Options and opportunities with the DUNE Near Detector

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LABORATORIUM FÜR HOCHENERGIEPHYSIK
LHEP
UNIVERSITÄT BERN

Disclaimer:
only the LAr TPC option addressed here

Motivations

Intrinsic benefits of using a LAr TPC for the DUNE near detector:

- Same neutrino cross-section as the far detector
- Argon's high density leads to increased statistics
- Efficient proton detection
- Ability to separate electrons and gamma

Issues related to high-flux particle beams:

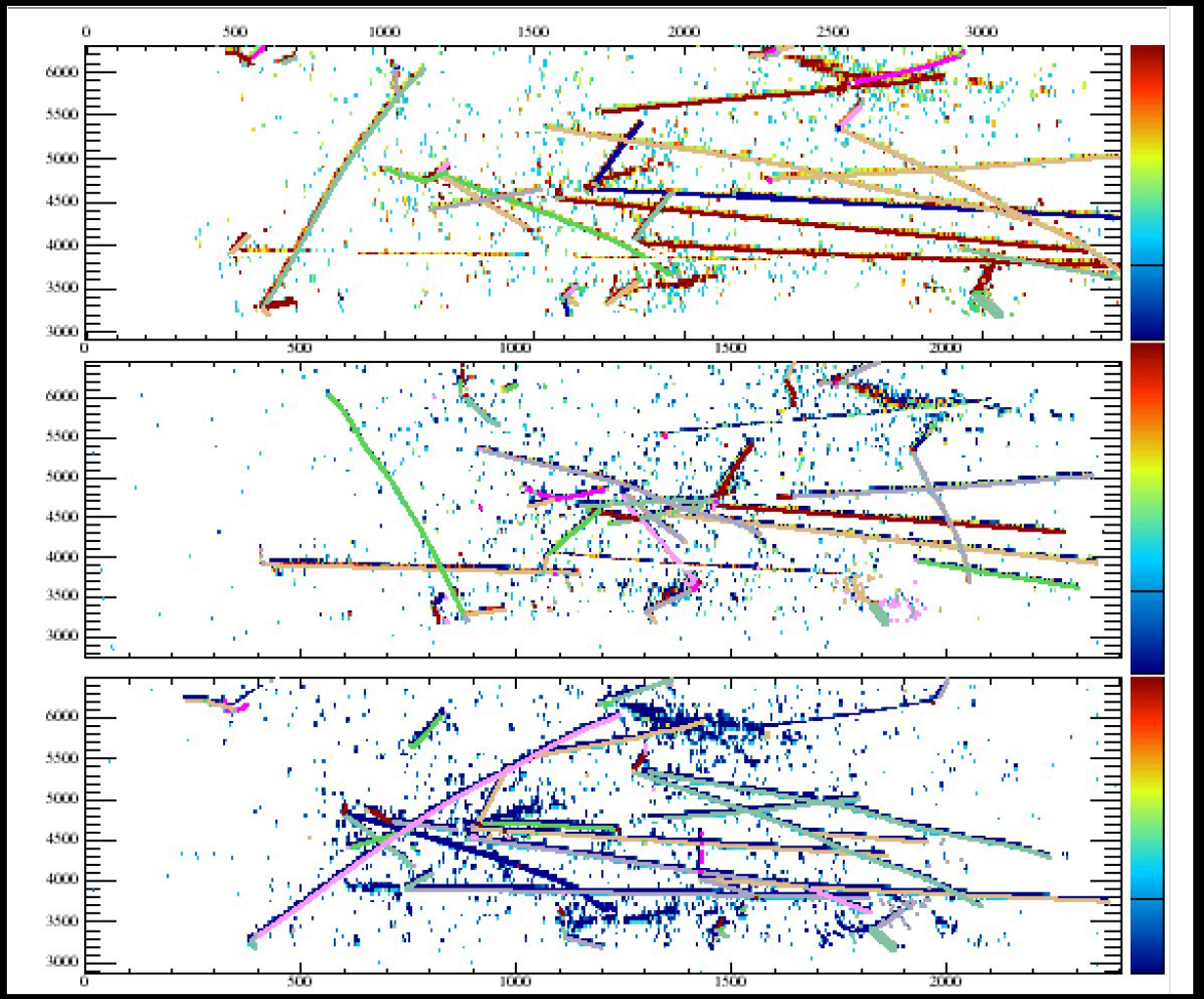
- Long drift-times lead to event pile-up
- Long drift-times also requires higher voltages and higher purity argon
- Unconfined scintillation light: more complicated coincidence trigger
- Event pile-up worsened by ambiguities on wire the readout system
- Inhibitive drawback: down-time cost involved in repair or upgrade work

Motivations

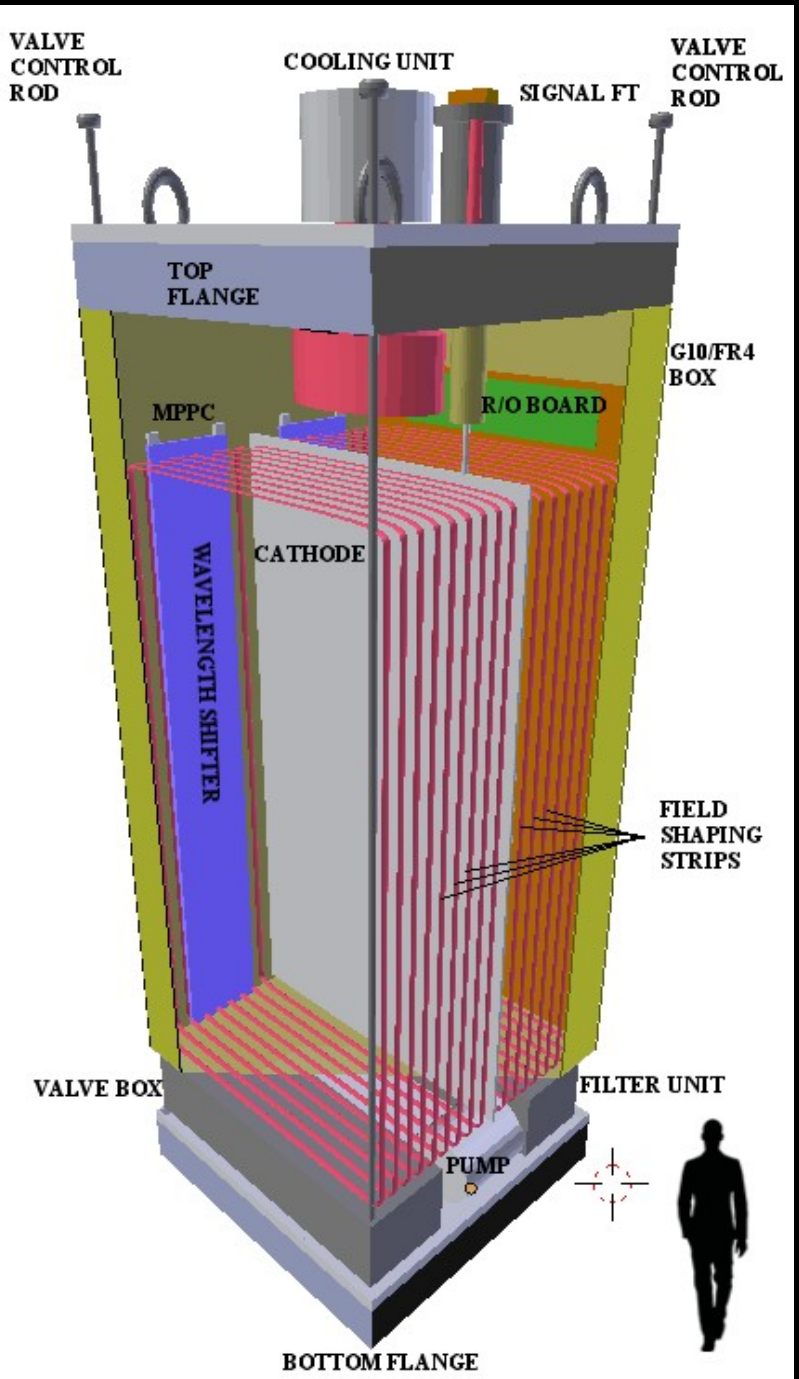
Proposal to overcome the potential problems:

- Propose the use of a modular TPC design with pixel-readout
- Modules separated into a number of self-contained TPCs
- Shorter drift-times: less stringent purity requirements and lower voltages
- Light contained with in each module, allowing for a more accurate trigger
- Modules continually upgraded without causing or costing significant down-time
- Pixel-readout: provide 3D readout, serving to reduced reconstruction ambiguity and enabling more advanced triggers

This is a typical ND event assuming the MicroBooNE detector



Sarah Lockwitz



The ARGONCUBE concept

- LAr purification: recirculation through Oxygen-traps
- Temperature: individual cryo-cooler unit
(removes heat input from electronics and heat leaks)

- Cathode bias (-100 kV) supplied via HV feed-through
- Resistive divider for field shaper
- Relatively low voltage => breakdown-free setup
- Electrically transparent container => low dead volume

- PCB-technology for R/O plane manufacturing
- Pad arrays for charge readout, *e.g.* 4x4 mm^2 pads
- 8x8 pads ROI served by one R/O ASIC at the PCB back
- Mechanically robust production technology
- Low failure cost

- Light collection via WLS light guides
- Light readout with SiPMs in coincidence

The present ARGONCUBE Collaboration

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Most of the people are already DUNE collaborators

For more information:

CERN SPSC LoI 243, 2015

Answer of the CERN SPSC:

*The Committee **received with interest** the Letter of Intent SPSC-I-243 describing the proposed R&D to assess the feasibility of fully modular liquid argon TPCs (ArgonCube).*

*The SPSC **encourages** the ArgonCube collaboration to conduct the first stage of the proposed project at the University of Bern. The Committee **expects** the first stage to investigate open questions such as LAr purity, detector mechanics, charge readout options, data compression and event reconstruction which should be answered before the collaboration considers submitting a proposal for future steps.*

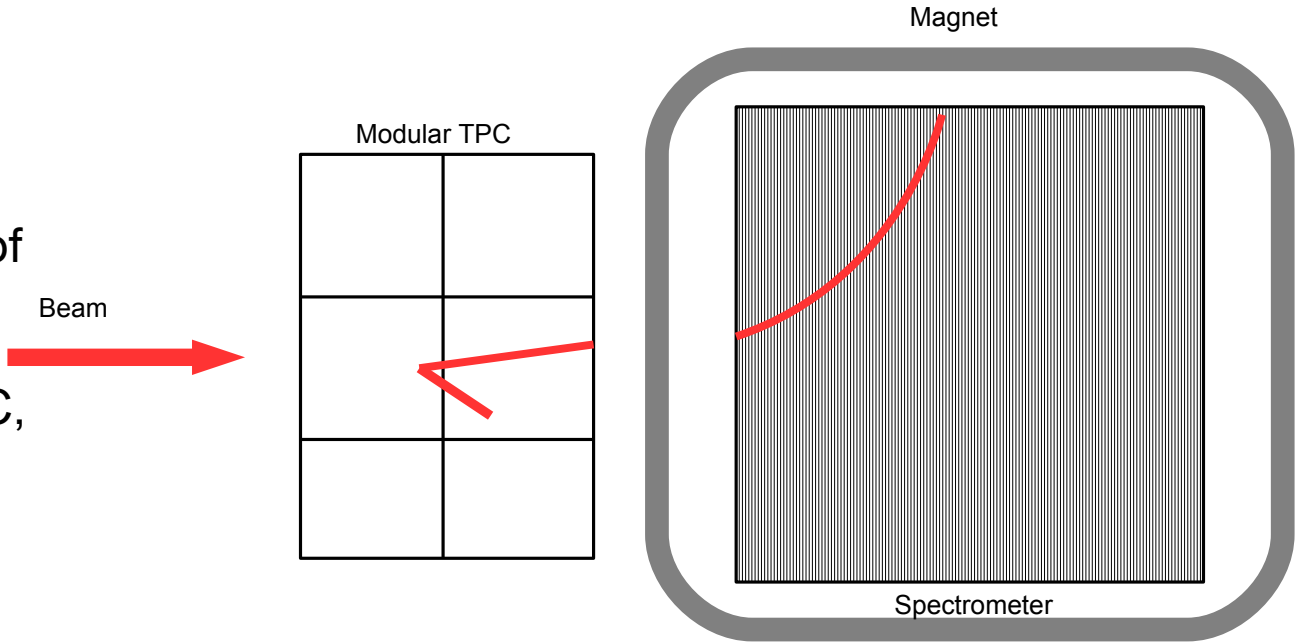
An ARGONCUBE detector for DUNE ND?

Options for DUNE ND: non magnetized LAr TPC

Hybrid detector.

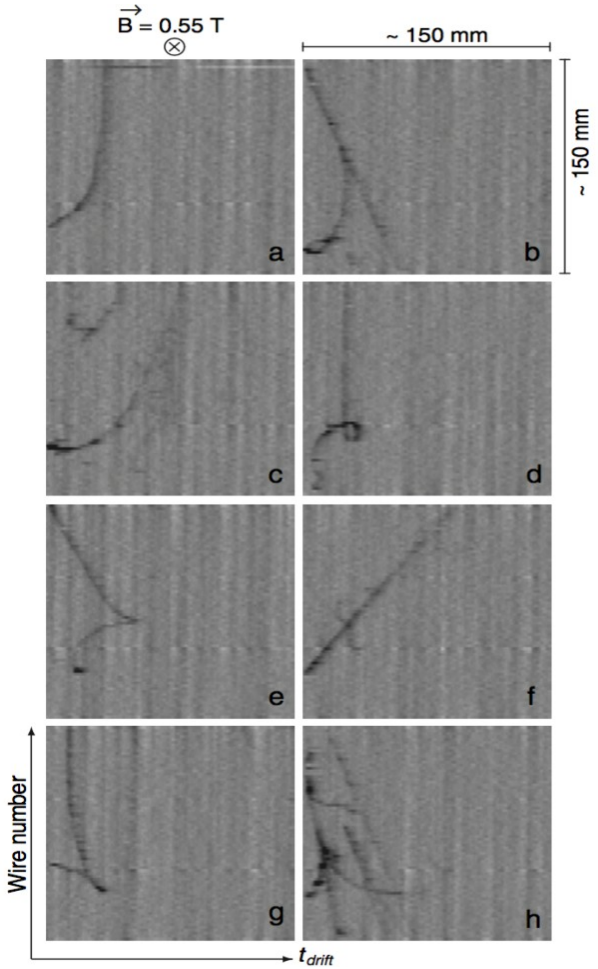
Modular LArTPC upstream of spectrometer.

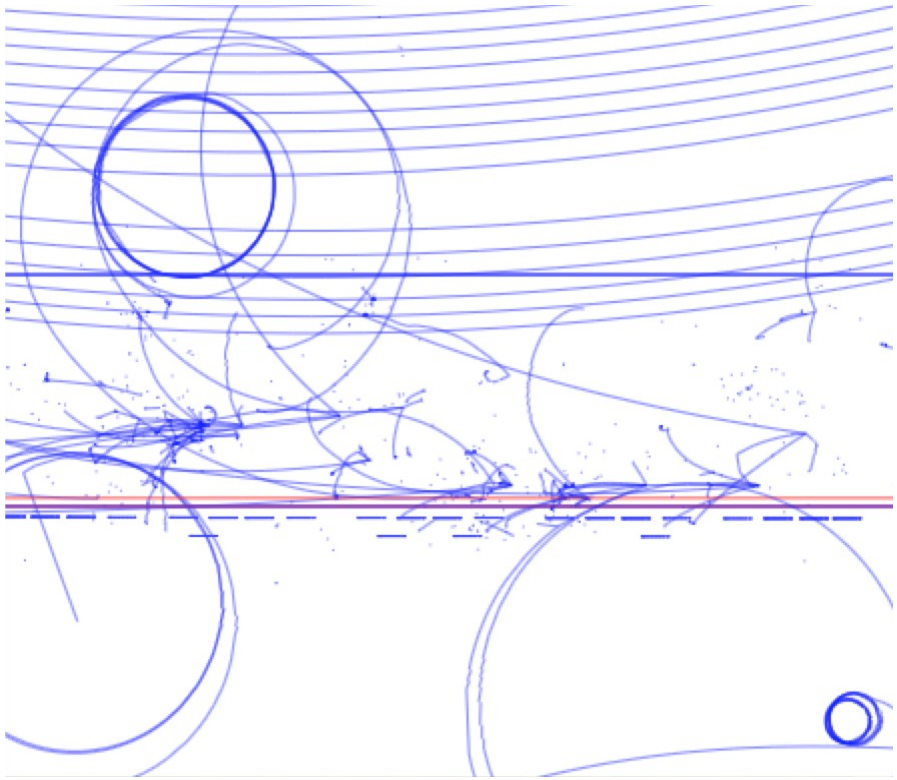
With only a 4 m long LArTPC, ~100t is achievable



Magnetize the TPC?

- Neutrino/antineutrino analysis – ID e+/- & μ+/-
- Momentum measurement less dependent on containment





Magnetized MicroBooNE

Real events collected with the LAr TPC in a B-field of 0.55 T.
A. Badertscher, et al. 2005

