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Comparison of the Monte-Carlo models for proton–proton interactions DPMjet and DTUjet

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Summary
In this note we present a comparison between the DPMjet and DTUjet generators in the case of the LHC collision simulation. Concerning DPMjet, we compare the results obtained from two different postprocessing methods. For the purpose of the evaluation of the energy deposition to the few percent level, the two generators appear equivalent.

Distribution:
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1 Motivation

The evaluation of the heat deposited by collision debris requires the use of Monte-Carlo event generators. Former results [1] used stand-alone DTUjet. The new program generation is DPMjet called directly from FLUKA [2].
The goal is to ensure that our understanding of the output files and units is correct.

2 Description of the simulation conditions

The two proton beams collide head on without crossing angle along the z-direction with a momentum of 7 $\frac{\text{TeV}}{\text{c}}$. The number of collisions available for DTUjet is 1300 while in DPMjet simulations we took into account 9999 collisions. In all cases we consider colliding beams with vanishing beam size and divergence.

The DPMjet generator is not called directly but through the FLUKA software. We have two different runs of the generator: the first run was launched by Stefan Roesler (Run1), the second one by Christine Hoa (Run2) [3]. The secondaries are dumped by FLUKA with two different options for output file formats and after postprocessed.

The data of the DTUjet output are taken from an archived file [1].

In the followings some important features of the emerging particles (*secondaries particles*) will be compared:

- the mean number of secondaries emerging from the collision
- the total energy conservation
- the momentum conservation in the three directions
- the coherence in the relation between momentum and total energy
- the distribution of secondaries versus their pseudorapidity.

3 Comparison between DPMjet and DTUjet

3.1 The mean number of secondaries per collision

In Figure 1 the mean number of secondaries generated from our p–p collision is shown. There is a good agreement between the three generators. The 2% of discrepancy between DTUjet and DPMjet is compatible with the statistical uncertainty. Some kinds of particles are considered separately: they are the families that play the most important role in the total energy recovery.

3.2 Conservation of the total energy

We present in the Figure 2 the test on the energy conservation. In all cases the energy is conserved at least to a $4\ 10^{-4}$ level (Table 1).

- the data obtained form DPMjet are more precise for this aspect than those from DTUjet (the vertical scale is different)
- the best accuracy and statistical behavior is observed in Run2 (10^{-5} level centered on zero)
- in the two other cases a bias is observed

This last feature can be is simply due to the precision format of the file but it has to be investigated.

3.3 Distribution of energy among secondaries

In Figure 3 is shown the difference between the three generators in term of the mean total energy per collision. The mean total energy for a collision is ≈ 14 TeV.

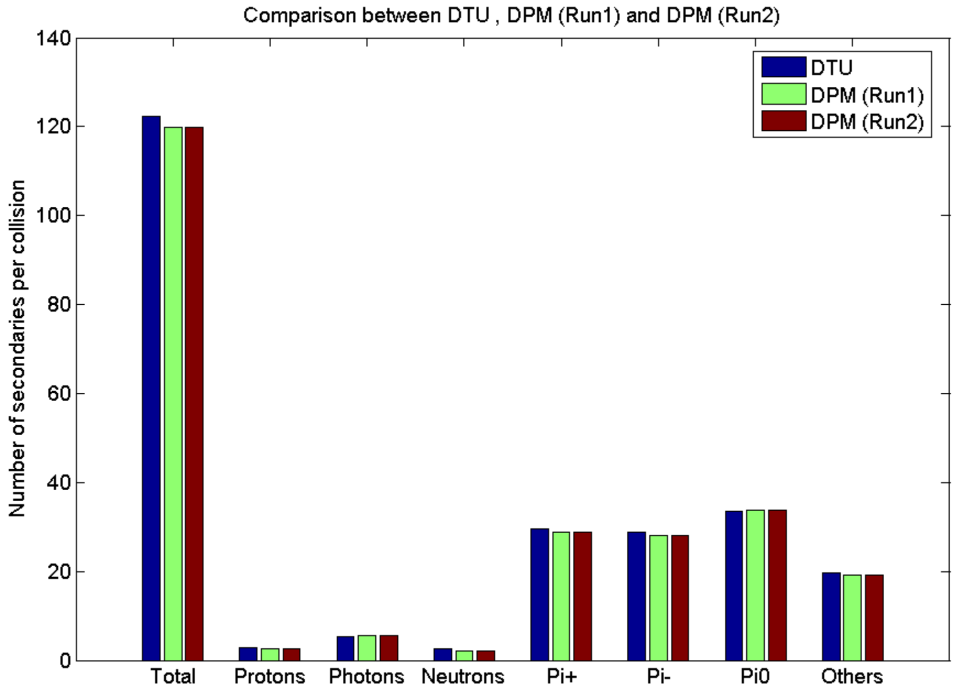

Fig. 1: The mean number of secondaries per collision.

