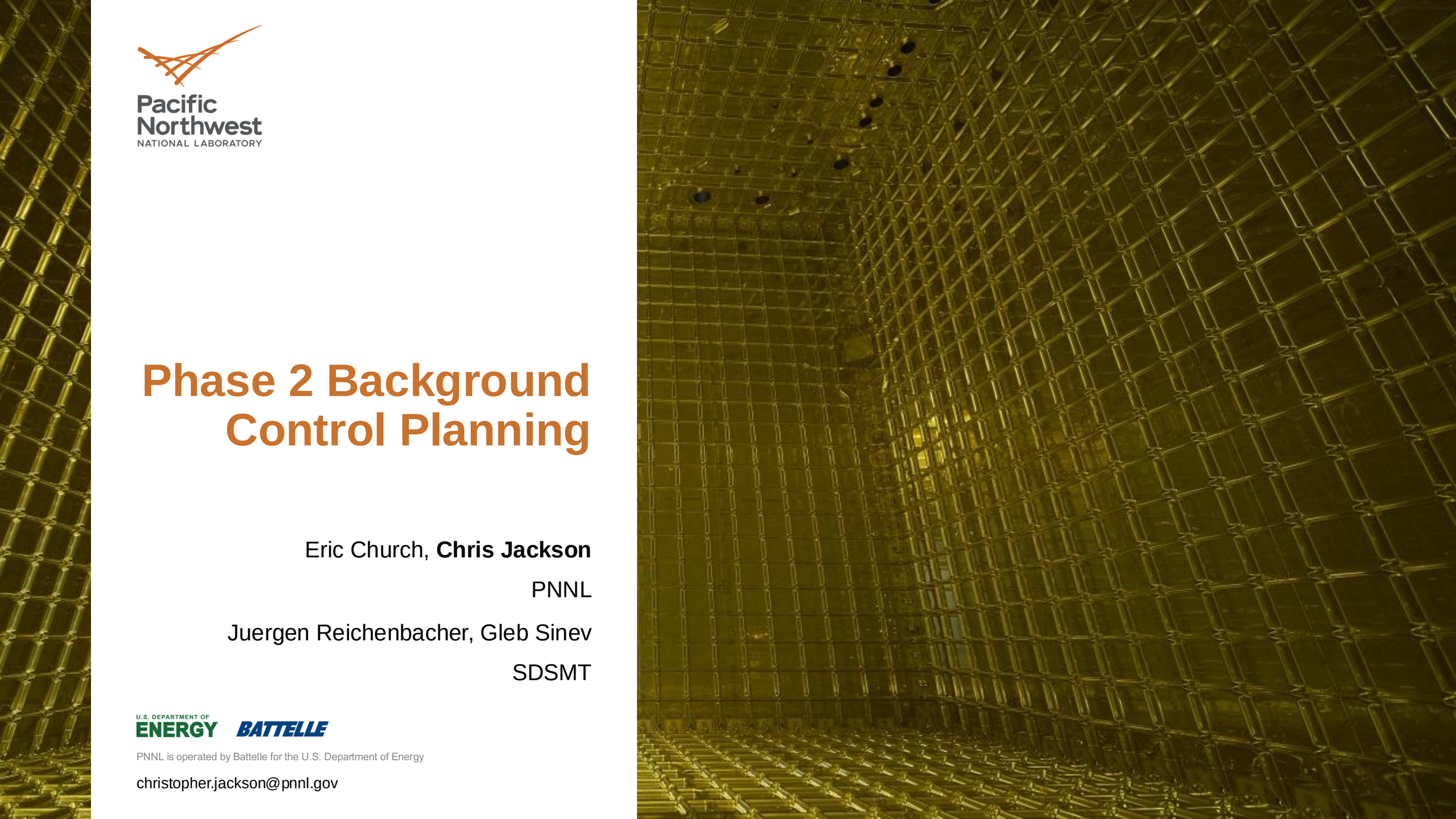

Phase 2 Background Control Planning

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SDSMT

