Experience on developing a radiation protection standard

ISO 24427-2025 Radiological protection – **Medical proton accelerators** –Requirement and - recommendations for shielding design and evaluation

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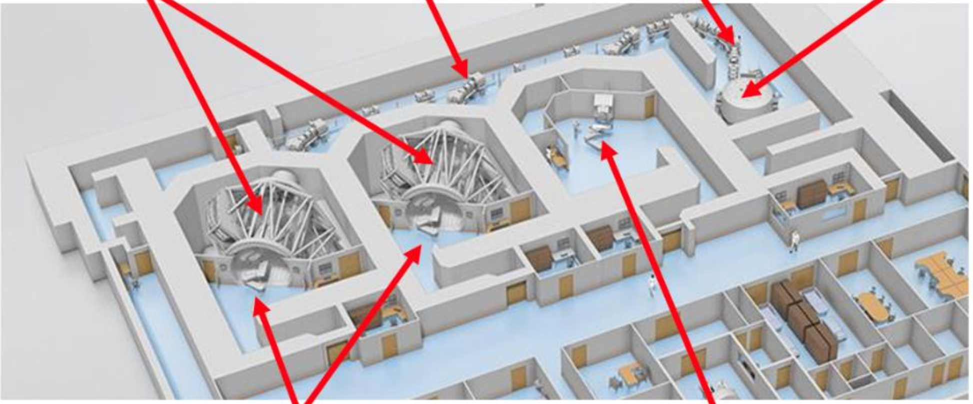
Content

Background of ISO 24427

Proton Therapy is already widely used. And the number is rising!

Particle Therapy Centers worldwide, most are Proton Therapy Centers*:

- In-operation: ~ 127 centers
- Under Construction: ~ 34 centers
- In Planning Stage: ~39 centers



The radiation shielding is one of the key issues for a PT center

- proton beam is of energy up to ~250MeV, strong secondary radiation field are produced
- multiple beam loss points
- as meters-thick barriers are needed, the design, commissioning and operation including the buildings can be capital and time consuming. **The capital cost of radiation shielding walls can be as much as that of medical proton accelerator**

[* https://www.ptcog.ch/index.php/facilities-in-operation](https://www.ptcog.ch/index.php/facilities-in-operation)

** Terapia del protón: Detrás de las escenas | OncoLink

Background of ISO 24427

Relevant existing documents at the international or national levels

International

- **PTCOG Report 1** Shielding design and radiation safety of charged particle therapy facilities
- **ISO 16645-2016** Radiological protection – Medical **electron** accelerators – Requirement and recommendations for shielding design and evaluation.
- **(IAEA-TECDOC-1891 Regulatory Control of the Safety of Ion Radiotherapy Facilities)**

National

- National Standards: GBZ/T 201.5-2016, DIN 6875-20:2016-08
- Technical reports: NCRP Report No.144,
- Other scientific publications: K. Tesch, S. Agosteo …

