

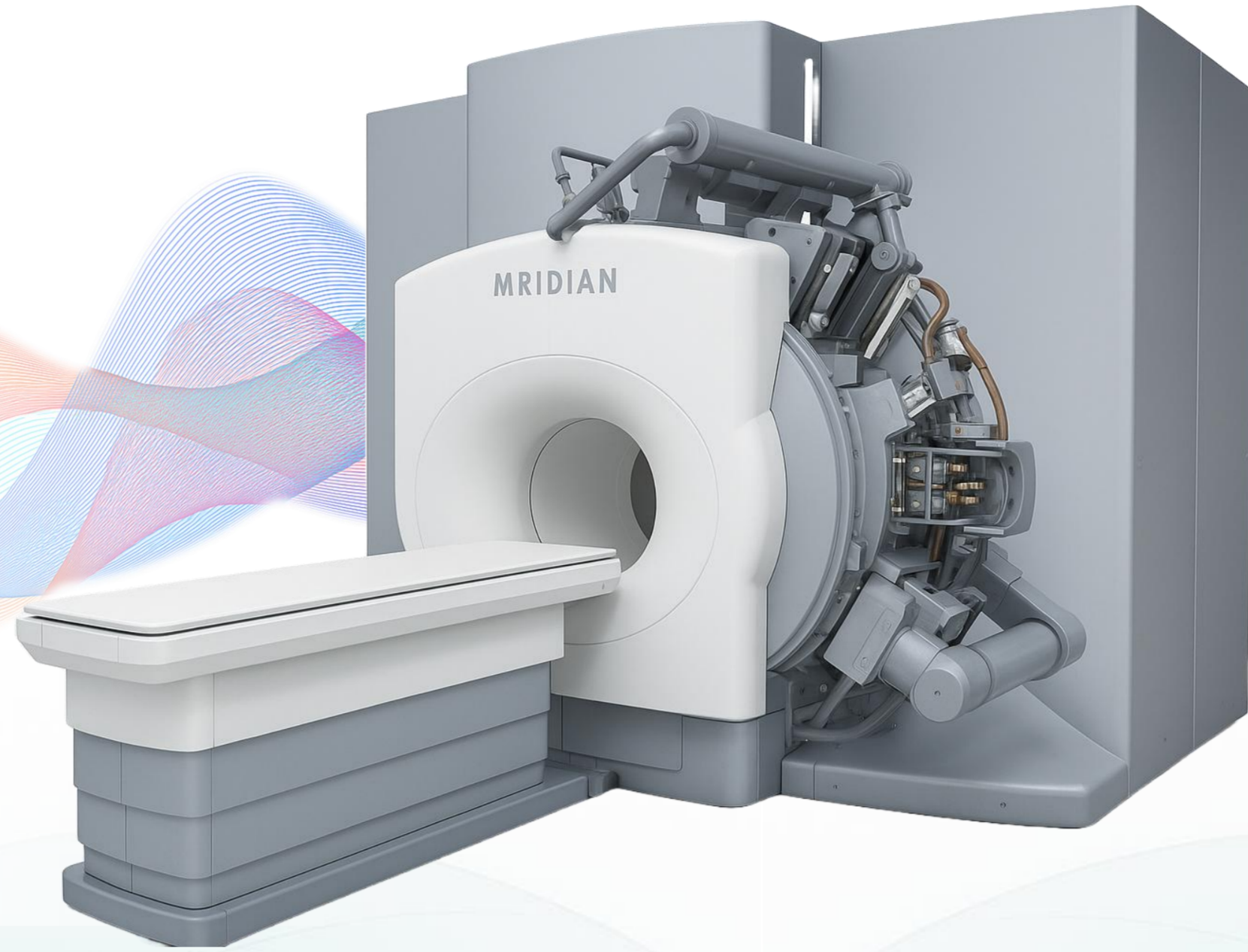
Adaptive fractionation on the MR-Linac: A reinforcement learning approach to exploit interfractional motion

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MR-Linac

- Hybrid device combining **magnetic resonance (MR) imaging** with **radiation therapy (RT)**
- MR provides **soft-tissue contrast** not visible in X-Ray scans
- No additional dose for imaging!
- On-table dose delivery adaptations** considering target organ locations
- **Enables new Therapies** tailored to the patients

