THE DARKSIDE-20k EXPERIMENT

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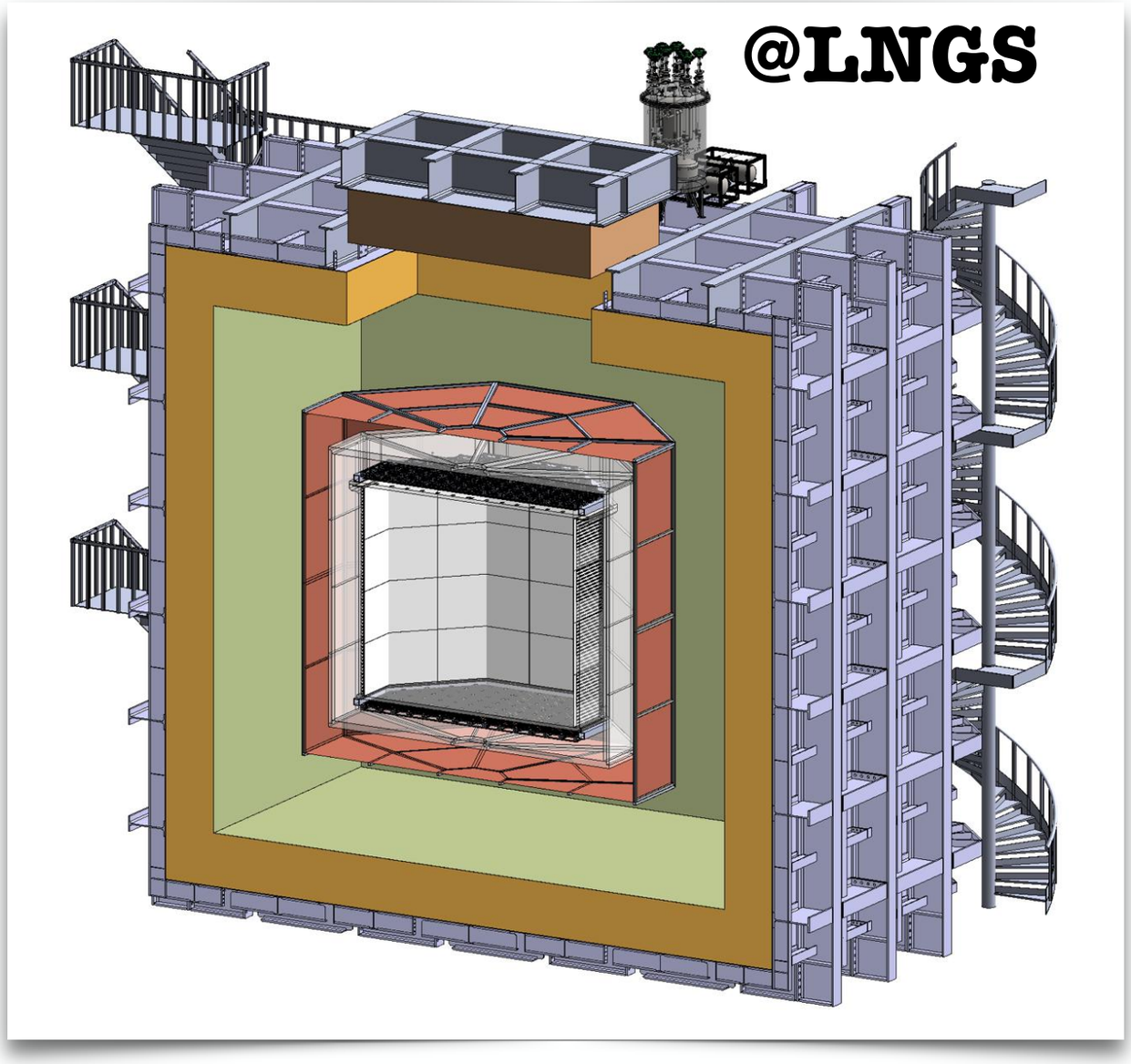
OUTLINE

- The DARKSIDE-20k overview
- Progress with the detector development:
    - Underground Argon (URANIA & ARIA)
    - TPC
    - Photo-electronics
- Background free experiment:
    - Nuclear recoil
    - Veto design
- High-mass sensitivity

GLOBAL ARGON DARK MATTER PROGRAM

- Darkside-50
- DEAP-3600
- miniCLEAN
- ArDM

DS-20k

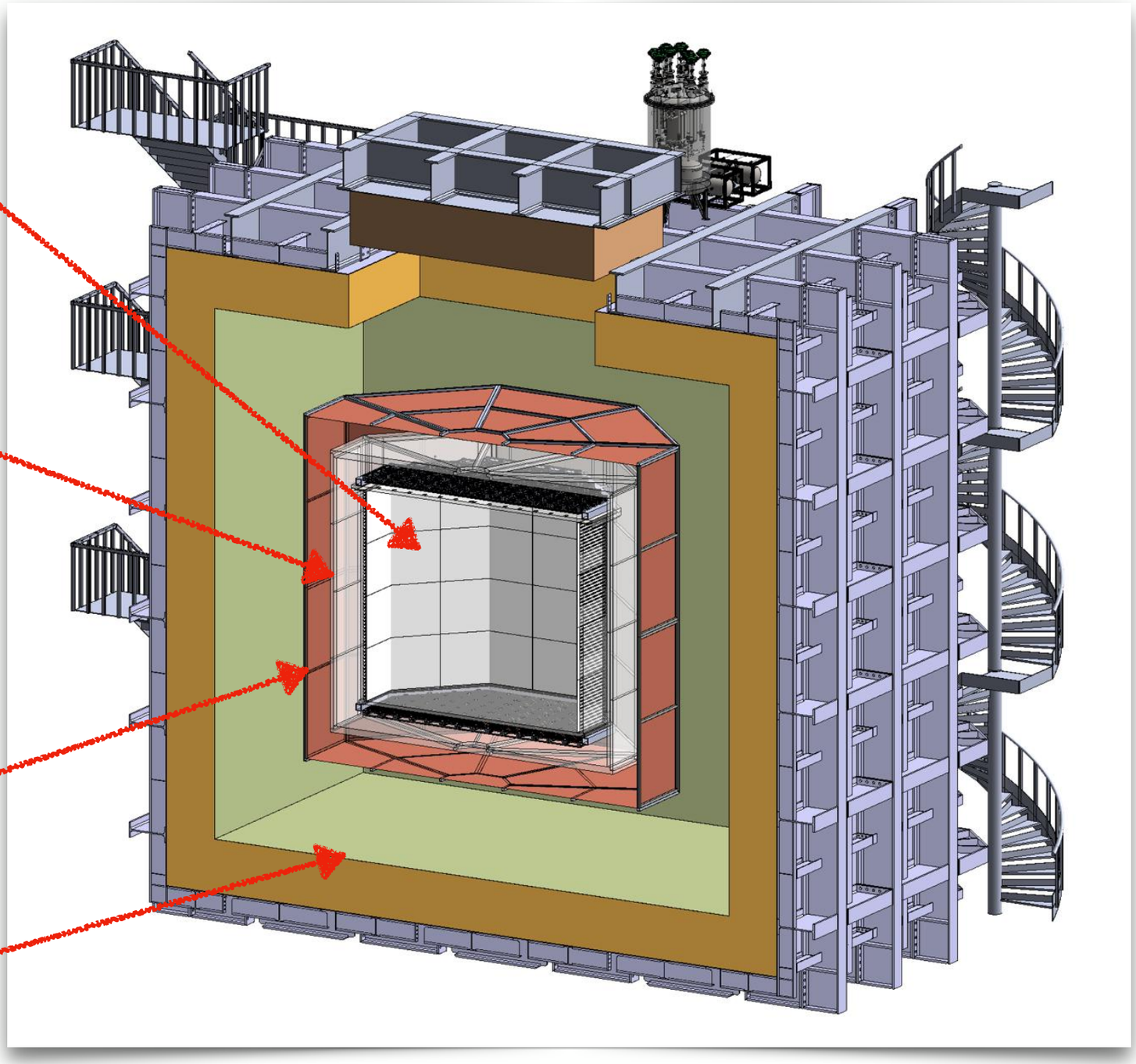


DS-20k goal :
- Background free < 0.1 event in 100 t x yr
- High mass WIMP sensitivity

https://indico.cern.ch/event/765096/contributions/3295671/attachments/1785196/2906164/DarkSide-Argo_ESPP_Dec_17_2017.pdf

