Testbeam results for the first real-time tracking system based on artificial retina algorithm

Marco Petruzzo Università degli Studi and INFN, Milano

Istituto Nazionale di Fisica Nucleare

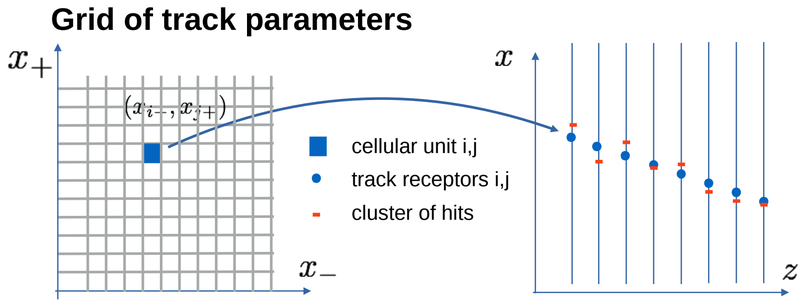
Abstract: we present the testbeam results of an embedded tracking system prototype[1] based on artificial retina algorithm, capable to reconstruct tracks in real time with a latency <1 μs and with track parameter resolutions that are comparable with the offline results. The maximal event rate that the telescope can accept is 300KHz and it is determined by the Beetle readout chip. The test was carried out using a 180 GeV/c proton beam at the CERN SPS.

Artificial retina algorithm

The artificial retina algorithm[2] is inspired from neurobiology and it is based on a grid of cellular units tuned to recognize specific tracks. Each cell, in parallel, provides a response ("Weight") to the measured positions from the tracking device that is proportional to how close the precomputed track is to the measured points.

A track candidate is identified for each local maximum in cell's grid and the track parameters are obtained via interpolation of the Weight values near the local maxima. The algorithm is highly parallelized and particularly suitable for implementation in FPGA and application to high energy physics experiments.

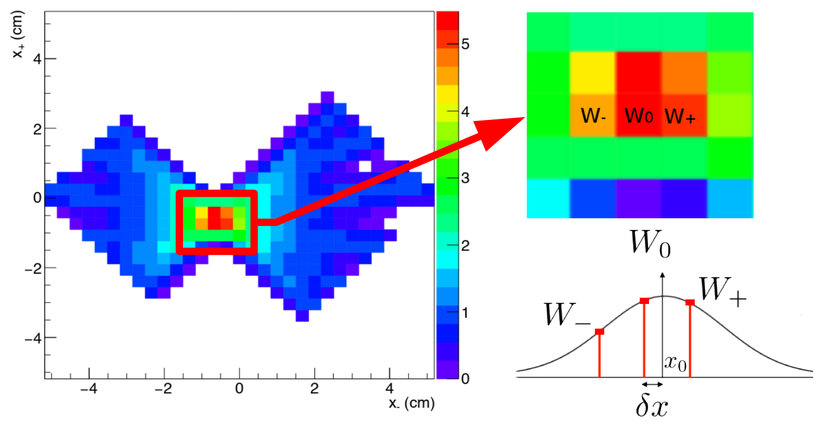
Grid of track parameters



Each cellular unit is associated to a set of track receptors, placed at the intersections of the track with the tracking planes. The response of the (i,j)th cellular unit is a function of the hit-receptor distances s_{ijk} and it is defined as:

$$W_{ij} = \sum_k \exp\left(-\frac{s_{ijk}^2}{2\sigma^2}\right)$$

Retina response for a single track event



The interpolation along both the directions provides track parameters with offline-like quality even using a coarse grid

