30th International Cosmic Ray Conference - Merida, Mexico, 3 — 11 July 2007

Preliminary measurements of carbon and oxygen energy spectra from the second flight of CREAM

Riccardo Zei

(University of Siena & INFN)

for the CREAM Collaboration

H.S. Ahn[1], O. Ganel[1], J.H. Han[1], K.C. Kim[1], M.H. Lee[1], A. Malinin[1],
E.S. Seo[1,2], R. Sina[1], P. Walpole[1], J. Wu[1], Y.S.Yoon[1,2], S.Y. Zinn[1]
[1] Institute for Physical Science and Technology, University of Maryland, College Park, MD 20742, USA
[2] Department of Physics, University of Maryland, College Park, MD 20742, USA

N.B. Conklin, S. Coutu, S.I. Mognet
Department of Physics, Penn State University, University Park, PA 16802, USA

P.S. Allison, J.J. Beatty, T.J. Brandt
Department of Physics, Ohio State University, Columbus, OH 43210, USA

J.T. Childers, M.A. Duvernois
School of Physics and astronomy, University of Minnesota, Minneapolis, MN 55455, USA

M.G. Bagliesi, G. Bigongiari, P. Maestro, P.S. Marrocchesi, R. Zei
Department of Physics, University of Siena & INFN, Via Roma 56, 53100 Siena, Italy

J.A. Jeon, S. Nam, I.H. Park, N.H. Park, J. Yang
Department of Physics, Ewha Womans University, Seoul 120-750, Republic of Korea

