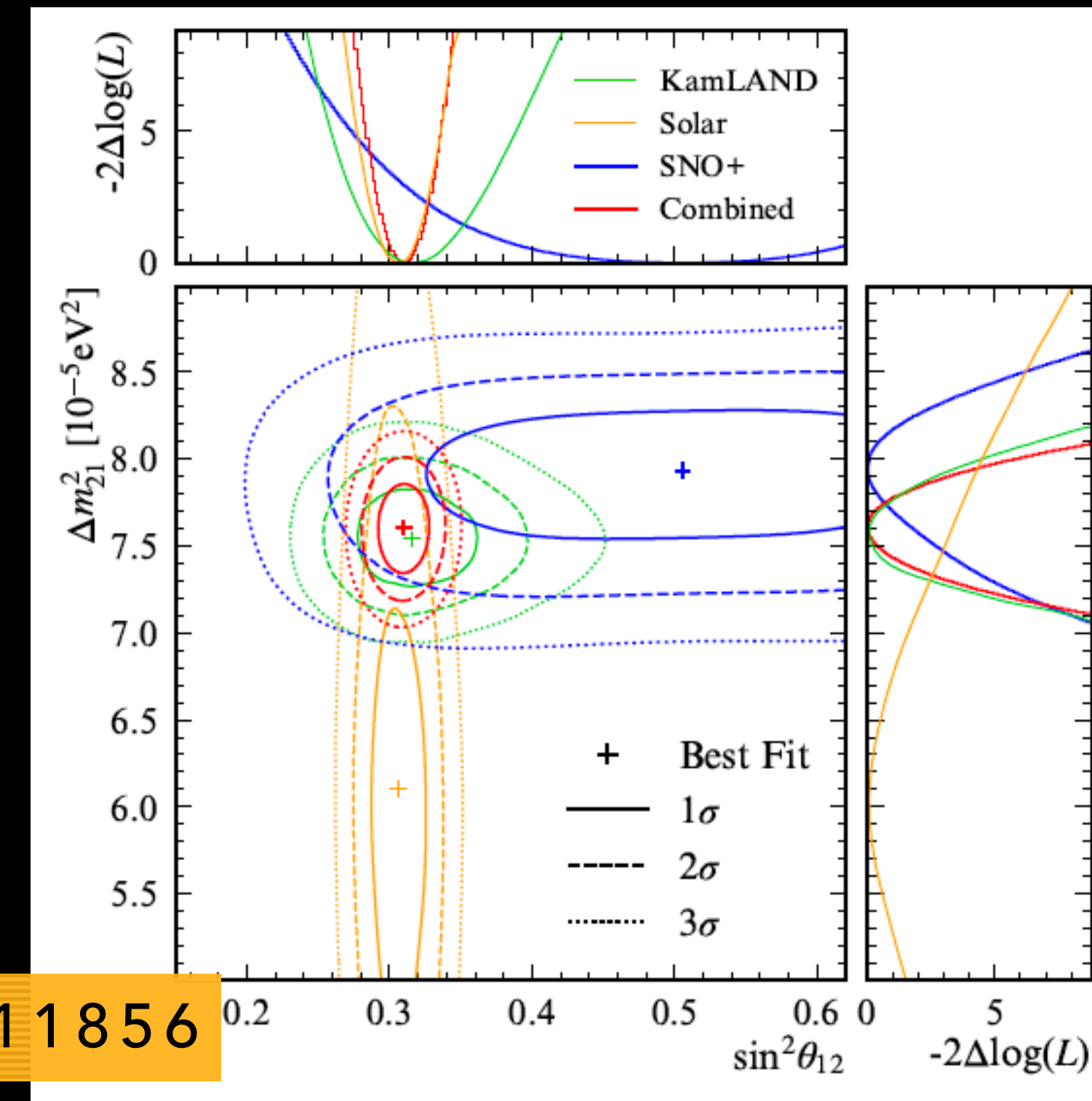
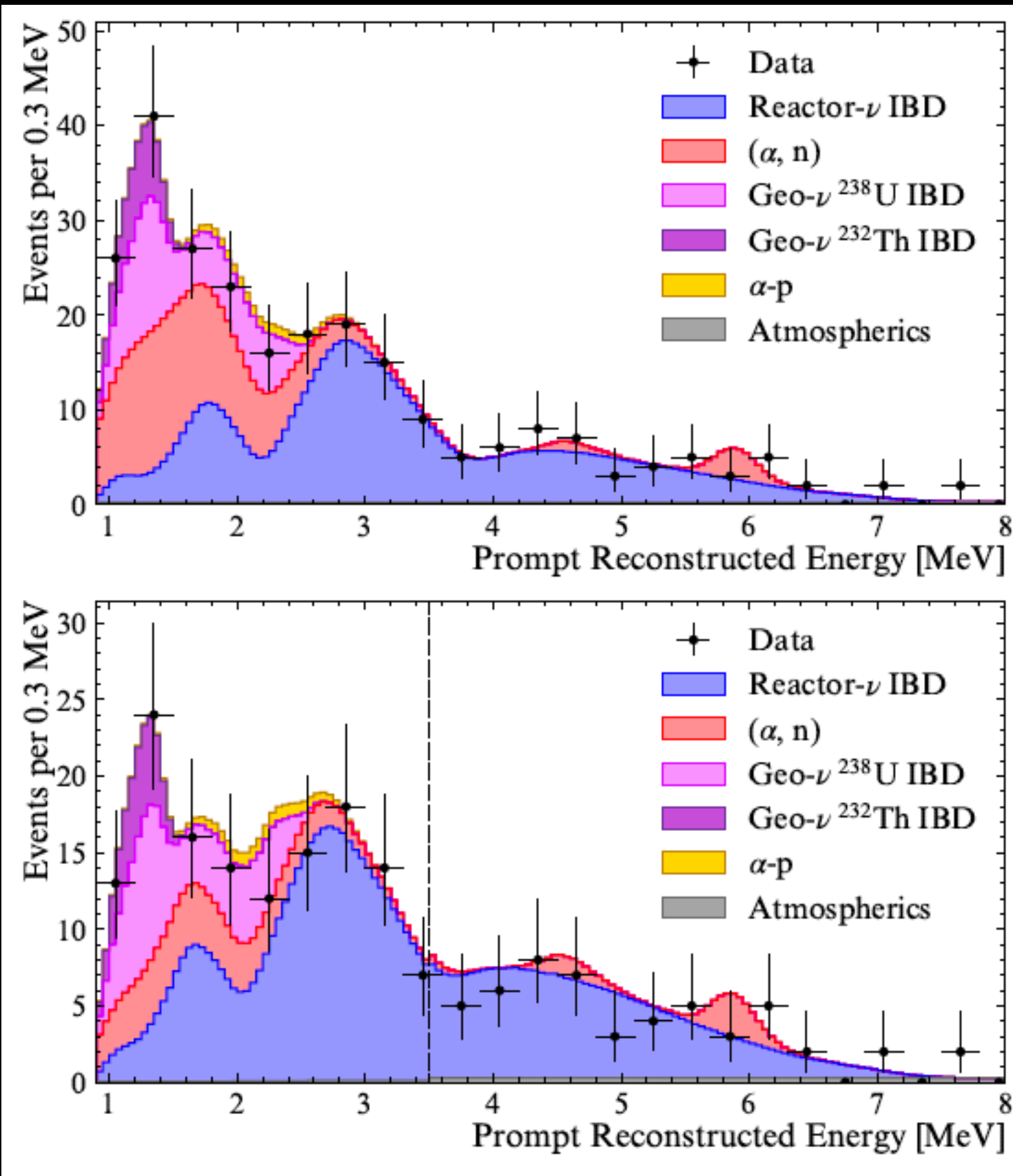
SNO+ COLLAB., PHYS. REV. LETT. 135, 241803





	Fit	Fit (con.)	Fit (α, n) cut
Δm_{21}^2 [$\times 10^{-5} eV^2$]	$7.93^{+0.21}_{-0.24}$	7.63 ± 0.17	7.56 ± 0.17
$\sin^2 \theta_{12}$	0.505 ± 0.134	0.310 ± 0.012	0.311 ± 0.012
Geo- $\bar{\nu}$ [TNU]	60^{+23}_{-22}	61^{+23}_{-22}	49^{+13}_{-12}
Geo- $\bar{\nu}$ U/Th	$3.38^{+1.39}_{-1.41}$	$3.30^{+1.41}_{-1.44}$	$3.29^{+1.42}_{-1.48}$

- Antineutrino signal fit with reactor and geo-neutrino components
- Recent improvement: classifier for (α, n) background, benefited from calibration
- Results
 - $\Delta m_{21}^2 = 7.93^{+0.21}_{-0.24} \times 10^{-5} eV^2$ close to KamLAND, also in precision
 - First geoneutrino measurement in the Americas: $49^{+13}_{-12} TNU$



ANTINEUTRINO PHYSICS GROUP
LEADER: SOFIA ANDRINGA

[HTTPS://ARXIV.ORG/PDF/2511.11856](https://arxiv.org/pdf/2511.11856)

