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Findings of the Cyclowest Radiation Survey for the GE PETtrace Cyclotron at the Bayswater Site

Dr Samer Bakr

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- Overview of Cyclowest site in Bayswater
- Cyclotron and Radiation Fields
- RP For Workers, Public and Environment
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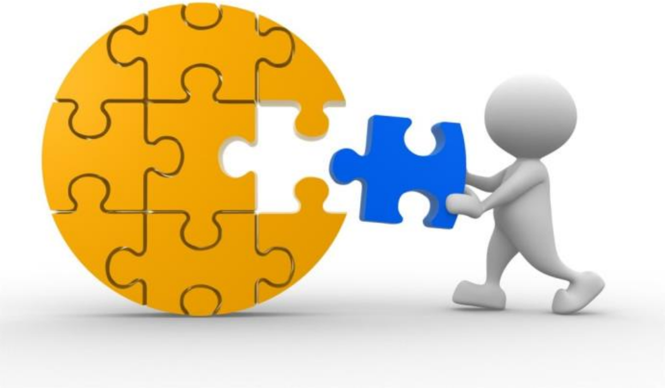
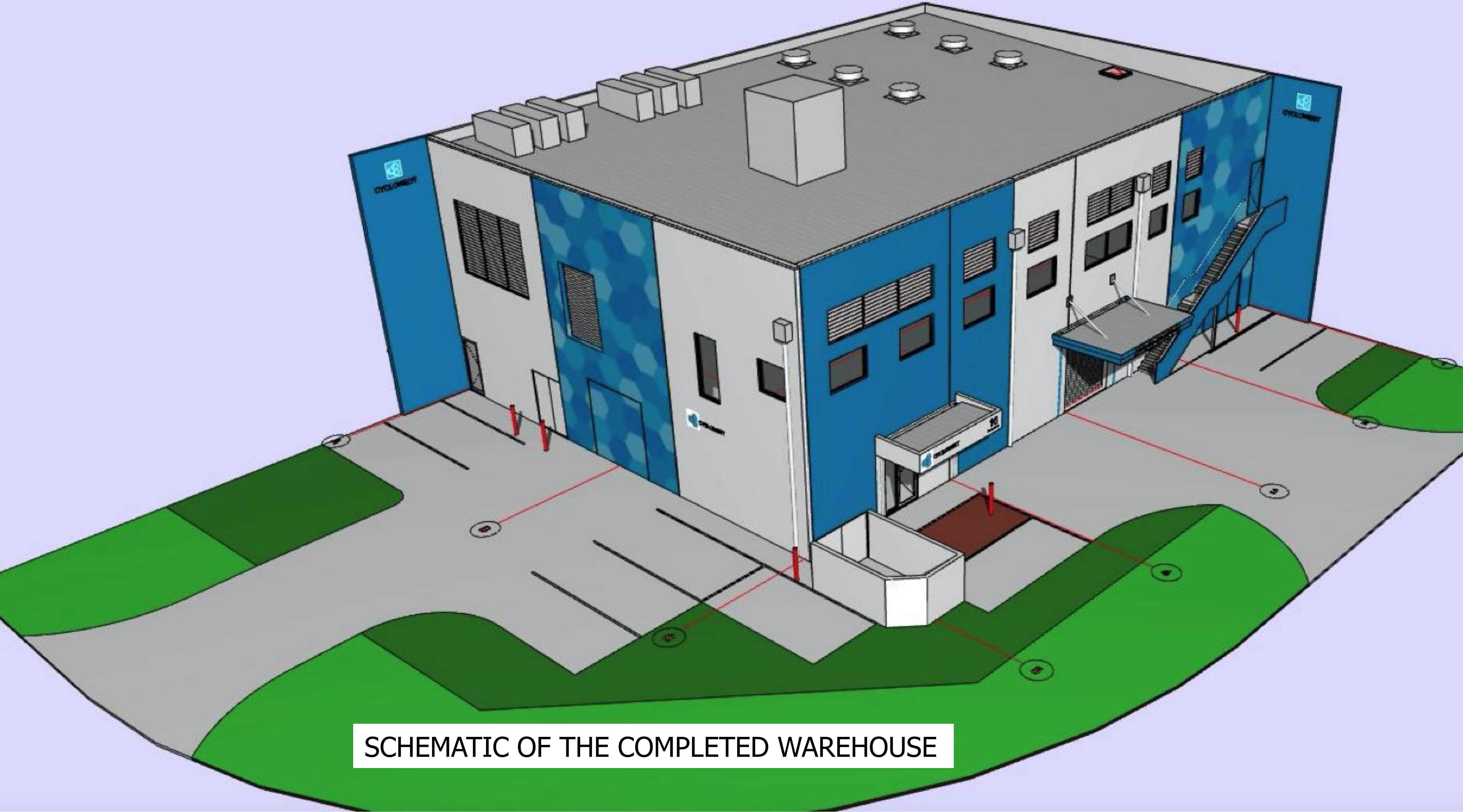
- Radiation Survey Study
- Conclusion

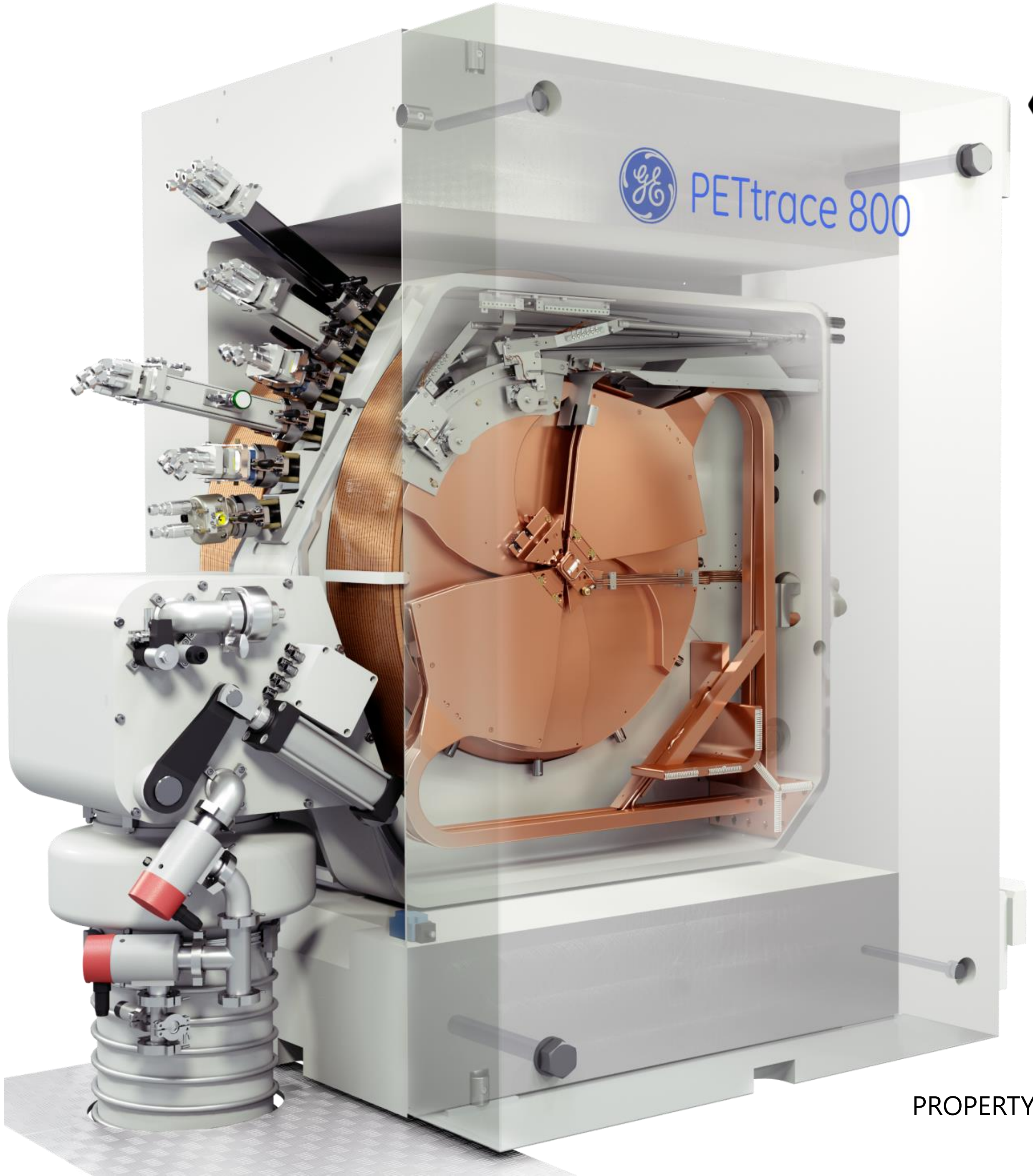
Bayswater WA

- The state currently has only one facility, operated by the WA government, and it is unable to meet the full level of demand in Perth.
- Cyclowest exists to meet the current rapidly growing demand for PET radiopharmaceuticals in WA.
- Our new private service will complement this and expand the overall capacity of the health sector to diagnose and treat West Australians.





