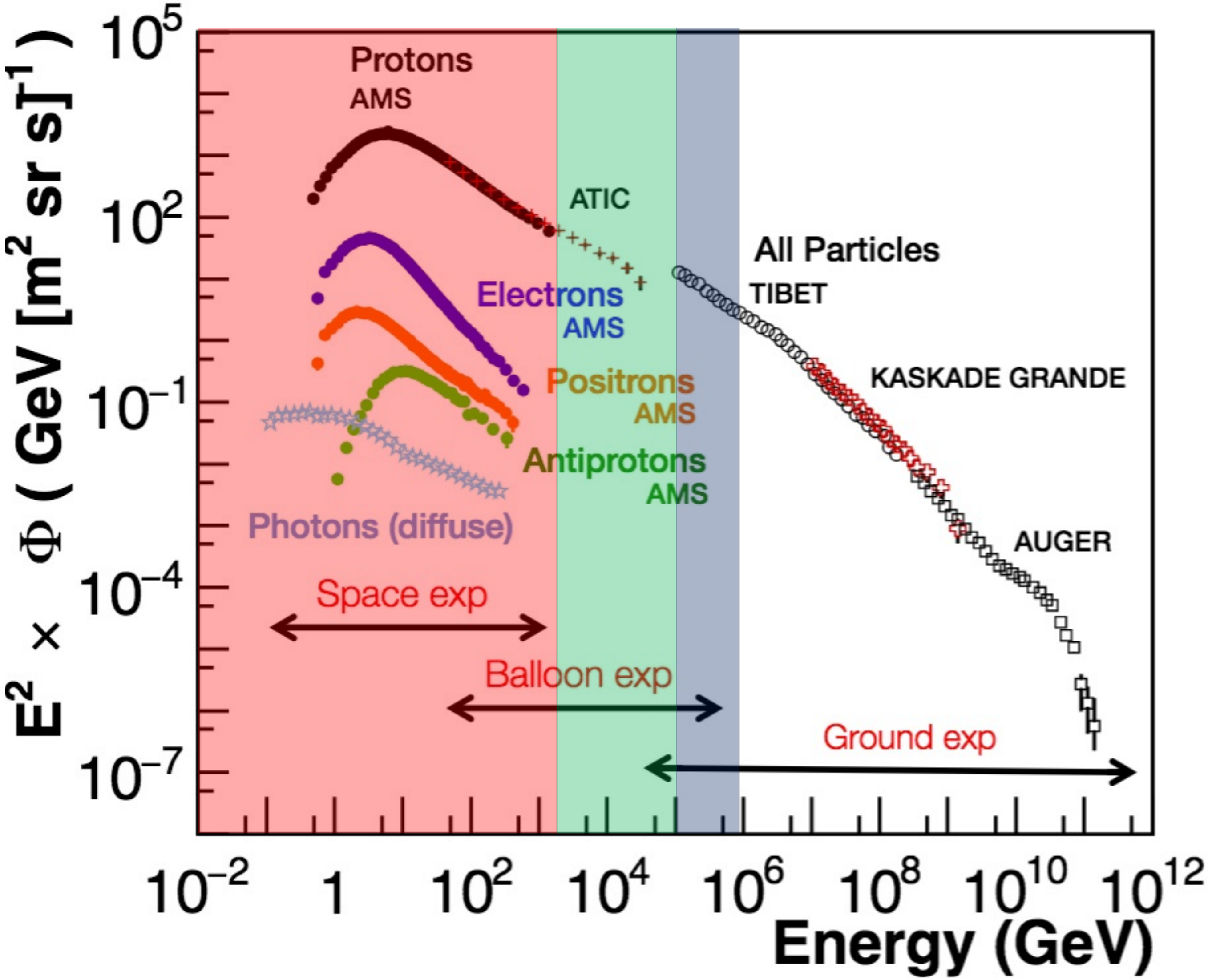
HERD_DMP: STATO E RICHIESTE 2024

Direct and accurate measurement of single species



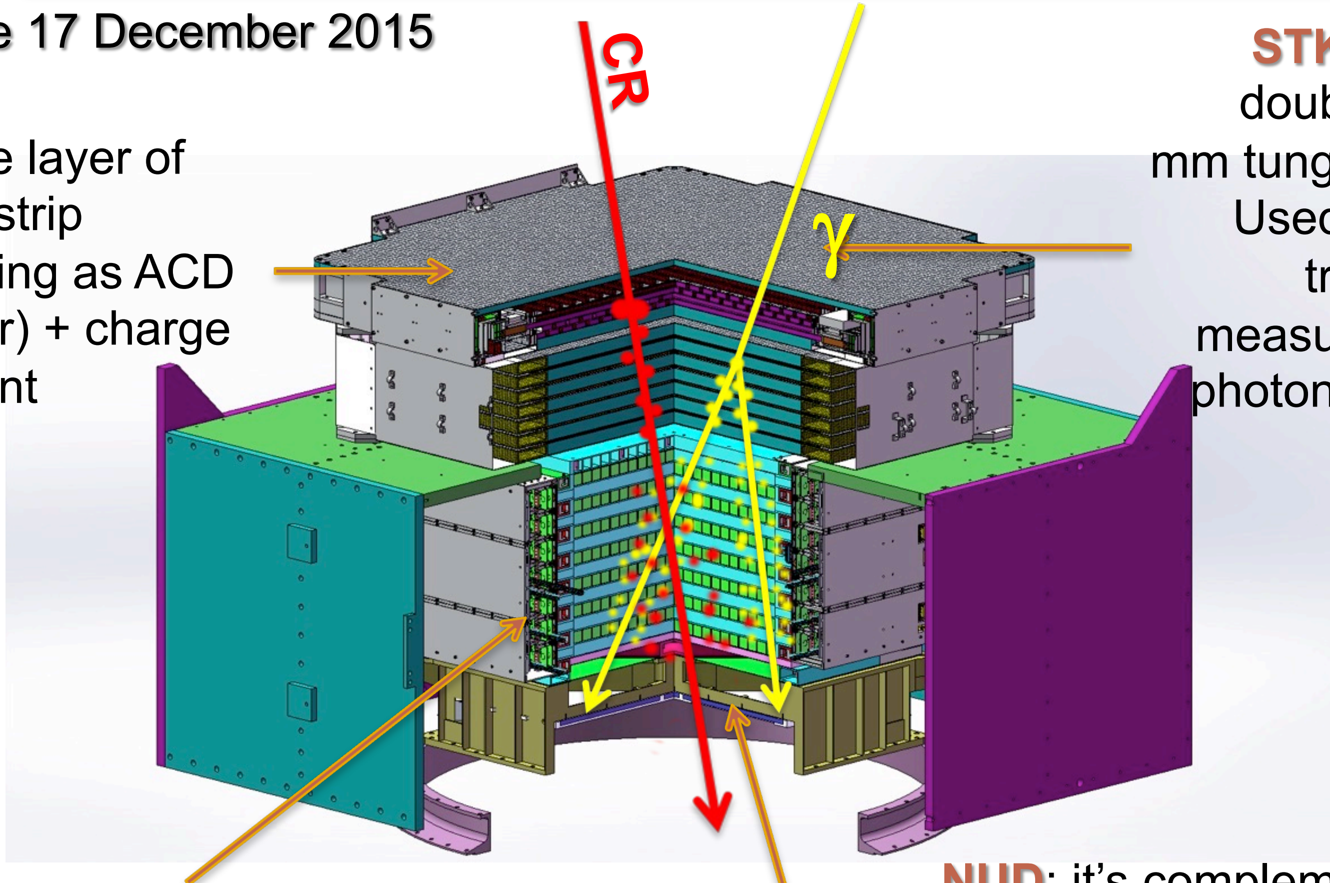
The goal is to measure directly (i.e. in space) each single CR species up to the highest energy possible

This means increasing the detector area (AMS-02 [~ TeV] and DAMPE [~ 100 TeV]) but also exploring new paradigms (HERD [~ PeV])

The DAMPE detector

In orbit since 17 December 2015

PSD: double layer of scintillating strip detector acting as ACD (anti-counter) + charge measurement

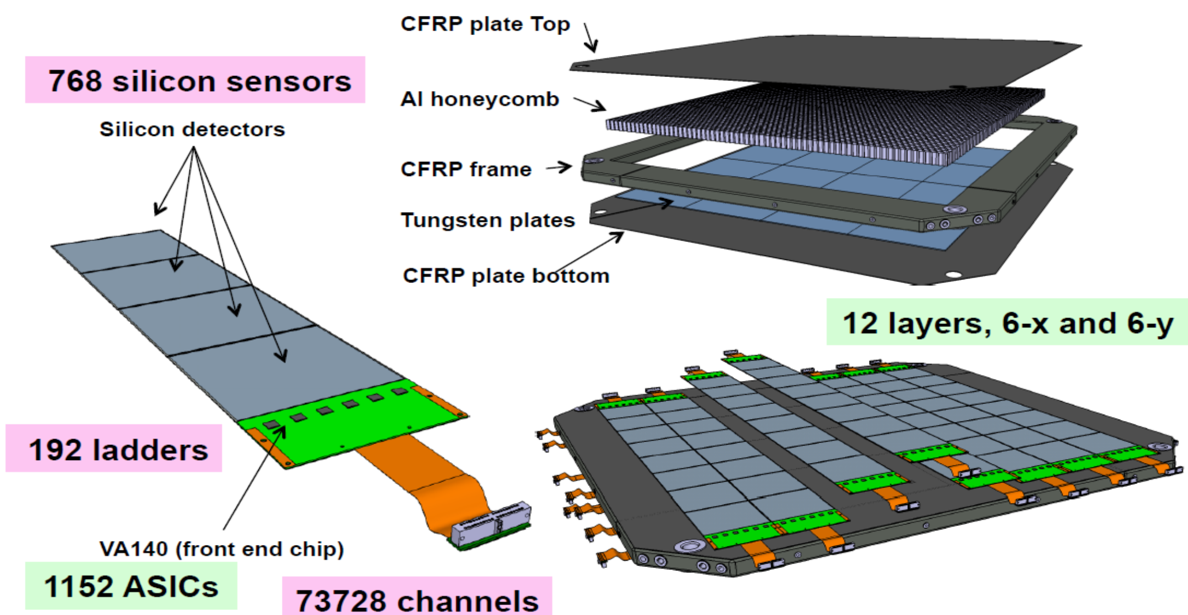


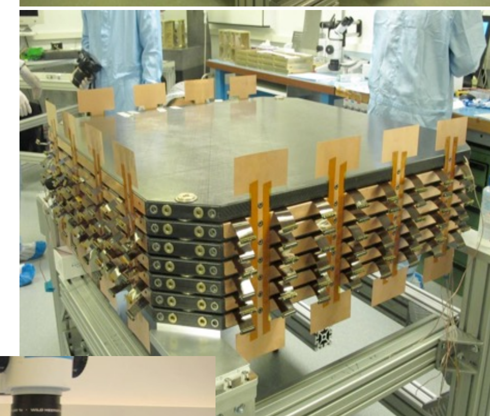
STK: 6 tracking double layer + 3 mm tungsten plates. Used for particle track, charge measurement and photon conversion (~ 2 X_0)

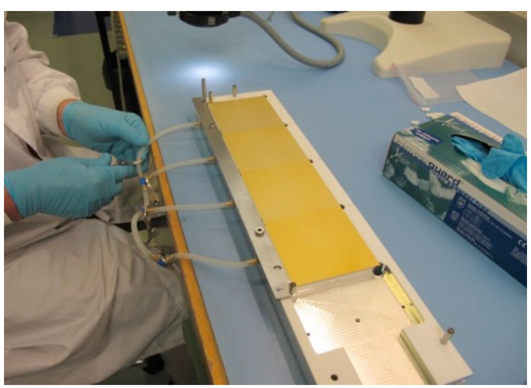
BGO: the calorimeter is made of 308 BGO bars in hodoscopic arrangement (~31 X_0). Performs energy measurements, hadron/lepton identification (*e/p rejection*), and trigger

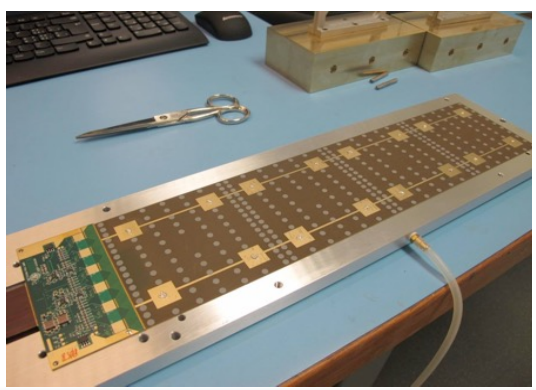
NUD: it's complementary to the BGO e/p rejection, by measuring the thermal neutron shower activity. Made up of boron-doped plastic scintillator