DUNE TIMELINE AND PLANS



2023 2024 2025 2026 2027 2028 2029 2030 2031

ProtoDUNE@CERN

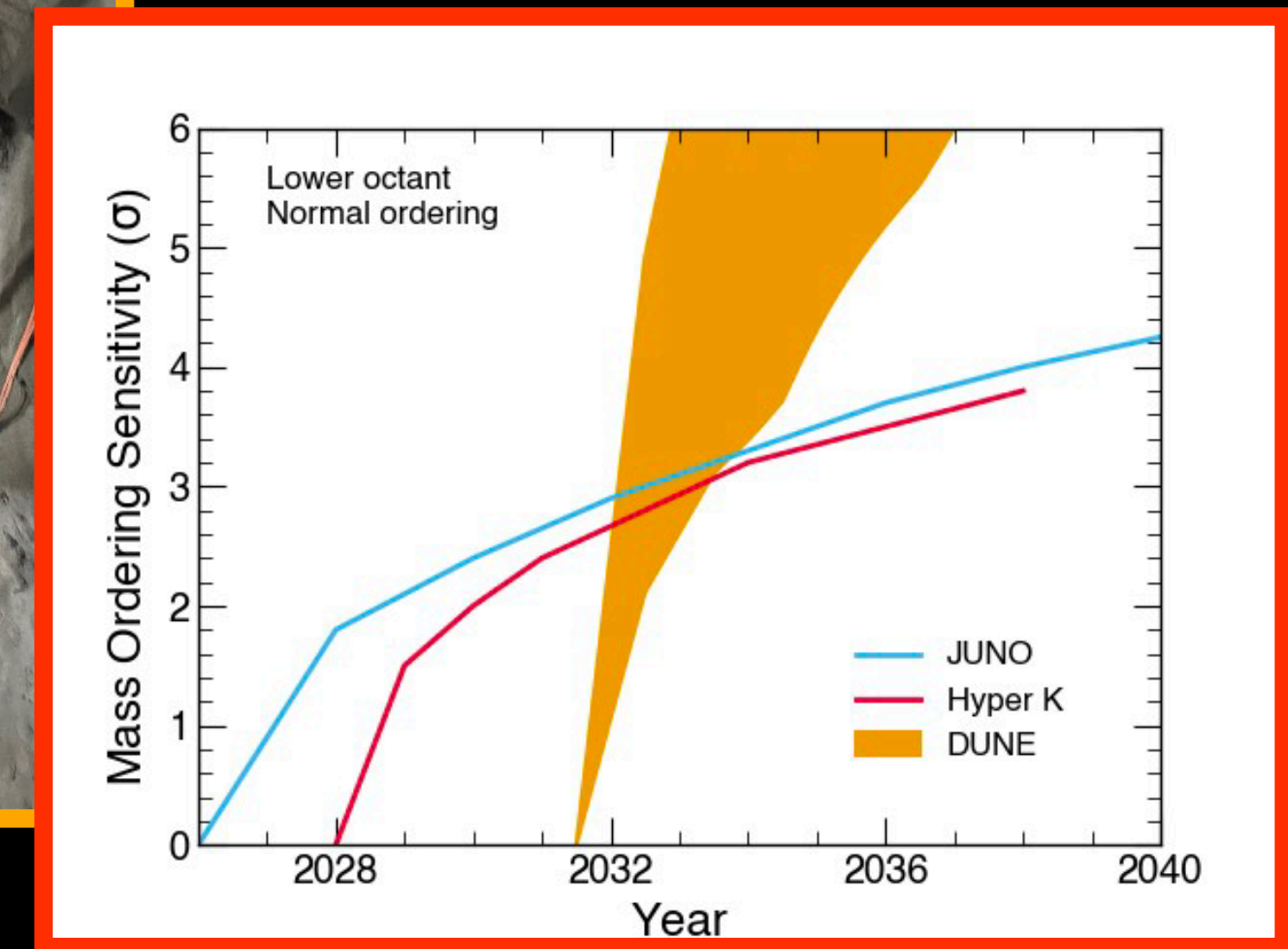
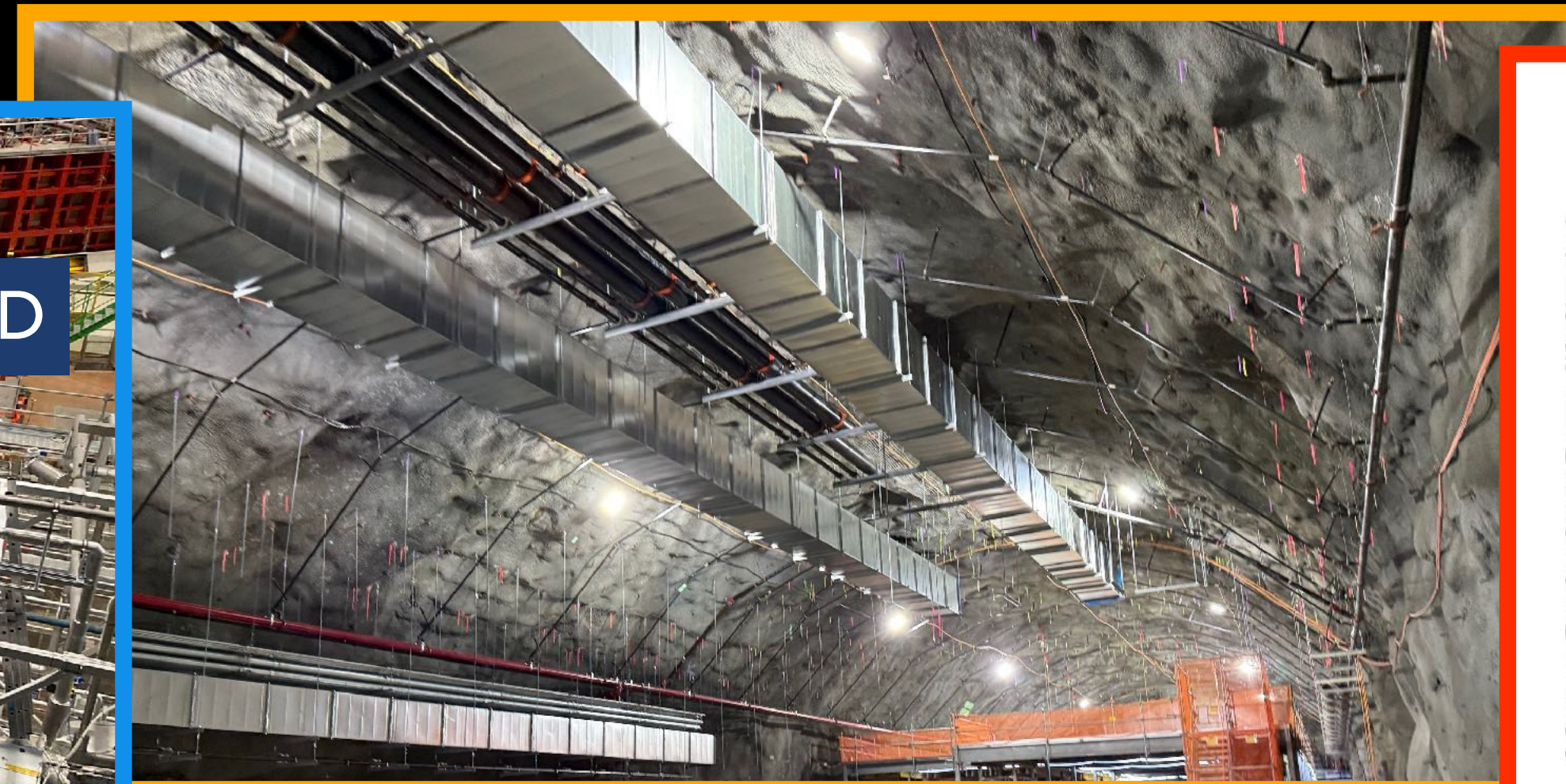
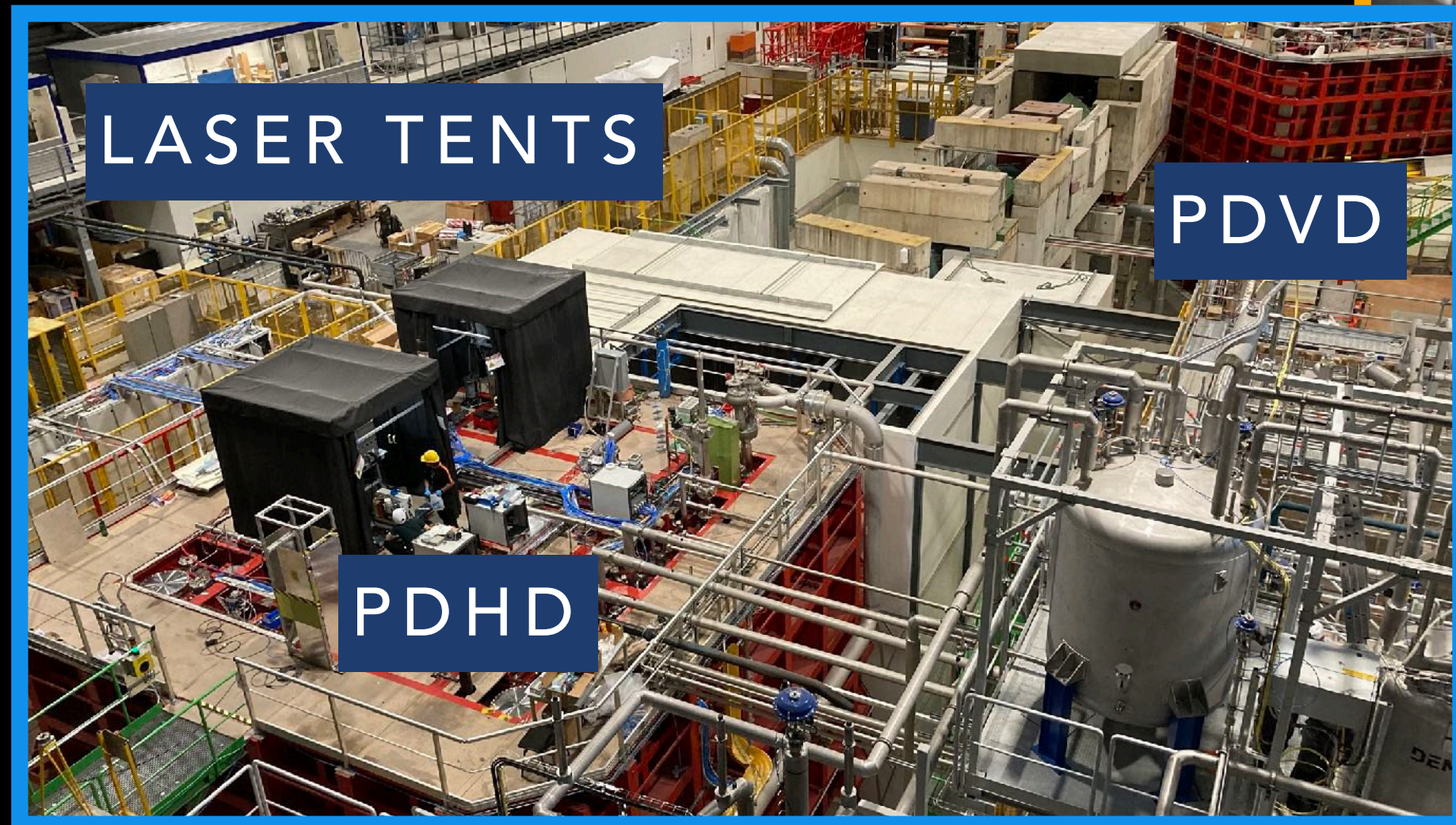
installation
operation of PD Horizontal Drift
2025: delay due to safety reviews
ongoing: PD Vertical Drift

