Tourniquet Section 01
4/2/2020

Equipe Neutrino (DUNE/protoDUNE dual-phase)

Bilan 2015-2020

Dario Autiero

Composition actuelle de l'équipe

- Permanent physicists:
  - ***D.Autiero, S.Galymov, P. Lebrun(1), J. Marteau(2), E.Pennacchio,***
- Engineers from Electronics and Informatic services:
  - ***E.Bechetoille, F.Berthet, B.Carlus, C.Girerd, H.Mathez, D.Pugnere W. Tromeur***
- PhD Students :
  - ***Q. David (Detection of supernova neutrinos and associated developments of the DAQ system for DUNE)***
  - ***T. Kosc (nutau detection, LBL 3 flavours analysis in DUNE)***
- Postdocs:
  - ***D.Caiulo (AIDA2020)***

(1) P. Lebrun main activity: Comet

(2) J. Marteau main activity: Volcano Tomography, IP2I deputy director

Evolutions récentes:

- 2 permanents :
  - **S. Galymov** (CR1) 2017
  - **P.Lebrun** joined the IP2I neutrino group and DUNE in 2019 (main activity: Comet)

- 1 PhD thesis :
  - **D.Caiulo** (21/4/2017, supervisor: D. Autiero) – Charge readout analysis in Liquid Argon Time Projection Chambers for neutrino and astro-particle physics (→ Postdoc at INFN Pisa 2017-2018)

- 1 postdoc :
  - **D. Caiulo**
    - postdoc AIDA2020 since October 2018, AIDA2020 WP8 Task 8.3 on charge readout and dual-phase technology

Production scientifique

- Long standing contributions and experience of the group in the study of neutrino oscillations since the beginning of the 90's (Nomad,I216,OPERA,T2K,DUNE)

- R&D program on the charge readout of large liquid argon time projection chambers since 2006, LAGUNA-LBNO design study → fruitful application to 3x1x1 and protoDUNE dual-phase detectors at CERN and DUNE dual-phase Electronics Consortium.

- LIO LABEX Liquid Argon TPC R&D program since 2013 → unique laboratory equipped in France with full LAR TPC chain, support to charge readout electronics developments. Coordination of LAr R&D in AIDA2020, continuation in AIDANOva.

- Among the founders of DUNE in 2014→ participation to International Interim Executive Board, writing of the DUNE EOI, main contributions to the construction and consolidation of the DUNE collaboration (2015-now)

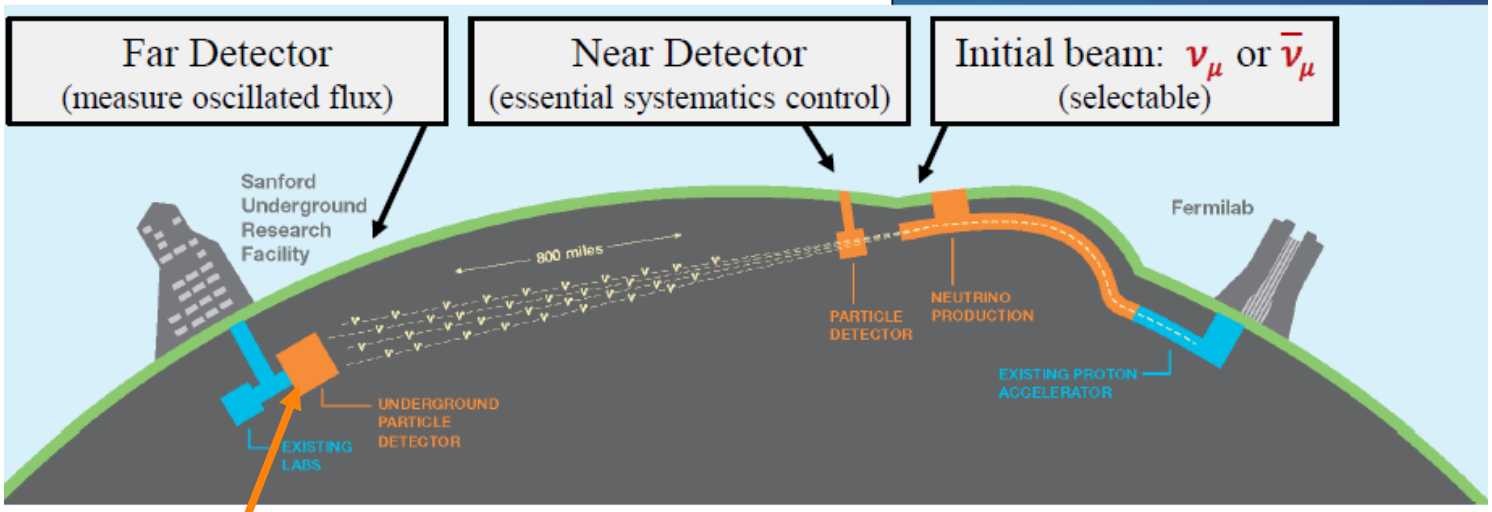
- Responsibility at IP2I of the complete charge readout electronics chain/DAQ for the 3x1x1 prototype and ProtoDUNE dual-phase.

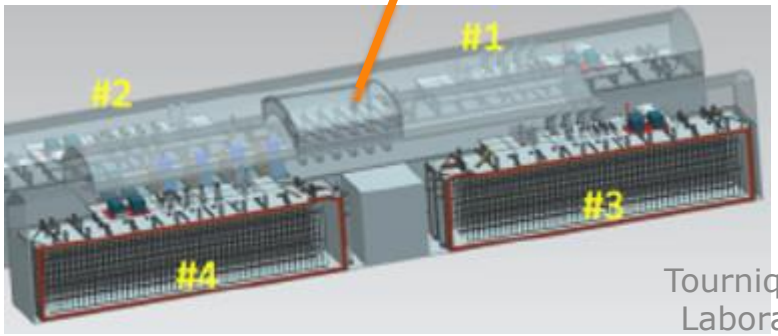
- Coordination of protoDUNE dual-phase, software/computing/analysis. Coordination of IN2P3 DUNE Master Project

- Leadership of DUNE Far Detector Consortium for DP-Electronics (France,Japan,USA)

DEEP UNDERGROUND NEUTRINO EXPERIMENT

A next generation experiment for **neutrino science**, **supernova physics**, and **physics beyond the Standard Model**





- Neutrino beam 1.2 – 2.4 MW
- 40 kton Far Detector mass in 4 modules of 10 kton each of Liquid Argon
- Operation foreseen since 2026

Joint USA-Europe initiative for a common long-baseline experiment based on the liquid argon Time Projection Chamber technology

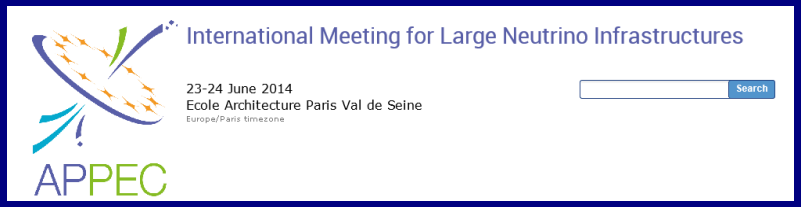
→ **Merging of previous efforts EU (LAGUNA-LBNO) US (LBNE), CERN support (European Strategy)**

Quick developments since July 2014:

- **Top priority of the USA P5 committee (HEP strategy in the USA) May 2014**

→ **Reformulation of the program**

- **APPEC Meeting on Neutrino Infrastructures Paris June 2014**



- **August 2014: creation of an Interim International Executive Board (IIEB) for LBNF chaired by the Fermilab Director N. Lockyer, active IP2I contribution**

→ **ELBNF Letter of Intent (LOI)**

- **January 2015: Presentation of the LOI to the FNAL PAC (LBNF (facility) + ELBNF (experiment): 40 kton at Homestake (1300 km from FNAL), 1.2 MW beam upgradable to 2.4 MW, excavation works to be started in 2017**

- **March 2015: Formation of the collaboration and choice of the final name for ELBNF: DUNE**

LBNF Groundbreaking 21/7/2017

→ Start of civil engineering works for LBNF

Première pierre pour l'expérience neutrinos internationale DUNE aux États-Unis

Le 21 juillet 2017 marque le début des travaux pour la construction d'un détecteur de neutrinos géant. L'expérience DUNE (*Deep Underground Neutrino Experiment*) est un projet international auprès de l'infrastructure LBNF (*Long Baseline Neutrino Facility*) dont le démarrage est prévu d'ici à 2026 au Fermilab, près de Chicago. En France, les chercheur.e.s de six laboratoires IN2P3 et CEA sont impliqués sur les prototypes de détecteurs (ProtoDUNE) qui serviront de modèle pour la construction de ces détecteurs de neutrinos de prochaine génération.

Le neutrino est une particule élémentaire particulièrement difficile à détecter. Il interagit peu avec la matière et traverse la Terre par milliards à chaque seconde, la plupart du temps sans laisser de trace. Son rôle pourrait être crucial pour comprendre l'origine de l'asymétrie matière-antimatière dans l'univers. La mise en évidence d'une violation de cette symétrie nécessite des expériences sur faisceau de nouvelle génération comme l'experience DUNE (*Deep Underground Neutrino Experiment*), qui doit être installé sur le faisceau de neutrinos LBNF. À son démarrage, vers 2026, ce faisceau de neutrinos sera le plus intense au monde.

DUNE sera composé de deux détecteurs qui observeront les neutrinos produits sur le parcours du faisceau. L'un proche de la source sera situé au Fermilab et l'autre installé 1300 km plus loin au laboratoire souterrain de Sanford, dans le Dakota du Sud. Ce détecteur lointain sera rempli par 70 000 tonnes d'argon liquide refroidi à -185°C.

http://www.in2p3.fr/recherche/actualites/2017/nouvelle_experience_dune.html

http://news.fnal.gov/2017/07/construction-begins-international-mega-science-experiment-understand-neutrinos/

Le prototype double-phase ProtoDune, en construction au CERN. © CERN

Far Detector Consortia

Single-Phase

- APA: Christos Touramanis (Liverpool)
- Photon Detection System: Ettore Segreto (Campinas)
- TPC Electronics: Dave Christian (FNAL)

Dual-Phase

- CRP: Dominique Duchesneau (LAPP)
- Photon Detection System: Ines Gil Botella (CIEMAT)
- TPC Electronics: Dario Autiero (IPNL)

Joint SP/DP

- HV System: Francesco Pietropaolo (CERN)
- DAQ: Giovanna Lehmann Miotto (CERN)
- Slow Controls/Instrumentation: Sowjanya Gollapinni (Tennessee)
- Computing: Heidi Schellman (Oregon State)
- Calibration: Jose Maneira (LIP)

