The new generation of sustainable X-ray irradiators

IAEA International Conference on Accelerators for Research and Sustainable Development

Arnaud Pierard – Product Manager

24th May 2022

Certified B Corporation | Life, Science.

INDUSTRIAL SOLUTIONS

iba

Context and agenda

- **Very strong demand** for high-power X-ray in the second part of 2021 and continuing in 2022.
- Increasing activities in **US and Asia**.
- **X-Ray represents more than 50%** of the demand for IBA Industrial accelerators.

- Increase in the number of projects partially funded by governments when focus is put on improving sustainability.
- IBA aims at a corporate level to be **carbon-neutral in 2030** and puts sustainability at the core of its values.

Certified B Corporation

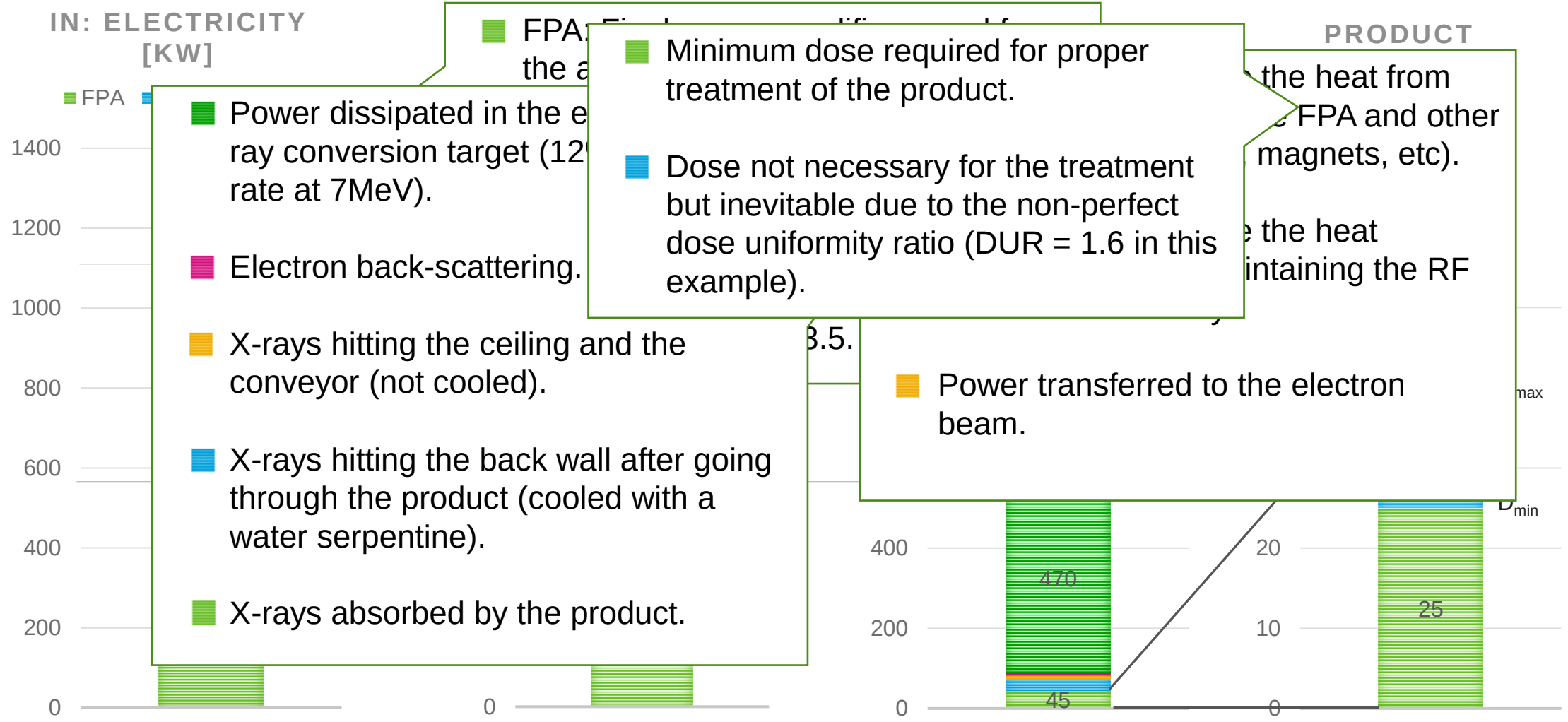
The reality of X-ray irradiation today

X-ray brings a lot to the table.
But it has its drawbacks.

- Electrical impact of the treatment of 100 000 m³ of product:
  - Electrical consumption.
  - Equivalent amount of CO_2 generated by this consumption.

Case	Dose [kGy]	Density [g/cm³]	Energy [MeV]	Beam Power [kW]	Irradiation time [Hours]	Electrical Consumption [MWh]	CO_2 generated (Germany) [Tons]	CO_2 generated (China) [Tons]
Palette Food 1	1	0.5	7	190 (X-ray)	1 700	831	331	635
Palette Food 2	1	0.5	5	150 (X-ray)	3 600	1 528	610	1 171
Palette Medical	25	0.15	7	560 (X-ray)	8 100	9 640	3 847	7 385
Box Medical	25	0.15	10	100 (E-beam)	3 400	1 113	444	853

The main challenge of X-ray



- Power dissipated in the e… ray conversion target (12… rate at 7MeV).
- Electron back-scattering.
- X-rays hitting the ceiling and the conveyor (not cooled).
- X-rays hitting the back wall after going through the product (cooled with a water serpentine).
- X-rays absorbed by the product.

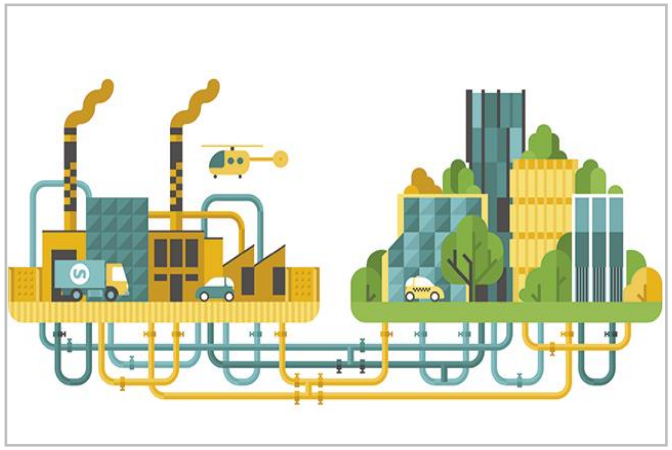
- Minimum dose required for proper treatment of the product.
- Dose not necessary for the treatment but inevitable due to the non-perfect dose uniformity ratio (DUR = 1.6 in this example).

- Power transferred to the electron beam.

