Meson Structure Functions at the EIC

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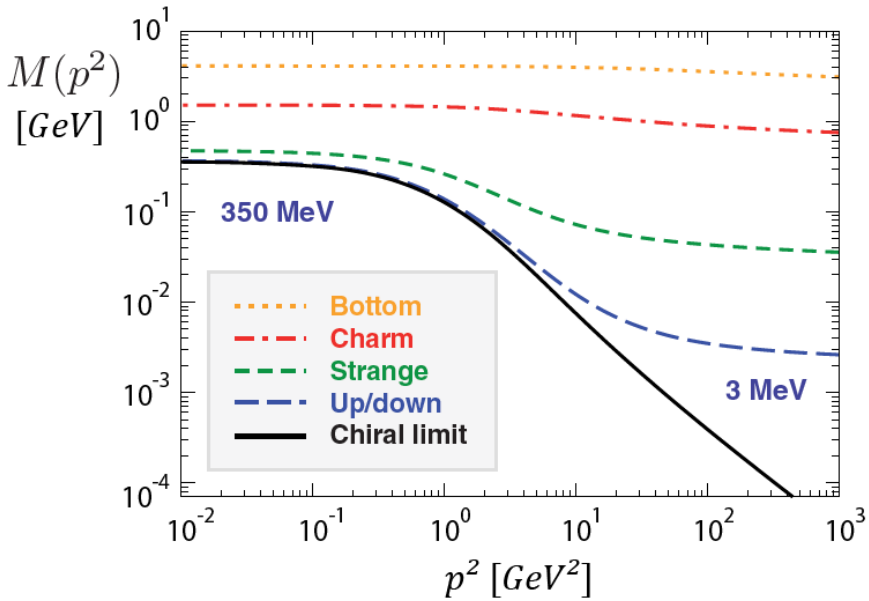
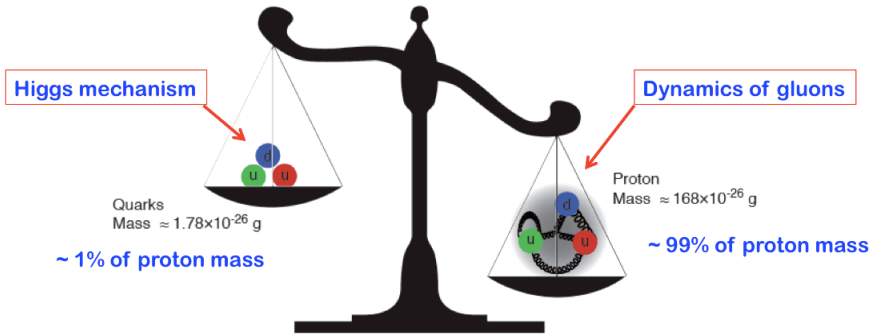
The Incomplete Hadron: Mass Puzzle

"Mass without mass!"





The light quarks acquire (most of) their masses as effect of the gluon cloud.

The strange quark is at the boundary - both emergent-mass and Higgs-mass generation mechanisms are important.

Proton: Mass ~ 940 MeV

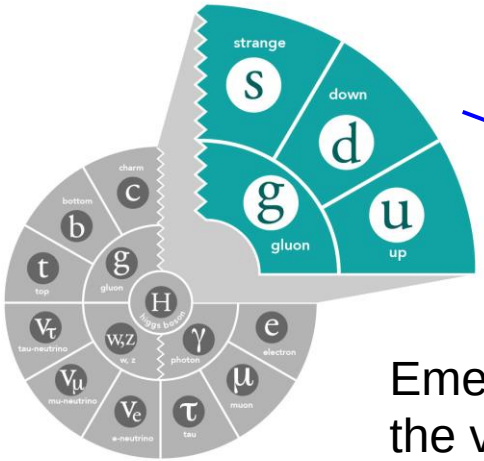
preliminary LQCD results on mass budget, or view as mass acquisition by DCSB

Pion: Mass ~ 140 MeV

mass enigma – gluons vs Goldstone boson

Kaon: Mass ~ 490 MeV

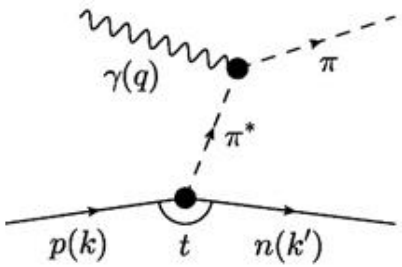
at a given scale, less gluons than in pion



