WG5 "QCD & γ-γ physics"
QCD-1 plans: High-precision α_s

FCC-ee QCD & γγ PWG5 meeting

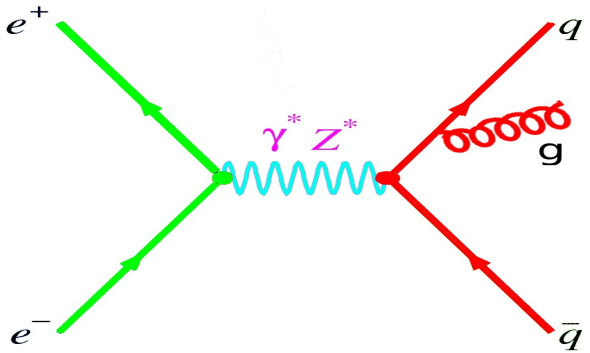
CERN, 3th June 2014

David d'Enterria, Peter Skands

CERN

QCD physics at FCC-e^+e^-

- e^+e^- collisions provide an extremely clean environment with fully-controlled initial-state to probe q,g dynamics:

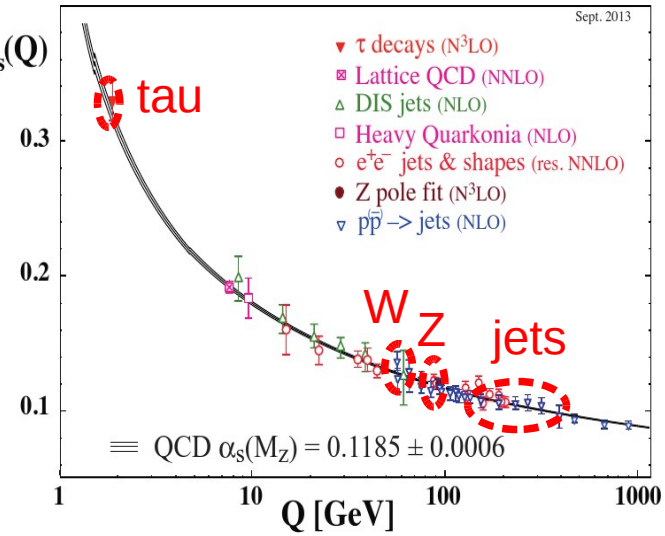


Advantages compared to p-p at the LHC:

- Electroweak initial-state with known kinematics
- No QCD "underlying event"
- Smaller QCD radiation (only in final-state)
- Smaller non-pQCD uncertainties (no PDFs)

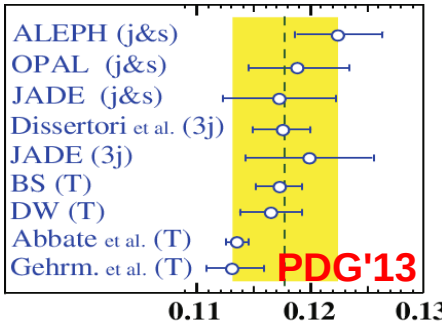
- FCC vs. LEP2: Orders-of-magnitude higher statistics (and higher Q^2)

- Key measurements:
  - Strong coupling α_s with <1% uncertainties through various observables.
  - Colour reconnection (m_{top})
  - High-precision QCD: multi-jets
  - High- precision QCD: q,g,c,b fragmentation
  - $\gamma\gamma$ physics: $F^{\gamma}_2(x,Q^2)$, BFKL via VV,...
  - ...



Multi-prong determination of α_s coupling

- α_s = crucial parameter for SM precision fits, couplings unification,...
  <1% uncertainties required
- Event shapes/thrust (NNLO+N^{3}LL), jet rates (NNLO): reduced npQCD uncertainties at FCC.
- Z,W hadronic decays (N^{3,4}LO):



$$R_Z \equiv \frac{\Gamma(Z \to \mathrm{h})}{\Gamma(Z \to l)} = R_Z^{\mathrm{EW}} N_C \left(1 + \sum_{n=1}^{4} c_n \left(\frac{\alpha_s}{\pi}\right)^n + \mathcal{O}(\alpha_s^5) + \delta_{\mathrm{m}} + \delta_{\mathrm{np}}\right) \quad \rightarrow 10^{12}\ Z\text{'s}$$

$$B_h \equiv (\Gamma_{\mathrm{had}}/\Gamma_{\mathrm{tot}})_W \quad \rightarrow 5\times10^{7}\ WW\text{'s} \qquad \nearrow 10^{11}\ \tau\text{'s}$$