Far Detector Construction & Installation@SURF

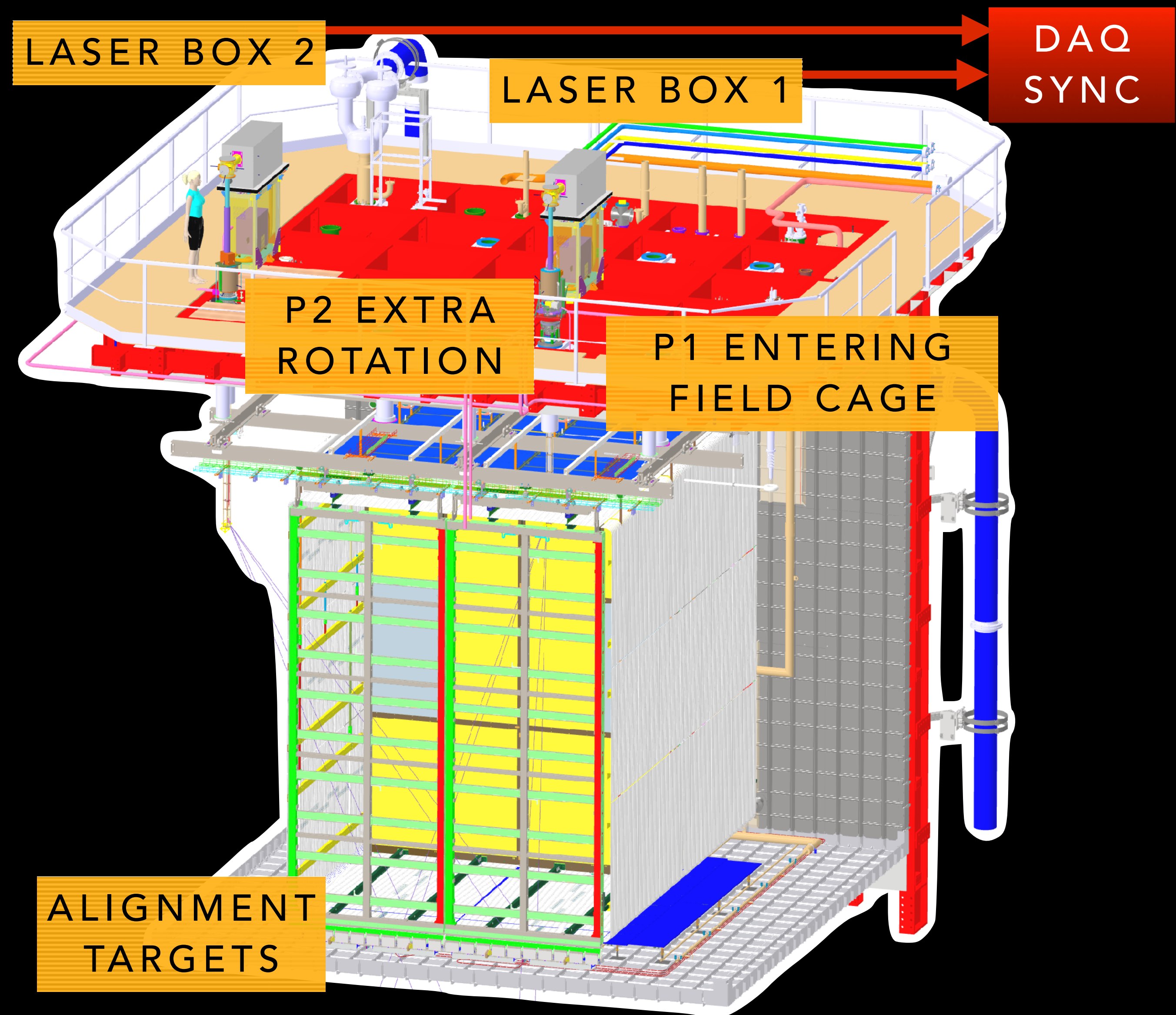
start with FDVD, then HD
build laser calibration HW @ LIP
install at SURF in 2028/29

Physics

2030: live for atmospheric, supernova and solar neutrinos
2032: beam starts!



