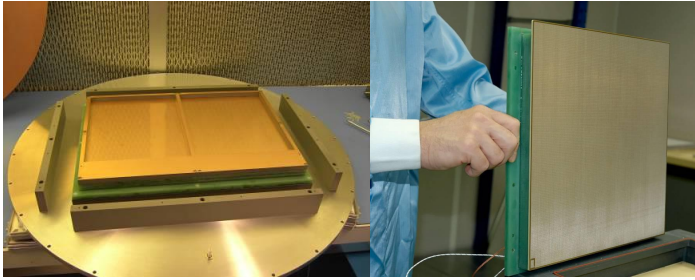


# Neutrinos@IFAE

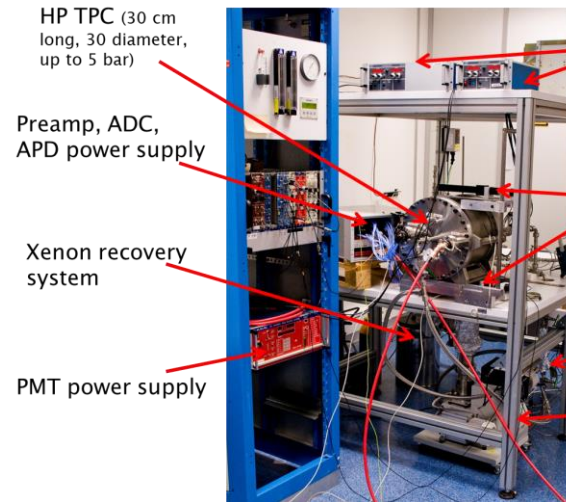
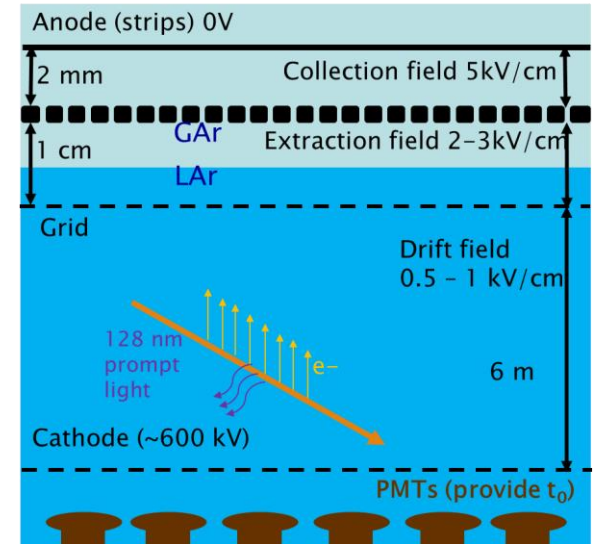
## Detector R&D

Thorsten Lux



Gas detector R&D with MPGD (MM & GEM) readout

LAr TPC R&D



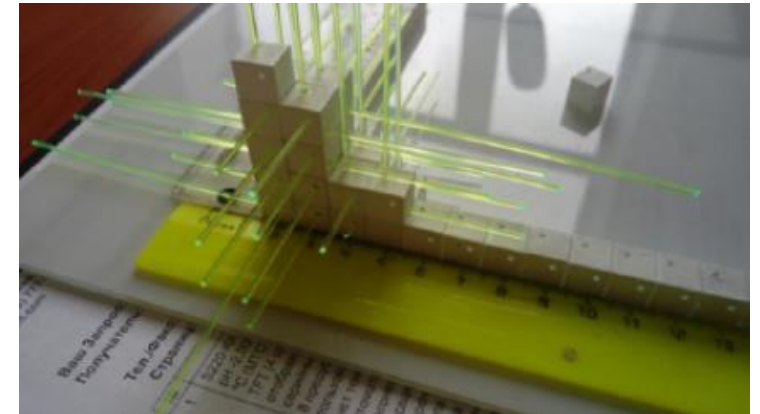
HV power supplies (20 and 35 kV)

