Kaon Tagged Deep Inelastic Scattering (TDIS) C12-15-006A

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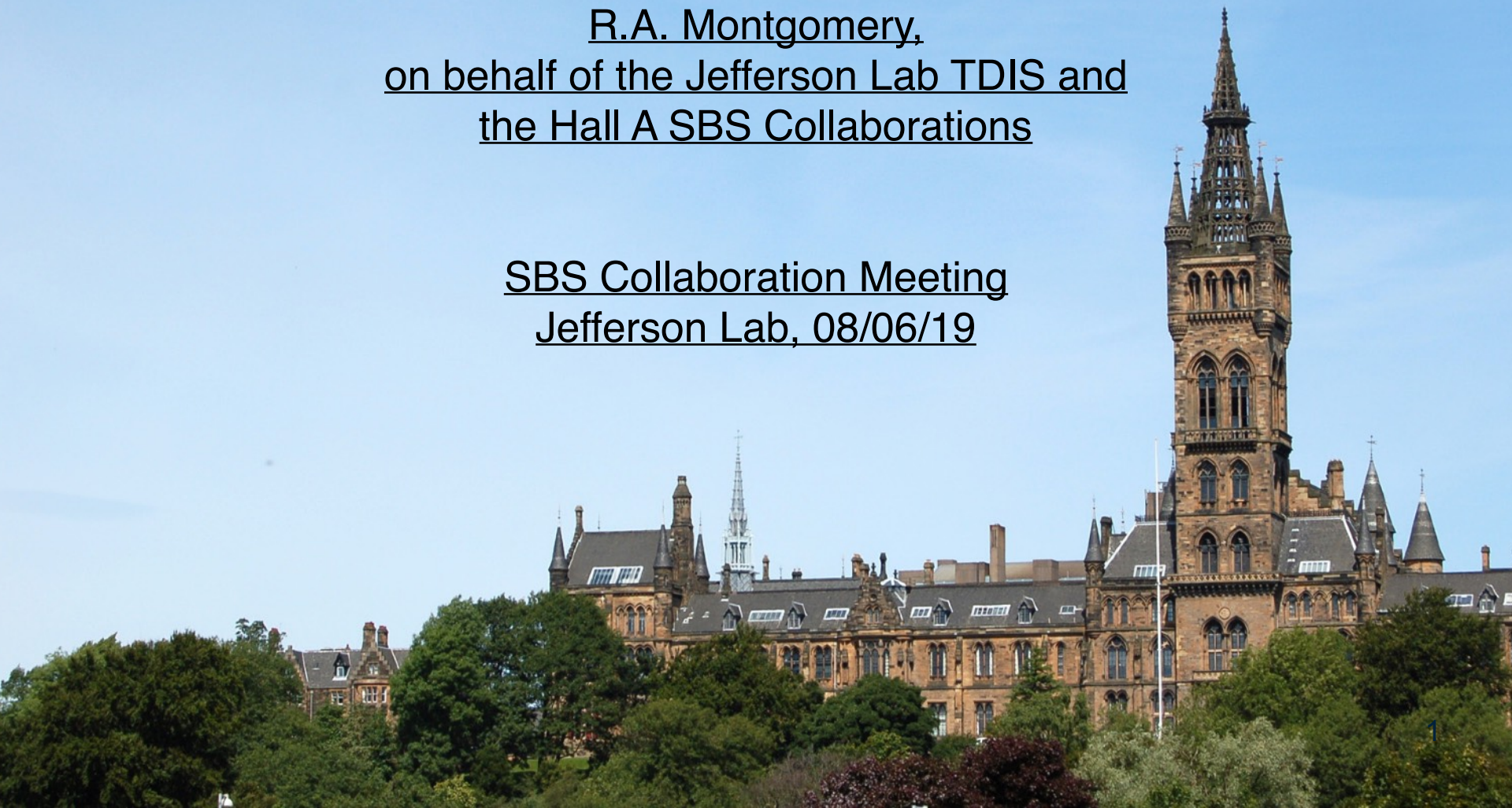
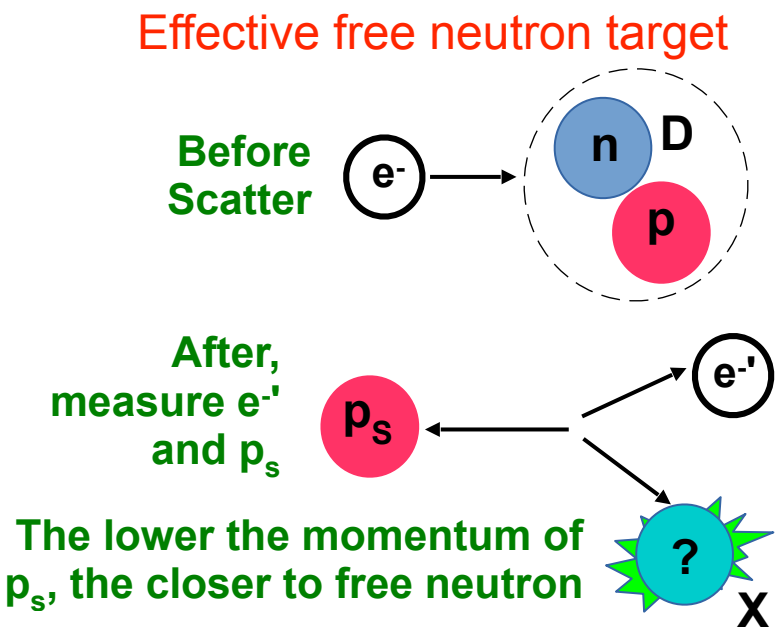
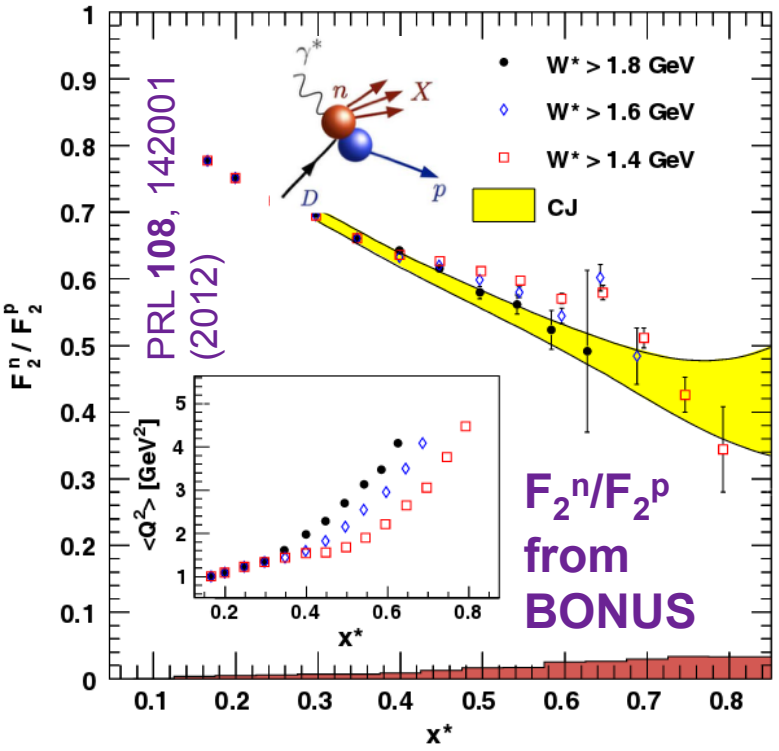
on behalf of the Jefferson Lab TDIS and
the Hall A SBS Collaborations

