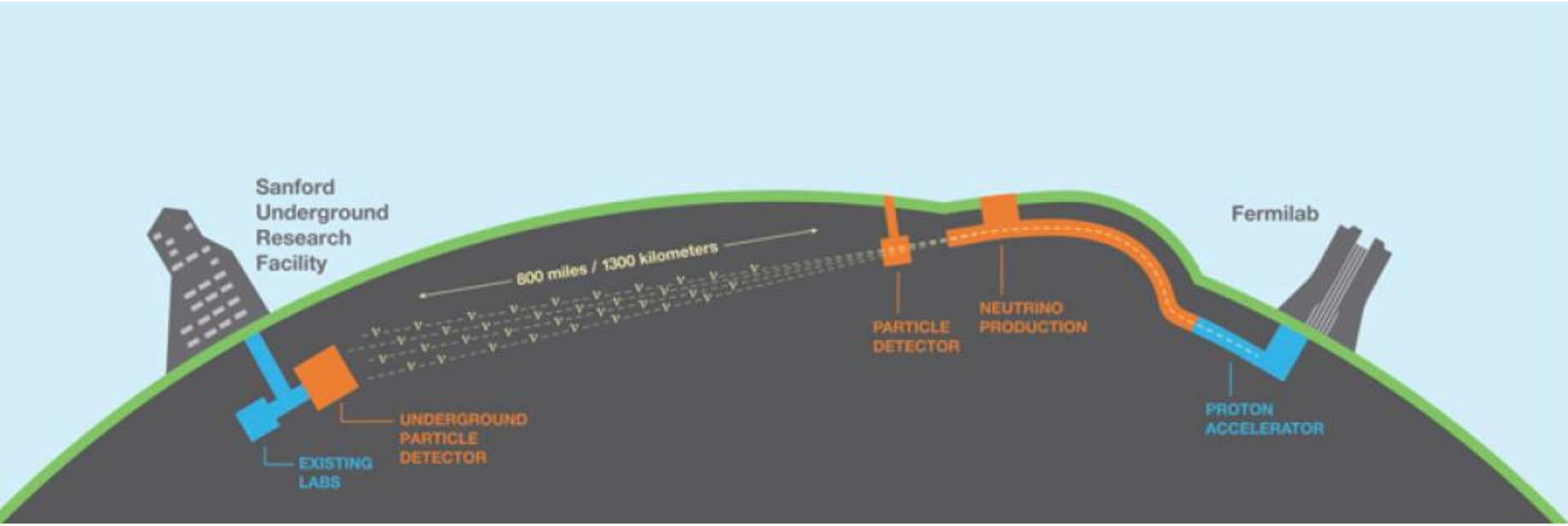
DUNE@IGFAE



D. González-Díaz (IGFAE)

Barcelona, March-2023, DRD-Spain meeting

Participantes

P. Amedo[1], J. Baldonedo[2], C. Benítez[3], E. Casarejos[2], J. Collazo[2], D. González-Caamaño[1], A. Fernández-Prieto[1], D. J. Fernández[1], D. González-Díaz[1], S. Leardini[1], J. Llerena[1], M. Morales[1], L. Olano[1,*], J. Padín[1], J. Martín-Albo[3], A. Segade[2], M. Tuzi[3]

1. Instituto Galego de Física de Altas Enerxías (IGFAE)
2. Universidade de Vigo
3. Instituto de Física Corpuscular (IFIC)

*Ahora en Nanogune.

antiguos miembros: M. Fontaíña, P. Ameijeiras, S. Bounasser, I. Pardo, J. Rocabado, A. Saá-Hernández, A. Sánchez-Bravo

Principales proyectos relacionados con I+D (en IGFAE)

1. Unleashing Light Timing In a Massive Argon TPC Experiment (ULTIMATE)
   - Fuente: FPN-Retos
   - Responsable: D. Gonzalez-Diaz (IP at IGFAE y coordinador), J. Collazo (IP en Univ. Vigo)

2. AIDAinnova (package: High Pressure TPCs)
   - Fuente: EU
   - Responsable: D. Gonzalez-Diaz (WP7 Gaseous Detectors, Task 7.4, IGFAE)

3. Gas TPCs with fast timing capability (T0) for the DUNE Near Detector
   - Fuente: IGNITE (IGFAE)
   - Responsable: D. Gonzalez-Diaz (IP)

4. Resistive materials and resistive-MPGD concepts & technologies
   - Fuente: **RD51 (CERN)**
   - Responsable: Shikma Bressler (IP), D. Gonzalez-Diaz (IP), J. Veloso (IP)

5. Development of OTPCs for neutrino physics and other strange processes
   - Fuente: Xunta de Galicia
   - Responsable: D. Gonzalez-Diaz (IP)

6. New scintillating gases and structures for scintillation-based gaseous detectors
   - Fuente: **RD51 (CERN)**
   - Responsable: D. Gonzalez-Diaz (IP), E. Baracchini (IP)

Documento requerido por los organizadores de este workshop

OPEN CHALLENGES IN DETECTOR TECHNOLOGIES (DRD: GASEOUS DETECTORS)

Group: DUNE@IGFAE
Date: Dec 2022

1. **Full optical readout of high pressure argon TPCs**
    - Development of new avalanche-multiplication structures compatible with high-pressure operation of argon-based OTPCs (glass GEMs, glass Micromegas).
    - Development of TimePix cameras for the readout.
    - Introduction and full characterization of wavelength-shifting mixtures (e.g., Ar-CF_4).
2. **New structures for electroluminescent-based chambers**
    - Development of rugged and scalable electroluminescent structures based on very-thick MPGD-like structures.
    - Development of VUV-transparent substrates (natural or using solid wavelength-shifting, e.g., TPB).
3. **New resistive-protected structures for dual-phase detectors**
    - Development of new resistive materials (diamond-like carbon, YSZ/Fe_2O_3 -based ceramics) for protection of conventional MPGD structures (e.g. RPWELL).

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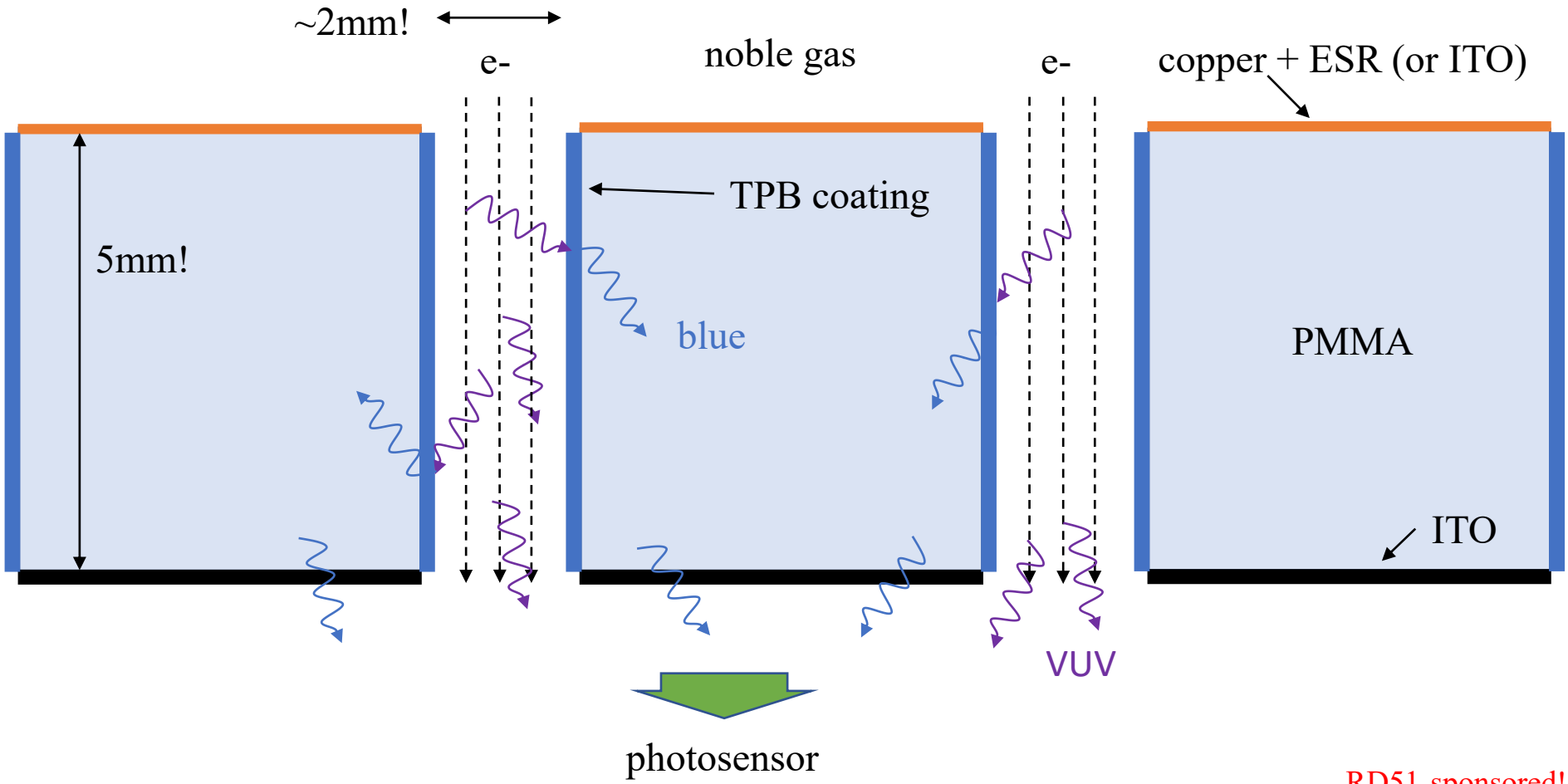
1. Nuevas estructuras para cámaras basadas en electroluminiscencia

1. Nuevas estructuras para cámaras basadas en electroluminiscencia (I)

idea: la electroluminiscencia en gases (e.g., TPCs para materia oscura en fase dual, NEXT…) require muy alta tensión (15-20kV, idealmente). Usar estructuras rígidas radiopuras, perforadas (estilo MPGD), transparentes y recubiertas con TPB.

FAT-GEM: **F**ield-**A**ssisted **T**ransparent **G**as **E**lectroluminescence **M**ultiplier

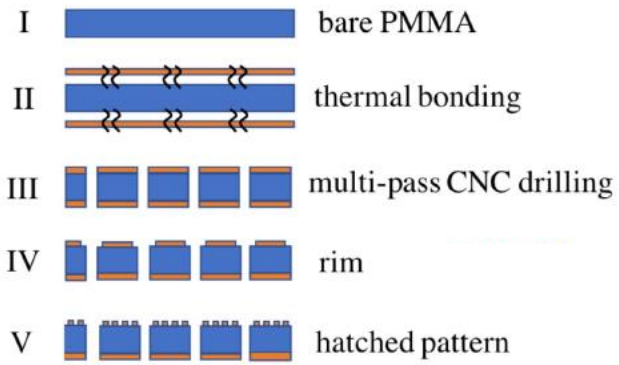


RD51-sponsored!

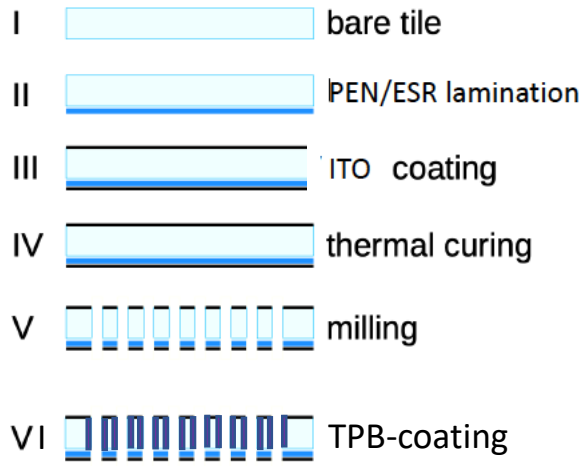
1. Nuevas estructuras para cámaras basadas en electroluminiscencia (II)

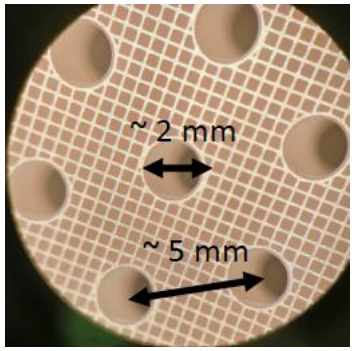
idea: la electroluminiscencia en gases (e.g., TPCs para materia oscura en fase dual, NEXT…) require muy alta tensión (15-20kV, idealmente). Usar estructuras rígidas radiopuras, perforadas (estilo MPGD), transparentes y recubiertas con TPB.

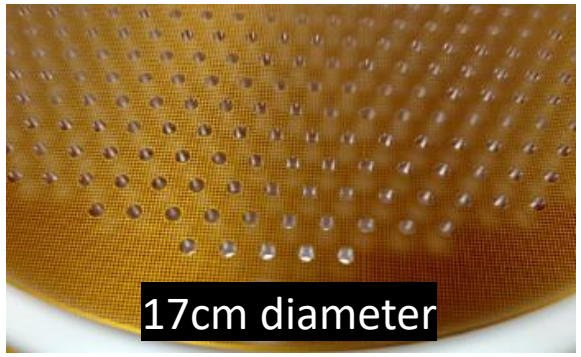
CERN workshop



Warsaw workshop







no isotope detected after 47 days!

