A SILICON STRIP DETECTOR FOR STAR

SSD STAR

star.in2p3.fr

IReS Institut de Recherches Subatomiques STRASBOURG Strasbourg, France

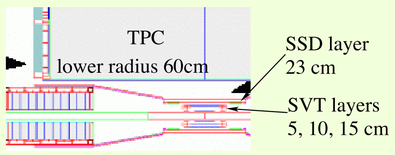
Wydział Fizyki Politechnika Warszawska Warsaw, Poland

SUBATECH Nantes, France

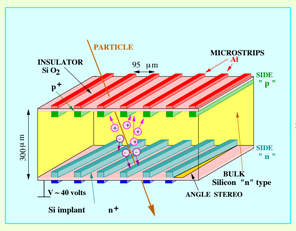
Goals

Introduction

In order to extend the tracking performances in the central part of the STAR detector a barrel of Silicon Strip detectors (SSD) will be inserted between the Time Projection Chamber (TPC) and the Silicon Vertex Tracker (SVT). This yields an extra space point which helps for the extrapolation of tracks determined in the TPC toward the interaction point via the SVT hits.



Characteristics of SSD



* double sided
* wafer size 75x42 mm
* 768 strips per side
* the pitch is 95 µm on both sides
* the stereo angle is 35 mradian
* the depletion voltage is around 30 V

Requirements and constraints

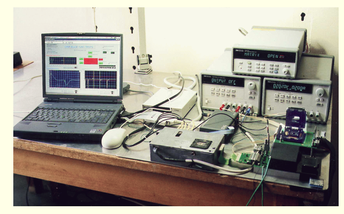
To reach the assigned goal, the position has to be determined in two dimensions with a resolution of around 30 µm in Rϕ and 800 µm in Z. Also, due to the high density of tracks expected at RHIC, dN/dy around 2000 in central collisions which makes a hit density up to 0.3 cm^{-2}, the granularity of the strips has to be high enough so that the occupancy level stay below 5%.
This constraint imposes a large number of independent channels.

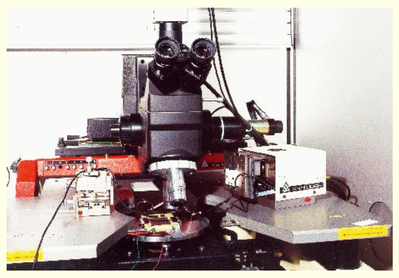
500 000 channels

Production & Tests

A128c readout chip test

Readout chips, as well as Costar control chips, are tested on a dedicated automatic test bench. The 5000 chips are individually tested in order to determine their defective channels and gain.





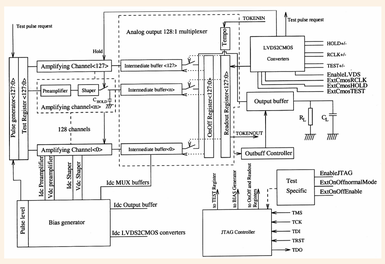
Detector tests

All 400 delivered detectors have been tested on an automatic probe station which yields all strip characteristics (leakage current, coupling capacitor, resistance).
These results provide:
* the depletion voltage
* the leakage currents
* the number of dead strips on each side

Design

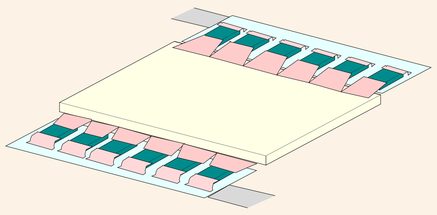
Readout chip

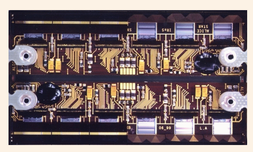
The A128C readout chip has an analogue and a numeric part. The former treats the signals from the strips of the detector whereas the latter is intended for remote control and tuning of the first functionality.
The main characteristics are:
* 128 input channels
* 13 MIP's dynamical range
* ENC = 290 e + 8 e /pF
* JTAG numeric controller
* shaping time adjustable between 1.4 and 2 µs



Module assembly

The barrel is made of 320 detection modules (20 ladders of 16 modules each). A module consists of one detector, 12 readoud chips placed on two hybrids (one per side). Due to the large density of hits, there is one electronic channel for each strip of the detector.
Thus, the chip has to be located as near as possible to the detector itself. A special bonding technique, the Tape Automated Bonding (TAB) is used to assemble all this elements together.
It allows to fold the two hybrids supporting the Front End Electronics (FEE) on top of the detector, making the module a compact object whose size does not exceed the sensitive area of the detector.





