# Understanding nucleosynthesis by Gamma-Ray and AntiMatter Survey (GRAMS)

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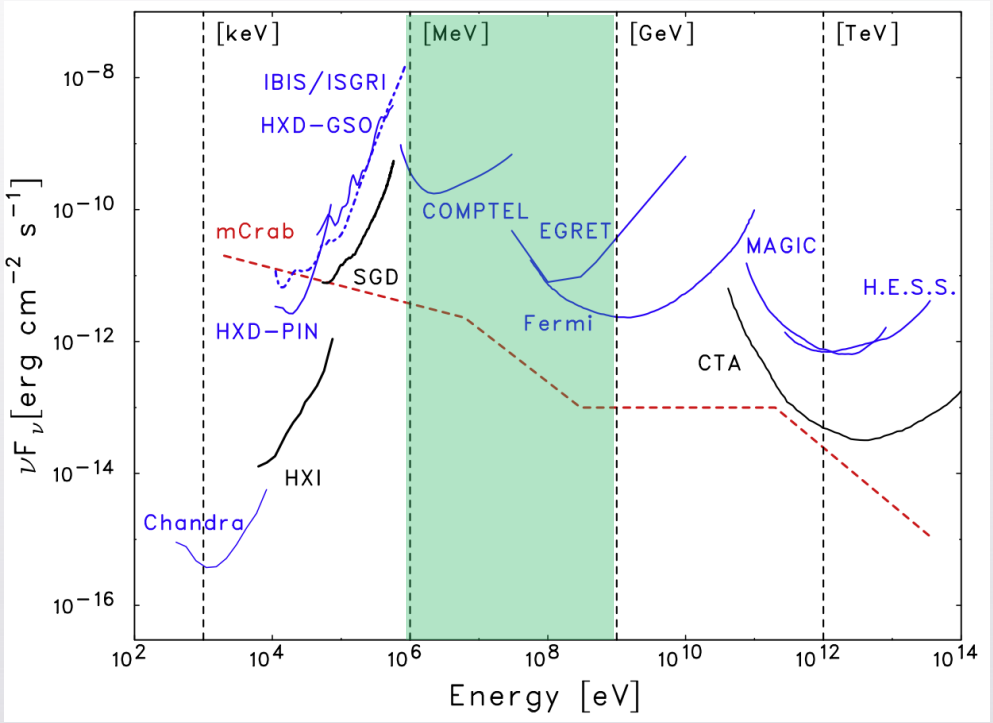
# Introduction

- *r*-process: main production process of heavy elements
- The direct gamma-ray line observation leads us to make a quantitative study of nucleosynthesis but has not been made yet.
- Due to the lack of the sensitivity around the MeV range ("MeV Gap")

->**New MeV gamma-ray detectors with better sensitivity are required.**

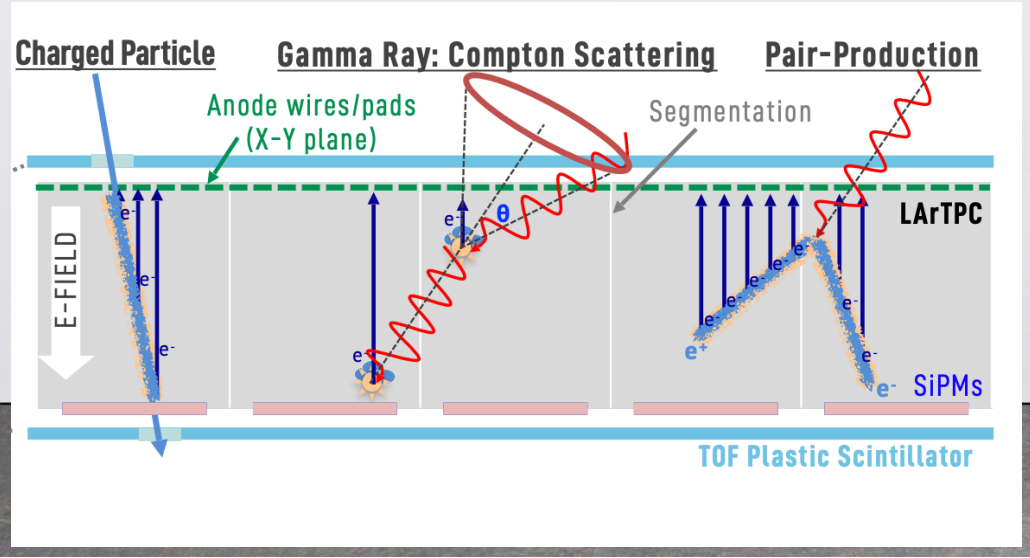



Sensitivity around MeV band (Takahashi+13)