SCHEMATIC OF THE COMPLETED WAREHOUSE


PETtrace 800

Principle of Operation

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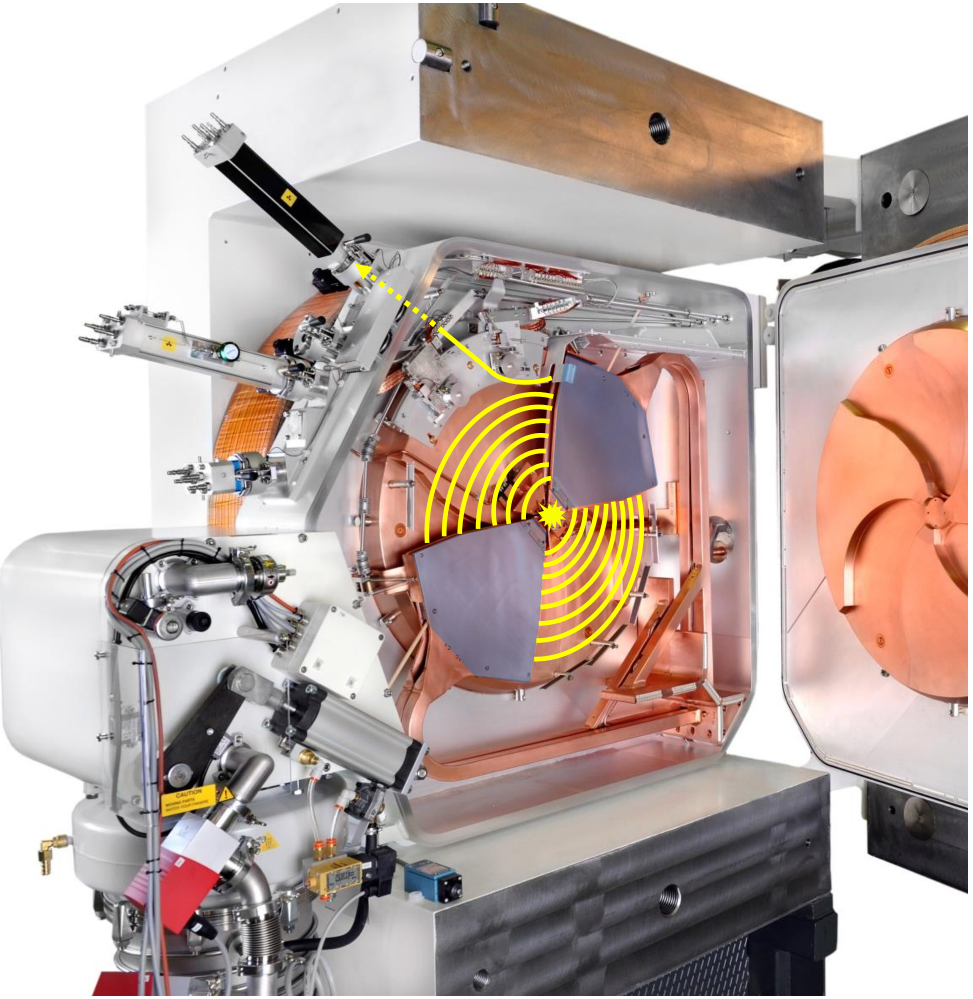
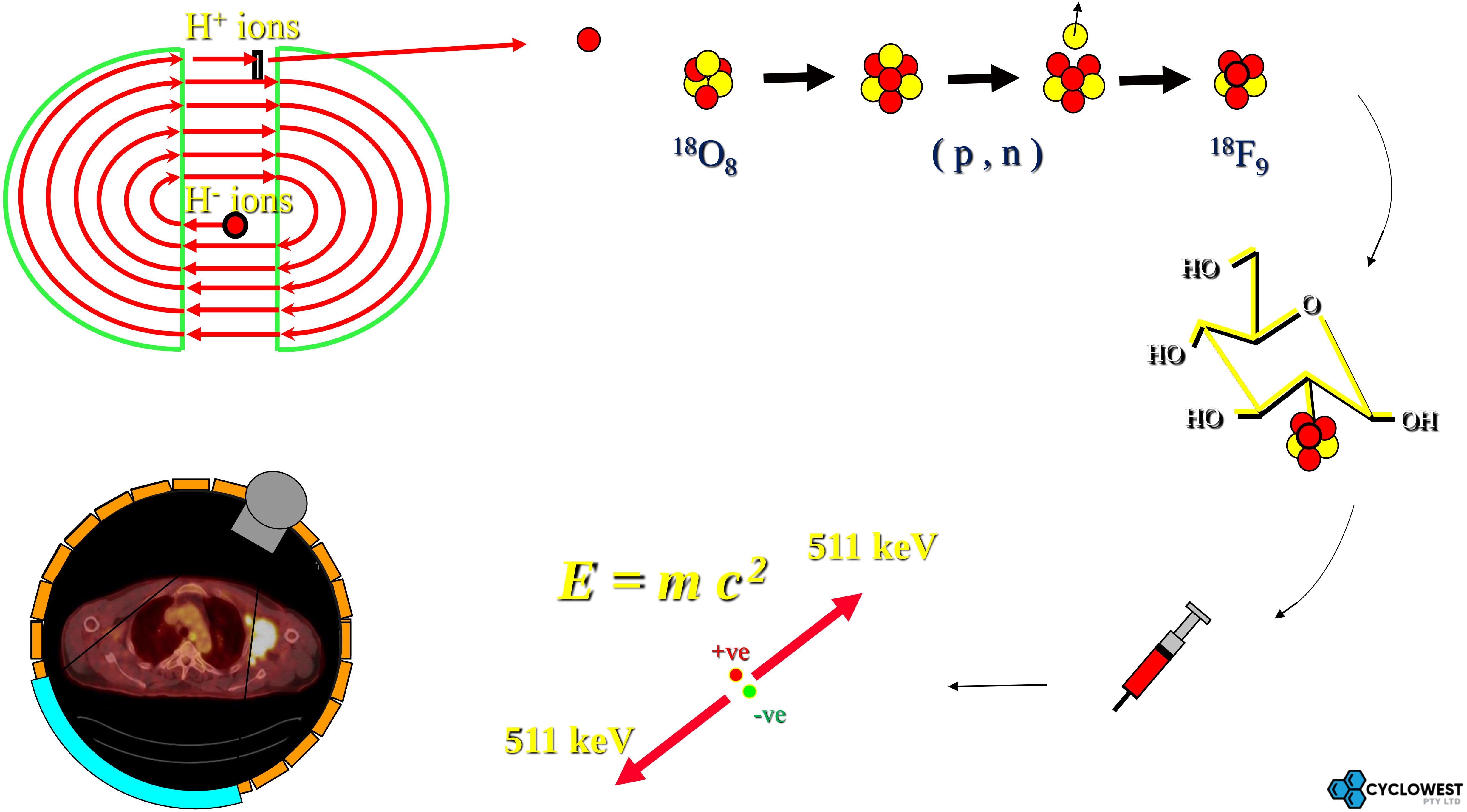
- NEGATIVE IONS are CREATED in the center of the cyclotron.
- IONS are EXTRACTED from the Ion Source using Alternating High Voltage.
- IONS are ACCELERATED using Alternating High Voltage.
- IONS are KEPT IN ORBIT by a Static Magnetic Field.
- IONS' POLARITY is CHANGED from negative to POSITIVE using a stripping foil.
- POSITIVE IONS bend in the opposite direction in the magnetic field.
- Positive Ions BOMBARD THE MEDIA in the Target.





