FHT 3511

Calibration of a PET-stack monitor based on coincidence technology

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Content

- the idea
- the requirements
- the concept
- the hardware
- the user interface
- Summary

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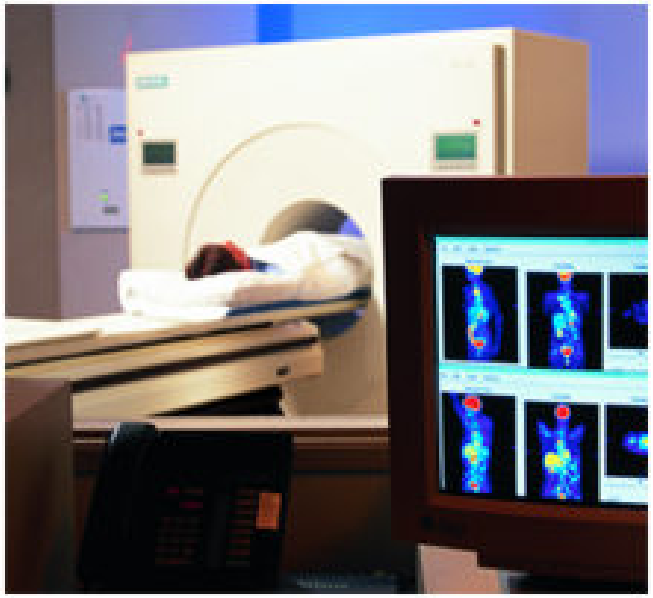
PET Specifics

Production

Application



Half-life of PET-isotopes: 2 - 110 minutes

Multiple production facilities required!

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Requirements: Where and Why

- **Where:**

  Measurement of the activity release in stack during production

- **Why:**

  Despite short half life time of nuclides
  - daily production = ongoing exposure of neighborhood
  - 2 hard gammas per decay
  - facility in down town locations
  - initially no filters
  - release varies strongly depending on handling of process
  - regulator's request

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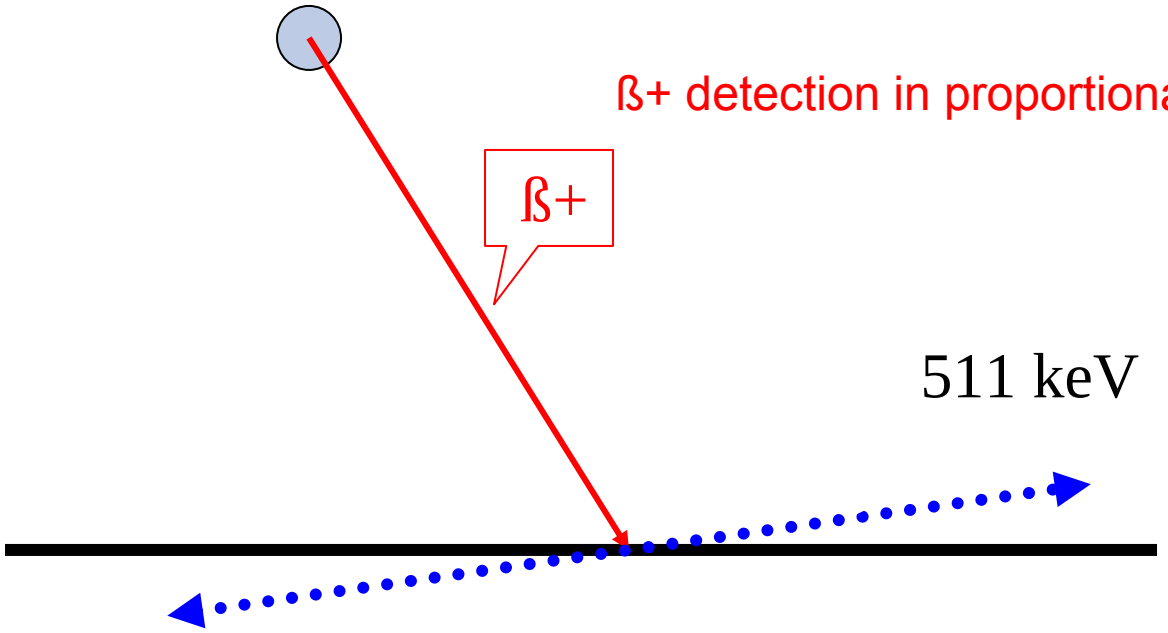
ß+-decay in the gas flow

Conventional Monitoring Problems:

ß+ : Fragile window, specific calibration (geometry, isotope)
γ: Specific calibration (geometry); long range cross talk



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Isotopes

nuclide	t 1/2	ß+ energy / range	511 keV	other gamma
PET-isotopes:				
C-11	20.4 m	1.0 MeV / 3 m	200 %	no
N-13	10.0 m	1.2 MeV / 4 m	200 %	no
O-15	2.0 m	1.7 MeV / 6 m	200 %	no
F-18	110 m	0.6 MeV / 1.3 m	194 %	no
Na-22	2.6 y	0.5 MeV	180 %	1274 keV (100 %)
Ge/Ga-68	271 d	1.9 MeV	178 %	1077 keV (3 %)

Conclusions:

- Different calibration factors for beta+ detection monitors
- Same calibration factor for gamma based monitors

