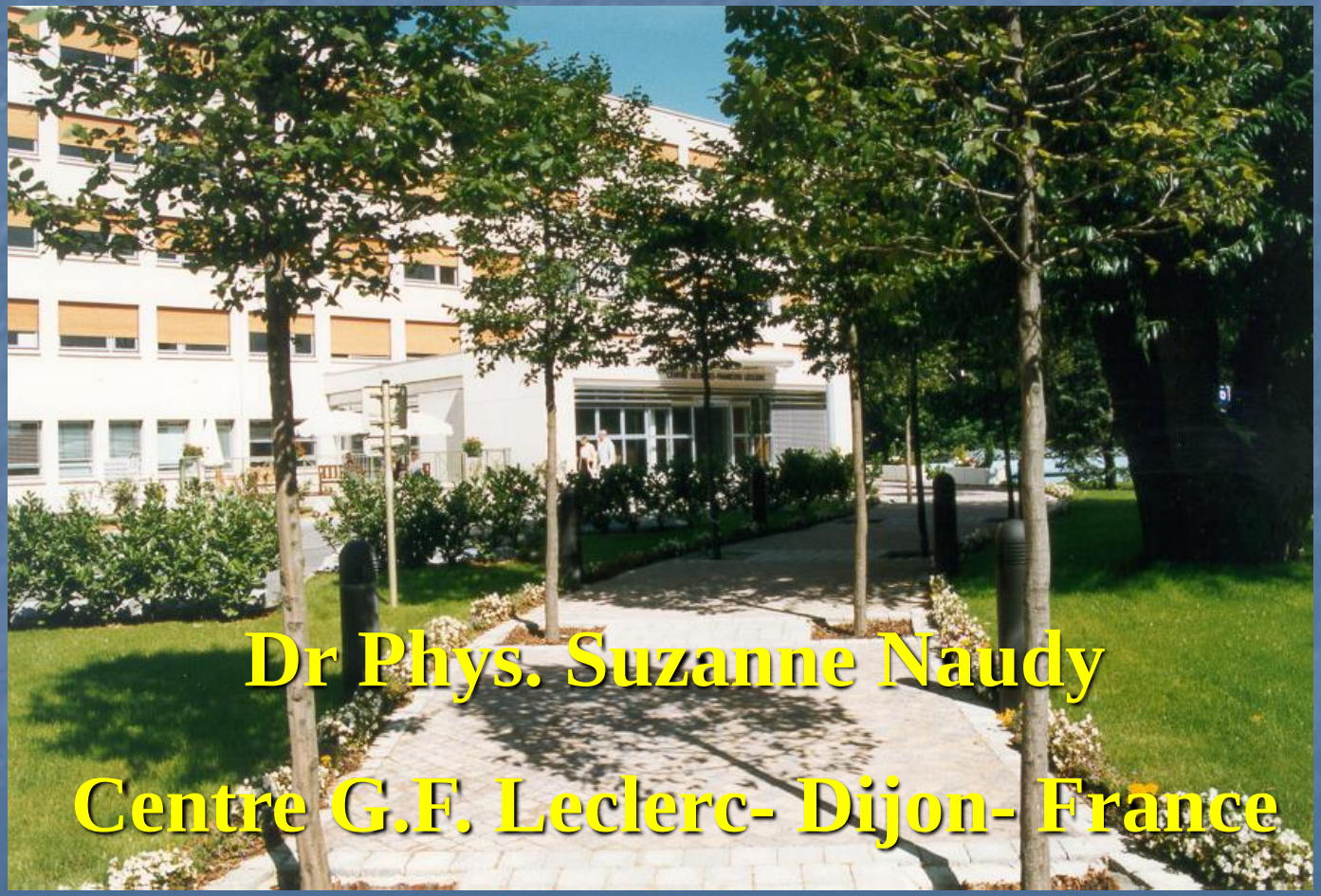
Quality Assurance for Intensity Modulated Radiation Therapy



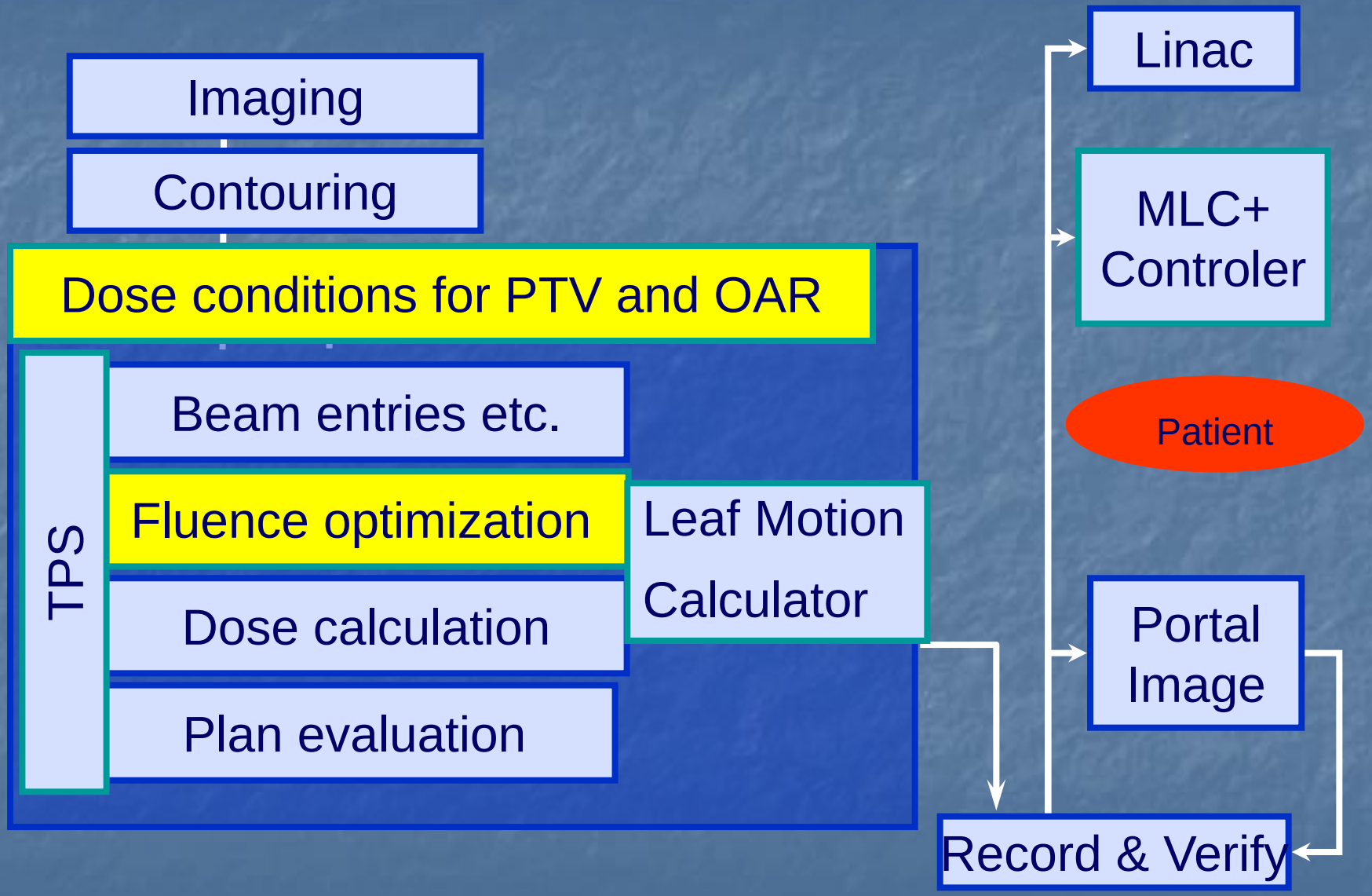
Dr Phys. Suzanne Naudy

Centre G.F. Leclerc- Dijon- France

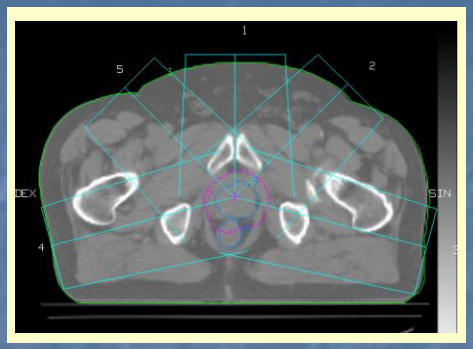
Part 2: Patient related QA

- Is my IMRT system able to deliver the planned dose?
- Is the patient always in the same position?
- Is the target volume always in the same position?

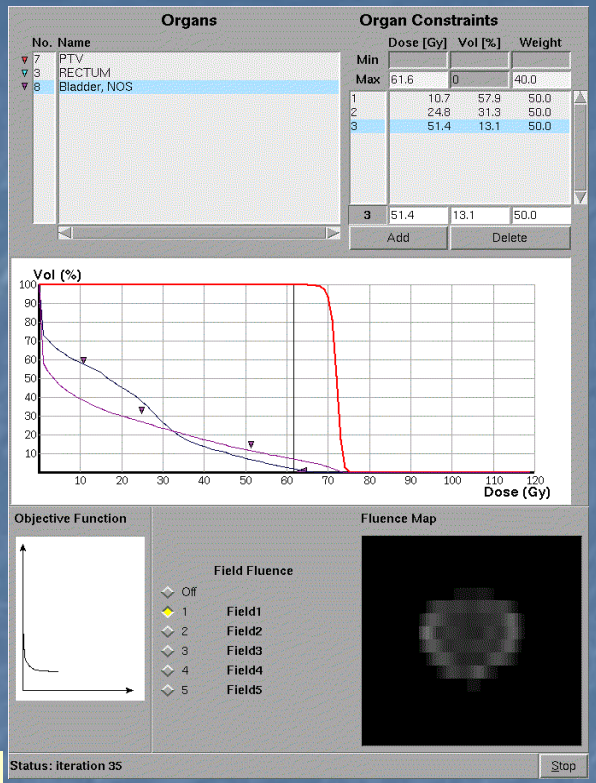
The IMRT Process using Linac + MLC



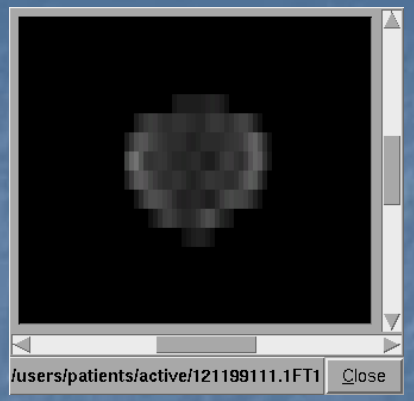
beam geometry



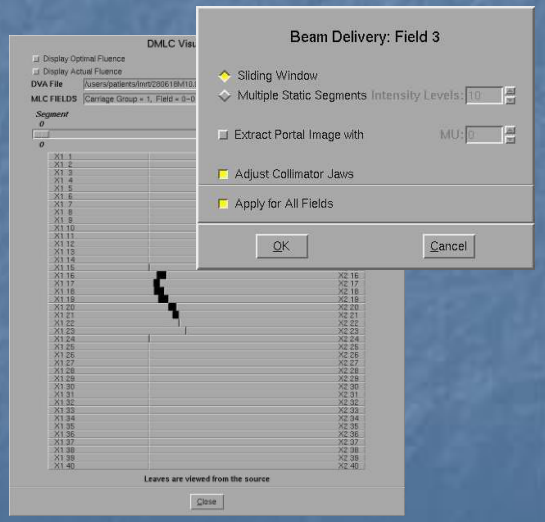
intensity optimisation



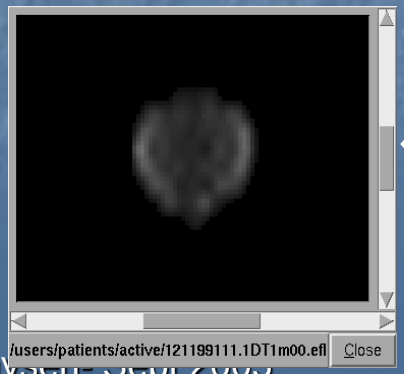
optimised fluence map



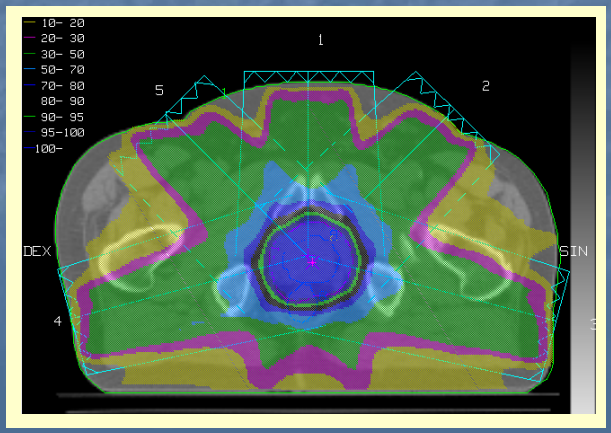
dLMC (sliding window)



