Opportunities with protoDUNE-SP

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European Neutrino Meeting LBNF/DUNE

CERN, 8 April 2016

UNIVERSITY OF LIVERPOOL

DUNE

Outline

- What is protoDUNE-SP / NP-04
  - What we are inviting you to *join*
- Aims
  - Why you should join
- Schedule
  - Why *join now*

- What we will be doing in the next 3(+) years
  - Opportunities for *new participants*

- Discussion

A rapidly developing landscape

2013

- Long Baseline collaborations: LBNE, LBNO
- ~1 kton demonstrators: LAr1, WA105
- *the question was posed: what if we test both technologies in one cryostat at CERN?*

2014

- Long baseline collaborations merge into DUNE
- CERN commits significant resources to the Neutrino Platform

2015

- 1st DUNE collaboration meeting
- protoDUNE-SP proposal to SPSC, approval by SPSC and RB

2016 protoDUNE-SP management, organisation, project launched

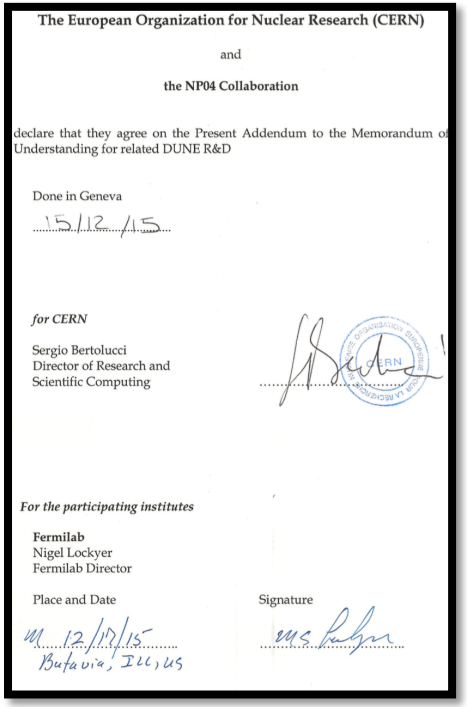
2017 construction, installation

2018 commissioning, data taking

protoDUNE-SP / NP-04

The prototype of the DUNE single-phase Far Detector (FD) at the CERN Neutrino Platform (NP).

- Project under the DUNE management
- 770 t (ICARUS T300: 380 t)



The European Organization for Nuclear Research (CERN)

and

the NP04 Collaboration

declare that they agree on the Present Addendum to the Memorandum of Understanding for related DUNE R&D

Done in Geneva

15/12/15

for CERN

Sergio Bertolucci
Director of Research and Scientific Computing

For the participating institutes

Fermilab
Nigel Lockyer
Fermilab Director

Place and Date

12/12/15
Batavia, Illinois

Signature

- SPSC-P-351 proposal submitted 06/2015

https://cds.cern.ch/record/2022751?ln=en

- NP-04 approved by SPSC & Research Board
- CERN-Fermilab MoU signed 12/2015

- Lots of challenges in the next few years:
  - planning & design, construction, data collection, data processing, reconstruction, analysis and journal publications

protoDUNE-SP management

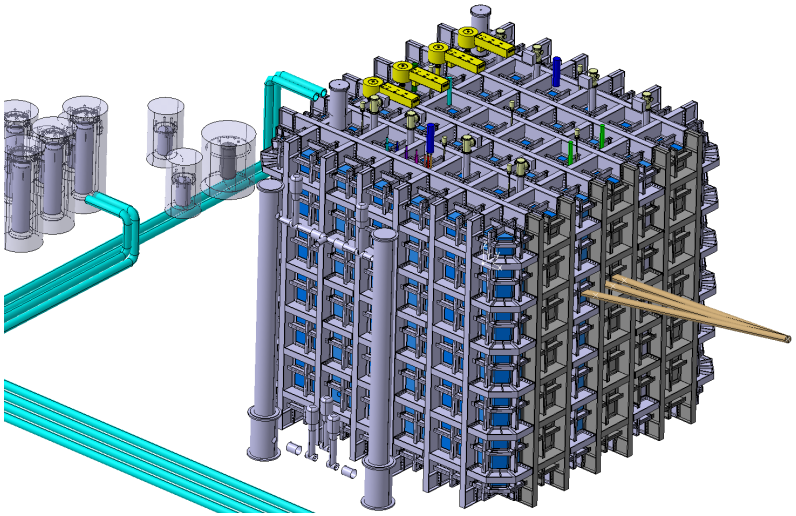
- Coordinators / spokespersons
  - Flavio Cavanna cavanna@fnal.gov