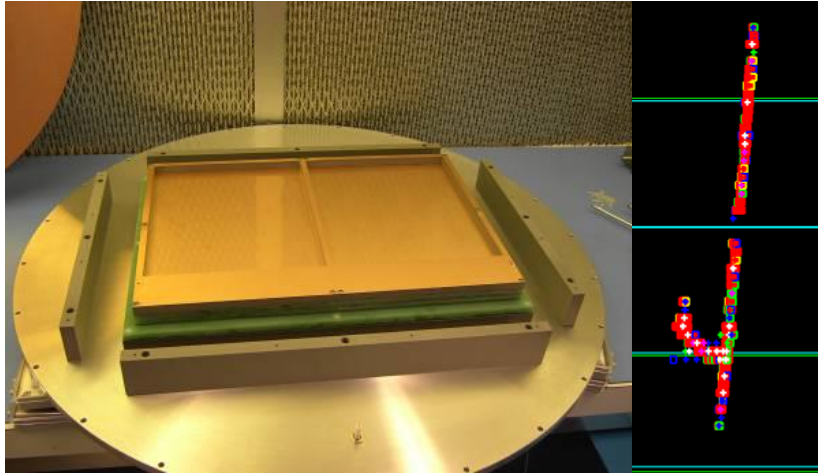
Cosmic ray trigger

Getter

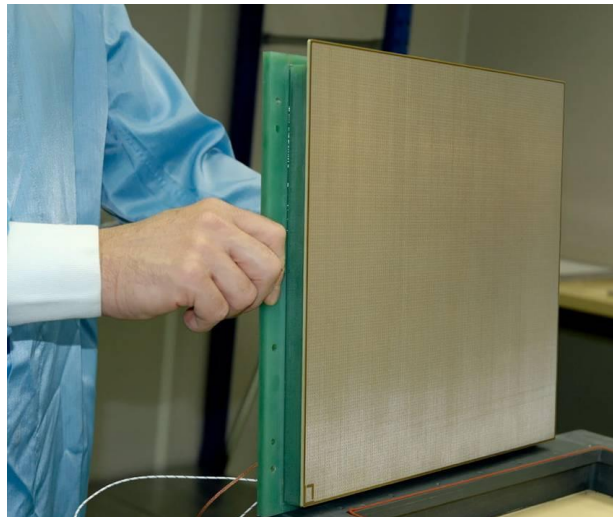
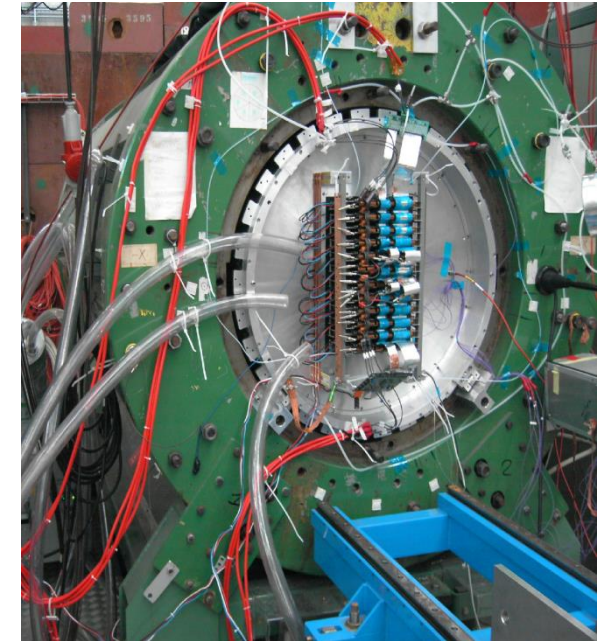
Gas detector R&D with light readout

Plastic scintillator detector R&D

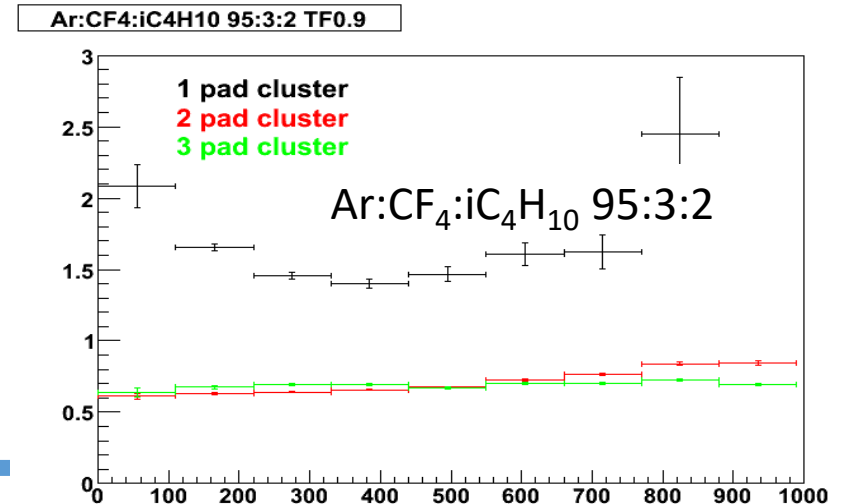




- Started in 2005 with MPGD R&D for TPC readout
- First time with more than one MPGD readout module
- Technologies: GEMs and Bulk Micromegas
- Gas choice simulations

