Detection of hardware problems of the HERA–B vertex detector via occupancy analysis

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Reported by

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Abstract

HERA–B is an experiment at the HERA storage ring in the Deutsches Elektronen-SYnchrotron, DESY, laboratory in Hamburg, which serves to search for CP symmetry violation in the decay of neutral B mesons via the "gold-plated" decay $B^o/\bar{B}^o \rightarrow J/\Psi\, K^0_s$. The B mesons are produced in proton–nucleus interactions by protons hitting an internal wire target which makes the design of a forward magnetic spectrometer necessary. An important component of the HERA–B experiment is the Vertex Detector System (VDS) because it has to measure the evidence for reconstructing the $J/\Psi \rightarrow e^+e^-$, $\mu^+\mu^-$ decay vertices and the parameters of all tagging particles. Thus its task is to measure primary and secondary vertices with high spatial resolution.

In this report it will be showed how some hardware problems, in terms of an observable called occupancy, come into view from this detector part and how to handle them.

Contents

Chapter 1

HERA–B & the vertex detector

HERA–B is one of the four experiments at the proton storage ring HERA at DESY (Deutsches Elektronen-SYnchrotron) laboratory in Hamburg.

In HERA–B 920 GeV protons interact inelastically with a fixed internal target producing $b\bar{b}$ quarks at a center of mass energy of 42 GeV. If we look into the beam direction, behind the target first the VDS is found, which uses the same principle of all the forward spectrometer detectors: it is an arrangement of a number of detectors perpendicular to the beam axis [1], [2].

The VDS is essentially built up by 64 double sided microstrip detectors. Each one is 280 μm thick and has an active area of 50×70 mm^2. The detector sides contain 1280 implanted readout n^+-strips (n-side) and 1024 implanted readout p^+-strips (p-side) which are rotated by 90° against each other and tilted by 2.5° with respect to the detector edge to provide different stereo views. These 64 detectors are arranged in eight planes which are called superlayers, where the first seven ones are placed in a 2.5 m long vacuum vessel and the eighth behind the exit window of the VDS vessel. Each superlayer is divided into four quadrants, each one consisting of two double sided detectors, which are mounted back-to-back. A manipulator steering enables for lateral and radial movements. As designed and described above the detectors deliver the lateral (n-side) and radial (p-side) distribution of the hits [2], [3].

The complete VDS covers a polar angle from 10 to 250 mrad.

Chapter 2

The characterization of detector views

The signals coming from the detector strips are used as an input for analog readout chips which amplify, shape and also buffer the data until they should be read out by the second level trigger.

Constrained by the bunch crossing frequency and timing dependencies the chips have a short peaking time of the signal, a latency of $\approx 10\ \mu$s and a multi–event–buffer accepting up to 8 first level triggers. In addition they are designed for a hard radiation environment. These so called HELIX chips fulfill the requirements. The number of channels integrated on those readout chips is 128 and according to the numbers of silicon strips on p-side or n-side which are integer multiples (8 or 10) of this number. So each strip is used as an input channel.

2.1 The main goal

The topic of this report is to find a possibility to flag areas of the detector modules, especially complete chips, which deliver fake data. In a subsequent step these areas should not be read out anymore.

As an input of the presented first analysis, the occupancies of the detector sides are used which are produced by an online monitoring program using the detector's raw data. The occupancy is the distribution of hits as a function of the silicon microstrips. As described before a certain behavior of the occupancy is expected: n-side yield an azimutal or more or less symmetric distribution while p-side should show a behavior similar to $\frac{1}{r^2}$, with r being the distance from the proton beam.

