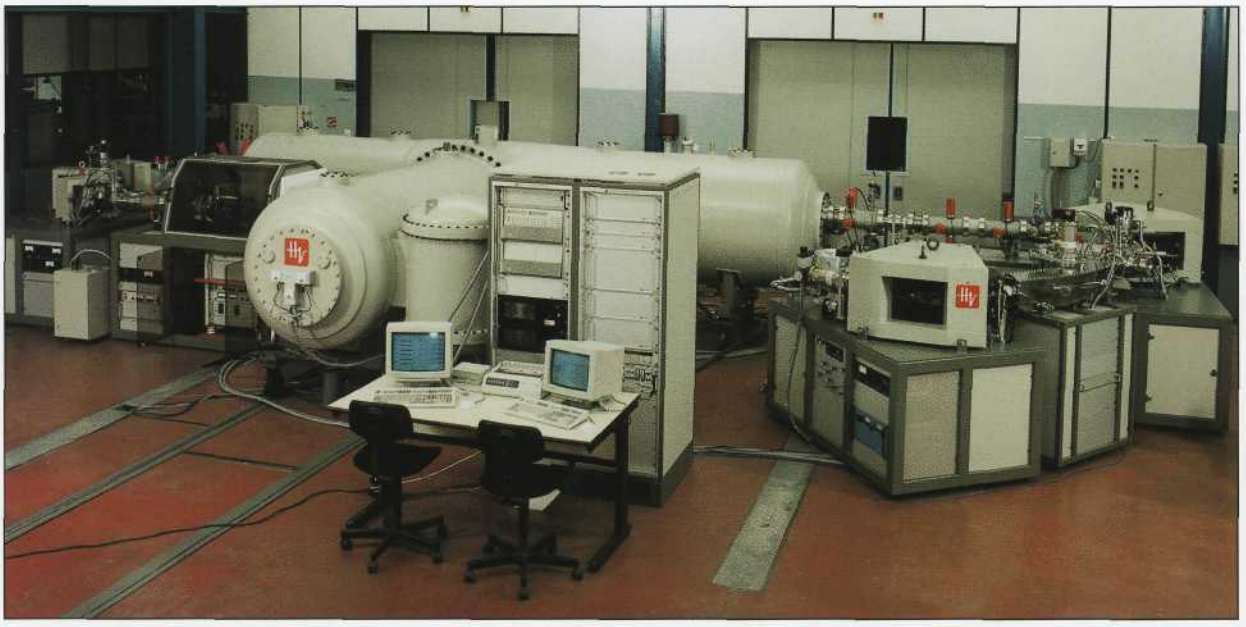
ACCELERATOR MASS SPECTROMETERS

DEDICATED AND MULTI ELEMENT SYSTEMS



^{14}C ^{26}Al ^{41}Ca ^{236}U

^{10}Be

^{3}H ^{36}Cl ^{129}I

HIGH VOLTAGE ENGINEERING

Particle Accelerator Systems for the scientific, educational and industrial research communities

