GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

Status and prospects of DEAP-3600 after the third fill with liquid Ar

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on behalf of the DEAP collaboration

XVII CPAN days
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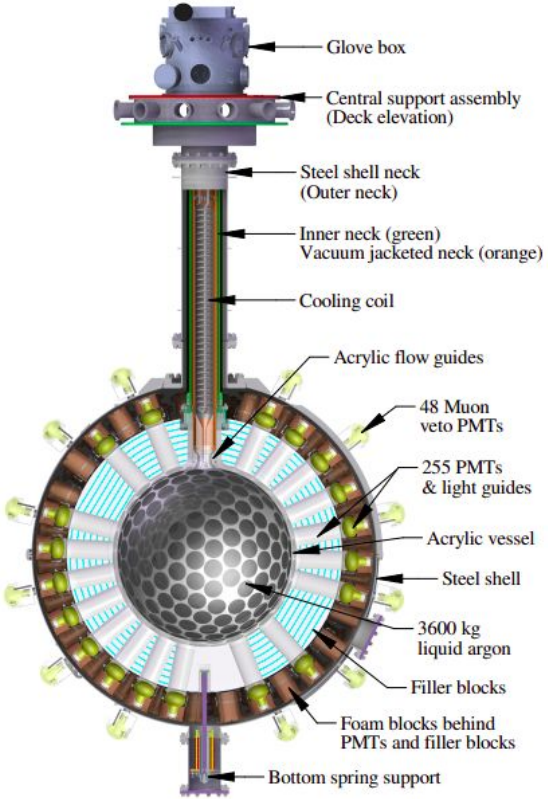
The DEAP-3600 detector

First detector for the DM direct search with more than 1 tonne of target.

So far, it has established the most stringent limits for WIMP interaction using non-Xe target in single phase (LAr)

It constitutes a relevant milestone in the path for next generation of Ar detector within the GADMC.

The DEAP-3600 detector

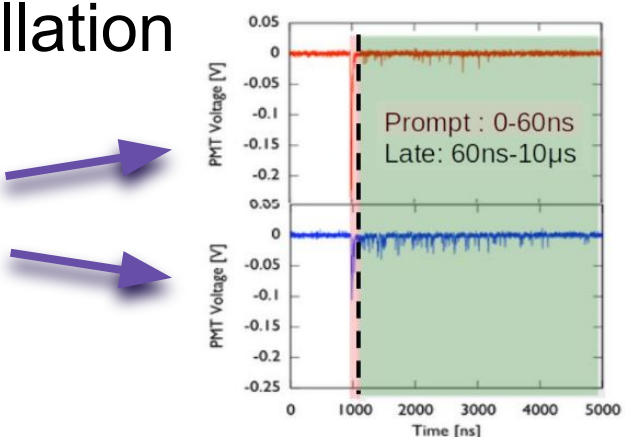


Main remarks outside to inside

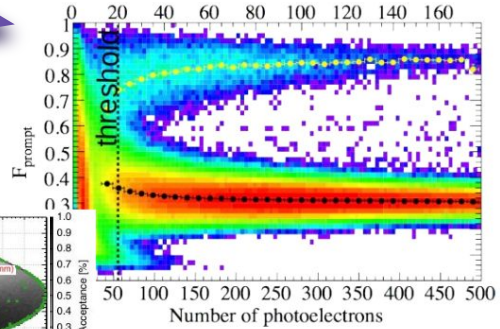
- Located 2km underground at SNOLAB, Canada: 6000 m.w.e where the muon flux is 0.03 muon/m^2/day
- Placed inside a muon veto (water tank with 48 PMTs detecting Cherenkov light)
- 255 PMTs: 8” - 32% QE - 75% coverage
- Bonded 50 cm long light guides
- In-situ vacuum evaporated TPB on inner 10 m^2 surface
- 3.3 tonne LAr target in ultraclean 85 cm radius acrylic vessel

