

THE USE OF CYCLOTRON FOR PET/CT SCAN IN INDONESIAN HOSPITALS AND FUTURE COLLABORATION*

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Abstract

In Indonesia there are only three hospitals, which using cyclotrons for cancer detection (PET scans). These three hospitals are located in one place: Jakarta. With 1.4 percent of the Indonesian population are developing tumor/cancer, compared to the number of hospitals, which have advanced PET technology from cyclotrons, it will be a major task for the government to empower the production and overseas collaboration in the cyclotron industry.

INTRODUCTION

PET (Positron Emission Tomography) has been effectively used to detect cancer [1]. with the accuracy of the imaging result, this technology is becoming the most useful forms of diagnostic imaging [2]. Instead of the quality of PET scan for imaging, the effectiveness of PET scan can be improved if it combined with CT (Computed Tomography) scan to perform a PET/CT scan. The first combined technology of PET and CT scan has been proposed by Townsend and his colleagues [3]. From that point, the progress of this technology has been spread over throughout the world. The use of the cyclotron to obtain the radioactive substance (¹⁸F-fluorodeoxyglucose) for PET scan has been improved linearly with the progress of PET scan improvement. The main problem of PET and CT combinations into a PET/CT scan is that this device is costly [4]. However, since the accuracy of this PET/CT scan is undoubtedly much better than PET and CT scans separately, this technology preserves a great contribution of medical sciences.

While two decades has passed and PET/CT scan is widely acknowledged, the use of PET/CT scan is not highly performed in any country. But contrary, In Indonesia the only hospitals, which using PET/CT scan for cancer diagnoses are only three: Gading Pluit Hospital, MRCCC Siloam Hospital, and Dharmais Cancer Hospital [5]. All of them are located in Jakarta (Indonesian capital).

With the population of 237 million in 2010¹ [6], Indonesia ranked 4th among all of the countries in the world. The number of people who have diagnosed with cancer are 347,792

or 1.4 percent [7] of the Indonesian population. Among all of the numbers, only 2,221 patients are diagnosed with PET/CT scan in Dharmais Hospitals [8].

Most of the main hospitals in Indonesia are using CT scan for cancer diagnosis. The bill for performing CT scan in Rumah Sakit Akademik Universitas Gadjah Mada as a university hospital is almost reaching 100 US Dollar [9]. In other side, the bill of each PET scans diagnosis in Siloam Hospital and Gading Pluit Hospital are respectively 670 US dollar [10] and 820 US dollar [11].

Based on the data in [6] the average of minimum of monthly salary per region standardized by government in Indonesia is 120 US Dollar. In fact, 11.47 percent of the Indonesian population is stated at the level of poverty, which means their salary is under that level. Instead of those realities, the average salary for workers in public sectors [12] in Indonesia are varied in number, but the range of their basic salary is 120 US Dollar-450 US Dollar.

INDONESIAN RESEARCH ON CYCLOTRON

BATAN² (National Nuclear Energy Agency) is an Indonesian Nuclear agency. Located in four separated areas on Java island: (Serpong) Tangerang, Jakarta, Bandung and Yogyakarta. BATAN in Serpong has cyclotron [13] which was running for about 24 MeV-27 MeV and 60 μ Ampere of maximum of ¹H beams available. The cyclotron has been installed since 1990³, but recently, it is not well operated.

The cyclotron was used for PET scans in early years instead of its application in radiobiology, material sciences, agricultural applications, etc. With so many applications, it was a great loss for the agency about the condition of the facility recently. In addition to the cyclotron in Serpong, the research of manufacturing a new cyclotron is still progressing positively. BATAN in Yogyakarta has their own interest to design a cyclotron [15]. The 13 MeV cyclotron is still in developing state since 2014 which the design has been carefully prompted in early years [16, 17].

Based on [18], the magnet specification of 13MeV Cyclotron can be described via Table 1. Currently, the magnet runs smoothly. Also, the home-made ion source has been

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¹ the data can be viewed via [6], the site shows the data of Indonesian population for each 10 years, the next one is 2020

² abbreviation of Badan Tenaga Nuklir Nasional

³ Historically the application of cyclotron has been used since 1970 in BATAN [14]

constructed and tested [19]. It works in 8 kV with the ion beam current of 35 μ A. However, BATAN still works on Dee's and vacuuming the cyclotron. Due to the result, in next year those problems are expected to be solved.

Table 1: Magnet Specifications of Cyclotron

PROTON ENERGY	13MeV
Accelerated Ions	Ions
Ion Source Type	Internal
Sector Number	4
Valley Gaps	120 mm
Hill Gaps	40-50.78 mm
RF Frequency	77.64 Hz
B_0	1.274 79 T
Maximum B_{Hill}	1.942 116 T
Minimum B_{valley}	0.7689 T
Coil current	2×44012 ampere-turn
Poles radius(R)	0.48 m
Hill Angles	$35^0 - 44^0$ from magnet center
v_r (v_r Average)	0.99-1.04391(1.0256)
v_z (v_z Average)	0.07-0.40199(0.36202)
Phase shift	$\pm 13^0$
Magnet dimensions	1.96m \times 1.30m \times 1.21m
Magnet weight	17.3ton

The main goal of this 13 MeV cyclotron at BATAN is acting as a prototype for the future generation of the next Indonesian cyclotrons. Once this cyclotron is finished, we may propose for the next project: increasing the number of successful cyclotrons for PET scan on medical applications.