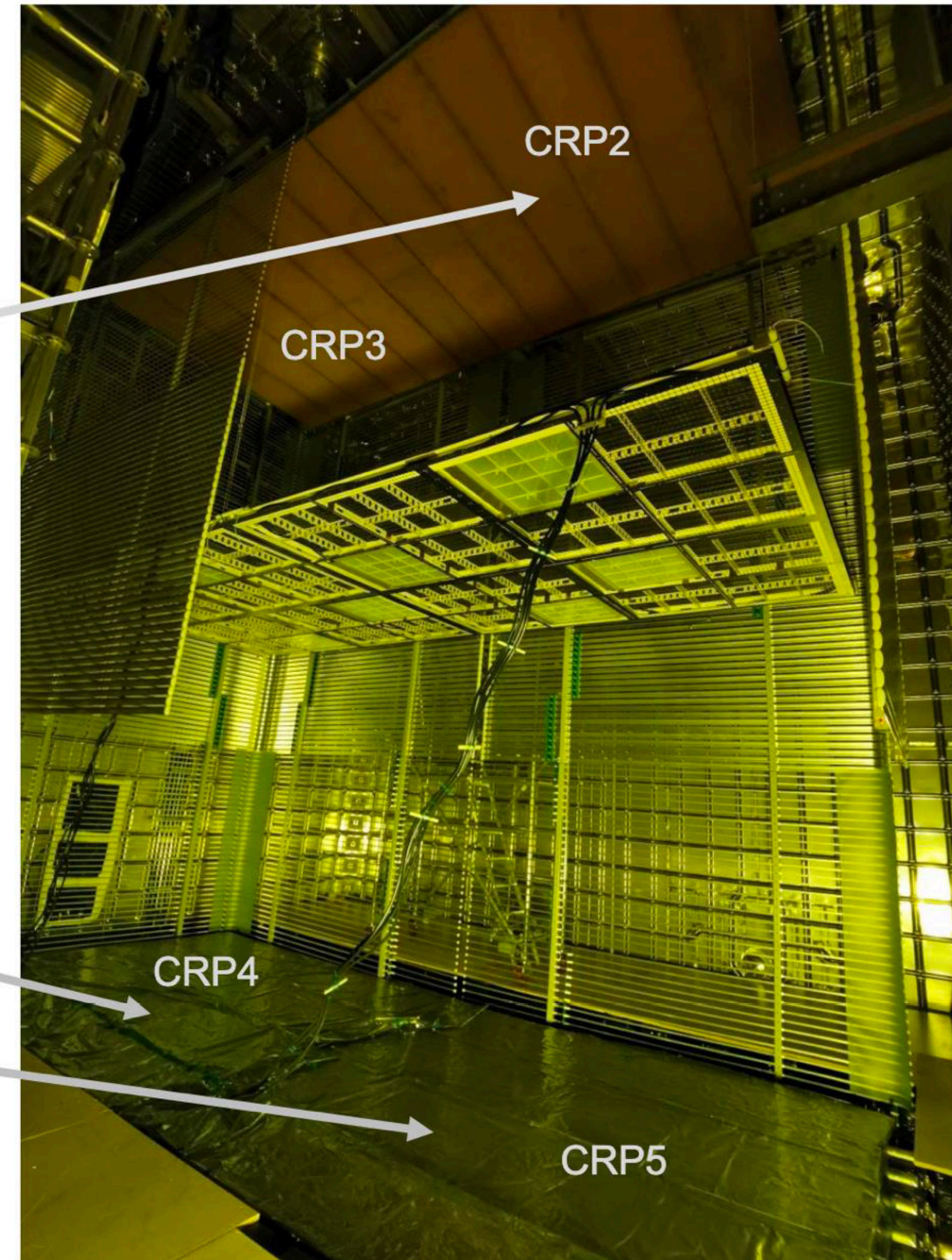
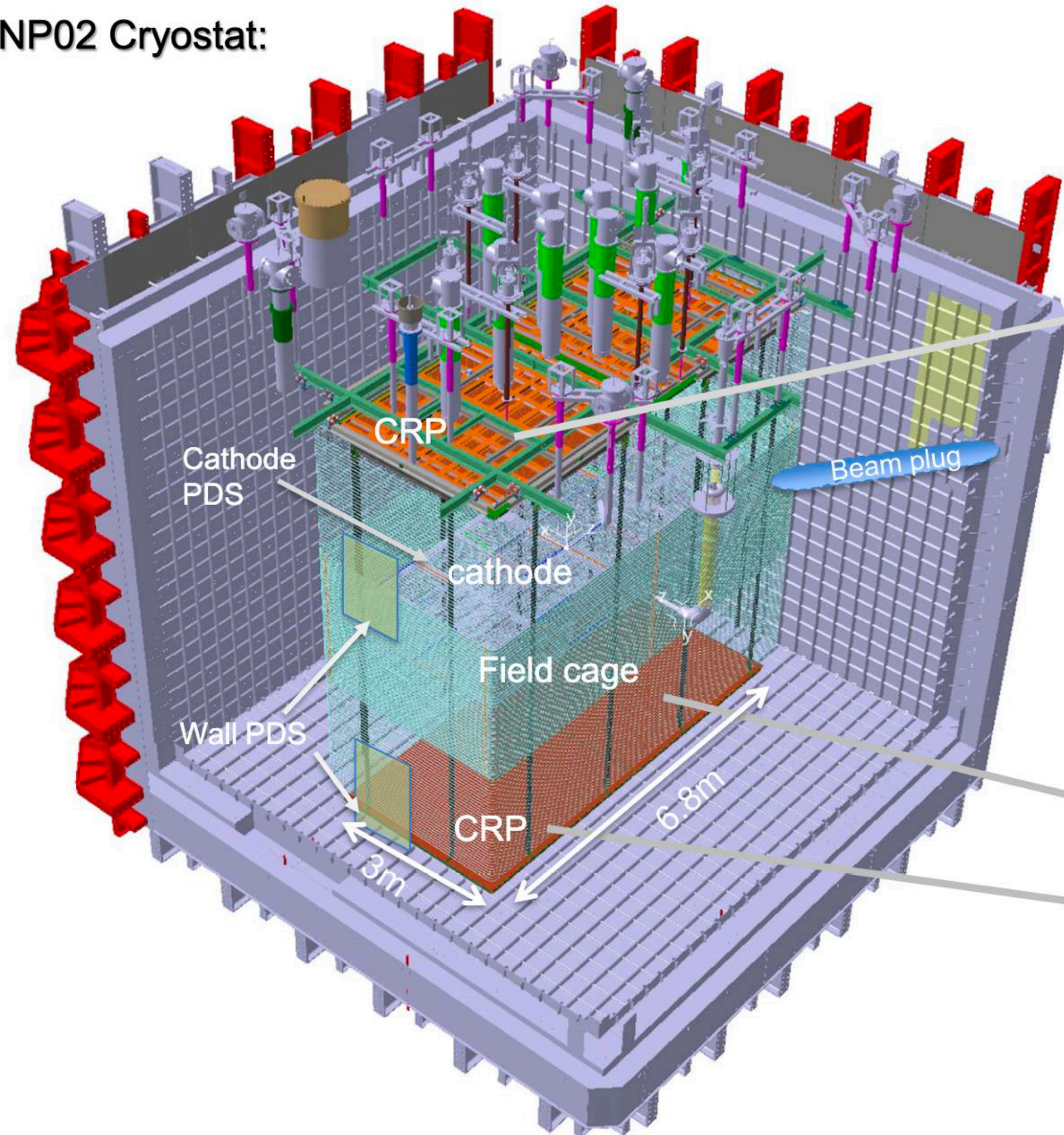
- Several improvements for DUNE
 - Periscopes entering field cage (P1)
 - External periscopes with extra movement (P2)
 - Alignment targets: PIN diodes, mirrors
 - Integration with DAQ
- Goals
 - Map space-charge distortions
 - Measure detector misalignments
 - Characterize charge collection in APAs
 - Characterize electron lifetime



ProtoDUNE-VD

NP02 Cryostat:

Detector orientation



PD-VD CALIBRATION SYSTEM

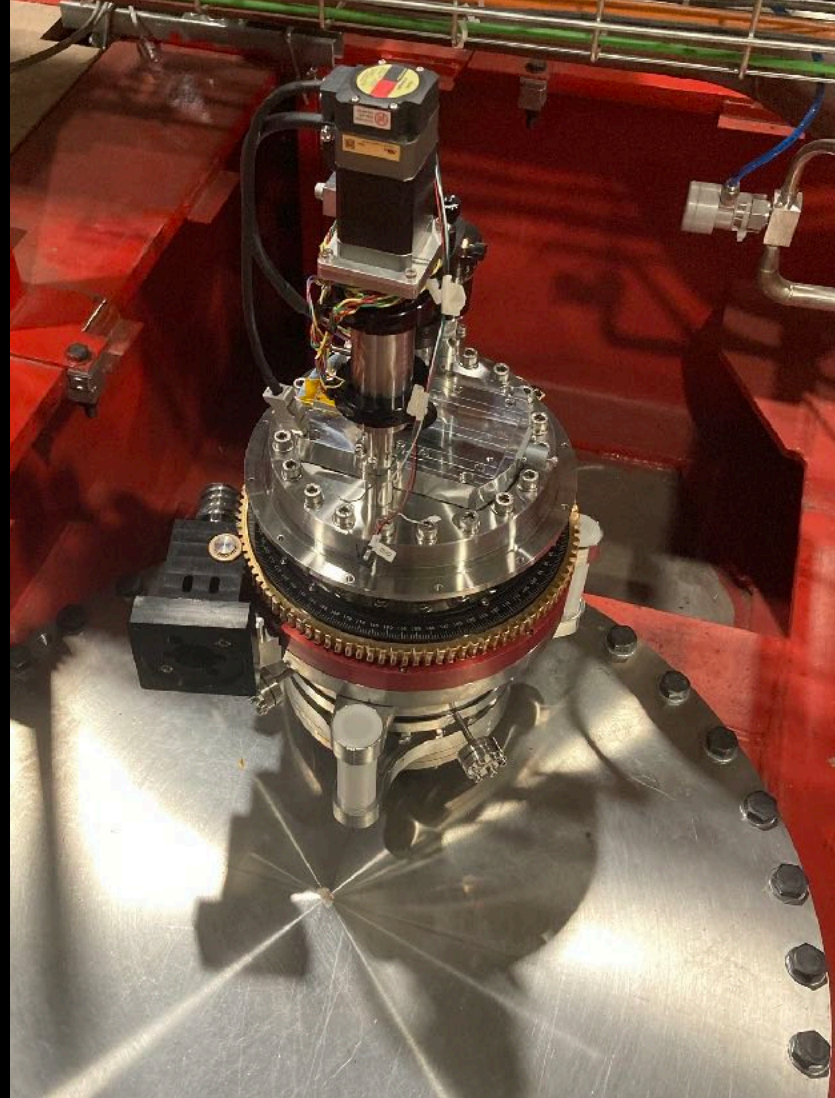
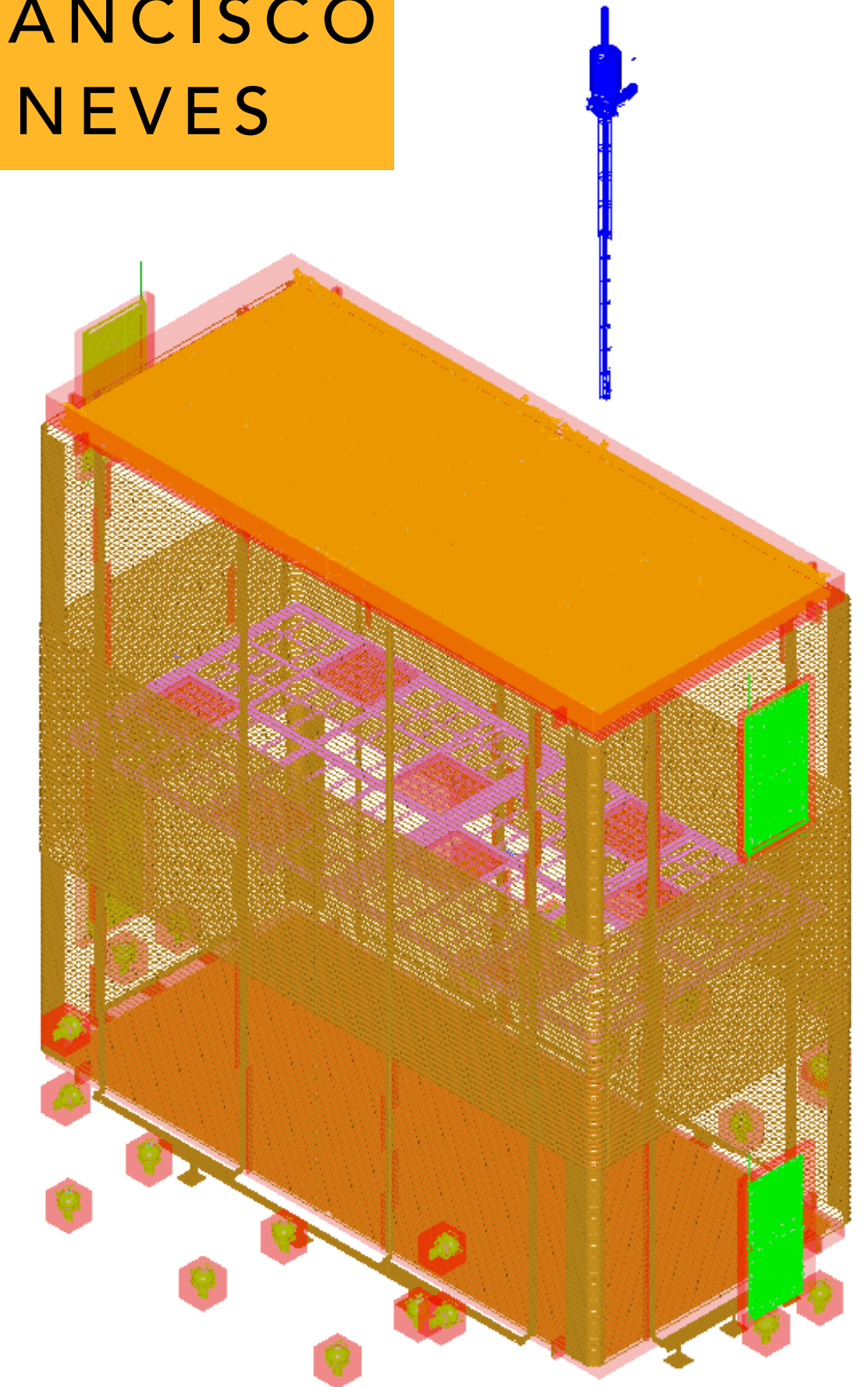


