DAΦNE TECHNICAL NOTE

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A comparison between data and simulations of the DAΦNE beam induced backgrounds in KLOE

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Abstract

A comparison between the background simulation predictions in the KLOE interaction region and the corresponding KLOE data has been performed. These studies show an agreement between the expected spatial distribution of the background and the vertex distribution due to background events observed in KLOE. A qualitative agreement has also been found between the expected and measured background rates.

Table 1: DAΦNE parameters used for simulations.

Particles/bunch [10^{10}]	2.0
Hor. Emittance[mm $\cdot$ mrad]	1
Coupling Factor	0.01
Bunch length [cm]	1.9
Relative Energy Spread	$4.0 \cdot 10^{-4}$
RF Voltage [KV]	100

1 Introduction

Since the first period of data taking KLOE has suffered from large beam induced background, mainly due to Touschek scattering. Simulation and tracking studies have been performed in order to understand and control the source of background and to find the proper actions that may allow to reduce these rates. Data have been analysed by KLOE and compared to simulated results.

1.1 Simulations of Touschek Background

Reduction of beam induced background is a particularly difficult task in a short machine like DAΦNE. In a low energy machine background arises mainly from Touschek effect: off-momentum particles can exceed the momentum acceptance given by the RF bucket or may hit the aperture when displaced by dispersion. In addition, a betatron oscillation is excited if the momentum change happens in a dispersive region.

During KLOE data taking runs the machine induced background at KLOE has been reduced by adjusting several optical parameters like the orbits in the interaction region, the strength of sextupoles or the β_x value in the interaction point.

Studies have also been carried out to provide a predictive and reliable code that could reproduce the machine induced background. In this frame, the home developed tracking code [3] 'STAR' (Simulations of Touschek pARticles) has been upgraded. Many features have been added, like the tracking of the Touschek scattered particles along the machine and over many turns. All the magnetic elements have been considered, including the non linear terms like sextupoles and the octupolar terms in wigglers. STAR is used to predict the locations where the off-energy particles get lost. The simulation code is used to study the present collimators performance [2] and to find possible positions where additional scrapers could reduce background. The main beam parameters used for the simulations presented here are summarised in Table 1.

Touschek lifetime is determined by the momentum acceptance, by the bunch volume integrated over the lattice structure and by the current. In the DAΦNE rings we distinguish two regions: straight sections with vanishing dispersion and arcs with high dispersion. Particles scattered in the straight section with vanishing dispersion undergo a momentum deviation, but gain no additional betatron oscillation, and will therefore not add to the background. However, particles scattered in the arcs suffer additional horizontal betatron

Table 2: Contributions of the four arcs to the losses in KLOE IR. The numbers are referred to a total e+ beam current of $\simeq$ 700 mA; simulations have been performed without scrapers. Central column: particles lost from the splitter magnet upstream the IP to the other splitter. Right column: particles lost close to the IP.

Background rates (MHz)		
DAΦNE arcs	KLOE IR	s [-1,1] m
PL1	16.1	2.4
PL2	0.0	0.0
PS2	0.7	0.0
PS1	7.5	0.3
Total	24.3	2.7

oscillations and can therefore get lost on the vacuum chamber inside the interaction regions, hence producing background at the experiment. The long straight section with non vanishing dispersion has been neglected because the betatron oscillation gained by the Touschek off-energy particles is small with respect to the one in the arcs.

In the simulation, Touschek scattered particles are generated separately in the four arcs PL1, PL2, PS2 and PS1 for the positron beam (and similarly for the electron beam). In this way the different contributions from each arc to the experiment as well as to the total beam losses can be studied separately. It is worth pointing out that non linearities significantly contribute to the losses in the KLOE IR.

In particular it is found that only two out of four arcs mostly produce the Touschek particles which are eventually lost in KLOE IR, they are the closest and the farthest one to KLOE (PL1 and PS1 respectively). This is roughly explained by the important role played by the horizontal betatron phase of the particle at the position of the Touschek scattering. The particles that get lost have been counted as background in KLOE if they have a longitudinal coordinate between -5.06 m and 5.0 m, i.e. particles lost between the two splitter magnets and inside the upstream one. The four arcs contributions to the KLOE background rate are shown in Table 2; the results refer to the positron beam.