SBS Collaboration Meeting
Jefferson Lab, 08/06/19



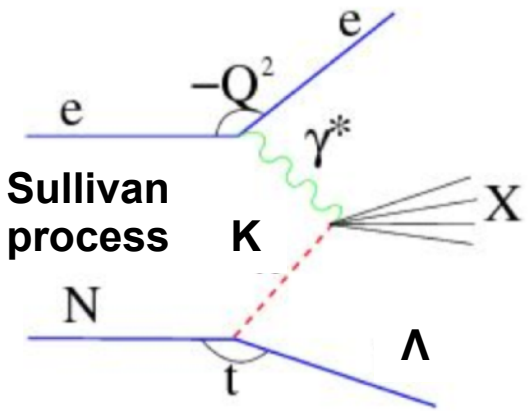
Spectator Tagging = Effective Free Targets





- e.g. BONUS - neutron valence structure (F_2^n), input global PDF fits (https://www.jlab.org/theory/cj/)
- p_s tagged coincident DIS e^- scattered from "free" neutron ($eD \rightarrow ep_sX$)
- Low momentum p_s - neutrons barely off shell
- Upcoming BONUS12 - better precision, higher x, W^2
- Proton SF known exceptionally well, neutron on the way, but **light meson SF largely unknown experimentally, yet also basic building blocks of matter ➠ pion and kaon TDIS**

Kaon TDIS



- Tag nucleon's strange mesonic content directly
- Sullivan process:
  - Effective targets not readily found in nature
  - Novel probe of mesonic cloud
  - Hard scattering from kaon partonic content

<u>Pion/Kaon TDIS:</u>

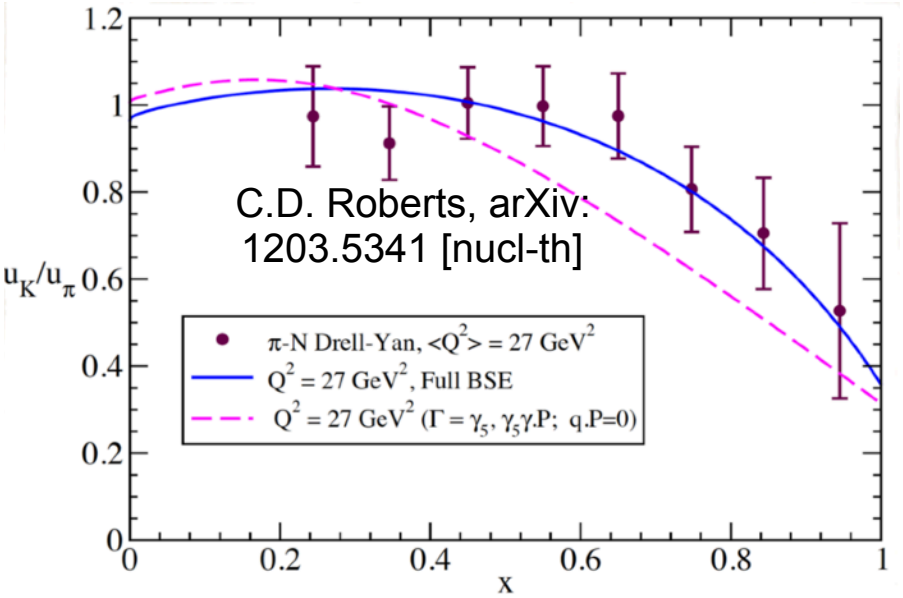
- Pion and kaon structure functions (SF) in valence regime
- Independent pion measurements w/ proton (world first) and neutron targets
- World-first direct extraction kaon SF

<u>Kaon TDIS:</u>

- **C12-15-006A kaon TDIS** run group proposal accepted PAC45 July 2017 ("natural extension")
- Conditionally approved, as pion TDIS (same set-up/27-day beam time)
- Physics approved - no return to PAC, internal technical review
- Recent white paper submitted on need for pion/kaon structure experiments now and at EIC (arXiv:1907.08218v1 [nucl-ex])

Kaon TDIS Motivation

- Kaon SF unknown experimentally
- Existing kaon structure data from Drell Yan only, practically non-existent
  - Valence region (overlapping w/ TDIS) e.g. below CERN NA3 (1980s)

