Activation of TRT Detector at High Luminosity

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Ref : **ATL-INDET-2000-013**

"Induced Radioactivity in the ATLAS Inner Detector - TRT"

TRT COMPONENTS

Detector components: Straw (C, O, N, H) - Wire (W, Au) - End plugs and C-fibre structure (C, O, N, H) - WEBs for the End-Cap TRT (SiO, epoxy[O,C,N,H], solder[Pb, Sn], Cu)

Active gas and cooling: Active gas (Xe, CF_4, CO_2) - Cooling gas (CO_2) - Cooling liquid (C_4F_{10})

Pipes: Stainless steel (Cr, Mn, Si, Fe, P, S, Mo)

Squirrel cage: Al (Cr, Zn, Ti, Cu, Mn, Mg, Si, Fe,)

ASDBLR and DTMROC boards: Printed circuits (Cu), Solder (Pb, Sn), Capacitors, Resistors, Electronic chips (Si, pins?), Connectors (?)

Cables: Cu, Ag

Conductive plating: Optalloy (Zn, Sn, Cu)

We have <u>not</u> considered: Patch pannels, PPB, PPF1, cables and pipes from PPF1 to PP2

ACTIVITY CALCULATION

$$A = \Phi \,.\, \sigma \,.\, N \,.\, M \,.\, X \,.\, (\text{build-up}) \,.\, (\text{decay})$$

Φ : the neutron flux (kHz/cm^2)

σ : the neutron capture cross-section (10^{24} barn),

N : the number of parent atoms per unit mass (atoms/g)

M : the mass of element considered (g)

X : the number of particles emitted per decay

build-up : $1 - e^{-(\lambda \,.\, T)}$

decay : $e^{-(\lambda \,.\, t)}$

T : irradiation time

t : decay time

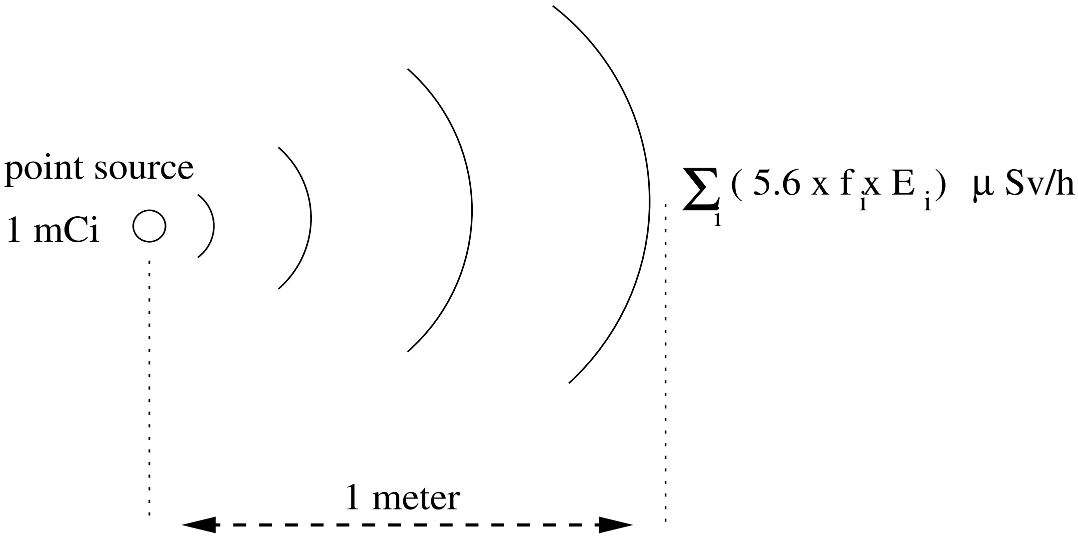
λ : $(\ln 2)/T_{1/2}$

Units: 1 Ci = 3.7 x 10^{10} Bq

DOSE RATE CALCULATION

$$1 \text{ Sv} = 1 \text{ J/kg}$$

Gamma radiation dose rate :

