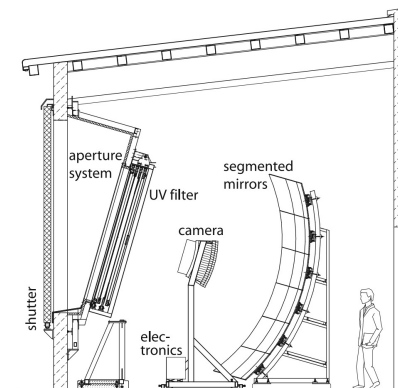


# Auger - Roma “Tor Vergata”

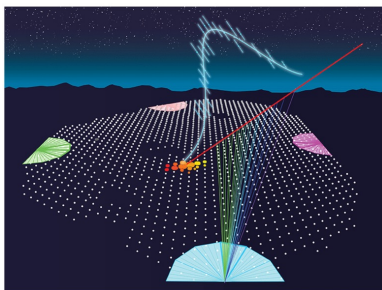
V. Verzi	Primo Ricercatore INFN	80%
G. Salina	Dirigente di Ricerca INFN	50%
G. Rodriguez Fernandez	Ricercatore INFN	20%
G. Matthiae	Prof. ordinario	0%

G. Salina leader del *Calibration Analysis task*

V. Verzi leader del *Energy Spectrum task*  
responsabile *FD camera*

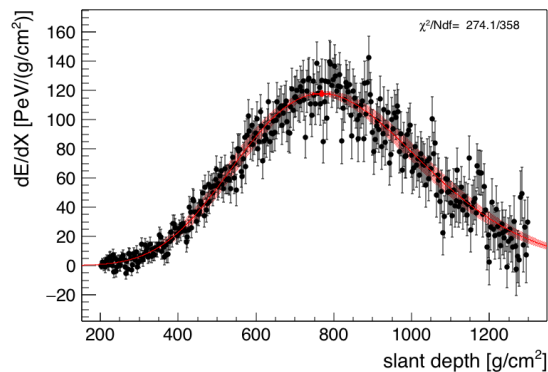


# Fit of the longitudinal profile

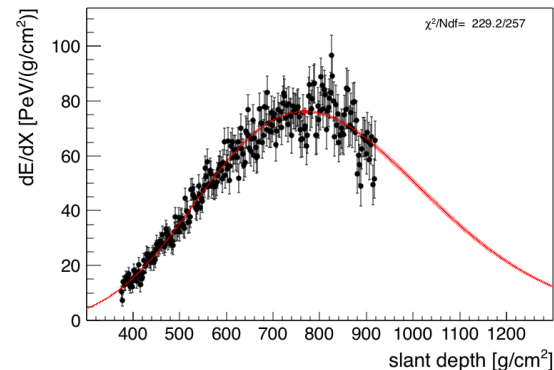


Gaisser-Hillas function

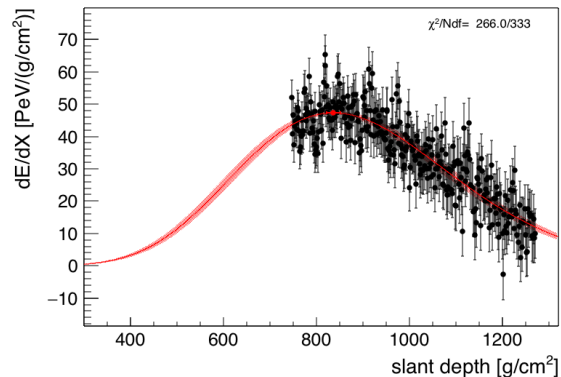
shower fully contained in the f.o.v.



