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

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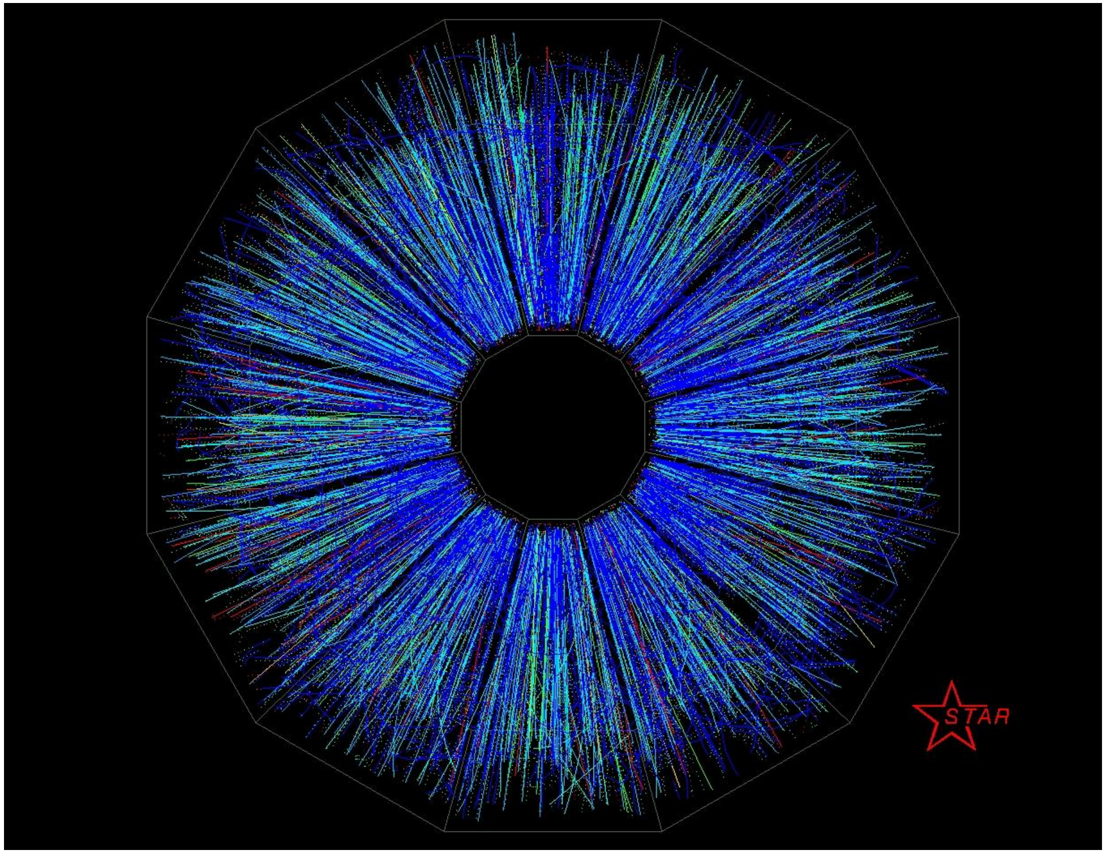
History, principle of operation
Advantages

New ideas with MPGDs

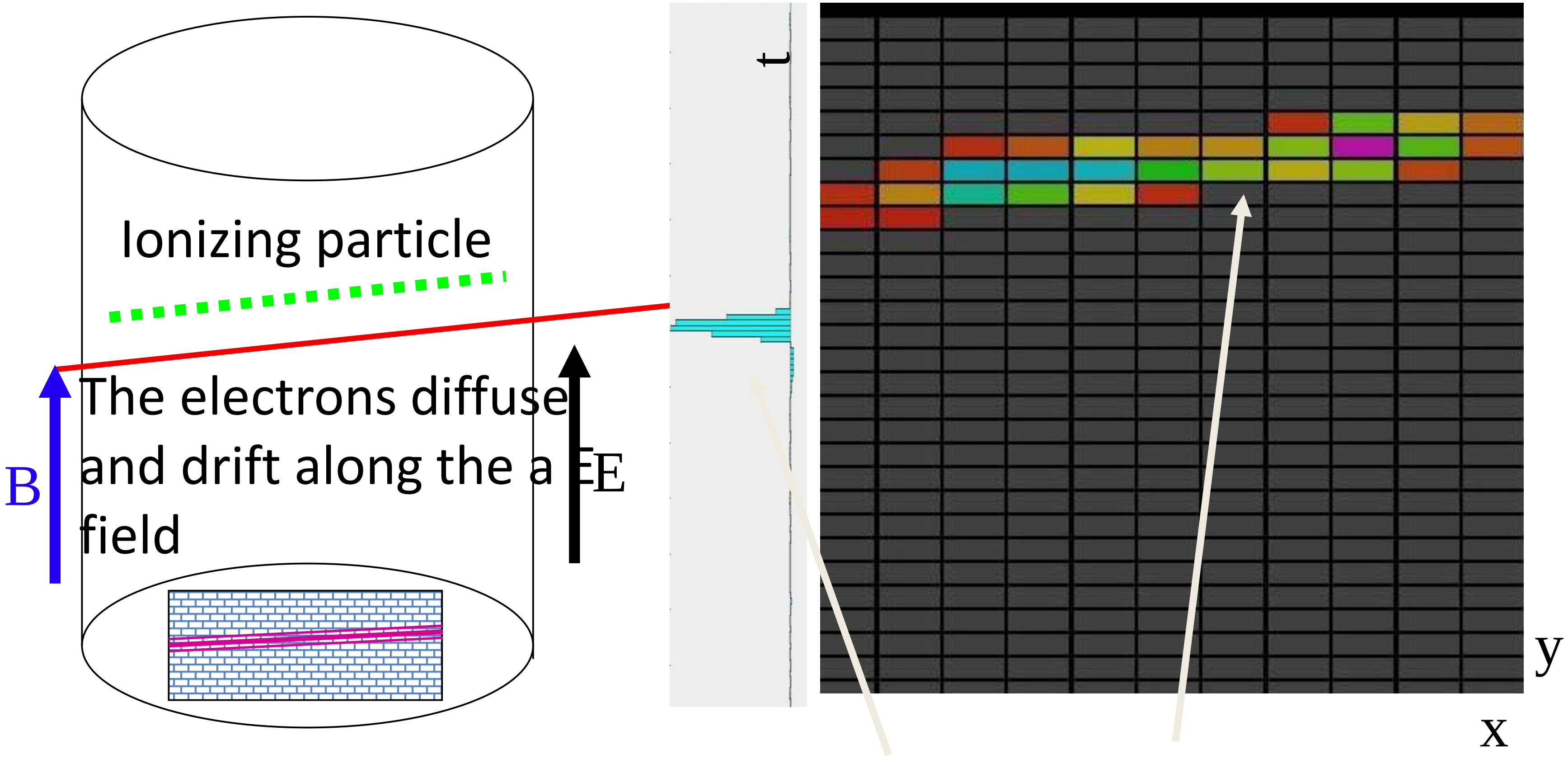
Projects in progress
- Nuclear Physics
- Neutrino oscillations
- Neutrinoless dble β decay
- Dark matter search
- ILC

