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# Inelastic Boosted DM search in DEAP-3600

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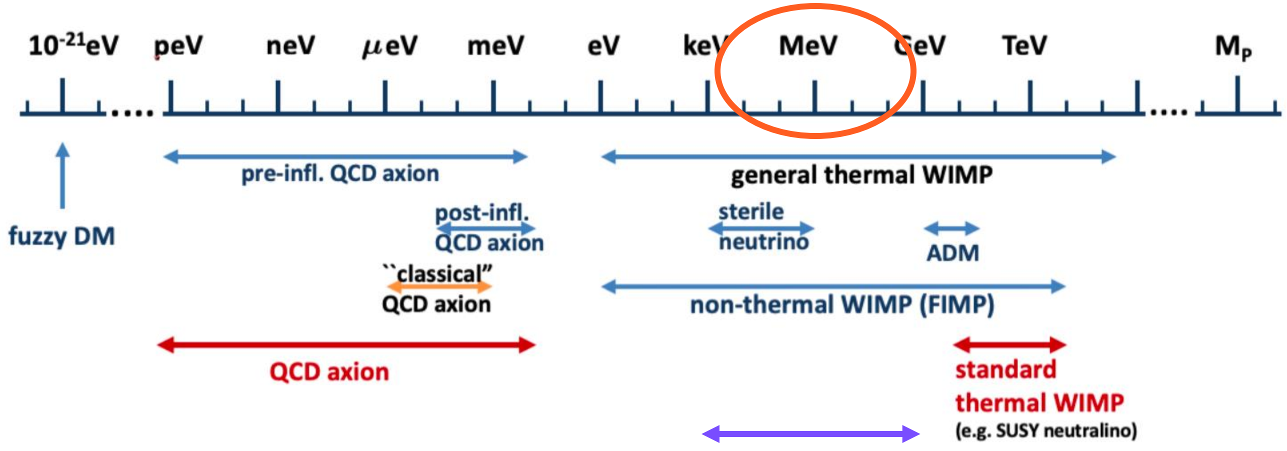
01/02/2024

# Dark Matter candidates - Inelastic Boosted DM search

- general properties: cold, non-baryonic, does not dissipate its energy, stable (or extremely long lived)

APPEC Committee Report, arXiv:2104.07634




## Inelastic Boosted Dark Matter at direct detection experiments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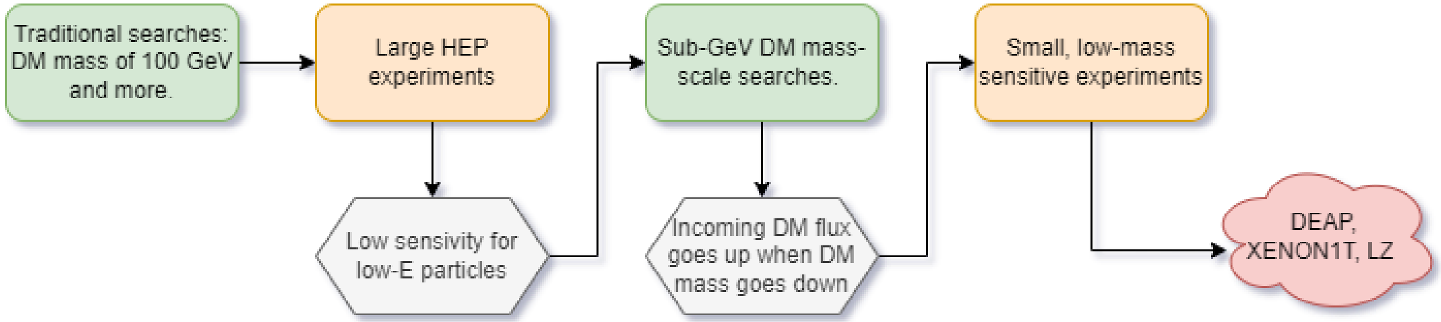
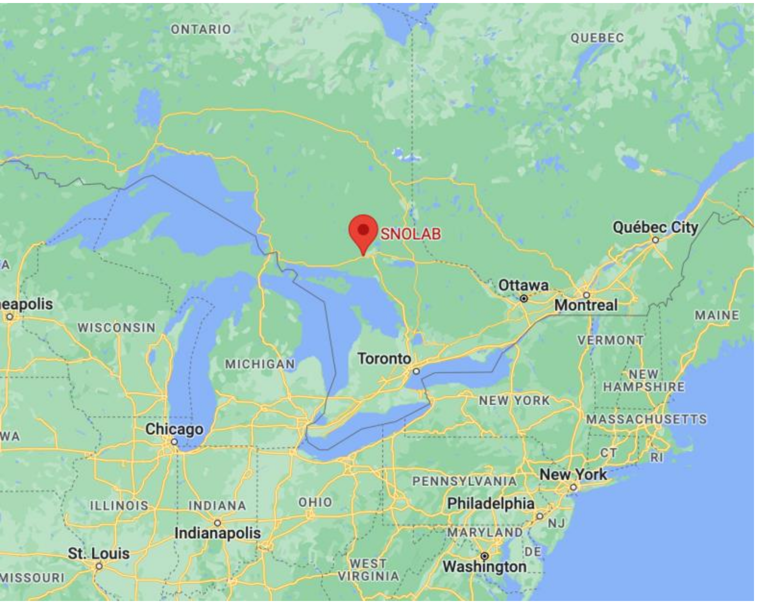
[d] *Department of Physics & IPAP, Yonsei University, Seoul 03722, Republic of Korea*