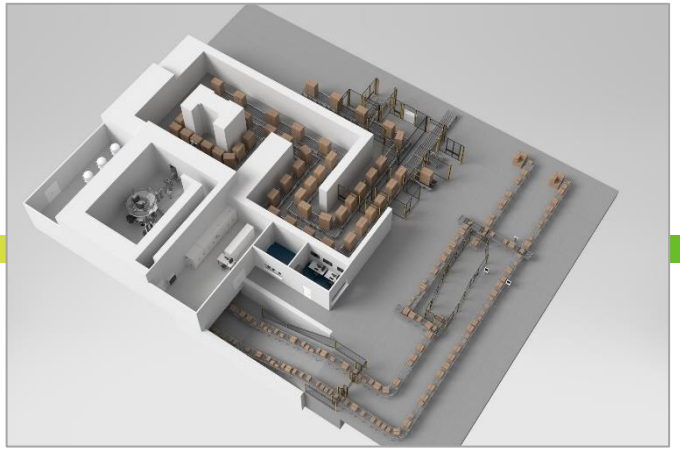
Value for a TT1000 Rhodotron at 7 MeV x 80 mA = 560 kW

What can we do about it? Where can we improve?

1. ACCELERATOR TECHNOLOGY



2. HEAT RECOVERY



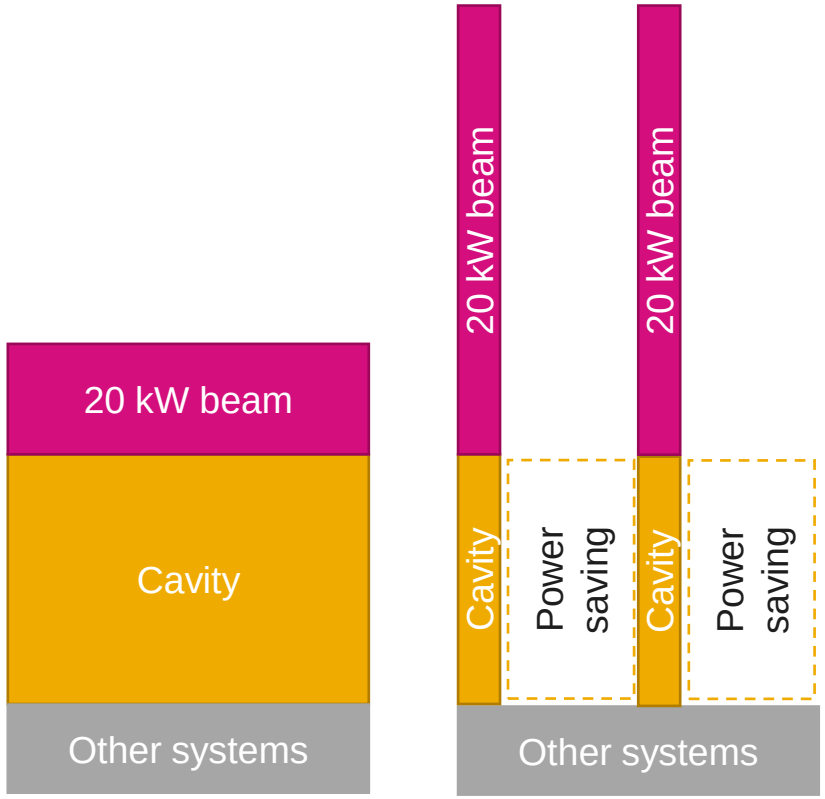
3. PROCESS OPTIMIZATION

4. ELECTRICITY PRODUCTION

1. Accelerator technology

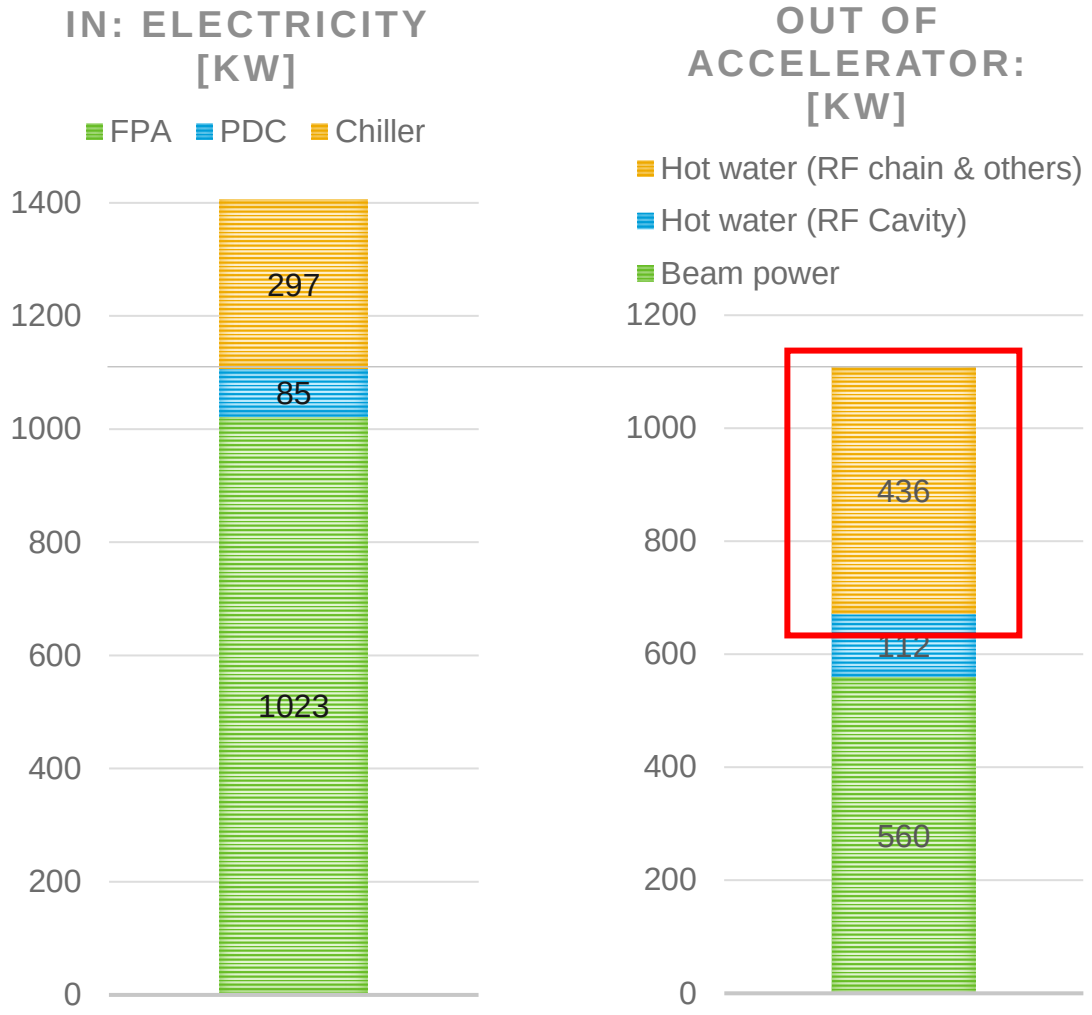
Pushing towards more electrical efficiency

Pulsing the RF in the cavity allows to improve the electrical efficiency…
But **only for low power machines** not suited for X-ray irradiation.

