

vDUNE, a Virtual Tour of the DUNE South Dakota Laboratory

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For the DUNE Collaboration

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<https://bit.ly/chep23-vdune>



VALLEY CITY
STATE UNIVERSITY



Motivation

Education and Outreach (E&O) is an important activity for the High Energy Physics community. For example, informing the public on the goals and status of an experiment such as DUNE has multiple beneficial impacts.

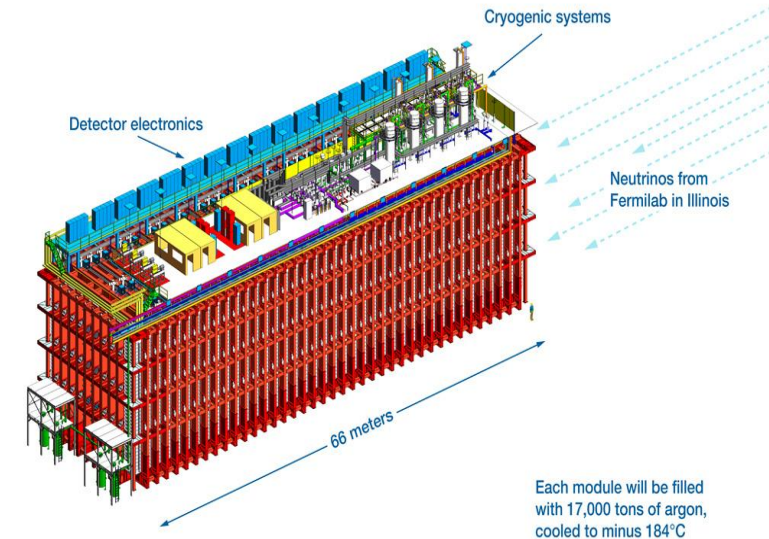
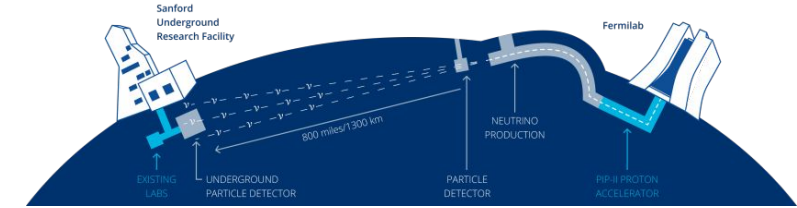
The construction of the DUNE laboratories is underway, and anticipated to operate for another decade, it makes good sense to excite interest in the endeavors of HEP physicists by fashioning E&O events, such as those for high school students by QuarkNet.

A compelling story line to younger students is on what a “Day in the life of a HEP physicist” might be, and we suggest a virtual lab tour could inspire interest.

Recollecting on graduate school days, the Soudan 2 Underground Laboratory hosted tours of the lab regularly, these popular among parents and their children, and some twenty years later, regularly do I hear from a student, friend, or an acquaintance who reported a memorable tour of the Soudan lab in Northeastern Minnesota, USA.

Motivating our work is two fold: the DUNE underground lab is a ways away, and its design, once complete, might not be as friendly to public tours as the Soudan 2 lab once was.

For that, vDUNE.



Ag Cab Lab Project

In an earlier life (~2014), as STEM director, colleagues, students, and I worked to develop a virtual farming experience for youngsters as a way to draw attention to the complex and innate problem solving nature of a farmer.

Then we used a real Case tractor head, instrumented the steering wheel, brakes, and selected controls using an Arduino, that allowed patrons a real world opportunity to plow and seed a field, combine corn, virtually.

The simulation software used was Blender, and ultimately a combination of Blender and Unreal Engine to build on the excitement.

We would haul the rig around to county and state fairs where patrons were always excited to ride in the AgCab Lab.

A permanent installation of the AgCab Lab is in place at the North Dakota Heritage Center & State Museum, in Bismarck.

