ミニワークショップ「超伝導ウィグラーによる高エネルギー放射光の発生とその応用」2003年3月24-25日、SPring8

KEK陽電子施設の紹介とSPring-8への期待

高エネルギー加速器研究機構
物質構造科学研究所
低速陽電子実験施設
栗原俊一

・はじめに
・KEKサイトの紹介
・フェーズI, II, III
・陽電子線源部
・ビームライン
　高電圧化→エネルギー可変、試料GND
・実験ステーション
・放射光との共通点、相違点
　e+を消費する実験　KEKB、JLC、イオンビーム…
　　→　専用加速器　専用装置
・SPring-8への期待

光子→電子陽電子対生成

micropole undulator
Csonka(Univ. Oregon) , Kuripanov(INP) ICPA10(1994)

○リング、あるいはシンクロトロンでの陽電子生成の利点
・発生部をいくつも置ける。（Linac ではビームダンプ直前に１ヵ所だけ）したがって同時に複数の陽電子実験が可能。
・試料を接地電位に置いて、発生部を最適な電位にそれぞれ保てる。
・中性子を気にせずに構築が可能。
・以上から運用上、発生部とそれに続く陽電子輸送路を放射光における基幹チャンネルに対応させて扱うことが可能。

○コメント
・光子発生点からモデレーターまでを磁場の影響のない程度離す。陽電子のモデレーターはできるだけ外部磁場の無い場所に。
・モデレーターに適切な引き出し電圧を印加する。これはモデレーターと下流側の輸送ラインとで決まる。
・低速陽電子が発生したかどうかを調べるためにはモデレーターでの消滅γ線と区別できる程度陽電子を輸送して消滅γ線を測定するのが望ましい。
・磁場輸送ラインは簡単なダクトとソレノイド（テストには50ガウス程度で良い。単層巻のコイルで十分）の組み合わせで可能。

SUGGESTED INTENSE POSITRON SOURCE BASED ON (MICROPOLE) UNDULATOR INDUCED PAIR PRODUCTION

by

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ABSTRACT

The construction of an Intense Positron Source (IPS) is suggested. The intensity of the produced positrons is to exceed that of any other existing source by orders of magnitude. The instantaneous intensity is to be 10^3 to 10^6 times higher yet. Fast positrons are to be produced in pulses of time duration ≈ 1 ns to 10 ps. Slow positron pulses of order ≤ 100 ps are expected. The phase space density of positrons at production will be in excess of what can be achieved by other methods.

The IPS is to consist of 1.) an undulator (usually a micropole undulator, i.e. an undulator with submillimeter period) in which gamma rays in the MeV range will be generated by electron beams circulating in a storage ring; 2.) a heavy metal target, in which e^+e^- pairs will be produced by the generated gamma rays; 3.) moderators to thermalize the produced positrons; and 4.) a transport system through which the slow positrons will move.

Spinoff benefits provided by the suggested device include the following: The equipment may be used to create (or destroy) nuclear isotopes in a controlled manner (i.e. without producing unwanted species); to produce (or destroy) in a controlled way chemical elements; to produce well collimated intense photon beams in the multi 100 MeV range for nuclear physics research, with intensities many orders of magnitude higher than can be achieved today; to generate intense bursts of neutrons; to supply fast positrons produced at high intensities (10^{16} to 10^{17} s^{-1}) and within a small transverse phase space, to future High Energy Colliders, thereby perhaps even eliminating the need for damping rings.

inches) coils can be used. The compensating dipole coils, attached to separate, low current power supplies, stir the positrons along and near the center line of the transport system.

For most applications the emerging slow positrons will be accelerated from thermal energies to several keV. This can be accomplished by placing the target assembly on an insulated stand at high potential. The positrons are thus accelerated while travelling from the moderator to the far end of the transport system, which is grounded.

4. Possible host machines

There are several storage ring candidates on which the proposed Intense Positron Source (IPS) may be installed to demonstrate its capabilities. These rings include the following (See Table 2):

PEP at the Stanford Linear Accelerator Center,
APS at the Argonne National Laboratory,
TRISTAN at KEK, Tsukuba,
ESRF, in Grenoble,
PETRA II, in Hamburg,
SPRING-8, at Nishi Harima in Japan,
LEP, at CERN,
B-Factory High Energy Ring, proposed at the Stanford Linear Accelerator Center,
B-Factory High Energy Ring, proposed at Cornell University.

One of the best candidates, PEP, is not operating at this time, for budgetary reasons. APS is under construction; ESRF is being commissioned at the time of this writing; TRISTAN is operating, and a better magnet lattice for it is expected in the near future for dedicated running; the use of PETRA II as a partially dedicated synchrotron radiation source has been approved, and its detailed planning is ongoing; SPRING-8 is under development; LEP is now used only for high energy physics experiments, but there is interest to harness its capabilities for other purposes; in addition, two B-Factories have been proposed. And, already, the next generation (the "fourth") of lightsources is being discussed.

It is clear, therefore, that an increasing number of potential host machines will become available in the near future, and they will offer a wide variety of electron beam characteristics.

In Table 2 the relevant design parameters for certain potential host machines are given.

Table 3 lists several parameters of interest in connection with positron production:

1. The (micropole) undulator wavelength, $\lambda_\mu(3)$, required to generate γ-rays with maximum energy $\varepsilon_{\gamma M}$ = 3 MeV.

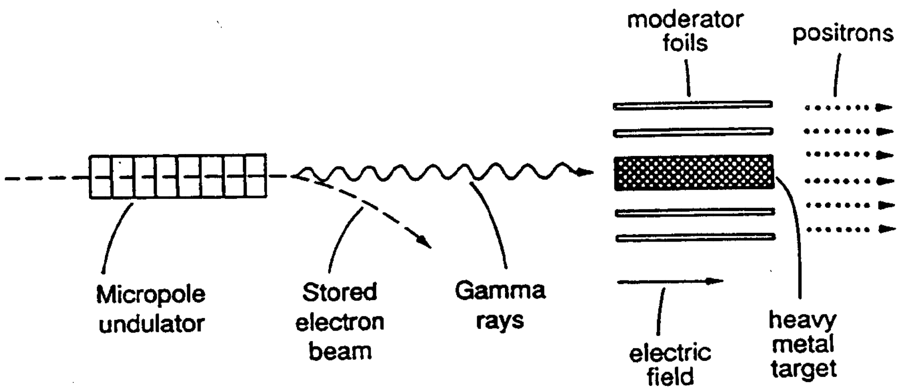


Figure 1.

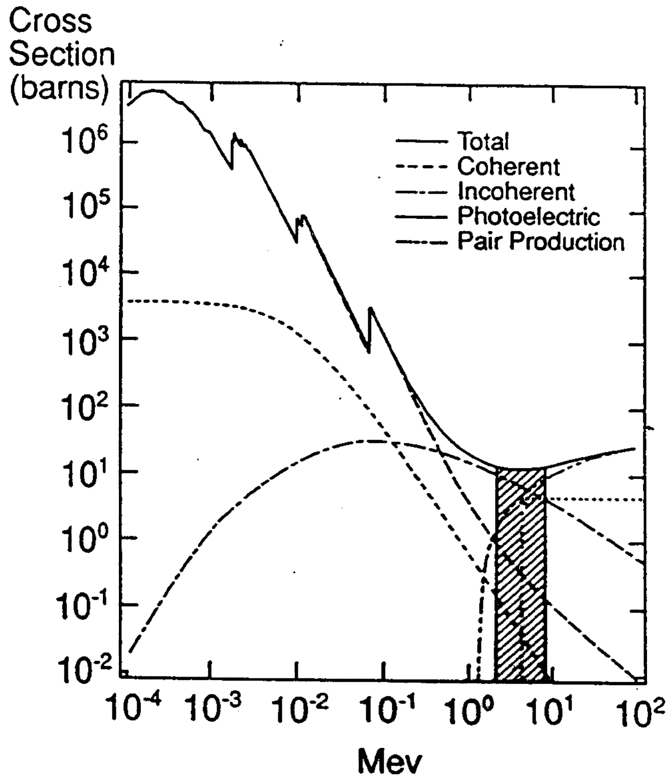


Figure 3.