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 2γ, 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

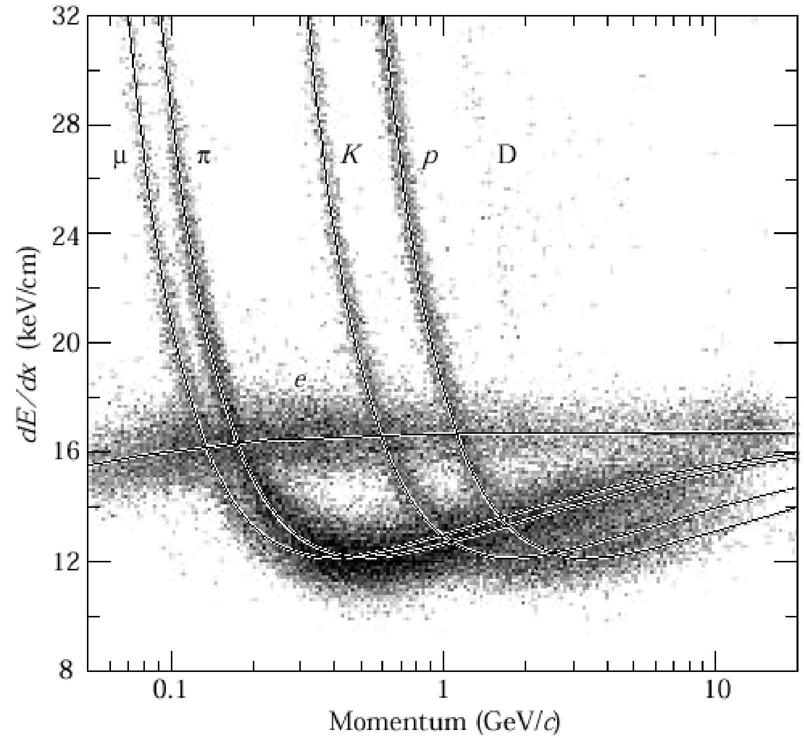


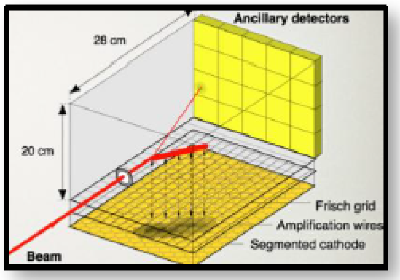
Figure 25.3: PEP4/9-TPC dE/dx measurements (185 samples @8.5 atm Ar-CH_4 80–20%) in multihadron events. The electrons

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

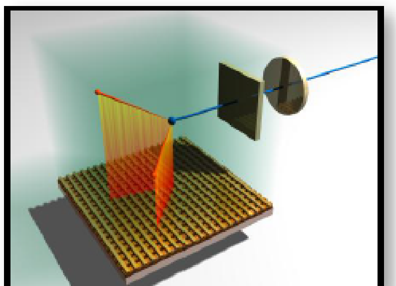


MAYA

(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.

Image Warsaw coll.

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

actar TPC

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

Instrument	N° Ch	Hosting lab.	Funding Agency
SπIRIT,	10k	NSCL, Riken, … , Jp	DOE, RIKEN, …
ACTAR TPC	16k	GANIL, IRFU, IPNO…, Fr	ERC, GANIL, IN2P3,
LAMPS	2.5 -> 20k	IBS Korea, Korea	IBS
AT-TPC	10k	NSCL, …, US	NSF
N_TOF	2.5k	CERN, IRFU, …	IRFU
CNS-AT	2.5k	Univ. Tokyo, Jp	CNS
E-15	6k	J-PARC, … ,Jp	J-PARC
ELI-TPC	1k	Univ. Warsaw, Pl	ELI-NP
FARCOS	5k	INFN-Catania, It	INFN-Catania
TexAT-P	2 - >32k	Texas A&M, US	Texas A&M
ND-TPC	1k	Univ. ND, US	Univ. ND
Shanghai-TPC	1k	CAS, Cn	CAS
NEXT	1 - > 5k	Univ. of Zaragosa, Es	Univ. of Zaragosa
Lanzhou-TPC	2k	IMP, Cn	IMP
S^3	4k	SPIRAL2, Fr	GANIL, IRFU
SpecMAT	2.5k	KU Leuven	ERC
Focal-Plane	256	Orsay, IN2P3, Fr	IN2P3
eTPC	1k	Univ. Warsaw	ELI-NP
SSD	2k	IFNF-Catania, It	INFN-Catania
MINOS	6k	IRFU	ERC

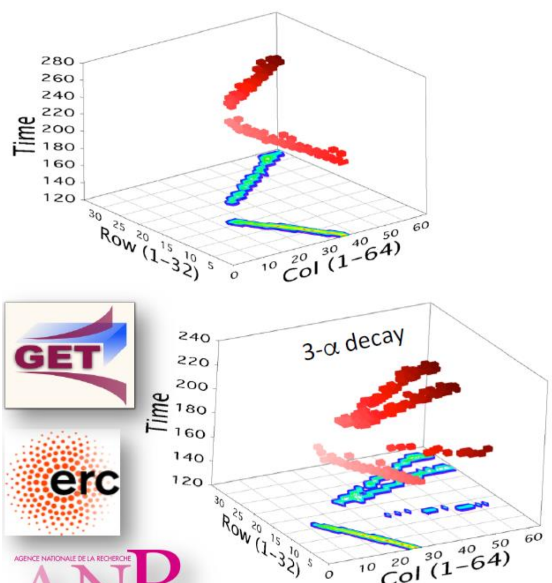
80k Channels Total
20 experiments
4ch to 20k ch

