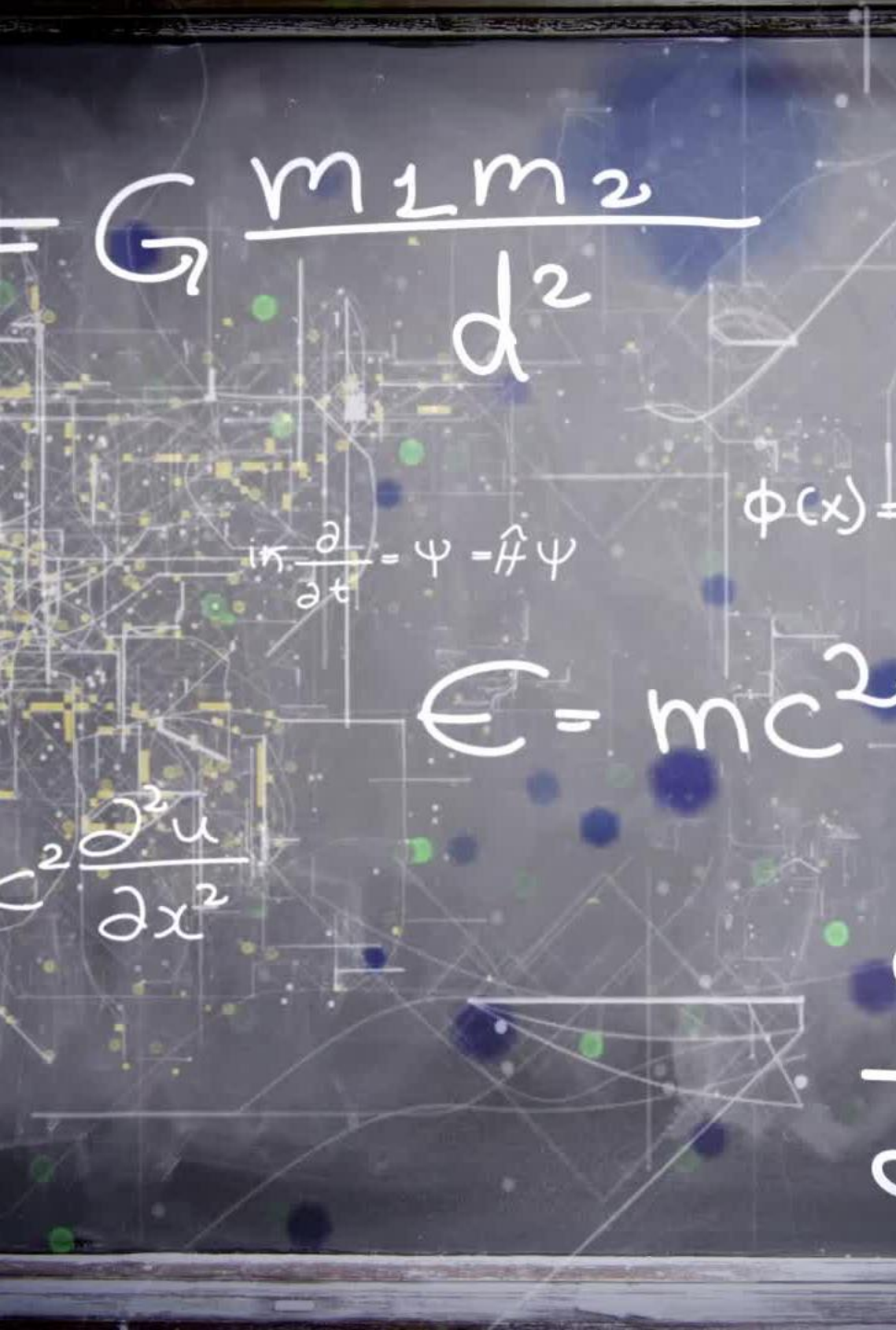




Srovnání filmové dozimetrie a systému OCTAVIUS pro pseudo-3D verifikaci VMAT plánů se zavedenou chybou

Tereza Hanušová

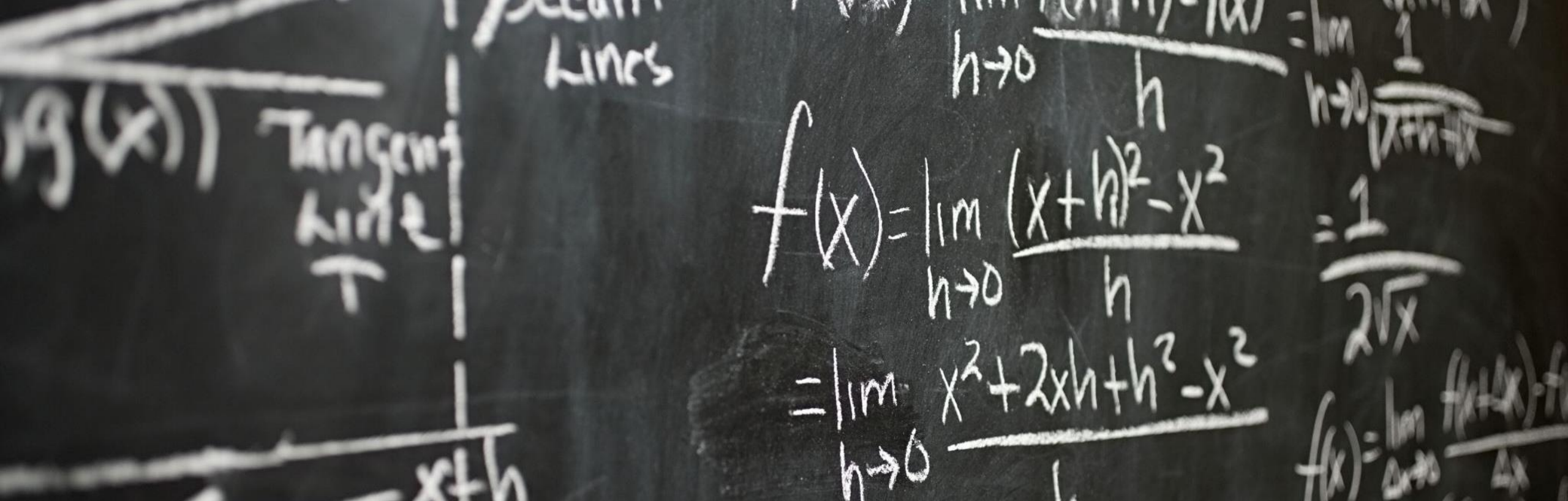
Fakulta jaderná a fyzikálně inženýrská ČVUT v Praze

