# The benefits of delivering SABR using Varian TrueBeam & FFF

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NHS Greater Glasgow

Operating:

- 7 Varian Clinacs (C/D, eX & iX)
- 3 Varian TrueBeams
- 2 Varian TrueBeam STx

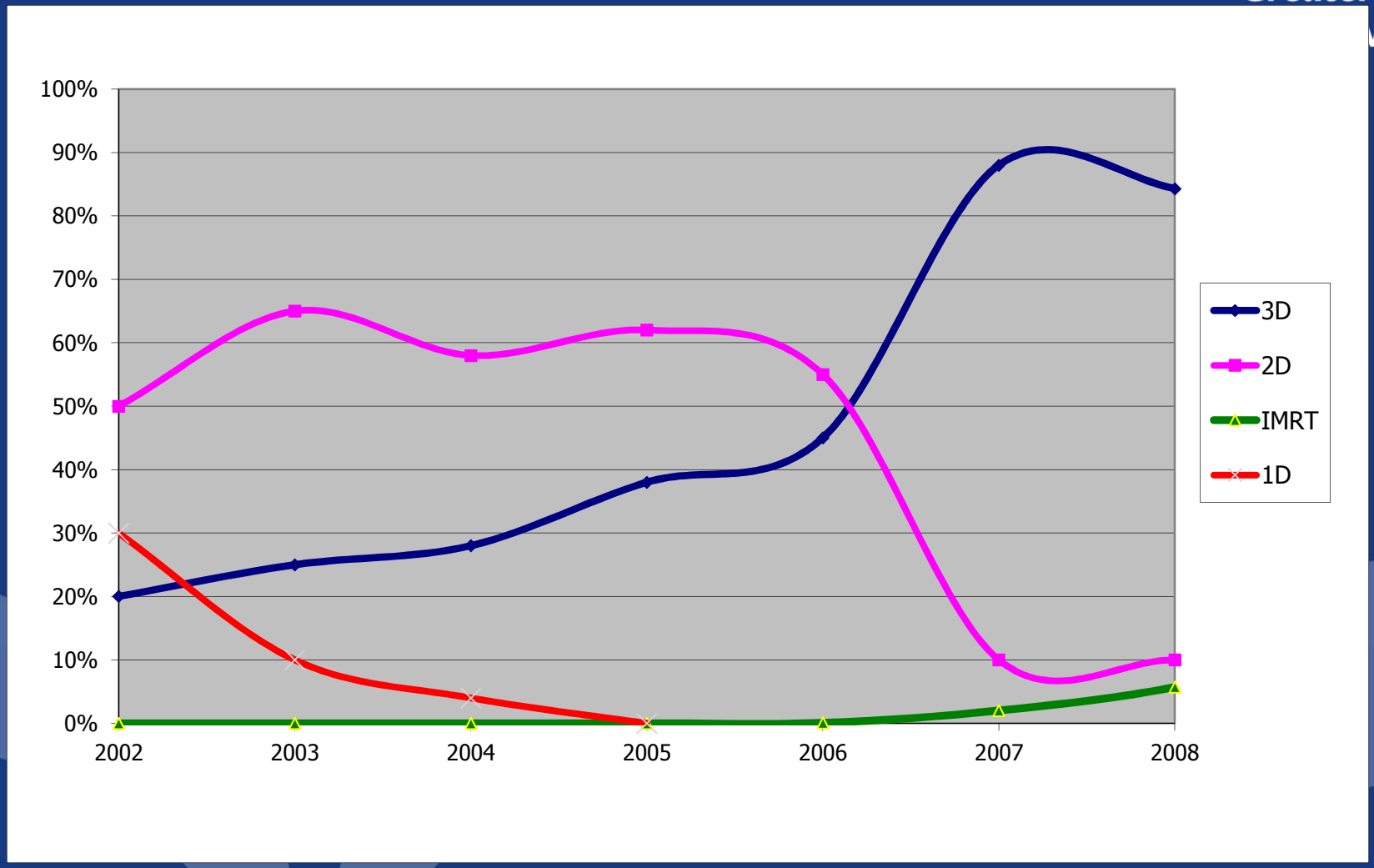
- 8xIGRT & 8xRapidArc capable
- All TrueBeams have FFF mode
- Approx 50 Eclipse workstations & FAS calculation servers

May 16

New Satellite Facility in Lanarkshire (2 bunkers & CT/planning)

- 6 TrueBeam & 2 STx
- Providing 8xFFF capable linacs & 10 RA linacs
- 4 Calypso systems

# Radical Practice - 2008



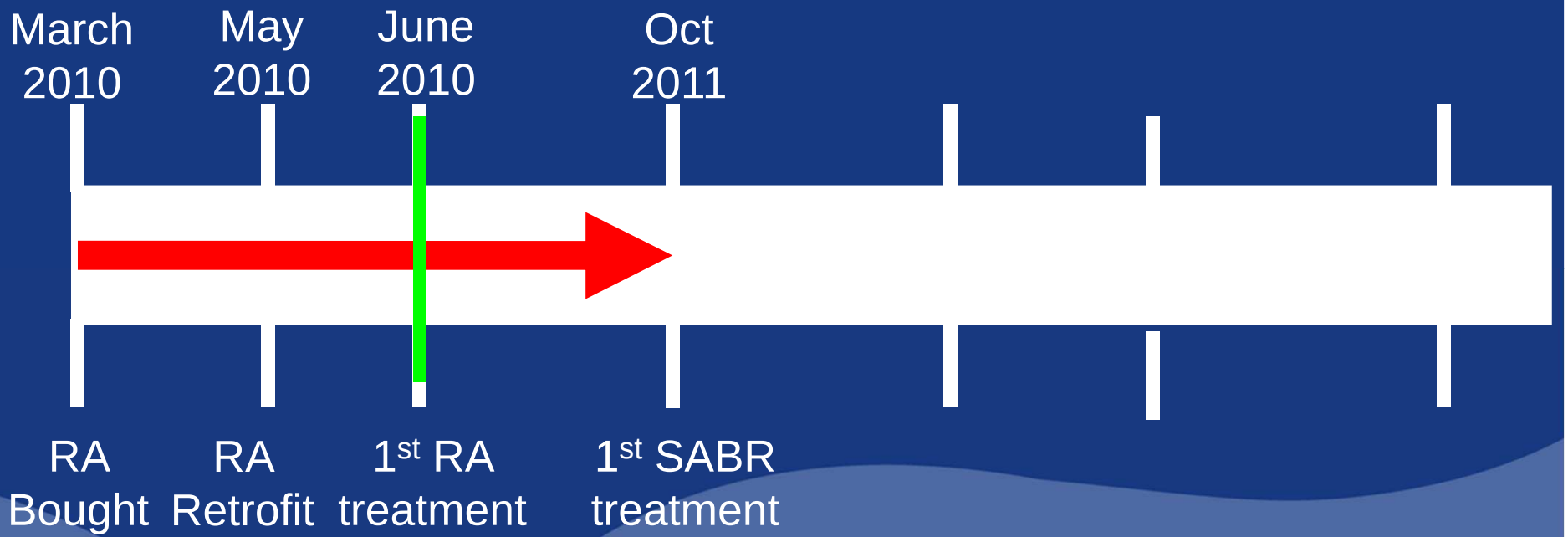
# Current Practice (2015)

- Treated >5,000 RapidArc patients, across 20+ clinical sites with c.250 RA plans per month
- Offer adaptive planning for H&N, lung & gynaecological sites
- Offer SABR:
  - Lung
  - Prostate
  - Gynaecological
  - Accredited for COMET

Treated over 300 SABR patients since 2010

- >250 patients treated using FFF

# Timeline

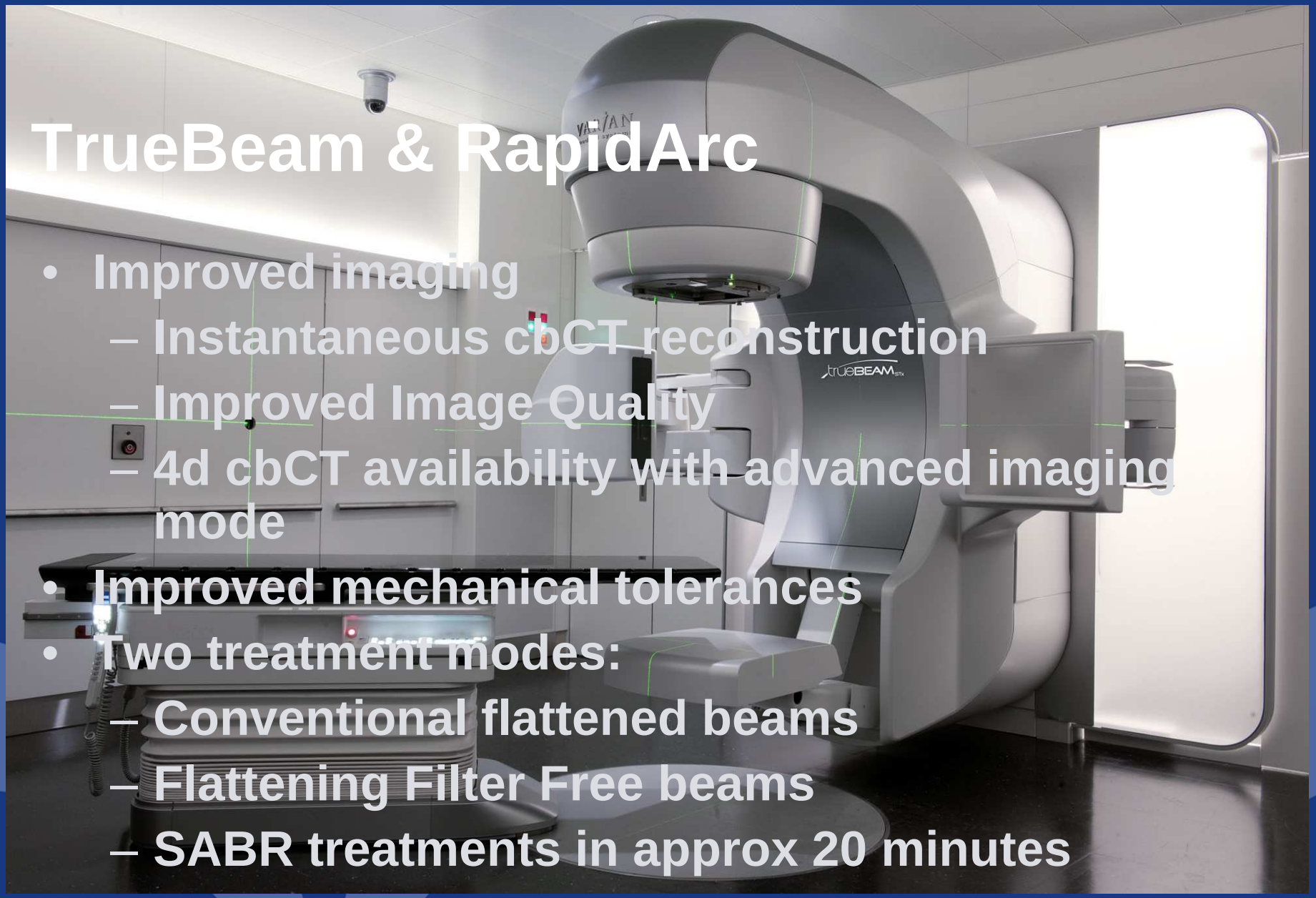

March 2010
May 2010
June 2010
Oct 2011
RA Bought
RA Retrofit
1st RA treatment
1st SABR treatment

