Energy spectra of cosmic ray nuclei of some hundred MeV/nucleon inside the ISS

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- MIR experiment
- planned experiment inside the ISS
- test exposure to carbon ions from GSI Darmstadt Germany
- cross sections for nuclear fragmentation in heavy targets, experimental results and empirical formula

Experimental results in comparison to model predictions.

Differential Energy Spectrum of Cosmic Ray Iron Ions inside the MIR Space Craft

W. Günther et al. / Radiation Measurements 31 (1999) 585–590

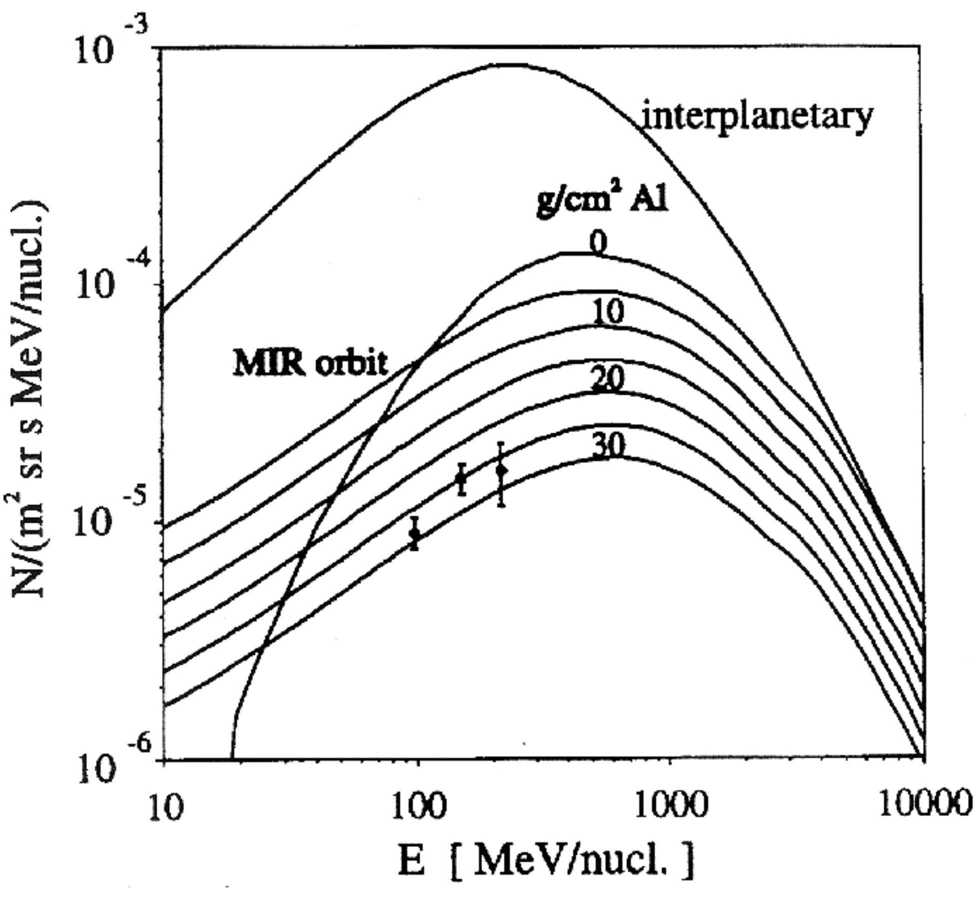
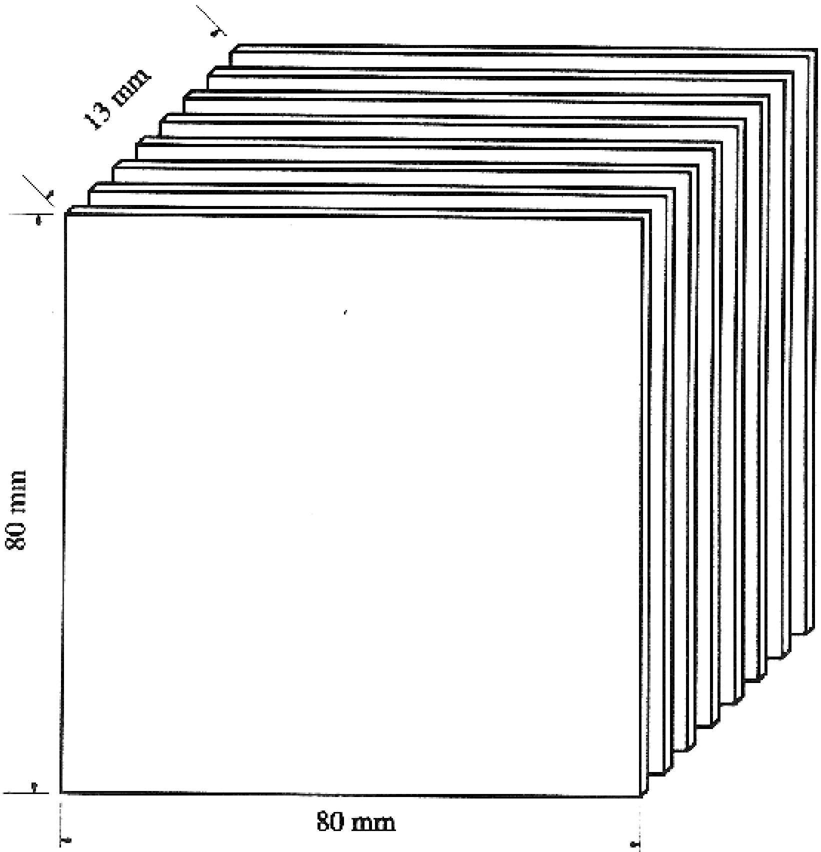


