CLINIQUE Pasteur TOULOUSE

# Intelligence artificielle pour la segmentation automatique du Pelvis et Thorax et pour la génération de plans de traitements de cancers pelviens en radiothérapie externe


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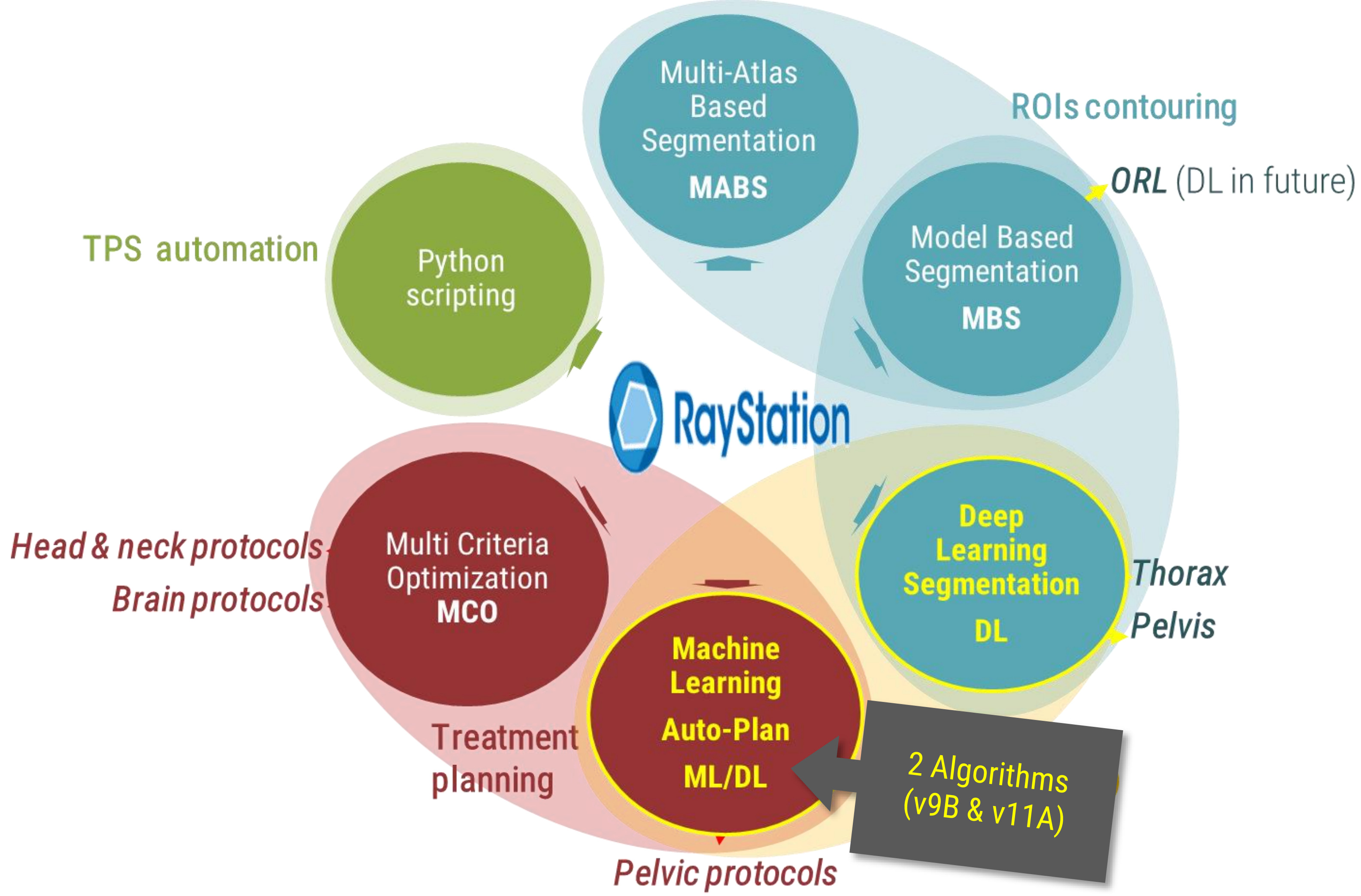
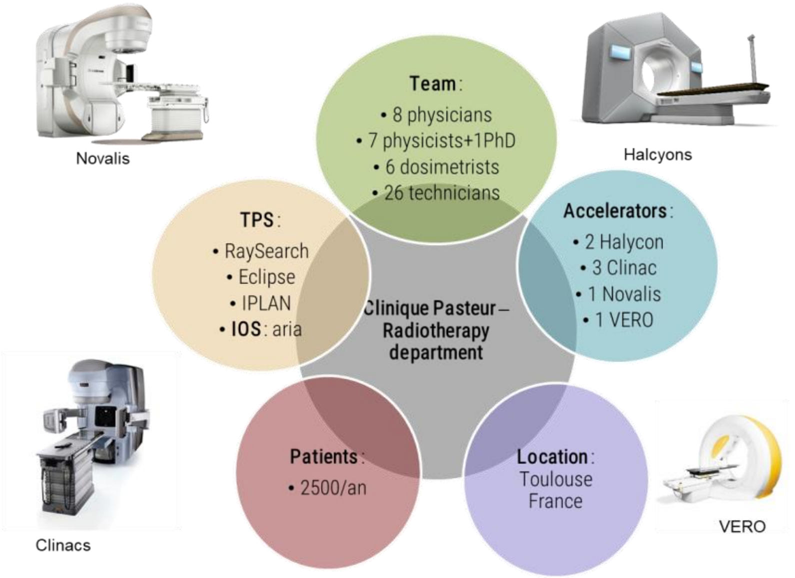
# Raystation






**Choice of Raystation :**

- Unifying TPS
- Automatic organ contouring
- Automatic treatment planning
- Automate TPS with Python script

