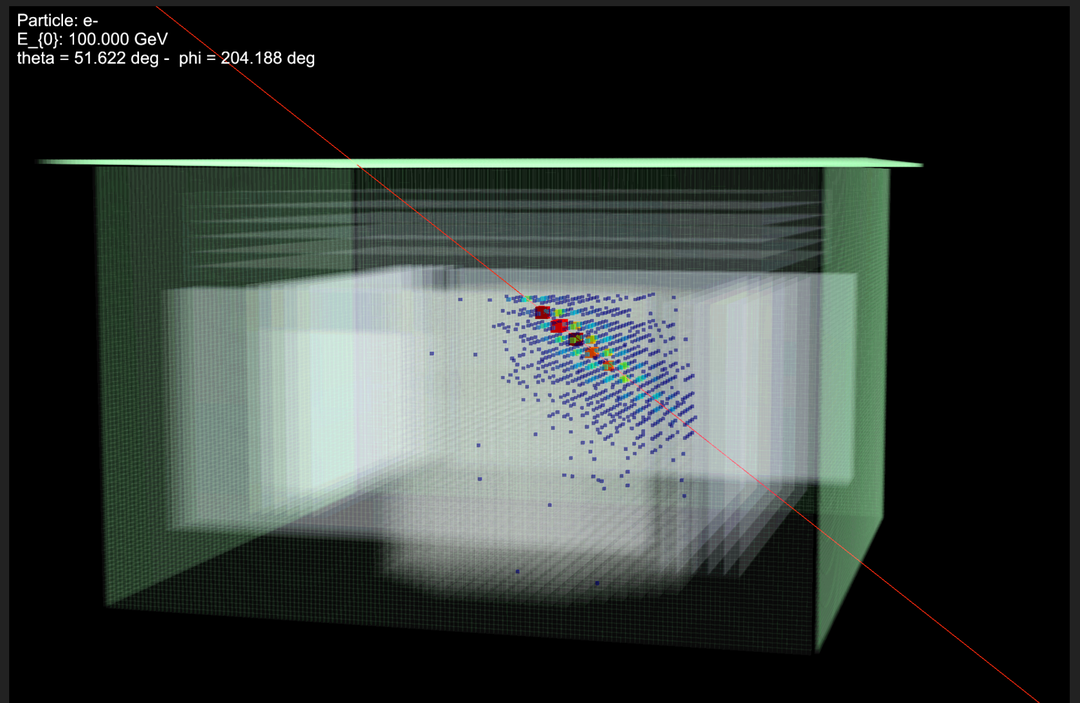
V. FORMATO - 15/07/2020 C.D.S. ROMA TOR VERGATA

HERD

THE HERD MISSION

- HERD: flagship and landmark scientific experiment, China-led large international collaboration
- Main Scientific Objectives:
  - Dark matter: dark matter search with unprecedented sensitivity
  - Cosmic-ray: Precise cosmic ray spectrum and composition measurements up to the knee energy
  - Gamma-ray: Gamma-ray monitoring and full sky survey



Energy range (e/γ)	10 GeV - 100 TeV (e); 0.5 GeV - 100 TeV (γ)
Energy range (CR)	30 GeV - 3 PeV
Angular resolution	0.1 deg.@10 GeV
Charge resolution	0.1-0.15 c.u
Energy resolution (e)	1%@200 GeV
Energy resolution (p)	20%@100 GeV – PeV
e/p separation	~10^{-6}
G.F. (e)	>3 m^2sr@200 GeV
G.F. (p)	>2 m^2sr@100 TeV
Field of View	+/-70 deg (targeting +/-90 deg)
Lifetime	>10 years
Mass	~4000 kg
Envelope	~3000*2300*1550 mm^3