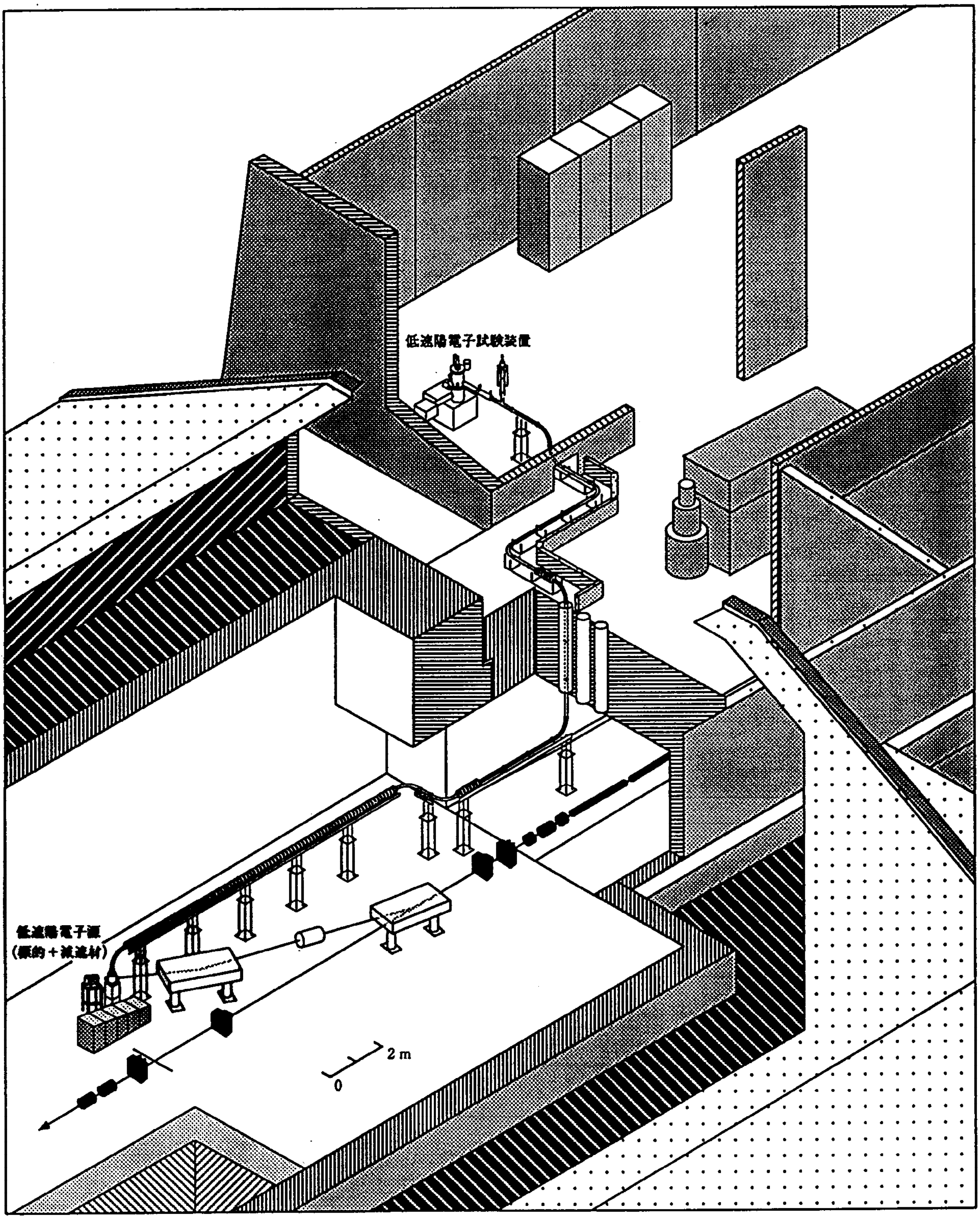
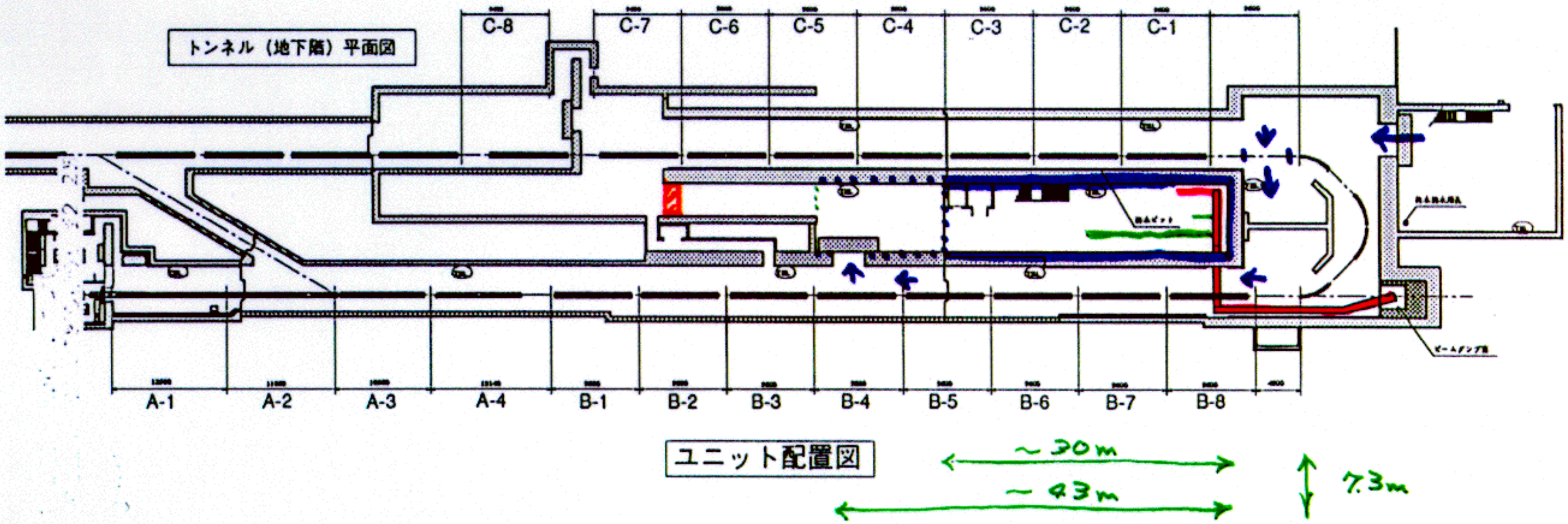
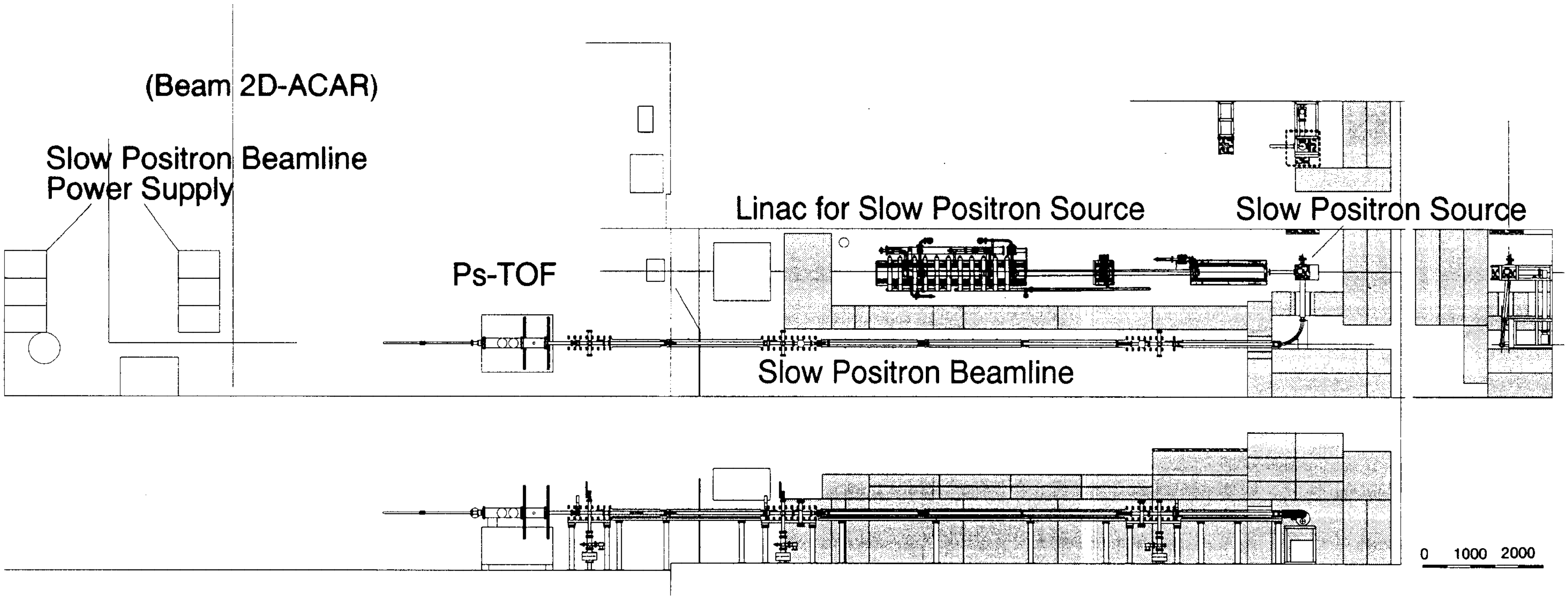