2.2 The hardware problems

In several runs one can extract from the occupancies that complete chips have problems, i.e. the numbers of hits is too much low (dead chips) or too much high (hot chips) compared to the expectation from real particle flux. As an example, fig. 2.1 shows occupancies of superlayer eight taken with the Run 17261. Plot Occ 60000, corresponding to a n-side, shows an entirely dead chip and in plots like Occ 60601, Occ 60602, and Occ 60902, corresponding to p-sides, one recognizes complete hot chips. Examples for good occupancies are Occ 60600 and Occ 60603 for n-sides, and Occ 60901 for a p-side. In general p-sides show significant drops of the occupancy at the detector edges according to shorter strips due to the stereo angle.

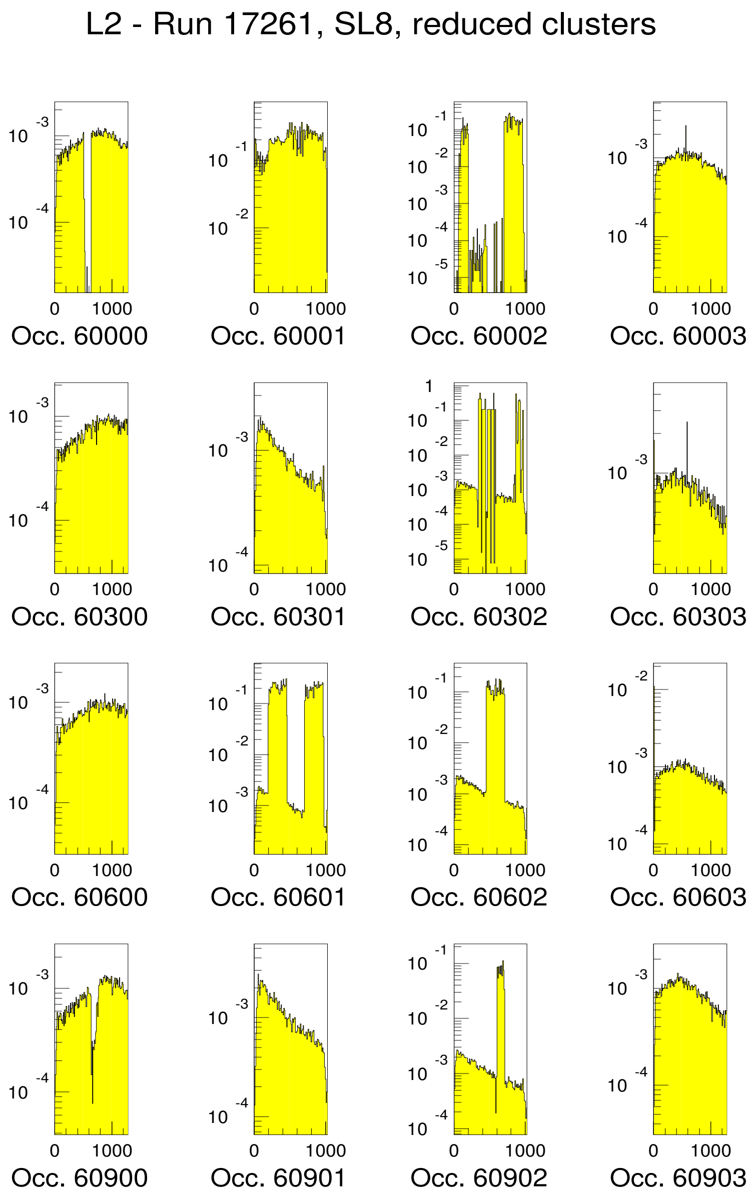

Figure 2.1: *Occupancy plots for superlayer 8 with data taken in run 17261, only clusters accepted by a hard signal–to–noise cut are used.*

Chapter 3

A possibility to handle problematic detector areas

As explained before there are some areas of the silicon microstrip detectors, which have serious problems. In order to prevent their read out, a reasonable cut for them is necessary.

The idea is to make a default occupancy plots for the two type of sides each, and then compare with any run. For calculating the default plots it is necessary to check carefully as many runs as possible, then get a feeling which of those runs are the best ones, i.e. with high statistics and select the best sides to average them. This goal was performed in a PAW environment by looking at 20 different runs randomly. The results of this default plots are displayed in fig. 3.1. They are smooth and they also show the expected behavior.