S. Minnick
Department of Physics, Kent State University, Tuscarawas, New Philadelphia, OH 44663, USA

S. Nutter
Department of Physics, Northern Kentucky University, Highland Height, KY 41099, USA

L. Barbier
Astroparticle Physics Labroratory, NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA

CREAM flights

CREAM-I: 2004/05 campaign

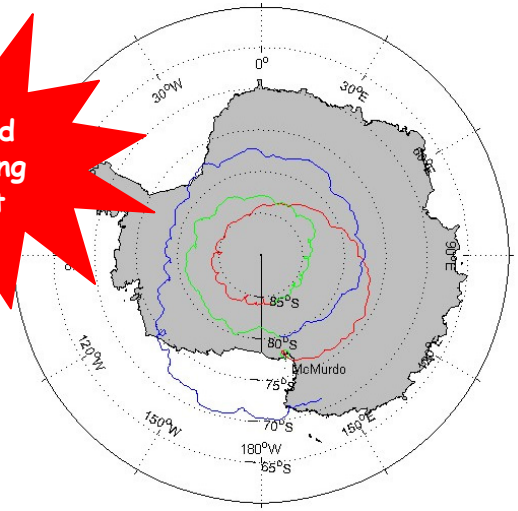
- Total flight time ~ 42 days

~ 42M science events collected

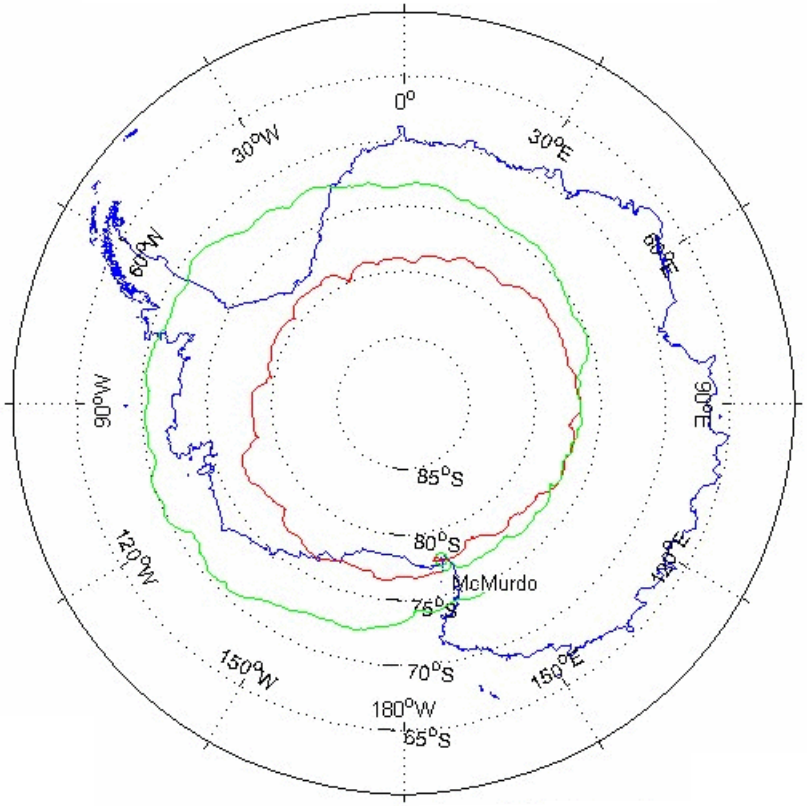
CREAM-II: 2005/06 campaign

- Total flight time ~ 28 days
- ~ 27M science events collected

Record breaking flight



CREAM-II trajectory

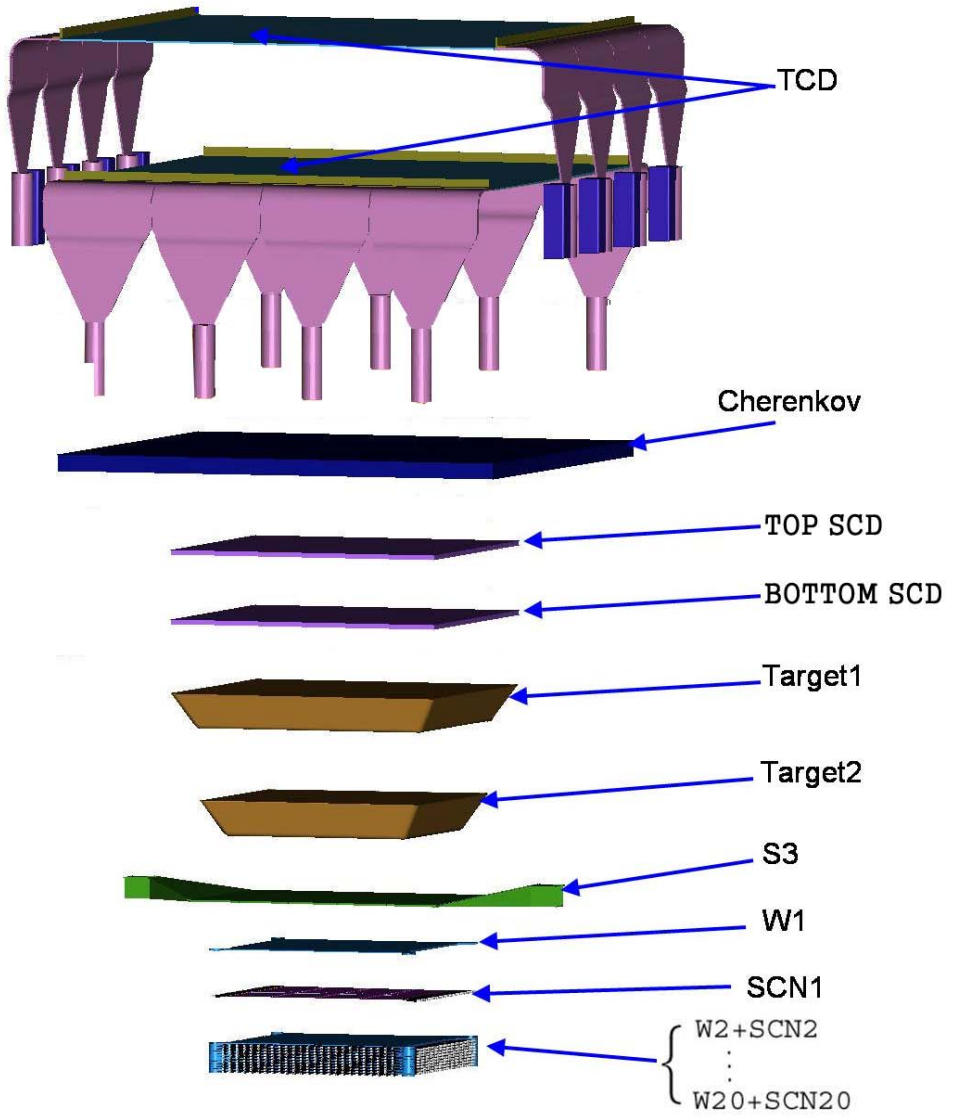


For the present analysis, only a subset of CREAM-II data was selected

Effective Live Time ~ 17 days

Altitude 38—40 km. Average atmospheric overburden ~ 3.9 g/cm²

Instrument configuration (2nd flight)



Timing Charge Detector (TCD)

- scintillator paddles (2 charge measurements)
- backscatter rejection by fast pulse shaping

Cherenkov Detector (CD)

- acrylic radiator (charge measurement)
- vetoes low energy particles

Silicon Charge Detector (SCD)

- 2 layers of Si pixels (2 charge measurements)
- backscatter rejection by fine segmentation

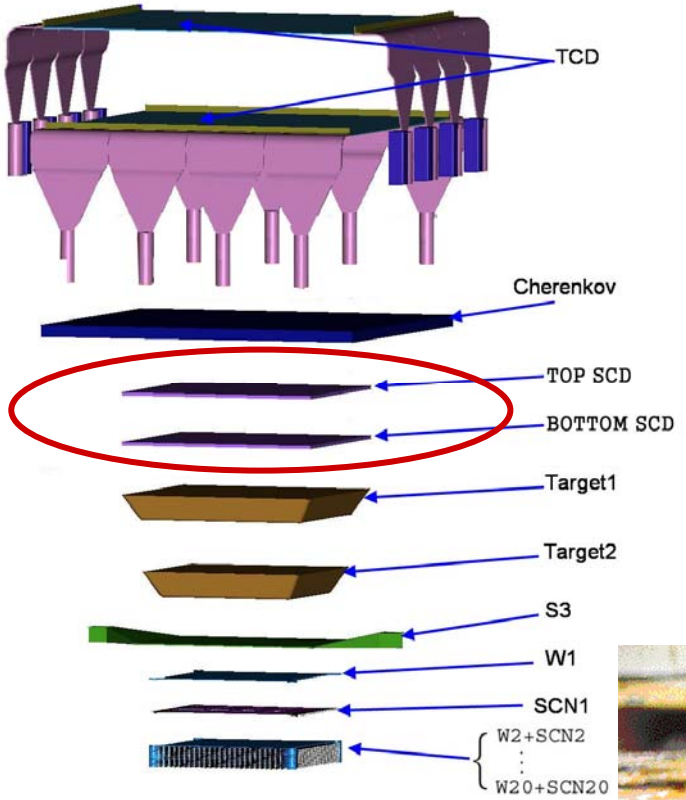
Target (T1,T2)

- 19 cm densified Graphite (~ 0.5 λ_{int} , ~ 1 X_0)
- induces a hadronic interaction

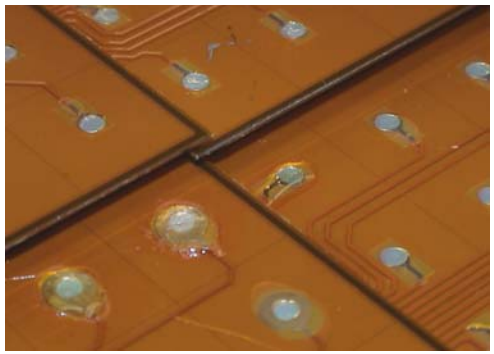
Tungsten Sci-Fi Calorimeter (CAL)

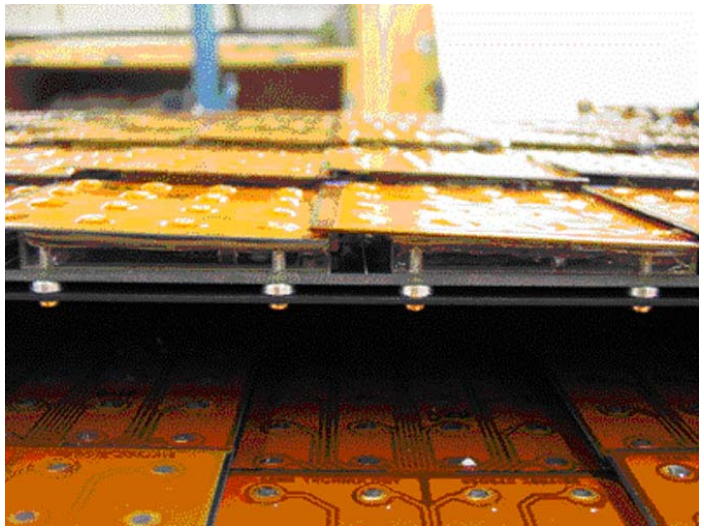
- 20 X_0; 1 cm granularity (energy measurement)

