ENERGY DEPOSITION IN THE TRIPLET AND TAS ISSUES *

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Abstract

Energy and power deposition in the low-beta insertion magnets may be the limiting factor in the choiche and/or performance for luminosity upgrade configuration for LHC. In this paper, after a general review of the problem about the type and properties of the secondary particles, the effect of the Target Secondary Absorber (TAS), for different distance l* of the insertion from the Interaction Point (I.P.) in various configurations is reported. Then the effect of the magnetic sequence of the quadrupoles for the two crossing plane, horizontal and vertical (H,V) is evaluated. Moreover the effect of the magnetic field of the solenoid is computed. All theese parametric studies tend to have a scaling law of the energy deposition in the insertion magnets vs. all the parametrs involved.

INTRODUCTION

The evaluation of the energy and power deposition in the triplet magnet is a key point in the performance of an LHC luminosity upgrade scenario. As a matter of fact the power deposed scales with the luminosity and the beam dynamics of the secondary particles may differ significantly from one configuration to another. The effect of the various elements and parameters involved must be carefully evaluated, in order to have a feeling of the relative importance of the parameters and try to obtain a scaling law of the power deposition as a function of all the parameters. The energy deposition in the insertion is computed with the FLUKA [1][2] montecarlo code.

This paper is extracted from a talk given at the workshop CARE-HHH-APD IR'07, hold in Frascati, November 2007, (see [3] for more and larger plots), and summarize many studies performed in the last year, after the analogous workshop hold in Valencia in October 2006; here only the main results are reported, corresponding reference are indicated for detailed results plots and discussion.

It is worth noting that the values of power deposition and their location must not be considered as real and referred as an actual power deposition in the tripled once the upgrade configuration is adopted.

The values have only a relative meaning, just to qualitatively evaluate the effects of the parameters involved in the problem.

In order to have an actual situation with reliable values, all the parameters must be taken into account, for example the beam pipe thickness and shape (in the actual situation it is designed and optimized in order to avoid backscattering to the detector), the presence of valves and vacuum pumps, whose effect may be locally important.

To this aim the study of the actual LHC layout (version 6.5) has been separately performed [4].

SECONDARIES

1300 p-p 7 TeV events, as from DTUJET[5] event generator, are used as source events, the particles realized (secondaries) are then tracked along the insertion magnetic structure and treated by FLUKA as soon as they interact with the line elements. The 7 TeV p-p interaction type are the inelastic scattering, the single diffractive and the elastic scattering, the corresponding cross sections are 60 mb, 12 mb and 40 mb respectively. For this study only the inelastic scattering and single diffractive events are important, giving a cross section of 72 mb. In order to have a safety factor, 80 mb will be considered. The most numerous (75%) particles produced are pions (27% of the total particles are π^0), about 82% of the energy is carried by pions and protons and neutrons, while protons and neutrons carry the highest specific energy (about 980 GeV/part for protons and about 600 GeV/part for the neutrons).

The pseudorapidity distribution of the secondary particles versus the energy, (Fig.1) shows many particles

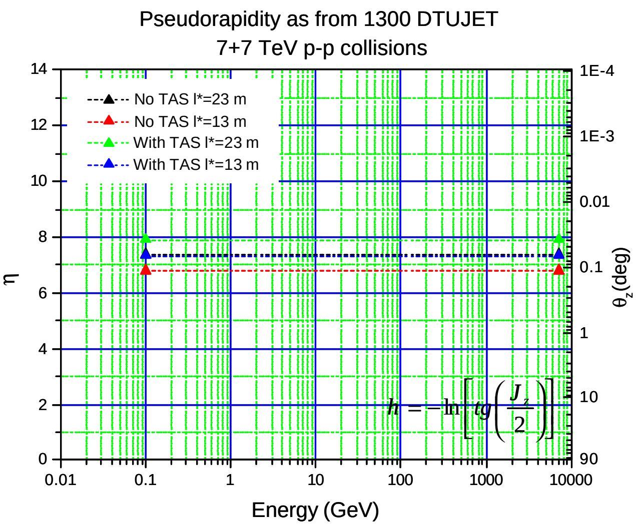

Figure 1: Pseudorapidity of the secondary particles, the marked lines show the pseudorapidity cuts correponding to different angular acceptance with or without the TAS.

with low energy and high transverse momentum (that will be absorbed by the detector and absorbed or degraded by the beam pipe). The particles inside the angular acceptance of the beam pipe/TAS (the ones lying above the marked lines) are the most energetic and can depose their energy in the quadrupoles.

Because of this pseudorapidity distribution the total energy impinging on a triplet element decrease as the element approach the IP. As a matter of fact the contribution to the energy deposition can be splitted into

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two terms, the energy impinging on the internal surface and the energy impinging on the front one. Approaching the IP, the energy impinging on the front surface decreases, while the one on the internal surface increases, leading to a decrease of the total energy hitting the element as shown in Fig. 2.