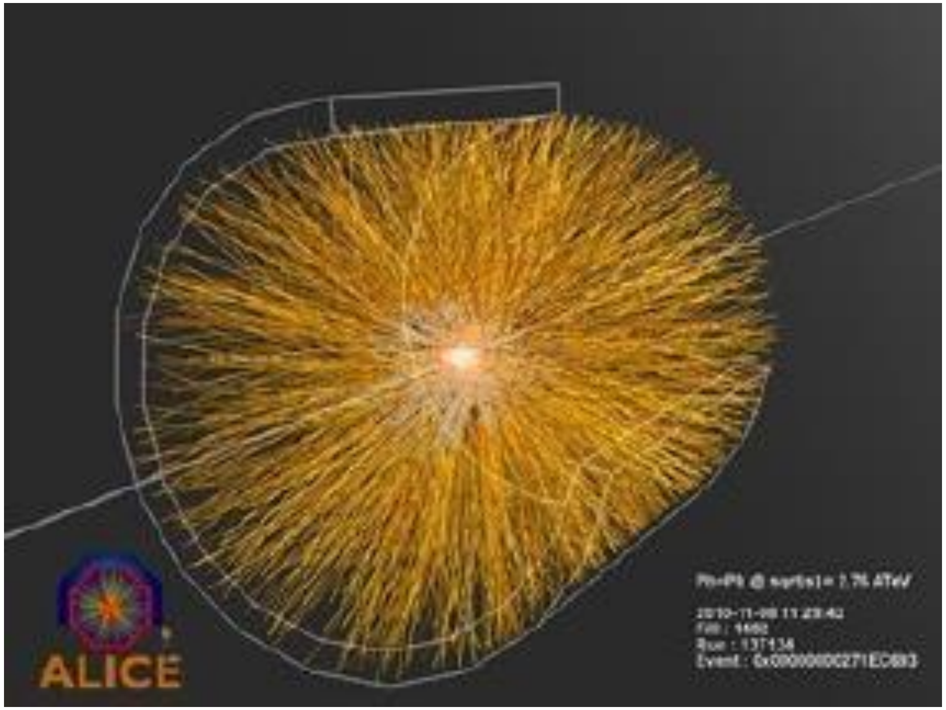
Listed by E. Pollaco mid 2016

Nuclear Physics

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

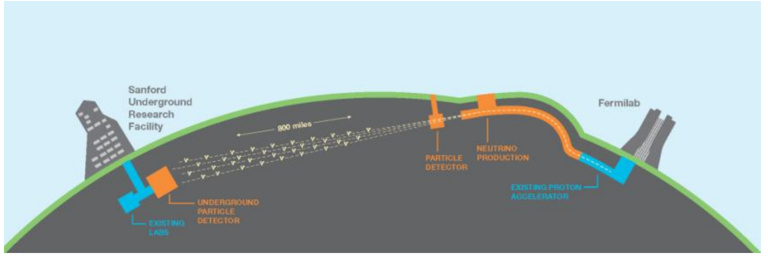
ACTAR-TPC



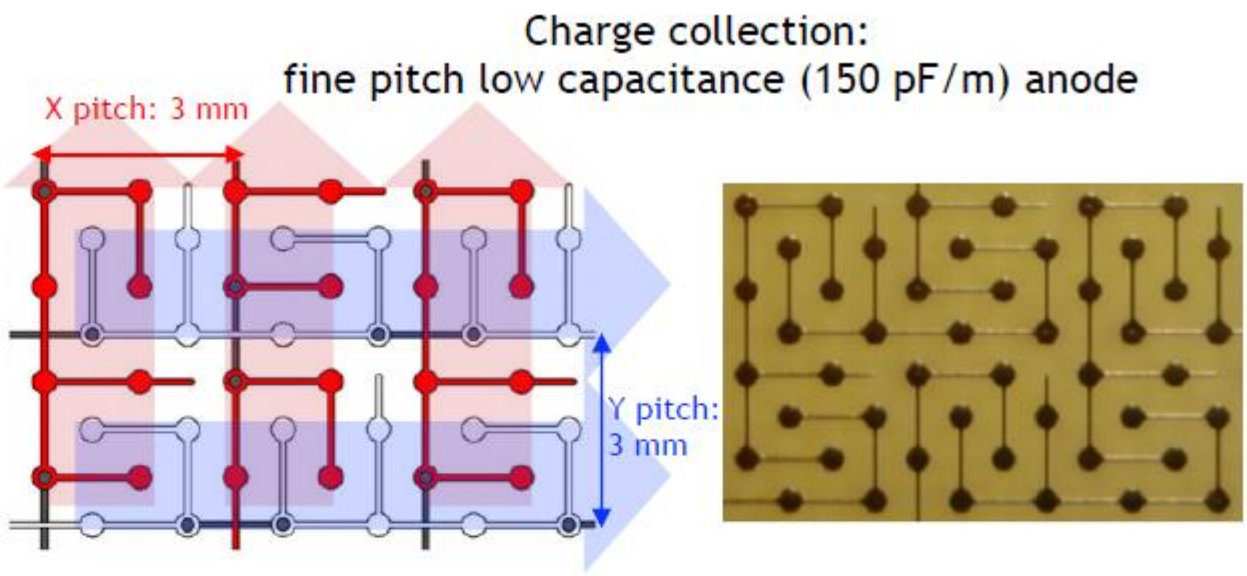


20 to 25 TPC projects for Nuclear Physics

Neutrino oscillations
Long baseline experiments

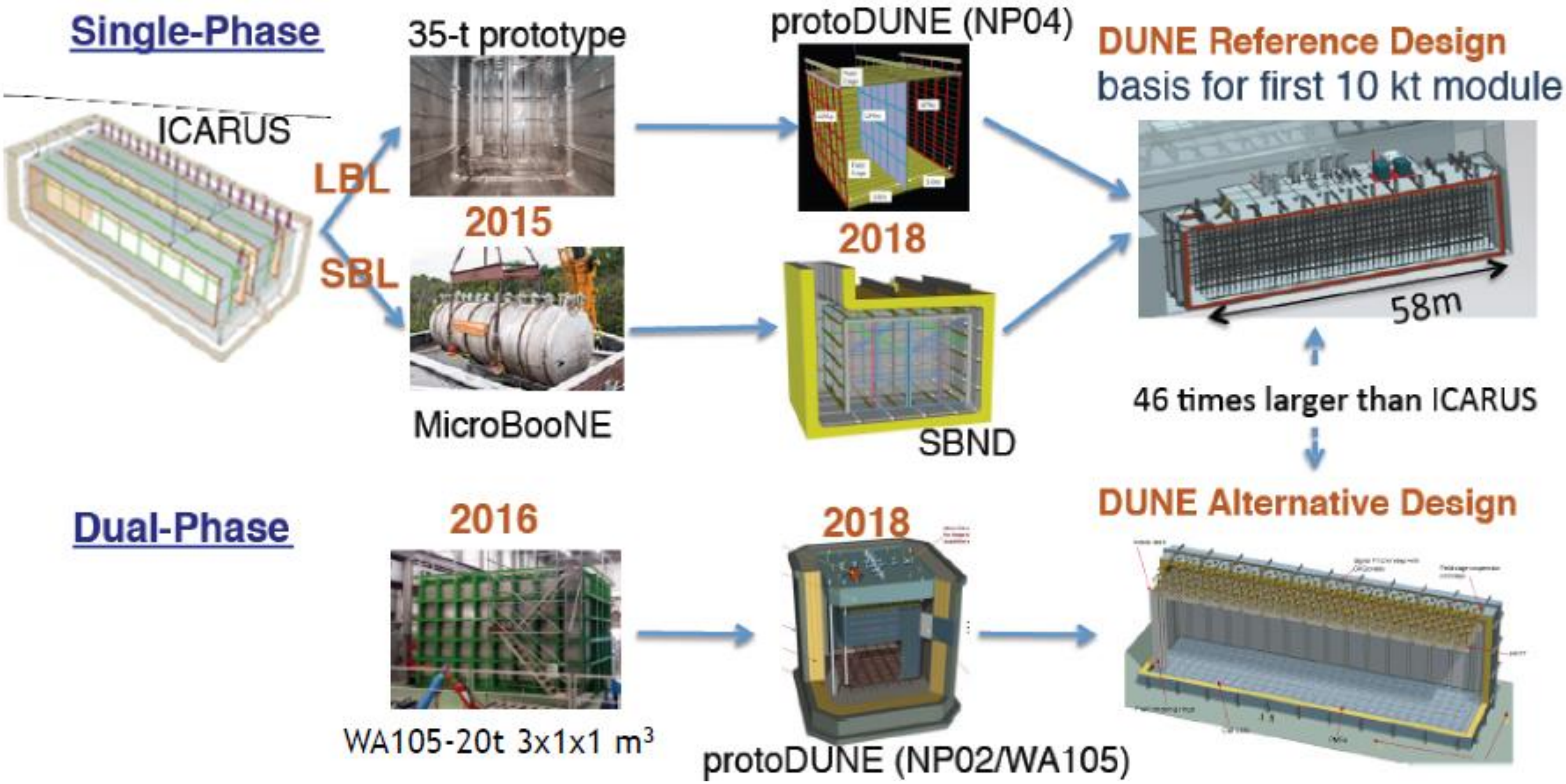