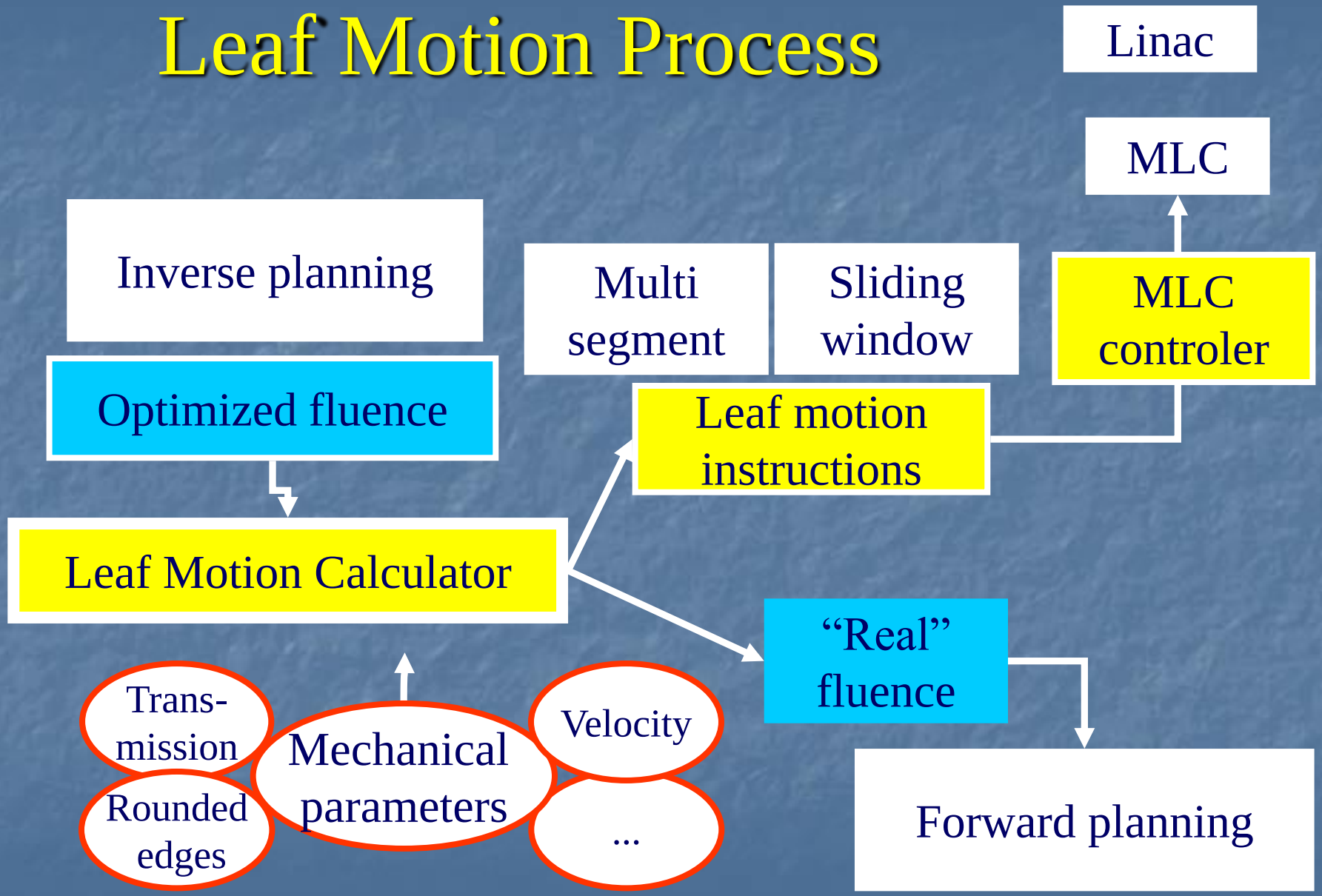
deliverable fluence map



dose distribution



Leaf Motion Process



Part 2: Patient related QA

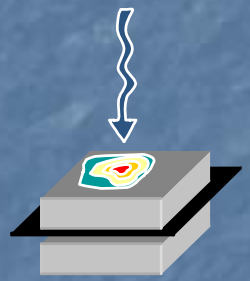
- **Is my IMRT system able to deliver the planned dose?**
- Is the patient always in the same position?
- Is the target volume always in the same position?

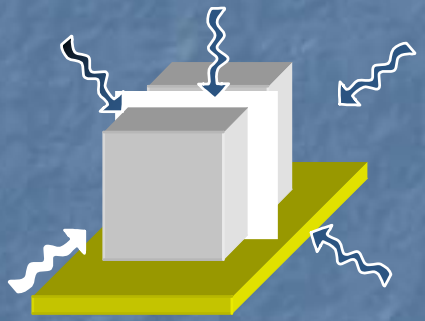
Verification of the dosimetric accuracy of the calculated dose distribution

- Pre-treatment QA: IMRT field check without patient
  - Prerequisite:
    - Equipment related QA
    - Treatment Planning system configuration

IMRT field check without patient

2 different approaches





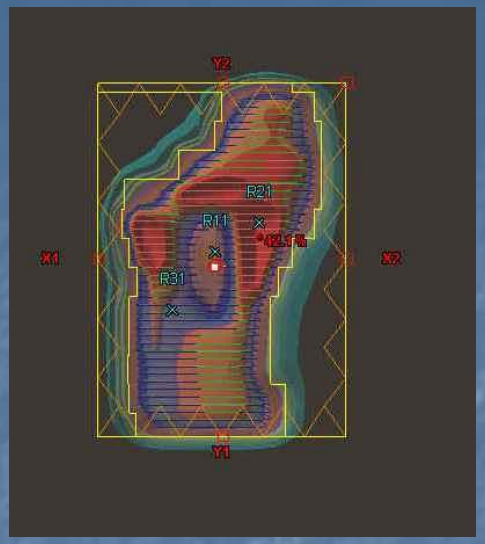
- **Field-related QA**

Detection of error origin

- **Plan-related QA**

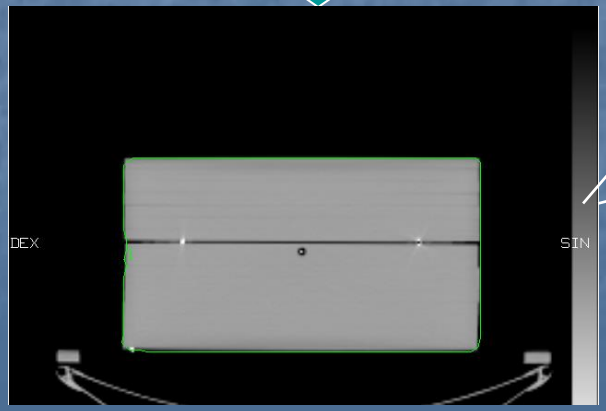
Summed dose distribution

- Point wise measurement with ion chamber
  - Absolute dose comparison
    - **Easy**
    - **Results immediately available**
    - **Problems in high gradient regions**
    - **Needs machine time availability**



Patient deliverable fluence map

Import



Calculate

Measure

Point dose

Absolute point dose comparison

Absolute dose check analysis

Results Dijon : first year Δ= (Pmes- Pcalc)/ Pcalc (%)

25 patients,

40 treatment plans

654 measurements points.

Δ mean : –2.1%

Standard deviation : 1.93%.

Extremes : +35.8% , –38.4%.

??

80 points : 5% < Δ <10%. (absolute value)

17 points : Δ > 10%. (absolute value)

Results analysis : influence of dose gradient

Gradient (%/mm)	Δmean (%)
G<0.5	2.24
0.5<G<1	2.55
1.0<G<1.5	2.14
1.5<G<2.0	2.53
2.0<G<3.0	2.78
3.0<G<7.0	3.48

In low gradient area : Δ max $\leq$ 3%

Results analysis : influence of detector positioning accuracy in high gradient area

- Same field and same point: Gradient 9,2 %/mm
- Two different operators: 3O « full » phantom set up/ operator

Expected dose : 0,341 Gy
Measured mean dose : 0,318 Gy Δ = -6,8%

	oper.1	oper. 2	Δ max
Dmax	.391 Gy	.380 Gy	14.7 %
Dmin	.271 Gy	.260 Gy	-23.9 %

Abs (Δ max) = 2 x gradient

Positionning accuracy = ± 2 mm

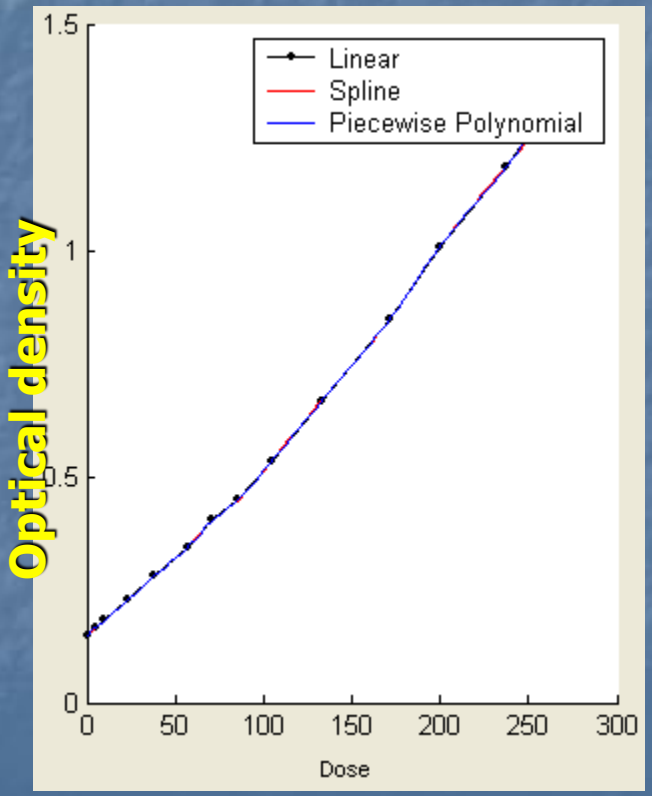
Results analysis : influence of TPS configuration

Δ mean : –2.1% ??