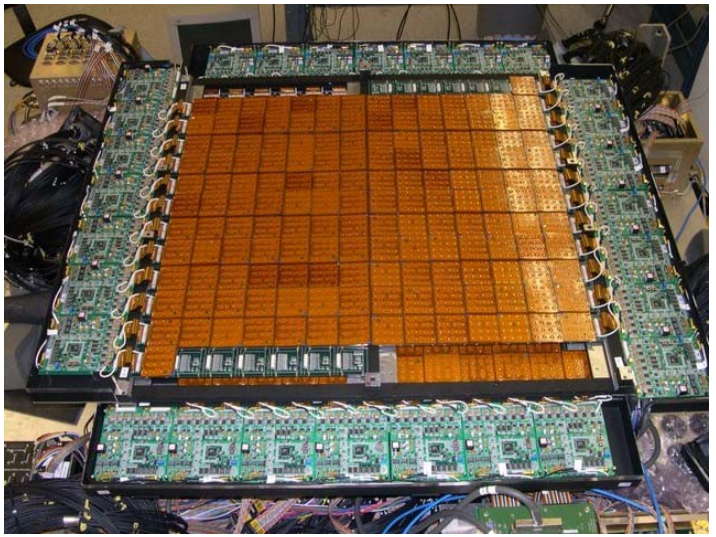
Silicon Charge Detector (SCD)



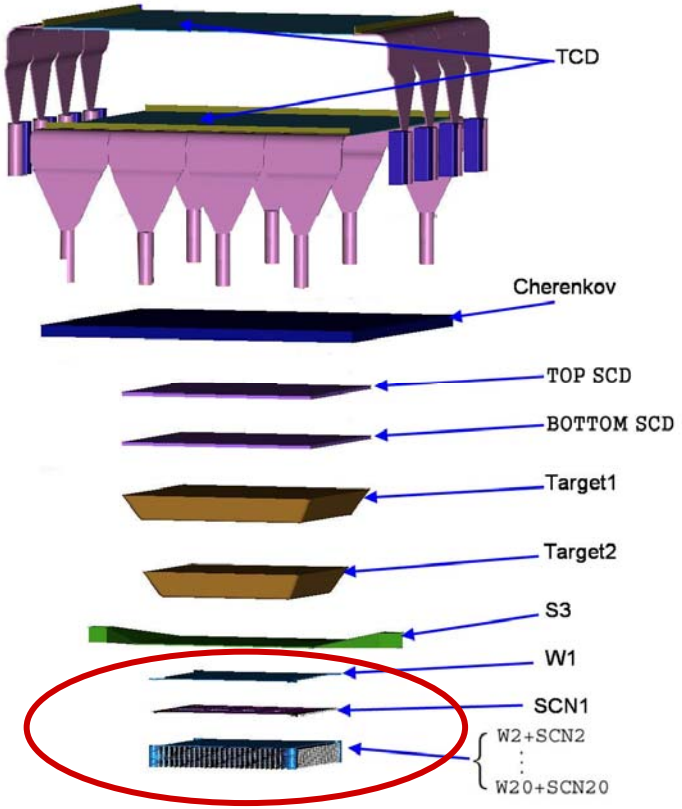
- 2 layers of sensors
- 380 μm thick Si sensor
- 16 pixels per sensor
- pixel size ~ 2.1 cm^2
- 2496 channels/layer were readout
- No dead area between sensors
- Active area per layer ~ 0.52 m^2
- particle-ID by charge measurement from Z=1 to Z=33



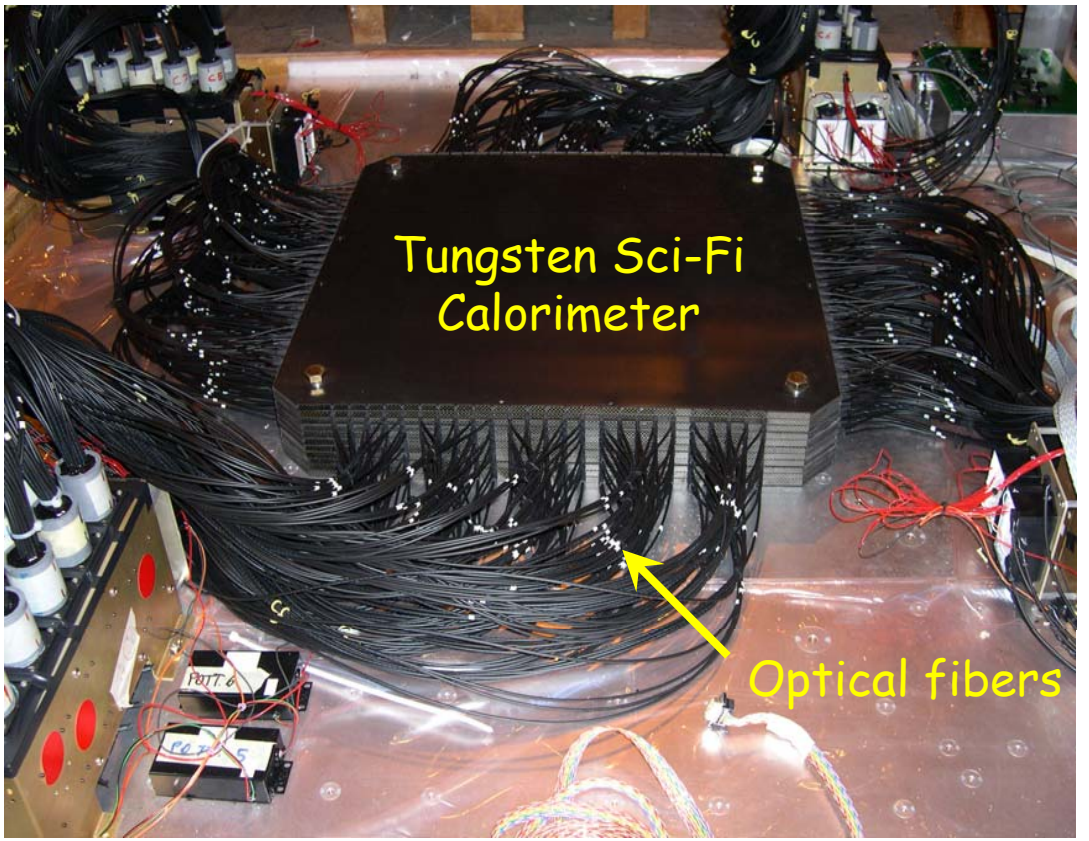




Tungsten Sci-Fi Calorimeter



- Active area 50x50 cm^2
- Longitudinal sampling: 3.5 mm W (1 X_0) + 0.5 mm Sci-Fi
- Transverse granularity: 1 cm (20 fibers ~ 1 Moliere radius)
- Total of 20 layers (20 X_0 , ~ 0.7 λ_{int}): alternate X-Y views
- 2560 channels (3 gain ranges) readout by 40 HPDs