Huge Double-phase Argon TPCs are being built, equipped with LEMs/THGEMs, for the underground DUNE experiment. The final goal is 10-50 kiloton (the largest TPC ever). Demonstrators of 3 m3, 6x6x6 m3, and an even larger one, are being built at CERN.

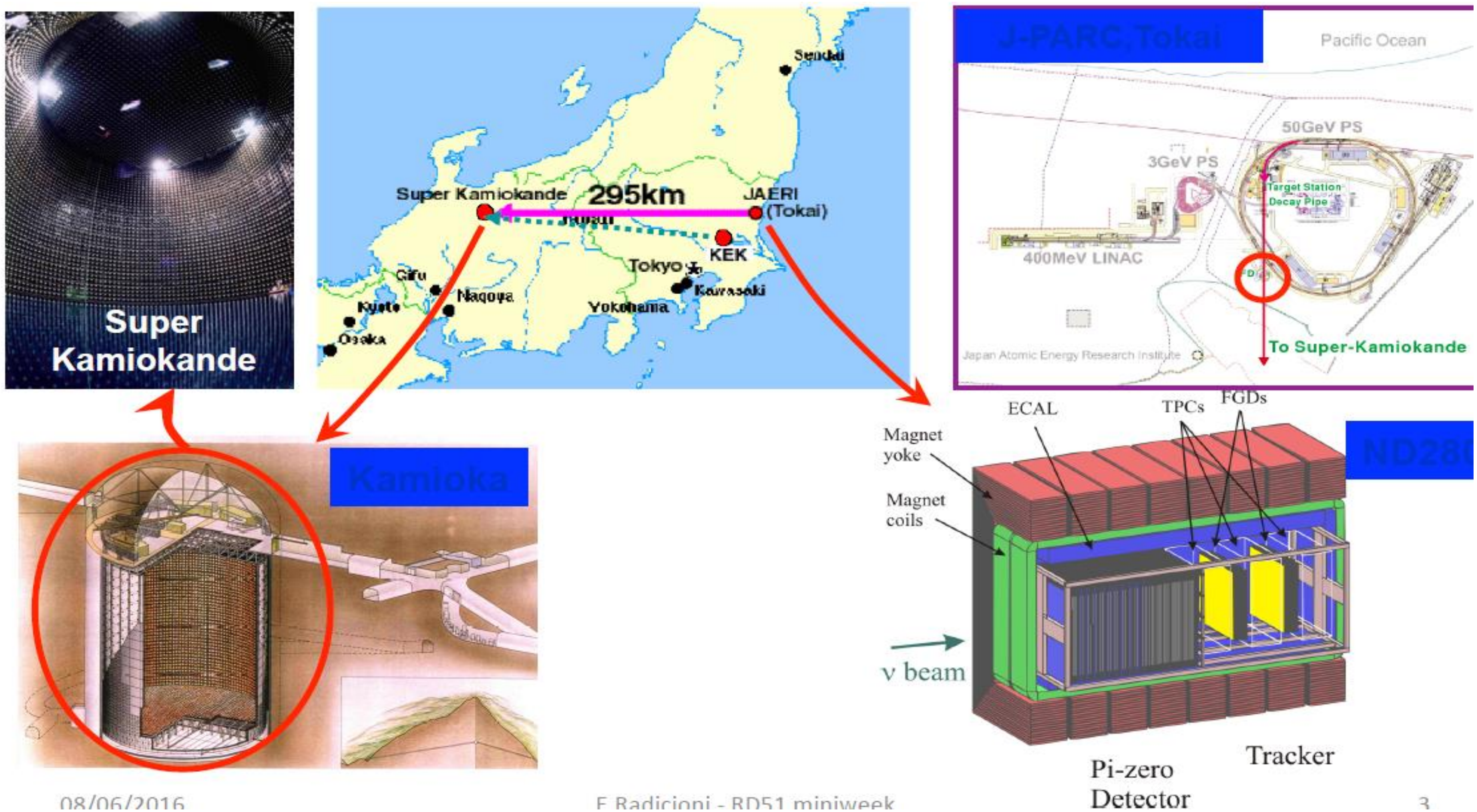


Note: R&D still on-going for other concepts (ArgonCube :magnetized modular detector)