HERD IN ITALY

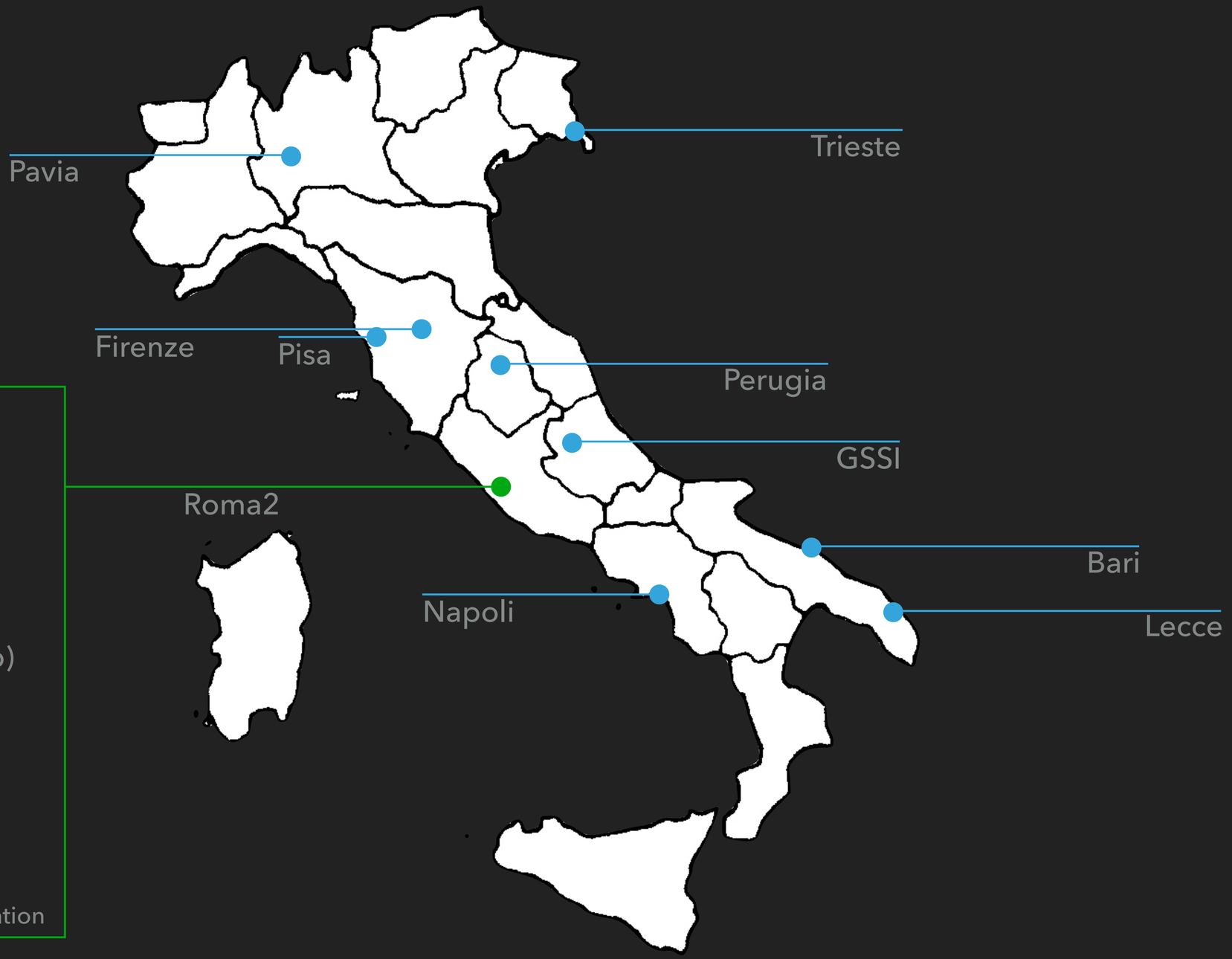
FTE ~34

Resp. Nazionale
G. Ambrosi - Perugia

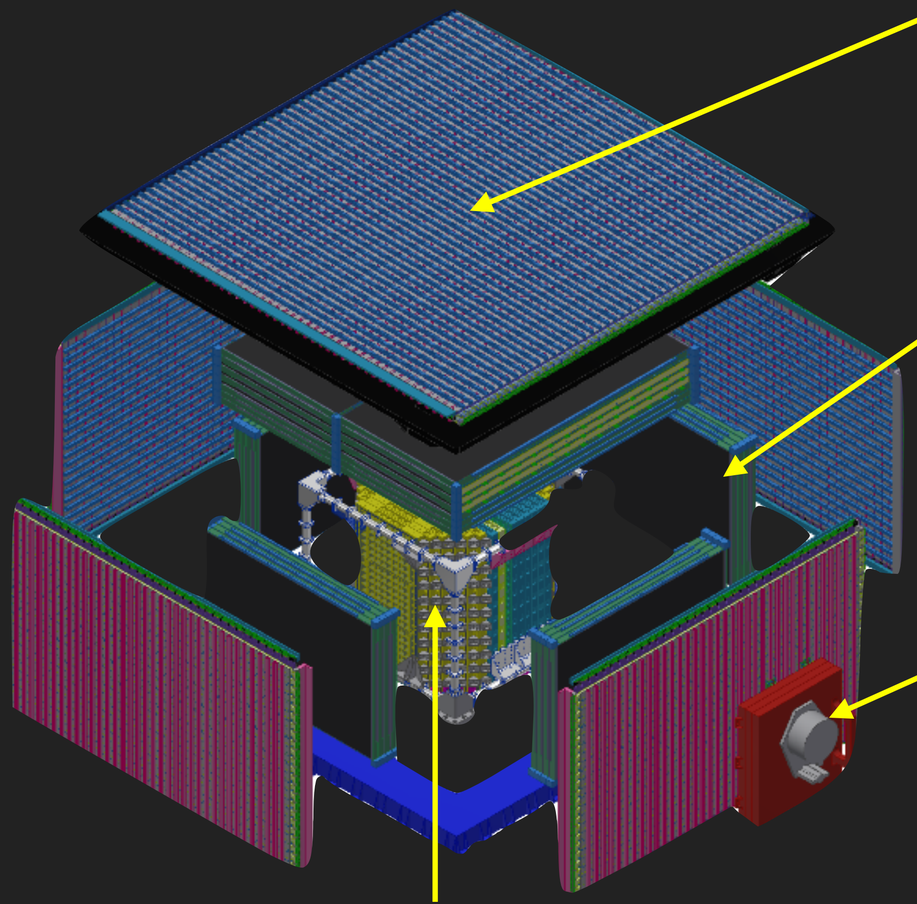
Anagrafica (PG->RM2)
V. Formato 20%
V. Di Felice 20%
D. Gasparrini 30%

Attività / Responsabilità
Test beam & software (Tracker working group)
Experiment software
MC production coordination
Data analysis & simulation:

- SCD / Tracker design and performance
- Tracking of hadrons and showers
- Performance of photon measurements
- Calorimeter reconstruction and lepton/hadron separation



THE HERD PAYLOAD

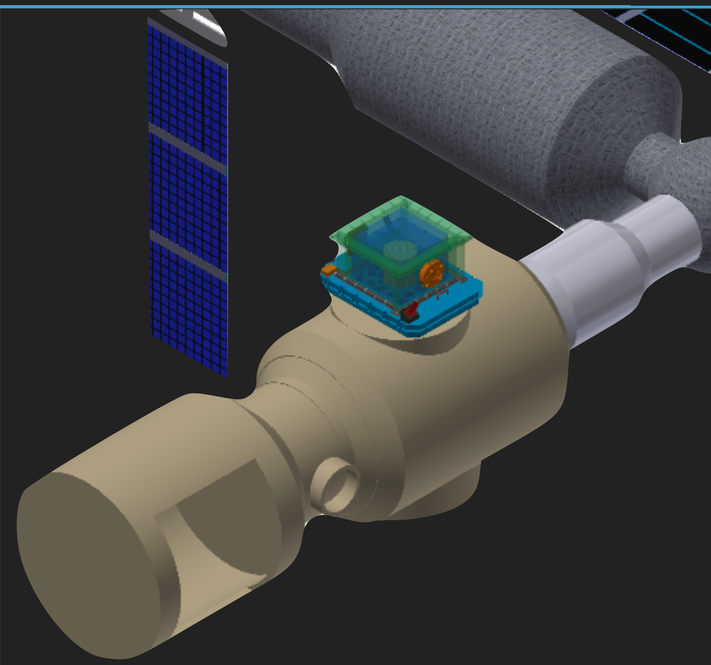


PSD
Gamma identification
Charge measurement

Tracker
Charge measurement
CR trajectory
Gamma converting/tracking

TRD
TeV CR calibration

CALO
3-d imaging calorimeter: Energy measurement & Particle identification



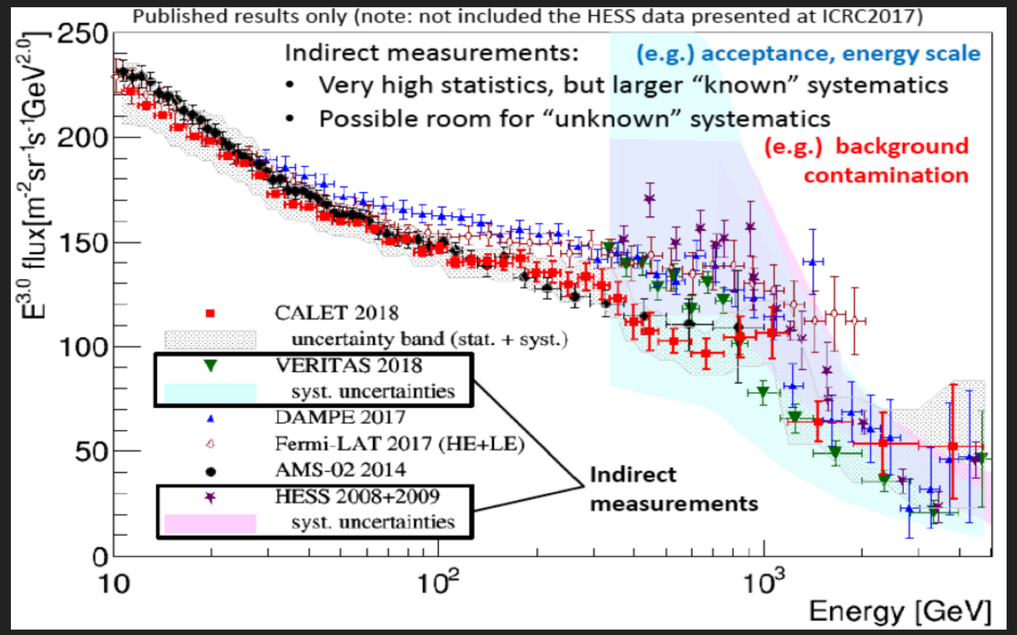
- HERD on China-Italy Module
  - Feasibility study (preliminary) on HERD & China-Italy MODULE is finished by a joint team from CSU, IHEP, CAST and TAS-I.
  - Technically feasible with low risk

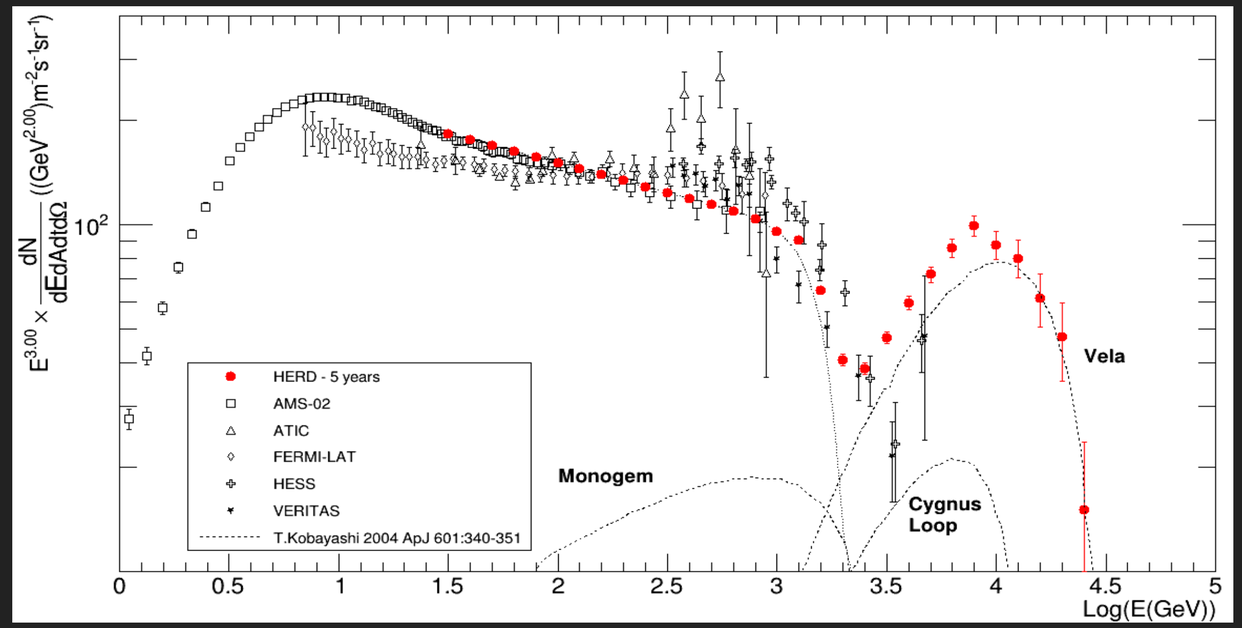
PHYSICS OBJECTIVES

Measure the total lepton flux ($e^+ + e^-$)

Indirect search for dark matter and/or unexpected high energy CR sources

Need:
Large collection power
Excellent energy resolution
High hadron rejection





Recent measurements show a spread in the lepton flux measurement pointing to a systematic uncertainty not yet understood.

