



Emmanuel Uwitonze

Detection of treatment delivery errors in Radiotherapy with EPID imaging systems through 2D deep learning approach-based in-vivo dosimetry

Metrics for 2D alert system

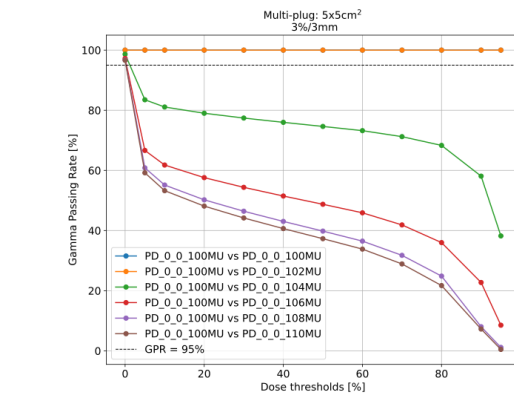
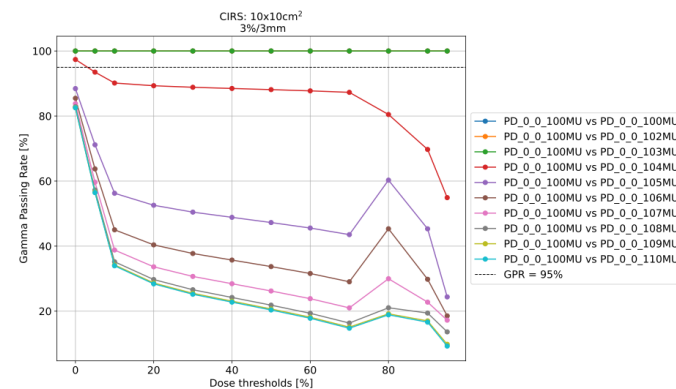
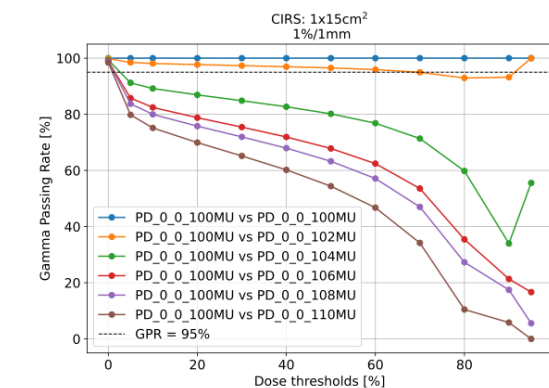
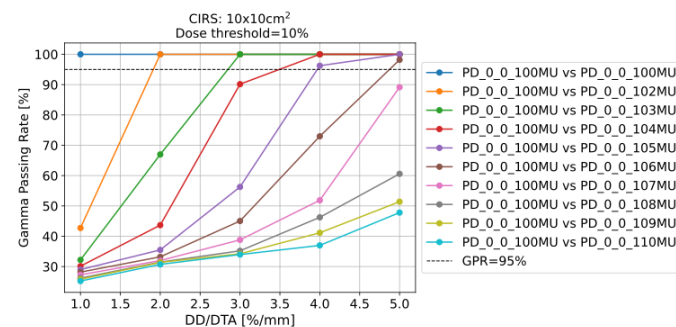
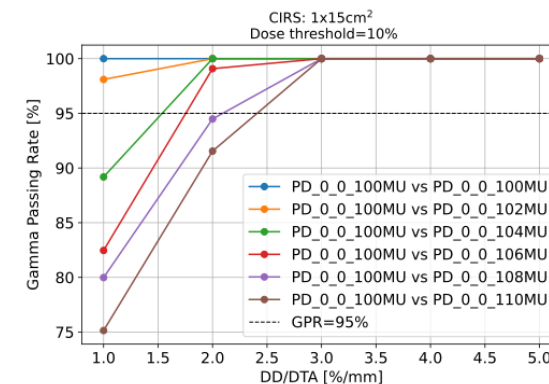
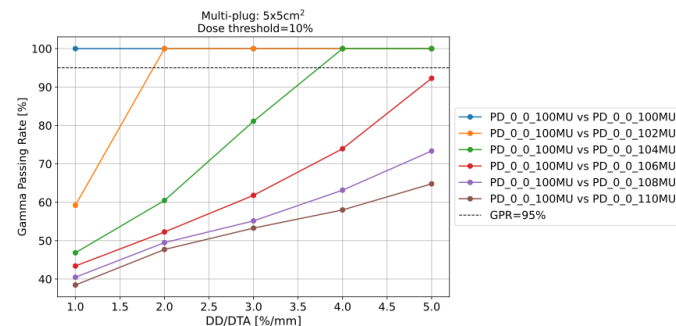
1. Gamma passing rate (GPR) metric: $> 95\%$, AAPM TG307
2. Dose difference-related metrics ($< \pm 2\%$, AAPM TG 142):
 - relative mean absolute dose difference, reMADD,
 - relative mean dose difference, reMDD,
 - relative integral dose difference, reIDD,
 - relative peak dose difference, rePDD,
 - relative root mean square error, reRMSE

GPR

Dependence on:

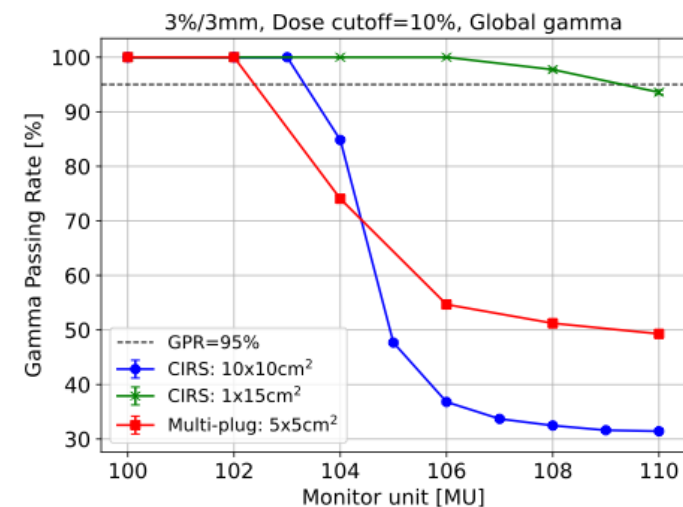
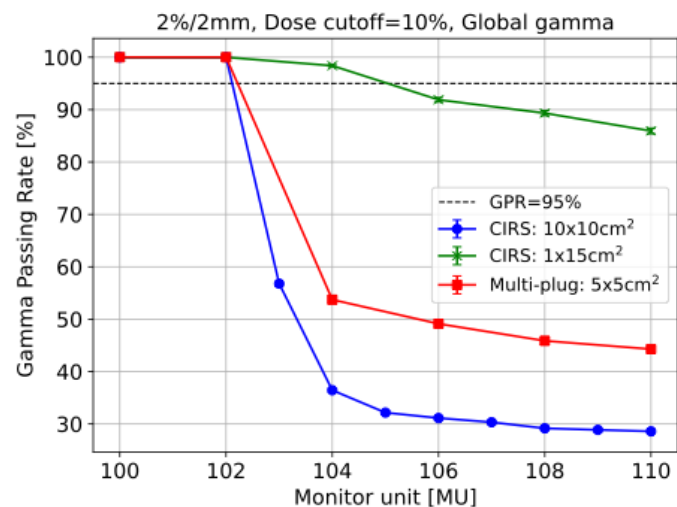
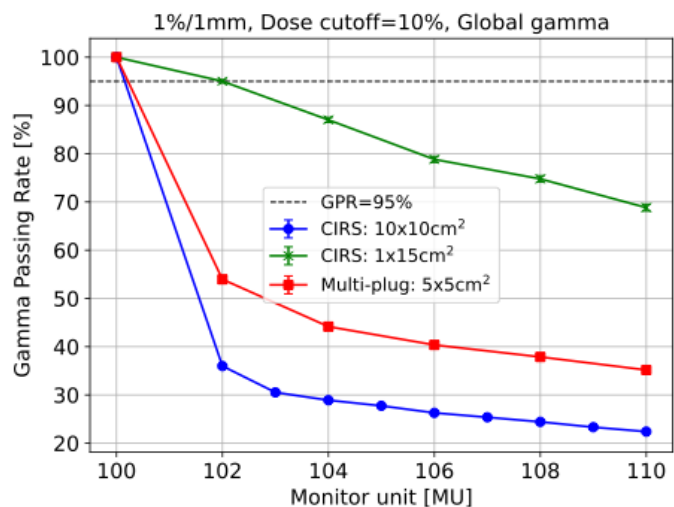
.DD/DTA criteria

- Dose threshold
- Phantom



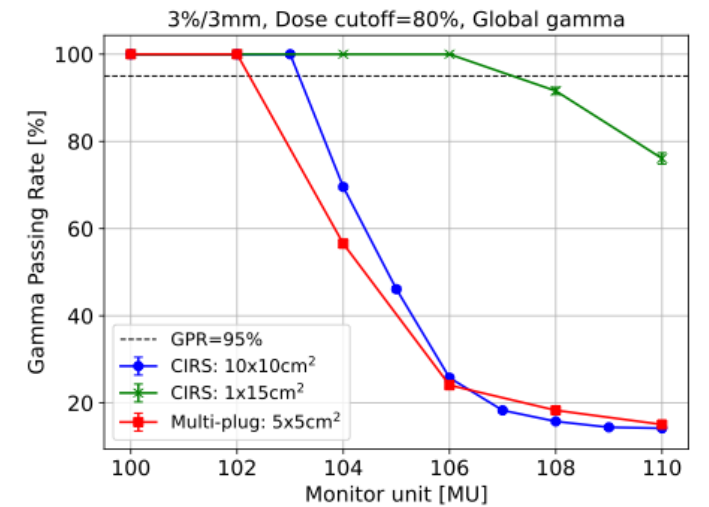
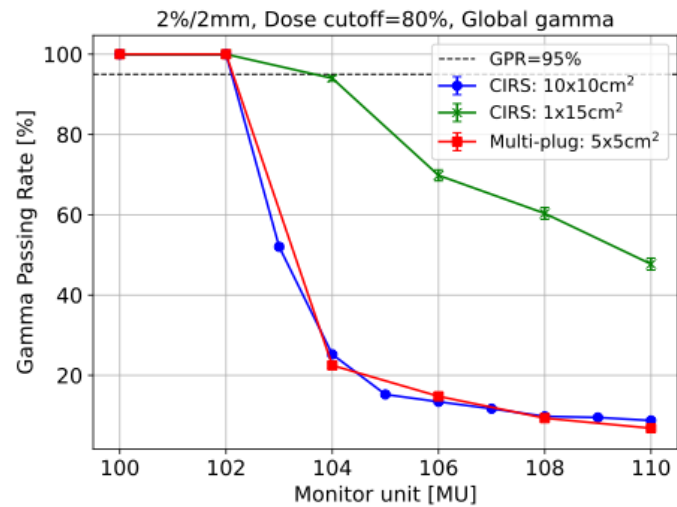
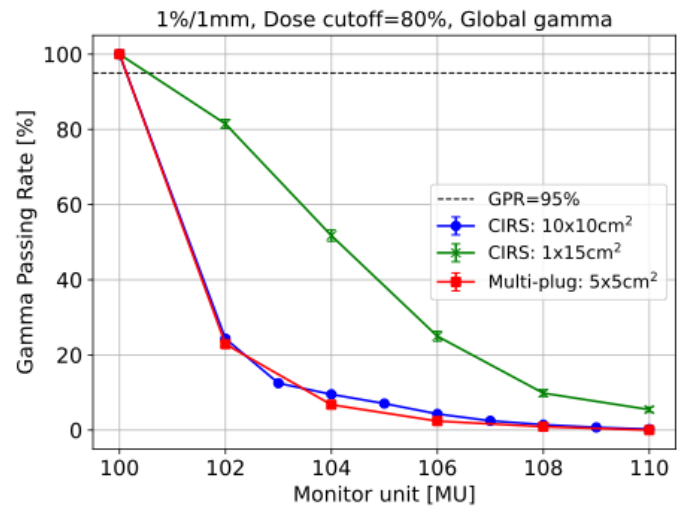
1MU delivery error- Gamma passing rate (GPR)

- GPR<95%: alarm ⚠



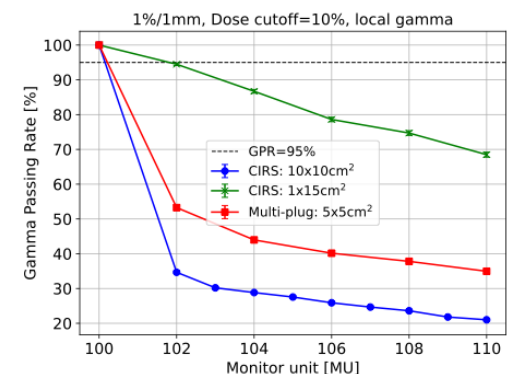
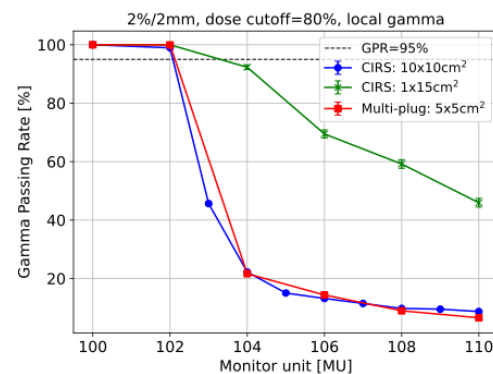
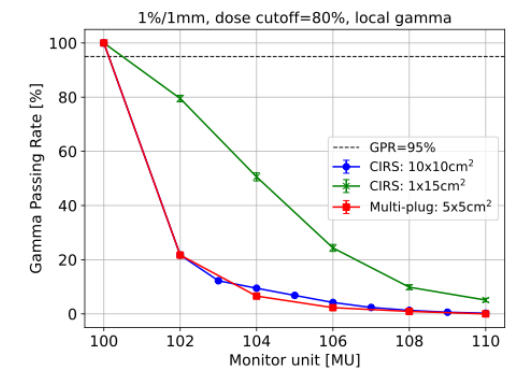
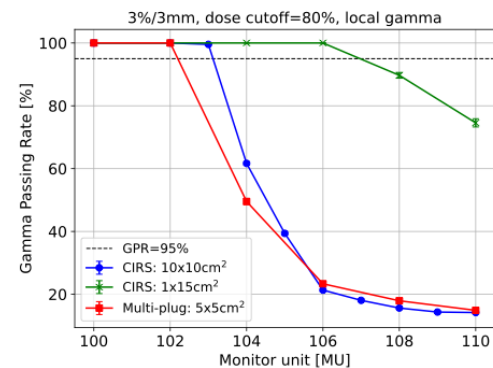
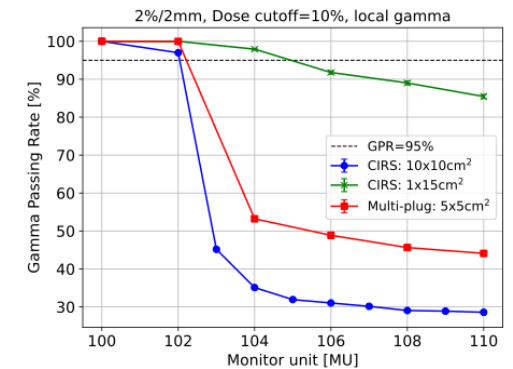
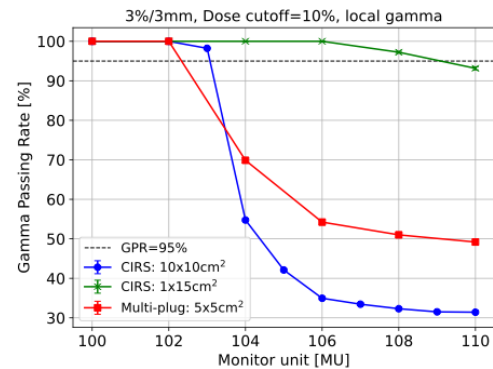
GPR<95%: alarm !

