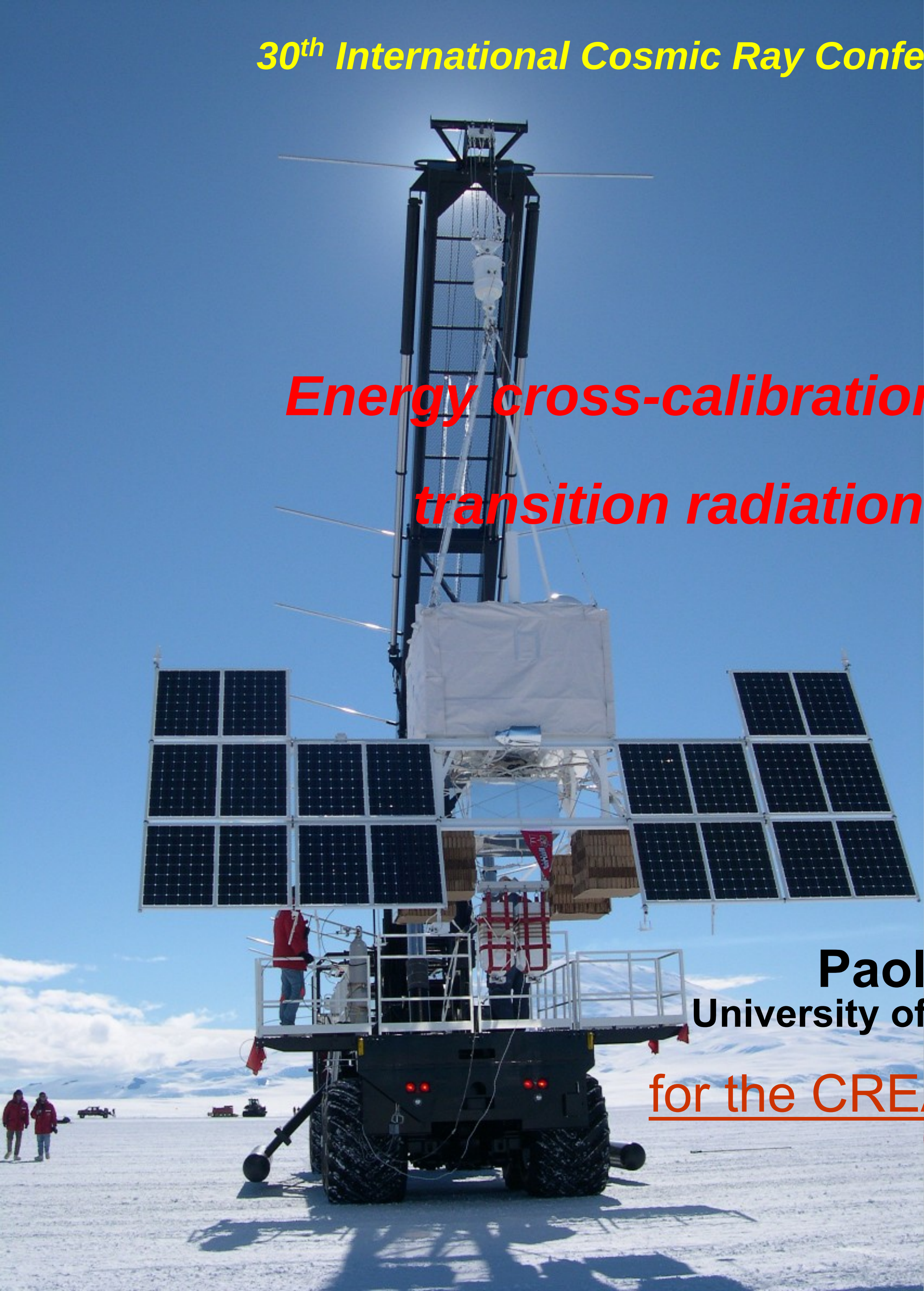
30th International Cosmic Ray Conference: July 3-11, 2007, Merida



Energy cross-calibration from the first CREAM flight: transition radiation detector vs. calorimeter

Paolo Maestro
University of Siena & INFN (Italy)

for the CREAM-I collaboration

<u>P. Maestro</u>[7], H.S. Ahn[2], P.S. Allison[5], M.G. Bagliesi[7], J.J. Beatty[5], G. Bigongiari[7], P.J. Boyle[3], T.J. Brandt[5], J.T. Childers[6], N.B. Conklin[4], S. Coutu[4], M.A. DuVernois[6], O. Ganel[2], J.H. Han[8], H.J. Hyun[8], J.A. Jeon[8], K.C. Kim[2], J.K. Lee[8], M.H. Lee[2], L. Lutz[2], P.S. Marrocchesi[7], A. Malinine[2], S. Minnick[9], S.I. Mognet[4], S. Nam[8], S. Nutter[10], H. Park[11], I.H. Park[8], N.H. Park[8] E.S. Seo[1,2], R. Sina[2], S. Swordy[3], S.P. Wakely[3], J. Wu[2], J. Yang[8], Y.S. Yoon[1,2], R. Zei[7], S.Y. Zinn[2]

