# The Beauty Contiguity Processor of the BEATRICE experiment

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The Beauty Contiguity Processor (BCP) is an impact parameter trigger for beauty search in the fixed target experiment WA92/BEATRICE at CERN. It is composed of 11 FASTBUS modules and is based on a custom designed ASIC chip.High interconnectivity among processing elements (bidimensional lattice) and highly parallel algorithms (contiguity masks) allow for separate counting of tracks belonging to primary and secondary vertices in less than 30 $\mu s$ for any track multiplicity. An overview of both the algorithm and the processor architecture is given.

## Introduction

Among the various strategies to face the heavy-quark problem,the selection of events with evidence of at least one secondary vertex has proved to be very effective ( see ref. [1],[2]).

In the following we will show how this strategy has been pursued using a contiguity processor which has been operated as the main second level trigger of the WA92 experiment (see ref. [3]) during 1992 data taking.

## Detectors and readout layout

The WA92 vertex telescope consists of 12 silicon microstrips planes,2048 strips,25 $\mu m$ pitch each (fig. 1 shows a real event from 1992 data taking, full lines are Z planes,dotted lines Y planes). Six planes are used to measure the Z coordinate and six to measure Y. Only the Z planes are used at the trigger level.Ten more planes (512 strips,20 $\mu m$ pitch,5 Z and 5 Y) located upstream of the target (Cu or W,2 mm thick) are used as beam monitor.The second and last Z planes are used at the trigger level for finding the vertex position in the target. The front-end and the readout system are fully described in ref. [4]. Their relevant features exploited at the trigger level are:

- zero supression at the front-end level
- readout speed of 200 ns/hit

## Trigger algorithm

The trigger algorithm should find tracks crossing the detector and flag them as primary or secondary tracks according to their impact parameter (IP). It is executed in the following steps:

1. the Z coordinate of the interaction point,$z_v$,is extrapolated using the position of the beam.The center of the target is assumed to give the position along the X coordinate
2. writing the equation of a straight line in the x-z plane in the form
$$z = bx + z_v + h \tag{1}$$
($h = 0$ for primary tracks,$IP \simeq \mid h \mid$ for secondary tracks), the transformation
$$z_i^{'(j)} = \frac{x_6}{x_i}(z_i^{(j)} - z_v) \quad j = 1, ..., n_i \quad i = 1, ..., 6 \tag{2}$$
is applied to all the $n_i$ hits from plane $i$. This transformation maps primary tracks into parallel tracks while secondary tracks are mapped into hyperbolae
3. hits belonging to parallel ( i.e. primary ) tracks are erased and the few points left are used to look for secondary tracks
4. for hyperbolae tracks ( i.e secondary tracks ) the impact parameter is calculated observing that adding to eq. (1) after the transformation (2)
$$s_i(h)w \simeq h\frac{x_i - x_6}{x_i} \quad i = 1, ..., 6 \tag{3}$$
where $w$ is the microstrip pitch and $s_i$ is the integer function of $h$ that better approximates eq. (3),the equation of a track having IP $= \mid h \mid$ becomes a constant function of $x$. If such a constant track is found we can calculate its IP from $s_1$ i.e. from the shift function (the function that transform a track with impact parameter $h$ in a primary track) relative to the first microstrip plane.

## The processor architecture

The architecture of the BCP is based on a bidimensional array of processing elements (PE),each of them behaving like a very simple processor. The organization of the array reflects the detector structure,the number of PE's being equal to the number of microstrips (6x2048). All the PE's are driven by the same clock and they execute the same instruction stream,making the BCP a single instruction multiple data machine (SIMD).A rectangular mesh of switches helps to explain the functional principle.

In fig. 2 small dots represent PE's with an internal flag reset to zero, large dots are PE's with the flag set to one,the flag being set according to the detector output. Each PE is connected to its 4 neighbours by a set of switches. If,for each large dot corresponding to a microstrip fired,we close a few switches around it,following a programmed rule (Contiguity Mask),in case of a track crossing the detector a connective path from bottom to top will be created. A voltage applied to the bottom row should then be detected at the top row level. This property is exploited to find the primary tracks and delete the associated hits (fig. 3),then to find secondary tracks and measure their IP,which is proportial to the number of shifts needed to make the bottom and top registers electrically connected (fig. 4). Due to this particular architecture,the time needed to reconstruct the tracks and measure their IP neither depends on the actual number of tracks nor on the number of hits in the event but only on the number of instructions executed by the processor. The number of hits in the event (but not the number of tracks) affects only the time needed for the readout of the detector.