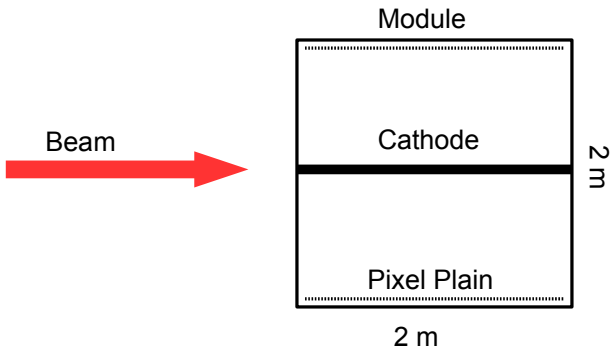
Options for DUNE ND: magnetized LAr TPC

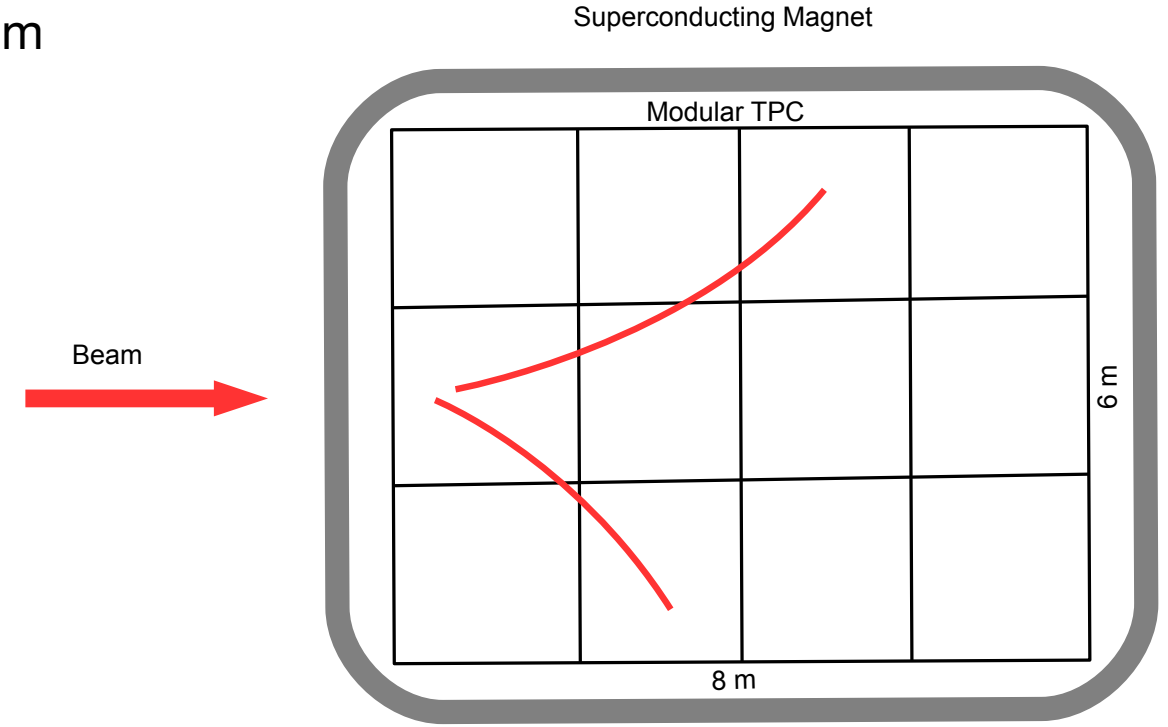
Modular TPC total 6 m x 8 m x 3 m
- ~ 200 t

Module 2 m x 2 m x 3 m.
- 1 m drift length

E-Field 100 kV

B-field 1T





James Sinclair and Martin Auger

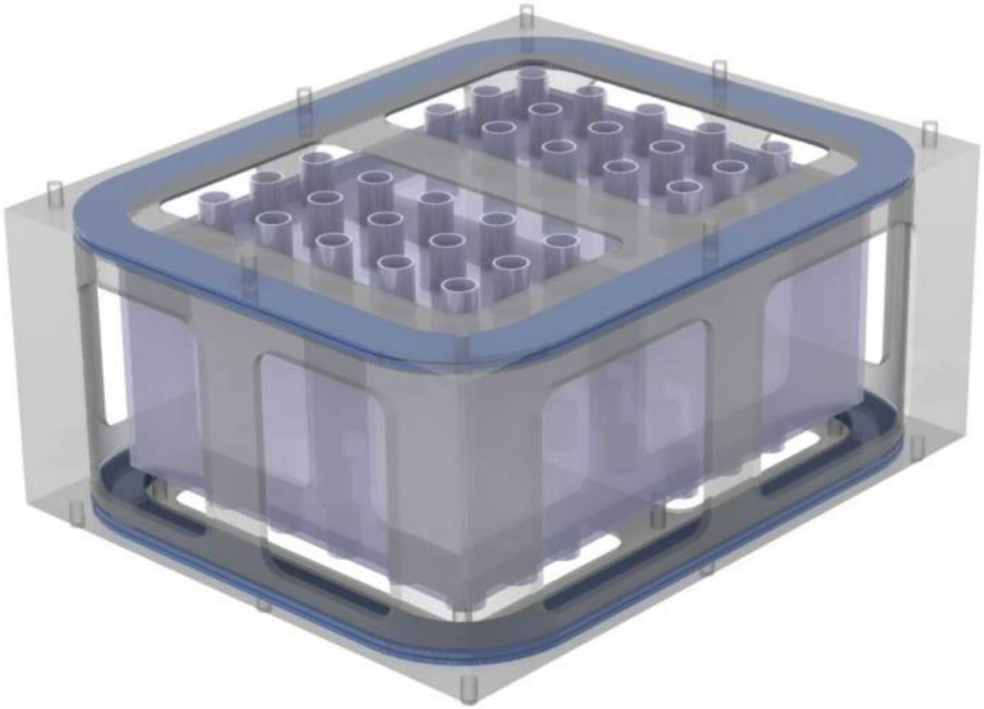
Modular LArTPC

Within superconducting Helmholtz coil

Unlike Solenoid, Helmholtz minimizes material surrounding TPC

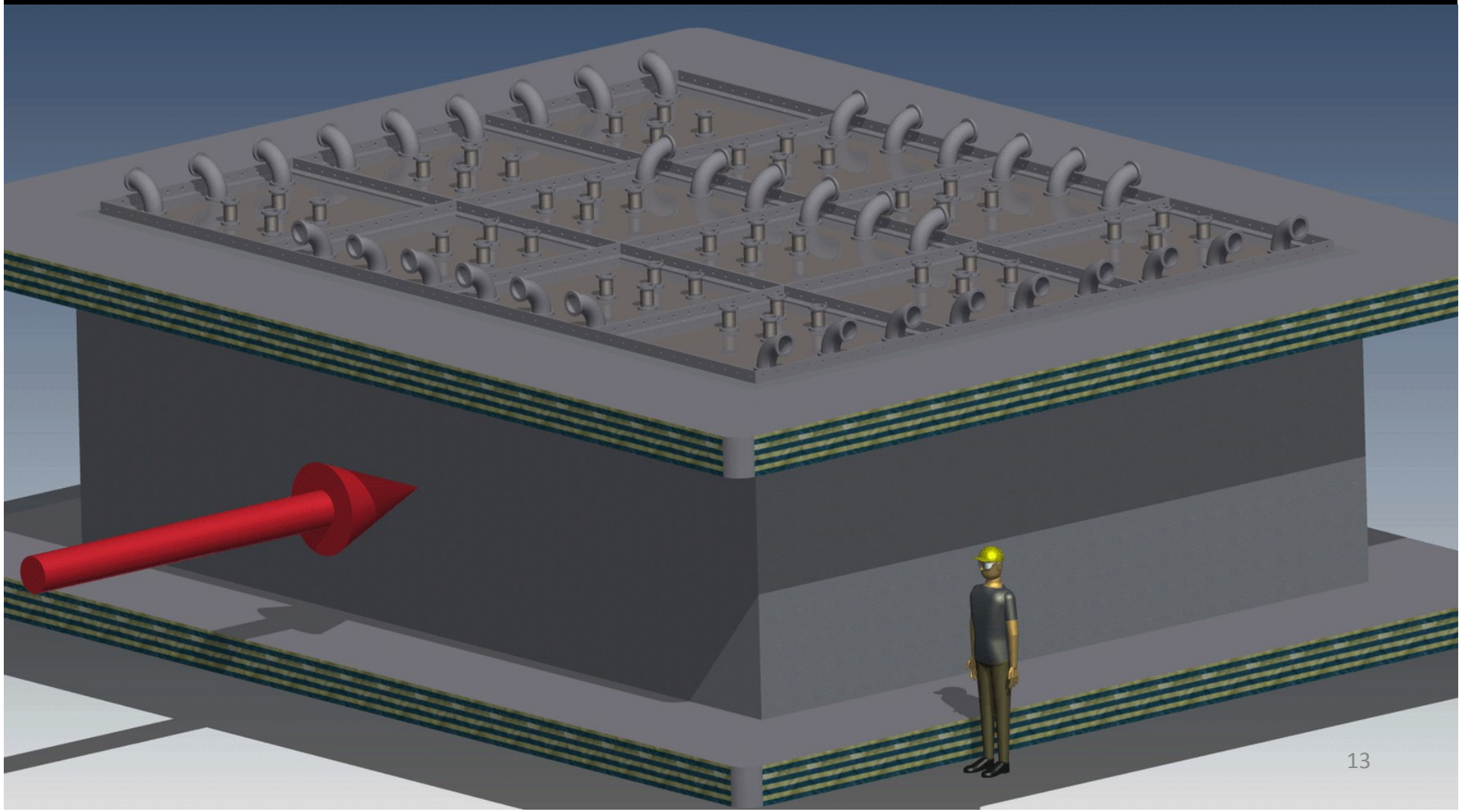
More info:
http://essay.utwente.nl/65557/

L.Y. van Dijk



Magnetized ARGONCUBE-like LAr TPC

SC Helmoltz coil



(non exhaustive) LAr TPC R&D shopping list

- Demonstrate modular concept: building ARGONCUBE modules
- Build a TPC with superconducting Helmotz coils
- Pixel readout: test different options; cost & power dissipation
- Prove pixel readout over long drift distances: building a prototype
- Novel light collection system (triggering)
- Cryogenics & ancillary modular systems
- Calibration system
- …

Need to establish an intense R&D program in view of the DUNE ND

Extend the present effort on ARGONCUBE to address R&D issues related to a LAr TPC option for DUNE ND

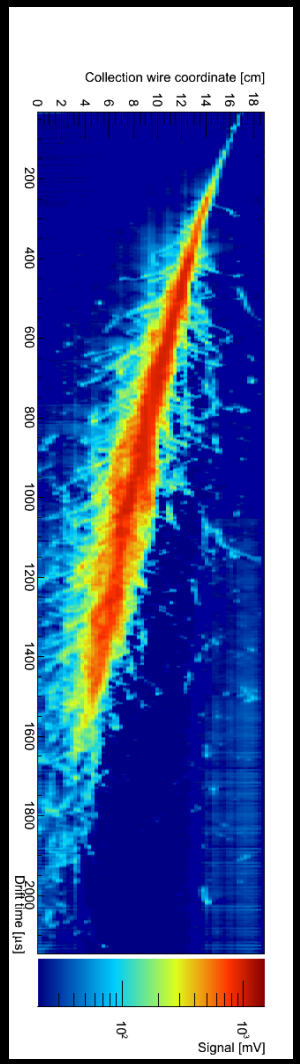
There-phase program:

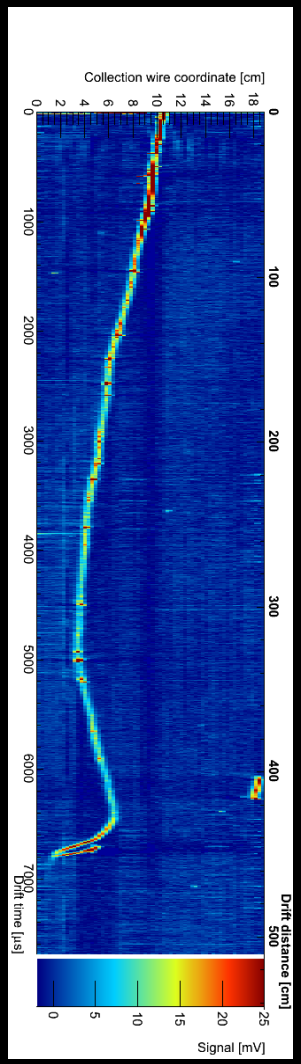
1) Study components, materials, test different technological solutions and realize a series of small-scale prototypes tailored to specific technology innovations for the modularity, the charge readout, operation in B field. Different aspects of the detector design to be addressed: mechanics, cryogenics, light detection and processing electronics.

2) Realize demonstrator devices (ARGONCUBE modules). Integrate components developed in combined tests of all the technologies with cosmic rays and define viable detector configuration for a larger scale implementation.

3) Perform a full performance characterization of the adopted solutions. On the basis of achievements from Phase 2 design a full-scale ND detector.

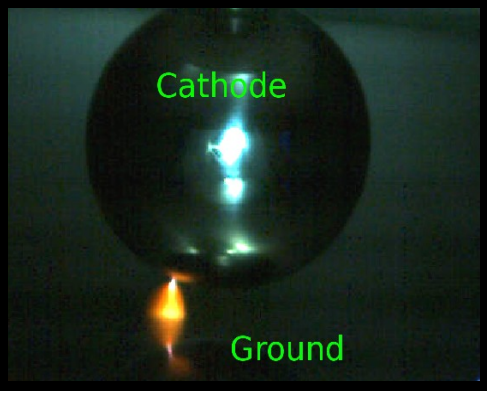
Examples of R&D activities currently in progress at LHEP-AEC Bern

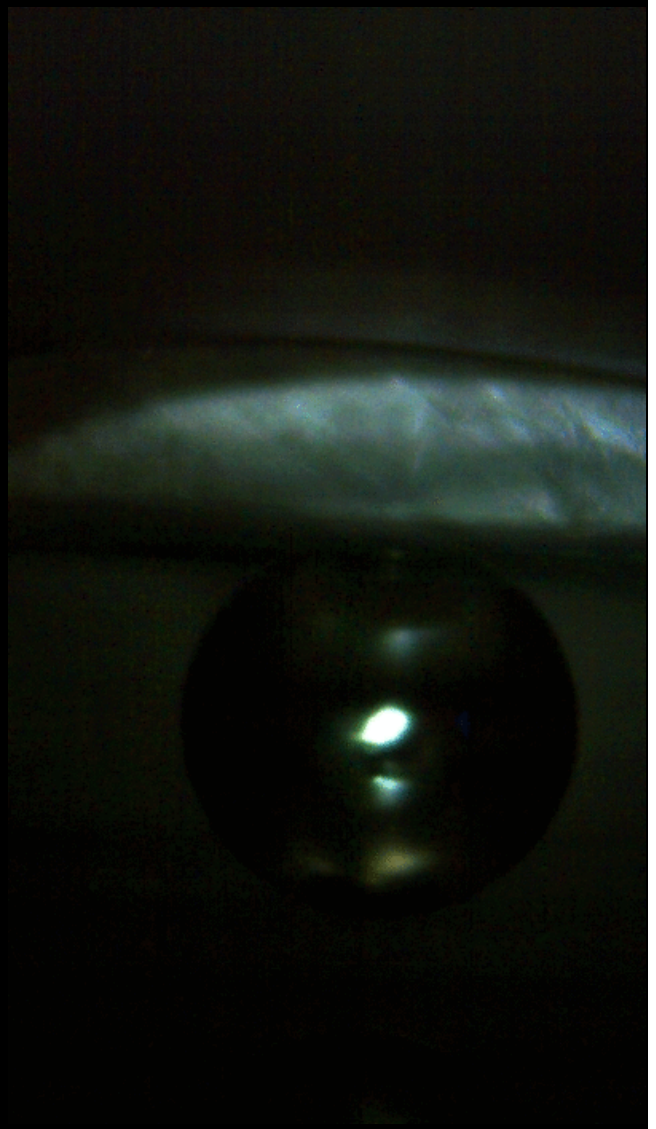




Measurements of electric rigidity of LAr

- Maximum voltage initially reached in ARGONTUBE: 120 kV due to breakdowns in LAr.
- Unexpected behavior: assumed dielectric strength of liquid argon of ~2 MV/cm
- Such a high value obtained from measurements at a small anode cathode gap (~100 microns). Does not hold for large distances (centimeter scale).
- Theoretical understanding: positive feedback in the ion accumulation process in the vicinity of the cathode.
- Additional measurements. Movie: breakdown in liquid argon between spherical cathode of 5 cm in diameter and a plane anode at 100 kV.
- Based on our understanding: coating the cathode with a slightly conductive dielectric layer (natural poly-isoprene) allowed reaching record performance of 400 kV, corresponding to a drift field of 800 V/cm, for 5 m long drift distance.

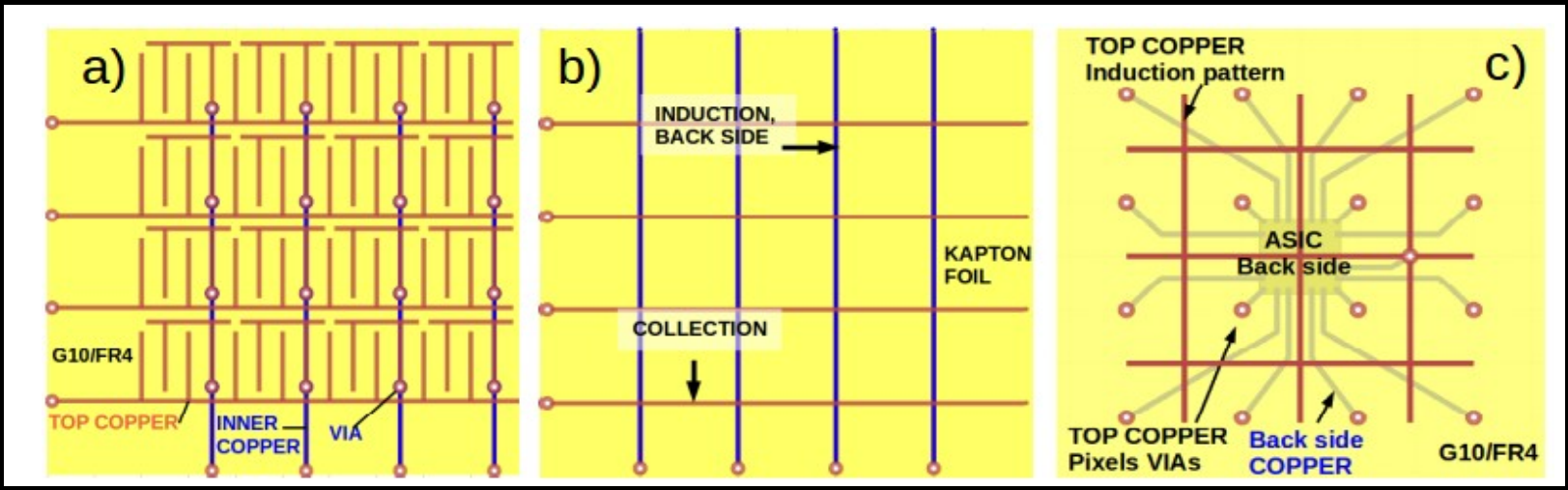




Igor Kreslo

Future activities

Pixel readout

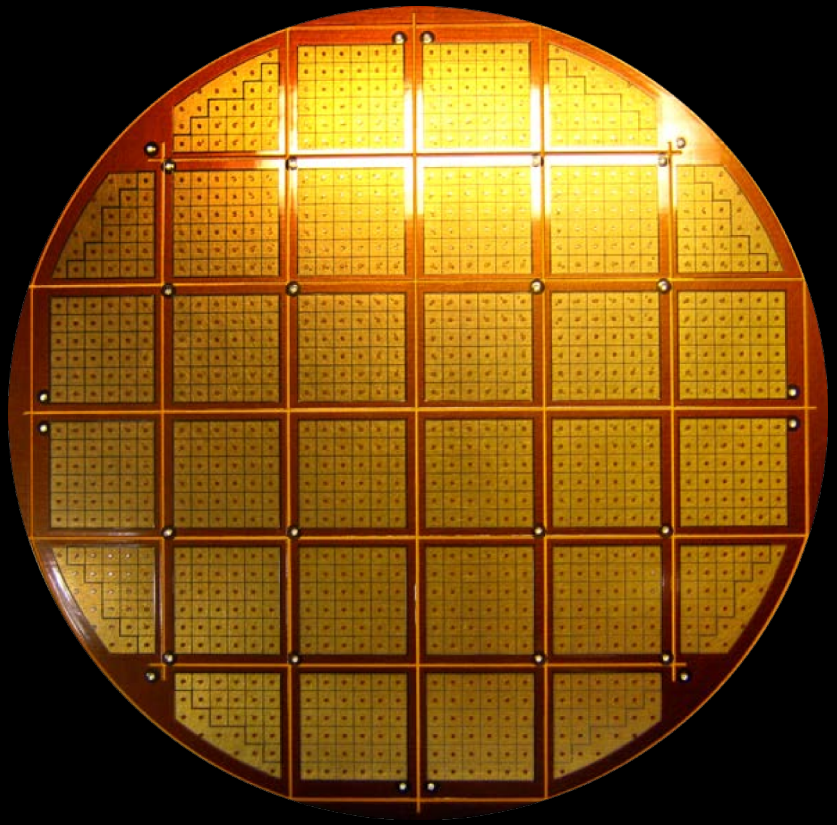


a) collection-only projective one-sided scheme: pattern made of thin strips on a thick substrate with 50/50 charge sharing.