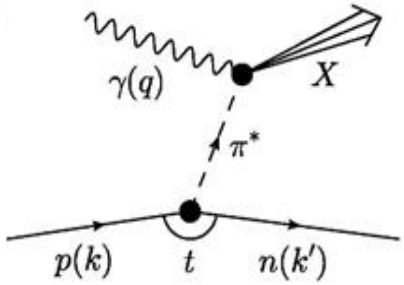
Emergent mass of the visible universe

Technique - Towards the Pion/Kaon SF

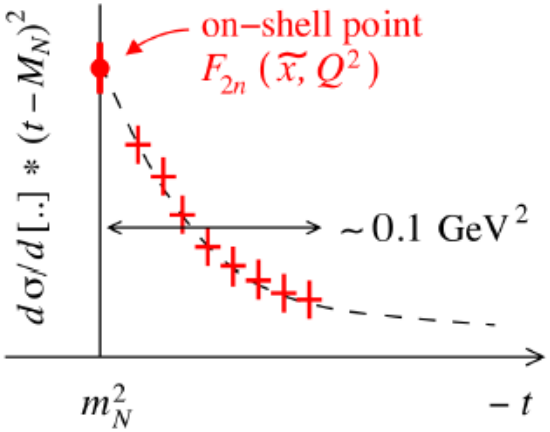
- The **Sullivan process can provide reliable access to a meson target** as *t* becomes space-like if the pole associated with the ground-state meson is the dominant feature of the process and the structure of the (off-shell) meson evolves slowly and smoothly with virtuality.



Elastic Form Factor



DIS

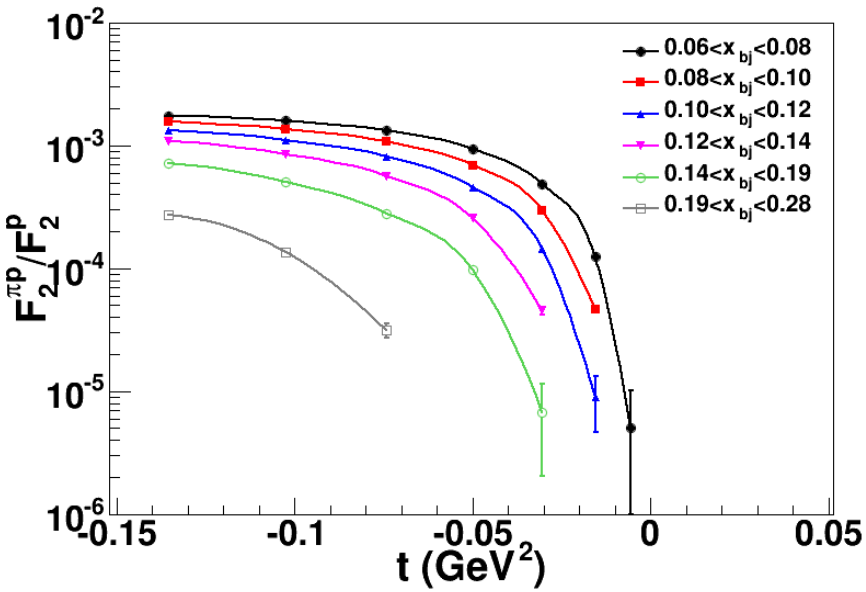


- Recent **theoretical calculations found that for -t ≤ 0.6 GeV^2, changes in pion structure do evolve slowly** so that a well-constrained experimental analysis should be reliable, and the Sullivan processes can provide a valid pion target.
- To **check these conditions** are satisfied empirically, one can **take data covering a range in *t*** and compare with phenomenological and theoretical expectations.

Feasibility – Versatility and Luminosity is Key

Why would pion and kaon structure functions, and even measurements of pion structure beyond (pion GPDs and TMDs) be feasible at an EIC?