	Acrylic (mBq/kg)	FAT GEM (mBq/cm^2)
U-238/Pa-234m	<340	<0.741
U-238/Pb-214	<2.8	<0.006
U-238/Bi-214	<2.3	<0.007
Th-232/Ac-228	<8.8	<0.021
Th-232/Pb-212	<2.9	<0.007
Th-232/Tl-208	<6.3	<0.014
U-235/U-235	<1.9	<0.006
K-40	<17	<0.036
Co-60	<0.74	<0.002
Cs-137	<1.1	<0.002

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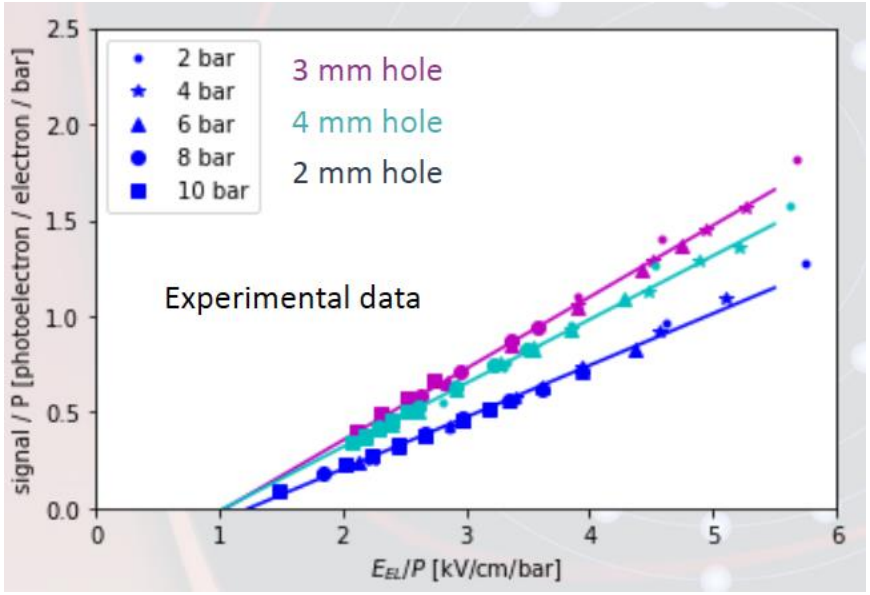
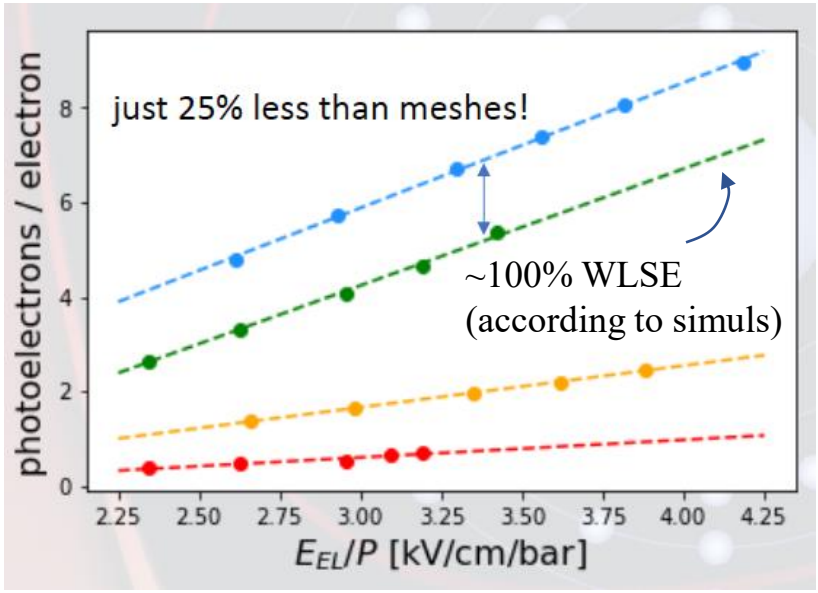
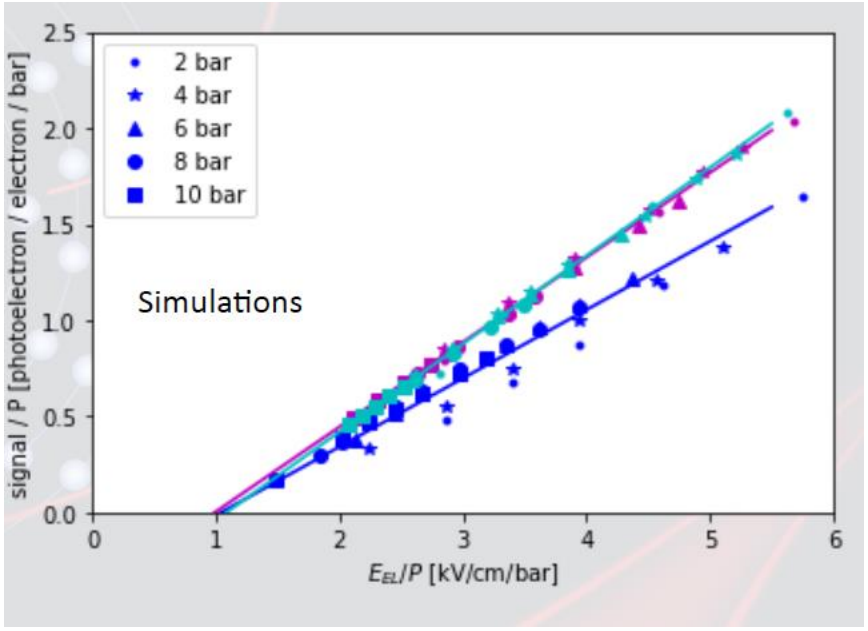
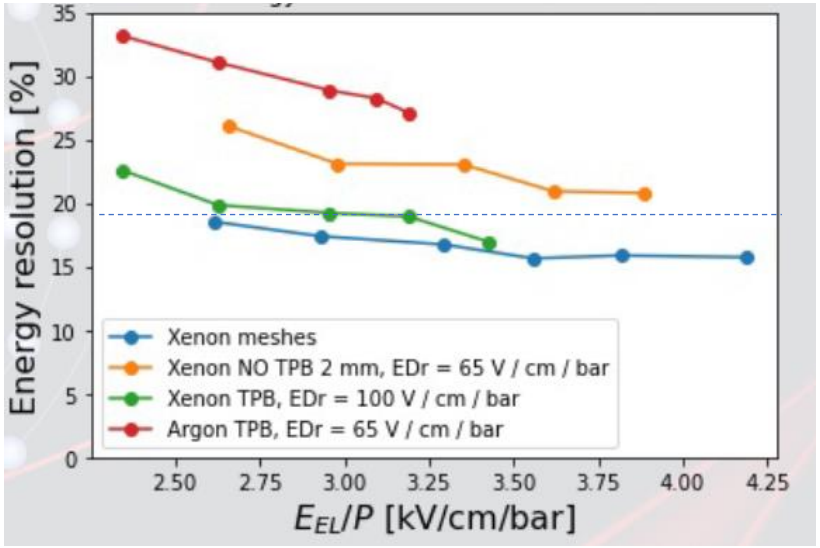
1. Nuevas estructuras para cámaras basadas en electroluminiscencia (III)



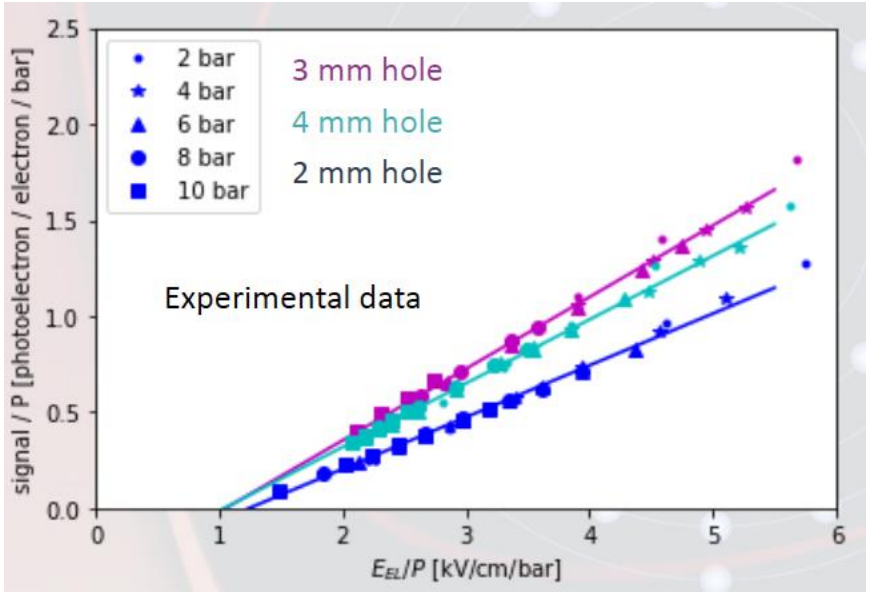




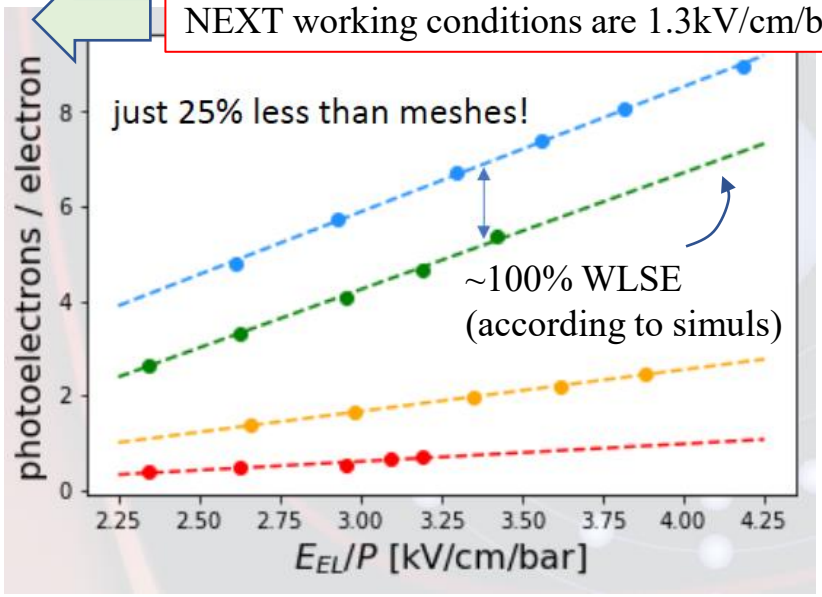


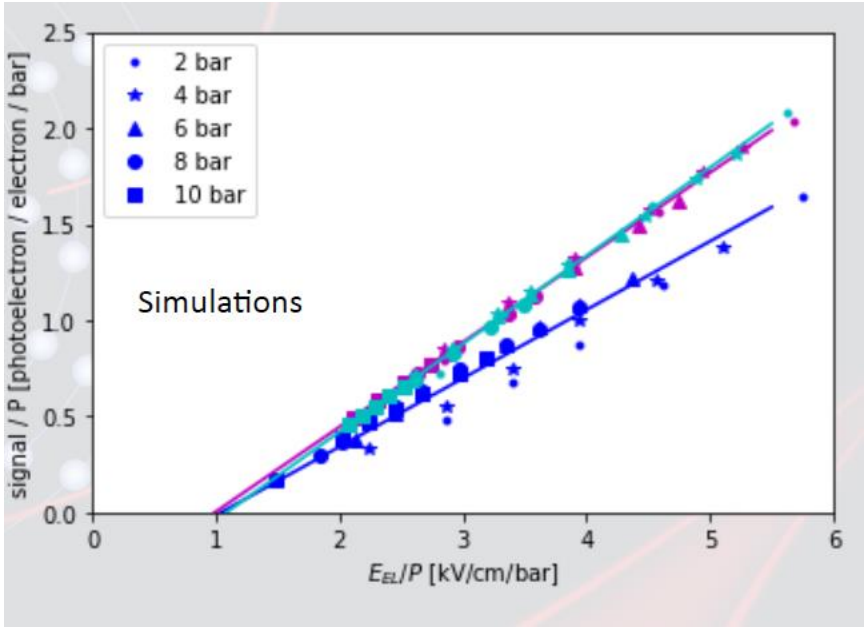
RD51-sponsored!

1. Nuevas estructuras para cámaras basadas en electroluminiscencia (III)

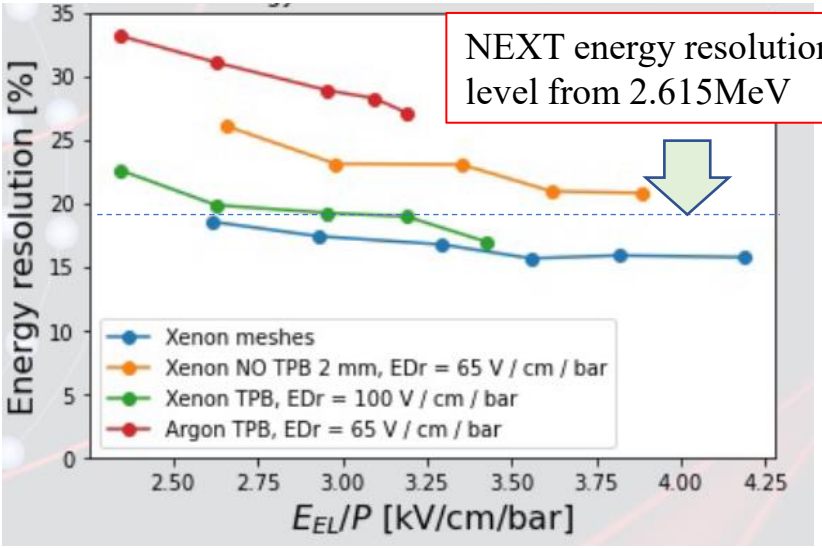


NEXT working conditions are 1.3kV/cm/bar!