1 Dept. of Physics, University of Maryland, College Park, MD 20742 USA

2 Inst. for Phys. Sci. and Tech., University of Maryland, College Park, MD 20742 USA

3 Enrico Fermi Institute and Dept. of Physics, University of Chicago, Chicago, IL 60637, USA

4 Dept. of Physics, Penn State University, University Park, PA 16802, USA

5 Dept. of Physics, Ohio State University, Columbus, Ohio 43210, USA

6 School of Physics and Astronomy, University of Minnesota, Minneapolis, MN 55455, USA

7 Dept. of Physics, University of Siena and INFN, Via Roma 56, 53100 Siena, Italy

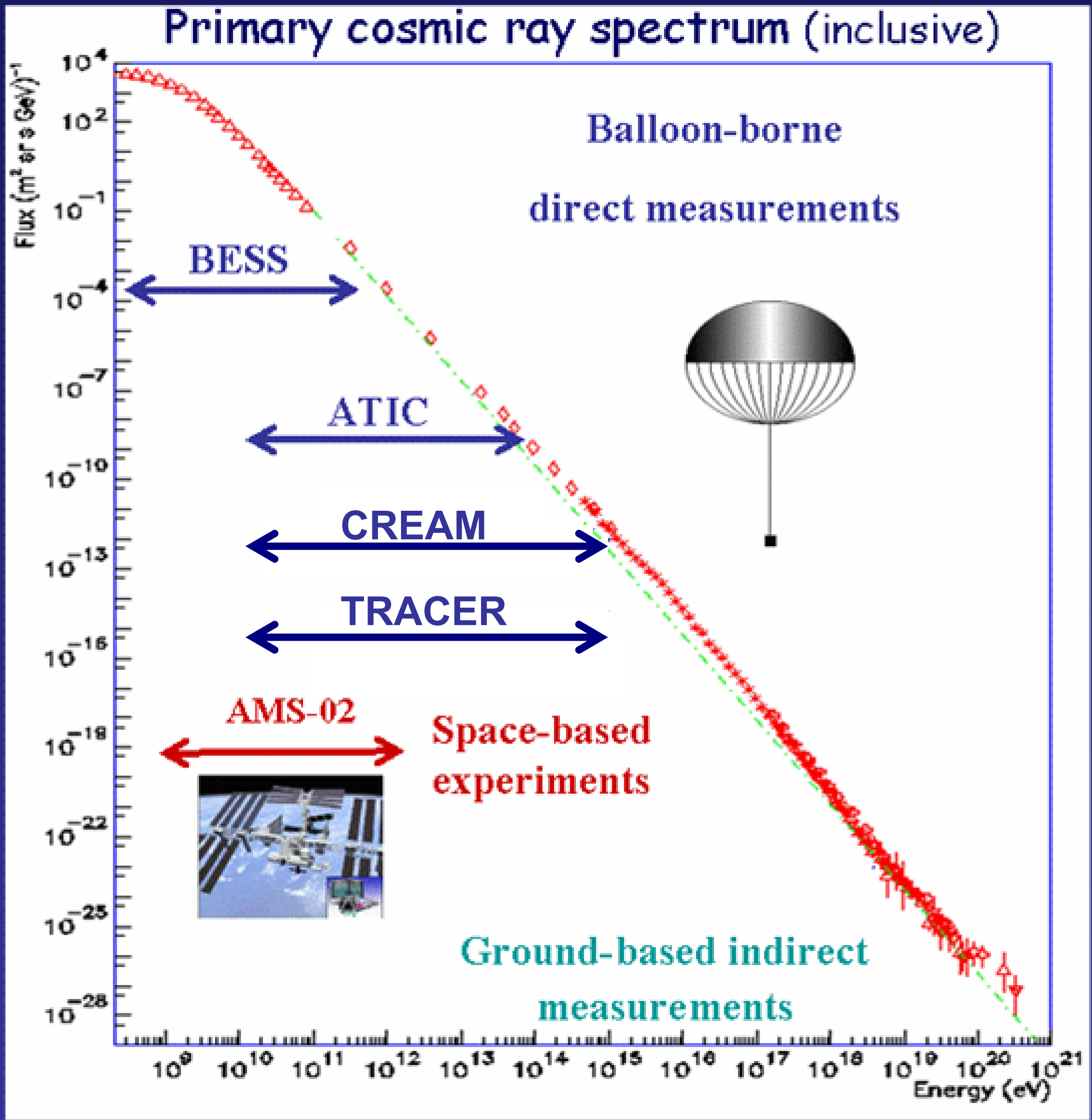
8 Dept. of Physics, Ewha Womans University, Seoul, 120-750, Republic of Korea

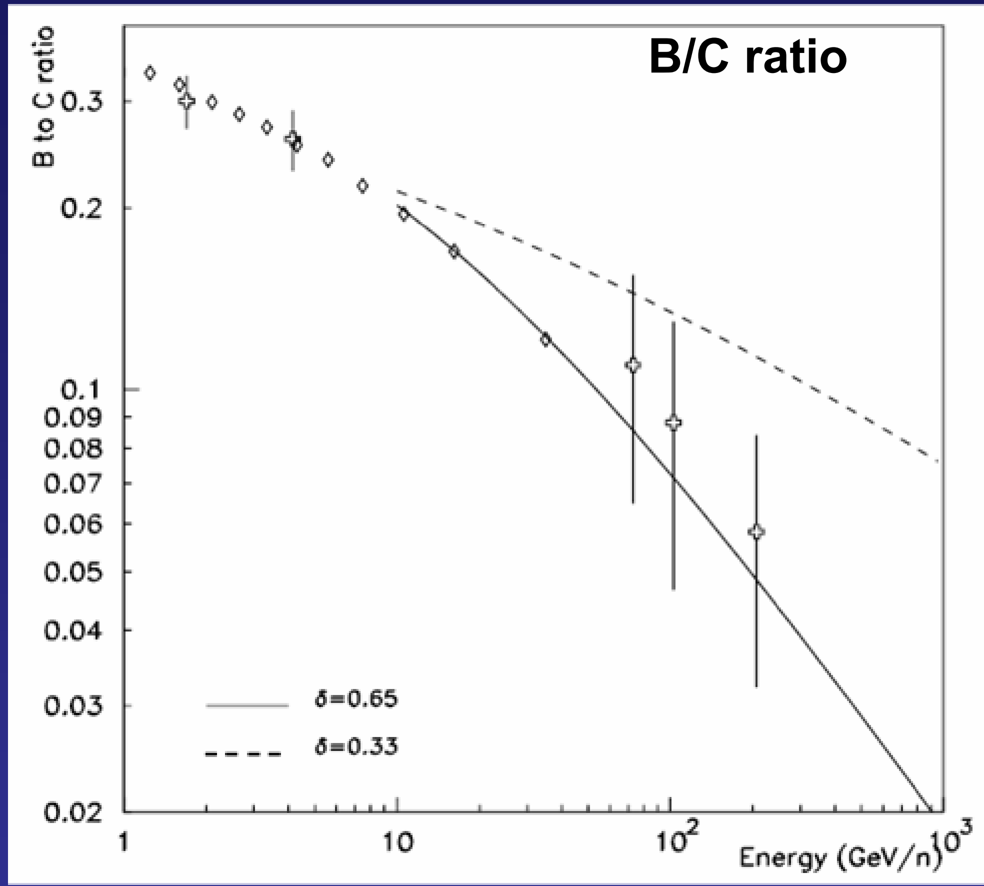
9 Dept. of Physics, Kent State University Tuscarawas, New Philadelphia, OH 44663, USA

10 Dept. of Physics and Geology, Northern Kentucky University, Highland Heights, KY 41099, USA

11 Dept. of Physics, Kyungpook National University, Taegu, 702-701, Republic of Korea

CREAM main science goals





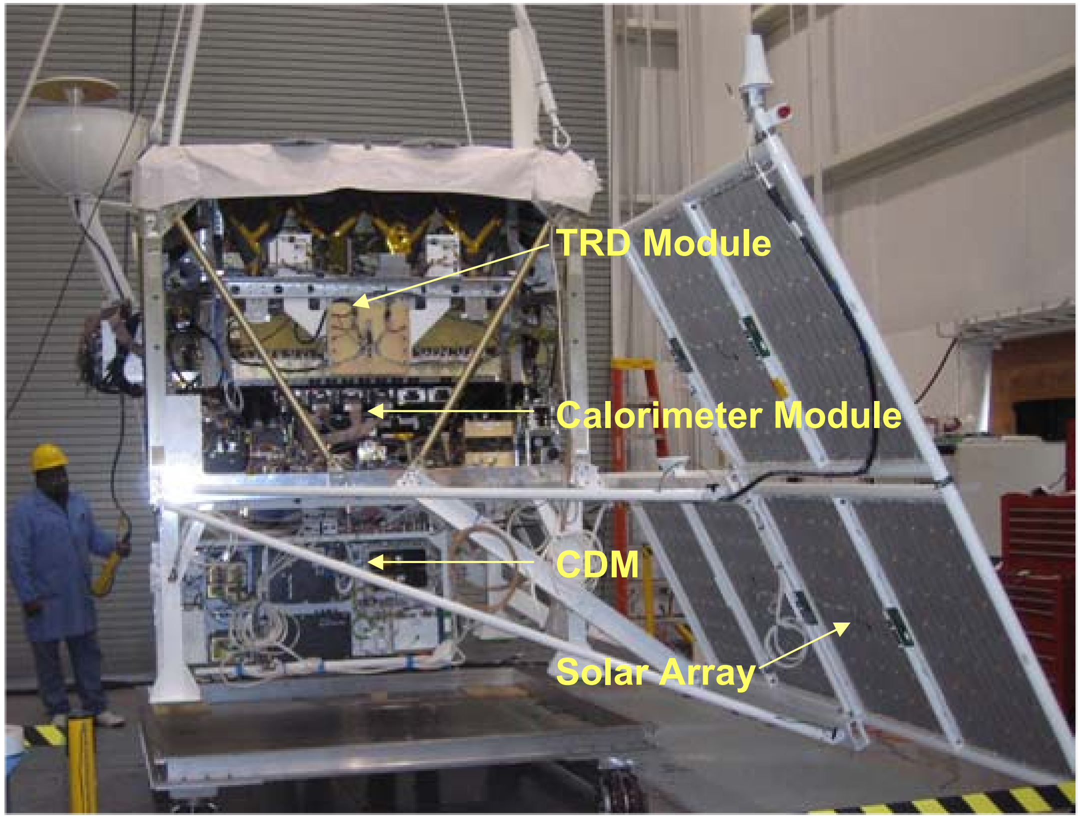
measurement of B/C ratio up to **500 GeV/n**
(test of propagation models)

