ATLAS Internal Note
MUON-NO-142
25 March 1997

XTOMO, A Prototype of the X-Ray Tomograph for High Precision Measurements of the MDT Muon Chambers

G.D.Alexeev, I.P.Boyko, G.A.Chelkov, M.A.Ignatenko,
Z.V.Krumstein, Yu.V.Sedykh, L.S.Vertogradov
JINR, Dubna, Russia

D.G.Drakoulakos, C.W.Fabjan
CERN, Geneve, Switzerland

H.Breuker
MPI, Munich, Germany

24 March 1997

(Presented at WCC-95 conference)

Abstract

In the framework of the collaboration between JINR and CERN muon groups a 600 mm linear X-ray Tomograph (**XTomo**) was constructed and tested.

A cross section of a 6-layer MDT muon chamber prototype has been scanned by a narrow, (0.05×15) mm^2, X-ray beam. Two methods of localization of signal wires inside the Al drift tubes were tested:
(a) in the 'passive' mode the absorption of the X-rays by the wires was detected by an external scintillator counter;
(b) in the 'active' mode the photoelectrons from the wires knocked out by the X-ray quanta were detected by the drift tubes themselves.

An accuracy of 10 μm in the measurements of the wires positions can be achieved by using commercial devices.

1 Introduction

The use of a narrow X-ray beam for the localization of signal wires inside drift tubes was proposed in [1]. Different methods were successfully tested in [2] and [3]. On this basis two years ago the project for a small prototype X-ray scanning device for high precision measuring of the ATLAS MDT muon chambers (**XTomo**, X-ray Tomograph, [4]) was presented by the Dubna group. In the end of 1994 it was realized by the collaboration of the CERN and JINR muon groups (with an important contribution of MPI group).

X-ray tomography is meant to be a part of the mass production technology for the ATLAS MDT muon chambers. At the first step of this project, the **XTomo** prototype was used to illustrate the method and for measuring the small MDT modules from different laboratories. In the future a Large X-ray Tomograph could be installed in the general Acceptance Control Center (at CERN) for checking the wire positions in muon chambers before their installation in to the shaft [5]. After the measurement of all chambers a coordinate calibration information file (consisting of small corrections of position for every signal wire) could added to the Calibration Data Base of the Muon Spectrometer.

This note describes the first step in the development of the **XTomo** method: from the autumn of 1994 to the middle of February 95 when these results were presented at the WWC-95 (Vienna) conference [7].

This note is organised as follows: section 2 describes the design and technical parameters of the X-ray scanner prototype, section 3 gives the first results of **XTomo** tests and section 4 presents the conclusions.

2 Technical Description

Two principal schemes of measuring the wire positions of MDT chamber's were tested. A cross section of the chamber was scanned by the very narrow (0.1×10 mm^2) X-ray beam. In case of the so called 'passive' scanning mode, fig.1, the output intensity of the X-ray beam was measured by a scintillator counter. In the 'active' scanning mode, fig.2, the localization of the signal wire was made by measuring the counting rate from the drift tube itself. The scanning step was equal to 20 μm. For reconstruction of the wire positions two independent scans ('stereo - measuring') must be done.

Due to the regular structure of the MDT drift tube packages there is a set of preferable directions for the X-ray beam corresponding to the minimal thickness of the absorber material (Al) in the beam path. Here the most suitable scanning angle values were tested, i.e. $\pm 30^o$ relative to the chamber surface normal incidence.

A 1.5 m supporting 'bridge' was installed in the middle of a heavy iron table. The digital moving table (Linear Stage) was fixed to one side of its horizontal beam. The height of the 'bridge' can be changed by adding or removing the standard (20 cm) blocks that compose its 'legs'.

The tabletop of the Linear Stage keeps the Scanning Head - aluminium plate with X-ray tube and collimator slits. The X-ray beam goes from top to bottom and lies in a vertical plane. Its inclination angle ('scanning angle') can be changed from -45^o to $+45^o$ relative to the vertical with a step of 7.5 degrees by remounting the Scanning Head on the tabletop.

The supporting table was composed by two iron plates ($2.5 \times 1.5 \times 0.1$ m^3) with a 2 cm gap between them. This gap was safe against back-scattering of the residual X-ray beam. The measured MDT muon chamber [1] was placed under the 'bridge' so that signal wires were perpendicular to the X-ray beam (with an accuracy of 1 mrad). By shifting along the table, different cross sections of the chamber could be scanned.

The general block scheme is shown in fig.3. The main parts of the X-ray Tomograph prototype are listed below:

1. Precise electro-mechanical Scanner.
2. X-ray Scanning Head.
3. HV Power Supply for the X-ray tube.
4. IBM 386 Personal Computer with mathematics coprocessor.
5. Motion Controller that connects the Scanner with the PC, consisting of:
    - motor power supply;
    - interface card;
    - library of the standard commands.
6. Detector(s) of the X-ray beam.
7. Data Acquisition crate (CAMAC) with electronics and PC interface.
8. Software:
    - on-line steering program;
    - off-line analysis programs.

Detailed description of the main parts follows in the next subsections.

2.1 X-Ray Installation

A standard X-ray installation was used with a rather moderate ($\simeq 1$ %) high voltage and anode current stabilization. A high voltage power supply unit (max=50 kV, 3 kW, with two parallel outputs) [2] was connected with an X-ray unit by a 6 m long flexible cable.

---

[1] Production of MPI, Germany.

[2] Production of BUREVESTNIK firm, St.Peterburg, Russia, 1980.

The X-ray source – called 'diffraction analysis' X-ray tube (max=60 kV, 20 mA, with **Mo** or **W** anode and 0.2×8 mm^2 focus spot) [3] – with a water cooling head were mounted inside the metallic radiation protected body of the X-ray unit. The total weight is around 10 kg.

The X-ray radiation is emitted isotropically through the **Be** window of the tube having an angular coverage of 12^o. The effective angular range seen by the collimating system was 3^o. Under such a small angle the focus spot image was equal to 0.01×8 mm^2 !

The X-ray installation was equipped by a set of 'interlocks', i.e. over-voltage, over-current and drop of water pressure. A special interlocked fence prevented the access to the X-ray beam zone.

2.2 Scanning Heads

The X-ray scanning head consists of the X-ray source unit, a small Linear Stage and two collimating slits mounted on the common **Al** plate. There was also some **Pb/Cu** radiation protecting cover.

The X-ray unit itself was fixed on the Linear Stage (50 mm travelling distance, $\leq 1\ \mu$m resolution, computer ruled) [4] so that it could move along its axis in a direction almost perpendicular (87^o) to the X-ray beam direction, to account for the 3^o X-ray angular range.

Two collimating slits, C1 and C2, define the direction, profile and divergence of the X-ray beam. The slit is made out of two small **Ta** 'cheeks' fixed on an **Al** support. The other dimension of the beam's profile is constrained by an additional lead mask fixed on the same support. A micrometer head was incorporated into the output collimator C2. By adjusting the position of the 'cheek' the width of the output collimating slit can be changed.

The cross section of the X-ray beam just after the collimator C2 was equal to 0.05×5 mm^2. Other width values, from 10 μm to 100 μm, were also tested. The distance between the X-ray tube's focus spot and C2 was $\approx$ 500 mm, so the *working* divergence of the beam can be estimated as 10^{-4} rad $\approx$ 100 μrad.

The first collimator, C1, with cross section 0.04×8 mm^2 was placed near the X-ray tube. As it was mentioned earlier the projection of the focus spot image on the surface perpendicular to the beam direction was equal to 0.01×8 mm^2. So, this collimator didn't restrict the *working* X-ray intensity at all. The use of *two* collimating slits aimed at fixing precisely the X-ray beam direction (axis) even in case of changing or reinstalling the X-ray tube. A special procedure was carried out to align the X-ray focus spot with respect to the collimators within a few microns.

Two scanning heads, HEAD1 and HEAD2, were used in the tests corresponding to the two different scanning modes which will be described later and are shown in figures 1 and 2. In the case of the 'passive' mode (fig.1) a small NaI scintillator counter was mounted after the C2 collimator slit.

---

[3] 21, production of SVETLANA firm, St.Peterburg, Russia, [8].

[4] ATS0300, production of AEROTECH firm, USA, [9].

2.3 Linear Positioning Stage

The**XTomo** scanning system was based on a Linear Positioning Stage [5] with the travelling distance 600 mm, accuracy 5 μm and repeatability 1 μm. It was supplied with a DC Servo motor (200 Wt), precision ground ballscrew mechanical drive system (4 mm lead) and Linear Incremental Encoder (± 5 μm accuracy). Load carrying capability in working *side* position was 45 kg, total weight 81 kg.

PC-bus based Motion Controller with motor driver crate [6] were used to control both Linear Stages - the main 600 mm and the additional 50 mm ones. This system can control up to 4 axis of movement simultaneously. The PC-bus card has 24 kB memory and a rather sophisticated programming environment. There is a menu-driven access to a wide range of features including axis-tuning, parameter-setting, system diagnostics and so on.

There are set of parameters that define the quality of a linear stage (see from [9], p.87). Except for the 'longitudinal' (x-position) accuracy for the **XTomo** application such parameters as 'straightness' (z-position) and 'pitch' (angular position θ_y in the xz-plane) are important. The commercial firm supplies calibration curves for these values. They contain deviations between the theoretical and the actual positions of the tabletop as function of the x-coordinate value measured by help of laser interferometry measuring tools.