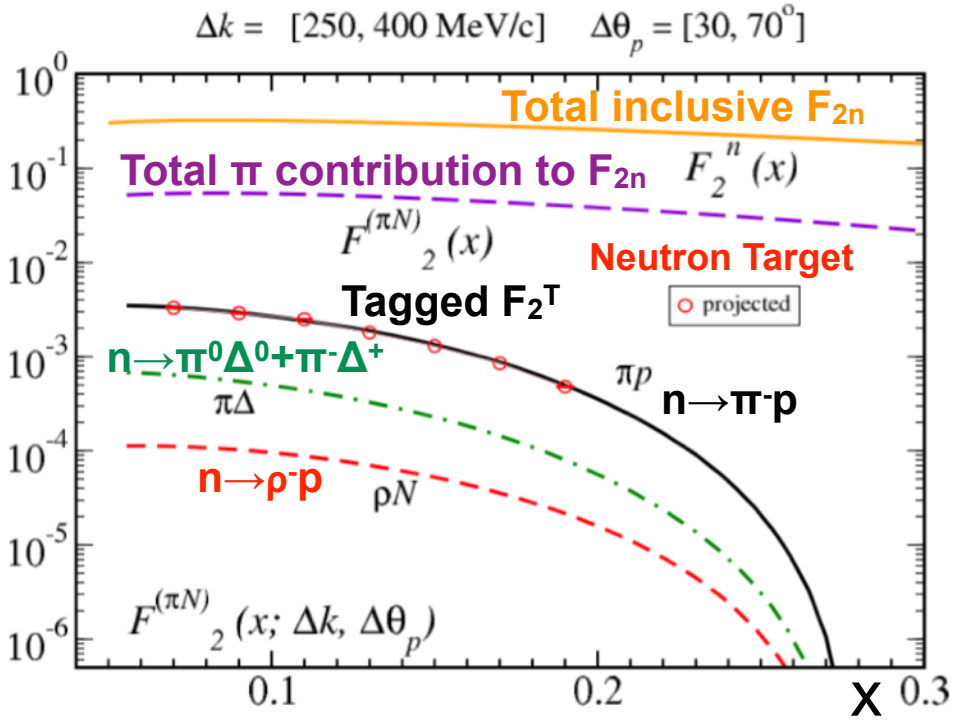


DSE prediction for ratio of u-quark distributions in kaon and pion

- Fundamental test QCD
- Kaon exchange - ΛN interaction, nuclear equation of state (astrophysics)
- Access to sea quarks and glue on hadronic level
- Insight to nucleon mass enigma (cannibilistic gluons vs massless goldstone boson)
- Kaon SF - access to study momentum fraction carried by gluon content of kaon
- For much more info see proposal…

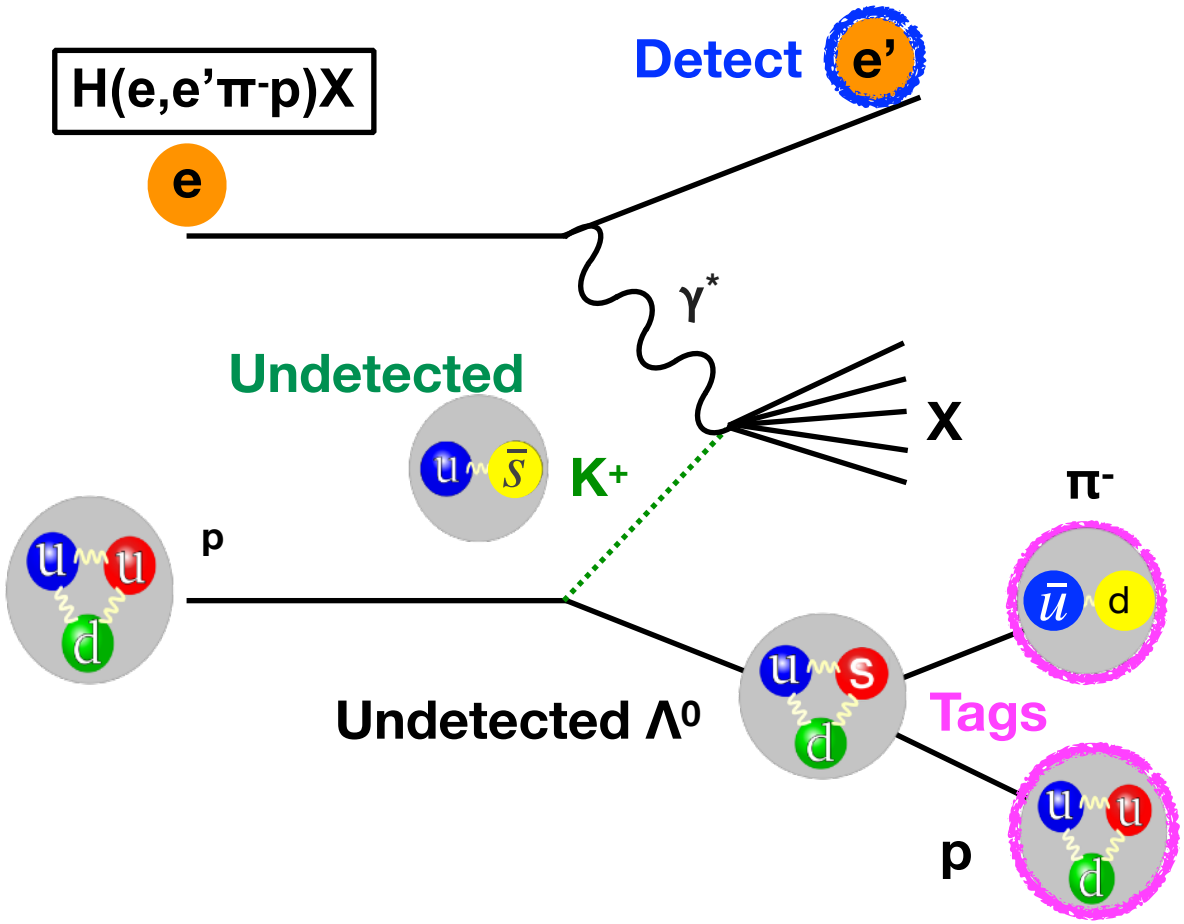
Background Measurement for Pion TDIS

- Pion TDIS predictions based on phenomenological pion cloud model (T.J. Hobbs)
- Tagged signal orders of magnitude less than total inclusive F_2 (hence high luminosity etc)
- Assuming pion exchange most dominant
- Mesonic content/flux factors unknown, both pion and kaon TDIS measurements will be extremely useful experimental tests
- Kaon TDIS essentially gives background measurement for pion TDIS



e.g. pion TDIS, neutron target, tagged contributions to F_2 from different exchanges

