Precise Dose Verification in Proton Therapy via F-18

ADVANCED TECHNIQUES ENSURING ACCURATE CANCER TREATMENT DELIVERY

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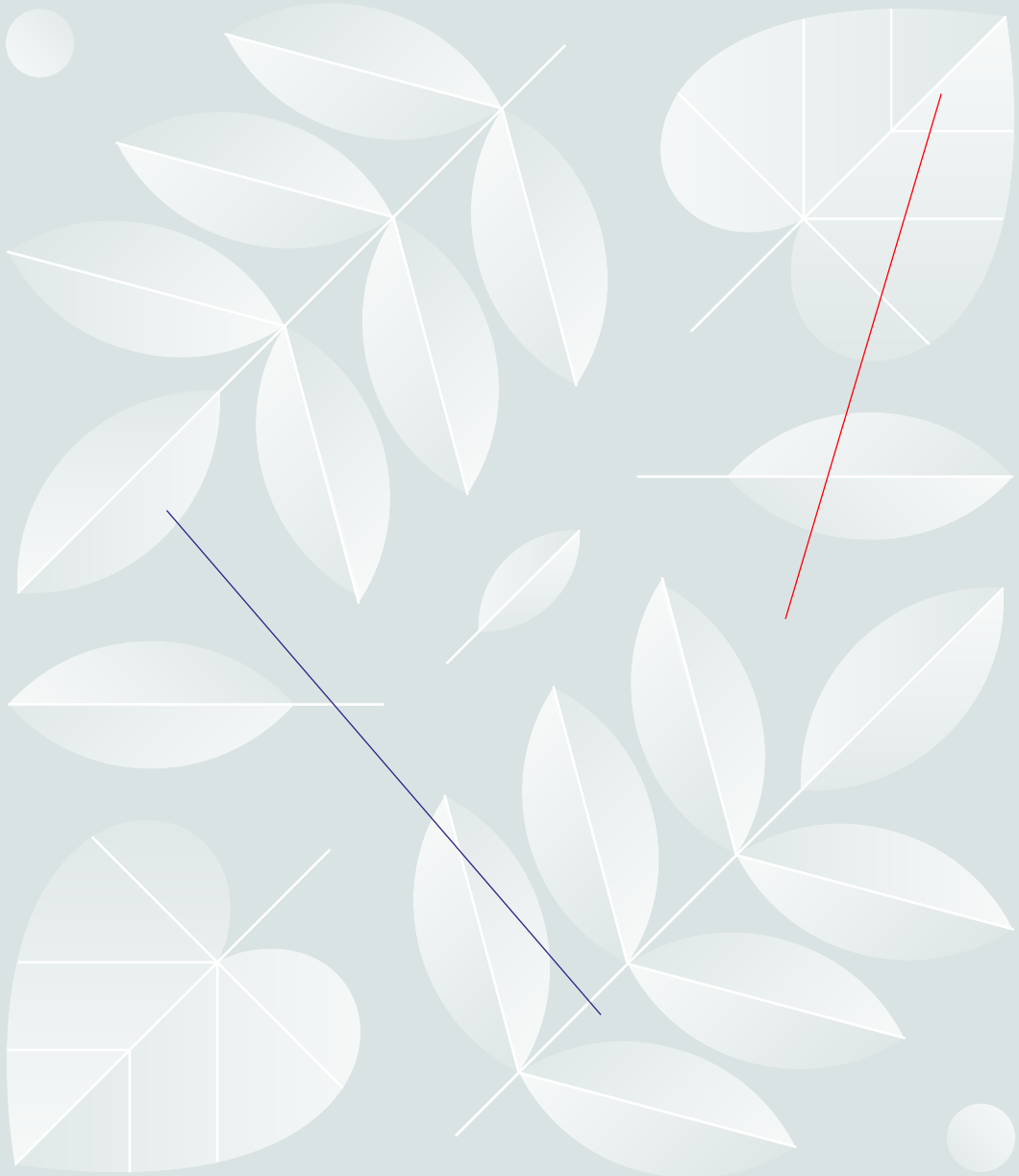
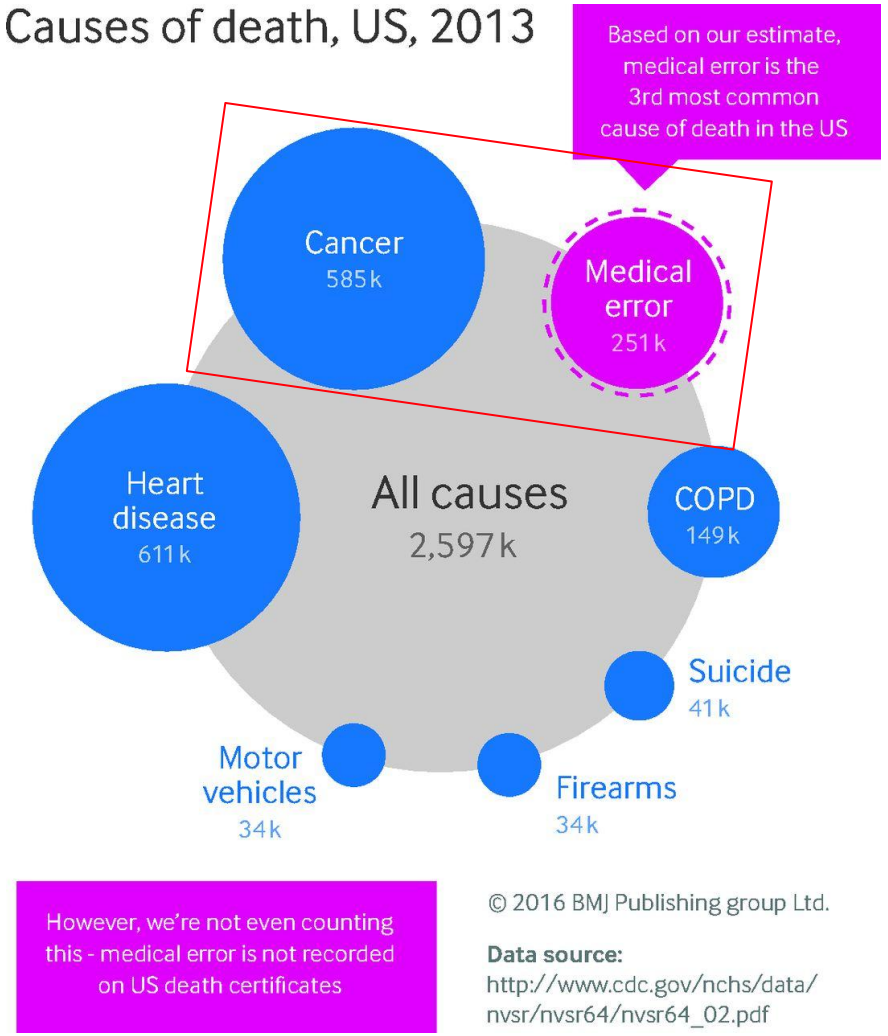


