HERD Trigger Studies

J. Casaus, F. Giovacchini, M.A. Velasco
CIEMAT
A. Oliva
INFN-Bologna

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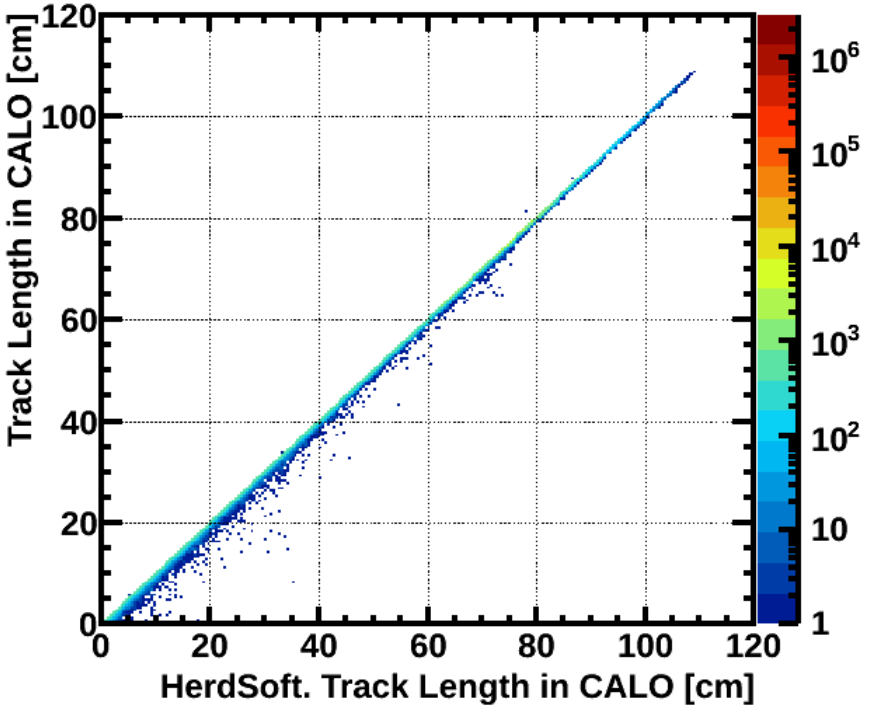
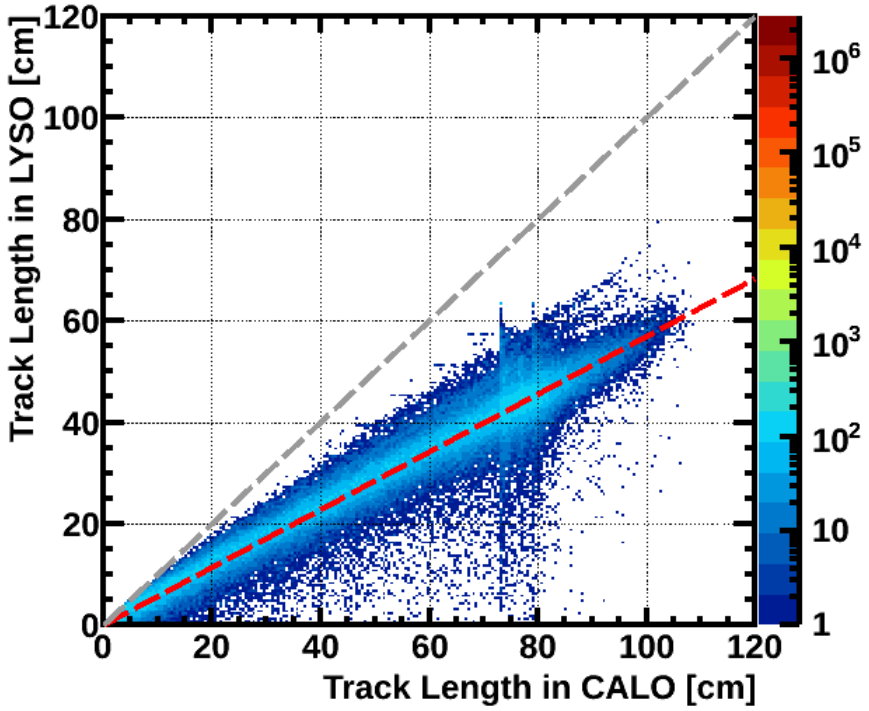
Introduction

- The goal of the exercise is to compute the expected particle rates with the baseline design of the trigger
- provide a cross check to the reference study in the HERD proposal using newly developed HerdSoftware
- Basic ingredients
  - Trigger Definition
  - Simulated Samples
  - Particle Fluxes

Geometrical Acceptance

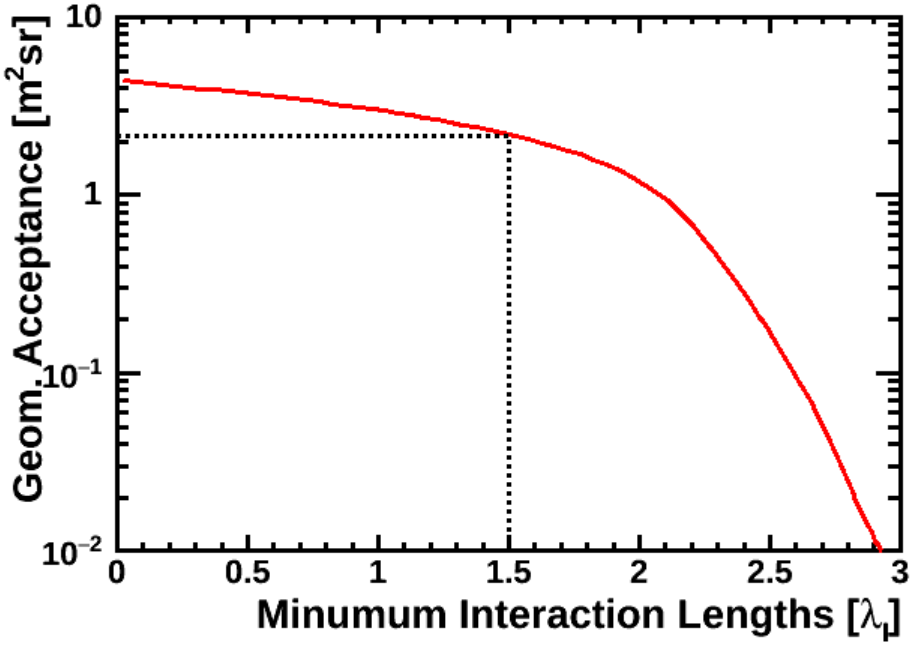
- Validation against available tool in HERD Software of a new tool developed to evaluate length in LYSO for each primary track parameters
- Good agreement for computed length inside CALO envelope volume
- Ratio of depth in LYSO and length in CALO volume reflects the packing factor of the current crystal arrangement (57%)

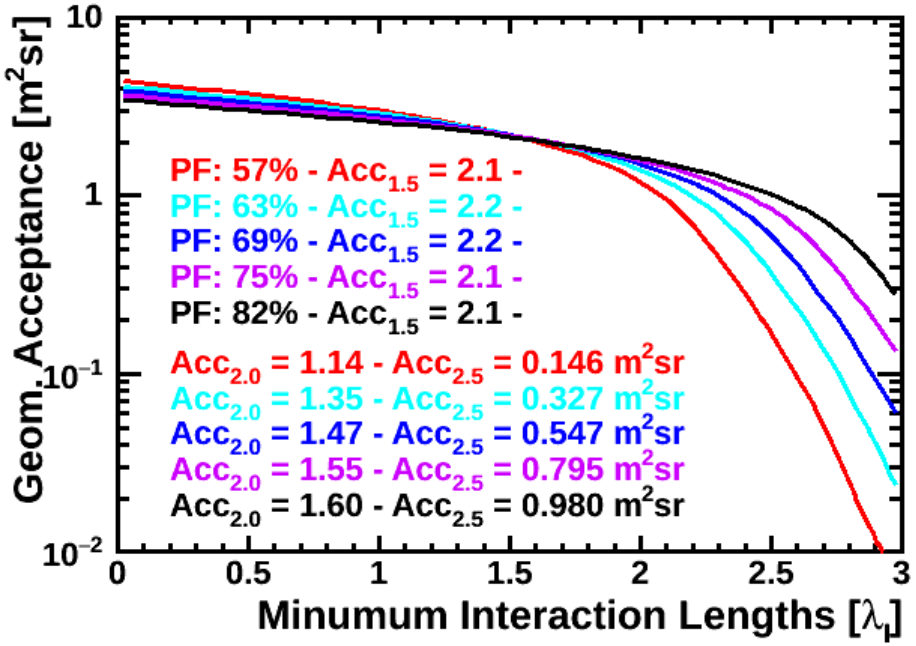




Geometrical Acceptance

- Evaluation of geometrical acceptance for down going particles as a function of the track length in CALO yields 2.1 m^2sr for lengths above 1.5 λ_I
- The dependence on the packing factor can be easily quantified, e.g., a PF of 69% would increase the geometrical acceptance for lengths above 2.5 λ_I by a factor 3.7, from 0.15 to 0.55 m^2sr, while keeping the current value for lengths above 1.5 λ_I





