235th AAS Meeting

Jan 8th 2020

# THE GRAMS PROJECT

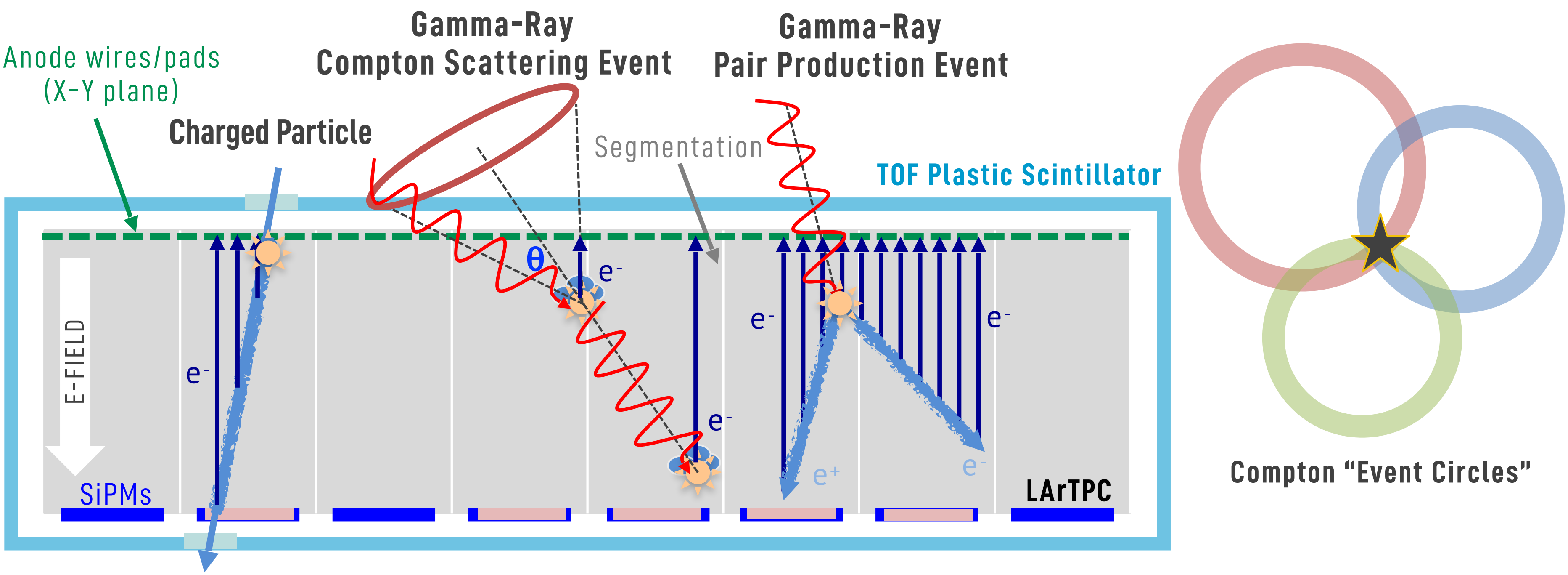
## GAMMA-RAY AND ANTIMATTER SURVEY

TSUGUO ARAMAKI, SLAC

# GRAMS DETECTION CONCEPT: MEV GAMMA-RAYS



**LArTPC (Liquid Argon Time Projection Chamber) surrounded by Plastic scintillators**
**LArTPC measures scintillation light and ionization electrons**



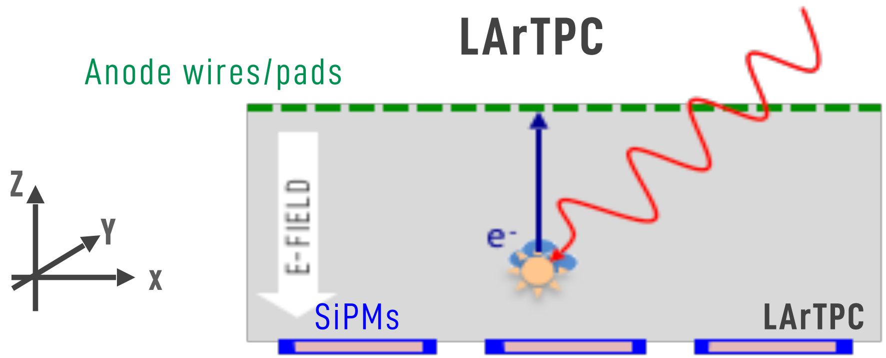

**Plastic Scintillators**: **Veto** incoming charged particles

**LArTPC**: **Compton camera** and **calorimeter**

- Scintillation light at **SiPMs to trigger events**
  **Signal localized by segmentation to reduce coincident background**
- Wires/pads on anode plane (X, Y), drift time (Z) to provide a **3D image/track**
- **Well-studied, widely-used** in **large-scale DM/neutrino** experiments