図　　　低速陽電子ビームライン

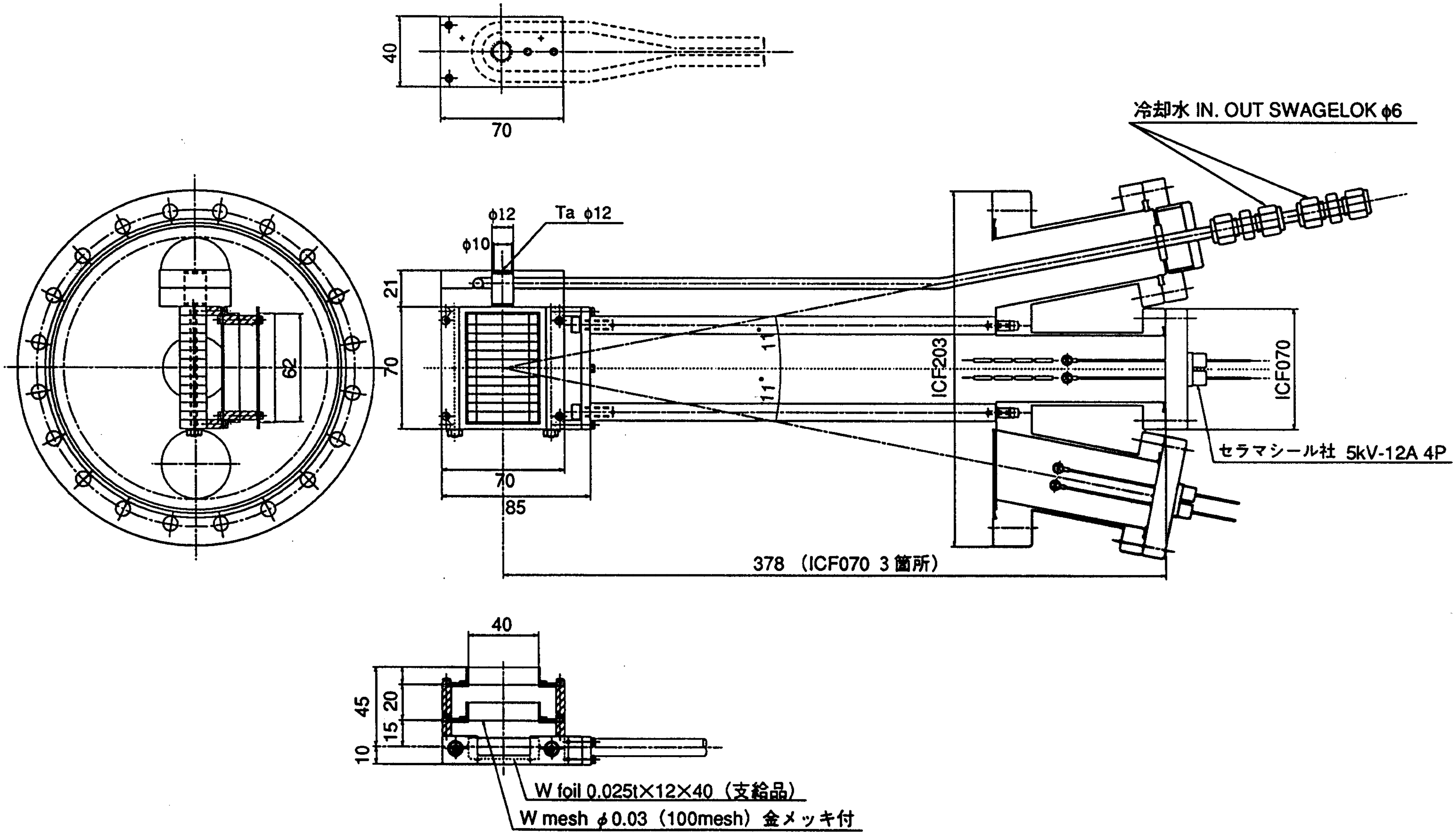

トンネル（地下階）平面図
C-8
C-7
C-6
C-5
C-4
C-3
C-2
C-1
A-1
A-2
A-3
A-4
B-1
B-2
B-3
B-4
B-5
B-6
B-7
B-8
ユニット配置図
~30m
~43m
7.3m

