

Energy spectra of cosmic-ray nuclei at high energies measured by CREAM

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Cosmic ray backgrounds in dark matter searches, Stockholm, January 25-27



Cosmic Ray Energetics And Mass (CREAM)

Balloon-borne experiment

Direct detection of cosmic rays

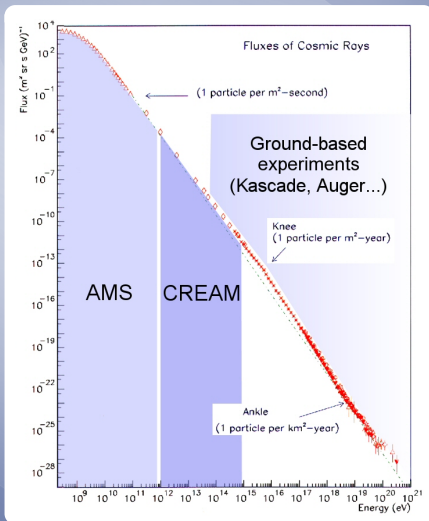
Energy range

10^{12} to 10^{15} eV

Scientific goals

Measurement of the elemental cosmic-ray fluxes (H to Fe)

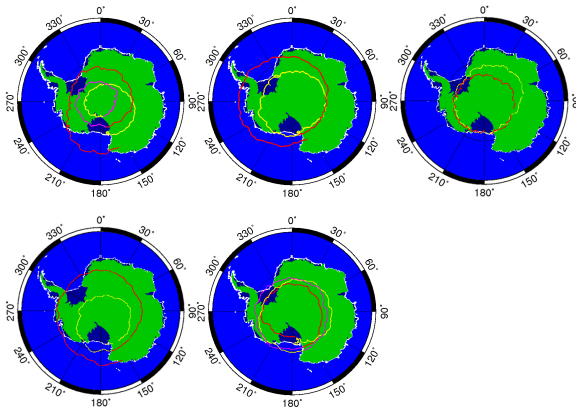
- cosmic-ray propagation study;
- Search for an elemental cosmic-ray cut-off below the knee





CREAM flight campaigns

5 flights over the Antarctic continent



Five successful flight campaigns in 04/05, 06/07, 07/08, 08/09, and 09/10

12 circumnavigations of the South Pole

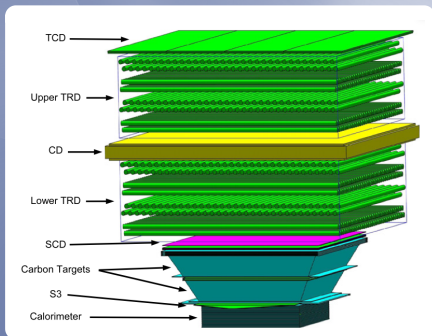
Culmulative exposure of 157 days

6th flight in preparation

CREAM flight duration exceeds all prior balloon-borne experiments!



CREAM sub-detectors

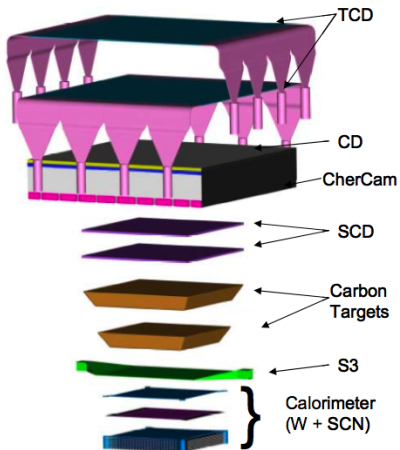


CREAM-I/II sub-detectors

- *Timing Charge Detector (TCD):*
Z, vetoes albedo particles
- *Transition Radiation Detector (TRD) (only CREAM-I):*
 γ
- *Cherenkov Detector (CD):*
Z, vetoes non-relativistic particles
- *Silicon Charge Detector (SCD):*
Z
- hadronic calorimeter:
E



CREAM sub-detectors

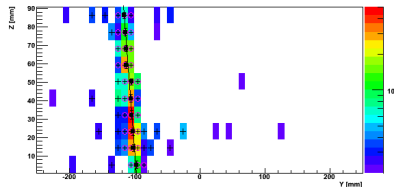
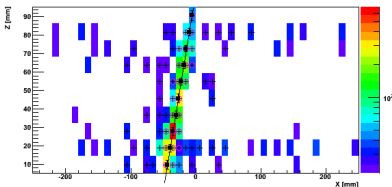
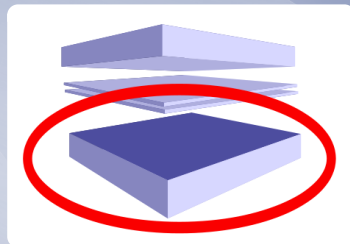