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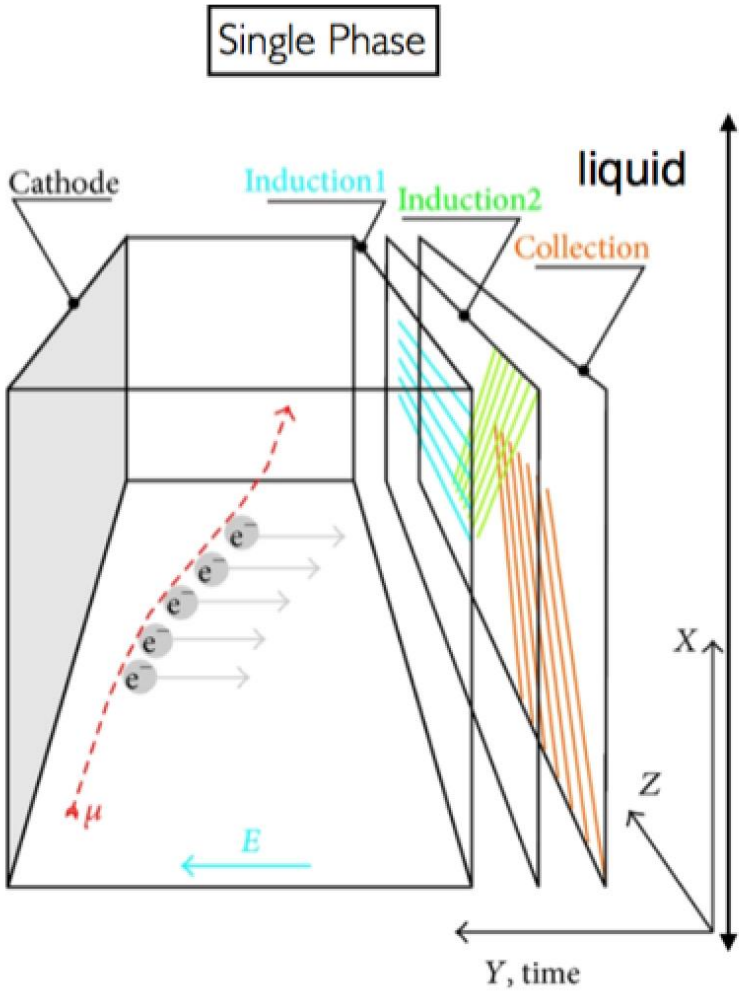
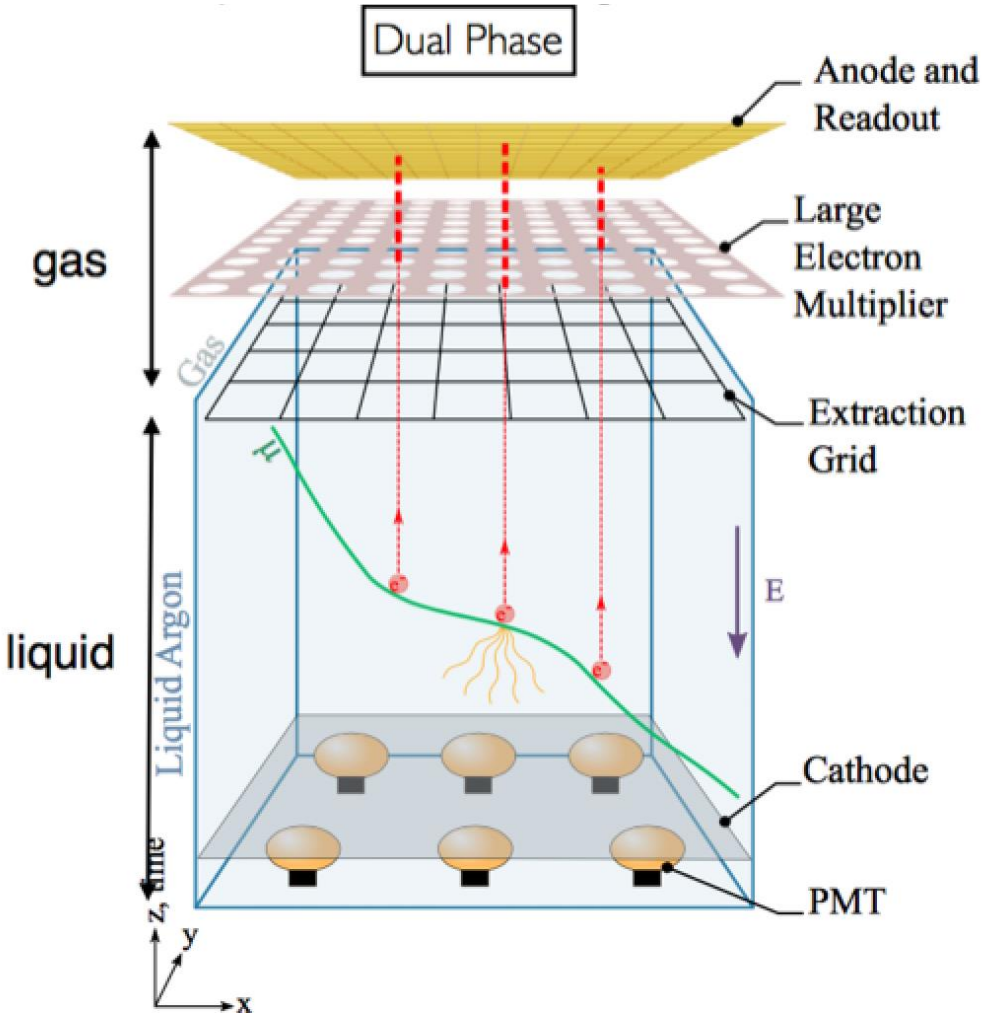
Far Detector:

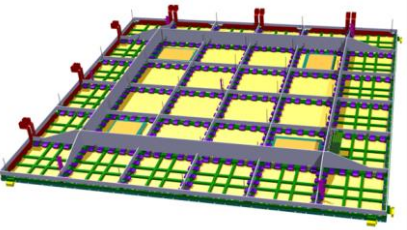
- Intermediate Design Report (Summer 2018)
- Technical Design Report (Detectors + Physics) being completed now

Liquid Argon Time Projection Chamber readout

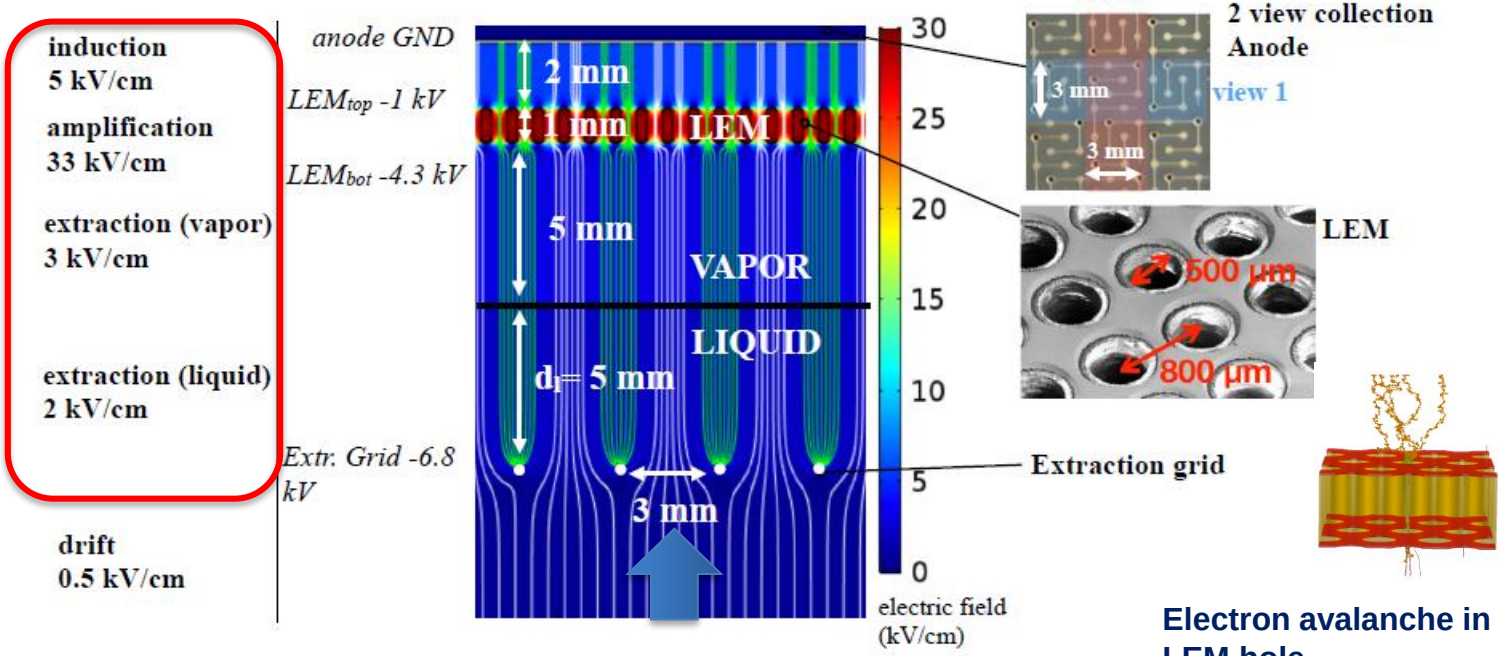




Dual-phase readout



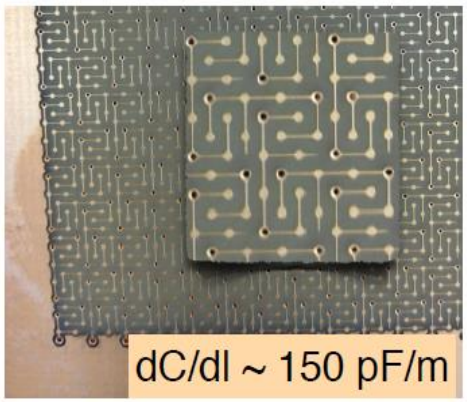
Charge Readout Plane integrating LEM-anode sandwiches

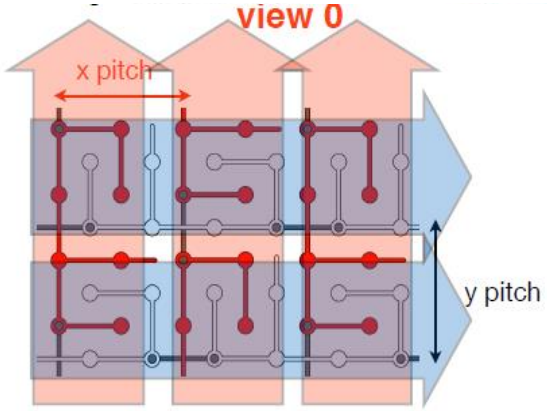


Electron avalanche in LEM hole

50x50 cm^2 LEM

50x50 cm^2 anodes with 2 collection views





view 1

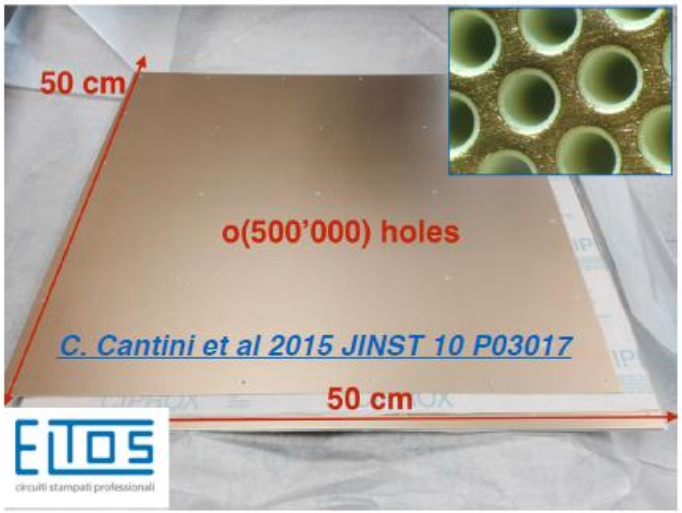
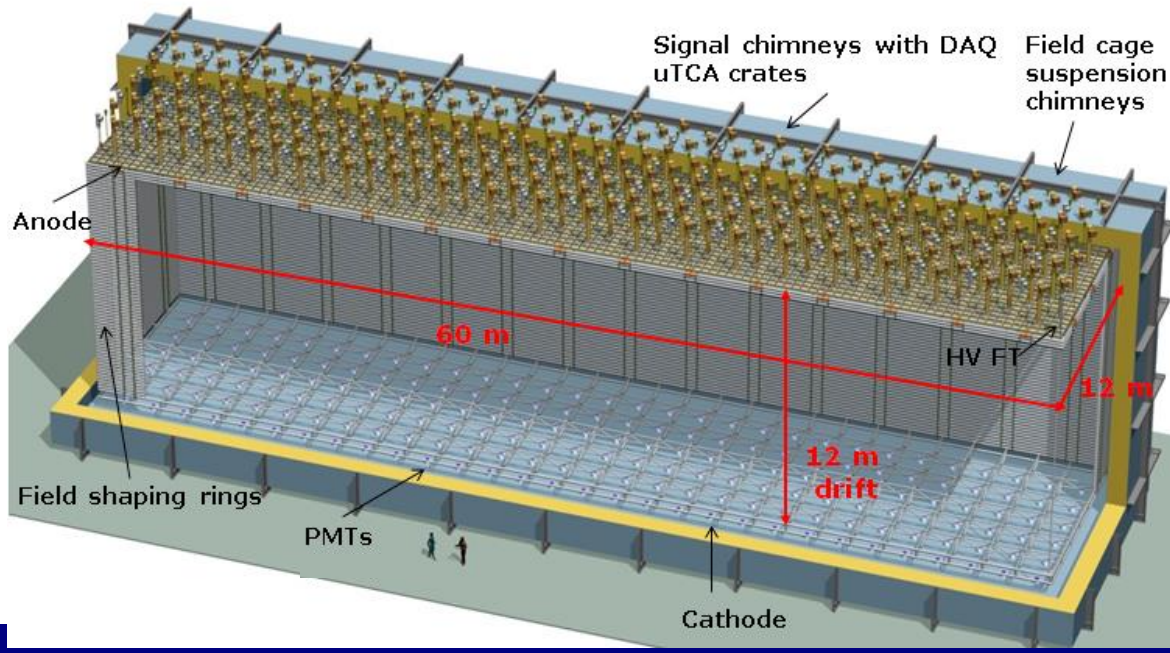


