Status and Future Developments of TPC’s with MPGD readout systems

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History, principle of operation
Advantages

New ideas with MPGDs

Projects in progress
- Nuclear Physics
- Neutrino oscillations
- Neutrinoless dble $\beta$ decay
- Dark matter search
- ILC

Conclusions
Principle of operation

electrons are separated from ions

A magnetic field reduces diffusion

Localisation in time and in x-y
Introduction

Invented 40 years ago by Dave Nygren, the TPC concept (with wire chamber readout) was first applied in High Energy Physics:

- TPC 2$\gamma$, LEP (ALEPH and DELPHI), neutrino cross-section measurements

And then in studies of Quark-Gluon Plasma (very high multiplicity events: STAR, ALICE).

Cryogenic gases were proposed as active medium (ICARUS)

20 years ago, the MPGD readout was proposed. It now finds dozens of applications
Advantages

Can cover a large volume with little matter and few electronic channels
Allows continuous tracking
Can provide the target
Active target TPCs

Time projection chambers for (fundamental) nuclear physics

**MAYA**
(GANIL and coll.)

- Nuclear reactions
- Pads (hex): 2D proj.
- Wires: drift time

**CENBG TPC**

- Ions stopping and decay
- X-Y strips
- Energy & time: 2x 1D proj.

**Optical TPC**
(Warsaw)

- Ions stopping and decay
- CCD cam.: 2D proj.
- PM + sampling: global time dist.

Development of a new TPC for a large (nuclear) physics case:

GANIL, CENBG, IPNO (F)
Leuven (B), Santiago de C. (S)

Active target challenges:
Large range in ionization
(from MIP to 5000 x more)
### Nuclear Physics

#### Table of projects

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| 80k Channels Total |
| 20 experiments     |
| 4ch to 20k ch       |

Listed by E. Pollaco mid 2016
Nuclear Physics

Heavy ions : large multiplicities
Upgrade ALICE : wires -> GEMs
Challenge : large ion backflow.

20 to 25 TPC projects for Nuclear Physics
Huge Double-phase Argon TPCs are being built, equipped with LEMs/THGEMs, for the underground DUNE experiment. The final goal is 10-50 kiloton (the largest TPC ever). Demonstrators of 3 m³, 6x6x6 m³, and an even larger one, are being built at CERN.

Note: R&D still on-going for other concepts (ArgonCube: magnetized modular detector)
Neutrino oscillations
Long baseline experiments

Single-Phase
ICARUS

35-t prototype
2015
MicroBooNE

protoDUNE (NP04)

DUNE Reference Design
basis for first 10 kt module

58m
46 times larger than ICARUS

Dual-Phase
2016
WA105-20t 3x1x1 m³

protoDUNE (NP02/WA105)

DUNE Alternative Design
Neutrino oscillations: T2K Near Detector

Goal of the 280 m near detector: measure cross-sections and beam content in electron neutrino

Includes 3 Micromegas TPCs
10 years of operation!
Add 4 horizontal TPCs to the existing 3. Use charge spreading, new grounding scheme (mesh at ground).
Neutrino-less double-beta decay

Several projects in progress, mainly $^{136}$Xe TPCs
1 ton necessary
Extreme radio-purity
Very good energy resolution
Good granularity for topological discrimination
PANDA-X III

In Jinping underground lab (Sechouan, China)

5 TPC modules
In 10m-deep highly-purified water pool
200kg 10 bar gaseous Xenon mixture with 1% tri-methyl amine (TMA)
Copper structure for low radioactivity
2 half TPC, 1.5m diameter and 2 m long in total
Read-out on both end-caps

Equipment of the first 200 kg underway.
Probably Microbulk Micromegas

Prototype field cage assembled

25/05/2017
Many projects of WIMP search have already given results (see J. Galan’s talk)

Future:
- Go to lighter gas targets to explore low masses
- Become directional to beat the solar neutrino background
ILC tracking
ILD 4 technologies

Micromegas

European GEMs

Standard kapton triple GEM with ceramic spacers

Mesh on top of a charge-dispersing resistive anode

GridPix

Integrated grid on 55 µ digital pixels

Asian GEMs

Give record resolutions. New techniques to stretch GEM foils, to cool at room temp…
Recently it was shown in a beam test that a Large Aperture gating GEM was transparent enough (with a few V across) to electrons, not to damage the resolution significantly (Yumi Aoki)
In the few-keV domain, the photo-electric effect dominates and the emitted electron direction keeps track of the polarization.

Under study by several groups (R. Bellazzini et al., Hua Feng et al., Tsinghua group, O. Limousin et al., Saclay group with Calliste chip,...)

The first sealed prototype

Small-gap single-GEM or Micromegas

NASA low-outgassing specifications
γ – Ray Astrophysics and polarimetry

HARPO (Hermetic Argon Polarimeter) -> balloon phase (ST3G) -> satellite

D. Bernard
Conclusion

MPGDs are now at the heart of increasingly many TPC projects.

New techniques are being developed for these.

Starting new projects (ALICE and other Nuclear Physics, polarimetry, T2K-II, Dark Matter search, Double-beta decay, ILC tracking...) will require expertise on MPGDs: long life to RD51!
THERE IS ALWAYS A TPC FOR YOU!

- TPC
- MPGD
- Readout
- Gas
- Liquid
- Spherical
- Cylindrical
- GEM
- LEM/THGEM
- Micromegas
- Cerenkov
- Ion Back flow
- High pressure
- Low pressure
- Atmospheric
- Space charge
- dE/dx
- Gating