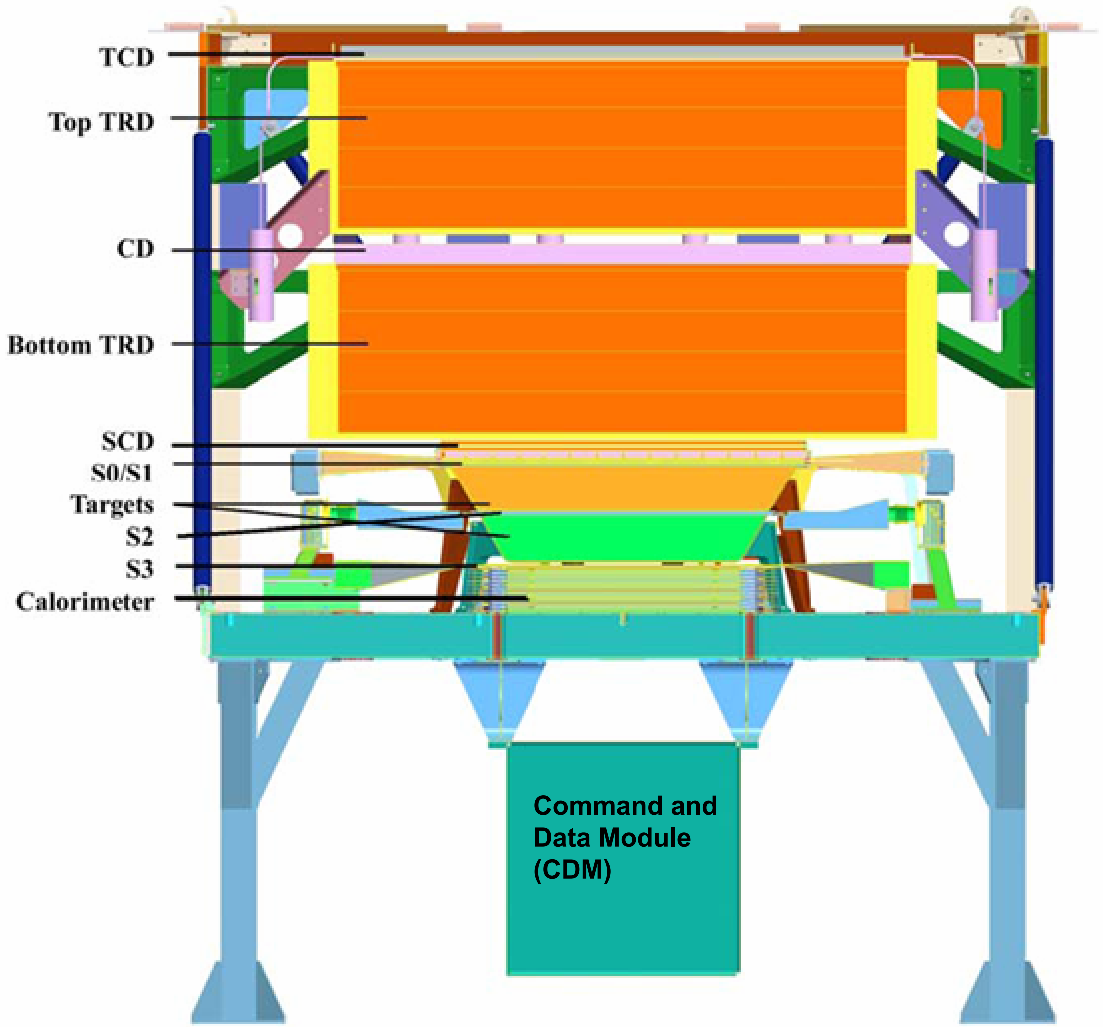
CREAM can measure individual energy spectra and elemental composition ($1 \leq Z \leq 26$ and above) of cosmic rays **up to 1000 TeV**

Search for:
- a **cutoff in the proton spectrum** at E ≥ 100 TeV
- a change in the elemental composition approaching the “knee”

CREAM-1 instrument

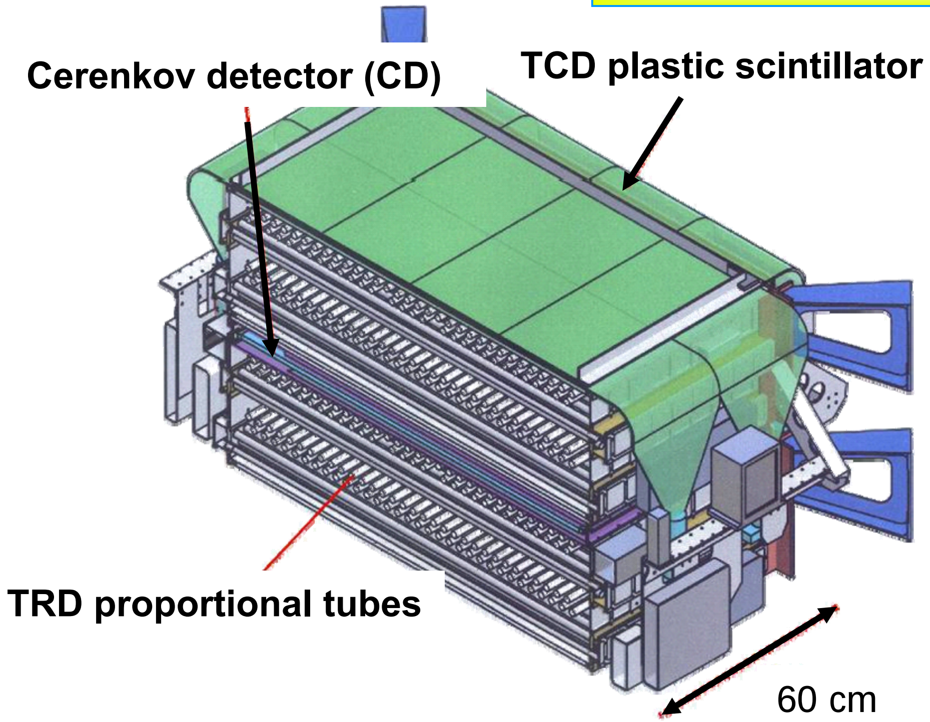
- ➢ 3 independent charge measurements
  - Timing-based Charge Detector (TCD)
  - Pixelated Silicon Detector (SCD)
  - Scintillating fiber Hodoscopes
- ➢ 2 independent energy measurements
  - Transition Radiation Detector (Z > 3)
  - Tungsten Sci-Fi calorimeter (Z ≥ 1)
- ➢ Tracking provided by TRD and CAL



