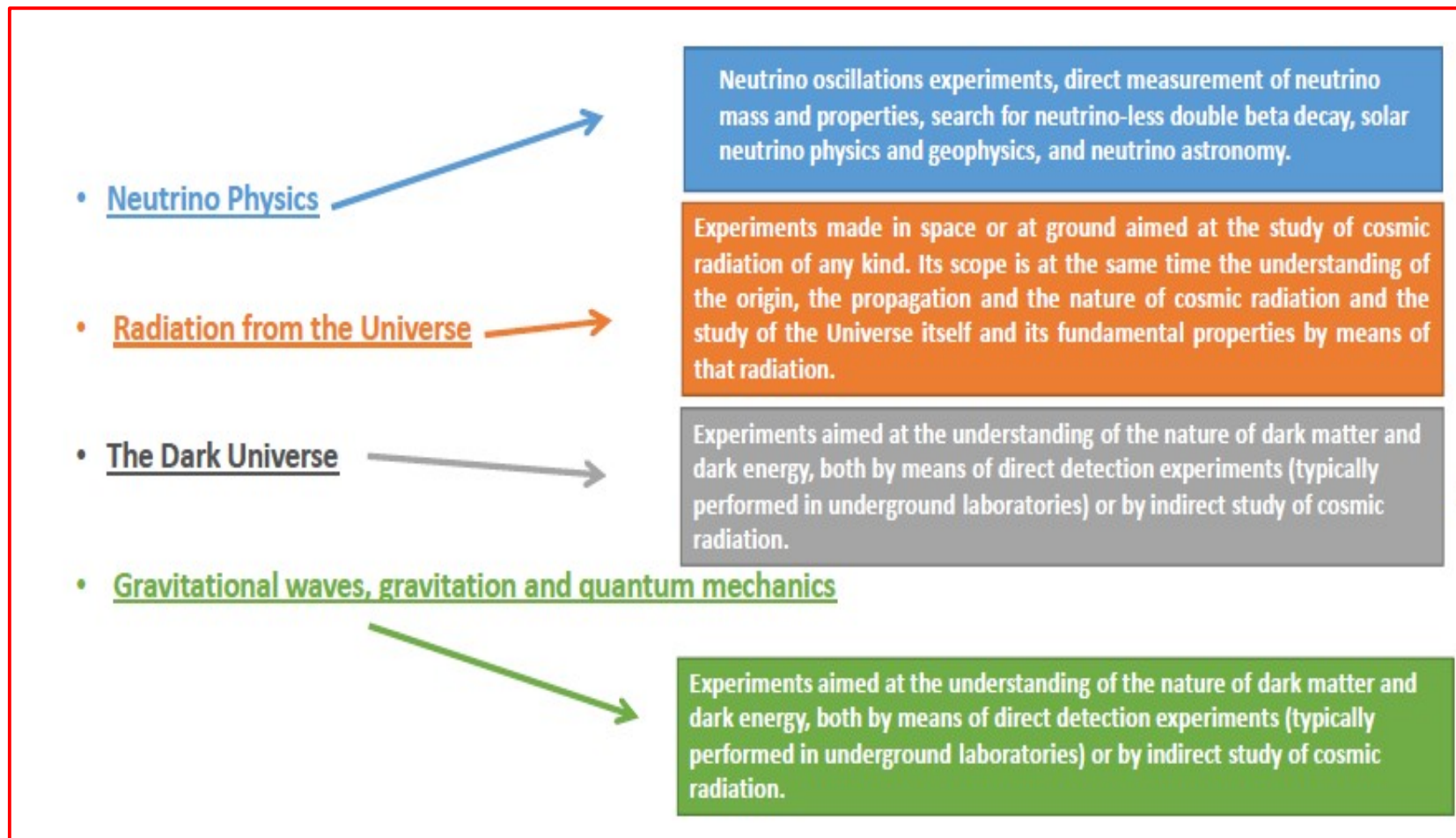


# REPORT attività di GRUPPO 2

## Principali Aree di ricerca di CSN2



AUGER 2 Perrone Lorenzo

EUCLID\_2 2 Nucita Achille

HERD\_DMP 2 Surdo Antonio

SABRE 2 Cataldi Gabriella

SPB2 2 Scherini Viviana

## GRUPPO 2 Lecce

5 Sigle

22 Ricercatori [5 Dottorandi]

3 Tecnologi

18 FTE

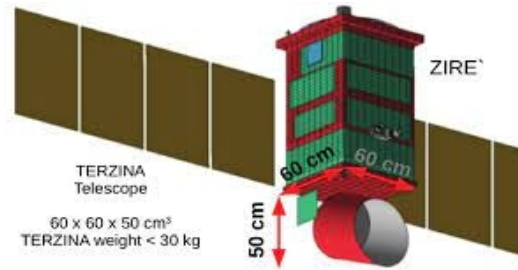
## Anagrafica preliminare

cognome	nome	contratto	profilo	stato	aff	AUGER	EUCLID_2	HERD_DMP	SABRE	SPB2	Percentuale
Totale(FTE)						8.95	2.4	3.8	2.45	0.4	
Alemanno	Francesca			Contratto non Trovato	2			20			HERD_DMP - 20%
Bernardini	Paolo	Ass	Incarico di Ricerca scientifica	Attivo	2			40			HERD_DMP - 40%
Casilli	Elisabetta	Ass	Scientifica Dottorandi	Attivo	2			100			HERD_DMP - 100%
Cataldi	Gabriella	Dip	Primo Ricercatore	Attivo	2	70			30		AUGER - 70% SABRE - 30%
Coluccia	Maria Rita	Dip	Tecnologo	Attivo	2	20					AUGER - 20%
Conte	Matteo	Ass	Scientifica Dottorandi	Attivo	2	100					AUGER - 100%
Creti	Pietro	Dip	Primo Tecnologo	Attivo	2	15		30			AUGER - 15% HERD_DMP - 30%
De Giorgi	Maria Luisa	Ass	Scientifica Ricercatori/Professori università	Attivo	2				100		SABRE - 100%
De Oliveira Franco	Danelise	Dip	Assegno di Ricerca	Scaduto		10					AUGER - 10%
De Palma	Francesco	Ass	Incarico di Ricerca scientifica	Attivo	2	60		40			AUGER - 60% HERD_DMP - 40%
De Paolis	Francesco	Ass	Incarico di Ricerca scientifica	Attivo	4		50				EUCLID - 50%
De Vito	Emanuele	Ass	Scientifica Assegni non INFN	Attivo	2	100					AUGER - 100%
Epicoco	Italo	Ass	Tecnologica Ricercatori/Professori università	Attivo	2	100					AUGER - 100%
Ghose	Essna	Ass	Scientifica Dottorandi	Attivo	2			100			HERD_DMP - 100%
Giaccari	Ugo Gregorio	Dip	Ricercatore	Attivo	2	90					AUGER - 90%
Khattak	Sana Gul	Ass	Scientifica Dottorandi	Attivo					100		SABRE - 100%
Martello	Daniele	Ass	Incarico di Ricerca scientifica	Attivo	2	100					AUGER - 100%
Miccoli	Alessandro	Dip	Tecnologo	Attivo	1				15		SABRE - 15%
Nucita	Achille	Ass	Incarico di Ricerca scientifica	Attivo	2	60	40				AUGER - 60% EUCLID - 40%
Orofino	Vincenzo	Ass	Scientifica Ricercatori/Professori università	Attivo	4		50				EUCLID - 50%
Perrone	Lorenzo	Ass	Incarico di Ricerca scientifica	Attivo	2	80				20	AUGER - 80% SPB2 - 20%
Sacquegna	Simone	Ass	Scientifica Dottorandi	Attivo	2		100				EUCLID - 100%
Scherini	Viviana	Ass	Incarico di Ricerca scientifica	Attivo	2	80				20	AUGER - 80% SPB2 - 20%
Strafella	Francesco	Ass	Associazione Senior	Scaduto	4		0				EUCLID - 0%
Surdo	Antonio	Dip	Primo Ricercatore	Attivo	2			50			HERD_DMP - 50%

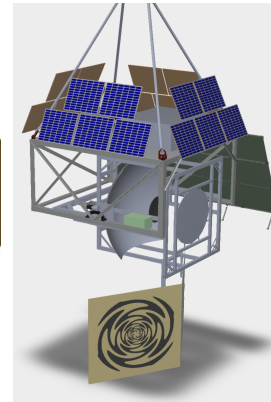
# Attività di Lecce in a nutshell



DAMPE (HERD)



PBR-NUSES



Pierre Auger Observatory

Caratterizzazione della radiazione cosmica per via diretta (**spazio**) ed indiretta (**superficie**)

- spettro energetico
- composizione
- direzioni di provenienza
- particelle neutre (fotoni, neutrini, neutroni)



**Multi-messenger astronomy per lo studio della fisica fondamentale**

- Ricerca di dark matter
- Interazioni adroniche
- Scenari BSM

SABRE



EUCLID



# *L'Osservatorio Pierre Auger*

Image:  
S.Saffi

R. Assiro, G. Cataldi, M.R. Coluccia, M. Conte, A. Corvaglia, P. Creti, F. de Palma, E. De Vito, I. Epicoco, D. Franco, U. Giaccari, D. Martello, A. Miccoli, A. Nucita, L. Perrone, C. Pinto, F. Ricciardi, V. Scherini

# The Pierre Auger Observatory

~ 400 members, 17 countries



## 3000 km<sup>2</sup>

## Surface detector

array of 1660 Cherenkov stations on a 1.5 km hexagonal grid of 3000 km<sup>2</sup>  
Dense sub-array (750 m) of 24 km<sup>2</sup>

## Fluorescence detector

4+1 buildings overlooking the array (24 + 3 HEAT telescopes)

## Radio detector

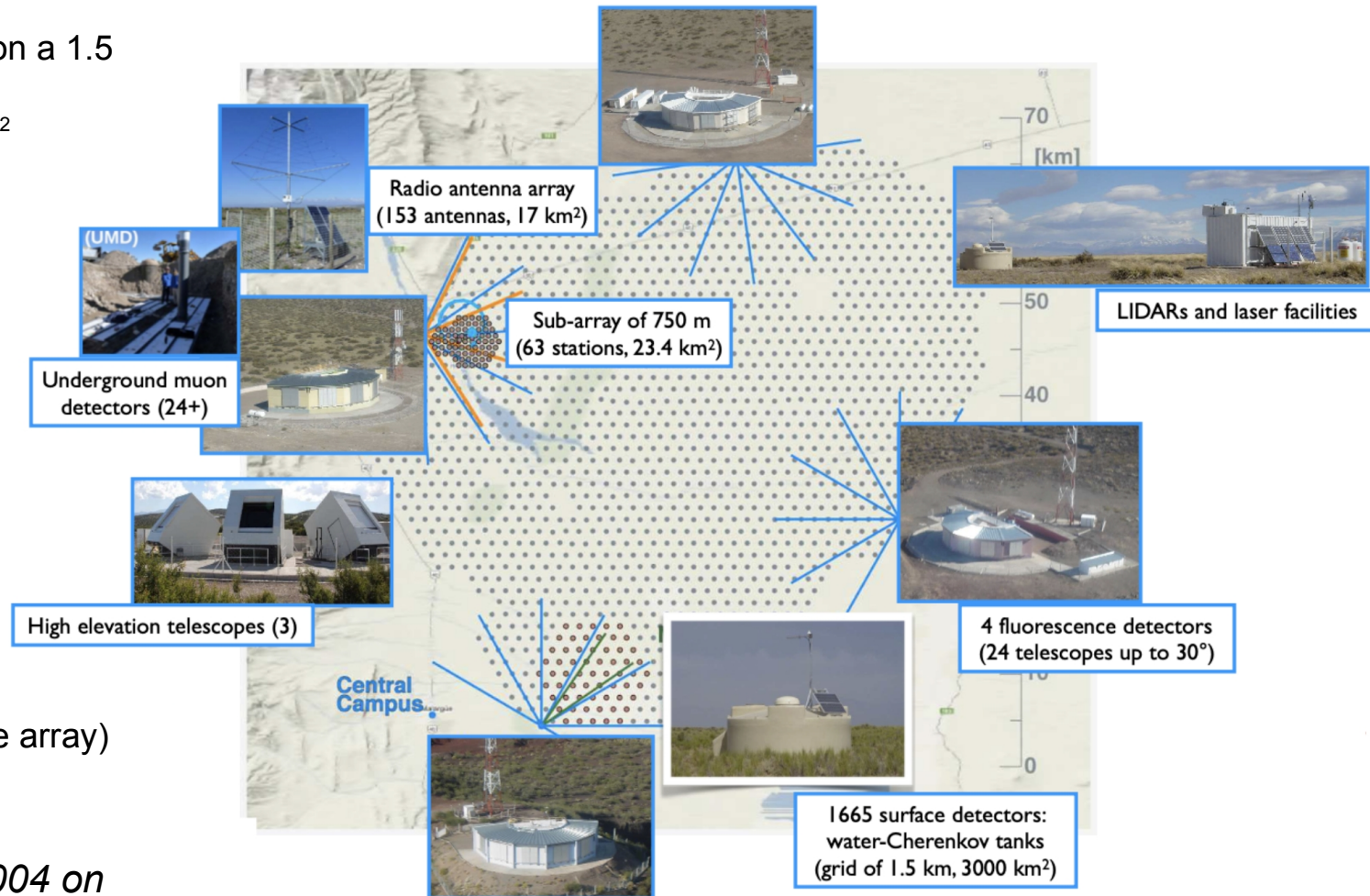
153 Radio Antenna → AERA

## Muon Detectors

Buried scintillators (region of dense array)

**Phase 1** : data taking from 2004 on  
(from 2008 with the full array in operation):

- Over 120.000 km<sup>2</sup> sr yr for anisotropy studies
- Over 90.000 km<sup>2</sup> sr yr for spectrum studies



**Phase 2 - the AugerPrime upgrade**  
Data taking from 2023 to 2030...  
Multiple detectors

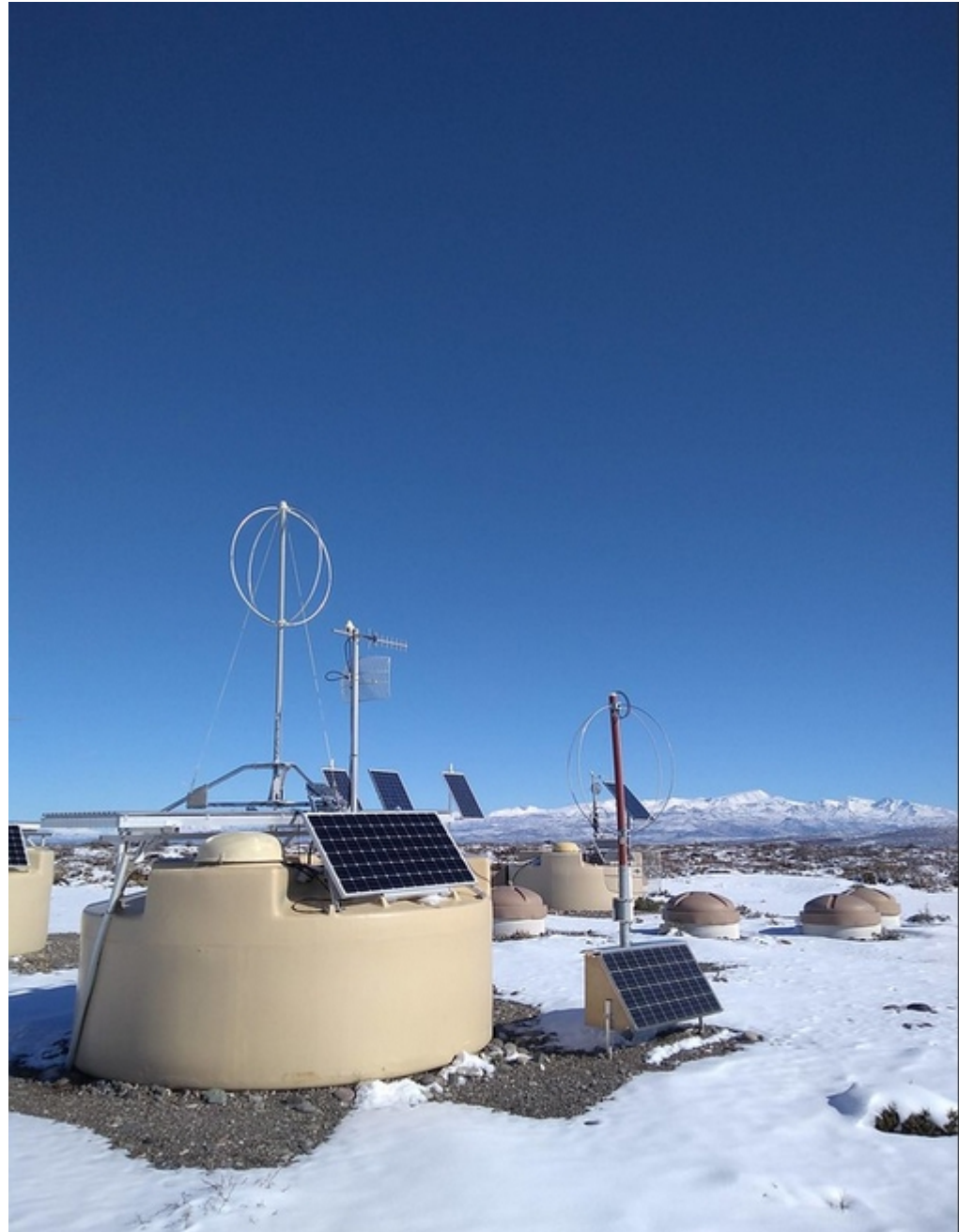
## Upgrade del detector di superficie

Attività di design/costruzione di SSD con leadership del gruppo di Lecce che oggi coordina la verifica e messa a punto della performance sul campo (Malargue) delle stazioni SSD e le failures di produzione

Attività di design, implementazione e controllo della UUB con significativa partecipazione del gruppo di Lecce negli anni. Supporto a SITAEL (prod) mantenuto nel tempo fino ad oggi (Roberto, Pietro)

**Tutte le stazioni tradizionali sono ora equipaggiate con nuova elettronica UUB, scintillatori (SSD), relativi PMTs e small PMTs.**

**Fase di completamento l'installazione delle antenne radio (~65%)**



# Il gruppo di Lecce: responsabilità

## Science/Detector

Referente per il calcolo di Auger al CNAF (fino a Giugno 2024) (G. Cataldi)

Task leader per Data Release Task (V. Scherini)

Task leader per SSD (D. Martello)

## Istituzionali

Chair del Collaboration Board (fino ad Aprile 2024, ora Lecce rappr.) (L. Perrone)

Membro del Conference Committee (U. Giaccari)

# Il gruppo di Lecce: partecipazione a conferenze 2024

V. Scherini	ICHEP	Luglio 2024
M. Conte	SIF 2024	Settembre 2024
E. De Vito	RICAP 2024	Settembre 2024
E. De Vito	CRIS-MAC	Giugno 2024



# Attività di analisi a Lecce 2024-2025

## Performance del rivelatore ibrido

FD/SD calibrazioni, on-time e produzione dei dati ibridi  
→ grazie a Fulvio e Antonio per il supporto nel calcolo!

