容积旋转调强放疗系统的验收调试及质量保证

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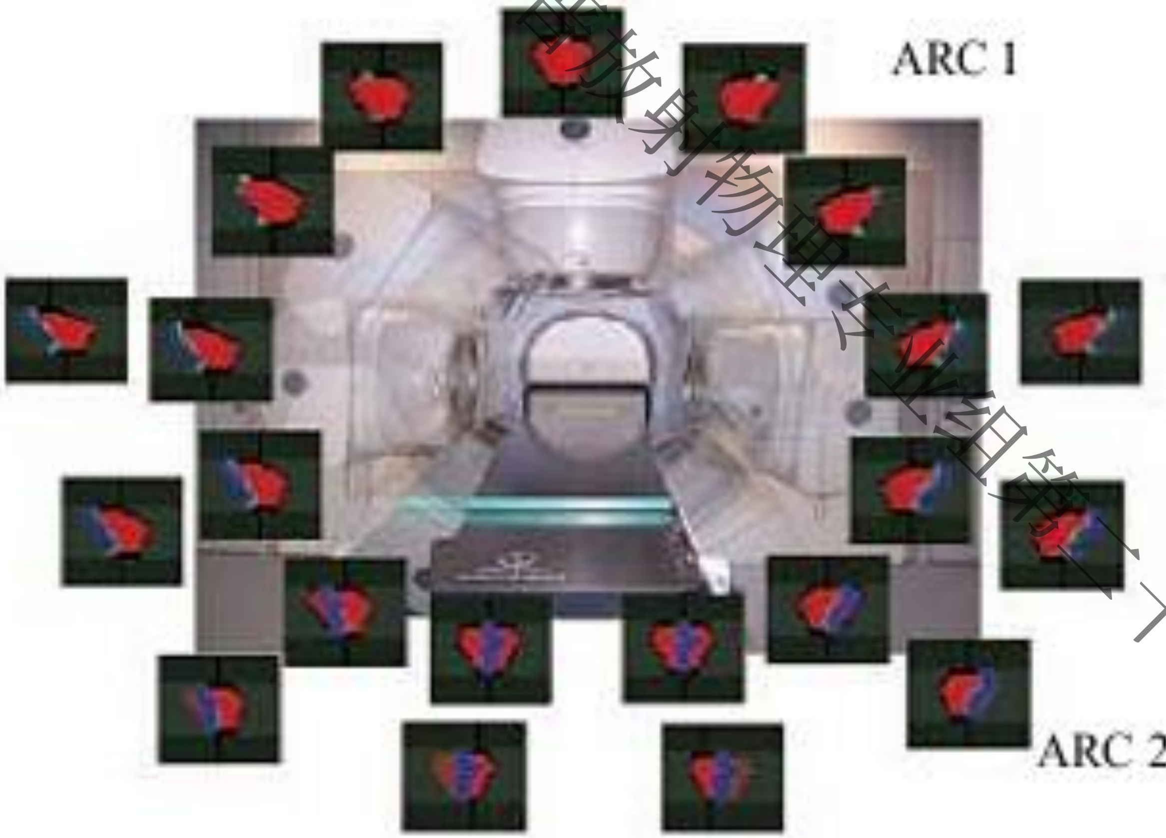
放射治疗科

报告内容

- 容积旋转调强（VMAT）简介
- VMAT系统验收测试
- VMAT系统质量保证

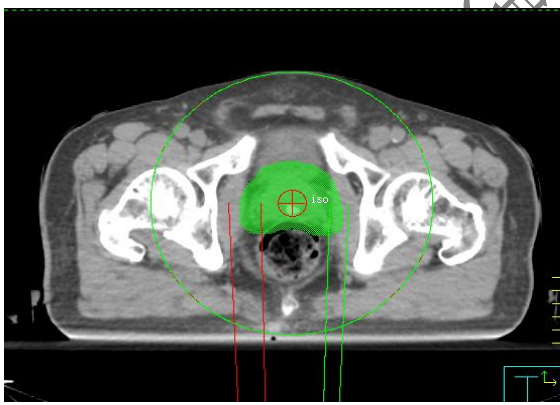
容积旋转调强（VMAT）



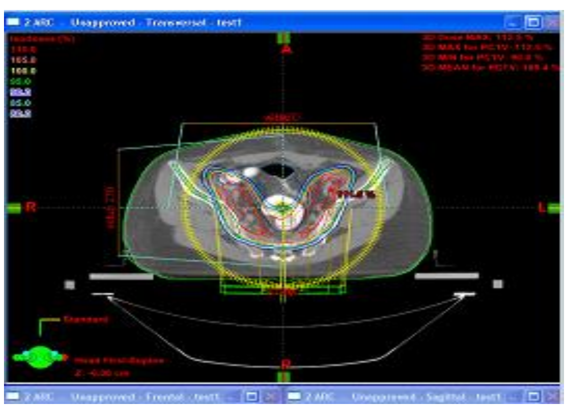
- 机架旋转，转速可变
- MLC叶片连续运动
- 射线连续照射，剂量率可调

天津肿瘤医院RapidArc系统

- 计划设计



Pinnacle^3 SmartArc



Varian Eclipse V10.0

- 治疗实施

Varian Clinac iX

Varian Clinac iX

- Variable dose rate
  - 0-600 MU/min
- Variable gantry speed
  - 0.1-4.8 degree/s
- Variable MLC speed
  - 0-2.5 cm/s

RapidArc验收测试

RapidArc

IMRT

常规技术+适形

Linac (Mechanical、radiation、safety)