On the basis of such calibration curves the *accuracy* and *repeatability* can be estimated for every parameter. The accuracy values are defined as the amplitudes of the curves: Δx = ± 5 μm; Δz = ± 6 μm; $\Delta\theta_y$ = ± 5 arc sec. The repeatability values are defined as maximum of standard spreads of these curves when the measurements are repeated: σ(x) $\leq$ 1 μm; σ(z)$\leq$ 1 μm; $\sigma(\theta_y)$ $\leq$ 1 arc sec.

The Motion Controller programs can use calibration curves so to take into account all systematic deviations. After that the Linear Stage is exact on the 'repeatability level'.

2.4 Electronics & Software. Scanning cycle

The simple data acquisition system was based on a CAMAC crate with an interface to PC. The signals from the scintillator counter or/and drift tubes were selected and shaped by the standard electronic blocks and then counted by scalers. In parallel, an additional $f = 100\ kHz$ timing signal was counted by a separate scaler.

The steering program, SCAN3.C, written on the language C, controlled the Linear Stage and data acquisition. The main tasks of the program: initialization of the CAMAC and AEROTECH softwares, scanning cycle and storing the data on the output file. There were three kinds of data: X [mm] – coordinate value, G – time generator counting and I – counting(s) of the X-ray quanta.

The most simple scanning cycle was realized. The Linear Stage moved continuously with a constant velocity v = 0.5 mm/s. Through steps of s = 20 μm the

---

[5] ATS5000, production of AEROTECH firm, USA, [9].

[6] UNIDEX 500, production of AEROTECH firm, USA, [9].

content of the scalers and x-coordinate value were written to memory; then the scalers were cleared and counting process repeated. All measured distances was scanned twice in the forward and backward directions.

The measuring time t was a bit less then $T = s/v = 20 \cdot 10^{-3}/0.5 = 40$ ms due to computer processing speed. By this reason its real value was measured by the timer signals counting. The X-ray counting value was corrected by the formula:

$$S = I * T/t = I * T/(G\ /\ f) = I/G * (T * f) = 4000 * I/G$$

Off-line program (like PICTURE.KUM) written in the PAW environment finds and fits positions of the "wire peaks" on the curve $S = S(X)$.

3 Measuring of wire positions in MDT muon chamber

The MPI 1 m^2 drift chamber was the first prototype of the ATLAS MDT muon chamber's technology, [10]. The outer diameter of the drift tubes – 30 mm, wall thickness – 0.4 mm, diameter of the **W** signal wires – 100 μm. Two glued 3 - layers drift tubes packages are fixed with a gap of 400 mm between them.

The chamber was placed under the scanner so that (a) the wires were *near parallel* to the collimating slits of the Scanning Head and (b) so that the MDT cross section was *near perpendicular* to the chamber axis scanned by the X-ray beam. Special fixation screws were used to adjust the position of the chamber with an accuracy $\approx$ 1 mrad. It was enough to keep negligible decreasing of the 'wire peaks' on the $S = S(X)$ curve (due to (a)) and corrections to the 'wire – wire' distances (due to (b)).

3.1 'Passive' mode scanning

The resulting scanning curve $S = S(X)$, fig.4, presents in reality a very detailed 'X-ray transparency' picture projected under $\approx 30^o$ for the 3-layers drift tubes package of the MDT muon chamber. There is large X-ray absorption in the Al drift tubes' walls whose direction was tangent to the X-ray beam. The depth of the *wire signals* is equal to 50%.

These data were measured with such **XTomo** parameter values:

- X-ray tube high tension – 36 kV, anode current – 15 mA;
- C2 collimating slit dimensions – 0.05 × 5 mm^2;
- scanning step – 20 μm, scanning velocity – 0.5 mm/s;
- scanning angle of the X-ray beam inclination – 29^o.

From the fig.4 it can be seen that X-ray counting rate on the level $2 \cdot 10^3$ per step $= 2.5 \cdot 10^4$ per sec was achieved (after $6 \times 0.4 = 2.4$ mm thickness of Al). So, the statistical error contribution is negligible in these measurements.

To avoid overlapping of the wire signals from different drift tube layers the scanning angle value 29^o was used instead of 30^o. In fig.5 the shape of wire signals is shown. About 8 – 10 points per peak is enough to fit them with a very good accuracy, (see fig.5). The fitting was done by a Gaussian curve with the help of the standard CERN Minuit program.

Direction of the scanning head movement (X-coordinate axis) was near parallel to layers of the chamber. So using the measured projections the relative wires *in-layer* positions could be estimated well. The measured distribution of the distances between wires have a mean value was equal to 30.10 mm and a standard deviation - 39 μm. This result was in agreement with the optic microscope measurements at MPI [10].

Such scans (on distances of $\sim$ 300 mm) were repeated forward and backward eight times. Repeatability (see parameters of the Linear Stage, Section 2.3) better then 2 μm was confirmed, fig.6.

3.2 'Active' mode scanning

The X-ray Generator mentioned in the previous section was tested firstly in in the Laboratory of Nuclear Problems, JINR, Dubna, September 1995. During this job a new modification of the 'active' mode was proposed. Unlike [3] a 'white' (bremsstrahlung) X-ray energy spectrum and special electronegative gas admixture were used [6]. This method was investigated more carefully here with **XTomo**.

Fig.2 shows the scanning scheme for 'active' measuring of the MDT muon chamber. A new scanning head (HEAD-2) formed a narrow X-ray beam *before* the chamber (width of the output collimating slit is 50 μm and the divergency is 100 μrad). So, the total 6-layer depth of the MDT muon chamber could be scanned.

First of all the general features of the X-ray radiation penetrating through **Al** material were checked: fig.7 shows the X-ray intensity as a function of the **Al** filter thickness while fig.8 shows the same for the X-ray energy spectrum shape. These measurements were done by using a small NaI (2 cm) scintillator counter with a spectrometrical amplifier.

The chamber was filled with a CO_2 gas, with a high voltage tension near 4 kV. The Drift tubes' preamplifiers [7] of every layer were "ORed" and connected to separate scalers. Format of the raw data: X – coordinate value; G – timing generator counting; I1, I2,...,I6 – counts from the layers.

Fig.9(a) presents the drift chamber counting rate as a function of x-position of the scanning beam, $S = S(x)$ curve, for case of pure CO_2 working gas. Parameters of the X-ray Scanning Head: high tension U=40 kV, anode current I=10 mA, collimating slit C2 = 50 μm; estimated primary intensity $I_0 = 10^2$ kHz. There was measured the second layer of the chamber. Shape of the $S(x)$ curve is defined by two factors: *negative* — decreasing of the X-ray intensity due to absorption in Al material, and *positive* — the X-ray quanta detecting efficiency of the drift tubes.

Clear and sharp positive 'scanning signals' are produced by electrons knocked out from the wires. Response of the drift tube's sensitive volume is nearly proportional

---

[7] Production of JINR, Dubna for the MDT muon beam tests.

to the working gas thickness along the X-ray beam. There is also negative ('shadow') scanning signal from the previous layer's wires.

It can be surmised that electrons are knocked out from the inner surface of Al tubes, but only from the very thin layer of the metal. So changing of the Al material thickness along the X-ray beam (inside the drift tube's walls) cannot influence much the shape of the 'positive' response.

From analysing the $S(x)$ curve the wire position as different distances from the tube's walls (in direction perpendicular to the X-ray beam) can be extracted.

An attempt to increase the 'signal/background' ratio for the sensitive wire scanning signals was made by using a working gas with an electronegative gas admixture. Fig.9(b) shows the results of repeating scannings (under other inclination angle values) with a CO_2 + 3%Fr13 working gas. This regime provides only a very small sensitive area around the wire inside the 'dead' drift tubes.

Once more, the positive response (scanning signal) of drift tubes has two components: the narrow one — from wire, and the more broader — from gas. On the background of the 'gas signal' a shadow - the 'wire signal' - from the previous layer of chamber is detected.

The total signal from drift tubes can be fitted by the superposition of two Gaussians, see fig.10 ($\sigma_{wire} \approx 70\ \mu$m, $\sigma_{gas} \approx 1$ mm). There was investigated behavior of the $R = A_w/A$ ratio, where A_w is value of *wire signal*, A is sum of the *wire* and *gas* signals.

Fig.11 illustrates the measured relation between the R and amount of the Fr13 admixture in the chamber working gas. It's clear that too large amounts of the admixture were used. The optimal value of the **Fr13** admixture lies in the range (0 - 3)%.

Due to the absorption in material of chamber, the X-ray quanta that scan the more deep layers have a more 'hard' energy spectrum. Fig.12 shows the measured relation between the R value and the **Al** material thickness that the X-ray beam passed (last point corresponds to the 6th layer). There is certain evidence — the 'signal/background' ratio for the 'active mode' scanning is improving with the X-ray quanta energy.

IMPORTANT NOTE The demands to the X-ray beam inclination angles values and to the relative position between two MDT drift tubes packages are **the same** for these two modes (i.e. passive and active).

4 Conclusion

A X-ray scanning device based on commercial components (X-ray unit, Linear Positioning Stage) can measure positions of the signal wires in a real MDT muon chamber with a few micron accuracy. The X-ray quanta counting rate on the level of 10^3 per step can be achieved with 0.5 mm/s scanning velocity. So, a 2-meters width MDT muon chamber can be measured twice with 5 cross sections during $2{\cdot}10^3$ [mm]$\times 2 \times 5/0.5$ [mm/s] ≈ 7 [hours]. This figure can be decreased approximately 5 times if the 20 μm step scanning will be done only around the wires positions. Due to a very good defined geometry structure of MDT chamber the positions of all wires can be predefined by the steering computer.