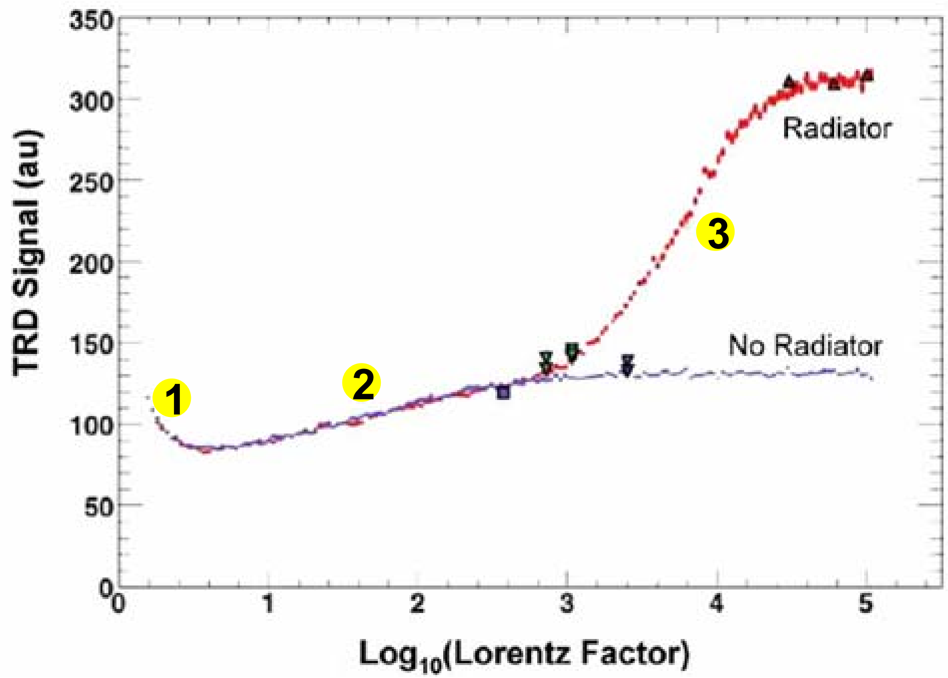


- ➢ Collecting Power: ~ 0.3 m^2 sr for Z=1, 2
  ~ 1.3 m^2 sr for Z>3
- ➢ Launched from McMurdo base
  42 days flight (Dec. 16th 2004- Jan. 27th 2005)

TRD module



- 512 single-wire mylar thin-walled proportional tubes
- 2 cm diameter tubes filled with Xe/CH_4 (95/5%) @ 1 atm
- 16 layers of 32 tubes with alternating X/Y orientations
- Tubes embedded in polystyrene foam radiator
- Dual gain Amplex readout
- Sensitivity to Z>3   Resolution on impact point < 5 mm
- CD: 1 cm Acrylic radiator with WS bars readout

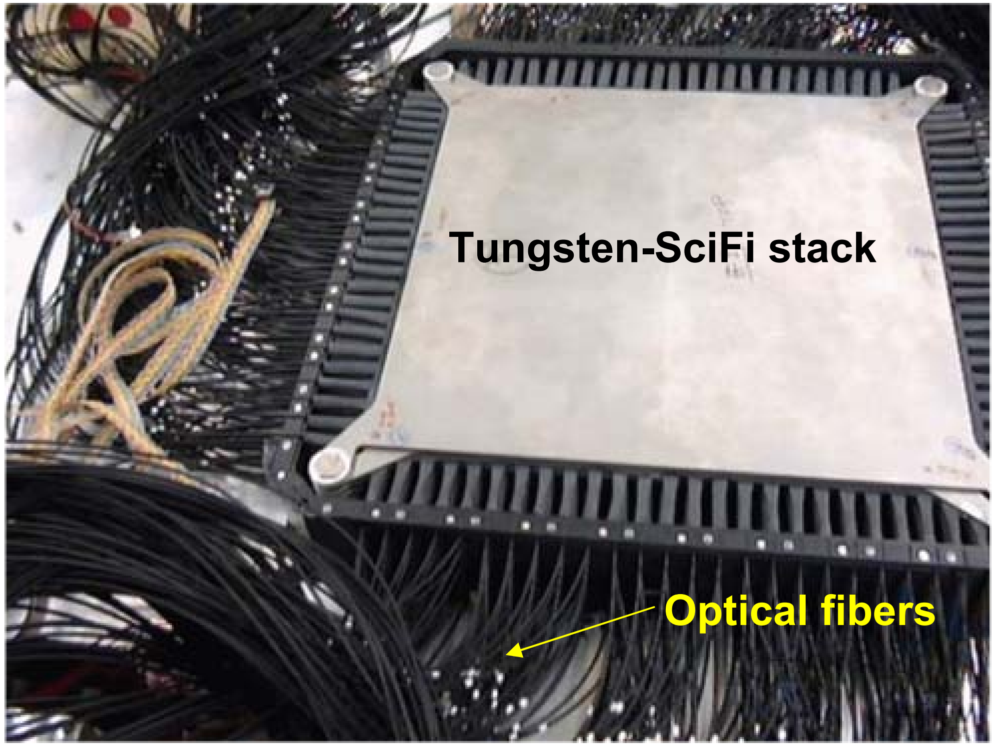


- Energy measurement in different intervals:
  1. Cerenkov signal $1.35 < \gamma < 10$
  2. Multiple dE/dx sampling $10 < \gamma < 500$
  3. TR X-rays $500 < \gamma < 20000$
- Calibration at CERN with p, e^- and π beams.