HERD Trigger Definition

- The Global Trigger (GT) is obtained from the logical combination of the particle-dedicated sub-triggers, built from the deposited energies in CALO and PSD
  - HE (High Energy particle) requires high energy deposition in CALO
  - LEG (Low Energy photon) low energy deposition in CALO and PSD veto
  - LEE (Low Energy Electron) low energy deposition in CALO
  - Unbiased: low energy in CALO, for trigger efficiency evaluation
  - Calibration Trigger: low energy deposition in CALO. Specific mode to detect penetrating particles.
- CALO trigger inputs are defined based on the total energy deposition in the outmost 3 crystal layers (shell) and in the central crystals (core).
- CALO core and shell inputs map high and low energy particle triggers: Low Energy electrons and photons only fire shell crystals, whereas High Energy particles will fire shell and core crystals
- In practice, 10 shell units (octagon, top, bot.) and 1 core unit are defined.
- PSD veto applies to the maximum of the energy depositions per PSD side

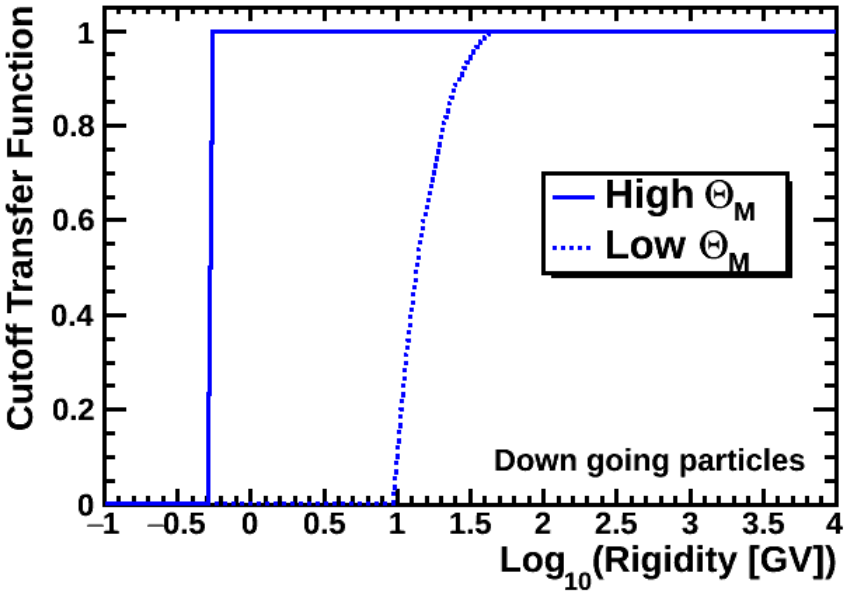
MC Samples

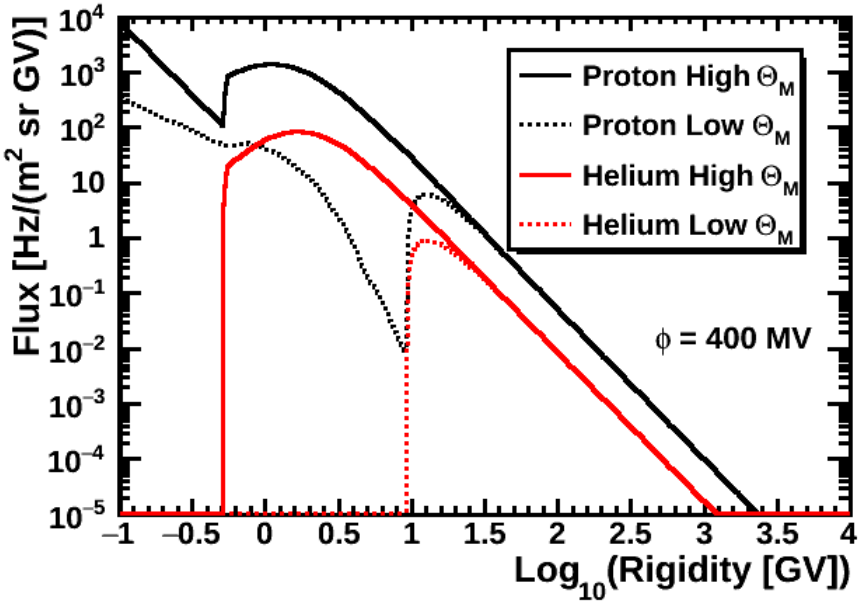
- Relevant particle species to evaluate sub-trigger and GT acceptances
- Protons, electrons, gamma and helium nuclei at ~30 fixed energy points logarithmically spaced ranging from 0.1 GeV to 8.2 TeV
- (1-3)x10^6 particles per particle species and energy point generated isotropically from a hemisphere containing the detector volume
- Only down going particles will be considered
- Trigger logic applied to output files after digitization

Particle Fluxes

- GCR from GALPROP subject to solar modulation and Earth rigidity cutoff
- Under cutoff secondary particles obtained from AMS-01 measurements

  (Caveat: under cutoff flux directionality is not considered yet. Important for HERD)
- No SAA or radiation belts included at this stage
- Lookup tables containing the individual particle fluxes on a grid of orbit positions for solar MIN and MAX have been produced. Only Results for solar MIN are presented
- A geomagnetic cutoff transfer function for isotropic down going particles is obtained for each orbit position and applied to GCR flux