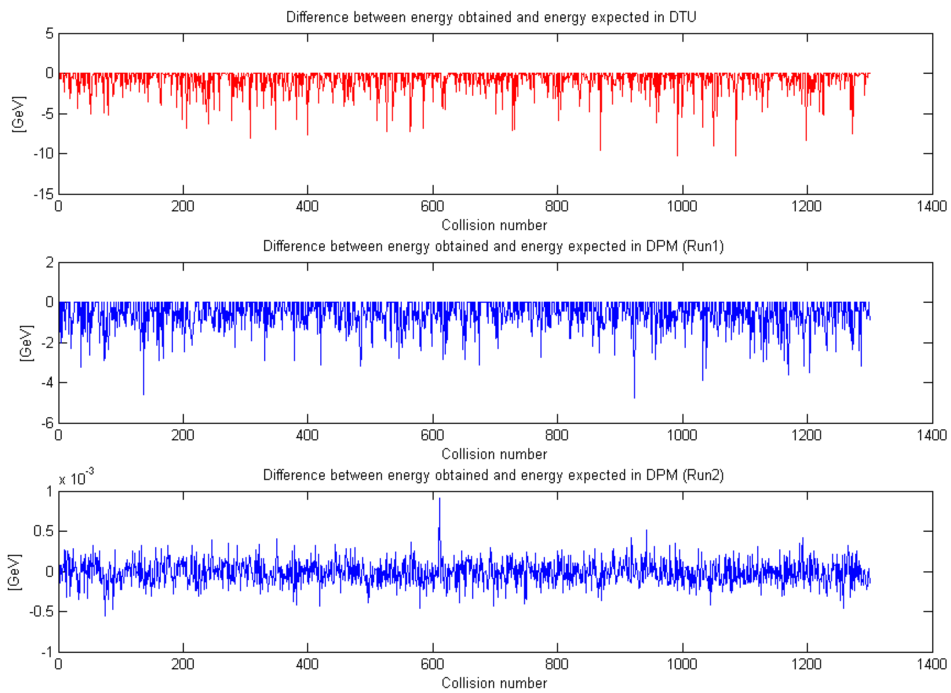

Fig. 2: Conservation of the total energy.

	Mean [GeV]	Standard deviation [GeV]	Skewness [GeV]
DTUjet	-0.785	1.436	-2.810
DPMjet (Run1)	-0.566	0.729	-1.637
DPMjet (Run2)	$1.319\ 10^{-5}$	$1.492\ 10^{-4}$	0.188

Table 1: Statistics on energy conservation's error.