NEXT energy resolution level from 2.615MeV



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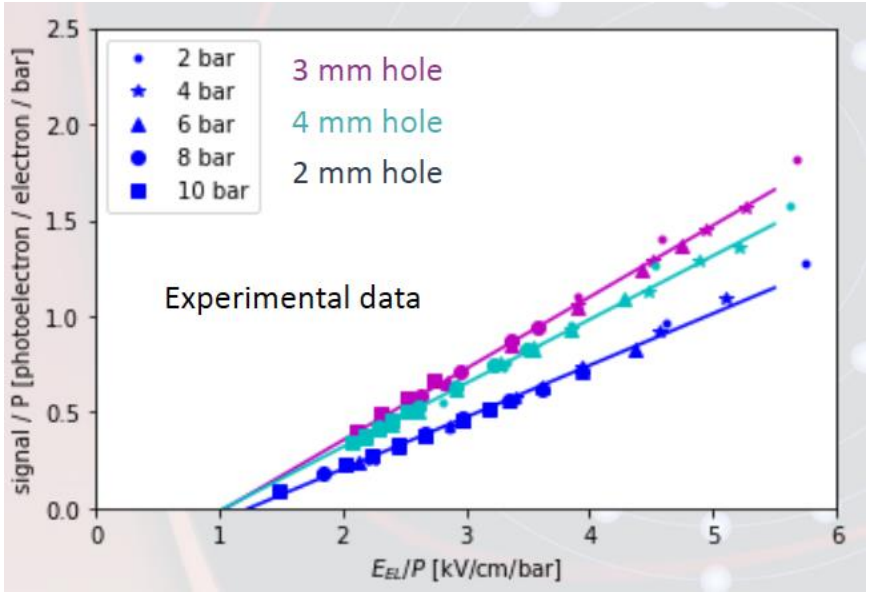
1. Nuevas estructuras para cámaras basadas en electroluminiscencia (III)



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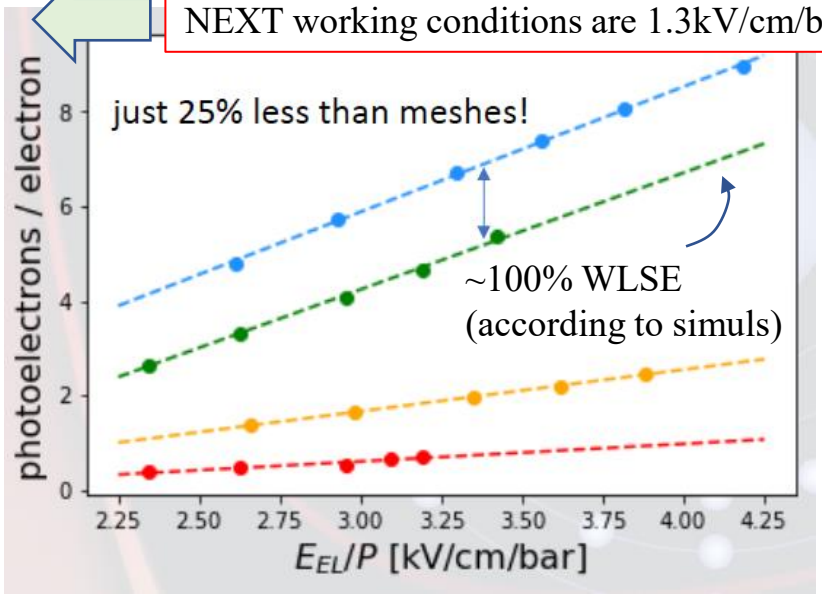

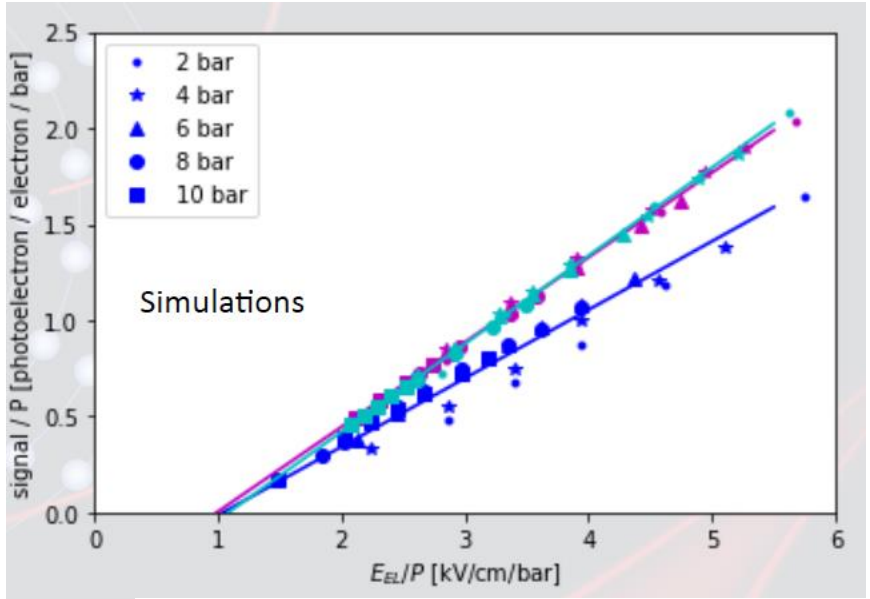

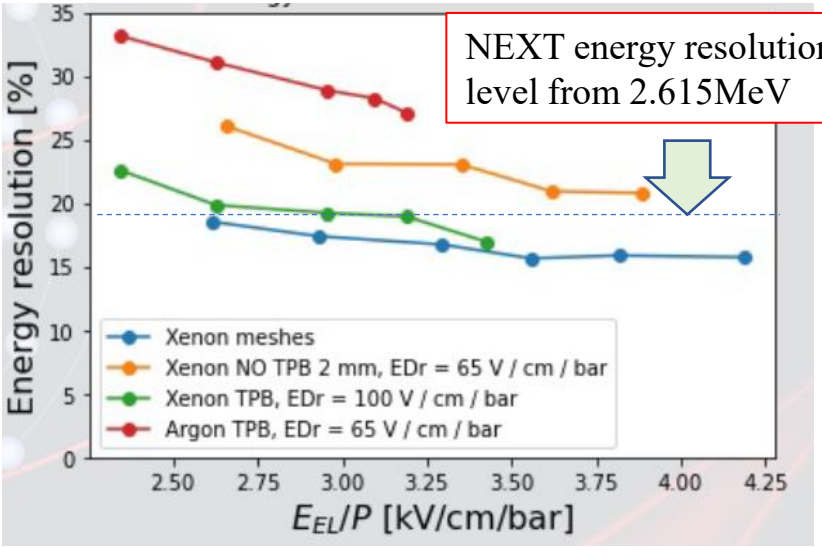

already better than conventional amplification based on meshes

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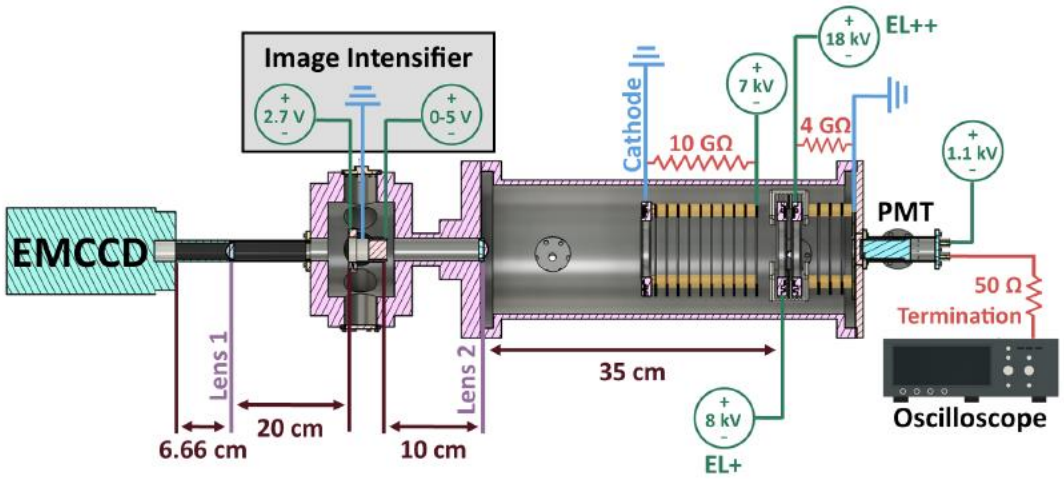
1. Nuevas estructuras para cámaras basadas en electroluminiscencia (IV)

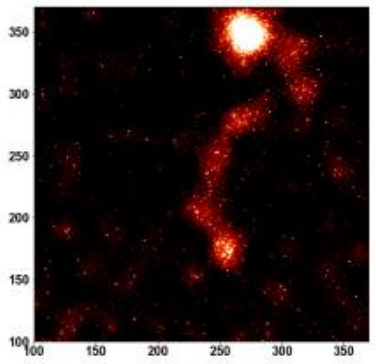
Por hacer (no requiere financiamiento estratégico):

- Estudiar la estabilidad en el tiempo.
- Estudiar la resolución límite (sospecha: estamos todavía limitados por el setup!)
- Evaluar su uso en NEXT-CRAB (camera-read)

NEXT-CRAB-0: A High Pressure Gaseous Xenon Time Projection Chamber with a Direct VUV Camera Based Readout

C. Adams,[b] J. Asaadi,[a] J. Baeza-Rubio,[a] K. Bailey,[b] N.K. Byrnes,[a,1] D. González-Díaz,[d] A. Higley,[b] B.J.P. Jones,[a] K. Mistry,[a] I.A. Moya,[a] D.R. Nygren,[a] P. Oyedele,[a,c] I. Parmaksiz,[a,2] L. Rogers,[b] K. Stogsdill,[a] (author list not final)





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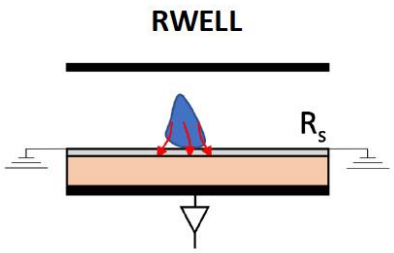
2. Nuevas estructuras protegidas resistivamente para fase dual

2. Nuevas estructuras protegidas resistivamente para fase dual (I)

idea: estabilizar el proceso de multiplicación en detectores de fase dual usando materiales resistivos. La clave, encontrar materiales con conductividad **electrónica** en el rango adecuado!

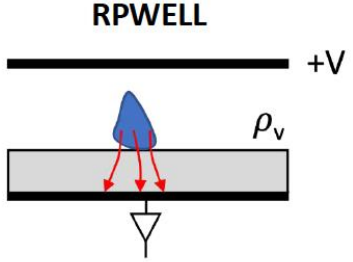
Diamond-Like Carbon (DLC) coatings

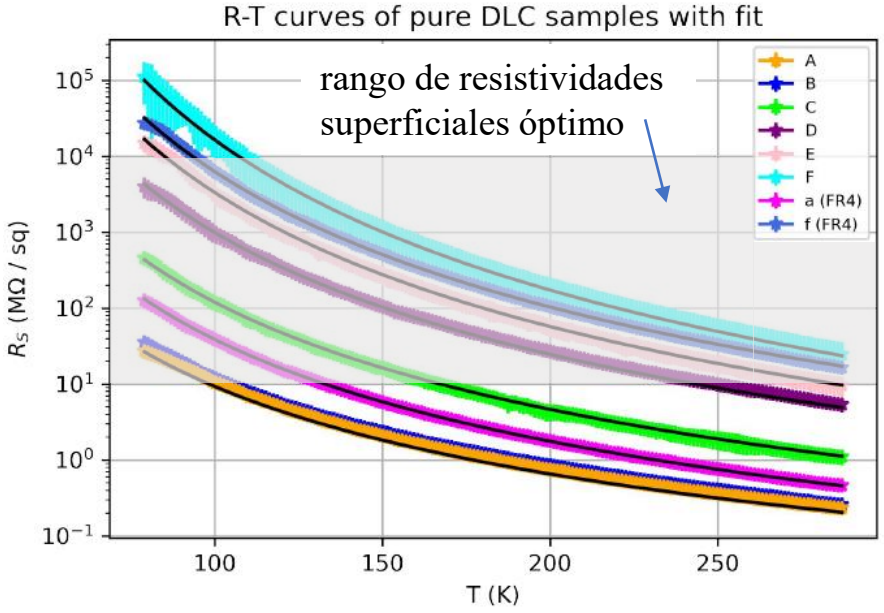
Developed at Hefei (China)

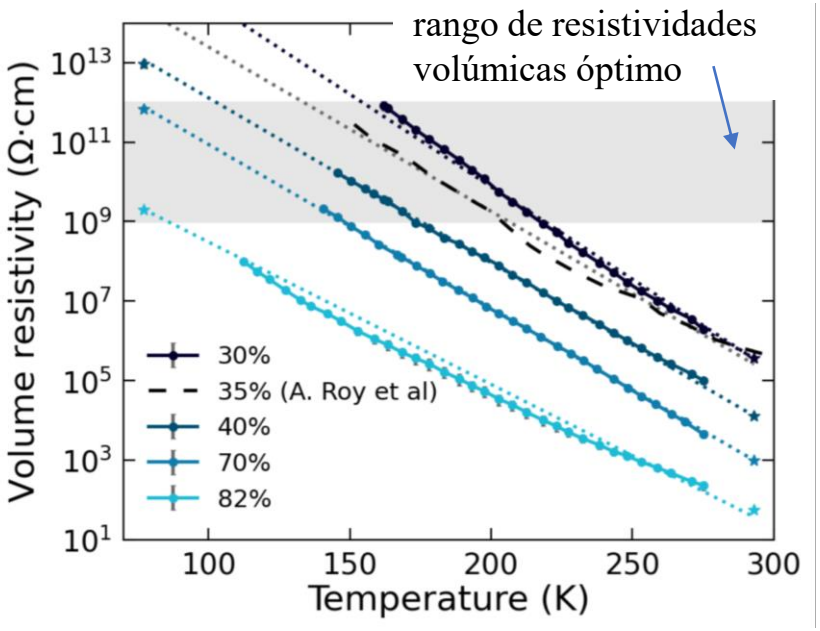


YSZ/Fe_2O_3 ceramics

Developed in-house





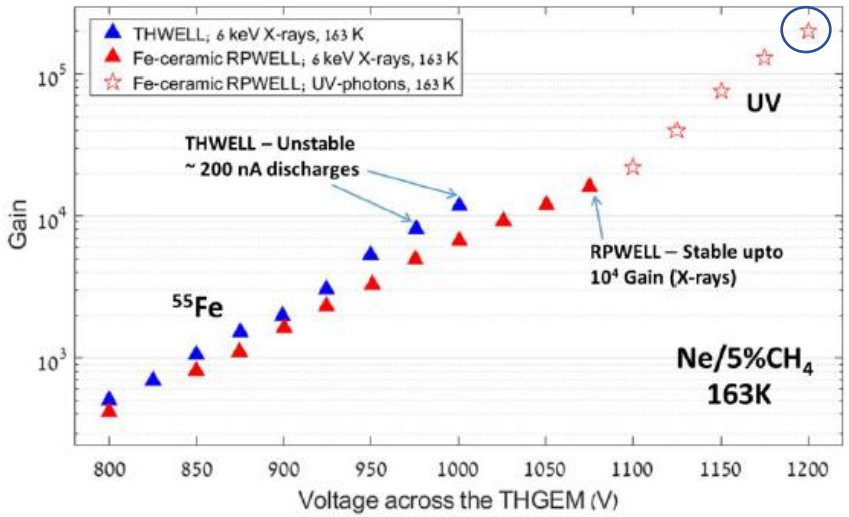


RD51-sponsored!