In the Appendix A the special kumac can be found to compare any run with the default occupancies and to plot the result. The main part of the kumac can be summarized in the algebraic equation:

$$\epsilon = \frac{\mathrm{Occ\,(Current\,run)} - \mathrm{Occ\,(Default\,run)}}{\mathrm{Occ\,(Defaultrun)}} \tag{3.1}$$

As ϵ is defined, the value of zero of a bin means a perfect agreement with the default plot.

Using the current run 17261 as an input for this special kumac, it displays fig. 3.2 for the eighth superlayer. It clearly shows the hot and dead chips compared with the default occupancies. For example, plot Diff 60000 shows that a value smaller than -0.9 for ϵ is corresponding to a dead chip. In fact this cut is useful for dead chips in general. In comparison the plots Diff 60601, Diff 60602 and Diff 60902 show an ϵ value greater than +10. After making the same analysis for 10 runs the mentioned ϵ values appear to be reasonable cuts for problematic chips.

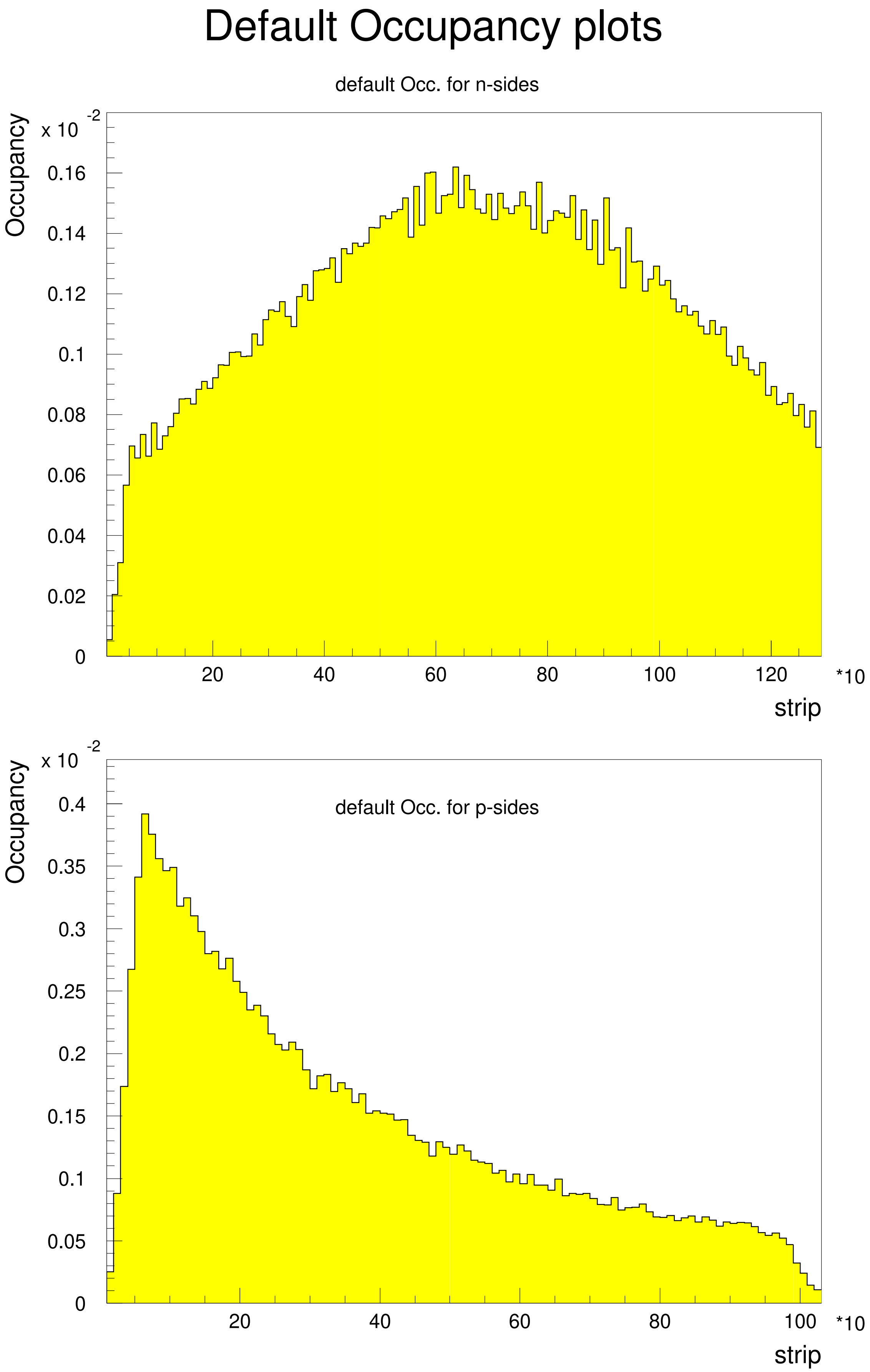

Figure 3.1: *Default occupancy plots for n-sides and p-sides.*

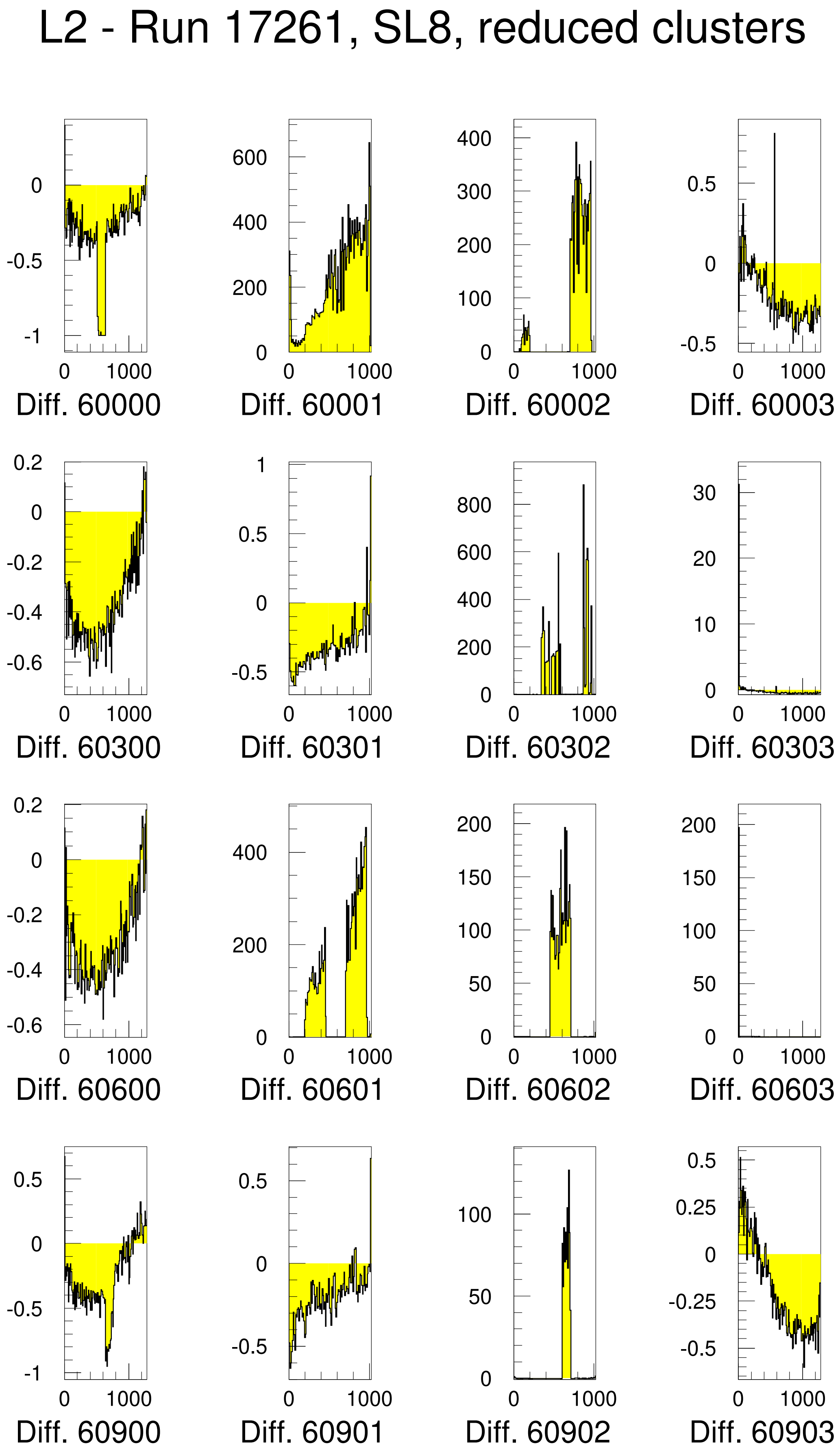

Figure 3.2: *Comparison plots for superlayer 8 with run 17261 as a current run.*

Chapter 4

Conclusions & Outlook

In this report the typical behavior of problematic chips on both sides of the silicon microstrip detectors during data taking has been shown. After making a comparison to the corresponding default occupancies reasonable cuts can be extracted:

$$\text{For dead chips} \rightarrow \epsilon \leq -0.9$$
$$\text{and for hot chips} \rightarrow \epsilon \geq 10.0.$$

The kumac that provides this comparison could be used in the future as an input to implement a code extension in the raw data online monitoring in order to find these problematic chips during data taking and to flag them as not to be read out anymore.

