GDR Neutrino - 29/30 May 2017 - APC, Paris

Status of WA105/ ProtoDUNE-DP

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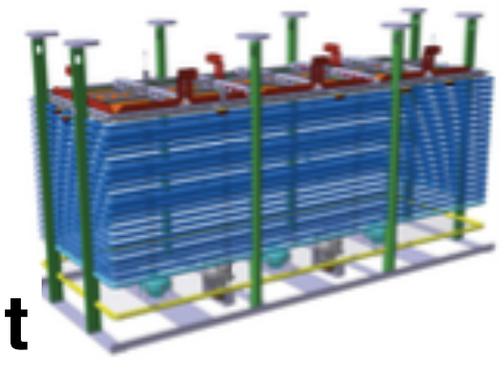
DUNE Dual Phase strategy @CERN

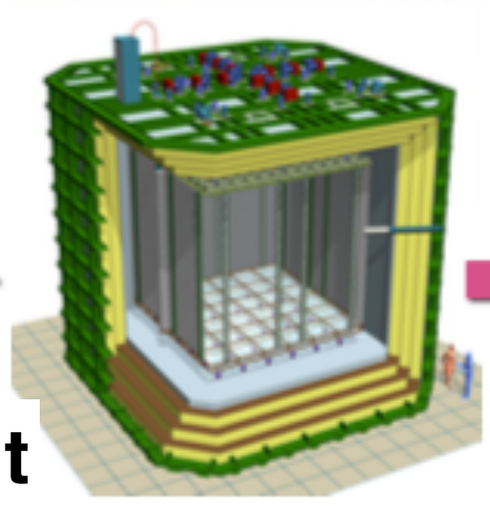
⇒ **See D. Duchesneau's talk yesterday**

25 t



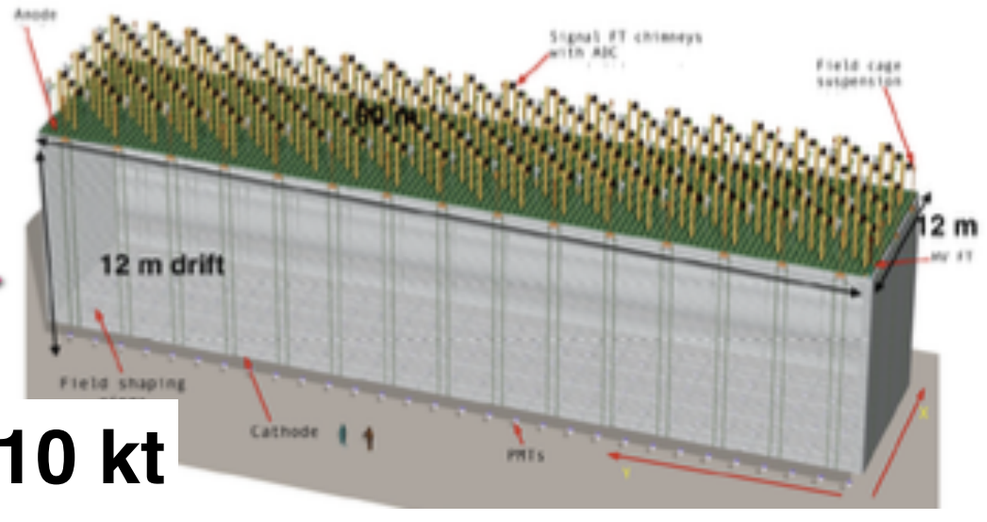
3x1x1 m³
@CERN (2016-2017)

300 t



ProtoDUNE-DP, 6x6x6 m³
@CERN (2016-2019)

10 kt



DUNE FD-DP, 60x12x12 m³
@SURF (> 2020)

Technical goals

Feasibility of 10kt-scale DP technology

- Scalable **large surface charge readout** (3x3 m^2 modules)
- **Argon high purity** for exploiting long drift distances (6-12 m)
- **Stable HV power supply** for drift E~0.5-1 kV/cm and field cage design
- **Production QA/QC and installation chain** in view of the underground detector assembly.

Scientific goals

Characterize the detector in a test beam

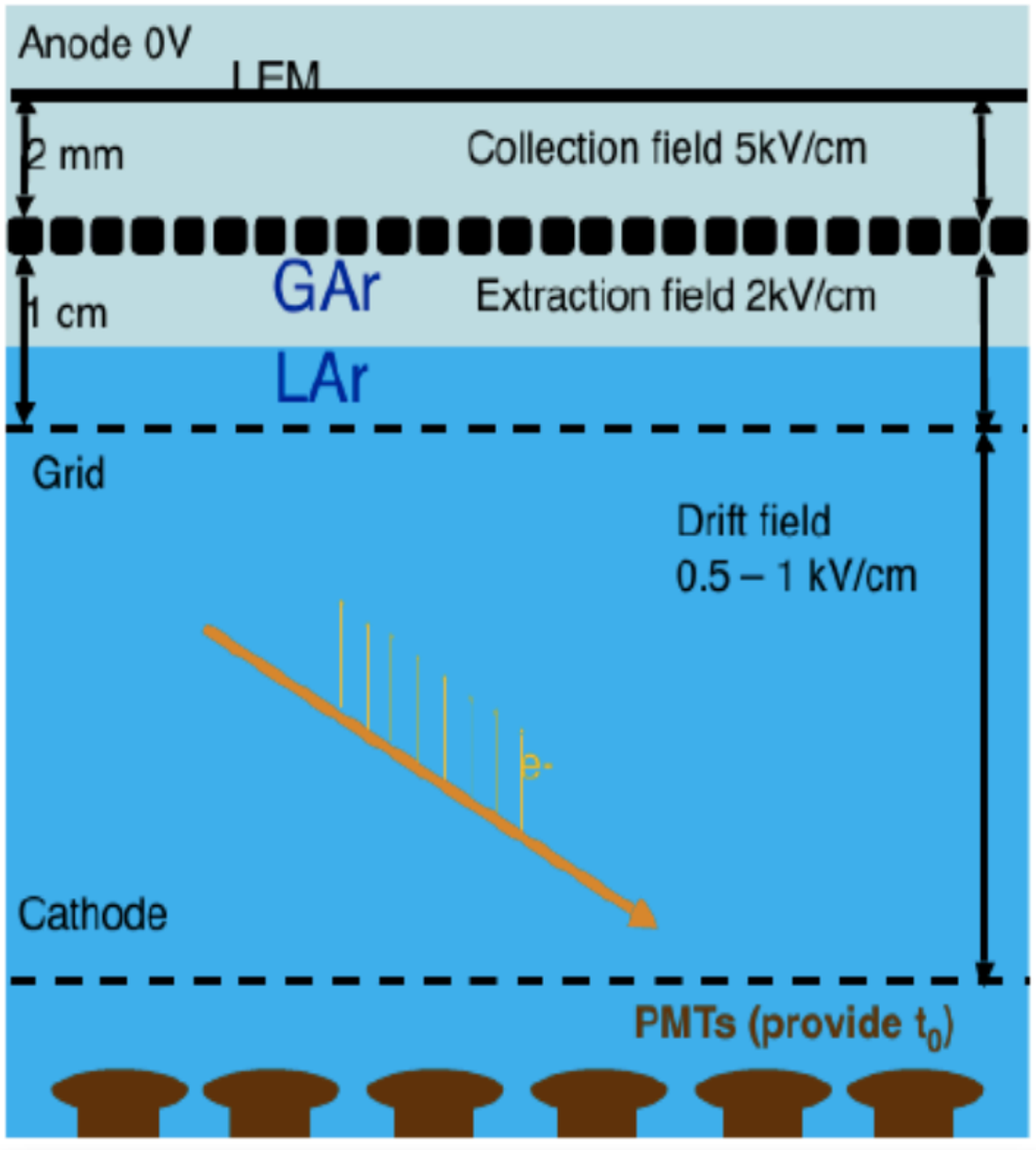
- **PID** performances
- **e/π^0 rejection capabilities**
- Calibrate energy scale and resolution for **hadronic and electromagnetic showers**
- Validate **software simulation and reconstruction** tools
- **DUNE physics potential**

Advantages of Dual-Phase

⇒ **See D. Duchesneau's talk yesterday**

Dual Phase offers some advantages:

- Better resolution (3mm pitch w.r.t. 5mm in SP)
- Tunable gain in GAr → higher S/N ratio
- Only charge collection, no induction planes needed
- Only two planes: less ambiguities in recon.
- Longer drifts are possible → No dead materials in the LAr active volume
- Fewer readout channels