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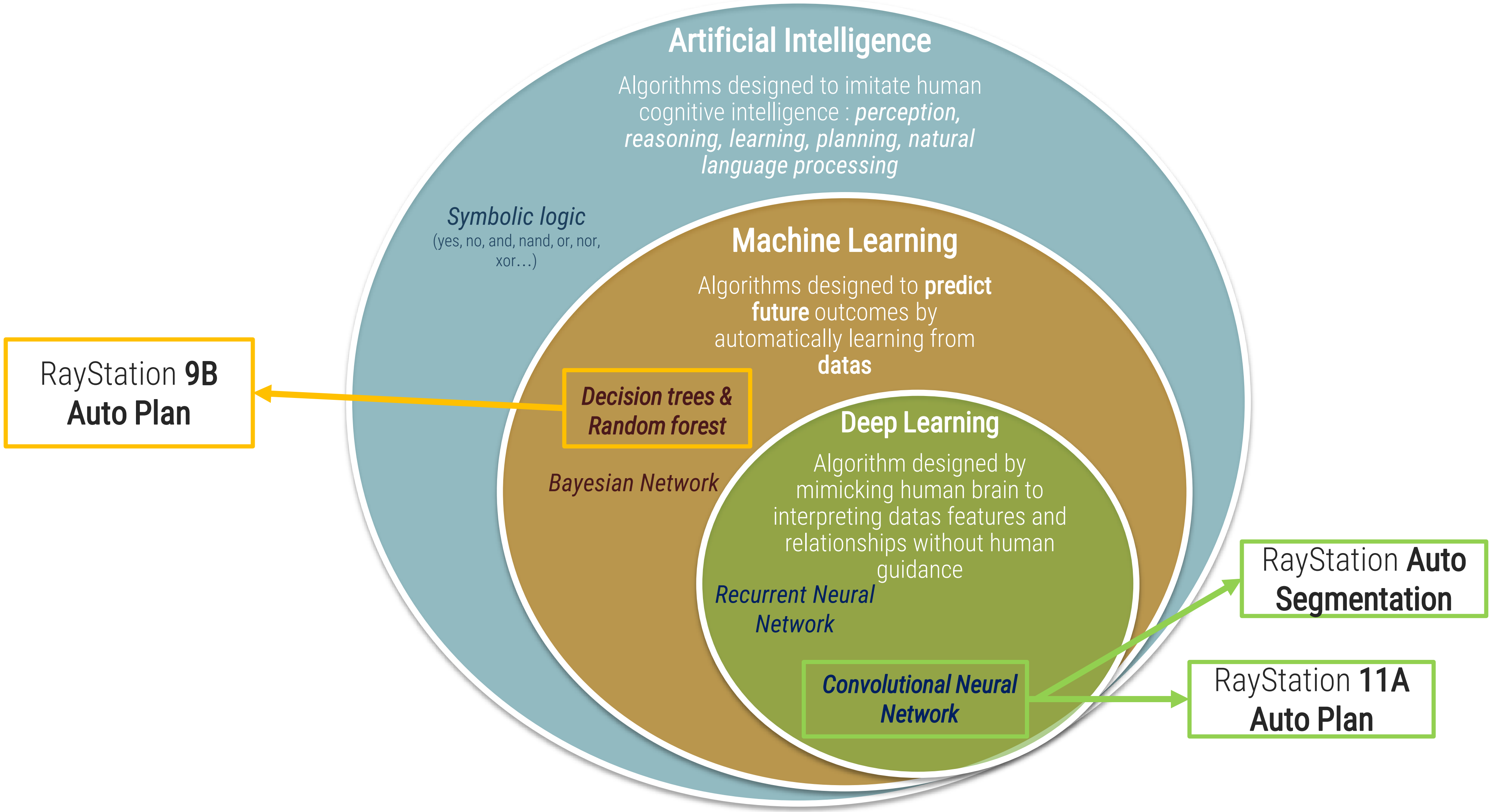
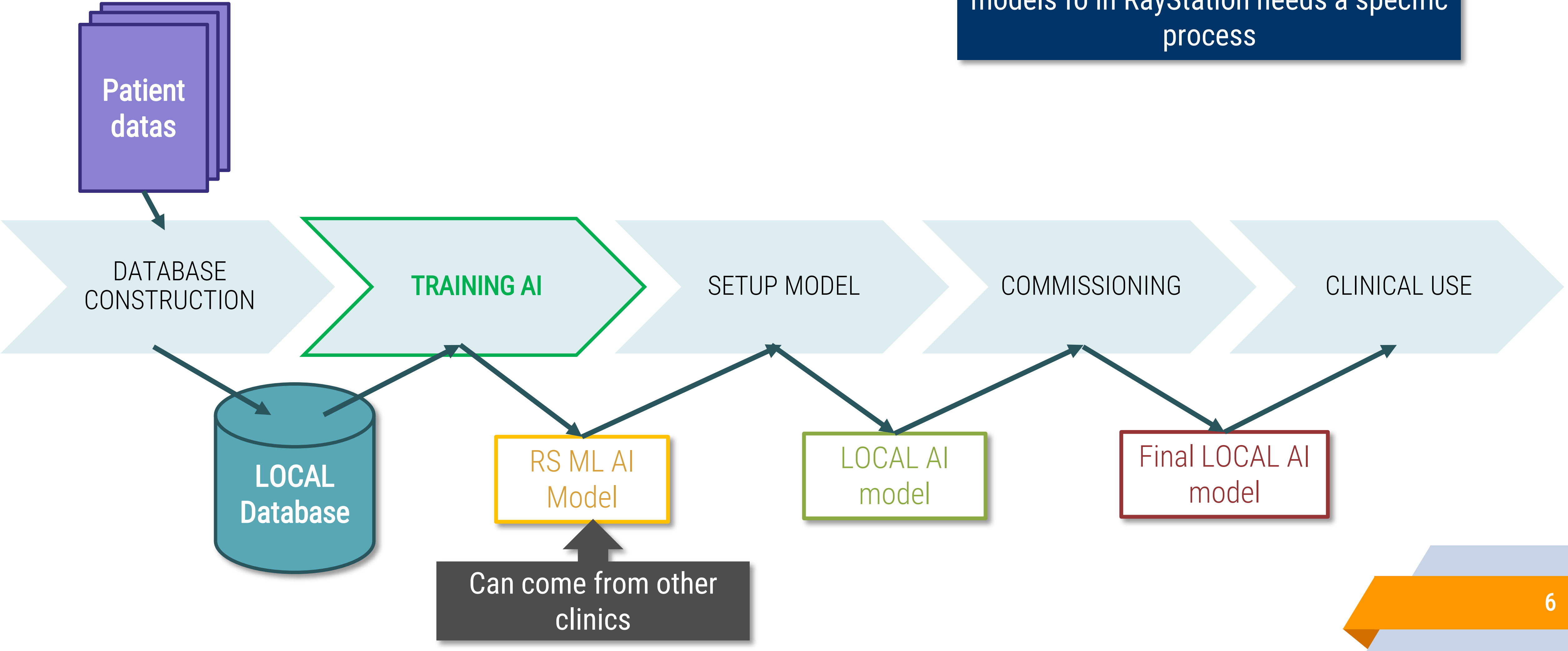
# IA to generate treatment plans in RayStation



# Process to use Artificial Intelligences in RayStation



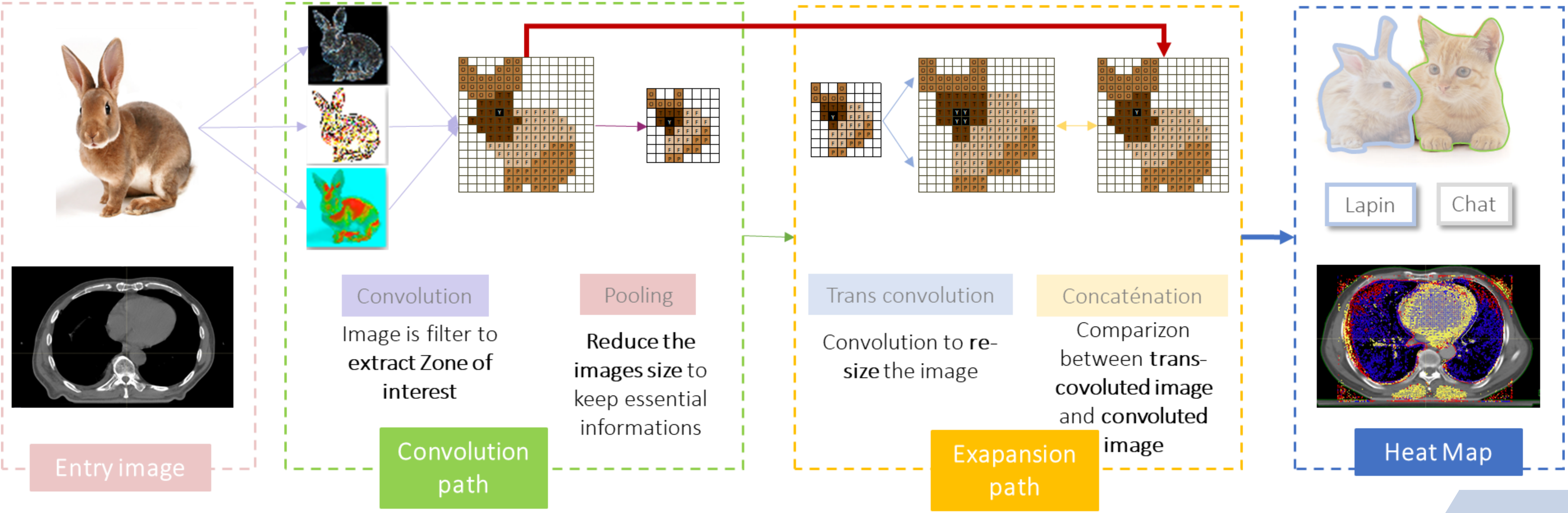
Clinical use of Artificial Intelligences models fo in RayStation needs a specific process



# Algorithm for automatic segmentation



FCNN **gives a category (ROI)** to every voxel of the image



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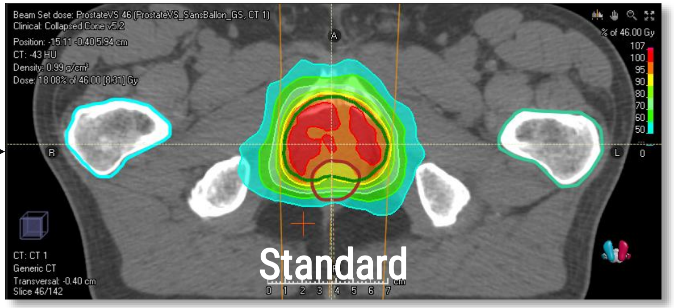
# 11A algorithm for automatic treatment plan generation

## Treatment plan generation with « standard » optimization

Dose goal

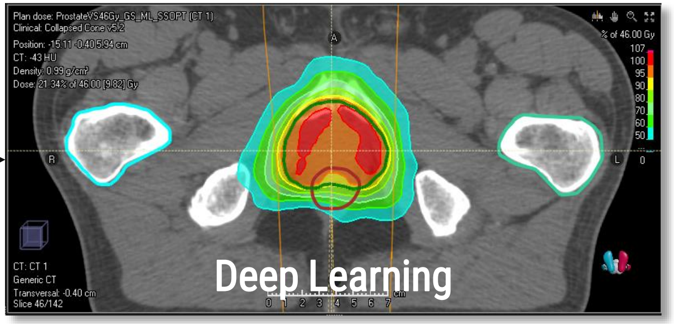
Image → Contours → Beams → Optimization → Dose →




## Treatment plan generation with a model of Machine Learning

ML model

Image → Contours → Dose → Beams → Mimicking →




**Contracting path** : Gives **compact features map** thanks to **convolution** and **pooling** functions.

**Expansion path** : **Allows precise localization of the features map**. Thanks to up-**convolution** and **copy/crop** functions.

