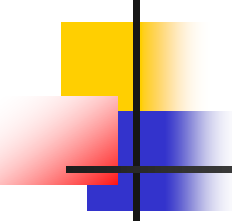


VMAT 初步应用探讨

迟子锋 刘丹

河北医科大学第四医院





VMAT的概念

旋转治疗&动态调强

最大可调节参数：

射线能量

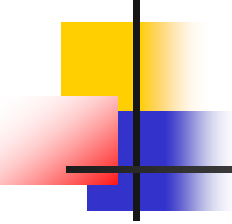
射野方向（弧）

机架转速

剂量率

MLC

准直器及治疗床



VMAT的优势

低MU：诱发肿瘤可能性减小？

低治疗时间：患者舒适度
器官内运动
治疗效率
生物效应？

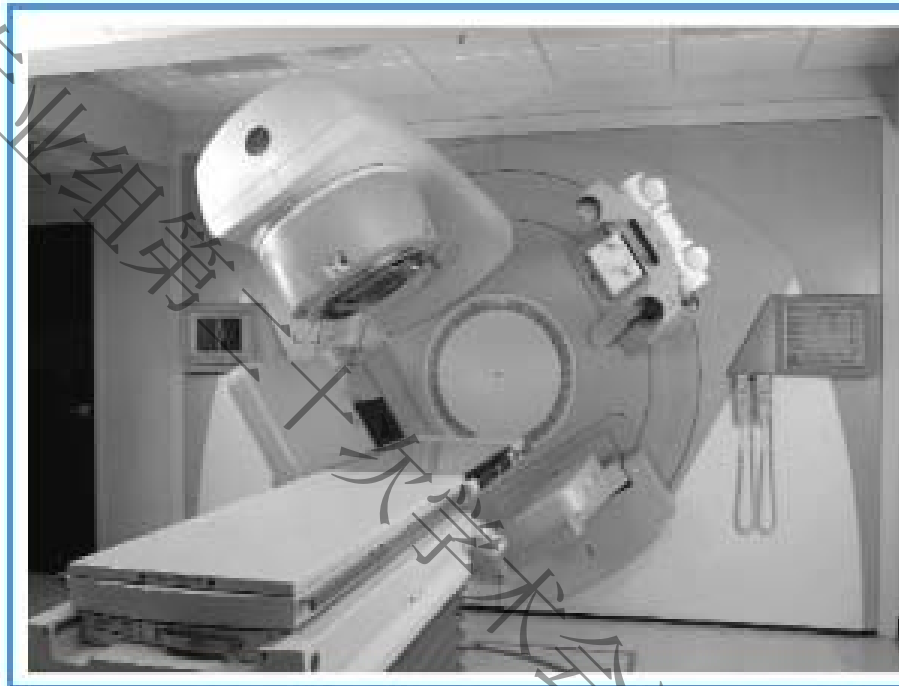
剂量优势？

VMAT

Varian



Tomotherapy

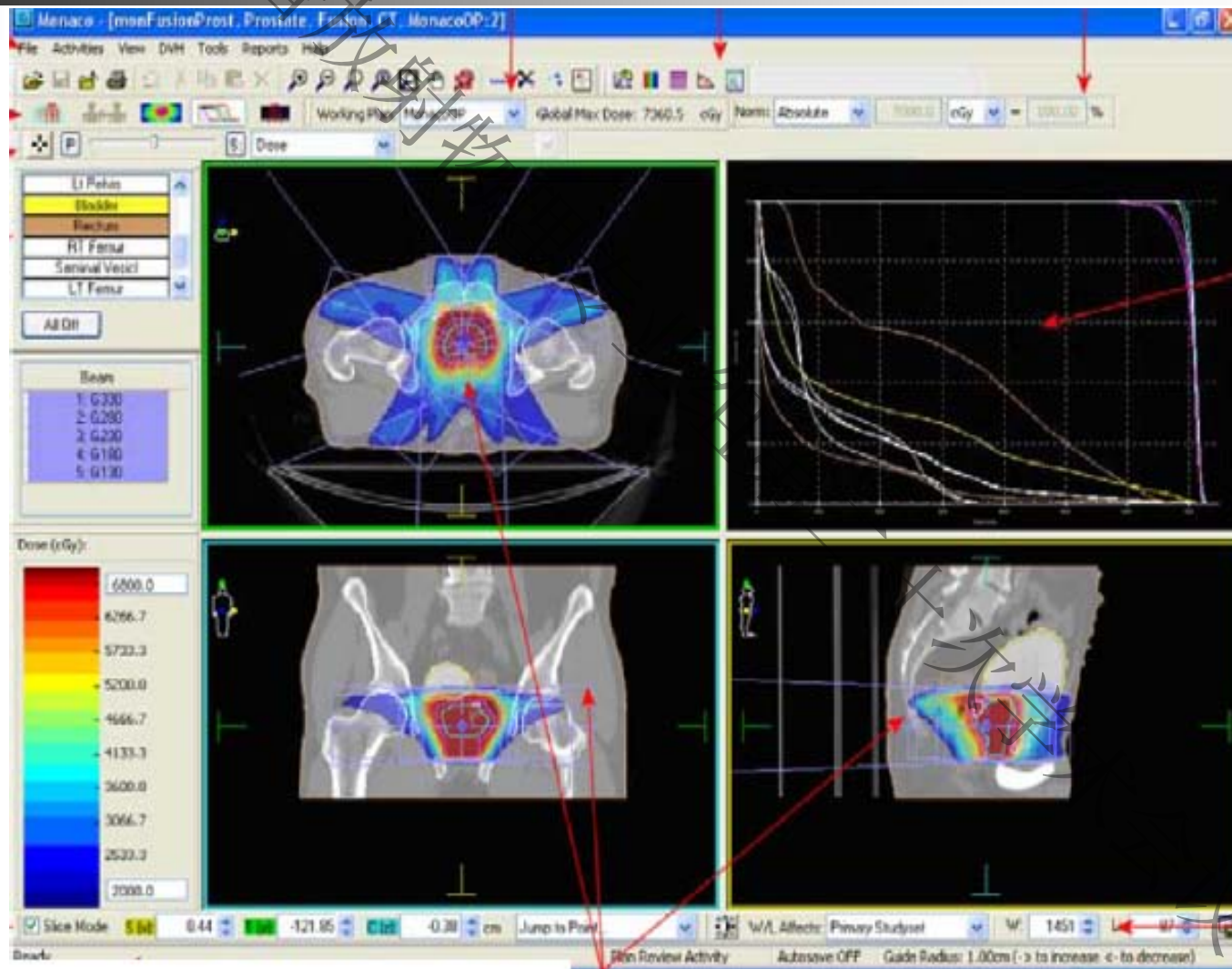


Elekta

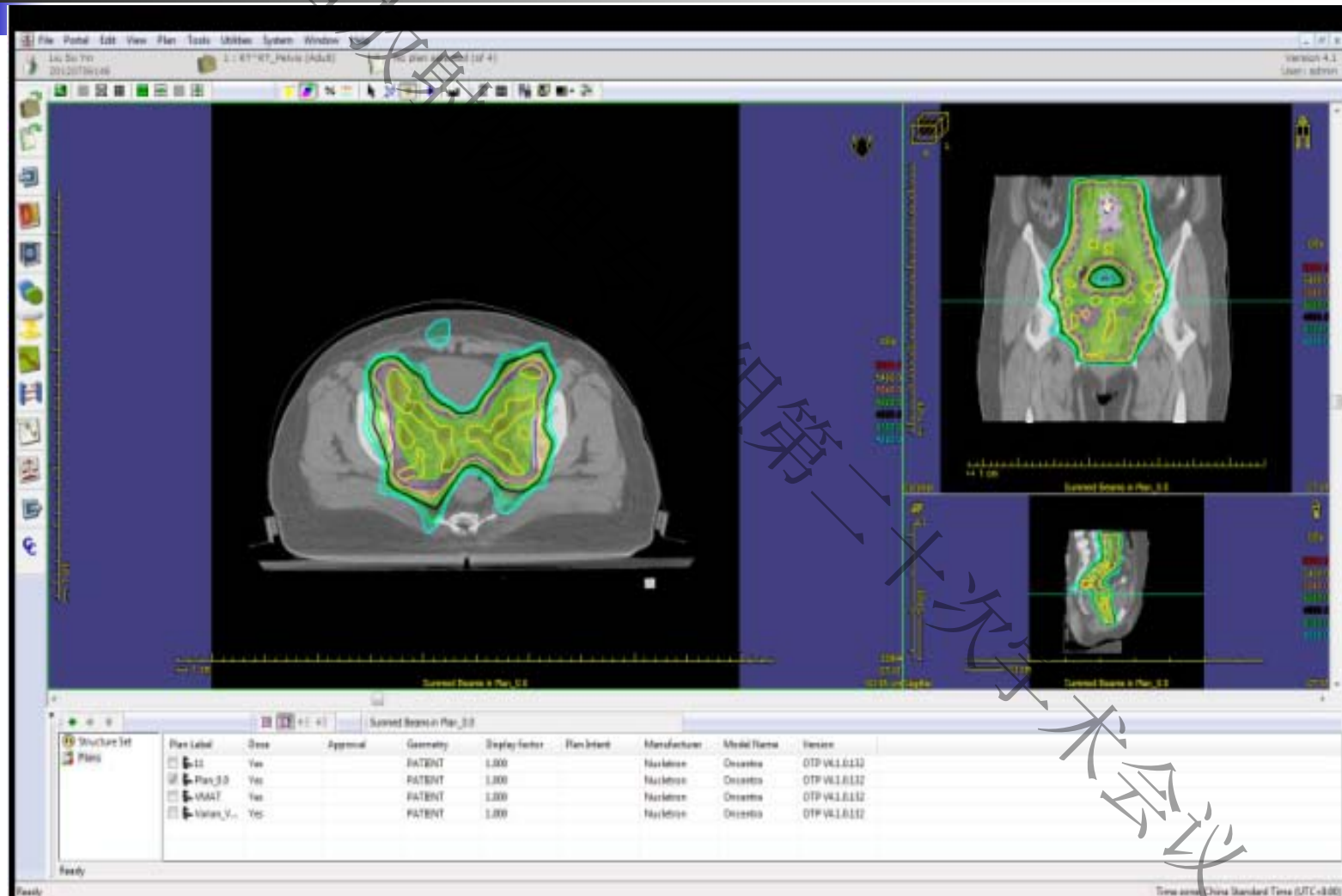
VMAT设备-六维床



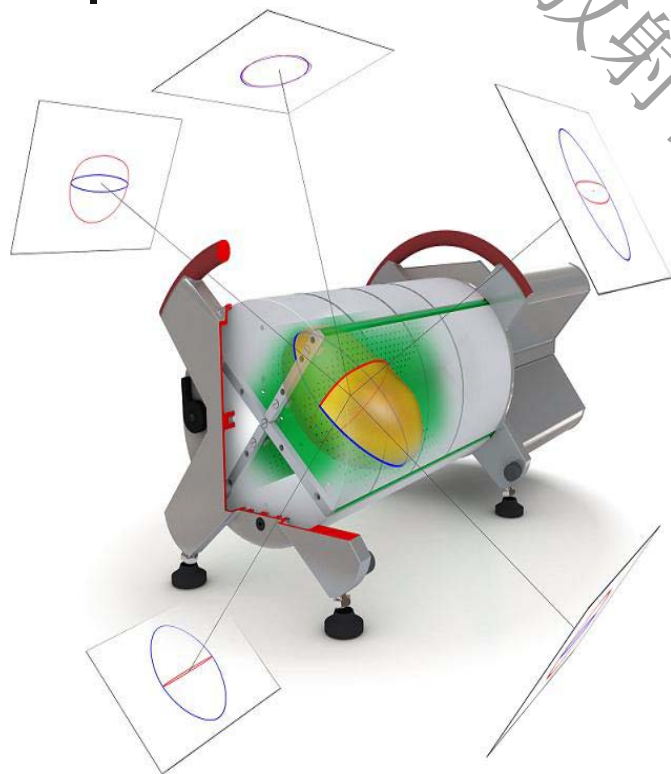
VMAT设备-Monaco



VMAT设备-Oncentra



VMAT设备-Delta4



- 两组正交的探测器组成，共有1069个P-型电离室
- 在 $6\text{cm} \times 6\text{cm}$ 中心区域，电离室中心距离5mm；在外围区域，电离室中心距离10mm
- 最大探测面积 $38 \times 20\text{cm}$
- 每个电离室面积 0.78mm^2 ，灵敏度 5nC/Gy ，稳定性 $1\%/k\text{Gy}$ (6MV光子束)，温度灵敏 $0.32\%/k\text{Gy}$
- 收集任意入射角度的粒子信息，测量中心点的吸收剂量
- 三维分布的吸收剂量的最高分辨率达 $1 \times 0.05\text{mm}^2$
- 使用Delta⁴控制软件进行伽玛、DTA分析等

VMAT设备-MOSIAQ

Joe Gannon [logout]

James Bond [choose patient]

Back Forward Home Schedule Chart Treatment Shortcuts

James Bond
DOB: 05/22/1928 Attending MD: Joe Gannon, M.D.
MedRx: 93-0017 Referring MD: Marcus Welby, M.D.
Di: Prostate Gland: Adenocarcinoma, T2, N0, M0 Stage 2

Alerts: DNR, HOH, NIS, VAD, DPA HC, HC HH [edit]

Allergies: Food allergy (peanuts), rash [cancel]

Chart Appointments Flowsheet Notes

Diagnoses and Interventions

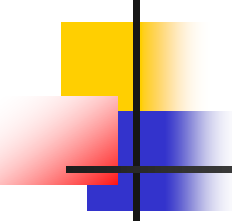
Type	Description	Date
D	Prostate Gland neoplasm, T2, N0, M0 Stage 2	9/27/2004
D	Document: Path Report	9/23/2004
I	Image: Dx CT	9/23/2004
D	Document: Consult	9/24/2004
C	Radiation Oncology Course: 1	9/27/2004
I	Treatment Plan (scanned plan)	9/28/2004
R	Prostate - 18XLMC	9/30/2004
F	Field 1 RPO Prostate	9/30/2004
S	Sim 1 RPO Prostate	9/30/2004
I	DRR	9/30/2004
S	Setup	9/30/2004
F	Field 2 Rt Lat Prostate	9/30/2004
F	Field 3 RAO Prostate	9/30/2004
F	Field 4 LAO Prostate	9/30/2004
F	Field 5 Lt Lat Prostate	9/30/2004
D	Document: Weekly Treatment Summary	10/1/2004
D	Document: CXR PA and Lat (eSCAN results)	10/4/2004
O	Order: Lab - CBC w/ Diff	10/4/2004
M	Medication: ABX-EGF, 215mg, IV weekly x8wks	10/4/2004
D	Diabetes	9/5/2003

Prostate 5 Field Transverse isodose

Site: Prostate
Technique: 5 Field
Image: Transverse isodose

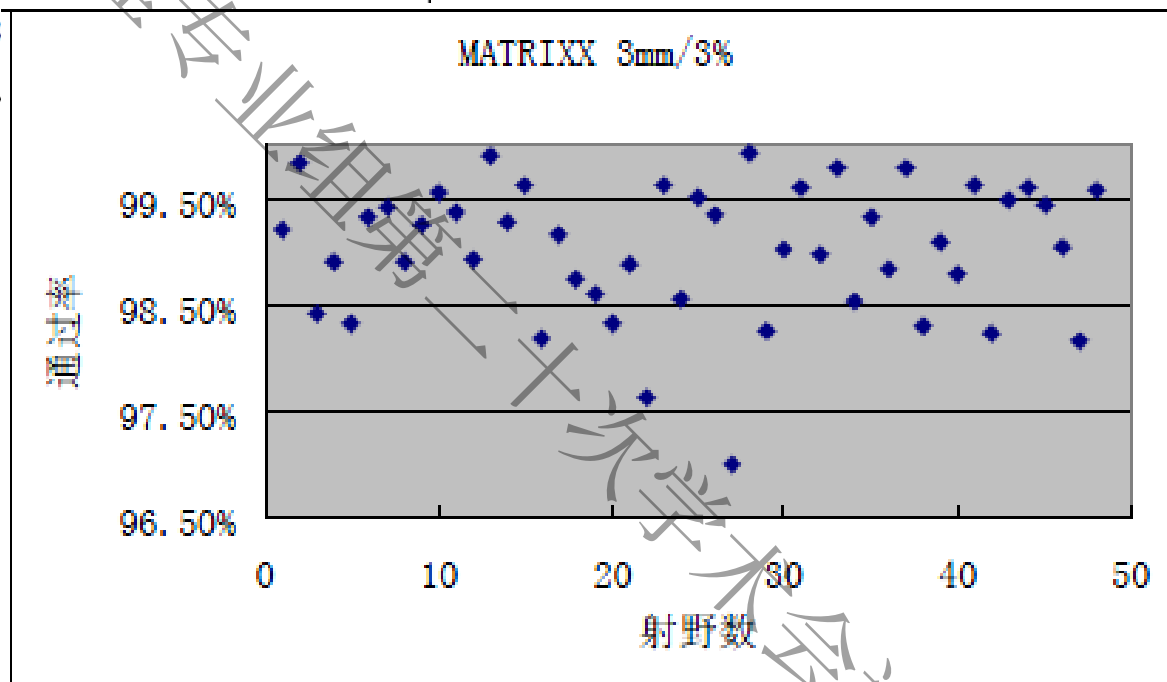
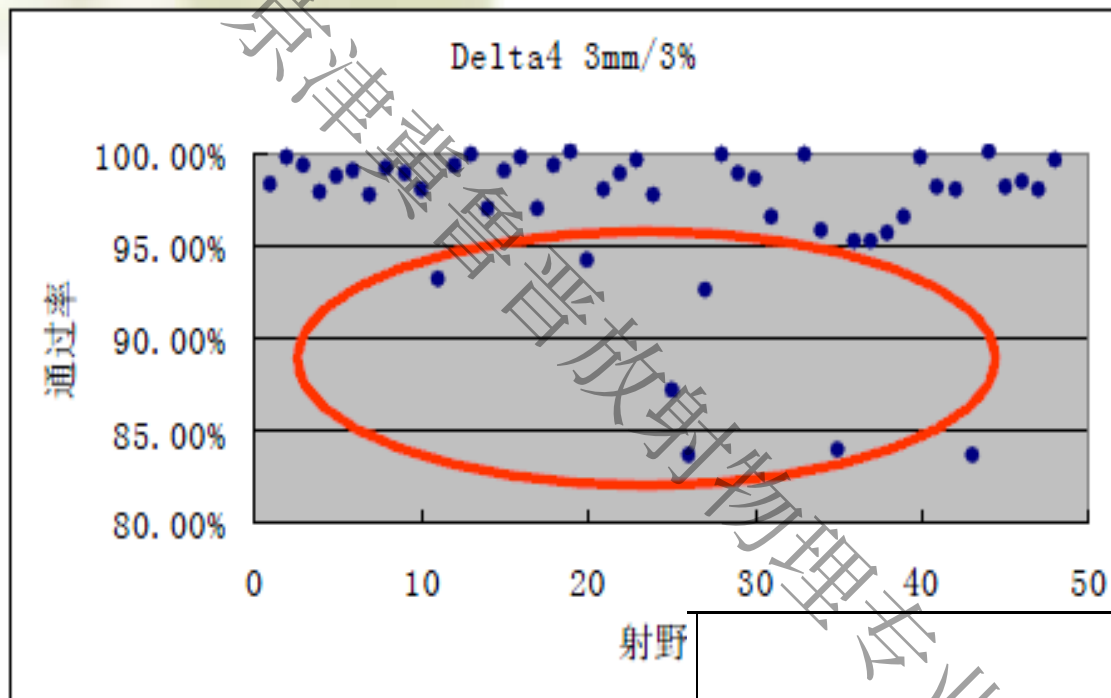
Prostate28