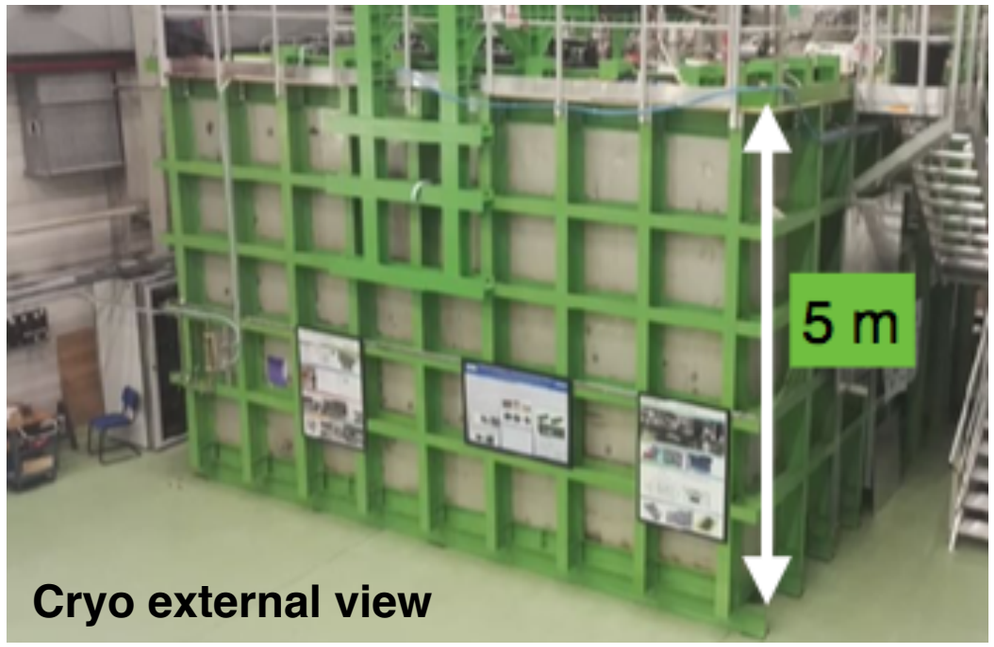


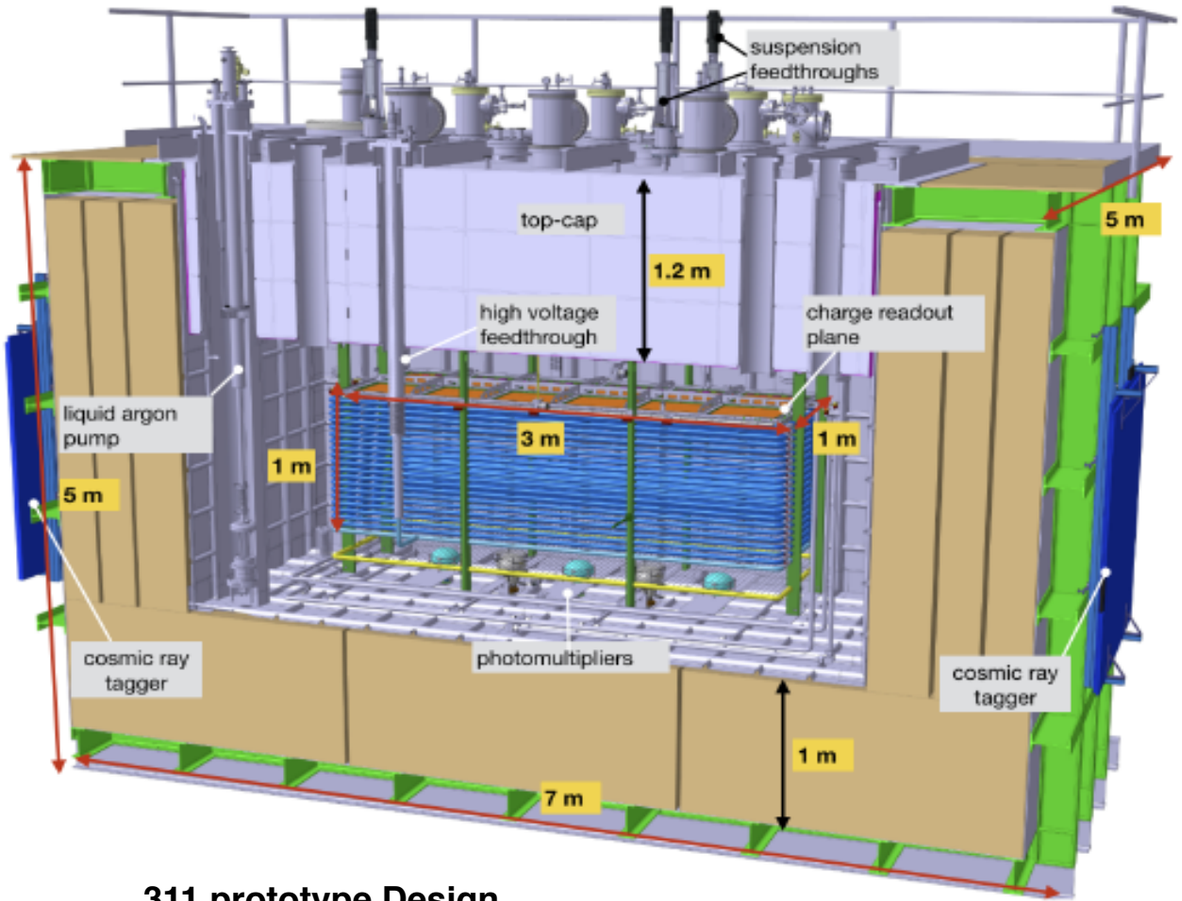
With a stable large gain (>10), DP technology may be especially interesting for DUNE non-beam physics program

The 3x1x1 prototype

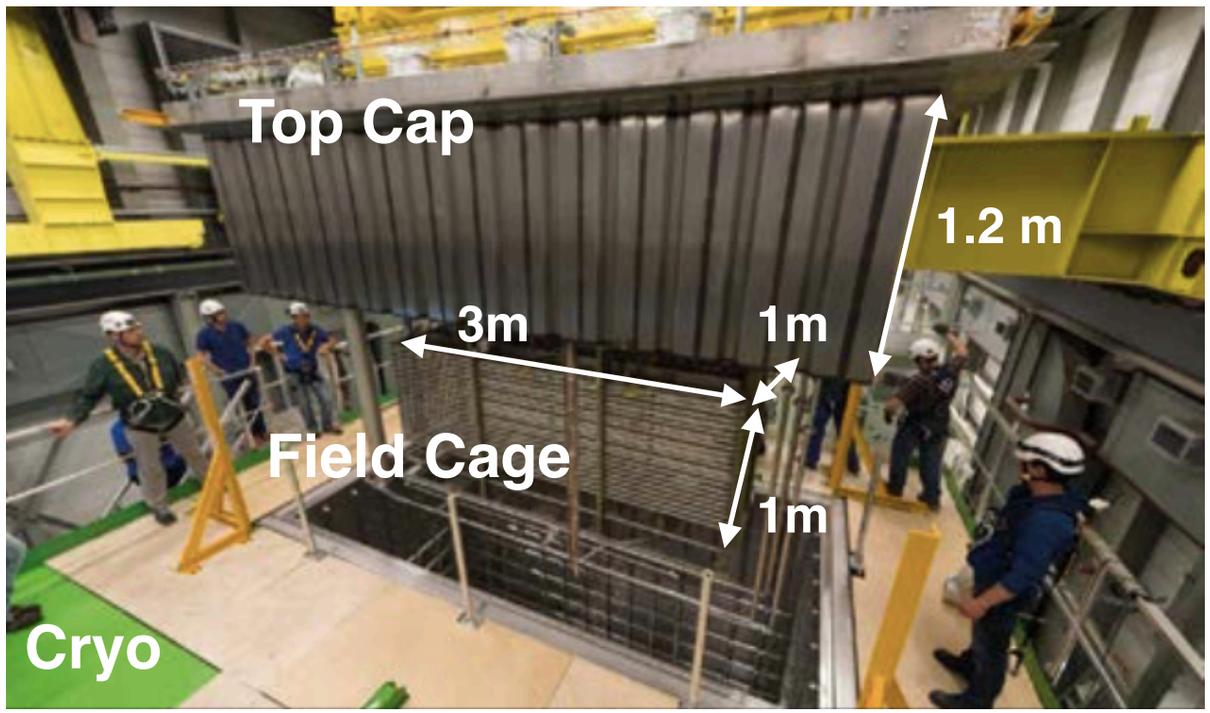
1st step towards the kt scale for DP

- 1 m drift, 25 tons LAr DP pathfinder prototype
- Test production and quality of the component
- Design validation
- Data with cosmic muons





311 prototype Design



Field cage installation @CERN (Summer 2016)

3x1x1 goals

- **Not a full-scale demonstrator:**
  - Cannot really proof the feasibility of a kt DP LAr TPC
  - Not very large vessel and field cage structure,
  - No event containments or exposure to Hadronic beams
- **The goal is:**
  - Fully engineered version of many detectors for large DP TPCs
  - Routine QA/QC and mass production for the components
  - Cryogenics installation, feedthroughs, …
- **With data:**
  - Realistic noise measurements
  - GAr gain stability over time, LAr purity measurement
  - First validation of the software sim/recon. chain with **cosmic muons**
  - **…**

Timeline

detector construction

Jan-July 2016

- Jan-May: LEMs selection, CRP alignement + contact testing (warm + cold)
- May July: drift cage assembly, PMT installation + testing, complete HV + sensor testing,
- July 4th: insertion in cryostat

commissioning

Aug 2016 -Feb 2017

- Aug-Nov: re-testing of all sensors, inspections, running of full DAQ, 300 kV HV feedthrough test+ insertion
- Aug-Feb: installation of cryogenics system + debugging, re-cabling, leak checks,..

cool down + filling trial

Feb 2017- present

- Feb-March: piston purge, cooling down(s),
- March-present: cryostat investigations.
- May: LAr pump test, filling trial

From S. Murphy talk at the last DUNE Collaboration meeting (may 2017): https://indico.fnal.gov/getFile.py/access?contribId=5&sessionId=1&resId=0&materialId=slides&confId=12345

Timeline

Valuable experience, many lessons learnt,

Jan-July 2016

- Jan-May: LEMs selection, CRP alignement + contact testing (warm + cold)

✓ **Smooth installation according to schedule,** no major surprises
✓ **Fully engineered versions of many detector components for large DP LAr TPCs,** validation of industrial solutions, ..
✓ **First overview of the complete system integration**: set up full chains for Quality Assessment, ..

