Monoenergetic Fast Neutrons: Powerful Tool for Nuclear and Material Studies

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Outline of the presentation

- Deuterium gas target design and construction.
- Neutron production from deuterium gas target by DROSG code.
- Neutron Shielding and safety calculations using MCNP code.
- $^{20}Ne(\alpha,\gamma)^{24}Mg$ cross-section at stellar energies.
- Conference/schools/Workshops etc. and Foreign Visits.
- Deliverables and achievements.
- Impact of Project on Researcher & Host Institution.

Piestany Accelerator Laboratory (PAL)

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Deuterium gas target design and construction

- **^{2}D(d,n)^{3}He will be used for neutron production at PAL.**
- The employment of gas cell appears to be most optimal, since it provides sufficient yield of neutrons.
- The deuterium gas target facility at Institute for Nuclear Research (ATOMKI) at Debrecen, Hungary and Physikalisch Technische Bundesanstalt (PTB) at Braunschweig, Germany had been visited and critically reviewed.

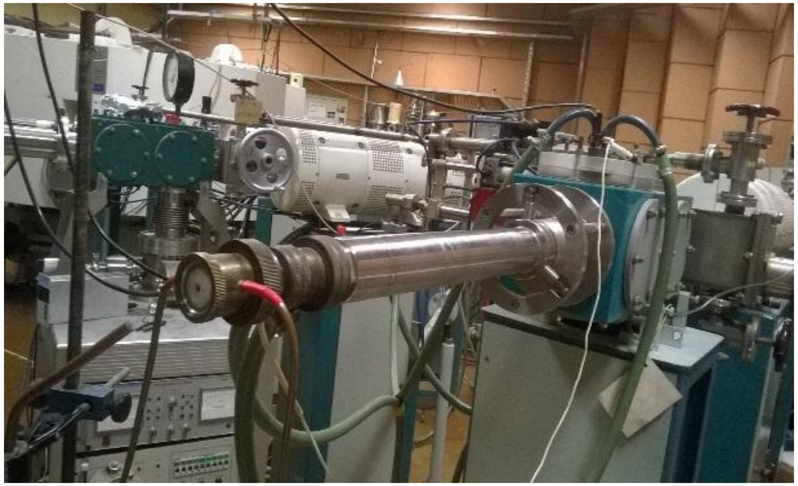

Fig.1 D_2 gas target at ATOMKI, Debrecen, Hungary.

Fig. 2 D_2 gas target at PTB, Braunschweig, Germany.