## Misura dello spettro energetico

spettro ibrido in particolare (misura di ankle e soppressione)

## Open data

Messa a punto dei tool e interazione con task di analisi  
- frazione innalzata dal 10% al 30% entro fine 2024

## AugerPrime

Studio della performance del detector upgradato.  
Sviluppo di algoritmi con NN per la ricerca di cluster nei dati e nelle simulazioni

Ricerca di fotoni primari con tecniche di ricostruzione basate sul modello di  
“universalità”

Ricerca di neutrini con il rivelatore di fluorescenza

**astronomia  
multi-messenger**

Ricerca di neutroni

Anisotropia

# Mini-Workshop: the multi-messenger physics program at the Pierre Auger Observatory

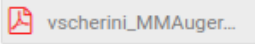
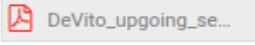
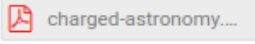


Monday 29 Jan 2024, 15:00 → 17:00 Europe/Rome

aula magna M0 (Dip. Matematica e Fisica - Ed. Fiorini)

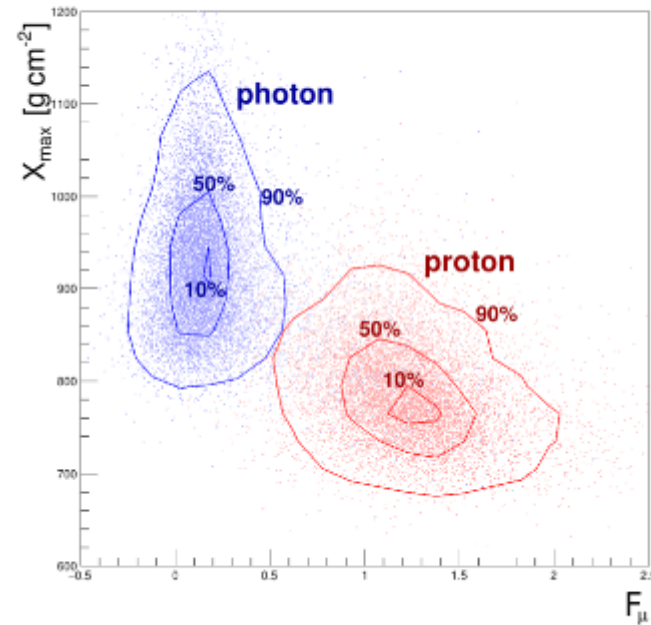
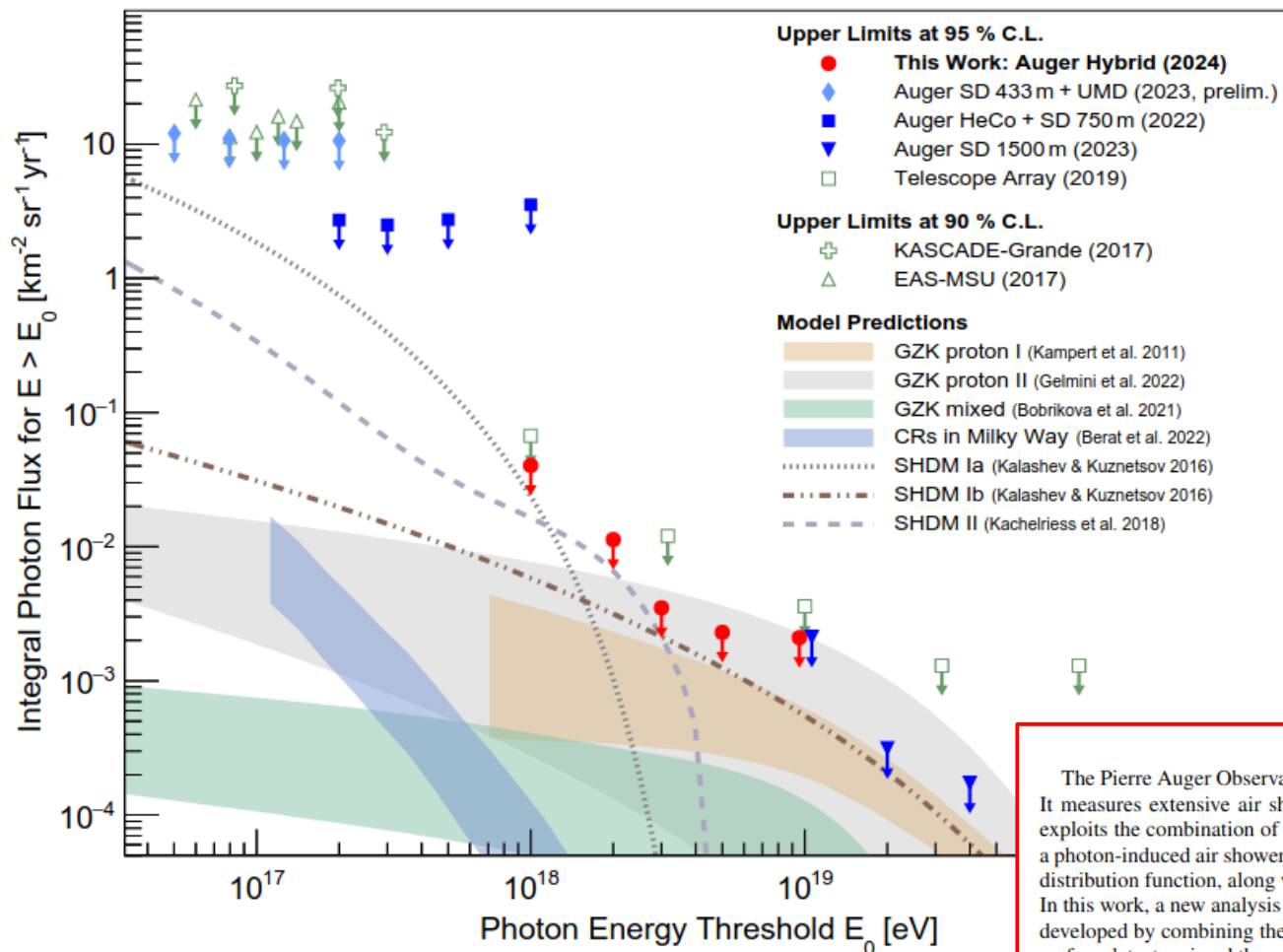
Lorenzo Perrone (Istituto Nazionale di Fisica Nucleare)

**Description** Overview of experimental results and advanced analysis techniques. Multi-flavour pastries.

- |               |  |     |  |
|---------------|--|-----|--|
| 15:00 → 15:15 | <b>The Pierre Auger Observatory in the context of Multi Messenger Physics</b><br><b>Speaker:</b> Viviana Scherini (Università del Salento and Istituto Nazionale di Fisica Nucleare)<br>  | 15m |  |
| 15:15 → 15:35 | <b>Search for photons above <math>10^{18}</math> eV by simultaneously measuring the atmospheric depth and the muon content of air-showers at the Pierre Auger Observatory</b><br><b>Speaker:</b> Pierpaolo Savina (GSSI and Istituto Nazionale di Fisica Nucleare)   | 20m |  |
| 15:35 → 15:55 | <b>Search for upward-going showers consistent with the anomalous ANITA events with the Fluorescence Detector of the Pierre Auger Observatory</b><br><b>Speaker:</b> Emanuele De Vito (Università del Salento and Istituto Nazionale di Fisica Nucleare)<br> | 20m |  |
| 15:55 → 16:15 | <b>Search for point sources of neutrons in the data of the Pierre Auger Observatory</b><br><b>Speaker:</b> Danelise Franco (INFN Lecce)  | 20m |  |
| 16:15 → 16:35 | <b>Studies of anisotropies in the arrival direction of cosmic rays at different scales</b><br><b>Speaker:</b> Ugo Gregorio Giaccari (Istituto Nazionale di Fisica Nucleare)<br>   | 20m |  |
| 16:35 → 16:55 | <b>AugerPrime: enhanced capability of separating primary masses with machine learning techniques</b><br><b>Speaker:</b> Matteo Conte (Università del Salento and Istituto Nazionale di Fisica Nucleare)  | 20m |  |
| 16:55 → 17:00 | <b>Multi-flavour pastries</b>  | 5m  |  |

# Search for photons above $10^{18}$ eV by simultaneously measuring the atmospheric depth and the muon content of air-showers at the Pierre Auger Observatory

Submitted to PRD



Analisi sviluppata nella tesi di Pierpaolo Savina

(Dated: June 11, 2024)

The Pierre Auger Observatory is the most sensitive instrument to detect photons with energies above  $10^{17}$  eV. It measures extensive air showers generated by ultra high energy cosmic rays using a hybrid technique that exploits the combination of a fluorescence detector with a ground array of particle detectors. The signatures of a photon-induced air shower are a larger atmospheric depth of the shower maximum ( $X_{\max}$ ) and a steeper lateral distribution function, along with a lower number of muons with respect to the bulk of hadron-induced cascades. In this work, a new analysis technique in the energy interval between 1 and 30 EeV (1 EeV =  $10^{18}$  eV) has been developed by combining the fluorescence detector-based measurement of  $X_{\max}$  with the specific features of the surface detector signal through a parameter related to the air shower muon content, derived from the universality of the air shower development. No evidence of a statistically significant signal due to photon primaries was found using data collected in about 12 years of operation. Thus, upper bounds to the integral photon flux have been set using a detailed calculation of the detector exposure, in combination with a data-driven background estimation. The derived 95% confidence level upper limits are 0.0403, 0.01113, 0.0035, 0.0023, and 0.0021  $\text{km}^{-2} \text{sr}^{-1} \text{yr}^{-1}$  above 1, 2, 3, 5, and 10 EeV, respectively, leading to the most stringent upper limits on the photon flux in the EeV range. Compared with past results, the upper limits were improved by about 40% for the lowest energy threshold and by a factor 3 above 3 EeV, where no candidates were found and the expected background is negligible. The presented limits can be used to probe the assumptions on chemical composition of ultra-high energy cosmic rays and allow for the constraint of the mass and lifetime phase space of super-heavy dark matter particles.

Migliori UL nel range 1-10 EeV

Utilizzati per constraints sulla SHDM

# A search for the anomalous events detected by ANITA using the Pierre Auger Observatory\*

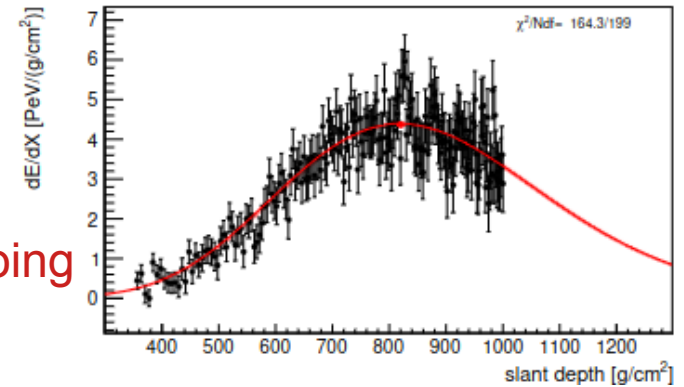
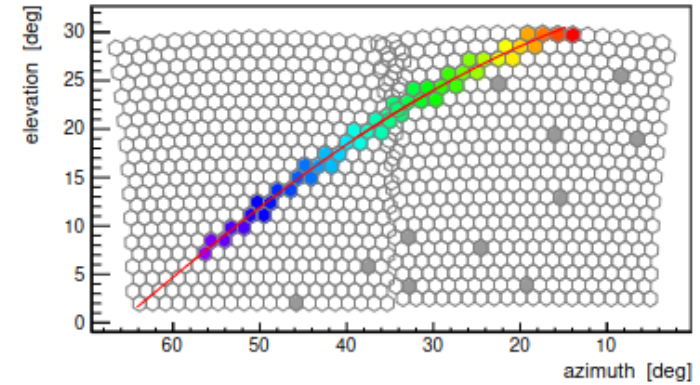
(Dated: January 17, 2024)

A dedicated search for upward-going air showers at elevation angles exceeding  $20^\circ$  and energies  $E > 0.1$  EeV has been performed using the Fluorescence Detector of the Pierre Auger Observatory. The search is motivated by two “anomalous” radio pulses observed by the ANITA flights I and III which appear inconsistent with the Standard Model of particle physics. Using simulations of both regular cosmic ray showers and upward-going events, a selection procedure has been defined to separate potential upward-going candidate events and the corresponding exposure has been calculated in the energy range  $[0.1-33]$  EeV. One candidate event has been found in the search period between 1 Jan 2004 and 31 Dec 2018, consistent with an expected background of  $0.27 \pm 0.12$  events from mis-reconstructed cosmic ray showers. This translates to an upper bound of the integral flux of  $(7.2 \pm 0.2) \times 10^{-21} \text{ cm}^{-2} \text{ sr}^{-1} \text{ y}^{-1}$  and  $(3.6 \pm 0.2) \times 10^{-20} \text{ cm}^{-2} \text{ sr}^{-1} \text{ y}^{-1}$  for an  $E^{-1}$  and  $E^{-2}$  spectrum, respectively. An upward-going flux of showers normalized to the ANITA observations is shown to predict over 34 events for an  $E^{-3}$  spectrum and over 8.1 events for a conservative  $E^{-5}$  spectrum, effectively dismissing the interpretation of the anomalous events as upward-going showers.

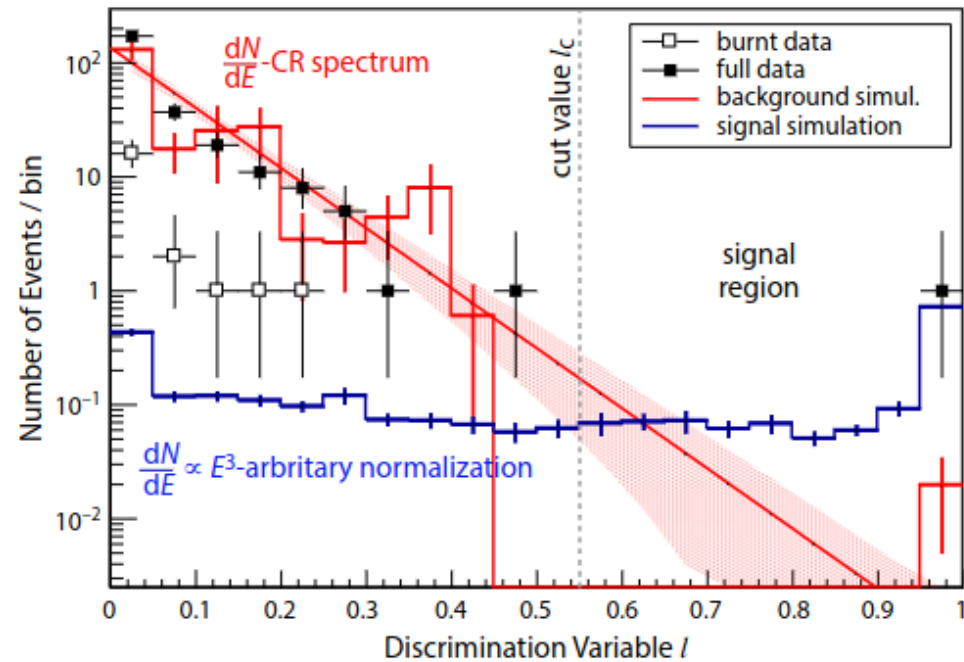
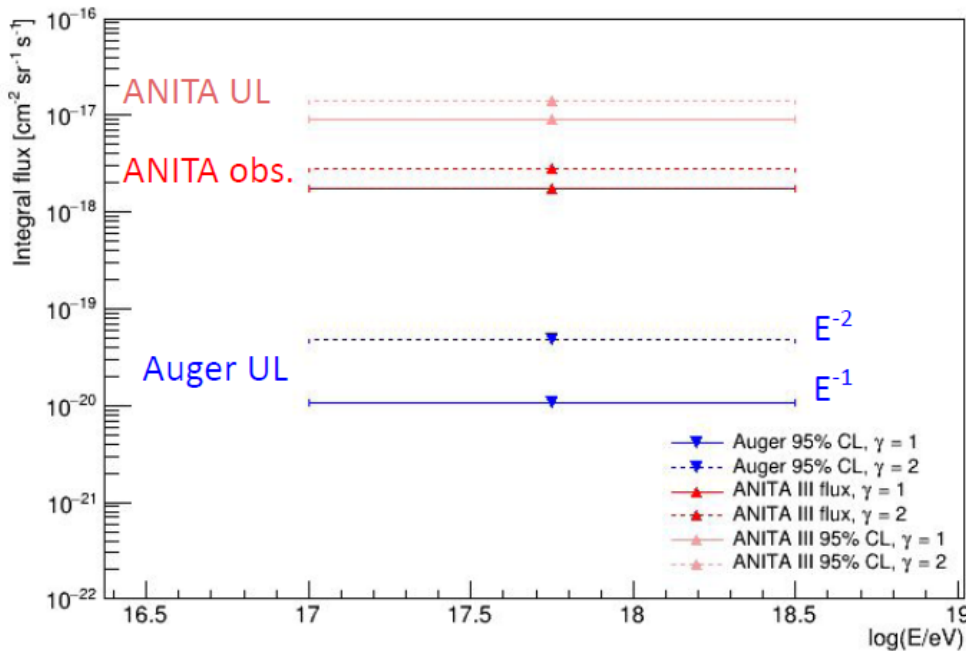
Submitted to PRL

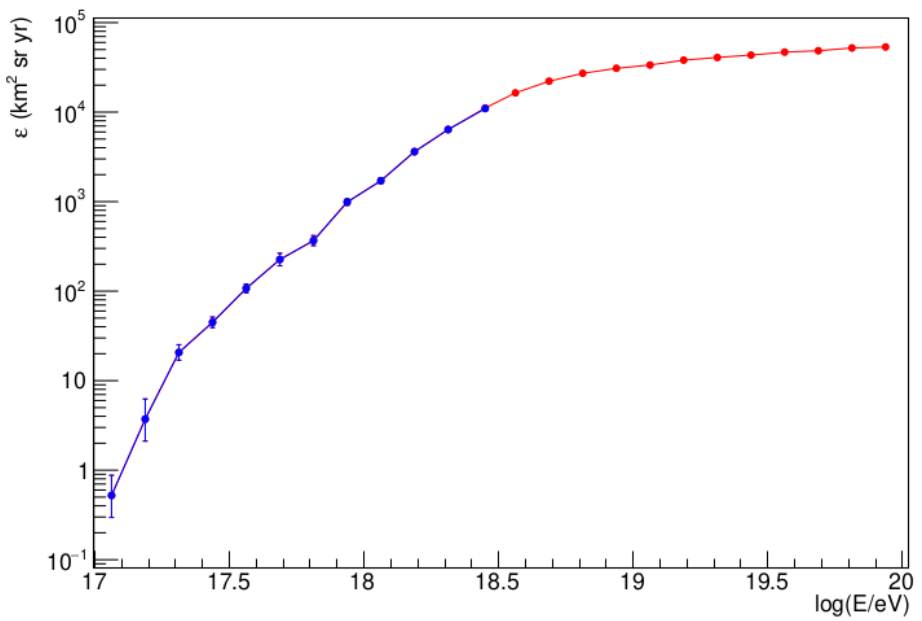
PhD Thesis, E. De Vito → adesso RTDA

Presentato a ICRC 2023 e CRIS-MAC 2024



Simulated upward-going event



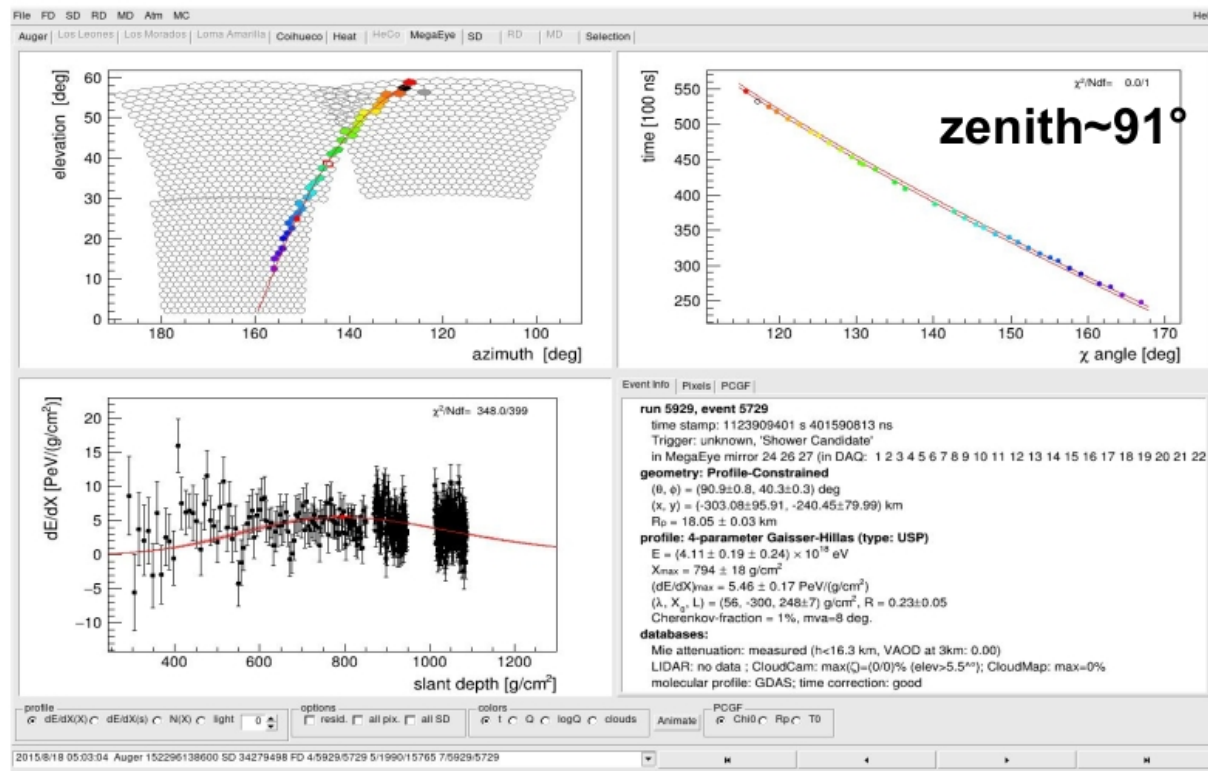


Attività attuale: estensione del calcolo della sensibilità (exposure) alle energie piu' alte

Rilevante per indagare scenari BSM

Estensione ad angoli piu' inclinati → eventi stratosferici

Sinergia possibile con future osservazioni dallo spazio



Interazione con progetto PNRR Spoke 2 M4C2 (Università del Salento)