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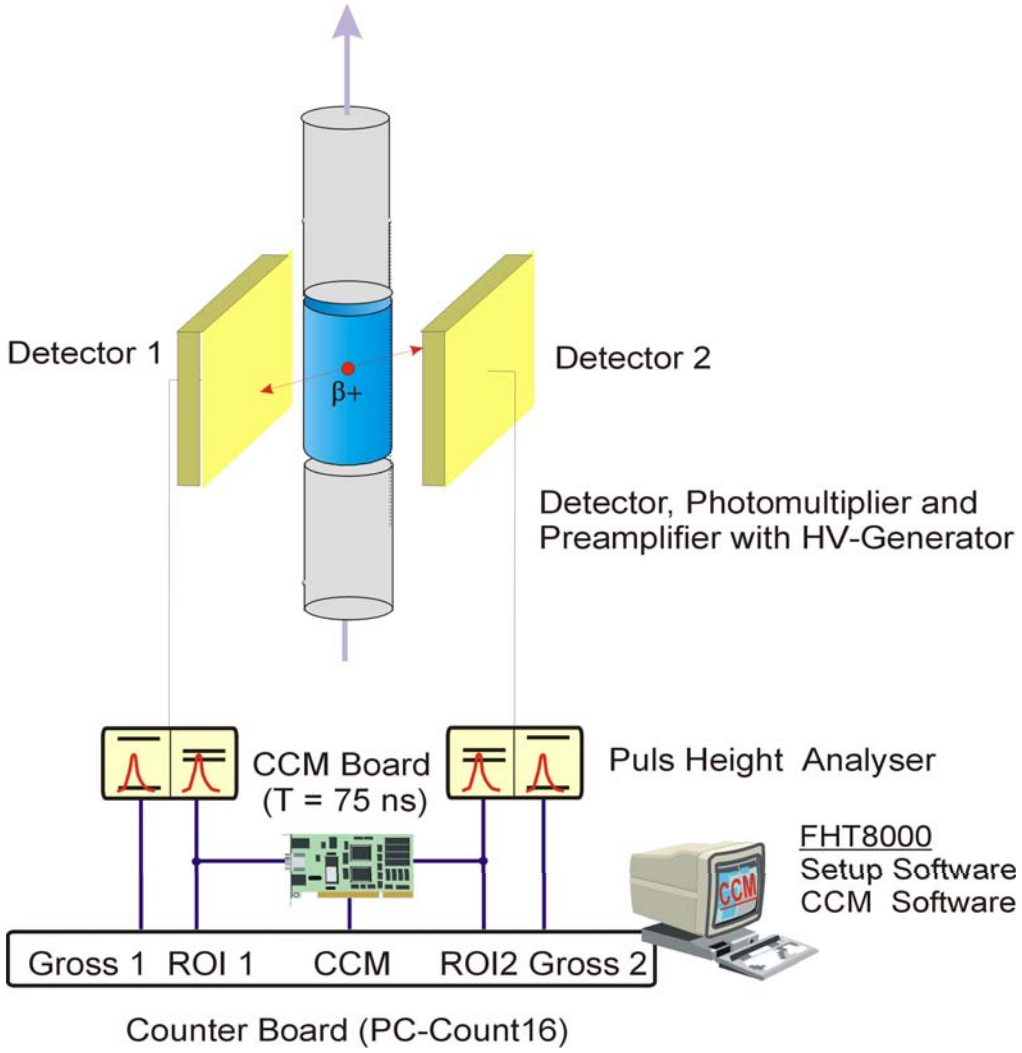
Confined volume – virtual shielding



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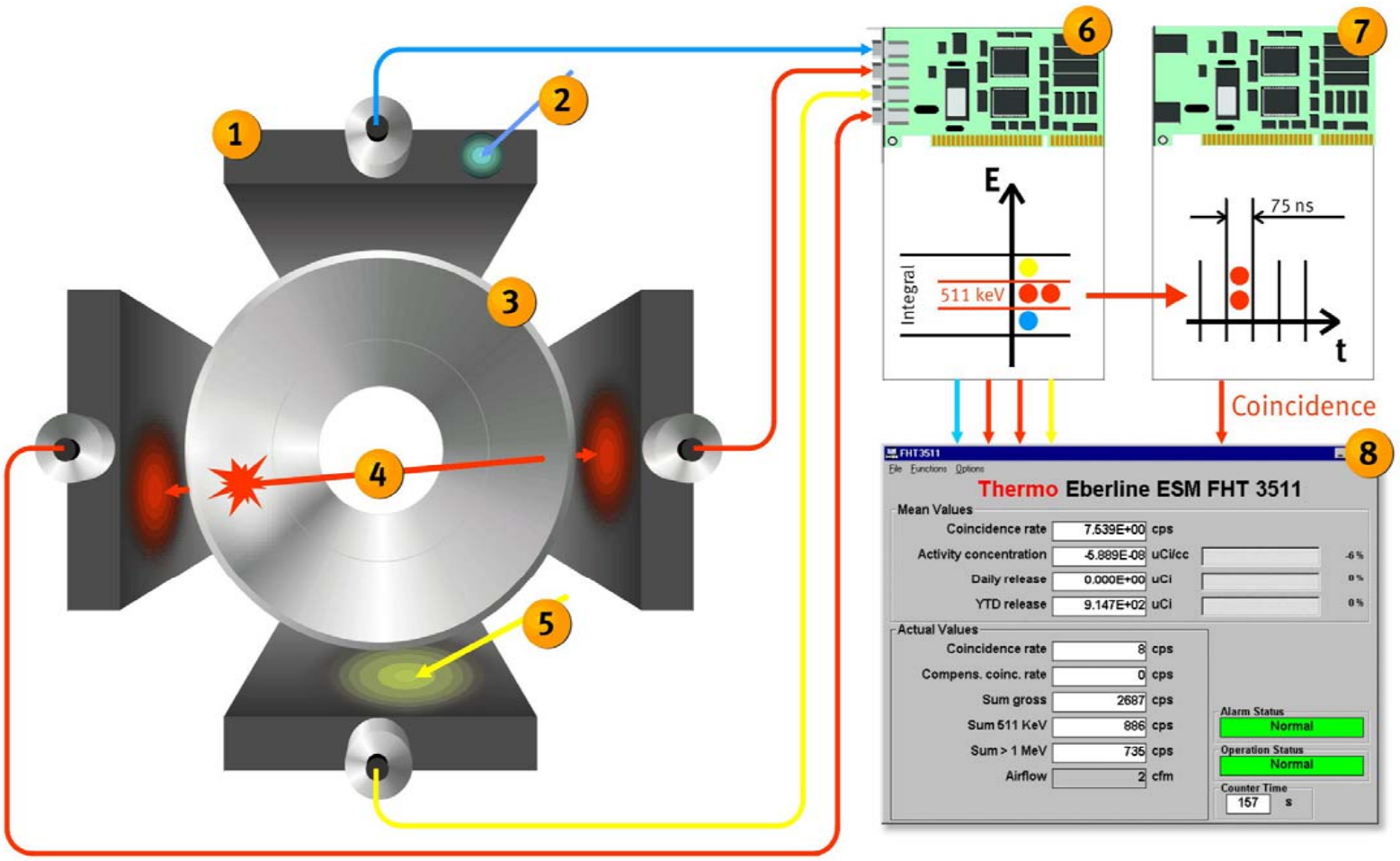
Some more details



