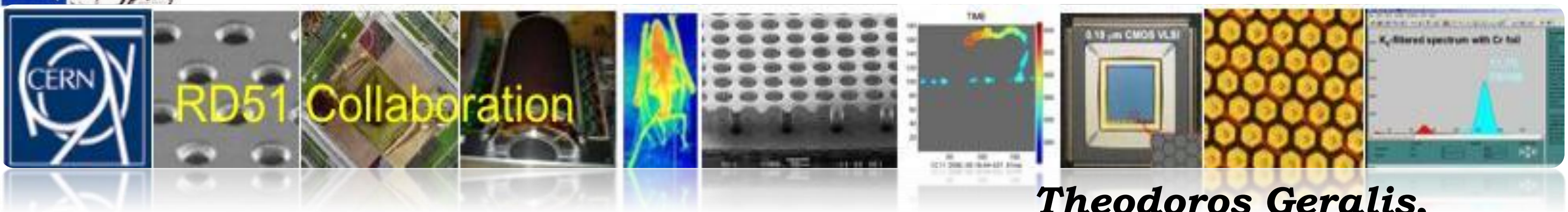
Introduction to the RD51 Collaboration

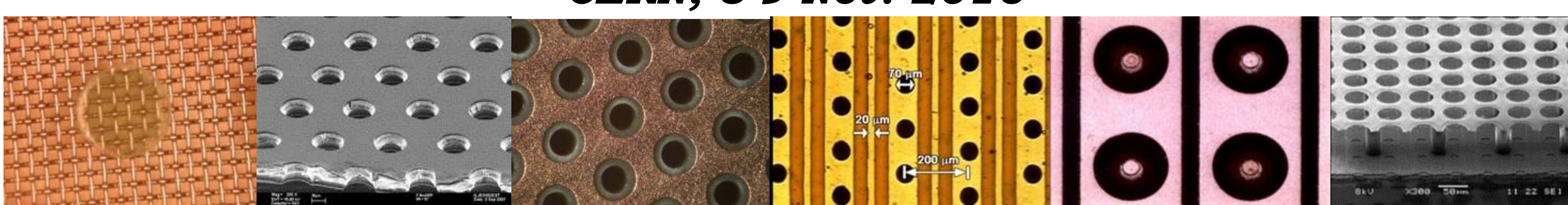


Theodoros Geralis,
NCSR Demokritos, Greece
On behalf of the
RD51 collaboration

OUTLINE

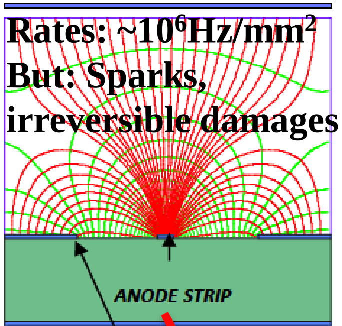
- **RD51/MPGD history**
- **Organization/Infrastructures**
- **Technological achievements**
- **Applications**

Workshop on Neutrino Near Detectors based on gas TPCs
CERN, 8-9 Nov. 2016

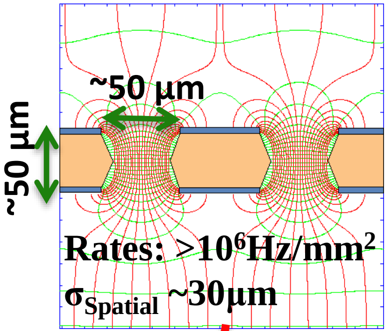


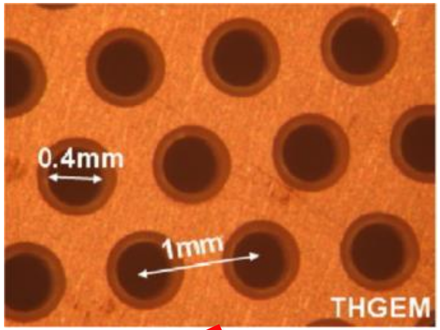
From Multi-Wire Proportional Chambers to Micro Pattern Gaseous Detectors

MSGC: Oed 1988

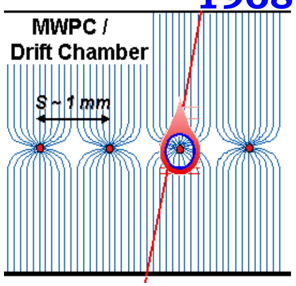


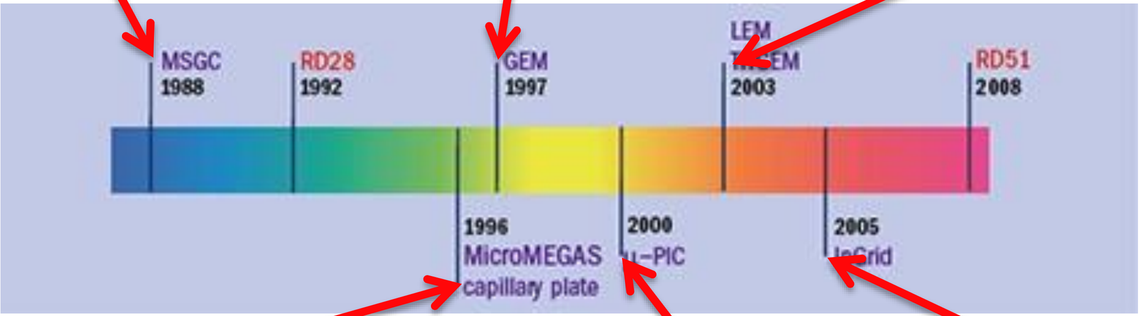
GEM:Sauli 1997





MWPC: Charpak 1968

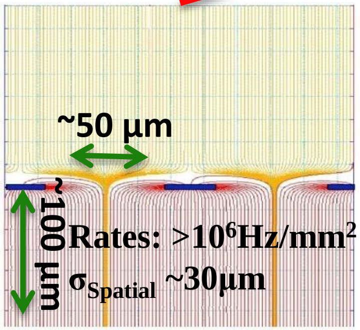




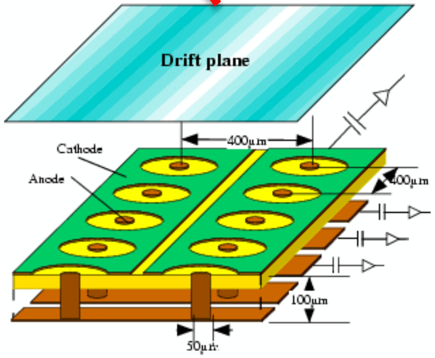
RD51 Collaboration:

86 Institutions

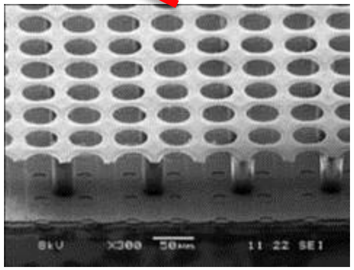
500 Scientists



Micromegas: Giomataris 1996



µ-PIC

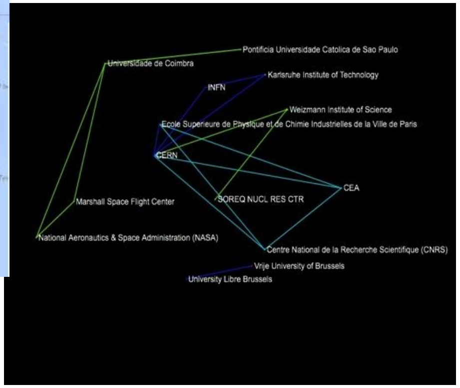


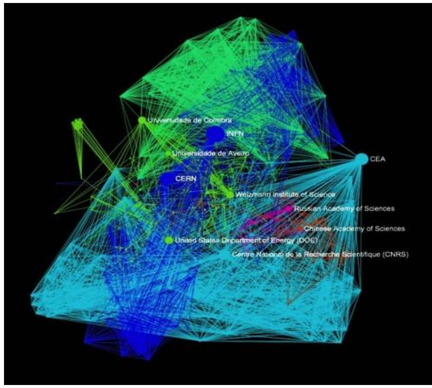
Ingrid

The RD51 Collaboration

Main objectives:

- MPGD technological development
  - Provide the collaboration framework
  - Develop common simulation packages
  - Develop common read out electronics
- Access to "MPGD know-how"
- Foster Industrial production





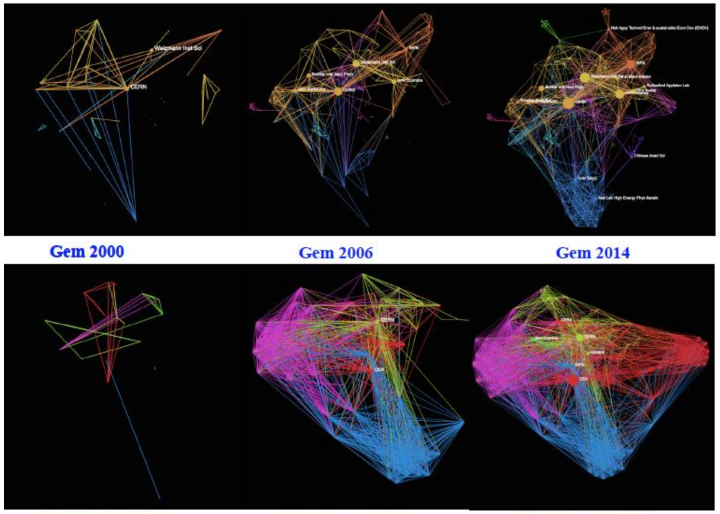
Map: RD51

Current year:	1998
Organisations:	40/717
Clusters:	5
Publications:	35/1059

Map: RD51

Current year:	2015
Organisations:	717
Clusters:	12
Publications:	1059

→ huge growth in interest in the MPGD technologies



Gem 2000 | Gem 2006 | Gem 2014

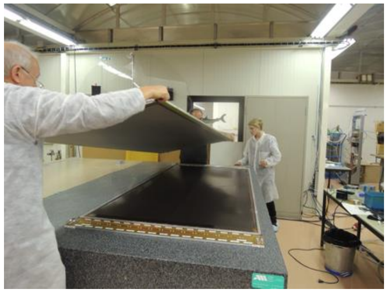
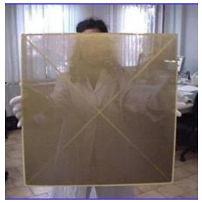
Micromegas 2000 | Micromegas 2006 | Micromegas 2014

Collaboration Spotting Software: http://collspotting.web.cern.ch/)

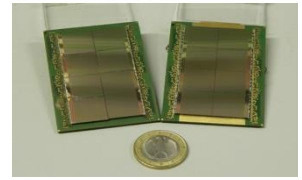
The RD51 Collaboration: Working Groups

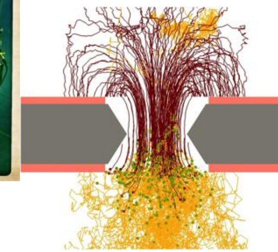
RD51

WG1: Technological Aspects
New Detector Structures

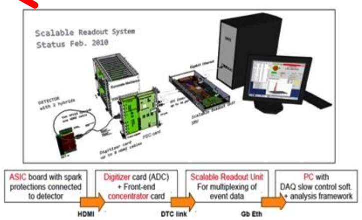



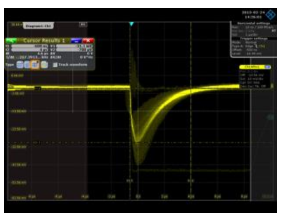

WG2: Detector Physics and Performance
RD51 Common Projects





WG5: MPGD Electronics



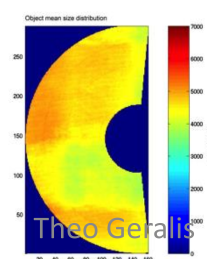


WG4: Modeling of Physics Processes
Software Tools

WG7: Common Test Facilities


WG3: Applications, Training and Dissemination

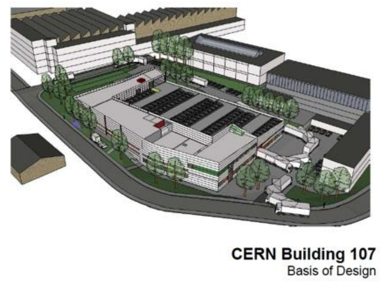

WG6: Production and Industrialization


RD51 related infrastructures:

1) EP DT MPT Workshop (Head: Rui De Oliveira)

The heart of the MPGD Globe: Design, prototyping, production
New infrastructure (building, MPGD production machines, clean room etc) will be soon ready

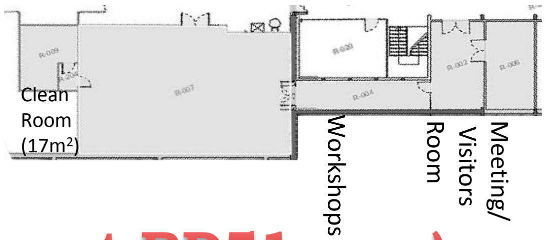


2) GDD Laboratory (RD51)

The Detector R&D laboratory:

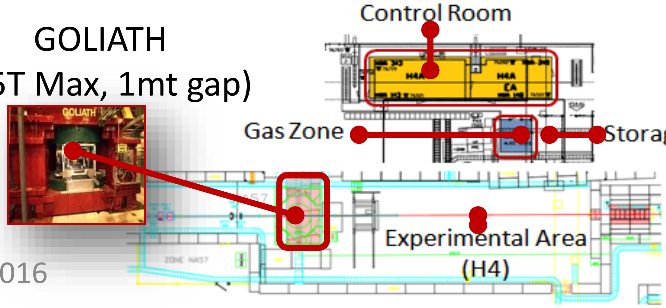
- **Permanent users (ALICE, ATLAS, ESS)**
- **Temporary Users stations**
- **Cosmic stands, X-ray and radioactive sources**
- **Clean room, Workshop**
- **Vacuum and Gas System**
- **MPGD Electronics support**
- **15 visiting groups, synergies with companies**

Laboratory (140m²)



3) Test Beam Area (SPS/H4 semi permanent RD51 area)

GOLIATH
(1.5T Max, 1mt gap)



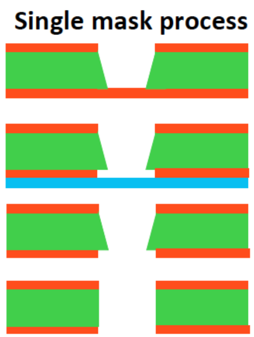
R&D for Experiment
HEP Experiments:
LHC upgrades
CERN & Others
Applications
Electronics