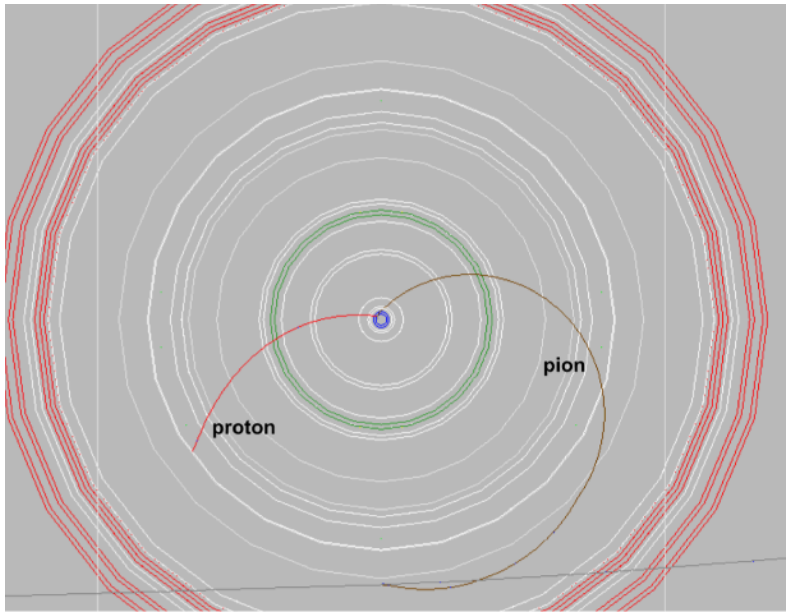
Kaon TDIS Measurement

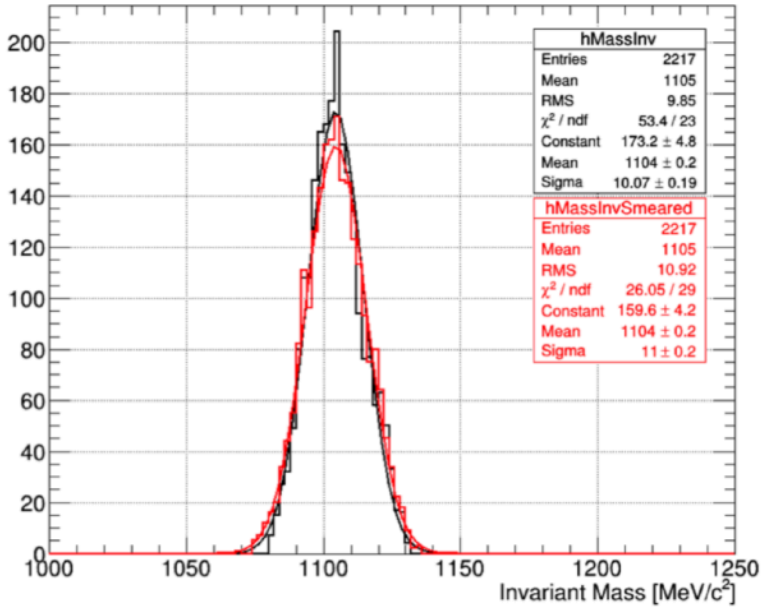


1st direct kaon SF extraction

- Analogous to pion TDIS, direct probe of nucleon's mesonic content
- Final state hadrons extremely low momentum due to required extrapolation to pole (t → space-like/meson pole dominance)
- Novel detector - mTPC - also essential in kaon TDIS to tagging very low momentum Λ^0 decay hadrons (60 - 400 MeV/c)

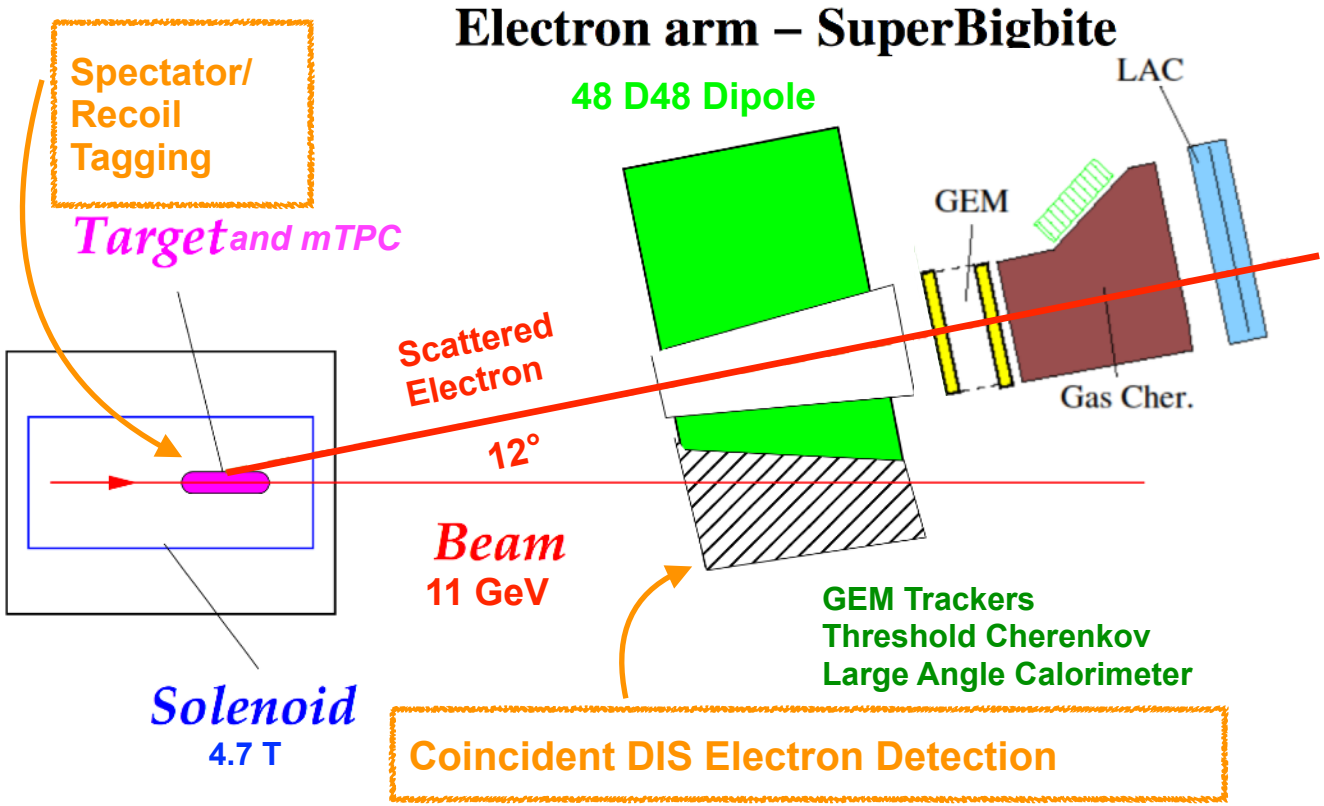
Kaon TDIS Measurement





- $p\pi^-$ decay angle in CMS back to back with common decay/displaced vertex
- Λ^0 reconstructed from $p\pi^-$ invariant mass