# SABR....How do we increase capacity & improve quality....?

# Challenges & Solutions (2011)

- Two Clinacs with RapidArc capability
  - Capacity issues & waiting time requirement
  - Competing clinical demands
  - Time to image & treat SABR was a perceived barrier
    - Limited to 4 SABR patients per month
    - Upwards of 40 minutes for RapidArc Lung SABR
    - Booking issues and ‘wasted’ slots
    - cf H&N RapidArc in 10 mins
- Linac & TPS Procurement
  - 1 TrueBeam STx
  - 2 TrueBeams
  - 1 Additional RapidArc Retrofit
- Requirement to Commission Additional Functionality

# TrueBeam & RapidArc



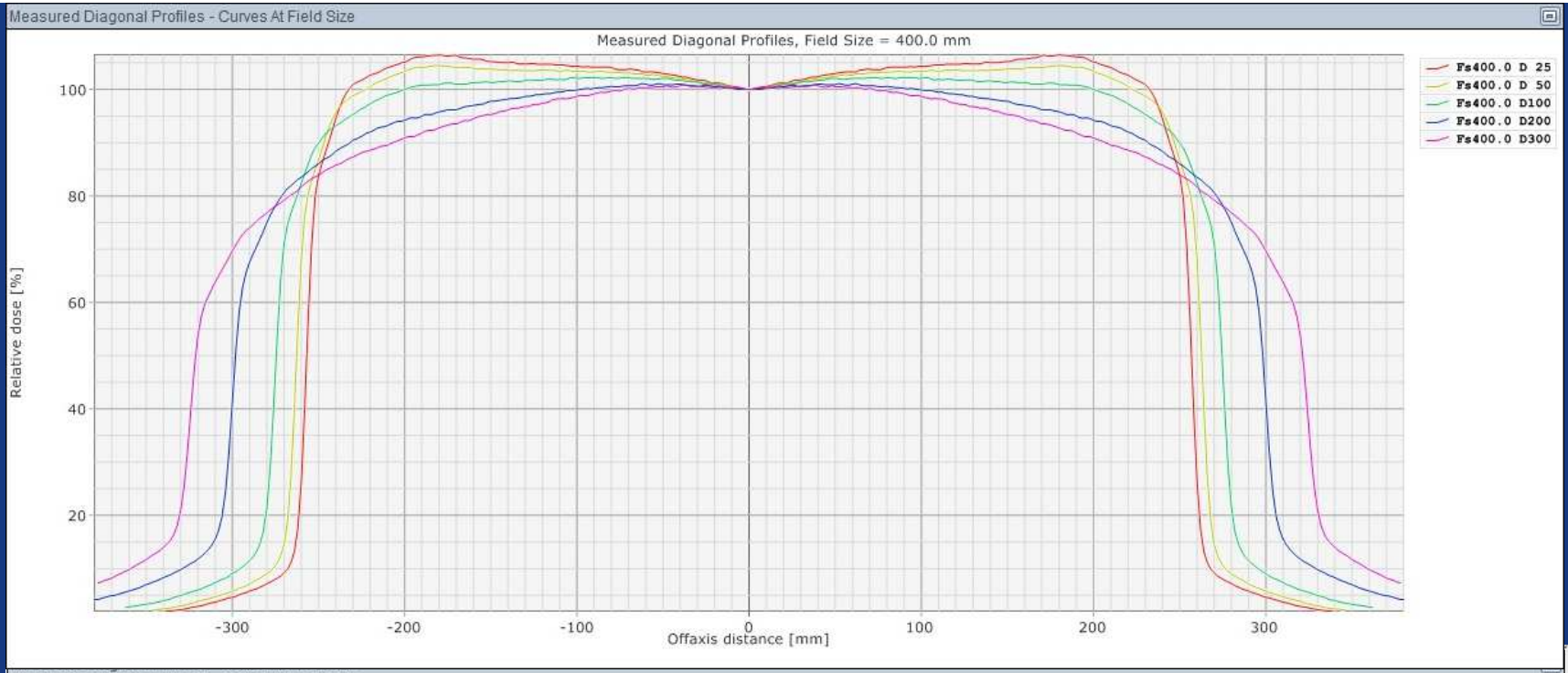

- Improved imaging
  - Instantaneous cbCT reconstruction
  - Improved Image Quality
  - 4d cbCT availability with advanced imaging mode
- Improved mechanical tolerances
- Two treatment modes:
  - Conventional flattened beams
  - Flattening Filter Free beams
  - SABR treatments in approx 20 minutes

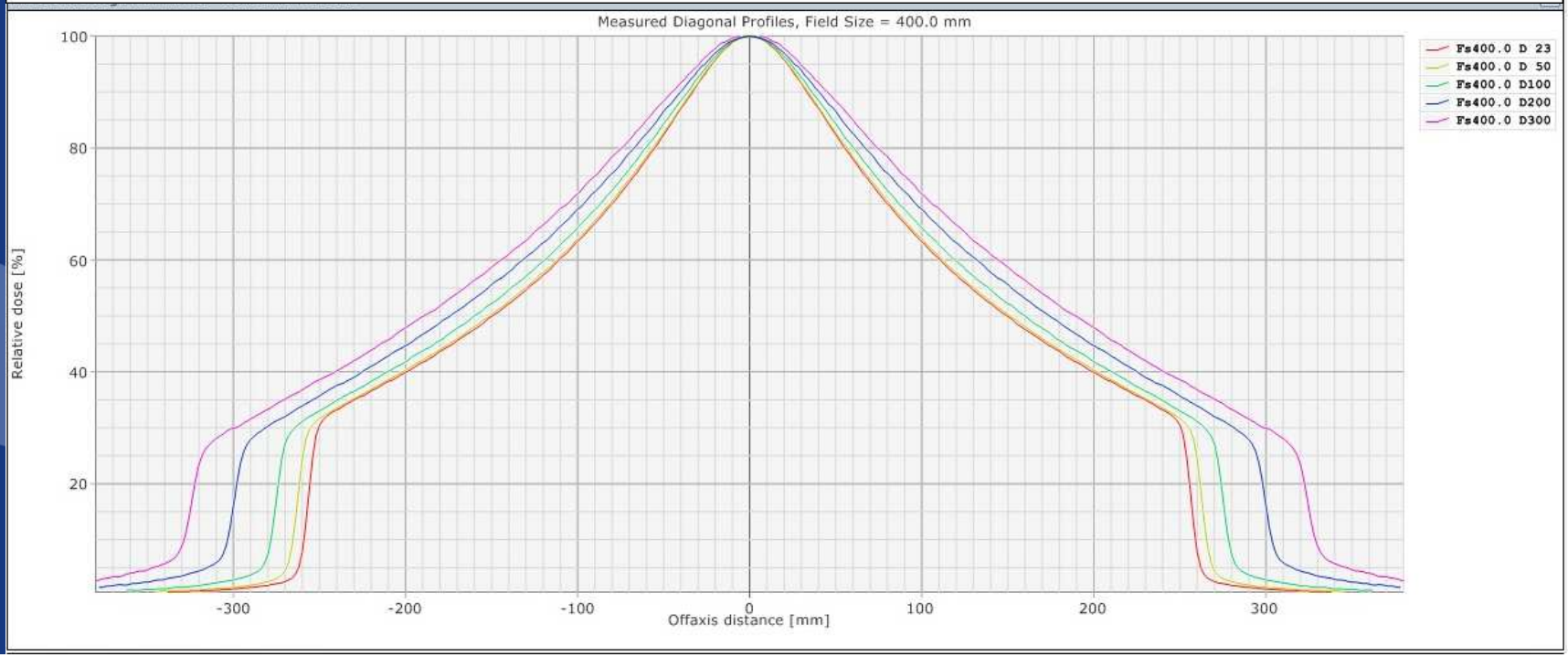
# TrueBeam


- MLC type
  - STx comes with a High definition MLC
  - Standard Model with Millennium 120 MLC
- Has RapidArc Capability
  - Variable Gantry Speed, DoseRate and MLC movement
  - Has the facility to gate RapidArc plans
- Integrated system
- Jaw tracking

# Flattening Filter Free Mode

- Conventional linac use filters to give a flat beam at depth
- RapidArc modulates the MLC to give a peaked beam

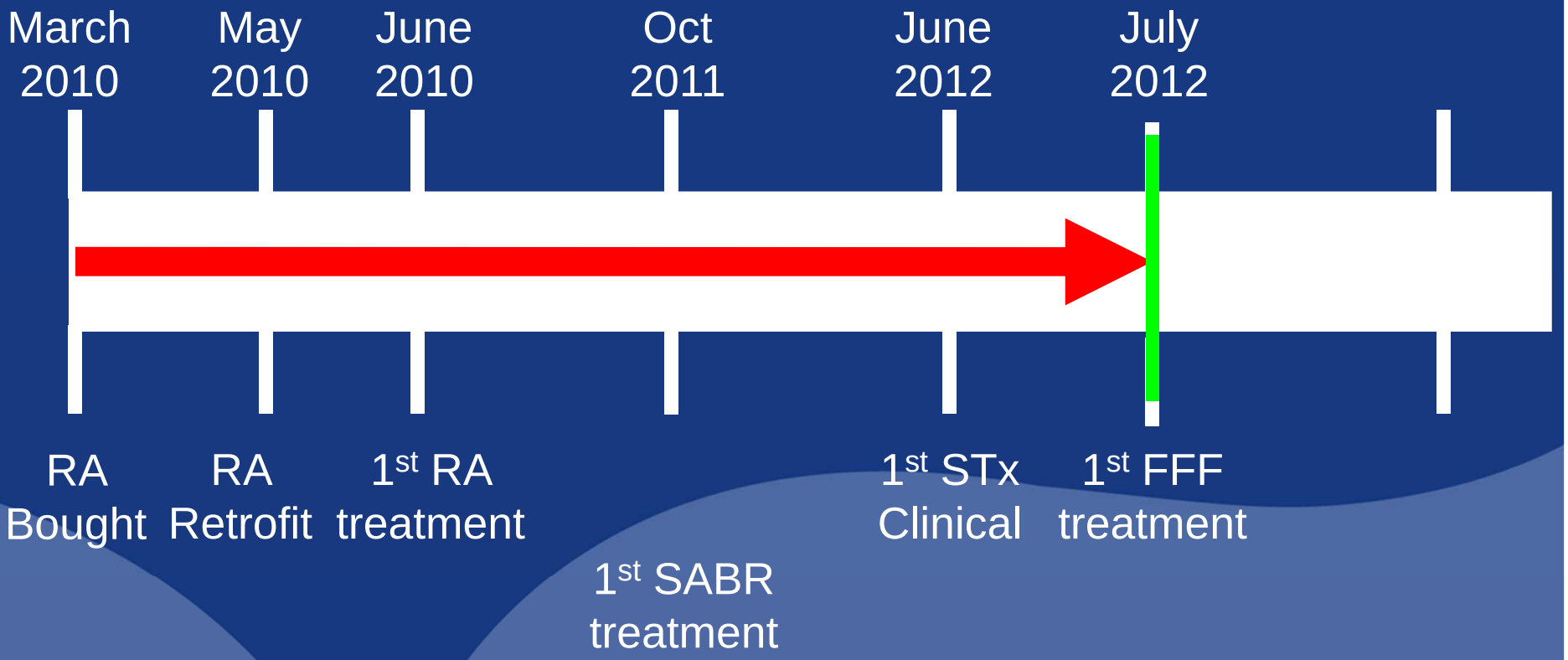

Measured Diagonal Profiles - Curves At Field Size
Measured Diagonal Profiles, Field Size = 400.0 mm
Relative dose [%]
Offaxis distance [mm]
Fs400.0 D 25
Fs400.0 D 50
Fs400.0 D100
Fs400.0 D200
Fs400.0 D300