- τ hadron decay (N^{3,4}LO) $R_\tau \equiv \frac{\Gamma(\tau^- \to \nu_\tau + \mathrm{hadrons})}{\Gamma(\tau^- \to \nu_\tau e^- \bar{\nu}_e)} = S_{\mathrm{EW}} N_C \left(1 + \sum_{n=1}^{4} c_n \left(\frac{\alpha_s}{\pi}\right)^n + \mathcal{O}(\alpha_s^5) + \delta_{\mathrm{np}}\right)$

Method	Current relative precision	Future relative precision
e^+e^- evt shapes	expt $\sim$ 1% (LEP) thry $\sim$ 1–3% (NNLO+up to N^{3}LL, n.p. signif.)	< 1% possible (ILC/TLEP) $\sim$ 1% (control n.p. via Q^2-dep.)
e^+e^- jet rates	expt $\sim$ 2% (LEP) thry $\sim$ 1% (NNLO, n.p. moderate)	< 1% possible (ILC/TLEP) $\sim$ 0.5% (NLL missing)
precision EW	expt $\sim$ 3% (R_Z, LEP) thry $\sim$ 0.5% (N^{3}LO, n.p. small)	0.1% (TLEP [10]), 0.5% (ILC [11]) $\sim$ 0.3% (N^{4}LO feasible, $\sim$ 10 yrs)
τ decays	expt $\sim$ 0.5% (LEP, B-factories) thry $\sim$ 2% (N^{3}LO, n.p. small)	< 0.2% possible (ILC/TLEP) $\sim$ 1% (N^{4}LO feasible, $\sim$ 10 yrs)

Snowmass'13, arXiv:1310.5189

Backup slides

WG5 mandate: Physics objectives

- Determine best achievable EXP & TH precision on α_s measurement via: Z,W,τ hadronic decays widths, jet rates, event shapes, ...
- Explore other competitive QCD physics opportunities opened in e+e-.
- Evaluate photon-photon physics possibilities via EPA fluxes: Higgs, anomalous quartic gauge couplings, anomalous top,τ e.m. moments,...

- Set goals for sub-detector performance (including forward $e^{\pm}$ taggers for $\gamma\gamma$ physics) and experimental-conditions so that syst.~stat. Uncertainties for the measurements
- Define experimental/phenomenological software needs to make possible these measurements and their interpretation with the required precision.
- Help evaluating the QCD impact on rest of FCC measurements. Provide design study for "background" event generators for QCD and $\gamma\gamma$ processes.

WG5 mandate: Managerial objectives

- Joint experiment-phenomenology group with 2 (bi-annual) conveners:
  2014-2016: D. d'Enterria (dde@cern.ch), P.Skands (Peter.Skands@cern.ch)
- Build international collaboration with synergies with similar e^+e^- (linear or circular) collider studies.
- Attract people for the studies relevant to the group.
- Maintain high level of contacts with the other WGs.
- Create sub-groups (with sub-conveners) matching the scientific objectives.
- Appoint editors towards the production of intermediate reviews and a contributions to final Yellow Report.
- Report progress to the physics coordination at monthly FCC-ee physics meetings.

WG5 mandate: Timescales & deliverables

- "Exploration" phase (Feb'14 – March'15): Identify all possible options and potential studies, including requirements and constraints.
  - ☛ Deliverable: Interim written report for review milestone workshop

- "Analysis" phase (March'15 – Sept'16): Detailed studies of the identified baselines.
  - ☛ Deliverable: Interim written report for review milestone workshop

- "Elaboration" phase (Sept'16 – Dec'17): Delivery of all information required for the final Conceptual Design Report (CDR) of the study.

☛ Final Yellow Report (early 2018) to be included into the FCC CDR.

JOIN THE QCD & PHOTON-PHOTON WG5 ACTIVITIES !