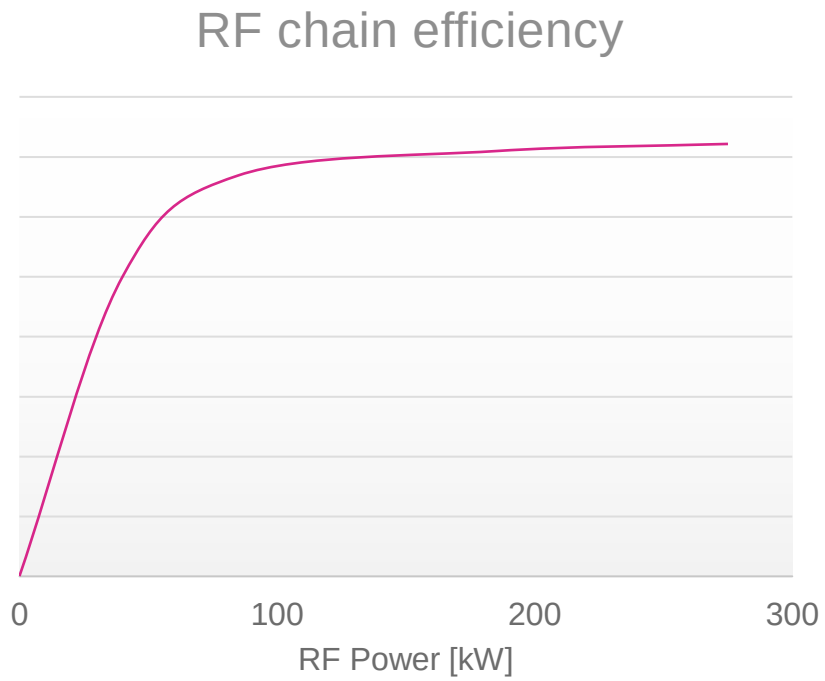


Value for a TT1000 Rhodotron at 7 MeV x 80 mA = 560 kW

Pushing towards more efficiency

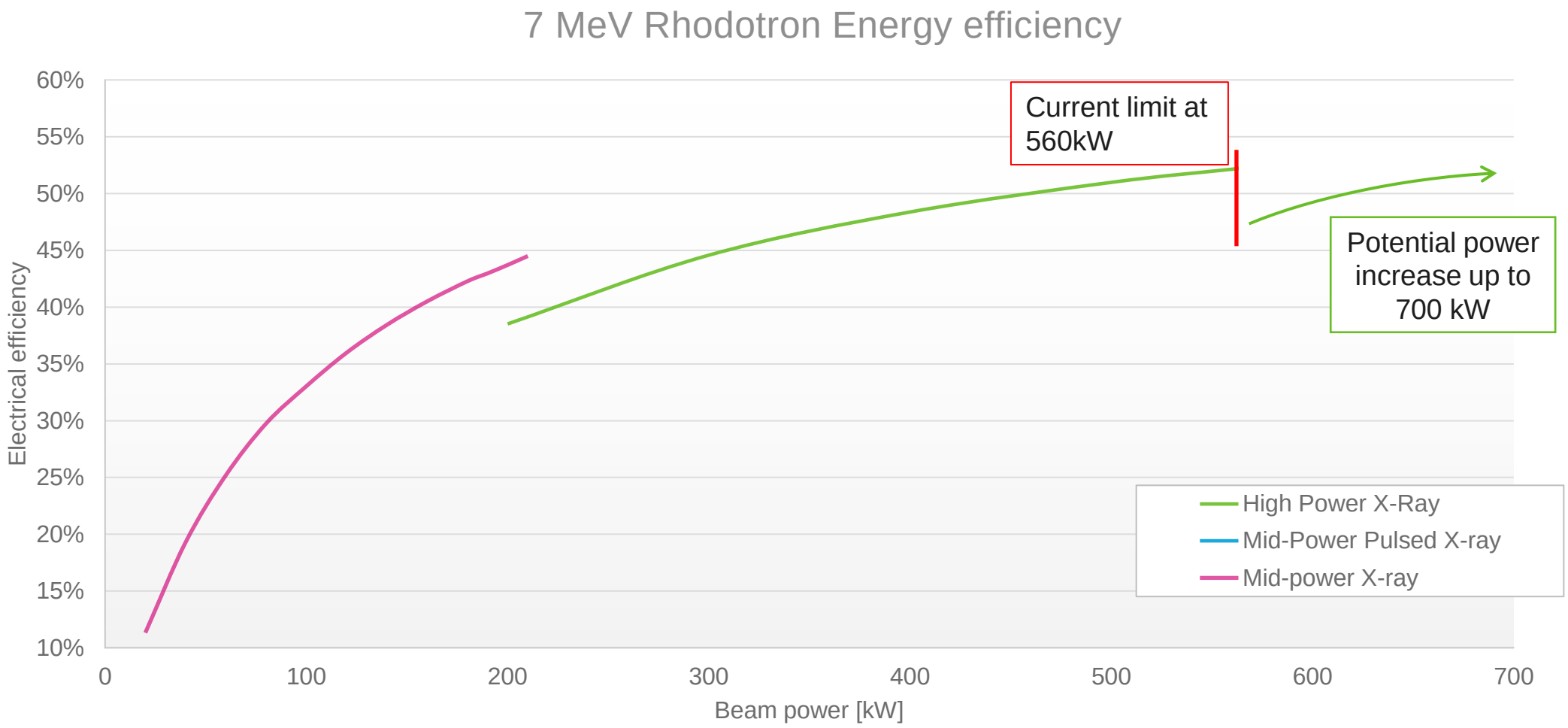


Increasing the power brings the RF chain in a **regime** with more **favorable electrical efficiency.**



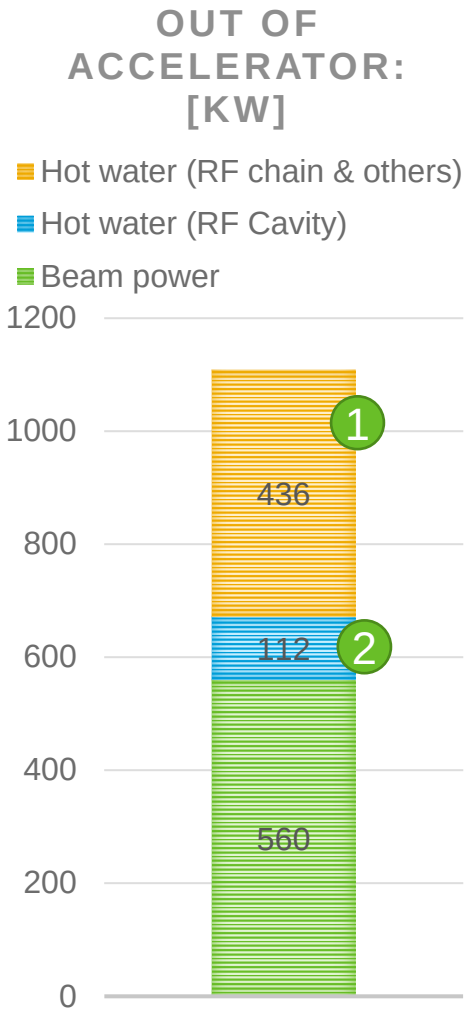
Value for a TT1000 Rhodotron at 7 MeV x 80 mA = 560 kW