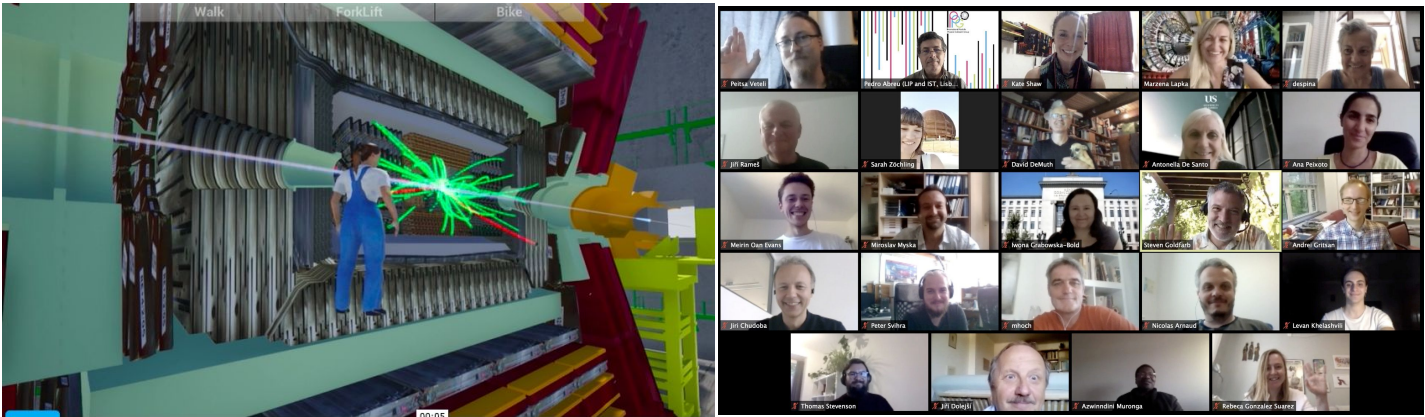


ICHEP 2020 Jul 28 - Aug 6

During the pandemic, I had the opportunity to attend ICHEP to discover, “CMS in your pocket: between serious game and demonstration tool,” by Pierre Van Hove (2020/07), who reported building a virtual CMS detector and lab for E&O purposes.

Their work is exciting, and I reached out to Lucas (B.S. Digital Media Arts, Northwestern College, MN, M.S. Software Engineering UMN), our AgCab Lab software engineer, and we started to hack together vDUNE.

Here we provide an overview of our vDUNE work.



The International Particle Physics Outreach Group - Reaching Across the Globe with Science	Steven Goldfarb	virtual conference	15:30 - 15:50
Current Status of International Particle Physics Masterclasses	Uta Bilow et al.	virtual conference	15:50 - 16:10
Netzwerk Teilchenwelt: Coordinated Outreach and Recruitment of Young Talents in Germany	Uta Bilow	virtual conference	16:10 - 16:30
Global Cosmic	Nicolas Arnaud	virtual conference	16:30 - 16:50
Coffee Break		virtual conference	16:50 - 17:20
ATLAS Virtual Visits – Take part from anywhere in the world	Ben Carlson	virtual conference	17:20 - 17:40
CMS Virtual Visits: engaging audiences worldwide into conversation about cutting edge science	Cecilia Uribe Estrada	virtual conference	17:40 - 18:00
Getting the public closer to the experimental facilities: How Virtual Reality helps HEP experiments engage public interest	Ana Peixoto		
Development of Mixed Reality Software Applications for the ATLAS Experiment	Mariam Pirtskhalava	virtual conference	18:20 - 18:40
The ATLAS public website - Evolution to Drupal 8	Meirin Oan Evans	virtual conference	18:40 - 19:00