The DEAP-3600 detector: Ar scintillation

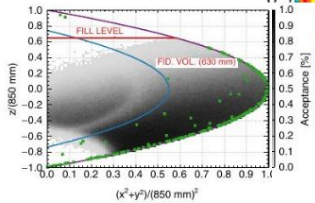
- Nuclear recoils populate mostly single state, which decays promptly (8 ns)
- Electronic recoils populate mostly triplet state, which has a slower decay (1.4 μs)
  Eur. Phys. J. C 80,303 (2020)



- Pulse shape discrimination helps to reject gamma and beta backgrounds
  Eur. Phys. J. C 81,823 (2021)



- Position reconstruction and fiducialization allow us to reduce surface and external backgrounds
  JINST 20 P07012 (2025)



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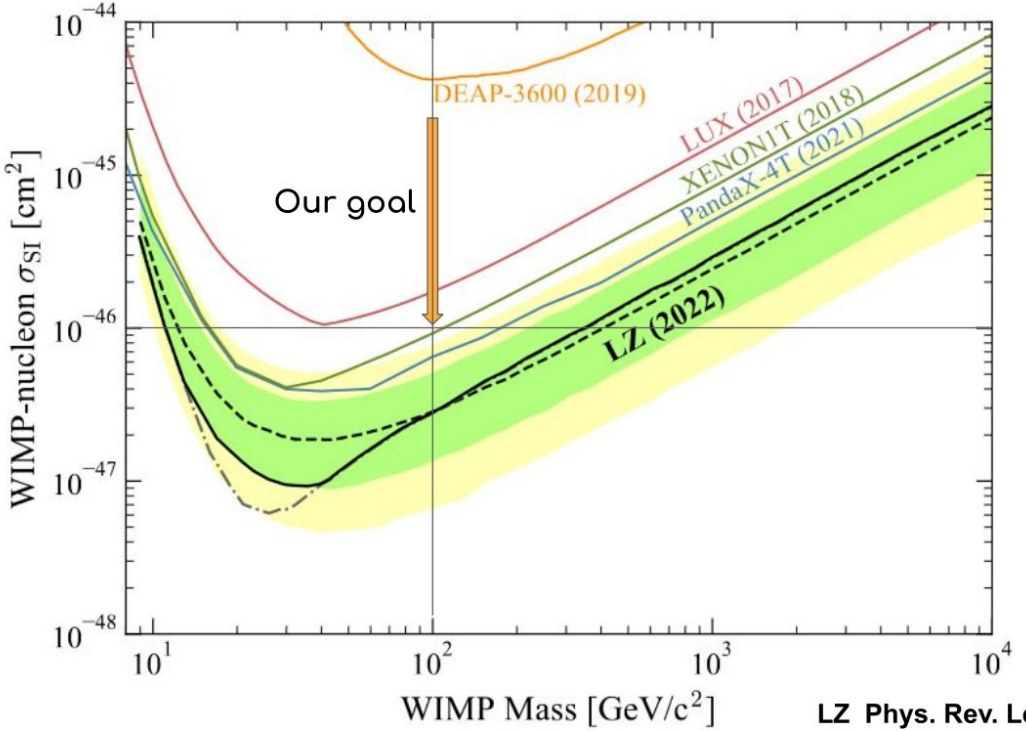
The DEAP-3600 detector: sensitivity prospects



World-leading sensitivity for WIMP searches in LAr experiments

LZ Phys. Rev. Lett. 131, 041002 (2023)

The DEAP-3600 detector: updates and goals

★ Introducing hardware upgrades to recover WIMP sensitivity

- ^{210}Po background in the neck.
- Presence of dust in the inner volume.