Neutrino oscillations
Long baseline experiments



Neutrino oscillations: T2K Near Detector

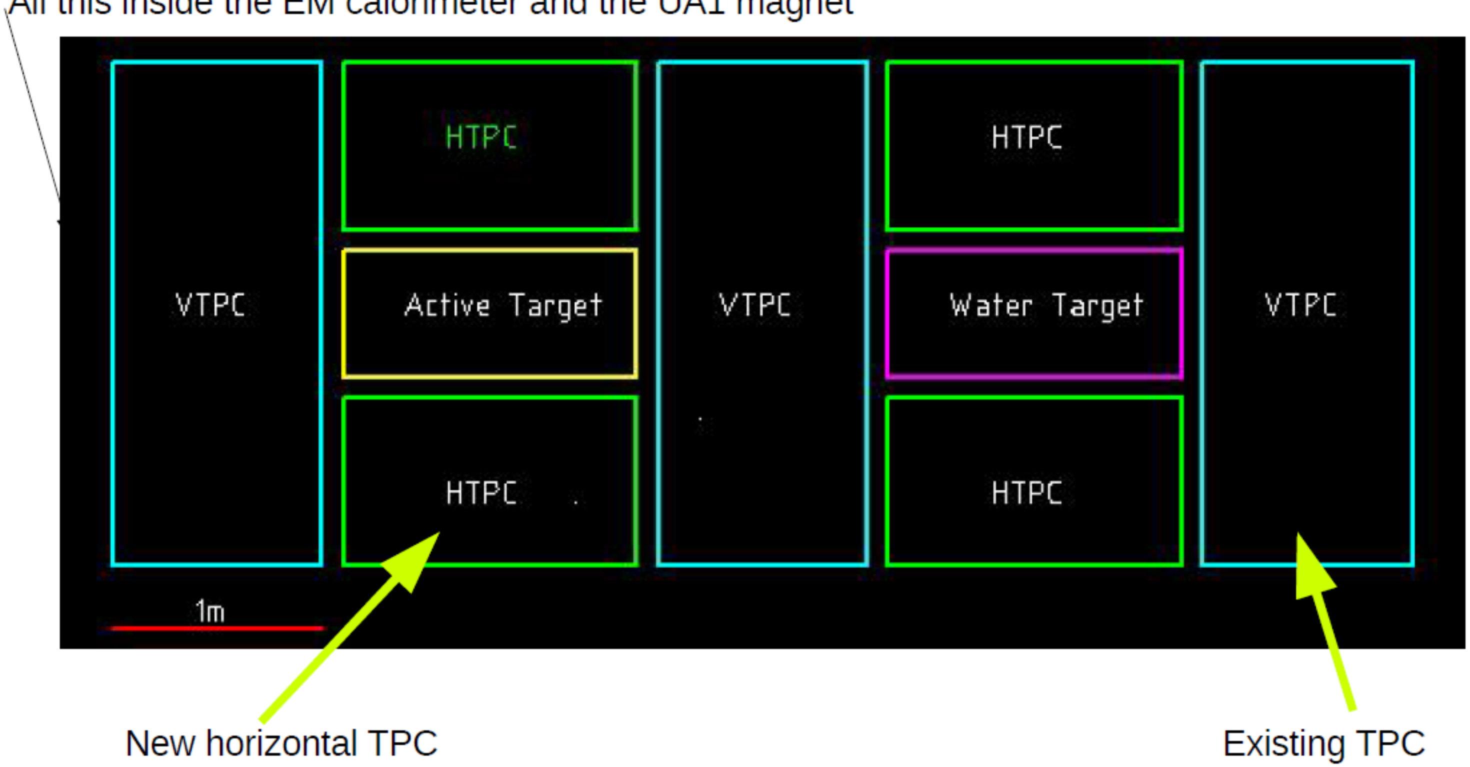


Goal of the 280 m near detector : measure cross-sections and beam content in electron neutrino

Includes 3 Micromegas TPCs
10 years of operation!

The baseline design for the upgraded ND280

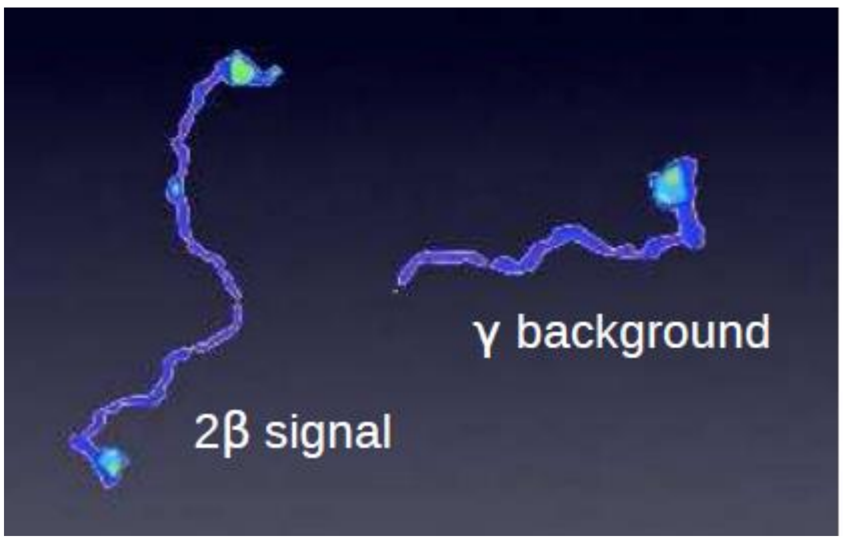
All this inside the EM calorimeter and the UA1 magnet