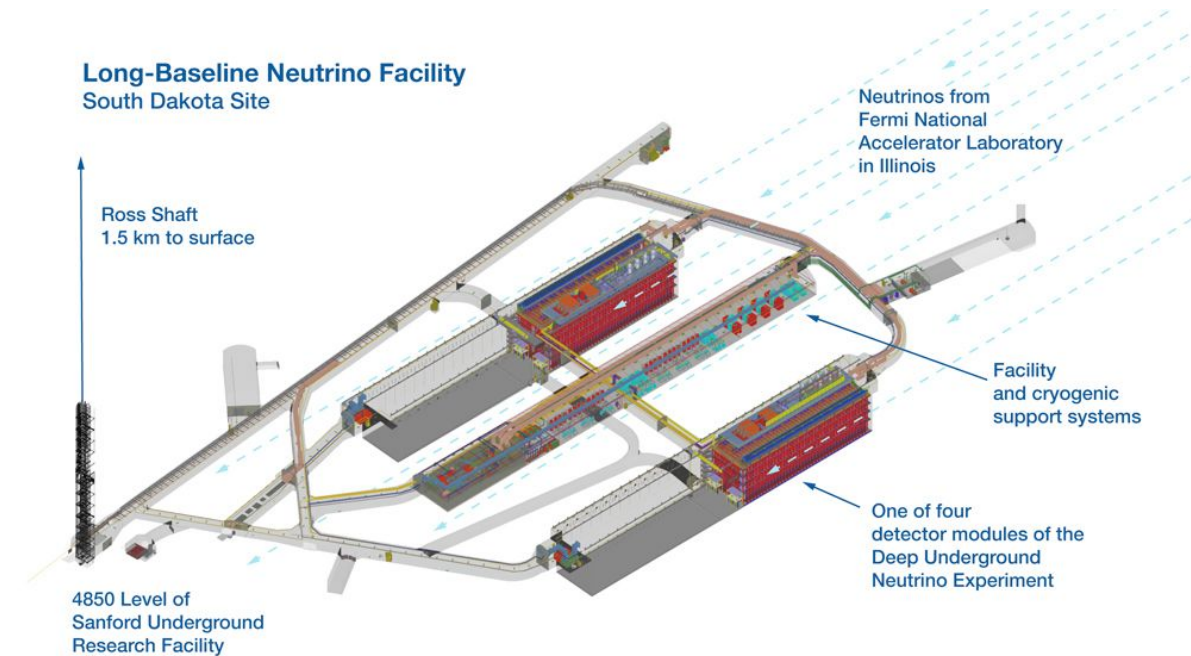
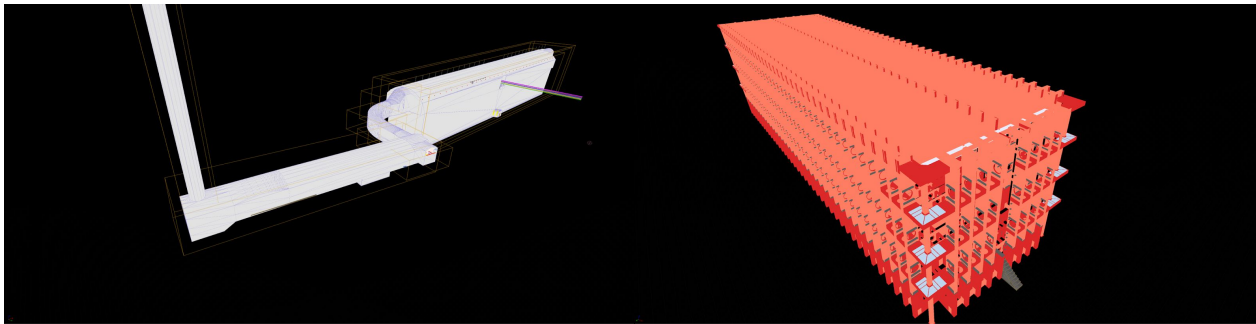
CMS in your pocket: between serious game and demonstration tool	Pierre Van Hove	virtual conference	15:30 - 15:50
Development of Web-Based Detector Display Application Tracer for ATLAS Experiment	Levan Khelashvili	virtual conference	15:50 - 16:10
In pursuit of authenticity – CMS Open Data in education	Peitsa Veteli	virtual conference	16:10 - 16:30
ATLAS Open Data at 13TeV - The journey to a fully educational HEP dataset	Dr Kate Shaw	virtual conference	16:30 - 16:50
Coffee Break		virtual conference	16:50 - 17:20
The University of Michigan Semester Research Program at CERN	Steven Goldfarb	virtual conference	17:20 - 17:40
An Outreach to the Public: Science of the Large Hadron Collider Exhibit	Andrei Gritsan	virtual conference	17:40 - 18:00
Astroparticle Physics Outreach Program for High-School Students	Carla Aramo	virtual conference	18:00 - 18:20
ENGAGING DIVERSE AUDIENCES WORLDWIDE TO THE QUEST FOR GRAVITATIONAL WAVES	Dr Nicolas Arnaud	virtual conference	18:20 - 18:40