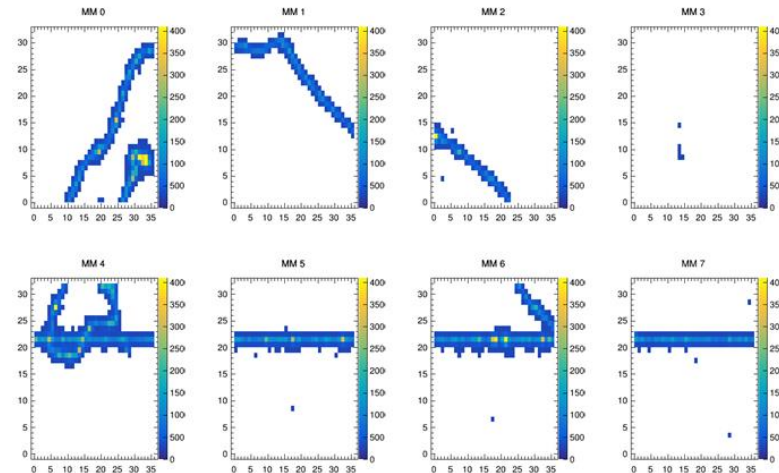
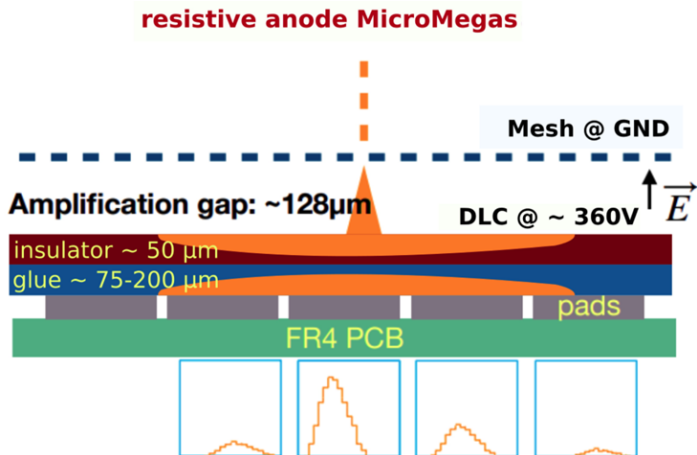
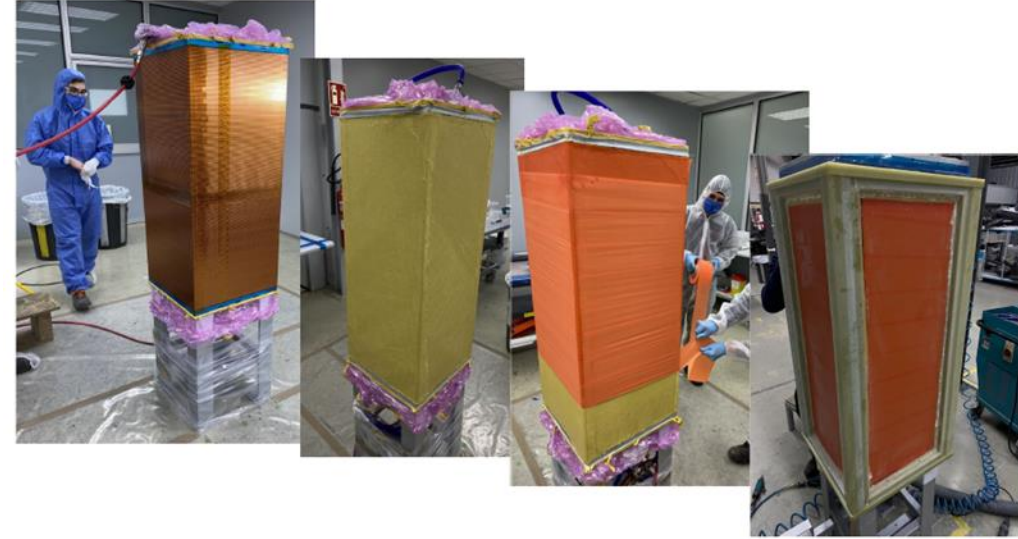


- Experiment: T2K ND280
- First full size TPC with MM readout
- Collaborators: INFN Bari, UniGe, IFIC, Saclay, RWTH Aachen