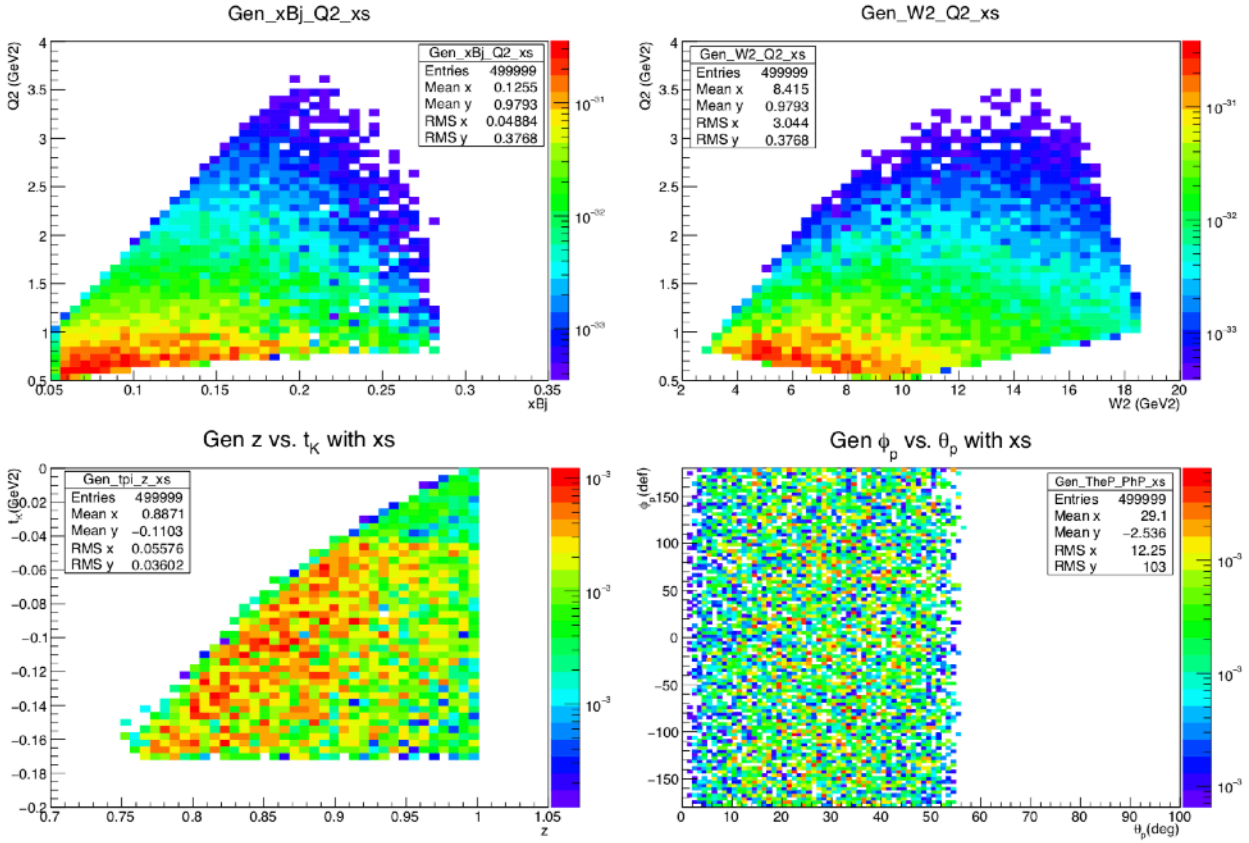
Experimental Setup



TDIS measurements very challenging: lots of exciting activities/ R&D on-going (detector simulations, design, testing, prototyping, software development)

- No change in set up/run plan from pion TDIS
- Run at same time as pion TDIS, for H target only
- Small cross-section = high density straw target, 11GeV e^- beam @ 50μA, $3x10^{36}cm^{-2}s^{-1}$ luminosity, SBS for e- with large acceptance ~70msr; high-rate capable mTPC to cope with backgrounds
- All data obtained simultaneously (apart from H/D target swap)

Kaon TDIS EG

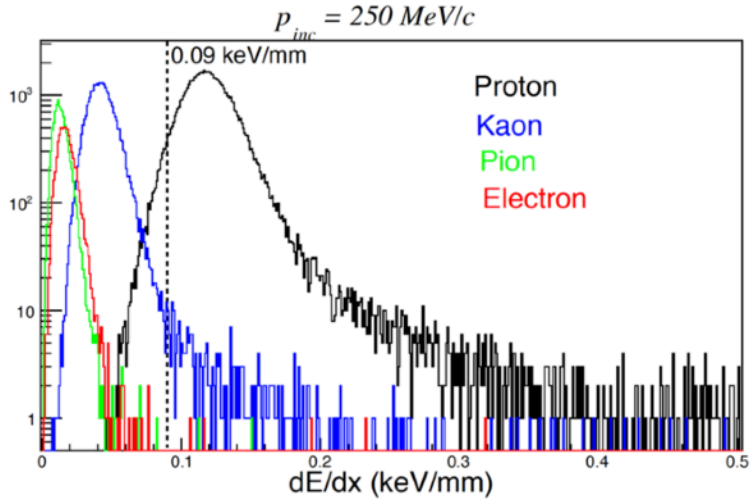


- Kaon TDIS event generator exists (written by K. Park)
- Chiral effective theory for strange quark asymmetry w/ meson exchange model (includes all Feynman diagram contributions to s-bar PDF in nucleon)
- For more info see proposal
- Compatible/embedded as sub-routing functioning within g4sbs
- Should be committed soon on tdis_dev branch of g4sbs GitHub with option to switch between pi/K (would like to perform final cross-check first)

Items for Immediate Study

- Recent efforts focussed on mTPC re-design simulation implementation
- Now should focus on validation of previous kaon TDIS simulations
  - cross-check variations with previous results from rTPC
  - vital to study possible improvements
  - likely to start these studies end of summer

- Examples of action items:
  - dE/dx for PID and separation of pions from electrons
  - achievable momentum resolution with new shorter chamber lengths
  - location of mTPC in solenoid for proton/pion acceptance/efficiency



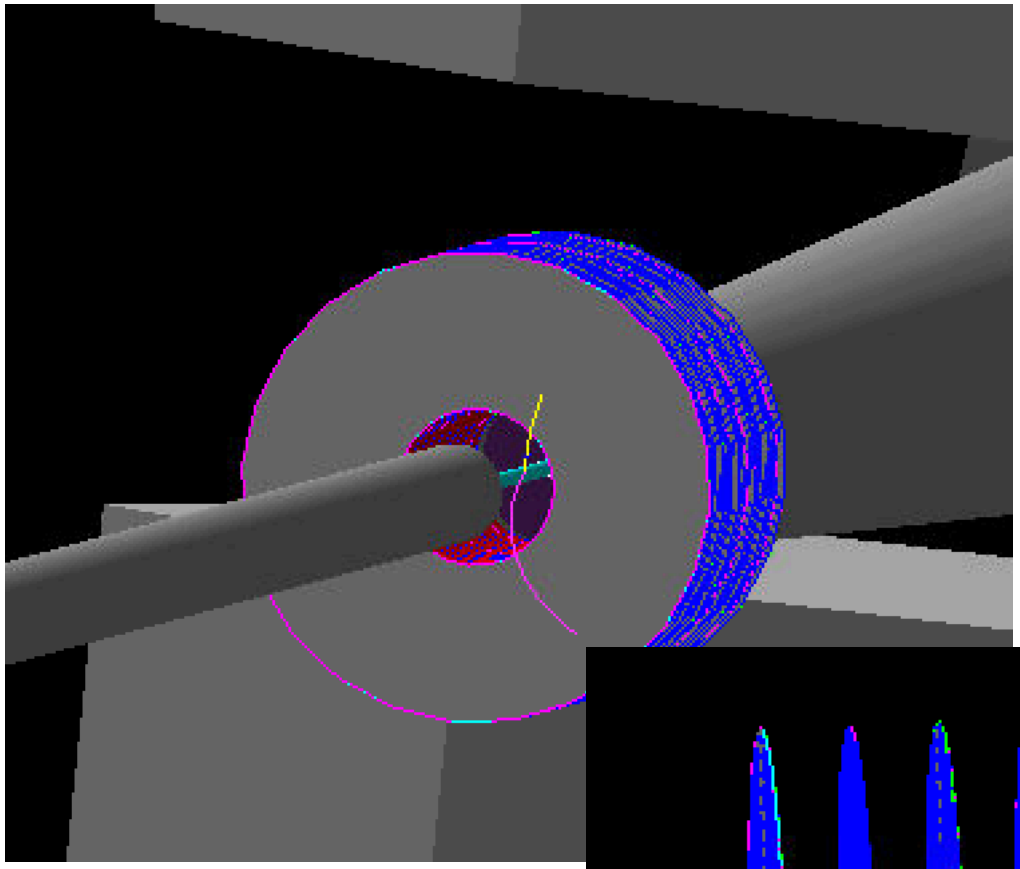
Back to back track patterns/ vertex info should help

