# Design and Development of Micro-Strip Stacked Module Prototypes for Tracking at S-LHC

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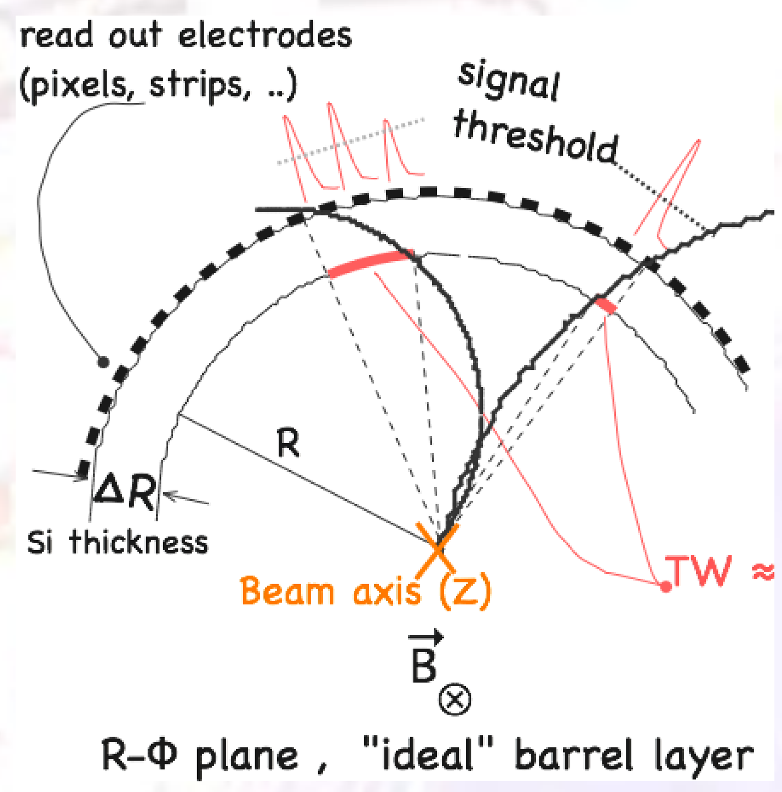
## Motivations

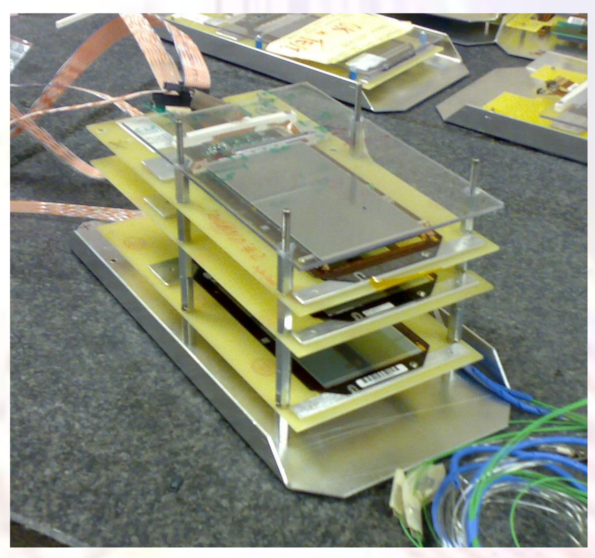
**Tracking detectors at future hadron colliders will operate in extreme experimental conditions. The already envisaged upgrade of the LHC machine, Super LHC (S-LHC), will operate at an instaneous luminosity of about $10^{35}$ $cm^{-2}s^{-1}$, with a considerable increase of occupancy and pile up with respect to the present condition. Both CMS and ATLAS need a consistent upgrade to maintain the actual physics performances at S-LHC, in particular the inner detectors will be completely replaced. Moreover, the unprecedented density of tracks and the high level of pile-up expected at S-LHC, will require also a drastic change of the trigger strategy and electronics to select the interesting events. The inclusion of tracking information in the Level-1 decision could give a great benefit in the event selection. The design of a tracking based trigger for S-LHC, is an extremely challenging task, simulation studies show that this can be achieved by correlating hits on two closely spaced silicon strip sensors. This work focuses on the design and development of micro-strip stacked prototype modules. We will present the results of tests performed on the prototype modules in terms of the noise performance of the proposed stack geometry.**