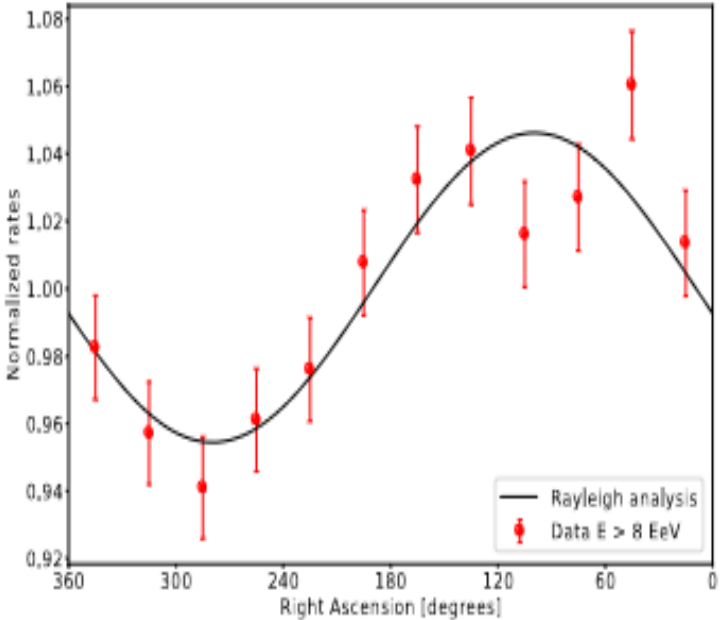
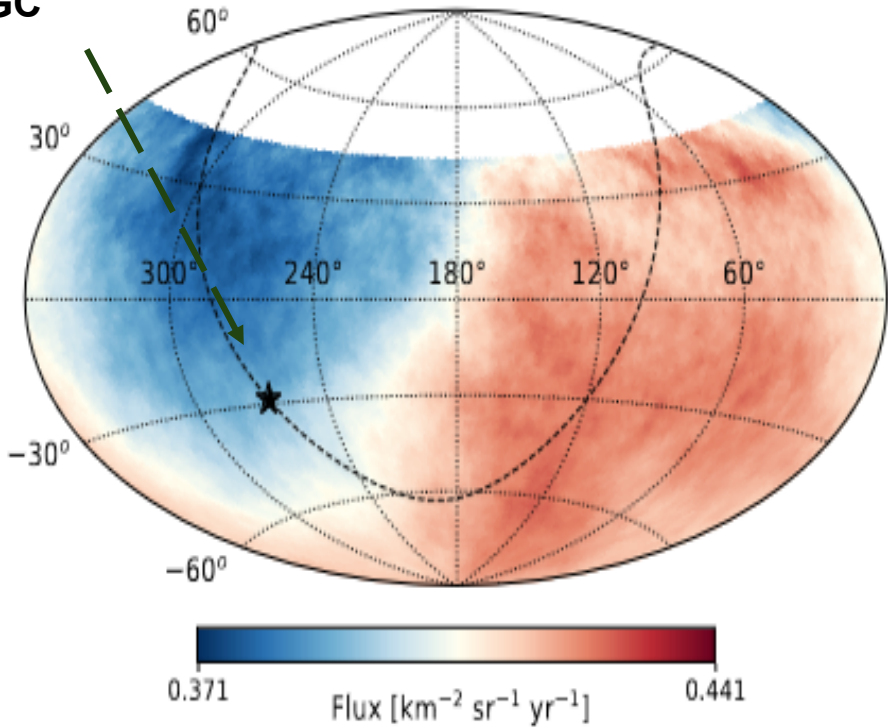
# Large scale analysis $E \geq 4$ EeV: dipole 3D reconstruction

Auger Phase 1 dataset

$E$ [EeV]	$N$	$d_{\perp}$ [%]	$d_z$ [%]	$d$ [%]	$\alpha_d$ [°]	$\delta_d$ [°]	$P(\geq r_1^{\alpha})$
4-8	118,722	$1.0^{+0.6}_{-0.4}$	$-1.3 \pm 0.8$	$1.7^{+0.8}_{-0.5}$	$92 \pm 28$	$-52^{+21}_{-19}$	0.14
$\geq 8$	49,678	$5.8^{+0.9}_{-0.8}$	$-4.5 \pm 1.2$	$7.4^{+1.0}_{-0.8}$	$97 \pm 8$	$-38^{+9}_{-9}$	$8.7 \times 10^{-12}$

→ **6.9  $\sigma$**

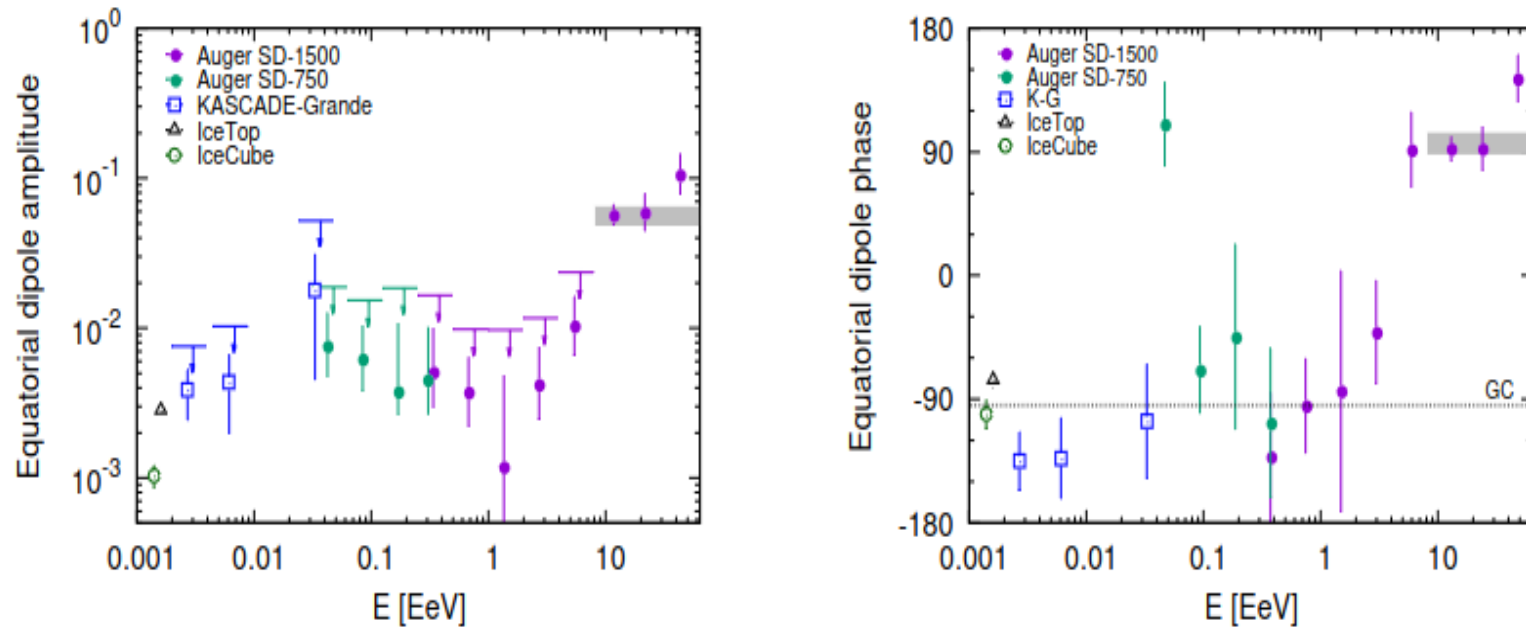
Dipole direction  $\sim 113^\circ$  away from the GC



Equatorial coordinates, smoothed by a top-hat window of  $45^\circ$

EB members: G.Golup, L. Caccianiga, M. Schimassek, S. Mollerach, **U. Giaccari**, R. Menezes de Almeida, B. Dawson (SC)

# Large scale analysis in R.A. at $E \geq 0.03$ EeV



Even though the results for the lower  $E$  have a  $P > 1\%$ , amplitudes grow from below 1% to above 10% and phases shift from  $\sim$ GC to the opposite direction

**=> suggests a transition of the origin of the anisotropies from galactic to extragalactic**

# Neutron analysis

EB members: Lorenzo Caccianiga, **Danelise de Oliveira Franco**, Federico Maria Mariani, Paul Sommers, Geraldina Golup, Esteban Roulet, Lorenzo Cazon

We search for an event excess that could indicate a neutron flux.

Observed CR density



CR density obtained from isotropic distributions

We assign a weight representing the probability density of an event coming from the direction of the target:

$$w_i = \frac{1}{2\pi\sigma_i^2} \exp\left(-\frac{\xi_i^2}{2\sigma_i^2}\right)$$

$\xi_i$ : angular distance  
 $\sigma_i$ : angular uncertainty

By summing all the weights in the data set, we obtain the cosmic ray density at the position of the target:

$$\rho = \sum_i^N w_i$$

$N$  → Number of events in the data set



# Status

◆ We have the final results for the **SD-1500** and the **SD-750** data sets.

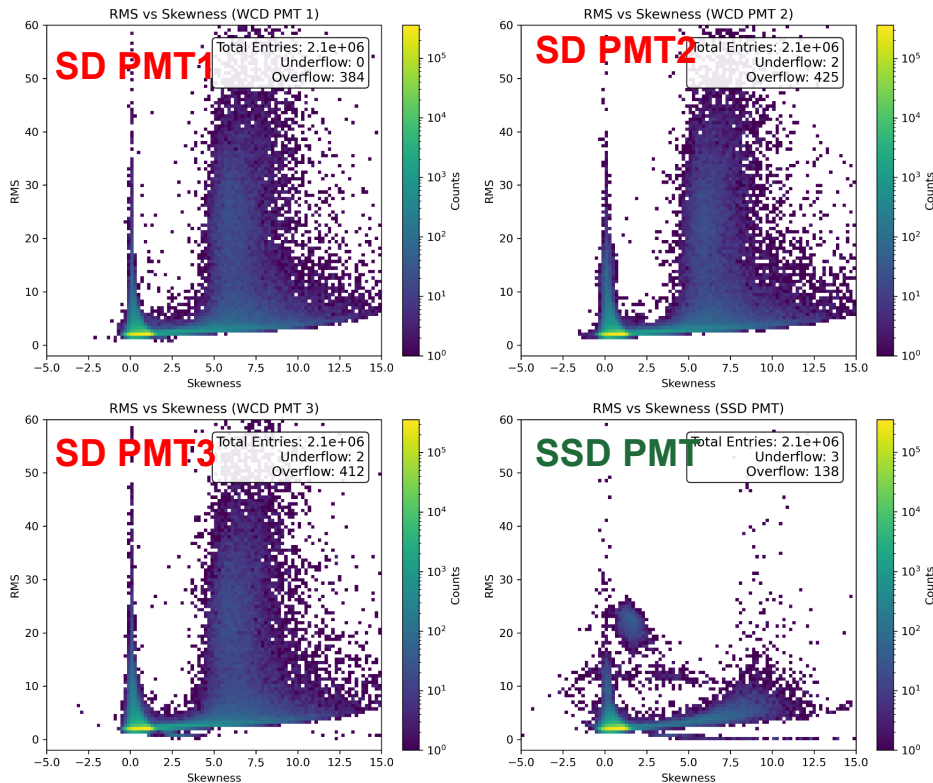
◆ We are investigating an interesting candidate source, the pulsar **J1946-5403**. For the SD-1500, we obtained a  $p$ -value of  $5 \times 10^{-5}$  for the direction of this target. We are studying the possibility of including it as a **single-element target set** for the **SD-750 data set**.

We are preparing two GAP notes related to the neutron analysis: one with a detailed description of the method and the other with details about the feasibility of testing the pulsar J1946-5403 using the SD-750 data set.

◆ We are writing the paper and hope to have the first draft in the coming weeks.



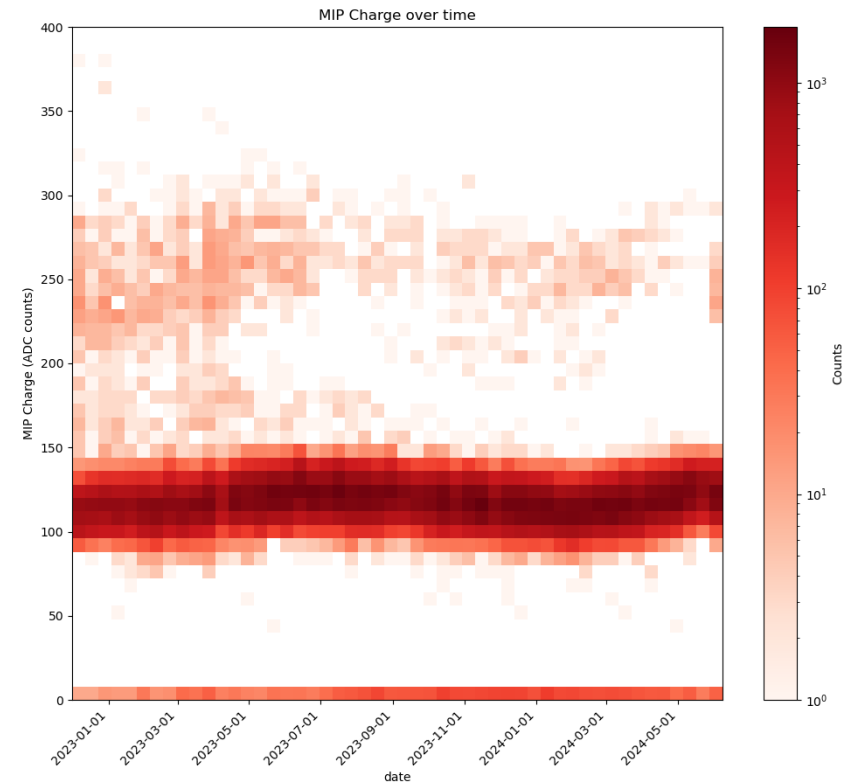
# Studio della performance del rivelatore upgradato



Nuova elettronica UUB

Stabilità temporale di SSD

MIP vs time since 2023



Stabilità della baseline per SD (PMT 1,2,3) and per SSD

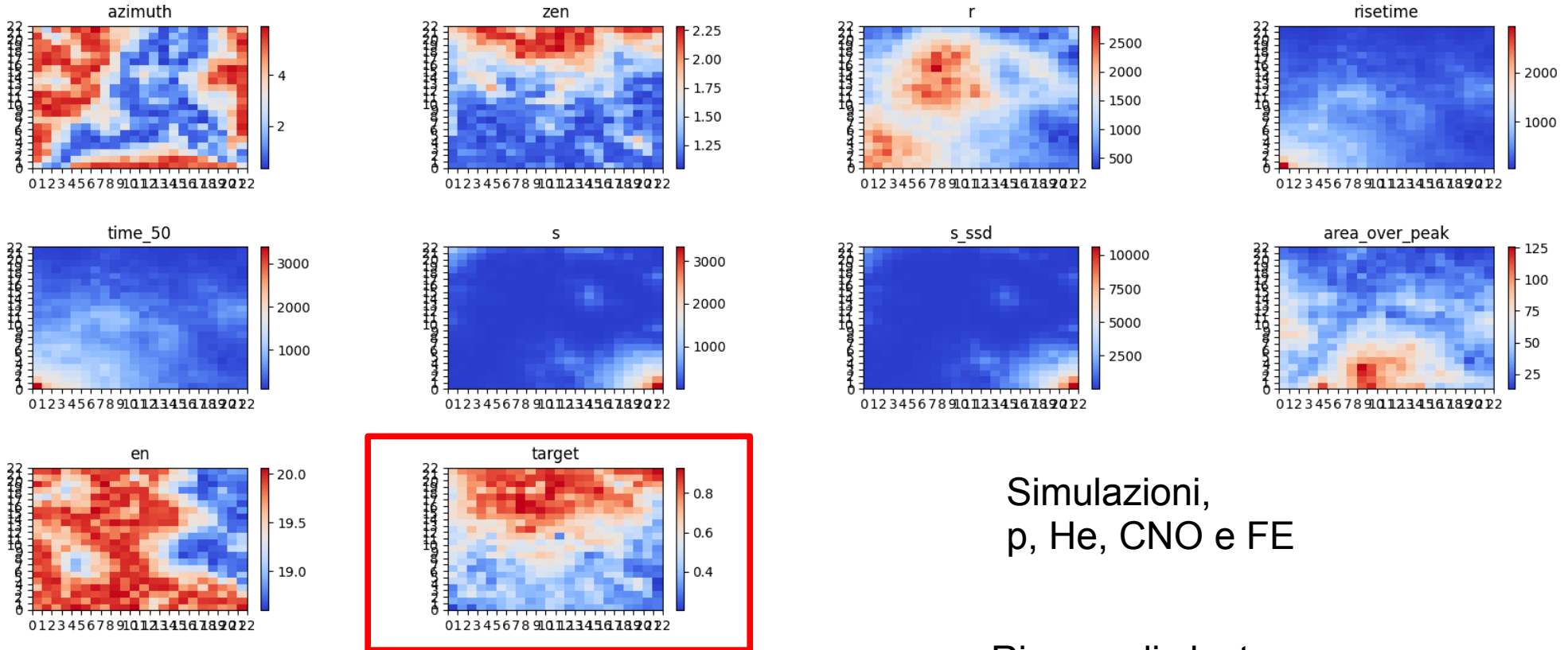
RMS vs Skewness

Presenza residuale di bad periods (alta RMS e bassa Skewness) e/o segnali con early peaks (alta RMS, alta Skewness)

# Analisi dati con Reti neurali, studi di composizione di massa con il rivelatore upgradato

Ricerca di cluster con reti neurali non supervisionate

M. Conte  
A Nucita



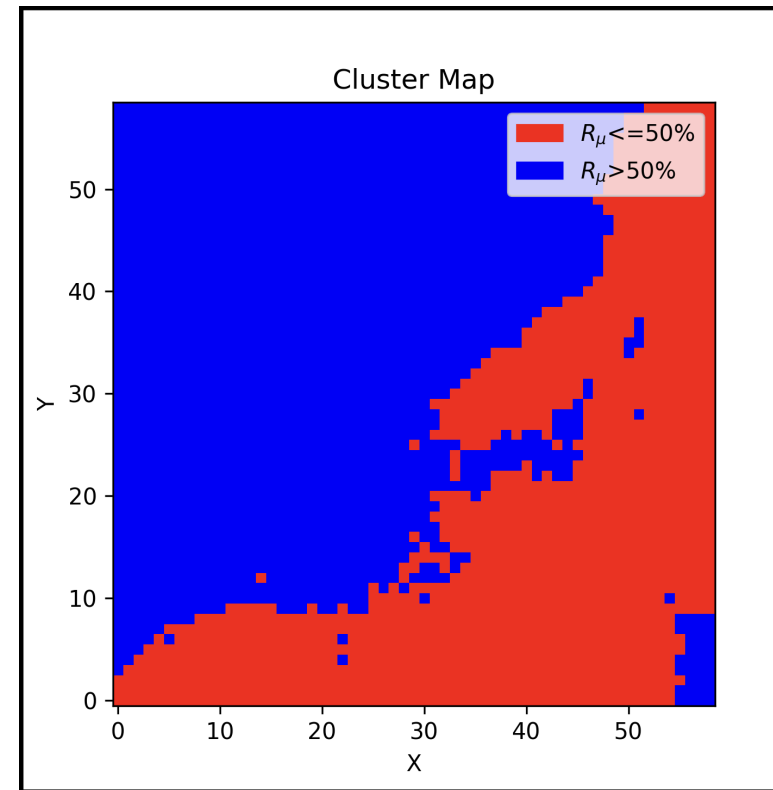
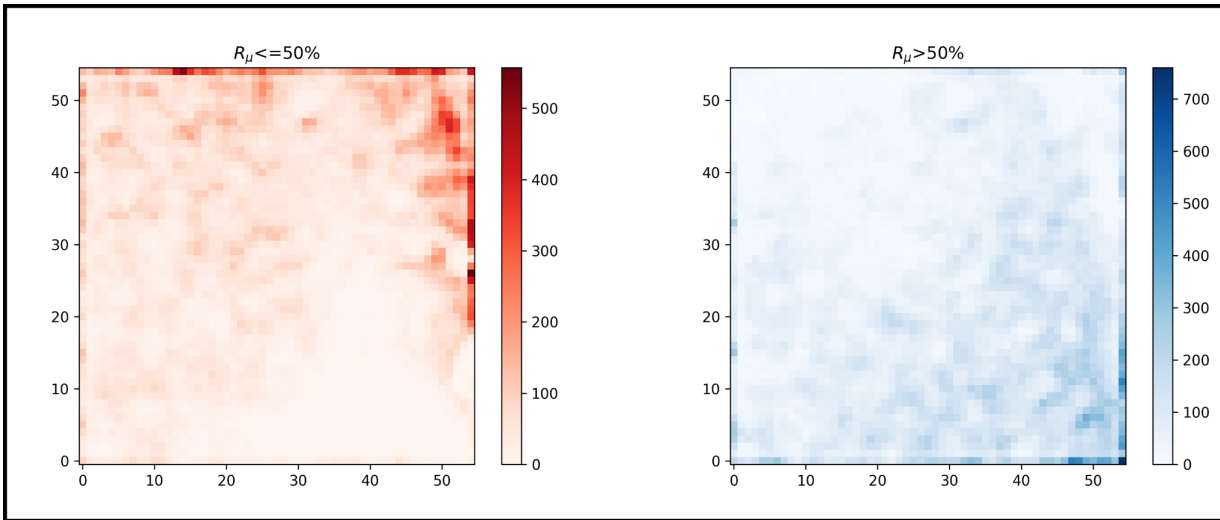
Simulazioni,  
p, He, CNO e FE

Ricerca di cluster  
correlati tra il target e le  
osservabili passate alla  
rete

