

СООБЩЕНИЯ
ОБЪЕДИНЕННОГО
ИНСТИТУТА
ЯДЕРНЫХ
ИССЛЕДОВАНИЙ

Дубна

97-104

E13-97-104

J.Budagov, M.Cavalli-Sforza¹, Yu.Ivaniushenkov¹,
A.Karyukhin², S.Kopikov², A.Lebedev, Yu.Lomakin,
L.Miralles¹, M.Nessi³, M.Recasens¹, N.Russaĳovich,
E.Starchenko², V.Tsoupko-Sitnikov*, A.Zaitsev²

RADIOACTIVE SOURCES
FOR ATLAS HADRON TILE
CALORIMETER CALIBRATION

¹Institute of High Energy Physics, University of Barcelona, Spain

²Institute of High Energy Physics, Protvino, Russia

³European Organization for Nuclear Research (CERN), Geneva, Switzerland

*Contact person at JINR, e-mail: tsoupkov@proton.jinr.dubna.su

1997

activity increase up to 10 mCi. Also the next specifications lie in the basement of the source design:

1. The radioactive material should be contained within a durable and hermetized shell (stainless steel is supposed to be sufficient); its outer surface purity with respect to radioactive contamination is considered as obviously imperative requirement.
2. Outer diameter of the hermetized source container for wire mechanical driving system should not exceed 1 mm, while this value for hydraulic and pneumatic ones might be slightly over 2 mm.
3. The z-axial length of the space, where the radioactive substance is concentrated within the container, should be reduced to minimum and match to 3 mm width of the tile. Meeting this requirement provides the tile irradiation to be more efficient and, consequently, procures the possibility of reducing the irradiation and data acquisition time. That simple phenomenon is illustrated in Fig. 3.

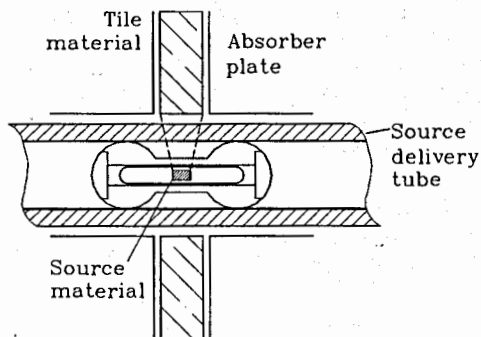
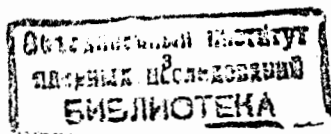


Fig. 3: Source location with respect to irradiated tile; influence of the source length on the efficiency of the system

4 Radiolysis of Fluid in Hydraulic Drive System

At the present stage of the development of hydraulic source driving system two substances are considered as possible candidates for their use as working fluid in the system: distilled water and perfluorohexane (trademarks "PERFTORANE", "Fluorinert PPI/FC72/PF5060", hereinafter "Perftorane") which simply presents completely fluorinated normal hexane C_6F_{14} .

Direct contact of strong radioactive source with the liquid implies that problems of the liquid radiolysis and its implications (at least radiation corrosion of the source and surrounding surfaces) should be considered. In this connection an assessment had been carried out of the rate of radiolysis products release within the liquid-filled space around the source being stored in the system; an estimation had been made of possible degradation of the liquid properties, as well as possible reactions of radiolysis products with aluminium source capsule surface.



The rate of radiolysis products release around the source was calculated using the formulae

$$\frac{dN}{dt} = \int_0^r G \cdot 4\pi r^2 \rho D(r) \cdot dr,$$

where N is the number of a product molecules formed, G - radiation yield of the reaction, ρ - the fluid density, $D(r)$ - absorbed radiation dose in dependence on the distance r to the source (see Fig.4).

Using well-known G -values for water and ones for Perftorane extracted from [3], we predict formation of $2.5 \cdot 10^{-6}$ mole H_2O_2 after a yearly continuous storage of the source within the water filled garage in hydraulic drive system. Assuming the free fluorine release might occur when Perftorane irradiated, we also accept the possibility of 20 μ -thick fluoride film formation on the source outer surface after the same term of its storage in Perftorane. Taking into account that 1 year is approximately equal to the time of the source contact with the fluid over the whole period of the calorimeter operation, we conclude that the radiation corrosion process presents no danger to the system performance or safety.