Fig. 6. Experimental results in comparison to model predictions.

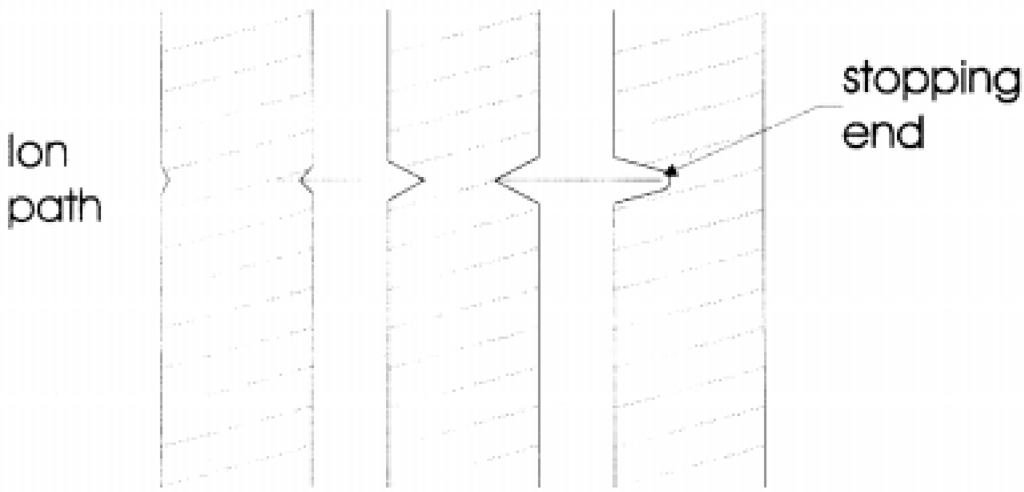
Planned experimental set-up for the ISS experiment



Stack of 20 detector foils
(CR-39 with reduced sensitivity)
(the thickness of each foil is 650 µm)

3 stacks mounted perpendicular to each other

Trajectory of a low energy nuclei in adjacent detector foils



Acceptance as a function of particle range

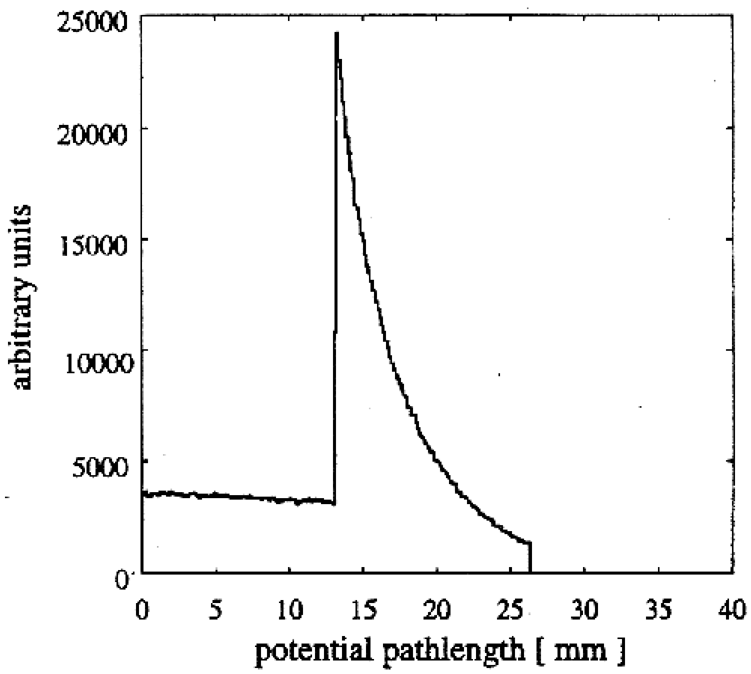


Fig. 4. Distribution of potential path lengths in the experiment.

