CALET: a calorimeter for cosmic-ray measurements in space

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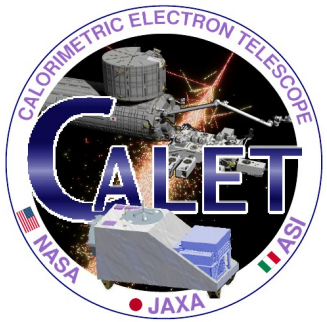
on behalf of the CALET collaboration



SciNeGHE – Lecce – 22/6/2012

Plan of the presentation

- **Introduction to CALET**
  - The collaboration
  - The instrument
  - Performance (energy resolution etc.)
- **Expected results**
  - Electrons and positrons
  - Gamma rays
  - Nuclei

Participating institutions

Italy

- University of Siena
- University of Florence & IFAC (CNR)
- University of Roma Tor Vergata
- University of Padova

United States

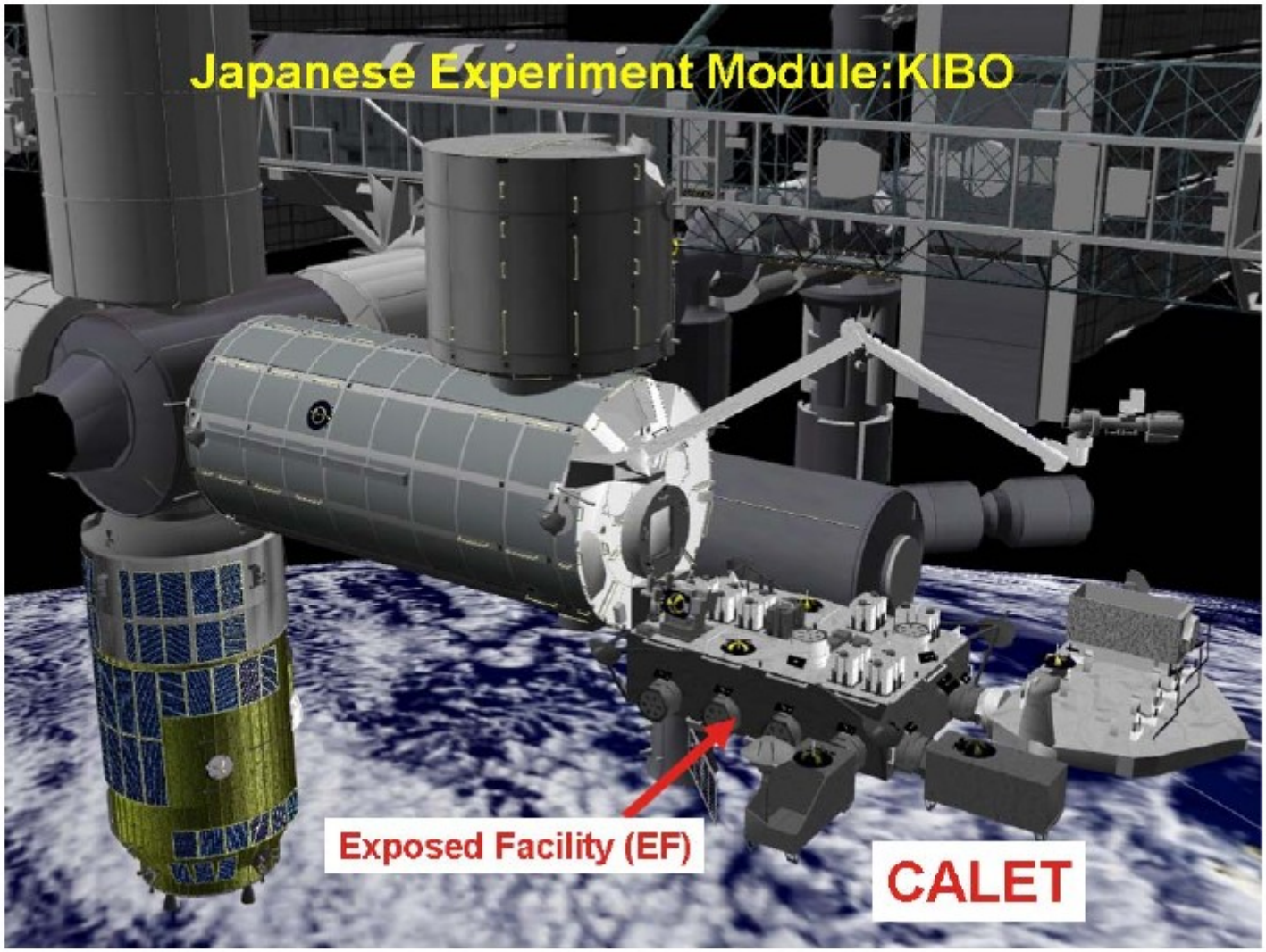
- NASA/Goddard Space Flight Center
- Louisiana State University
- Washington University in St. Louis
- University of Denver

Japan

- Waseda University
- JAXA/Space Environment Utilization Center
- JAXA/ Institute of Aerospace and Astronautical Sciences
- Kanagawa University,
- Aoyama Gakuin University
- Shibaura Institute of Technology
- Institute for Cosmic Ray Research, University of Tokyo
- Yokohama National University
- Hirosaki University
- Tokyo Technology Inst.
- National Inst. of Radiological Sciences
- High Energy Accelerator Research Organization (KEK)
- Kanagawa University of Human Services
- Saitama University
- Shinshu University
- Nihon University
- Ritsumeikan University

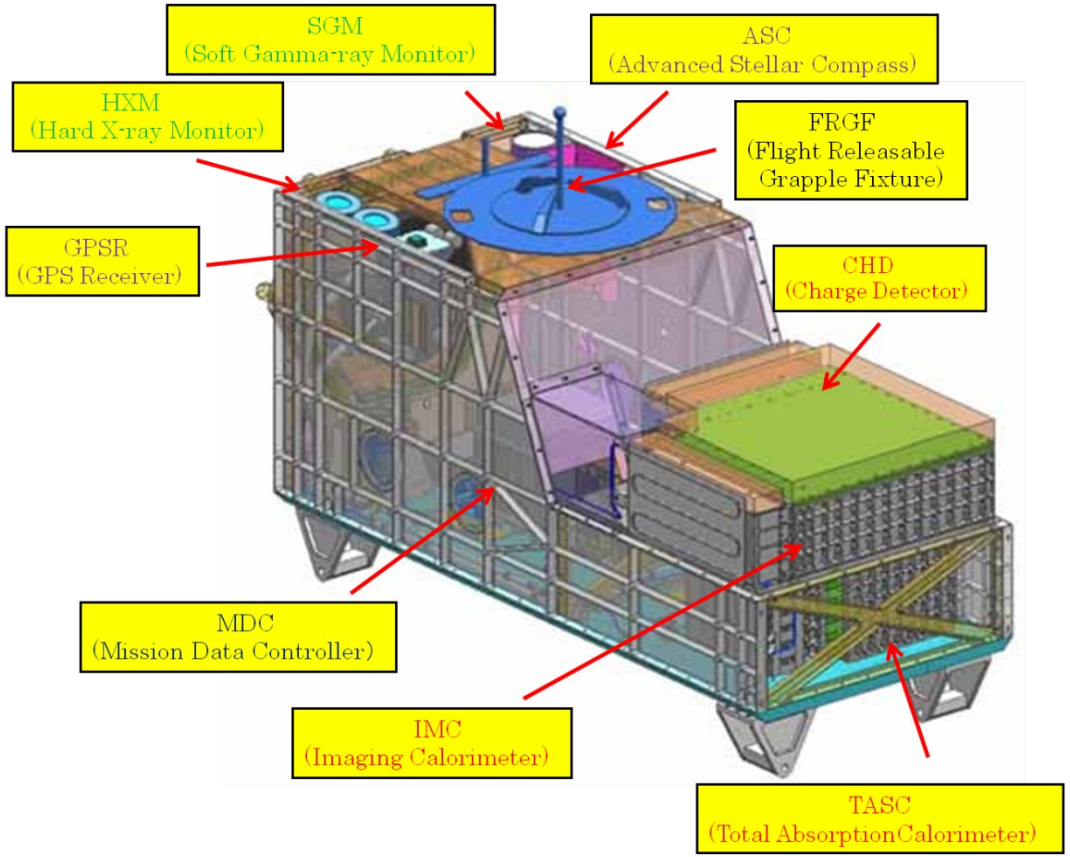
CALET is a CERN Recognized Experiment

A space experiment for cosmic-ray measurements



CALET will be mounted on the Japanese Module on the ISS
Foreseen launch: 2014
Planned duration: 5 years