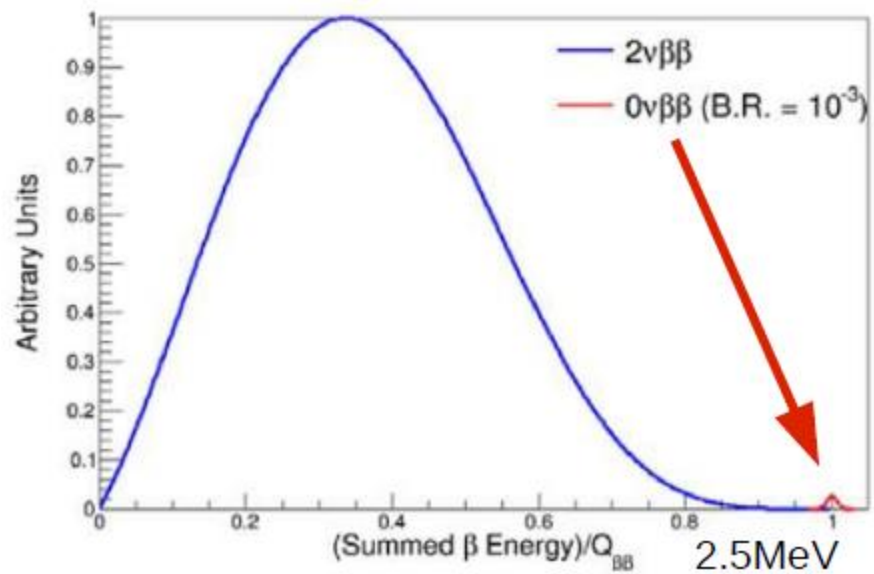


Add 4 horizontal TPCs to the existing 3. Use charge spreading, new grounding scheme (mesh at ground).

Neutrino-less double-beta decay

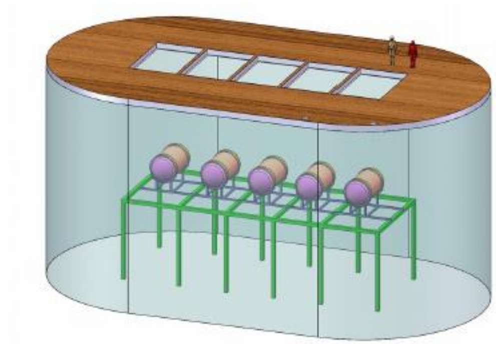
Several projects in progress, mainly ^{136}Xe TPCs
1 ton necessary
Extreme radio-purity
Very good energy resolution
Good granularity for topological discrimination





PANDA-X III

In JinPing underground lab (Sechouan, China)



5 TPC modules

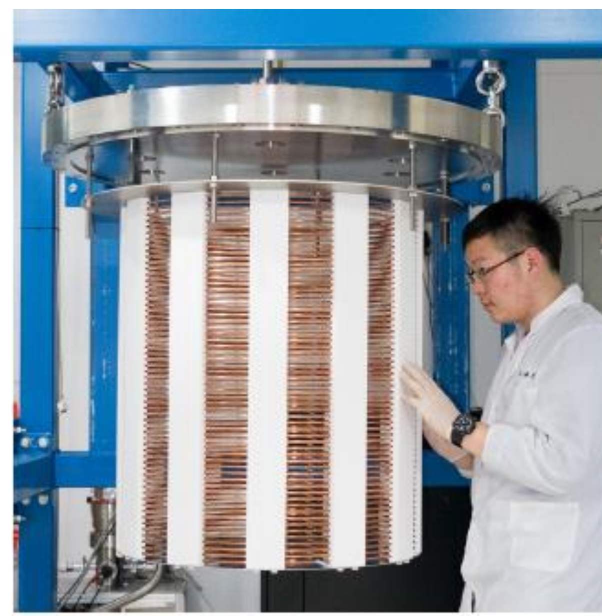
In 10m-deep highly-purified water pool

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

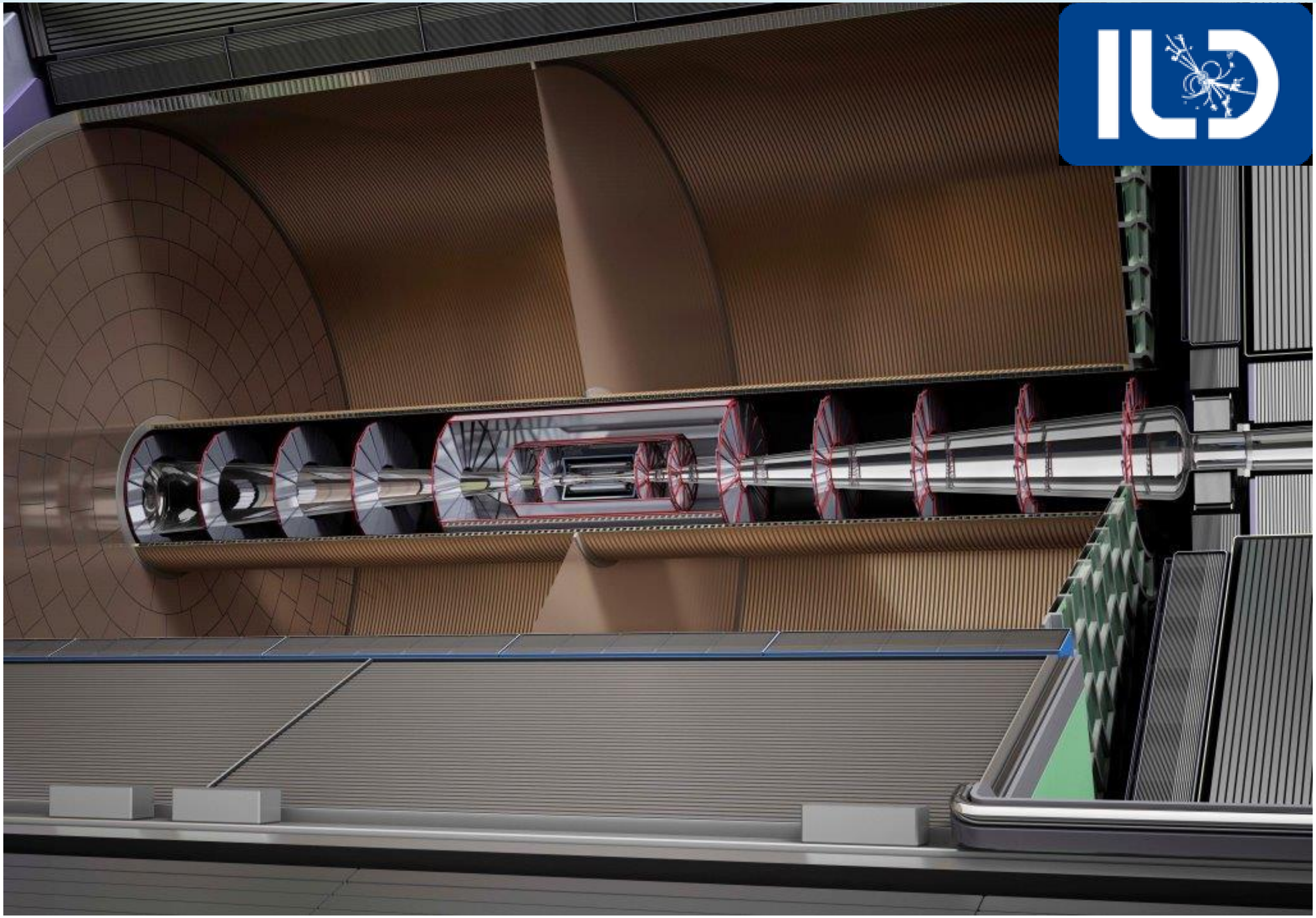
Dark Matter search

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

Future :