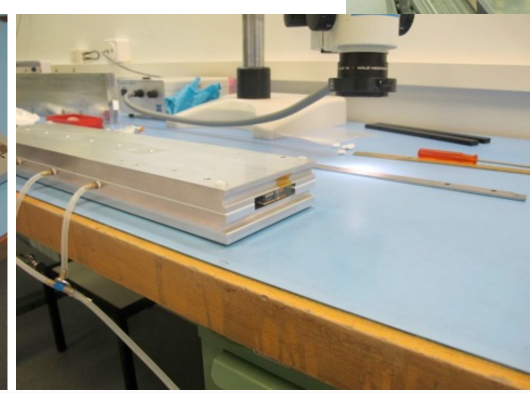
The Silicon TracKer (STK)







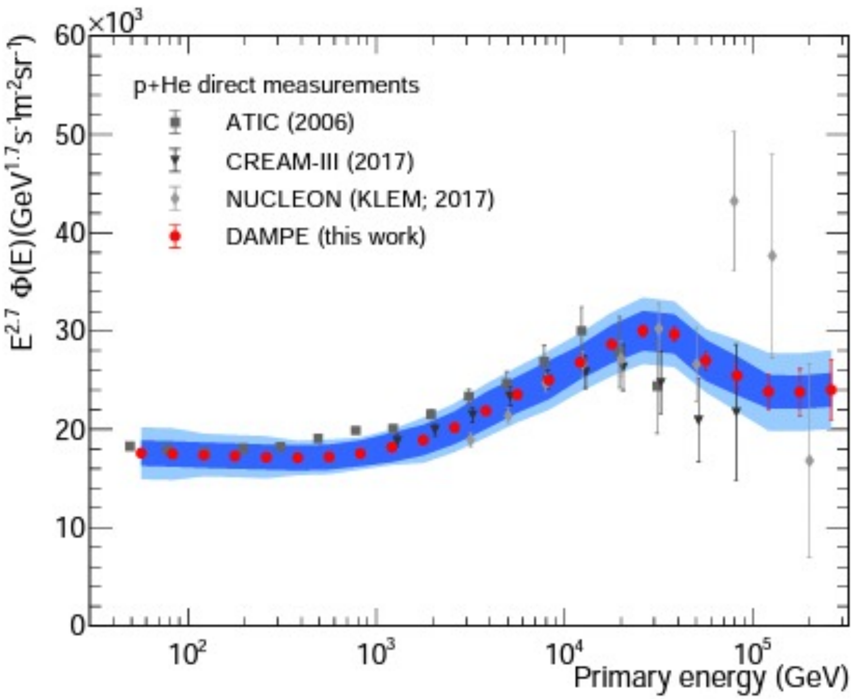


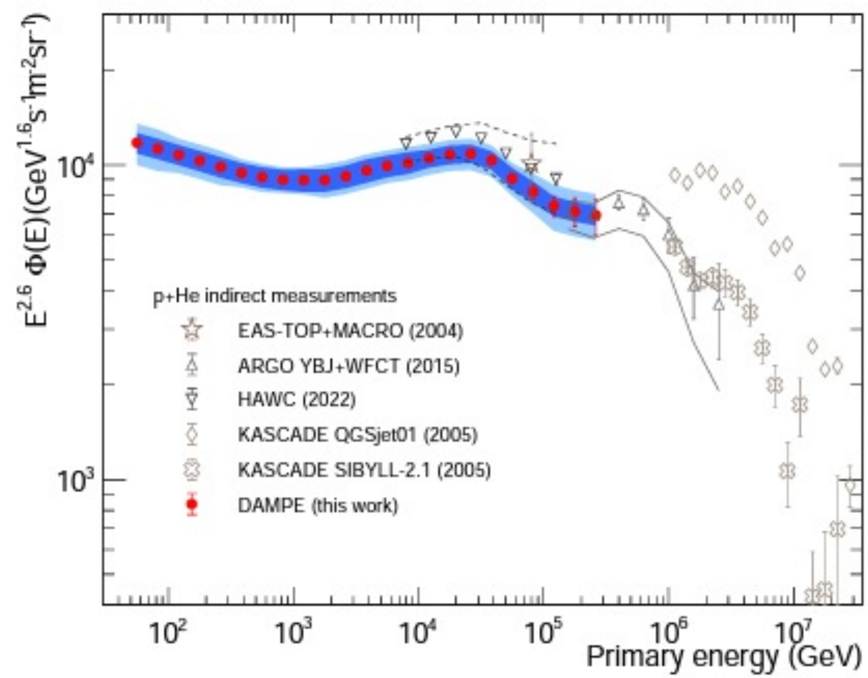


Recent results

Measurement of the cosmic p+He energy spectrum from 46 GeV to 316 TeV with the DAMPE space mission

F. Alemanno[1,2], C. Altomare[3], Q. An[4,5], P. Azzarello[6], F. C. T. Barbato[1,2], P. Bernardini[7,8], X. J. Bi[9,10], I. Cagnoli[1,2], M. S. Cai[11,12], E. Casilli[7,8], E. Catanzani[13], J. Chang[11,12], D. Y. Chen[11], J. L. Chen[14], Z. F. Chen[11,12], P. Coppin[6], M. Y. Cui[11], T. S. Cui[15], Y. X. Cui[11,12],





2022 – ongoing: $e^+ + e^-$

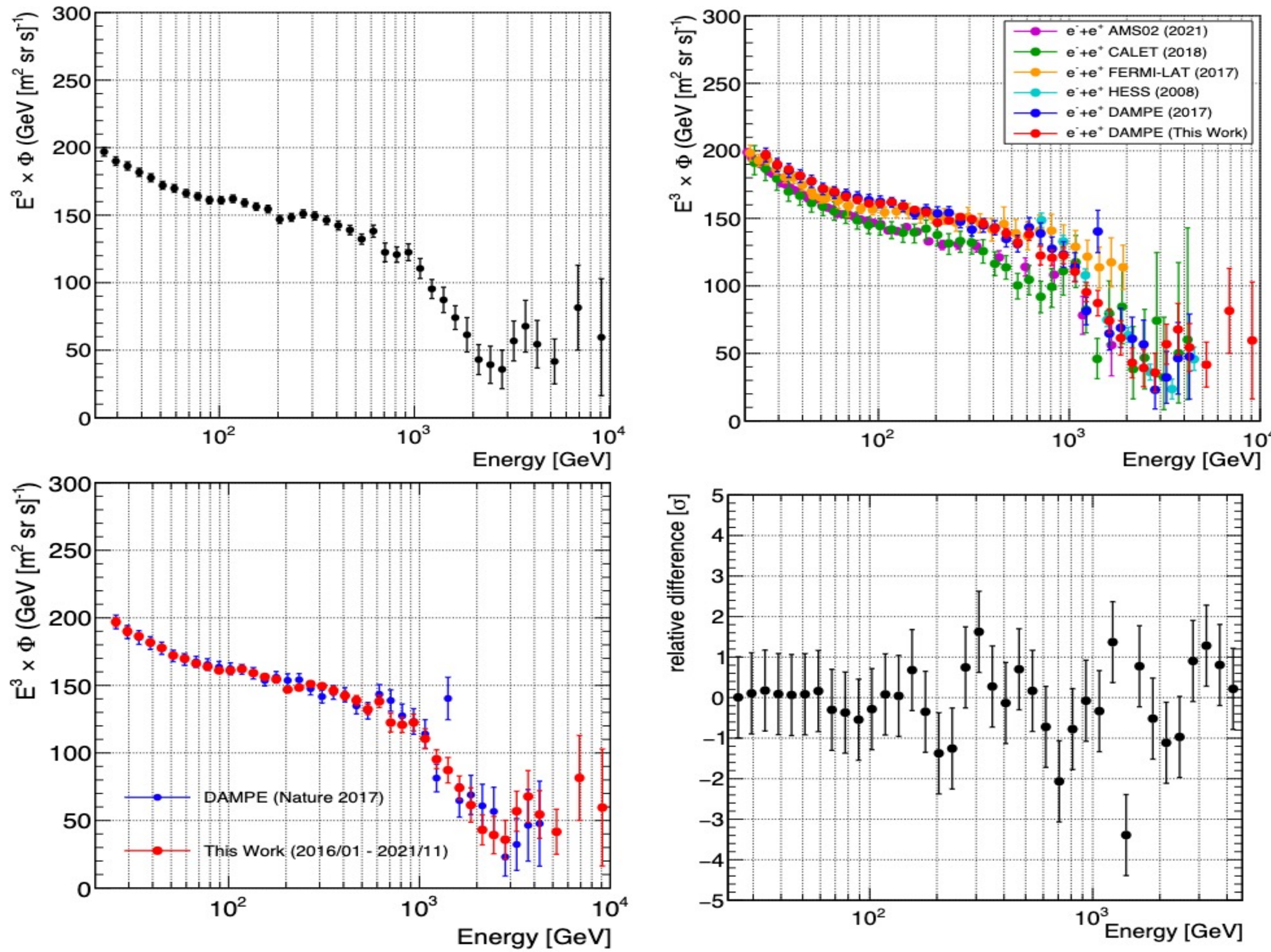


Figure 5.16: **(top left)** Measurement of the all-electron flux from 20 GeV to 10 TeV using about six years of data, from 2016/01 to 2021/11. **(top right)** Comparison

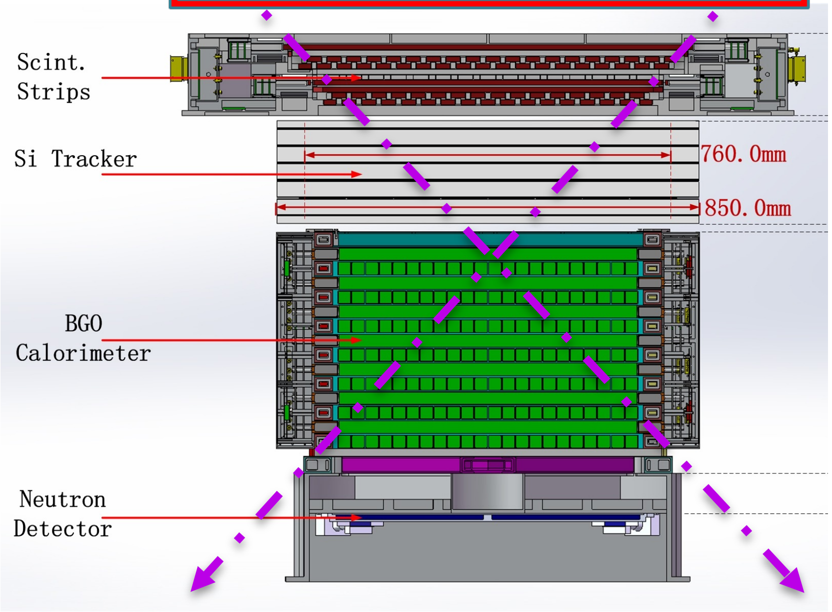
<u>Enrico Catanzani's PhD Thesis</u>

The measurement:
- is compatible with the Nature measurement
- improve the statistical error of the Nature measurement
- extend the energy reach
- confirm the "raise" after ~ 3 TeV

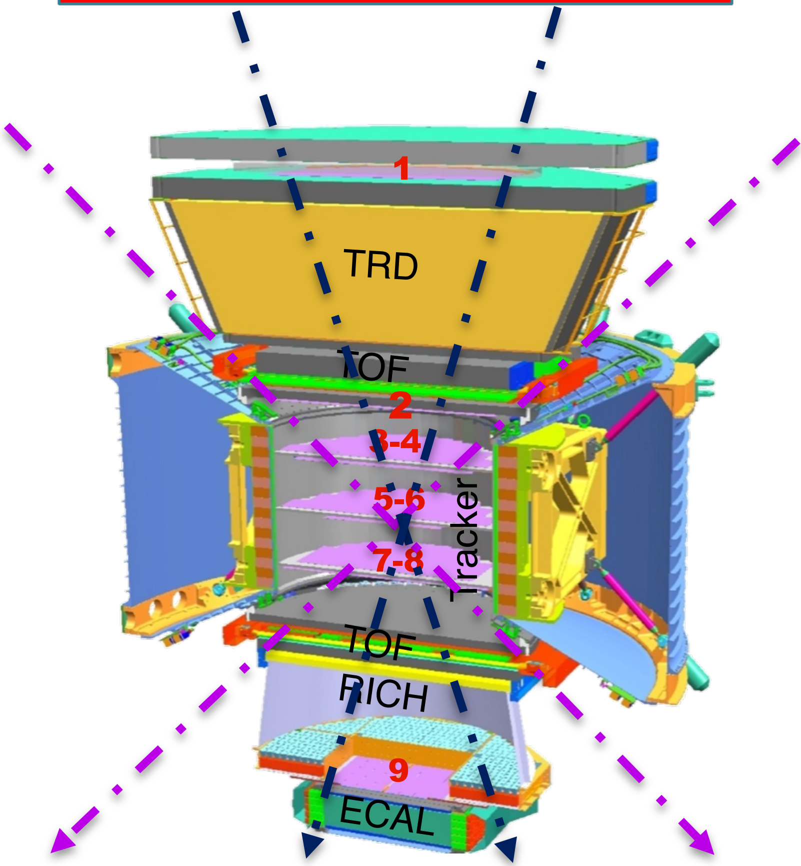
From October we'll have Chengming Liu as "INFN Research Grant for non-Italian". He's already working on DAMPE