Introduction and Background

Fig 1 Most common causes of death in the United States, 20132.



Martin A Makary, and Michael Daniel BMJ 2016;353:bmj.i2139 https://doi.org/10.1136/bmj.i2139

https://www.cdc.gov/nchs/fastats/leading-causes-of-death.htm

See also : http://doi.org/10.1136/bmj.l4185

Introduction to Proton Therapy and Dose Verification

Proton Therapy Advantages

Proton therapy uses the Bragg peak for precise energy deposition, minimizing damage to healthy tissues.

Challenges in Dose Delivery

Small uncertainties in range or positioning can cause significant dose deviations, impacting treatment safety.

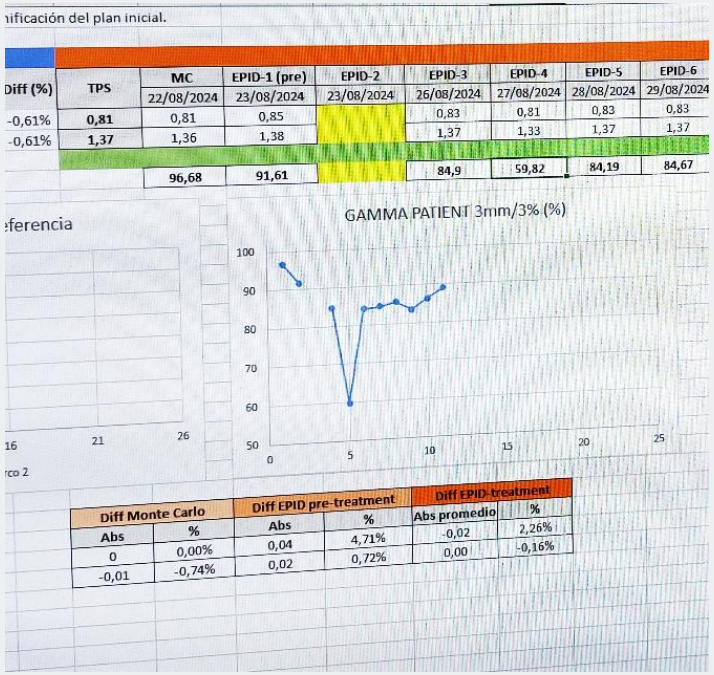
Importance of Dose Verification

Accurate dose verification prevents underdosing tumors or overdosing healthy tissue, improving treatment outcomes.

F-18 PET Imaging for Verification

F-18 isotope combined with PET imaging enables non-invasive and precise dose verification in proton therapy.