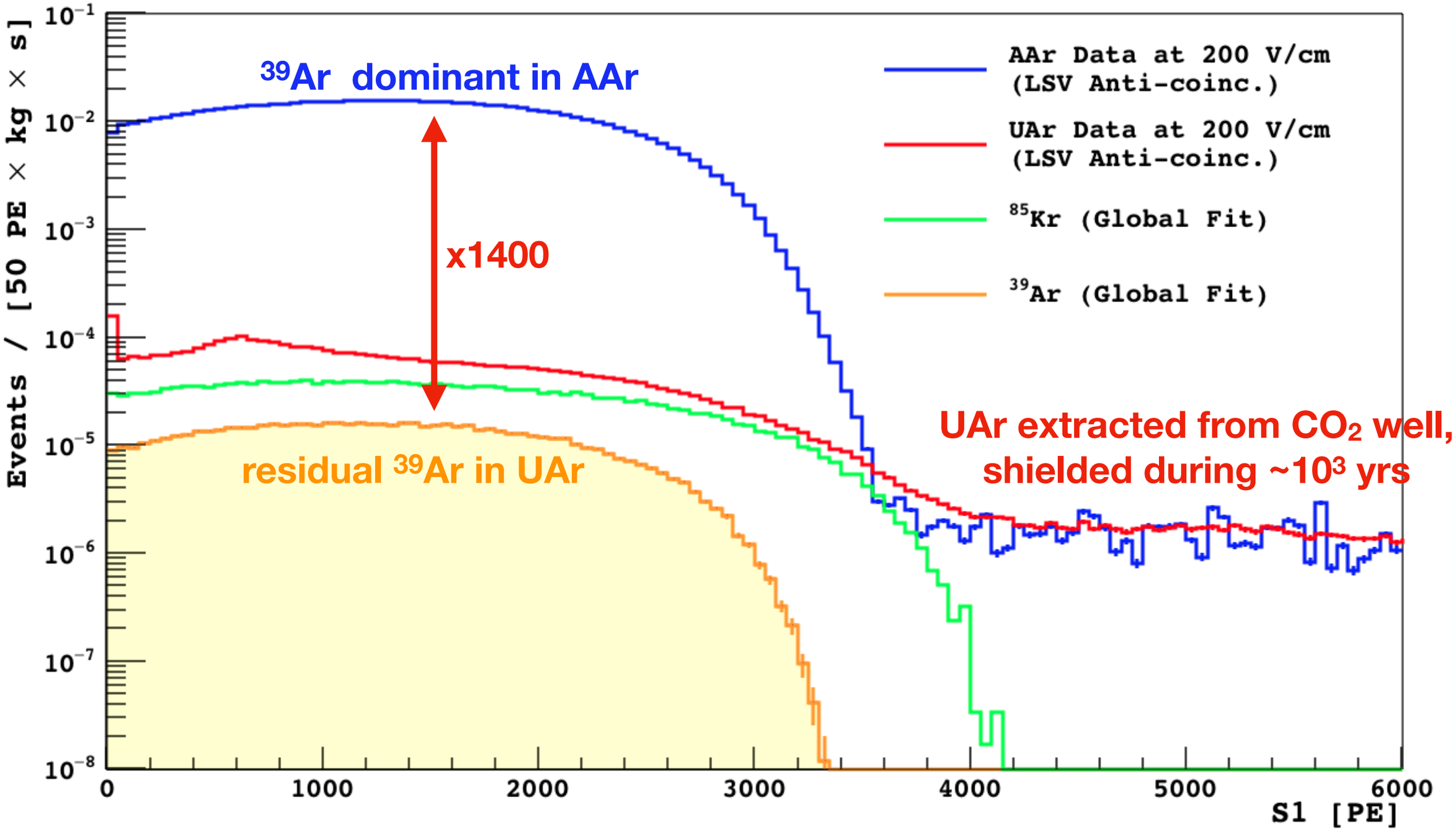
DARKSIDE-20k

- 50 t of Underground Argon (UAr) in the TPC
- 8920 Silicon-photomultiplier (SiPMs) for the TPC readout
- Gd-loaded acrylic shell
- 600 t of Atmospheric Argon (AAr) around the acrylic shell
- 3000 SiPMs for the veto readout
- Copper cage
- Protodune like cryostat



UNDERGROUND ARGON (UAr)

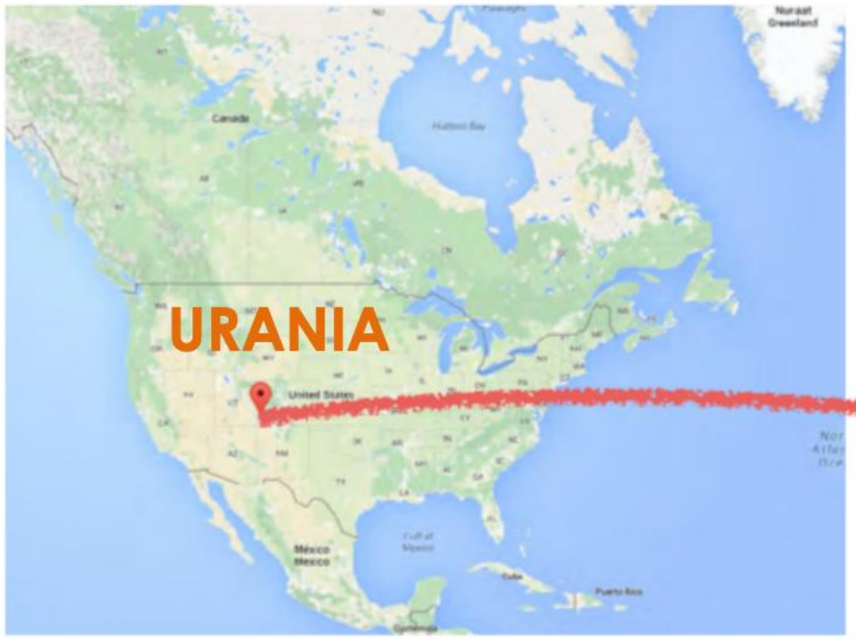
^{39}Ar is produced in atmospheric argon by **cosmogenic activation**. Beta emitter with endpoint at 565 keV and half life of 269 y. Nominal **activity of atmospheric argon: ~ 1 Bq/kg.**