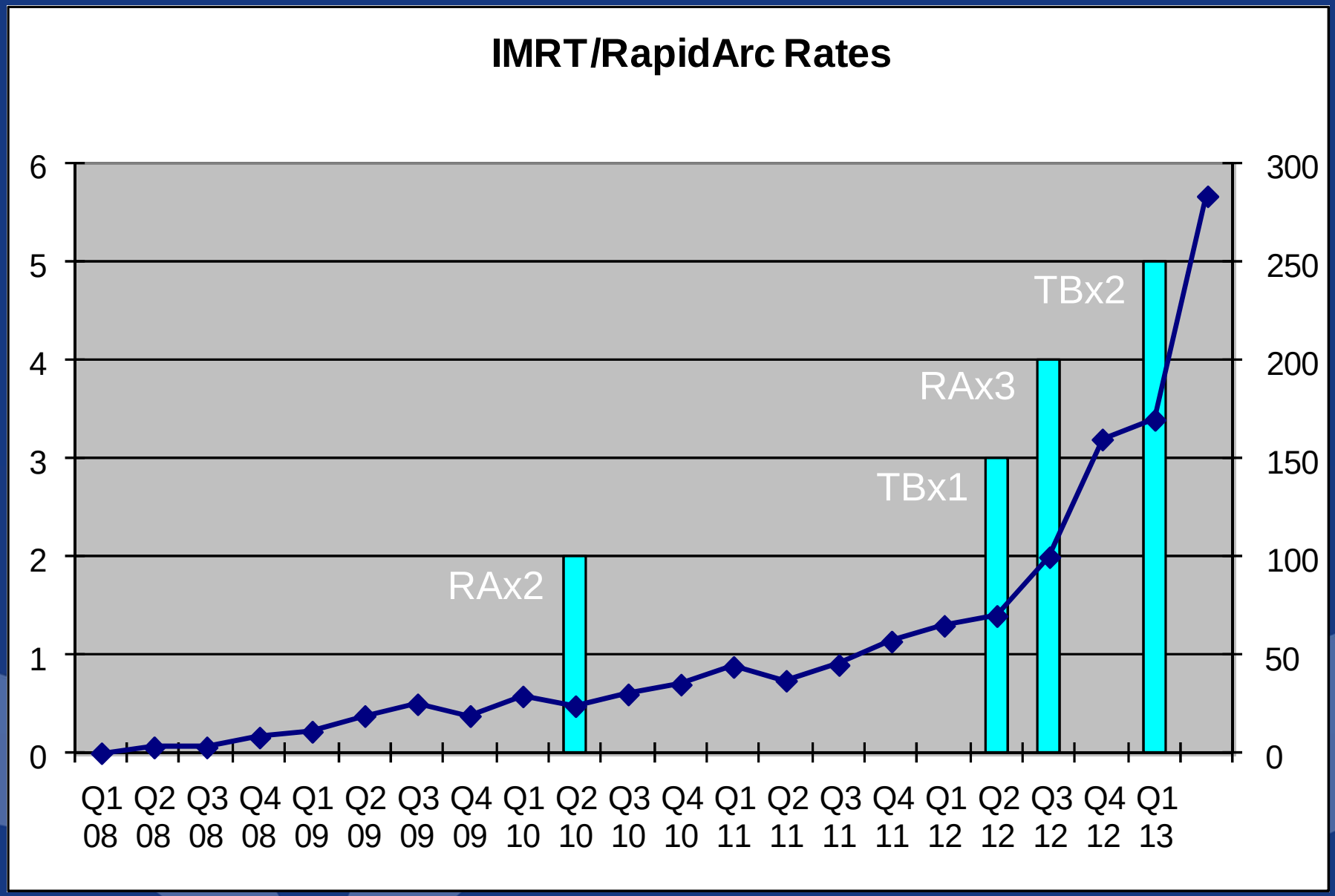

Measured Diagonal Profiles, Field Size = 400.0 mm
Relative dose [%]
Offaxis distance [mm]
Fs400.0 D 23
Fs400.0 D 50
Fs400.0 D100
Fs400.0 D200
Fs400.0 D300

# Flattening Filter Free Mode

- Conventional linac use filters to give a flat beam at depth
- RapidArc modulates the MLC to give a peaked beam
- Removing the flattening filter:
  - Reduced the requirement to modulate the beam
  - Increases dose rate by up to a factor of 4
  - Improved deliver time up to 5 times faster
  - SABR delivery: 11 Gy in 2 minutes
  - Reduced head scatter- reducing the out of field dose
  - Takes advantage of the beams natural fall off
- Selected to use 10FFF @ 24 Gy/min

# Timeline


March 2010
May 2010
June 2010
Oct 2011
June 2012
July 2012
RA Bought
RA Retrofit
1st RA treatment
1st SABR treatment
1st STx Clinical
1st FFF treatment


IMRT/RapidArc Rates
6
5
4
3
2
1
0
300
250
200
150
100
50
0
TBx2
RAx3
TBx1
RAx2
Q1 08
Q2 08
Q3 08
Q4 08
Q1 09
Q2 09
Q3 09
Q4 09
Q1 10
Q2 10
Q3 10
Q4 10
Q1 11
Q2 11
Q3 11
Q4 11
Q1 12
Q2 12
Q3 12
Q4 12
Q1 13

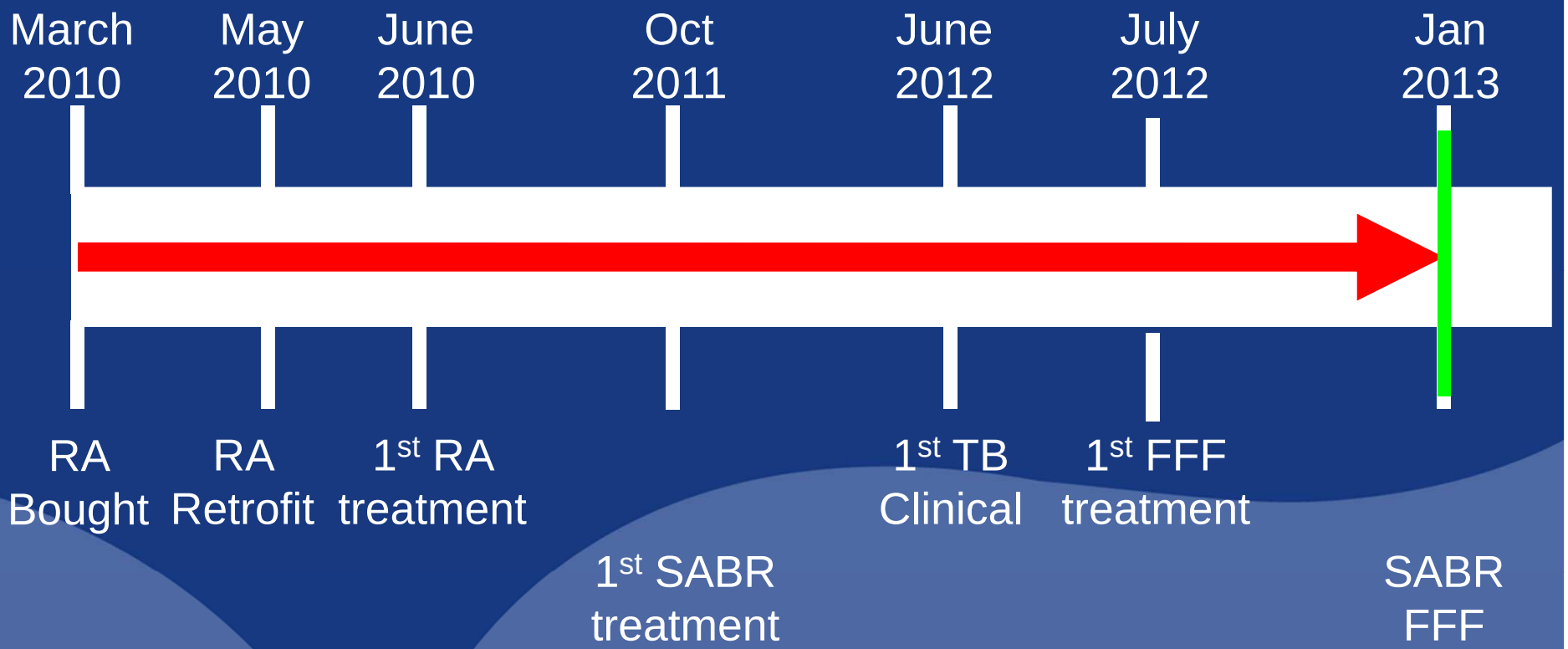
# Challenges (2012)

- Single STx
  - Two differing energies
  - Differing MLC's
  - Back-up plan required
- Resourcing Dual SABR Planning
- Calculation times
  - Version of RapidArc (8.6) not ideal for Lung planning
  - Differences in PRO and AAA
  - Two days of a senior physicist time per plan
  - Two plans per patient

# Solutions (2013)

- Training Program for Physics Staff
  - Test plans used for training
  - Experience in SABR planning developed
- ARIA upgraded to version 10.0.28
- New software accounts for the difference of PRO & AAA
  - Less repeat iterations
- New algorithm offers faster inverse calculation times
- Procurement of a 2nd STx 2013
- Procurement of  FAS (framework application servers)
  - Distributed dose calculations
  - RapidArc calc times of 1 min for simple site
  - SABR calc times of 5 mins