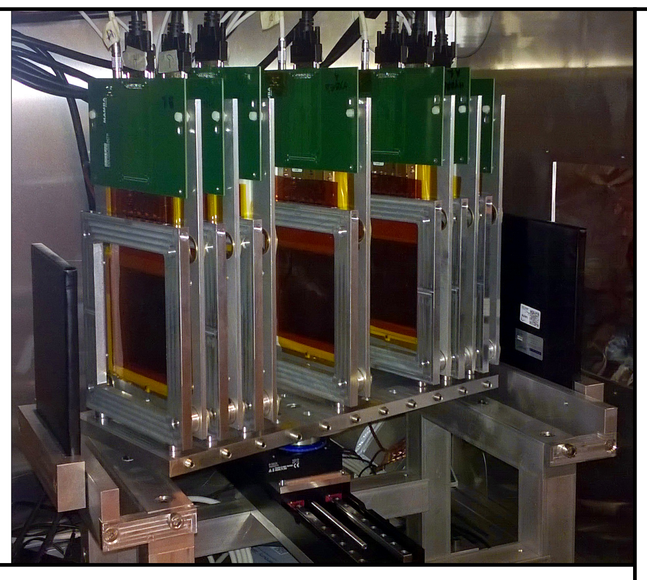
Telescope system

7 single-sided silicon strip (STM OB2) sensors:

- ~10x10cm² active area
- 512 strips
- 183μm pitch
- 500μm thickness

Two plastic scintillators providing the trigger

Linear and rotation stages

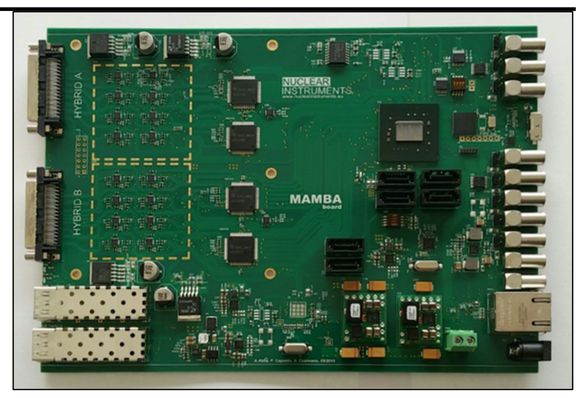


DAQ+Retina board

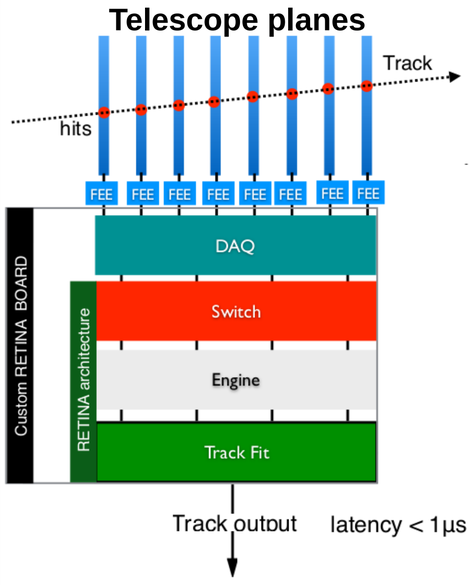
Custom board based on Xilinx Kintex 7 FPGA

Up to 8 planes readout at 300KHz (max. trigger rate of the Beetle chips)