A Day in the Life of a HEP Physicist

Detecting Supernova neutrinos has an alluring and tractable storyline for middle and high school aged children, and prompts an interest in the development of a Masterclass that would focus on:

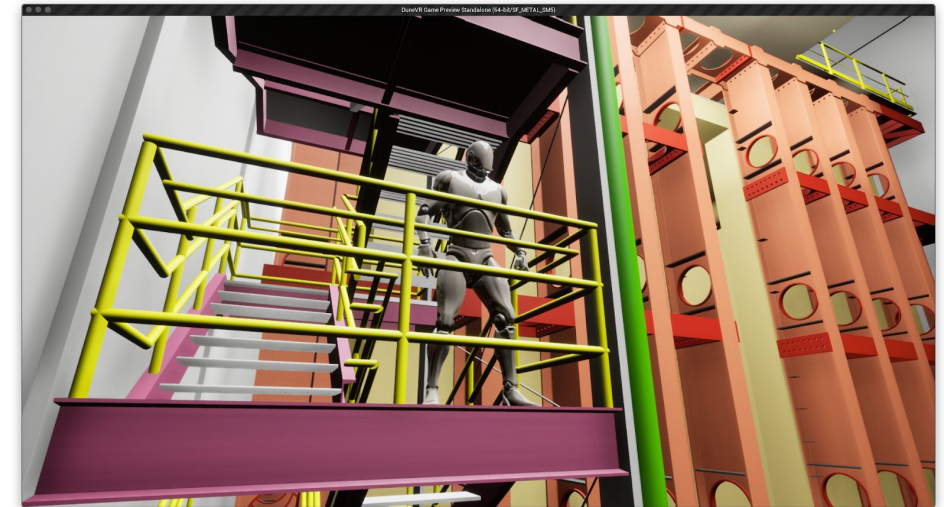
- Supernova dynamics, neutrino generation
- DUNE detector design, and operation.
- Event scanning, classification,
- Histogramming, statistics, ...

As a part of the envisioned one day workshop, participants would be treated to a lab tour of the DUNE Facility in Lead, SD, USA, obviously virtually!



