0.11 REFERENCES.

0-1 Manufacture of the Forward TRT Prototype, ATLAS INDET Note-78, Technical Note TA1/94-26

0-2 V.Ivanov et al., An X-ray Measurement Station for the ATLAS Endcap TRT Calibration, ATLAS INDET Note -161(1996)

0-3 Preamplifier for the driftchamber of the R807 Experiment.

0-4 V.Ivanov et al. An X-ray Station for the ATLAS Endcap TRT Calibration, part 2, ATLAS Indet Note - 162,1996.

Important question of the design is the temperature stability of the detector. Two wires of the cell was monitored in period of three days. On Figure 0-20 is shown dependence of the wires positions and difference between the wires position in time. The temperature was changed by two degree over day. The absolute positions of the wires are moved within 32 arcsec (155 µm on the distance 1 m.). The difference between the wires position was stable within 30µm. The changes in the positions of the wire could be explained by the movement of the wheel itself and the BDD with the metallic table.

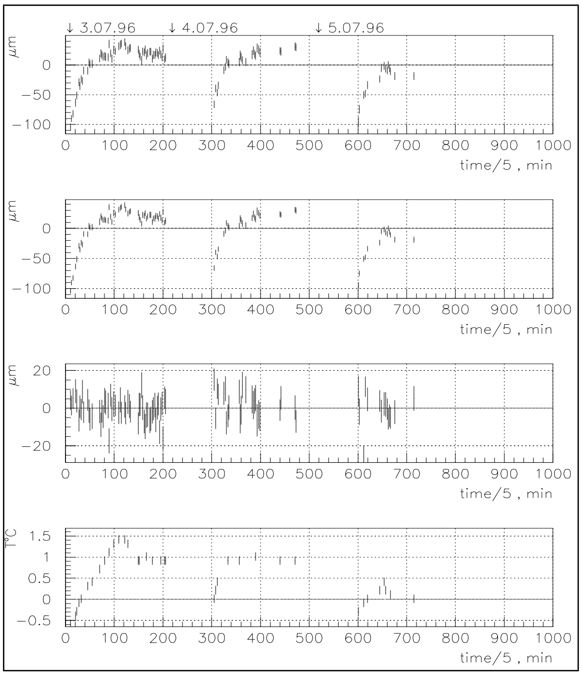

Figure 0-20 Position of the wires in time..Two top picture are position of two different wires in time. Third plot is the difference between wires position in time. Bottom plot is temperature of the wheel in time.

0.10 CONCLUSIONS.

From the experience we got from the construction and tests of the TRT wheel prototype we can make two type of conclusions. The first one is a group of questions which for our opinion was solved successfully, and second one is a group of problems need to be solved in the future final design.

As a “positive” results could be consider experience for assembly of the wheel from point of view time and manpower need for it. The mechanical stability of the wheel is quite satisfactory. The results of the X-ray measurements shows us that spread of the wires position is less then 100µm. It’s fully satisfy to value coming from the pattern recognition requirements. The mechanical behaviour of the straws is stable in the time.

The problems need to be solved during the final design work could be selected into the three groups:

1. How to obtain and maintain straight straws at the level 300µm eccentricity at production and during assembly.

2. High voltage robustness need to be improved.

3. The problem of the gas tightness should be solved.

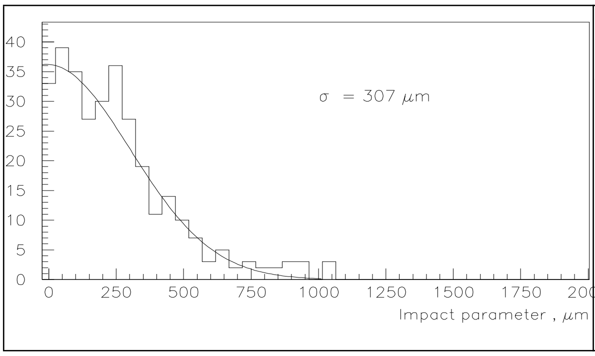

Figure 0-17 Impact parameter distribution.

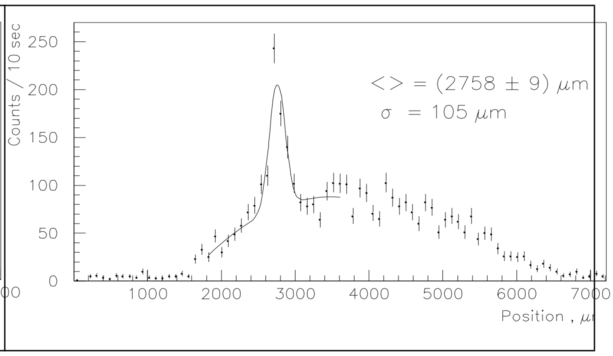

Figure 0-18 Straw profile for straw with badly installed wire.

As it was mentioned early the design of the wire guides could provide the off-set of the wire only in the one direction. Several wires which was selected as straws with badly installed wires