Aug 2016 -Feb 2017

- Aug-Nov: re-testing of all sensors, inspections, running of full DAQ, 300 kV

✓ **smooth installation of cold piping,**
✓ warm piping installation took longer than anticipated
✓ some troubleshooting during cryogenic system commissioning
✓ ->delays

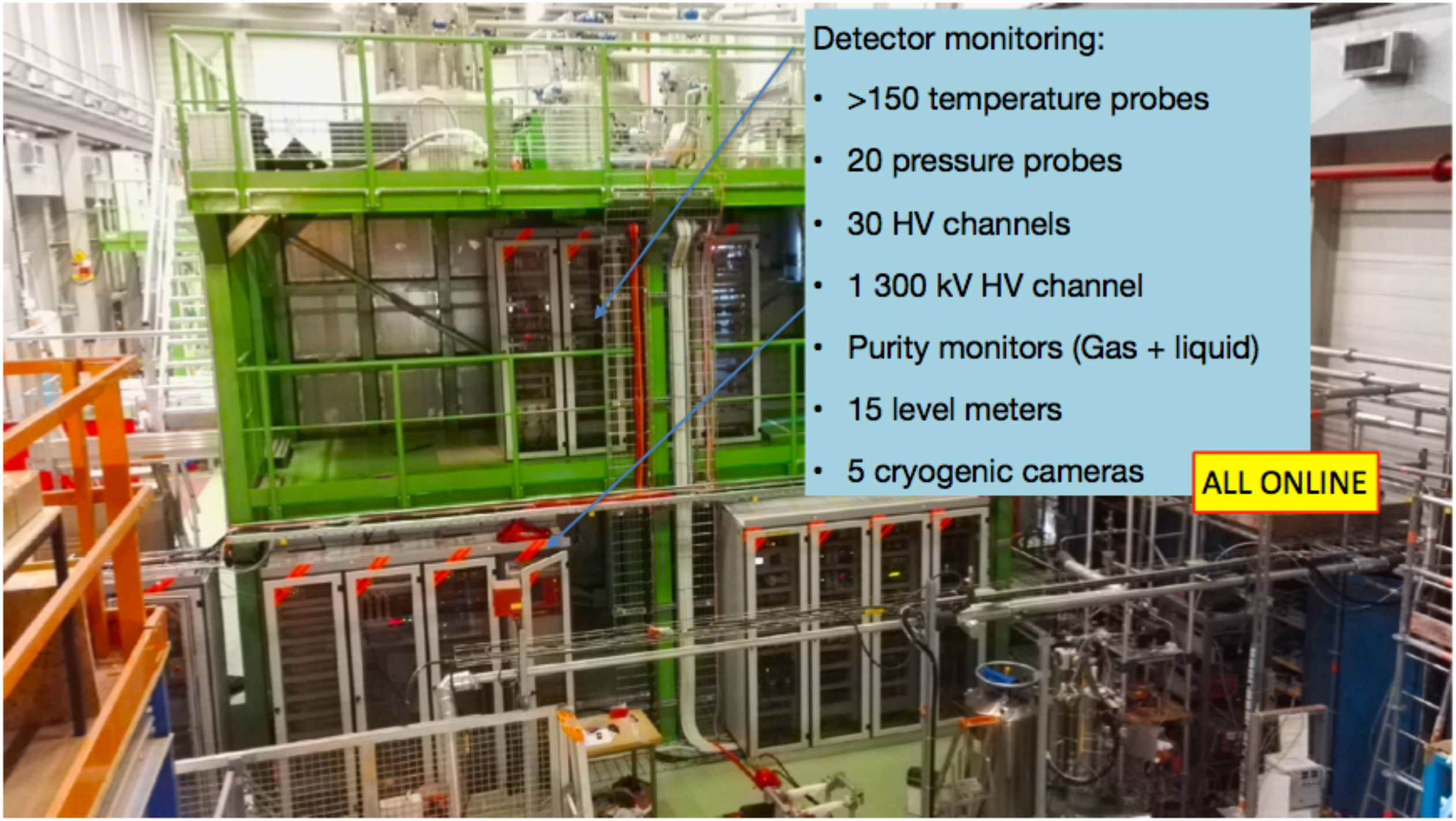
Feb 2017- present

- Feb-March: piston purge, cooling down(s),

✓ **First operation of a GTT made cryostat**
✓ successful piston purge
✓ Investigation of the cryostat related issues by CERN.

From S. Murphy talk at the last DUNE Collaboration meeting (may 2017):
https://indico.fnal.gov/getFile.py/access?contribId=5&sessionId=1&resId=0&materialId=slides&confId=12345

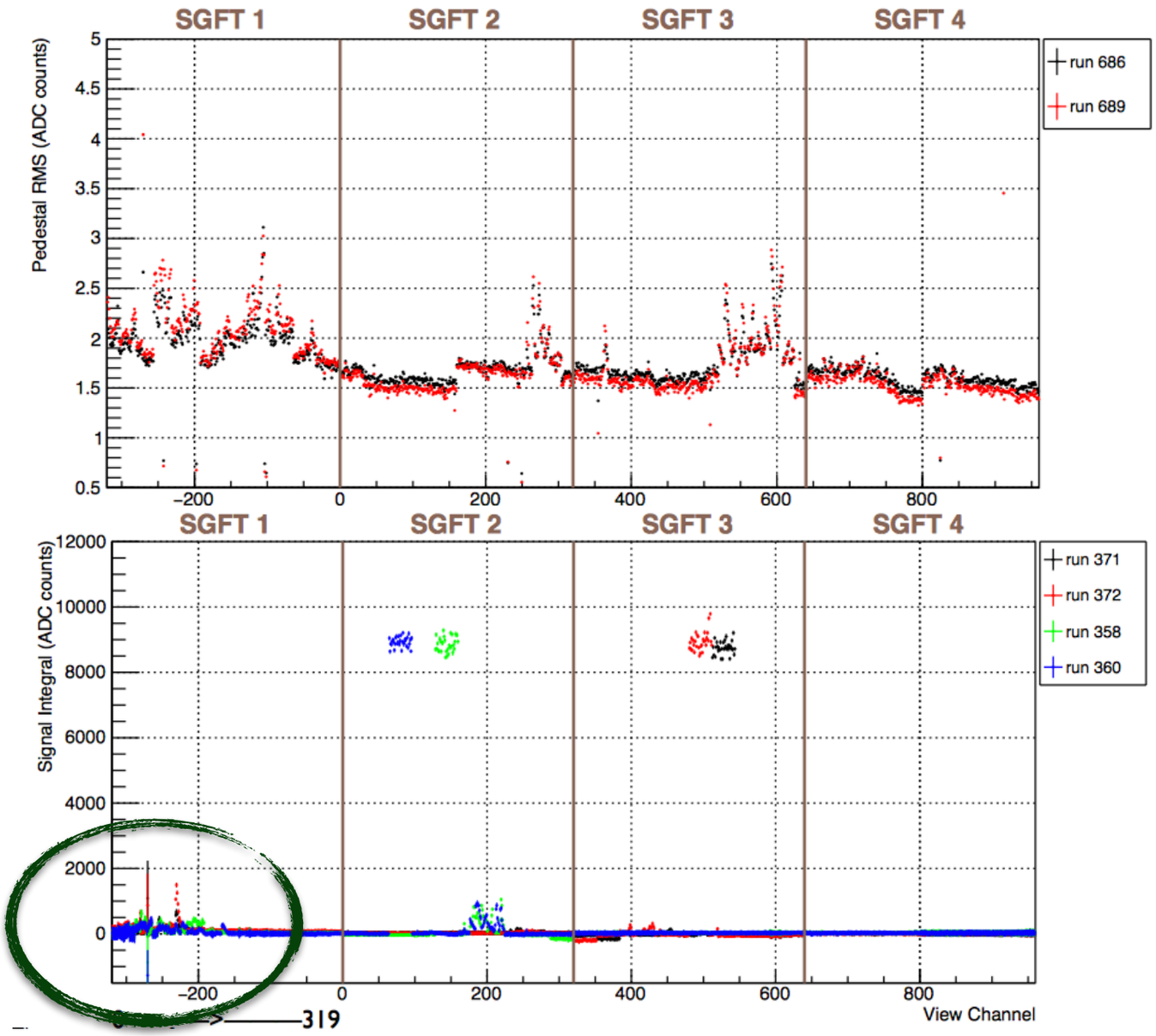
Fall 2016-detector ready



From S. Murphy talk at the last DUNE Collaboration meeting (may 2017):
https://indico.fnal.gov/getFile.py/access?contribId=5&sessionId=1&resId=0&materialId=slides&confId=12345

Noise checks

First noise measurements performed last winter:



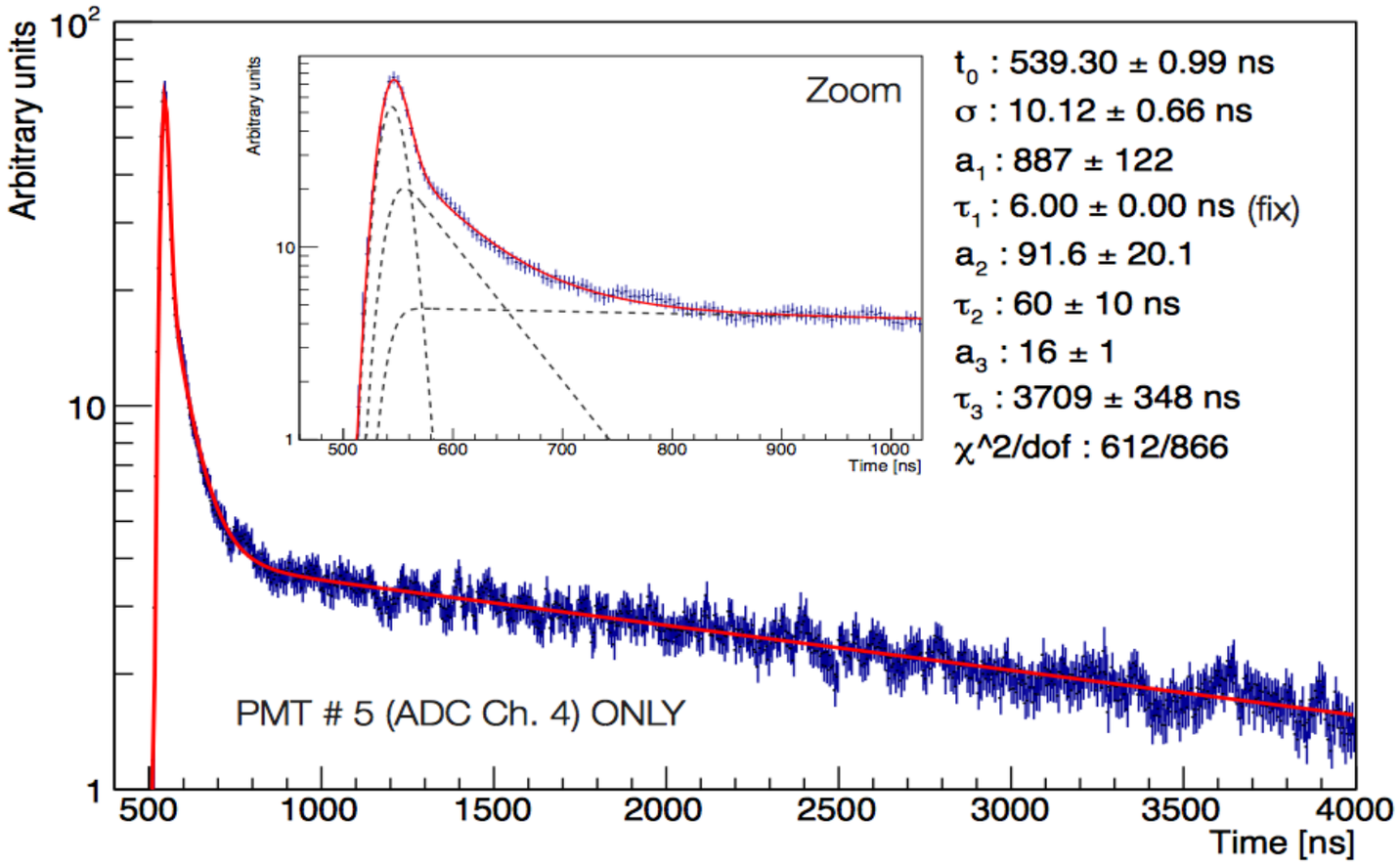
- Noise at room temperature
- Lowest noise condition has a pedestal RMS ~ 1.74 ADC
- Measure reproduced 2 weeks later