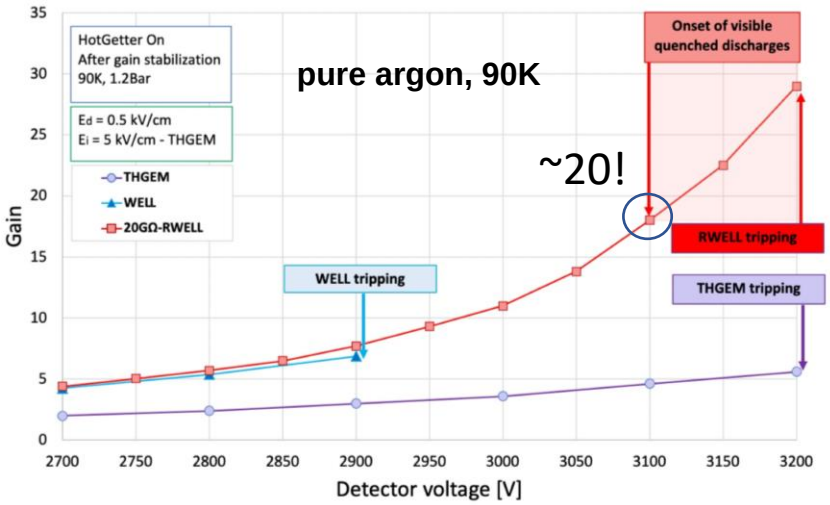
2. Nuevas estructuras protegidas resistivamente para fase dual (II)

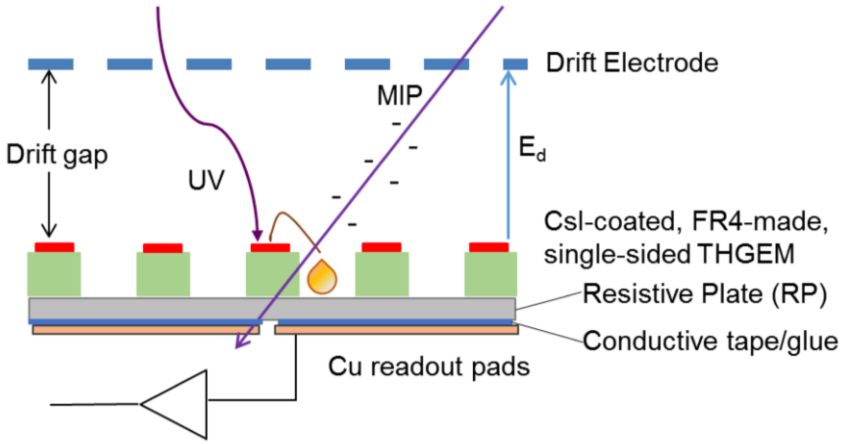
ceramic-protected structure

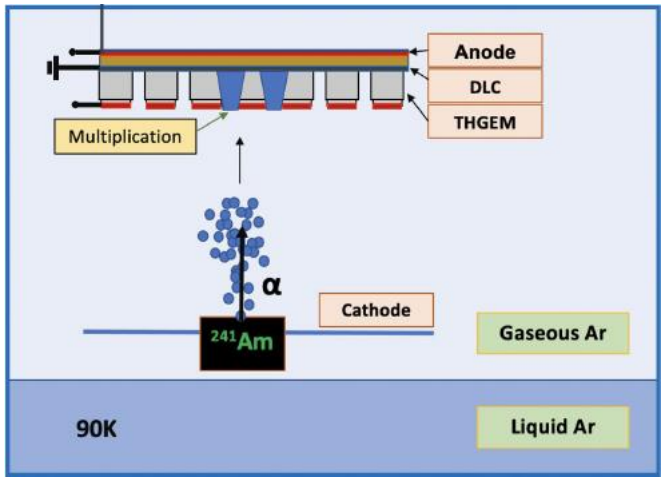
>10^5!



diamond-like carbon –protected structure







and excellent stability with time and transported charge up to C/cm^2 !

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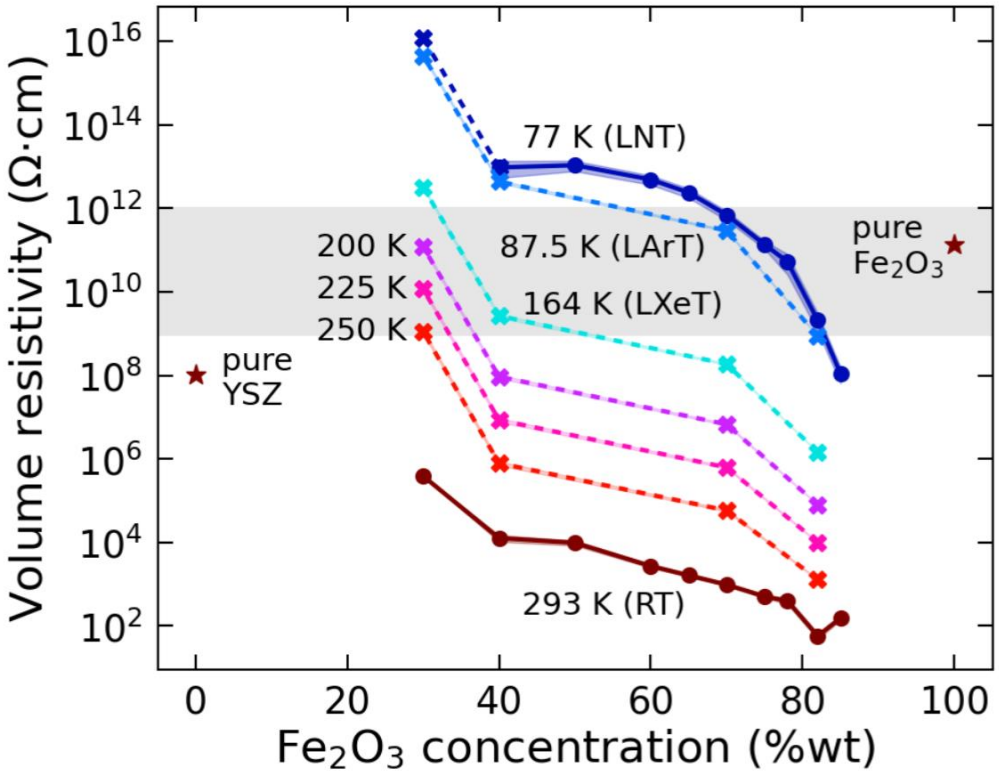
2. Nuevas estructuras protegidas resistivamente para fase dual (scope)

Por hacer (no requiere financiamiento estratégico):

- Estudiar la viabilidad de las cerámicas a temperatura ambiente para RPCs.
- Desarrollo de una nueva geometría para fase dual (en fase de patente).
- Explorar usos comerciales.



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3. Lectura óptica completa para TPCs de argon a alta presión

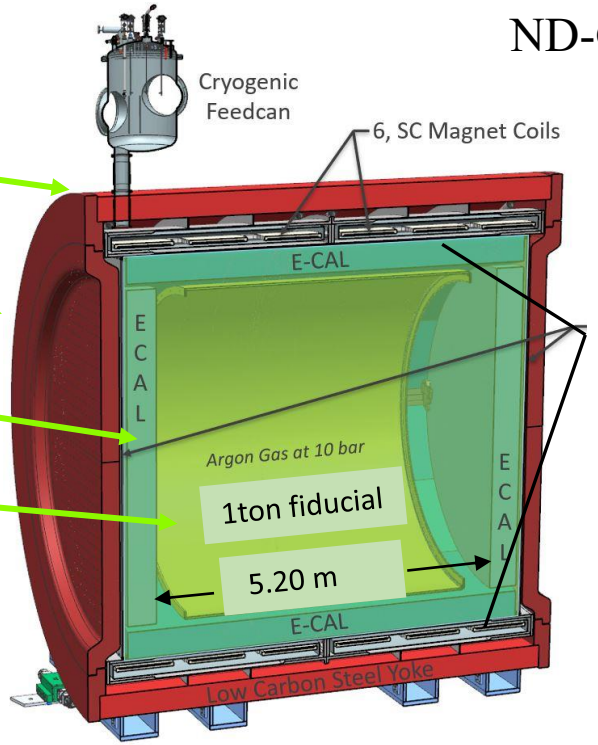
3. Lectura óptica completa para TPCs de argon a alta presión (I)

yoke (+ muon tagger)