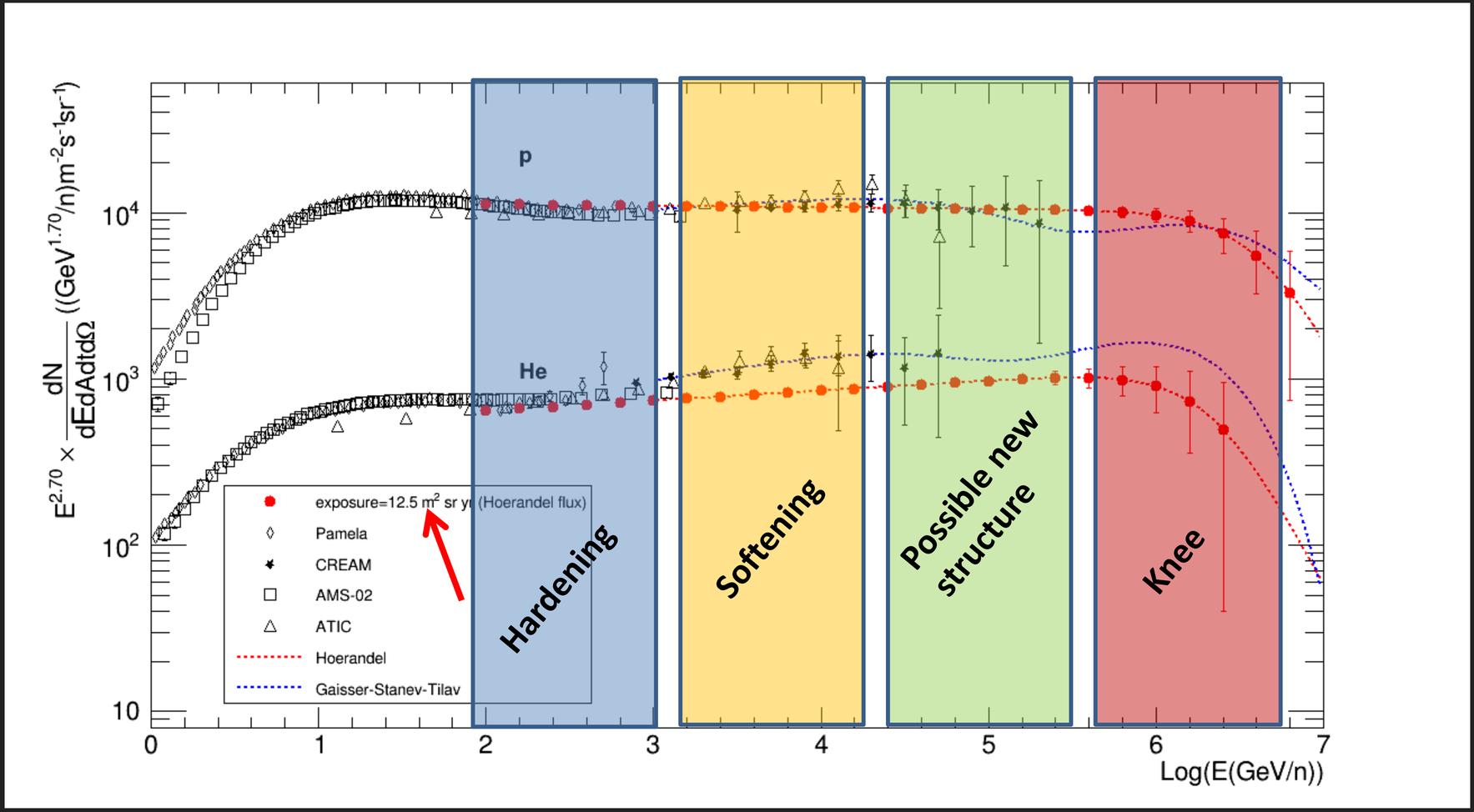
-> Need reliable energy scale calibration

Projection for $e^+ + e^-$ total flux in 5 years under relatively optimistic assumptions:

- No energy bin optimization
- Energy independent GF = 3.6 m2 sr
- No dead time nor inefficiency (real times might be longer..)
- AMS-02 power law (above 30GeV) + cutoff + nearby sources

HERD PROJECTION FOR 5 YEARS – PROTON, HELIUM SPECTRA

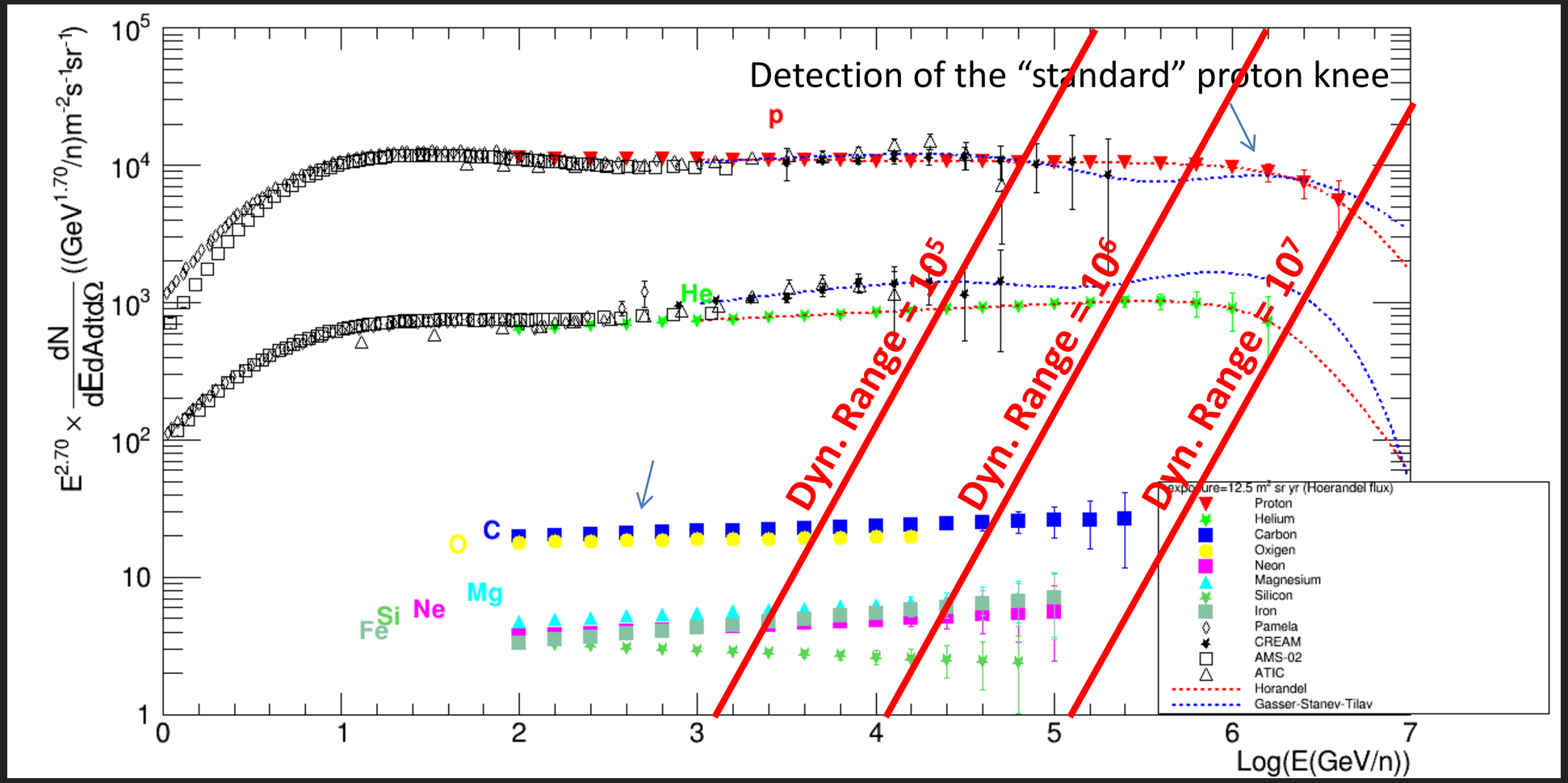
For the first time one single experiment will be able to probe all the funny structures in the CR spectra: Hardening, Softening, Possible new structure, Knee



