# Secondary Neutron and Cosmic Ray Stud
# ISS Using SSNTD Stacks,
# BRADOS Projects, 2001 - 2003


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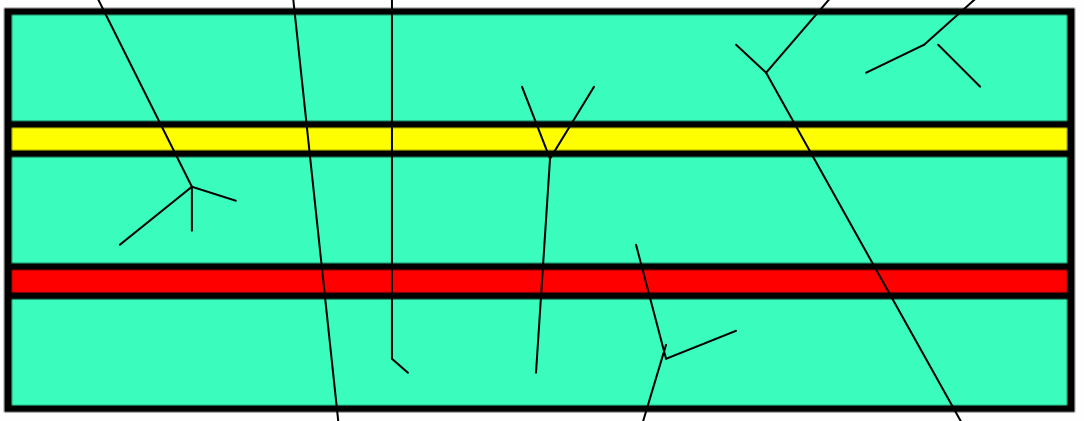
# Brados-1 stack composition




| Layer No. | Material | Density, g/cm$^3$ | Thickness, μm | Thickness, mg/cm$^2$ |
|---|---|---|---|---|
| 1, 3, 5 | CR-39 | 1.3 | 1180 | 153.4 |
| 2 | Ti | 4.52 | 50 | 22.6 |
| 4 | Macrofol | 1.28 | 195 | 24.5 |

Total thickness: 507.3 mg/cm$^2$, Area of 1 sheet: 10 cm$^2$

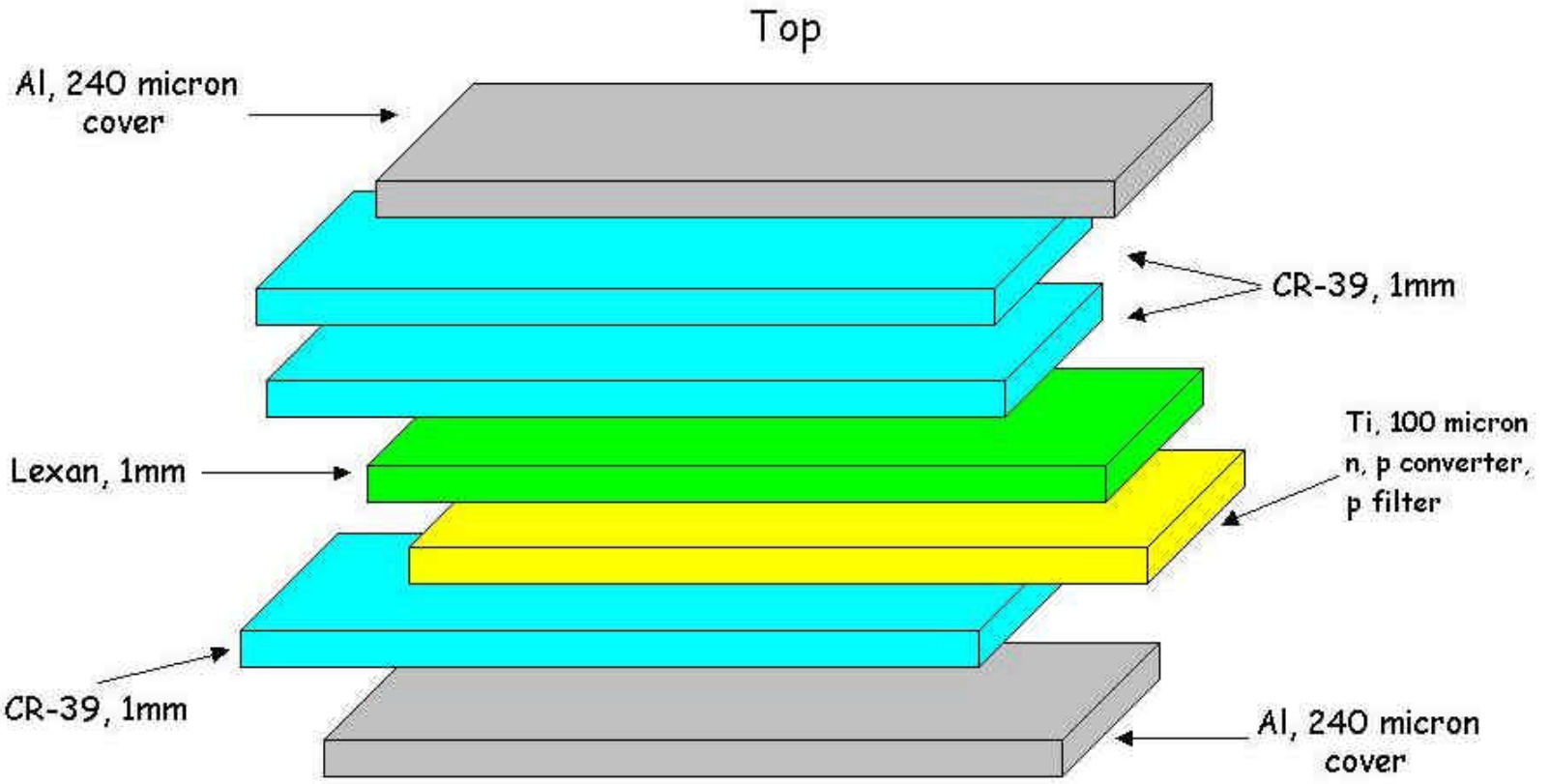
7 of them were placed at different positions in the Service Module

**Stacks launched on 24-02-2001 by Progress 244**

**248 days flight time**

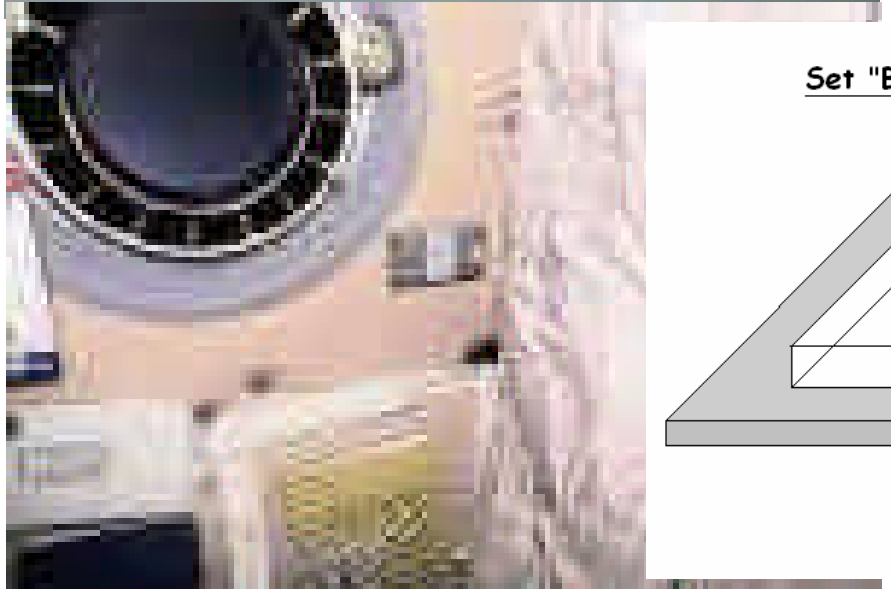
**Returned to Earth on 31-10-2001 by Sayouz TM-32**