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Introduction

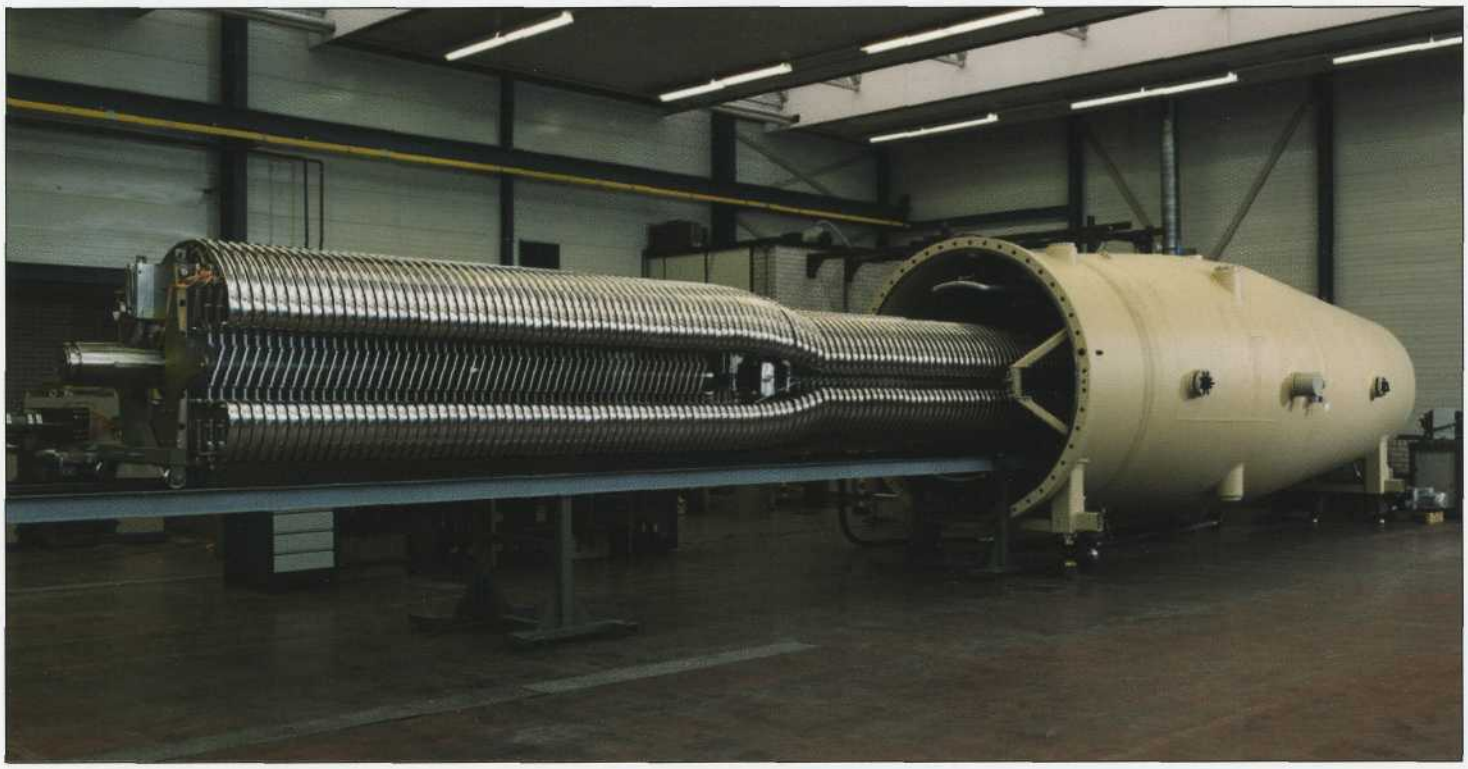
Accelerator Mass Spectrometry (AMS) provides high precision isotopic information from milligram and sub-milligram samples by direct analytical determination of the isotopic ratios.

Where conventional scintillation counting methods provide information about concentration of radio isotopes based on radioactive decay and measurement of ß particles emitted from the sample, AMS directly counts the individual isotopes after separating them according to their mass-to-charge ratio. AMS is preferred over scintillation counting as AMS requires far less sample material and provides higher sample throughput because of higher counting rates.

Precision and reproducibility

The central feature of the HVE mass spectrometer concept is a "state of the art" Tandetron accelerator characterized by high reliability, extremely low noise level, high terminal voltage stability and low terminal voltage ripple.

The HVE Tandetrons are equipped with a purely electronic HV power supply that has the advantage that it has no moving parts. As a result there are no vibrations, which might result in terminal voltage fluctuations. Moreover ripple & stability values and dynamic behavior are stable over many years of operation whereby maintenance of the components in the pressure tank is seldom, if ever, needed.



5.0 MV Tandetron accelerator

AMS makes measurements possible that can not be done by other counting techniques because there is not enough sample material or the number of samples is simply too high.

Initially applied in archeology for ^{14}C-dating AMS is today used to measure isotopic ratios of numerous elements including Be, Al, Cl, Ca, I and U. It is applied in fields like geophysics, oceanography, environmental and paleoclimatic studies, hydrology, biomedicine, biochemical kinetics, material research, non-proliferation safeguarding and monitoring, nuclear and atomic physics, nuclear astrophysics and trace element analysis.

Sensitivity

The extreme sensitivity achievable with AMS can not be reached with conventional analytical isotope ratio mass spectrometers. AMS solves the interference problem originating from molecules and molecular ions with practically the same mass-to-charge ratio as the isotope under investigation. Typical minimal concentration ratios which can still be determined by AMS are in the range of 10^{-15}.

Since precision and reproducibility are key issues in AMS, stability is of paramount importance for an Accelerator Mass Spectrometer.

Terminal voltage transients that can be tolerated in an experimental nuclear physics environment are absolutely unacceptable in AMS as it can destroy data obtained from samples that may be irreplaceable.

