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Improvements On Cyclotron Gas Target Cooling System Using COMSOL Multiphysics®

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Outline

-Introduction

-Aim

-Multiphysics Model

-Results and Discussion

-Conclusion

Medical Accelerators at KFSHRC

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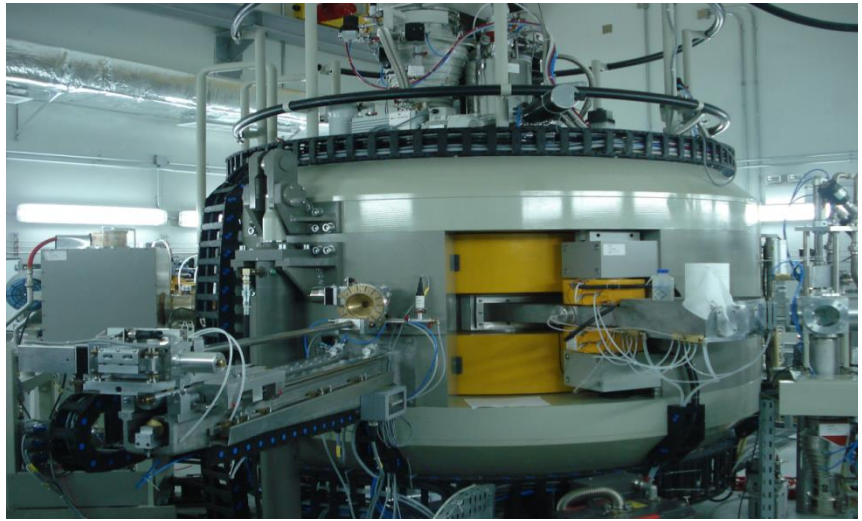
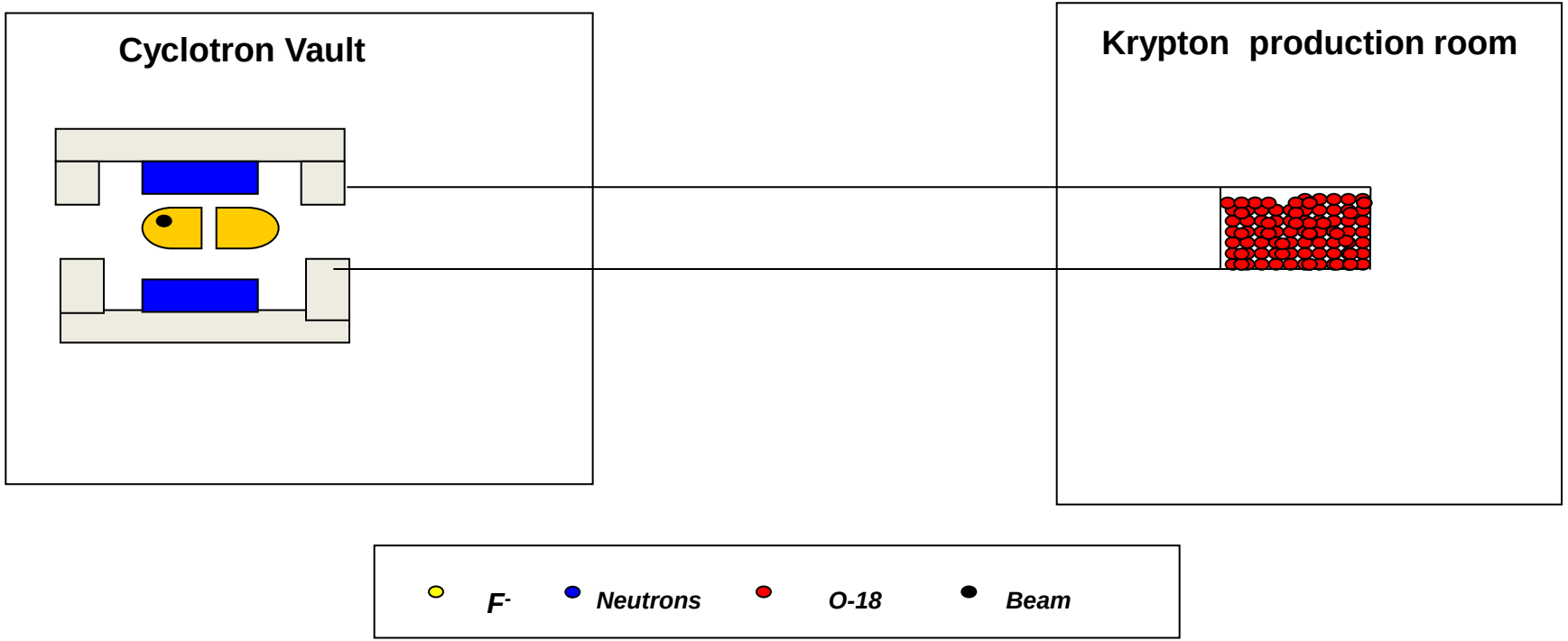
The C-30 Cyclotron