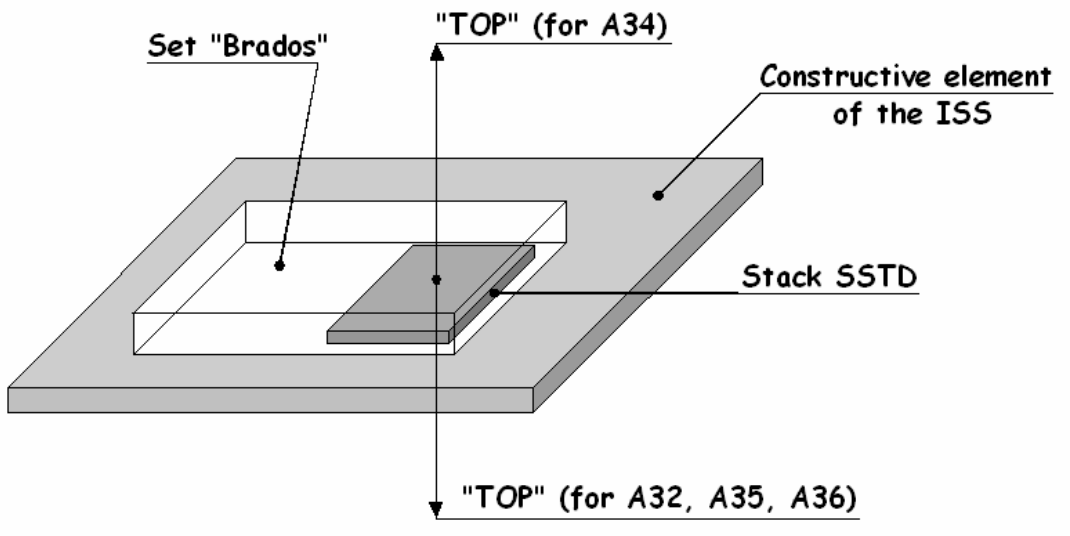
# Composition of BRADOS -3 stacks

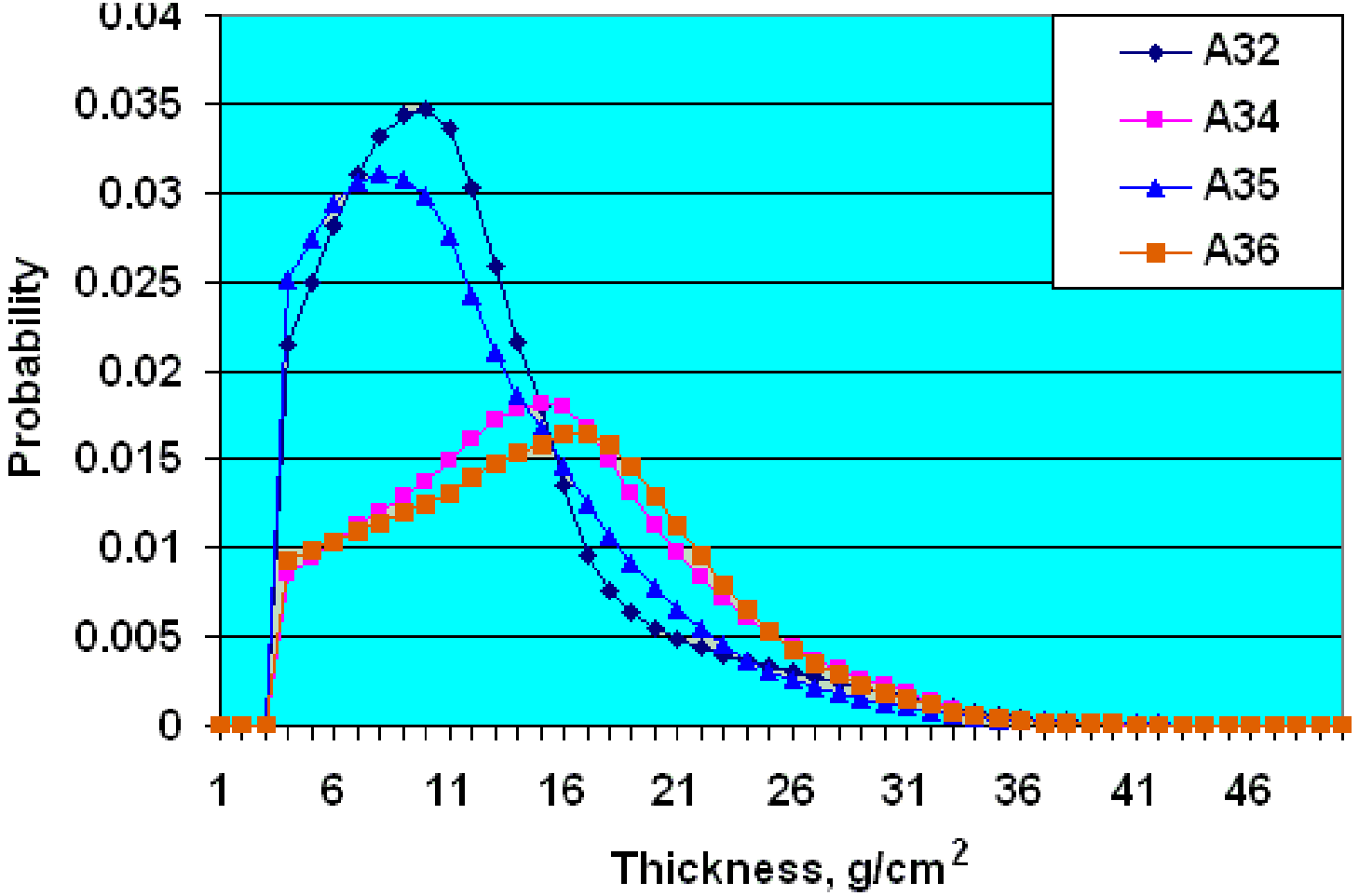


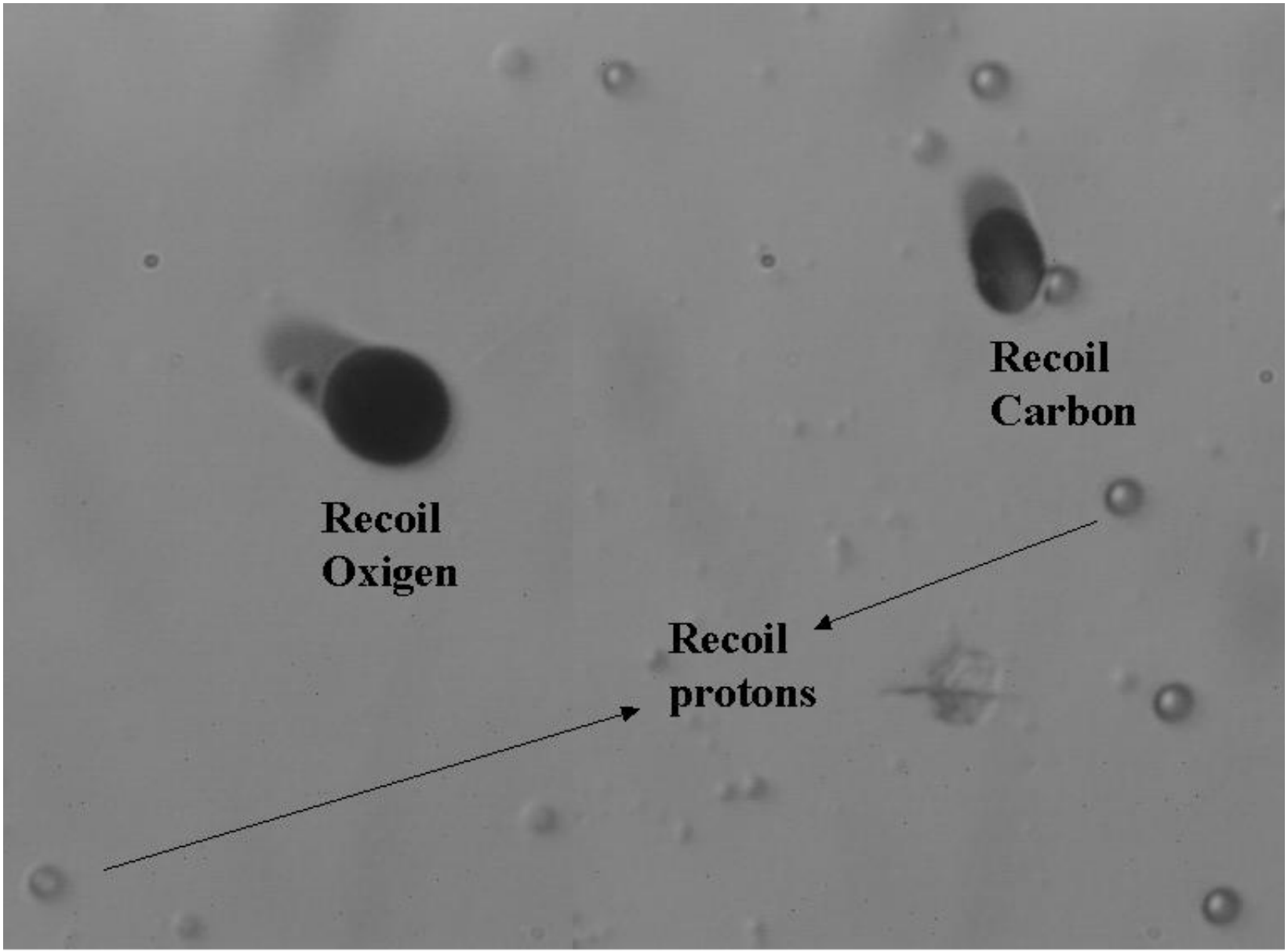

СМ БРАДОЗ
СБОРКА БРАДОЗ-2
PACK BRADOS-2
(A18)