Similarly minor fluctuations in terminal voltage can cause changes in transmission of the beam through the accelerator and reduce the reproducibility of the results.

Single or multi element systems

Depending on the application(s) HVE Tandetron Accelerator Mass Spectrometers are available in two versions: as dedicated systems for a single element or as multi element systems for multiple elements. System extensions for other ion beam techniques including ion implantation, RBS-C, PIXE, ERD and NRA are available as well.

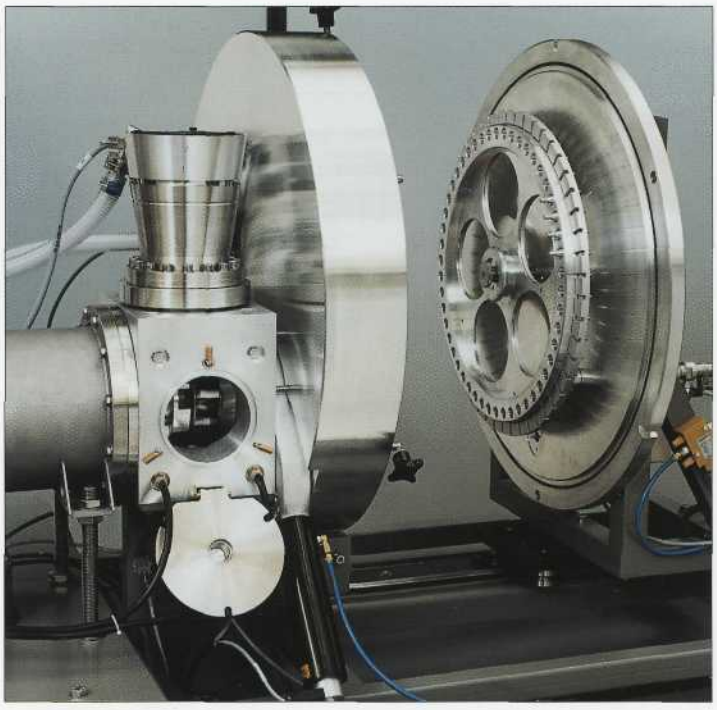
Solid as well as gaseous samples

The HVE Tandetron AMS systems are equipped with a 50 (optional 200) sample hybrid sputter source that accepts solid samples as well as gaseous samples (CO_2), whereby the later can be admitted from ground potential, allowing on-line integration of a GC or CHN analyzer.

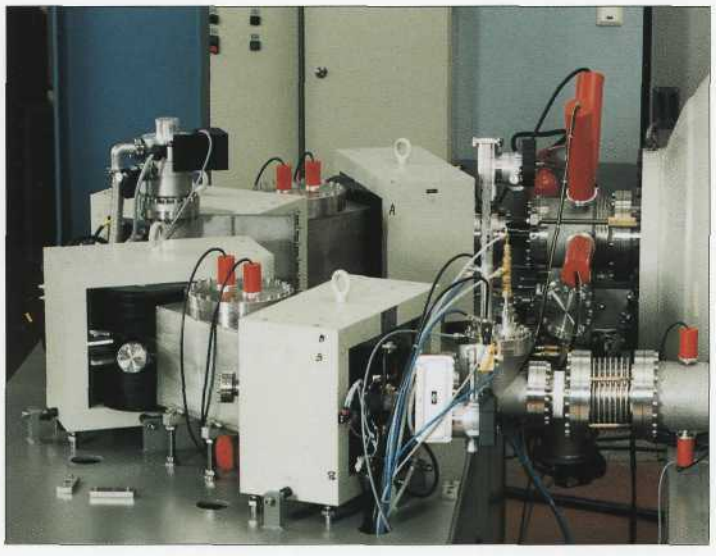
An unique feature of the HVE hybrid AMS source is that the source embodiment rests at earth potential. It eases source access, avoids the necessity for a large high-voltage protection cage and ensures a safe and virtually radiation free operation.

Samples to be analyzed are transferred from the carousel to the interior of the ion source to avoid cross-contamination from sample to sample during the sputter process. A vacuum pump located directly on the source body in close vicinity to the ionizer ensures optimal pumping speed and low memory effects in the case of CO_2 samples.

A pneumatic gate valve between source and carousel allows the ionizer to be kept at temperature for extended lifetime and avoids breaking the vacuum during carousel exchange. Sideways insertion of the source head in an exact and reproducible manner makes source maintenance easy and quick.