vDUNE Project Summary

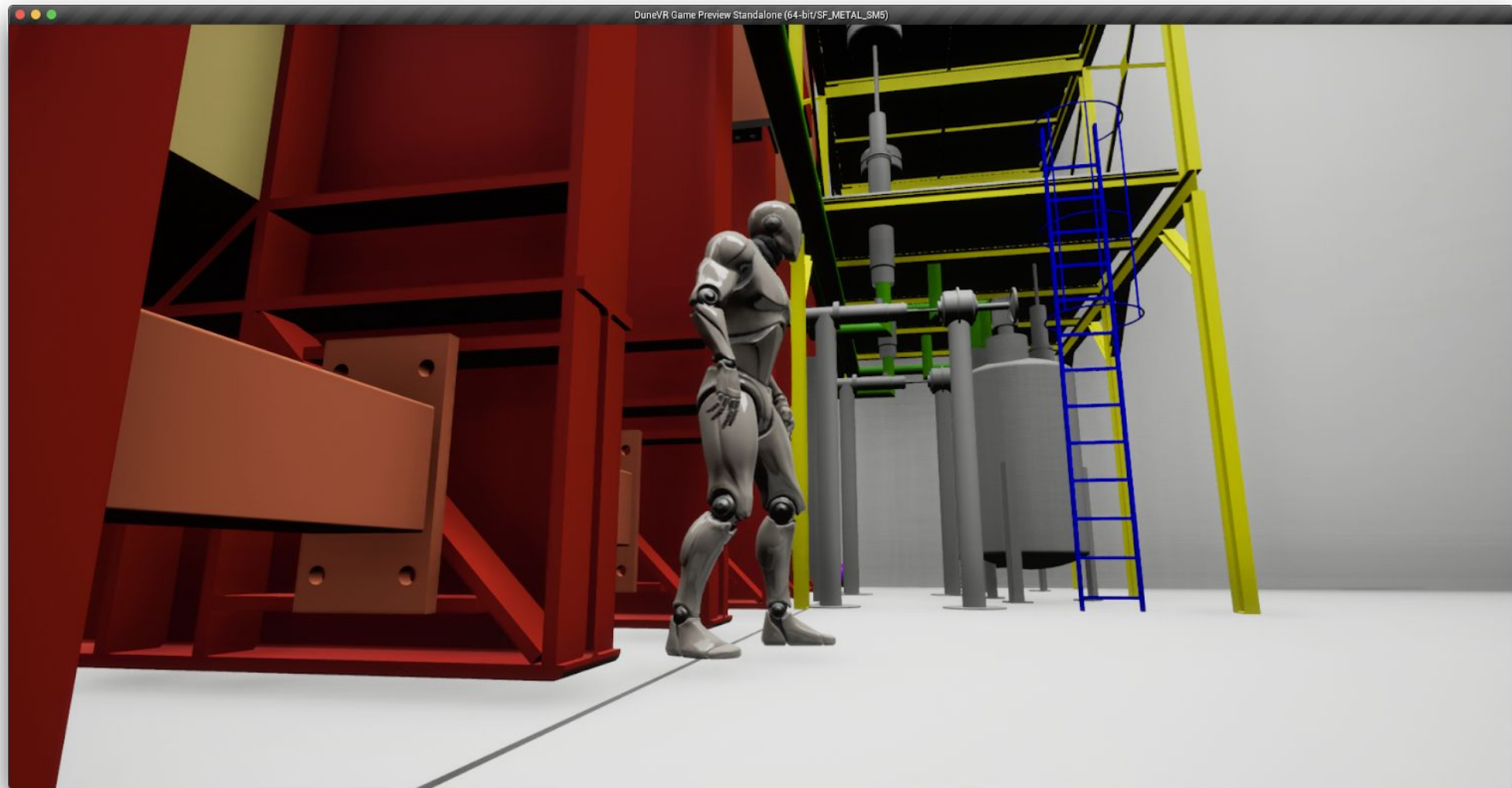
We are building a virtual reality simulation of the Sanford Underground Research Facility, where the DUNE is being built; our focus is to inspire young students to be scientists. The simulation includes the ability to roam the large multi cavern laboratory, as well as navigate within the first of four particle detectors. Key learning outcomes are for an understanding of the workings of the Liquid Argon Time Projection Chamber, and to better understand the day in the life of a high energy particle physicist.