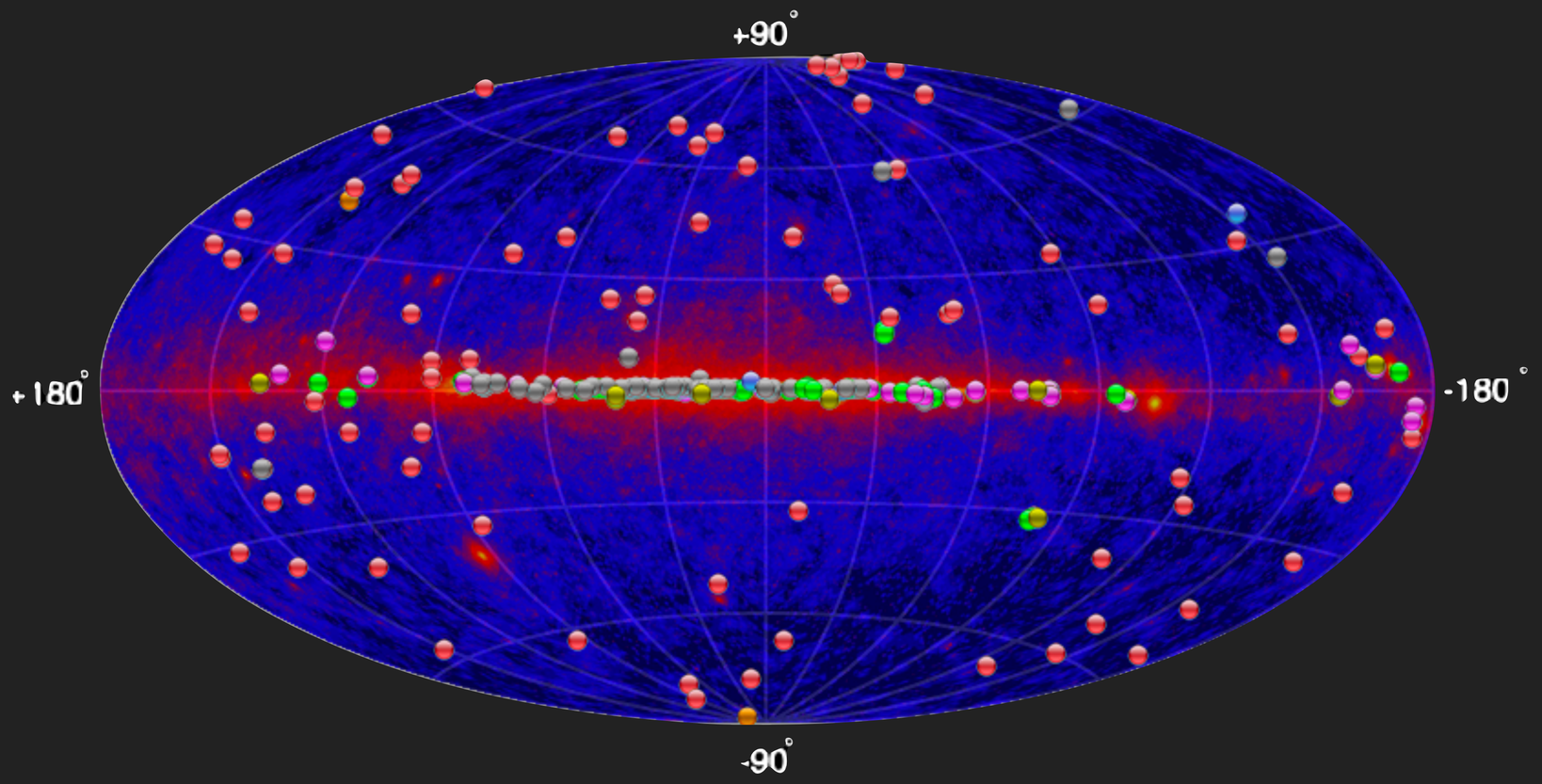
HERD PROJECTION FOR 5 YEARS – PROTON, HELIUM SPECTRA

Precision measurement of hardening, softening, and spectral indexes for most of the nuclei (primaries and secondaries)

The dynamic range is a fundamental issue even more important than geometric factor itself!



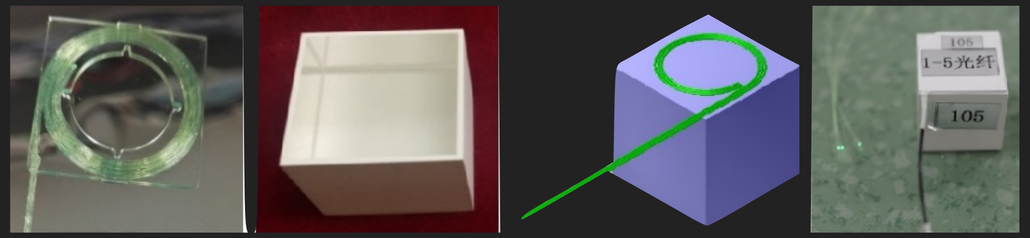
GAMMA RAY PHYSICS

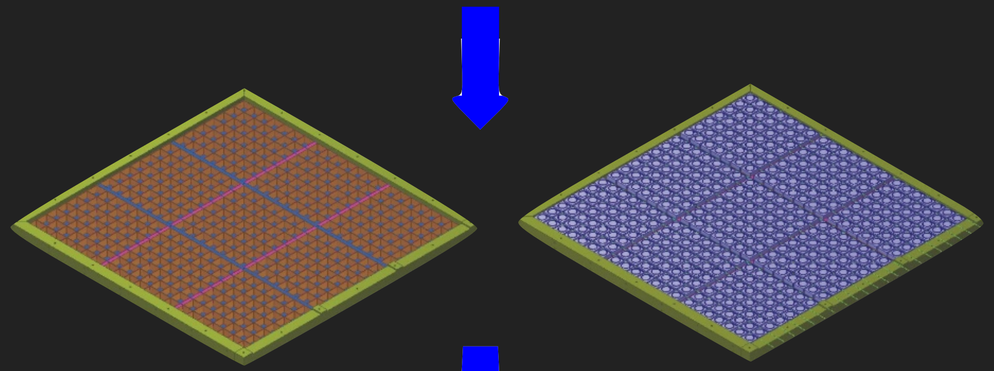


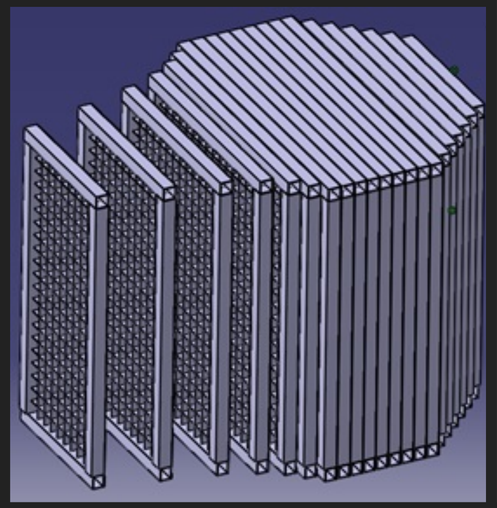
(TeV gamma ray catalog, superimposed to the Fermi-LAT catalog)

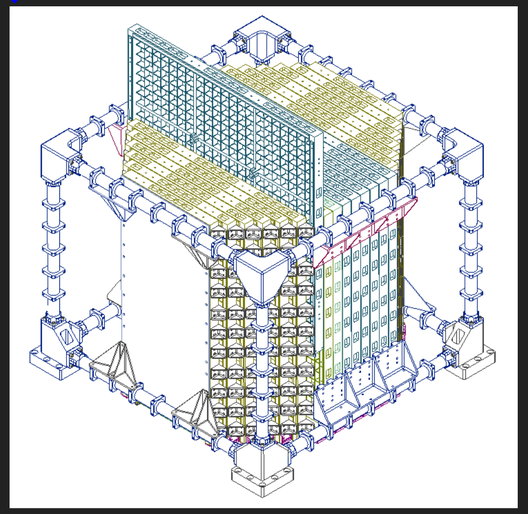
High geometric factor and good energy resolution provide a nice opportunity for Gamma ray monitoring and full-sky survey up to the multi TeV region