- ❑ $L_{EIC} = 10^{34} = 1000 \times L_{HERA}$
- Detection fraction @ EIC in general much higher than at HERA
- ❑ Fraction of proton wave function related to pion Sullivan process is roughly 10^{-3} for a small –t bin (0.02).
- ❑ Hence, pion data @ EIC should be comparable or better than the proton data @ HERA, or the 3D nucleon structure data @ COMPASS
- ❑ If we can convince ourselves we can map pion (kaon) structure for –t < 0.6 (0.9) GeV2, we gain at least a decade as compared to HERA/COMPASS.



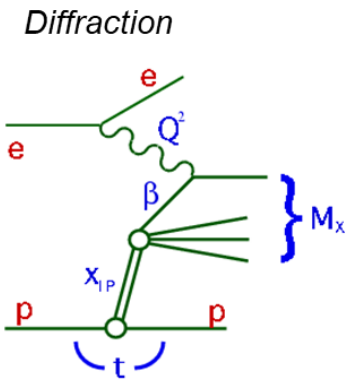
*Ratio of the F_2 structure function related to the pion Sullivan process as compared to the proton F_2 structure function in the low-t vicinity of the pion pole, as a function of Bjorken-x (*Jefferson Lab TDIS Collaboration, JLab Exp. C12-15-005 Proposal*)*

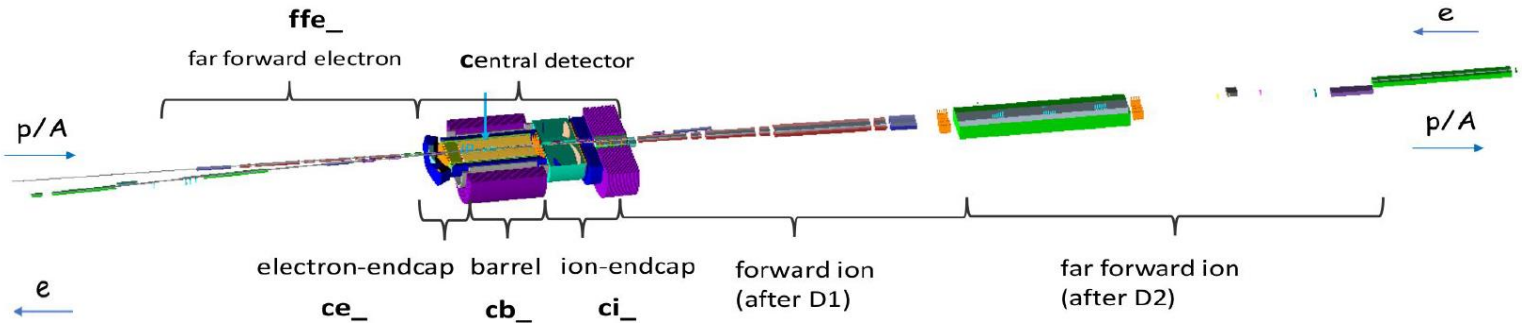
Meson SF – Forward Detector Requirements

Need excellent detection capabilities, and good resolution in –t

- Reconstruction of energy and position to sufficiently constrain the scattering kinematics and 4-momentum of the pion
- FFQ and ZDC: $\delta p_L/p_L \sim 10^{-4}$, $\delta p_T \sim 20$ MeV, complete coverage to $p_T=0$
- Good hadronic calorimetry to for large-x resolution

Process	Forward Particle	Geometric Detection Efficiency (at small –t)
$^1H(e,e'\pi^+)n$	n	> 20%
$^1H(e,e'K^+)\Lambda$	Λ	50%
$^1H(e,e'K^+)\Sigma$	Σ	17%