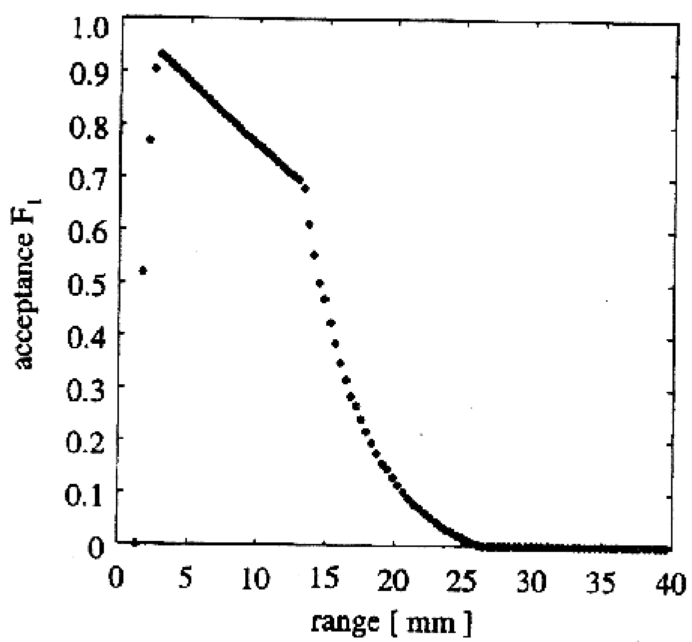
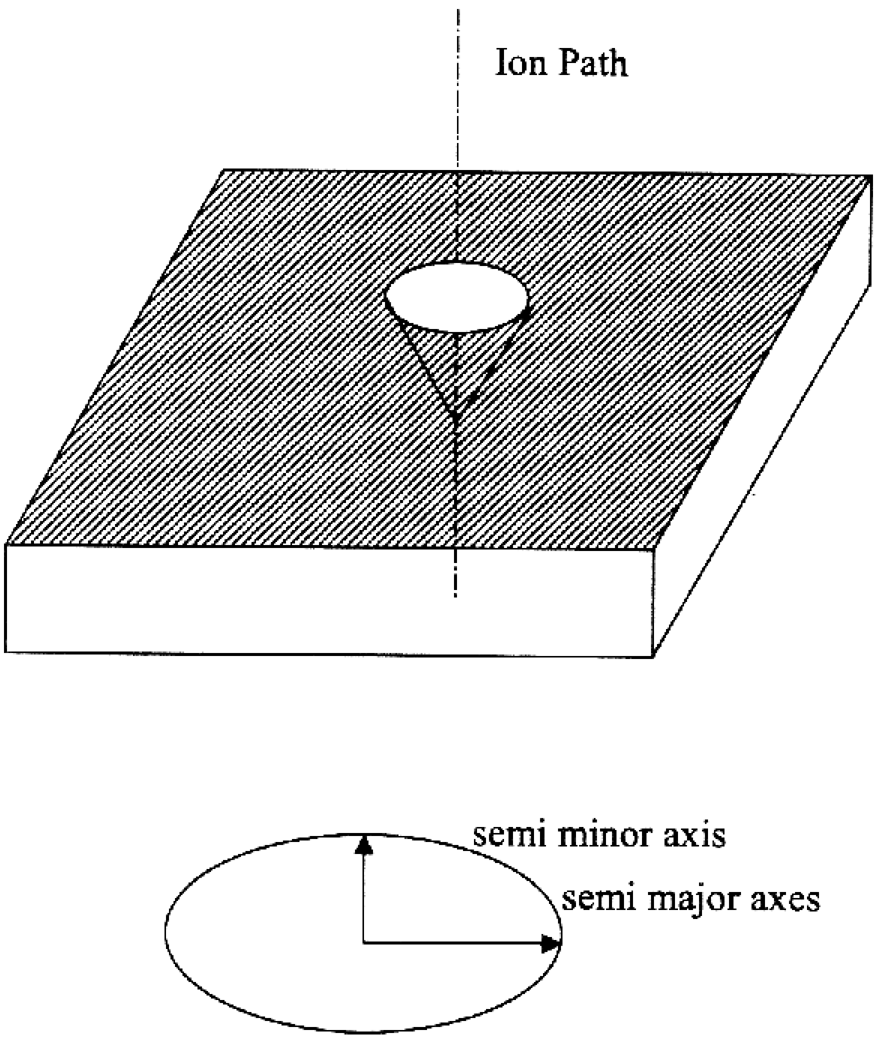