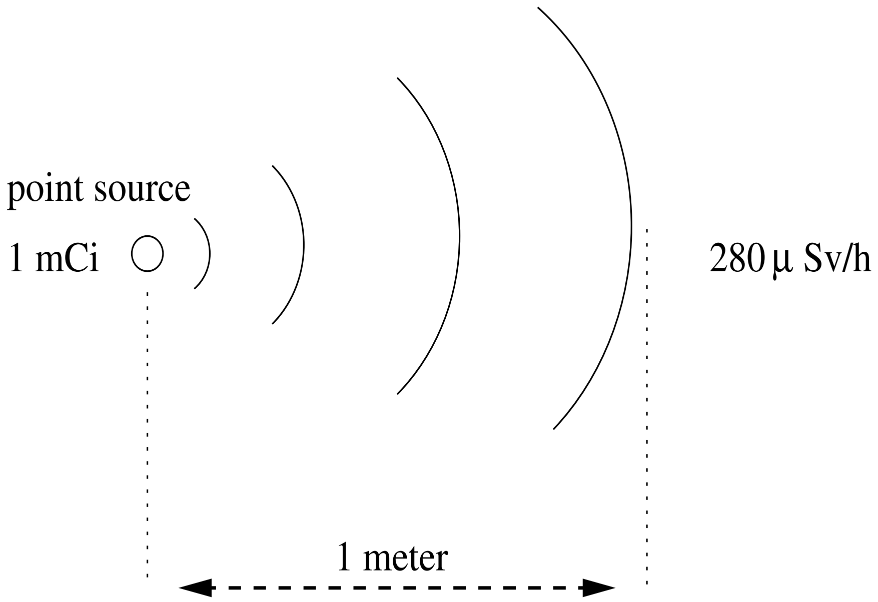


i : number of different photon energies

f_i : fraction of photons with energy E_i

E_i : photon energy in MeV

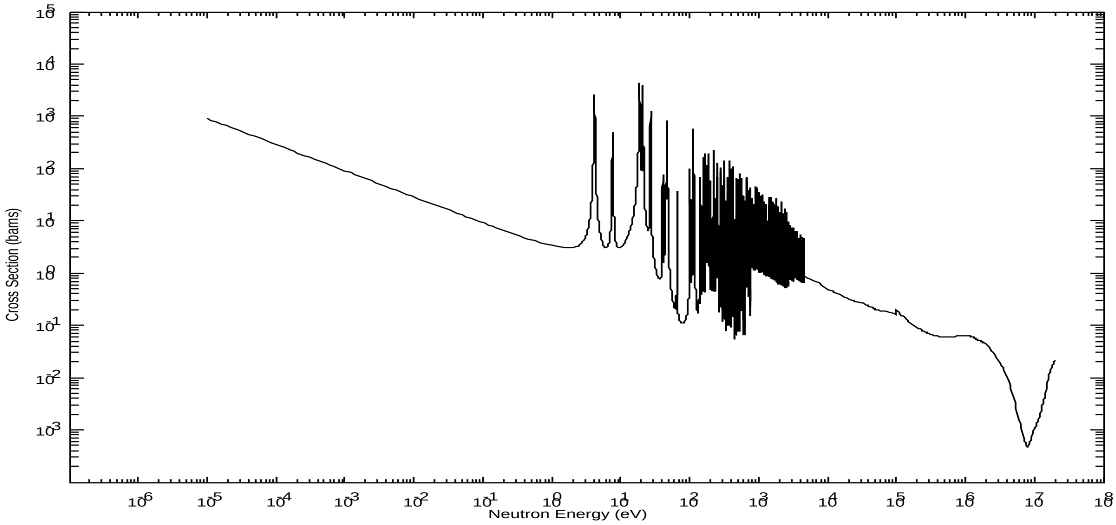
Beta radiation dose rate :



ACTIVATION PROPERTIES OF ELEMENTS

Natural abundance
Possible isotopes produced through neutron capture
Level of neutron capture cross-section
Half-life of the radioisotope

