

# RHIC run V data analysis with the Silicon Strip Detector in the STAR experiment

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*Le Silicon Strip Detector (SSD) est la quatrième couche du détecteur de vertex de l'expérience STAR auprès du collisionneur RHIC. Durant l'année 2005, le SSD était entièrement assemblé pour la prise de données des collisions Cuivre-Cuivre au RHIC. Nous présentons à partir de ces données les performances du détecteur. Parallèlement, un travail de développement de logiciel du traitement des données relatives au SSD a été effectué afin d'implémenter les étapes de calibration nécessaires pour l'analyse des données.*

The Silicon Strip Detector (SSD) is a fourth layer of silicon detectors of the STAR experiment, thus completes its inner tracking device. The goal of STAR is to study heavy ion collisions in order to probe the existence of the Quark Gluon Plasma (QGP), a deconfined state of nuclear matter. Strangeness enhancement, such as  $K_s^0$ ,  $\Lambda$ ,  $\Xi$  and  $\Omega$  particles production, has been proposed as one of the signatures of formation of the QGP [1]. STAR central tracking device is a large cylindrical Time Projection Chamber (TPC), which provides momentum measurement and allows particle identification. Closer to the beam axis, the inner tracking system is dedicated to precise measurement of the primary vertex and increase of detection efficiency of secondary particles. It includes the Silicon Vertex Tracker (SVT) arranged in 3 layers surrounded by the SSD.

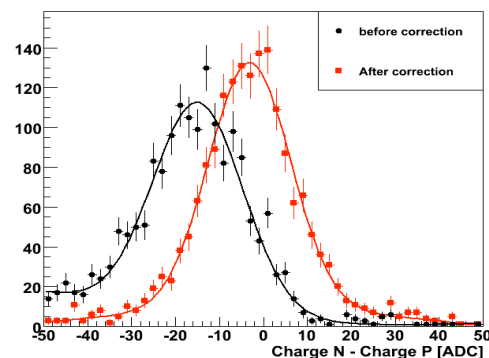
The SSD was proposed to enhance the tracking capabilities at mid-rapidity by improving the pointing resolution from the TPC through SVT. It uses double-sided silicon microstrip sensors and consists of 320 detector modules arranged on 20 ladders, forming a barrel at a radius of 23 cm from the beam, inserted between the SVT and TPC [2].

The RHIC run of 2005 (run V) with Cu+Cu collisions at  $\sqrt{s} = 62$  and 200 GeV was the first time where the inner tracking device was fully operational.

Performances and offline Calibrations tasks of the detector are presented here. To take

advantage of the high spatial resolution given by the silicon strip technology in the data reconstruction, several corrections like the charge calibration and Lorentz effect correction have to be done. Software development has been done to implement these tasks.

The charge calibration corrects for the difference between charges collected by strips on each side (namely P and N side strips), due to electronic readout. Since SSD uses double sided detectors, the same charge deposit is expected for each side for a given detection module. **Fig. 1** shows the correction of the charge deviation before (left) and after (right) applying a gain correction for hits in a given wafer. The distribution after gain correction is centered on 0.



**Fig. 1:** Difference of charge measured on P side with the charge measured on N side without (black) and after (red) gain correction

The charge matching (comparison between the charge collected on P and N sides) is used to disentangle ambiguities due to the hit reconstruction in a high particle environment. One impact of the charge calibration is to reduce the number of ambiguous reconstructed hits due to geometrical association of clusters [3].

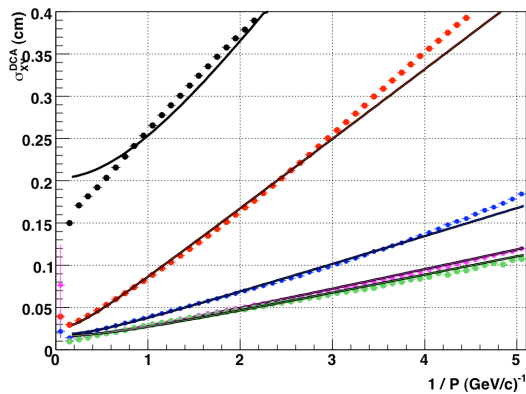
Another correction implemented for the first time in the software was to take into account of the Lorentz effect[4], present in silicon detector because of the presence of a magnetic field of 0.5 T (created by the magnet that surrounds the TPC) and the electric field imposed to deplete a silicon wafer.

After alignment of the silicon detectors with respect to the TPC, we studied the tracking efficiency of the SSD. The improvement due to the SSD was confirmed by a better distance of closest approach of tracks to the primary vertex of the collision (DCA). The DCA resolution has 3 components (the vertex resolution, depending on the number of tracks used for its calculation, the track pointing resolution, depending on the detection and alignment resolution and by the multiple coulomb scattering (MCS) in silicon detector which evolves as the inverse of the momentum of track). It can be expressed by:

$$\sigma_{DCA}^{XY} = \sqrt{a^2 + \left(\frac{b}{P}\right)^2}$$

the 2 first contributions and  $b$  the MCS contribution [5].

**Fig. 2** shows the DCA resolution as standard deviation of track DCA to primary vertex using TPC only (black) and adding the SSD (red) then the 3 layers of the SVT.