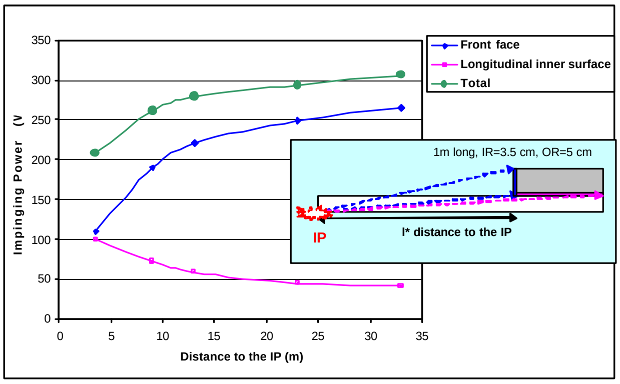

Figure 2: Energy impinging vs the distance from IP.

The decreasing/increasing of the energy depends on the aspect ratio of the element; for typical magnet geometry the above results can be applied.

The power carried by one 7 TeV beam is about 7760 W (with a luminosity $L=8.64\text{x}10^{34}$ cm^{2} s^{-1}) of which about 60% is carried by charged particles, the energy deposition mechanism is mainly due to electromagnetic showers (about 73%) (see the high amount of π^0, as told in the previous section) and ionisation by heavy charged particles (about 15%).

TAS AND ITS EFFECTS

The main functions of the TAS are the reduction of the angular acceptance toward the insertion magnets, and to shield the first quadrupole.

Previous parametric studies about the energy deposition in the triplet vs. l* [6] showed that

- The highest peak power deposition occurs in Q2a (the second quadrupole),
- This peak power deposition is almost constant for l* variations between 13 to 23 m,
- The power deposed into the TAS is almost constant for the l* variations considered.
- The TAS affects only the total power deposed into Q1, having negligible effect on the peak power in it.

This facts and other studies [7] demostrate that the TAS must not be considered as a passive tool but an actual part of the insertion whose effect must be carefully evaluated.

Here the studies performed to evaluate the TAS effect were done for l*=23 m, $L=8.64\text{x}10^{34}$ cm^{2} s^{-1} and quadrupole aperture of 100 mm. The cases studied were:

- NO TAS at all
- Adaped TAS (aperture of 20 mm).
- External front shielding of Q1 without interfering with the beam pipe

The results were compared with the "nominal" configurations of TAS opening of 17 mm.

The results showed that the TAS does not affect the maximum peak power in the front part of Q1 (as shown in slide n°11 of the presentation related to this talk) [3], the main effect is in a more azimuthally spreaded power distribution in the front part of Q1(slide 12 [3]).

In this slide the last case is not reported because the external shield only affects the total power deposition in Q1 and only in it.

The shielding effect of the front absorber on the peak power in the front part of Q1 can be seen in slide 12 [3].

The absolute maximum of the peak power, occuring at the front of the second quadrupole, is unaffected by the TAS, while the maximum peak power in Q1, occuring at its end is affected by the TAS (slide 13 [3]).

QUADRUPOLE FIELD SEQUENCE

The quadrupole field of the triplet, according to the usual convention for LHC is FDDF, but some upgrading scenarios can forsee a DFFD sequence. This fact together with the considerations that the crossing planes for IP1 (ATLAS experiment) is vertical (V) while for IP5 (CMS experiment) is horizontal (H), induced to investigate possible correlations between the quad sequence and crossing plane.

The results (as from slides 18 and 19 for [3]) show a symmetry between DFFD_H with FDDF_V and DFFD_V with FDDF_H. If the peak power is considered (slide 19[3]) the maximum of the deposition does not occur at the same longitudinal position, and the value of the maximum differs for the different configuration. The case FDDF_H (CMS) is less critic showing a lower peak power deposition, almost half than in FDDF_V).

DETECTOR SOLENOID FIELD EFFECT

The two high luminosity experiment (ATLAS and CMS) have different detector solenoid field and dimension, CMS has a peak value of 4 T while ATLAS have 2 T (see slide 20 [3] for the geometric charateristics).

The effect of this field on the power deposition in the triplet has been evaluated, (as shown in slide 20,21 and 22[3]) the power deposition in the triplet does not depend on magnetic field of the solenoid.

CONCLUSIONS AND PERSPECTIVES

Many parameters affecting the power deposition in the triplet have been investigated. The TAS is effective in shielding the first quadrupole, but has negligible effect on the others and on the peak power levels. The crossing plane influence the actual FDDF layout, being more critical for the ATLAS experiment (V plane).

The detector solenoid field has no effect on the triplet.

Further studies are necessary in order to get a scaling law of the power deposition, by varying the various parameters involved, i.e. the aperture of the quadrupoles, their material composition and technology (NbTi or Nb_3Sn), the quadrupole gradient, the crossing angle.

The next step in the study will be the investigation of the quadrupole aperture effect.

All the studies reported have a continuous feedback and comparison with similar studies performed at FERMILAB performed with the MARS code, in particular a comparison of the two codes has been carried out using the same simplified IP5 model (considering only the first quadrupole) and parameters, with good agreement [8].

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