For 80% dose threshold



Local gamma

- Similar to global

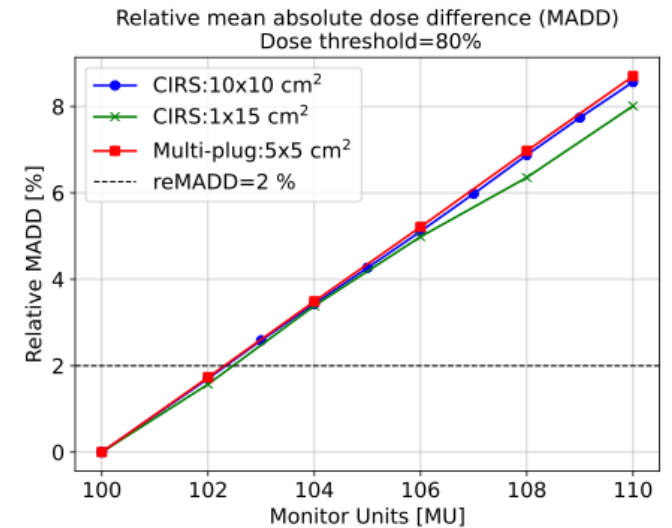
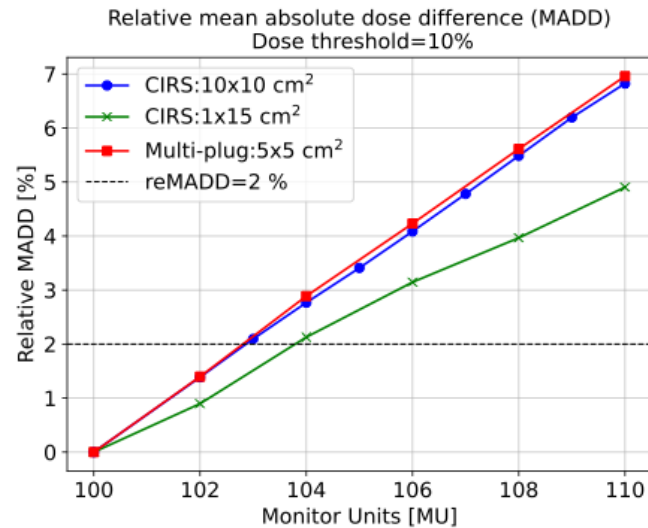
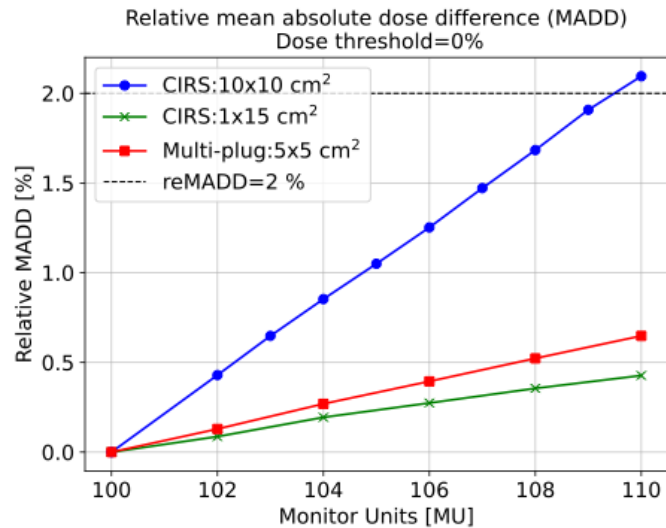


1 MU delivery error-relative mean absolute dose difference (reMADD)

$$\text{reMADD} = \frac{\frac{1}{N_{\text{ieT}}} \sum_{i=1}^{N_{\text{ieT}}} |D_{\text{e},i} - D_{\text{r},i}|}{D_{\text{r},i}^{\text{max}}} \times 100\%$$

Dependence:

- dose threshold
- phantom
- reMADD>2%: alarm ⚠

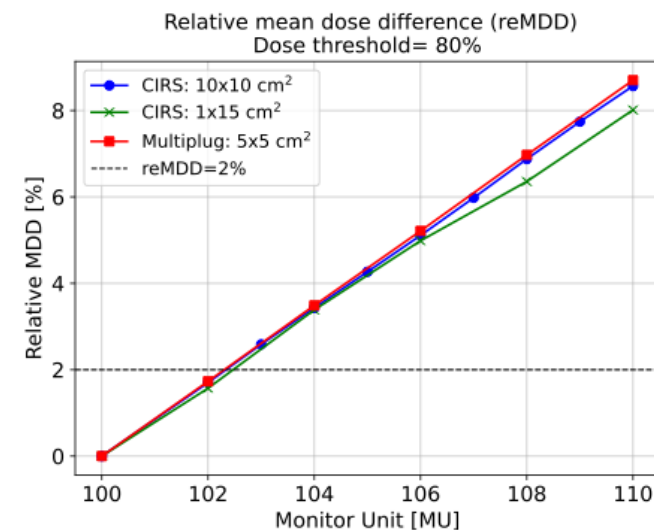
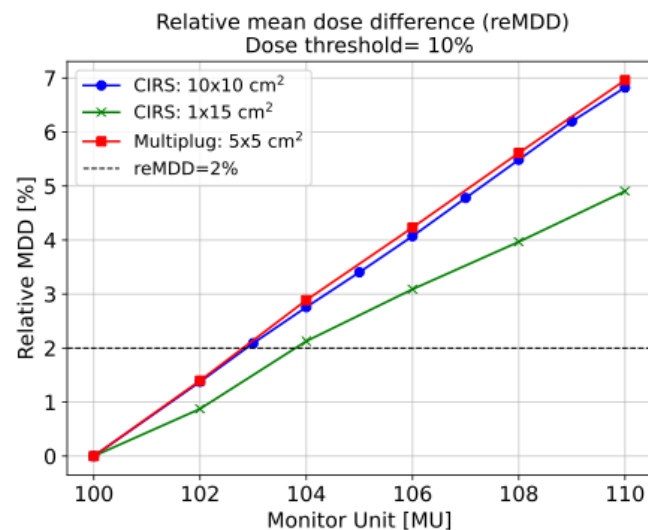
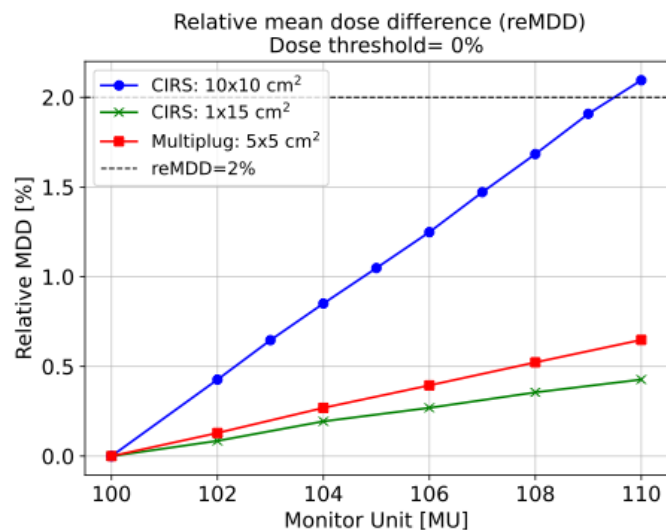


1MU delivery error- relative mean dose difference (reMDD)

Dependence:

- . dose threshold
- . phantom
- . reMDD>2%: alarm ⚠

$$\text{reMDD} = \frac{\frac{1}{N_{i \in T}} \sum_{i=1}^{N_{i \in T}} (D_{e,i} - D_{r,i})}{D_{r,i}^{\max}} \times 100\%$$

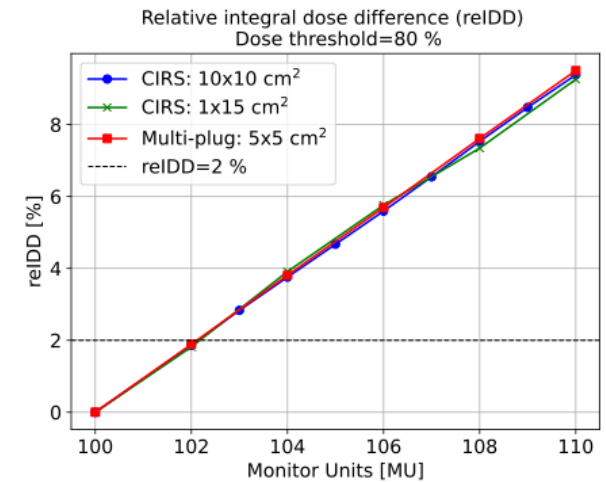
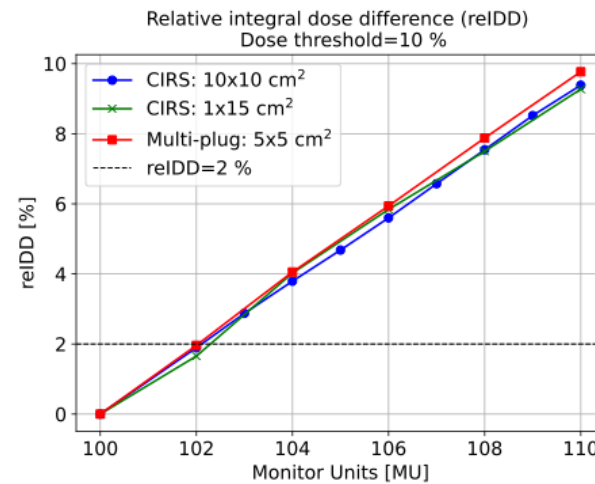
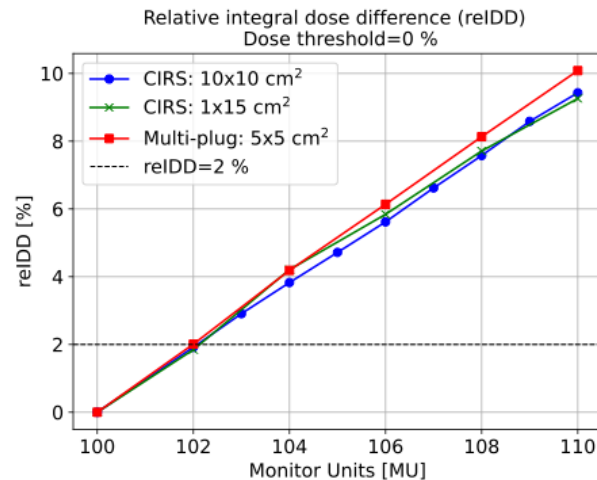


1MU delivery error-relative integral dose difference (reIDD)

$$\text{reIDD} = \frac{\sum_{i=1}^{N_{i \in T}} D_{e,i} - \sum_{i=1}^{N_{i \in T}} D_{r,i}}{\sum_{i=1}^{N_{i \in T}} D_{r,i}} \times 100\%$$

Weak dependence:

- dose threshold
- Phantom type
- $\text{IDD} > 2\%$: alarm ⚠

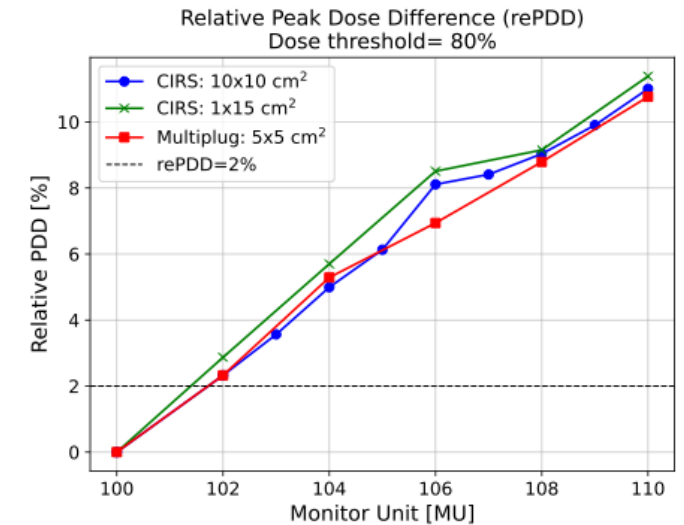
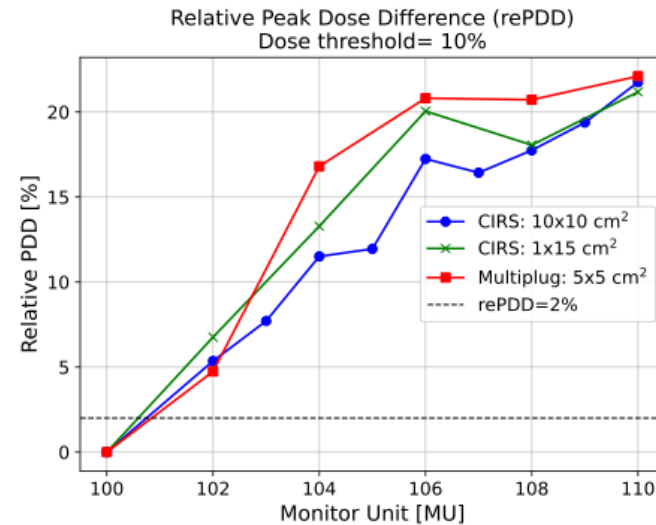
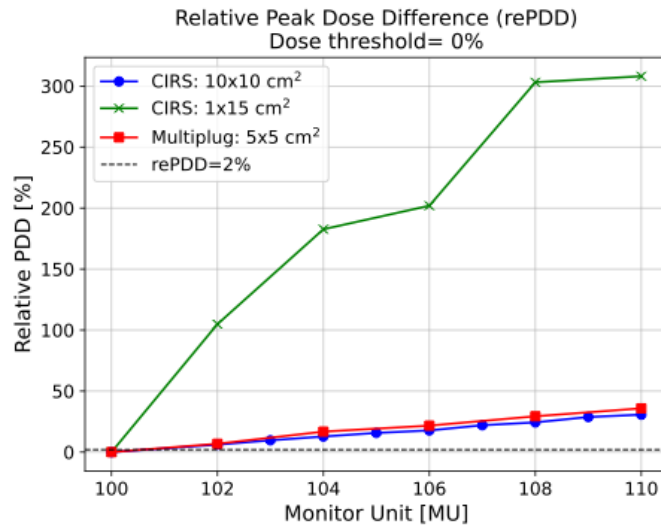