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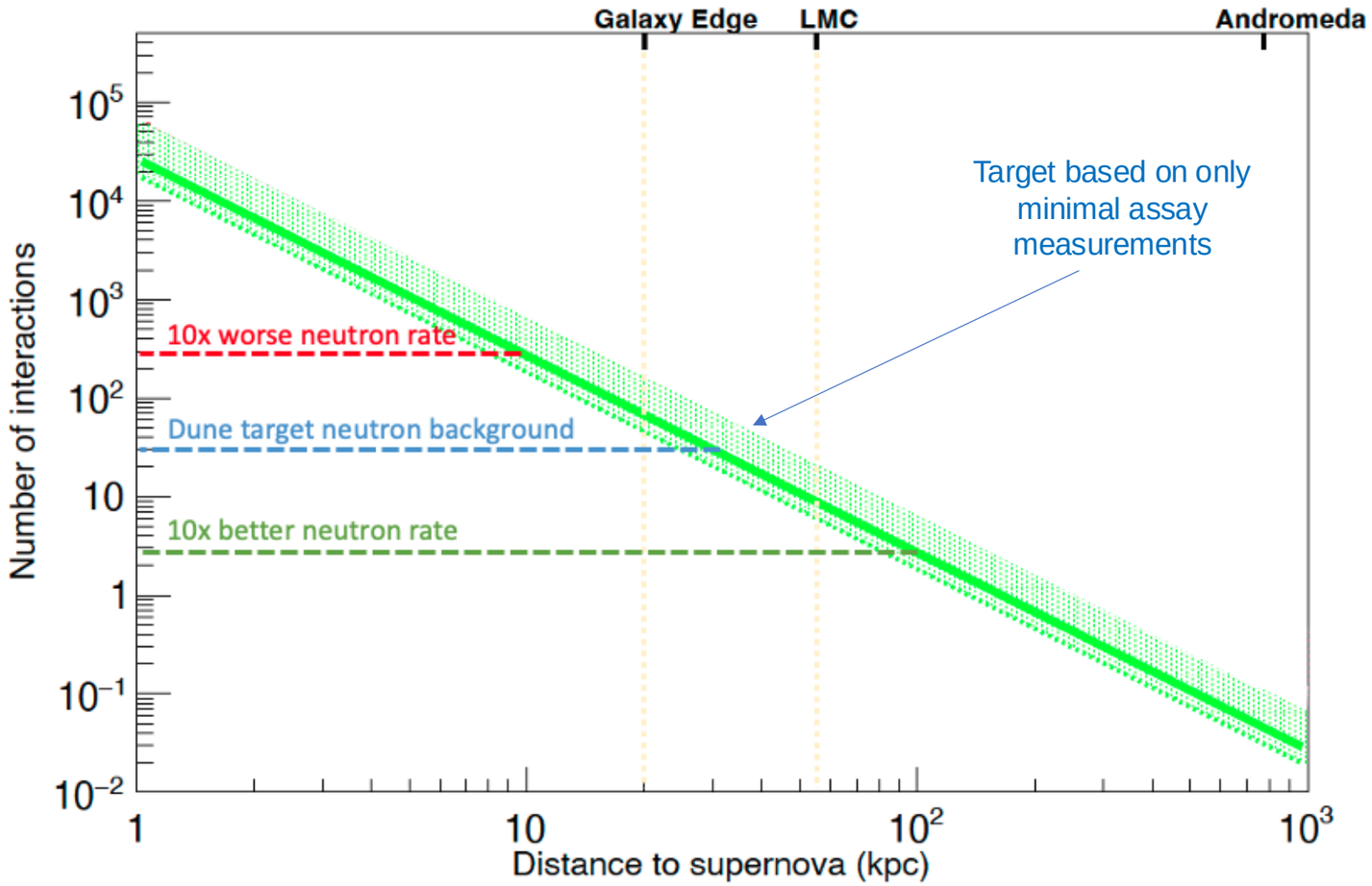
Supernova Neutrino Burst Sensitivity