# Timeline

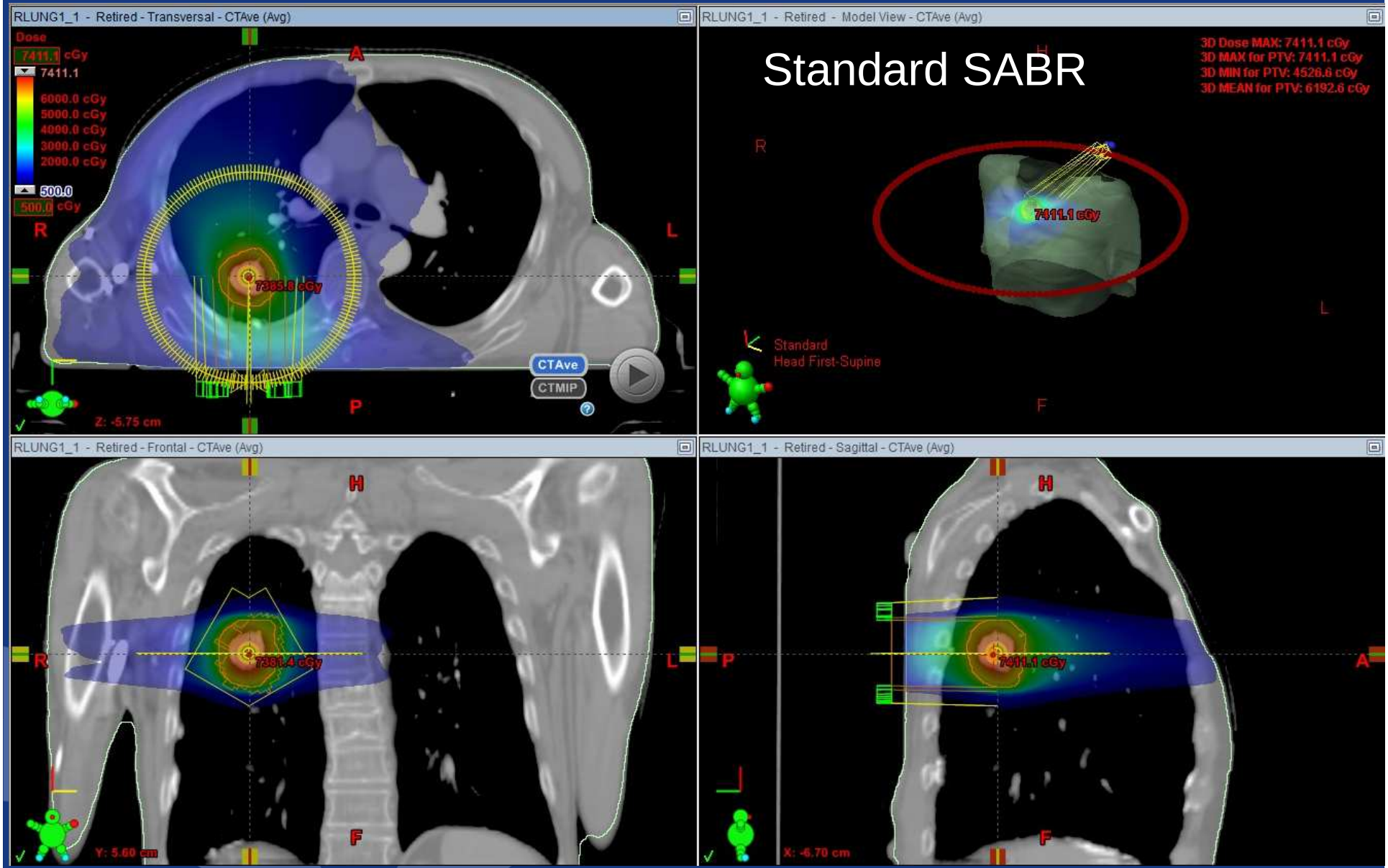

March 2010
May 2010
June 2010
Oct 2011
June 2012
July 2012
Jan 2013
RA Bought
RA Retrofit
1st RA treatment
1st SABR treatment
1st TB Clinical
1st FFF treatment
SABR FFF

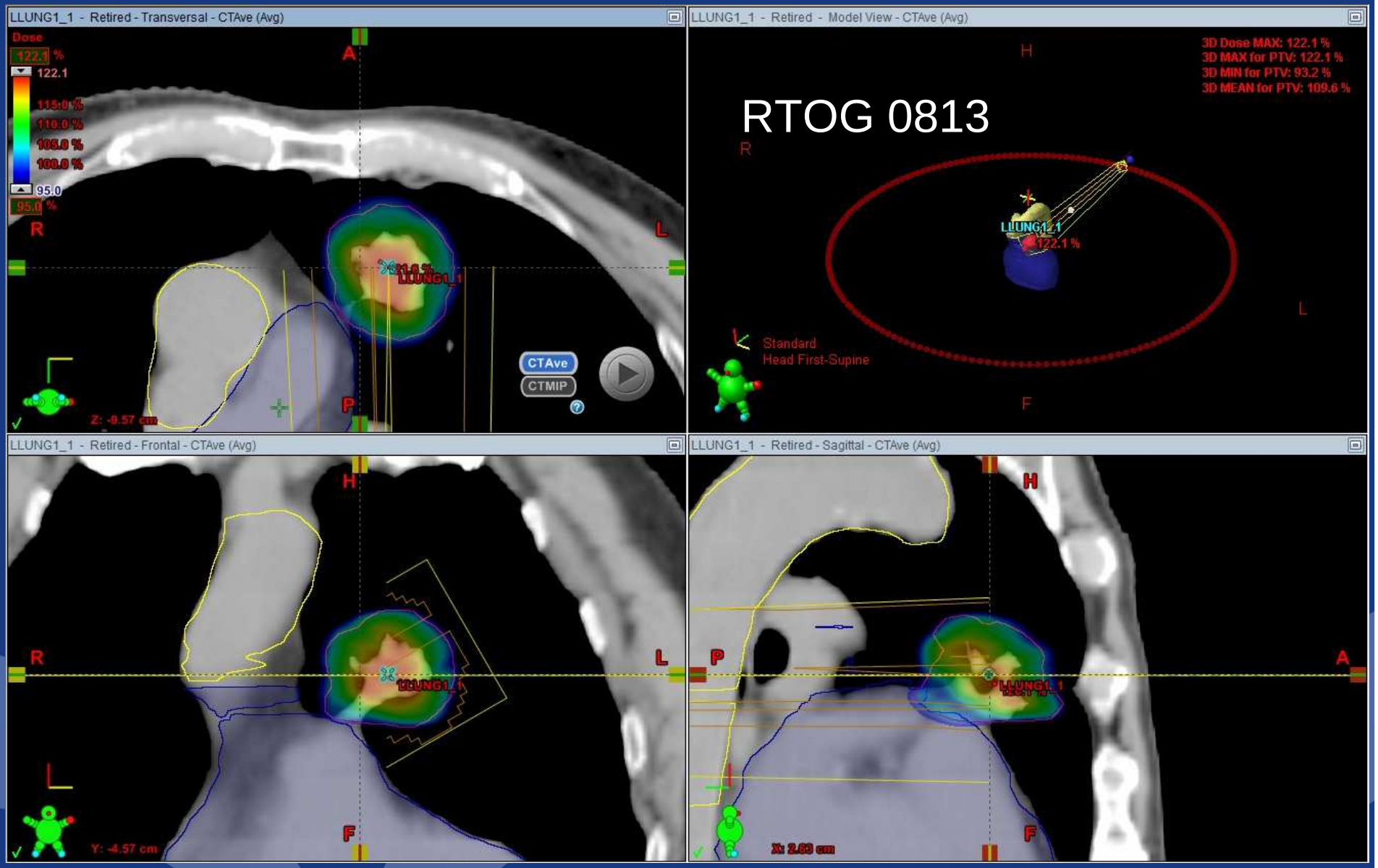
# Case 1: Lung SABR

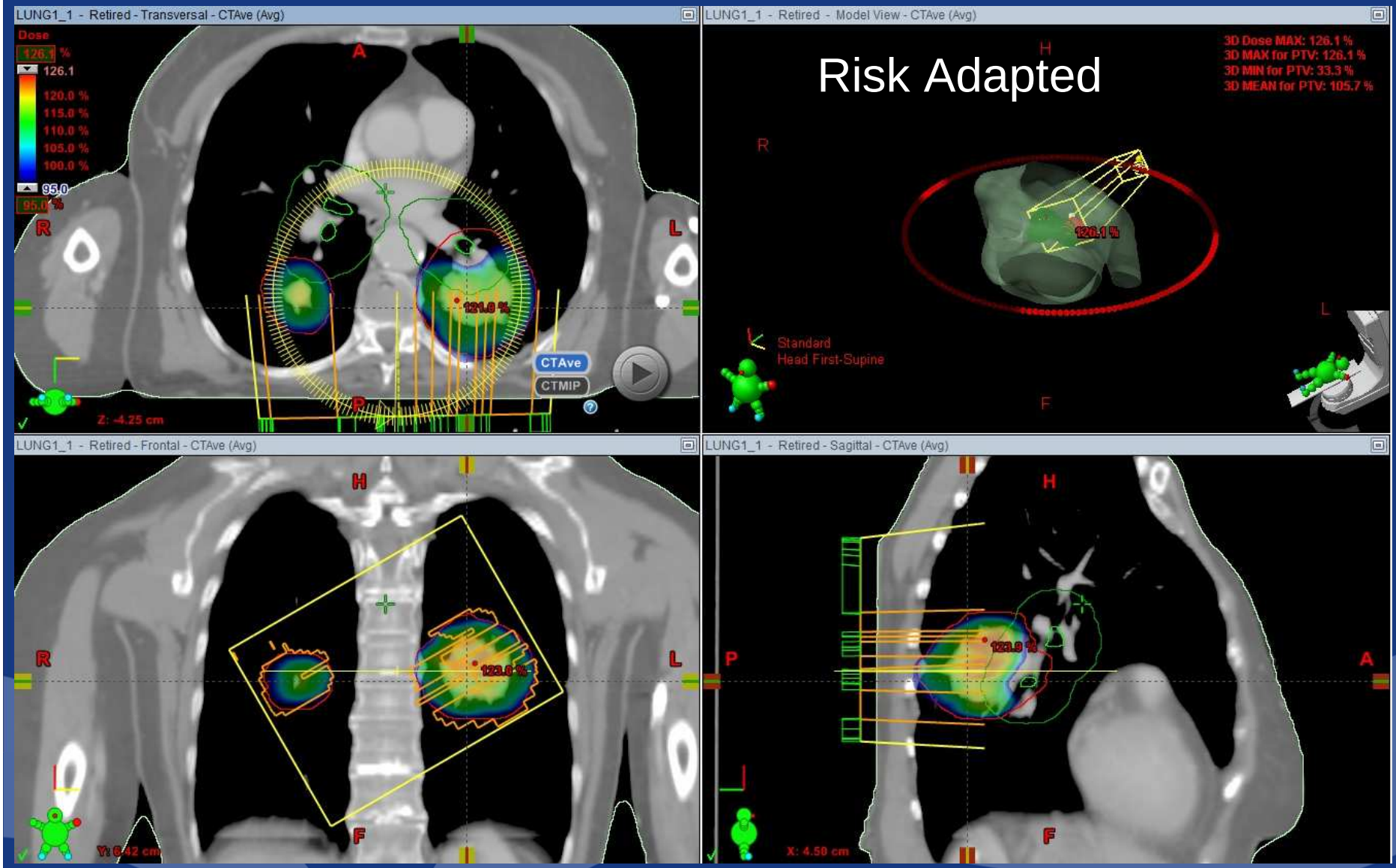
# Lung SABR: Plan Types

- Standard SABR:
  - Follow principles of ROSEL
  - 54Gy/3# for lowest risk patients
  - 55Gy/5# for tumours overlapping chest wall
  - GTV>5cm & PTV within 2cm of proximal bronchial tree are excluded
- Central lesion SABR:
  - Follow principles of RTOG 0813
  - PTV <163cc and central lesions
- Risk Adaptive SABR


RLUNG1_1 - Retired - Transversal - CTAve (Avg)
Dose
137.2 %
137.2
130.0 %
120.0 %
110.0 %
95.0
95.0 %
A
R
L
P
136.8 %
CTAve
CTMIP
Z: -5.75 cm
RLUNG1_1 - Retired - Model View - CTAve (Avg)
Standard SABR
3D Dose MAX: 137.2 %
3D MAX for PTV: 137.2 %
3D MIN for PTV: 83.8 %
3D MEAN for PTV: 114.7 %
H
R
137.2 %
L
Standard
Head First-Supine
F
RLUNG1_1 - Retired - Frontal - CTAve (Avg)
H
R
L
136.7 %
F
Y: 5.60 cm
RLUNG1_1 - Retired - Sagittal - CTAve (Avg)
H
P
A
137.2 %
F
X: -6.70 cm