- End of 2010
- Negative ions
- 30 MeV (Variable energy)



Radiopharmaceuticals is the final product

Nuclear Reactions Inside A Target



Hardware System of krypton Target

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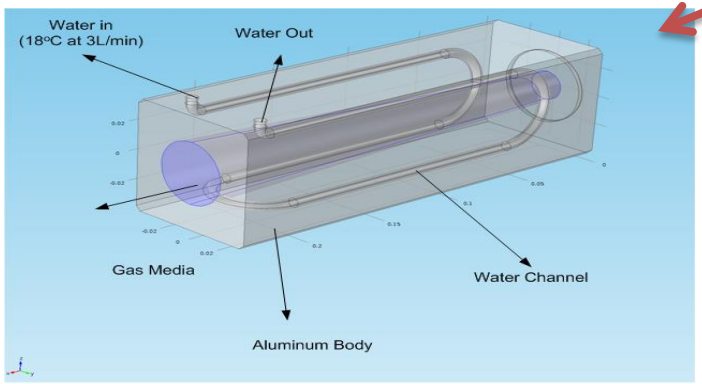
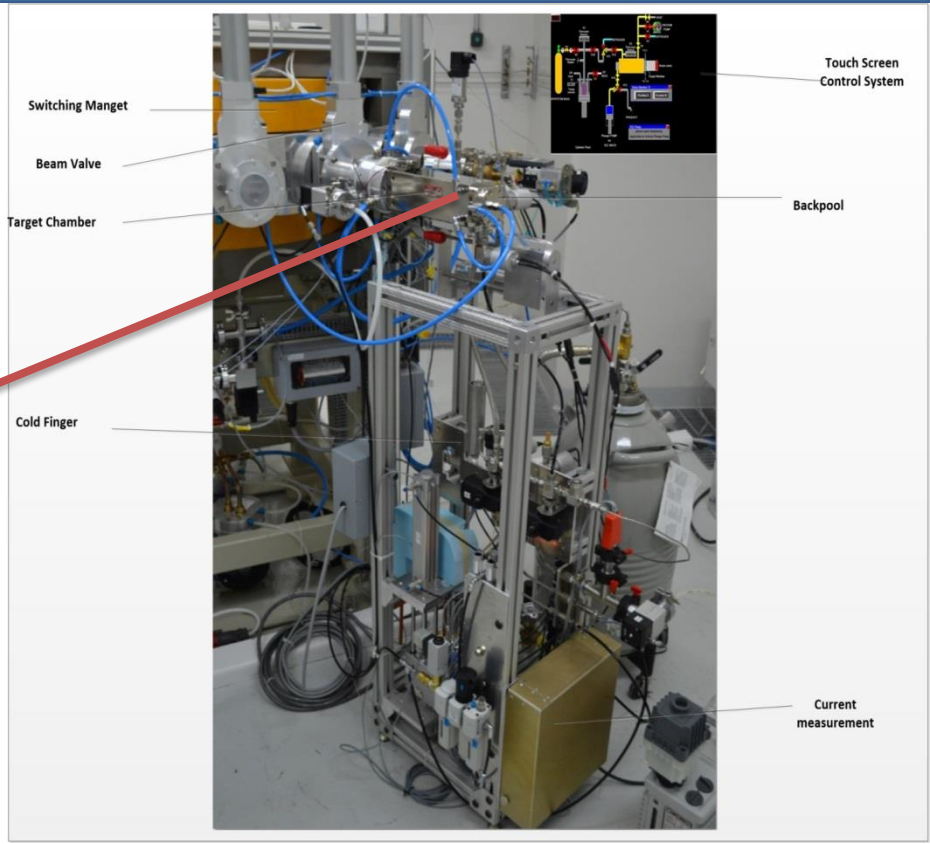
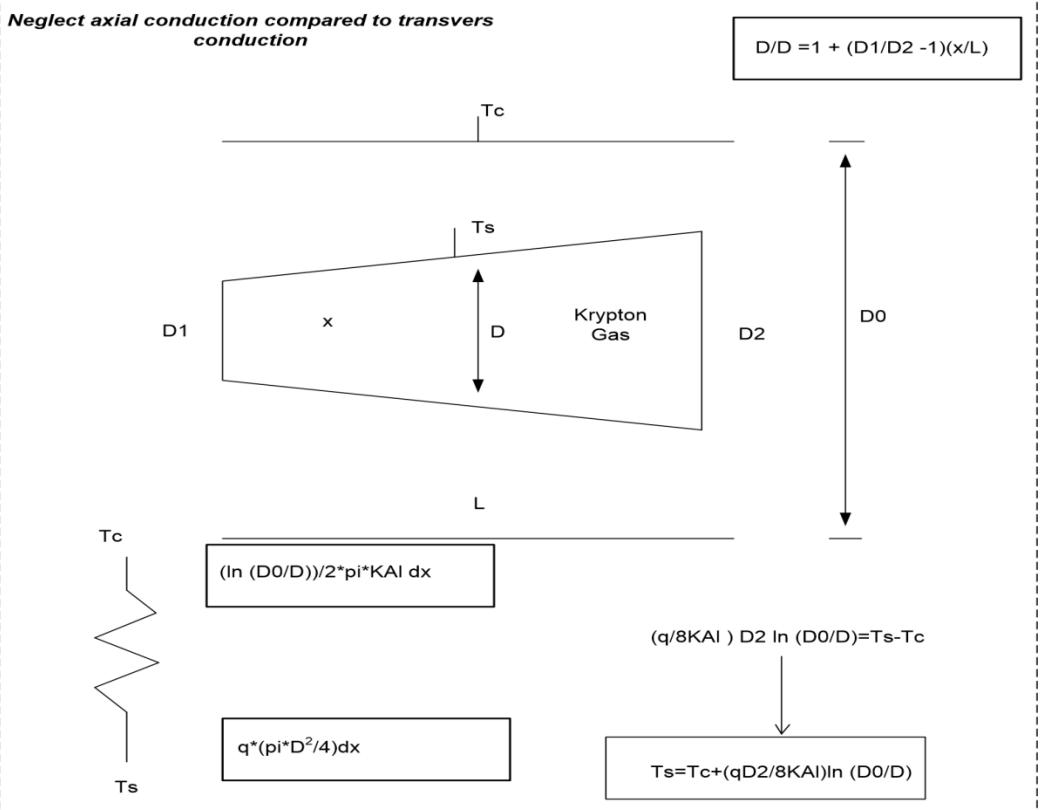
Efficient cooling not only ensures that the Kr gas will remain in the target, but also allows the material to be irradiated at higher beam currents, which in turn allows production of more radioisotopes in a given time.