RapidArc验收测试

- 针对机架转动、叶片运动和剂量率变化的测试
  - 旋转过程中MLC位置变化
  - 测试剂量率与机架运动速度的关系
  - 测试剂量率与叶片运动速度的关系

RapidArc验收测试

- 参考文档

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ELSEVIER

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PHYSICS CONTRIBUTION

COMMISSIONING AND QUALITY ASSURANCE OF RAPIDARC RADIOTHERAPY DELIVERY SYSTEM

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Purpose: The Varian RapidArc is a system for intensity-modulated radiotherapy (IMRT) treatment planning and delivery. RapidArc incorporates capabilities such as variable dose-rate, variable gantry speed, and accurate and fast dynamic multileaf collimators (DMLC), to optimize dose conformality, delivery efficiency, accuracy and reliability. We developed RapidArc system commissioning and quality assurance (QA) procedures.
Methods and Materials: Tests have been designed that evaluate RapidArc performance in a stepwise manner. First, the accuracy of DMLC position during gantry rotation is examined. Second, the ability to vary and control the dose-rate and gantry speed is evaluated. Third, the combined use of variable DMLC speed and dose-rate is studied.
Results: Adapting the picket fence test for RapidArc, we compared the patterns obtained with stationary gantry and in RapidArc mode, and showed that the effect of gantry rotation on leaf accuracy was minimal (≤0.2 mm). We then combine different dose-rates (111–600 MU/min), gantry speeds (5.5–4.3°/s), and gantry range ($\Delta\theta$ = 90–12.9°) to give the same dose to seven parts of a film. When normalized to a corresponding open field (to account for flatness and asymmetry), the dose of the seven portions show good agreement, with a mean deviation of 0.7%. In assessing DMLC speed (0.46, 0.92, 1.84, and 2.76 cm/s) during RapidArc, the analysis of designed radiation pattern indicates good agreement, with a mean deviation of 0.4%.
Conclusions: The results of these tests provide strong evidence that DMLC movement, variable dose-rates and gantry speeds can be precisely controlled during RapidArc. © 2008 Elsevier Inc.

RapidArc, Commissioning, QA.

INTRODUCTION

Intensity-modulated radiotherapy (IMRT) has been established as accurate, reliable, and efficient in delivering conformal radiotherapy (1, 2). By maximizing tumor dose while sparing normal tissues, IMRT can improve the efficacy of radiotherapy. Delivery of IMRT is possible using different methods: for example, in slice-by-slice rotational therapy using binary collimation (3, 4), or computer-controlled multileaf collimators (MLC) in static (SMLC for segmental MLC) or dynamic (DMLC or sliding window) mode (1, 5).

Another IMRT method was proposed by Yu, combining gantry rotation and aperture changes for intensity-modulated arc therapy (IMAT) (6). Clinical implementation of IMAT was initially hampered because the optimization algorithm generated plans difficult to deliver with conventional linear accelerators (linacs) and MLCs. Subsequent research led to direct aperture optimization, that takes into account the constraints of varying the aperture shape with SMLC (7–9). That development led researchers to evaluate the potential of applying direct aperture optimization to IMAT optimization, constraining the plans to be deliverable by the linac systems (10, 11). One IMAT approach involves several gantry rotations and thereby increases treatment time. Another approach, proposed by Otto as volumetric modulated arc therapy (VMAT), requires only one gantry rotation and produces dose distributions equivalent to or better than those of IMRT (12).

The IMAT or VMAT approach has a number of potential advantages (6, 12). In being able to deliver radiation from 360°, it may offer more conformal dose distributions relative to IMRT using only a limited number of fields and gantry directions. Plan optimization becomes simpler, as it obviates questions of beam number and direction. Compared with tomotherapy, the use of a cone beam improves delivery efficiency significantly. Specifically, by using a volumetric irradiation volume, VMAT is five to 15 times more efficient, in terms of treatment time and monitor units, than the slice-by-slice tomotherapy (12). Another important factor is that

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Conflict of interest: Drs. C. Clifton Ling, Yves Archambault, and Jiri Bocanek are affiliated with Varian Medical Systems.
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VARIAN
medical systems

RapidArc commissioning

PROCEDURE

RapidArc

Revision 1.0.0

Table of content

Introduction

- *Purpose*

  The purpose of this document is to provide high level description of the RapidArc QA files as well as simple instructions for using them. This document and its accompanying files are not and should not be considered as any form of recommendation from Varian on what constitutes a complete RapidArc machine QA program.

  For a discussion on RapidArc machine QA, the reader is encouraged to refer to: *Ling et al., Commissioning and Quality Assurance of RapidArc™ Radiotherapy Delivery System, Int. J. Radiation Oncology Biol. Phys., Vol. 72, No. 2, pp. 575–581, 2008*

  The RapidArc QA files described in this document are designed after the work in this paper and can be used to reproduce the similar tests.

- *Scope*

  This document and its accompanying RapidArc QA files are provided for Varian linear accelerators equipped with either the Millennium 120 MLC or the Millennium HD120 MLC and RapidArc. They are provided for the 6MV X-ray beam and a dose rate of 600MU/min. Test plans for other energies or dose rates can be obtained by importing the RapidArc QA files into Eclipse or ARIA and changing the energy or dose rate. Please refer to the RapidArc QA files description section below for more details about the files.