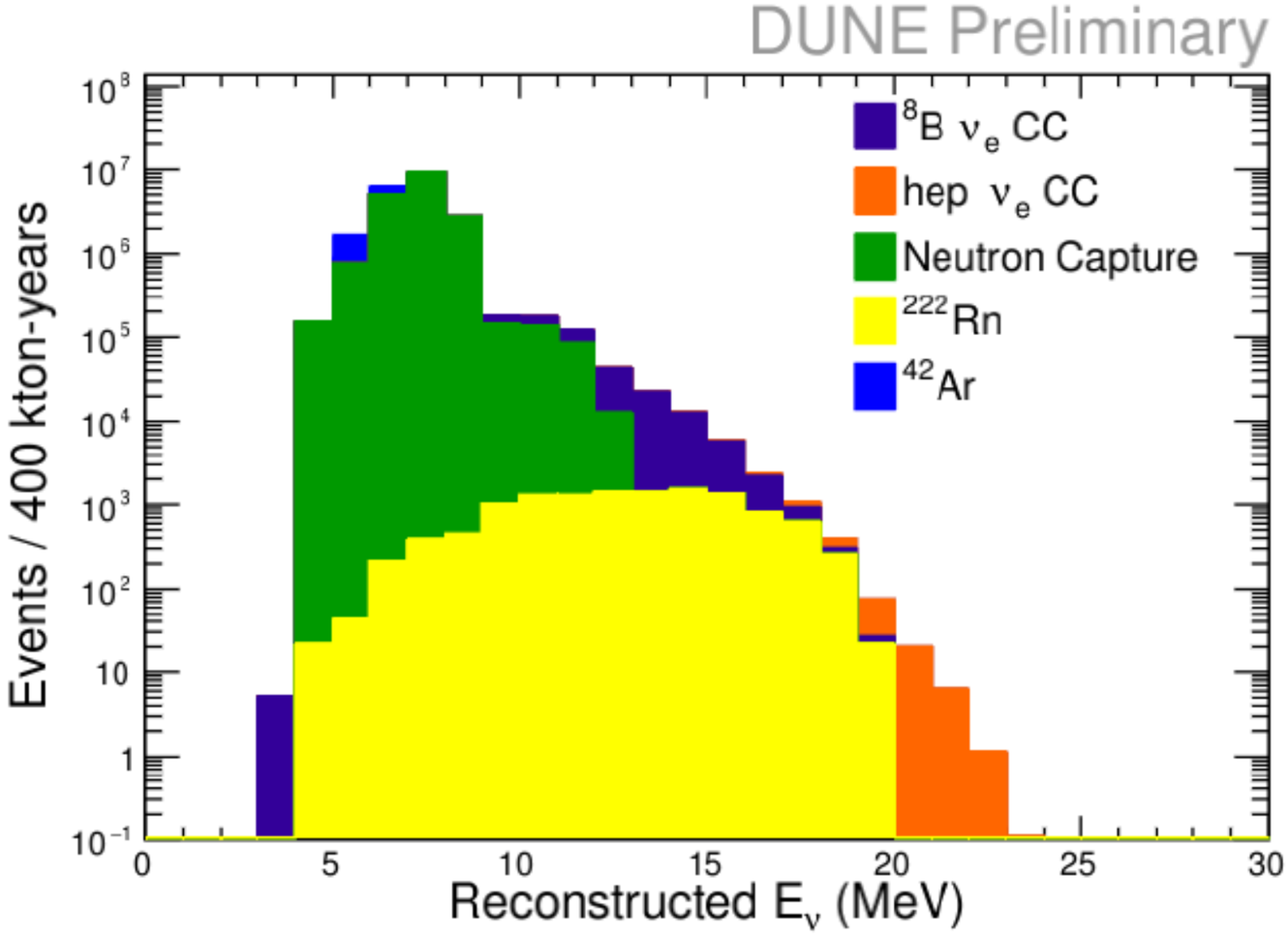
- **Supernova** physics is one of the **primary science goals**
  - Neutron backgrounds can imitate neutrino signal
    - ✓ ~5Hz neutron rate expected
  - Background level sets supernova trigger requirements
  - Too many neutrons → risk of missing distant supernova



Solar Neutrino Physics

- **Solar neutrino** physics is an ancillary DUNE goal and **motivation for many Phase 2 options**
- ***Only*** possible in DUNE if background levels are low enough

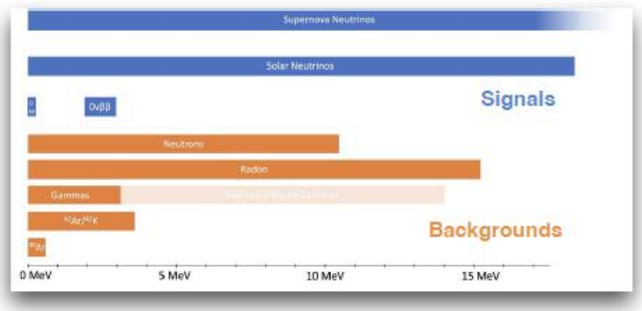
- Neutrons and radon are primary backgrounds to
  - a Boron-8-neutrino precision measurement of solar mass splitting
  - *hep*-neutrino discovery