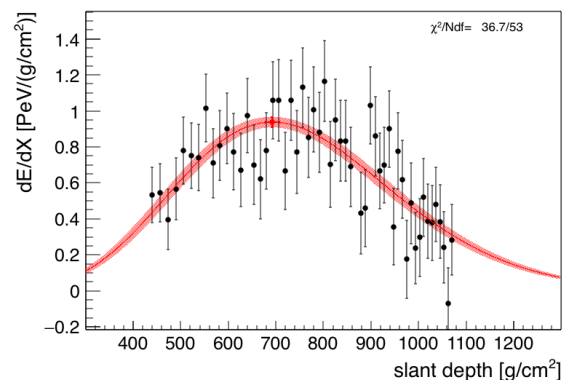
shower that stops at ground



shower close to the telescope



low energy shower



$X_{\max}$  always observed

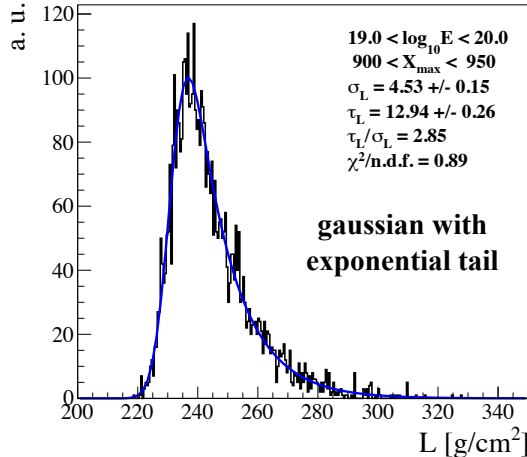
integral (=energy) needs  
an extrapolation

# Gaisser-Hillas function

$$GH\left(\frac{dE}{dX}(X_{\max}), X_{\max}, p_1, p_2\right)$$

shape parameters fitted together  
 $dE/dX|_{\max}$  and  $X_{\max}$

fit helped by constraints on  $p_i$   
 around “physical” values



width of  
the profile

## Shower Profile Fitting

José Bellido, Bruce Dawson, Lorenzo Perrone,  
 Francesco Salamida, Michael Unger and Valerio Verzi

GAP2022\_050, November 2022

Over that past year the fitting technique of the longitudinal shower profile has been subject of a long discussion. The debate concerns the constraints in the profile shape fit. These constraints are needed in order to ensure a correct extrapolation of the fit function beyond the range of observations and therefore to obtain a reliable estimation of the calorimetric energy of the showers. The matter is very technical and characterized by objectively subtle details that have generated significant confusion. In this note we explain in detail the logic followed in the Foundations task over recent years that have brought significant improvements to the profile fitting technique, and we demonstrate the soundness of the estimation of both energy and  $X_{\max}$  in the presence of the fit constraints.