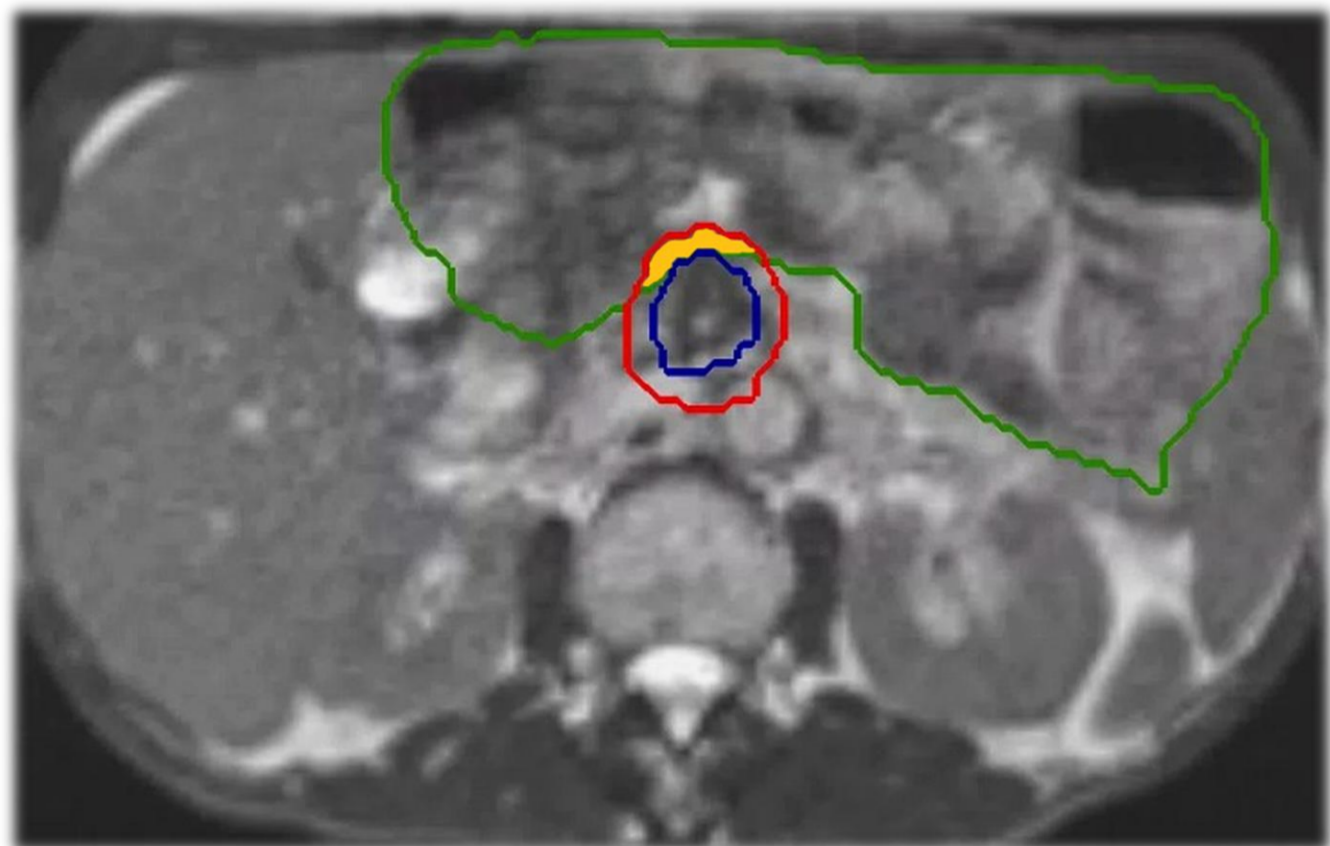


- The MRIDIAN system is composed of a split superconducting magnet
- A rotating gantry assembly placed at the gap holds all linac components
- 0.35 T MRI with inplane resolution of 1.5mm x 1.5mm and slice thickness of 1.5mm and 3mm
- Two-dimensional cine MR images (live MR "video") can be acquired in one plane