Slow Positron Facility

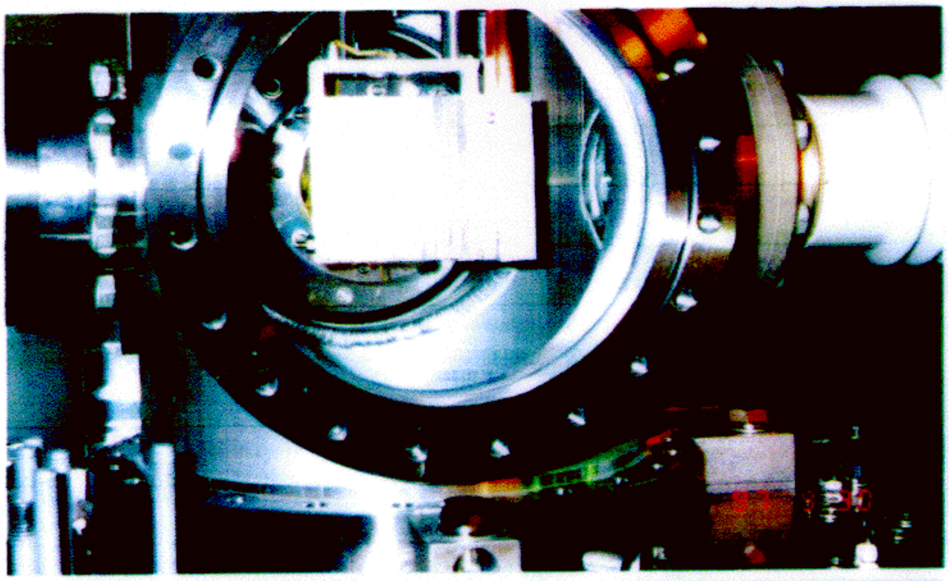


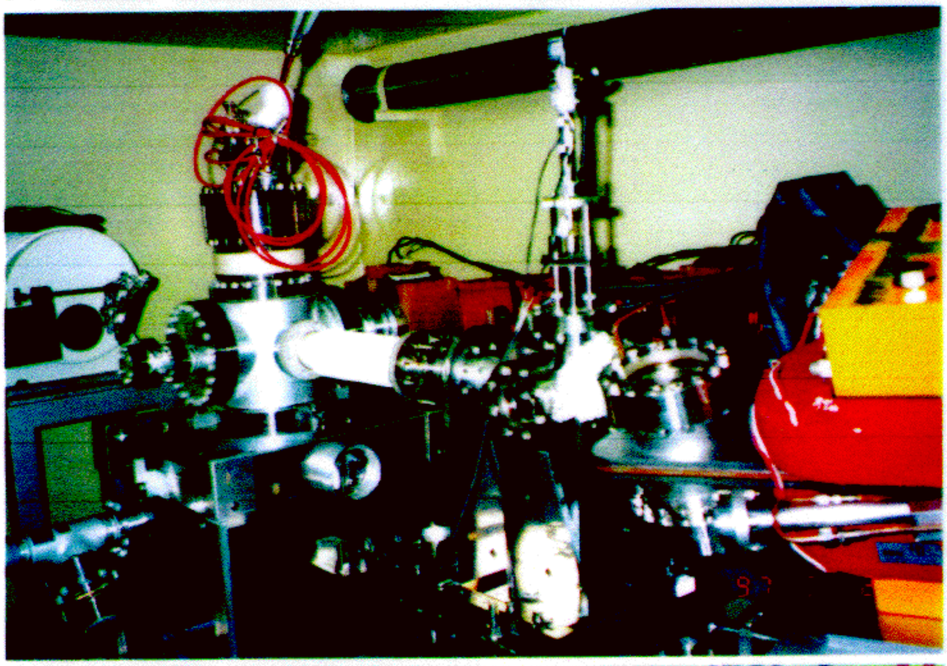
primary electron beam: 50MeV 1kW secondary positron beam: 0.01~(60)keV 10^8e+/s

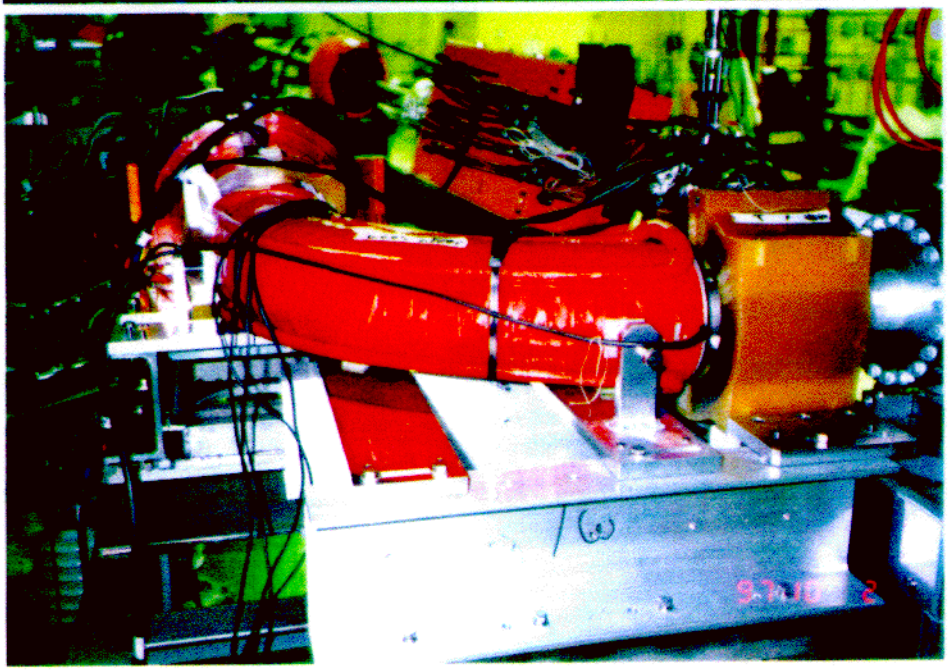
水冷式ターゲット

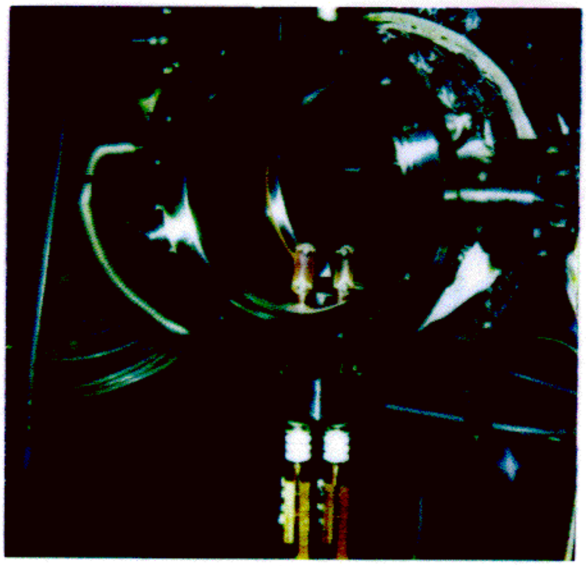
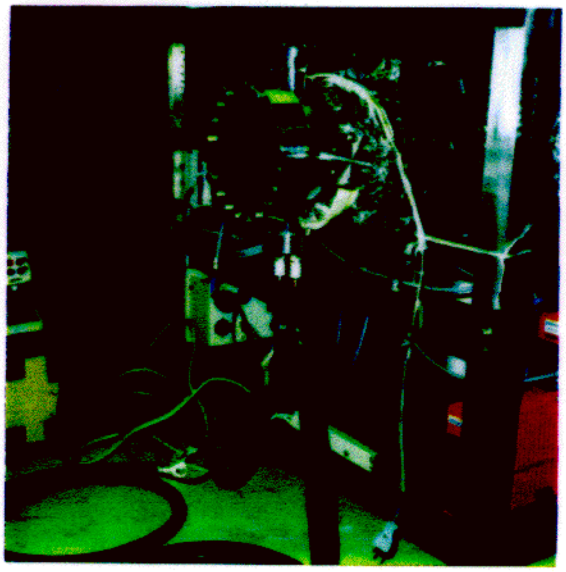