### Contents

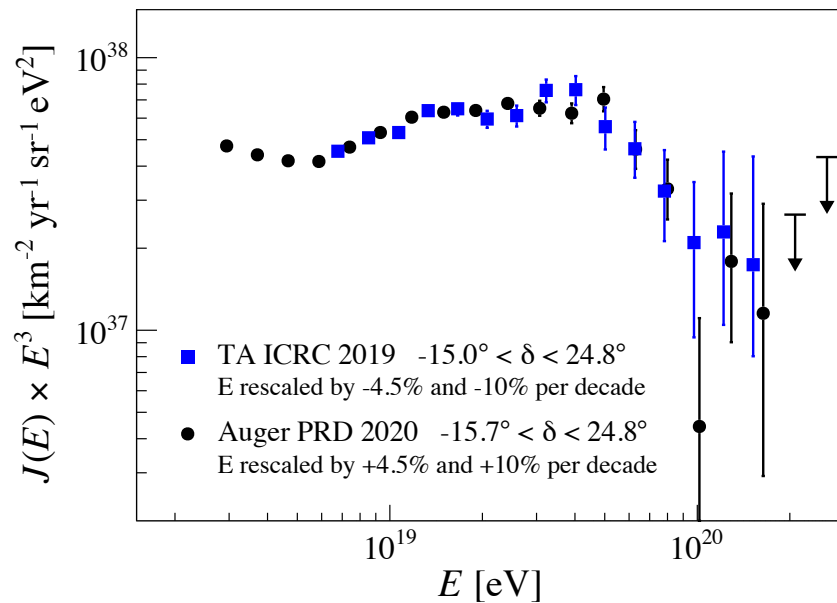
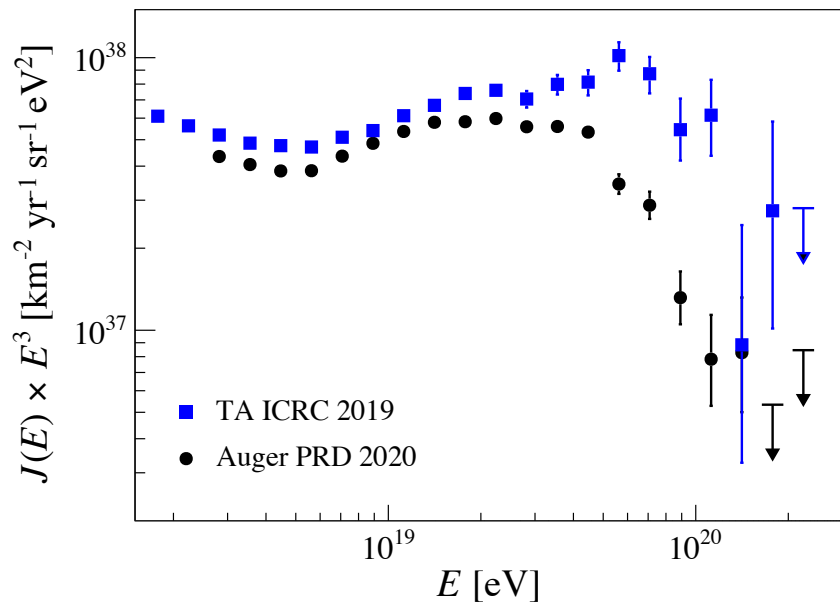
1	Introduction	2
2	The Gaisser-Hillas function - in terms of $X_0$ and $\lambda$ and in terms of $R$ and $L$	3
2.1	Correlation between $X_0$ and $\lambda$ and between $R$ and $L$	3
2.2	Properties of the shape parameters $X_0$ , $\lambda$ , $R$ and $L$	4
3	“Universality” of shower profiles	5
4	Unconstrained fits of real shower profiles	6
4.1	Correlation between the Gaisser-Hillas coefficients	8
4.2	Correlation of the Gaisser-Hillas coefficients with $X_{\max}$	8
5	Quality of real shower profiles (after quality and FoV cuts)	9
6	Definition and implementation of the constraints in the fit of the shower profile	10
6.1	Constraints for the <i>Classic</i> shower profile fit	11
6.2	Adding a constraint in the profile width to the <i>Classic</i> shower profile fit	12
6.3	Constraints for the <i>USP</i> shower profile fit	14
6.3.1	Constraints for the <i>USP</i> shower profile fit using Gaussian distributions	14
6.3.2	Improving the constraint for the $L$ parameter using an exponentially modified Gaussian distribution	16
7	Performance of the constrained fit of the shower profile	19
7.1	$E_{\text{cal}}$ and $X_{\max}$ biases	19
7.2	Resolution on $E_{\text{cal}}$ and contribution of the profile fit to the systematic uncertainty in the energy scale	23
7.3	Performance in reconstructing the shape parameters	28
7.4	Further studies of the effect on real data of the different versions of the constrained fit	31
8	Summary and discussion	33
A	Derivation of the coefficients $R$ and $L$	37
B	Fitting algorithm of the energy deposit stored in the ADSTs	37

# Auger vs TA: spectrum

V. Verzi et al. (Auger and TA)  
UHECR 2022

agreement in the common declination band after the rescaling  $\Delta E/E = 9\% + 20\% (\log_{10} E - 19)$  (?)