CALO

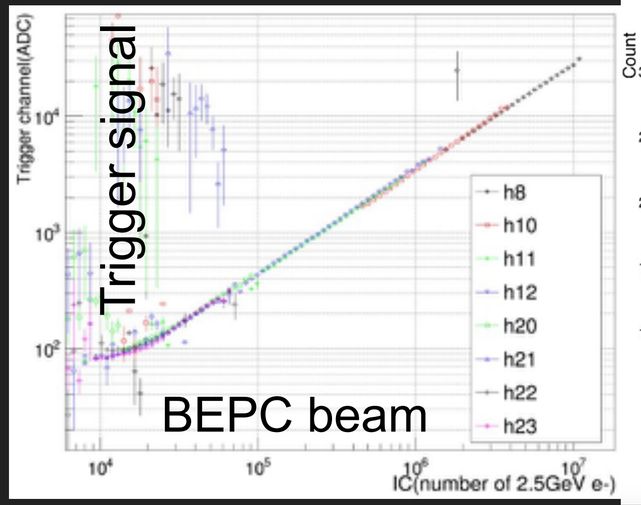


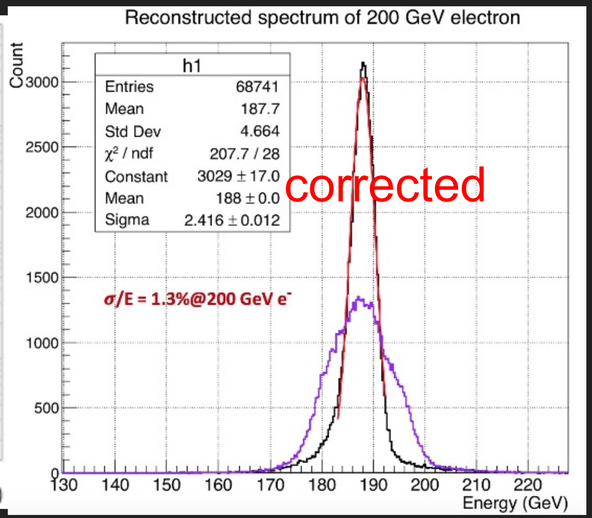






- CALOrimeter (3 N.I.L. and 55 R.L.)
  - A 3-d crystal array (~7500 LYSO crystals)
  - IsCMOS camera
  - Trigger sub-system
- Novel readout method
  - WLSF + IsCMOS
  - Linearity of LYSO+WLSF verified.
  - Energy measurement of WLSF + IsCMOS is verified.

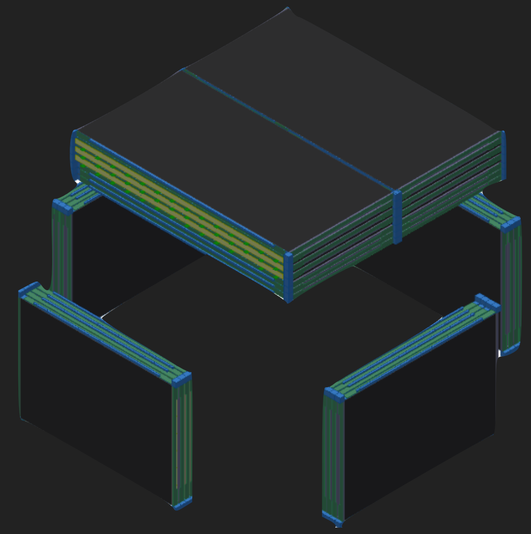




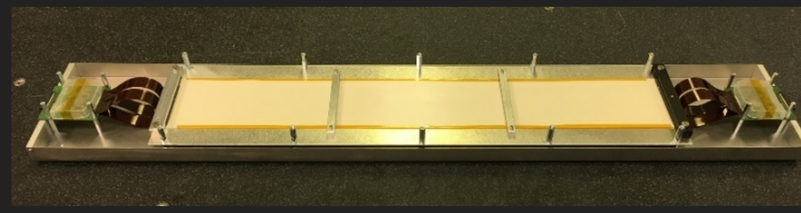
TRACKER

Charge measurement
CR trajectory
Gamma converting/tracking

Item	Value
Coverage ratio	>80%
Z measurement	Z = 1 - 20 (26); 0.1-0.15 c.u
Angle resolution	0.1 deg.@10 GeV
Layers of SSD	6 X/Y (top);3/6 X/Y (Lateral)
Active converter	1 R.L.
Dead time	<2 ms
Working mode	External trigger
Eff. Area (top)	~133 cm*133 cm
Eff. Area (lateral)	~114 cm*66.5 cm
Channels	~240,000/368,000

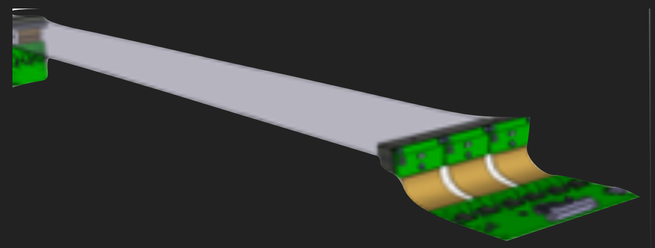


Default approach: single sided microstrip silicon detector (DAMPE)



DAMPE STK ladder

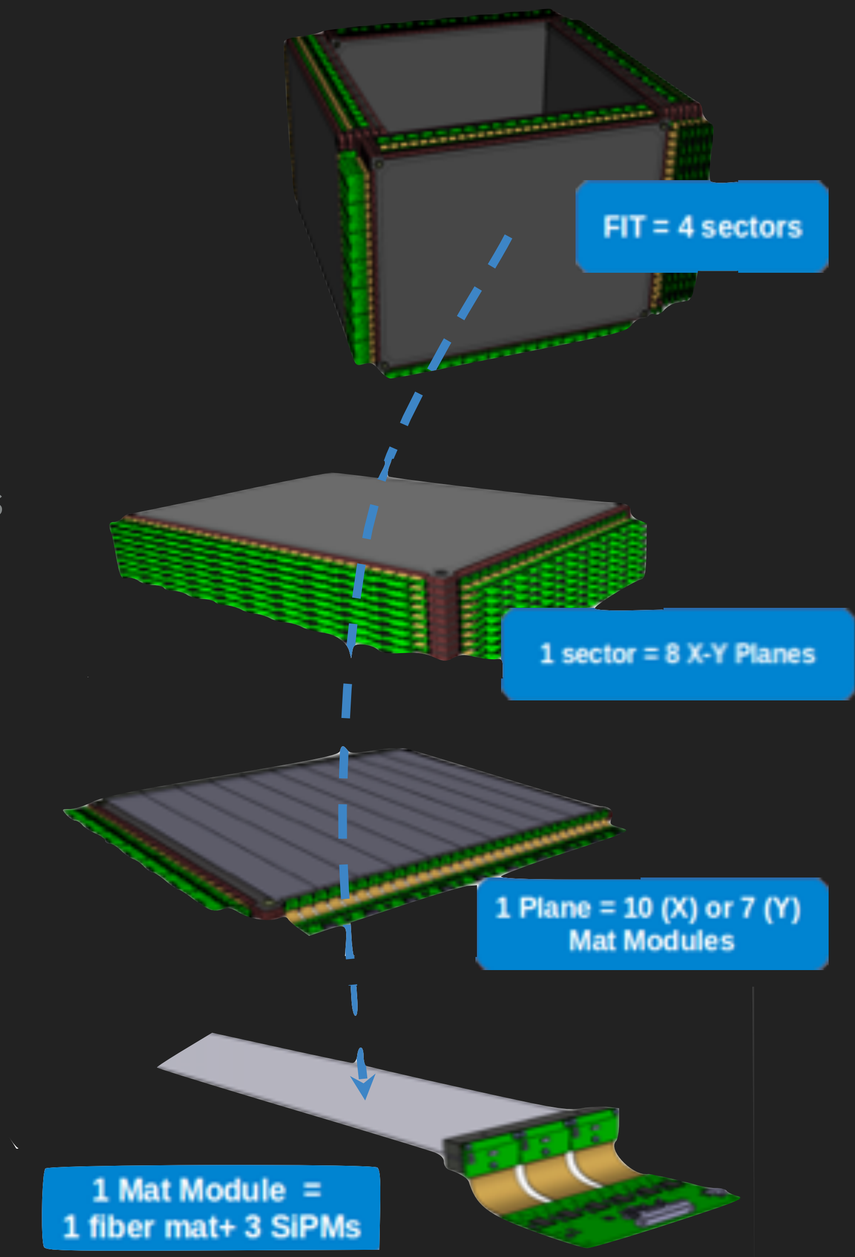
Alternative configuration: scintillating fibers read by SiPM (LHCb)



