Ⅲ. 核 物 理

Intentionally Left Blank

CNIC-01638/28
CNNC-0003

Comparisons of the Simulation Results Using Different Codes for ADS Spallation Target

YU Hongwei FAN Sheng SHEN Qingbiao ZHAO Zhixiang
China Institute of Atomic Energy, Beijing, 102413
WAN Junsheng
Northwest Institute of Nuclear Technology，Xian, 710024

Abstract: The calculations to the standard thick target were made by using different codes. The simulation of the thick Pb target with length of 60 cm, diameter of 20 cm bombarded with 800, 1000, 1500 and 2000 MeV energetic proton beam was carried out. The yields and the spectra of emitted neutron were studied. The spallation target was simulated by SNSP, SHIELD, DCM\CEM (Dubna Cascade Model \Cascade Evaporation Mode) and LAHET codes. The Simulation Results were compared with experiments. The comparisons show good agreement between the experiments and the SNSP simulated leakage neutron yield. The SHIELD simulated leakage neutron spectra are in good agreement with the LAHET and the DCM\CEM simulated leakage neutron spectra.

Key words: Comparison, Simulation, Spallation target, ADS

INTRODUCTION

Since the nuclear power system of the accelerator-driven sub-critical facility system (ADS) has obvious environment and source benefit, the nuclear energy scientists and engineers pay fully attention on the study of the ADS nuclear power system[1~4]. In China , the rapid increasing industry will need more and more energy , so the government of China thinks much of the

*Corresponding author, Tel. +86-10-69357729, Fax.+86-10-69357008, E-mail: hongwei@iris.ciae.ac.cn

study of ADS system; the study of ADS system is sponsored by the national fund. Based on the technical situation in China, Chinese scientists have proposed a two-stage plan[5]. The first stage is to build a proton linac of 150 MeV beam energy and 3 mA intensities. And a conceptual validity device will be built based on the light water reactor located in China Institute of Atomic Energy. The second stage will be characterized by a proton beam of approximately 1500 MeV energy and a few mA intensities.

The spallation neutron source is a link for transmutation and applications. The proton beam tube and the spallation target constitute the combination part of the accelerator and the sub-critical reactor, which is the important component part of the ADS. The physical study on the spallation target is one of the basic studies of the ADS design. From the point of view on the engineering application the basic problems such as spallation neutron yield, energy deposition, radiation damage, and radioactivity accumulation are firstly concerned. There exist several Monte-Carlo codes, such as HETC[6], LAHET[7], etc., most of them can solve the above problem. An intercomparison of the computer simulation of a proton beam interaction with heavy extended targets has been finished by 12 Laboratories[8]. Most of the groups have used some version of the well-known High Energy Transport Code (HETC) in combination with one of the neutron transport codes: MORSE, MCNP. And some groups (CDF and INFN) performed calculations with GEANT, FLUKA packages, which are employed usually at simulation of installations in high energy physics.

In China, we employed SNSP, SHIELD, and CEM\DEM codes for the calculations of the spallation target[9,10], so it is necessary to compare the simulated results using different codes for the ADS Target .

1 THE SIMULATED RESULTS AND COMPARSION

The thick Pb target with length of 60 cm and diameter of 20 cm was used in the calculations. The Pb target bombarded with 800, 1000, 1500 and 2000 MeV energetic proton beam was simulated by SNSP, SHIELD, and DCM\CEM codes.

SNSP was developed in China Institute of Atomic Energy. In the code, the macroscopic particle transport is calculated with Monte Carlo simulation and micorscopic nuclear data are obtained from the experimental data and systematic or empirical formulas, but the bind energy, excited energy, and the fission energy in the nuclear reaction processes are calculated based on the changing of the masses of nuclei. The energy conservation is approximately considered.

The SHIELD[11~13] , developed in the Russia group, INR of Russia, is a Monte-Carlo code that is ideologically similar to the HETC code. We have carried out the studies on the differential cross section of (p, xn) reaction, the neutron yield, the spallation fragment, the radiation damage and the energy deposit proton-induced with intermediate energy on the heavy target by using the SHIELD code [10,14~16].

The following are the comparsions of the simulation results using SNSP, SHIELD, DCM\CEM (Dubna Cascade Model \Cascade Evaporation Mode) and LAHET codes .

1. 1 Spallation neutron yield

The neutron yield is an important data for the practical application in the ADS study. It is related with the incident proton energy and the target material.