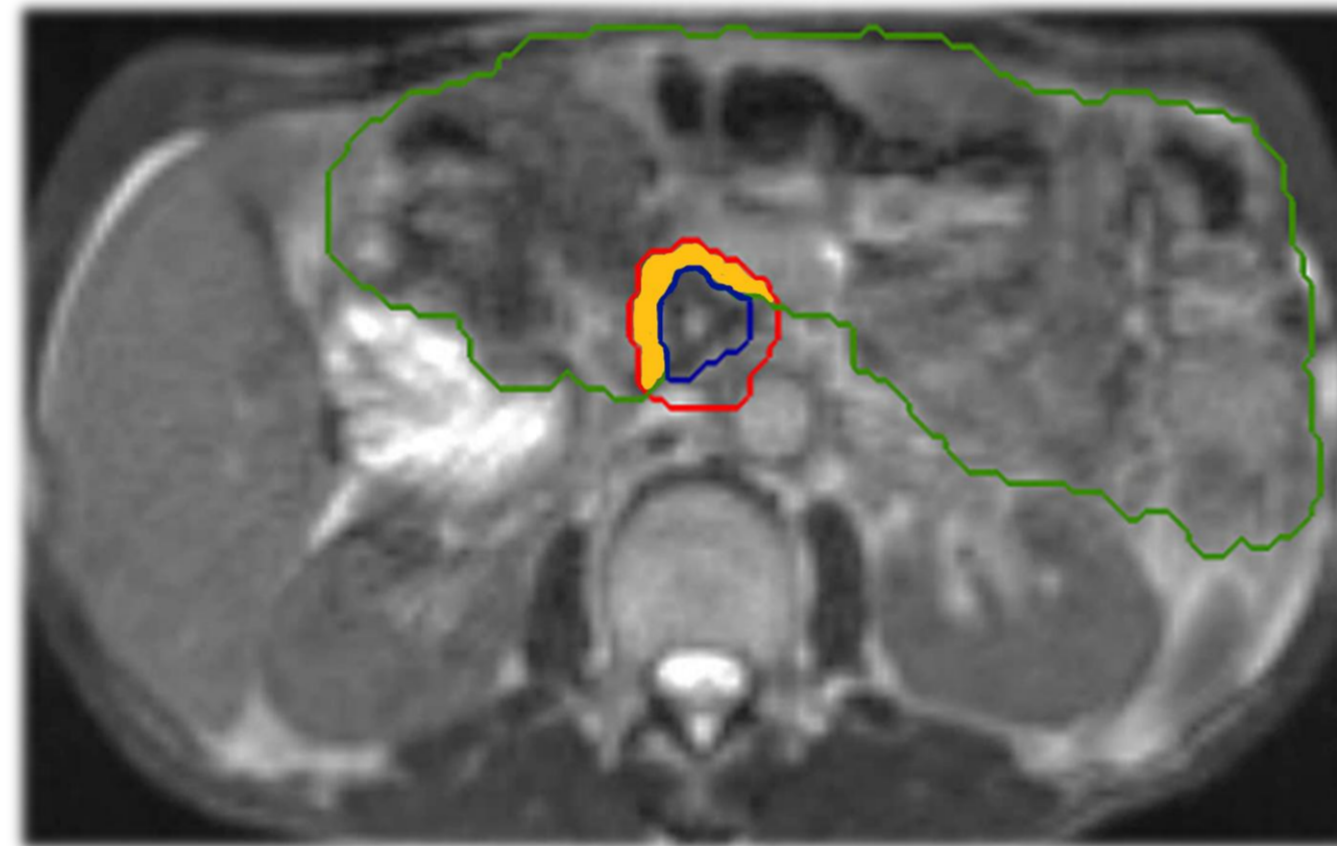
Tumor Motion and Dose Delivery

- In general, **radiation doses to the tumor** are not delivered in one radiotherapy session but **divided into several fractions** with **equal (uniform) doses**
- Fractionation allows normal tissue to recover between the sessions while still sufficiently damaging tumor tissue