The *active* mode scanning using the white X-ray spectrum and Freon13 gas admixture was successfully investigated.

The main result of this job was the complex test of the X-ray Tomograph prototype and its components: X-ray unit, Linear Stage, data acquisition system and software.

4.1 Acknowledgments

This work was fulfilled from June 1994 (when JINR-CERN X-Ray Tomography Collaboration was established) to middle of February 1995 (when these results were presented to WCC-95 Conference). The X-Ray Laboratory was placed in CERN, building 157/R-014.

The constant attention and support from the ATLAS (CERN and JINR) managements helped very much.

We are especially thankful to Prof. F.Dydak (MPI) and Prof. M.Dris (NTUA) for their essential support on the starting phase of this project.

References

[1] Yu.Bonyushkin, A.Korytov, Z.Krumstein, V.Malishev, L.Vertogradov, (Joint Institute for Nuclear Research, Dubna, USSR) 'Proposal for tomograph coordinate calibration of drift tube package', EMPACT Note 240, July 1990. See section APPENDIX 1.

[2] L.Vertogradov, 'High precision wire positions measuring in the drift tube package by the X-ray scanner (XTomograph)', ATLAS Internal Note, MUON-NO-041, 11 May 1994.

[3] O.L.Fedin, A.I.Smirnov (Petersburg Nuclear Physics Institute) 'On a possibility to use a narrow X-ray beam for straw proportional tubes alignment', RD-6 Note 51, 16.02.1994.

[4] 'Proposal of X-ray Scanning Device for High Accuracy Measurement of Wire' Positions inside Drift Tube Package (prototype)', was sent to ATLAS Muon Chamber Engineering meeting, Amsterdam, NIKHEF, 30 May 1994. See section APPENDIX 2.

[5] 'ATLAS Technical Proposal', CERN/LHCC/94-43, LHCC/P2, 15 December 1994, page 125.

[6] I.P.Boyko, L.S.Vertogradov, V.I.Dodonov, V.V.Juravlev, M.I.Ignatenko, Z.V.Krumstein, M.Yu.Nikolenko, G.A.Chelkov 'Space positions measuring of the signal wires inside drift tubes by help of X-ray beam', (in Russian), Short Messages of JINR, No. 2[70]-95, Dubna, 1995.

[7] G.Alexeev, I.Boyko, H.Breuker, G.Chelkov, D.Drakoulakos, C.W.Fabjan, M.Ignatenko, Z.Krumstein, Yu.Sedykh, L.Vertogradov, 'High Precision Measuring of wires' positions by the X-ray scanning', poster report presented by L.V. on the international Wire Chamber Conference, Vienna, February 1995. *NOTE* It's pity, but due to some organization failures this report wasn't included to the resulting NIM publication.

[8] Catalog: 'X-ray Tubes, Portable X-ray Units', SVETLANA Electron Device Mfg.Corp., Russia, 194156, Sanct-Peterburg, Engels pr., 27.

[9] Catalog: 'AEROTECH Motion Control Product Guide', 1993. We contacted with Germany AEROTECH GMBH, Neumeyerstr.90, 8500 Nürnberg 10.

[10] G. Alexeev et al., 'High Pressure Drift Tubes for ATLAS', ATLAS Internal Note, MUON-NO-029, 28 October 1993, 74p.

Figures

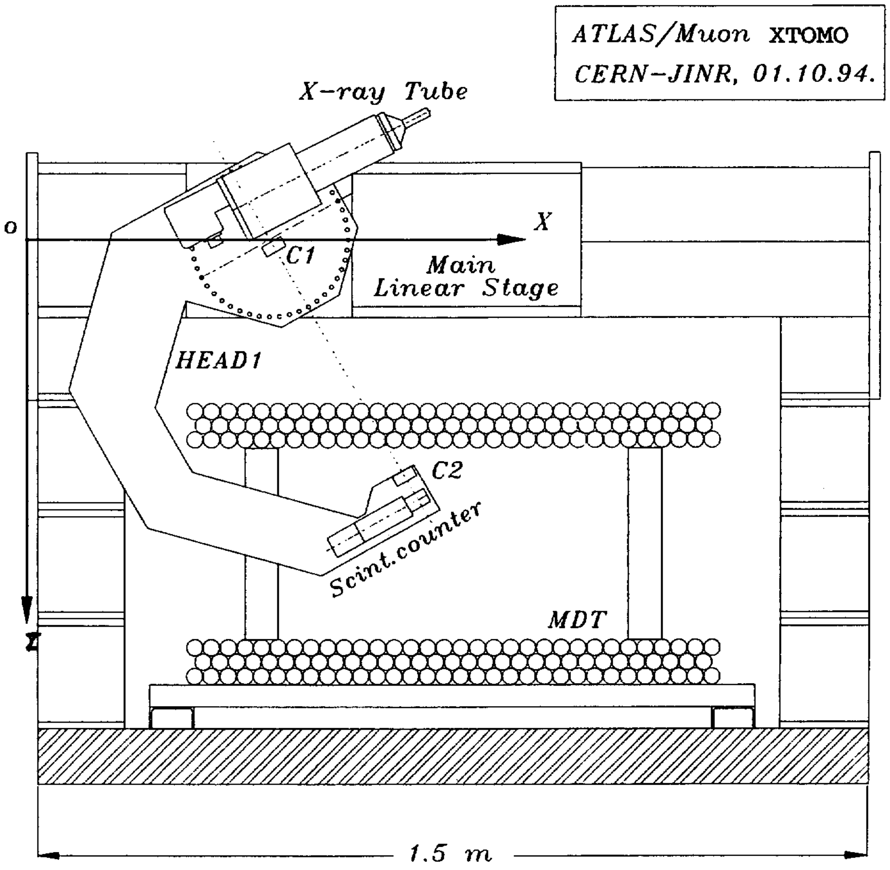


Figure 1: 'Passive' mode scanning scheme: the drift tube package placed between the collimators C1 and C2, X-ray quanta are detected by a scintillator counter.

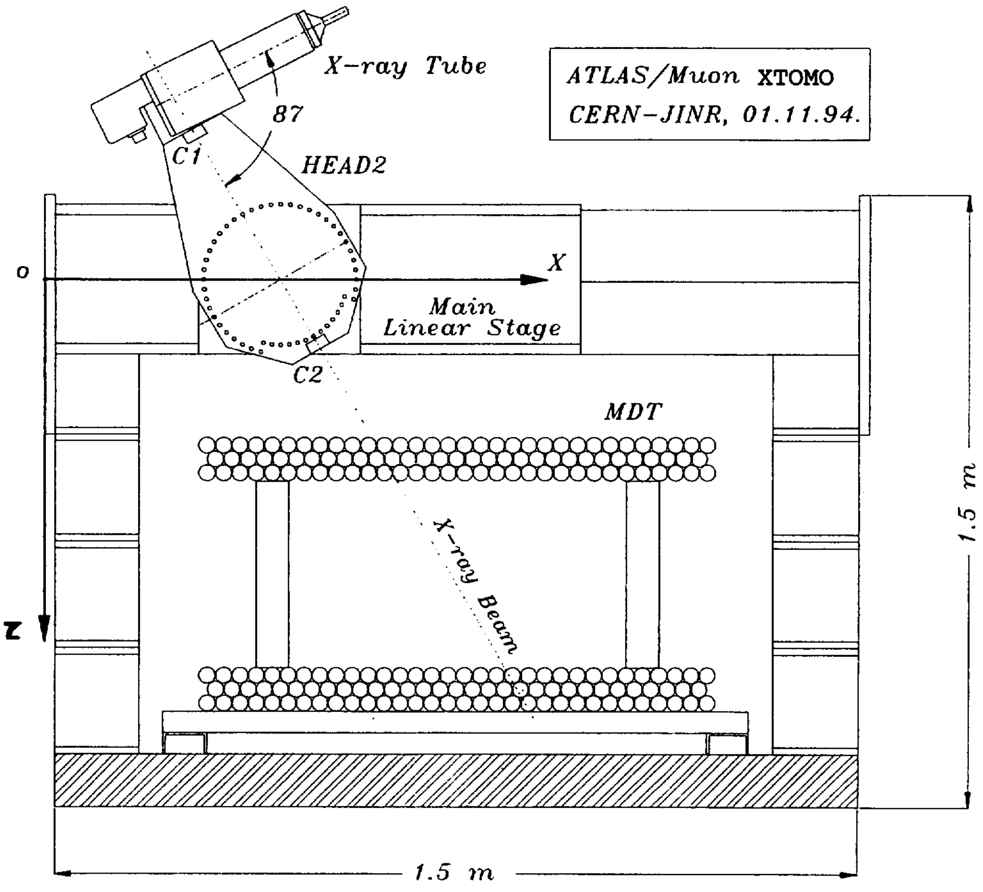
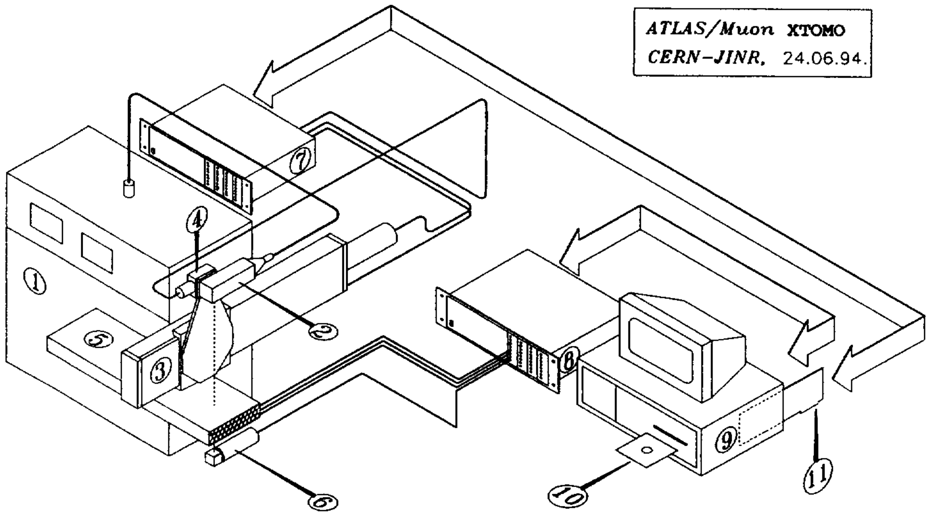


Figure 2: 'Active' mode scanning scheme: the X-ray beam is formed before the chamber, X-ray quanta are detected by the drift tubes.