Current operating experiments: "telescopes"

DAMPE Field of View ~ 1 sr
→ Acc ~ 0.3 m² sr



AMS Inner ~ 0.5 m² sr
AMS Full Span ~ 0.05 m² sr



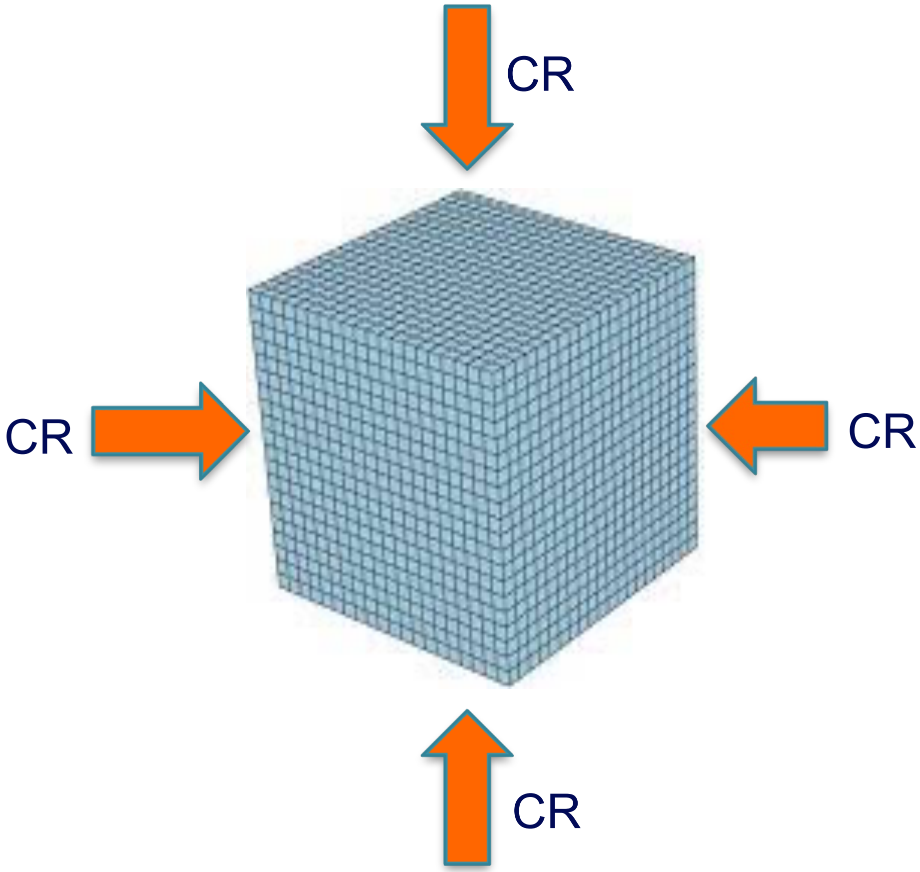
All the current and past detectors are designed as 'telescopes': they're sensitive only to particles impinging from "the top"
limited FoV → small acceptance

New paradigma - CaloCube

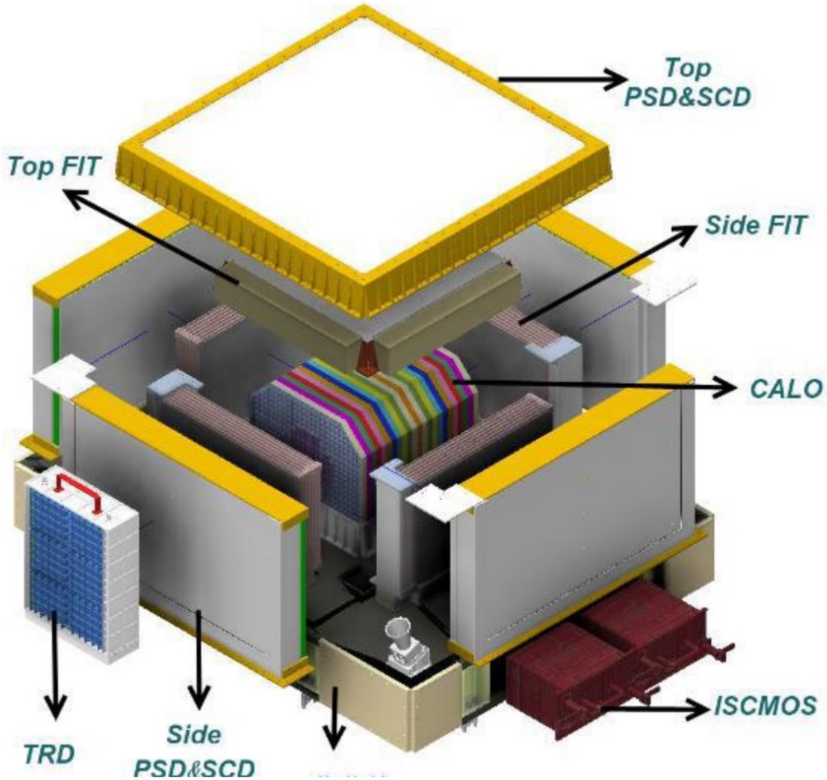
- Exploit the CR "isotropy" to maximize the effective geometrical factor, by using all the surface of the detector (aiming to reach $\Omega = 4\pi$)

- The calorimeter should be highly isotropic and homogeneous:
  - the needed depth of the calorimeter must be guaranteed for all the sides (i.e. cube, sphere, …)
  - the segmentation of the calorimeter should be isotropic

→ this is in general doable just with an homogeneous calorimeter

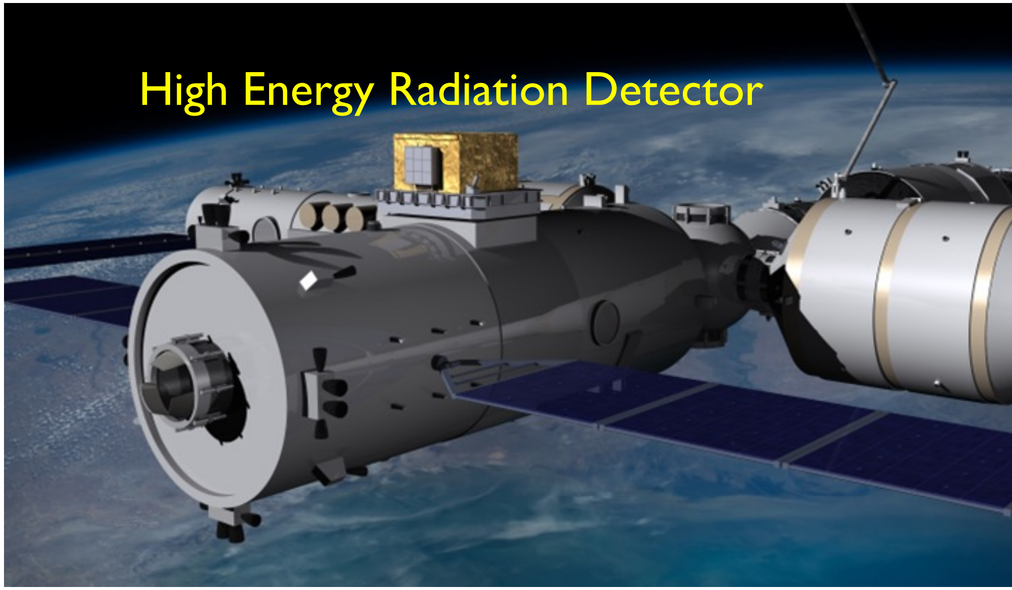


HERD on the CSS



Based on the DAMPE and AMS heritage:

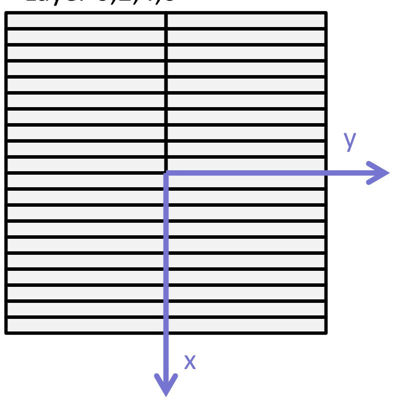
- central "isotropic" calorimeter
- Fiber Tracker
- Plastic Scintillator Detector
- Silicon Charge Detector / tracker
- TRD on one side to calibrate the absolute energy scale



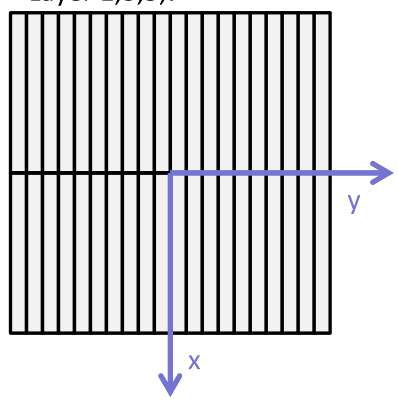
Silicon Charge Detector - SCD

SCD Top: 190 × 190 cm^2, 20 × 20 ladders

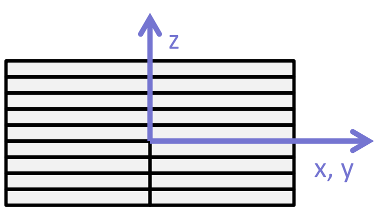
Layer 0,2,4,6



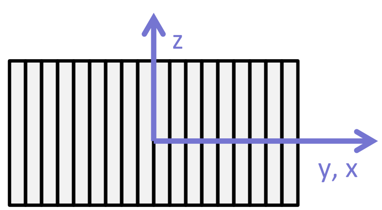
Layer 1,3,5,7



SCD Side: 98 × 175 cm^2, 2 × 9 or 1 × 18 ladders



Layer 0,2,4,6



Layer 1,3,5,7

Wafer 9.5 × 9.5 cm^2

SCD Top Ladder with 10 wafers (2 halves)

SCD Side Ladder with 9 wafers (1/2 halves)

896 ladders of 9 or 10 wafers

8284 wafers

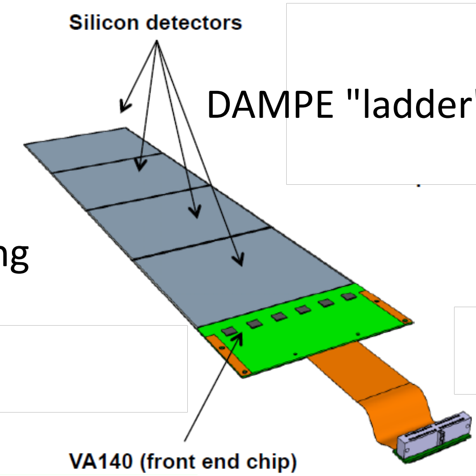
75.7 m^2 active area

With respect to, for example, the DAMPE "ladders", <u>SCD ones will be 2.5 longer</u>:

- this is challenging for the S/N

- this is challenging for the vibrations during the launch

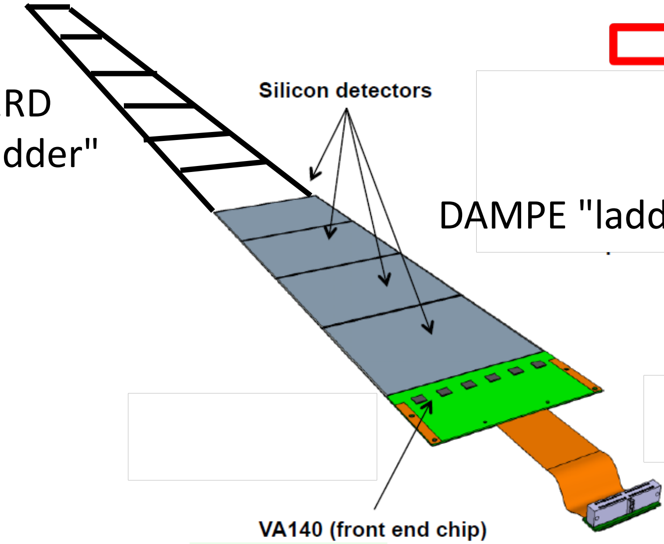
DAMPE "ladder"