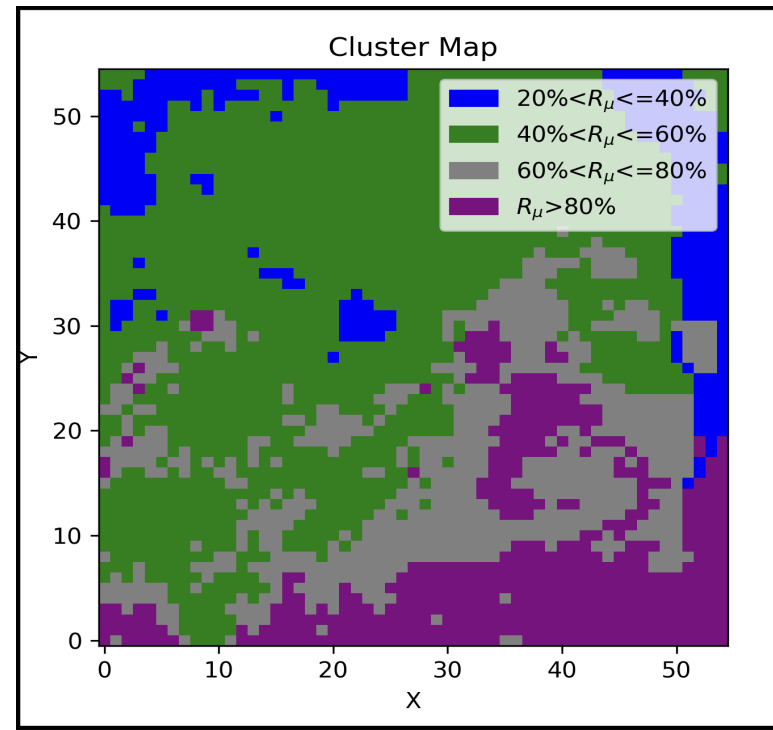
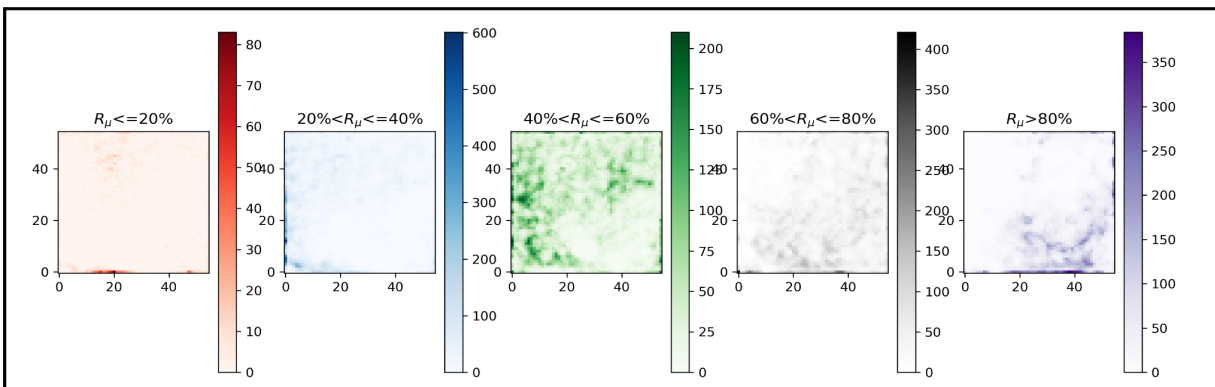
Test su dati simulati.  
9 osservabili ricostruite passate alla rete  
**1 target (proxy per il numero di muoni)**

Calcolo condotto su GPU della sezione

## Mappa a due livelli



## Mappa a cinque livelli



Interazione con progetto PNRR Spoke 2  
M4C2 (Università del Salento)

# Pierre Auger Observatory Open Data

March 2024 release

<https://opendata.auger.org>

doi 10.5281/zenodo.4487613

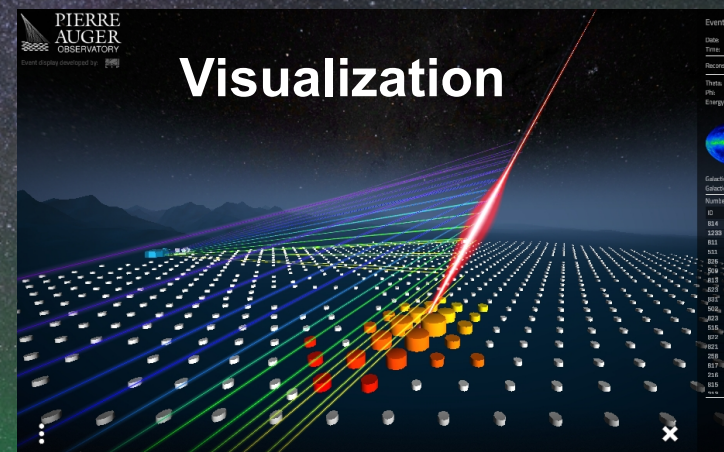
10% cosmic ray data → 30% at the end of 2024  
100% atmospheric data

Close to raw data and higher level reconstruction

Surface and Fluorescence Detectors

JSON and summary CSV files

Python code for data analysis



## Datasets

[the released datasets and their complementary data](#)



## Visualize

[an online look at the released pseudo raw cosmic-ray data](#)



## Analyze

[example analysis codes in online python notebooks to run on the datasets](#)



## Outreach

[a page dedicated to the general public](#)

# March 2024 release

**Dataset:** 10% SD-750 events + HeCo hybrid events  
used for calibration

[Eur. Phys. J C \(2021\) 81:966](#)

**Source:** [AugerWiki/InfillSpectrumPaper2021](#)

- data tar files (Herald, ADST, root)
- scripts (SDCalib.cc, CIC ...)
- plots

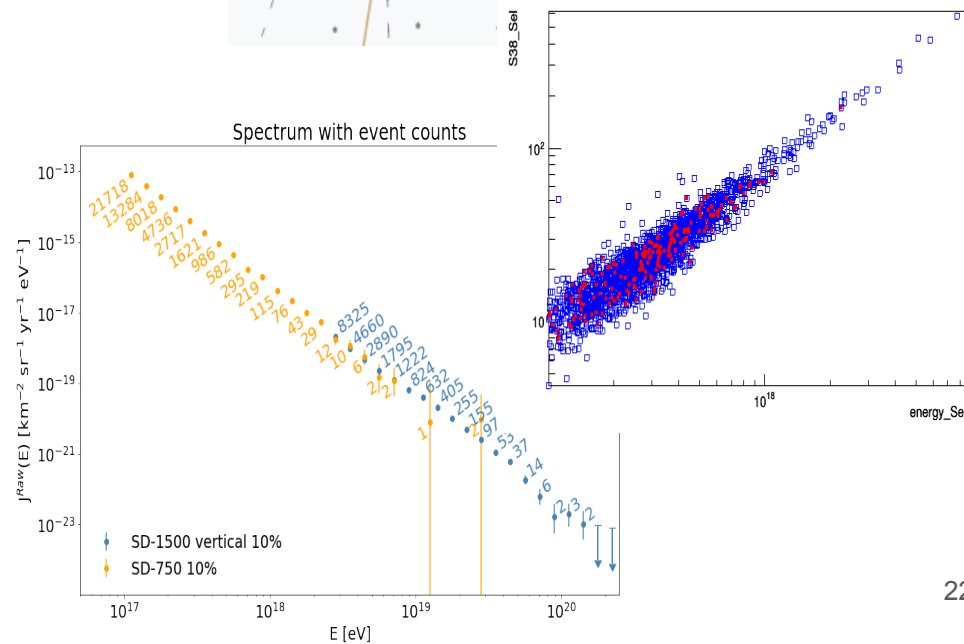
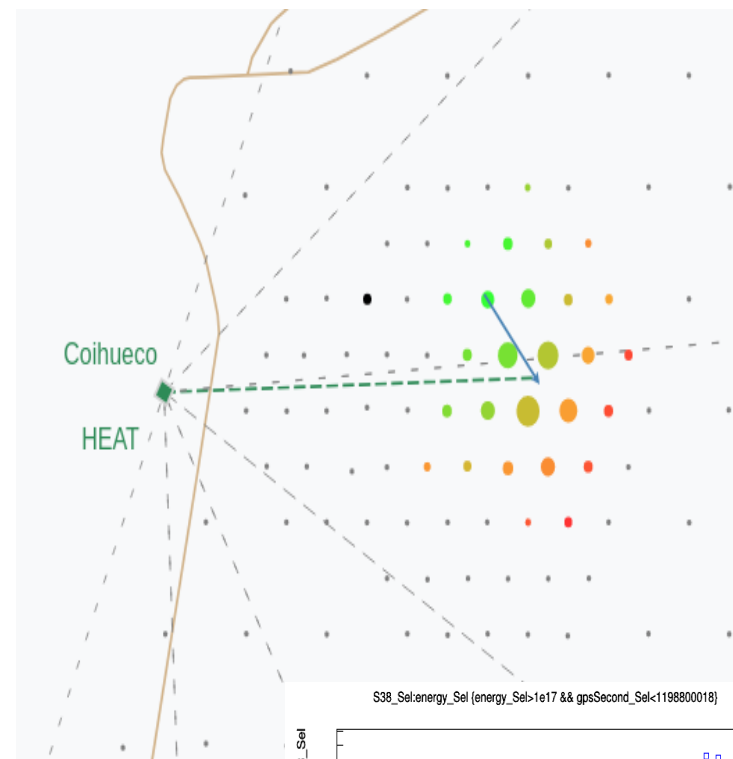
**SD-750:** 54477 events  $E > 0.1 \text{ EeV}$   $H < 40^\circ$   
**He-Co hybrids for calibration:** 197 events

**Notebooks:** updated spectrum

**Catalog:** raw traces and updated description

**TODO:**

- update arXiv paper in view of submission to journal
- transfer the development page hosted in Catania  
<https://labauger.ct.infn.it/opendata/>



# Il gruppo di Lecce:

## partecipazioni ad Editorial Boards attivi

**NIM paper su SSD** : D. Martello, G. Cataldi, R. Coluccia, M. Conte

**PRL, search for upward-going neutrinos** : E. De Vito, L. Perrone

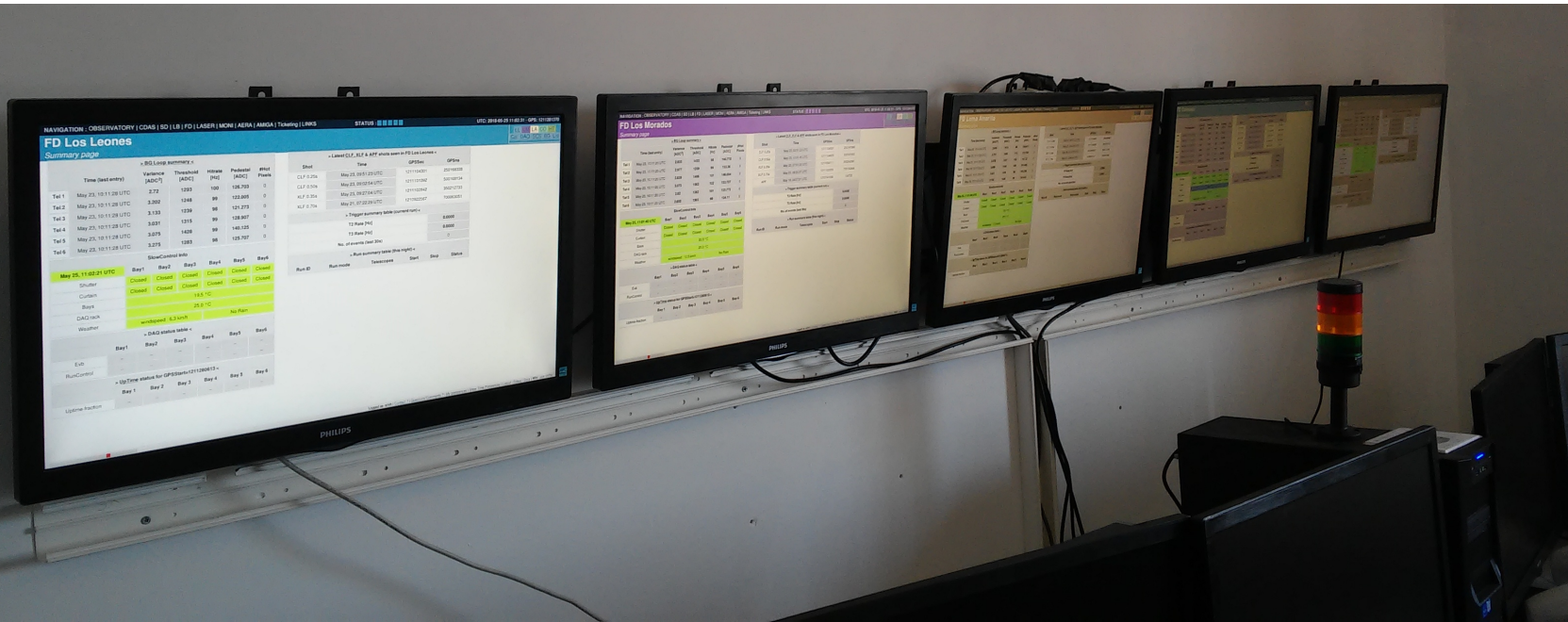
**Open Data** : V. Scherini

**PRD, search for photons** : P. Savina, L. Perrone, V. Scherini

**APJ, anisotropy**: U. Giaccari

**JCAP, search for neutrons**: D. Franco

# Control room remota per il rivelatore di fluorescenza



## Turni FD remoti eseguiti

- Maggio – Giugno 2024

## 2 Turni SD remoti eseguiti

- Ottobre 2023

- Luglio 2024

Necessità di un upgrade software prima della prossima campagna di presa dati  
Procedura richiesta a tutte le remote control room.



# Accesso a servizi per il 2025

Supporto nella gestione e software upgrade della control room remota di Auger  
Assistenza nella fase di transizione del data center di Auger da Lyon al CNAF  
Supporto durante la scuola internazionale ISAPP (Giugno 2025)  
Setup di un server locale di test per la gestione degli open data di Auger

Richieste al servizio **calcolo e reti**  
**3 mesi/persona**

Supporto per la verifica della performance sul campo (gestione eventuali emergenze)

Richieste all'officina **meccanica**  
**2 mesi/persona**

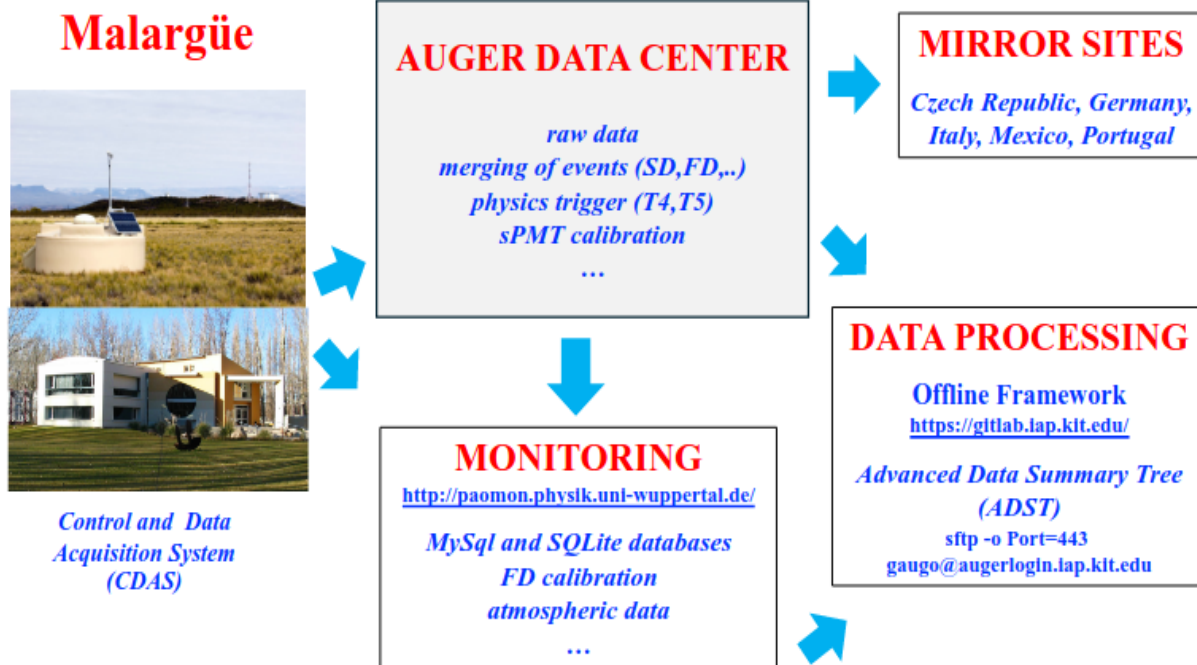
Verifica dell'installazione del funzionameneto delle schede UUB

Richieste al laboratorio di **elettronica**  
**2 mesi/persona**

# Auger Data Center Lyon → CNAF

Endorsement dal CB di Auger a INFN per il trasferimento da Lyon al CNAF (Aprile 2024)

Impegno per Auger Italia, gruppo di Lecce coinvolto direttamente



Requisiti in breve:

600 TiB disco

1.3 PiB tape

Incontro preliminare al CNAF per iniziare la procedura in caso di approvazione delle richieste

Ringrazio Enrico Fasanelli per i consigli ed il supporto in questa fase preliminare. Supporto del servizio calcolo richiesto per il 2025 (3 Mesi/Persona)

# Richieste per il 2025 (Preliminari)

**Sommario** →      Consumo      5K  
                                  Missioni      64K  
                                  Trasporti      7K

consumo	Componenti e altre minuterie per supporto all'attivita' di test dell'elettronica in situ, per la calibrazione dei moduli SSD in laboratorio e per interventi di manutenzione dei moduli SSD in situ.	5.00	0.00			5
missioni	2 turni FD presa dati in situ (4K per partecipante) 8.00 0.00	8.00	0.00			64
	Partecipazione a meeting di collaborazione in situ. Due meeting (Marzo 2025 e Novembre 2025) 3 Fisici per il meeting di Marzo (3K x3) 6 Fisici per il meeting di Novembre (3Kx6)	27.00	0.00			
	2 turni tecnici (1 Fisico, 1 Tecnico, in concomitanza con il meeting di collaborazione di Novembre 2K x 4). Verifica sui moduli SSD installati nel campo e commissionig nuova elettronica UUB.	8.00	0.00			
	4 missioni per 2 fisici (2K * 4) al CNAF per le operazioni di trasferimento dell'Auger data center da Lyon al CNAF	8.00	0.00			
	Riunione con i referee, 2 Fisici (0.5 K x 2)	1.00	0.00			
	Partecipazione al meeting Auger di analisi (L'Aquila, Maggio 2025), 6 fisici (1.5x6)	9.00	0.00			
	Partecipazione gruppo di lavoro europeo su attivita' multi-messenger per 2 fisici.	3.00	0.00			
trasporti	Trasporti in situ per 1 turno FD (2K) 1 turno tecnico (2K) + Trasporti per partecipazioni ai meeting (1K per meeting di Marzo + 2 K per meeting di Novembre)	7.00	0.00			7
<b>Totale</b>						<b>76</b>

# DAMPE/HERD: Attività 2024

## DAMPE

- Analisi dei dati di volo (>8 anni): flusso e spettro energetico dei nuclei dei Raggi Cosmici
  - **Spettro (p+He)**, pubblicato recentemente su PRL (F. Alemanno)
  - **Spettro del gruppo di nuclei massa intermedia Ne, Mg, Si** (E. Casilli)
- Produzione dati simulati per le analisi
  - Partecipazione a Shift/Monitor per la produzione Monte Carlo in Europa
- **Responsabilità**
  - Coordinamento della produzione MC in Europa (Recas/Bari e Ginevra) e del Calcolo dell'esperimento F. de Palma
  - Convenor Working Group sui raggi Cosmici A. Surdo

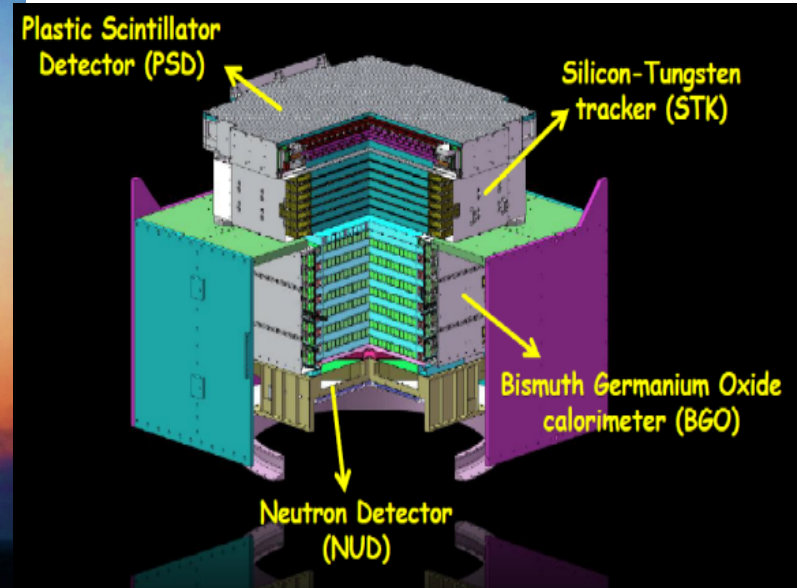
## HERD

- Attività software e di laboratorio:
  - Simulazione eventi con *HERDSoftware* per design e ottimizzazione geometria del PSD  
(accettazione, ermeticità, reiezione del back-splash, ..) (E. Ghose)
  - Test dell'elettronica (ASIC) + Trigger per i gamma col gruppo di Barcellona (E. Ghose)
- Supporto e partecipazione ai Beam-test al CERN (PS e SPS, autunno '23) per:
  - ottimizzazione del design del PSD (Plastic Scintillator Detector)
  - studio performances dei vari sub-detectors, in particolare del PSD
- Analisi dei dati dei Beam-test relativi al PSD

# DAMPE mission



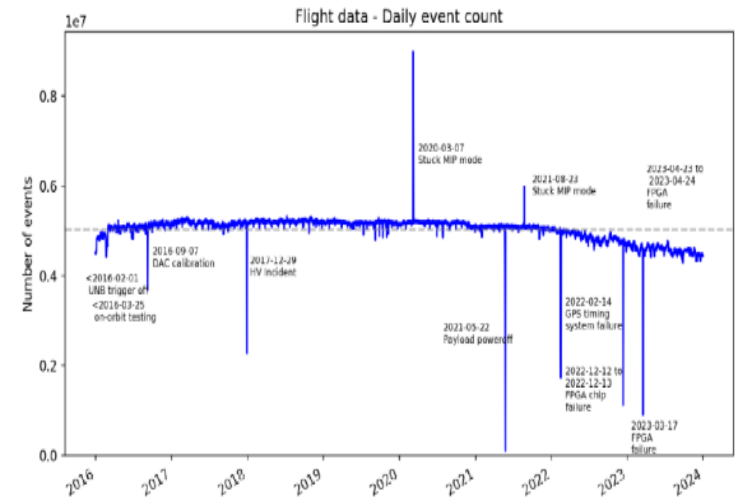
Jian Satellite Launch Center  
December 17th, 2015



