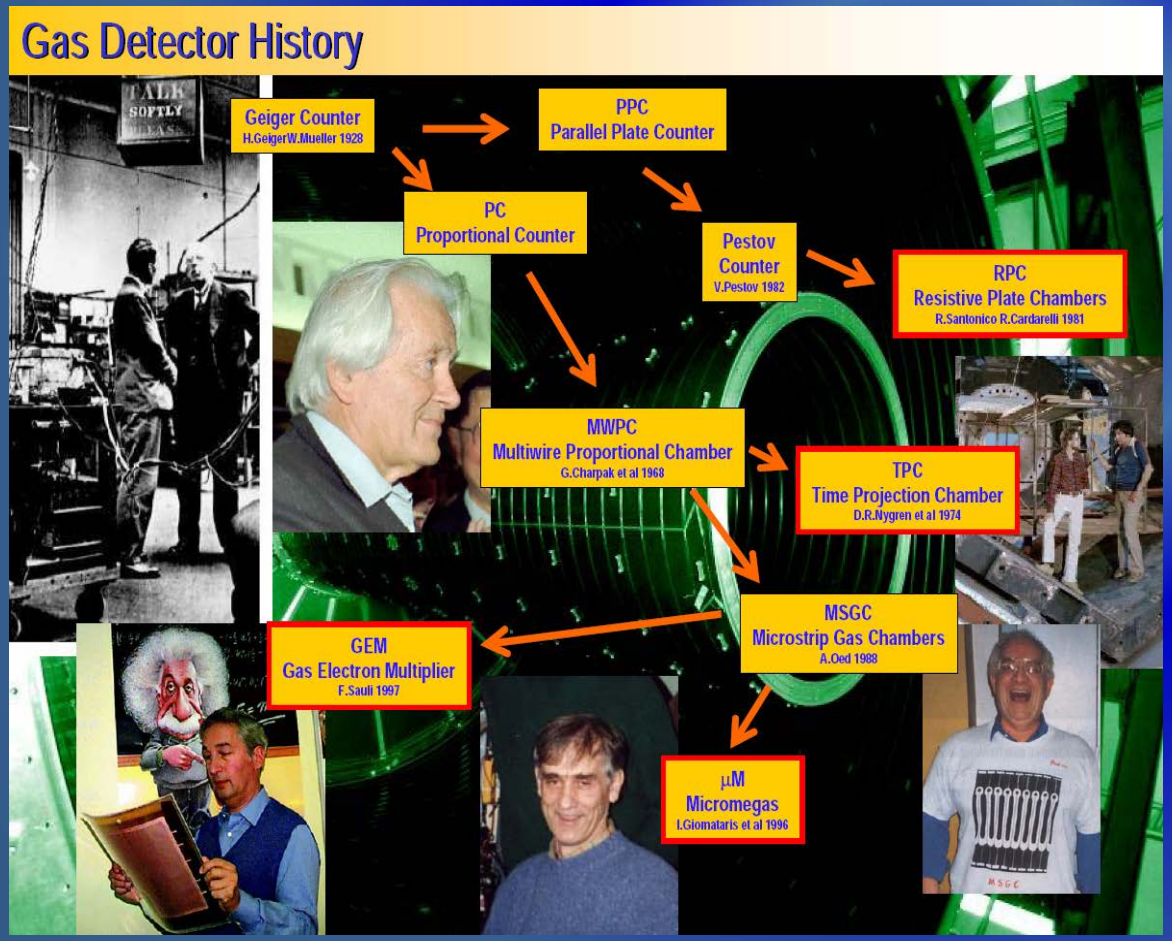
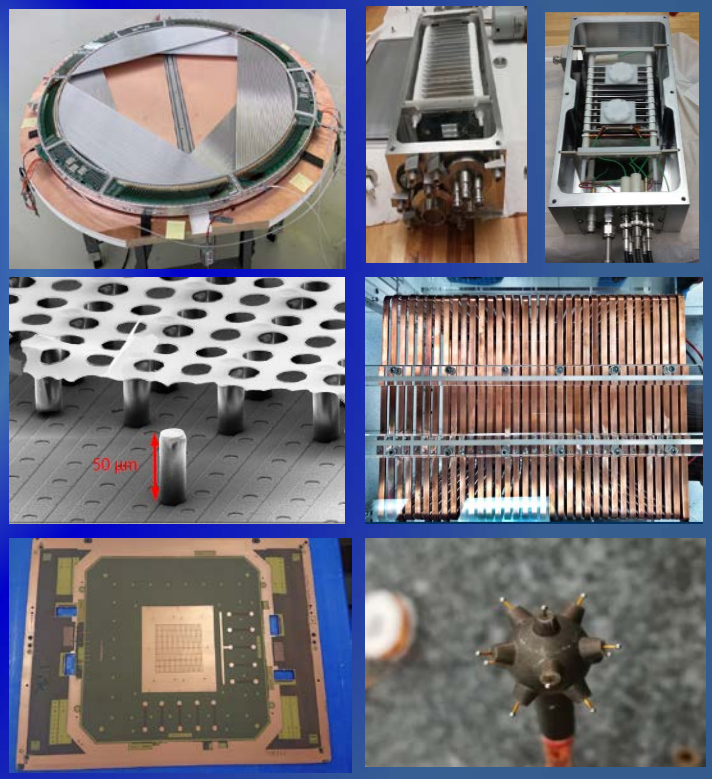
Gaseous Detectors Summary Report

Conveners:

Sven Vahsen (University of Hawaii)
Maxim Titov (Irfu, CEA Saclay)





CPAD Instrumentation Frontier Workshop 2021, Stony Brook, USA, March 18 - 22, 2021

Gaseous Detectors Sessions & Talks @ CPAD2021 Workshop

4 parallel sessions @ CPAD ; ~ 25 abstracts submitted to Gaseous Detectors Track

CPAD Instrumentation Frontier Workshop 2021

Gaseous Detectors Parallel Sessions & Track (version - 12.03.2021)

Thursday, 18 March 2021, Session – I (12:00 – 13:40 US EST)
Session Chair: Sven Vahsen (University of Hawaii, USA)

12:00 – 12:20 (#37) TPC Development by the LCTPC Collaboration for the ILD Detector at ILC – Jochen Kaminski (University Bonn, Germany)

12:20 – 12:40 (#148) Status and prospects of TPC module and prototype R&D for CEPC - Huirong Qi (Institute of High Energy Physics, CAS, China)

13:00 – 13:20 (#31) Options for gain elements and gas mixtures in a high rate EIC Time Projection Chamber - Dr Bob Azmoun (BNL, USA)

13:00 – 13:20 (#95) A novel TPC concept for a fast tracker for MAGIX - Stefano Caiazza (KPH Institute - JGU Mainz, Germany)

13:20 – 13:40 (#108) NEWS-G: Search for Light Dark Matter with Spherical Proportional Counters - Konstantinos Nikolopoulos (University of Birmingham, UK)

Thursday, 18 March 2021, Session – I (14:00 – 16:00 US EST)
Session Chair: Maxim Titov (Irfu, CEA Saclay, France)

14:00 – 14:20 (#71) Detecting neutrinos and measuring nuclear quenching factors with spherical proportional counters - Marie Vidal (Queen's University, UK)

14:20 – 14:40 (#110) Recent advancements on the spherical proportional counter instrumentation for NEWS-G - Ioannis Katsioulas (University of Birmingham, UK)

14:40 – 15:00 (#170) CYGNUS: Imaging of low-energy nuclear recoils in gas TPCs - Sven Vahsen (University of Hawaii, USA)

15:00 – 15:20 (#75) Vector tracking in low-energy nuclear recoils - Peter Lewis (University of Bonn, Germany)

15:20 – 15:40 (#60) The CYGNO TPC: Optical Readout for Directional Study of Rare Events - Davide Pinci (INFN - Sezione di Roma, Italy)

15:40 – 16:00 (#128) Electroluminescence studies for CYGNO - Directional Dark Matter search with an optical TPC - Dr Cristina M B. Monteiro (Department of Physics, University of Coimbra, Portugal)

Friday, 19 March 2021, Session – I (12:00 – 13:40 US EST)
Session Chair: Sven Vahsen (University of Hawaii, USA)

12:00 – 12:20 (#82) Performance and stability of a High Granularity Resistive Micromegas at high particle rates - Massimo Della Pietra (University of Naples "Federico II"/INFN, Italy)

12:20 – 12:40 (#149) The CGEM-IT of the BESIII experiment: preliminary results of the cosmic data taking - Giulio Mezzadri (INFN-IHEP Fellow, Italy/China)

12:40 – 13:00 (#147) Gaseous Time Projection Chamber for Ultra-low Radioactive Material Screening - Haiyan Du (Shanghai Tong University, China)

13:00 – 13:20 (#97) Towards studying photonuclear reactions with active-target TPC - Mateusz Fila (University of Warsaw, Poland)

13:20 – 13:40 (#47) A High-Pressure Gaseous-Argon TPC as a Component of DUNE Near Detector - Dr Tanaz Mohayai (Fermilab, USA)

Friday, 19 March 2021, Session – I (14:00 – 15:10 US EST)
Session Chair: Maxim Titov (Irfu, CEA Saclay, France)

14:00 - 14:20 (#178) Gas-filled Neutron Imager Operating in Ionization Mode - Graham Smith (BNL, USA)

14:20 - 14:40 (#80) A Low Energy Recoil Tracker Hyperbolic Drift Chamber - Lucien Causse (IJCLab, France)

14:40 - 15:00 (#160) Lessons from Mu2e Tracker Construction and Mu2e-II Tracker Opportunities - Daniel Ambrose (University of Minnesota, USA)

If you are a speaker, please also be sure to check the official schedule directly in Indico as we get close to the conference, in case there are schedule changes:
https://indico.fnal.gov/event/46746/sessions/17781/#all

Gaseous Detectors-related talks @ CPAD:

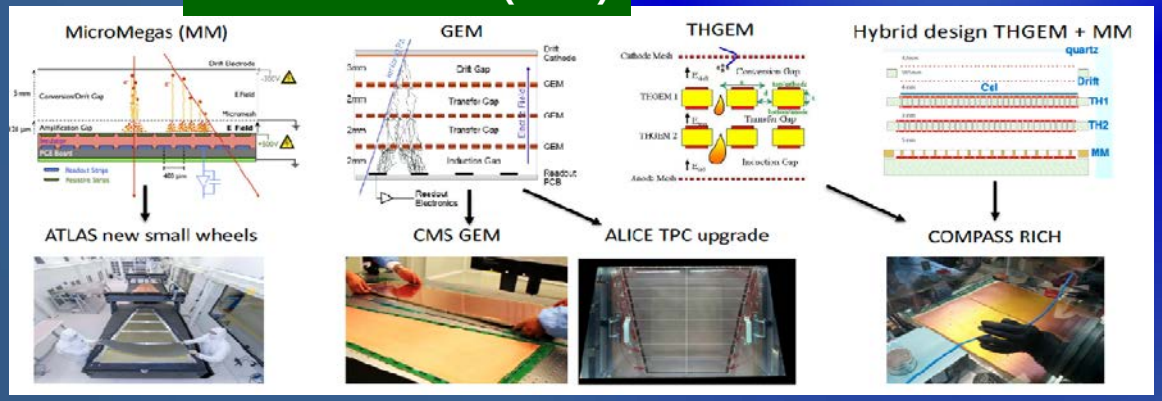
- ✓ 19 – Gaseous Detectors Track (11 – MPGDs)
- ✓ 3 - Early Carrier Track
- ✓ 2 – Photon Detectors Track
- ✓ 2 – Nobel Elements Track
- ✓ 3 – Low Background / Low Threholds Track
- ✓ 2 – Readout and ASICs