Neutron capture cross-section of ^{180}W :



SELECTION CRITERIA

Ignore if ;

$T_{1/2} << 1$day or 10 years$< T_{1/2}$

$\sigma_{\text{neutron capture}} < 10^2$ barn

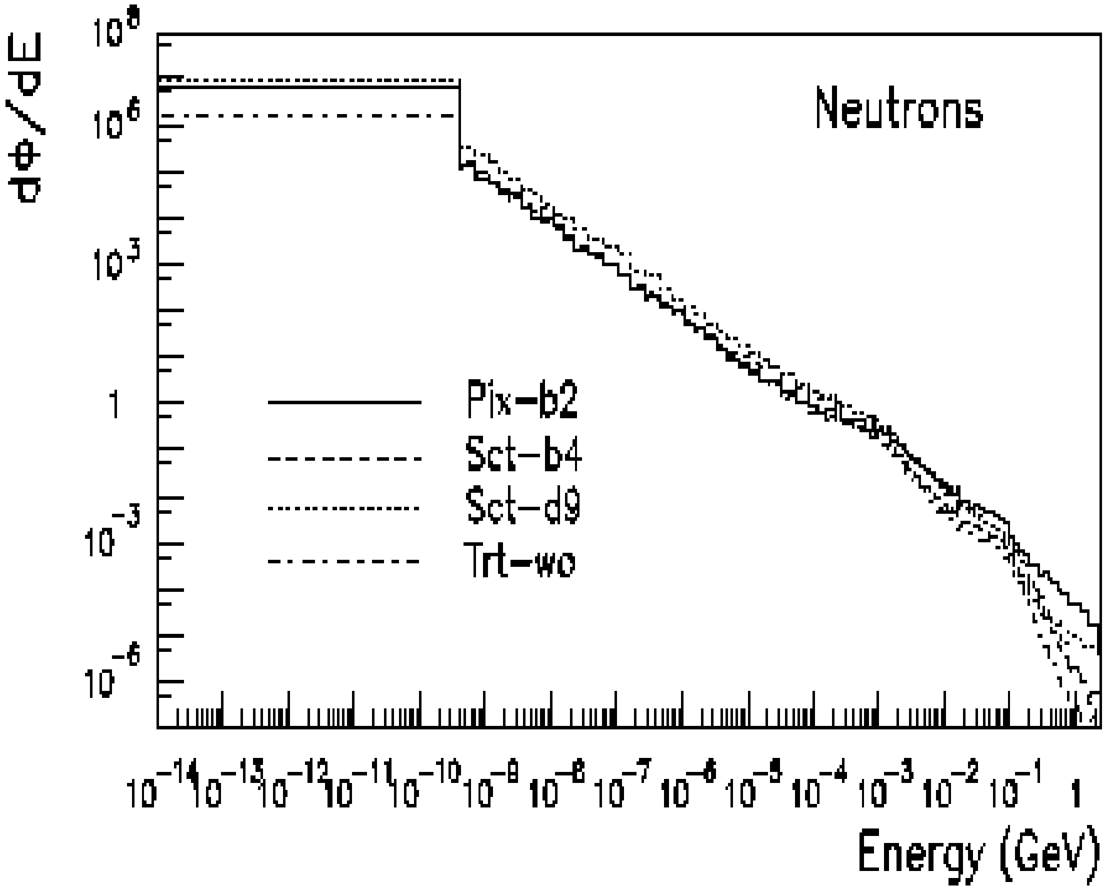
Active gas is an exception ;

Ignore if $T_{1/2} < 1$ minute.

