High-precision $\alpha_S(m_Z^2)$ determinations from future FCC-ee $e^+e^- \to$ hadrons data below the Z peak

Letter of Interest submitted to Snowmass 2021

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The huge amount of data expected to be collected at the FCC-ee [1] offers several possibilities for unprecedentedly precise measurements of the strong coupling constant in the very "clean" environment of e^+e^- collisions [2]. The highest precision of the measurements can be assured not only thanks to the sheer amount of high-quality data, but also to the wide range of center-of-mass energies at which the data sets will be collected.

In the scope of the FCC-ee CDR [1], two mutually non-exclusive methods exist for an extension of e^+e^- data collection below the Z peak [3]. The first one is to organize a dedicated data taking from 30 to 90 GeV center-of-mass energies in such a way such as to record 10^9 $e^+e^- \to$ hadrons events using several intermediate beam energies. The second one consists in using the $e^+e^- \to \gamma +$ hadrons radiative events recorded during the foreseen data taking at and around the Z pole.

Recently, the data taken below the Z peak in multiple experiments played a crucial role in performing precise $\alpha_S(m_Z^2)$ extractions using event shape observables [4, 5, 6] and jet rates [7, 8], and naturally complemented the measurements obtained at higher center-of-mass energies. Therefore, it is expected that, by combining the measurements below and above the Z peak within the same experiment, it will be possible to reach per-mil (experimental) precision in the $\alpha_S(m_Z^2)$ extraction, essentially eliminating experimental uncertainties.

The data collected at energies below the Z peak will provide input for the $\alpha_S(m_Z^2)$ extractions from the global electroweak fits [9], and complement the datasets for other methods, e.g. $\alpha_S(m_Z^2)$

from hadronic τ decays [10]. The same data will also be crucial for a deeper understanding and improved modeling of non-perturbative effects, which are more prominent at lower center-of-mass energies.

The importance of the run conditions and the detector design for both methods of data taking at lower center-of-mass energies than the Z pole will be evaluated, in particular regarding: i) the overall angular acceptance of the detector; ii) the possible Particle Identification for flavour (b/c/other) identification of the jets; iii) the availability of hadron ($\pi/K/p$) identification. The resulting detector requirements and optimal run conditions will be spelled out. The opportunities brought in by dedicated intermediate-energy runs for improving the detector calibration, validation of the Monte Carlo event simulations and the event reconstruction will also be studied. This study might result in a more detailed running proposal.

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