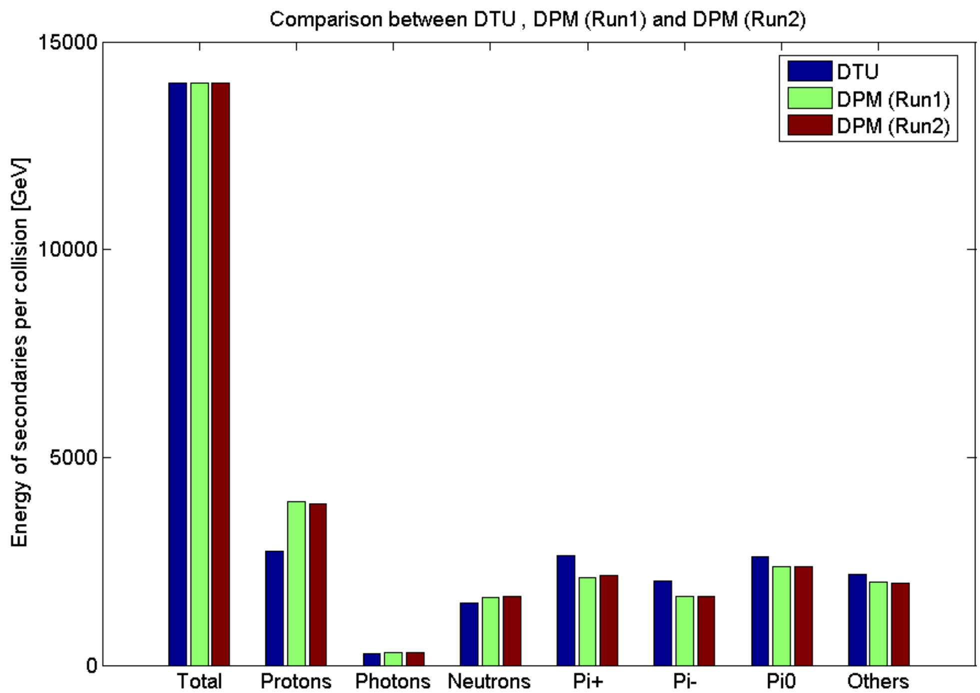

Fig. 3: Distribution of energy among the secondaries.

3.4 Conservation of the momentum

In Figures 4–6 we represent the check of momentum conservation. In all cases, the transverse momenta are conserved to better than $0.6\ \frac{GeV}{c}$. The two results derived from DPMjet are very similar and better by two orders of magnitude as compared to DTUjet . For the z-momentum (Figure 6) the violation reaches up to 5 GeV in DTUjet while it is 3 orders of magnitude lower for DPMjet. Both runs of DPMjet show the same small positive bias for the longitudinal momentum.

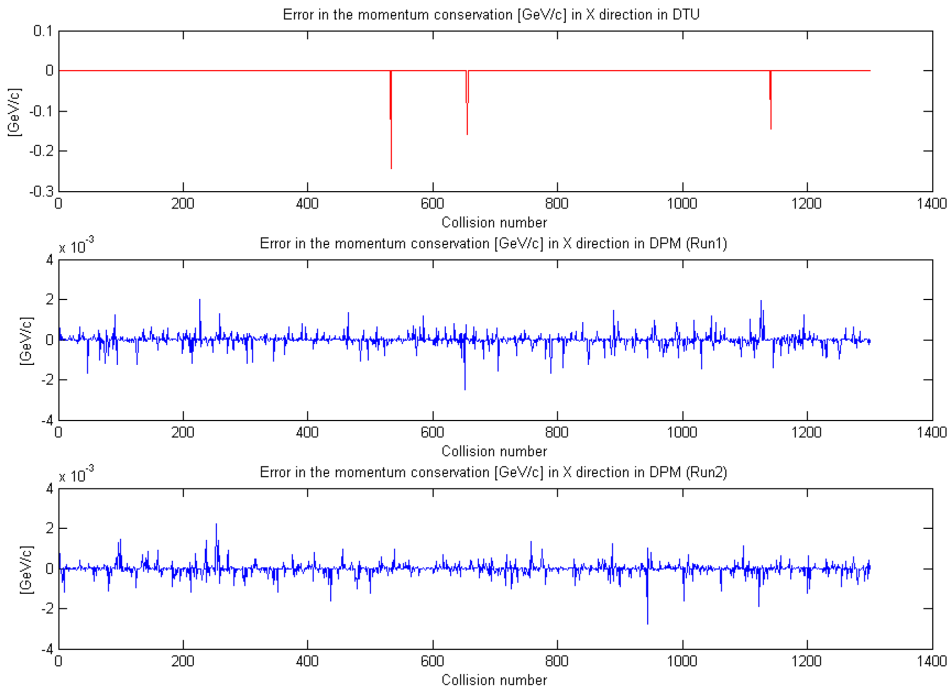

Fig. 4: The x-momentum conservation.

3.5 Coherence in the relation between energy and momentum

We checked the internal coherence (for the first 500 secondaries) between the momentum and the total energy: we plotted the quantity

$$pc - \sqrt{E^2 - E_0^2}$$

that should be zero: this is true in both generator within good accuracy except two evident 1 GeV spikes in DPMjet (Run1) (Figure 7).

3.6 The standard deviation of the transversal momenta

Since we are interested in the energy deposition on the collider's components it is fundamental to have a precise estimation of the angular distribution in the secondaries energy. In Figure 8 we show the p_x standard deviation. The p_y standard deviation behaves in a very similar way due to the cylindrical symmetry of the source. These quantities are intimately connected with distribution of the debris in the three-dimensional space.