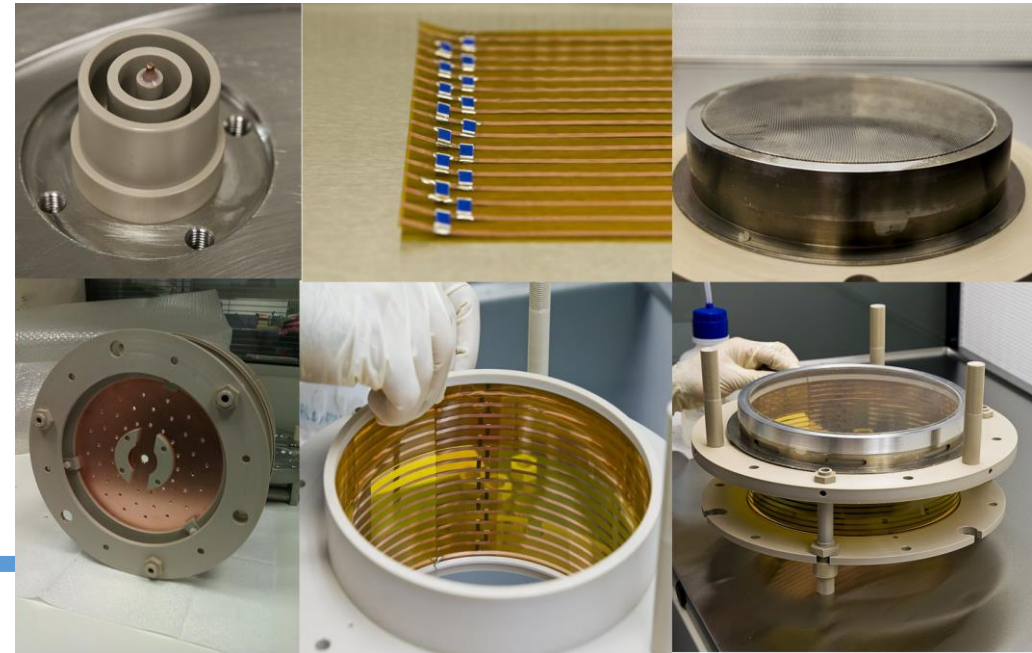
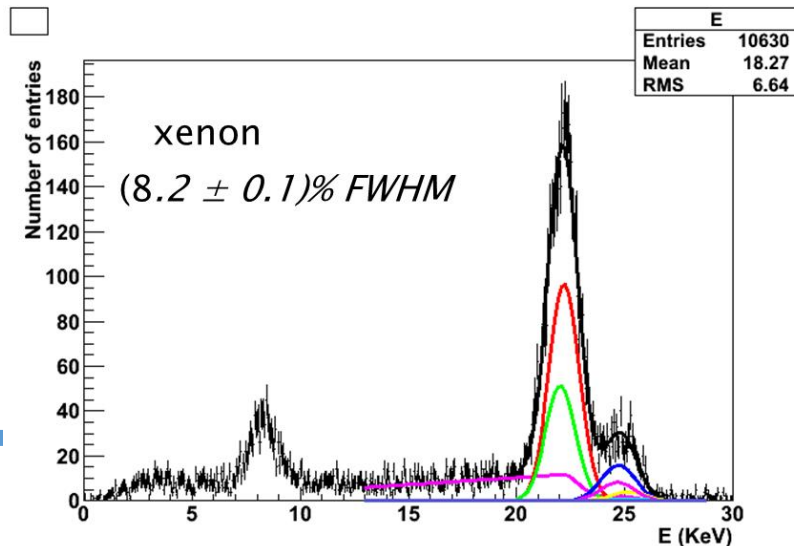
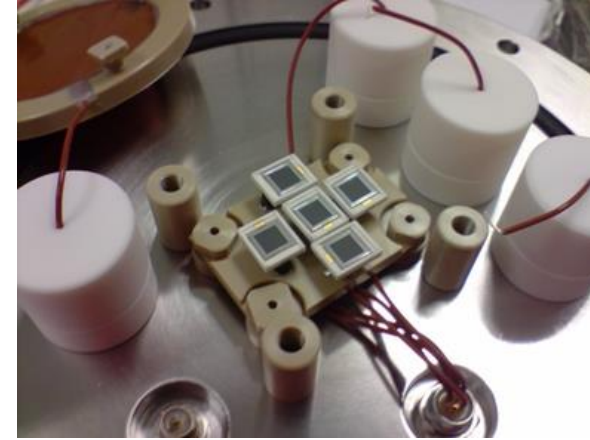




- Experiment: T2K ND280 (Upgrade)
- 2 new TPCs being built
- Field cage and resistive anode MM (ERAM) R&D
- Field cage built by Spanish company (NEXUS SL)
- First full size field cage made of composite materials => example for future low material budget field cages
- ERAM better performance due to charge spread => interesting for e.g. possible ILC TPC
- Collaborators: INFN Padova/Bari, Saclay, LPHNE Paris, RWTH Aachen