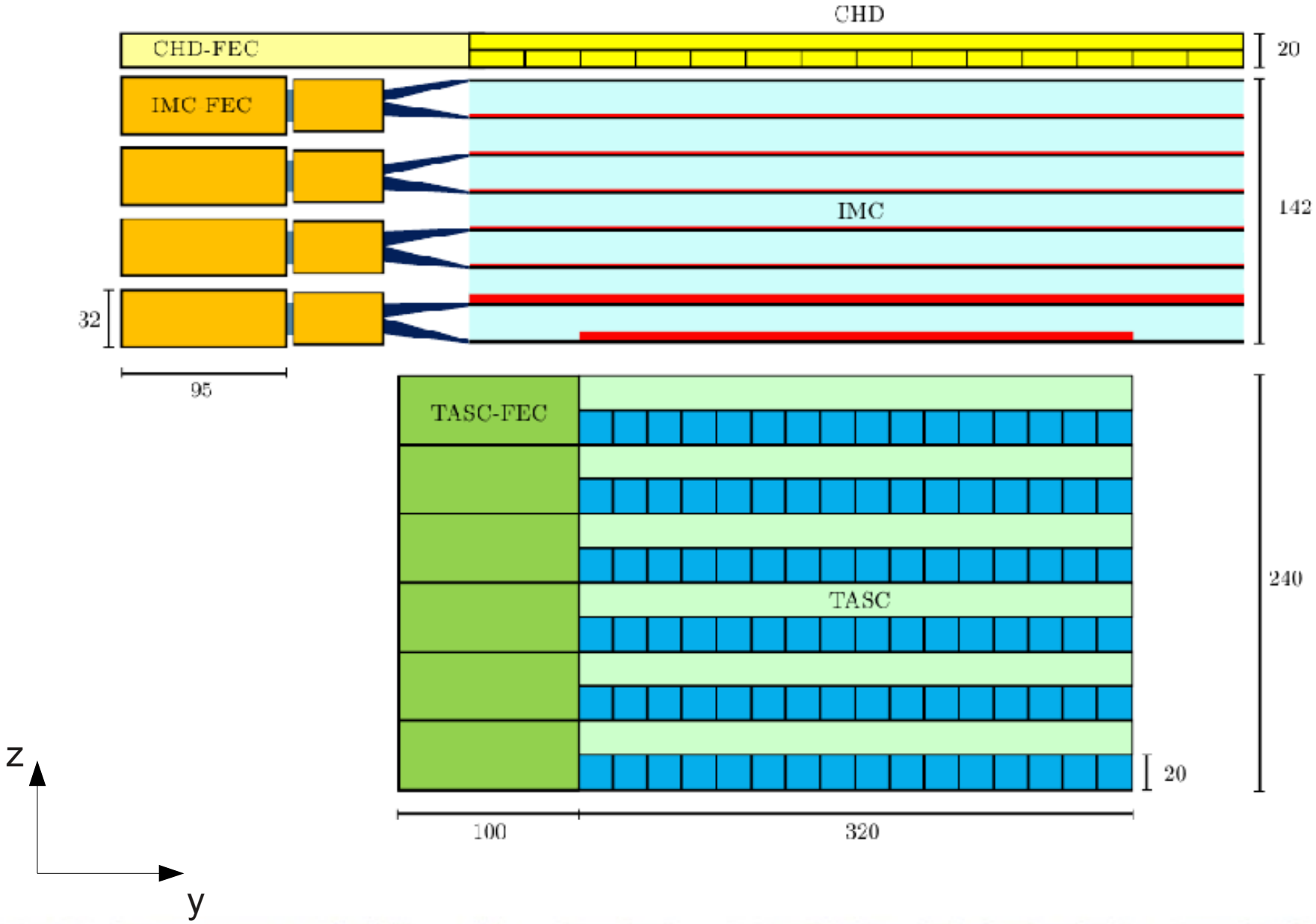
Payload overview



Items	Specification
Mission Equipment	CAL: Calorimeter CGBM: Gamma-ray Burst Monitor
Launch Carrier	HTV-5
Launch Target Date	CY 2014
Mission Period	More than 2 years (5 years target)
Mass	650kg (Max)
Envelope	Standard Payload Size
Power	~ 600 W
Data Rate	Medium Data Rate : 300 kbps Low Data Rate : 20 kbps

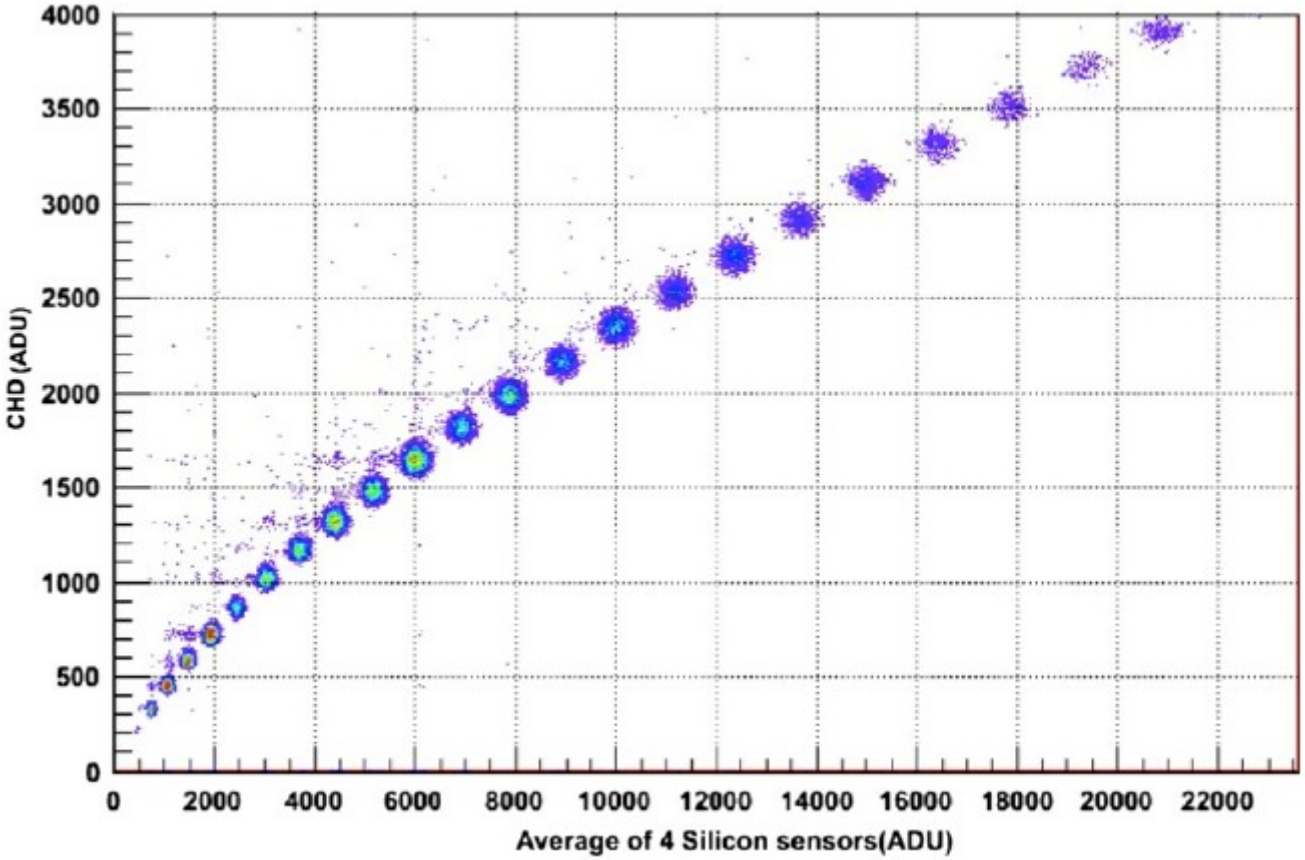
CALET Detector System	Support Sensor	JEM/EF Equipment
CAL: CHD,IMC, TASC+MDC CGBM : HXM, SGM	GPSR ASC	FRGF

Instrument overview



CHD (CHarge Detector)

- 14 pads per view, EJ200 plastic scintillator (polyvyniltoluene, PVT)

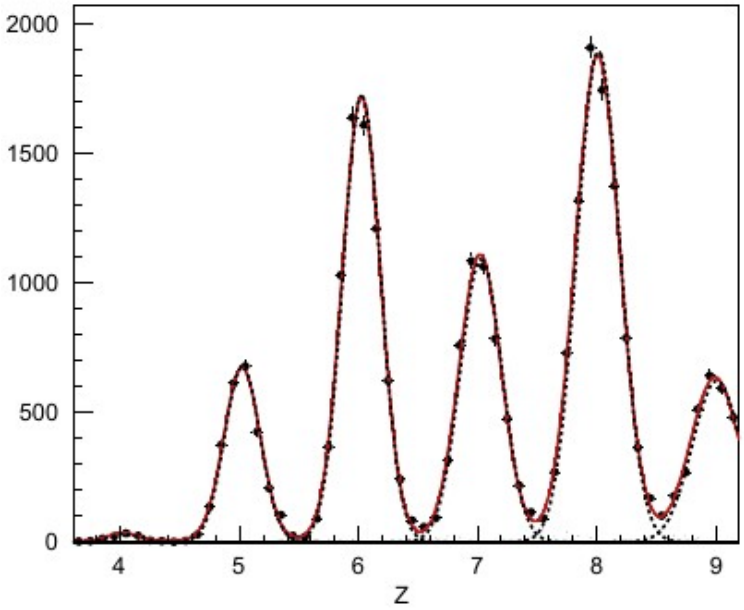


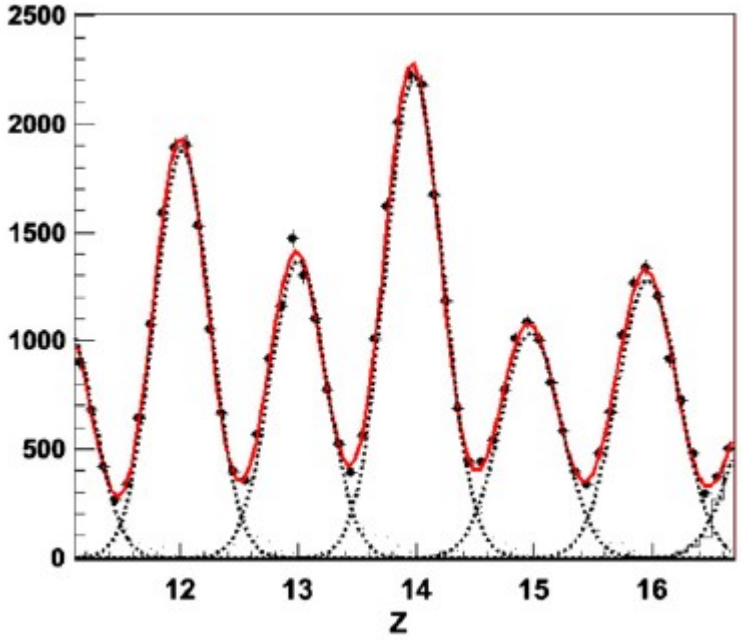
CHD response vs Si tracker @ GSI test beam (Marrocchesi et al., 2011)