U-NET

Faster than 9B version

**Dose Mimicking** : Transform the predicted dose distribution to a clinically deliverable treatement plan

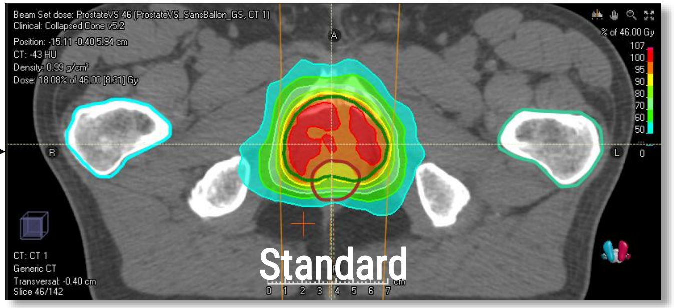
# 9B algorithm for automatic treatment plan generation



## Treatment plan generation with « standard » optimization

Dose goal

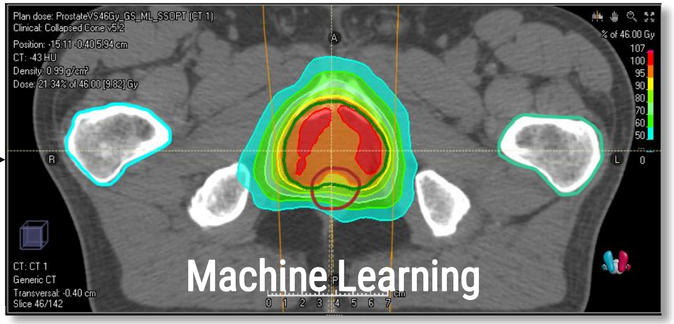
Image → Contours → Beams → Optimization → Dose →




## Treatment plan generation with a model of Machine Learning

**ML model**

Image → Contours → Dose → Beams → Mimicking →




**cARF**: Several Atlas of Random Forest **link dose per voxel with patient features** (CT and contours)

**Sélection**: A random **forest select the most relevent Atlas** with Bhattacharyya distances (leaf value vs reference value)

**Super Forest**

**Dose Mimicking :** Transform the predicted dose distribution to a clinically deliverable treatement plan

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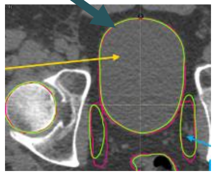
LOCAL Database

RS ML AI Model

Can come from other work teams

LOCAL AI model

Final LOCAL AI model

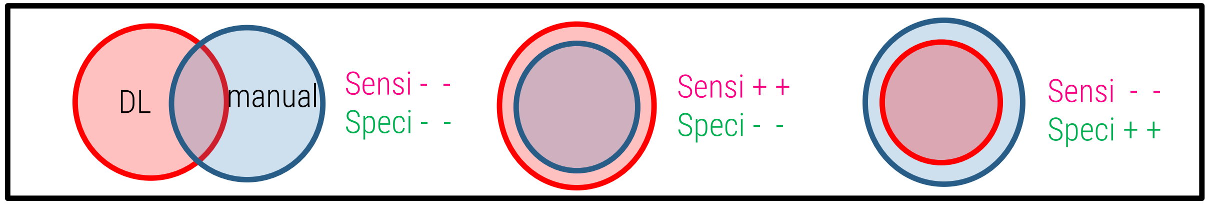


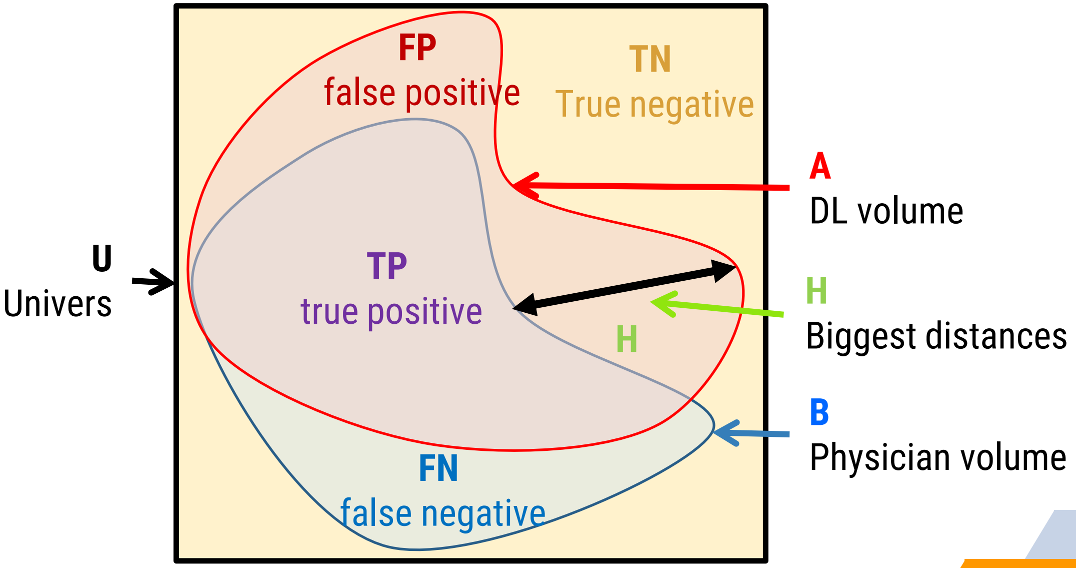
# Method to evaluate of Auto segmentation

- **Compare timing** of manual contours VS segmentation
- **Calculation** similarity **index** : Dice, Jaccard, Sensibility et Specificity and Mean and Hausdorff **distances** (**H**)
- **If bad results** (all index < 0,8) : **Qualitative review of physician** to decided to accept or not the auto segmentation model

$$Dice = \frac{2TP}{A + B} \qquad Jaccard = \frac{TP}{TP + FP + FN}$$

$$Sensibility = \frac{TP}{B} \qquad Specificity = \frac{TN}{U - B}$$



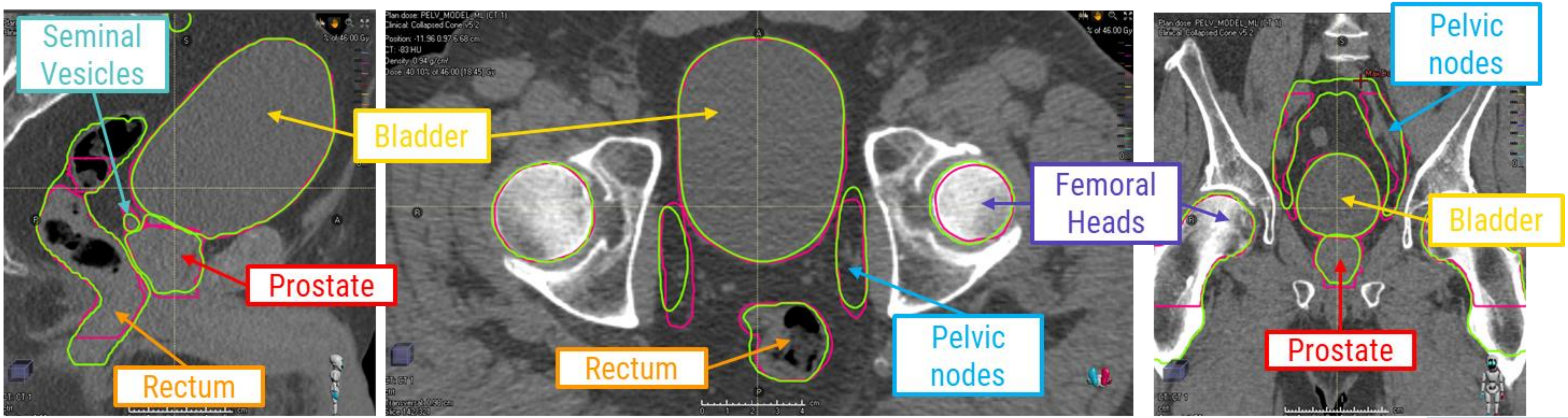



# Automatic segmentation of Pelvis



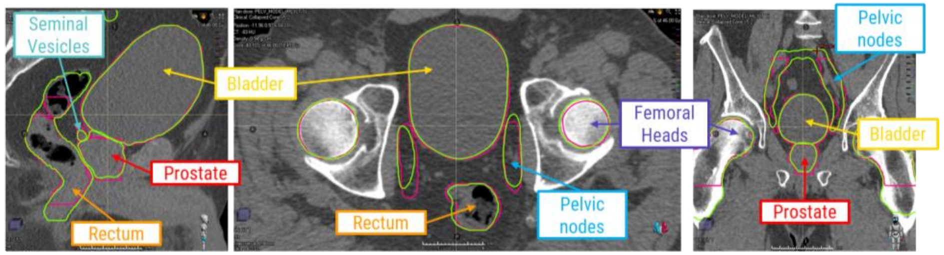
Physician contours : minimum 10 minutes

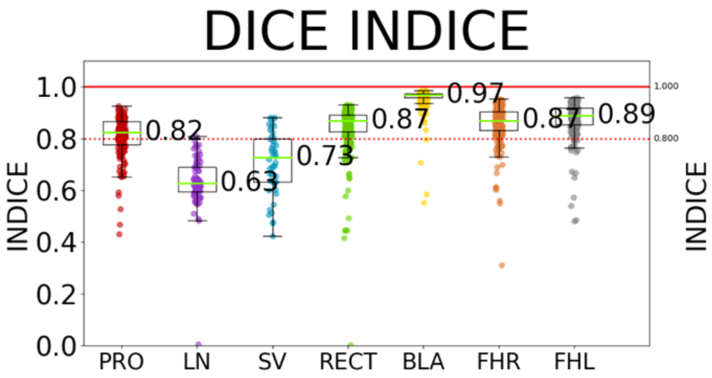
**Deep Learning contours : 30 secondes**