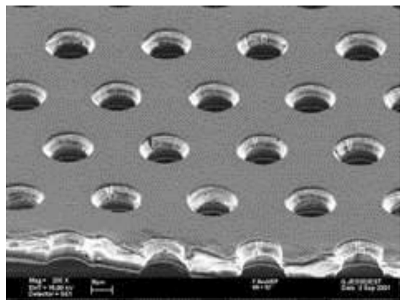
Organize test beam
3 times (2 weeks)/year

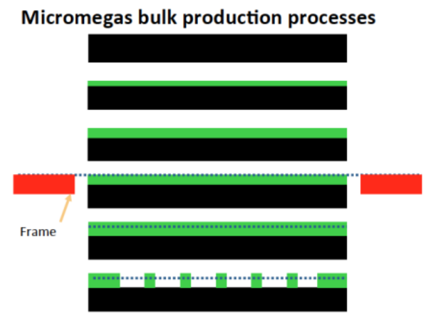
RD51 Technological achievements (I)

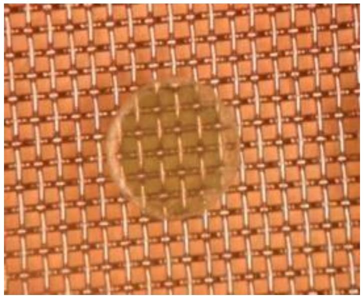
- **Large MPGDs production/industrialization of GEM, THGEM, Micromegas:**

  single mask GEM | Bulk Micromegas





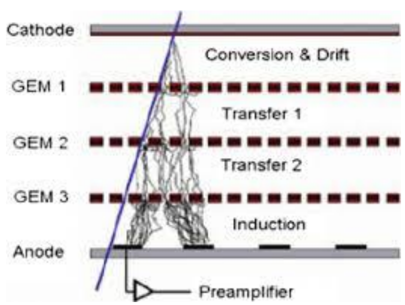


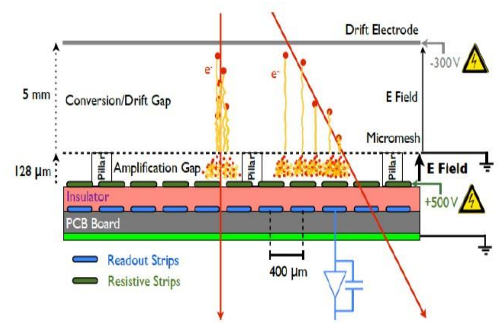


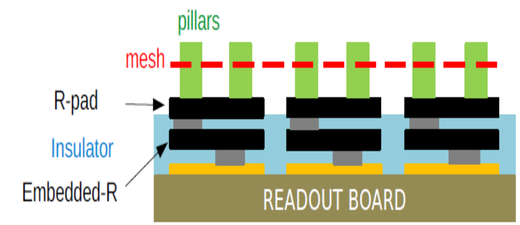
- **High rates and spark mitigation:**

  Staged Gain: multiple layers
  GEM, THGEM, MHSP

  Resistive coating, buried resistors
  Micromegas, RETGEM, RPWELL





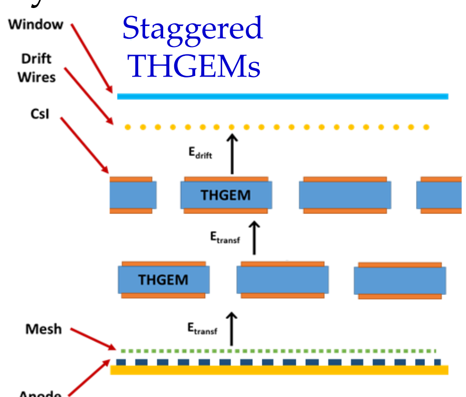


RC-constant controlled with embedded R-pattern

RD51 Technological achievements (II)

- **Ion Back Flow (IBF)**, Application in TPCs (field distortion) and photon detection (photocathode protection): Multiple Layers

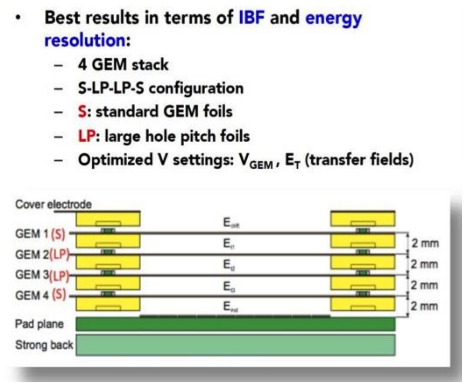
Hybrid: THGEM+ CsI and MM



COMPASS RICH

IBF ~ 5. 10^{-2}

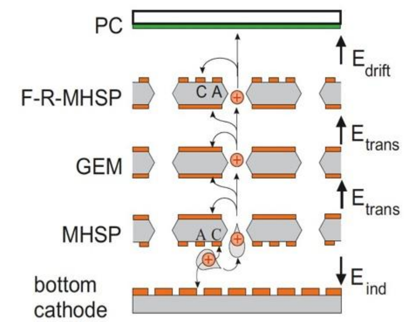
Multi layer GEM



ALICE TPC

IBF ~ (5 – 25) . 10^{-3}

stack MHSP/GEM/F-R-MSHP



IBF ~ (1-3) . 10^{-4}

- **Radiation hardness**
  LHC MPGD Upgrades (ATLAS NSW project - Resistive Micromegas and CMS GEM muon chambers) proven to withstand the equivalent of 10 years of operation at the HL-LHC. Irradiation with: neutrons, X-rays, α and β.

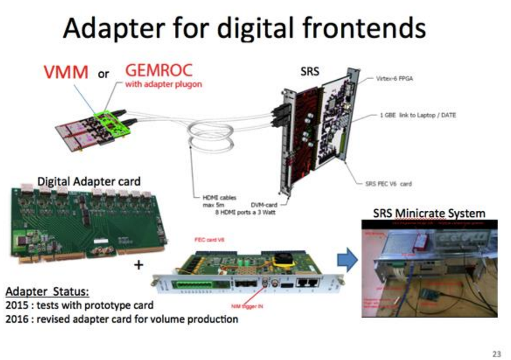
RD51 Technological achievements (III)

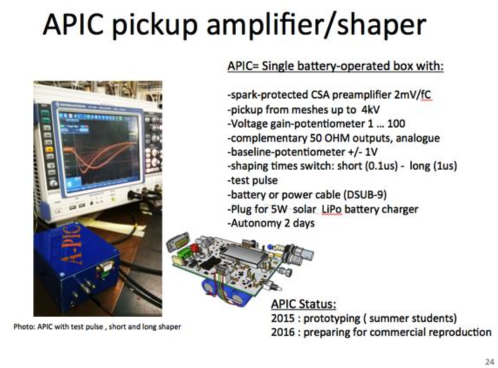
- **Sealed detectors** (purity) for space and non-laboratory applications

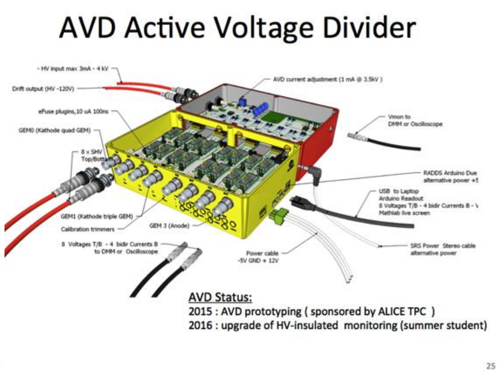
- **Physics simulations and tools**

  Software tools: Magboltz (transport equations), Degrad (cluster size), Garfield++ (speeding up), optimization of charging up simulation
  Modeling of Physics processes: Penning in Ne mixtures, CO2 impact, GEM gas gain dependence on hole diameter, impact of mesh geometry to micromegas