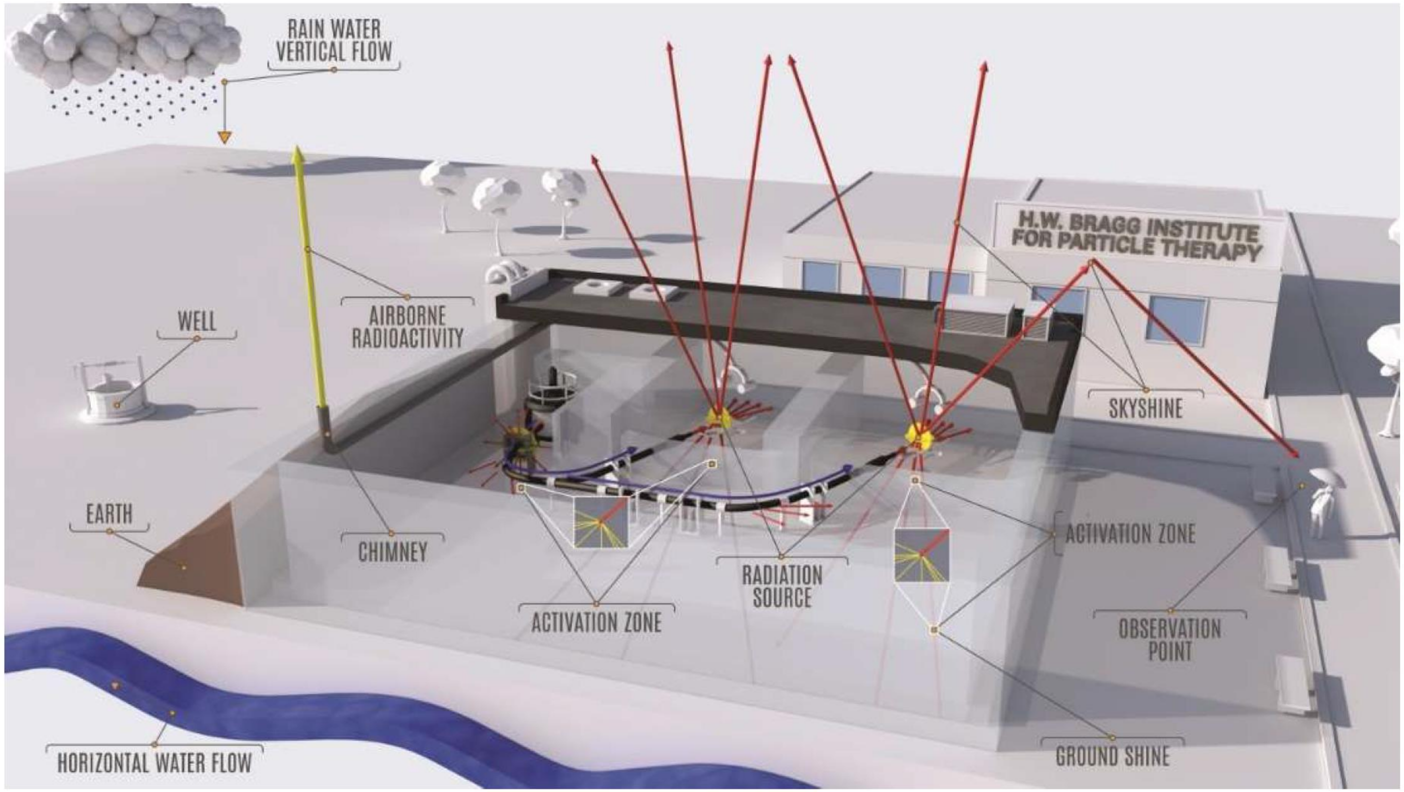
NO international standard for medical proton accelerators yet!

<u>An international standard for medical proton accelerators radiation shielding design and evaluation will help a lot!</u>

Background of ISO 24427

the radiation safety issues and the environmental impacts of PTC:

- **direct radiation**
- **skyshine (and ground shine),**
- **air activation and airborne radioactivity, and ground activation.**



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* IAEA-TECDOC-1891

ISO 24427

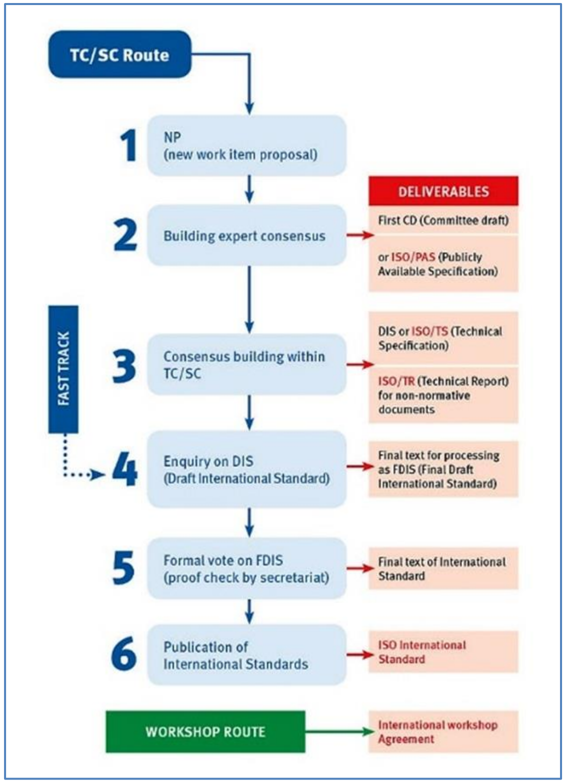
ISO 24427:2025 Radiological protection – Medical proton accelerators – Requirement and recommendations for shielding design and evaluation