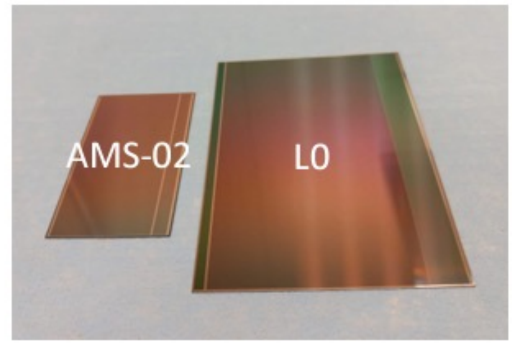


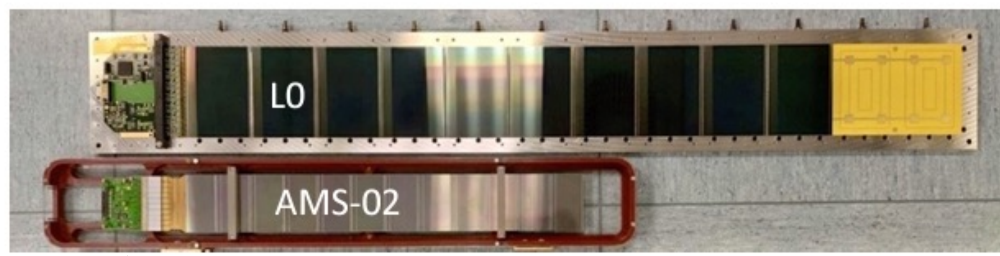
HERD-SCD and sinergy with AMS-L0

HERD "ladder"

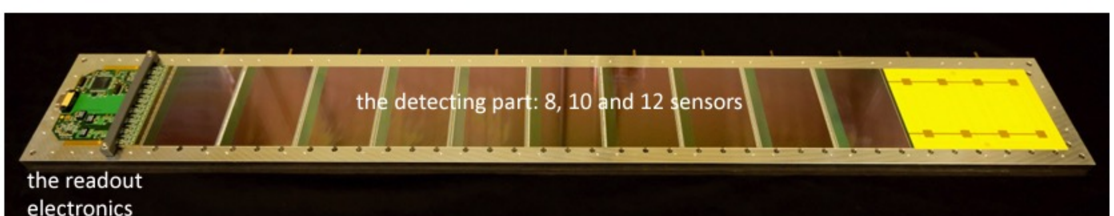
DAMPE "ladder"







AMS-L0 "ladder"



L0 Electronic Front End (LEF)

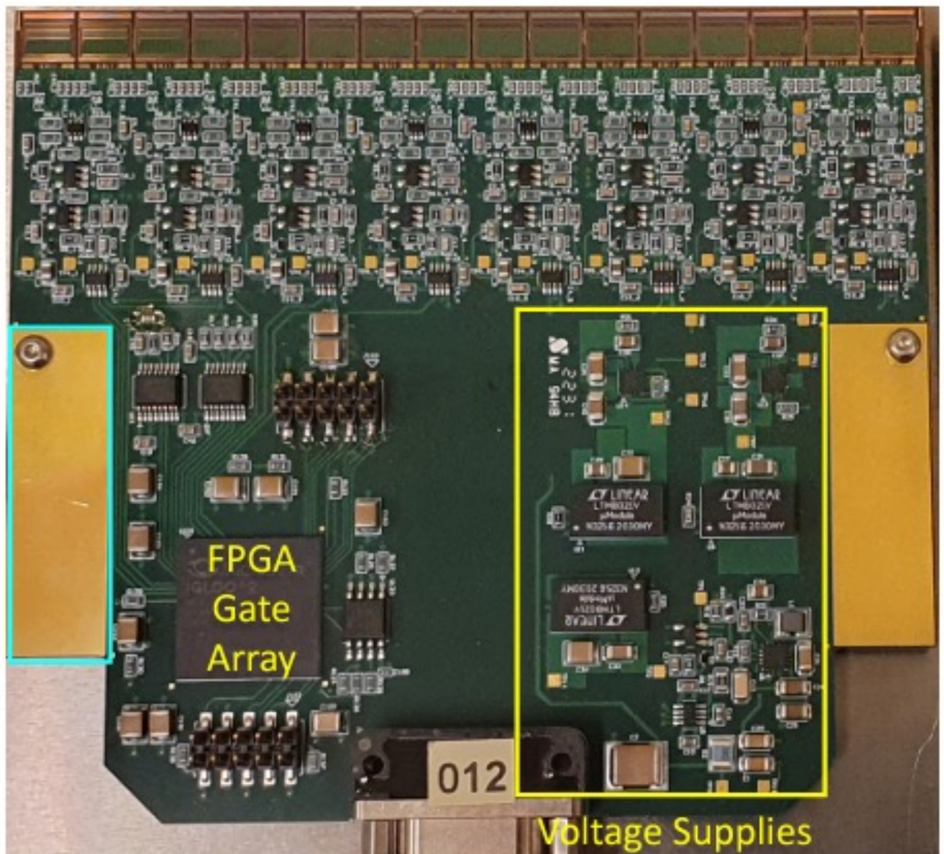
8 Amplifiers

8 14-Bit, 2.5Msps, Serial Sampling ADCs, 4096mV

Thermal Strips

1. Heat path to radiators.

2. Ground path to chassis



16 IDE1140, 1024 strips

Each IDE1140 ("VA")

- 64 channels charge amplifier/ shaper.
- Sample and hold.
- 64 channels analog multiplexor.
- 2.6 uA per 1 fC differential current output

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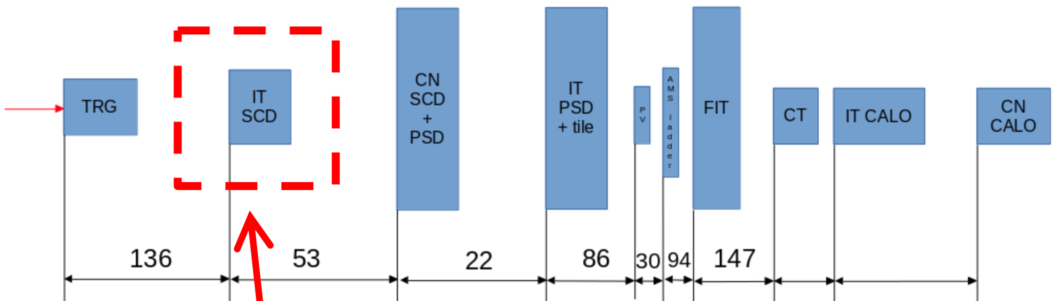
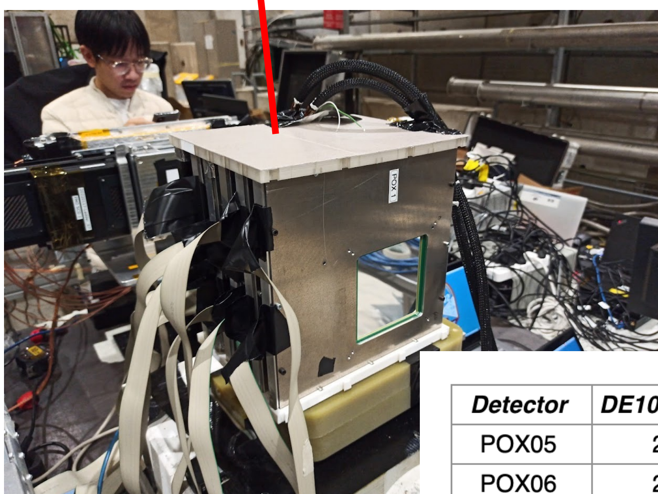
HERD-SCD BT campaign 2022



8 similar sensors mounted in orthogonal pairs in frames, on a polymer base:

- 96×96 mm^2.
- 150 μm thickness.
- 12 μm strip width.
- 50 μm implantation pitch (2 floating).
- 150 μm readout pitch.
- 640 strips.
- 4X and 4Y independent position estimations.

2 different configurations have been tested.



Configuration 1 (runs < 184)

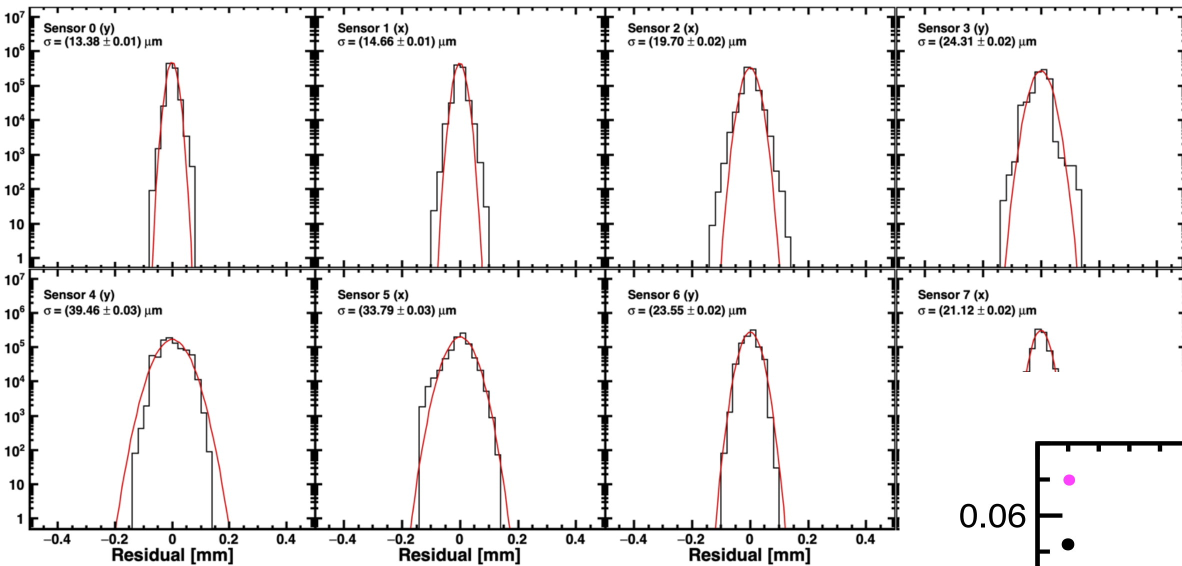
Detector	*DE10Nano*	*Connector*	*View*	*ID*	*Z (mm)*
POX05	2	J5	-Y	0	0
POX06	2	J7	X	1	6.5
POX12	3	J5	-X	2	31
L13	3	J7	Y	3	37.5
POX3MOD	4	J5	-Y	4	62
STRIP Y	4	J7	X	5	68.5
L10	5	J5	-Y	6	93
L09	5	J7	X	7	99.5

Configuration 2 (runs ≥ 184)

Detector	*DE10Nano*	*Connector*	*View*	*ID*	*Z (mm)*
POX05	2	J5	-Y	0	0
POX06	2	J7	X	1	6.5
POX12	3	J5	-X	2	31
L13	3	J7	Y	3	37.5
POX01	4	J5	-Y	4	62
POX02	4	J7	X	5	68.5
L10	5	J5	-Y	6	93
L09	5	J7	X	7	99.5

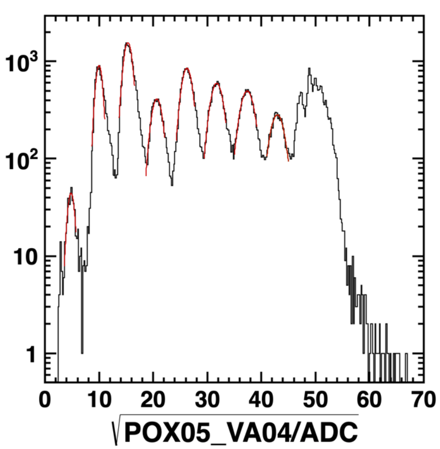
HERD-SCD BT campaign 2022

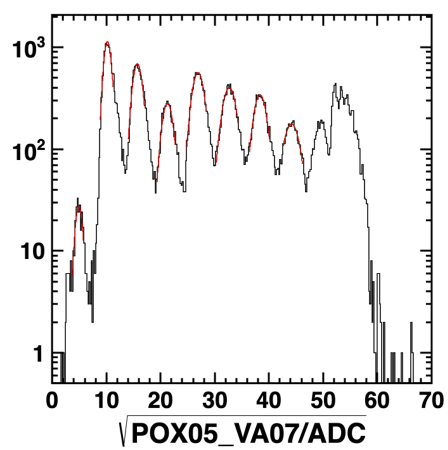
Residuals with point for for configuration 2 (runs≥184).