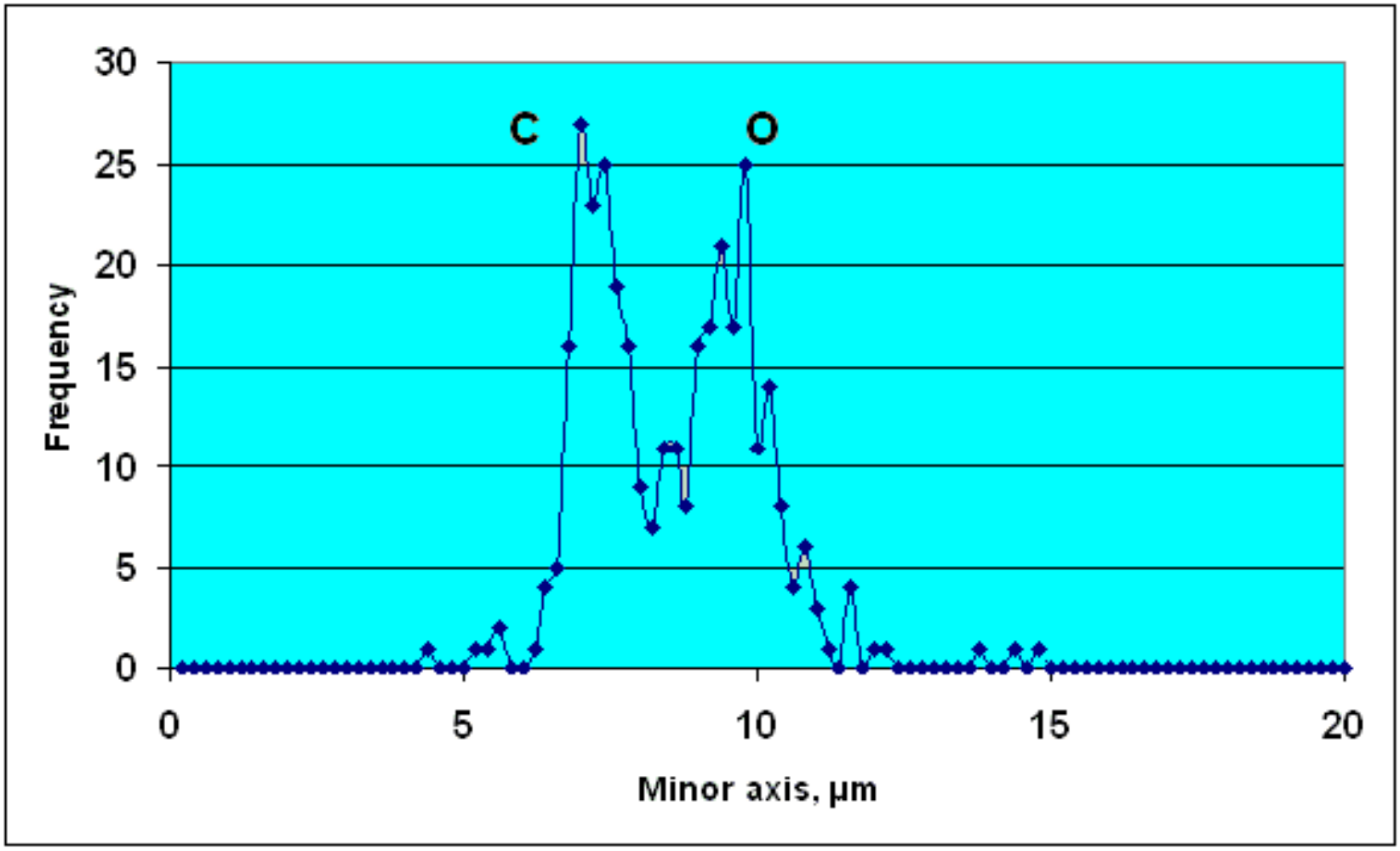
# BRADOS - 3

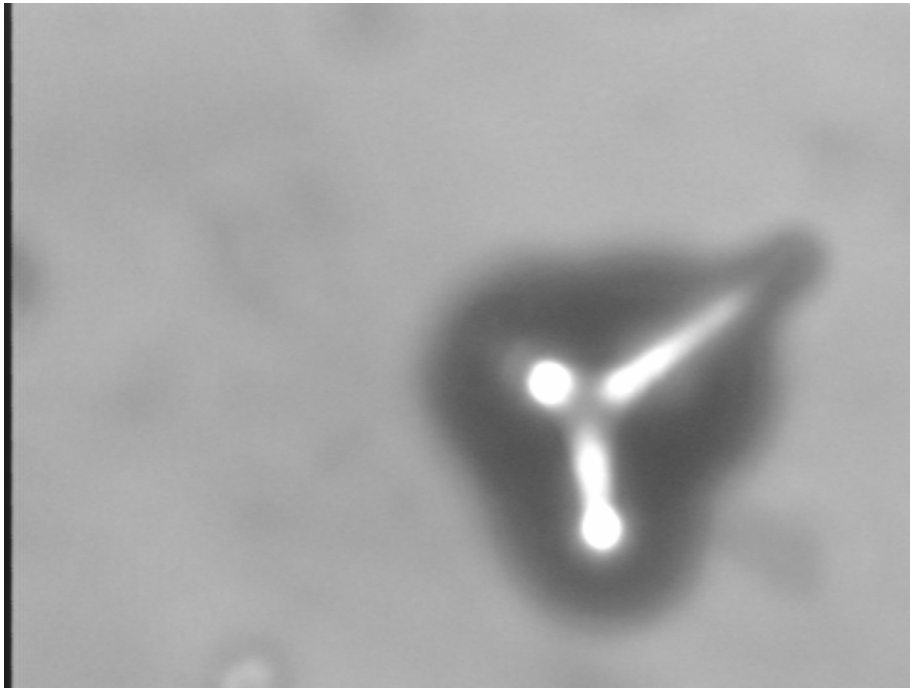



Set "Brados"
"TOP" (for A34)
Constructive element
of the ISS
Stack SSTD
"TOP" (for A32, A35, A36)


0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
Probability
1
6
11
16
21
26
31
36
41
46
Thickness, g/cm2
A32
A34
A35
A36


Recoil
Carbon
Recoil
Oxigen
Recoil
protons


30
25
20
15
10
5
0
Frequency
C
O
0
5
10
15
20
Minor axis, µm

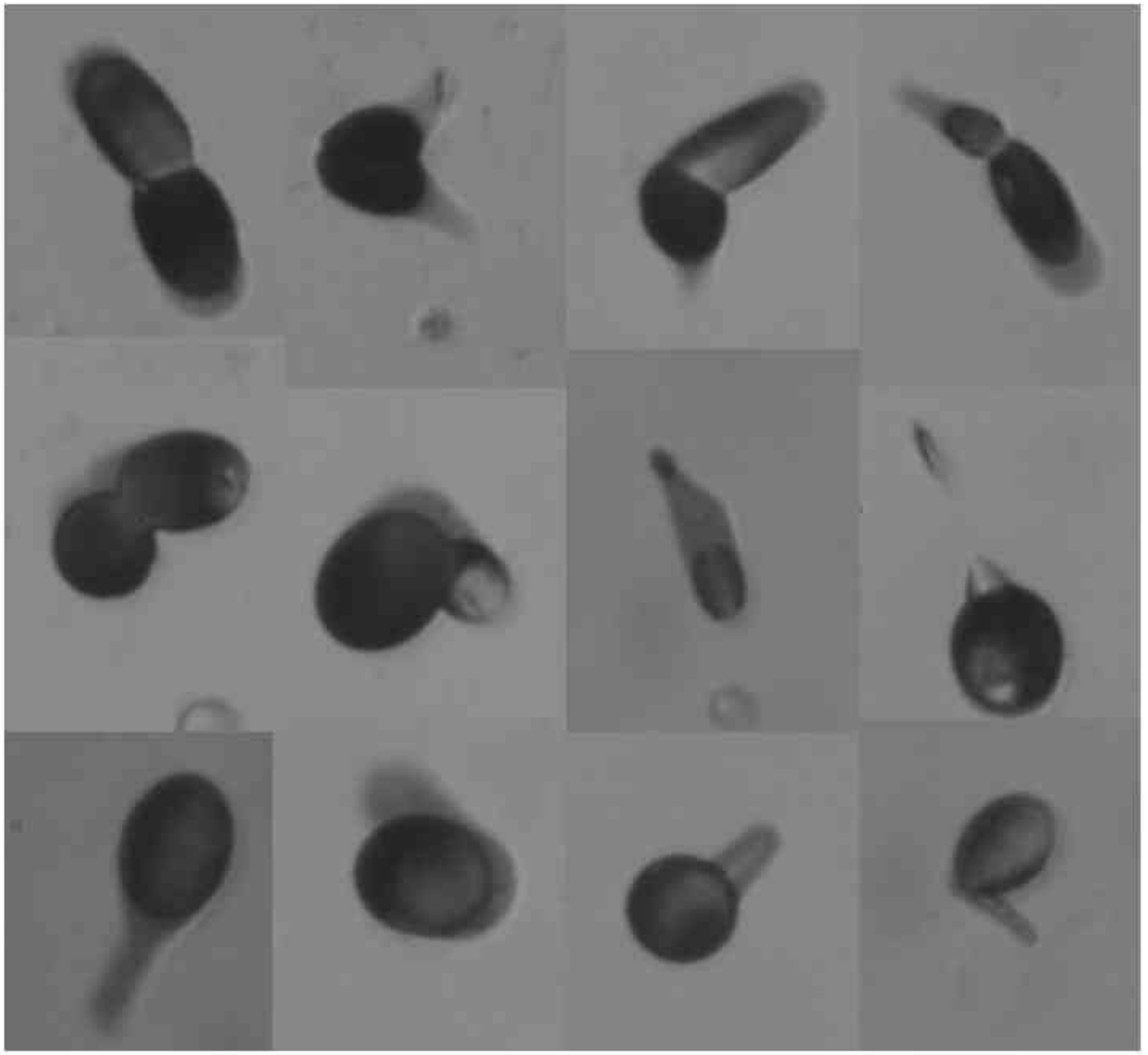


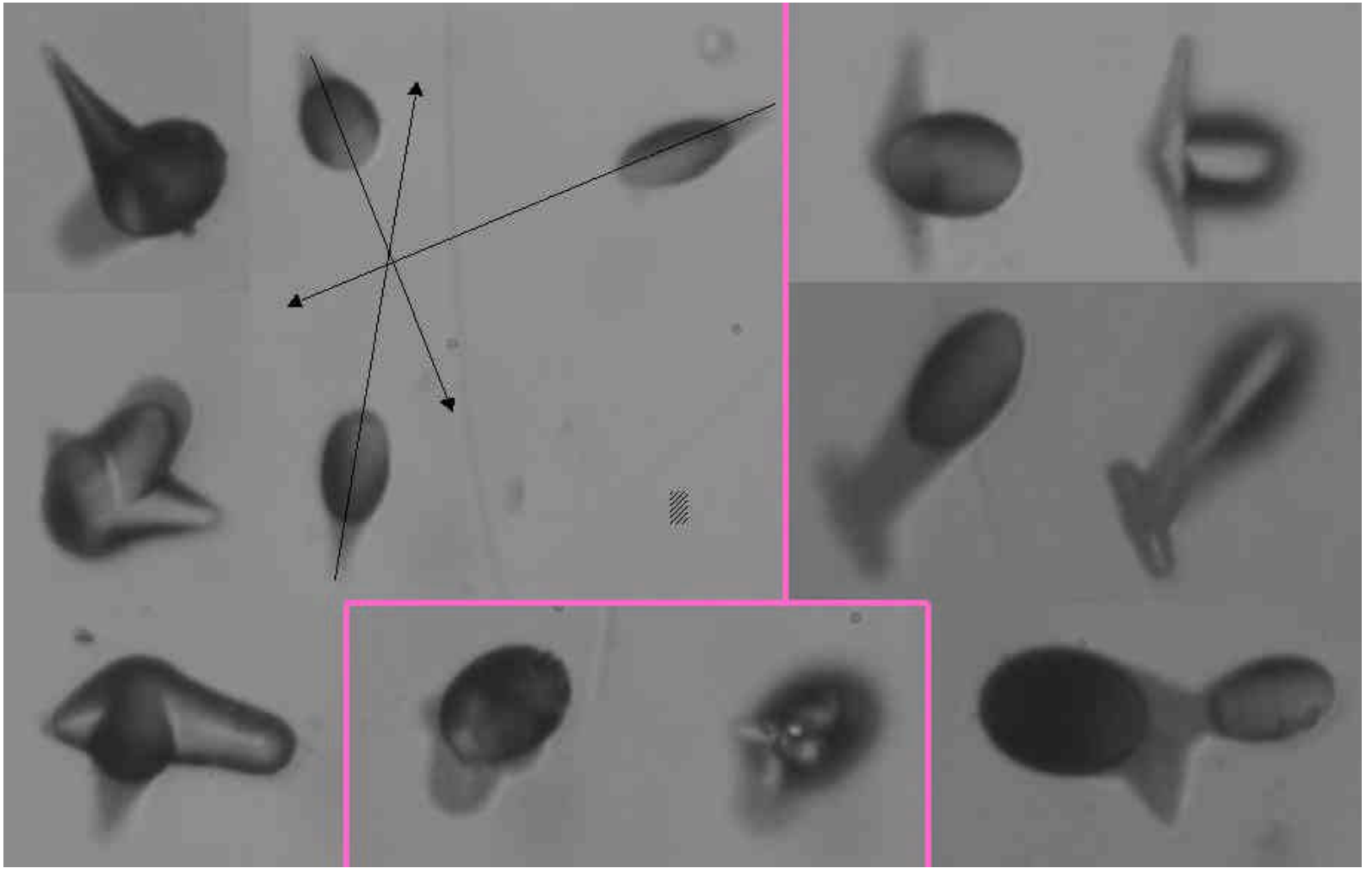
**Three-focal presentation of tracks originated from $^{12}C(n,n',3\alpha)$ interaction**