**ALTITUDE: 500 km**  
**PERIOD: 95 minutes**  
**ORBIT: Sun-synchronous**  
**FULL SKY SCAN: two/year**

The Lecce group mainly involved in data analysis for the flux measurement of Cosmic Ray components

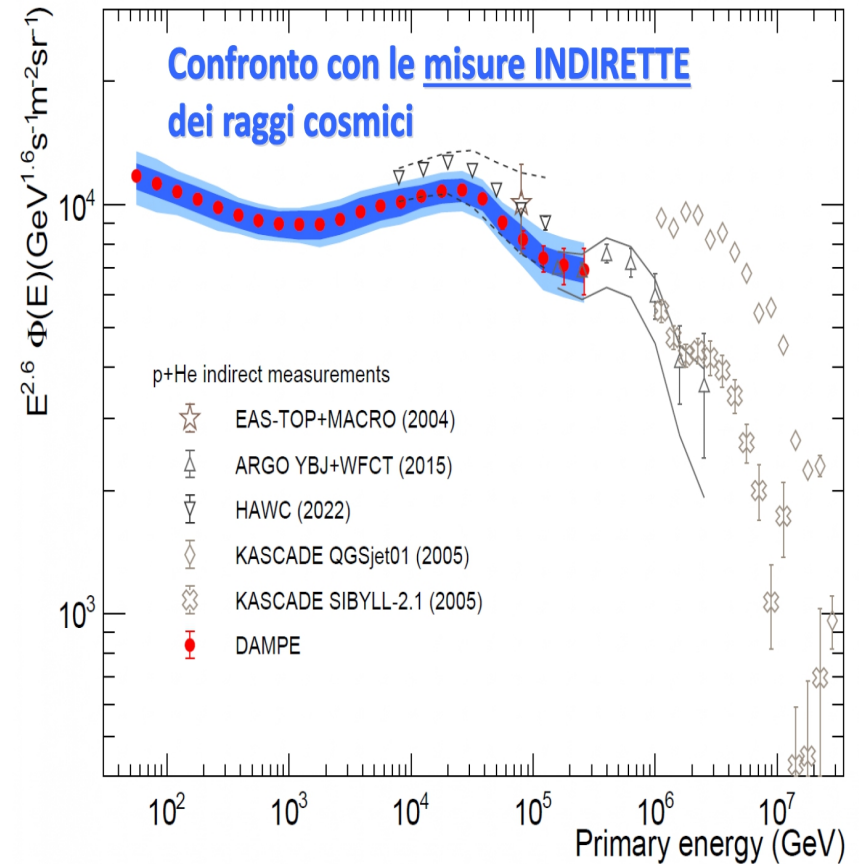
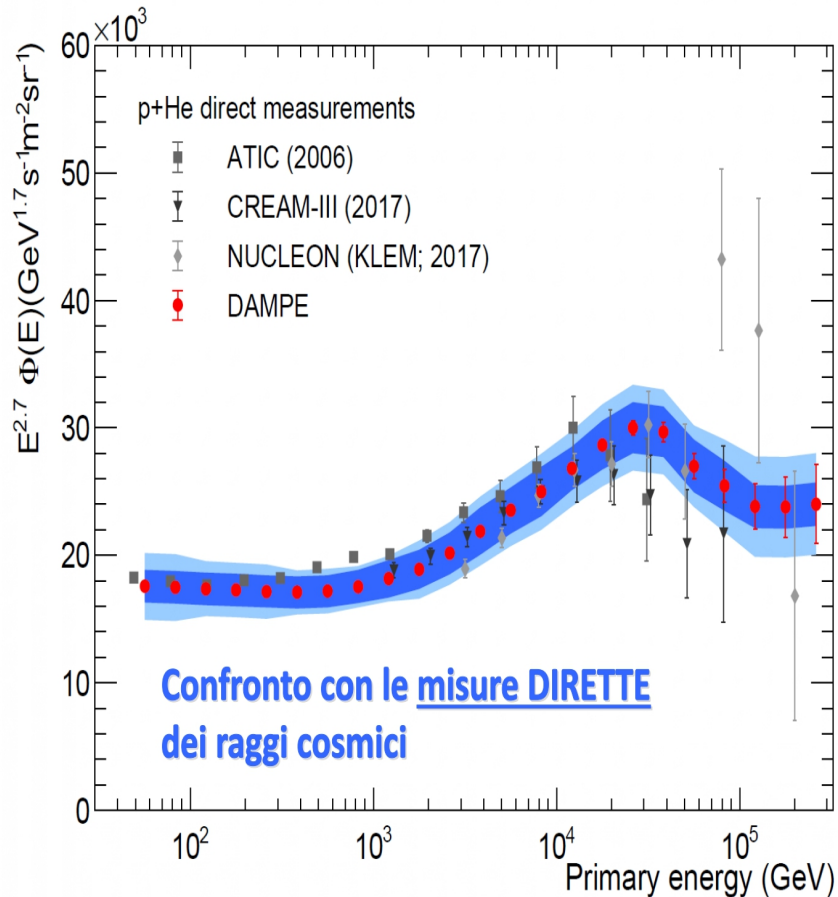
## FLIGHT DATA



> 8 years of smooth Data-taking in Flight

# DAMPE: Combined spectrum p+He

- Presented at ICRC-2023 (Nagoya, Japan) and several Conferences ...
- SIF-2023: Talk selected as one of the best -> Published on Nuovo Cimento (F. Alemanno)



**Spectrum softening feature in agreement with that observed in the separate p and He spectra**

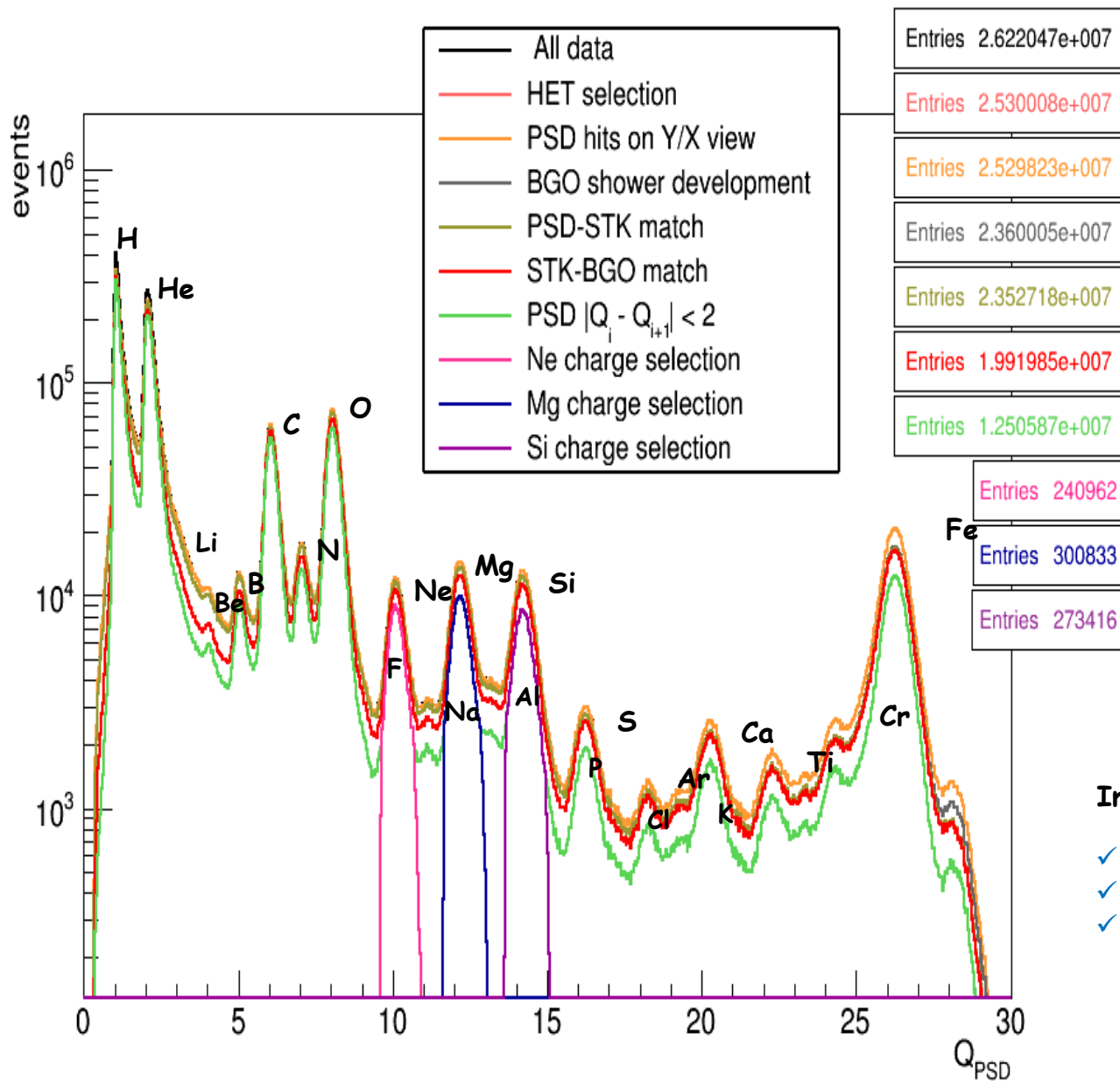
**Energy range bridging to indirect measurements**

## Measurement of the cosmic $p + \text{He}$ energy spectrum from 50 GeV to 0.5 PeV with the DAMPE space mission

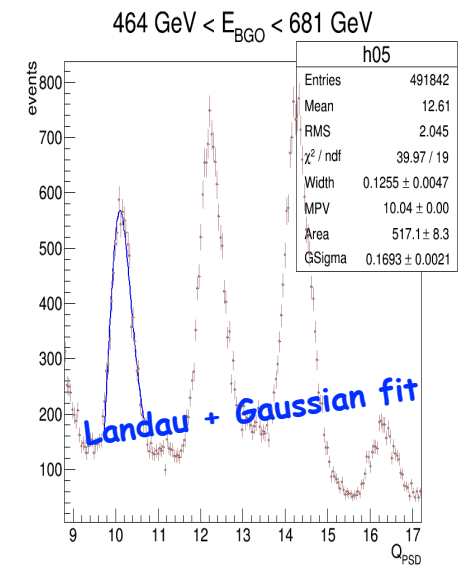
F. Alemanno,<sup>1,2,†</sup> C. Altomare,<sup>3</sup> Q. An,<sup>4,5</sup> P. Azzarello,<sup>6</sup> F. C. T. Barbatto,<sup>1,2</sup> P. Bernardini,<sup>7,8</sup> X. J. Bi,<sup>9,10</sup> I. Cagnoli,<sup>1,2</sup>  
M. S. Cai,<sup>11,12</sup> E. Casilli,<sup>7,8</sup> E. Catanzani,<sup>13</sup> J. Chang,<sup>11,12</sup> D. Y. Chen,<sup>11</sup> J. L. Chen,<sup>14</sup> Z. F. Chen,<sup>11,12</sup> P. Coppin,<sup>6</sup>  
M. Y. Cui,<sup>11</sup> T. S. Cui,<sup>15</sup> Y. X. Cui,<sup>11,12</sup> H. T. Dai,<sup>4,5</sup> A. De Benedittis,<sup>7,8,‡</sup> I. De Mitri<sup>Ⓞ</sup>,<sup>1,2</sup> F. de Palma,<sup>7,8</sup> M. Deliyergiyev,<sup>6</sup>  
A. Di Giovanni,<sup>1,2</sup> M. Di Santo,<sup>1,2</sup> Q. Ding,<sup>11,12</sup> T. K. Dong,<sup>11</sup> Z. X. Dong,<sup>15</sup> G. Donvito,<sup>3</sup> D. Droz,<sup>6</sup>  
J. L. Duan,<sup>14</sup> K. K. Duan,<sup>11</sup> R. R. Fan,<sup>9</sup> Y. Z. Fan,<sup>11,12</sup> F. Fang,<sup>14</sup> K. Fang,<sup>9</sup> C. Q. Feng,<sup>4,5</sup> L. Feng,<sup>11</sup>  
M. Fernandez Alonso,<sup>1,2</sup> J. M. Frieden,<sup>6,8</sup> P. Fusco,<sup>3,16</sup> M. Gao,<sup>9</sup> F. Gargano,<sup>3</sup> K. Gong,<sup>9</sup> Y. Z. Gong,<sup>11</sup> D. Y. Guo,<sup>9</sup>  
J. H. Guo,<sup>11,12</sup> S. X. Han,<sup>15</sup> Y. M. Hu,<sup>11</sup> G. S. Huang,<sup>4,5</sup> X. Y. Huang,<sup>11,12</sup> Y. Y. Huang,<sup>11</sup> M. Ionica,<sup>13</sup> L. Y. Jiang,<sup>11</sup>  
Y. Z. Jiang,<sup>13</sup> W. Jiang,<sup>11</sup> J. Kong,<sup>14</sup> A. Kotenko,<sup>6</sup> D. Kyratzis,<sup>1,2,||</sup> S. J. Lei,<sup>11</sup> W. H. Li,<sup>11,12</sup> W. L. Li,<sup>15</sup> X. Li,<sup>11</sup> X. Q. Li,<sup>15</sup>  
Y. M. Liang,<sup>15</sup> C. M. Liu,<sup>4,5</sup> H. Liu,<sup>11</sup> J. Liu,<sup>14</sup> S. B. Liu,<sup>4,5</sup> Y. Liu,<sup>11</sup> F. Loparco,<sup>3,16</sup> C. N. Luo,<sup>11,12</sup> M. Ma,<sup>15</sup>  
P. X. Ma,<sup>11</sup> T. Ma,<sup>11</sup> X. Y. Ma,<sup>15</sup> G. Marsella,<sup>7,8,¶</sup> M. N. Mazziotta,<sup>3</sup> D. Mo,<sup>14</sup> M. Muoz Salinas,<sup>6</sup> X. Y. Niu,<sup>14</sup> X. Pan,<sup>11,12</sup>  
A. Parenti,<sup>1,2</sup> W. X. Peng,<sup>9</sup> X. Y. Peng,<sup>11</sup> C. Perrina,<sup>6,8</sup> E. Putti-Garcia,<sup>6</sup> R. Qiao,<sup>9</sup> J. N. Rao,<sup>15</sup> A. Ruina,<sup>6</sup>  
Z. Shangguan,<sup>15</sup> W. H. Shen,<sup>15</sup> Z. Q. Shen,<sup>11</sup> Z. T. Shen,<sup>4,5</sup> L. Silveri,<sup>1,2</sup> J. X. Song,<sup>15</sup> M. Stolpovskiy,<sup>6</sup> H. Su,<sup>14</sup> M. Su,<sup>17</sup>  
H. R. Sun,<sup>4,5</sup> Z. Y. Sun,<sup>14</sup> A. Surdo,<sup>8</sup> X. J. Teng,<sup>15</sup> A. Tykhonov,<sup>6</sup> J. Z. Wang,<sup>9</sup> L. G. Wang,<sup>15</sup> S. Wang,<sup>11</sup> S. X. Wang,<sup>11</sup>  
X. L. Wang,<sup>4,5</sup> Y. Wang,<sup>4,5</sup> Y. F. Wang,<sup>4,5</sup> Y. Z. Wang,<sup>11</sup> Z. M. Wang,<sup>1,2,††</sup> D. M. Wei,<sup>11,12</sup> J. J. Wei,<sup>11</sup> Y. F. Wei,<sup>4,5</sup>  
D. Wu,<sup>9</sup> J. Wu,<sup>11,12</sup> L. B. Wu,<sup>1,2,‡‡</sup> S. S. Wu,<sup>15</sup> X. Wu,<sup>6</sup> Z. Q. Xia,<sup>11</sup> H. T. Xu,<sup>15</sup> J. Xu,<sup>11</sup> Z. H. Xu,<sup>11,12</sup> Z. L. Xu,<sup>11</sup>  
E. H. Xu,<sup>4,5</sup> Z. Z. Xu,<sup>4,5</sup> G. F. Xue,<sup>15</sup> H. B. Yang,<sup>14</sup> P. Yang,<sup>14</sup> Y. Q. Yang,<sup>14</sup> H. J. Yao,<sup>14</sup> Y. H. Yu,<sup>14</sup> G. W. Yuan,<sup>11,12</sup>  
Q. Yuan,<sup>11,12</sup> C. Yue,<sup>11</sup> J. J. Zang,<sup>11,|||</sup> S. X. Zhang,<sup>14</sup> W. Z. Zhang,<sup>15</sup> Yan Zhang,<sup>11</sup> Yi Zhang,<sup>11,12</sup> Y. J. Zhang,<sup>14</sup>  
Y. L. Zhang,<sup>4,5</sup> Y. P. Zhang,<sup>14</sup> Y. Q. Zhang,<sup>11</sup> Z. Zhang,<sup>11</sup> Z. Y. Zhang,<sup>4,5</sup> C. Zhao,<sup>4,5</sup> H. Y. Zhao,<sup>14</sup> X. F. Zhao,<sup>15</sup>  
C. Y. Zhou,<sup>15</sup> and Y. Zhu<sup>15</sup>

(DAMPE Collaboration)\*

# DAMPE: Ne-Mg-Si analysis (*E. Casilli*)



Charge selection performed by using **Langaus** fit to different BGO energy bins



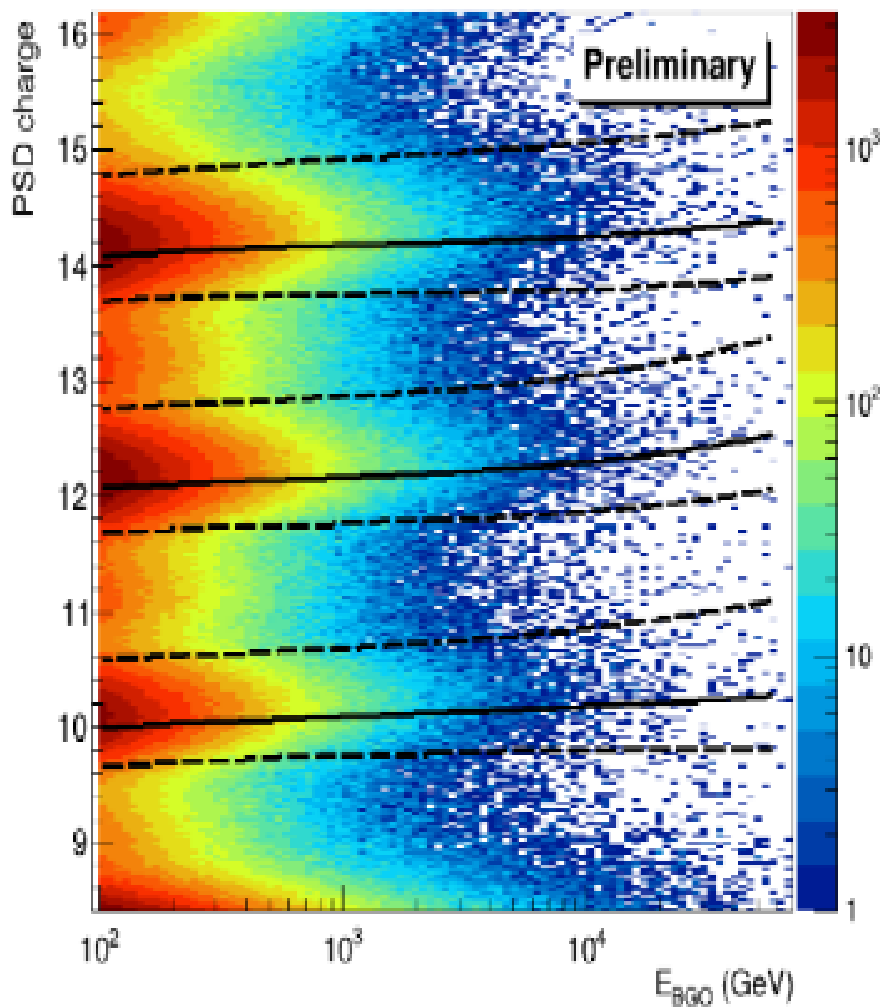
Implemented in the current analysis:

- ✓ BGO quenching effect (MC)
- ✓ BGO saturation correction (Data and MC)
- ✓ Track reconstruction with ML methods

