THE NEW CYCLOTRON OF THE ROSSENDORF PET CENTER

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The Rossendorf PET Center is equiped with the IBA cyclotron CYCLONE 18/9. The cyclotron and the chemistry modules are undergoing functional tests. Official acceptance tests are planed for November 1995. This poster gives a status report and an overview of the Rossendorf PET cyclotron facility with it's main components.

1. The Rossendorf PET Center

In the Rossendorf PET Center cooperate the Research Center Rossendorf Inc. and the Technical University of Dresden. It`s scietific programme is dedicated to fundamental radiochemical, radiopharmaceutical, biomedical research and clinical application.
Our PET Center is equiped with the PET cyclotron CYCLONE 18/9 inclusive an external beam transport line, radiochemical laboratories for research purposes and radiopharmaceutical production according to GMP rules (Good Manufacturing Practice) and the Siemens PET camera ECAT EXACT HR (+).
On grounds of local conditions the existing U-120 cyclotron building is used for the CYCLONE 18/9. The 500 m distance to the radiopharmaceutical laboratories is bridged by our own developed radionuclide transport system.

2. The Rossendorf CYCLONE 18/9

2.1 Technical Aspects

Figure 1 shows the CYCLONE 18/9 in the new vault of the cyclotron building. The installation work has already been done and now the accelerator is undergoing functional tests.

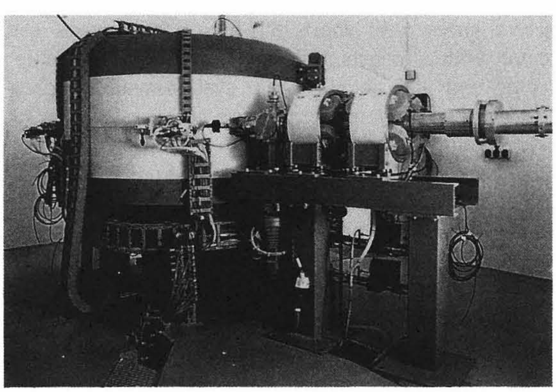

Figure 1: CYCLONE 18/9 in the new vault

The CYCLONE 18/9 can accelerate protons/deuterons (negative ions) to energies of 18/9 MeV. Beam currents on strippers are 80/35 µA, respectively. Dee voltage is 32 kV, max. RF power 10 kW. In Rossendorf we use 6 of the 8 target ports. Dual beam is possible at ports 3/7 and 4/8 (comp. figure 2).
The CYCLONE 18/9 will be used for the production of the following PET radionuclides (s. table 1).

Table 1: Production of PET Radionucldes

Nuclide	Half-life min	Chem. form after irradiation	Reaktion	Target	Target at port	Expect. max. yield GBq (mCi)
^{18}F	110	$[^{18}F]F^-$	$^{18}O(p,n)^{18}F$	$[^{18}O]H_2O$	8	74 (2000)
		$[^{18}F]F_2$	$^{20}Ne(d,\alpha)^{18}F$	Ne+0.2% F_2	3	11 (300)
^{15}O	2	$[^{15}O]O_2$ $[^{15}O]CO_2$	$^{14}N(d,n)^{15}O$	N_2-O_2-mix N_2-CO_2-mix	7	9.25 (250)
^{13}N	10	$[^{13}N]NH_3$	$^{16}O(p,\alpha)^{13}N$	$^{nat}H_2O$	1	14.8 (400)
^{11}C	20	$[^{11}C]CO_2$	$^{14}N(p,\alpha)^{11}C$	N_2-gas	4	74 (2000)

The layout of the Rossendorf PET cyclotron facility is given in figure 2.

2.2 Radiation Protection, Safety, Security

Calculation of the **wall thickness** of the vault were made by Siemens AG (= supplier of the Rossendorf CYCLONE 18/9) by use of the computer programs MORSE and LEAKAGE [1] assuming a predicted concrete density of 2.35 g/cm^3 and gave these results:
- Outer walls (cellar level) 1.40 m
- Wall to control room 2.35 m
- Ceiling 1.90 m.

Our own estimation (based on [2]) were within the same range. An average concrete density of 2.55 g/cm^3 was determined during the building phase [3].