JM,
VLADIMIR
SOLOVOV

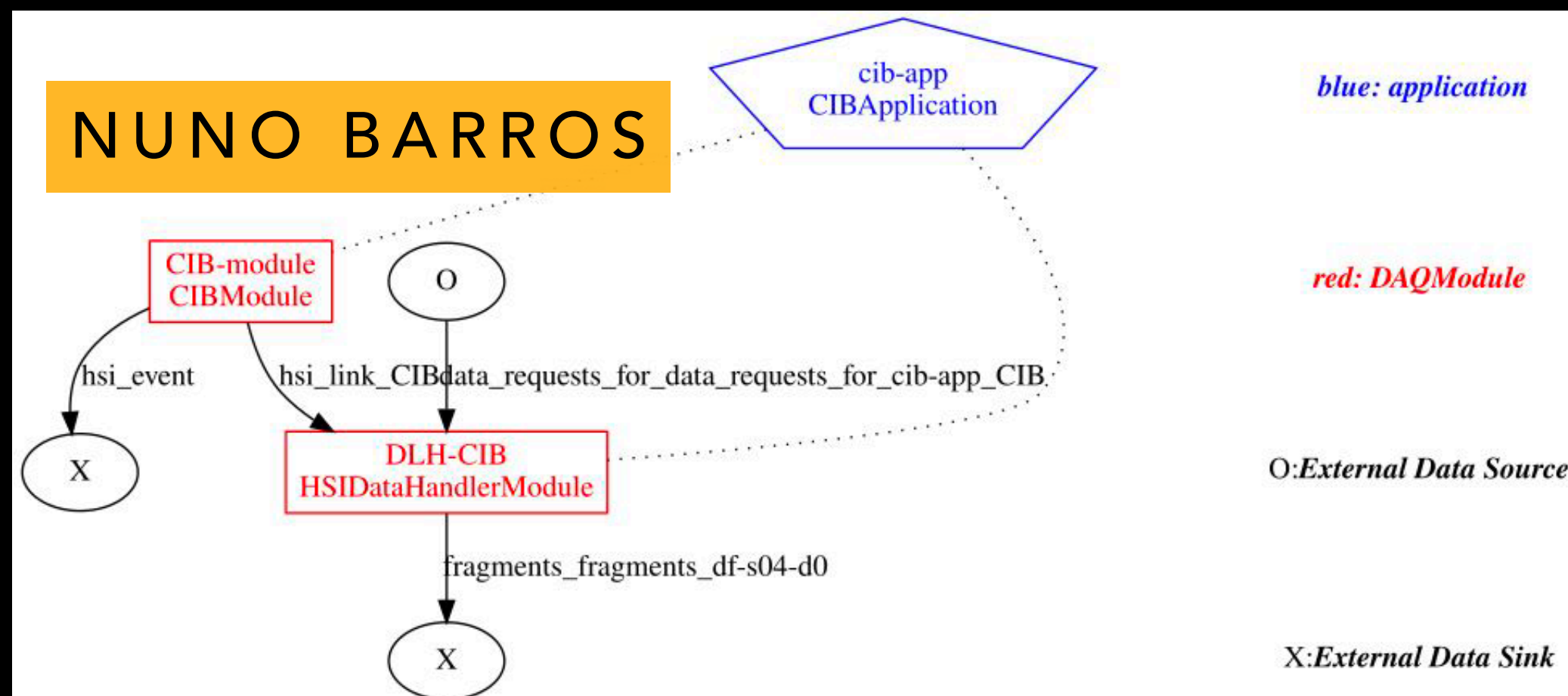


- One laser system in PD-VD
- LIP built feedthroughs and steel part of periscope
- Other systems carried over from PD-HD
- People involved in installation at CERN: Nuno Barros, Wallison Campanelli, JM, Vladimir Solovov, Joana Vences
- Several upgrades to electronics/DAQ software (Nuno Barros) and gNavigator control software (Francisco Neves)