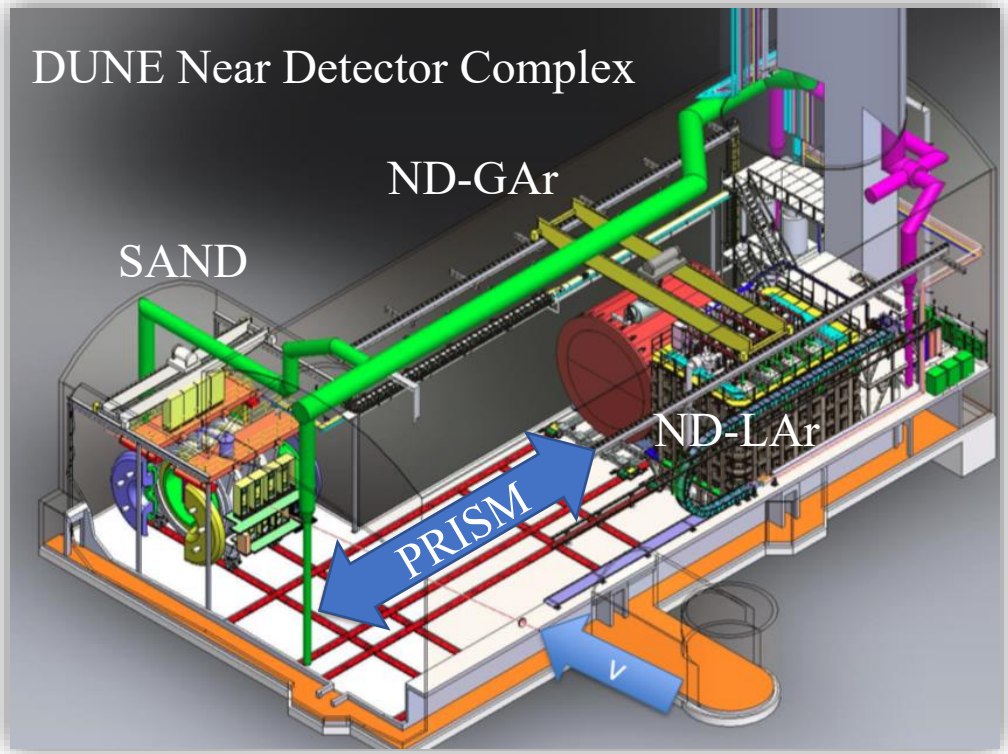
yoke

calorimeter

Time Projection Chamber

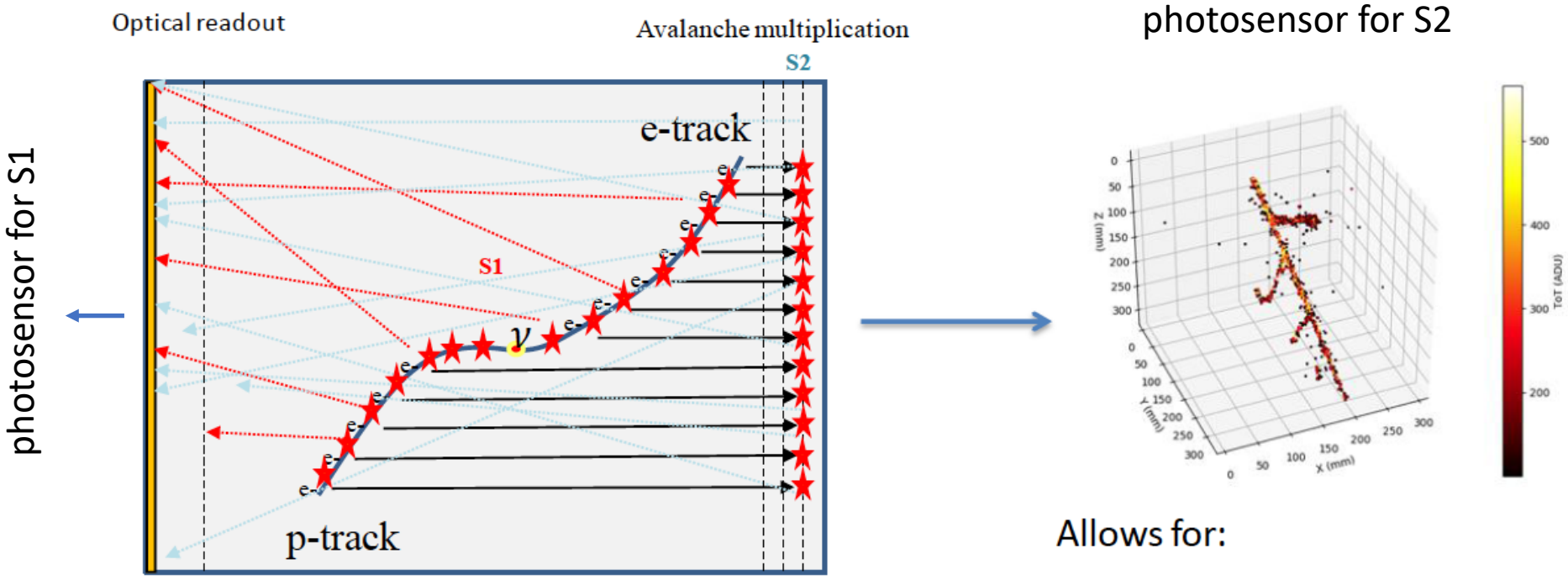


pressure vessel



diseño base basado en lectura clásica en modo carga

3. Lectura óptica completa para TPCs de argon a alta presión (II)



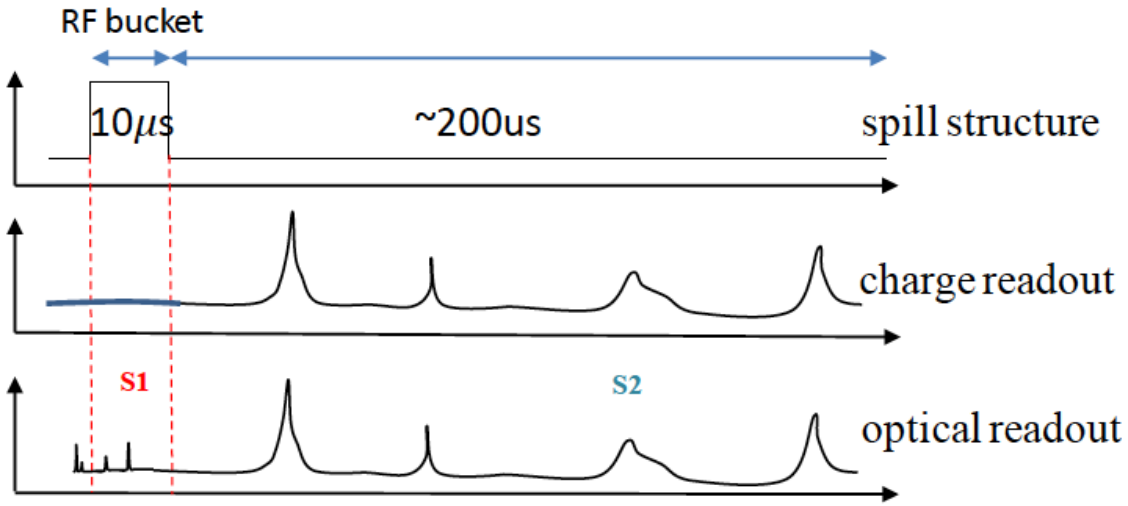
Allows for:

-2 mm scale space sampling

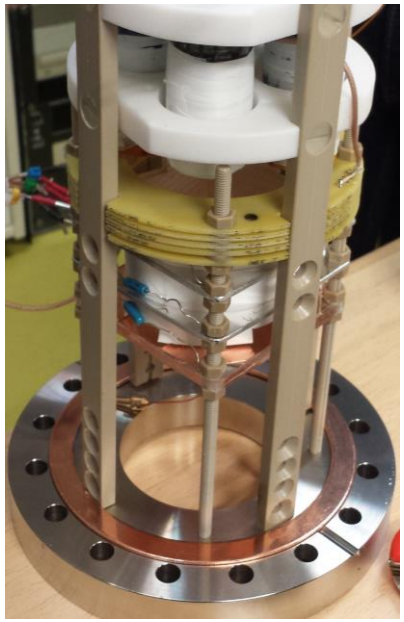
-T0 in TPC

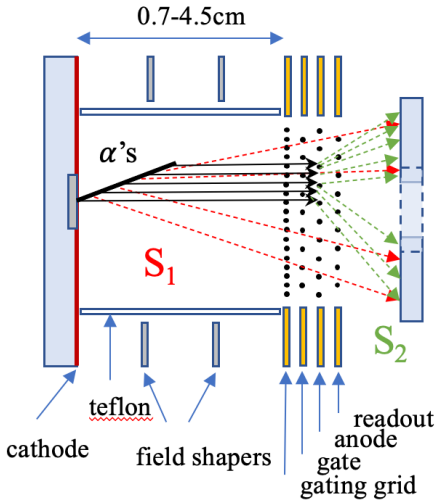
-Spill assignment of TPC contained events

-Amplification and readout stages electrically decoupled

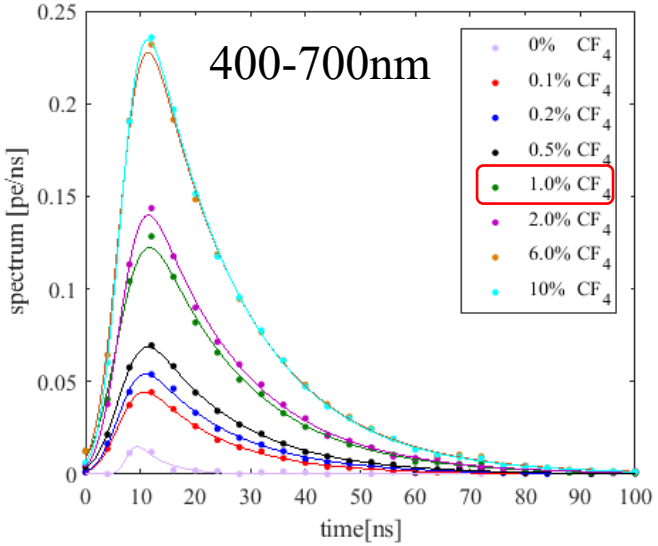


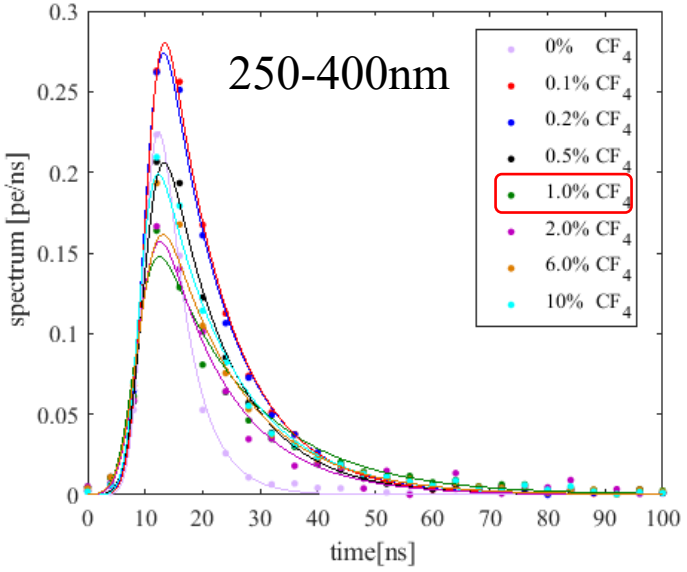
Enabling asset 1: rendimiento de centelleo primario, espectro, perfil temporal **(hecho)**



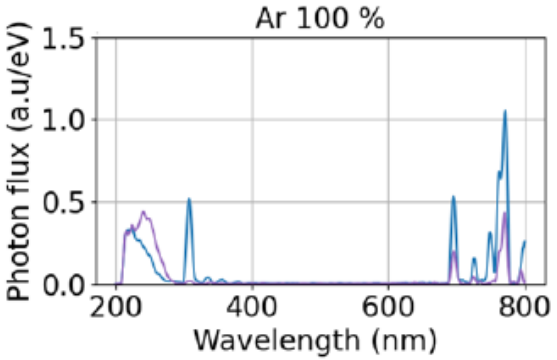


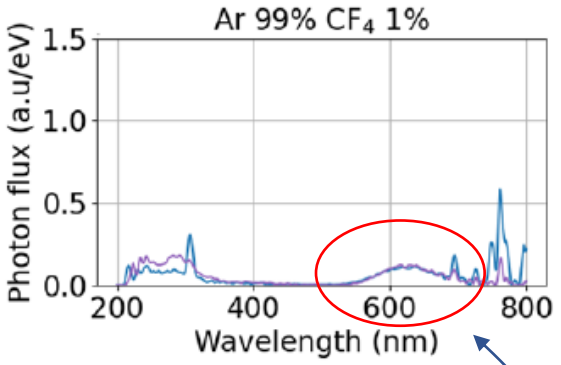
scintillation time profile for α-tracks





spectrum for x-rays





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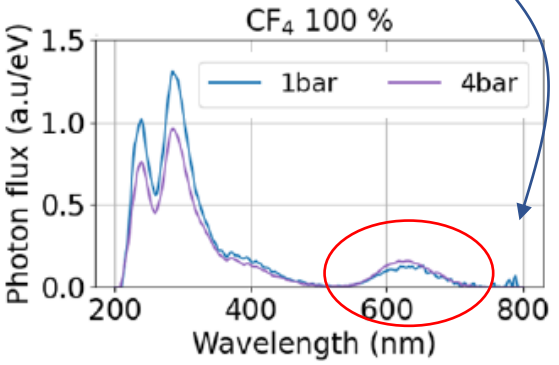
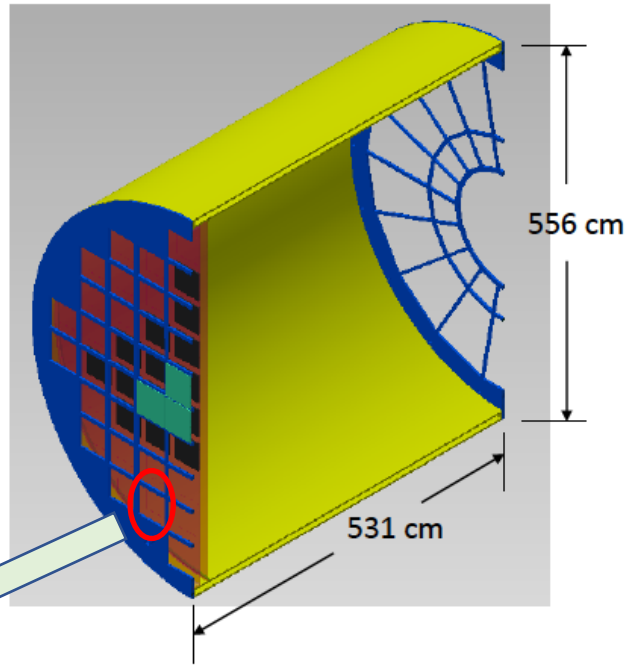
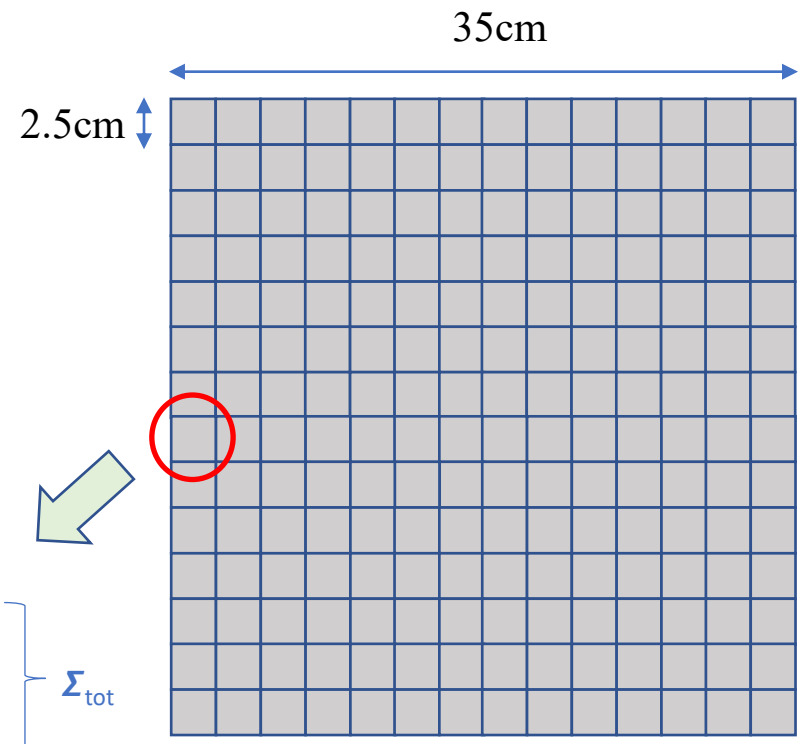


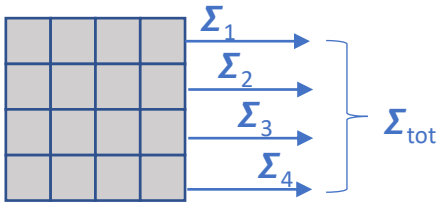
Propuesta conceptual del plano del fotosensor primario

- ~125-150 modules in cathode plane
- ~256 tiles per module
- 16 SiPMs (6*6mm^2) per tile
- ~32000 readout channels

layout optimization ongoing

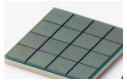




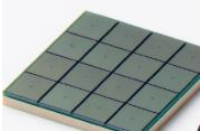


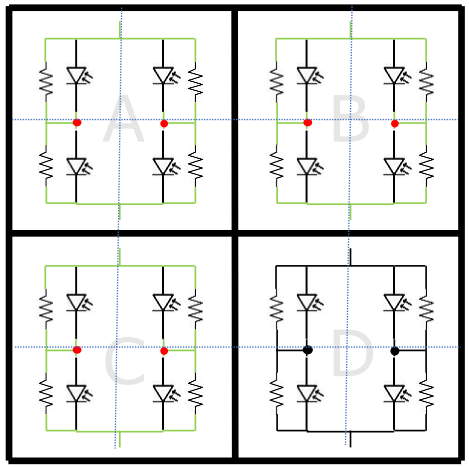
Hamamatsu

S13360-series

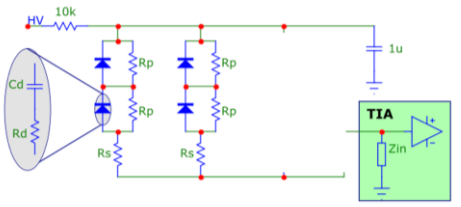


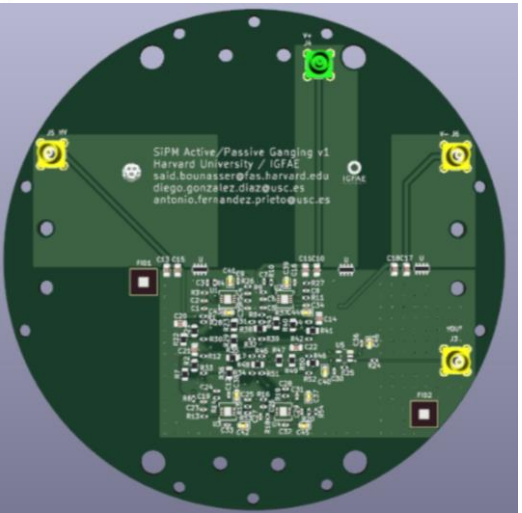
Enabling asset 2: ‘ganging’ de SiPMs rápido **(en marcha)**