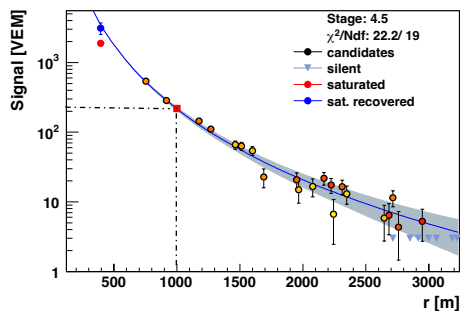
not fully understood (complicated instrumental effect related to the SD and FD reconstructions)



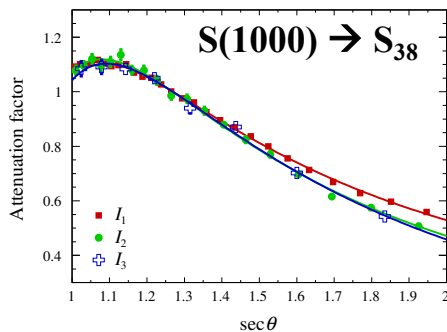
# The experimental techniques

Auger

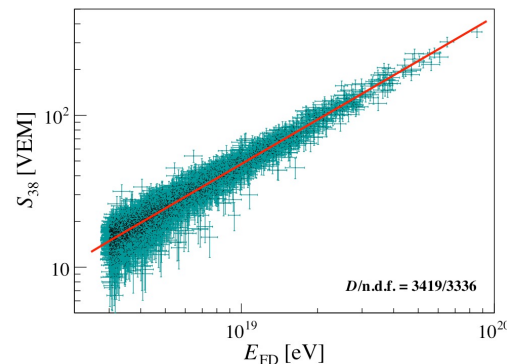
S(1000)



attenuation from CIC

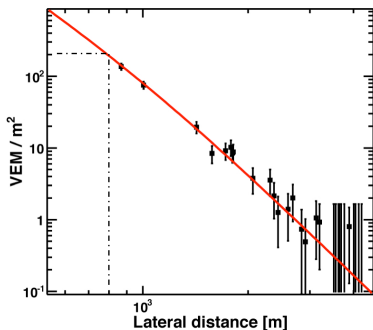


power law from hybrids

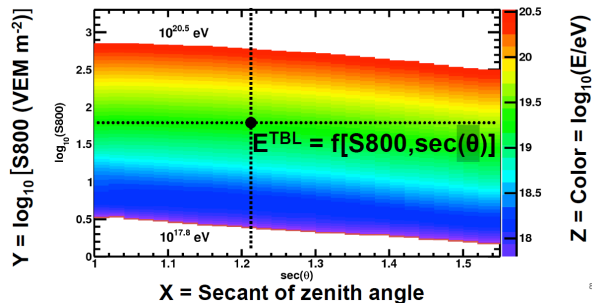


TA

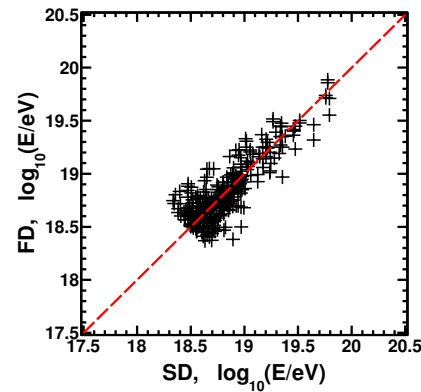
S(800)