FRANCISCO
NEVES

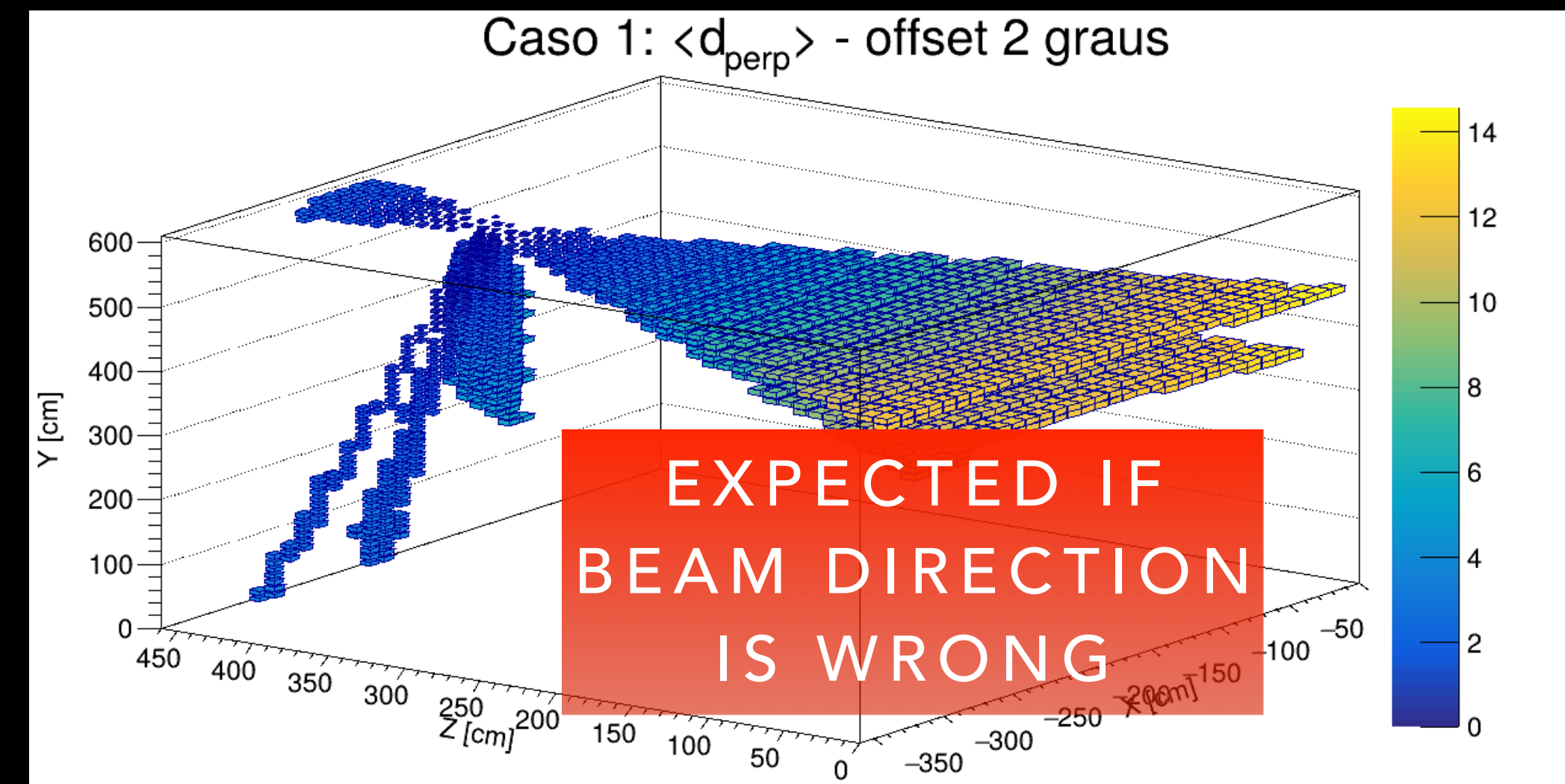
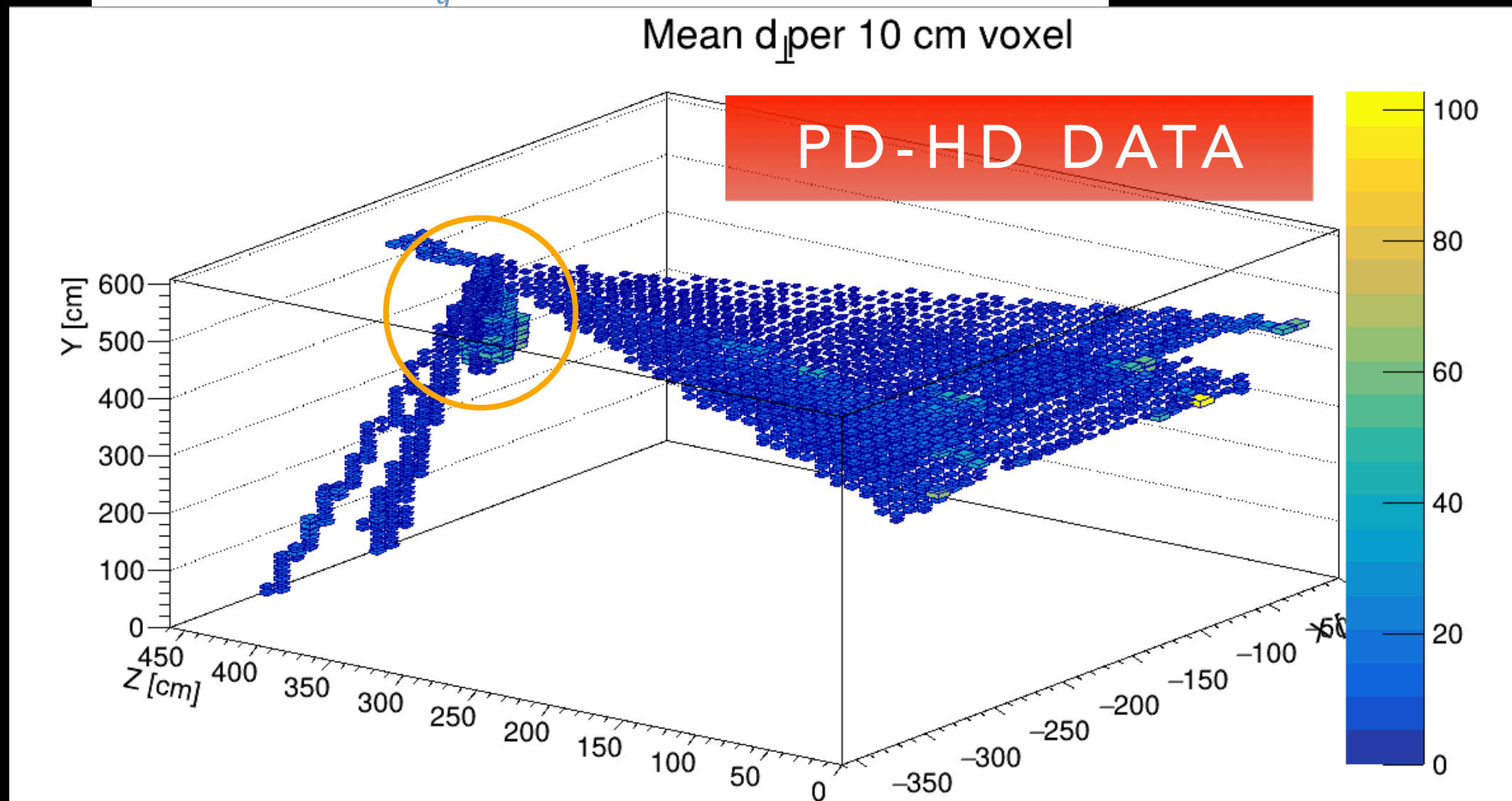
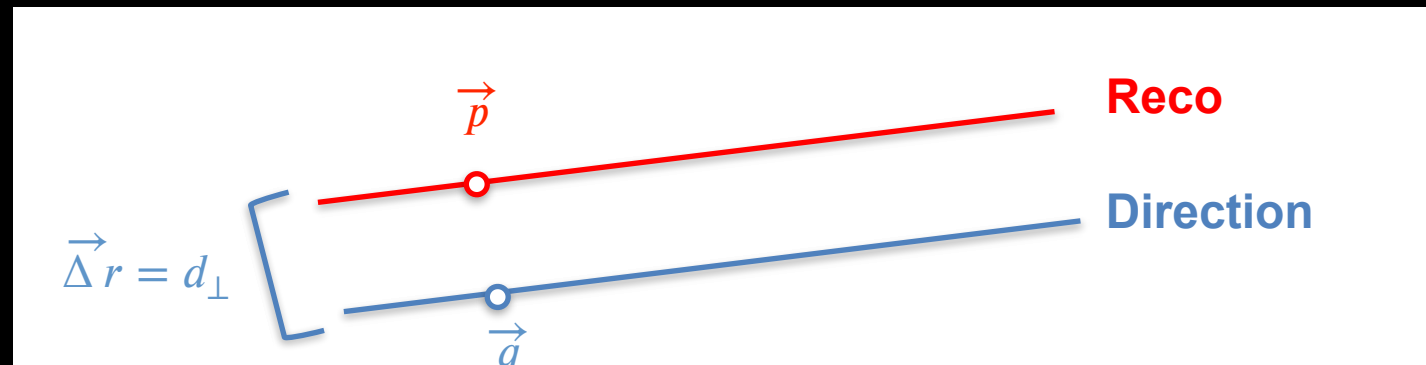
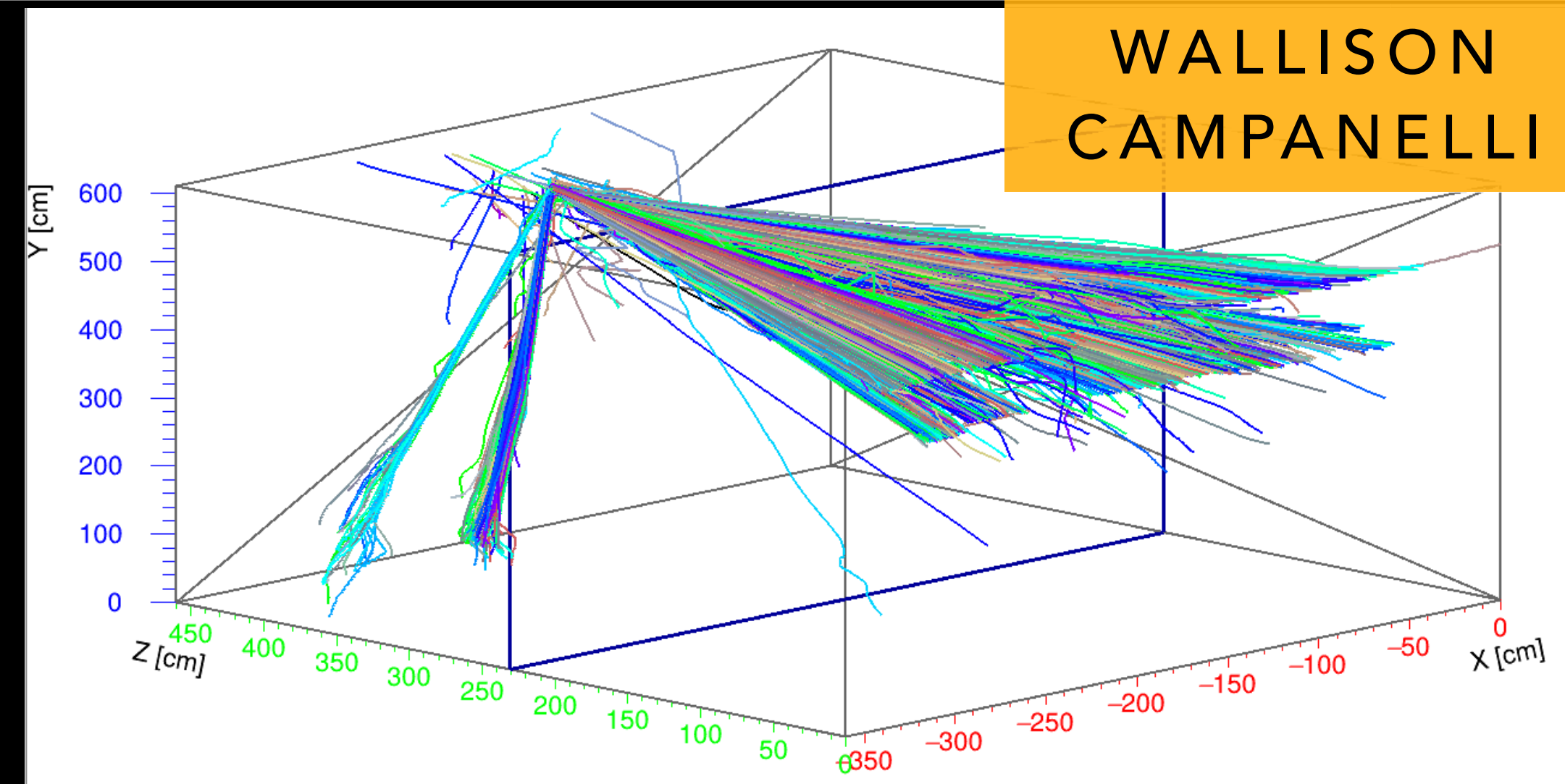