Fakultní Thomayerova nemocnice

Ivana Horáková, Irena Koniarová

Státní ústav radiační ochrany, v.v.i.





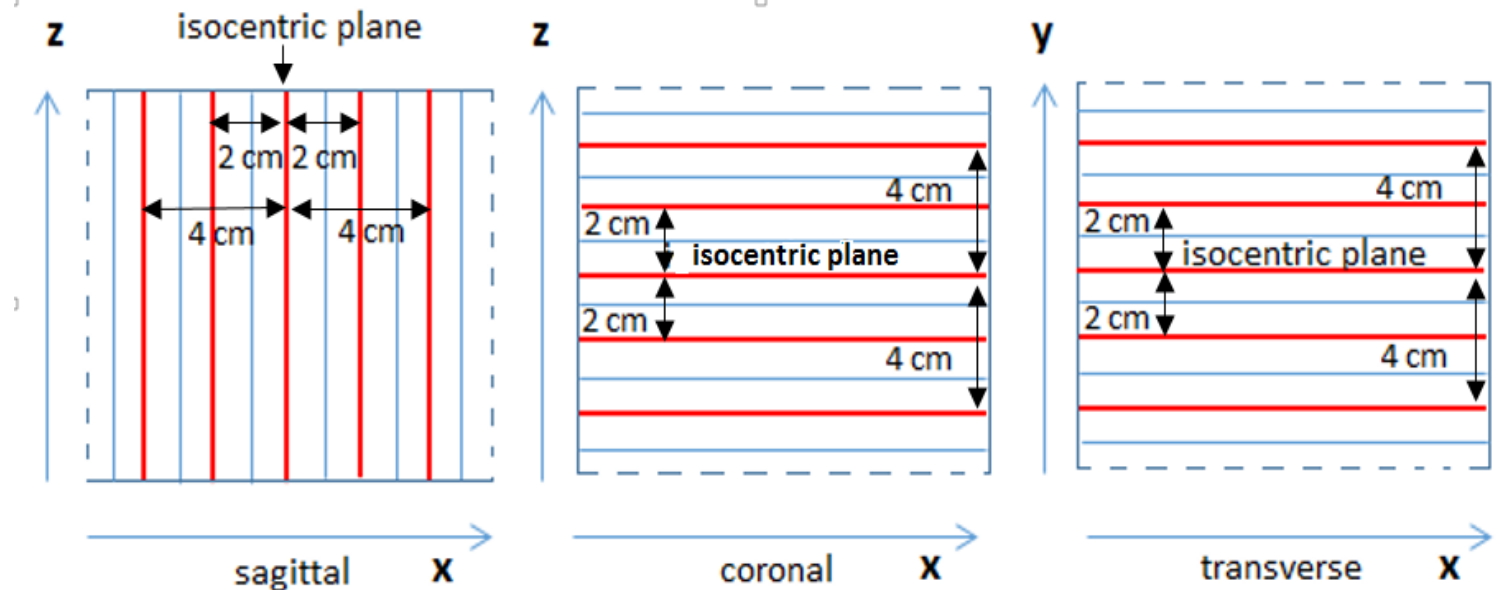
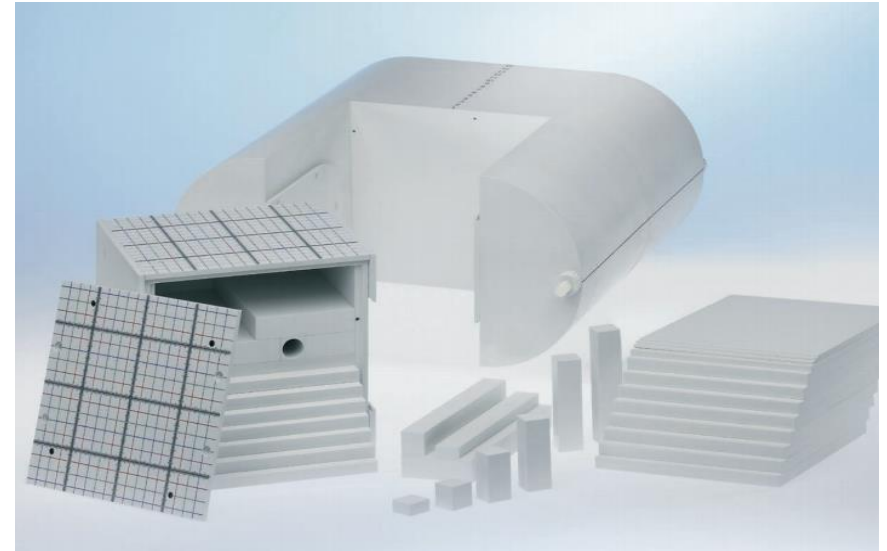
METODY