Physics Letters B 780 (2018) 543–552

# DEAP-3600



ONTARIO
QUEBEC
SNOLAB
Québec City
Ottawa
Montreal
MAINE
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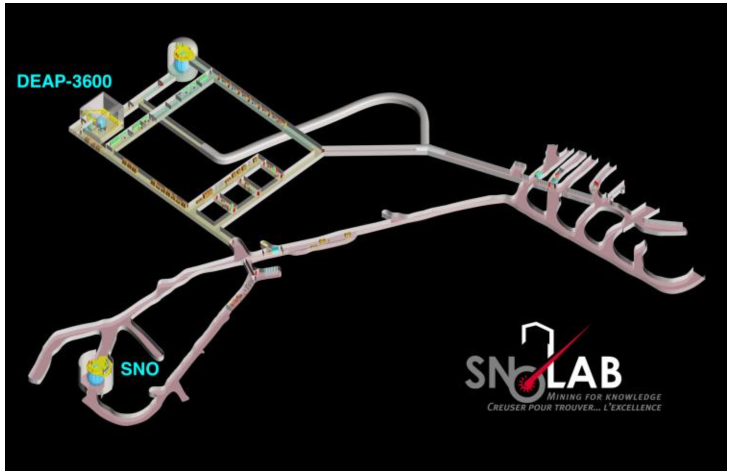
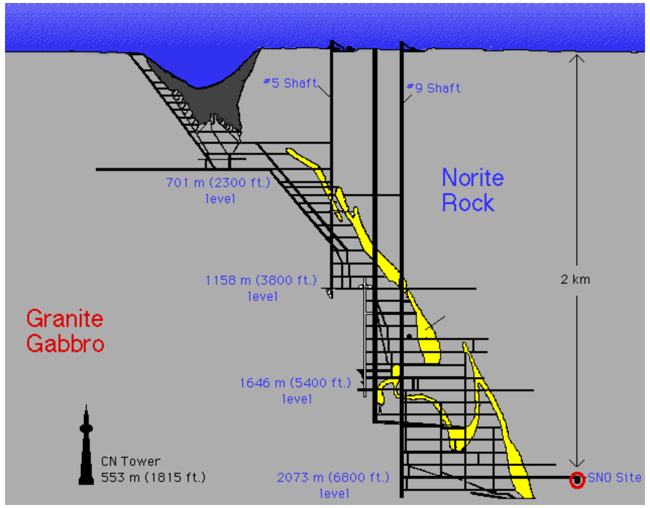
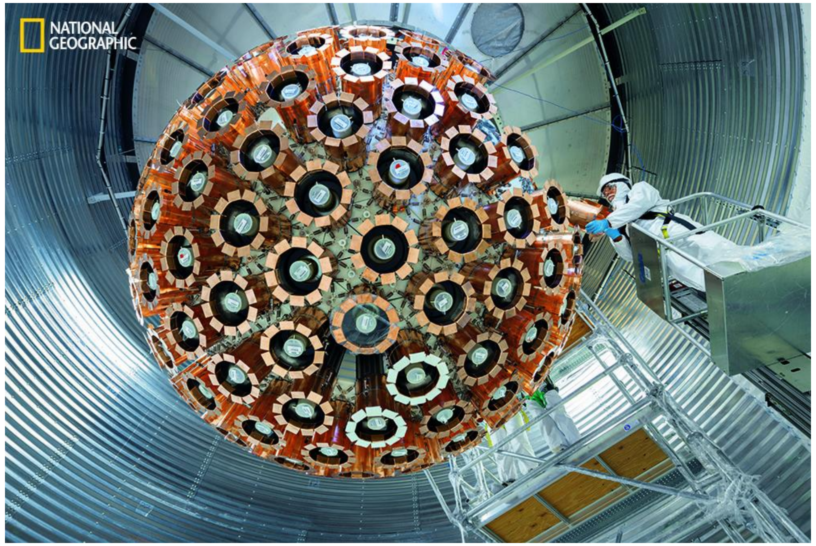
VERMONT
MICHIGAN
Toronto
NEW HAMPSHIRE
NEW YORK
MASSACHUSETTS
Chicago
CT
RI
PENNSYLVANIA
New York
ILLINOIS
INDIANA
OHIO
Philadelphia
Indianapolis
MARYLAND
NJ
St. Louis
DE
WEST VIRGINIA
Washington
MISSOURI

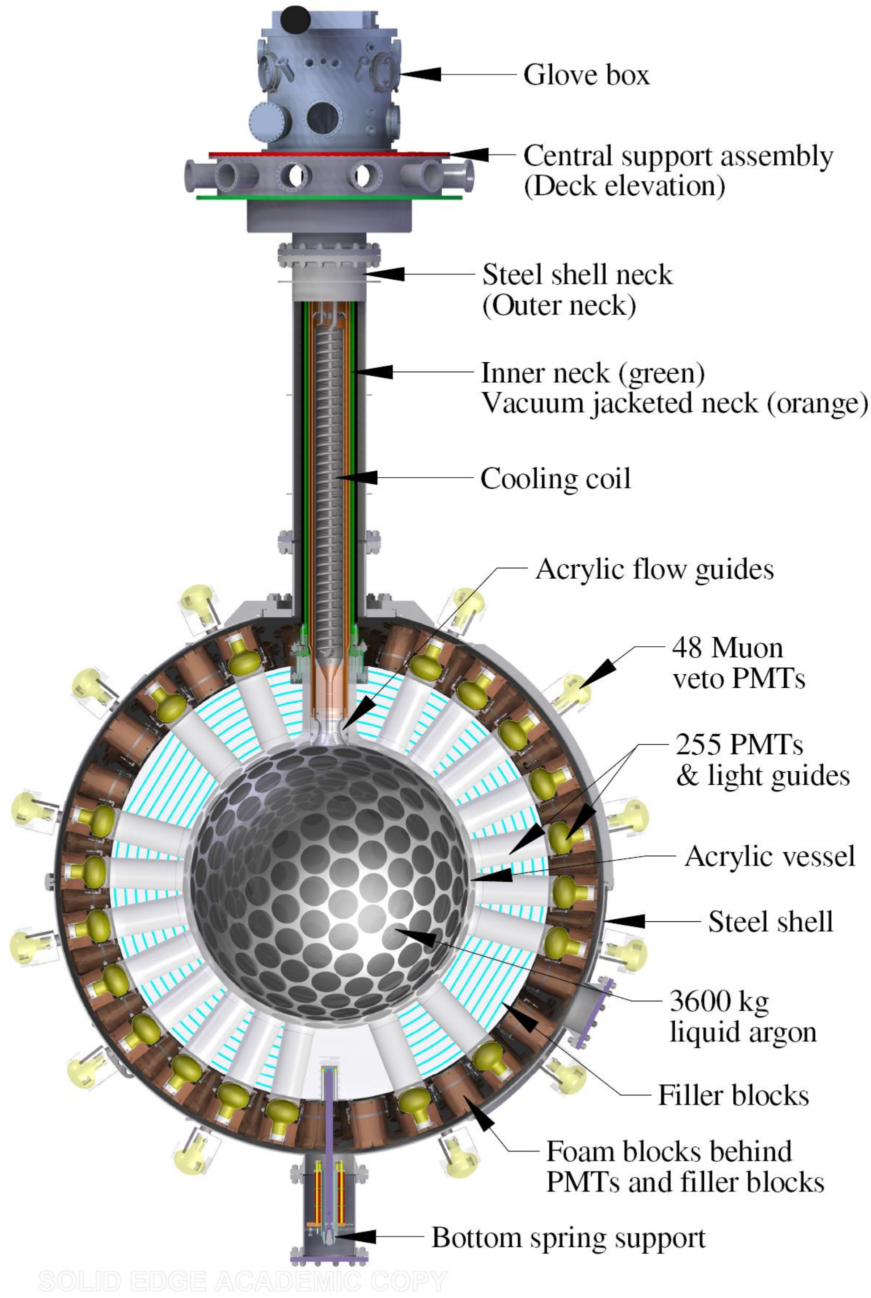
DEAP-3600
SNO
SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