Probability of creating a track of particle in RTCP gas volume (%)

Reaction / Offset(mm)	$H(e,e'\Lambda)X$	$H(e,e'p)X$
tracked particle type	$(p{:}\pi^-{:}p\pi^-)$	(p)
0	(40:50:33)	74.4%
100	(40:50:33)	74.6%
200 (nominal)	(40:52:35)	74.6%
500	(40:54:36)	75.7%
600	(40:54:37)	75.9%
1000	(41:55:38)	75.8%

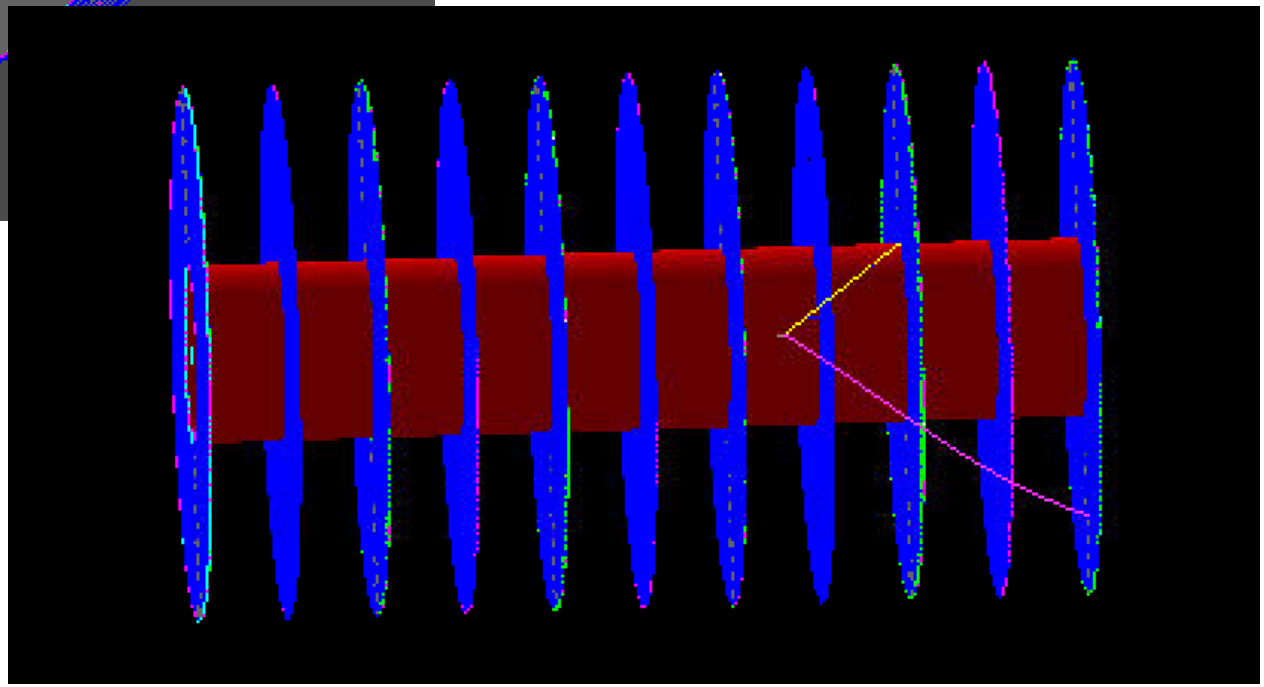
Optimising mTPC for proton acceptance will help both pi and K TDIS