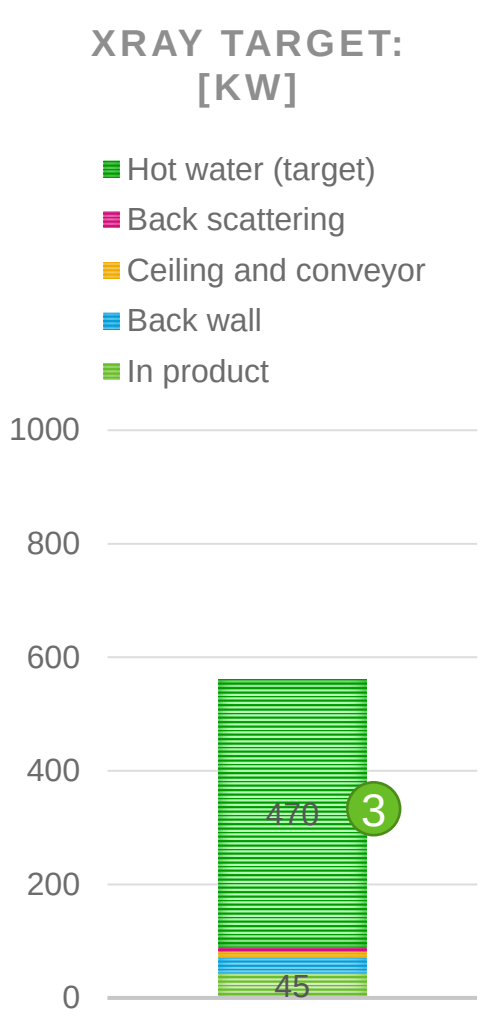
Pushing towards more efficiency



2. Heat recovery

Can we **recover the heat** from the water exchanger?

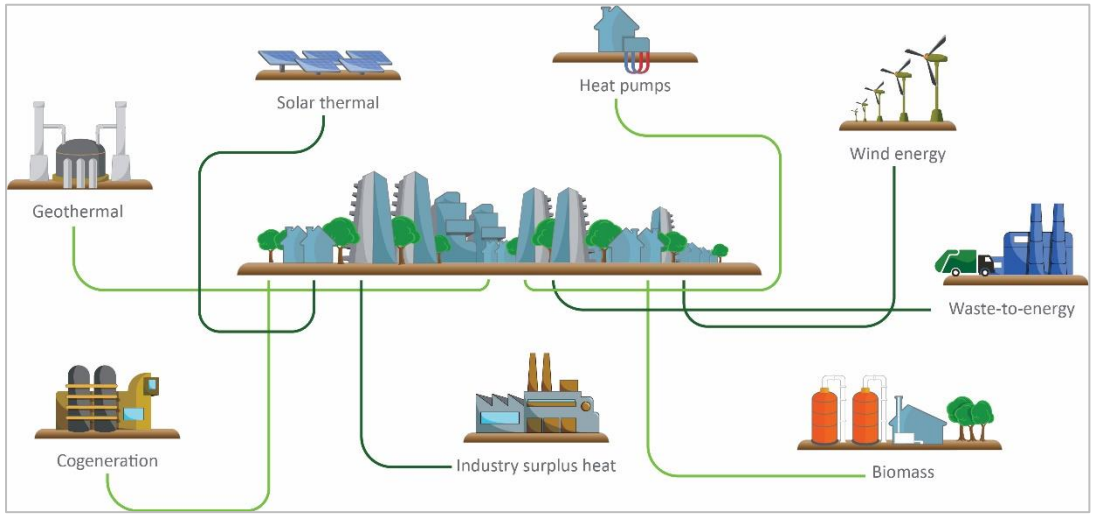




1. RF chain and others cooling group (436 kW)
   - In: 20 °C
   - Out: **31 °C**
2. Cavity cooling group (112 kW)
   - In: 20 °C
   - Out: **31 °C**
3. Target cooling group (470 kW):
   - In: 20 °C
   - Out: **46 °C**

Can we **recover the heat** from the water exchanger?

Low temperature water from 1 and 2 can be used to **heat the warehouse and the offices**. We are also investigating whether it could be suitable for shared **heating network** on a project-by-project basis.

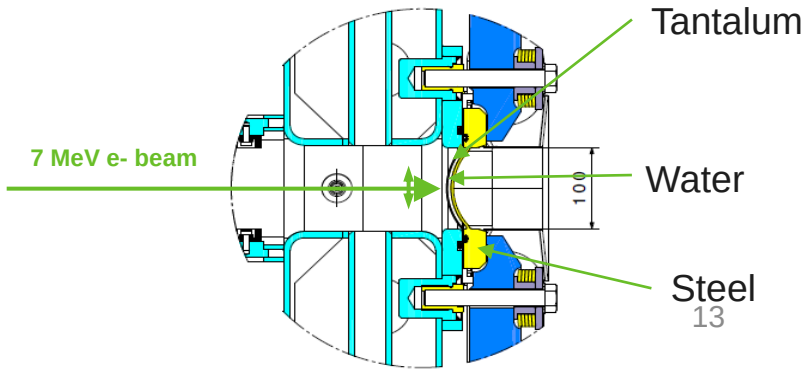


Source: reuseheat.eu

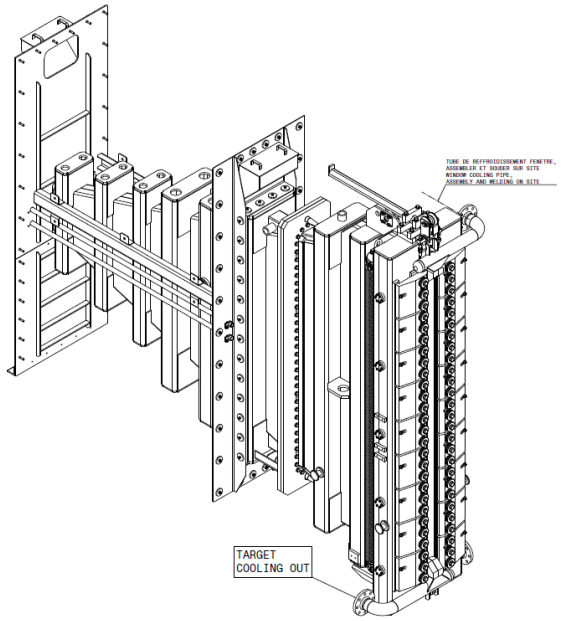
1. RF chain and others cooling group (436 kW)
   - In: 20 °C
   - Out: **31 °C**
2. Cavity cooling group (112 kW)
   - In: 20 °C
   - Out: **31 °C**
3. Target cooling group (470 kW):
   - In: 20 °C
   - Out: **46 °C**

Can we **recover the heat** from the water exchanger?

Higher temperature from 3 can be used in other **industrial processes**, such as **ethylene oxide** sterilization.