Appendix A

The comparison kumac

```
macro occupancies run=17261

********************    Some messages      **********************

  MESS
  MESS 'Call: eric <run>'
  MESS 'every page ==> one SL'
  MESS 'sort of the runs ==> reduced occupancies'
  MESS
  WAIT

*************    Open a FORTRAN formatted text file   ************
*************     Define a constant for the histID    ************

  fort/fil 20 occ_diff.ps
  meta 20 -111
  const = 400000

*******************    Setting of plots     **********************

  exec ~/kumac/kumac_tj/style_expert
  set xsiz 19
  set ysiz 28
  set xmgl 3.2
  set xmgr 2.
  set ymgl 2.
  set ymgu 3.
  opt nsta
  set xwin 2.6
  opt utit
  set gsiz 0.5
  set ygti 1.
  set dmod 1
```

```
  set ylab 0.8
  set xlab 1.6
  set hcol 1105
*  opt zfl
*  opt logy

******************  Calling the default plots   ******************

  exec /data/herab/hbvds/output/his/eric/default

********************    Unzip the [run]     **********************

  IF [run].ne.0 THEN
    p = 1
    close [p]
    hi/del *
    sh gunzip /data/herab/hbvds/output/his/eric/dmon_vds_slt_[run].his.gz
    hi/file [p] /data/herab/hbvds/output/his/eric/dmon_vds_slt_[run].his
  ENDIF


******************    The first three SL    *********************

  DO i=1,6
   IF [i]=1 THEN
    zone 3 4 | 7 8
    DO n=0,2
     WAIT
     zon = 0

*    **************    Setting of titles     ***************

      hi/cre/title_glo  '  L2 - Run '//[run]//', SL'//$EVAL([n]+1)//', reduced clusters

*
     DO k=0,3
      DO l=0,3
       IF [l].NE.1 THEN
        zon = [zon]+1
        m=[k]*3
        id = [i]0[m][n][l]
        MESS [id]
*       opt logy
        histID = $EVAL([id]+[const])

        IF ([l].EQ.0 .OR. [l].EQ.3) THEN
          ve/cre vn[histID](128)
```

```
        ve/cre dif_vec_n[histID](128)
        ve/cre  vdifn[histID](128)
        hist/get_vect/contents [histID] vn[histID]
        ve/op/vsubtr vn[histID] def_vec_n dif_vec_n[histID]
        hist/cre/1dhisto 7[histID] dif_n[histID] 128 0 1280
        ve/op/vdivide dif_vec_n[histID] def_vec_n vdifn[histID]
        hist/put_vec/contents 7[histID] vdifn[histID]
        pl 7[histID]
      ELSE
        ve/cre vp[histID](102)
        ve/cre dif_vec_p[histID](102)
        ve/cre  vdifp[histID](102)
        hist/get_vect/contents [histID] vp[histID]
        ve/op/vsubtr vp[histID] def_vec_p dif_vec_p[histID]
