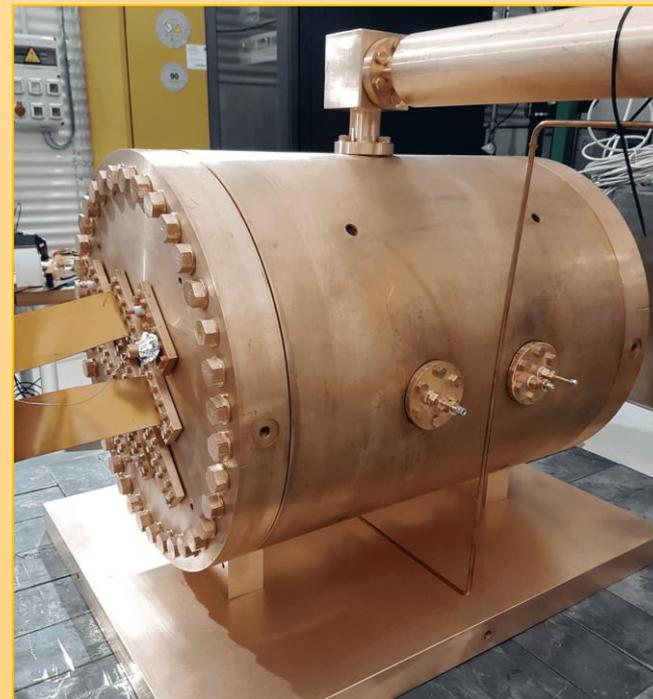
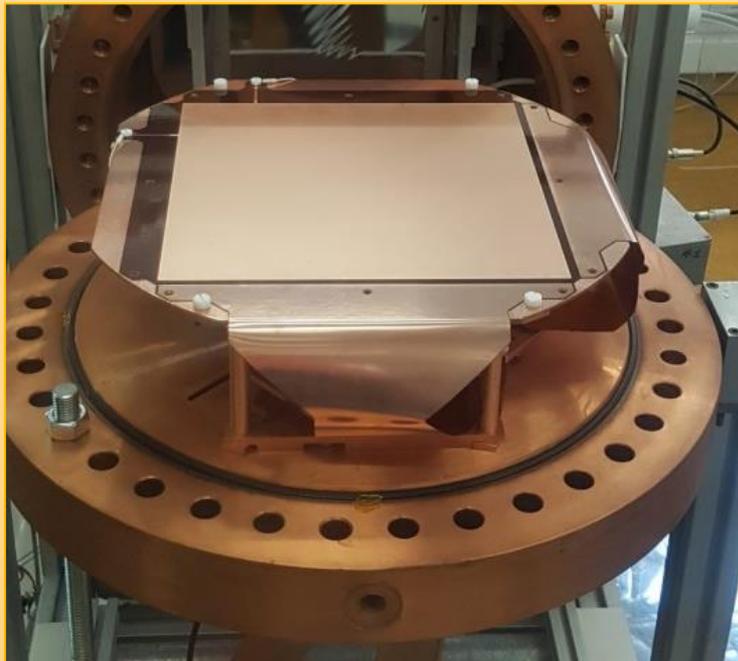


Prospects about TRES-DM: a low-mass WIMP detector at LSC



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19th MultiDark Consolider Workshop, Miraflores de la Sierra,
Madrid, 23-25 May 2022



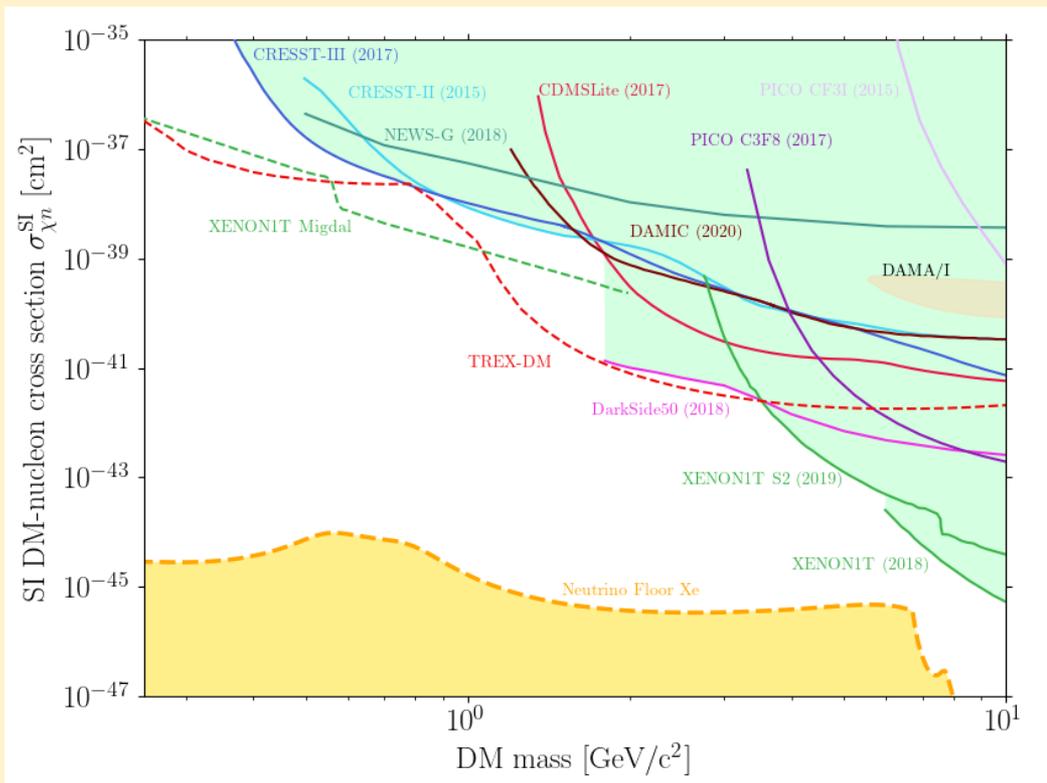
DM in the low mass frontier

Dark matter searches have explored vast regions of the parameter space.

Above $10 \text{ GeV}/c^2$: approaching to the neutrino floor.

But below $10 \text{ GeV}/c^2$: curves several orders of magnitude higher.

TREX-DM: high pressure TPC with light element (**neon**) to improve sensibility at low masses.



