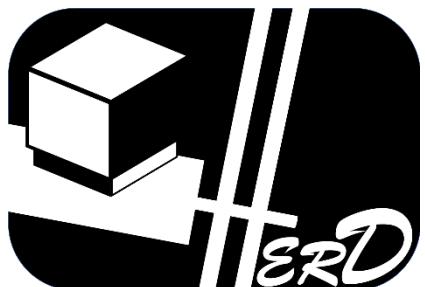


# Gamma-ray performance of the HERD trigger system

Luis Fariña on behalf of the HERD Collaboration

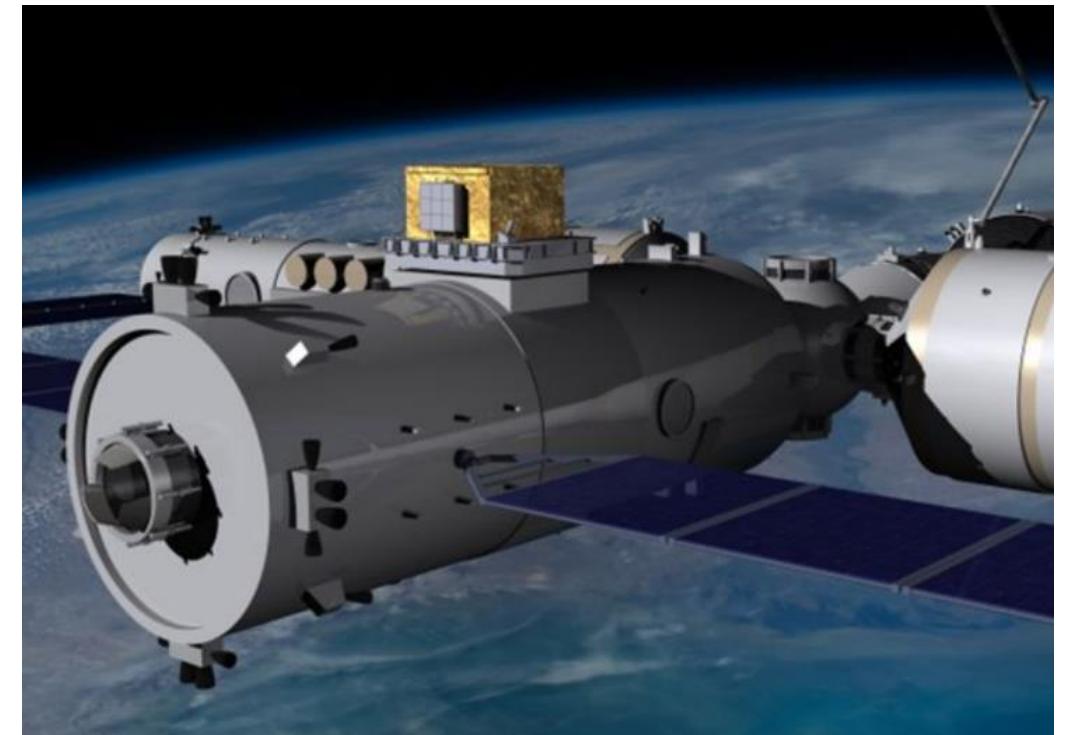
IFAE-BIST



# Introduction to HERD

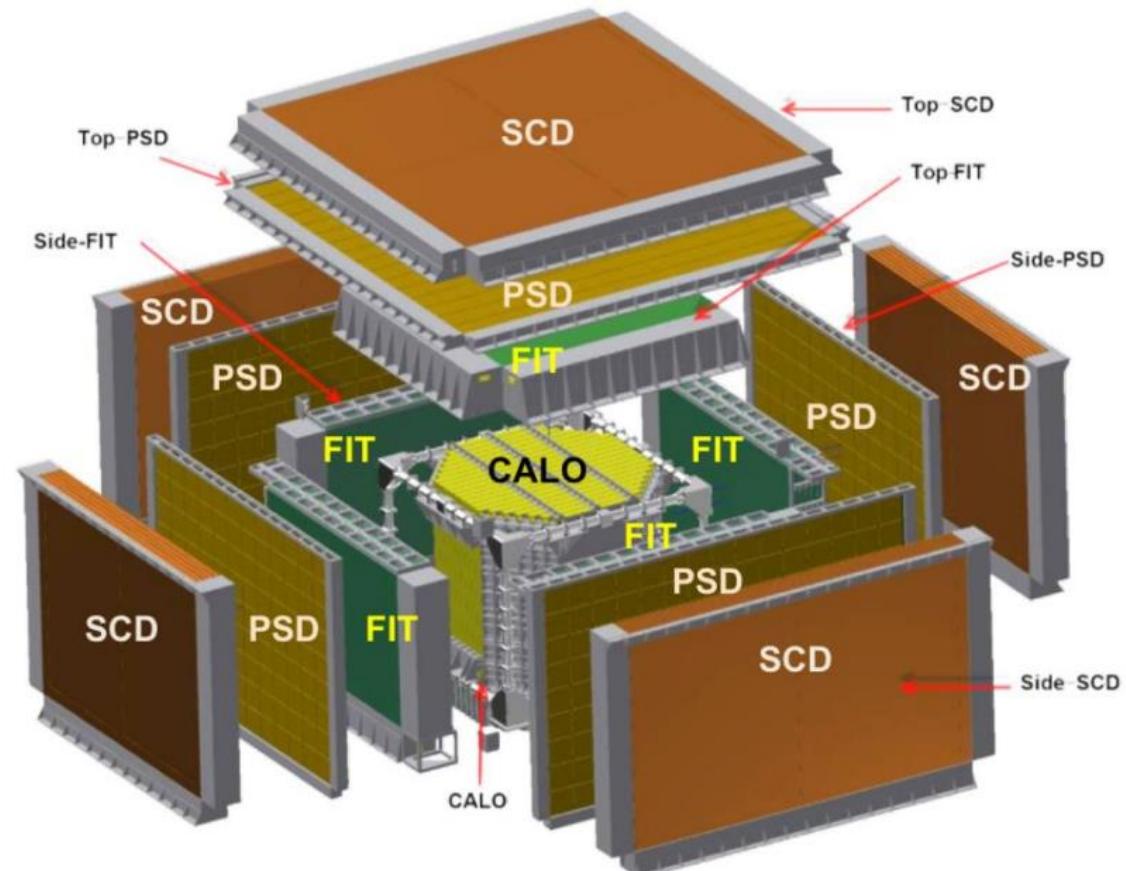
- Launch: 2027
- Aboard the CSS
- Detector of cosmic- and gamma-rays
- Objectives:
  - cosmic ray flux up to the knee region
  - indirect signal of DM
  - monitor the gamma-ray sky

$\gamma$ energy range	Energy resolution	PSF
> 100 MeV	1% @ 200 GeV	~ 0.1 deg @ 10 GeV