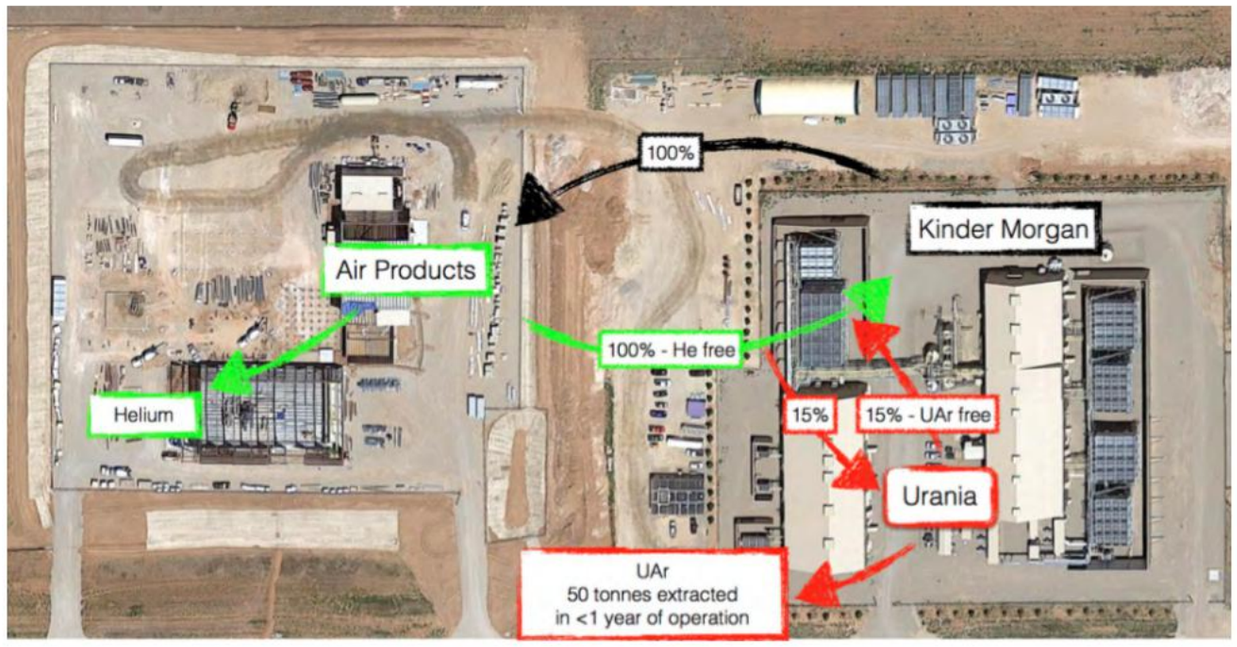


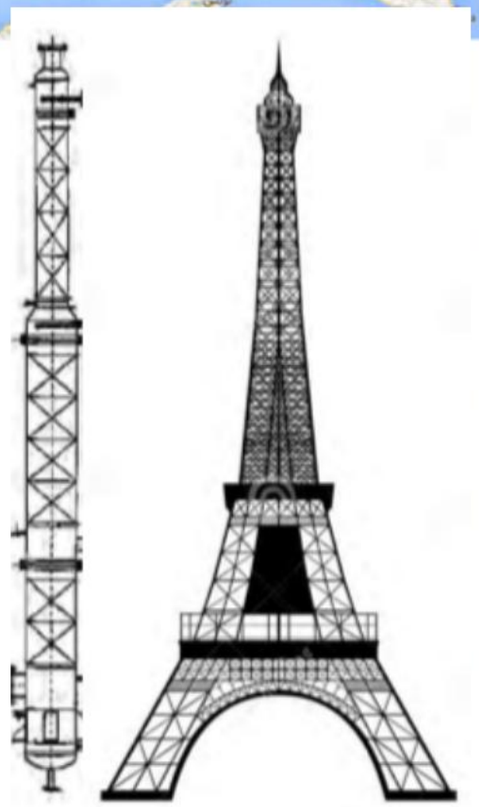
URANIA/ARIA

Extraction of UAr from Colorado
-> 99.9% purity

Purification of UAr: 10 kg/d obtaining a ^{39}Ar depletion factor 10

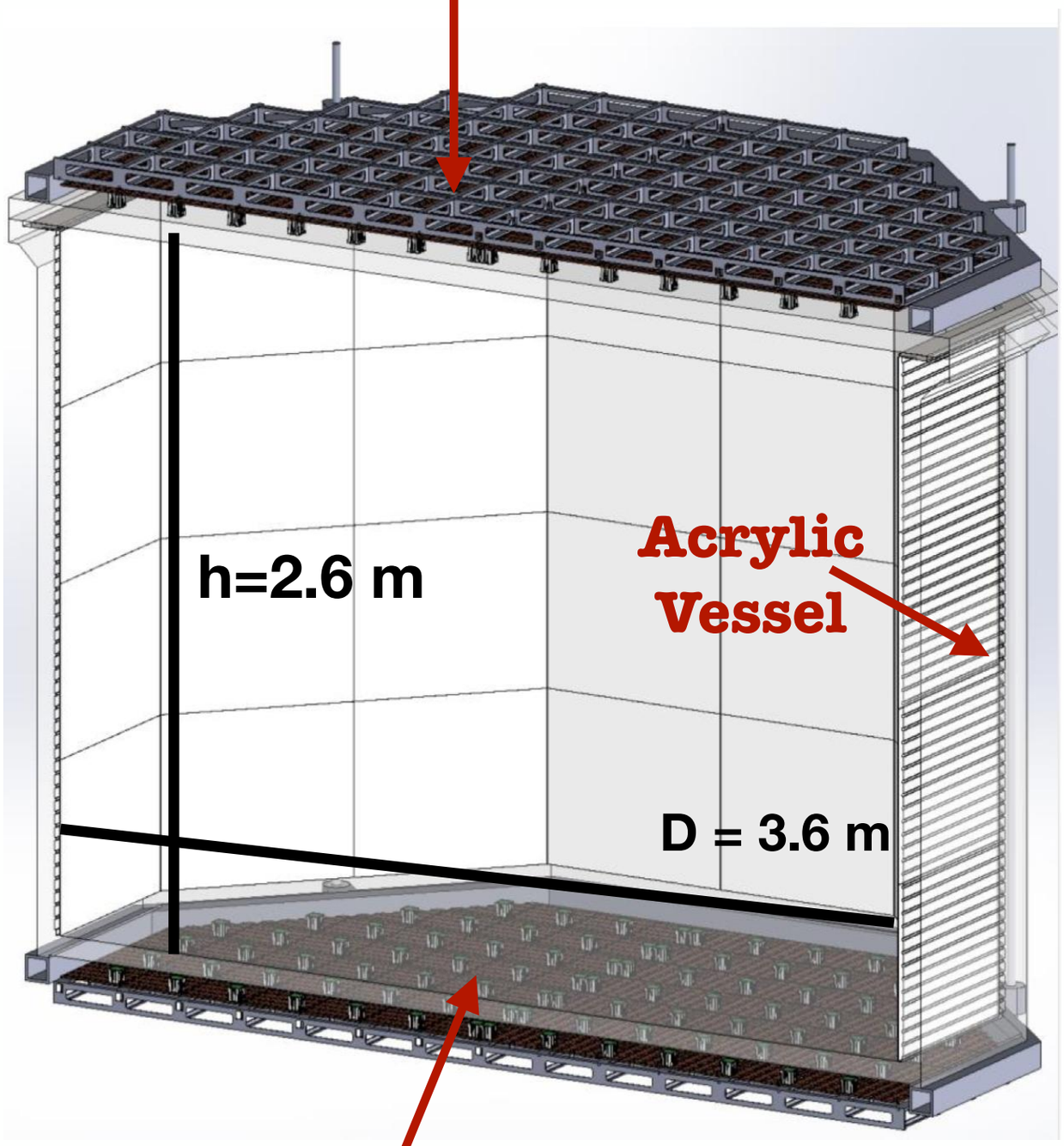






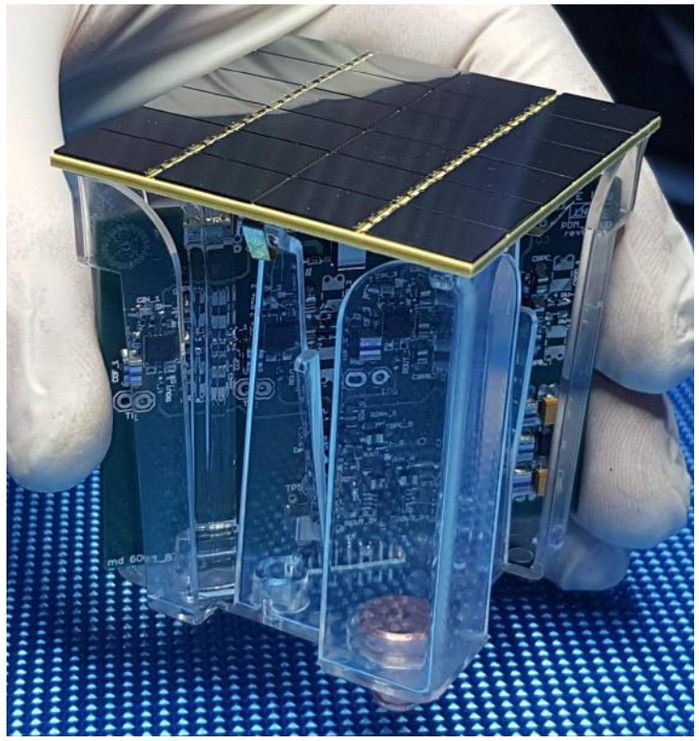
TPC

- Dual phase Liquid Argon volume: **50 t of UAr**
- Ultra pure acrylic vessel
- Photosensor module on the top and bottom of the TPC
- Photosensor modules and vessel immersed in the AAr
- Drift field =200 V/cm
- Reflector panel (DEAP like):
  - Acrylic in order to minimize the neutron background
  - ESR foils in order to minimize Cerenkov background
- ESR reflectivity 98% at 420 nm
- High Light Yield: 9 pe/keVee (200 V/cm)

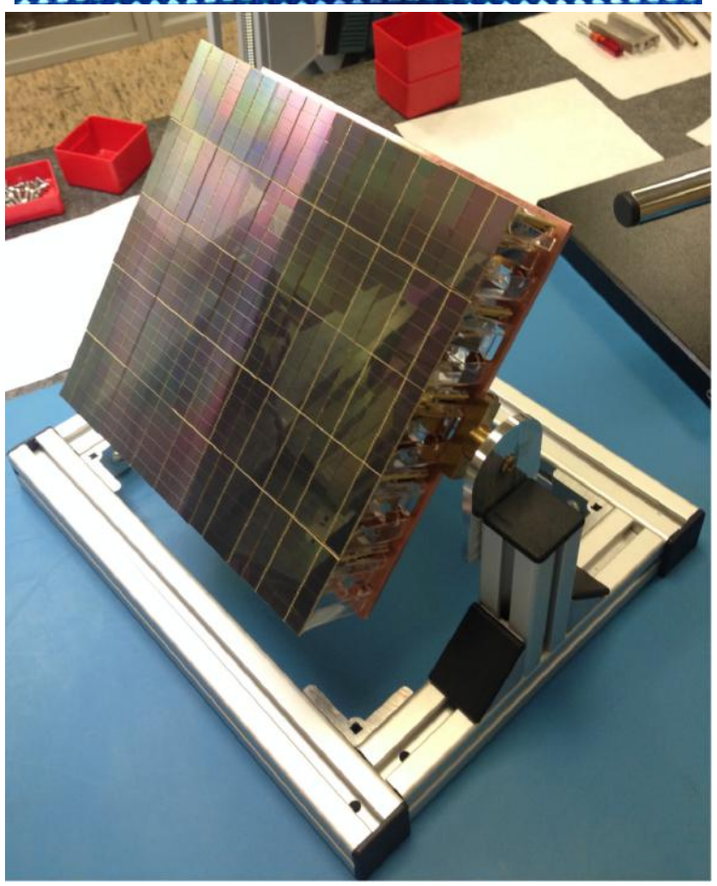


PHOTOSENSOR

- Silicon photomultiplier (SiPMs):
  - Particle detector efficiency
    PDM = 40%
  - Dark Current rate
    DCR = 0.1 Hz/mm^2
  - Time Resolution: 10 ns
- Radio-purity up an order on magnitude than PMTs
- Photo-detector Module (PDM):
  24 SiPM->6x4 array
- Motherboard: 25 PDMs arranged in 5x5 matrix