RLUNG1_1 - Retired - Transversal - CTAve (Avg)
Dose
7411.1 cGy
7411.1
6000.0 cGy
5000.0 cGy
4000.0 cGy
3000.0 cGy
2000.0 cGy
500.0
500.0 cGy
A
R
L
P
7385.8 cGy
CTAve
CTMIP
Z: -5.75 cm
RLUNG1_1 - Retired - Model View - CTAve (Avg)
Standard SABR
3D Dose MAX: 7411.1 cGy
3D MAX for PTV: 7411.1 cGy
3D MIN for PTV: 4526.6 cGy
3D MEAN for PTV: 6192.6 cGy
R
7411.1 cGy
L
Standard
Head First-Supine
F
RLUNG1_1 - Retired - Frontal - CTAve (Avg)
H
R
L
7381.4 cGy
F
Y: 5.60 cm
RLUNG1_1 - Retired - Sagittal - CTAve (Avg)
H
P
A
7411.1 cGy
F
X: -6.70 cm


LLUNG1_1 - Retired - Transversal - CTAve (Avg)
Dose
122.1 %
122.1
115.0 %
110.0 %
105.0 %
100.0 %
95.0
95.0 %
A
R
L
P
LLUNG1_1
CTAve
CTMIP
Z: -9.57 cm
LLUNG1_1 - Retired - Model View - CTAve (Avg)
H
R
L
F
3D Dose MAX: 122.1 %
3D MAX for PTV: 122.1 %
3D MIN for PTV: 93.2 %
3D MEAN for PTV: 109.6 %
RTOG 0813
LLUNG1_1
122.1 %
Standard
Head First-Supine
LLUNG1_1 - Retired - Frontal - CTAve (Avg)
H
R
L
F
LLUNG1_1
Y: -4.57 cm
LLUNG1_1 - Retired - Sagittal - CTAve (Avg)
H
P
A
F
LLUNG1_1
X: 2.69 cm


LUNG1_1 - Retired - Transversal - CTAve (Avg)
Dose
126.1 %
126.1
120.0 %
115.0 %
110.0 %
105.0 %
100.0 %
95.0
95.0 %
A
R
L
P
121.8 %
CTAve
CTMIP
Z: -4.25 cm
LUNG1_1 - Retired - Model View - CTAve (Avg)
Risk Adapted
3D Dose MAX: 126.1 %
3D MAX for PTV: 126.1 %
3D MIN for PTV: 33.3 %
3D MEAN for PTV: 105.7 %
H
R
126.1 %
Standard
Head First-Supine
L
F
LUNG1_1 - Retired - Frontal - CTAve (Avg)
H
R
L
F
123.6 %
Y: 0.42 cm
LUNG1_1 - Retired - Sagittal - CTAve (Avg)
H
P
A
F
123.8 %
X: 4.50 cm

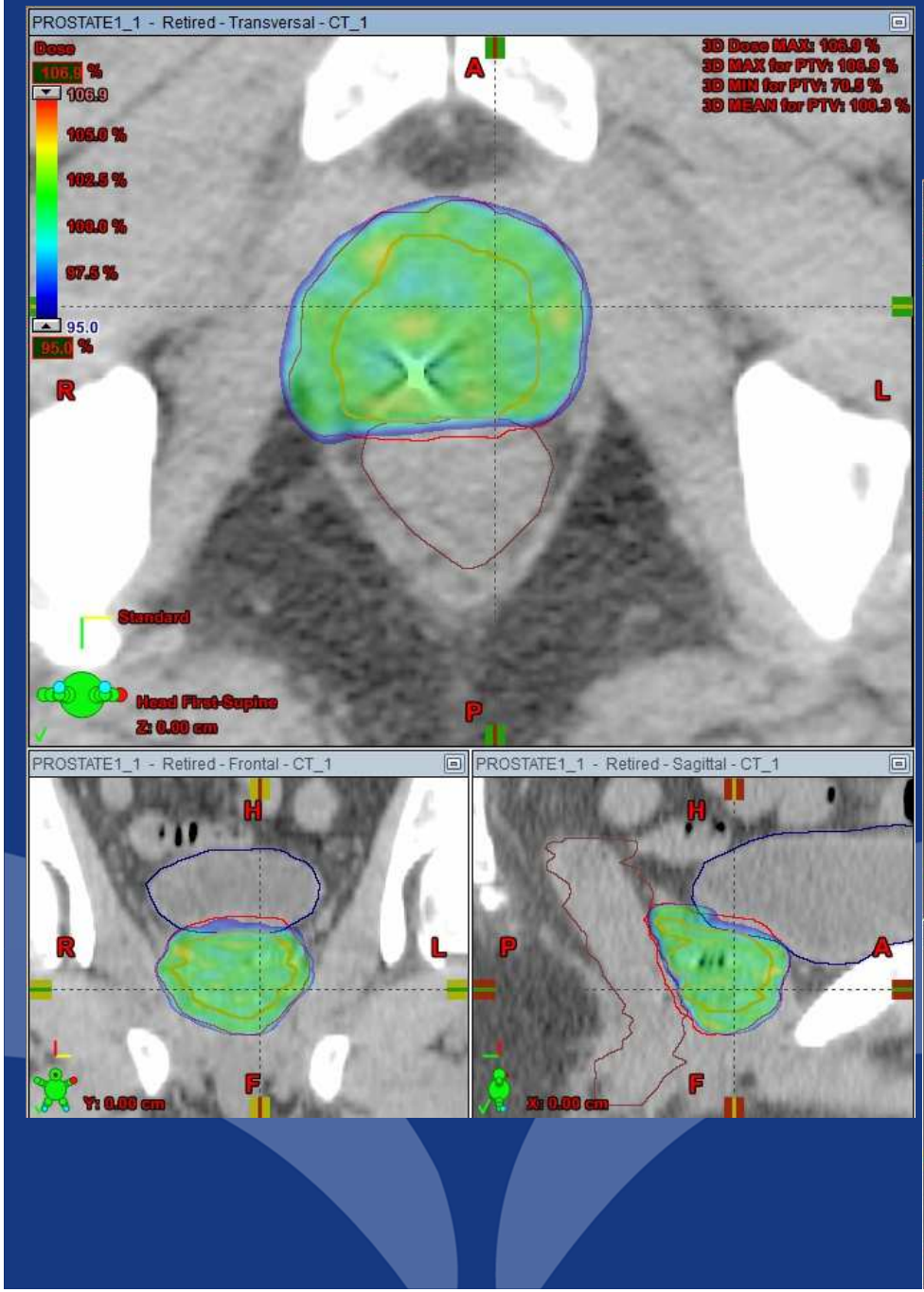
# Complex Planning Constraints

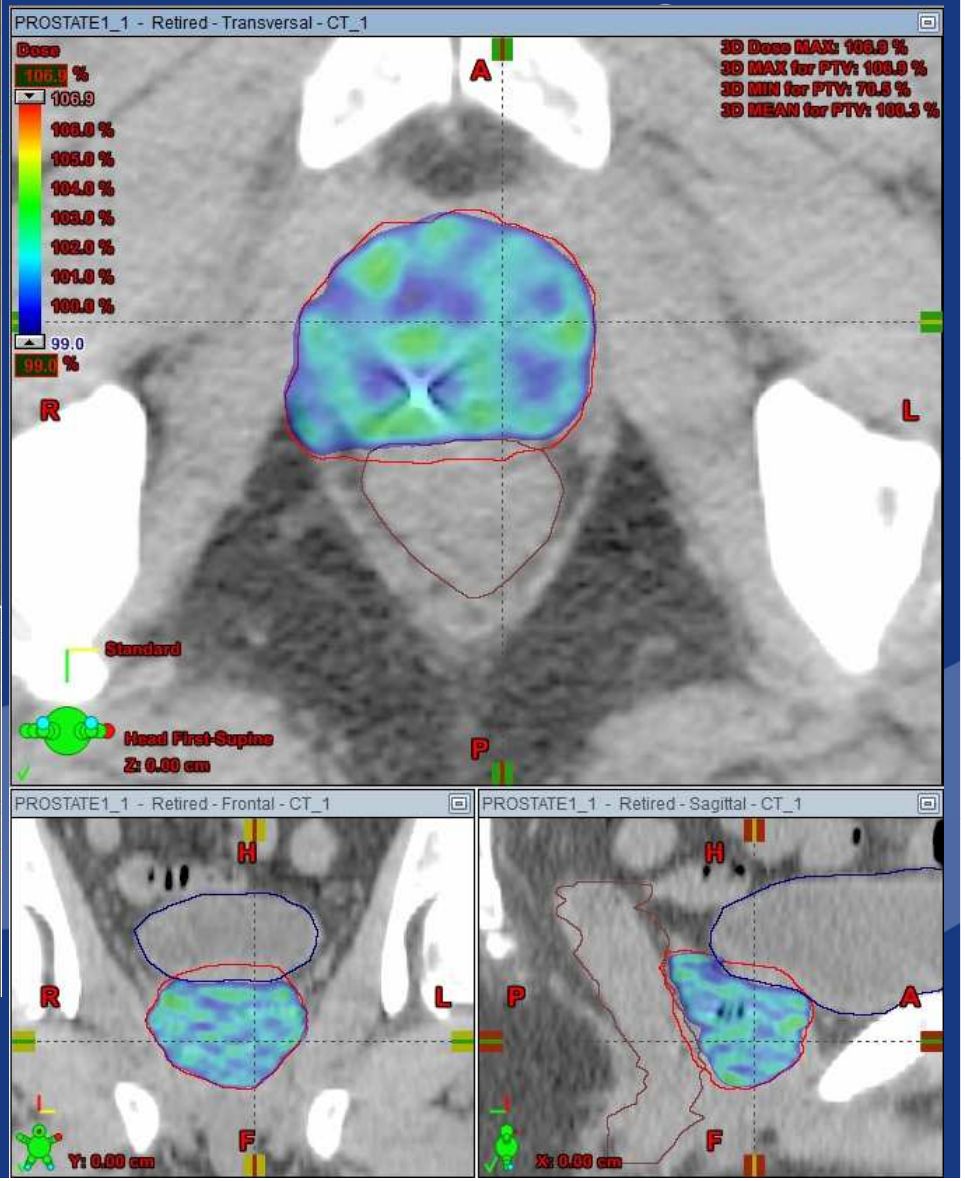
| OARs | Standard SABR | | | Central/Risk Adapted | | |
|---|---|---|---|---|---|---|
| | Constraint | Max Dose | Minor Deviation | Constraint | Limit | Max Dose |
| Cord | Max Pt | 25Gy | 25-28Gy | <0.25cc<br><0.5cc | 22.5Gy<br>13.5Gy | 30Gy |
| Oes | 1cc | 27Gy | 27-28.5Gy | <5cc | 27.5Gy | 105% of Px |
| Ipsilateral B Plexus | 1cc | 27Gy | 27-29Gy | <3cc | 30Gy | 32Gy |
| Heart | 1cc | 27Gy | 27-29Gy | <15cc | 32Gy | 105% of Px |
| Trachea & Bronchus | 1cc | 32Gy | 32-35Gy | <4cc | 18Gy | 105% of Px |
| Skin | 1cc | 24Gy | | <10cc | 30Gy | 32Gy |

# Case 2: Prostate SABR

# Phase 1 Clinical Trial (2014-15)

- Initially for 20 patients
- Increased to 40 cases
- 28 patients to date
- Px of 35Gy in 5#
- OAR constraints taken from Milan
- All plans have met dose constraints
- Fused MR & CT imaging
- Seeds matched
- cbCT before and after treatment
    - no requirement for mid treatment cbCT
    - 2 minute beam delivery with FFF