BLOCK SCHEME:

① *High Voltage Unit*
② *X-Ray Tube*
③ *Scanning Linear Stage*
④ *Small Linear Stage*
⑤ *MDT Chamber*
⑥ *Scintillator Counter*
⑦ *Crate with the Motor Driving Blocks*
⑧ *CAMAC crate*
⑨ *Personal Computer (IBM386)*
⑩ *Support Software*
⑪ *PC bus-based Motion Control Board*

Figure 3: Block scheme of the X-ray Tomograph installation.

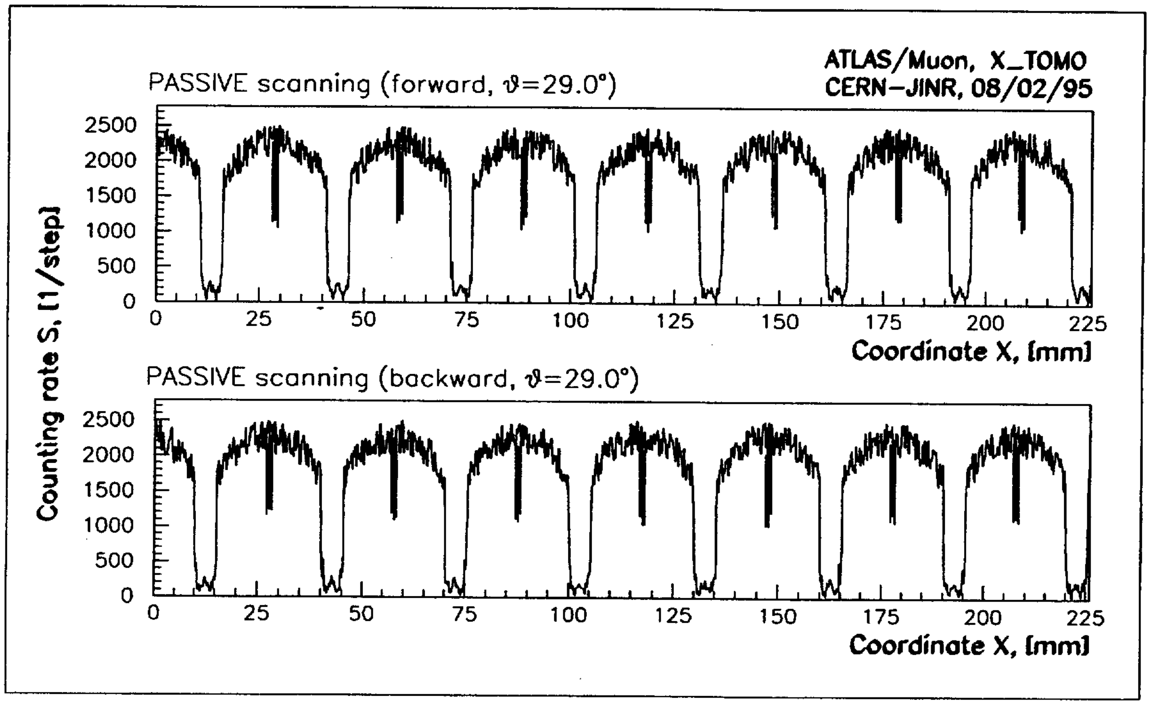


Figure 4: The 'passive' mode scanning curve: X-ray quanta counting (per step) as a function of the X-coordinate value.

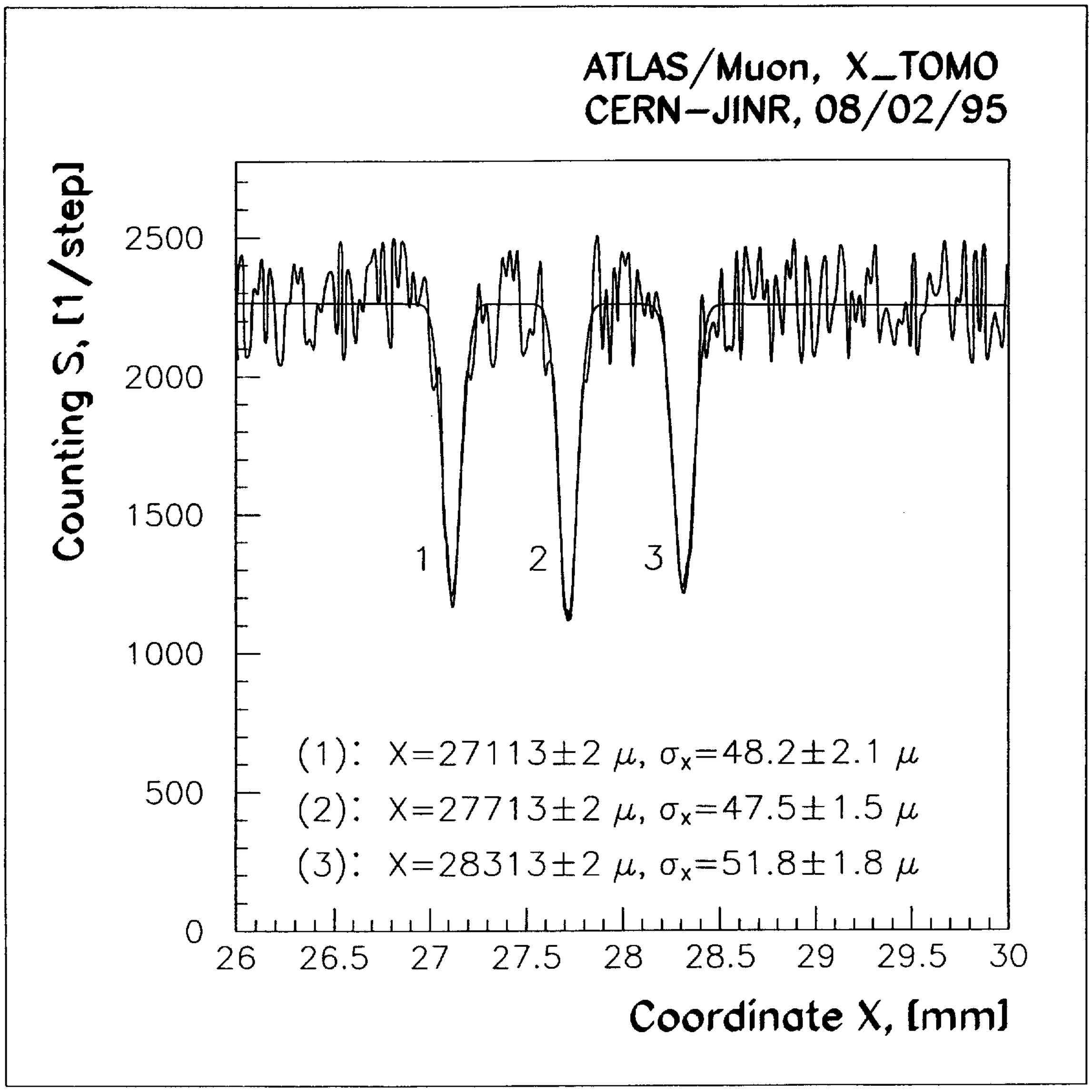


Figure 5: 'Passive' mode scanning: the shape of wire signals (3 peaks from the 3-layer drift tube package). There is shown fitting curve and its parameters values.