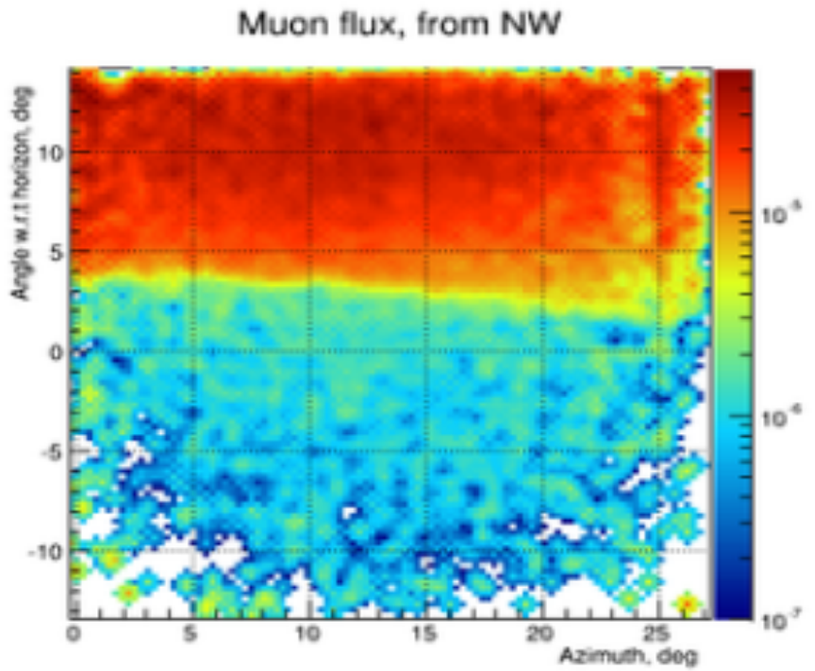
- Pulsed measures (150 fC)
- Wire cross talks of ~ 5% → More studies needed

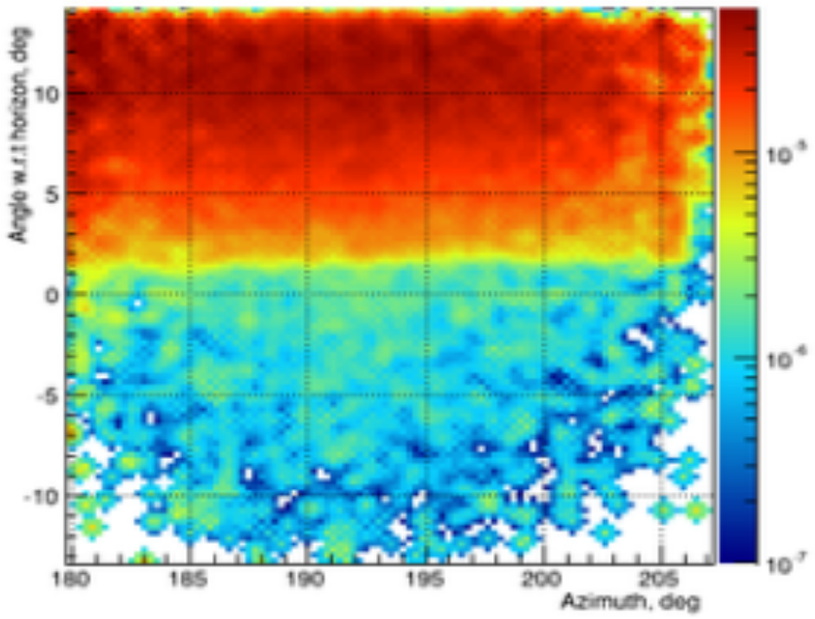
See at the last WA105 Collaboration Meeting (March 2017):

- **L. Zambelli:** https://indico.fnal.gov/getFile.py/access?contribId=41&sessionId=1&resId=0&materialId=slides&confId=13938

Light readout and cosmic muon tagger







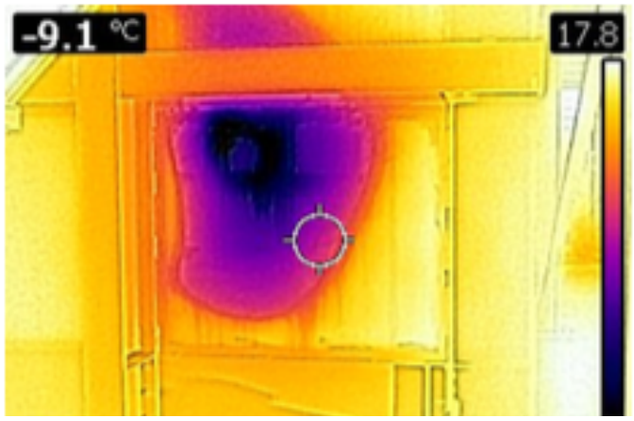
Status of Light readout system of 3x1x1

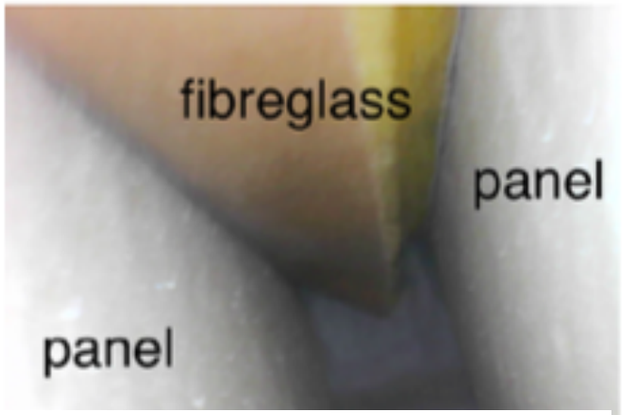
- 5 PMT correctly installed and operative
- Cosmic ray tagger is installed and operative
- Scintillation time response on detector as expected

See at the last WA105 Collaboration Meeting (March 2017):

- **A. Remoto**: https://indico.fnal.gov/getFile.py/access?contribId=37&sessionId=1&resId=0&materialId=slides&confId=13938
- **I. Krelso**: https://indico.fnal.gov/getFile.py/access?contribId=38&sessionId=1&resId=0&materialId=slides&confId=13938

Status of 3x1x1 commissioning





See S. Murphy talk at the last DUNE Collaboration meeting (May 2017):
https://indico.fnal.gov/getFile.py/access?contribId=5&sessionId=1&resId=0&materialId=slides&confId=12345

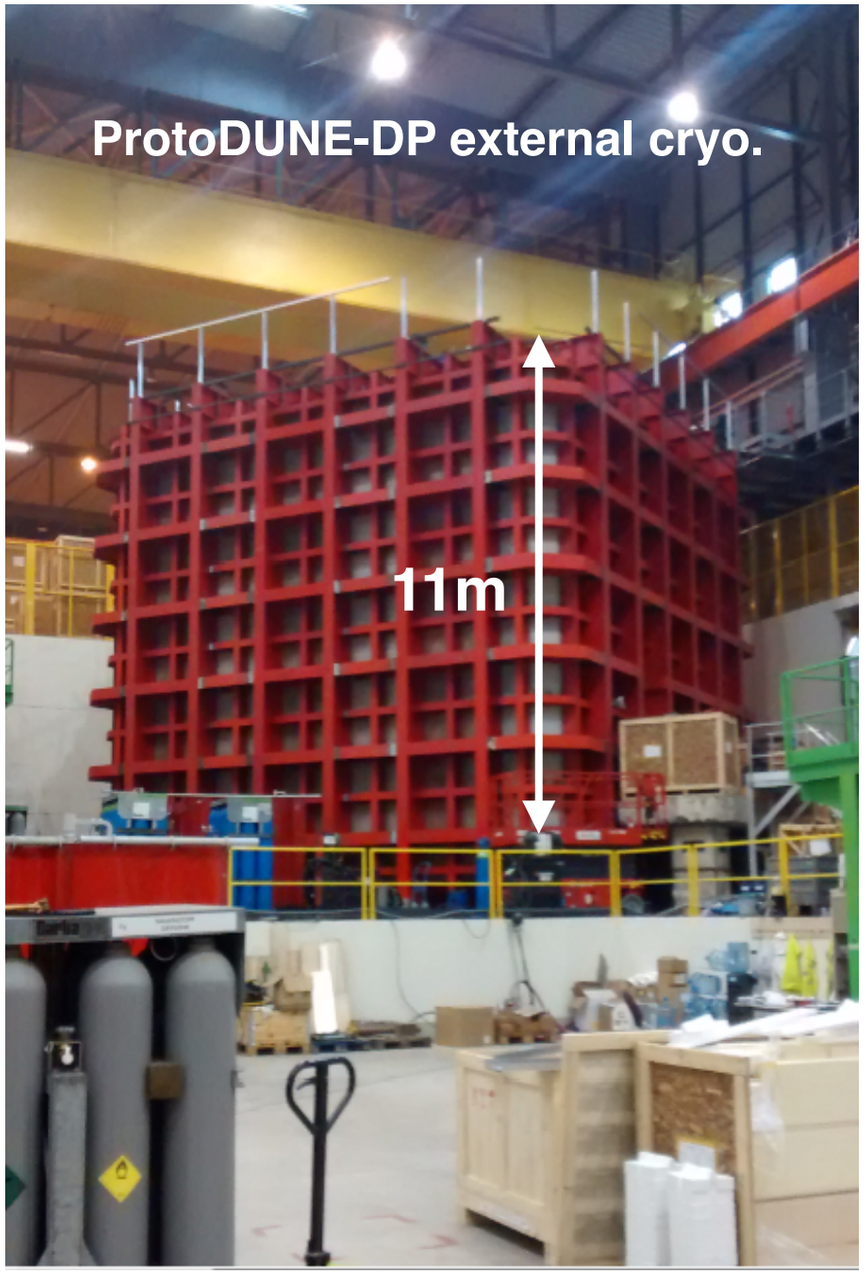
Issues during cooling down:

- Cooling down started last February. Interrupted twice, cause multiple cold spots on the outer structure
- Investigation for the cause of the cold spots as well as a solution to fix it is still under investigation by CERN and GTT
- Leak from the membrane has been excluded. Local defects in the insulator
- This defect shouldn't be present for 6x6x6 (different cryo. design)

Last update: cryostat is being filled (1.25 m on 15/05) with heat conditions larger than expected. Unknown if cryogenic conditions will allows stable operations

Status of the 6x6x6 prototype

Construction of the 6x6x6 prototype started last fall:



- Cryo. external structure completed
- Installation of insulation should be completed by the end of May

⇒ **See D. Duchesneau's talk yesterday**

More at D. Autiero talk at the last DUNE Collaboration meeting (May 2017):
https://indico.fnal.gov/materialDisplay.py?contribId=79&sessionId=1&materialId=slides&confId=12345

Status of software

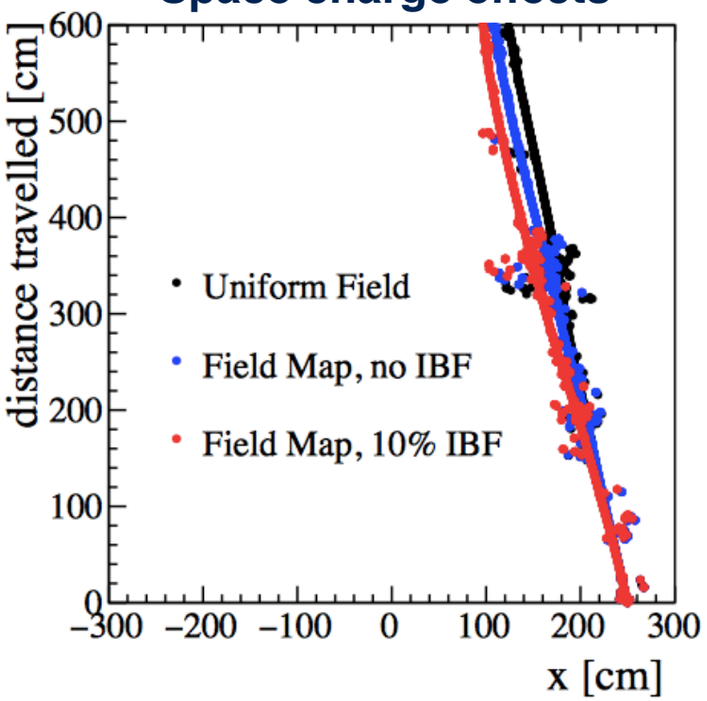
Necessary codes for 3x1x1 operation are ready

- Online monitoring processes
- Data flow and computer storage @CERN are operative
- Sim/recon. is completed

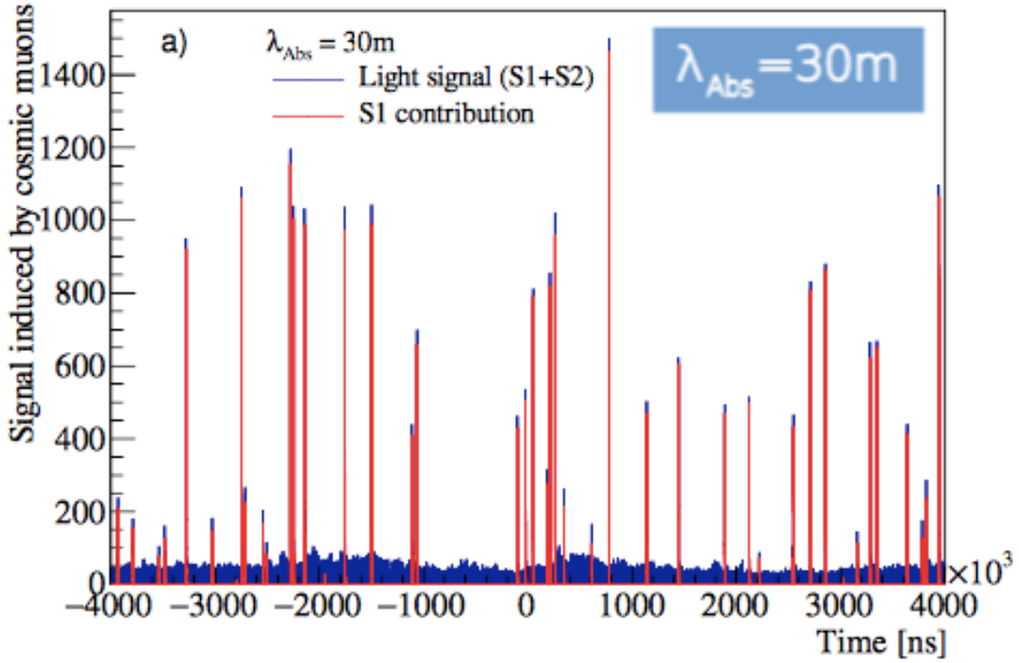
Most efforts are focused on reconstruction

- Standard hit, cluster and track finding are operative
- Space charge effects
- Cosmic ray tagging through light

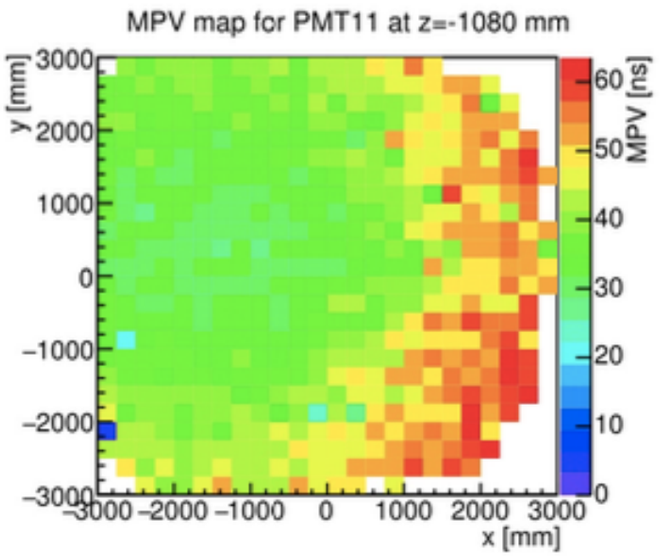
Space charge effects



Light signal simulation



Light Map



Software: WA105Soft/Qscan

Native framework for analysis in DP

Update on the most recent progresses @ WA105 collaboration meeting:

E. Pennacchio: https://indico.fnal.gov/getFile.py/access?contribId=15&sessionId=4&resId=0&materialId=slides&confId=13938

A. Chappuis: https://indico.fnal.gov/getFile.py/access?contribId=20&sessionId=4&resId=0&materialId=slides&confId=13938

L. Zambelli: https://indico.fnal.gov/getFile.py/access?contribId=19&sessionId=4&resId=0&materialId=slides&confId=13938

Coordination with LArSoft

LArSoft is the Fermilab framework used for liquid argon SP TPC: ArgoNeuT, uBoone, Larlat, … and that will be used for ProtoDUNE and DUNE - FD SP

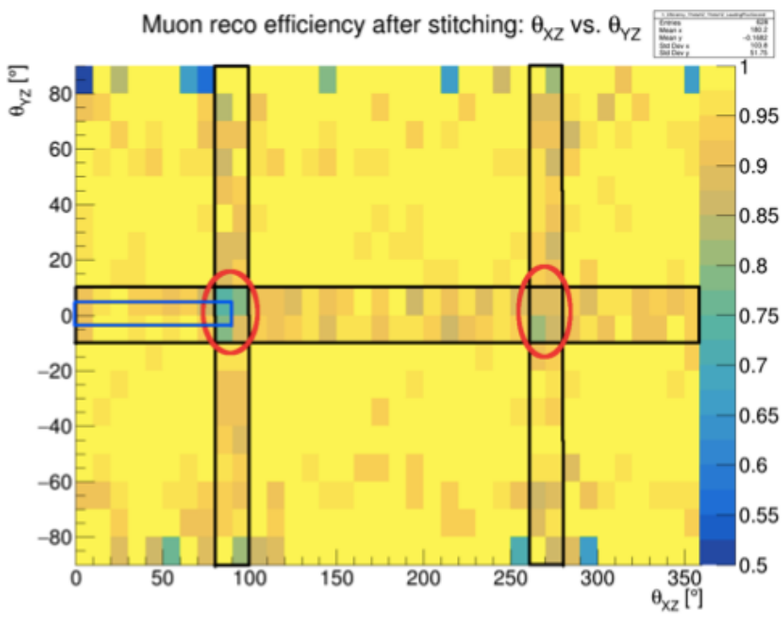
DP simulation in LArSoft is envisaged for sharing synergies with the SP team in view of DUNE-FD. Efforts in this sense started only few months ago.