# WHY LARTPC?





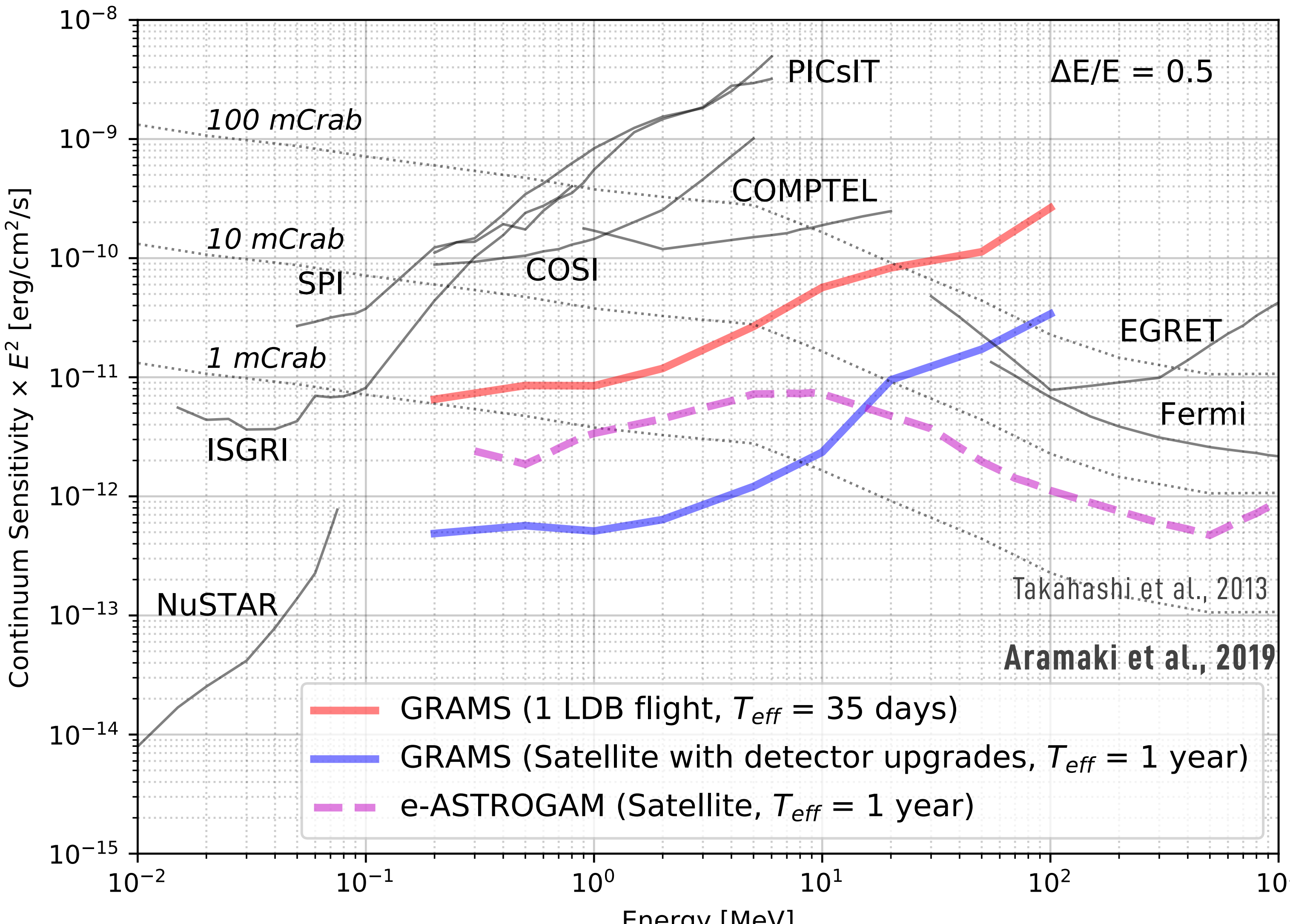


| | LArTPC | Semiconductor (Si/Ge) |
|---|---|---|
| ρ (g/cm³) | 1.4 | 2.3/5.3 |
| $T_{operation}$ | ~80K | ~240K/~80K |
| Cost | $ | $$$ |
| Signal | scintillation light + Ionization electrons | electrons, holes |
| X, Y Positions | wires on anode plane (X-Y) | double-sided strips |
| Z position | from drift time | from layer # |
| # of Layers | 1 layer | multi-layers |
| # of Electronics | # | ### |
| Dead Volume | almost no dead volume | detector frame, preamps |
| Neutron bkg | Identified with pulse shape | No rejection capability |

**LARTPC IS COST-EFFECTIVE AND EASILY EXPANDABLE TO A LARGER-SCALE, MUCH LESS CHANNELS/ELECTRONICS REQUIRED, ALMOST NO DEAD VOLUME**

