LHC-B

Vertex Trigger

LHC-B Level-1 Vertex Topology Trigger

User Requirements Document

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Prepared By: P. Mato
[Document Author/Editor]

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Abstract

Document Abstract (Use Body Abstract tag).

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Document Change Record

Record all changes between this and previous revision in a Document Change Record (DCR) table. A new DCR per revision is required.

Table 2 Document Change Record (of changes made since issue ...)

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1 Introduction

With the goal of producing the technical proposal for LHC-B later in the year, we need to start building a repository of information concerning the requirements, design issues and possible implementations of the vertex trigger. For that purpose, we are embarking on producing three documents: the user requirements document, the functional specification document and the implementation studies document.

1.1 Purpose of the document

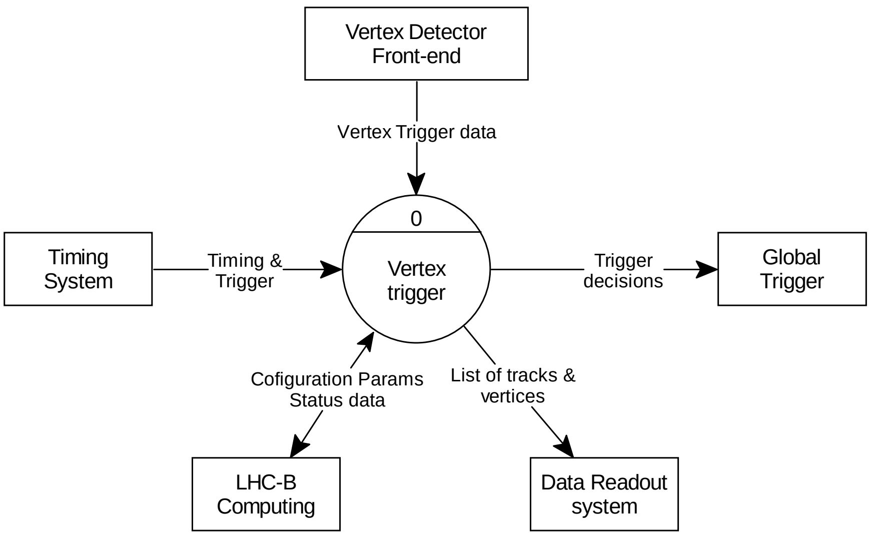
The purpose of this document is to describe in detail the requirements for the vertex topology trigger. We need to know what are the capability features for the trigger system and its interaction with the other sub-systems (i.e. data acquisition, timing and control, etc.).

This is supposed to be a living document, it is to be updated whenever we get a better understanding of what the vertex topology trigger should so. So, new requirements can be added, modified or removed.

1.2 Scope of the project

The Vertex Topology Trigger (VTT) has the function of implementing the vertex topology algorithm. The current algorithm is described in Section 2.3.The context diagram for the Vertex Trigger system is shown in the following figure.

Figure 1 Vertex Trigger context diagram



1.3 Definitions, acronyms and abbreviations

1.3.1 [Definitions]

1.3.2 [Acronyms]

CERN European Laboratory for Particle Physics

LHC Large Hadron Collider

1.3.3 [Abbreviations]

DAQ Data Acquisition System

DCS Detector Control System (formerly called Slow Control system)

VTT Vertex Topology Trigger as part of trigger Level-1 of the LHC-B

VD Vertex Detector

1.4 References

[1] K. Krisebom et al. (The LHC-B Collaboration), *LHC-B Letter of Intent*, CERN / LHCC 95-5, LHCC / I8, 1995.

[2] The LHC-B Collaboration, *Trigger and Data Acquisition System for the LHC-B Experiment: Current Status and Work Programme*, LHC-B 97-008, CERN / LHCC 97-14, 1997.

1.5 Overview of the document

The document is structured in two major sections: the first section will describe in a general way what the vertex trigger system should do and which are its constraints. Section 2 lists the specific requirements.

2 General Description

The current trigger strategy for LHC-B [1] which is described in some detail in [2], incorporate four level of triggering. Level-0 consists of the high-p_T trigger for electron, muon and hadron. In Level-1, the tracking and vertex topology triggers are executed in custom-built electronics while the data are still stored in the front-end electronics. After Level-1 decision, the data are transferred from the font-end electronics to the Level-2 buffers. The level-2 and Level-3 algorithms are executed in processors using the data from these buffers. In the following sections we focus on the description of the requirements for the vertex topology trigger.