PROSTATE1_1 - Retired - Transversal - CT_1
Dose
106.9 %
106.9
105.0 %
102.5 %
100.0 %
97.5 %
95.0
95.0 %
3D Dose MAX: 106.9 %
3D MAX for PTV: 106.9 %
3D MIN for PTV: 78.5 %
3D MEAN for PTV: 100.3 %
A
R
L
P
Standard
Head First-Supine
Z: 0.00 cm
PROSTATE1_1 - Retired - Frontal - CT_1
H
R
L
F
Y: 0.00 cm
PROSTATE1_1 - Retired - Sagittal - CT_1
H
P
A
F
X: 0.00 cm


PROSTATE1_1 - Retired - Transversal - CT_1
Dose
106.9 %
106.9
105.0 %
104.0 %
103.0 %
102.0 %
101.0 %
100.0 %
99.0
99.0 %
3D Dose MAX: 106.9 %
3D MAX for PTV: 106.9 %
3D MIN for PTV: 78.5 %
3D MEAN for PTV: 100.3 %
A
R
L
P
Standard
Head First-Supine
Z: 0.00 cm
PROSTATE1_1 - Retired - Frontal - CT_1
H
R
L
F
Y: 0.00 cm
PROSTATE1_1 - Retired - Sagittal - CT_1
H
P
A
F
X: 0.00 cm

| NORMAL TISSUE DOSE CONSTRAINTS | |
|---|---|
| **Rectum** | |
| Dose [Gy] | Constraint[%] |
| V18 | 35 |
| V28 | 10 |
| V32 | 5 |
| V35 | 1 |
| **Bladder** | |
| V35 | 1 |
| **TARGET DOSE ACHIEVED** | |
| | Aim |
| GTV | V95%>99% |
| PTV | V95%>95% |
| PTV | 1cc<107% |

# Case 3: Gynaecological SABR

# Reasons for SABR

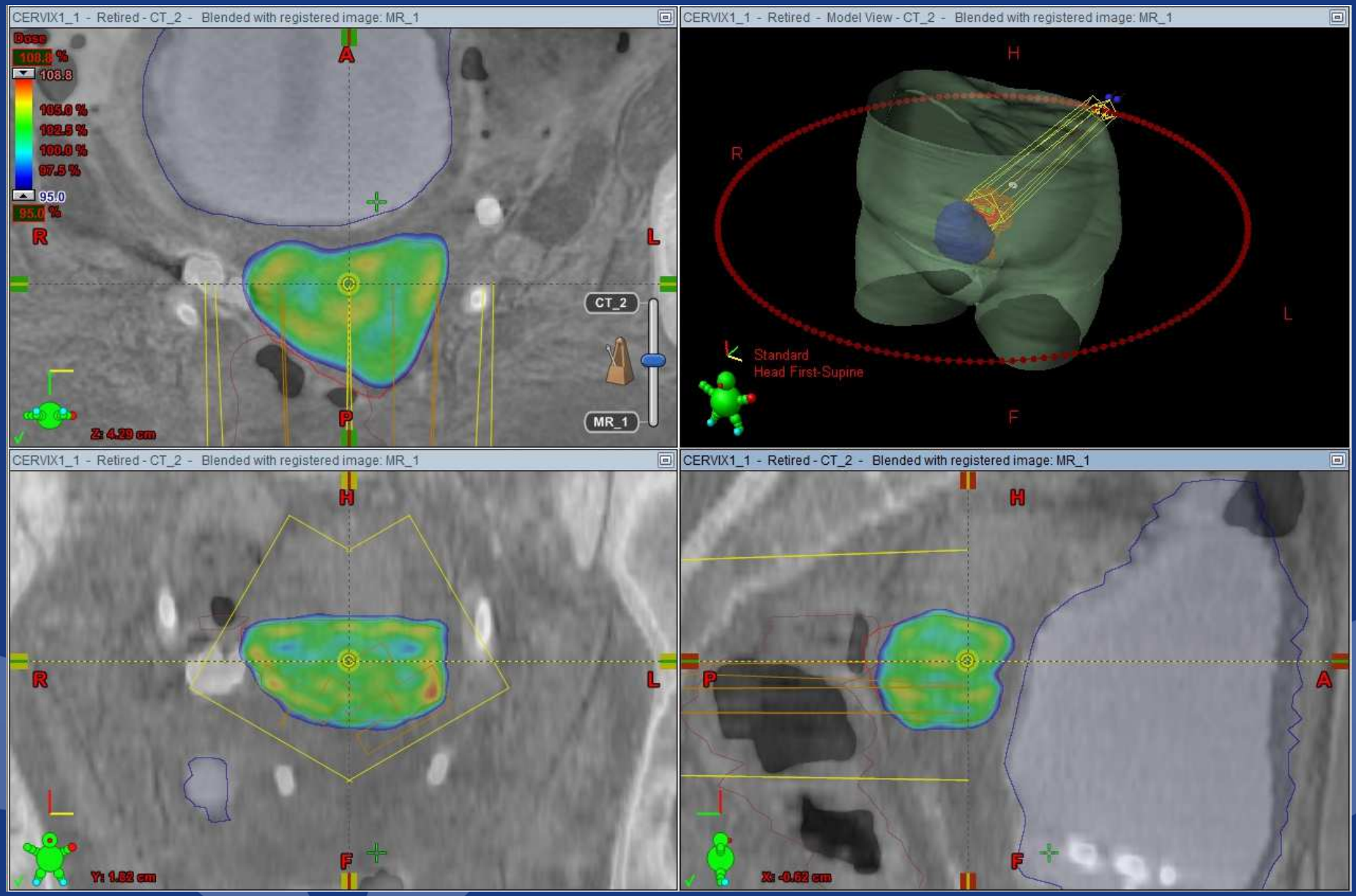
- Recurrence at tumour site
- Nodal Recurrence
- Patients not suitable for HDR

- Prescription dose?
- OAR constraints?

# Gyn SABR Case Study

- Recurrence at primary site limiting clinical options
- Patient had previous EBRT & HDR
- Patient did not tolerate previous Tx well

- Decision to use SABR
- 35 Gy in 5#
- COMET trial constraints
- Fused MR&CT
- Delivered on TrueBeam STx with 10FFF
- At 16 months, complete remission
- Patient tolerated treatment very well


CERVIX1_1 - Retired - CT_2 - Blended with registered image: MR_1
Dose
108.8 %
108.8
105.0 %
102.5 %
100.0 %
97.5 %
95.0
95.0 %
A
R
L
P
CT_2
MR_1
Z: 4.29 cm
CERVIX1_1 - Retired - Model View - CT_2 - Blended with registered image: MR_1
H
R
L
F
Standard
Head First-Supine
CERVIX1_1 - Retired - CT_2 - Blended with registered image: MR_1
H
R
L
F
Y: 1.82 cm
CERVIX1_1 - Retired - CT_2 - Blended with registered image: MR_1
H
P
A
F
X: -0.62 cm

# Challenges (2013-15)

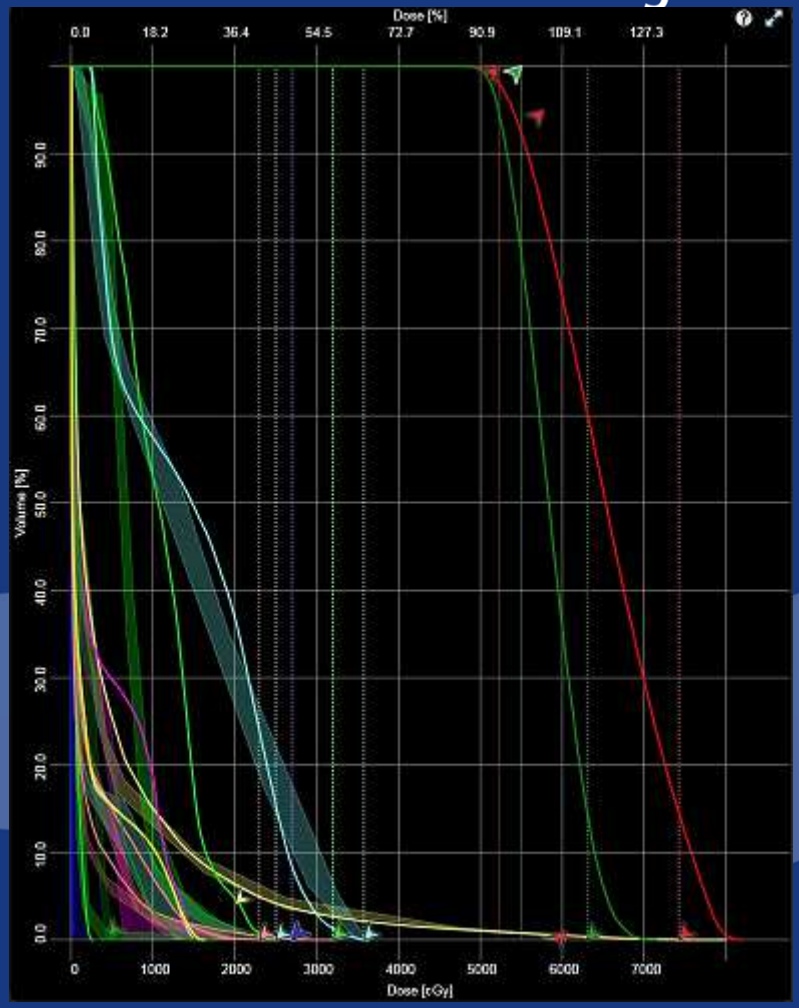
- Limitation is no longer linac based
- How do we increase the number of patients/sites?
  - Clinician time for voluming
  - Clinician time for online match approval
  - Complex planning, insufficient no. of senior staff
  - Machine time for Pre-Treatment IMRT QA

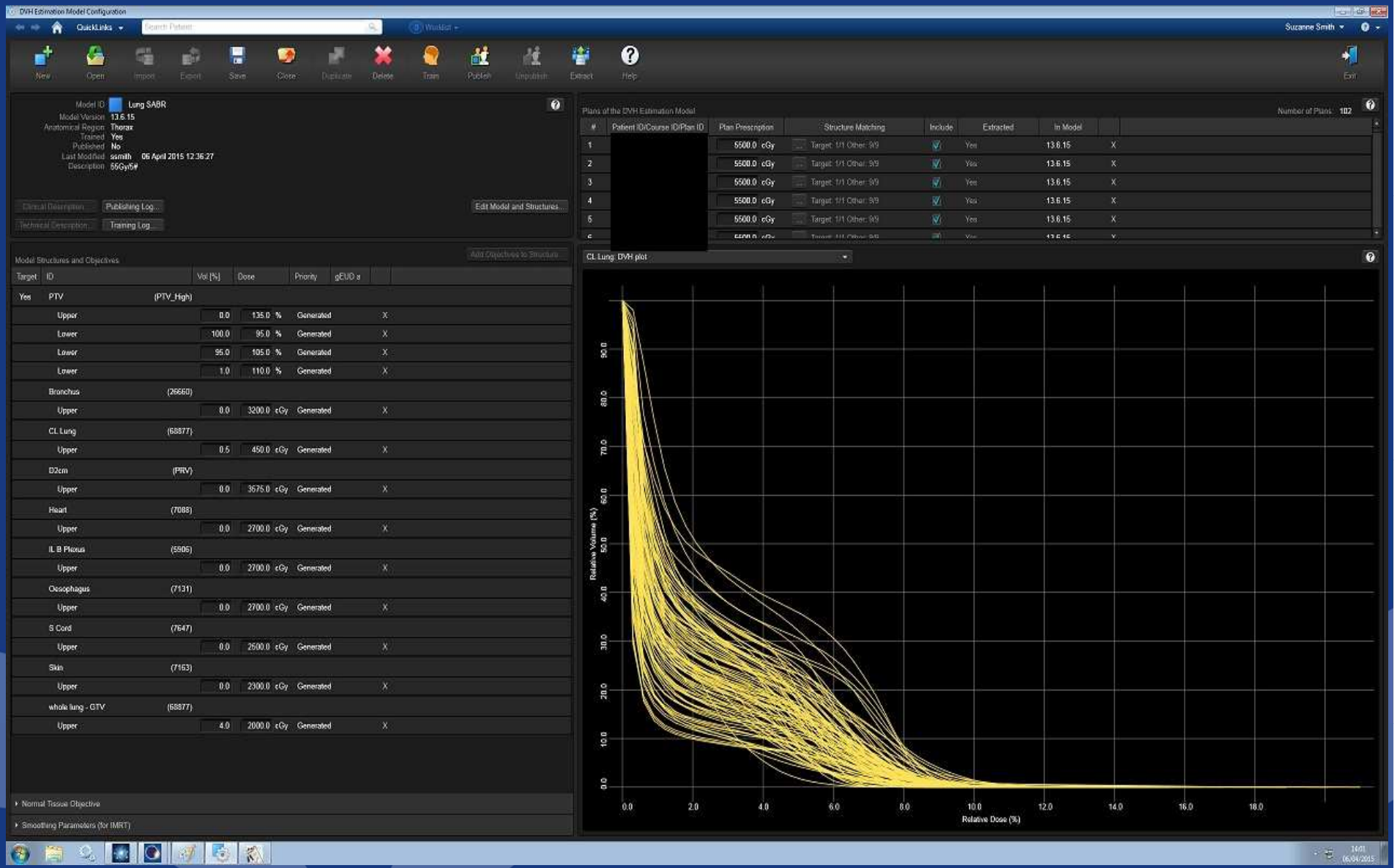
# Solutions (2013-15)