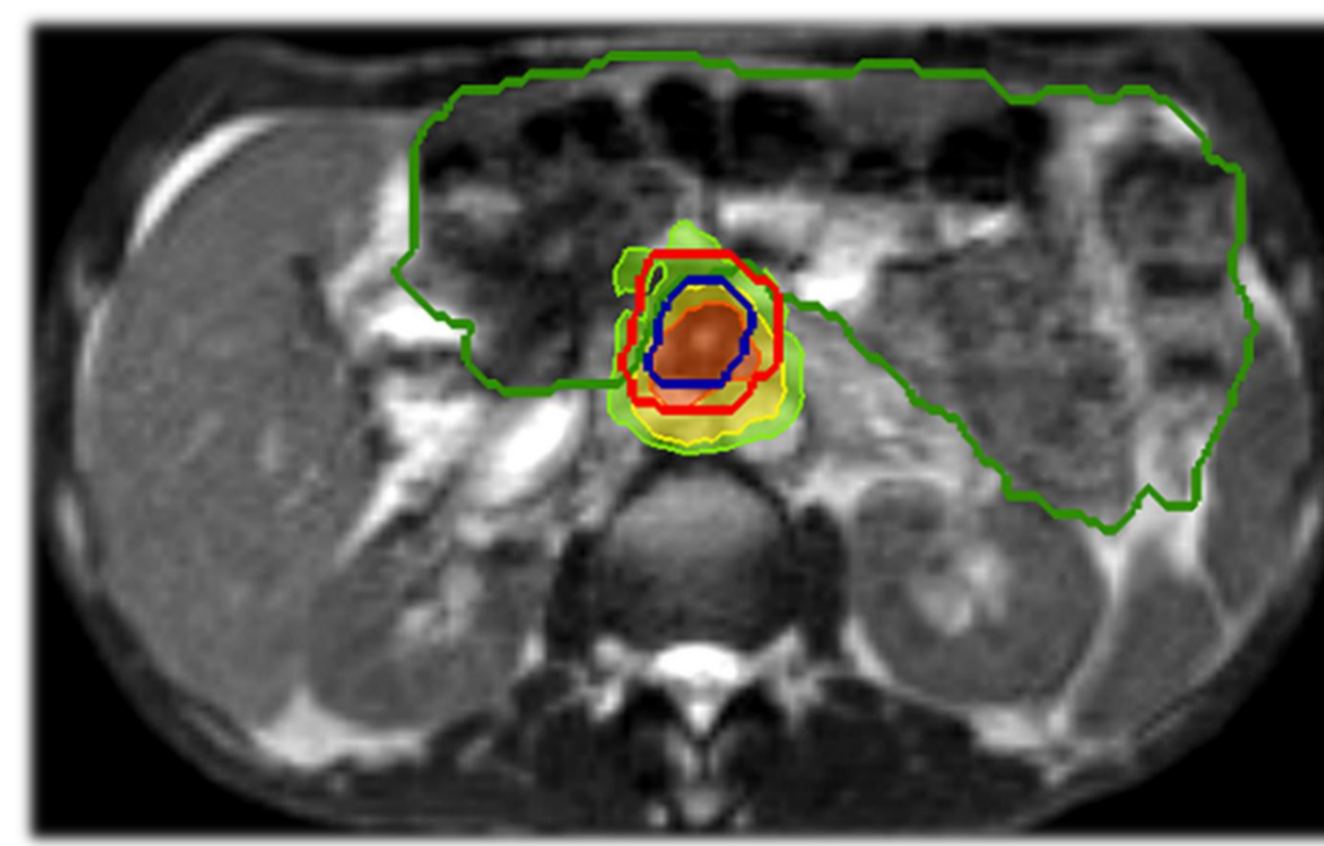
First fraction



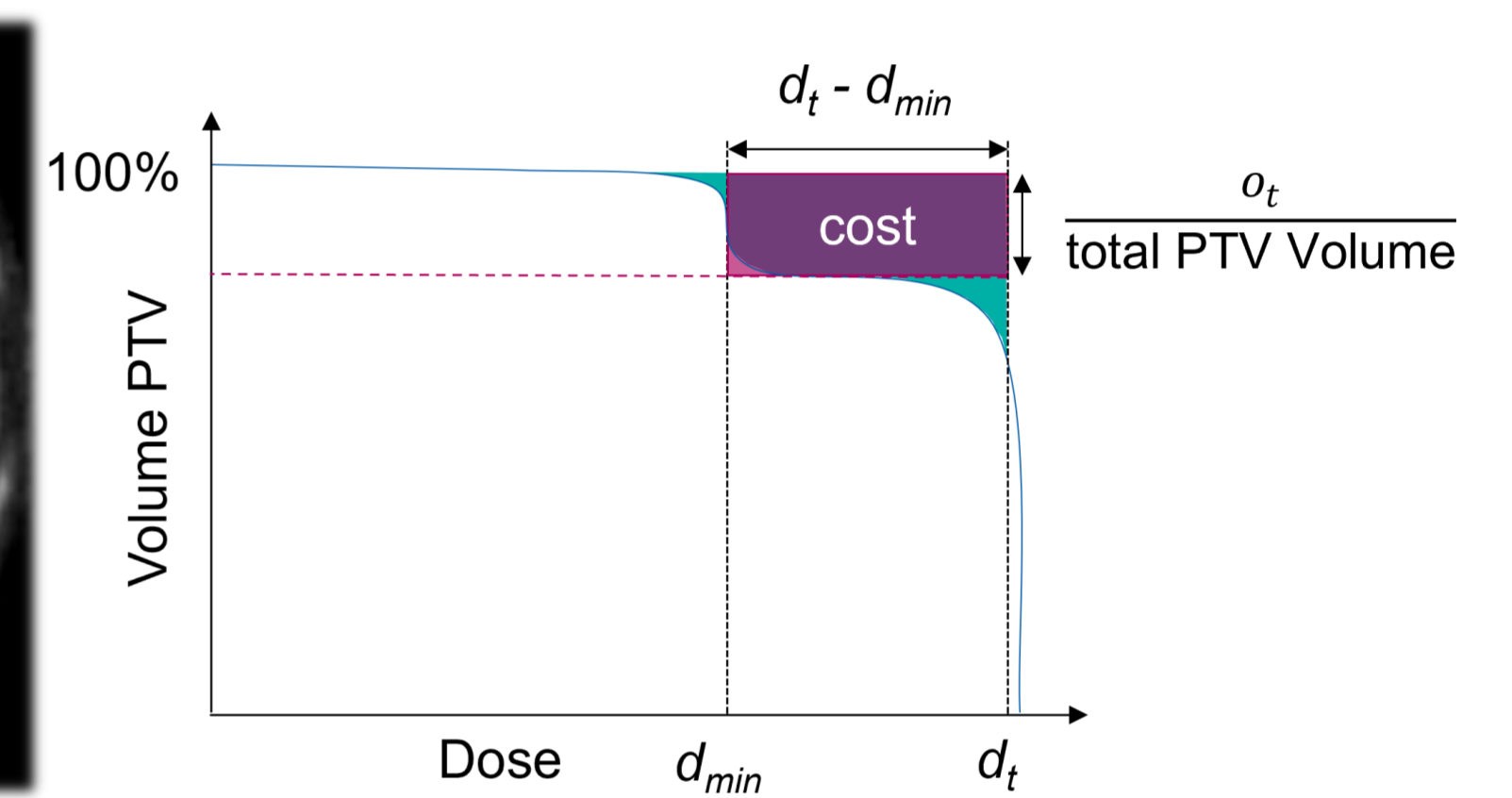
Second fraction



Dose Distribution



DVH



Visualized interfractional motion of a patient at the MR-Linac. The organ at risk, the bowel, is outlined in green while the tumor is outlined in blue and red. The yellow filling highlights the varying overlap volume between tumor and bowel.

Dose distribution and Dose Volume Histogram (DVH). The larger the overlap, the more dose we have to compromise in the tumor as we can only deliver the minimum dose d_{min} into the overlapping volume resulting in the underdosage marked as cost.

- In between fractions the **tumor and organs move** → we have to adapt for organ motion when delivering dose
- However, we can **exploit the interfractional motion** to deliver **more dose into the tumor** while sparing organs!