Some attention should be paid to the possible aluminium ordinary electrochemical corrosion when it contacts with water. To prevent this some preserving layers (Ni, Cr) should be deposited on the aluminium, or the latter should be replaced with other corrosion-resistant material, or Perftorane rather than water should be applied.

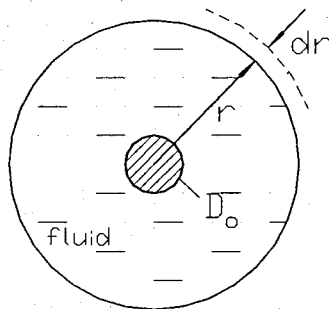


Fig. 4: Illustration of the calculation procedure of radiolysis products release rate

5 Source Preparation Procedure

Commercially available ^{137}Cs originating from nuclear fuel reprocessing plays part of the substrate in the source preparation procedure. Concentration of short-lived Cs-134 ($T_{1/2}=2.9$ yrs) should be thoroughly controlled by means of semiconductor detector gamma-spectroscopy and is permitted to be no higher than 0.3 % of total source activity. In this case the drift of the source γ -radiation intensity and energy composition, caused by the decay of the short-lived component, would not exceed the permitted value of the calibration uncertainty.

Cesium fraction, retained during 20 years after separation from fresh spent nuclear fuel, satisfactory meets this requirement.

Implantation of 10 mCi of ^{137}Cs into the small-volume (1.5 μ l for mechanical option and 3 μ l for pneumatic and hydraulic ones) and strictly confined space within the inner container of the source appeared to be the most complicated task of the procedure. The volume, occupied by 10 mCi of carrier-free ^{137}Cs , lies within the range of 0.2 - 0.5 μ l, if cesium applied as water-free chloride or nitrate. At the same time commercially available ^{137}Cs is well-known to be contaminated with considerable quantities of inorganic impurities (Fe, Co, Ni, Cu, Cr, Mn, Ca, Ba, K, Na), having the volume in chloride or nitrate form tens times exceeding the useful one of cesium. The situation is also aggravated by the ability of these substances to absorb intensively water if exposed to open air. All the points mentioned above make inevitable the thorough radiochemical purification of cesium purchased for the source preparation.

5.1 Cesium Purification and Preconcentration

Procedures of anion and cation exchange chromatography were applied for cesium purification from accompanying elements and its further concentration (see the scheme in Fig.5), which then was followed by the activity implantation into the source container. Glass column 450 mm filled with anion exchange resin Dowex 1X8 was used for Fe, Co, Ni, Cu, Mn, Cr elimination in 12 M HCl media; at the second stage alkali earth elements were eliminated by elution with ammonium citrate solution from column 2.580 mm, filled with cation exchanger Aminex A5. Separation of cesium from alkali metals was then carried out on the same column by means of stepwise elutriation with hydrochloric acid.

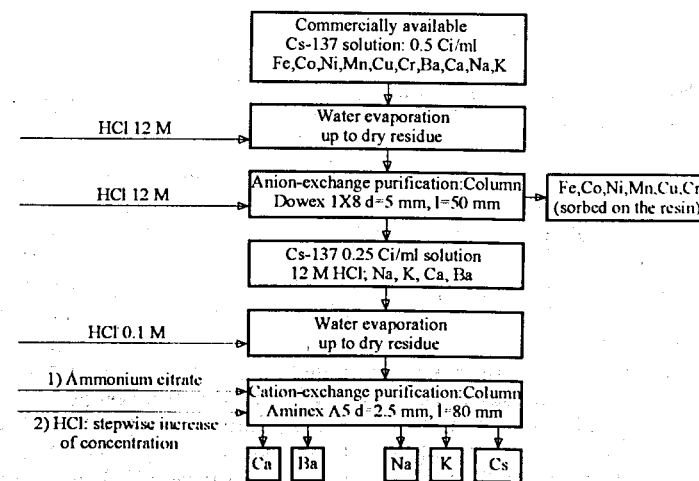
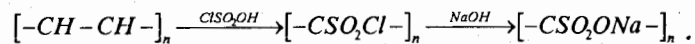


Fig. 5: Scheme of cesium-137 purification procedure

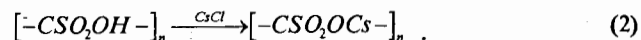
5.2 Cesium Implantation into the Source Container