1MU delivery error- relative peak dose difference (rePDD)

Dependence:

- dose threshold
- phantom
- rePDD>2%: alarm ⚠

$$\text{rePDD} = \max \frac{D_{e,i} - D_{r,i}}{D_{r,i}} \times 100\%$$

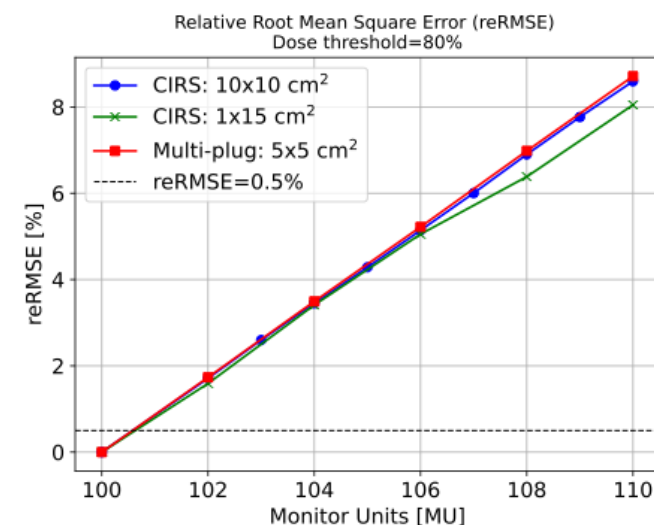
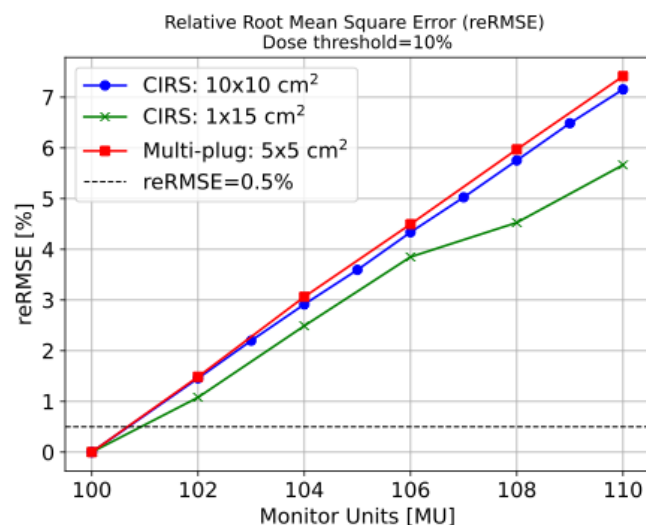
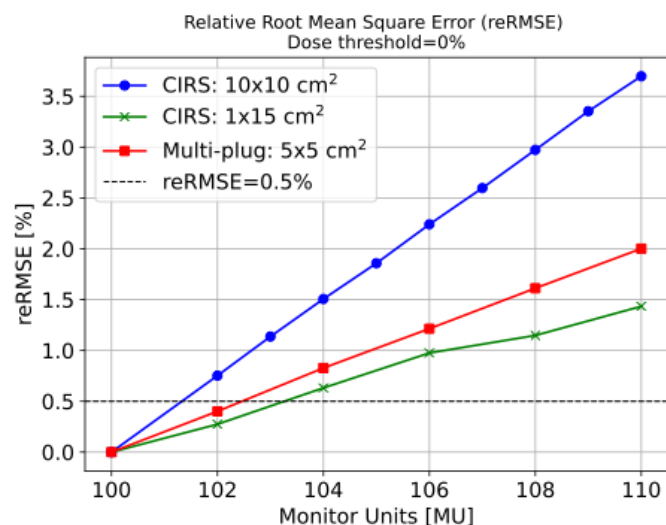


1MU delivery error- relative root mean square error (reRMSE)

Dependence:

- dose threshold
- phantom
- reRMSE>0.5%: alarm ⚠

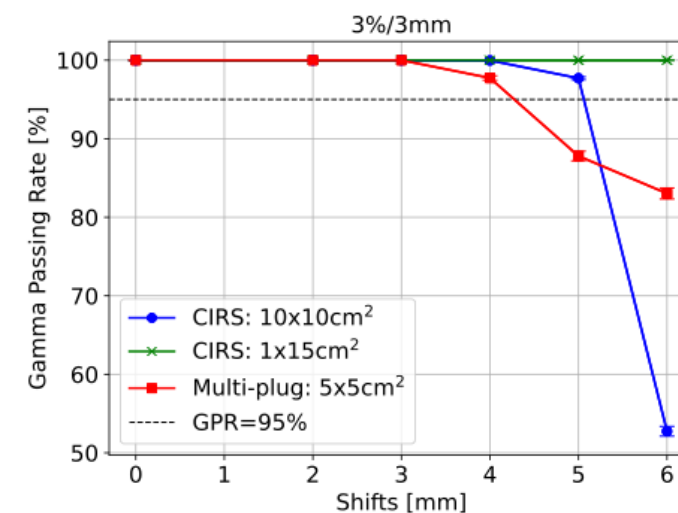
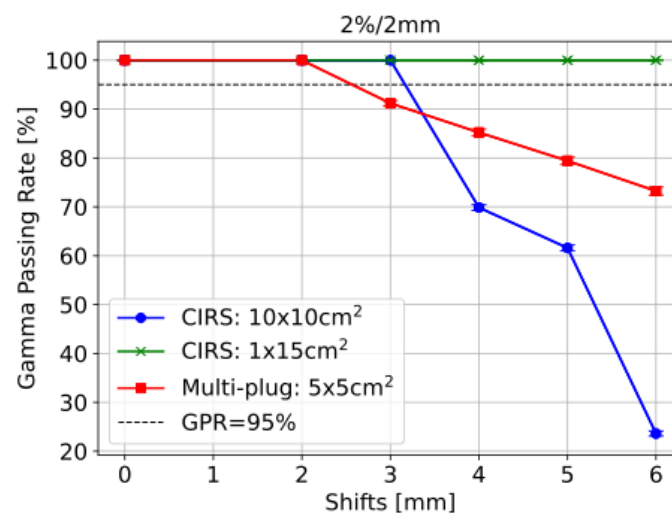
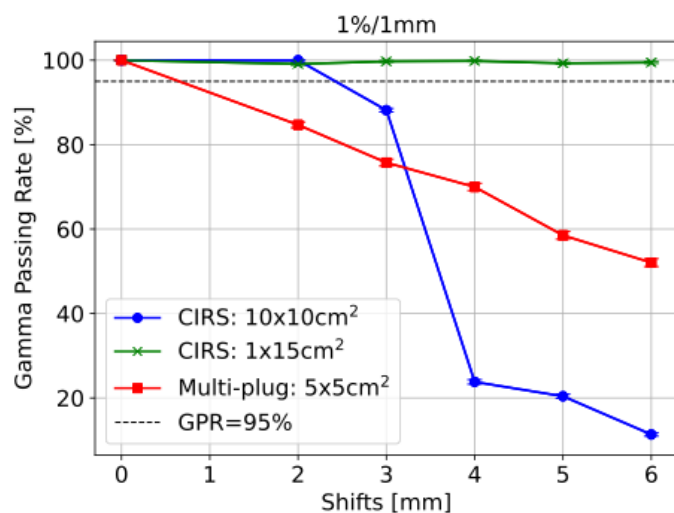
$$\text{reRMSE} = \frac{\sqrt{\frac{1}{N_{i \in T}} \sum_{i=1}^{N_{i \in T}} (D_{e,i} - D_{r,i})^2}}{D_{r,i}^{\max}} \times 100\%$$



2 Setup error- positioning

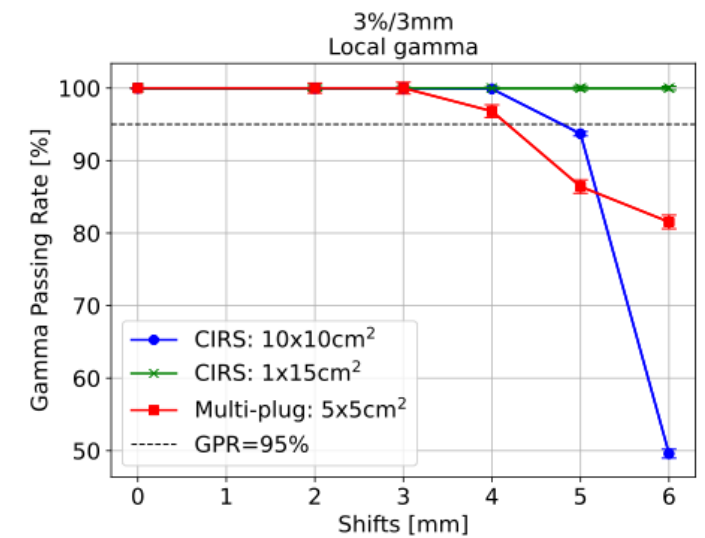
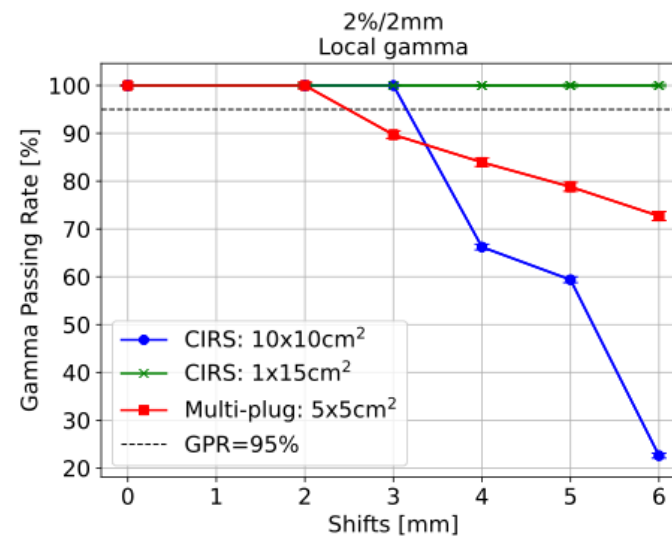
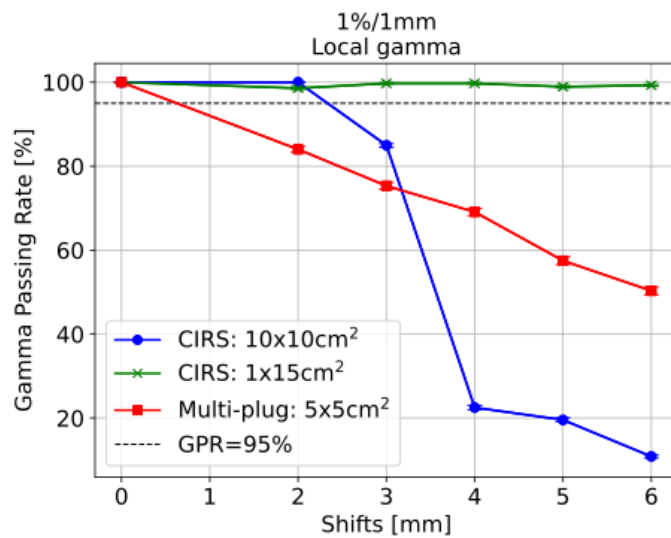
-Gamma passing rate
(GPR)

- GPR<95%: alarm ⚠
- Dose threshold: 80%
- Global gamma



Local gamma

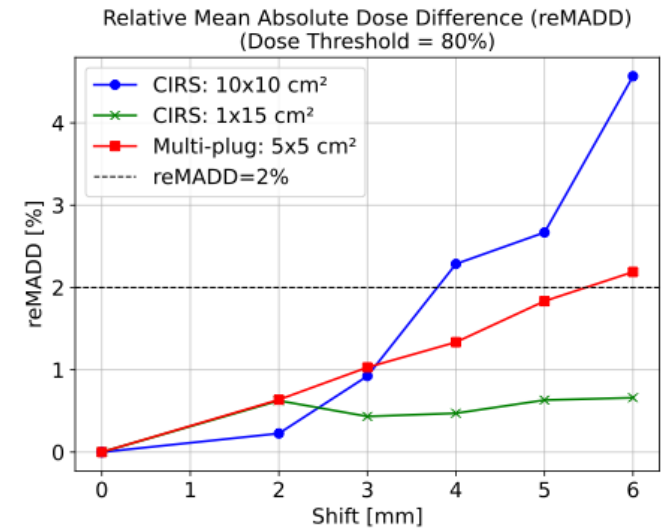
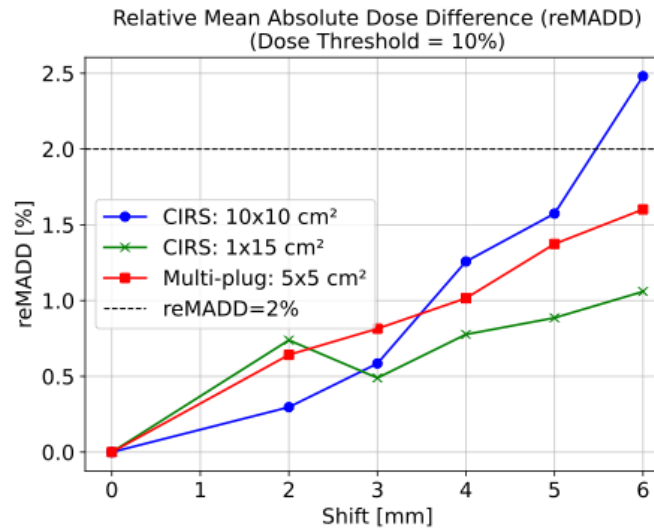
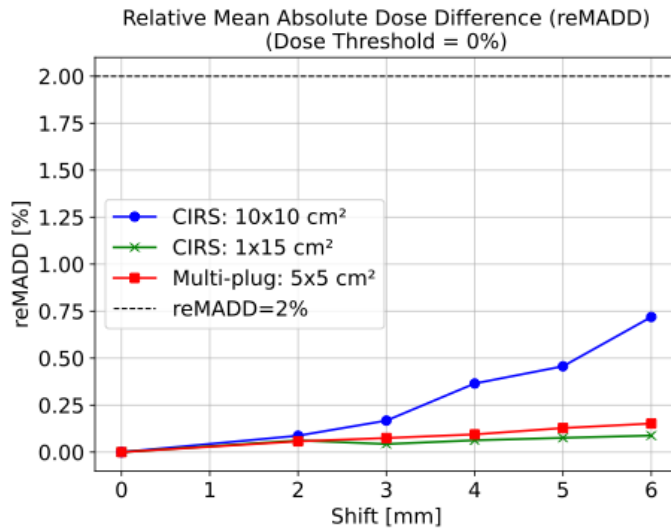
- GPR < 95%: alarm ⚠