# GRAMS MEV GAMMA-RAY CONTINUUM SENSITIVITY





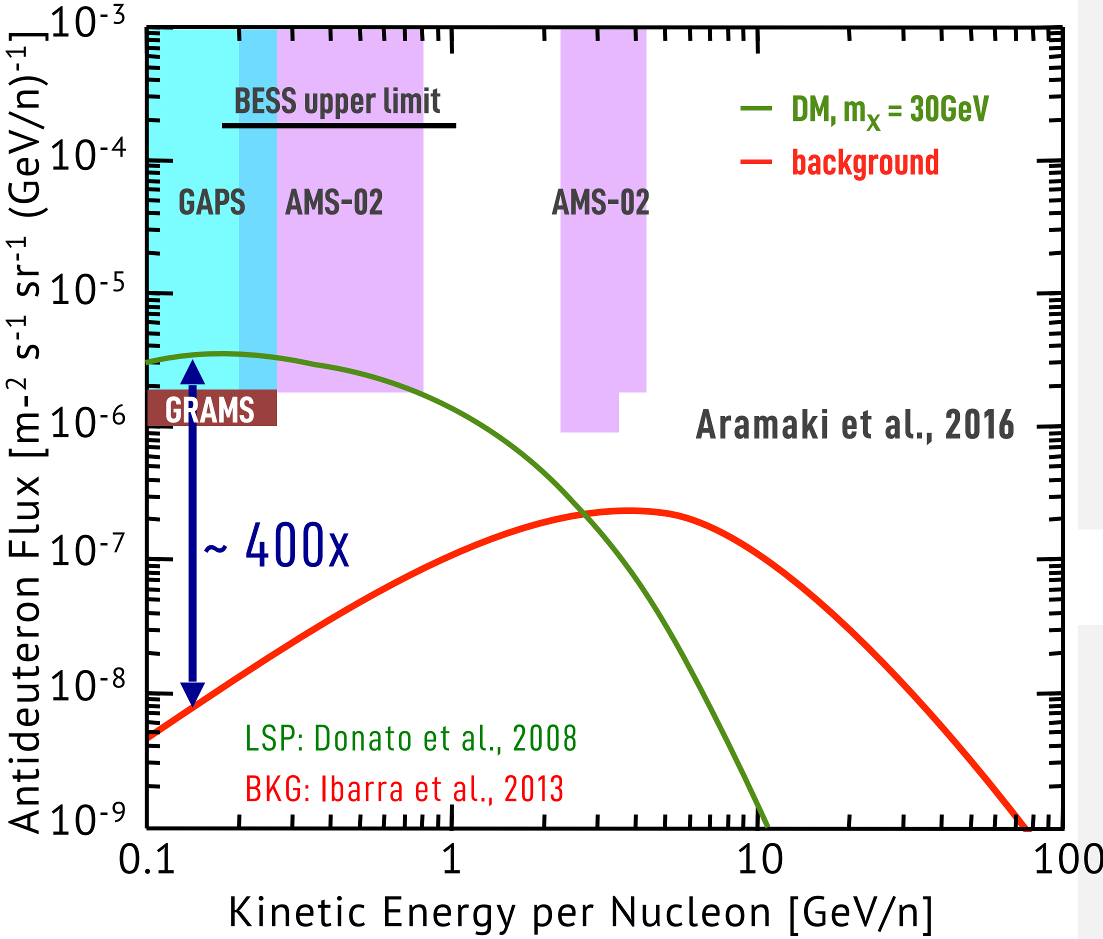

**SINGLE BALLOON FLIGHT: AN ORDER OF MAGNITUDE IMPROVED**

**SATELLITE MISSION: COMPARABLE (BETTER) TO FUTURE MISSIONS**

# WHY ANTIDEUTERONS?

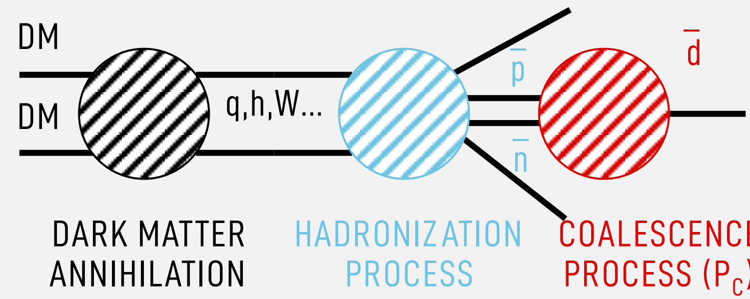