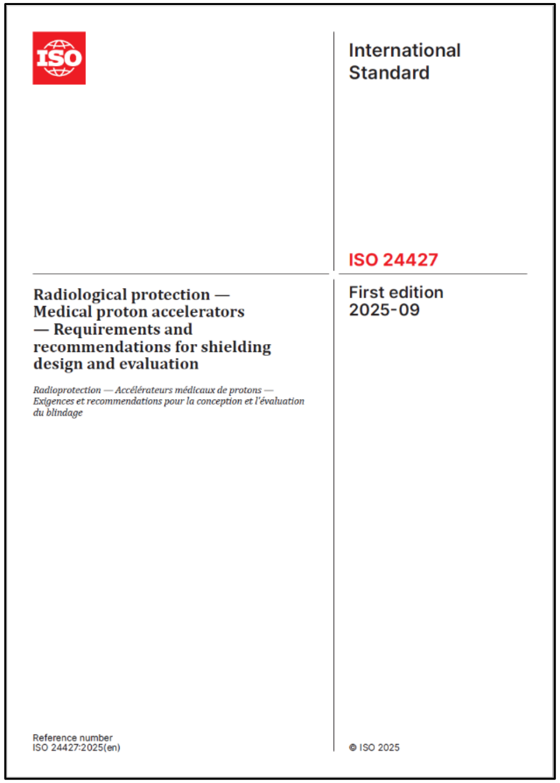
WG: TC85/SC2/WG23

Shielding and confinement systems for protection against ionizing radiation

Milestones

- Call for participants
- consensus within:
  - WG
  - Committee
  - ISO members
- approves with ballotings





International Standard

ISO 24427

Radiological protection — Medical proton accelerators — Requirements and recommendations for shielding design and evaluation

Radioprotection — Accélérateurs médicaux de protons — Exigences et recommandations pour la conception et l'évaluation du blindage

First edition
2025-09

Reference number
ISO 24427:2025(en)

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ISO 24427

- Specify the requirement and recommendations for shielding design and evaluation of medical proton accelerators
- **Clear responsibilities of each stakeholders as well as their interactions.**

Promote the construction and operation efficiently.

- **Clarify the source terms and radiation fields around a proton accelerator and the correlated subsystem**
- **Standardize the analytical method for radiation attenuation and the radiological monitoring (measurements)**

Act as a fair technical reference

- Meters-thick barrier (concrete walls) around the entire accelerator system to attenuate the secondary radiation
- Normalized safety and operation mechanism

Promise the radiation safety of PT center and personnel

TOC

Highlights

Applicable to 70 MeV to 250 MeV medical proton accelerators.

- **the specifications on the shielding design goals,**
- **the roles of stakeholders**
- **radiation sources and transmission**
- **direct comparison of difference calculation method and the prioritization of Monte Carlo simulation in radiation shielding design and evaluation**
- **…**
- **TADR vs IDR**

Lessons learned

Ensuring adequate protection for both workers and the members of the public from medical proton accelerator radiation is a cooperative effort. General guidance on the roles, responsibilities, and interaction among the various stakeholders involved in this process is provided.

the roles of stakeholders,

- the regulatory body
- manufacturer of the proton therapy system
- general contractor/architectural firm
- radiation protection officer or other
- medical physicist or other
- the licensee or other

It is highly noted that the roles, responsibilities, and interaction of the stakeholders depend on the commercial contracts between them and should be in accordance with existing national regulation. The licensee of a proton therapy system is primarily responsible for the radiation safety.