MPGD Technologies @ RD51 Collaboration

MPGDs in the LHC Experiments:

Experiment / Timescale	Application Domain	MPGD Technology	Total detector size / Single module size	Operation Characteristics / Performance	Special Requirements / Remarks
COMPASS TRACKING > 2002	Fixed Target Experiment (Tracking)	3-GEM Micromegas w/ GEM preampl.	Total area: 2.6 m^2 Single unit detect: 0.31x0.31 m^2 Total area: ~ 2 m^2 Single unit detect: 0.4x0.4 m^2	**Max.rate**: ~100kHz/mm^2 **Spatial res.**: ~70-100μm (strip), ~120μm (pixel) **Time res.**: ~ 8 ns **Rad. Hard.**: 2500 mC/cm^2	Required beam tracking (pixelized central / beam area)
TOTEM TRACKING: > 2009	Hadron Collider / Forward Physics (5.3≤|η| ≤ 6.5)	3-GEM (semicircular shape)	Total area: ~ 4 m^2 Single unit detect: up to 0.03m^2	**Max.rate**:20 kHz/cm^2 **Spatial res.**: ~120μm **Time res.**: ~ 12 ns **Rad. Hard.**: ~ mC/cm^2	Operation in pp, pA and AA collisions.
LHCb MUON DETECTOR > 2010	Hadron Collider / B-physics (triggering)	3-GEM	Total area: ~ 0.6 m^2 Single unit detect: 20-24 cm^2	**Max.rate**:500 kHz/cm^2 **Spatial res.**: ~ cm **Time res.**: ~ 3 ns **Rad. Hard.**: ~ C/cm^2	Redundant triggering
COMPASS RICH UPGRADE > 2016	Fixed Target Experiment (RICH - detection of single VUV photons)	Hybrid (THGEM + CsI and MM)	Total area: ~ 1.4 m^2 Single unit detect: ~ 0.6 x 0.6 m^2	**Max.rate**:100 Hz/cm^2 **Spatial res.**: <~ 2.5 mm **Time res.**: ~ 10 ns	Production of large area THGEM of sufficient quality
ATLAS MUON UPGRADE CERN LS2	Hadron Collider (Tracking/Triggering)	Resistive Micromegas	Total area: 1200 m^2 Single unit detect: (2.2x1.4m^2) ~ 2-3 m^2	**Max. rate**:15 kHz/cm^2 **Spatial res.**: <100μm **Time res.**: ~ 10 ns **Rad. Hard.**: ~ 0.5C/cm^2	Redundant tracking and triggering; Challenging constr. in mechanical precision
CMS MUON UPGRADE CERN LS2	Hadron Collider (Tracking/Triggering)	3-GEM	Total area: ~ 143 m^2 Single unit detect: 0.3-0.4m^2	**Max. rate**:10 kHz/cm^2 **Spatial res.**: ~100μm **Time res.**: ~ 5-7 ns **Rad. Hard.**: ~ 0.5 C/cm^2	Redundant tracking and triggering
ALICE TPC UPGRADE CERN LS2	Heavy-Ion Physics (Tracking + dE/dx)	4-GEM / TPC	Total area: ~ 32 m^2 Single unit detect: up to 0.3m^2	**Max.rate**:100 kHz/cm^2 **Spatial res.**: ~300μm **Time res.**: ~ 100 ns **dE/dx**: 11 % **Rad. Hard.**: 50 mC/cm^2	- 50 kHz Pb-Pb rate; - Continues TPC readout - Low IBF and good energy resolution

JINST15 C10023 (2020)



- ✓ CERN – RD51 collaboration):
  https://rd51-public.web.cern.ch/welcome
  ~ 90 RD51 institutes in 25 countries
  9 Institutes from the USA

- ✓ Scaling up MPGD detectors, while preserving the typical properties of small prototypes, allowed their use in the LHC upgrades
  → Many emerged from the R&D studies within the CERN-RD51 Collaboration

- ✓ **Future RD51 activities for advanced MPGD concepts includes Generic « Blue-Sky » R&Ds:**

  - **Resitive materials & architectures;**
  - **Fast and precise timing;**
  - **Hybrid detectors (MPGDs + CMOS, optical readout of MPGDs, …);**
  - **Novel materials & fabrication techniques (MEMS, nanotechnology, sputtering, novel PCs, 3D printing)**
  - **…**

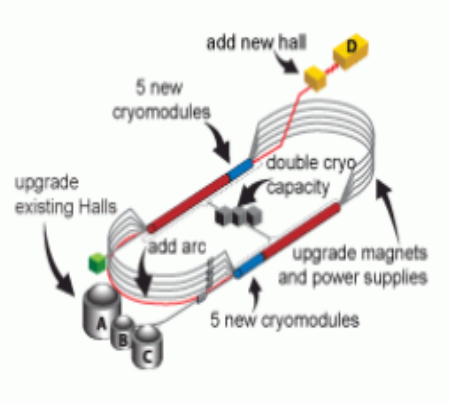
arXiv: 1806.09955

MPGD Developments for Future Experiments @ Jlab

✓ There is a lot of synergy & complementarity for MPGD R&D Needs between Energy Frontier Colliders and Nuclear Physics Experiments

12 GeV CEBAF @ Jefferson Lab (TJNAF)

- Continuous Electron Beam Accelerator Facility (CEBAF)
- World premier facility to probe the quark structure of nucleus
- 12 GeV polarized electron beam
- Four Experimental Halls (A, B, C D)



Hall B: MPGD technology: large µRWELL

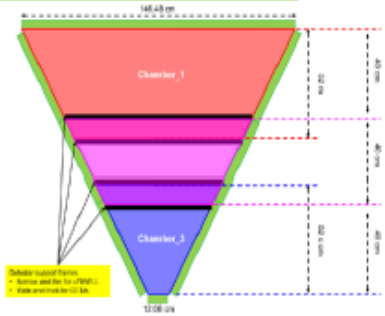
Key Requirements:

- Low mass ⇒ reduce multiple scattering
- Large area 1500 mm x 1500 mm
- Moderate rate: ~20kHz / cm^2
- Timing performance < 10 ns

Applications: Tracking

- High Luminosity CLAS12 Upgrade: Forward R1 and central trackers
- Proton radius Exp: PRad-II trackers

CLAS12 High-Lumi R1 tracker segment



K. Gnanvo

Hall A & C: MPGD technology: GEMs

Applications: Tracking

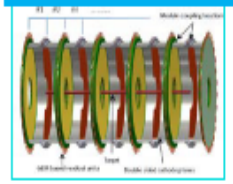
- SBS: Super Bigbite Spectrometer
- TDIS: multi-TPC proton recoil detector
- SoLID: Solenoid Intensity Device
- MOLLER
- LAD Experiment (Hall C)

Requirements are Challenging

- High Luminosity (10^{37}-10^{39})
- High data rate
- High background
- Low systematics
- High Radiation
- Large scale (Like RHIC)
- New Technologies
  - GEM's
  - Shashlyk Ecal
  - Pipeline DAQ

SoLID detector

TDIS mTPC with GEMs



Hall D: MPGD technology: µRWELL / GEMs

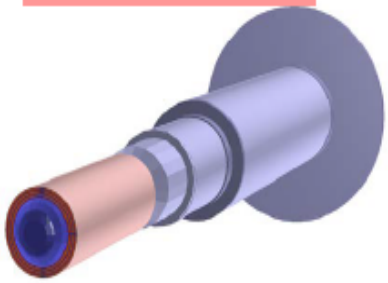
Key Requirements:

- Low mass ⇒ reduce multiple scattering
- Large area 1500 mm x 1500 mm
- Low to moderate rate: ~20kHz / cm^2
- Timing performance < 10 ns

Applications: Tracking & PID

- MPGD-based Transition radiation Detectors
- GLUeX Inner Tracker: Cylindrical uRWELL layers

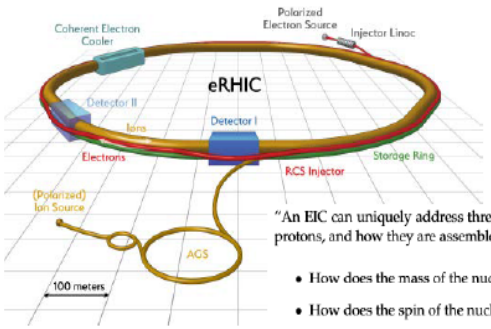
GLUeX cylindrical tracker

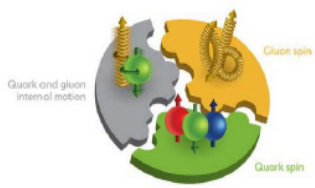


MPGD Developments for Future EIC Collider

- ✓ All proposed EIC concepts feature a form of large MPGD detectors:
  Tracking (GEM, Micromegas, μWELL), PID-RICH (THGEM+MM, GEM), TRD (GEM)

Electron Ion Collider (EIC)





"An EIC can uniquely address three profound questions about nucleons — neutrons and protons, and how they are assembled to form the nuclei of atoms:

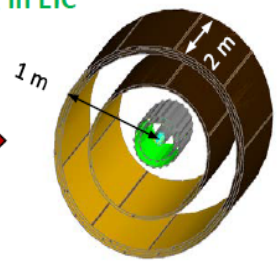
- How does the mass of the nucleon arise?
- How does the spin of the nucleon arise?
- What are the emergent properties of dense systems of gluons?"