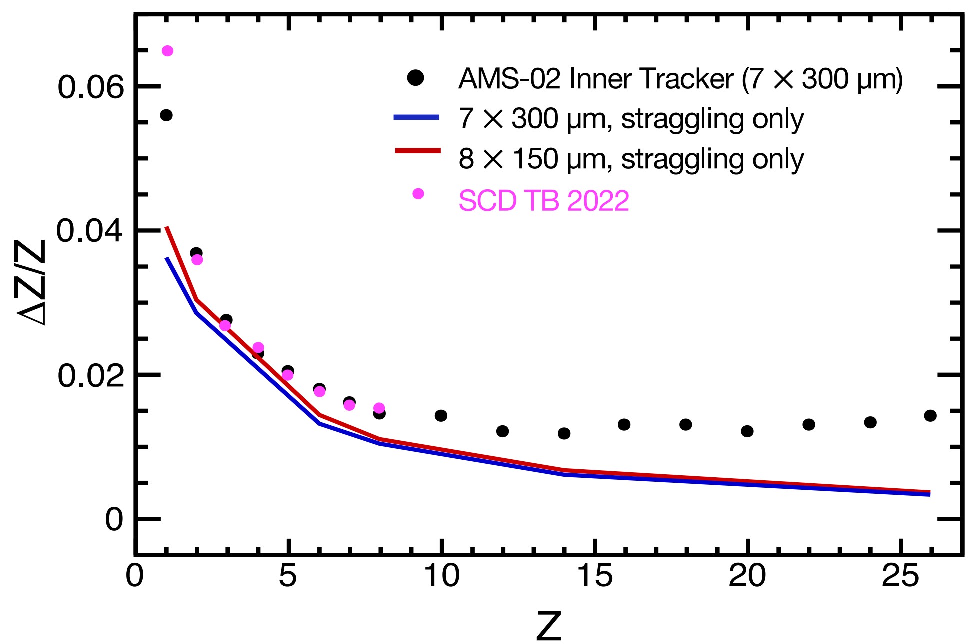


We've a double role in BT:

- test (spatial resolution and charge resolution) our prototypes
- provide tracks and charge measurements to all the detectors under test





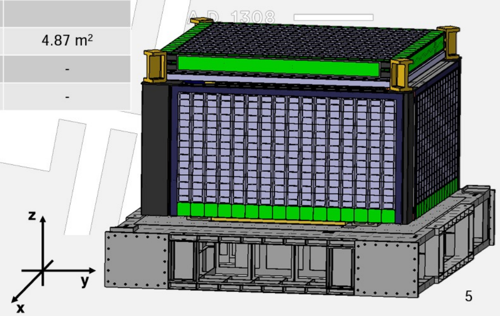


HERD-SCD: mechanics

Detector specs.

Plane position (global ref)	Detective area X (global ref)	Detective area Y (global ref)	Detective area Z (global ref)
X+	-	4.87 m²	4.87 m²
X-	-	4.87 m²	4.87 m²
Y+	4.87 m²	-	
Y-	4.87 m²	-	4.87 m²
Z+	9.73 m²	9.73 m²	-
Z-	-	-	-

Total number of tiles top: 2048
Total number of tiles per side: 1024
Total number of tiles: 6144
Silicon size: 97.5 x 97.5 mm²
Total silicon area: 58.41 m²



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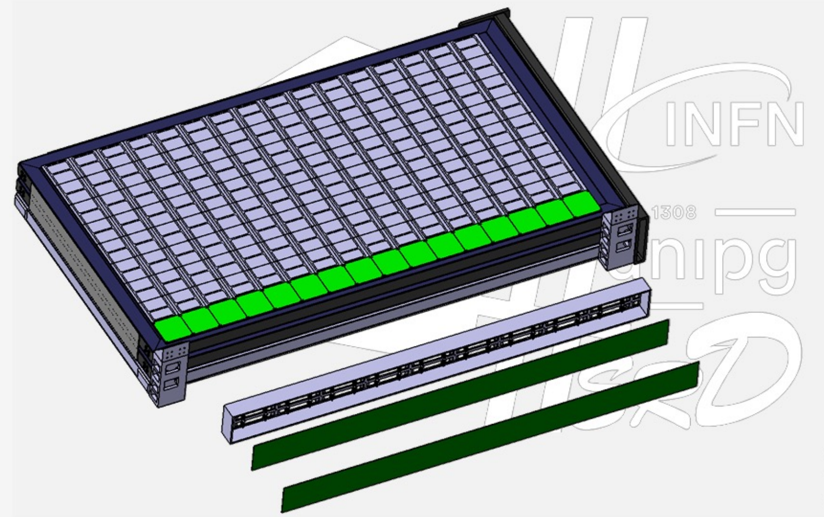
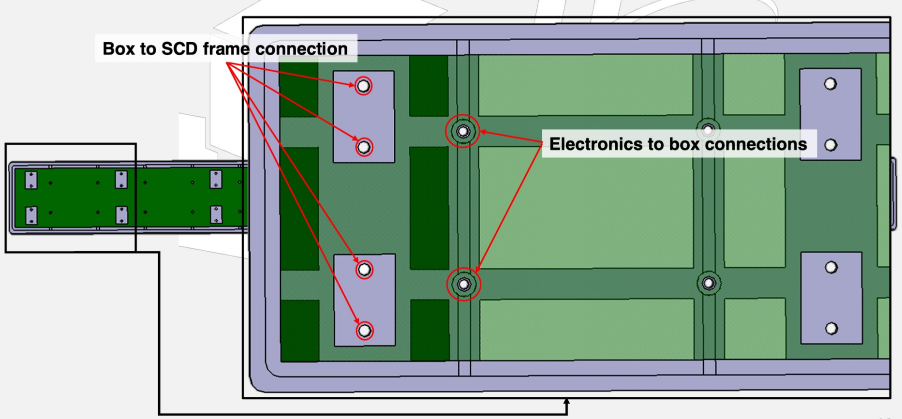
Fan-out electronics



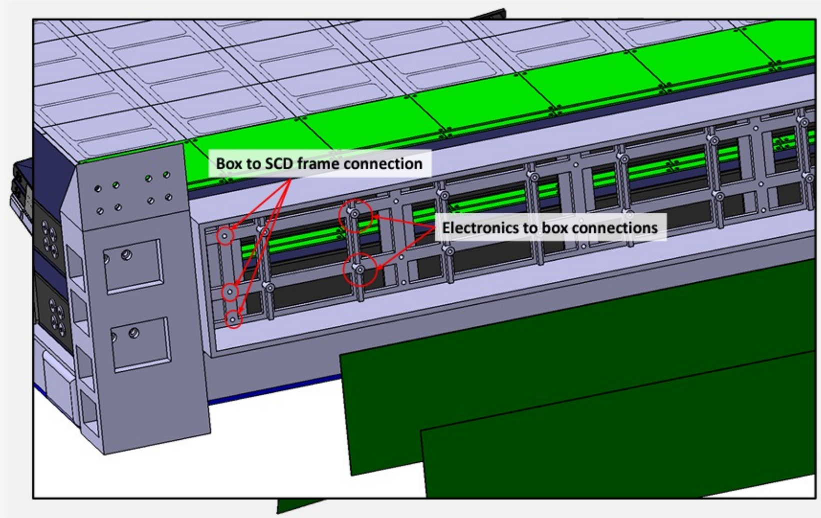
Side fan-out electronics

Box and boards

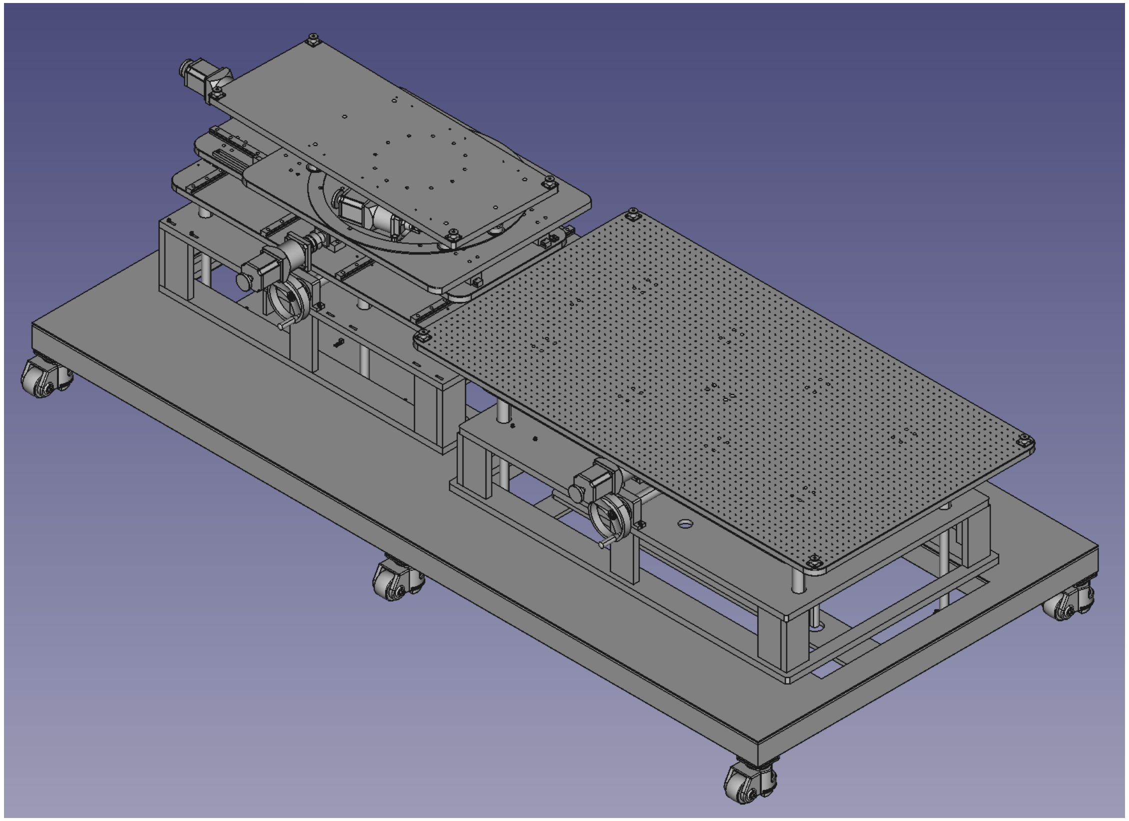


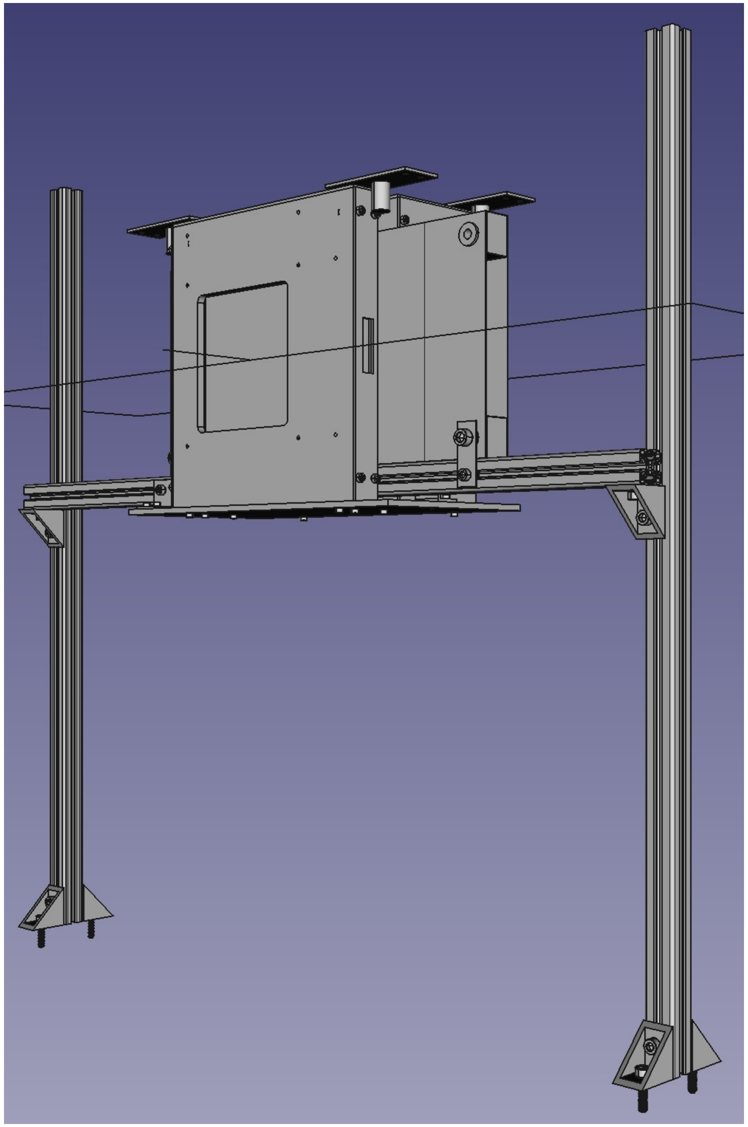
12

Fan-out electronics



HERD-SCD: mechanics for BT





Intense BT campaign in 2023:

- CERN PS – 1 week in September 2023
- CERN SPS – 2 week in October 2023

We always had a good support from CERN but since 2023 we're also Recognized Experiment: RE44

ASTRA chip

Il chip è finalmente stato prodotto, tagliato e consegnato a Perugia: ora inizia il bello per noi!