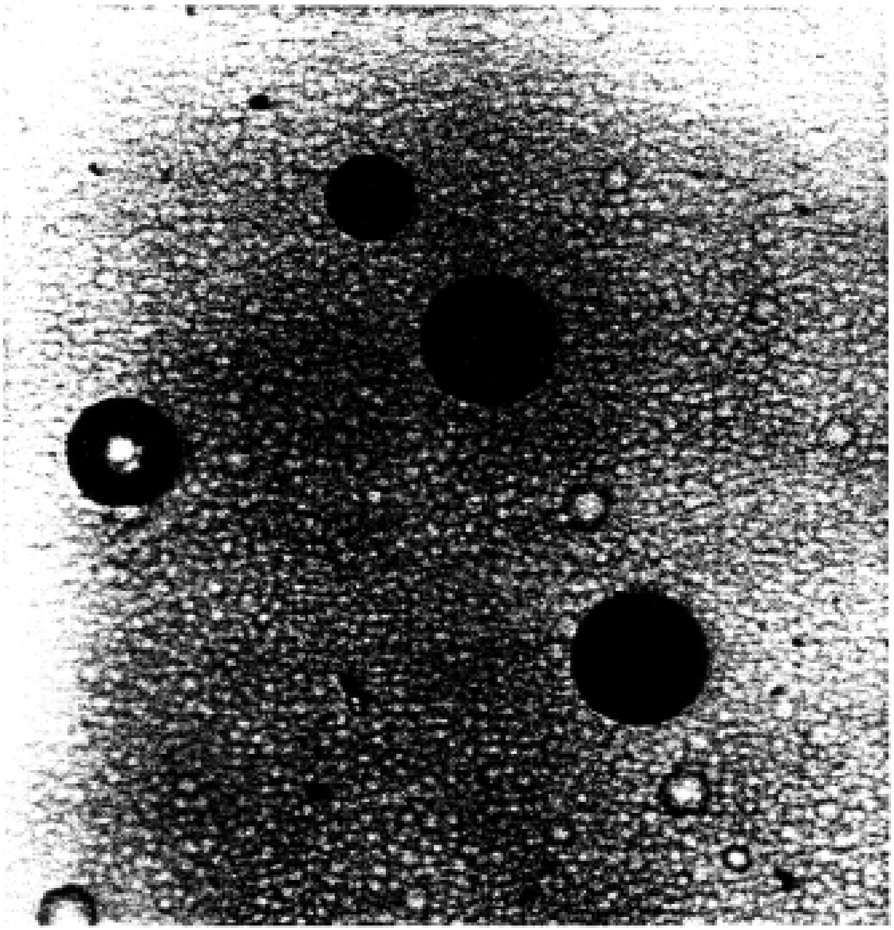
Fig. 5. Acceptance function F_1 to detect a particle with range R in the stack.