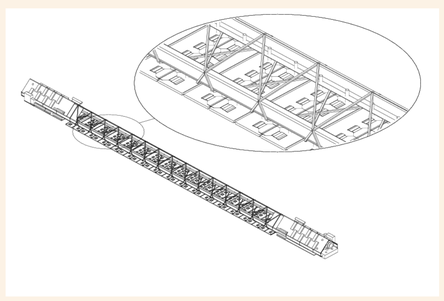
real size

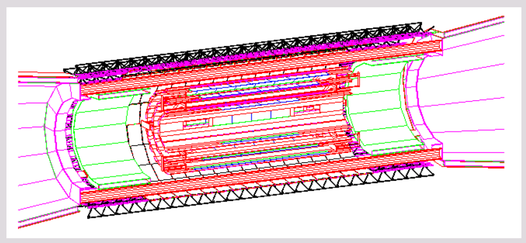
The total thickness including electronics and mechanical support represents around 1% of radiation length

Mechanical support

Ultra–light and rigid ladders made of carbon fiber were designed to support 16 modules each and the associated electronics boards which allows the readout of these modules.

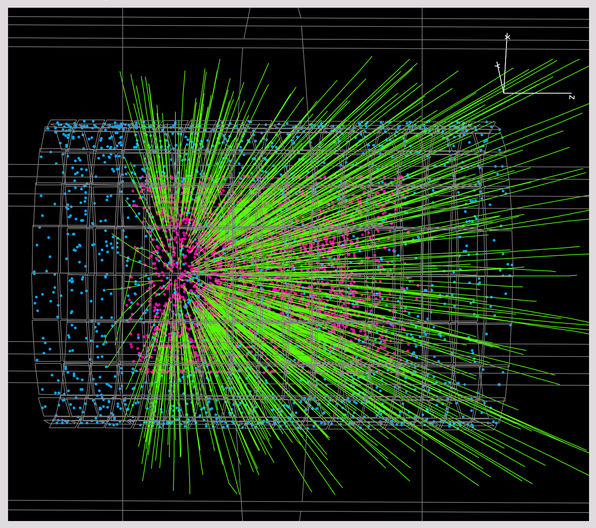
The cooling is perform by sucking up air at one end of each ladder which can be considering as a tube. This technique has been chosen so as to minimize the thickness of materials.

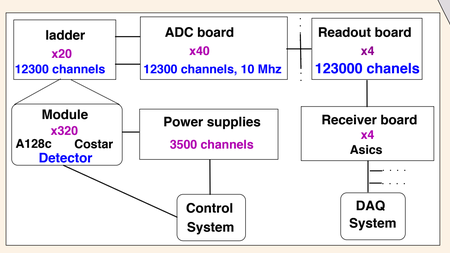




The SSD surrounding the 3 SVT layers as installed in STAR.

A simulated Au+Au collision, the blue dots indicate space points reconstructed in the SSD layer. The tracks on the left are hidden to reveal the SSD contribution.



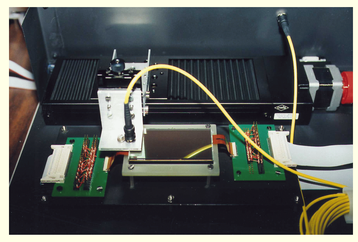


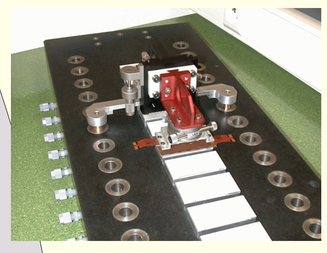
DAQ & Control

Due to the large number of channels to acquire, the Analog to Digital Converters have been placed on the detector itself, at the ladder end cap.Then each numeric channel goes through a dedicated Asics that computes pedestal, noise, suppresses zero and eventually compresses the data.
The control system has been designed in such a way that almost all parameters, from power values to shaping time, can be remotely controlled and adjusted. The COSTAR chip has been created for this purpose and is located on the module itself.

Module tests

Although each component is tested separately, it is important to test assembled modules to check their functionality.
Using a LED coupled to a 3D–movable table, all strips are individually stimulated.
Relevant parameters for the operation of the SSD are measured:
* pedestal, noise and gain of each channel
* operating voltage and leakage current





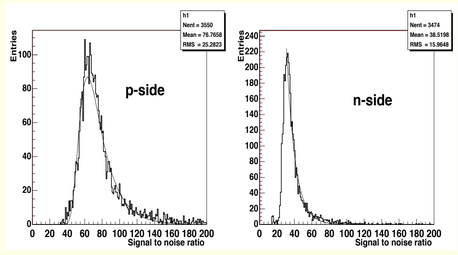
Assembly

The assembly of 16 modules onto a ladder makes use of a dedicated mechanic and optic bench. Each module is first set on a very precise, optically checked, position. Once the alignment realized, the mechanic ladder is glued onto the modules. Then readout boards are also glued on the end cap of the ladder and all modules are electrically connected to them.
An acquisition test of the whole ladder is then performed to check if all channels are still alive.