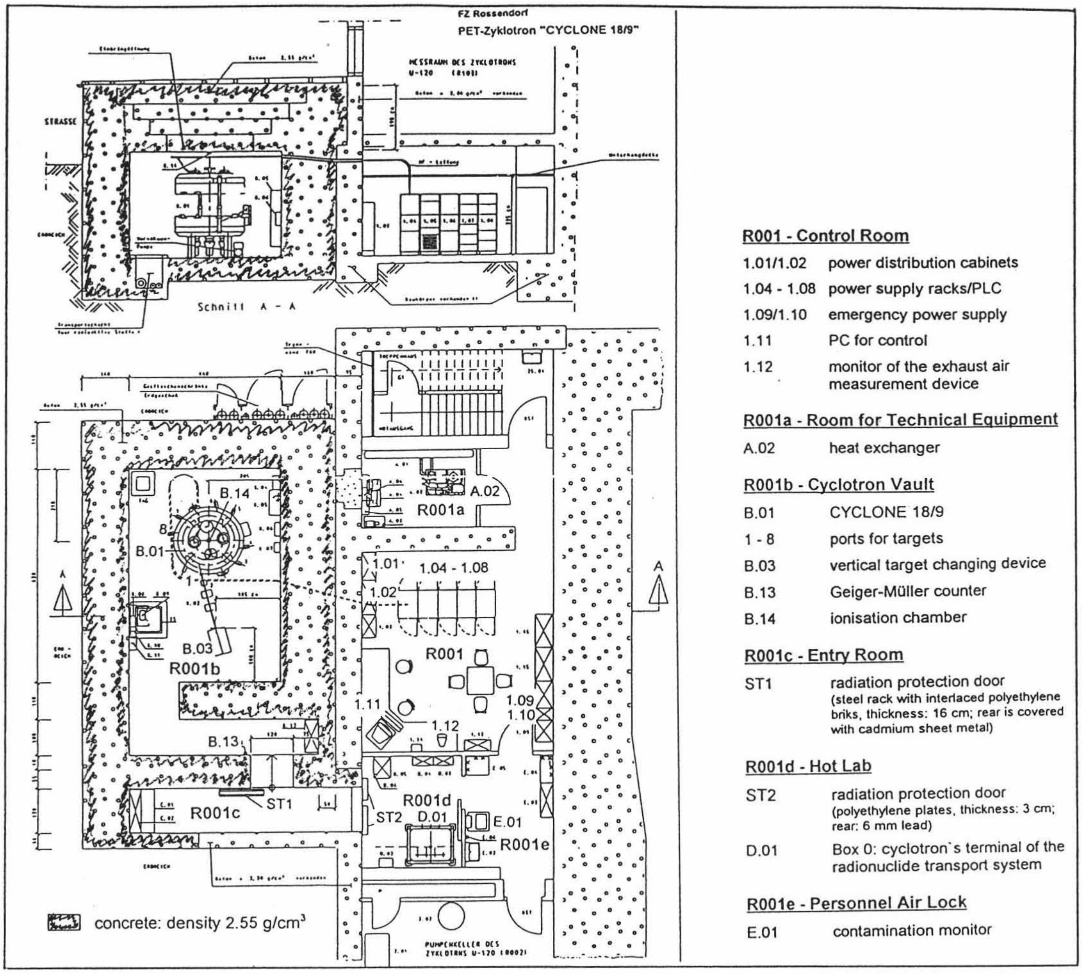

Figure 2: Layout of the Rossendorf PET cyclotron facility

The **radiation protection areas** are
without beam:
controlled area - R001b, R001c, R001d
prohibited area - no
with beam:
controlled area - R001d
prohibited area - R001b, R001c.

For personnel security we installed an **external interlock system** that works with four independent components:

- Emergency stop buttoms in each room
- Sensors of the fire warning facility in each room
- ST1/ST2 door security circuit (comp. fig. 2)
- Pressure condition in the vault: -50 Pa ± 20 Pa (ST 1 door will be sealed airtight by an inflatable rubber tube which has to be filled with compressed air).

The interlock system switchs off beam/prevents beam if one of these conditions is not in OK status.

An **exhaust air emission measuring** facility was installed for both the new PET cyclotron and the U-120 cyclotron [4] to fulfil the demands of our authority.