- Limitation is no longer linac based
- How do we increase the number of patients/sites?
  - Clinician time for voluming
  - Clinician time for online match approval
  - Complex planning, insufficient no. of senior staff
  - Machine time for Pre-Treatment IMRT QA
- OAR delineation by Physics and Radiography Staff
- Online matching & approval by Radiographers
- March 15
  - ARIA/Eclipse 13.6 (new PO algorithm)
  - RapidPlan
  - New automated delineation tools – SmartSeg/Adapt

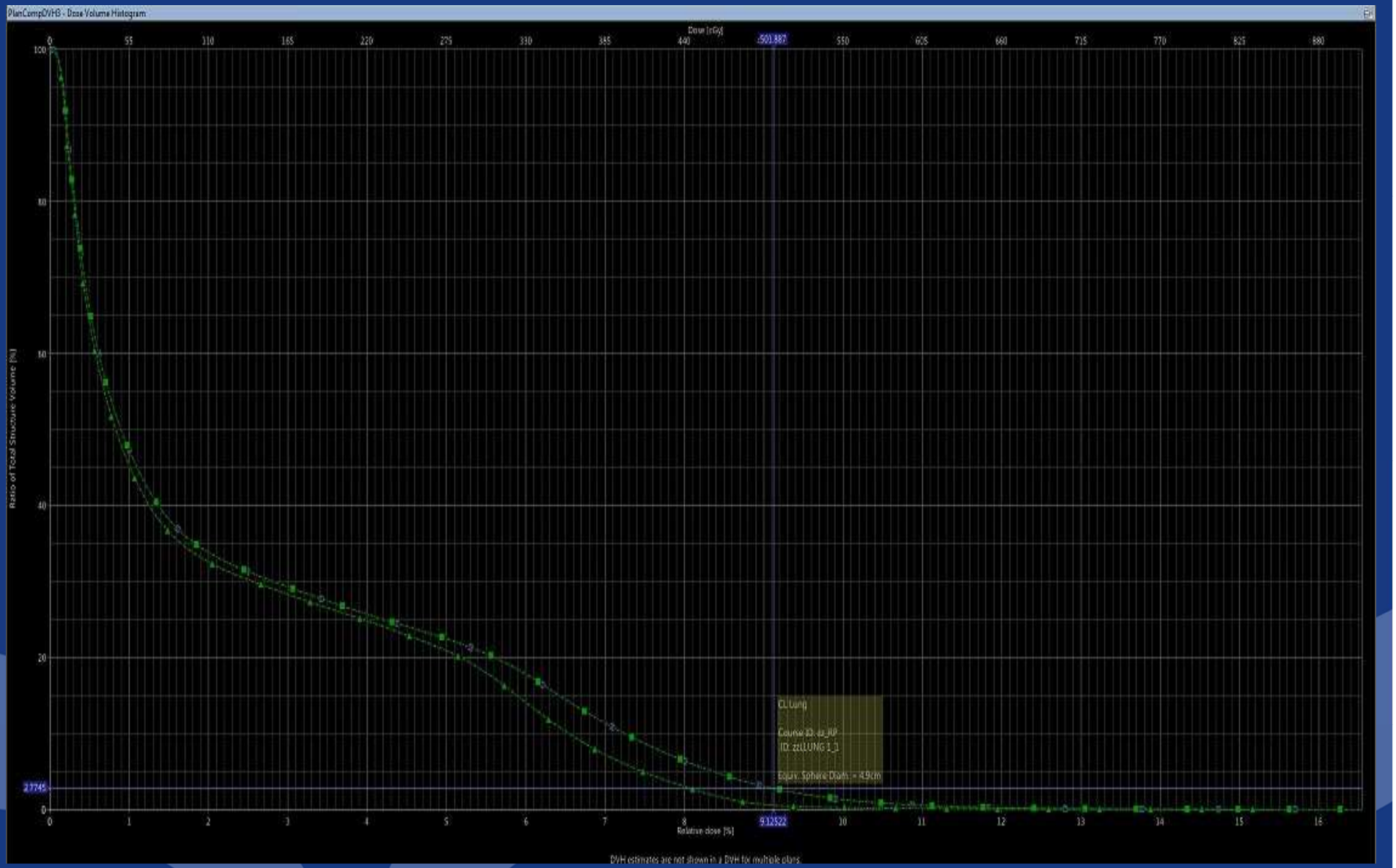
# RapidPlan

- Knowledge Based Objective Estimation Algorithm
- Method for estimating DVHs:
  - Based on patient geometry
  - Previous knowledge contained in a set of existing patient cases
- Standardised contouring required- patient QA
- Used in conjunction with Smart Segmentation