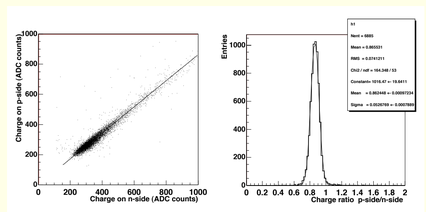
Prototype performances

Several prototypes have been realized and tested in CERN beam (PS and SPS). The test bench used a silicon tracker as a reference to estimate the spatial resolution of the SSD under test.
The Signal over Noise ratio observed (around 40 to 60) allows the following nominal spatial resolution:

$\sigma_{R\phi} = 15\mu$ m $\sigma_Z = 733\mu$ m

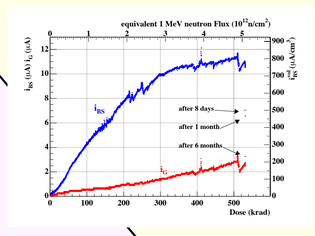


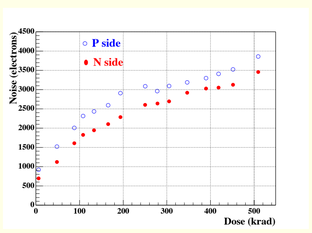
To alleviate ambiguous hits due to the high density environment of STAR, the matching of charges collected on each side of a double–sided detector for the same particle is used. Charge matching measured during this tests leads to a relative error below 7%.

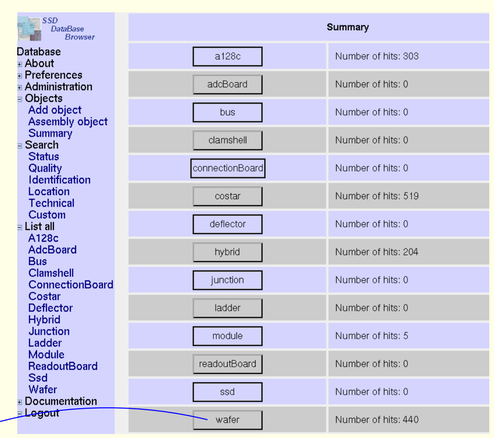


Radiation hardness

The cumulated irradiation dose expected in STAR at the SSD level should not exceed 1 kRad per year (5.10^{12} neutrons of 1 MeV/cm per year). Nevertheless extended tests of the module have been made with 20 MeV protons up to 500 kRad. The obtained results demonstrate that the radiation environment will not be a problem for the SSD.

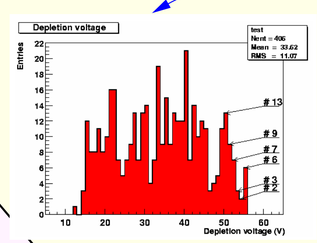






Production database

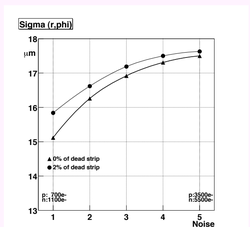
Over 7000 components enter in the SSD, all of them have to be tested. It is mandatory to register all these data into a dedicated database interfaced both with test stands (automatic transfer of data) and with WWW. This interface has many functionalities helping in the management, specially in the best possible choice, of all the components.

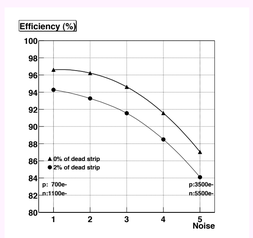


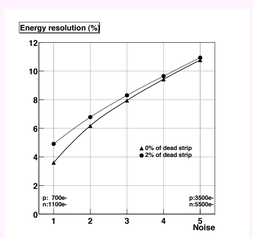
Tracking performances

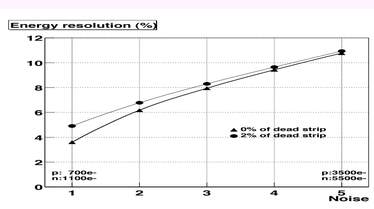
Hit reconstruction

For central collisions, the number of hits on each side of a single module may reach 10 units leading to ambiguities in the association of hits from one side to another.
The 7% resolution obtained for the charge matching allows for the evaluation of probabilities for each possible association. Using such a method, the hit reconstruction algorithm yields in standard noise condition a spatial resolution below 20 microns and a resolution on energy loss around 5% (required for particle identification using dE/dx).





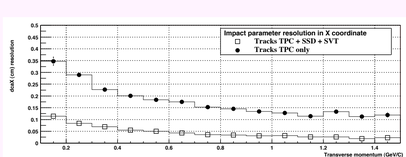




Tracking

Along with the addition of the SSD layer in between the last SVT layer and the TPC, an upgrade of the tracking algorithm has been proposed.

To benefit of the SSD key position, the new developped method extrapolates tracks found in the TPC and tries to associate them to points reconstructed in the SSD and then in the three SVT layers. This is done iteratively for different track criteria (transverse momemtum, primary tracks...)
The overall gain in track efficiency is of the order of 46% with respect to the original method.



poster made by J.Baudot, IReS Strasbourg