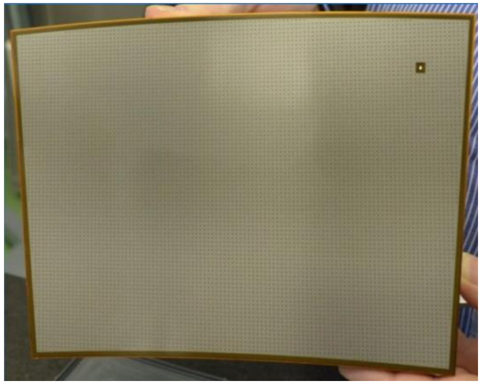
- go to lighter gas targets to explore low masses
- Become directional to beat the solar neutrino background

ILC tracking



ILD 4 technologies

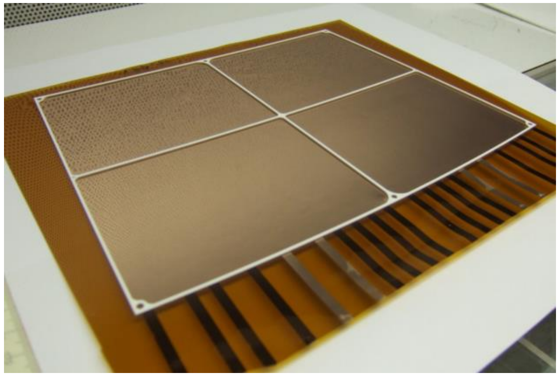
Micromegas



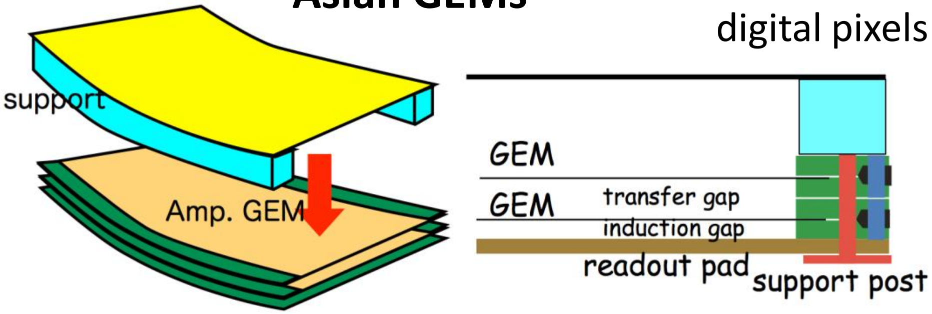
Mesh on top of a charge-dispersing resistive anode

European GEMs

Standard kapton triple GEM with ceramic spacers

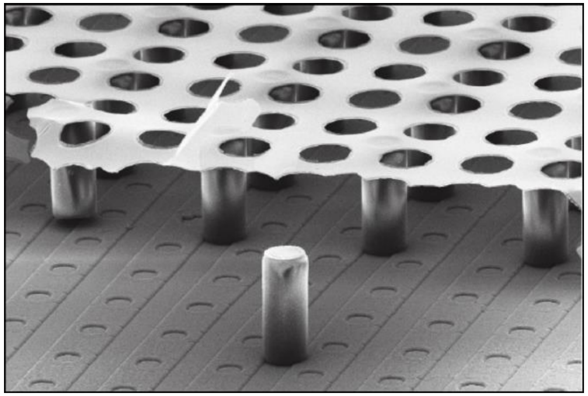


Asian GEMs



GridPix

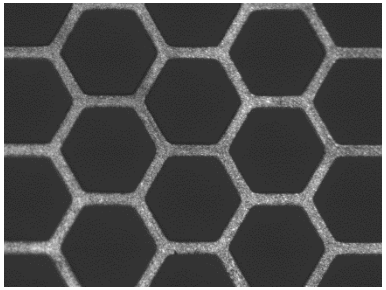
Integrated grid on 55 µ digital pixels

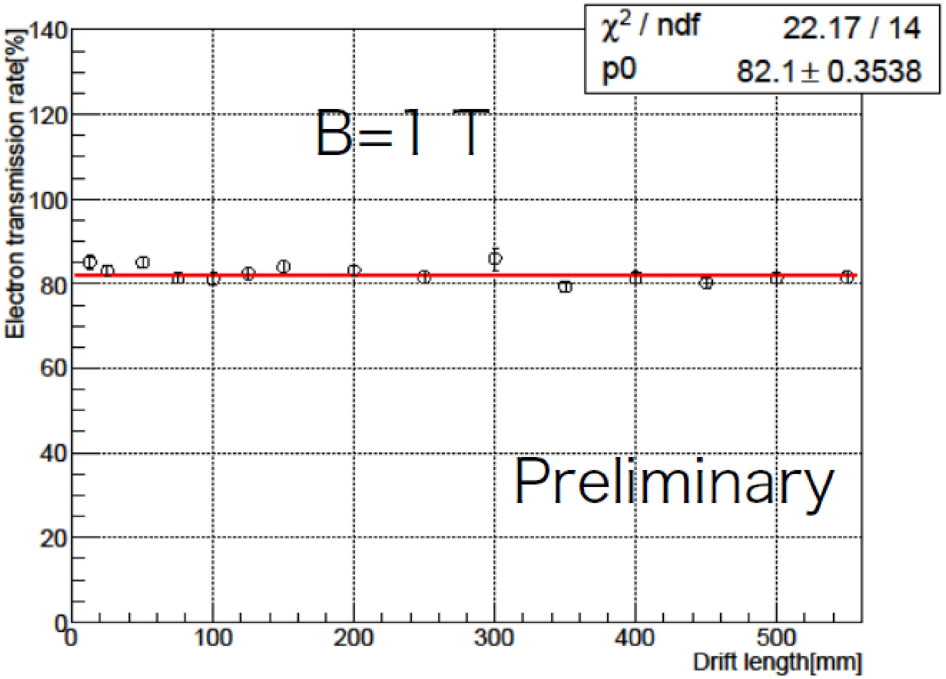


Give record resolutions. New techniques to stretch GEM foils, to cool at room temp…

gating

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)

