PAUL SCHERRER INSTITUT

PSI

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FLASH radiotherapy

Workshop ACHIP, 23rd June 2020

Outline

1. My area of expertise

- Radiation therapy, more specifically **proton therapy**
- Interests: dosimetry, beam modelling, beam delivery and more recently FLASH with protons


Gantry 1


Gantry 2


Optis 2


Gantry 3

2. Short recap of the main points of 2018 presentation

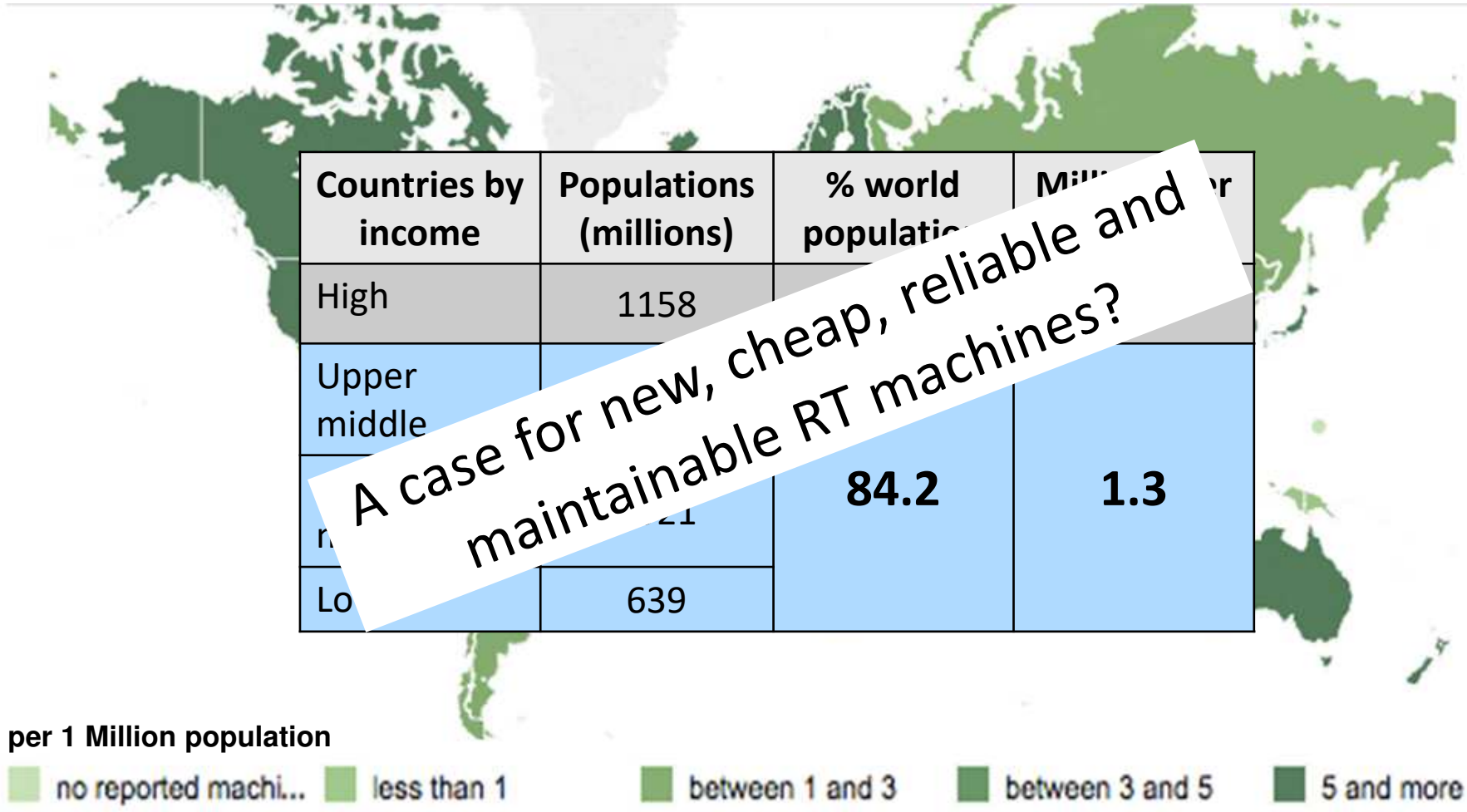
- Cheap and reliable radiotherapy machine
- A case for intraoperative radiation therapy?