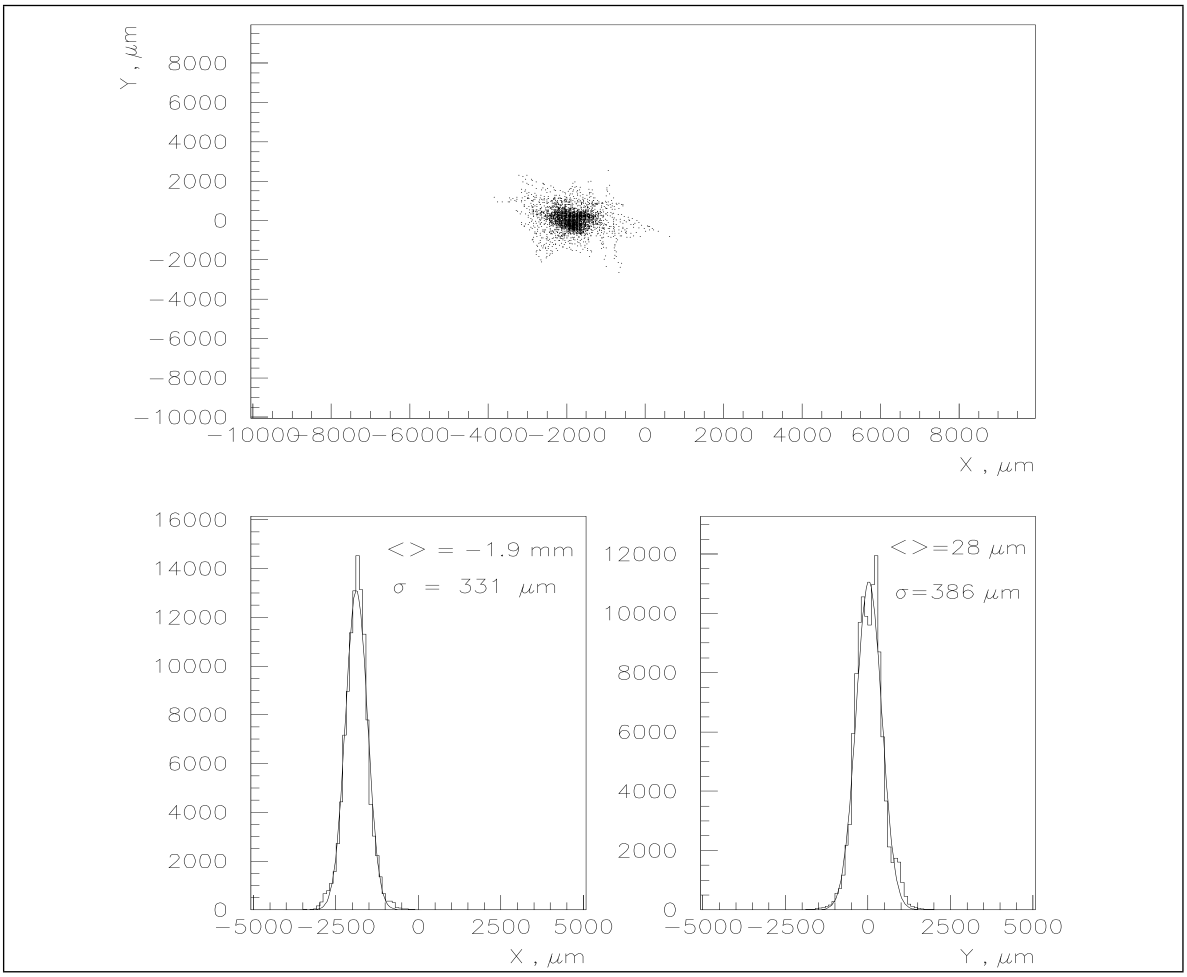

Figure 0-19 Distribution of the crossing points of the wires.

was scanned by X-ray beam at the level of outer wheel. On the Figure 0-18 is presented some examples of that scan. The eccentricity of the wires got from this pictures in the good agreement with Fe55 measurements (Figure 0-8).

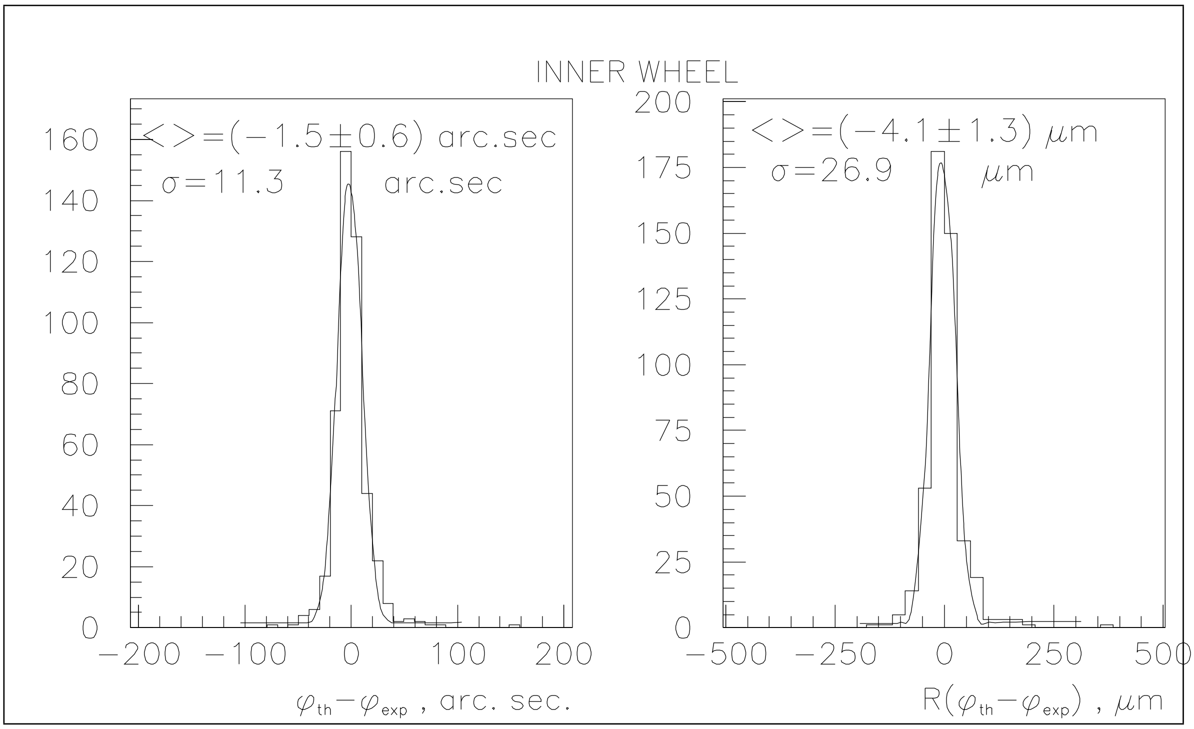

Figure 0-15 Distribution of the difference between the measured position of the wire and theoretical one at the level of inner wheel.