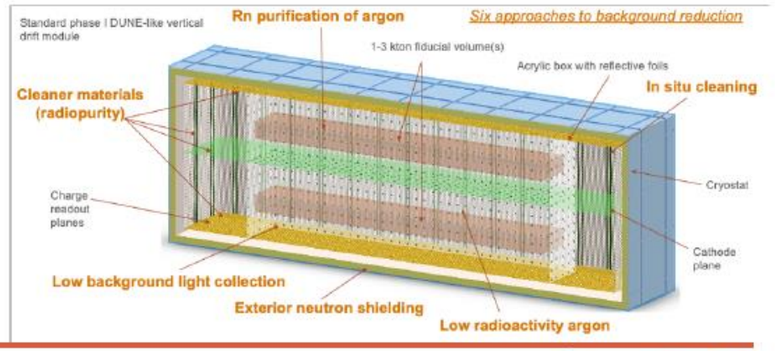


DUNE Phase 2 Plans

Background Control is Key for Low Energy Physics

- Enhancement of DUNE physics to lower energies relies on lower radioactive backgrounds
- Realistic background target extends threshold down to 5 MeV, just above the ^{42}K beta endpoint from ^{42}Ar
- Most significant radioactive backgrounds and mitigation strategies being explored
  - *External neutrons and gammas → passive shielding (e.g., water)*
  - *Internal backgrounds from detector materials → careful material selection programs*
  - *Radon gas → inline radon trap, detector materials with low radon emanation*
  - *Intrinsic argon backgrounds (^{39}Ar, ^{42}Ar) → argon from underground sources*
  - *use underground argon in an acrylic vessel, reduce background (e.g., SLoMo)*

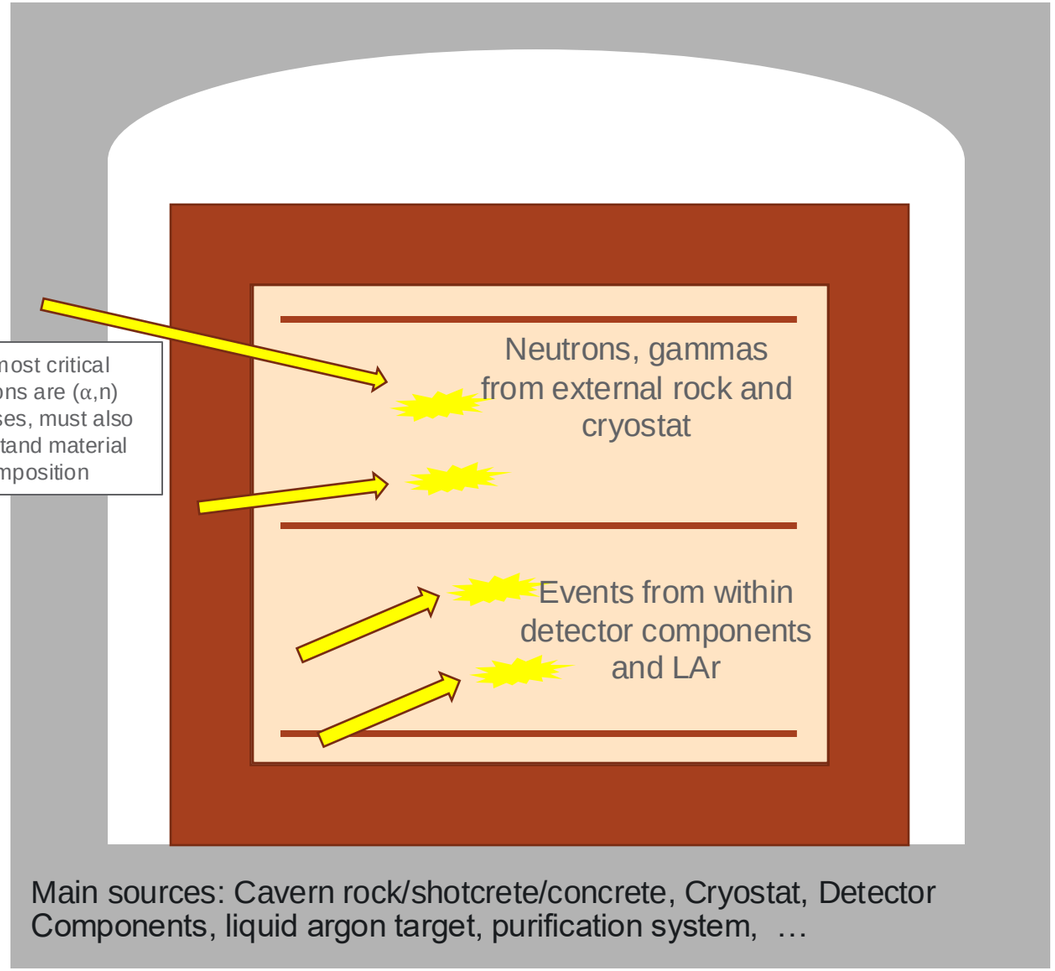




S Gollapinni, CPAD Nov 2024, https://indico.phy.ornl.gov/event/510/timetable/#20241121.detailed

- Many Phase 2 options targeting low energy physics
- A motivation for:
  - Enhanced light collection
  - Short charge track readout through pixelation
  - Target improvements
- All will need radioactive background control to be most effective
- **Phase 2 will need a background specification to ensure low energy physics**