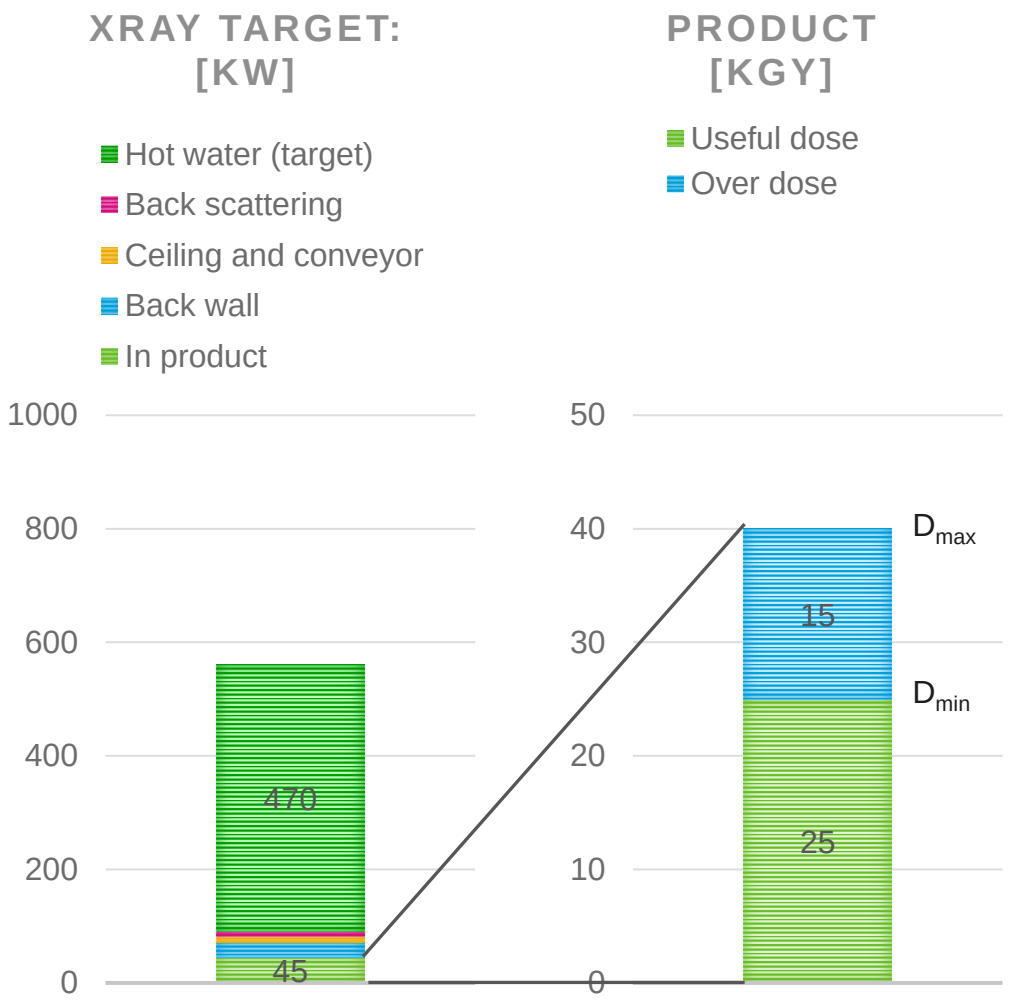
1. RF chain and others cooling group (436 kW)
   - In: 20 °C
   - Out: **31 °C**
2. Cavity cooling group (112 kW)
   - In: 20 °C
   - Out: **31 °C**
3. Target cooling group (470 kW):
   - In: 20 °C
   - Out: **46 °C**



IBA is also investigating a new target design that would allow much high temperatures in the target, which would in turn make **cogenerating** electricity possible.

3. Process optimization

3. Process optimization: do more with the same power

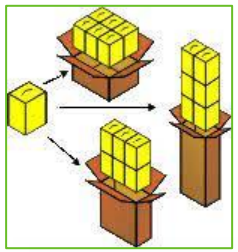


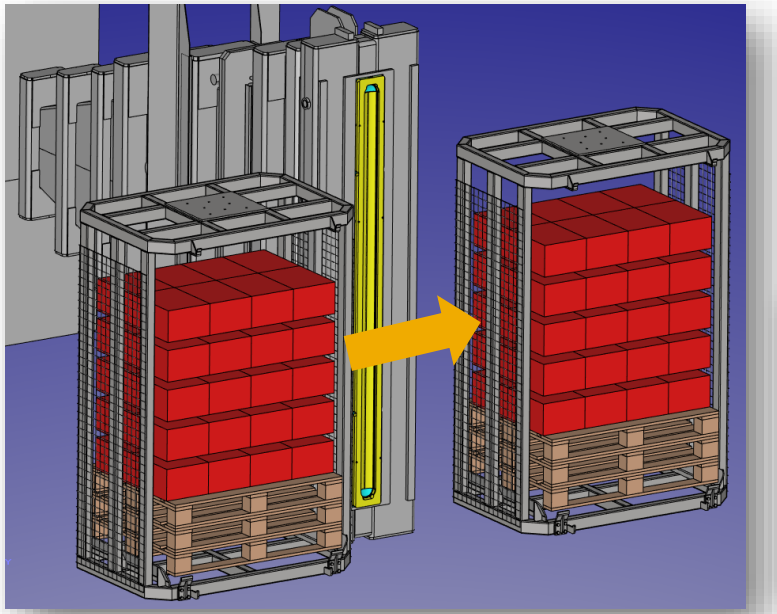
Increasing the minimum dose* means **increasing the throughput**, ultimately **increasing the efficiency** of the process!

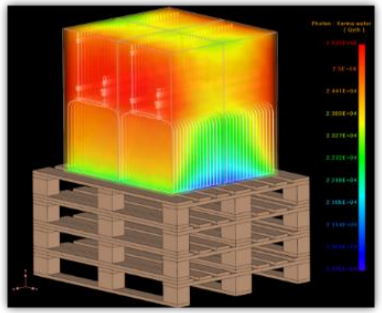
* Without increasing the maximum dose!

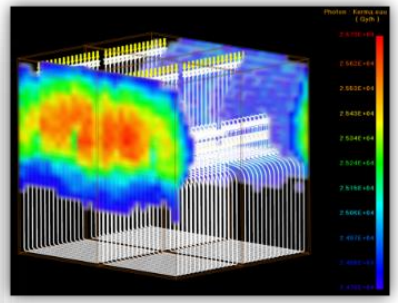
How can we do that? By optimizing **the packaging**…