Detector Snapshot



Detector Snapshot



vDUNE: Measurement Tool Demonstration

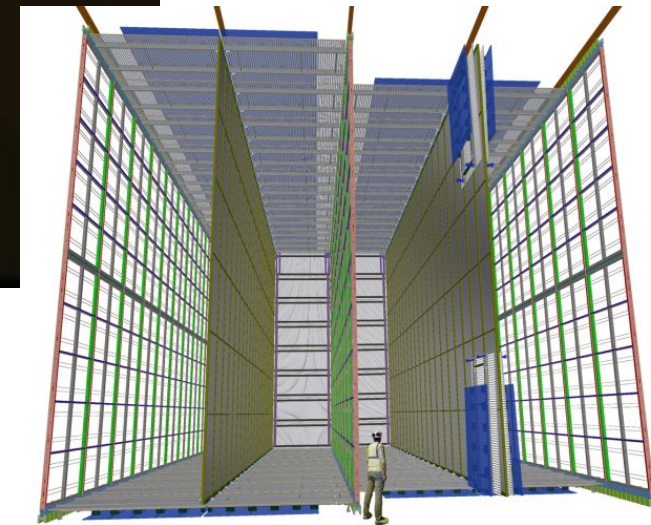


<https://youtu.be/u3D-IgAFOow>

Inside Proto-vDUNE



<https://youtu.be/p25mG4d6CMw>

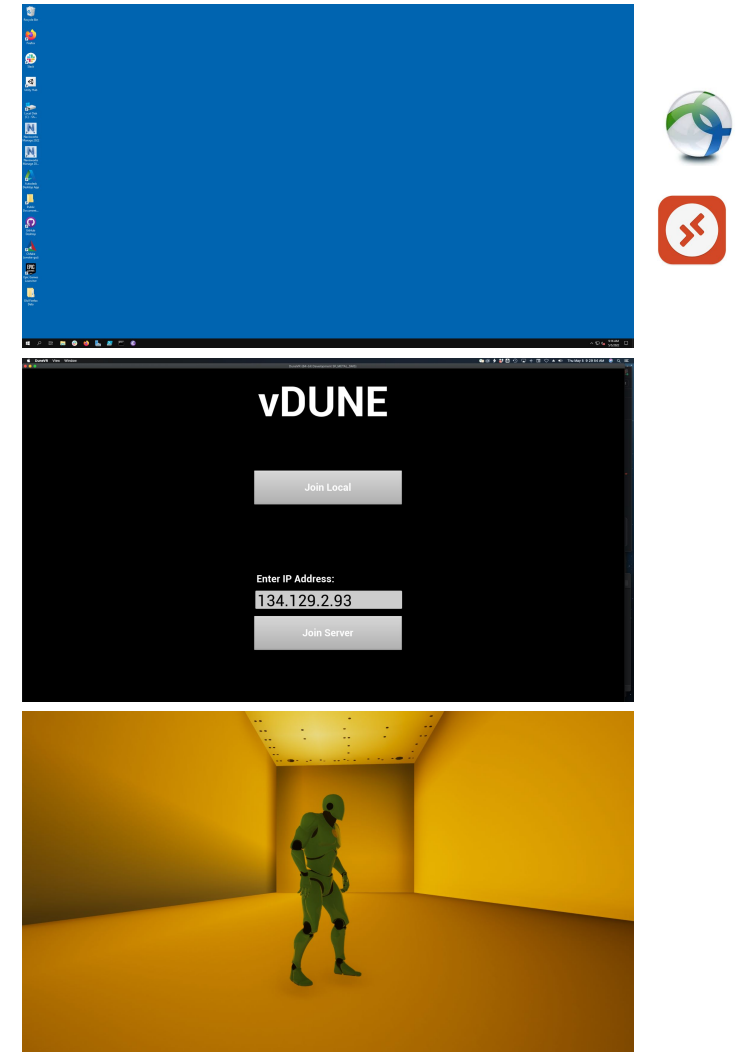


vDUNE Server

A dedicated Windows server has been built at the Valley City State University campus that hosts the Unreal Engine (Epic Games) where highly precise CAD files (Autodesk NavisWorks) accessed from the CERN EDMS site have been rendered. In addition to Unreal, Blender is utilized for model building.

The VCSU server is accessed via VPN using the Cisco Anytime application which requires credentialing for individual users, and the Microsoft Remote Desktop application which both developers access on Mac OS.

A feature of the networked Unreal server is to allow multiple players to join simultaneously in the game, just as would be the case for multiplayer games such as Call of Duty, Halo, or Fortnite.



Needed: video demonstrating the poster room on the surface, with touchability, and jumping down the rabbit hole

Multi-avatars

The vDUNE server provides a mechanism for multiple players which we suggest is ideal for enhancing the education and outreach efforts for DUNE.

In one of several use cases, during a student engagement, an organizer would project the screen of a client machine for viewing by a group of teachers.

Multiple players (experts) would join the game, each uniquely colorized, and with a specific expertise: CPA, APA, Cryogenics. These experts would provide a detector operations tour, highlighting their respective components.

In another use case, students within a classroom could simultaneously join the game, and navigate freely, asking questions to a roving expert or experts.

Using the vDUNE server, multiple players have been demonstrated; more work remains.



In this snapshot, two avatars roam the interior of a basic DUNE detector mockup. We are exploring skinning the avatars with unique colors, so as each can be recognizable.

Game Share

An aim is to provide individualized realtime tours of SURF and the DUNE detectors which will have us developing custom instances of the game which are designed for selected audiences, e.g. high school students.

- For multiplayer, a file (200 Mb) is distributed via a Google share.
- Secure user access to the vDUNE server requires management.
- A Github repository has been established for this project, which allows for tracking and resolving issues.
- Slack is used for project management.
- A ticketing system is being selected for bug reporting and task assignments.
- A document system (GitHub/ReadtheDocs) is being developed, possibly as a Docker-ized Wordpress site.
- Project Tools: EDMS CERN, Navisworks (nwg) conversion to (fpx) for Unreal Engine import, and Unreal Editor (4.25.3), Blender, and possibly AutoDesk Maya, 3DS Max.
- Notable: Unreal has native Oculus Rift plugins.

