USER MANUAL OF *ALOHEP*

v0.9.1 (*beta*)

17/10/2016

1. INTRODUCTION

a. The Motivation

This software (ALOHEP: A Luminosity Optimizer for High Energy Physics) is simply a Collision Point Simulator for the linac-ring type electron-proton colliders.

There are several beam-beam simulation programs for linear e^+e^- and photon colliders. Unfortunately, no similar programs exist for ep colliders. In order to understand and analyze electron-proton beam interactions at collision points, this software is developed as a numerical program that considers beam dynamics. At this stage luminosity, beam-beam tune shift and disruption are included in.

It is obvious that luminosity values with nominal beam parameters can be calculated analytically [1]. However, when beam dynamics is deeply analyzed considering time evolution of beam structures, it becomes almost impossible to make analytical solutions. These affects become time-dependent due to varying beam sizes during collision. The work on the upgraded version which will include time dependent behaviour of beams during collision as well as γp collider options is under progress. In addition, in order to achieve highest luminosity values at the collision, beam parameters should be optimized. For this reason an additional interface is being developed. It will optimize luminosity and give required beam parameters within pre-determined parameter interval.

b. General Structure

ALOHEP has a Java based environment and therefore will be *platform-independent*. You can see the detailed explanation of the interface structure and instructions in Section 2.

The software requires you to enter the main parameters of electron and proton accelerators as input. Then, right after the luminosity computation, two new frames appear:

1- A frame showing a representation of collision,
2- A frame showing final results.

The results are also exported to a text file.
Finally, the current version (v0.9.1) is a beta version and therefore quite open to your feedback, comments and also questions. We are trying to develop the software as "user-firendly" as possible. Do not hesitate to contact us:
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c. History of the Software

The first idea of ALOHEP is arised at TOBB University of Economics and Technology (Ankara / Turkey) while discussing if there were an accurate method to optimize luminosity of linac-ring type ep colliders. We decided that numerical computation via a code would give more realistic results and come up with the first downloadable version of ALOHEP (v0.9.1). As new versions become available, performed changes will be listed in the corresponding manuals.

v0.9.1

- Luminosity computation of electron-proton collision at linac-ring type colliders considering beam dynamics and time dependence of beam parameters.

2. DOWNLOAD & INSTRUCTIONS

a. Download

You can access ALOHEP at:
http://www.hepforge.org

b. Installation & Run

In fact you may even don't need any extra installation under favour of Java. You can run the program only with a double-click in all operating systems. You can also run ALOHEP from a command-line interface (terminal or shell).

Platform: All platforms.

System Requirements: Java (we recommend to install java-7-openjdk or a higher version.)

To run via terminal/shell: `java -jar ALOHEP_beta_v0.9.1.jar`

c. Instructions

ALOHEP Main Frame:

When you run the program, you will come across with a frame that requires main collider parameters from the user. The left column includes electron beam's and the right one includes proton beam's parameters. You may enter them one by one or modify some of the existing well-known accelerators' default parameters. You can click the check-boxes below the parameters (e.g., LHC-p) to perform the latter one.

Electron beams usually have much smaller size compared to the hadron beams which would lead to unacceptable beam-beam tune shift. A common proposal as a solution to this problem is transversely matching of the beam sizes. Therefore, we added a checkbox named "matched beams" which simply matched the transverse beam size of electron to the transverse size of proton beam. Beta function of electron beam is increased in order to realize this. One should note that the lower limit of β_{proton} at interaction point is assumed to be 0.1 m (see [1] and references therein) however increasing $\beta_{electron}$ is reasonable and we assume no upper limit for β function.

Settings:

In the current version you may set four different parameters in the Settings frame; namely, disruption maximum limit, beam-beam parameter maximum limit, number of representative particles and electron beam power.

Disruption Limit: Default limit value is 25. However one may change this limit regarding his/her individual design (e.g., beam aperture and/or beam separation processes).

Beam-beam Parameter Limit: Default limit value is 0.01. Similarly, one may change this limit in the *Settings* section.

Number Of Representative Particles: Default value is 1000. This value does not directly related with the number of charged particles (e.g., N_e or N_p). It determines the representative points for each beam in the visual simulation which starts automatically after the luminosity computation. In addition, computation of beam size evaluation utilizes these points' motions and therefore directly affects the simulation time.

Electron beam power: Default limit is 50 MW. Electron beam power is proportional to energy, frequency and number of electrons.