The goal of this operation is to transfer pure cesium chloride into the inner space of the source container which is 0.8 mm (mechanical option) and 1.4 mm (pneumatic and hydraulic options) in diameter. Losses of the radioactive substance and radioactive contamination of the container outer surface should be imperatively avoided. Several means are considered to be suitable for implementation of such task :

1. Intermittent pumping-drying of preliminary purified and concentrated cesium solution into the inner space of the container. This method is feasible when dealing with containers of larger diameter (hydraulic and pneumatic options) and unacceptable for the mechanical option container because of its too small inner volume.
2. Ion exchange thread might be used as the support for ^{137}Cs during its packing into the metal tube. For such thread preparation the polyethylene wire of $\varnothing 0.8\div 1.2$ mm can be used as a substrate. Ion exchange groups introduction into polyethylene polymeric structure can be accomplished by means of its sulphuration with chlorosulphonic acid followed by alkali hydrolysis:



Hydrolysis stage is followed by the transformation of ion-exchanger obtained into H-form (1) and then saturation of the thread with ^{137}Cs from its neutral solution (2):



Purity of the cesium solution with respect to non-radioactive impurities constitutes the crucial factor affecting the value of the resulting source specific activity.

Application of such technology allows linear source preparation with length up to 500 mm and linear specific radioactivity $\approx 12\div 18$ mCi per cm. These threads cut into appropriate pieces can be easily inserted into containers.

3. Cation exchange resin (graines $\approx 0.7\div 1.2$ mm in diameter) can be used instead of ion exchange thread with other details of the procedure kept intact.
4. Rods preparation of fusible glass, containing ^{137}Cs , and their insertion into the inner space of the source container. The necessary value of cesium specific activity in the rods is easily attainable in this technology as well as ease in dealing with these rods during their packing and hermetization in the source. Nevertheless this method is not convenient for "by the piece" production because of the small chemical yield of the procedure when dealing with small quantity of radioactive glass, and becomes reasonable only for bunch production of more than 10 sources simultaneously.

In our work we used slightly modified technology described under number 3 in the list above.

5.3 Source Hermetization

After cesium implantation into the source container, hermetization of the latter by means of electrical welding under noble gas atmosphere follows. During the welding the container is tightly pinched within a copper set providing extensive heat exchange to prevent cesium salt overheating and evaporation (Fig. 6); all the operations are carried out in an air-tight ventilated box. Then etching with hydrochloric acid solution is carried out for elimination of possible trace surface contamination, followed by mechanical polishing of the welded point.

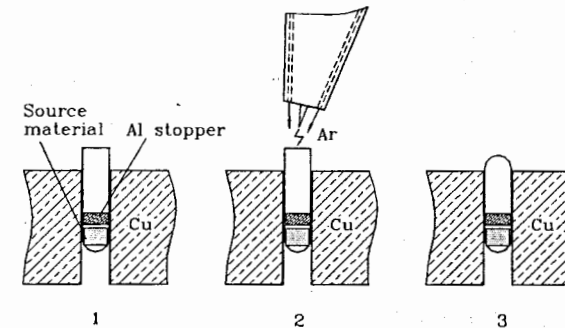


Fig. 6: Scheme of the source container hermetization by electrical welding

6 Results

Using procedures described above three tentative sources have been manufactured (one for each option of source delivery system). Characteristics of the sources produced are summarized in Table 1; a typical γ -spectrum of a source got with a semiconductor detector is presented in Fig.7.

Technical design of the source assemblies for mechanical, pneumatic and hydraulic source delivery systems are presented in Fig.8, Addendum 1 and Addendum 2 respectively. In accordance with the design developed by Barcelona and Protvino groups, two last assemblies include inner source containers along with non-radioactive additional parts (capsules, wires) facilitating the source movement and delivery within calorimeter stack.

Authors are happy to express their deep gratitude to Prof. Dr. V.A.Khalkin (JINR) for consultations and recommendations in the field of radiochemistry as well as to Dr. G.Roubaud and Dr. H.Schombacher (CERN) for useful discussions of some radiation chemistry issues. We are also grateful to Dr. V.N.Pavlov (JINR) for technical consultations and V.I.Sobolev (JINR) for assistance in the source manufacturing.