The hybrid sputter source with target chamber in open position



Simultaneous injector (recombinator)

Simultaneous and sequential injection

Two different injection concepts are available: simultaneous injection and sequential injection.

With simultaneous injection the different isotopes are separated, analyzed, recombined and simultaneously injected into the accelerator. HVE simultaneous injectors are based on a patented four magnet configuration that, inherent to its design, ensures recombination on identical trajectories and independence of parameter settings.

With sequential injection the different isotopes are analyzed and injected into the accelerator one at a time. HVE sequential injectors are equipped with a beam blanking unit to define with nanosecond precision the duration with which the isotopes are transported through the accelerator. It eliminates the uncertainty resulting from relatively long settling time of the bouncer voltage and allows for a higher bouncing frequency which in turn reduces the adverse influence of source glitches thereby optimizing precision.

While simultaneous injection is an entirely DC-operation, sequential injection cycles through the isotopes whereby intensity differences of several orders of magnitude between the isotopes are usual for elements with long lived radioisotopes used in AMS. This leads to different beam loading for the accelerator causing small terminal voltage fluctuations that may influence precision.

As a result simultaneous injection is the preferred method for very high precision AMS measurements. However, while for heavier elements instrumentation for simultaneous injection becomes impractical large and expensive, sequential injection can easily cover the entire periodic table.

Sequential injector (bouncer)

Multi element HE mass spectrometer

Optimum terminal voltage

The optimum terminal voltage depends on the isotope species to be analyzed and on the required precision, background and detection efficiency and is as such determined by the application(s). HVE Tandetron AMS systems are available with different terminal voltages up to including 6.0 MV.

Magnetic & electrostatic suppression

HVE Tandetrons are equipped with large diameter high conductance accelerator tubes to maintain a low pressure along the accelerator tubes. The accelerator tubes itself are provided with a proprietary arrangement of magnetic and electrostatic suppression for removal of secondary electrons and backgrounds from particles that have charge exchanged within the accelerating fields.

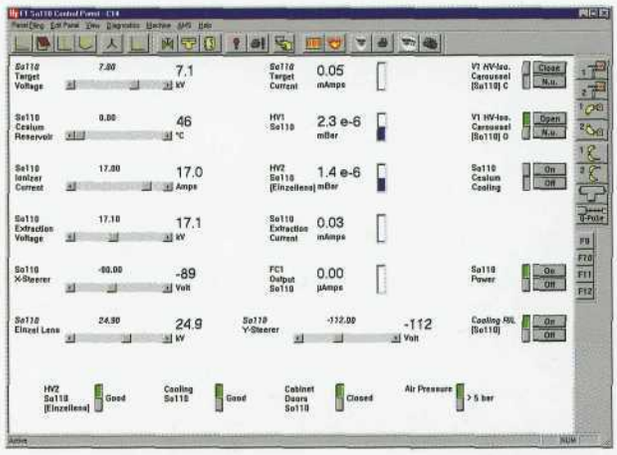
Accelerator tubes

Dedicated ^{14}C HE mass spectrometer

High energy mass analysis

After acceleration the remaining backgrounds are further reduced in *a high energy mass spectrometer that consists of an electrostatic* energy analyzer and, depending on the isotopes to be analyzed and the required background for each of the isotopes, one or two magnets. The rare isotope is measured in a two anode ionization chamber able to measure both $^{dE}/_{dx}$ and E_{final} for each particle whereas the stable isotope(s) of interest are measured in Faraday cup(s) with electron suppression.

High energy mass spectrometers are available either as dedicated for a single element or for multiple elements. A foil can be inserted after the first magnet to introduce an additional difference in energy between the isotope of interest and the isobaric background, what allows to remove the later with the following electrostatic analyzer. The foil is needed for elements such as ^{10}Be and can be replaced via a vacuum lock without venting the spectrometer. This foil is also part of the patented double foil arrangement, which also optimizes the detection of ^{36}Cl.