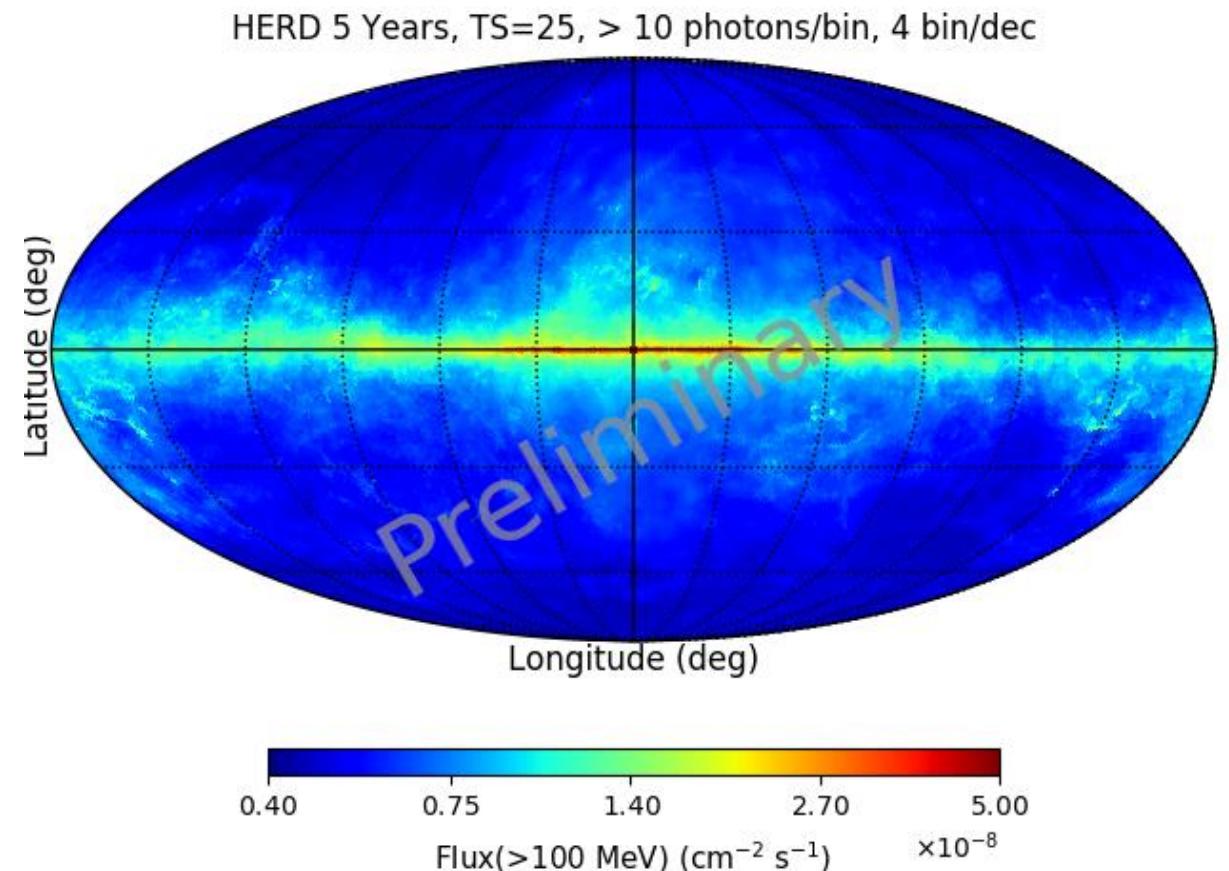
# HERD: subdetectors

Subdetector	Use	Technology
CALO	Energy reconstruction	LYSO
FIT	Track reconstruction	Scintillating fibers
PSD	Anticoincidence veto	Scintillating tiles
SCD	Charge reconstruction	Silicon strips
TRD	Calibration	TRD



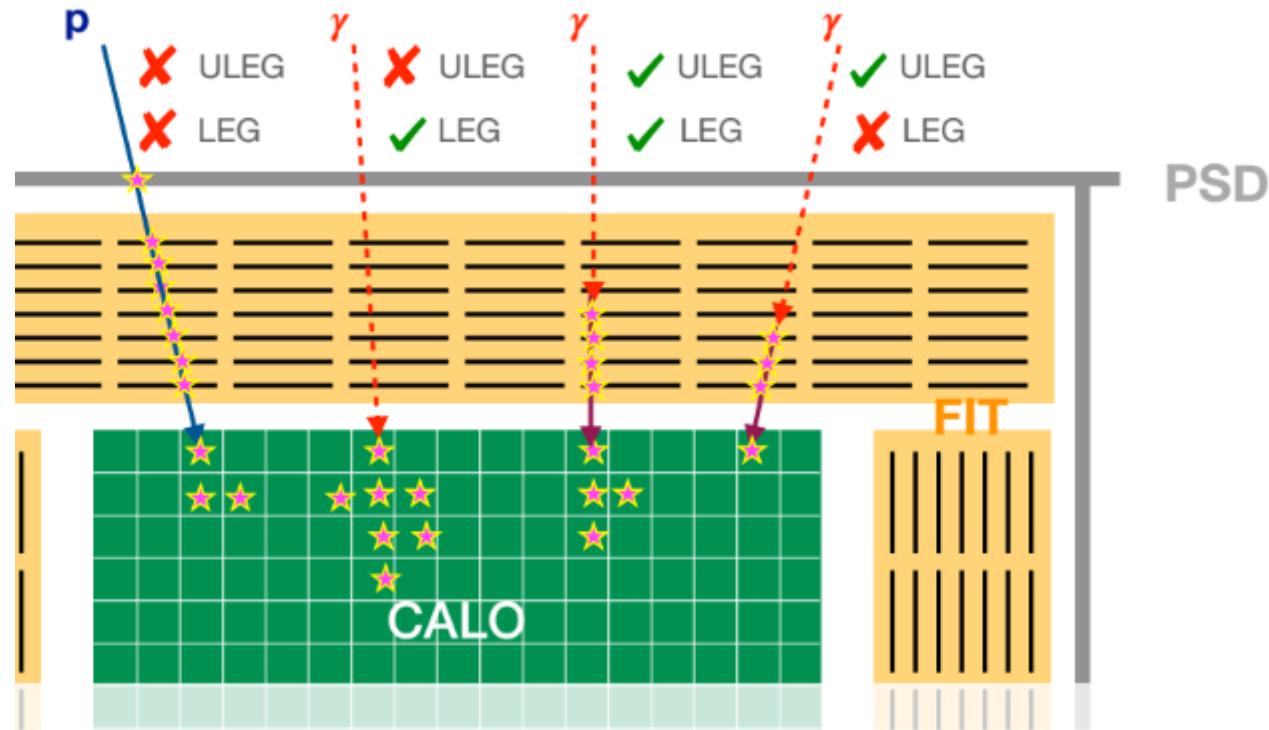
# Why gamma-rays with HERD?

- All-sky monitoring ( $2\pi$  FOV)
- Synergy with ground observatories:  
CTA, LHAASO, ...
- Concurrent observation with  
upcoming GW detector upgrades



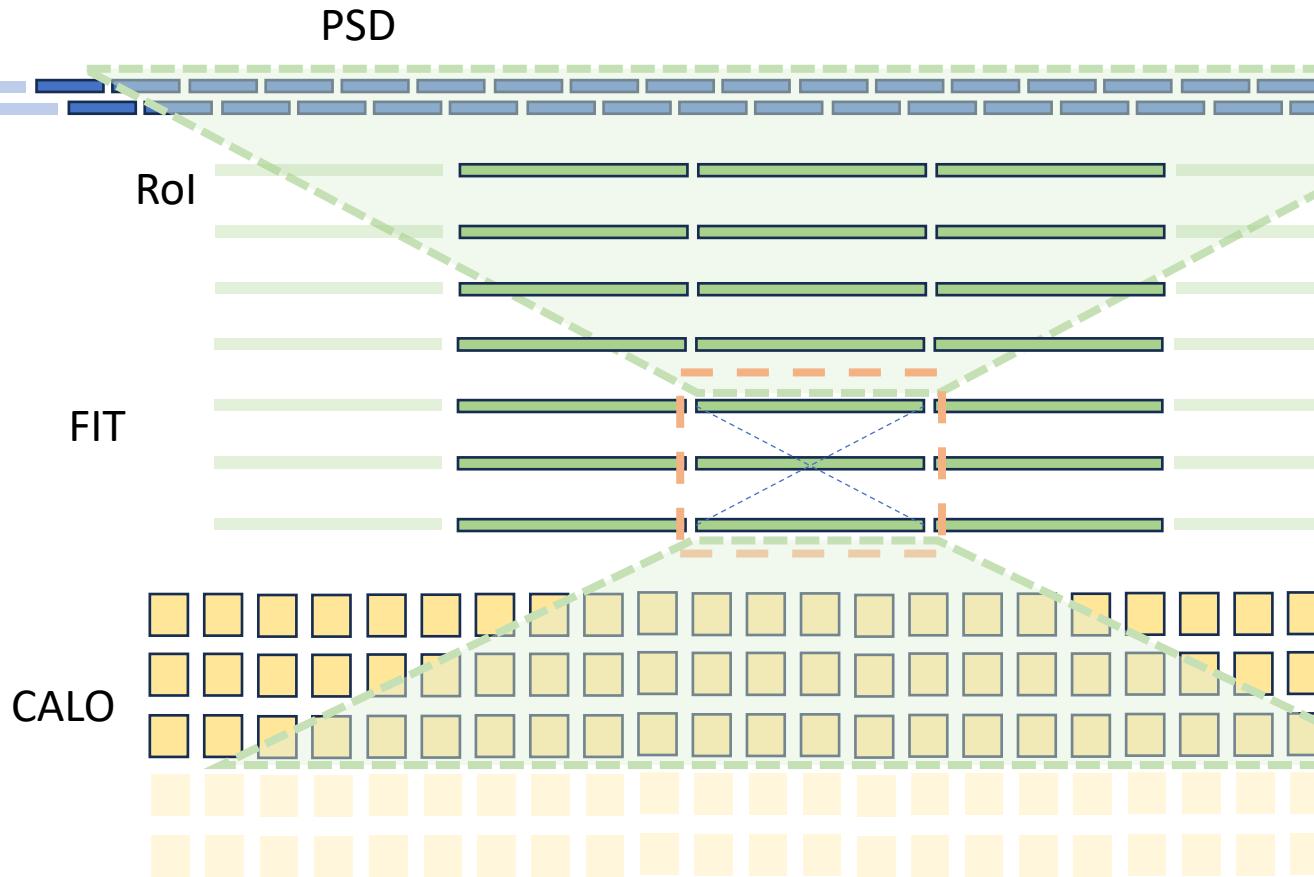
# The LEG and HE triggers

- HE (high energy):
  - $E_{CALO} > 15 \text{ GeV}$
- LEG (low energy gamma):
  - Main condition:  $E_{CALO} \gtrsim 500 \text{ MeV}^*$   
\*PMT+IsCMOS CALO threshold
  - No veto in PSD region
- ...and below these thresholds?
  - ULEG: trigger from the FIT