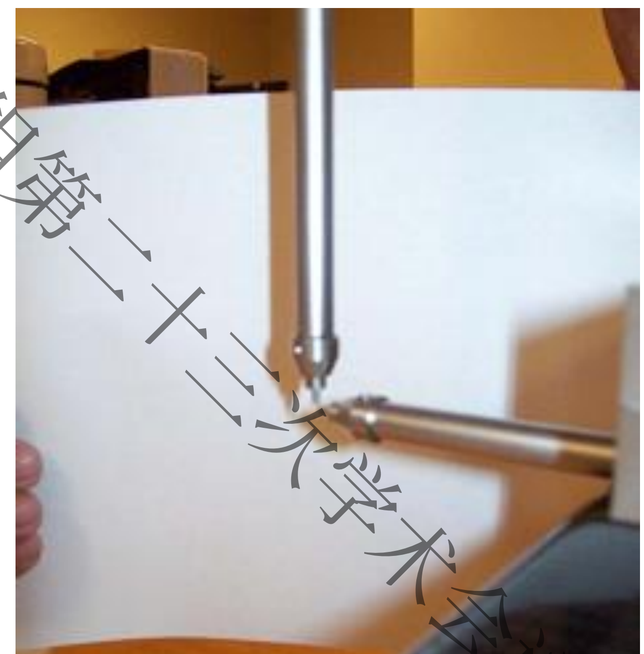
RapidArc验收测试

- General Machine Performance
  1. 机架旋转角度校准
  2. 等中心校准
  3. 旋转中的剂量准确性
  4. 机架角度对动态MLC剂量准确性影响
- Rapidarc Specific Commissioning Procedures
  1. 静态下MLC到位精度
  2. VMAT模式下MLC的到位精度
  3. 机架速度和剂量率组合测试
  4. MLC速度和剂量率组合测试

RapidArc验收测试

- General Machine Performance

  1. 机架旋转角度校准　　(0°,90°,180°,270°) < 0.5°
  2. 等中心校准　　（Gantry,Coll） ±1mm



RapidArc验收测试

- General Machine Performance

3. 旋转中的剂量准确性

指形电离室+平衡帽

➢ 测量6X、10*10cm 、Gantry 180° 以下MU的输出量为X（72MU、1800MU）

➢ 测量6X、10*10cm 、Arc 360° 以下MU的输出量为Y（72MU、1800MU）

➢计算X/Y

➢Tolerance = ±1%

MU	X/Y
72	1.002
1800	0.994

RapidArc验收测试

- General Machine Performance

 4. 机架角度对动态MLC剂量准确性影响

- ➢ 指形电离室+平衡帽
- ➢ 测量6X、4*10cm 、100MU，Dosimetry_M120.dcm 。在（0° 、90° 、180° 、270° ）的输出量分别为X0 、X90 、X180 、X270
- ➢ 计算(X-Xmean)/ Xmean
- ➢ Tolerance = ±2%

(X0-Xmean)/ Xmean	**0.8%**
(X90-Xmean)/ Xmean	**1.2%**
(X180-Xmean)/ Xmean	**1.3%**
(X270-Xmean)/ Xmean	**1.0%**

RapidArc验收测试

- Rapidarc Specific Commissioning Procedures

  1. 静态下MLC到位精度

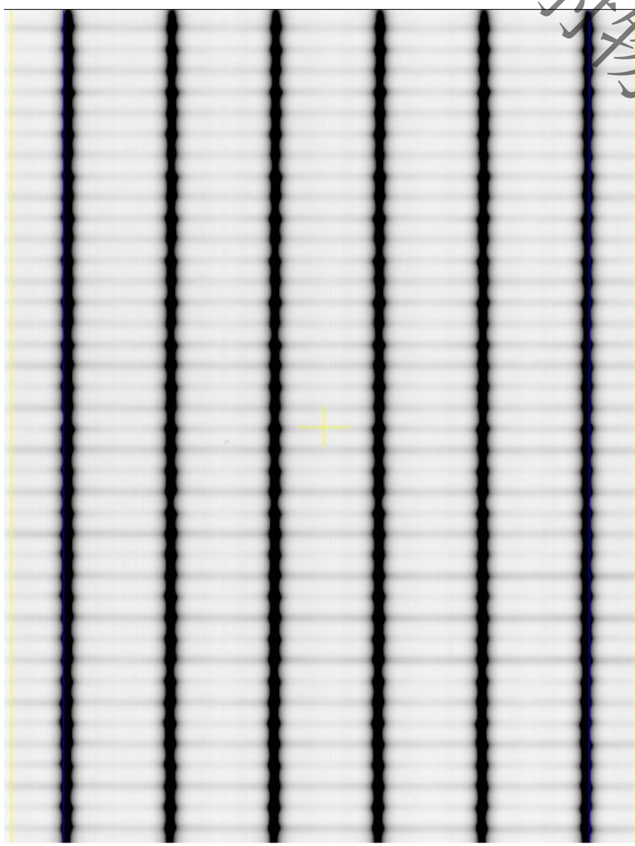
     --与VMAT模式下比较

- EPID
- 6X、PicketFenceStatic_M120.dcm，100MU,获取该计划在（0°、90°、180°、270°）的MLC到位精度
- Tolerance =±1mm