Simulations have been performed for one bunch with 10 mA current. The rates have been scaled for a bunch current of $\simeq$ 15 mA with 47 bunches, corresponding to a total beam current of 700 mA which is about the current used for KLOE data taking at the runs used for the comparison. Simulations have been performed with scrapers out.

The upper plot in Figure 1 shows the distribution of the particles hitting the beam pipe along the KLOE IR for the PL1 arc contribution. The lower plot of figure 1 shows instead how losses are distributed turn by turn. The behaviour is very sensitive to the non linearities which have been considered in the simulation. From figure 1 (upper plot) it appears that there are essentially 3 regions of particles which may eventually produce background in the experiment:

1. particles reaching the physical aperture in the splitter magnet;

2. particles hitting the beam pipe around the low-β quadrupoles ($-3\ m < s < -1.5\ m$);

3. particles hitting the beam pipe around the IP ($-1\ m < s < +1\ m$).

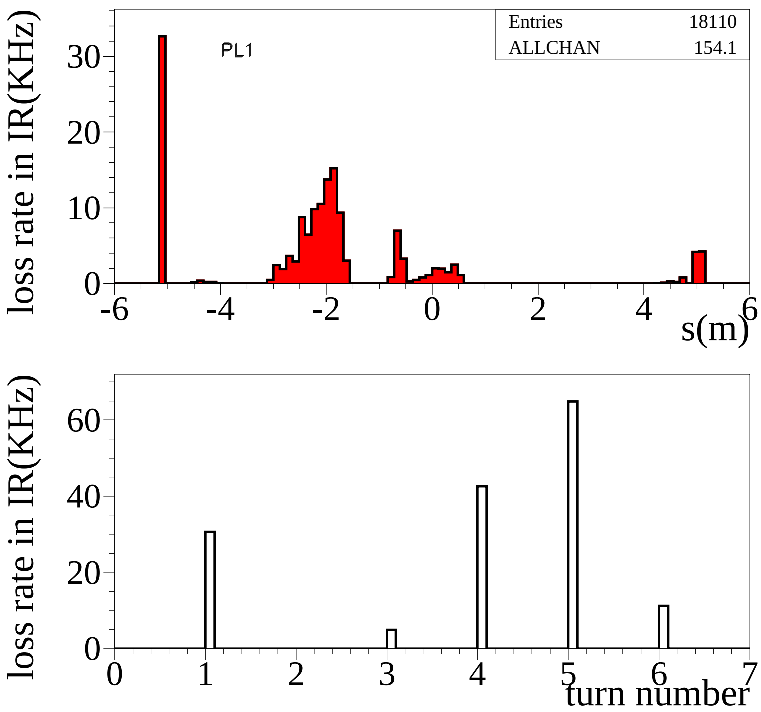

Figure 1: Touschek background from arc PL1. Upper plot: Distribution along the IR of the particles hitting the beam pipe; lower plot: expected KLOE background rate as function of the number of turns. Rates are evaluated for 1 bunch of 10 mA current.

Background coming from these 3 categories are expected to exploit different signatures in the KLOE detector. In particular, the background coming from region 1 and 2 is partially shielded by the low-β quadrupoles, as figure 2 shows. Figure 2 shows the trajectories of the particles which are Touschek scattered in arc PL1 which hit the vacuum chamber and get lost in the KLOE IR.

The particles are tracked as if they went straight. The plot is top view and it appears clearly that the positrons are lost mostly at the external region of the machine, corresponding to Touschek particles with a positive ΔE/E. It appears that the positrons lost inside the splitter magnet and in the external horizontal region of the pipe (region 1 and 2) hit mostly the first focusing low-β quadrupole. On the contrary, the particles which hit the pipe just close to the IP (region 3) have a radial angle such that they do not go out the beam pipe. The expected contribution to background from region 3 is reported in the right column of Table 2 and will be the subject of the comparison with the KLOE