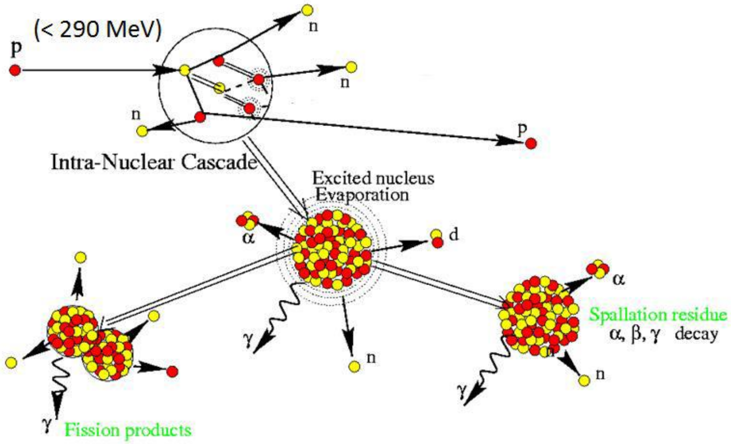
Lessons learned

radiation sources

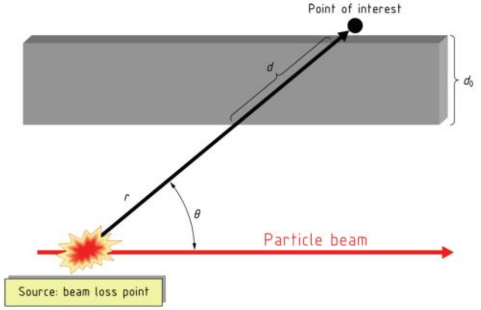
Proton hits target nucleus, producing prompt radiation

- **Intra-Nuclear Cascade (INC): cascade of reactions within nucleus, forward peaked nucleon emissions…**
- **Evaporation of Nucleons and Fragments: isotropic emissions**