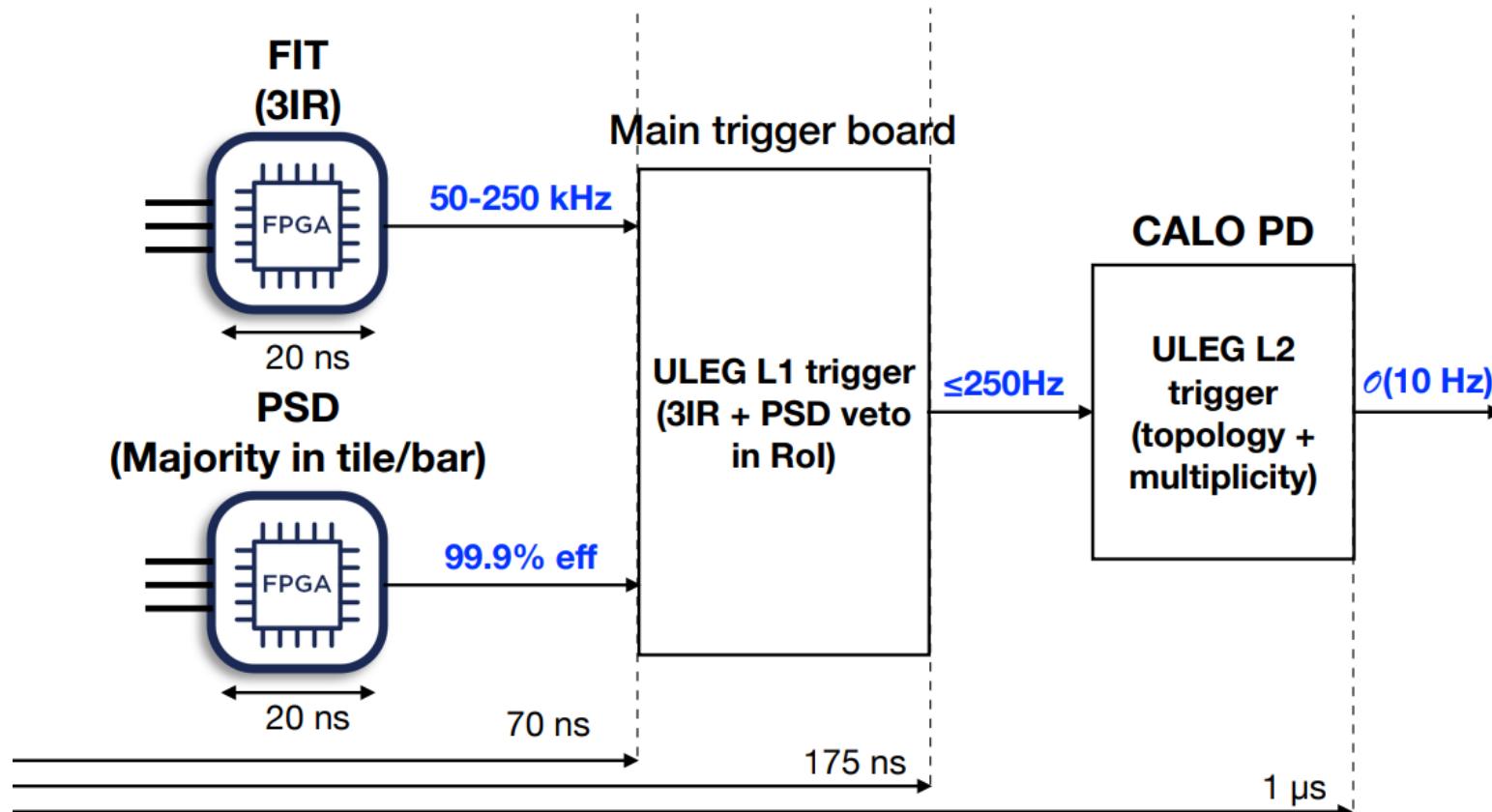


# ULEG elements and levels

- L0: 3IR in FIT mats; veto in PSD
- L1: 3IR + no veto in PSD
  - Look for veto in a RoI
- L2: L1 + threshold in CALO
  - Deposition > 100 MeV



# ULEG HW implementation



- Baseline option: 5 x FIT & PSD trigger signals (1 per sector)
- To be studied: finer PSD RoI (3, 5, ... RoI/sector) w/ corresponding FIT segmentation
- Adjustable CALO PD threshold to control final rates

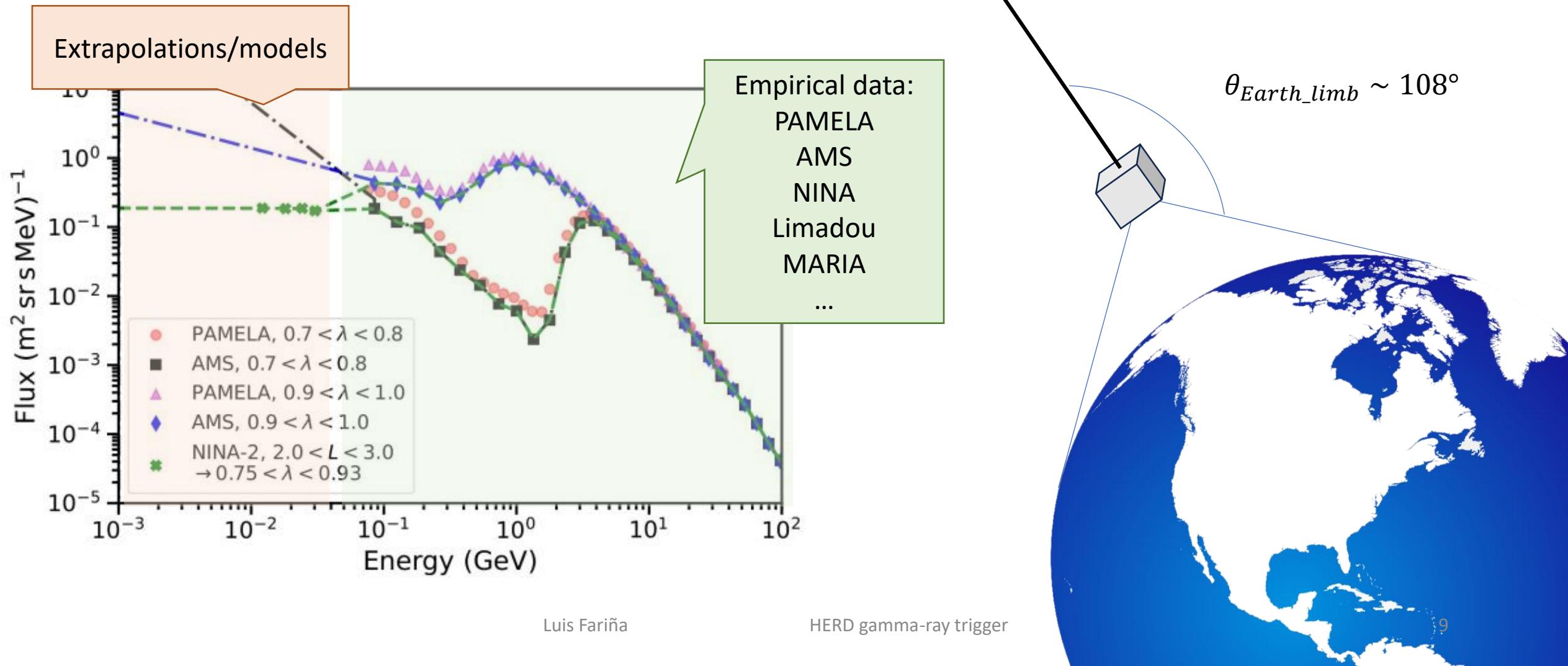
# Trigger simulations

- Need to understand:
  - Occupancy in the electronics (element activation rates)
  - Trigger rates at each level
  - Efficiency on gamma-rays
  - Diagnose any shortcomings in the design
- Monte Carlo study:
  - Simulation suite available in HerdSoftware

$$\frac{dN_{sel}}{dt} = \int \frac{d\Phi(E, \theta, \phi)}{d\Omega dE} A_{eff}(E, \theta, \phi)$$

$$A_{eff}(E, \theta, \phi) = S_{gen}(\theta, \phi) \frac{N_{sel}(E, \theta, \phi)}{N_{gen}(E, \theta, \phi)}$$