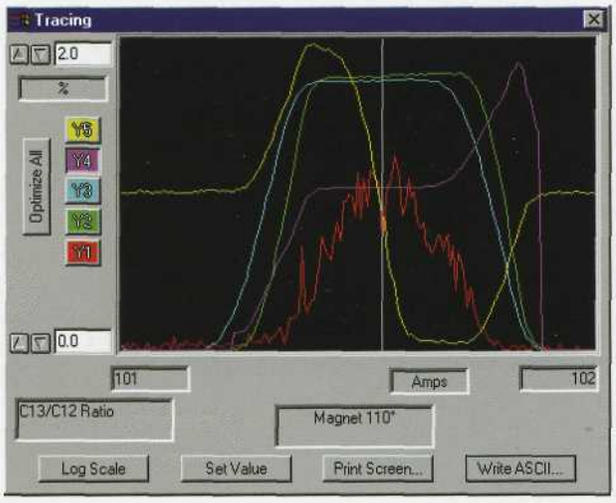


Full control automation

The HVE Accelerator Mass Spectrometers use modern automation techniques to achieve maximal use and optimal performance on a day-to-day and month-to-month basis.

A dedicated Microsoft™ Windows based software program, developed in-house at HVE and running on an industrial personal computer provides user friendly interfaces. It allows automatic start up & shut down and automated tuning, system control & monitoring as well as on-line data analysis.

All system parameters can be controlled using a mouse and/or keyboard whereby the actual readings are shown in an interactive sequential format or in a graphic format simultaneously as a function of time without the need for additional conventional control knobs, read outs or oscilloscopes.

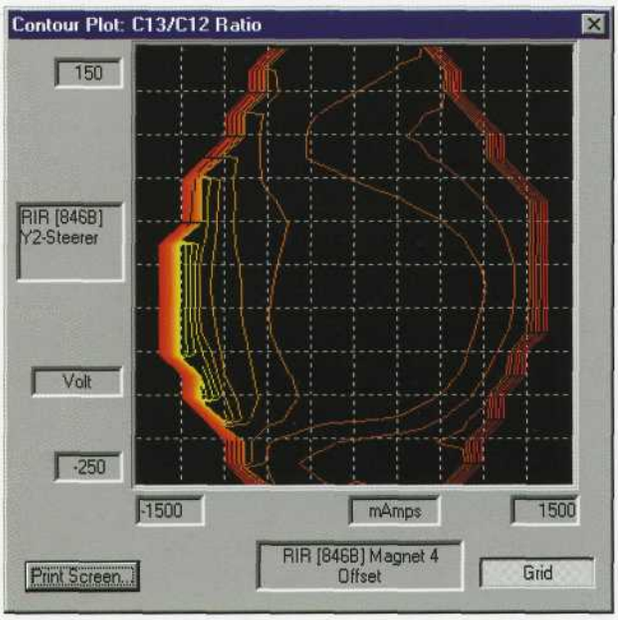


System control, safety and diagnostics

As with all HVE tandetron systems a wide range of system control, safety and diagnostic features are embedded in the software. Automated tuning is supported by Tracing & Mapping functions, Teach & Playback capability and visualization of Beam profiles & Cross sections on the computer screen.

Automatic and unattended self start up & shut down allows maximum system use. Routines for the remote control of the ion source, the vacuum system and terminal voltage conditioning are included.

Critical parameters are protected by interlock functions organized in well defined software/hardware configurations. Subroutines such as Trending, Data Logging & Reports are available for system diagnostics.



AMS features

An AMS system has to measure intensities from two or three different ion beams. The final results will be ratios of these intensities. Ratio scan functions are included in the software in order to tune the system for all beams correctly and to achieve maximum flat top tuning for the ratios.

The entire sample handling and data collection process is included in the software package and gives maximum freedom to the users daily wishes. User predefined batches are controlling unattended the measuring sequence of all samples inserted in the source magazine or subsets of these samples. Every sample can be loaded multiple times. For testing purposes single samples can be measured as well.

The final results include trending of the ion beam intensities and their ratios as a function of time and basic calculations of final isotopic ratios per sample loading. Easy access to the collected data's of the measured samples from well organized tree structures are available for post-analysis purposes.