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Impact of Coincidence Measurement

Typical Data (12 inch dia.)

	efficiency	background	limit of detection (t = 600 s)
• gross γ:	60 %	5000 cps	0.6 kBq/m3
• ROI:	20 %	1500 cps	1.0 kBq/m3
• CCM:	2 %	10 cps	0,9 kBq/m3

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Online Subtraction of Background

PET activity as per the CCM method

$$R_{pet} = R_{coi} - R_{stat} - R_{comp}$$

R_{pet}	count rate due to coincident γ-annihilation quanta
R_{coi}	total coincident count rate of all detectors
R_{stat}	statistical coincidence count rate
R_{comp}	count rate due to Compton scattering of natural high energy gamma nuclides (Tl-208 at 2.615 MeV of the natural Th-232 decay chain) and of cosmic rays

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Arbitrary Coincidences

Statistical coincidence count rate

$$R_{stat} = T_{gate} \cdot \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} R_{w,i} \cdot R_{w,j}$$

T_{gate}	gate time of the coincidence circuit (typically 75 ns)
$R_{w,i}$, $R_{w,j}$	gross count rates in the PET windows of the detectors j, i
n	number of detectors
i, j	index

Example:

$$R_{stat} = \frac{n}{2} \cdot (n-1) \cdot T_{gate} \cdot R_w^{\,2} \qquad n = 6;\ R_w = 950\, s^{-1}$$

$$R_{stat} = 1 s^{-1} (T_{gate} = 75\, ns)$$

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Double Detection of High Energy Events

False Coincidences

Double detection of
- natural gamma rays > 1,5 MeV
- high energy radiation from cyclotron

Depending on:
- setting of energy window
- weather
- operation of cyclotron

High energy (> 1 MeV) counts can be used for compensation!

Observation:
The same compensation factor for Rn-washout and cyclotron can be applied!

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Details of Compensation

Dynamic compensation of Compton scattering

$R_{comp} = Factor \cdot R_{comp}^{gross} - Offset_{cosmic}$

R_{comp}^{gross}	high energy gamma (app. 1000 - 4000 keV) gross count rate (Tl-208 at 2.615 MeV of the natural Th-232 decay chain and cosmic rays)
Factor	proportionality factor between high energy gross gamma and CCM channel count rates
$Offset_{cosmic}$	contribution of cosmic rays only

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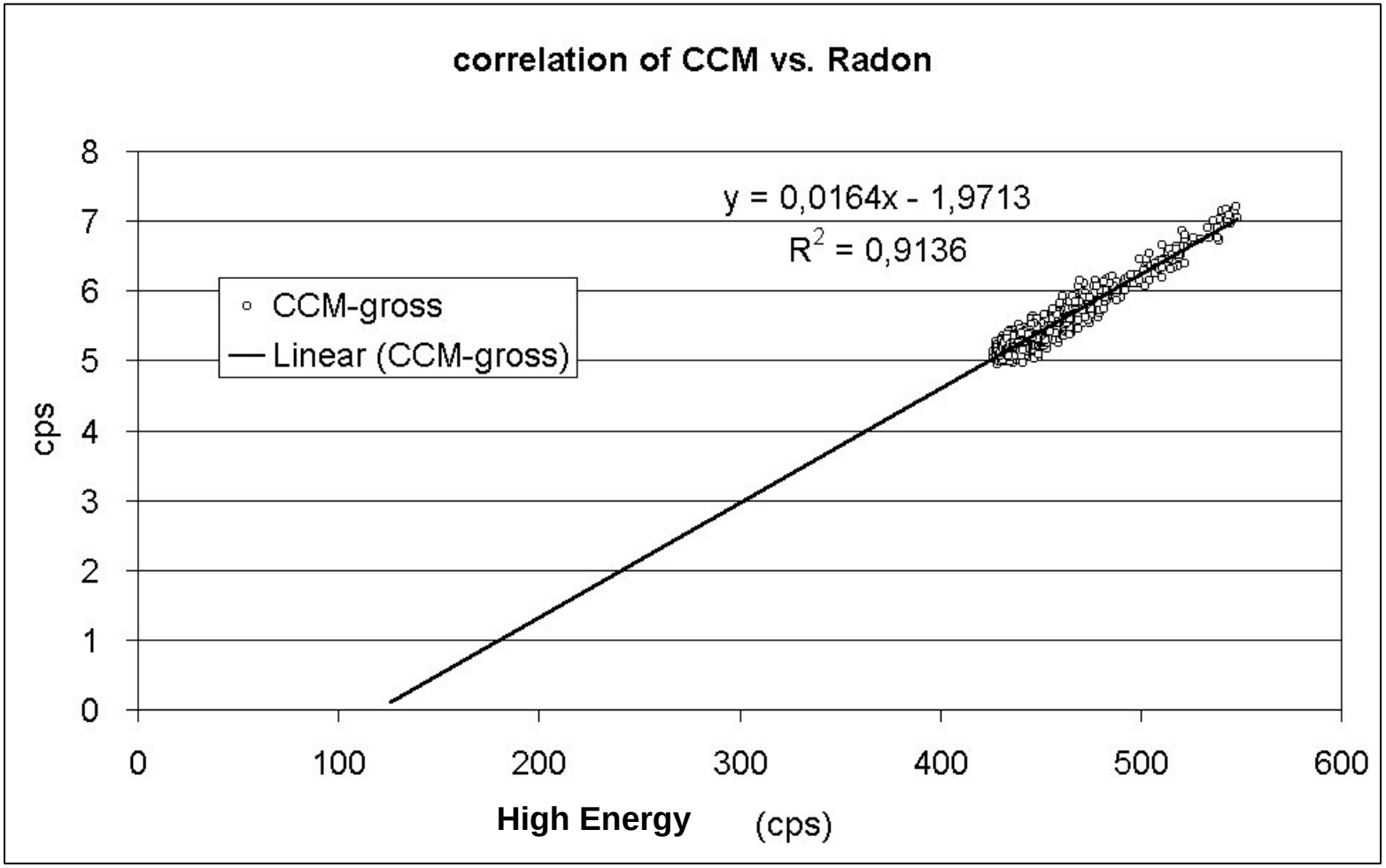
Long Term Observation of Rn-Impact