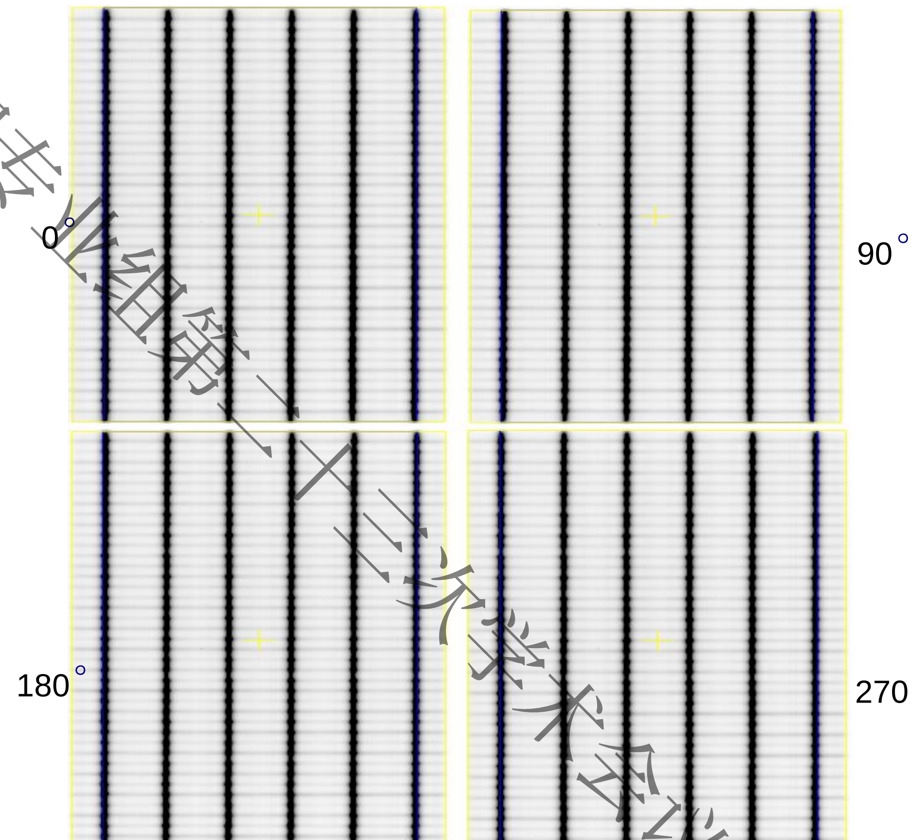
RapidArc验收测试

- RapidarcSpecific Commissioning Procedures

  1. 静态下MLC到位精度



90°



<1mm

RapidArc验收测试

- RapidarcSpecific Commissioning Procedures

  2. VMAT模式下MLC的到位精度

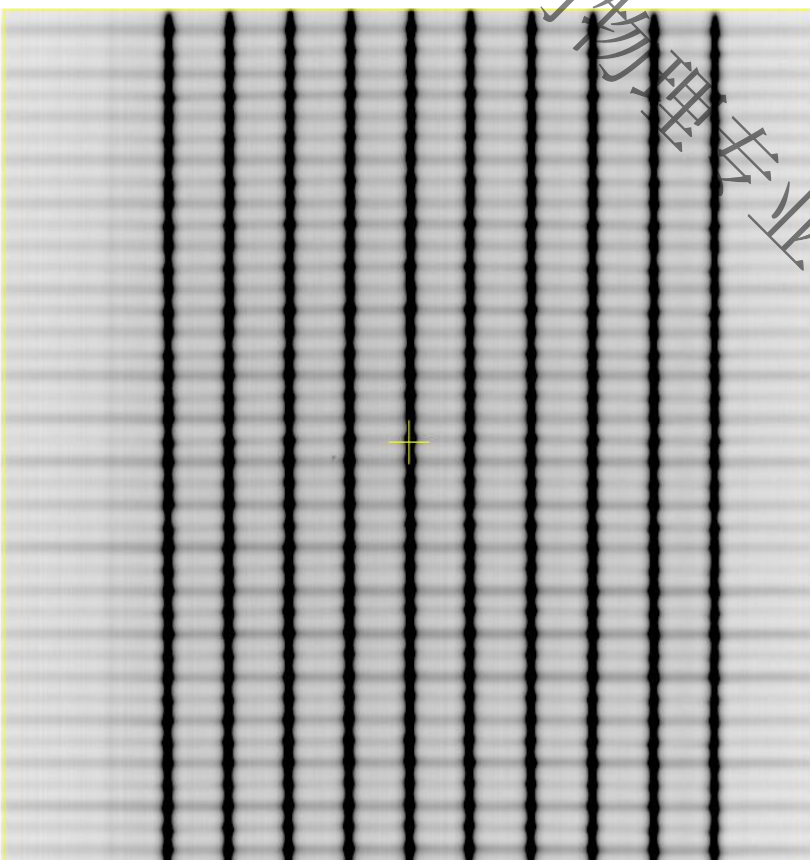
➢ 6X、PicketFenceRA_M120.dcm，获取该计划在旋转（179°-187°）过程中的MLC到位精度