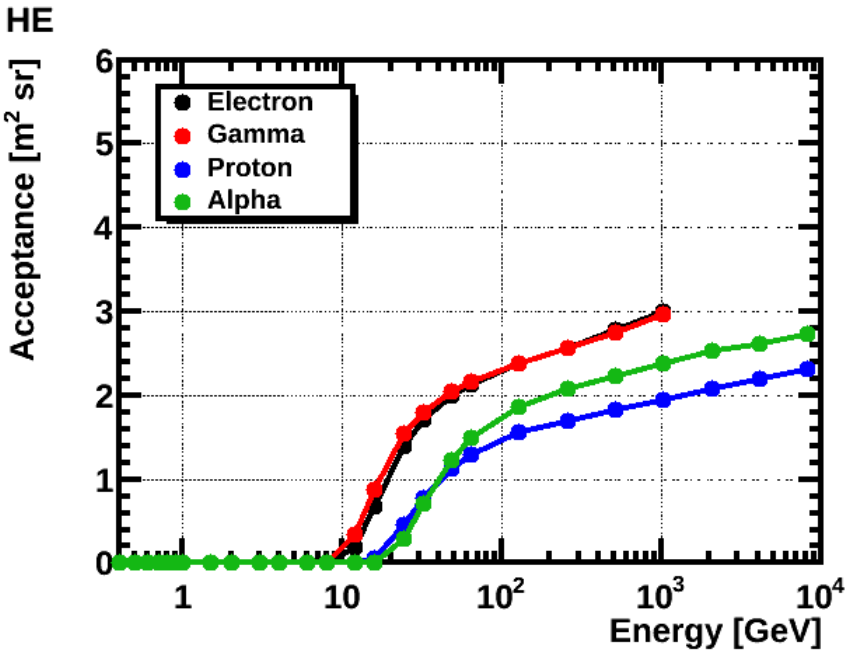


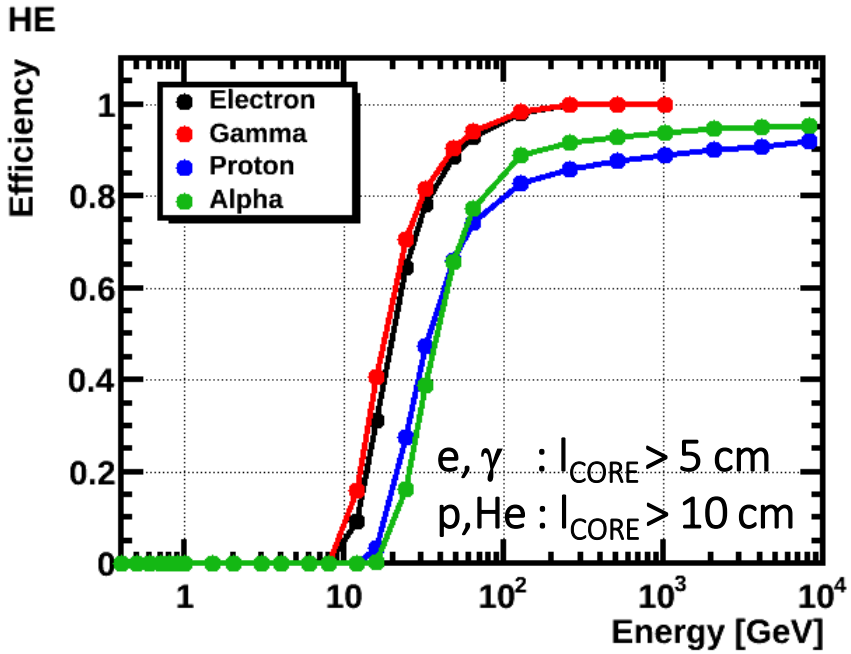


HERD Trigger Definition

There are two nominal operation modes of based on the GT configurations

1) Science mode is composed of logical OR of individual sub-triggers
   - ❑ HE (High Energy) Trigger
     - CALO core energy deposition above 10 GeV (Ecore > 10 GeV)
     - HE Average Rate : 54 Hz – Max Rate : 55 Hz
       - Proton : Ave.: 38.6 Hz (Max.: 39.0 Hz)
       - Helium : Ave.: 15.4 Hz (Max.: 15.9 Hz)

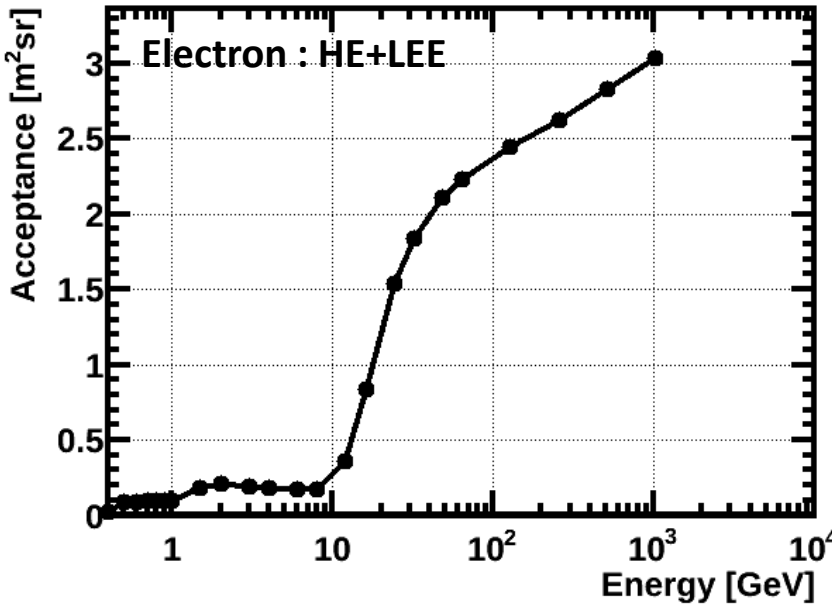


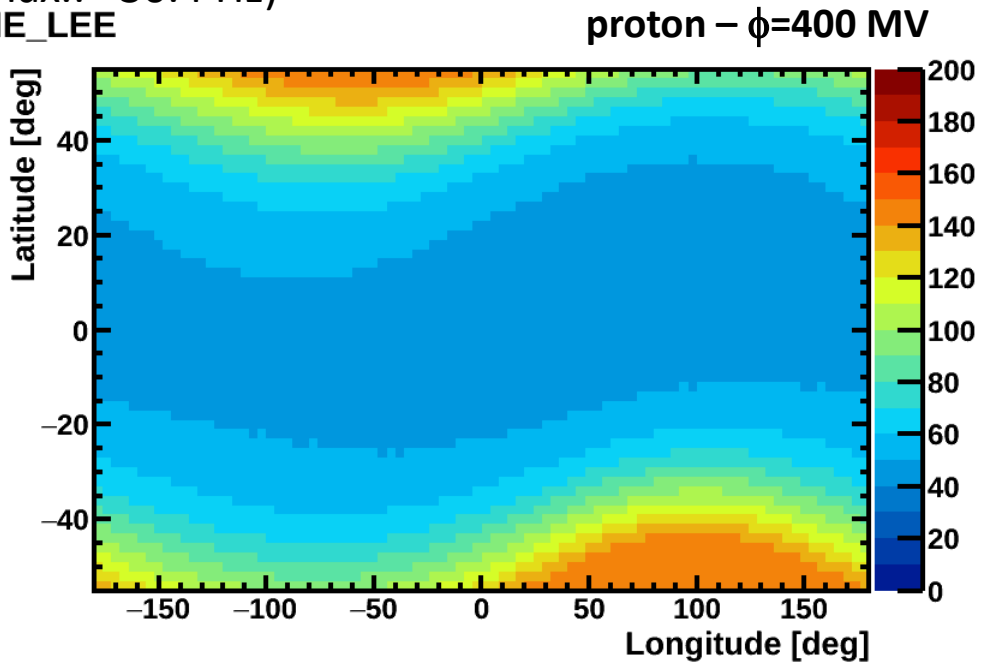


HERD Trigger Definition

There are two nominal operation modes of based on the GT configurations

1) Science mode is composed of logical OR of individual sub-triggers
   - ❑ LEE (Low Energy Electron) Trigger
     - (Eshell > 0.35 GeV AND Ecore < 0.06 GeV) OR (Eshell > 1 GeV AND Ecore < 0.6 GeV)
       N.B. Only shell corresponding to a lateral side where TRD is mounted is considered
     - LEE Average Rate: 43 Hz – Max Rate : 138 Hz (East-West effect important at Low E!)
       - Proton : Ave.: 35.3 Hz (Max.: 107.1 Hz)
       - Helium : Ave.: 7.8 Hz (Max.: 30.4 Hz)