Table 1. Characteristics of the model sources

Source delivery system	Technical design of the source assembly	Total activity, mCi	Share of ^{134}Cs , %
mechanical	source container \varnothing 1.0 mm with attached 6 m long wire	4.20 ± 1.70	0.26
pneumatic wire assisted	source container \varnothing 2.0 mm crimped within brass capsule with attached auxiliary wire	9.0 ± 1.0	0.2
hydraulic	source container \varnothing 2.0 mm crimped within aluminium capsule	8.0 ± 1.0	0.2

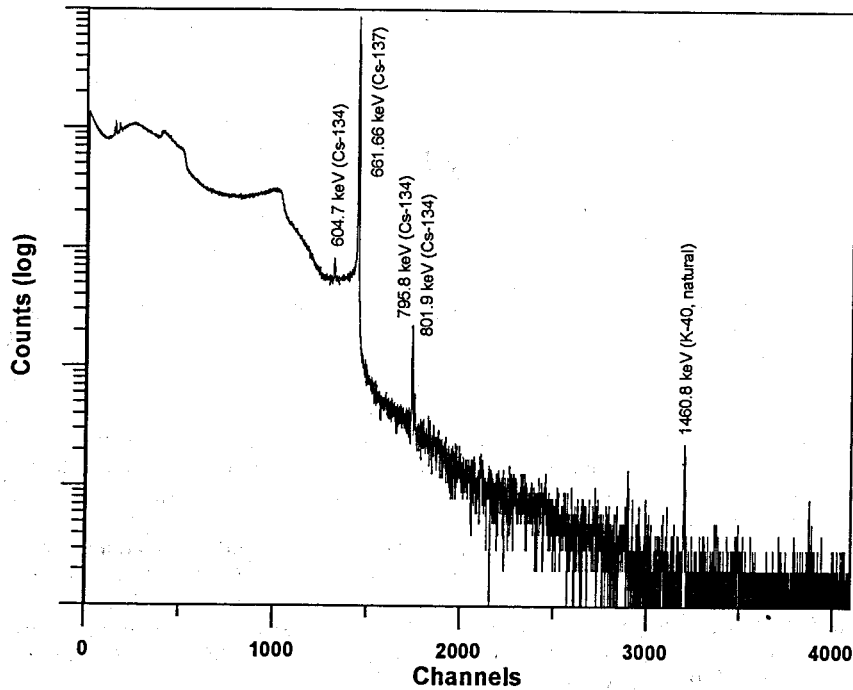


Fig. 7: Gamma-spectrum of 4.2 mCi cesium-137 source got with a coaxial HPGe detector ($V=50 \text{ cm}^3$); source set at 250 cm distance from the detector

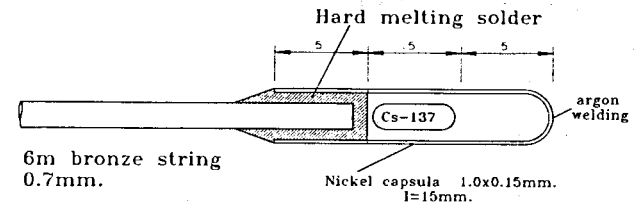
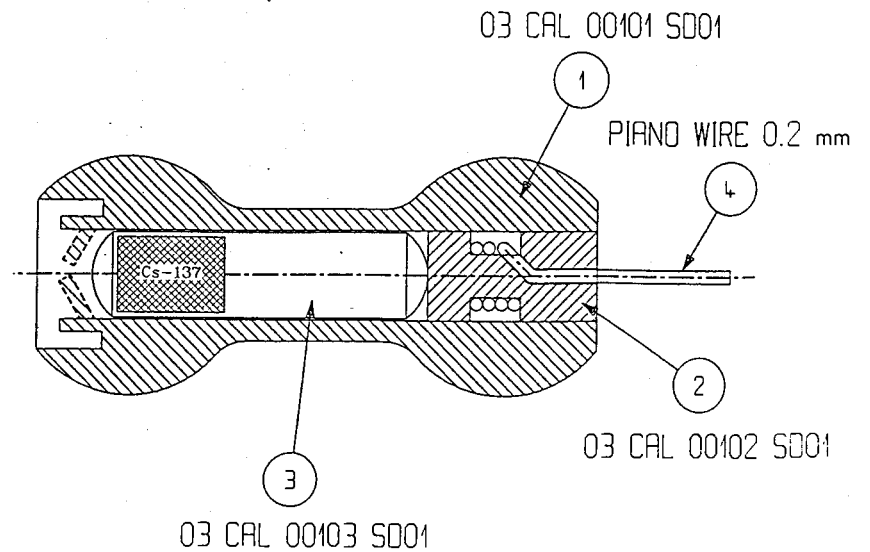
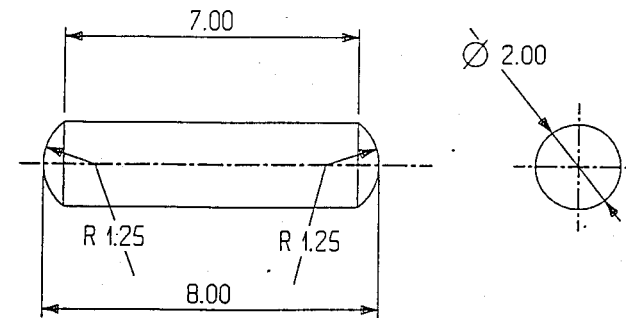