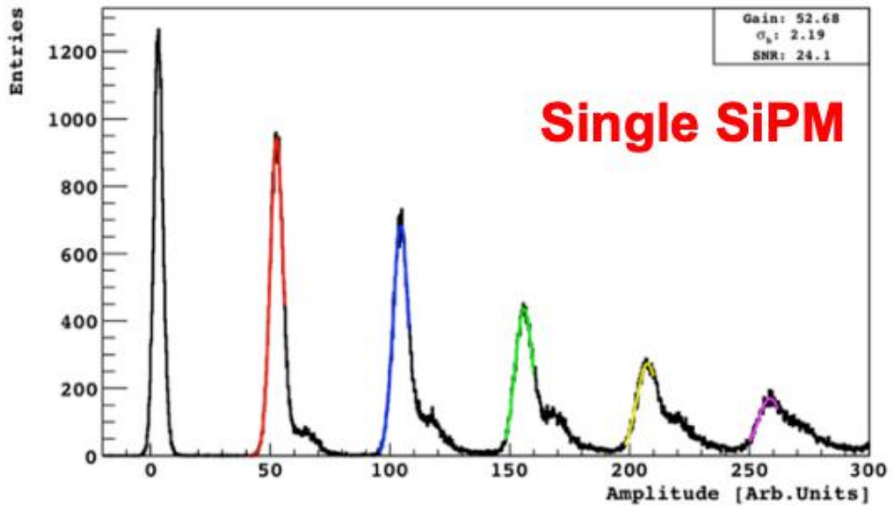
PDM

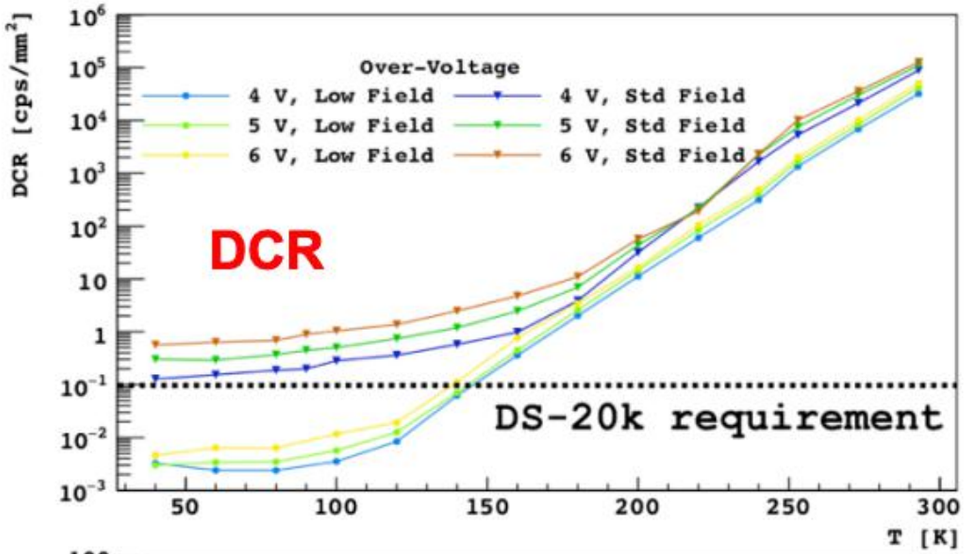


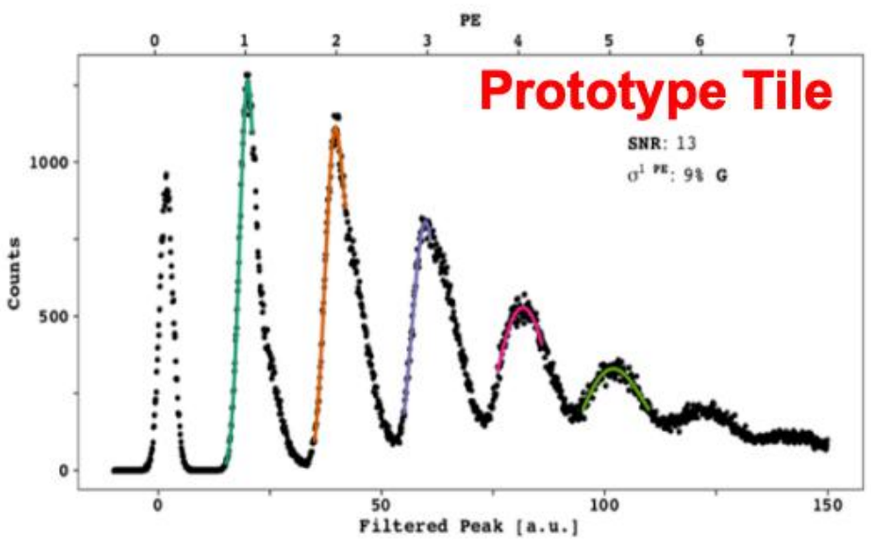
Two first Motherboard are successfully assembled

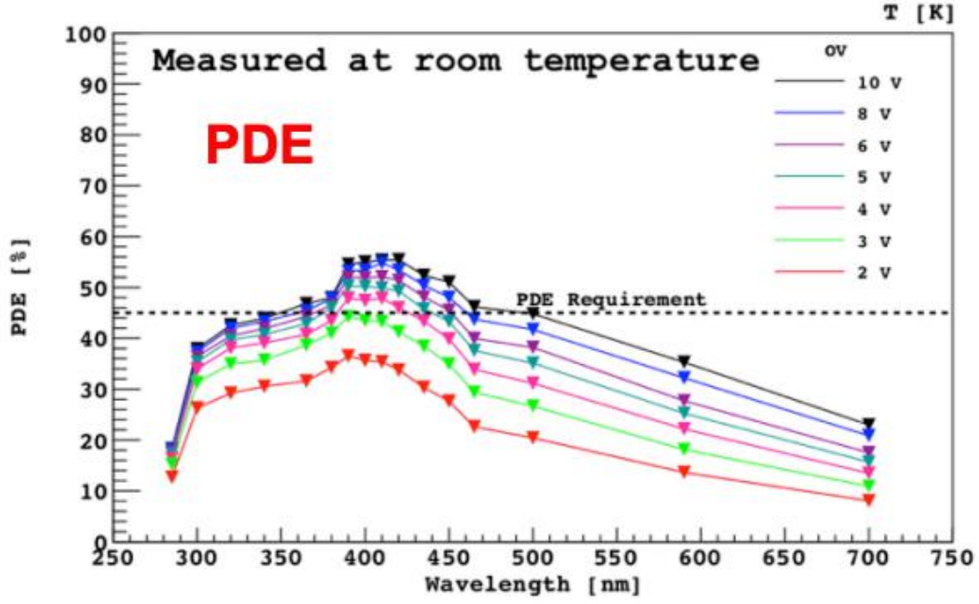
PHOTOSENSOR PERFORMANCE

	DS-20k requirement	SiPM tile (PDM)	
Surface	5x5cm^2	24cm^2 prototype 25cm^2 final PDM	✓
Power dissipation	<250mW	~170mW	✓
PDE	>40%	50% · ε_{geom} = 45%	✓
Noise Rate	<0.1cps/mm^2	0.004cps/mm^2	✓
Time Resolution	O(10ns)	16ns	✓
Dynamic Range	>50	~100	✓





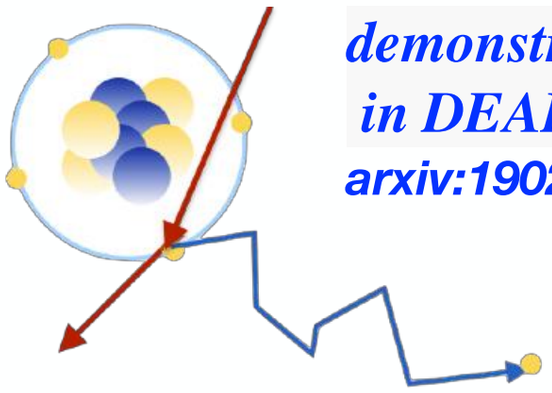




BACKGROUND

Electron recoil: γ and e

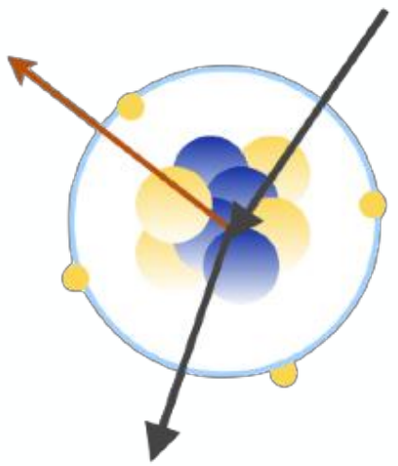
- Solar pp neutrino
- ^{238}U and ^{232}Th decay chain: the principal comes form ^{222}Rn
- ^{39}Ar β-decay
- ^{85}Kr β-decay



ER reduction for DS-20k demonstrated already in DEAP-3600
arxiv:1902.04048

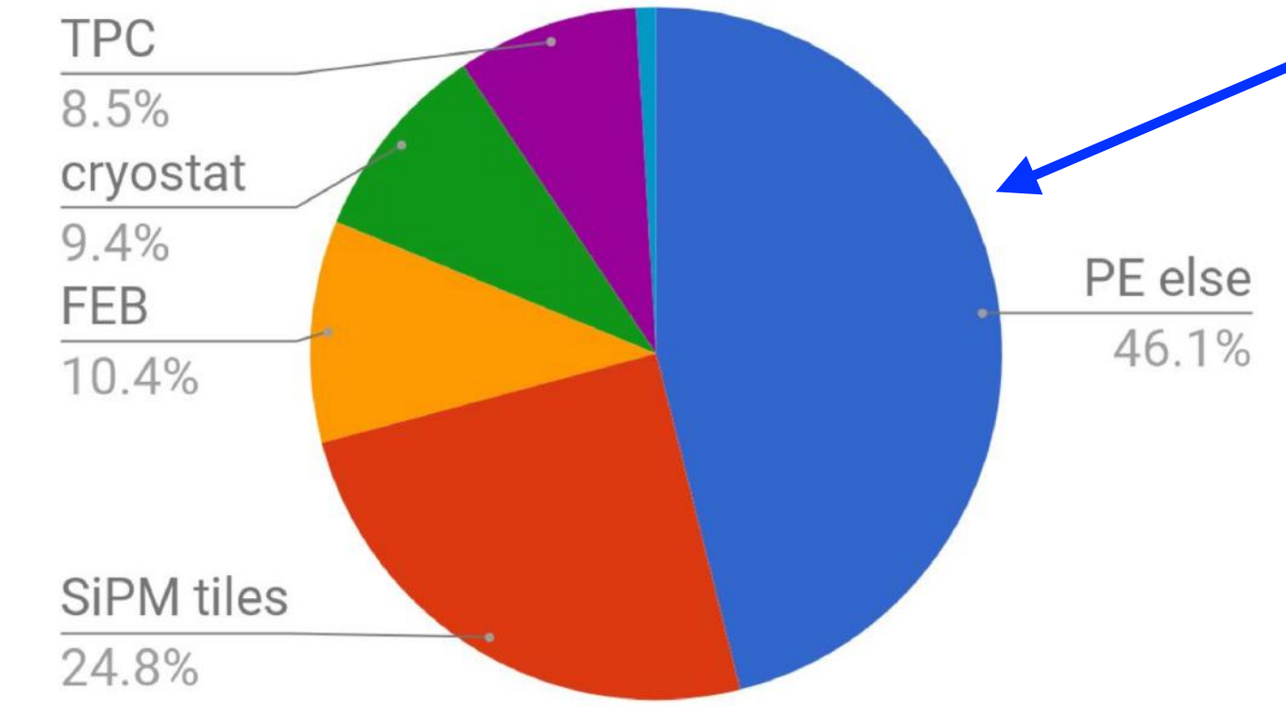
Nuclear recoil: neutrons, α

- ^{238}U and ^{232}Th contaminations of the detector material
- Cosmogenic interaction due the cosmic ray
- (α,n) reaction in the detector material
- Spontaneous fission decays