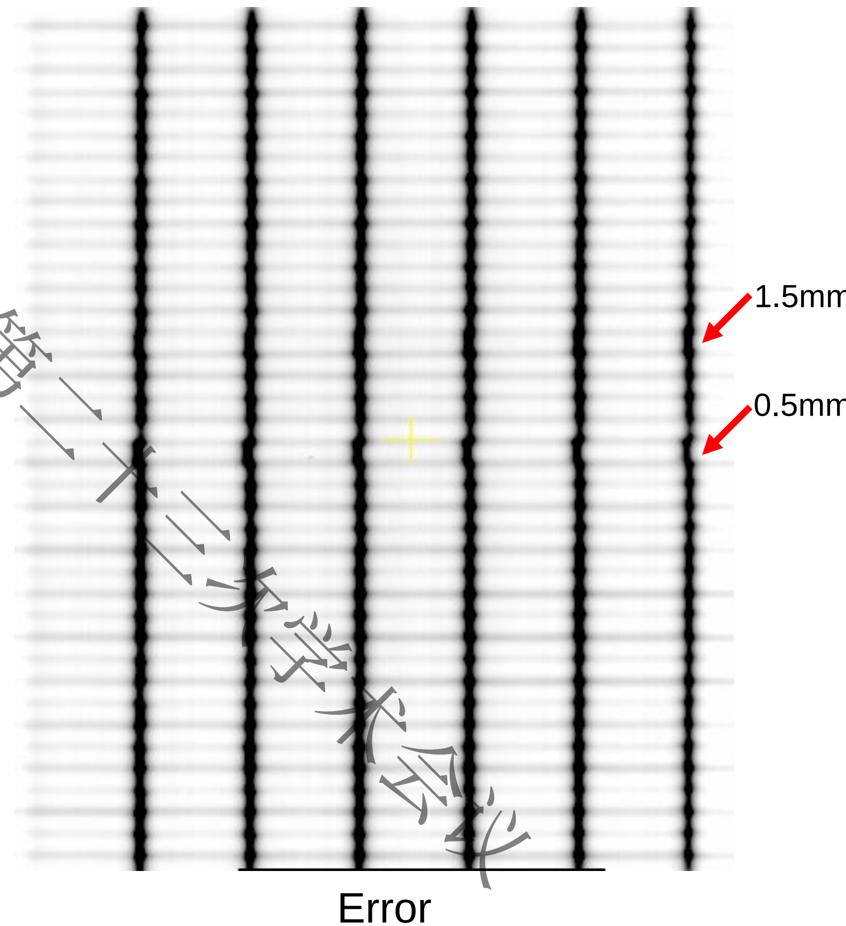
➢Tolerance =±1mm

RapidArc验收测试

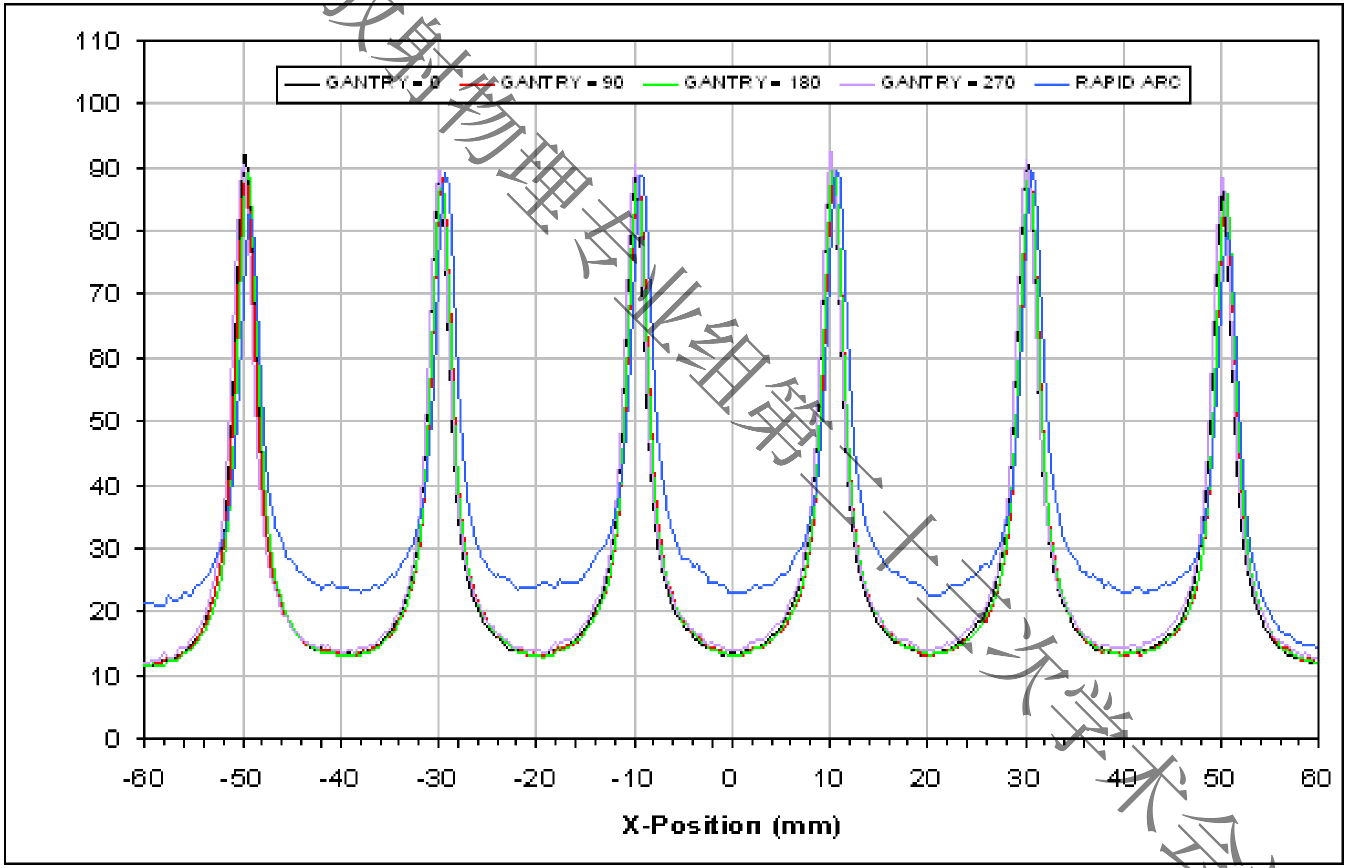
- RapidarcSpecific Commissioning Procedures