Navigating High Prim Environments

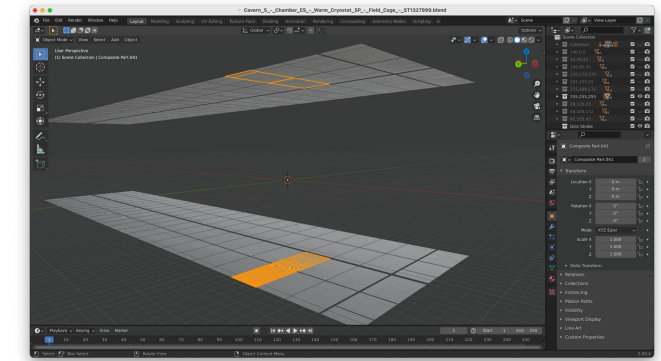
A complicating factor is in the immense size of the files that are used to render the detector halls and detectors, the geometry files can exceed billions of polygons.

While navigating a “full” detector, for example, CPU and memory requirements are restrictive, when game play can become intermittent on computers typical to students.

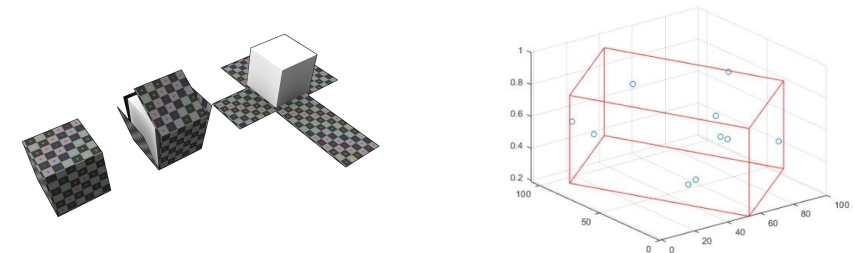
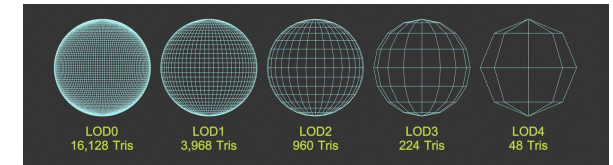
Unreal has built in systems to render events proximally, but algorithms are needed to develop the softened views, particularly while navigating within the extremely high polygon DUNE detectors.

Research is underway that investigates the using shell scripts (Python) that can streamline the effort to texturize elements of the detector so as to allow for a more fluid interaction within high geometry environments.

For example, as an avatar roams the interior of the DUNE detector, high resolution rendering is proximal.



As an avatar navigates the inner workings of a particle detector, a bounding box (BB) of smaller proportion is established. From within this BB, a highly detailed detector is rendered, while adjacent spaces are sequentially rendered with fewer and fewer polygons so as to ensure smoother mobility.



Simulation Tools

Our preliminary work has allowed us to provide several proof of concept features:

- Laser pointer - actuated by keystroke (v), acts to touch items, crosshairs form.
- Dimension tool - actuated by keystroke (m) for measure, then crosshairs form where touched, second keystroke (p) for place, touch second point (p) is focused, dimension determined shows up in the window, with a line drawn between the two points - it might be that the dimension is laid in the direction of the laser beam.
- Poster zoom tool - full detailed conference posters are placed throughout the lab as a geocache game.
- Ball drop tool - demonstrate gravitational fields as a supporting metaphor for electric fields.
- Pickup objects - then verify in your inventory - these items are stored in a clientside JSON file.

Virtual Lab Tour Script

Avatars, assemble at the head frame, board the elevator, descend into the earth, converse on the way down, occasional illuminations while passing level stokes, until reaching the 4850' level.

After exiting the elevator, the participants receive a quick safety lesson, then are escorted around the cavern, along the way, posters are positioned on the walls, some with embedded YouTube videos, participants can stand together to peruse the poster, chat privately, move on to another poster, or group.