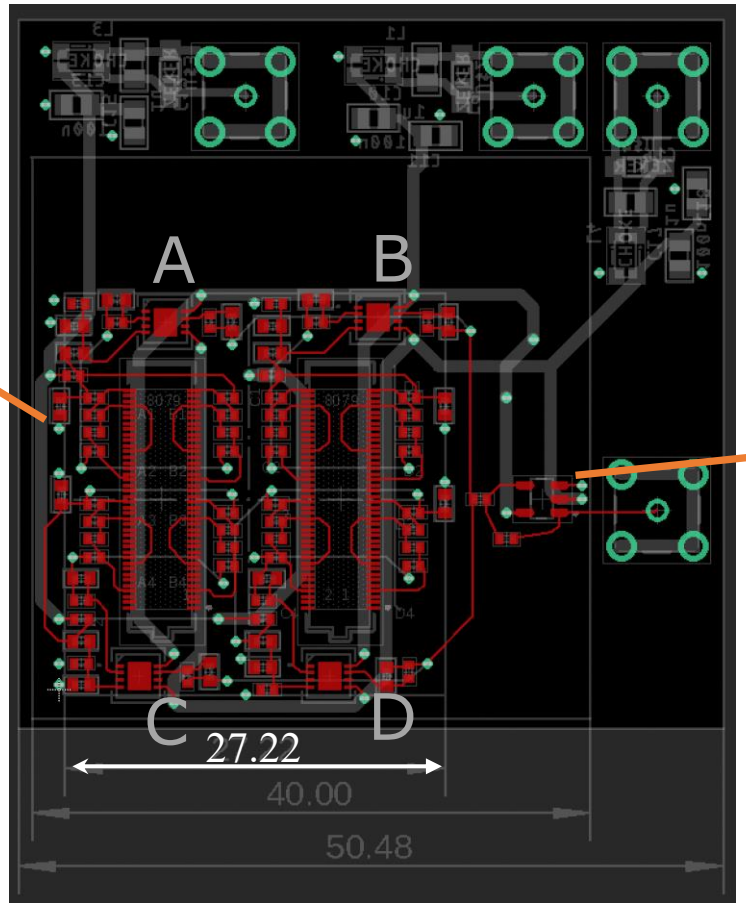


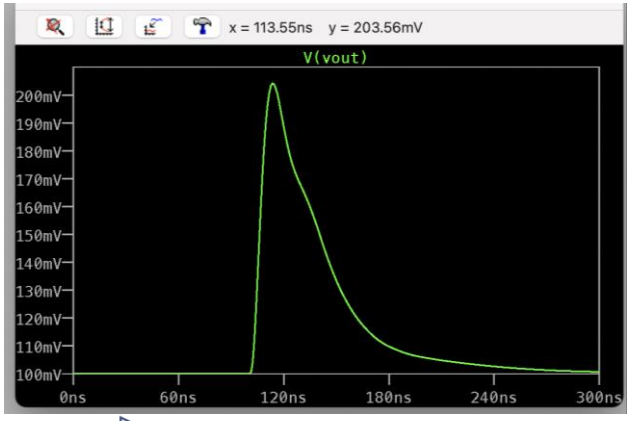


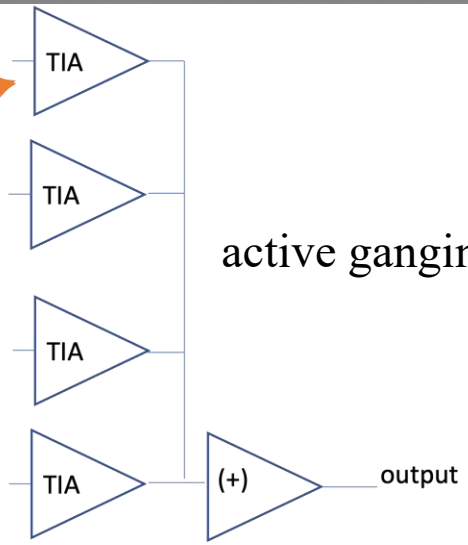
passive ganging











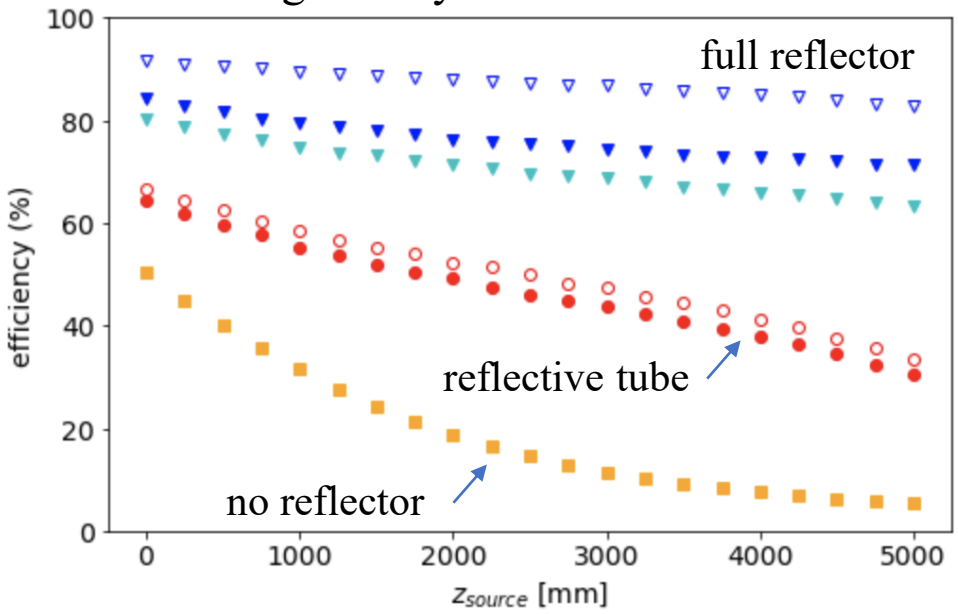
active ganging

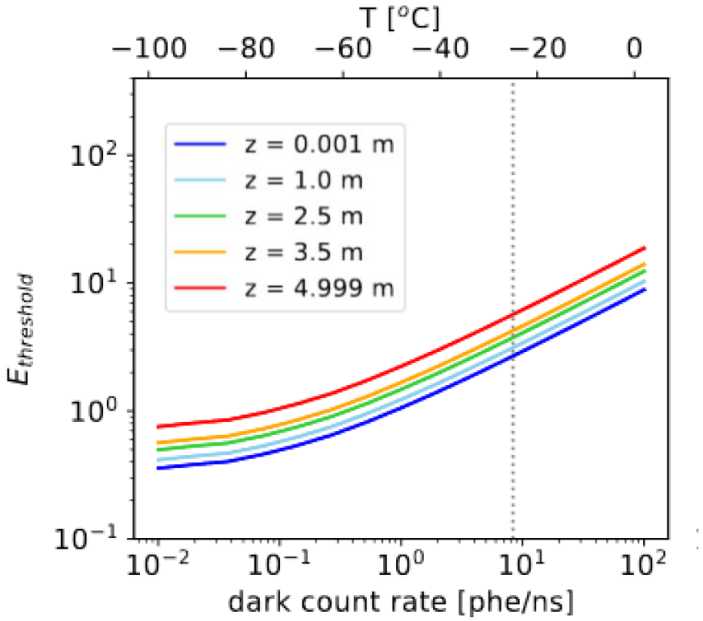
- Rise Time$_{(10\% \text{ to } 90\%)}$: 15ns
- Fall Time$_{(90\% \text{ to } 10\%)}$: 62ns
- Amplitude single-photon: 76mV
- Noise estimate: 152μV
- Power consumption: **480mW**.
- Estimated T0 resolution: <1.5ns.

~x4 bit higher than previous estimate 😐

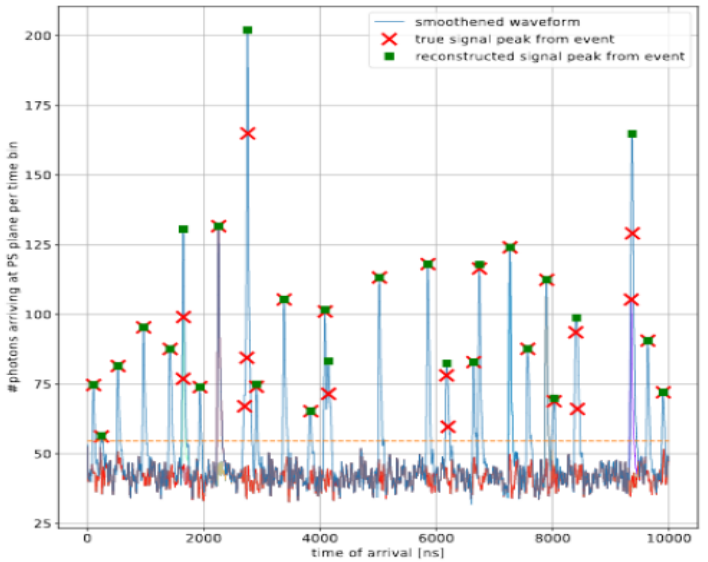
Enabling asset 3: sensibilidad, reflectores/colectores **(evaluado por simulación)**

visible light ‘easy’ to collect with reflectors

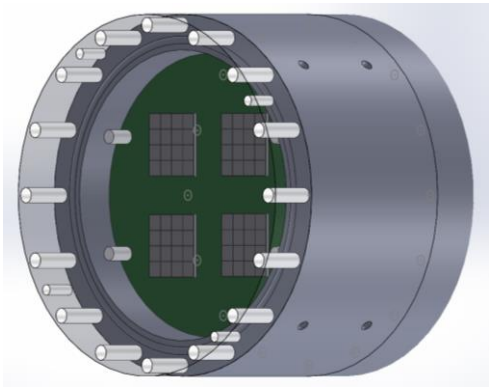


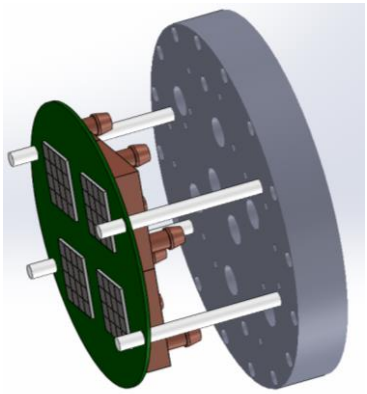


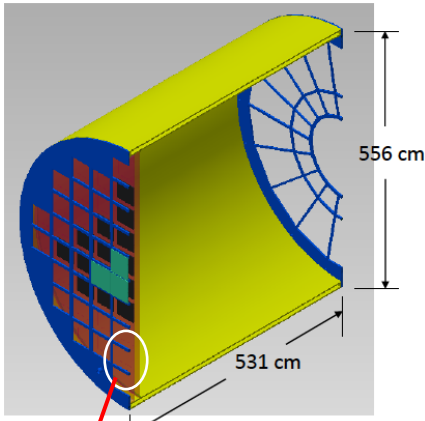
Pulse reconstruction doable near the tracking threshold (5MeV), but cooling needed!