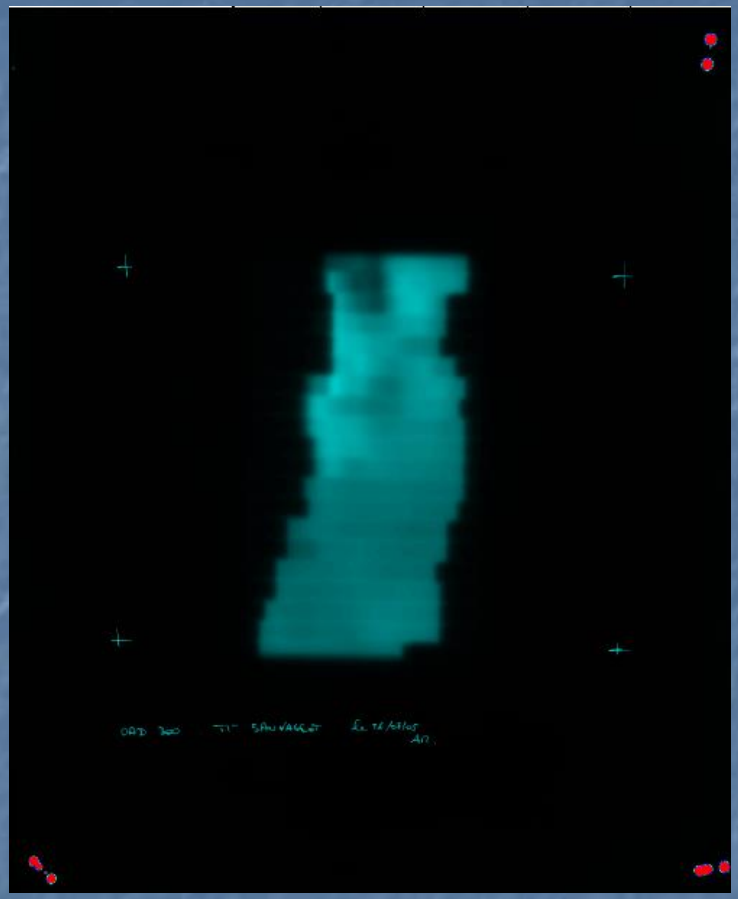
MLC transmission value entered in the TPS not correlated to the MLC and therefore not taken into account

READ THE USERS DOCUMENTATION +++

- 2D measurement with film
  - **Full dose information, even in high gradient regions**
  - **Careful film calibration**
  - **necessary**
  - **Analysis is time consuming**



Measured versus calculated dose distribution 2D analysis



Film with registration marks

Calculated dose matrix

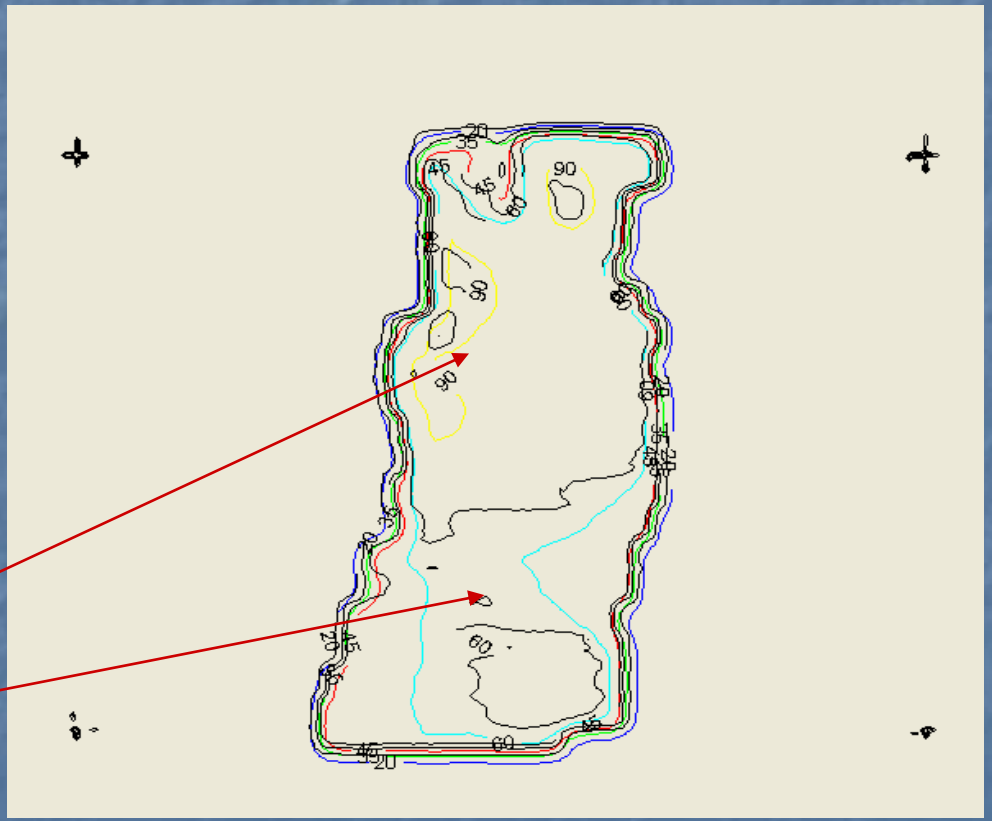
Align and calibrate

2D overlay

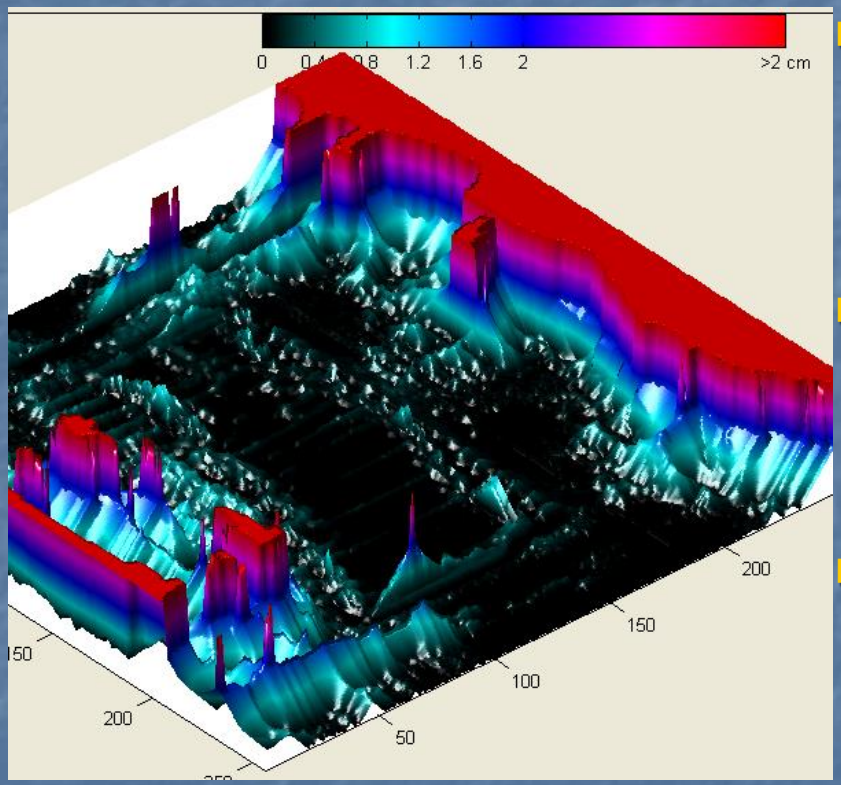
Can be misleading

- **High dose gradients**
- **Hot spots**
- …

?



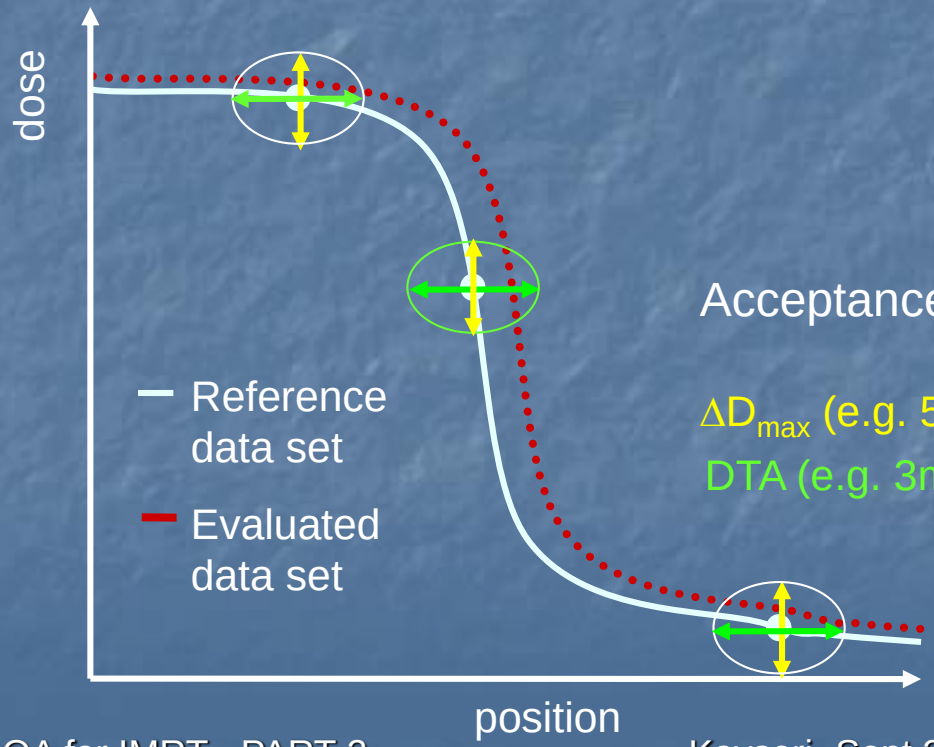
Distance to agreement



- DTA(P) = min{d(P,P0)}
  such $D_{mes}(P) = D_{calc}(P0)$
- $d(P,P0) = ((x_p-x_{p0})^2 + (y_p-y_{p0})^2)^{1/2}$
  (distance beetween P and P0
- High sensitivity in low gradient areas

Gamma index

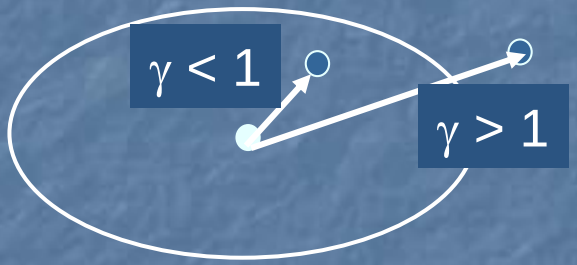
- $\Gamma = \min\{(DTA(P)/DTA_{lim})^2 + (Abs(Diff(P)/Diff_{lim})^2\}^{1/2}$
- Acceptance, if $\Gamma < 1$



Acceptance:

ΔD_{max} (e.g. 5 %)

DTA (e.g. 3mm)