Status (as of Sept 2021) of searches for SI elastic WIMP-nucleus scattering + TREX-DM projections
Source: prepared by the group

TREX-DM projected figures:

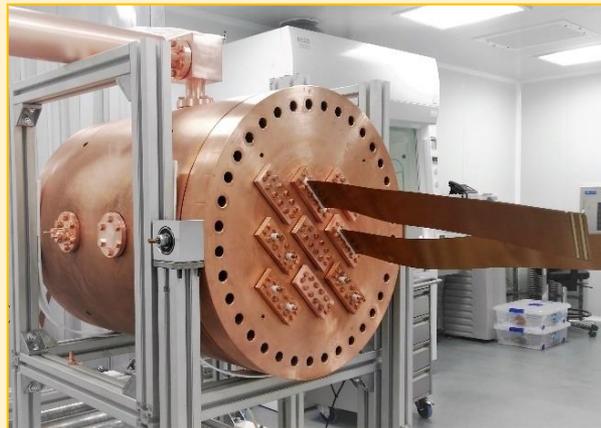
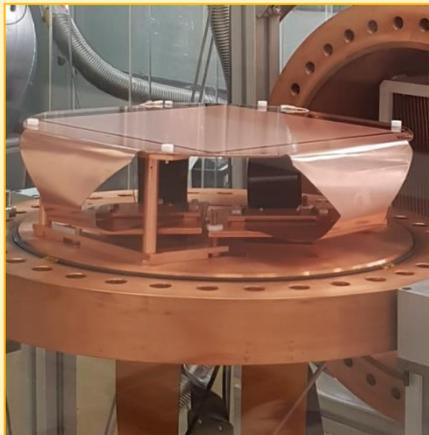
- Background: 1 counts/keV/kg/day
- Threshold: 0.1 keVee
- Exposure: 0.3 kg y (Ne @ 10 bar, 2 y)

Motivation and goals

TREX-DM (*TPC for Rare Event eXperiments-Dark Matter*)

R&D project conceived to:

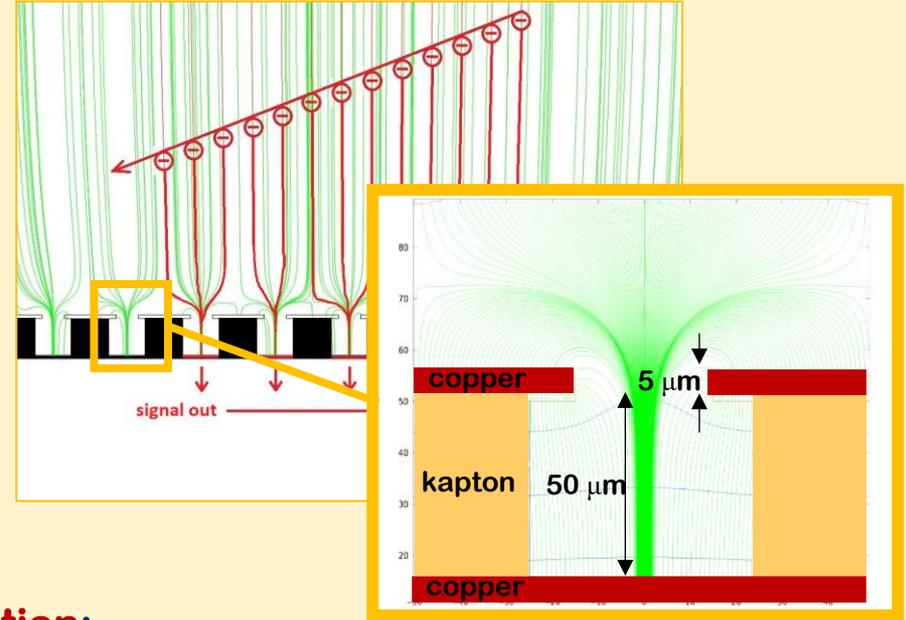
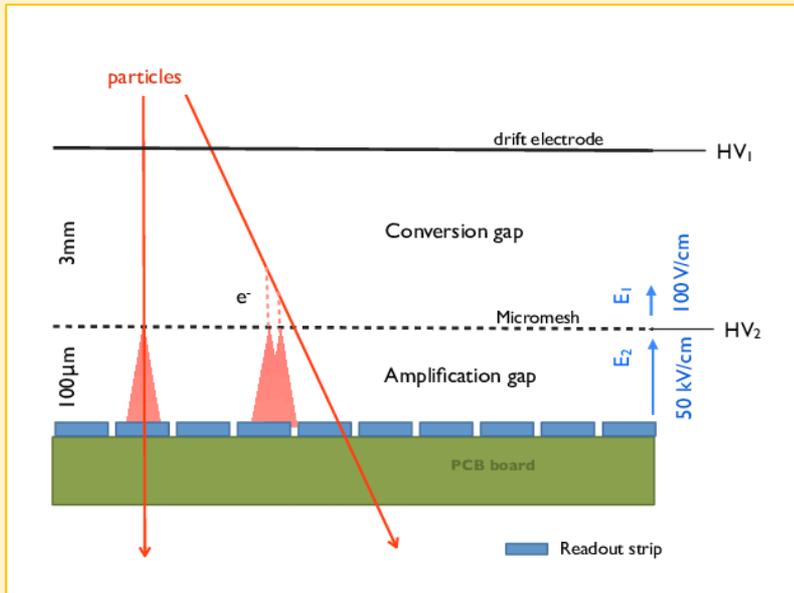
- look for **low-mass WIMPs**
- using a gaseous detector: Time Projection Chamber
- ~20 l of **pressurized gas** (~0.16 kg Ne at 10 bar, current tests at 4 bar)
- equipped with novel Micro-MESH Gaseous Structure (**Micromegas**) readouts
- at the **Canfranc Underground Laboratory (LSC)** in Spain



Requirements to search for low-mass WIMPs:

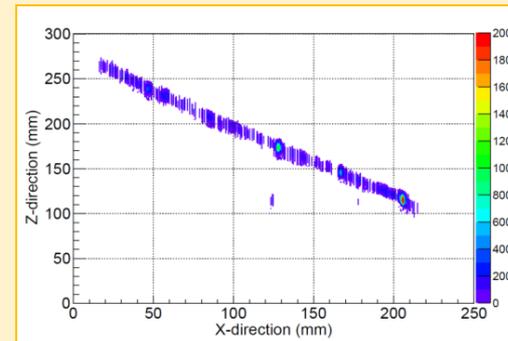
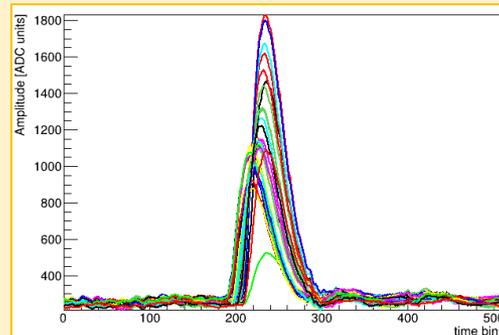
- **Very low energy threshold** ($<1 \text{ keV}_{ee}$)
- **Light elements as target**
- **Radio-pure components** to reduce background

Detector: Micromegas



- Important advantages for **rare-event detection**:

- **Topological information**: to discriminate background from expected signal by dark matter (few microns track \rightarrow point-like event)
- **Low intrinsic radioactivity**: made of kapton and copper, potentially very clean
- **Scaling-up**

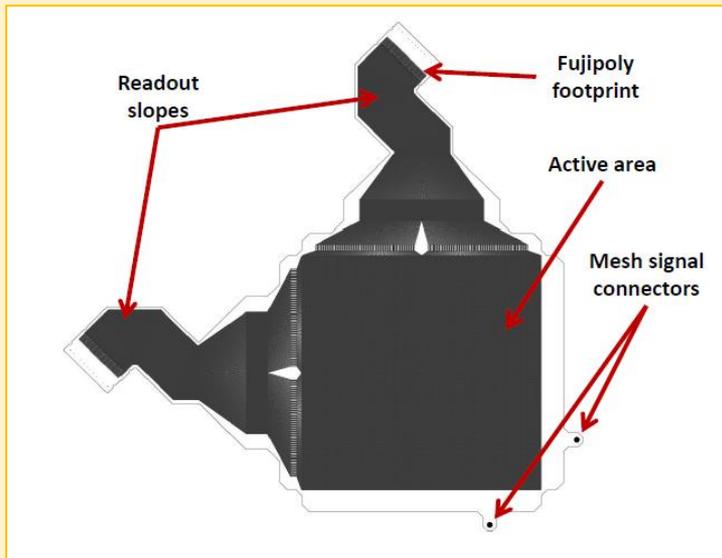


Detector: Micromegas

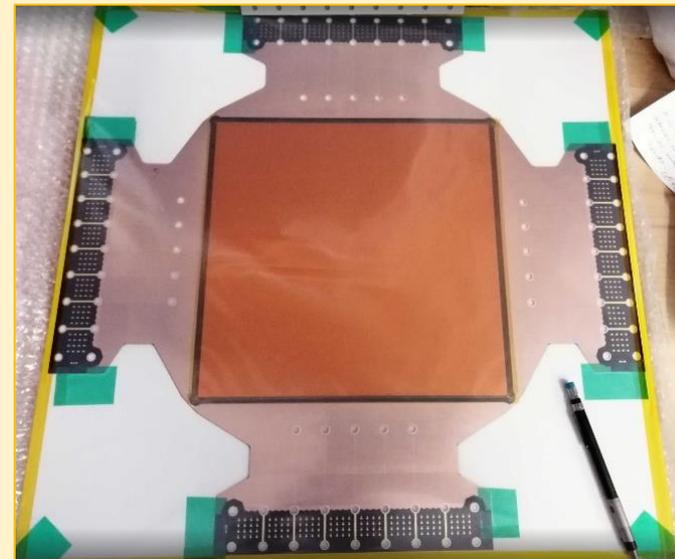
New Microbulk Micromegas readouts: the largest surface ($\sim 25 \times 25 \text{ cm}^2$) ever produced with this technology.

- Two planes manufactured at CERN, **256 X strips, 256 Y strips, $\sim 1 \text{ mm}$ pitch**
- **Flat cables** take out signals from strips and connect to the interface cards out of the vessel
- Connections at both sides of flat cables made now by special radiopure connectors
- Current detectors are being upgraded

Current design



New design

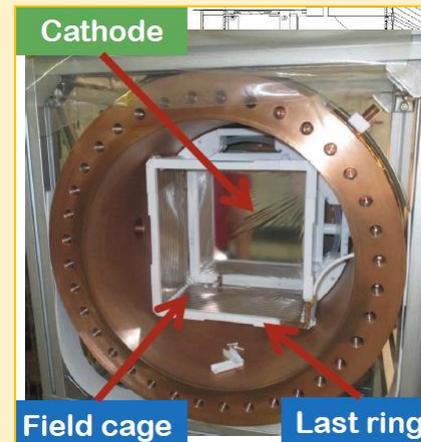


Detector: vessel and gas system



Vessel:

- Cylindrical vessel made of copper
- Designed to operate safely at 10 bar, certified as pressure equipment before installation at LSC



Gas system:

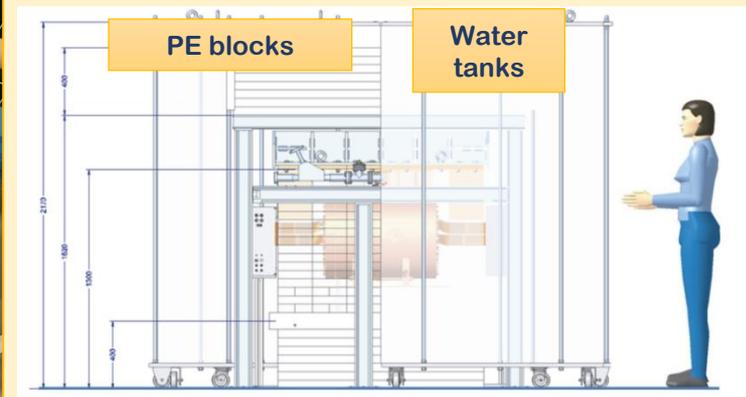
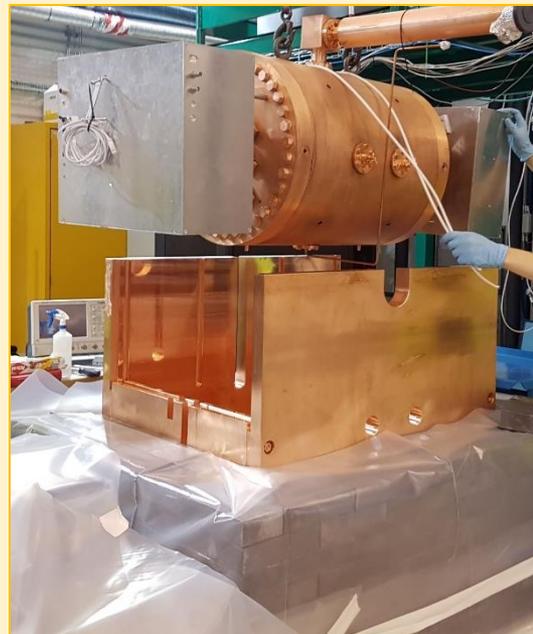
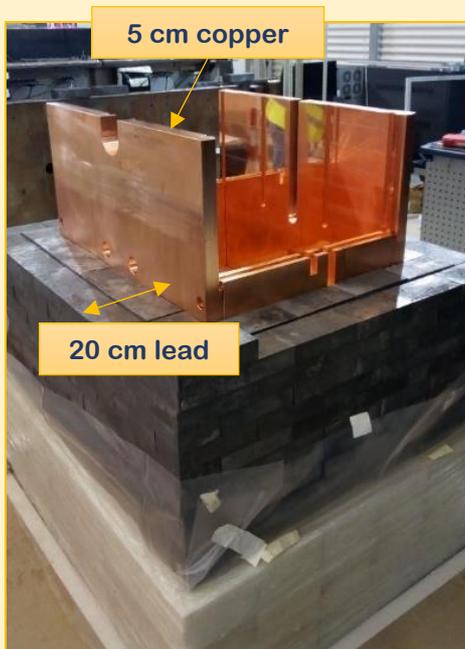
- Designed for non-flammable gases
- Recirculation part + purification branch



Detector: shielding

At hall A of the Canfranc Underground Laboratory (2450 m.w.e.)

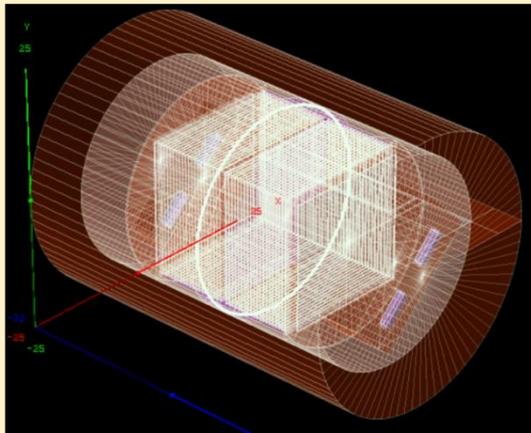
- Muon reduction: $\sim 10^5$
- DAQ outside the shielding: non radiopure electronics far from detector
- Neutron shielding foreseen: polyethylene ceiling + water tanks.



Background model

- Simulation based on **Geant4** (Physics processes) + **REST-for-Physics code** (electron generation in gas with Garfield, diffusion effects during drift, charge amplification at Micromegas, signal readouts)
- Inputs for main background sources
 - Measured fluxes of **environmental backgrounds** in LSC (gammas, neutrons, muons)
 - **Activity measurements** from an extensive material screening program, mainly based on germanium gamma spectrometry at LSC
- Points to 40K in the Micromegas detectors as the main limiting source of background
 - X4 achieved reduction in new Micromegas
- The expected background levels are in the range $1-10 \text{ c keV}^{-1} \text{ kg}^{-1} \text{ day}^{-1}$ (= 1-10 dru)
 - Best measured levels: 80 dru

“REST-for-Physics, a ROOT-based framework for event oriented data analysis and combined Monte Carlo response”
<https://arxiv.org/pdf/2109.05863.pdf>



“Background assessment for the TREX Dark Matter experiment”
<https://arxiv.org/pdf/1812.04519.pdf>



Micromegas



Flat cables



Connectors

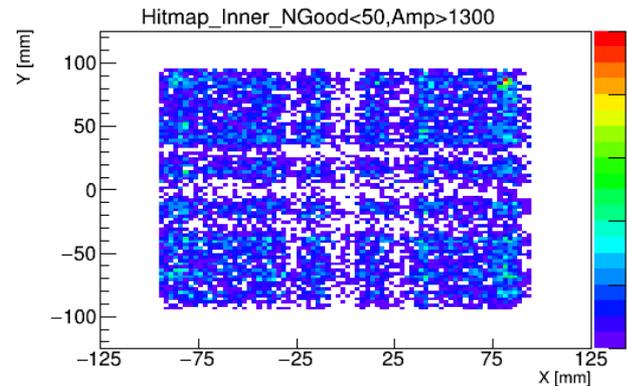
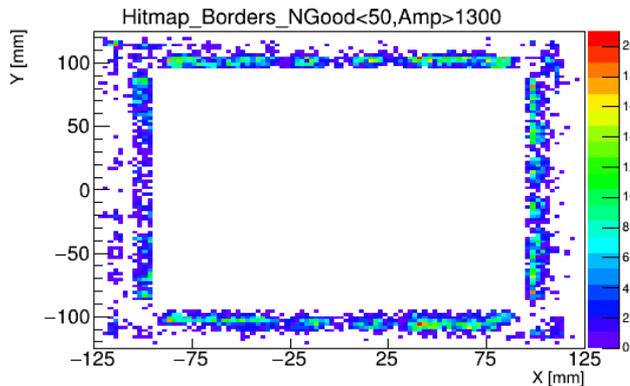
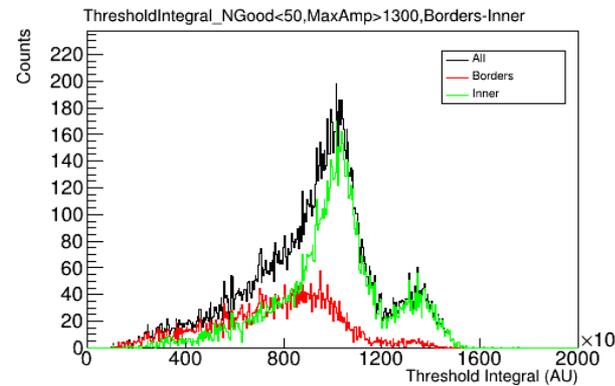
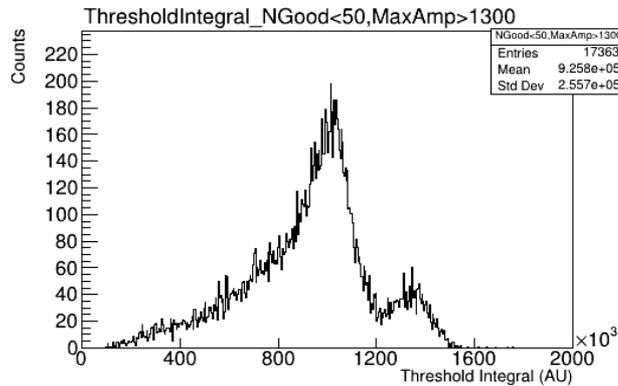
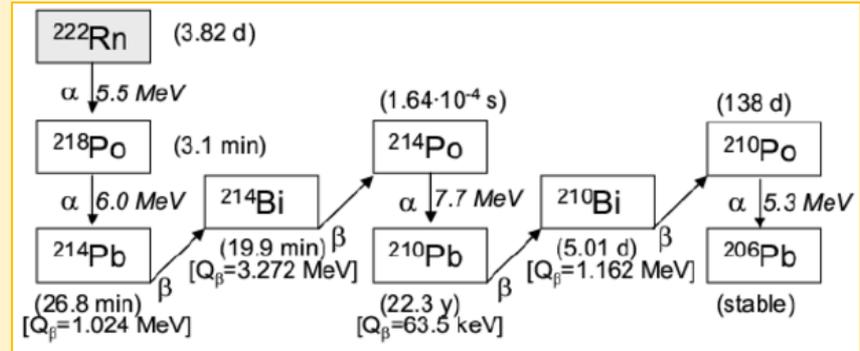