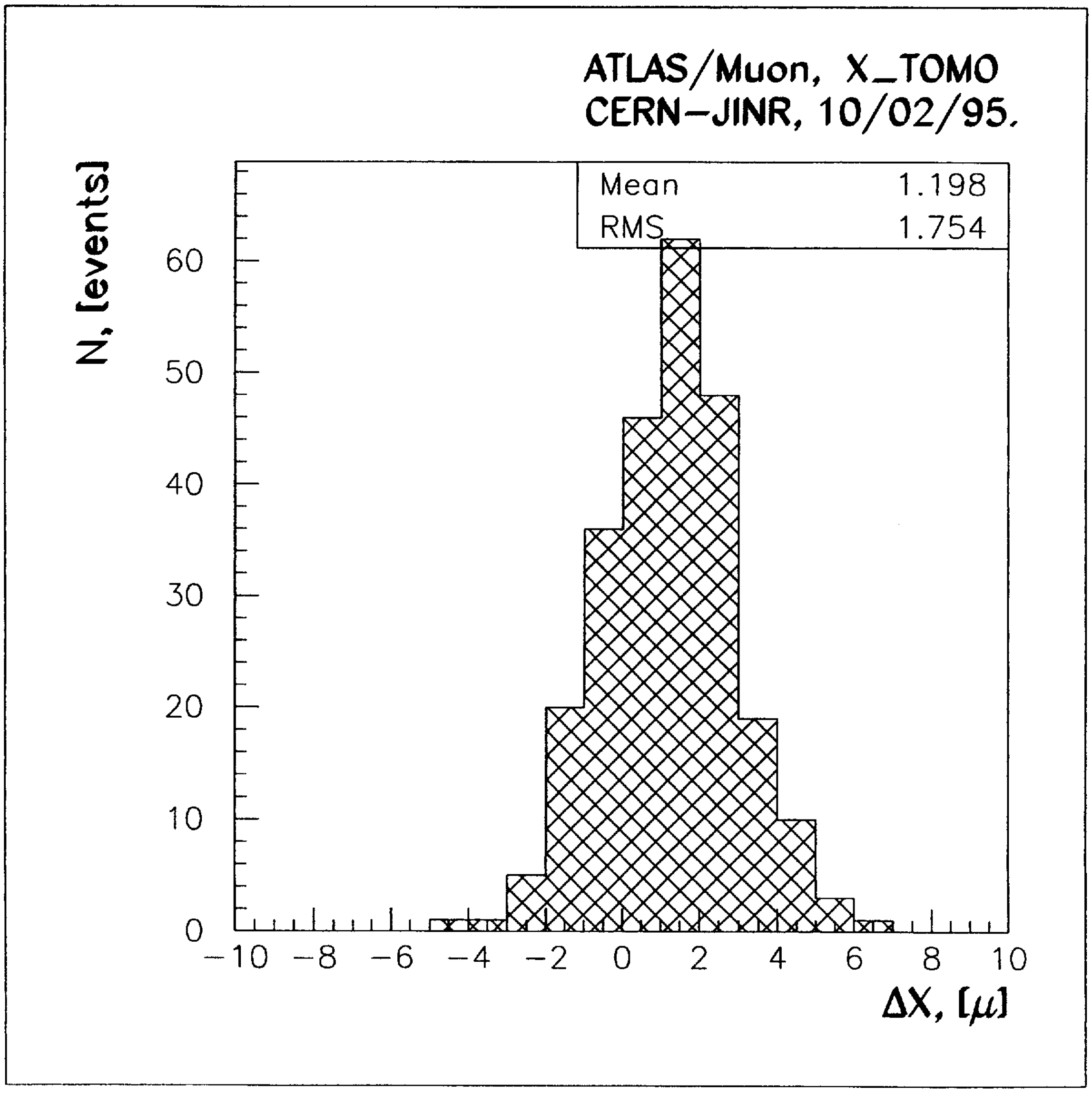


Figure 6: Repeating forward - backward scanning: distribution of the differences in measurements of the same interwire distances.

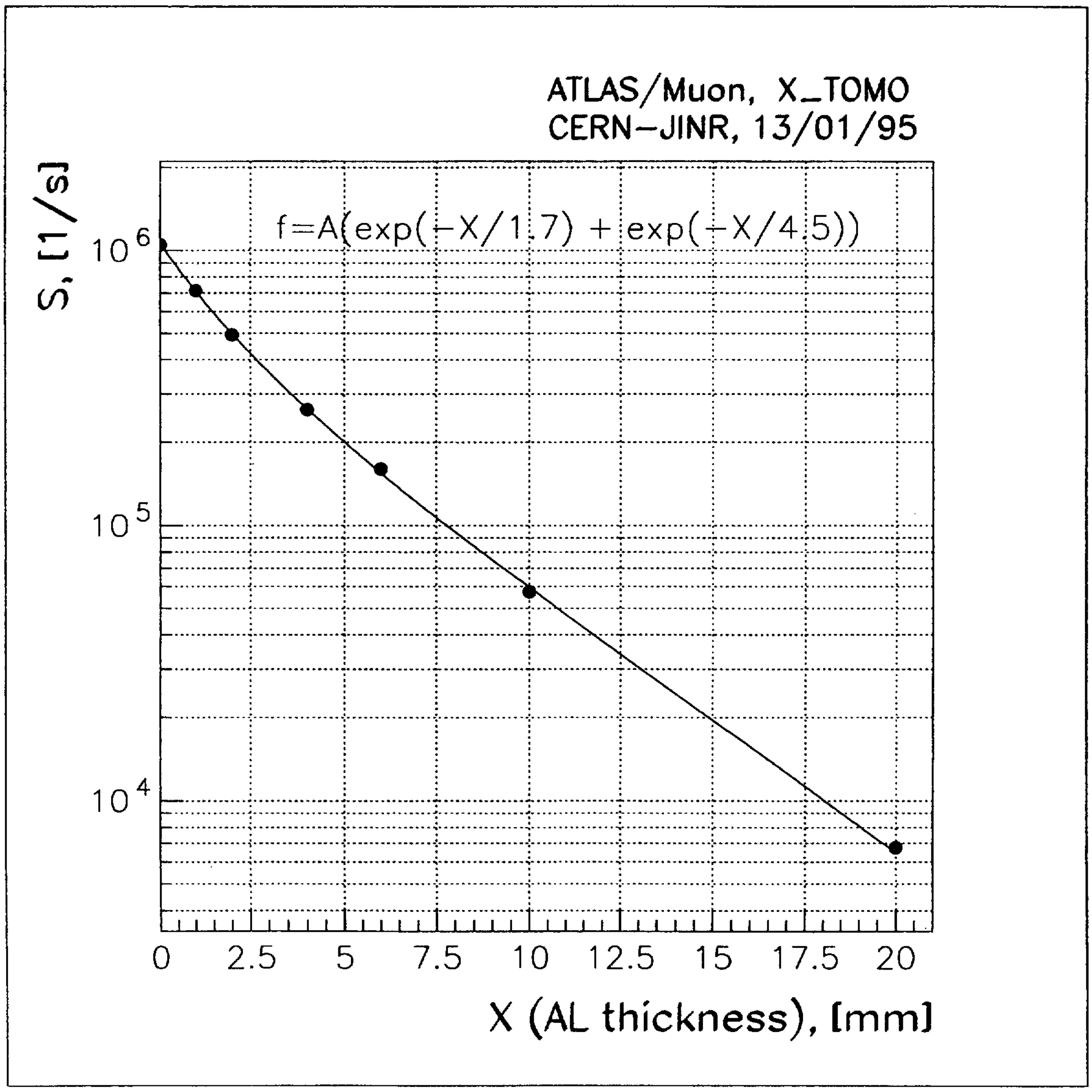


Figure 7: X-ray intensity as a function of the **Al** filter thickness. The X-ray tube parameters: Mo anode, 40kV, 10mA.