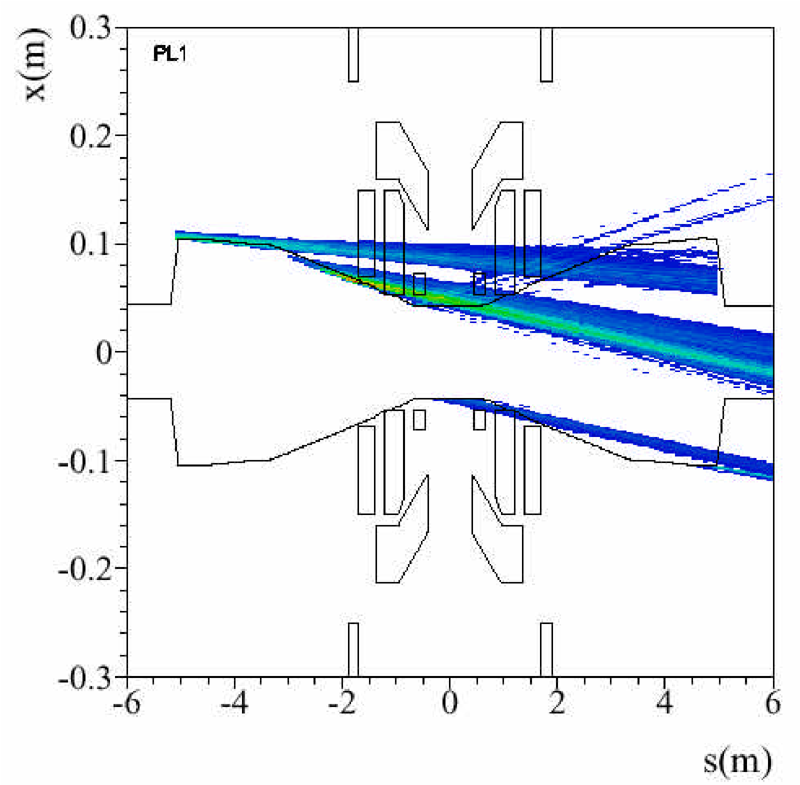

Figure 2: KLOE IR top view: trajectories of Touschek scattered particles from arc PL1 contribution.

data. Since in this case the products of the primary interactions induced by the Touschek particles are not shielded and can be measured precisely with the KLOE detector. A quantitative comparison between the simulated background rates for region 1 and 2 with experimental data requires detailed detector simulations that are still in progress.

As table 2 shows, arc PS1 is expected to contribute significantly to KLOE background rates. In this case the trajectories of the particles hitting the beam pipe are reported in figure 3 and are very similar to the ones coming from arc PL1. The corresponding longitudinal position is shown in the upper plot of Figure 4. They get lost at the third and fourth machine turn (see lower plot of Figure 4). Arcs PL2 and PS2 are found not to contribute significantly to the KLOE background rate, as reported in Table 2. Anyway, the small fraction of positrons Touschek scattered in arc PS2 get lost in the splitter and in the external horizontal side. If these particles are assumed to go on straight, they eventually hit the first low-β quadrupoles. They get lost at the sixth turn.

2 Comparison with KLOE background analysis

The first 200 s of the KLOE run 19766 acquired on June 26th 2001 have been analysed and compared to the expected background simulated with the same DAΦNE parameters sets. They have been chosen for the analysis[4]. In this run DAΦNE operated with 47