2.1 Vertex Detector layout

The LHC-B vertex detector shown in Figure 2 comprises 18 stations of silicon strips and is situated between z = -22 cm and z = +56 cm. Close to the interaction region (the rms bunch-crossing length is 5 cm), the silicon stations are separated by 4 cm. The last two stations are separated by 8 cm. Each detector station consists of 6 ϕ sectors (60°), each with two planes for r and ϕ measurements respectively.

Figure 2 Side view of the LHC-B silicon vertex detector.

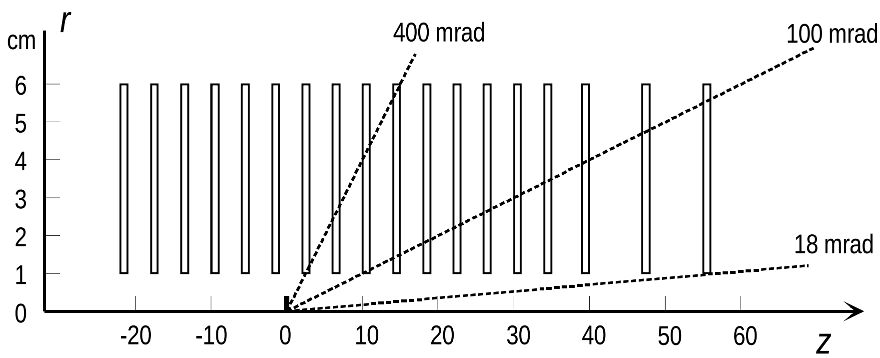


Figure 3 Schematic drawing for one detector station showing the 6 ϕ sectors.

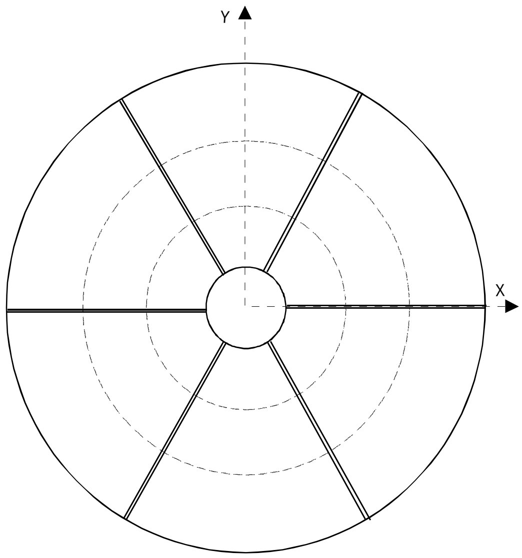
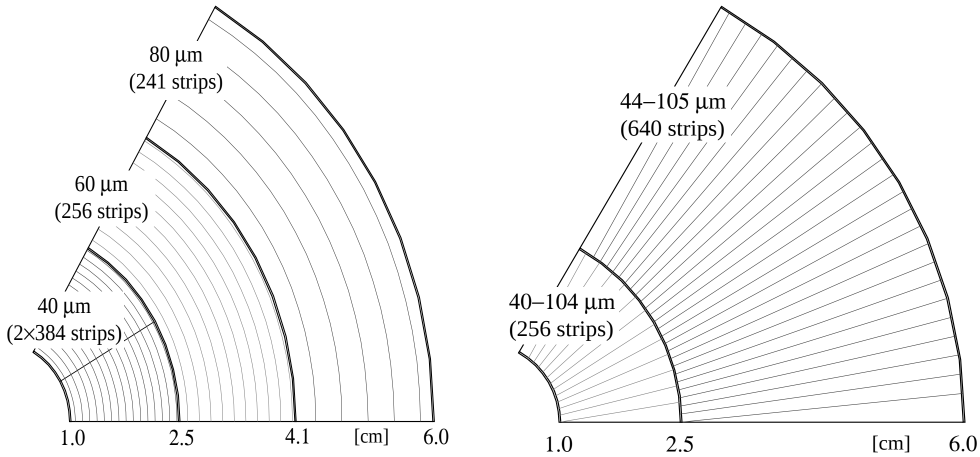


Figure 4 Schematic drawing for one r-detector and one ϕ-detector.