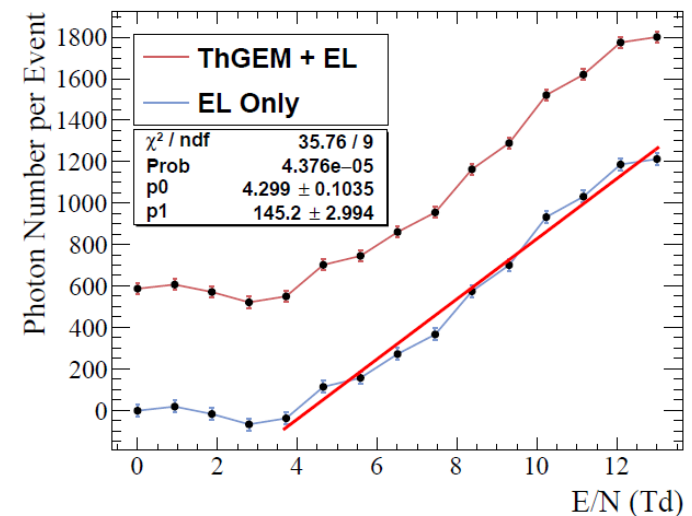
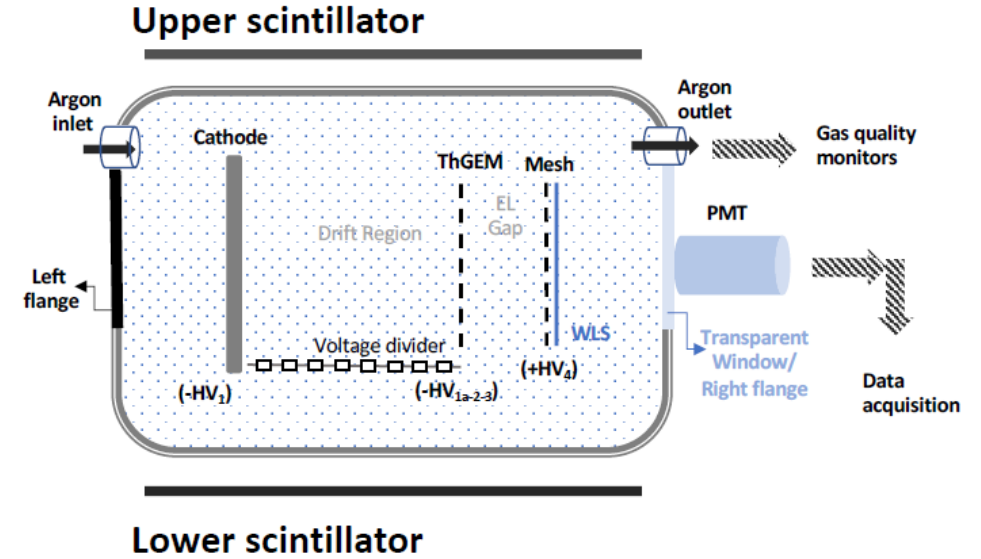
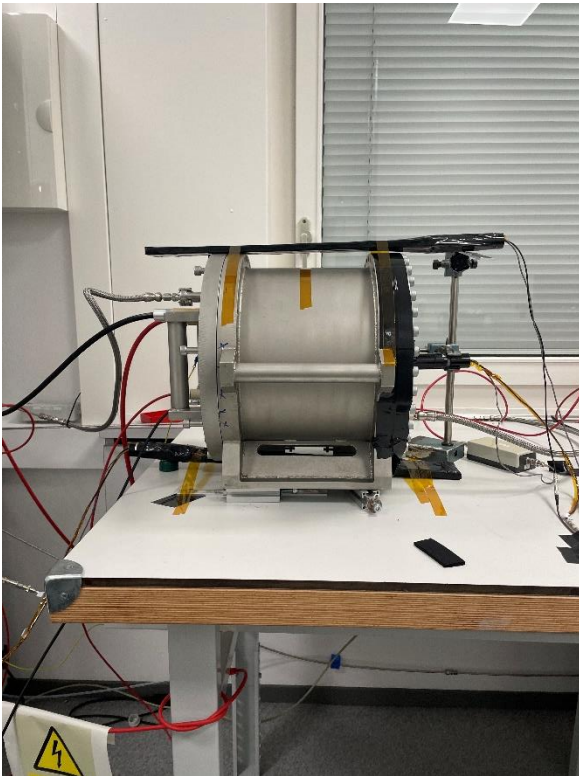


- Started in 2007
- Experiment: NEXT
- Electroluminescence (EL) light readout based on APDs
- HP detector filled with pure Xe
- Collaborators: UniZaragoza, IFIC, Coimbra, CIEMAT

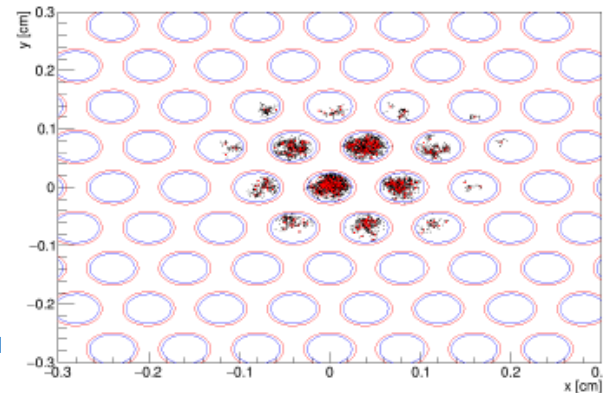
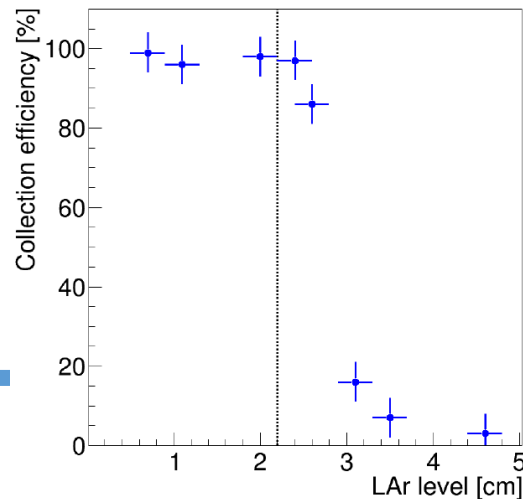
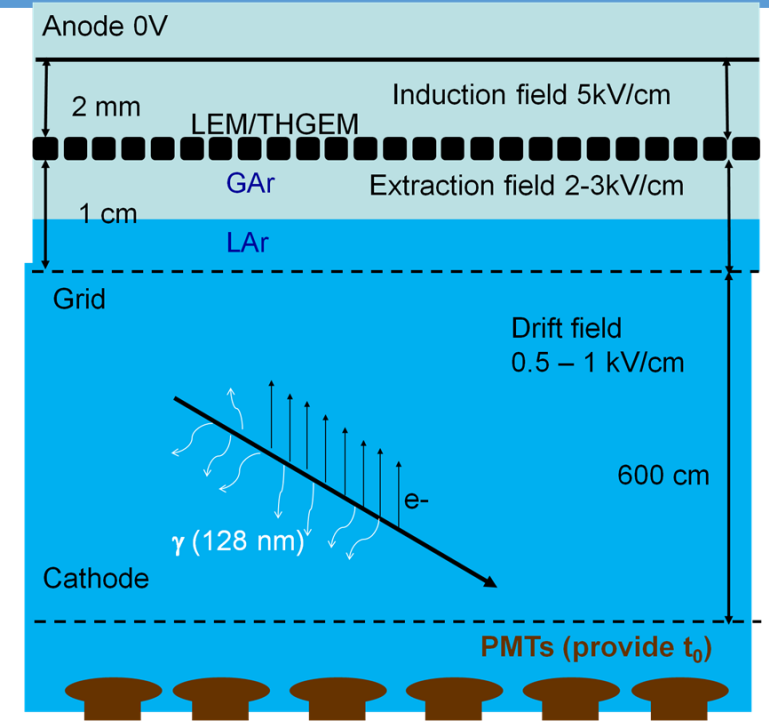