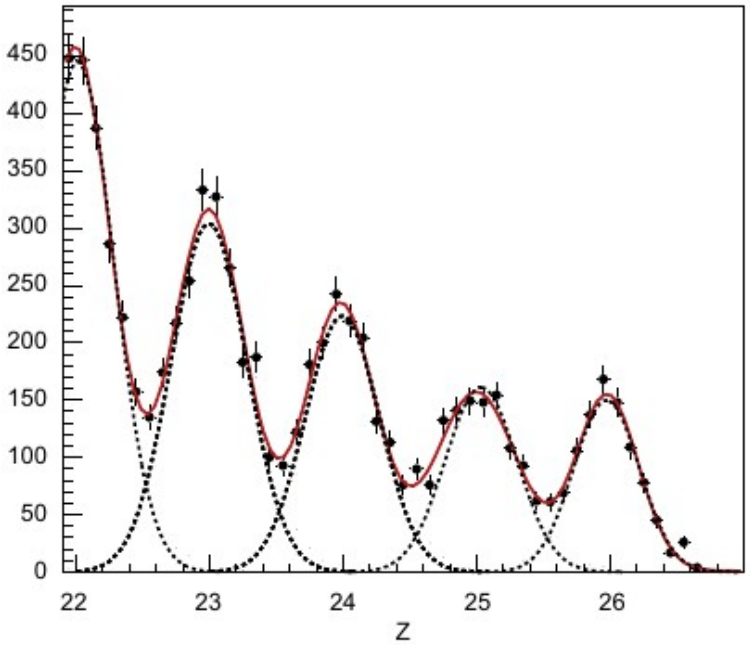
CHD discriminates between different |Z|

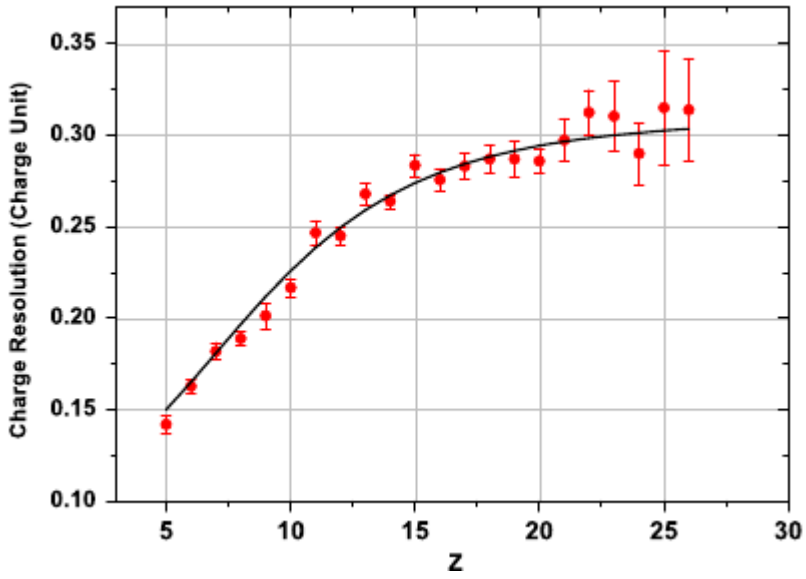
- Electron/proton separation will require a different (topologcal) approach

Charge discrimination:

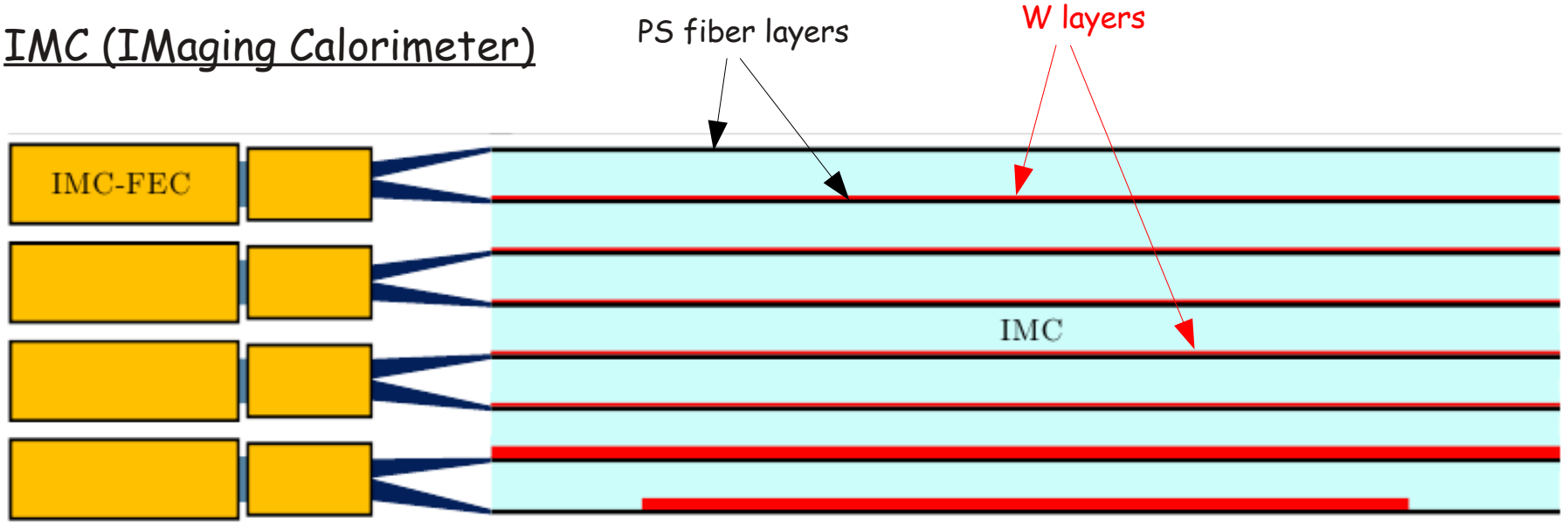






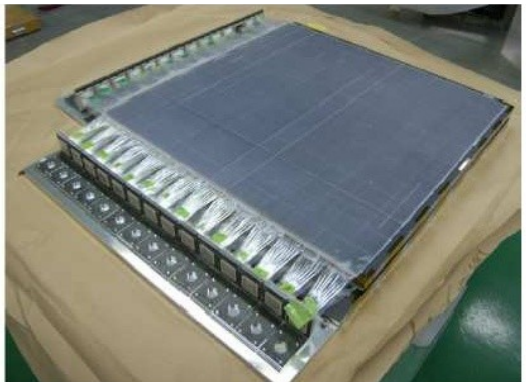


IMC (IMaging Calorimeter)



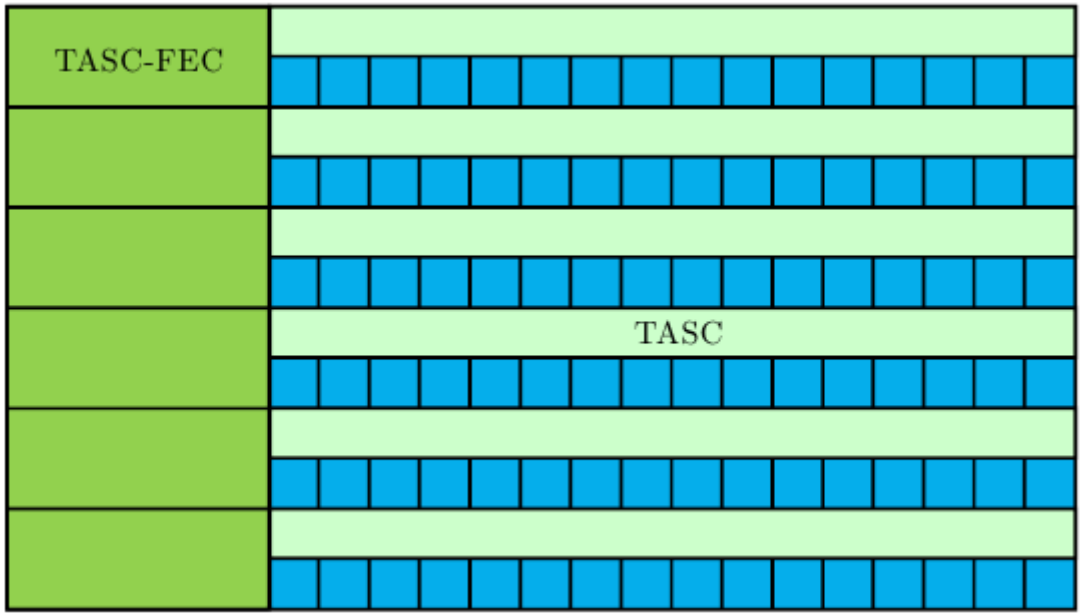
- 8 layers, 448 polystyrene fibers (1mm section) per view
- W layers above PS fibers (except for 1st layer), variable thickness
- Total depth: ~ 3 X_0, ~ 0.1 λ