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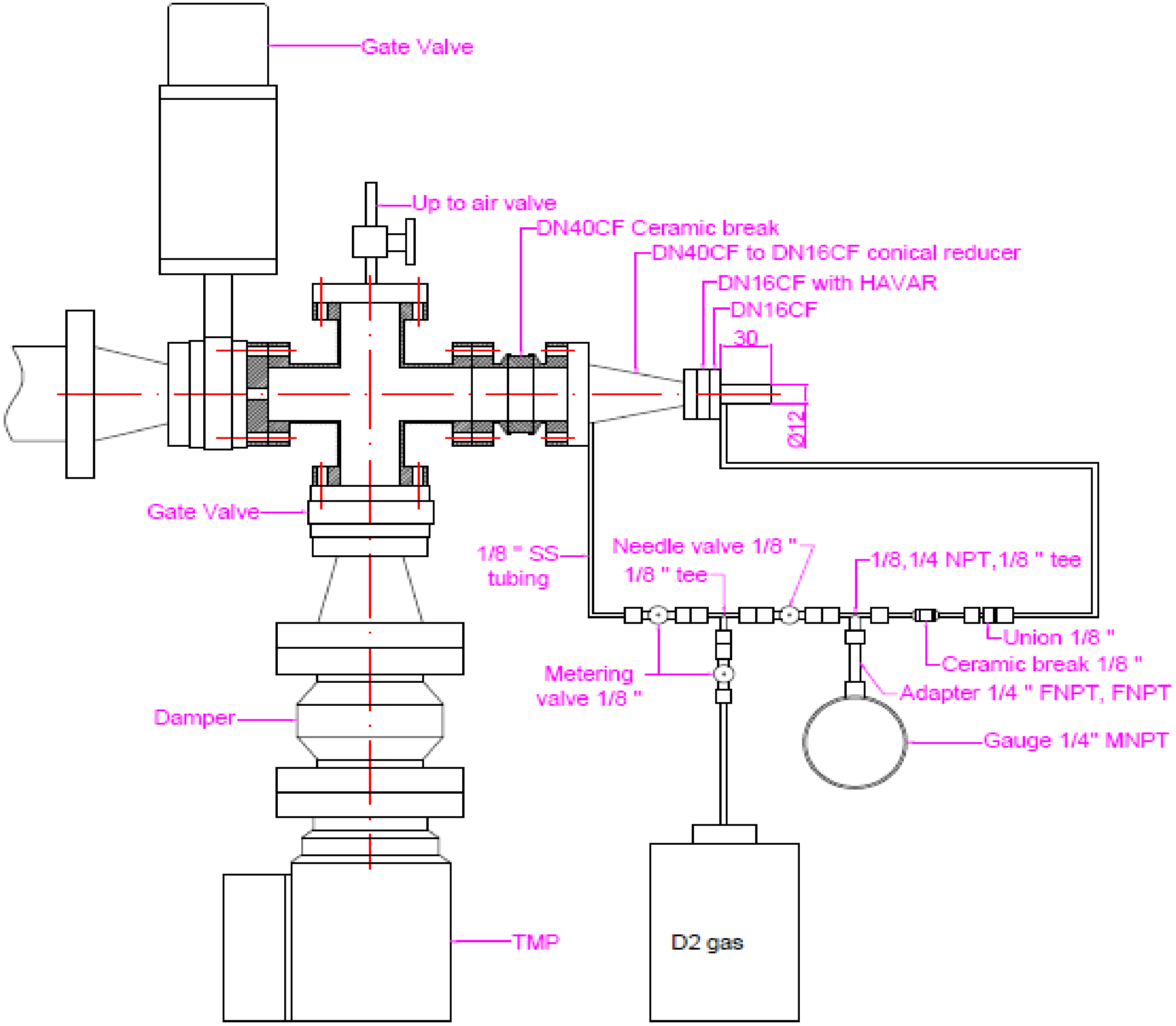
Deuterium gas target design at Institute of Physics, SAS for PAL



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Neutron production from deuterium gas target by DROSG code

- Accelerator is capable of delivery of beams of protons or deuterons with energy from 100 keV up to 4 MeV. It can also accelerate the alpha particle beam up to 6 MeV.
- Nuclear reaction $^2D(d,n)^3He$ will be mainly used for neutron production.
- Thus, this reaction has been simulated by DROSG code to get the neutron energy and angular distribution.

Table 1. Neutron emission of $D(d,n)^3He$ reaction by DROSG code

Deuteron Energy (MeV)	Cross-section (mb/sr)	Neutron energy (MeV)	Angle (Degree)	Neutron Yield (n/sr.sec)
1	27.87	4.14	0.00	7.46 x 10^5
	11.89	1.75	180.00	3.16 x 10^5
1.5	36.59	4.70	0.00	1.46 x10^6
	13.15	1.69	180.00	5.25 x 10^5
2	43.31	5.24	0.00	2.27 X 10^6
	13.67	1.65	180.00	7.15 x 10^5
2.5	49.24	5.75	0.00	3.14 x 10^6
	13.97	1.63	180.00	8.98 x 10^5
3	54.83	6.26	0.00	4.15 x 10^6
	14.22	1.62	180.00	1.07 x 10^6
3.5	60.24	6.76	0.00	5.25 x 10^6
	14.45	1.62	180.00	1.26 x 10^6
4	65.46	7.26	0.00	6.50 x 10^6
	14.68	1.63	180.00	1.45 x 10^6