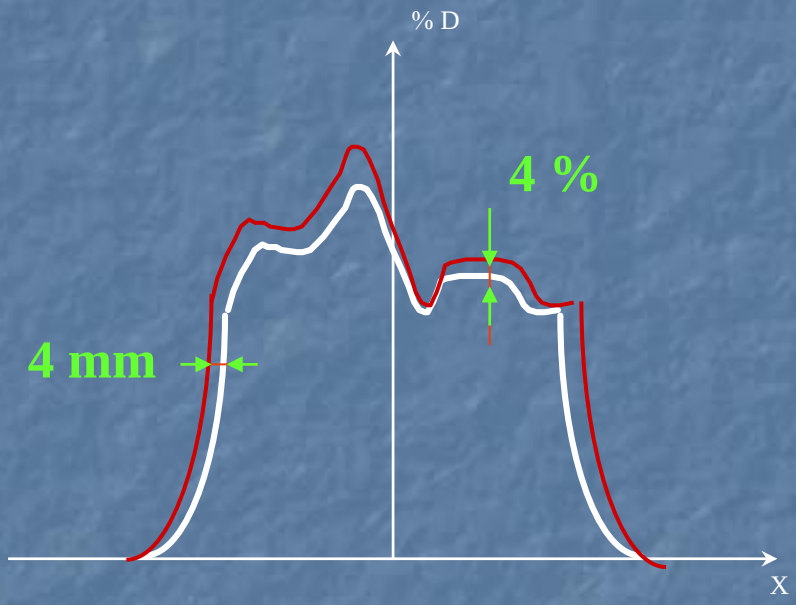


Acceptance limits for 2D dose distribution

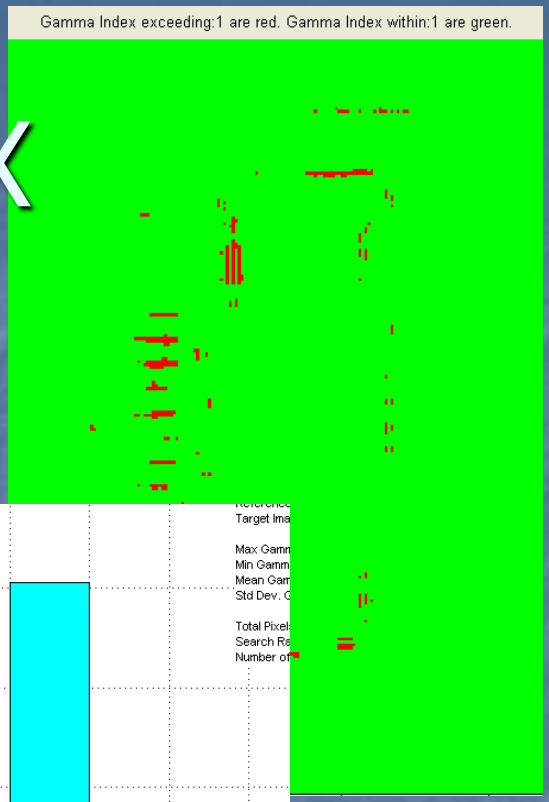
Based on local accuracy assesment

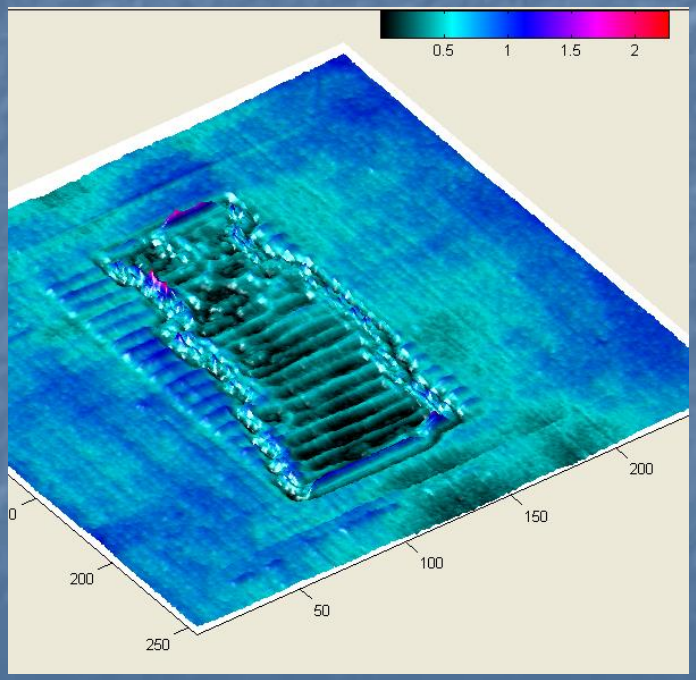
< 4 mm : high gradient and penumbra

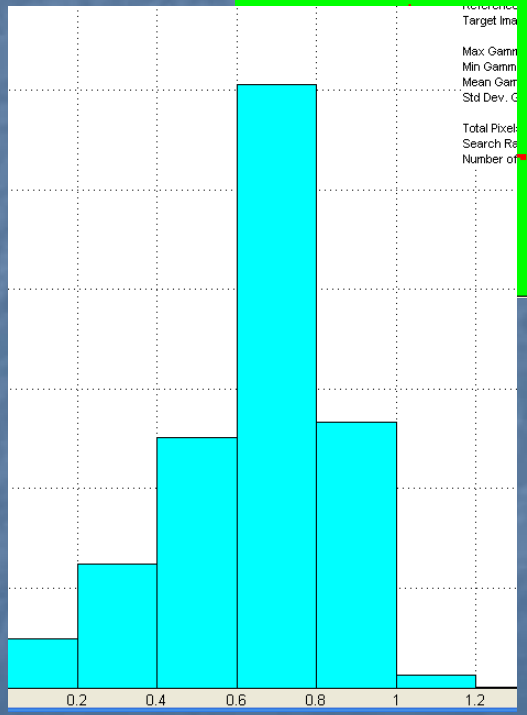
< 4 % : low gradient



GAMMA INDEX


Gamma Index exceeding:1 are red. Gamma Index within:1 are green.


0.5
1
1.5
2
0
200
250
50
100
150
200


0.2
0.4
0.6
0.8
1
1.2

Yes: my IMRT system is able to deliver the planned dose with acceptable accuracy

but

I need physics and machine time

Pretreatment IMRT Patient related QA

TEST	Physics Time	Machine Time
Create plan verification	15 min	
Calculate dose points	15 min	
Shot and process 5 films	20 min	15 min
Analyse 5 films	60 min	
Dose measurements (15 points)	30 min	30 min

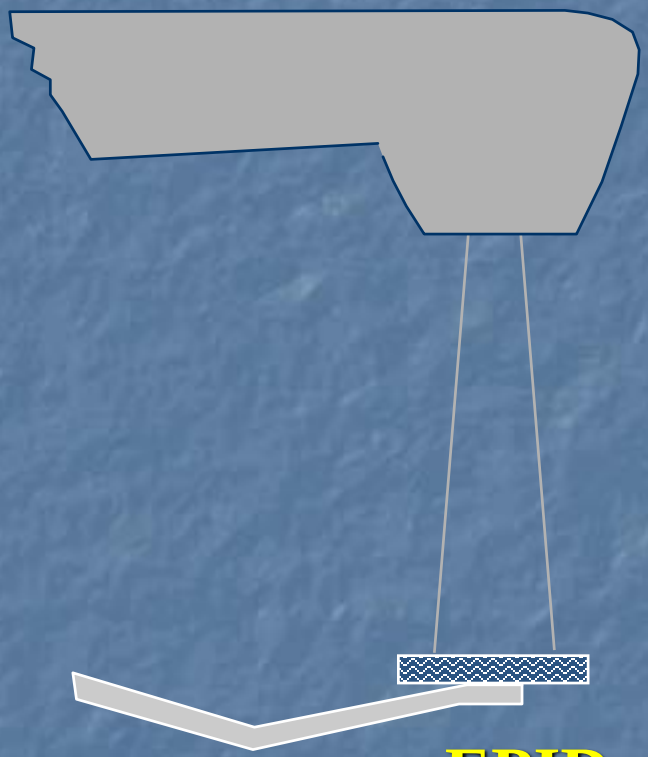
2D measurement with EPID

- **Full dose information**

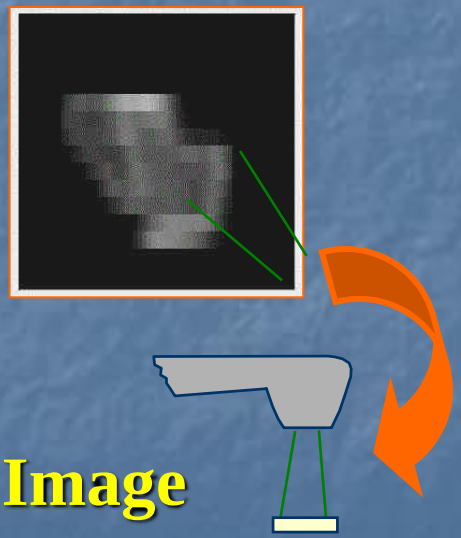
- **Needs**
- **Portal dose prediction software on TPS**
- **Dosimetric acquisition mode for portal images**
- **Portal image detector calibration**
- **Software for comparison**

- Work in progress

QA of the IMRT process of the Eclipse-Helios solution

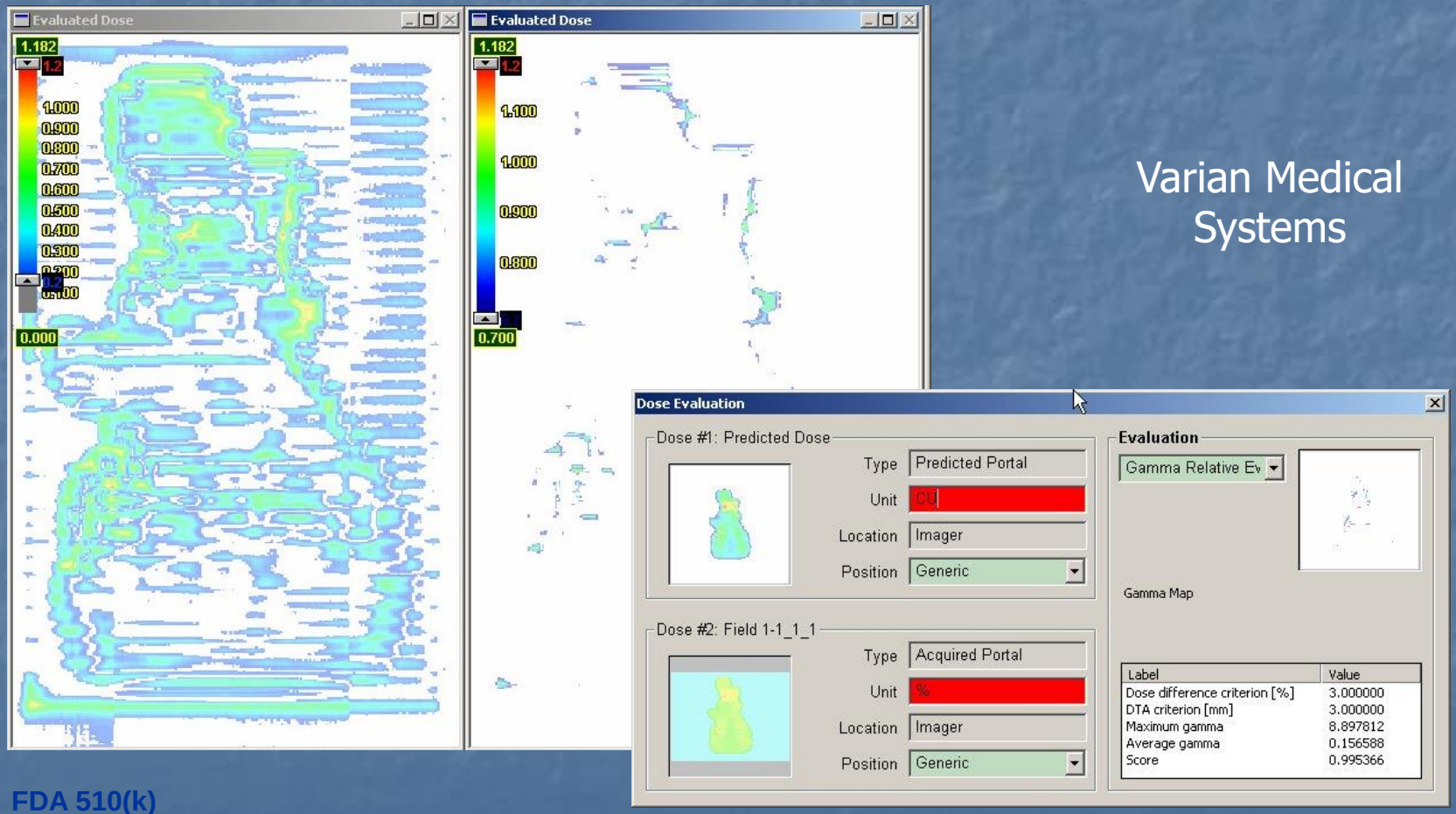


EPID
Dosimetric Image



Predicted Image

PV Dosimetry - Gamma Evaluation



Varian Medical Systems

FDA 510(k)

Part 2: Patient related QA

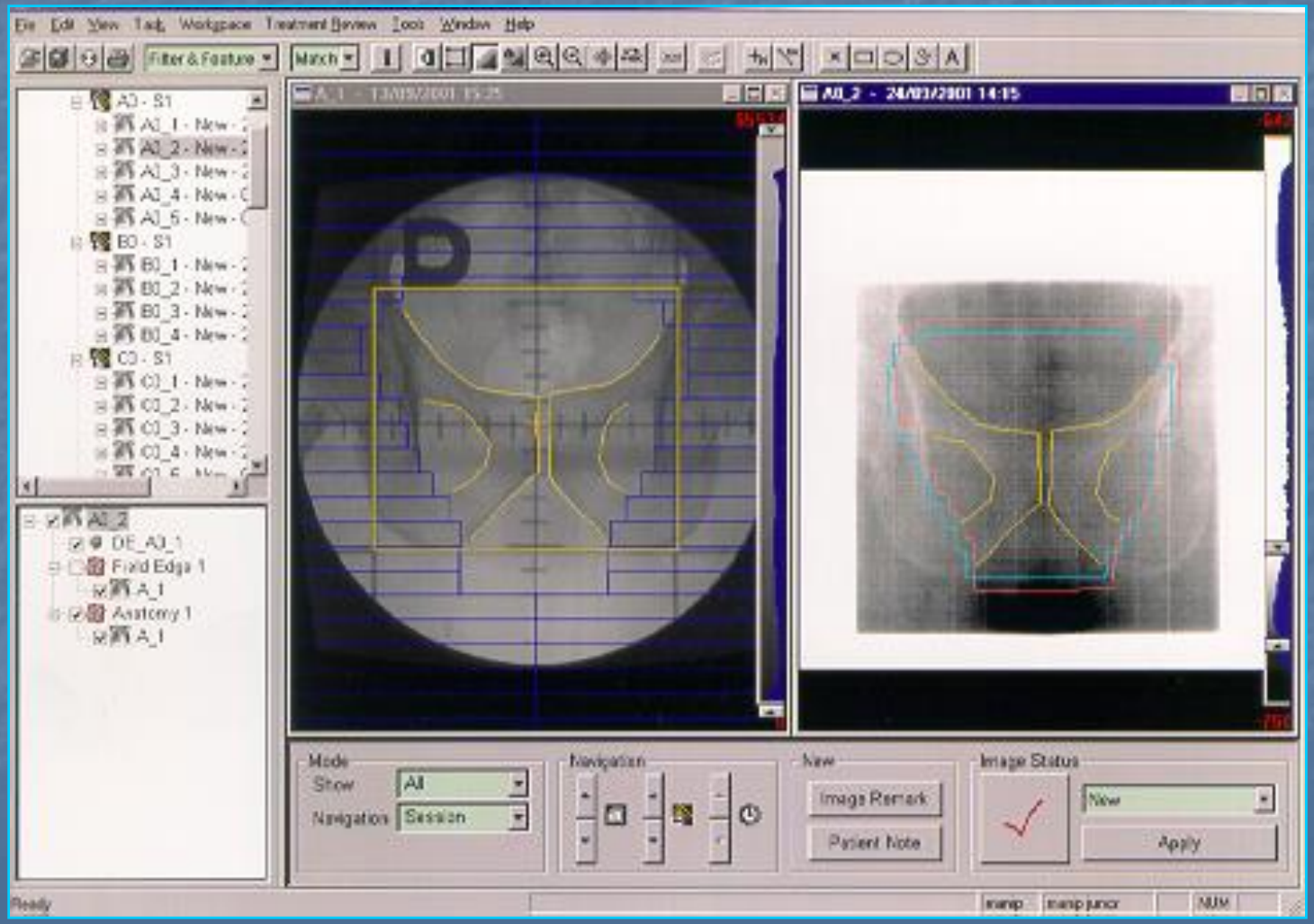
- Is my IMRT system able to deliver the planned dose?
- **Is the patient always in the same position?**
- Is the target volume always in the same position?