HERD Trigger Definition

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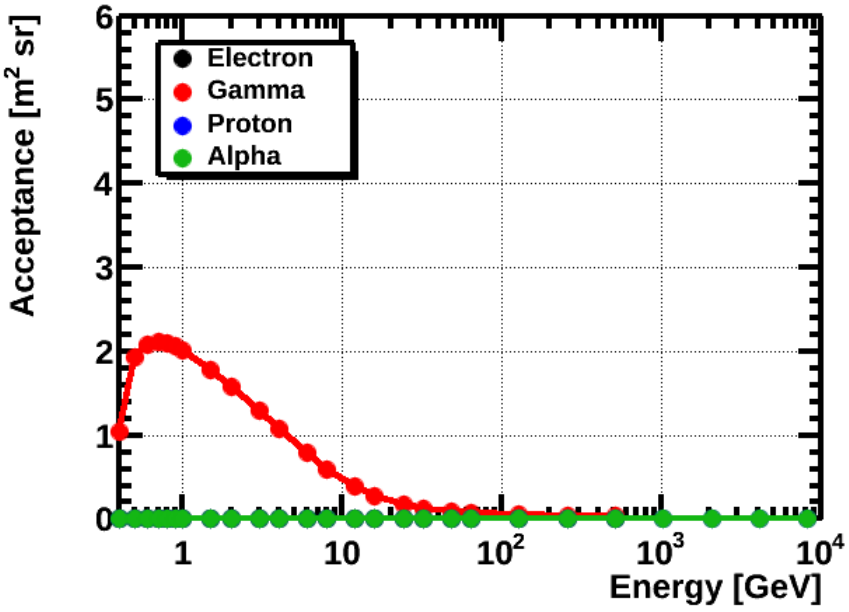
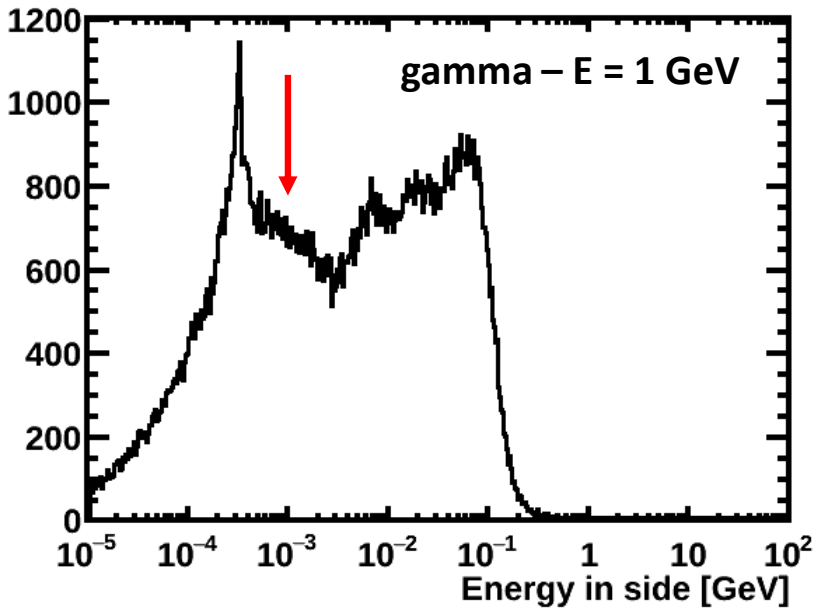
1) Science mode is composed of logical OR of individual sub-triggers
   - ❑ LEG (Low Energy Gamma) Trigger
     - Eshell > 0.35 GeV AND PSD veto (PSD Side Energy < 1 MeV)
     - LEG Average Rate: 1.7 Hz – Max Rate : 9.5 Hz
       - Proton : Ave.: 1.4 Hz (Max.: 7.9 Hz)
       - Helium : Ave.: 0.3 Hz (Max.: 1.6 Hz)
     - If a PSD inefficiency of 0.1% is included we get a bkg. rate < 10 Hz (see next)

LEG

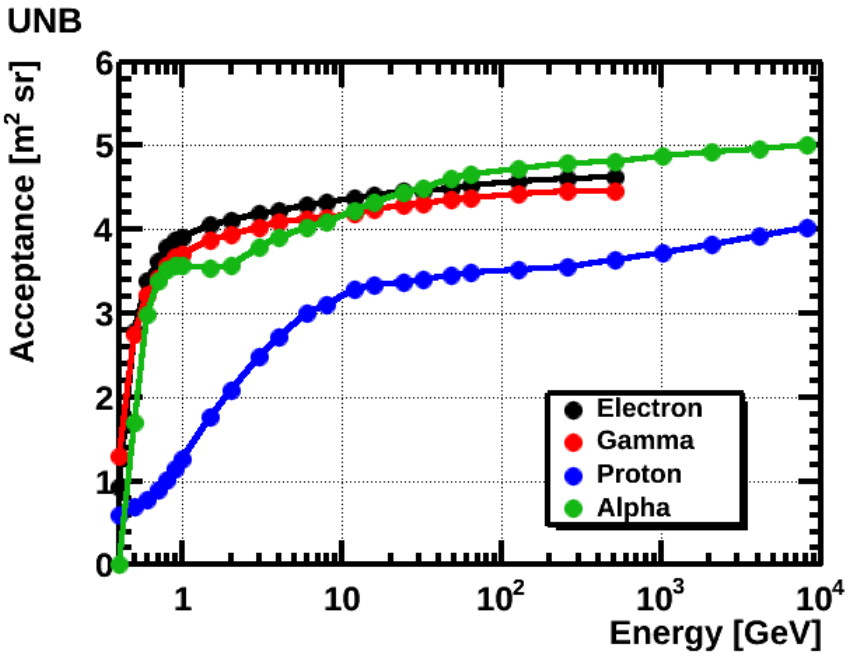


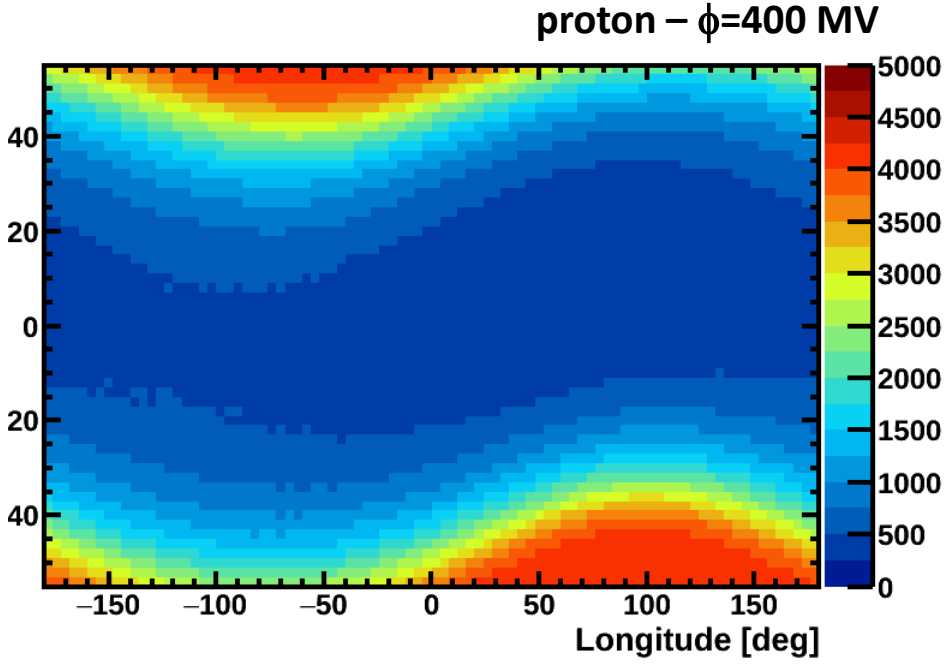


HERD Trigger Definition

There are two nominal operation modes of based on the GT configurations

1) Science mode is composed of logical OR of individual sub-triggers
   - ❑ Unbiased trigger
     - Eshell > 0.35 GeV with 1/1000 prescaling factor
     - UNB Average Rate: 1.8 kHz – Max Rate : 5.1 kHz
       - Proton : Ave.: 1.5 kHz (Max.: 4.1 kHz)
       - Helium : Ave.: 0.3 kHz (Max.: 1.0 kHz)