Backgrounds in DUNE



*As most critical neutrons are (α,n) processes, must also understand material composition

Main sources: Cavern rock/shotcrete/concrete, Cryostat, Detector Components, liquid argon target, purification system, …

Significant number of assays still required due to detector size, supplier changes, and number of components

Summary Table of Propagation of External Backgrounds (HD/VD Rates are Estimates only w/o DUNE Reco Sim)

external background	4pi flux in cavern [cm^-2 s^-1]	reduction factor	attenuation factor	area factor	4pi flux at LAr [cm^-2 s^-1]	rate in full LAr (VD) [Hz]	rate in HD [Hz]	
cavern neutrons	2.94E-06	21.816	10.908	1.3687	2.70E-07	5.34E+00	4.63E+00	predicted and 4.6+/-1.1 Hz in HD from simulation of 1x2x6
n-capture gammas from cryostat	N/A	N/A	N/A	1.3687	1.68E-06	3.32E+01	1.50E+00	predicted rates [Hz] w/ approx. gamma-att. for 1.5 MeV
n-capture gammas from rock/shotcrete	3.75E-06	13.807	6.9035	1.3687	5.44E-07	1.08E+01	4.87E-01	predicted rates [Hz] w/ approx. gamma-att. for 1.5 MeV
cavern gammas from rock/shotcrete	12.60418	23.985	11.9925	1.3687	1.0510	2.08E+07	9.40E+05	predicted rates [Hz] w/ approx. gamma-att. for 1.5 MeV
foam gammas	N/A	N/A	N/A	1.0000	0.0441	8.72E+05	3.95E+04	predicted rates [Hz] w/ approx. gamma-att. for 1.5 MeV

⇒ rate in full LAr (VD) from cavern gammas from rock/shotcrete is ~21 MHz mostly at outer edges compared to ~17 MHz Ar-39 rate uniformly distributed

⇒ neutron capture rates in LAr expected to be below critical SNB trigger rate of 10 Hz

⇒ high energetic gammas with energies up to 11 MeV enter at comparable rates to fast neutrons

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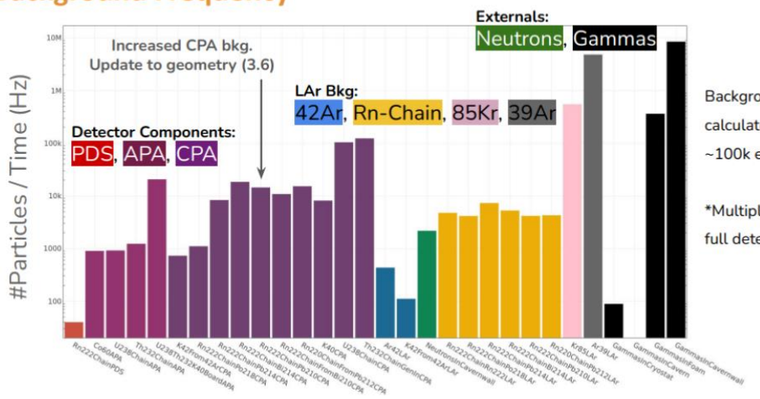
HD 1x2x6 radiological_model_decay0_v3_6.fcl Final

HD Background Model: Background Frequency

Sergio's validation

DEEP UNDERGROUND NEUTRINO EXPERIMENT



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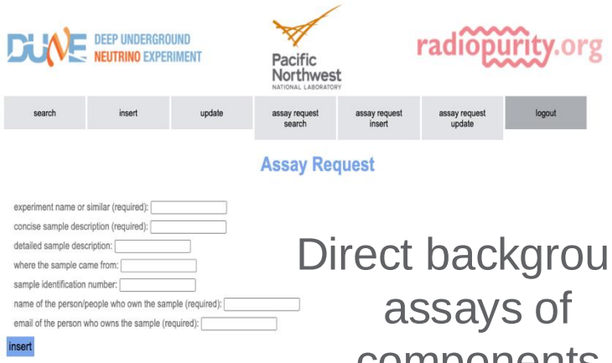
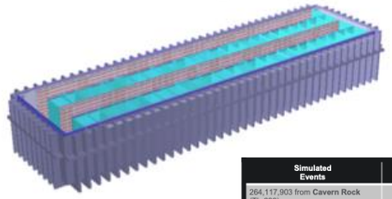
J. Reichenbacher, Sep 2024 Collaboration Meeting, https://indico.fnal.gov/event/62283/contributions/299263/attachments/181445/248863/DUNE_CollaborationMeetingSantaFe_newRadiologicalModel3update_9Sept2024_JR_.pdf