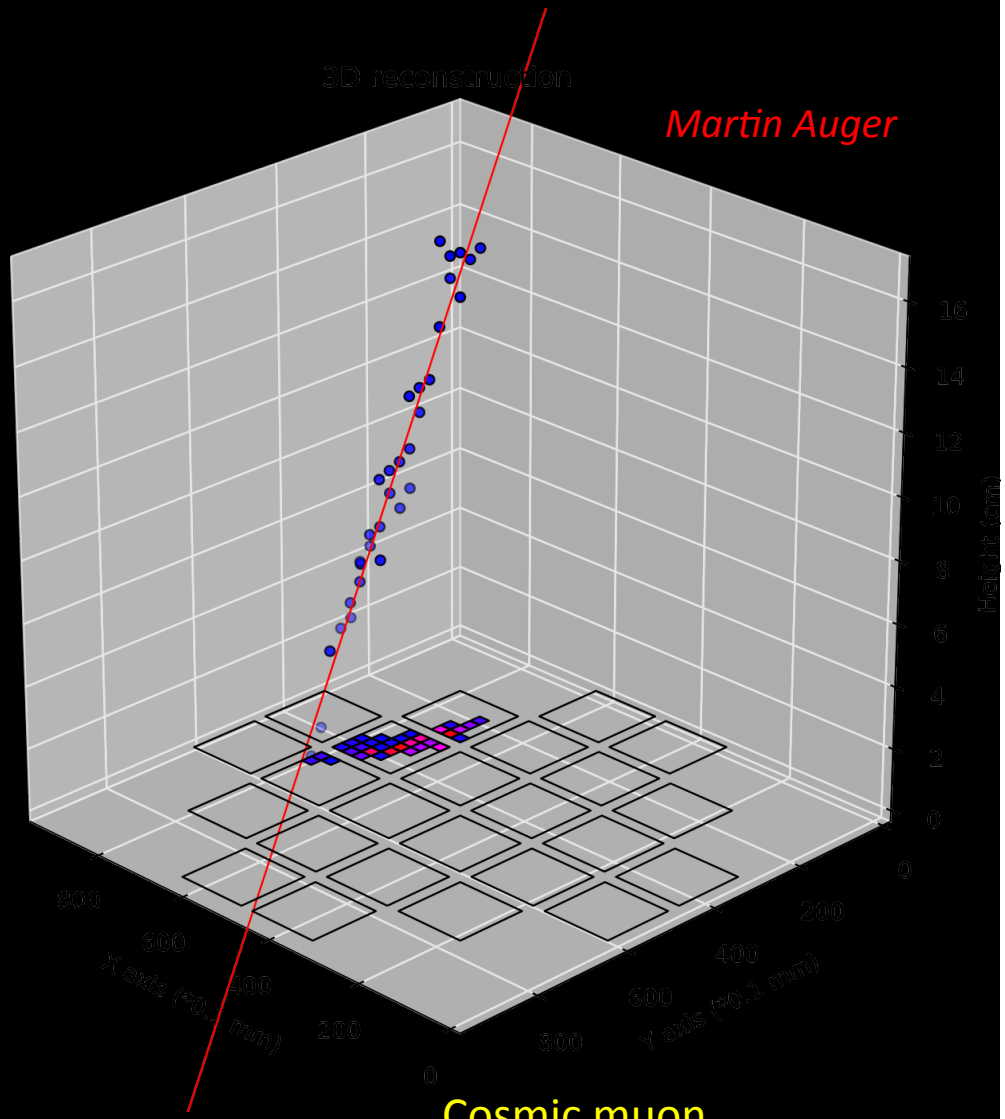
b) A projective double-sided scheme on a thin dielectric foil.

c) A pixelated scheme with an ROI induction grid; one such ROI is with 4x4 pixels (circles).

First results (gas TPC)

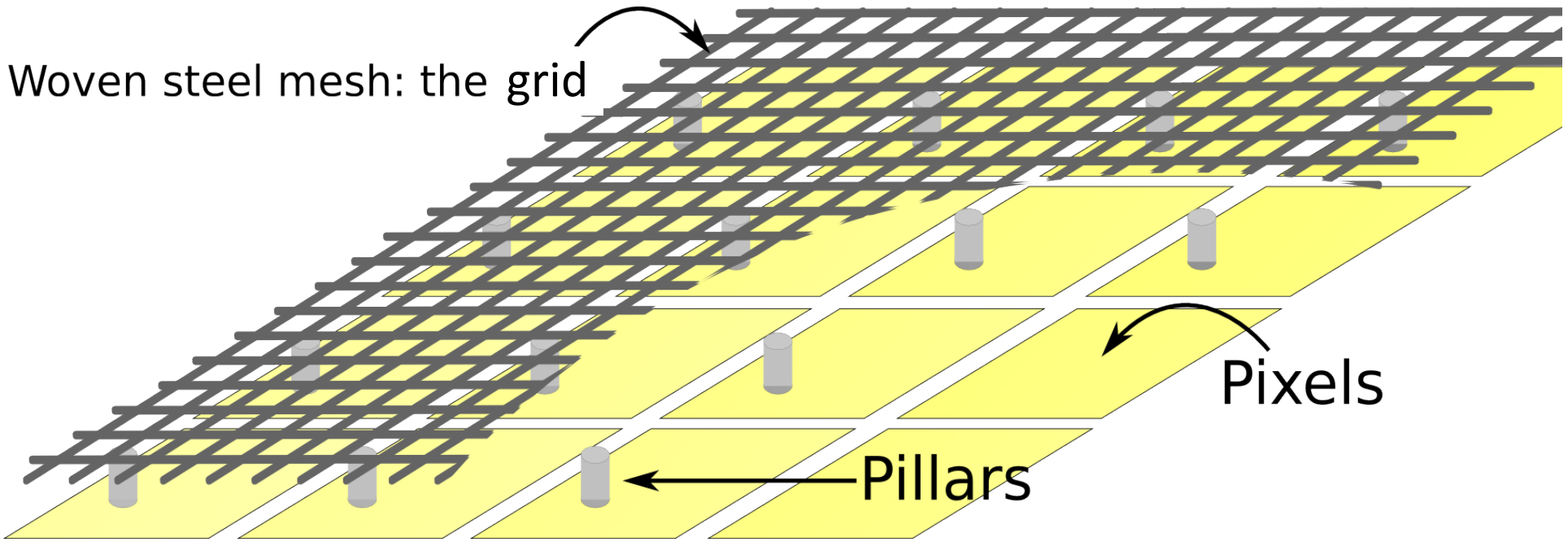


MicroMegas (ROI)