Efforts for a fully operative DP sim/recon chain in LArSoft are ongoing:

- Adapt LArSoft to DP Geom. (Drift direction rotation and GAr simulation)
- Light simulation for DP
- Cosmic/Beam Halo and Cosmic Ray simulation for ProtoDUNE could be exported from the SP models
- Assess the existing performances of the recon. tools for DP:
  - Lover lever recon: hit finding and clustering
  - Higher lever recon: track and shower recon.

Coordination with LArSoft: reconstruction

Improving tools for reconstruction: deconvoluted hit-finding and recon. track efficiency

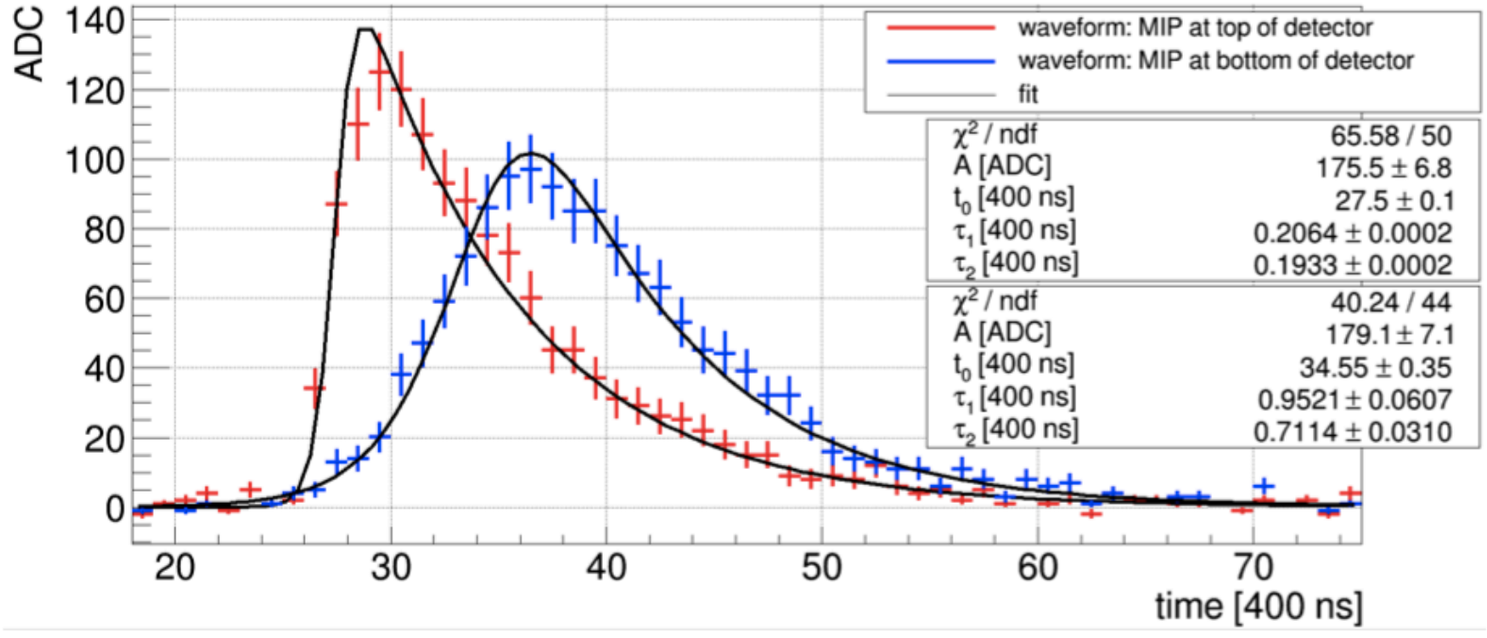


Track reconstruction efficiency:

- ~97% for isotropic monochromatic muons
- Problematic direction identified
  - // to wire planes
  - // drift direction

Increase recon. efficiency with hit finding on raw waveform:

- Less artifacts introduced with deconvolution
- Using “realistic” noise from 3x1x1 measures …



Latest results at the DUNE collaboration meeting (May 2017):

C. Alt: https://indico.fnal.gov/materialDisplay.py?contribId=50&sessionId=15&materialId=slides&confId=12345

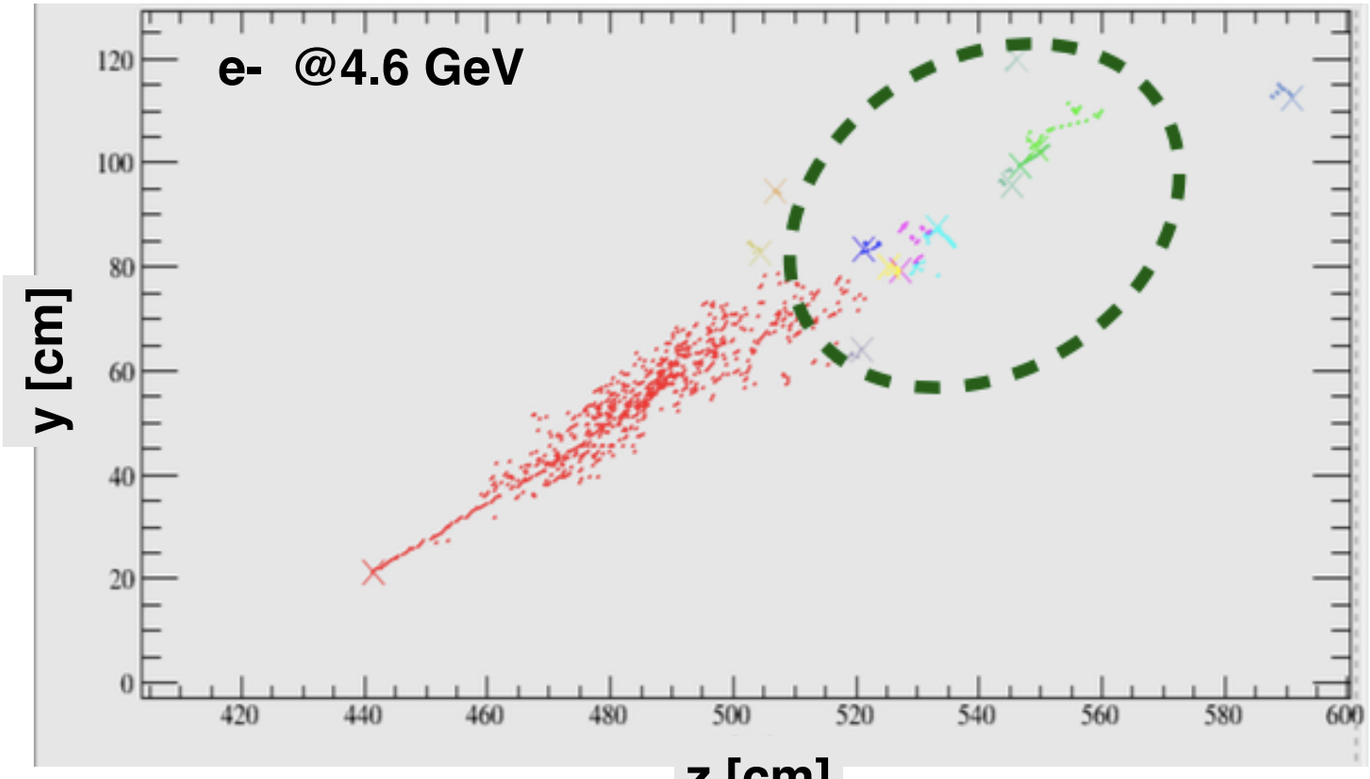
Coordination with LArSoft: recon/analysis

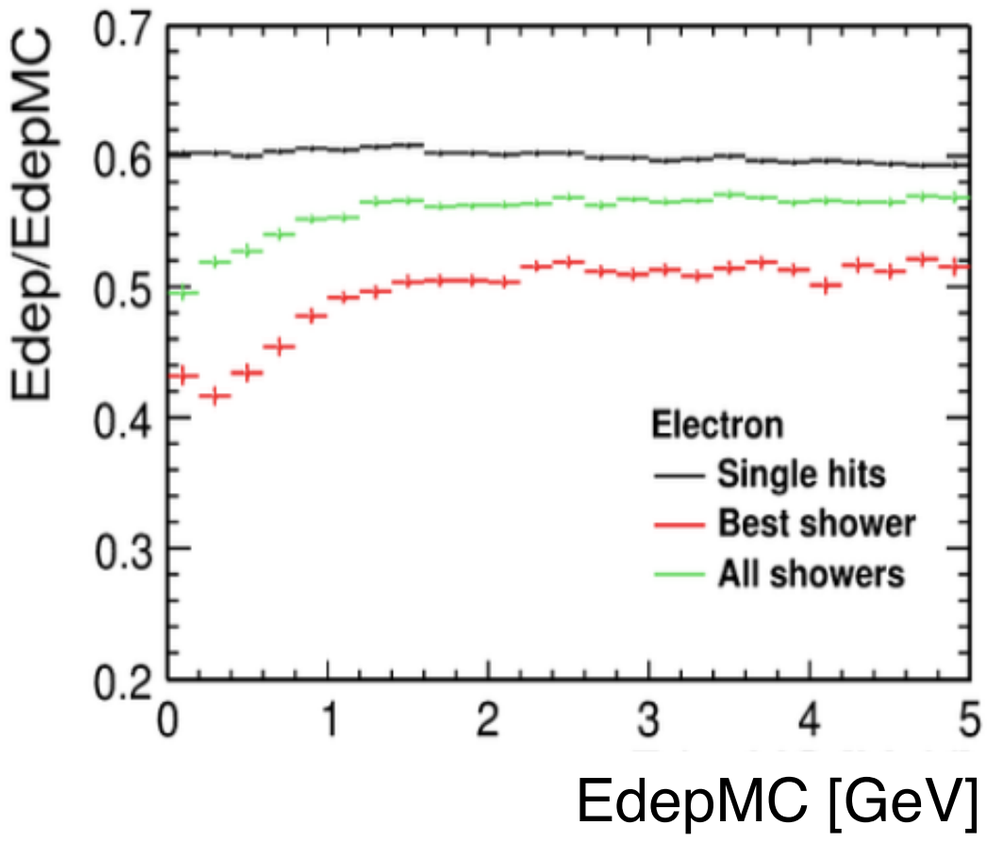
Preparing tools for reconstruction: Showers

Showers are of particular interests for ProtoDUNE and DUNE physics program:

- Em and had. showers calibration
- Electron induced cascades are CC events signal / Gamma induced cascades are NC background

Shower recon. efficiency w.r.t. to energy: highlight issues in standard recon.