2D Model Calculations



- Ts: Inner Al surface temperature
- Tc: Average cold water temperature
- q: Heat flux
- D1: inlet distance of the convergent tube
- D2: Outlet distance of the convergent tube
- D0: Distance between the cold water tube and the center line of the convergent tube.
- KAl thermal conductivity of aluminum.

Simulation Parameters

- 3D model was designed and imported into the COMSOL environment.

- The heat source was calculated from alternative software called SRIM that can calculate the stopping power (MeV/mm2) induced by cyclotron protons inside the gas.

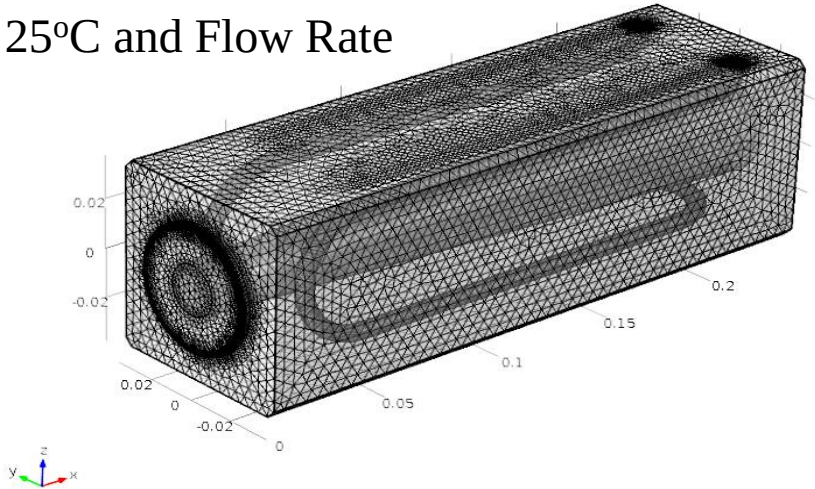
- Data was imported and interpolated into COMSOL.

- Target Length is 240 mm.

- Collimation System of 1 cm^2 stopping mean at the back of the target.

Simulation Parameters

- Assumptions:
  - Conjugate Heat Transfer model
  - Stationary Study and parametric Sweep for T and FL.
  - 5 bar pressure inside the gas target.
  - Slight modification on the water pipes.
  - Water temperature varies between 1 and 25^{o}C and Flow Rate between 0.5 to 10.0 L/min.



