MONTE-CARLO SIMULATION MODULE FOR LIDOS.RFQ.DESIGNER CODE

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New criteria arise when high-current CW linacs are considered. The main requirements for such linacs are maximal RF intensity reduction, very small beam losses.

Minimization of CW beam losses in RFQ linac places more stringent requirements upon beam perturbations. Instrumental errors in vane manufacturing, installation and adjustment are sources of such perturbations. Even with very small cell parameter deviations the potential of such perturbations is high enough both for beam transmission reduction and beam quality degradation. A reason enough to such statement is provided by the fact that trajectories even for "ideal" (without perturbations) RFQ channel are spaced in the immediate vicinity of vane surfaces.

Hence to choose RFQ channel optimal parameters random perturbation influence have to be taken into account and estimation of tolerances must be given. The goal of the LIDOS.RFQ.Designer package [1-5] development is to help user to solve this problem. It will be recalled that the package contains codes with three levels of mathematical model complexity.

The first-level codes make only a preliminary choice of the main parameter arrays on the basis of a simplified physical model. These codes are richly supplied with visual information that helps to find the best linac version quickly. Separate algorithm branch allows using output parameter table obtained by PARMTEQ codes as initial information

The second-level codes are used for channel data calculations with the real shape of the RFQ vanes and real RF fields. Information from the first level codes is used here as input data.

The third-level codes are based on information from the first and second level codes and on complex PIC-models that are needed for a correct beam simulation in the chosen channel version.

New version of the package contains the fourth level - "Statistics". Random realizations of channel taking into account deviations of vanes from their ideal positions are generated. From cell to cell the random deviations are statistically independent. To compute the position of vane surface we base on the parameters: *r* - the distance from axis to cell beginning, *m* - vane modulation and *L* - cell length. With perturbations the parameter *r* is changed over a random value *Δ*. For cell numbered *k* we use $\tilde{r}_k = r_k + \Delta_k$. In turn the deviations of any vane inside cell are statistically independent also. Such perturbation leads to changes in focusing field gradient, deviation of accelerator axis from ideal line (axis may be presented as polygonal line), quadrupole symmetry violation. As a result there are transverse beam mismatching, coherent beam oscillations about real accelerator axis and transverse phase volume increase produced by its.

If the channel is divided into sections then another perturbation are independent deviations of any vane ends inside section.

The code simulates beam dynamics for every version of channel. To decrease the time, taken to statistic calculation, the visualization of current version can be switched off. Because it takes the calculation of many random version for sufficient statistic (as a rule no less than 50), this procedure is very time consumed, so it is possible to stop calculations and to continue it after any time beginning from last version.

The part Advisor offers the supplementary visual information for tolerance estimation. In [6] we define parameter S - sensitivity of period to perturbations. In this case this parameter is determined by relation

$$S = \left(B \int_0^1 \rho(\tau) \left| \cos 2\pi\tau \right| d\tau \right)^2 ,$$

where *B* is focusing parameter, *ρ* is the envelope of matched beam with the emittance of unity in the ideal channel.

Visual information presents the plot of sensitivity versus number of cell as well as statistic estimation of effective emittance growth and beam center transverse displacement. The error integrals are calculated in according with relations given in [6]: if σ^2 is mean square value of focusing field gradient relative error then the probability that effective emittance growth would be no more than *x* is determined by function $P(x) = 1 - e^{-(\ln x)^2/\Delta^2}$, where $\Delta^2 = \frac{\sigma^2}{4} \sum_{k=1}^{N} S_k$ If σ^2 is error of axis transverse displacement then the probability that center of output beam displacement would be no more than *x* is determined by function $P(x) = 1 - e^{-x^2/\Delta^2}$, where $\Delta^2 = \sigma^2 \sum_{k=1}^{N} S_k$. For both cases S_k is sensitivity of cell numbered *k*, *N* is total number of cells. The general view of picture is shown in the Fig.1.

The examples of output pictures of new part "Statistics" are shown in the Fig.2-5. The RFQ channel with the frequency 175 MHz, accelerating protons from energy 0.05 MeV to energy 2 MeV have been used as example. The statistic have been calculated for two values of tolerance - 10 μm (Figs.2,4) and 25 μm (Figs.3,5).