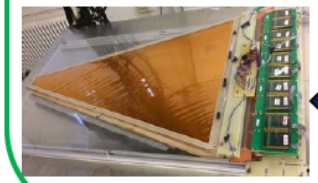
These questions call for an EIC with capabilities that far exceed any current or past colliding beam accelerator facility:

Large MPGDs for Tracking in EIC

Barrel Tracker: (μRWELL, μMegas)

- ❑ Low mass & large cylindrical MPGD layers
- ❑ Moderate rate: ~kHz / cm²
- ❑ Timing performance < 10 ns
- ❑ Technical challenges: Low mass & large area





End cap Trackers: (GEMs, μRWELL, μMegas)

- ❑ Low mass & large area 200 cm x 50 cm
- ❑ Moderate rate: ~kHz / cm²
- ❑ No technical challenges:

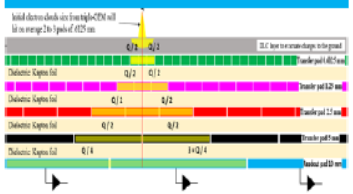
K. Gnanvo (eRD6 and eRD22: Detector R&D programs for EIC)

High-performance & low-channel count anode readout PCBs

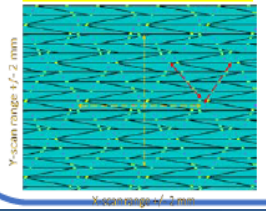
Ongoing R&D projects:

- ❑ Capacitive-sharing readout structures
  - ❑ Pads, 2D strips (U/V, X/Y, R/φ)
- ❑ 1D & 2D zigzag readout structures
  - ❑ 1D strips & pads

Capacitive-sharing R/O



2D Zigzag R/O

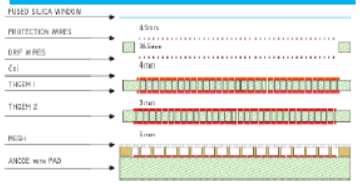


Applications:

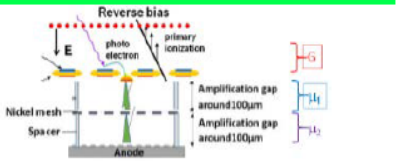
- ❑ Anode readout for MPGD trackers
- ❑ Pad readout for TPC readout layer
- ❑ Pad readout for GEM-RICH, MPGD-TRD, LAPPD & dual RICH detectors for PID

PID with MPGDs

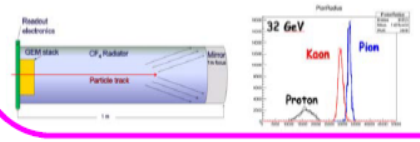
High Momentum RICH Detector: 2 x THGEMs + Micromegas



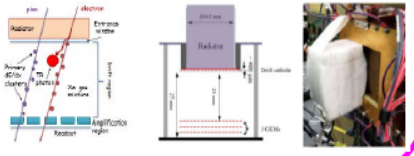
ePID with HBD++: 2-stack Micromegas



Hadron PID - RICH: Quintuple GEMs



eID: GEM-TRDs

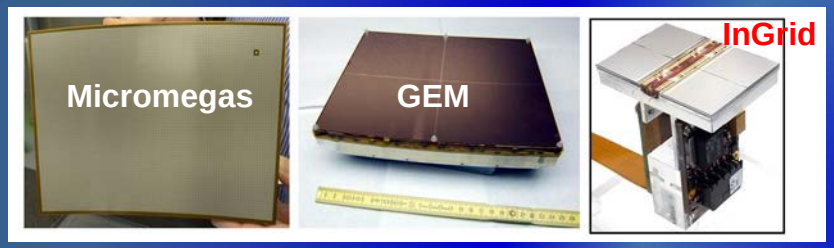


LCTPC Collaboration: MPGD-Based TPC for the ILD Detector at ILC

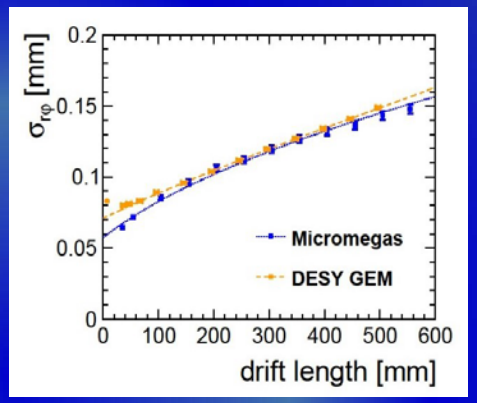
✓ **New TPC generations use MPGD-based readout: e.g. ALICE Upgrade, T2K, ILC, CepC, EIC**

Three MPGD options are foreseen for the ILC-TPC:

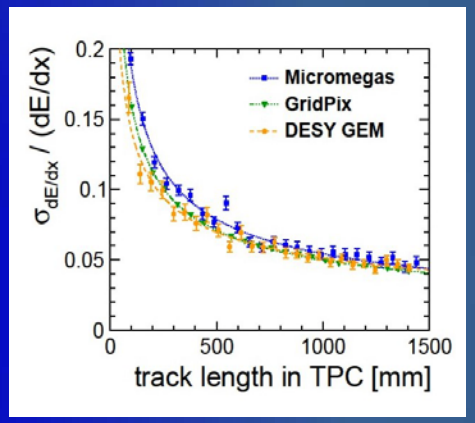
→ Wet-etched / Laser-etched GEMs
→ Resistive Micromegas with dispersive anode
→ GEM + CMOS ASICs, « InGrid » concept
(integrated Micromegas grid with Timepix chip)



Spatial resolution of σ_T ~ 100 um and dE/dx res. < 5% have been reached with GEM, MM and InGrid)

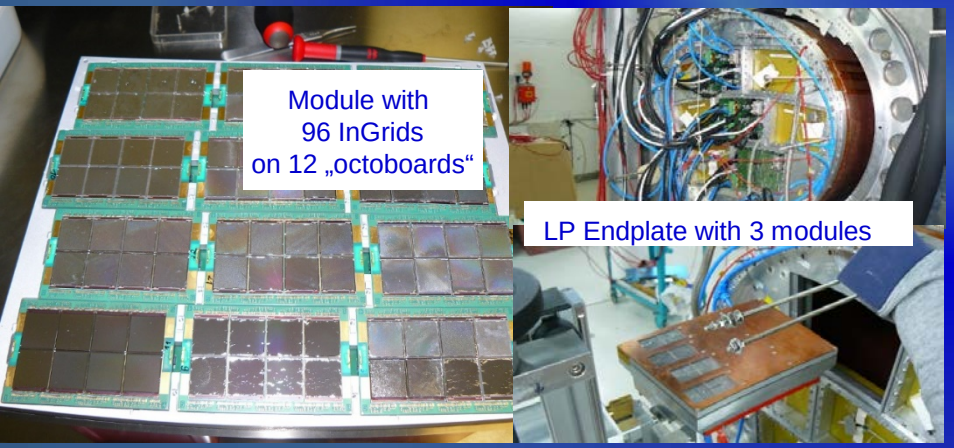


arXiv: 2003.01116



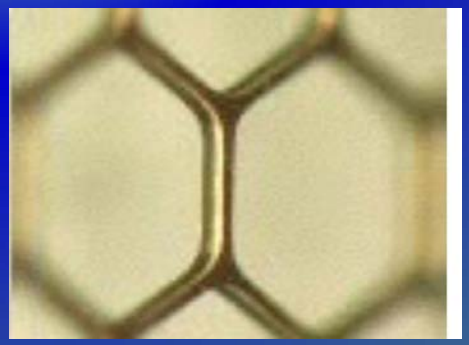
J. Kaminski

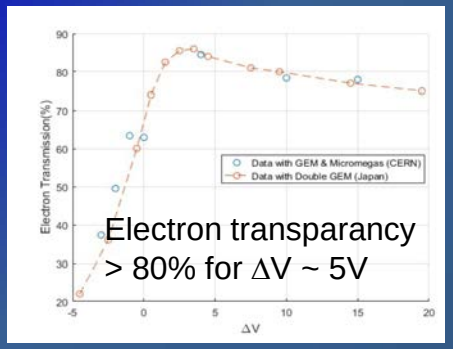
Studies in Large TPC Prototype: 120 "InGrid" Assembly
320 cm² active area, 10,5 mio. channels, RD51-SRS



ILC: gating scheme, based on large-aperture GEM

→ Machine-induced background and ions from gas amplific.
→ Exploit ILC bunch structure (gate opens 50 us before the first bunch and closes 50 us after the last bunch)



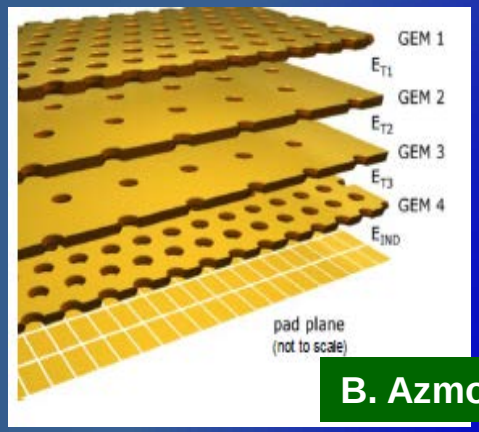


❖ First use of InGrid in experiment CAST (since 2014)
❖ Future potential applications: IAXO, CYGNUS, …

MPGD-Based TPC Developments @ CPAD2021

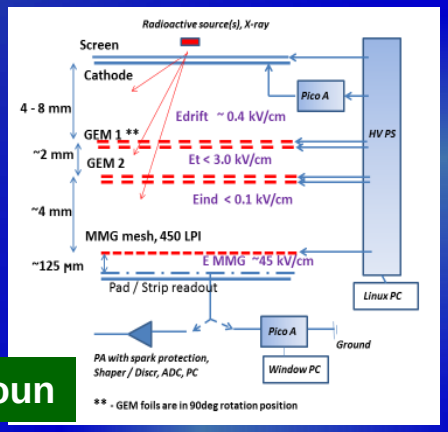
High-rate TPC for Electron-Ion Collider (R&D inherited from ALICE TPC Upgrade):

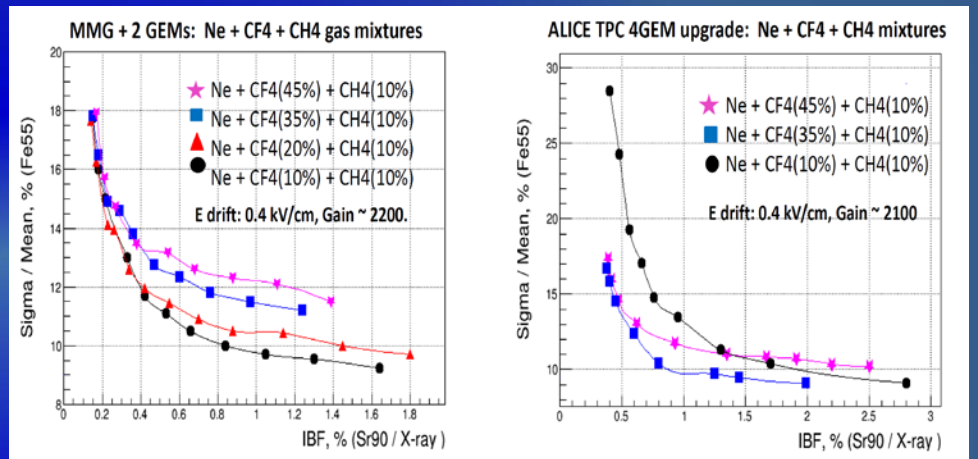
4GEM Structure with mis-aligned hole pattern



B. Azmoun

Hybrid: Micromegas + 2 GEM scheme





- For the MMG + 2GEM option **10 percent of CF_4** provides the best performance in terms of energy resolution and IBF, while for the 4GEM option **~35 - 40%** performs best.