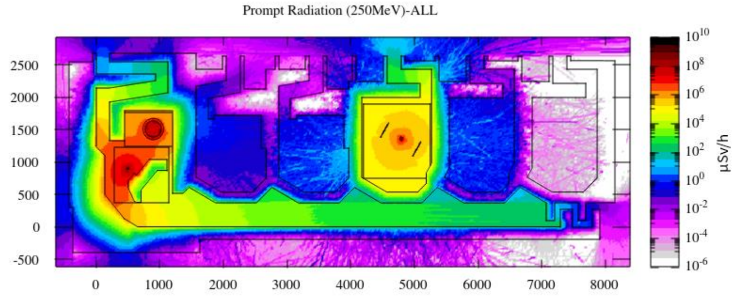
and activation and decay…



radiation shielding design & calculation



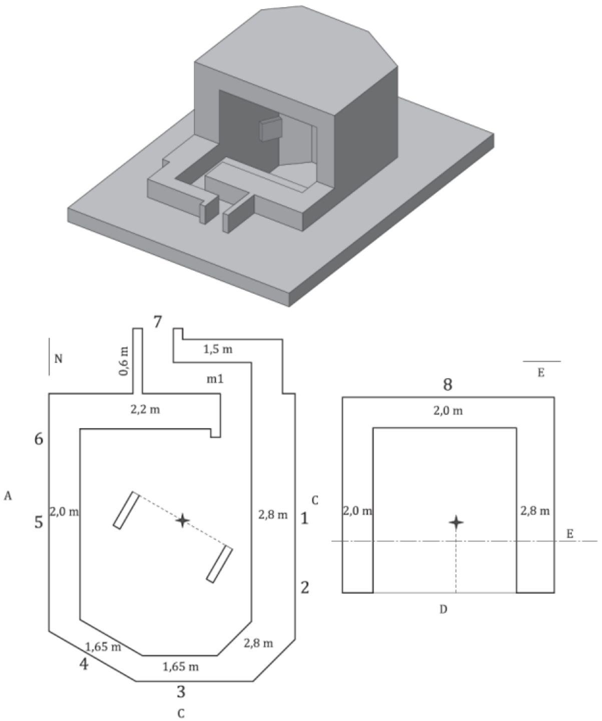
Analytical method – PK models



MC codes

Lessons learned

direct comparison of difference calculation method



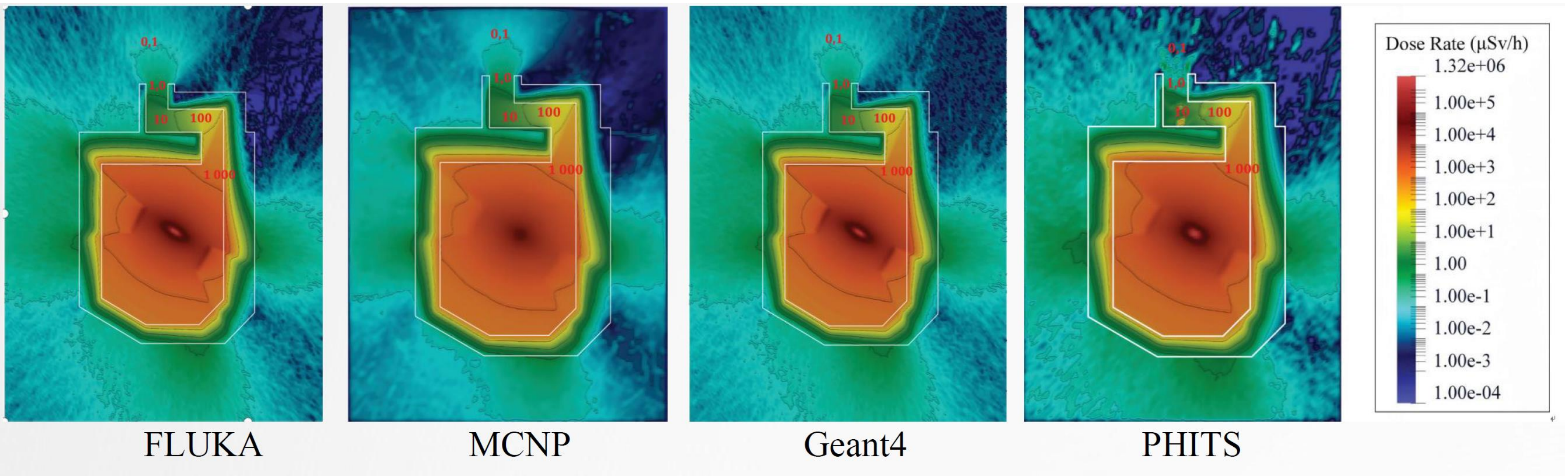
No.	Point of interest	FLUKA µSv/week	MCNP µSv/week	Geant4 µSv/week	PHITS µSv/week	Neutron dose by the basic point kernel method µSv/week	Neutron dose by the self-contained representation of the point kernel method µSv/week
1	Due east outside barrier	0,62	0,51	0,61	0,73	0,15	3,86
2	East outside barrier on the rotating plane	0,062	0,058	0,065	0,038	0,006	0,28
3	Due south outside barrier	0,67	0,56	0,66	0,56	0,315	6,05
4	Southwest out-side barrier	0,34	0,49	0,33	0,49	0,090	1,27
5	Due west outside barrier	0,81	0,60	0,81	0,92	1,11	17,77
6	West outside barrier on the rotating plane	0,41	0,20	0,40	0,27	0,048	1,61
7	Outside the maze door	0,072	0,093	0,071	0,093	0,647	18,48
8	Right above the roof	0,62	0,56	0,61	0,52	0,025	0,92

PK models vs MC codes

Lessons learned

the prioritization of Monte Carlo simulation

- Monte-Carlo simulation can provide simulation on non-standardized geometry of shielding barriers, customized materials of targets and shielding barriers, which is not possible by calculation with analytical methods.
- Monte-Carlo simulation should be technically preferred when applicable.



Lessons learned

evaluation: TADR vs IDR

- **TADR - time averaged dose rate, like "mSv per year"; the shorter the averaging period the more complex.**
- **IDR - instantaneous dose rate. For pulse operation, IDR is more like a "theoretic value". IDR is introduced by some countries, without really specifying the "instant" or measurement technique, USE ONLY WHEN NECESSARY !**

IAEA:	advice that there may be some countries that regulate TADR for short intervals or IDR.
USA/Thailand:	20μSv in any one hour
Germany:	20μSv per week; but < 3mSv/h IDR
China:	2.5 μSv per hour IDR – instantaneous!
UK:	7.5μSv per hour IDR; averaged over 1min by ACOP
Singapore:	10μSv per hour IDR "outside the X-ray room"