Building A Background Model

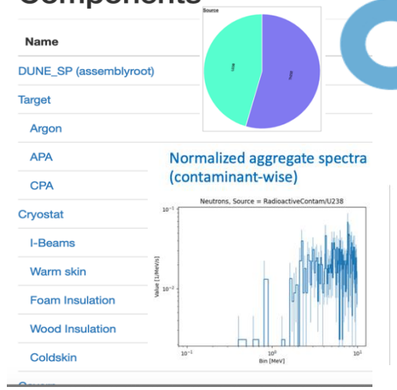


Direct background assays of components

GEANT4/LArSOFT radioactive background simulations



Simulated Events	Primary Neutrons	Neutron Captures	Primary to Capture Ratio	Background Neutron Rate
264,117,903 from **Cavern Rock** (Th-232)	20,086,210	2,133	9,416 : 1	1.01 Hz
263,387,927 from **Cavern Rock** (Early U-238)	20,090,100	2,130	9,432 : 1	0.157 Hz
263,876,810 from **Cavern Rock** (Late U-238)	20,089,190	2,189	9,177 : 1	7.27 Hz
184,403,118 from **Cavern Rock** (U-238 SF)	14,063,850	1,471	9,561 : 1	0.514 Hz



βackγroμnd EXplorer

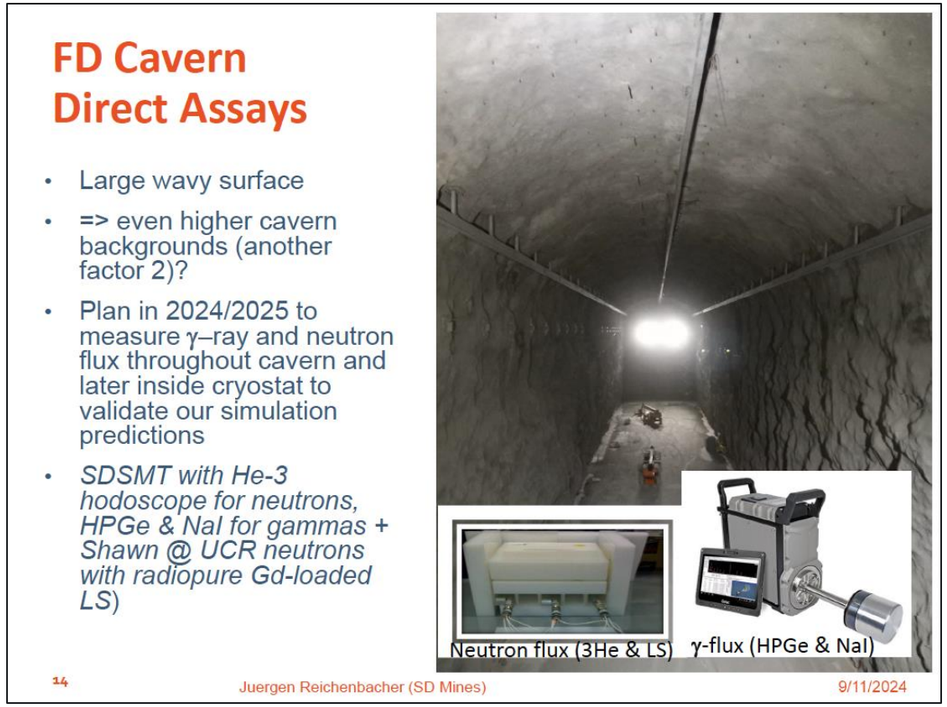
Develop background model and budget

Set construction material specification to achieve physics sensitivities

Background Control Planning Considerations

- Need:
  - to measure radioactive background levels in all significant (size/proximity to argon) components
  - ideally understanding consistency across production (multiple assays)
  - Need to prioritize limited resources
- Prioritize order (roughly), considering importance to FD3 and production schedule, as:
  - Cavern + Cryostat
  - Vertical Drift
  - Horizontal Drift
  - Cleanliness during construction
  - Potential module 3 materials

- Planning to measure external backgrounds directly in cavern



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Phase 2 Schedule

https://edms.cern.ch/ui/#!master/navigator/document?P:101609965:101609988:subDocs

Notional FD3 and FD4 Timeline (Technically Limited Schedule)

- Earliest installation start in 2029 with FD3 completed in 2034 and FD4 in 2036
- The final schedule for FD4 will be driven by the technology choice and extent of upgrades planned in the case of a LArTPC