**in CR-39, exposed at CERF in CR position**

**(TASTRAK, 6n NaOH, 70 °C, 12 h etching)**

| REACTION | THRESHOLD ENERGY |
|---|---|
| $^{12}C(n,3\alpha)$ | 15 MeV |
| $^{12}C(n,T)$ | 10 MeV |
| $^{12}C(n,D)$ | 8 MeV |
| $^{12}C(n,p)$ | 5 MeV |





## We learnt from CERF exposures

**Conversion factor for H* is 1.19 mSv $cm^2$, (depends on the operation parameters)**

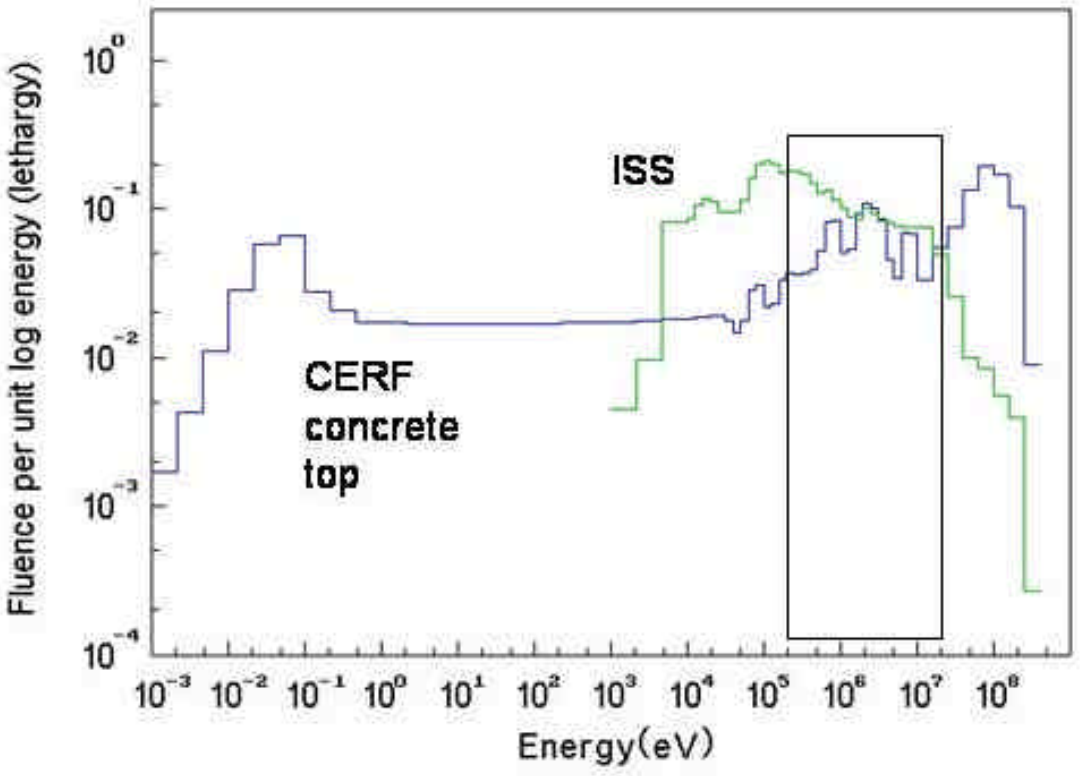
**Response for C an O recoils: $R=2.4 \times 10^{-6}$**

**Response for charged particle production: $R=4.8 \times 10^{-7}$**

**Valid for the neutron spectrum at**

**CERF facility, concrete roof position**

**TASTRAK CR-39, etched in 6 N NaOH at 70 $^{o}$C for 6 h**




| Data | | ISS | CERF |
|---|---|---|---|
| Averaged energy in MeV, $E_{threshold}$=1 keV | | 3.38 | 46.8 |
| Fluence ratio $E_{threshold}$=1 keV | E>5 MeV | 0.134 | 0.557 |
| | 200keV<E<20MeV | 0.509 | 0.456 |
| H* conversion in pSv $cm^2$ $E_{threshold}$=1 keV | E>1 keV | 218 | 312 |
| | E>5 MeV | 453 | 350 |
| | 200keV<E<20MeV | 365 | 406 |

Table 2 The neutron ambient dose equivalent rates at different position in the Zvezda (Service) modul of the ISS, measured during the BRADOS 1, 2 & 3 (B1, B2, B3) experiments.

| H* rate μSv/d | Location in the Service module: box and panel numbers | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | A11<br>443 | A12<br>240 | A13<br>110 | A14<br>457 | A15<br>318 | A16<br>110 | A16<br>110<br>orthogonal<br>position | Notes |
| | 52 | 39 | 47 | 54 | 73 | 68 | 63 | B1* |
| | 37.8 | 42.0 | 26.4 | 29.5 | 36.1 | 31.2 | 35.7 | B1^ |
| | 18.9 | 27.4 | 21.8 | 21.0 | 19.8 | - | 29.0 | B2^ |
| | - | 44 | - | 35 | 35 | 27 | - | B3** |

* Palfalvi et al, 2004a, the neutron energy range considered was between 200 keV and 20 MeV, measured by SSNTD stacks.

** Palfalvi et al, present work, the neutron energy range considered was between 200 keV and 20 MeV, measured by SSNTD stacks.

^ Berger, 2003, total neutron dose, obtained by TLD measurements applying HTR technique.

# Neutron fluxes

**f > 1 keV  2.42 $cm^{-2}$ $s^{-1}$,  Brados-1, Panel 443 ***

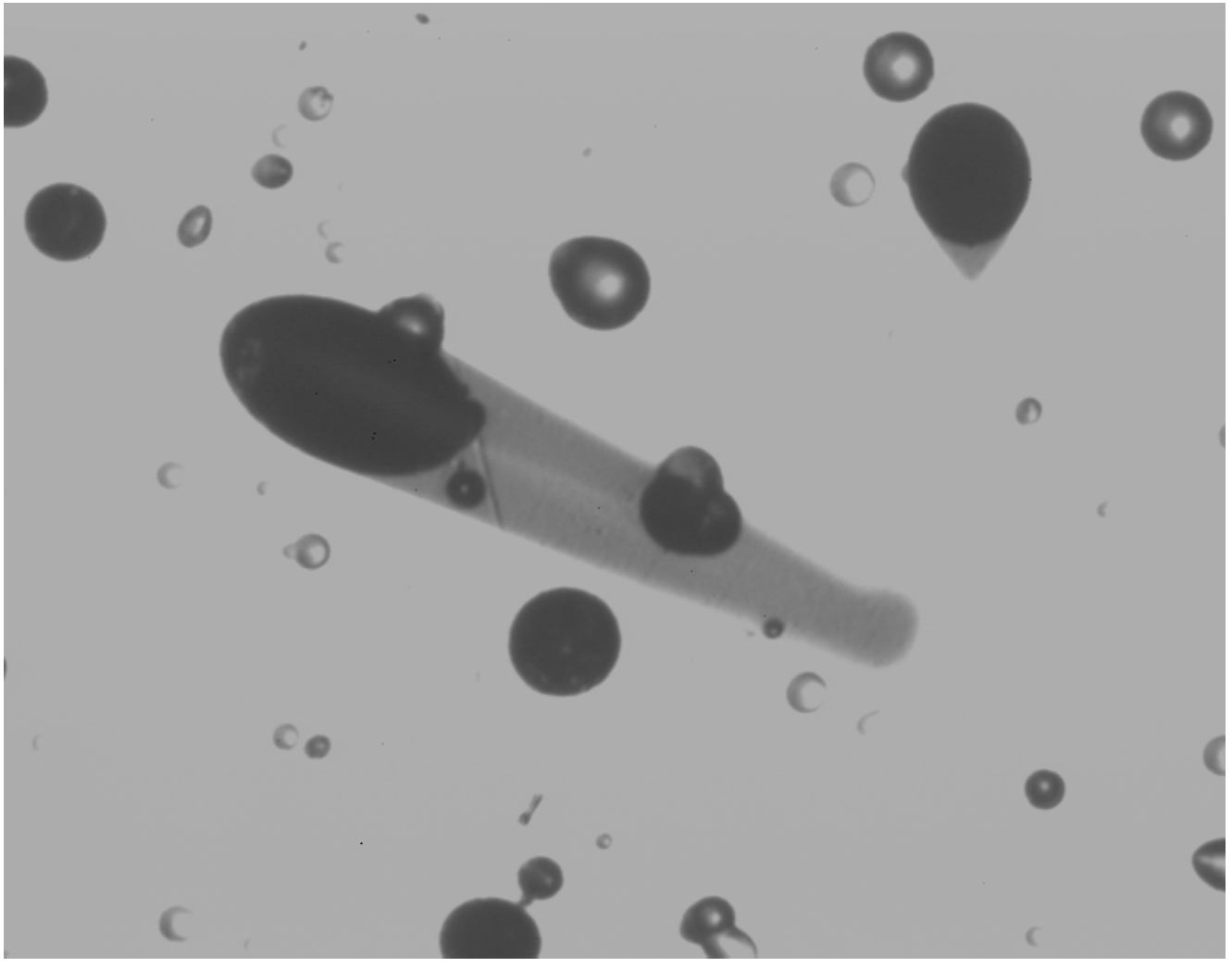
**f > 1 keV  ~ 5 $cm^{-2}$ $s^{-1}$,  Armstrong, calculated**