Table 1 Comparisons of numbers of leakage neutrons generated per proton for ϕ20 cm×60 cm Pb terget

$E_{p,in}$/MeV	800	1000	1500	1600	2000
SNSP	17.72	22.74	33.57	35.59	43.08
SHIELD	18.20	23.97	36.121	38.38	46.40
DCM\CEM	17.82	22.4		32.1	
LAHET[8]	14.30				
Exp.	17.75[17] 16[17]	19.5[18]		35.65[17]	

From above comparisons we can see the yields of the leakage neutrons are increasing with the increasing of the incident proton energy. The comparisons show the good agreement between the experiments and the SNSP simulated leakage neutron yield as shown in Fig. 1. The agreement between the experiments and other simulated leakage neutron yield may be good in some of the energetic proton but poor in some others. The differences of the simulated results are small below 1000 MeV energetic proton, and become big above 1000 MeV energetic proton.

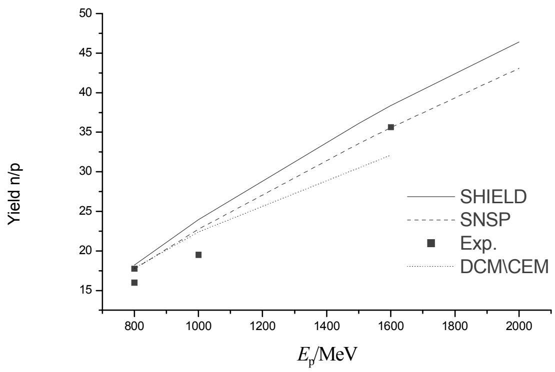

Fig. 1 Enery dependence on the number of leakage neutrons generated per incident proton

1. 2 Leakage neutron spectra

Another important data for the practical application in the ADS study is the leakage neutron spectra. The characterization of the leakage neutron spectra is usually using normalization neutron spectra. The normalization neutron spectra $P(E)$ is expressed as:

$$P(E) = (\mathrm{d}N / \mathrm{d}E) / N$$

Where N is neutron yield and E is the kinetic energy of neutron.

The normalization leakage neutrons spectra for different energetic proton beam are similar. The Fig. 2 is the normalization leakage neutrons spectra for 800 MeV energetic proton beam. From the Fig. 2, we can see the leakage neutron energies extend to 800 MeV, but the most leakage neutron energies are below 15 MeV. The SHIELD simulated leakage neutron spectra are in good agreement with the LAHET and the DCM\CEM simulated leakage neutron spectra. All of the simulated leakage neutron spectra are reasonable.

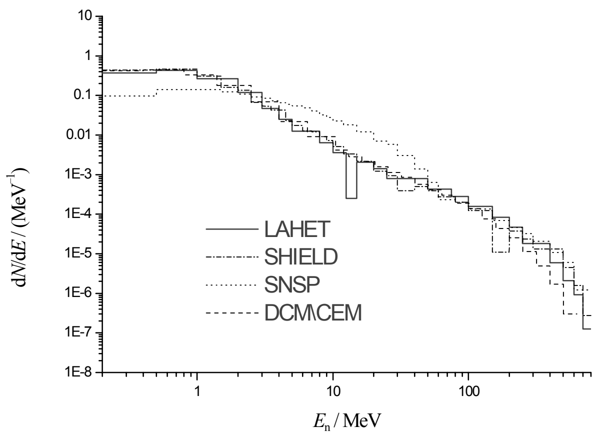

Fig. 2 Comparison of the normalizatio leakage neutron spectra for 800 MeV proton

2 SUMMARY

The comparisons shows good agreement between the experiments and the SNSP simulated leakage neutron yield , the agreement between the experiments and other simulated leakage neutron yield may be good in some of the energetic proton but poor in some others. The SHIELD and DCM\CEM simulated leakage neutron spectra are consistent with the LAHET simulated leakage neutron spectra.

From this work, we also can conclude that the method of SNSP code is of credibility, but it needs more experimental data and more studing of systematics of intermediated energy proton to extend it. Our next plan is to do the above work.

The project is sponsored by China Ministry of Science and Technology under contract G1999022600.