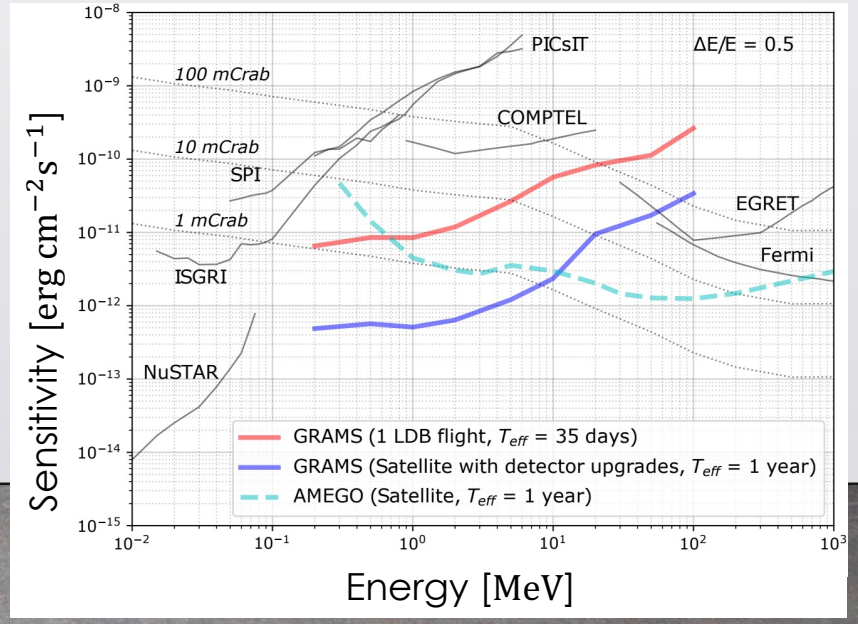
# Gamma-Ray and AntiMatter Survey (GRAMS)

- **Japan-US mission for a balloon-borne / satellite MeV gamma-ray detector,** aiming to launch in the late 2020s or 2030s.
- Liquid Argon time-projection chamber(LArTPC) is used as Compton camera, which makes it easy to increase the volume of the detector
  ->**high sensitivity**

GRAMS detection concept (Aramaki+20)

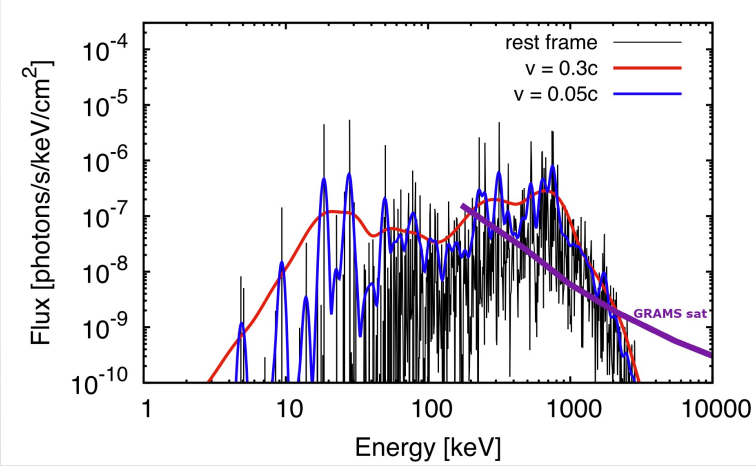



Sensitivity around MeV band(Aramaki+20)