In photon radiotherapy, with PTW Dosimetry VeriQA, dose can be verified



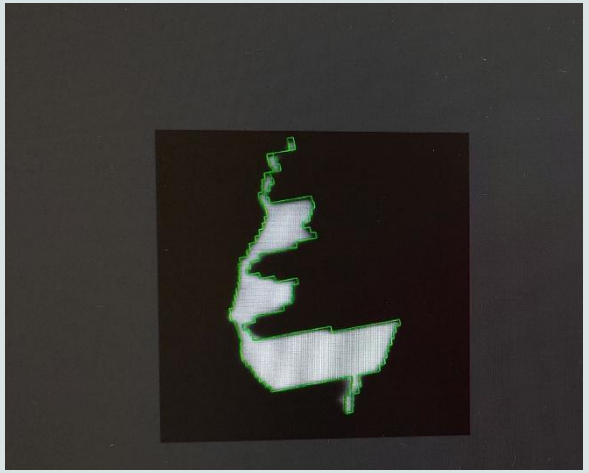
ificación del plan inicial.

Diff (%)	TPS	MC	EPID-1 (pre)	EPID-2	EPID-3	EPID-4	EPID-5	EPID-6
		22/08/2024	23/08/2024	23/08/2024	26/08/2024	27/08/2024	28/08/2024	29/08/2024
-0,61%	0,81	0,81	0,85		0,83	0,81	0,83	0,83
-0,61%	1,37	1,36	1,38		1,37	1,33	1,37	1,37
		96,68	91,61		84,9	59,82	84,19	84,67

eferencia

GAMMA PATIENT 3mm/3% (%)

Diff Monte Carlo		Diff EPID pre-treatment		Diff EPID treatment	
Abs	%	Abs	%	Abs promedio	%
0	0,00%	0,04	4,71%	-0,02	2,26%
-0,01	-0,74%	0,02	0,72%	0,00	-0,16%



Fundamentals of F-18 in Proton Therapy

Role of F-18 and PET Imaging

F-18 Isotope in PET Imaging O-18(p,n)F-18

Fluorine-18 is a positron emitter used in PET scans to visualize isotope distribution after proton therapy.

Delayed Imaging Advantage

F-18's 110-minute half-life allows delayed imaging, enabling patient transfer and accurate scanning post-irradiation.