Fiber readout: Hamamatsu H7546B multianode PMT (64 channels)



IMC provides particle's track and finely-segmented information about initial development of EM showers

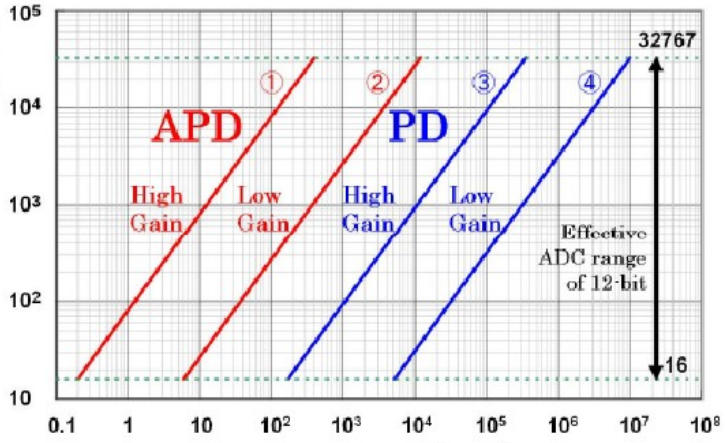
TASC (Total AbSorption Calorimeter)



- 12 layers, 16 lead tungstate (PWO) logs (2 cm section) per view
- Homogeneous calorimeter
- Total depth ~ 27 X_0, ~ 1.2 λ
- Energy resolution for $e^{\pm}$ above 100 GeV: ~ 2 %

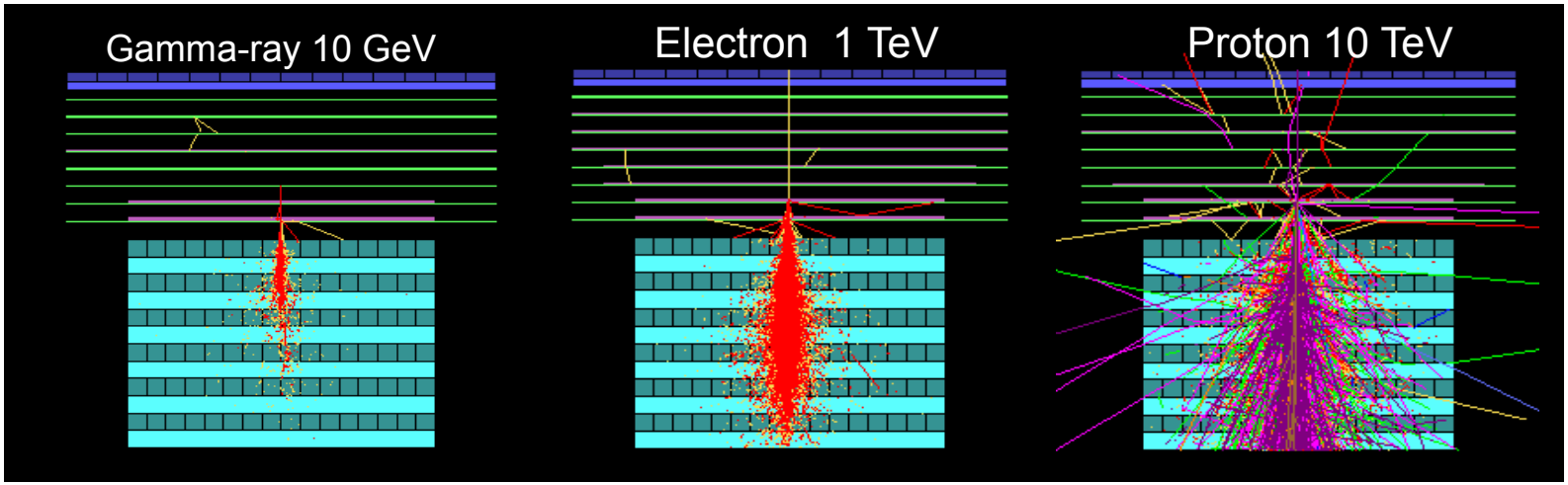
Readout: APD + PD, Hi and Low gain shapers for each → 4 regimes → high dynamic range (0.5 → 10^7 MIP)

TASC provides energy measurement in a wide range and information about shower development

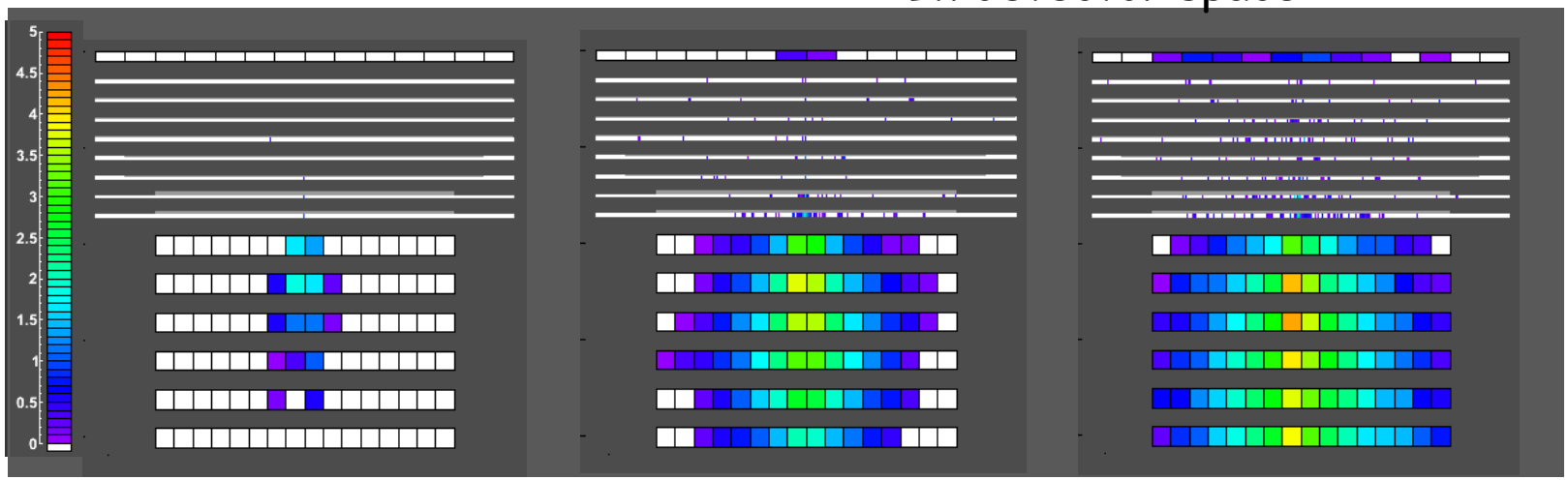


Different particles as seen by CALET

Simulation



In detector space

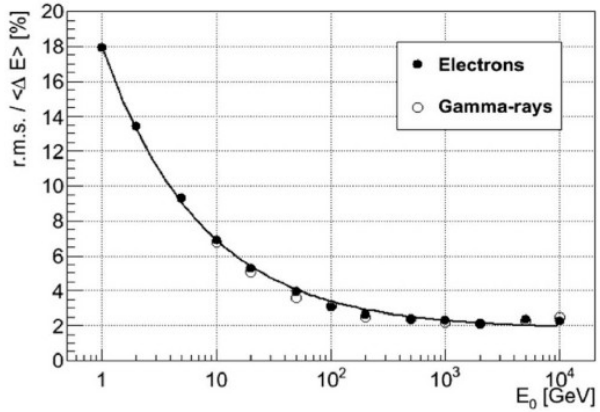


Proton rejection power of ~ 10^5 can be achieved with IMC and TASC shower imaging capability.