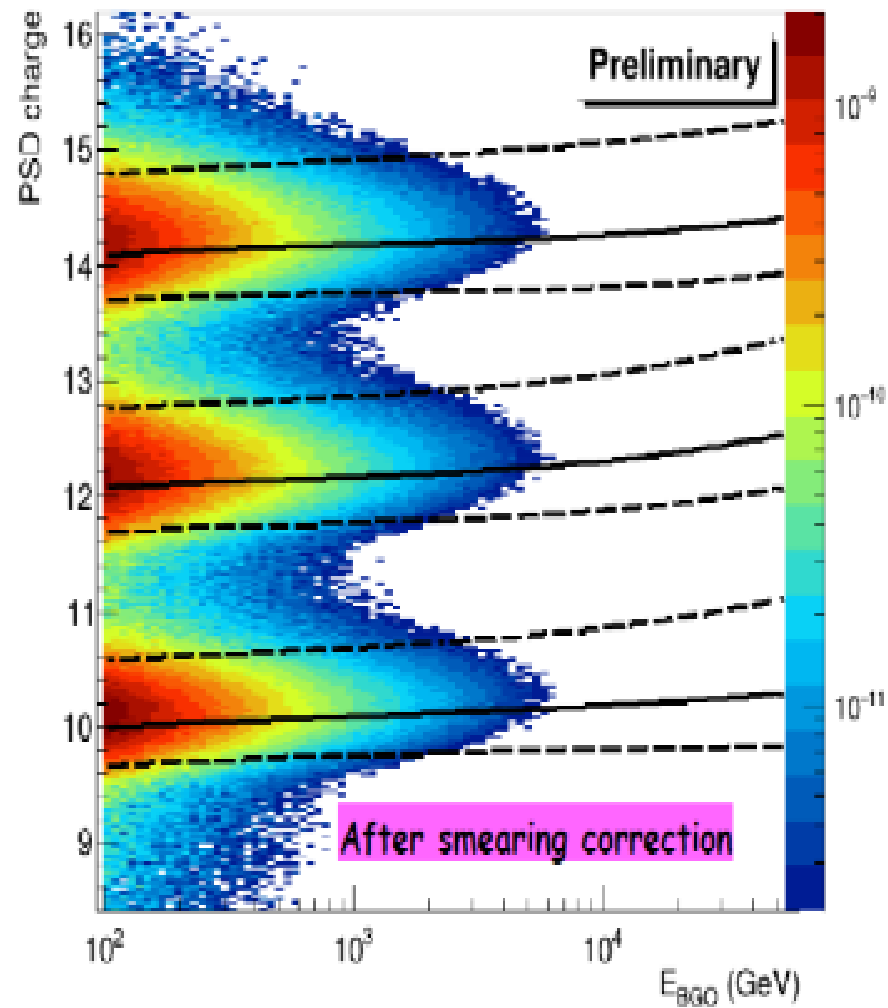


# Charge selection (Ne-Mg-Si)

FLIGHT DATA



MC DATA

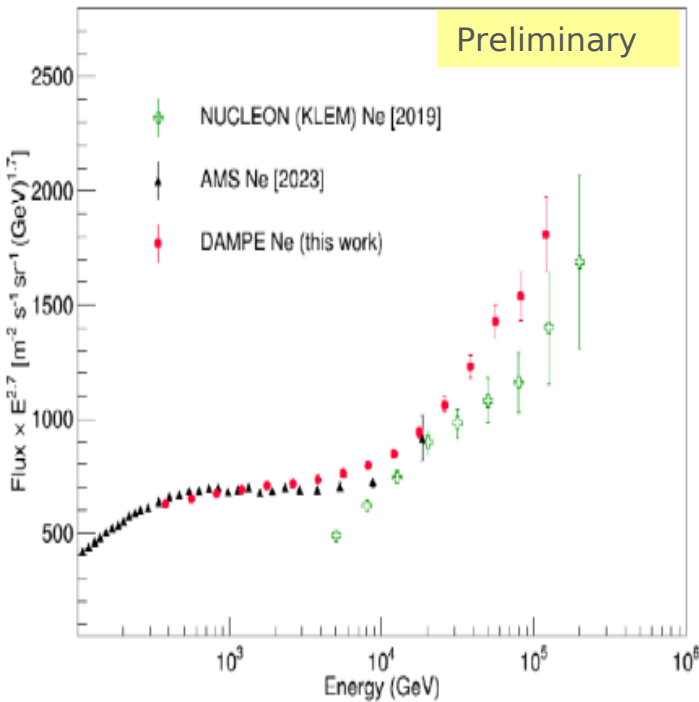


Charge selection:  $MPV - 1.8 \sigma < PSD \text{ charge} < MPV + 3.2 \sigma$       $\sigma_{TOT} = \sqrt{\sigma_L^2 + \sigma_G^2}$

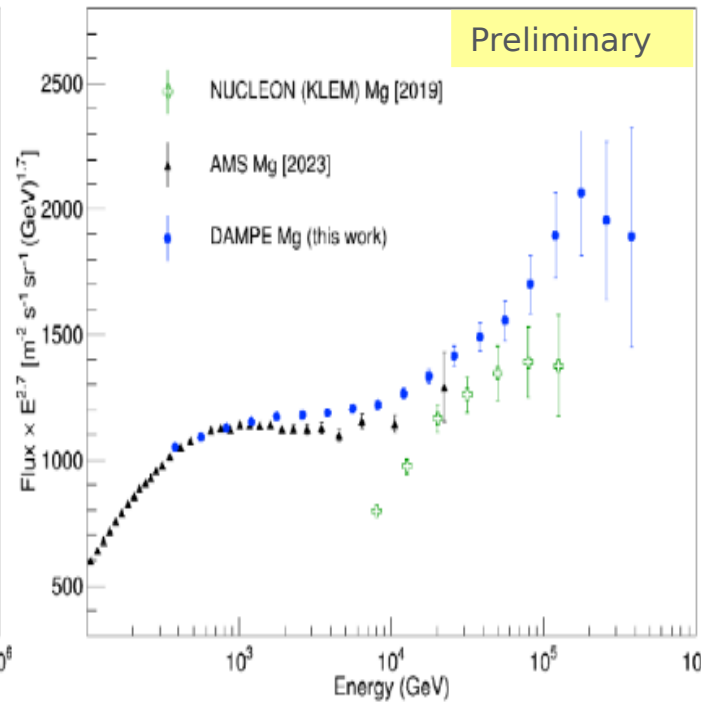
# Preliminary fluxes up to 100/500 TeV

Neon

A=20

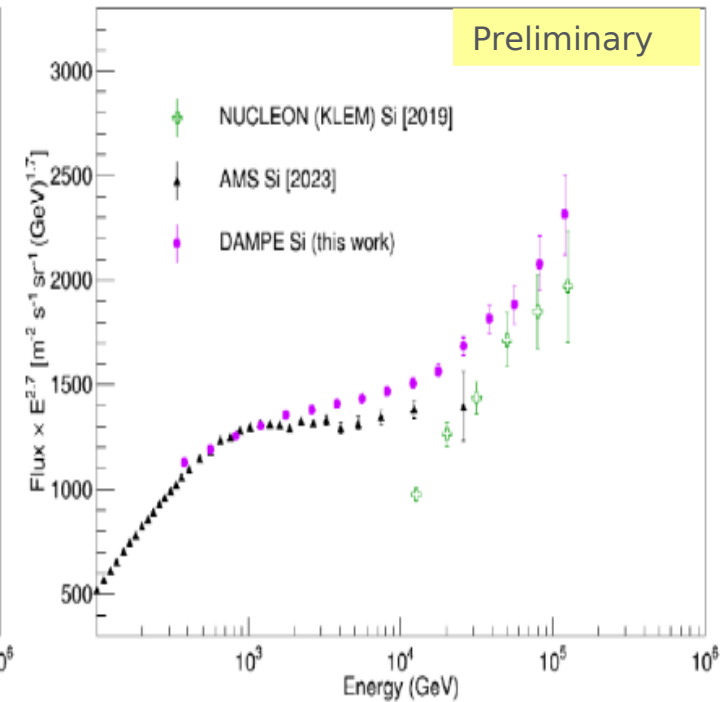


Magnesium A=24



Silicon

A=26



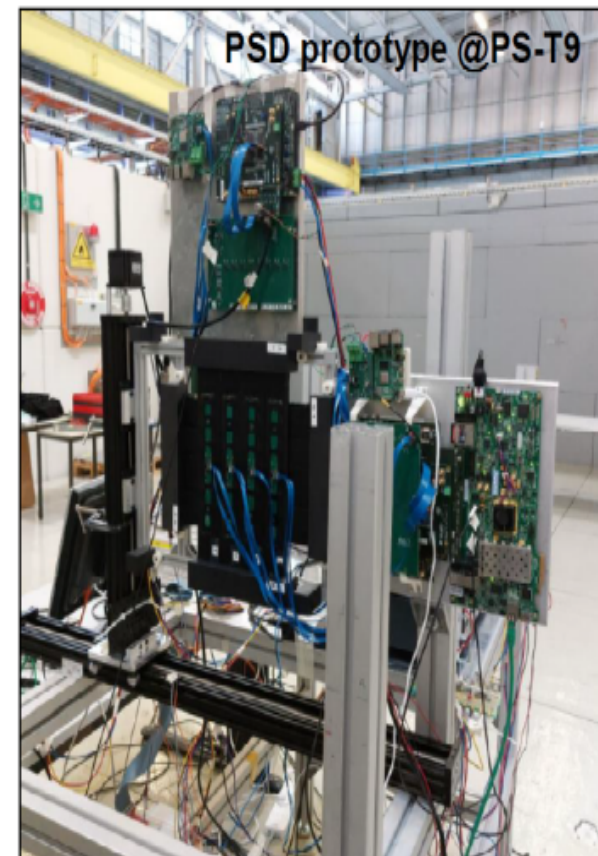
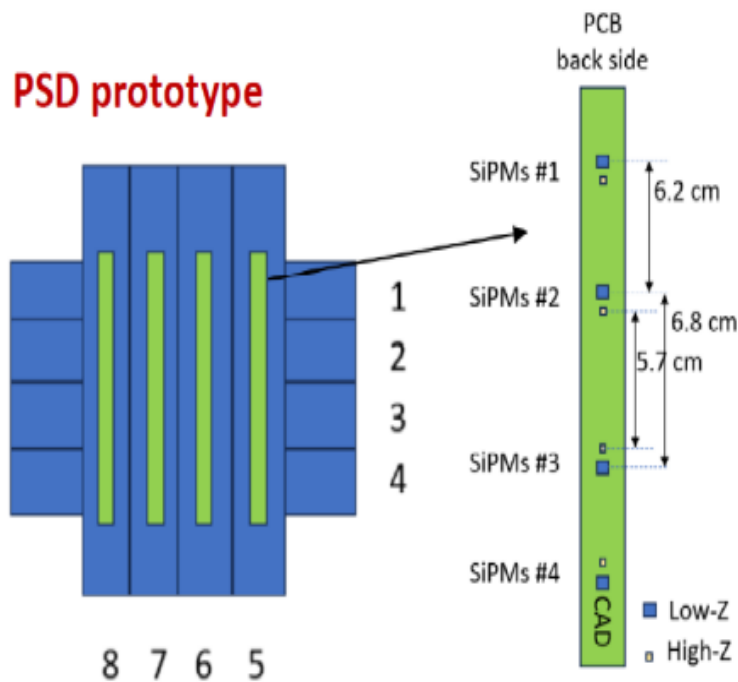
- Evidence of hardening above  $\sim 2\text{-}3$  TeV (in agreement with AMS estimate of  $\sim 200$  GV).
- Hint of the softening above 100 TeV for Magnesium.
- Evaluation of Systematic uncertainties in progress (HET Efficiency, Charge Efficiency, Contaminations, Hadronic model, ..)

*To be presented in several Conferences (SIF, ECRS-2024)*

# HERD activities

- Event Simulation with *HERDSoftware* for detector design and PSD optimization
- Contribution to the development of PSD, whose main goal is to implement the trigger for gamma-rays
- Tests/validation of Trigger electronics for gamma rays with Barcellona group (E. Ghose)
- Participation to the Beam-test campaign at CERN for testing the detector prototypes

## 2023 Beam-test @ CERN



# Attività per il 2024-2025

## DAMPE

- Continuazione analisi dati di volo sul flusso dei Raggi Cosmici
- Coordinamento, shift e monitor della produzione MC per le analisi

## HERD

### Stato attuale

- Finanziamento ASI per 1 anno (2025)
- Partecipazione di Istituzioni italiane solo su Software e (futura) analisi-dati (tre sezioni INFN per ora coinvolte)

### Attività prevista per il 2025

- Supporto al completamento di una faccia 1:1 del detector e alla successiva campagna di Beam-test al CERN nel corso del 2025
- Simulazione eventi con *HERDSoftware* per design e ottimizzazione geometria del PSD (accettanza, ermeticità, rejection del back-splash, ..) (E. Ghose)
- Test dell'elettronica (ASIC) + Trigger per i gamma col gruppo di Barcellona (E. Ghose)

## Richieste finanziarie 2025 (preliminari)

### Missioni

- MEETING: 1 meeting di Collaborazione DAMPE in Italia (3 pp x 3 gg) s.j. 2.5 k€
- MEETING: 1 meeting di Collaborazione DAMPE in EU (3 pp x 5 gg) 3.5 k€
- MEETING: 1 meeting di Collaborazione DAMPE in Cina (2 pp x 5 gg). (Sj all'effettiva organizzazione del meeting). 4.0 k€
- TURNI: Beam-Test al CERN su HERD-PSD (2pp x 10 gg). (Sj all'assegnazione di fascio) 4.0 k€

Nome	Ruolo	%
Alemanno Francesca	Assegnista	20
Bernardini Paolo	Prof Ordinario	0
Casilli Elisabetta	Dottoranda - Dott. Unisalento	100
de Palma Francesco	Prof Associato	40
Ghose Essna	Dottoranda - Dott. Nazionale	100
Surdo Antonio	Primo ricercatore - INFN	40
<b>TOTALE FTE</b>		<b>3.0</b>

### Servizi:

1 mese/persona Elettronica

**+ 20% Pietro Creti**

# NUSES-Terzina & PBR mission

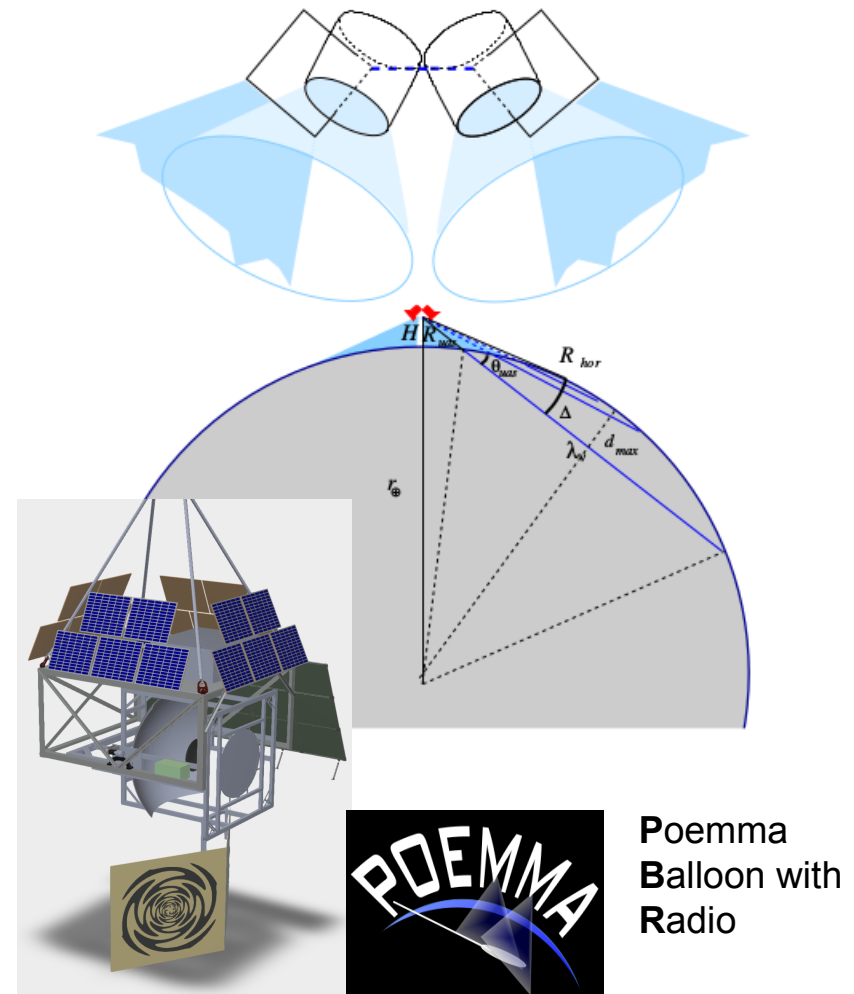
→ INFN + ASI agreement

Goals: observing Astroparticles from Sub-Orbital and Orbital Space

- first observation of high energy cosmic ray showers from space through **Fluorescence & Cherenkov signals**
- certify HE neutrino detection feasibility through Cherenkov emission in the Earth skimming geometry

Looking at the atmosphere limb (just above) for CR detection and (just below) for neutrinos detection

**Viviana Scherini (responsabile) 20%**  
**Lorenzo Perrone 20%**



# CORSIKA simulation productions @ Lecce

## Test set

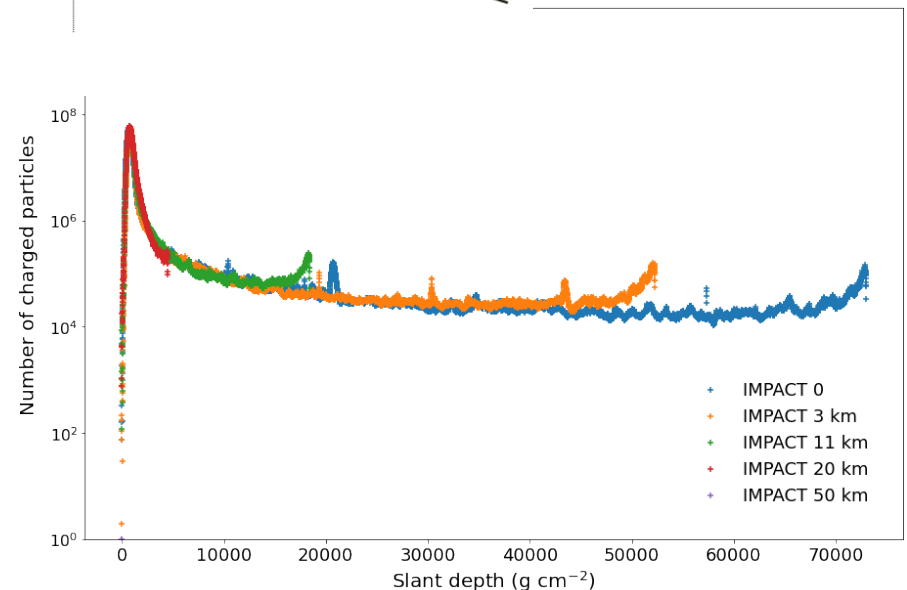
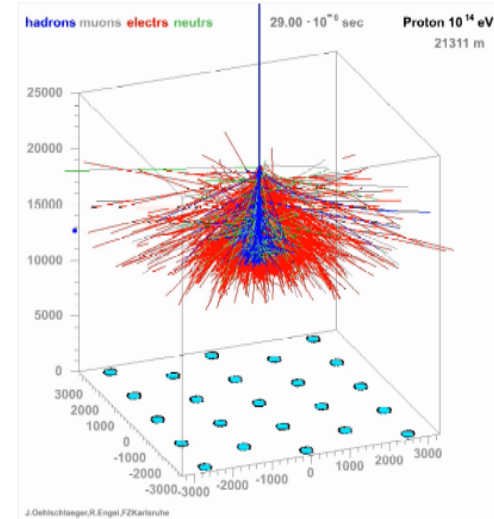
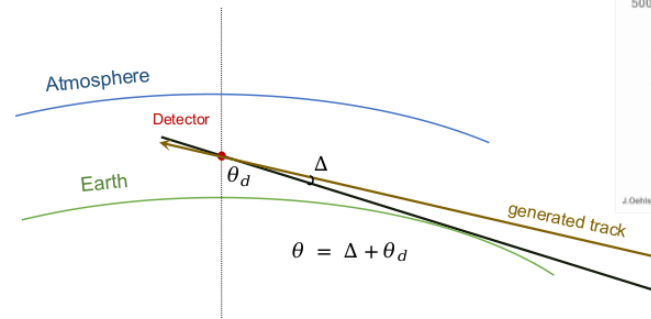
- fixed energy  $10^{17}$ , zenith angle  $79^\circ - 89^\circ$   
100 showers per bin ( $1^\circ$  steps)
- different primaries P – Fe – O

## Energy dependence set

- energy bins  $\lg(E/eV)$  15 – 20  
100 showers per bin (0.5 in log steps)
- fixed angle  $89^\circ$ , Proton

## Impact parameter option set ~15000 sh/prim

- Corsika v 77500 with Fluka 2021-2
- P – He – Fe
- energy spectrum  $E^{-1} \log(E/eV)$  [15.5,20],  
different impact parameter (horizontal shower)
- impact parameter [0, 1.5, 2.2, 3.2, 4.8, 7.1,  
10.5, 22.9, 33.8, 50 ] km