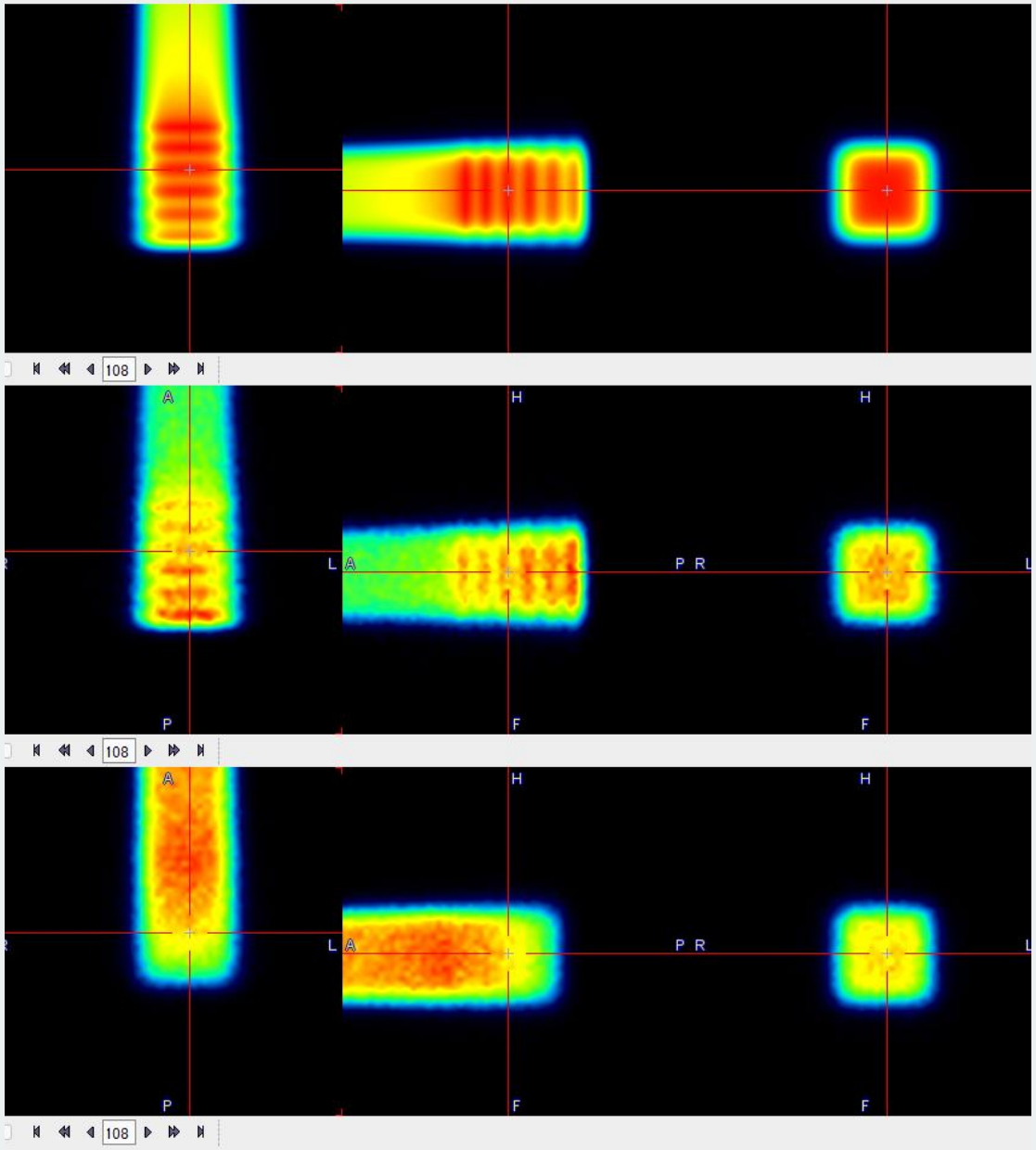
Dose Verification Using PET

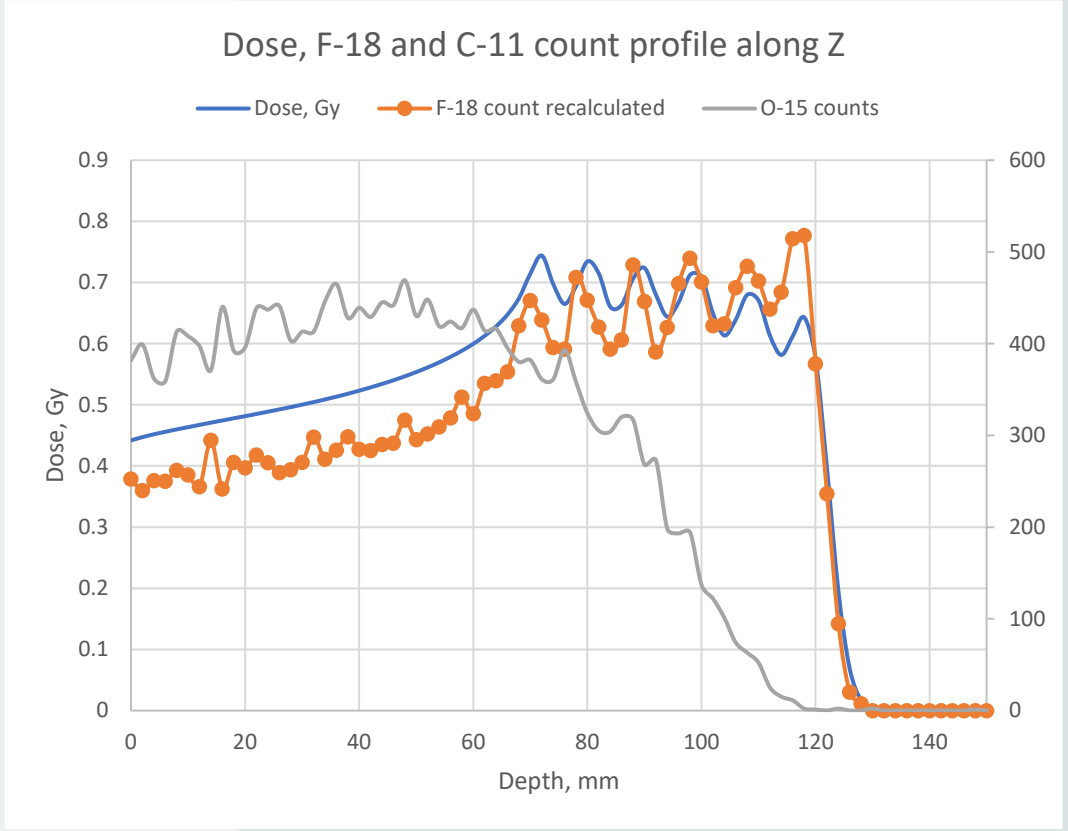
PET imaging maps proton interaction regions, providing an indirect method to verify dose distribution in tissues.

Advanced Dose Estimation

Algorithms and simulations convert isotope activity from PET into dose estimates, improving proton therapy accuracy.

From https://s1.pplstatics.com/elcorreo/www/multimedia/2025/11/07/hospital-005.jpg