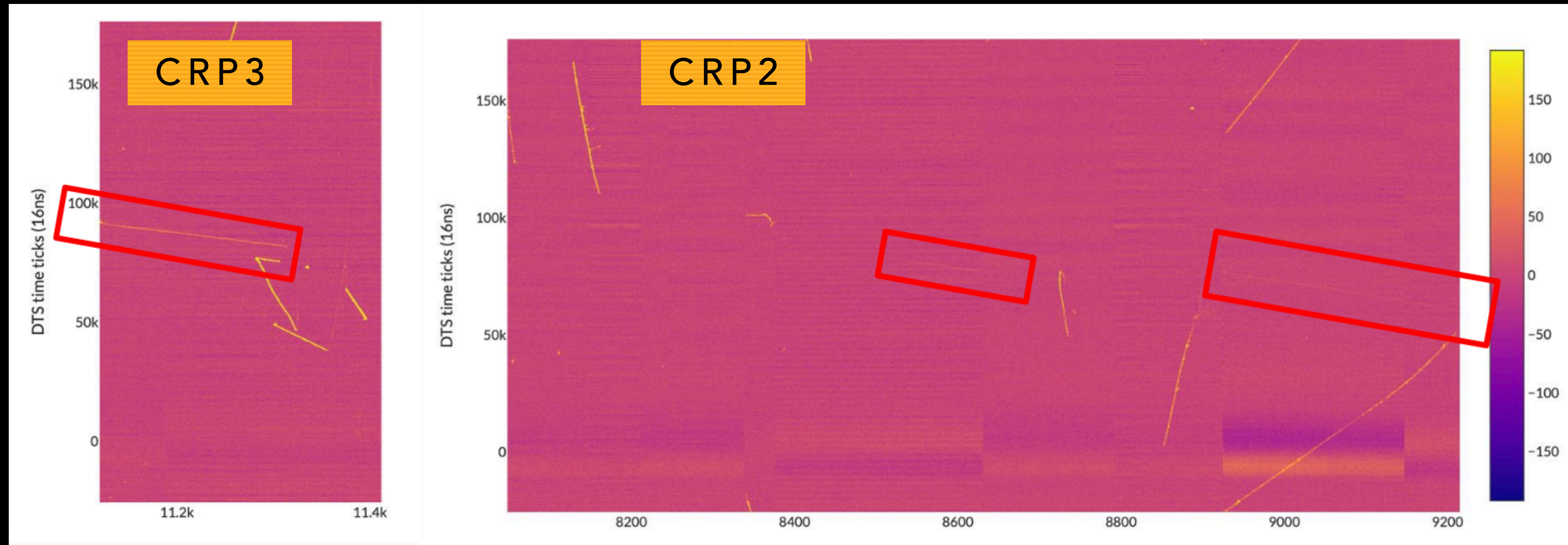
NUNO BARROS



PD-HD LASER ANALYSIS

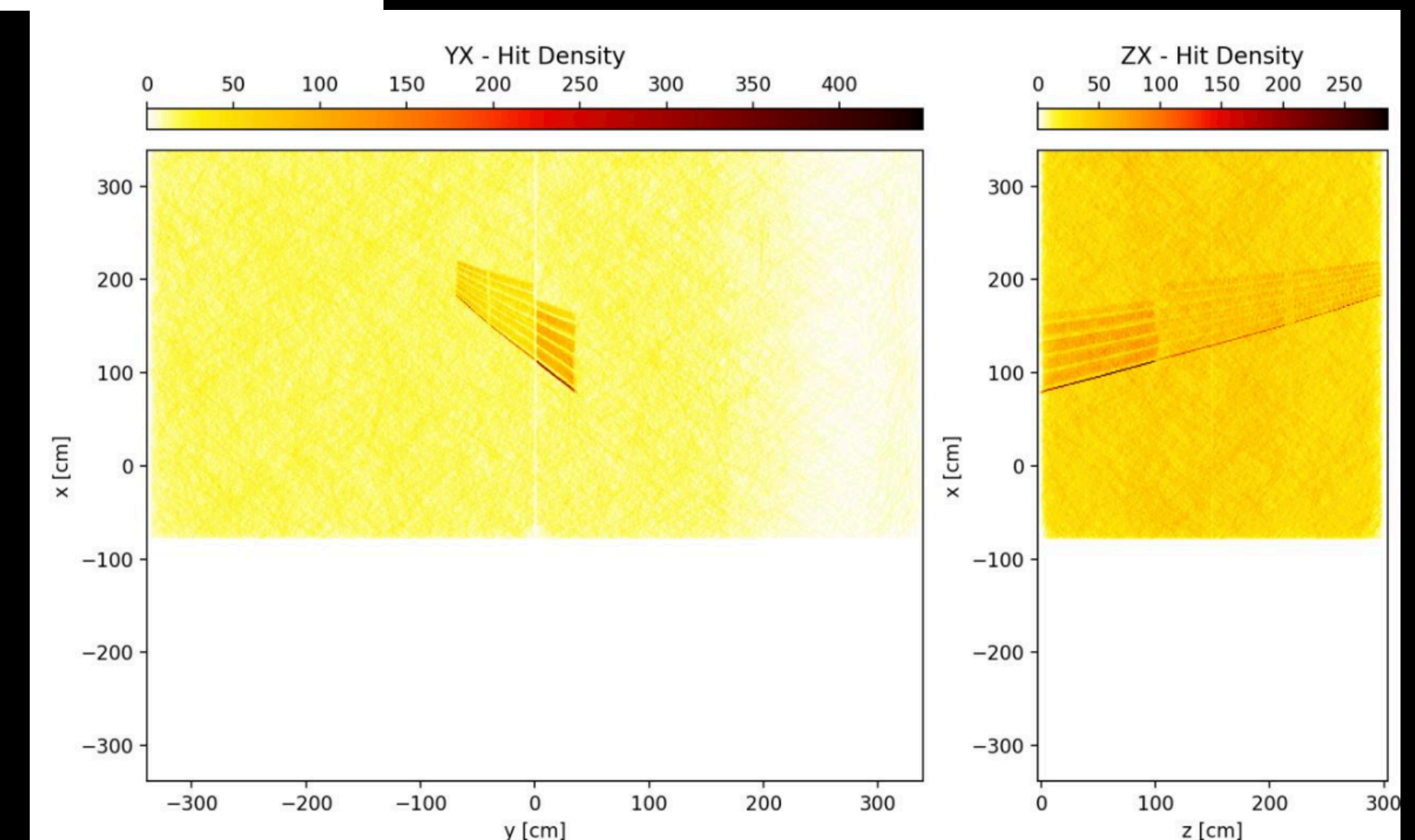
- All validated data reconstructed with LArSoft
- Laser system position data matched with detector events
- Calculate orthogonal distance between reconstructed ionization and laser tracks