KaonTDIS EG Events Ran through mTPC Geant4



Yellow = proton
Red = pion

Original observations confirm efficiency will be determined by proton acceptance



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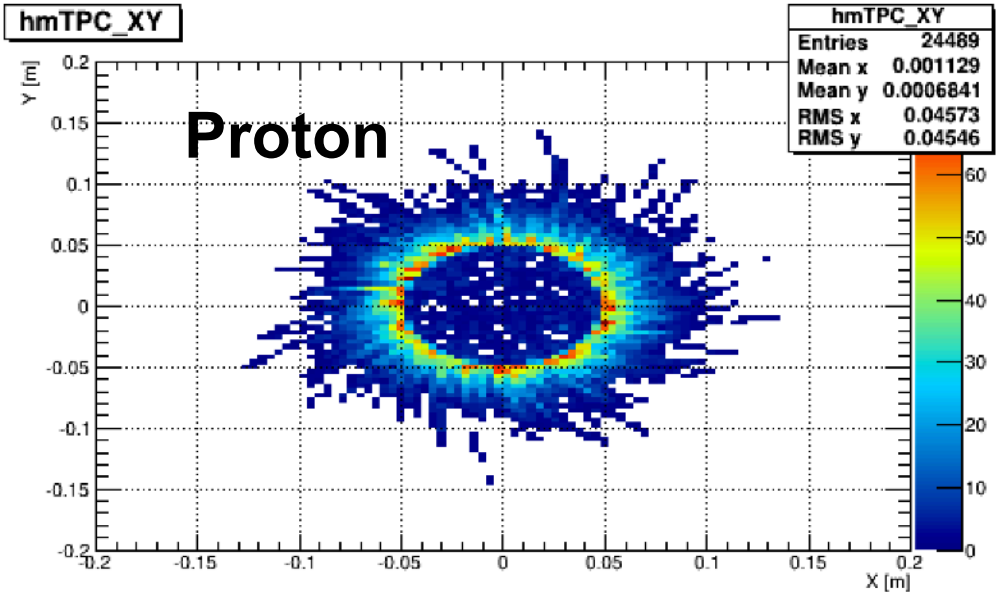
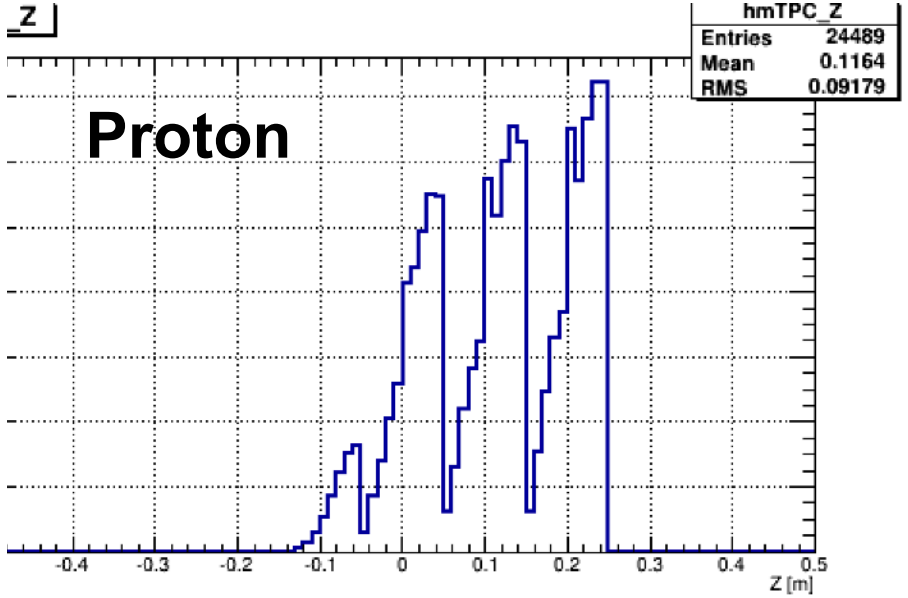
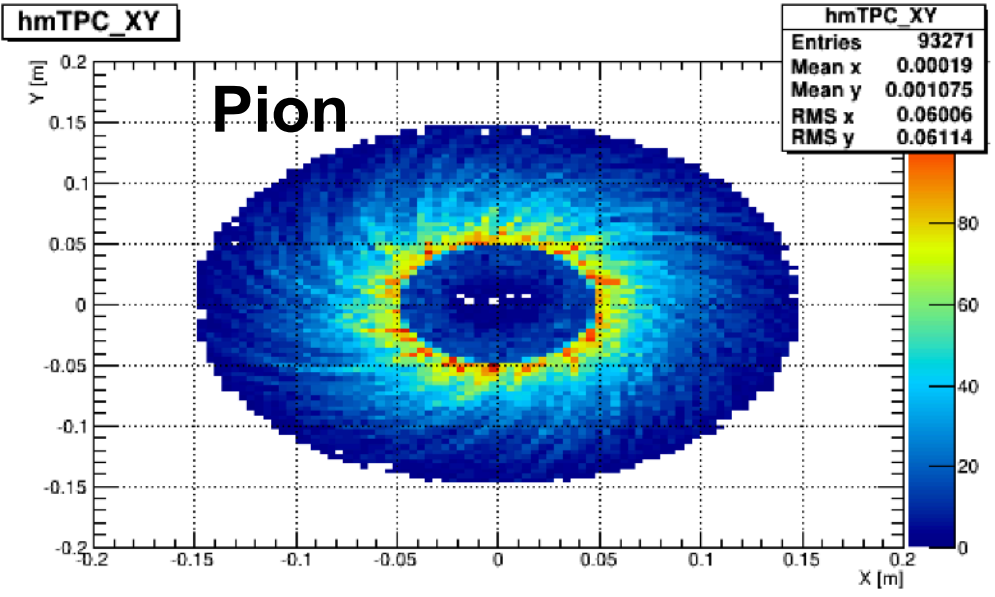
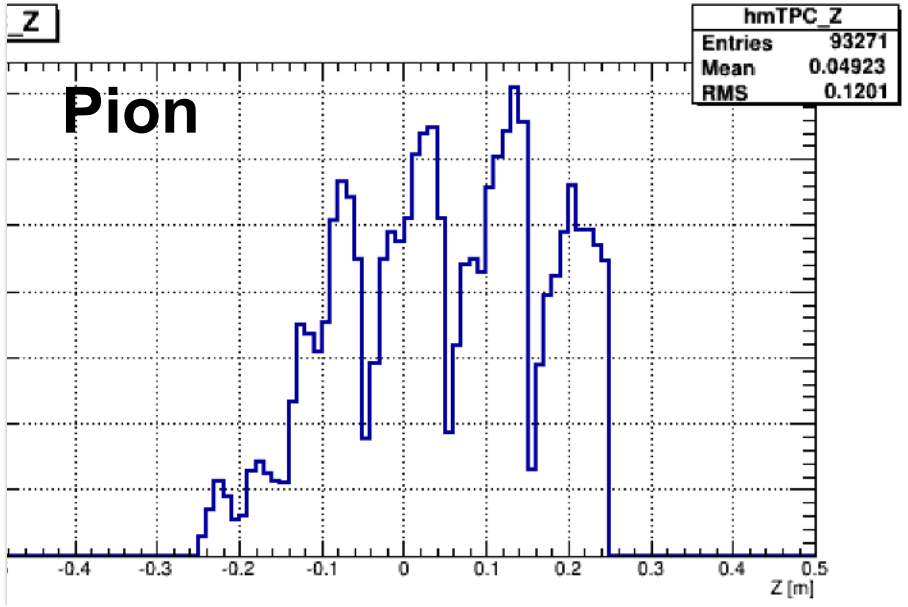
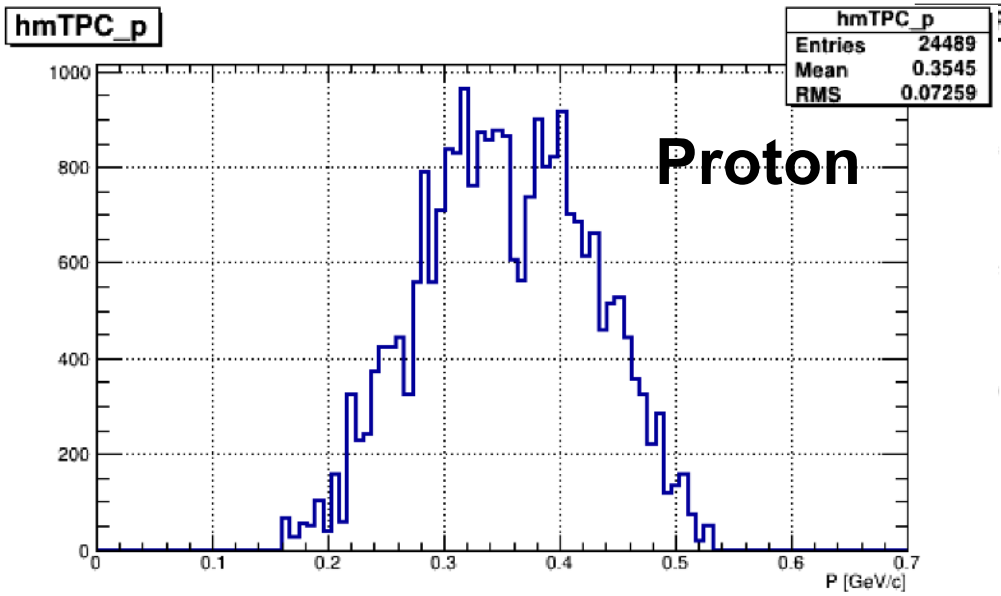