AGET chips



Radon background

- Since first runs in 2020, evidence of **contamination from Rn**.
- Special low gain (HE) runs show alpha events.



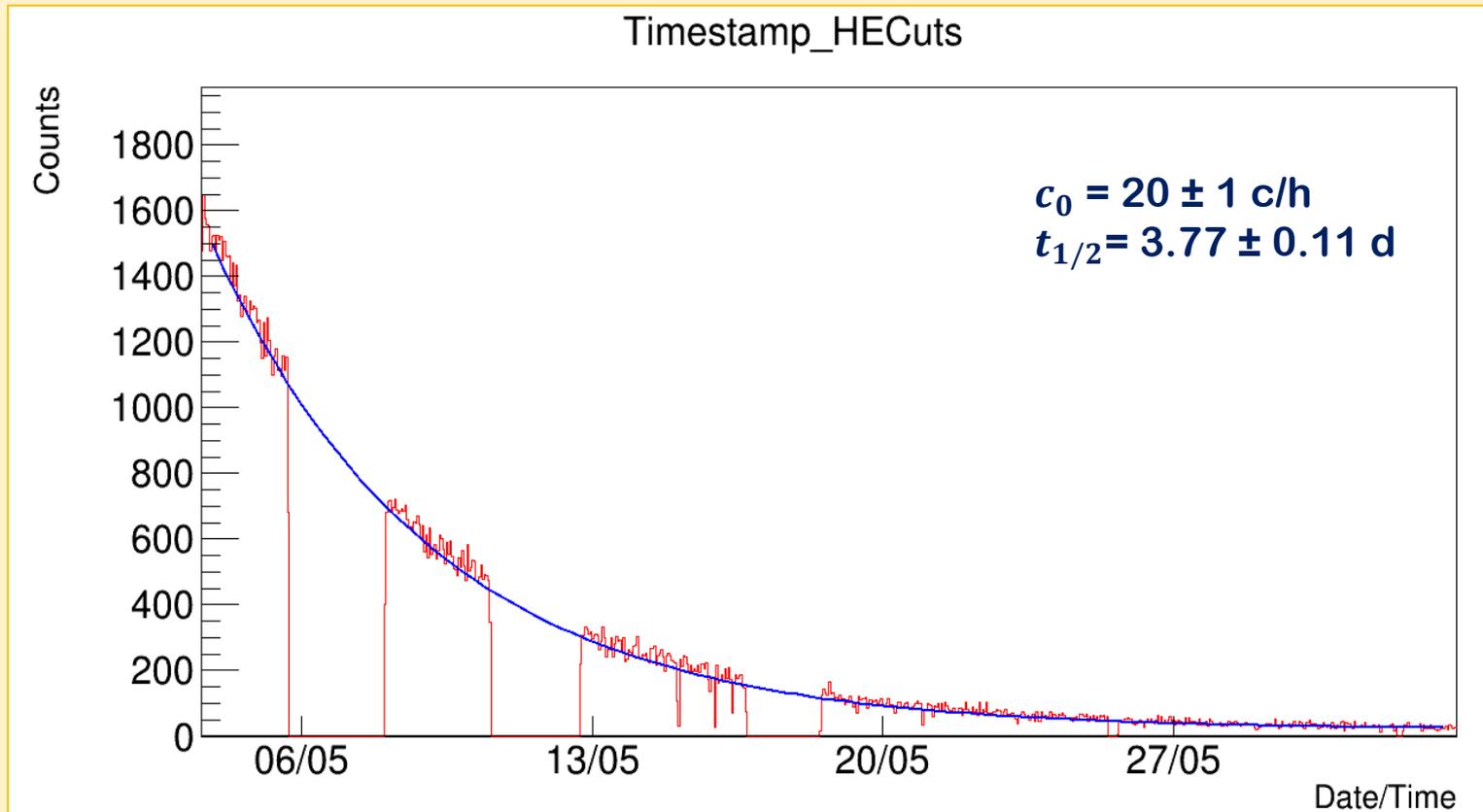
- **Black:** “5 MeV peak” (5.5 + 6.0 + 5.3) and “7 MeV peak” (7.7 MeV)
- **Green:** Inner, Rn + progeny
- **Red:** Borders, surface ^{210}Pb (5.3 MeV from ^{210}Po)

Radon background

- **Low energy (LE)** and **high energy (HE)** runs during 1 month in **seal mode**
- They supported the hypothesis of Rn + constant component: decrease in alpha rate and background rate in 0-50 keV after cuts