Filmová metoda

- EBT3 film
- I'mRT Phantom (Scanditronix Wellhöfer)
- EPSON Perfection V700 Photo
- MATLAB
 - 2D gama analýza
 - 3D gama analýza

Prostorové rozlišení:

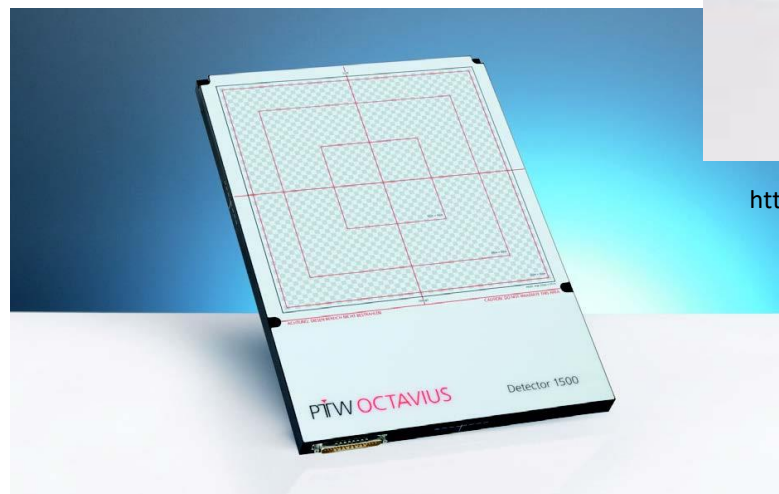
0,35 mm



System OCTAVIUS

- Válcový rotační fantom s inklinometrem
- Pole ionizačních komor OCTAVIUS 1500
- VeriSoft verze 8.0
 - 2D gama analýza
 - 3D gama analýza

Prostorové rozlišení:
7,1 mm



OCTAVIUS Detector 1500 Array | PTW (omnia-health.com)



<https://www.ptwdosimetry.com/en/products/OCTAVIUS-4d/>



VMAT plány



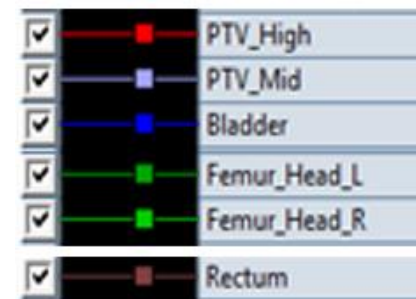
Klinický plán

- Prostata (+ kousek SV)
- RapidArc – Varian TrueBeam
- 18 MV
- Eclipse 16.1, AAA algoritmus
- 2 plné kyvy, kol. 30° a 330°
- 70 Gy ve 28 frakcích

Plány s chybou

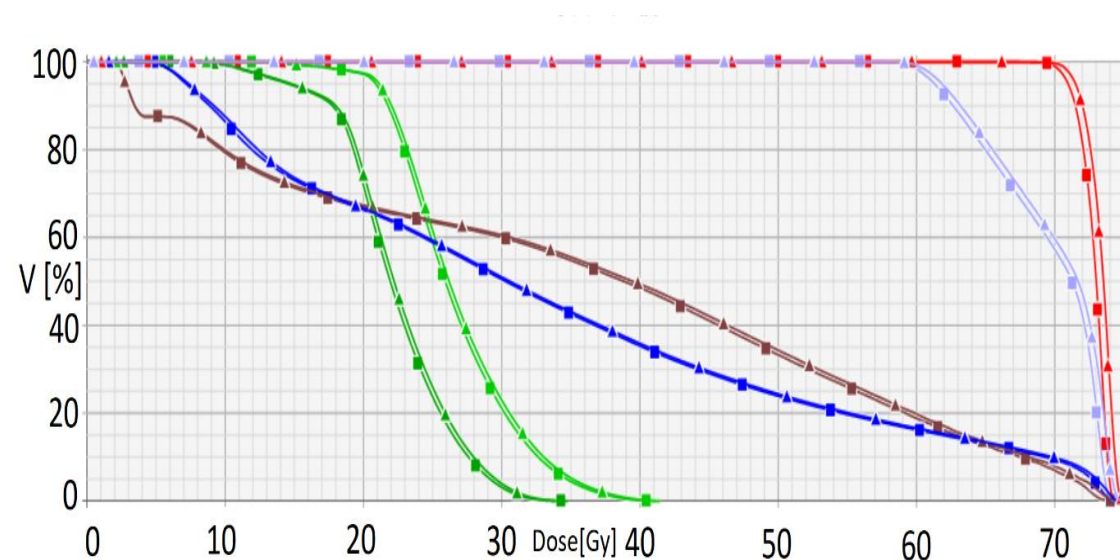
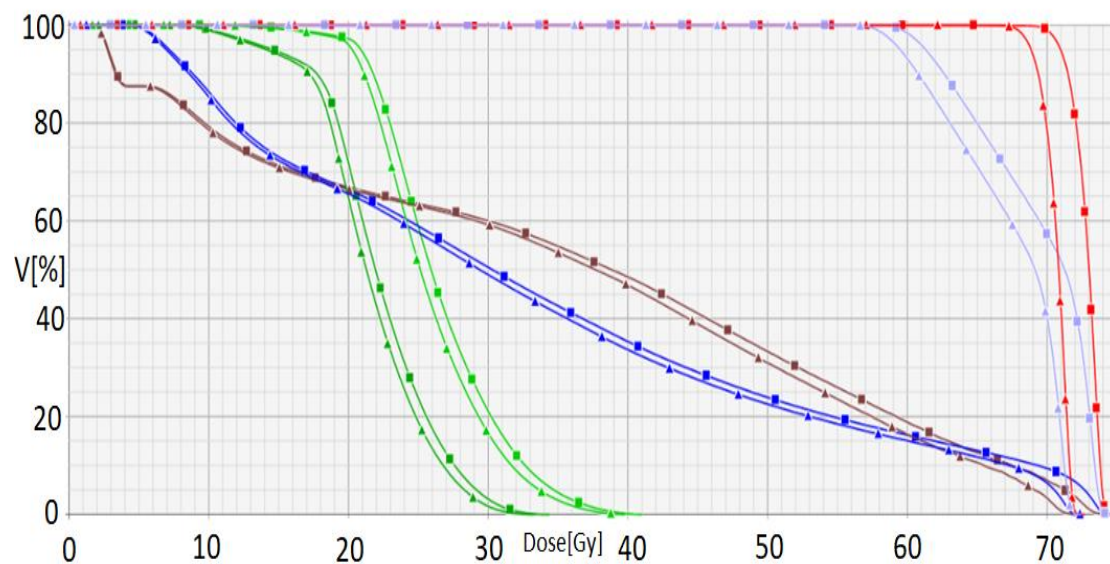
MU error	MLC leaf position error	
3% decrease in both arcs	1 mm X1 leaf bank shift (all leaves)	3 mm X1 leaf bank shift (all leaves)
	In each control point	In each control point
	In 1 arc	In 1 arc
	Segments wider	Segments wider