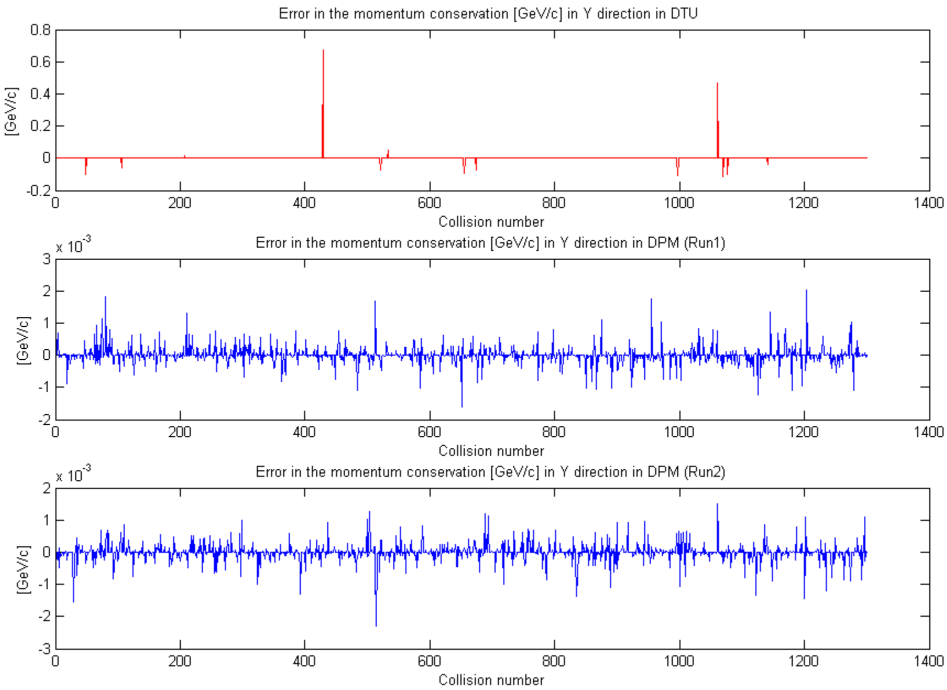

Fig. 5: The y-momentum conservation.

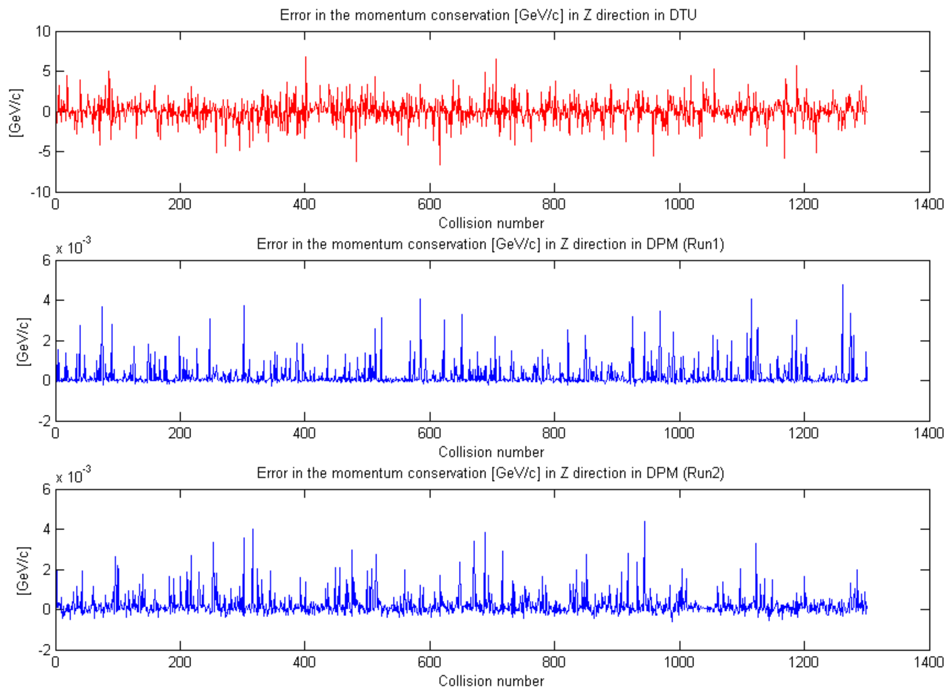

Fig. 6: The z-momentum conservation.