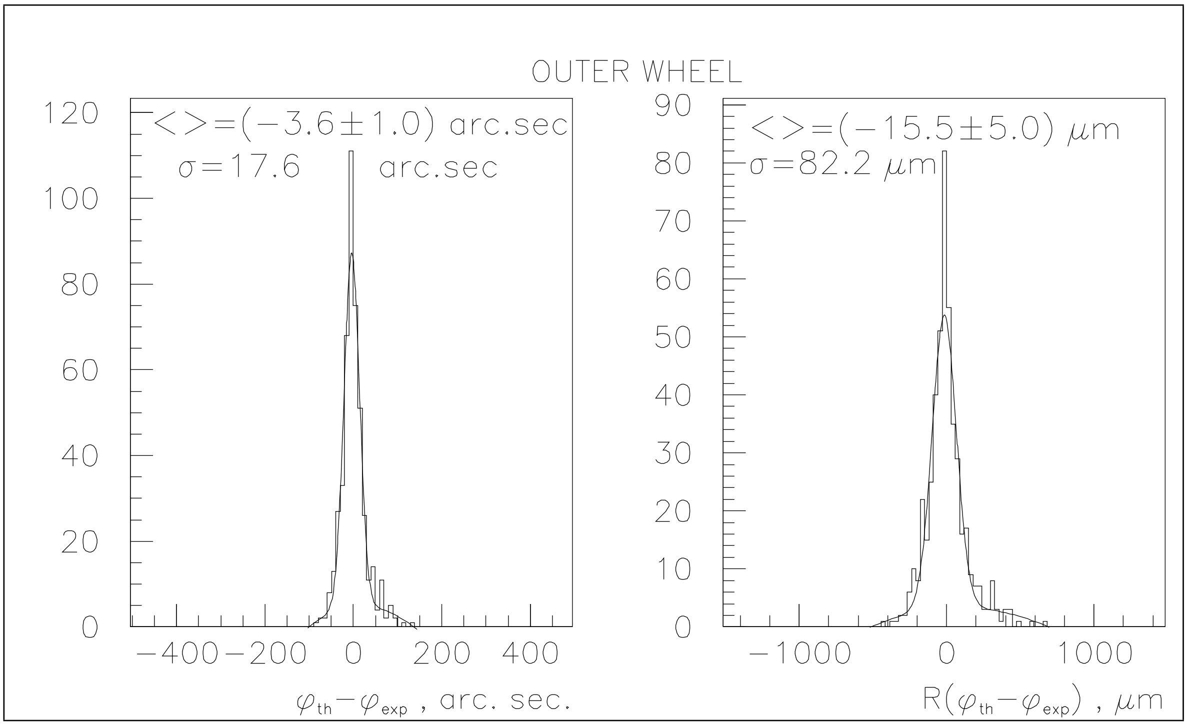

Figure 0-16 Distribution of the difference between measured position of the wires and theoretical one at the level of outer wheel.

On Figure 0-14 is shown set-up used for the measurements of the wires position in the TRT wheel prototype. The BDD device was placed on the solid metallic table in front of the wheel. The distance between the wheel and the BDD was of ~ 1200 mm. The axis of the BDD was adjusted in respect to centre of the wheel with accuracy of ~ 200 μm. All measured wires was scanned by X-ray beam at two points corresponding elevation angles θ= 25.2 grad. and θ = 37.7 grad. The corresponding centre of the wires $\phi 1$ and $\phi 2$ were obtained after that scan. Two values were calculated for each wire using these data. The first one is a angle ϕ of the each wire in the system of coordinate of the wheel. The second one is a impact parameter ρ which is the distance between the wire-line and the centre of coordinate of the wheel.

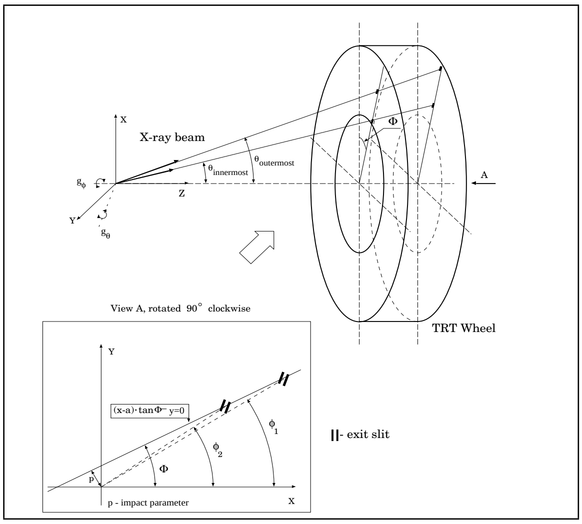

Figure 0-14 Set-up for wires position measurements.

The 10 cells (1280 wires) were scanned by X-ray beam. These were uniformly distributed on the wheel. Because 28% of the straws doesn't have a signal for different reason (see chapter 6 for detail) we can analyse information from about 800 straws.

The mean value of the wire position errors is of 5μm. The detail description of the procedure of the measurements and discussion of the factors could affect on the results you can find in the ref.[0-4]. In this note we will concentrate on the wire position results which could affect on the design of the wheel.

As was mentioned before the straws proportional tubes are placed in the holes drilled in the frames with an accuracy of 20μm. Additional pieces used to hold the straws in the wheels will increase spread of the wires position in respect to axis of the holes. Taking to the account the tolerances of that pieces we can expect accuracy of the wires position of 30μm for the inner wheel and of 60μm for the outer wheel. Difference between the inner and outer wheels accuracy due to design of the prototype ref.[0-1]. The distributions of the differences between the wires position measured and the theoretical one are shown on the Figure 0-15 (inner wheel), and on Figure 0-16 (outer wheel). The width of these distributions given us the real spread of the wires position we have in the prototype. At the level of outer wheel we have bigger spread (σ= 97μm) then we could expect. The reason is most probably come from the design of the wire guide which should provide a centring of the wire inside the straw. The positioning of the wire in the guide depends from the wire off-set in respect to guide when the wire hold by the fixation pin. For the inner wheel level this off-set rather bigger then in case of the outer wheel, because of design. For that reason we have a bigger spread of the wires position in case of the outer wheel.

The impact parameter distribution is shown on Figure 0-17. It's rather wide distribution with mean value of the ρ- parameter of ~250 μm. The FWHM of that distribution is of 300μm. But there are tail up to 1 mm., which is more probably due to badly installed wires at the level of outer wheel.

On Figure 0-19 is shown the distribution of the crossing points of the two wires- pair over all statistic. It seems the mean value of the central part of this distribution could be called as "centre of the wheel".

0.9 MEASUREMENTS OF THE WIRE POSITIONS.

A TRT wheel is a basic building block of the ATLAS Transition Radiation Tracker, which will contribute to tracking performance of the detector. In order to minimize the errors in detecting and tracking high-energy particles the position of the wires inside the TRT wheels should be known with high precision.

To measure the wires position we have used the Beam Directing Device (BDD) which was developed by PNPI. Detail description of the constriction, calibration of the BDD could be found in ref.[0-4]. The idea of that method is to scan straw proportional tube by very narrow X-ray beam (50μm width) in transverse direction and to counts the number of signals from the straw at each points of the scan. The straws proportional tube should be at the working conditions. It's so-called "active method".