Plány s chybou – klinická relevance



3% MU

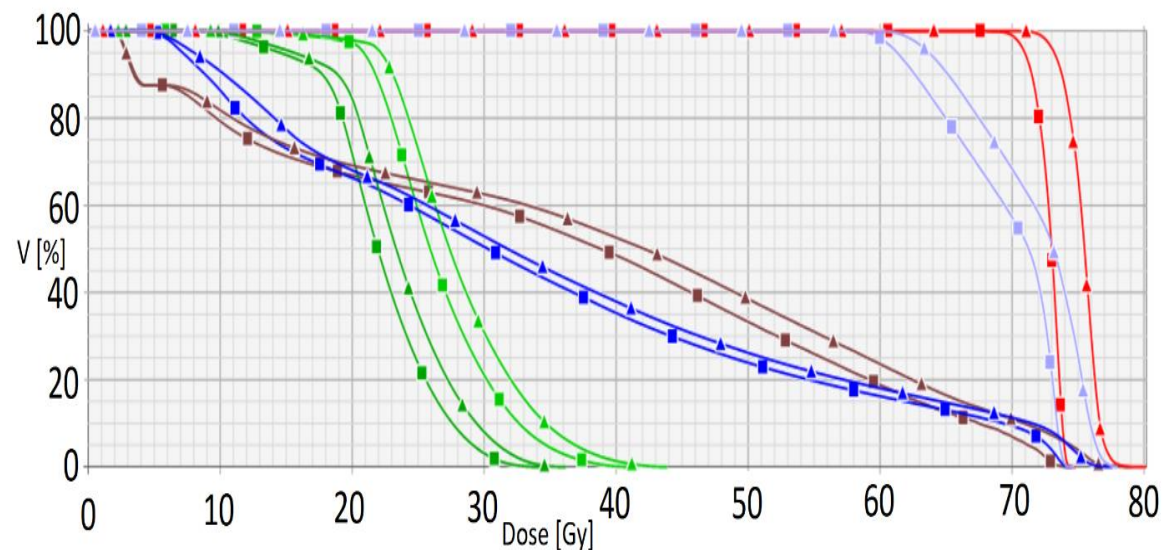
1 mm posun label



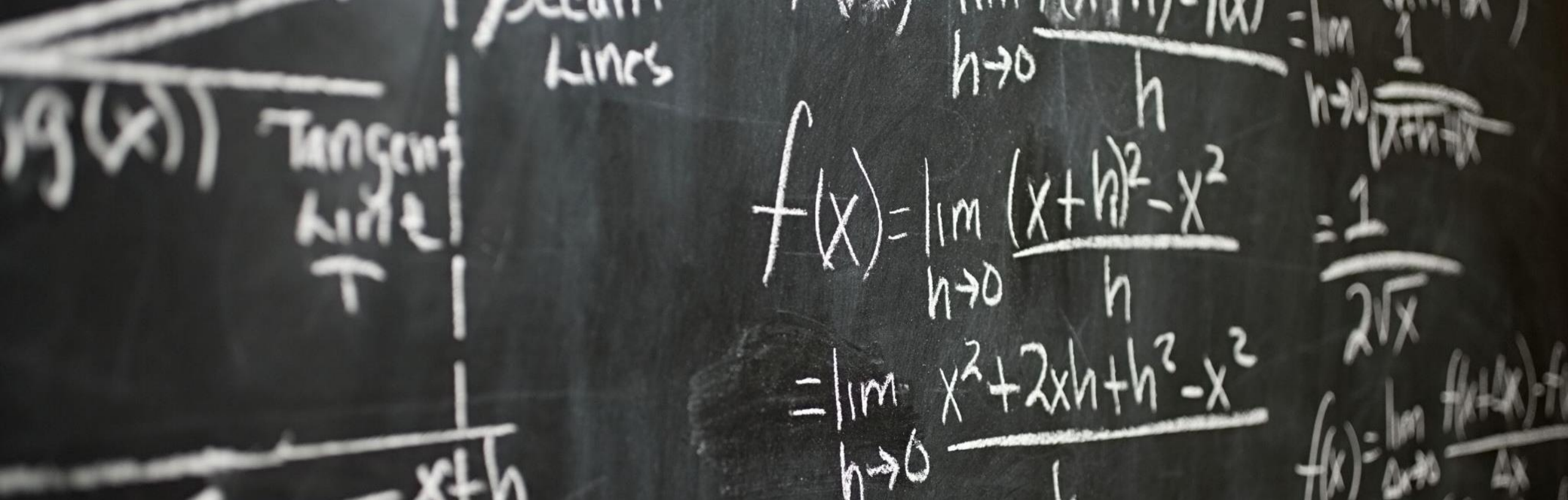
Plány s chybou – klinická relevance



3 mm posun label



☒	PTV_High
☒	PTV_Mid
☒	Bladder
☒	Femur_Head_L
☒	Femur_Head_R
☒	Rectum



VÝSLEDKY

Klinický VMAT plán



2D gamma score	MATLAB 2D code					MATLAB 3D code, local normalization				
	Gamma score [%]					Gamma score [%]				
Planes:	-4 cm	- 2 cm	iso	+ 2 cm	+ 4 cm	-4 cm	- 2 cm	iso	+ 2 cm	+ 4 cm
transverse	99.0	99.4	98.0	99.2	27.8	-	99.4	99.2	99.7	-
sagittal	99.2	99.4	96.7	99.0	95.7	-	99.5	98.2	99.1	-
coronal	98.4	100.0	98.5	98.0	94.7	-	100.0	98.8	98.0	-
VeriSoft v. 8.0 (from OCTAVIUS 4D)						Pseudo-3D gamma score (MATLAB 3D code) [%]				
Gamma score [%]										
Planes:	-4 cm	- 2 cm	iso	+ 2 cm	+ 4 cm	Local normalization:				
transverse	100.0	100.0	99.0	100.0	100.0	99.1				
sagittal	99.9	99.9	99.9	99.9	100.0	Global normalization:				
coronal	100.0	100.0	99.8	100.0	100.0	99.1				

Klinický VMAT plán



VeriSoft v. 8.0 (OCTAVIUS 4D)									
3D gamma score [%]	99.5								
Dose level [% of normalization value]	10	30	50	70	80	85	90	95	100
Gamma score [%]	99.4	99.5	99.8	99.6	99.5	99.4	99.3	99.1	100.0



Plány s chybou

Plane no.	2D gamma score [%]													
	EBT3 film pseudo-3D method							OCTAVIUS 4D pseudo-3D method						
	Original clinical plan	1 mm leaf bank shift	Difference	3 mm leaf bank shift	Difference	3% MU error	Difference	Original clinical plan	1 mm leaf bank shift	Difference	3 mm leaf bank shift	Difference	3% MU error	Difference
1	99.0	34.8	-64.2	43.8	-55.2	44.5	-54.5	100.0	100	0	100.0	0	100.0	0
2	99.4	98.9	-0.5	95.5	-3.9	99.9	0.5	100.0	100	0	97.2	-2.8	99.4	-0.6