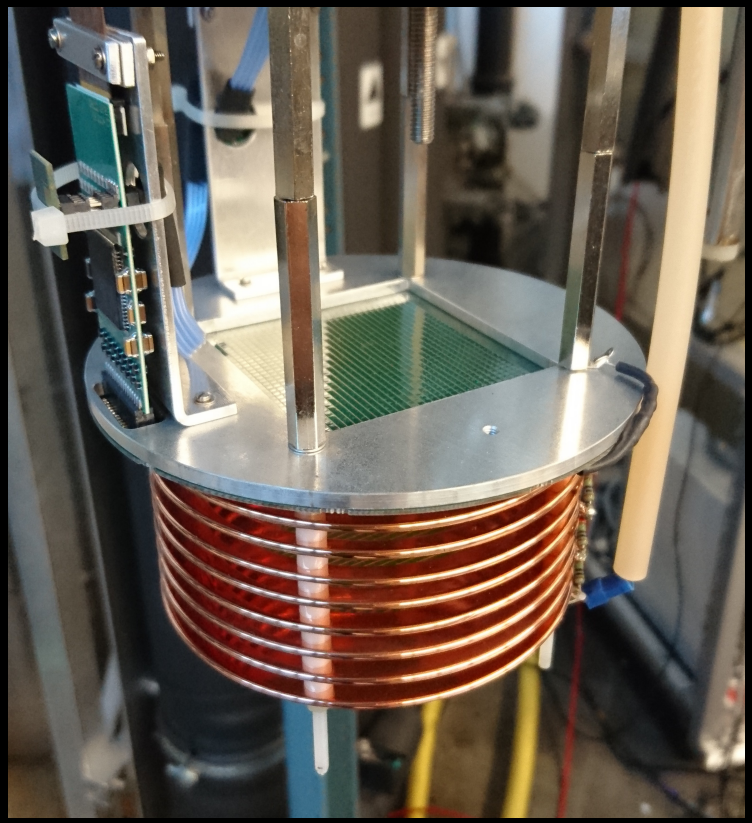


Cosmic muon

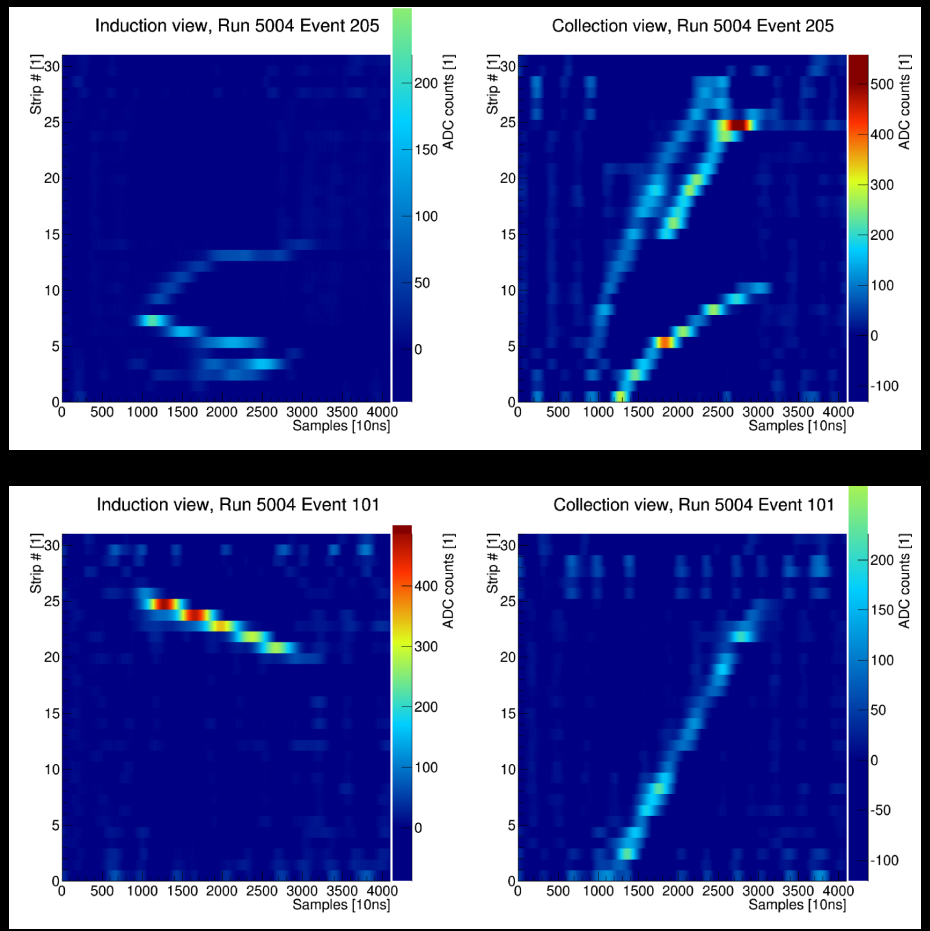
MicroMegas: principle



Small LAr TPC, 2-sided strips on PCB

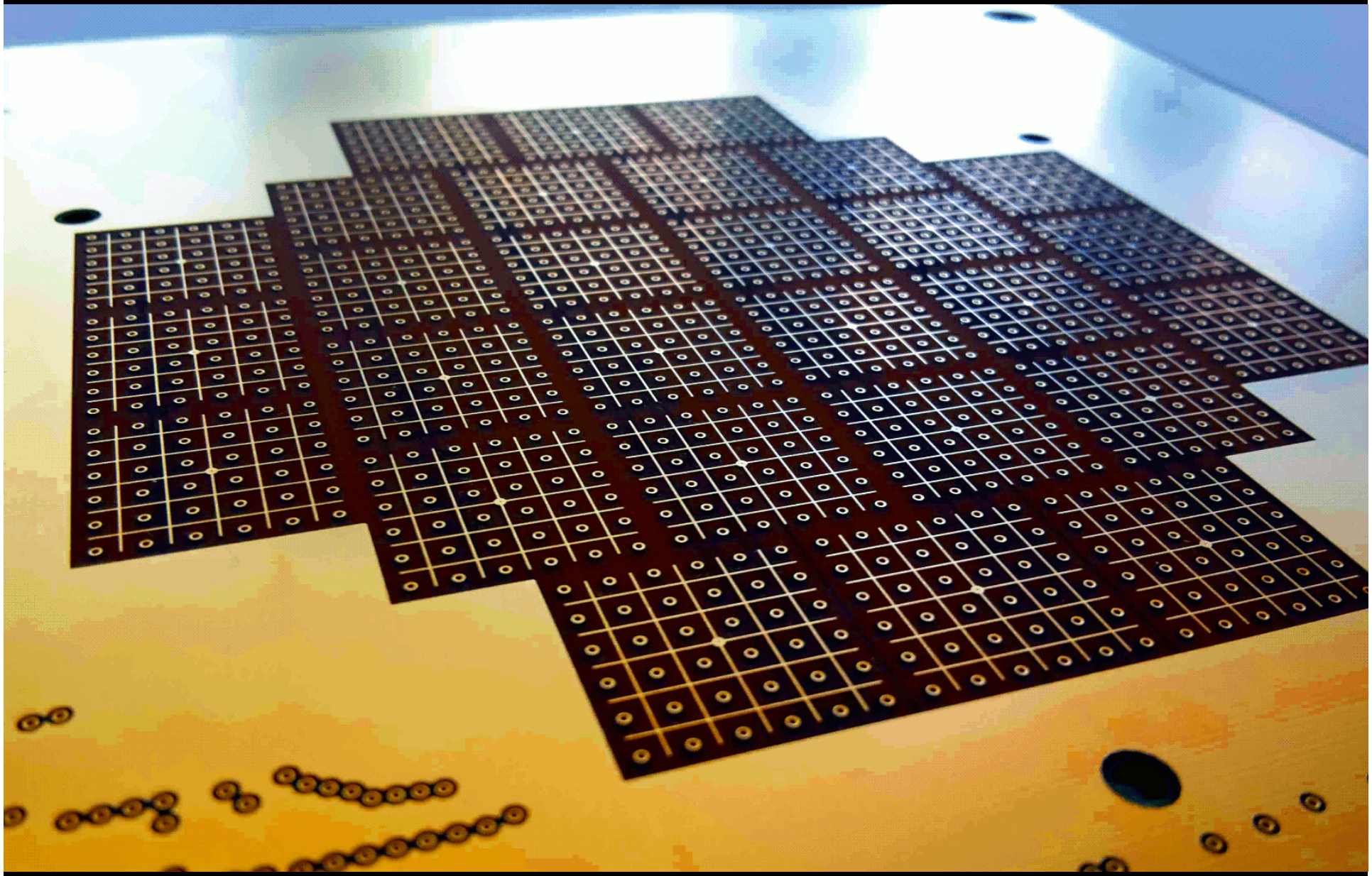


Damian Göldi

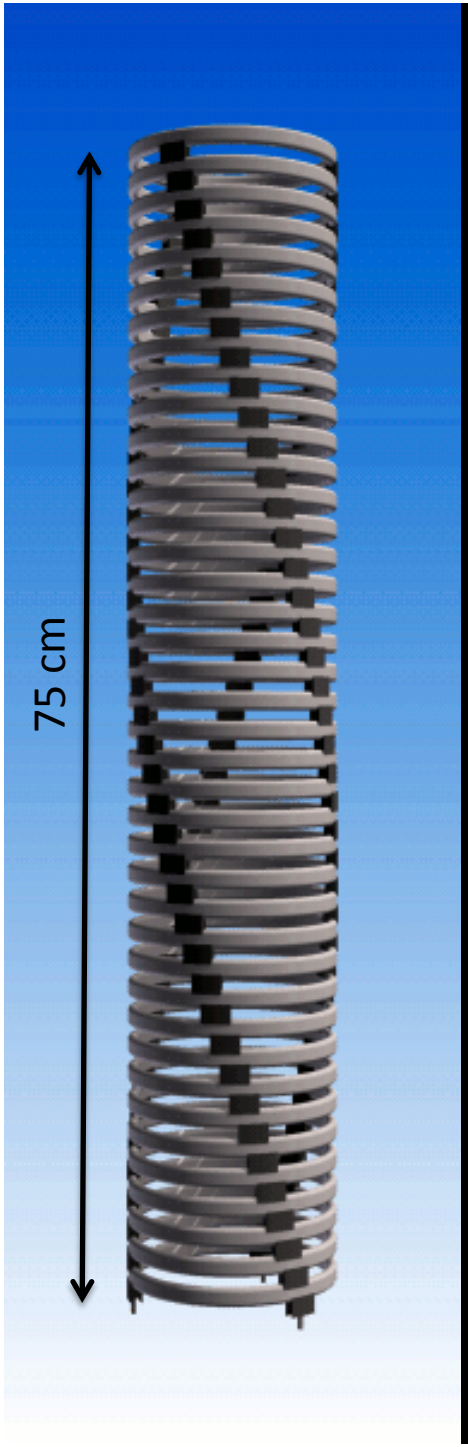


Cosmic muons

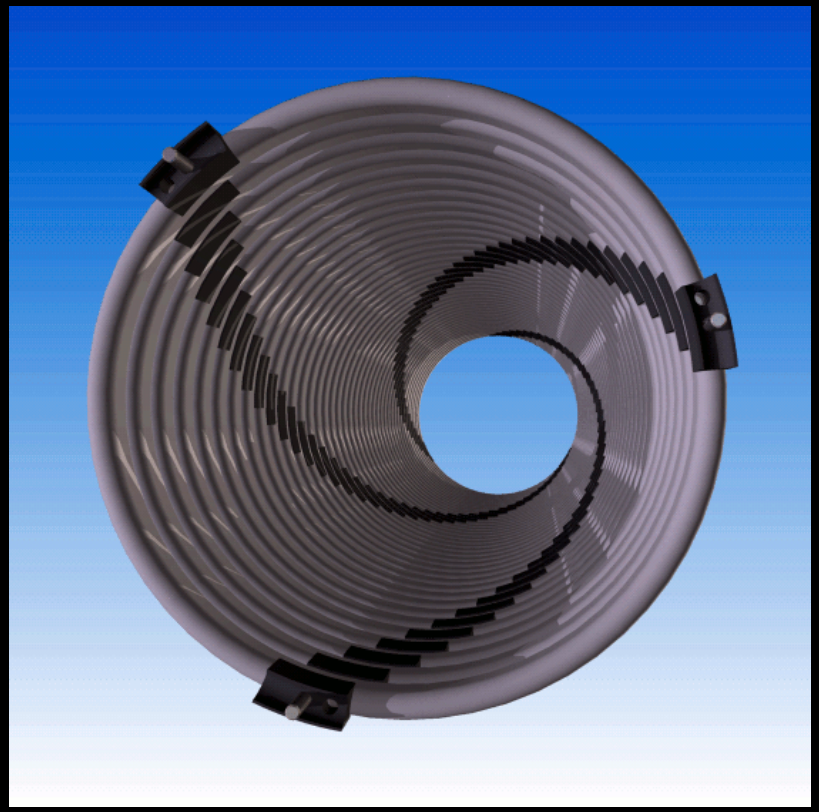
New pixel board: 1-sided for future TPC prototype

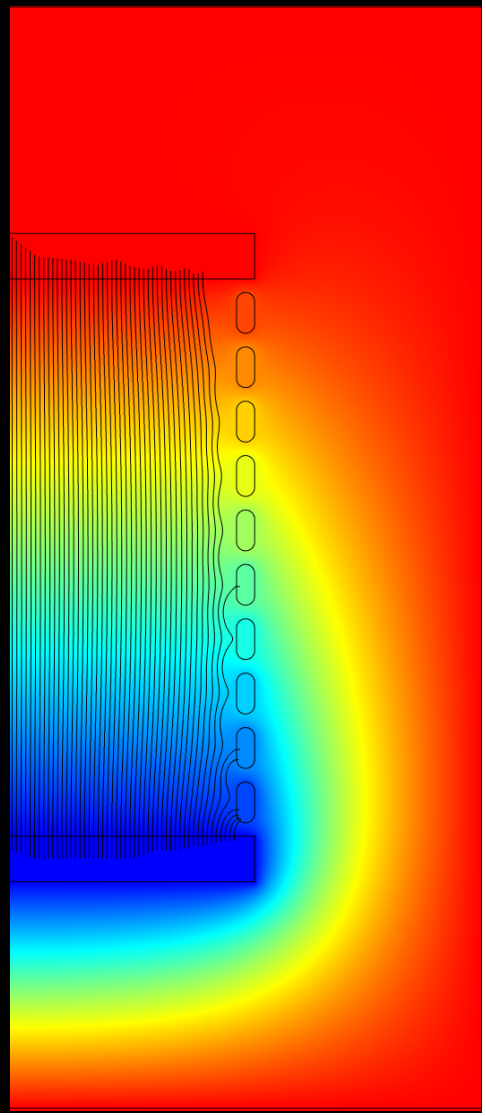


Prototype TPC being built: verify "long" drift with pixel readout