The PE array is actually built using a dedicated ASIC chip (15000 equivalent gates),64 PE are implemented in one chip and 192 chips are needed to realize the whole trigger. The chips are housed in 8 FASTBUS boards (BCPS for Beauty Contiguity Processor Slice),each of them holding 24 chips.The processor comprises 3 more modules,2 FBCT (Feros to Beauty Contiguity Trigger interface) and 1 BCPC (Beauty Contiguity Processor Controller). The FBCT modules receive the data from the detectors,execute steps 1 and 2 of the trigger algorithm and send the transformed coordinates to the BCPS modules through the FASTBUS auxiliary backplane. Coordinates are also corrected to take into account misalignement among the planes. The processing in the FBCT takes 100 ns/hit and it is pipelined to the readout from the detector,not adding further dead time to the trigger (apart for the time needed to find the primary vertex position, about 300 ns). Lastly the BCPC module generates the control and clock signals,counts the tracks for each IP class and takes the final trigger decision.

## Programming language and simulator

We have defined a dedicated programming language and a compiler has been writen for the BCP using the VAX Macro assembler.

The BCP architecture that has a "step-lock" control structure does not allow the tracing of the program which is running on it.To overcome this limitation that makes very difficult the program debugging and validation, we have designed an interactive cross-simulator running the same source program on a VAX computer. This simulator has proved to be extremely useful in writing and debugging the trigger programs.

## Issues from 1992 data taking

The BCP has been successfully operated during the 1992 BEATRICE data taking. During this period some 90 milions triggers have been collected. While the data analysis is under way,some considerations can be made about the performances of the processor.

The original trigger program was designed to reconstruct tracks having 6 hits,one per plane.Based on last year run experience,the program has been modified to accept tracks with at least 5 hits,allowing for one plane to be missing. This has been achieved by modifying the Contiguity Mask Network. The processing time required has increased from 10 $\mu s$ to 30 $\mu s$, in addition to the readout time (about 10 $\mu s$).

The processor performances have been cross-checked with an off-line filter which has confirmed the processor results,with a very good matching between the tracks found by the BCP and the filter.

# References

[1] J.F.Baland et al.,Nucl. Phys. B1 (1988) 303

[2] G.Darbo and L.Rossi,Fast Trigger for Beauty hadroproduction study,Nucl. Inst. and Meth. A289(1990)584-591

[3] M.Adamovich et al.,WA92:a fixed target experiment to study beauty in hadronic interactions,Nucl. Physics B(Proc. Suppl.)27(1992) 251-256

[4] A.Beer et al.,A highly integrated trigger and readout system for a silicon microstrip detector installed at the Omega spectrometer at CERN CERN/ECP 91-27,Presented at the 1991 IEEE Nuclear Science Symposium and Medical Imaging Conference,5-9 November 1991,Santa Fe,USA

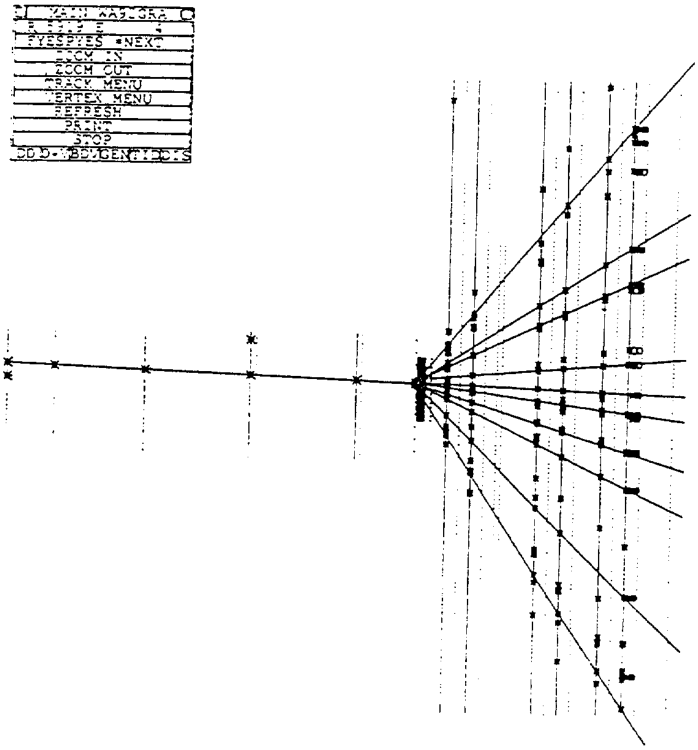
MAIN WAS-GRA
YESPYES *NEXT
ZOOM IN
ZOOM OUT
TRACK MENU
VERTEX MENU
REFRESH
PRINT
STOP