# NUSES & PBR @ Lecce

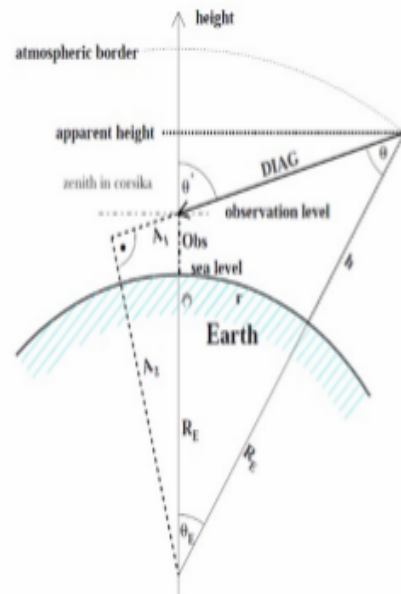
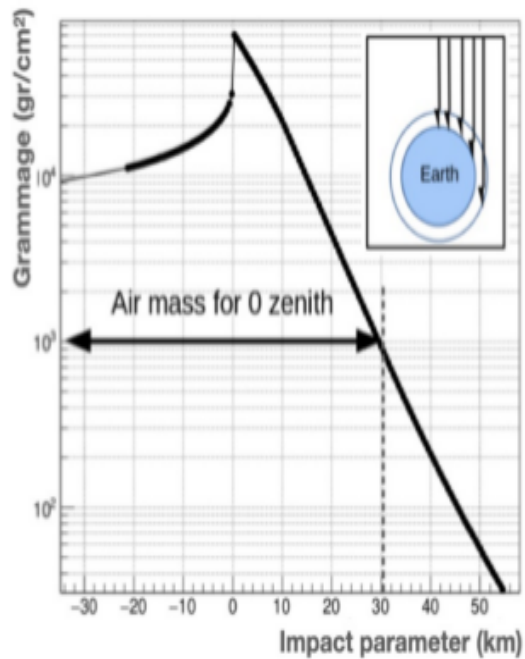
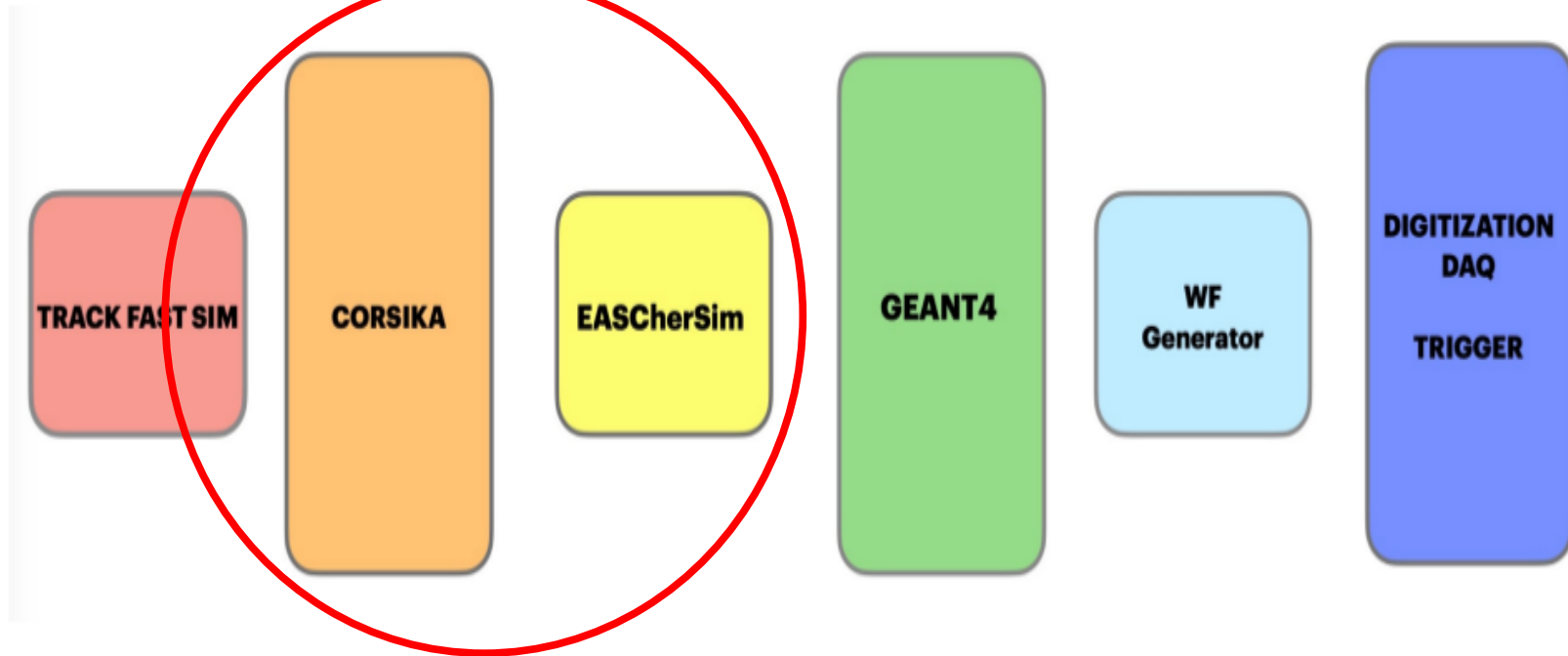
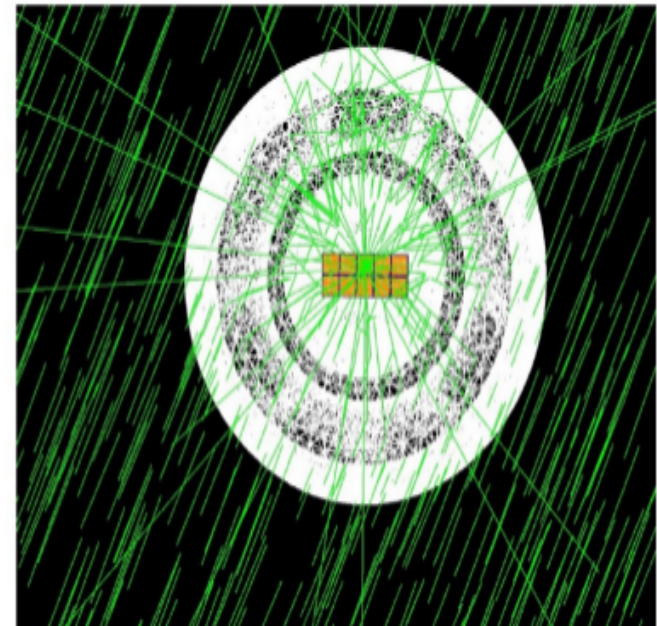


Figure 5: Downward movement in curved geometry.





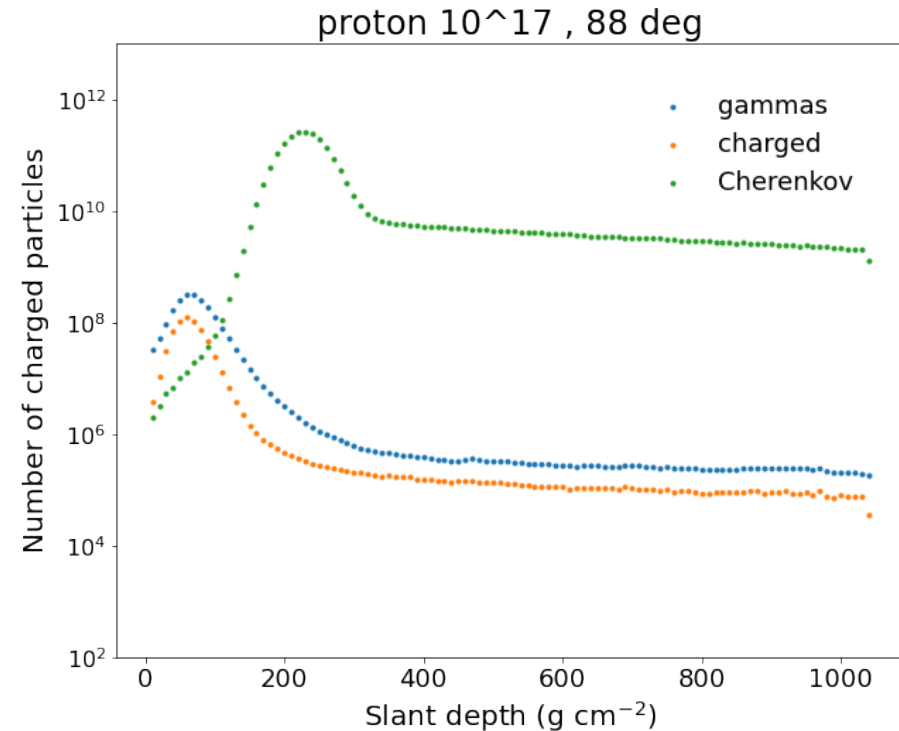
# Next productions

## Next productions in the pipeline

- testZ            energy bins, zenith downgoing 79-89°  
                      specific for balloon observation level
- testCH            CORSIKA compiled with Cherenkov  
                      option for comparison with EasCherSim  
                      photon signal

## First test of Cherenkov option

- longitudinal files produced
- work needed on the CORSIKA binaries  
for comparison of estimated signal with  
realistic 3d distribution





# EUCLID

## Lecce

### Status and present results. The future.

---

**Main Activity 2024 as Lead of Euclid SSO-SWG and as members of Euclid Transient-SWG, SL-SWG, and LU-SWG**

**•Calibration Phase: Phase Diversity Campaign**

- Developing codes for the detection of SSOs to be run at the EUCLID SOC in ESA/ESAC (Madrid, Spain) and *INFN* dedicated server.
- Simulations for LU-SWG
- Classification SOM to be applied on Strong lenses classification
- Our calibration software used by the Transient-SWG for Supernova Detections (with success)



Team

AA. Nucita, A. Franco, F. De Paolis,  
F. Strafella S. Sacquegna, E.Orofino.

# Attività del gruppo INFN di Lecce nell'anno 2024

Il gruppo INFN di Lecce ha la leadership del gruppo di ricerca denominato SSO-SWG per la ricerca, classificazione e caratterizzazione degli **oggetti del sistema solare osservati** dal satellite Euclid.

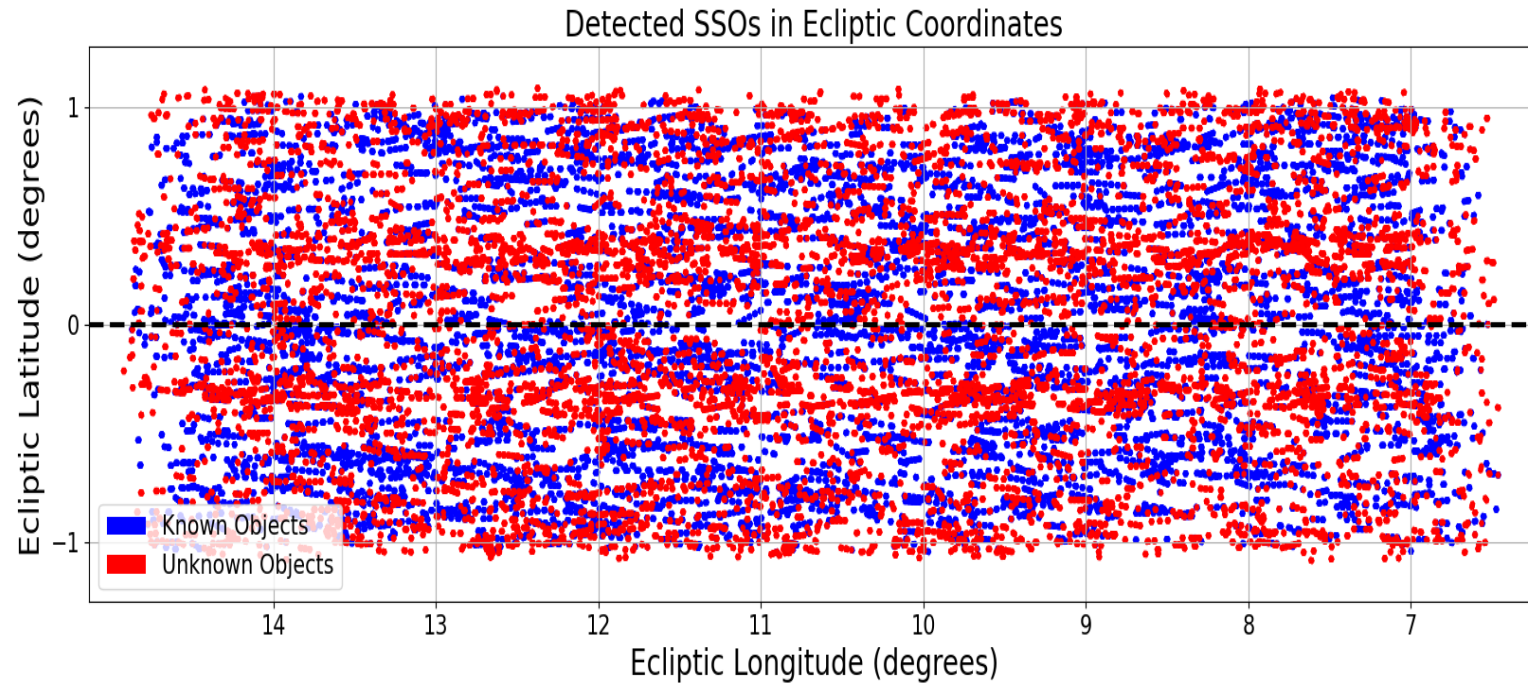
In particolare fino a Maggio 2024, il gruppo ha condotto l'analisi di un set di dati di Phase Diversity Calibration acquisiti osservando verso l'eclittica. E' stato quindi sviluppato un set di codici necessari alla calibrazione astrometrica e fotometrica delle immagini della camera VIS. In particolare, la qualità della **calibrazione astrometrica** raggiunge il valore di circa 10 mas per immagine/quadrante (con una tipica rms di 3 mas , dipendendo dal numero di oggetti di riferimento effettivamente osservati nelle immagini).

I software sviluppati hanno permesso di osservare oltre 12000 oggetti SSO dei quali circa 2000 sono nuove scoperte.

I codici sono stati anche condivisi con il gruppo INAF responsabile del Transient-SWG che, con il supporto del nostro codice, ha raggiunto la precisione astrometrica tale da permettere la scoperta di nuove supernovae (**circa 200**) nelle immagini di calibrazione Euclid/VIS. I risultati ottenuti sono stati apprezzati dal consorzio Euclid tanto da meritare 2 contributi nelle sessioni plenarie dell'ultimo Euclid Consortium Meeting.

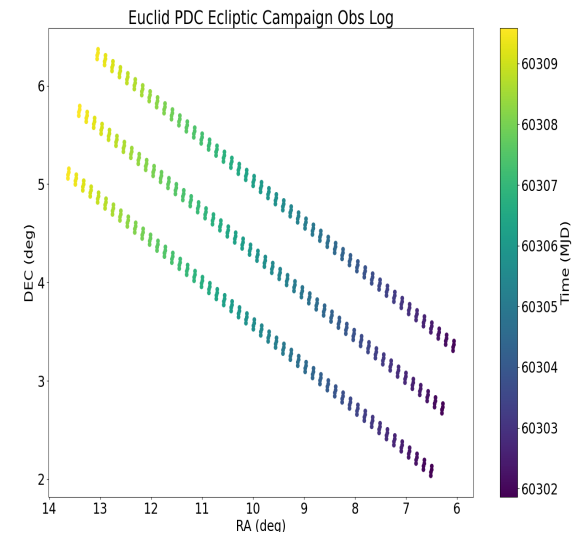
Sviluppo della libreria Kohonen-som per l'analisi non supervisionata con early stopping.

# PDC Results



**EC ENDORSEMENT FOR USING PDC data**  
**ANALYSIS on a dedicated INFN (LECCE, ITALY)**  
**2 PhD students full time (M. Pontinen, S.Sacquegna)**  
**1 Fellow (A. Franco)**

**43 179** detected SSO streaks  
23 048 (53.4%) matched to 2334 known SSOs: ~10 streaks per SSO  
20 131 (46.6%) streaks from unknown objects: ~2000 new SSOs  
<1% false-positive rate



## **Attività prevista per il 2025**

Nel corso dell'anno 2025, il gruppo INFN di Lecce manterrà la leadership del gruppo di ricerca denominato SSO-SWG per la ricerca, classificazione e caratterizzazione degli oggetti del sistema solare osservati dal satellite Euclid. La pipeline di detezione (attualmente installata su un server INFN presso la sezione di Lecce) verrà spostata sul sistema DataLab di ESA. La migrazione è già in atto e si prevede di completarla entro Febbraio 2025.

A regime, il gruppo inizierà ad analizzare i dati della survey (per i quali ha l'endorsement all'uso da parte del Consorzio Euclid e di ESA) per la ricerca di SSO.

A partire da ottobre 2024, il gruppo di Lecce (che ha una grande expertise nell'analisi dei dati di altra energia nella banda 0.5-15 keV) sarà anche impegnato per il LU-SWG nella ricerca di correlazioni delle sorgenti X (identificate dal satellite XMM-Newton) e le galassie di bassa luminosità superficiale identificate nelle immagini Euclid ERO di Fornax e Perseo.

In collaborazione con il gruppo di ricerca Transient-SWG, inizierà la fase di calibrazione dei dati NISP per la stima delle magnitudini degli oggetti SSO nelle varie bande fotometriche di Euclid.

In collaborazione con il gruppo SL-SWG, il gruppo di Lecce applicherà un software di classificazione sviluppato per l'analisi non supervisionata dei dati per la ricerca di lenti gravitazionali forti.

		Percentuale di partecipazione
<b>De Paolis</b>	Francesco	50%
<b>Franco</b>	Antonio	100%
<b>Nucita</b>	Achille	40%
<b>Orofino</b>	Vincenzo	50%
<b>Sacquegna</b>	Simone	100%
<b>Strafella</b>	Francesco	*

Interessati a intervenire sul progetto? (Sviluppo software / Parallelizzazione)

Capitolo	Descrizione	Parziali (K-EUR)	Parziali SJ (K-EUR)	Totale/Cap (K-EUR)	Totale /Cap SJ (K-EUR)
<b>missioni</b>	3 ke per partecipazione al prossimo meeting internazionale Euclid, 1 ke per partecipazione al prossimo meeting italiano su Euclid, 2 ke per partecipazione ad una conferenza di interesse scientifico. 2 ke per fronteggiare le spese di viaggio per 1/2 membri del team dell'unità INFN di Lecce presso il SOC Euclid a Madrid	8.5	1.5		0
<b>pubblicazioni</b>	Spese di pubblicazione su una rivista di interesse astrofisico (ApJ)	1.00	0.00	1	0
<b>inventario</b>	Richiesta di 1ke per l'acquisto di un nuovo laptop per obsolescenza	1	0	1	0
<b>Totale</b>	/		0	10.5	1.5

**Si richiede l'intervento del servizio di Calcolo per 2 m/persona**

# SABRE: status of activities and future

- **Search of DM with ultra-pure NaI(Tl)**

- SABRE is an experiment for the direct detection of dark matter through the phenomenon of annual modulation. Due to the relative velocity between the Earth, which orbits the Sun with a period of one year, and the dark matter that permeates the galaxy, the latter should appear to us as a "wind" with varying speeds depending on the time of year. The SABRE experiment could measure this effect as an annual variation in the number of particles passing through the detector, which is made of scintillating sodium iodide crystals - NaI(Tl). A twin detector in the southern hemisphere (SABRE South, in Australia) will also help demonstrate the cosmic origin of this phenomenon by excluding seasonal effects, which would have an opposite modulation in the two hemispheres.
- Dark matter is extremely difficult to observe due to its low probability of interacting with matter. For this reason, SABRE, like all other direct dark matter detection experiments, must protect itself from interference by other particles, such as cosmic rays, by operating in underground laboratories. A prototype of SABRE, the SABRE Proof of Principle (PoP), has been put into operation at the Gran Sasso National Laboratories (LNGS). SABRE South, on the other hand, will be located in the Stawell gold mine in Australia, which aims to host the first underground laboratory in the southern hemisphere.

# Experiment status

**MoU:** The SABRE North and South collaborations have drafted a MoU for the SABRE experiment, submitted to INFN CSN2 in July 2023 and to the LNGS Director. This MoU has been put on hold until the TDR is also completed.

**TDR for SABRE North presented at CSN2 INFN- june 2024.**

ATTIVITA' A LECCE 2025



Fig. 2 – Pictures from the operations performed in the SABRE glove box inside the CR1 Radon-free clean room in Hall C.

**WP2 - Detector modules** WP leader:

**Gabriella Cataldi (INFN Lecce).**

- Procurement of PMTs (Gabriella Cataldi)
- PMTs characterization (Gabriella Cataldi, Maria Luisa De Giorgi)
- Assembly of the detector modules (Giulia D'Imperio, Gabriella Cataldi)

**WP3 - Experimental Site & Shielding**

- executive design of the shielding (Alessandro Miccoli)
- assembly of the shielding (Giuseppe Di Carlo, Alessandro Miccoli)

**WP5 - Material Screening & Simulations**

material screening (Maria Luisa De Giorgi)



# INFN Lecce and UniSalento

**PRIN 2022 PNRR: PUNTO** (ProdUction of ultra-pure NaI detecTOrs by zone refining) -  
PI: Aldo Ianni.



**The SABRE enclosure is  
the scientific  
demonstrator of MAD**

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## HOME

**Il Progetto MAD – La metamorfosi Additiva del Design** (Cod. ARS01\_00717) – presentato in risposta all'Avviso Pubblico Prot. n. 1735 del 13/07/2017 emanato dal MIUR (Ministero dell'Istruzione, dell'Università e della Ricerca) – è finanziato dal Fondo Europeo di Sviluppo Regionale (FESR) nell'ambito del PON R&I 2014-2020 – Asse 2 – Azione II – OS 1.b) e dal FSC (Decreto di Concessione Prot. n. 1547 del 29/09/2020).

Il Soggetto Capofila del partenariato pubblico-privato è l'*Istituto Nazionale di Fisica Nucleare (INFN)*.