2 Positioning-relative mean absolute dose difference (reMADD)

$$\text{reMADD} = \frac{\frac{1}{N_{\text{ieT}}} \sum_{i=1}^{N_{\text{ieT}}} |D_{\text{e},i} - D_{\text{r},i}|}{D_{\text{r},i}^{\text{max}}} \times 100\%$$

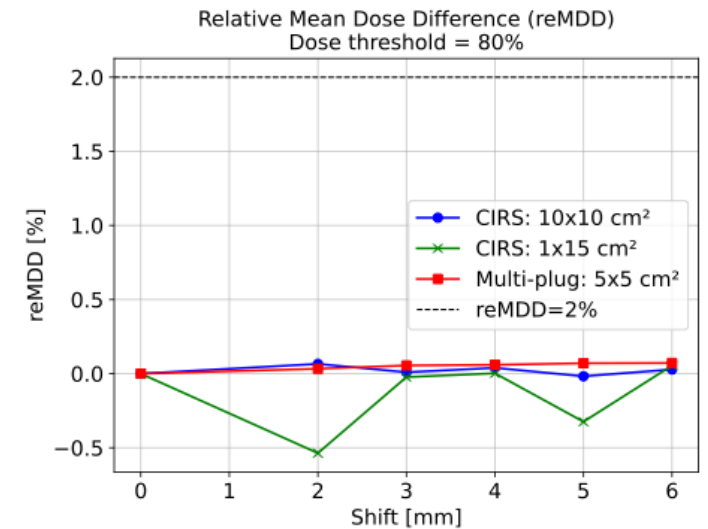
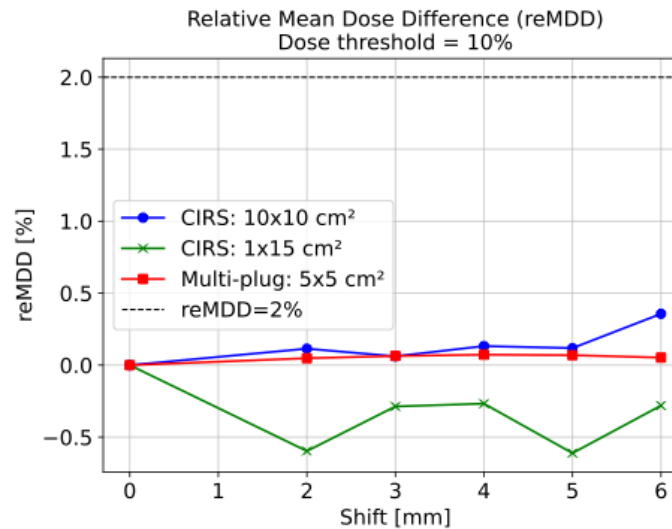
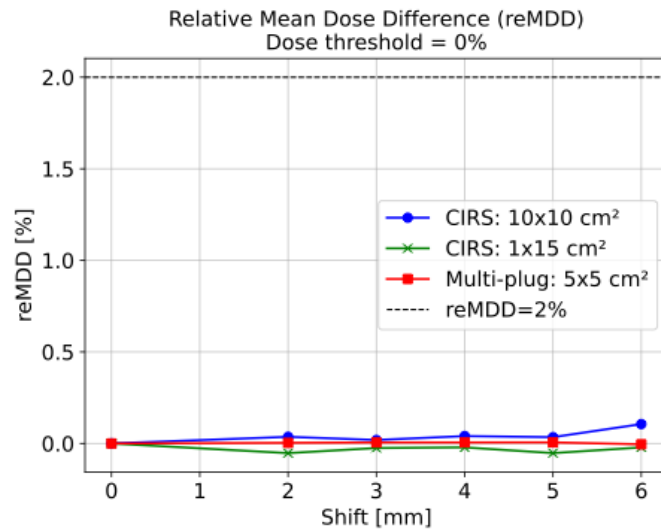
reMADD>2%: alarm ⚠



2 Positioning-relative mean dose difference (reMDD)

$$\text{reMDD} = \frac{\frac{1}{N_{ieT}} \sum_{i=1}^{N_{ieT}} (D_{e,i} - D_{r,i})}{D_{r,i}^{\max}} \times 100\%$$

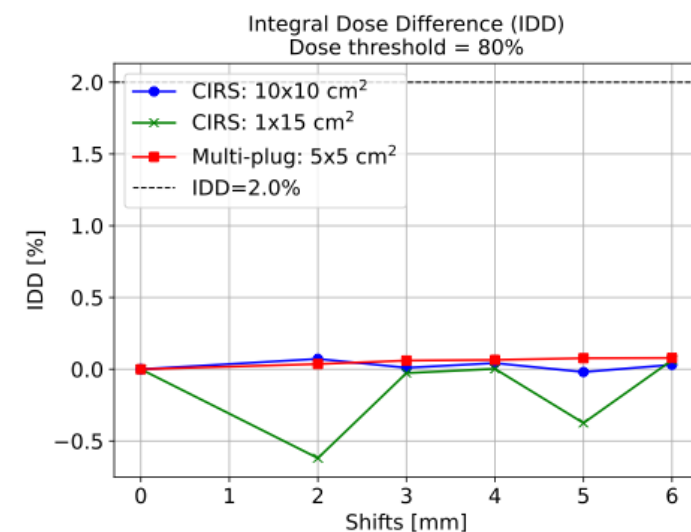
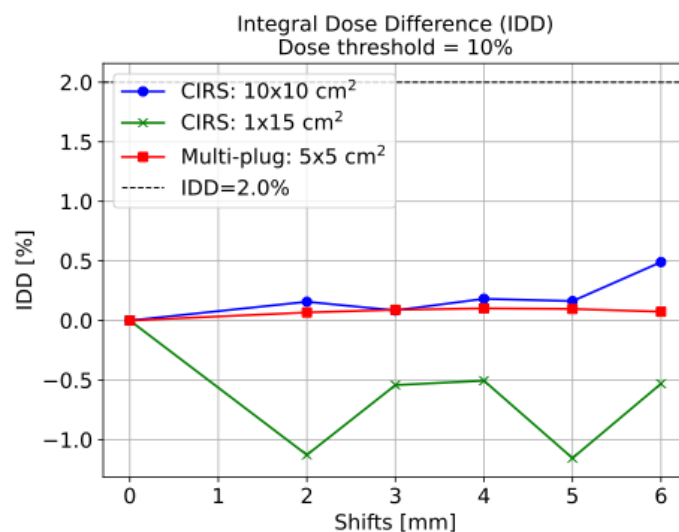
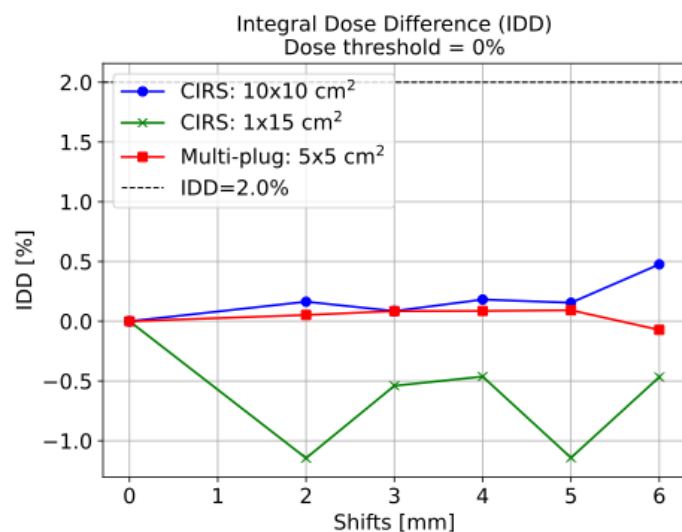
reMDD > 2%: alarm ⚠



2Positioning-relative integral dose difference (reIDD)

$$\text{reIDD} = \frac{\sum_{i=1}^{N_{i \in T}} D_{e,i} - \sum_{i=1}^{N_{i \in T}} D_{r,i}}{\sum_{i=1}^{N_{i \in T}} D_{r,i}} \times 100\%$$

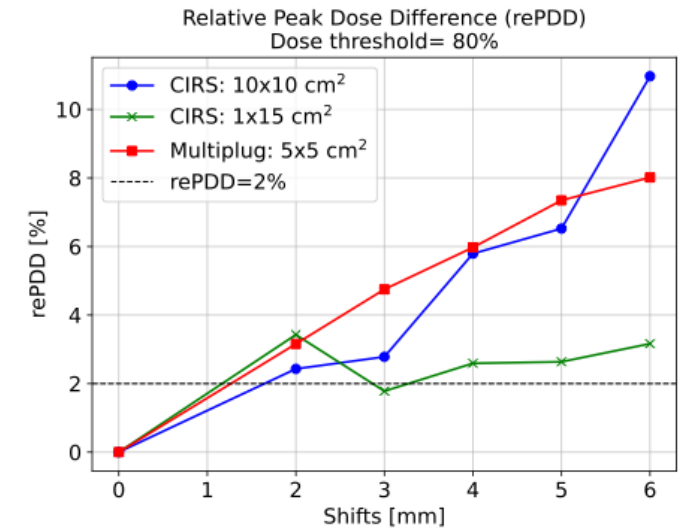
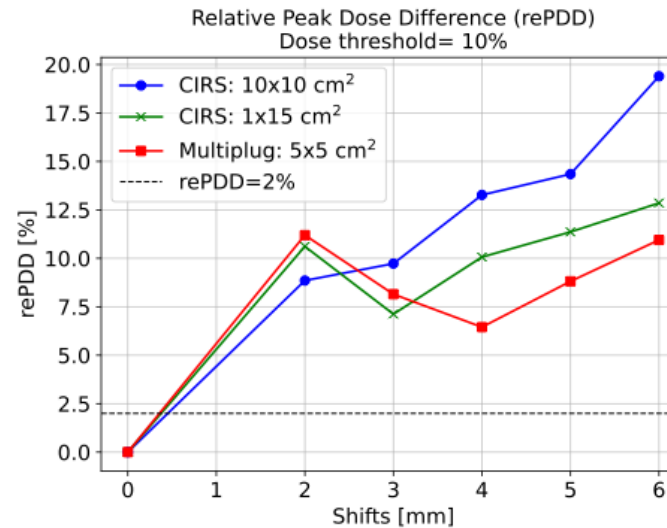
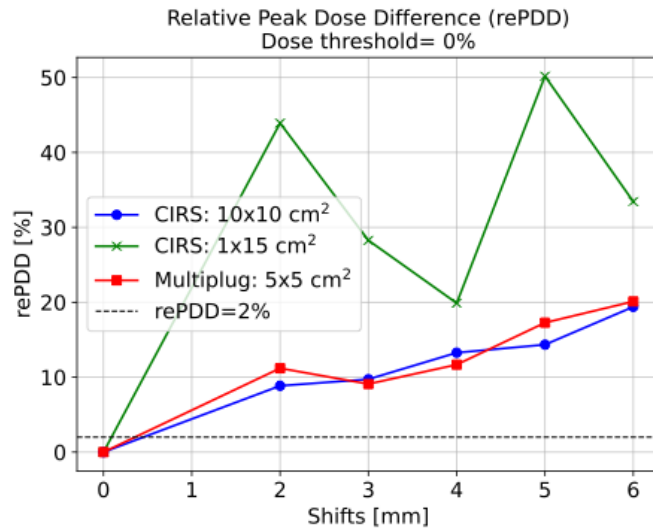
reIDD > 2%: alarm ⚠