Verification of the patient positioning

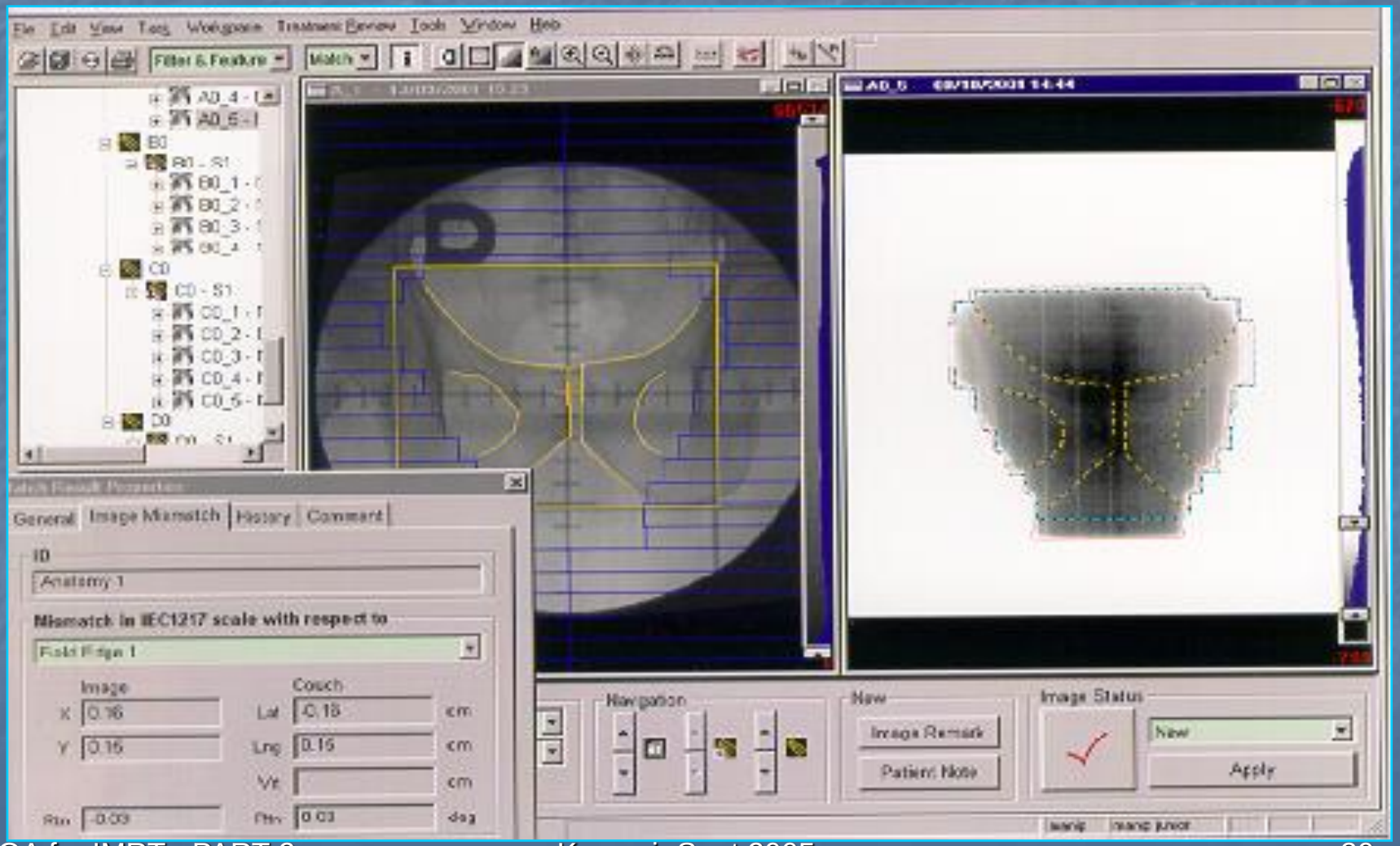
- Transfer of the static method of patient positioning verification to IMRT treatment
- Strategy
- Action level

Static method

Anatomical landmarks drawn on reference image and portal image

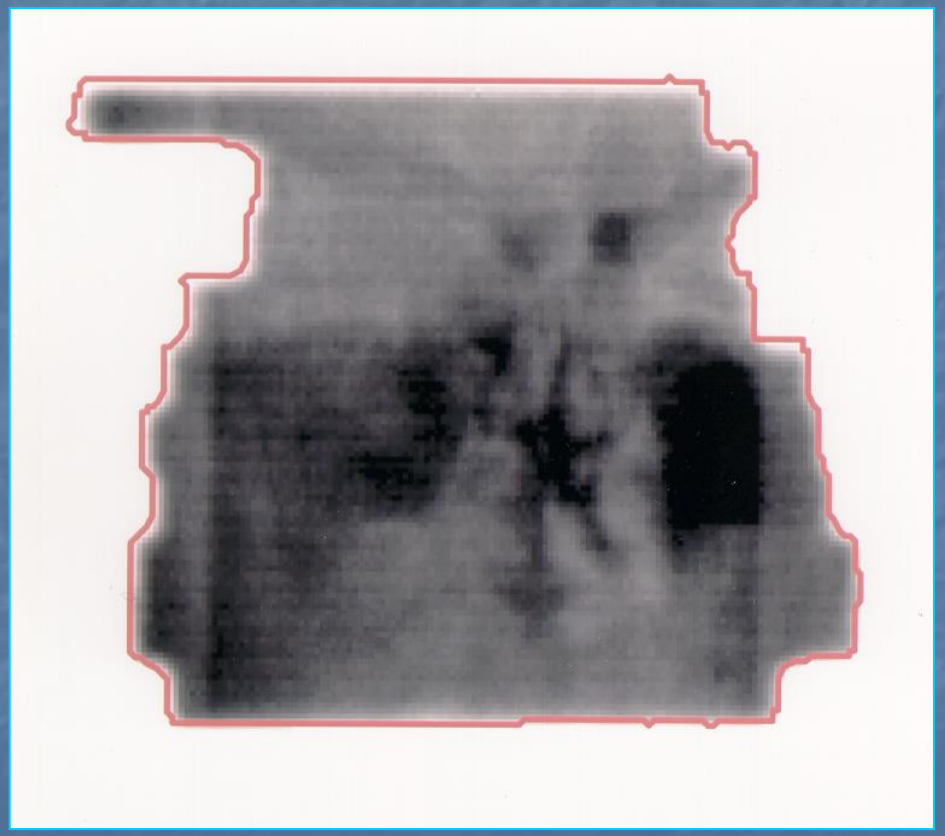


Automatic matching and calculation of deviations

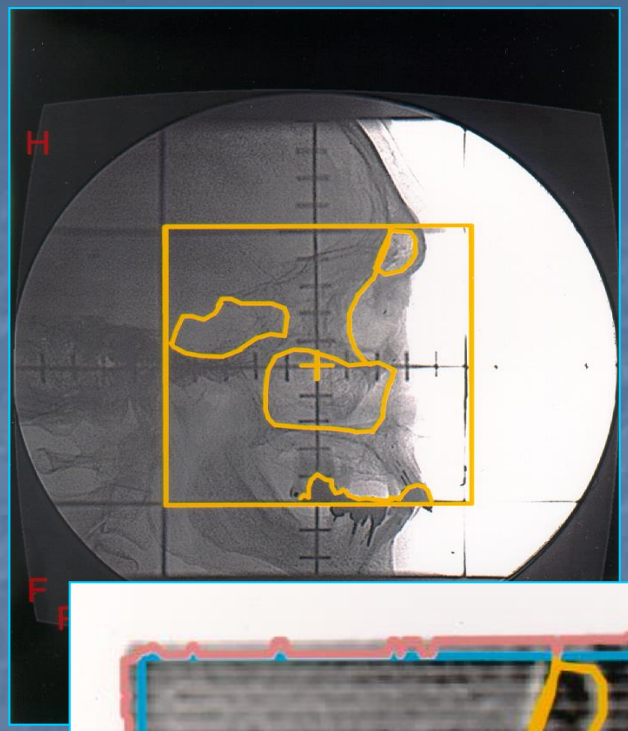


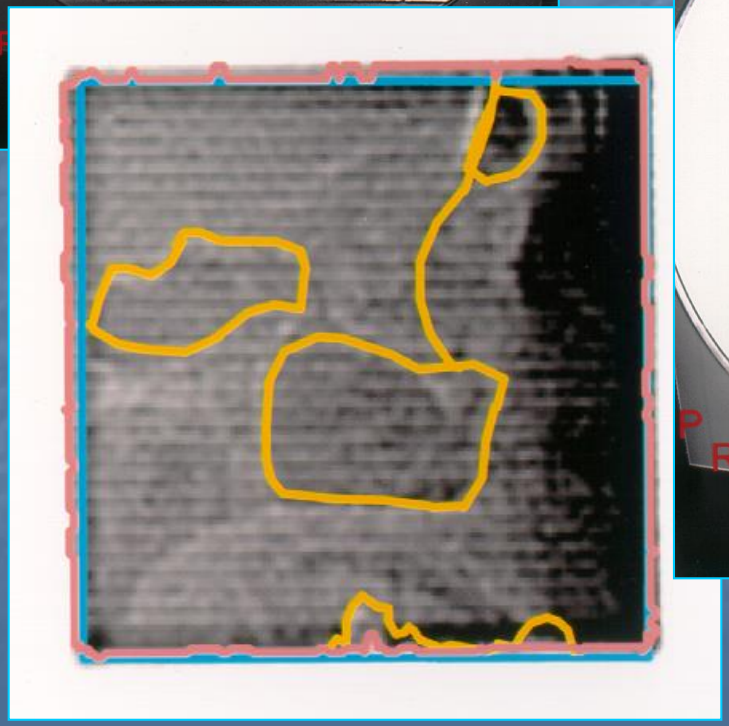
IMRT field portal image

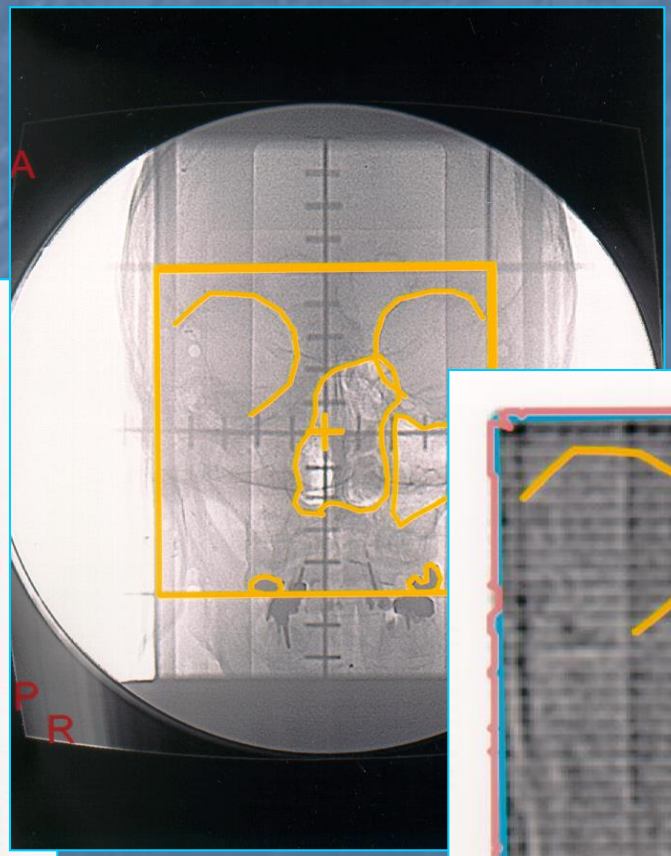
- Composite
- Washed anatomical landmarks
- Useless !!