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Details of ROI-Settings

Setting of Windows

1. Gross gamma window (app. 50 - 1000 keV)

2. High energy (Compton) (app. 1000 - 4000 keV)

3. CCM window (app. 250 - 600 keV)

4. CCM window pulses $\rightarrow$ multi coincidence circuit
   $\rightarrow$ coincidence count rate R_{coi} for all detectors

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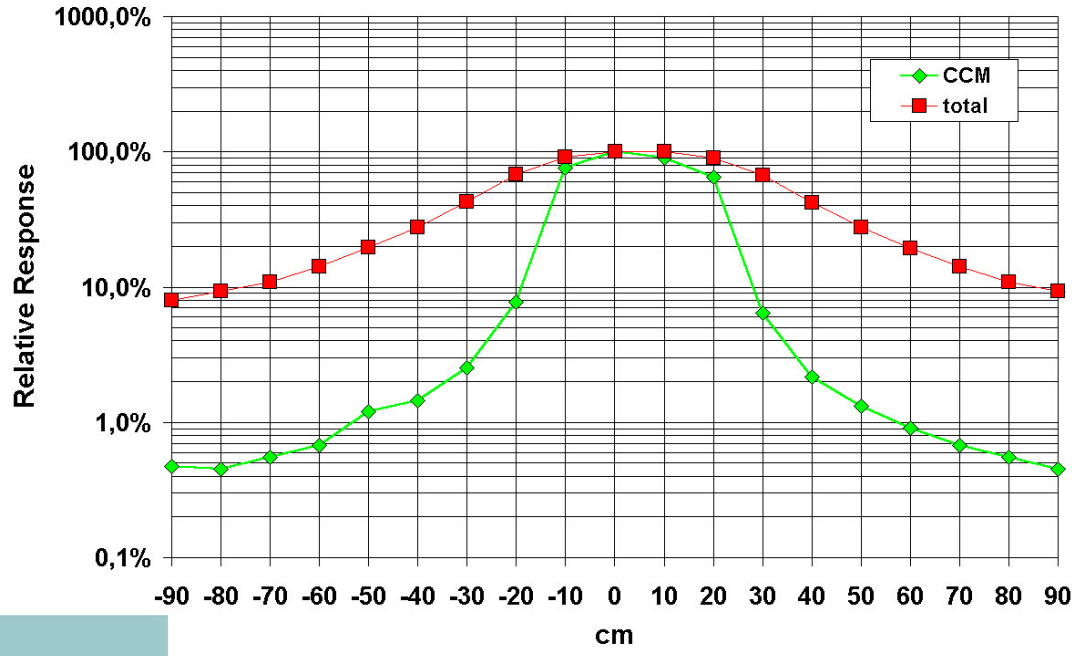
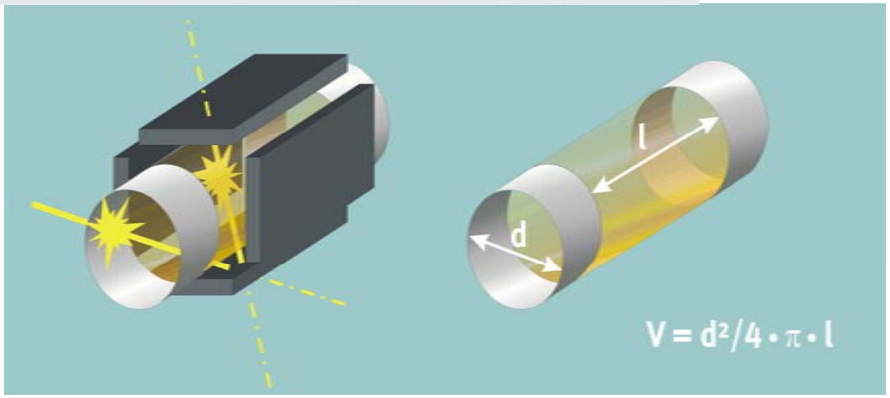
Concept: the confined volume