Table 1.2: Quantities of items or parameters for the 12.096 kt DP module

Item	Number or Parameter
Anode plane size	W = 12 m, L = 60 m
CRP unit size	W = 3 m, L = 3 m
CRP units	4 × 20 = 80
LEM-anode sandwiches per CRP unit	36
LEM-anode sandwiches (total)	2880
SFT chimney per CRP unit	3
SFT chimney (total)	240
Charge readout channels / SFT chimney	640
Charge readout channels (total)	153,600
Suspension feedthrough per CRP unit	3
Suspension feedthroughs (total)	240
Slow Control feedthrough per sub-anode	1
Slow Control feedthroughs (total)	80
HV feedthrough	1
HV for vertical drift	600 kV
Voltage degrader resistive chains	4
Cathode modules	80
Field cage rings	197
Field cage modules	288
PMTs (total)	720 ($1/m^2$)

Dual-Phase DUNE FD: 20 times replication of Dual-Phase ProtoDUNE (drift 6m → 12m) DUNE Conceptual Design Report, July 2015

Active LAr mass:12.096 kton, fid mass:10.643 kton, N. of channels: 153600



Advantages of dual-phase design:

- Gain in the gas phase → robust and tunable S/N, lower detection threshold, compensation for charge attenuation due to long drift paths
- Finer readout pitch (3.125 mm), implemented in two identical collection views (X,Y) on 3m long strips
- Long drift projective geometry: reduced number of readout channels (153,600 for DP less than half of equivalent SP FD), absence of dead materials in the drift volume
- Fewer construction modules
- Full accessibility and replaceability of cryogenic front-end (FE) electronics during detector operation

ProtoDUNE-DP accessible cold front-end electronics and uTCA DAQ system 7680 ch (IPNL)

Full accessibility provided by the double-phase charge readout at the top of the detector

➢ **Digital electronics at warm on the tank deck:**

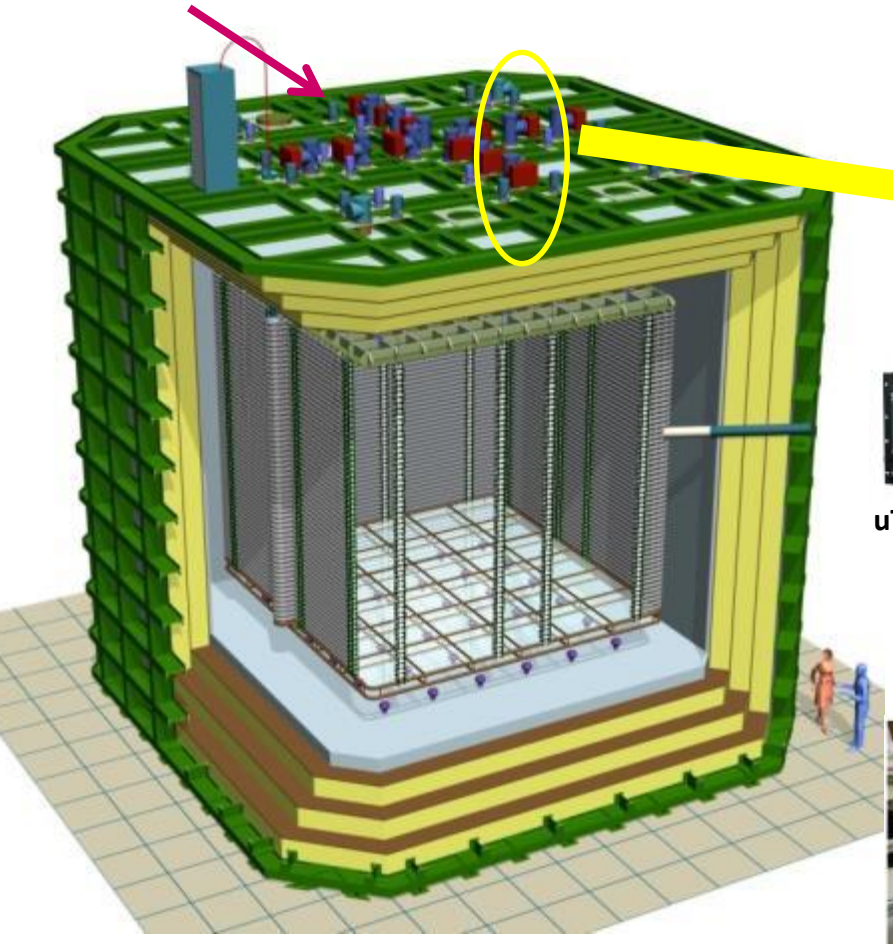
- Architecture based on uTCA standard
- 1 crate/signal chimney, 640 channels/crate

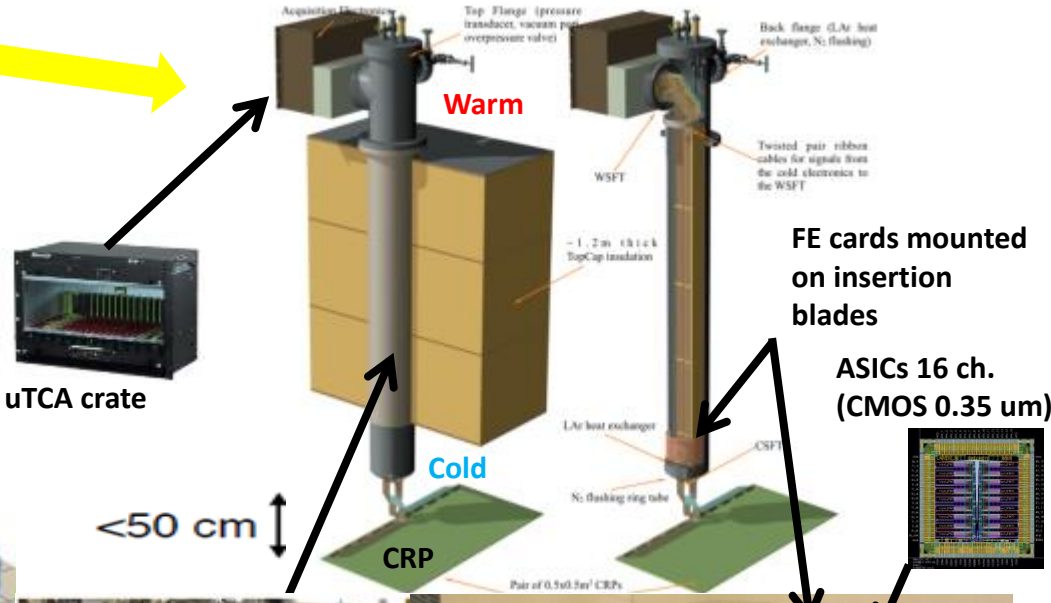
→ 12 uTCA crates, 10 AMC cards/crate, 64 ch/card

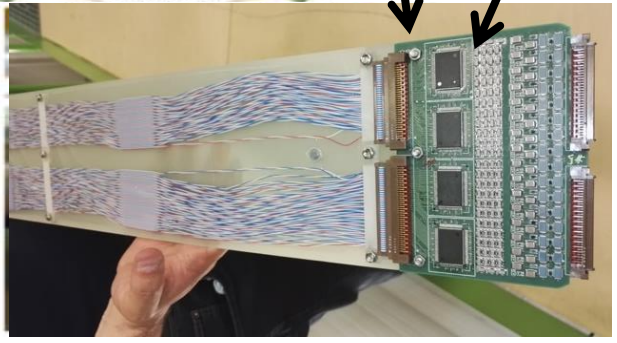
➢ **Cryogenic ASIC amplifiers (CMOS 0.35um) 16ch externally accessible:**

- Working at 110K at the bottom of the signal chimneys
- Cards fixed to a plug accessible from outside

→Short cables capacitance, low noise at low T





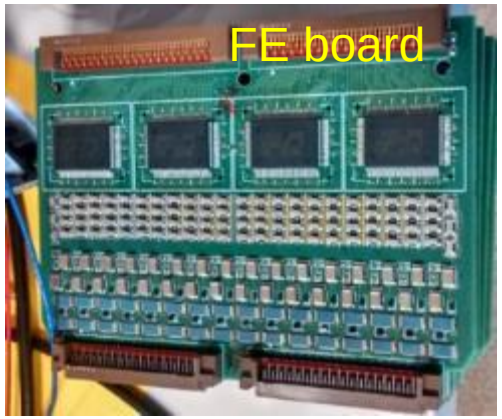


Signal chimney

Charge readout electronics components chain already massively implemented in ProtoDUNE-DP (1/20 of DUNE 10 kton). Final system also for DUNE 10 kton.

(R&D since 2006, long standing effort long standing effort aimed at producing low cost analog and digital electronics, tailored to DP configuration)

Main components ASIC amplifiers, ADCs, FPGAs, IDT memories already procured in 2015-2016. 3x1x1 pre-production batch in 2016.