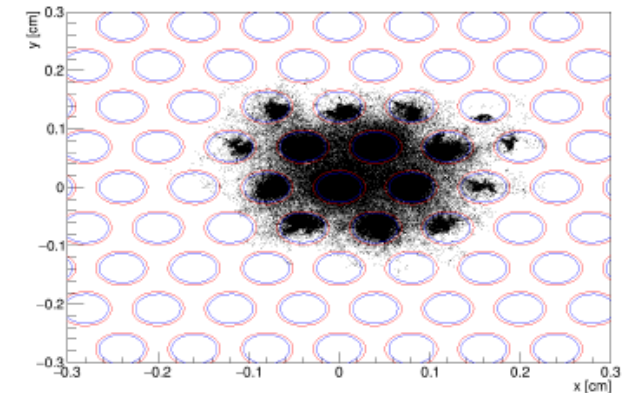
- HP setup transferred to UniGe (2019)
- Modified and used by PhD student
- EL studies with pure argon
- Aim: tracking with SiPM array
- Experiment: pure R&D with neutrino interaction vertices in mind
- Collaborators: UniGe, INFN Bari
- Providing experience and simulations done for LAr TPC



- Dual phase LAr TPC with MPGD-based charge readout and PMT-based readout for primary scintillation light
- Experiment: WA105 => later ProtoDUNE-DP
- CIEMAT/IFAE provided photon detection system
- R&D: WLS, light transport in LAr, simulation studies of charge readout (produces also EL), ion studies in LAr
- Collaborators: CIEMAT (Neutrino/DM), CERN Neutrino Platform, ETH Zurich, Saclay

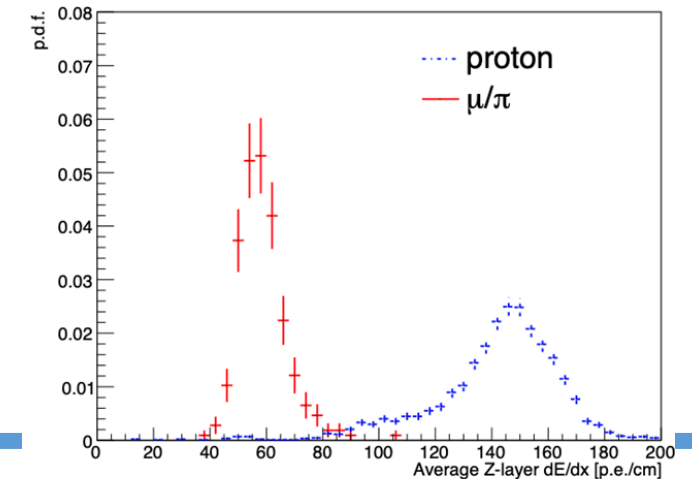
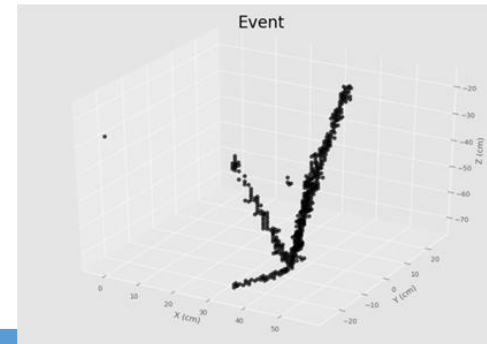
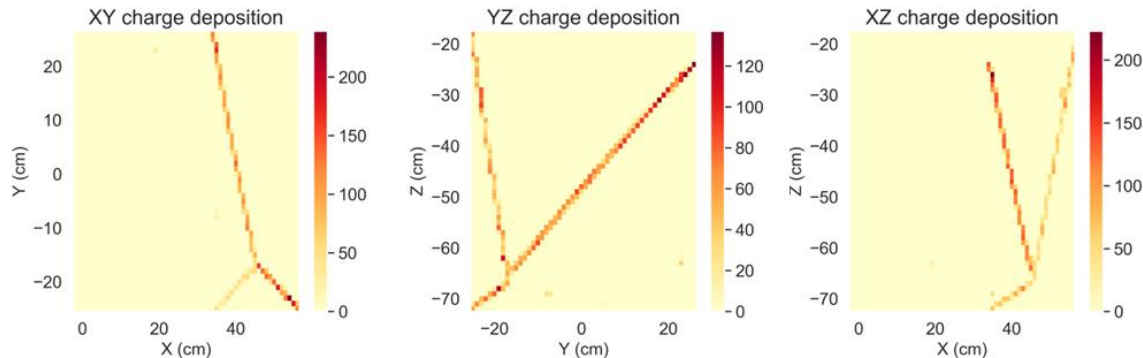
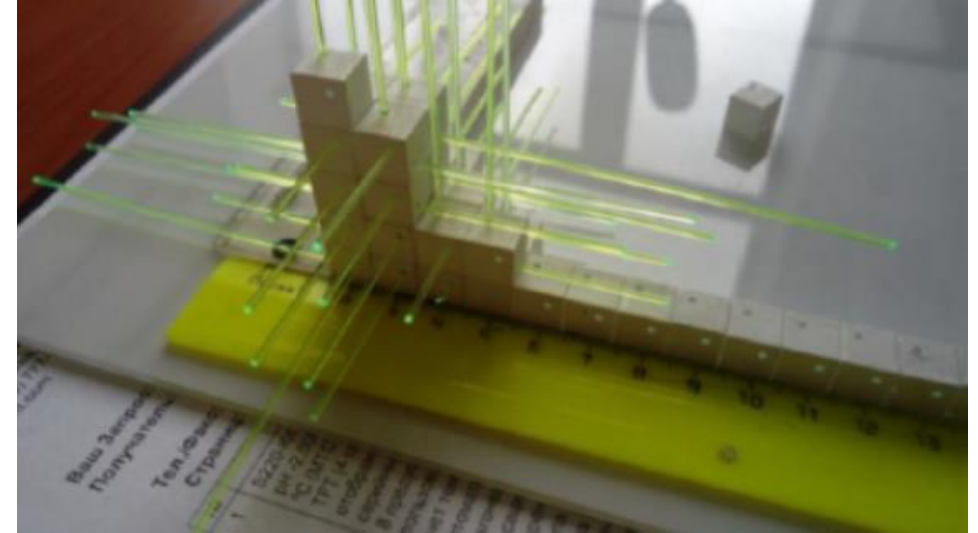