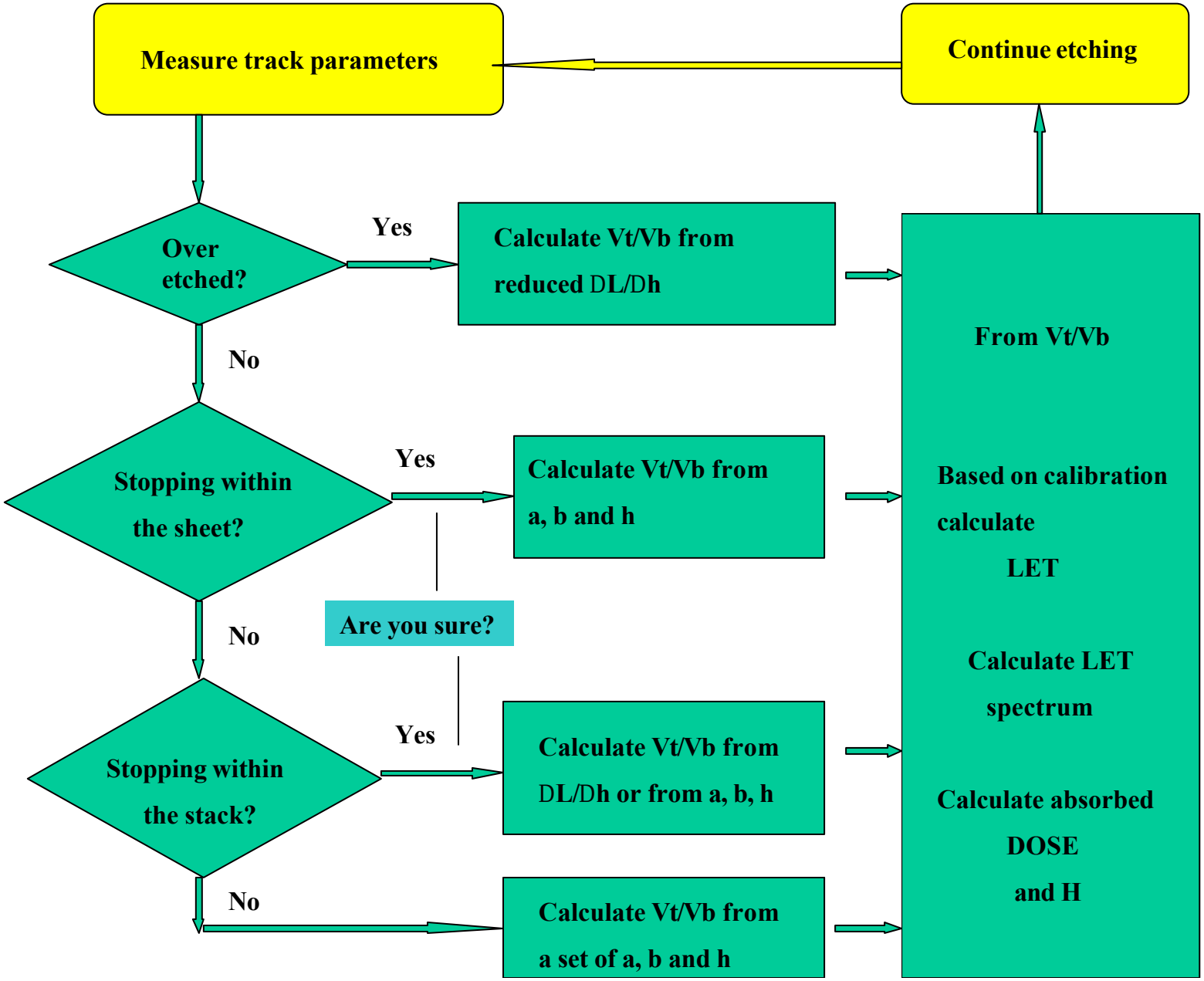
**1 keV > f > 5 MeV  2.1 $cm^{-2}$ $s^{-1}$, ***

**f > 5 MeV  0.32 $cm^{-2}$ $s^{-1}$, * (~12 % of total)**

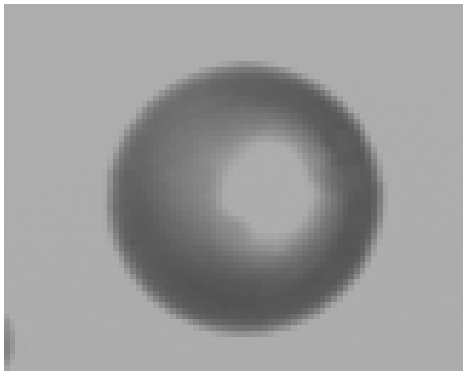
**200 keV > f > 20 MeV  1.24 $cm^{-2}$ $s^{-1}$, ***

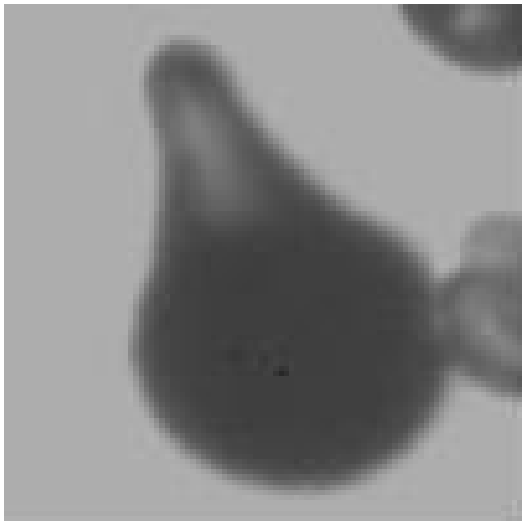
# BRADOS-1, 248 days, 6N NaOH 70 °C 20 h

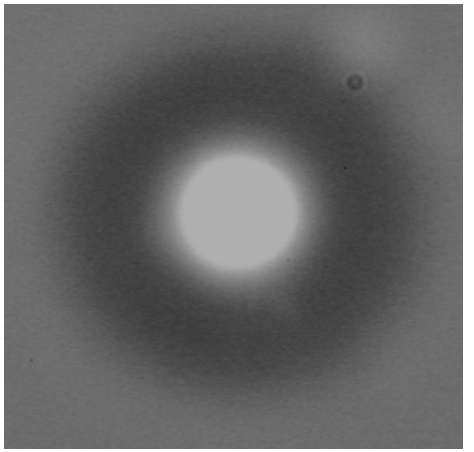


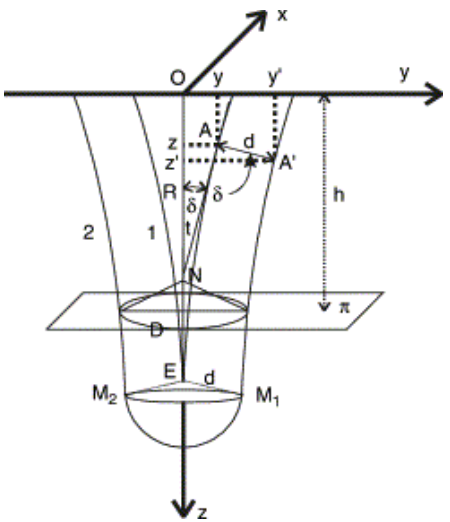

Measure track parameters
Continue etching
Over etched?
Yes
Calculate Vt/Vb from reduced DL/Dh
No
Stopping within the sheet?
Yes
Calculate Vt/Vb from a, b and h
Are you sure?
No
Stopping within the stack?
Yes
Calculate Vt/Vb from DL/Dh or from a, b, h
No
Calculate Vt/Vb from a set of a, b and h
From Vt/Vb
Based on calibration calculate LET
Calculate LET spectrum
Calculate absorbed DOSE and H

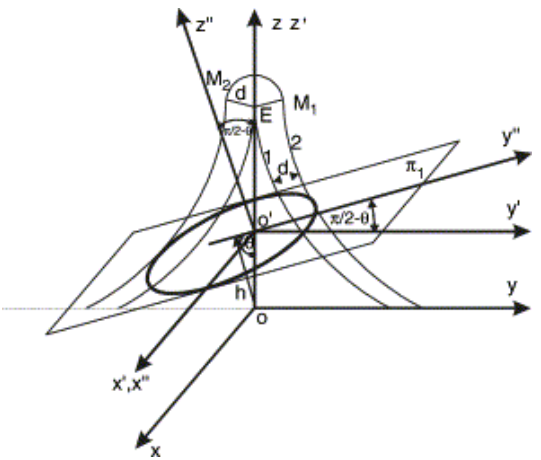
# 3DTrack formation dynamics, after Nikezic, 2003.