Fiber Tracker (FIT) Mat

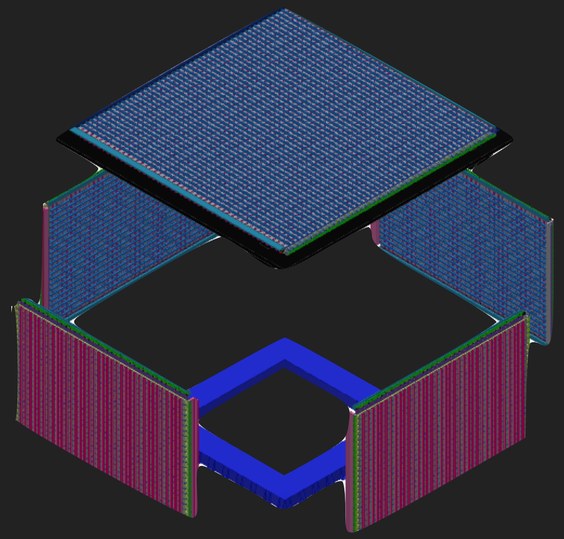
FIBER TRACKER

- New “10 μm” SiPM arrays tested during 2018 beam test:
- Spatial resolution: σ = 51 μm;
- Light yield: MIP Mean Peak Value (MPV) ~9 p.e. (400 GeV/c proton)
- The 1st FIT module space qualification tests and readout electronics are in progress.
- The procurement of fiber mats will be completed this week, then the production of the modules will start after mats delivery.
- The design of the prototype tray is being finalized. Then prototype trays will be assembled.
- The Barcelona (ICCUB) group has obtained funding to design the FIT FE ASIC.
- The simulation for a single FIT module has been completed, the overall simulation is in progress.

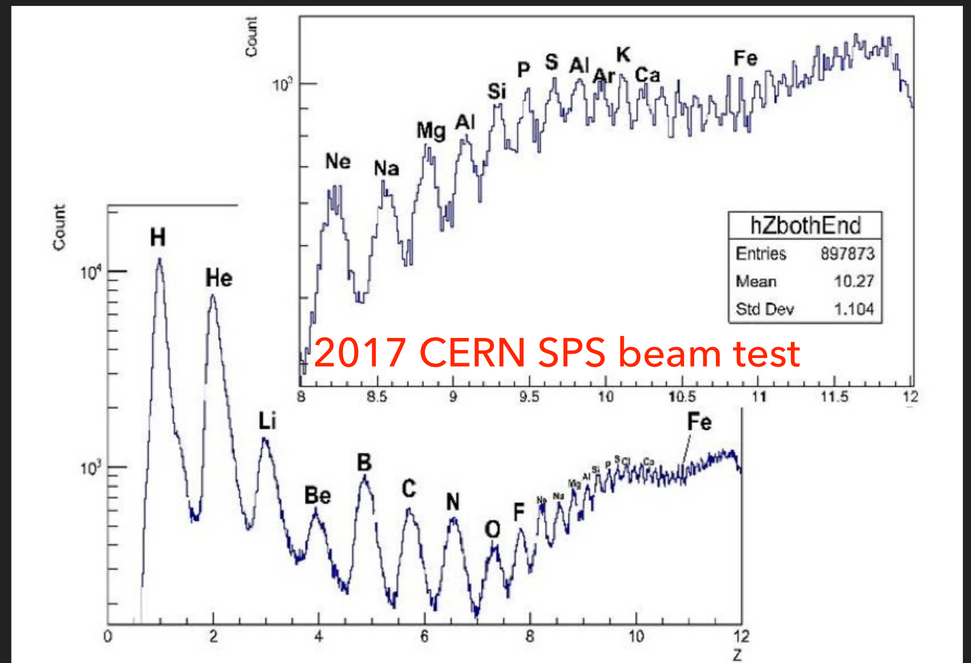


PSD

- Low energy gamma identification
- Charge measurement
- Design
  - 1 X/Y layer on top and 4 lateral sides
- X layer for LE photon trigger
- X & Y layers for Z measurement and e/gamma discrimination
  - 1 X layer on bottom side
  - SiPM + IDE3380 ASIC
- Low & high range to cover Z=1-26
- Redundancy SiPMs



PS bar readout by
2*4 SiPMs

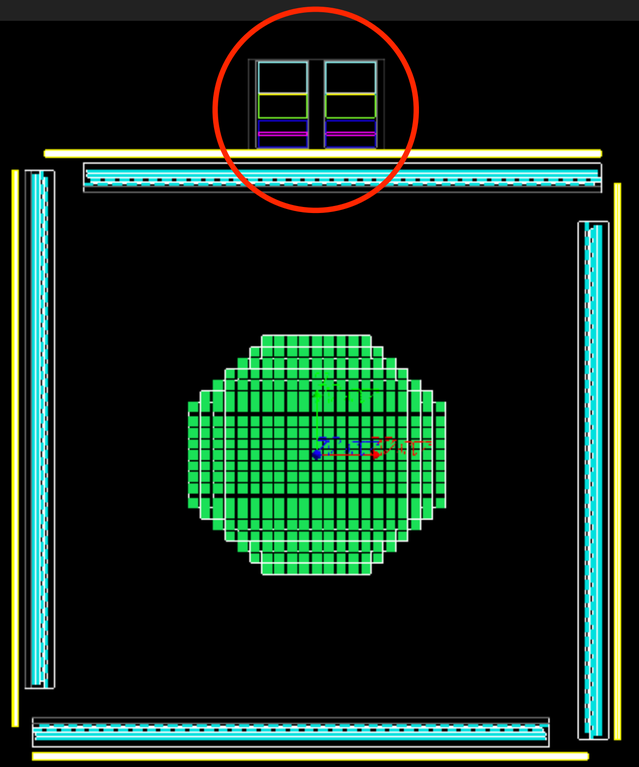


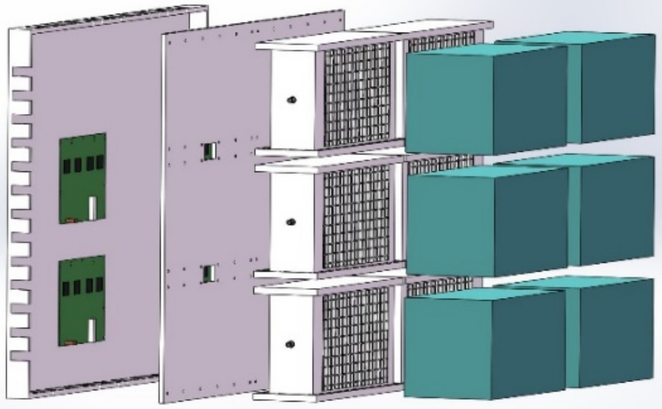
Two options being considered:

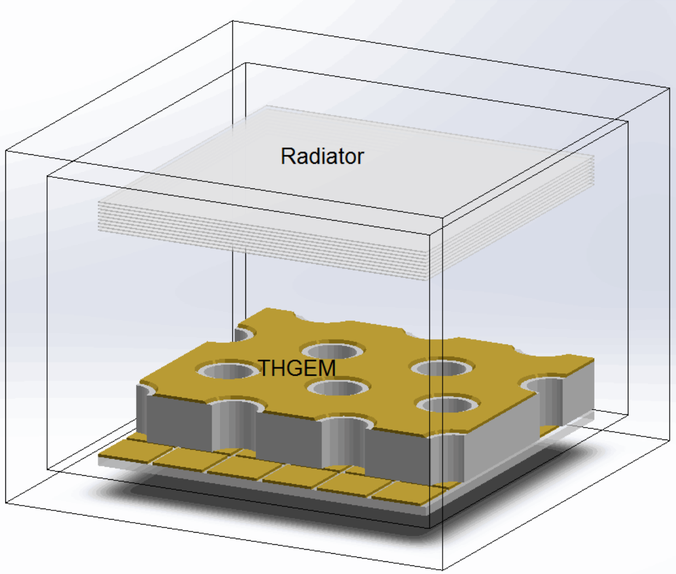
- Double layer of X-Y long bars
- Single layer of staggered square tiles (10cm x 10cm)