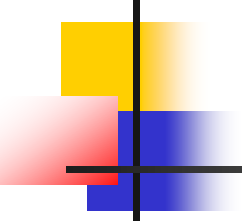
Slice 9: Z = -2.000



VMAT-可能存在的问题

- 物理实现方式及其限制因素：机架转速，**MLC**，剂量率，弧的数目
- 治疗计划优化算法：**MLC**漏射；凹凸槽效应
- **VMAT QA**：机架转速；剂量率；**MLC**





VMAT-文献回顾

- Cozzi L等对盆腔肿瘤的计划进行了比较，适形度略好于IMRT，但均匀性较差。对于临近或是与靶区交界的危及器官，其高剂量体积和平均受量均低于IMRT，靶区外低剂量区域明显增加。
-Radiother Oncol 2008;89:180-191
- Oliver M等利用模体对RapidArc，IMRT及螺旋断层放疗进行了计划质量比较。RapidArc计划的适形度（CI）、均匀性（HI）及对模拟危及器官的保护均好于后两者；靶区外受到低剂量（<5Gy）辐照的体积介于后两者。
-J Appl Clin Med Phys, 2009, 10: 117-131

VMAT-文献回顾

- **Cao D等比较了IMAT和螺旋断层放疗的计划质量。对于肺癌，螺旋断层放疗的平均肺受量和V20高于IMAT；对于前列腺癌，螺旋断层放疗的膀胱和直肠的受量高于IMAT；对于头颈部肿瘤，IMAT使用非共面射野，眼球和腮腺平均量、脑干和视交叉最大量均小于螺旋断层放疗。**

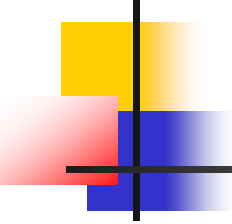
Int J Radiat Oncol Biol Phys, 2007, 69: 240-50

- **在Karl Ottoa 的有关治疗时间方面的统计:**

1.5~3 min singleArc

< 5min doubleArc

- **Min Rao et al平均MUs总量下降: H&N :20 %
Lung:16 %
Prostate:14 %**

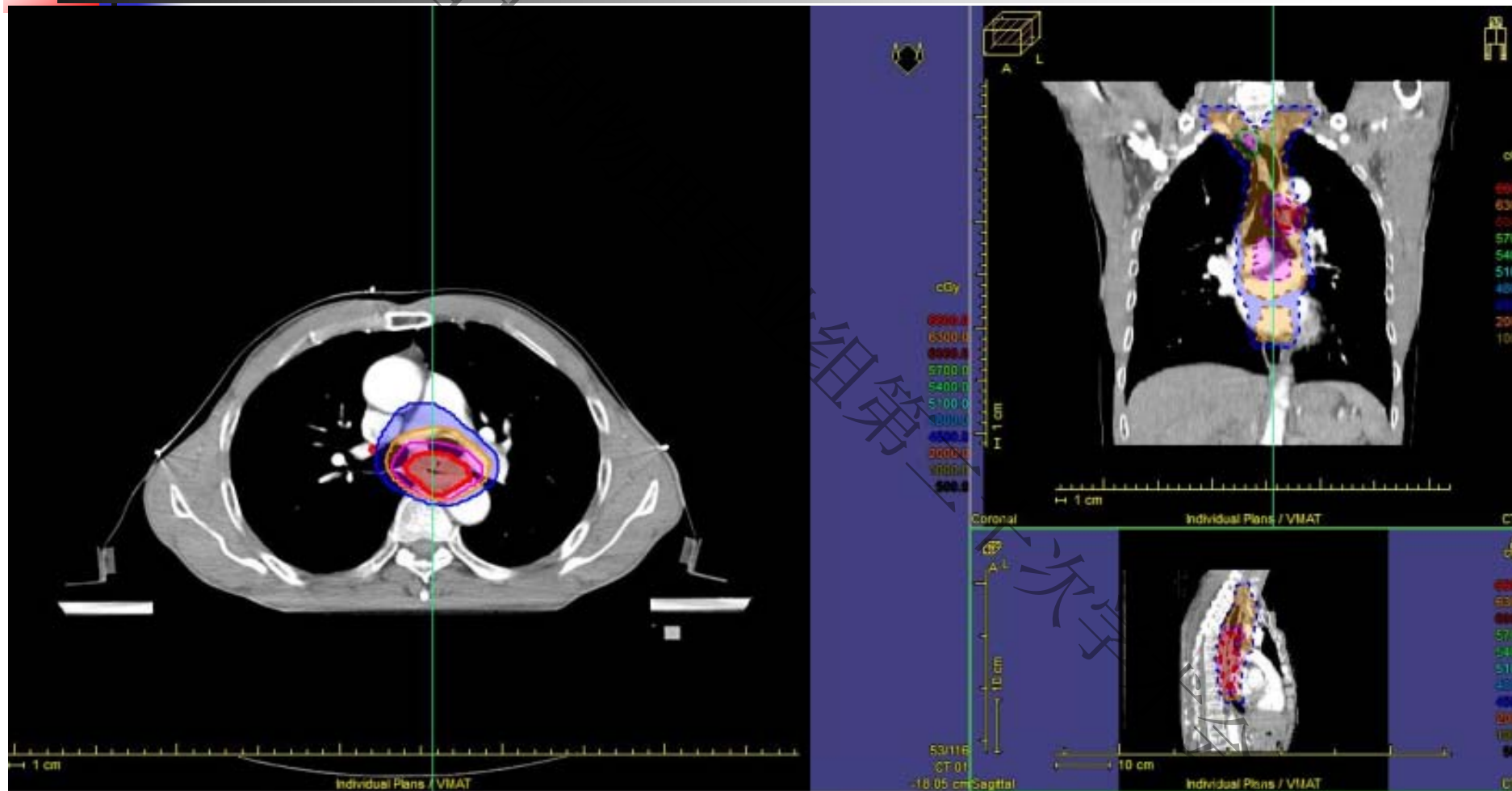


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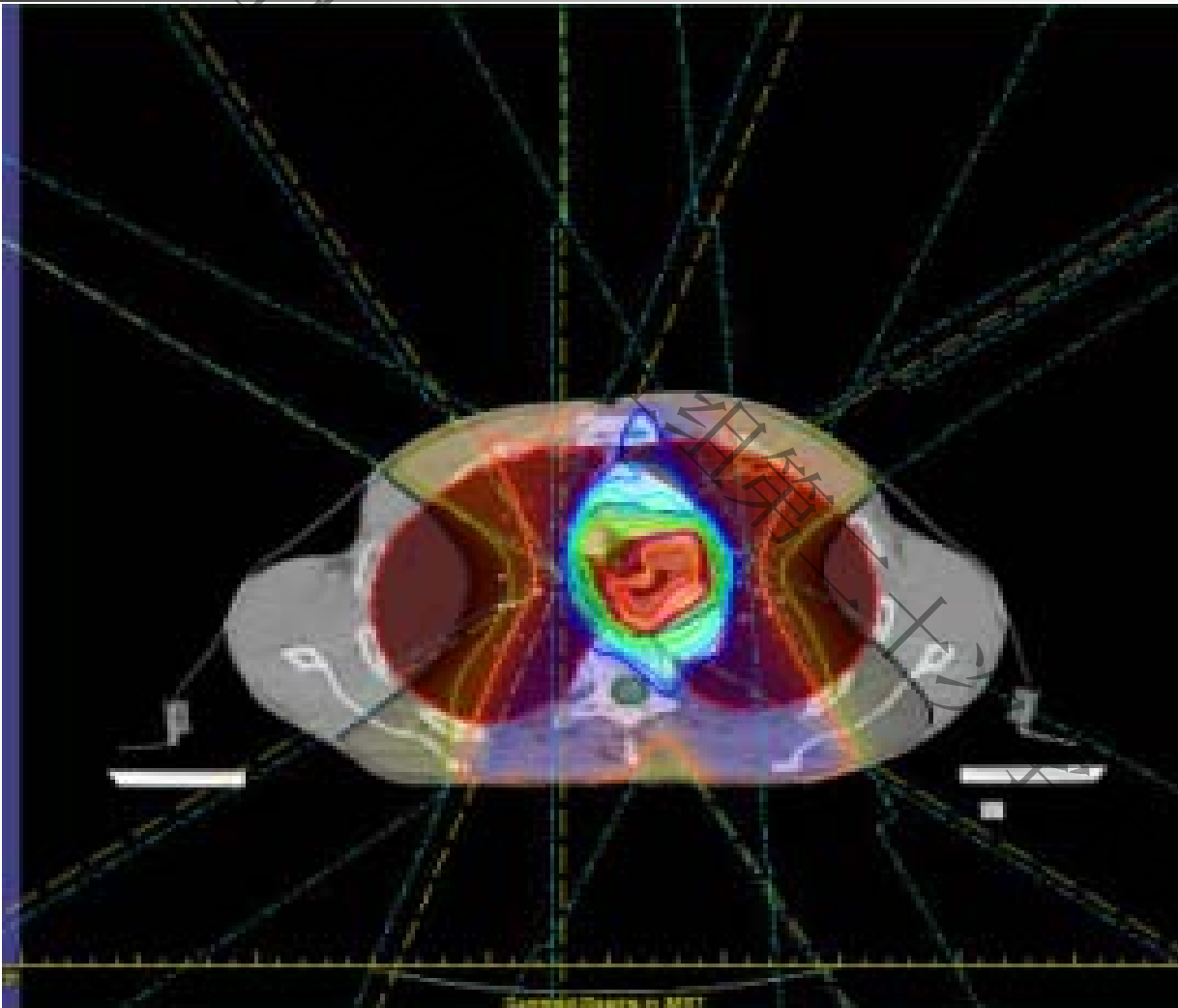
VMAT临床初步应用