Fig. 1

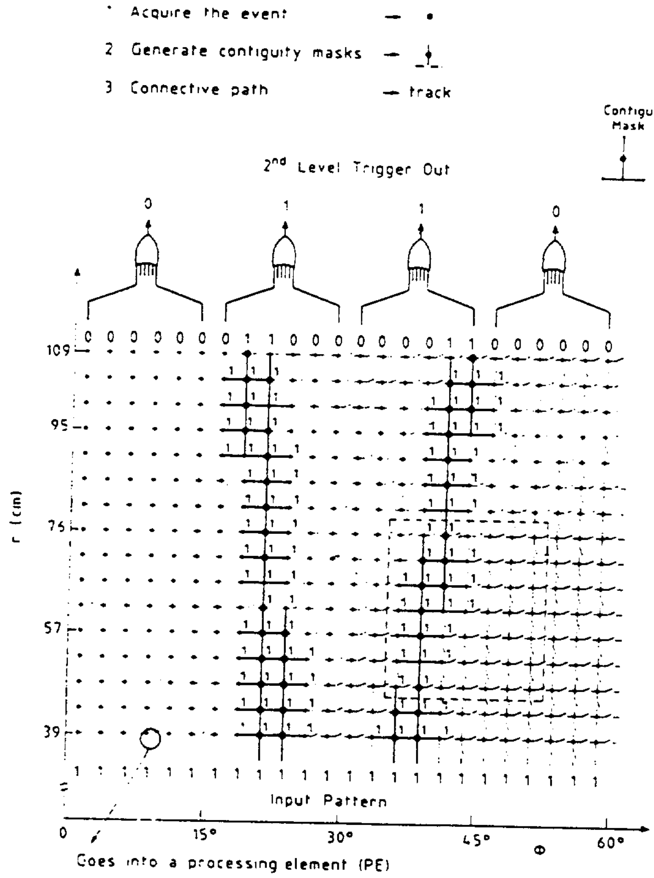
1 Acquire the event — •
2 Generate contiguity masks
3 Connective path — track
Contiguity Mask
2nd Level Trigger Out
0
1
1
0
0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0
109
95
76
57
39
r (cm)
1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1
Input Pattern
0
15°
30°
45°
60°
Φ
Goes into a processing element (PE)

Fig. 2

Search and Erase Primary Vertex Tracks

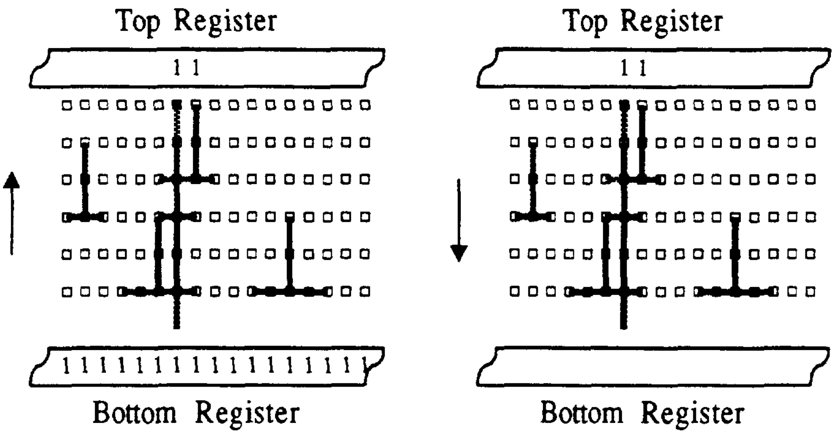

Fig.3

Search for Impact Parameter Tracks

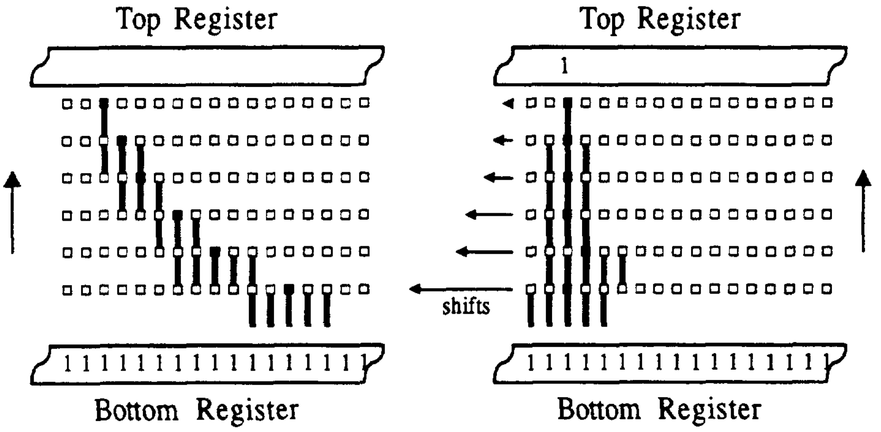

Fig.4