On-board Retina algorithm



Telescope planes

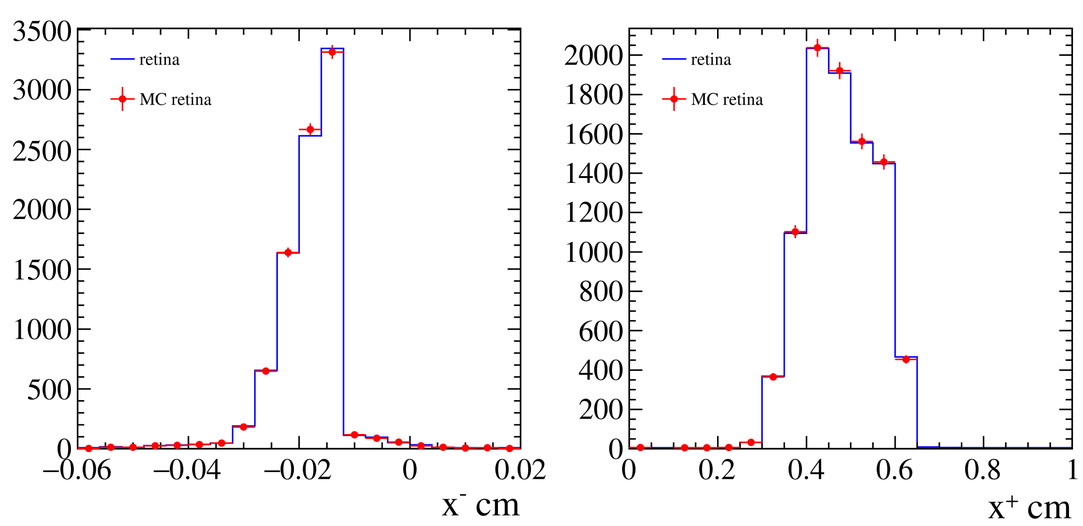


Artificial retina architecture

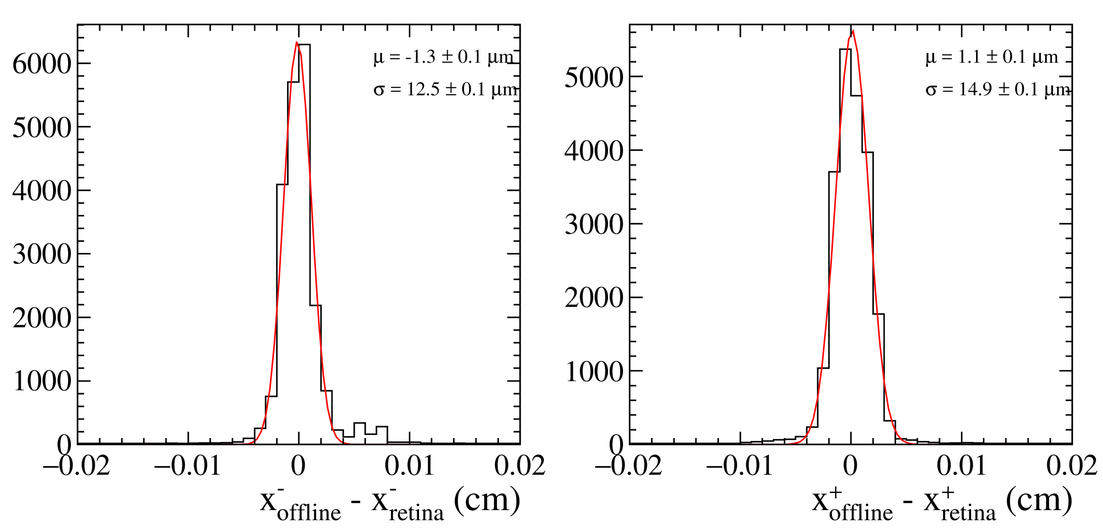
- The switch delivers in parallel the hits from the telescope to the cellular units
- 512 cellular units (engines), distributed in the track parameters space, evaluate the retina response
- The track fitter finds the local maxima and evaluate the track parameters via interpolation

The pipelined architecture allows sub-μs latencies

Testbeam at SPS - Results



Track parameters distribution determined by the artificial retina. Testbeam data processed by the MAMBA board (retina) and verified using the artificial retina simulated response (MC retina).



Distribution of the residuals for the track parameters evaluated using a simple χ² minimization algorithm (offline) and track parameters from the artificial retina algorithm

Conclusions and future plans

The first real-time tracking system based on artificial retina algorithm has been successfully tested on beam at SPS, using an embedded system with DAQ and tracking functionalities.

Results from the artificial retina are in agreement with results from offline analysis and simulations of the retina response to real testbeam data

Next steps:

- Implementation of the artificial retina algorithm on a new board with multiple UltraScale FPGAs
- Test of the upcoming system with simulated data from LHCb experiment at 40MHz input rate

References:
[1] N. Neri et al., POS(TIPP2014)199
[2] L. Ristori, NIM A 453 (2000) 425-42

Co-authors: A. Abba[1,#], F. Caponio[1,#], M. Citterio[1], S. Coelli[1], J. Fu[1,2], A. Merli[1,2], M. Monti[1], N. Neri[1].
[1]INFN, Sezione di Milano, [2]Università degli Studi, Milano, [#]now at Nuclear Instruments.

The 25th International Workshop on Vertex Detectors, La Biodola (Italy), Sept. 25-30, 2016