Neutron Shielding and safety calculations using MCNP

- The MCNP Code is the internationally recognized code for analyzing the transport of neutrons and gamma rays.
- The dimension of the hall is 15.5 m x 12 m x 10 m.
- Point isotropic neutron source of 7 MeV has been considered at the center of the hall in modeling. The wall of the hall has been labeled as Px, Py, Pz.
- The neutron fluence was taken as 1x10*^{6} n/sec as it has been predicted by DROSG
- Material used in the calculations. (1) HDPE and (2).Aluminum

Neutron Shielding and safety calculations using MCNP

Case 1. 3 cm thick High Density Poly Ethylene (HDPE), Density: 0.93 gm/cm*3

Neutron Dose outside the Hall.

No.	Surface	Neutron Dose (Sy/hr)	Neutron Dose (mSv/y)
1.	Px	9.17323E-08	0.80
2.	Px (opposite wall)	8.78630E-08	0.70
3.	Py	1.05947E-07	0.92
4.	Py (opposite wall)	9.78332E-08	0.85
5.	Pz (top)	4.98896E-08	0.43

Photon Dose outside the Hall.

No.	Surface	Photon Dose (Sv/hr)	Photon Dose (mSv/y)
1.	Px	2.61239E-10	0.0029
2.	Px (opposite wall)	2.83603E-10	0.0024
3.	Py	2.88945E-10	0.0025
4.	Py (opposite wall)	2.63932E-10	0.0023
5.	Pz (top)	2.07091E-10	0.0018

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Neutron Shielding and safety calculations using MCNP

Case 2. 5 cm thick Aluminum, Density: 7.2 gm/cm*3

Neutron Dose outside the Hall.

No.	Surface	Neutron Dose (Sv/hr)	Neutron Doe (mSv/y)
1.	Px	1.01431E-07	0.91
2.	Px (opposite wall)	9.12364E-08	0.79
3.	Py	1.29992E-07	1.12
4.	Py (opposite wall)	1.23118E-07	1.07
5.	Pz (top)	6.44074E-08	0.56

Photon Dose outside the Hall.

No.	Surface	Photon Dose (Sv/hr)	Photon Dose (mSv/y)
1.	Px	9.78131E-10	0.0085
2.	Px (opposite wall)	9.74331E-10	0.0085
3.	Py	1.08902E-09	0.0095
4.	Py (opposite wall)	1.08991E-09	0.0095
5.	Pz (top)	6.23240E-10	0.0054

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${}^{20}Ne(\alpha,\gamma){}^{24}Mg$ cross-section at stellar energies

- Helium burning process are responsible for the synthesis of carbon from helium, and by further α-particle addition for the production of ${}^{16}O$, ${}^{20}Ne$, and perhaps ${}^{24}Mg$. The cross-section measurement for helium burning reactions at stellar energies is challenging task due to low cross-section.
- A literature survey indicates that there are various measurements available for ${}^{12}C(\alpha,\gamma){}^{16}O$, and ${}^{16}O(\alpha,\gamma){}^{20}Ne$ reactions at stellar energies but there has been no such many measurement for ${}^{20}Ne(\alpha,\gamma){}^{24}Mg$ at stellar energies.
- It is planned to measure cross-section for ${}^{20}Ne(\alpha,\gamma){}^{24}Mg$ at stellar energies using 2 MV Tandetron facility at Piestany.
- The preliminary studies has already been performed for the experiment which includes requirement of experimental infrastructure (i.e, Germanium detectors, scintillator detectors and on-line data acquisitions system), neon target preparation, and theoretical calculations.

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$^{20}Ne(\alpha,\gamma)^{24}Mg$ cross-section at stellar energies

- **Neon Target:** Neon targets will be produced by implanting ^{20}Ne into Tantalum backing at E_{Ne} = 30-70 KeV.
- We wish to implant ^{20}Ne ions in Tantalum and have peak concentration of 5 x 10^{18} atoms/cm^3. It should have peak concentration depth (i.e. projected range) of about 100 nm (1000 Angstrom) below the Tantalum surface.
- 500 kV ion implanter facility at Slovak University of Technology at Tranava will be used for neon target preparation.