H^+ ions
H^- ions
$^{18}O_8$
(p , n)
$^{18}F_9$
HO
O
HO
HO
OH
$E = m c^2$
511 keV
+ve
-ve
511 keV
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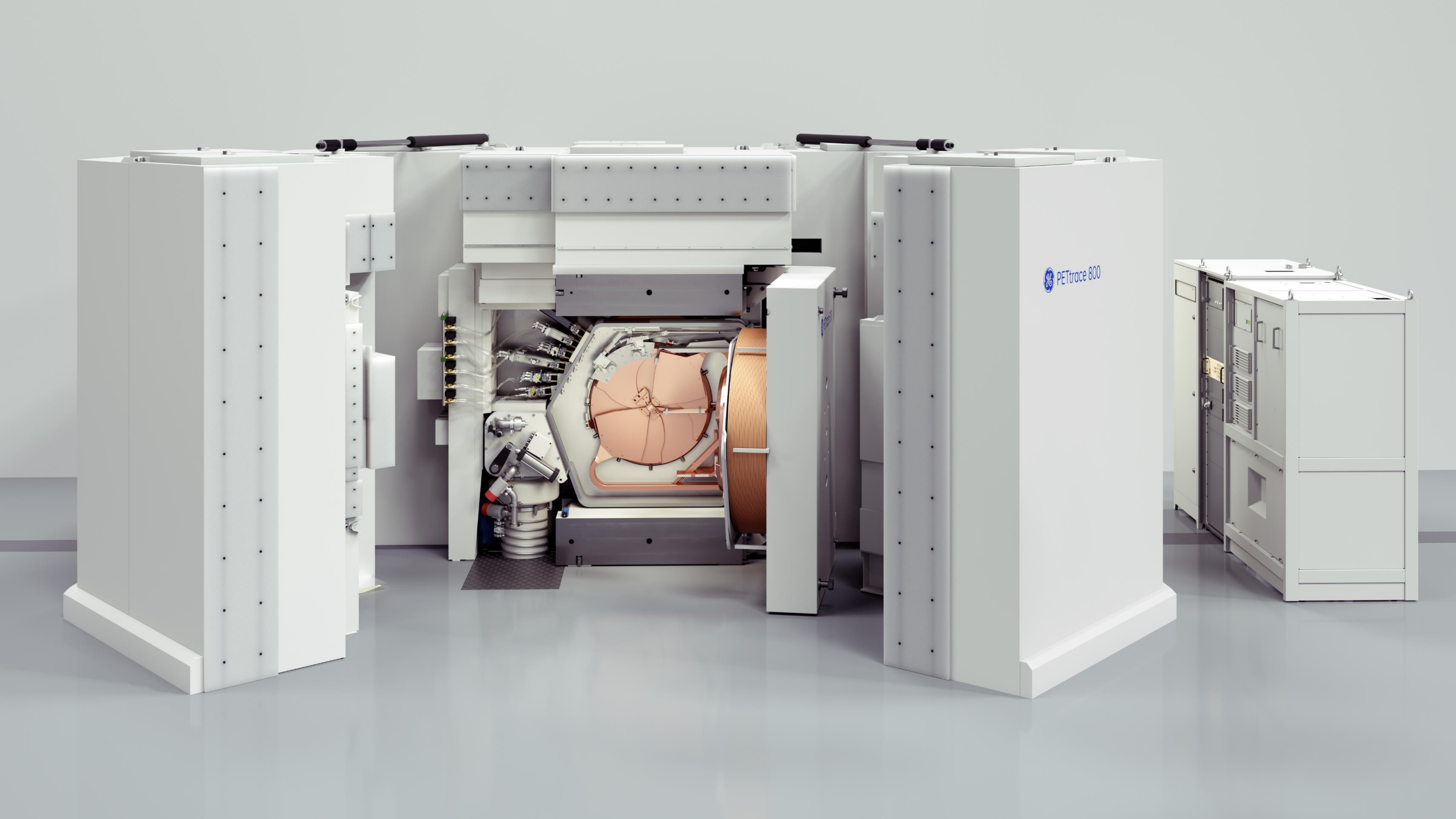
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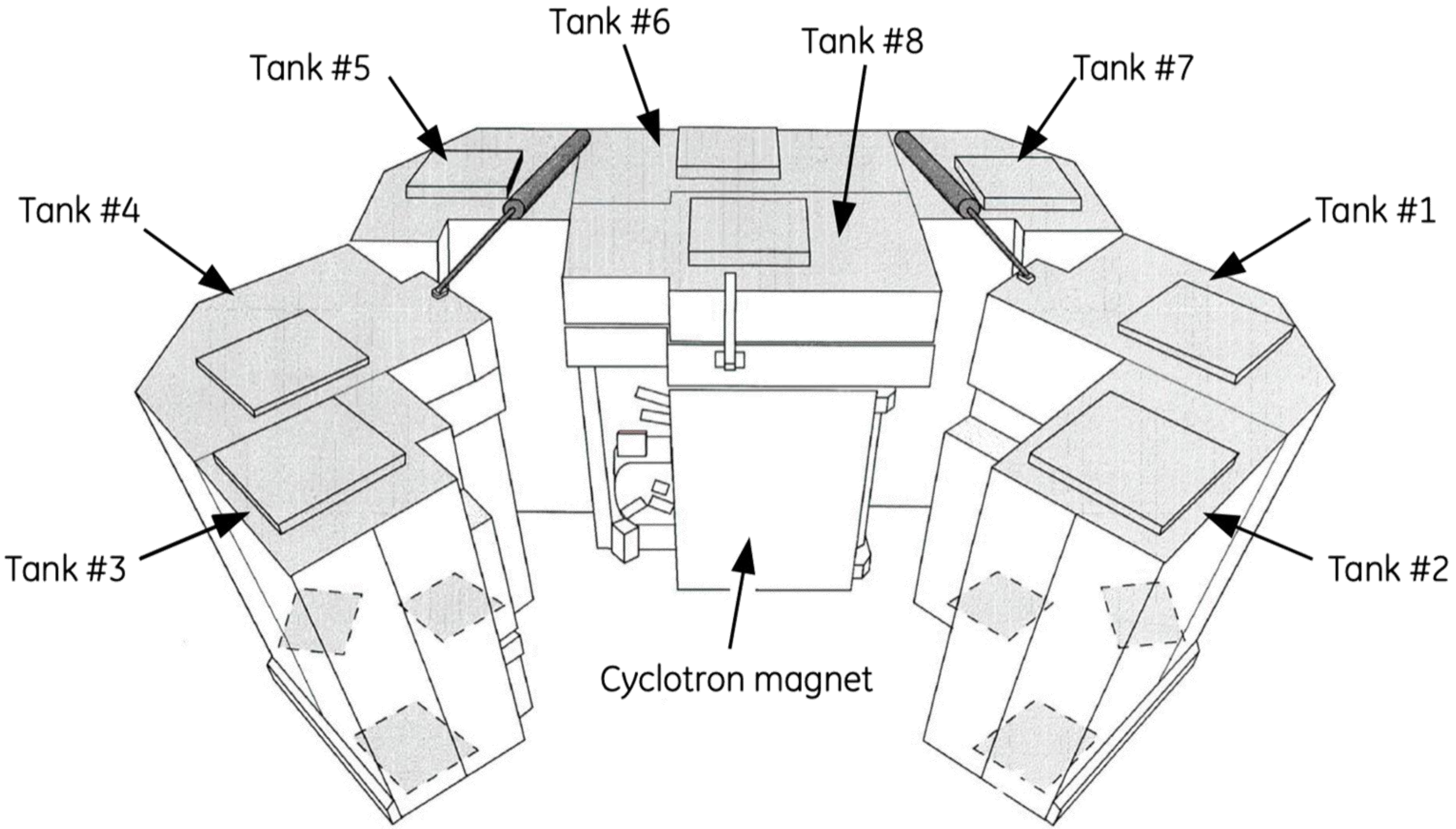
Key Equipment



- These lead plates will be adjusted inside the tanks for extra shielding before filled with borated water.

- The tanks from inside.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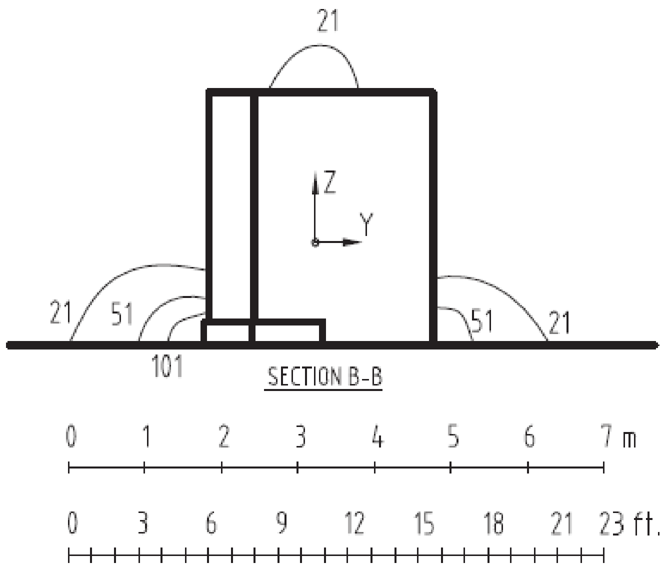
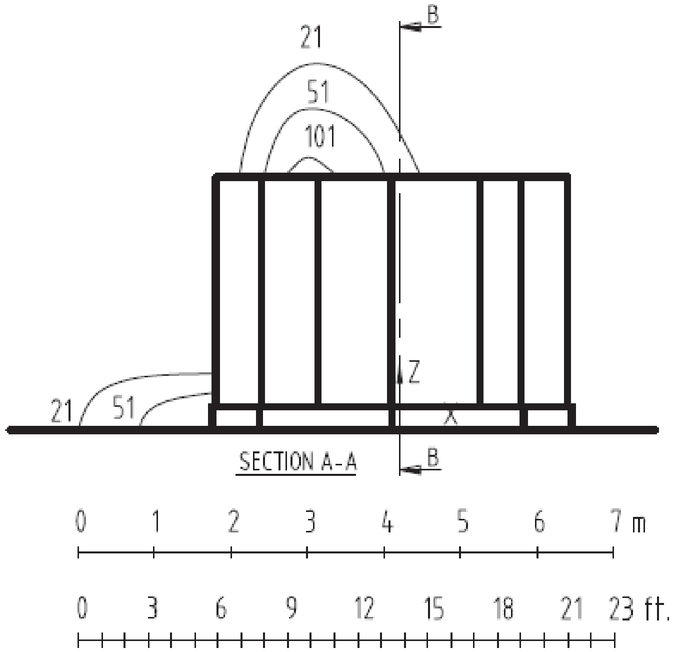
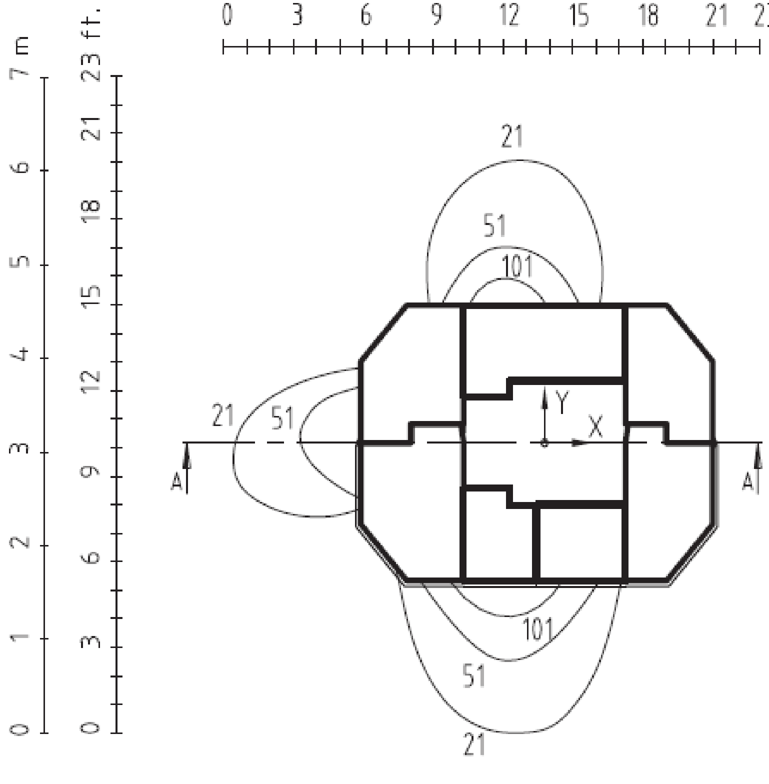