Low-gain runs (alphas)

$$c_0 + c_1 e^{-c_3 t}$$



Radon background

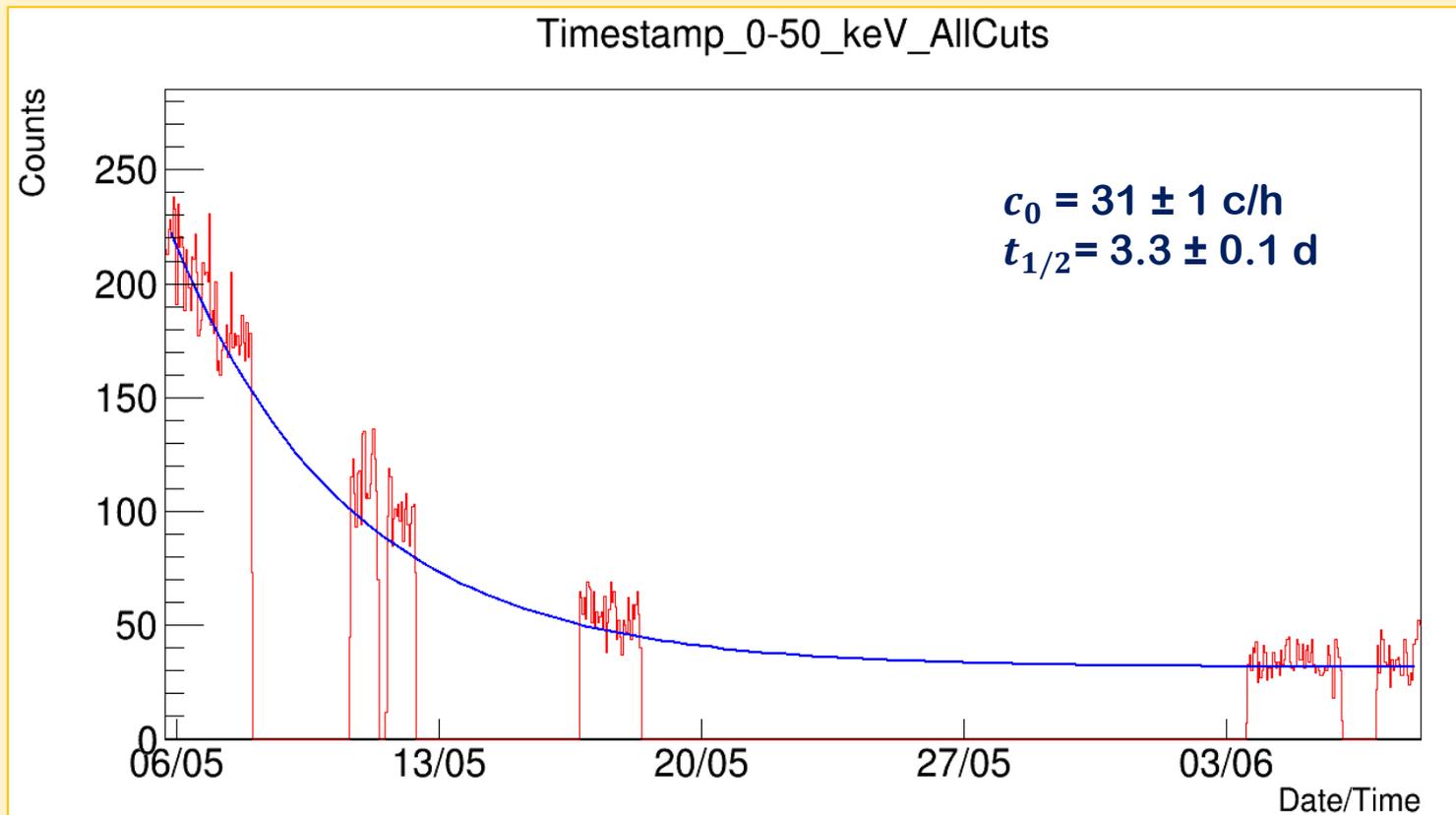
LE runs follow the **same background reduction** as HE runs.

Strongly supports the relation between alphas from ^{222}Rn chain and low energy events

Best solution found: remove filters (main source of ^{222}Rn) and work in **low flow open loop** (0.5-0.9 l/h)

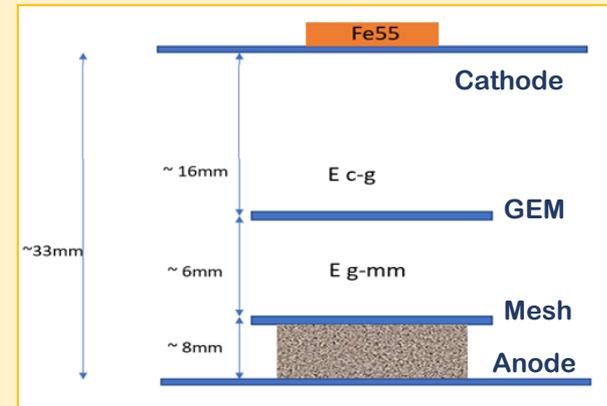
Nominal-gain runs (low energy)