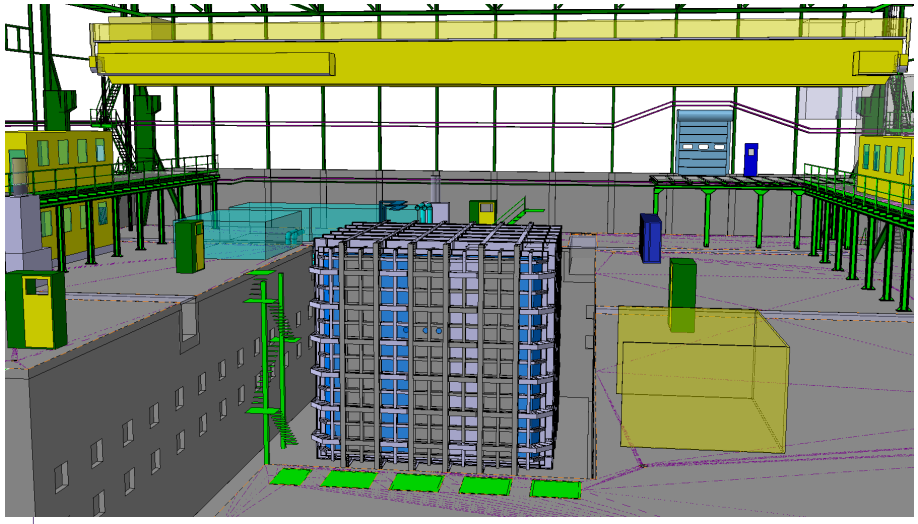
  - Christos Touramanis c.touramanis@liv.ac.uk

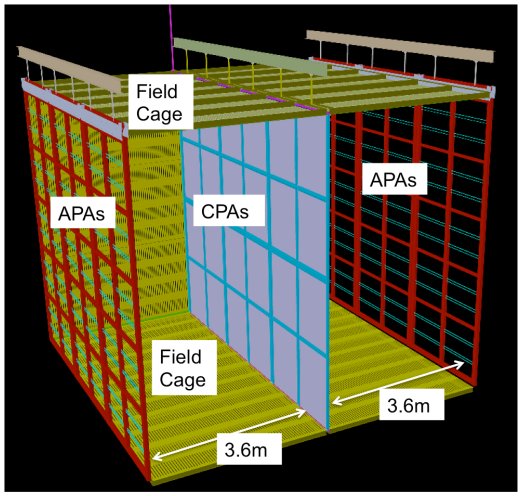
- Deputy Coordinator
  - Thomas Kutter kutter@phys.lsu.edu

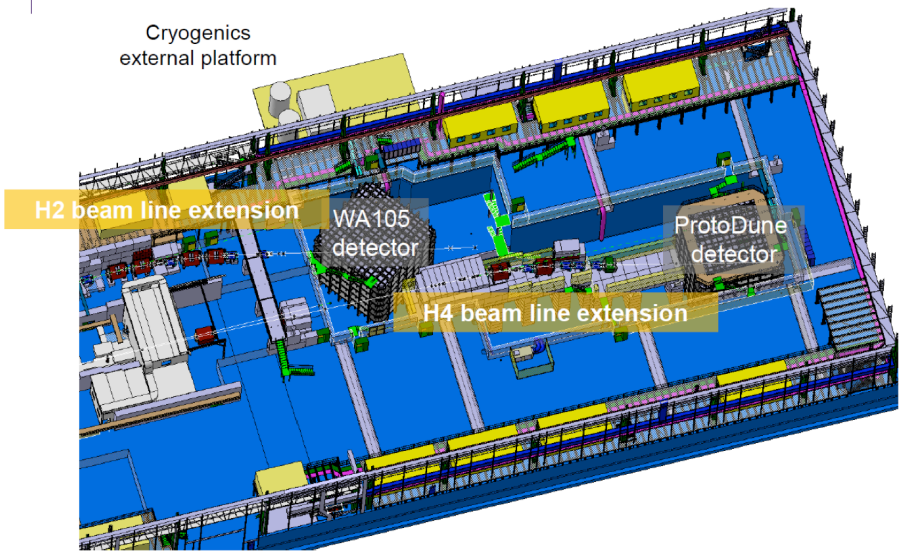
- Project Manager
  - Maria Chamizo Llatas maria.chamizo@cern.ch

The detector









Aims: technical

High-level protoDUNE aims:

- Mitigate the risks in the current detector designs
- Establish the construction facilities required for full-scale production of detector components
- Identify and mitigate potential issues with construction methods and detector performance

➢ Underpin DUNE CD2

More specifically:

- Characterize detector performance with full-scale detector components
- Develop multiple manufacturing sites
- Validate installation plans

Ideal project to:

- Apply and enhance, or
- Develop

your group's expertise and know-how in LAr TPCs

Aims: understanding the TPC

- Evaluate cold electronics
- Develop and assess TDAQ strategies and algorithms
- Assess detector systematics
- Validate / tune MC simulation with real data
- Validate / develop reconstruction and calibration
- Study particle interactions (kaons, pions, muons)

Develop and characterize:

- Particle ID
- e/γ separation
- Hadron / em shower energy reconstruction

Ideal learning ground for students, postdocs (and faculty)

Key contributions to DUNE optimisation

Best preparation for DUNE physics.