        hist/cre/1dhisto 7[histID] dif_p[histID] 102 0 1024
        ve/op/vdivide dif_vec_p[histID] def_vec_p vdifp[histID]
        hist/put_vec/contents 7[histID] vdifp[histID]
        pl 7[histID]
      ENDIF

*      pl [histID]
      opt liny
      IF $HINFO([histID],'ENTRIES')=0 THEN
       zone 3 4 [zon] s
       null 0 10 0 10 a
       itx 0 -2.7 'Diff. '//[id]
      ELSE
       null 0 10 0 10 sab
       itx 0 -2.7 'Diff. '//[id]
      ENDIF
     ENDIF
    ENDDO
   ENDDO
  ENDDO

********************    The last five SL    ***************************

   else
    zone 4 4 | 7 8
    wait
    zon = 0

*    **************    Setting of titles     *****************

      hi/cre/title_glo  '  L2 - Run '//[run]//', SL'//$EVAL([i]+2)//', reduced clusters
*
    do k=0,3
```

```
     do l=0,3
      zon = [zon]+1
      m=[k]*3
      id = [i]0[m]0[l]
      mess [id]
*      opt logy
      histID = $EVAL([id]+[const])

      IF ([l].EQ.0 .OR. [l].EQ.3) THEN
        ve/cre vn[histID](128)
        ve/cre dif_vec_n[histID](128)
        ve/cre  vdifn[histID](128)
        hist/get_vect/contents [histID] vn[histID]
        ve/op/vsubtr vn[histID] def_vec_n dif_vec_n[histID]
        hist/cre/1dhisto 7[histID] dif_n[histID] 128 0 1280
        ve/op/vdivide dif_vec_n[histID] def_vec_n vdifn[histID]
        hist/put_vec/contents 7[histID] vdifn[histID]
        pl 7[histID]
      ELSE
        ve/cre vp[histID](102)
        ve/cre dif_vec_p[histID](102)
        ve/cre  vdifp[histID](102)
        hist/get_vect/contents [histID] vp[histID]
        ve/op/vsubtr vp[histID] def_vec_p dif_vec_p[histID]
        hist/cre/1dhisto 7[histID] dif_p[histID] 102 0 1024
        ve/op/vdivide dif_vec_p[histID] def_vec_p vdifp[histID]
        hist/put_vec/contents 7[histID] vdifp[histID]
        pl 7[histID]
      ENDIF

*      pl [histID]
      opt liny
      if $HINFO([histID],'ENTRIES')=0 then
       zone 4 4 [zon] s
       null 0 10 0 10 a
       itx -6 -2.7 'Diff. '//[id]
      else
       null 0 10 0 10 sab
       itx -6 -2.7 'Diff. '//[id]
      endif
     enddo
    enddo
   endif
  enddo

*  close 20
**************      Zip the [run]       *******************
```

```
  sh gzip dmon_vds_slt_[run].his
*

  set *
  opt *

  hi/cre/title_glo  ''

  close 20
  close 1

return
```

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