TECHNICAL ISSUES FOR CYCLOTRON'S CONSTRUCTION

In order to construct a cyclotron there are constraints which need to be solved [20]: financial, structural, political, conceptual, organisational, and human resources. The problem arises when one of those criterias is missing.

It has always an issue for some developing countries cannot meet some of criterias above. Since it is said from [20], planners should consider operational and maintenance cost which typically 10 percent of the capital costs per annum. Last but not least, the need of human resources or professionals cost more money. It can be a great deal to the government, for instance, if the benefits of this device are not fully understood [20].

Based on the financial problem. Most developing countries do not have many options for their budget. They need to spend their budget effectively in some areas. That's why spending their budget for cyclotron is dramatically being the last of any option. They may argue, MRI and CT scan are sufficient and there are other medical issues which need to be primarily solved.

Even for countries which have quite amount of budget, they need to do a cost-benefit ratio since this cyclotron-construction project is really spending a lot of money. They

may need to consider about a new room/building to spend a new cyclotron. Also, they need to consider the population in that area which their cyclotrons won't be wasted.

It is said that government should calculate the cost-effectiveness analysis, the cost-effective ratio, the cost-utility analysis, and the cost-benefit analysis⁴. However, one might realise that in some countries, the government should calculate their citizen's annual salary per region. For example, the minimum wage of Jakarta as Indonesian capital in 2014 [6] is 186.1 US Dollar. However, the average minimum wage of Indonesia is 120 US Dollar. It is obvious why Jakarta has three cyclotrons at once based on the population and its wage level. On the contrary, one need to remember that all of the cyclotrons in Jakarta are owned by private sectors, not government.

THE REASON TO BUILD A CYCLOTRON FOR PET SCAN IN INDONESIA

It has been stated in above explanation that build such a device is extremely costly. We need to realise the constraints of developing accelerator especially cyclotron. While the developer of cyclotron (government or private sector) should reconsider its beneficent factors while considering the constraints involved.

In order to build cyclotrons in Indonesia, all of the constraints must be solved. However, since the research on cyclotron is not the one of government priorities at present [21]. There are some problem in basic health care, some infrastructure building, which need to be solved in no time.

Instead of those problems, we may realise, cyclotron has locally used by three private hospitals in Jakarta for a PET scan. Even with the trace of the Indonesian economic problem, there is no sign that they have made the false judgment to perform their cyclotron facility in Jakarta.

This fact looks contradiction with the data we gave in the previous section. By comparing the PET(and CT) scan bill and a minimum wage of Jakarta's citizen, it is technically seemed impossible to build such facility in Jakarta based on those data. However, it is stated by [22] in 2011, Jakarta has highest PAD⁵ (Regional Authentic Income) ratio and tax ratio in Indonesia. However, by putting those data, each person in Jakarta pays almost 400 US Dollar, which means it is far compared by average salary in Indonesia (120 US Dollar). It means that there is an indication of very huge of wage-gap in Jakarta, or in other words, there are so many people living in Jakarta which are incredibly rich. Until this point, we may realise the reason of PET facilities are existed in Jakarta. Also, we may argue that in private sector's point of view, these cyclotron facilities are economically promising.

It is clear from the above explanation that by finding its beneficent of cyclotron in PET facility, it may become a background of BATAN to once again build a new cyclotron

⁴ The full explanation can be read in [20] page 22

⁵ abbreviation of Pendapatan Asli Daerah

in 2014 [23], which expected to construct cyclotron prototypes capable of producing radioisotopes for PET in 2019. Once this cyclotron works, it will produce a radioisotope for PET. We hope after finishing this cyclotron, the radioisotope can be served for a PET scan. Since this cyclotron is constructed in Yogyakarta, after finished, it will serve PET scan facility in that area.

It will take time to make true data about the benefits of the cyclotron. However, it's worth to try since it will be served as the problem-solver of cancer treatment in Yogyakarta. It has been stated in [20], once cyclotron can be centralized in such area, it can lower the cost of the PET scan. Basically, the main purpose of this cyclotron project is making this new technology affordable for any citizen and increase the cancer-cure rates in Indonesia.

CONCLUSION

Constructing a cyclotron for PET scan is actually needs enormous efforts since there are so many constraints. The first main problem which need to be solved is about the budget and its cost benefits. Build the PET/CT facility costs more than 2.48 Million US Dollars [20]. For some developing countries, it would be an impossible for them to make a policy including the construction of the PET/CT facility. Also, one may need to consider the siting-cost, annual cost, staff cost etc. With BATAN in Serpong which already has the cyclotron facility and BATAN in Yogyakarta is still progressing in cyclotron construction, there is a sign that even with the tight budget, we can still manage our effort to build such facilities.

Another problem to build a PET/CT facility is that a country need to reconsider the cost-benefit ratio and its effectiveness toward the needs of citizens in order to persuade the government to construct a PET/CT facility. Once the problem settled, there will be a chance to construct such facility. In another case, there will be an open collaboration through this construction for mass production. It can be either local collaboration and international collaboration. The purpose is clear, mass producing the cyclotron for PET scan facility to increase the cancer-cure rate In Indonesia.

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