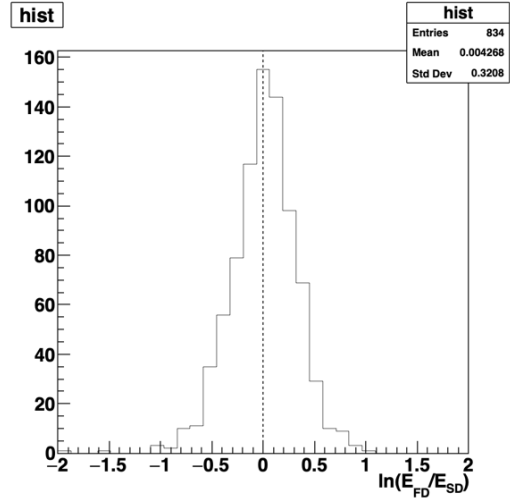
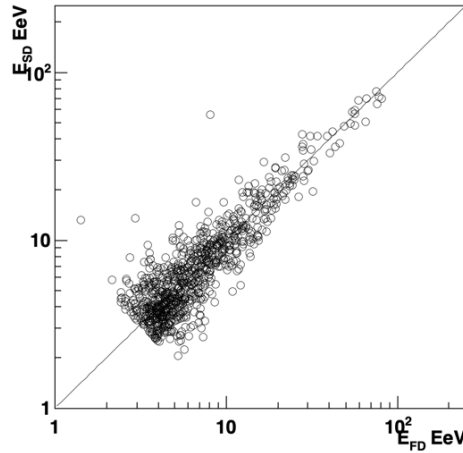
energy from MC look-up table  
 QGSJetII-03 proton



rescaling factor from hybrids



How well the TA SD energies are aligned to the FD ones ?

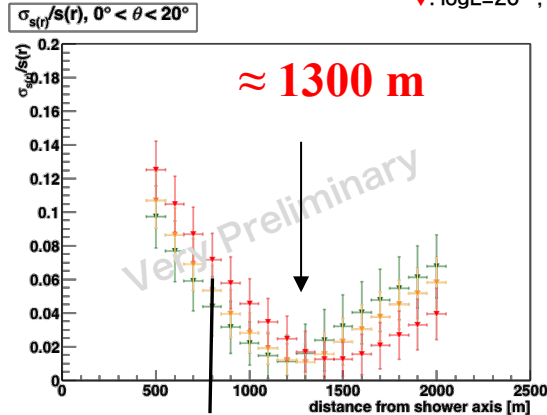


TA energy estimation using Auger data-driven approach:

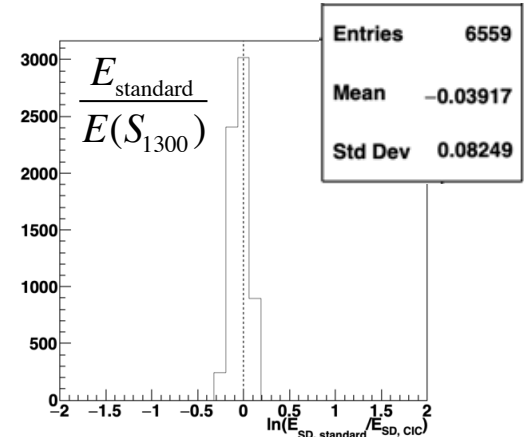
- “optimal distance”
- CIC
- power law calibration