#5 Shaft
#9 Shaft
701 m (2300 ft.) level
Norite Rock
1158 m (3800 ft.) level
2 km
Granite Gabbro
1646 m (5400 ft.) level
CN Tower 553 m (1815 ft.)
2073 m (6800 ft.) level
SNO Site

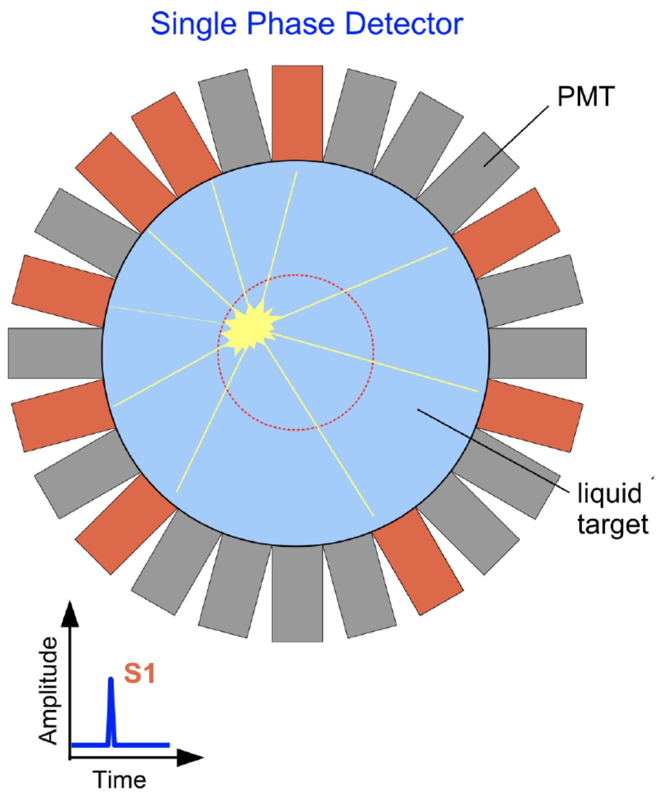



NATIONAL GEOGRAPHIC

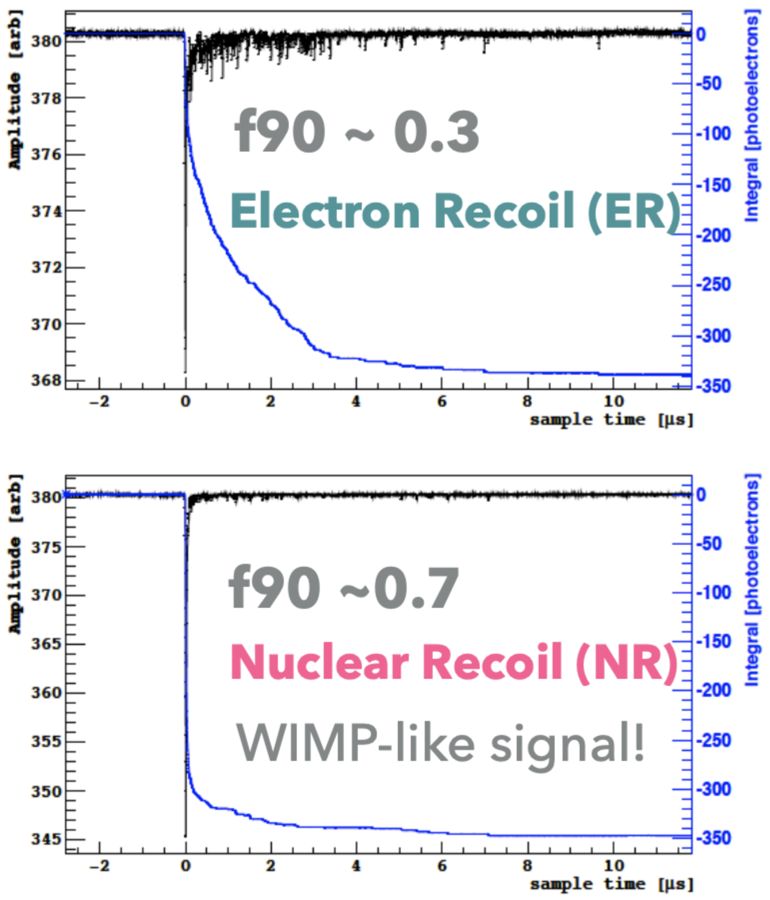



Glove box
Central support assembly (Deck elevation)
Steel shell neck (Outer neck)
Inner neck (green)
Vacuum jacketed neck (orange)
Cooling coil
Acrylic flow guides
48 Muon veto PMTs
255 PMTs & light guides
Acrylic vessel
Steel shell
3600 kg liquid argon
Filler blocks
Foam blocks behind PMTs and filler blocks
Bottom spring support

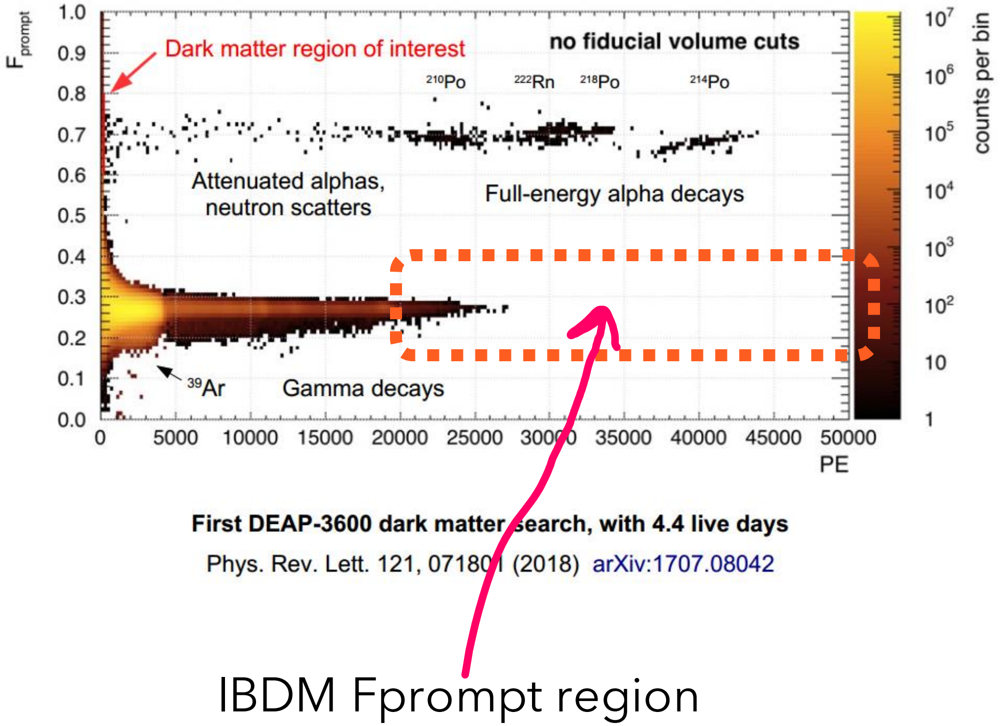
# Pulse Shape Discrimination in LAr




PSD: tool to distinguish light from a recoiling electron and nuclear recoil




PE/S1: total integral of the primary scintillation pulse (photoelectrons, PE)