# Particle fluxes in HERD's environment

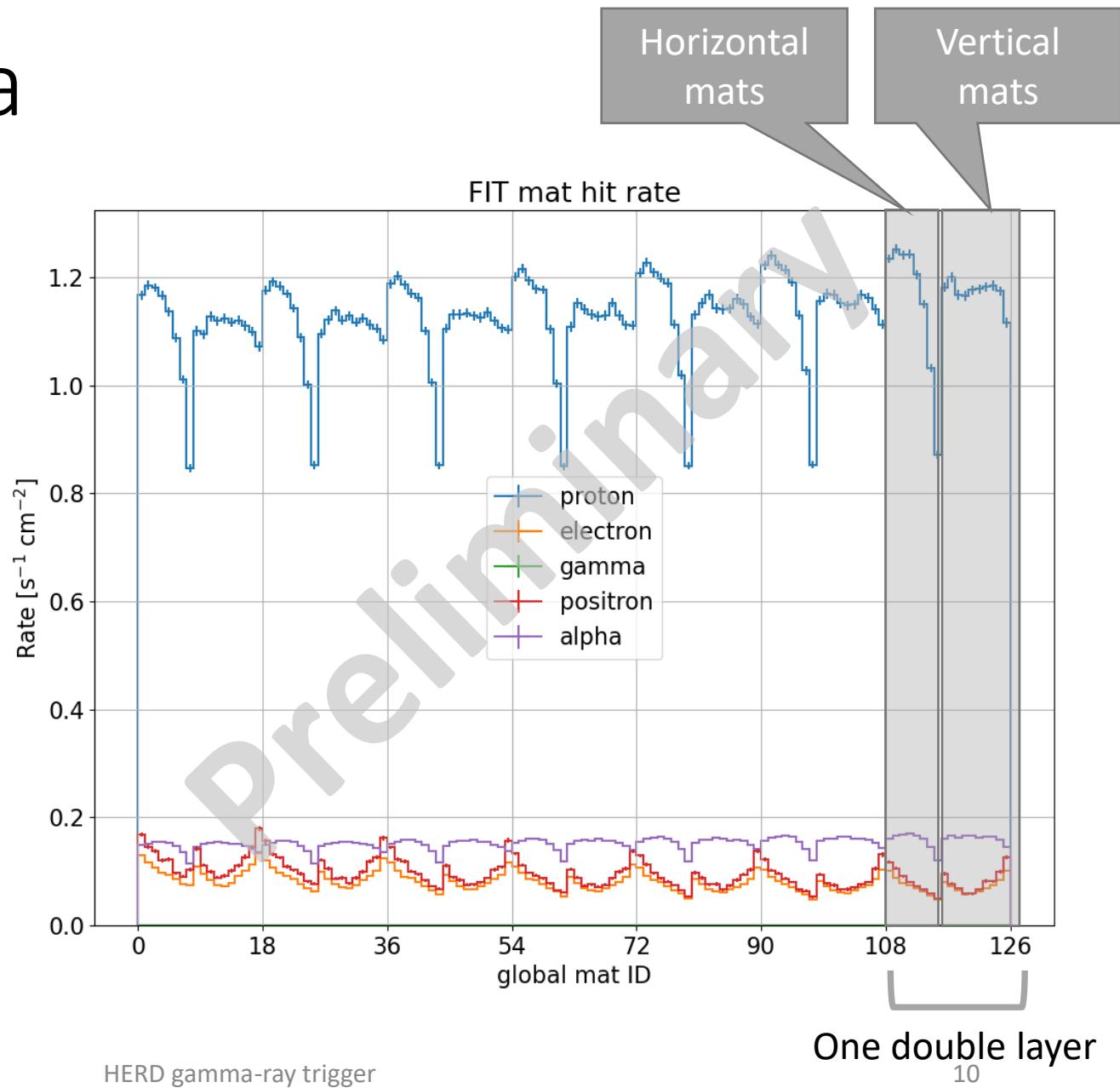
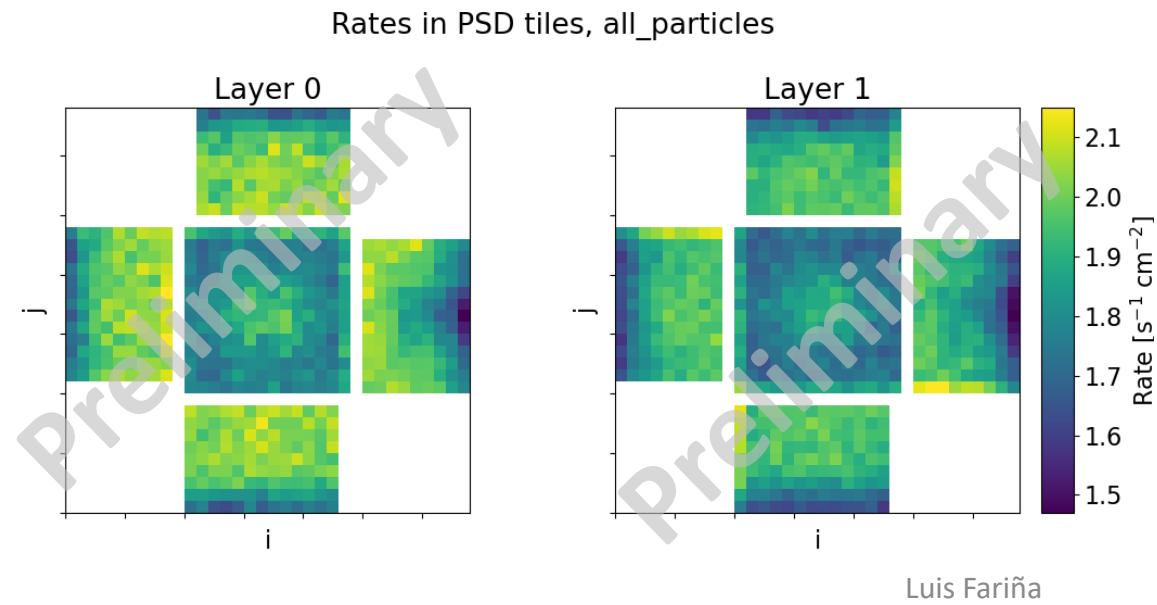


# Rates per surface area

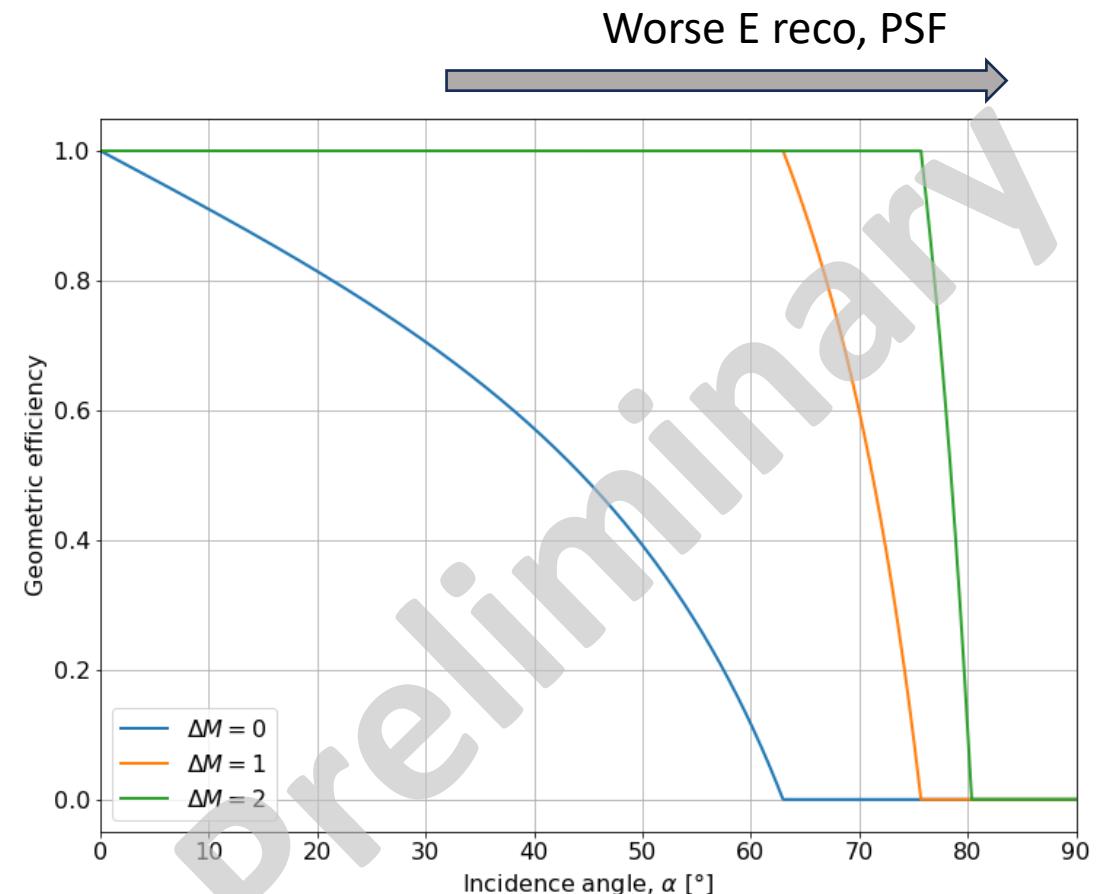
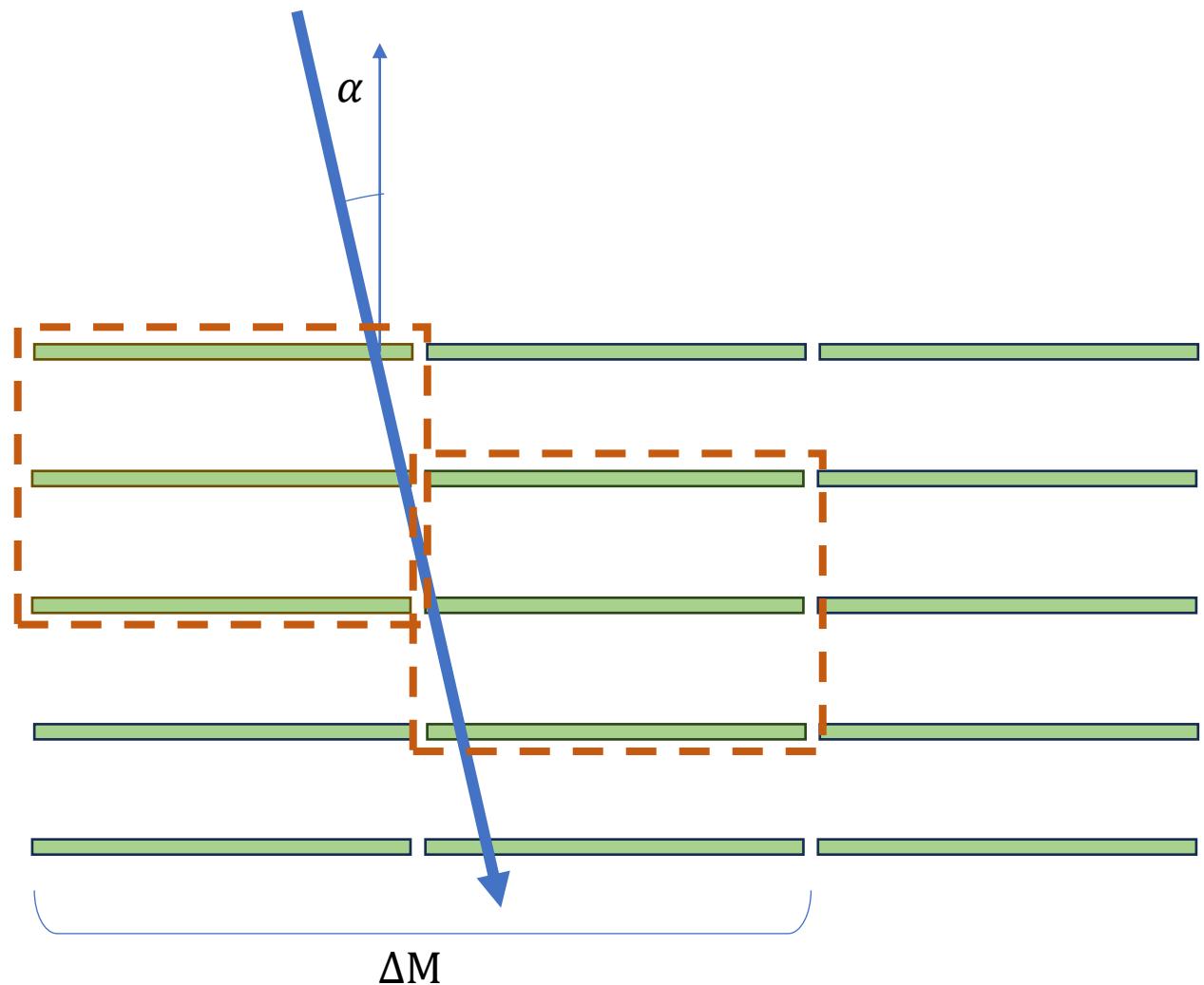
MAX RATES at high  $\Theta$ :