- **Read-out electronics**
  Scalable Readout System: Development of the readout system for MPGDs adaptable to various FE ASIC chips (APV25, VMM2, GEMRoc)
  Development of generic electronic devices for MPGDs:



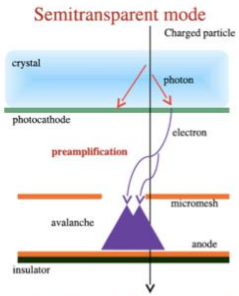




Generic Detector R&D

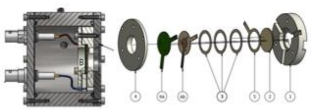
Collaboration with Saclay and Princeton

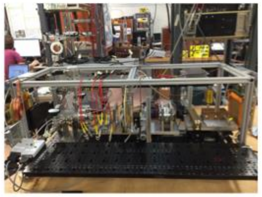
Fast timing with MM

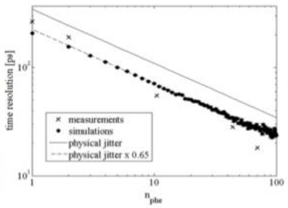


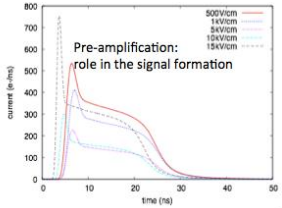
Aim at < 50ps resolution
- Cherenkov radiator
- Photocathode
- 200um drift
- MicroMeGas

R&D on:
- photocathode protection
- photocathode alternatives
- secondary emitter materials









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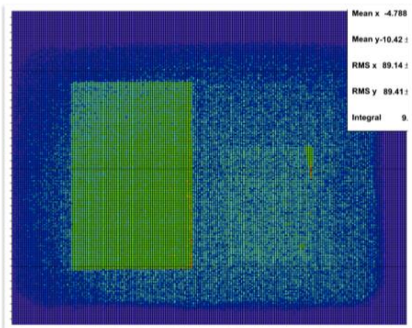
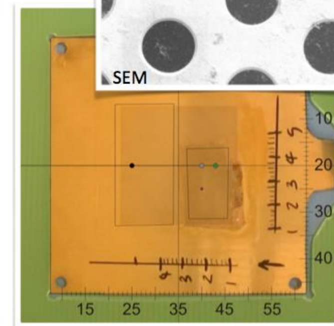
Collaboration with UCL

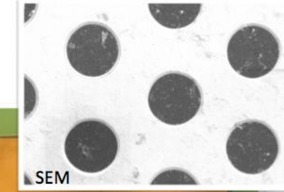
Graphene

Membrane opaque to ions and transparent to electrons
- solution of the ion back-flow in gaseous detectors
- protective layer on photocathodes
- enhancement of electron emission

~99% (suspended)
graphene tri-layer coverage







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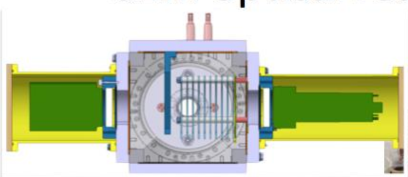
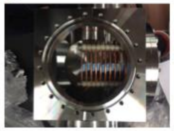
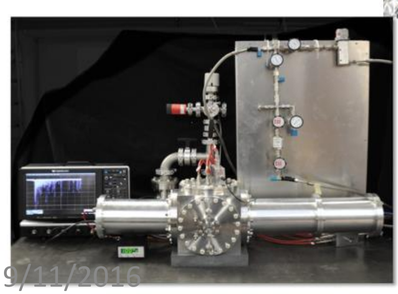
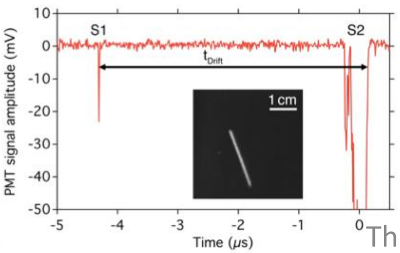
GEM optical readout and OTPC



Study:
- Visible (near UV and near IR) scintillation of gasses
- Event topology study
- Imaging







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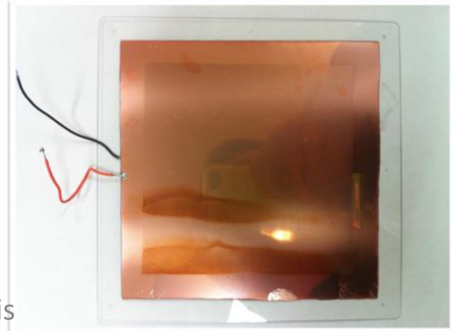
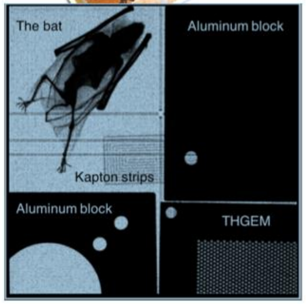
Collaboration with Tokyo University

Glass GEM

Photo Etchable Glass 3 (PEG3):
Rigid (self sustained structure)
'Laser assisted etching' opens new possibilities
Slightly conductive (milder charge-up)
Clean and low outgassing (sealed operation)

Imaging with electronic readout





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MPGD Technologies for Present and Future:

- **Hadron / Nuclear Physics Experiments-Heavy Ion Facilities**
- **High Energy Physics**
- **Hadron / Lepton Colliders**
- **Photon / Neutron Detection**
- **Neutrino Physics / Dark Matters Detection**
- **X-Ray Detection and γ-Ray Polarimetry**

MPGD Technologies: LHC experiments Upgrades

Challenges: Ultra high rates, radiation harsh environment, longevity, large area detectors

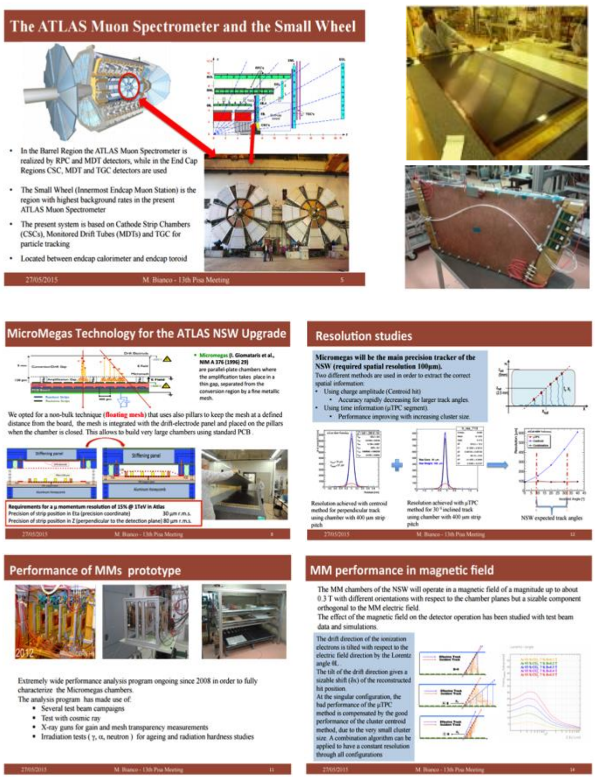
Present:

TOTEM (GEM), LHCb (GEM)

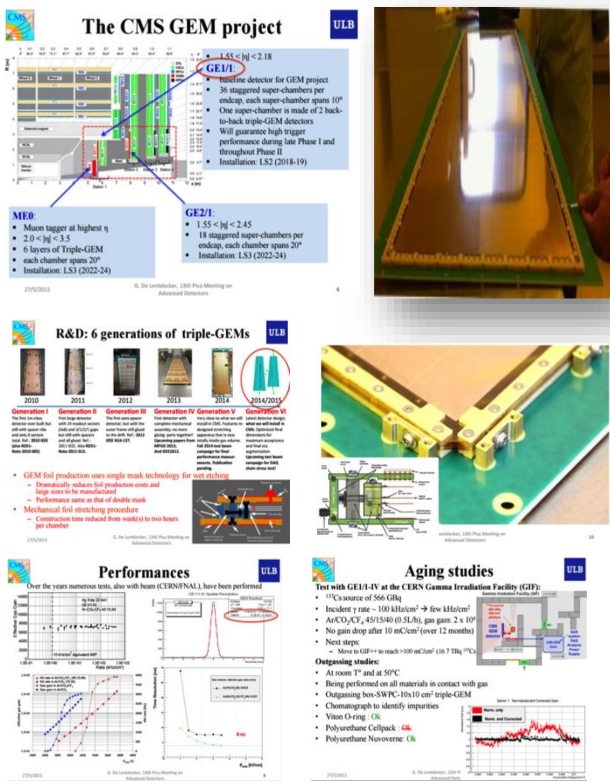
Future:

ATLAS Muon System NSW (μM), Muon tagger μ-PIC, CMS Muon System (GEM), ALICE (GEM TPC), FCC Collider (GEM, THGEN, Micromegas, μ-PIC, InGrid)

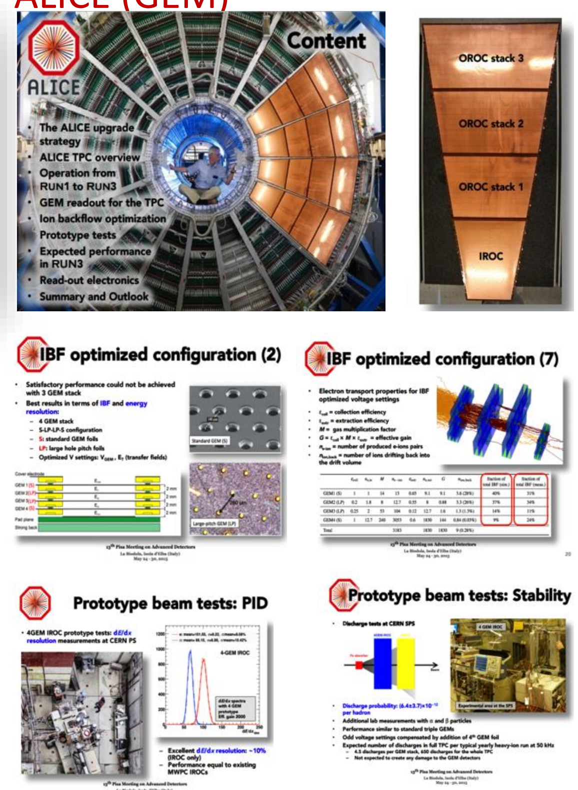
ATLAS NSW (mm)



CMS (GEM)



ALICE (GEM)



MPGD Technologies: Hadron and Nuclear and Heavy Ion Physics experiments

Challenges: Ultra High rates, IBF

Present:

COMPASS (GEM, μMegas, THGEM RICH), rates: 100kHz/mm^2

First experiment to use MPGDs (GEM, Micromegas and recently THGEM)

KEDR (GEM), Rates: 1MHz/mm^2

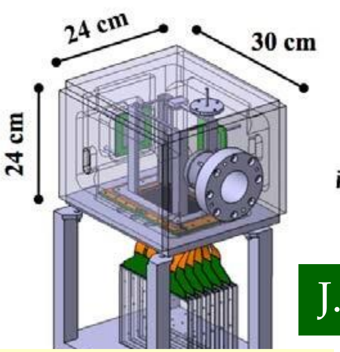
CLAS12: Cylindrical MM

Future: JLAB: SBS, pRad, SoLID (GEM, NP, tracking), JPARC: E42, E45 (Hadron Physics, ACTAR TPC

The ACTAR TPC Project

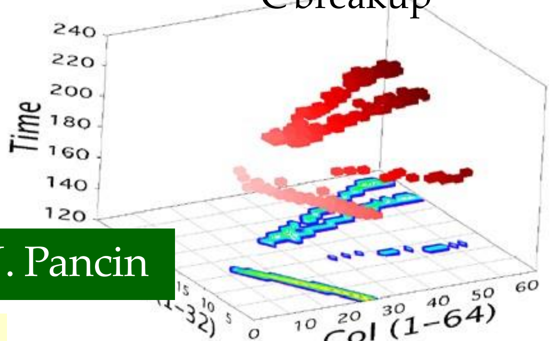
(gas is used as a secondary target for nuclear reactions):

Goal: Nuclear structure with rare-isotope beams



MM-based readout

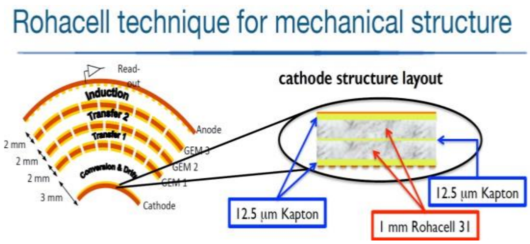
^{12}C breakup



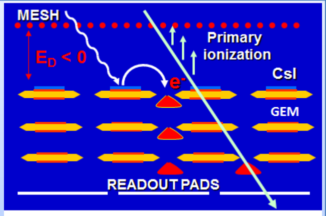
J. Pancin

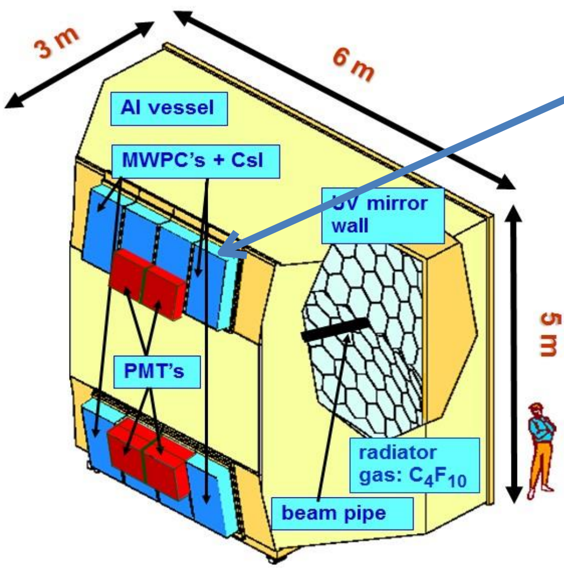
$^4He(^{12}C,3\alpha)^4He$

Cylindrical GEM for BESIII Experiment @ e+e- collider Beijing

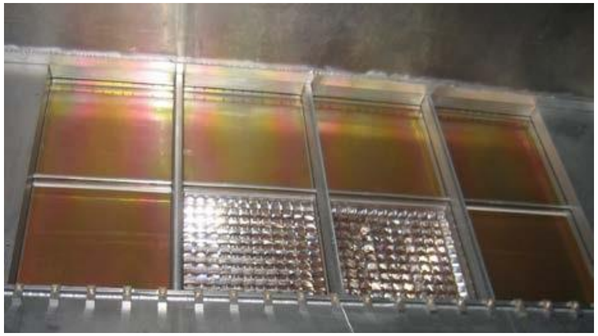


MPGD Technologies: Photon detection
Challenges: IBF photocathode protection
Present:
COMPASS (THGEM RICH)
Future: JLAB: SBS, pRad, SoLID (GEM, NP, tracking), JPARC: E42, E45 (Hadron Physics, ACTAR TPC