  $\Rightarrow$ Geant4 based MC tuning

  P.J. Boyle et al. *Proc. of 28° ICRC (2003) 2233*

Calorimeter

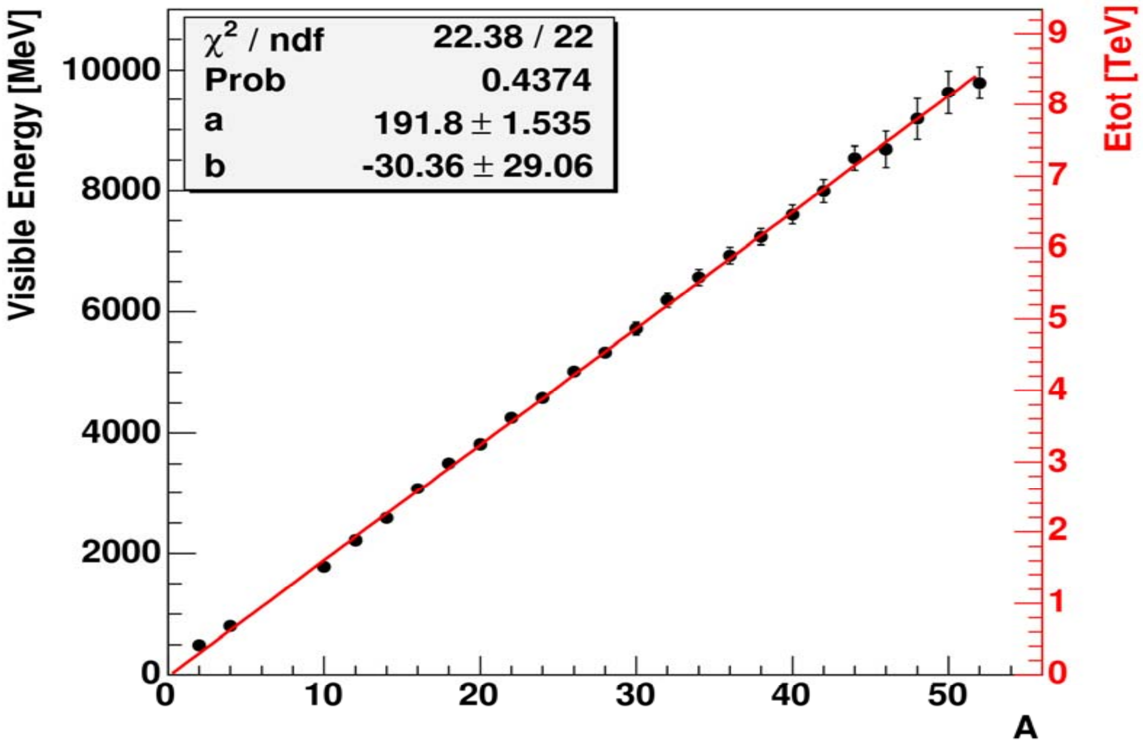


- Preceded by a graphite target (~ 0.5 λ_{int})
- Active area 50 × 50 cm^2
- Longitudinal sampling : 3.5 mm W (1 X_0) + 0.5 mm Sci-Fi
- Transverse granularity : 1 cm (19 fibers ~ 1 Moliere radius)
- Total of 20 layers (**20 X_0** , ~ 0.7 λ_{int}): alternate X-Y views
- 2560 channels (3 gain ranges) readout by 40 HPDs

Ion beam test

A/Z = 2 @ 158 GeV/n

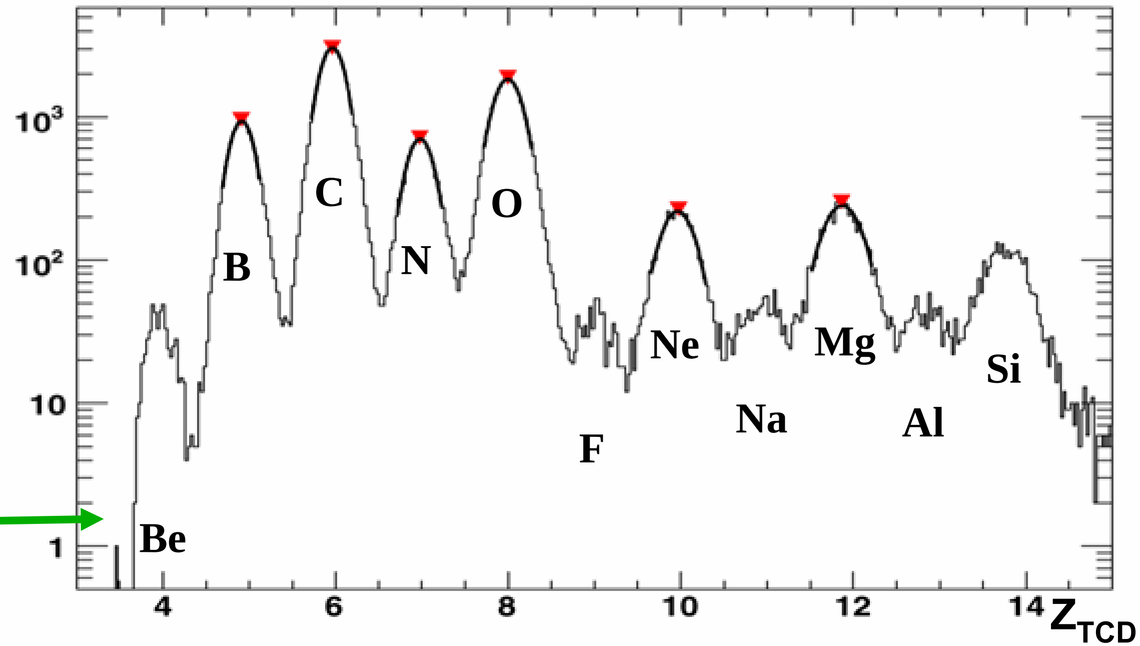
Good linearity up to ~ 8.2 TeV

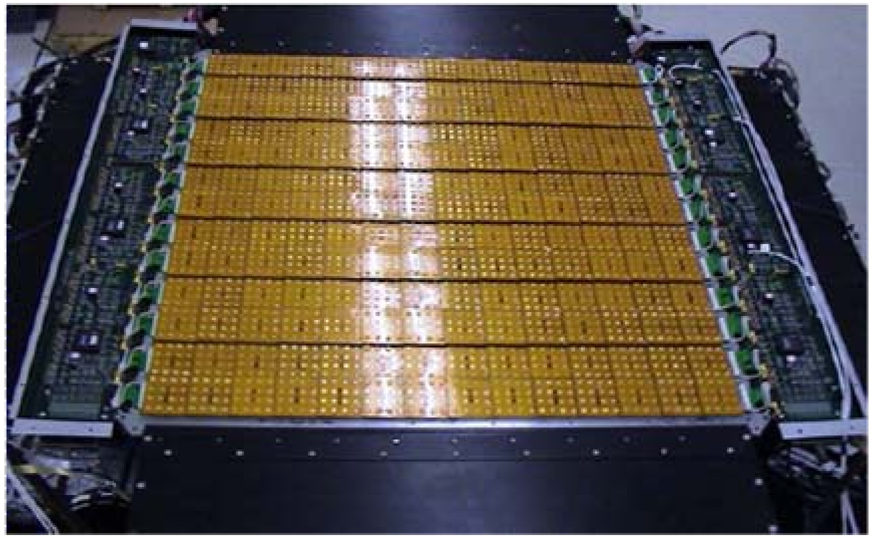


Cosmic-ray charge identification

➢ Timing Charge Detector (TCD)

