RADIATION PROTECTION FOR FLASH RT, INTEGRAL DOSE (ICRP) OR INSTANTANEOUS DOSE RATE?

Open consultation on Metrology for Radiation Protection

Support for technological trends: EURAMET's Work Programme on 'Metrology for Industry (Call 2023)'

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Sordina IORT Technologies

ICRP RECOMMENDATIONS…

Principles of Radiological Protection

International Commission on Radiological Protection (ICRP)

International Commission on Radiological Protection (ICRP)

The Commission aims to make recommendations concerning basic frameworks for radiological protection and protection standards. The Commission consists of the Main Commission and four standing Committees (radiation effects, doses from radiation exposures, protection in medicine, and application of the Commission's recommendations).

(Reference) Dose limits excerpted from ICRP Recommendations

	1977 Recommendations	1990 Recommendations	2007 Recommendations
Dose limits (occupational exposure)	50 mSv/year	100 mSv/5 years and 50 mSv/year	100 mSv/5 years and 50 mSv/year
Dose limits (public exposure)	5 mSv/year	1 mSv/year	1 mSv/year

mSv: millisieverts

“ The 2007 Recommendations of the International Commission on Radiological Protection”
Annals of the ICRP Volume 37/2-4, 2008

The quantity to be considered is the integral dose over time, that is, for public

$$\left[\int_{1\ Jan}^{31\ Dec} IDR(t)dt\right] < 1\ mSv\ ^{*}$$

Considering 50 working week per year, the limit scales down to

20 µSv/week

* IDR is used for explicative purposes

… HOW NCRP RECEIPT ICRP

NCRP REPORT No. 151

STRUCTURAL SHIELDING DESIGN AND EVALUATION FOR MEGAVOLTAGE X- AND GAMMA-RAY RADIOTHERAPY FACILITIES

NCRP REPORT No. 151

3.3 Time Averaged Dose-Equivalent Rates

When designing radiation shielding barriers it is usual to assume that the workload will be evenly distributed throughout the year. Therefore, it is reasonable to design a barrier to meet a weekly value equal to one-fiftieth of the annual shielding design goal (NCRP, 2004). However, further **scaling the shielding design goal to shorter intervals is not appropriate** and may be incompatible with the ALARA principle. Specifically, the **use of a measured instantaneous dose-equivalent rate (*IDR*), with the accelerator operating at maximum output, does not properly represent the true operating conditions and radiation environment** of the facility. It is more useful if the workload and use factor are considered together with the *IDR* when evaluating the adequacy of a barrier.

For this purpose, the concept of time averaged dose equivalent rate (TADR) is used in this Report along with the measured or calculated *IDR*.

The TADR is the barrier attenuated dose-equivalent rate averaged over a specified time or period of operation. TADR is proportional to *IDR*, and depends on values of *W* and *U*. There are two periods of operation of particular interest to radiation protection, the week and the hour.

NCRP REPO

Weekly TADR

$$R_W = \frac{IDR\ W_{pri}\ U_{pri}}{\dot{D}_o}$$

R_W = TADR averaged over 40-hr week (Sv week^{-1})
IDR = instantaneous dose-equivalent rate (Sv h^{-1}) measured at $\dot{D}_o$

$\dot{D}_o$ = absorbed-dose output rate at 1 m (Gy h^{-1})

If R_w x T is less than P, the barrier is adequate

NCRP REPORT No. 151

…n (NRC) specifies that the dose … external sources not exceed 0.02 mSv … derives from the maximum number of … performed in-any-one-hour when the time for setup of the procedure is taken into account.

$$R_h = N_{max}\ \overline{H}_{pt}$$

N_{max} = maximum number of patient treatments in-anyone-hour with due consideration to procedure set-up time

$\overline{H}_{pt}$ = average dose equivalent per patient treatment at 30 cm beyond the penetrated barrier