Analog cryogenic FE:

- **Cryogenic ASIC amplifiers DP-V3, 0.35um CMOS → production performed at the beginning of 2016**
- **64 channels FE cards with 4 cryogenic ASIC amplifiers**
- **First batch of 20 cards (1280 channels) operational on the 3x1x1 (fall 2016-spring 2018)**
- **Production or remaining FE cards for 6x6x6 launched in 2017: batch of 120 cards for 4 CRPs, extensive testing in 2018**

AMC digitization cards:

uTCA 64 channels AMC digitization cards (2.5 MHz, 12 bits output, 10 GbE connectivity)

- **First batch of 20 cards operational on the 3x1x1 (fall 2016-spring 2018)**
- **Production or remaining AMC cards for 6x6x6 launched in 2017: batch of 120 cards for 4 CRPs, extensive testing in 2018**

White Rabbit timing/trigger distribution system:

- **Components produced in 2016 for the entire 6x6x6, Full system architecture operational on the 3x1x1 (fall 2016-spring 2018) including uTCA White Rabbit MCH**

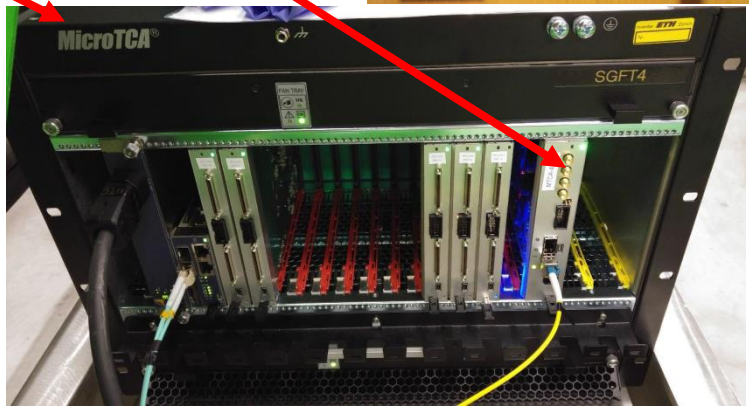
Readout system for a 10 kton dual-phase module (IP2I R&D)

Total number of charge readout channels: 153600
(+light readout channels 720)

- Cryogenic ASICs (16 ch): 9600
- Cryogenic FE cards (64 ch): 2400

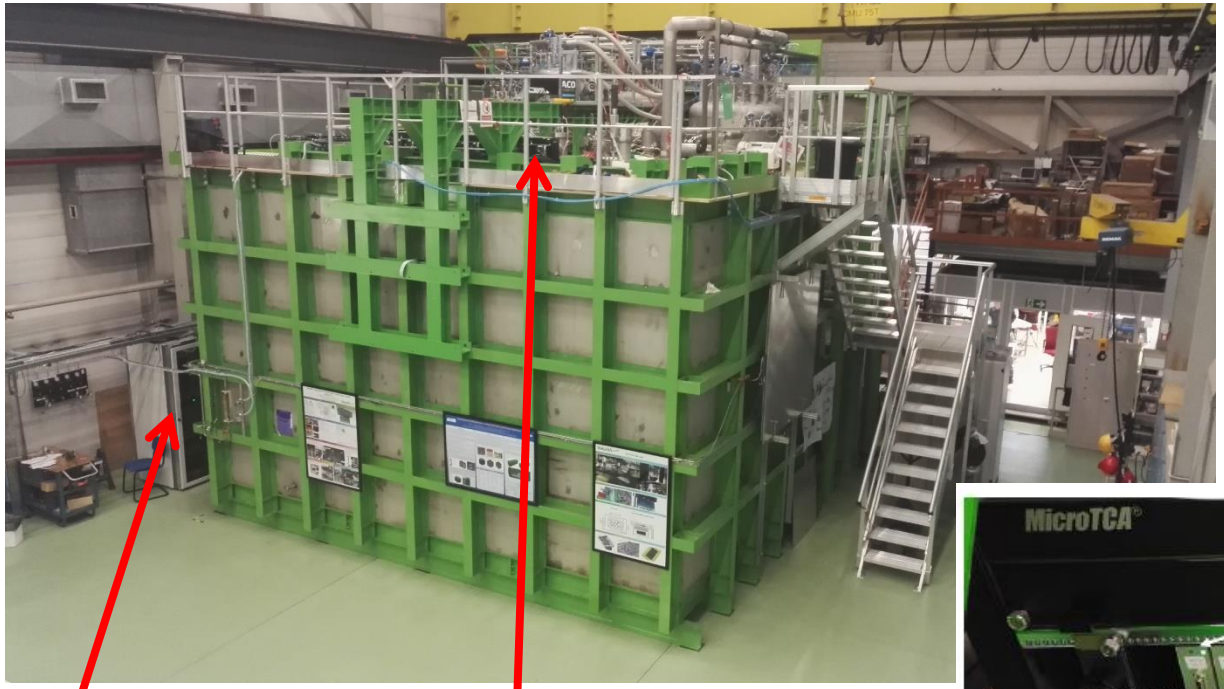
- AMC cards (64 ch): 2400 + 45 for LRO
- uTCA White Rabbit MCH: 240 + 5 for LRO
- uTCA crates (including MCH,PU,FU): 240 + 5 for LRO
- 10 Gbe optical links to backend: 240 + 5 for LRO
- VHDCI cables (32 ch) 4800

White Rabbit switches (18 ports): 16



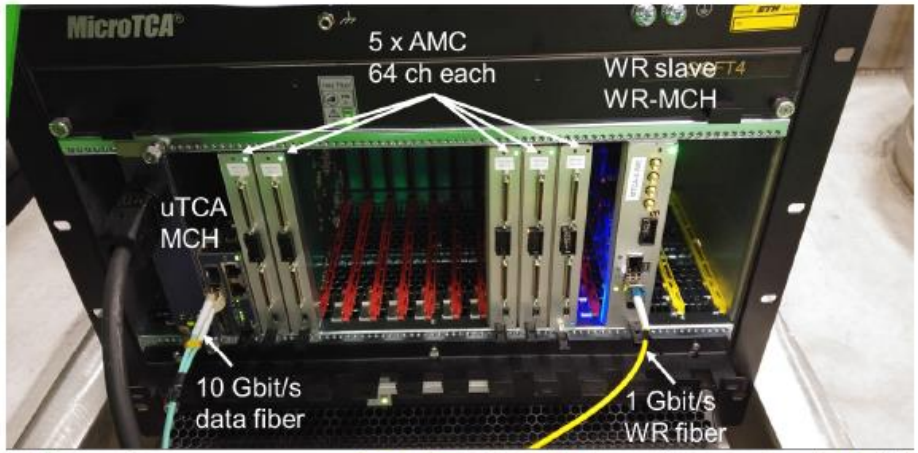
ProtoDUNE dual-phase: 12 chimneys/uTCA crates (120 AMCs, 7680 readout channels)

→ 3x1x1: 4 chimneys/uTCA crates (20 AMCs, 1280 readout channels)



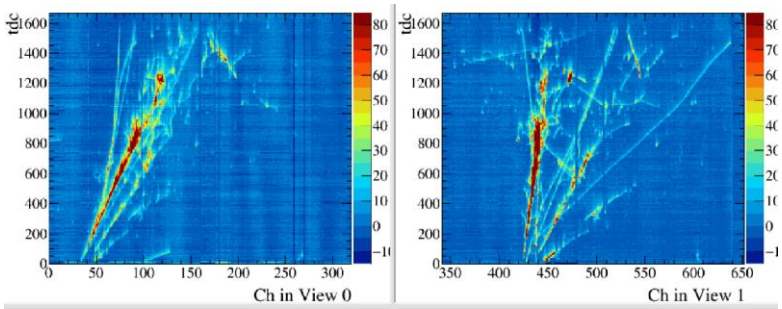
Signal Chimneys and uTCA crates

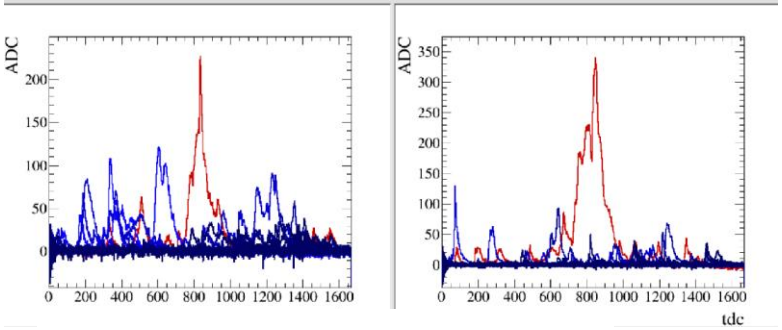
Electronics/DAQ system operational in the period November 2016-March 2018

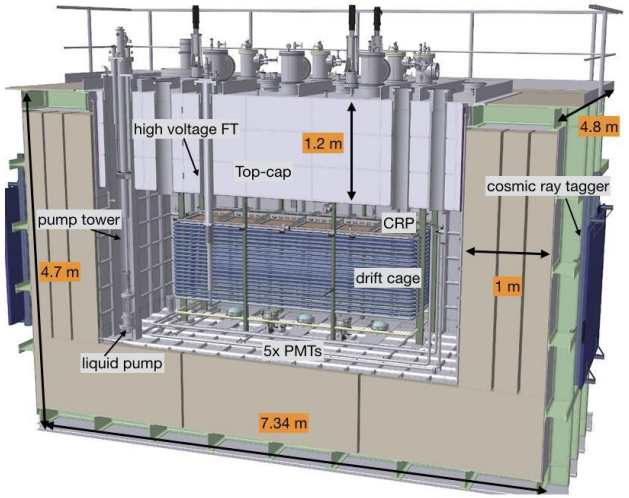


Event builder, network, GPS/White Rabbit GM, WR Trigger PC

3x1x1 detector operation June-November 2017







- **Successful in proving the dual-phase concept for a LArTPC at the 3m² readout scale.**
- **1st cryostat prototype built with LNG tank techniques (GTT)**
- **Pre-productions, estimation of costs**
- **Integration procedures, QA, installation, commissioning**
- **Good performance of FE electronics and readout system**
- **Feedback and improvements on LEMs and CRP design**

A 4 tonne demonstrator for large-scale dual-phase liquid argon time projection chambers

B. Aimard[q], Ch. Alt[g], J. Asaadi[v], M. Auger[b], V. Aushev[p], D. Autiero[s], M.M. Badoi[j], A. Balaceanu[j], G. Balik[q], L. Balleyguier[s], E. Bechetoille[s], D. Belver[d], A.M. Blebea-Apostu[j], S. Bolognesi[k], S. Bordoni[i,1], N. Bourgeois[s], B. Bourguille[f], J. Bremer[a], G. Brown[v], L. Brunetti[h], D. Caiulo[s], M. Calin[c], E. Calvo[d], M. Campanelli[f], K. Cankocak[m], C. Cantini[g], B. Carlus[s], B.M. Cautisanu[j], M. Chalifour[s], A. Chappuis[q], N. Charitonidis[a], A. Chatterjee[v], A. Chiriacescu[c], P. Chiu[g], S. Conforti[s], P. Cotte[k], P. Crivelli[g], C. Cuesta[d], J. Dawson[a], I. De Bonis[q], C. De La Taille[k], A. Delbart[k], D. Desforge[k], S. Di Luise[f], B.S. Dimitru[j], F. Doizon[a], C. Drancourt[q], D. Duchesneau[q], F. Dulucq[k], J. Dumarchez[r], F. Duval[p], S. Emery[k], A. Ereditato[b], T. Esanu[c], A. Falcone[v], K. Fusshoeller[g], A. Gallego-Ros[d], V. Galymov[s], N. Geffroy[q], A. Gendotti[g], M. Gherghel-Lascu[j], C. Gigant[r], I. Gil-Botella[d], C. Girerd[s], M.C. Gomoiu[j], P. Gorodetzky[s], E. Hamada[a], R. Hanni[b], T. Hasegawa[n], A. Holin[f], S. Horikawa[g], M. Ikeno[n], S. Jiménez[d], A. Jipa[c], M. Karolak[k], Y. Karyotakis[q], S. Kasai[o], K. Kasami[n], T. Kishishita[n], I. Kreslo[b], D. Kryn[a], C. Lastoria[d], I. Lazanu[c], G. Lehmann-Miotto[a], N. Lira[v], K. Loo[m], D. Lorca[b], P. Lutz[k], T. Lux[l], J. Maalampi[m], G. Maire[s], M. Maki[n], L. Manenti[f], R.M. Margineanu[j], J. Marteau[s], G. Martin-Chassard[t], H. Mathez[s], E. Mazzucato[k], G. Misitano[m], B. Mitrica[j], D. Mladenov[a], L. Molina Bueno[g], C. Moreno Martínez[l], J.P. Mols[k], T.S. Mosu[j], W. Mu[g], A. Munteanu[j], S. Murphy[g], K. Nakayoshi[n], S. Narita[l], D. Navas-Nicolás[d], K. Negishi[l], M. Nessi[a], M. Niculescu-Oglinzanu[j], L. Nita[c], F. Noto[o], A. Noury[a], Y. Onishchuk[p], C. Palomares[d], M. Parvu[c], T. Patzak[s], Y. Pénichot[k], E. Pennacchio[s], L. Periale[g], H. Pessard[q], F. Pietropaolo[e], Y. Piret[k], B. Popov[r], D. Pugnere[s], B. Radics[g], D. Redondo[d], C. Regenfus[g], A. Remoto[q], F. Resnati[g], Y.A. Rigaut[g], C. Ristea[c], A. Rubbia[g], A. Saftoiu[j], K. Sakashita[n], F. Sanchez[l], C. Santos[s], A. Scarpelli[a], C. Schloesser[g], L. Scotto Lavina[r], K. Sendai[n], F. Sergiampietri[e], S. Shahsavarani[v], M. Shoji[n], J. Sinclair[b], J. Soto-Oton[d], D.L. Stancu[j], D. Stefan[a], P. Stroescu[j], R. Sulej[u], M. Tanaka[n], V. Toboaru[j], A. Tonazzo[s], W. Tromeur[s], W.H. Trzaska[m], T. Uchida[n], F. Vannucci[s], G. Vasseur[k], A. Verdugo[d], T. Viant[g], S. Vihonen[m], S. Vilalte[q], M. Weber[b], S. Wu[g], J. Yu[v], L. Zambelli[q], M. Zito[k]