3. FLASH radiotherapy with electrons

- Basics
- Specifications

Vision for world class radiotherapy

World-wide distribution of RT machines (as of 30 Jan 2017)



Countries by income	Populations (millions)	% world popula...	Mill... ...r
High	1158		
Upper middle		84.2	1.3
r...	...21		
Lo...	639		

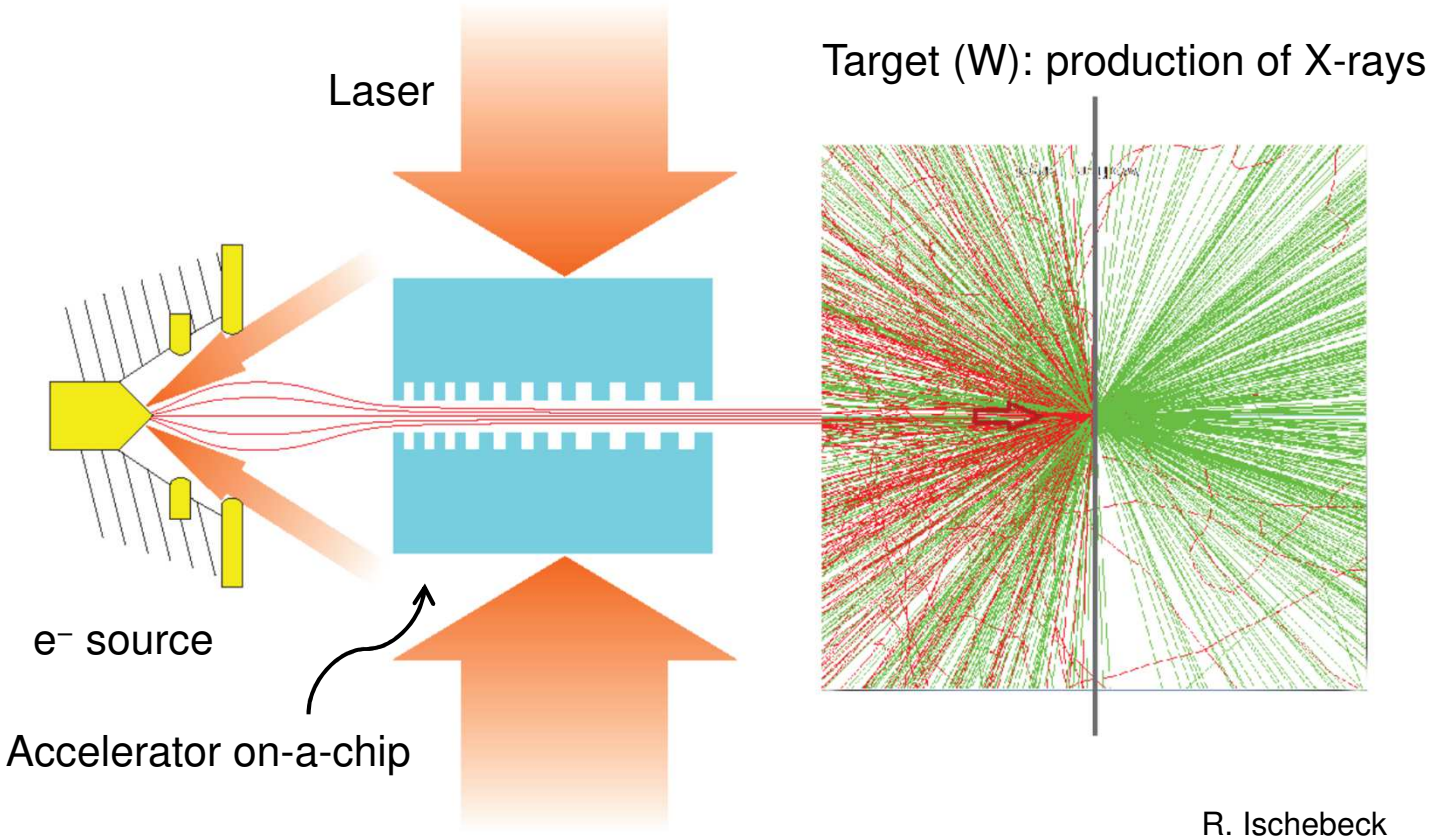
A case for new, cheap, reliable and maintainable RT machines?