Same recoil of the WIMP

NEUTRON RECOIL



The principal source of neutrons background comes from the photo-electronics system

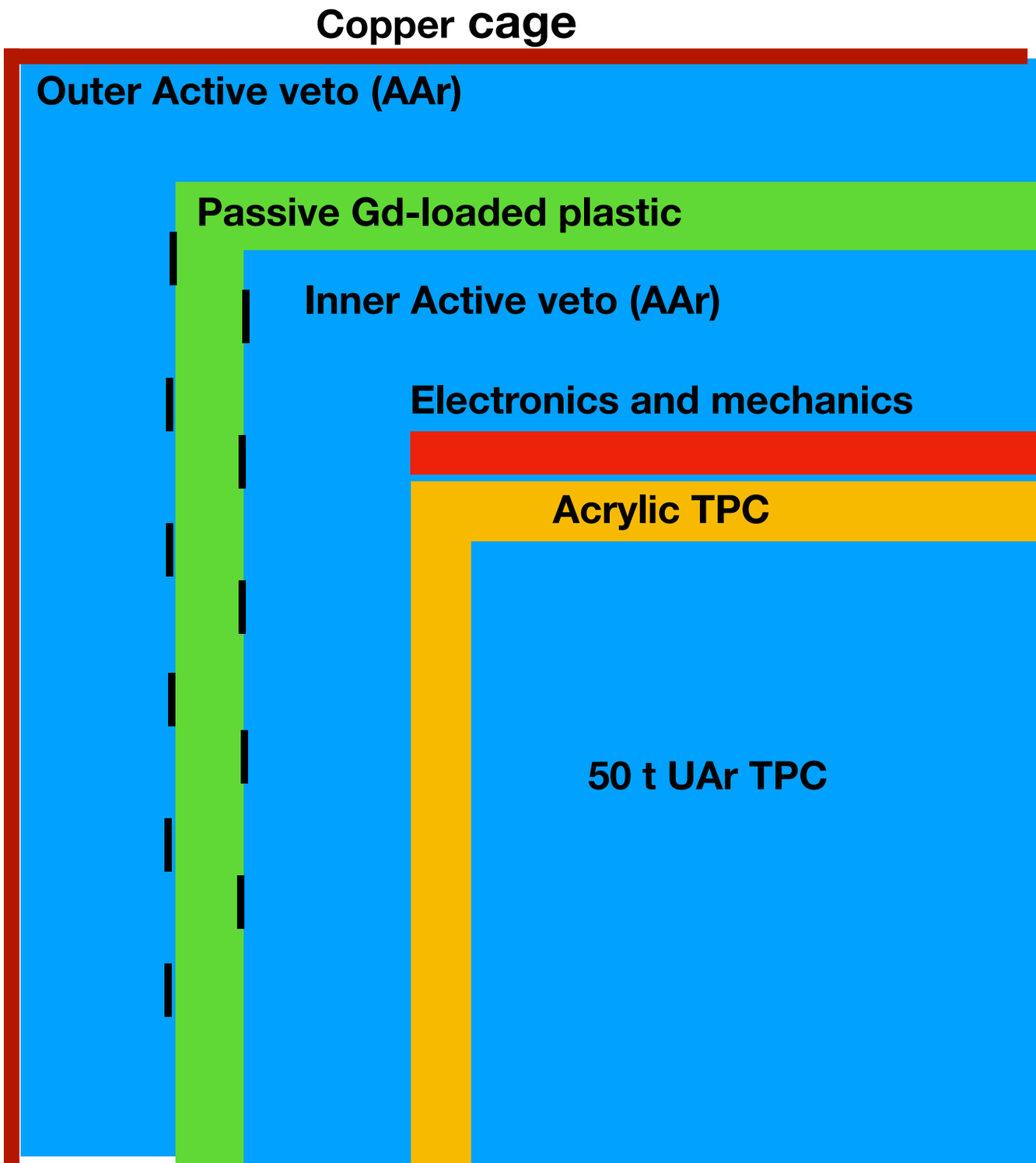
Improvement in the background reduction:

- Cuts on multi-scatter events
- Veto system

THE VETO DESIGN

The veto consists in:

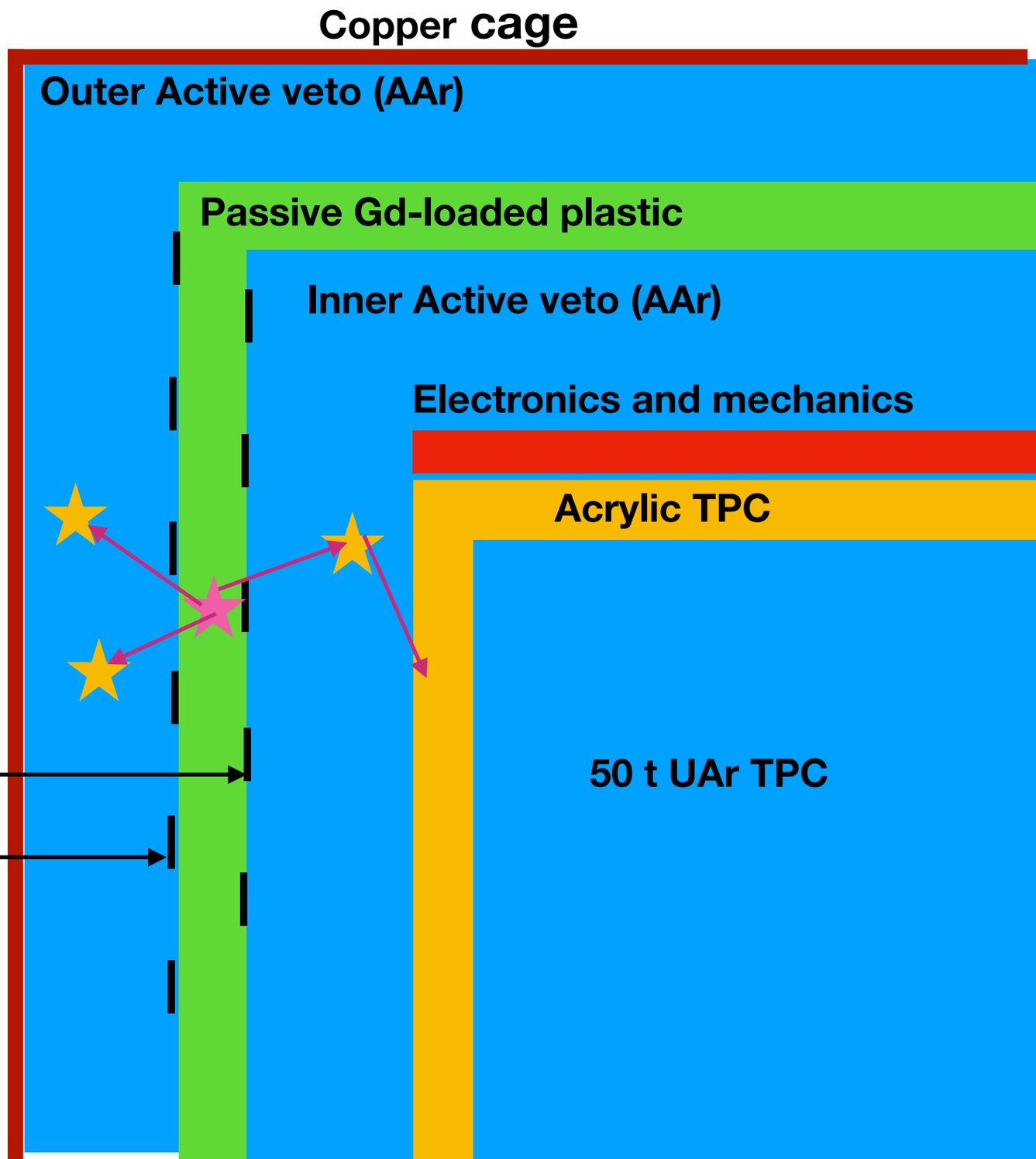
- An inner buffer of AAr surrounding the TPC (40 cm)
- A passive acrylic shell (10 cm) loaded with 1-2% of Gadolinium (neutron capture)
- An outer buffer of AAr (40 cm)
- Faraday cage (copper cage) for optical insulation and electrical shield



THE VETO DESIGN

How is neutron capture detected?