Summary of performance figures

- Sensitivity:
  - Electrons: 1 GeV – 20 TeV
  - Hadrons (H → Fe): some 10 GeV – 1000 TeV
  - Gamma rays: 10 GeV – 10 TeV (GRB > 1 GeV)
    - Soft gamma rays: 30 keV – 30 MeV
    - Hard X-rays: 3keV - 3MeV } CGBM

- TASC energy resolution:
  - Electrons and gamma rays: ~ 2% @ E > 100 GeV
  - Protons: ~ 40% @ 1 TeV
  - Nuclei: ~ 30% @ 50 GeV/n (^{12}C and ^{56}Fe)



- CHD charge resolution: (0.15 – 0.30)e (for $2 \leq Z \leq 26$)

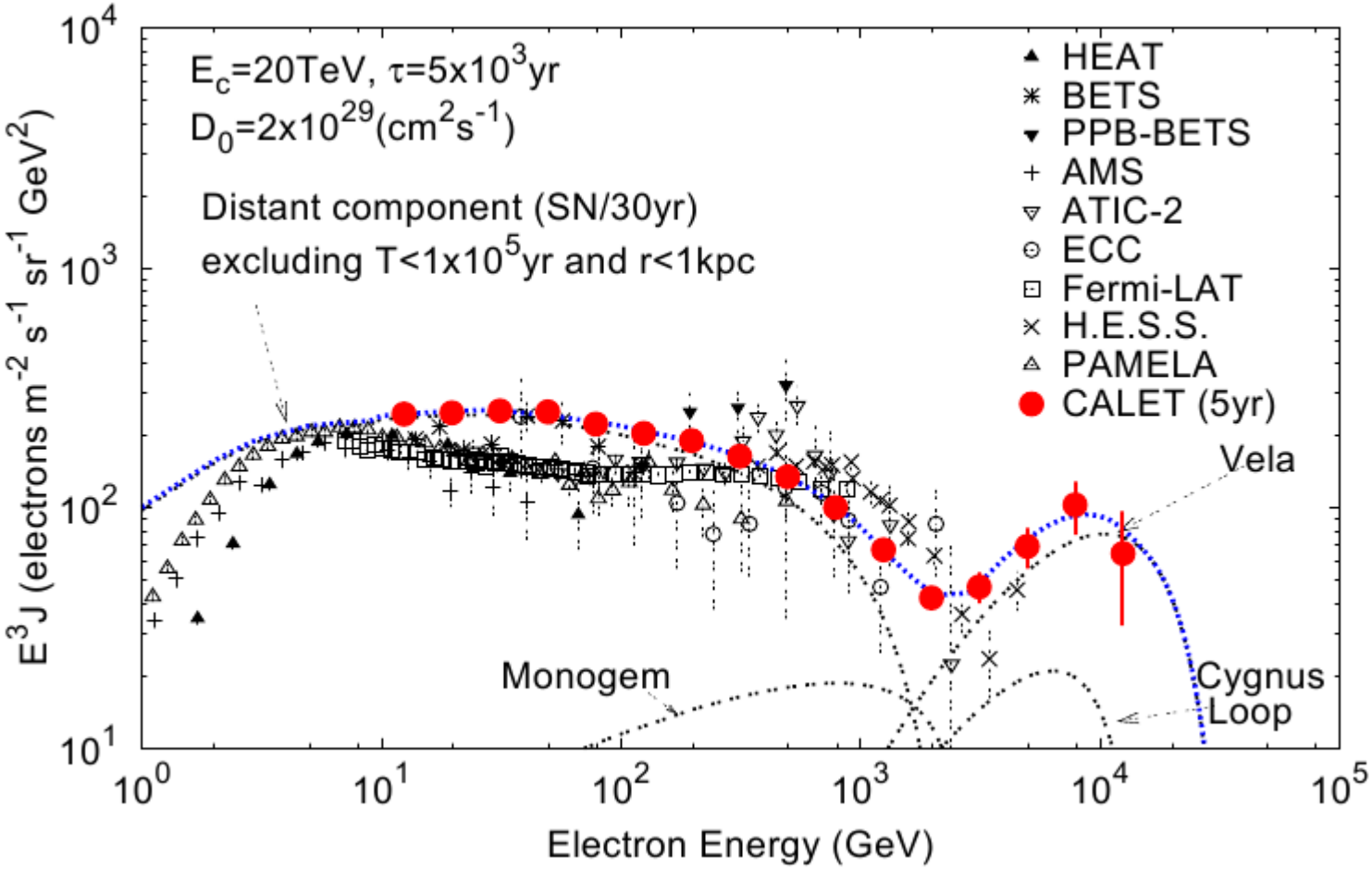
- e/p rejection power: ~ 10^5

- Acceptance: 0.12 m^2 sr for $e^{\pm}$, 0.10 m^2 sr for gamma rays

- Angular resolution (for gamma rays): 0.24° - 0.76°

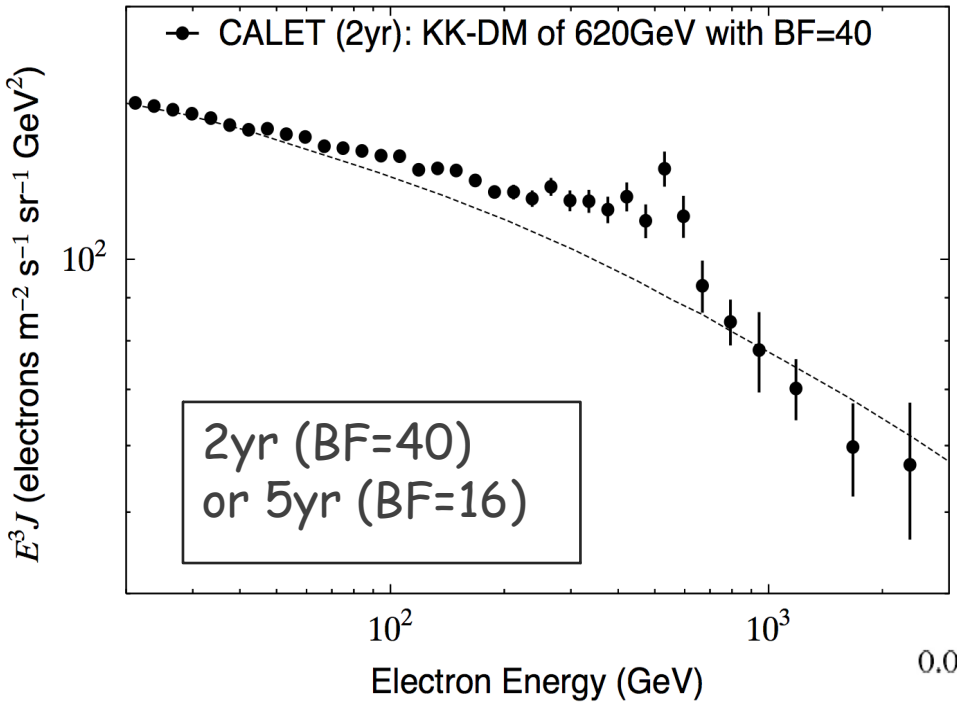
- Planned duration: 5 years

Electrons from nearby SNR sources

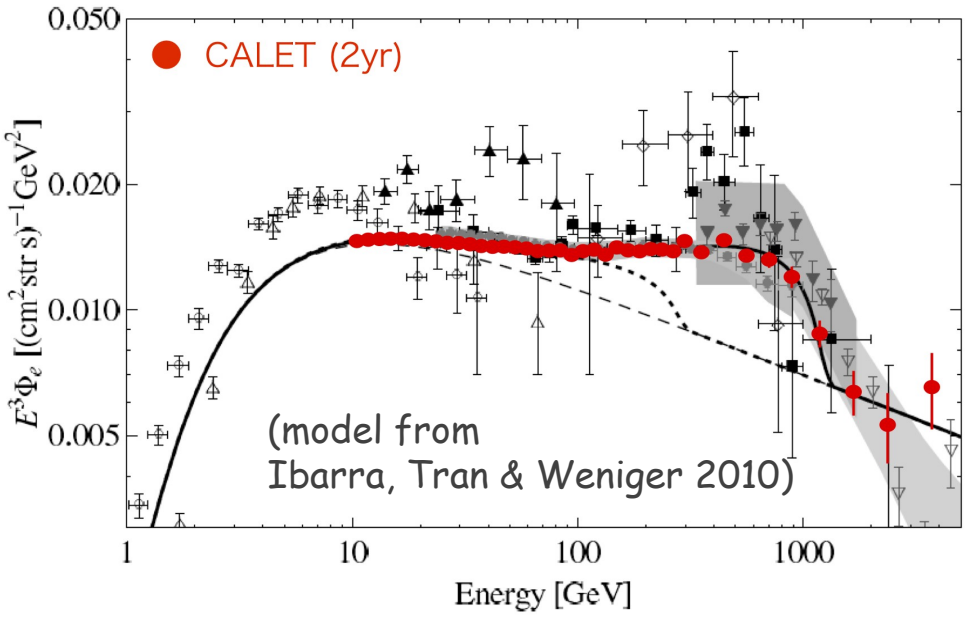


(blue line from Kobayashi et al. 2004)