京津冀晋放射物理学会第十次学术会议

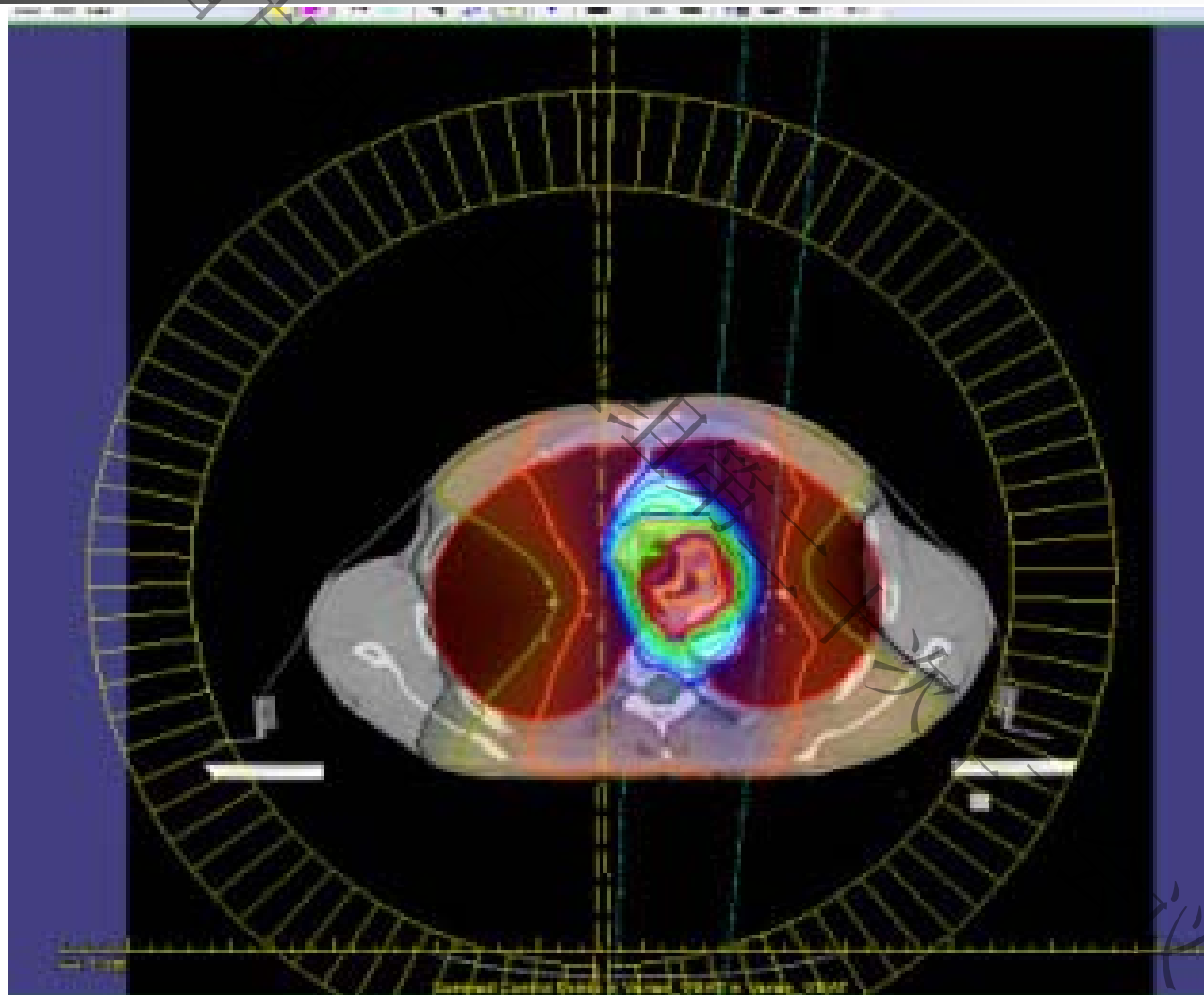
VMAT-计划设计



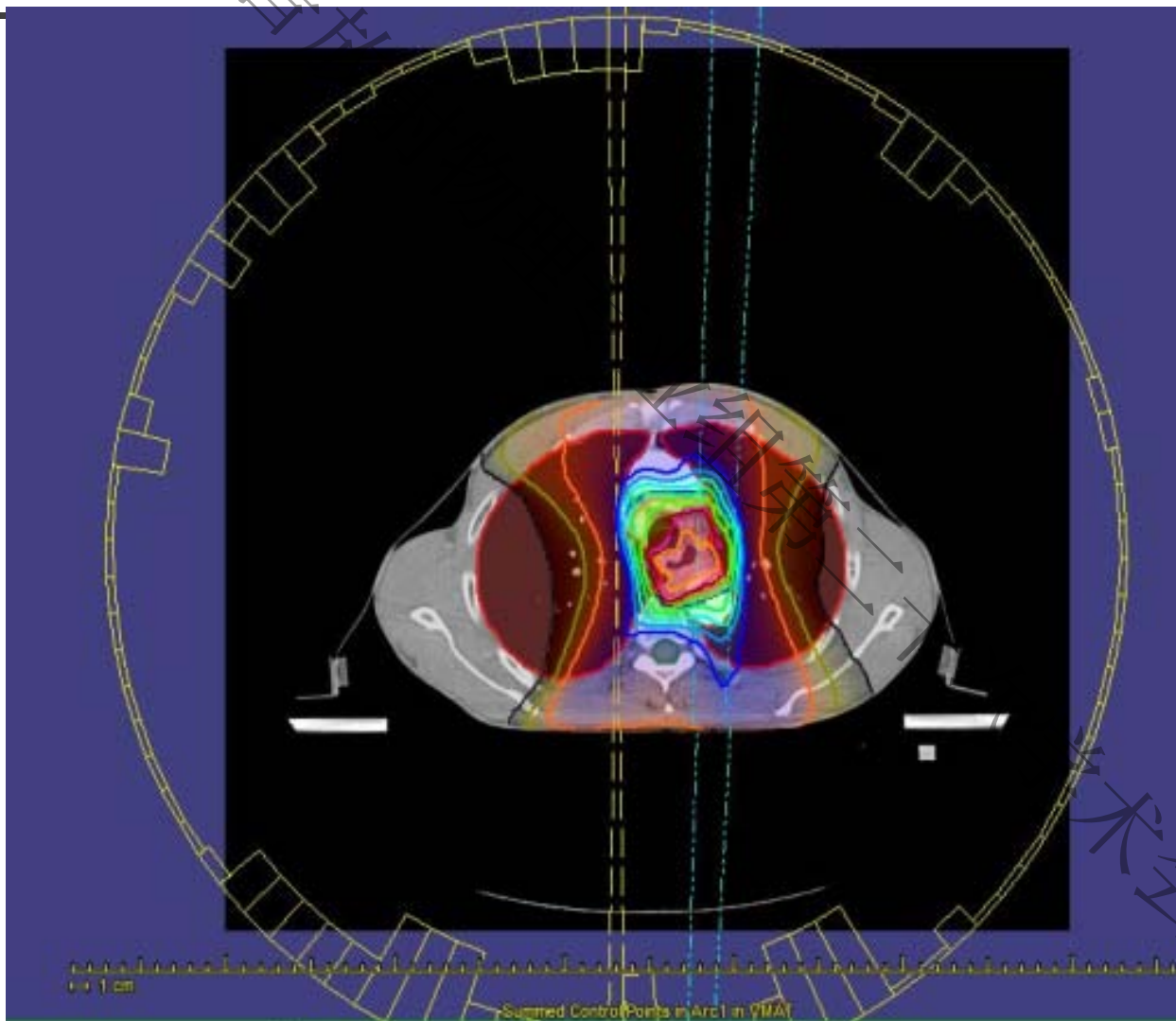
VMAT-计划设计



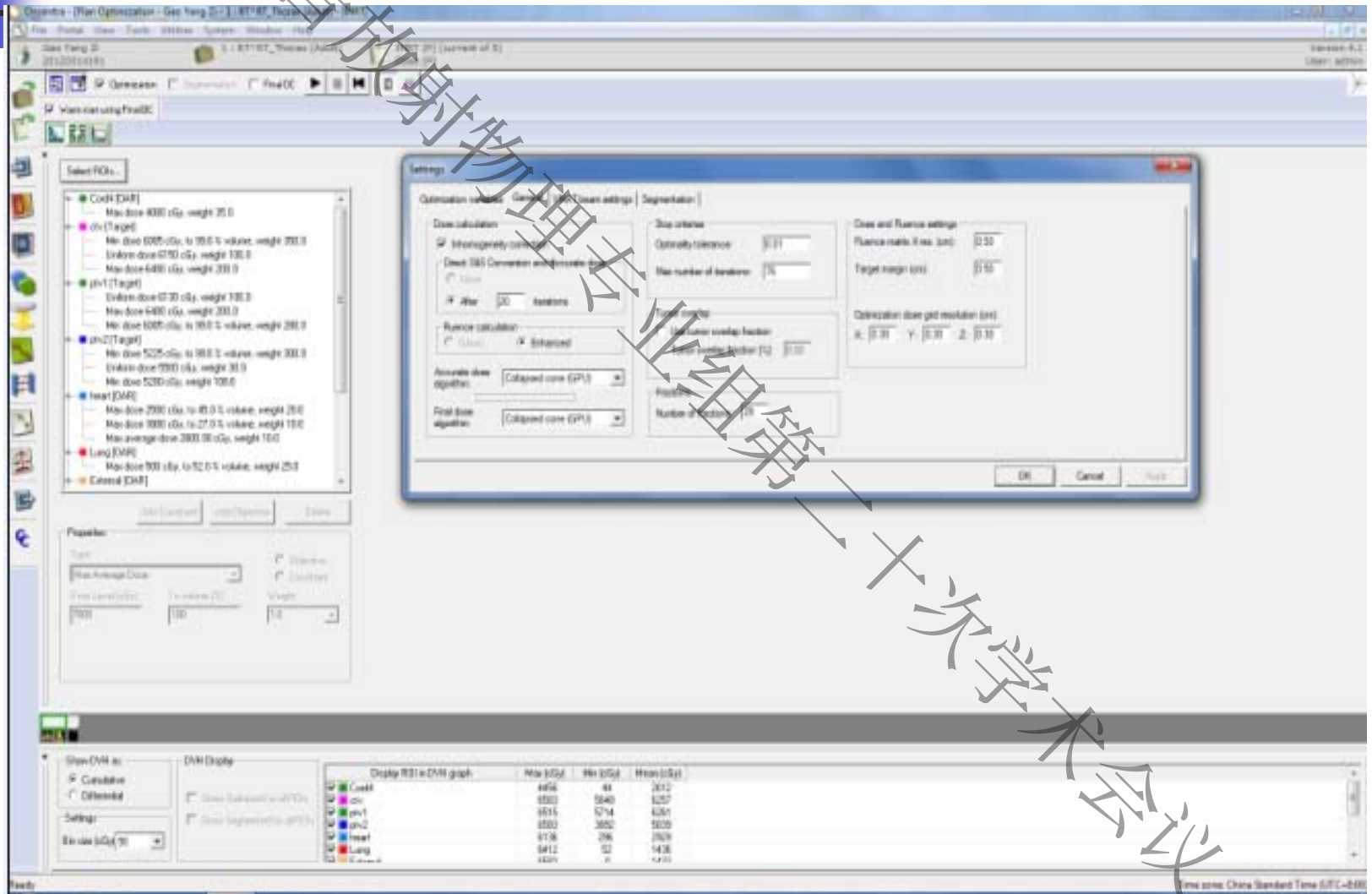
VMAT-计划设计



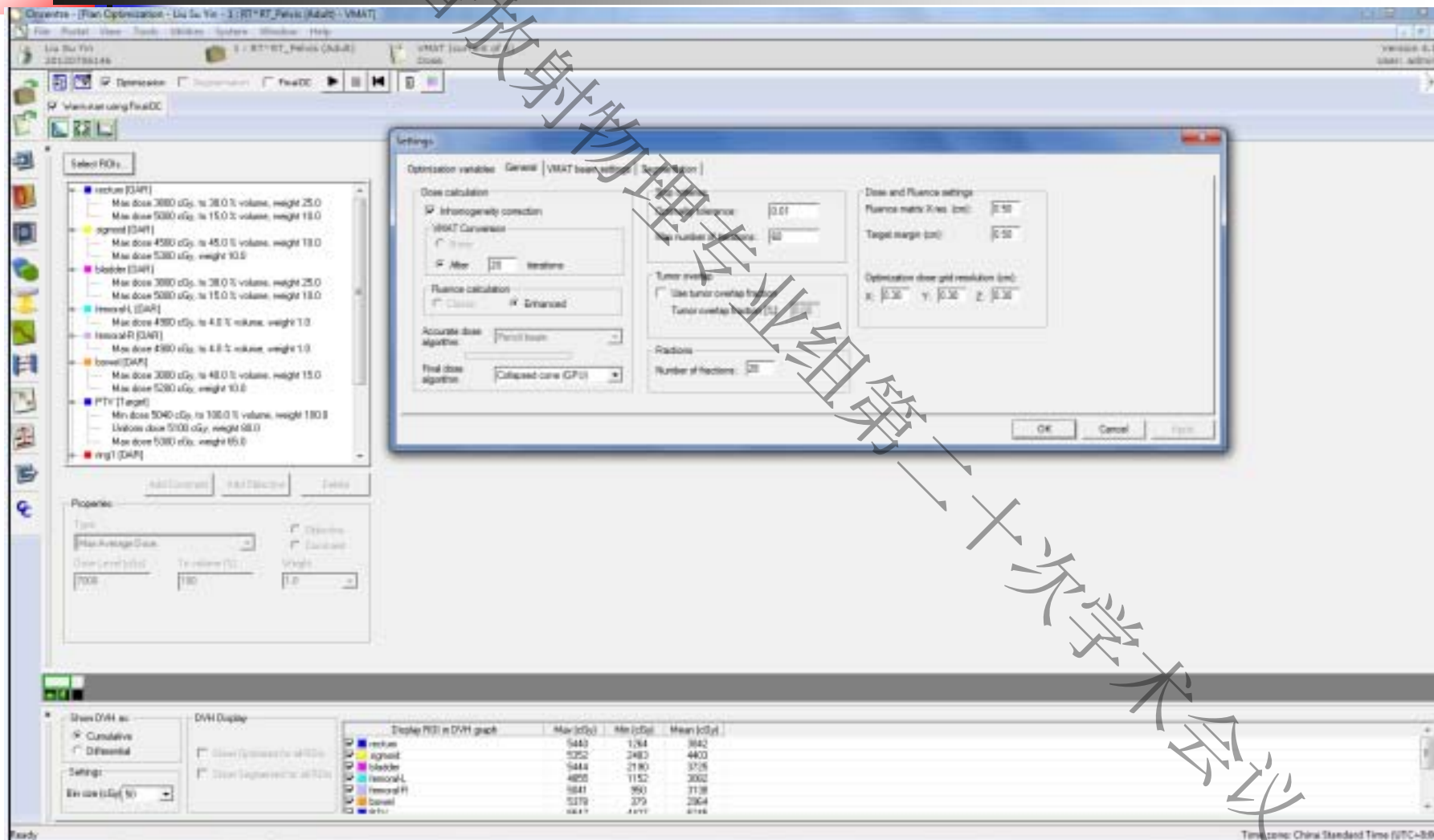
VMAT-计划设计



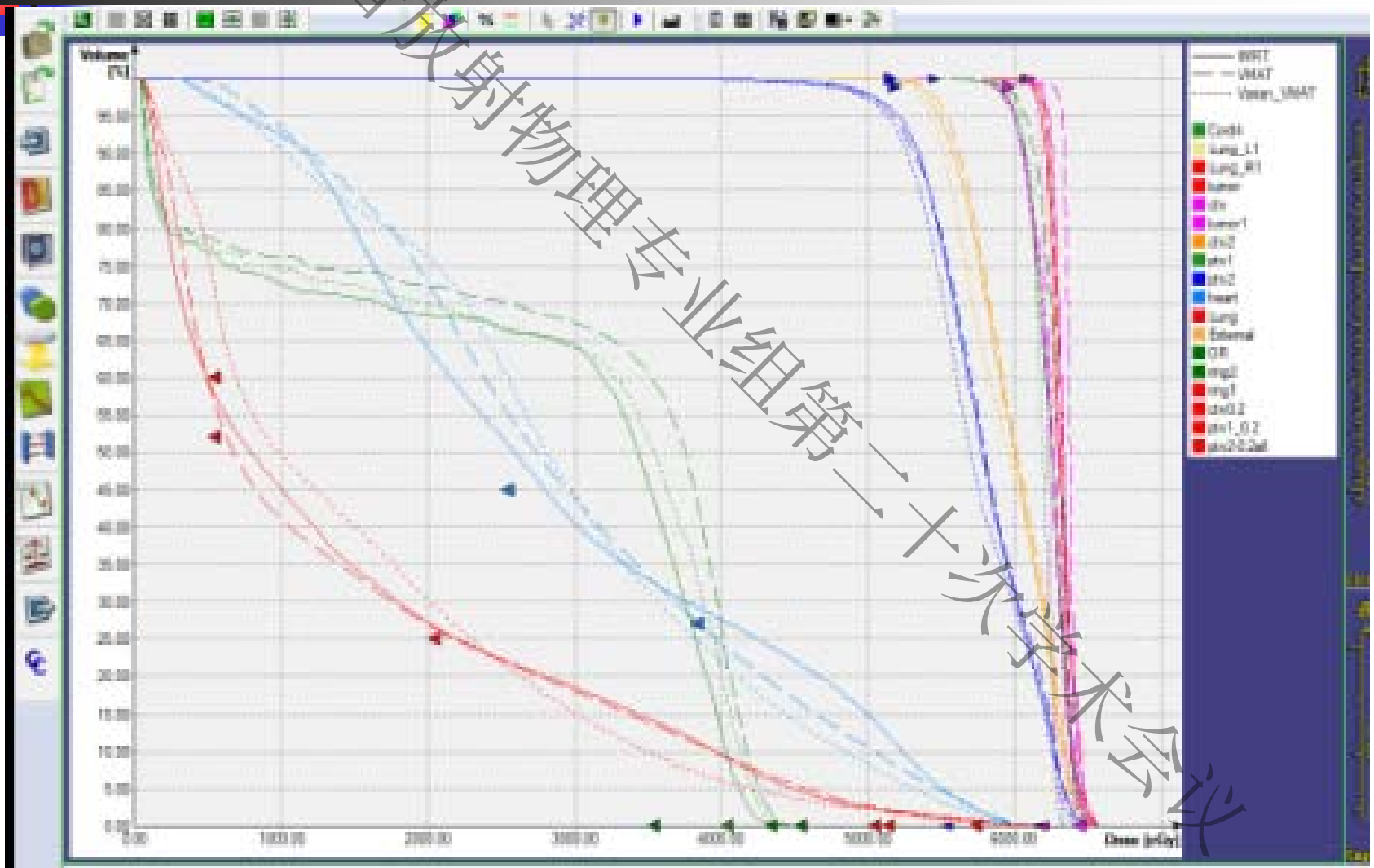
VMAT-计划设计



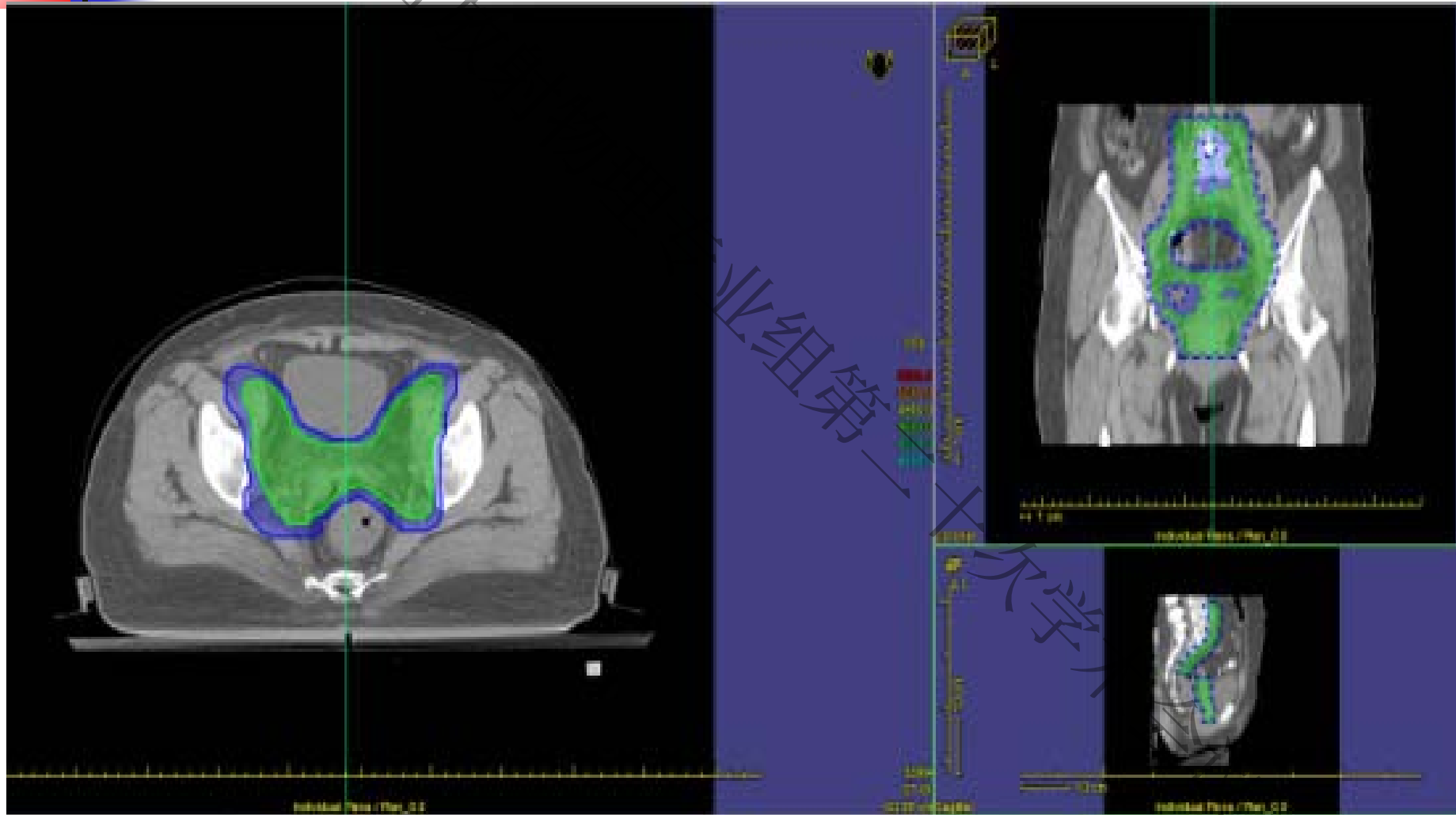
VMAT-计划设计



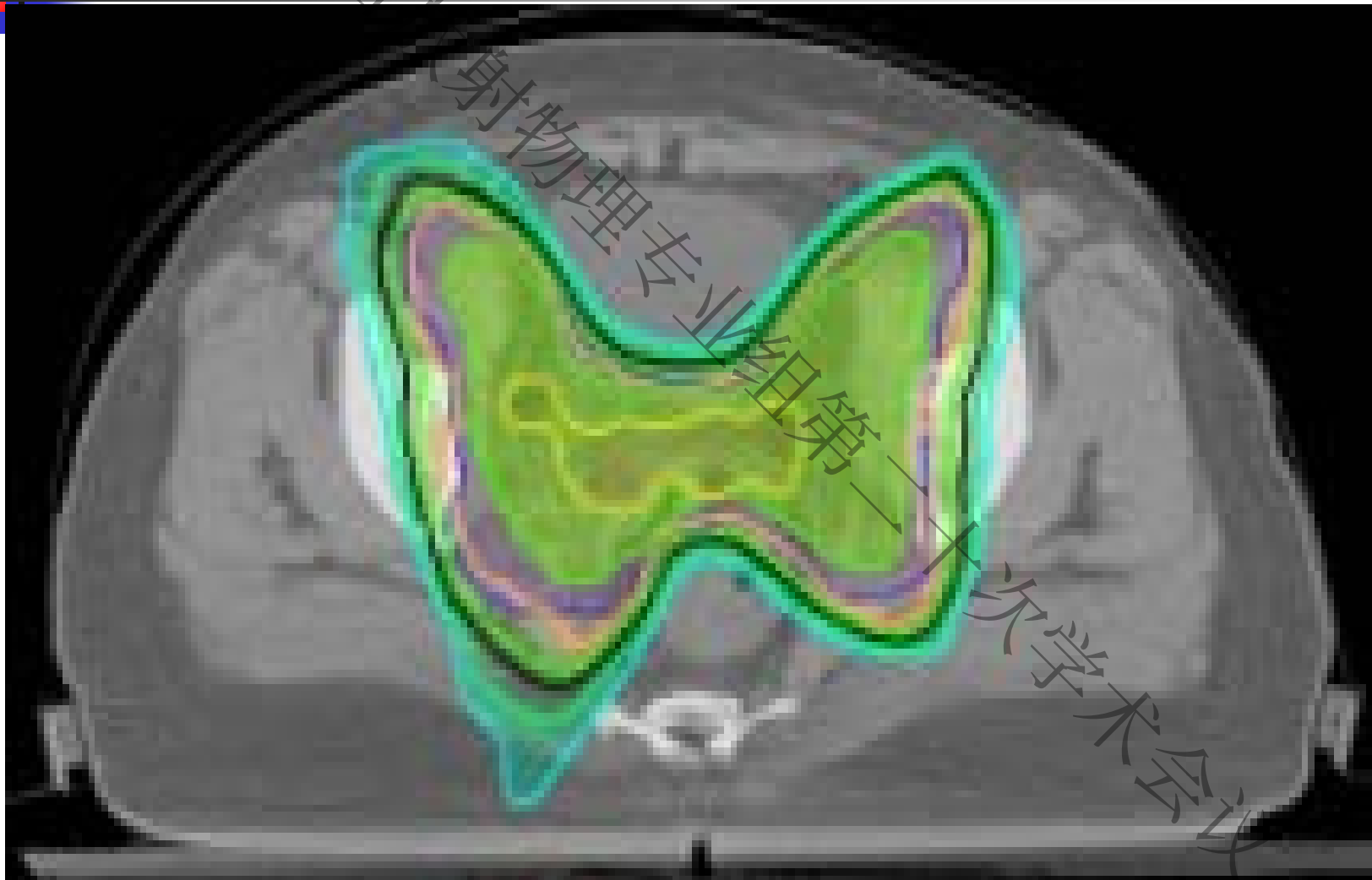
VMAT-计划设计



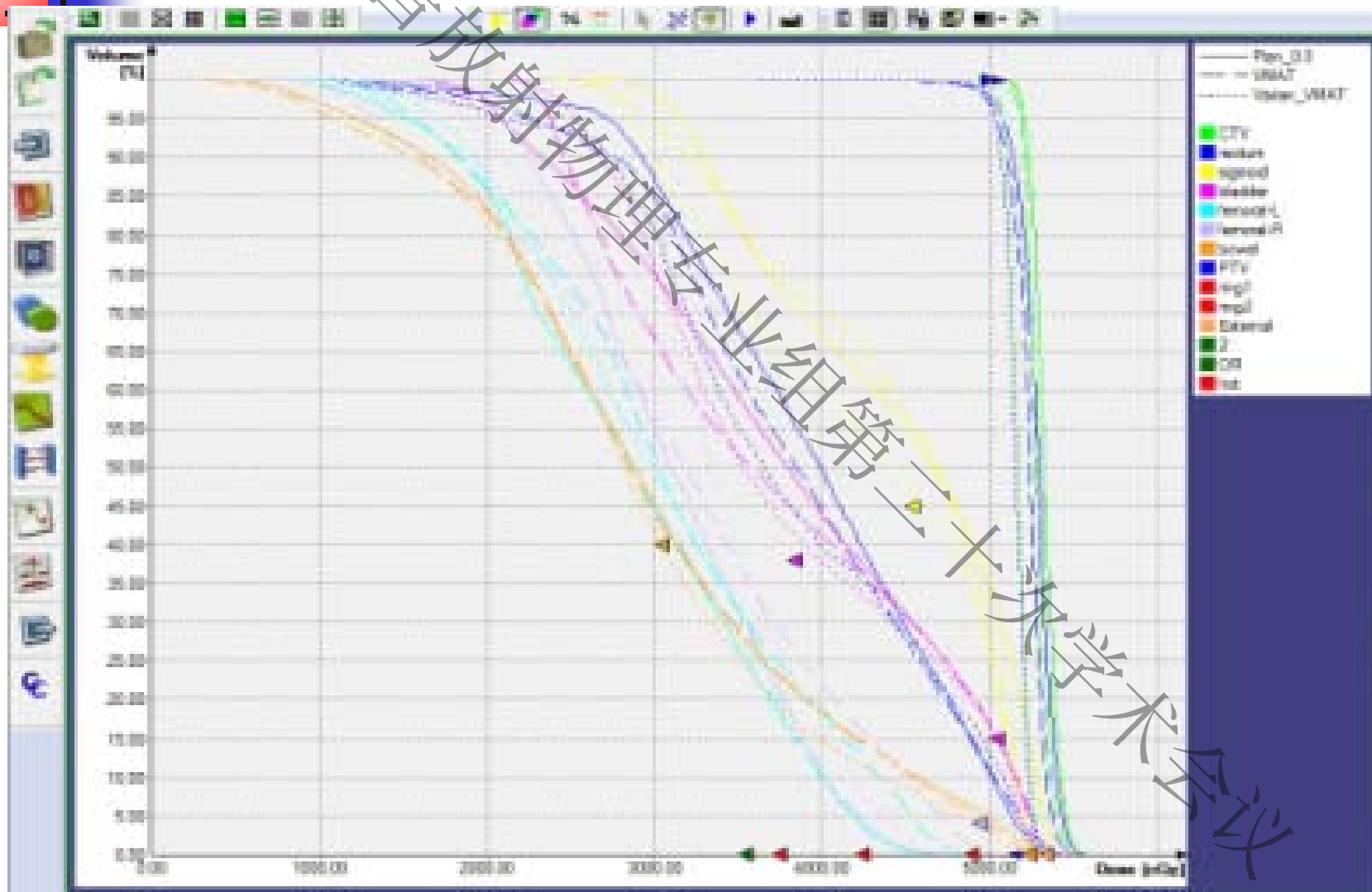
VMAT-计划设计



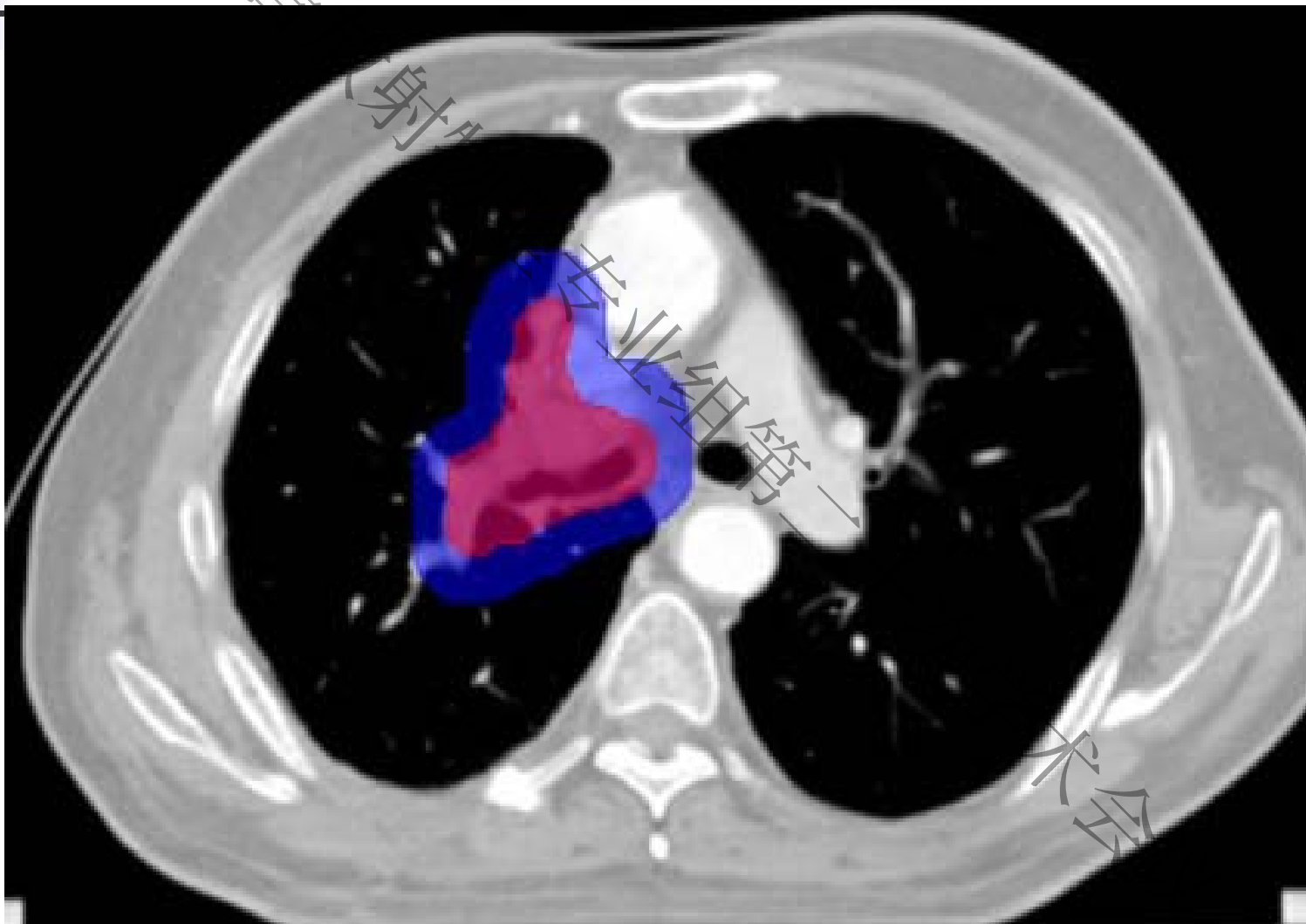
VMAT-计划设计



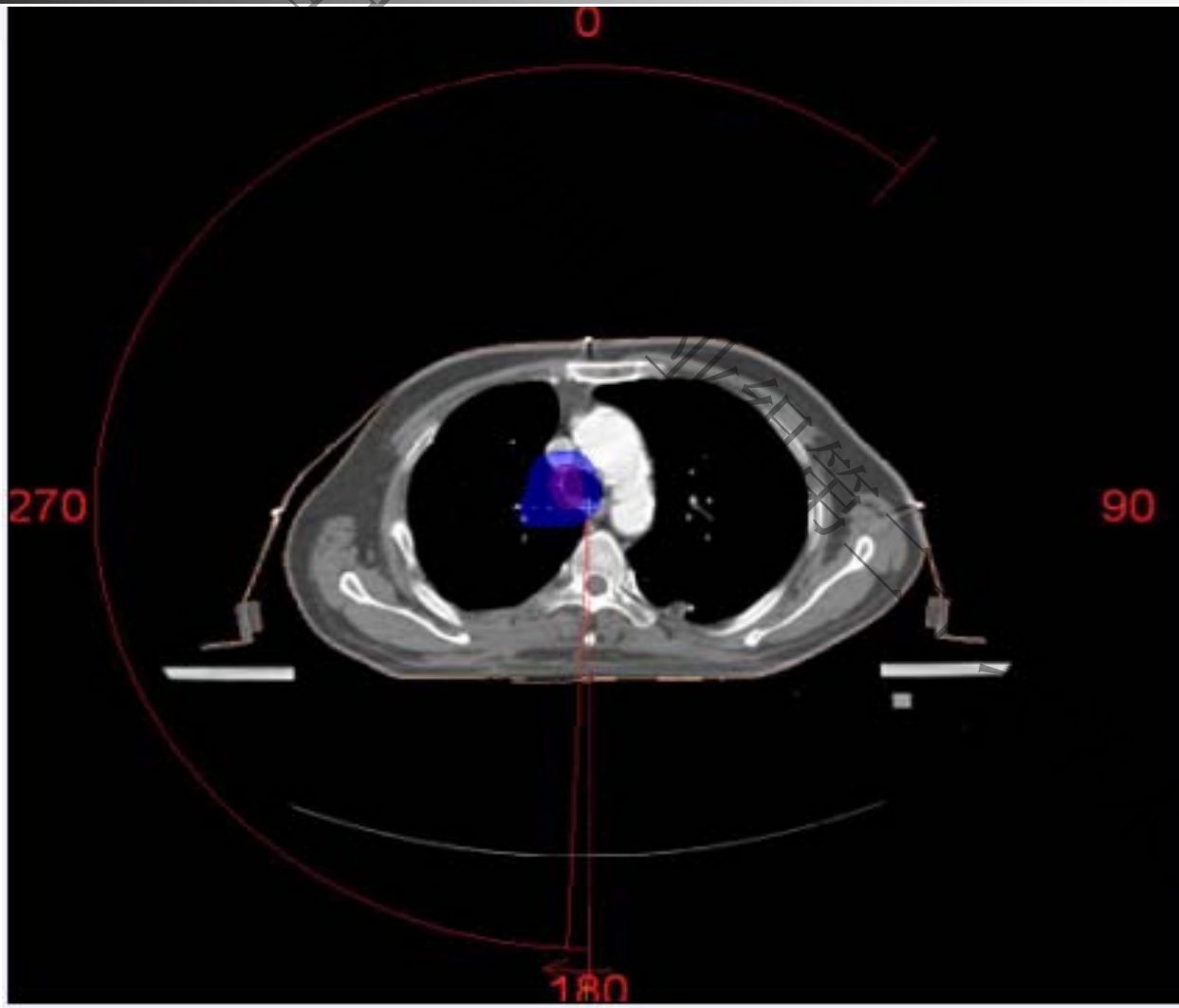
VMAT-计划设计



VMAT-计划设计 Monaco



VMAT-计划设计



VMAT-计划设计

IMRT Calculation Properties

Calculation Parameters		Global Parameters	
Grid Spacing (cm):	0.50	Minimum Electron Density: Use with Fill option.	1.000
Monte Carlo Variance per Control Point (%):	4.00	Minimum CT Number: Use with Clear option.	-200
Number of Fractions:	30	Auto Flesh Margin (cm):	0.20
Prescription (cGy):	6000.0	Surface Margin (cm):	0.30
Secondary Algorithm:	Monte Carlo Photon	Beamlet Width (cm):	0.20
		Target Margin:	Normal (8mm)