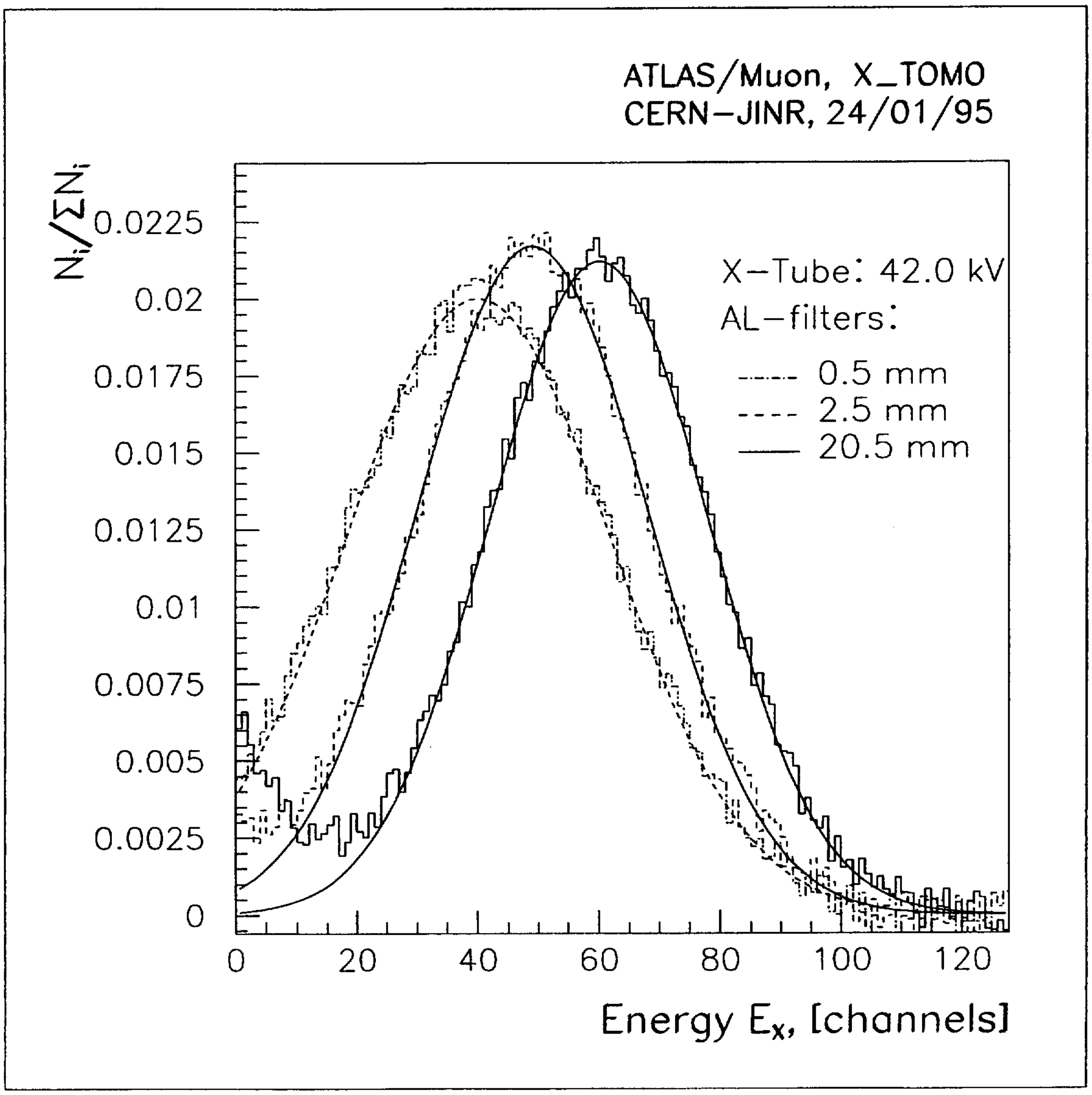


Figure 8: Changing of the X-ray energy spectrum shape with the thickness value of the **Al** filter. Energy resolution of the used **NaI** scintillator counter was equal $\approx 30\%$.

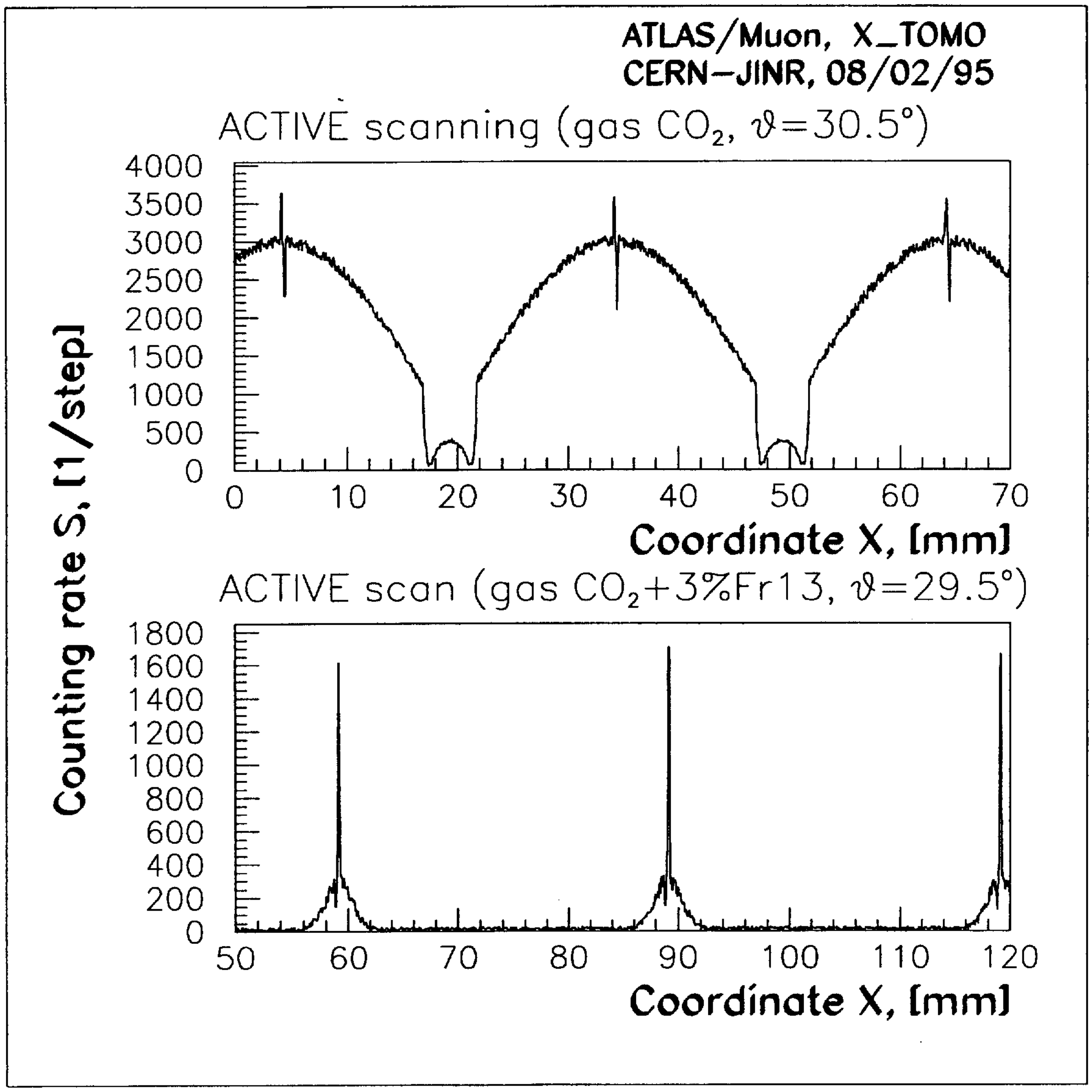


Figure 9: The 'active' mode scanning curves measured from the second layer of the muon chamber: (a) CO_2 working gas, whole drift tube's volume is sensitive; (b) CO_2 + 3 %Fr13 mixture working gas, only a small volume around the wire is sensitive.

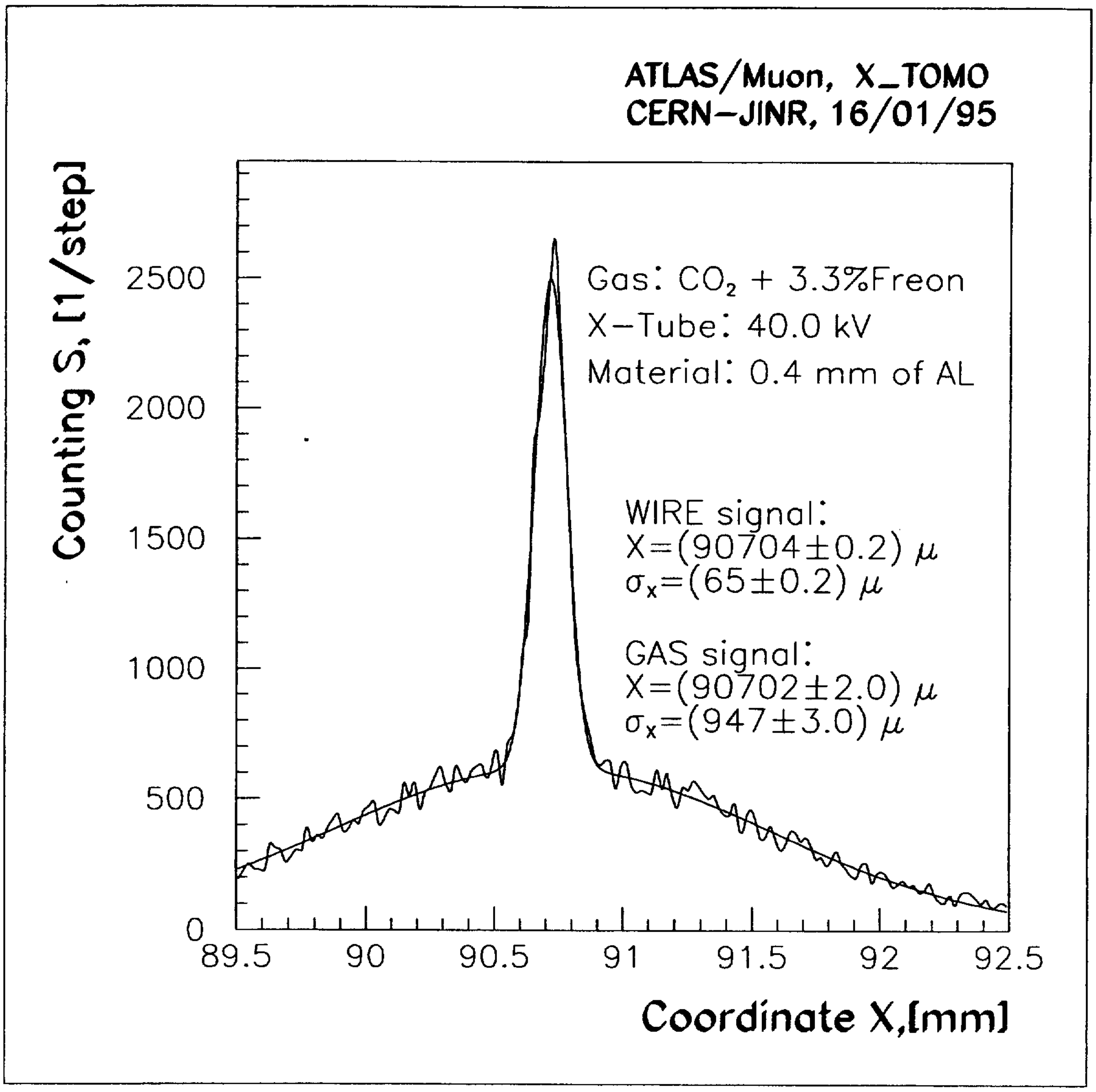


Figure 10: "Active" mode scanning (with **Fr13** admixture): the shape and fitting of the *wire signal*. Definition of the *relative* value of the wire signal: $R = A_w/A$, where A_w – *wire signal* value, A – total (*gas + wire*) signal value.