REFERENCES

1 Van Tuyle G, Takahashi H, Todossw M, et al. Driven Sub-Critical Target Concept for Transmutation Nuclear Wastes, BNL-11973, Upton,N.Y., (1991)

2 Bowman C D, Arthur E D, Lisowski P W, Lawrence P, et al. Nuclear Energy Generation and Waste Transmutation Using an Accelerator-Driven Intense Thermal Neutron Source. Nucl. Instr. And Meth., 1992, A320: 336

3 Carminati F, Klapisch R, Revol J P, Roche C H, Rubio J A, Rubbia C. An Energy Amplifier for Cleaner and Inexhaustible Nuclear Energy Production Driven by Particle Beam Accelerator, CERN/AT/93-47(ET), CERN 1993

4 Rubbia C, Rubio J A, Buono S, Carminati F, Fietier N, et al. Conceptual Design of a Fast Neutronn Operated High Power Energy Amplifier, CERN/AT/95-45(ET), CERN (1995)

5 ZHAO Zhixiang, et al. Corpus of Conceptual Research on the Accelerator-driven Sub-criticalsystem, CNIC-01468,CNNC-0002

6 Cabriel T A, Alsmiller R G, Guthrie M P. An extrapolation method for predicting nucleon and pion differential production cross sections from high-energy(>3 GeV) nucleon-nucleus collisions, ORNL-4542, Oak Ridge National Laboratory(1970)

7 Prasl R E, Michael Bozoian. Adaptation of the multistage preequilibrium model for monte-carlo method(1), LA-UR-88-3238, Los Alamos National Laboratory (1988)

8 Michel R and Nagel P. Specifications for an international codes and model intercomparison for intermediate energy activation yields, NEA/NSC/DOC(95)8, OECD/NEA (1995)

9 SHEN Qinbiao, TIAN Ye, ZHAO Zhixiang, LIU Guisheng, DING Dazhao. The Monte-Carlo Calculations for the Spallation Neutron Source of ADS, Report on Accelerator-Driven Radiological Clean Nuclear System, China Institute of Atomic Energy, Beijing: (1996)

10 XU Chuncheng, YE Yanlin, CHEN Tao, YING Jun, MA Jingguo, LIU Hongtao, Study on The Parameter of the Lead Spallation Target. High Energy Physics and Nuclear Physics, 1999 23(4):402 (in Chinese)

11 Sobolevsky N, International Code Comparison for Intermediate Energy nuclear Data Thick Target Benchmark for Lead and Tungsten, NSC/DOC(96)-15 (1996)

12 Dementyev A V, Sobolevsky N M, YU,Ya.Stavissky, Neutron Yield from Extended Lead Target under Incident Protons of 0.1 to 100 GeV. Nucl. Instr. and Meth., 1976, A374: 70

13 Dementyev A V, Gurentsov, Ryazhskaya O, Sobolevsky N M. Production and Transport of Hadrons Generated in Nuclear Cascade Initiated by Muons in the Rock. Nucl. Phys., B70:486, (1999)

14 FAN Sheng, YE Yanlin, XU Chuncheng, CHEN Tao, et al. The Analysis of Distribution for the Spallation Fragment Proton-Induced with Intermediate Energy, Nucl. Phys. Rev., 2000 17(2):91 (in Chinese)

15 FAN Sheng, YE Yanlin, XU Chuncheng, CHEN Tao, et al. The Radiation Damage Effect on the Spallation Neutron Target of ADS, (1) The Displacement Atoms. Atomic Energy Sci. and Tech., 2000 34(6):499~506 (in chinese)

16 FAN Ssheng, YE Yanlin, ZHAO Zhixiang,CHEN Tao, et al. The Radiation Damage Effect on the Spallation Neutron Target of ADS, (2) The Gas Production. Atomic Energy Sci. and Tech., 2001 35(2):164~168 (in chinese)

17 Vasilkov R G, et al. Proceedings of ICANS-XI, Roport KEK-90-25, V. I, 1990. 340

18 Lone M A, et al. Nucl. Instr. Meth. In Phys. Research, 1987, A256:135

用不同程序模拟计算 ADS 散裂靶结果的比对

于洪伟　樊胜　申庆彪　赵志祥

中国原子能科学研究院，北京，102413

万俊生

西北核技术研究所，西安，710024

摘　要：利用不同的程序对 ADS 散裂靶进行了模拟计算。用 SNSP, SHIELD, DCM\CEM (Dubna Cascade Model \Cascade Evaporation Mode) 和 LAHET 等程序计算了长 60 cm，直径 20 cm 的圆柱形铅靶，分别在 800, 1000, 1500 and 2000 MeV 的质子轰击下所产生的泄漏中子产额和能谱分布。模拟结果与实验数据进行了比较，对泄漏中子产额而言，SNSP 模拟的结果与实验符合较好，SHIELD, DCM\CEM 和 LAHET 计算的泄漏中子能谱分布比较一致。

关键词：比对　模拟　散裂靶　ADS