Because a different probability of X-ray interaction in the working gas and in the wire material the number of signals coming from straws depends from place where X-ray beam cross the straw. The typical "straw profile" observed after the straw-scan is shown on Figure 0-12. The ac-

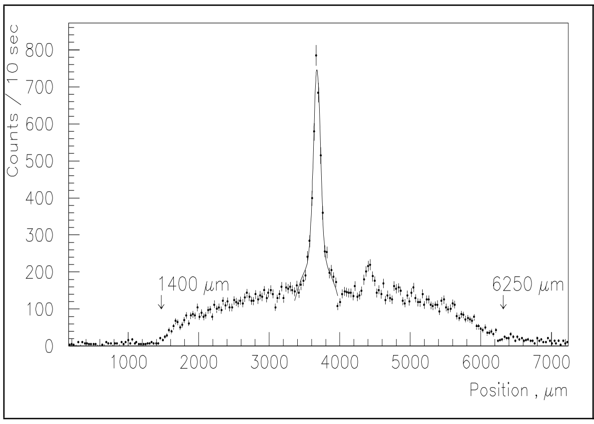

Figure 0-12 Typical straw profile after X-ray scan

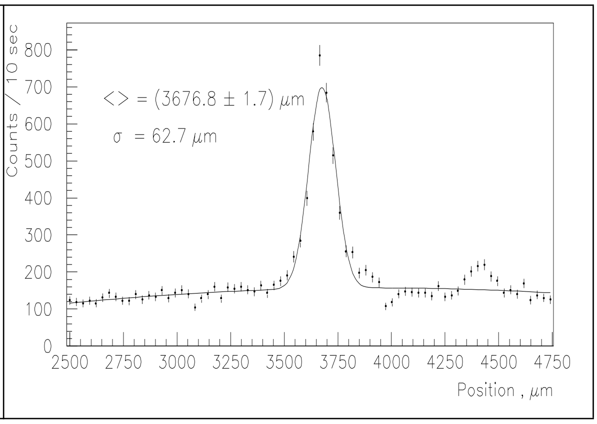

Figure 0-13 "wire region" after X-ray scan.

curacy of the wire position on distance of ~ 1m. using that method is order of few microns (Figure 0-13).

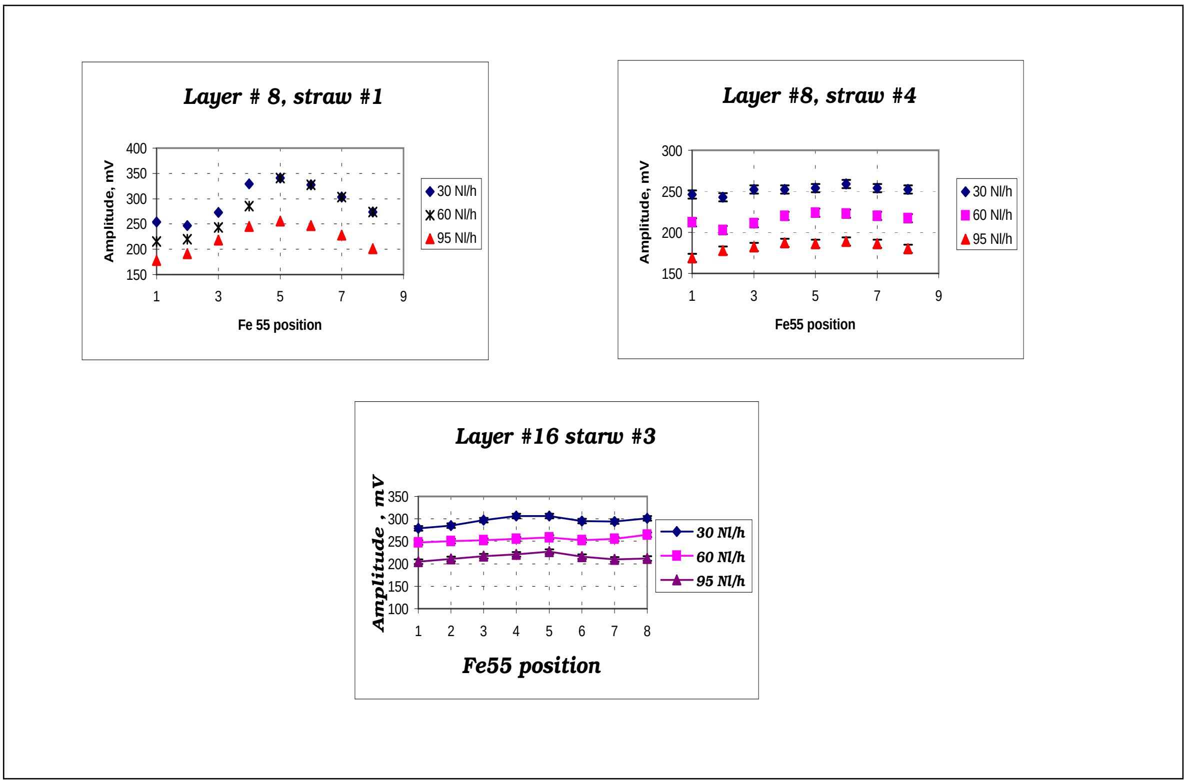

Figure 0-10 Dependence straw signal vs Fe55 position for different gas flux (several typical examples).

There are two important conclusions from these data. The straw have a maximum eccentricity of the wire at the middle of the straw length. There are drop of the signal amplitude in the last ~ 5-10 cm, in the direction of the gas flow. This drop does not depends from the value of the gas flux and most probably due to outgassing from the straw surface. Taking into account this point we can estimate the straws straightness after measurements of the amplitude of the signal only at two points: at the middle and at the edge of the straw at the gas flux input. The straw eccentricity distribution got for the measurements at two points is shown on the Figure 0-11.

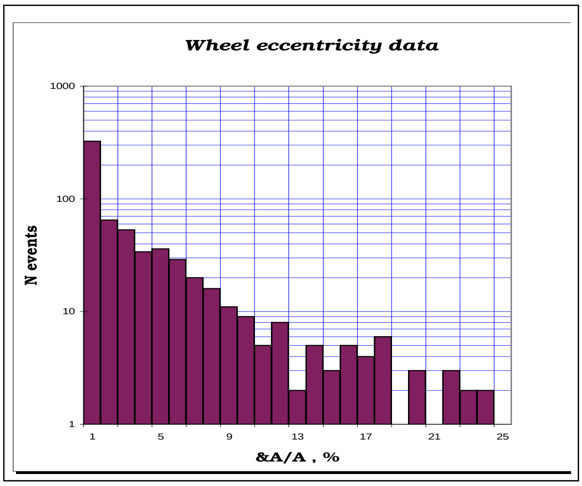

Figure 0-11 &A/A distribution after measurements of the straw straightness at two points.

where Amax and Amin are maximum and minimum amplitude of the signal. The correspondence between &A/A parameter and eccentricity of the wire is shown on the Figure 0-8.