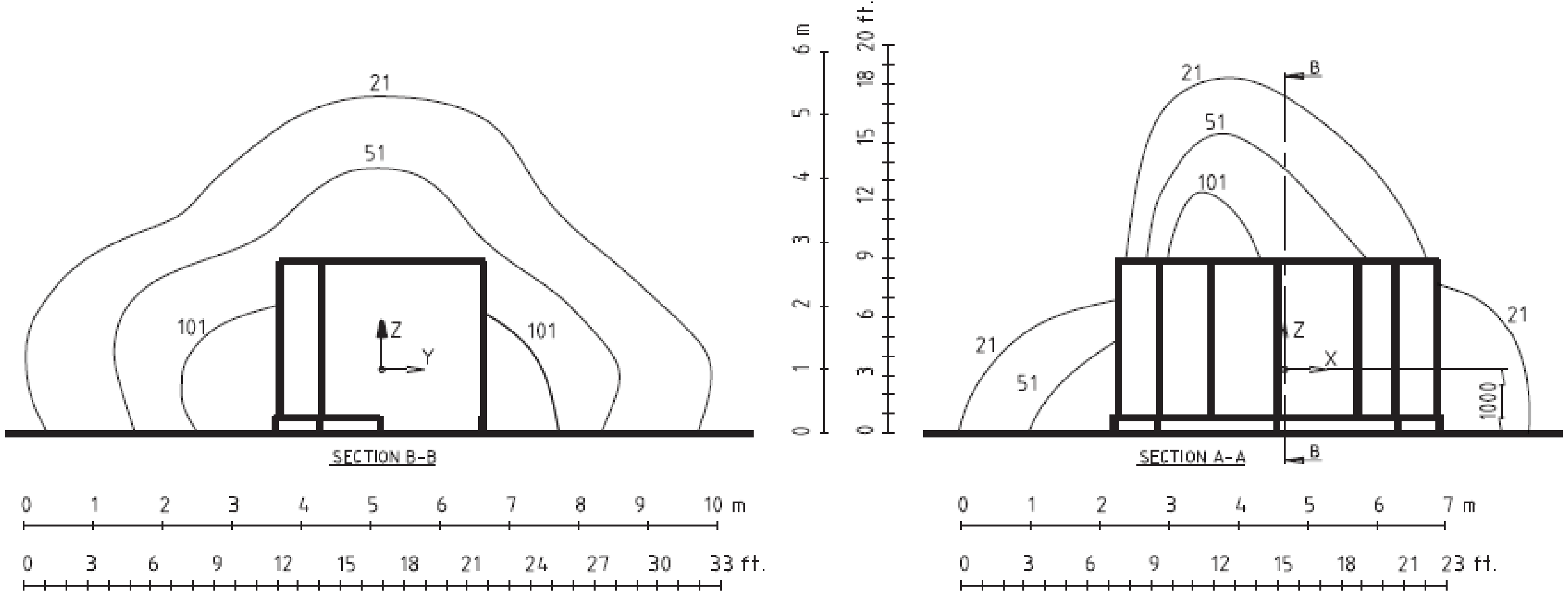


NEUTRON DOSE RATE CONTOURS (µSv/h)

18F- production on enriched water (>95%).
160 µA total beam current.

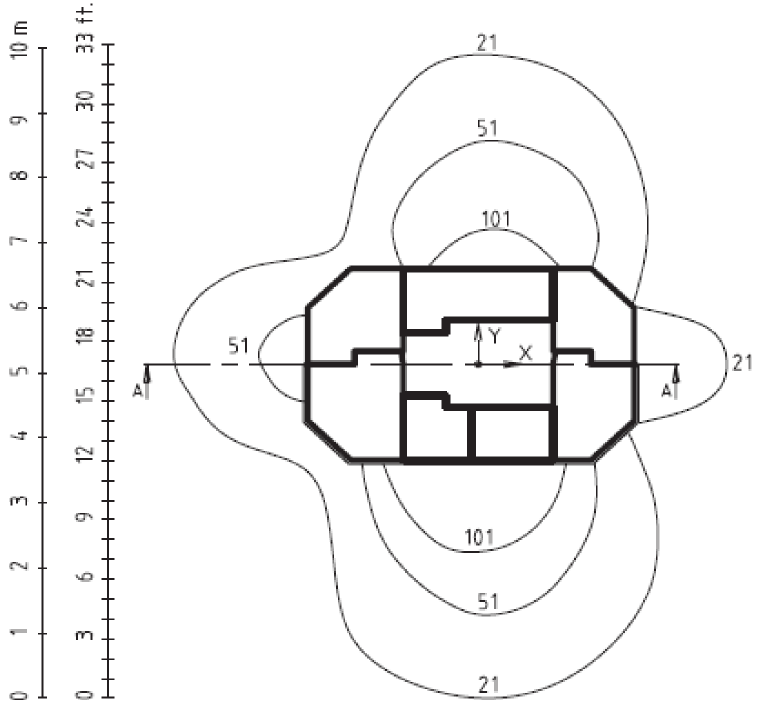


MEASURED FROM FLOOR LEVEL



GAMMA DOSE RATE CONTOURS (μSv/h)

18F- production on enriched water (>95%).
160 μA total beam current.