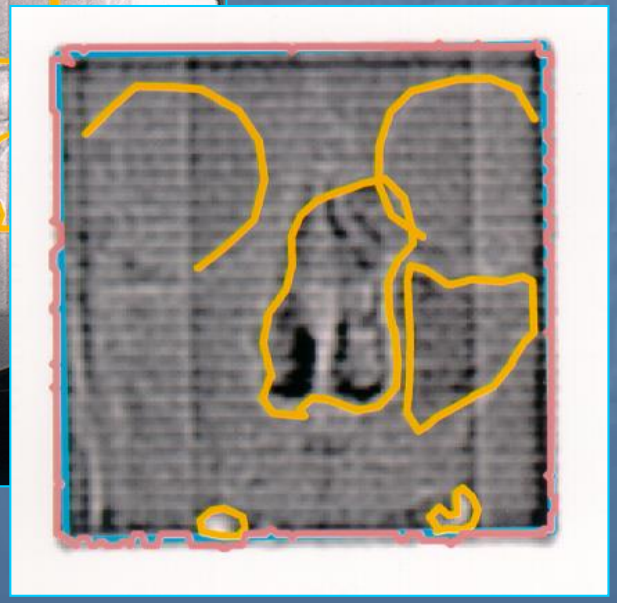


Orthogonal static vérification fields using the IMRT plan isocentre







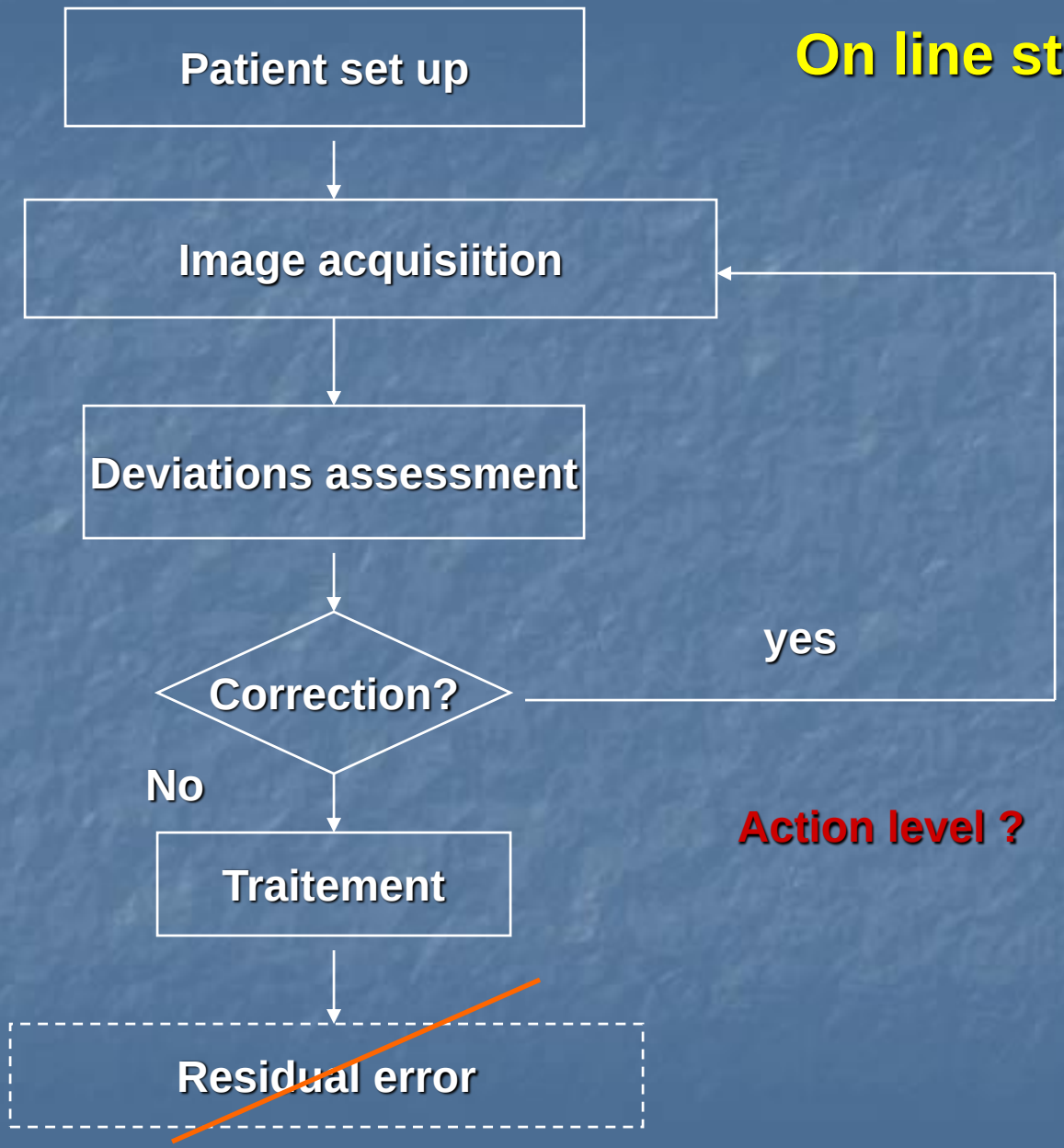


2 Strategies

- Real time adjustment
- Daily assesment and correction of systematic and random error

- Offline procedure
- Early identification of systematic error
- Weekly follow up of deviations

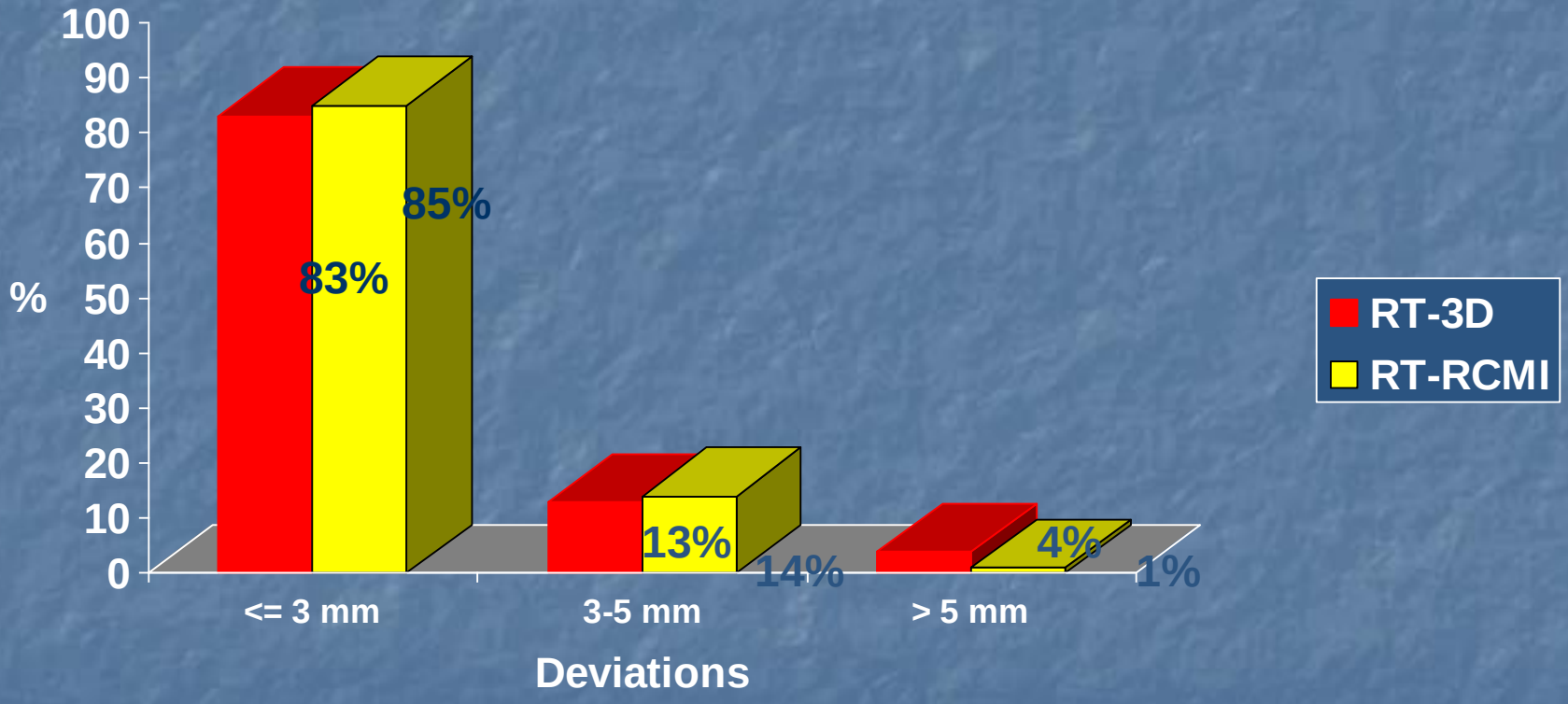
On line strategy



Action level
Local accuracy assesment +++

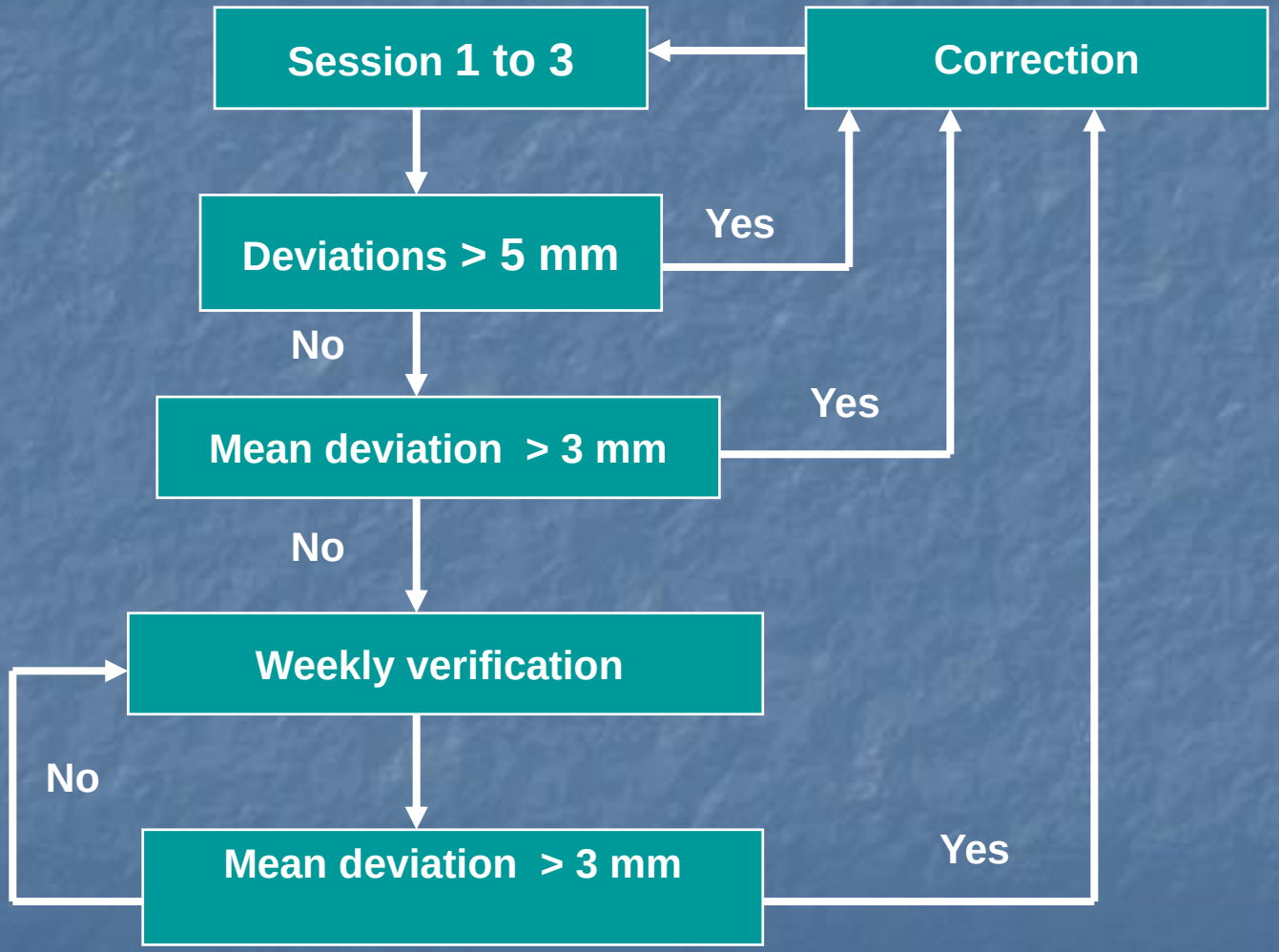
- Correction if dev ≥ 5mm
- Mean dev (D3) and standard dev of the 3 first sessions (SD3)
- Mean dev (DT)and standard dev of all measurements (SDT)
- Number of fractions with dev > D3

