Study of pion and eta decays

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The physics / basic idea of the LOI

- Neutral pion: the lightest meson
  - Prominent role for studying low-energy properties of strong interaction
  - $\pi^0 - \gamma^{(*)} - \gamma^{(*)}$ vertex described by electromagnetic TFF
    - Can be extracted studying various decay channels ($\pi^0 \to e^+e^-\gamma$, $\pi^0 \to e^+e^-$)
    - Probes π^0 structure, enters HLbL scattering contribution to $g-2$
- Study hidden physics in low-energy QCD sector
  - Right-handed currents: V. Bernard, M. Oertel, E. Passemar and J. Stern, JHEP 01, 015 (2008)
  - Axion: see, e.g., very recent Daniele S. M. Alves, arXiv:2009.05578 [hep-ph]
  - ...
  - Several hints already present in data
- Manifest via small deviations from SM predictions
  - $\pi^0 \to e^+e^-$ (3.3 $\sigma \to \approx 2\ \sigma$)
  - $g-2$ (3.6 σ)
  - F_π obtained from EM (2γ) decay (or from lattice) vs. weak decay ($\hat{F}_\pi$)
    - $F_\pi^2 = \hat{F}_\pi^2(1+\epsilon)$
- Above π^0 decay modes can be extended to corresponding η (or kaon) decays
  - Interesting physics expected in $\eta \to \gamma\gamma$
    - Anomaly, chiral corrections, two-loop corrections
    - Important for precise calculation of $\pi^0 \to \gamma\gamma$
    - Measurement planned at JLab

What is required for the LOI to succeed

- Precise measurements hand in hand with precise calculations
- Radiative corrections now ready for many channels
  - $\pi^0 \to \gamma\gamma$: K. Kampf, B. Moussallam (2009)
  - $\pi^0 \to e^+e^-\gamma$: K. Kampf, M. Knecht, J. Novotný (2006), TH, K. Kampf, J. Novotný (2015), TH, E. Goudzovski, K. Kampf (2019)
  - $\pi^0 \to e^+e^-e^+e^-$: K. Kampf, J. Novotný, P. Sanchez-Puertas (2018)
  - $\pi^0 \to e^+e^-$: P. Vaško, J. Novotný (2011), TH, K. Kampf, J. Novotný (2014), TH, S. Leupold (2015)
  - $\eta^{(\prime)} \to \ell^+\ell^-\gamma$: TH, K. Kampf, S. Leupold and J. Novotný (2018)
- Under preparation
  - e.g., $\eta \to \gamma\gamma$: may be crucial for π^0 and η program at JLab
- No new facilities required → stronger dedication at the existing ones
  - Typically, these processes are not the prime goals at related experiments
  - Example: $\pi^0 \to e^+e^-$
    - Measure independently and compare to the KTeV result
    - Accessible at NA62, although suppressed by trigger settings
    - Extract $\chi^{(r)}(M_\rho)$: universal for $P \to \ell^+\ell^-$ (assuming LFU), compare to $\chi^{(r)}$ from $K_L \to \mu^+\mu^-$
  - Example: $\pi^0 \to e^+e^-\gamma$
    - Measure a_π more precisely
    - Discrepancy in $R = \Gamma(\pi^0 \to e^+e^-\gamma)/\Gamma(\pi^0 \to \gamma\gamma)$ between model-independent calculation and KTeV
      - Abouzaid et al., Phys. Rev. D 100 (2019)

What do you plan to do during Snowmass

- It is vital to deepen and extend our knowledge regarding $\pi^0/\eta - \gamma^{(*)} - \gamma^{(*)}$ vertex
  - Further theoretical (including BSM) and phenomenological studies of pion decays
    - $\pi^0 \to \gamma\gamma, \pi^0 \to e^+e^-\gamma, \pi^0 \to e^+e^-, \pi_{\ell 2}, \ldots$

    and related eta decays
  - Interplay with rich experimental program in this area
  - Confirmation of discrepancies or their disappearance expected

- Schedule for next half a year
  - Proceed on the $\eta \to \gamma\gamma$ calculation
  - Preliminary results on $\pi^0 \to e^+e^-$ from NA62
  - In parallel, first results from $g-2$ should be available

What do you hope to get out of Snowmass

- Promote close collaboration between phenomenologists, lattice groups and experiments
  - NA62 at CERN
  - PrimEx(-II) and JEF at JLab
  - REDTOP at Fermilab
  - KLOE-2 at DAΦNE
  - ...
- Further studies from different points of view
  - Resolve discrepancies between SM prediction and experiment
    - Or their better/deeper understanding
  - Extract hadronic quantities more precisely from data
- Feedback from experiments
  - What might be interesting we concentrate on