Confined measurement of 511 keV gamma radiation

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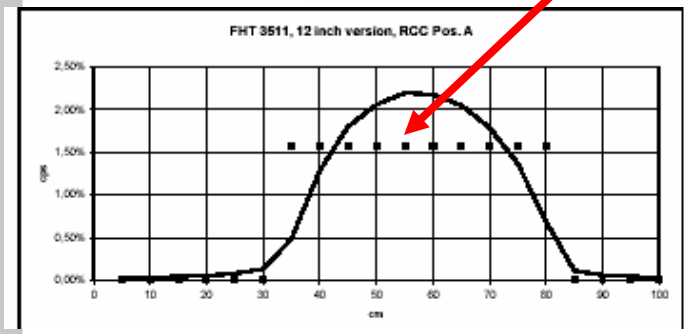
Calibration Factors

	FHT 3511	FHT3511 A	FHT 3511 B	FHT 3511 D
Diameter Duct [inch]	12	16	20	24
Volume for Detection [liter]	36,5	64,9	101,3	145,9
ACE Ge-68 [cps/kBq]	17,1	10,6	7,5	5,8
CFA Ge-68 [Bq/cps]	58,6	94,7	133,8	171,3
CFA PET [Bq/cps]	52,2	84,3	119,1	152,5
CFC PET [(Bq/m³)/cps]	1430	1300	1175	1045
CFC PET [(µCi/cc)/cps]	3,86E-08	3,51E-08	3,18E-08	2,82E-08



ACE Ge-68 — Averaged coincidence efficiency for a Ge-68 point check source

CFA Ge-68 — Coincidence calibration factor referring to a point check source
CFA Ge-68 [Bq/cps] = (ACE Ge-68 [cps/kBq])$^{-1}$ * 10^3 [Bq/kBq]

CFA PET — Coincindence calibration factor corrected for PET nuclides
CFA PET = CFA Ge-68 * 89/100

CFC PET — PET coincidence calibration factor referring to the volume used for detection

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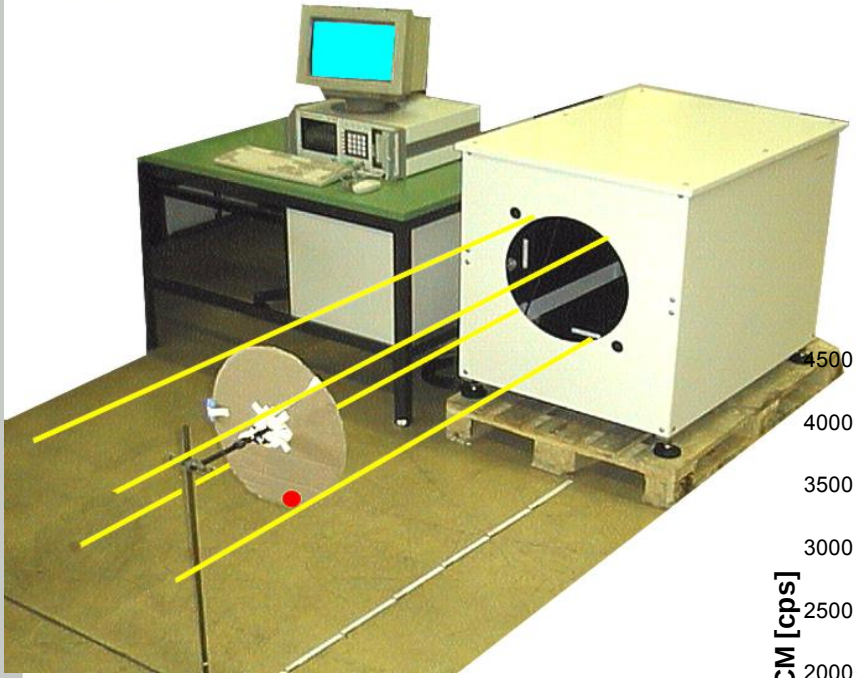
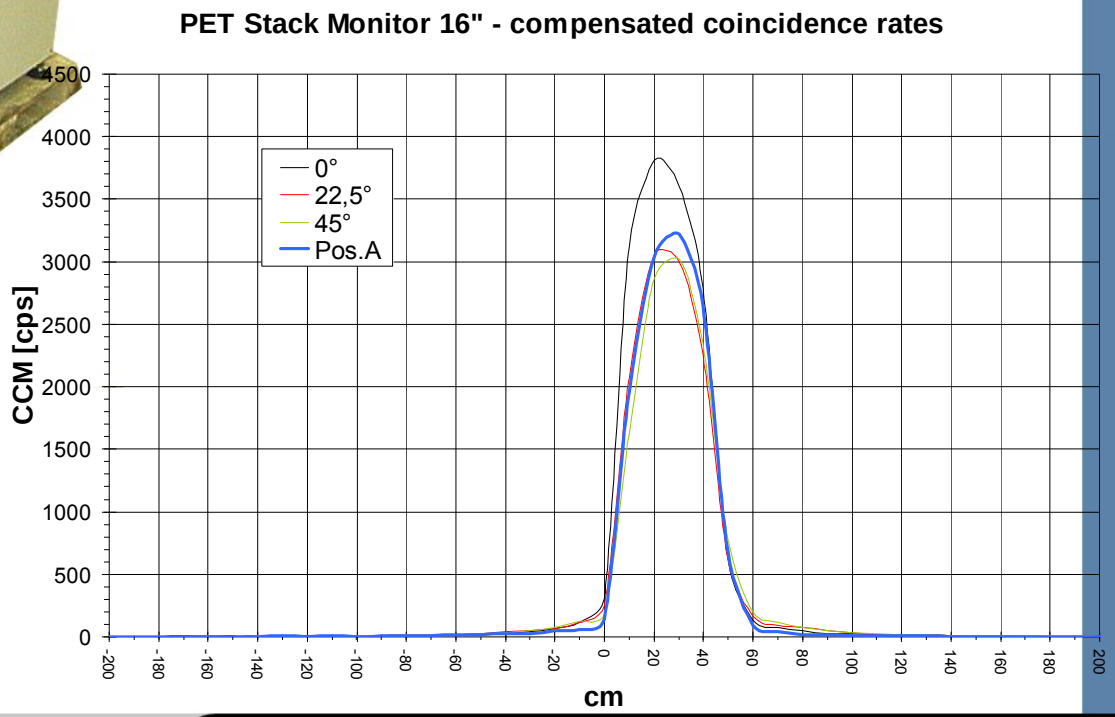
Concept: verification of axial symmetry