Dijon results : on line strategy



Ref: Dr Barillot

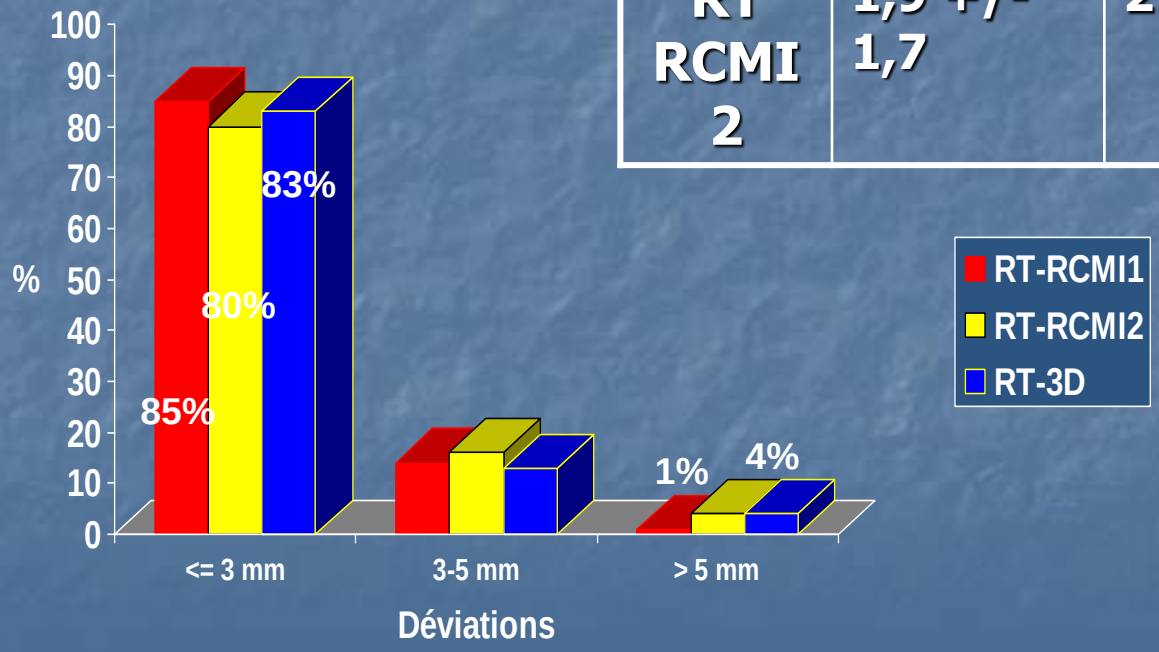
Off line strategy



Dijon results:

Off line strategy

	Mean dev +/- SD		
	X Ant-Post	Y Cranio-Caudal	Z Latéral
RT RCMI 1	1,6 +/- 1,6	1,6 +/-1,3	1,8 +/- 1,2
RT RCMI 2	1,9 +/- 1,7	2 +/-1,5	1,4 +/- 1,2



Caution

- PTV= CTV + margin

- Small margin ≠ on line procedure

Yes: I am able to assess and correct patient set up errors to reach acceptable tolerance level

without

Significant interference on patient flow

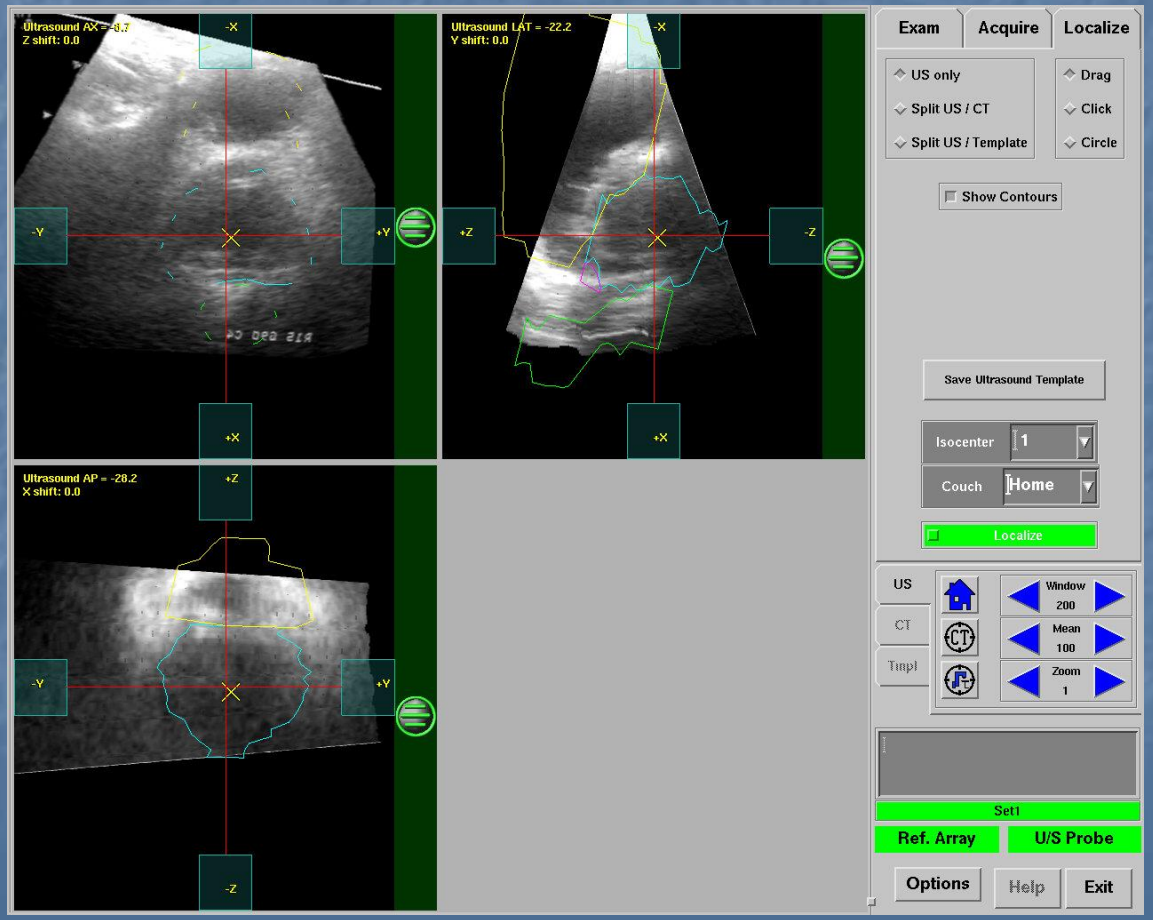
Part 2: Patient related QA

- Is my IMRT system able to deliver the planned dose?
- Is the patient always in the same position?
- **Is the target volume always in the same position?**

Ultrasound targeting

Goal:Interfraction motion

- **Bat SXI ®:** Elekta North American Scientific Inc
- **Sonarray ®:** Varian



Ultrasound targeting : Basic Process (Sonarray)

Localisation of linac isocenter in the treatment room

Patient set up according to 3D CT based treatment plan

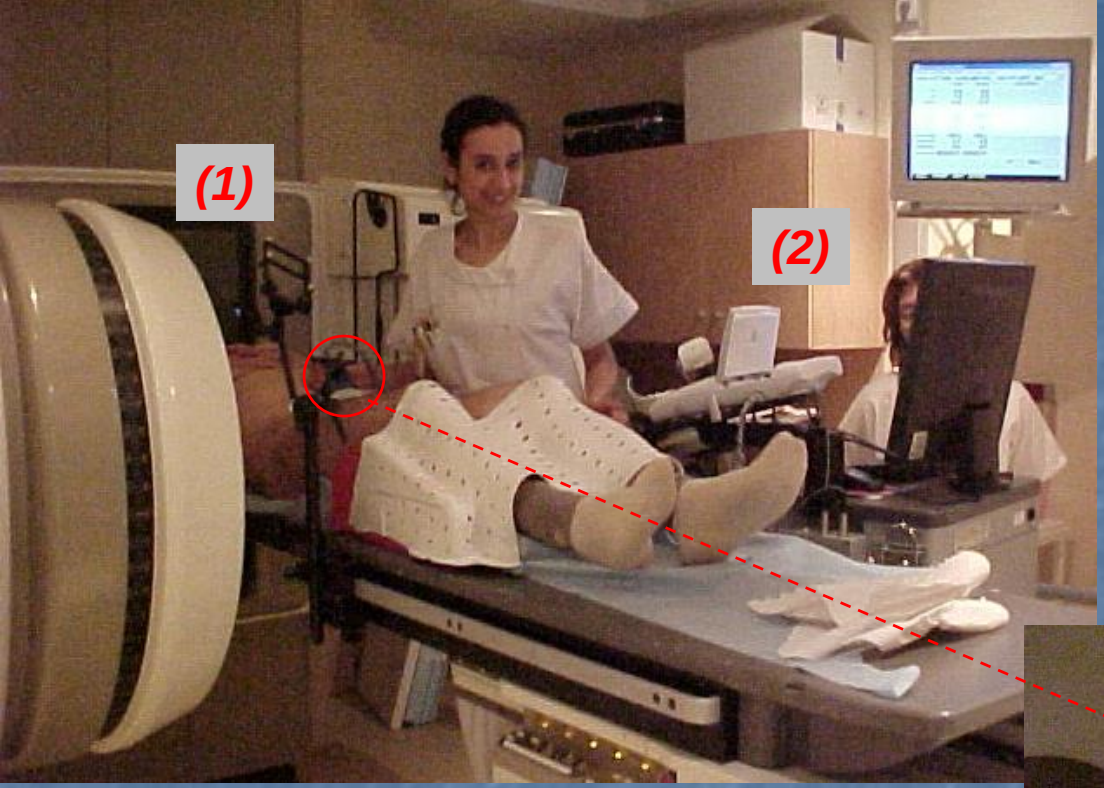
Acquisition of spatially localized 3D-ultrasound images