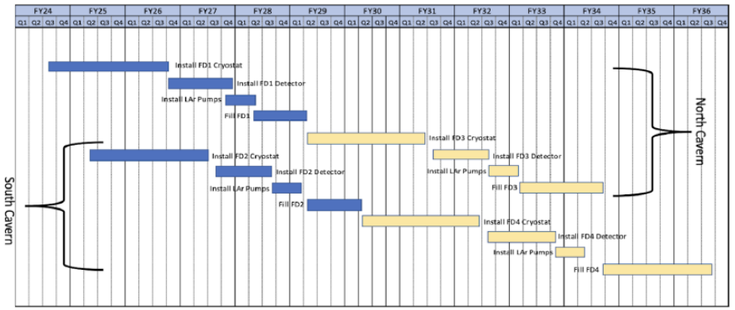
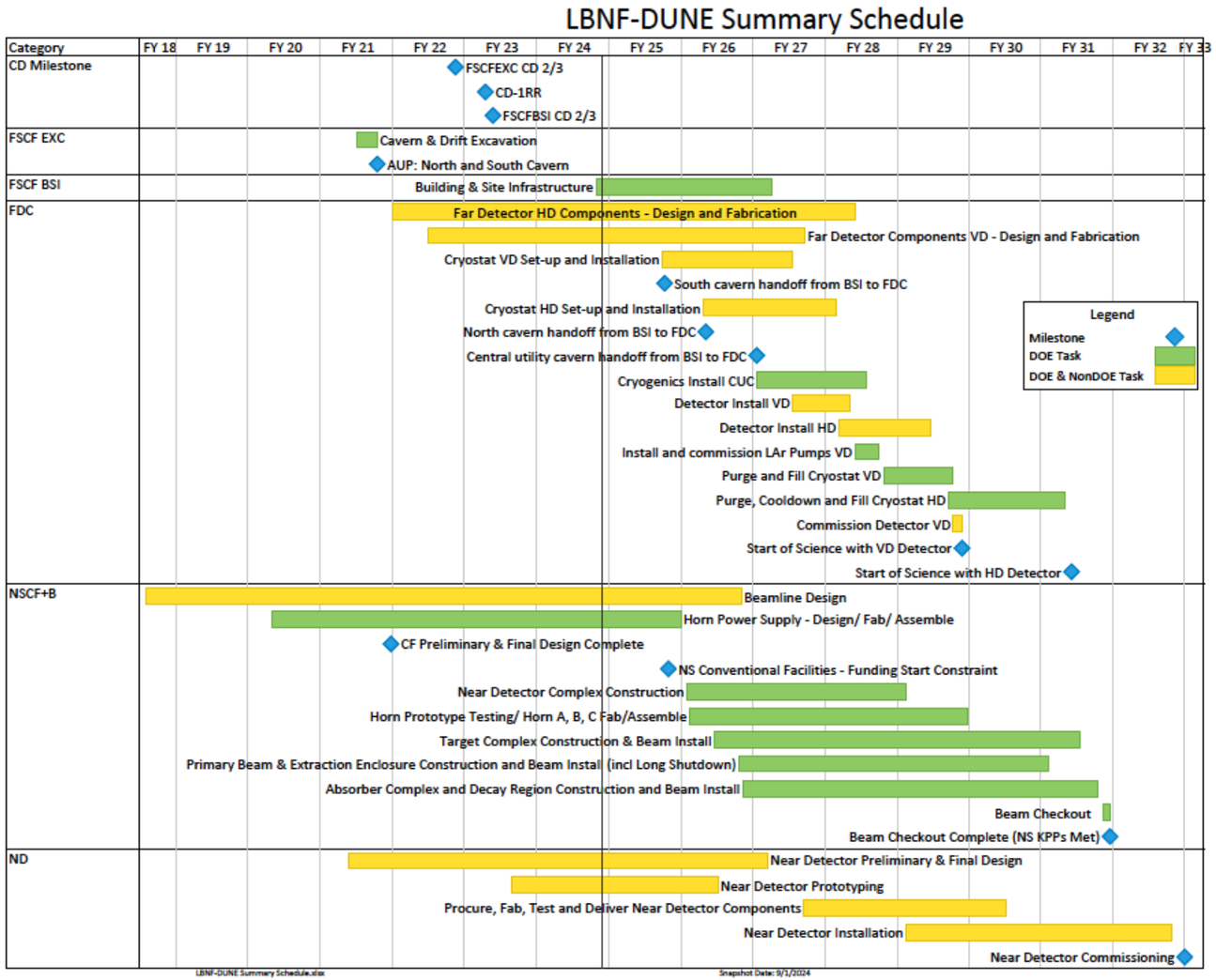