FIT:  $\sim 1.7 - 3.5 \text{ cm}^{-2} \text{ s}^{-1}$

PSD:  $\sim 2.2 - 5.2 \text{ cm}^{-2} \text{ s}^{-1}$



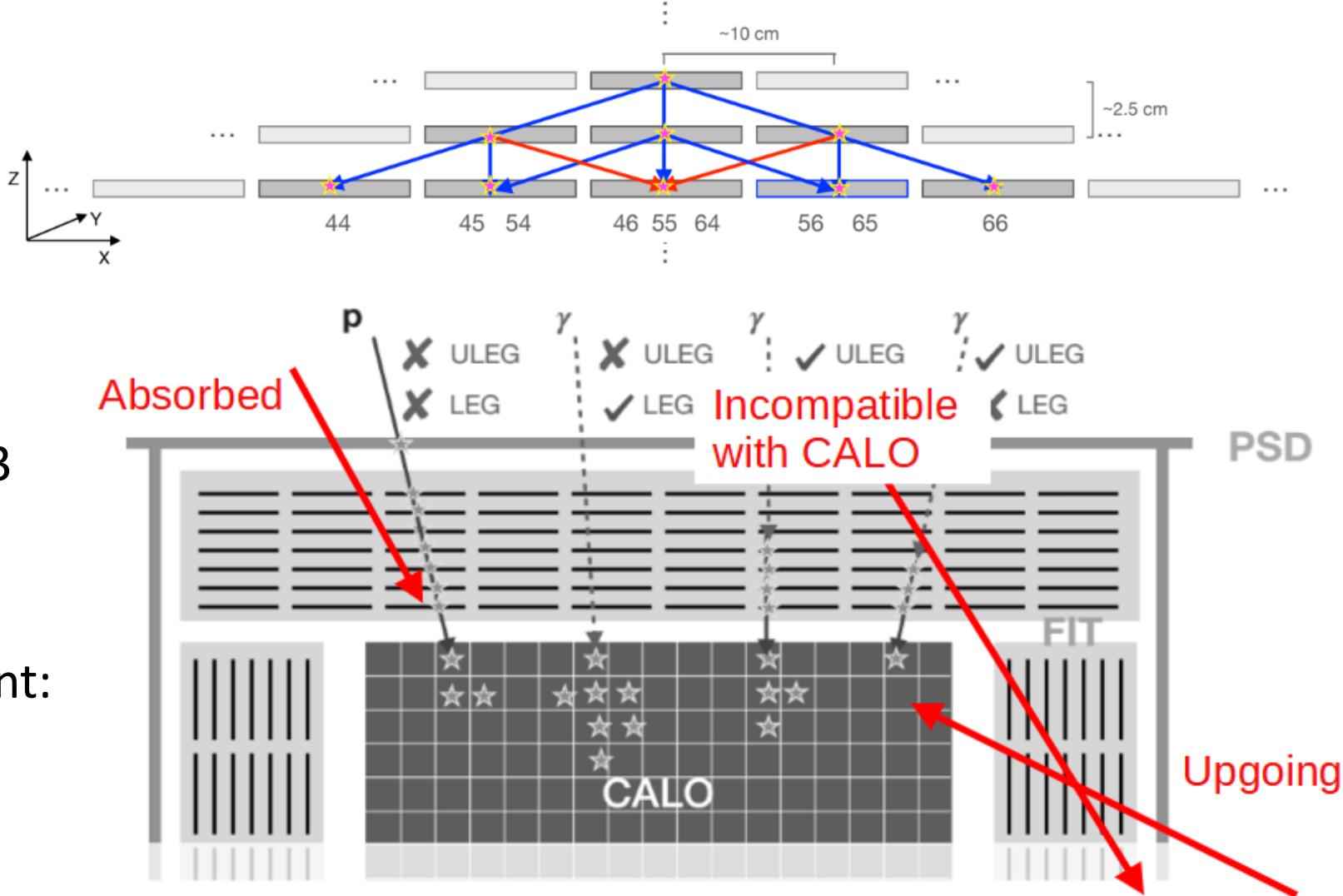
# 3IR design



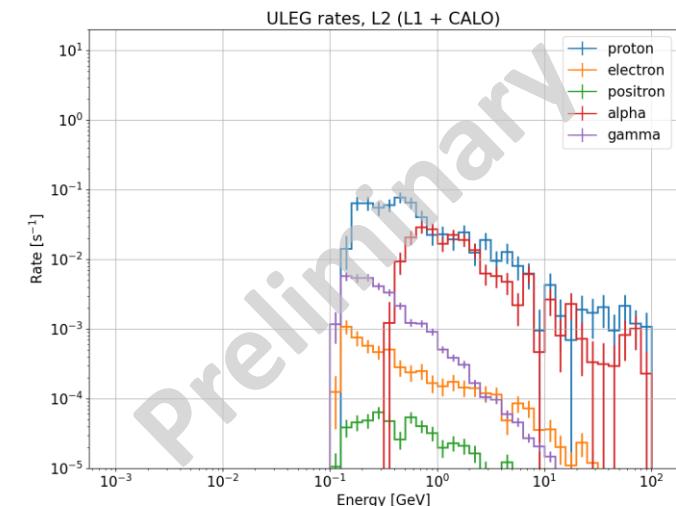
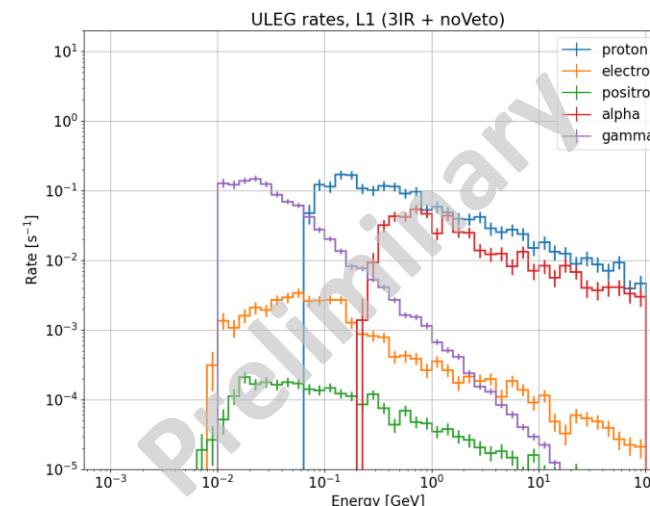
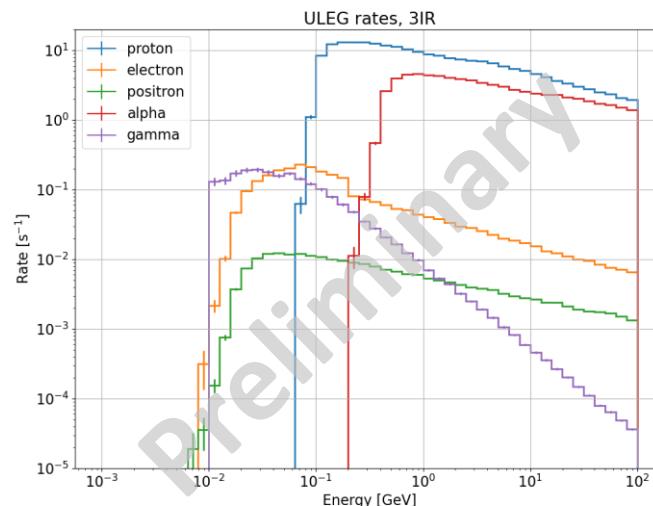
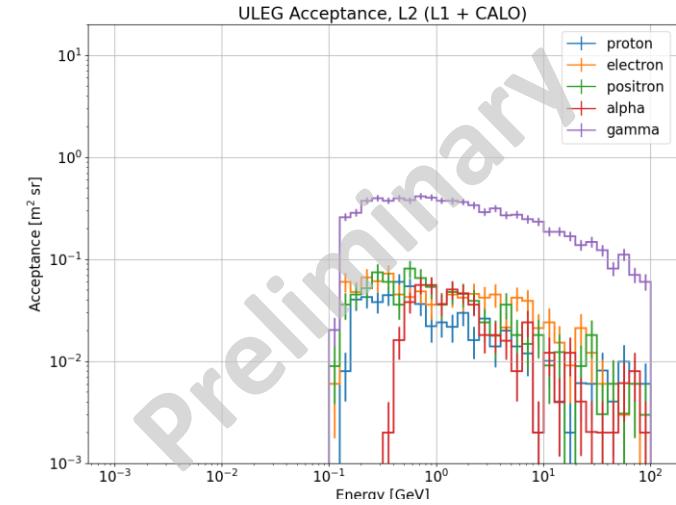