Timeline drivers

- First test beam operation before LHC LS2
  - SPS proton operation currently foreseen to end 10th October 2018
- A period of operation with cosmic rays during LS2 (2019-2020) is *foreseen*
  - full technical characterization of the detector components in view of DUNE CD2
- A successive extended test beam run after LS2 is *under consideration*
  - fulfil the quest for a more complete calibration of the response of the detector to different particle species.

Schedule outline

Currently ongoing:

- Design, development, pre-production of components
- Design, planning of infrastructure at CERN

Activities at CERN:

- 02/16 -- DAQ development
- 12/16-03/17 Facilities construction & set up in EHN1
- 05/17-01/18 Acceptance, tests, installation of TPC
- 02/18-04/18 Cryostat close, tests, fill & cool-down
- 05/18-06/18 Detector commissioning
- 07/18-12/18 Beam data taking

The team at CERN

A core team of (mainly) postdocs and students is required at CERN to carry out the experiment.

- A part of the team must be at CERN from January 2017 to participate in setting up facilities and labs, including DAQ infrastructure and systems
- A full team must at CERN from May 2017 for reception/testing/ integration/installation of all systems
- The CERN team plus shifters must be at CERN in May-October 2018 for commissioning and collection of beam and cosmics data

➢ Working on setting up the CERN core team and agreeing their schedules

An open door policy

- DUNE member institutes' interests captured recently
- Pools of groups identified to cover all major items / areas
- Deliberate decision not to freeze plans before all inputs are in:
  - All of you are invited to get in contact, declare your interests and discuss options
  - We aim to have a complete division of responsibilities in June
- No contribution is too small
- No offer is too big
- A great opportunity to join DUNE:
  - Make visible contributions and gain valuable expertise
  - Work at CERN, with all its advantages
  - Integrate in the collaboration, find "your place" for the long science expedition and discoveries in 2025-2040

Areas not covered here

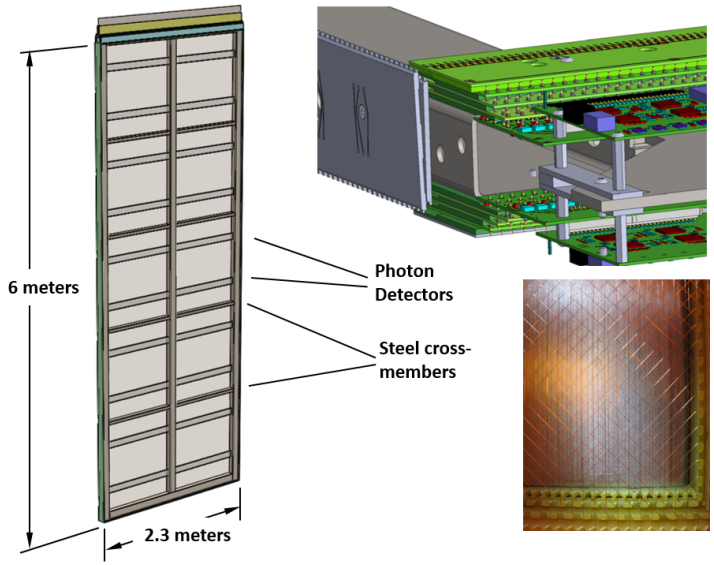
- Physics:
  - MC simulations to optimise aspects of the detector; trigger strategies; and the beam data taking strategy
  - Further development of full detailed MC
  - Development of event reconstruction; event display; calibrations; analysis tools
  - Development of analyses to measure interaction kinematics and cross-sections
- Computing model; data handling and processing; software
  - See talk by Robert Sulej

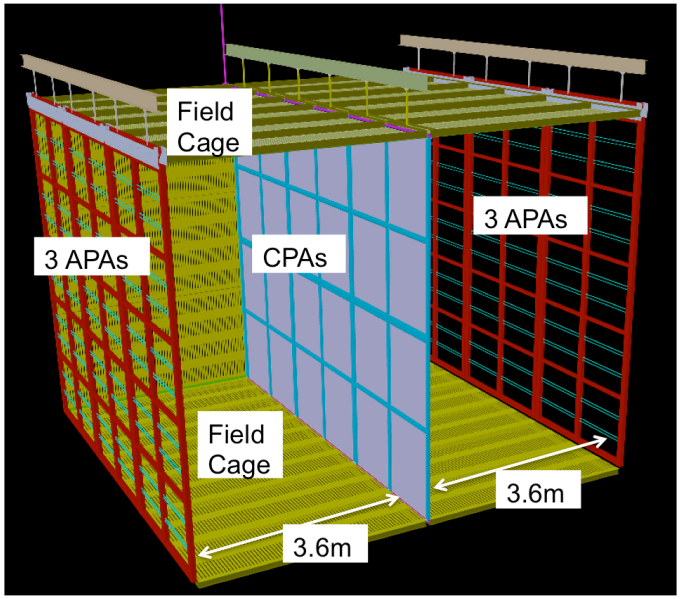
Many opportunities in these areas, please contact us