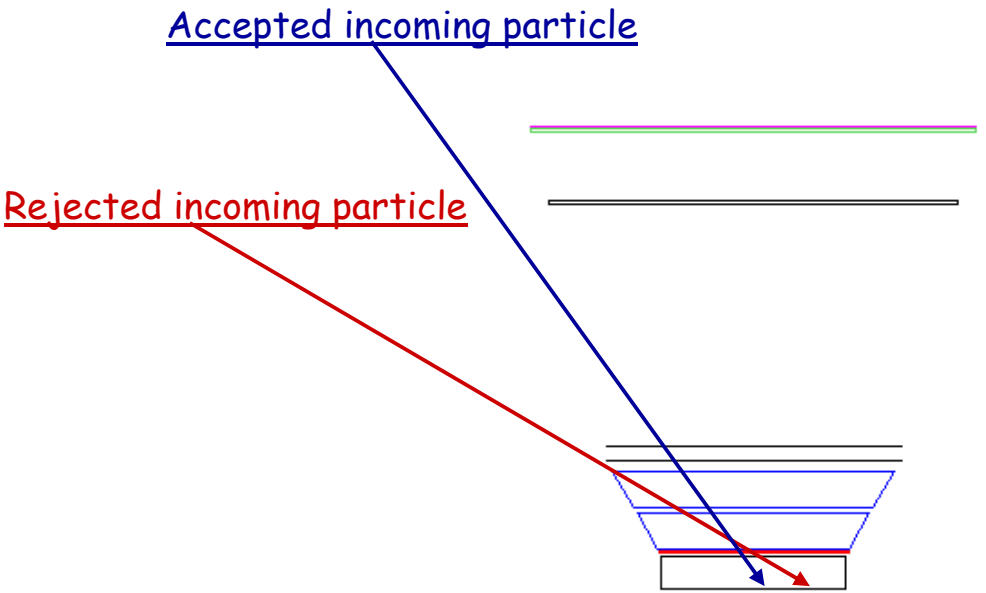
Geometric Factor

Monte Carlo Generation: FLUKA 2005.6 with hadronic interaction package DMPJET-3

Carbon (Oxygen) nuclei isotropic generation according to power-law spectrum in the energy range 600 (800) GeV – 100 TeV

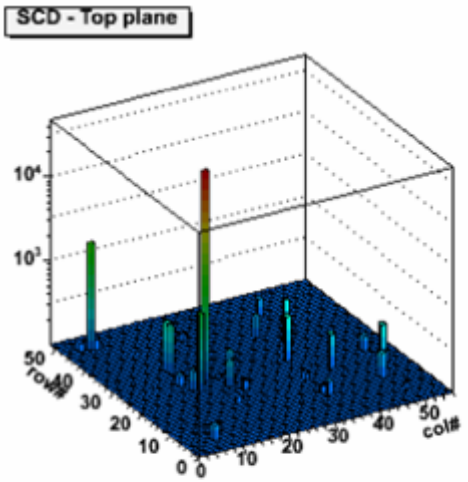
Geometrical Acceptance is calculated selecting events crossing both SCD Top Plane and CAL Top Layer

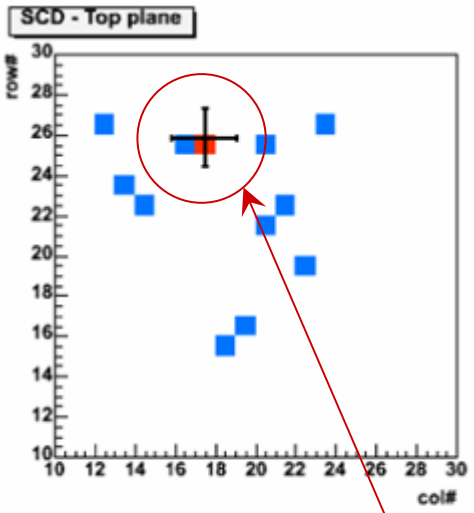
Selected fiducial region:
SCD top plane side = 78 cm
CAL top plane side = 50 cm