		Avoidance Margin:	Normal (8mm)

OK Cancel

VMAT-计划设计

Sequencing Parameters: VMAT

Max. # of Control Points / Arc:	90
Target Dose Rate (MU/min):	200.00
Estimated Delivery Dose Rate (MU/min):	200.00
Min. Segment Width (cm):	0.60
Fluence Smoothing:	Medium
☐ Constant Dose Rate	

OK Cancel

VMAT-计划设计

Prescription

Constraints | Sensitivities

Structure	Cost Function	On/Off	Status	Reference Dose (cGy)	Multicriterial	Isoconstraint	Isoeffect	Relative Impact
ptv	Target EUD	☒	On			6100.0	0.0	
	Quadratic Overdose	☒	On	6400.0		50.0	0.0	
	Quadratic Underdose	☒	On	5900.0		40.0	0.0	
	Underdose DVH	☒	Off	6000.0		99.00	0.00	
	Maximum Dose	☒	On			6450.0	0.0	
Cord4	Serial	☒	On		☐	4400.0	0.0	
	Maximum Dose	☒	On			4500.0	0.0	
heart	Parallel	☒	On	3000.0	☐	50.00	0.00	
	Parallel	☒	On	4000.0	☐	30.00	0.00	
lung	Parallel	☒	On	500.0	☐	60.00	0.00	
	Parallel	☒	On	3000.0	☐	35.00	0.00	
	Parallel	☒	On	2000.0	☐	20.00	0.00	
	Parallel	☒	On	1000.0	☐	20.00	0.00	
patient	Quadratic Overdose	☒	On	5800.0		50.0	0.0	
	Quadratic Overdose	☒	On	4800.0		50.0	0.0	
	Quadratic Overdose	☒	On	4000.0		50.0	0.0	

