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# A NOVEL APPROACH FOR AN INTEGRATED STRAW TUBE-MICROSTRIP DETECTOR

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**Abstract**

We report on a novel concept of silicon microstrips and straw tubes detector, where integration is accomplished by a straw module with straws not subjected to mechanical tension in a Rohacell® lattice and carbon fiber reinforced plastic shell. Results on mechanical and test beam performances are reported on as well.

PACS.: wire chambers, straw tubes, HEP detectors, silicon detectors, silicon microstrips, beauty quark, CP violation.

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## 1 CONCEPT

Modern physics detectors are based on tracking subcomponents, such as silicon pixels and strips, straw tubes and drift chambers, which require high space resolution, large geometrical acceptance and extremely large-scale integration. Detectors are often requested demanding requirements of hermeticity and compactness that must satisfy the minimization of materials. We have developed an integration solution that accommodates straw tubes and silicon strips in a common structure.

Our novel design utilizes straw tubes mechanically non-tensioned and embedded in a Rohacell® lattice.

## 2 BTEV DETECTOR

Experiment BTeV[1] at the Fermilab proton-antiproton collider Tevatron produces and studies the elementary particles composed of the heavy quark beauty, in order to investigate the phenomenon called CP violation, and understand if the Standard Model of particles and interactions is sufficient to describe the world we live in. BTeV is composed of tracking detectors (pixel, strips, straws) for detection of charged particles, RICH Cerenkov detector for identification of pions, kaons and protons, crystal EM calorimeter for detection of neutral particles (photons and $\pi^0$), and muon detector.

## 3 M0 CONCEPT

M0 is a special straw module which houses straw tubes and supports silicon microstrip detectors planes. M0 is made of straw tubes embedded in a Rohacell® foam, inside a Carbon Fiber Reinforced Plastic (CFRP) shell. CFRP is chosen to allow the fabrication of a rigid mechanical structure with high transparency to incoming particles. CFRP is also used for M1 modules, conventional straw tubes sub detectors that act as struts sustaining the mechanical tension of remaining straw modules. Six straw-microstrips stations are deployed in BTeV, each station made of three views, each view made of two half-views. Straw lengths vary from 54 cm in the first station to 231 cm in the sixth station.

## 4 FEA VALIDATION

A Finite Element Analysis (FEA) of these structures allows us to estimate the displacements of the M0 and M1 modules under the loads of the micro-strips and straws tubes. Time stability and maximum displacements of the order of 10μm are requested, in order not to spoil the space resolution of microstrip detectors. The FEA analysis has been carried on the M0 of the sixth station, the longest straw length. A straw load of 1.4N in each corner of M0 has been simulated to reproduce the mechanical tension of wires. A load of 12.3N and a momentum of torsion of 2Nm have been applied to simulate the weight of the micro-strip. The used material properties are reported in the table below. FEA shows a maximum displacement of 15μm (4 μm in the axial direction, 2μm x direction, 11μm y direction), close to the required specification. We have used shell elements for the simulation of the carbon fiber reinforced polyester structure and bricks for the Rohacell® simulation. Beam elements were used for introducing glue between the CRFP modulus and the cylindrical plate where microstrips were placed.

| | M0 and M1 structure | Micro strip Cylinder | Rohacell Foam |
|---|---|---|---|
| Thickness [mm] | 0.07 each ply with fibres disposition of $0°/90°/0°$ | 0.07 each ply $(0°/90°/0°)$ with a Rohacell foam of 5cm | 2 |
| $E_{11}$ [GPa] | 260 | 590 | 0.019 |
| $E_{22}$ [GPa] | 10 | 10 | - |
| $G_{12}$ [GPa] | 7.2 | 7.2 | - |
| $\nu_{12}$ | 0.3 | 0.3 | 0.3 |

## 5 Tomography and FBG

A check of the eccentricity of the straws and of their positions in the grooves can be done with tomography method. The tomography uses X-ray and can reconstruct sections of the scanned region. Due to the short X-ray wavelength of about 0.1nm, the technique determines the amount of inner surfaces and interfaces of micrometer dimensions. Computed images are reconstructed from a large number of measurements of X-ray transmission. The result images are bidimensional, but a 3-D image is allowed using a digital reconstruction.