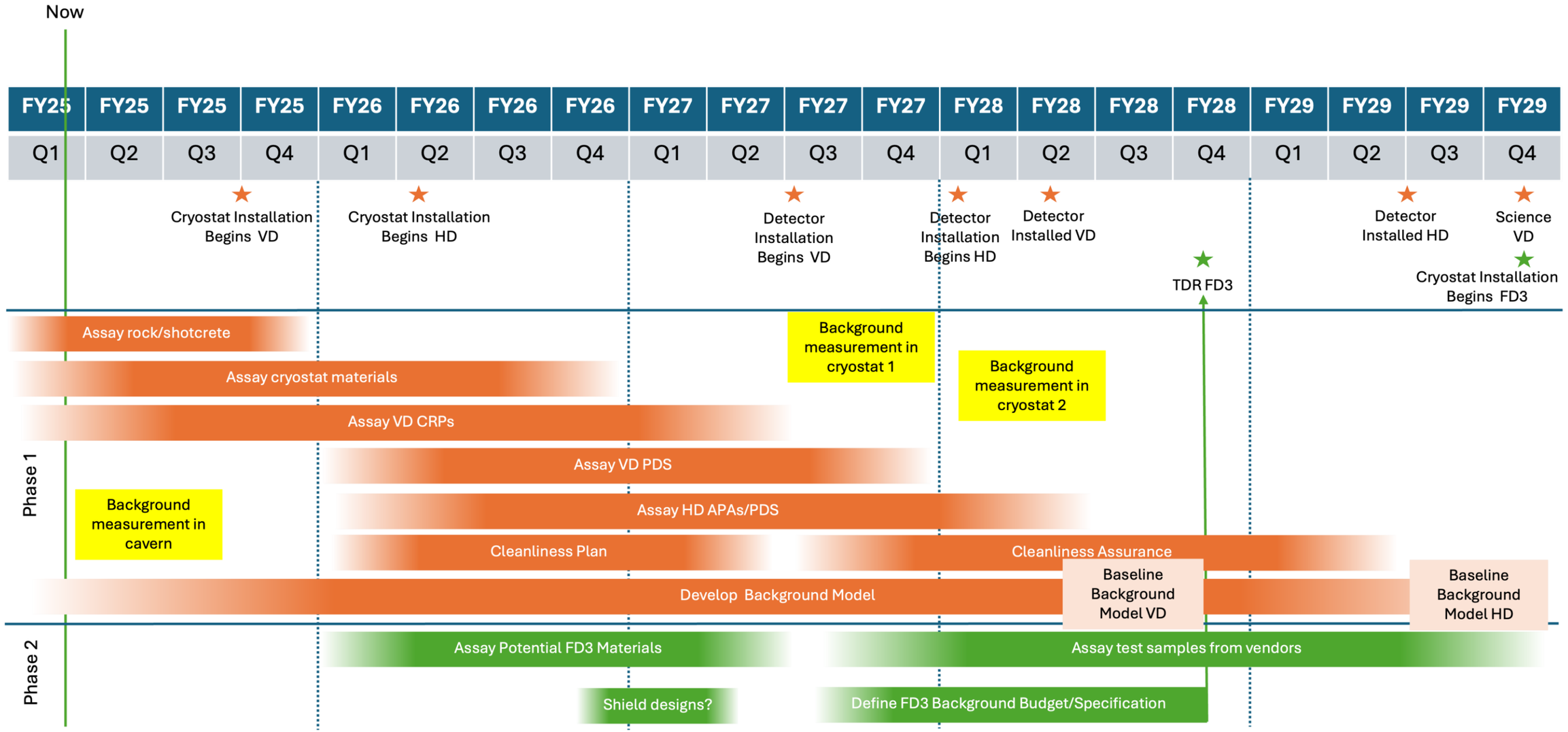
Figure: *A notional, technically limited schedule for FD3/4 assuming it is a vertical drift LArTPC similar to FD2*

S Gollapinni, CPAD Nov 2024, https://indico.phy.ornl.gov/event/510/timetable/#20241121.detailed



- Assuming technically limited schedule and latest version of project schedule

Low Energy Science: Radioactive Background Model Timeline



Conclusions

- Background control is a concern for DUNE low energy physics
- This physics motivates many Phase 2 options (Module 3 and 4)

- Currently developing prioritized plan to understand backgrounds in Phase 1…
- … and optimize potential materials for Phase 2 Module 3
- Will require combination of:
  - Material assays and direct background measurements
  - Simulation and background model building

- Aiming to define radioactive background budget and specification in advance of Module 3 TDR
- Support from Phase 2 group will be important

Pacific Northwest
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Thank You