Dark matter search: electrons+positrons



$(e^+ + e^-)$ spectrum from Kaluza-Klein Dark Matter annihilation



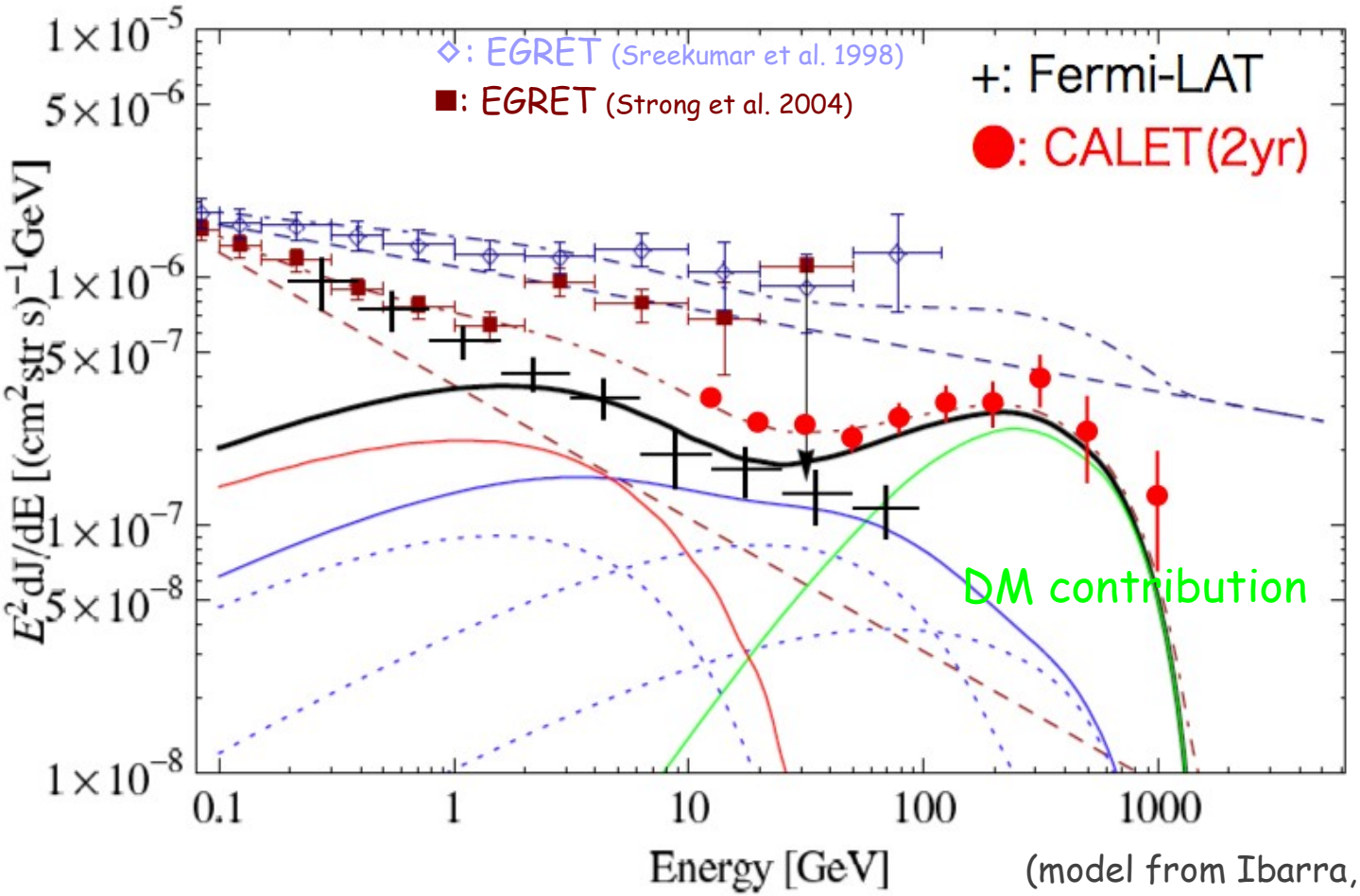
$e^+ + e^-$ flux from fermionic DM decay:

$\Psi_{DM} \rightarrow l^+ l^- \nu$

M_{DM} = 2.5 TeV (solid line)

$\tau_{DM} = 1.5 \times 10^{26}$ s

Dark matter search: diffuse extragalactic gamma rays



Diffuse gamma-ray flux from extragalactic fermionic DM decay:

$\Psi_{DM} \rightarrow l^+l^- \nu$

M_{DM} = 2.5 TeV

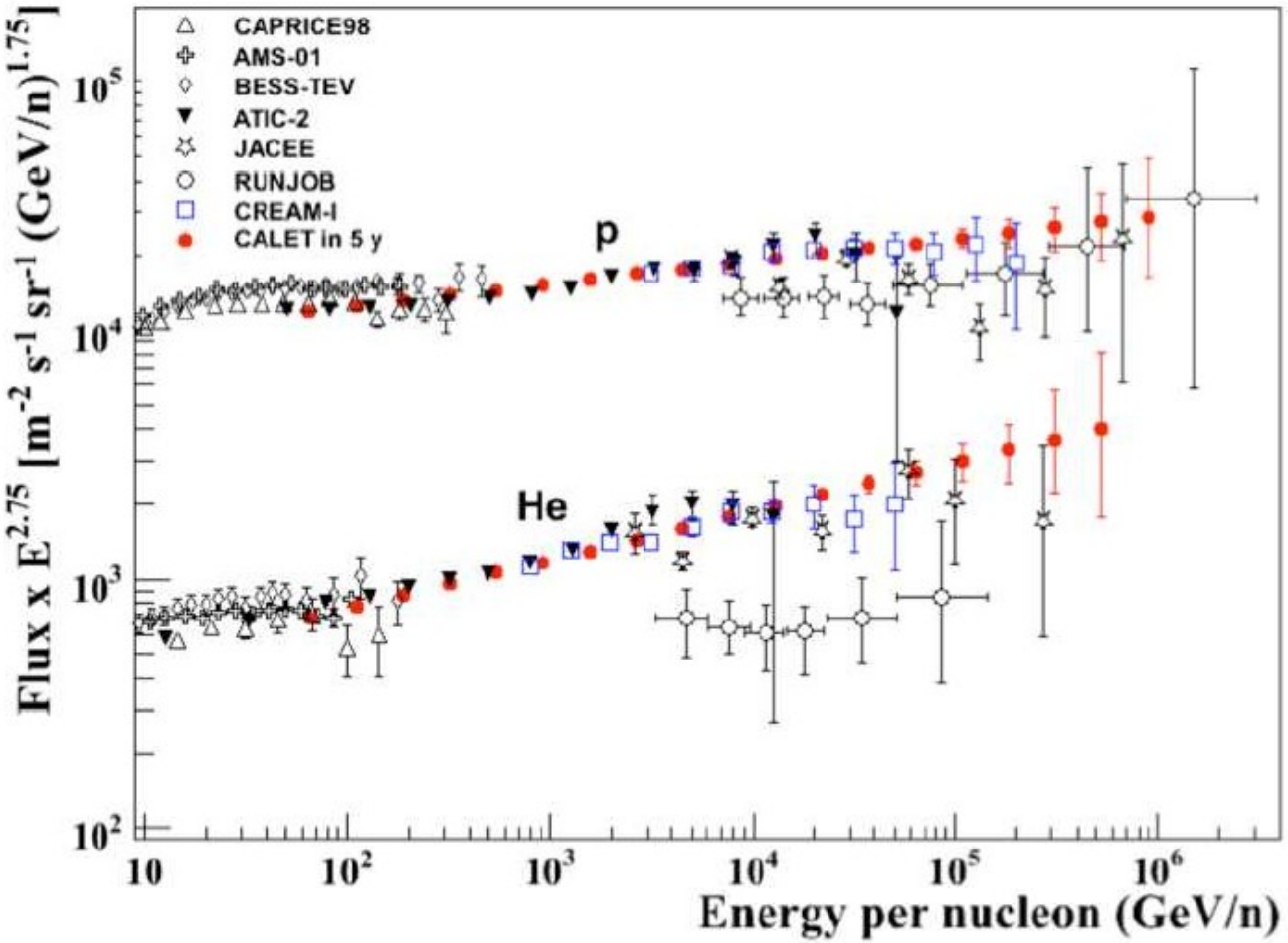
$t_{DM} = 1.5\times10^{26}$ s

(model from Ibarra, Tran & Weniger 2010)

- Galactic latitude: |b|>10°
- CALET error bars are only statistical ⚠
- Fermi-LAT data taken from A.A.Abdo et al., 2010 (EGB, 1 year data, statistical+systematic errors)