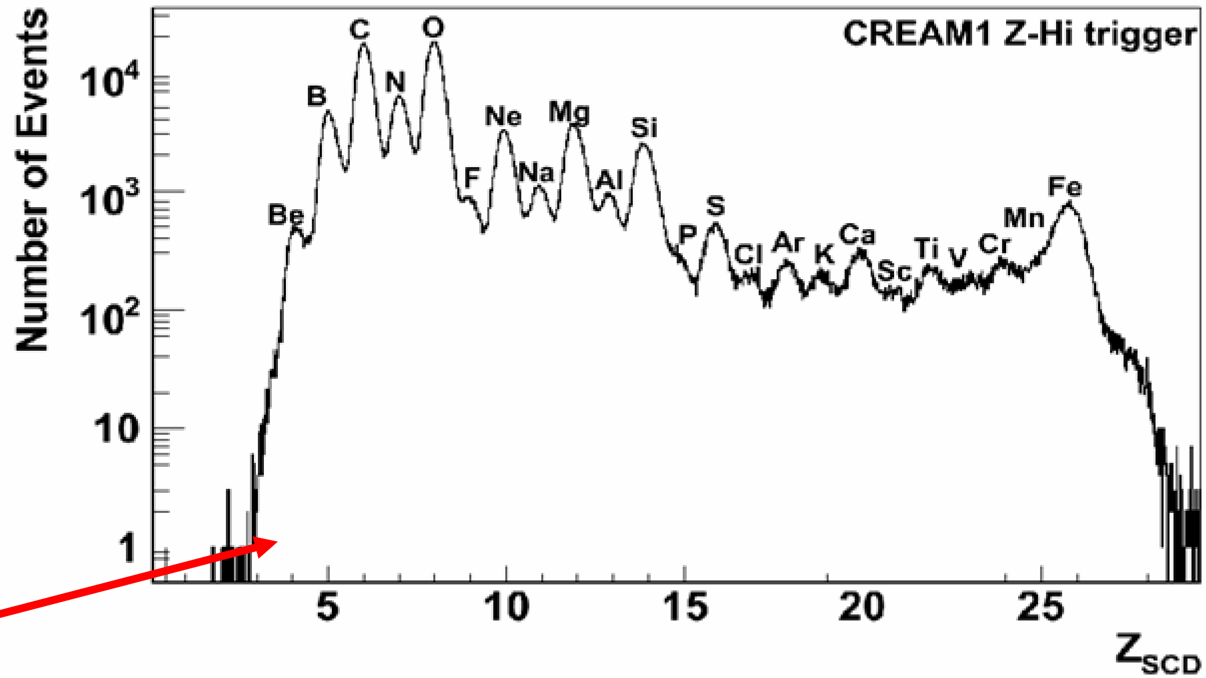
- 5 mm thick fast (< 3 ns) plastic scintillator paddles
- charge measurement from H to Fe (σ~ 0.2-0.35 e)
- backscatter rejection by fast pulse shaping





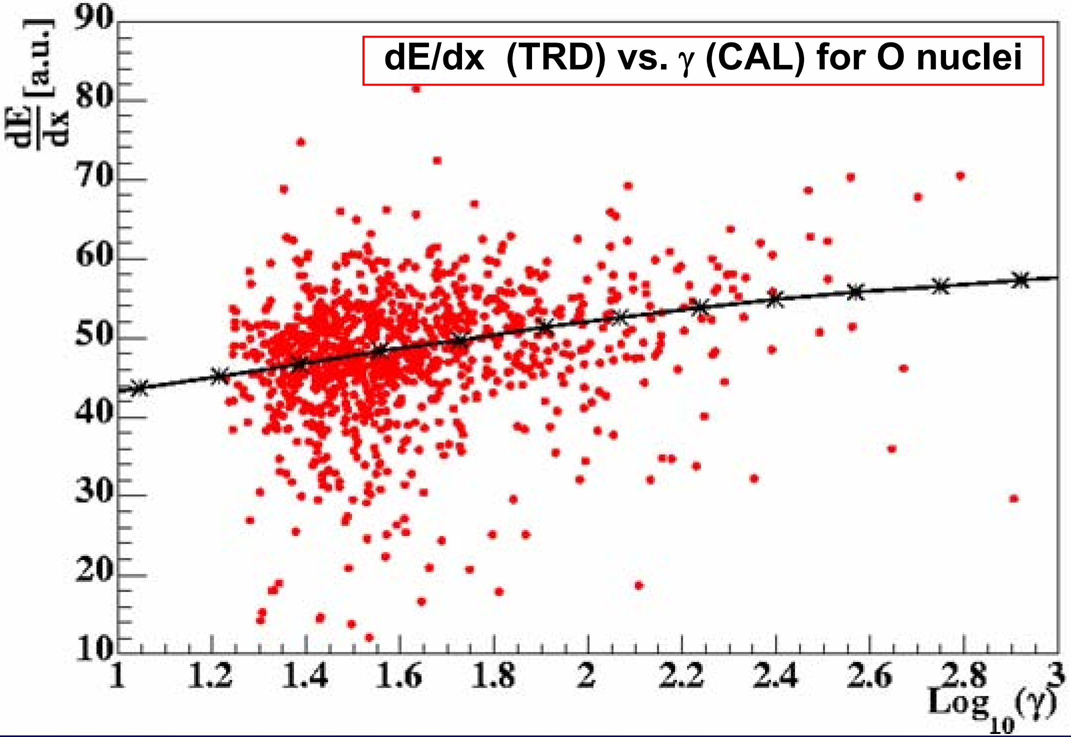
➢ Silicon Charge Detector (SCD)

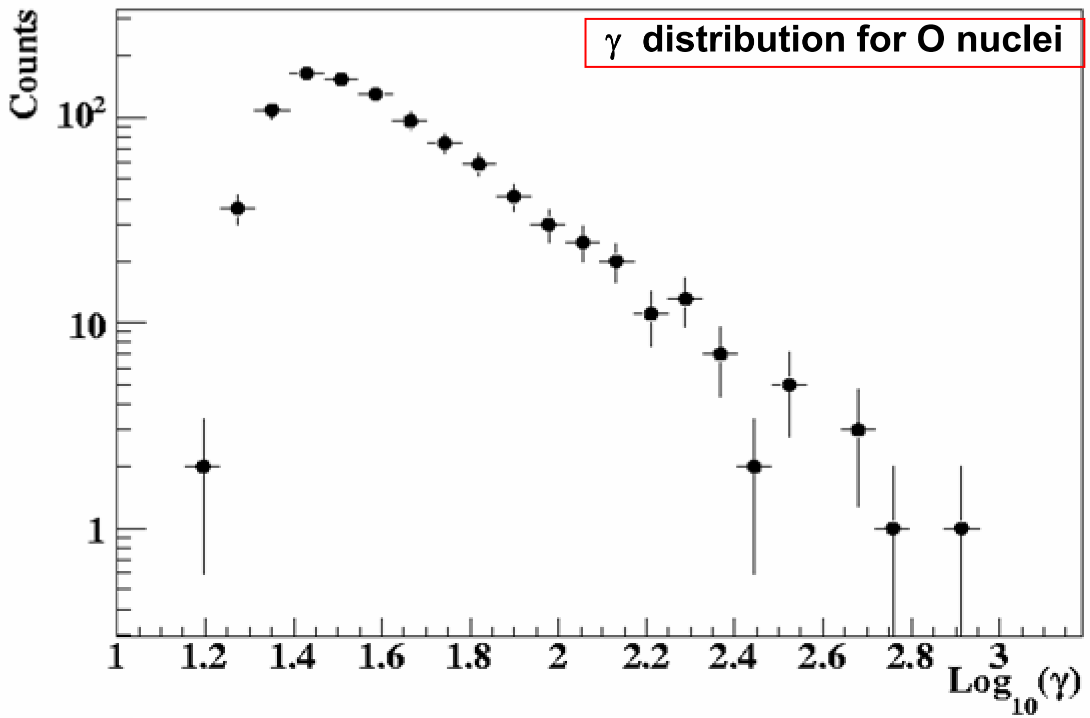
- 2912 Si pixels, 380 μm thick. Active area ~ 0.65 m^2
- charge measurement from Z=1 to Z=26 (σ~ 0.1-0.3 e)