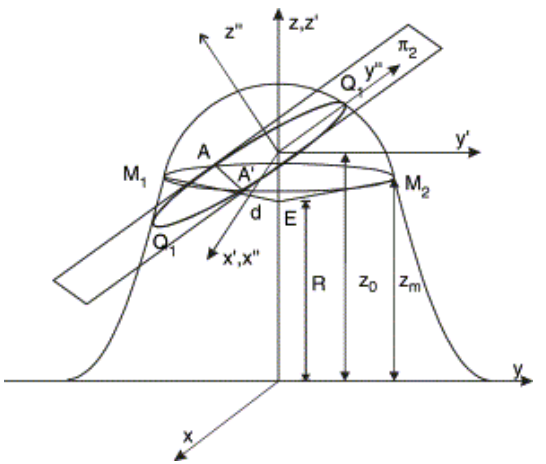






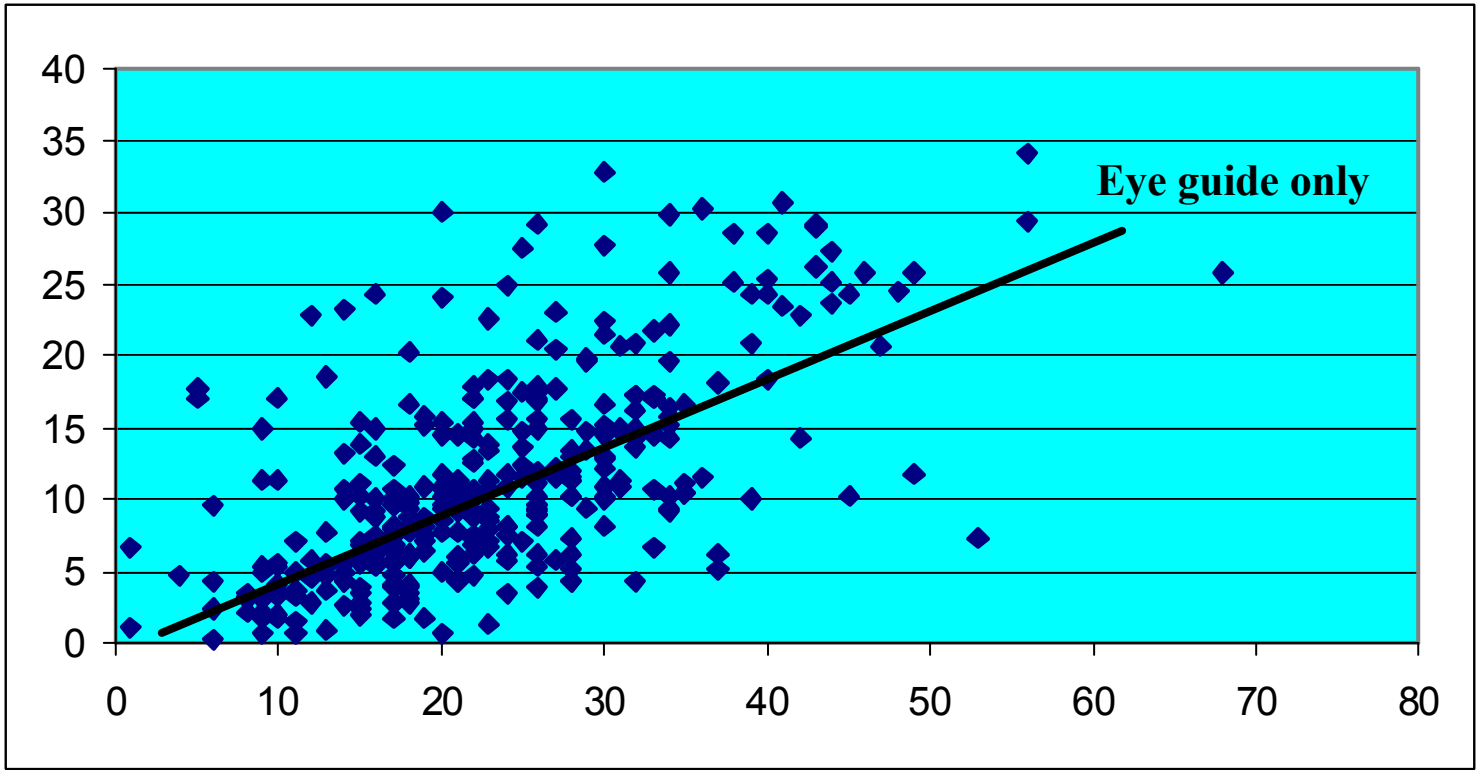


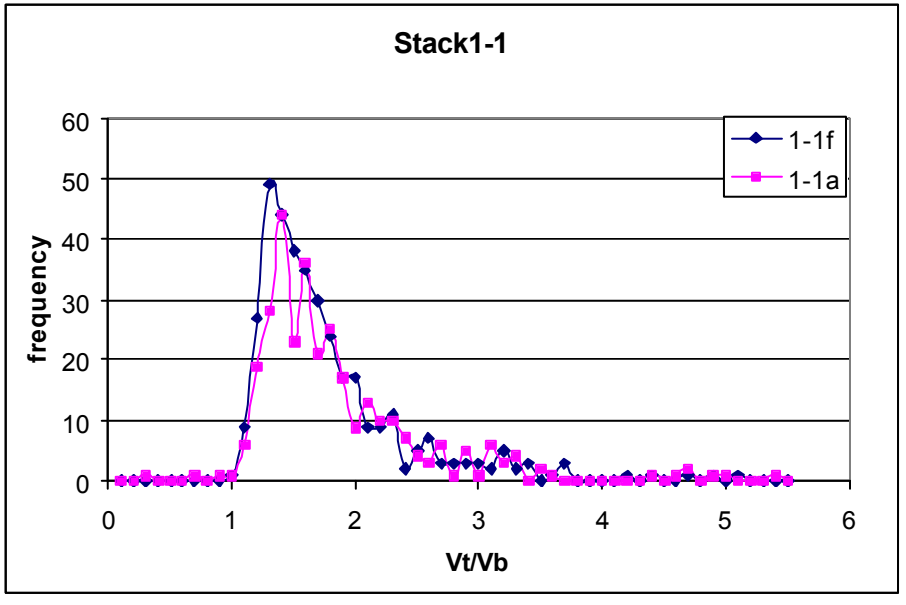



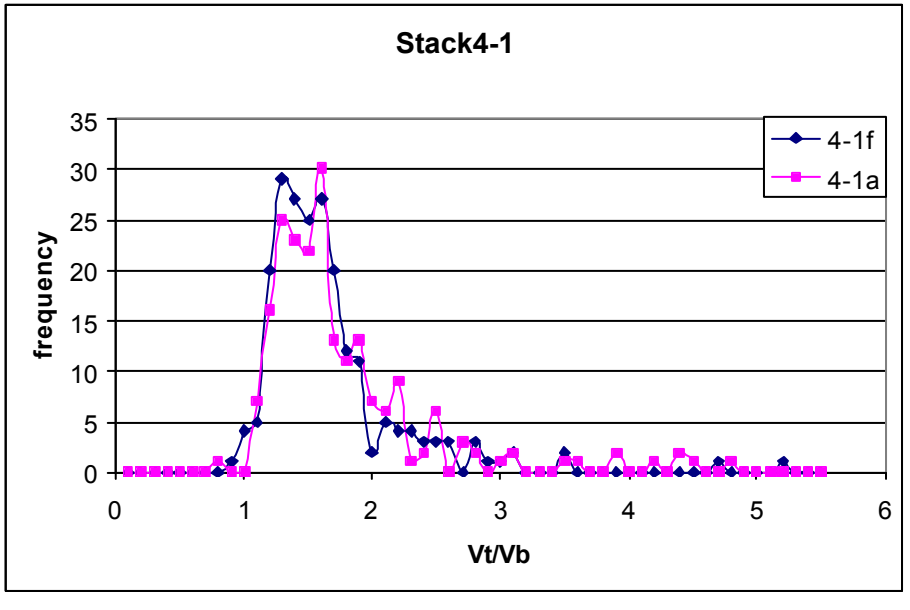
# Reduced track diameter vs. Residual Path length