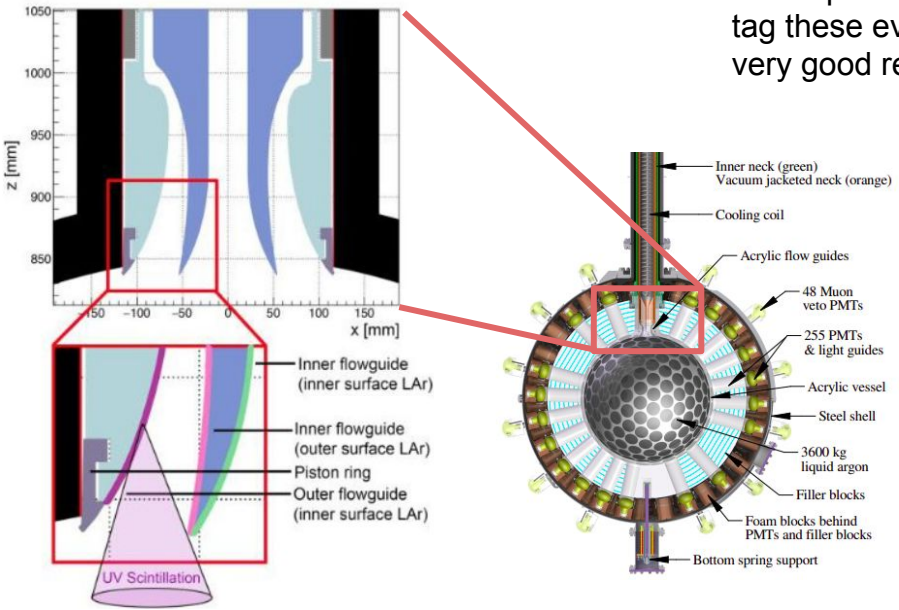
★ Finalize refined Dark Matter searches analysis

★ Learning for future LAr detectors (Darkside-20k, ARGO)

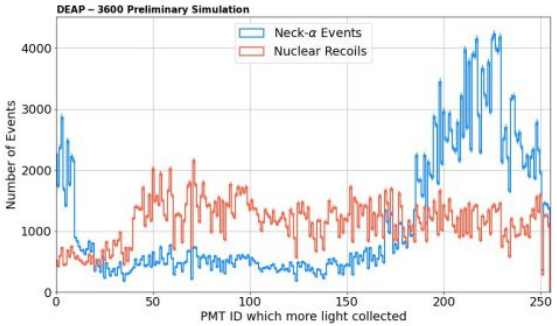
★ More physics with DEAP: first ^{39}Ar activity measurement,solar neutrinos, exotic DM candidates, …

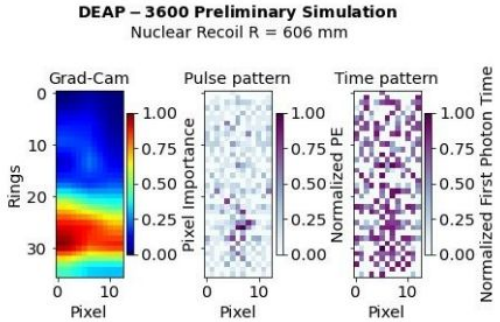
Recovering WIMP sensitivity

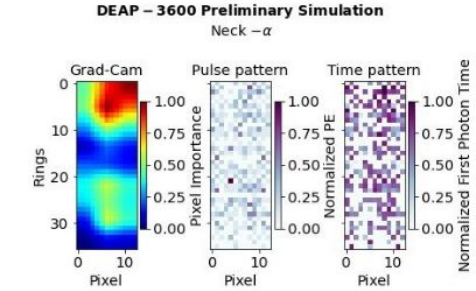
^{210}Po in the neck produces α particles very hard to identify