$$\sigma_{s(r)}/S(r)$$

- ▼: logE=19, tasd
- ▼: logE=19.5, tasd
- ▼: logE=20, tasd

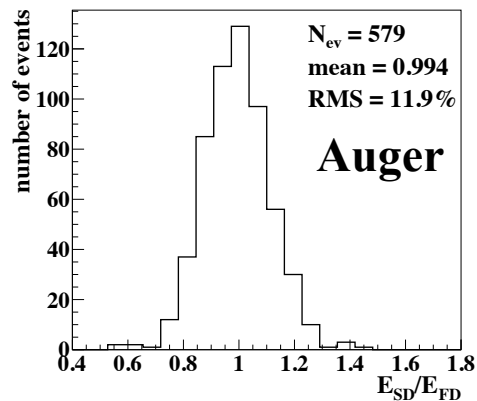
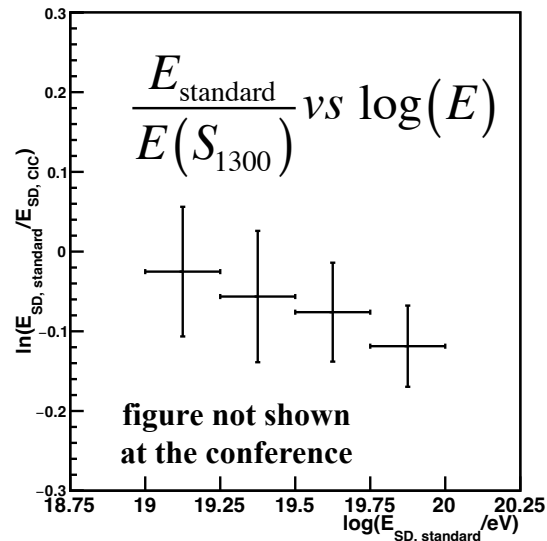
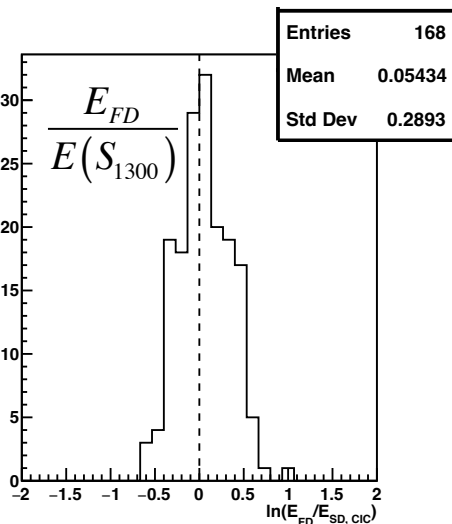
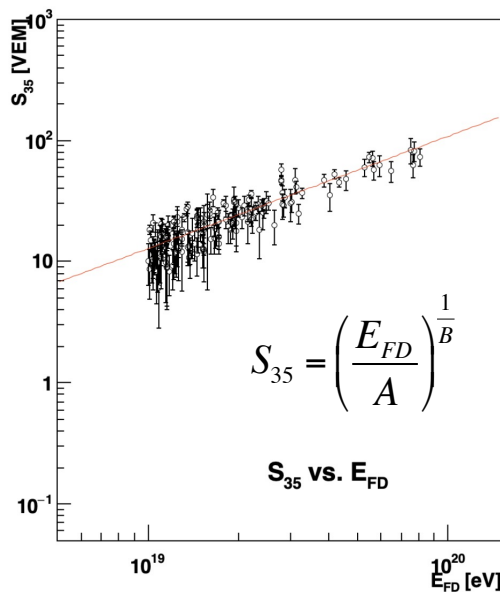


800 m



**CIC based energy estimations go in the opposite direction to explain the differences in the spectra !**

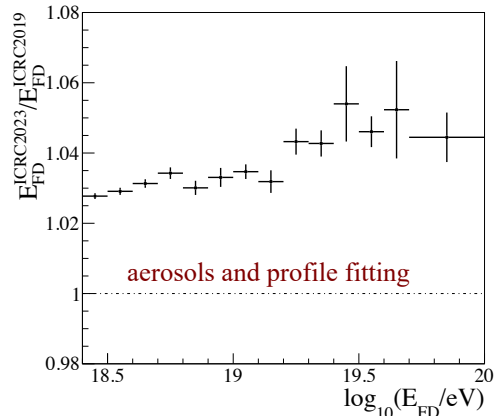
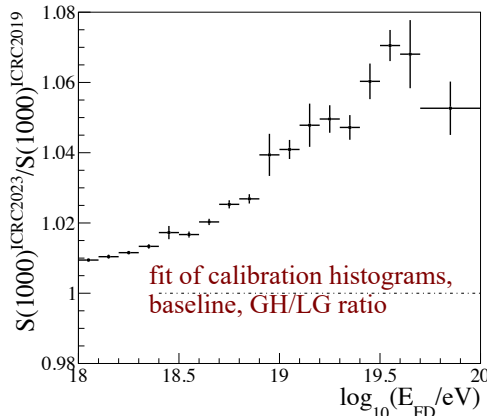
**Soundness of the energy calibration fit ?**