MPGD-based TPC for CePC Collider

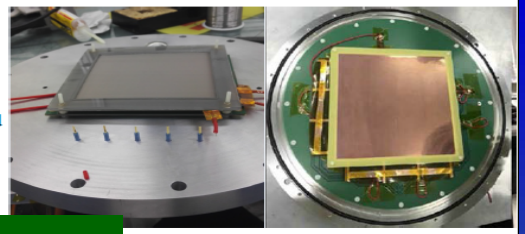
High luminosity (Z-peak) → No Gating possible

TPC detector module@ IHEP

- Study with GEM-MM module
  - New assembled module
  - Active area: 100mm×100mm
  - X-tube ray and 55Fe source
  - Bulk-Micromegas assembled from Saclay
  - Standard GEM from CERN
  - Avalanche gap of MM:128μm
  - Transfer gap: 2mm
  - Drift length:2mm~200mm
  - pA current meter: Keithley 6517B
  - Current recording: Auto-record interface by LabView
  - Standard Mesh: 400LPI
  - High mesh: 508 LPI
  - Pixel option for the consideration in 2020

DOI: 10.1088/1748-0221/12/04/P0401 JINST，2017.4
DOI: 10.1088/1674-1137/41/5/056003 , CPC,2016.11
DOI: 10.7498/aps.66.072901Acta Phys. Sin. 2017,7
DOI: 10.1142/S2010194518601217 (SCI) 2018
DOI: 10.1088/1748-0221/13/04/T04008 (SCI) 2018
DOI: 10.1007/978-981-13-1316-5_20 (SCI) 2018

$50\times50mm^2$ 2015-2016 → $100\times100mm^2$ 2017-2018 → $200\times200mm^2$ 2019-2020



GEM-MM detector cathode

H. Qi

Open Field-Cage GEM-based TPC for the MAGIX Experiment

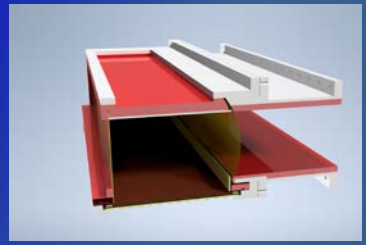
The MAGIX TPC
- Versatile detector for a versatile experiment with a long future ahead
- Innovative approach to achieve fast readouts on low energy particles
- First full-scale prototype under development

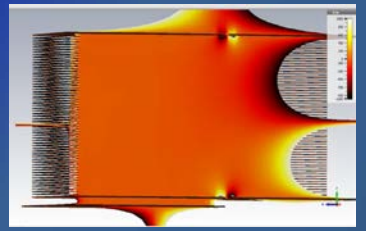
The open field cage concept
- Removing the field cage on the entry window of the TPC to minimize the material before the sensitive volume
- Extending the field shaping in the vacuum to minimize distortions even without field cage in the open window

VMM3 large scale integration
- One of the largest users of the VMM3 ASICs in combination with the SRS system

Innovative calibration system
- A network of optical fibers producing photoelectrons to evaluate static distortions
- Reference laser tracks to evaluate the dynamic distortions

The GEM stack
- 3 GEMs are the minimum required for stable operations and low IBF
- The prototype will allow to install up to 4 GEMs for performance comparisons

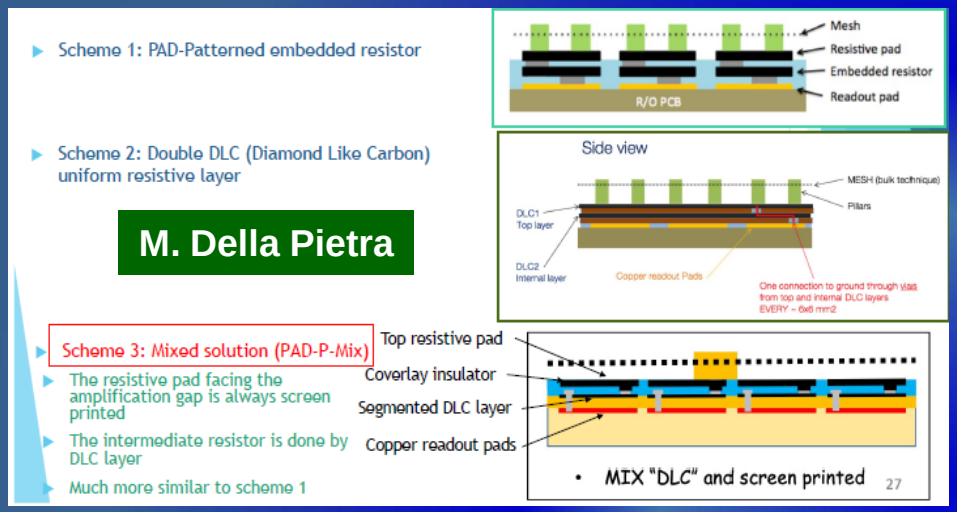




S. Caiazza

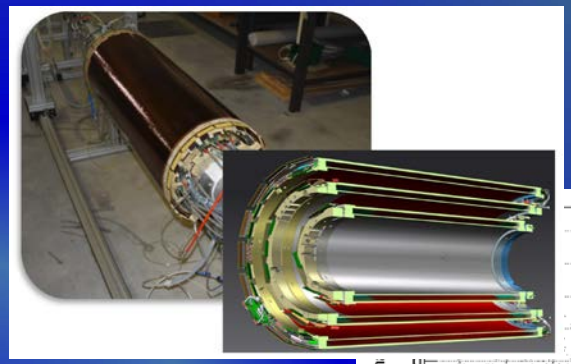
Several Examples of MPGD Developments @ CPAD2021

Pixelated Restitive Micromegas Studies for high rates (~10's MHz/cm²):



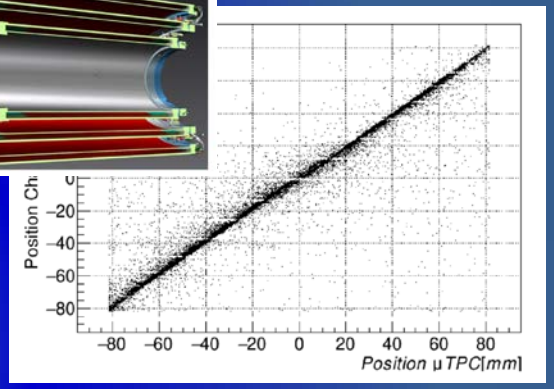
M. Della Pietra

Cylindrical GEMs for BES-III Experiment:



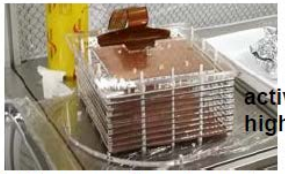
G. Mezzadri

μTPC readout is being implemented for cylindrical geometry



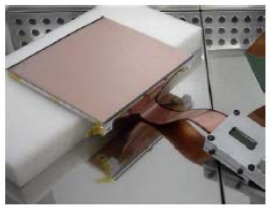
Micromegas-based TPC for Radioactive Material Screening

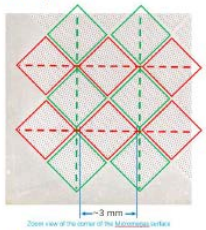
Prototype TPC



active volume hight:10cm

Field cage and readout plane

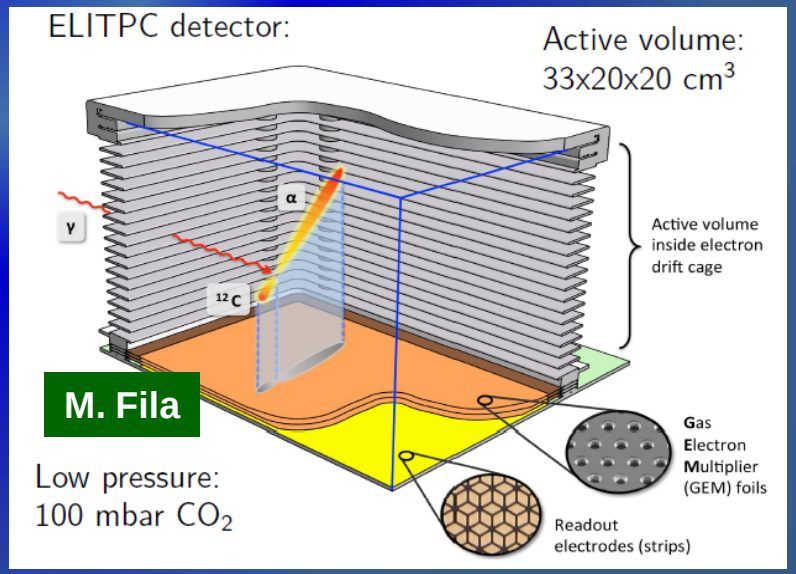




The Micromegas readout module
(20 x 20 cm²)
Read out with 64 Y strips and 64 X stips

H. Du

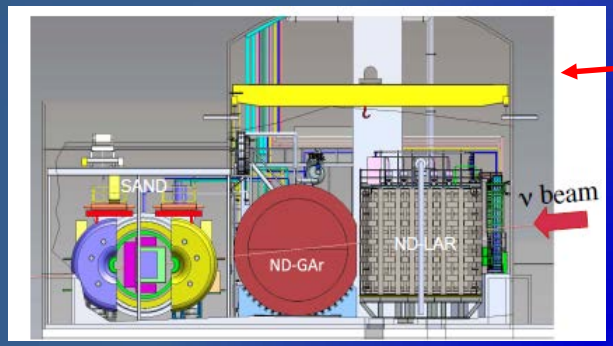
Study of photonuclear reactions with active-target GEM-based TPC



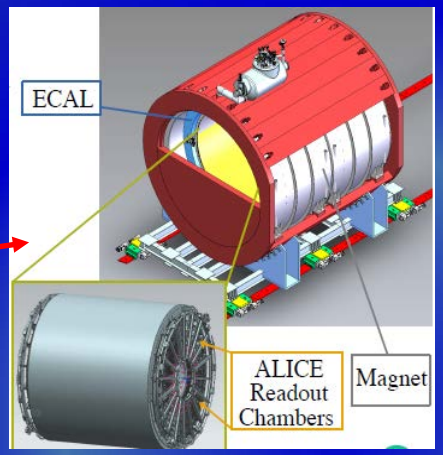
M. Fila

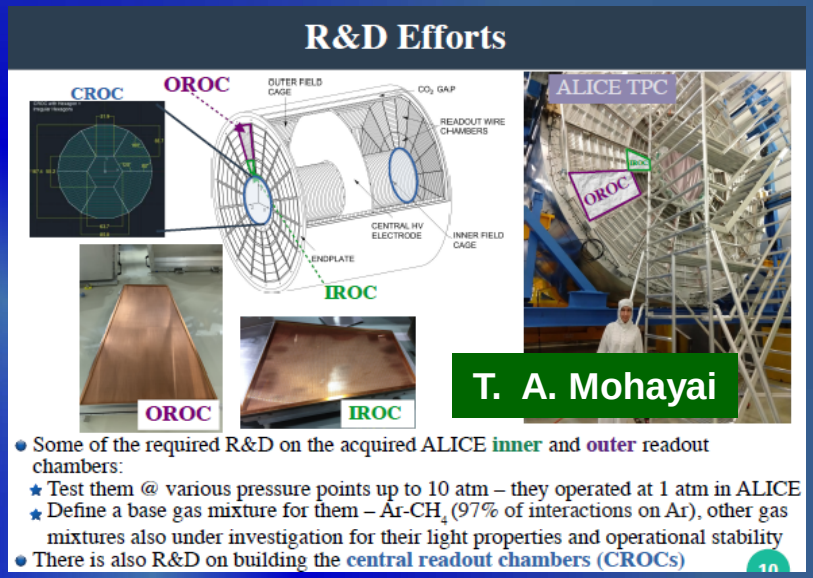
Gaseous Detectors @ FERMILAB Experiments

✓ High-Pressure Gaseous-Argon TPC for the DUNE Near Detector:



DUNE Near Detector Complex;





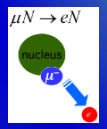
T. A. Mohayai

High Pressure Gas Ar TPC:

- ✓ Re-use ALICE's MWPC
- ✓ Ar-CH4 (90-10) at 10 atm
- ✓ HPgTPC will be surrounded by ECAL & superconducting magnet