2 Positioning-**relative peak dose difference (rePDD)**

$$\text{rePDD} = \max \frac{D_{e,i} - D_{r,i}}{D_{r,i}} \times 100\%$$

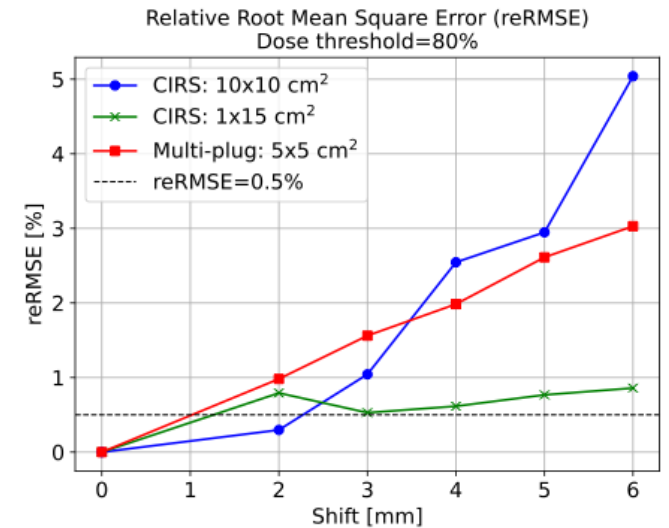
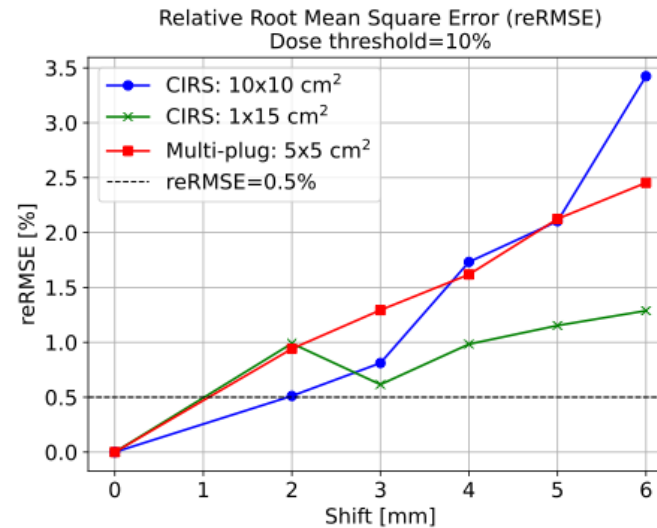
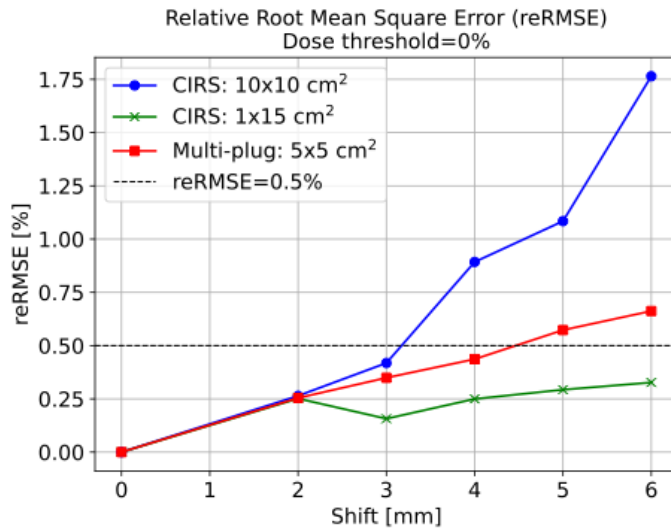
rePDD > 2%: alarm ⚠



2Positioning-relative root mean square error (reRMSE)

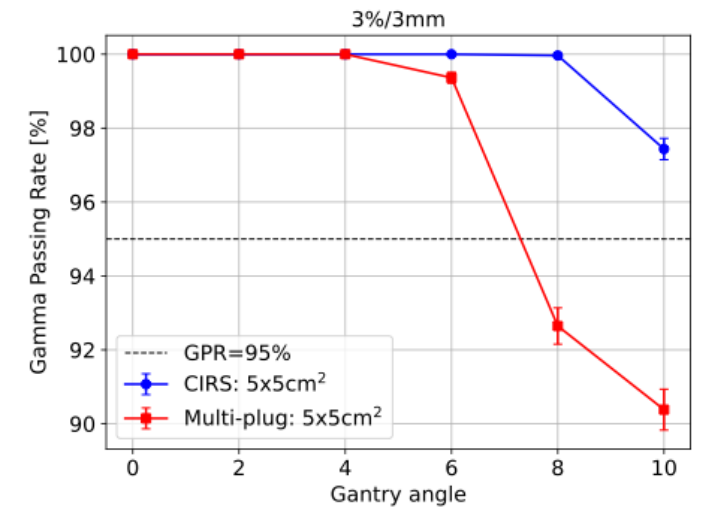
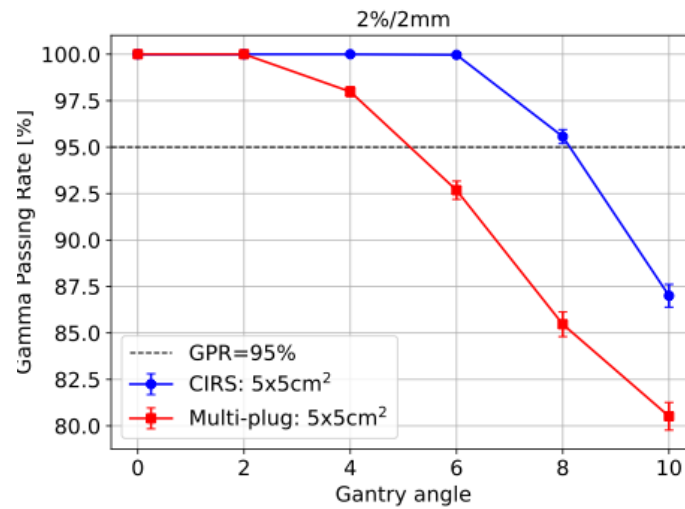
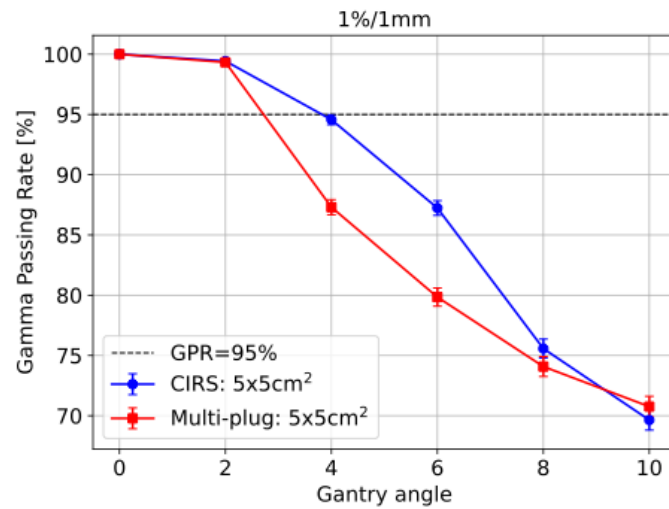
$$\text{reRMSE} = \frac{\sqrt{\frac{1}{N_{i \in T}} \sum_{i=1}^{N_{i \in T}} (D_{e,i} - D_{r,i})^2}}{D_{r,i}^{\max}} \times 100\%$$

reRMSE>0.5%: alarm ⚠



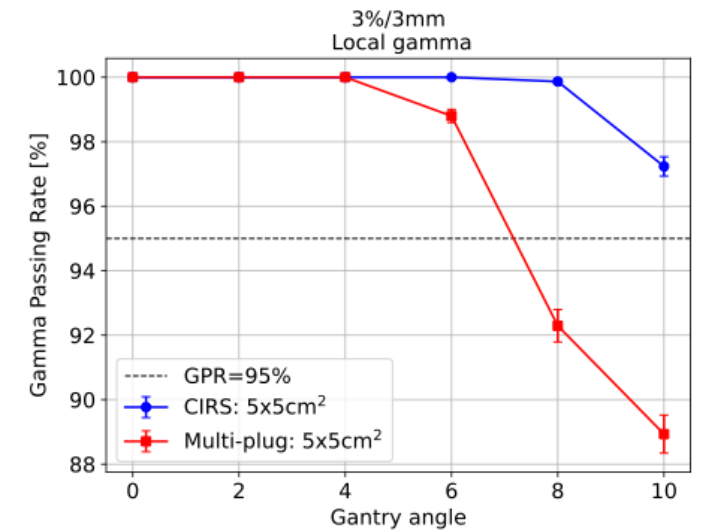
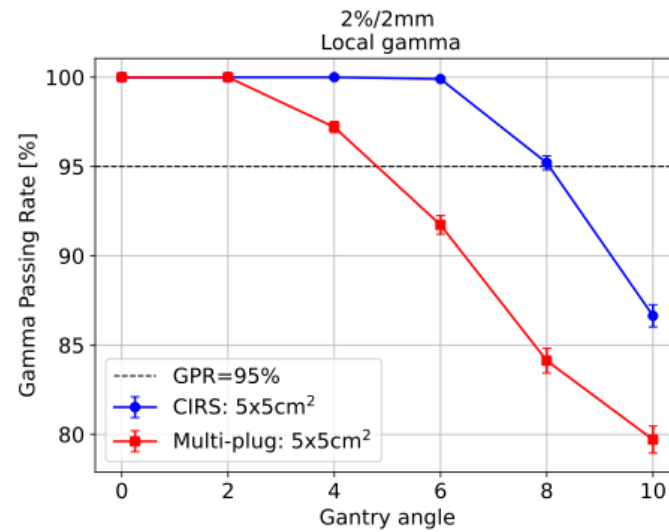
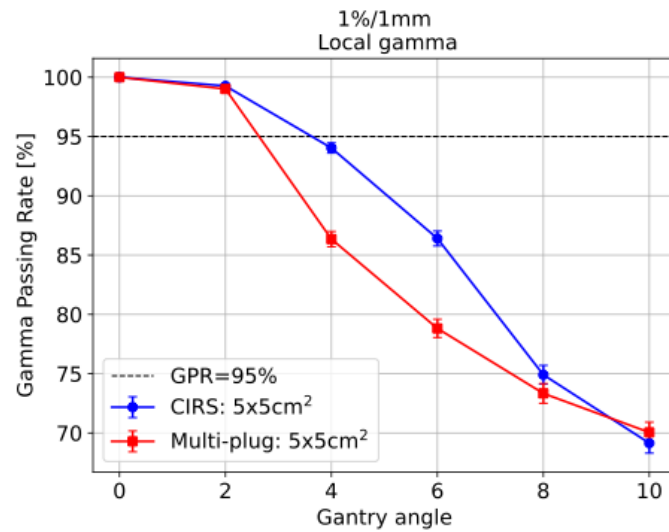
3 Setup-Gantry angle-**Gamma** passing rate (GPR)

- GPR<95%: alarm ⚠



Local gamma

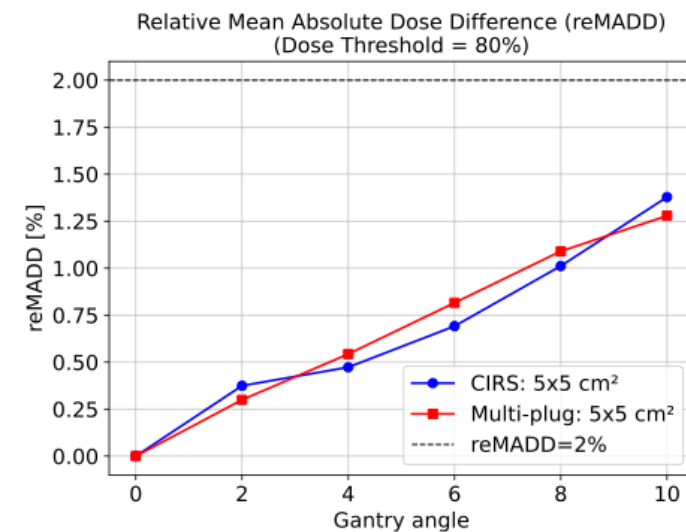
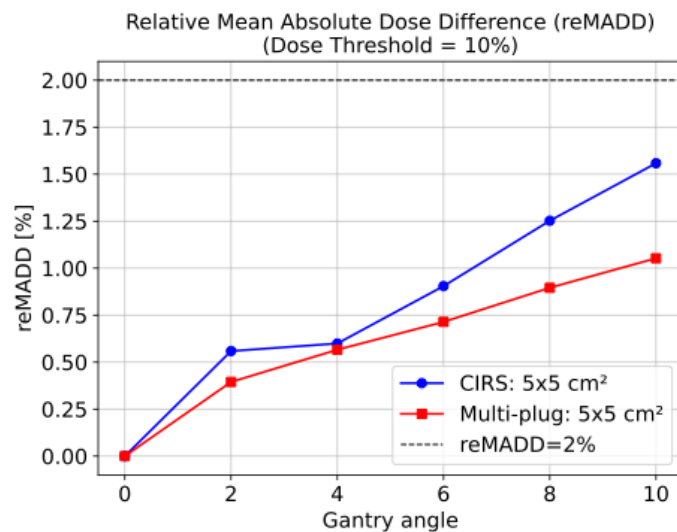
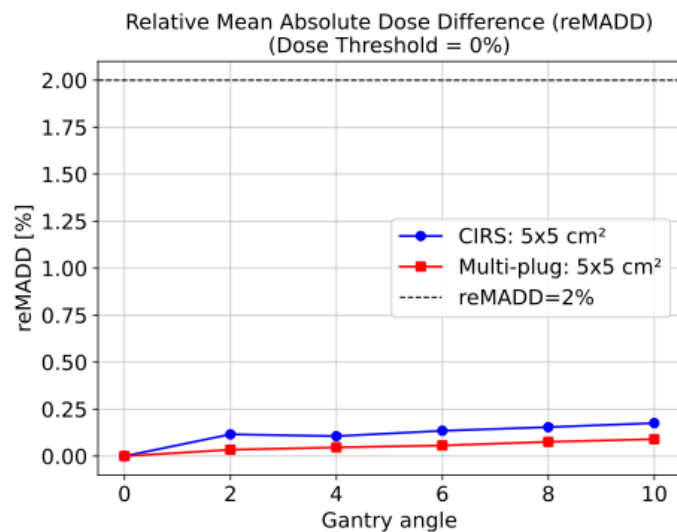
- GPR<95%: alarm ⚠
- Dose threshold: 80%



3Gantry angle- relative mean absolute dose difference (reMADD)

$$\text{reMADD} = \frac{\frac{1}{N_{\text{ieT}}} \sum_{i=1}^{N_{\text{ieT}}} |D_{\text{e},i} - D_{\text{r},i}|}{D_{\text{r},i}^{\text{max}}} \times 100\%$$