**First DEAP-3600 dark matter search, with 4.4 live days**

Phys. Rev. Lett. 121, 071801 (2018) arXiv:1707.08042

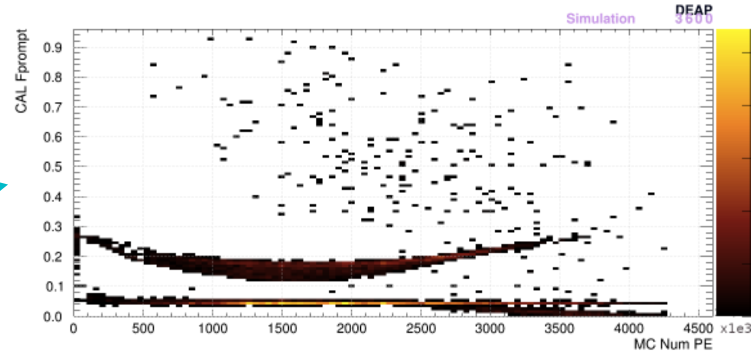
Analysis steps:

- Calculate number of (expected) signal events (S) per time period
- Calculate number of bkg (B) events per time period
- Calculate S/B and appropriate uncertainties.

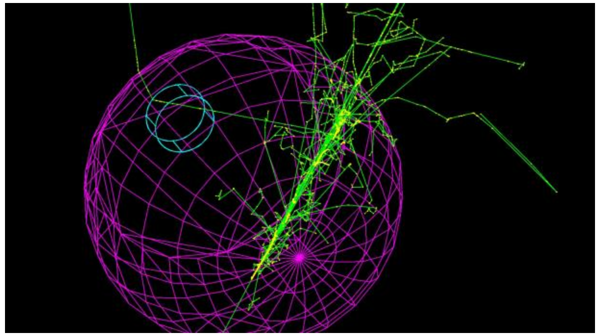
# Main results from previous year

Calculation of all the (kinematic) variables present in the theoretical model in a frame of DEAP experiment.

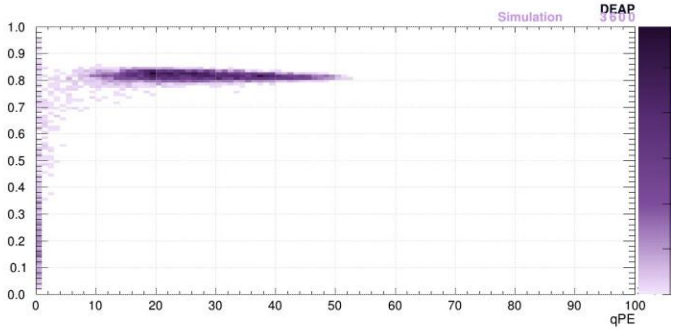
First implementation of the Monte Carlo simulator for DM signal together with generation sample data for all working points referenced in Giudice paper.




Preparing events visualization using .heprep data format.



Identifying high Fprompt events with Cherenkov radiation present in the simulation.