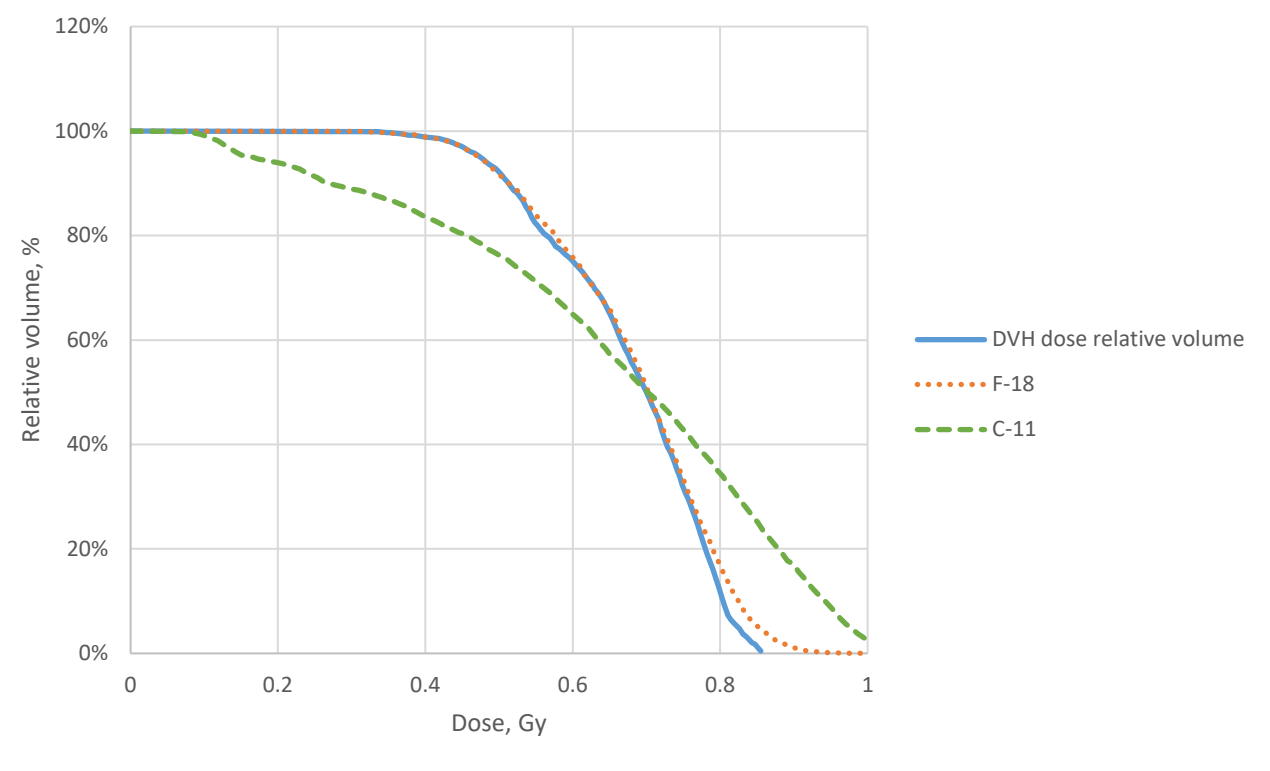
(Top) **Dose** profile in three planes for 2x2x2 mm pixel. 0.74 Gy dose.

(Middle) **β+ F-18 atoms** production in three planes

(Bottom) **β+ C-11 atoms**

Cold color scale with low in blue and high in red.