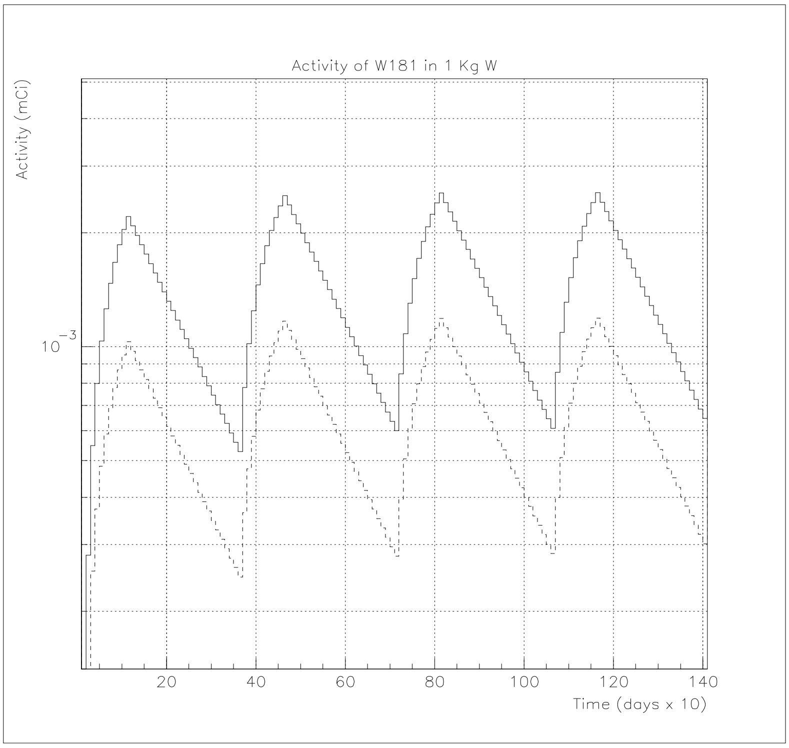
Elements	Natural Isotope	Radioisotope produced in (n,γ) reaction	Maximum total neutron capture cross-section	Result
Tin - $_{50}Sn$	^{112}Sn (0.97%)	^{113}Sn (τ=115.1 days)	$3x10^3$ b	consider
		^{113m}Sn (τ=21 min)	$3x10^3$ b	ignore
	^{114}Sn (0.65%) & ^{115}Sn (0.34%)	none	-	-
	^{116}Sn (14.54%)	^{117m}Sn (τ=14 days)	$3x10^3$ b	consider
	^{117}Sn (7.68%)	none	-	-
	^{118}Sn (24.22%)	^{119m}Sn(τ=293.1day)	10^3 b	consider
	^{119}Sn (8.58%)	none	-	-
	^{120}Sn (32.59%)	^{121}Sn (τ=27 hours)	10^2 b	consider
		^{121m}Sn(τ=55 years)	10^2 b	ignore
	^{122}Sn (4.63%)	^{123}Sn (τ=129.2 days)	50 b	consider
		^{123m}Sn(τ=40 min)	50 b	ignore
	^{124}Sn (5.79%)	^{125}Sn (τ=10 days)	$6x10^2$ b	consider
		^{125m}Sn (τ=10 min)	$6x10^2$ b	ignore
Xenon - $_{54}Xe$	^{124}Xe (0.1%)	^{125}Xe (τ=16.9 hours)	$4x10^4$ b	consider
		^{125m}Xe (τ=1min)	$4x10^4$ b	ignore
	^{126}Xe (0.1%)	^{127}Xe (τ =36.4 days)	$3x10^3$ b	consider
		^{127m}Xe (τ=1 min)	$3x10^3$ b	ignore
	^{128}Xe (1.9%)	^{129m}Xe (τ=8.9 days)	10^3 b	consider
	^{129}Xe (26.4%)	none	-	-
	^{130}Xe (4.1%)	^{131m}Xe (τ=11.9 days)	$4x10^2$ b	consider
	^{131}Xe (21.2%)	^{132m}Xe (τ=8.4 msec)	$2x10^4$ b	ignore
	^{132}Xe (26.9%)	^{133}Xe (τ=5.2 days)	10^2 b	consider
		^{133m}Xe (τ=2.2 days)	10^2 b	consider
	^{134}Xe (10.4%)	^{135}Xe (τ=9.1 hours)	10^2 b	consider
		^{135m}Xe (τ=15.3 min)	10^2 b	consider
	^{136}Xe (8.9%)	^{137}Xe (τ=3.8 min)	10 b	ignore