*Principle of operation, a low pT track produces a wider cluster in the stacked module.*

## Staked Sensors Prototypes

**All the equipment and electronics used belong to the present CMS tracking system. The detectors are spare micro-strip silicon devices designed to equip the inner part of the silicon micro-strip tracker. The two sensors in a stacked module unit are glued one on top of the other. The bottom sensor is glued on the same plane of the read-out electronics, while the top one has been glued with a vertical separation of 2000 µm using an insulating Aluminium Nitride spacer 600 µm wide. The effective distance between the mid planes of the two sensors is, in average, about 2380 m. The strips of the two sensors are wire-bonded to the front end electronics (APV25) where the signal is shaped and sampled. The read-out of modules is performed using the 40 MHz CMS-like system, with only minor changes.**

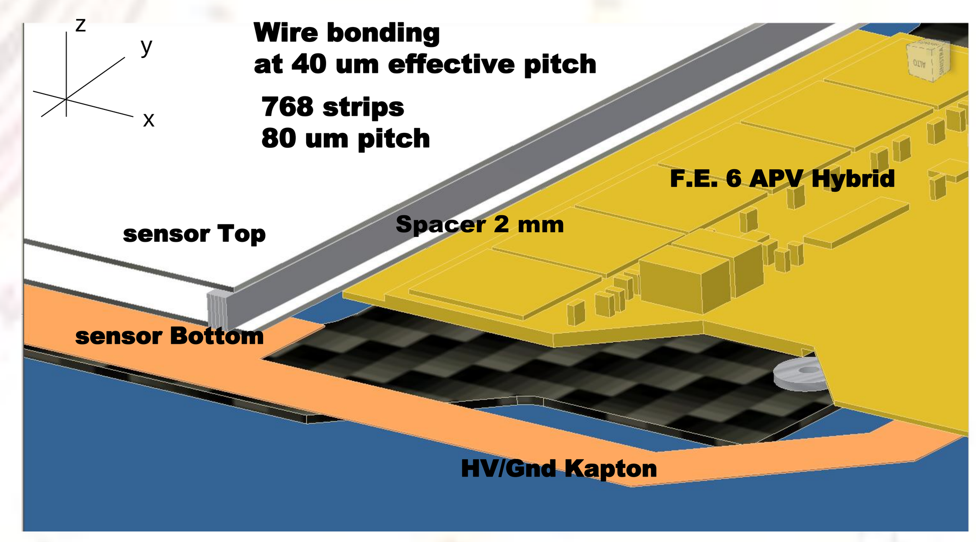


*Mini telescope made of a stacked prototype and two CMS module used as a cosmic muon tracker*

## Two Different Geometries:

### Module A

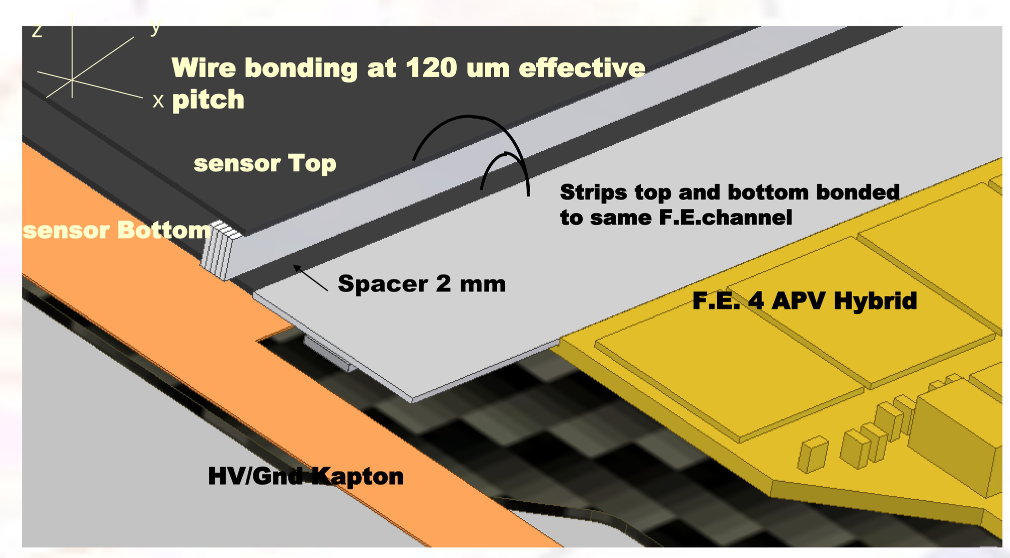
**two micro-strip devices with 768 strips each, designed at 80 µm pitch, which are connected directly to the APV hybrid with effective pitch of 44 µm and 768 channels through the following scheme: each pair of corresponding strips in the two sensors is wirebonded to a pair of neighbouring readout channels. A charged particle crossing both detection planes orthogonally generate hits that will show up in adjacent readout channels. Thus, we expect to detect this type of event from the presence of a cluster of minimum width.**