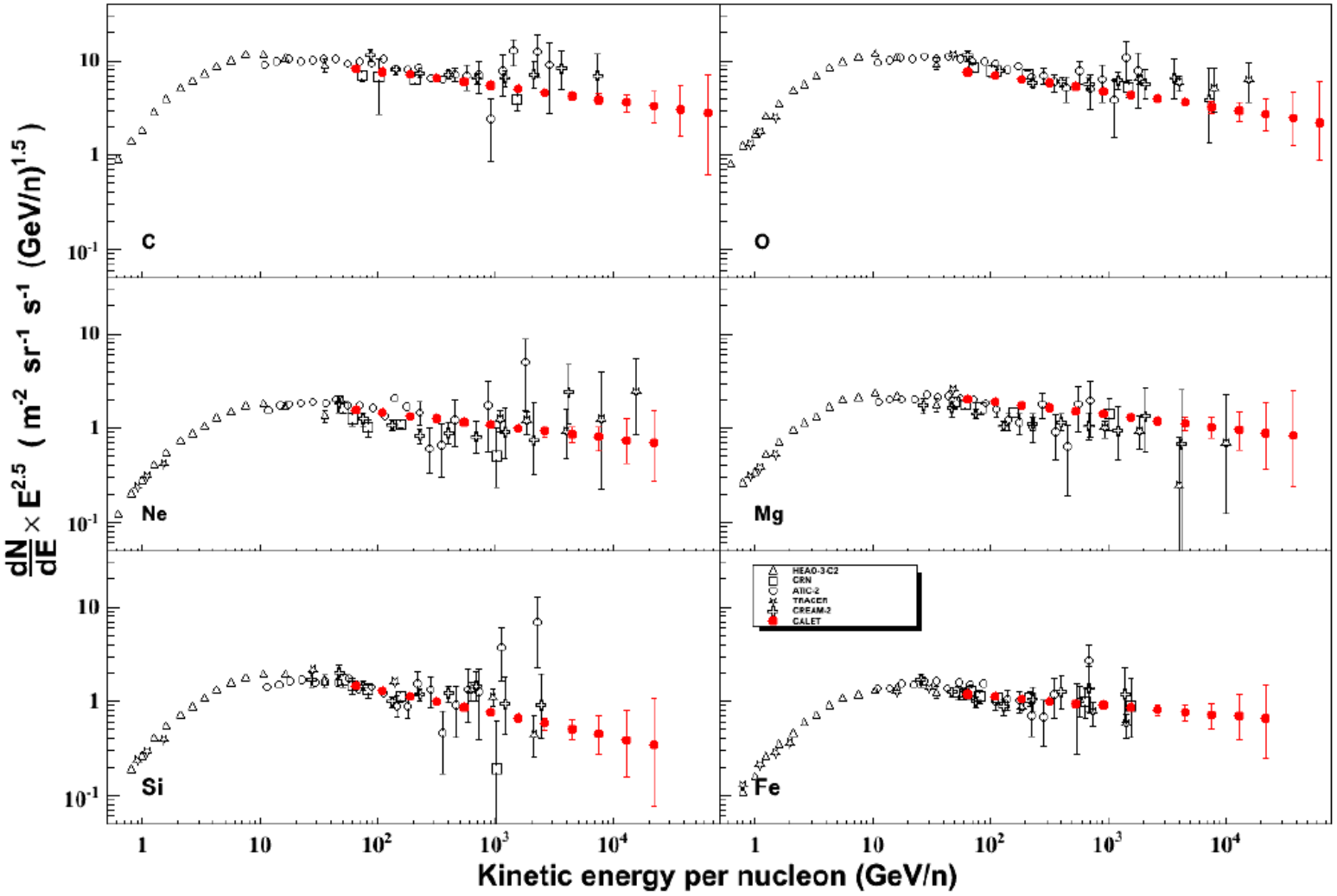
Protons and helium

(spectral indexes and normalizations
from CREAM data, Y.S. Yoo et al. 2011)



Heavier nuclei

(normalizations and spectral indexes from Hörandel 2002)

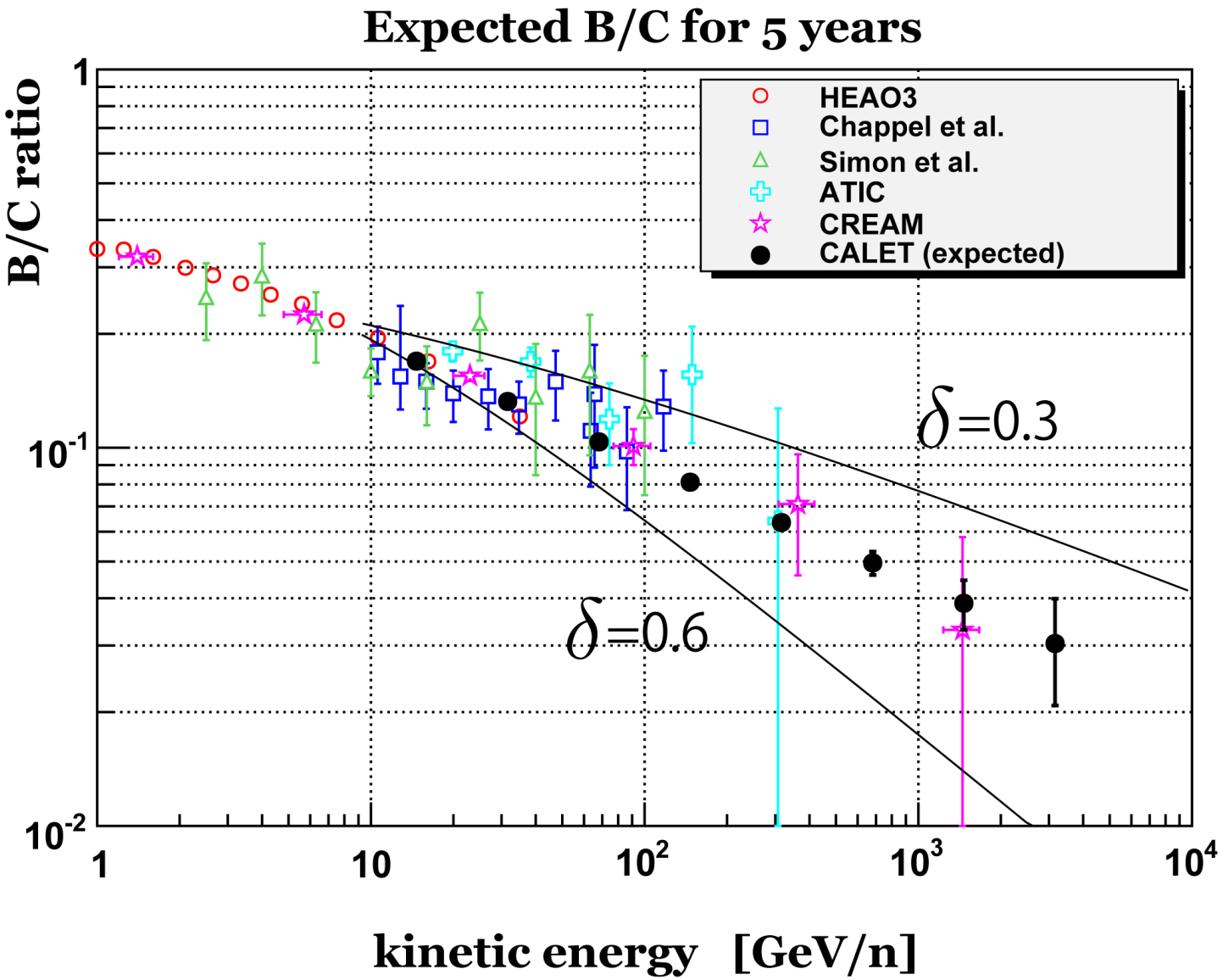


5 years exposure

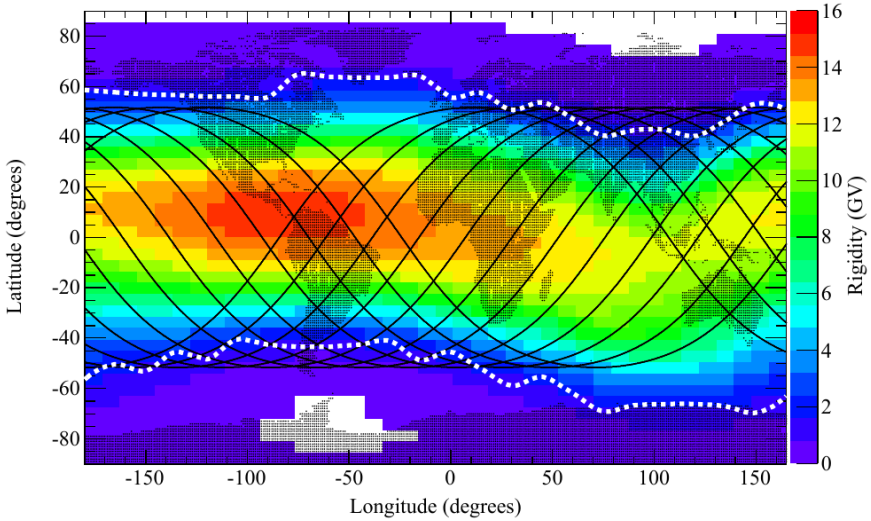
Interaction within 0.5 λ

Energy resolution: 40% (constant)

B/C ratio

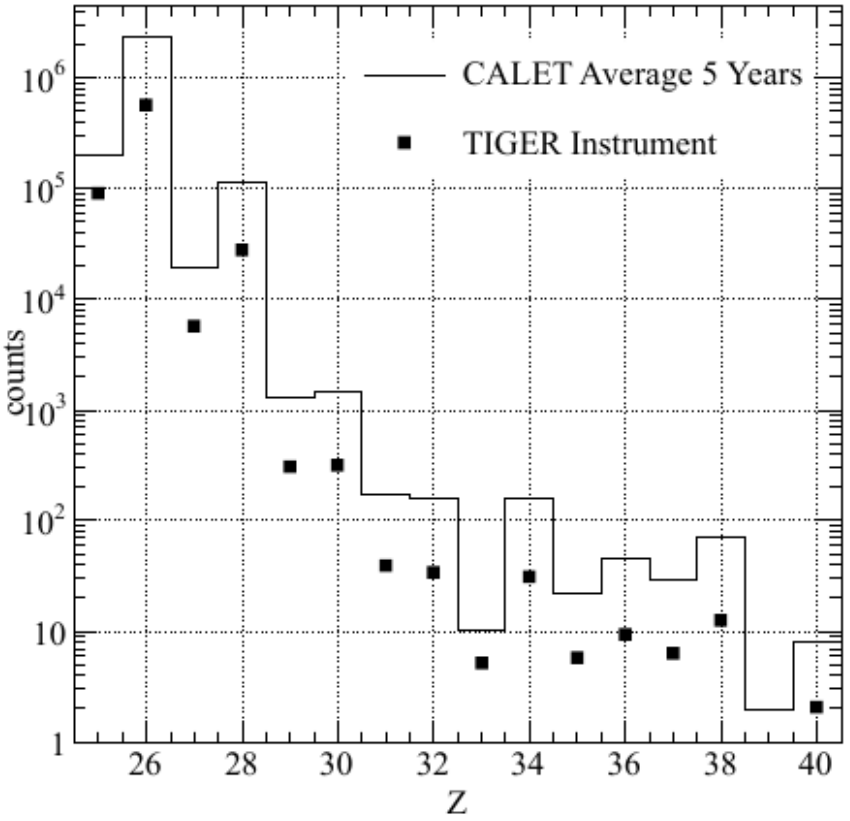

Expected B/C for 5 years
B/C ratio
kinetic energy [GeV/n]
HEAO3
Chappel et al.
Simon et al.
ATIC
CREAM
CALET (expected)
δ=0.3
δ=0.6
1
10^-1
10^-2
1
10
10^2
10^3
10^4