(a) Charge



(b) Photons

- Experiment: T2K ND280 (Upgrade)
- 2 new plastic scintillator detectors:
  - Novel 3D scintillator tracker: SuperFGD
  - Time-of-Flight detector with 150 ps resolution
- Participated in data taking, key contributions to data analysis, ML techniques for event reconstruction, simulations
- Collaborators: ETH Zurich, CERN, UniGe, INR, Stony Brook



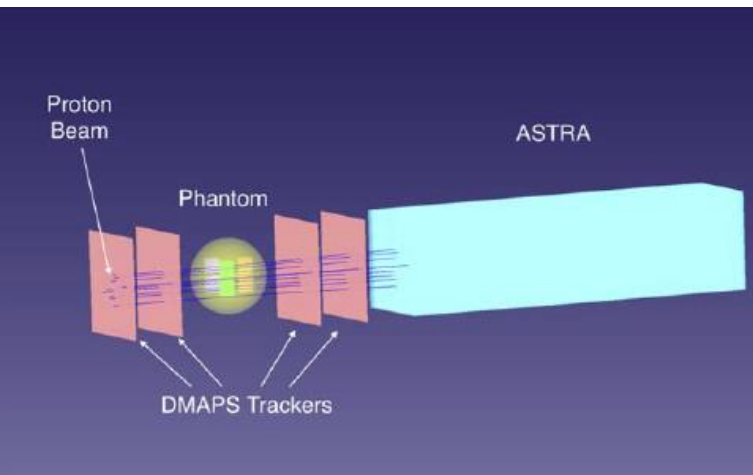
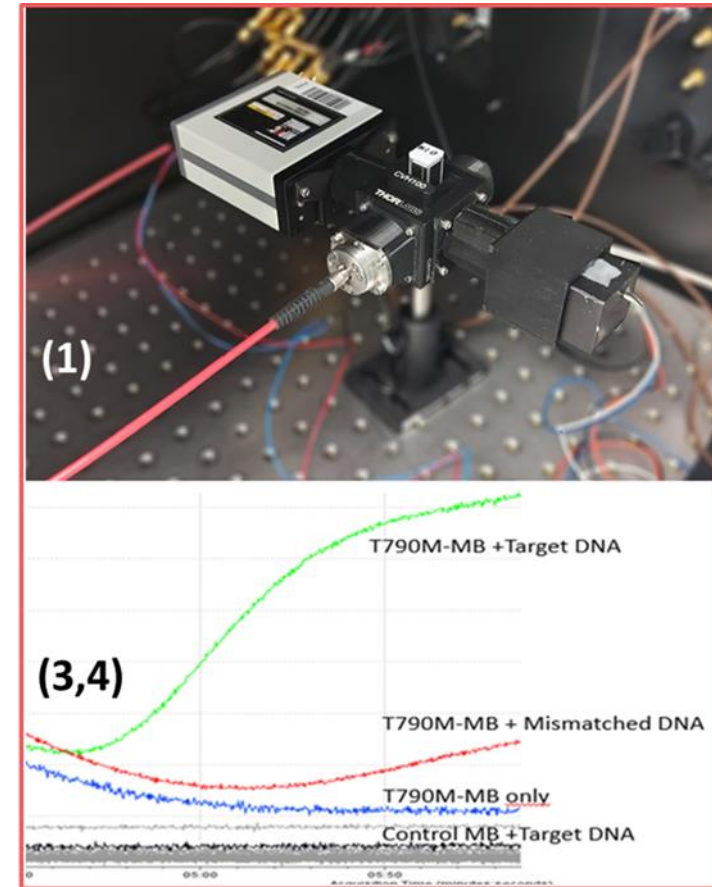
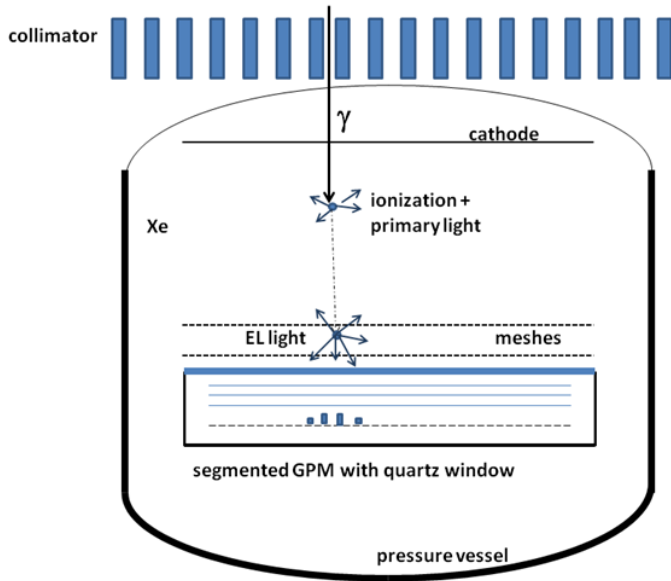