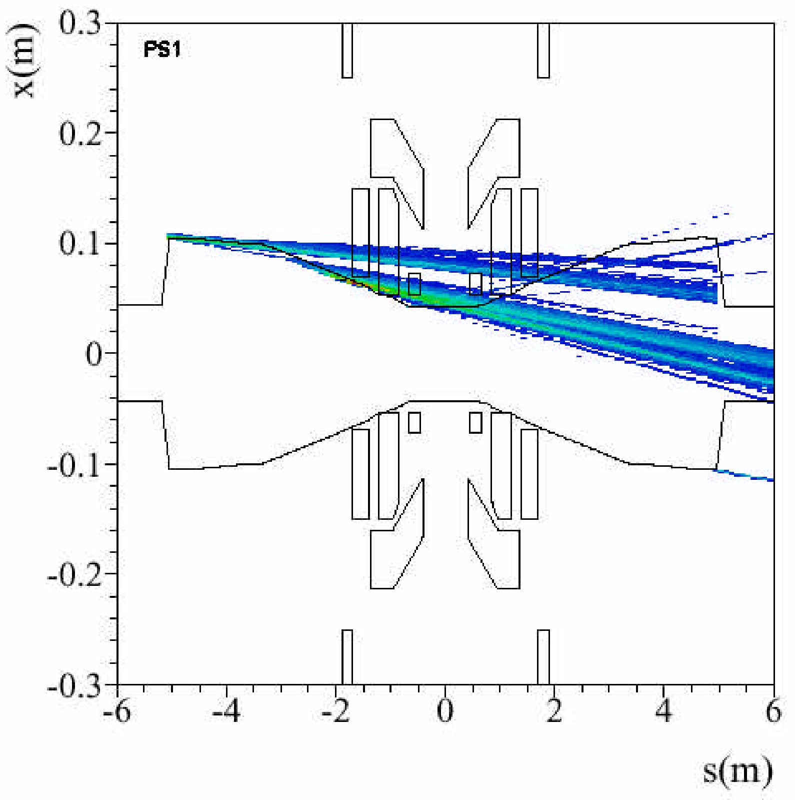

Figure 3: Touschek particles generated in PS1 eventually lost in KLOE IR.

bunches and with an initial current of $\simeq 700\ mA$ for the positron beam and $\simeq 600\ mA$ for the electron beam.

Figure 5(left) shows the expected distribution in the machine plane of the background particles hitting the beam pipe in the region 3 defined before ($|s| < 100$ cm). It can be noticed that there are two peaks corresponding to the quadrupole regions in the external side of the machine. This background component is due to Touschek particles with a positive $\Delta E/E$. The background hits in the central region are mainly due to Touschek particles with a negative $\Delta E/E$ that reach the physical aperture in the internal part of the machine. Figure 5(right) shows the expected hits distribution along z; the peaks around the quadrupole regions are more visible with respect to figure 5(left). The total expected background rate is about 5 MHz, for an electron beam current of 600 mA and positron beam current of 700 mA.

The KLOE analysis results show the evidence for photo-production events induced by machine background. Therefore, a toy simulation (see [4] for details) has been used to evaluate, starting from the STAR output, the rate of the photo-production induced by background and of the corresponding interaction point distribution. The results are shown in Figures 6(left) and 6(right). The expected rate is about 280 Hz in agreement with the rate observed by KLOE, which is about 300 Hz. It has to be stressed that this agreement must be considered only a qualitative one, as the detector acceptance has not been included in the toy simulation. In addition, the toy simulation is based on simplified assumptions and therefore it is difficult to estimate the uncertainties on the expected rate.

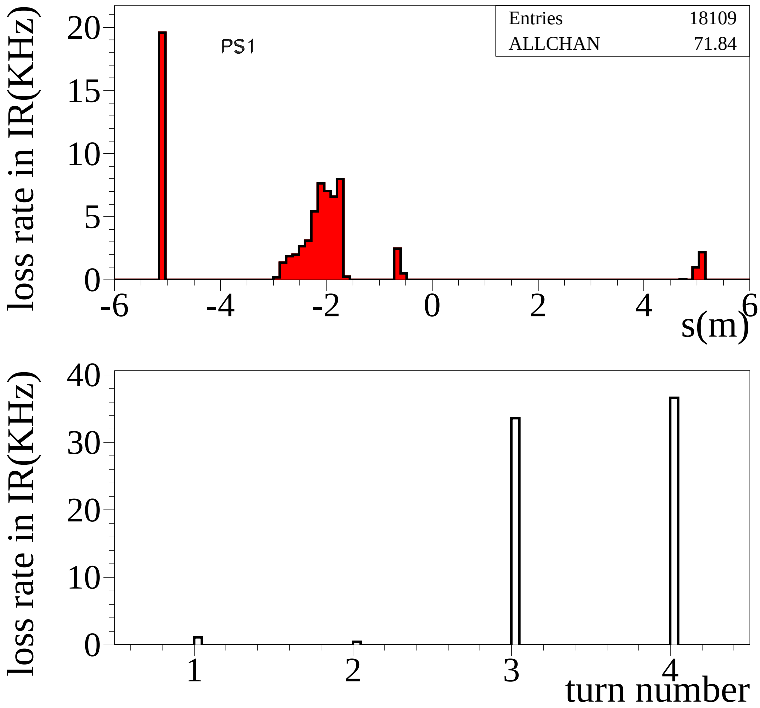

Figure 4: Particles Touschek scattered in arc PS1. Upper plot: Expected distribution along the ring of the particles hitting the vacuum chamber and consequently lost; lower plot: Expected KLOE background rate as function of the number of turns.

Nevertheless, the predicted rate has the same order of magnitude of the observed one.