Visual Simulation of Collision at Interaction Point:
After you click the "Calculate Luminosity" button the initial main frame freezes until the computation is fully performed. If you *run the program from terminal/shell* then you can see the "estimated remaining time". If not, then the remaining time is also printed on the Main Frame. When the computation is complete, a new frame exhibiting the collision at interaction area automatically appears. No extra collider parameter computation is performed in the meantime.

- One can pause/play the simulation using the "*play*" button below the frame.
- The scale of the propagation direction and the scale of the horizontal direction are not matched. One can see them from the corresponding axes.
- The upper-left part shows the time-dependent beam sizes during collision.

Final Results:
Probably, the most important frame is this one. Luminosity with and without beam dynamics consideration is given in this frame in addition to the nominal disrupion and beam-beam parameter results. In addition, these results are exported to a text file (*FinalResults.txt*) which also includes the collider parameters and whole settings.

3. BACKGROUND PHYSICS

Current version (v0.9.1) only considers linac-ring type ep colliders. General expression for luminosity of this type lh colliders is given by (l denotes lepton, h denotes hadron):

$$L_{lh} = \frac{N_l N_h}{4\pi\, max[\sigma_{x_h}, \sigma_{x_l}] max[\sigma_{y_h}, \sigma_{y_l}]} \kappa\, f_{rep}\, N_b$$

where

$$\kappa = \begin{cases} 1 & (BS_e/BS_p) > 1, \\ (BS_e/BS_p) & (BS_e/BS_p) \leq 1; \end{cases}$$

where N_l and N_h are numbers of leptons and hadrons per bunch, respectively; σ_{xh} (σ_{xl}) and σ_{yh} (σ_{yl}) are the horizontal and vertical hadron (lepton) beam sizes at IP. N_b denotes number of bunches, f_{rep} means pulse frequency for linac. BS_e (BS_p) is bunch spacing of electron (proton) beam. If bunch spacing of electron beam is larger than that of proton beam, taking κ =1 is appropriate to determine the collision frequency of linac-ring lh collider. Otherwise, the factor (BS_e/BS_p) should be introduced to the equation. The asymmetry between these two cases can be explained by the difference between one-pass linacs and ring accelerators. If bunch spacing of hadron beam in a ring accelerator is larger than the bunch spacing of lepton beam in a one-pass linac (which is tangential to the ring accelerator), then some of the lepton bunches would be dissipated from collisions with a ratio of (BS_e/BS_p). If not so, one does not need to introduce the reverse factor (BS_p/BS_e) to the luminosity equation.

Some of the accelerator parameters mentioned above can be rearranged in order to maximize L_{lh} but one should note that there are some main limitations that should be considered. One of these limitations is lepton beam power. Other limitations for linac-ring type lh colliders are due to beam-beam effects. In general, a better focusing is needed to have high luminosity values at interaction points (IP). However, although an intensely focused beam including charged particles with large Lorentz factor ($\gamma >> 1$) does not have a strong influence on its internal beam particles, due to canceling of Lorentz forces one another (space charge effects diminish with $(1/\gamma)^2$), this situation does not hold for the encountered beam. Deflection of particles under this electromangetic interaction is called as disruption. When this interaction causes an angular kick in opposite beam's particles, it is called beam-beam tune shift. While beam-beam tune shift affects hadron (proton, ion) and muon beams, disruption has influence on electron beams. See [1] for more details.

The current version computes the motion of electron and proton particles due to the effects mentioned above in a roundabout way. A numerical calculation for L_{lh} is performed regarding time dependent beam parameters. Motions of the beams are computed step by step with a default total number of time steps. Thus, more realistic effects of beam dynamics is ensured to calculate luminosity. The program also assumes that the Gaussian charge density distributions along the transverse directions are preserved during collision and locates initial representative particles regarding these distributions.

4. WHAT IS NEXT?

We plan to put *ALOHEP v1.0.0* in service as soon as possible. If you want to cite the beta version, corresponding reference is at the very end of this manual. A detailed manuscript (about physics and the simulation details) will be available when the complete program is announced. Here is the list of the things that are planned to be in the next versions:

- An *optimization section* is under progress.

- Computation is going to be extended for any charge distribution.

- A novel code will be implemented for photon-hadron colliders.

- e – Nucleus (Pb) collisions are going to be included.

- We also would like to hear any suggestions from you.

5. REFERENCES

1. Y. C. Acar, A. N. Akay, S. Beser, H. Karadeniz, U. Kaya, B. B. Oner and S. Sultansoy, "FCC Based Lepton-Hadron and Photon-Hadron Colliders: Luminosity and Physics"; arXiv:1608.02190 (2016).*

   *This reference includes only a brief explanation for the software. A detailed manuscript (about physics and the simulation details) will be available when the complete program is announced.