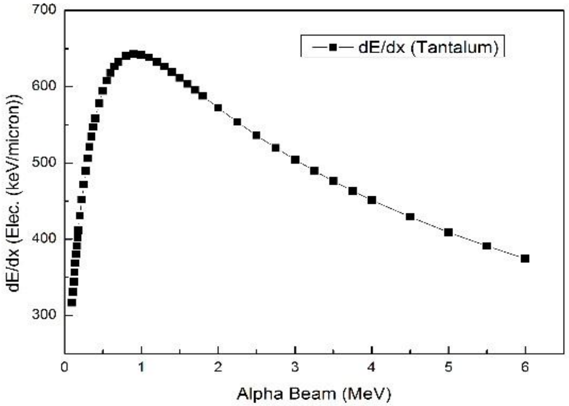

Fig. 4. Energy loss of α-particles on Tantalum target.

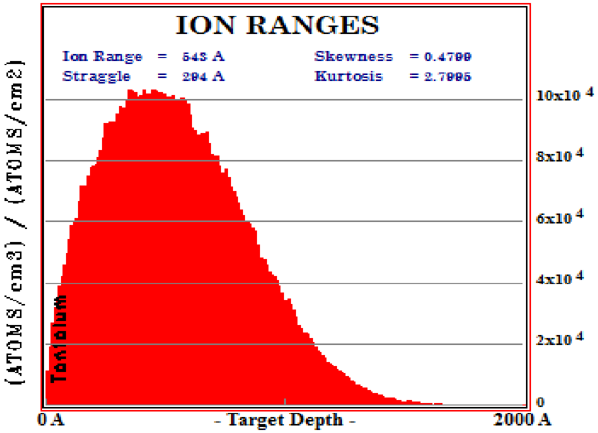

Fig. 5 Ion range of ^{20}Ne into Tantalum at E_{Ne} = 70 keV.

Conference/schools/Workshops etc. and Foreign Visits

Conference/schools/Workshops etc.

1. Spring Workshop on GEANT4 (SWG-2015) simulations on low energy nuclear physics from April 26 – May 1, 2015 at Častá-Papiernička Centre, Slovakia.
2. ISTROS -2015 Conference held at Častá-Papiernička Centre, Slovakia from 1-6 May, 2015.
3. Joint ICTP-IAEA School on “Nuclear Data Measurements for Science and Applications” in Trieste, Italy from 19/10/2015 - 30/10/2015

Foreign Visits

1. **Jyvaskyla, Finland:** JR121 experiment at JYFL, Jyvaskyla, Finland from 10-14 June, 2015.
2. **Brno, Czech Republic :** Deliver invited talk at Brno University of Technology, 10-11 August, 2015
3. **Debrecen, Hungary:** Visit for D_2 gas target facility at Institute for Nuclear Research (ATOMKI)—D2 Gas target design, 1-2 March, 2016
4. **Brunswick, Germany:** Visit for D_2 gas target facility at Physikalisch Technische Bundesanstalt (PTB), 10-11, March, 2016
5. **Dubna, Russia:** Experiment at Flerov lab at Joint Institute of Nuclear Research (JINR), 2-12 May, 2016**.**

Deliverables and achievements

(1). State of art D_2 gas target design for neutron production at Piestany facility,
(2). Simulation of Neutron production from deuterium gas target by DROSG and
(3). Neutron Shielding and safety calculations using MCNP for Piestany facility.

Impact of Project on Researcher & Host Institution:

- The current project has boost the scientific career of researcher.
- Developed new international collaboration with esteemed institutes like PTB, Braunschweig, ATOMKI Debrecen**,** JINR Dubna, University of Kentucky, and NDS, IAEA. The construction of the tandem laboratory has established important home basis for experimental programme of the Department of Nuclear Physics, Institute of Physics.
- Experiments performed here will complement existing program in foreign laboratories. Important added value is possibility of training of students of all degrees and postdocs.
- This appears to be optimal way of training of highly skilled professionals not only for fundamental nuclear research but also for nuclear industry.

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