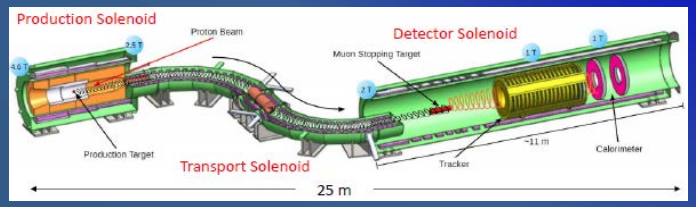
✓ Mu2e Tracker Construction & Future Mu2e-II Tracker Opportunities:

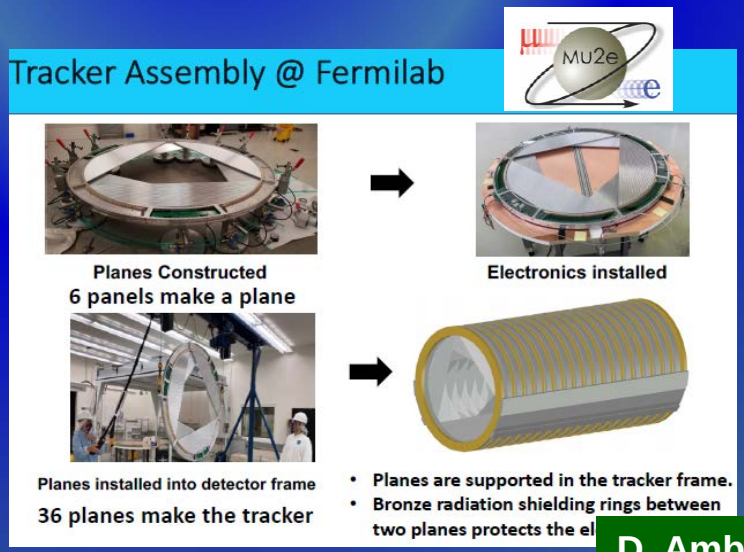
$$R_{\mu e} = \frac{\mu^- + N(A,Z) \to e^- + N(A,Z)}{\mu^- + N(A,Z) \to \nu_\mu + N(A,Z-1)}$$



Mu2e Tracker: Straw tubes in 1T B-field:

- Segmentation to minimize occupancy
- Thin walls minimize multiple scattering
- No support structure in tracking region
- High radiation survival (struct. & electr.)

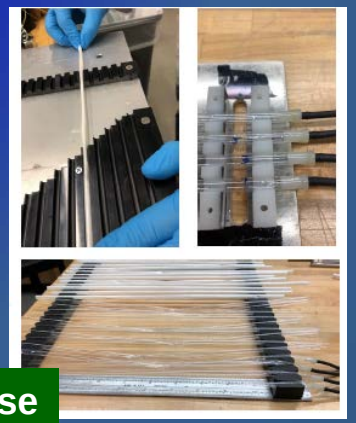




D. Ambrose

Mu2e-II tracker: how to make straws thinner ?

8 μm mylar straws

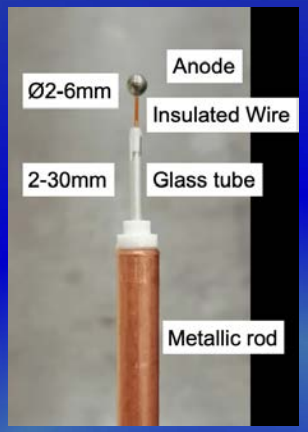


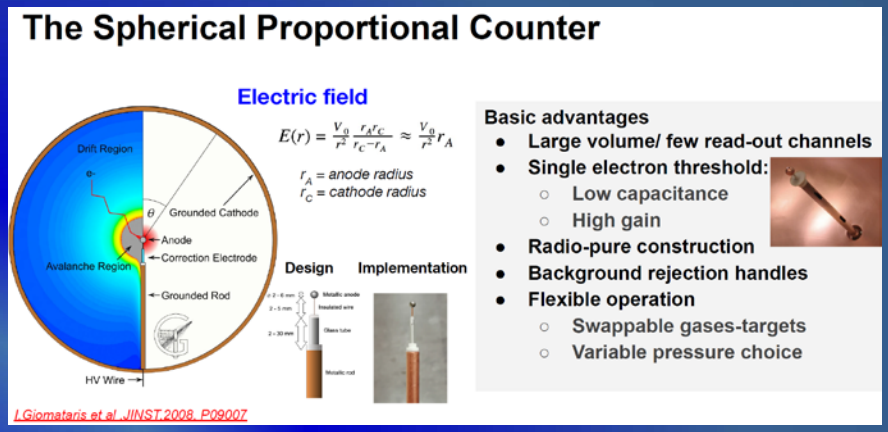
NEWS-G: Search for Dark Matter with Spherical Proportional Counters

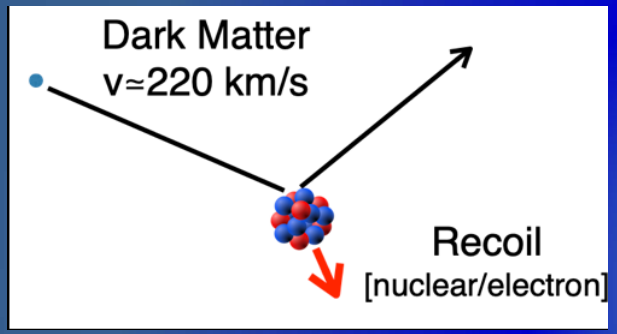
NEWS-G Collaboration: 5 countries, 10 institutes, ~40 collaborators

Three underground laboratories:

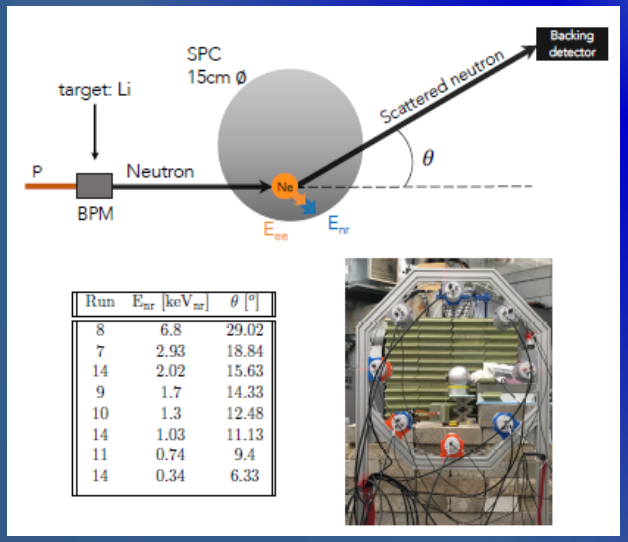
- ✓ SNOLAB
- ✓ Laboratoire Souterrain de Modane
- ✓ Boulby Underground Laboratory







Nuclear Quenching Factor measurements:

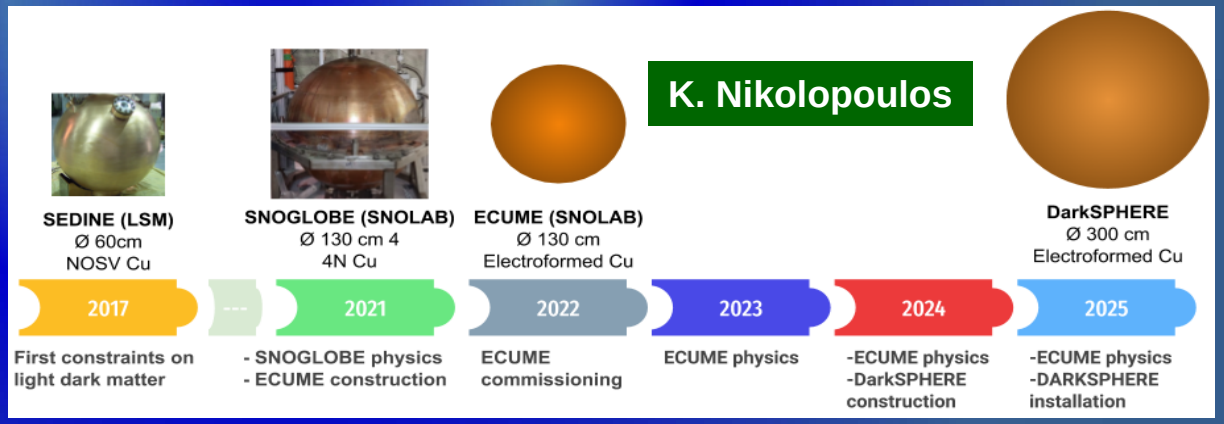


Run	E_{nr} [keV$_{nr}$]	θ [°]
8	6.8	29.02
7	2.93	18.84
14	2.02	15.63
9	1.7	14.33
10	1.3	12.48
14	1.03	11.13
11	0.74	9.4
14	0.34	6.33

Increasing Target Mass and Reducing Background:

- ✓ **ACHINOS, electroformation, …**
- ✓ **Several detectors scheduled for the coming years**
- ✓ **Eventually sensitivity could reach neutrino floor**

K. Nikolopoulos



CEνNS & NEWS-G

M. Vidal

- **CEνNS opens a window to investigation non-standard neutrino interactions**
  - First observations by COHERENT in NaI (2017) and Ar (2020)
  - Unique complementarity with DM searches as sensitivity reaches the neutrino floor
- **NEWS-G3: A low-threshold low-background sea-level facility**
  - Environmental and cosmogenic background studies towards reactor CEνNS studies
  - Shielding: Layers of pure copper, polyethylene, and lead, with active muon veto
  - Commissioning in 2021

Recent Instrumentation Advances for NEWS-G Experiment

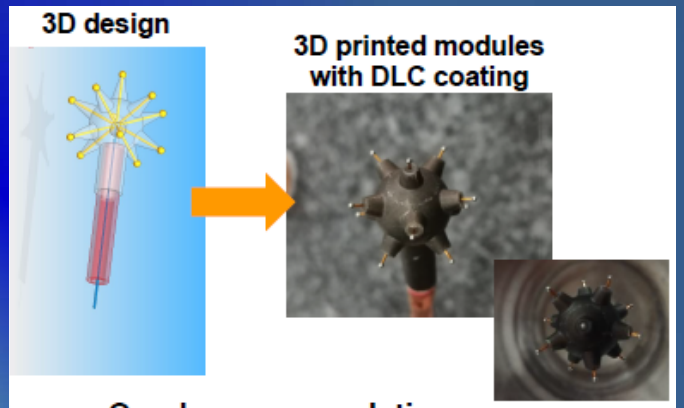
✓ ACHINOS: Multi-anode sensor
- Multiple anodes placed at equal radii
- Decoupling drift and amplification fields
- Opportunity: individual anode read-out

Αχινός (greek. sea urchin)

Decouples electron drift and multiplication
- Small anode size → high gain
- More anodes → Efficient charge collection

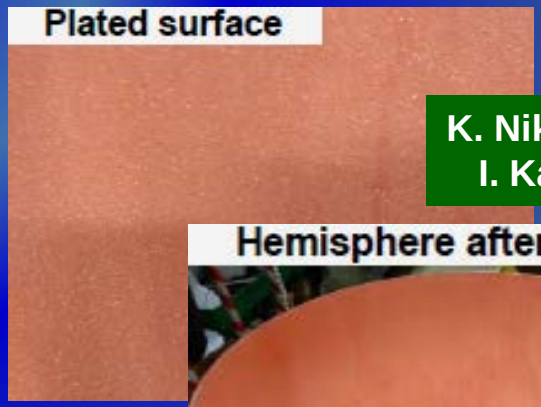
Allows for increased target mass
- Larger volume
- Higher pressure