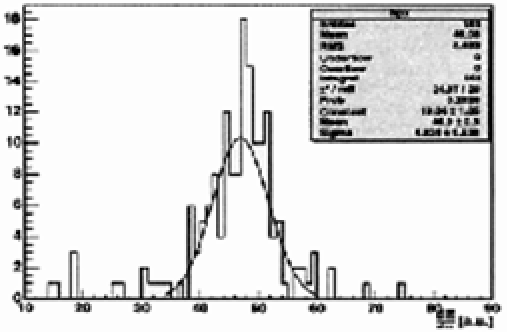


Selection of Oxygen and Carbon samples for cross-calibration

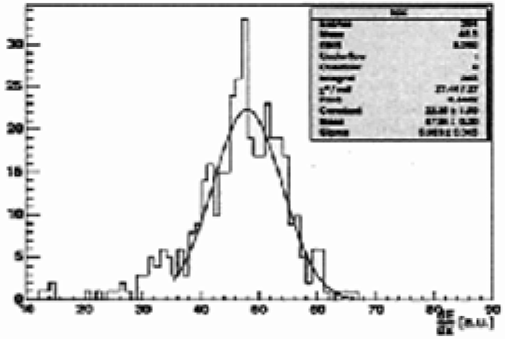
- TRD track reconstructed with at least 4 hit tubes in each view
- CAL shower imaged with shower axis length > 6 X_0
- Track parameters and dE/dx in TRD are extracted with a likelihood fit
- dE/dx's independently measured in X and Y views are required to be compatible within 20%
- Lorentz factor γ is calculated using CAL estimate of the primary particle energy
- Charge identification is based on TCD paddles crossed by primary particle track





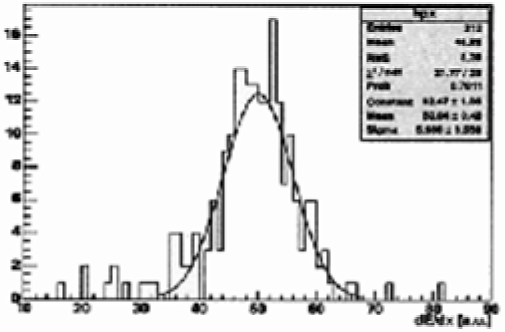


$1.2 < \mathrm{Log}_{10}\,\gamma_{CAL} < 1.4$

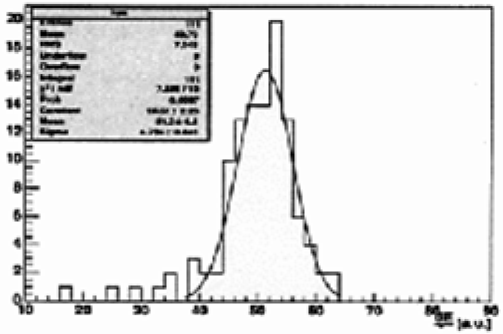


$1.4 < \mathrm{Log}_{10}\,\gamma_{CAL} < 1.6$

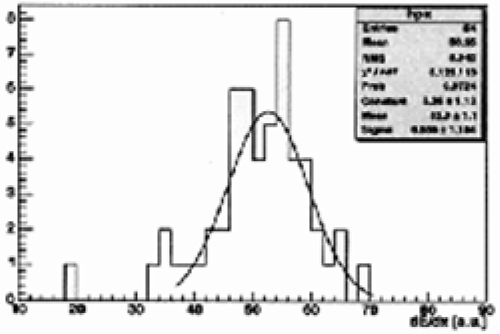
Oxygen selection



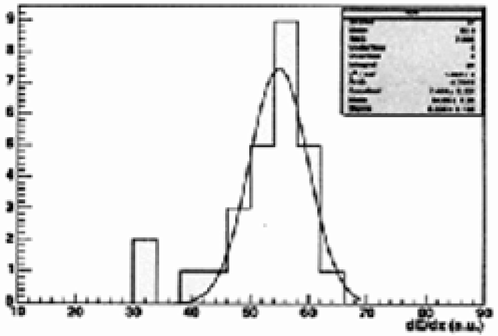
$1.6 < \mathrm{Log}_{10}\,\gamma_{CAL} < 1.8$



$1.8 < \mathrm{Log}_{10}\,\gamma_{CAL} < 2.0$



$2.0 < \mathrm{Log}_{10}\,\gamma_{CAL} < 2.2$



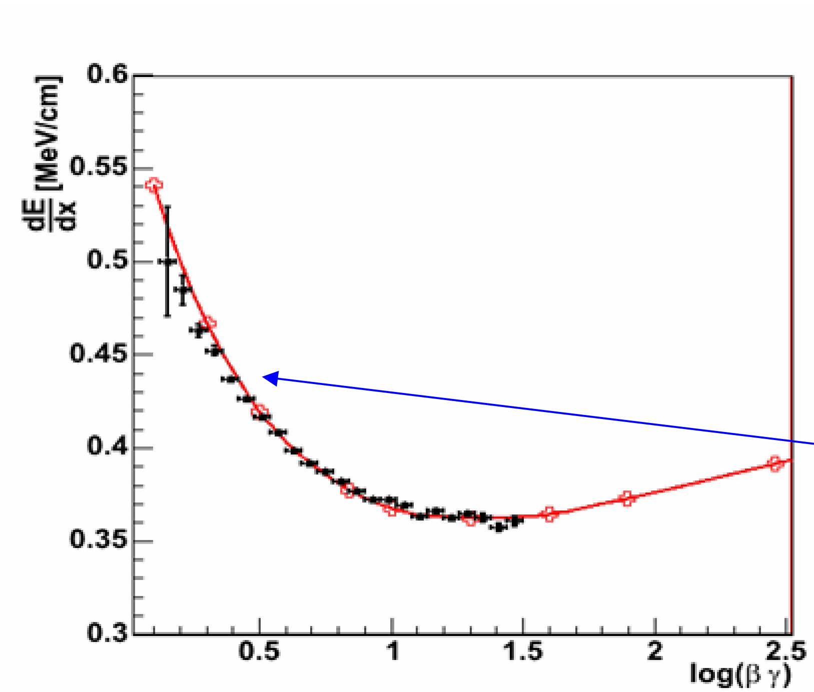
$2.2 < \mathrm{Log}_{10}\,\gamma_{CAL} < 2.4$