  2. VMAT模式下MLC的到位精度





2. VMAT模式下MLC的到位与静态比较



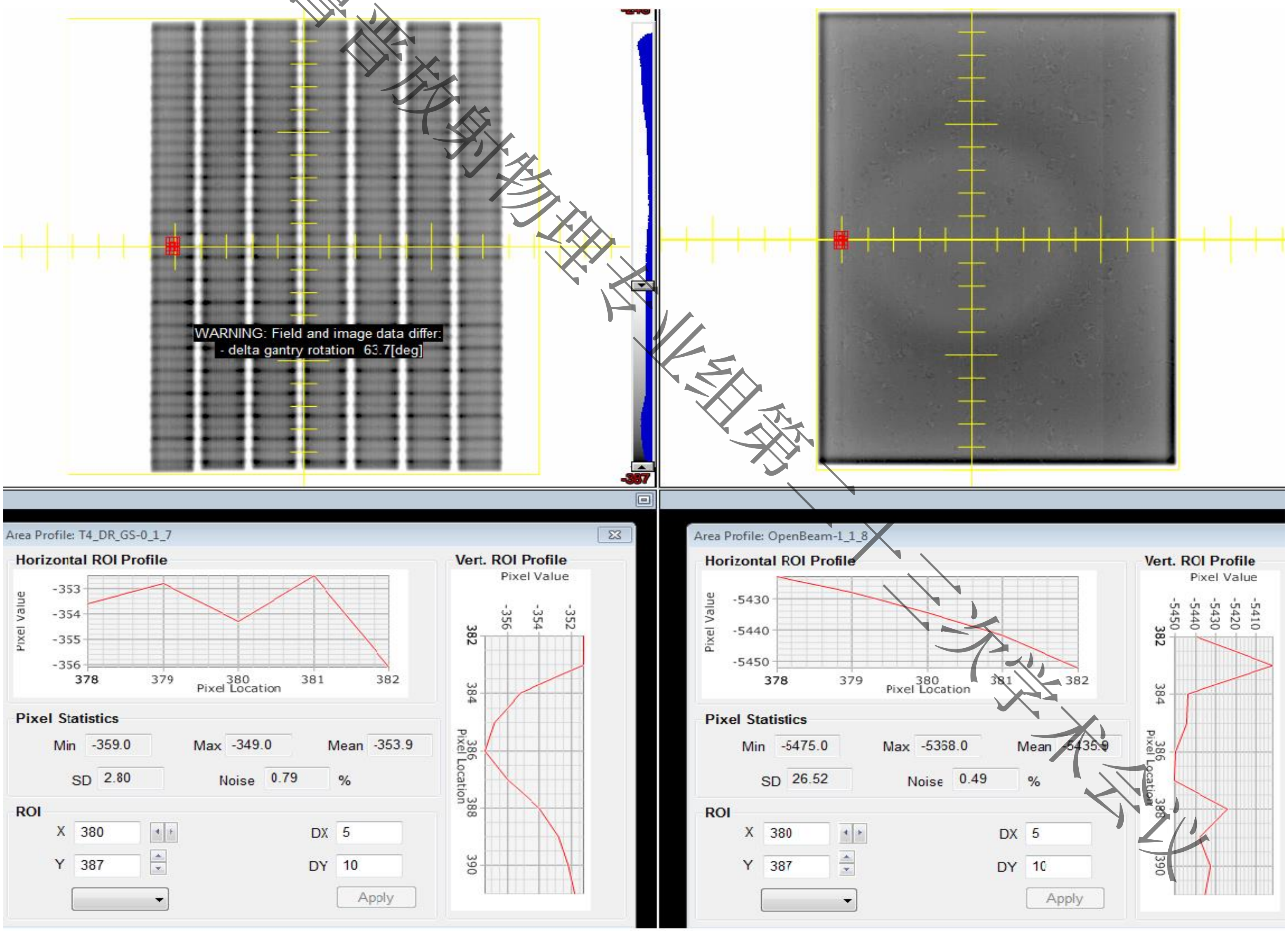
RapidArc验收测试

- RapidarcSpecific Commissioning Procedures

3. 机架速度和剂量率组合测试

- 6X、DoseRateGantrySpeed_M120.dcm，获取该计划在
  旋转（179° -242° ）过程中的分布图
- 7种不同剂量率和机架速度的组合
- 6X、14*20cm，开野照射
- 利用开野归一，分析不同照射位置处的剂量差别
- Tolerance =±2%

机架速度和剂量率组合测试



机架速度和剂量率组合测试

位置/值	-5	-3	-1	1	3	5	7
Darc	-353.9	-357.2	-355.9	-352.9	-352.6	-354.9	-349.2
Dopen	-5435.9	-5508.4	-5530.4	-5545.1	-5525	-5572.8	-5436.4
Rcorr=Darc/ Dopen*100	6.51	6.48	6.44	6.36	6.38	6.37	6.42
diff=Rcorr/R mean*100-100	1.4%	0.93%	0.31%	-0.93%	-0.62%	-0.78%	0.0%