Individual readout TPC-like capabilities to the SPC

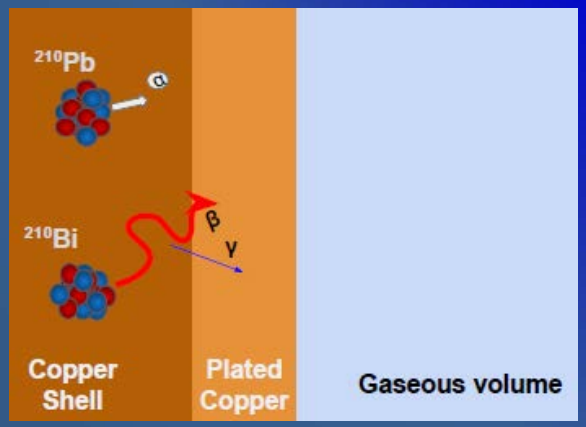


- Good energy resolution
- High pressure operation (> 2 bar)
- High gain
- Stability
- Multi-anode readout

✓ Electroplating Copper – Background Mitigation
- Internal shield: add layer of extremely radio-pure copper
  →500μm deposited in 2 weeks (~36μm/day)
- First large-scale underground radio-pure electroformation



K. Nikolopoulos
I. Katsioulas



Background: Bremsstrahlung X-rays from ^{210}Pb and ^{210}Bi β-decays in Cu

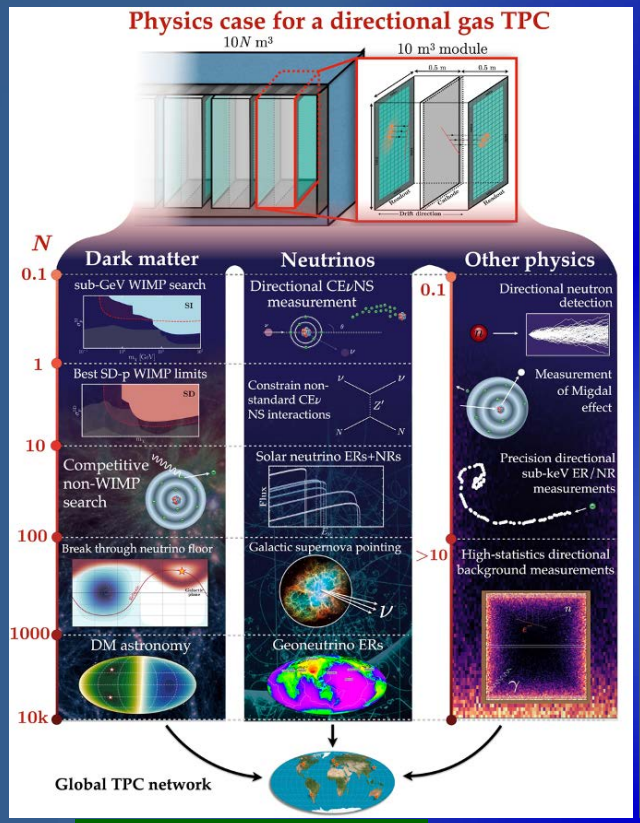
Layer of ultra-pure Cu on the inner surface of the detector.

Suppresses ^{210}Pb and ^{210}Bi backgrounds by factor 2.6 (under 1 keV)

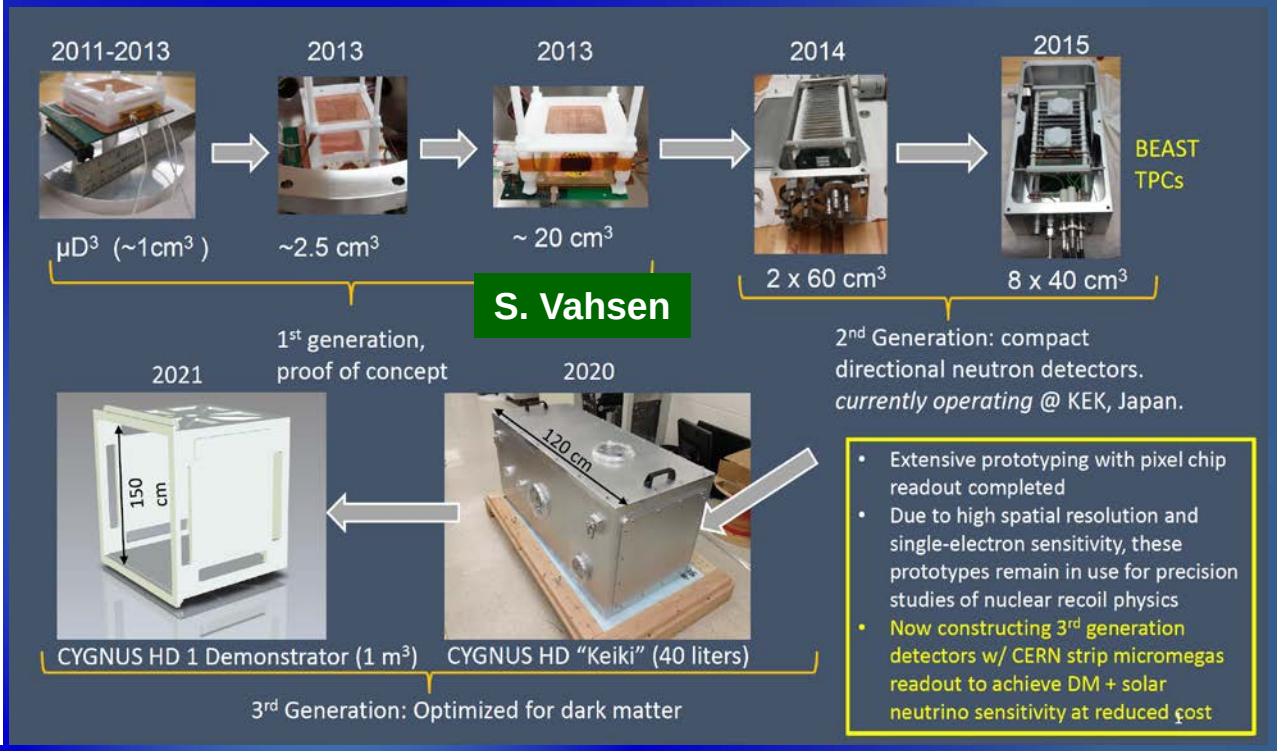
Using PNNL expertise a 500 um electroplated copper was deposited on the inner surface at LSM.

CYGNUS: MPGD TPCs for Low-Energy Nuclear Recoil Imaging

Multi-Site Galactic Recoil Observatory with directional sensitivity to WIMPs and neutrinos



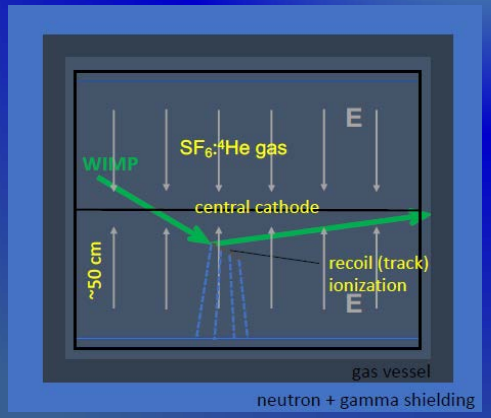
3D vector directionality in gas TPC w/ highly segmented readout



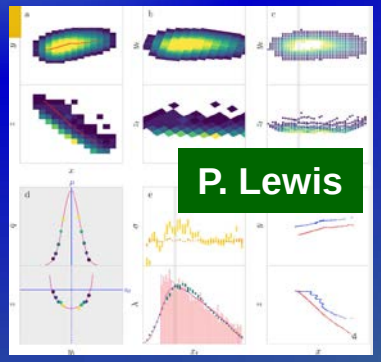
arXiv: 2102.04596

CYGNUS Proto-collaboration:

55 members from six countries: US (6 Faculty members), UK, Japan, Italy, Spain, China



Vector Tracking at Low Energies:

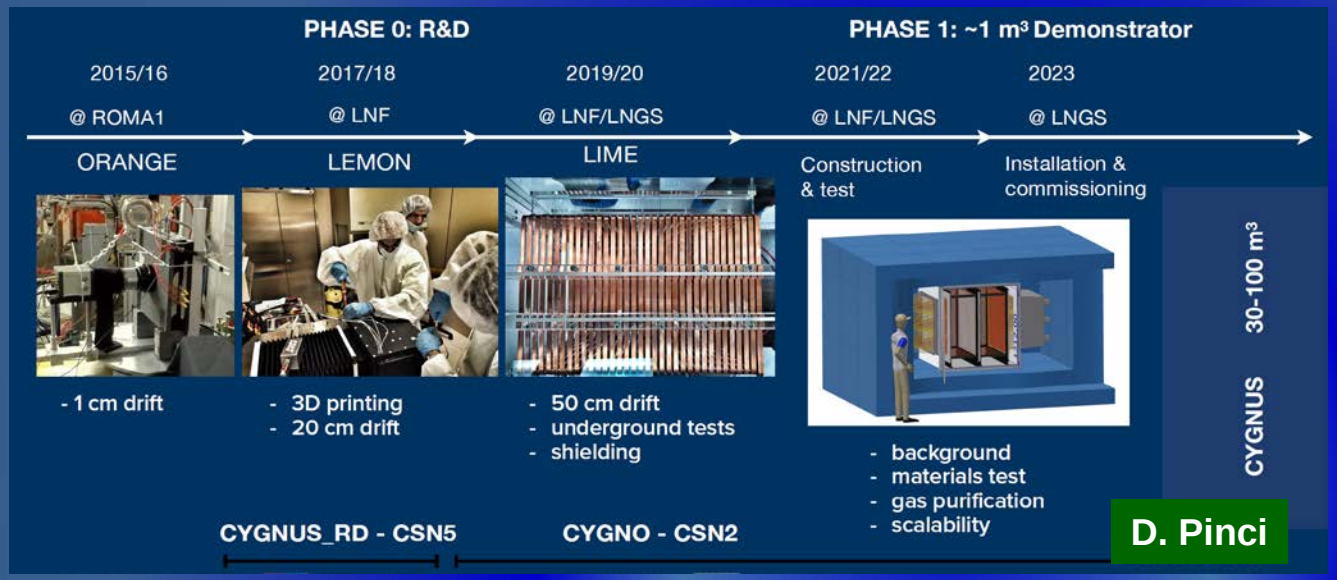


✓ Using primary track recovery, performance is limited by:
- integration effects,
- amplification dispersion,
- drift diffusion