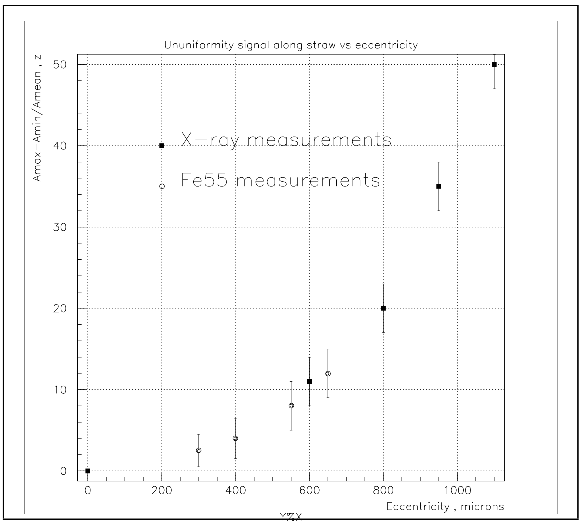

Figure 0-8 Correspondence of &A/A parameter and a eccentricity of the wire inside straw.

The first category is the straws with &A/A <5% (an eccentricity less then 300µm).The second one is the straws with &A/A between 5% and 10% (eccentricity between 300(m and 400(m). The third category is the straws with &A/A >10%.

To have best performance of the detector, straws should be straight at the level of &A/A <5%.

The first signal test was done with wheel in the vertical position still fitted to assembly table. 12 cells of 75 were tested. These were distributed in groups of three cells at approximately 90 degree to one another.

After wheel was removed from the assembly table and installed in the final position the second signal test was carried out. 11 cells uniformly distributed around the wheel were tested. The

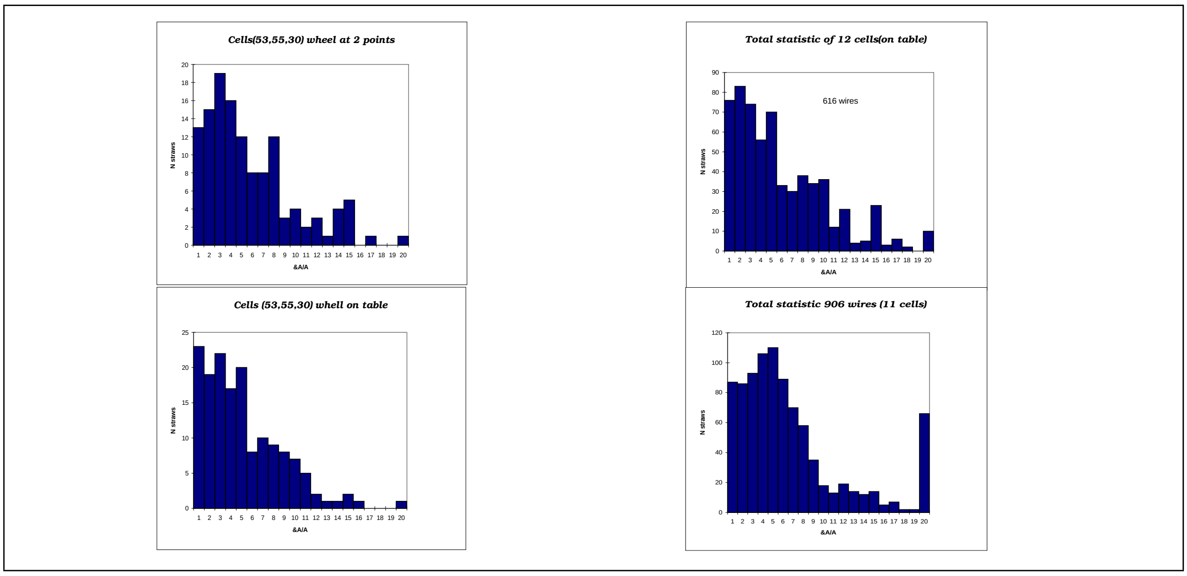

Figure 0-9 &A/A parameter distributions of the wheel for different cases.

summary of results is presented on Figure 0-9.

The comparison of the results for wheel on the assembly table and wheel in the final position shows that there are no big difference from point of view straws straightness.

The results mentioned above was got after measurements at three points along the straw length (at the edges and at the middle of the straw). To see the behaviour of the signal along the straw more carefully one cell of the wheel was scanned by Fe55 source at eight’s points. Some typical examples of that scan is shown on the Figure 0-10.

Important question for the detector is the minimum gas flux providing uniform signal in the detector. There are two problems needs to be understood. The first one, it is a minimum gas flux we need to have the uniform signal amplitude along the straw. On the Figure 0-6 is shown dependence of the signal amplitude in the straw of the wheel prototype versus gas flux. In case of the wheel prototype the minimum working gas flux per straw is of 0.2 cm3/min.

The second question: what minimum gas flux provide the uniform amplitude distribution within the one cell? To get answer for second question additional investigation need to be done in the future.

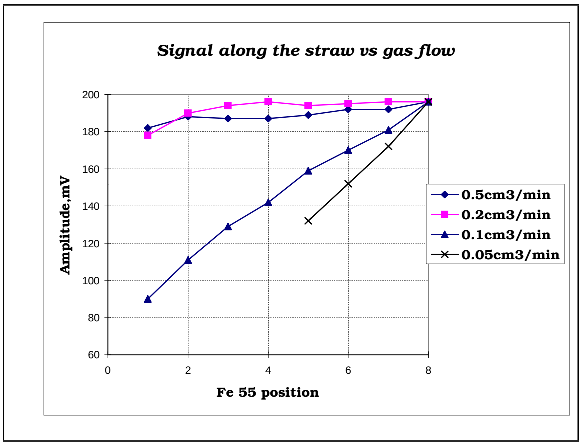

Figure 0-6 Amplitude of the straw signal vs gas flux.

0.8 STRAW STRAIGHTNESS TEST.

Eccentricity of the wire inside the straw is a important parameter of the detector performance. Two factors could affect on eccentricity wire inside the straw. It's either a straightness straw or position of the wire in the wire guides.

To understand what eccentricity of the wires in the wheel prototype, we have irradiated straws at different points along the axis of the straw by Fe55 source. In case of "ideal" straight straw the amplitude of the signal at different points will be the same. If the straw was curved or wire was fixed not at the centre of the wire guides, the amplitude will rise up because the electric field will be higher at the region where distance between wire and straw is smaller.