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[b] University of Bern, Albert Einstein Center for Fundamental Physics, Laboratory for High Energy Physics (LHEP), Bern, Switzerland
[c] University of Bucharest, Faculty of Physics, Bucharest, Romania
[d] Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
[e] CERN, Geneva, Switzerland
[f] University College London, Dept. of Physics and Astronomy, London, United Kingdom
[g] ETH Zurich, Institute for Particle Physics, Zurich, Switzerland
[h] Fermilab, Batavia, IL, USA
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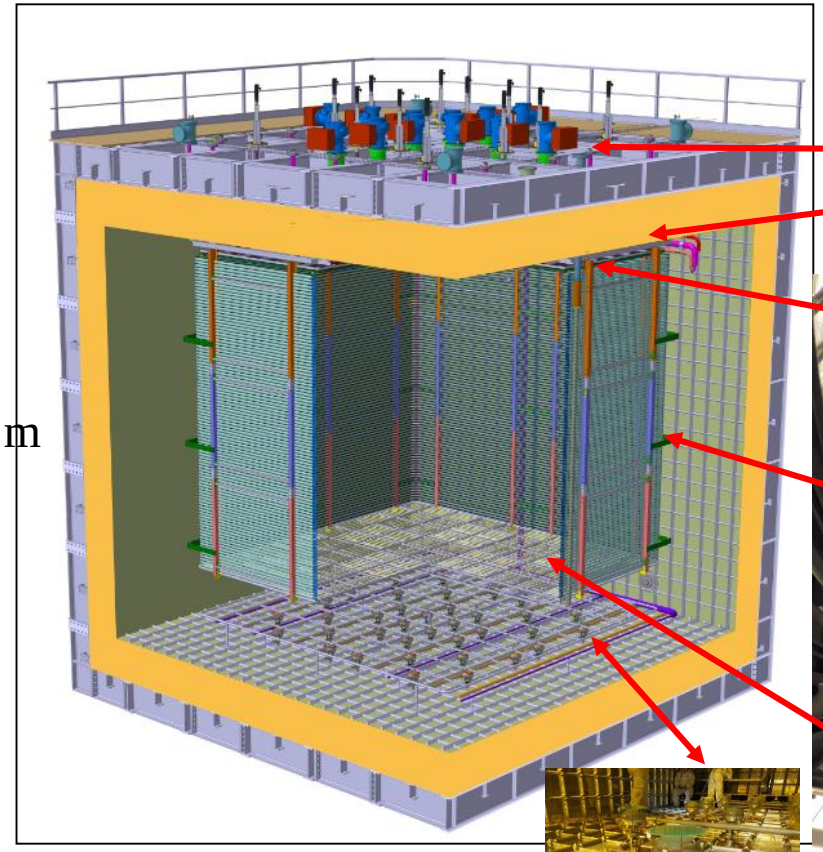
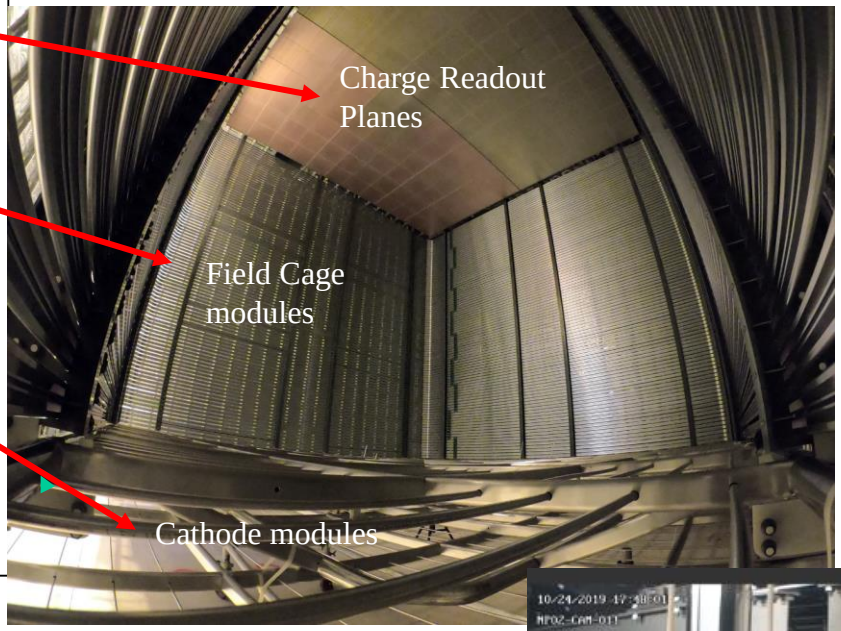
[j] Horia Hulubei National Institute of R&D for Physics and Nuclear Engineering - IFIN-HH, Magurele, Romania
[k] IRFU, CEA Saclay, Gif-sur-Yvette, France

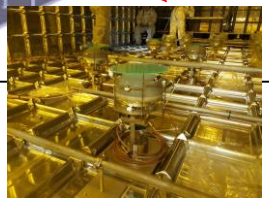
- **62 pages paper** on 3x1x1 published on JINST: https://arxiv.org/abs/1806.03317

10 kton dual-phase design based on protoDUNE dual-phase, full scale demonstrator:
6x6x6 active volume → 1/20 of 10 kton readout system

Operating at CERN since August 2019

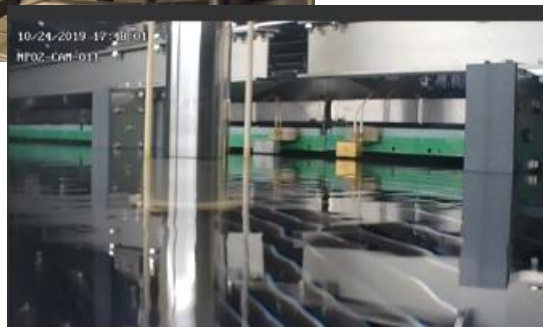






36 cryogenic photomultipliers with wavelength shifting coating

Inside view of the detector filled with LAr

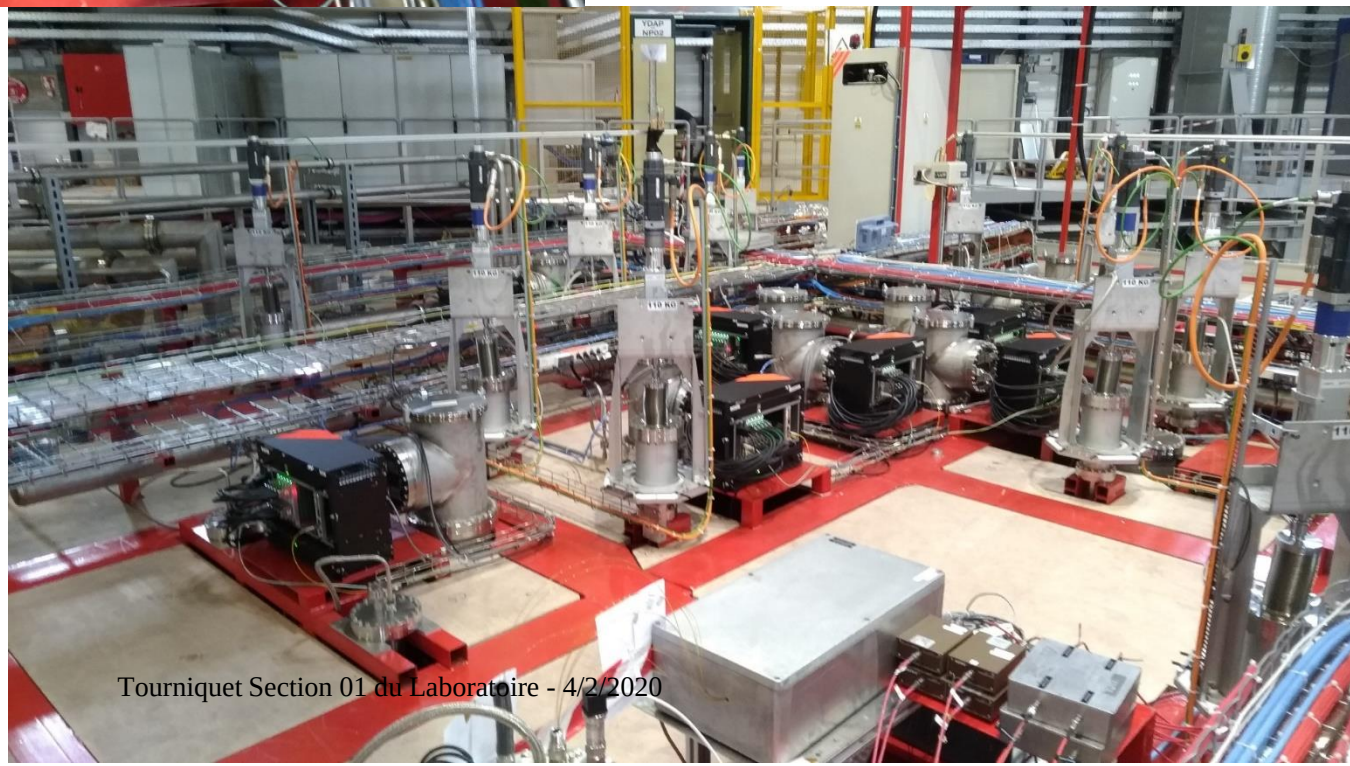


Subsystems designed/provided by IP2I:

- **Cryogenic front-end electronics, low Voltage distribution system**
- **uTCA and data network infrastructure**
- **Front-end digitization AMC cards**
- **Timing/synchronization and trigger system**
- **Online back-end DAQ system + online storage and online processing**
- **DAQ and computing software**

ProtoDUNE dual-phase:

- **12 chimneys/uTCA crates**
- **120 Cryogenic front-end cards**
- **120 AMC cards**
- **12 White Rabbit slave nodes**
- **7680 readout channels**



symmetry
dimensions of particle physics

topics

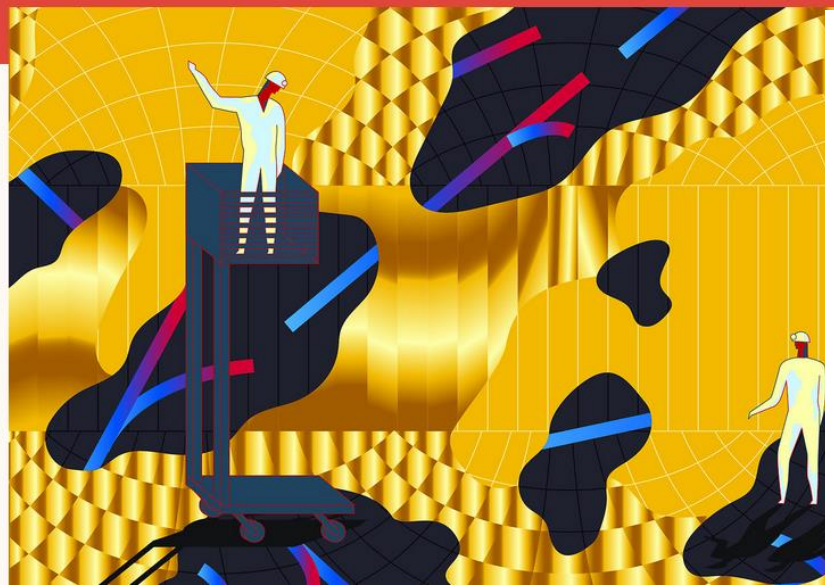
follow +

A joint Fermilab/SLAC publication

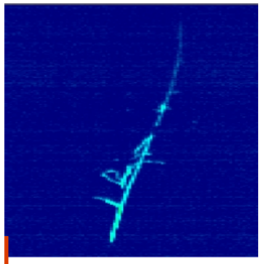
DUNE scientists see particle tracks with dual-phase technology

10/14/19 | By Kurt Riesselmann

Scientists working at CERN have started tests of a new neutrino detector prototype that uses a promising technology called "dual phase."



https://www.ip2i.in2p3.fr/spip.php?article2302&lang=fr



Trace de rayon cosmique observée dans protoDUNE double phase en août 2019. Image : ProtoDUNE

Actualités Agenda International Vie de l'ins

L'IN2P3 Recherche Innovation Formation Médiation scientifique

Accueil › Actualités

Une nouvelle technologie innovante pour détecter les neutrinos testée à grande échelle au CERN

10 octobre 2019

RÉSULTATS SCIENTIFIQUES PHYSIQUE DES NEUTRINOS PHYSIQUE DES PARTICULES

Les scientifiques de la collaboration ProtoDUNE au CERN ont commencé à tester un tout nouveau prototype de détecteur de neutrinos, en utilisant une technologie très prometteuse, appelée "double phase". Si les premiers résultats obtenus se confirment, cette nouvelle technologie sera utilisée à une plus grande échelle pour l'expérience internationale DUNE aux États-Unis. Les scientifiques français des laboratoires IN2P3 et du CEA jouent un rôle de premier plan dans le développement et la mise en route de ce détecteur innovant.

L'expérience internationale DUNE, dont le démarrage est prévu d'ici à 2026 au Fermilab, près de Chicago, aura pour mission d'éclaircir les mystères des neutrinos, les particules de matière les plus abondantes de l'Univers. Mais ces neutrinos sont des particules extrêmement difficiles à détecter, traversant la matière par milliards chaque seconde sans laisser de trace. Les détecteurs de l'expérience DUNE seront donc des détecteurs à la fois géants et extrêmement précis.

A - / A+

Contact(s)

Dario Autiero
Laurent Vacavant
Perrine Royole-Degieux

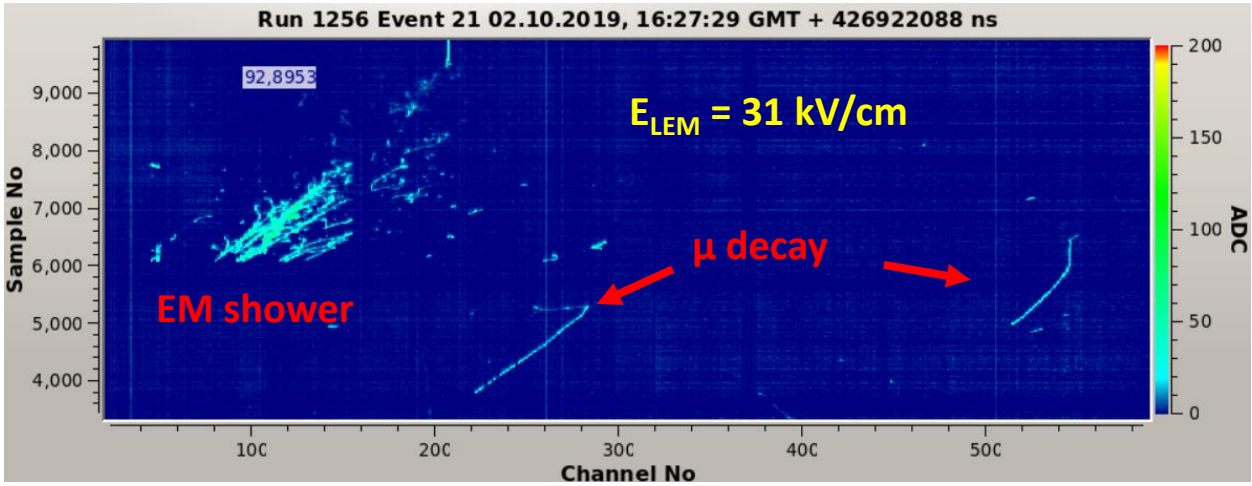
Partager ce contenu

Imprimer

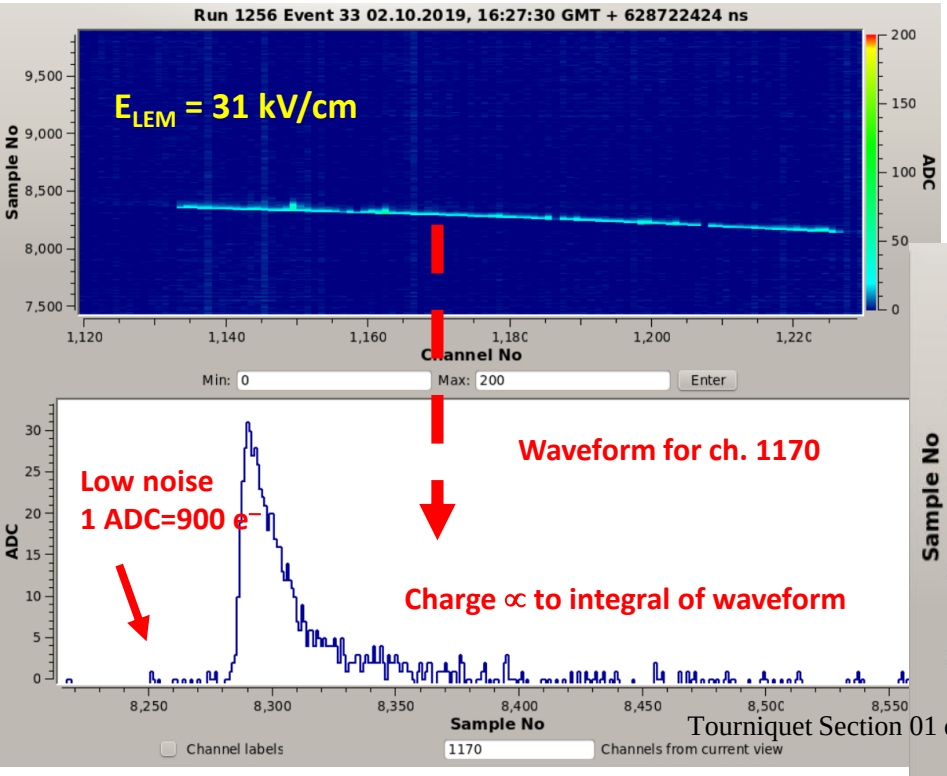
https://in2p3.cnrs.fr/fr/cnrsinfo/une-nouvelle-technologie-innovante-pour-detecter-les-neutrinos-testee-grande-echelle-au

Cosmic ray events
in protoDUNE dual-phase

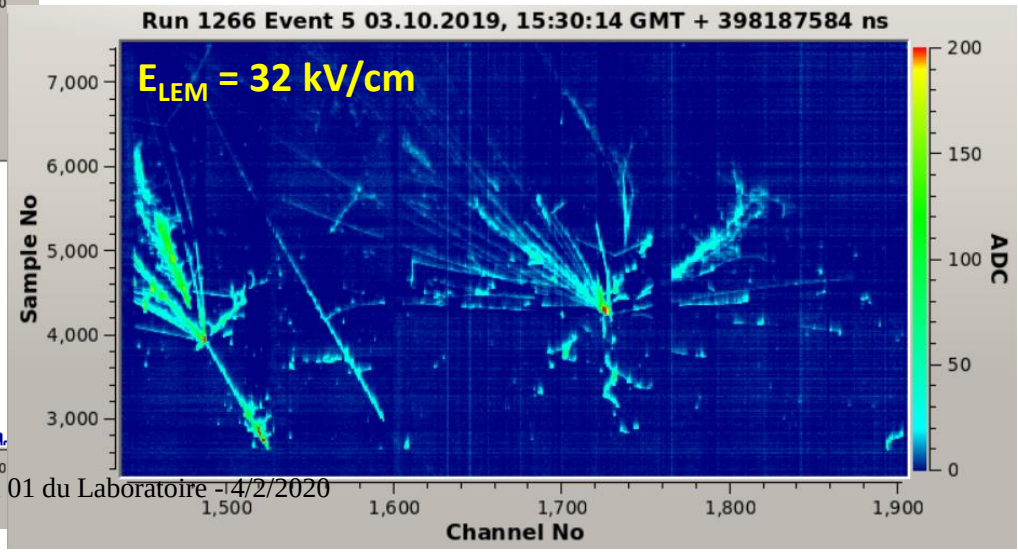
Electromagnetic shower + two muon decays



Horizontal muon track

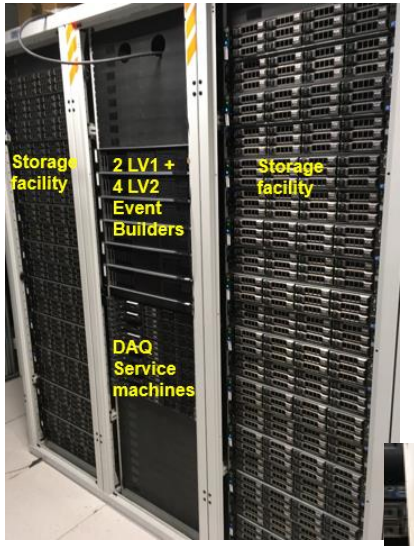


Multiple hadronic interactions in a shower

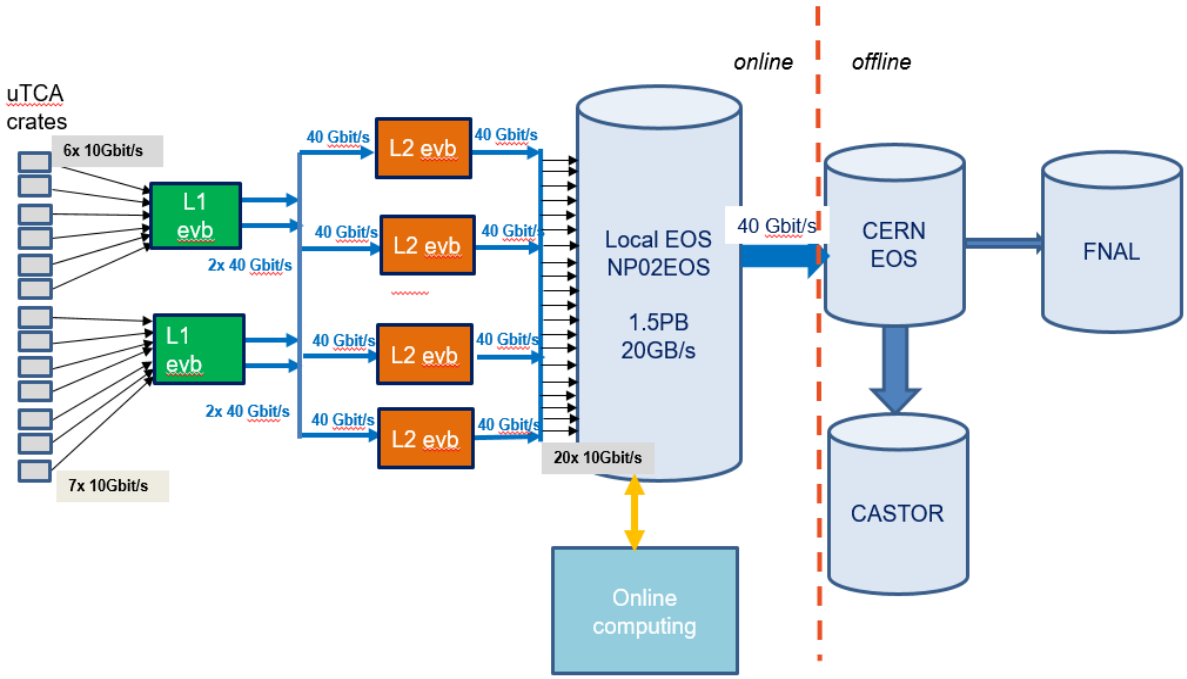


The big-data/DAQ challenge

ProtoDUNE dual-phase DAQ/online storage facility /online processing system (IP2I)