- Talk at ICHEP2024 (G. Cataldi)
- Poster presentation at SOUP 2024 (S.G. Khattak)

# Richieste 2025

	LECCE
<b>FTE</b>	<b>3.0</b>
Missioni	25?
Consumo	3.5?
Trasporti	1.5?
<b>TOTALE</b>	<b>30</b>

TBC

# Anagrafica 2025

Chemseddine Ananna	50 % (AR MAD)
Gabriella Cataldi (RL)	30 %
Maria Luisa De Giorgi	100 %
Sana Gul Khattak	100 % (PhD)
Alessandro Miccoli	20 %

TBC

## INFN LECCE AND UNIVERSITÀ DEL SALENTO

- Chemseddine Ananna
- Gabriella Cataldi
- Maria Luisa De Giorgi
- Sana Gul Khattak
- Alessandro Miccoli

**5 mesi-persona  
Servizio Meccanica  
5 mesi-persona  
Servizio Elettronica**

G.Cataldi

BACKUP

# Telescope focal plane

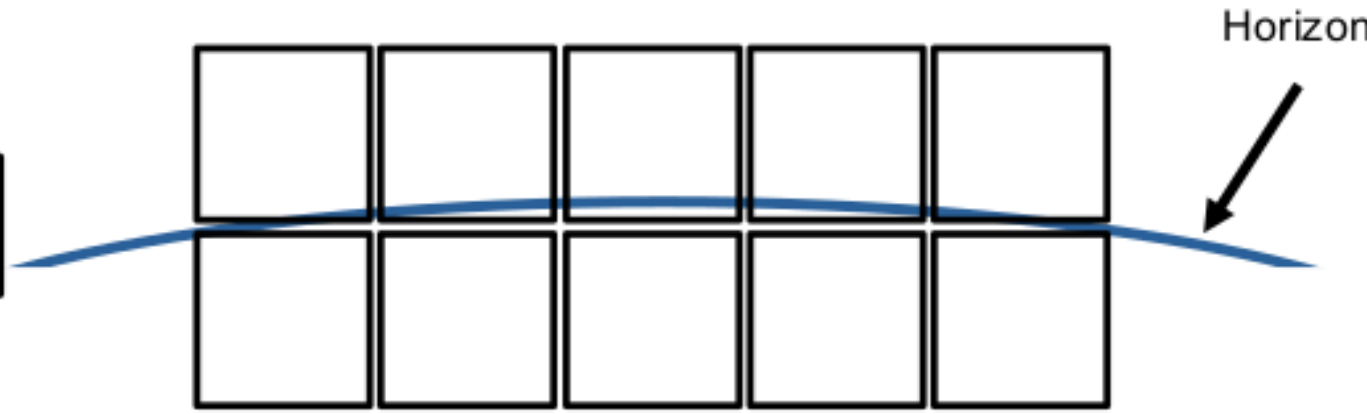
SiPM arrays: 8 x 8 channels

Pixel: 3 x 3 mm<sup>2</sup>

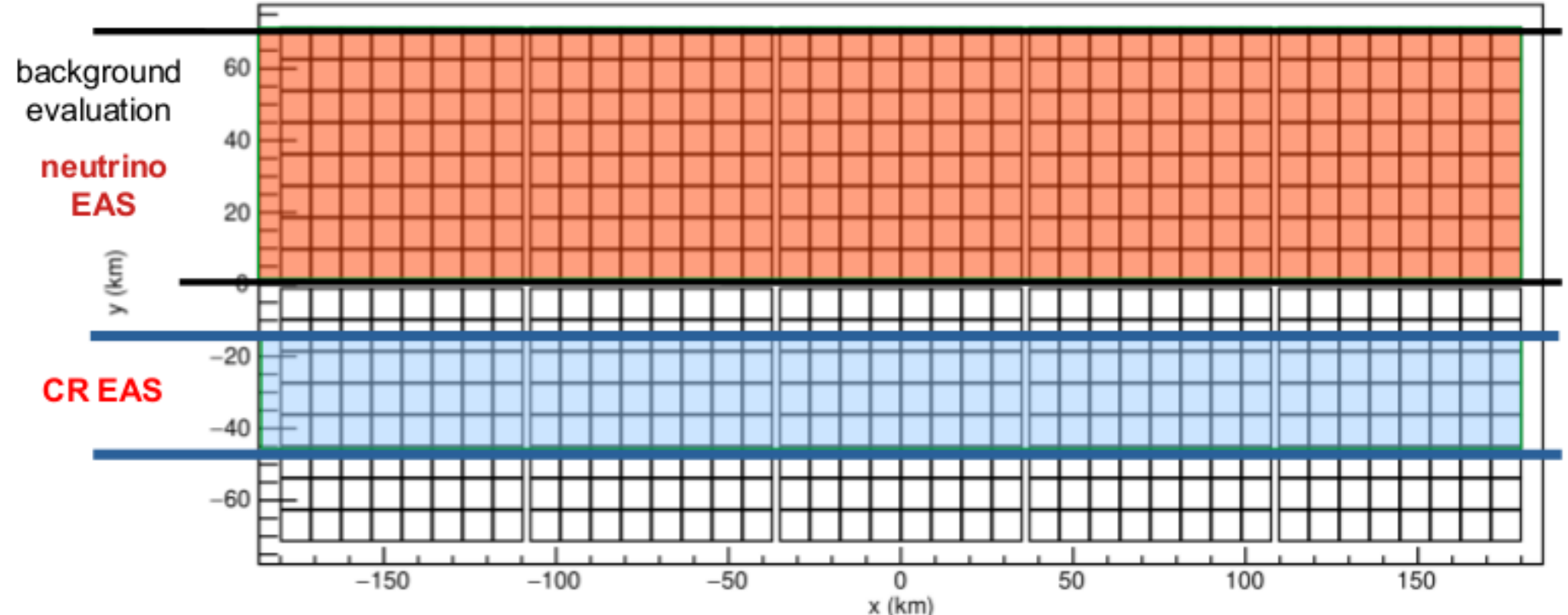
Pixel FoV:  $\text{atan}(r_{\text{pix}}/F_L) \sim 0.18^\circ$

5 x 2 = 10 SiPM arrays in total  
(8 x 8) x 10 = 640 pixels (channels)

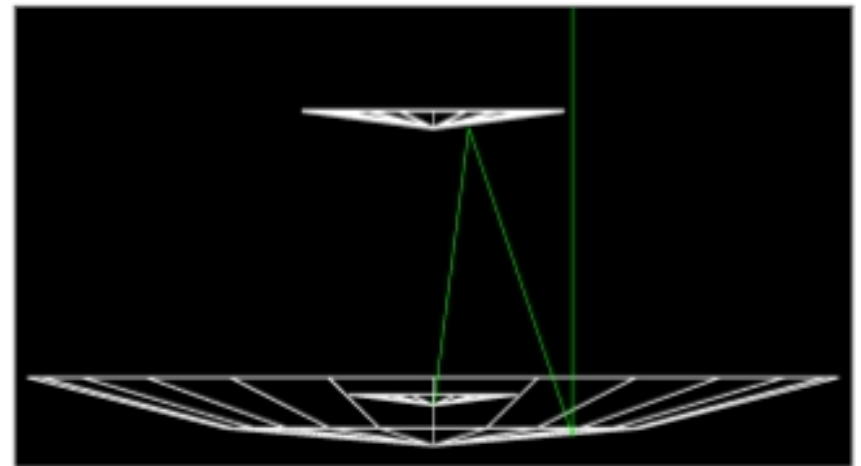
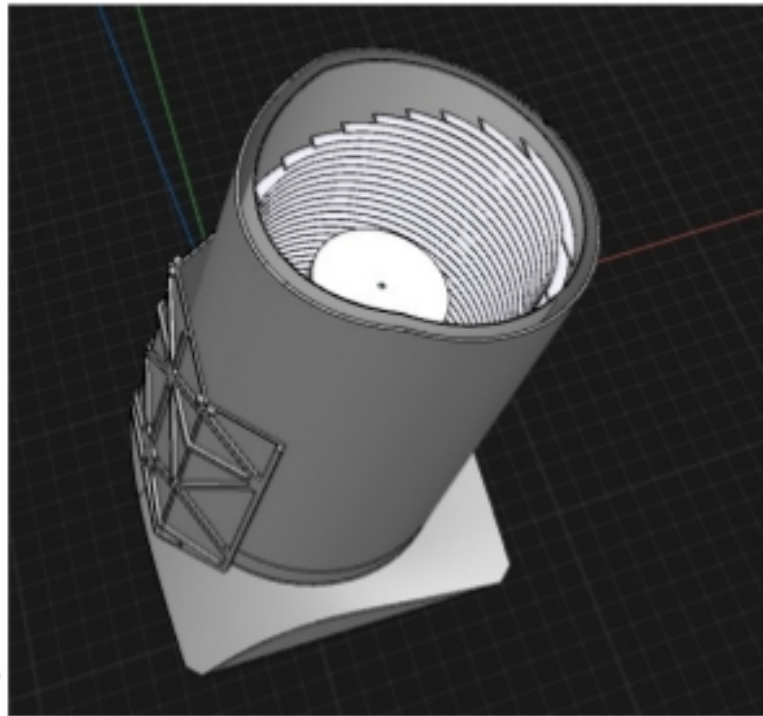
Array dim. : 25.3 x 25.3 mm<sup>2</sup>  
Array Eff. area : 24 x 24 mm<sup>2</sup>



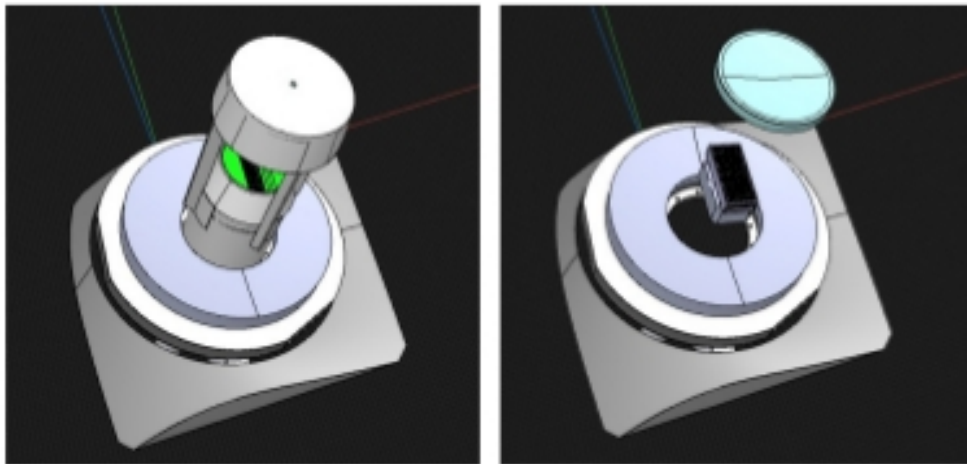
Camera plane with projection on the Earth (total area 360x140 km<sup>2</sup>)



# Terzina telescope

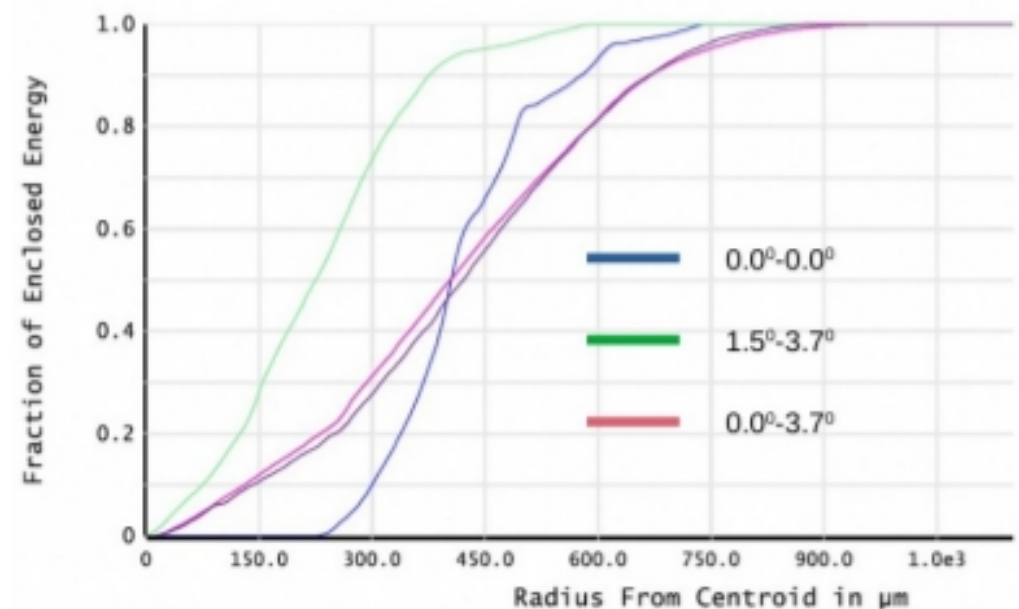


- ✓ Equivalent focal length  $F_L = 925$  mm
- ✓ Field of View (FoV) :  $7.2^\circ$
- ✓ Point spread function (PSF) :  $<1.0$  mm
- ✓ Effective area of the telescope :  $0.1$  m<sup>2</sup>
- ✓ M1 paraboloid, M2 hyperbole



Terzina total weight ~40 kg

Point spread function for different inclination angles



**2023-2024 Activity of SWG-SSO in the framework of a pilot study (with CAL field) endorsed by ESA and EC**  
**A golden recipe to solve astrometry and achieve a reasonable good level (and routinely) at quadrant level**  
**Down to  $\leq 10$  mas (depending on # references)**

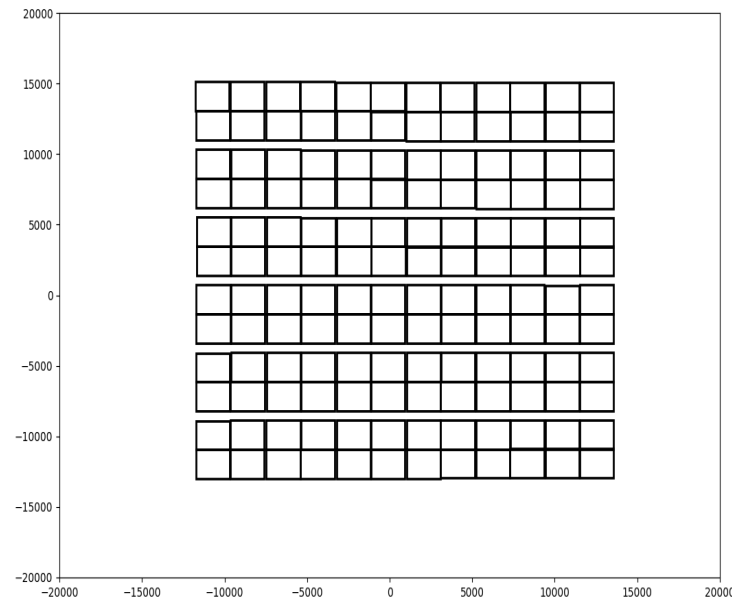
- 1) Reduction done on quadrant level (144 HDUs): bias, flat, mask, prescan/overscan. Output is a 144 HDU mosaic.
- 2) A few fundamental keywords copied from 0 header in raw data to any of the other 144 HDUs (RAOBS, DECOB, PA).  
A few other keywords generated:

CRVAL1, CRVAL2 (from RAOBS, DECOB),  
CDELTA1, CDELTA2 (from pixel size),  
CROTA2 (from PA)  
CRPIX (updated to account for cuts on  
prescan/overscan regions)

**A first guess on quadrant WCS**

$$\begin{aligned} CD1\_1 &= CDELTA1 * \cos(CROTA2) \\ CD1\_2 &= -CDELTA2 * \sin(CROTA2) \\ CD2\_1 &= CDELTA1 * \sin(CROTA2) \\ CD2\_2 &= CDELTA2 * \cos(CROTA2) \end{aligned}$$

- 3) Run a local installation of **astrometry.net**. During the call, using a set of **CRPIX1**, and **CRPIX2** values coming from an observation already astrometrically corrected (let's call this VIS Geometry Map). **C<sub>dij</sub>** values are updated by **astrometry.net**.  
**Downsampling 5.**



Output could be a feedback for further OBS ID

Using **GAIA DR3**, **UNWISE** and **PANSTAR** catalogues extracted towards (**RAOBS**, **DECOBS**) and extraction radius **R=3** degrees. When astrometry fails, **CRPIX1,2** kept from the VIS Geometry Map, **C<sub>dij</sub>** kept from the surrounding successful quadrants.  
**No-Tweak (no polynomial deformations) at this stage.**

# Main Challenges

- The SABRE (Sodium-iodide with Active Background Rejection) basic idea was proposed by Frank Calaprice in 2009. The strategy included the development of a low background NaI powder and a detector exploiting a liquid scintillator active veto to enhance the crystal's background rejection. The effort made by the SABRE group led to the **production of a low background NaI powder**, named Astro Grade, developed in collaboration with Sigma-Aldrich (currently Merck). A number of **prototype crystals** were grown in collaboration **with Radiation Monitoring Devices**, Inc. (RMD) from Astro Grade. In 2015 the SABRE detector was proposed to be deployed at LNGS to carry out an independent search for dark matter through annual modulation, based on radio-pure NaI(Tl) crystals, and with sufficient sensitivity to confirm or refute the DAMA claim.

A long R&D phase



**2,654,574** events recorded by the SD-1500 between January 1, 2004 and December 31, 2022.

$-90^\circ \leq \text{declination} \leq 45^\circ$

Energy  $\geq 1$  EeV

**SD-1500:** 12 target sets resulting in a total of **888** Galactic candidate sources with a declination up to  $45^\circ$ .



**1,455,168** events recorded by the SD-750 between August 1, 2008 and December 31, 2022.

$-90^\circ \leq \text{declination} \leq 20^\circ$

Energy  $\geq 0.1$  EeV

**SD-750:** 6 target sets resulting in a total of **166** Galactic candidate sources with a declination up to  $20^\circ$  and within a distance of 1 kpc.

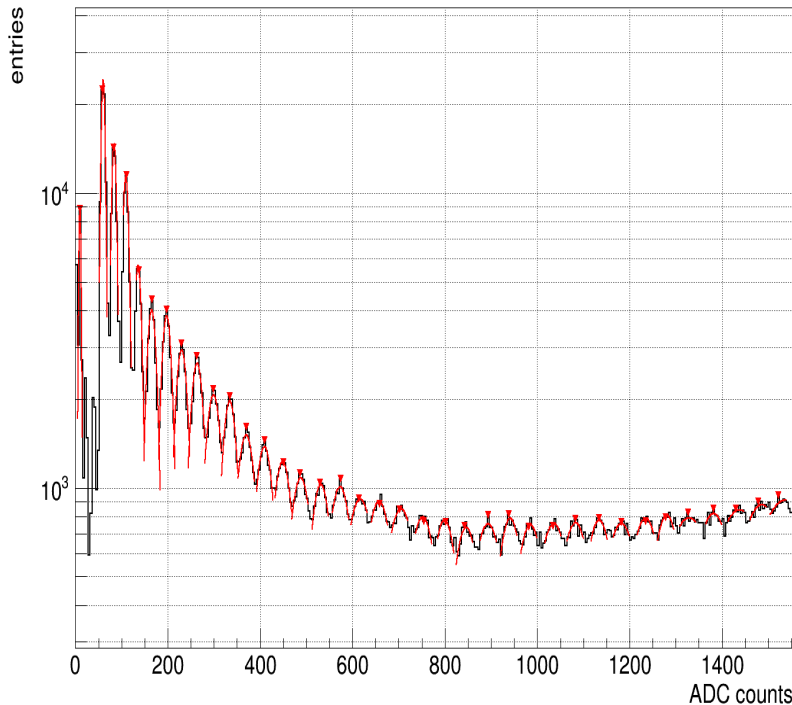


# Analysis of Beam-test data for PSD

**Beam: Pb ions of E= 330 GeV**

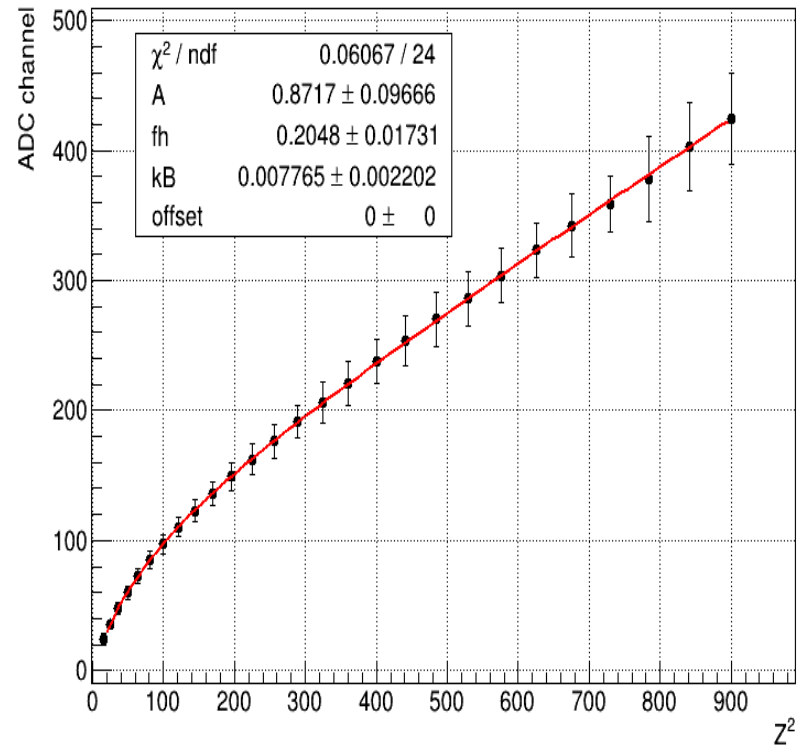
Ion fragments of  $Z < 40$  clearly identified

Tile ADC - Spill



ADC spectrum with Gaussian fits of the peaks

Birks' law fit - Tile



PSD: Correlation between signal amplitudes (ADC) and  $dE/dX \sim Z^2$  well fitted by Birks law