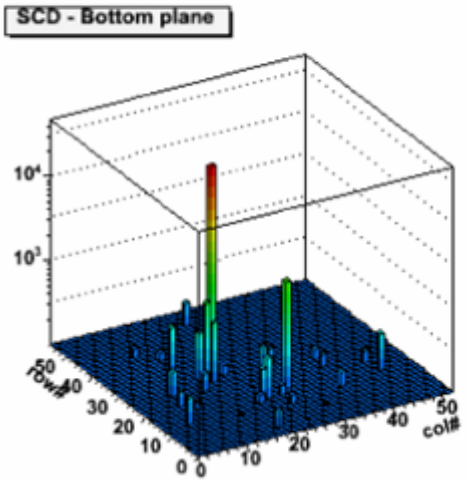


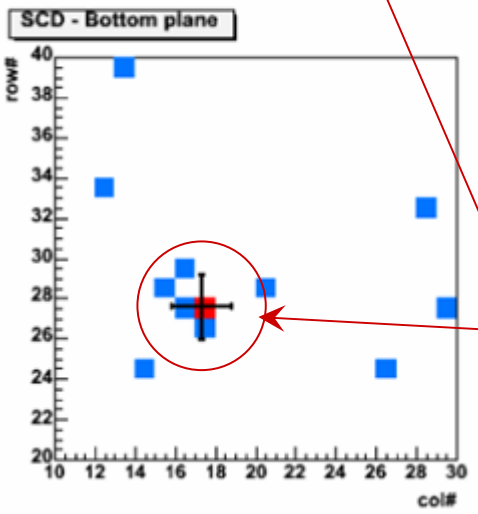
$G_F \sim 0.46\ m^2\ sr$

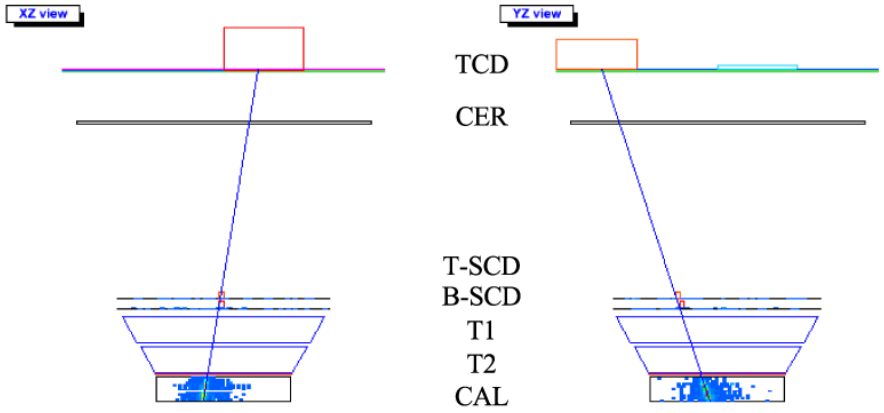
Shower reconstruction & Charge-ID





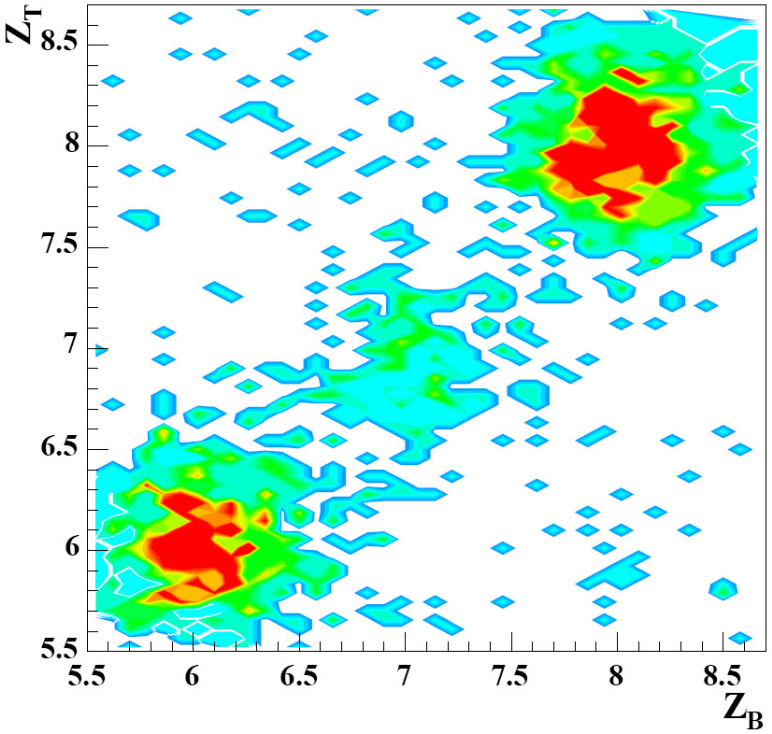






- Shower imaging (lateral/longitudinal) with CAL
- Fit of the shower axis
- Back-projection of CAL track to SCD
- The track is matched with the SCD pixel hit by the incoming particle
- Rejection of backscattered particles
- Charge identification of the incoming particle (a consistent charge assignement from the 2 layers is required)

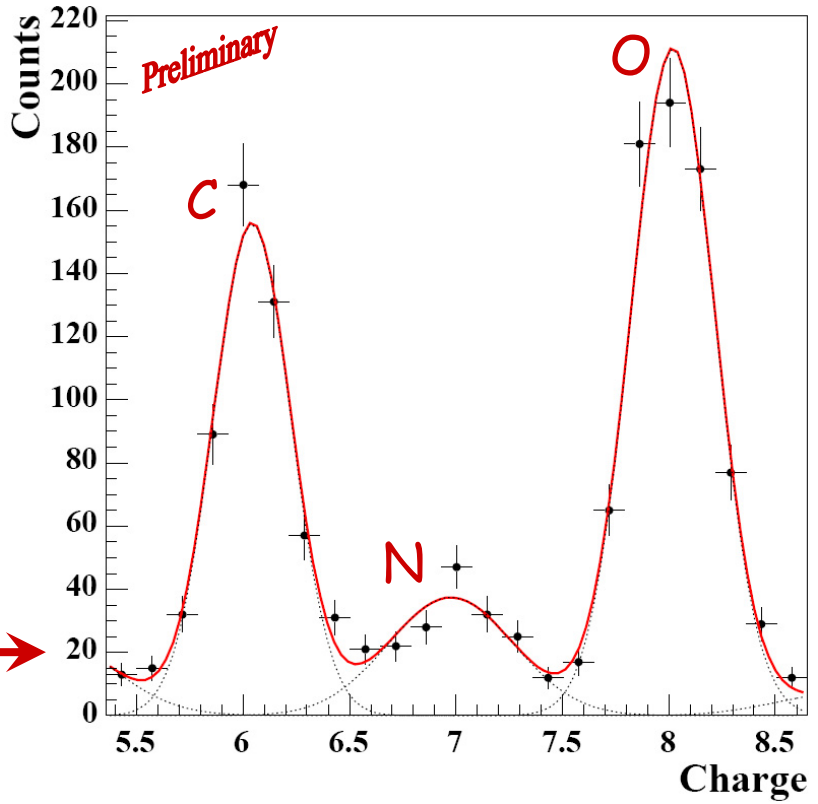
Observed charge distribution in SCD



Consistency 30% cut: $0.7 \leq \frac{S_{Top}}{S_{Bottom}} \leq 1.3$

$$Z^2_{Rec} \propto \left(\frac{S_{Top} + S_{Bottom}}{2} \right)$$

pathlength correction applied



Carbon & Oxygen: σ ~ 0.2e

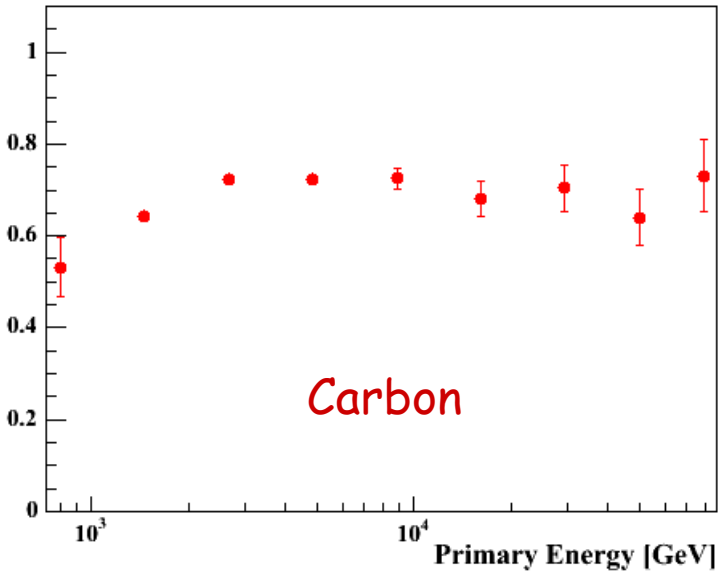
- Indicative of charge resolution
- NOT representative of elemental abundances