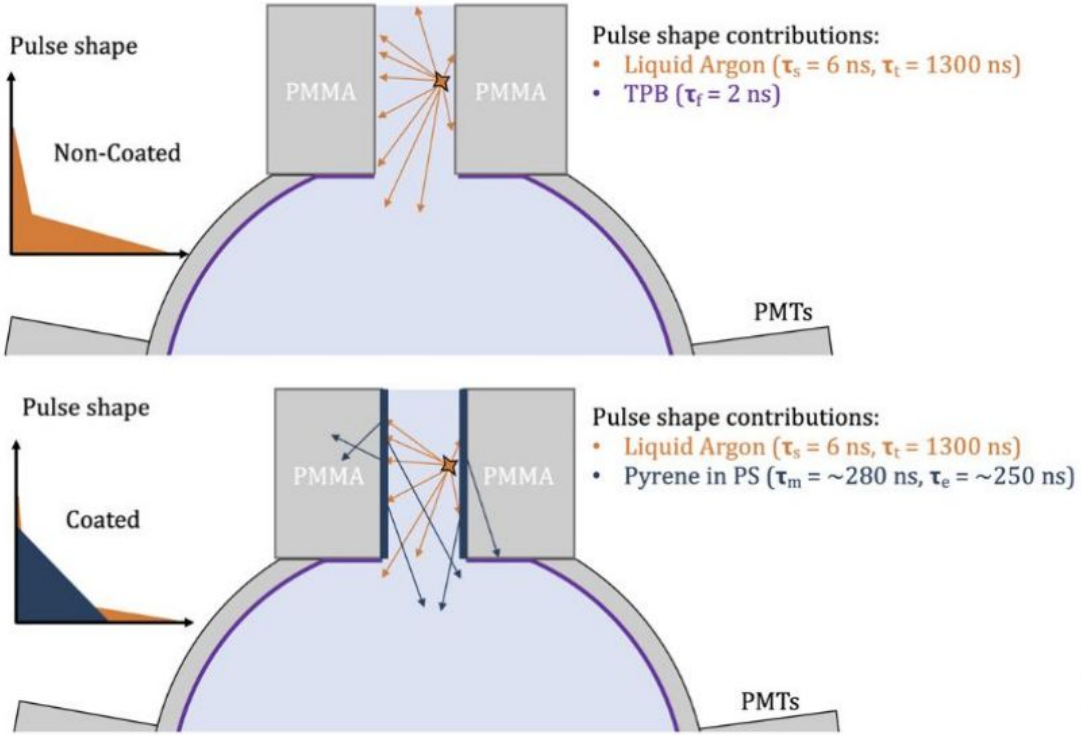
CNN specifically trained to tag these events gives very good results!







Recovering WIMP sensitivity



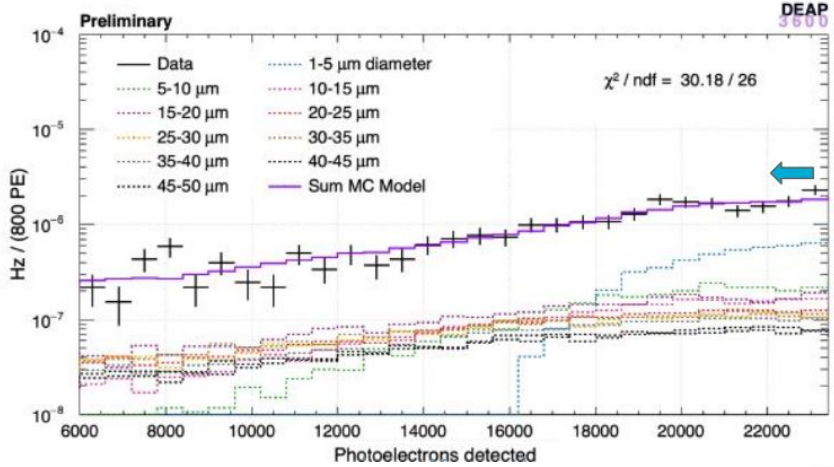
Fixed including WLS to the surface so that neck events will have:

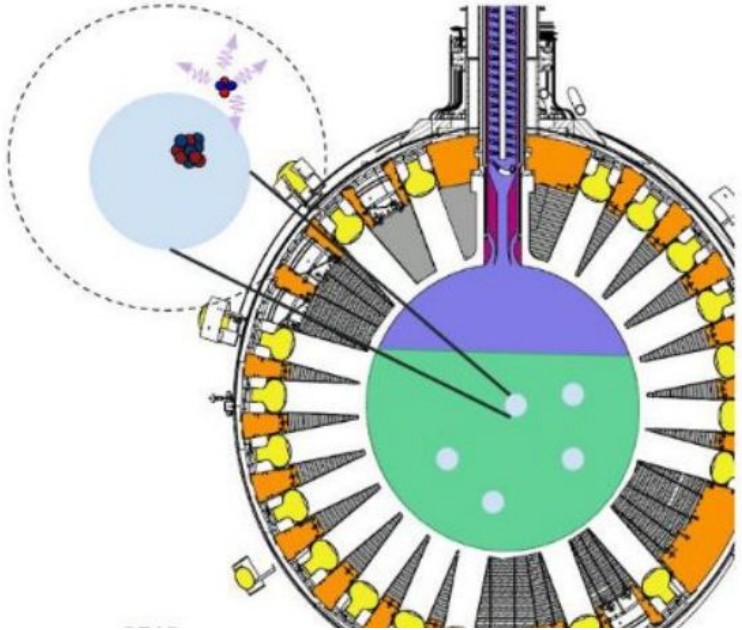
- different time profile
- distinct PSD pattern
- more light collected
- Out of the ROI