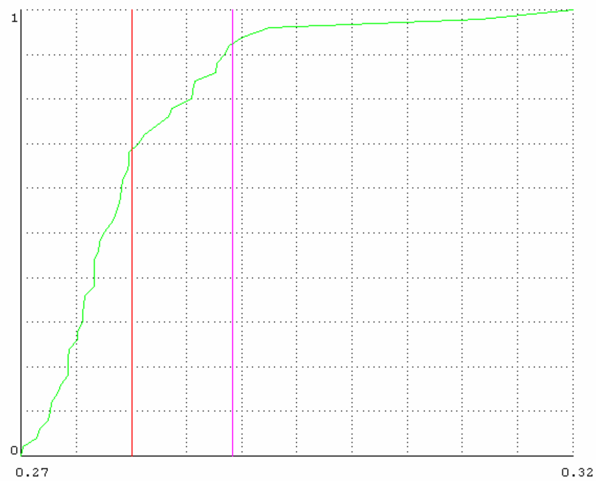

Fig.2.
Statistics of *RMS-Emittance XX′*
Mean - 0.28, Sigma - 0.01, Ideal - 0.28

Probability	Value
0.7	0.28
0.8	0.29
0.9	0.29
0.95	0.29

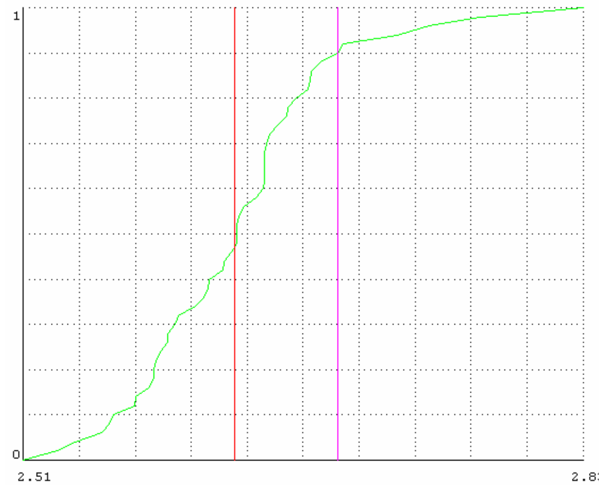

Fig.4.
Statistics of *Total Emittance XX′*
Mean - 2.63, Sigma - 0.06, Ideal - 2.60