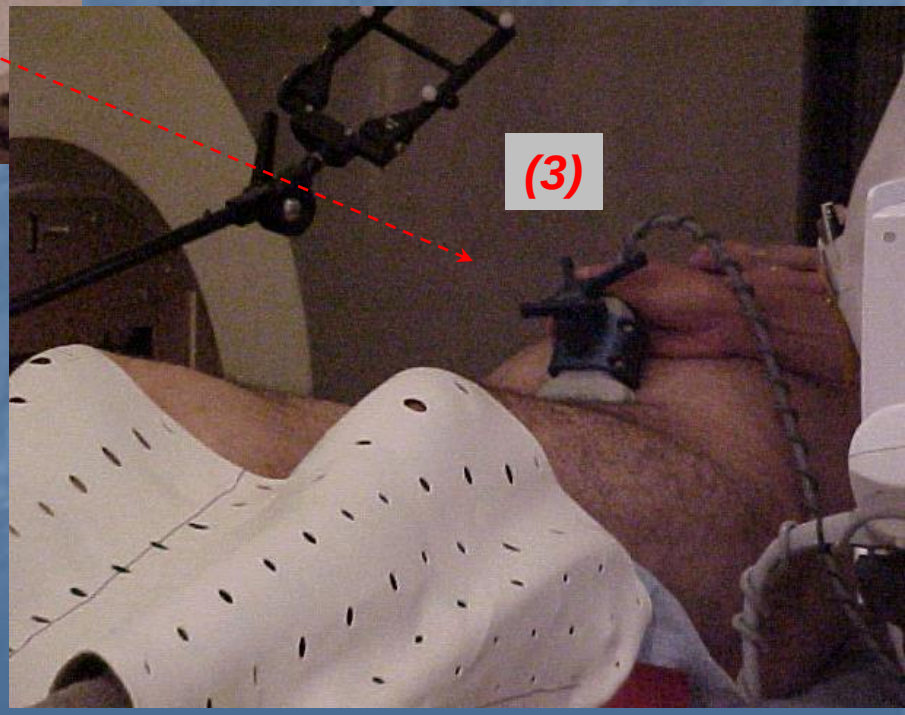
Target matching on CT and US images

Calculation of target coordinates in the treatment room

Set up target at linac isocenter

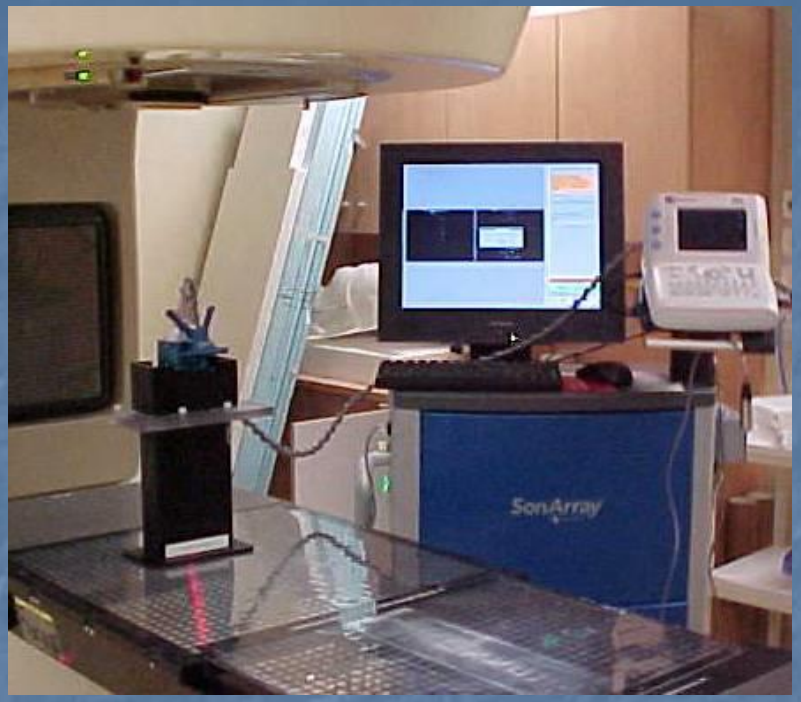
Treatment delivery





1 : **Fiducial array connected to treatment couch.**
2 : Computer .
3 : US probe equiped with fiducial array .
4 : Infrared camera detects active and passive fiducials

Gantry mounted Isocenter calibration jig



US probe calibration phantom

Results in Dijon:

Transabdomninal US imaging for prostate treatment

- 20 patients
- 2 excluded: poor quality US image
- Acquisition time : 2 min
- Results :mean dev ± SD (mm):
  - X = -0,3 ± 4,4
  - Y = -2,9 ± 4,7
  - Z = 4,1 ± 6,1

S.Payan and K. Peignaux- SFPM – 2003

Yes: I am able to take into account interfraction mtion of the target volume

and even

In the future

Image guided radiotherapy

- Elekta Synergy : linac + on board imaging system
- Varian Trilogy : linac +on board imaging system
- Siemens Primatron : Primus + Somatom sliding gantry CT scan)

Goal

- Set up adjustment
- Target Tracking
  - **Using**
- « On board or in room » KV volume imaging
- Volumetric imaging matching

On board imaging

Radiographic mode: KV- KV

Goal

Interfraction Motion

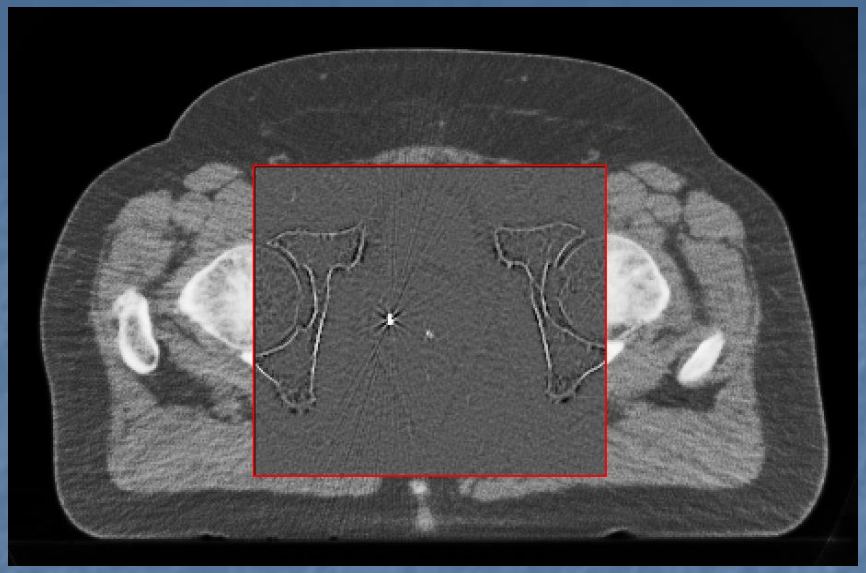
- setup KV images in the treatment room,
- Compare current images to reference images

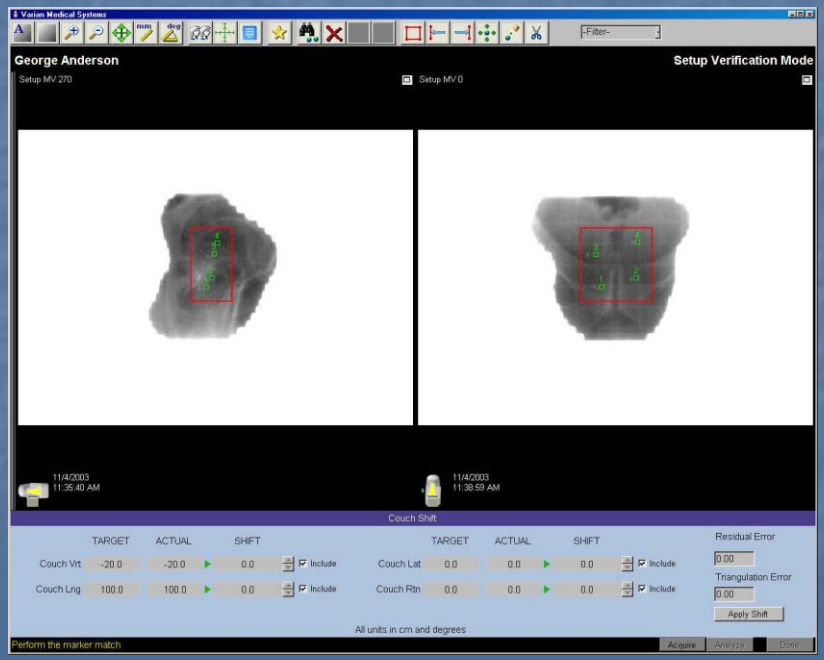
Marker Matching Mode

Goal

Interfraction Motion

- Compare current marker seeds to reference marker seeds
- Calculate couch motion required to correct setup



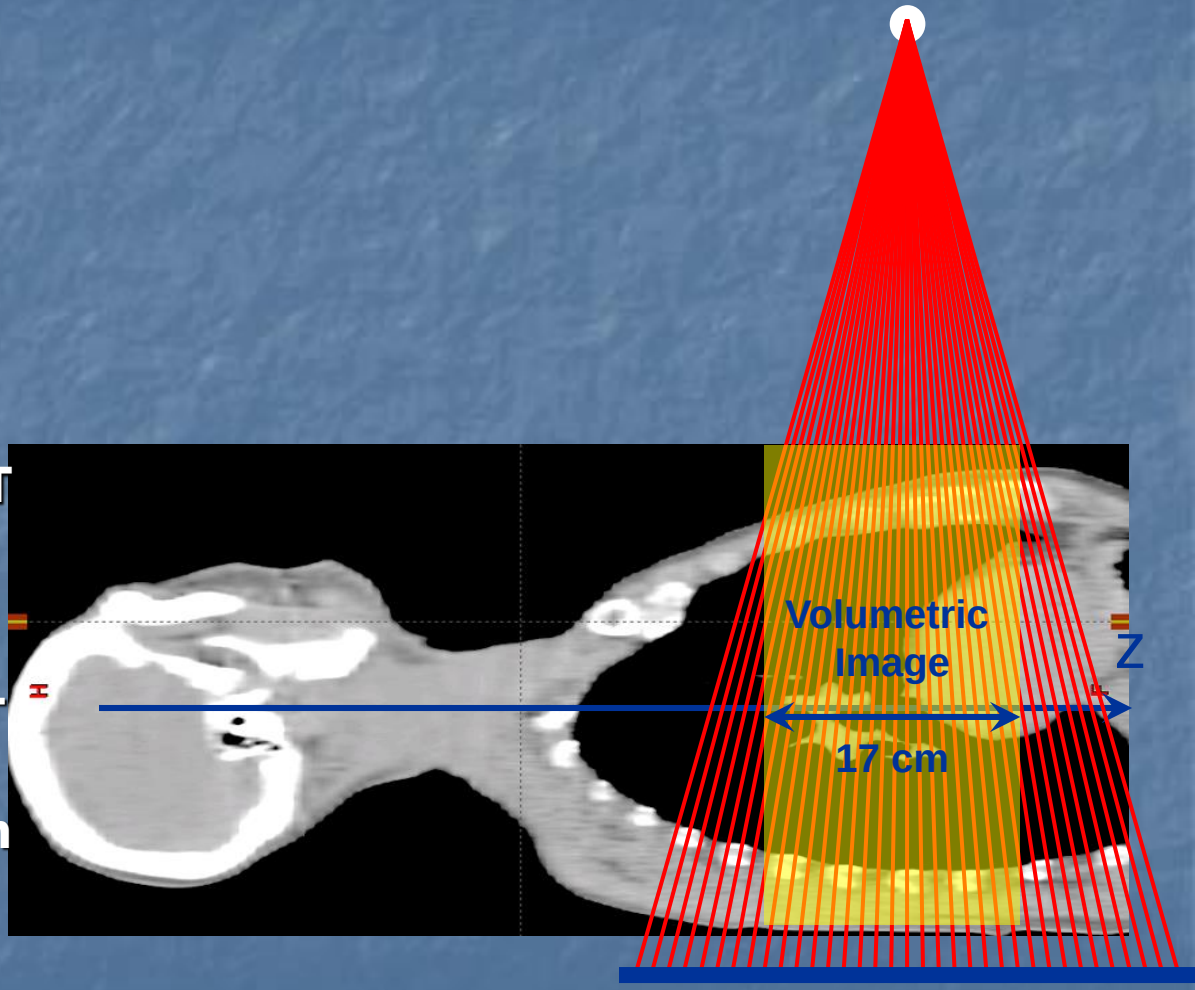


Cone Beam CT Mode –

Goal

Interfraction Motion

- **Remotely acquire CBCT**
  - **Complete reconstruction**
- **Compare current CT images to reference CT images**
- **Calculate couch motion required to correct setup**



Cone Beam

FDA 510(k)

Yes: **I should even be able to track the target while the beam is on**

Then

Reduce margins and/or escalade dose ?

Plan to implement IMRT ?

Dont be scared :

KEEP ALERT!

Equipement QA
Immobilization
CT simulation
Treatment planning
Post planning verification
Patient setup, correction & verification
Treatment delivery
Quality assurance


THANK YOU FOR YOUR
ATTENTION