# From HEP to Applied Physics

HP TPC lead to ERC Consolidator proposal reaching the 2<sup>nd</sup> stage

LAr calibration system R&D basis for cancer detection R&D funded by ATTRACT H2020 grant in collaboration with Leitac Technologies SL

Scintillator tracker R&D basis of idea for energy measurement detector for proton CT. Funded by PDC grant. Collaborators: UniBirmingham, UniGe. Applied for patent.



# Future Plans: Introduction

- Given by Spanish HyperK MOU => participation in a future ND280 Upgrade for HyperK
- 2 objectives for the HyperK ND280 Upgrade:
  - Improved electron (anti)-neutrino cross-section measurement
    - ⇒ possibly scintillator tracker with mass of 7-10 t (HyperFGD)
    - ⇒ SuperFGD concept with 2 million single cubes not scalable
  - Water target to measure cross-section on same target as in FD
    - ⇒ at least 2 t of target mass
    - ⇒ Challenge 1: Precise measurement of vertex activity (not visible in WC detectors)
    - ⇒ Challenge 2: Interaction should be with H<sub>2</sub>O and not surrounding material/additives
- First finish the current ND280 Upgrade => Q1/2024
- Then intensify simulation studies to optimize HK ND280 Upgrade design

# Future Plans: R&D Options

## 2 Options:

### HyperFGD:

- 3D printed? => ETH started to work on this => would solve scaling problem
- LiquidO-like? => light sharing might improve event reconstruction as in MPGDs
- PlasticO? => opaque plastic scintillator?
- **DRD6 ? DRD2 (as LiquidO)?**
- Baseline choice

### Novel H2O target:

- Water interleaved with scintillator bars? => 2D readout only
- 3D printed hollow scintillator cubes filled with H2O? => How to get fibers along 3 axes?
- Active water with <1% scintillator thanks to novel quantum materials? => still a dream
- **DRD2 with input from DRD5? Partly DRD6?**



# Manpower, Collaborations, Leadership

- Estimation of manpower extremely difficult since R&D is done in phases
- Group philosophy: everybody should participate on some level on R&D projects
- Estimated manpower for HyperK Upgrade R&D:
  - ~1 FTE from 2 staff scientist
  - 1-1.5 FTE from PhDs
  - 0.5 FTE from engineers
  - 1 FTE from PostDocs
  - Master students
- All R&D projects carried out highly international (see previous slides)
- R&D related leadership positions: technical coordinator and co-leader of ND280 Upgrade project / CERN experiment NP07

# Funding

- Moderate funding needed for next 3-years due to feasibility study phase and collaboration with international partners
- HK ND280 Upgrade project
  - 10-15 kEuro/year for material to e.g. 3D printing material: requested
  - 0.5 FTE/year additional technical support: requested
  - 2-year PostDoc: NextGeneration EU funds
  - 1 PhD: Next Generation EU funds
- Proton CT Scintillator Detector: ASTRA
  - 108 kEuro from Prueba de Concepto grant
  - Synergies with HK ND280 Upgrade project

# Summary

- Long history in DRD in IFAE Neutrino Group
- R&D projects are experiment and not technology driven
- Working normally in international collaborations
- IFAE is member of RD51, excellent community network, and would like to continue in DRD1
- Near future plans defined by HK MOU commitment
- Not fully clear how this R&D would fit in the considered DRD collaborations => seems general problem
- Wish: DRDs come with scheme for moderate funding for blue-sky research