Results show how a precision of about 20μm can be reached on the measurement of straws radii. The maximum variation from circularity allowed is 100μm. The BTeV detectors utilize Fiber Bragg Grating (FBG) sensors to monitor online the positions of the straws and microstrip. The optical fiber is used for monitoring displacements and strains in mechanical structures such as the presented straw tubes-microstrip support. A wavelength selective light diffraction along the FBG sensor is placed in the fiber, and it permits an on-time monitoring of the support. According to these proprieties, an FBG sensor is going to be placed in the M0 and M1 structure between the Rohacell® foam and the CFRP strut.

## 6 Prototype

MOX prototypes have been fabricated in order to study the construction procedures, mechanical properties, material characterization, and physical behaviour for detection of particles, in test beam set-ups. The most demanding design requirement is the assembly of straws in a close pack, with no mechanical tension applied. Several gluing techniques have been examined and tested to determine the optimal technique. Straw tubes are glued together in three layers, and the upper and lower layer are glued to the Rohacell® foam.

Glues with different viscosity, and several gluing techniques, have been used. Glues tested range from cianoacrylate (Loctite 401) to epoxy (Eccobond series). Gluing techniques ranged from brush, to injection, to spray gluing. The most promising results have been obtained by using Eccobond 45W and catalyst mixture (1:1 by weight), diluted with dimethylcheton solvent. For each 40g of glue-catalyst mixture, 40cm$^3$ of solvent was used.

The assembly process proceeds as follows. Stainless steel rods are inserted in each straw tube. A straw layer is formed by locating 48 straws on machined grooved plate. The glue-solvent mixture described is sprayed, with 2bar air pressure, and 20cm distance between spray gun and straw layer. After curing at room temperature, straw layers are sprayed again and layers are superimposed. After additional curing, stainless steel rods are removed from straws. Conductive contact is accomplished via spraying of Eccobond 57C.

## 7 COSMIC RAY AND TEST BEAM RESULTS

Preliminary results with cosmic rays show very clean pulses in gas mixtures of interest for BTeV (Ar-$CO_2$ 80/20), as shown in Fig.5. Prototypes have been exposed to beam particles in the Frascati Test Beam Facility [7]. Preliminary results show the expected response of prototype to minimum ionizing particles. The distribution of drift times of gas ions to the straw wire (Fig.6) over the straw 2mm radius is compatible with the drift velocity in Ar-$CO_2$ (80/20) gas mixture used.

## 8 CONCLUSIONS

We have developed a novel concept for integration of straw tubes tracking detectors and silicon microstrip detectors, for use in HEP experiments at hadron colliders. In our design, silicon microstrips are integrated to a straw tube special module MOX via a CFRP mechanical structure. Detailed Finite Element Analysis shows that deformations affect negligibly the tracking performances of the system. A complete system based on Fiber Bragg Grating sensors --- acting as optical strain gauges --- monitors the position of each sub detector with a micron-resolution. The special straw tube module MOX is realized via straws embedded in a rohacell lattice with no need of mechanical tension. Preliminary results show that the MOX can provide the 100μm resolution needed by the BteV tracking detector requirements.

## 9 ACKNOWLEDGEMENTS

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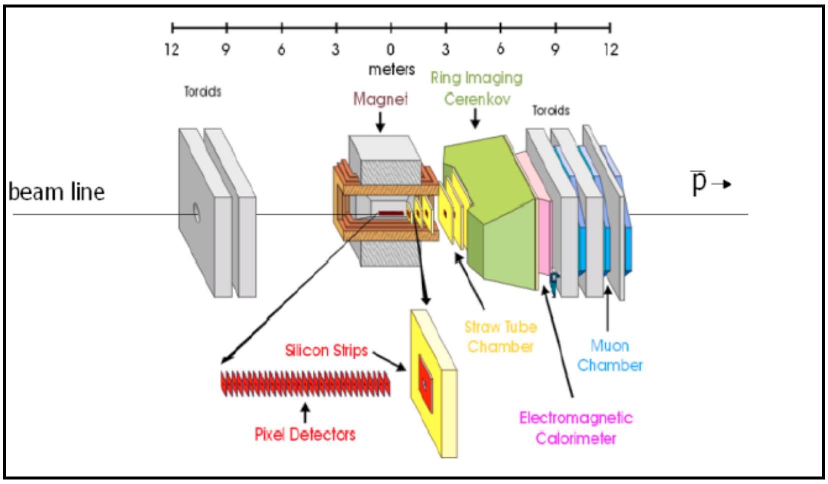