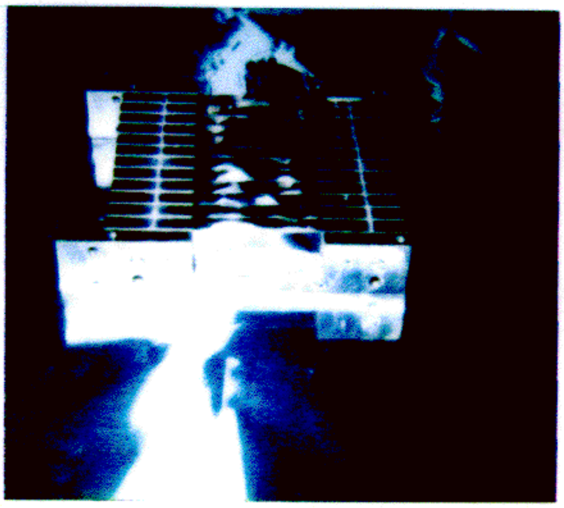
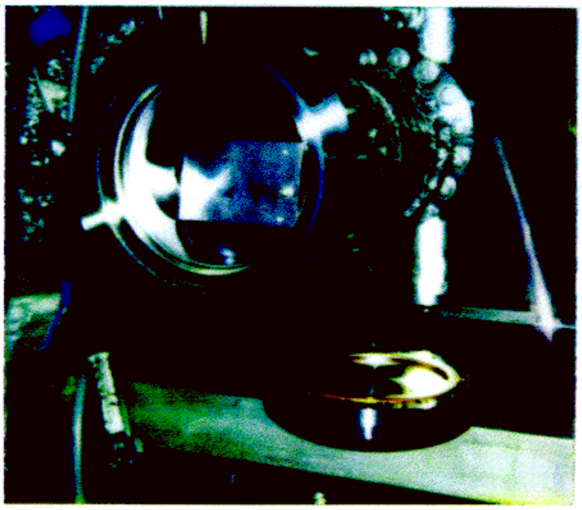
40
70
冷却水 IN. OUT SWAGELOK φ6
φ12
Ta φ12
φ10
21
70
62
11°
11°
ICF203
ICF070
セラマシール社 5kV-12A 4P
70
85
378 (ICF070 3箇所)
40
45
20
15
10
W foil 0.025t×12×40 (支給品)
W mesh φ0.03 (100mesh) 金メッキ付