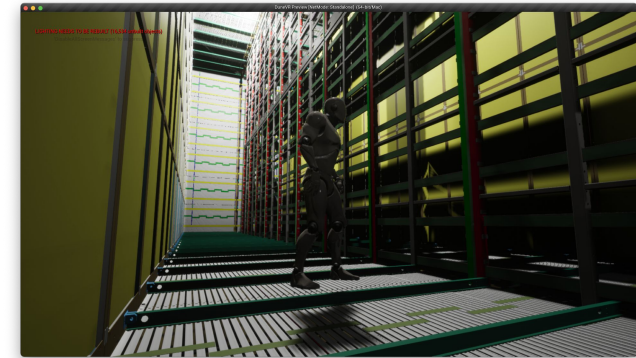
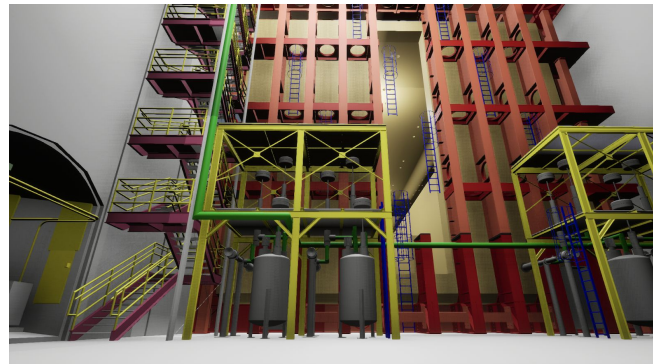
The participants walk a long way to the first cavern to see the full DUNE detector in all its glory. Tour guides explain its operation, point out technical components, walk along catwalks and on the top of the detector.

Participants enter into the detector through the TCO and walk to the far end of the detector, where they touch detector elements to learn their function.

An event is projected in the detector space, participants can wander around looking up at the event from different perspectives.

Summary

- A featureful virtual experience of the deep underground laboratory at Lead, SD, USA is being developed as an E&O activity for high school level students.
 - Supporting the story of a day in the life of a particle physicist is a central theme.
 - Integration of this virtual experience into relevant Masterclasses is anticipated.
- Navigating high prim environments is confounding.
- We hope to push this project out to an open environment, inviting contribution, sharing benefit.
- More work is needed.



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Backup slides follow

CHEP 2023 Abstract

Deep underground, the removal of rock to fashion three soccer field sized caverns is underway, as are detector prototypings. In 2024, the first DUNE far detector will be constructed as a large cryostat, instrumented as a traditional tracking calorimeter but in a cold bath of xenon doped liquidized argon. An Epic Game Unreal Engine rendered 3D simulation of the underground laboratory has been developed from electronic engineering drawings for the purpose of outreach to middle and high school students and to stimulate an academic interest to know more about high energy physics to a computer savvy generation of students. and ideally enroll in high school and college classes that might one day lead to becoming a HEP scientist. An overview of the project and a virtual lab tour will be provided in this presentation.

DUNE Neutrino Masterclass Progress Report

Course Overview: The Supernova Neutrino Masterclass will be a specialized learning experience for teachers focusing on supernova neutrino generating processes and detector level physics while emphasizing the practices of high energy particle physicists as well as providing students a memorable hook into STEM disciplines. With NDSGC funding, the masterclass curriculum will be developed for teachers to include:

1. Supernova Neutrinos:
 - a. Fusion in the Sun, neutrino production, and Homestake Lab history presented in Geodome Theatre [4].
 - b. Core collapse and neutrino production (infall, neutronization burst, accretion, cooling), particle acceleration [5].
2. Detector Level Physics
 - a. Liquid Argon detection, particle interactions, energy loss, track length, pulse-height, angular distribution.
 - b. Visual scan and classification of Monte Carlo events containing supernova neutrinos, radiological background, noise, and atmospherics.
 - c. Construct data histograms, discuss statistical parameters, compare data.
3. Life as a STEM-icist:
 - a. Spreadsheets, data management, graphing, analysis, utilizing probabilistic techniques such as Monte Carlo for modeling reality.



NASA Space Grant program promoting STEM education and research throughout North Dakota through K-12 and college programs and public outreach efforts



**2018 Summer Faculty Fellowship
Recipient**



[#ed-masterclass](https://dunescience.slack.com)