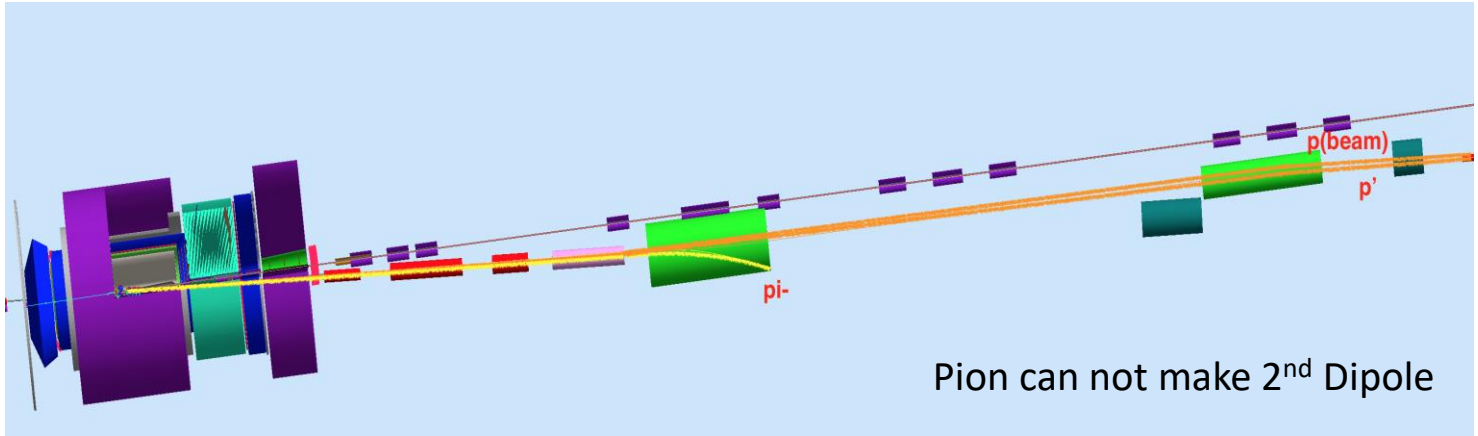


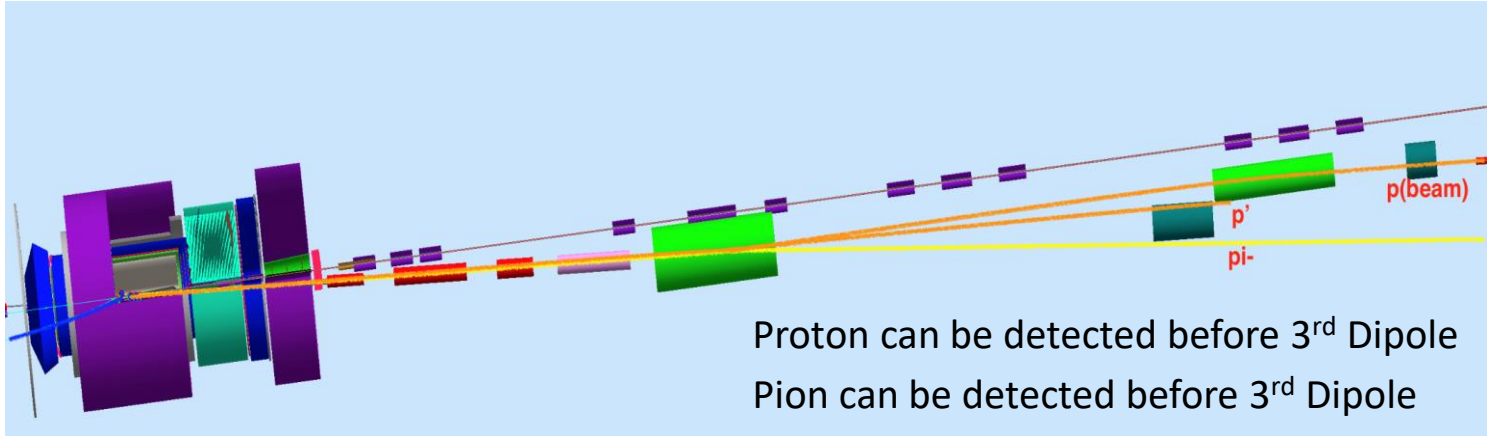


Meson SF – Forward Detector Requirements

Need excellent detection capabilities, and good resolution in –t

- **Final states (Λ, Σ) also require <u>detection of decay products</u>, which have to be tracked though the very forward spectrometer**





Meson SF - Key Experiments at the EIC

- Hadron masses in light quark systems
  - Pion and kaon parton distribution functions (PDFs) and generalized parton distributions (GPDs)
- Gluon (binding) energy in Nambu-Goldstone modes
  - Open charm production from pion and kaon
- Mass acquisition from Dynamical Chiral Symmetry Breaking (DCSB)
  - Pion and kaon form factors
- Strong vs. Higgs mass generating mechanisms
  - Valence quark distributions in pion and kaon at large momentum fraction x
- Timelike analog of mass acquisition
  - Fragmentation of a quark into pions or kaons

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