A CASE OF STUDY: IOERT

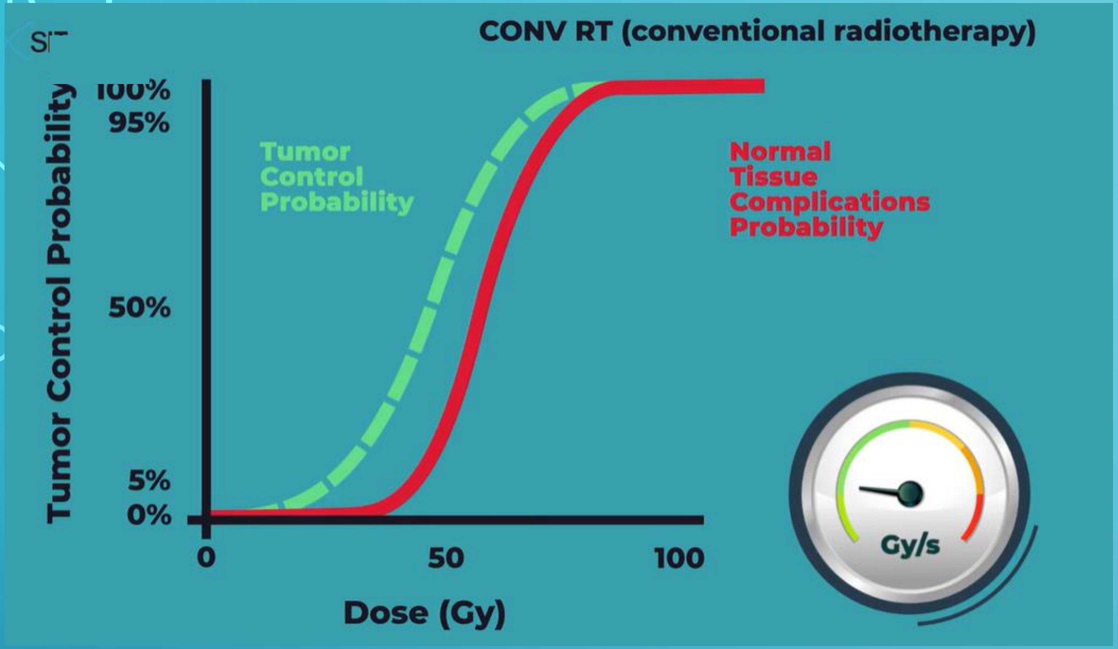
IOeRT is performed by means of mobile miniaturized linacs which can deliver the treatment within the Operating Room.

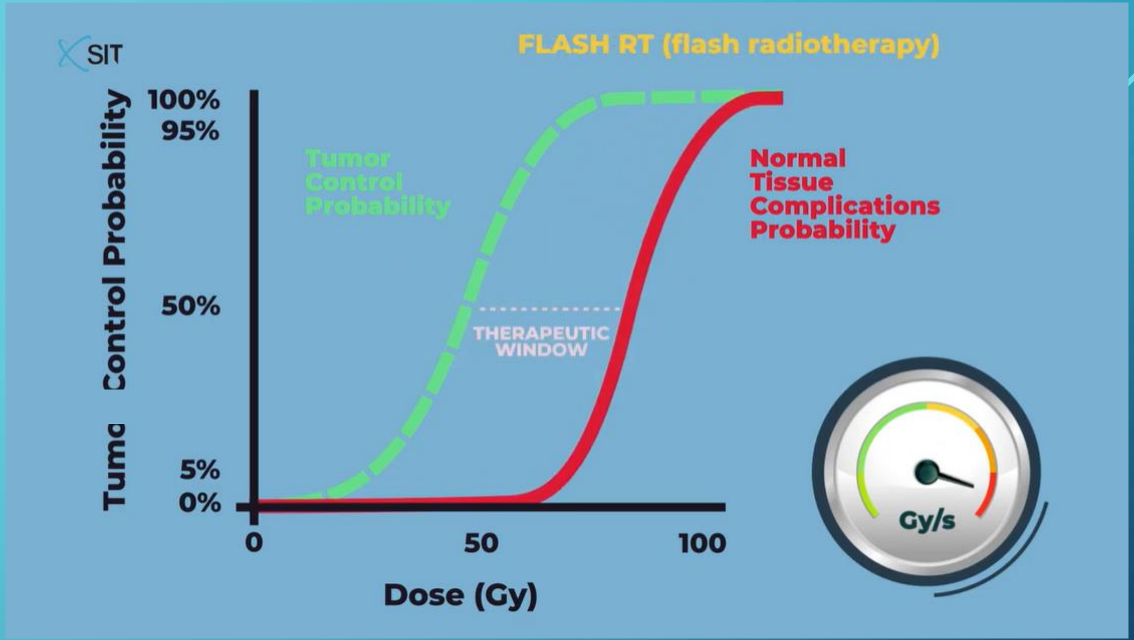
In the following, , LIAC HWL (https://www.soiort.com/liac-hwl/) RP performances are considered, as long as it is 'The best in the class ‘ in terms of RP performances.