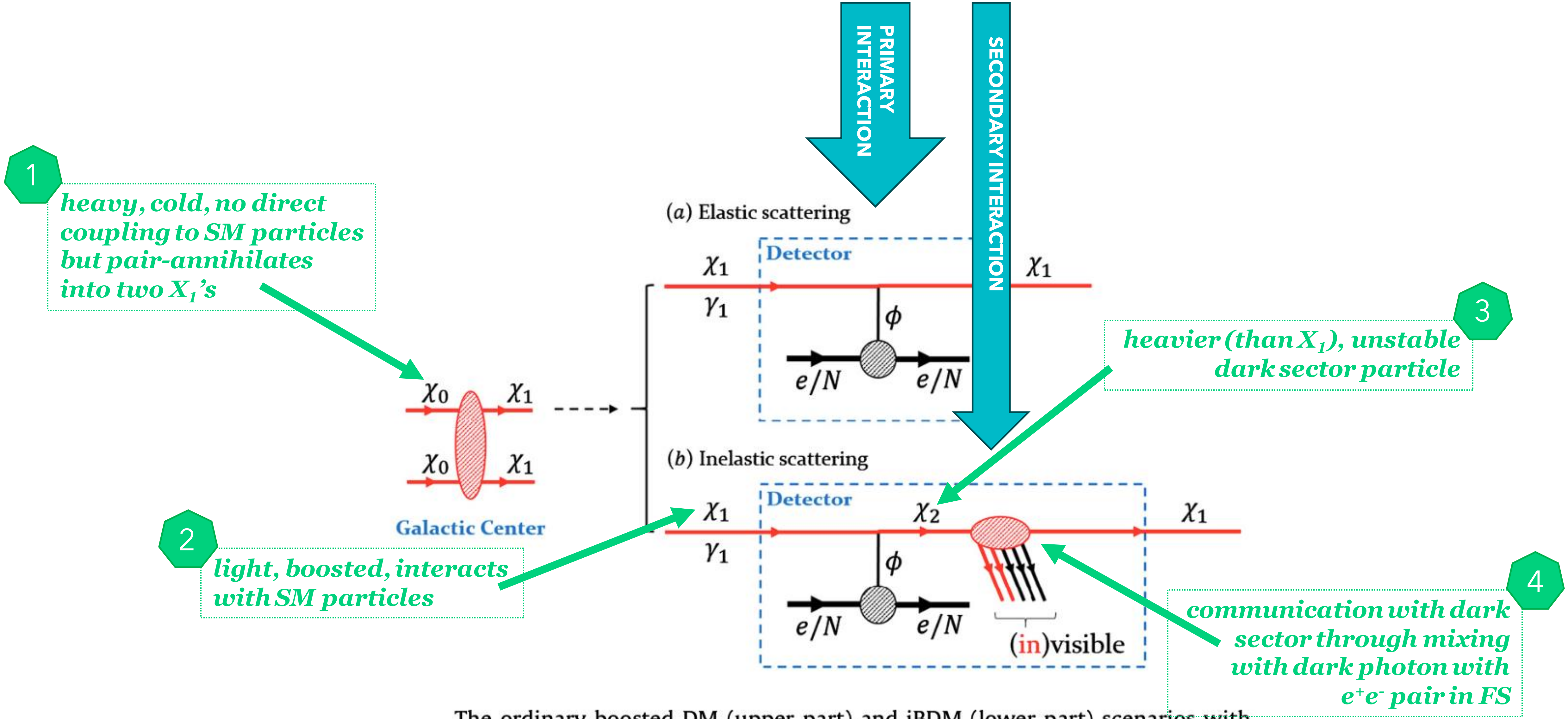



Work-in-progress

**Thank you!**

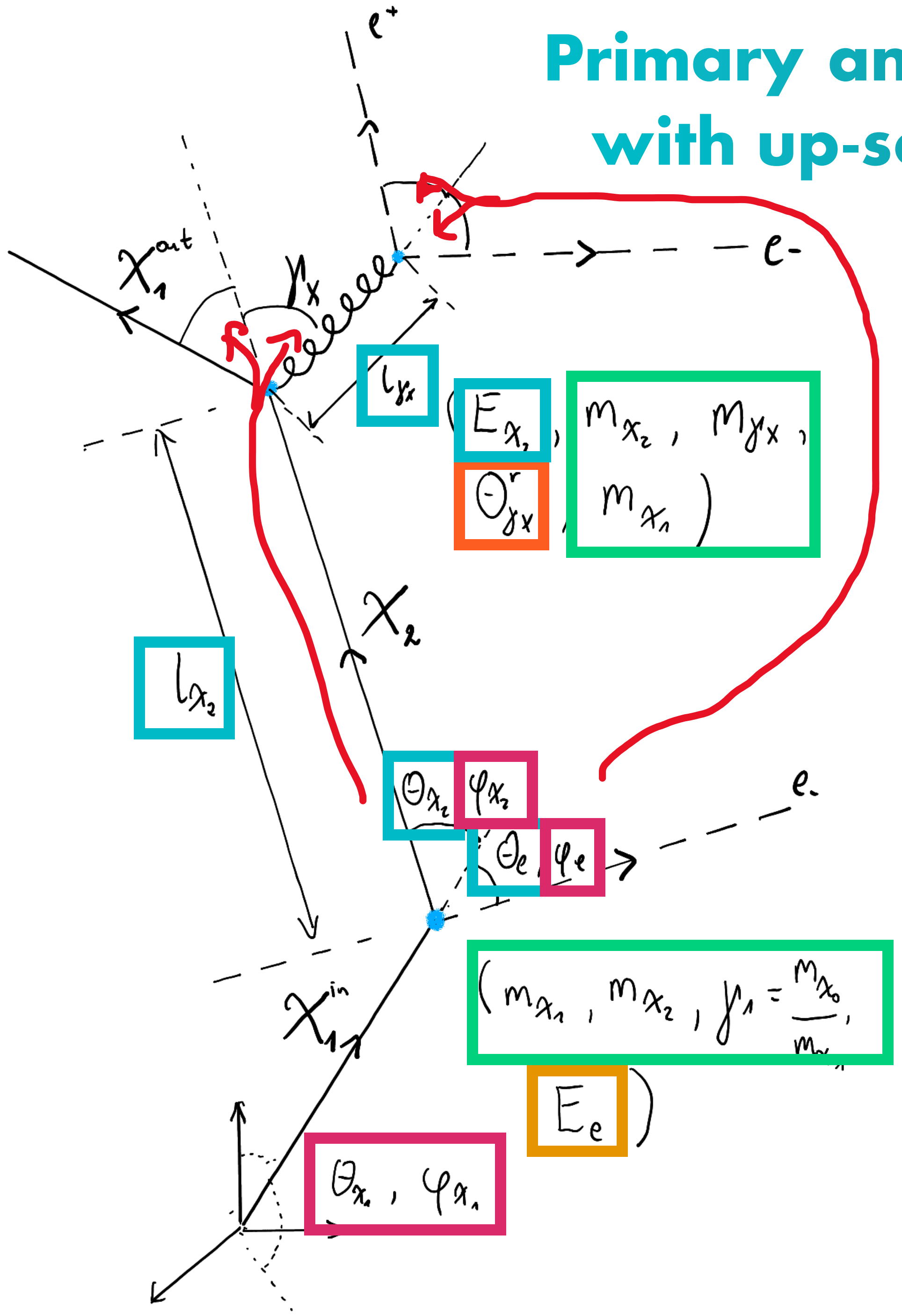
# Backup

# IBDM model




The ordinary boosted DM (upper part) and iBDM (lower part) scenarios with the relevant DM-signal processes under consideration.