Latest results at the DUNE collaboration meeting (May 2017):

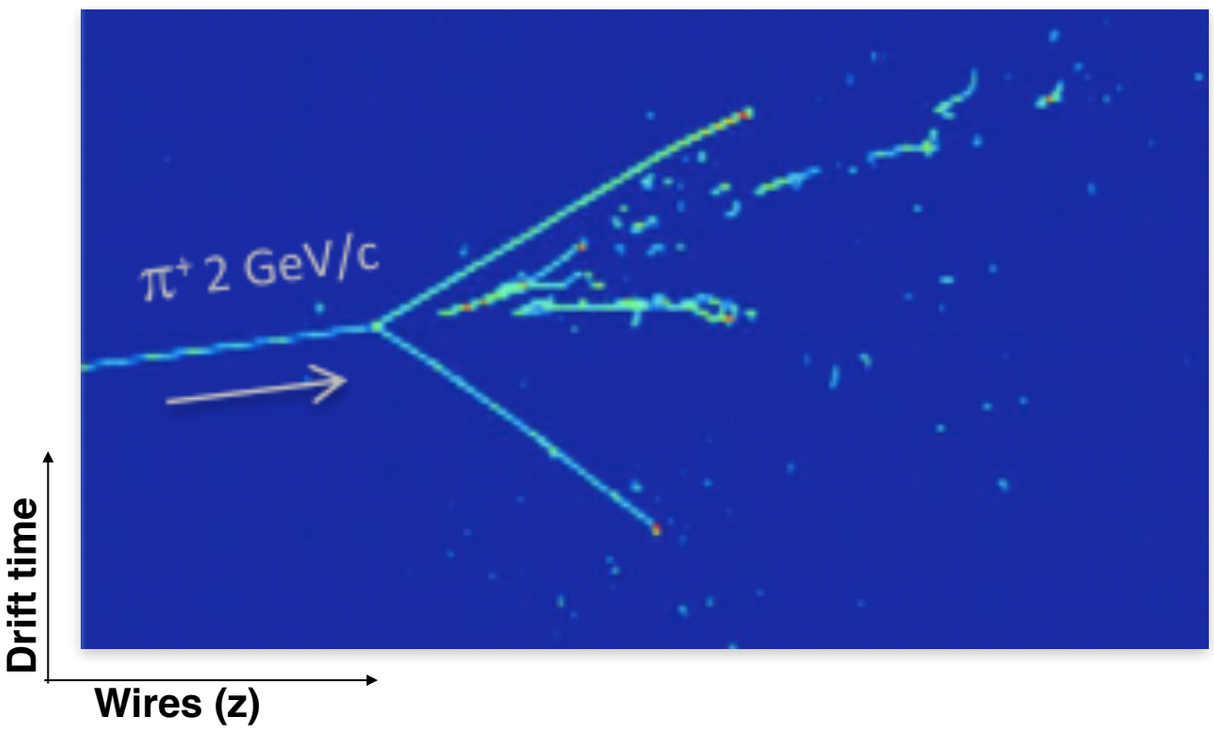
A. Scarpelli: https://indico.fnal.gov/getFile.py/access?contribId=48&sessionId=15&resId=0&materialId=slides&confId=12345

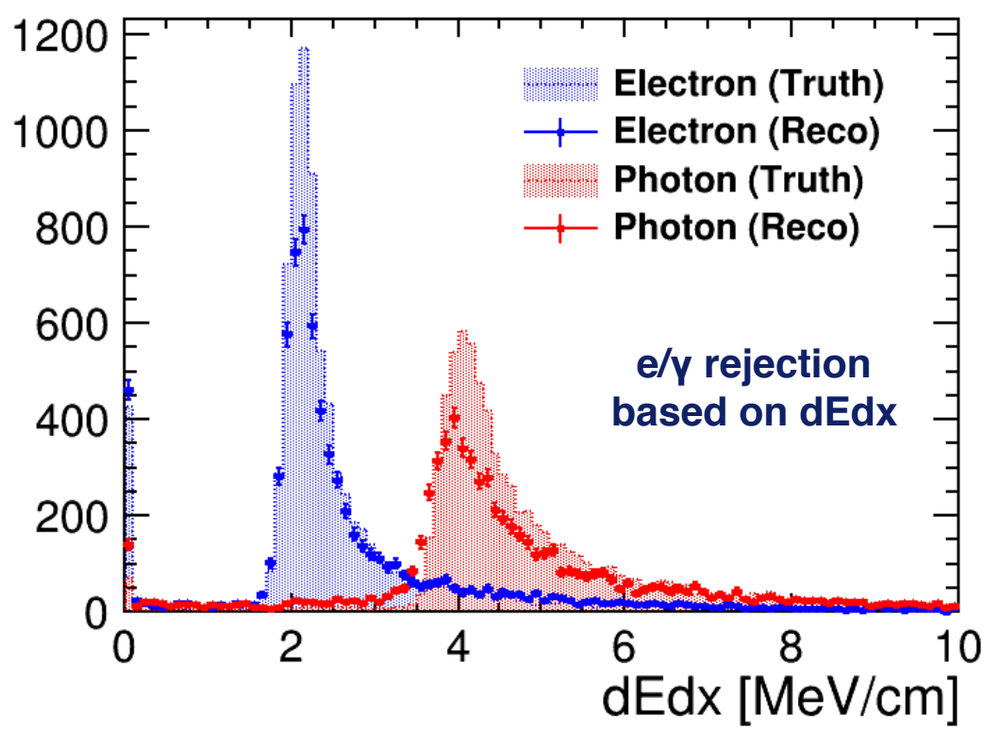
Coordination with LArSoft: reconstruction

Preparing π0 rejection studies in DP

π0→γγ from NC events are the main background for CC events :

- Topological rejection: γ conversion gap from neutrino vertex
  - Depends on topology
  - Overlaps with hadrons may shade it
- Topological rejection: stopping power from the first part of the cascade
- Both approach relies on correct shower/track identification and distinction…





Latest results at the DUNE collaboration meeting (May 2017):

A. Scarpelli: https://indico.fnal.gov/getFile.py/access?contribId=48&sessionId=15&resId=0&materialId=slides&confId=12345

Coordination with LArSoft: reconstruction

Preparing π0 rejection studies in DP

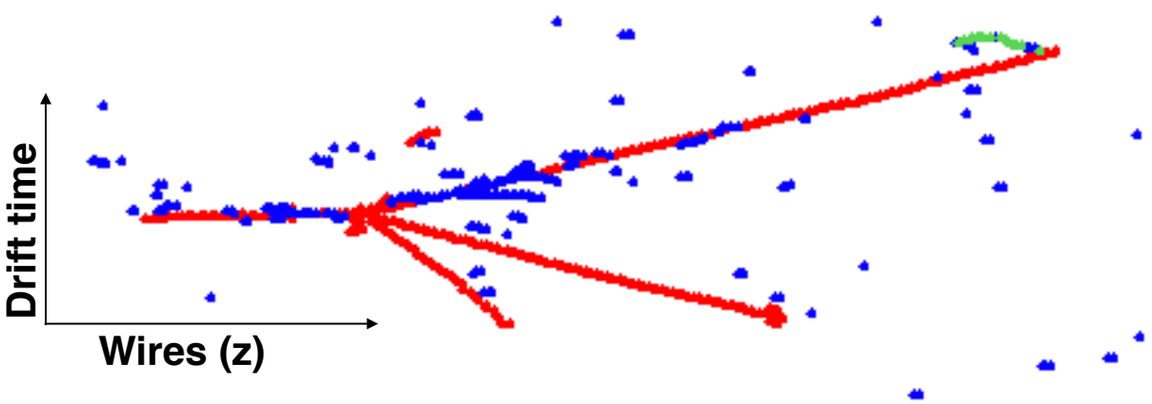
Applying convolutional neural network!

- Pixel-wise classification of the image based on the surrounding pattern:
  - **Track-like** or **Shower-like**
  - Shower-like and **Michel-electron**
- Run type recon./analyis only on type like improving capabilities of standard recon./ analysis
- Promising approach for DP (higher resolution w.r.t. SP)

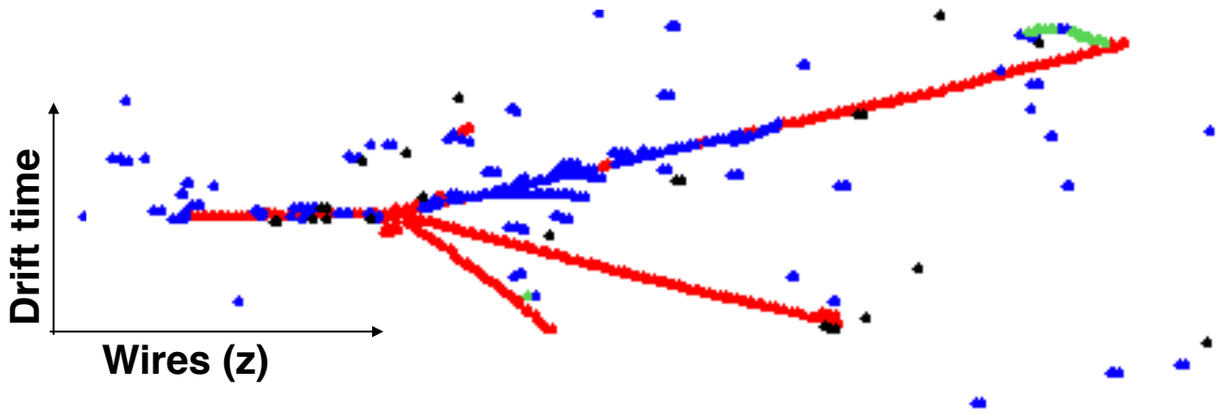
➡ **Validation with Protodune 6x6x6 and 3x1x1 data** 🤞🏼