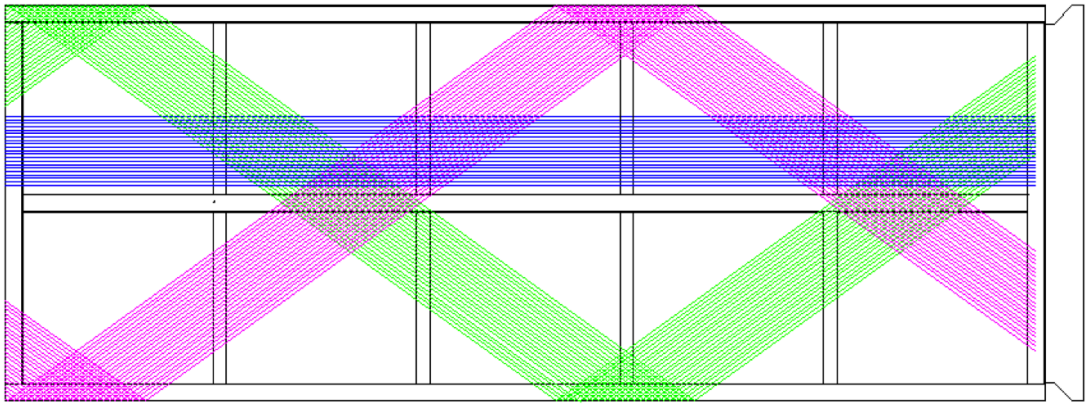
A combination from these areas, and HW contributions:

- great for PhDs
- Ideal for postdocs' career development

TPC hardware: APA







TPC hardware

- The main components of the protoDUNE-SP detector are engineering prototypes for the DUNE far detector
- Managed by DUNE FD WG; central design by BNL
- APA: most complex, critical element (6 units)
  - Two production sites (PSL/USA, Daresbury/UK)
- Cold Electronics: BNL
- Stony Brook, BNL, CERN, U. Chicago for Field Cage, HV system and CPAs

There are opportunities to join in at every stage.

You are welcomed to join installation/integration at CERN.

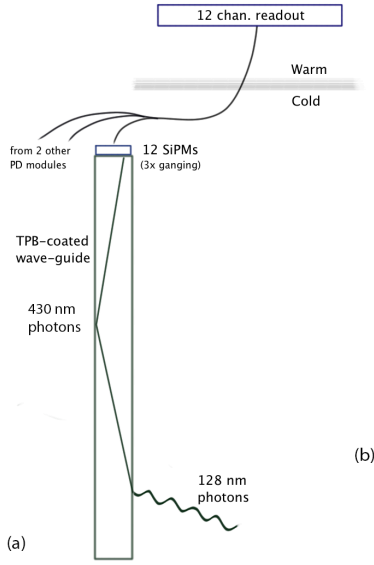
If you have bigger ambitions please let us know!

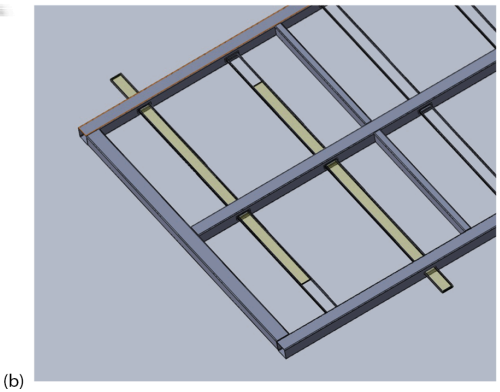
Photon Detectors

- Requirements:
  - Detect sufficient light to measure efficiently time and intensity of events depositing >200MeV (atmo, proton decay)
  - Detect sufficient light to measure time of events depositing <200MeV (SN)
    - Min. photon yield: 0.1 pe/MeV
    - Photon time resolution: 1 microsec
  - Integrated in the TPC modular design; compatible with LAr purity requirements; minimum radioactivity
  - Readout system to record continuous waveforms
- Default design choice:
  - Lightguides coated and doped suitably to shift the LAr scintillation light (128nm) and transport it to solid state detectors

Photon Detector

- wave-length shifter bars couple to ganged SiPMs
- Other technologies may be prototyped
- More advanced technologies for DUNE could be considered
- Simulation activities to better tie technical requirements to scientific requirement welcomed