Specs

- **32** or **64 channels**: Pre-Amp + Shaper + Sample&Hold
- Multiplexer with **analogue voltage output** (to be connected to an external ADC)
- Low **power consumption**: < 1 mW/channel
- High **dynamic range**: 10k to 1000k electrons → 1.6-160 fC
- Low **noise**: SNR > 10 → ENC < 1000 electrons at C_{in} = 100 pF
- Adjustable **shaping time**: τ = 1-10 µs
- **Fast OR** (64 channels) [illegible] signal ([illegible] PATH)
- **Bonding pad** only on [illegible] sides (detector input – output, control, bias and power)

Summary

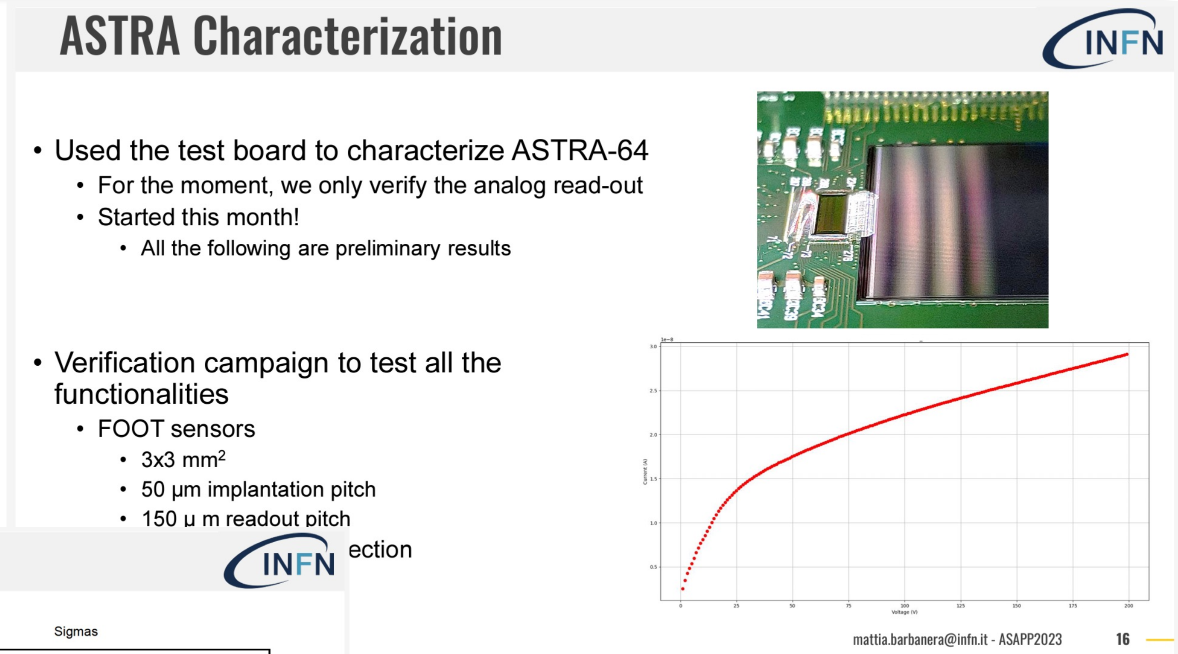
- LFoundry 110 nm CMOS technology
- Chip area = 3 x 3.5 mm^2
- 32 channels (100 µm pitch), layout [illegible] to 64 channels (and 50 µm [illegible])
- Front-End compatible fo[illegible]
- Programmable peaking time (1.5-8.5 µs)
- Configurable gain to make it suitable for different sensors topologies (i.e. 150-300 µm thickness sensors)
- ENC = 800 e- @ C_{in} = 100 pF and [illegible] µs
- Power consumption [illegible]
- Front-End design defi[illegible] almost completed (schematic level): some minor optimizations ongoing
- Back-end blocks under development: discriminator, FAST-OR, MUX, output buffer (some IPs available)

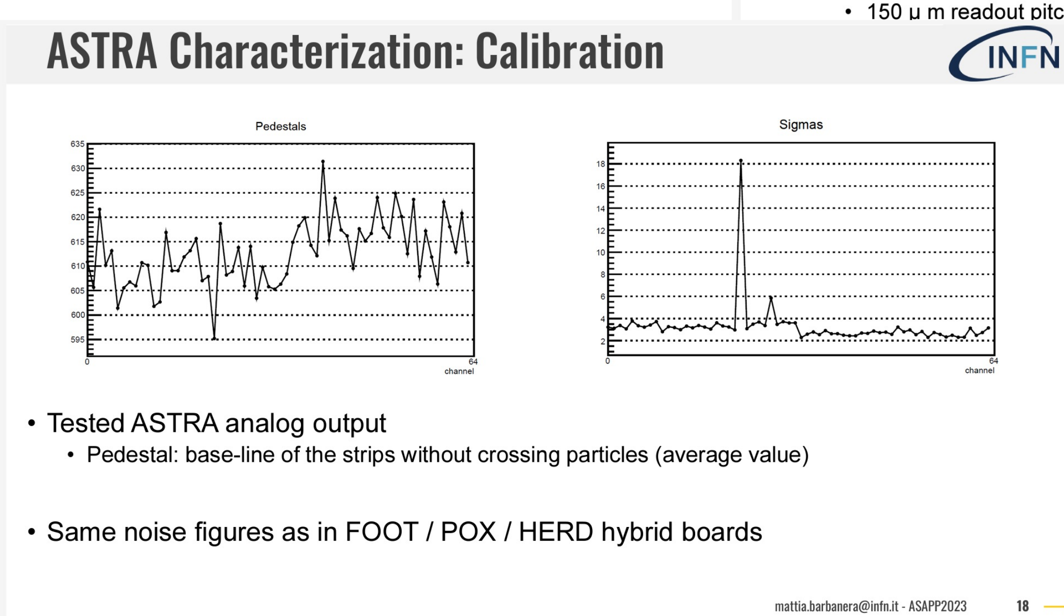
The work on the HERD S[illegible] the development [illegible] by the INFN-TO group of M. [illegible] Rocha Rolo) of a new ASIC for Si micro-strip.

The role of Perugia will be:
- development of the DAQ system to read-out the ASIC
- test of the ASIC bonding it to our sensors

ASTRA chip

The ASIC has been tested and seems working as per specs (https://indico.cern.ch/event/1208314/contributions/5342893/attachments/2672207/4632553/ASAPP23_Barbanera_ASTRA.pdf)





If all the performances will be confirmed, the ASIC will be a very valuable replacement for the VA:

- custom and upgradable design
- production in-house
- …

Accordo ASI-INFN per HERD

ACCORDO n. 2023-8-HH.0

all'ACCORDO QUADRO tra ASI ed INFN

Codice Unico di Progetto (CUP) F83C23000100005

per

"Sviluppo e test dei prototipi di rivelatori di responsabilità italiana per la missione High Energy cosmic-Radiation Detector (HERD)"

Accordo per 4M€:
- 2M€ cofin. INFN (spese fatte sulla sigla di CSN2 e personale staff)
- 2M€ finanziamento "fresco" ASI

Responsabile scientifico:
G. Ambrosi

L'accordo finanzia:
- contratti
- missioni
- hardware

		0	0.00	0.00	0	0.00	0.00
		36,368		**1,209,459.96**	**23,568**	**1,008,900.36**	**200,559.60**
INTERNAL SPECIAL FACILITIES	Type of Unit	N° of unit	Unit rates in N.C.				
0	0	0.0	0.00	0	0.0	0	0
0	0	0.0	0.00	0	0.0	0	0
0	0	0.0	0.00	0	0.0	0	0
0	0	0.0	0.00	0	0.0	0	0
0	0	0.0	0.00	0	0.0	0	0
0	0	0.0	0.00	0	0.0	0	0
2 Total Internal Special Facilities cost				**0**		**0**	**0**
OTHER COST ELEMENTS	Amounts in N.C.	OH %	X Amounts =				
3. 1 Raw Materials	960,000	0.00%	0	960,000.00	254,784	254,784.00	705,216.00
3. 2 Mechanical parts	382,200	0.00%	0	382,200.00	101,436	101,435.88	280,764.12
3. 3 Semi finished products	45,000	0.00%	0	45,000.00	11,943	11,943.00	33,057.00
3. 4 Electi.-electron.components	550,090	0.00%	0	550,090.00	145,994	145,993.89	404,096.11
3. 5 Hirel parts							
a) procured,company	0	0.00%	0	0.00	0	0.00	0.00
b) procured by third party	0	0.00%	0	0.00	0	0.00	0.00
3. 6 External Major Product	223,560	0.00%	0	223,560.00	79,271	79,271.33	144,288.67
3. 7 External Services	220,000	0.00%	0	220,000.00	58,388	58,388.00	161,612.00
3. 8 Transport insurance	12,000	0.00%	0	12,000.00	3,185	3,184.80	8,815.20
3. 9 Travels	333,822	0.00%	0	333,822.00	283,749	283,748.70	50,073.30
3.10 Miscellanous	17,500	0.00%	0	17,500.00	6,125	6,125.00	11,375.00
3 TOTAL OTHER DIRECT COSTS	**2,744,172**			**2,744,172.00**	**944,875**	**944,874.59**	**1,799,297.41**
4 SUB-TOTAL COST				**3,953,631.96**		**1,953,774.95**	**1,999,857.01**
GENERAL EXPENSES	Cost item to which % applies	Base in NC to which % applies	%				
5 General & Admin.Expenses (if applicable)	200,560	1. LABOUR	0.0%	0.00		0.00	0.00
6 Research & Develop. Exp. (if applicable)	0	0	0.0%	0.00		0.00	0.00
	0	0	0.0%	0.00		0.00	0.00
(to be specified)				0.00		0.00	0.00
8 Total Cost of All Work Packages				3,953,631.96		1,953,774.95	1,999,857.01
9				0.00		0.00	
10 Sub-total				3,953,631.96		1,953,774.95	1,999,857.01
11 Profit (5% on item 8 - item 3.9)				0.00		0.00	0.00
12 Cost without additional charge (SUBCO)				**0.00**		**0.00**	**0.00**
13				0.00		0.00	0.00
14 Total				3,953,631.96		1,953,774.95	1,999,857.01
15				0.00		0.00	0.00
16 TOTAL FOR ASI				**3,953,631.96**		**1,953,774.95**	**1,999,857.01**
17 TOTAL WP ASI				**115,155.00**		**115,155.00**	**0.00**
18 TOTAL				**4,068,786.96**		**2,068,929.95**	**1,999,857.01**

Attività affini: PRIN

≡ PRIN 2022 - Progetti di Rilevante Interesse Nazionale

Valutazione

Project code: **2022JNF3M4**

Project title: **Pentadimensional Tracking Space Detector - PTSD**

Coordinator: **DURANTI Matteo** ERC: **PE2_4**

University: **Istituto Nazionale di Fisica Nucleare**

The Project will contribute to the advancement of basic detector technology beyond the state of the art, reinforcing the Italian "detector school". A succesfull demonstration of a 5D light detector will undoubetdly strengthen the scientific community and will contribute to the internationalization of Italian detector development standings. The project abides to the Do Not Significant Harm approach and the dissemination and sharing of scientific knowledge plan is sound. Proper attention is given to potential social and economic impacts, especially in the aereospace industries.	*As to the awarded scoring, kindly provide the relative motivations by answering, also aggregately, the following questions:* *1. Does the project advance knowledge?* *2. Does the project measure up to the challenges that research faces in terms of technological innovation and industrial applications?* *3. Does the project respect the principle of Do Not Significant Harm (DNSH)?* *4. Will the project have an impact on the scientific community? How will it strengthen it?* *5. Will the project increase the internationalisation of Italian research?* *6. Will the project contribute to social welfare and/or cultural development?* *7. Does the project propose actions to disseminate knowledge and its results?*