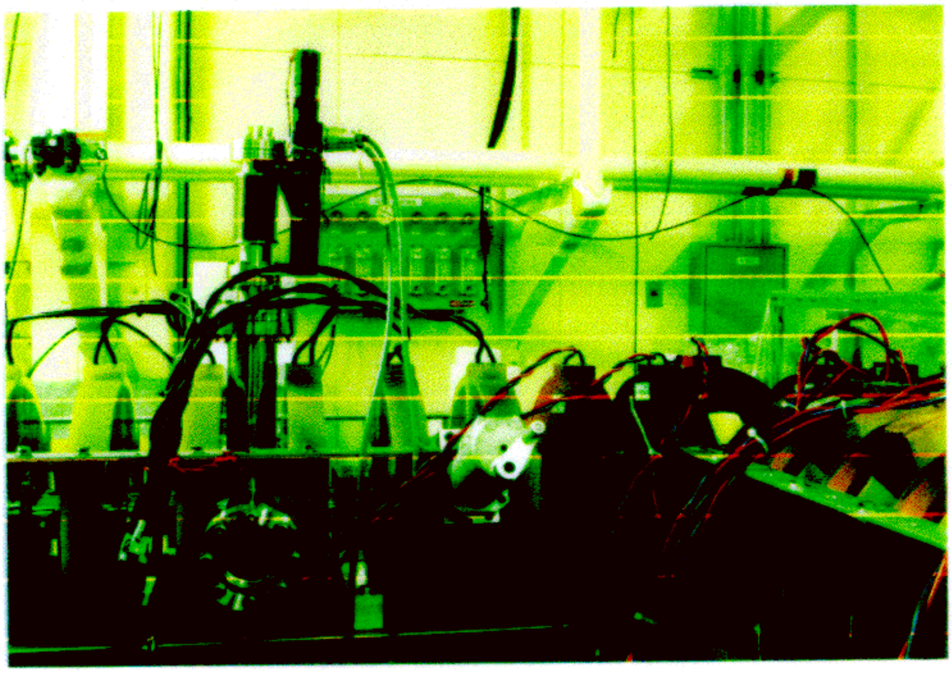


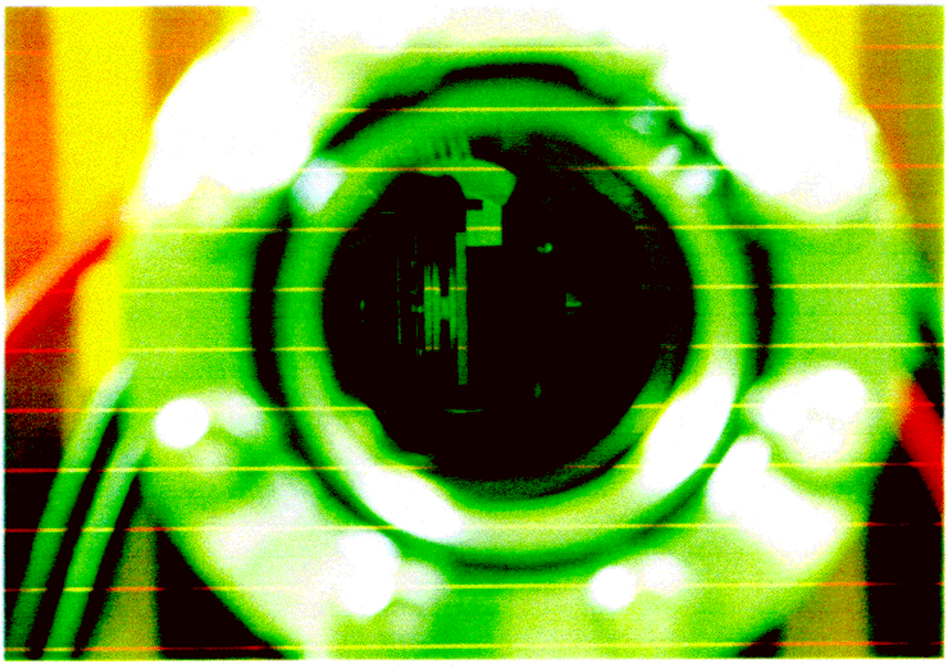


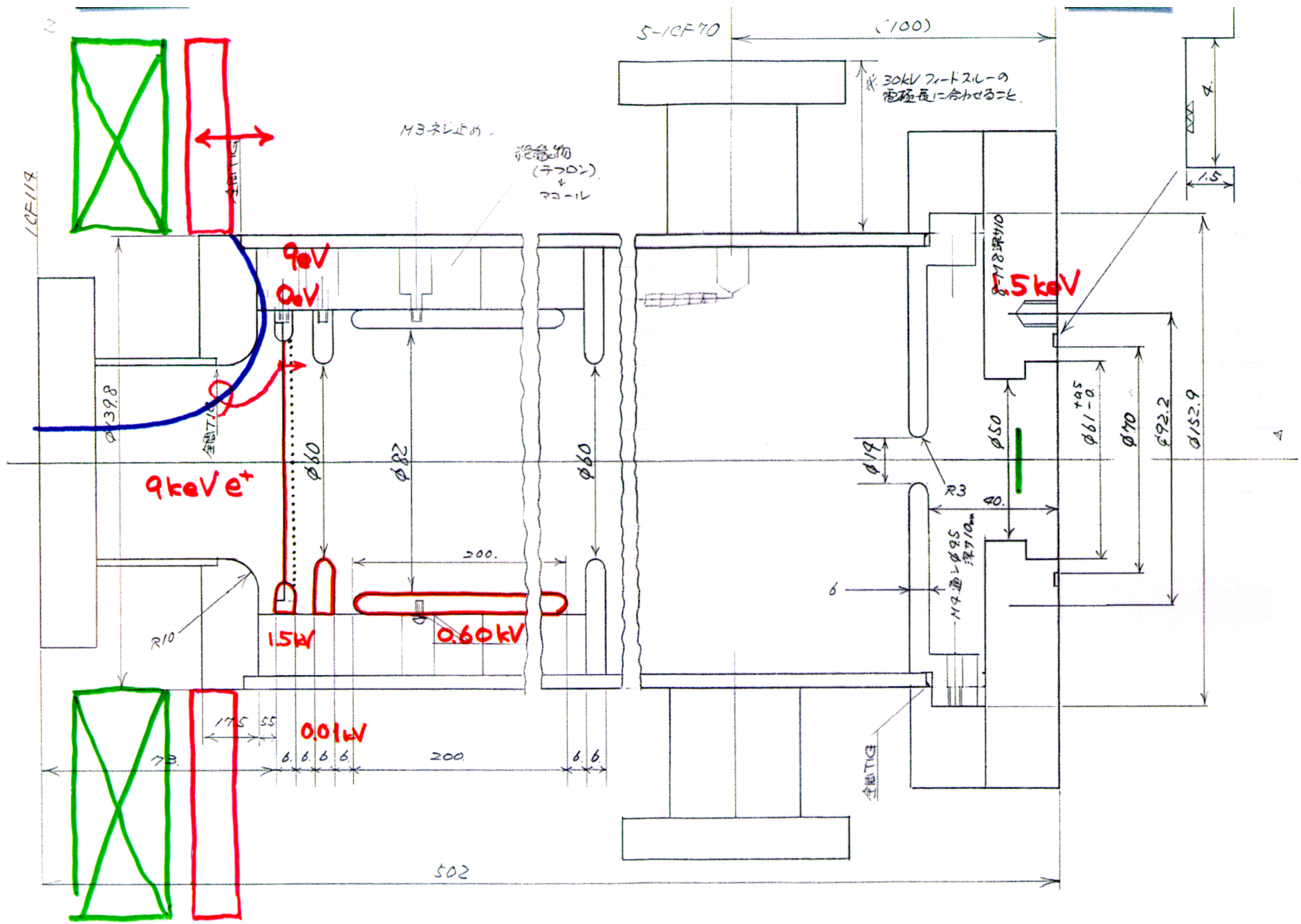



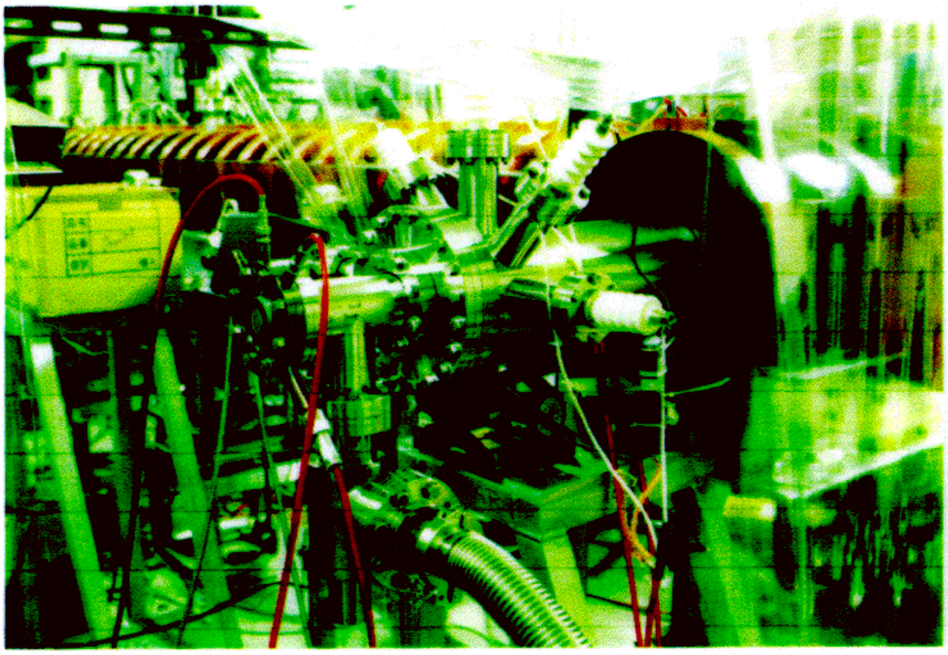

An excellent improvement in the positron yield was achieved by annealing of the moderator assembly (tungsten foils) at 2270 K for 10 minutes under ultra-high-vacuum conditions. A slow-positron flux of 1×10^8 e^+/s was successfully achieved with a 2.0-GeV, 2-kW primary electron beam power. The achieved conversion efficiency has almost reached our designed goal; we can therefore expect a slow-positron intensity on the order of 10^9 e^+/s with a maximum beam power of 30 kW in the near future.