New contributors welcomed

DAQ

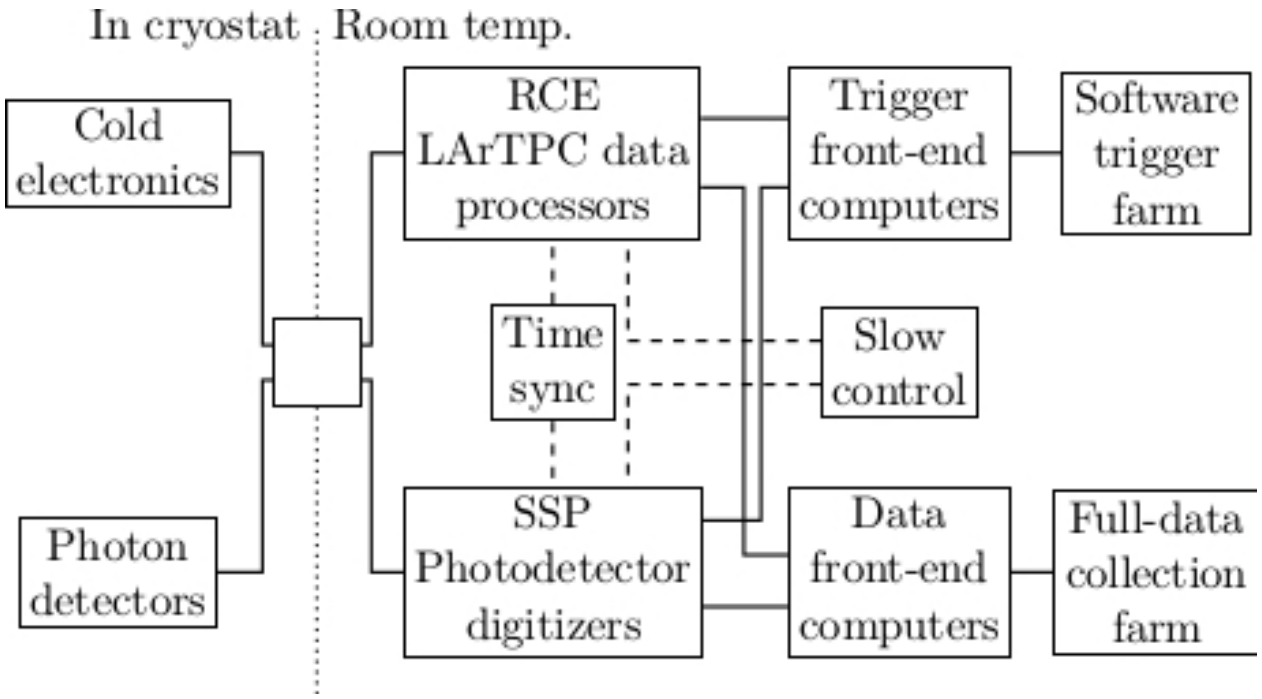
- 6 APAs, 2560 channels each, 2 MHz 12 bit ADCs
- Photon detectors, 120 channels, 64MHz 16 bit ADCs
- Trigger using beam counters, Cerenkov
- Using SPS beam spill

- DAQ challenge is continuous readout and triggering

DAQ

- Data acquisition is challenging because of large volume of data produced.
  - Raw rate pre-trigger TPC: 46GB/s
  - Trigger reduction: less than a factor 10
- Two modes of protoDUNE-SP data taking foreseen:
  1. Triggered mode – from beam counters. Expect to run at about 50Hz which gives 225 events per spill, (max rate (on all the time) would be about 400Hz). Inter-spill gap is sufficient to drain data to computers. Used in first runs.
  2. Continuous mode (like far detector), used later. Test data filtering techniques in both FPFGAs and computers.

DAQ baseline layout



DAQ R&D programme

- *Several avenues under investigation:*
- Warm interface electronics
  - with/without FPGA
  - different line rates and protocols
- DAQ boards
  - Current RCE to be upgraded from 35 t
  - New FELIX DAQ board - PCIe board for ATLAS upgrade
- Timing and Triggering
  - White Rabbit timing system used in dual phase
  - triggering on beam (synchronous)
  - triggering on Supernova (asynchronous, huge data volumes)
  - timing and trigger distribution
  - integration of new systems with current DAQ hardware
- New methods of slow control

DAQ simulation

- Simulation studies
  - Compression
  - Zero-suppression
  - Triggering
  - Readout geometry
- Timing simulation
  - How to best split our data in time?
- 35 t data to be studied
  - provides important constraints on the above
- **New contributions welcomed!**

Online computing

- protoDUNE will require a compute centre
  - Everything from logbooks to storage racks
  - Network topology and requirements to be studied
  - Coordination with CERN IT
  - Comparable data rates to LHC experiments!
- Run control
  - Develop/Adapt a GUI
  - backpressure/throttling system
- Databases
- Online processing and monitoring
- improvements to artDAQ - event filter framework

DAQ commissioning tasks

- Create a DAQ slice using 35 t as a model
- Setup computing infrastructure, run control, monitoring
- Test new electronics components arriving at CERN
- Expand to full protoDUNE
  - Data challenge
- Data taking in 2018
  - We'll need shifters!