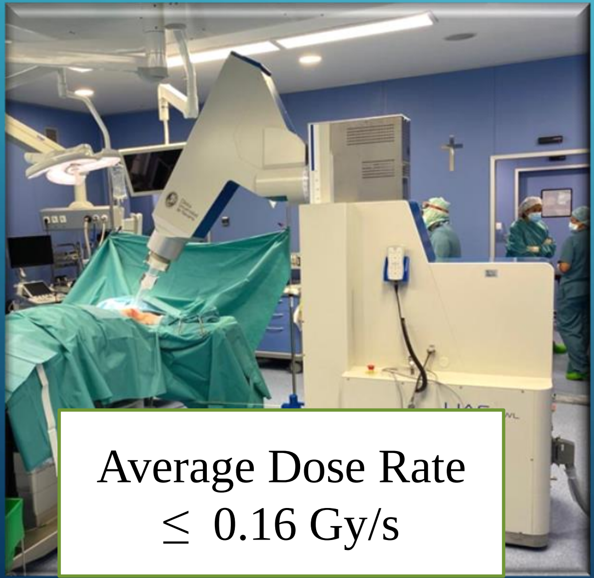
However whatever linac considered, the results would be pretty similar.

The stray radiation produced should be analyzed upstairs, in the installation plane and downstairs; for sake of brevity, calculation are performed in installation plane only.

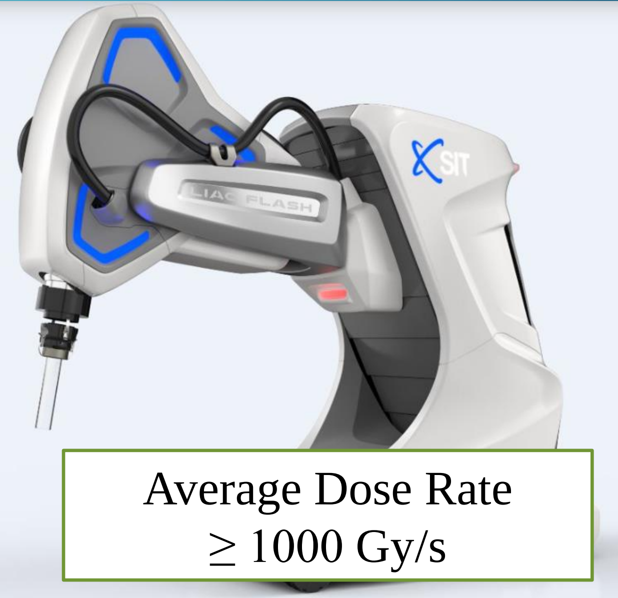
What is happening in terms of Average Dose Rate