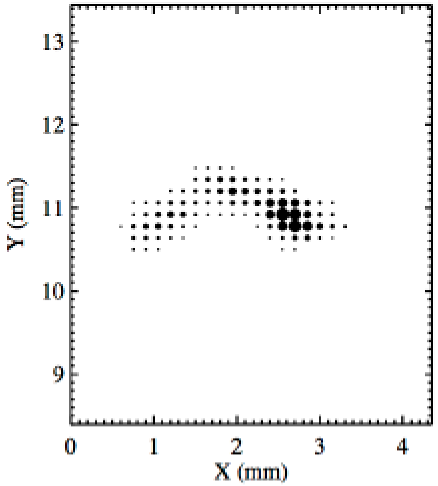




X-ray polarimetry

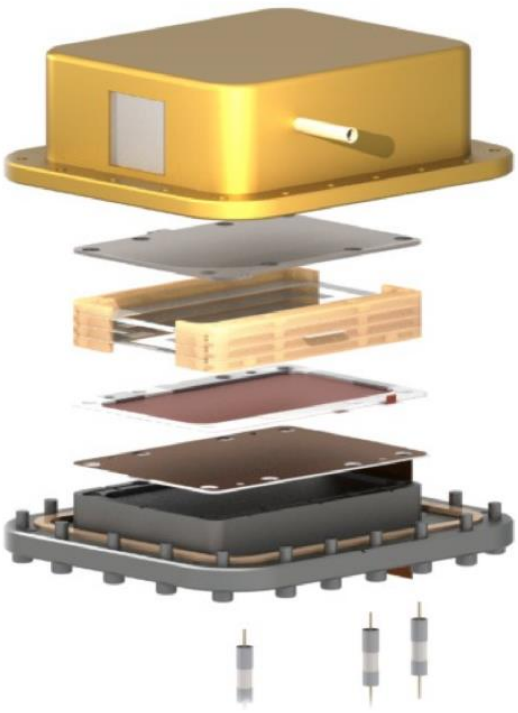
In the few-keV domain, the photo-electric effect dominates and the emitted electron direction keeps track of the polarization.

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



Small-gap single-GEM or Micromegas

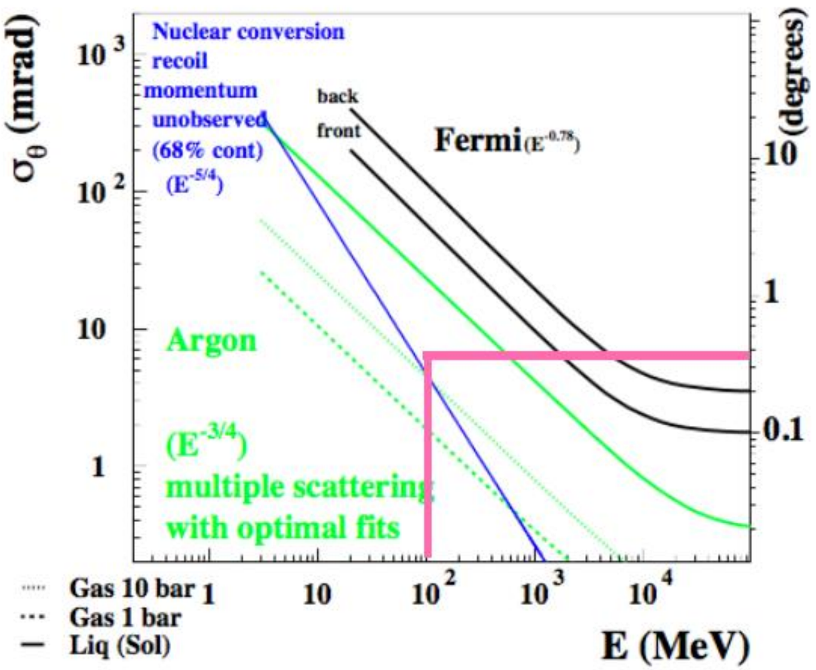
The first sealed prototype

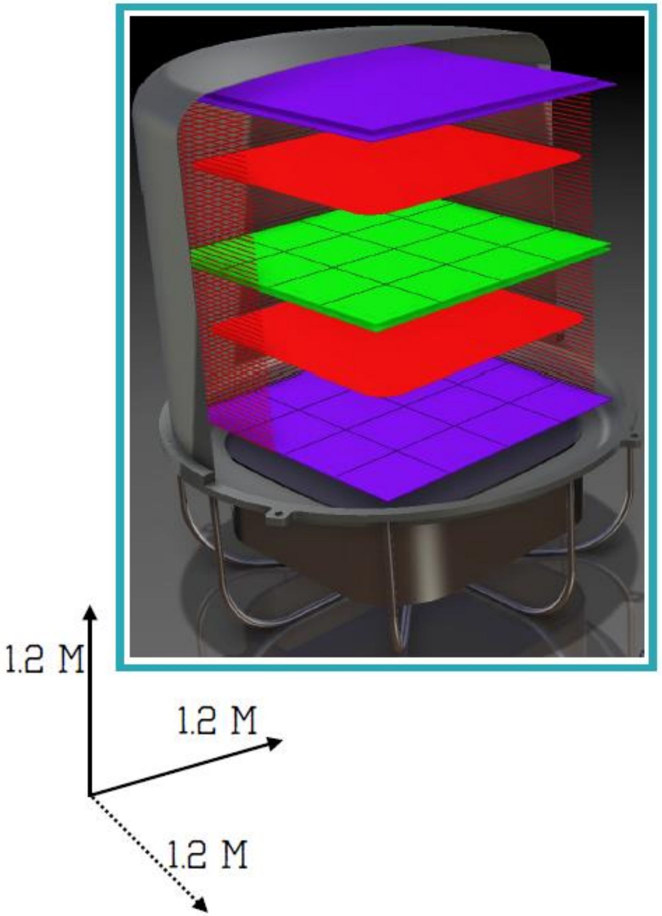


NASA low-outgassing specifications

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 developped 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!

High pressure

RADIOPURITY

GAS

Low pressure

Continuous readout

Atmospheric

LIQUID

LEM/THGEM

Spherical

Cerenkov

GEM

Optical readout

Ion Back flow

cylindrical

Micromegas

Space charge

dE/dx

gating