MEASURED 1000mm [39.37"] ABOVE FLOOR

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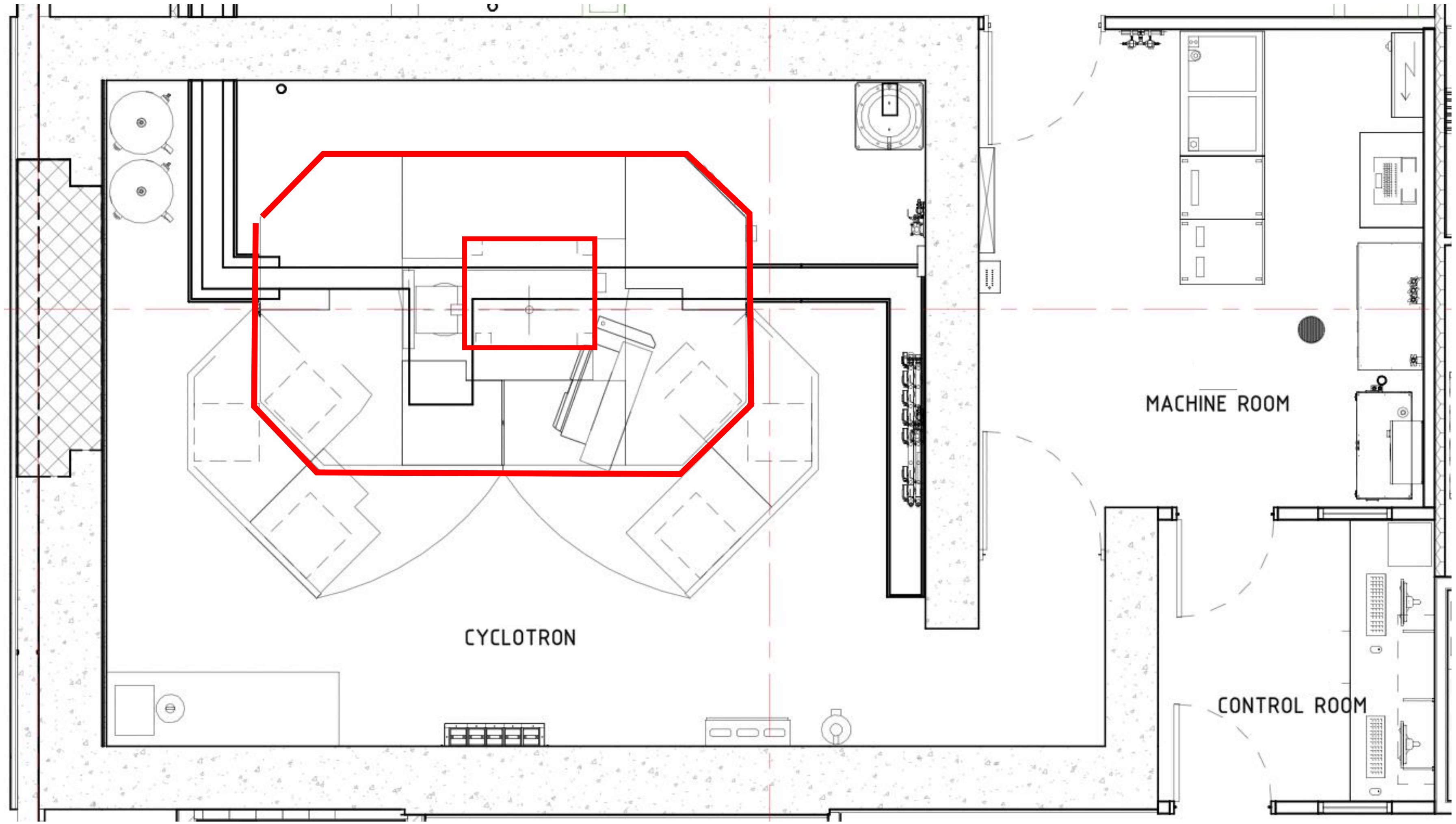
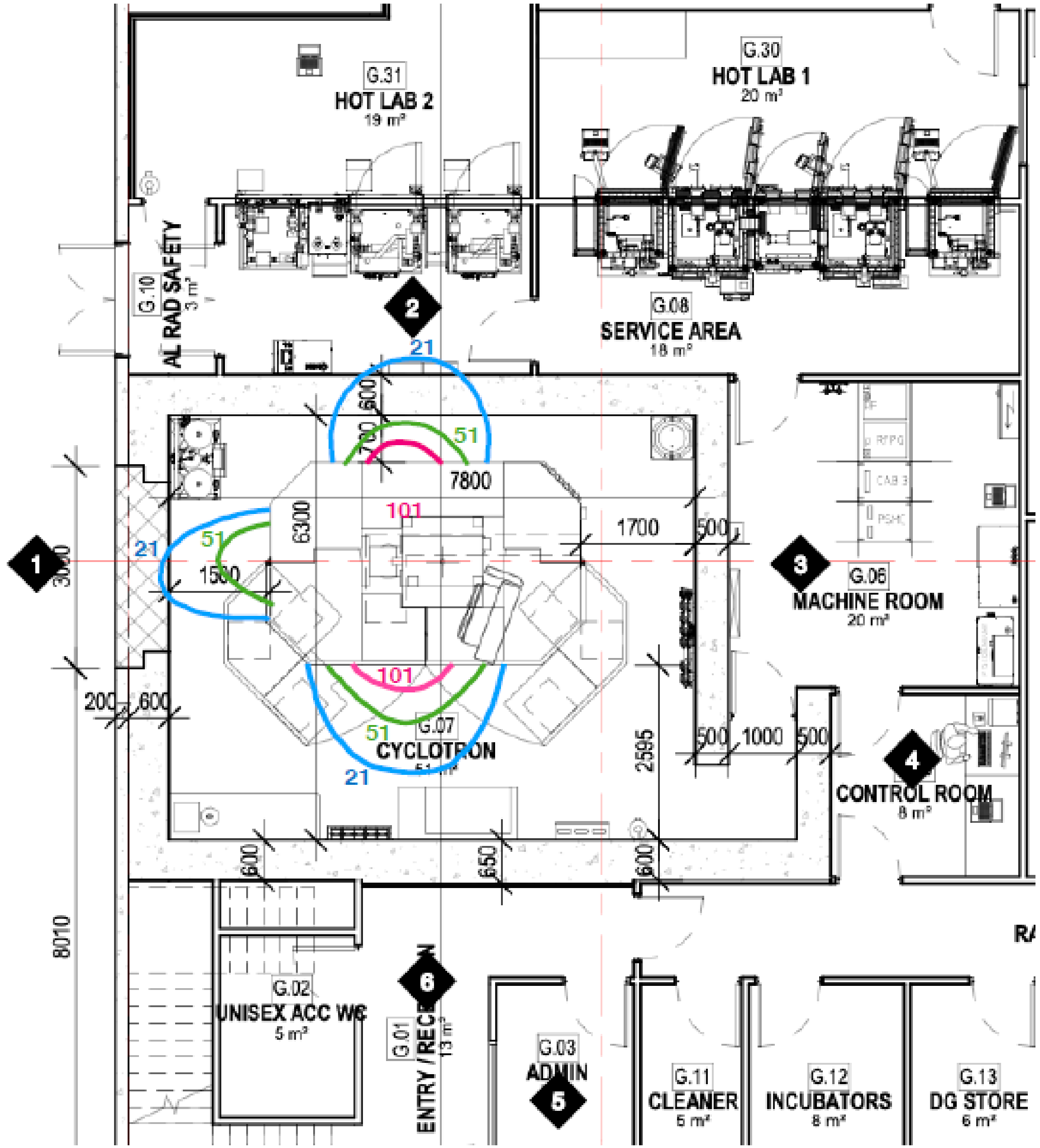
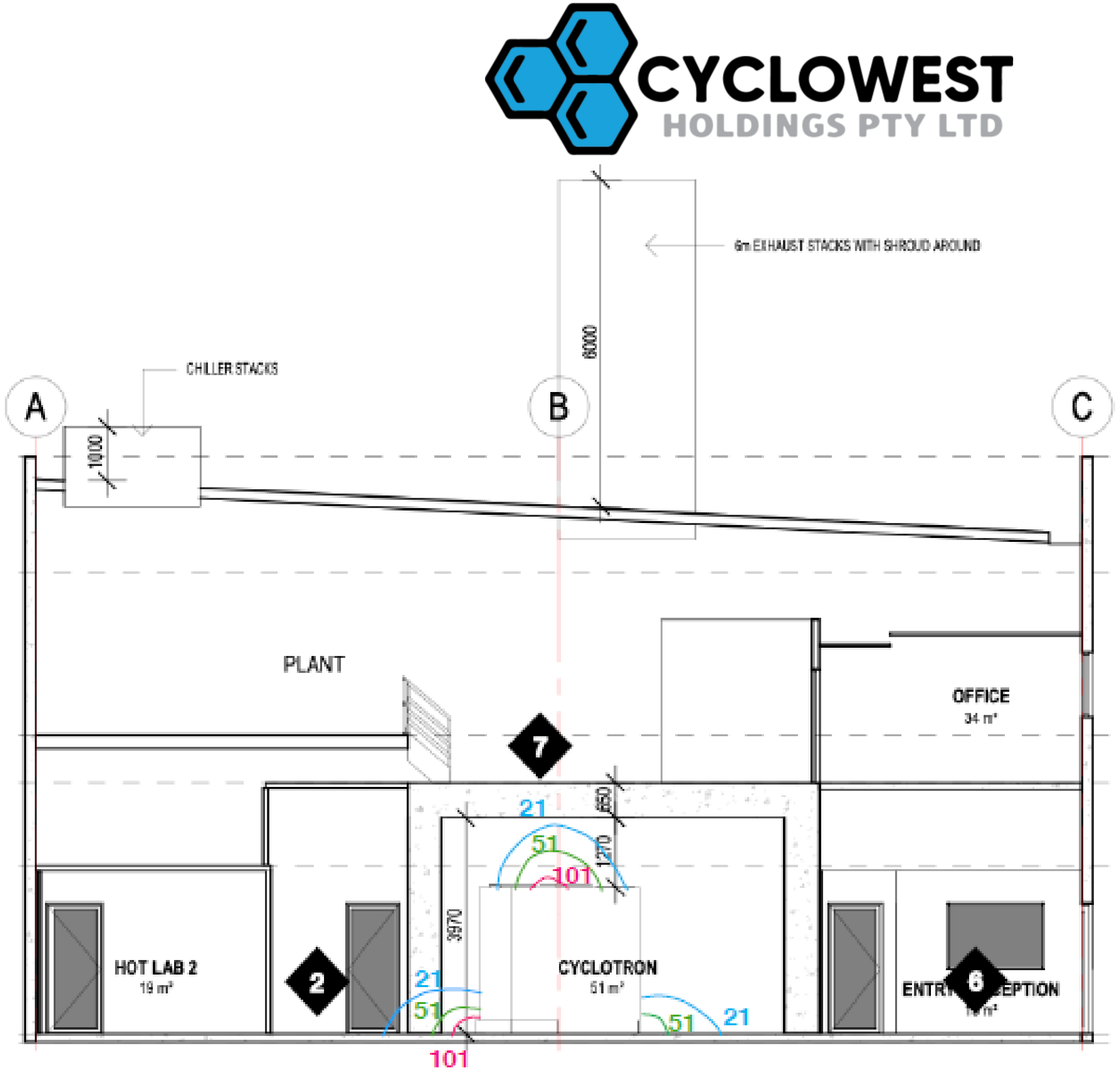
Bunker Configuration



Neutrons



G.31
HOT LAB 2
19 m²
G.30
HOT LAB 1
20 m²
G.10
AL RAD SAFETY
G.08
SERVICE AREA
18 m²
G.06
MACHINE ROOM
20 m²
G.07
CYCLOTRON
CONTROL ROOM
8 m²
G.02
UNISEX ACC WC
5 m²
G.01
ENTRY / RECEPTION
13 m²
G.03
ADMIN
G.11
CLEANER
5 m²
G.12
INCUBATORS
8 m²
G.13
DG STORE
6 m²
7800
1700
500
6300
1500
3000
200
600
2595
1000
650
8010
21
51
101
1
2
3
4
5
6