π+ at 2GeV

Classification from Truth



Classification from CNN



Latest results at the DUNE collaboration meeting (May 2017):

A. Scarpelli: https://indico.fnal.gov/getFile.py/access?contribId=48&sessionId=15&resId=0&materialId=slides&confId=12345

Conclusion

3x1x1 prototype

- Fully commissioned and (in principle) ready for data
- Issue with Cryostat added several months of delays and could not allow stable operating condition.
- Experience with 3x1x1 catalyzed progresses on 6x6x6:
  - First overview on the complete system integration and fully engineered components
  - Foreseen practical and legal aspects and retrieve risks

6x6x6 prototype

- Construction is ongoing at CERN

Software

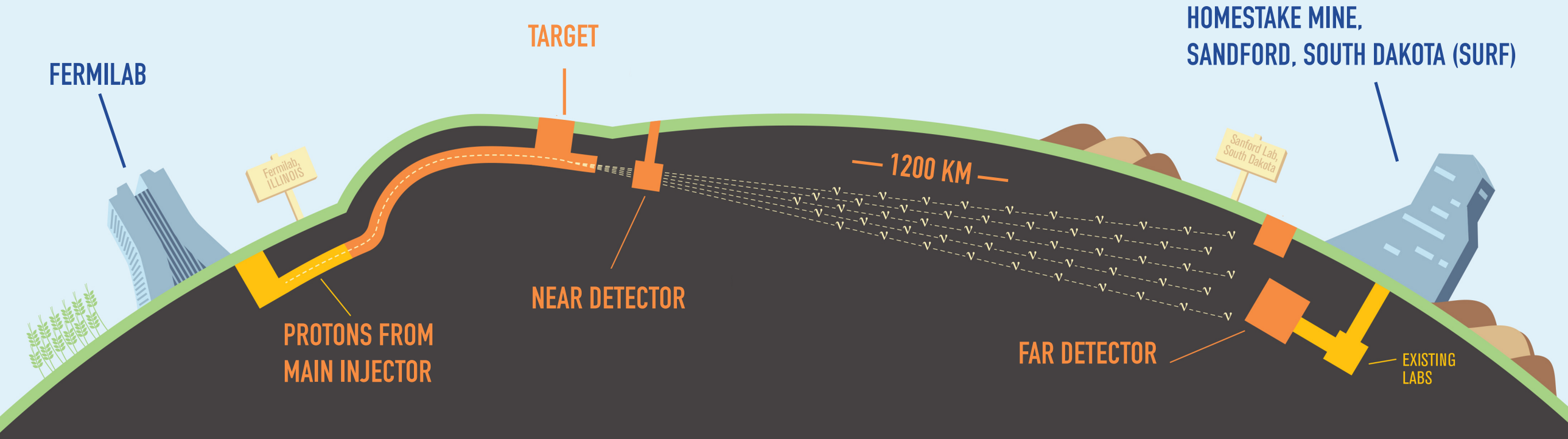
- Data flow for 3x1x1 is in place → exported for 6x6x6
- Full standard sim/recon. chain is completed and operative on WA105soft/Qscan
- Synergies with SP through the implementation of DP in LArSoft in view of DUNE

Thank you!

Backup slides

Introduction: the DUNE Experiment

Large international collaboration: 800 scientists from 146 institutes



Accelerator Neutrino:

- Precision measure on oscillation parameters
- Mass Hierarchy
- Discovery of CP violation for leptons

Neutrinos from natural sources:

- Supernovae core collapse
- Atmospheric neutrino flux

DUNE FD:

- **LArTPCs** (Single Phase and Dual Phase)
- **4** cryostats, **10kt fiducial volume** each
- Commissioning
- First data

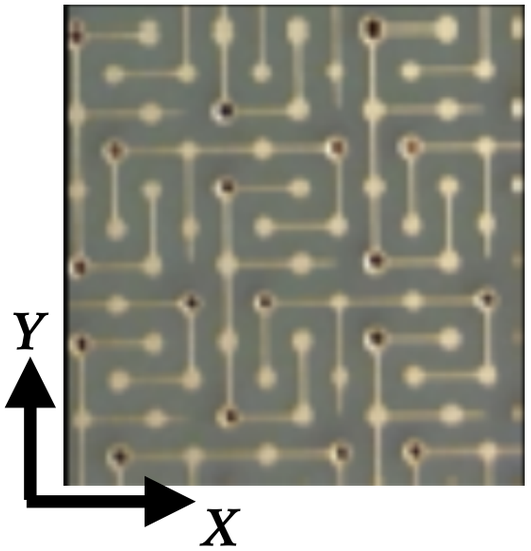
Prototyping efforts at CERN:

- Large scale tests of the LArTPCs and DUNE -FD design
- ProtoDUNE-Single Phase
- **ProtoDUNE-Dual Phase and WA105**

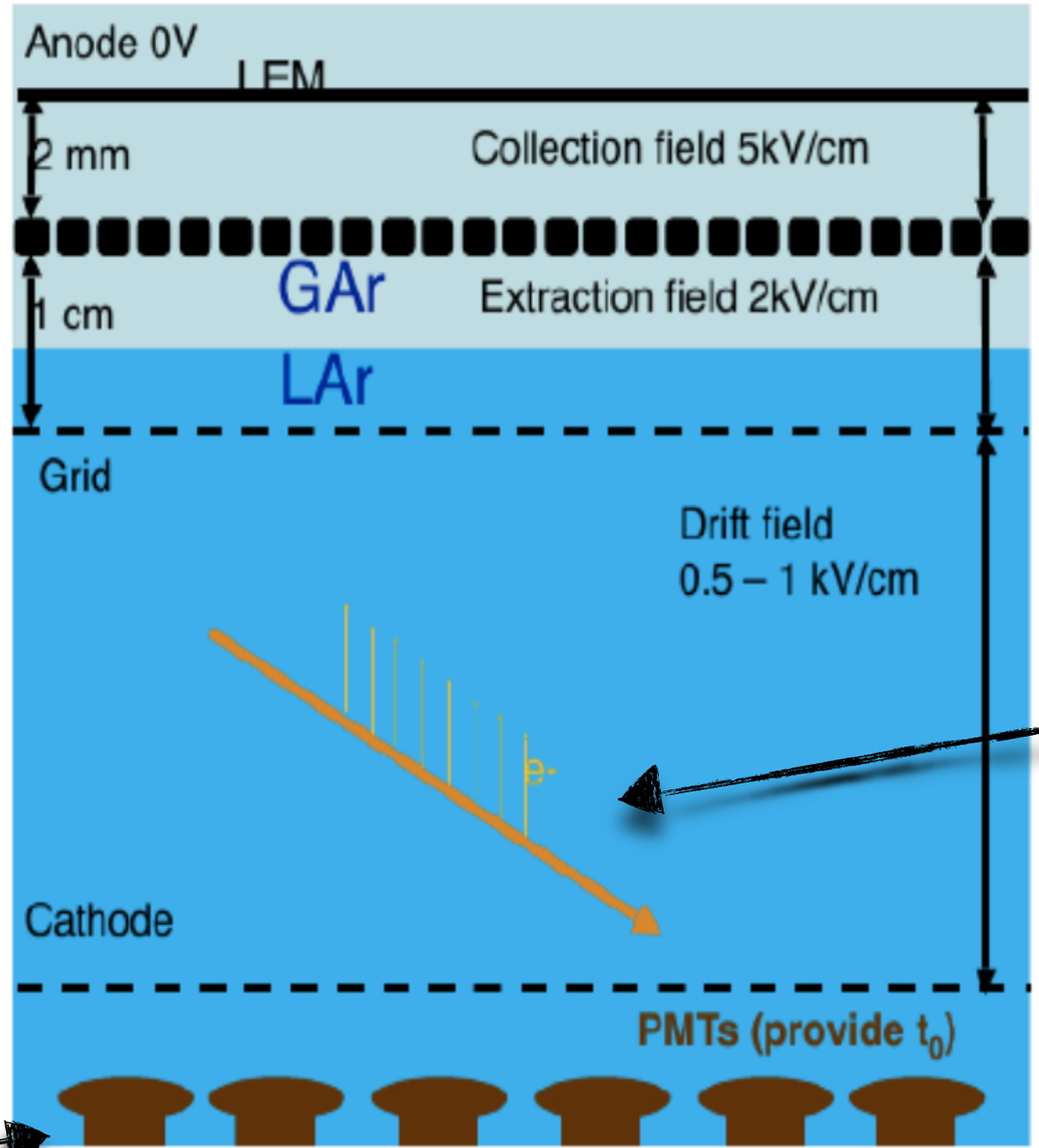
Dual-Phase working principle

Anode PCB

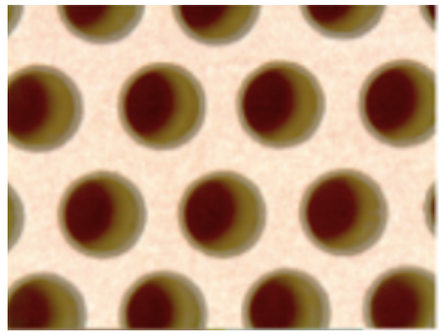
XY charge collection strips: 3mm pitch in each coordinate



Concept of Dual-Phase (not to scale)



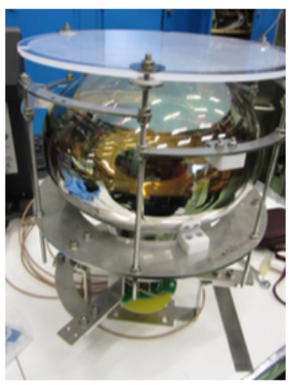
A LEM (Large Electron Multiplier) amplificate the signal before its collection



Charged particle interact with Ar (70% of energy into ionization, 30% into scintillation)

Ionization electrons drift thanks to a drift field (v ~ mm/us)

Scintillation photons are collected by the PMTs. t_0 of the event



Readout (LEM+Anode) has a modular structure with 3x3m^2 units. Easy scalable to multi-kt