## BACKGROUND-FREE DM SEARCH AT LOW-ENERGY




### PRIMARY FLUX

### DM ANNIHILATION/DECAY




### SECONDARY FLUX

### COSMIC RAY INTERACTION

$\bar{d}$

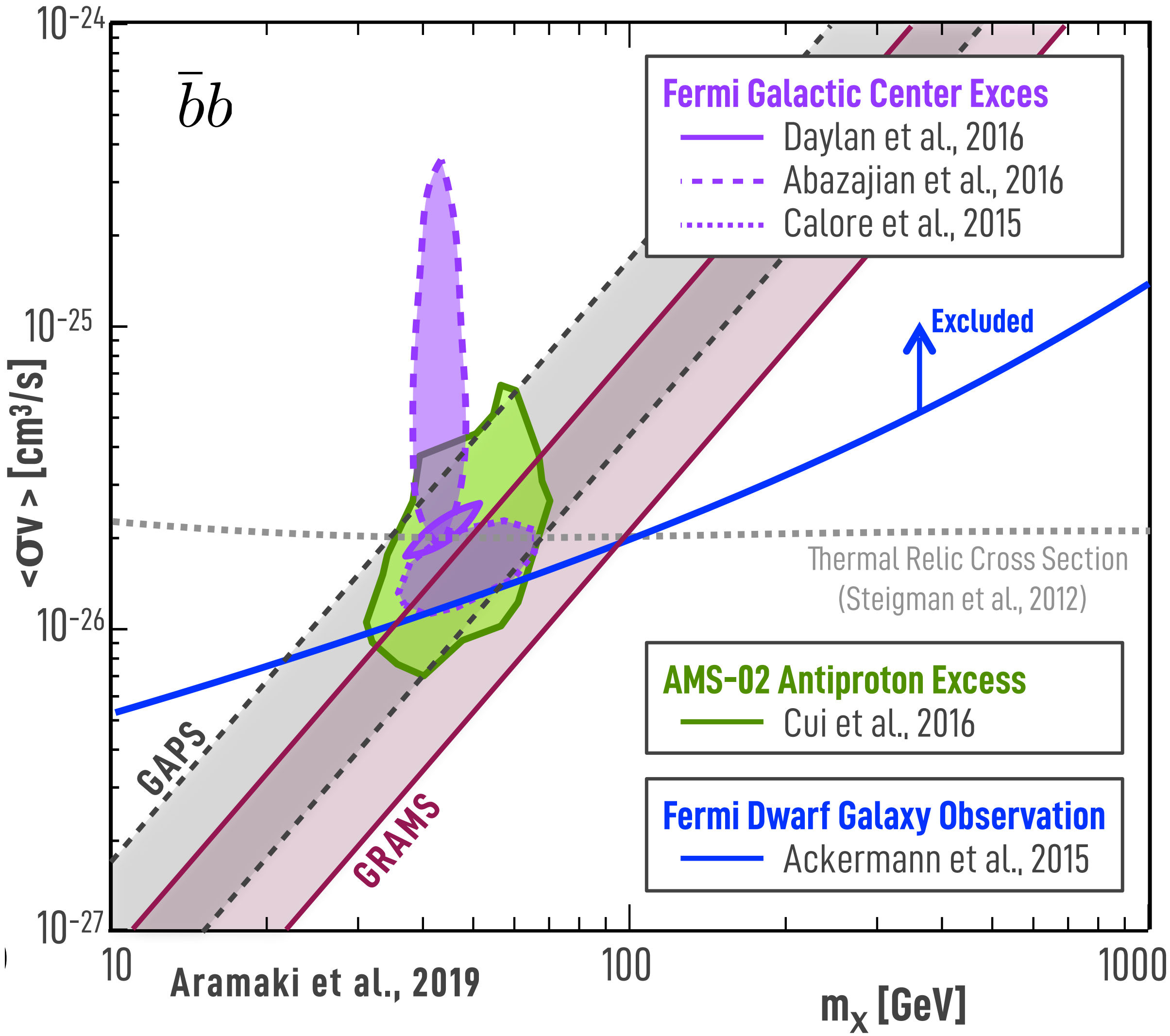
p (CR) +H (ISM) $\rightarrow$ p + H + p + n + $\bar{p}$ + $\bar{n}$