NIM A 1034 (2022) p 166683

Recovering WIMP sensitivity

No recirculation system present in the detector caused tiny **dust particles** to be present within LAr volume.





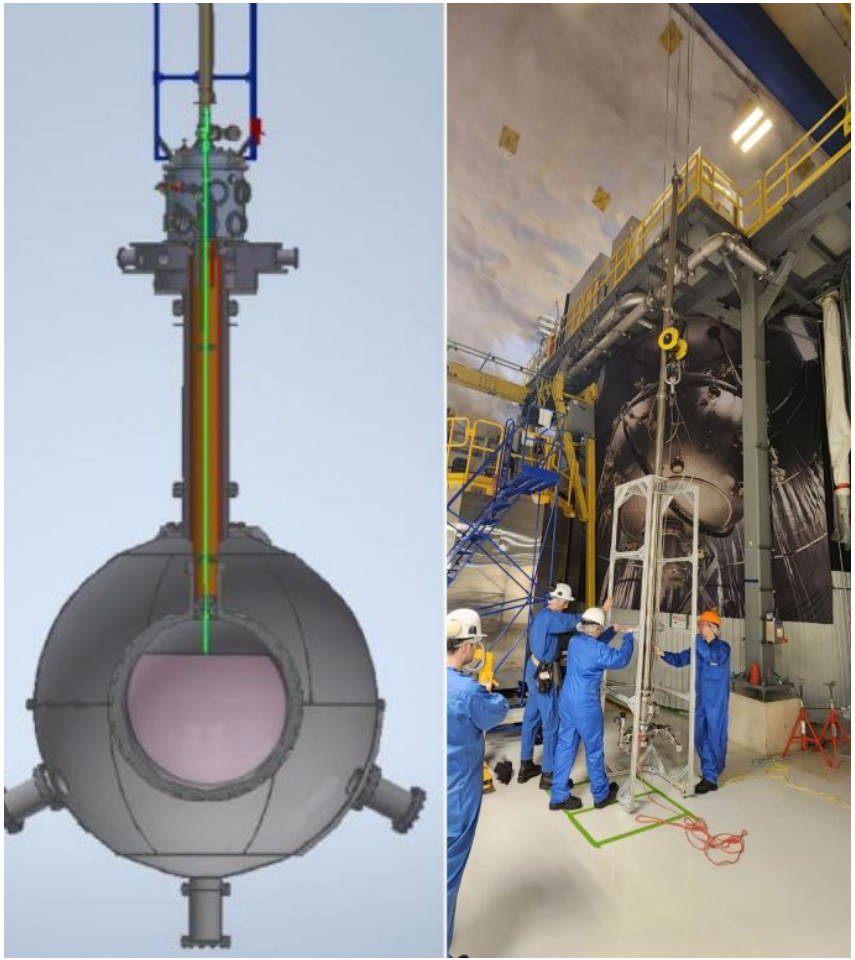
This dust introduced degraded α, constituting a source of background

Recovering WIMP sensitivity

Fixed:

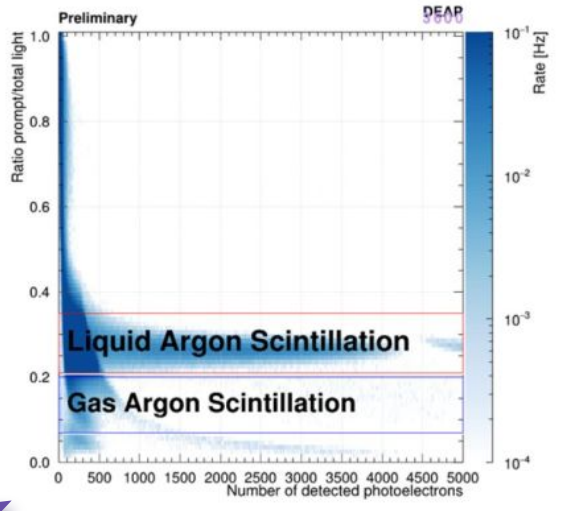
Installation of a filtration + recirculation system which removes the dust from the target

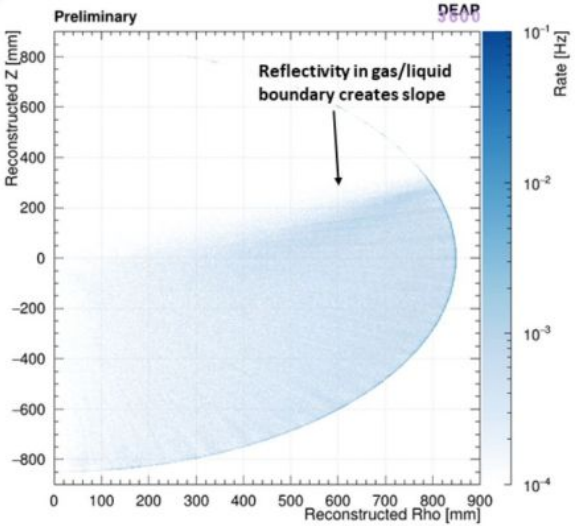
The external cooling also helps preventing condensation in the neck!



Current status and WIMP search prospects

- ★ Neck upgrade finished
- ★ Detector cool down and Ar **third fill finalized on July**
  - First glance to third fill data
- ★ Data taking for ~2 more years, until DarkSide-20k is running
- ★ Finalize refined analysis and unblind





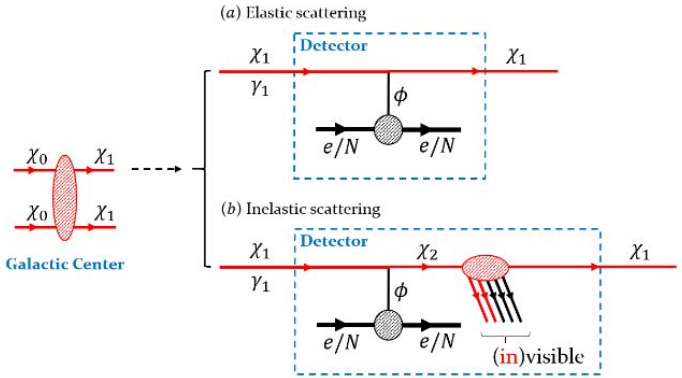
More physics with DEAP

- ★ ^{39}Ar activity in atmospheric Ar precision measurement Eur. Phys. J. C 83, 642 (2023)
- ★ ^{39}Ar half life first direct measurement Eur.Phys.J.C 85 (2025) 7, 728
- ★ Alpha quenching in LAr Eur.Phys.J.C 85 (2025) 1, 87

- ★ Detecting ^{8}B solar neutrinos (coming soon)
- ★ Solar axion search
- ★ Muon flux and instrumentation
- ★ Neutrinoless double electron capture in ^{36}Ar
- ★ Search for neutrinos in coincidence with GW

- ★ Exotic DM searches
  - ○ Best limits for xenon-phobic DM Phys. Rev. D 102, 082001 (2020).
  - ○ Prospection of unpopulated regions of the parameter space at Planck-scale masses (ultra heavy) Phys. Rev. D, 100, 072009 (2019).
  - ○ **Inelastic boosted dark matter**