TOTAL SCORE **95**

~ 200k€ di finanziamento:
- ~ 165 k€ INFN (M. Duranti)
- ~ 35 k€ ASI (V. Vagelli)

L'attività sarà inserita nel Progress Report (PAQ) di HERD come attività affine

Anagrafiche e richieste 2024

Persone	Posizione	FTE
Ambrosi	Staff	0.5
Barbanera	Staff	0.5
Brugnoni	Dottorando	1
Cianetti	Staff	0.5
Cossio	Staff	0.3
Duranti	Staff	0.5
Yazou	Dottorando	1
Mancini	Assegnista	1
Mussolin	Assegnista	0.5
Pauluzzi	Staff	0.5
Silvestre	Assegnista	1
Vagelli	Staff	0.5
		7.8

~ 8 FTE (*) / 12 Persone

Richieste 2023 @ CSN2
≈ 250 k€

Dal 2024 il Resp. Locale sarà Mattia Barbanera

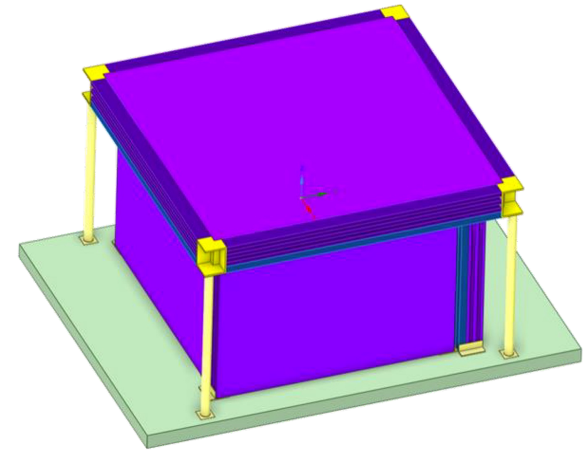
"impronta" sui Servizi di Sezione - 2024

Prevediamo:

- ~ 1 mesi-uomo su Officina Meccanica
- ~ 1 mesi-uomo STG-Camere bianche

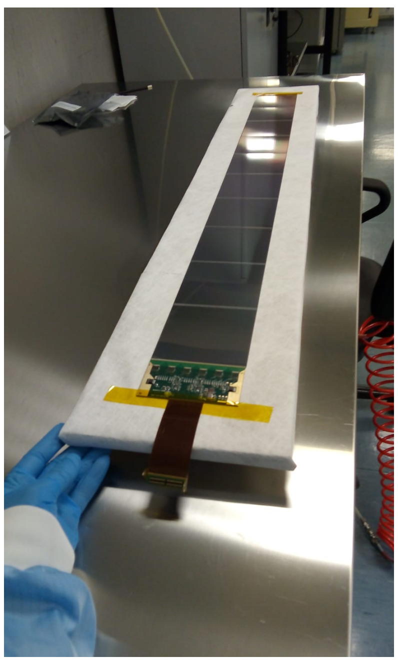
Backup

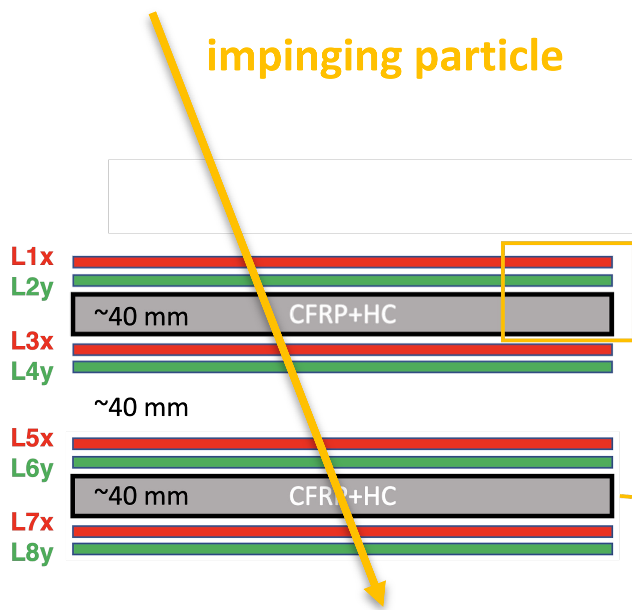
Silicon Charge Detector

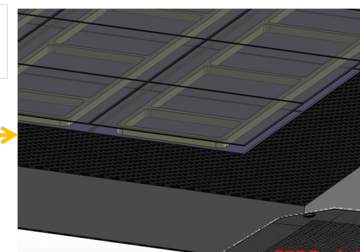


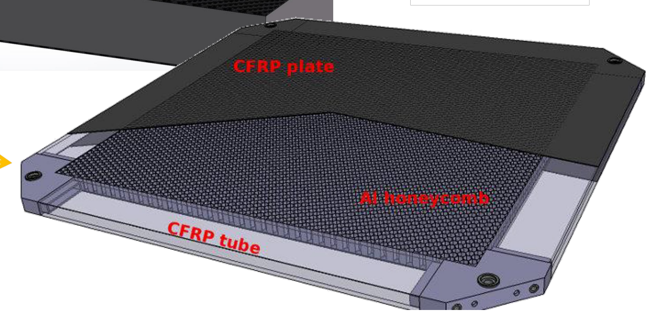
The Silicon "tracker" is mainly used as Silicon Charge Detector:

- microstrip silicon detectors, 50 (150) µm implant (readout) pitch
- 6 or 8 layers (3 or 4 *y* + 3 or 4 *x*), 2 super-planes
- material before the first layer as less as possibile (< 1 mm CFRP)
- long silicon ladders (~ 1 m) to save channels





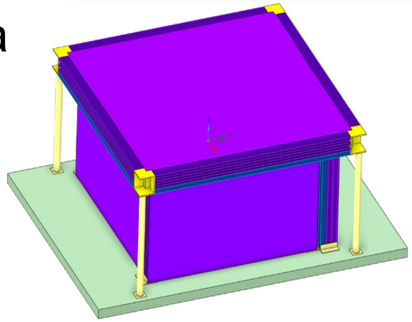




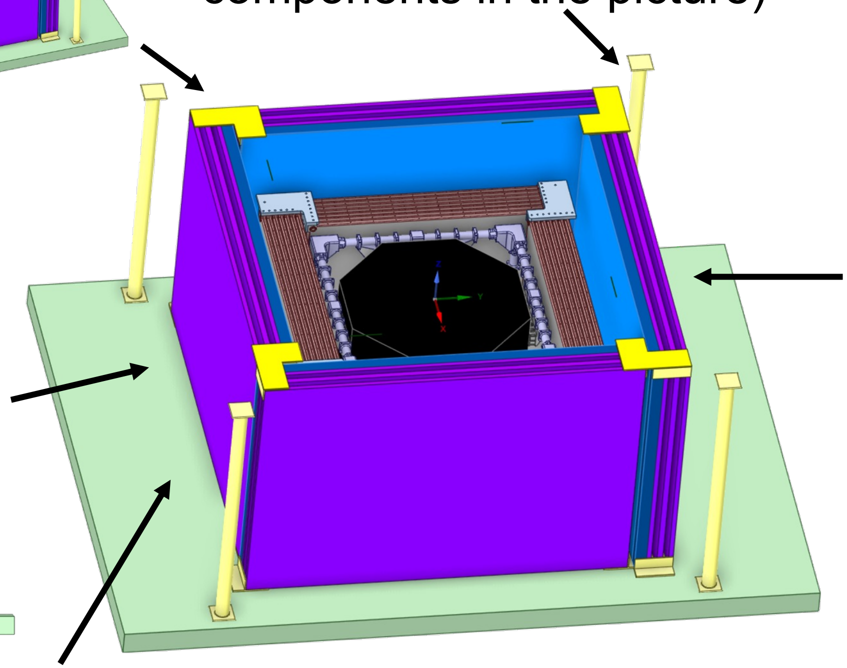
Honeycomb or orthogrid structure

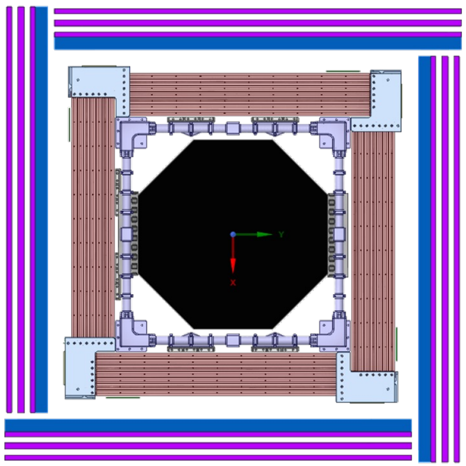
Contribution to the HERD detector general design

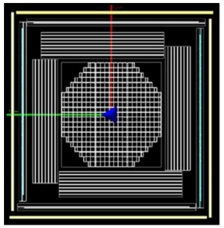
Design of a top cover which maximize PSD hermeticity. On-going activity with PSD team



Design of mechanical supporting external structure for the SCD detector (yellow components in the picture)







Hermeticity maximization following inputs from MonteCarlo simulation team

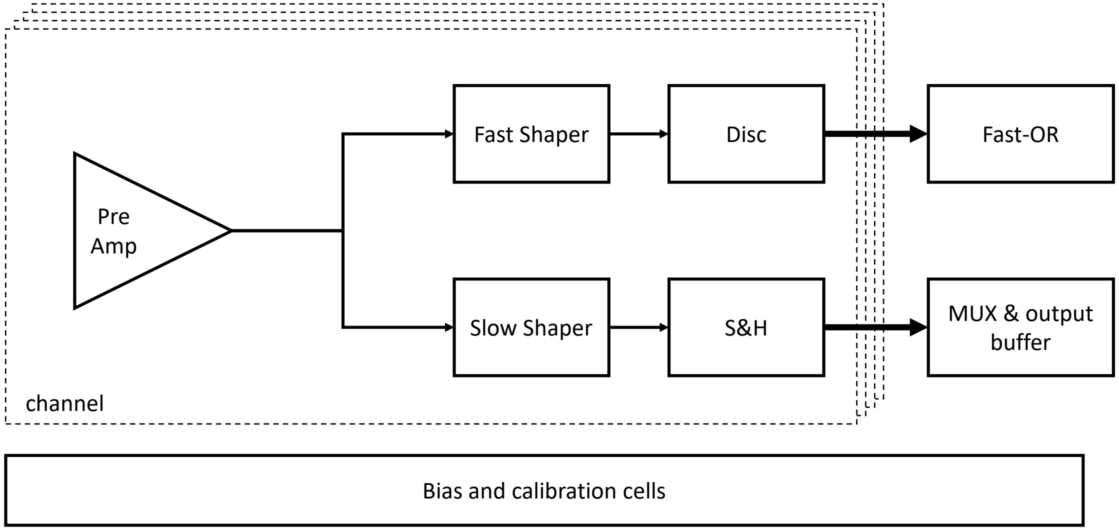
Relative experiments disposition under mechanical, thermal and integration constraints. Such as, the minimum required clearance for cables and thermal paths

<u>Compactness driven design. Aiming to a detector with a minimized number of dead areas</u>

ASTRA chip

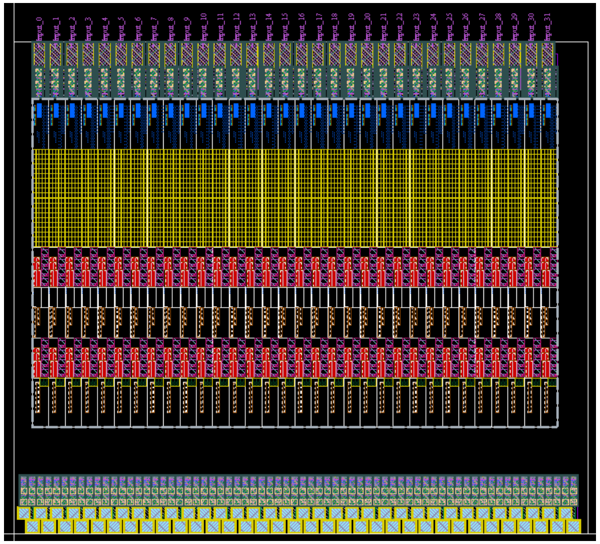
Specs

- **32** or **64 channels**: Pre-Amp + Shaper + Sample&Hold
- Multiplexer with **analogue voltage output** (to be connected to an external ADC)
- Low **power consumption**: < 1 mW/channel
- High **dynamic range**: 10k to 1000k electrons → 1.6-160 fC
- Low **noise**: SNR > 10 → ENC < 1000 electrons at C_{in} = 100 pF
- Adjustable **shaping time**: τ = 1-10 µs
- **Fast OR** (64-channels) output for timing signal (TRIGGER PATH)
- **Bonding pads** only on two opposite sides
  (detector inputs – output, control, bias and power)



