Measurement of total hadronic differential cross sections in the LArIAT experiment

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- [1] Peter W. Higgs. Broken symmetries and the masses of gauge bosons. *Physical Review Letters*, 13(16):508–509, oct 1964.
- [2] P.W. Higgs. Broken symmetries, massless particles and gauge fields. *Physics Letters*, 12(2):132–133, sep 1964.
- [3] Steve Ritz et al. Building for Discovery: Strategic Plan for U.S. Particle Physics in the Global Context. 2014.