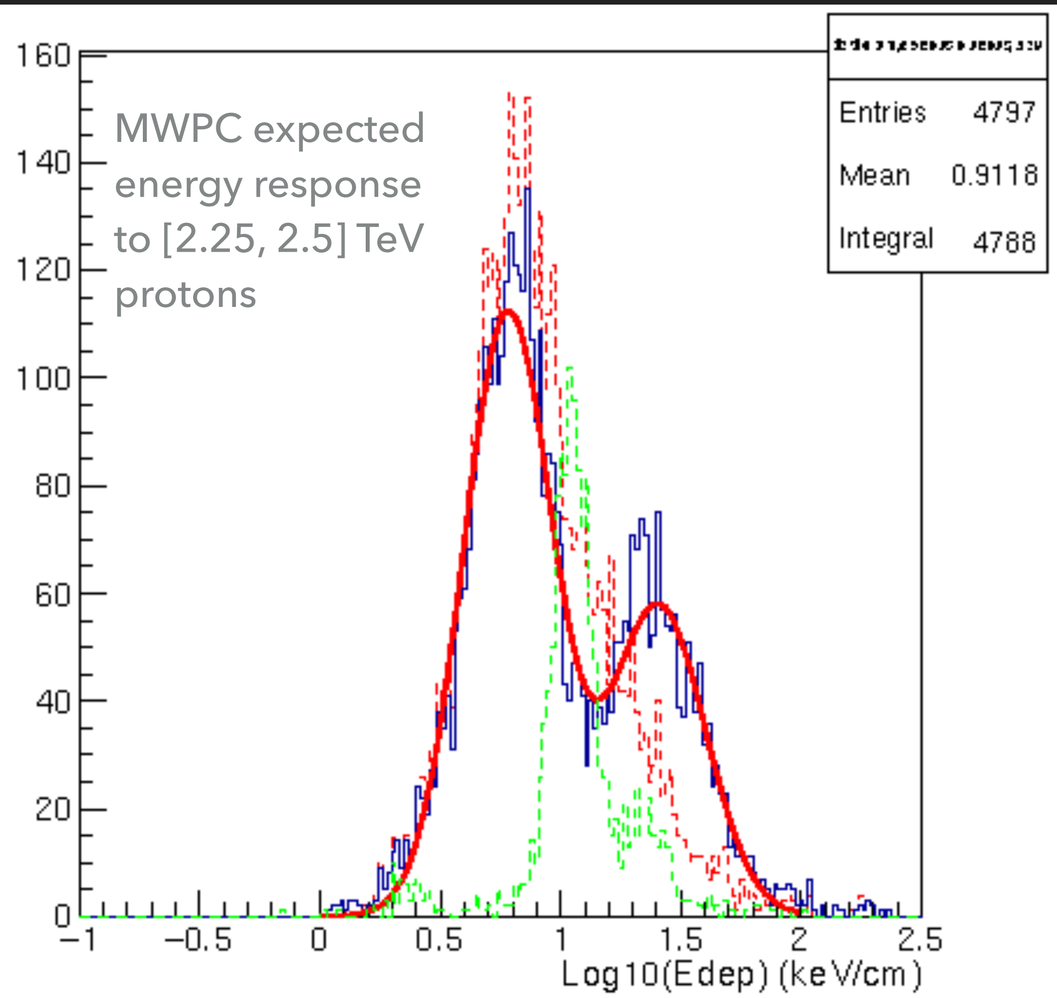
TRD PAYLOAD

TRD detector positioned on one side, dedicated to calibration of TeV energy scale of the calorimeter.