→ We deliver large doses when the overlap between tumor and organs are small and small doses when the overlap is large

Adaptive Fractionation

Adaptive fractionation deviates from uniform fractionation and **adapts the dose** to the daily patient anatomy

The **dose decision** in each fraction is a **nontrivial problem** as **future patient anatomy is unknown**

We define Adaptive Fractionation as an **Markov Decision Process** and **minimize the tumor underdosage**:

The tumor underdosage is defined by the overlapping tumor volume o_t that gets less than prescribed dose d_t

The overlap future overlap volumes are **unknown!**

The objective to minimize is the total underdosage over all fractions F

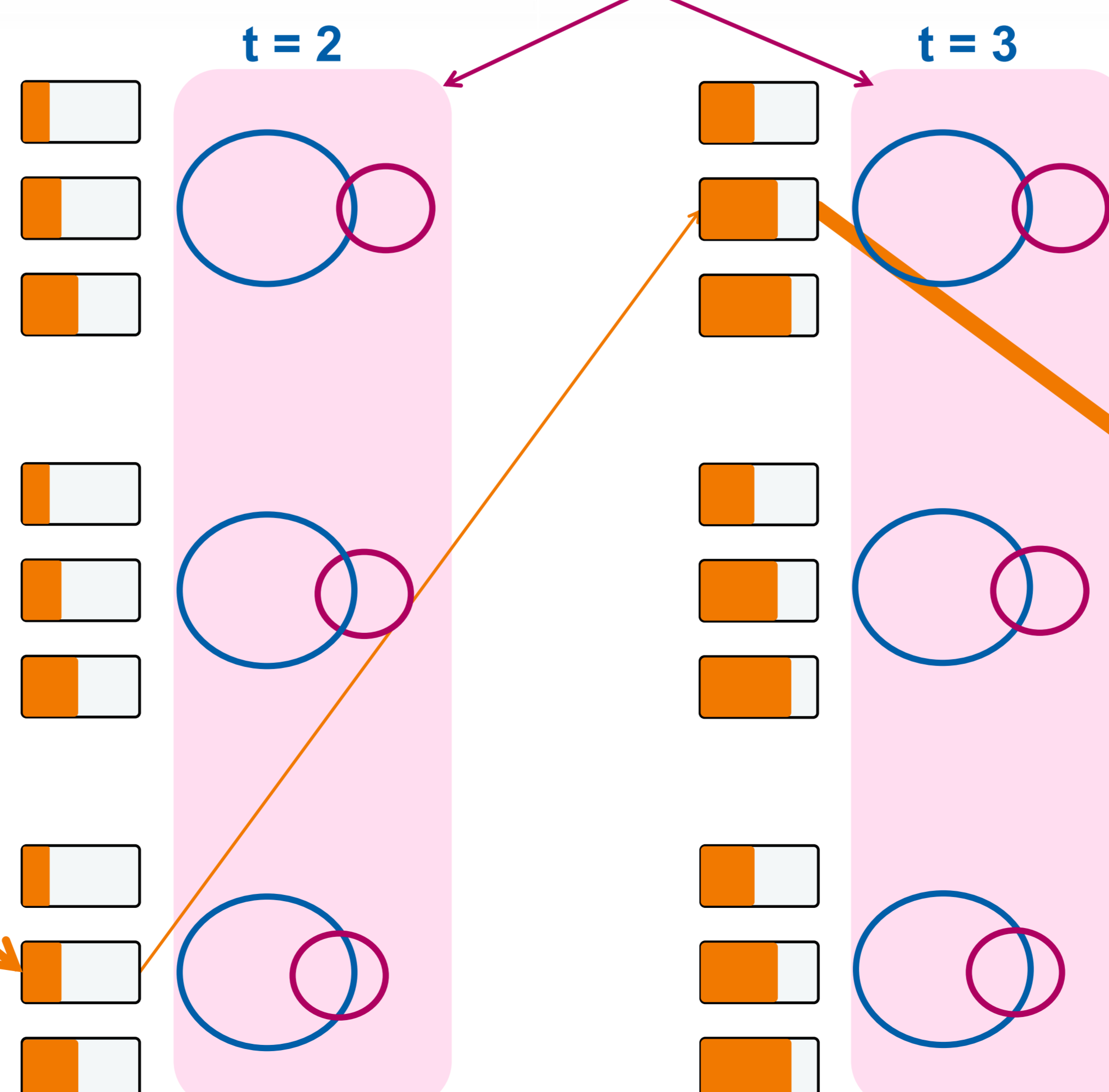
$$c_t = o_t \cdot (d_t - d_{min})$$

$$c_{total} = \sum_{t=1}^F o_t (d_t - d_{min})$$

Overlap volume o_t

Accumulated dose

Delivered dose d_t



Optimal path with minimum cost given the overlap volumes