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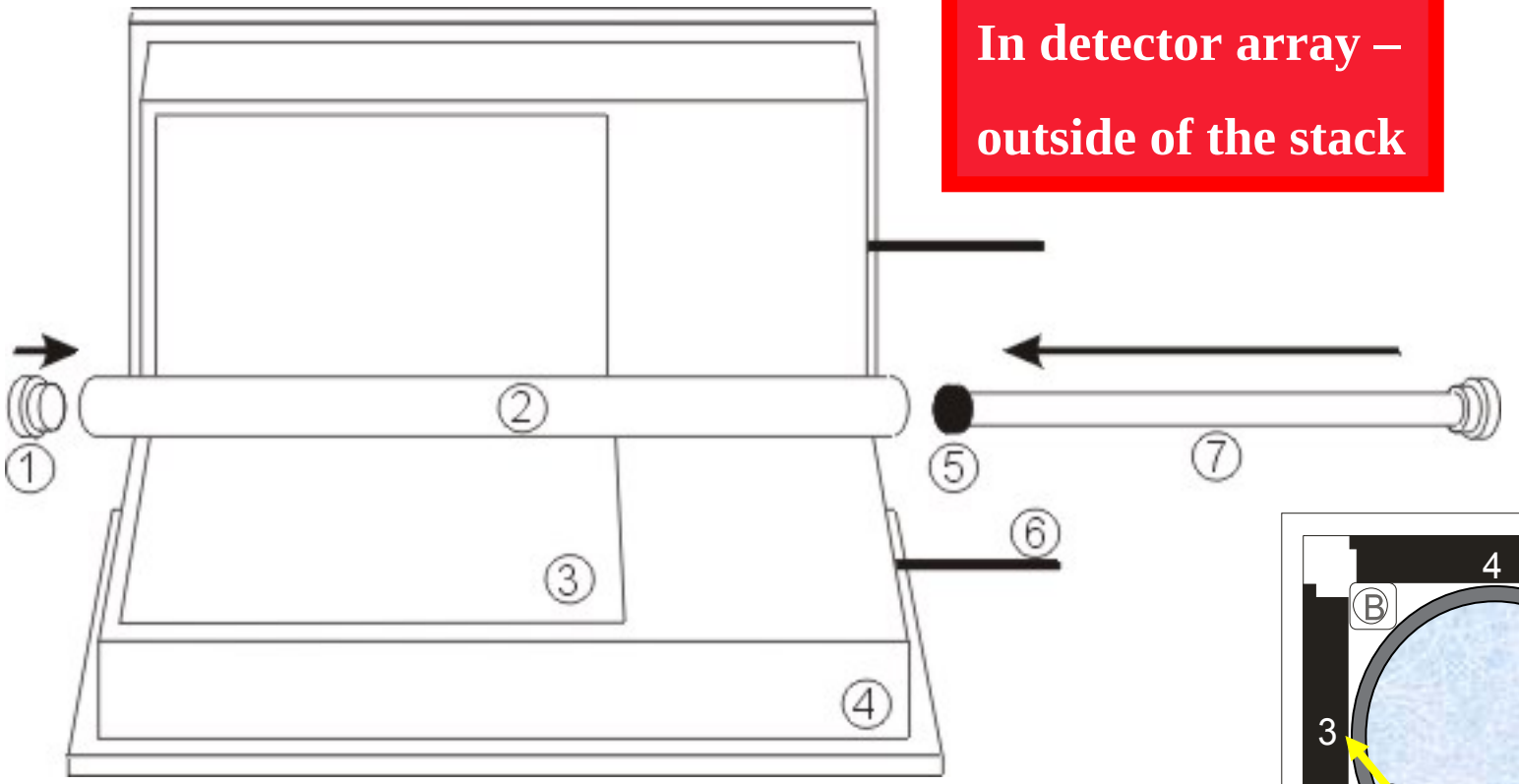
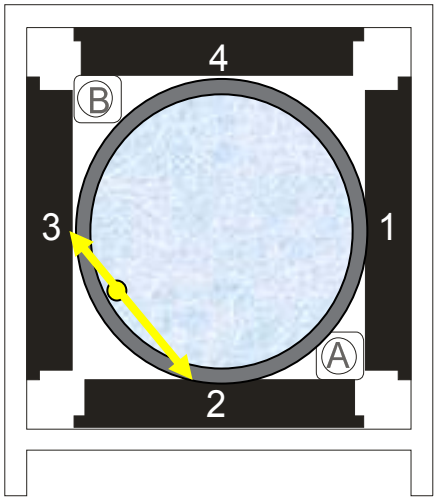
Concept: Check source position