# Phase 1 data set

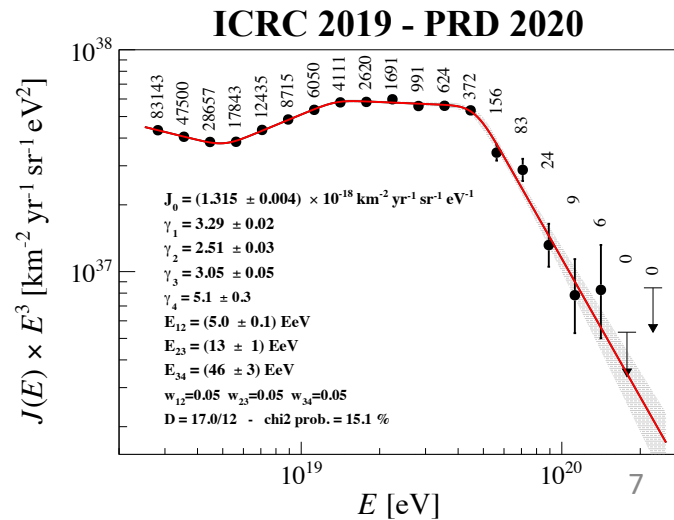
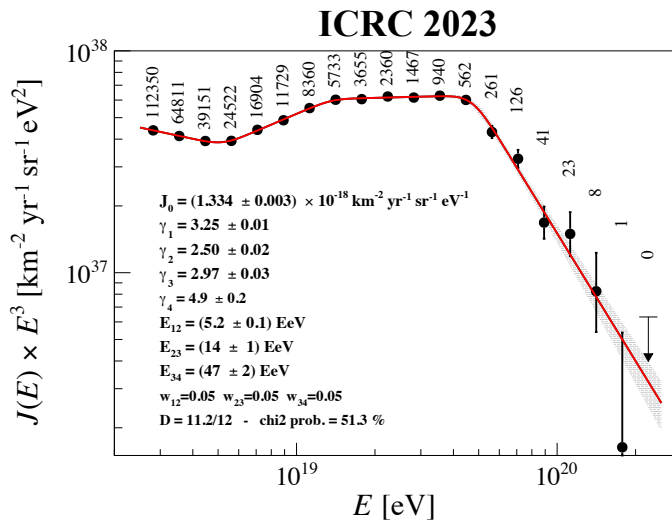
Mayor update of the SD rec. and update of FD rec.

- update of the CIC parameters
- update of the energy calibration



Data period:  
SD up to 31/12/2022  
FD up to 31/12/2021

Implemented in  
ICRC 203 data  
processing but work  
not yet concluded

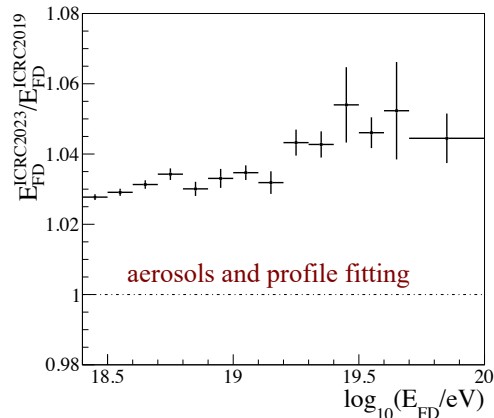
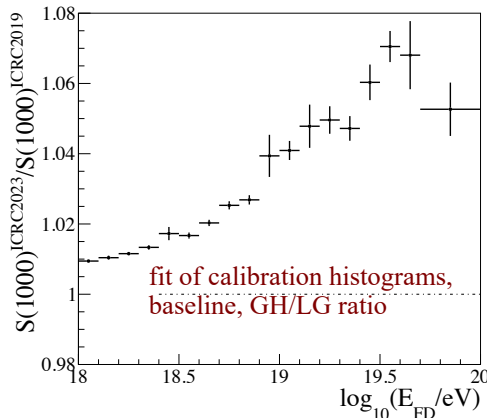