# Primary and secondary processes with up-scattering off *electrons*

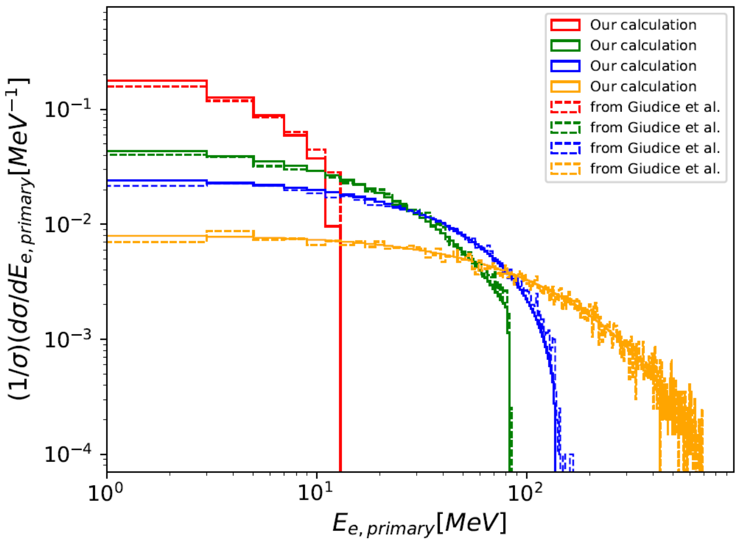


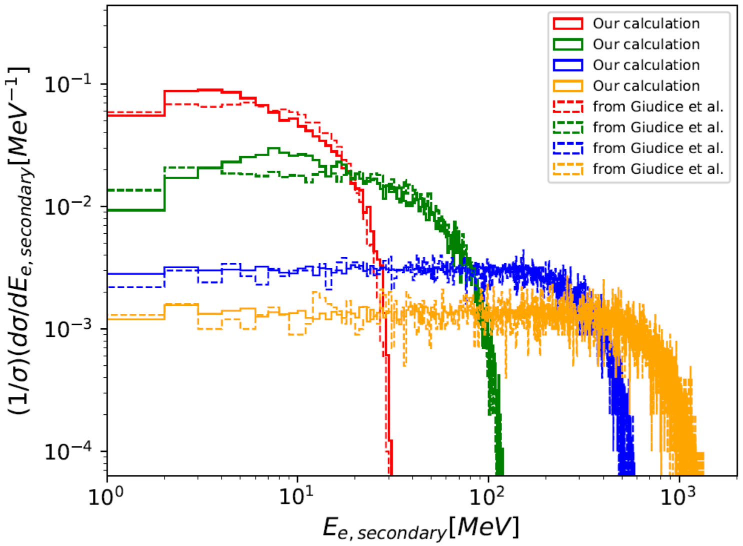

- Model assumption, i.e. reference point(s)
- Computed in Giudice's paper with MG MC
- Calculated from model
- Random – used for kinematical variables computation in model above
- Random at generator level

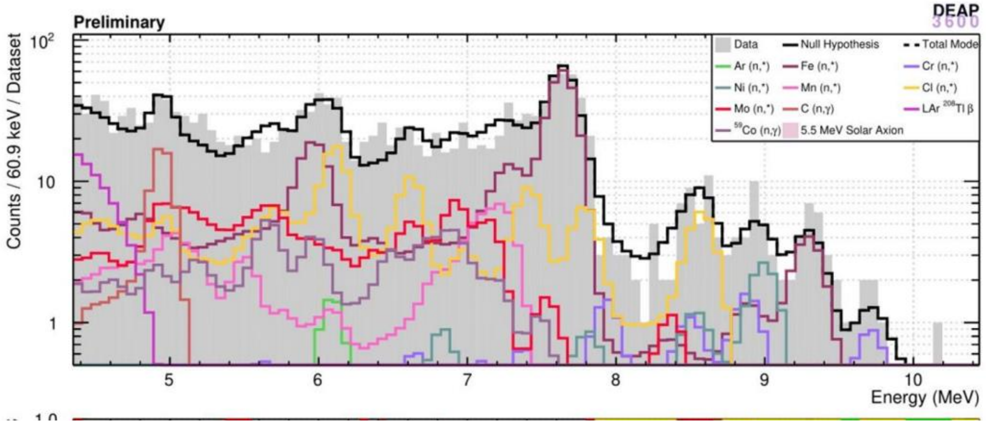
## General idea:

1. Calculate E/p, ϴ, ϕ for outgoing particles
2. Generate events with RAT/GEANT4
3. Do the analysis on real data

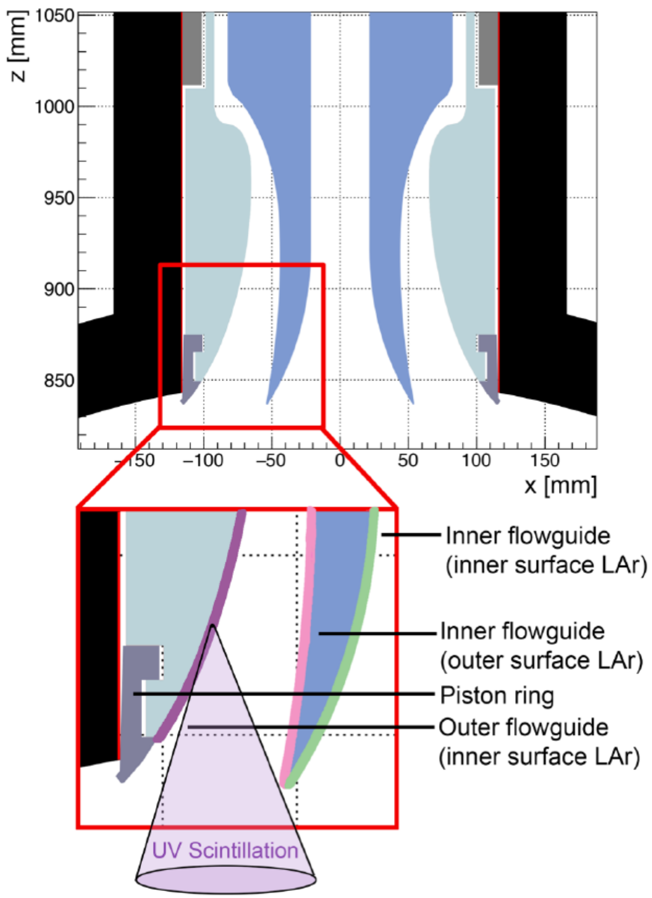
# Model implementation



# Background




| | Source | $N^{\text{CR}}$ | $N^{\text{ROI, LL}}$ | $N^{\text{ROI}}$ |
|---|---|---|---|---|
| $\beta/\gamma$'s | ERs | $2.44 \times 10^9$ | $0.34 \pm 0.11$ | $0.03 \pm 0.01$ |
| | Cherenkov | $< 3.3 \times 10^5$ | $< 3890$ | $< 0.14$ |
| $n$'s | Radiogenic | $6 \pm 4$ | $11^{+8}_{-9}$ | $0.10^{+0.10}_{-0.09}$ |
| | Cosmogenic | $<0.2$ | $<0.2$ | $<0.11$ |
| $\alpha$'s | AV surface | $<3600$ | $< 3000$ | $< 0.08$ |
| | AV Neck FG | $28^{+13}_{-10}$ | $28^{+13}_{-10}$ | $0.49^{+0.27}_{-0.26}$ |
| | **Total** | N/A | $< 4910$ | $0.62^{+0.31}_{-0.28}$ |