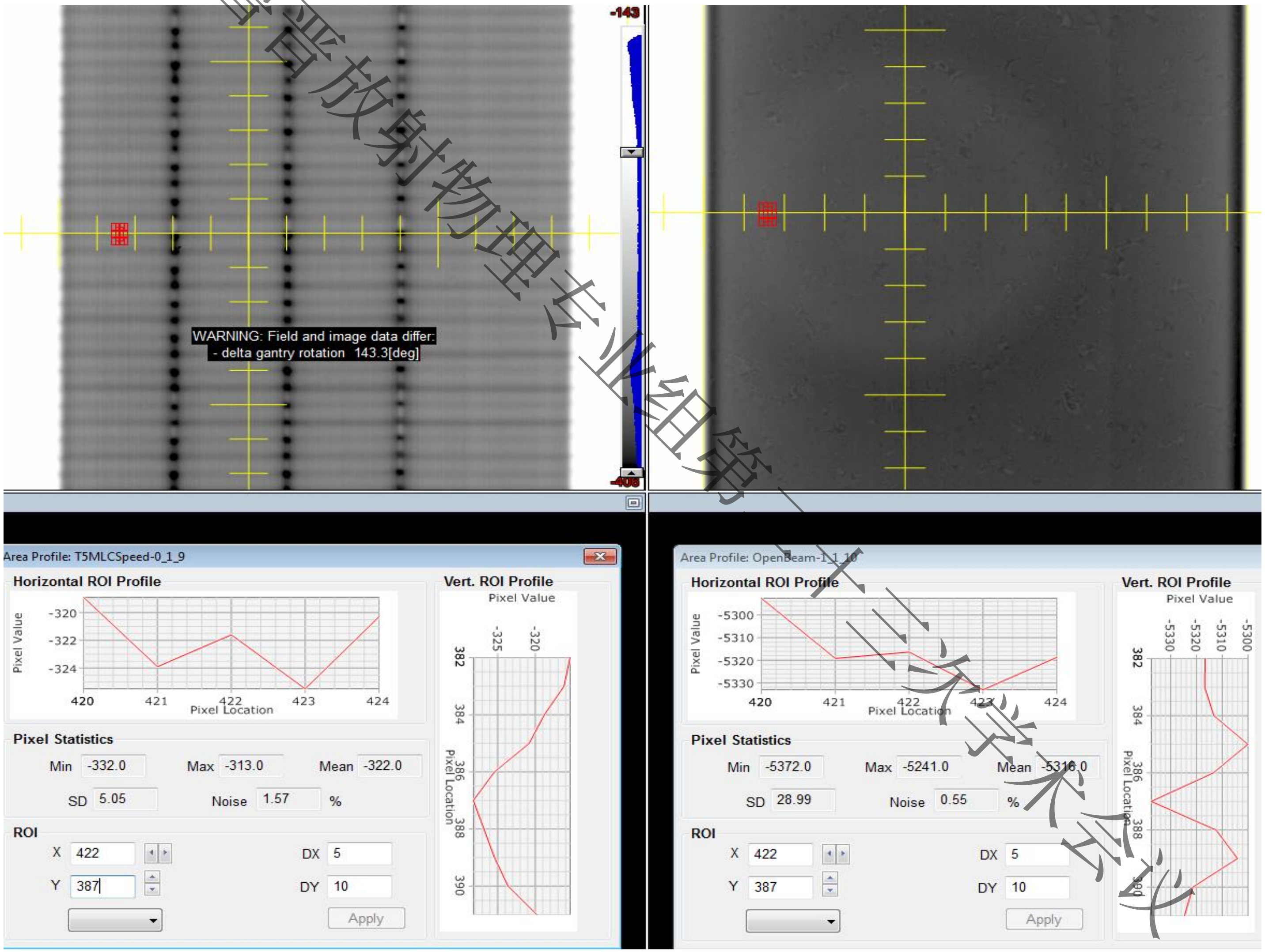
RapidArc验收测试

- RapidarcSpecific Commissioning Procedures

  4. MLC速度和剂量率组合测试

  - 6X、MLCSpeed_M120.dcm，获取该计划在旋转（170°-26°）过程中的分布图
  - 叶片运动速度：0.46、0.92、1.84、2.46 cm/s
  - 6X、12*20cm，开野照射
  - 分析不同照射位置处的剂量差别
  - Tolerance =±2%

MLC速度和剂量率组合测试



MLC速度和剂量率组合测试

位置/值	-4.5	-1.5	1.5	4.5
Darc	-322	-326.7	-328.5	-327.1
Dopen	-5316	-5443.9	-5494.5	-5540
Rcorr=Darc/Dopen*100	6.06	6.00	5.98	5.90
diff=Rcorr/Rmean*100-100	1.17%	0.17%	-0.17%	-1.5%

质量保证

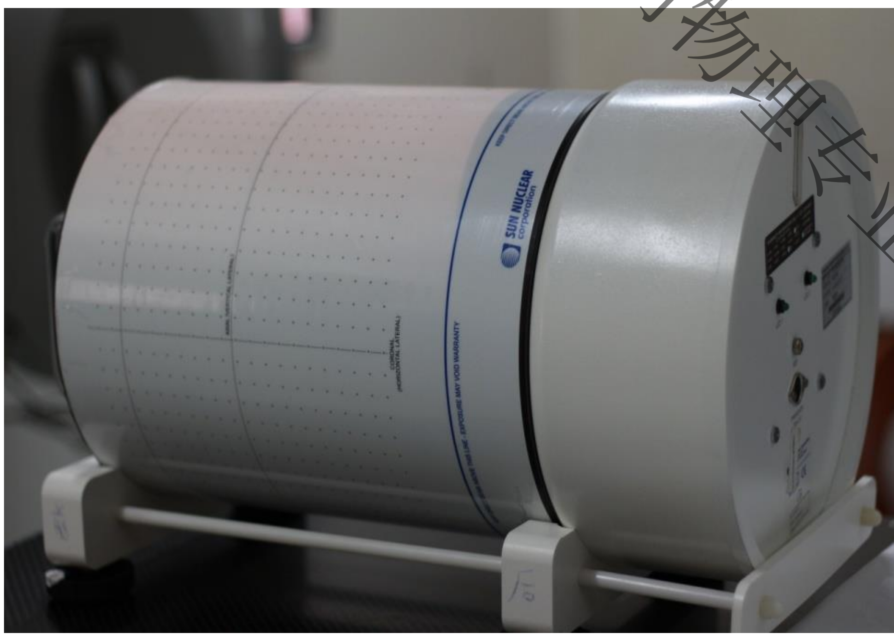
- 机器质量保证:
  - AAPM TG40 TG142
  - 以Rapidarc Commissioning为基础
  - 每月一次EPID或者免冲洗胶片照射