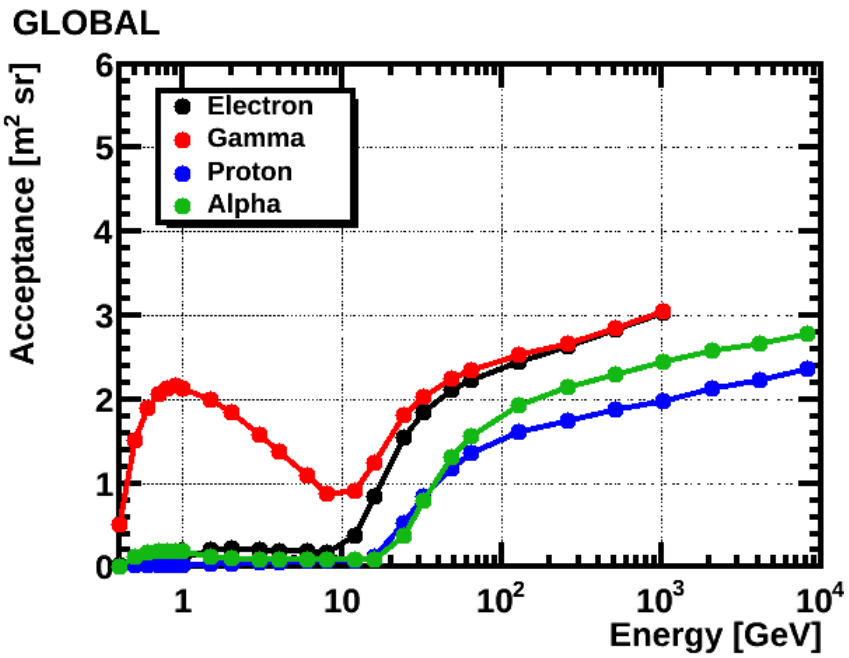


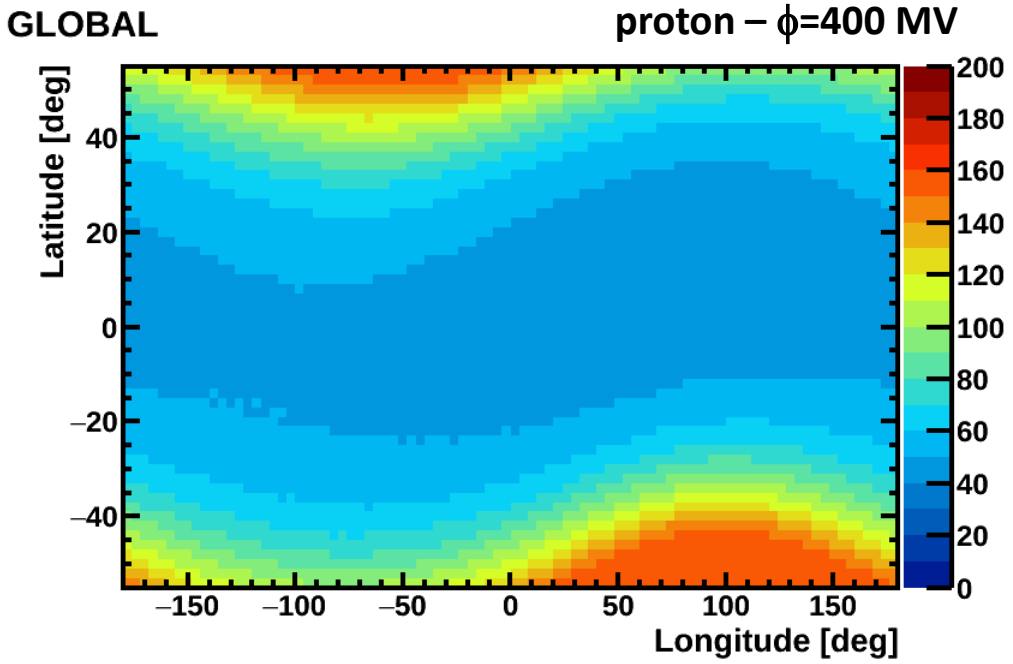


HERD Trigger Definition

There are two nominal operation modes of based on the GT configurations

1) Science mode is composed of logical OR of individual sub-triggers
   - ❑ GLOBAL : HE + LEG + LEE + UNB
     - Average Rate: 101 Hz – Max Rate : 207 Hz
       - Proton : Ave.: 76.8 Hz (Max.: 158.1 Hz)
       - Helium : Ave.: 23.8 Hz (Max.: 48.9 Hz)

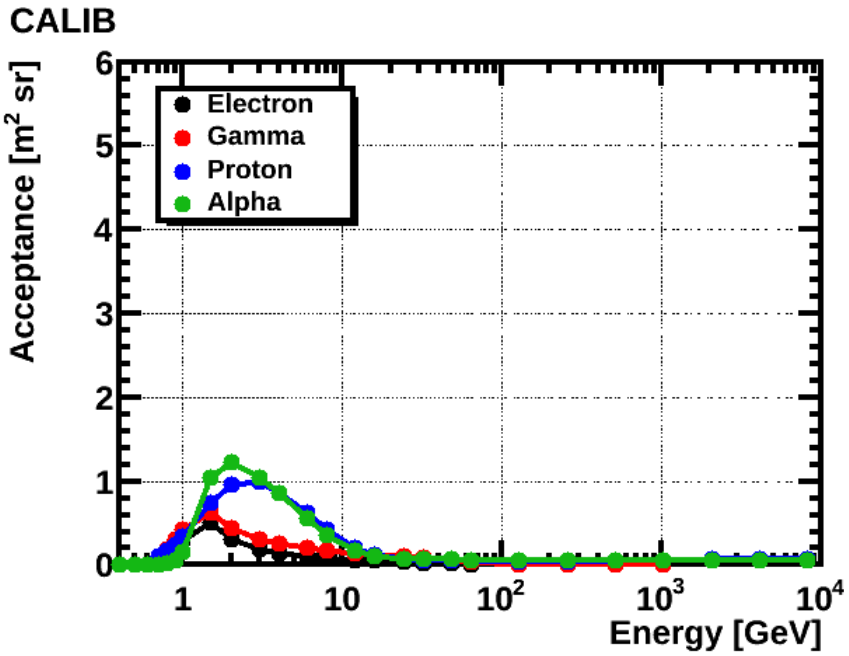


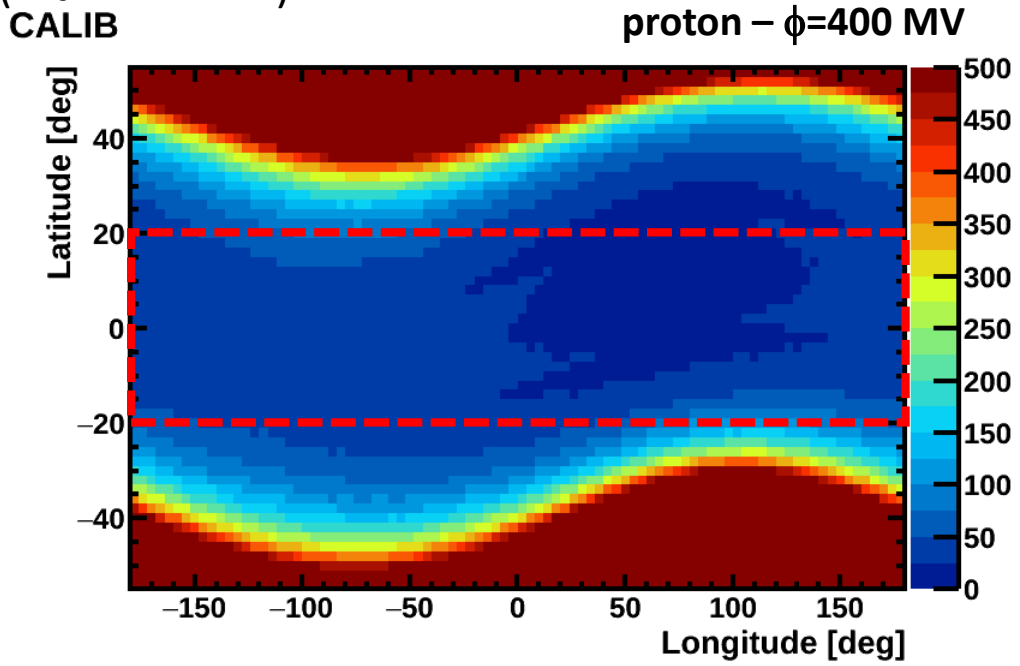


HERD Trigger Definition

There are two nominal operation modes of based on the GT configurations

2) Calibration Mode
   - ❑ MIP Trigger
     - 0.1 GeV < Eshell < 0.8 GeV AND Ecore > 0.5 GeV.
     - operated only at the equator (latitudes between -20° and 20°)
     - Average Rate: 37 Hz – Max Rate : 94 Hz (may change a lot with directional flux!)
       - Proton : Ave.: 35.5 Hz (Max.: 89.6 Hz)
       - Helium : Ave.: 1.8 Hz (Max.: 4.7 Hz)