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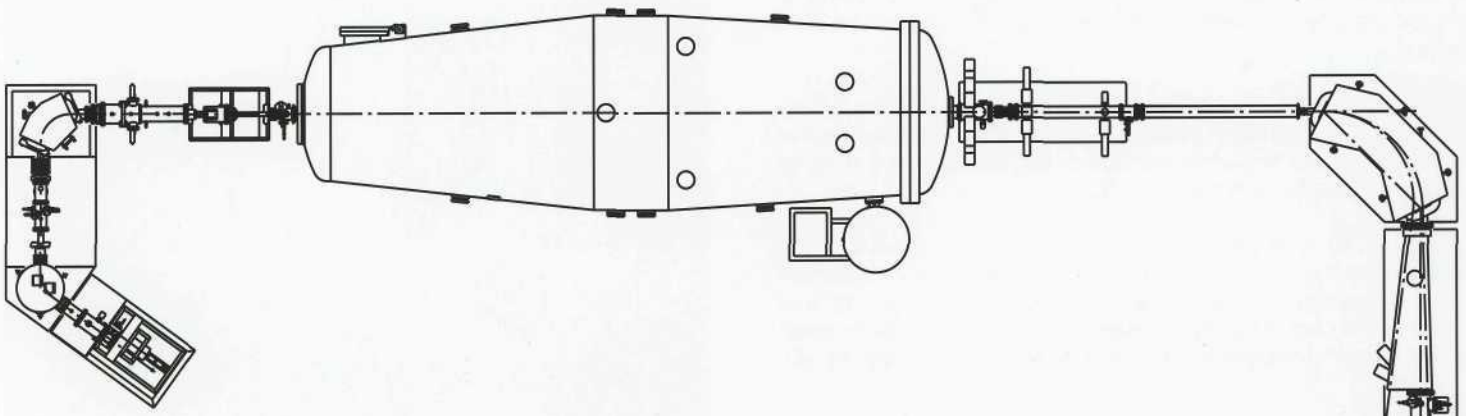
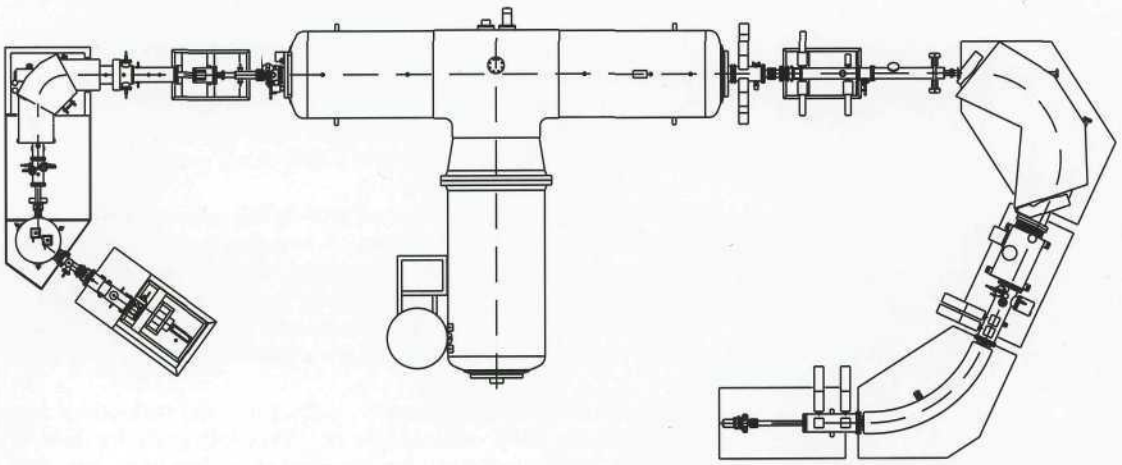
System layouts

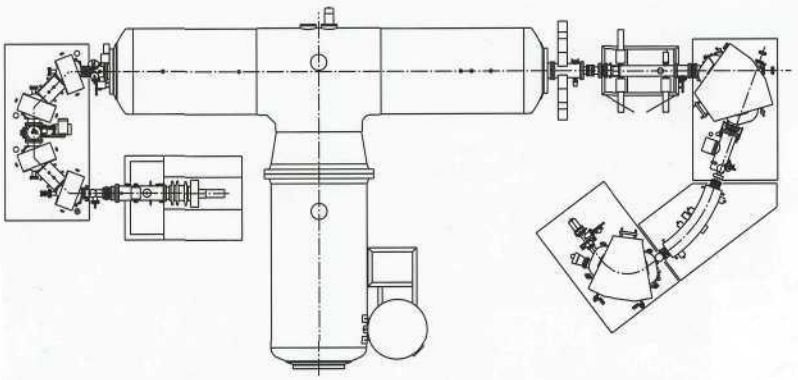
5.0 MV Tandetron AMS with Bouncer



3.0 MV Tandetron AMS with Bouncer



3.0 MV Tandetron AMS with Recombinator



1.0 MV Tandetron AMS with Bouncer