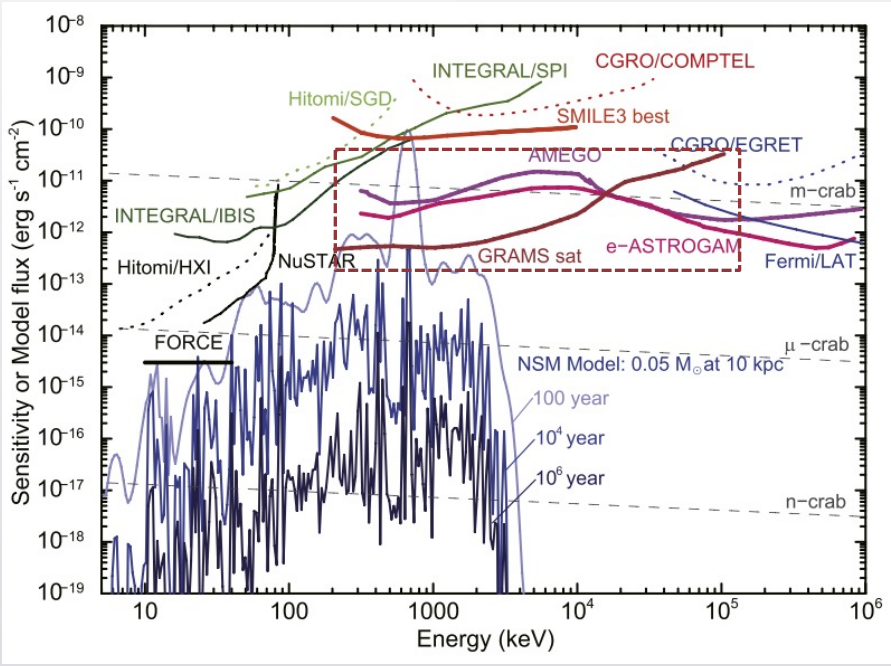
# Nuclear gamma-ray observed by GRAMS

- Neutron star merger (NSM) could be observed
- This gives us the further information about the NSM.




Sensitivity of GRAMS (purple, exposure: 1 day) and spectral model 1 day after NSM (Hotokezaka+16, edited)

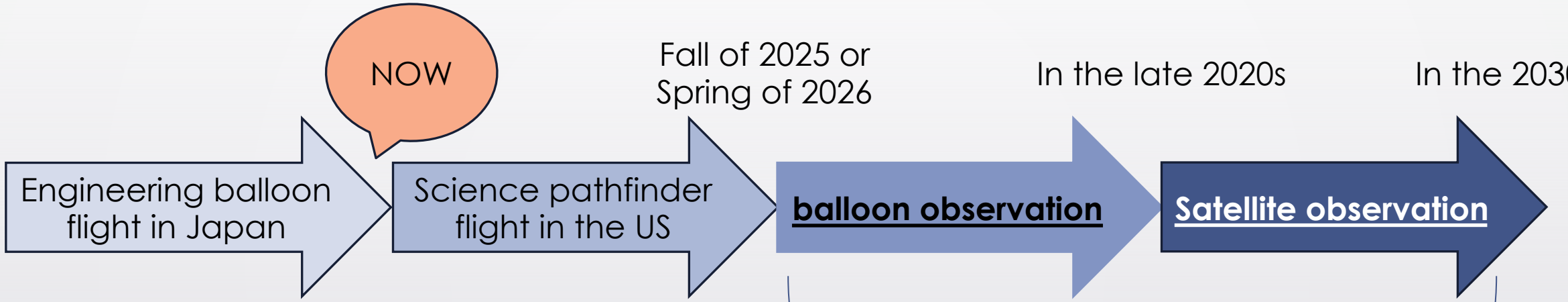
- The neutron star merger remnant could be observed.
- We could estimate or constrain the rate of *r*-process.




Sensitivity and nuclear gamma-ray model (Terada+22)

GRAMS is an all-sky monitor -> **We could detect gamma-ray from many objects simultaneously**

# Status and Plan of GRAMS




- Safe LAr handling
- Confirm the proper operation of LArTPC
- Obtain environmental radiation at the balloon altitude

- Taking science data of MeV gamma-ray from the space using a prototype detector
- This flight will be funded by NASA

# The engineering balloon flight in Japan

- We performed an engineering balloon flight in this July.
- We have mainly 3 successes
  - Confirmed safe handling of LAr at the balloon altitude **(First time in the world).**
  - Verified the proper operation of LArTPC detector **(First time in the world).**
  - Obtained the environmental radiation data at the balloon altitude.

The moment to launch the balloon

# Conclusion

- The direct detection of nuclear gamma rays leads us to the further study of nucleosynthesis.
- **GRAMS is a next-generation MeV gamma-ray observatory with better sensitivity** than current instruments aiming at a balloon-borne mission in the late 2020s and a satellite mission in the 2030s.
- With such good sensitivity of GRAMS, we could observe the neutron star merger remnants in the galaxy, which can estimate or constrain the rate of *r*-process.
- **We successfully conducted an engineering balloon flight in Japan** and operated an LArTPC in the sky for the first time.