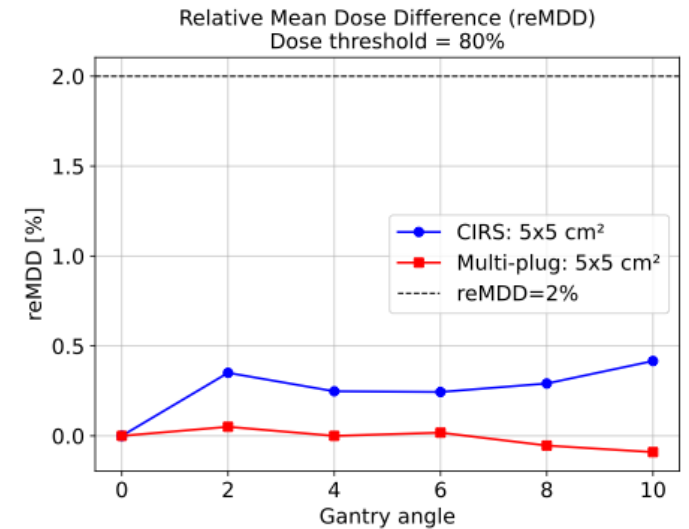
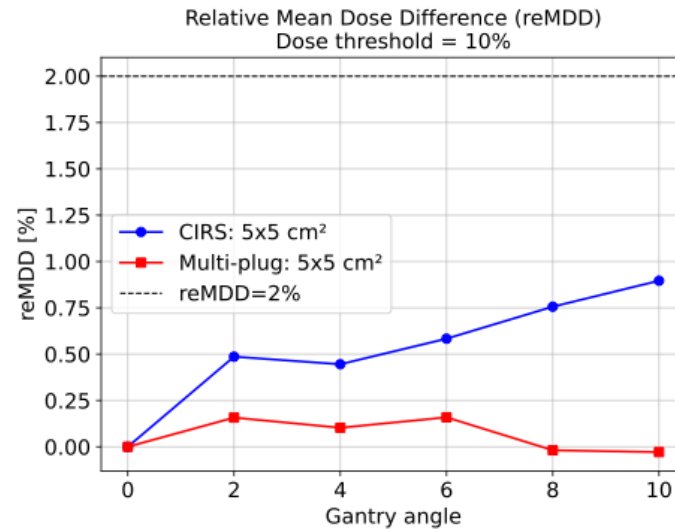
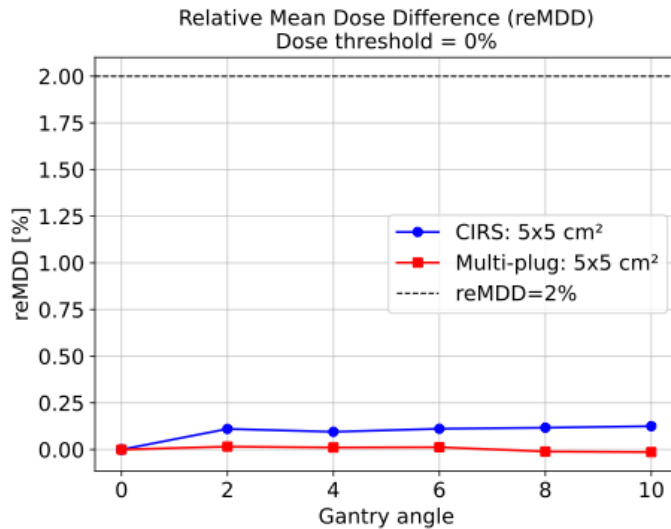
reMADD>2%: alarm ⚠



3Gantry angle- relative mean dose difference (reMDD)

$$\text{reMDD} = \frac{\frac{1}{N_{i \in T}} \sum_{i=1}^{N_{i \in T}} (D_{e,i} - D_{r,i})}{D_{r,i}^{\max}} \times 100\%$$

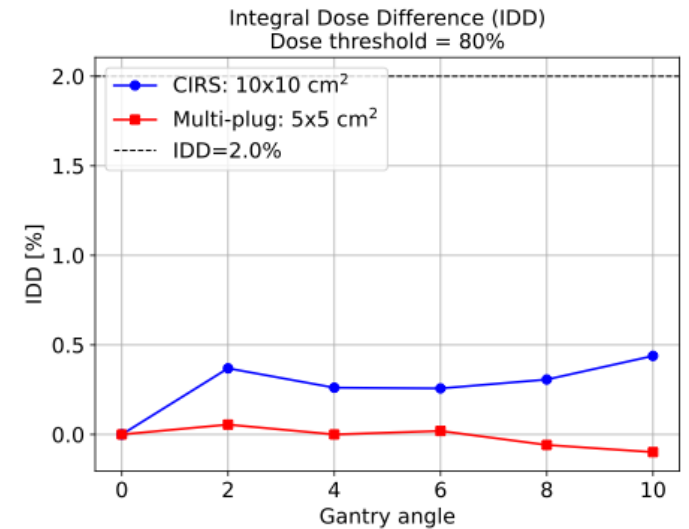
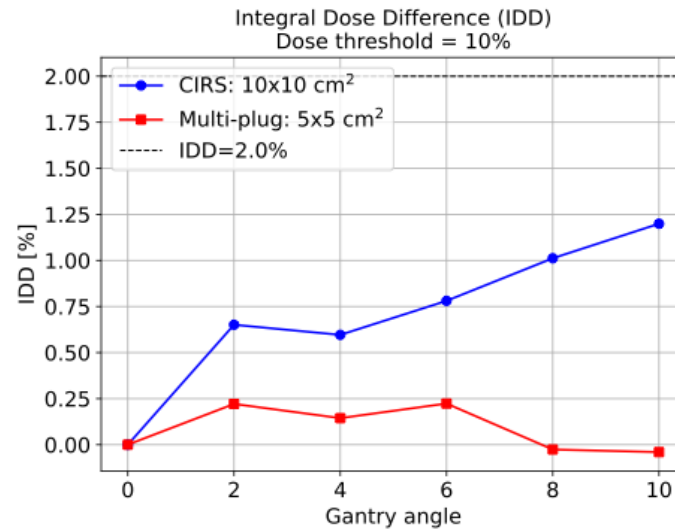
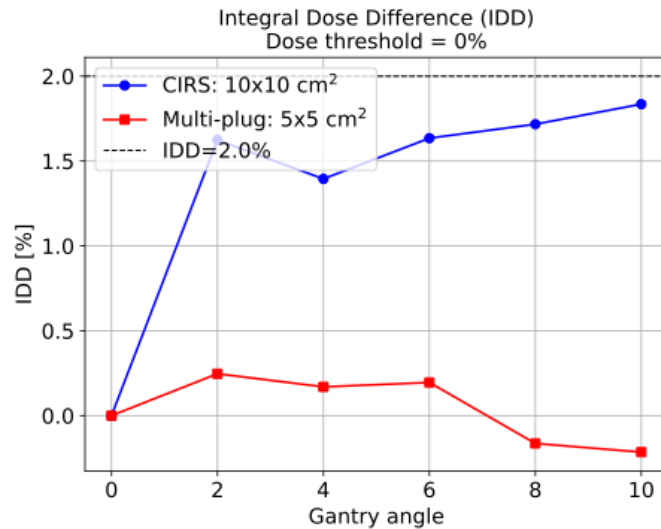
reMDD>2%: alarm ⚠



3Gantry angle- relative integral dose difference (reIDD)

$$\text{reIDD} = \frac{\sum_{i=1}^{N_{i \in T}} D_{e,i} - \sum_{i=1}^{N_{i \in T}} D_{r,i}}{\sum_{i=1}^{N_{i \in T}} D_{r,i}} \times 100\%$$

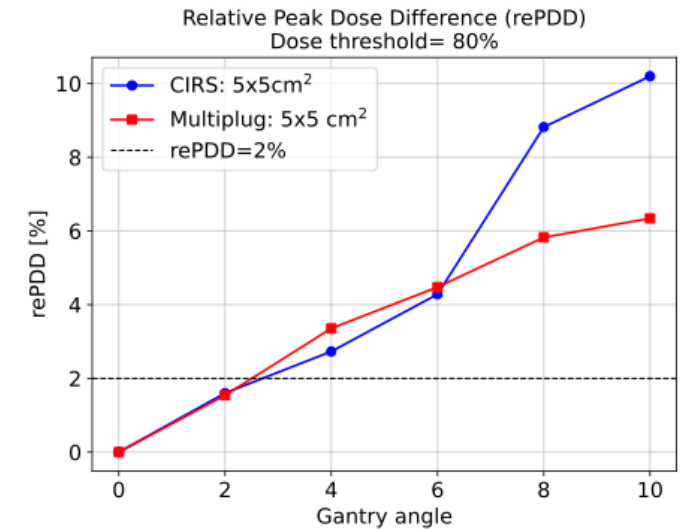
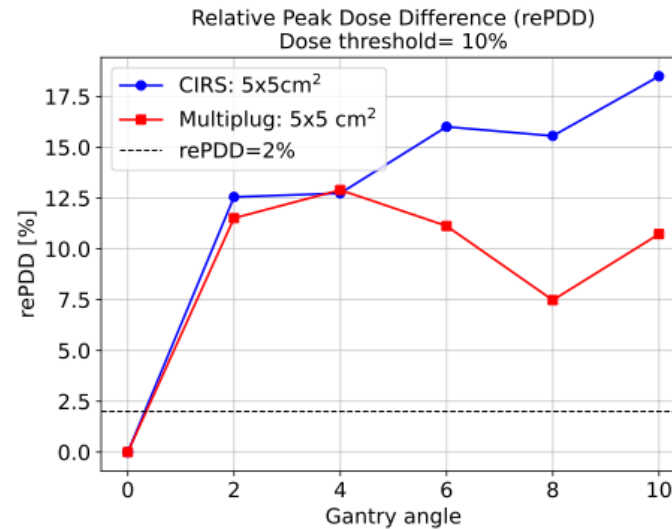
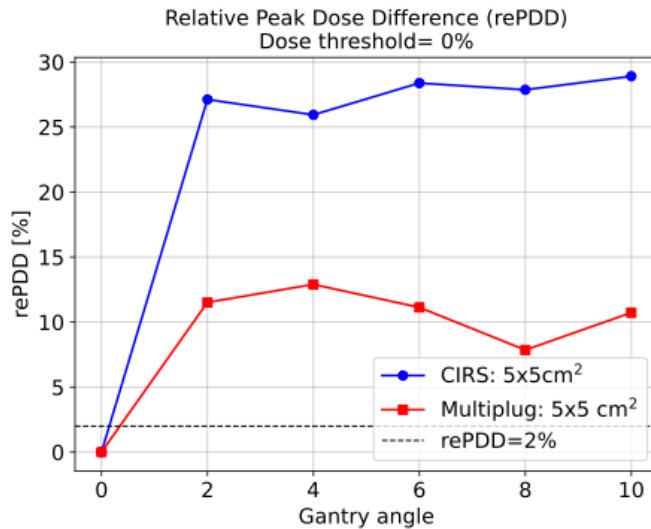
reIDD>2%: alarm ⚠



3Gantry angle- relative peak dose difference (rePDD)

$$\text{rePDD} = \max \frac{D_{e,i} - D_{r,i}}{D_{r,i}} \times 100\%$$

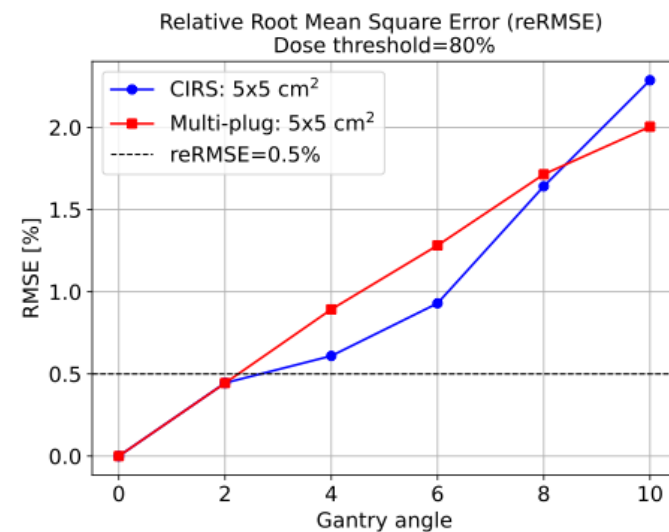
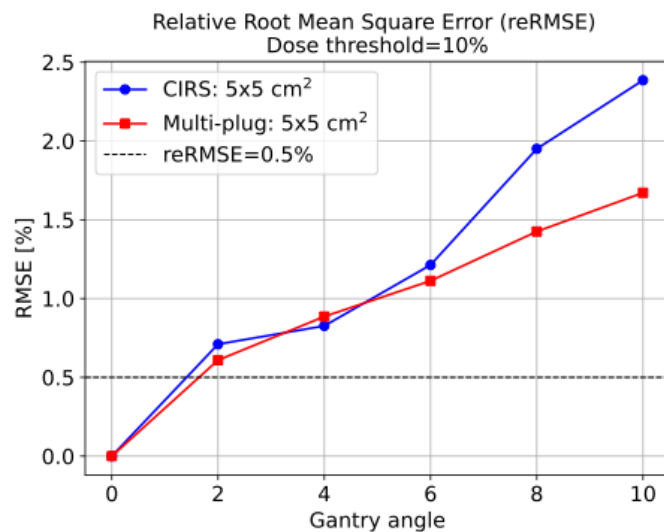
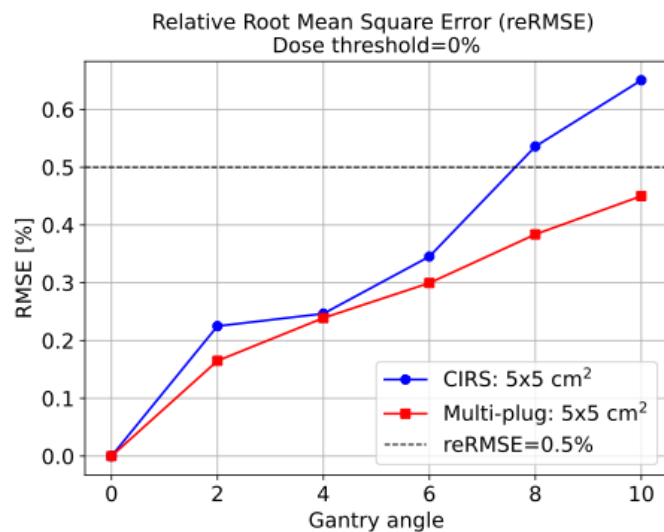
rePDD>2%: alarm ⚠



3Gantry angle- relative root mean square error (reRMSE)