Sketch of a typical etch cone

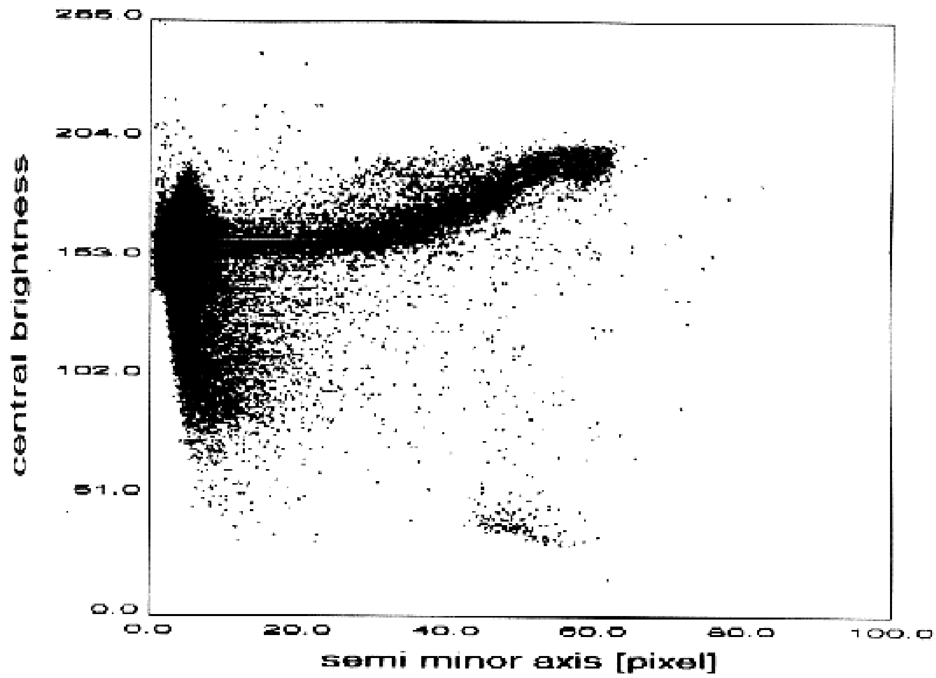


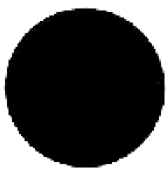
Measured semi minor and semi major axes of the etch cone opening