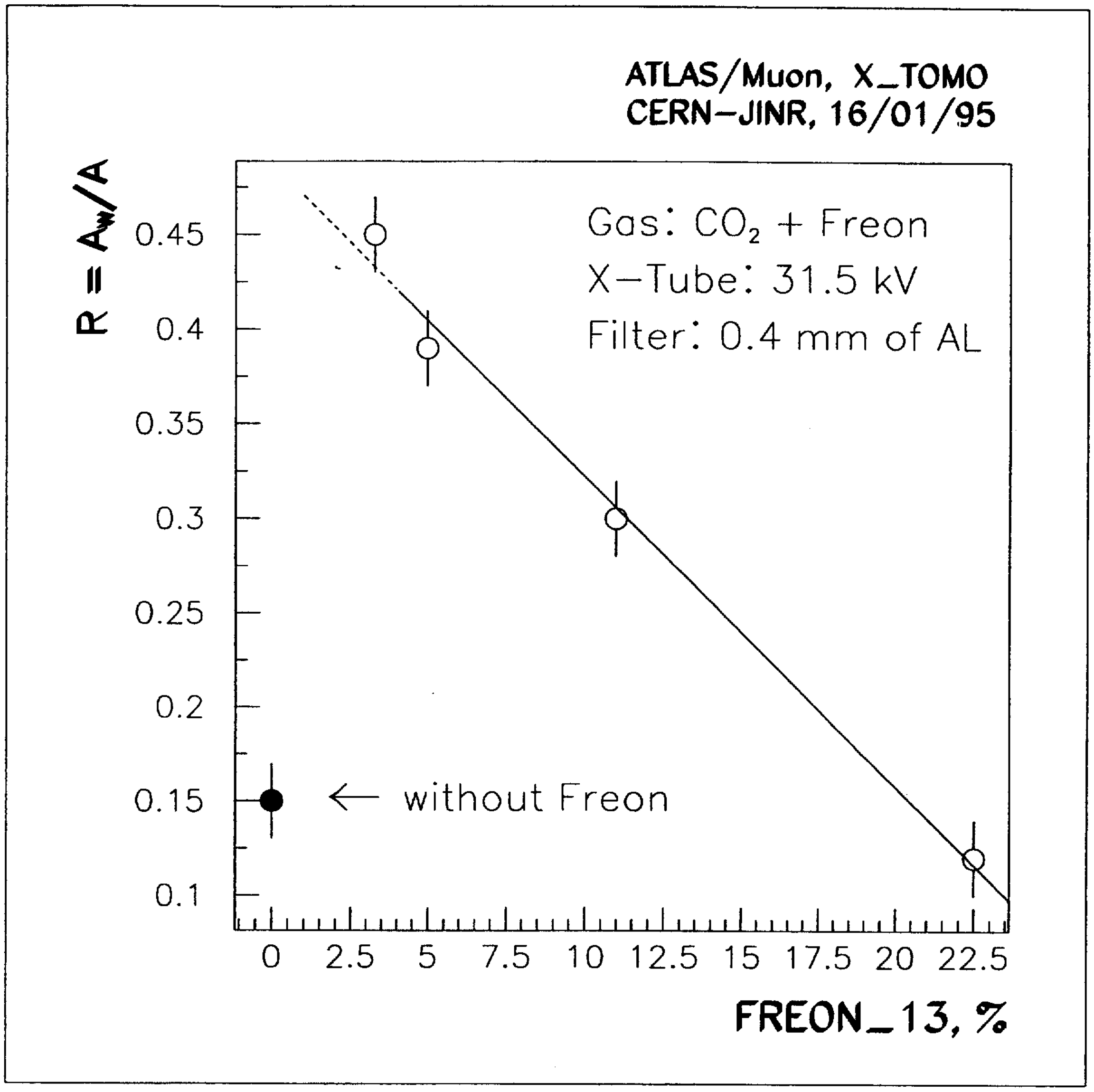


Figure 11: The relative wire signal value as a function of the **Fr13** admixture amount.

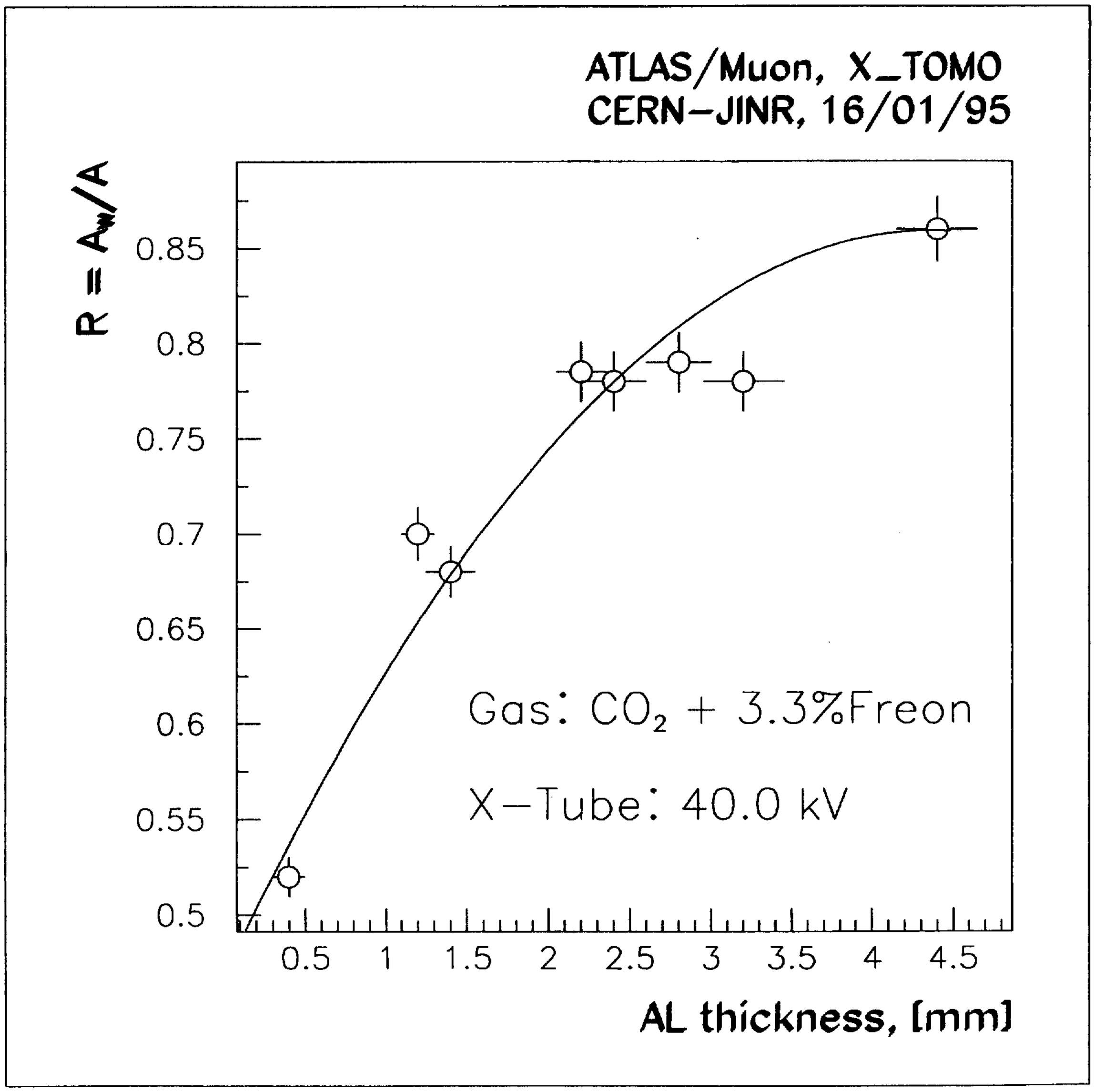


Figure 12: The relative wire signal value as a function of the Al material thickness placed before the measured wire.

APPENDIX 1. Extract from the "EMPACT Note 240, 1990" (Copy)

2. OUR CONCEPT

There are some proposals for multilayer (*muon*) modules made out from drift tubes, [1]-[4]. They hope to attain the high precision spacing of sensitive wires by using traditional high precision mechanical devices.

In our case the mechanical structure of the module is demanded to be only as a rigid and stable support for the sensitive wires. It provides also an approximate knowledge about wire spacings with 0.5 mm accuracy. A more then an order improvement of this accuracy (20 micron) will be achieved by means of the "coordinate calibration" measurement procedure using the X-ray tomograpfy. The coordinate calibration data for each wire is stored in a computer memory as usual detector calibration constants accessible by the off- or on-line softwares.

We try to follow a *mass production* philosophy: firstly to make one complex and high precision measuring device and then - produce a thousand cheap modules. So we don't want to make the thousand high precision mechanical devices!

5. TOMOGRAPH MOCKUP

We made a device that maintains the X-ray tube (7.8 keV, 100 microA), two well collimated slits (0.05 x 5 mm sq., base 50 mm) and CsI scintillator, viewed by two photomultypliers. With microscope cariage we could manually move our sample exposing it in the beam, and to measure its displacement up to 5 micron accuracy in a 20 mm range.