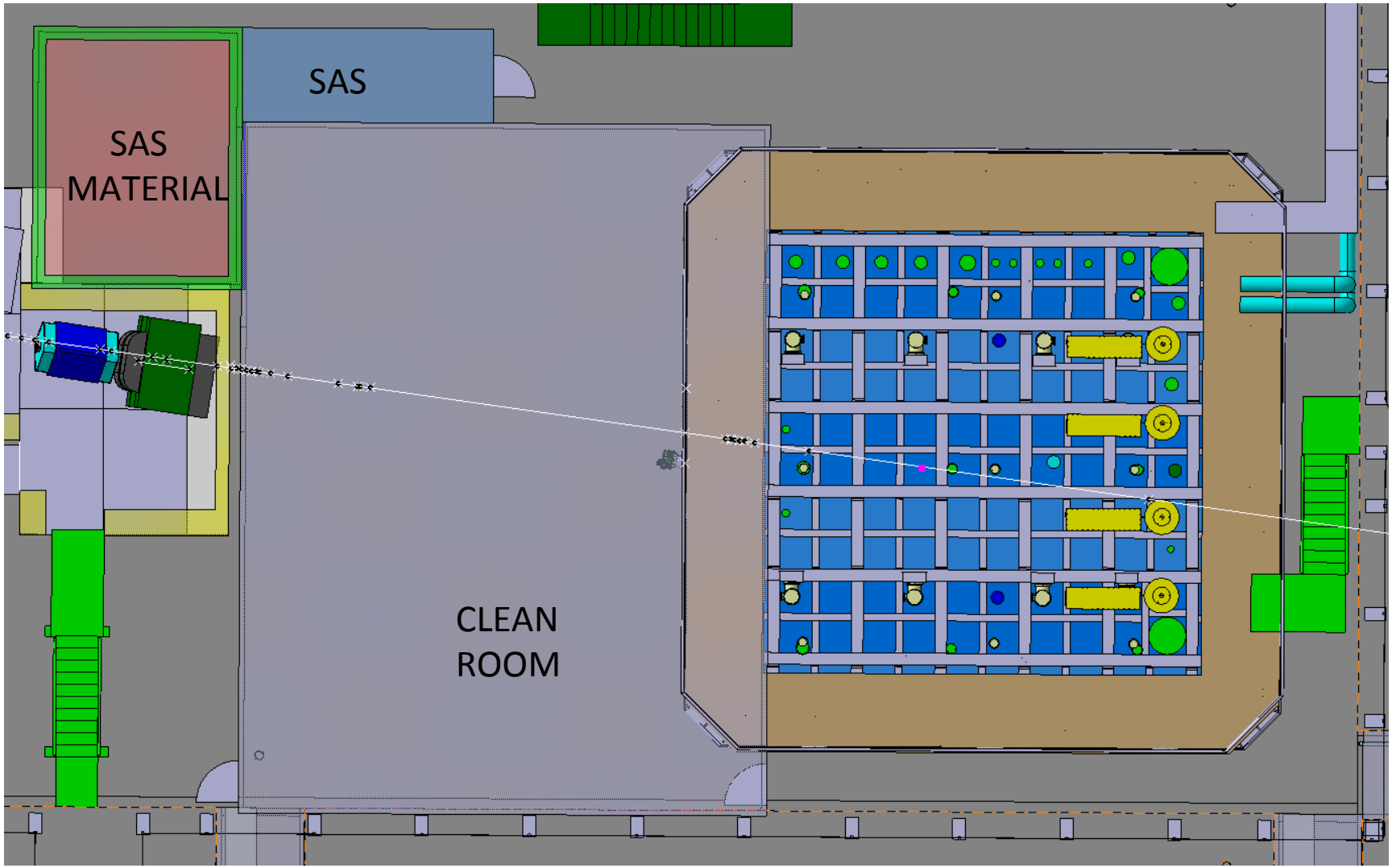
In protoDUNE-SP we have our own DAQ team