Video image

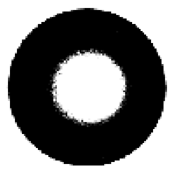


Plot of all automatically measured objects on one test foil side





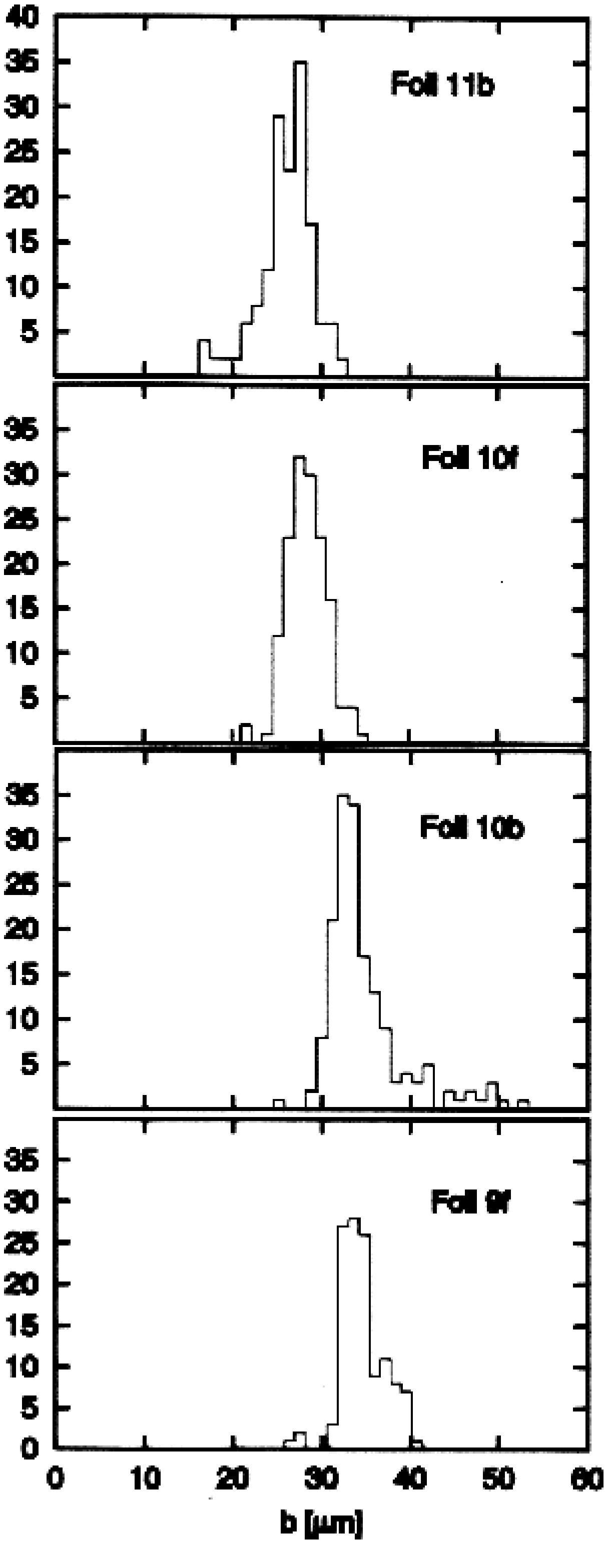
dark



with some brightness
at the centre

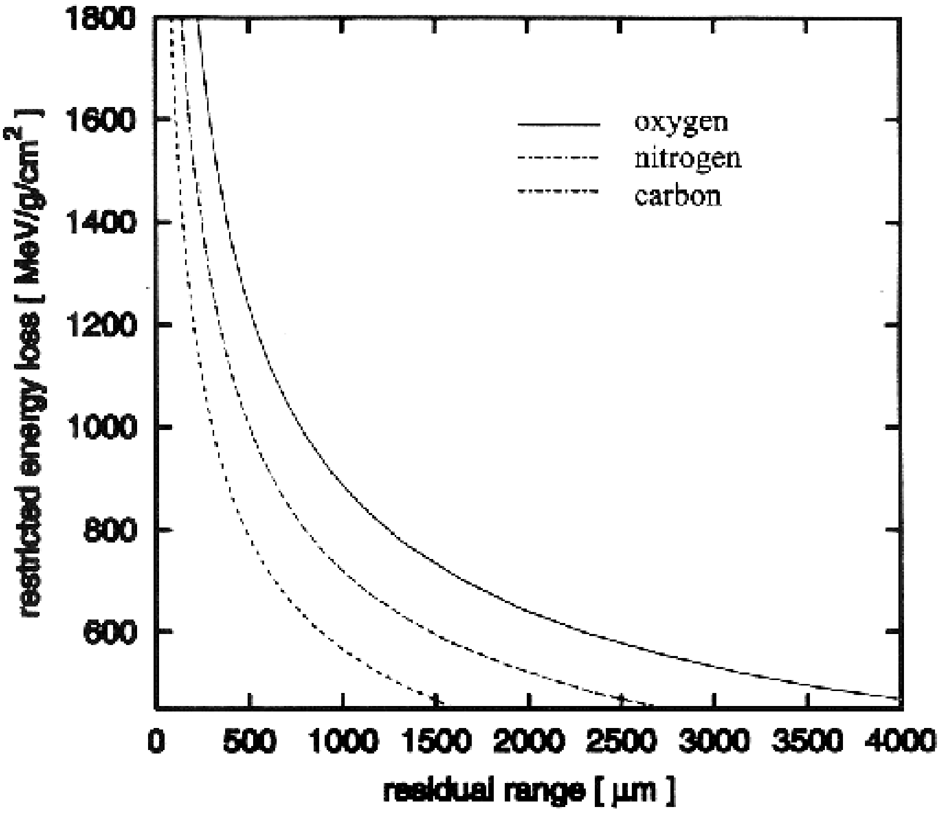
view of the objects as seen in the microscope with the use of reflected light

Histogram of measured semi minor axes b on adjacent foil sides for a test foil exposed to carbon ions



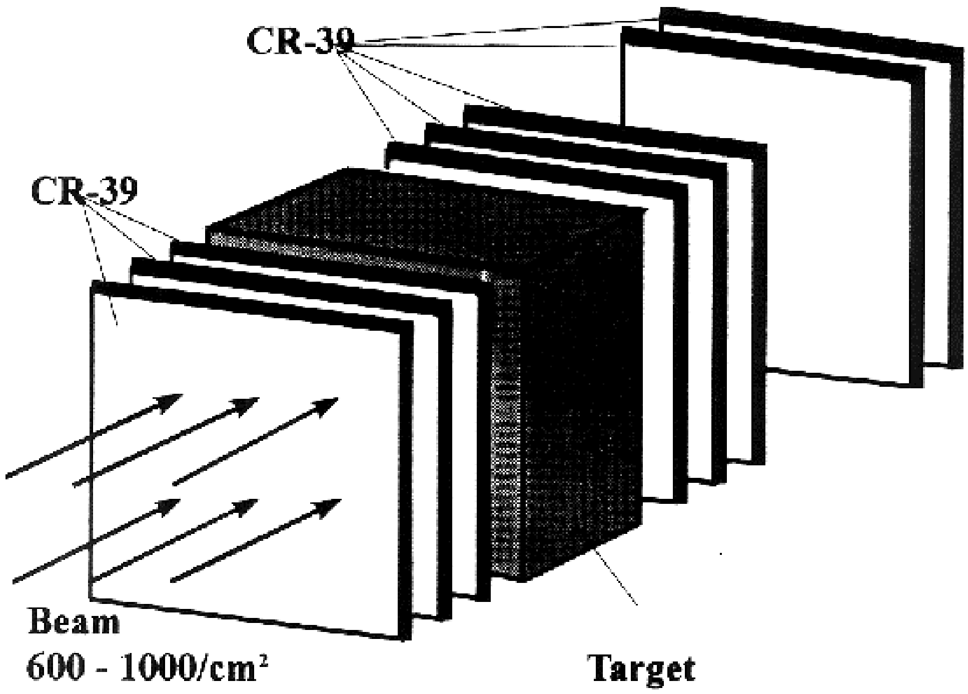
semi minor axes

Calculated energy loss of low energy ions against the residual range in the stack