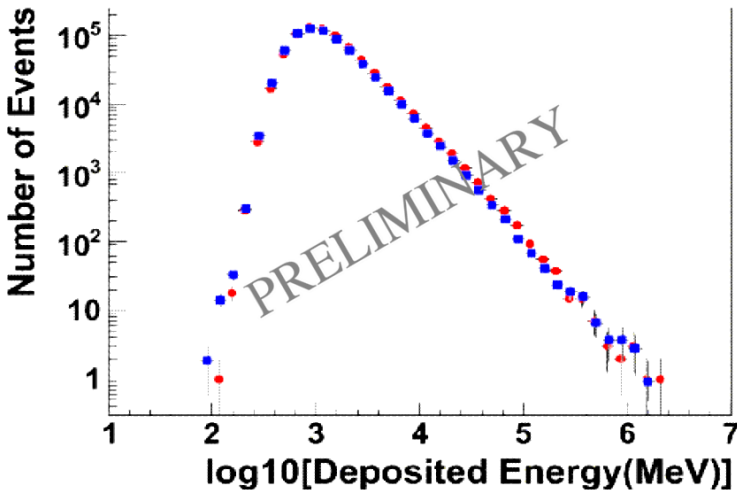
CREAM-III/IV/V sub-detectors

- *Timing Charge Detector (TCD):*
Z, vetoes albedo particles
- *Cherenkov Detector (CD):*
Z, vetoes non-relativistic particles
- *Cherenkov Camera (CherCam):*
Z
- *Silicon Charge Detector (SCD):*
Z
- hadronic calorimeter:
E



The hadronic calorimeter

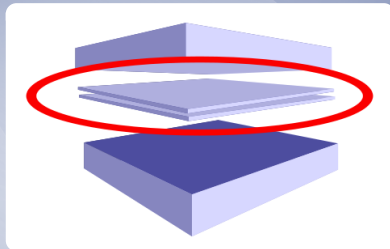
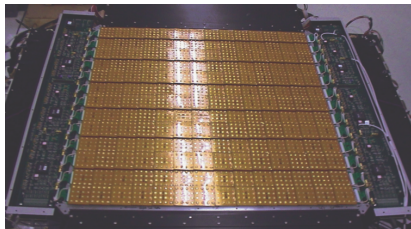


 Energy deposit in CREAM-III (red) et IV (blue)

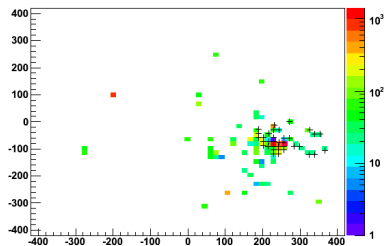
[J. H. Han *et al.*, 31st ICRC, 2009]



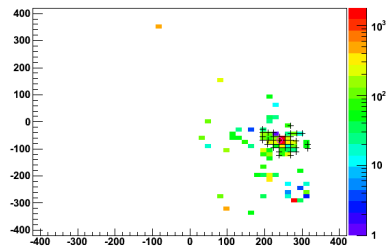
The Silicon Charge Detector (SCD)