UH nuclei



White lines: 600 MeV/n Geomegnetic cutoff
Black lines: ISS orbit

(B.F. Rauch et al, proceedings of ICRC 2011)



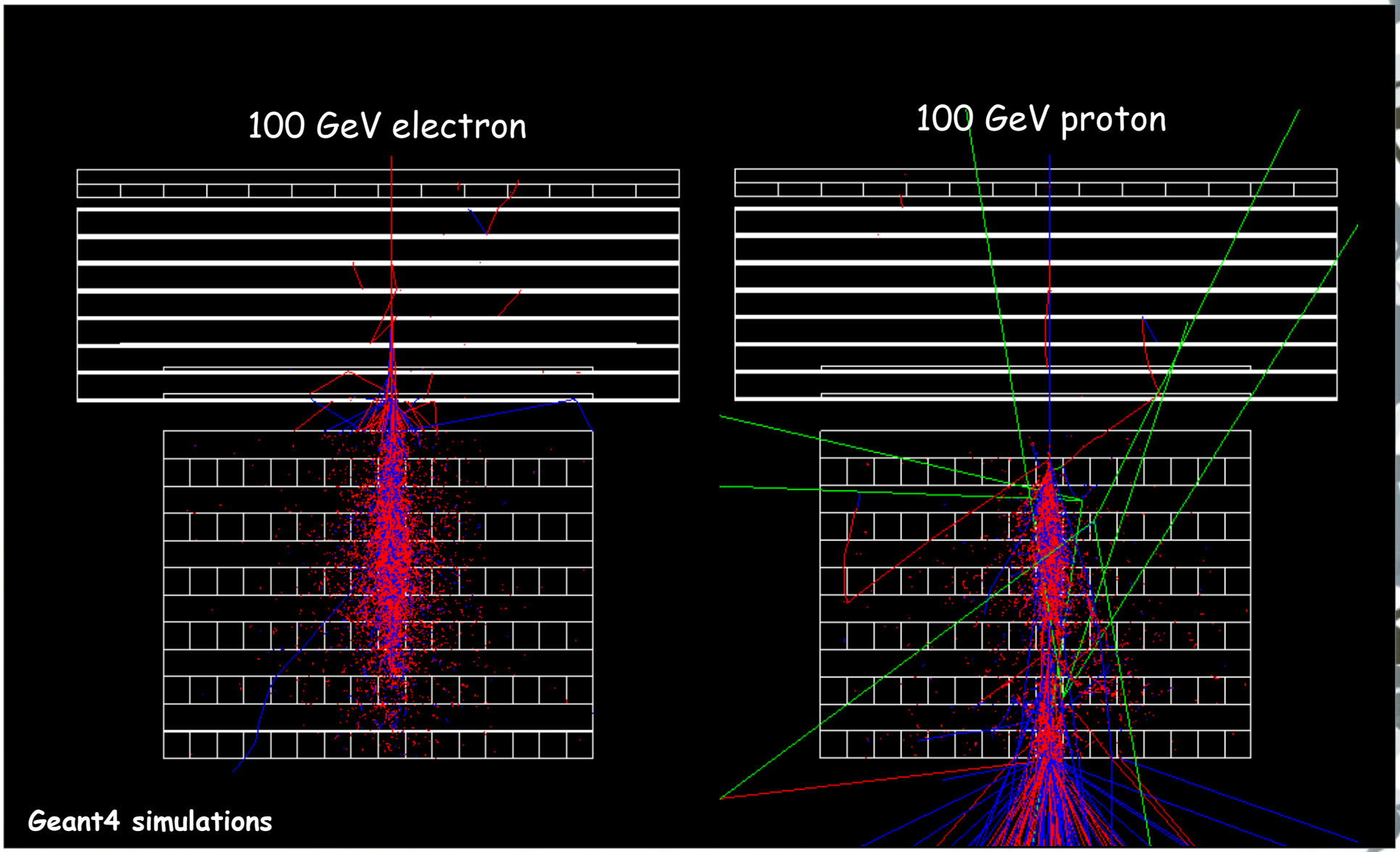
- CHD charge resolution is ~ constant above 600 MeV/n
- No need for energy measurement → No passage through TASC required
- Enlarged acceptance: 0.40 m^2 sr

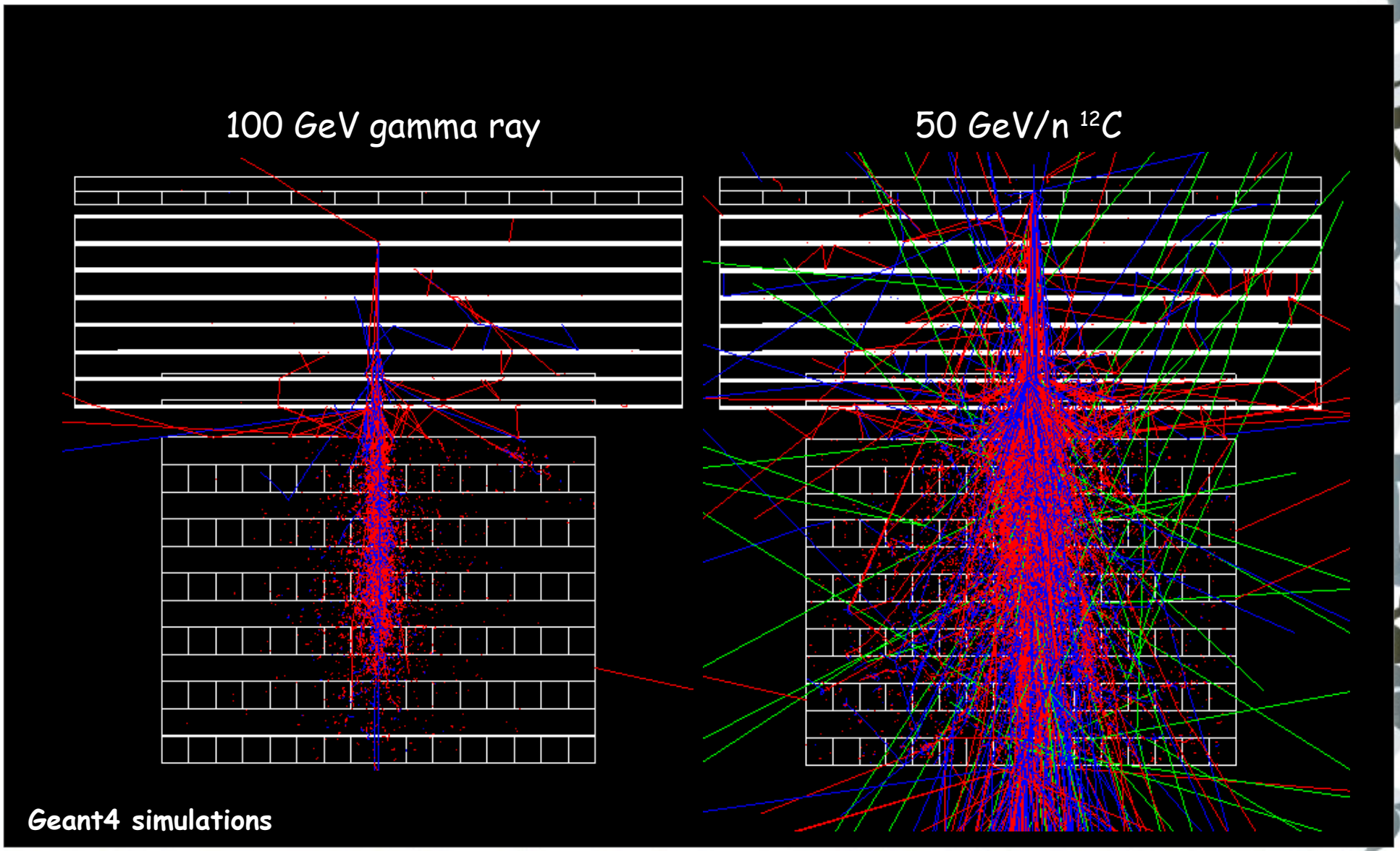
Summary

- CALET is a space-based calorimeter designed to perform cosmic-ray measurements with high energy resolution, mainly aimed at the $e^{\pm}$ component
- Its main instrumet is a deep, homogenous, segmented PWO calorimeter which provides both an excelelnt energy resolution and a high e/p rejection power
- It will investigate the spectrum of many cosmic ray species in a broad energy range, providing valuable information for indirect DM search and study of acceleration and propagation mechanisms.

Spares

CALET at work




100 GeV gamma ray
50 GeV/n ^{12}C
Geant4 simulations