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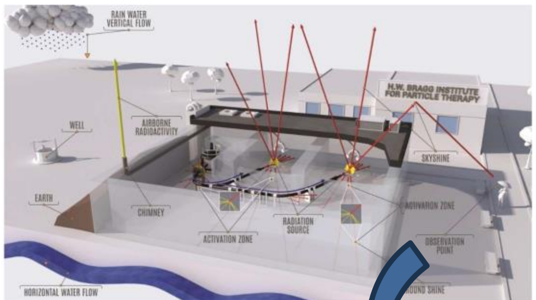
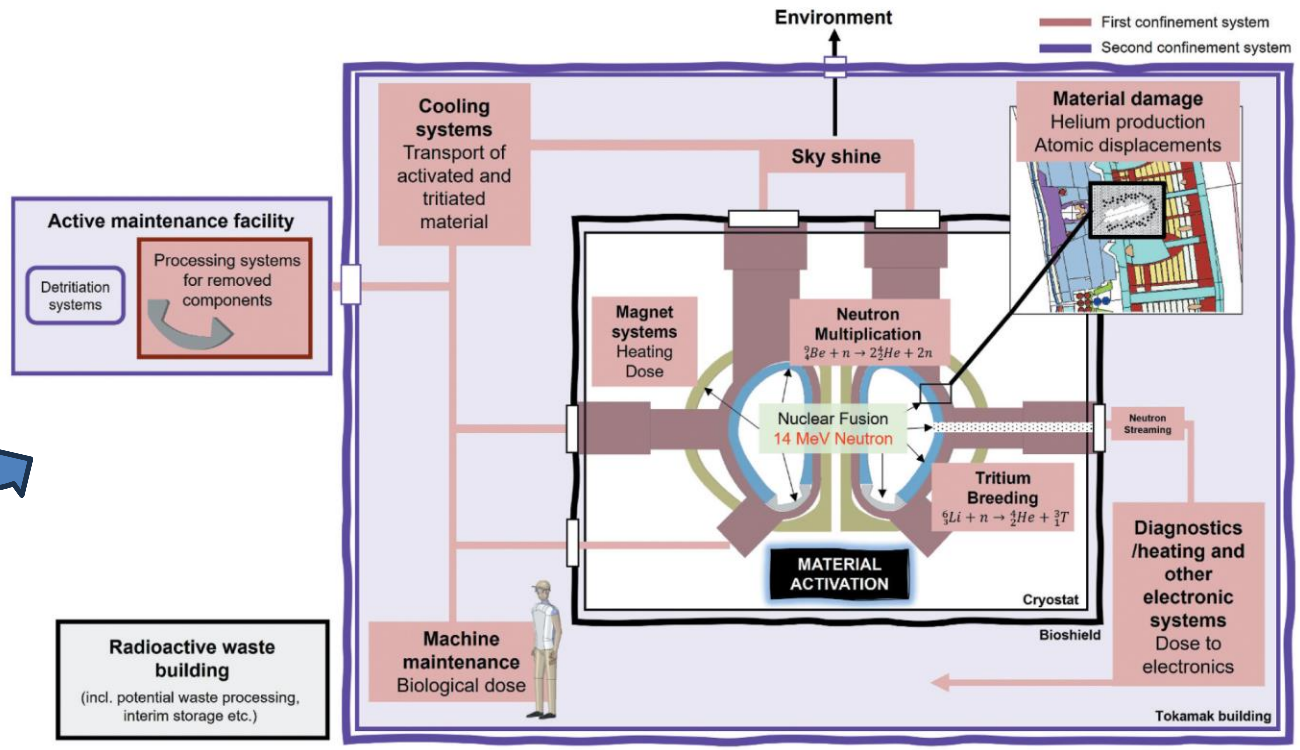
* Radiation Shielding, Meissner Consulting GmbH, PTCOG 58 – Manchester, UK (2019)

Radiation safety issues of fusion device

the radiation safety issues of fusion device (Tokamak)





- ✓ **direct radiation**
- ✓ **skyshine**
- ✓ **activation**

and more:

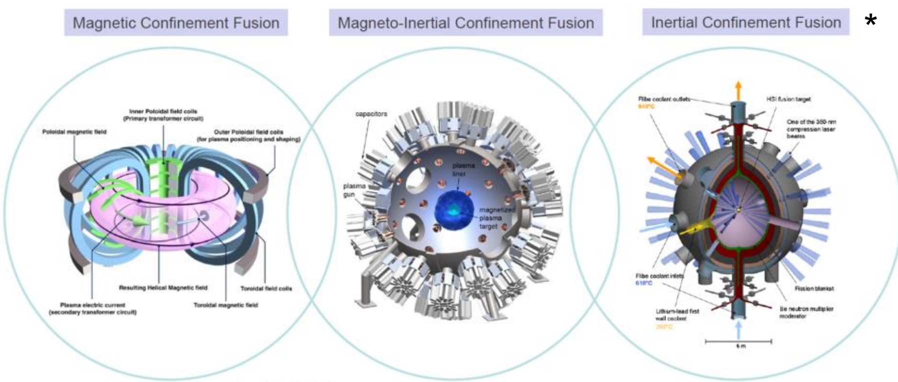
- **SDDR**
- **Tritium**
- **ACPs**
- **other source: magnetic energy, liq He…**