3	98.0	98.8	0.8	100.0	2.0	99.7	1.7	99.0	100	1	95.4	-3.6	98.5	-0.5
4	99.2	98.1	-1.1	96.8	-2.4	99.6	0.4	100.0	100	0	98.2	-1.8	98.8	-1.2
5	27.8	53.6	25.8	42.3	14.5	74.9	47.1	100.0	100	0	100.0	0	100.0	0
6	99.2	97.4	-1.8	92.9	-6.3	92.7	-6.5	99.9	100	0	99.7	-0.2	99.6	-0.3
7	99.4	93.2	-6.2	94.1	-5.3	97.1	-2.3	99.9	99.9	0	91.0	-8.9	97.1	-2.8
8	96.7	97.8	1.1	96.8	0.1	98.4	1.7	99.9	99.9	0	90.7	-9.2	97.4	-2.5
9	99.0	97.2	-1.8	31.4	-67.6	99.3	0.3	99.9	100	0.1	89.9	-10	96.8	-3.1
10	95.7	85.1	-10.6	22.9	-72.8	83.1	-12.6	100.0	99.9	-0.1	100.0	0	97.7	-2.3



Plány s chybou

Plane no.	2D gamma score [%]													
	EBT3 film pseudo-3D method							OCTAVIUS 4D pseudo-3D method						
	Original clinical plan	1 mm leaf bank shift	Difference	3 mm leaf bank shift	Difference	3% MU error	Difference	Original clinical plan	1 mm leaf bank shift	Difference	3 mm leaf bank shift	Difference	3% MU error	Difference
11	98.4	74.5	-23.9	74.3	-24.1	79.9	-18.5	100.0	100	0	100.0	0	99.9	-0.1
12	100.0	96.1	-3.9	96.2	-3.8	99.7	-0.3	100.0	99.9	-0.1	95.6	-4.4	95.7	-4.3
13	98.5	93.9	-4.6	97.4	-1.1	99.5	1.0	99.8	99.8	0	87.0	-12.8	97.3	-2.5
14	98.0	99.0	1.0	75.1	-22.9	90.6	-7.4	100.0	100	0	94.2	-5.8	99.0	-1
15	94.7	83.8	-10.9	87.2	-7.5	95.6	0.9	100.0	100	0	96.6	-3.4	100.0	0
13 planes passing 95% tolerance 8 planes passing 95% tolerance Average difference: -6.7% 6 planes passing 95% tolerance Average difference: -17.1% 9 planes passing 95% tolerance Average difference: -3.2% 15 planes passing 95% tolerance 15 planes passing 95% tolerance Average difference: +0.1% 10 planes passing 95% tolerance Average difference: -4.2% 15 planes passing 95% tolerance Average difference: -1.4%														