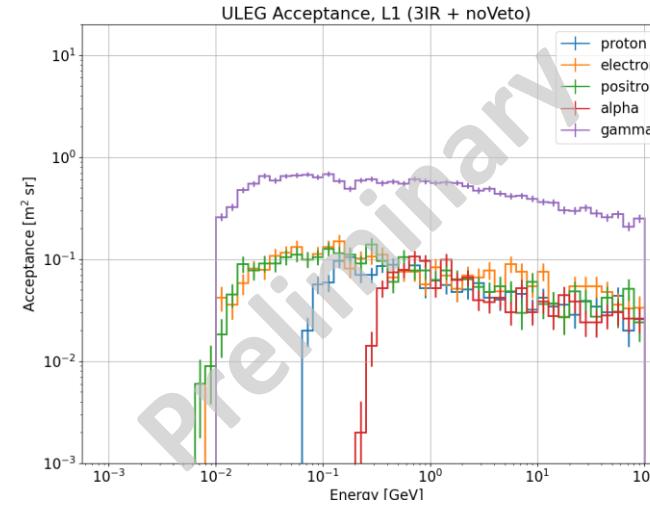
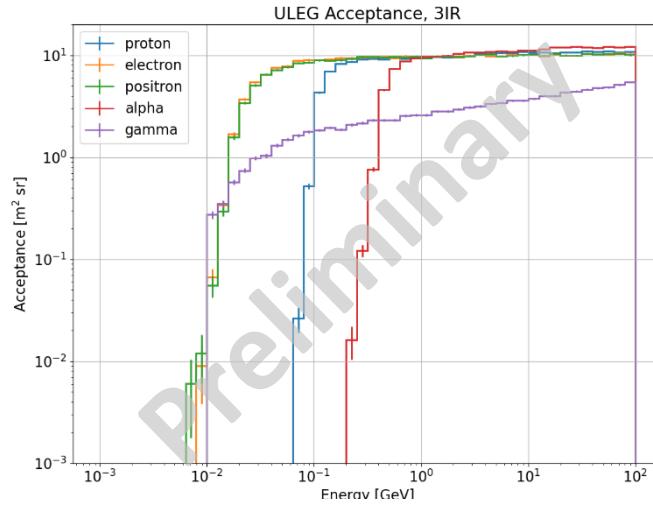
- Can only get so far by instrumenting more layers
- Look at the nearest neighbors to increase efficiency

# 3IR design

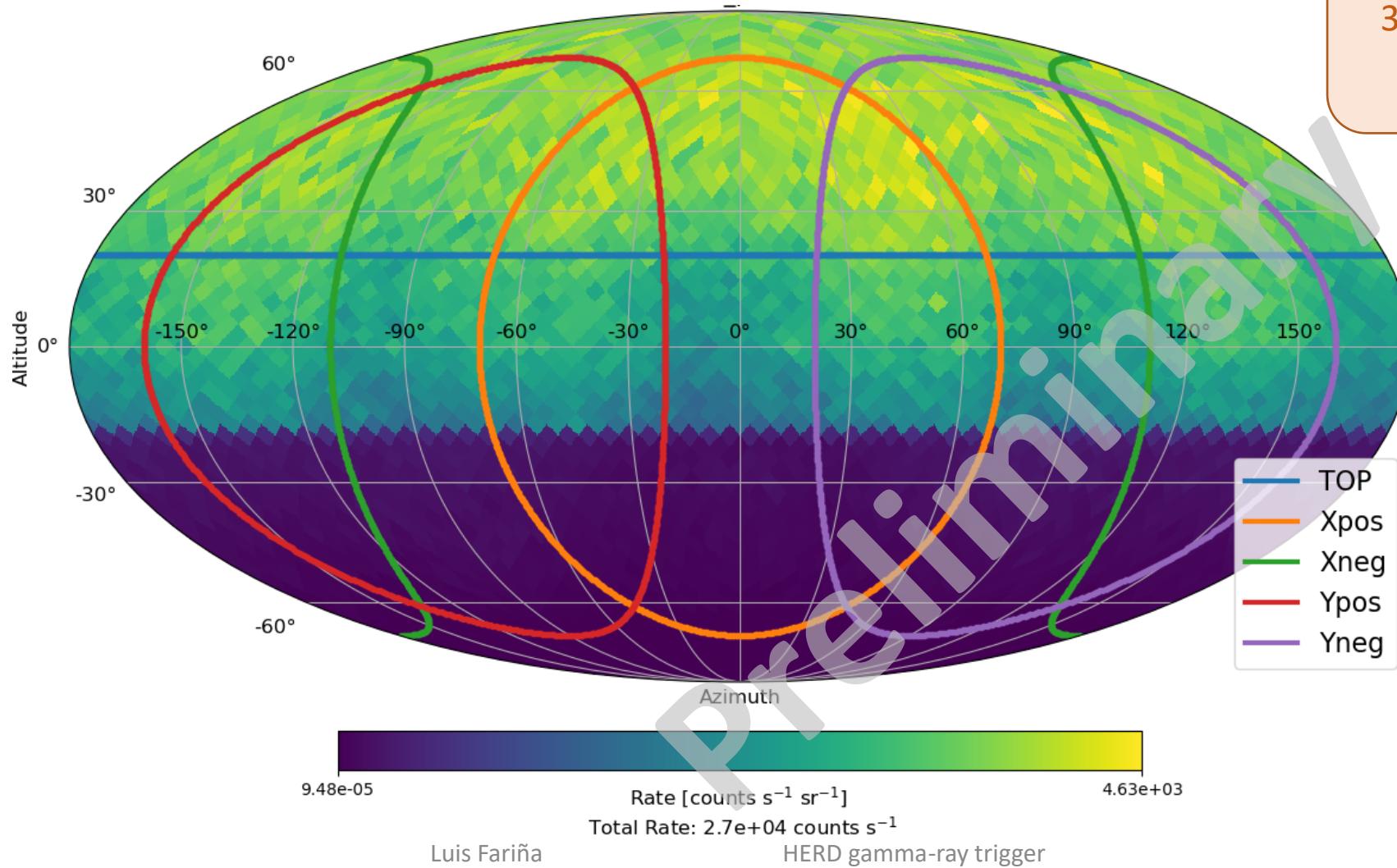
- Instrument only deepest 3 layers
- Remove patterns that point:
  - Away from the CALO
  - Upwards