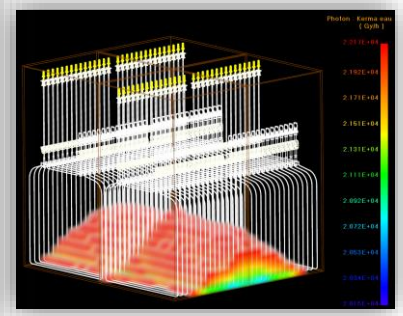
Product design & Packaging efficiency





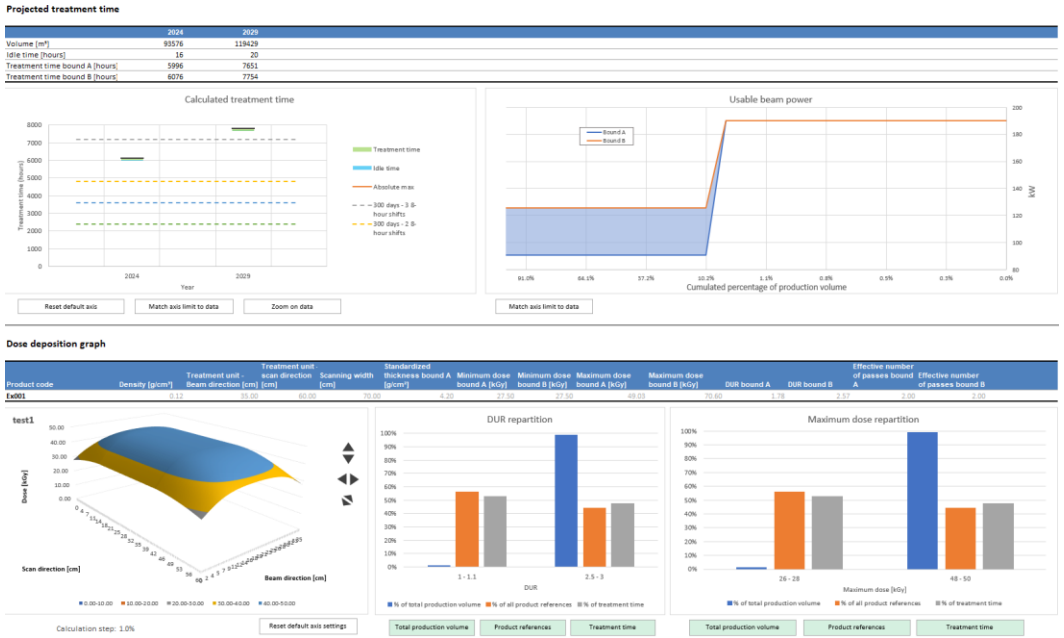


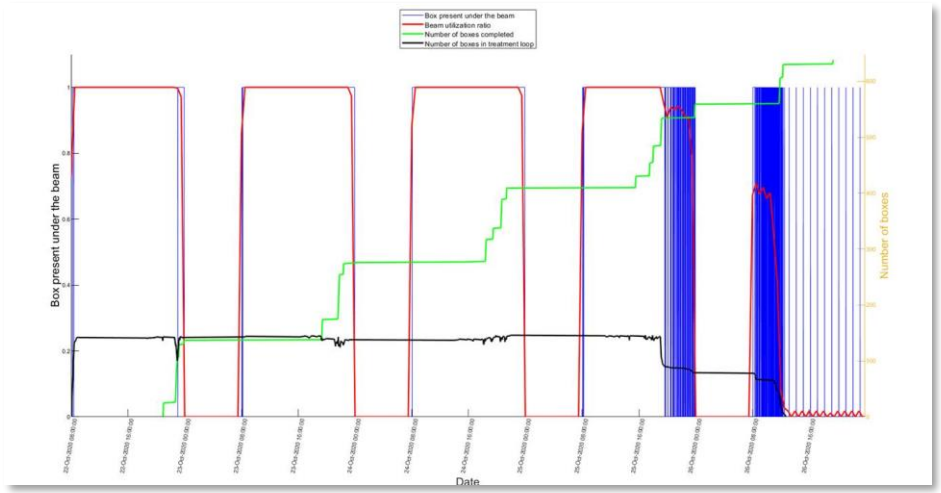


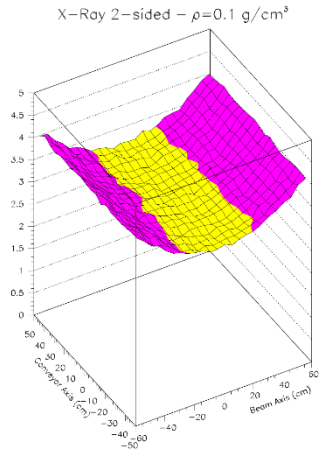


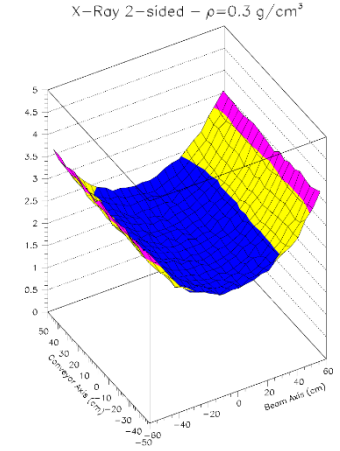
- Monte Carlo will play an important role to increase efficiency **from product design to parametric release**.
- IBA is collaborating with TRAD to deliver a ***user-friendly*** **Radiation Processing Tool** based on RayXpert.
- A benchmarking group & **2 key proof-of-concepts** with Industrial partners are ongoing.
- Presentations & Data at Kilmer & IMRP.

… using **smart** production planning optimization algorithms…









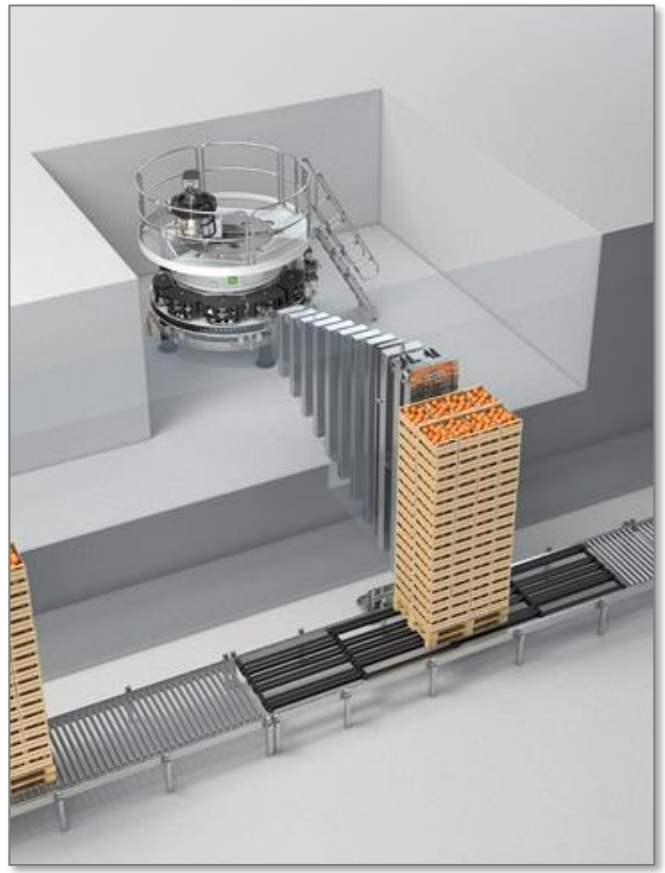
Digitalization is going to play a major role in improving the efficiency of irradiation systems.