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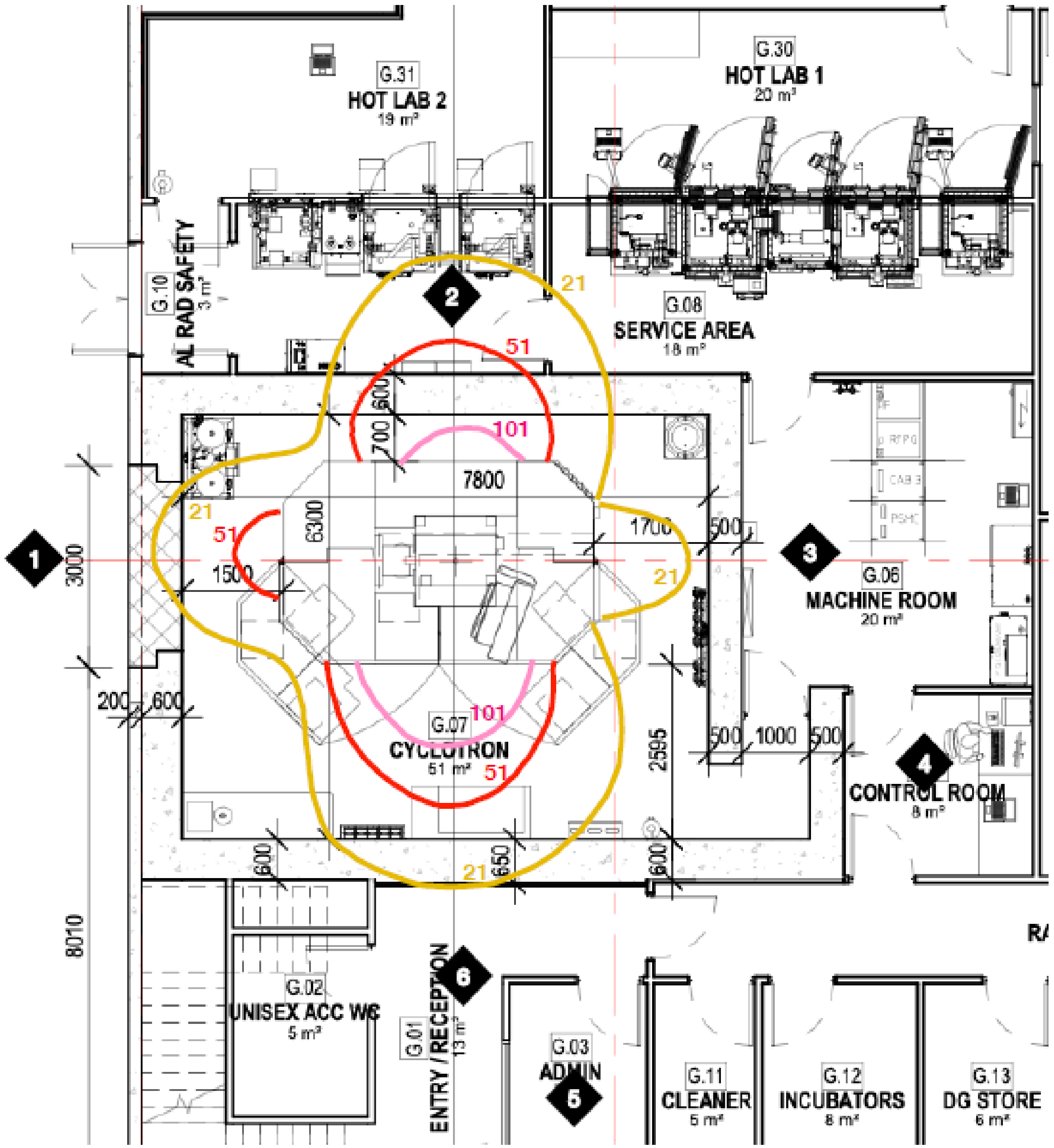
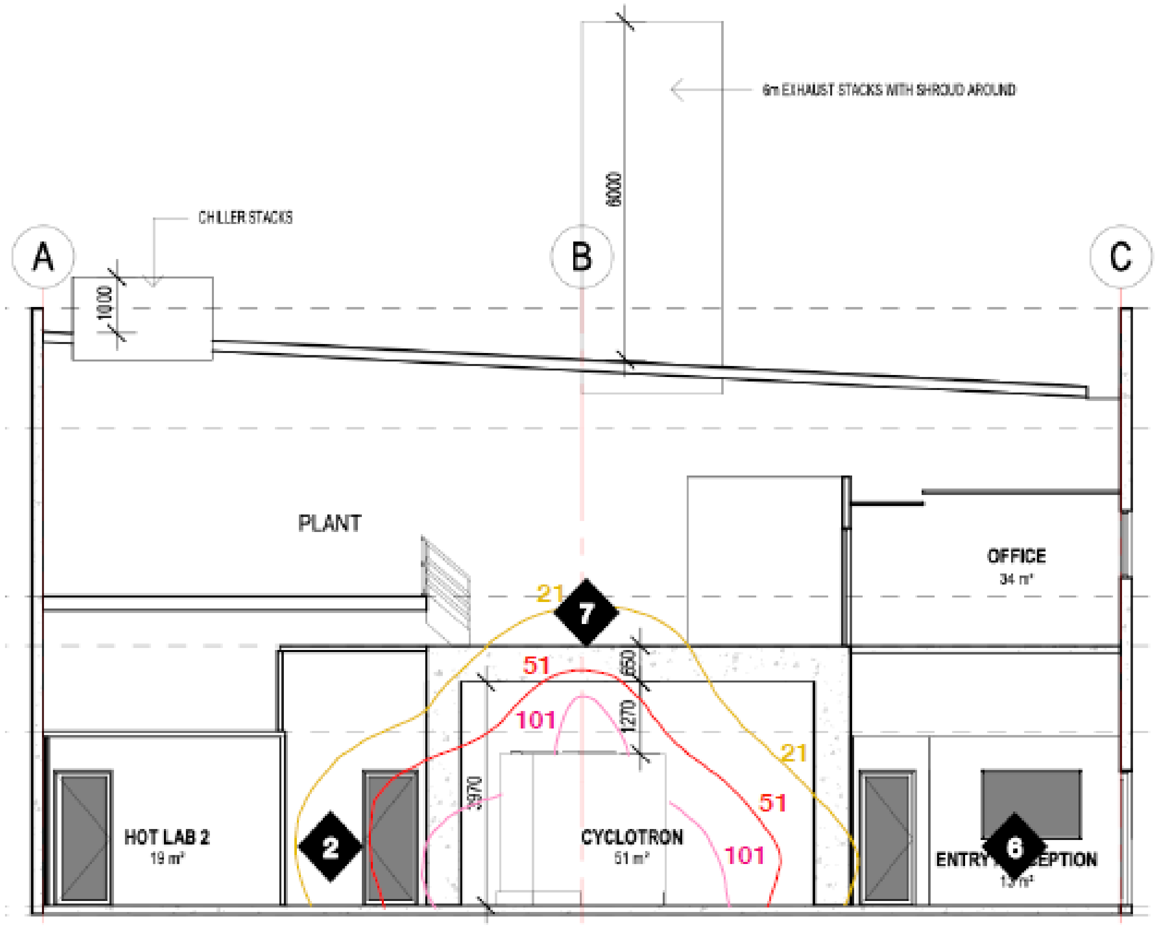
6m EXHAUST STACKS WITH SHROUD AROUND
CHILLER STACKS
A
B
C
1000
6000
PLANT
OFFICE
34 m²
HOT LAB 2
19 m²
CYCLOTRON
51 m²
3970
1370
650
21
51
101
2
6
7

Gamma





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Maximum Permissible Dose Rate

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$$10\%\ Occupational\ Annual\ Dose\ Limit\left(20\frac{mSv}{h}\right) = 2\frac{mSv}{h} = 40\frac{\mu Sv}{week} = {\color{red}1\frac{\mu Sv}{h}}$$

$$50\%\ Public\ Annual\ Dose\ Limit\left(1\frac{mSv}{h}\right) = 500\frac{\mu Sv}{h} = 10\frac{\mu Sv}{week} = {\color{red}0.25\frac{\mu Sv}{h}}$$

Shielding for Neutrons

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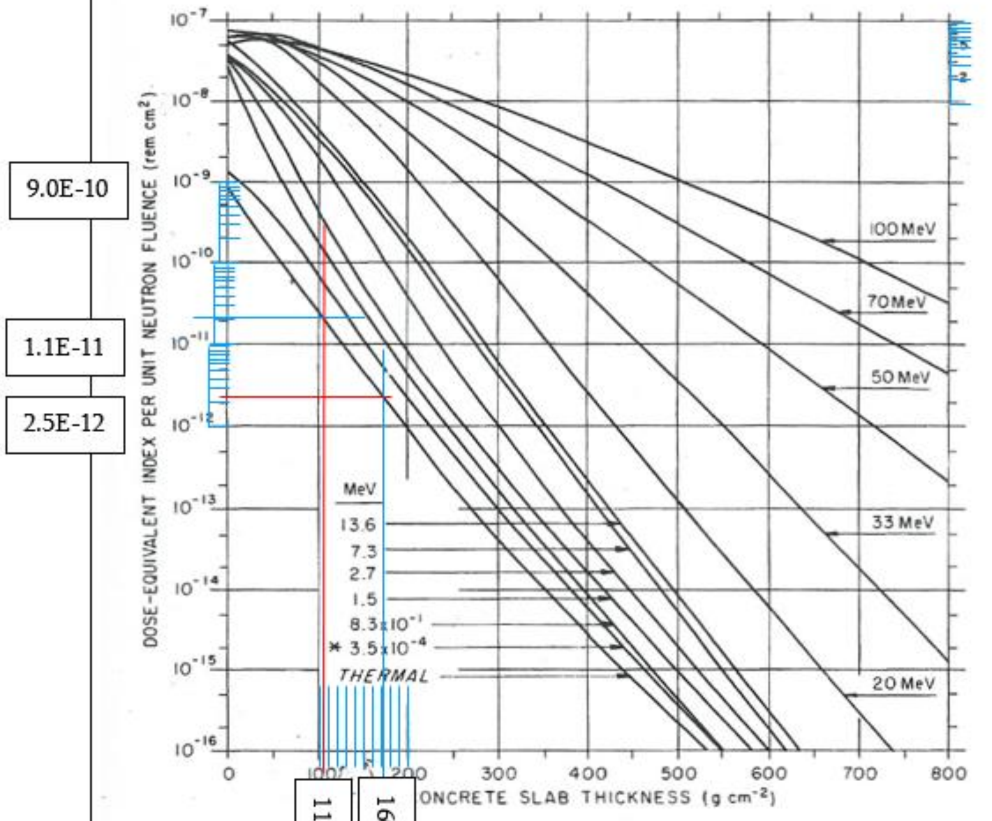
- NCRP 51 [Dose per N_{flux} vs $T_{Concrete}$]
- Ratio [neutron dose rate/public dose rate] [21/0.25=84]
- N_{flux}/84 → 45 cm of concrete.
- NCRP 51, NCRP 144 (+HVL)
- = 55 cm of concrete
- Extra safety (+10 cm)
- = **65 cm** of concrete
- 65 cm = 160 g.cm^{-2} → N_{flux} (0)/ N_{flux} (160) =300
- 21 μSv/h / 300 =0.07 μSv/h