Detection threshold ≈ 450 MeV cm^2 /g

Experimental set-up



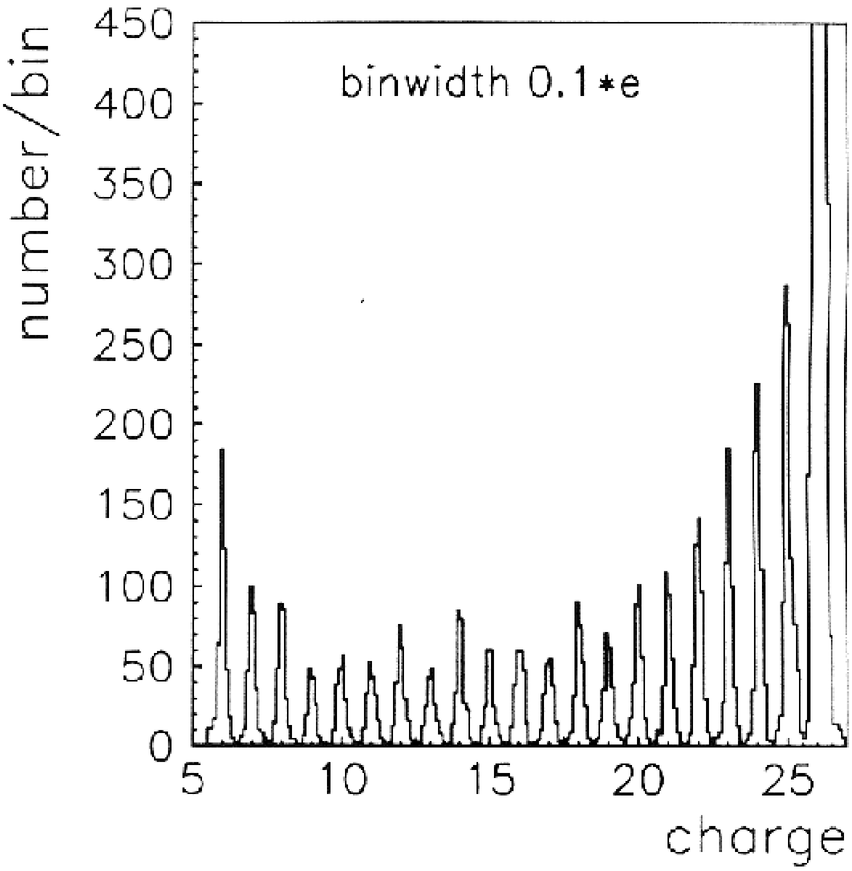
New experiments

Projectile	Target	Energy in the middle of the target [A MeV]	exposed
^{56}Fe	H	670	GSI (Germany)
^{56}Fe	C	670	GSI (Germany)
^{56}Fe	Al	410, 590, 650	GSI (Germany)
^{56}Fe	Cu	630	GSI (Germany)
^{56}Fe	Ag	625	GSI (Germany)
^{56}Fe	Pb	615	GSI (Germany)
^{28}Si	H	470	HIMAC (Japan)
^{28}Si	C	470	HIMAC (Japan)
^{28}Si	Al	450	HIMAC (Japan)
^{28}Si	Cu	445	HIMAC (Japan)
^{28}Si	Ag	440	HIMAC (Japan)
^{28}Si	Pb	430	HIMAC (Japan)

Earlier Experiments (same technique)
(Brechtmann, Winkel, Hirzebruch)

Projectile	Target	Energy in the middle of the target [A GeV]	exposed
^{56}Fe	H	1.639	Berkeley (USA)
^{56}Fe	C	1.639	Berkeley (USA)
^{56}Fe	Al	1.662	Berkeley (USA)
^{56}Fe	Cu	1.629	Berkeley (USA)
^{56}Fe	Pb	1.625	Berkeley (USA)
^{28}Si	H	1.05, 2.0, 14.5	Berkeley, Brookhaven
^{28}Si	C	1.05, 2.0, 14.5	Berkeley, Brookhaven
^{28}Si	Al	1.05, 2.0, 14.5	Berkeley, Brookhaven
^{28}Si	Cu	1.05, 2.0, 14.5	Berkeley, Brookhaven
^{28}Si	Ag	1.05, 2.0, 14.5	Berkeley, Brookhaven
^{28}Si	Pb	1.05, 2.0, 14.5	Berkeley, Brookhaven

Charge resolution for projektile fragments produced from 700 A M eV iron projektiles in collisions with Cu nuclei