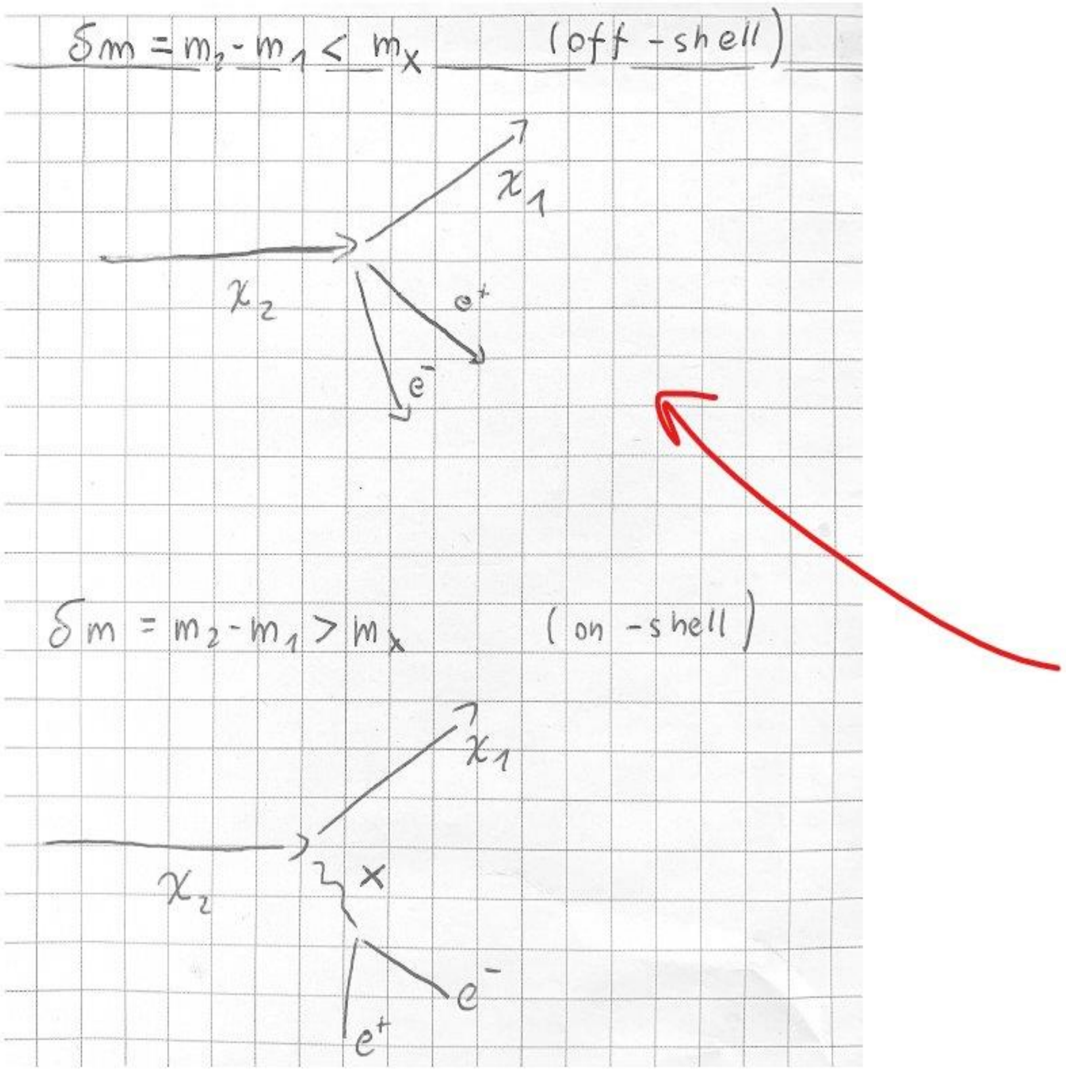
## Predicted number of events from each background source

For each background component a control region (CR) is defined by an event selection in the physics data.

AV - acrylic vessel

FG - acrylic flowguides

# Secondary process



# Sub-GeV iBDM results published recently

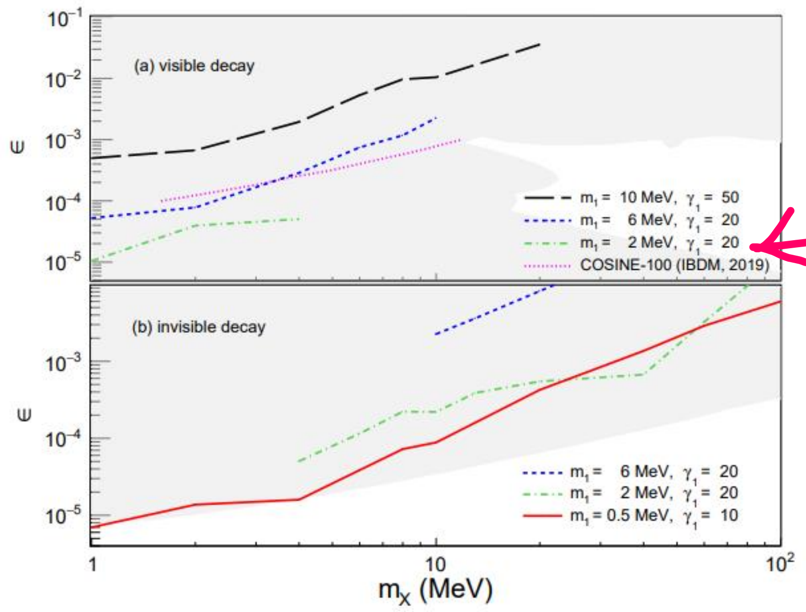



FIG. 3. Interpretation of the BDM searches with 1.7 years of COSINE-100 data in terms of the dark photon mass ($m_X$) and coupling ($\epsilon$) parameters is presented. (a) When $m_X < 2m_1$, our limits are compared with the currently excluded parameter space (shaded region) for the visible decay mode, including results from E141 [67], NA48 [68], NA64 [69], Babar [70], as well as bounds from the electron anomalous magnetic moment [71] and our previous IBDM search with 59.5 days of COSINE-100 data [24]. (b) When $m_X \geq 2m_1$, our limits are compared with the currently excluded parameter space (shaded region) for the invisible decay mode from NA64 [72] and Babar [73] experiments.