3D gama skóre

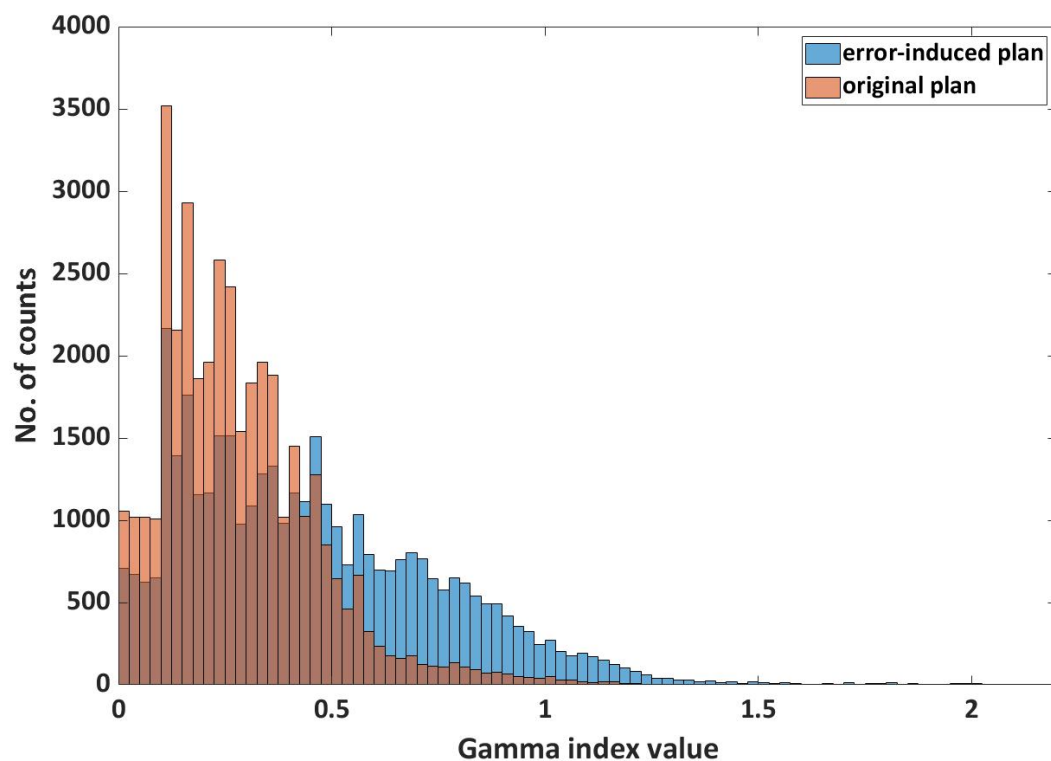


Pseudo-3D gamma score [%]	EBT3 film + MATLAB 3D code, local normalization	OCTAVIUS 1500 detector + OCTAVIUS 4D + VeriSoft v. 8.0
Original VMAT plan	99.1	99.5
1 mm leaf bank shift	97.6	100.0
3 mm leaf bank shift	89.7	96.9
3% MU error	98.3	99.2