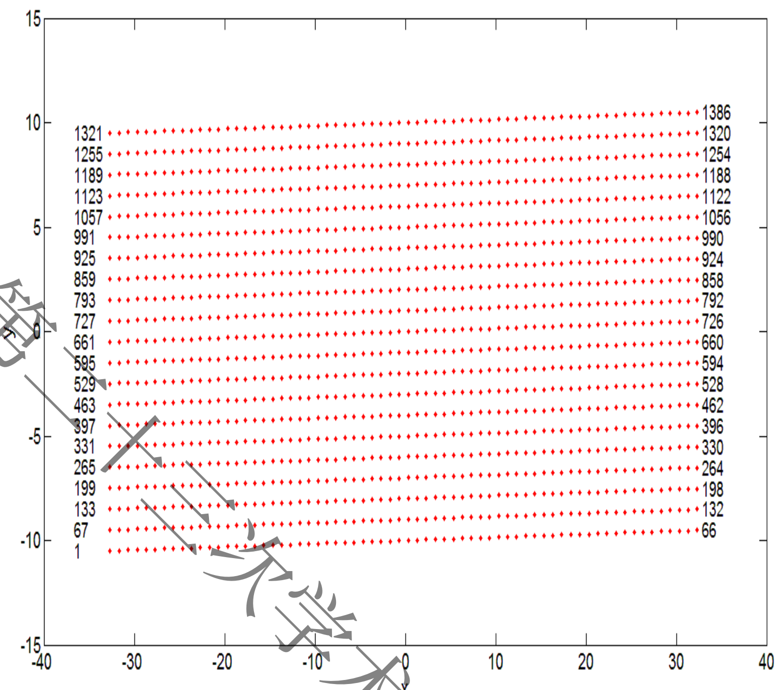
- 患者VMAT计划的剂量学验证

患者VMAT计划的剂量学验证

- 电离室+胶片
- 2D探测器矩阵:MapCheck, MatriXX等
- 3D探测器矩阵:ArcCheck,Delta4等

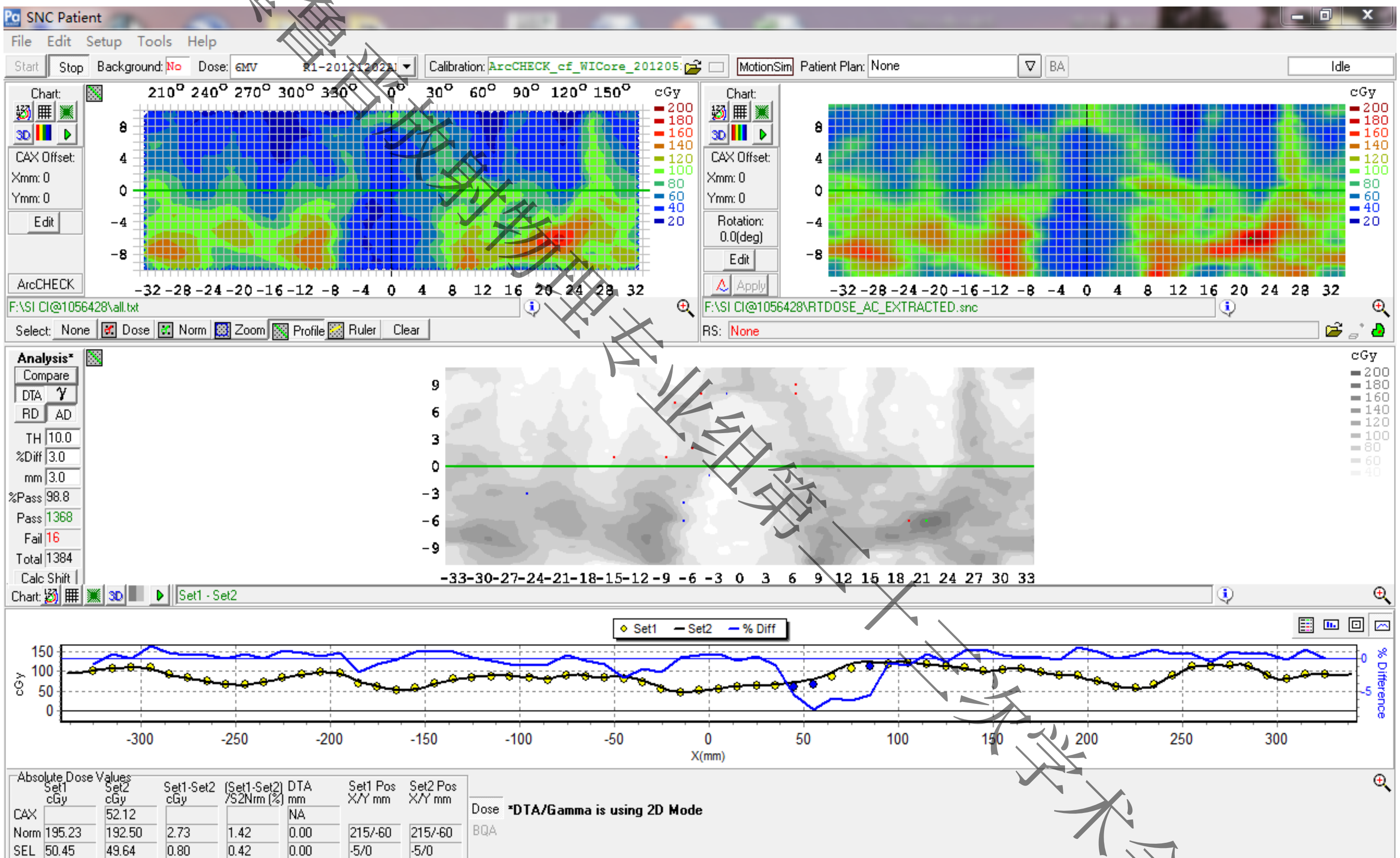
3D探测器矩阵





ArcCheck

Arccheck 结果分析



小结

- 在IMRT验收调试基础上，要针对VMAT增设以下测试例来验收调试加速器
  - 旋转过程中MLC位置变化
  - 测试剂量率与机架运动速度的关系
  - 测试剂量率与叶片运动速度的关系
- 要针对设备和患者开展VMAT日常应用的质保工作

- 感谢天津肿瘤医院放疗科各位同事

- Thanks for Attention