2.2 Trigger data

Each Si-strip in the r and ϕ detectors will produce a single binary information. The following table shows the data produced by the vertex detector to be use by the trigger.

Table 3 Number of strips

	A1+A2	**B**	**C**	**1 sector**	**1 detector**	**Total**
r-detector	768	256	241	1265	7590	136620
	D	**E**				
ϕ-detector	256	640		896	5376	96768
						233388

The average occupancy obtained from the Montecarlo is 5 hits in the A1+A2 region. (Needs to be completed with the distribution....)

2.3 The vertex topology trigger algorithm

2.3.1 Overview

The algorithm consists of seven consecutive parts:

- Track finding in the *r*-projection
- Calculation of the primary vertex position
- Impact parameter determination of all tracks
- 3-D reconstruction of large impact parameter tracks
- Track elongation
- Impact parameter determination in 3-D
- Search for 2 track vertices separated from primary vertex

2.3.2 Track finding

The track search is done independently in ϕ-sectors (6) and starts with the inner *r*-subsector (12). Three colinear hits in successive stations are used to define a track. The second *r*-hit can be in either in the inner or in the middle *r*-subsector. Only hits with $r_1<r_2<r_3$ are accepted. The colinearity cut requires:

$$\left| r_3 - \left(r_1 - z^r{}_1 \times \frac{r_2 - r_1}{z^r{}_2 - z^r{}_1} \right) \right| < Vrcut1 \times (z_3 - z_2)$$

where $z^r{}_i$ are the *z*-coordinates of the *r*-detectors. The track parameters (slope *m* and crossing with *r*-axis *b*) are calculated using the first (z_1, r_1) and last hit (z_3, r_3):

$$m = \frac{r_3 - r_1}{z^r{}_3 - z^r{}_1}$$

$$b = r_1 - z^r{}_1 \times m$$

The silicon stations are scanned in positive z- and negative z-direction in order to reconstruct also tracks in backward direction for a better primary vertex determination.

2.3.3 Primary vertex position

The *z*-coordinates of the intersection of 2d-tracks from opposite sectors (+-2 subsectors) in the *r-z* plane are histogrammed:

$$z = -\frac{b_1 + b_2}{m_1 + m_2}$$

The *z*-coordinate of the primary vertex is defined by the maximum bin of this histogram. A slightly better resolution is achieved if the weighted average of the maximum bin and its two neighbouring bins is calculated. The *x*- and *y*-coordinates are obtained in a similar procedure by histogramming the *x*- and *y*-coordinate of each track at the *z* of the primary vertex using the crude ϕ information given by the subsector number:

$$x = (b + z_{pr.} \times m) \times \cos(\phi_{sec.})$$

$$y = (b + z_{pr.} \times m) \times \sin(\phi_{sec.})$$

2.3.4 Impact parameter

For each 2d-track with a positive slope, the impact parameter with respect to the primary vertex is calculated:

$$\mathrm{IP} = -\frac{b + z_{pr.} \times m}{\sqrt{m^2 + 1}}$$

2.3.5 3-D reconstruction

A 3d reconstruction is in principle only necessary for tracks with large impact parameter, but in the simulation it is done for all tracks. The first two ϕ hits in the corresponding stations and sectors of the *r*-hits of a 2d track are used to together with the 2d-track to calculate an expected ϕ-coordinate in the third station:

$$\phi^{extr}{}_3 = \frac{z^{\phi}{}_3 - z^{\phi}{}_1}{z^{\phi}{}_2 - z^{\phi}{}_1} \times (\phi_2 - \phi_1) \times \frac{r_1}{r_3}$$

Only ϕ hits are used which are within +- Vpsel1 around ϕ_1. The following colinearity cut is used:

$$\left|\phi^{extr}{}_3 - \phi_3\right| < \frac{r_1}{r_{in}} \times Vpcut1$$

The 3d-track parameters are given by an unit direction vector and a point close to the first station hit by the track:

$$\begin{bmatrix} \mathrm{SLX} \\ \mathrm{SLY} \\ \mathrm{SLZ} \end{bmatrix} = \frac{1}{\sqrt{\mathrm{SLX}^2 + \mathrm{SLY}^2 + \mathrm{SLZ}^2}} \begin{bmatrix} \cos(\phi_1) & -\sin(\phi_1) & 0 \\ \sin(\phi_1) & \cos(\phi_1) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$\times \begin{bmatrix} \dfrac{r_1 - r_3}{z^r{}_1 - z^r{}_3} \\ \dfrac{\phi_3 - \phi_1}{z^{\phi}{}_3 - z^{\phi}{}_1} \times \left(r_1 - (z^r{}_1 - z^{\phi}{}_3) \times \dfrac{r_1 - r_3}{z^r{}_1 - z^r{}_3} \right) \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} (r_1 - (z^r{}_1 - z^{\phi}{}_1)) \times \dfrac{r_1 - r_3}{z^r{}_1 - z^r{}_3} \sin(\phi_1) \\ (r_1 - (z^r{}_1 - z^{\phi}{}_1)) \times \dfrac{r_1 - r_3}{z^r{}_1 - z^r{}_3} \cos(\phi_1) \\ z^{\phi}{}_1 \end{bmatrix}$$

2.3.6 Track elongation

In order to improve the impact parameter resolution, the last station hit by a track is searched for a *r* and ϕ-hit. If no *r* or ϕ-hit are found, the station before is tried. If again no *r* or *f*-hit is found, the *r* or ϕ-hit of the last station in the triplet is kept. The track parameters are recalculated using the first measured points and the last measured points found.

2.3.7 Impact parameter in 3-D

The impact parameter in 3d is calculated for each 3d-track relative to the position of the primary vertex (*x*,*y*,*z*).

2.3.8 Two track vertices

The distance of two tracks in space and the distance of their point of closest approach relative to the primary vertex is calculated. A cut on a minimum number of secondary vertex candidates is used.

2.4 General constraints

Describe the main constraints that apply and why they exist.

2.5 User characteristics

Describe who will use the system and when.

2.6 Operational environment

The vertex trigger will implemented with hardware and software. The hardware will be installed in the LHC-B experimental zone and eventually the control and monitoring of the system will be done remotely from the control room at the surface building. In this section we review some of the issues which are relevant for the environment where the trigger will be operated.

2.6.1 Geographical location and accessibility

A priory, the trigger hardware must be as close as possible to the sources of data and the destinations where the decisions need to be send in order to minimize overall latency and cost. For this reason, the installation of the trigger will favour a close location at the detector itself. The detector will be installed inside a vacuum vessel at the interaction point.

The detector and the surroundings are not accessible during the operation of the LHC accelerator due to radiation. It is expected to have periods of the order of several weeks of continuous operation. Therefore when designing the trigger, we have to take into account which parts of the system we can afford to install in the area with no free access and which parts will be installed in the electronics barracks which are foreseen behind thick concrete walls to allow free access of people without danger.

The reliability of the components installed in the areas with restricted access must be high enough in order to allow continuous operation for periods of several weeks. It must be possible to have full control of these components remotely from the control room at the surface.

2.6.2 Radiation environment

Radiation damage have been studied for the silicon detectors and front-end electronics. The damage degrades the overall performance. The radiation levels need to be estimated at the zones close to the detector where some part of the electronics for the vertex trigger will be installed. The choice of the type of electronics will depend on these estimations.

2.7 Assumptions and dependencies

2.7.1 Montecarlo

We are using the Phythia montecarlo to generate events for the vertex topology trigger studies in order to evaluate and quantify in terms of rejection and efficiency the possible algorithms. The response of the vertex detector is simulated using GEANT X.XX.

2.7.2 Detector performance

The performance of the vertex trigger (the efficiency for B events and the rejection of minimum bias) relies heavily on the expected performance of the detector. In particular, it relies on the single track resolution, and the signal to noise ratio. Many factors intervene in the track resolution like for instance the alignment of the detector, number of dead channels, etc..

2.7.2.1 Assumptions on the alignment of the detector

To be completed

2.7.2.2 Assumptions on the noise on the detector

Noise, common mode.

To be completed

2.7.3 Support structure

to be done

2.7.4 Roman pot

to be done

3 Specific Requirements

3.1 Capability Requirements

3.1.1 System requirements

UR SYS1 The vertex trigger should implement the vertex topology algorithm described in 2.3 .