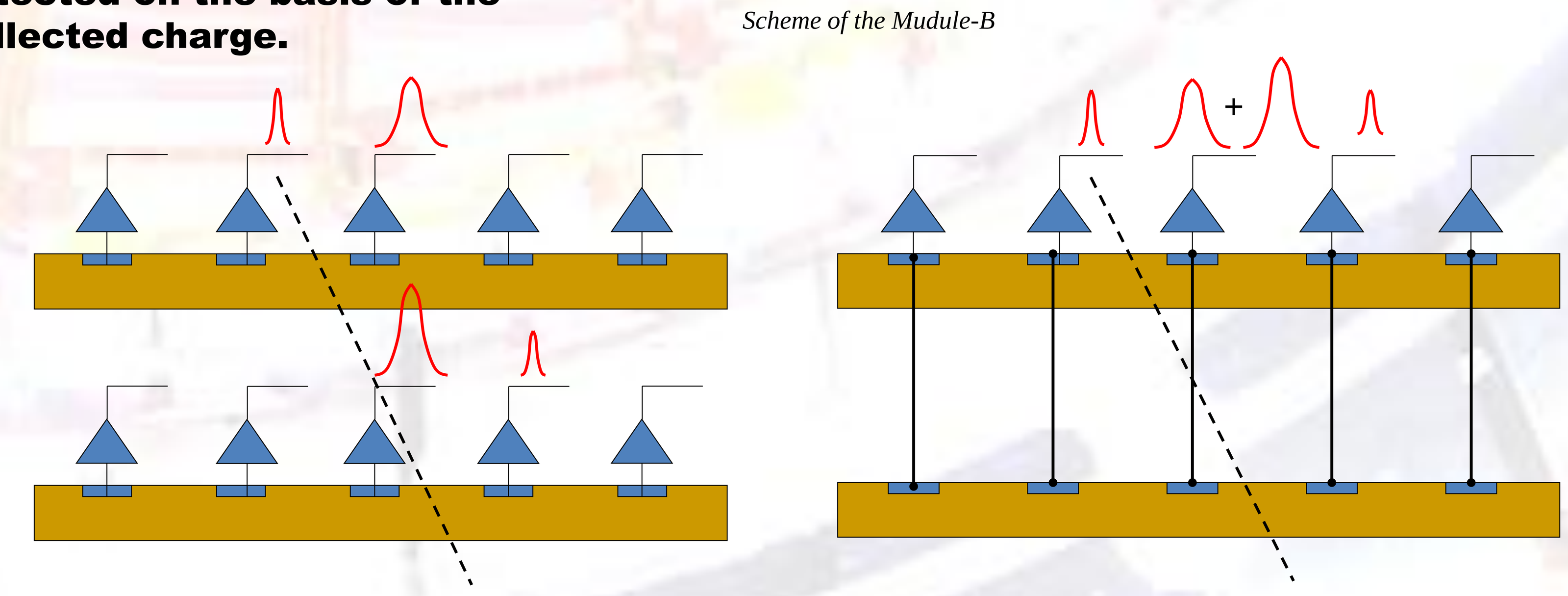

*Layout of the Mudule-A*

### Module B

**two micro-strip devices with 512 or 768 strips each at a pitch of 120 µm or 80 µm respectively, wire-bonded to the APV25 hybrid via a pitch adapter. In this scheme, each pair of corresponding strips in the two sensors is wire-bonded to the same read-out channel. In this conguration the strips connected to the same read-out channel collect the ionization charge produced by an orthogonal track and a spatial coincidence can be detected on the basis of the collected charge.**