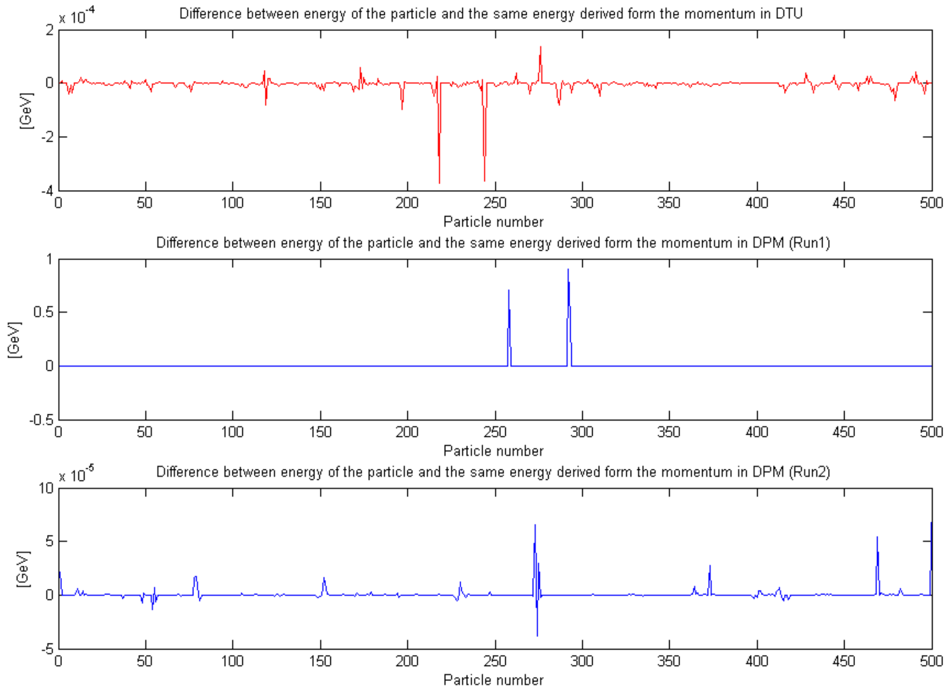

Fig. 7: Coherence in the relation between energy and momentum.

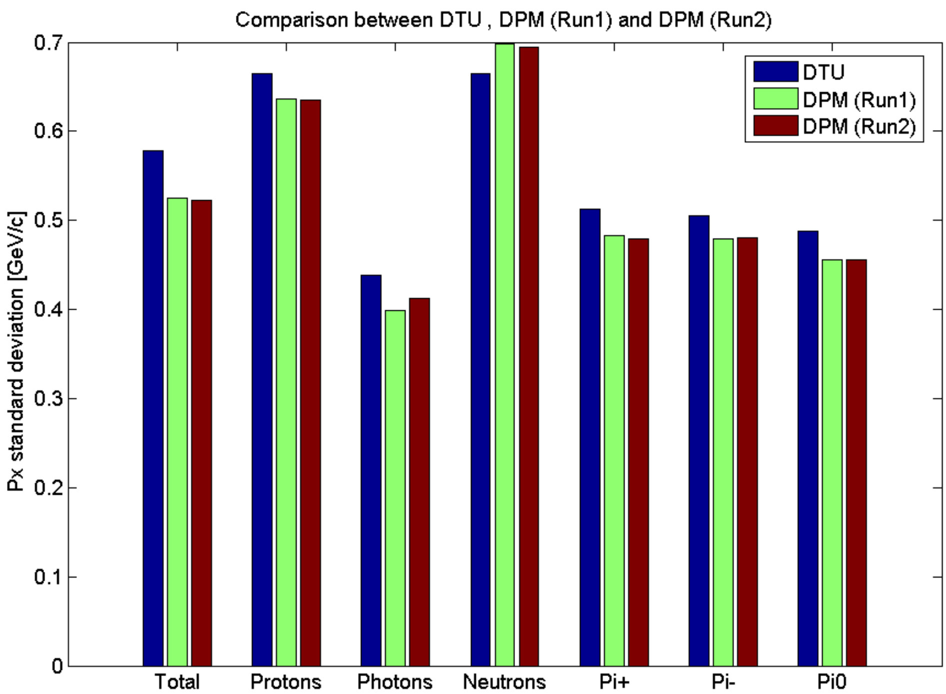

Fig. 8: Comparison on x-momentum standard deviation.