The so-called pick-up system for the exhaust air that is to be measured is placed in a new chimney on the roof of the cyclotron building. The ventilation facilities of both cyclotrons work independent of each other.The exhaust air tubing systems unite under the roof so that we only use one emission measuring facility for both cyclotrons. It contains of four main parts: a gas monitor for continuous monitoring of radioactive gases with short half-life, a continuous aerosol collector with a constant flow of air, a transportable gas collector unit and an electronic system with switches for thresholds and a lot of possibilities for presentation of the measured values.

The **cyclotron's control system** is based on PLC SIMATIC. It is possible to control the CYCLONE 18/9 with both the terminal 1 (cyclotron building) and the terminal 2 (radiochemical building). We work with the master-slave principle: the same information is to be shown on both screens, but control is only possible with the master terminal. There is a special procedure to overtake the control to the other terminal.

2.3 Results of Beam Tests

Until October, 5, the exits 1, 3, 4 and 7 have been tested yet. The results are given in table 2.

Table 2: Results of Beam Tests

Exit no. / Particle	1 / p	3 / d	4 / p	7 / d
Diameter of collimator / mm	10	16	16	16
Beam current / µA at Stripper	80	40	80	43
Target	55	27	50	23
Collimator	25	13	30	20

The measured instabilities of all the beam currents on targets during 30 minutes of irradiation time were less than ± 5 % and fulfiled the Rossendorf requirements of beam stability on target for production of radionuclides.

3. External Beam Transport Line

3.1 History and Future

The external beam transport line is a special development for Rossendorf. Target development for PET in Rossendorf began in 1983. A vertical target changing device for 8 targets was built in 1990 and is used now at the U-120 cyclotron for $[^{11}C]CO_2$, $[^{18}F]F_2$, $[^{18}F]F^-$ and $[^{15}O]O_2$ production and for solid targets. It is planed to couple the external beam transport line and the vertical target changing device (then equiped with PLC control too) in Spring 1996.
The external beam transport line is necessary for improvement of the reliability and availability of the targetry, future target development, production of other radionuclides and for training of technicians and radiochemists.

3.2 Layout

Calculations of the beam spot at the end of the beam line gave the result that it must be possible to reach a beam diameter less than 20 mm.
The layout of the beam line is shown in figure 3.
The Rossendorf targets (s. figure 4) will be connected to the helium and water cooling circuit of the CYCLONE 18/9 and into it's internal interlock system.

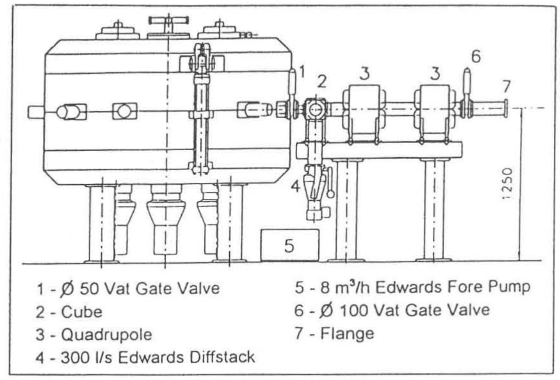

Figure 3: Equipment of the external beam transport

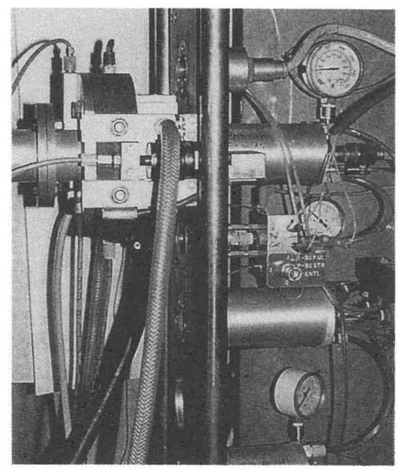

Figure 4: Detail of the vertical target changing device with 3 targets

3.3 Results of Beam Tests

Using a collimator of 12 mm inner diameter we measured the following beam currents (s. table 3). If required, it is possible to reach more beam current on target.

Table 3: Results of Beam Tests

Beam at	Protons / µA	Deuterons / µA
Stripper	37	29
Target	25	15
Collimator	12	14

During the tests we reached a diameter of the beam spot on a quartz both for protons and deuterons of aproximatly 15 mm. The measured instability of both the beam currents on the target during 30 minutes of irradiation time was less than ± 5 % and fulfiled the Rossendorf requirements.