The dependence of the signal versus position of the Fe55 source for the different straws is shown on the Figure 0-7. It's clear seen that we can select all straws in the three groups.

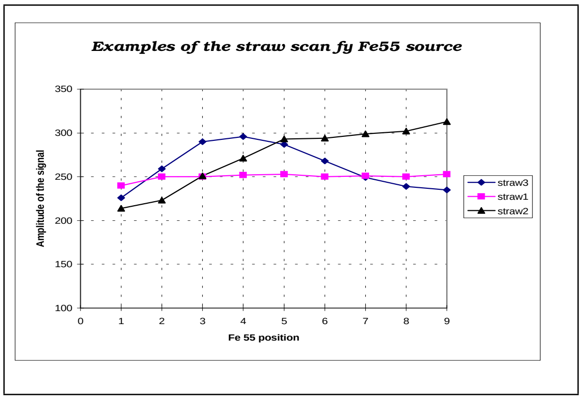

Figure 0-7 Dependence of straw signal vs Fe55 position.

The first is the group of the "banded" straws. The second is a group of the straws where wire was badly fixed in the wire guides. The third is a group of "good" straws. The banded straws group was separated into three category using &A/A parameter:

$$\frac{\delta A}{A} = \frac{(A_{max} - A_{min})}{A_{mean}}$$

The amplitude distributions of the straw signals inside the different cells are shown on Figure 0-5. To get the amplitude distribution for the cell #14 we introduced the gas mixture only

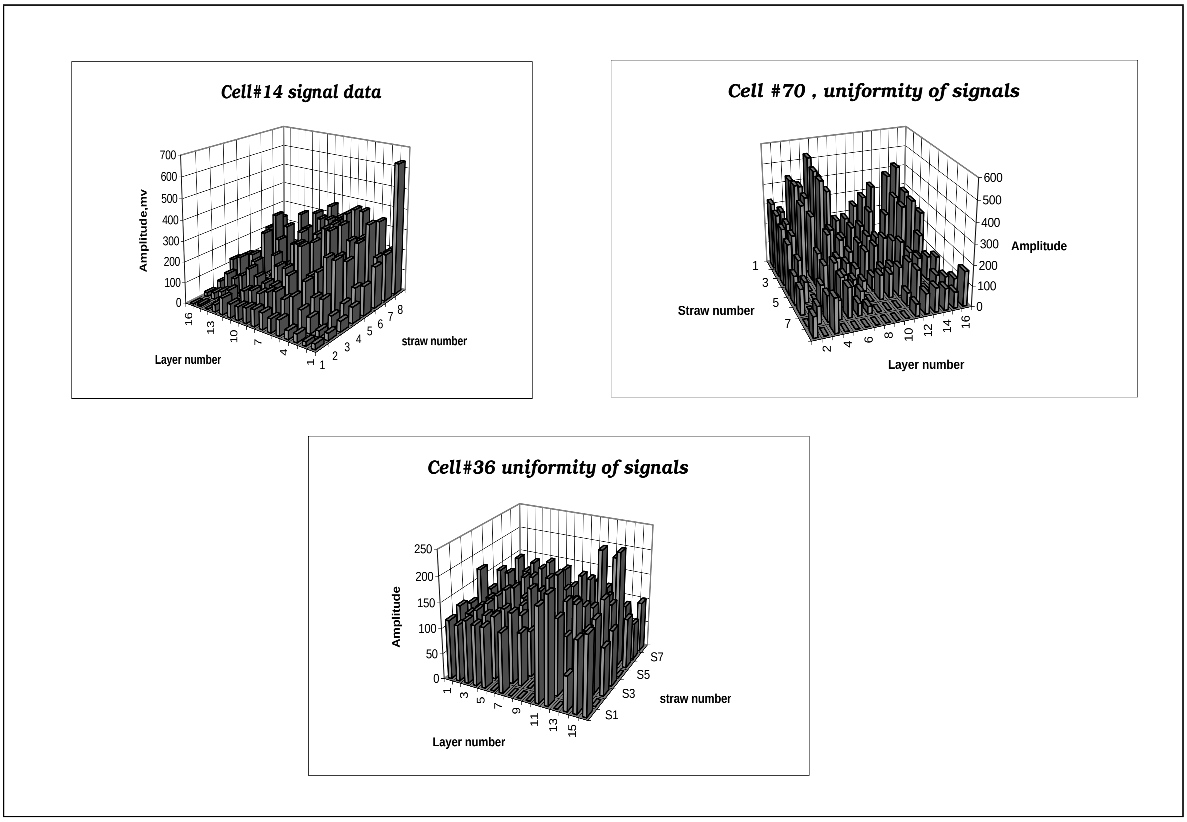

Figure 0-5 Examples of the signal amplitude distribution inside the different cells.

in that cell (not in the neighbouring). It's clear seen that there are rather big hole between the roof and the outer wheel, also between neighbouring cells. The straw #8 in the layer #1 has a bigger amplitude because wire was badly installed at the level of outer wheel (big eccentricity).

There are hole at the centre of the volume in the cell #70. It's most probably hole between the straw and the wheel.

The rest of the tested cells have a more uniform amplitude distributions inside the cell, cell # 36 for example. Some of the straws in the cell have a bigger amplitude because the wires was installed not at the centre of the straws at the level of outer wheel. We have understood where most of the leaks comes from and hopefully that problem could be solved in the final design of the wheel.

0.6 ELECTRONICS

To get signal from the straws a special connector between the roof motherboard and the preamplifiers was designed. It consist of 128 pins with spring placed on the board. These springs should provide the force enough to have good contact between the motherboard and the preamplifiers. Four printed circuits with 16 preamplifiers each are placed on the connector. Signals from the PA are coming to shaper amplifiers through 3 m length cables, and then after fan-out to the pick ADC (Figure 0-4). For the wheel test we have used PA for the drift chamber of the R807 Experiment ref.[0-3]. The PA has a rise time of 22 nsec. and the width of the signal on the base of 300 nsec. The noise level of the electronic channel was of 250 ev.