3.7 The distribution of the secondaries with respect to the pseudorapidity

We can consider also the the distribution of the secondaries with respect to the pseudorapidity η:

$$\eta = -ln\left(tan\left(\frac{\theta}{2}\right)\right) \quad \text{where} \quad \theta = \frac{p_{\perp}}{p_{\parallel}}$$

The η variable is often referred for hadron collisions as it is very similar to the rapidity that is a relativistic invariant. In Figure 9 the normalized histogram of events as function of pseudorapidity is shown: the integral of the functions yields the mean number of secondaries per crossings. There is a good consistency between the three curves.

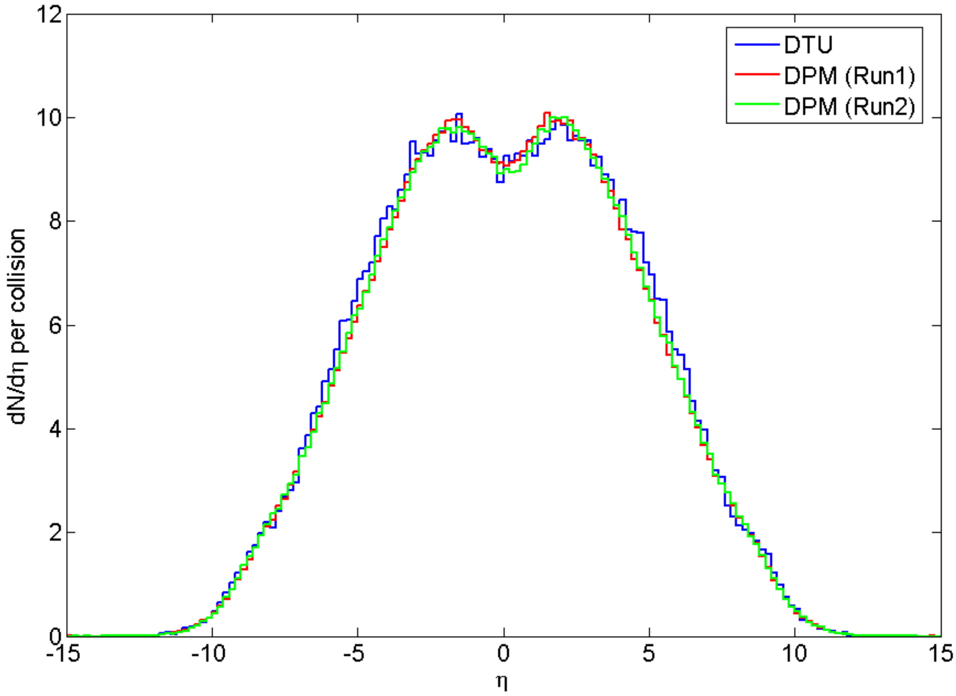

Fig. 9: Distribution of the secondaries with respect to the pseudorapidity.

4 Conclusion

In this work we presented a comparison study between the the DPMjet and DTUjet generators in the case of the LHC collision simulation. The two generators produce a similar number of particles with a similar energy repartition: this is confirmed by the distribution with respect to the pseudorapidity. The accuracy of the data obtained with DPMjet is higher than that of those from DTUjet for energy conservation and momentum conservation in the z-direction. For the purpose of the evaluation of the energy deposition to, at best, the few percent level, the two generators appear equivalent. The small difference in the energy conservation test between the DPMjet (Run1) and DPMjet (Run2) can be due to formatting issues during the postprocessing: this still needs a better understanding.

5 Acknowledgement

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References

[1] G. Ambrosio, F. Broggi, L. Rossi, *"Study of the stability of the LHC low beta inner triplet for a Nb_3Sn design"*, INFN/TC-99/04, 2 March 1999, Milan.

[2] A. Ferrari, P.R. Sala, A. Fassò and J. Ranft, *"FLUKA: a multi-particle transport code"*, CERN-2005-010, 12 October 2005, Geneva.

[3] C. Hoa, *"First Investigation on Energy Deposition with FLUKA on the D0 early separation scheme dipole"*, to be published.