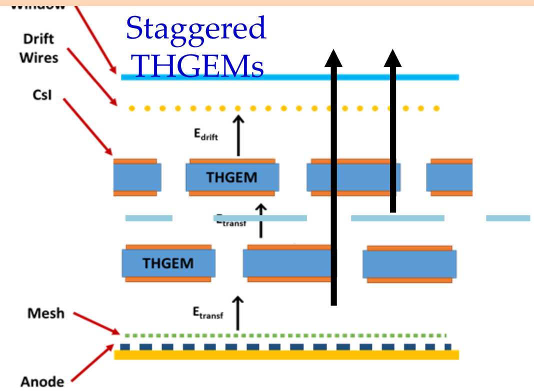


MWPC's + CsI



F. Tessarotto

Hybrid: THGEM+ CsI and MM



mass production ongoing

After a long-term fight for increasing electrical stability at high rates: MWPC robust operation is not possible at gain~10^5 because of photon feedback, space charge & sparks

PMTs not adequate → only small demagnification factor allowed; 5 m^2 of PMTs not affordable.

MPGD Technologies: Neutron detectors (ITER spallation sources, Macromolecular Crystallography Beam diagnostics)

Challenges: Low mass detectors

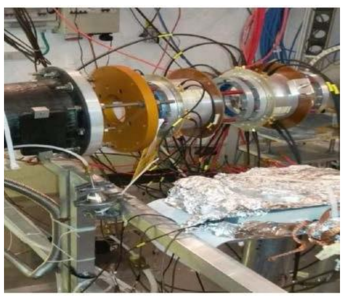
Present:

nTOF

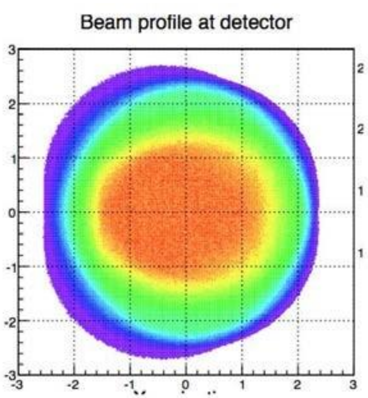
Future:

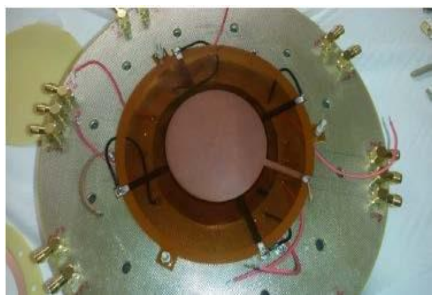
ESS (macromolecular crystallography, neutron scattering)

nTOF at CERN



Installation on NTOF





4 pad detector

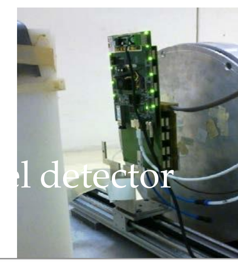
µMegas detector:

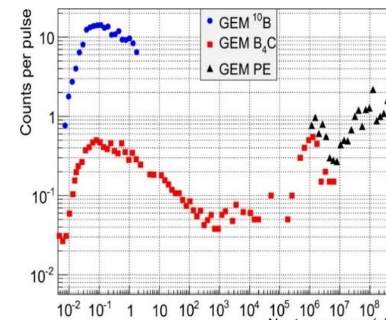
2 D reconstructed image

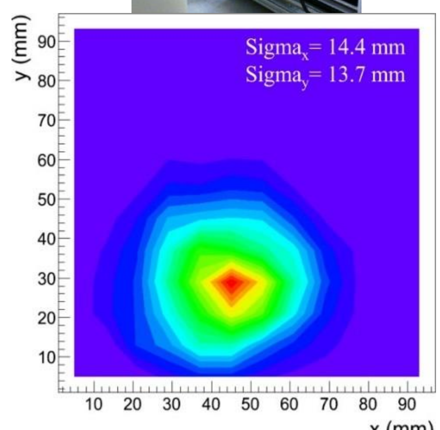
T. Papaevangelou

µM Neutron Monitor applied to fission reactor

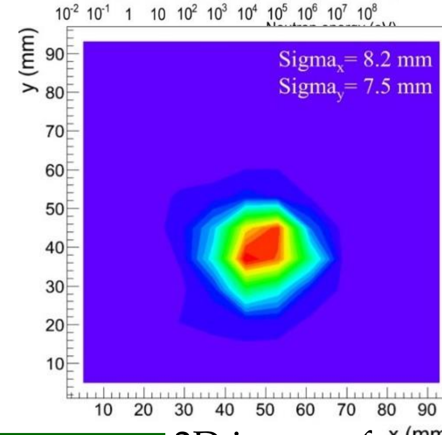
GEM detector







2D image of thermal neutron



F. Murtas

2D image of fast neutron

MPGD Technologies: Neutrino Physics

Challenges: Large area TPCs

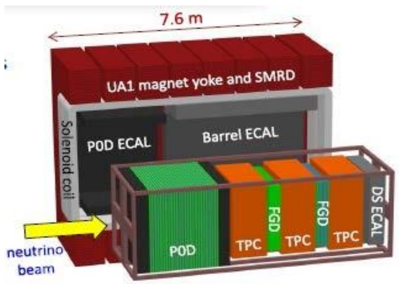
Present:

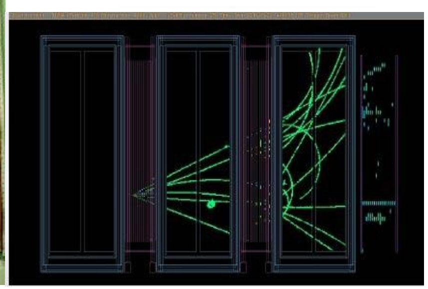
T2K (Japan), first large scale neutrino experiment with MPGD (9 m^2 TPC with micromegas)

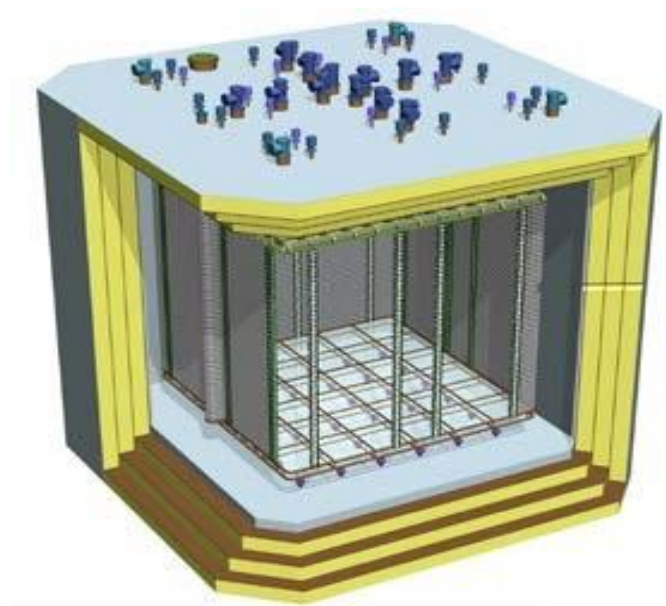
Future:

LBNO-DEMO (LAr TPC THGEM), DUNE 720 m^2 (LAr TPC THGEM), Ship (26 m^2 micromegas, GEM, mRWELL)

T2K experiment







- 72 Micromegas,120k channels (since 2009)
- Charge, momentum and dE/dx PID)
- Spatial resolution : 0.6 mm
- Momentum res.: 9% at 1 GeV
- dE/dx: 7.8 % (distinguish μ/e, identify ν_e)

MPGD Technologies: Dark Matter detection

Challenges: Ultra low background detectors < 10^{-7}cnts/keV/cm^2

Present:

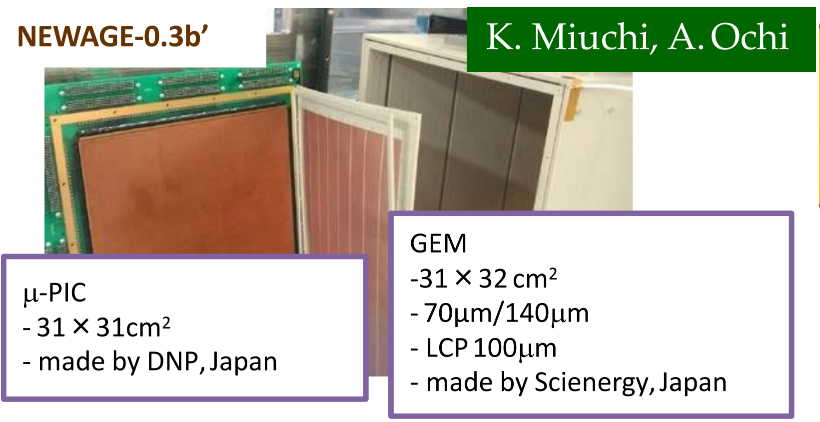
CAST (Micromegasµbulk and Ingrid), NEWAGE (Kamioka, TPC GEM, µPIC)

Future:

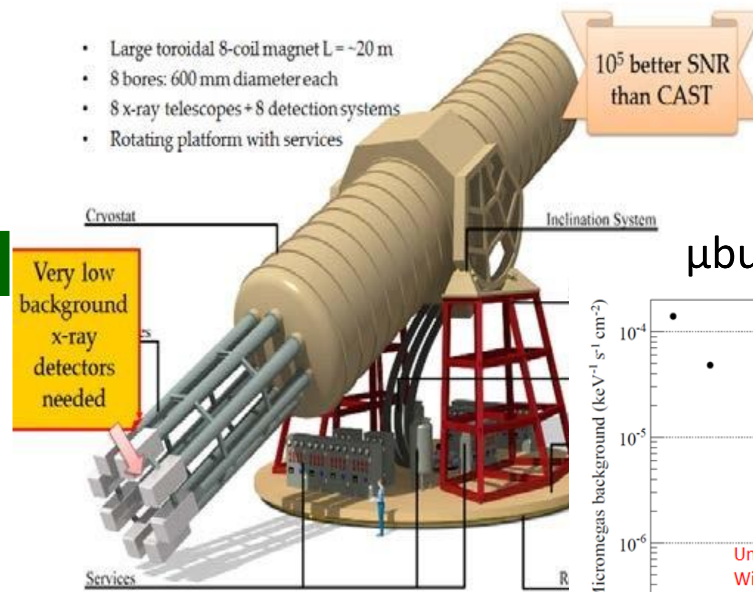
PANDA-X(TPC µbulk micromegas, DARWIN (THGEM GMPT), IAXO (µbulk micromegas)

NEWAGE
µ-PIC based TPC with electronics
Only DM experiment with 3-D tracks

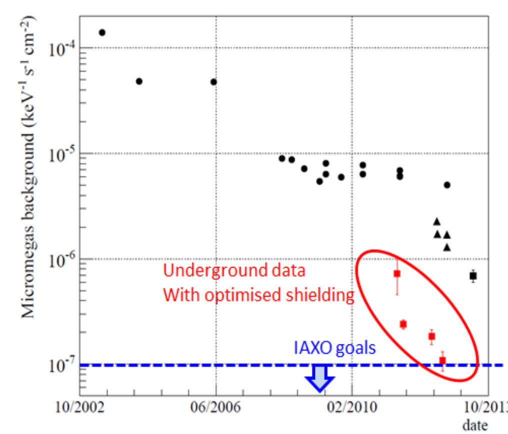
NEWAGE-0.3b'



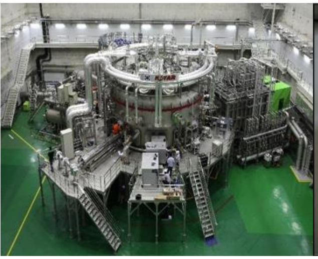
IAXO: Axion searches

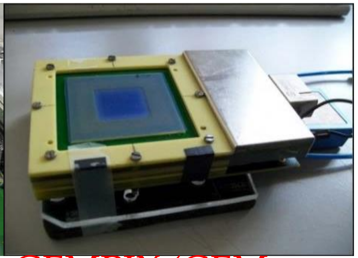


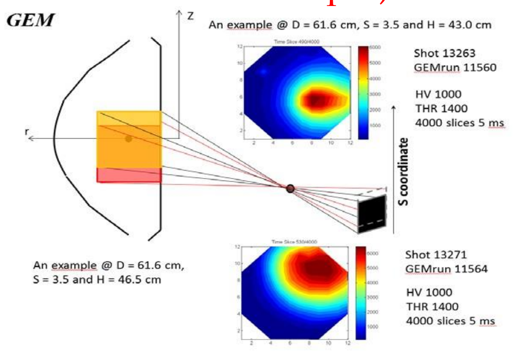
µbulk background



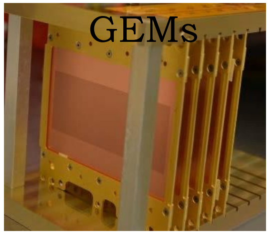
MPGD Technologies: X and γ ray detection and polarimetry
Astrophysics and fusion plasma monitor
Challenges: Track photoelectrons and low energy e
Present:
KSTAR Korea (Plasma monitor), SMILE II (γ-ray imaging, GEM and μPIC) , ETCC camera (GEM and μPIC) environmental γray monitoring
Future:
PRAXyS (TPC GEM x-ray polarimetry), CALISTE (piggy back micromegas, X-ray polarimetry)