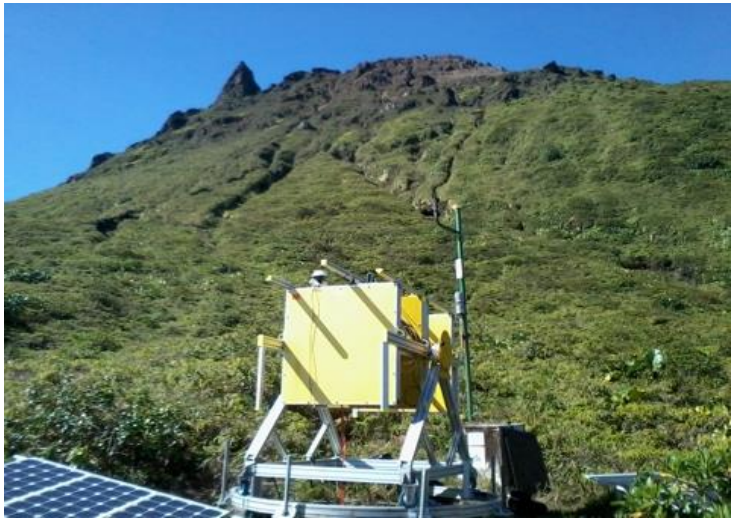
NP02 DAQ/network infrastructure



- ✓ **Excellent performance of front-end analog cryogenic electronics, digital uTCA front-end electronics and DAQ back-end system**
- ✓ **DAQ running at a few 10 Hz trigger rate, 2 M events (4ms drift) acquired corresponding to 200 TB, data transfered to CERN and FNAL**
- ✓ **Online fast reconstruction (15s/event) performed on real time on the online computing farm (450 cores)**

Volcano Tomography (J. Marteau)

The Diaphane project, initiated as a spin-off of the HEP experiments conducted at IP2I (OPERA, ALICE V0) to image active volcanoes with an innovative technique, has known successful extensions in the private sector, with non-invasive controls of blast furnaces (ArcelorMittal), nuclear evaporators (ORANO), tunnels boring machines (Alliance, Eiffage). The potential of the techniques and methods has triggered the interest of the Lyon SATT (PULSALYS) to launch a "maturation" program and the creation of a startup.



DIAPHANE PROJECT IN GUADELOUPE

COMET (P. Lebrun)

The E21 (COMET for Coherent Muon to Electron Transition) is an experiment at J-PARC, Tokai, Japan, which will search for neutrinoless conversion of muons into electrons in the field of a nucleus ($\mu- + N \rightarrow e- + N$); a lepton flavour violating process with a factor of 100 up to 10,000 improvement over existing limits. In COMET, the event signature is a single mono-energetic electron of 105 MeV with aluminum nucleus which has been chosen by this experiment. The observation or non-observation of a conversion of a muon into an electron in the field of a nucleus will bring essential information on physics beyond the Standard Model. An observation would give a strong signal to the community and help to refine the strategy for building new accelerators. COMET has the advantage to competitors to have a pulsed beam and by this way the sensitivity will be limited almost only by the power of the proton beam.
COMET collaboration accounts today of about 200 collaborators from 41 institutes distributed across 17 countries and plan to run a first phase in 2022. COMET is a new master project for IN2P3 based on an opportunity to participate mainly on the computing and simulation side with the CC-IN2P3. After an initial participation of LPNHE and CCIN2P3, LPC-CAEN, LPC-CLERMONT and IP2I joined this project in fall 2018 with the follow up in our side of one researcher and one computing engineer.

Organisation-fonctionnement du groupe

- The neutrino group at I2PI actually includes 5 physicists, 2 students and 6 research engineers. It is dedicated to DUNE, for which it ensures the IN2P3 leadership, and it represents the largest group in terms of FTE among the DUNE French groups. The group has been successfully completing all its objectives and reinforcing its international visibility during the last years despite it has been operating at practically constant number of permanent members. The group has been benefiting from the support of the European programs LAGUNA/LAGUNA LBNO and AIDA2020/AIDANova of the LABEX LIO and from the IN2P3 Master Project for WA105-DUNE. The group has been successfully taking the responsibility and providing to protoDUNE dual-phase all the charge readout electronics system and the timing and DAQ system which overall represent a contribution exceeding 0.5 Meur.

- The team has primary competences on neutrino physics, LAr TPC detectors and the associated electronics/DAQ, computing and physics analysis and provides leading roles and main support to protoDUNE-DP/DUNE France. The group has a fully dedicated core team for DUNE. Permanent physicists who have strong individual responsibilities in DUNE (Dario, Elisabetta, Slavic) have all also a complete vision of all the technical and physics aspects of the project

- All the R&D developments and their successful application to the construction of the 3x1x1 and protoDUNE-DP detectors where possible with a strong support and close work in collaboration/integration through several years with the IPNL/IP2I technical services and in particular the Electronics and Informatics services.

- Good connections/collaboration with theory group at IP2I for nuclear effects in neutrino interactions and n-nbar oscillations

Responsabilités : recherche, enseignement, autres

- Recherche :

- D.Autiero *member of the DUNE Executive Committee*, Consortium leader for DP-electronics , ProtoDUNE-DP co-coordinator, editor of the TDR DP Volume
- S. Galymov editor of TDR for DP-Electronics consortium, physics analysis co-coordinator for protoDUNE-DP, IN2P3 DUNE analysis Task Force
- E. Pennacchio ProtoDUNE-DP Computing Liaison, software/computing coordinator, IN2P3 DUNE software/computing Task Force

- Implications au niveau national:

  Coordination of the DUNE IN2P3 Master Project, DUNE TGIR preparation
  Chair of the Scientific Council of GDR neutrino

- Université:

  LIO LABEX project for the equipment of a laboratory student on experimental particle physics

- Implications dans la vie du laboratoire:
  - CS Labex LIO
  - Directeur adjoint

- Demandes et gestion de supports financiers spécifiques:
  - IN2P3 DUNE Master Project, LIO LABEX, AIDA2020/AIDANova, TGIR DUNE

Projet scientifique, anticipation

- Capitalize on the long-term investment in R&D, technical and scientific competences for the future of DUNE
- Contributions to computing/software/analysis in DUNE. Two thesis projects ongoing.
- Continuation of leadership in DUNE DP-Electronics consortium
- Continuation and running of protoDUNE-DP Phase II (after LS2), Implementation of the TGIR project, DUNE construction and commissioning

Auto analyse du groupe

Strengths:

- **Long standing group expertise (since the beginning of the 90's) of the group in neutrino oscillations**
- **Strong internal competences on all aspects of the experimental activities.**
- **Unique laboratory in France with LAr installation.**
- **Training capabilities for new people.**
- **Successful and coherent R&D program since 2006, with several funding supports and developments of competences on electronics /DAQ /computing.**
- **Large investments, strong international responsibilities and visibility.**

Weaknesses

- **Small number of recruitments in the last 20 years, significant workload on group members.**
- **DUNE as multi decade single experiment in a large collaboration may be a psychological barrier to newcomers despite its physics and technical richness.**
- **The previous aspect is enhanced by the fact that IN2P3 requires focusing on single activities.**
- **LAr TPC technology is sophisticated and imposes a relevant learning curve and training to newcomers and requires dedication.**

Opportunities

- **Very interesting research line and physics objectives.**
- **Long-term project with strong international support.**
- **I2PI possibility to have a large impact and visibility on the basis what invested and built up so far**
- **Further increase and consolidation in competences.**
- **Formation of young people.**
- **Impact on physics analysis, synergies with theory.**
- **Support different programs EU, LabEx.**
- **IN2P3 and IR/TGIR support.**

***Threaths*:**

- **Cancellation of big projects in the US. LBNF overcosts and consequent delays.**
- **Missed approval of the IR/TGIR project or reduced funding.**
- **Technological challenges.**

Annexes

Visibilité et rayonnement

Talks:

D.Autiero, 'WA105: Double Phase LAr prototype', ICFA Neutrino European Meeting, Paris, (08-10 January 2014)
D.Autiero, ''Neutrino Interaction Systematics for Oscillation Experiments ', Summary talk of the NuINT14 conference session, NuINT14, 19-24 May 2014, Selsdon Park Hotel, Surrey, UK
D.Autiero, 'WA105', Strategy Workshop on AstroParticle in Switzerland, Geneva, (11-13 June 2014)
V. Galymov 'Status of LBNO project' GDR neutrino meeting, LAL Paris 16-17/6/2014
V. Galymov 'The LAGUNA/LBNO neutrino observatory in Europe' International Conference on High Energy Physics (ICHEP), Valencia, Spain 2-9/7/2014
D.Autiero, 'LBNO-DEMO at CERN and beyond', OPEN LAGUNA 2014 Event, Helsinki, 27 August 2014
V. Galymov 'The effects of systematic uncertainties in long baseline neutrino experiments' NuPhys, Prospects in Neutrino Physics, London, United Kingdom 15-17/9/2014
D.Autiero, 'LBNO, What has been learned for a Fermilab hosted experiment?', Interim International Executive Board meeting, Fermilab, 23 September 2014
V. Galymov 'The WA105 experiment' International Workshop on Next Generation Nucleon Decay and Neutrino Detectors (NNN), Paris, France 4-6/11/2014
D.Autiero, 'The last months path to (E)LBNF ',GDR Neutrino meeting, Marseille, 26 November 2014
D.Autiero, 'R&D on liquid argon TPCs ', Seminaire LABEX LIO, IPNL, 28 November 2014
D.Autiero, 'An Open meeting for the scientific community to form LBNF: Panel Discussion with seeded questions as well as extended Q&A with audience', Participation as one of the six LBNF Panel members, CERN December 5, 2014
D. Autiero 'Status and plans of the WA105 Project ', 117th meeting of the SPSC committee, CERN April 14, 2015
D.Autiero 'Alternative TPC Design ', DUNE FD Design Review, Fermilab May 20, 2015
D.Autiero, 'Far Detector Alternate Technologies ', LBNF/DUNE CD-1-Refresh Director's Review, Fermilab June 3, 2015
D.Autiero ' Status and plans of the WA105 Project ', LBNF/DUNE DOE CD-1 Refresh Review , Fermilab July 15, 2015
V. Galymov, 'LBNO-DEMO (WA105): a large demonstrator of the Liquid Argon double phase TPC'
European Physics Society Conference on High Energy Physics (EPS HEP), Vienna, Austria 22-29/7/2015
D.Autiero, 'Lectures on Experimental Neutrino Physics', Summer School and Workshop on the Standard Model and Beyond , Corfu 1-11 September, 2015
D.Autiero, 'The Nobel Prize in Physics 2015', Special seminar at IPNL/FRAMA , IPNL Lyon 20 November, 2015
D. Autiero 'Opportunities with ProtoDUNE Dual Phase', European DUNE/LBNF meeting, CERN 7-8 April, 2016
D. Autiero, Planning for ProtoDUNE dual-phase', Long Baseline Neutrino Committee meeting, FERMILAB, 29/4/2016
D. Autiero, 'Status of ProtoDUNE-DP', DUNE RRB Meeting (DUNE Funding Agencies meeting), Sanford Laboratory 18 May, 2016
D. Autiero, Planning for ProtoDUNE dual-phase', Long Baseline Neutrino Committee meeting, FERMILAB, 12−14/6/2016
D. Autiero, ProtoDUNE−DP/1x1x3 m3 update', Long Baseline Neutrino Committee meeting, FERMILAB, 23−25/10/2016
V. Galymov, 'ProtoDUNE DP: prototype of dual-phase LAr TPC' Symposium on Large TPCs for Low-energy Rare Event Detection, Paris, 5-7/12/2016
V.Galymov,' Status and plans of the WA105 Experiment', SPSC meeting CERN 19-20/4/2016
D. Autiero, 'The experimental challenge of next long−baseline neutrino oscillations measurements with the DUNE liquid argon detector', Invited seminar at INFN Pisa 20/12/2016
D. Autiero, ProtoDUNE−DP/1x1x3 m3 update', Long Baseline Neutrino Committee meeting, FERMILAB, 22−25/3/2017
D.Autiero, 'WP8/NA7 Large scale cryogenic liquid detectors', AIDA 2020 mid−term review CERN, 20/4/2017
D.Autiero, 'ProtoDUNE dual−phase overview 'Design Review of Dual−Phase Proto− DUNE , CERN 24−25 April, 2017
D.Autiero, 'Charge readout FE electronics design 'Design Review of Dual−Phase Proto− DUNE , CERN 24−25 April, 2017
D. Autiero, 'ProtoDUNE−DP/1x1x3 m3 update', Long Baseline Neutrino Committee meeting, CERN 21−24/6/2017
D. Autiero, 'ProtoDUNE−DP/1x1x3 m3 update', Long Baseline Neutrino Committee meeting, SURF Laboratory, 25−28/10/2017