<click to add a new structure>

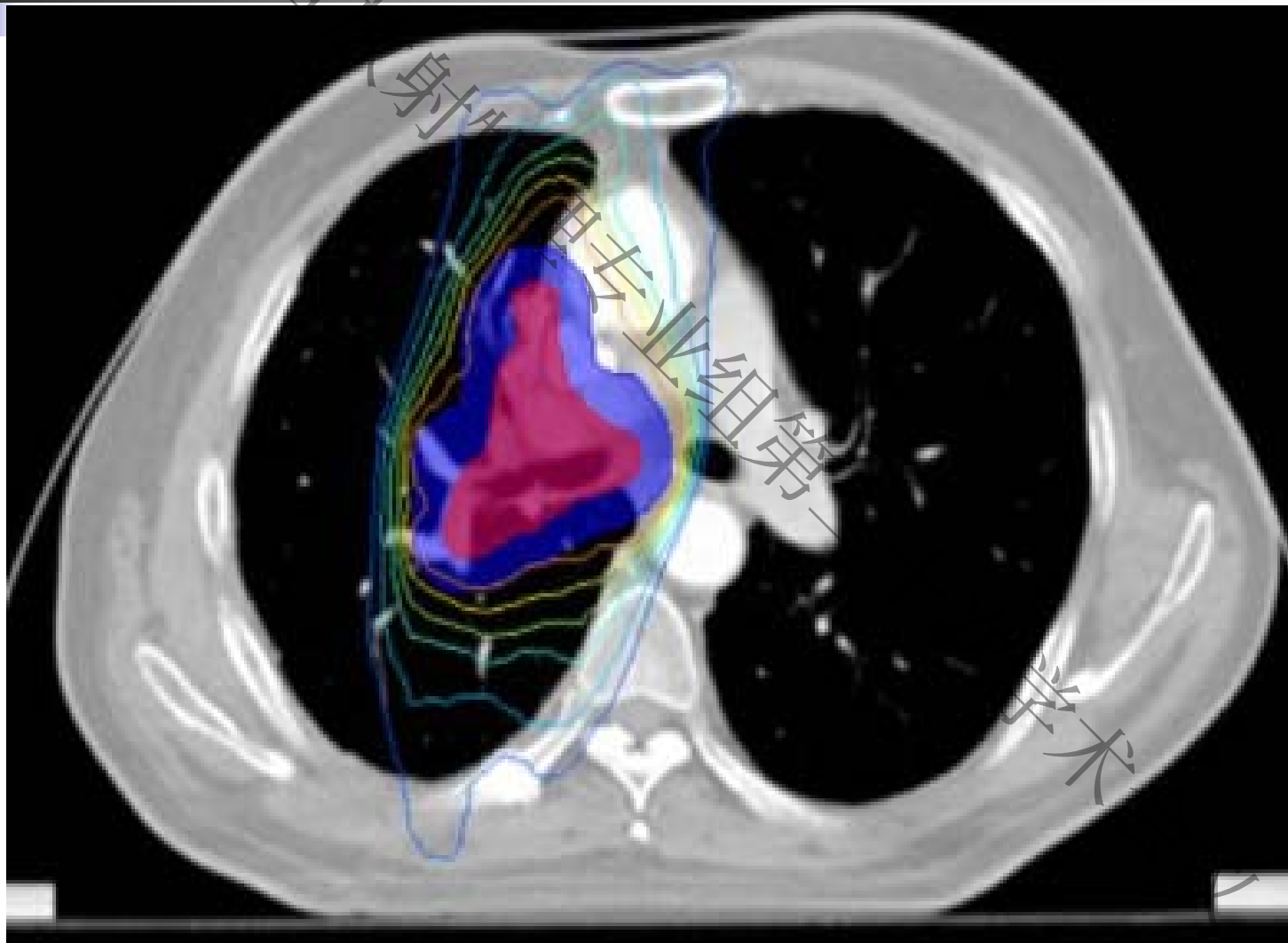
Optimization mode:

☒ Constrained (Normal Tissue Priority)

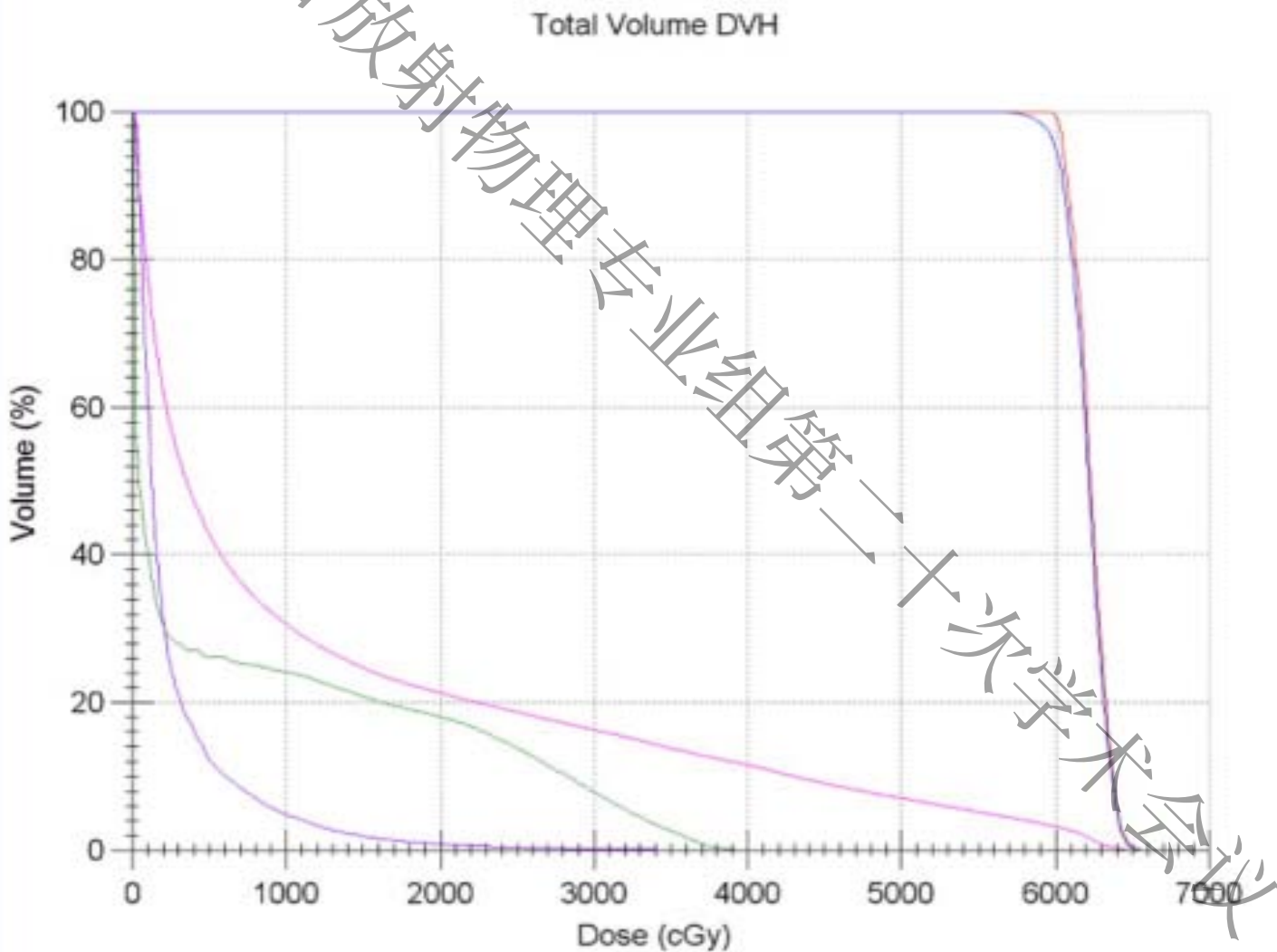
☐ Pareto (Target Volume Priority)

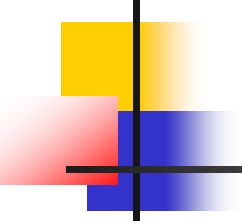
Print OK Cancel Apply

VMAT-计划设计



VMAT-计划设计

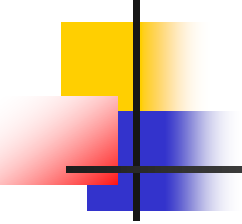




VMAT-计划设计

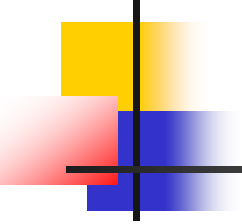
- **47例VMAT计划**，其中食管癌**23例**，宫颈癌**9例**，鼻咽癌**3例**，肺癌**9例**，其它**3例**
- **14例食管癌患者**，**IMRT、IMAT、VMAT计划比较**
- **21例患者**，食管癌患者**14例**，肺癌**2例**，直肠癌**2例**，其它**3例**

IMRT、VMAT计划比较
验证结果比较



VMAT-计划设计

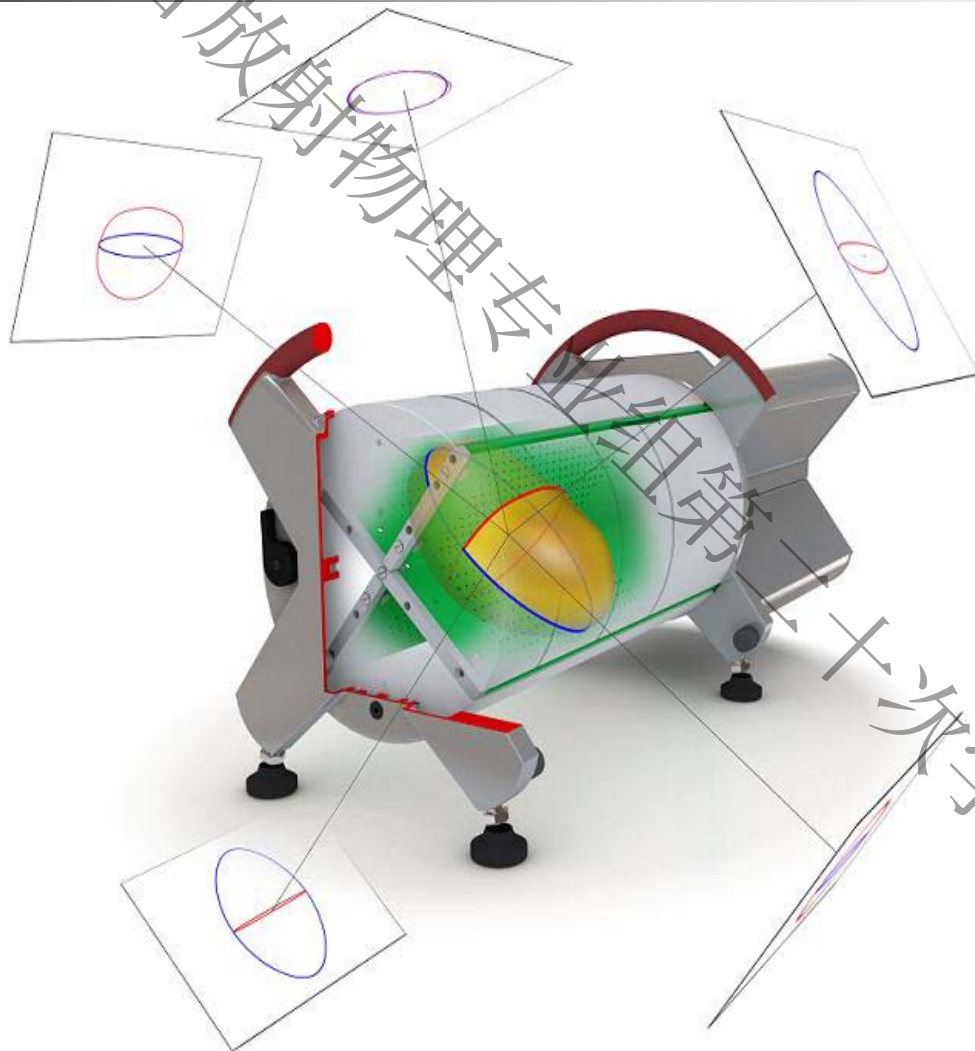
- 治疗时间: **32.7%**
- MU数: **82.4%**
- 心脏: 平均剂量 **110.5%**
V30 118.4%
V40 124.5%
- 脊髓: 最大值 **99.9%**

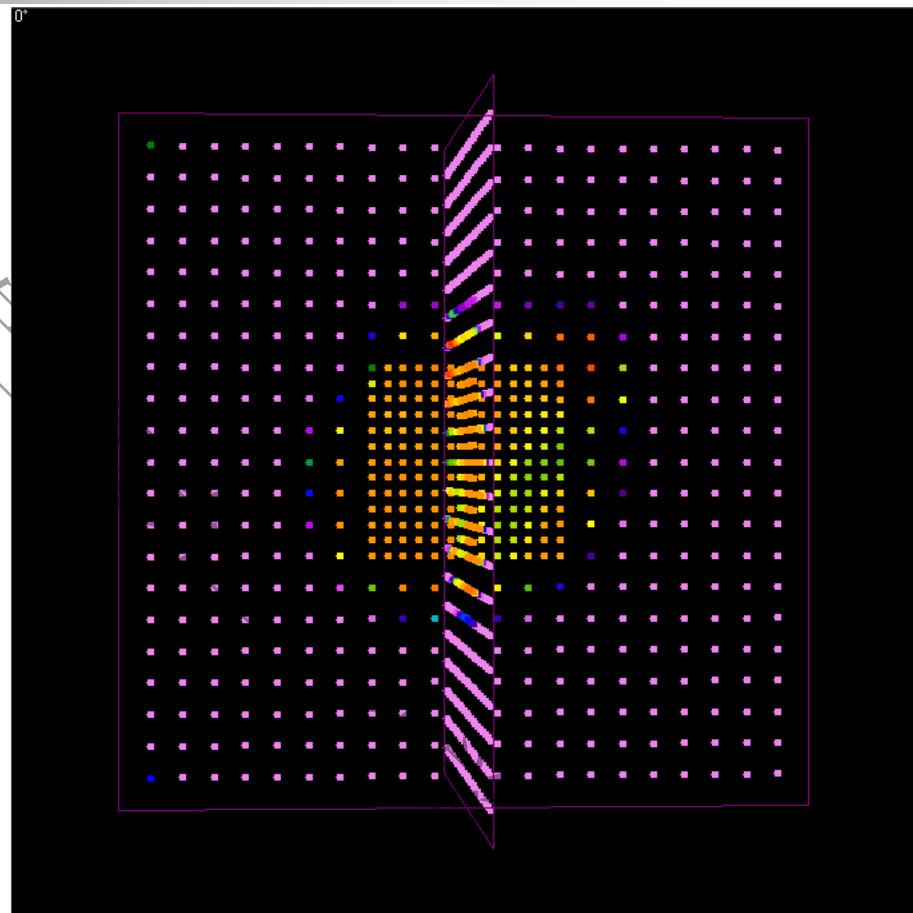
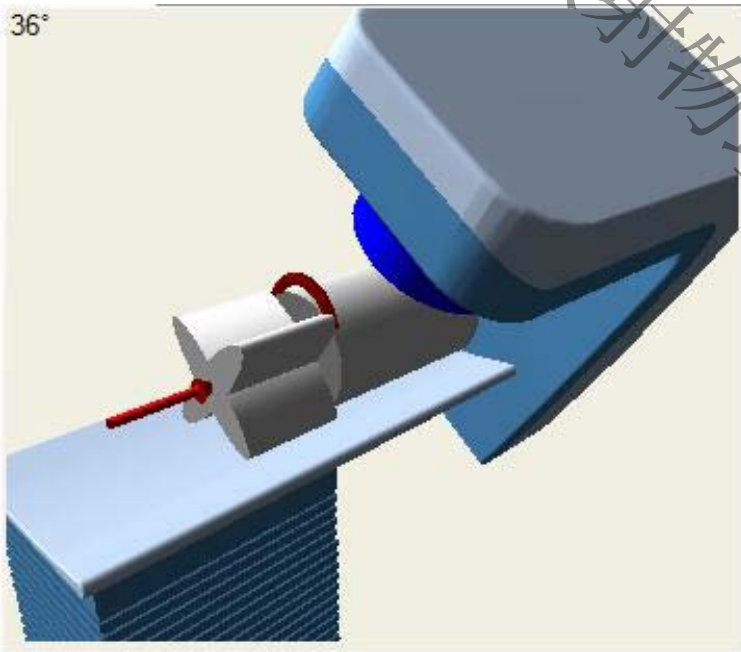


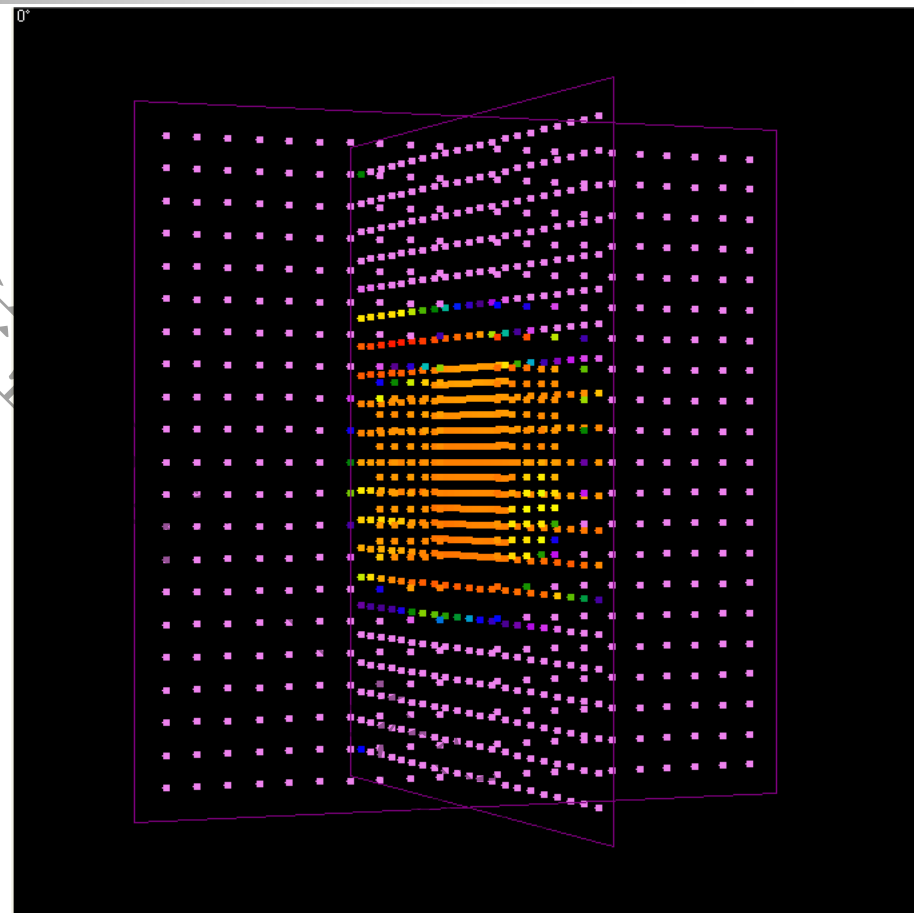
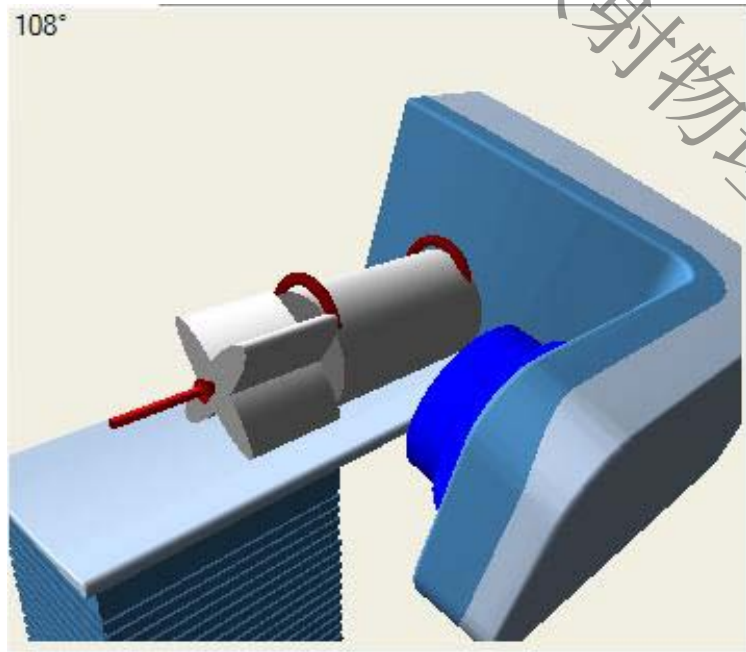
VMAT-计划设计