Dose Volume Histogram

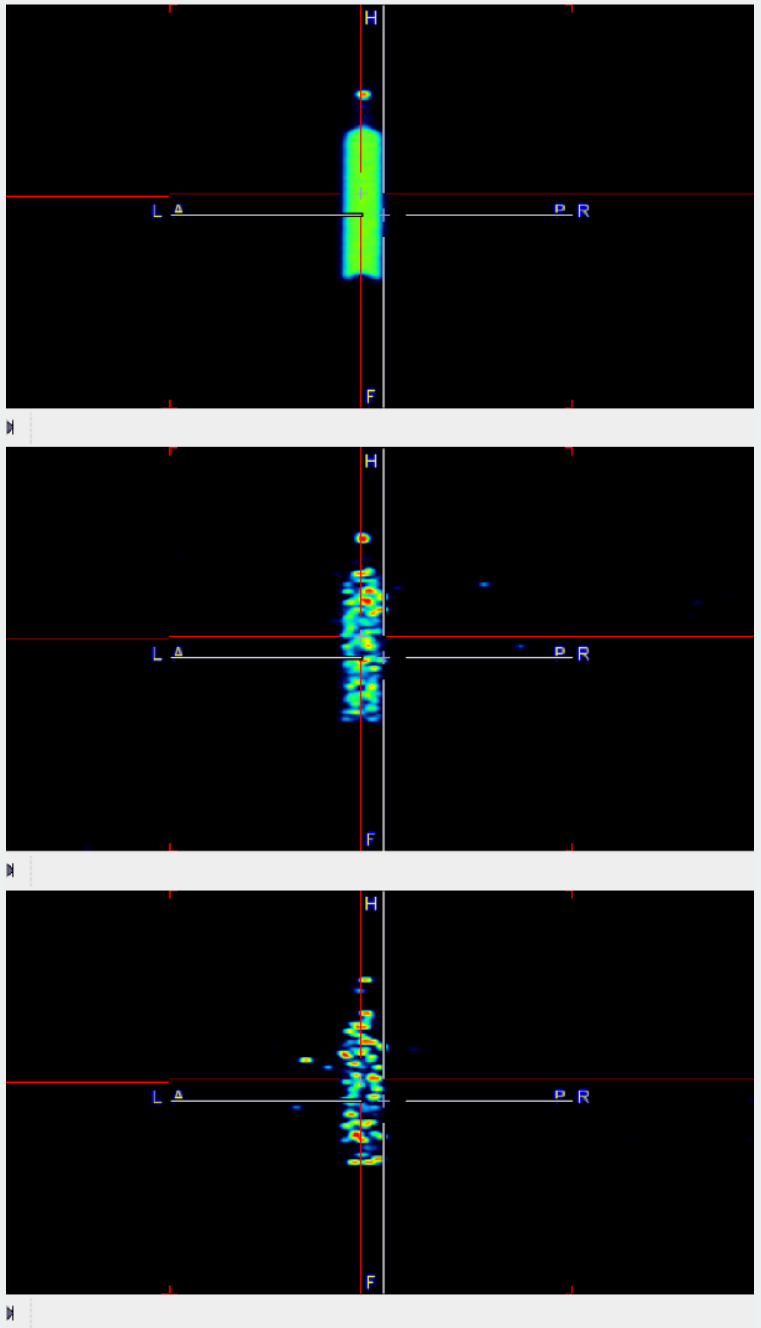


DVH analysis of dose (blue), C-11 (green) and F-18 isotope (orange)

Workflow and Mechanism

Process of Dose Verification Using F-18

STEP	DESCRIPTION
Proton Irradiation	Protons interact with tissue, producing F-18 isotopes
PET Imaging	Capture spatial distribution of positron emitters
Data Analysis	Compare PET activity map with Monte Carlo predictions
Dose Correlation	Convert isotope activity into dose estimates



PET scan of 35 mL syringe with [F-18]FDG

Preliminary result. *Activity measured in BGO-based scanner of a syringe of 30 mL of [F-18]fluorodeoxyglucose. GE Omni Legend 32 cm axial FOV 44 kcps/MBq*

Top *row activity concentration of 1 kBq/mL,*

middle *1 Bq/mL (corresponding to 31 Gy),*

bottom *0.3 Bq/mL (9.5 Gy).*

Courtesy of R Smith, U Cardiff, UK

Advantages and Challenges

Benefits and Limitations of F-18 Based Verification

Advantages of F-18 PET Imaging

F-18 PET imaging offers high spatial resolution and quantitative visualization of isotope distribution for precise dose verification.

Challenges in Dose Correlation

Biological washout and isotope diffusion reduce accuracy by blurring correlation between PET activity and actual absorbed dose.

Complex Data Interpretation

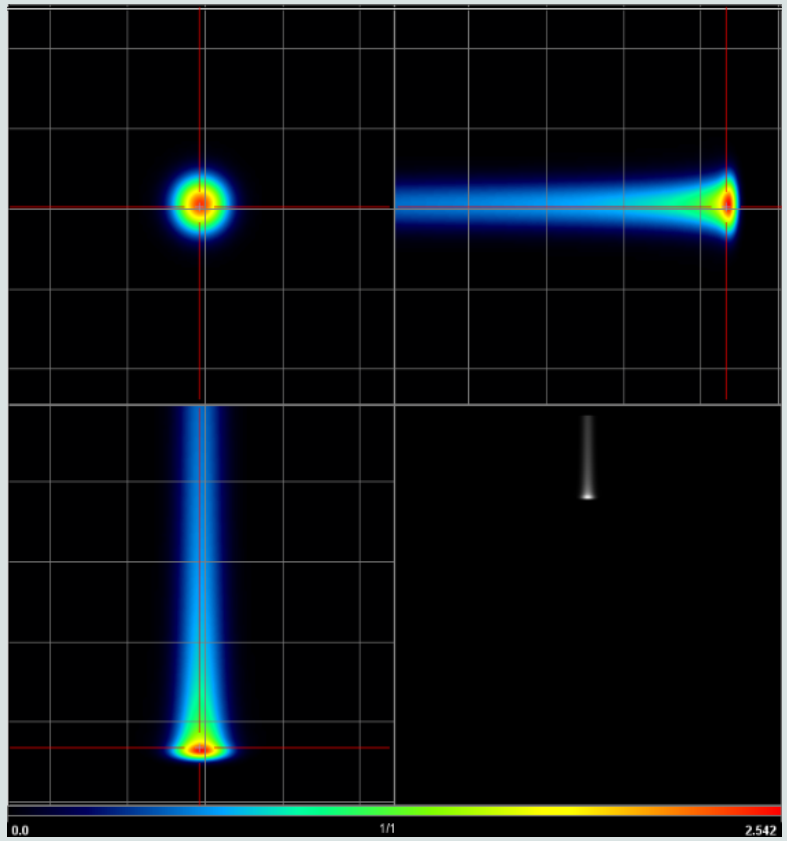
PET signals require complex conversion algorithms and computational models like Monte Carlo simulations for accurate dose interpretation.