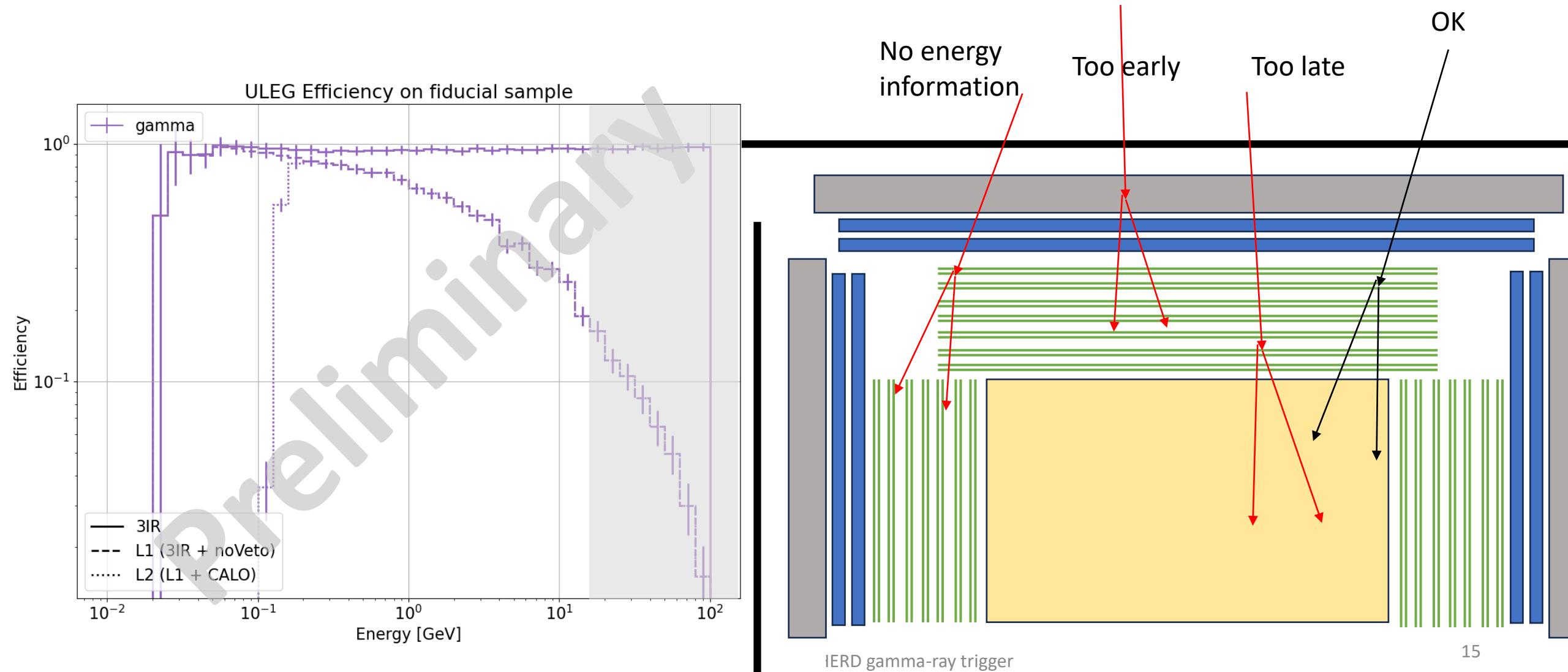
# ULEG acceptance and trigger rates



# Total 3IR rate for all species

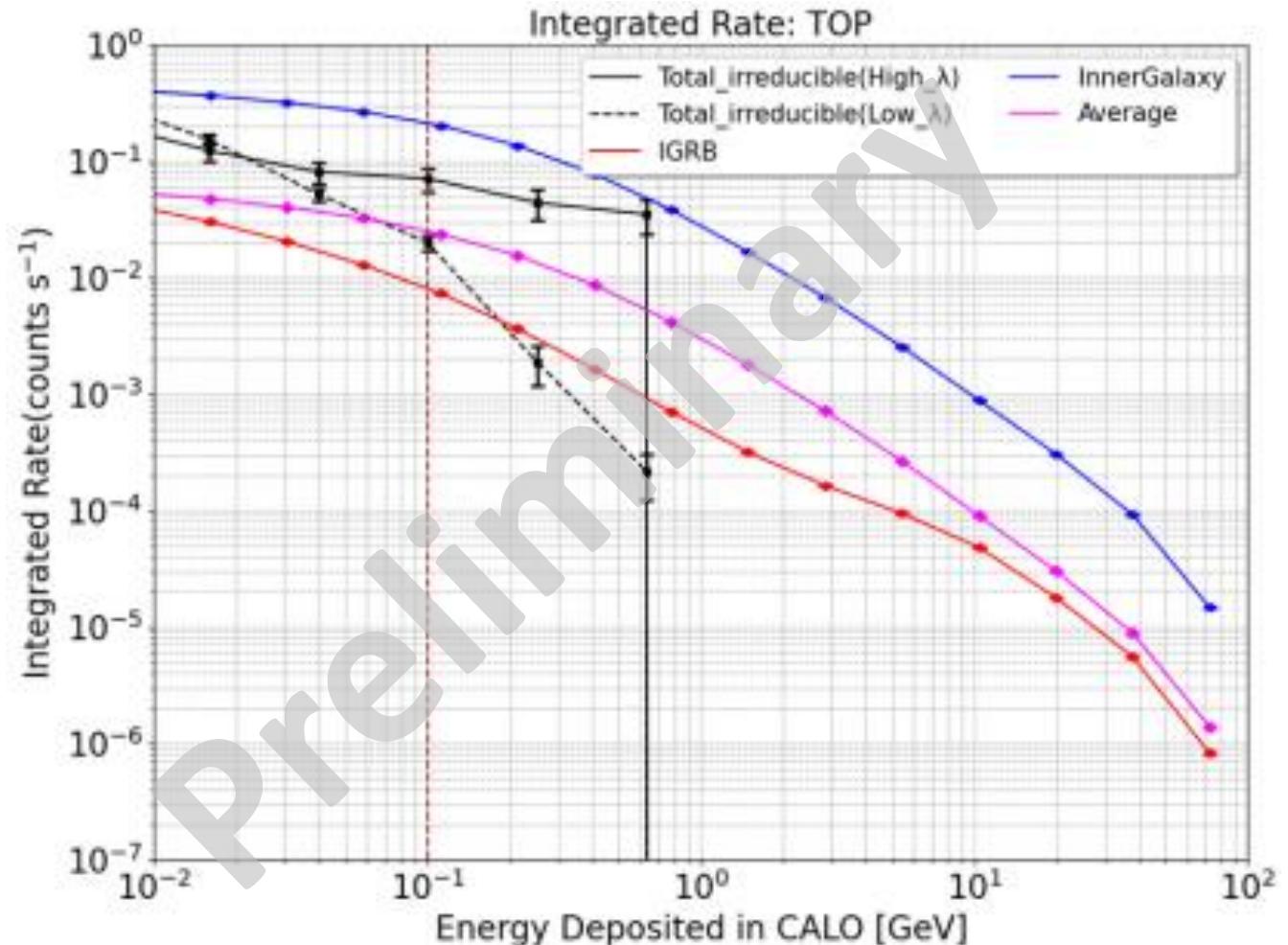
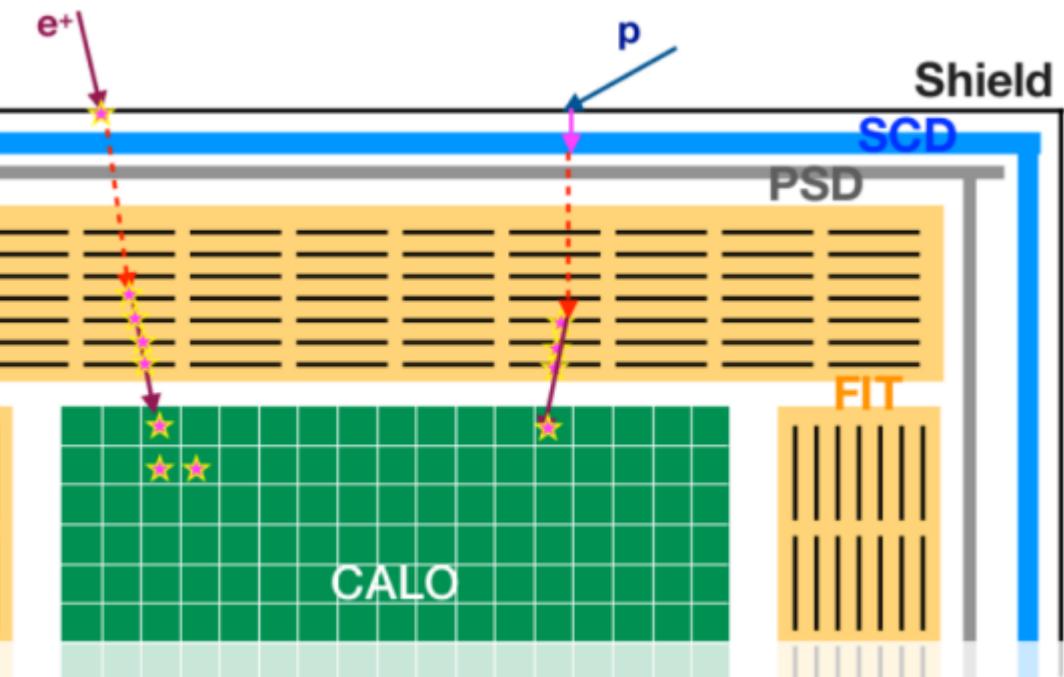