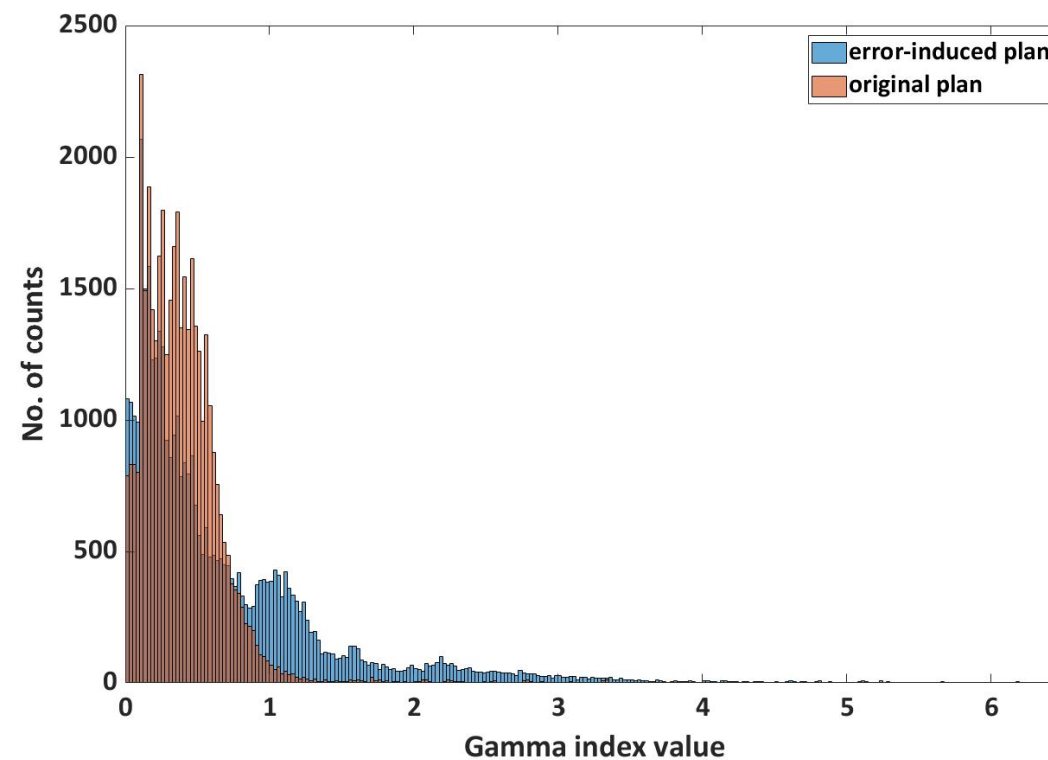
Histogramy



1 mm posun label



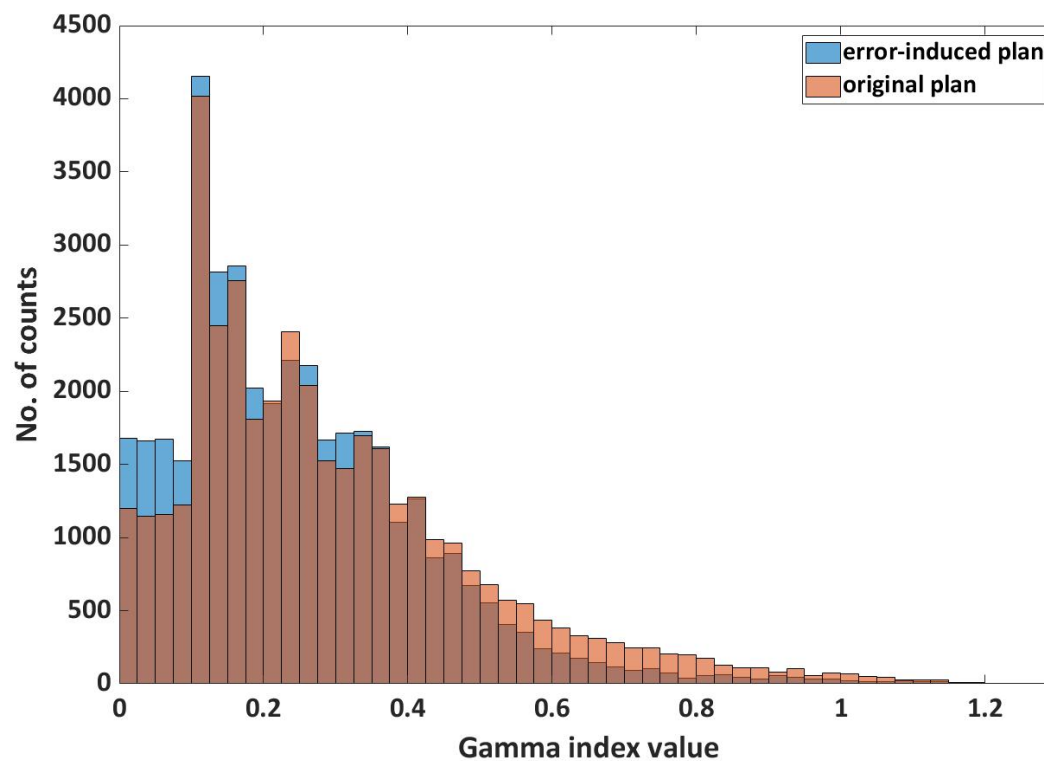
3 mm posun label



Histogramy



3% změna MU

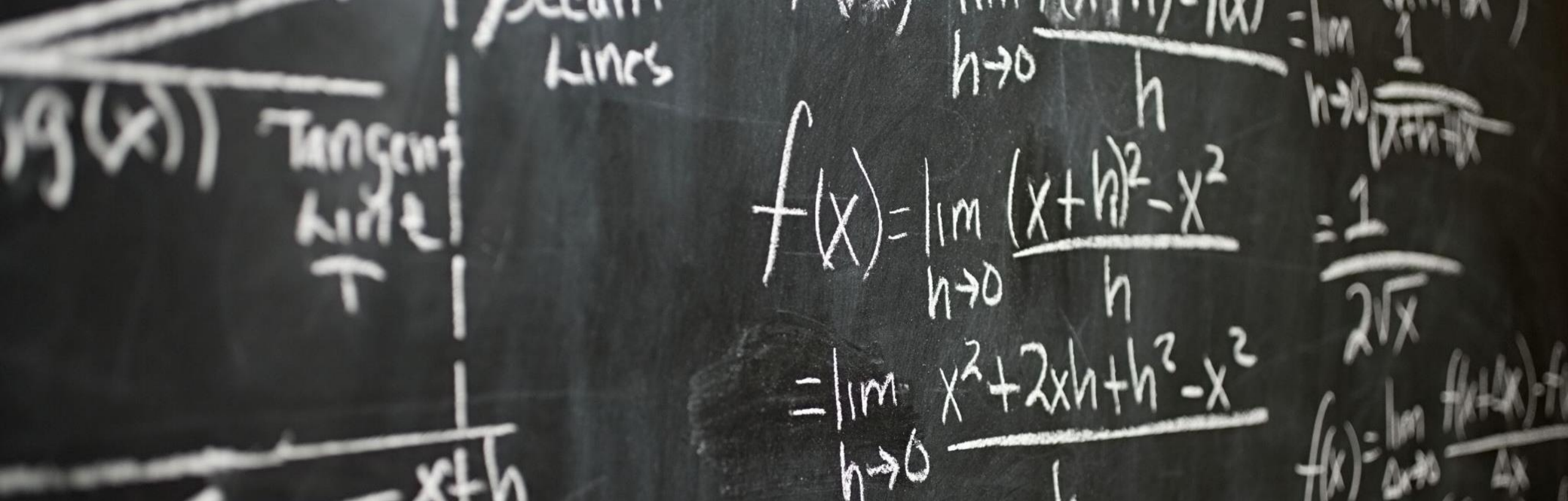


OCTAVIUS – 2 %/2 mm

Pseudo-3D gamma score [%]	OCTAVIUS 1500 detector
2%/2mm criteria	+ OCTAVIUS 4D
Original VMAT plan	99.6
1 mm leaf bank shift	99.5
3 mm leaf bank shift	85.5
3% MU error	94.6