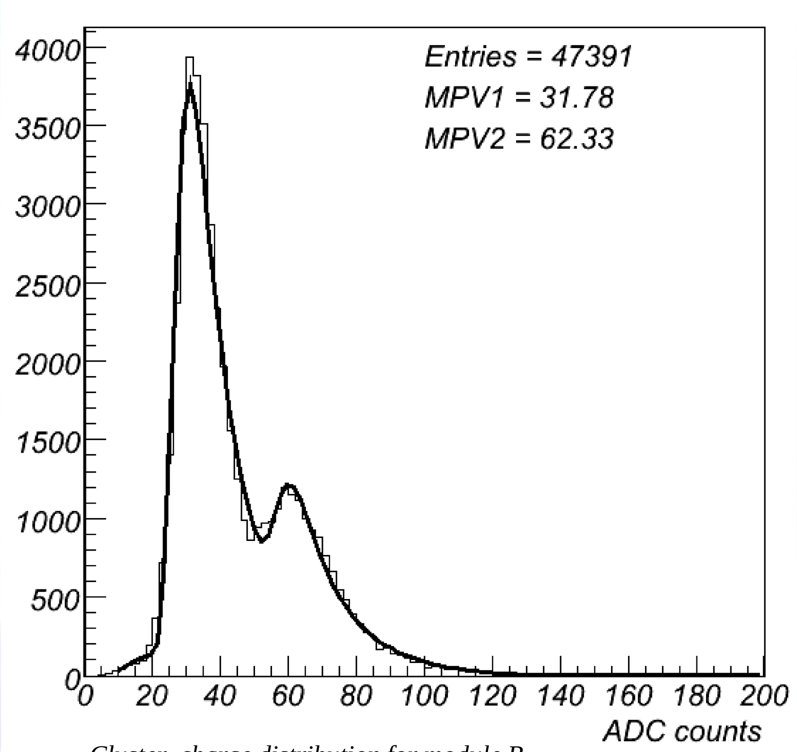



*Scheme of the Mudule-B*

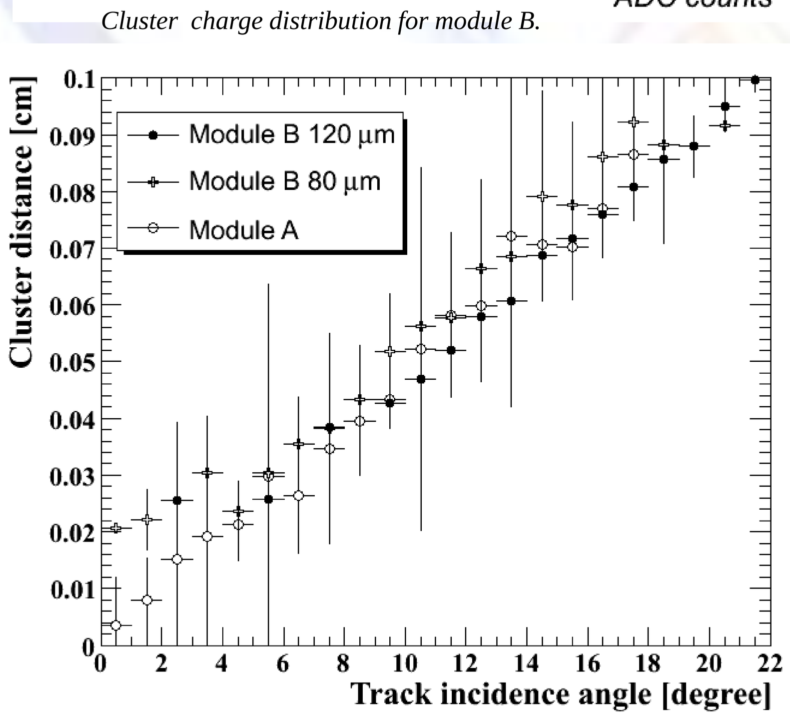


*Connections sheme in Module A (left) and B (right)*

## Measurements on Prototypes




*Cluster charge distribution for module B.*