$$c_0 + c_1 e^{-c_3 t}$$

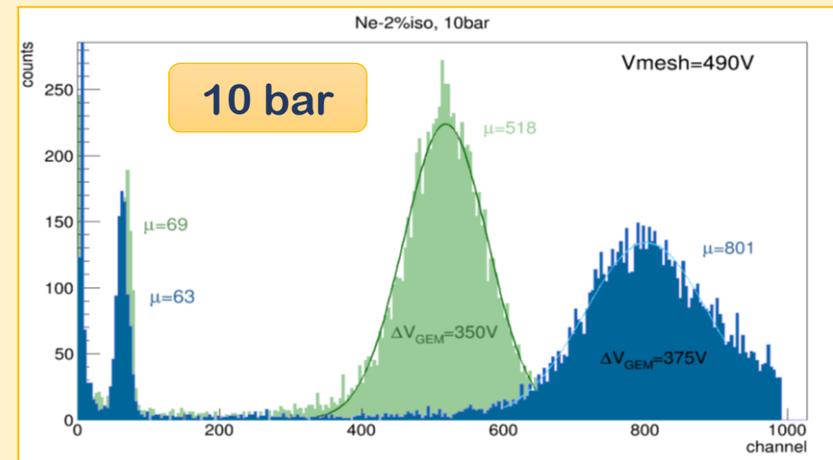
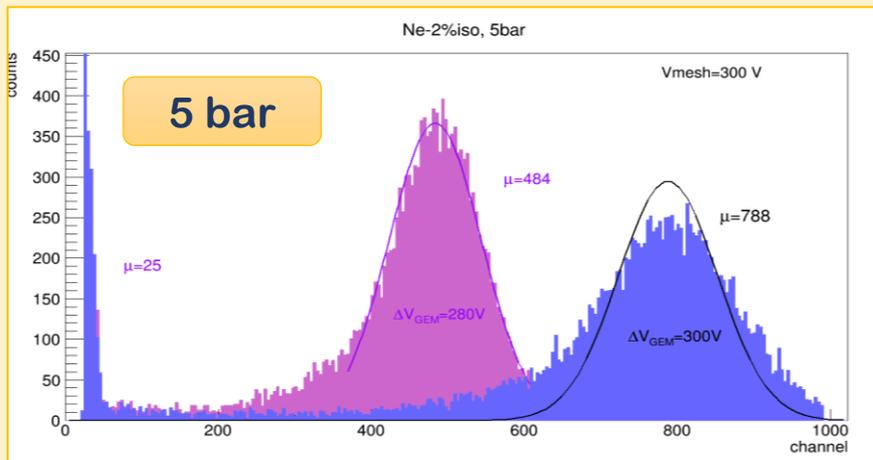


Prospects: GEM + Micromegas

- Very **low threshold** is one of the main requirements for low-mass WIMPs
- Roughly 3keV threshold now. Objective: below 1keV
- **GEM +MM** allows higher gain and lower threshold
- Preliminary test in small setup:
 - Factor ~ 10 easily achieved with low V_{GEM} operation
 - Systematically factors order 15 for medium V_{GEM}
 - Even factors >20 for high V_{GEM}



Pressure (bar)	Vmesh (V)	ΔV_{GEM} (V)	Pre-ampli factor
5	300	280	19
5	300	300	30
10	490	350	7.5
10	490	375	13

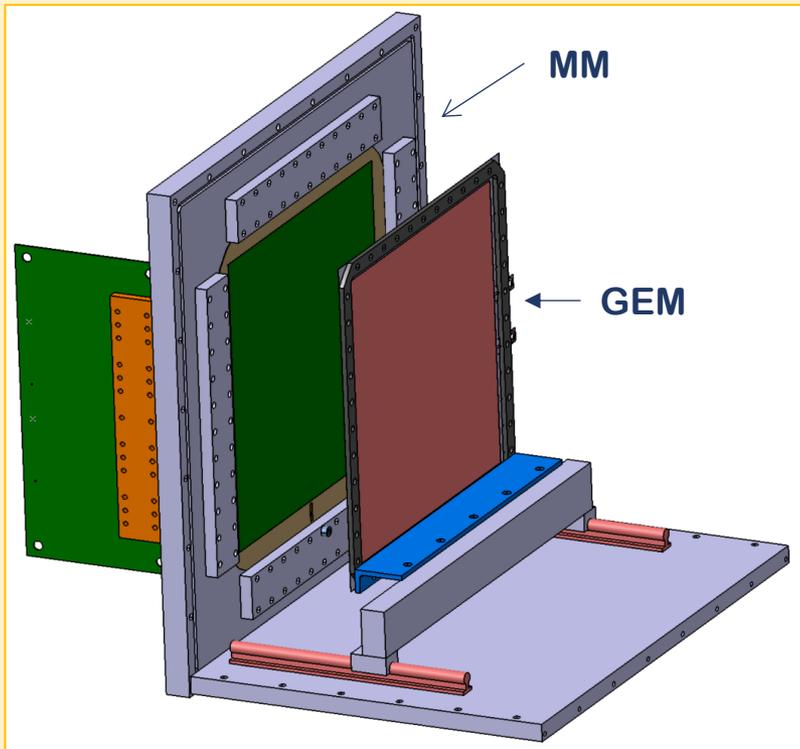


Prospects: GEM + Micromegas

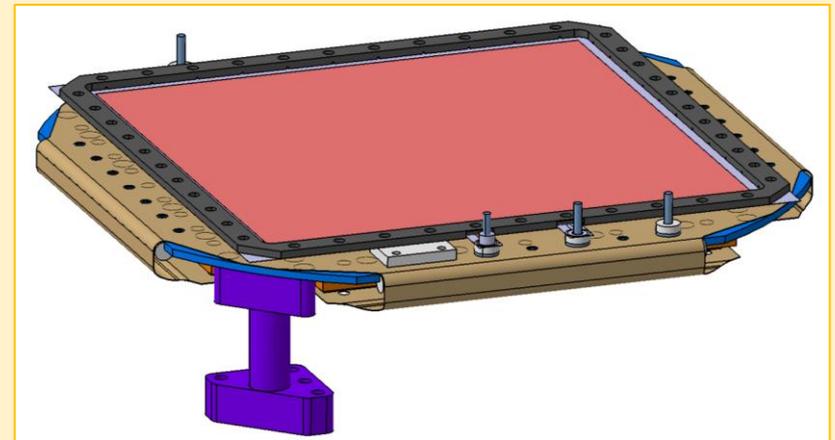
Full scale GEM for TRES-DM already produced

Test bench is being designed to try different configurations (distance, voltages, ...)