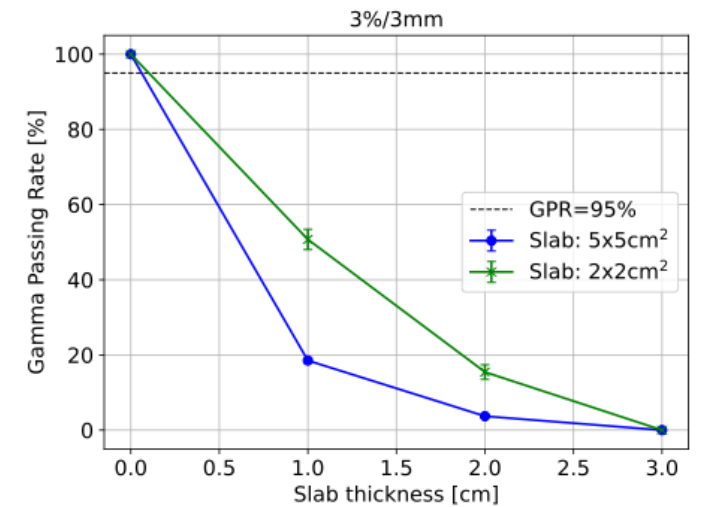
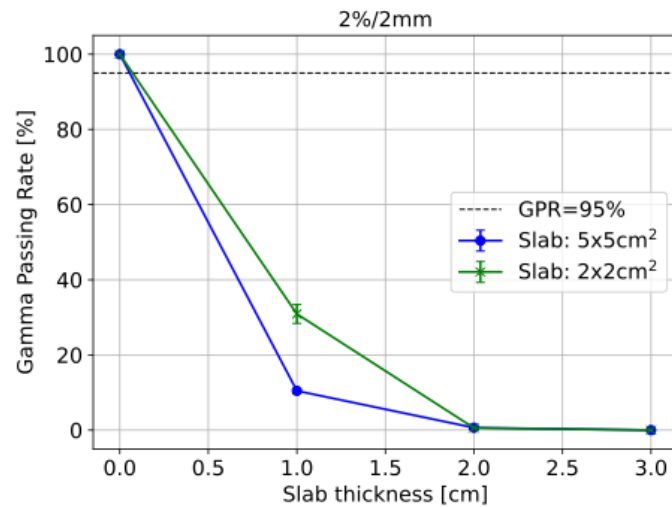
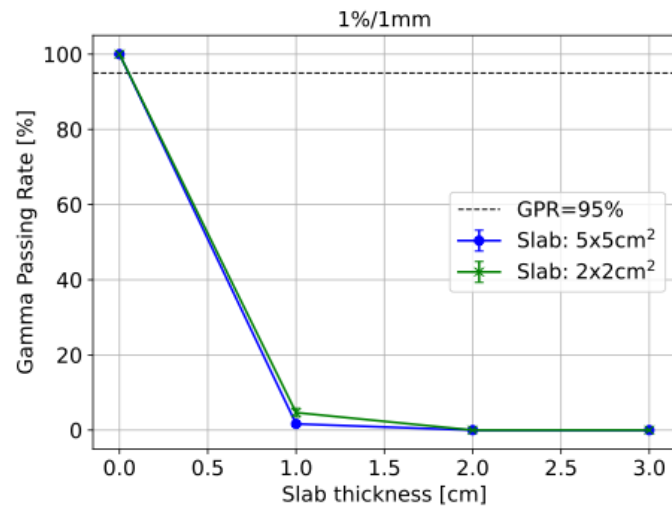
$$\text{reRMSE} = \frac{\sqrt{\frac{1}{N_{i \in T}} \sum_{i=1}^{N_{i \in T}} (D_{e,i} - D_{r,i})^2}}{D_{r,i}^{\max}} \times 100\%$$

reRMSE>0.5%: alarm ⚠



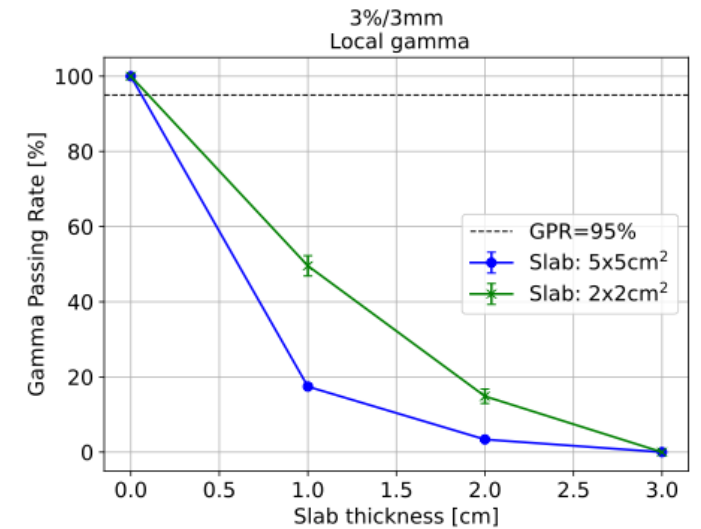
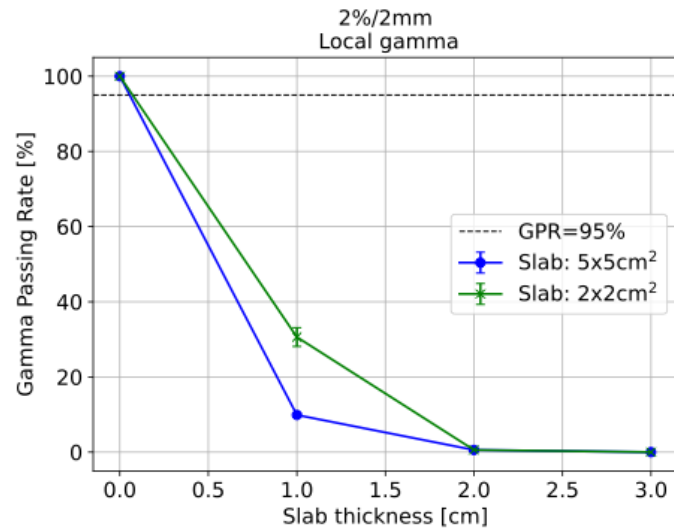
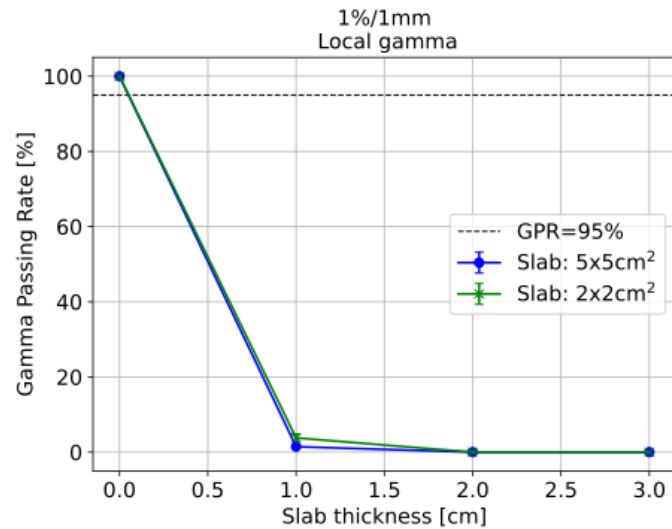
4 Anatomy change- Gamma passing rate (GPR)

- GPR<95%: alarm ⚠



Local gamma

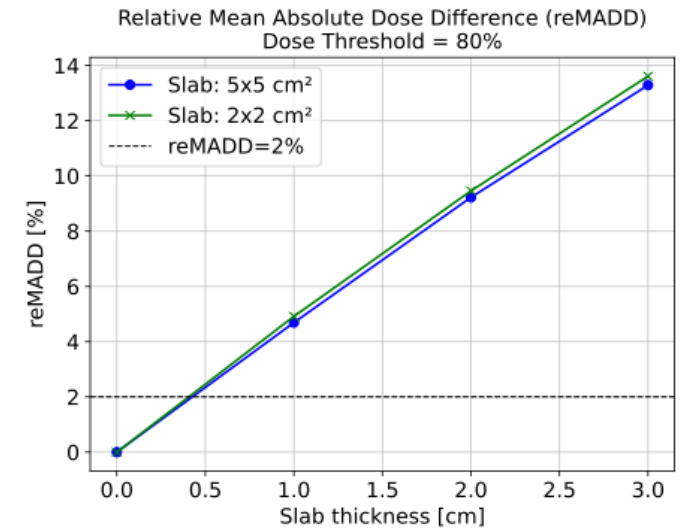
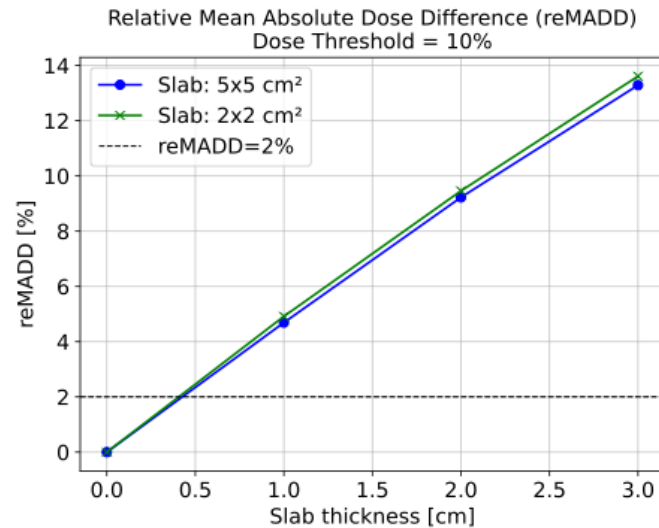
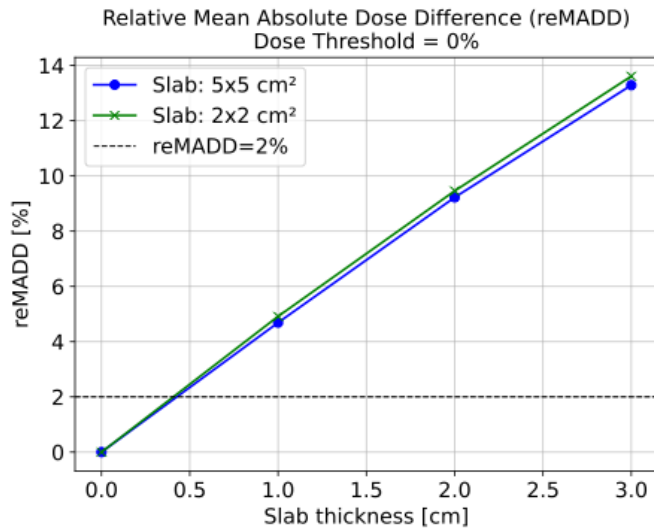
- GPR<95%: alarm ⚠
- Dose threshold: 80%



4Anatomy-relative mean absolute dose difference (reMADD)

$$\text{reMADD} = \frac{\frac{1}{N_{\text{ieT}}} \sum_{i=1}^{N_{\text{ieT}}} |D_{\text{e},i} - D_{\text{r},i}|}{D_{\text{r},i}^{\text{max}}} \times 100\%$$

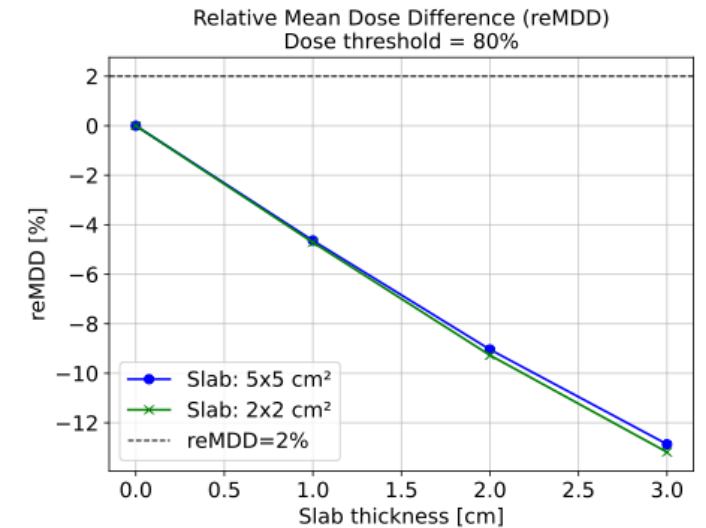
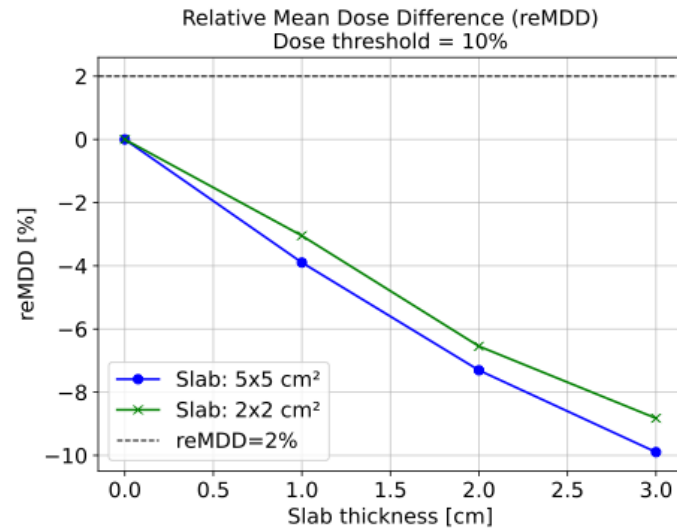
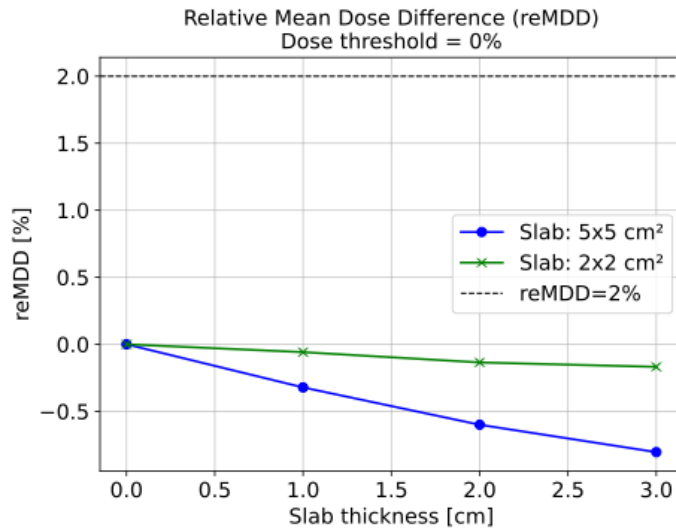
reMADD > 2%: alarm ⚠



4Anatomy-relative mean dose difference (reMDD)

$$\text{reMDD} = \frac{\frac{1}{N_{i \in T}} \sum_{i=1}^{N_{i \in T}} (D_{e,i} - D_{r,i})}{D_{r,i}^{\max}} \times 100\%$$