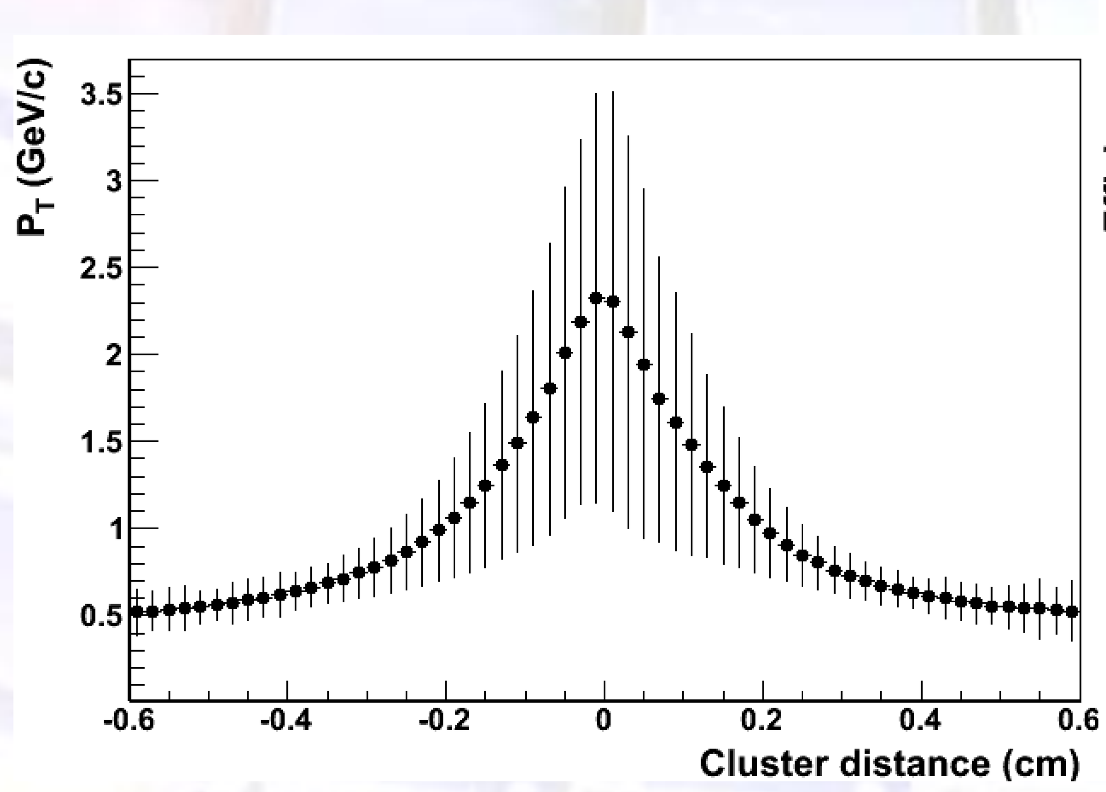



*Cluster distance as a function of the track incidence angle mesured with cosmic muons tracks using a three module telescope. A nice lenear behavior is observed.*