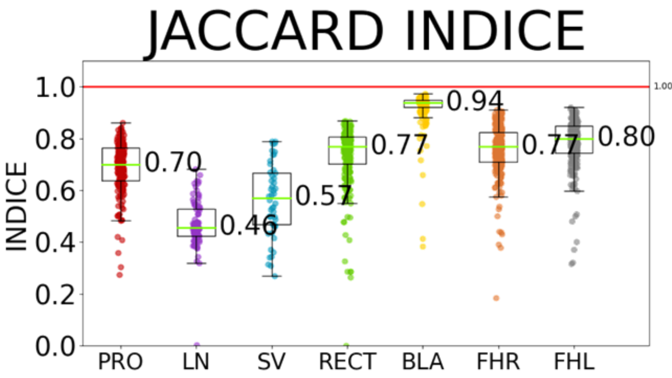


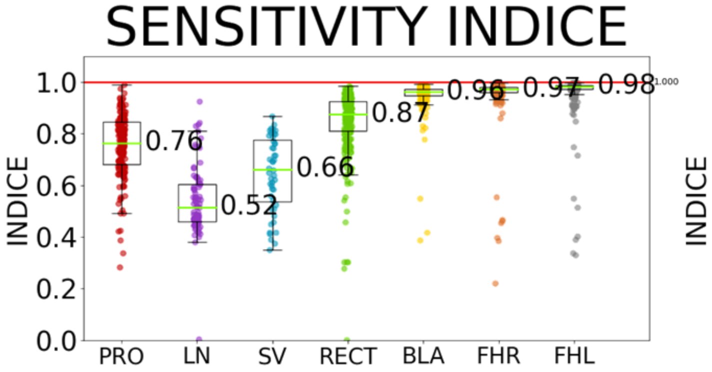
# Method to evaluate of Auto segmentation

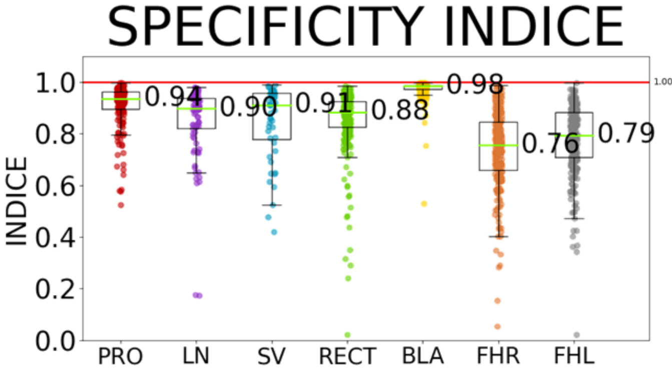


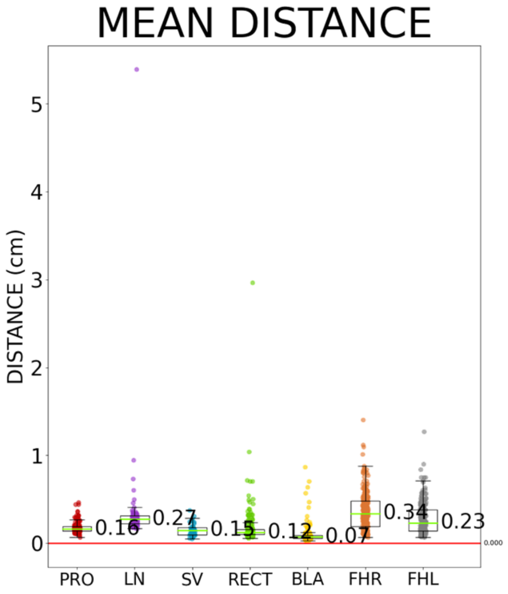


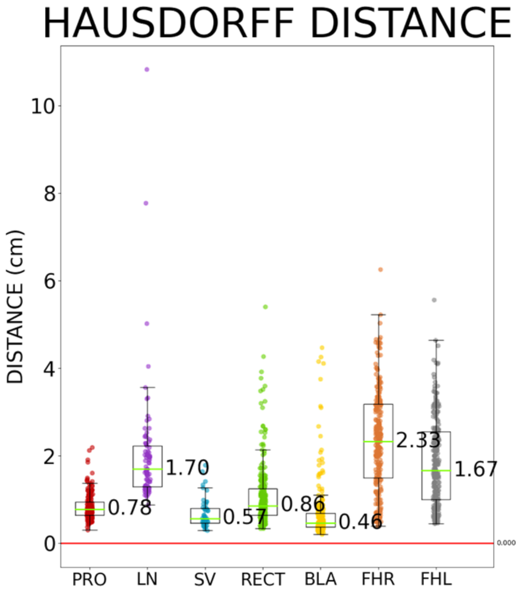



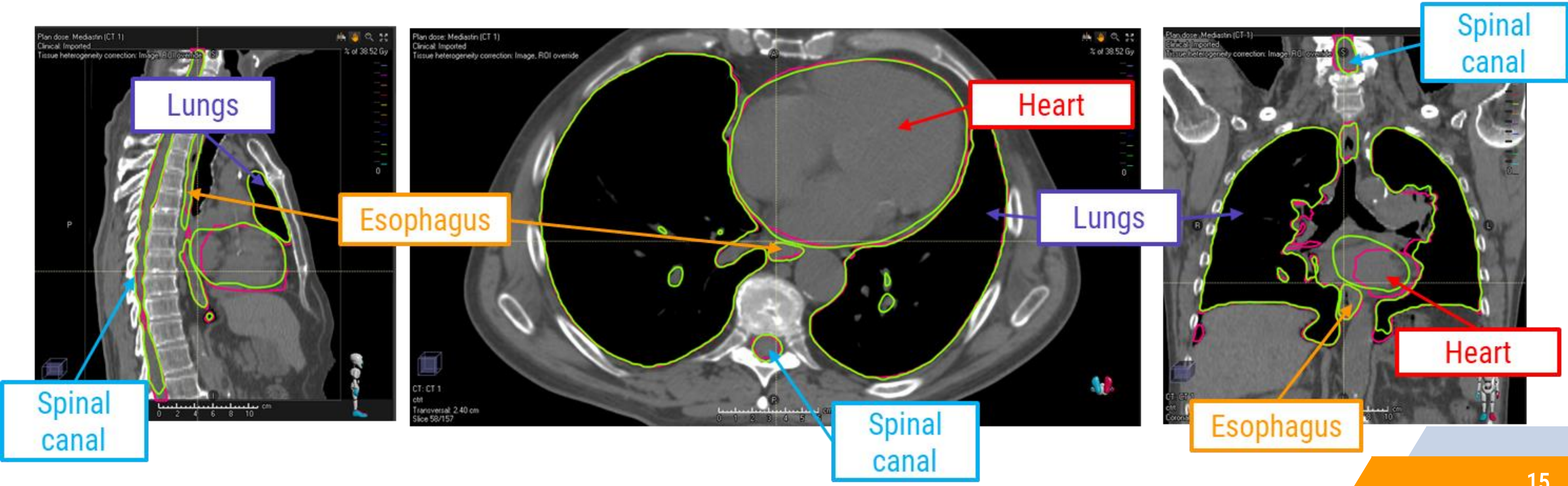

Dice < 0,8 for Seminal vesicles and Lymphatic nodes, but high specificity (accepted with manual corrections)
Dice > 0,8 for Prostate, Bladder, Rectum, Femoral Heads (accepted with manual corrections)
**Model accepted clinicaly**