Summary

- LFoundry 110 nm CMOS technology
- Chip area = 3 x 3.5 mm^2
- 32 channels (100 µm pitch), layout with scalability to 64 channels (and 50 µm pitch)
- Front-End compatible for both polarities
- Programmable peaking time (1.5-8.5 µs)
- Configurable gain to make it suitable for different sensors topologies (i.e. 150-300 µm thickness sensors)
- ENC = 800 e- @ C_{in} = 100 pF and T_p = 6.5 µs
- Power consumption < 0.6 mW/ch
- Front-End design defined and almost completed (schematic level): some minor optimizations ongoing
- Back-end blocks under development: discriminator, FAST-OR, MUX, output buffer (some IPs available)

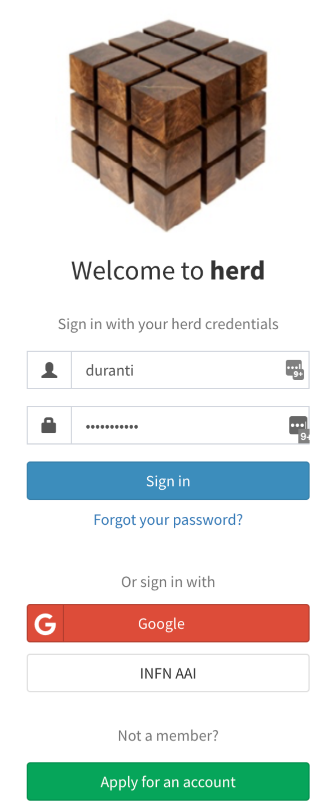


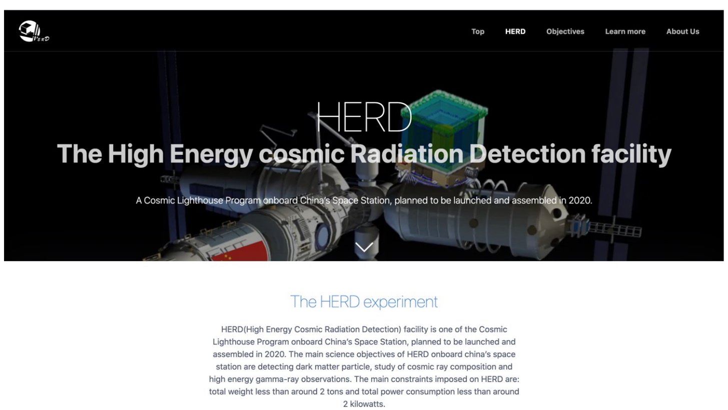
The work on the HERD SCD stimulated the development (mainly by the INFN-TO group of M. da Rocha Rolo) of a new ASIC for Si micro-strip.

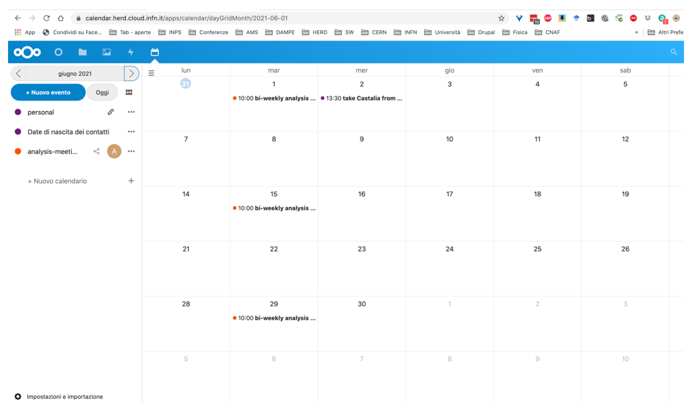
The role of Perugia will be:
- development of the DAQ system to read-out the ASIC
- test of the ASIC bonding it to our sensors

Computing infrastructure

- Centralized authentication and authorization server (INDIGO-IAM): https://herd.cloud.cnaf.infn.it
- Collaboration website (Grav) https://herd.cloud.infn.it
- Calendar and contact list (NextCloud): https://calendar.herd.cloud.infn.it
- Document repository (NextCloud): https://calendar.herd.cloud.infn.it
- Code repository (Gitlab)
- Batch system (HTCondor)
- Shared disk space (CVMFS)

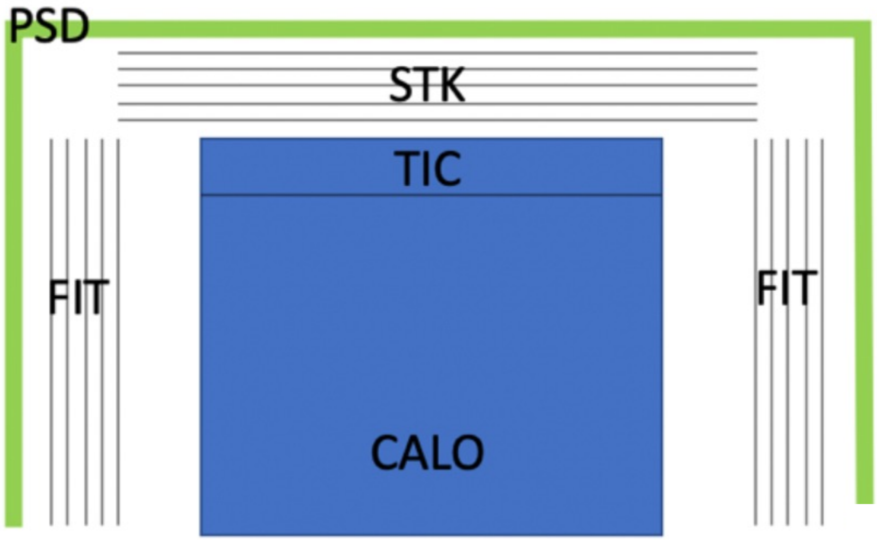






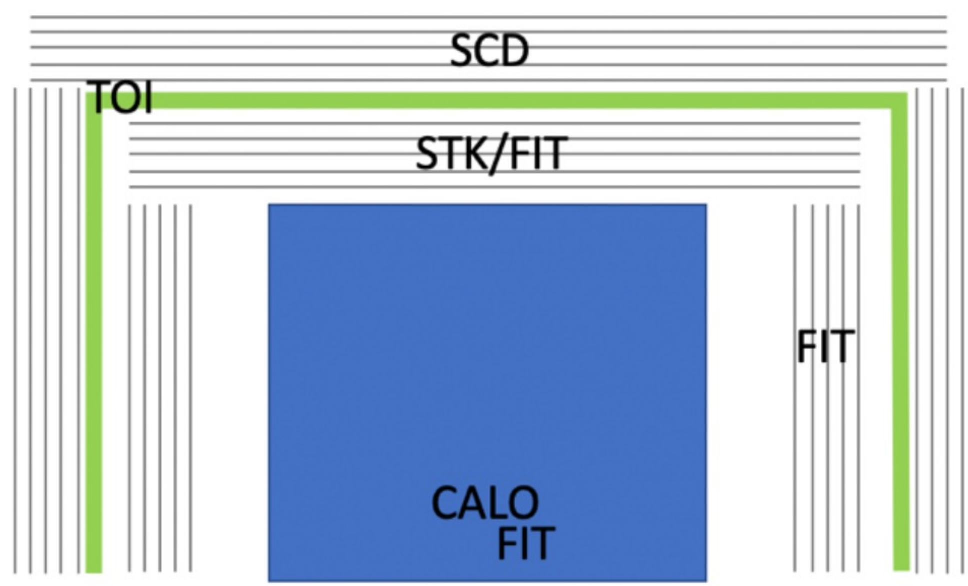
Perugia is quite active also in this "service" activities (togheter with Firenze and Rome2) and in particular all the services are being deployed on INFNCloud also thanks to the help of D. Spiga and D. Ciangottini

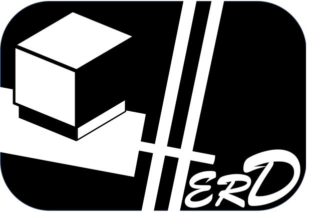
Final detector design



Last year we presented the status of the design as "on going" between to choices:
- "traditional" (i.e. a la DAMPE on the 5 sides
- "high accuracy for nuclei" (i.e. silicon tracker as Charge Detector and "top of the instrument")

Even if we're still in Phase A this is the final design that we're proceeding to "engineering":
- Silicon Charge Detector on the 5 sides, external
- hermetic Plastic Scintillator Detector
- Fiber Tracker
- Calorimeter

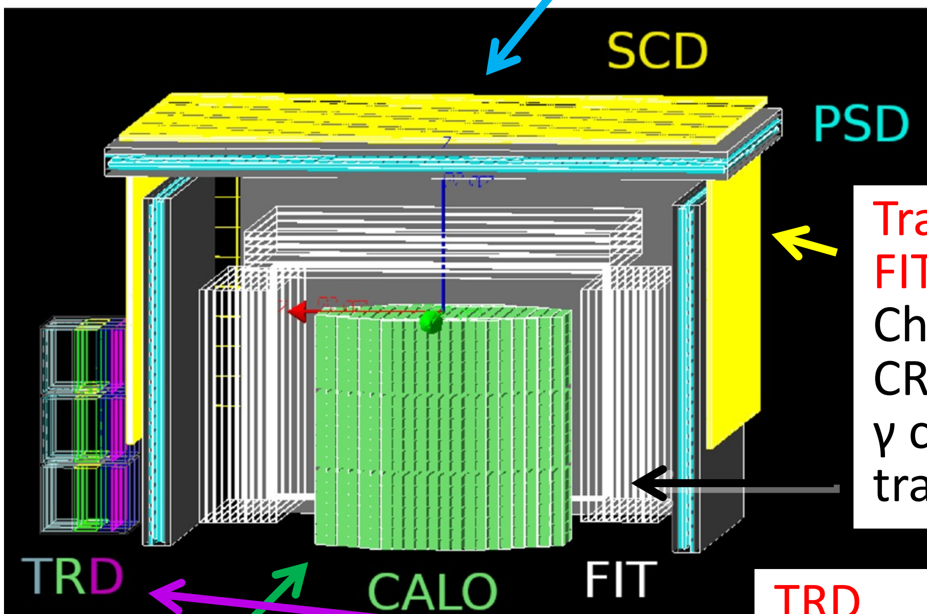




HERD detector

~ 600k readout channels

PSD, 5 sides
γ identification
Charge

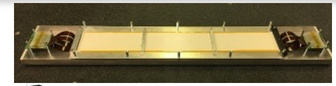


Tracker (SCD + FIT), 5 sides
Charge
CR trajectory
γ conversion & tracking

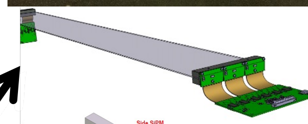
TRD
TeV CR calibration

CALO: 3-D
Energy
e/p separation

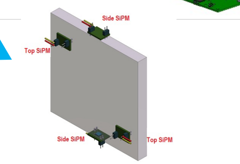
~7500 LYSO crystals (55 X_0, 3 λ_I)
Trigger sub-system
Dual readout with IsCMOS & PD/SiPM

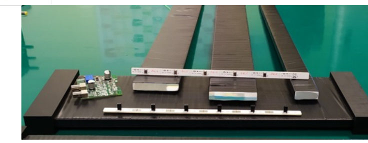


@INFN Perugia

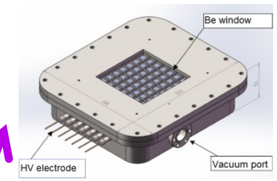


@Univ. of Geneva
@CIEMAT Madrid

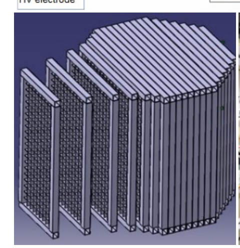




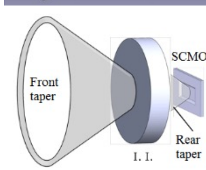
@INFN BA-GSSI-LE-PV-NA & IHEP



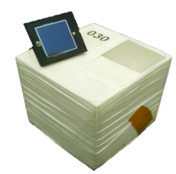
@Guangxi Univ.



@IHEP



@XIOPM



@INFN Florence
@CIEMAT Madrid