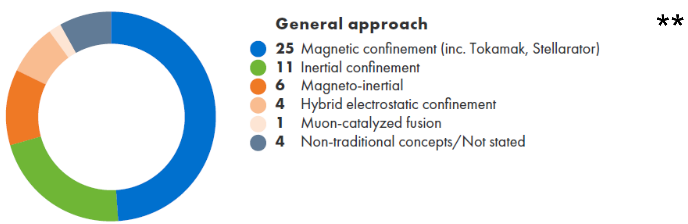
* Valentine, A. etc. Advancing Methods for Fusion Neutronics: An Overview of Workflows and Nuclear Analysis Activities at UKAEA. Fusion Science and Technology, 79(8) 1008–1022. https://doi.org/10.1080/15361055.2022.2141528

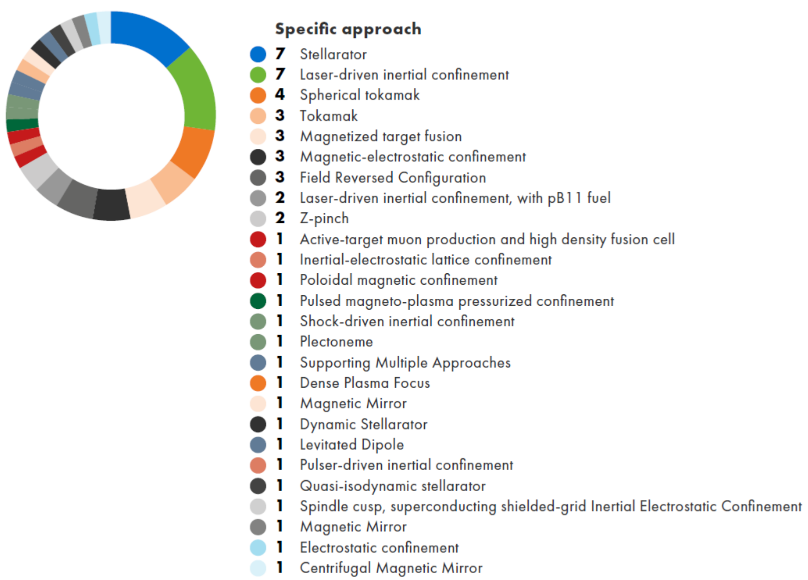
Radiation safety issues of fusion device

different fusion devices, the standard should be general

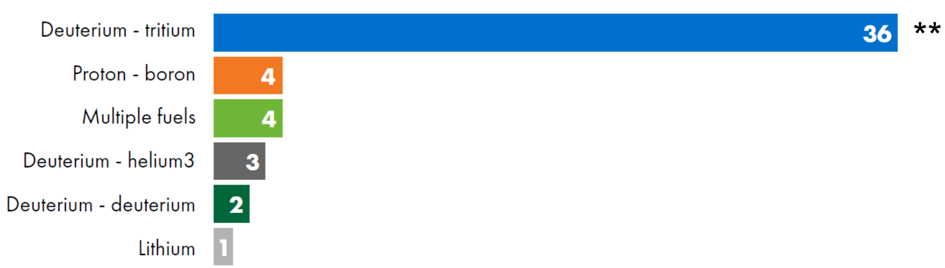
- **By General approach**







- **By Fuels**



* ML24067A227_Preliminary Draft NUREG-1556, Volume 22 (March 18, 2024)

** The global fusion industry in 2025, by FIA

Summary

- From ISO 24427 for medical proton accelerator, some experience are learned, such as, how to develop a standard in ISO; some lessons are learned, such as, the clarification of roles of stakeholder, the prioritization of Monte Carlo simulation in radiation safety design analyses, the prioritization of using TADR in design and evaluation.
- Fusion R&D are accelerating in recent years, the number of fusion devices are rising, the radiation safety of fusion devices shall be assured.
- The radiation safety issues and environmental impacts of fusion device are much more complicated. The corresponding radiation protection standards are expected, the corresponding work is of great importance.
- The radiation safety standard should be general, to fit lots of different concepts of fusion devices (Magnetic, Inertial and Magneto-inertial), with or without using tritium as fuel

Thank you!