Power Calculations for COMSOL Heat Source

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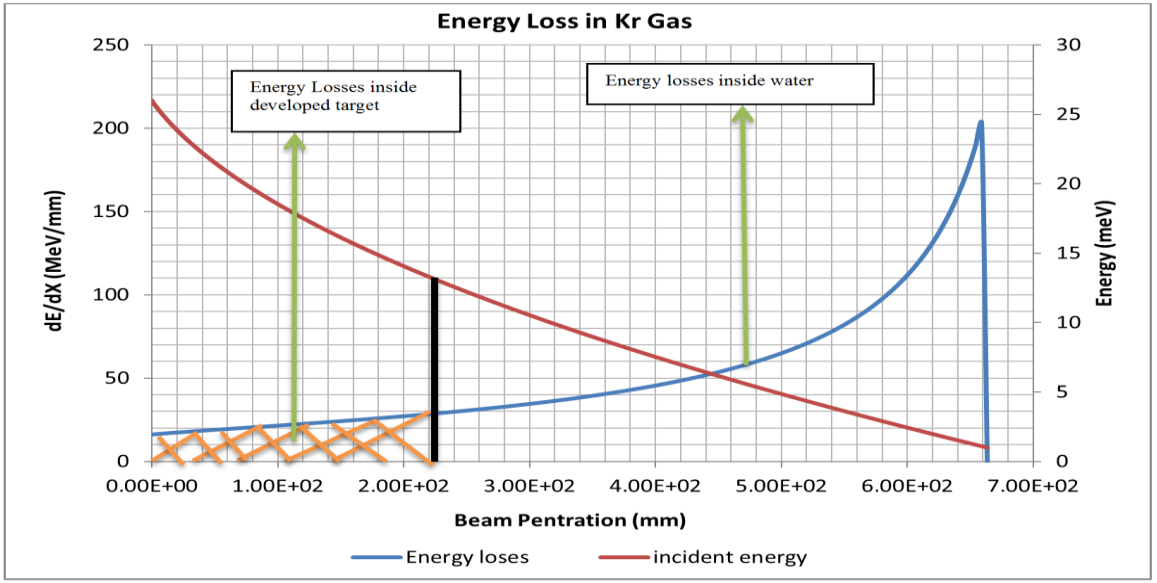
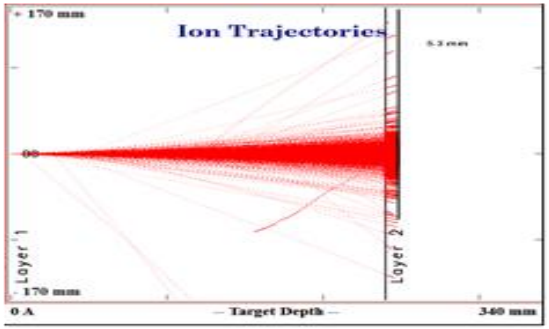
- Heat Source calculation was done in Sopping Range of Ions in Matter (SRIM).
-Energies from 26 to 20 MeV stopped inside the target.
-Power(w)=E(MeV)*I(uA)





Results and Discussion

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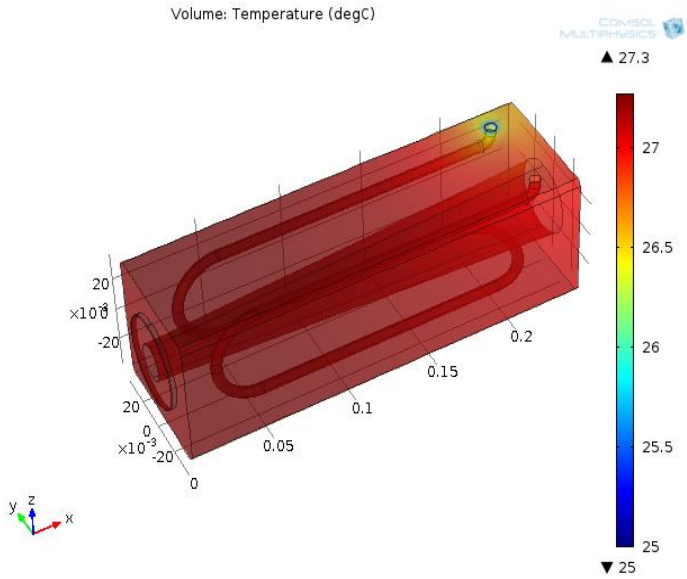
-Elevation in target temperature can be estimated from bombardment of high energy proton (26 MeV) and gas.

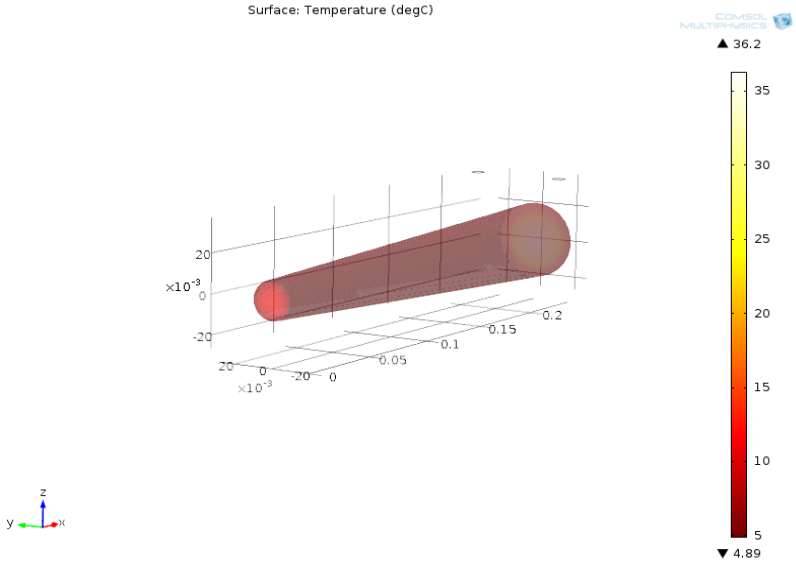
-In this case we have natural convection inside the gas medium