- Neutron capture on Gd produce a high energy γ (8 MeV)
- Scintillation light produced in the γ emission is detected by sensor placed on the two side of the plastic shell
- Optical readout ->3000 SiPMs disposed with a different coverage:
  - 2000 inside
  - 1000 outside

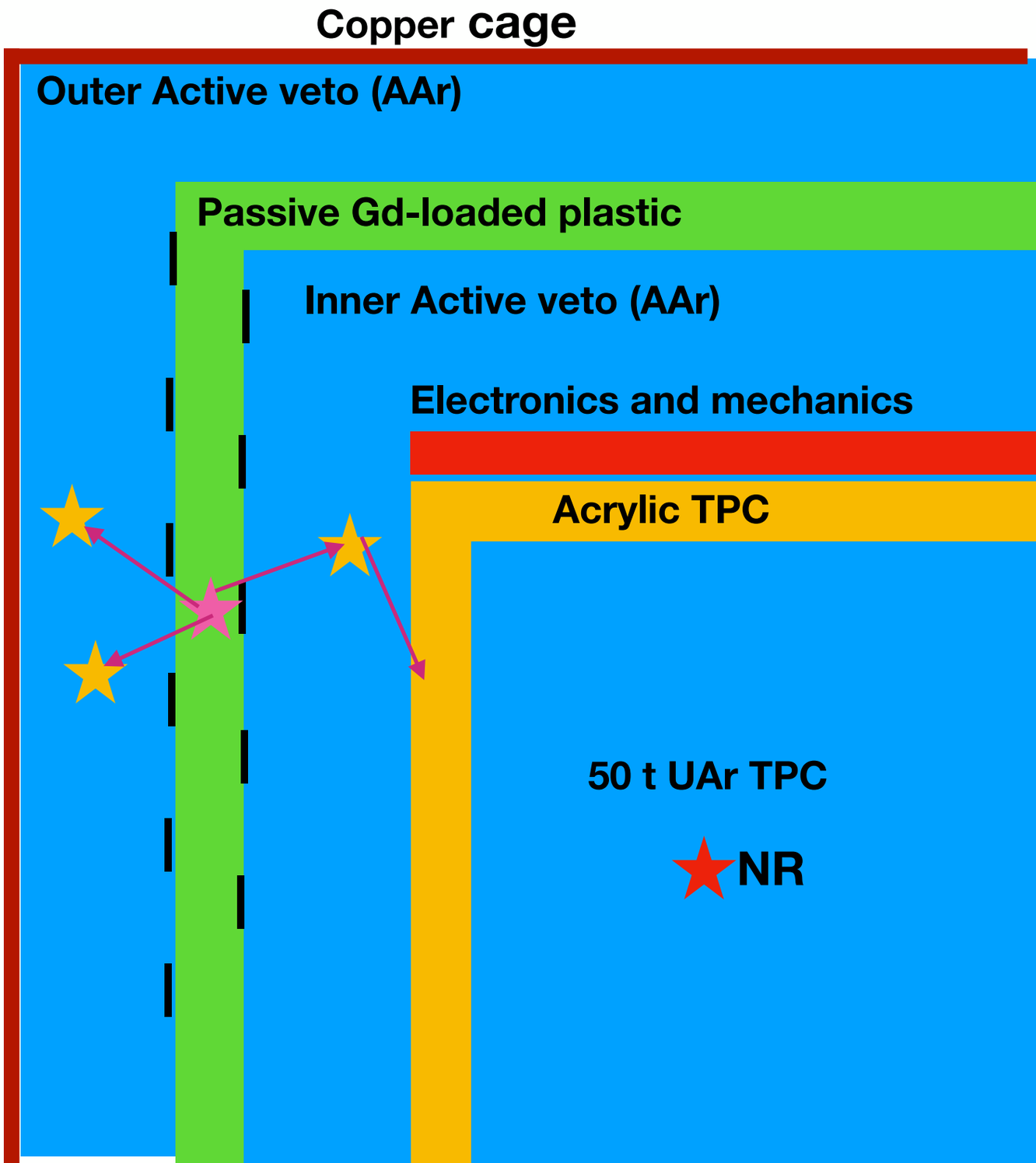


THE VETO DESIGN

How does veto system work?

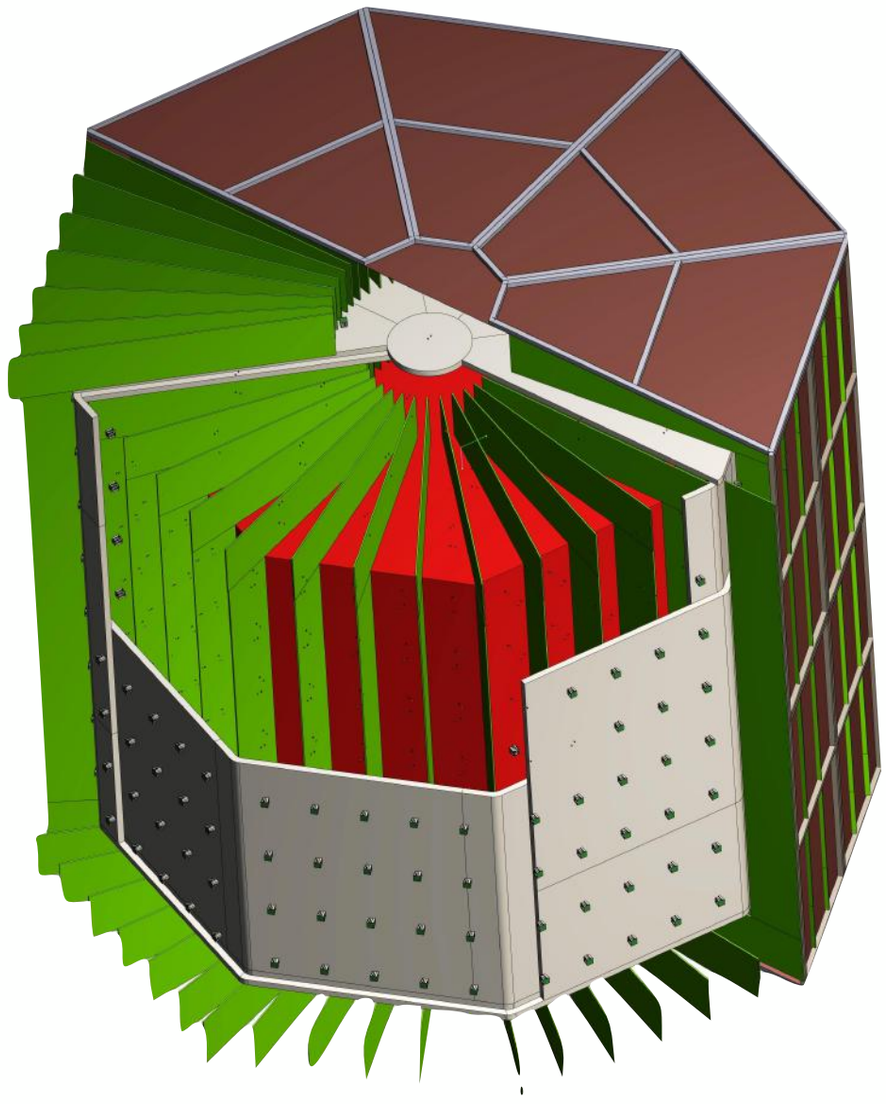
Neutron background rejection:

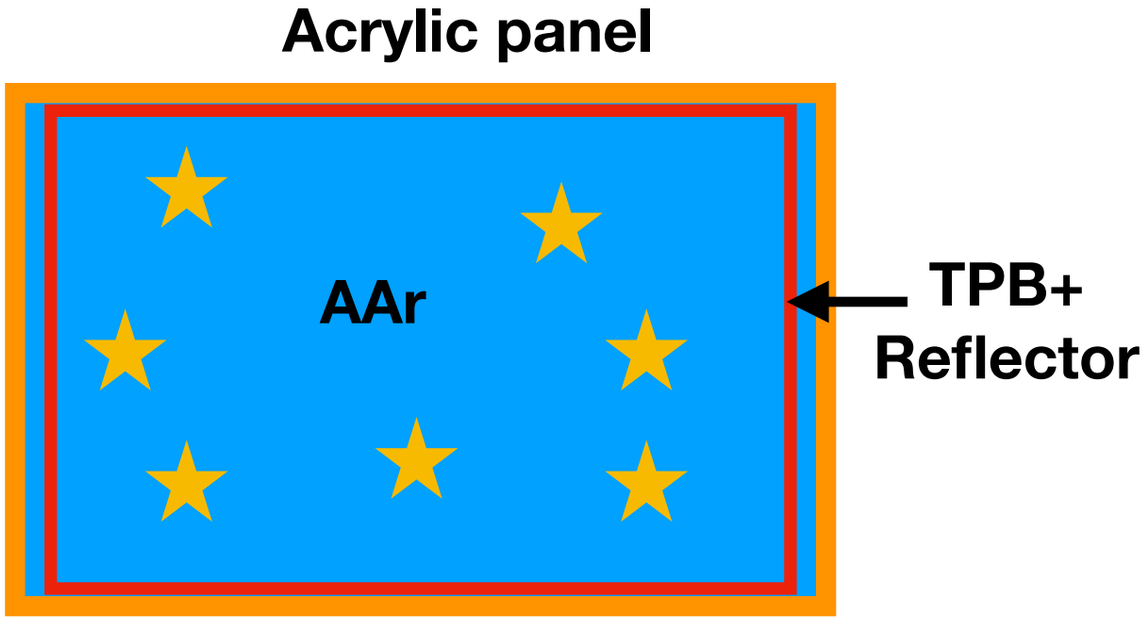
- Veto window is open after each NR event in the TPC (veto window = 800 μs)
- If the NR in the TPC is in coincidence with the signal in the veto-> rejection of the event in the TPC