*Figure 1: BTeV detector layout.*

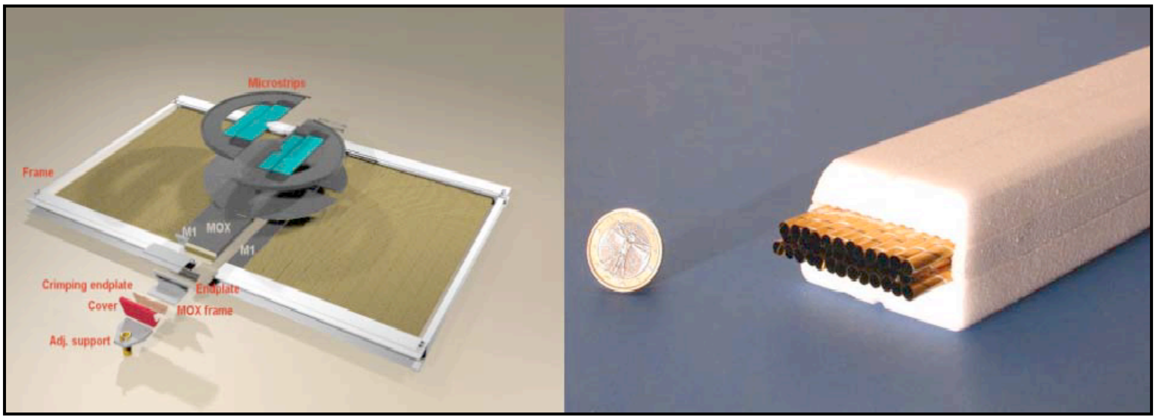


*Figure 2: BTeV microstrip and straws tubes integration (left); MOX prototype with straw tubes embedded in Rohacell®.*

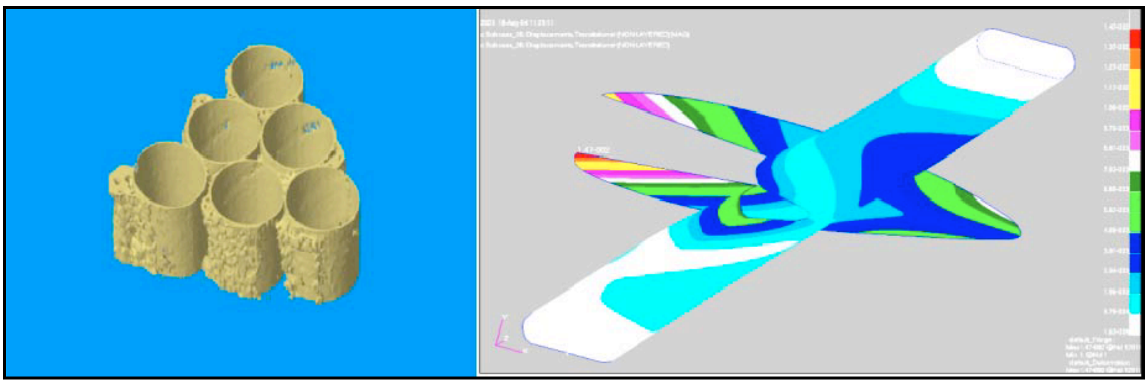

*Figure 3: Tomography 3D reconstruction of MOX prototype (left); FEA results on MOX CFRP shell(right).*

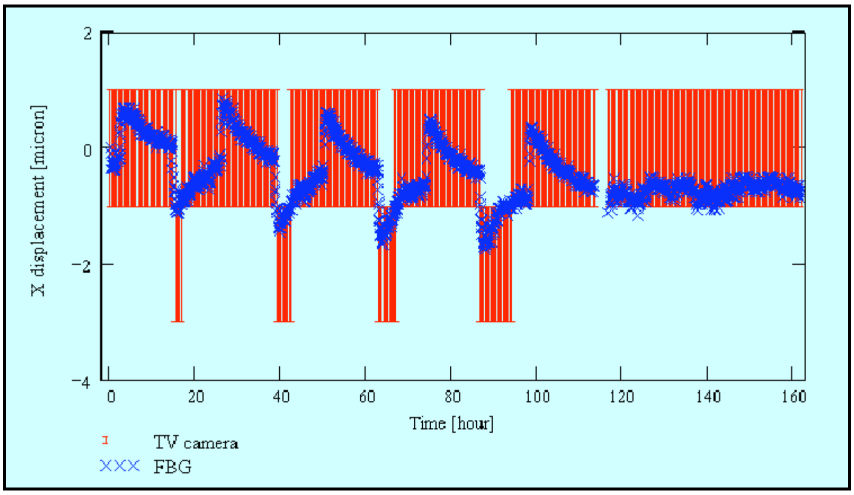


*Figure 4: FBG long-term monitoring stability results. FBG output (crosses) is validated by TV camera (bars).*