bSCD

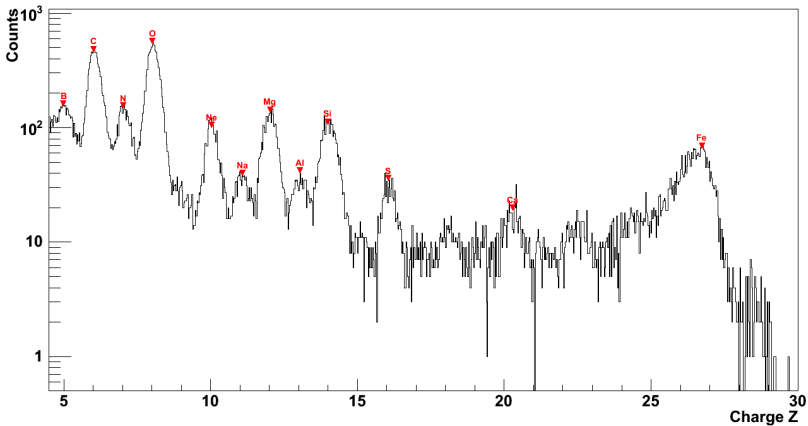


tSCD





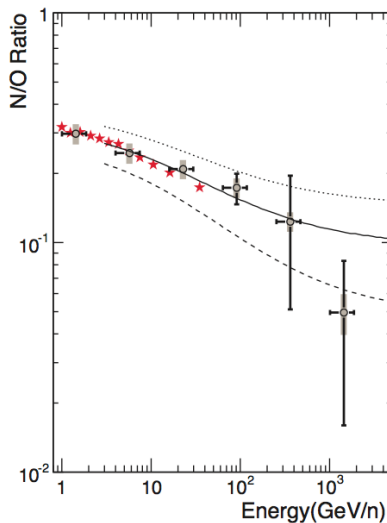
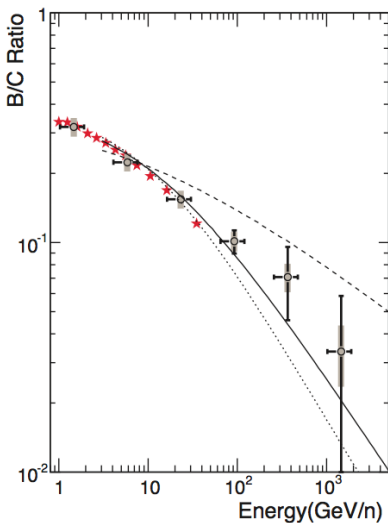
SCD charge distribution



[Putze, Ph.D. thesis, 2009]



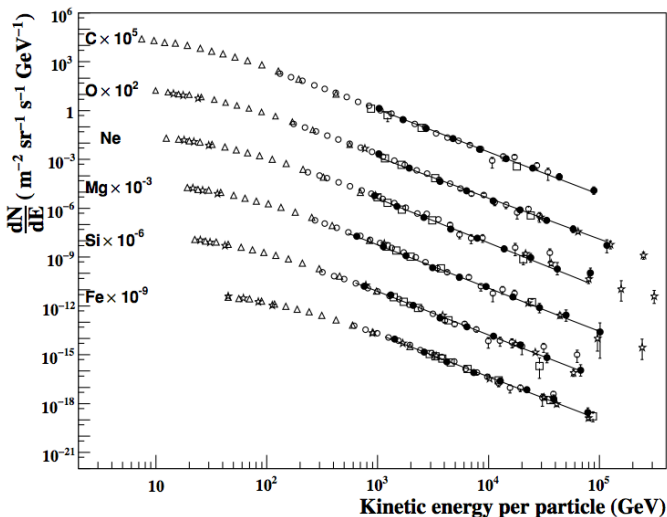
CREAM-I B/C and N/O ratios



[H. S. Ahn *et al.*, *Astropart. Phys.* 30:133-14, 2008]