# Automatic segmentation for Thorax

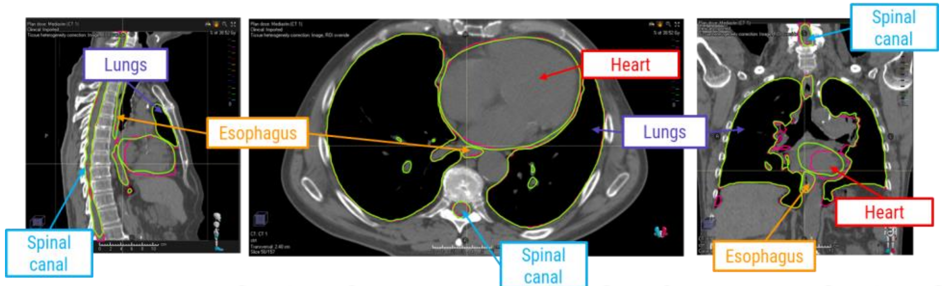


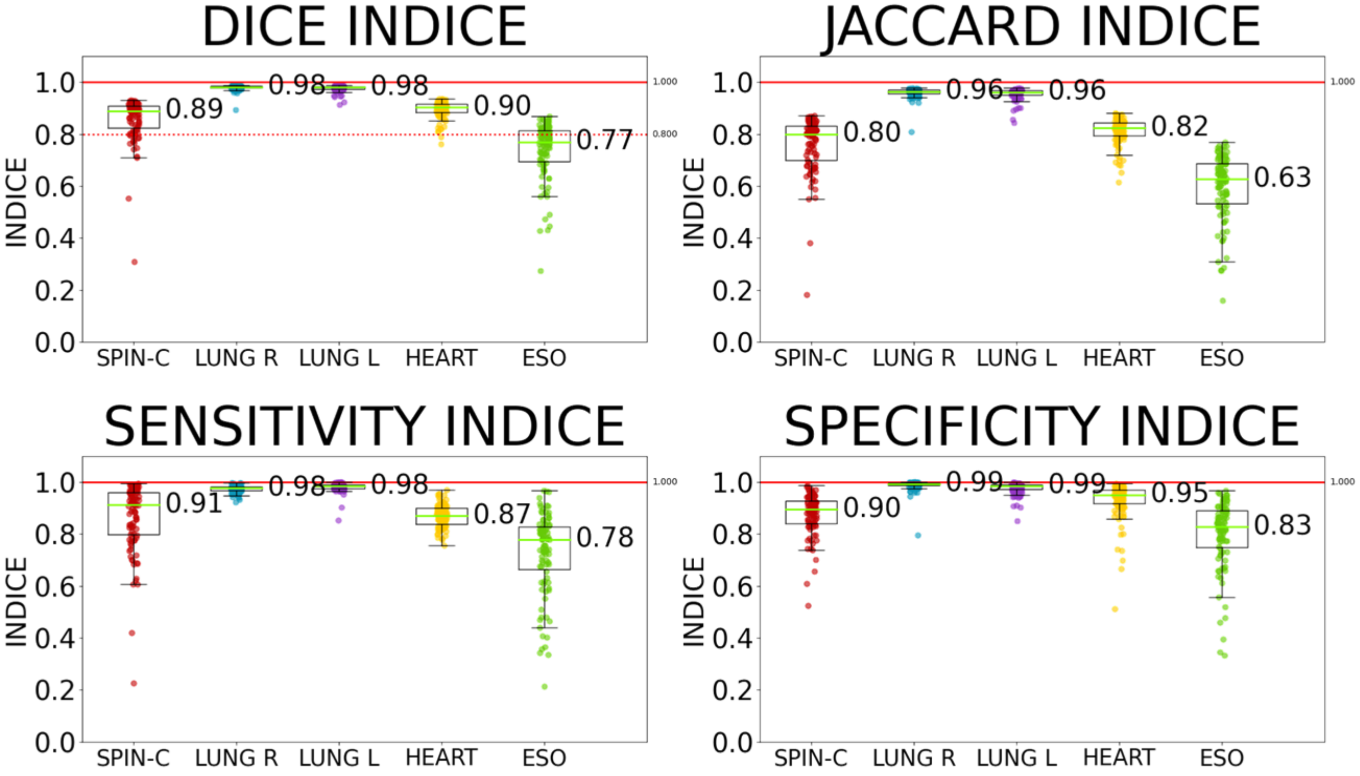
Physician contours : minimum 10 minutes

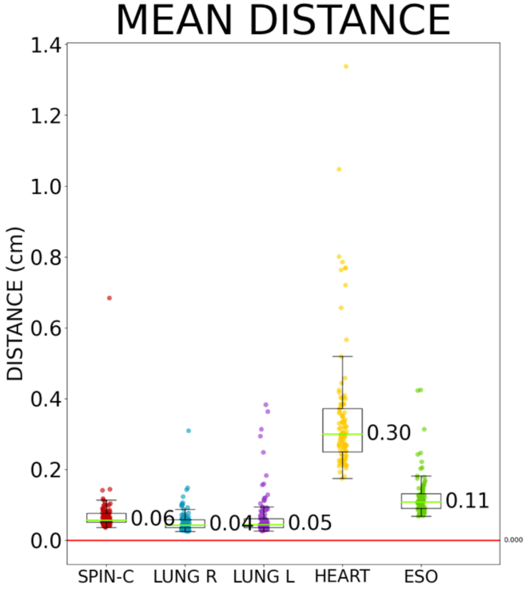
**Deep Learning contours : 30 secondes**

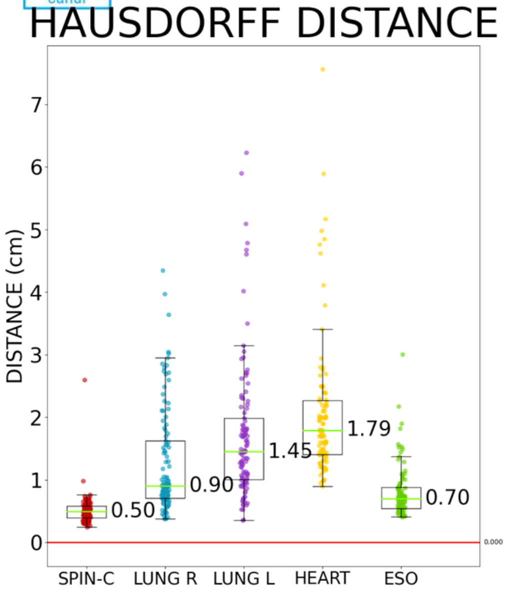


# Method to evaluate of Auto segmentation




Dice > 0,8 for Spinal canal, lungs and heart (accepted with manual corrections)

Dice < 0,8 esophagus (accepted **but new model for esophagus considered**)

**Model accepted clinicaly**

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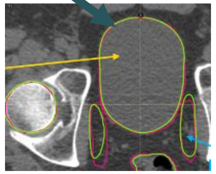

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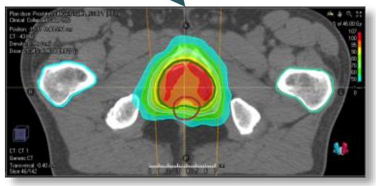
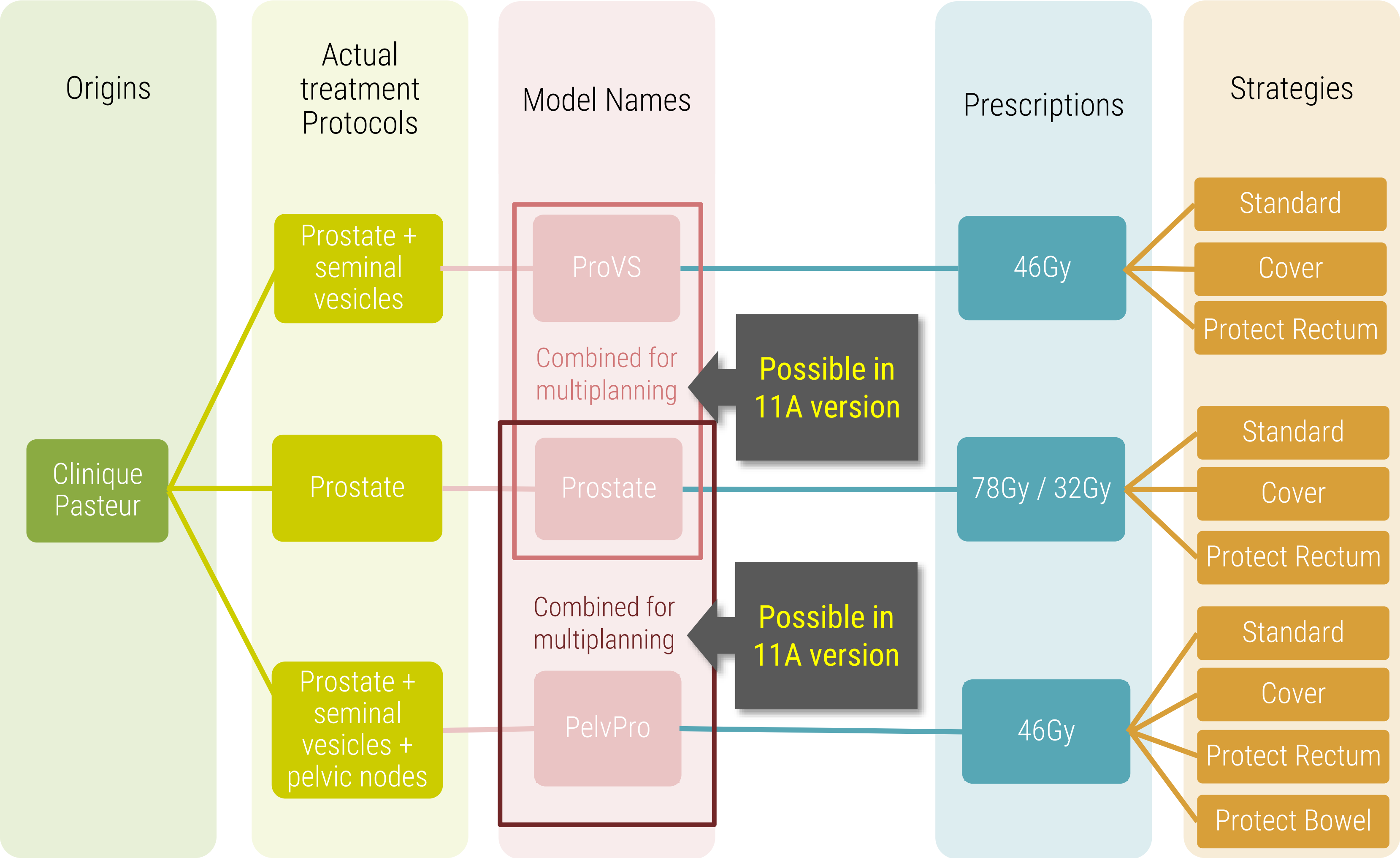