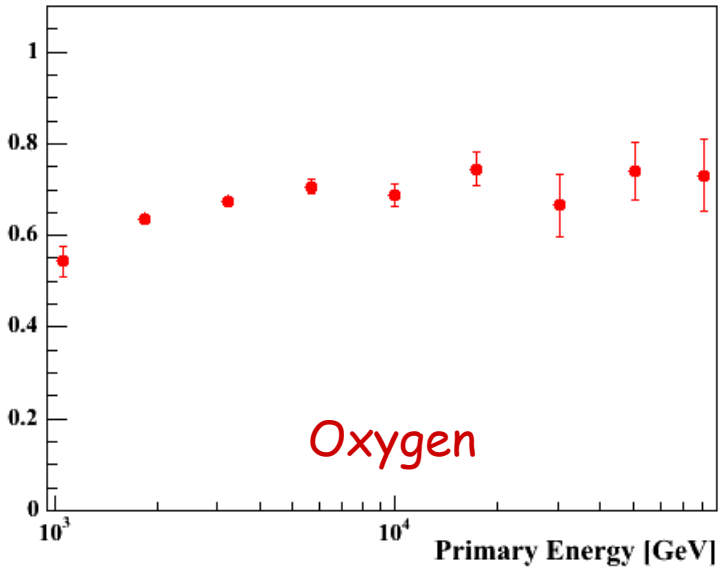
Charge Reconstruction Efficiency (Monte Carlo)

- Charge Reconstruction Efficiency is normalized to the number of triggered events

- MC algorithm for charge identification with SCD is the same as applied on flight data

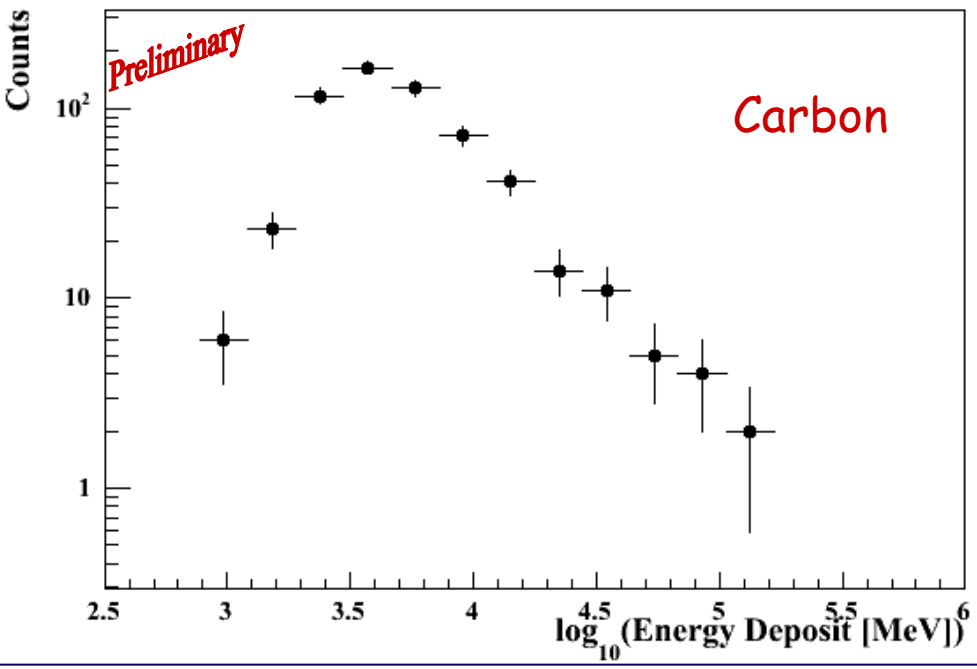
- Preliminary MC estimate of charge reconstruction efficiency is ~ 70% (above 2 TeV) including effects of SCD masked sensors

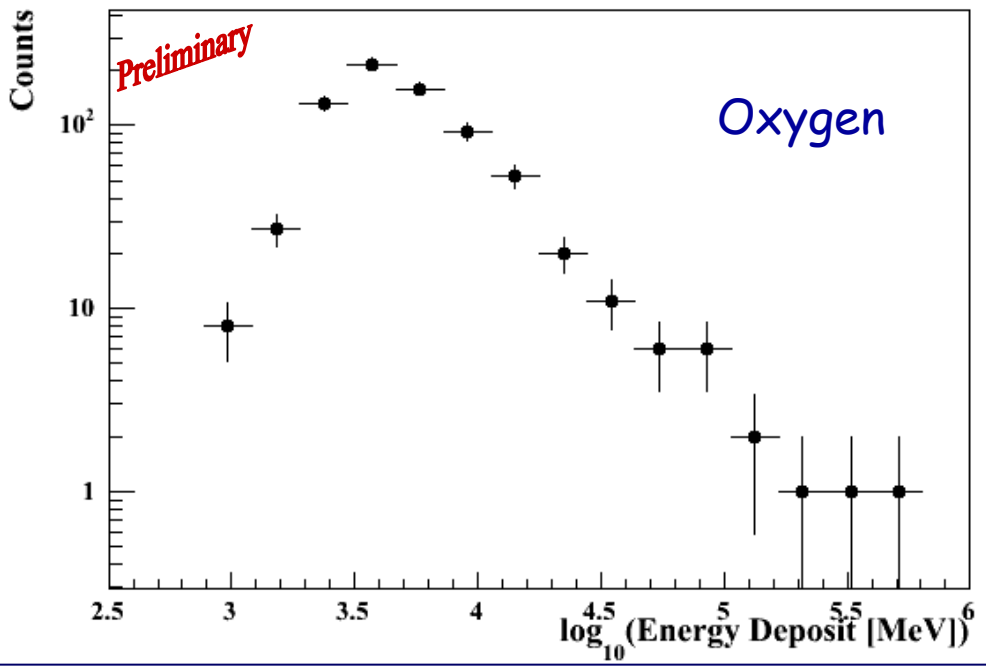




Flight DATA: carbon and oxygen energy deposit in CAL

All reconstructed showers inside selected fiducial region	39390	
After Consistency cut for SCD signals	10890	
Nuclei Charge Selection	728 (Oxygen)	583 (Carbon)