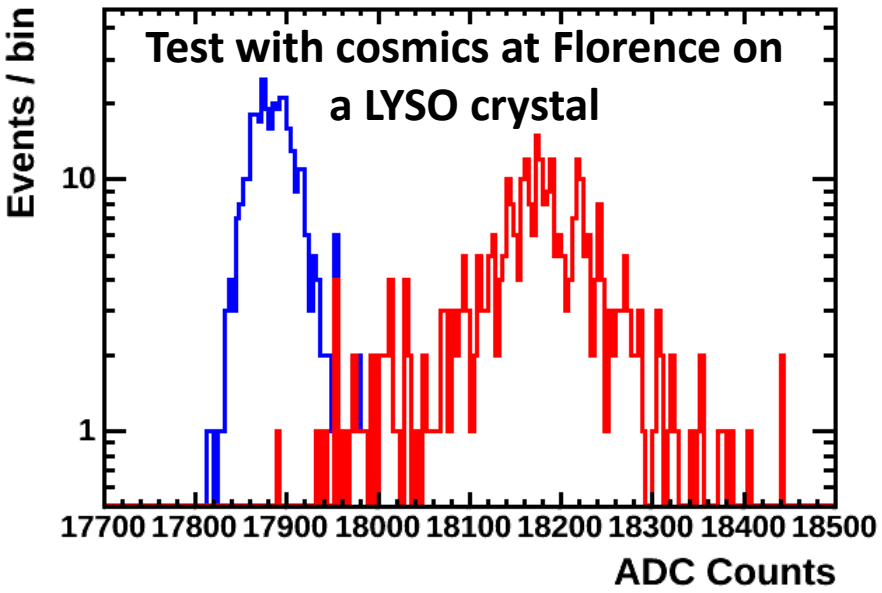
Summary

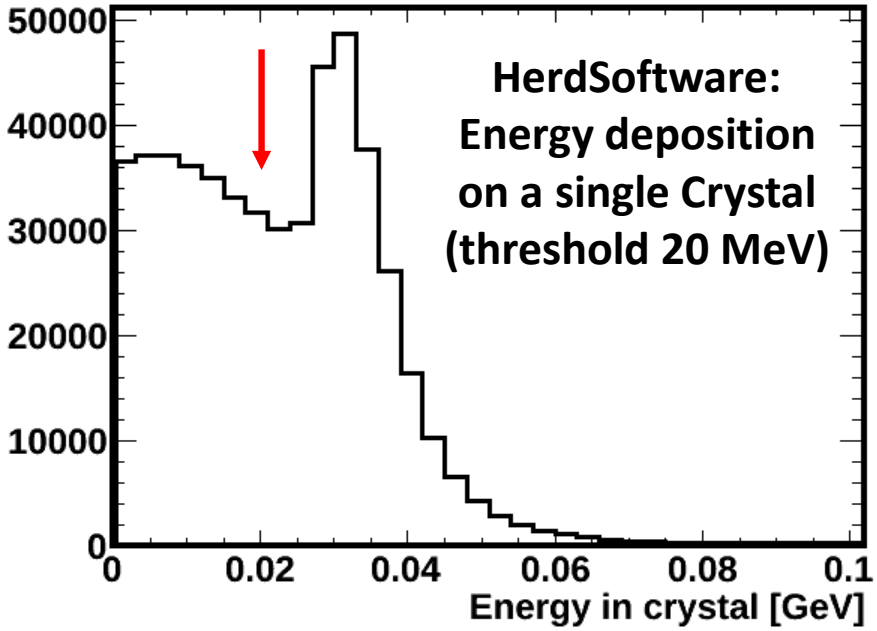
- HERD Proposal Trigger scheme replicated on MC files produced with latest HerdSoftware.
- We have completed a first implementation of the trigger logic following the description in HERD proposal.
- The first results in terms of expected rates show some discrepancies that need to be understood with the help of our IHEP colleagues.
- Being the trigger definition critical in HERD, we propose to set up a team to first tackle this issue and then explore possible optimizations of the trigger scheme to provide maximum physics reach.

HERD Topological Trigger

- PD readout provides complementary possibilities for HERD trigger since a trigger signal per equipped crystal will be available:
  - Multiplicity and event topology
  - Programmable trigger logic

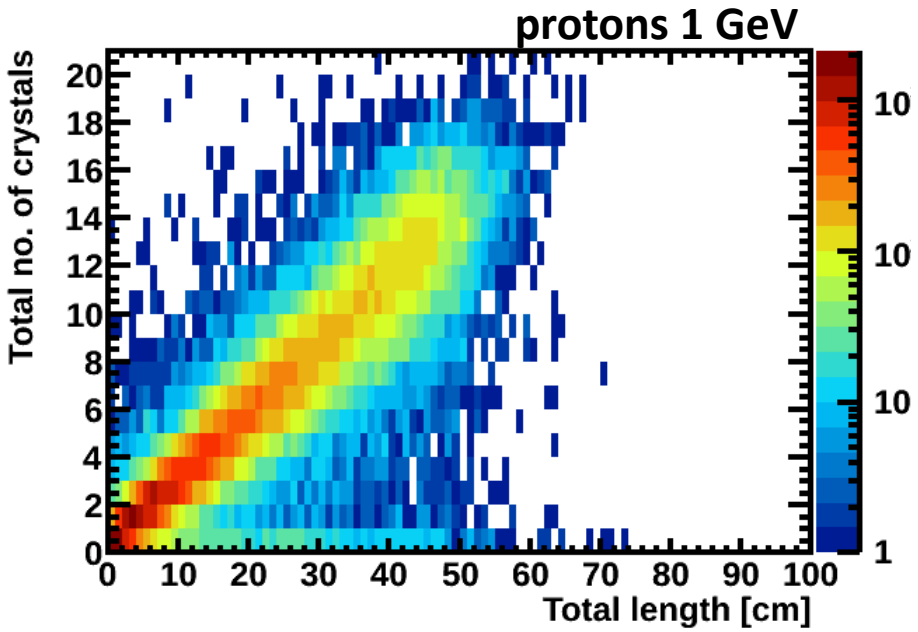
- Illustration with simple example for MIPs:

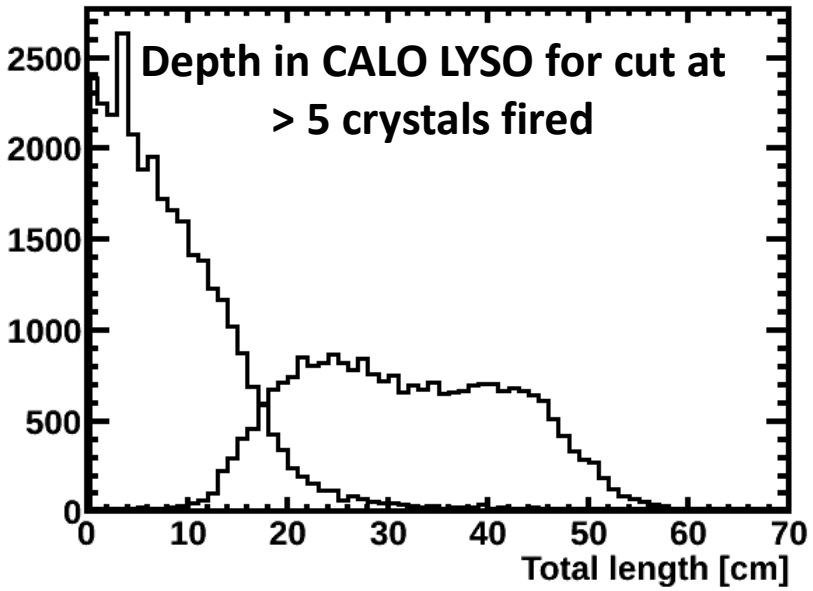




HERD Topological Trigger

- Illustration with simple example for MIPs:
  - Good correlation between total number of fired crystals and depth in LYSO allows selecting MIP events with different lengths in CALO