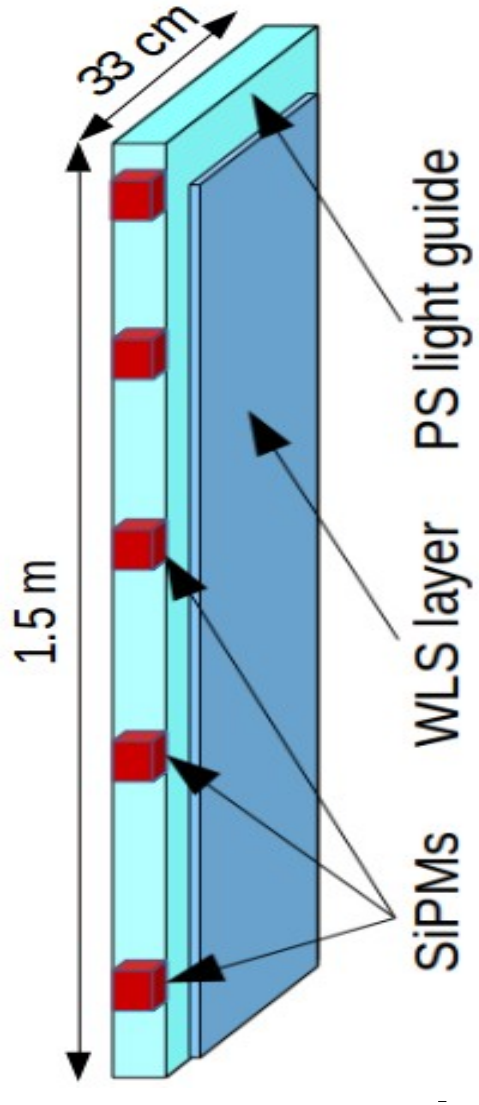


Francesca Stocker and Martin Auger





Light collection system



Scintillating light in the ARGONCUBE modules:

two planar acrylic light guides with layers of wavelength-shifter deposited on their surfaces (one per drift volume) placed on each side on top of the field shaping copper pattern, parallel to the drift field.

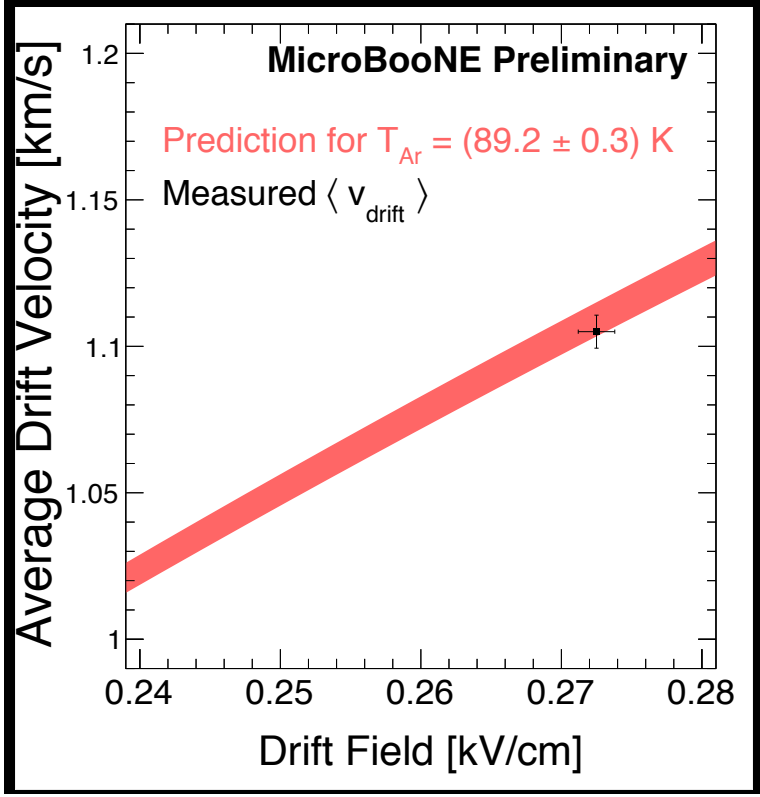
UV-laser calibration system

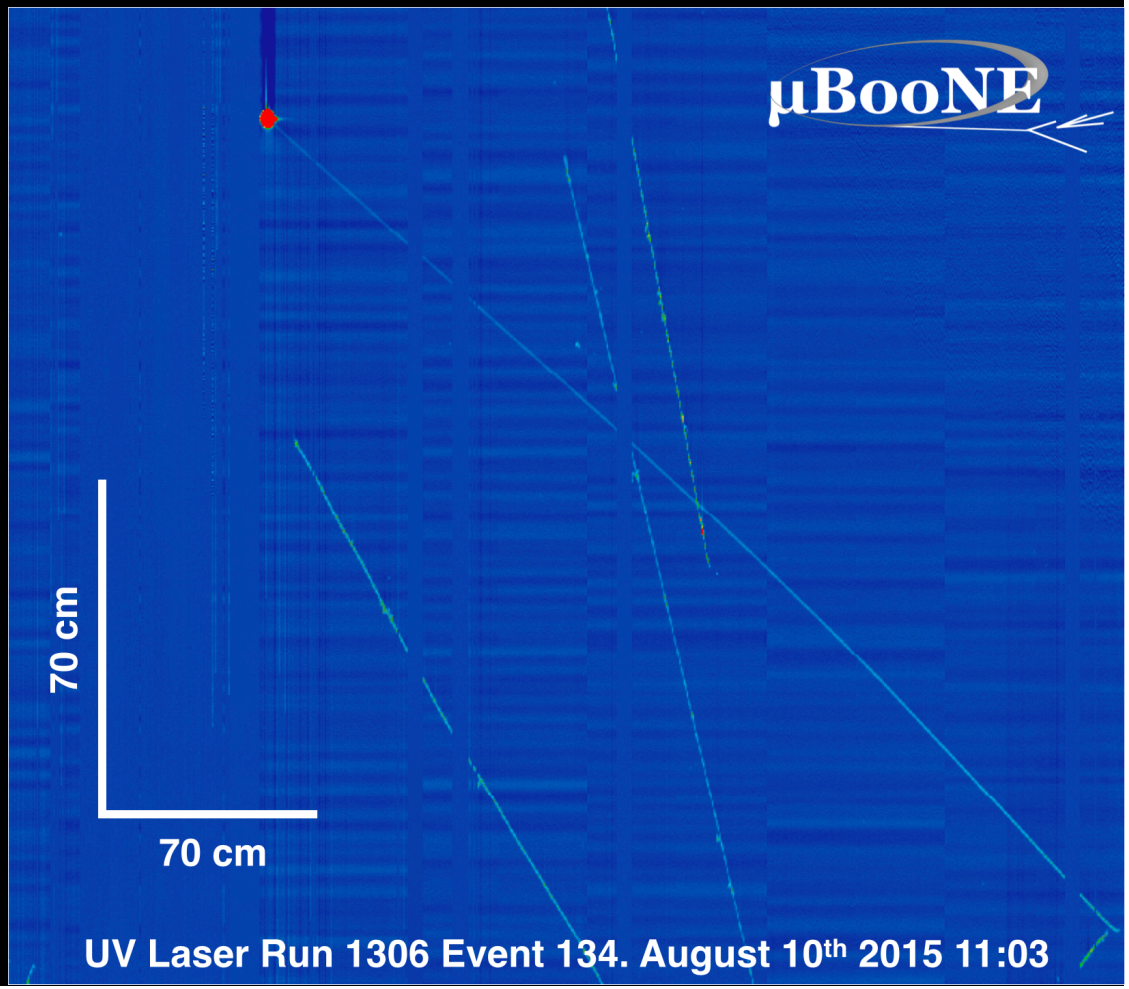
Technique pioneered at AEC-LHEP:

2009 JINST 4 P07011
NJP 12 (2010) 113024
JINST 9, T11007 (2014)

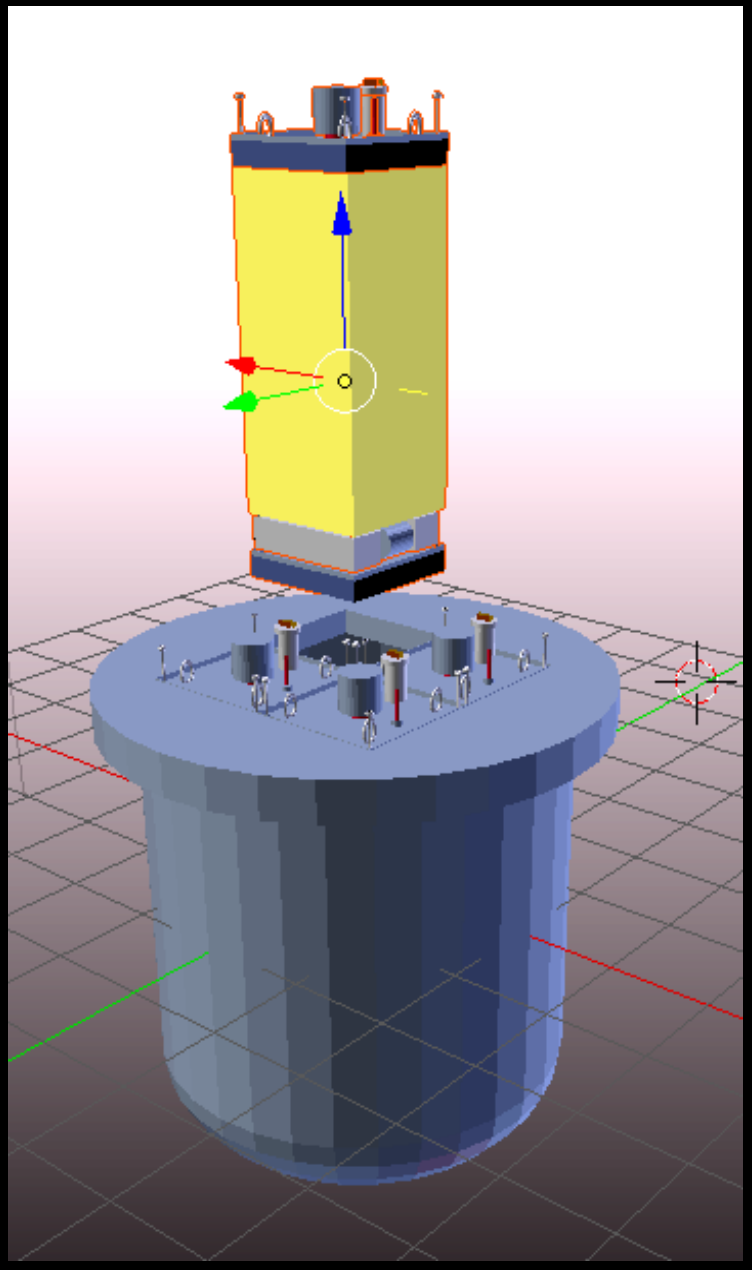
UV-laser calibration system:

- successfully applied to MicroBooNE
- being built for SBND
- being planned for DUNE FD





Phase 2 activities



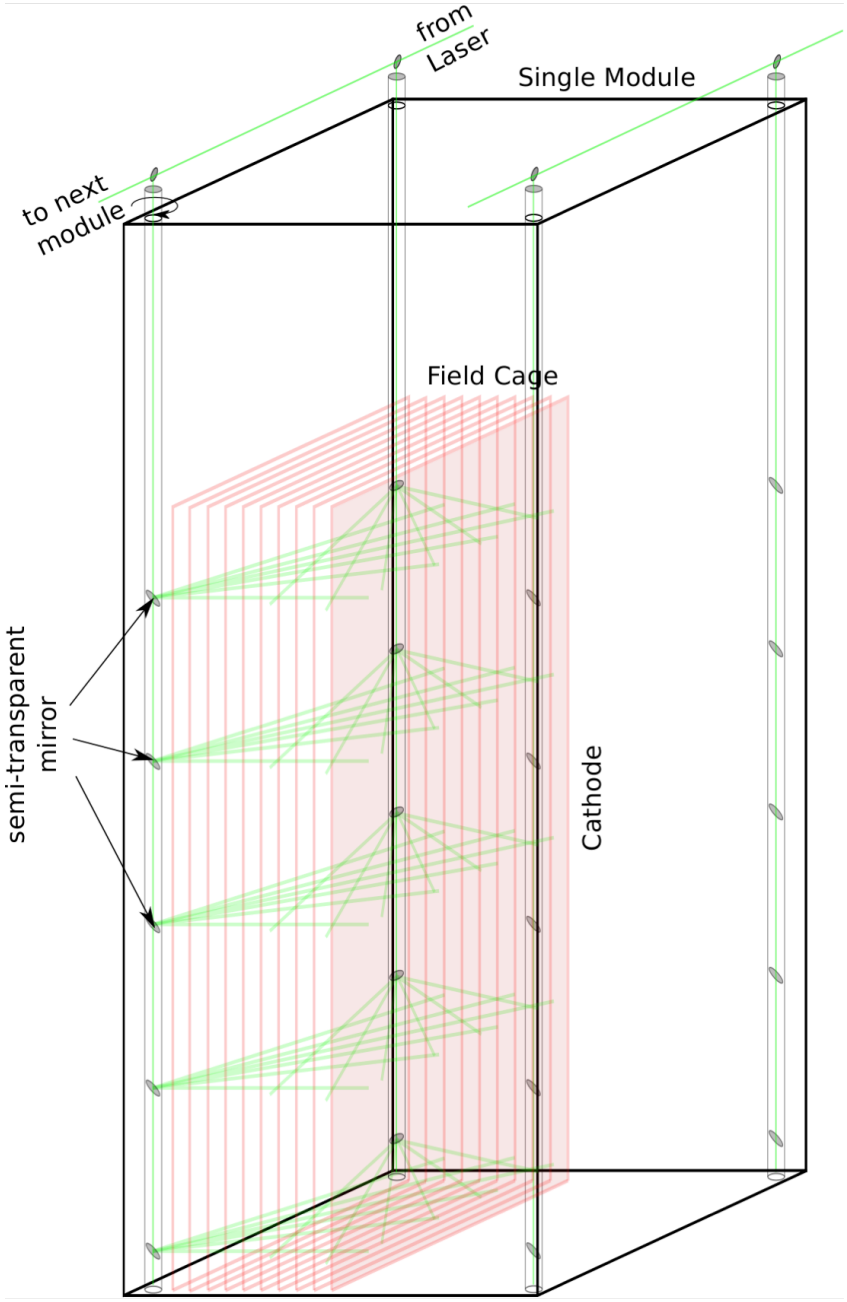
Igor Kreslo
Martin Auger
Dimitar Mladenov
Diamanto Smargianaki
Roger Hänni

UV-laser system for the ARGONCUBE modules

- Three independent laser systems, distribution between modules via beam splitter and semi-transparent mirror

- Introduction to module through optical feedthrough (analogous to MicroBooNE) at the corner of the modules

- Semi-transparent mirrors in liquid argon mounted on rotatable structure.



Build one reference module with wire readout

Neil Spooner

Wire frame for wire mounting (Sheffield group)

Remarks

- A LAr TPC is an asset for the DUNE ND
- Both options in/out magnetic field being considered/simulated/tested
- Detector choices/configurations cannot rely only on simulations
- A vigorous R&D program must be set up for all options: the only way to know how a technology works is to build and operate prototypes
- Extend the long-standing R&D program carried out in Bern since a decade
- Long shopping list of activities for the next years
- Interesting results already being obtained
- The plan is organized in three phases
- The ARGONCUBE design is a viable solutions
- Need strong collaboration of international (European?) partners