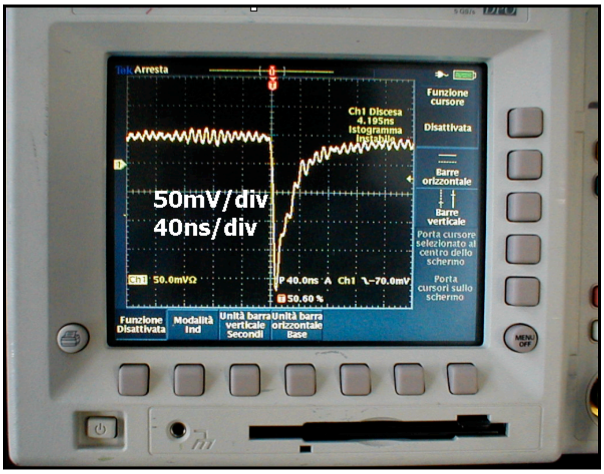


*Figure 5: Cosmic rays signals in M0X prototype.*

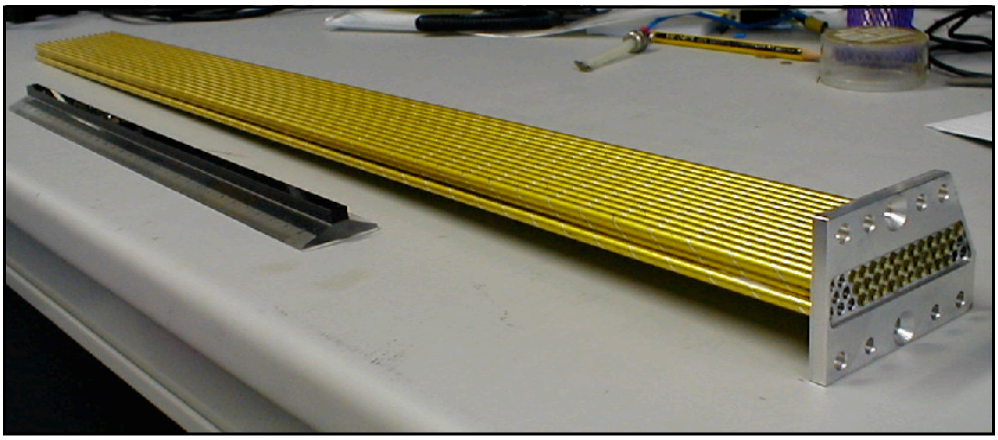

*Figure 6: MOX module prototype. Straw tubes are glued together and positioned between end-plates (one shown) without mechanical tension.*

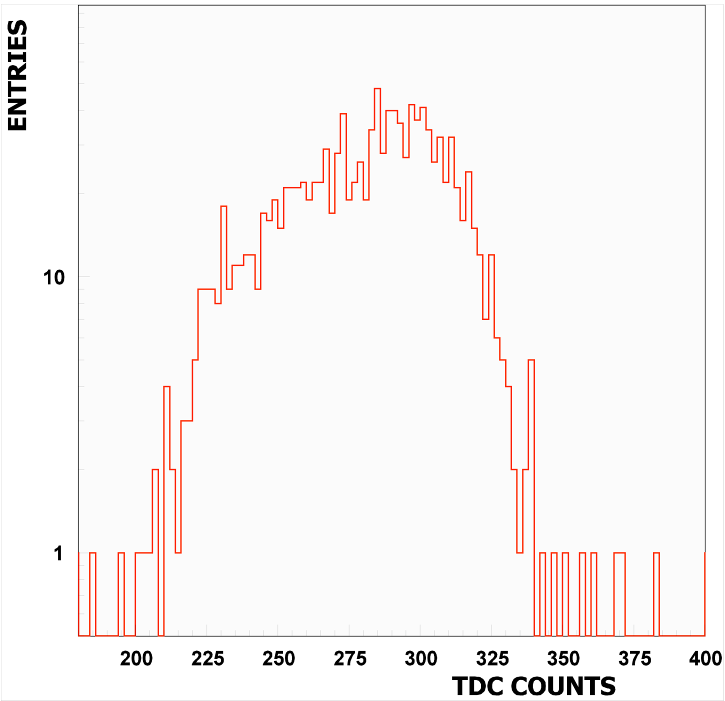


*Figure 7: Arrival times for beam particles to MOX wire. Times are expressed in Time-To-Digit-Converted channels (300ps/count).*