Visibilité et rayonnement

Talks:

D. Autiero, 'Dual−phase electronics ', DUNE Far Detector DAQ Design Workshop, 30−31/10/2017, Columbia University, New York
D.Autiero, 'Overview WP8 scientific goals', AIDA−2020 3rd Annual Meeting, Bologna, 24−27/4/2018
D.Autiero, 'Charge Readout and dual phase', AIDA−2020 3rd Annual Meeting, Bologna, 24−27/4/2018
D.Autiero, 'Current IN2P3 activities in DUNE/protoDUNE', Journée DUNE France, LPNHE Paris, 18−21/2/2018
D.Autiero 'DUNE et LBNF', Atelier Longbaseline, LAL Paris 23/1/2018
D.Autiero, 'DUNE', Conseil Scientifique IN2P3: Physique du Neutrino; CNRS Paris, 28−29/6/2018
D. Autiero, 'DP Electronics Consortium', Long Baseline Neutrino Committee meeting, FERMILAB, 18−21/2/2018
D. Autiero, 'DUNE dual-phase Overview: Technical, Schedule & Planning', Long Baseline Neutrino Committee meeting, FERMILAB, 21-24/5/2018
D. Autiero, 'The long-standing experimental effort on the study of neutrino oscillations and the DUNE experiment' ECOLE INTERNATIONALE DE PHYSIQUE SUBATOMIQUE (EIPS) IPNL 22-26 October 2018
D. Autiero, 'DUNE dual-phase IDR & TDR Status', Long Baseline Neutrino Committee meeting, CERN, 7-9/12/2019
D. Autiero, 'Proposal for ProtoDUNE-Double Phase (NP02) after LS2', SPSC meeting CERN 23/1/2019
D. Autiero, DUNE dual-phase TDR progress', Long Baseline Neutrino Committee meeting, FERMILAB, 1-3/4/2019
D.Autiero, 'Status of WP8 Large Cryogenic Liquid Detectors', AIDA−2020 4th Annual Meeting, Oxford, 1-5/4/2018
D.Caiulo, 'Charge readout and dual-phase technology', AIDA−2020 4th Annual Meeting, Oxford, 1-5/4/2018
D. Autiero, 'D. Autiero, 'The long-standing experimental effort on the study of neutrino oscillations and the DUNE experiment' ECOLE INTERNATIONALE DE PHYSIQUE SUBATOMIQUE (EIPS) IPNL 17 October 2019
D.Autiero Physique des neutrinos aux US, Séminaire Thématique Physique des neutrinos et matière noire, 28/10/2019
D.Autiero Les neutrinos, une clé pour une nouvelle physique, Séminaire du LabEx LIO : bilan et perspectives 15/11/2019
D.Autiero ProtoDUNE dual-phase Electronics and DAQ, Long Baseline Neutrino Committee meeting, CERN 5-7/12/2019
E.Pennacchio ProtoDUNE dual-phase Computing and analysis, Long Baseline Neutrino Committee meeting, CERN 5-7/12/2019

Visibilité et rayonnement

- Membership in the restricted IIEB committee which was set-up by the Fermilab Director in 2014 to write the LOI and launch DUNE;
- Leadership of the IN2P3 WA105/DUNE project since 2013;
- Leadership of the AIDA2020 WorkPackage 8 on large cryogenic detectors; Leadership of the AIDANova WorkPackage 9 on Neutrino detectors
- Leadership of the dual-phase Electronics Consortium in DUNE;
- Leadership of the dual-phase computing in DUNE and various additional responsibilities and coordination roles in hardware, software, analysis and computing

- Contribution to the book : “The State of the Art of Neutrino Physics, A Tutorial for Graduate Students and Young Researchers” (2017)
- Organization of the Journée DUNE France (2018)
- LAL Atelier Long-baseline Neutrinos (2018)
- Diaphane outreach activities: https://vimeo.com/139232294 and TV/radio interviews (France3, France 24, Radio France).

Evolution du groupe à venir
(FTE estimés)

Increase current group membership (~7 FTE) with new hiring, additional members from IP2I, students/postdocs.

Projection at the level of DUNE construction, TGIR project 10-13 FTE (general trend for IN2P3 groups in DUNE)

Production Scientifique
- Analyses de Physique -

- ***Charge readout analysis in Liquid Argon Time Projection Chambers for neutrino and astro-particle physics (assessment of dual-phase for proton decay, e/pi0 separation)***

- ***Detection of supernova neutrinos, exploitation of dual-phase potential at low energy***

- ***Charge readout analysis of protoDUNE-DP data: tracks reconstruction, determination of LEMs gain, purity assessment from charge attenuation along tracks***

- ***Events reconstruction in dual-phase with Pandora***

- **3 neutrinos phenomenology ν_τ CC analysis, development of 3 flavors measurements/constraints**

- ***Neutrino cross sections, nuclear effects, events reconstruction and neutrino energy determination***

- ***N-nbar oscillations***

Production Scientifique
- Contributions techniques -

- **Development of cryogenic front-end ASIC amplifiers, cryogenic front-end cards, low Voltage distribution system**
- **Development of uTCA and data network infrastructure**
- **Development of front-end digitization AMC cards**
- **Development of timing/synchronization and trigger system based on White Rabbit, of the uTCA slave nodes and of the trigger tagging station**
- **Development of the online back-end DAQ system including the online storage and online processing protoDUNE-DP**
- **Development of the DAQ and computing software protoDUNE-DP**
- **Development of the fast reconstruction software (QSCAN) for 3x1x1/protoDUNE-DP**
- **Development of simulation software for 3x1x1/protoDUNE-DP DUNE**
- **Development of Larsoft for dual-phase reconstruction/interface to protoDUNE-DP data, DUNE**
- **Development of DUNE computing for dual-phase**
- **Complete design and realization of the entire LAr TPC chain for the LIO LABEX LAr laboratory at IP2I (Cryogenics, vacuum system, purification system, HV system, TPC field cage, LEMs, charge readout, light readout system, slow control system, level meters, temperature and pressure measurements, feedthroughs)**
- **Development of DUNE DAQ back-end, interface to DP front-end, development of decompression and trigger primitives search in FPGA network cards**

Production scientifique
- Bilan des Publications 2015-2020 du groupe Neutrino

List of publications of the neutrino group:

The DUNE Far Detector Interim Design Report, Volume 3: Dual-Phase Module
DUNE Collaboration (B. Abi (Oxford U.) et al.). Jul 26, 2018. 280 pp.
FERMILAB-DESIGN-2018-04 e-Print: arXiv:1807.10340 [physics.ins-det]

The DUNE Far Detector Interim Design Report, Volume 2: Single-Phase Module
DUNE Collaboration (B. Abi (Oxford U.) et al.). Jul 26, 2018. 324 pp.
FERMILAB-DESIGN-2018-03 e-Print: arXiv:1807.10327 [physics.ins-det]

The DUNE Far Detector Interim Design Report Volume 1: Physics, Technology and Strategies
DUNE Collaboration (B. Abi (Oxford U.) et al.). Jul 26, 2018. 83 pp.
FERMILAB-DESIGN-2018-02 e-Print: arXiv:1807.10334 [physics.ins-det]

A 4 tonne demonstrator for large-scale dual-phase liquid argon time projection chambers
B. Aimard (Annecy, LAPP) et al.. Jun 8, 2018. 61 pp.
Published in JINST 13 (2018) no.11, P11003 FERMILAB-PUB-18-257-ND
DOI: 10.1088/1748-0221/13/11/P11003 e-Print: arXiv:1806.03317 [physics.ins-det]

Neutrino Oscillation Detectors and Methods
D. Autiero (Lyon, IPN). 2018. 28 pp.
Published in Adv.Ser.Direct.High Energy Phys. 28 (2018) 121-148 DOI: 10.1142/9789813226098_0003

The Single-Phase ProtoDUNE Technical Design Report
DUNE Collaboration (B. Abi (Oxford U.) et al.). Jun 21, 2017. 178 pp.
FERMILAB-DESIGN-2017-02 e-Print: arXiv:1706.07081 [physics.ins-det]

Measurement of the single p0 production rate in neutral current neutrino interactions on water
T2K Collaboration (K. Abe (Kamioka Observ.) et al.). Apr 24, 2017. 13 pp.
Published in Phys.Rev. D97 (2018) no.3, 032002 DOI: 10.1103/PhysRevD.97.032002
e-Print: arXiv:1704.07467 [hep-ex]

Updated T2K measurements of muon neutrino and antineutrino disappearance using 1.5× 1021 protons on target T2K Collaboration (K. Abe (Kamioka Observ.) et al.). Apr 21, 2017. 9 pp.
Published in Phys.Rev. D96 (2017) no.1, 011102
DOI: 10.1103/PhysRevD.96.011102
e-Print: arXiv:1704.06409 [hep-ex]

Search for Lorentz and CPT violation using sidereal time dependence of neutrino flavor transitions over a short baseline
T2K Collaboration (Ko Abe (Kamioka Observ.) et al.). Mar 3, 2017. 9 pp.
Published in Phys.Rev. D95 (2017) no.11, 111101 DOI: 10.1103/PhysRevD.95.111101
e-Print: arXiv:1703.01361 [hep-ex]

Production scientifique
- Bilan des Publications 2015-2020 du groupe Neutrino

Combined Analysis of Neutrino and Antineutrino Oscillations at T2K
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