**GAPS FIRST SCIENCE FLIGHT IS SCHEDULED FROM ANTARCTIC IN 2021**

**GRAMS: NEXT-GENERATION EXPERIMENT**

# GRAMS SENSITIVITY IN DM PARAMETER SPACE






Aramaki et al., 2019

**GRAMS COULD UNIQUELY INVESTIGATE FERMI GCE, AMS-02 ANTIPROTON EXCESS WITH ESSENTIALLY BACKGROUND-FREE ANTIDEUTRON MEASUREMENTS**

# TIMESCALE AND GRAMS COLLABORATION



- Detector R&D for proof of concept: in a few years
- First Balloon Flight: in 5-10 years
- Detector design upgrade: in 10 years
- Satellite mission: in > 10 years

GRAMS Concept Paper: Aramaki+, 2019

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Yuto Ichinohe

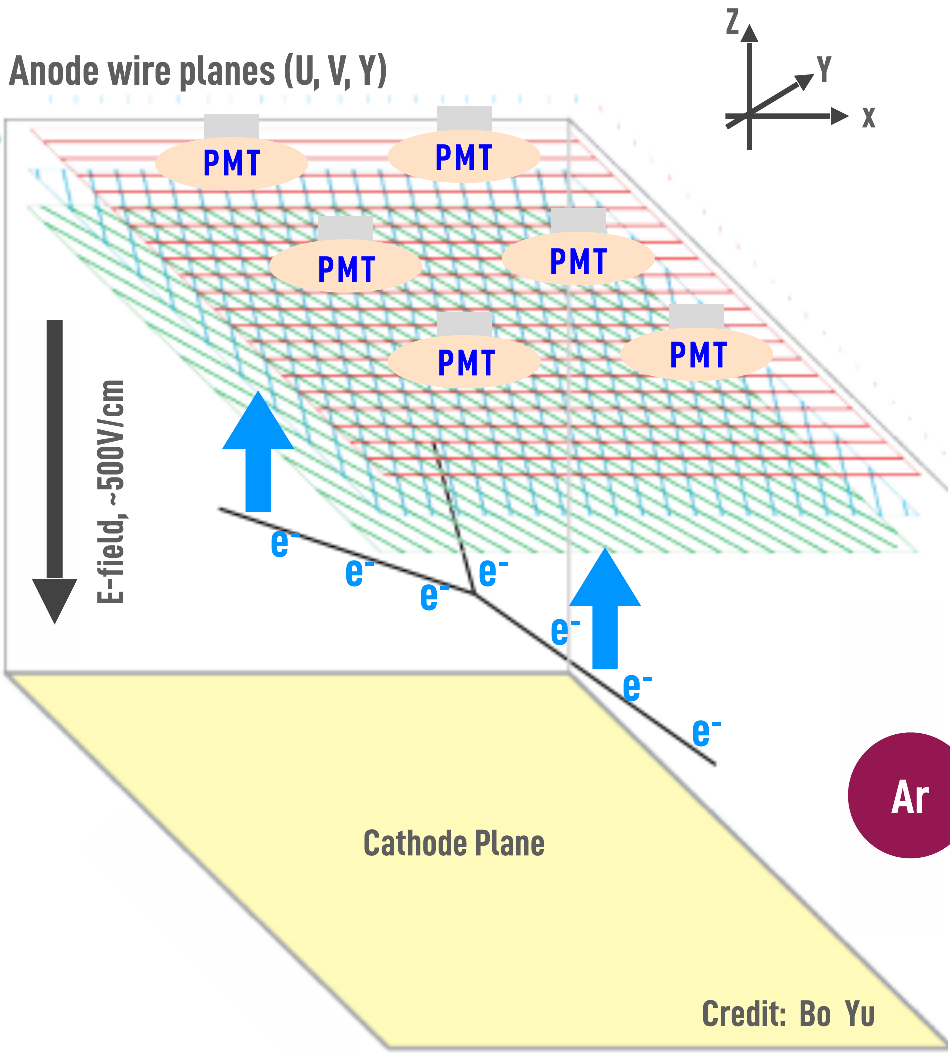
**Academia Sinica**

Meng-Ru Wu

Possible Gamma-Ray Detection from Galactic NSM Remnants: Wu+, 2019

# BACKUP

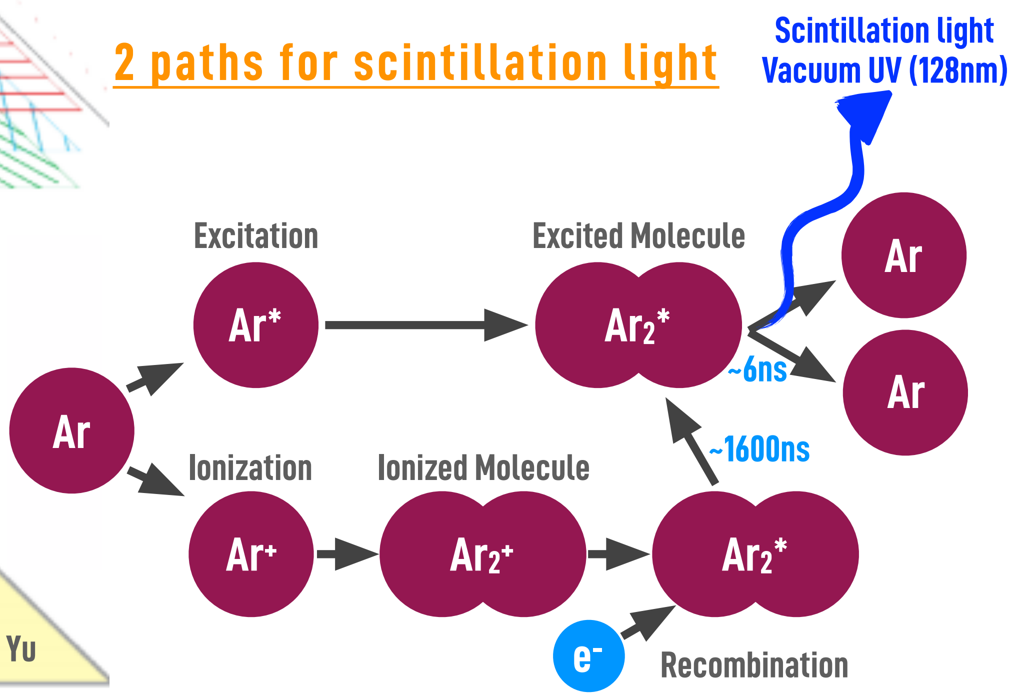
## LArTPC DETECTORS HAVE BEEN WELL-STUDIED AND WIDELY-USED FOR LARGE-SCALE NEUTRINO/DARK MATTER SEARCH EXPERIMENTS