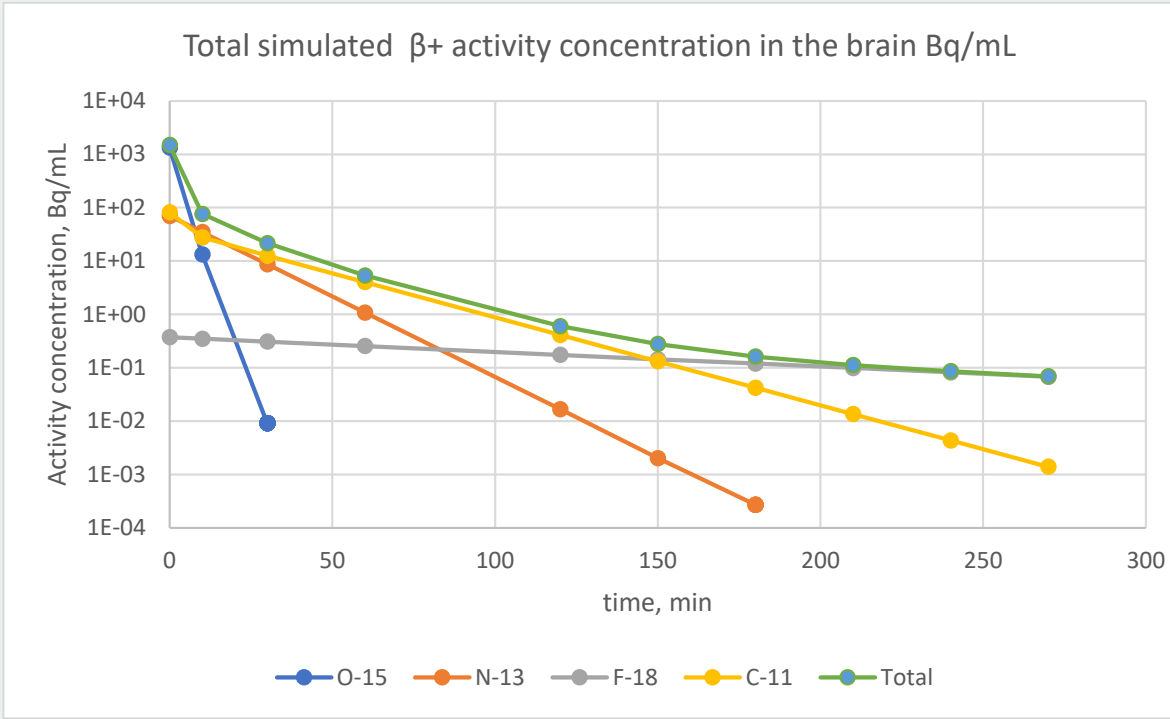
Future Research and Improvements

Ongoing research aims to refine F-18 PET techniques to enhance safety and precision in proton therapy dose verification.

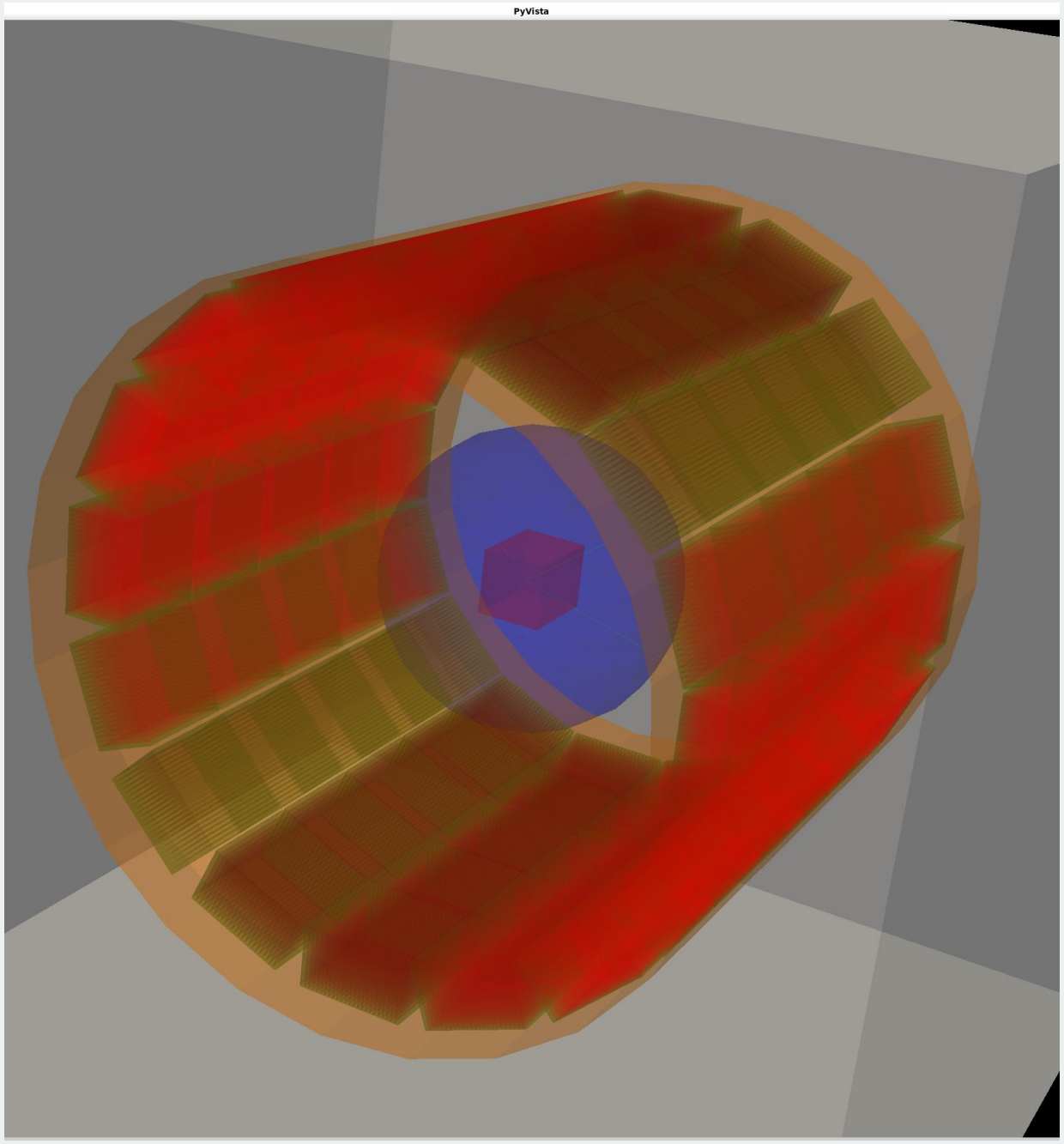
From https://s1.pplstatics.com/elcorreo/www/multimedia/2025/11/07/hospital-005.jpg