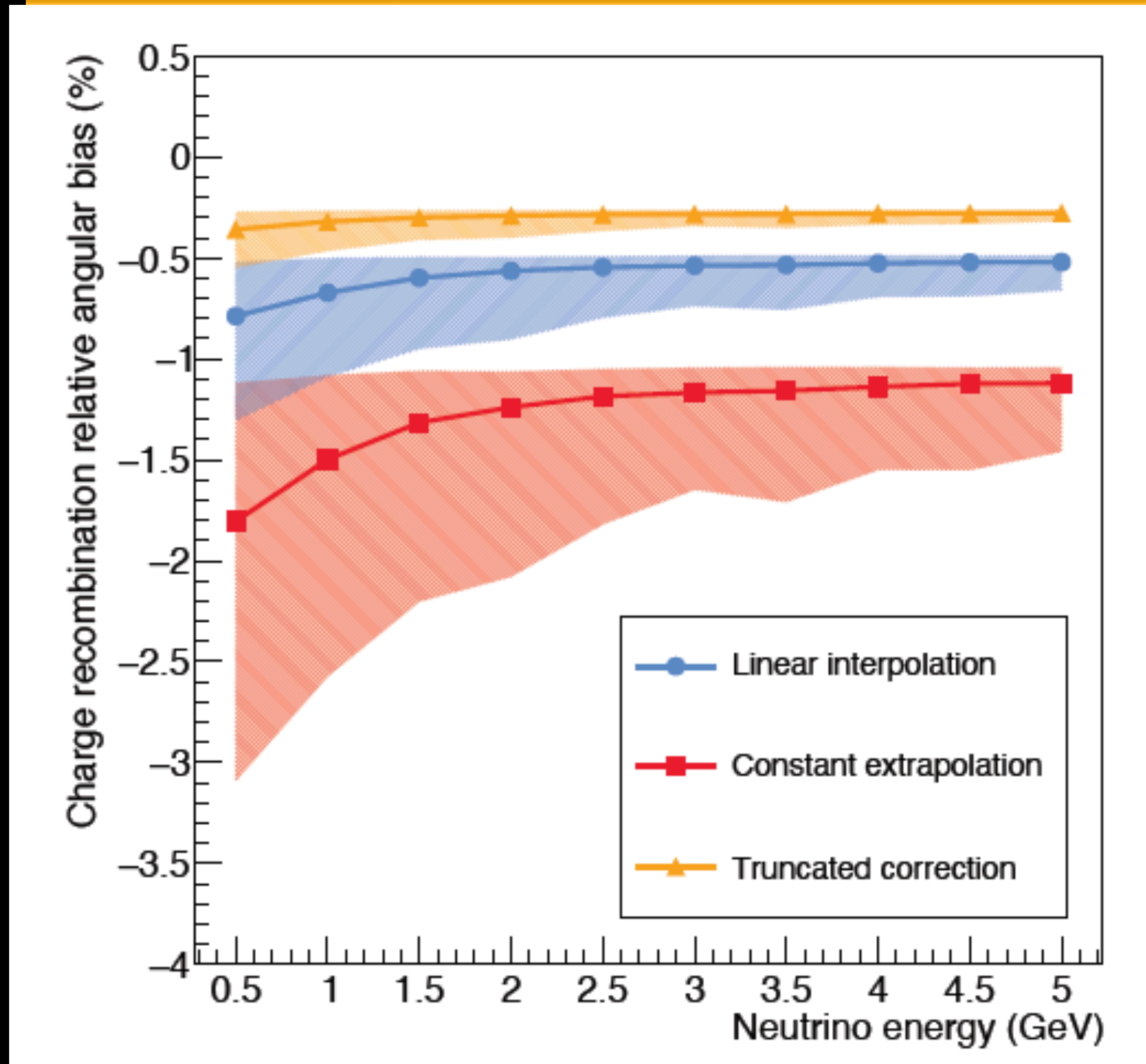
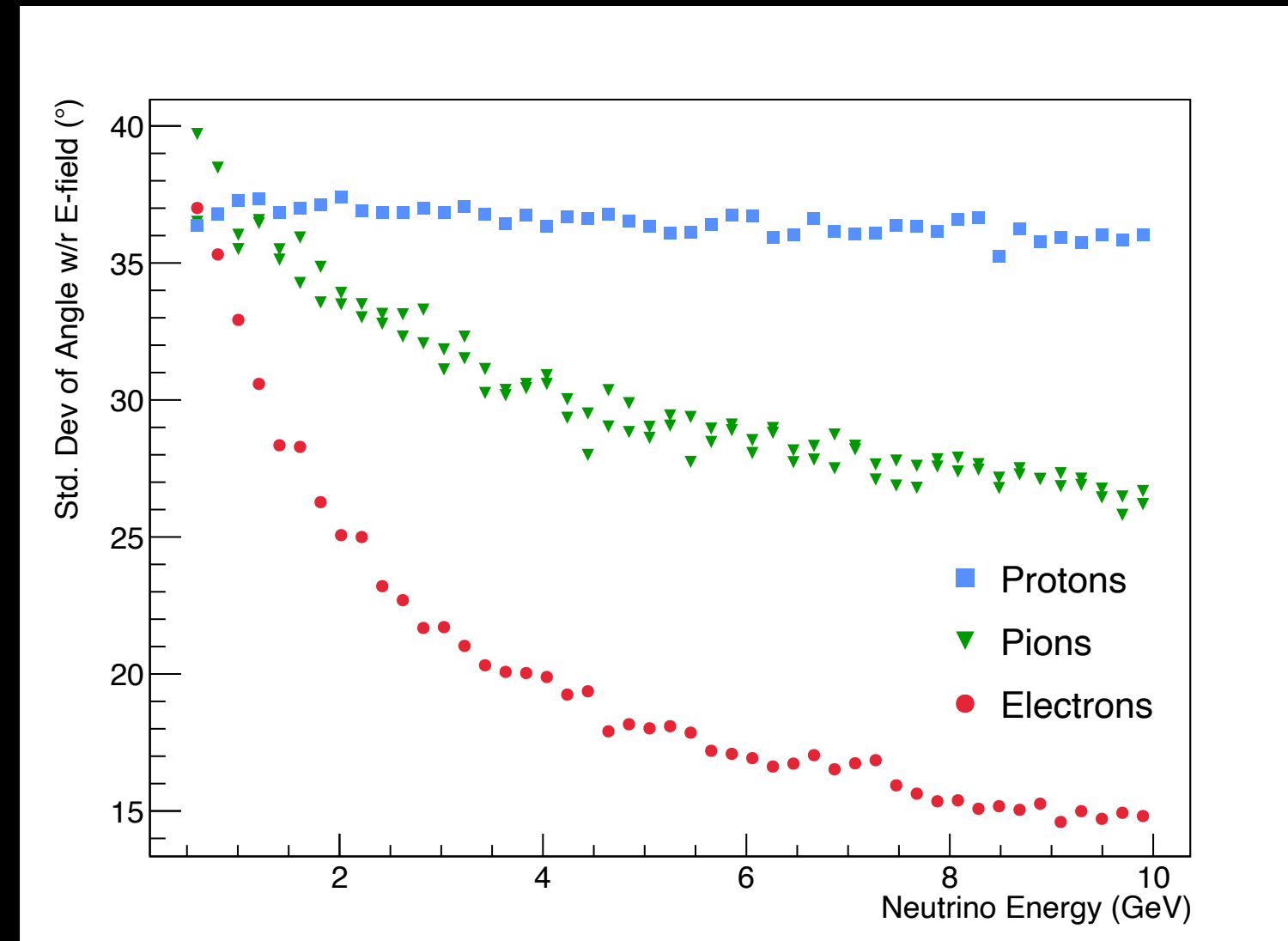
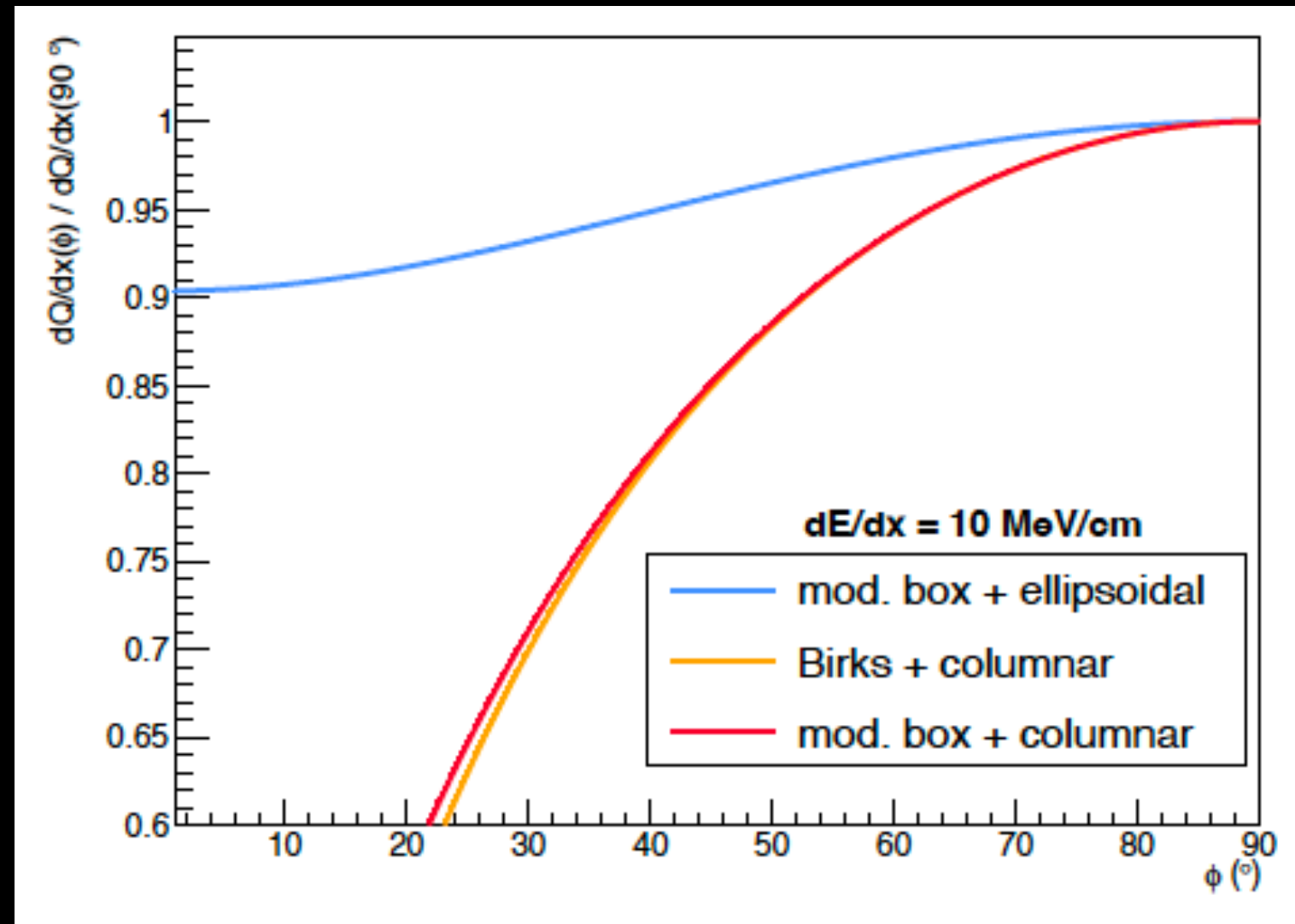
- Laser track triggered by CIB electronics
- Aiming at having segments in two readout units

Multi-track scan controlled by gNavigator →



- Impact of angular-dependent recombination on energy reconstruction
- Paper published

J. VENCES, JM, C. VILELA
2025 JINST 20 P09026



Electron-ion recombination depends on angle w/ electric field latest ICARUS results show small but non negligible effect

Electron kinematics electron from low energy neutrino interaction have wider angular distributions

Energy bias

If effect not corrected, bias between -0.6% and -0.9%

- SNO+
 - Improvements to antineutrino analysis
 - Careful analysis of scint. data before loading Tellurium
 - Contribute to DBD and solar data analysis
- DUNE
 - Operation of ProtoDUNE Vertical Drift calibration system
 - Laser data analysis
 - Construction of far detector VD laser system
 - Ramping up of physics analysis: FD systematics
 - Increase collaboration with Campinas (Brazil)

- STRENGTHS

- Experienced group with very complementary skills
- Many responsibilities within the two collaborations

- WEAKNESSES

- 0 postdocs
- 3 PhD students, still needs to increase

- OPPORTUNITIES

- Both SNO+ and DUNE have data
- Initial performance from PD-VD laser system appears to be very good
- AmoTech construction in Lisbon
- New collaboration with UniCamp, Brazil

- THREATS

- Uncertainty in national funding
 - >1 yr delay in PTDC result, FCERN not annouced yet
 - End of dedicated PhD calls
- Instability in international science funding, esp. USA