THE VETO DESIGN (2)

- The inner and outer Argon buffers are divided in sectors in order to reduce the ^{39}Ar pile-up
- Each sector consists in an acrylic panel filled with AAr
- The wall of each sector is covered by wavelength shifter TPB and reflector. The reflector improves the light collection for a better rejection of ^{39}Ar





VETO PERFORMANCE

WIMP-like events:

- Single recoil
- Energy range:
  7.5 keVee<energy<50 keVee
- Fiducial Volume:
  30 cm away the TPC walls

Neutron capture in the veto for WIMP-Like event

	fraction of captures[%]
Gd	49%
Ar	26%
H	15%
TPC SiPM Cu	7%

	Fraction of Untagged event[%]
Gd	5.5%
Ar	9.1%
H	57.7%
TPC SiPM Cu	22%

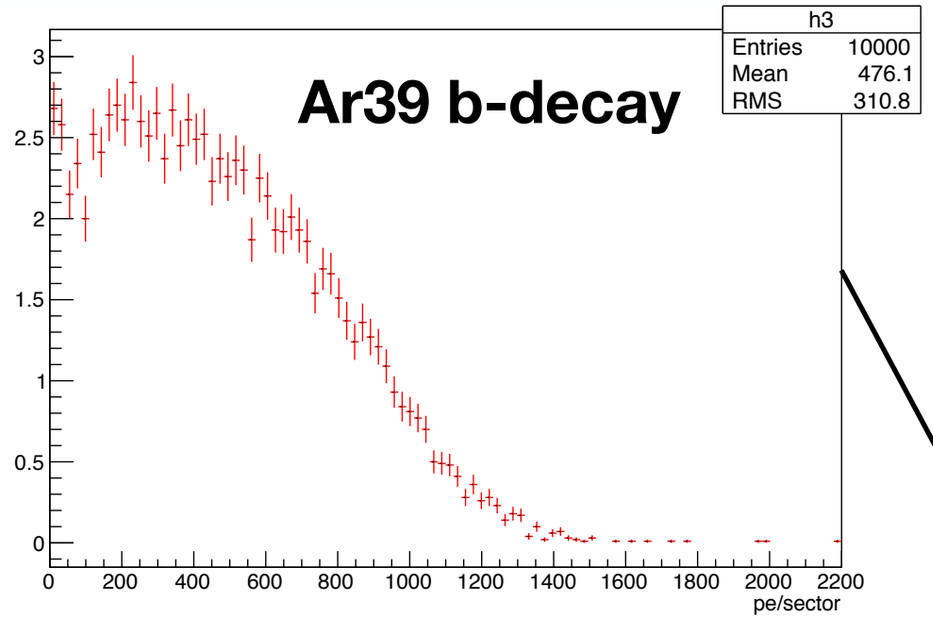
fraction of un-tagged WIMP-like event after a veto cuts requiring a **600 keV** in the inner buffer **OR 600 keV** in the outer buffer

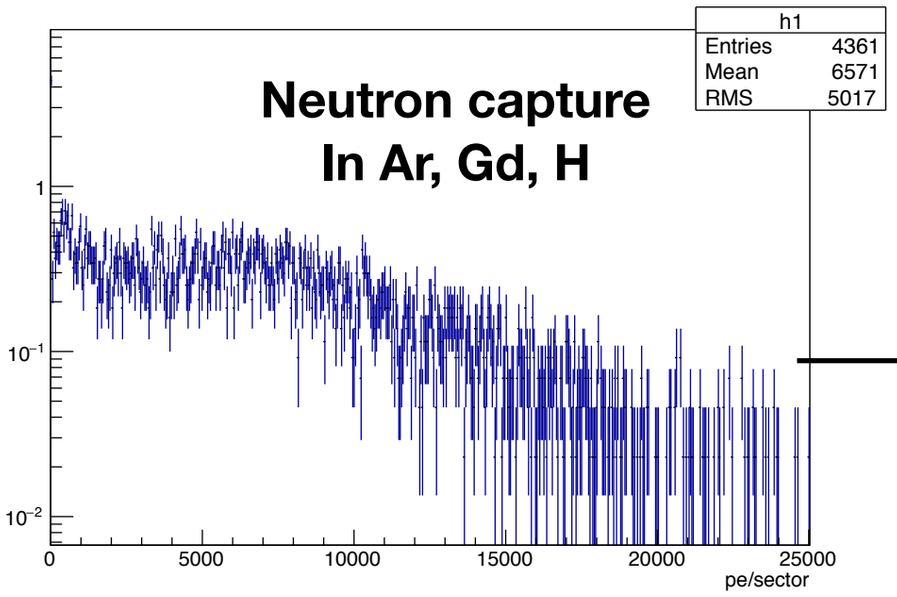
Total fraction of un-tagged WIMP like event: **10%**

VETO PERFORMANCE(2)

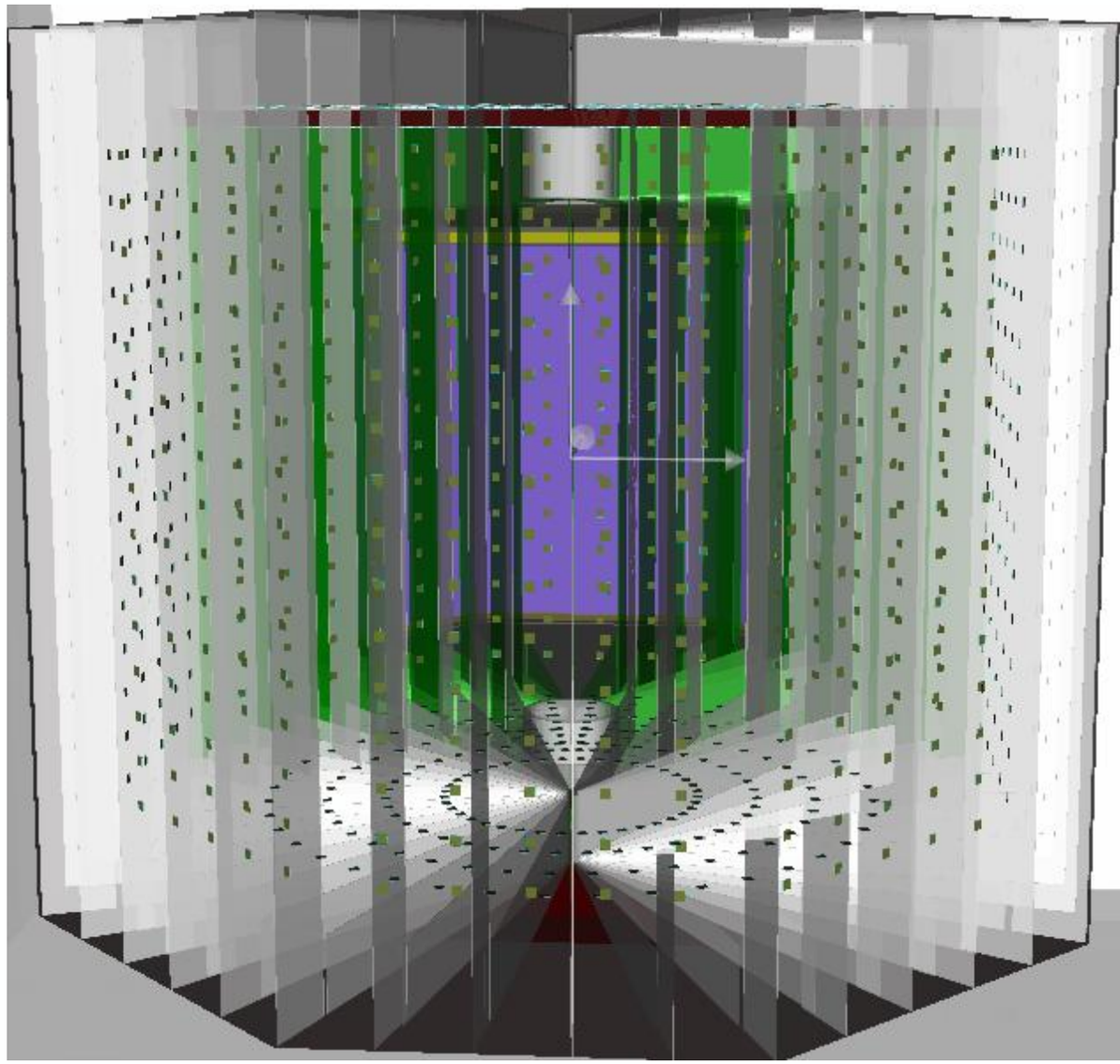
Light yield:

- 2.2 pe/keV per sector inner
- 1.2 pe/keV per sector outer





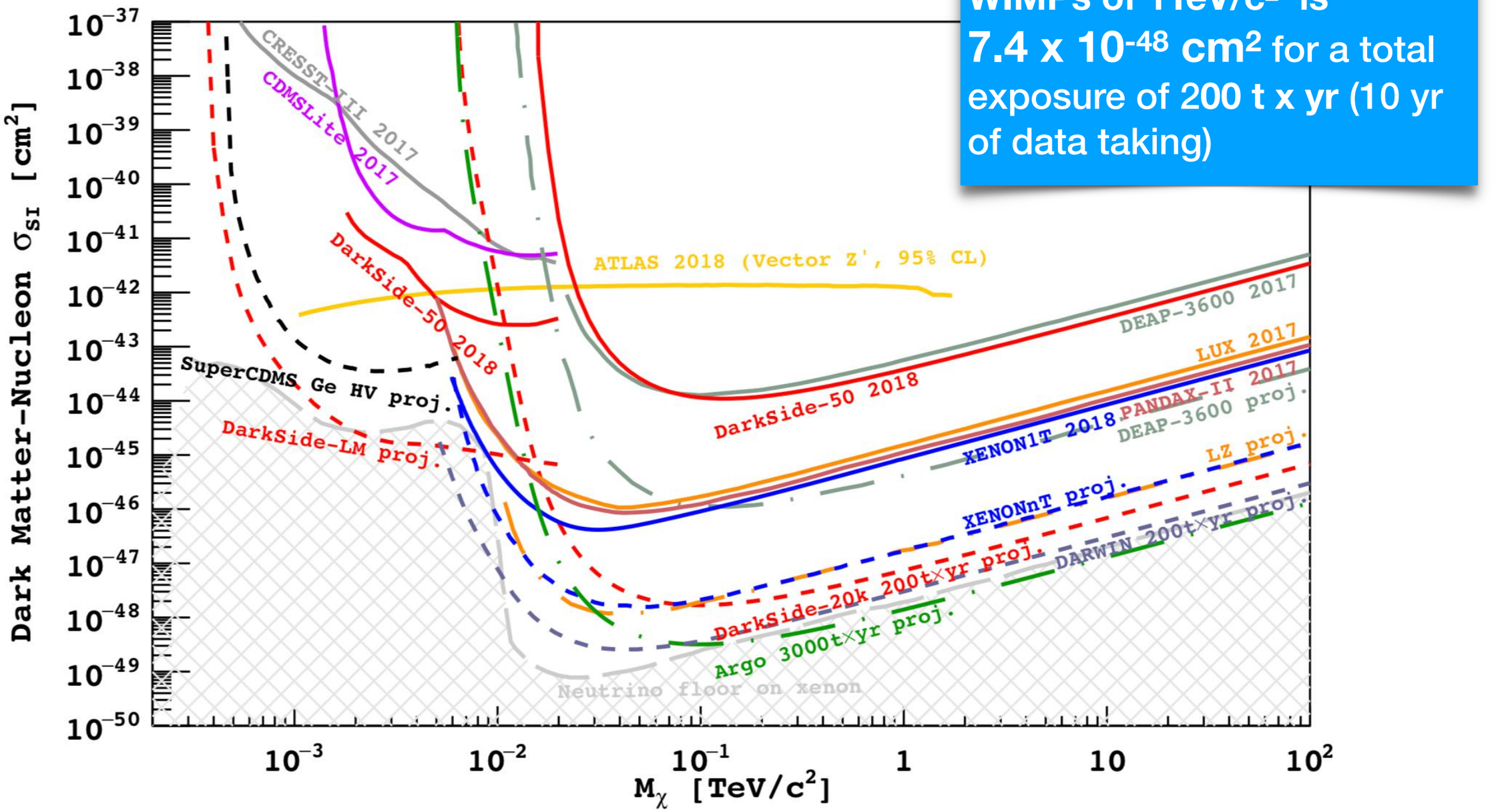
40 sector inside
40 sector outside



pe distributions
for the sector that
detected the
highest number of pe

DS-20k SENSITIVITY

Projected sensitivity for a WIMPs of 1TeV/c² is 7.4 x 10⁻⁴⁸ cm² for a total exposure of 200 t x yr (10 yr of data taking)



https://indico.cern.ch/event/765096/contributions/3295671/attachments/1785196/2906164/DarkSide-Argo_ESPP_Dec_17_2017.pdf

CONCLUSIONS

- DS-20k is a global Argon Dark Matter experiment which aim to to reach a high mass WIMP sensitivity in a background-free operation

- Progress in the detector development:
  - Two motherboard were successfully assembled
  - Ongoing improvement in the background rejection and veto system

- Data-taking will start in 2022

BACKUP

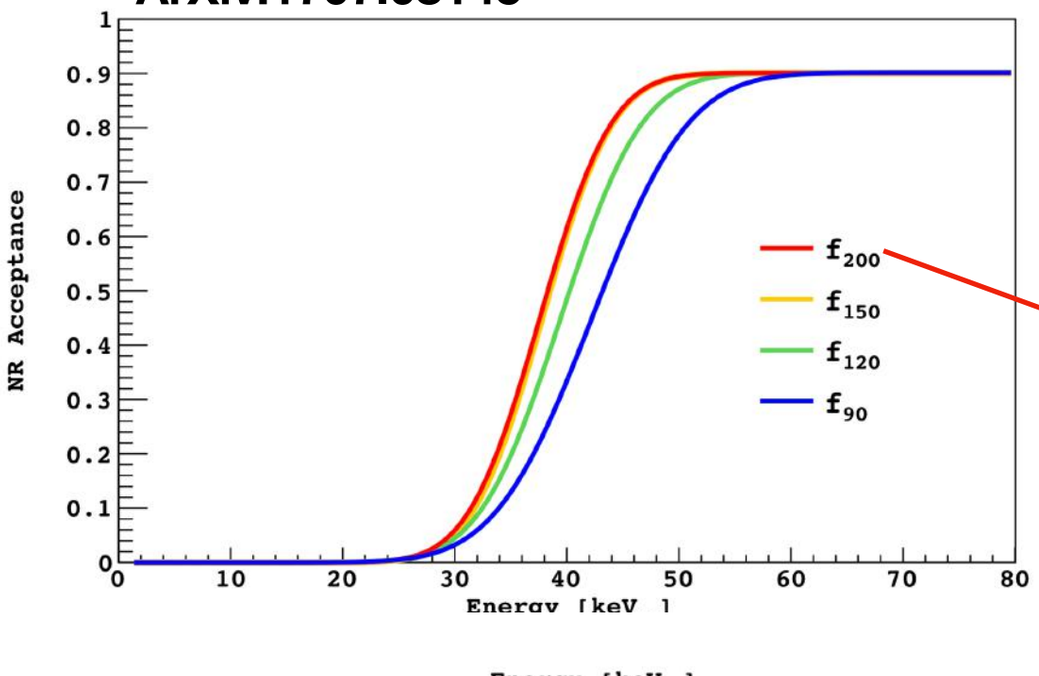
VETO PERFORMANCE: ONGOING STUDIES

- Optimize the number of sector
- Incorporate sector multiplicity into background rejection
- Exploring different TPB-reflector coating:
    - TPB-Acrylic-Reflector
    - TBP-Acrylic-Lar-Reflector

- Veto inefficiency of order of **10%** → $\frac{\text{Fraction of WIMP-like n event failing the veto cuts}}{\text{Fraction of WIMP-like n event in the TPC}}$
- Reduce the ^{39}Ar accidental rate

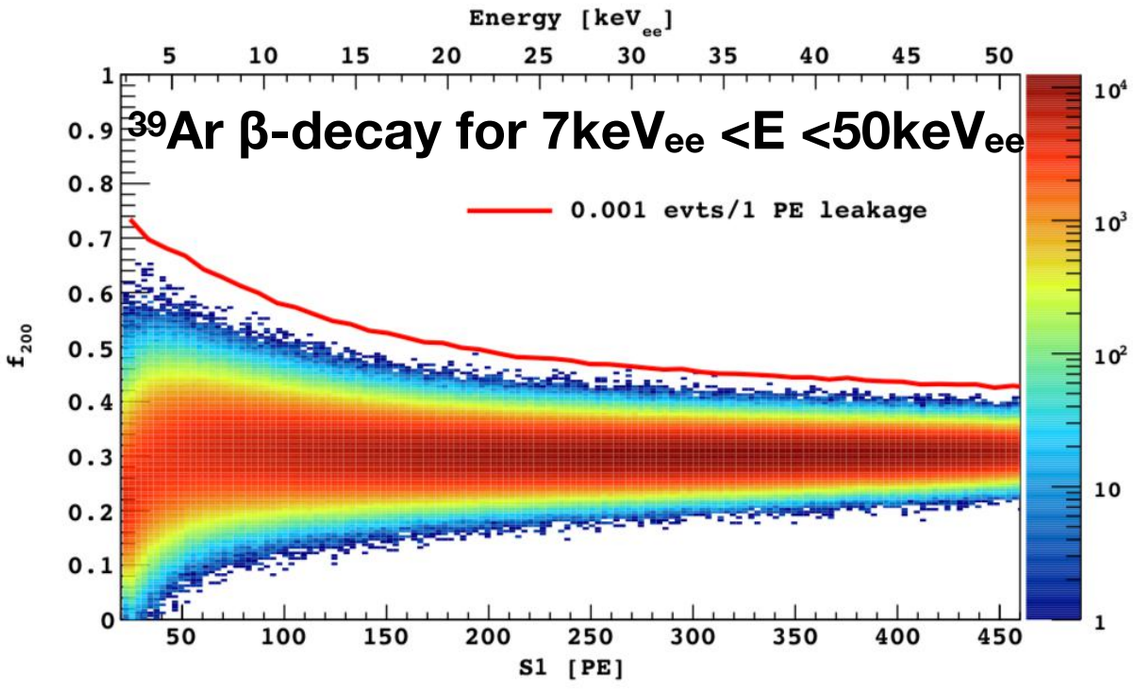
ElECTRON RECOIL

ArXiv:1707.08145



f_{200}= fraction of S1 light in the first 200 ns
f_{150}= fraction of S1 light in the first 150 ns (DEAP)
f_{120}= fraction of S1 light in the first 120 ns
f_{90}= fraction of S1 light in the first 90 ns (DS-50)

Pulse shape discrimination: f_{200} to reach a 90% of NR detection-efficiency



ER reduction factor is >3 x 10^9, more than sufficient to maintain a background-free operation

DEAP results (https://arxiv.org/pdf/1902.04048.pdf)