Future developments → « InGrid » & negative-ion TPC

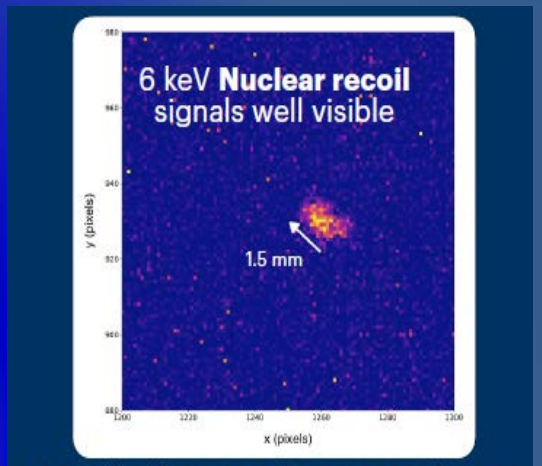
The CYGNO TPC: Optical Readout for Directional Study of Rare Events

CYGNO is working in the framework of CYGNUS: international Collaboration for realization of Multi-side Recoil Directional Observatory for WIMPs & ν's

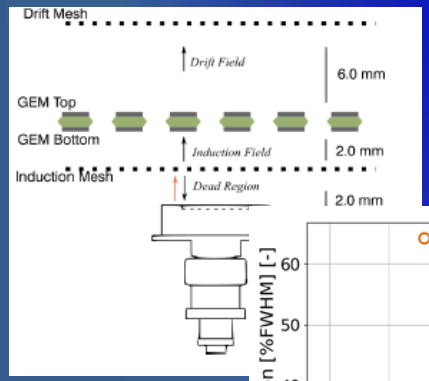


D. Pinci

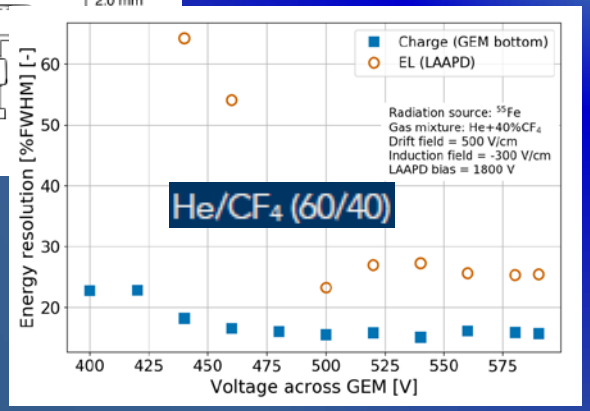
GEM Optical readout: Promising performance in a few keV region



A sizeable efficiency in the range 5-10 keV was measured while more than **95% (99%) ^{55}Fe photons** were **rejected**



Electroluminiscence studies: readout light produced during multiplication process in GEMs



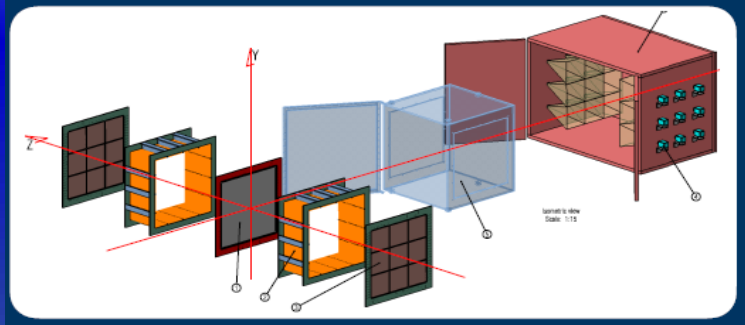
C. Monteiro

Optically readout TPC: 3D tracking (position and direction); total released energy measurement and dE/dx profile;

1M³ DEMONSTRATOR: BASELINE LAYOUT

1 m³ of **He/CF₄ 60/40** (1.6 kg) at **atmospheric pressure** with a composed by two 50 cm long TPC with a central cathode and a drift field of about 1 kV/cm;

Acrylic vessel ensuring gas tightness and high voltage insulation;



Each side equipped by a 3x3 matrix of LIME-like:

- sCMOS sensor 65 cm away;
- Almost 10^8 readout pixels 165 x 165 μm^2
- Fast light detector (PMT or SiPM).

Radioactivity shielding:

- **5 cm** thick **copper** box (Faraday cage too);
- **200 cm** of water.

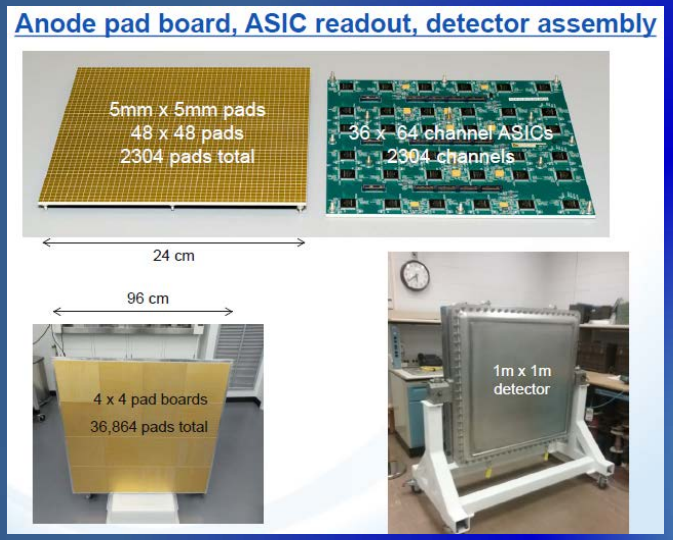
Gas-Filled Neutron Imager Operating in Ionization Mode

Thermal Neutron Detection in ^{3}He

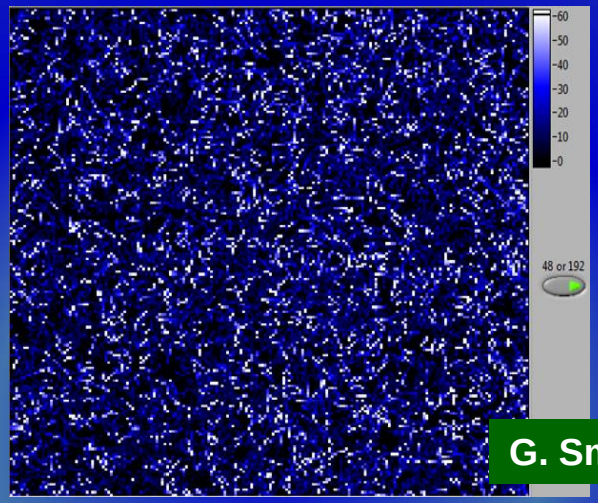
Installed at ANSTO's OPAL reactor

$n + {}^3He \rightarrow p + {}^3H + 764$ keV

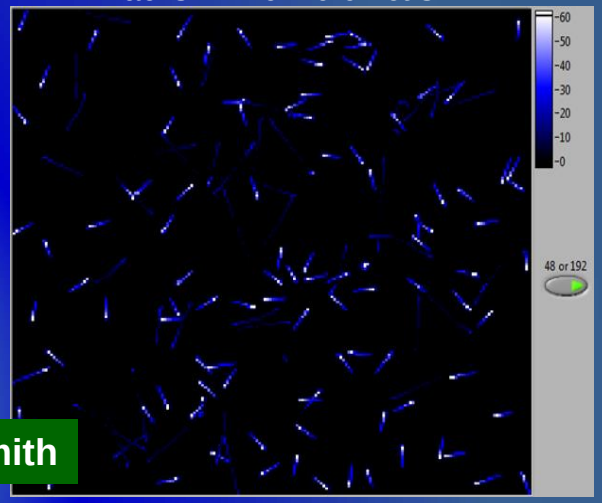
Ability to distinguish thermal neutron from fast neutrons



ADC (Energy) scale ≥ 5 pads
Tracks = 6318 ~ 1 ct s^{-1} m^{-2}



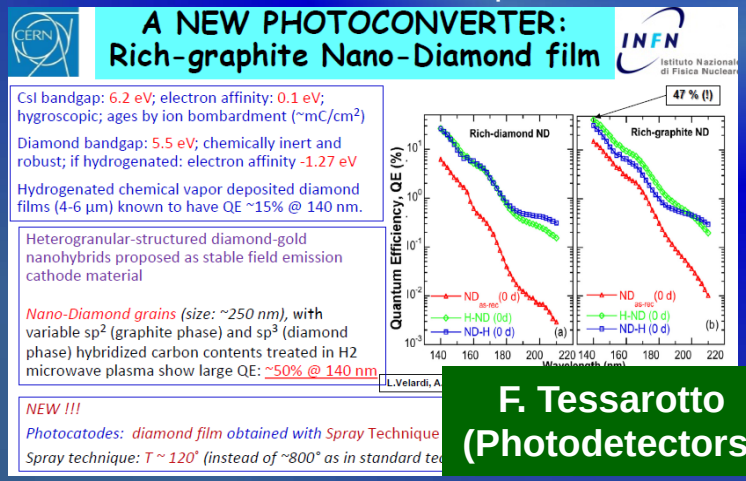
ADC (Energy) scale ≥ 15 pads
Tracks = 146 ~ 0.02 ct s^{-1} m^{-2}



G. Smith

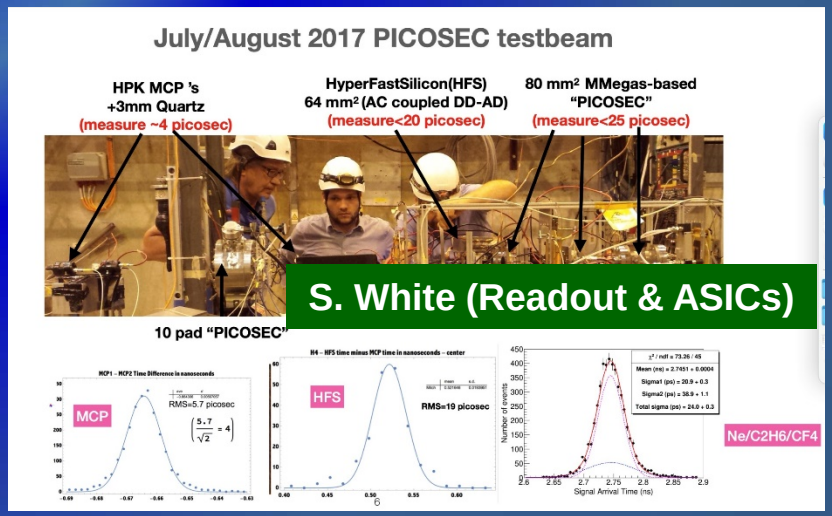
MPGD-based Cherenkov Detector for COMPASS and other applications (also for EiC)

Potential alternative to CsI photocathode



F. Tessarotto (Photodetectors)

Micromegas with picosecond-timing resolution (RD51 Picosec Collaboration)



S. White (Readout & ASICs)

SNOWMASS Instrumentation Frontier WG5: MPGD Topical Group

Conveners: Sven Vahsen (Univ. of Hawaii), Bernd Surrow (Temple Univ.), Maxim Titov (CEA Saclay)

- ✓ There has been a strong interest in MPGDs from US groups for Snowmass process
- ✓ Gaseous Detectors could be a potential area of growth in the US → MPGD applications span collider experiments, dark matter searches, neutrino experiments, nuclear physics, ...