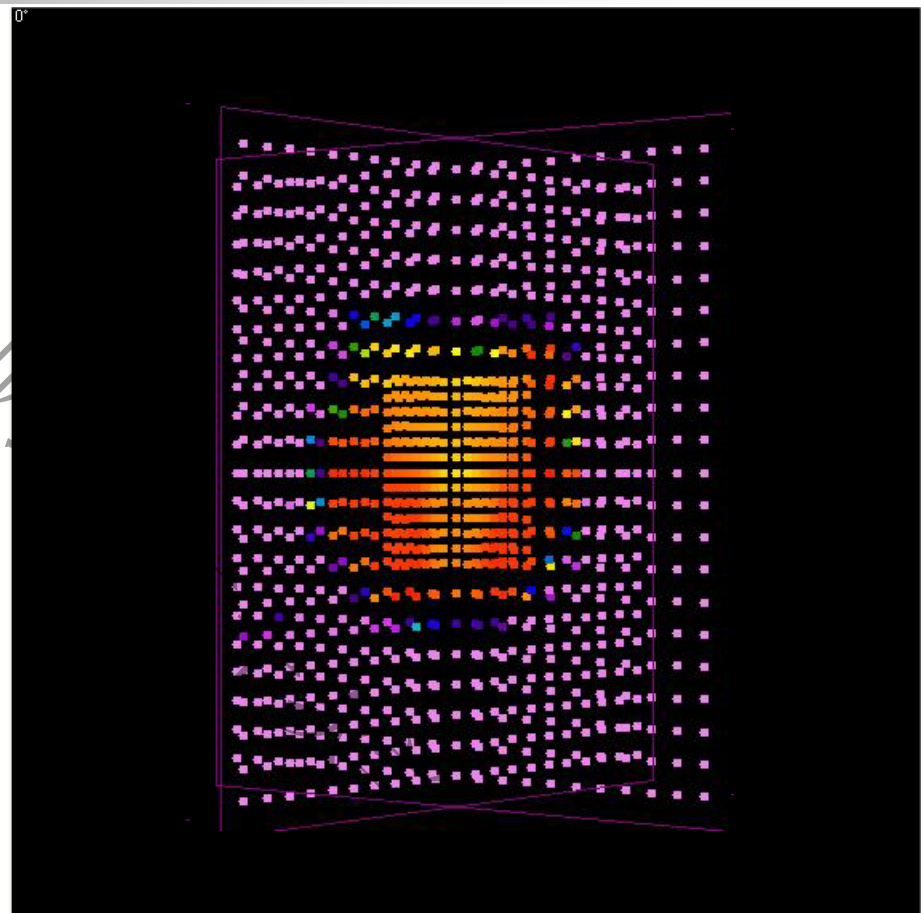
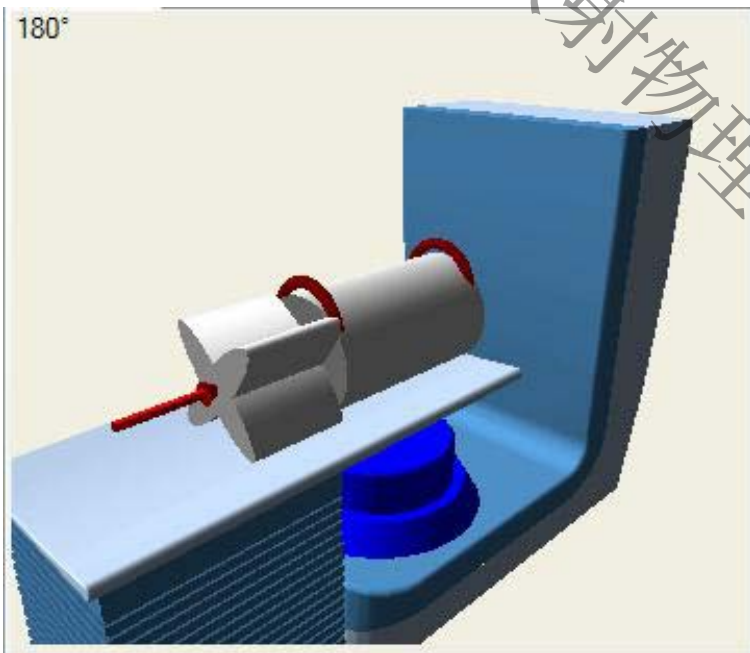
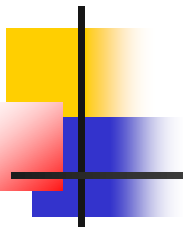
■ 双肺:	V5	101 %
	V10	94.2 %
	V15	96.2 %
	V20	94.0 %
	V25	90.5 %
	V30	90.4 %
	Vmean	98.7 %

VMAT-计划验证Delta4

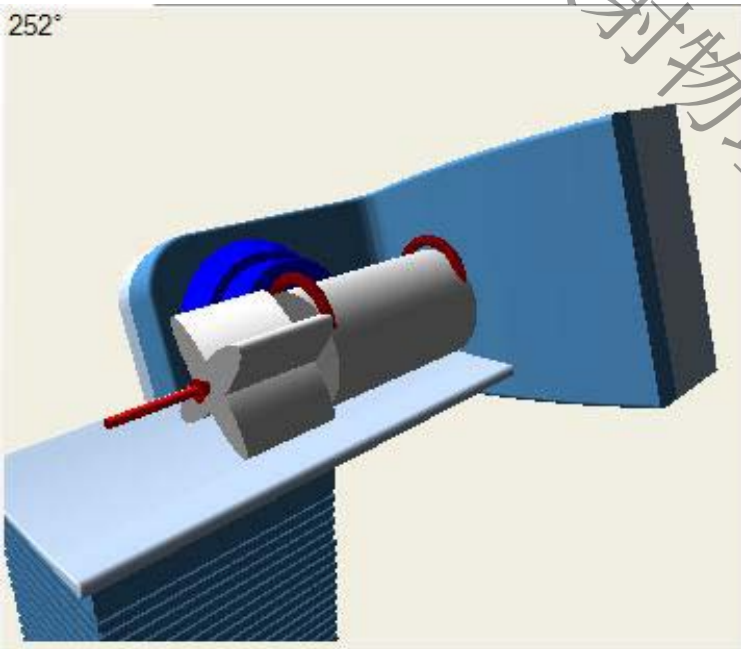




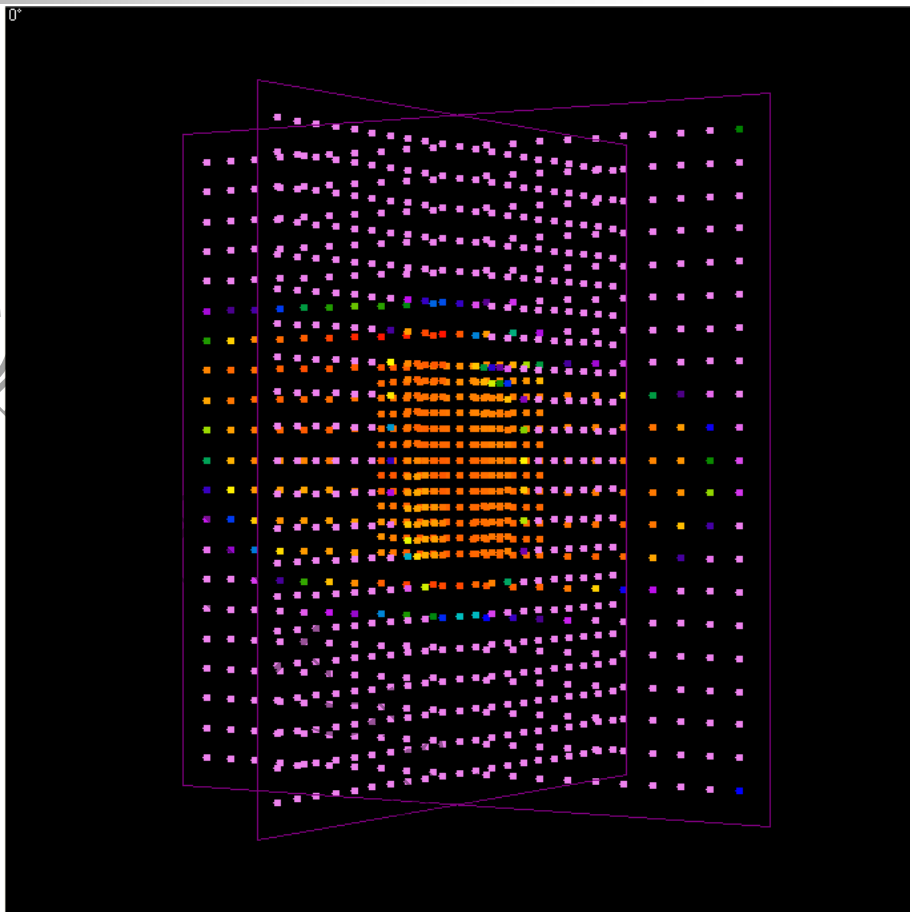


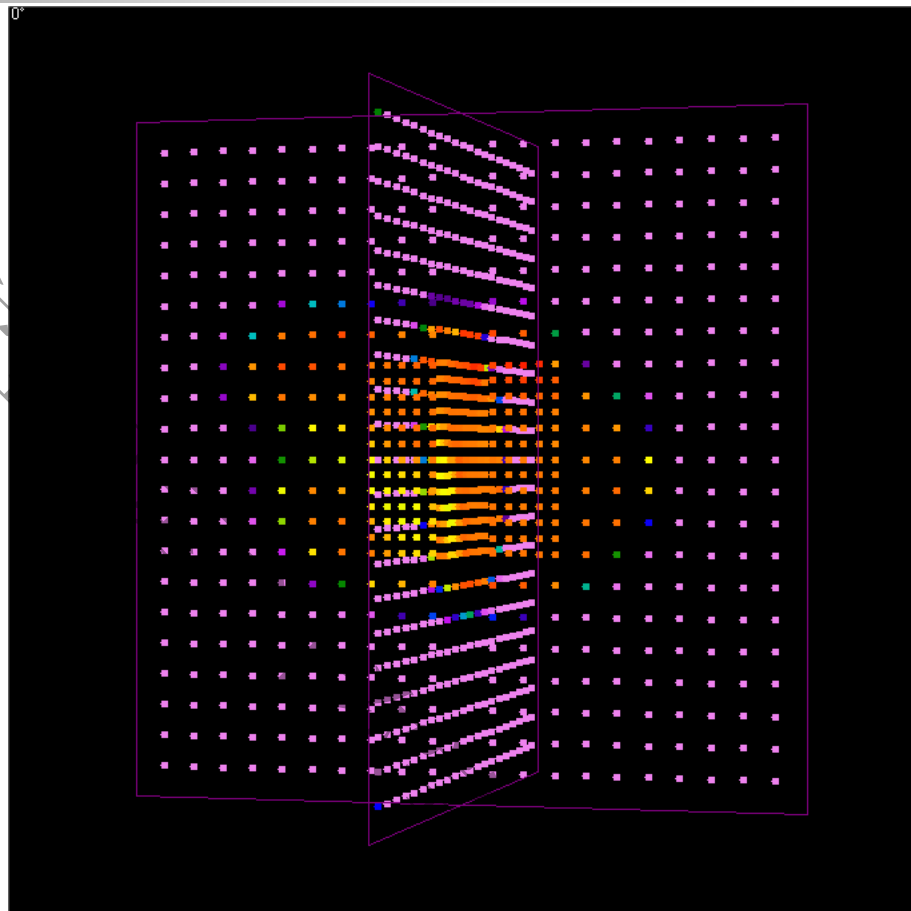
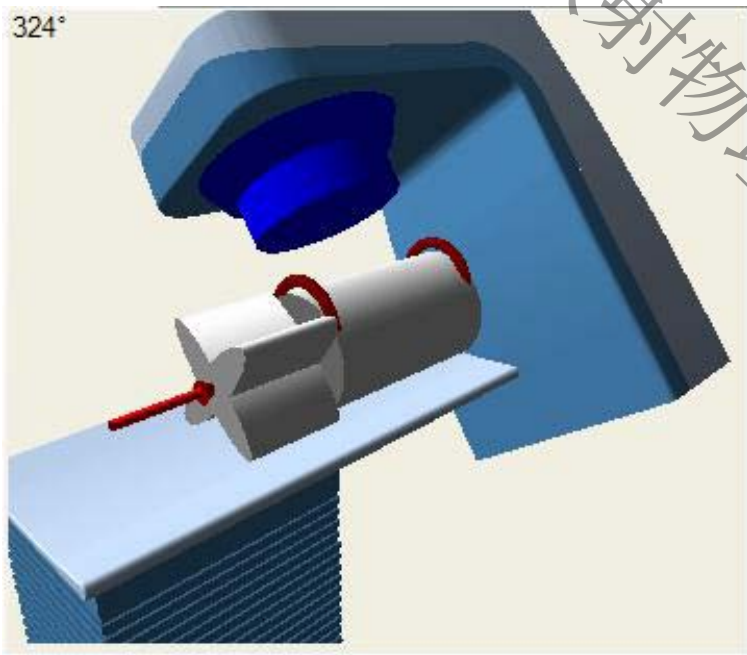


252°



0°





Reference Measurement

Information

Measurements should be done with an ion chamber in the Delta4 calibration phantom. The measured dose will later be used during absolute detector calibrations.

☒ Enter the reading and all factors.