## Short range particles, circular tracks

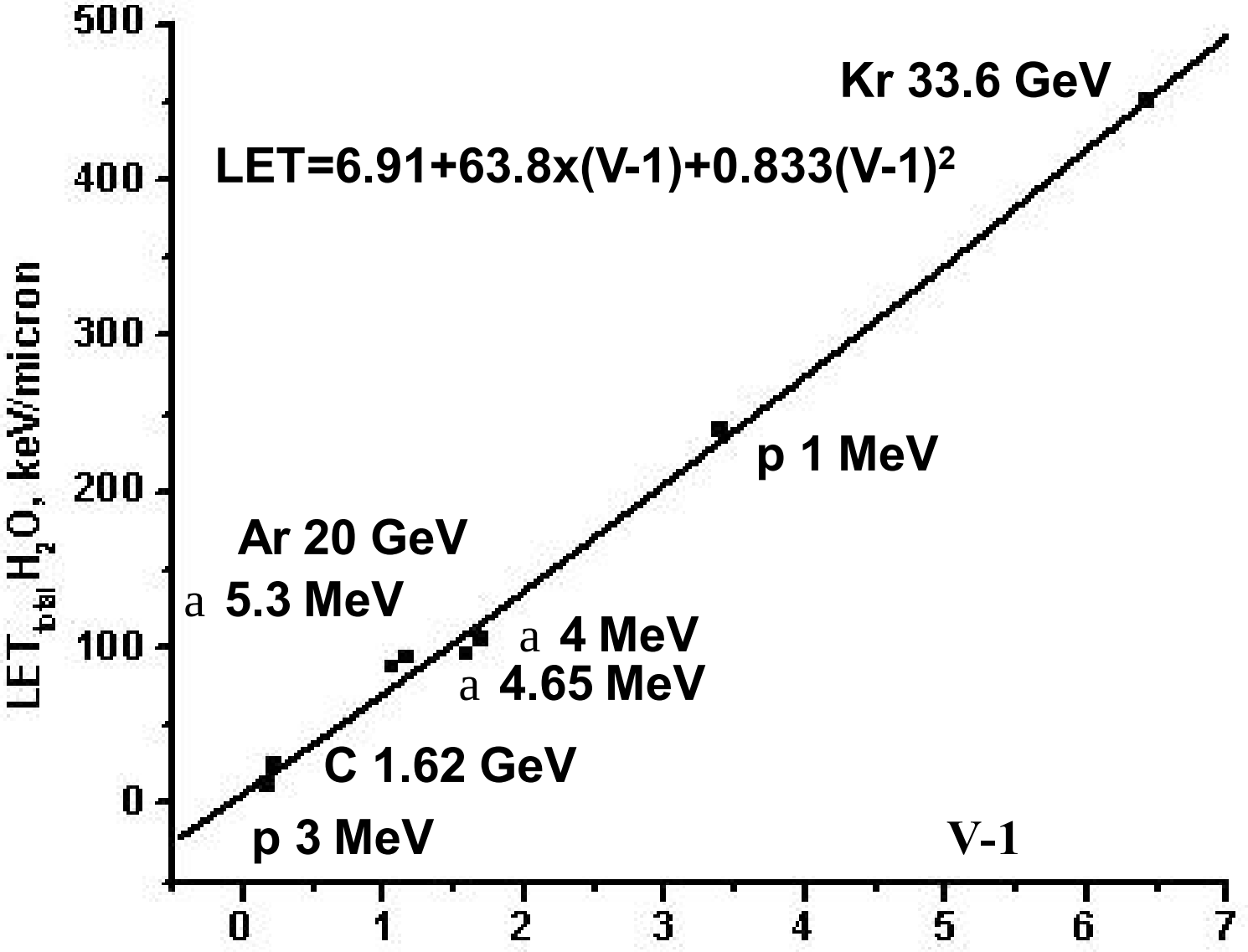


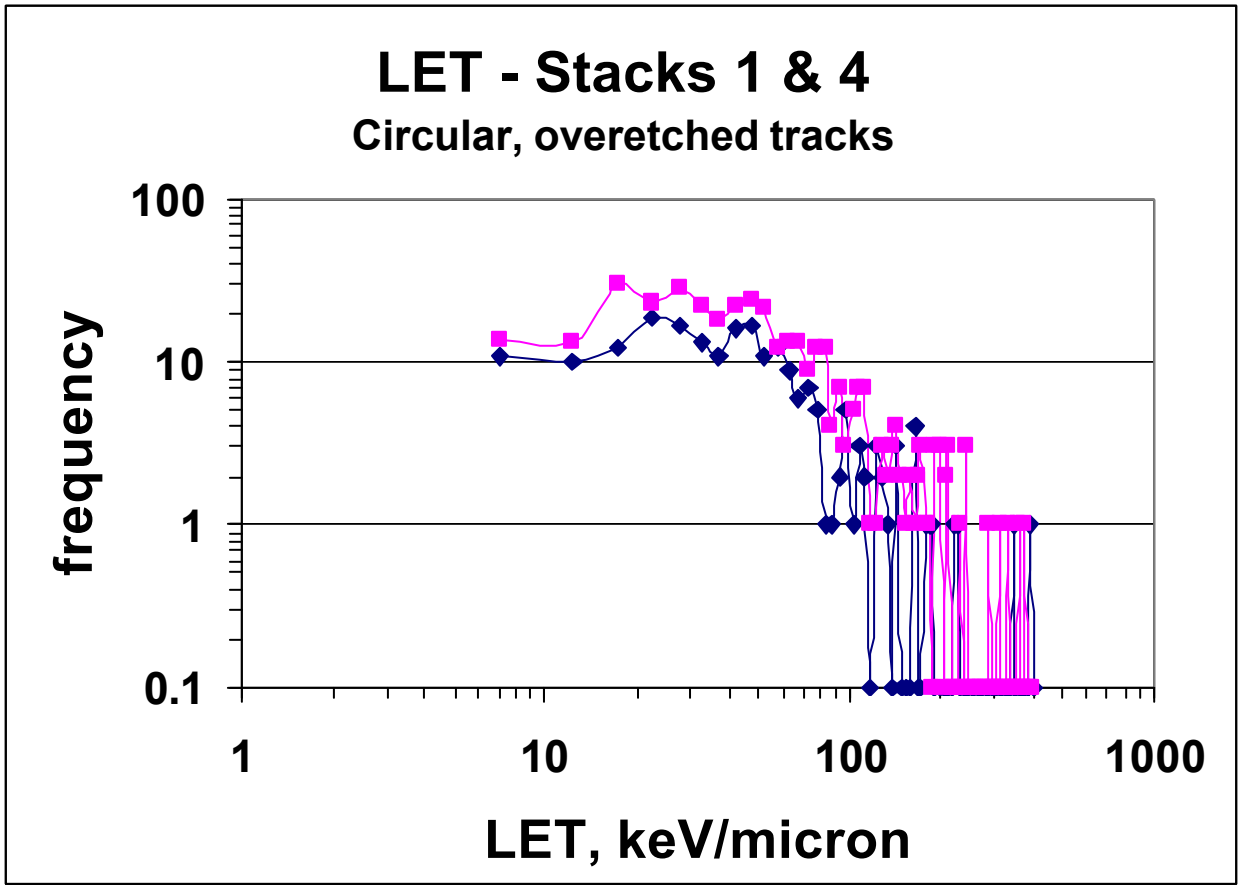



Stack No. 1> Panel 443
shielding ~ 10 g/cm$^2$

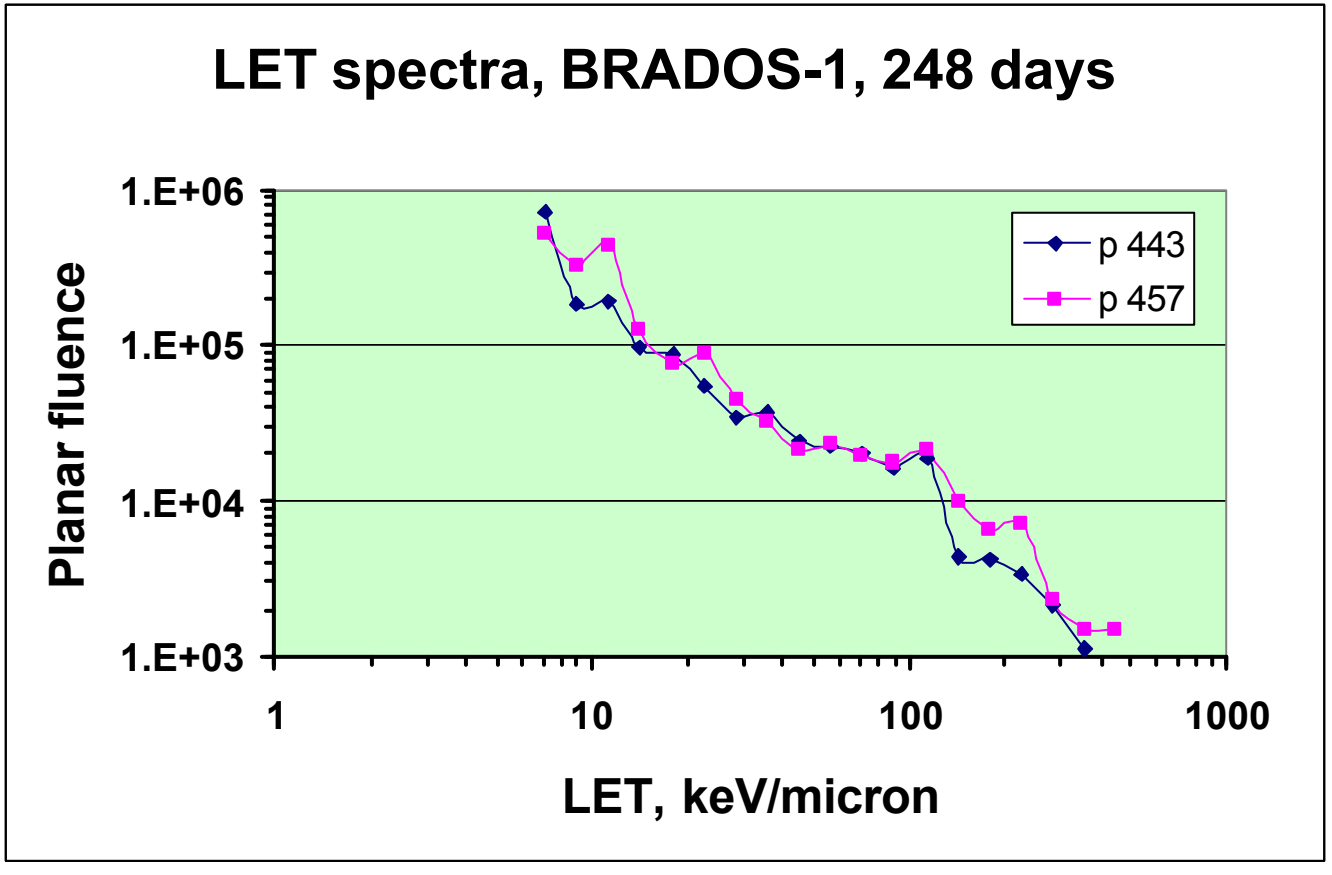



Stack No. 4> Panel 457
shielding ~ 15 g/cm$^2$


500
400
300
200
100
0
$LET_{total}$ $H_2O$, keV/micron
Kr 33.6 GeV
LET=6.91+63.8x(V-1)+0.833(V-1)²
p 1 MeV
Ar 20 GeV
a 5.3 MeV
a 4 MeV
a 4.65 MeV
C 1.62 GeV
p 3 MeV
V-1
0
1
2
3
4
5
6
7