Preliminary List of Snowmass White Papers:

	White Paper (WP) Topic	Executive Summary Length
1	MPGDs: Recent advances and current R&D	3
2	MPGDs for nuclear physics experiments	1.5
3	Recoil imaging for DM, neutrino, and BSM physics*	1.5
4	MPGDs for TPCs at future lepton colliders	1.5
5	MPGD for muon detection at future colliders	1.5
	Grand summary table + text	1

WP1: MPGDs: Recent advances & current R&D

LOI title	Contact
Development of the Micro-Pattern gaseous detector technologies: an overview of the CERN-RD51 collaboration	Silvia.DallaTorre@ts.infn.it
High precision timing with the PICOSEC micromegas detector	Christos.Lampoudis@cern.ch
Optical readout of MicroPattern Gaseous Detectors: developments and perspectives	florian.brunbauer@cern.ch
Pixelated resistive MicroMegas for high-rates environment	massimo.della.pietra@cern.ch
Trigger extensions for the scalable readout system SRS	Hans.Muller@cern.ch
A high-gain, low ion-backflow double micro-mesh gaseous structure	zhzhy@ustc.edu.cn
LOI from NSCL	cortesi@nscl.msu.edu

WP2: MPGDs for nuclear physics experiments

LOI title	Contact
Advanced Micro-Pattern Gas Detectors for Tracking at the Electron Ion Collider	hohlmann@fit.edu
Development of large micro pattern gaseous detectors for high rate tracking at Jefferson Lab	kgnanvo@virginia.edu
LOI from NSCL	cortesi@nscl.msu.edu
The role of MPGD-based photon detectors in RICH technologies	S. Dalla Torre (Trieste)
Snowmass 2021 Expression of Interest: MPGD-based Transition Radiation Detector	yulia@jlab.org

WP3: Recoil imaging for DM, neutrino, and BSM physics

Inter-frontier (Neutrino, Dark Matter, Instrumentation) White Paper on directional nuclear + electron recoil detection

LOI title	Contact
CYGNUS: a nuclear recoil observatory with directional sensitivity to dark matter and neutrinos	sevahsen@hawaii.edu
Optical readout of MicroPattern Gaseous Detectors: developments and perspectives	florian.brunbauer@cern.ch
Towards directional nuclear recoil detectors: tracking of nuclear recoils in gas Argon TPCs	David Caratelli (davidc@fnal.gov)
Dual-Readout Time Projection Chamber: exploring sub-millimeter pitch for directional dark matter and tau identification in ντC C interactions.	Elena Gramellini, elenag@fnal.gov
Directional detectors for CEνNS and physics beyond the Standard Model	Difft@oxy.edu Daniel Snowden Ifft
Trigger extensions for the scalable readout system SRS	Hans.Muller@cern.ch
The International Axion Observatory (IAXO): MPGD development	E. Ferrer Ribas esther.ferrer-ribas@cea.fr

WP4: MPGDs for TPCs at future lepton colliders

LOI title	Contact
Belle II detector upgrades	for TPC: Peter Lewis; lewis@physik.uni-bonn.de
Time projection chamber R&D	qihr@ihep.ac.cn
A time projection chamber using advanced technology for the International Large Detector at the International Linear Collider	A. Bellerive (Carleton)
A high-gain, low ion-backflow double micro-mesh gaseous structure	zhzhy@ustc.edu.cn

WP5: MPGD for muon detection at future colliders

LOI title	Contact
MPGDs for tracking and muon detection: progress review and updated R&D roadmap	hohlmann@fit.edu
Pixelated resistive MicroMegas for high-rates environment	massimo.della.pietra@cern.ch
Advanced GEM detectors for future collider experiments	A.Colaleo (Bari)
micro-RWELL detector	Giovanni.Bencivenni@lnf.infn.it

BACKUP SLIDES:

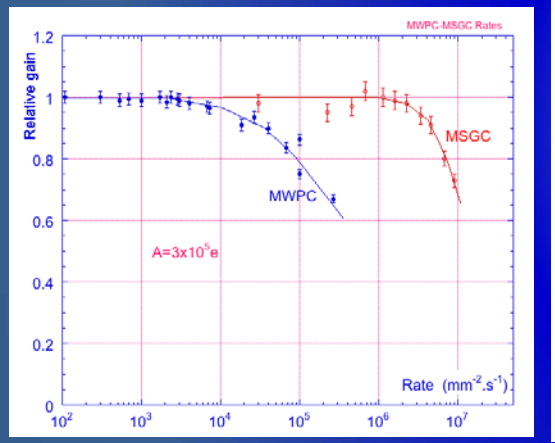
Gaseous Detectors @ Future Collider Experiments:

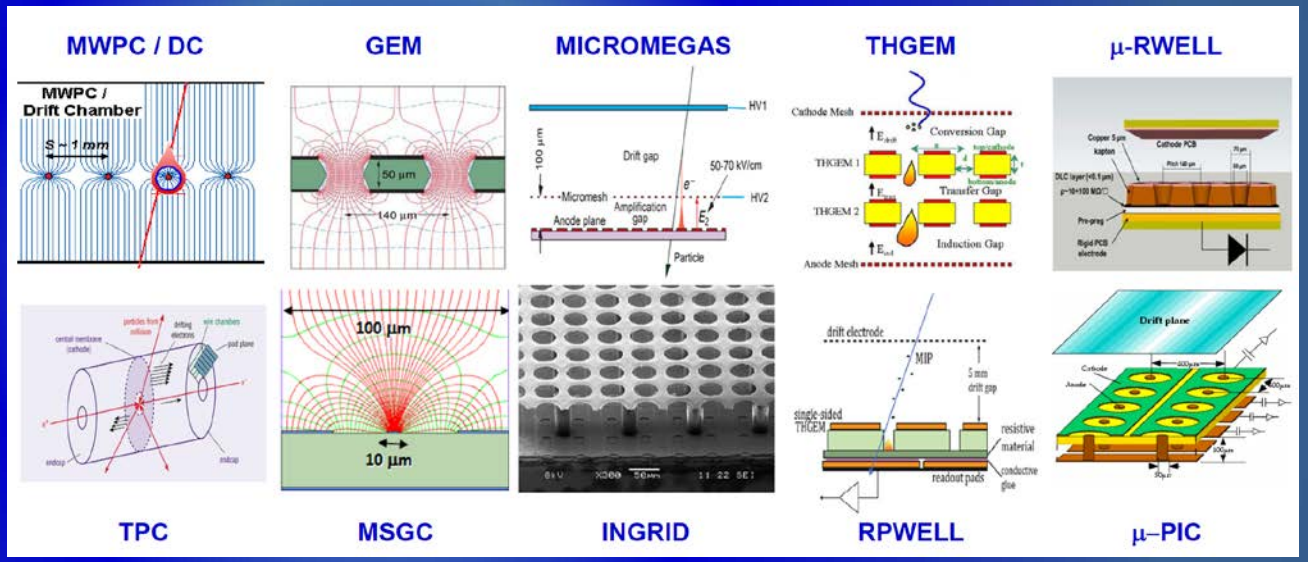
From Wire / Drift Chamber → TPC → Micro-Pattern Gas Detectors

Primary choice for large-area coverage with low material-budget (+ dE/dx measurement)

1990's: Industrial advances in photolithography has favoured the invention of novel micro-structured gas amplification devices (MSGC, GEM, Micromegas, …)

Rate Capability:
MWPC vs MSGC



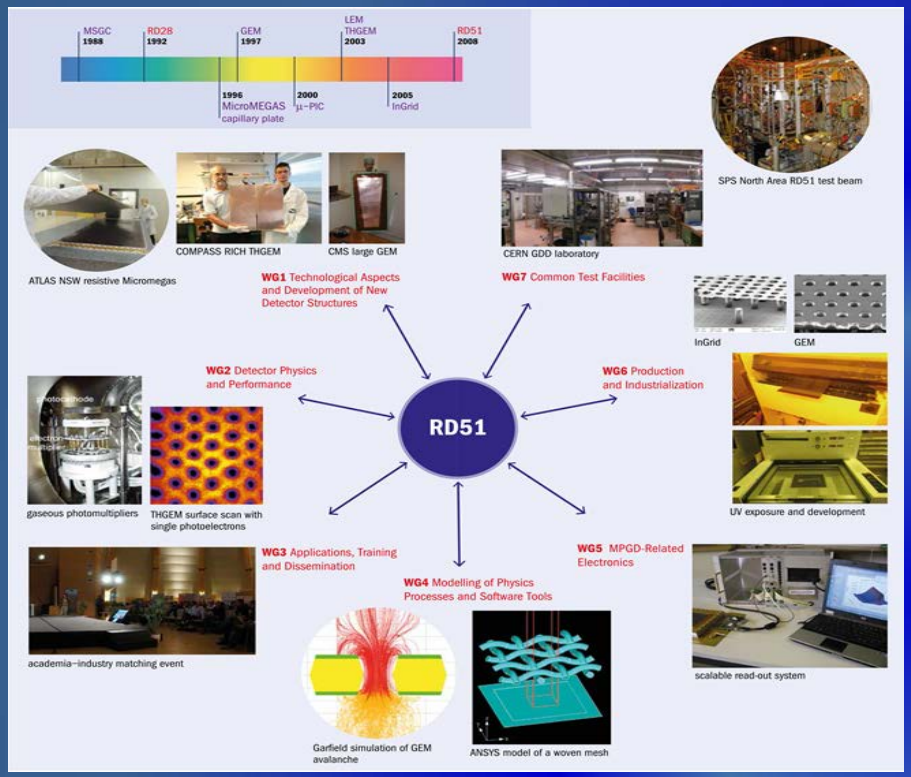


HL-LHC Upgrades: Tracking (ALICE TPC/GEM); Muon Systems: RPC, CSC, MDT, TGC, GEM, Micromegas;

Future Hadron Colliders: FCC-hh Muon System (MPGD - OK, particle rates are comparable with HL-LHC)
Future Lepton Colliders: Tracking (FCC-ee / CepC - Drift Chambers; ILC / CePC - TPC with MPGD readout)
Calorimetry (ILC, CepC – RPC or MPGD), Muon Systems (many gas det. are OK)

Future Election-Ion Collider: Tracking (GEM, μWELL; TPC/MPGD), RICH (THGEM), TRD (GEM)

Micro-Pattern Gaseous Detectors: RD51 Collaboration



- **CERN – RD51 website (recently updated):** https://rd51-public.web.cern.ch/welcome
- Today: ~ 90 RD51 institutes in 25 countries (9 institutes from the USA)
- RD51 proposal for extension beyond 2018: arXiv: 1806.09955
- Started in 2008, **RD51** technological collaboration approved by the CERN Research Board for the third five-years term (2018-2023)

Coordination through RD51 (« RD51 Model »):

Advance the technological development and application of MicroPattern Gas Detectors (MPGDs) and contribute to the dissemination of these technologies.

Development	Dissemination	Tools and facilities
Exploit existing technologies Large size single-mask GEMs Resistive Micromegas	**High-Energy Physics** ALICE, ATLAS, CMS, Compass, KLOE, BESIII	**Common infrastructures** (GDD lab, common test beam)
Develop novel technologies μPIC, μR-WELL, GRIDPIX	**Fundamental research beyond HEP** LBNO-DEMO, active-target TPCs	**Electronics** (Scalable Readout System SRS, instrumentation)
	Beyond fundamental research Muon radiography, n-detection, X-ray radiographies	**Simulation** (Garfield, Magboltz, Degrad, neBEM)

combination of generic and focused R&D with bottom-top decision processes, full sharing of “know-how”, information, common infrastructures →

This model can be exported to other detector domains