Delta4 calculates the dose: $D_{w,Q} = M_Q * N_{D,w,Q_0} * k_{Q,Q_0}$

Radiation Device: 2343

Parameter	Photon 6 MV
k_{elec}	1.000
k_{pol}	1.000
k_s	1.000
N_{d,w,Q_0} [Gy/nC]	1.000
k_{Q,Q_0}	1.000
T_{now} [°C]	
T_{calib} [°C]	22.000
P_{now} [kPa]	
P_{calib} [kPa]	101.325
M [nC]	
Dose [Gy]	

Machine Calibration

Reference Depth 10 cm

Reference SSD 100 cm

Expected Dose in Delta4

Calib Phantom .. [Gy/100MU] 1.4600

OK

Cancel

Help

Relative Detector Calibration

Detector Board(s)



D0031 0201



Settings

Rad Dev: 2349

Energy: Photon 6 MV

Field Size: 260x260 mm

SSD: 950 mm

Detector

Status:

Signal:

Factor:

Acc. Dose:

Measurements

☒ A - Center

☐ B - 10 mm up

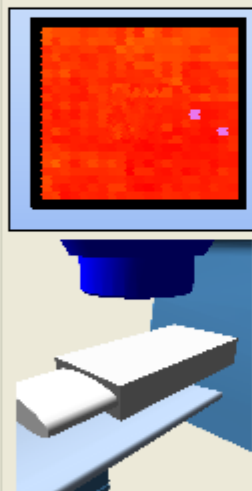
☐ C - 10 mm right

☐ D - 90 mm down

☐ E - 90 mm up

☐ F - 90 mm left

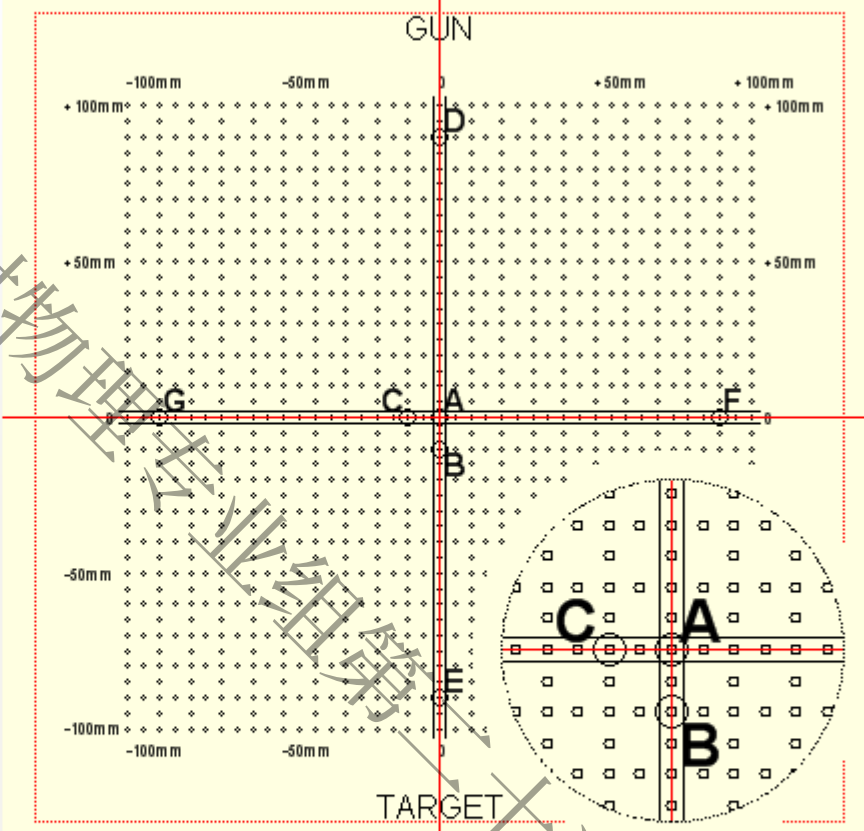
☐ G - 90 mm right



Phantom Location

Detectors

Detector Signal



OK

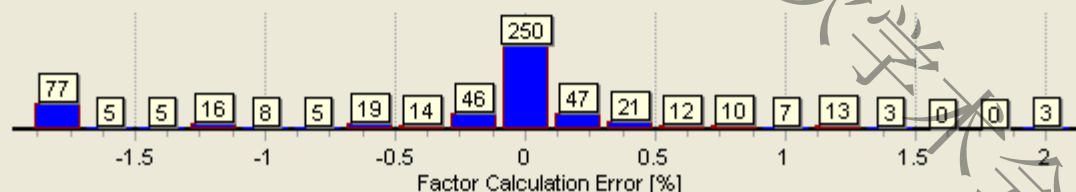
Cancel

Help

Measure

Clipboard

Summary



Find Normalization Detector

Relative Detector Calibration

Detector Board(s)



D0032 0414



D0032 0413

Settings

Rad Dev: 2349

Energy: Photon 6 MV

Field Size: 260x260 mm

SSD: 950 mm

Detector

Status:

Signal:

Factor:

Acc. Dose:

Measurements

☒ A - Center

☐ B - 10 mm up

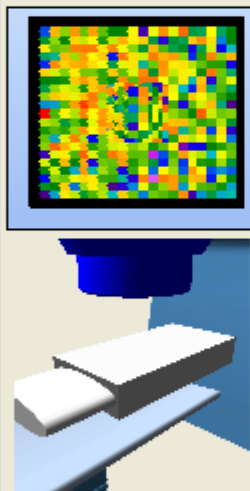
☐ C - 10 mm right

☐ D - 90 mm down

☐ E - 90 mm up

☐ F - 90 mm left

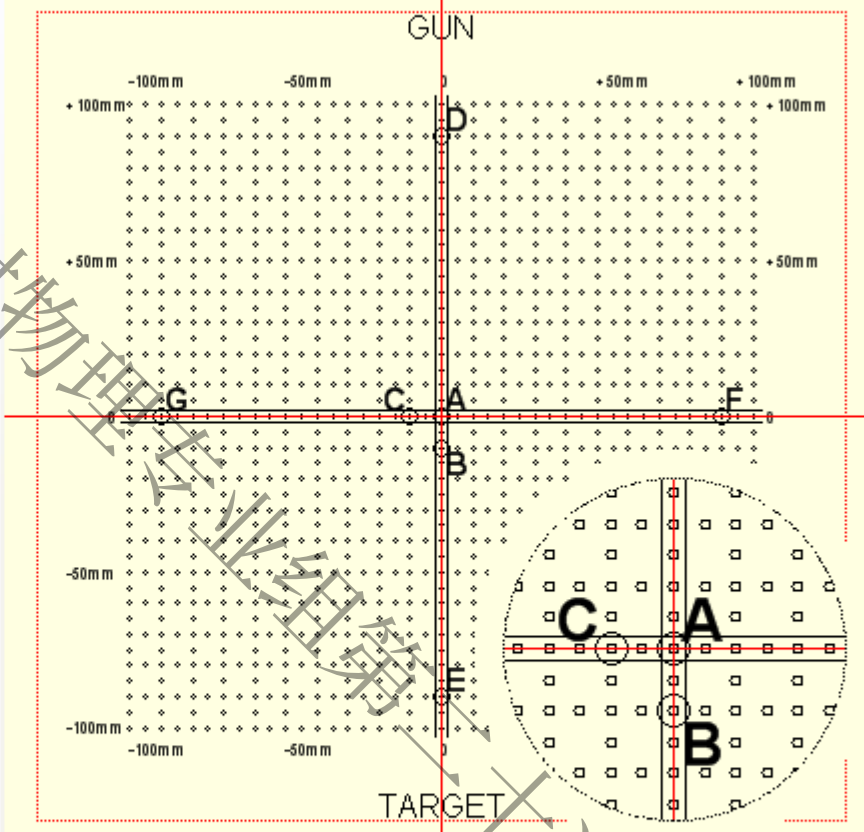
☐ G - 90 mm right



Phantom Location

Detectors

Detector Signal



OK

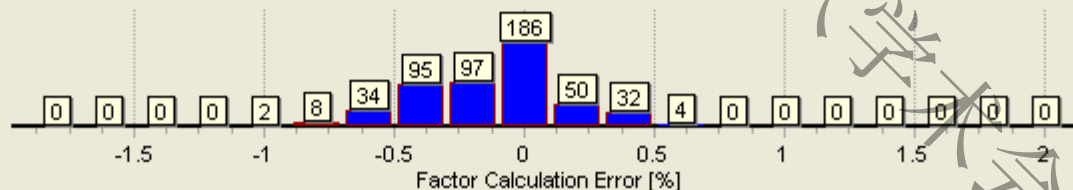
Cancel

Help

Measure

Clipboard

Summary



Find Normalization Detector

Absolute Detector Calibration



Detector Board(s)



D0031 0201



Settings

Rad Dev: 2349

Energy: Photon 6 MV

Field Size: 100 mm

SSD: 950 mm

Temp.: °C

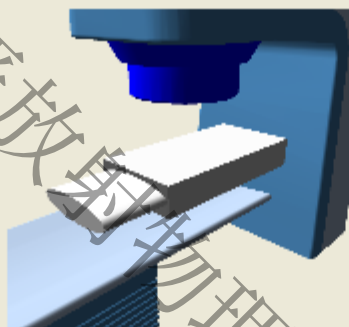
Notification

☒ Alert when the expected sensitivity drop exceeds 2.0 %

Calibrated Energies

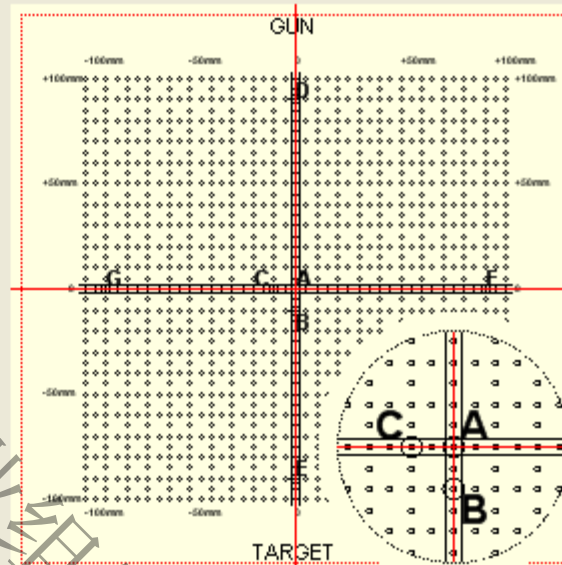
Energy		Factor	Temp.		Factor	Temp.
Photon 6 MV	2011-8-11 0:22:14	2.187E-8	20.0 °C			

Measurement



Dose already measured with ion chamber: 0.00000 Gy

☐ Overcompensation: 10 %



OK

Cancel

Help

Measure

Last relative calibration: 2011-10-9 16:35:31 Recalibrate before continuing?

Absolute Detector Calibration



Detector Board(s)



D0032 0414



D0032 0413

Settings

Rad Dev:

2349

Energy:

Photon 6 MV

Field Size:

100

mm

SSD:

950

mm

Temp.:

°C

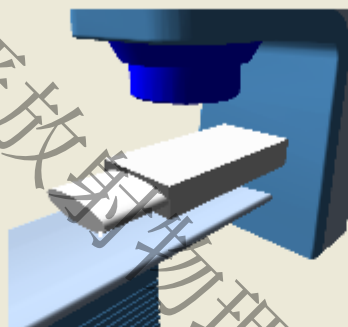
Notification

☒ Alert when the expected sensitivity drop exceeds 2.0 %

Calibrated Energies

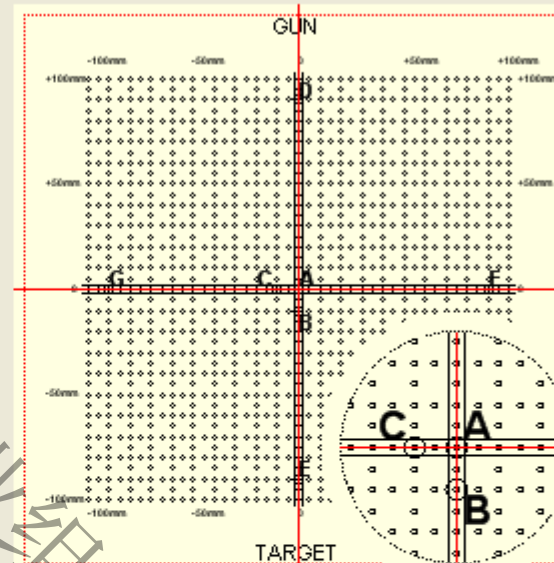
Energy		Factor	Temp.		Factor	Temp.
Photon 6 MV	2011-8-11 1:01:56	2.173E-8	20.0 °C	2011-8-11 1:01:56	2.173E-8	20.0 °C

Measurement



Dose already measured with ion chamber: 0.00000 Gy

☐ Overcompensation: 10 %



OK

Cancel

Help

Measure

Last relative calibration: 2011-8-11 0:59:10 Recalibrate before continuing?

Directional Detector Calibration

Detector Board(s)



D0031 0201



Settings

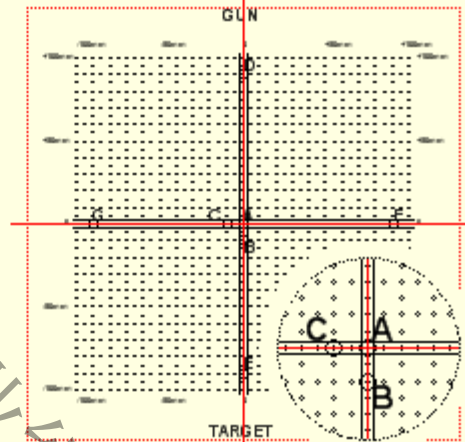
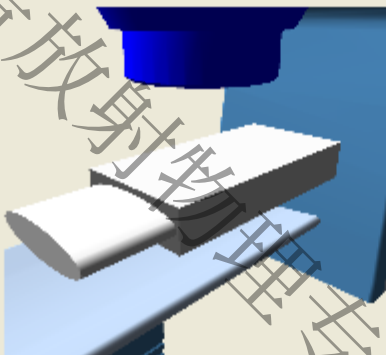
Rad Dev: 2349

Energy: Photon 6 MV

Field Size: 26x26 cm

SSD: 950 mm

Measurement



OK

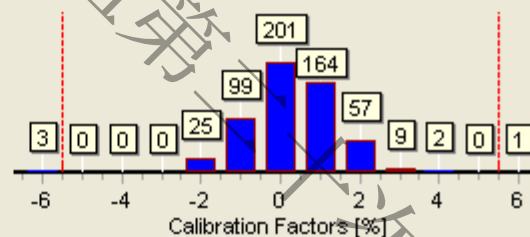
Cancel

Help

Measure

Calibrated Energies

Energy	Orientation	Measured
Photon 6 MV	Normal at pos A	2011-10-9 17:29
	Upside Down at pos B	by admin



Last relative calibration: 2011-10-9 16:35:31 Recalibrate before continuing?

Directional Detector Calibration

Detector Board(s)



D0032 0414



D0032 0413

Settings

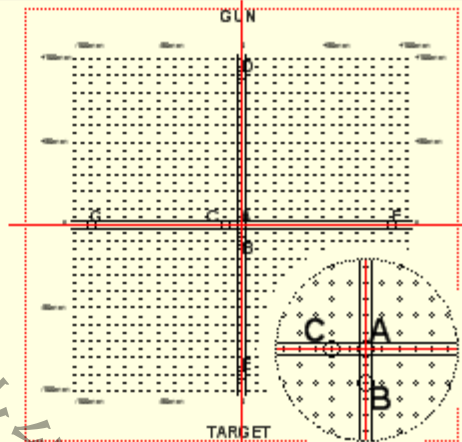
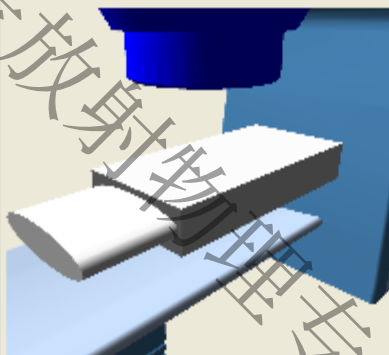
Rad Dev: 2349

Energy: Photon 6 MV

Field Size: 26x26 cm

SSD: 950 mm

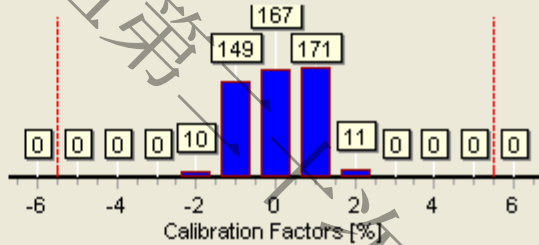
Measurement



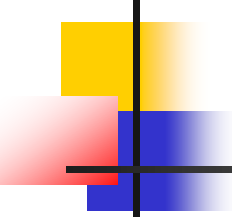
OK
Cancel
Help
Measure

Calibrated Energies

Energy	Orientation	Measured
Photon 6 MV	Normal at pos A	2011-8-11 1:07
	Upside Down at pos B	by admin



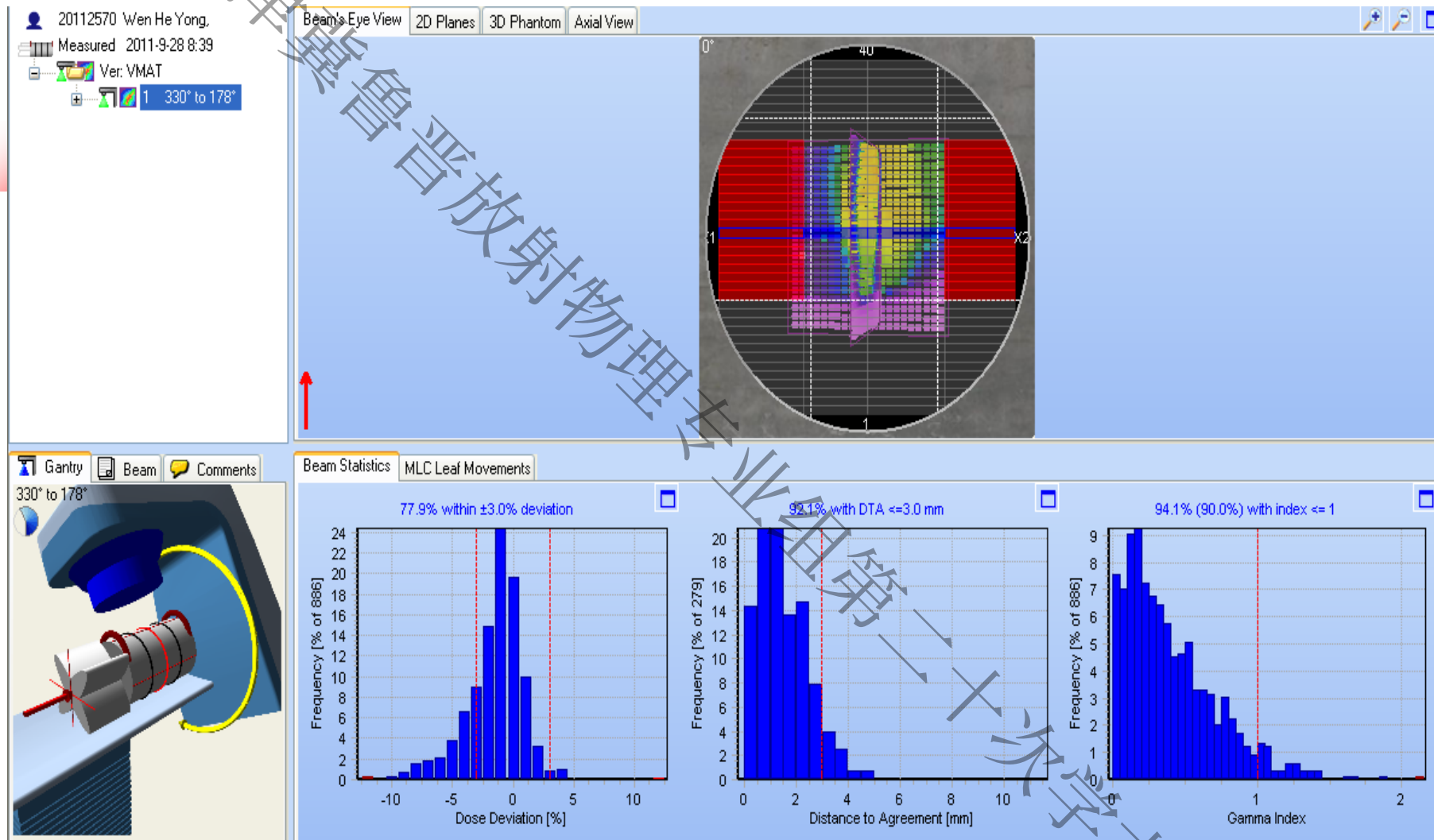
Last relative calibration: 2011-8-11 0:59:10 Recalibrate before continuing?