IAEA DIRAC Directory of RAdiotherapy Centres

T. Lomax

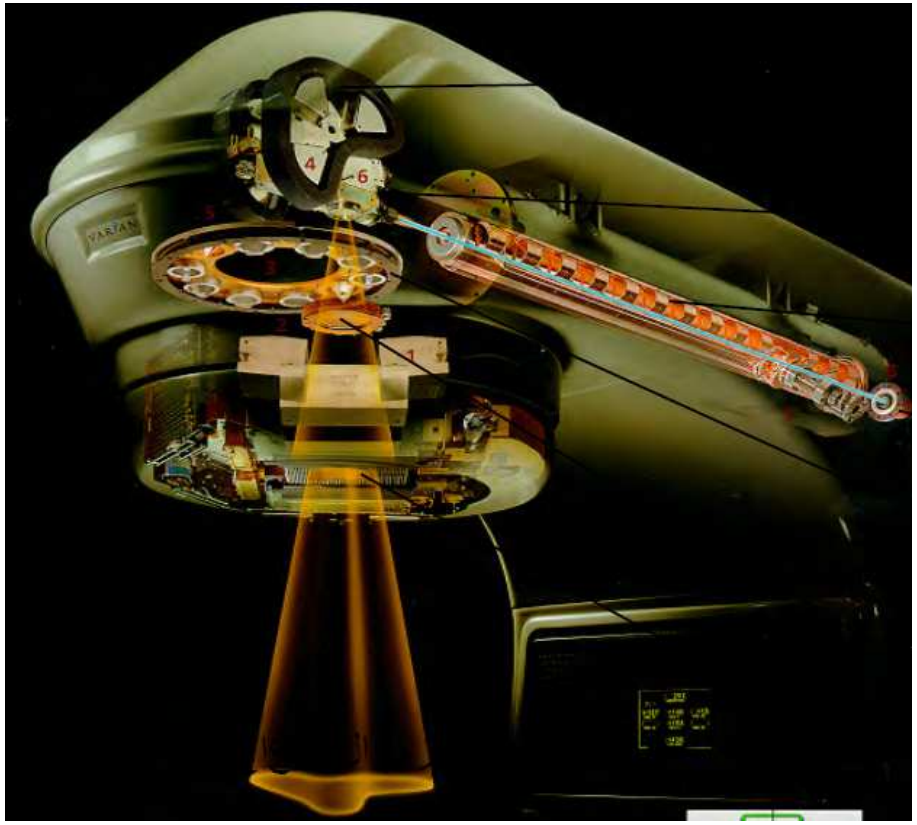
Production of photons from laser accelerated e⁻

The concept of a possible realization



What power and electron current is needed to reach a certain dose rate?

Classical RF linac for radiation therapy



Typical dose rate: 1 Gy/min

E_e = 4 … 22 MeV

$\tau = 10^{-6}$ s

f_{rep} = 100Hz

for photons production	direct e⁻ treatment
$I_{e,pk}$ = 100mA	$I_{e,pk}$ = 1mA

$I_{avg} = I_{pk} f_{rep} \tau$

$I_{e,avg} = 10^{-5}$A (= 10 µA)	$I_{e,avg} = 10^{-7}$A (= 0.1 µA)

$P\,[W] = I_e\,[\mu A] \cdot E_e\,[MeV]$

Power in the electron beam:	40 W … 220 W	0.4 … 2.2 W

Charged particle current density $I_{e,avg}/A$ for e⁻ treatments: 10^{-2} nA/cm² for 1 Gy/min