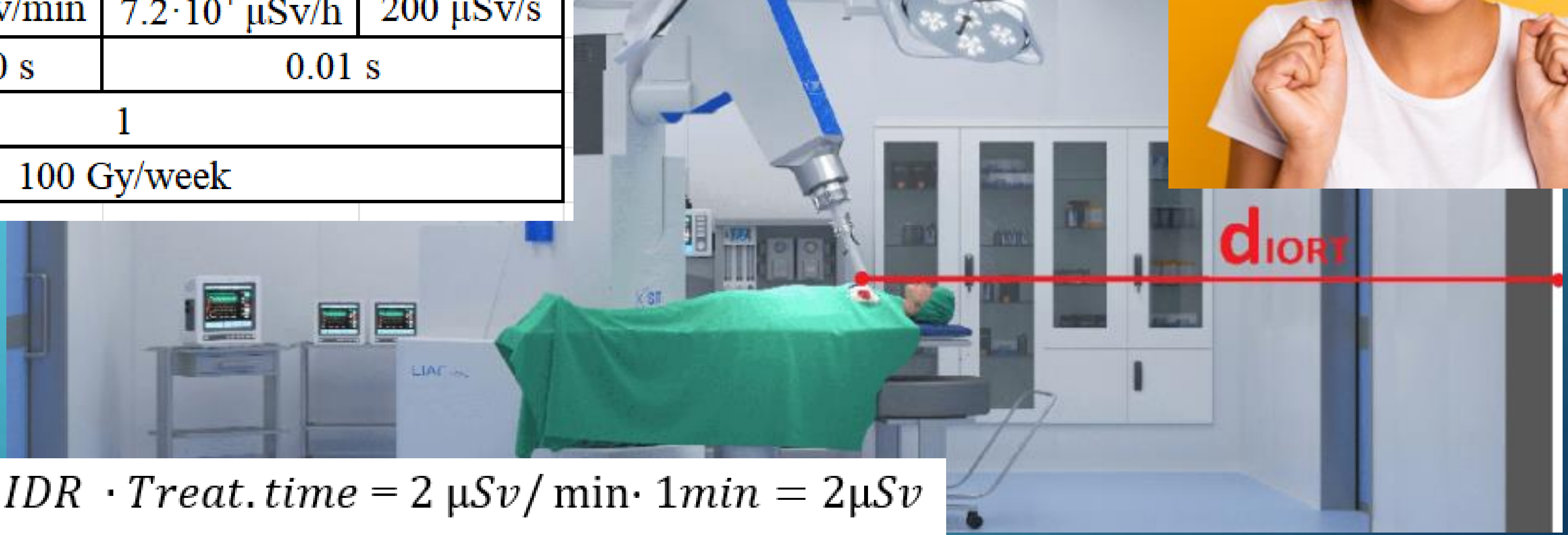
Average Dose Rate
$\leq$ 0.16 Gy/s



Average Dose Rate
$\geq$ 1000 Gy/s

IOERT RP ACCORDING TO ICRP & NRCP

	CONVENTIONAL		FLASH	
Stray Rad @ 3 m	<0,2 µSv/Gy			
Total Dose	10 Gy			
Average Dose Rate $\dot{D}_0$	10 Gy/min	0.17 Gy/s	$6\cdot10^4$ Gy/min	1000 Gy/s
Stray Rad IDR	120 µSv/h	2 µSv/min	$7.2\cdot10^4$ µSv/h	200 µSv/s
Treatment Time	1 min	60 s	0.01 s	
# MAX Patient/Hour	1			
MAX weekly W	100 Gy/week			



CONVENTIONAL $R_h = H_{pt} = IDR \cdot Treat.time = 2\ \mu Sv/\min \cdot 1min = 2\mu Sv$

FLASH $R_h = H_{pt} = IDR \cdot Treat.time = 200\ \mu Sv/s \cdot 0.01s = 2\mu Sv$

CONVENTIONAL $R_w = \frac{IDR \cdot W \cdot U}{\dot{D}_0} = \frac{120\,\frac{\mu Sv}{h} \cdot 100\,\frac{Gy}{week}}{600\ Gy/h} = 20\,\frac{\mu Sv}{week}$

FLASH $R_w = \frac{IDR \cdot W \cdot U}{\dot{D}_0} = \frac{7.2\cdot10^5\,\frac{\mu Sv}{h} \cdot 100\,\frac{Gy}{week}}{3.6\cdot10^6\ Gy/h} = 20\,\frac{\mu Sv}{week}$