Energy Deconvolution

Primary energy

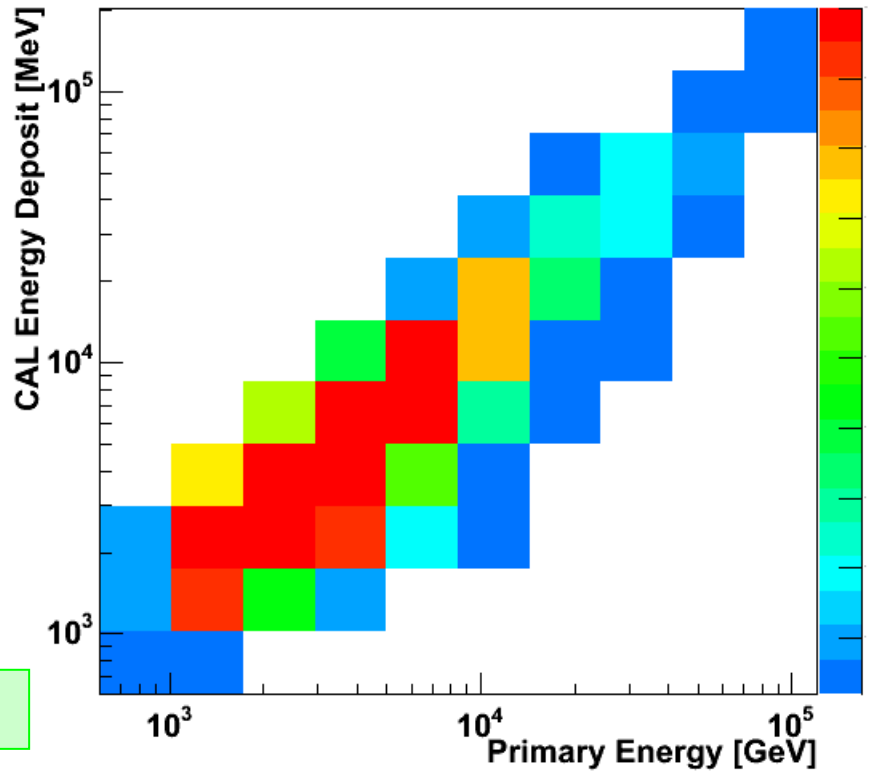
$$\varphi(E_d) = \int A(E_d, E)\Phi(E)dE$$

Deposited energy

Response function

For events surviving the selection cuts, both distributions of energy deposit and primary particle energy are divided into equidistant logarithmic bins.

Through their correlation plot, we can estimate the matrix elements Aij i.e. the probability that events in the deposited energy bin i come from the primary incident energy bin j.

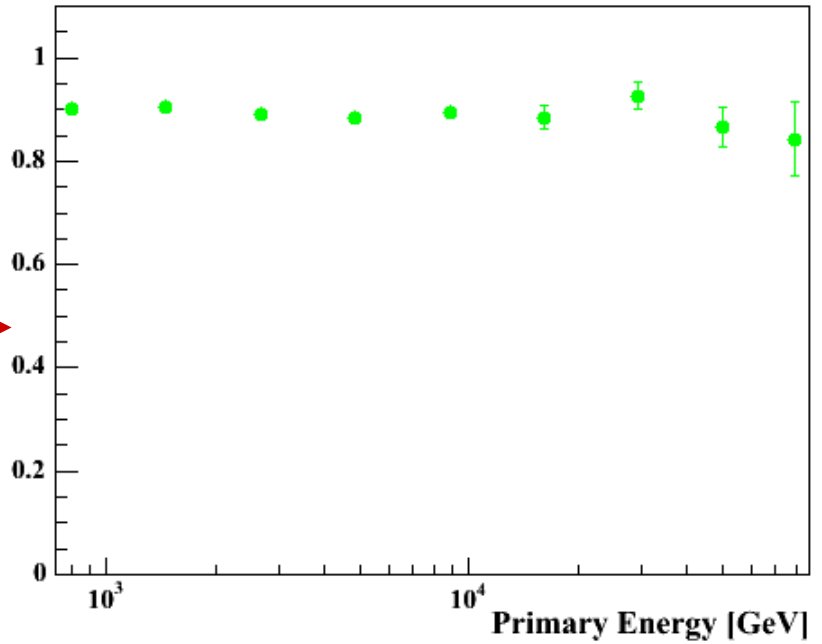


$A(E_d,E)$ is determined from Monte Carlo events

Correction to TOI (Top of Instrument): Interaction fractions

- A correction for particles interacting in the instrument was applied.

Fraction of Carbon/Oxygen nuclei interacting in the apparatus



Correction to TOA (Top of Atmosphere)

Through MC simulation the correction factor η is calculated for an (average) residual atmosphere overburden of ~ 3.9 g/cm^2.

Carbon = 0.86
Oxygen = 0.83

Absolute Flux

The unfolded counts N^{inc}, in each incident energy bin of size ΔE, are normalized to obtain the absolute differential fluxes at the top of atmosphere, given by

$$\Phi(E) = \frac{N^{inc}}{\Delta E} \times \frac{1}{G_F \cdot T_l \cdot \varepsilon \cdot \eta}$$