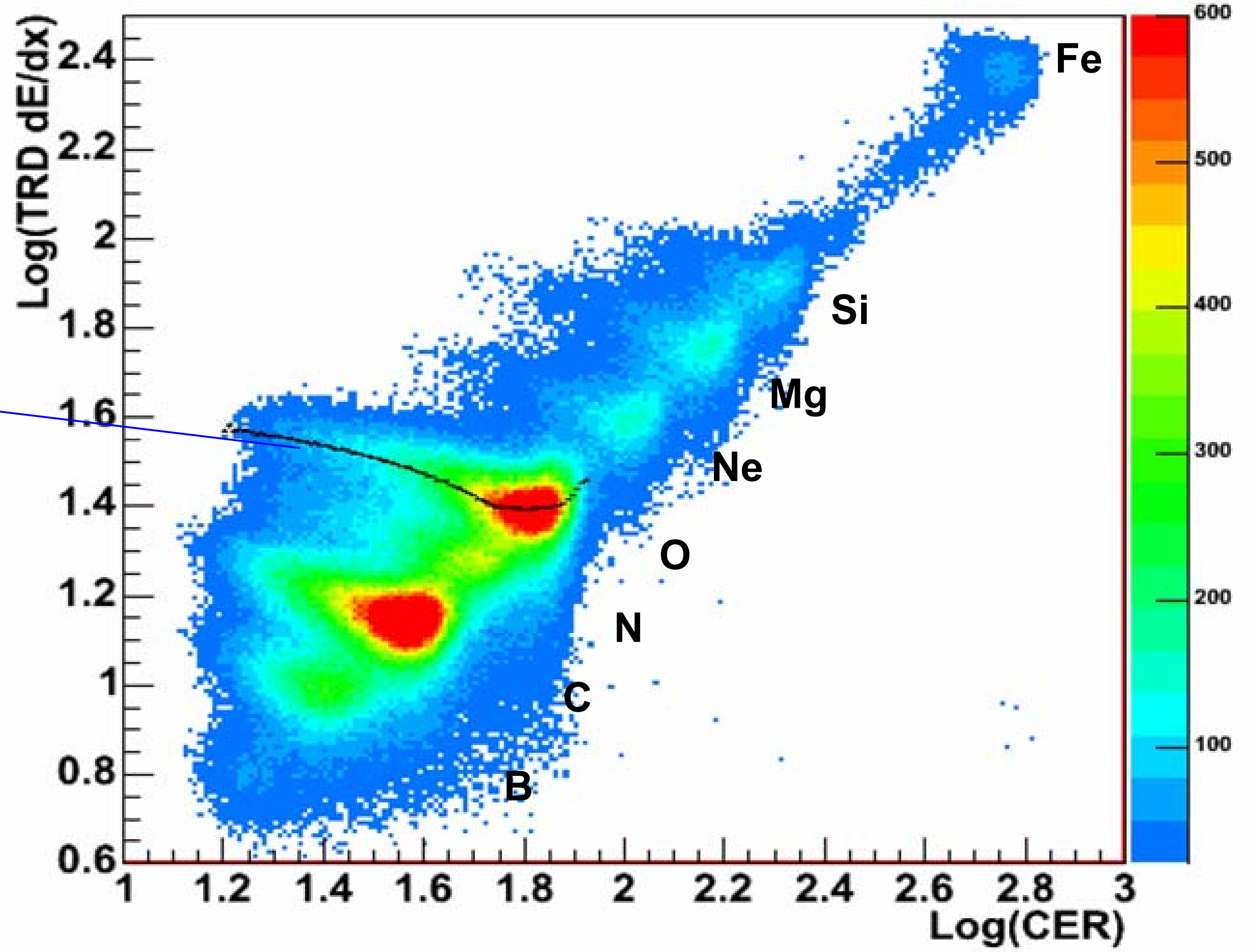
dE/dx distribution in different energy intervals

The range of measured γ in the TRD vs. CAL scatter plot is divided in equal logarithmic bins wherein mean values and standard deviations of both γ and dE/dx are calculated

TRD-CD calibration with flight data

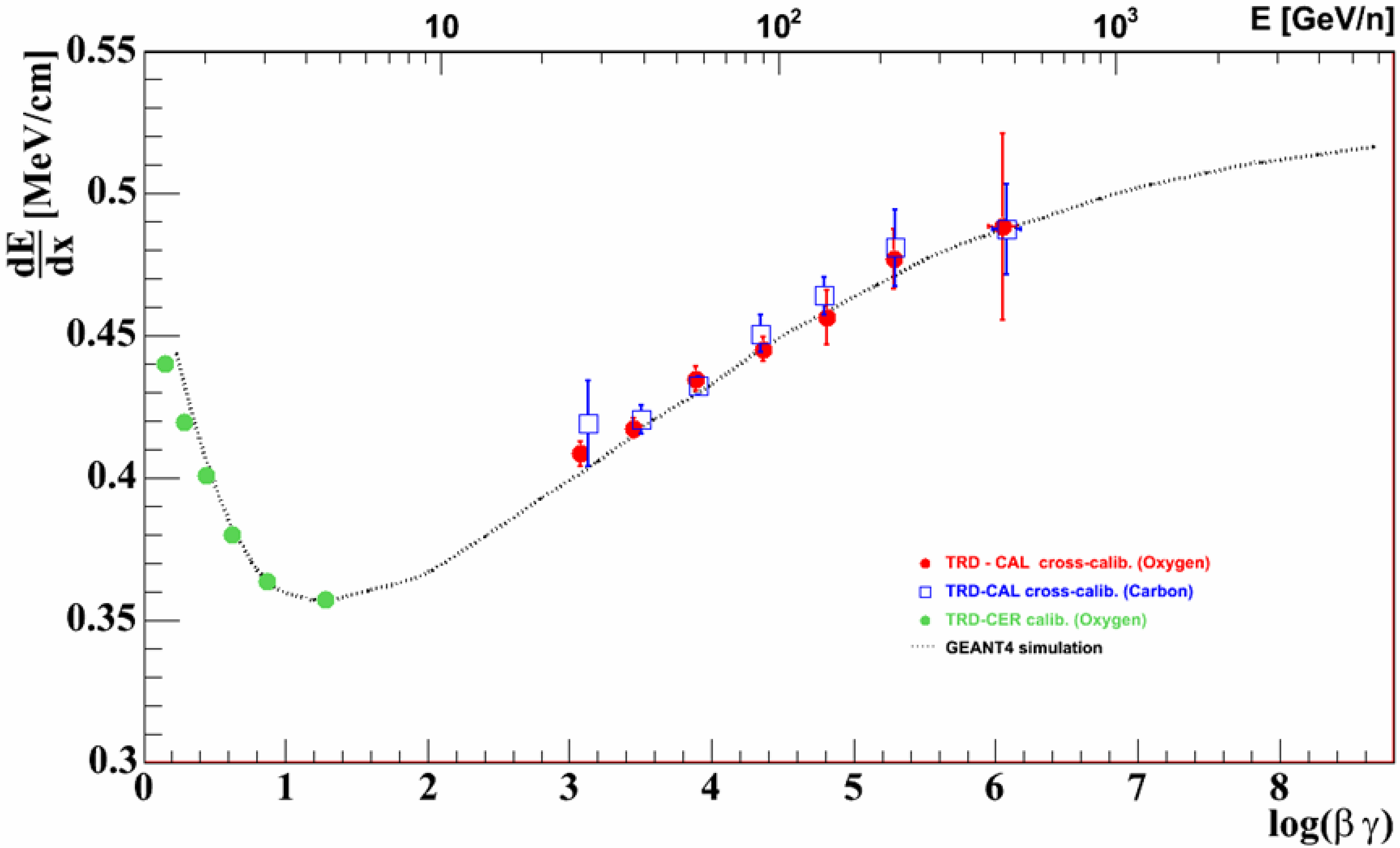
- TRD dE/dx vs. CD signal ⇒ calibration of the TRD response below the minimum of ionization (m.i.)
- Scale factor to convert dE/dx from arbitrary units to MeV/cm is obtained by matching the m.i. of O nuclei to MC simulated curve





TRD-CAL cross-calibration with flight data

- About 980 Oxygen and 750 Carbon events are used to cross calibrate in the relativistic rise region ($20 \leq \gamma \leq 400$)
- TRD response is in excellent agreement with MC prediction
- Cross-calibration in the TR region is under study



CREAM Impact site

Conclusions

- The possibility to cross-calibrate the energy scale of TRD and CAL is proved
- Absolute energy scale of the calorimeter was confirmed
- Geant4 based calibration of the TRD tubes is reliable