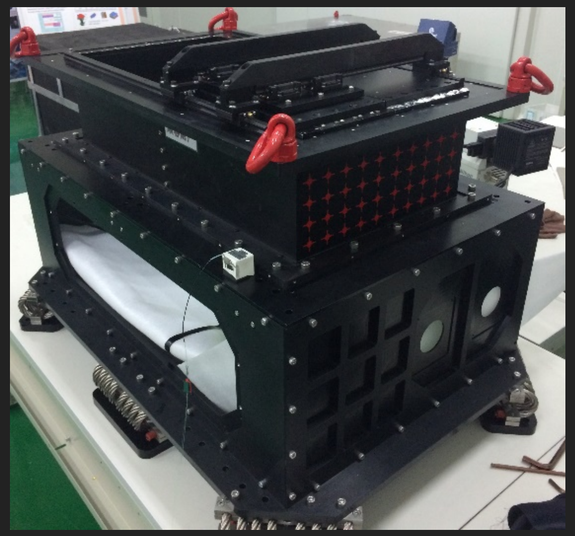




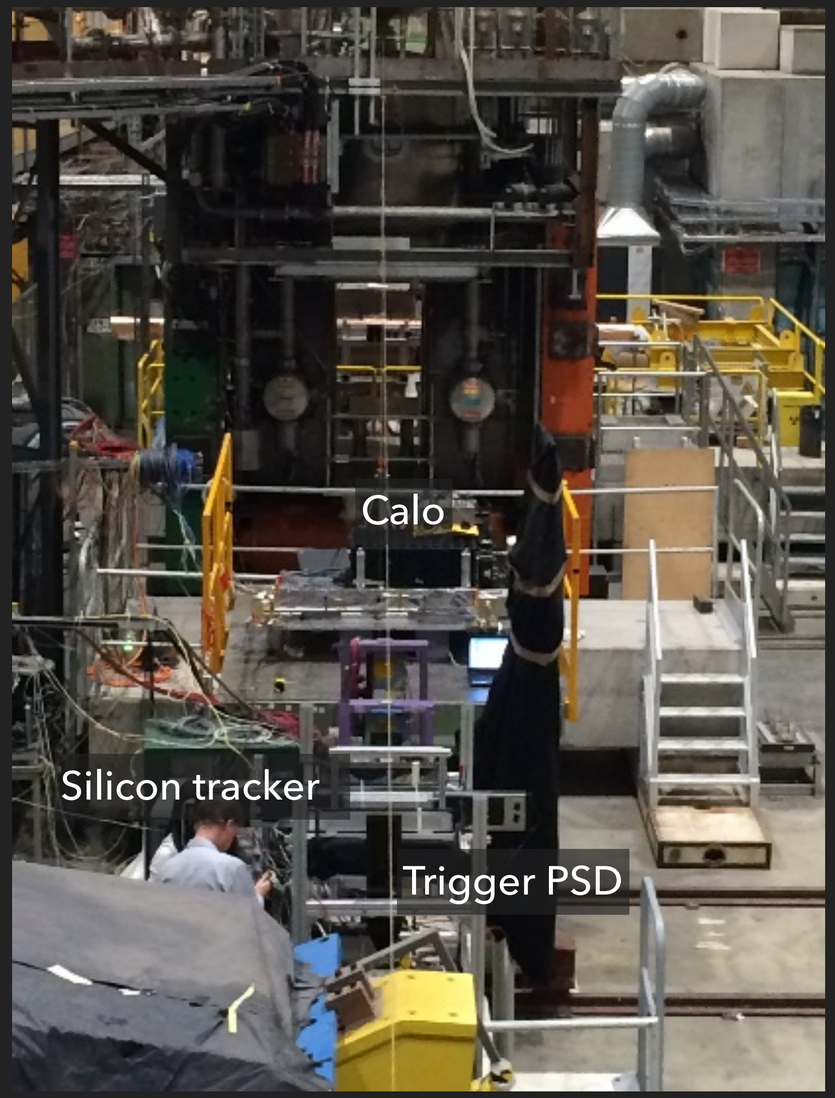


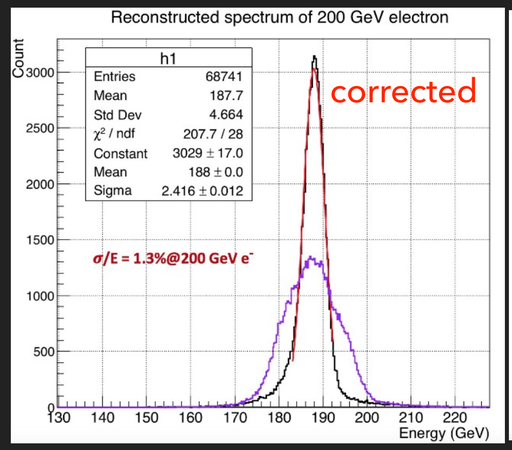
BEAM TEST CAMPAIGN

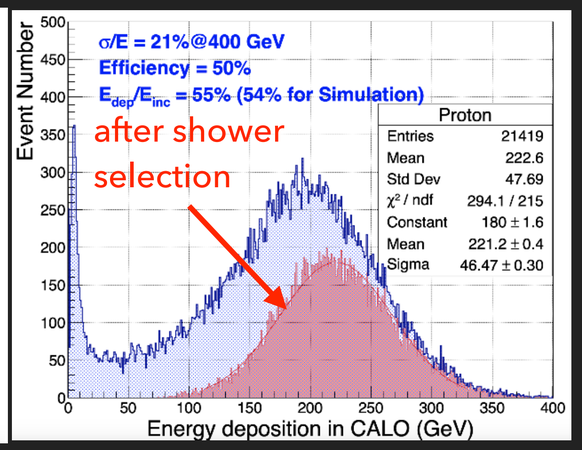
All key specifications of HERD instruments were tested & verified in the CERN SPS beam tests, with major participation from INFN sections.

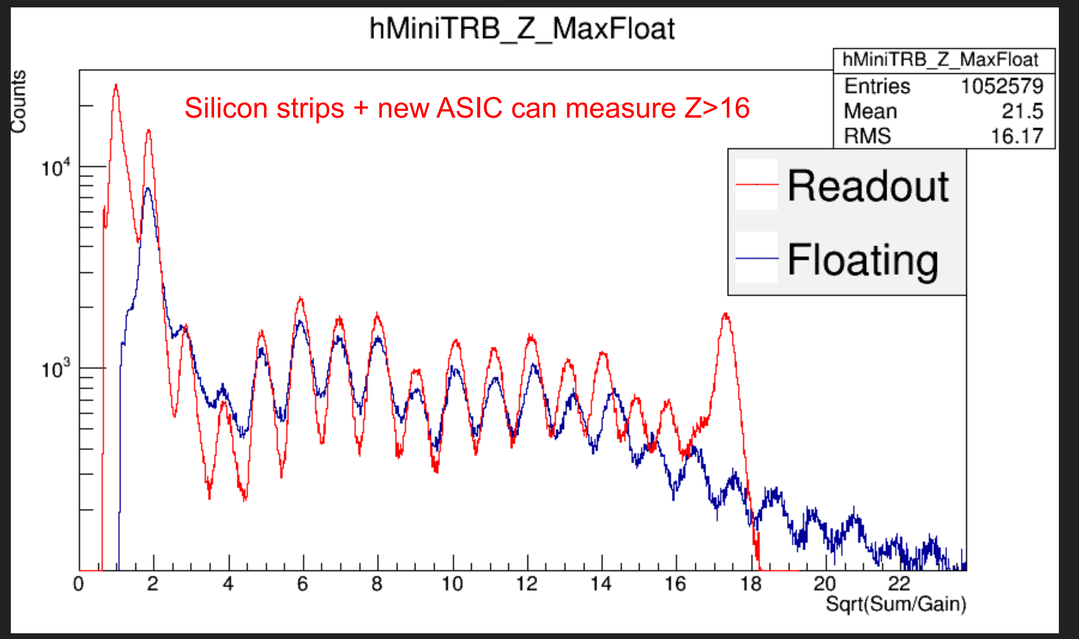


New prototypes for silicon sensors coming in 2020-2021, foreseen beam tests on ions@GSI

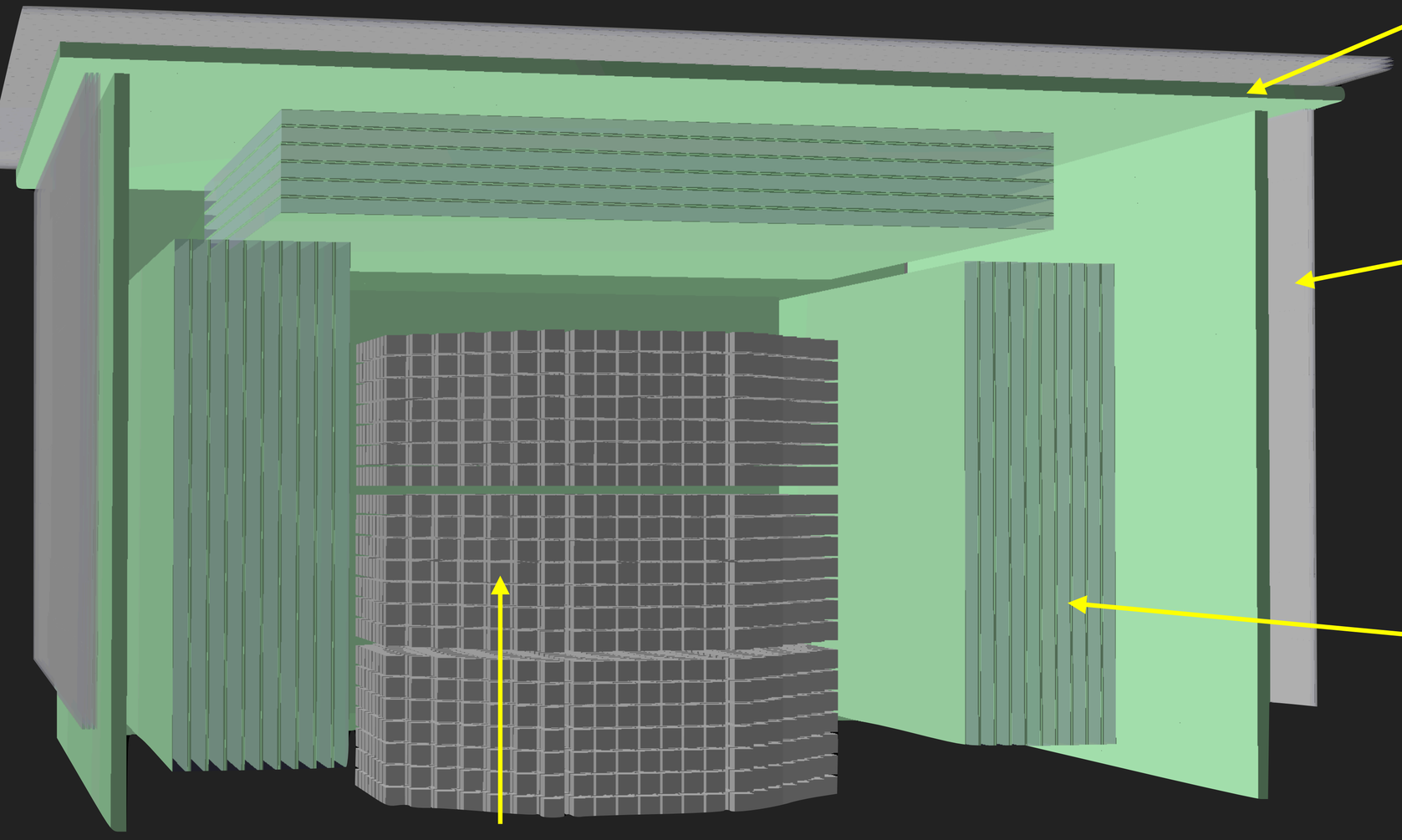








NEW CONFIGURATION UNDER STUDY



PSD
Gamma identification
Charge measurement

SCD
Charge measurement
Additional tracking help

Main area of responsibility for RM2 group:
- Beam test activities
- Official software implementation

Fiber tracker
CR trajectory
Gamma converting/tracking

CALO
3-d imaging calorimeter: Energy measurement & Particle identification

RICHIESTE

Ricercatori						
	Nome	Età	Contratto	Qualifica	Aff.	%
1	Di Felice Valeria		Dipendente	Ricercatore	CSN II	20
2	Formato Valerio		Dipendente	Ricercatore	CSN II	20
3	Gasparrini Dario		Dipendente	Ricercatore	CSN II	30
			Numero Totale Ricercatori	3	FTE: 0.7	

Missioni: 12k
(Meeting di collaborazione / management, organizzazione sessioni di lavoro e workshop interni, beam tests)