F.6 Dose-Equivalent Index Transmission Through Concrete of Monoenergetic Neutrons



Dose-equiv[...]ansmission per unit fluence (rem cm²) of monoenergetic neutrons incident normally on slabs of ordinary concrete (TSF-5.5, see Appendix H-2). Multi-collision dose-equivalent index per unit fluence is calculated to include the dose-equivalent index contribution by capture gamma rays produced within the slab. Energies noted on the curves refer to the average energies of neutrons in the energy bins chosen for the discrete-ordinate calculations, as follows:

Effectiveness of Neutron Barrier for Gamma

- $I = I_0 \div 2^{\left(\frac{x}{HVL}\right)} \rightarrow I\left[\mu\frac{Sv}{h}\right] = 21\left[\mu\frac{Sv}{h}\right] \div 2^{\left(\frac{65\,[cm]}{12\,[cm]}\right)} = \mathbf{0.49}\ \mu Sv/h$
- $0.07 + 0.49 = 0.56\ \mu Sv/h$

Control Room $\frac{2\times250}{2000} = 0.25 \rightarrow 0.56 \times 0.25 = \mathbf{0.14}\ \mu Sv/h < 1\frac{\mu Sv}{h}$

Car Park $\frac{0.5\times250}{2000} = 0.0625 \rightarrow 0.56 \times 0.0625 = \mathbf{0.035}\ \mu Sv/h < 0.25\frac{\mu Sv}{h}$

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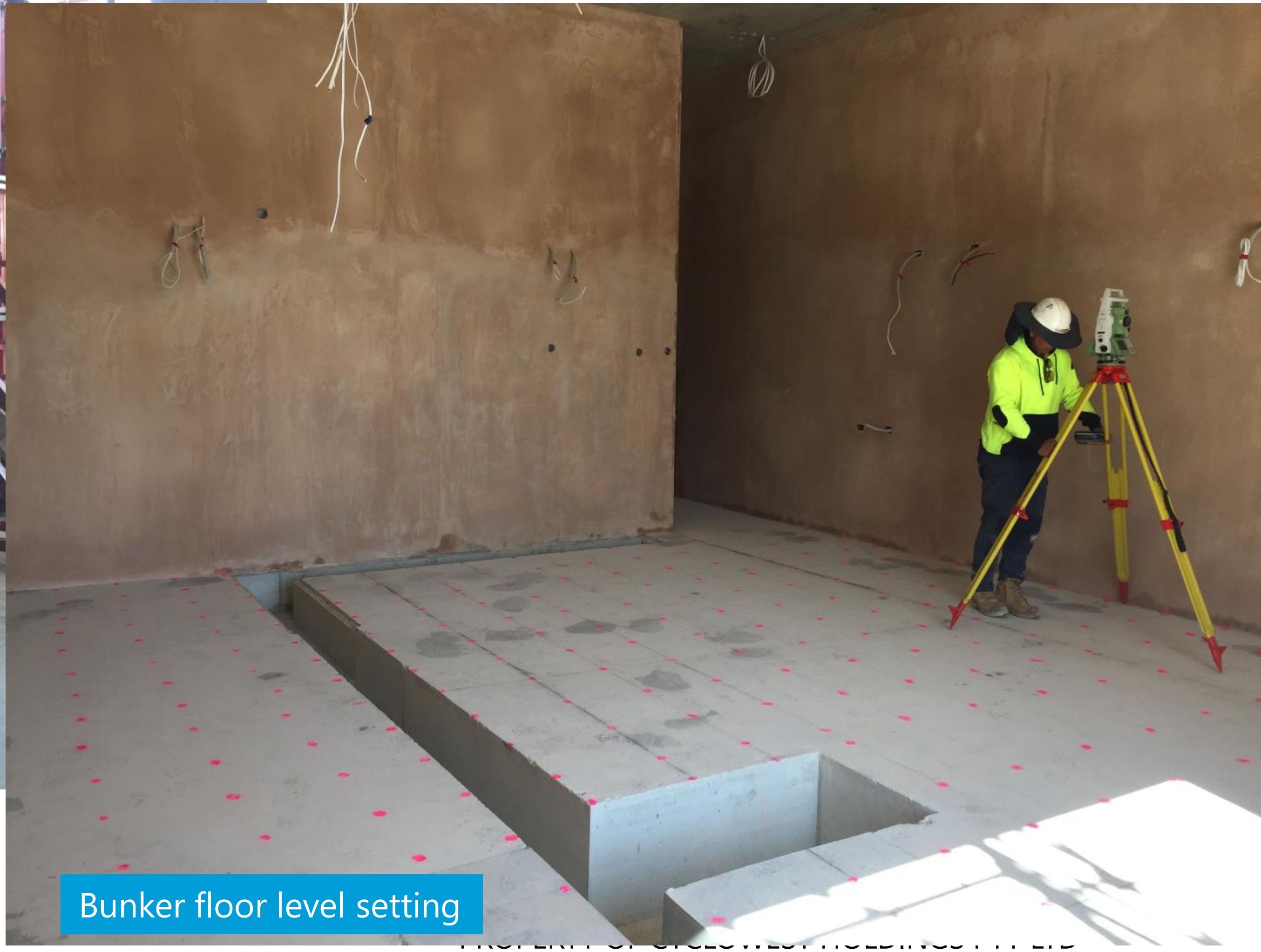
Bunker preparations