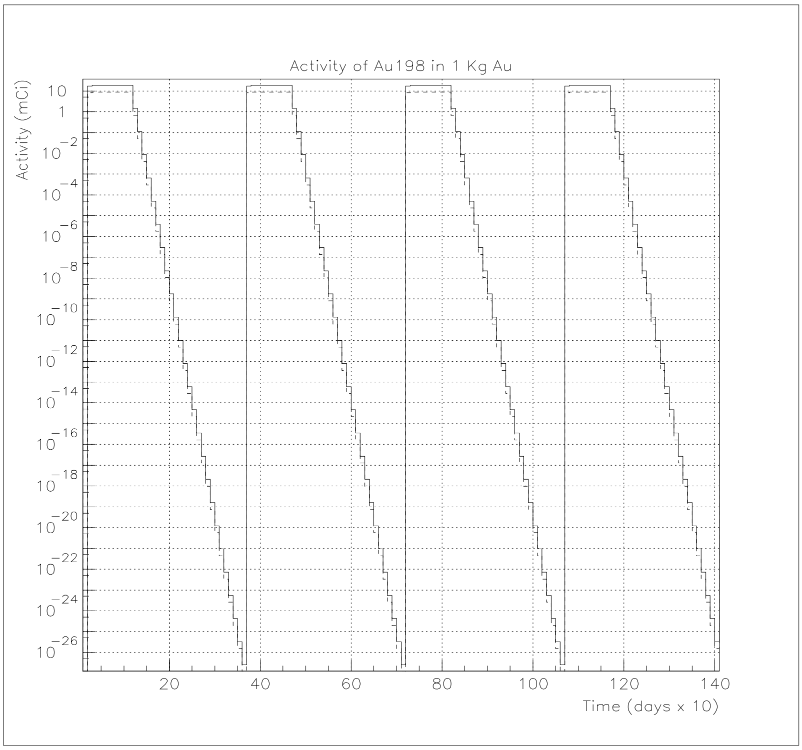
ATLAS NEUTRON FLUX

Energy Range	MINIMUM	MAXIMUM
0 - 1 keV	700 kHz/cm^2	1500 kHz/cm^2
1 - 10 keV	70 kHz/cm^2	150 kHz/cm^2
10 - 100 keV	70 kHz/cm^2	150 kHz/cm^2
0.1 - 1 MeV	150 kHz/cm^2	300 kHz/cm^2
1 - 10 MeV	150 kHz/cm^2	300 kHz/cm^2