Results and Discussion

The impact of lowering water cooling temperature was clearly significant on the gas by reducing its temperature. Aluminum body temperature has elevated after increasing the water's cooling temperature.

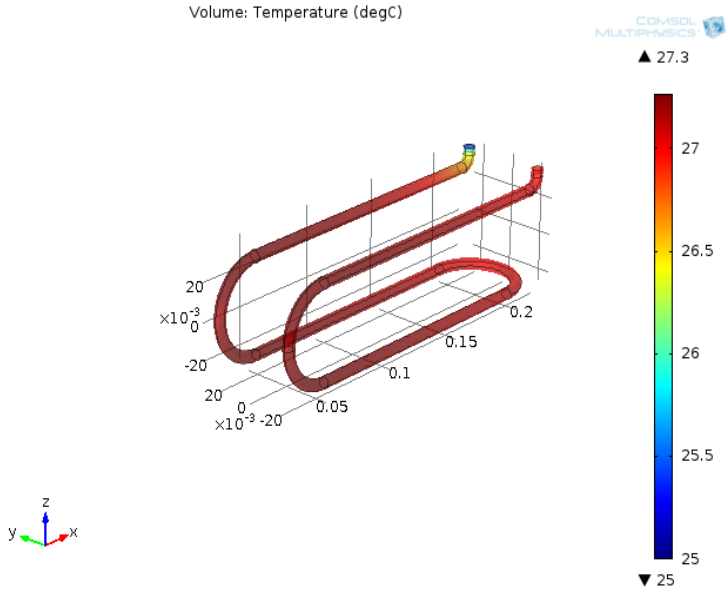
Water temp. at const. flow rate of 2 L/min	Kr. Temp °C).	Body Temp °C).
25	111	27.14
20	107.21	22.14
15	103.16	17.14
10	99.13	12.14
5	95.12	7.14
1	91.9	3.14



Results and Discussion

Table shows no significant effect of increasing flow rate (L/min) on gas temperature, nor for the body and pipe temperature. The later will be affected through conduction heat.

Water flow rate (L/min) at const. temp. of 20 °C	Kr Temp °C).	Body Temp°C).
0.5	107.3	22.26
1	107.28	22.22
2	107.21	22.14
4	107.09	21.98
6	106.97	21.84
8	106.86	21.17
10	106.77	21.59



Conclusion

COMSOL Multiphysics was utilized to simulate the heat transfer process during the nuclear reaction that produces the Kr-81m to determine the temperature of the gas and the body that contains it during the reaction.

A significant improvement was seen on cooling temperature of the gas and on the target body as the water temperature was decreased gradually.

Acknowledgment

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References

[1]P. W. WOJCIECHOWSKI, et. al. "A Semi-Quantitative Approach to the Design, Analysis and Operation of a Gas Target System, Radionuclide and Cyclotron Operations Department, King Faisal Specialist Hospital and Research Centre, 1987

[2] www. COMSOL Multiphysics

[3] M.A. Avila-Rodriguez,et. al."3D Modeling and Simulation of the Thermal Performance of Solid Cyclotron Targets", Excerpt from the Proceedings of the COMSOL Conference, 2007.

[4] WWW.SRIM.com

Thank you