A qualitative agreement is also found between the expected photo-production interaction point distributions and the observed ones. Figure 7 shows the distribution of the point of closest approach to the beam line of the charged tracks along the longitudinal coordinate. It can be noticed that there are two peaks in the region around the quadrupoles, as expected from background simulations (see figure 6(right)). Obviously the peak in figure 7 around s=0 is due to e^+e^- events. Figure 6(left) shows the expected asymmetry between the relative populations in the external and internal side of the machine (positive and negative x values). The asymmetry changes as a function of s: around quadrupoles the asymmetry is on the external part of the machine while around the IP there is a slight asymmetry on the internal part. The same feature has been observed in the KLOE data, as figures 8 show.

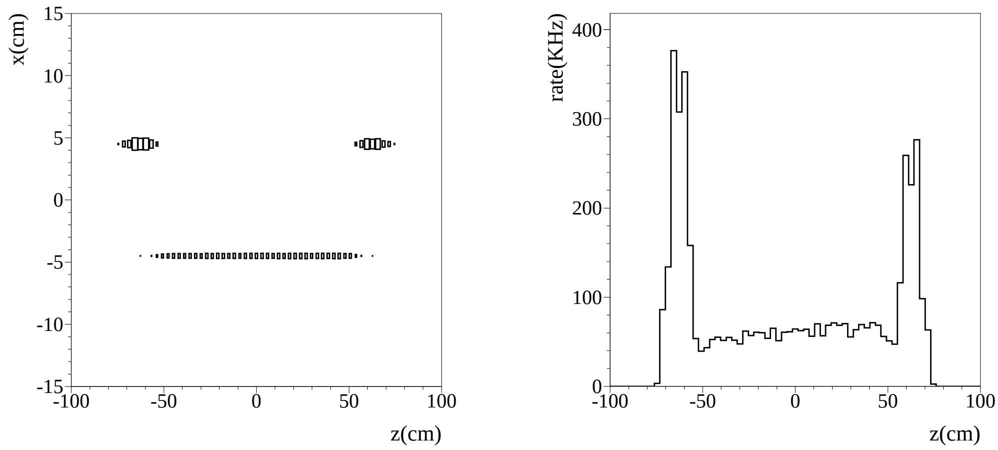

Figure 5: Distributions of the expected background hits on the beam pipe in the x-z plane (left) and on the z axis (right), from STAR simulation. Boxes size on left plot are proportional to background rate.

3 Conclusions

The results of the Touschek simulation show a huge background rate entering in the KLOE region. Most of this background is expected to hit the low-β quadrupole. The effects of this background component on the KLOE detector has not been evaluated yet. Simulations show that there is a minor background component hitting the beam pipe in the region close to the IP. This background component has been measured precisely in KLOE detecting the products of the induced photo-production processes. A qualitative agreement between the STAR predictions and the KLOE measurements has been shown both for the rates and for the background spatial distributions. The agreement reinforces the reliability of the developed simulation code. Further studies are in progress, including full tracking of Touschek particles in the KLOE detector in order to compare the whole predicted background rates with experimental data.

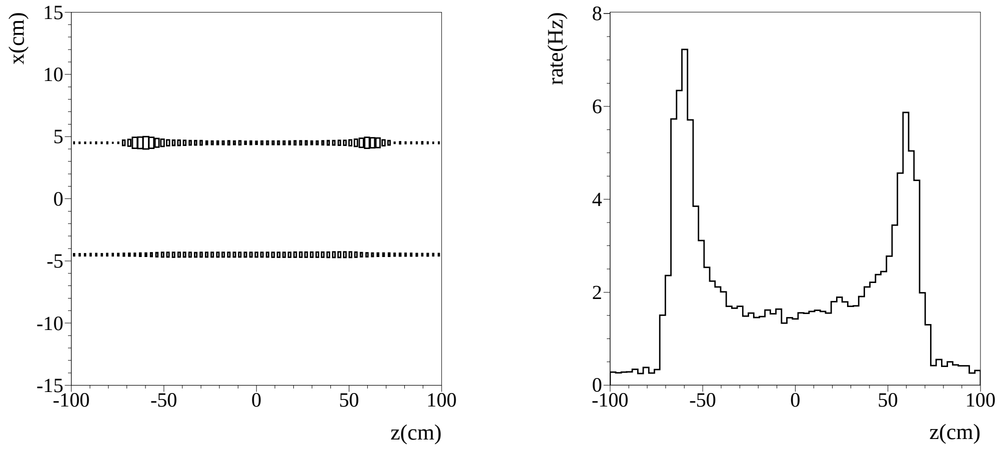

Figure 6: Distributions of the expected photo-production interaction point (STAR simulation and toy Monte Carlo) on the beam pipe in the x-z plane(left) and on the z axis (right). Boxes size on left plot are proportional to photo-production background rate.