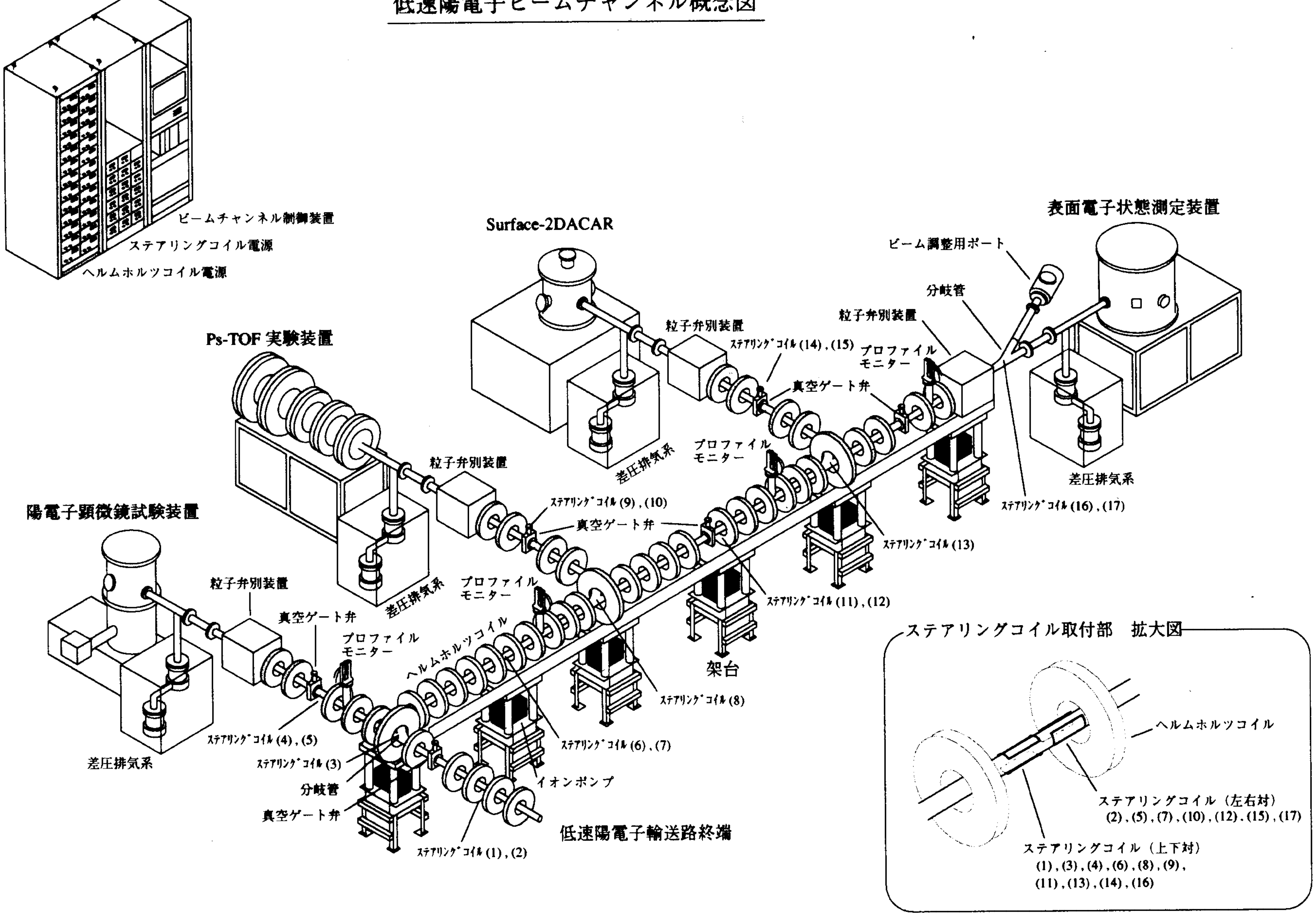




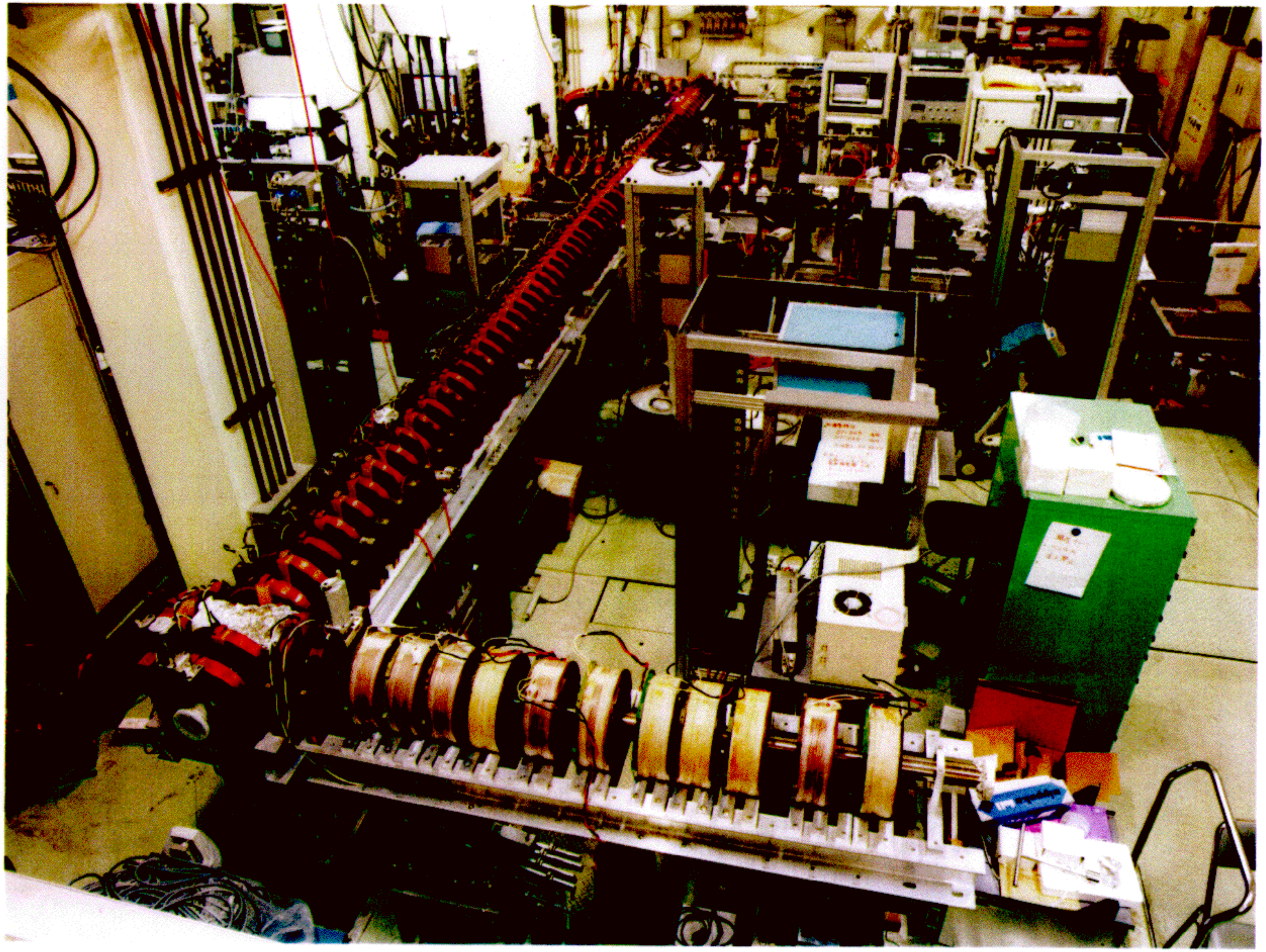
5-ICF70
(100)
※30kV フィードスルーの
電極長に合わせること
M3ネジ止め
絶縁物
(テフロン)
↓
マコール
ICF114
9eV
0eV
1.5keV
9keV e+
1.5kV
0.60kV
0.01kV
φ139.8
φ60
φ82
φ60
φ19
φ50
φ61
φ70
φ92.2
φ152.9
R3
R10
40.
200.
200.
6
17.5
5.5
73.
502
4.
1.5