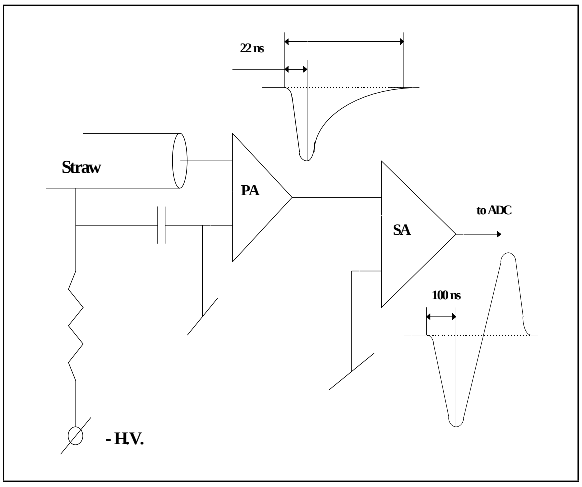

Figure 0-4 View of the one electronic channel.

The bad contact between connector and circuit on the roof, not stable cables contacts are seen for 15% of channels. These problems are not related to the wheel design.

In total, we have no information from about 28% of the straws. This can be summarized per cell as follows:

2 dead straws after rewiring

2 new dead straws since, because a slippage of the wire in the pin

1.5 groups of 8 straws have a discharge through the surface of the capacitor, short circuits or current leak at the level of few µA

9 not stable electronics channels

10 “floating” contacts of the Preamplifiers connector.

0.7 SIGNAL PROPERTIES.

All measurements for the wheel was done with Ar-CO2 mixture. It’s rather “tough” mixture from point of view discharge, but it’s a cheap and could be very simply prepared. By changing the composition of the components we can chose working voltage for the straws in the large scale (from 1300 V up to 2200V for the same gas gain).

Another reason could affect on signal is a gas tightness of the detector. As was mentioned early the wheel is separated into 75 cells. Each cell has a separate gas volume and should be gas tight. In case of leak some dangerous admixture could penetrate into the straws (oxygen, nitrogen, water etc.) and affect on the signal properties. Unfortunately the present design can’t provide gas tightness at the acceptable level ~ 0.1mbar/min. at the working gas flux. The leak rate we reached for the time being is around 5mbar/ min.

0.5 HIGH VOLTAGE ROBUSTNESS.

The straw proportional tubes of the wheel will operate under high voltage ~1800 V for the gas mixture Xe- 70%, CO2- 10% and CF4- 20%. It means that electrical system of the wheel should be stable from the point of view discharges and current leaks for the potential difference between the anode wires and the walls of the straws order of 2000 V. The set-up shown on Figure 0-3was used to understand the high voltage robustness of the system. At the beginning the wheel was tested at 1900 V. without gas mixture (in the air) and after that with Ar-CO2 mixture.

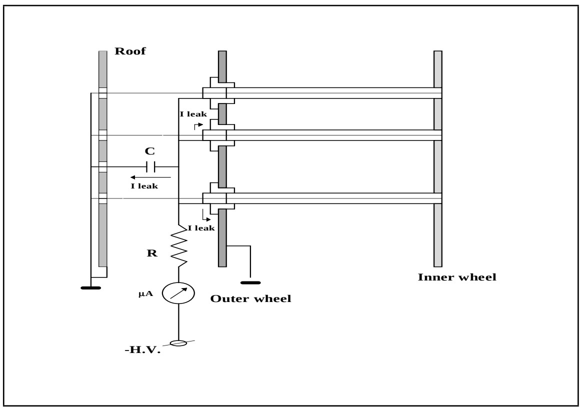

Figure 0-3 Set-up for wheel High Voltage Test.

Several “electrical” problems were found during the high voltage test. Four straws per cell in average have either broken wire or wire with low tension. That problem due to the big spread of the metallic pins diameter. These pins were used for fixation of the wires at the level of outer wheel.

In case of discharges a broken wire might come into the cell volume. If it is happened a group of more then 8 wires could be lost. On average two new wires per cell have appeared over almost a year, possibly because the wire tension has decreased (slippage in the pin).

Some group of the straws has a current leak through surface of the coupling capacitor. That leak of order few microampers is usually disappeared after ~ half an hour, but sometimes it is very stable. Several straws have a current leak through surface of the insulation socket to the ground. It should be noted that a current leak at the level 1-5 µA simulates signals indistinguishable from the particle signals.

To avoid the problems mentioned above a some improvements need to be done in the final design:

1. the wire fixation system should be more reliable
2. in case of wire broken it should not leave the straw tube
3. the surface of the capacitor should be open and in case of a problem could be possible to replace the capacitor by new one
4. the surface of the insulating element between the straw and the wheel should be big enough to avoid any current leak through it.

0.4 SET-UP FOR THE TEST.

The experimental set-up for the wheel test is shown on Figure 0-2. The straws was irradiated ei-

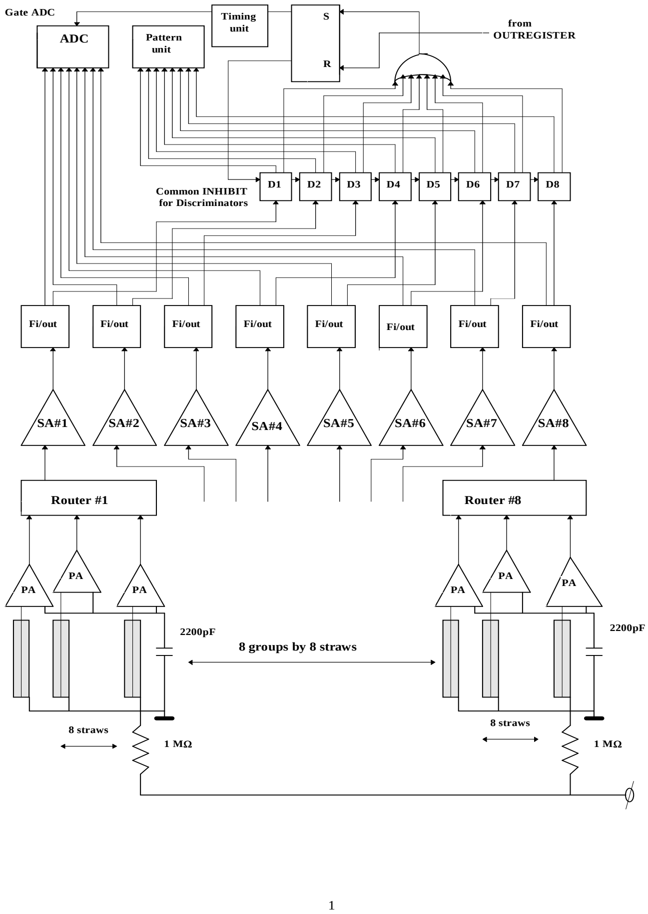

Figure 0-2 Set-up of Wheel prototype measurements

ther by Fe55 source, to get information about the wires eccentricity, or by X-ray apparatus to see position of the wires. The group of 8 straws is connected to the one router module. That module could have on the output signal from the straw you want to analyse at present time. Finally we can look at the signals from 8 straws at the same time. This electronic scheme was chosen to reduce background in the neighbouring straws in case of X-ray measurements and to minimize the number of electronic modules for test.