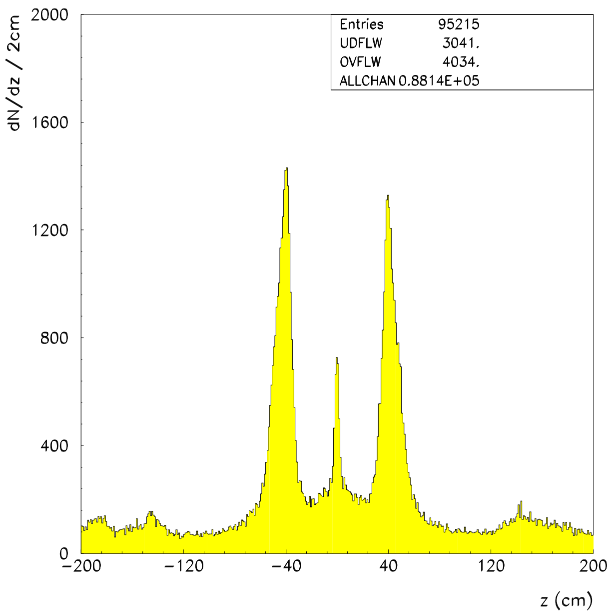

Figure 7: Longitudinal distributions of the point of closest approach to the beam line for tracks coming from photo-production events.

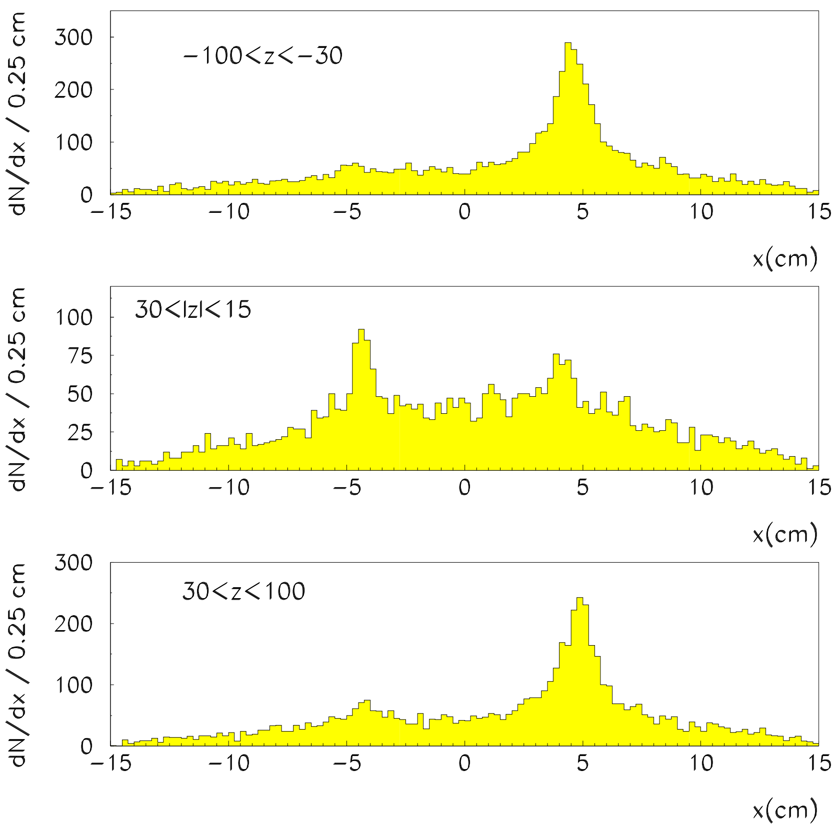

Figure 8: Measured distributions of charged vertex on the x axis; for s around the low-β quadrupoles region (top and bottom), s around the IP region (middle).

References

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