Propagation calculation

$$\frac{dN_j}{dx} = -\sigma_j \cdot N_j(x) + \sum_{i>j} N_i(x) \cdot \sigma_{ij}$$

with $x = N_A \cdot \rho \cdot t / A$

ρ: target density

t: depth

A: mass number of the target

$N_A = 6.022 \cdot 10^{26}\ kmol^{-1}$

j fragment subscript

i subscript of all possible particles with $Z_i > Z_j$

σ_j total charge changing cross section for charge Z_j

σ_{ij} elemental fragmentation cross section for the reaction $Z_i \rightarrow Z_j$

$N_1(x)$ number of beam particles in a target after a depth x

We will measure:

- Total cross section σ_{14}^{tot}
- Elemental cross section $\sigma_{14\rightarrow j}^{part}$

Parameterisation

$$\sigma_{nucl.}(P,T,F,E_{Proj.}) = \gamma_{PT} \cdot \sigma_{hyd.}(P,T=H,F,E^*) \cdot \begin{cases} 1 & \text{for } A_F < \frac{2}{3} \cdot A_P \\ enhf & \text{else} \end{cases}$$

with: $$enhf = \exp\left(e \cdot A_F{}^f \cdot \left(\frac{2}{3} \cdot A_P - A_F \right) \right)$$

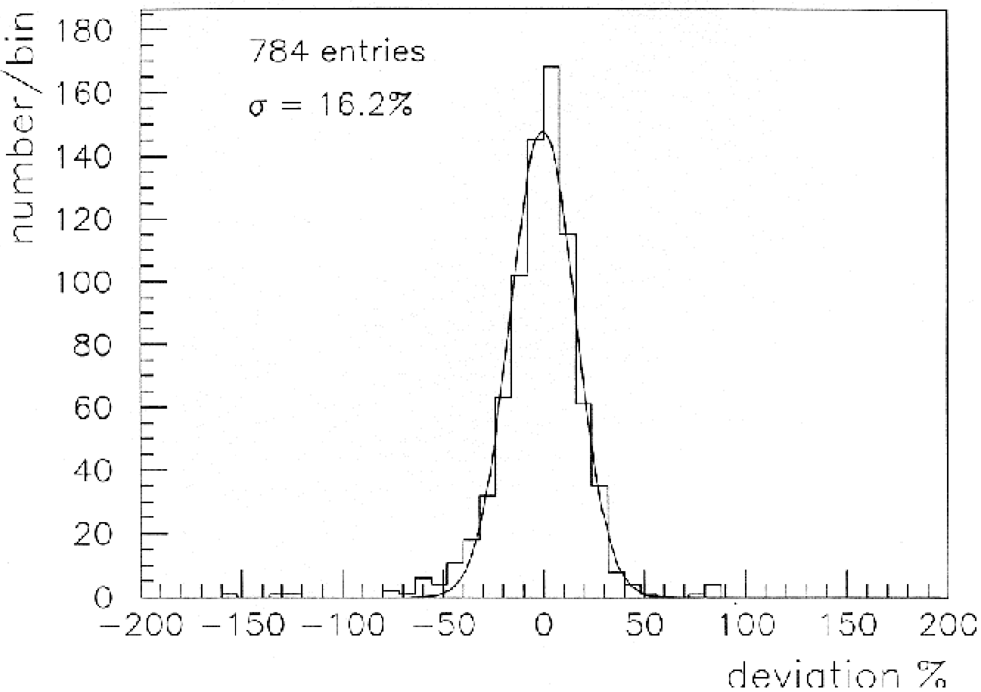
$$\gamma_{PT} = a \cdot A_T^{(-0.0011 \cdot A_P + 0.247)}$$

$$E^* = E_{Proj.} \cdot \frac{A_P^{2/3}}{\left(A_P^{1/3} + A_T^{1/3}\right)^2} \cdot c \cdot A_T^d \cdot \exp\left(\frac{b \cdot \Delta A}{A_T \cdot A_P} \right)$$

$$\sigma_{hyd.}(P,T=H,F,E^*) = \begin{cases} Z_P - Z_F < 15 & \text{Webber et al.} \\ \text{else} & \text{Silberberg und Tsao} \end{cases}$$

calculated parameters.					
a	b	c	d	e	f
0.94	32.	0.3	0.9	1.68	-0.96

The predictions of the parameterisation in comparison with 784 cross section for projectiles from ^{16}O to ^{56}Fe and targets from C to Pb



We found a standard deviation of 15.8% for the used predictions of $\sigma_{theo.}(P,T=H,F,E^*)$ from Webber et al. and Silberberg and Tsao et al. in comparison to the existing data for H target.

=> The elemental fragmentation cross sections for targets heavier than H can be scaled from the cross sections for H by using an energy modulation.