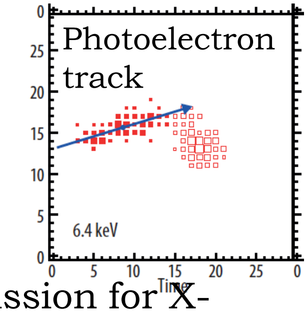

KSTAR Tokamak


GEMPIX (GEM + Timepix) for fusion



PRAXyS X-ray polarimetry

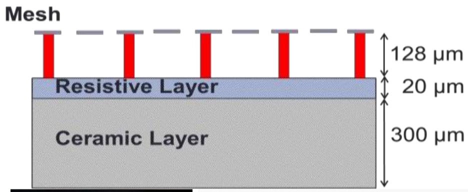


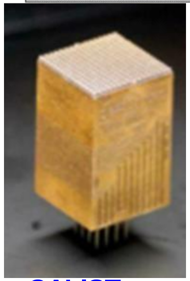


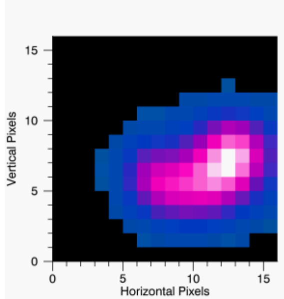
- The first dedicated mission for X-ray polarimetry in astrophysics
- US-Japan joint mission (NASA lead)
- The space craft carries two identical
- **GEM-TPC**

CALIST-MM: X-ray polarimetry

Piggyback Micromegas



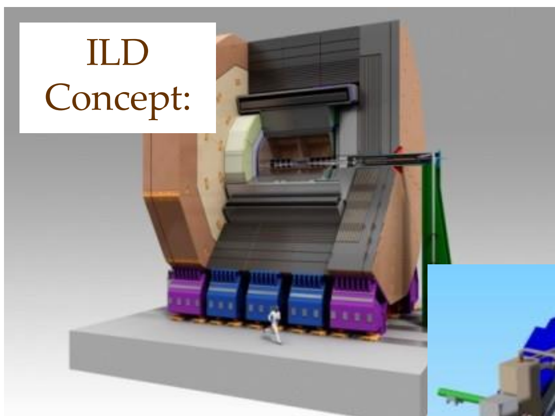

CALIST

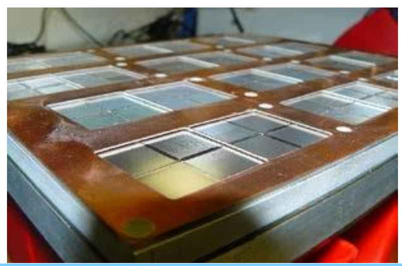


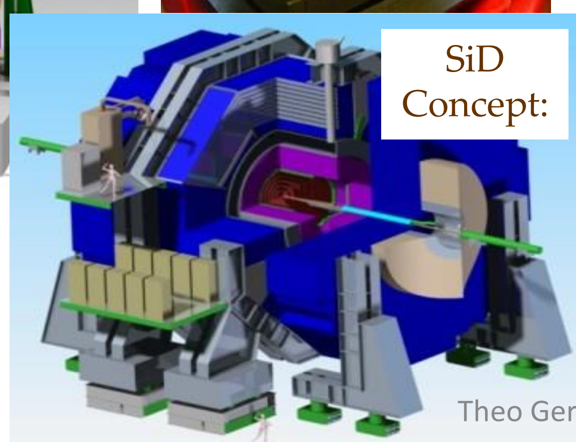
- 10 x 10 x 20,7 mm³ (Compact)
- 16x16 pixels : 8 ASICs of 32 channels
- Pixel Ø = 500 μm ; Pixel Pitch = 580 μm
- Consumption = 850 μW/channel (218 mW in total)
- Low Noise (ENC = 50 e- rms)

MPGD Technologies for the International Linear Collider

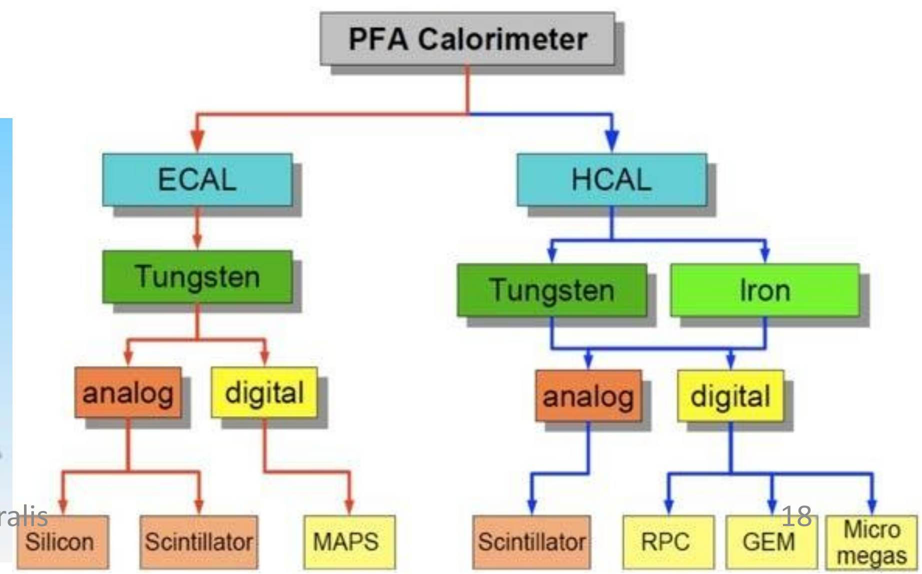
Experiment / Timescale	Application Domain	MPGD Technology	Total detector size / Single module size	Operation Characteristics / Performance	Special Requirements/ Remarks
ILC Time Projection Chamber for ILD: Start: >2030	High Energy Physics (tracking)	Micromegas GEM (pads) InGrid (pixels)	Total area: ~ 20 m^2 Single unit detect: ~ 400 cm^2 (pads) ~ 130 cm^2 (pixels)	**Max. rate**: < 1 kHz **Spatial res.:** <150μm **Time res.:** ~ 15 ns **dE/dx:** 5 % (Fe55) **Rad. Hard.:** no	Si + TPC Momentum resolution : $dp/p < 9*10^{-5}$ 1/GeV Power-pulsing
ILC Hadronic (DHCAL) Calorimetry for ILD/SiD Start >2030	High Energy Physics (calorimetry)	GEM, THGEM RPWELL, Micromegas	Total area: ~ 4000 m^2 Single unit detect: 0.5 - 1 m^2	**Max.rate:** 1 kHz/cm^2 **Spatial res.:** ~ 1cm **Time res.:** ~ 300 ns **Rad. Hard.:** no	Jet Energy resolution: 3-4 % Power-pulsing, self-triggering readout







Particle Flow Calorimetry (ILD/SiD):



MPGD Conferences and Special focus events

MPGD Conferences since 2009:

1st MPGD2009, Crete, Greece
2nd MPGD2011, Kobe, Japan
3rd MPGD2013, Zaragoza, Spain
4th MPGD2015, Trieste, Italy

4th MPGD2015, Trieste, Italy
140 participants, 120 abstracts

NEXT: 5th MPGD2017, Temple University, USA
May 22 – 26, 2017

Special focus MPGD events. Most recent :

- Academia-Industry Matching event:
  Second special workshop on **neutron detection** with MPGDs, CERN, March 2015
- Rd51 Academia-Industry Matching event:
  Special workshop on **photon detection** with MPGDs, CERN, June 2015
- Topical workshop on **resistive electrodes**, CERN, Dec. 2015
- Topical workshop on **discharges** in MPGDs, CERN, March 2016
- MPGD **Applications Beyond Fundamental Science** Workshop, Aveiro, Portugal, Sept. 2016

- Schools, visits, events

CONCUSIONS

RD51 collaboration contribution:

MPGD technologies have received enormous boost over the last decade

MPGDs are used in many scientific domains

MPGDs are used in many applications beyond Particle Physics

Exciting field for creative new ideas, attractive for young scientists !