Two kind of measurements was done using set-up mentioned above. The first one, it's a measurements of the straws straightness and the signal properties using Fe55 source. Second one it's a measurements of the wire positions in the wheel using the X-ray apparatus (BDD see ref.[0-2]).

precision of 20 μm. All straws were equipped with a copper/beryllium wires pretensioned with a 70 gram force. The detector is divided into 75 cells of 128 straws each. One cell has a separate gas volume, high voltage distribution system and motherboard read-out plate. Electrically each cell is divided into 16 group of 8 straws each.

The straws are made from two polyimide film, with 2000 Å aluminium covered with 4 μm carbon polyimide mixture. These two film are wound to form the 4 mm diameter straw with a wall thickness of 60 μm. The straws are then reinforced by gluing four carbon fibres along the straw wall, giving stable mechanical properties.

65 cells of the detector were equipped with a 50 μm wires and 10 cells with a 30μm wires. The position wires inside the straw is provided by wire guides (see ref.[0-1] for detail) with accuracy of 10 μm. The pieces used to attach the straws to the inner and outer wheel are different. As a result the precision of the wires position in respect to frames at the level of inner and outer wheels are different. We could expect the wire position accuracy at the level of inner wheel of 30 μm and at the level of outer wheel of 60 μm.

The straws in the wheel are under tension of ~ 150 grams per straw to avoid the possibility of the straws buckling due to the self weight of the device. To make the straws under tension the inner wheel was expanded by 200 μm in the radial direction before the straws were glued at the level of outer wheel. That procedure could affect on the straightness of the straws and therefore on the uniformity particle signals along the straw.

0.3 GOALS OF TEST.

The main goal of this tests is to understand problems we have in the design of the end-cap TRT. These problems could be divided into three main groups of questions:

1. Mechanical accuracy of the wires position and eccentricity of the wires inside the straws.
2. Mechanical behaviour of the detector in time, influence of the temperature and humidity.
3. Test of the design ideas (high voltage robustness, gas tightness of the detector, signal properties, choice of the materials etc.)

0.1 INTRODUCTION.

The combined straw tracker (TRT) as a part of the ATLAS inner detector has to provide tracking and contributes to the electron identification over the whole inner detector rapidity coverage. The detector is consist of 4mm diameter cylindrical drift tube (straws) layers interleaved with stacks of 15 μm polypropylene foils to produce transition radiation from relativistic particles.

The TRT detector will be built in three different blocks: two end-cap TRTs with radial straws and one barrel TRT with axially-oriented straws.

The end-cap TRT modules (18 at each end) have depths 13.4 cm along z and are of three different types (different number of straws).

0.2 ENGINEERING PROTOTYPE

To get experience with assembly, gas circulation, mechanical precision and stability, and high voltage robustness the full scale engineering prototype of the end-cap TRT was constructed (Figure 0-1). This is a full azimutal wheel with 9600 straws distributed in 16 planes. The straws

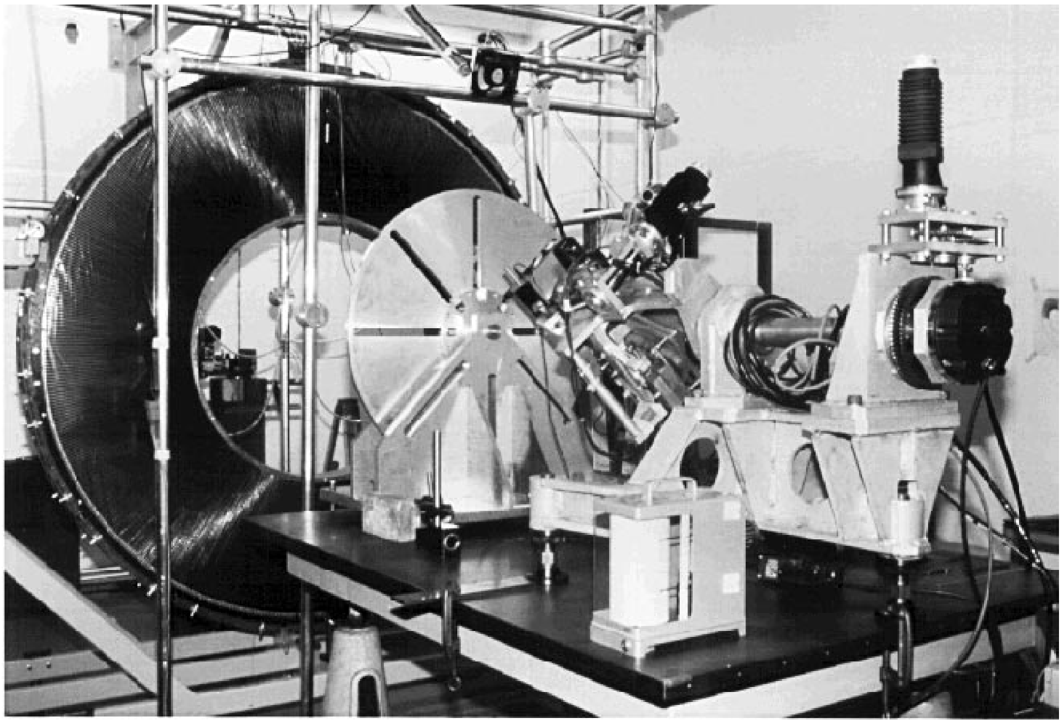

Figure 0-1 view of the TRT Wheel prototype and X-ray measuring device(BDD).

are held between an inner and an outer wheel. The outer wheel is made of a carbon-fiber composite and the inner one of Kevlar composite. The straw positioning holes were drilled with a

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E.David, M.Delattre, N.Dixon, A.Folley, O.Fedin, D.Froidevaux, W.Fuchs, C.Hauviller, V.Ivanov , A.Jelamkov, L.Kottelat, S. Muraviev, F. Perez, Y.Platonov, M.Price, C.Rivoiron, L.Rouleau, A.Smirnov, C.Schillinger, V.Schegelski

TEST OF THE TRT END-CAP WHEEL

1997