Intraoperative radiation therapy (IORT)

https://www.cancercenter.com/treatments/intraoperative-radiation-therapy/

With electrons: 3 … 12 MeV

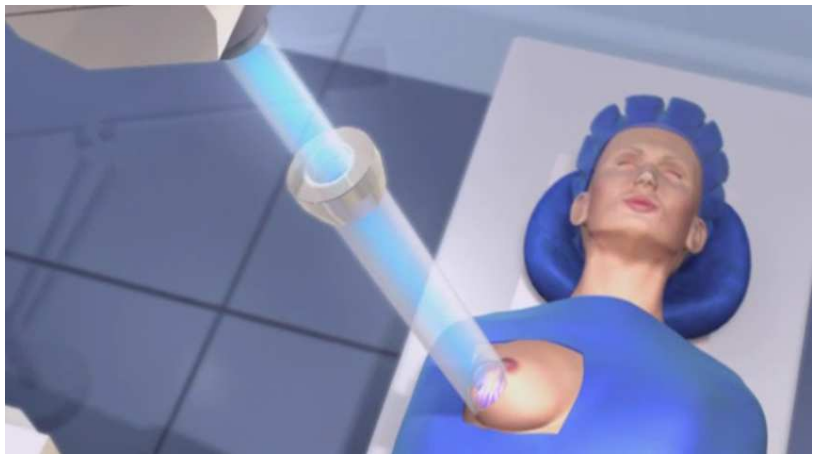
Dose rate: 20 Gy/min

With low energy X-rays: max 50 kV

I_e: 10^{-9} … 10^{-8} A (field size 10 cm^2 ... 100cm^2;factor 10'000 … 1'000 less than by a conventional linac with γ)

Power in the electron beam: as low as 10mW (10 MeV at 10^{-9} A)

Intraoperative radiation therapy (IORT)



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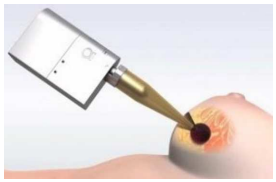


With low energy X-rays: max 50 kV

Power in the electron beam: ~10mW

I_e: 10^{-9} … 10^{-8} A

The next frontier

Accelerator on-a-chip at the tip of an endoscope, or similar

The FLASH effect: a new emerging research area

Observation:

- Major decrease of radiation induced side effects when dose delivered at extremely high dose rates with electron beams

Conventional **Flash**

34 Gy

31 Gy

28 Gy

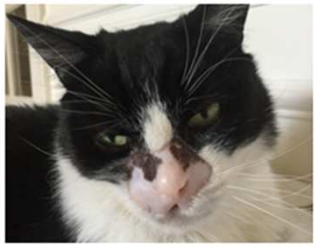
34 Gy

31 Gy

28 Gy

> 30 Gy/s (average)
> 70'000 Gy/s per pulse

Observed with e^- beams



VET CLINICAL TRIAL
Cat patients
Low toxicity
Good tumor control
Vozenin et al. 2018

Mini pig
Low toxicity
Vozenin et al. 2018

Dose rate considerations for FLASH

- Dose rates requirements for FLASH with electron beams are still being revised
- The time structure of beam delivery could be key for FLASH effects
- The dose rate per pulse may be the relevant parameter rather than the average dose rate over multiple pulses

Characteristic Linac at CHUV, Lausanne (Switzerland) used for FLASH

	FLASH*	CONV*	
τ (µs)	1.8	1.0	
f (Hz)	100 – 200	10	
$\dot{D}_m$ (Gy/s)	100 – 1'000	0.05	
$\dot{D}_p$ (Gy/s)	5.5 x 10^5 – 4.5 x 10^6	5 x 10^3	
$I_{e,avg}$	6 x 10^{-7} – 6 x 10^{-6} A	3 x 10^{-10} A	(for small fields ~10cm^2)
$I_{e,pk}$	3 x 10^{-3} – 3 x 10^{-2} A	3 x 10^{-5} A	(for small fields ~10cm^2)
	1.5 x 10^4 – 1.5 x 10^5 W		

* Oriatron eRT6 (M Jaccard *et al* Med. Phys. 45, 2018, 863 - 874), adapted

My thanks for your attention