… choosing the right system for the right application

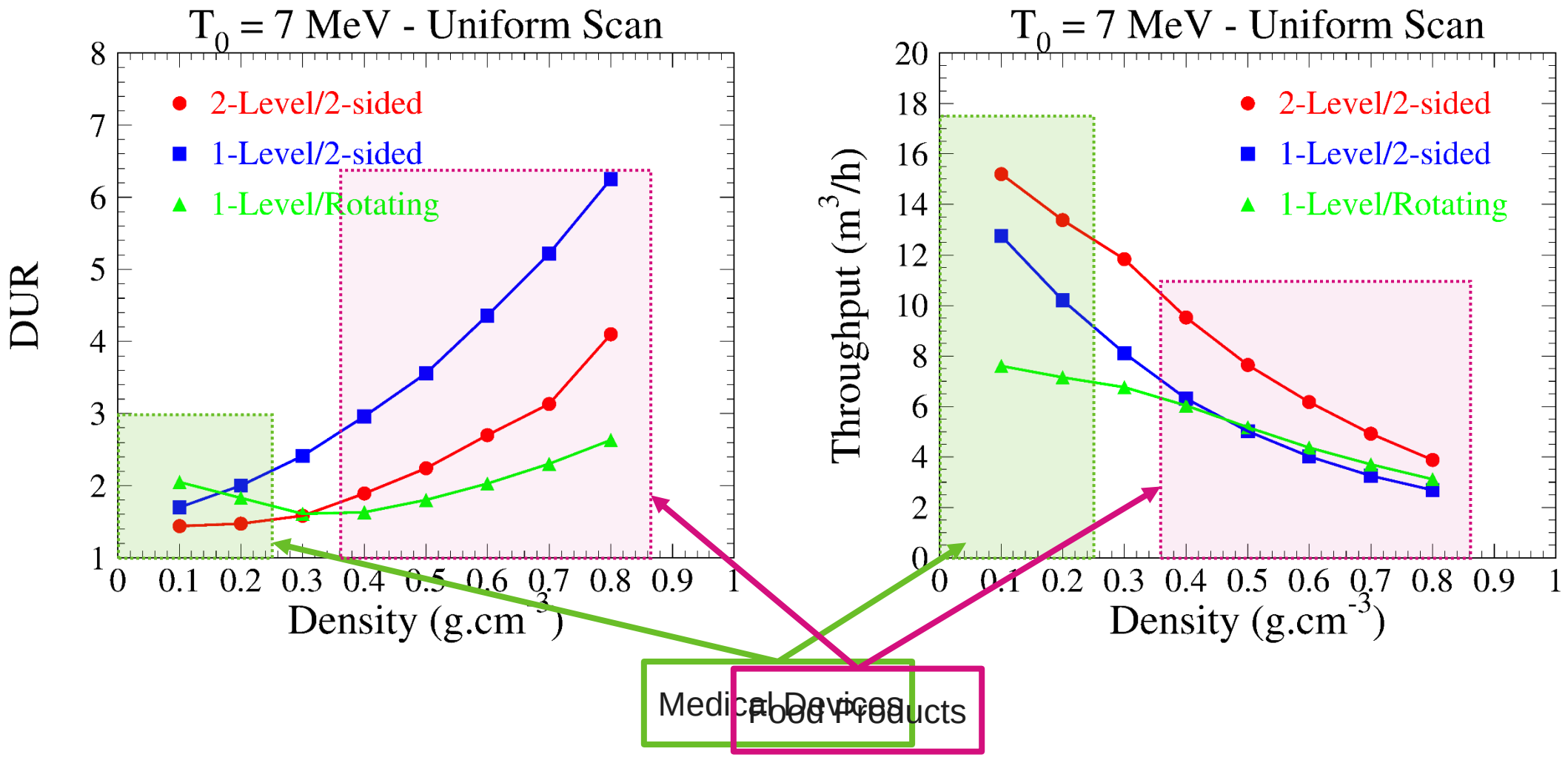
Double-level roller

Double-level overhead

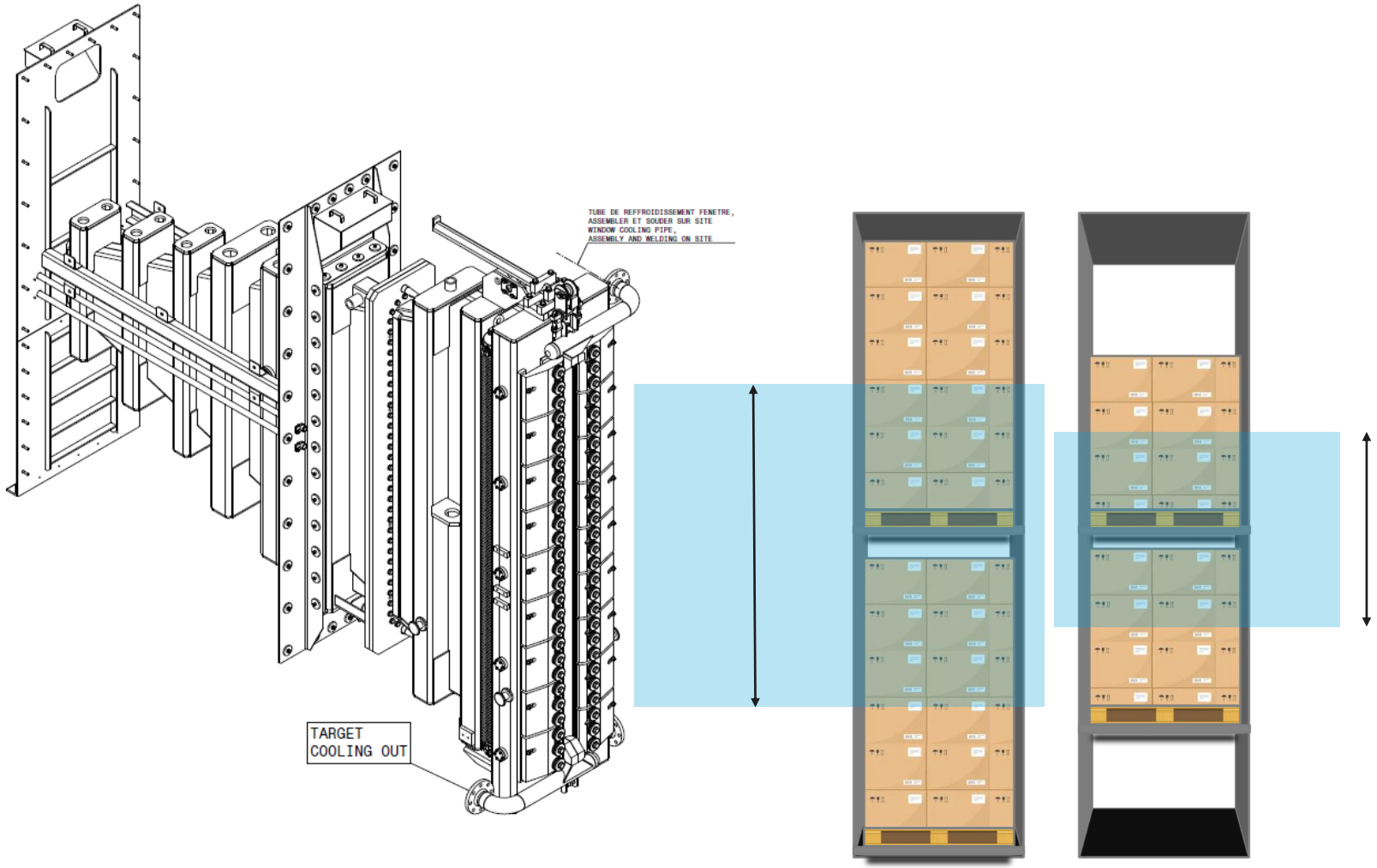
Singe-level roller



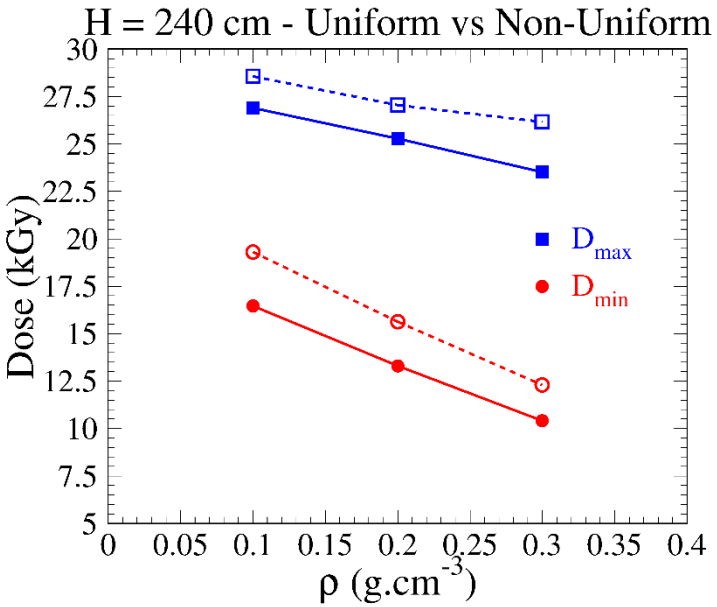
… optimizing the way we present the product to the beam…

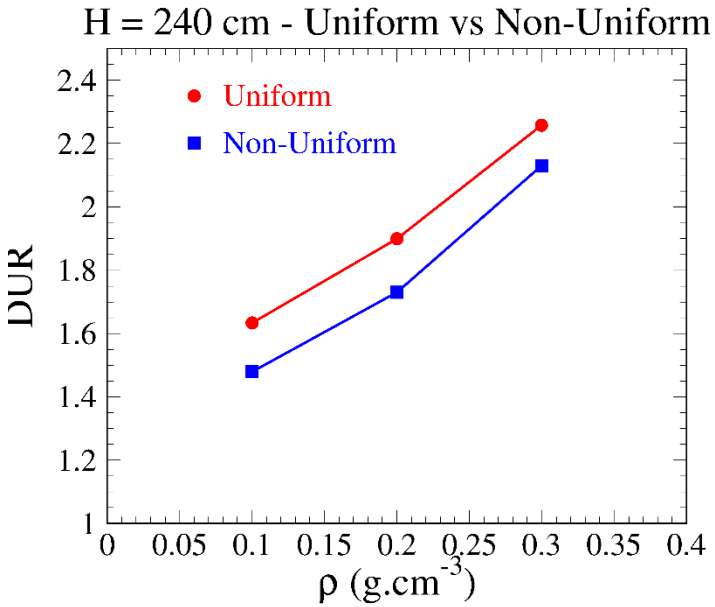


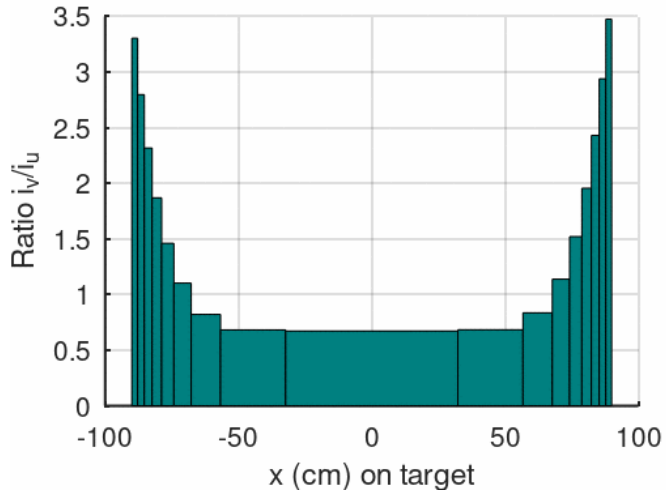
… optimizing how we **scan** the beam on the product...



… optimizing how we **scan** the beam on the product...







Very promising experimental results! Stay tuned for more info at IMRP!

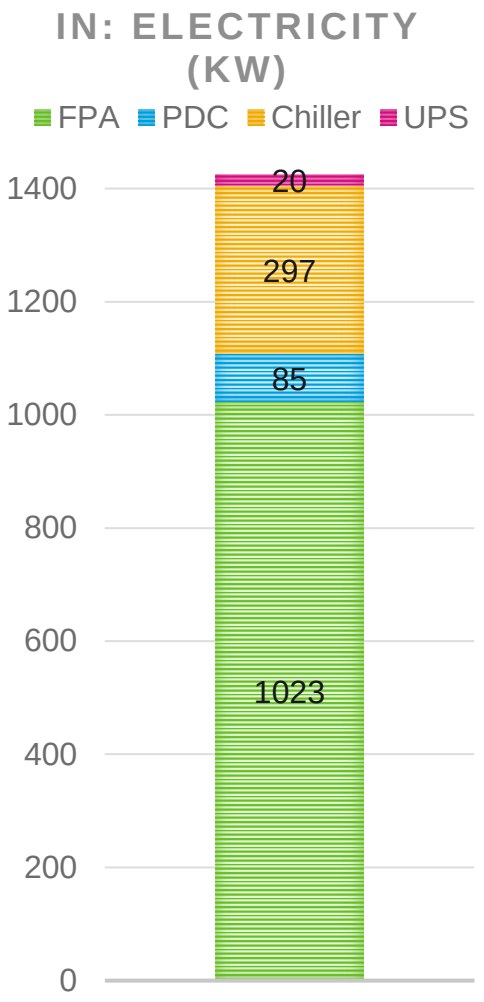
… and maybe even challenging the regulations!

- E-beam to X-ray conversion efficiency in the target **falls from 12% down to 8%** for an incident beam energy of 7 MeV and 5 MeV respectively!
- The lower penetration of X-rays at 5 MeV leads to worse DUR, further reducing the efficiency.
- For 0.5 g/cm³ food products, the **efficiency loss** is a large as **50%!**

Reviewing the regulations for food irradiation could make the process not only **more sustainable**, but also **more economically viable**, making it **more accessible to developing countries!**

4. Electricity Production

Producing clean electricity in-situ



- IBA is working to offer **collaboration with local contractors** to install renewables on site.
- The goal is to have **30% of the electricity** used for running the Rhodotron generated from the renewable source (~3500 MWh/year).

Coupled with a flywheel UPS, this also makes the factory **less dependant to the electricity provider** and **less prone to power interruptions**, which are still a major issue in developing countries for sensitive equipment like a Rhodotron.

Conclusions & perspectives

Life. Science.

Conclusions & perspectives

- After 20 years of constant innovation, **X-Ray is finally an evidence in the industry.**
- To compensate for the carbon footprint of X-ray, **several paths** must be taken simultaneously.
- Improving the efficiency of the accelerator is not going to cut it.
- The most significant improvements will likely come from **mastering the process** through **digitalization** and **optimizing the whole irradiation solution** through **digitalization**.

Thank you!