where

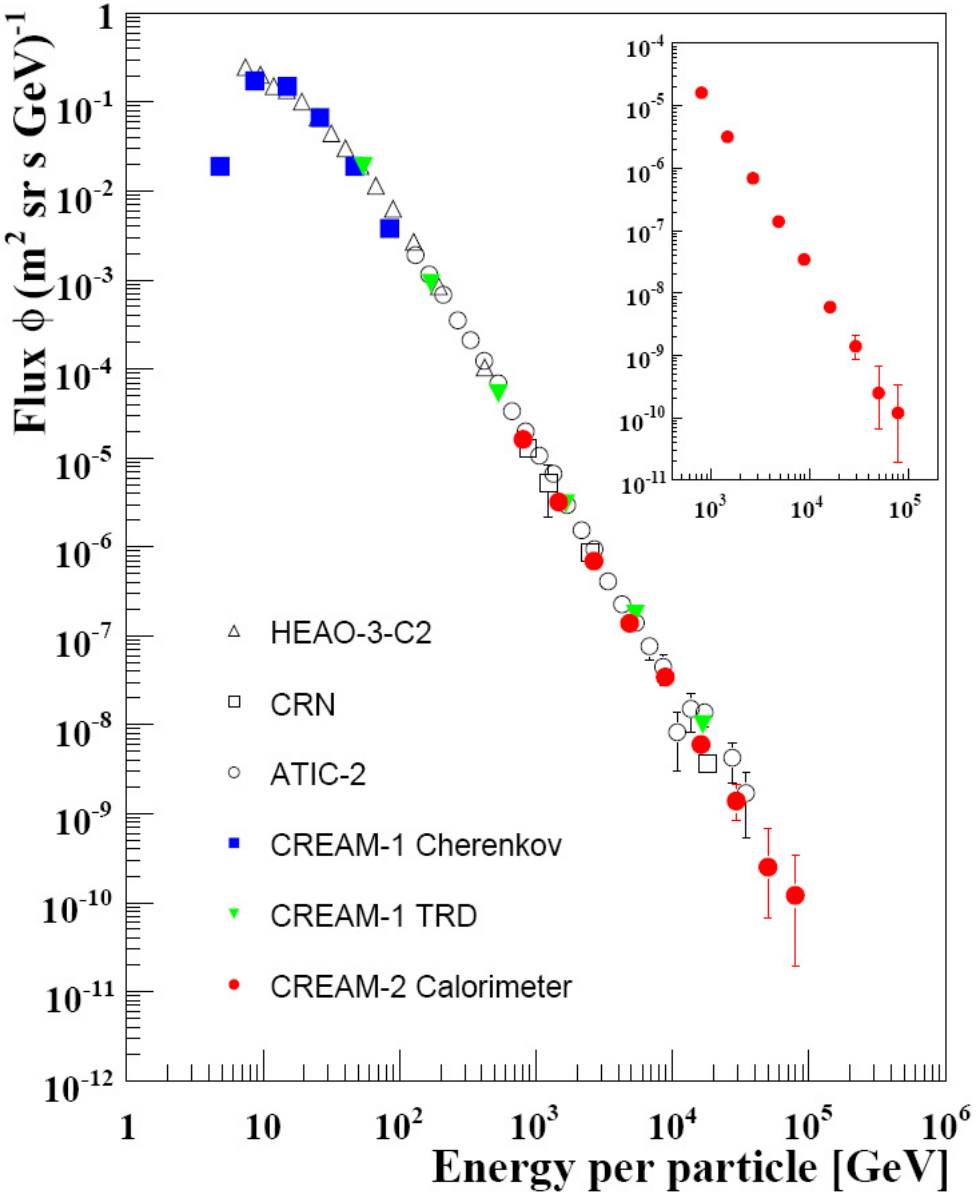
G_F = Geometric factor

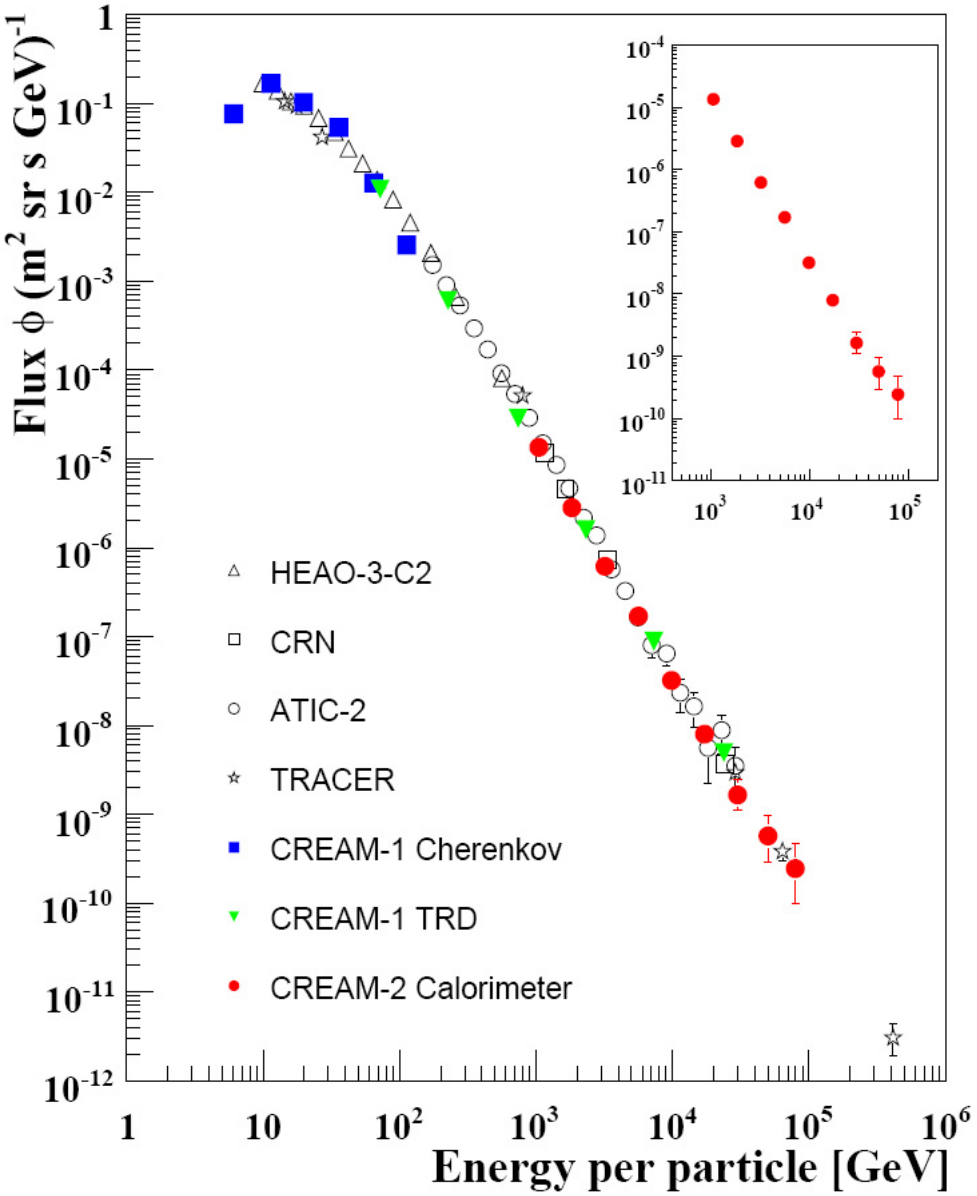
T_l = Live-time

ε = product of efficiencies , correction for interaction fractions

η = TOA correction

Preliminary Carbon & Oxygen energy spectra





Conclusions

- A preliminary analysis of the data indicates an excellent charge-ID from SCD and good performance of the imaging calorimeter and of the whole instrument
- Preliminary carbon and oxygen energy spectra are found to be consistent with previous measurements
- Analysis is on-going... more to come!

Thanks to:

- NASA
- NSBF/CSBF
- INFN/PNRA
- WFF
- NSF