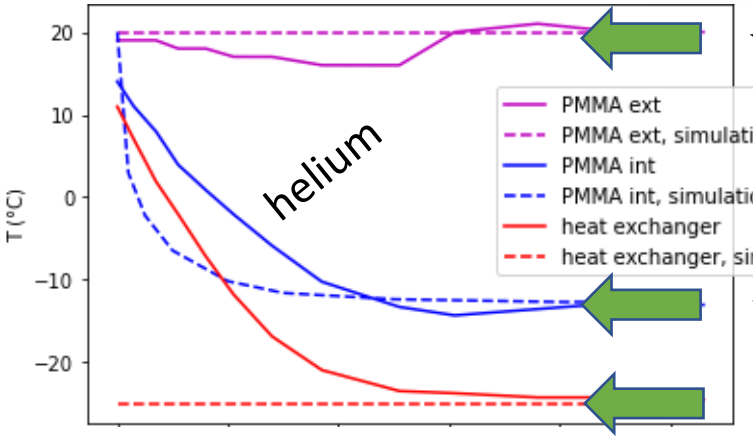


Enabling asset 4: enfriado de SiPMs con criostato activo **(en marcha)**





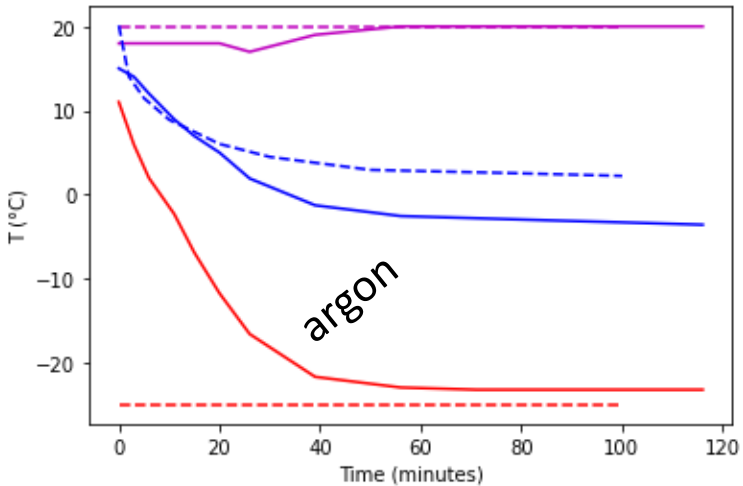


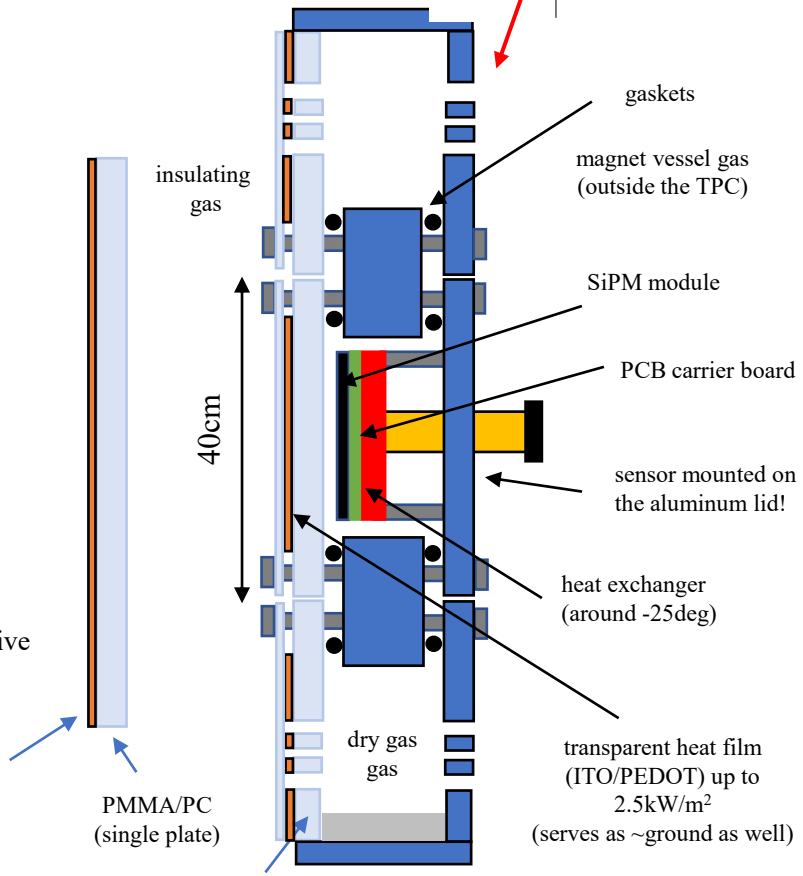


window (out)

window (in)

SiPM region

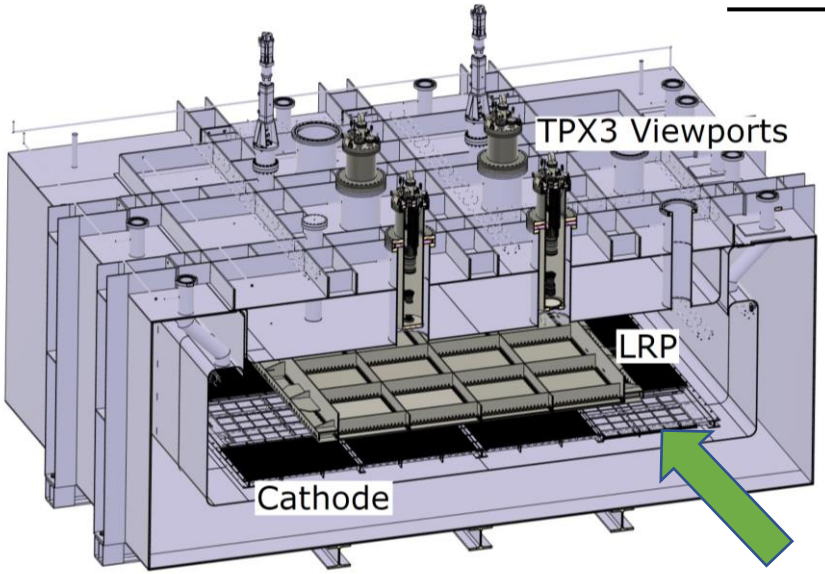




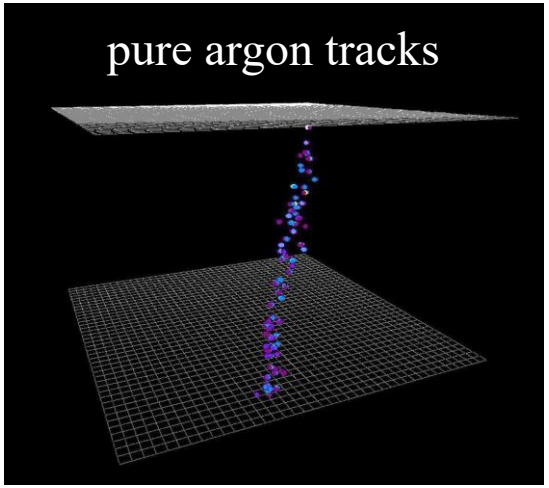
using individual PMMA/PC windows (20mm-thick) to minimize thermal stress (due to TEC) down to manageable levels

*not to scale

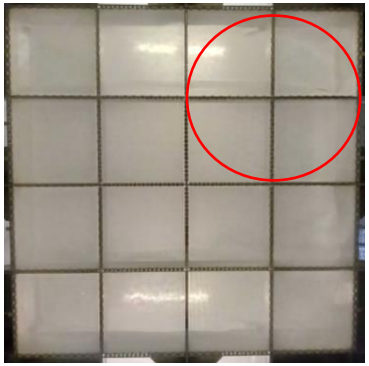
Enabling asset 5: cámaras TimePix **(hecho: coll. CERN-Liverpool-IGFAE)**



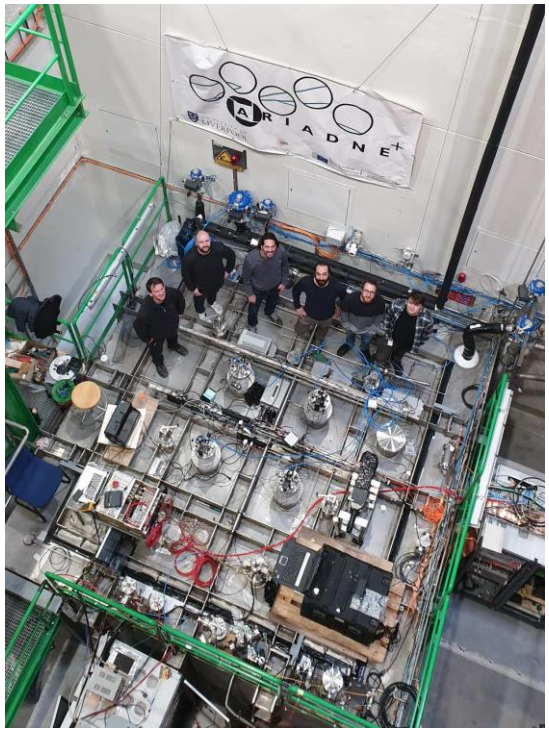
3D optical imaging!! (a unique feature of ARIADNE)



~1m^2 field-of-view



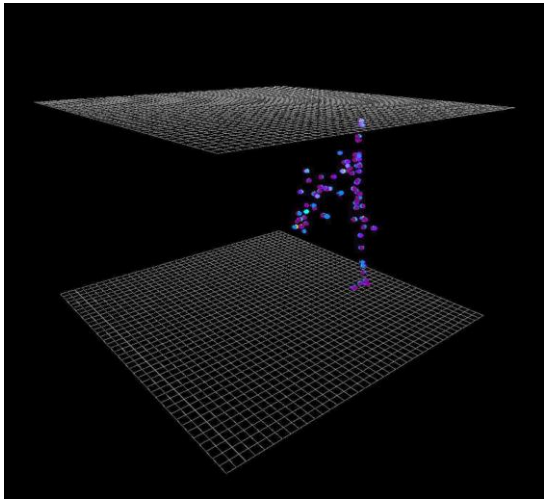
2m^2 glass GEMs



1x1m^2 -> Δ_x = 4mm

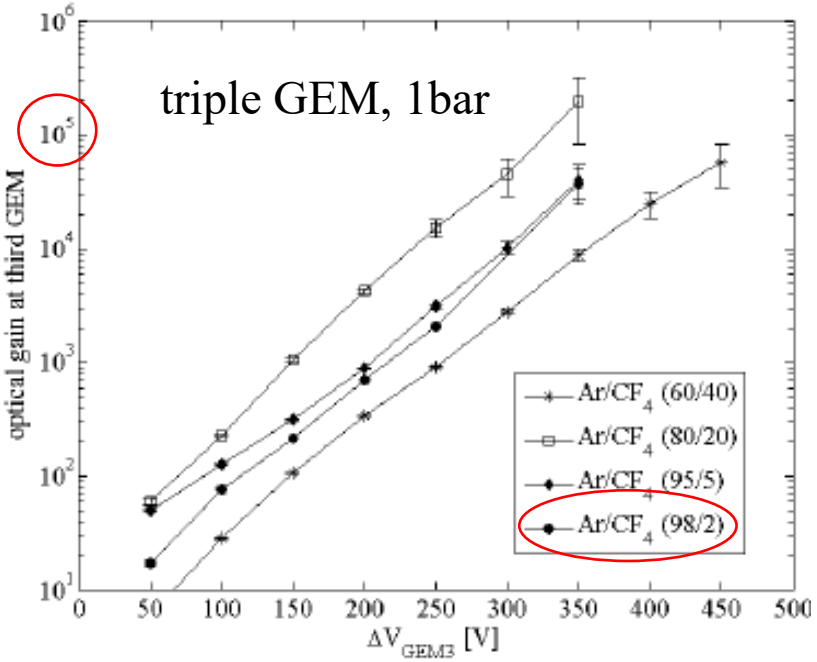
0.5x0.5m^2 -> Δ_x = 2mm

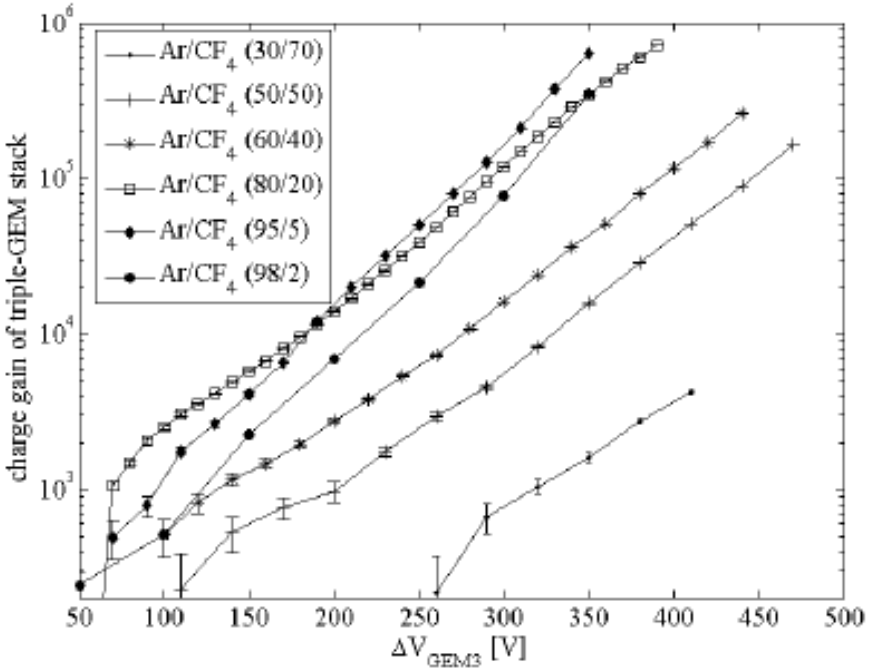
(80 TimePix cameras in ND-GAr)



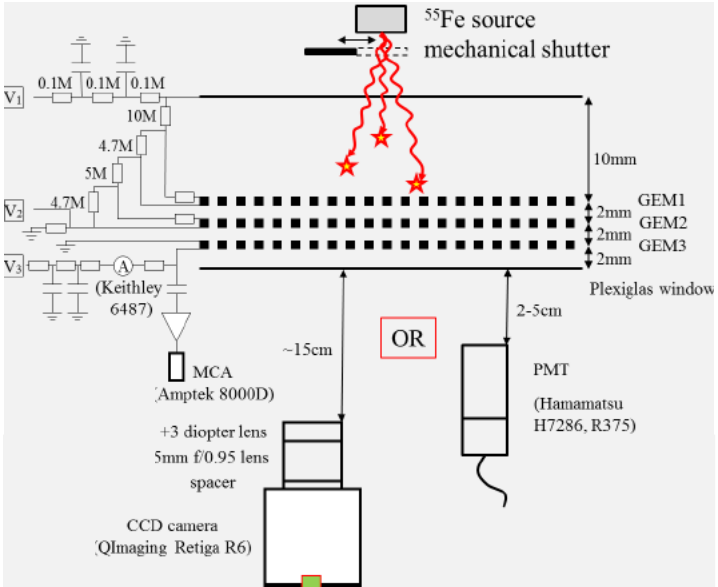
analysis ongoing!