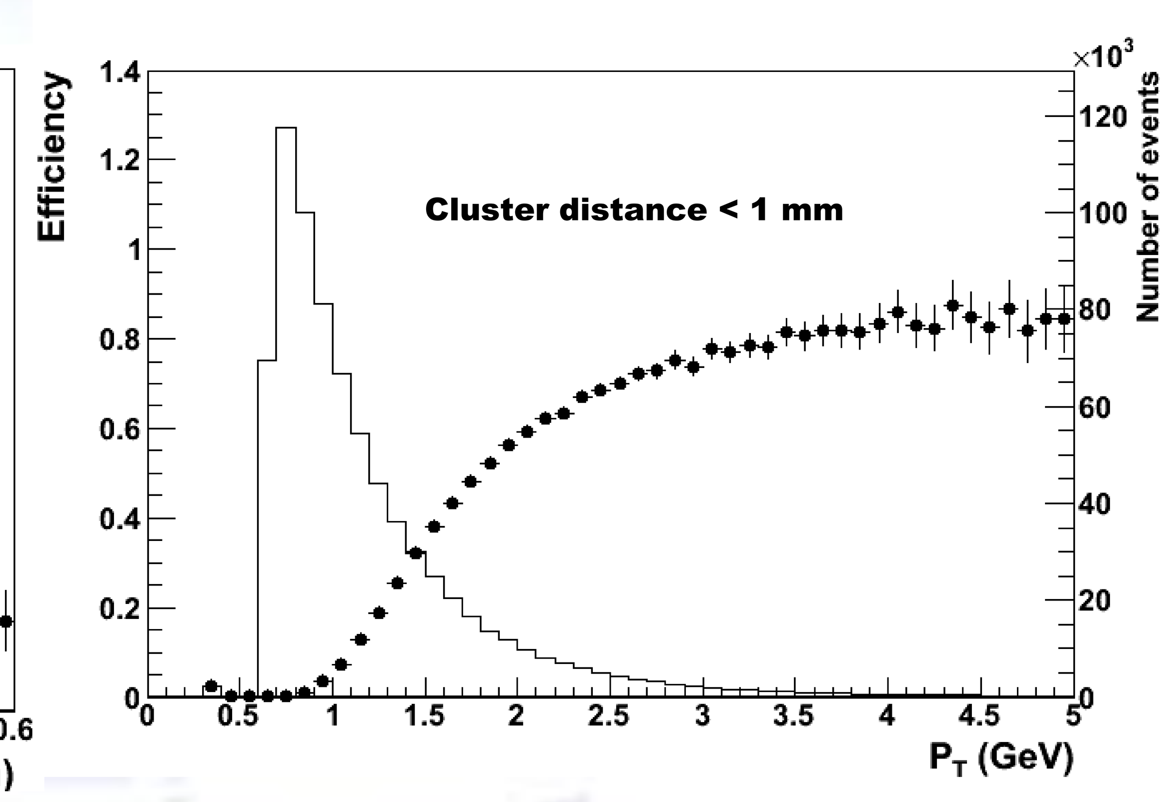
**All prototype modules have been qualified looking at single strip noise performance. Results follow expectations in both cases: the module A has performance comparable to benchmark CMS, micro-strip modules while the modules B show a higher noise level due to the increased capacitive load (two strips load capacitance in parallel). The cluster reconstructed charge for the B-modules shows large tails, compatible with a Landau distribution, but two peaks are visible. The second peak, corresponding to a value which is approximately double with respect to the first one, comes from those events where the charge from both sensors is collected as a single cluster by the same read-out channel. The tracking performance of stacked modules has been studied using a telescope made of 2 single sided CMS modules and a stacked prototype. For both A and B-modules the distance between reconstructed clusters on the stacked sensitive planes is measured versus the incidence angle of the track with respect to the orthogonal. A clear linear dependence is visible for angles larger than 5 degrees.**

## Validation with Collision Data

**The method has been validated using LHC collision data In particular the double sided micro-strip modules used to equip the Silicon Strip Tracker of CMS are very similar to stacked modules. In this conguration the modules are located at a radial distance of 69.6 cm from the beam axis and the sensors, with 120 µm strip pitch, are 2450 µm apart. Charged particle tracks, crossing these detectors, produce hits in both sensitive planes that are reconstructed as clusters and correlated in space by a dedicated offline analysis. In a solenoidal magnetic field, at a given distance from the beam axis, the angle of incidence of a track onto a detector plane is correlated to the charged particle momentum component orthogonal to the magnetic field direction. On a stacked module, low pT tracks produce spatially separated clusters, up to a few millimeters apart, while as the transverse momentum increases they close up and start to overlap. A cut on the distance between the clusters can allow discrimination between low or high pT tracks. The figure shows the efficiency to select high momentum tracks by applying a cut of 1 mm to the clusters distance. Tracks below 1 GeV/c are strongly reduced while the efficiency increases with transverse momentum up to a value close to 90%.**




*pT versus cluster distance for CMS double sided Si strip modules, the full circle are the mean of the distribution while bars represent the r.m.s*




*The histogram is the pT spectrum of charged tracks measured with CMS in 7 TeV collision data, the curve is the efficiency of a cut on the cluster distance at 1 mm.*