### 3D particle tracking in LArTPC

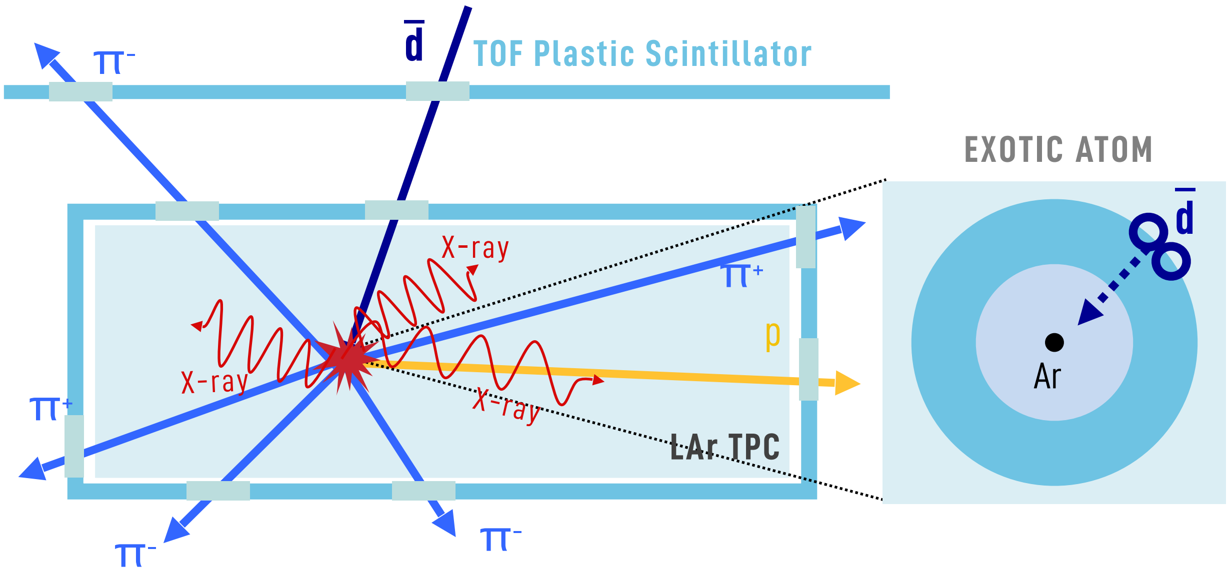
- Measure both scintillation light and ionization electrons
- Scintillation light is detected in PMTs
- Ionization electrons drift and are collected in anode wire planes

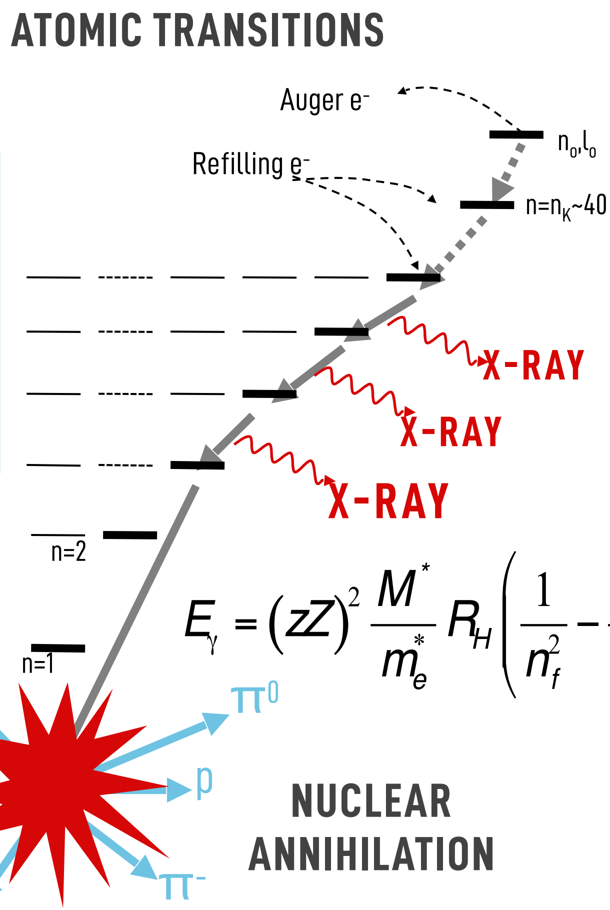
### 2 paths for scintillation light



# GRAMS ANTIMATTER DETECTION CONCEPT

## MEASURE ATOMIC X-RAYS AND ANNIHILATION PRODUCTS




$$E_\gamma = (zZ)^2 \frac{M^*}{m_e^*} R_H \left( \frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