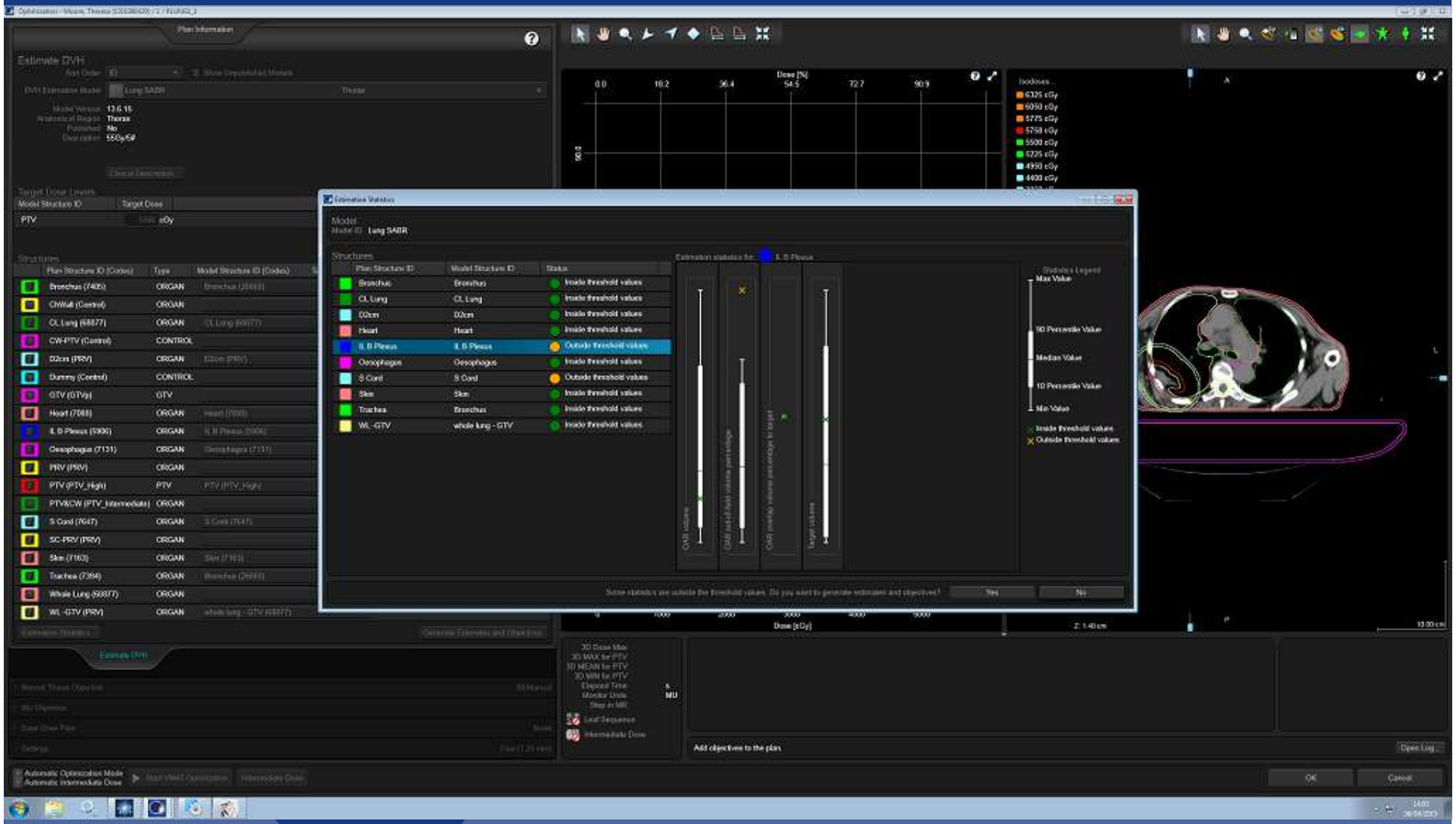




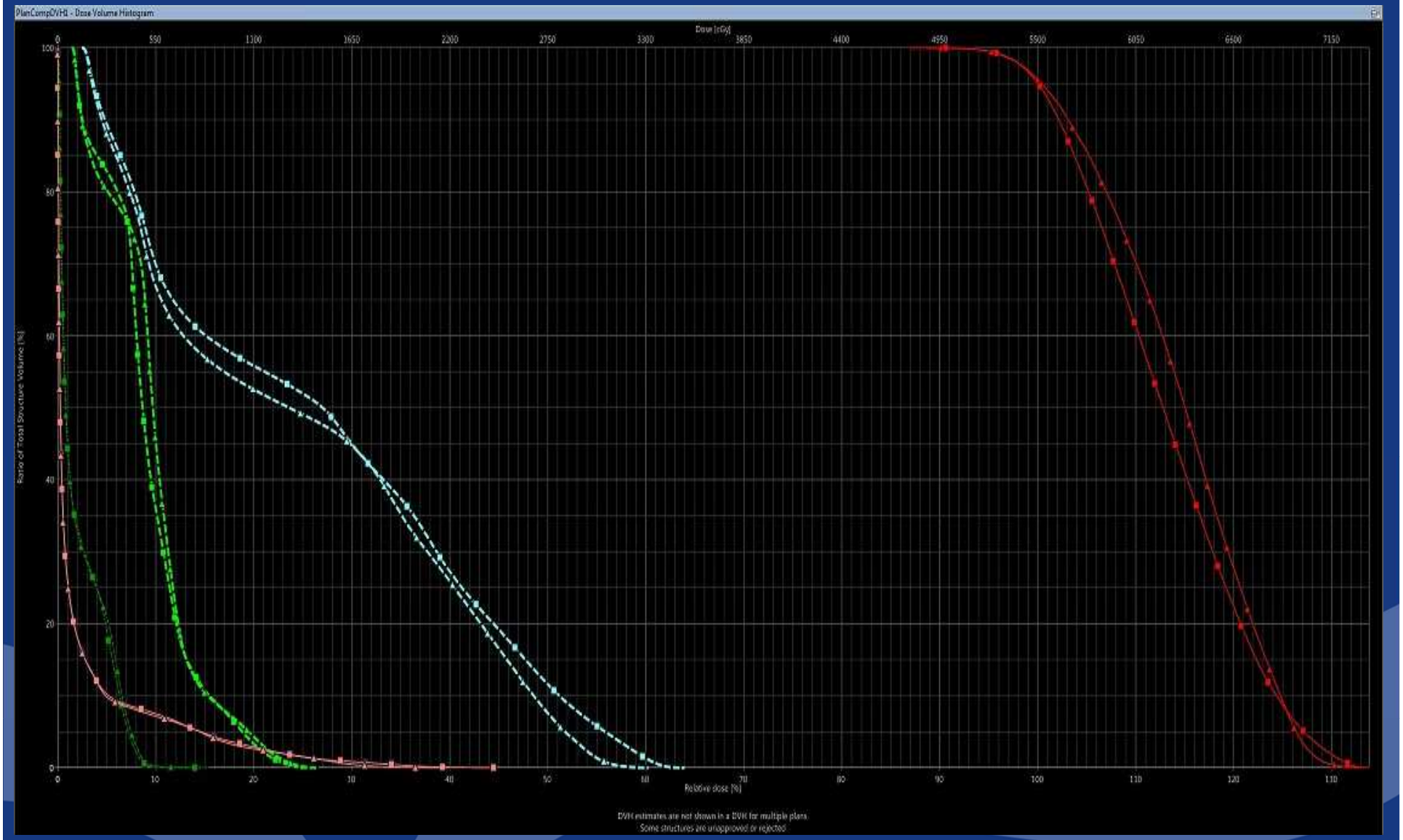

# Building a Model: 120 55Gy/5# Lung SABR plans



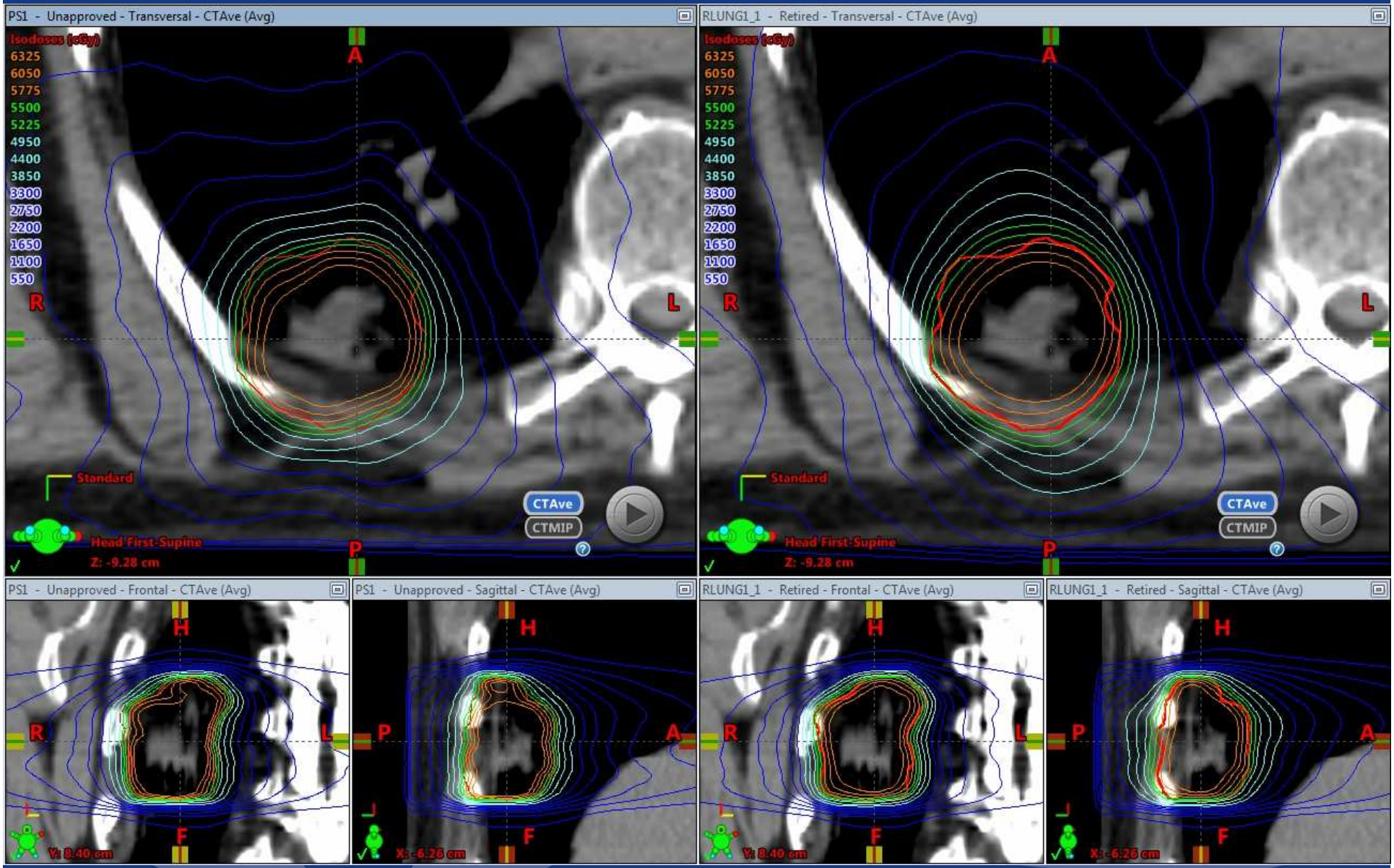

Comparison of two models: plan selection is crucial




# Quality assurance of OAR delineation & priority generation




# Physicist vs RapidPlan – decreased D2cm and improved PTV




# First Test RapidPlan in Glasgow – Lung SABR

# Conclusion - TrueBeam

- Treats all types of clinical case
  - Radiosurgery/SABR
    - In room time of approx 20 mins
  - Any standard 3D plan & palliation
  - Improved imaging & integrated system
    - 4d cbCT availability
  - FFF modes
  - Excellent QA results (no failures)
  - Gating

One accelerator for multiple solutions

# Conclusion – RapidPlan

- Calculate RapidArc in a fraction of the time
  - First two RapidPlan SABRs treated today
  - Standard SABR case 13 mins start to finish
  - Volume preparation takes longer than planning
  - Standardising planning
  - Increases the pool of planners that can advance plan
  - Reduce the requirement for dosimetry QA
  - OAR delineation QA
  - Complexity of different SABR techniques- multiple models?

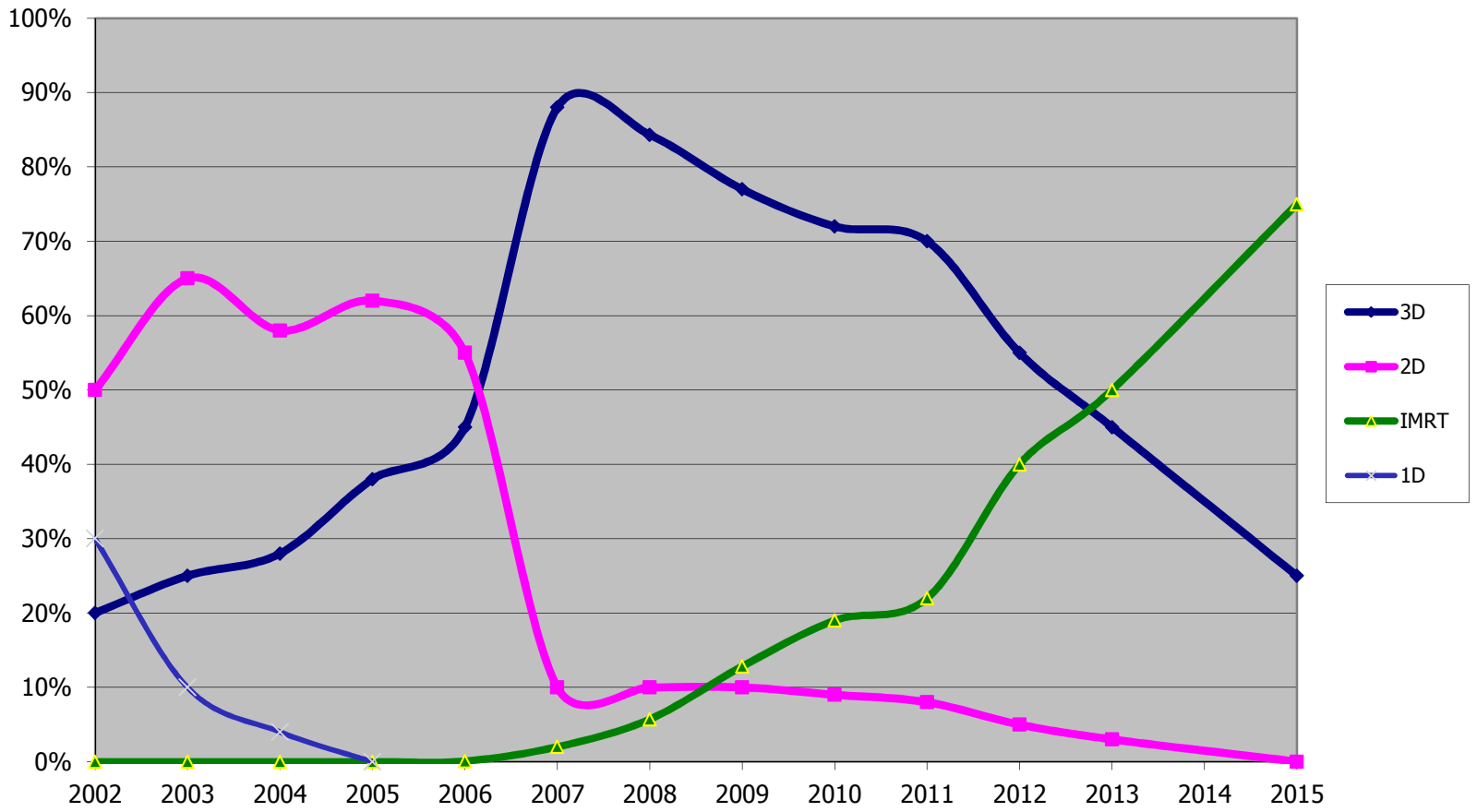
# Conclusion – Eclipse/RapidPlan

- Networking & FAS
  - 18 Framework Application Servers
  - RapidArc fields distributed across servers
  - No longer need to calculate to local client
  - Can use a Citrix based solution for calculation- no longer need to be at an Eclipse station
  - Standard RapidArc Brain 10 mins start to finish

SmartAdapt - RapidPlan – FAS - TB & FFF

Adaptive Planning?

# Current Practice



# Questions?