Bunker floor level setting


SRG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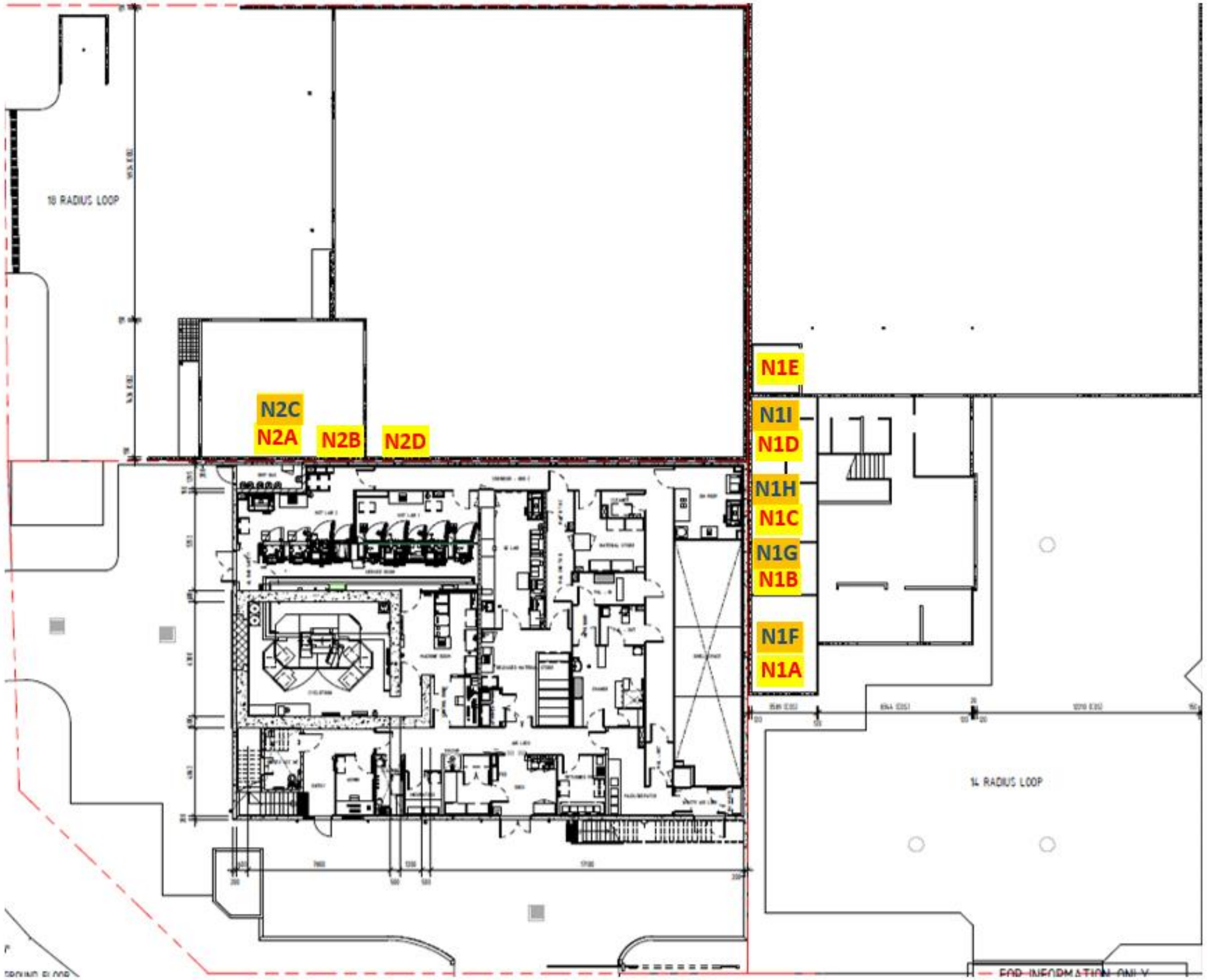
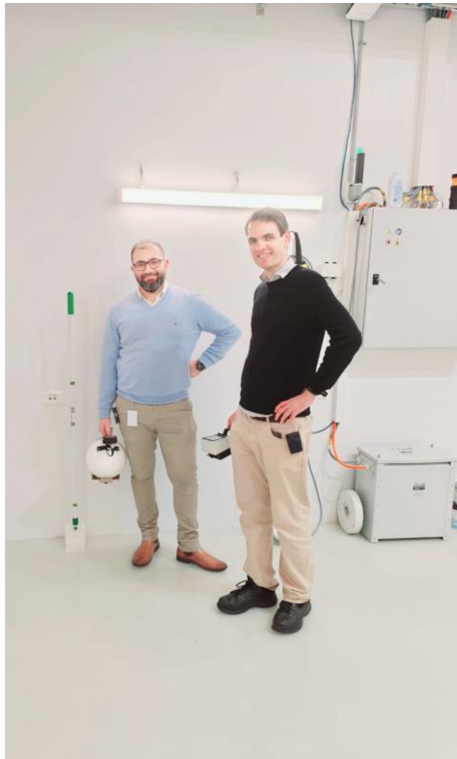
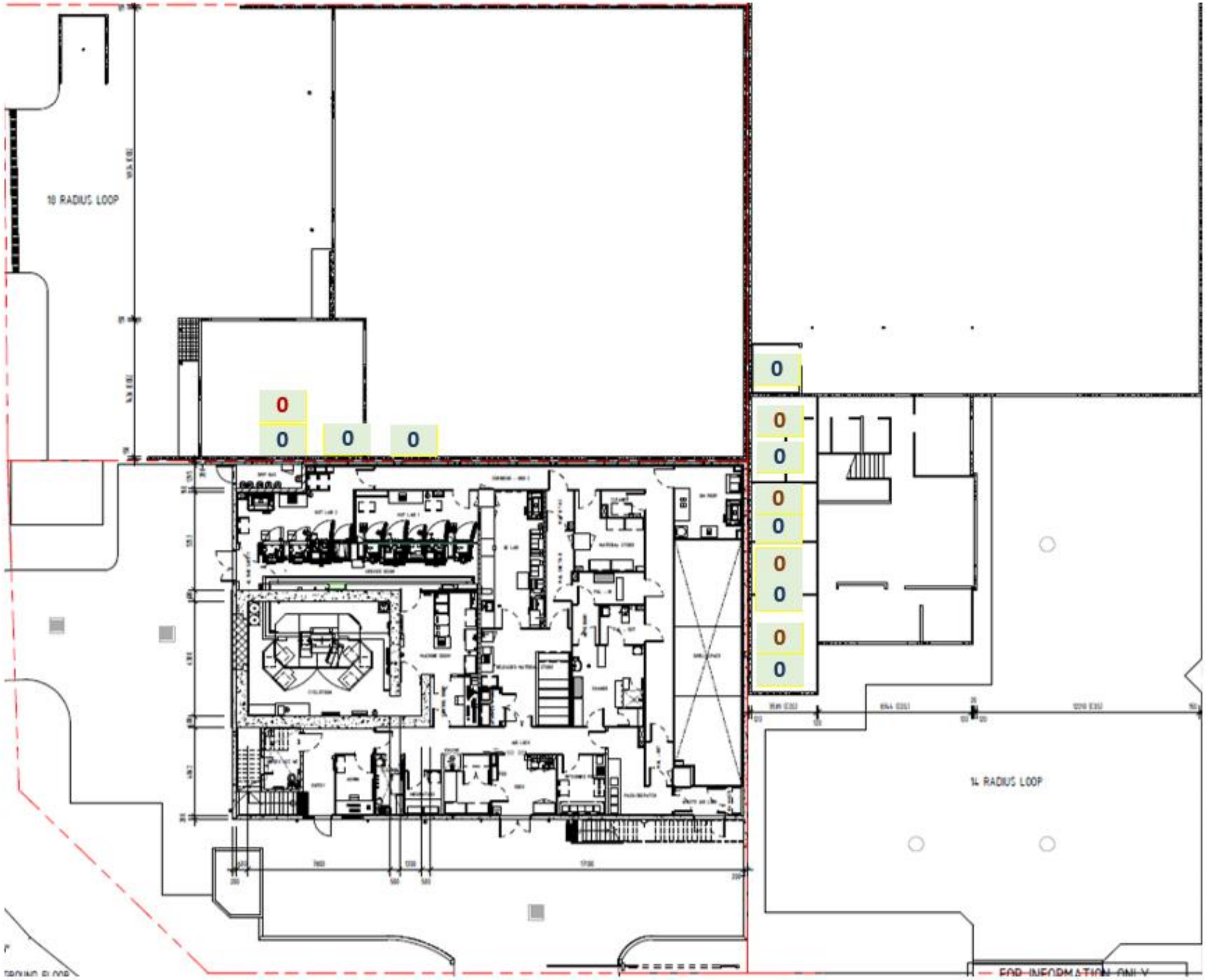
Radiation Survey Study 01





Radiation Survey Study Neutrons 02

Dose rate range (µSv/h)	
0 to 0.3	
0.3 to 10	
10 to 200	
200 and higher	



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Radiation Survey Study Gamma 03

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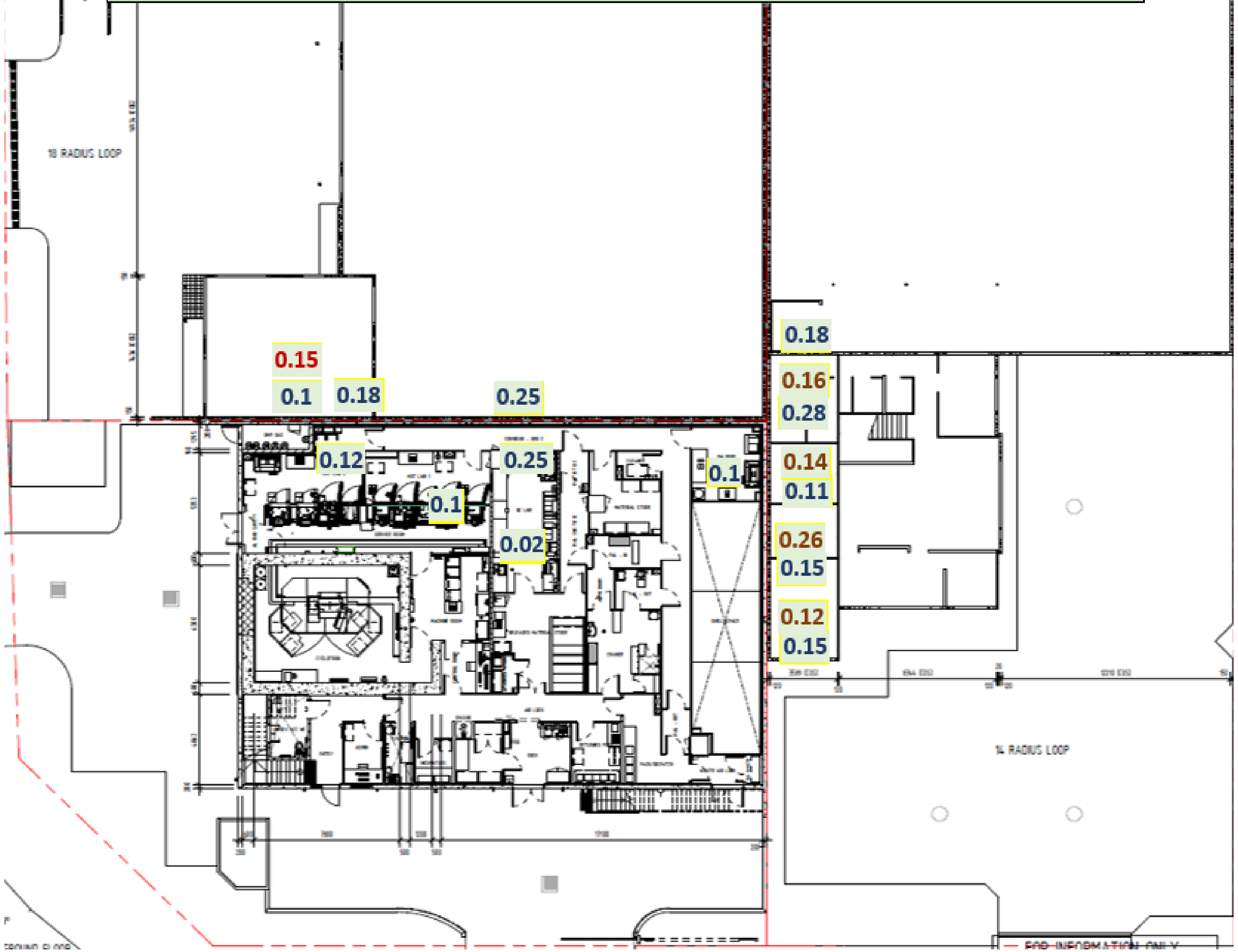
Dose rate range (µSv/h)	
0 to 0.3	
0.3 to 10	
10 to 200	
200 and higher	

P.S. The measured background radiation levels varied between 0.1 µSv/h and 0.29 µSv/h.



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Conclusion

- The barrier thickness has been determined for a GE PETtrace cyclotron
- A comprehensive radiation study was carried out using advanced equipment.
- The study covered multiple monitoring locations within and outside the facility.
- The Radiological Council of Western Australia's guidelines for radiation worker dose limits were considered.
- Notable gamma hotspots were found in the cyclotron's self-shielding tanks inside the bunker.
- These however do not result in any measurable elevated radiation dose rates outside of the bunker.
- This investigation confirms that cyclotron operational dose rates remain well within established safety thresholds.
- The overall radiation impact of the cyclotron on both the neighbours and the environment is deemed negligible and therefore well within acceptable limits.