In detector array – outside of the stack





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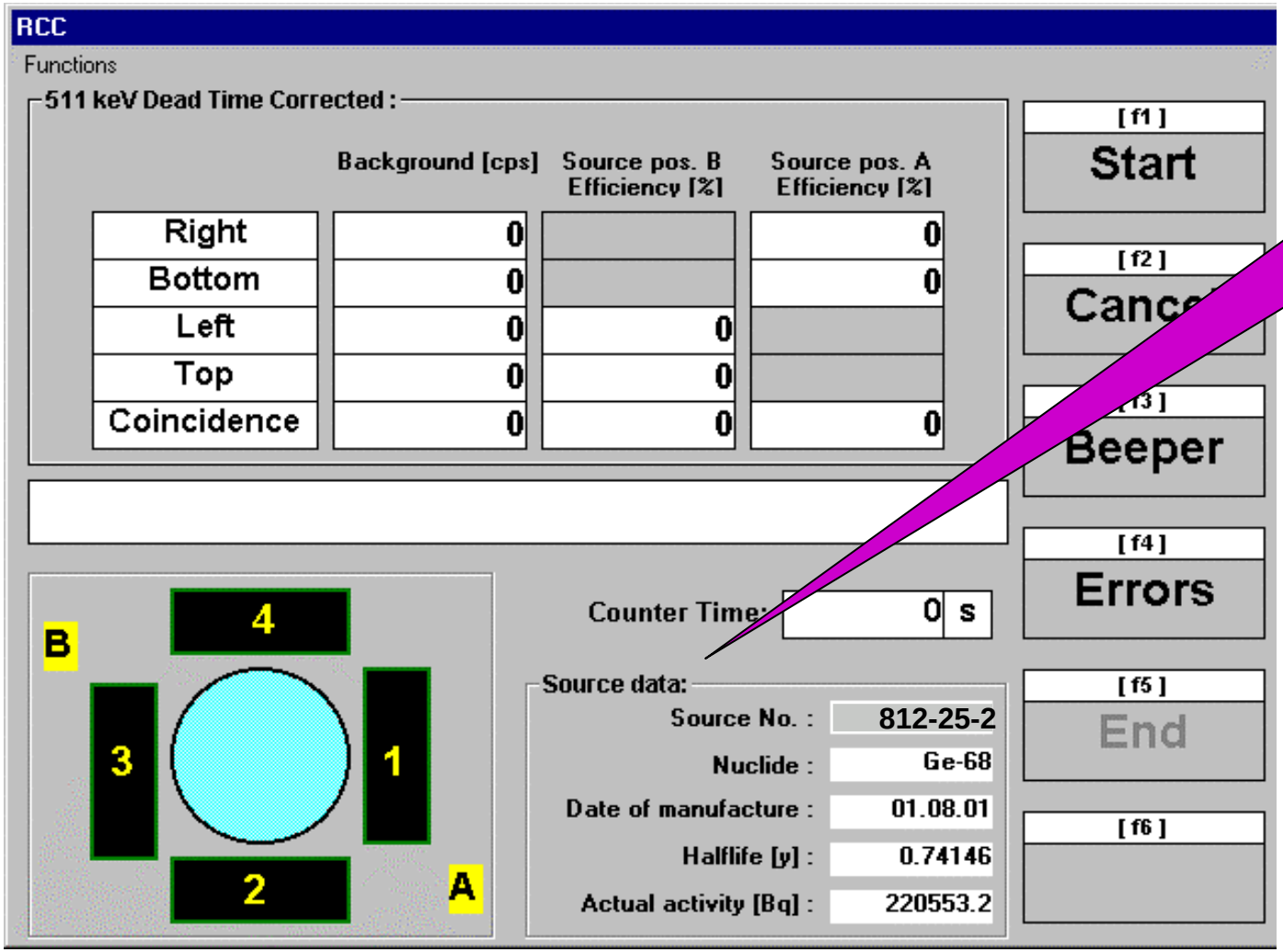
RCC (Recurrent Calibration Check)



Point Check Source – No hot Chemistry

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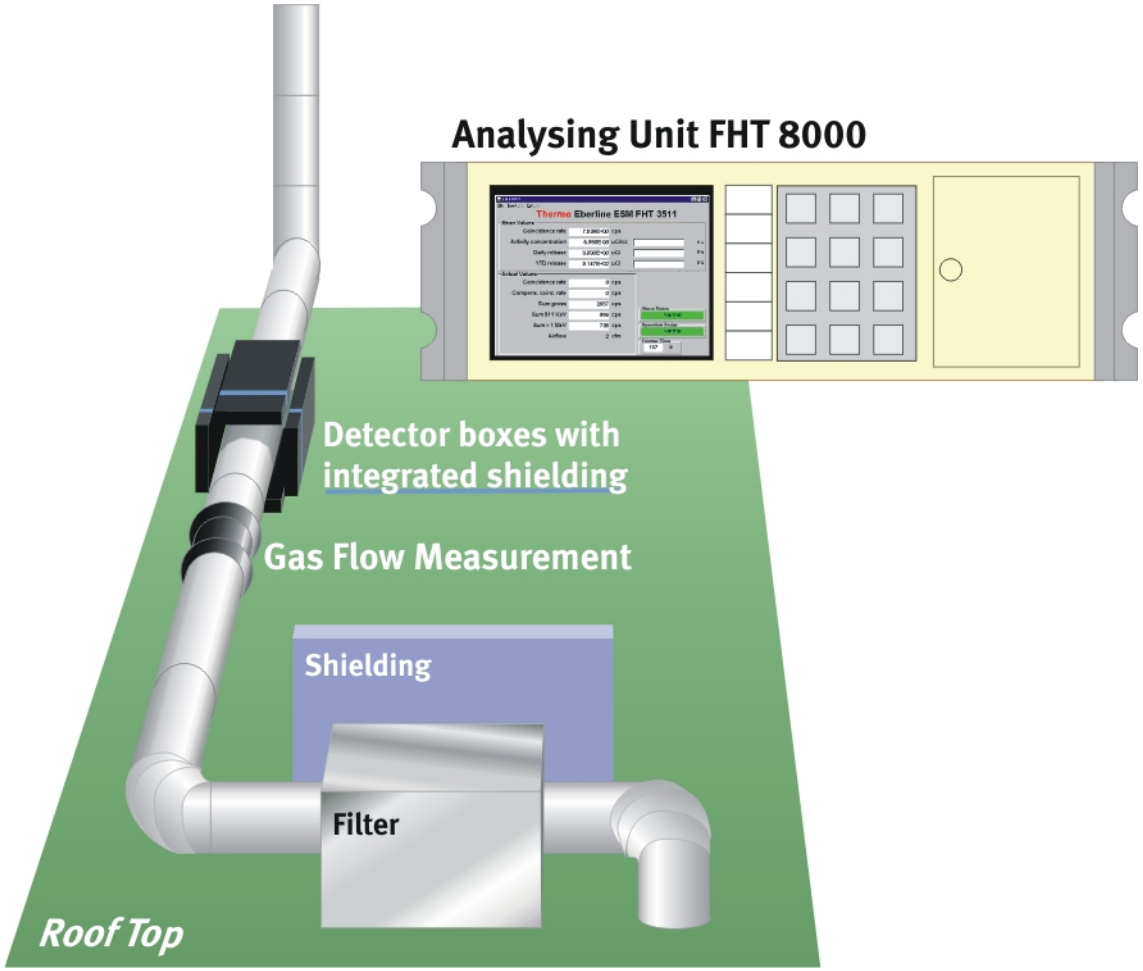
System Overview