Brain phantom activity concentration at 75 MeV p in needle beam (2.5 Gy)





Current Research and Future Directions



Clinical Applications and Innovations

Enhanced Dose Verification

F-18 based dose verification integrates PET imaging with computational models to improve accuracy in treatment monitoring.

Innovative PET Systems – HANPET Ø 25×25 cm 200 kcps/MBq

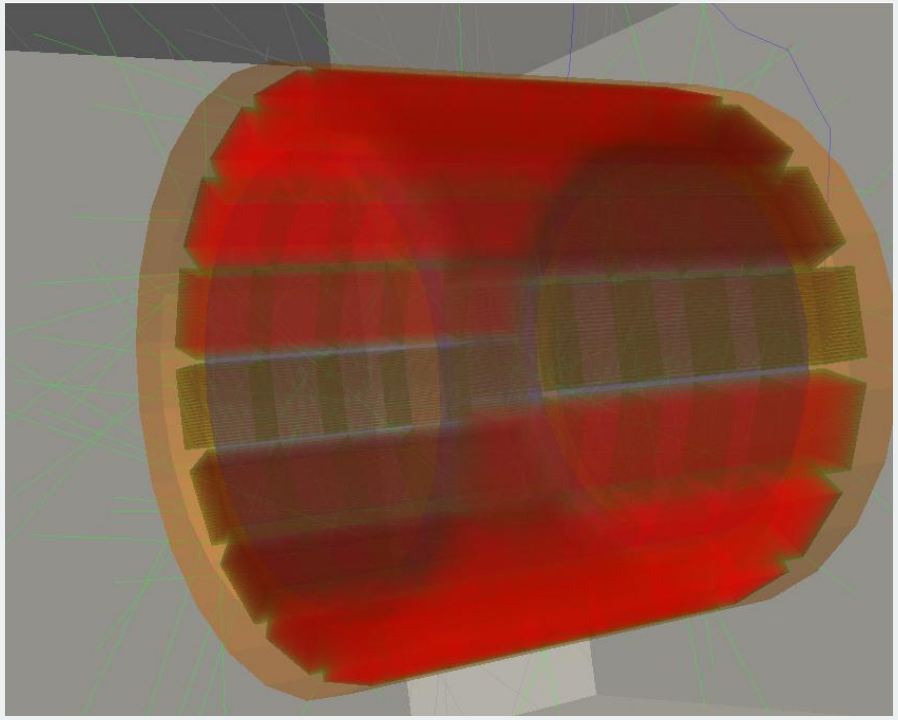
In-beam PET systems and hybrid imaging approaches enable real-time and comprehensive dose verification during irradiation.

Future Research Directions

Focus on isotope modeling, reducing biological washout, and applying AI to correlate PET activity with dose distribution.

Conclusion

Summary and Key Takeaways



Advancement in Dose Verification

F-18 PET imaging offers a non-invasive, high-resolution way to visualize isotope distribution in proton therapy.

Addressing Dose Delivery Challenges

This imaging technique tackles the critical challenge of ensuring accurate proton therapy dose delivery despite biological complexities.

Integration with AI and Modeling

Combining PET imaging with computational modeling and AI enhances precision and effectiveness in proton therapy.

Impact on Cancer Treatment

These innovations improve cancer treatment outcomes and advance particle therapy techniques.

Thank you!

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