IOERT RP ACCORDING TO IDR

	CONVENTIONAL		FLASH	
Stray Rad @ 3 m	<0,2 µSv/Gy			
Total Dose	10 Gy			
Average Dose Rate $\dot{D}_0$	10 Gy/min	0.17 Gy/s	$6\cdot10^4$ Gy/min	1000 Gy/s
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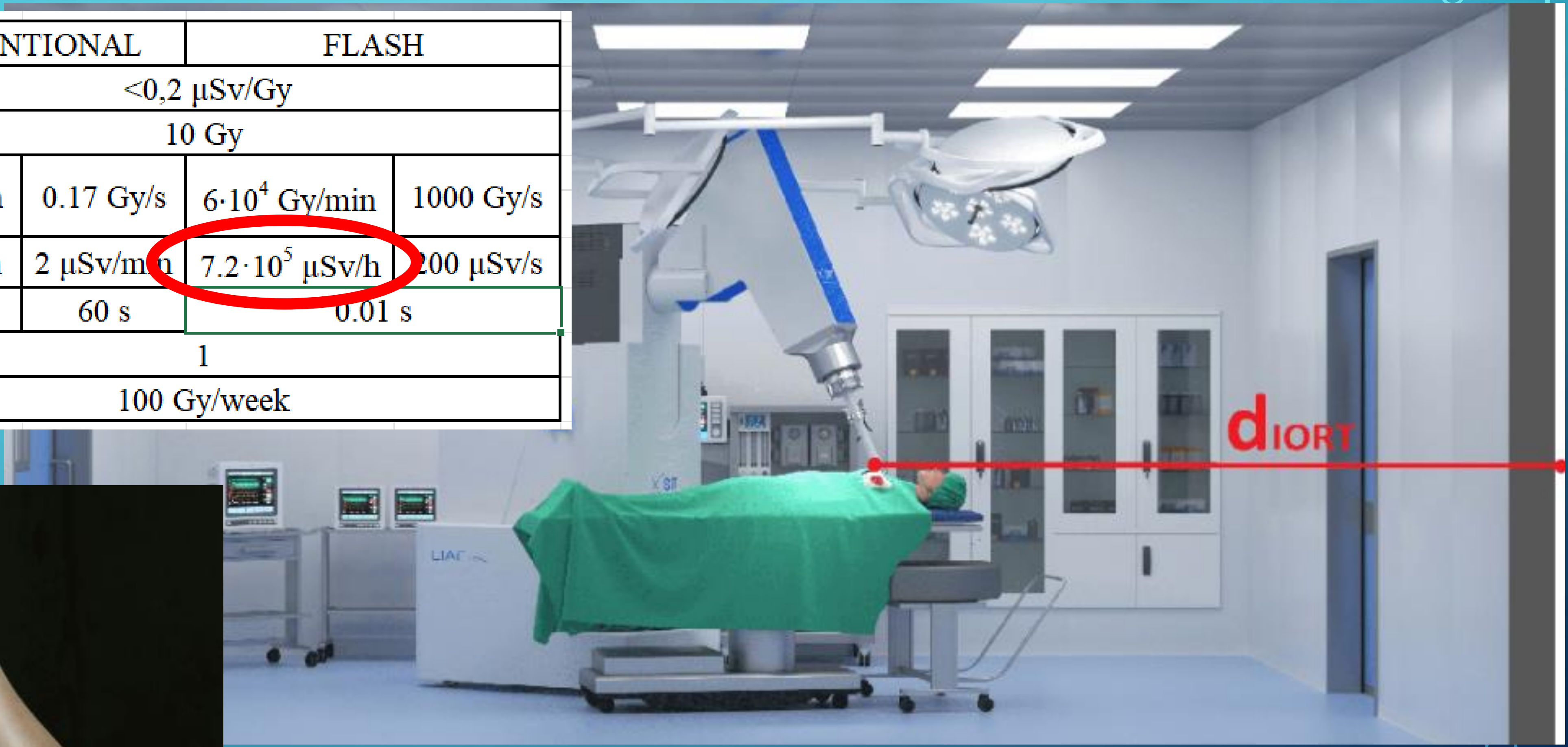
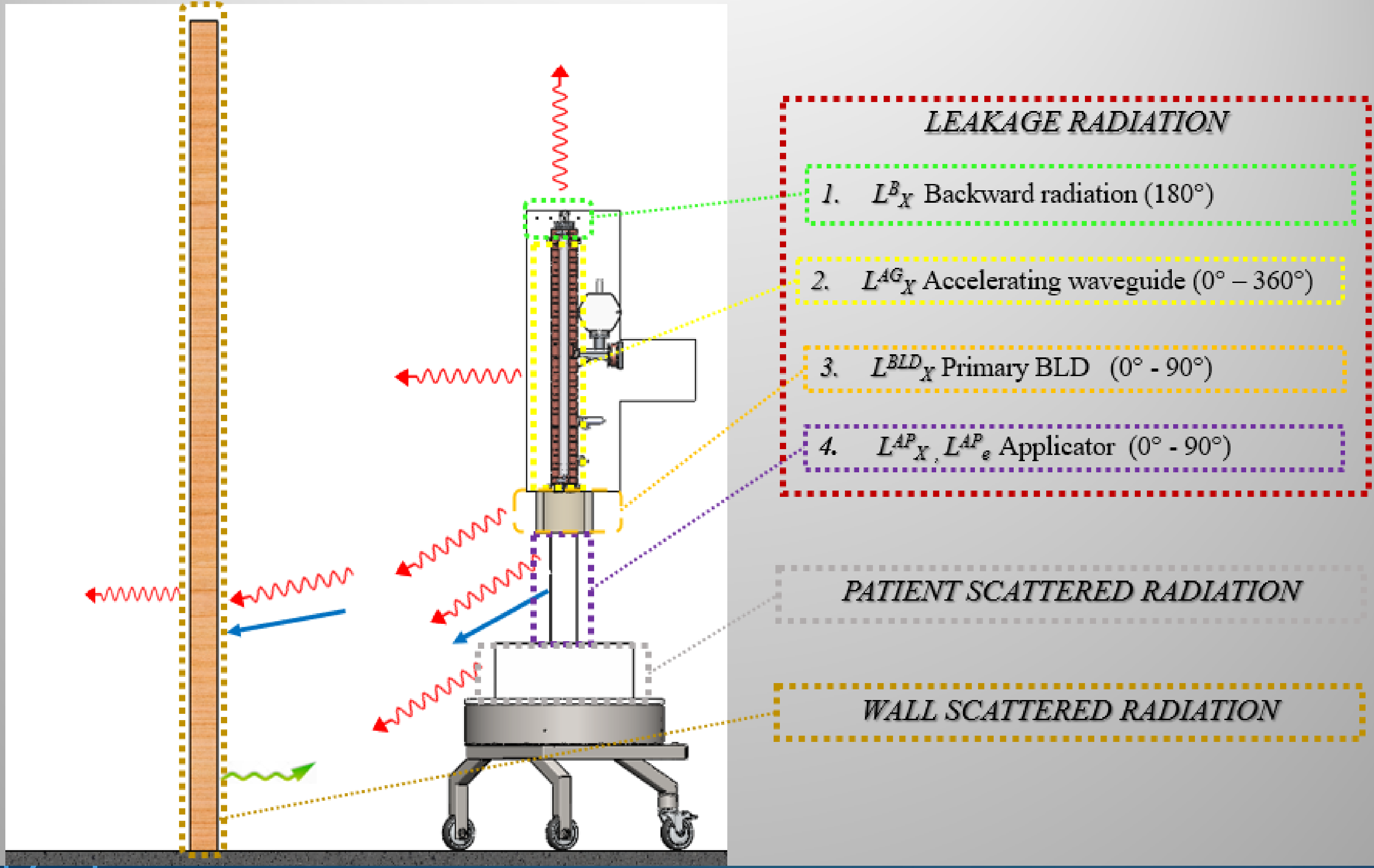


In order to lower IDR below 10 Sv/h …
…around 5 TVL would be needed, more than 75 cm of concrete each wall, and more than 120 on the floor (plus the beam stopper) …

IOERT RP &IDR… R&D last hope ? NO

$$\begin{cases} SR = PSR + LR + WSR \\ LR = L_X^B + L_X^{AG} + L_X^{PBLD} + L_X^{AP} + L_{e-}^{AP} \end{cases}$$



Stray Radiation produced by IOeRT linac has been thoroughly studied. The minimum amount possible is the PSR, which, for a 12 MeV beam, IS NOT LESS THAN 0.1 µSv/Gy.
Therefore, there is no technological solution available: only a correct regulatory approach can allow the Flash translation to the clinical practice!

WHAT WE WOULD LIKE…

- New metrology for Flash Radiation Protection
- New measuring devices for Flash Radiation Protection (some European Companies are already working on it)
- Last but not least: FLASH (with electron) is intrinsically green : less electrical power, smaller bunker, no material activation…