Hardware: Installed system

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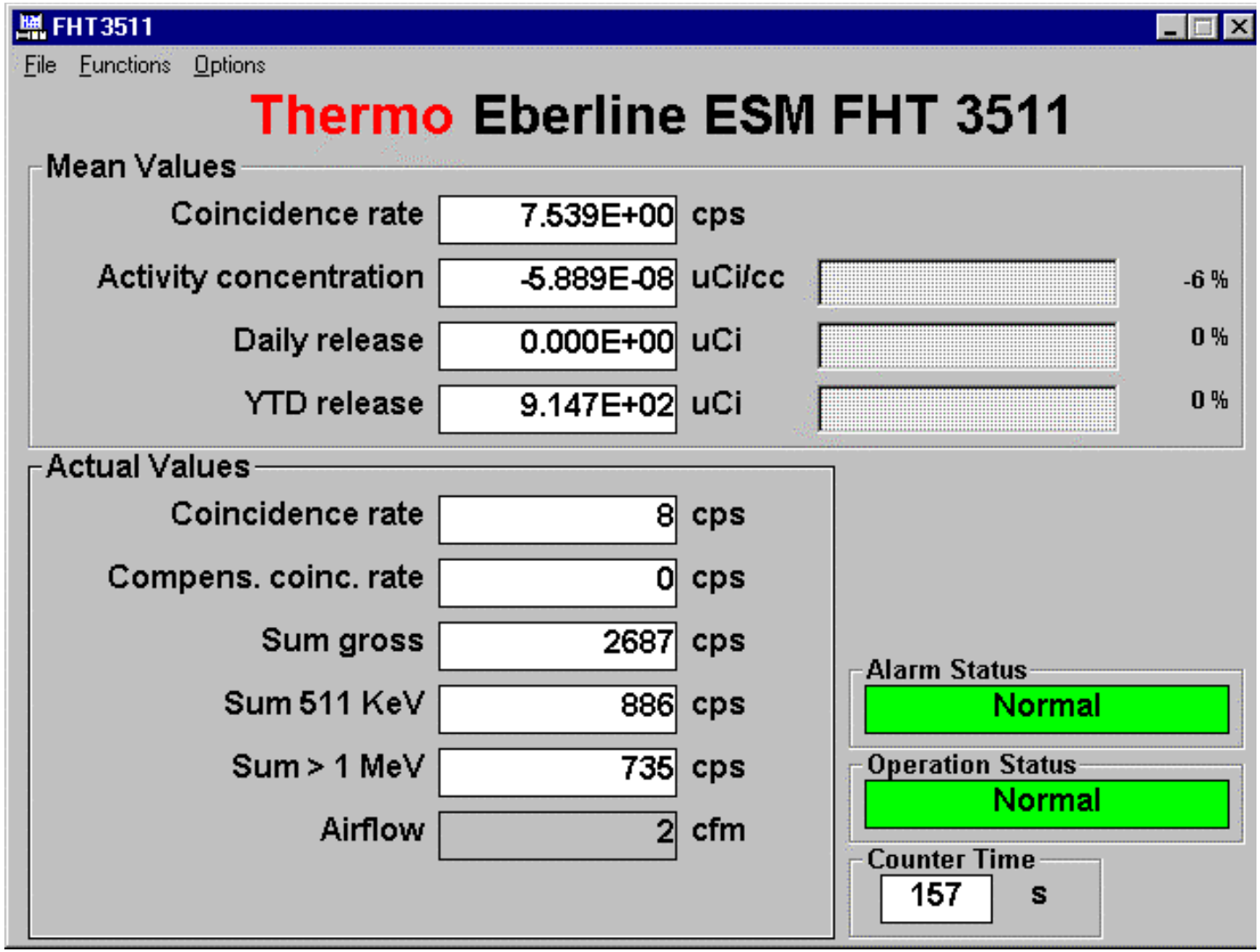
Data Display in Operation Mode



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Advantages of Coincidence Monitoring

- calibration with point check source – no hot chemistry
- direct measurement around existing stack
  - no by-pass required ***
  - no thin, large mylar entrance window
- as local as a beta measurement
- full external 511 keV background rejection
  - ⇒ calibration factor independent of facility design
  - ⇒ no cross talk from neighboring ducts
- calibration factor independent of positron energy
- no sealing problems
- appealing software package

*** *F-18 gets attached to by-pass walls – great underestimation of true release!*

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