**"Search for Boosted Dark Matter in COSINE-100",**

**[https://arxiv.org/abs/2306.00322](https://arxiv.org/abs/2306.00322);**

**Phys. Rev. Lett. 131, 201802 (2023)**

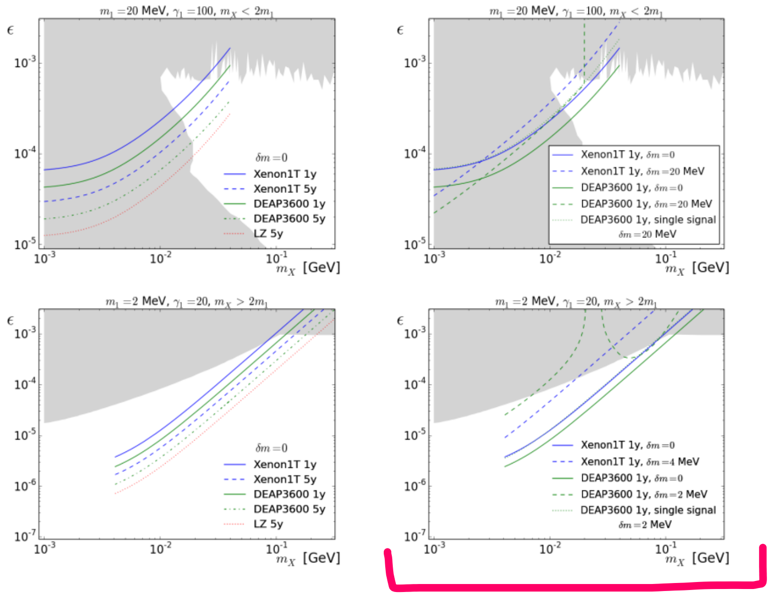
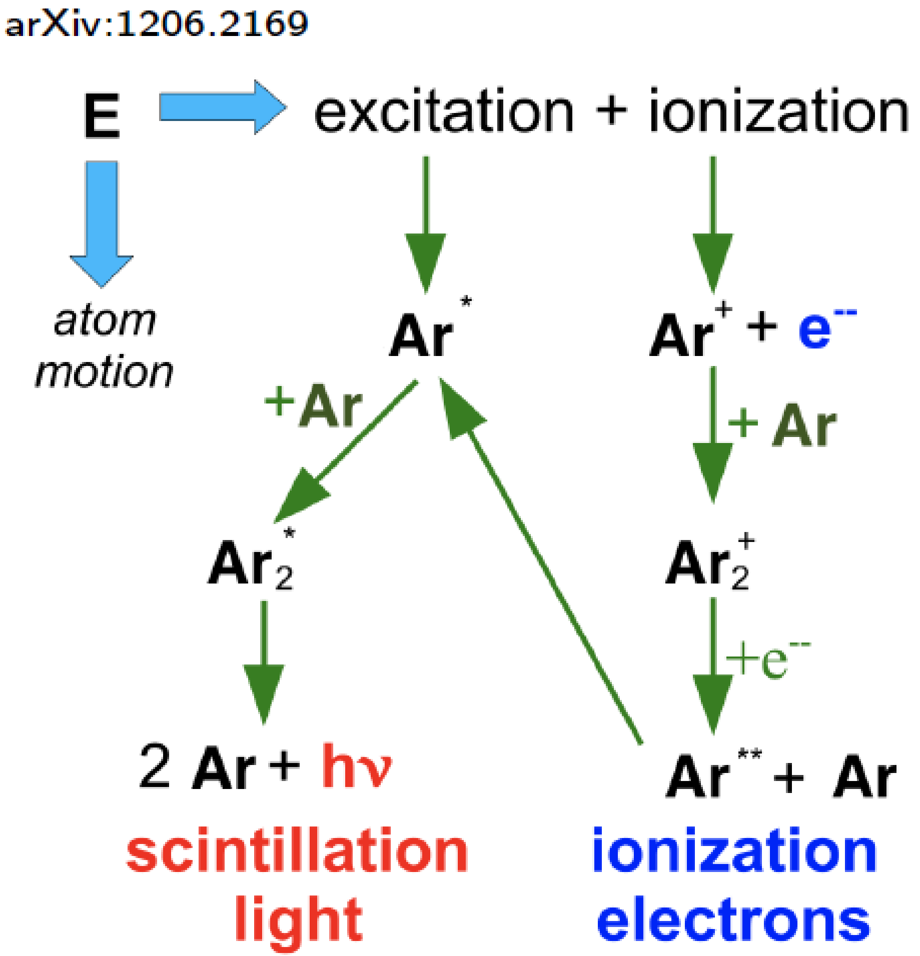
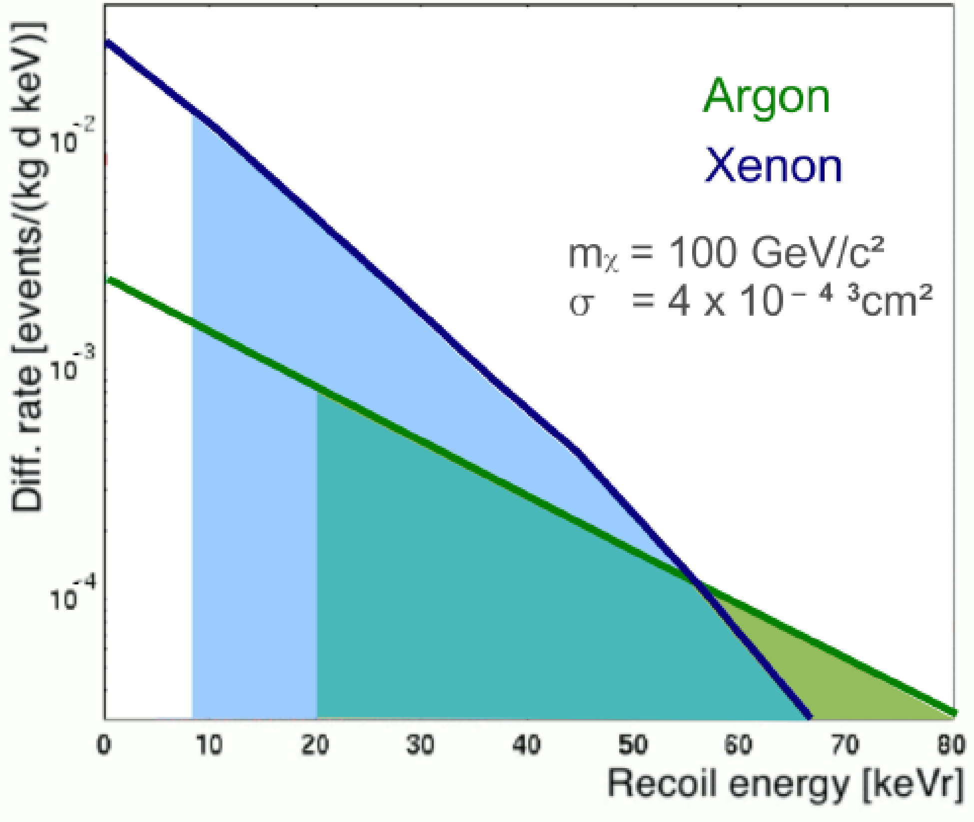



FIG. 6: Experimental reach at various experiments in the $m_X$–$\epsilon$ plane for the case in which the dark photon $X$ decays visibly (top panels) or invisibly (bottom panels). The grey regions show the currently excluded parameter space, as reported in Refs. [41] (top panels) and [42] (bottom panels). The left panels show the results of elastic scattering at different experiments, while in the right panels we compare cases of elastic ($\delta m = 0$) and inelastic ($\delta m \neq 0$) scattering.




excitation and ionization of the target (Xe works the same)

expected nuclear recoil spectra




experimentally achieved thresholds indicated by the colored areas