4. Radionuclide Transport System

4.1 Layout

The 500 m long Radionuclide Transport System (RATS) connects the cyclotron and the radiochemistry building (s. figure 5) and consists of two parts:

- Pneumatic post system for transportation of radioactive liquids
- Capillaries for transportation of radioactive gases

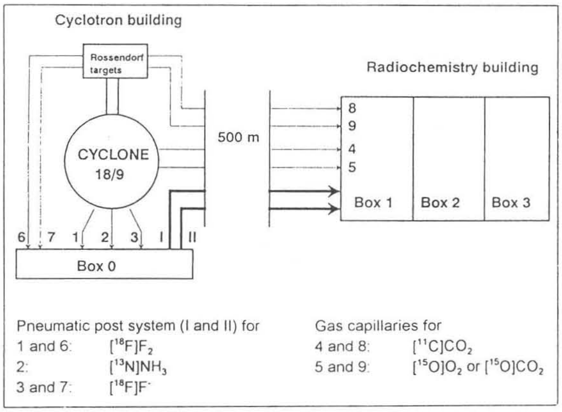

Figure 5: Layout of the RATS

Box 0 (= hot cell) contains the loading machine for the pneumatic post boxes and the distribution cabinet for further handling and transfer of [^{18}F]F$^-$, [^{18}F]F$_2$ and [^{13}N]NH$_3$ (s. figure 6). Box 1 (=hot cell) contains the unloading machine for the pneumatic post boxes and the distribution cabinet for transfer of the radionuclides into the boxes 2 and 3 (= hot cells) where the Rossendorf and IBA chemistry modules are placed.

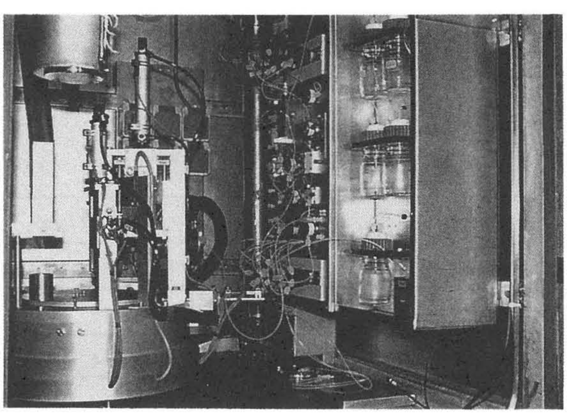

Figure 6: Box 0: left: loading machine, right: distribution cabinet

The pneumatic post system consists of 2 polyethylene tubes (inner diameter 33 mm, wall thickness 8.4 mm). The minimum bending radius is 1.5 m, the lenght of the pneumatic post box 110 mm and the pressure of the compressed air 4 bar.

4.2 Control of the RATS

The RATS is controlled by 2 terminals too using the same master-slave principle as for cyclotron's control. Figure 7 gives an example for the visualisation of the loading process of the pneumatic post box (POS 1: insert the box, POS 2: open the box, POS 3: fill the liquid into the vial within the box, POS 4, 5: send the box to the radiochemistry building).

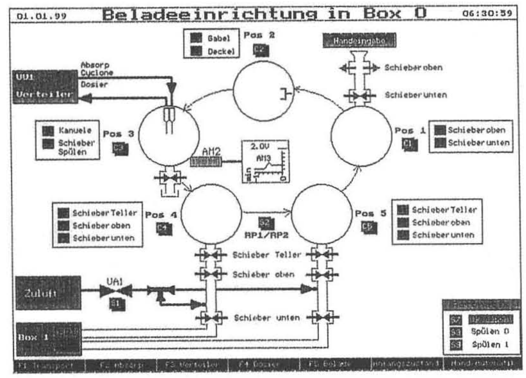

Figure 7: Example of the loading process

For a safe target unloading operation all signals between the 2 control systems are included in the interlock system.

4.3 Results

Loading time of the pneumatic post box is approximately 2 min, the transfer time to the radichemistry building 1:30 min. The tranfer time of [^{11}C]CO$_2$ and [^{15}O]O$_2$ is 3 min.

References

[1] Information of Siemens AG, 1992
[2] Sauermann, P.F., Jül-751-PC, April 1971
[3] Prüfbericht Nr. 93-12-1775-01, 23.09.93 Materialprüfanstalt/Bauwesen, Dresden
[4] Laboratorium EG & G Berthold, Bad Wildbad, Deutschland