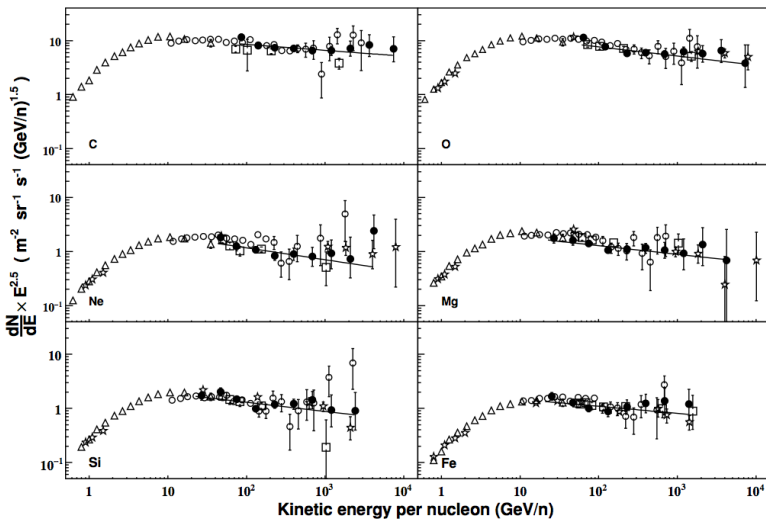
CREAM-II primary fluxes



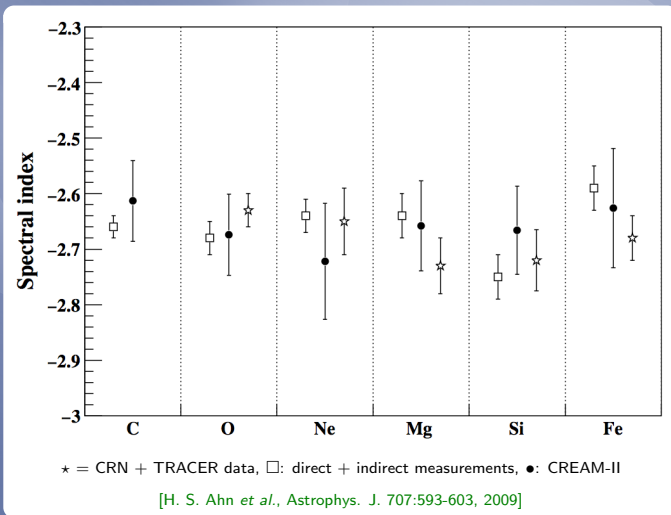
[H. S. Ahn *et al.*, *Astrophys. J.* 707:593-603, 2009]



CREAM-II primary fluxes times $E^{2.5}$



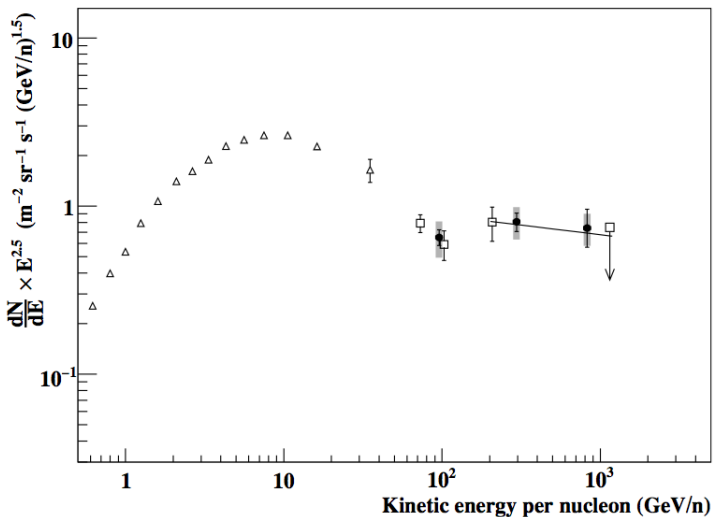
[H. S. Ahn et al., *Astrophys. J.* 707:593-603, 2009]

 CREAM-II spectral indices (single power-law fit)

Very similar spectral indices! Average spectral index $\bar{\gamma} = 2.66 \pm 0.04$



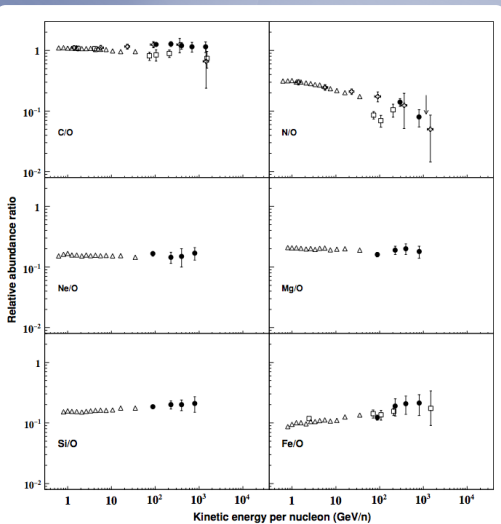
CREAM-II nitrogen flux



[H. S. Ahn *et al.*, *Astrophys. J.* 707:593-603, 2009]



CREAM-II primary to oxygen ratios



[H. S. Ahn *et al.*, *Astrophys. J.* 707:593-603, 2009]



Conclusion

- CREAM measures cosmic-ray nuclei with an **excellent charge resolution and a reliable energy determination**
- Measured proton and helium spectra agree with earlier experiments
- Energy spectra of the major primary heavy nuclei from **C to Fe measured up to $\sim 10^{14}$ eV**
- C to Fe spectra agree with earlier measurements and follow a power law with a similar spectral index $\bar{\gamma} = 2.66 \pm 0.04$
⇒ **Same origin, acceleration, and propagation processes**
- New nitrogen measurement at high energy with harder spectrum than at lower energies
⇒ **Secondary as well as primary contributions**
- **Data analysis of all five flights on-going**
⇒ **New precise cosmic-ray nuclei data at high energies on the way!**