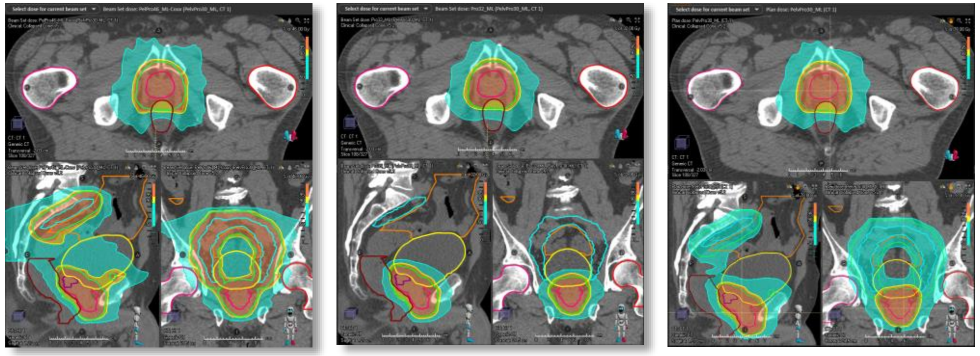
# LOCAL Pelvic models for auto planning

**3 LOCAL ML models in 9B and 5 LOCAL ML models in 11A** and their strategies from the **2 LOCAL databases**



# Method to evaluate of Auto Plans Commissioning of ML model





- **Qualitative review** of the **dose distributions** and **DVH** curves :
- **Quantitative evaluation** of the protocol specific **clinical goals**
- **Comparison** between the **automated plans with ML** and the **standard optimized plans** with **index** :

**Conformity index**

$$Conformity = \frac{Volume_{\ target}}{Volume_{\ isodose\_ref}}$$

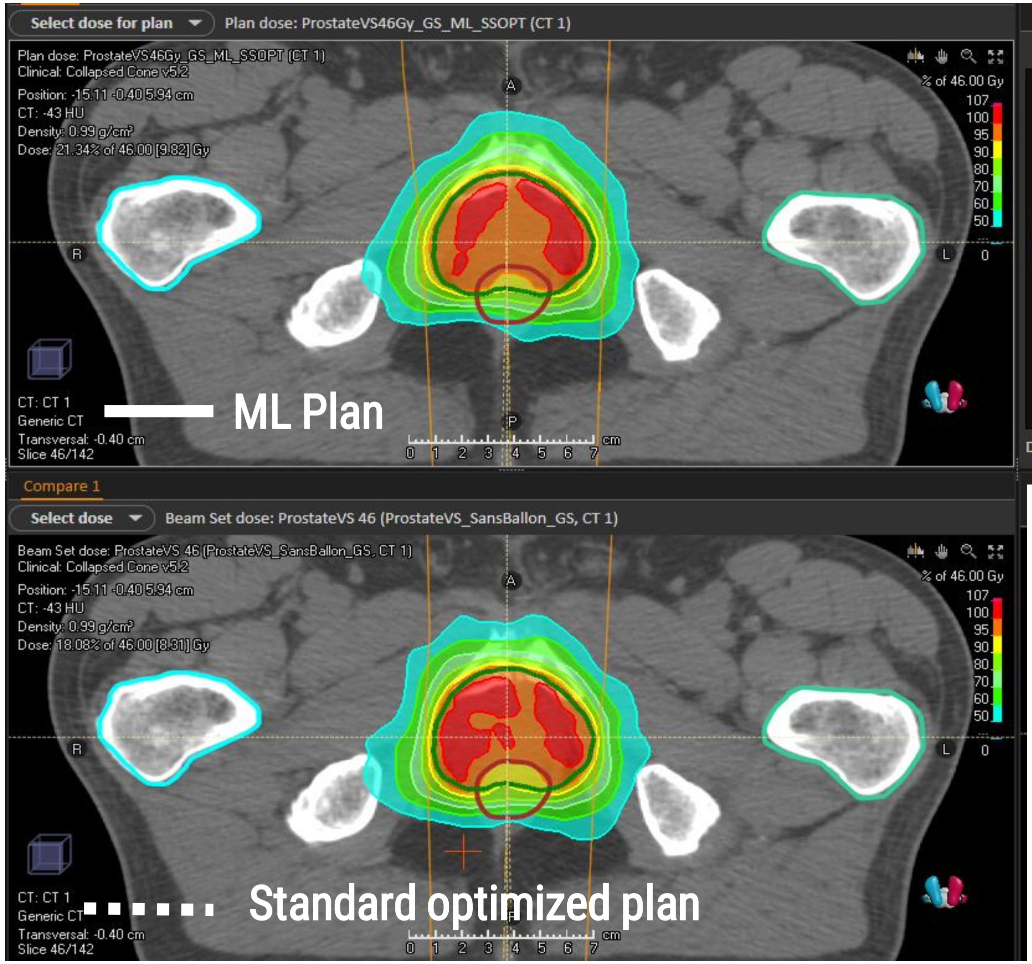
**Homogeneity index**

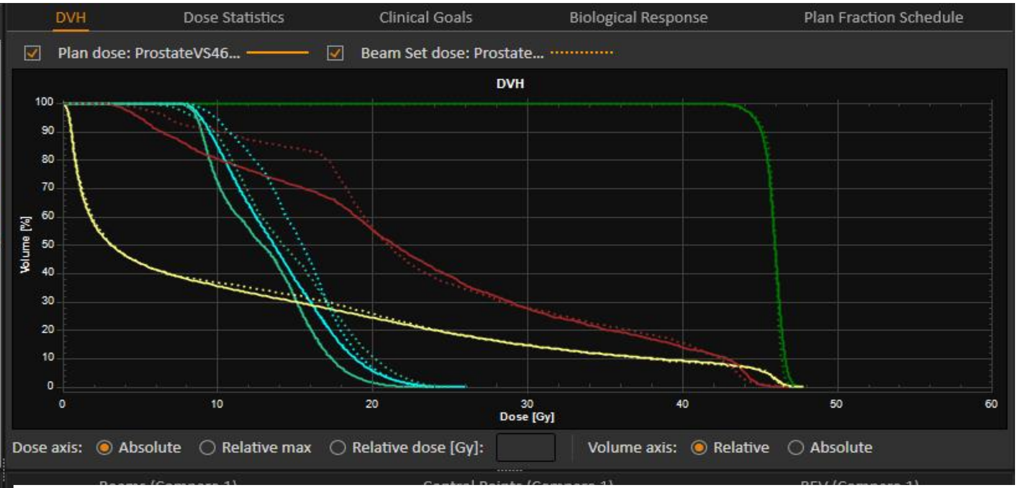
$$Homogeneity = \frac{D_2 - D_{98}}{D_{50}}$$