A time of flight (TOF) system tags candidate events and records velocity

The antiparticle slows down & stops, forming an excited exotic atom

De-excitation X-rays provide signature

Annihilation products provide additional background suppression

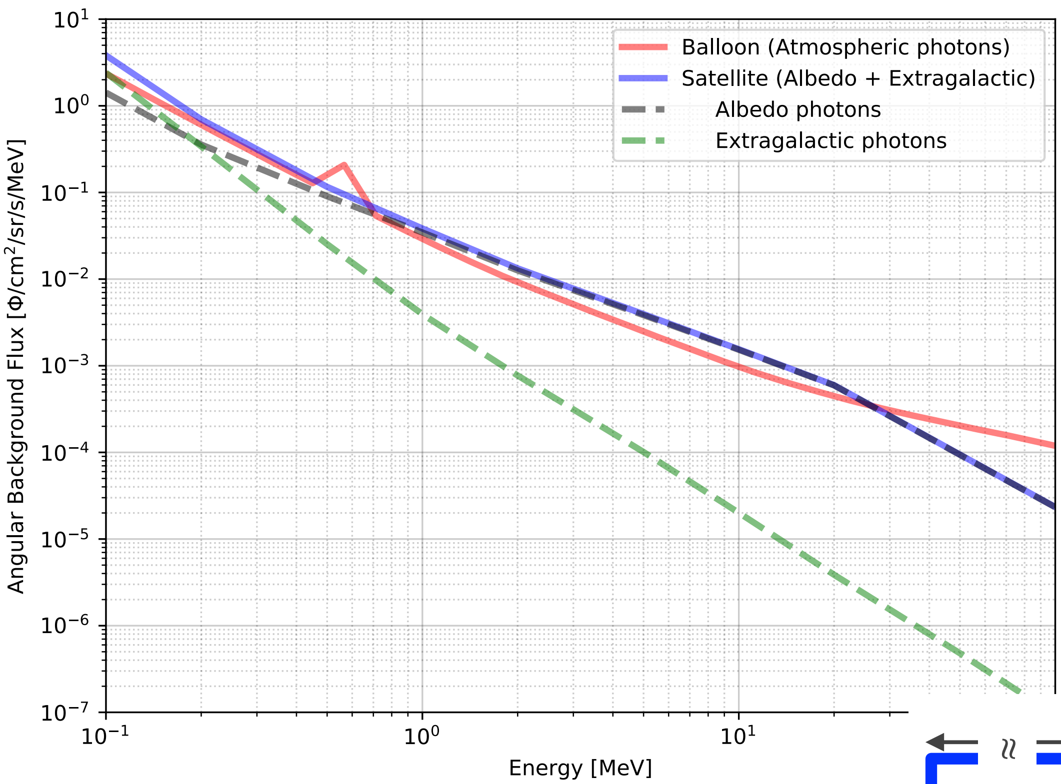
Aramaki et al., 2013

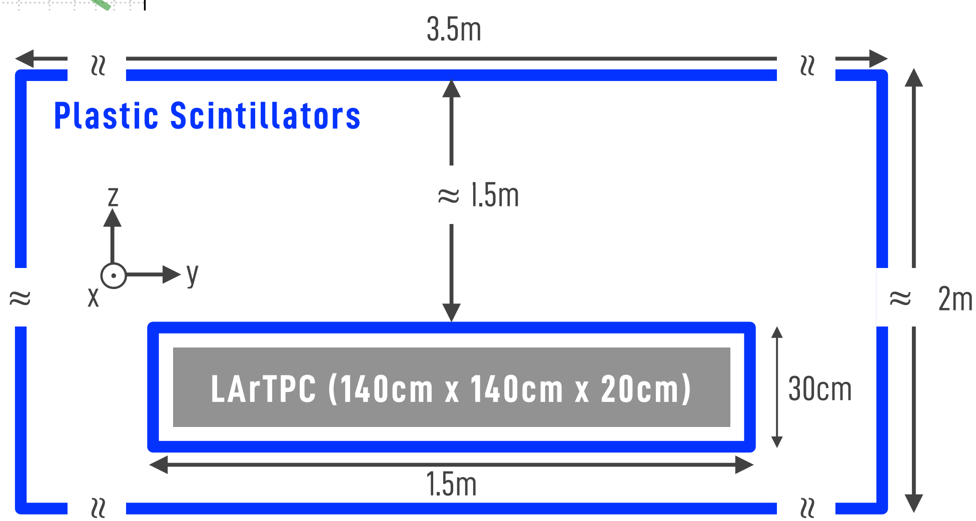
Concept proven with accelerator beam test

Cascade model developed for X-ray yields

# BACKGROUND AND DETECTOR DESIGN





# ANGULAR RESOLUTION AND EFFECTIVE AREA