模体计划的生成

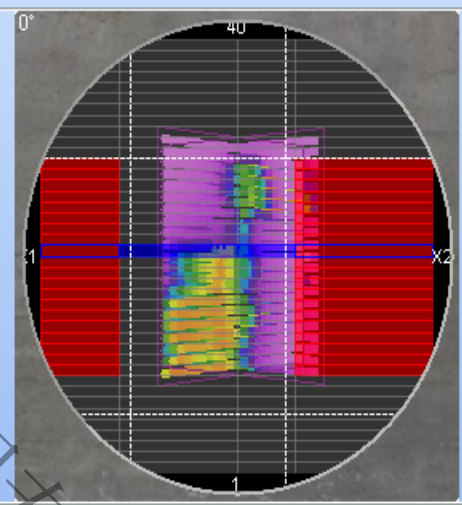
Delta⁴模体建立及计划生成:

- Delta⁴安装盘带有其模体的DICOM CT影像信息，根据CT扫描层厚不同，提供了多个DICOM模体文件，根据本地CT扫描层厚，载入相应的模体。
- 治疗计划带入Delta⁴模体中，优化参数与原计划完全相同，重新计算剂量



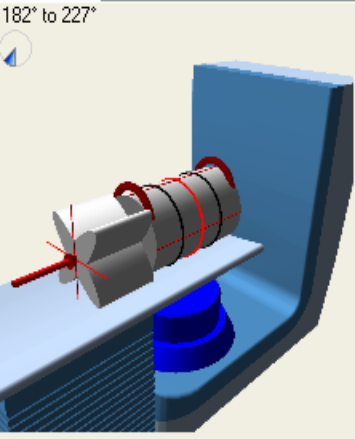
20112804 Zhang Wu Cheng,
Measured 2011-10-19 8:39
Ver: VMAT
1 182° to 227°
2 350° to 178°

Beam's Eye View 2D Planes 3D Phantom Axial View



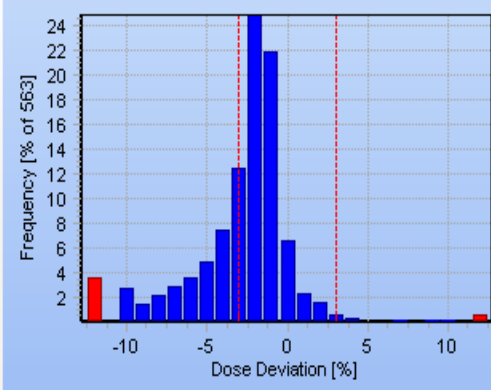
Gantry Beam Comments

182° to 227°

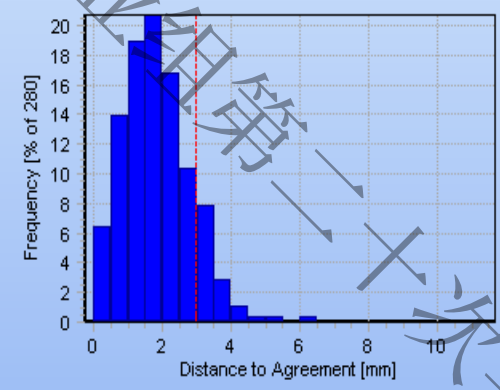


Beam Statistics MLC Leaf Movements

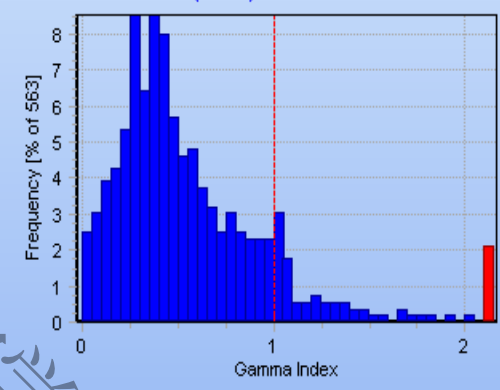
63.9% within $\pm 3.0\%$ deviation



87.1% with DTA ≤ 3.0 mm

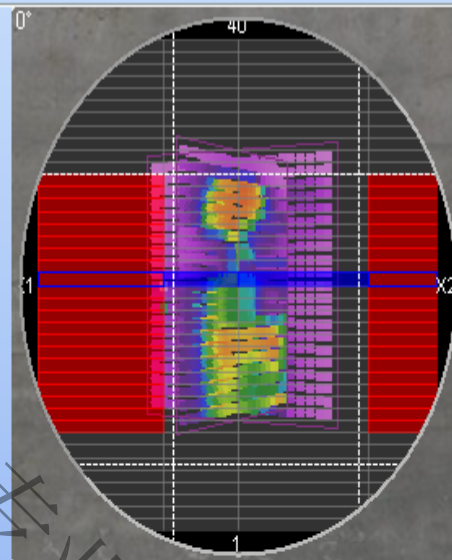


87.4% (90.0%) with index ≤ 1



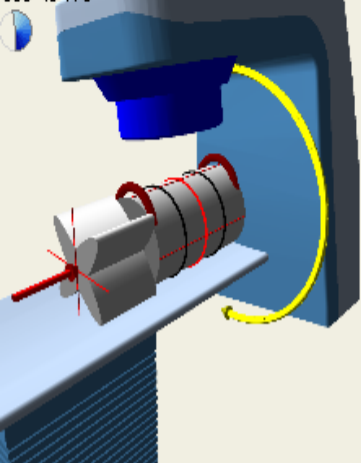
20112804 Zhang Wu Cheng,
Measured 2011-10-19 8:39
Ver: VMAT
1 182° to 227°
2 350° to 178°

Beam's Eye View 2D Planes 3D Phantom Axial View



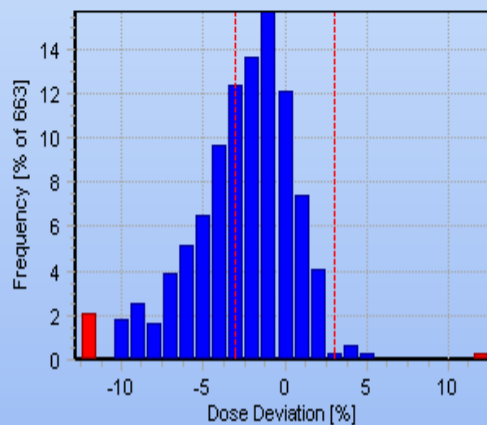
Gantry Beam Comments

350° to 178°

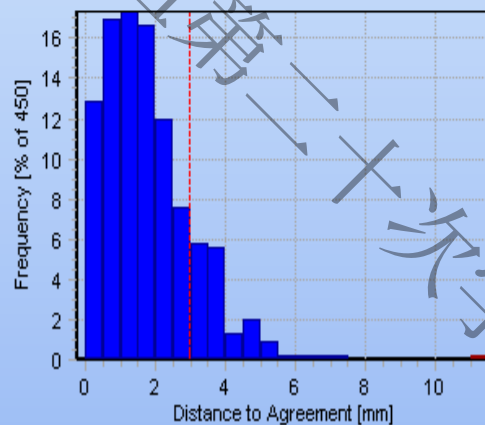


Beam Statistics MLC Leaf Movements

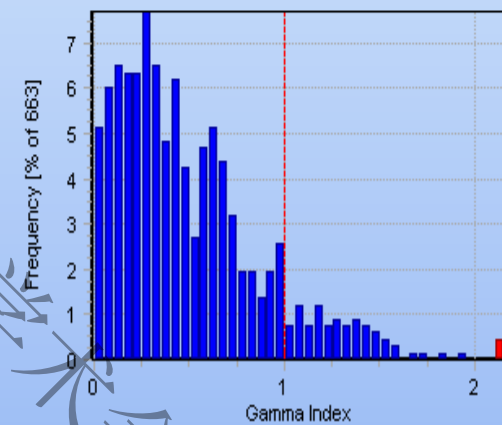
59.3% within $\pm 3.0\%$ deviation



83.3% with DTA ≤ 3.0 mm



89.6% (90.0%) with index ≤ 1



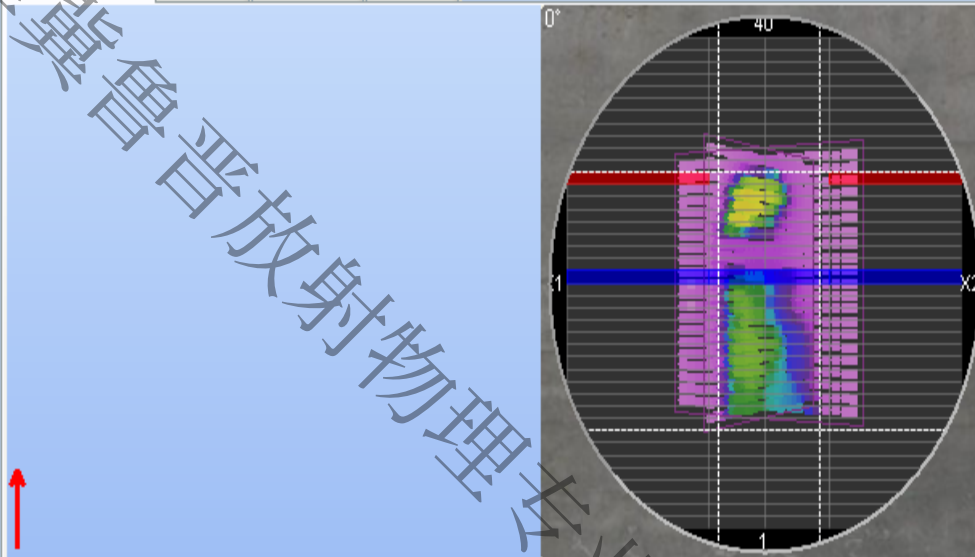
20112804 Zhang Wu Cheng,
Measured 2011-10-19 8:25

Beam's Eye View 2D Planes 3D Phantom Axial View

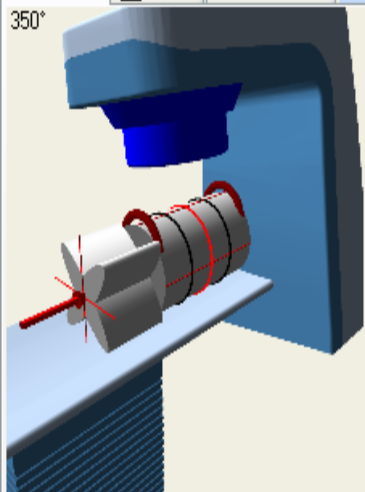


Ver: IMRT

- 1 230°
- 2 350°
- 3 60°
- 4 150°
- 5 175°

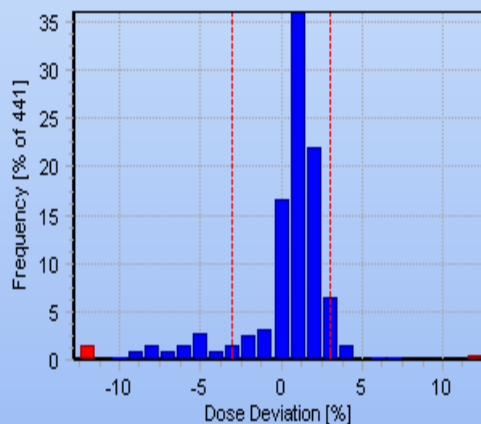


Gantry Beam Comments

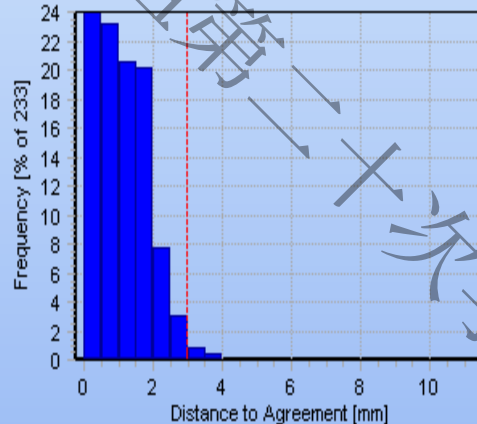


Beam Statistics MLC Leaf Movements

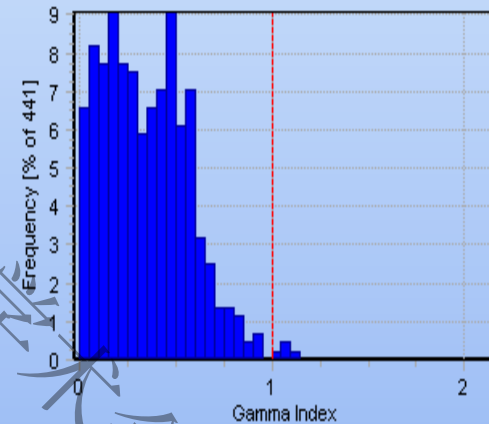
85.0% within $\pm 3.0\%$ deviation



88.7% with DTA ≤ 3.0 mm

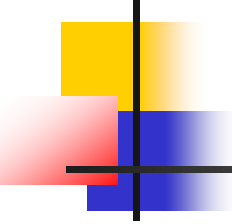


99.1% (90.0%) with index ≤ 1



1	部位	计划系统	治疗方式	DTA (%)	± 3mm/3%	± 2mm/2%	± 4mm/4%	± 5mm/5%	
2	腹部ptv 6300CGY	monaco	VMAT	98.9	99.1	89.1	99.7	99.7	180° 至 60°
3	右肺 6000CGY	monaco	VMAT	98.9	98.9	89.5	99.8	99.8	180° 至 70°
4	食管、右肺6000CGY	monaco	VMAT	98.9	99.3	93.8	99.6	99.8	180° 至 40°
5	腹部6000CGY	monaco	VMAT	95.3	97.7	88.5	99.7	99.8	
6	NPC 5000CGY	monaco	VMAT (两程)	92.7		78.5	97.9	98.7	182° 至 178°
7	2000CGY			91.6		82	98.1	99.3	182° 至 178°
8	腹部 6000CGY	monaco	VMAT	97.5	99	89.9	99.8	99.8	300° 至 160°
9	食管、右肺 5000CGY	monaco	VMAT	95.1	97.2	88.2	99.5	99.7	190° 至 70°
10	右肺 5000CGY	monaco	VMAT	95.3	98.6	94.5	99.6	99.7	180° 至 20°
11	右肺 6000CGY	monaco	VMAT	97.5	96.5	88.7	98.6	99.3	180° 至 40°

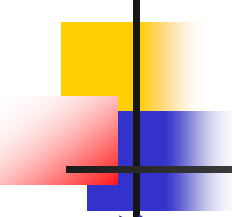
1	治疗方式	DTA≤3mm	DTA比(%)	Delta4通过率(±3mm/3%)	±2mm/2%	
2	VMAT	91.50%	92.80%	92.60%	93.50%	77.80%
3	IMRT	98.6%(97.6、99.4、99.2、99.3、94.6)		99.0%(99.2、99.8、99.0、98.5、99.0)	91.90%	84.70%
4	VMAT	94.40%	95.90%	92.50%	93.40%	79.20%
5	IMRT	98.4%(97.0、99.5、98.1、97.2、97.9)		99%(98.9、99.2、99.7、96.2、97.3)	93.70%	84.50%
6	VMAT	93.90%	105.40%	91.80%	99.00%	74.20%
7	IMRT	89.1%(88.7、99.2、98.4、94.3、98.1)		92.7%(92.6、99.3、98.7、96.2、98.1)	79.90%	92.90%
8	VMAT	96.30%	99.10%	93.70%	96.10%	80.10%
9	IMRT	97.2%(99.1、98.3、97.5、100、91)		97.5%(97.2、99.1、97.9、98.8、93.6)	84.10%	95.20%
10	VMAT	96%	107%	91.80%	103.60%	80.10%
11	IMRT	89.7%(96.8、95.6、95.3、92.2、90.8)		88.6%(98.5、95.4、93.7、85.5、92.5)	72.00%	111.30%
12	VMAT	97.30%	103.00%	92.80%	102.30%	80.30%
13	IMRT	94.4%(96.4、95.2、93.4、90.4、95.3)		90.1%(99.4、96.1、94.1、83.9、98.6)	71.40%	112.50%
14	VMAT	97.5%(76.7、96.5)	100.20%	92.5%(76.7、94.4)	109.30%	78.30%
15	IMRT	97.3%(90.5、93.4、93.4、92.9、82.6)		84.6%(96.5、75.5、89、94、92.9)	84.90%	92.20%
16	VMAT	98.30%	102.30%	97.30%	98.60%	86.10%
17	IMRT	96.1%(93.1、88.6、94.5、98.9、95.3)		98.7%(98、98.5、97.7、99.5、96.3)	90.90%	94.70%



VMAT-计划验证Delta4

通过率比较:

- DTA: 95.10%
- 3%/3mm: 91.8%
- 4%/4mm: 97.7%
- 5%/5mm: 99.2%
- 2%/2mm: 84.2%



体会与思考

将“正确”的剂量照射在正确的位置

- 设备
- 计划
- QA%QC?

二维矩阵：高效快速 问题？

EPID 精度？

三维方法：Delta4 and Arccheck 均匀模体？

Compass 在线（非均匀组织） 算法？

3DVH QA？

MC？

- 患者？

谢谢!

冀医四院