**Dose Gradient index**

$$Gradient = \frac{Volume_{\ isodose\ 50\%}}{Volume_{\ isodose\_ref}}$$

# Standard vs ML : review of the dose distributions and DVH curves



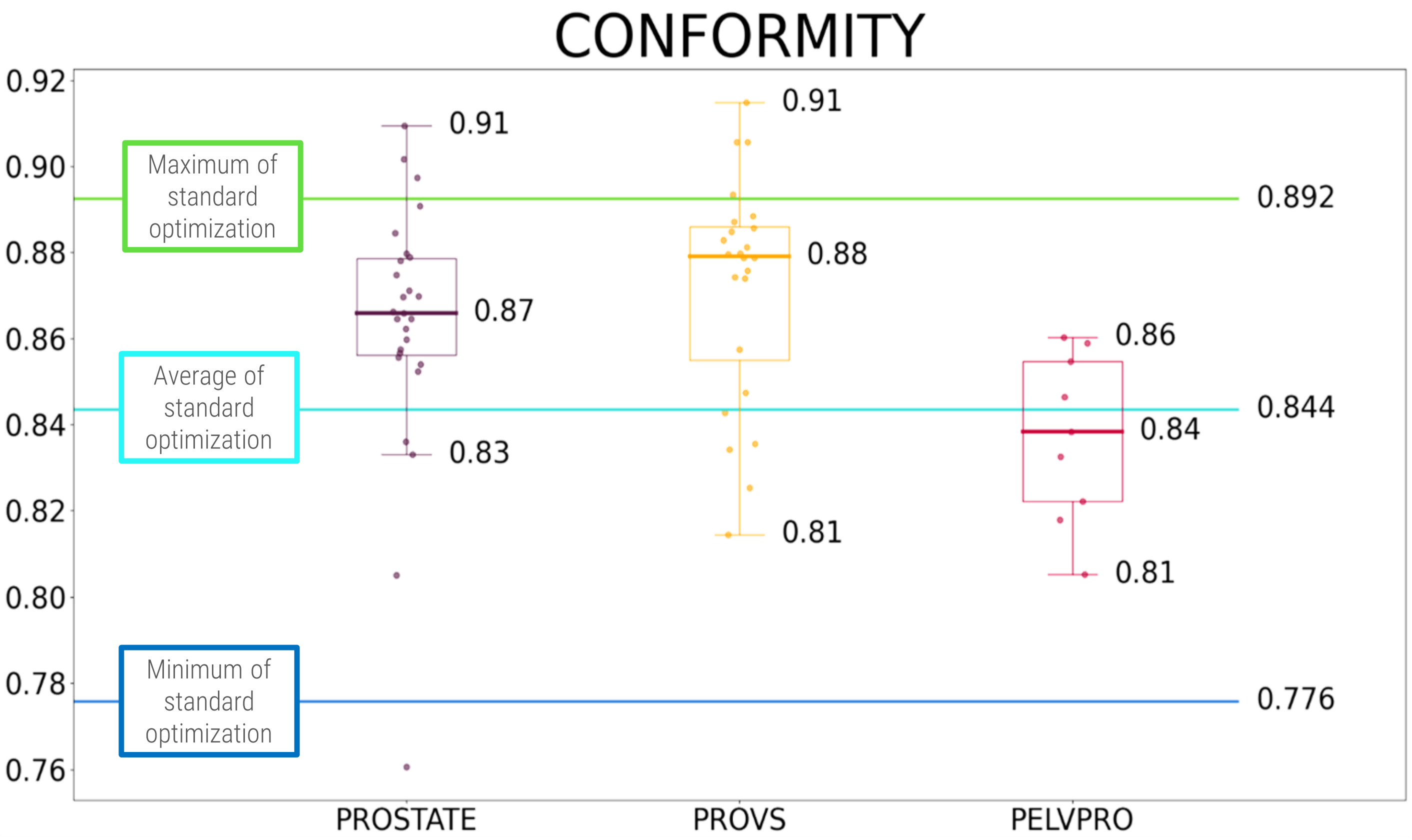

- ✓ **85% of 50 evaluated plans are clinically acceptable** without additional optimization
- ✓ ML algorithm generate plan in **16 minutes** = **twice faster** than standard optimization