# Phase 1 data set

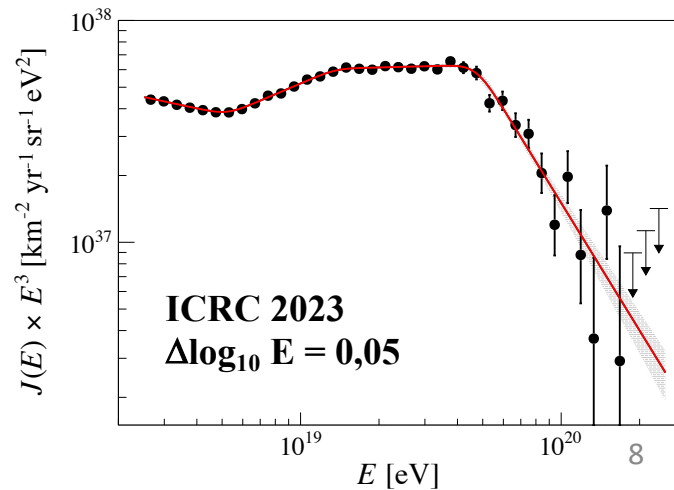
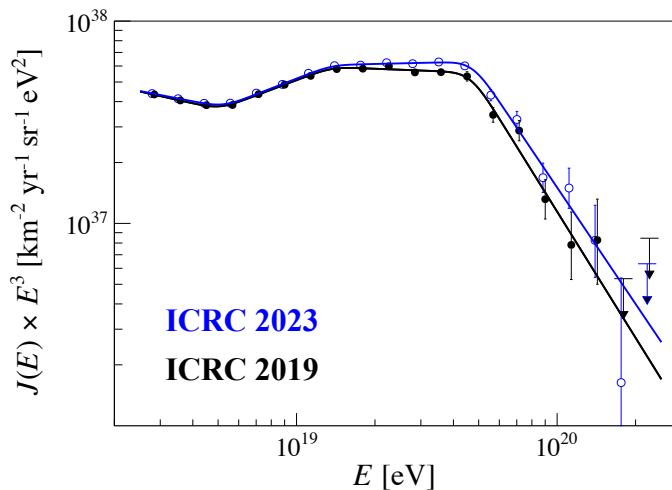
Mayor update of the SD rec. and  
update of FD rec.

- update of the CIC parameters
- update of the energy calibration



















Data period:  
SD up to 31/12/2022  
FD up to 31/12/2021

Implemented in  
ICRC 2013 data  
processing but work  
not yet concluded



# Richieste finanziarie

Capitolo	Descrizione	Parziali (k€)		Rimuovi	Modifica	Totale (k€)	
		Richieste	SJ			Richieste	SJ
missioni	Incontri istituzionali e con referee responsabile nazionale	2.00	0.00			20	0
	Partecipazione dal meeting della Collaborazione italiana Auger (2 persone x 1 keuro = 2 keuro)	2.00	0.00				
	Partecipazione a meeting di Collaborazione a Novembre e celebrazione AugerPrime (2 persone x 3 keuro = 6 keuro)	6.00	0.00				
	Turno di maintenance camere telescopi a fluorescenza (1 persona x 3 keuro)	3.00	0.00				
	Turno di presa dati FD a Malargue (1 persona x 4 keuro)	4.00	0.00				
	Partecipazione meeting di Collaborazione Aprile (1 persona x 3 keuro)	3.00	0.00				
spservizi	Common fund (dettagli nel Progress Report)	270.00	0.00			270	0
trasporti	Trasporti in situ per 1 turno FD e 2 meeting di Collaborazione	3.00	0.00			3	0
<b>Totale</b>						<b>293</b>	<b>0</b>