Need Essential
Priority High
Stability Stable
Source LHC-B
Verifiability verifiable

UR SYS2 The performance of the vertex trigger (the efficiency for B events and the rejection for minimum bias) should be compatible with the performance obtained using the Montecarlo.

Need Essential
Priority High
Stability Stable
Source LHC-B
Verifiability Verifiable

UR SYS3 The vertex trigger should accept new trigger data from the vertex detector with an average rate up-to 1 MHz. The instantaneous rate can be higher.

Need Essential
Priority High
Stability It may change after global trigger strategy defined.
Source LHC-B
Verifiability Verifiable

UR SYS4 The vertex trigger should accept new trigger data from the vertex detector from two consecutive bunch crossings.

Need Very desirable to reduce dead-time
Priority High
Stability It may change due to other constrains (trigger and timing distribution).
Source LHC-B
Verifiability Verifiable

UR SYS5 The trigger decisions will be delivered to the global trigger maintaining the temporal order.

This requirement is needed to simplify the front-end electronics for all the detectors.

Need Essential
Priority High
Stability It can be reconsidered after definition of front-end electronics model.
Source LHC-B
Verifiability Verifiable

UR SYS6 The total latency (time difference between the trigger data being received and the decision being delivered to the global trigger) should be less than 50 μsec.

Need Essential
Priority High
Stability It can be reconsidered. It depends on the available buffer in the front-end to store accepted Level-0 events while the Level-1 trigger is working.
Source LHC-B
Verifiability Verifiable

UR SYS7 The trigger data should consists of 1 bit produced by a discriminator with variable threshold per Si-strip.

See Table 3 for the details.

Need Essential
Priority High
Stability The exact number may change after detector optimization
Source LHC-B
Verifiability Verifiable

UR SYS8 The maximum trigger latency should not exceed 100 μsec.

As long as the decision are in temporal order (see URSYS5) the latency do not need to be always at the maximum and constant. Is the processing time of a given event exceeds the maximum limit then the processing should be aborted and a decision should be send to the global trigger. Which decision (yes or no) may depend on the results of the simulation studies.

Need Essential
Priority High
Stability The exact number may change after detector optimization
Source LHC-B
Verifiability Verifiable

3.1.2 Control and monitoring

UR CM1 The trigger should provide sufficient information to the LHC-B control system about to its internal operation that an accurate status display can be produced.

Need Essential
Priority High
Stability It will be specified with more details.
Source LHC-B
Verifiability Verifiable

UR CM2 The vertex trigger should monitor continuously it internal operation in order to produce alarms in case a fault is detected.

Need Essential
Priority High
Stability It will be specified with more details.
Source LHC-B
Verifiability Verifiable

UR CM3 The vertex trigger should add all the information necessary to the data transferred to the DAQ that would allow to check the performance of the trigger off-line.

It is envisaged that some events will be accepted unconditionally without taking into account the results of the vertex trigger. If the results are transferred to the DAQ system, then the performance of the trigger can be checked off-line.

Need Essential
Priority High
Stability It will be specified with more details.
Source LHC-B
Verifiability Verifiable

3.1.3 Timing distribution system interface

UR TD1 The trigger will received the LHC 40 MHz clock with a phase which will be adjustable +- 25 ns in steps of 100 ps.

Need Essential
Priority High
Stability It will be specified with more details.
Source LHC-B
Verifiability Verifiable

3.1.4 Front end interface

To be completed

3.1.5 Interface to the global trigger

UR GT1 The vertex trigger should send to the global trigger the summary information of its processing.

The minimal information which is absolutely needed is a single bit (yes/no). However it is envisaged to have more that one bit to qualify the decision and even to send a likelihood for each bit.

Need Essential
Priority High
Stability It will be specified with more details.
Source LHC-B
Verifiability Verifiable

3.1.6 Interface to the read-out system

UR RD1 The vertex trigger should behave as a normal data source (like a subdetector) vis-a-vis the read-out system.

This means that it should respond to the level-1 trigger decisions (the external decision coming from the global trigger) and make available the processed data of the event in question in the standard format and timing requirements.

Need Essential
Priority High
Stability Stable.
Source LHC-B
Verifiability Verifiable

3.2 Constraint requirements

Constraint requirements place restrictions on how the trigger system can be built and operated. For example, definitions of external communications, hardware and software interfaces may already exist, either because the system is a part of a larger system, or because the user requires that certain protocols, standards, computers, operating systems, library or kernel software be used.