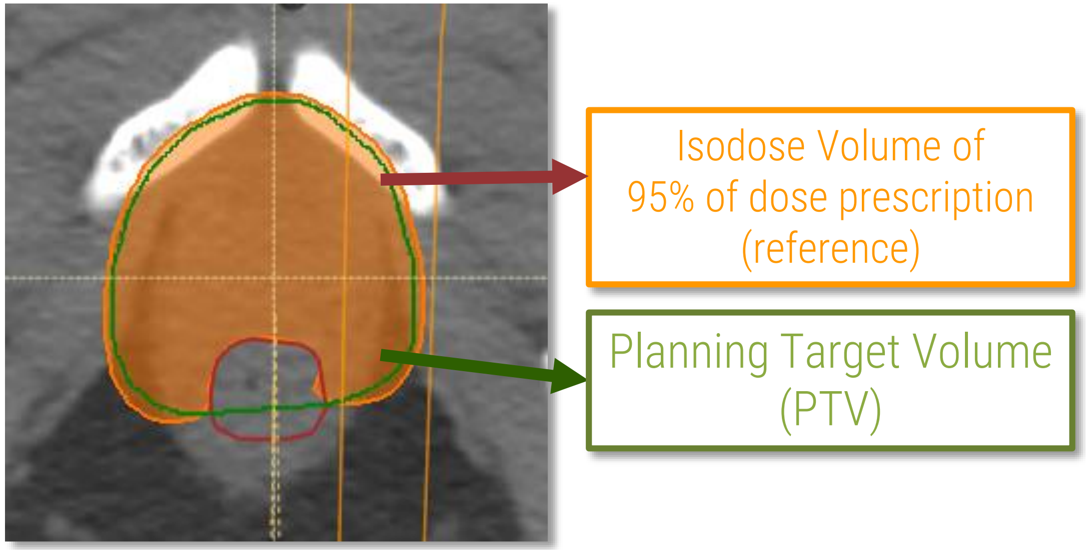
# Standard vs ML : Conformity index



$$Conformity = \frac{Volume_{\ target}}{Volume_{\ isodose\_ref}}$$

Goal = 1



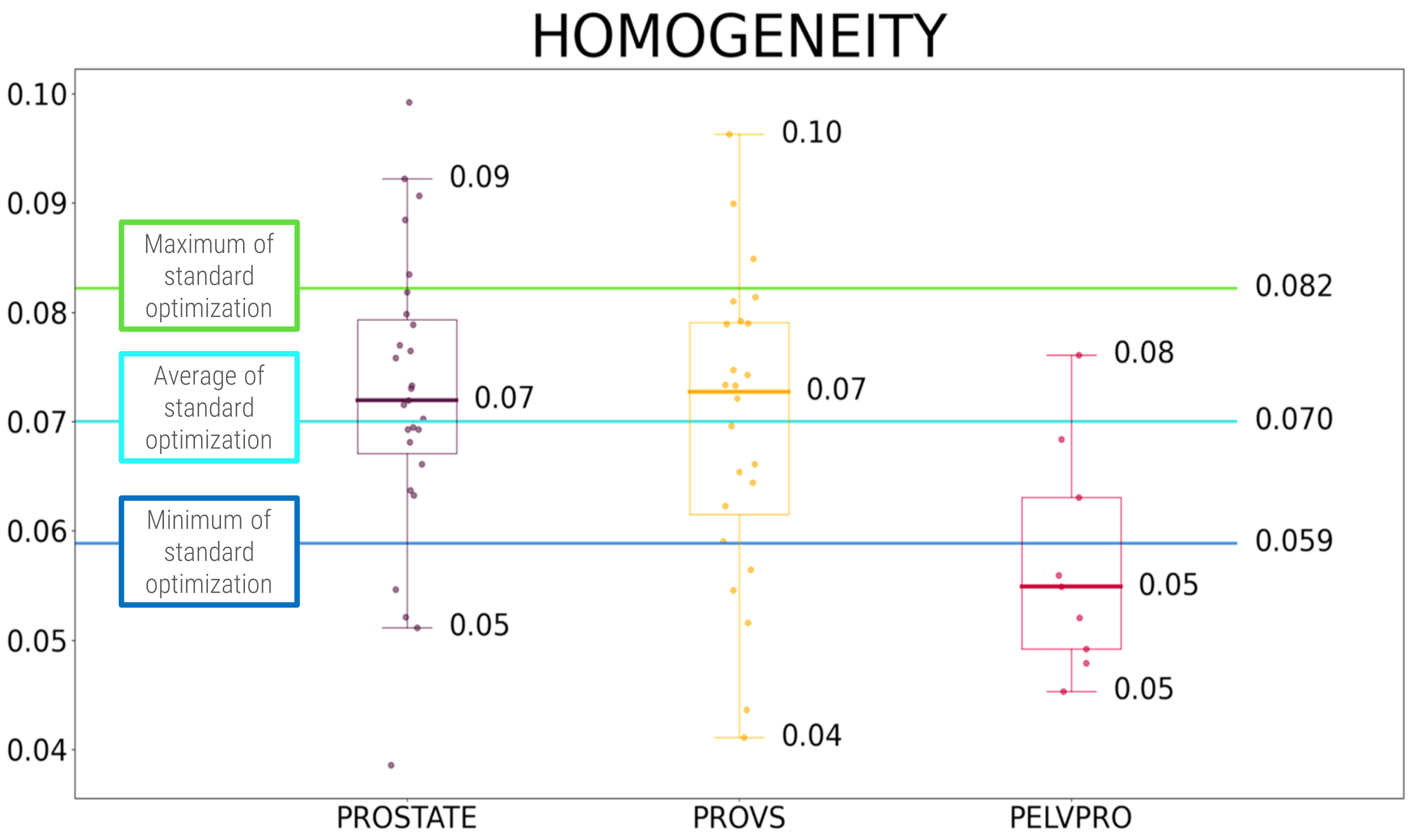



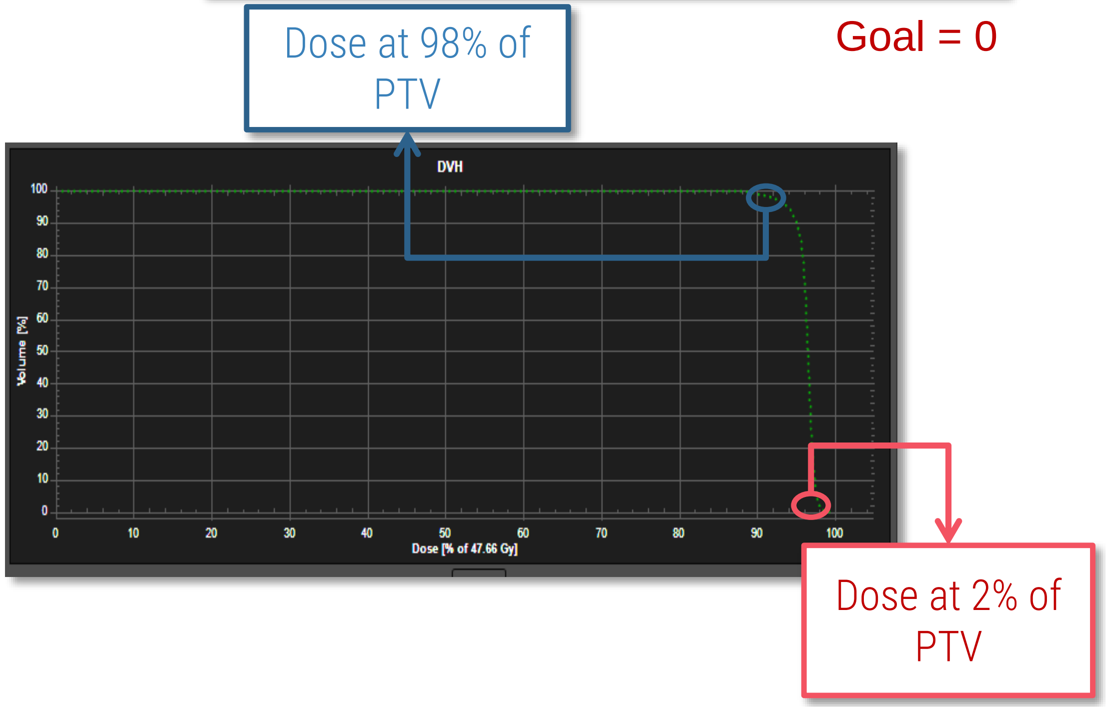

Results of ML between 0,91 and 0,76 : LOCAL ML models have **equivalent or best conformity** than standard optimized plans

# Standard vs ML : Homogeneity index

$$Homogeneity = \frac{D_2 - D_{98}}{D_{50}}$$

Goal = 0



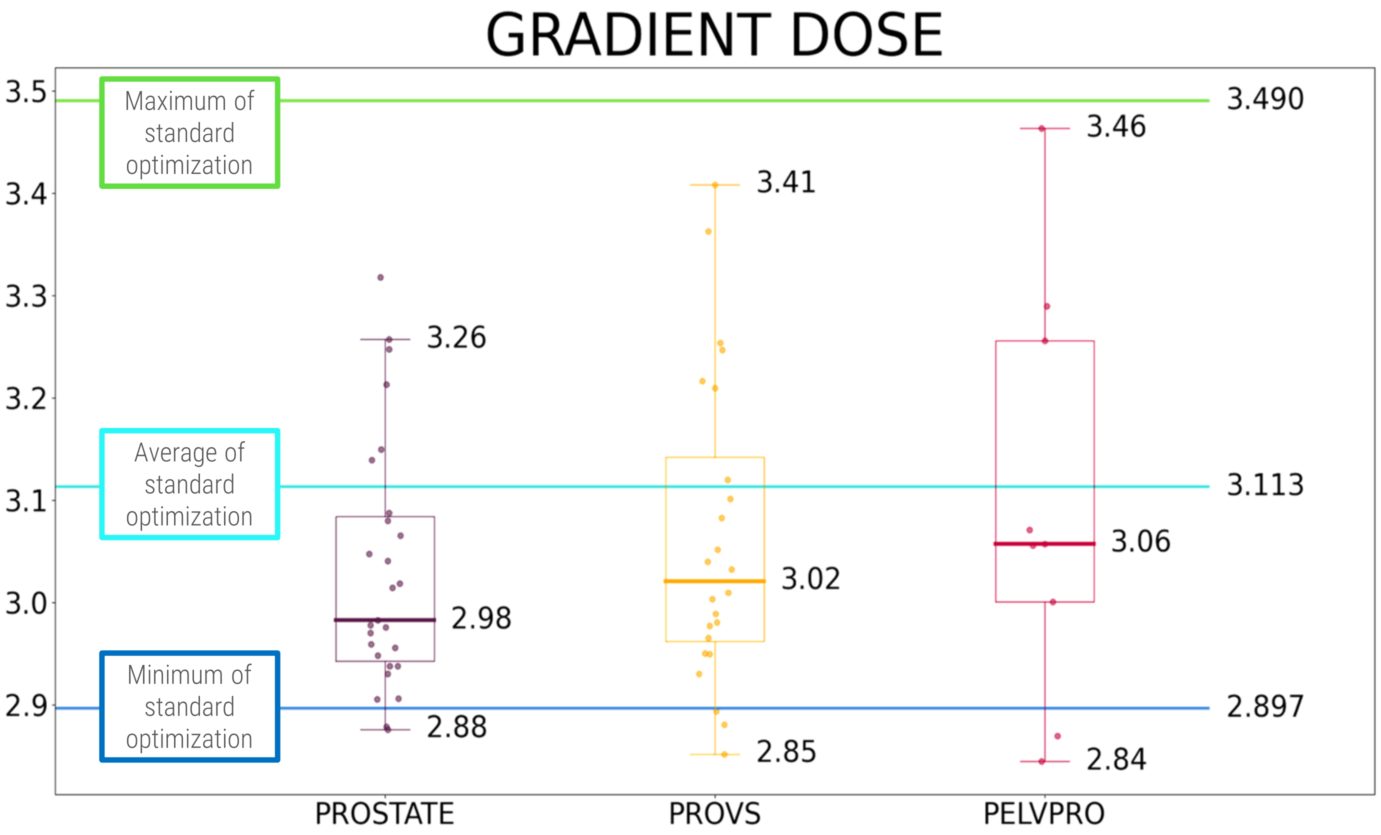



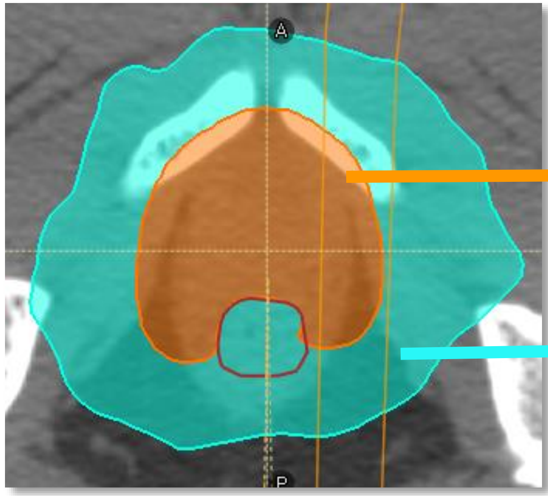

Results of ML between 0,04 and 0,1 : LOCAL ML models have **equivalent homogeneity** indices than standard optimized plan.

# Standard vs ML : Dose gradient index

$$Gradient = \frac{Volume_{\ isodose\ 50\%}}{Volume_{\ isodose\ \_ref}}$$

Goal = 1




Isodose volume of D95% (reference)

Isodose volume of D50%

Results of ML between 3,46 and 2,84 : LOCAL ML models **equivalent or best dose gradient** than standard optimized plans

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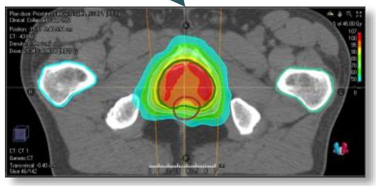

# Conclusion and future work



## Automatic segmentation

- ✓ **Fast calculation** (30 seconds)
- ✓ **Method reliable** (good results)
- ✓ RaySearch **provide commissionned model**
- X **Limited evaluation** (needs qualitative review : time consuming)
- X **Construction of database is time consuming**

- **Evaluation of ORL** model on going (verry promising)
- **New databases** to create **new models**
- Creation of **user friendly algorithm for database construction**

## Automatic planification

- ✓ **Fast calculation** (16 minutes / BeamSet)
- ✓ **ML plans are equivalent** to standard optimized plans
- ✓ **Adjustement** of model **very usefull**

  1 model = **several** close **treatment protocols** and **strategies**
- ✓ RaySearch **provide commissionned ML models** and systematically **help for adjustments**
- X **Construction of database** and **adjustement** of ML on-site **are time consumming** and need a **dedicated person**

- **Evaluation of the new algorithm** (9B VS 11A)
- Evaluation with **Complexity index**

**IA method allows homogenization of clinical practices and saves a considerable amount of time at least 2 times faster**