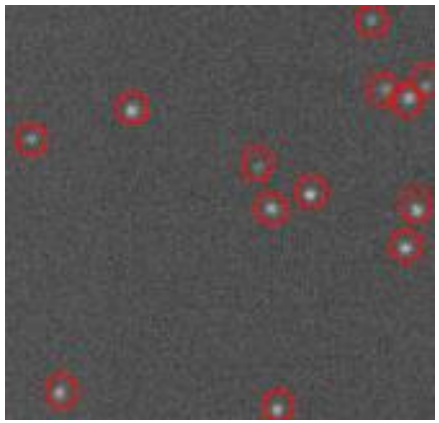
Enabling asset 6: Desarrollo de estructuras de alta ganancia óptica **(recién empezado)**





results obtained at CERN-GDD circa 2017



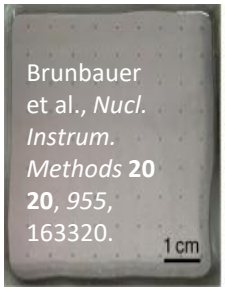


^{55}Fe x-rays (5.9keV)

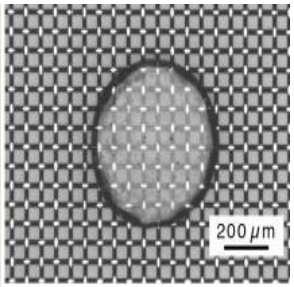
Enabling asset 6: Desarrollo de estructuras de alta ganancia óptica **(recién empezado)**

Several multiplication structures (some of them purposely designed for optical readout) have been procured

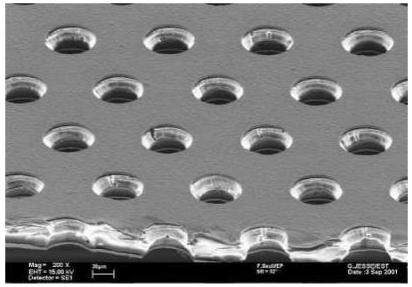
glass Micromegas

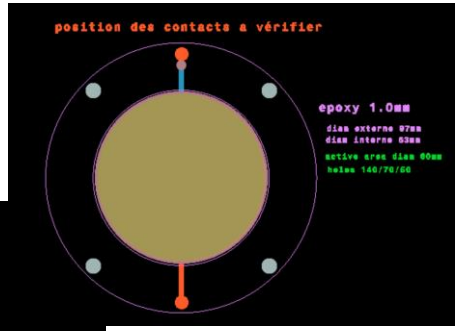


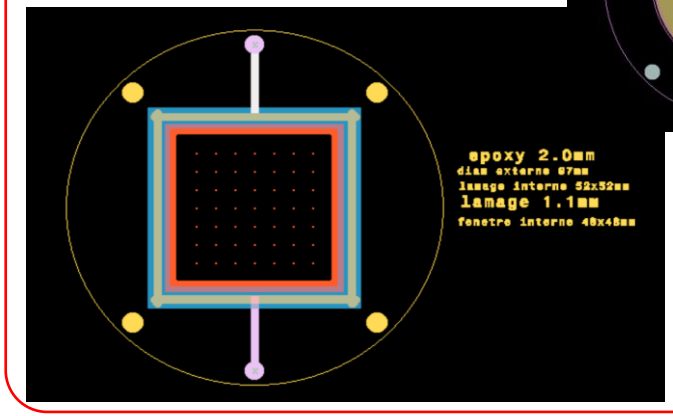
Brunbauer et al., *Nucl. Instrum. Methods* **20** **20**, *955*, 163320.



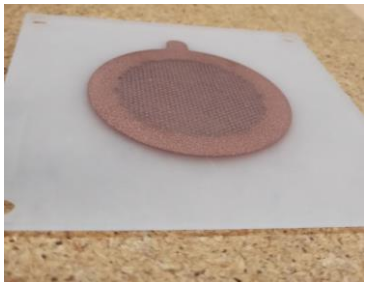
standard GEMs



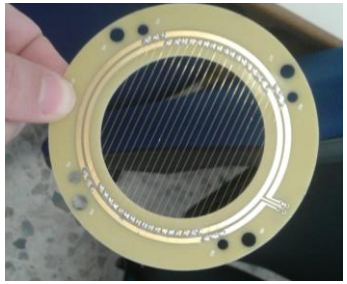




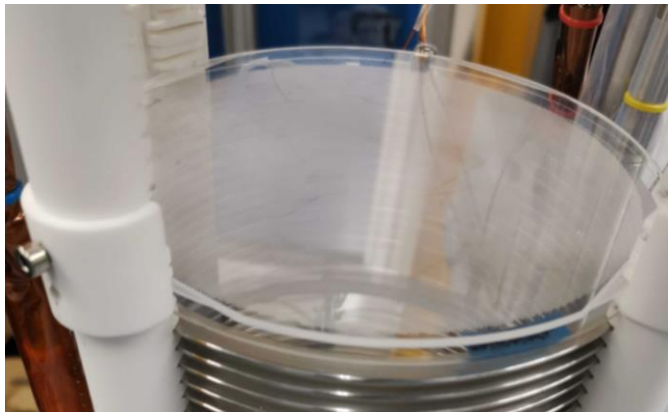
acrylic thick-GEMs



MWPCs

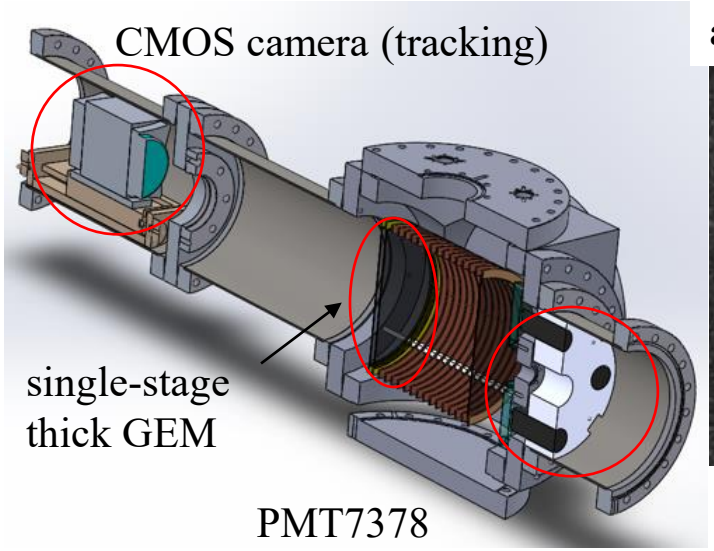


glass GEMs (from ARIADNE)

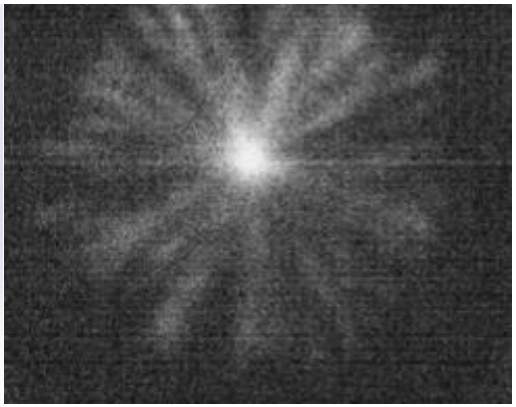


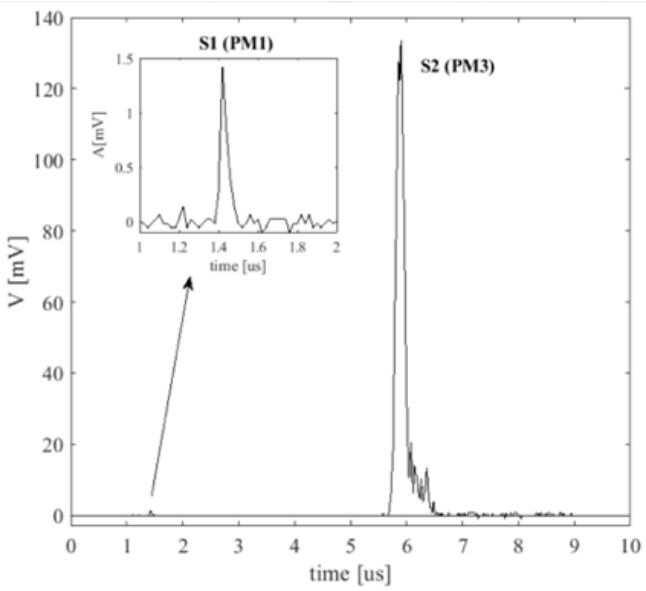
Enabling Primary Scintillation ('T0') in a tracking TPC (**technological demonstrator-I**)

- current OTPC (targeting fission studies):



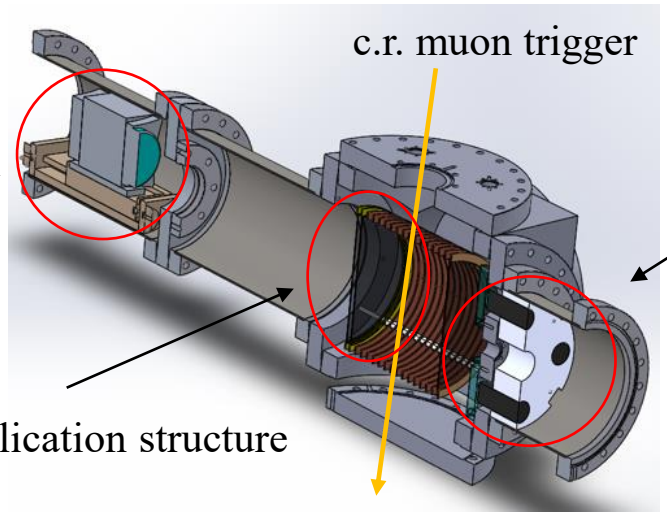
alpha tracks in CF_4 at 0.5bar



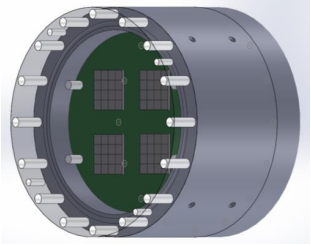


- future OTPC (targeting neutrino interactions):

Gaseous Argon T_0 GAT0

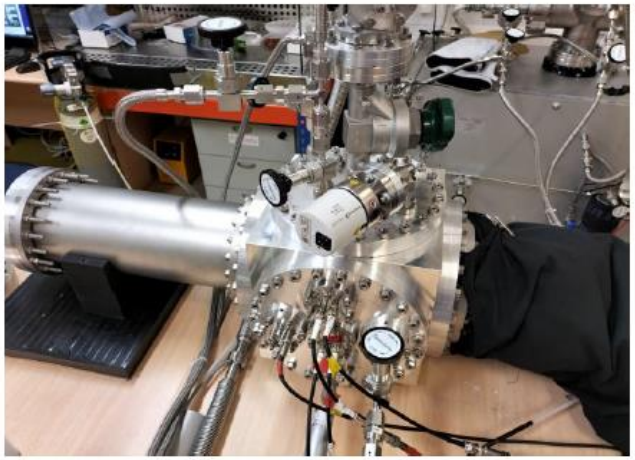


replace with SiPM sensor



Enabling Primary Scintillation ('T0') in a tracking TPC (**technological demonstrator-II**)

- The chamber was successfully operated at 1 bar with a double THGEM structure and 1% of CF4 !
- S1 and S2 were read with PMTs
- Next immediate upgrade is to use a CCD camera to try and see tracks

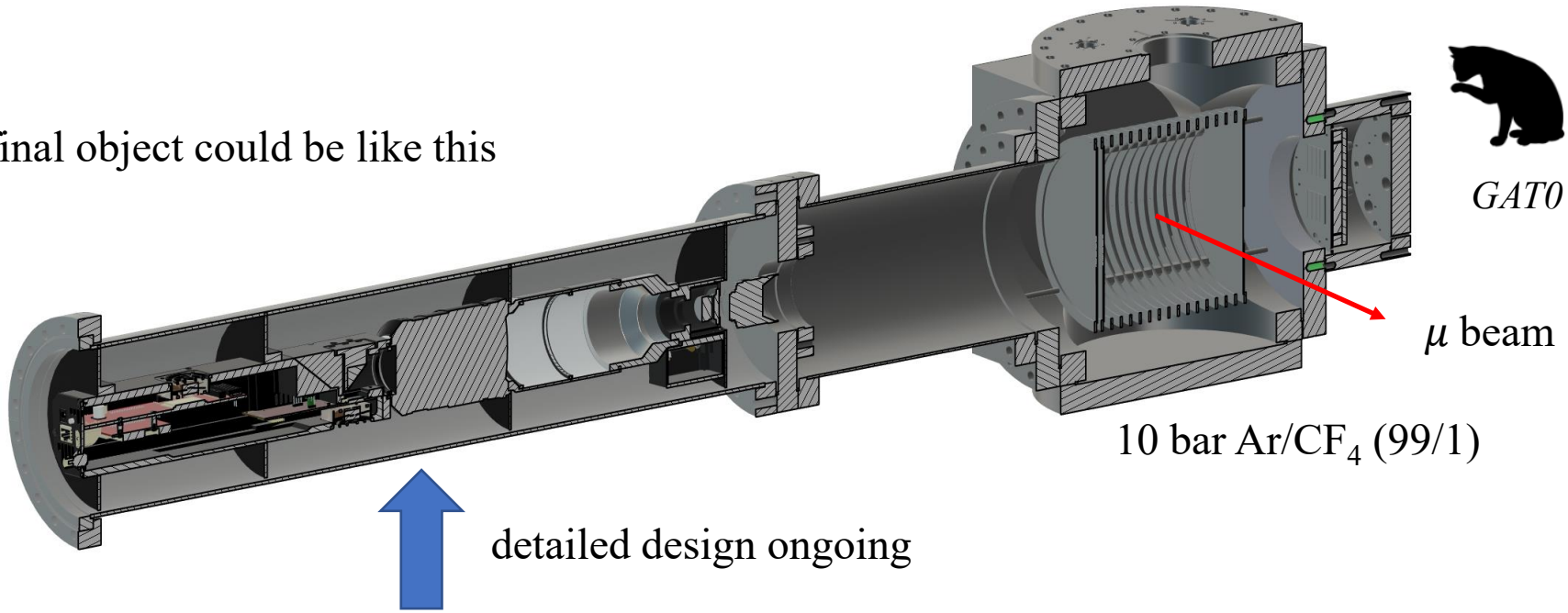


Enabling Primary Scintillation ('T0') in a tracking TPC (**technological demonstrator-II**)

Por hacer (no requiere financiamiento estratégico):

- 'Commisioning' con rayos cósmicos.
- Demostrar el concepto haz en 2024.

the final object could be like this



Conclusiones

Requiere financiamiento estratégico:

- El poder continuar realizando este tipo de actividades, **ninguna de las cuales ha sido financiada dentro del sistema español** (FPN aporta al último proyecto un 30% de lo solicitado, para poder poner el prototipo en haz. La fase de I+D se completó a través de otros proyectos, europeos, regionales y locales).