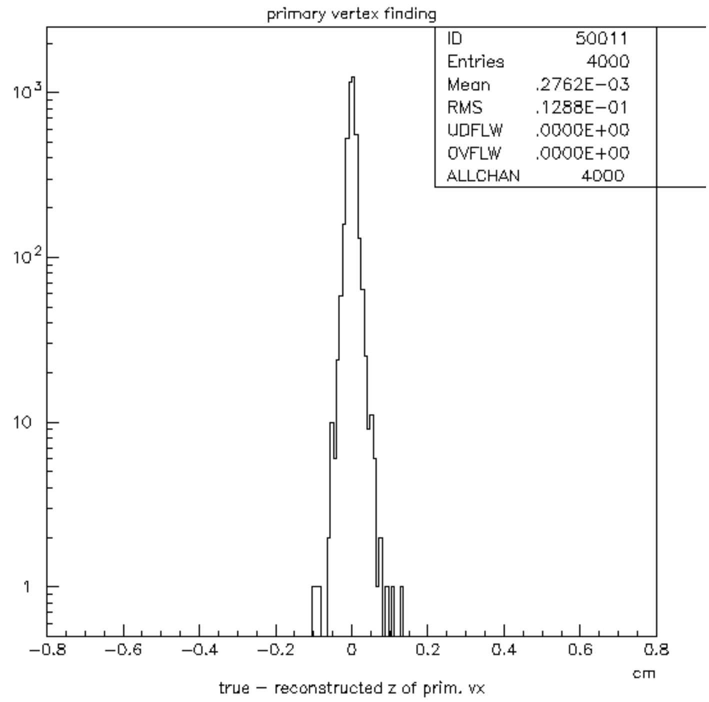
4 List of User Requirements

A Efficiencies and Resolutions using Montecarlo

A.1 Primary Vertex

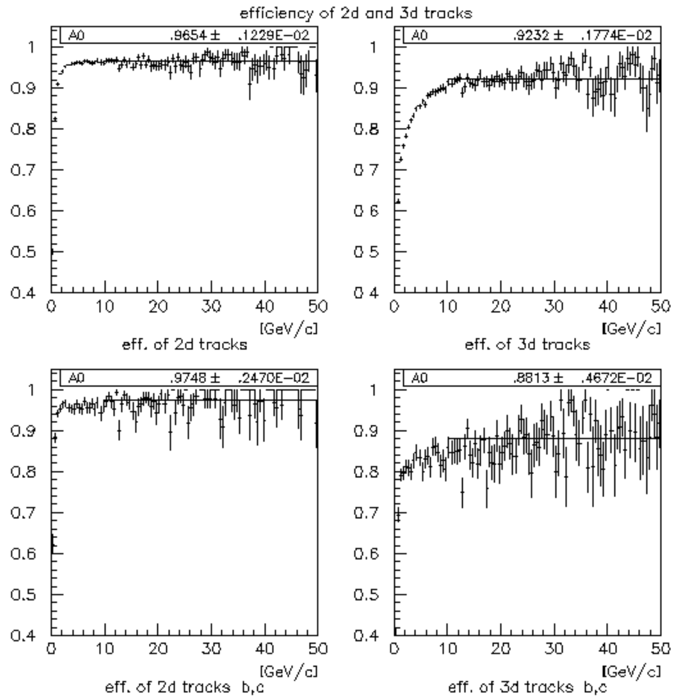
The efficiency of finding a primary vertex for 4000 events B–>ππ is 100%. The resolution in *z* is better than 100mμ.

Figure A.1 This plot shows the distribution of the z-coordinate of the true primary vertex minus the reconstructed primary vertex.



A.2 2-D and 3-D Tracks

Figure A.2 The efficiency of the vertex trigger track reconstruction is shown in the following plot as function of the particle momentum. The efficiencies are normalized to tracks which hit at least 3 silicon stations.



The efficiency to find the 2d-tracks with the present software and settings is about 97%, only a small difference if it is a track from a B-decay or a primary track. The efficiency to find 3d tracks is 92%, if it is a primary track and 88% if it is a track from a B-decay. The reason for the difference is still under investigation.

Some inefficiencies arise if tracks leave the sector boundaries. We require, that tracks stay inside one sector.