HERD Topological Trigger

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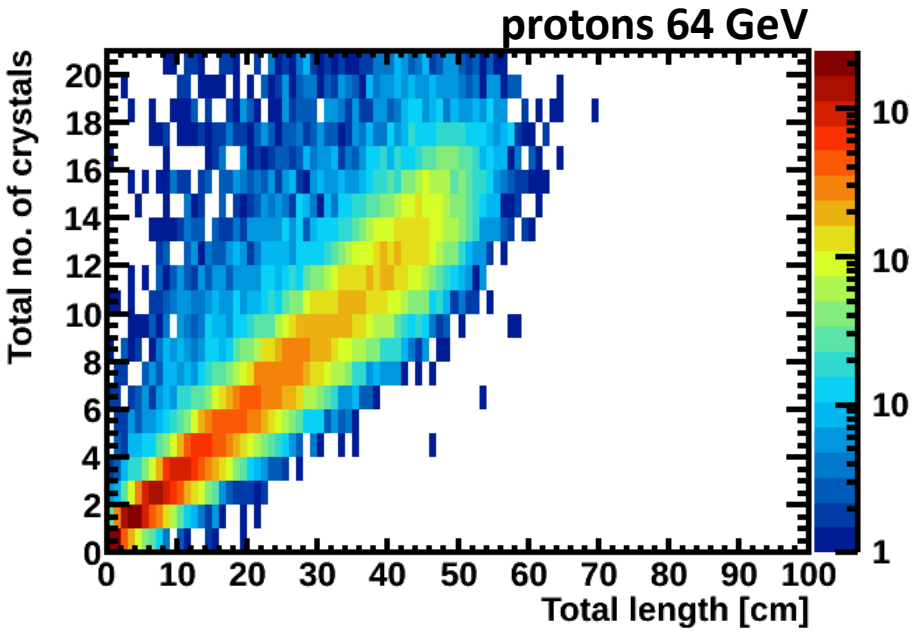
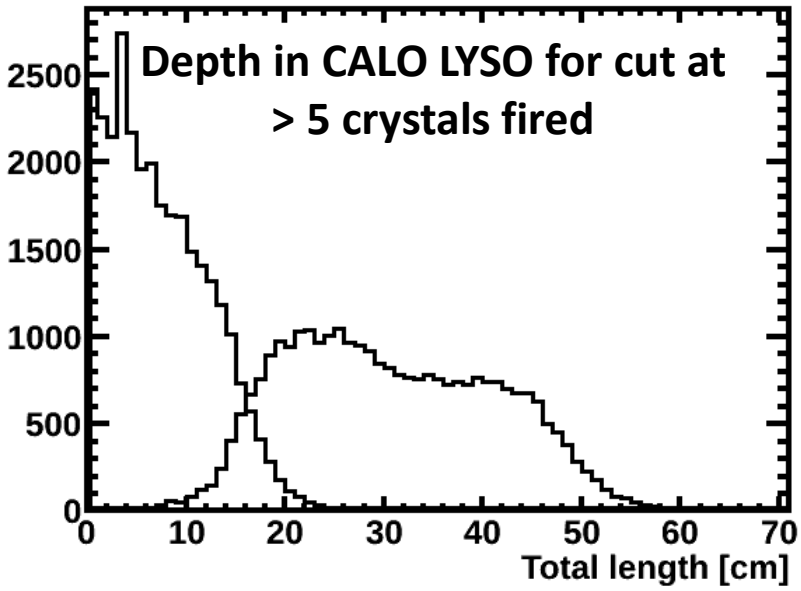
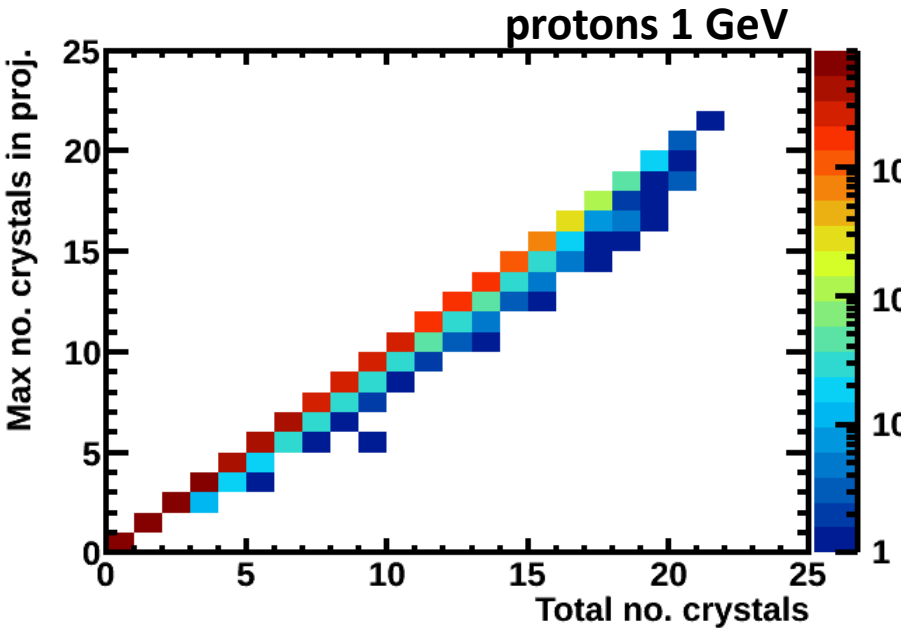
  - Good correlation between total number of fired crystals and depth in LYSO allows selecting MIP events with different lengths in CALO