MM-GEM test bench



MM-GEM in TRES-DM



Mobile platform for allowing different gaps MM-GEM

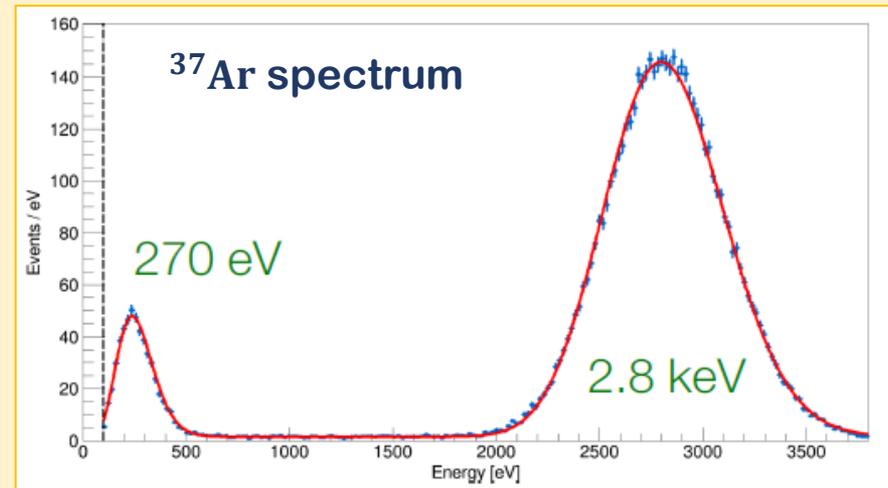
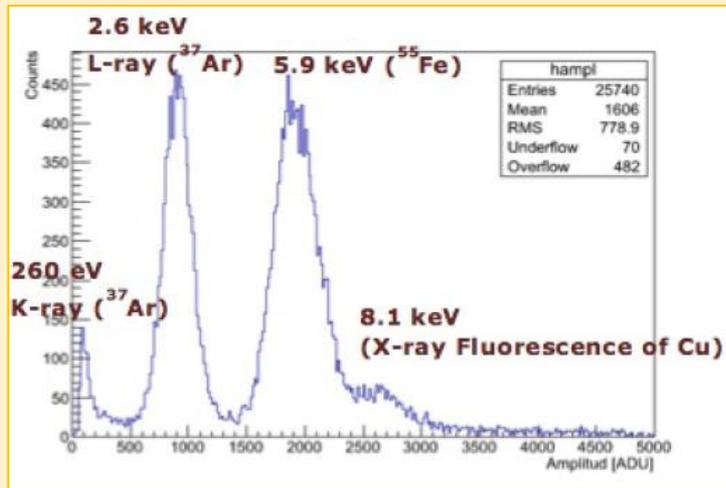
Prospects: Low energy calibrations

To test threshold properly low energy peaks are needed.

Not many isotopes with energies below 10keV: Cu fluorescence 8.1 keV, ^{55}Fe 5.9 keV

Best option for TRES-DM: ^{37}Ar

- Decay by electron capture, half life **35 days**
- **0.27** and **2.8** keV X-rays
- Gaseous isotope: uniform source in all the volume
- Can be produced irradiating ^{40}Ca powder with neutrons (also from ^{36}Ar)
- Has been used in other TPCs (News-G, Xenon1T...)



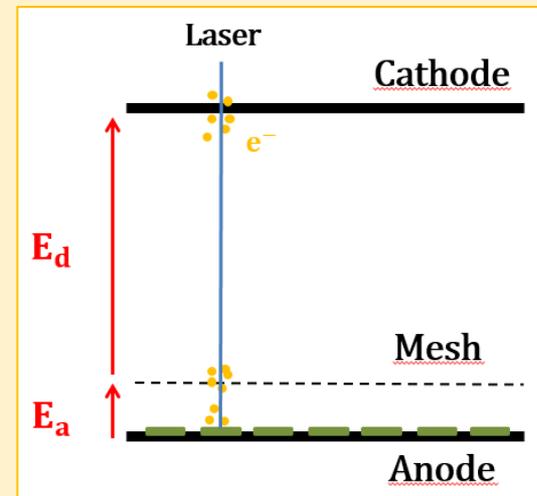
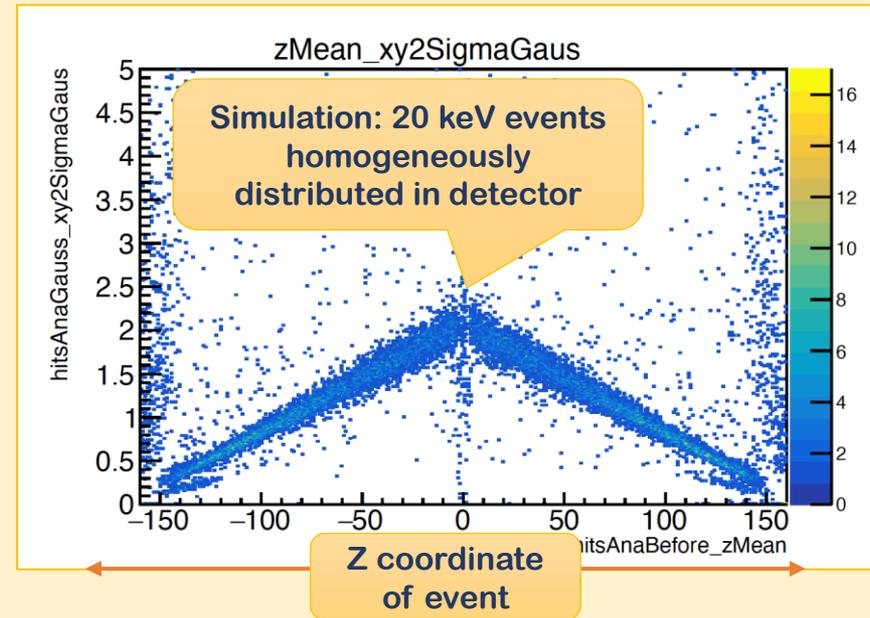
Prospects: Diffusion studies

Simulations suggest strong dependence between **Z position** of the interaction and **dimensions of the electron cloud** (diffusion coefficients)

Test experimentally with **laser calibrations**:

- Transparent window
- Parallel beam: probe different heights. Laser pulses trigger acquisition.
- Perpendicular beam: photoelectric electrons extracted from cathode and MM at same time.

Many properties of the gas can be tested: drift velocity, transversal/longitudinal diffusion, W-value, Fano factor...



Summary

TREX-DM: High Pressure TPC for low-mass WIMP searches with Micromegas detectors.

- Designed to exploit the excellent features of the technology for rare event searches:
 - low background levels and thresholds,
 - topological information
 - flexibility in target gas
 - possibilities of scaling up
- Underground operation at LSC
- Background reduction ongoing.
- Further improvements during this year: GEM+MM, low energy calibrations and diffusion studies

Gaseous time projection chambers for rare event detection: results from the T-REX project. II. Dark matter

I.G. Irastorza et al, JCAP 01 (2016) 034

TREX-DM: a low-background Micromegas-based TPC for low-mass WIMP detection

F. J. Iguaz et al, Eur. Phys. J. C 76 (2016) 529

**Thanks for your
attention!**