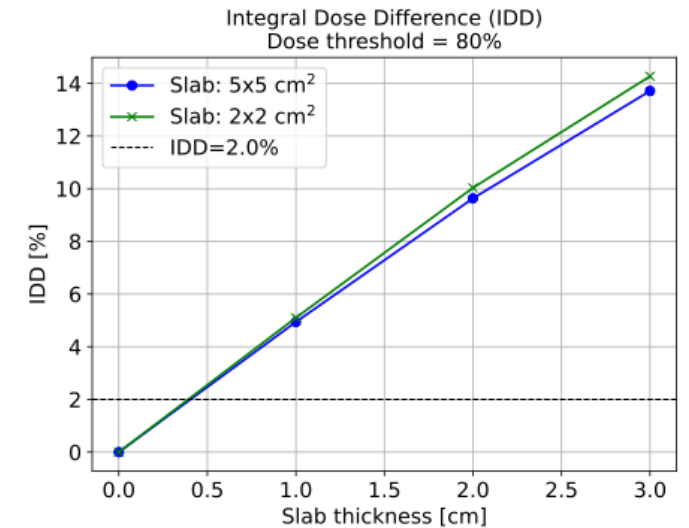
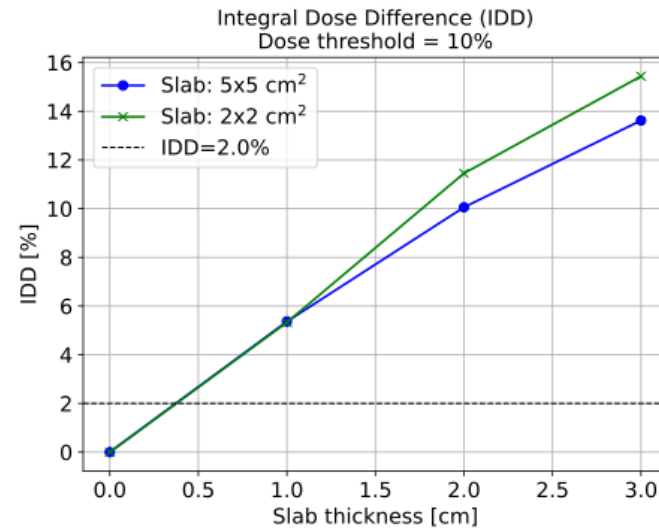
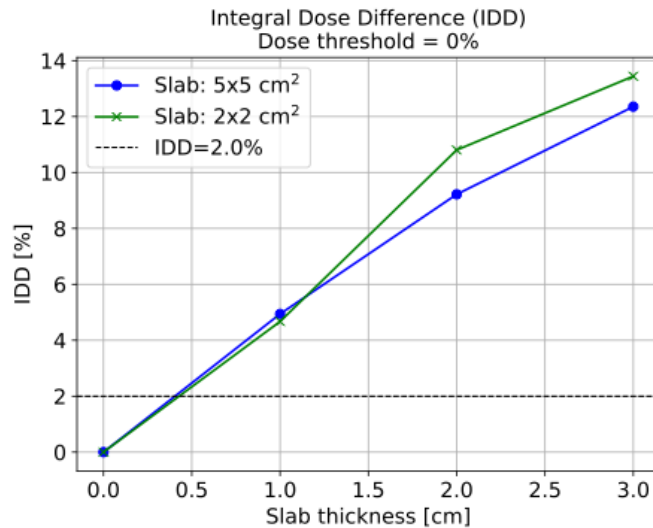
reMDD>2%: alarm ⚠



4Anatomy-relative integral dose difference (reIDD)

$$\text{reIDD} = \frac{\sum_{i=1}^{N_{i \in T}} D_{e,i} - \sum_{i=1}^{N_{i \in T}} D_{r,i}}{\sum_{i=1}^{N_{i \in T}} D_{r,i}} \times 100\%$$

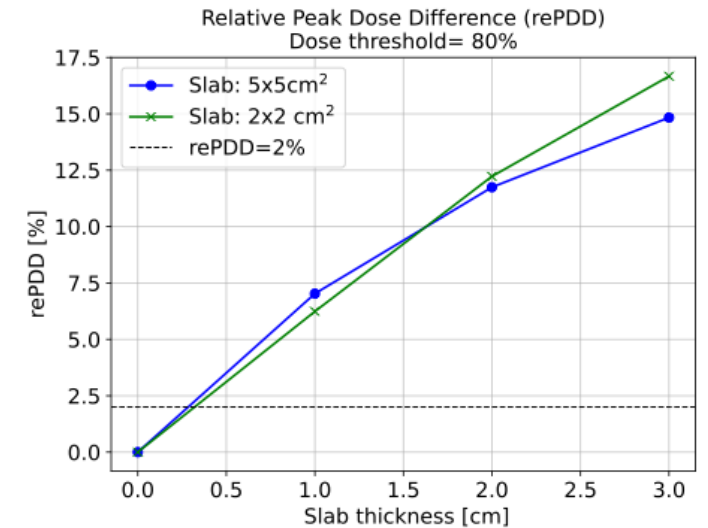
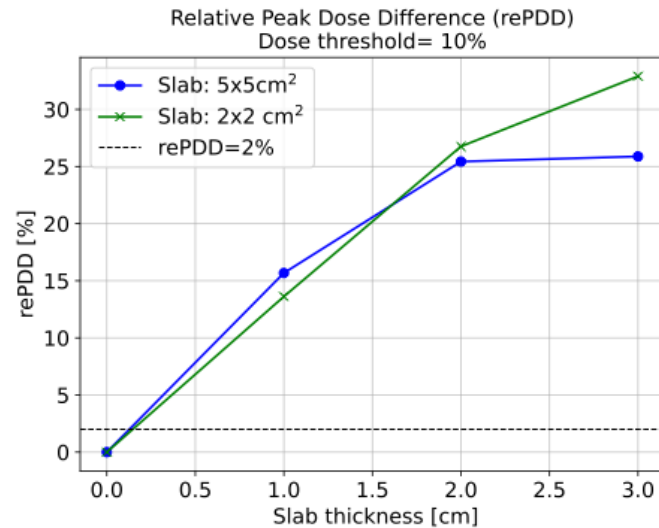
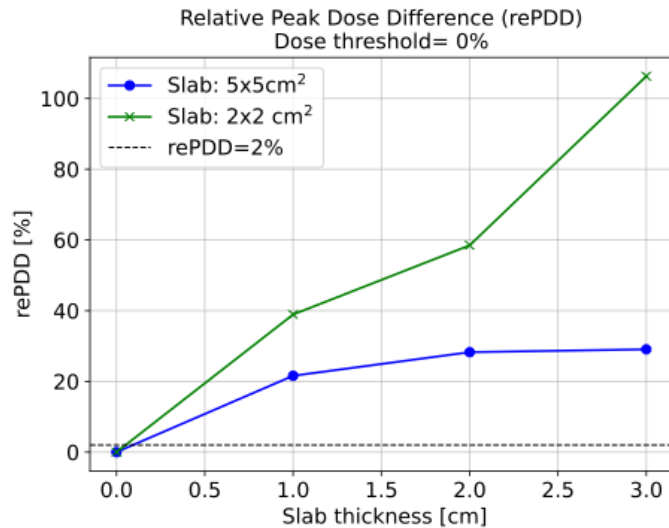
reIDD>2%: alarm ⚠



4Anatomy-relative peak dose difference (rePDD)

$$\text{rePDD} = \max \frac{D_{e,i} - D_{r,i}}{D_{r,i}} \times 100\%$$

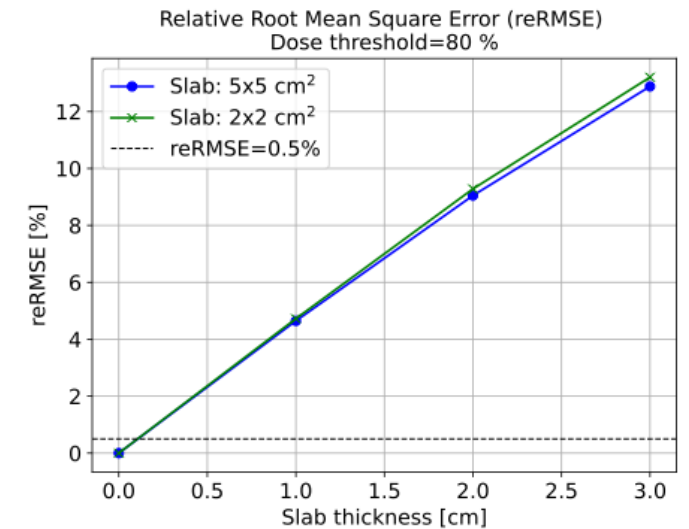
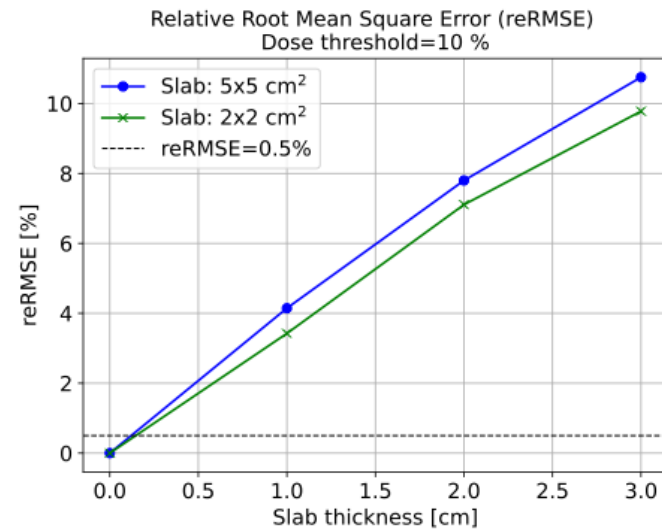
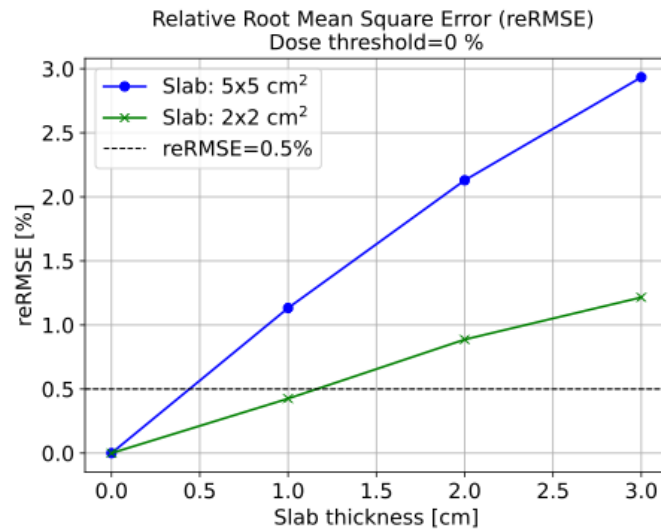
rePDD>2%: alarm ⚠

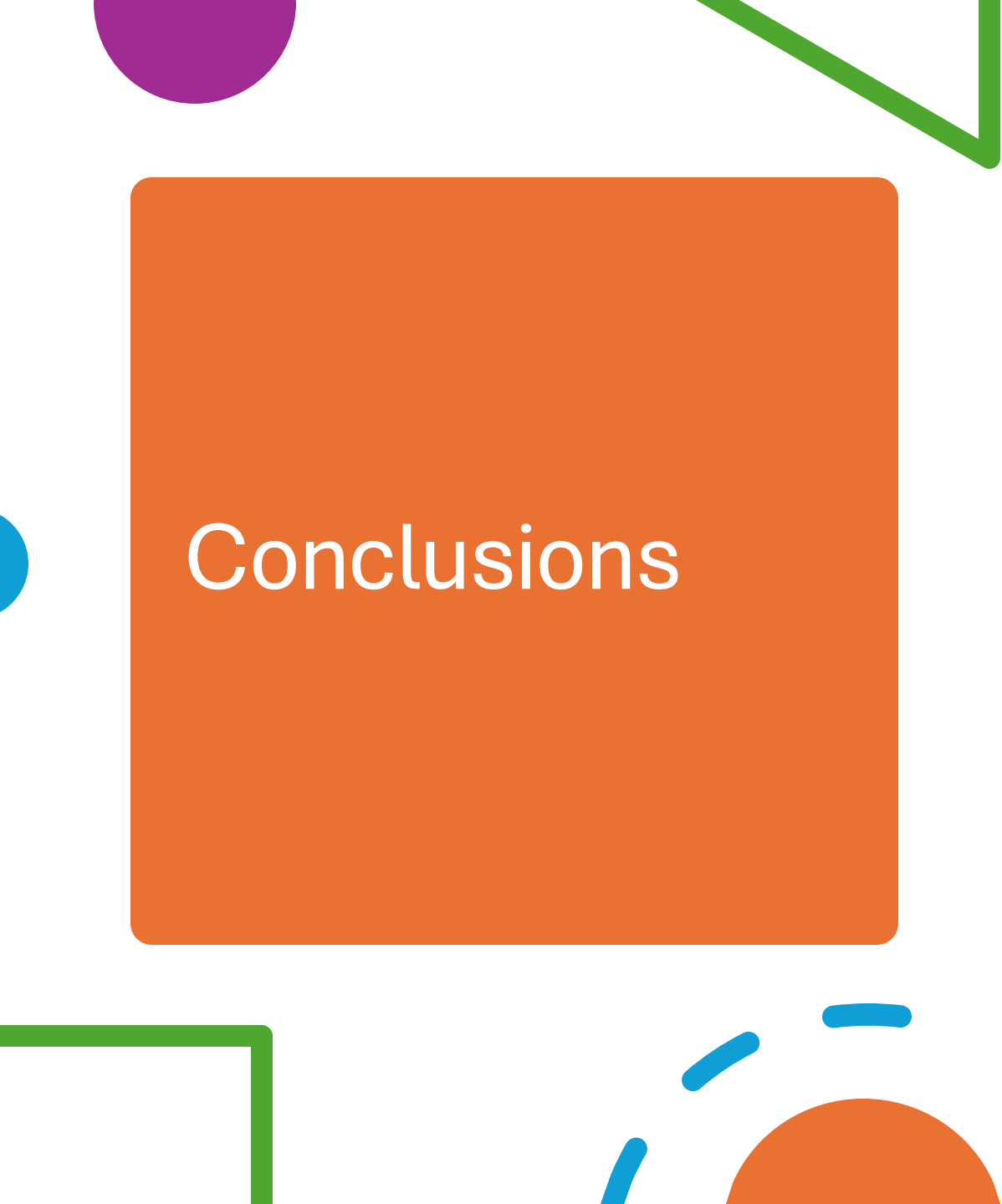


4Anatomy-relative root mean square error (reRMSE)

$$\text{reRMSE} = \frac{\sqrt{\frac{1}{N_{ieT}} \sum_{i=1}^{N_{ieT}} (D_{e,i} - D_{r,i})^2}}{D_{r,i}^{\max}} \times 100\%$$

reRMSE > 0.5%: alarm ⚠





Conclusions

1. Local gamma: small fields
 2. Tighter DD/DTA values
 3. Moderate dose thresholds: 10-80%
 4. Setup errors: need for GPR+ dd-related metrics
 5. Only: rePDD and reRMSE sensitive to setup errors
 6. Use of tighter values of dd-related metrics
- 

Grazie per l'Attenzione