Probability	Value
0.7	2.65
0.8	2.66
0.9	2.69
0.95	2.73

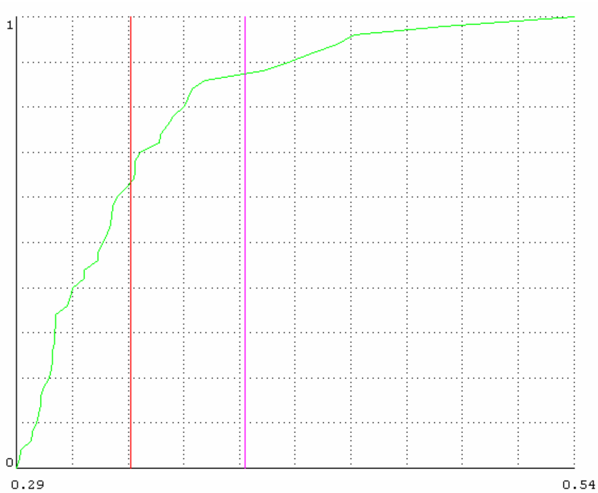

Fig.3.
Statistics of *RMS-Emittance XX′*
Mean - 0.34, Sigma - 0.05, Ideal - 0.28

Probability	Value
0.7	0.35
0.8	0.37
0.9	0.41
0.95	0.44

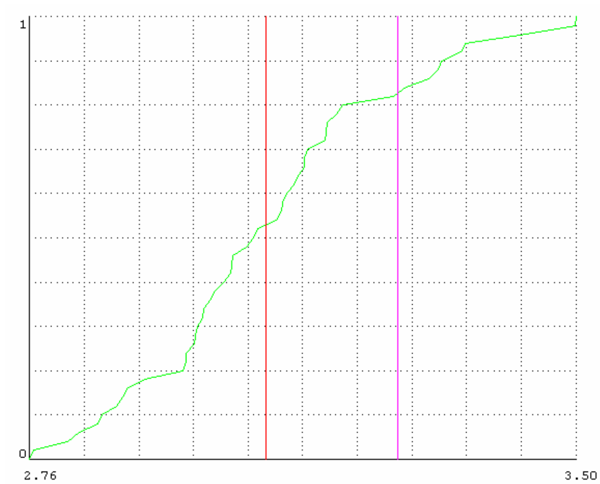

Fig.5.
Statistics of *Total Emittance XX′*
Mean - 3.08, Sigma - 0.18, Ideal - 2.60

Probability	Value
0.7	3.13
0.8	3.18
0.9	3.32
0.95	3.39

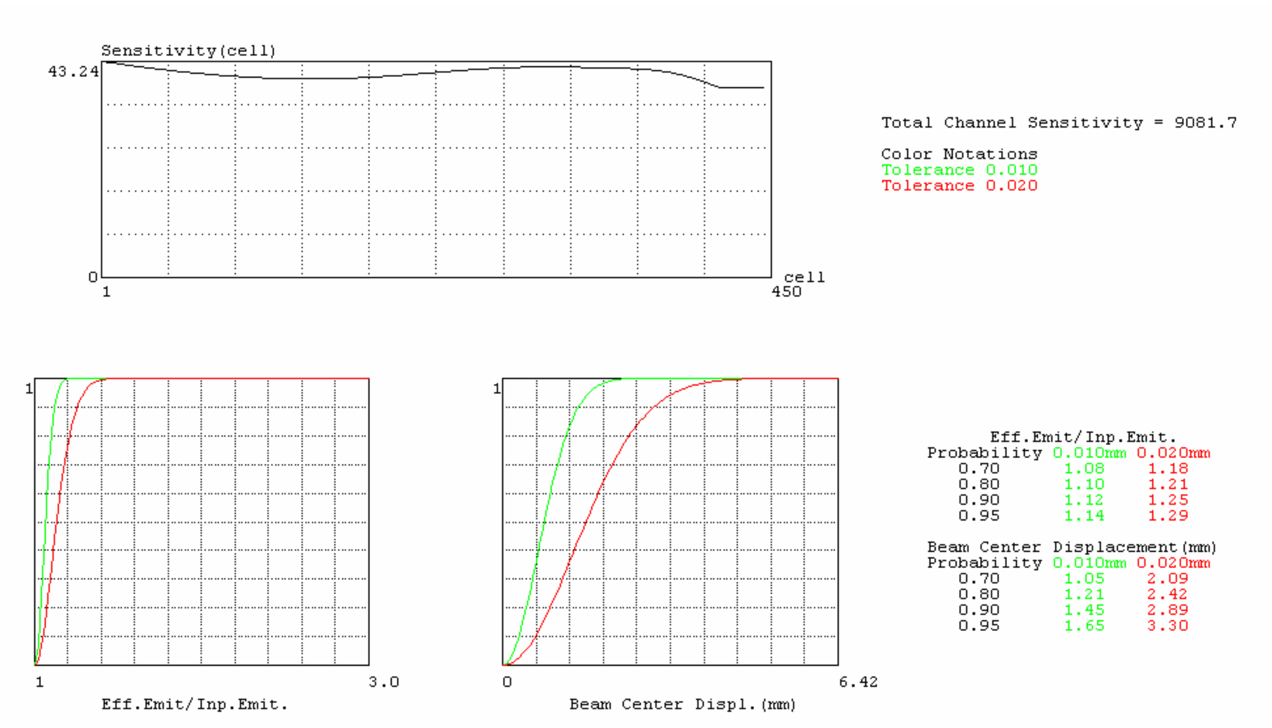

Fig.1.
"Statistics" module general view

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