Inelastic Boosted Dark Matter in DEAP-3600



There are no possible interactions between χ_0 and SM particles at tree level, but χ_1 can interact via a dark photon X. In the iBDM scenario there is a secondary process, the decay of the excited state χ_2

iBDM: multiparticle DM model in which

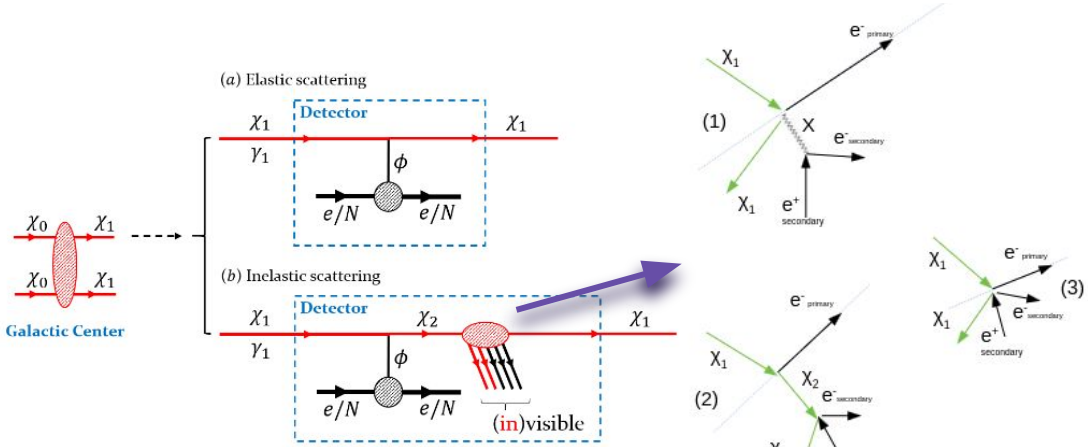
- χ_0, the dominant in mass hierarchy species, annihilates in the galactic center producing χ_1.
- The relic density of χ_0 is explained by the "assisted freeze out mechanism"
- Due to the difference in mass between the two species, χ_1 is boosted after the annihilation process, reaches the detector and inelastically scatters off matter, transitioning into a heavier unstable state χ_2, which then decays into visible particles ($e^+ + e^-$) via a dark photon X

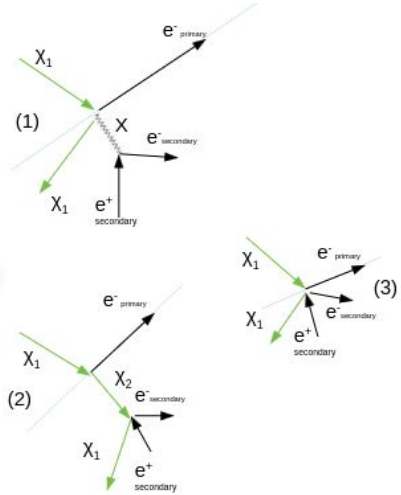
The parameter space for our inelastic process of study is

- χ_0 , χ_1 , χ_2 , X masses
- Coupling constants g_{12} , ϵ

Based on: *Physics Letters B*, *780*, 543-552 (2018)

Inelastic Boosted Dark Matter in DEAP-3600





Masses in MeV

	m_{χ_1}	m_{χ_2}	m_X	γ_1	ϵ
ref1	2	5.5	5	20	4.5×10^{-5}
ref2	3	8.5	7	50	6×10^{-5}
ref3	20	35	11	50	7×10^{-4}
ref4	20	40	15	100	6×10^{-4}

Expected signal: two vertex displaced by *O(*mm*)* (1), *O(*cm - m*)* (2).

Low threshold experiments, such as DEAP-3600, are particularly suitable for sub-GeV χ_0, where the boosted χ_1 flux is enhanced

So far some reference points of the rest of the mass-constants parameter space are under study to determine the acceptance in each case.

Based on: *Physics Letters B, 780,* 543-552 (2018)

Summary

- DEAP-3600 is the largest running LAr experiment dedicated for WIMP searchers, achieving a **world-leading sensitivity with this target**, as well as neutrino adsorption and ultra-heavy, multi-scattering DM
- There have been **improvements in hardware** to strongly reduce the α-induced backgrounds in the WIMP ROIs
  - Main contributions to this background (neck-α induced events and dust-α) are now included in PLR WIMP analysis (results coming soon)
- Learning for future LAr experiments (DarkSide-20k, ARGO, ...)
- With the **third-fill completed** even more results are expected!