Fig. 8: Technical design of the source for mechanical delivery system

ADDENDUM I

Design of the prototype source for pneumatic option of source drive system

Source tube (container) material: stainless steel, wall thickness 0.2 mm
Capsule material: brass

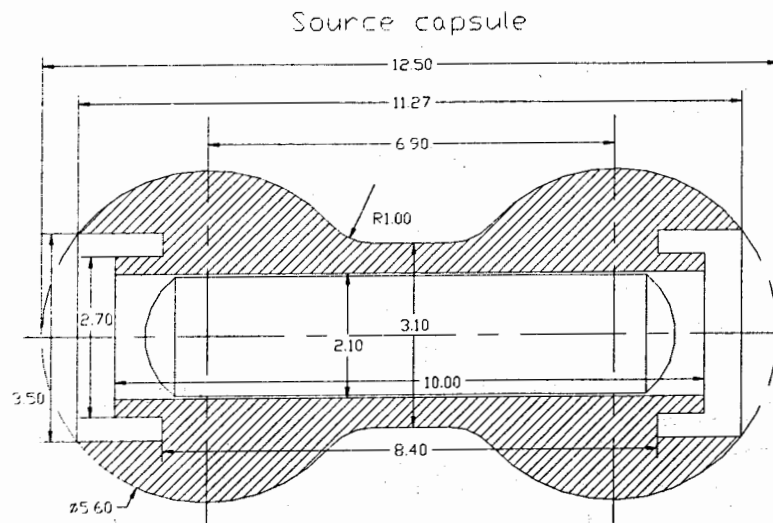
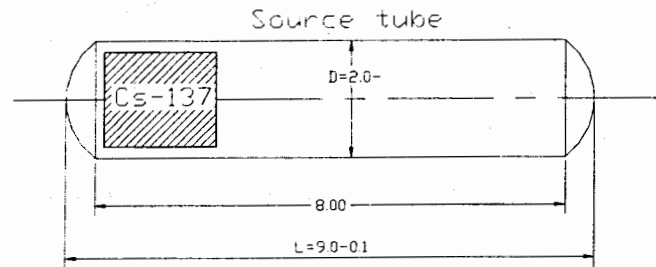


ADDENDUM II

Design of the prototype source for hydraulic option of source drive system

Source tube (container) material: stainless steel, wall thickness 0.2 mm

Capsule material: aluminium



Будагов Ю.А. и др.

E13-97-104

Радиоактивные источники для калибровки
адронного тайл-калориметра АТЛАС

В работе формулируются основные требования, предъявляемые к радиоактивным источникам для калибровочных систем адронного калориметра АТЛАС. Описывается разработанная в ЛЯП ОИЯИ технология изготовления таких источников. Представлены технические характеристики и дизайн пробных калибровочных источников, изготовленных в Дубне и испытанных на модуле-0 калориметра.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Сообщение Объединенного института ядерных исследований. Дубна, 1997

Budagov J.A. et al.

E13-97-104

Radioactive Sources for ATLAS Hadron Tile
Calorimeter Calibration

The main requirements for radioactive sources applied in the TileCal calibration systems are formulated; technology of the sources production developed in the Laboratory of Nuclear Problems, JINR is described. Designs and characteristics of the prototype sources manufactured in Dubna and tested on ATLAS TileCal module 0 are presented.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna, 1997