Plane no.	2D gamma score [%]						
	2%/2 mm criteria						
	OCTAVIUS 4D pseudo-3D method						
	Original clinical plan	1 mm leaf bank shift	Difference	3 mm leaf bank shift	Difference	3% MU error	Difference
1	100	100	0	75.5	-24.5	100	0
2	100	99.8	-0.2	87.1	-12.9	97.2	-2.8
3	99.6	99.6	0	84.9	-14.7	91.9	-7.7
4	99.7	99.6	-0.1	85.5	-14.2	90.3	-9.4
5	100	100	0	100	0	100	0
6	99.3	99.6	0.3	86.3	-13	92.4	-6.9
7	98.3	98.5	0.2	77.2	-21.1	88.0	-10.3
8	98.2	98.0	-0.2	72.3	-25.9	89.0	-9.2
9	98.0	97.3	-0.7	74.5	-23.5	86.1	-11.9
10	99.7	98.2	-1.5	93.8	-5.9	83.8	-15.9
11	100	100	0	95.4	-4.6	92.2	-7.8
12	99.8	99.4	-0.4	75.5	-24.3	87.1	-12.7
13	96.5	96.7	0.2	70.6	-25.9	85.1	-11.4
14	99.7	98.9	-0.8	71.1	-28.6	95.0	-4.7
15	100	99.9	-0.1	76.0	-24	97.8	-2.2
	15 planes passing 95% tolerance	15 planes passing 95% tolerance	Average difference: -0.2%	2 planes passing 95% tolerance	Average difference: -17.5%	5 planes passing 95% tolerance	Average difference: 7.5%

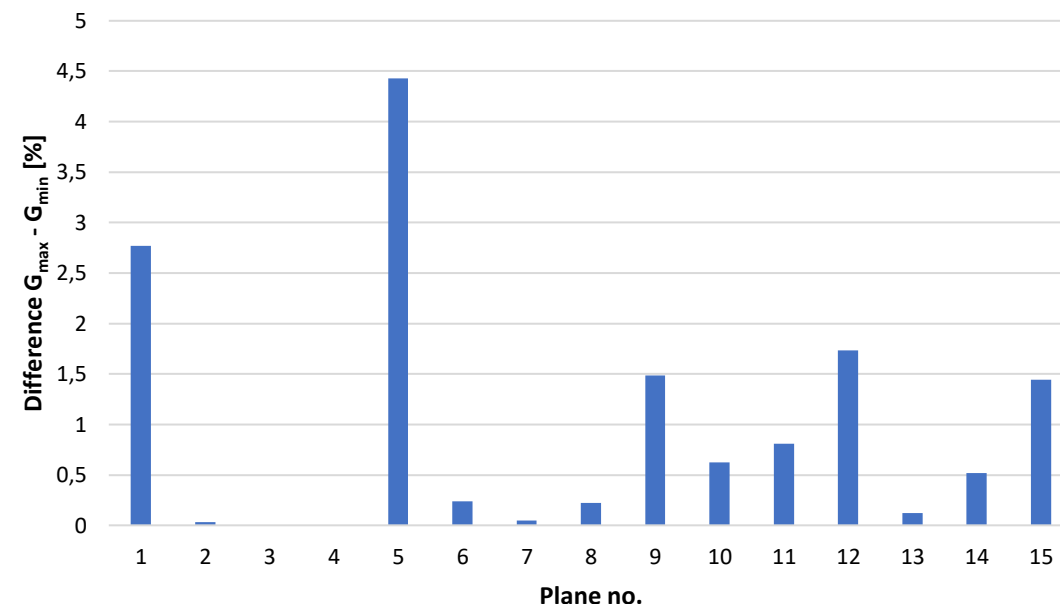


DISKUZE

Nejistoty

1) Nejistota filmové dozimetrie:

- Pro relativní dozimetrii **1,85%** (1σ)
- Pro absolutní dozimetrii **2,28%** (1σ)
→ Relativní gama analýza, kritéria 3 %/3 mm
- Propagace nejistot do gama skóre:
 - náhodný Gaussovský šum zavedený do dávkových distribucí, gama analýza provedena 50x na stejných datech (s šumem)
 - variabilita v gama skóre v důsledku nejistoty měření až 4,5%



2) Nejistota systému OCTAVIUS

- Přesnost rekonstruované dávkové distribuce* **2% - 6%**
- Nejistota měření dávky polem detektorů OCTAVIUS 1500 **1,75%** (1σ)
→ Nejistota/variabilita v gama skóre jistě $> 2\%$

Nízká gama skóre u filmové metody

- Filmová metoda není vhodná pro měření dávek $< 0,5$ Gy
- Krajní roviny ve 3D prostoru (4 cm od izocentra) ležely mimo PTV = dávky $< 0,5$ Gy
- **Film:** extrémně nízká gama skóre
- **Systém OCTAVIUS:** vždy 100% (i plány s chybou)



Závěr



- Filmová metoda odhalí všechny chyby s kritérii 3%/3 mm a 95%
- Filmová metoda odhalí lépe chyby v polohování lamel
- OCTAVIUS neodhalí chybu 1 mm v poloze lamel
- OCTAVIUS odhalí ostatní chyby až s kritérii 2%/2 mm a 95%
- Samotné 3D gama skóre neodhalí chyby (ani film, ani OCTAVIUS)
- Potřeba inspekce více 2D rovin

Vzpomínáme...