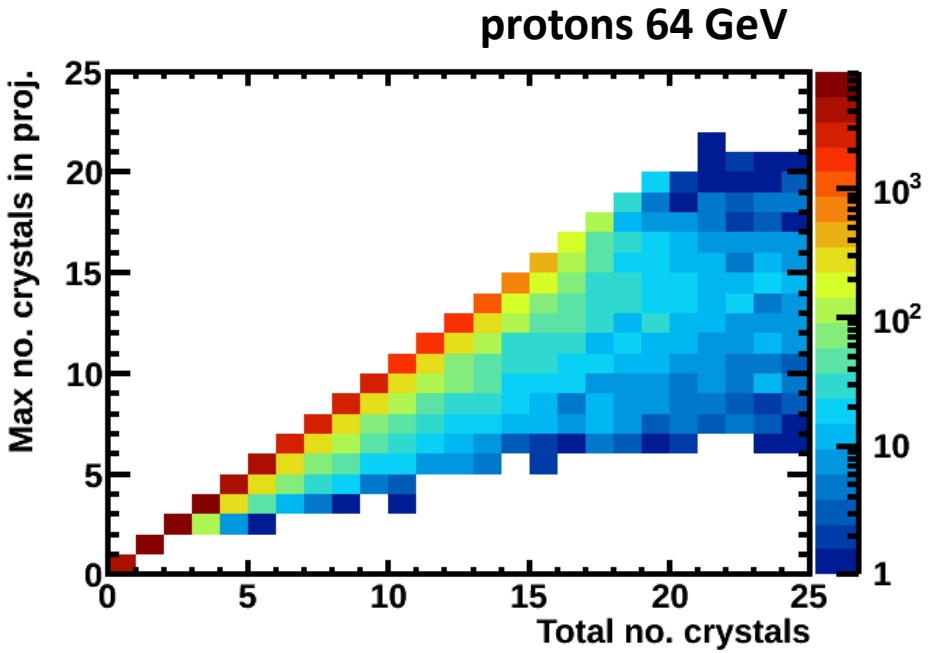




HERD Topological Trigger

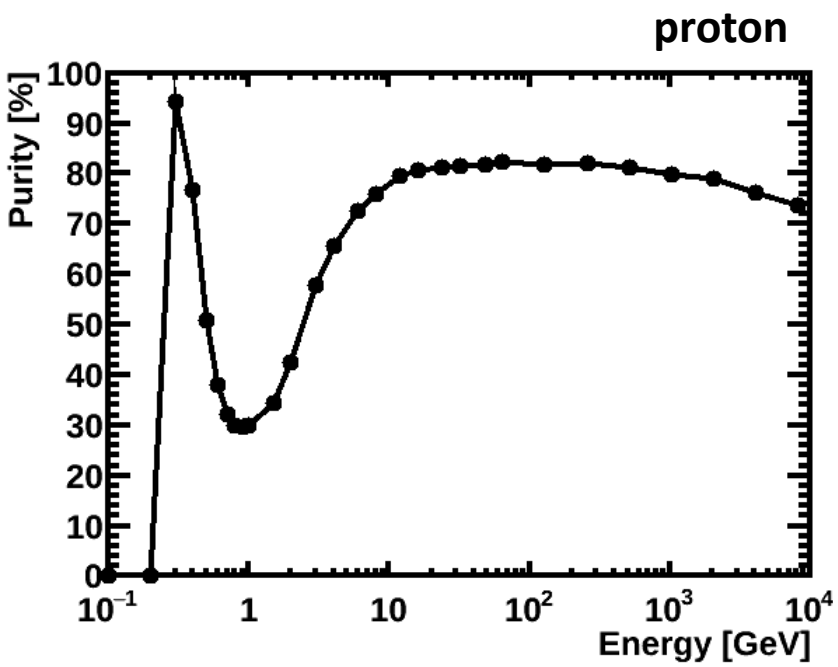
- Illustration with simple example for MIPs:
  - Good correlation between the maximum of (x,y,z)-projection and the number of fired crystals and depth in LYSO allows selecting MIPs from interacting particles

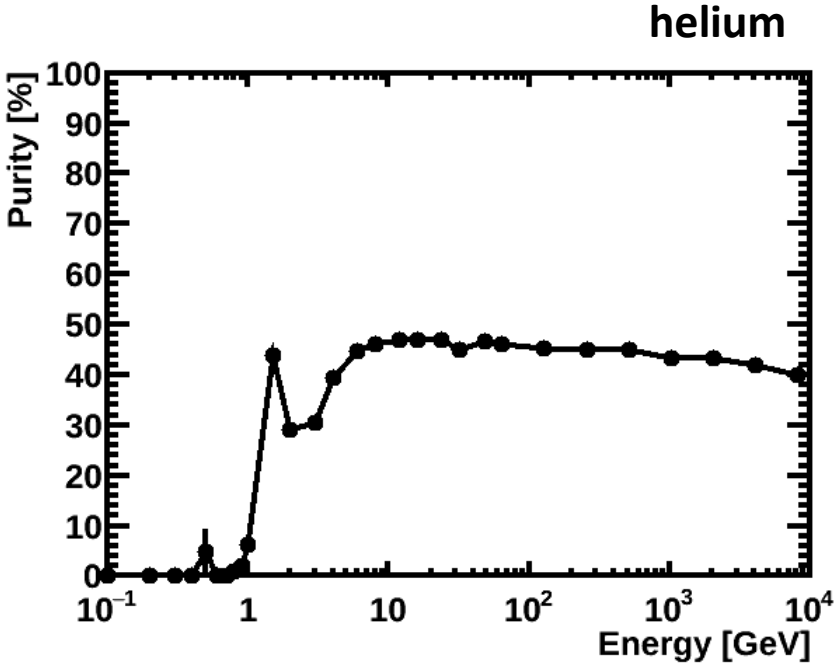




HERD Topological Trigger

- Illustration with simple example for MIPs:
  - Highly pure MIP sample selected at trigger level





HERD Topological Trigger

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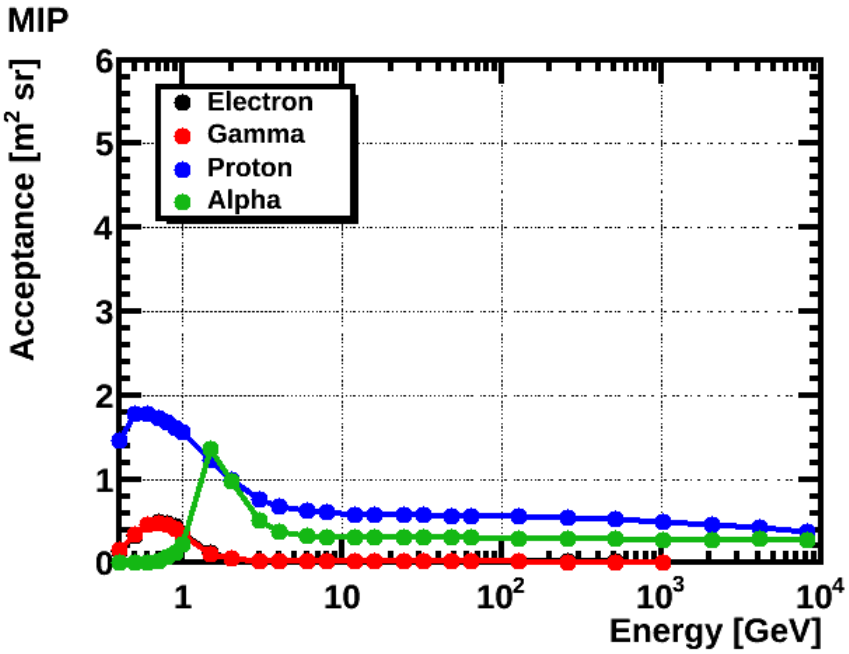
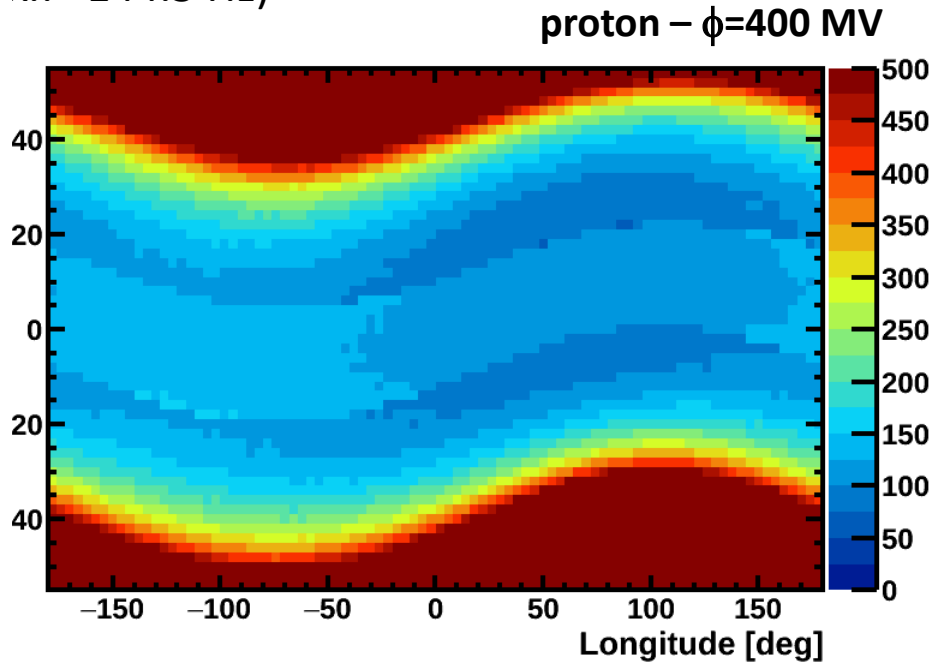
2) Calibration Mode
   - ❑ MIP Topo
     - Ncry > 5 && ΔNcry < 2
     - operated only at the equator (latitudes between -20° and 20°)
     - Average Rate: 697 Hz – Max Rate : 3971 Hz
       - Proton : Ave.: 660.6 Hz (Max.: 3826.1 Hz)
       - Helium : Ave.: 36.2 Hz (Max.: 144.5 Hz)





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- Being the trigger definition critical in HERD, we propose to set up a team to first tackle this issue and then explore possible optimizations of the trigger scheme to provide maximum physics reach.
- Detector offers new possibilities also for trigger improvements. We should also profit from the forthcoming massive MC simulation to address them.