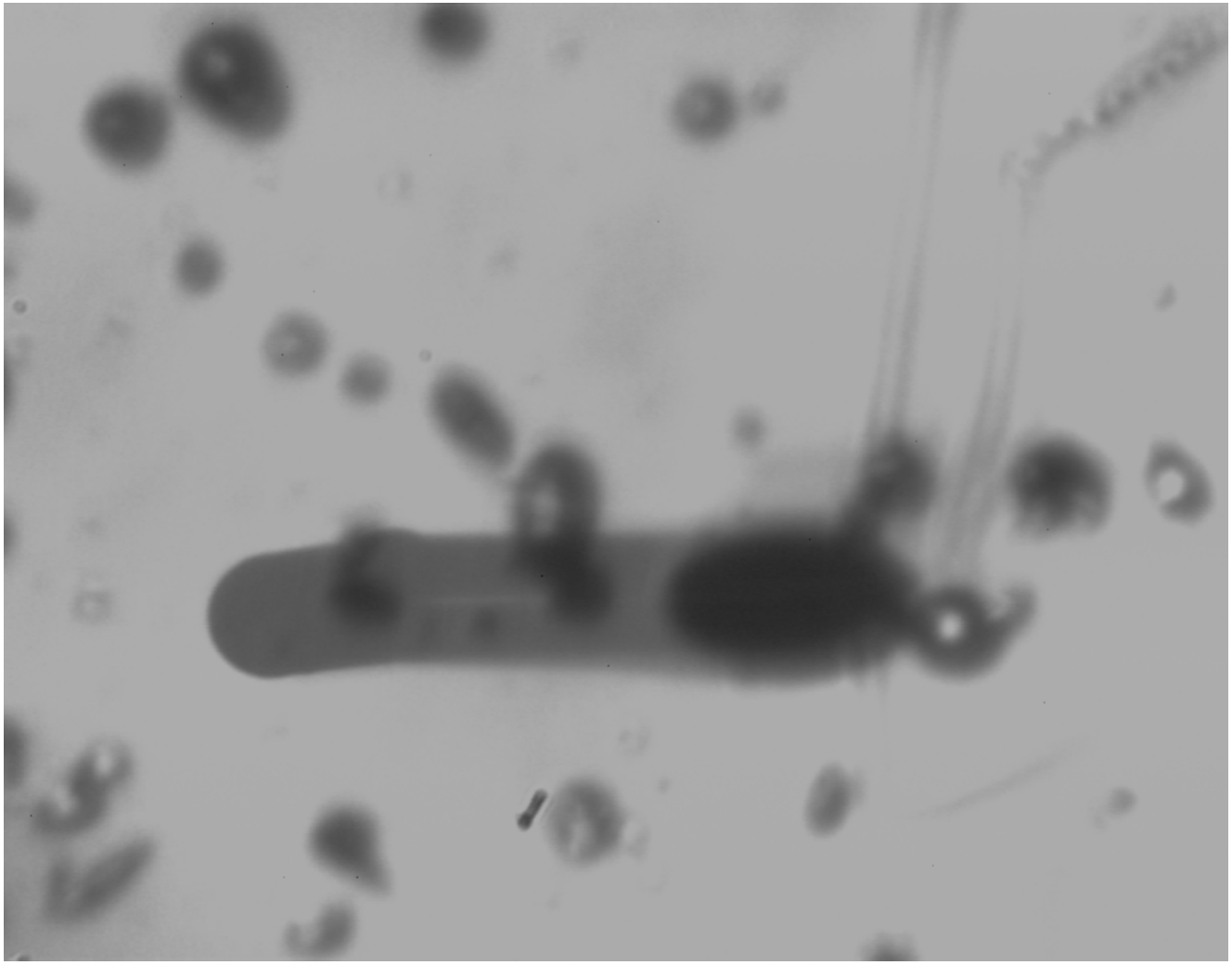


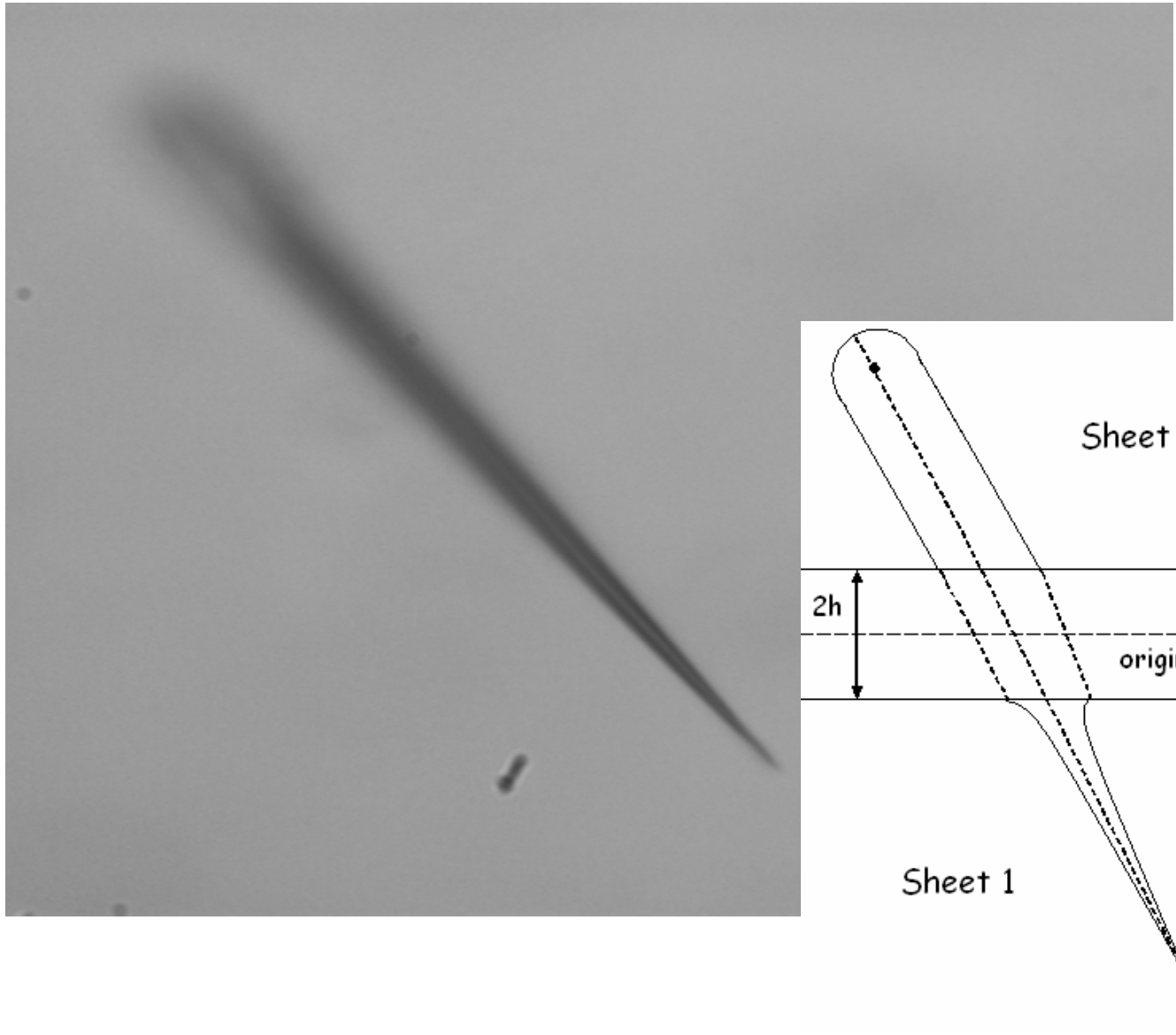

**The width of a LET interval is 5 keV/$\mu$m, the LET values are shown at the geometrical mean of the LET interval. The total number of tracks on Stack No. 1 upper sheet was 368, on Stack No. 4 it was 216, collected on 10 cm$^2$ area, during BRADOS-1, 248 days experiment.**

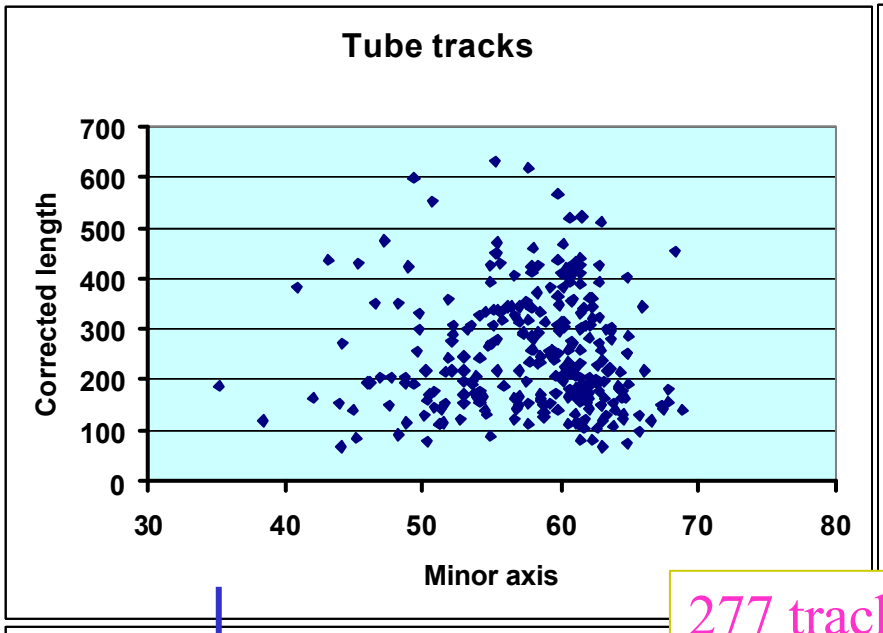


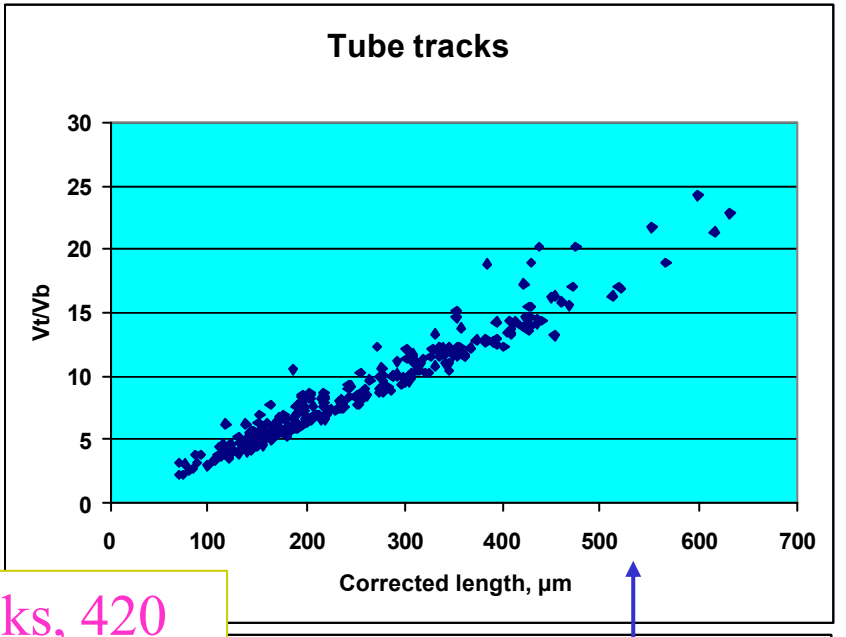

| | p. 443 | p. 457 |
|---|---|---|
| H (mSv/d) = | 267.9 | 315.3 |


Greetings to everybody from...
(Averaged age 28.2)
POLYVAR
POLYVAR




Sheet 2
2h
original interface
Sheet 1




277 tracks, 420 $cm^2$, 248 days