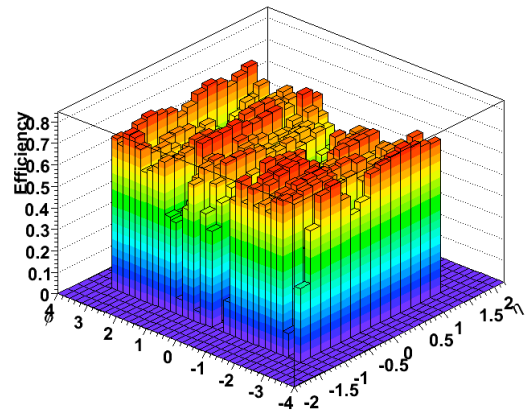
**Fig. 2:** DCA resolution in transverse plan

	TPC	TPC+ SSD	TPC+ SSD+ SVT(1)	TPC+ SSD+ SVT(2)	TPC+ SSD+ SVT(3)
$\sigma_{DCA}^{XY}$	2535	865	378	283	272
$\sigma_{DCA}^Z$	1763	1000	350	239	216

**TAB.1:** DCA resolution in  $\mu\text{m}$  at  $P = 1\text{GeV}/c$  vs. number of silicon hits in track fit

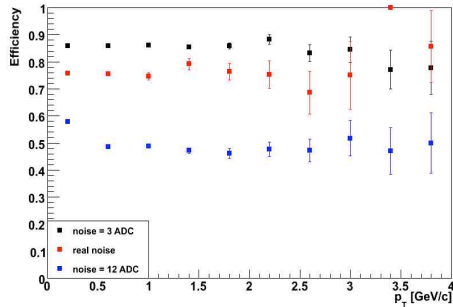
Contribution from tracking (parameter  $a$ ) is comparable with MCS at  $P = 1 \text{ GeV}/c$  thus confirmed the good alignment required for such precise detectors (see details in [5]). One can see from Tab.1 the improvement in the DCA resolution in both transverse and longitudinal directions by adding at least the hit from the SSD.

The tracking efficiency (defined as the ratio of the number of tracks including a SSD hit over all the tracks within the SSD acceptance) has been measured to 48% for the entire run V. However the efficiency varies locally sensors by sensors, as shown in **Fig. 3** that represents the tracking efficiency of each individual wafers due to different level of electronic noise.



**Fig. 3:** Tracking efficiency and as a function of  $(\eta, \phi)$  of tracks

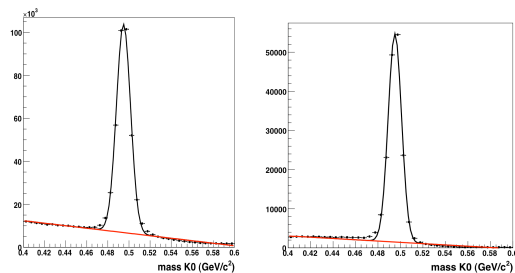
The noise dependence has been simulated on **Fig. 4** that shows the impact of noisy strips (then occurring more dead areas in the detector). The tracking efficiency, represented as a function of momentum, is decreasing when the level of strip noise increases.



**Fig. 4:** Tracking efficiency as a function of momentum

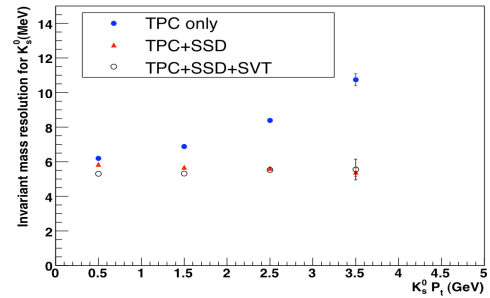
One of the original goals of the SSD is an improvement of the detection of short-lived particles decaying before reaching the TPC. The SSD hit should then increase the signal-to-background (S/B) of reconstructed secondary vertices. Based on the run V data, we see an improvement in term of  $K_S^0 \rightarrow \pi^+ \pi^-$  and  $\Lambda \rightarrow p \pi^-$  invariant mass reconstruction [6]. From **Fig. 5**, one can see the reduction of the combinatorial background in the  $\{\pi^+, \pi^-\}$  association due to a better track DCA resolution.

The signal is obtained by using a simultaneous fit of the signal and the background. The S/B has been evaluated to  $6.22 \pm 0.03$  for TPC only (**Fig. 5 left**) and to  $13.93 \pm 0.13$  when using the SSD (**Fig. 5 right**).



**Fig. 5:** Invariant mass reconstruction of  $K_S^0$  using TPC tracking only (left) and TPC+SSD tracking (right)

Requiring a SSD hit improves also the mass resolution of  $K_S^0$  for high  $p_T$  compare to TPC only (**Fig. 6**). This reflects the improvement of the single-track momentum resolution at high  $p_T$  when adding a SSD hit.



**Fig. 6:** Invariant mass resolution of  $K_S^0$  using TPC tracking only, TPC+SSD and TPC+SSD+SVT tracking

[1] J. Rafelski and B. Müller. *Strangeness production in the Quark Gluon Plasma*. *Phys. Rev. Lett.*, 48(16), 1982

[2] L. Arnold et al., *The STAR silicon strip detector SSD*. *Nucl. Inst. Methods*, A499, 2003

[3] B. Hippolyte et al., *Silicon Strip Detector Reconstruction Chain for the STAR experiment*, STARNOTE 0427

[4] J. Bouchet, *Performances du détecteur en silicium à micropistes de l'expérience STAR à RHIC*, thèse de l'Université de Nantes, 2007

[5] Y. Fisyak et al., *Overview of the inner silicon detector alignment procedure ad techniques in the RHIC/STAR experiment*, CHEP 2007

[6] J. Bouchet and V.N. Tram, *SSD performances in CuCu 200 GeV data*, in preparation

Les données du run V au RHIC ont clairement montrées ce qu'apporte le SSD en terme de trajectographie dans l'expérience STAR. Associé au SVT, une amélioration de la reconstruction des particules étranges est observée.

Les futures données des collisions Au+Au du run VII où la mesure du charme et de la beauté ouverte ( $D^0, D^{+/-}, B^{+/-}$ ) sont en cours d'analyse.