RESULTING ACTIVITIES



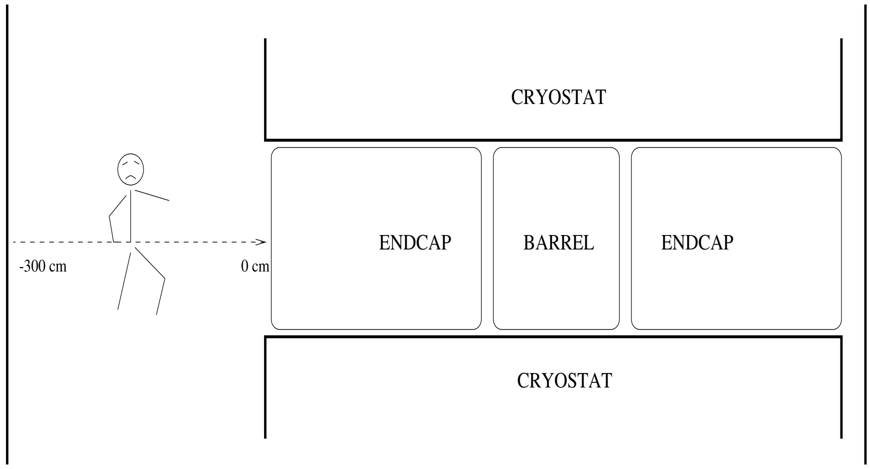


γ		TOTAL AMOUNT IN TRT (kg)	MAXIMUM GAMMA ACTIVITY (mCi)				
			0 d	2 d	10 d	20 d	30 d
TRT VOLUME	Xe	**15**	9.1	5.1	2.6	1.7	1.4
	W	**2.89**	46.2	11.6	0.1	0.0	0.0
	Au	**0.20**	19.0	11.5	1.5	0.0	0.0
EC OUTER SURFACE (uniform)	Cr	**8.01**	0.8	0.8	0.7	0.5	0.4
	Sn	**10.51**	0.2	0.2	0.2	0.1	0.1
	Zn	**1.41**	0.2	0.2	0.2	0.2	0.1
	Cu	**30.73**	0.6	0.1	0.0	0.0	0.0
	Fe	**27.46**	0.1	0.1	0.1	0.1	0.1
	Au	**0.025**	1.6	1.0	0.0	0.0	0.0
EC OUTER SURFACE (non-uniform)	Ag	**3.08**	7.4	7.4	7.2	7.0	6.7
	Cr	**2.54**	0.3	0.3	0.2	0.2	0.1
	Cu	**65**	1.2	0.1	0.0	0.0	0.0
	Fe	**10.12**	0.0	0.0	0.0	0.0	0.0
BARREL SIDE AREA	Sn	**3.52**	0.8	0.8	0.6	0.4	0.4
	Ag	**2.00**	4.8	4.8	4.6	4.6	4.4
	Cu	**4.5**	0.1	0.0	0.0	0.0	0.0
BARREL SERVICES	Ag	**1.92**	4.6	4.6	4.5	4.4	4.2
	Fe	**48.81**	0.2	0.2	0.2	0.1	0.1
	Cu	**40.6**	0.8	0.1	0.0	0.0	0.0
	Cr	**12.26**	1.3	1.3	1.0	0.8	0.6
CRYOSTAT	Fe	**4.75**	0.0	0.0	0.0	0.0	0.0
	Cr	**2.97**	0.3	0.3	0.2	0.2	0.1
	Zn	**2.97**	0.3	0.3	0.3	0.2	0.2
	Cu	**1.19**	0.0	0.0	0.0	0.0	0.0

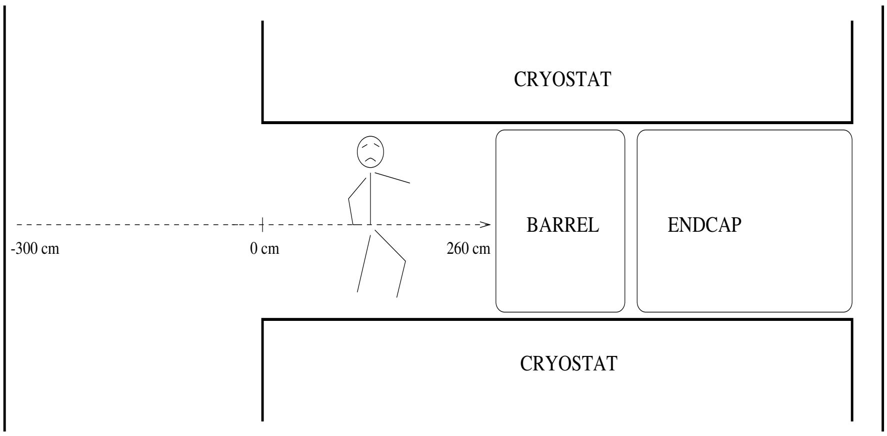
β		TOTAL AMOUNT IN TRT (kg)	MAXIMUM BETA ACTIVITY (mCi)				
			0 d	2 d	10 d	20 d	30 d
TRT VOLUME	Xe	**15**	3.7	2.5	0.9	0.2	0.1
	W	**2.89**	45.8	15.6	5.2	4.8	4.4
	Au	**0.20**	19.0	13.3	1.5	0.1	0.0
EC OUTER SURFACE (uniform)	Sn	**10.51**	1.1	0.6	0.2	0.1	0.1
	Cu	**30.73**	114	9.2	0.0	0.0	0.0
	Fe	**27.46**	0.1	0.1	0.1	0.1	0.0
	Au	**0.025**	1.6	1.0	0.1	0.0	0.0
EC OUTER SURFACE (non-uniform)	Ag	**3.08**	2.4	2.4	2.4	2.2	2.2
	Cu	**65**	241	19.3	0.0	0.0	0.0
	Fe	**10.12**	0.0	0.0	0.0	0.0	0.0
BARREL SIDE AREA	Sn	**3.52**	0.4	0.2	0.1	0.0	0.0
	Ag	**2.00**	1.5	1.5	1.5	1.4	1.4
	Cu	**4.5**	16.8	1.3	0.0	0.0	0.0
BARREL SERVICES	Ag	**1.92**	1.4	1.4	1.4	1.4	1.3
	Fe	**48.81**	0.2	0.2	0.2	0.1	0.1
	Cu	**40.6**	150	12.0	0.0	0.0	0.0
CRYOSTAT	Fe	**4.75**	0.0	0.0	0.0	0.0	0.0
	Cu	**1.19**	4.4	0.4	0.0	0.0	0.0