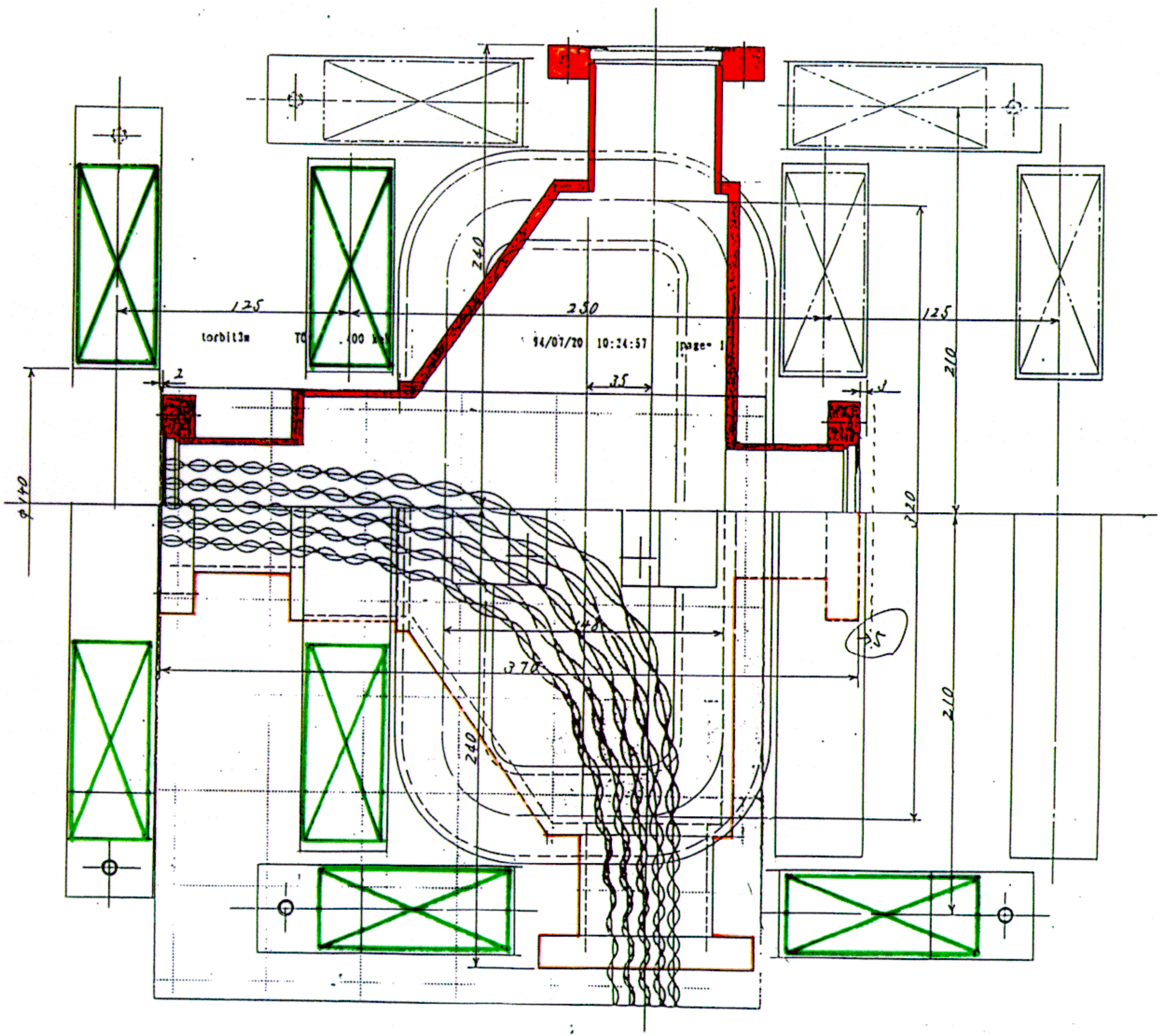


低速陽電子ビームチャンネル概念図



〔注〕　「ヘルムホルツコイル」は間引きして図示した。





125
250
125
torbit3m
94/07/20 10:24:57
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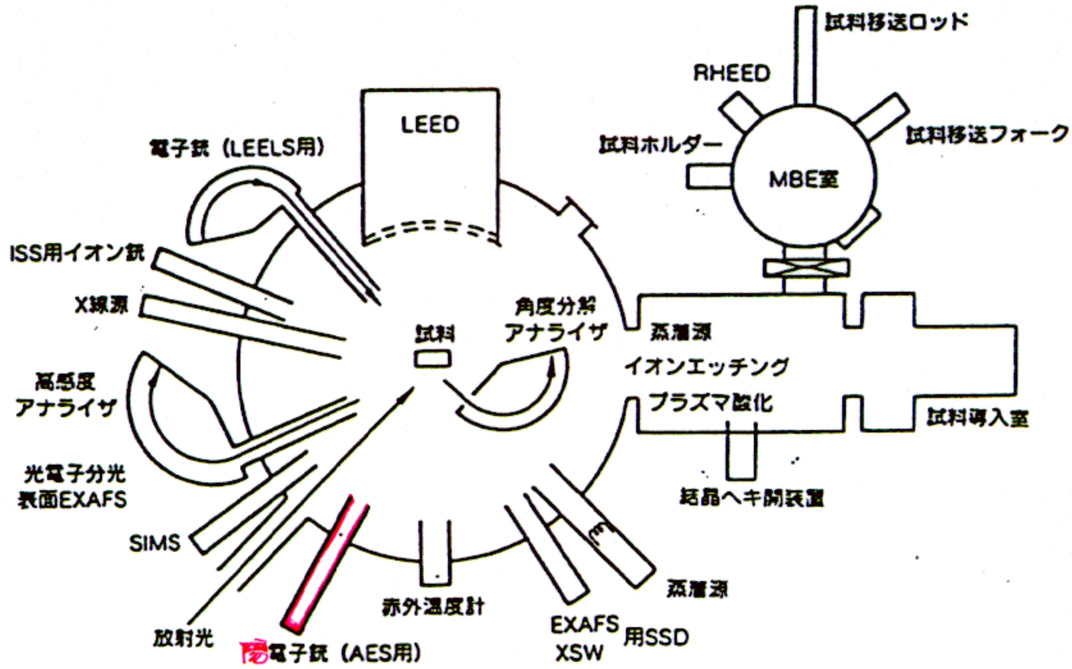
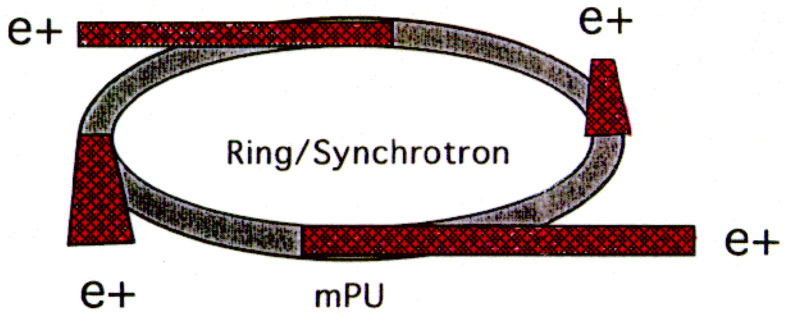
240
210
35
320
140
370
240
210

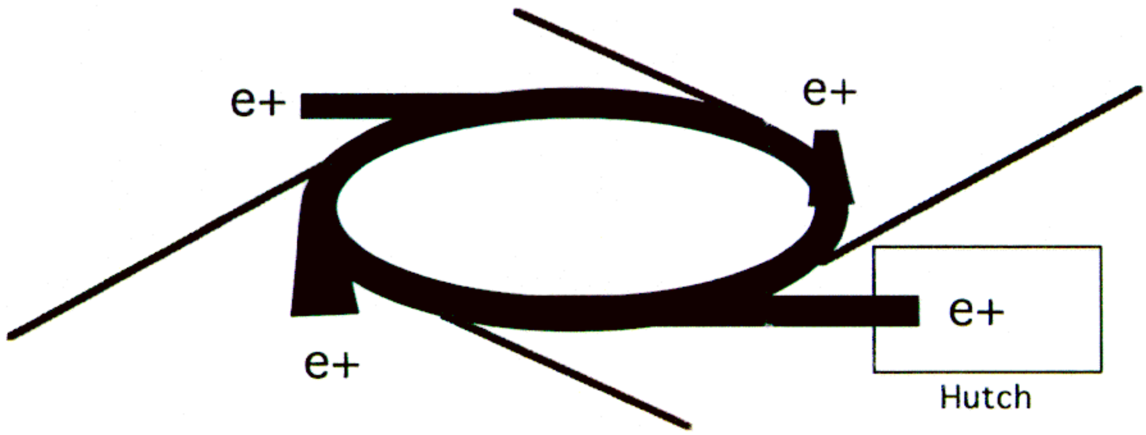


〔図１〕放射光利用 in situ 複合表面分析装置。＋低速陽電子

高エネルギー研月報 第19巻第2号



放射光風多サイト同時実験　基幹チャンネル=陽電子線源



放射光　陽電子　同時実験