Two samples with plastic and aluminum profiles, [5], packed into a plastic cover were scanned. Counting rate after the sample was equal to near 1000 per sec. Our first results are summarized in two figs: relative counting rate vs the sample's displacement. Average statistical error per point is equal to 5%. In the fig.1 we can see three "signals": from two wires (Be-Cu, 0.08 mm diam., and W, 0.05 mm diam.) and from the plastic profile's rib between them. It's important that *the wire signals are on a 50% level from the background value...* The same data for aluminum profile with one tungsten wire are in fig.2.

6. NEXT STEPS

This modest success inspires us to plan for the next future:

1. To install into our scanning device a new X-ray tube with molibdenum anode and more powefull. We will try to scan a package of drift tubes and strip plates.
2. To make the second tomography test device with automatic scanning in a range of 250 mm based on the JINR Spiral Reader, and storing information into computer memory.
3. To make a "demonstrative prototype" of (muon) module with several drift tubes and strip plate layers.

7. CONCLUSION

We now well understand that we have many problems on our way. Rigid module's frame; connection between the module's reference frame and that of the Tomograph (from one side) and the supermodule's reference frame (from another side); multilayer X-ray scanning by using, may be, inclined X-ray beam, and so on. Any forms of collaboration with members of the EMPACT community are welcomed...

REFERENCES:

(1) EMPACT, An Expression of Interest, May 25, 1990, "Muon System", pages 4-1.

(2) F.Gasparini, et al., NIM, A273 (1988), 485.

(3) The same as (1), proposal with aluminum profiles, L.Osborn, MIT, Massachusetts.

(4) Proposal with a fine strip readout, A.Korytov, JINR, Dubna.

(5) Many thanks to Mr Osborne for aluminum profile samples.

APPENDIX 2. "Proposal of X-ray Scanning Device for High Accuracy Measurement of Wire Positions inside Drift Tube Package (prototype), 30 May 1994" (Copy)

INTRODUCTION

Dubna group had proposed [1] to build on the base of its experience [2] a small X-ray Scanner so to use it in the Muon Detector's R&D at 1994 for:

1. Testing of mechanic accuracy of wire positionning in all possible MDT prototypes.
2. Ellaboration of method for positionning of the Alignment System's optic elements relative to the signal wires.

Another variant of the same methodic was proposed by St.Peterburg group for alignment of straw tubes in the Inner Detector, [3]. Now, in this common proposal we are planning to investigate both variants.
We hope the direct measurement of signal wire positions in the drift tube packages will be very important for the future MDT technology. So we invite other ATLAS muon groups to collaborate with us in this Project.

PARAMETERS of the X-ray Scanner prototype:

1. Scanning distance	$600mm$
2. Accuracy of positionning	$\pm 5\mu$
3. Cross section of the X-ray beam	$(0.05 \times 3)mm^2$
4. Inclination of the X-ray beam	$(0^o - 45^o)$
5. Energy of X-quanta	$(8 - 36)\ keV$
6. Counting rate	$10^{(3 - 4)} per\ sec$
7. Scanning time	$(10 - 20)$ *sec per wire*
8. Working position	horizontal, vertical
9. Total weight of the mechanical part	$< 50\ kg$

DESIGN

The Prototype has three main parts controlled by PC/AT:
TABLE: Linear Positioner with Motion Controller (AST6060/UNIDEX100, [4]).
SOURCE: X-ray tube, shield and collimating platform.
COUNTER: System of the X-quanta counting rate detection.

Mechanical part of the TABLE is mounted on a rigid rectangular shape support. The support can be fixed and aligned in working position on some foundation.

DC servo motor and position encoder are connected with the Motion Controller by cable 4.6 m long. A some program with the base motion commands can be stored in a 32kB memory of the Motion Controller which is connected with PC through interface RS232.

At the first measurements we are planning to use a rather weak X-ray tube with anode current up to 50 microA. With help of silicon cristall monochromator it is possible to control the energy of X-quanta, [3]. We can also to test a more poweful tube (10 mA). In the last case we need to use a HV cable to connect the tube with its power supply.

Collimator Platform is fixed on the tabletop of the Linear Positioner through manual rotary stage which provide an inclination of the X-ray beam in the range of 0 - 45 degree. Indeed, for the different variants of scanning we will use different collimating systems, see fig.1 (*Not reproduced here*).

USING

1. Cross section scanning of small packages of the drift tubes. It can be done on the table in horizontal position.
2. Scanning of two or three small packages, mounted on the side of some stiffener (MDT module's prototype), fig.1.
3. Alignment of the optic elements relative to positions of wires if any module's prototype will be equipped with the Internal RASNIK system.

REFERENCES

(1) G.Alexeev, Proposal of Dubna group on the Muon Workshop meeting at 31 March 1994.

(2) L.Vertogradov "High precision wires' positions measuring in the drift tube package by the X-ray scanner (XTomograph)", ATLAS Internal Note, MUON-NO-041, 3 May 1994.

(3) O.L.Fedin, A.I.Smirnov "On a possibility to use a narrow X-ray beam for straw proportional tubes alignment", RD-6 Note 51, 16.02.1994.

(4) Catalog: "AEROTECH, Motion Control Product Guide", 1993.

JINR, DUBNA 01.06.88.

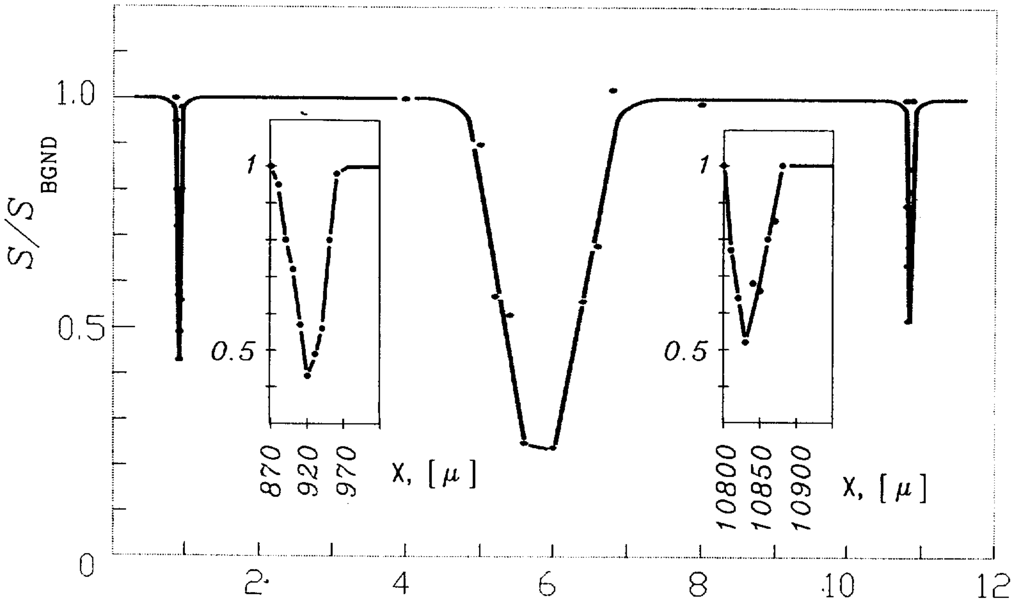


FIG. 1.

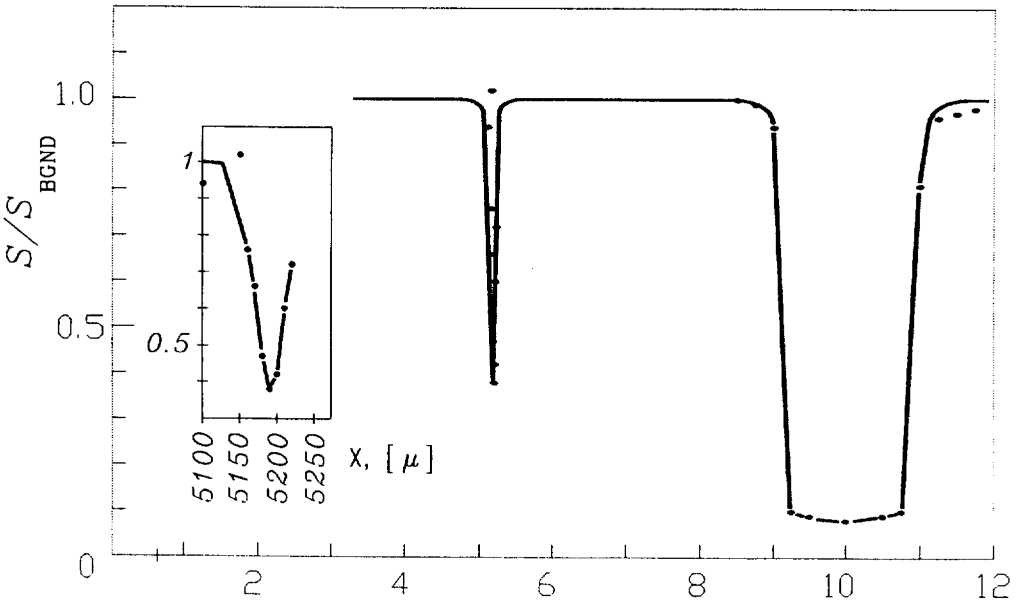


FIG. 2.