ACCESS SCENARIOS

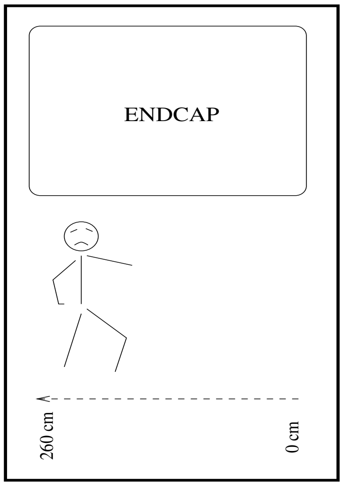
case 1:



case 2:



case 3:



EQUIVALENT DOSE RATES

γ	**Maximum gamma radiation dose rate at surface after:**		
	0 days	**2 days**	**10 days**
CASE 1	~112 μSv/h	~61 μSv/h	~35 μSv/h
CASE 2	-	~121 μSv/h	~73 μSv/h
CASE 3	-	~165 μSv/h	~105 μSv/h

CERN limit for γ radiation : 100 μSv/h

β	**Maximum beta radiation dose rate at surface after:**		
	0 days	**2 days**	**10 days**
CASE 1	~76 mSv/h	~10 mSv/h	~2 mSv/h
CASE 2	-	~13 mSv/h	~3 mSv/h
CASE 3	-	~32 mSv/h	~4 mSv/h

CERN limit for β radiation : 300mSv/year (for skin)

NOTE : This calculation for beta radiation dose neglects any air shielding which can be significant, since the range of a β particle in air is 3.7 meters per MeV (this corresponds to ~1mm/MeV in lead, ~1.5mm/MeV in stainless steel, ~4mm/MeV in aluminium)

CERN RADIATION LIMITS

CERN safety limits for gamma radiation :

AREA	MAX DOSE RATE
[1]NON-DESIGNATED	< 0.5 μSv/h
[2]SUPERVISED	< 7.5 μSv/h
[3]SIMPLE CONTROLLED	< 100 μSv/h

[1]: Public

[2]: Access free, no time limitation, site monitored

[3]: Limited access, individual monitoring, limited length of stay

15 mSv/year - 4 mSv/month maximum

design limit : 5 mSv/year - 1 mSv/month maximum

CERN safety limits for beta radiation :

Organ	Max Dose per year	Max Dose per hour
Hand, forearms, feet, ankles	< 500 mSv/y	< 250 μSv/h
Skin	< 300 mSv/y	< 150 μSv/h
Eyes	< 150 mSv/y	< 75 μSv/h

1 year is taken as 2000 working hours