Oxford, Liverpool, FNAL, CERN, SLAC, …

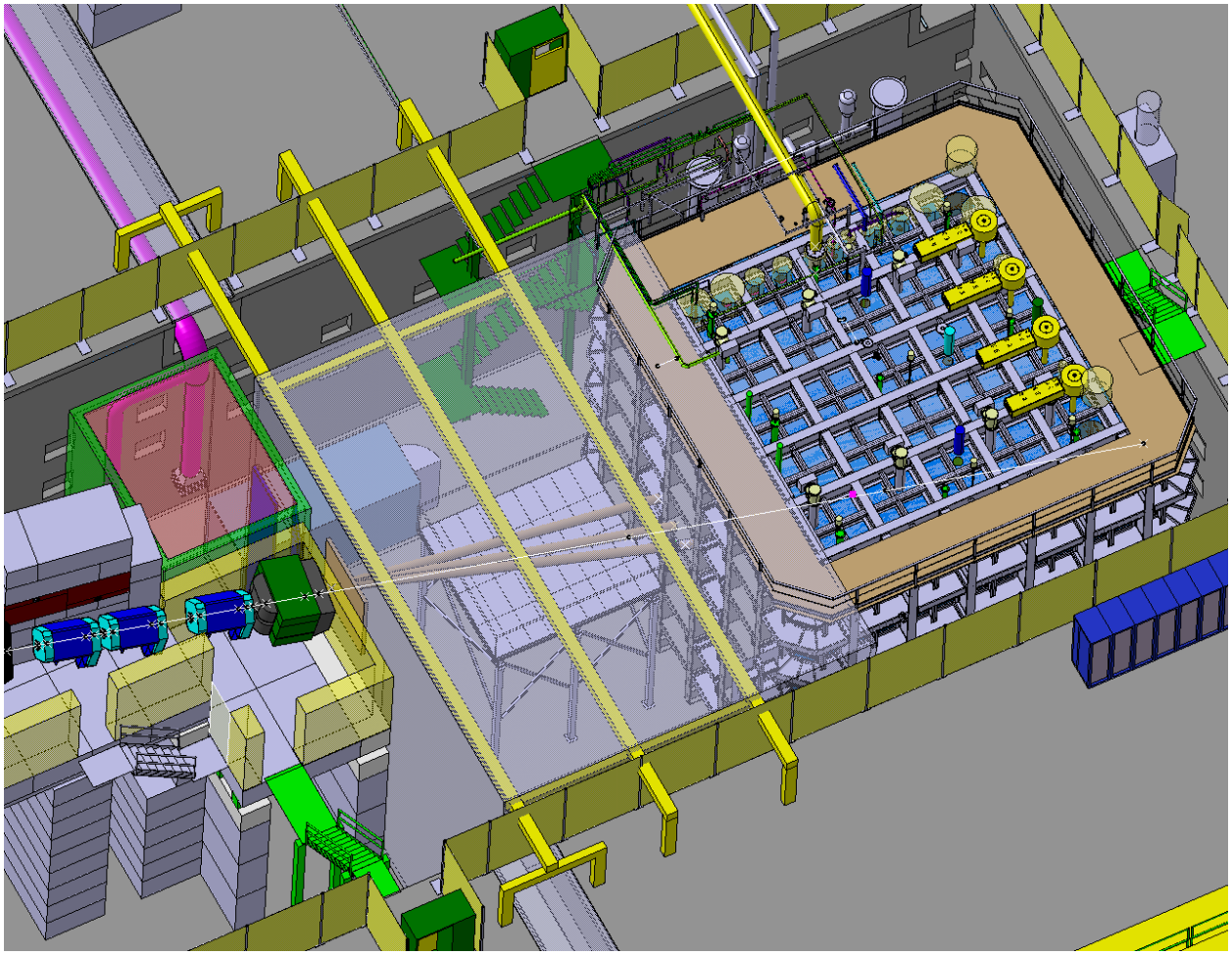
A very fertile ground for new participants

Installation, testing, integration

- All detector components will arrive at the clean room in EHN1
- Integration & tests of APA+CE+PD will take place in the clean room
- As soon as one APA is fully equipped and tested it will be inserted inside the cryostat for further tests
- Consecutive test cycles with increasing detector complexity
- Crucial to learn / debug how the detector works from a slice to a full detector
- All groups involved in the construction expected to participate in the installation
- New groups welcomed → ideal way to learn how the detector works


SAS
SAS
MATERIAL
CLEAN
ROOM

Clean room in EHN1



Other areas of activity

All crucial but no time to cover in detail in this presentation

Synergies with protoDUNE-DP and joint teams being developed

- Beam Line Detectors, and their integration into the TDAQ
- Cryogenics, including purity monitoring
- Calibration methods and systems, including possible dedicated UV laser system
- Cosmic muon tracker
- Beam window(s)

Summary

- protoDUNE-SP: a unique and timely opportunity to "dive" into the heart of DUNE activity, in an under-construction experiment at CERN (*Marzio Nessi: "jump on a moving train"*)
- You can (should) get involved immediately
- Opportunities for contributions in all aspects of the experiment

Contact:

DUNE spokespersons: Andre Rubbia, Mark Thomson

protoDUNE-SP coordinators: Flavio Cavanna, Christos Touramanis

backup

Indicative particle spectra

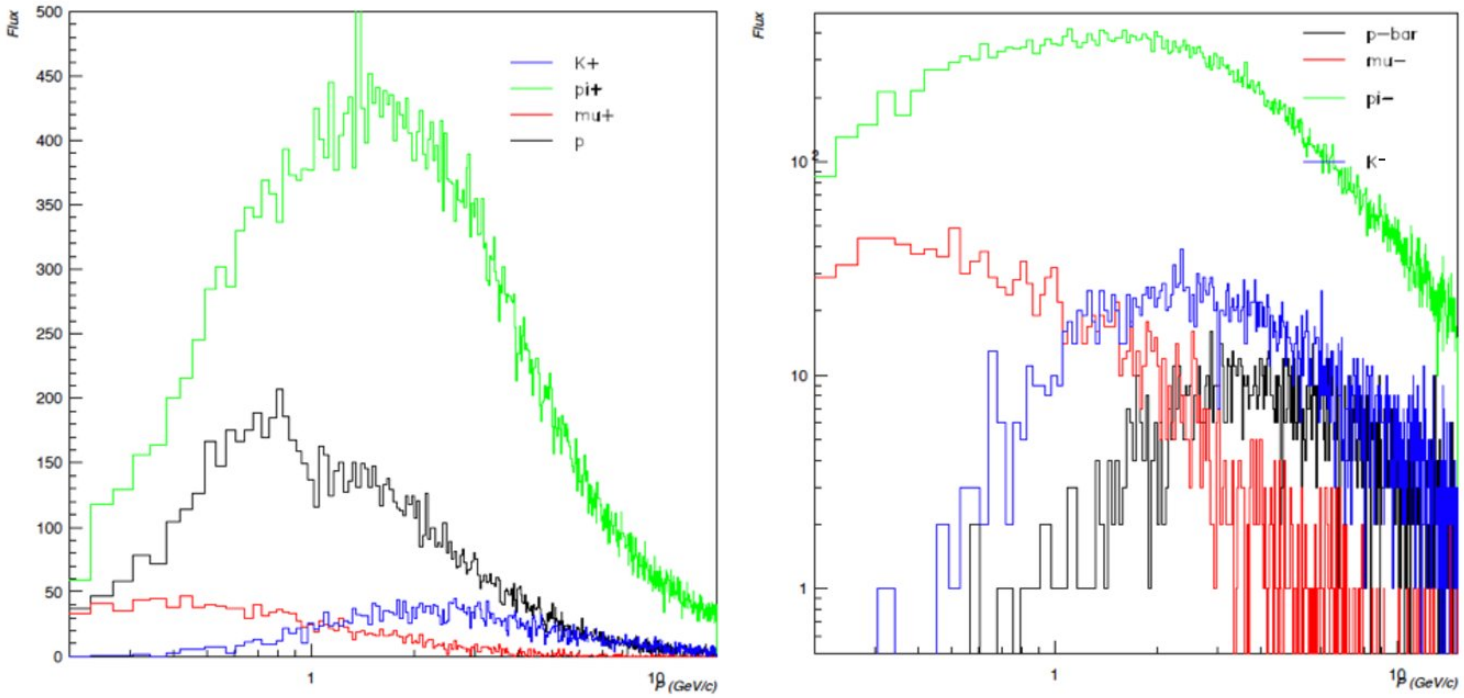


Figure 23: Simulated flux of charged secondary particles resulting from 100k π^+ each with an energy of 80 GeV impinging on a 15 cm copper target. The figure on the left is for positively charged and the figure on the right is for negatively charged secondary particles.

Comparison between SP and DP, and between ProtoDUNE and DUNE-FarDet.

	Single Phase		Dual Phase	
	ProtoDUNE	One 10kt module	WA105	One 10kt module
#sub detectors	1	1 to 4 modules	1	1 to 4 modules
Data pretrigger per detector GB/s	46	1,152	38	768
Data posttrigger per detector GB/h	O(2000)	O(500)	O(1600)	O(400)
Supernova event size (no compress)		11 TB		8 TB
#channels per APA	2560			
#APA in detector	6	150		
#channels in detector	15360	384,000	7680	153,600
Digitization frequency, #bits, data size	2 MHz, 12bit 12 bit		2.5 MHz 12 bit 16bit	
Drift distance (time)	3.6 m horizontal (2.4ms)		6m vertically (4ms)	
Beam trigger rate	100 Hz	1 Hz	100 Hz	1 Hz
Beam window	4.5 s	10 us	4.5 s	10 us
Time between spills	16.8s	1 s	16.8s	1 s
Other important triggers		continuous		continuous

Raw rate for 10s, no compression

To estimate these numbers: No compression (yet)
Underground: 1 trig/s, 2 drifts, 3% ROI
At EHN1: 50 trigs/s in beam, 1 drift, 30% ROI

Opportunities for new groups on DAQ

Currently organizing in 18 areas

- Physics requirements capture
- Simulation
- Warm Interface board
- Timing system
- RCE/COB readout hardware, firmware and ARM software for TPC
- Felix readout hardware, firmware for TPC
- Photon detector readout development (DAQ features)
- artDAQ development
- Backpressure and run start task force
- Slow control
- User interface + offline interface to DB
- Offline interface for data, data staging at experiment, online processing farm
- Trigger counter and beam timing inputs
- Beam position monitor input
- CERN APA tests
- Installation at CERN
- Commissioning at CERN
- DAQ support for running at CERN

Can adjust groupings once more people have joined

Some specific examples where contributions are immediately useful

Timing distribution:
We are collecting requirements and ideas and have one or two groups interested, but room for more help with hardware and firmware design, and resources.

Algorithms:
However quiet we make the detector, we will still benefit by doing compression in place. Studying ways to compress information in the presence of coherent noise, and implementing in either FPGA or software is very useful. Optimally, we would like a small library of techniques for when we turn on the detector.

Slow control:
Just beginning to define. Based on CERN systems. Try to make similar for ProtoDUNE single and dual phase. One group in place, others interested, more needed. Would suit either someone looking for big role including organization, or small roles initially (look after one type of measurement, or a particular display technique etc.)