# Efficiency on fiducial gamma-ray sample

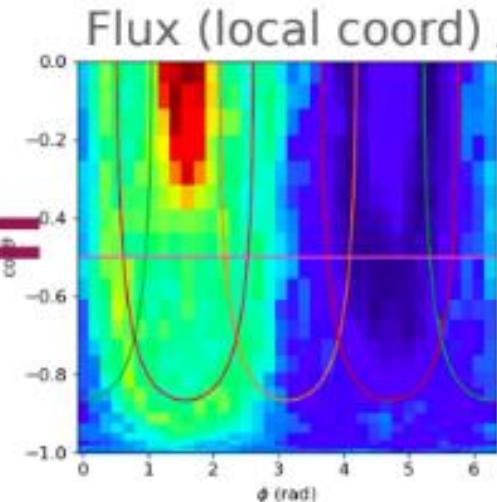
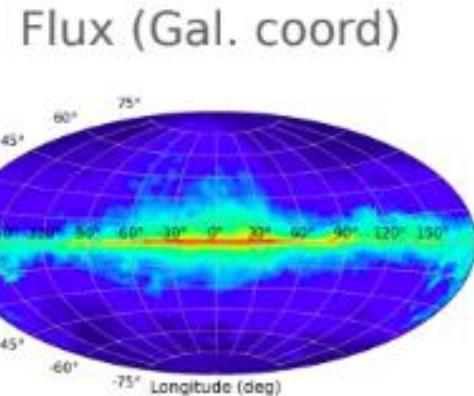
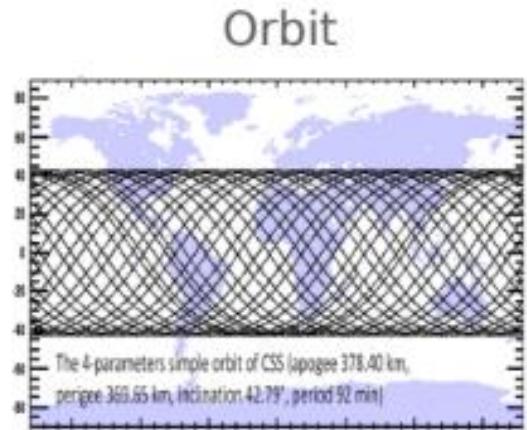


# Irreducible rates

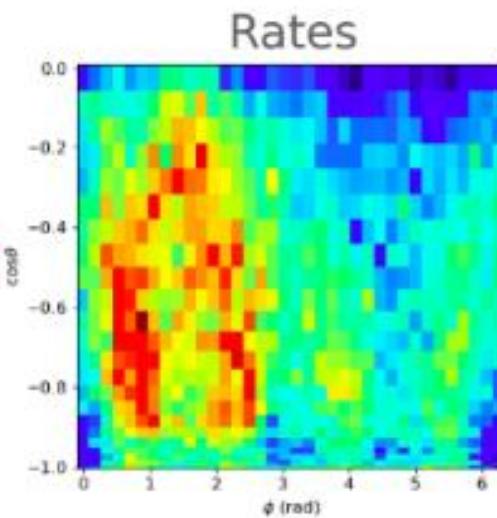
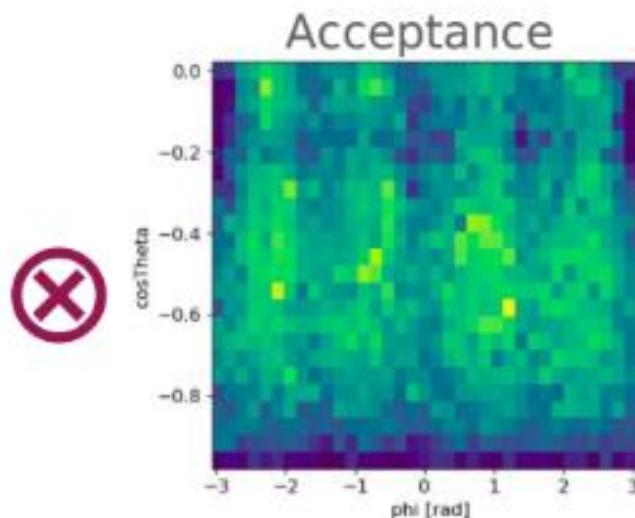
- CRs disguised as gamma
- How many?



# HERD gamma-ray exposure



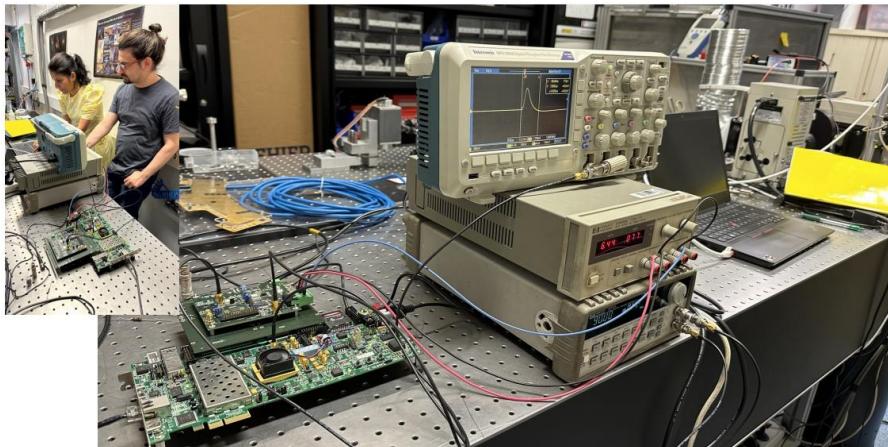
Source flux convolution with observing angle given HERD orbit



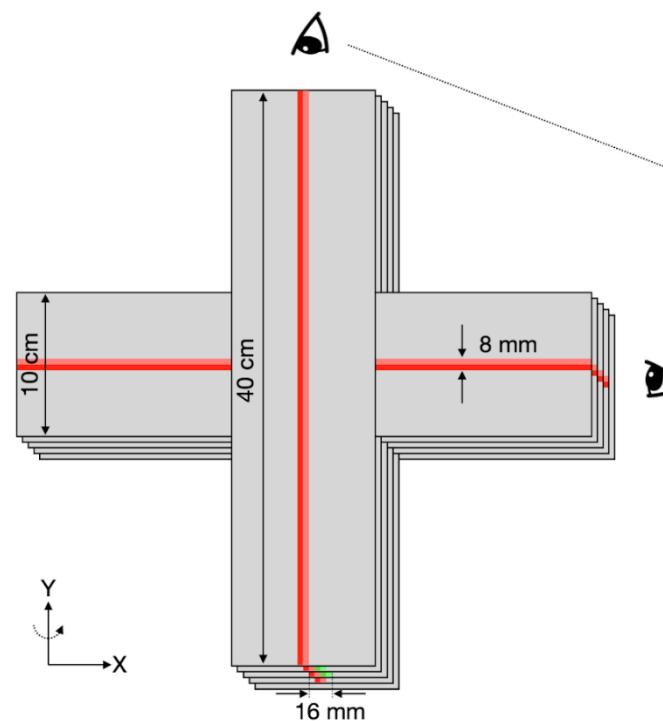
Simulate total exposure in given time frame

# Test Beam campaign

- Beam test campaign this Fall
  - Sep: protons @ PS
  - Oct: ions @ SPS
- Test ULEG proof-of-concept and BETA chip

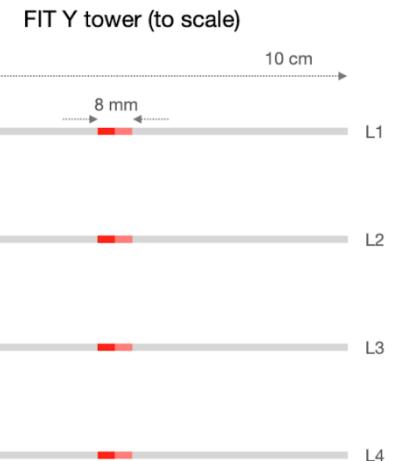
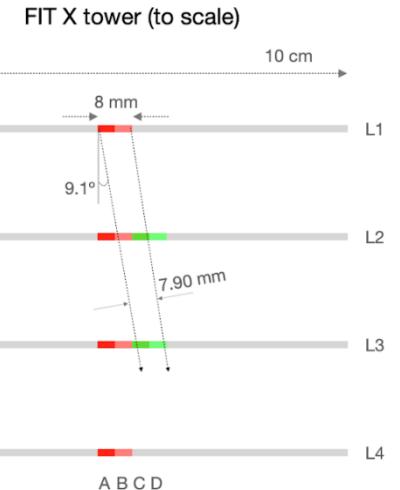


Luis Fariña



MiniFIT model for testing

HERD gamma-ray trigger



# Summary and conclusions

- We have presented a preliminary design of HERD's ULEG trigger
- This trigger will allow the detection of gamma-rays down to  $\sim 100$  MeV
- Elements of the design and the simulation will be further fine-tuned as the detector geometry is defined
- HW implementation will be tested at CERN in Fall 2023