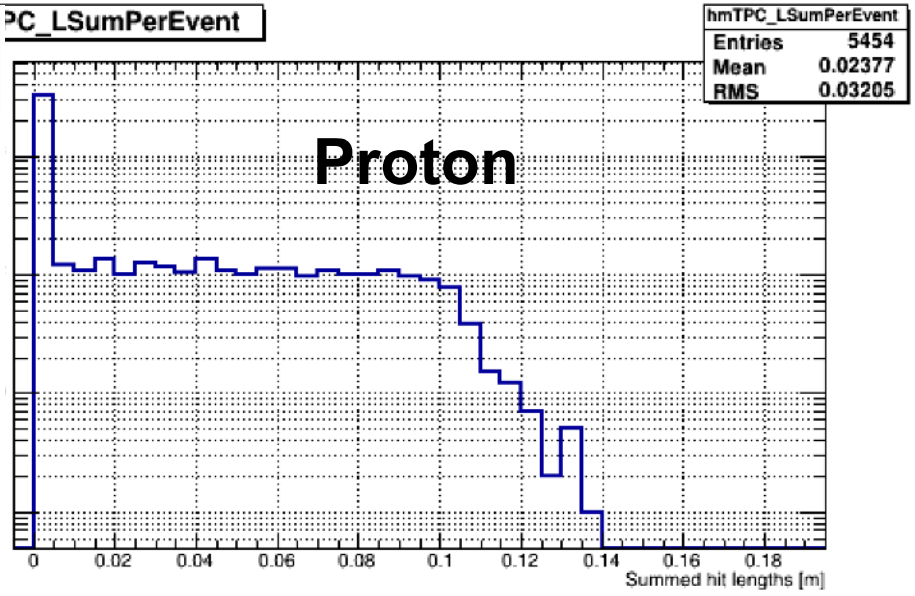


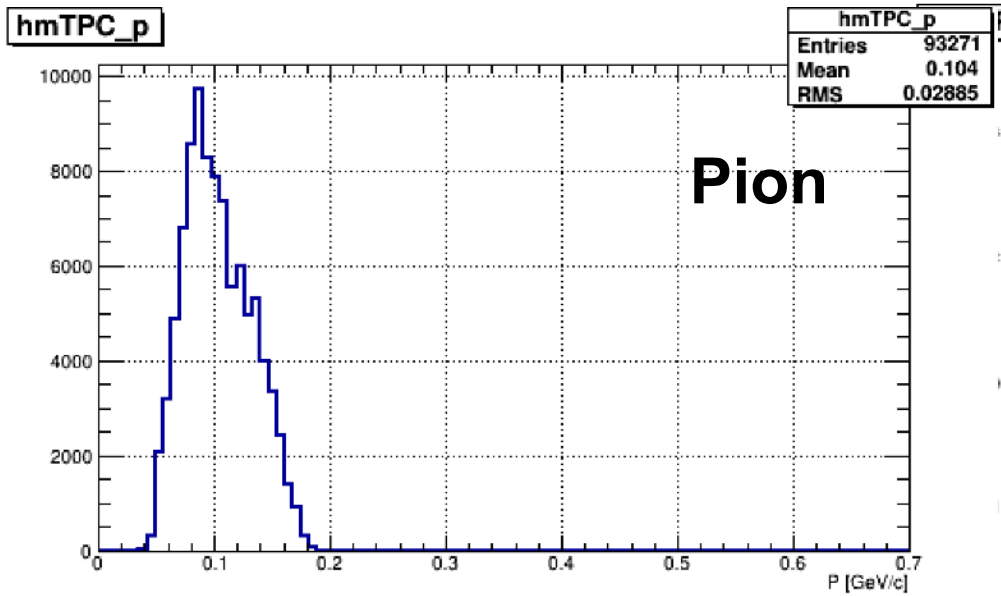


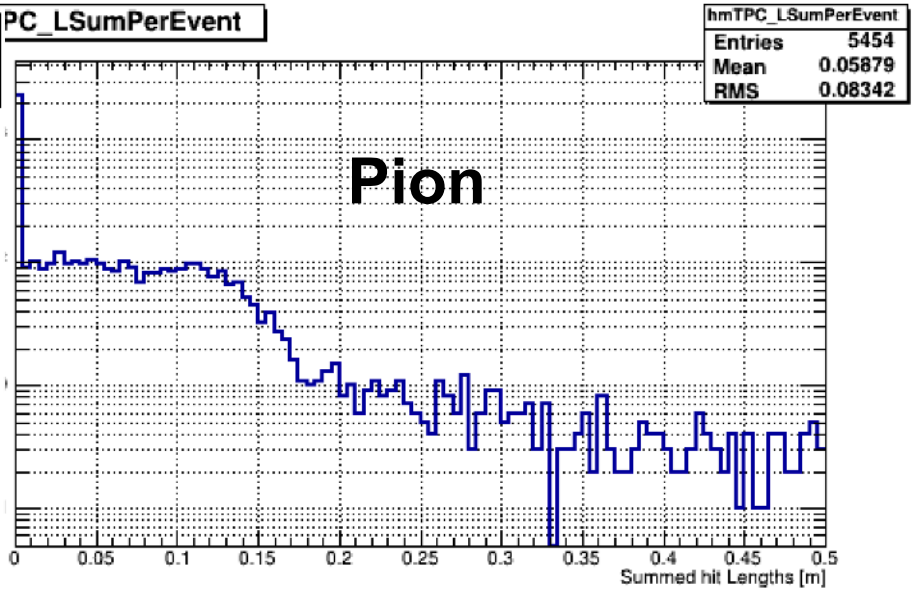


KaonTDIS EG Events Ran through mTPC Geant4

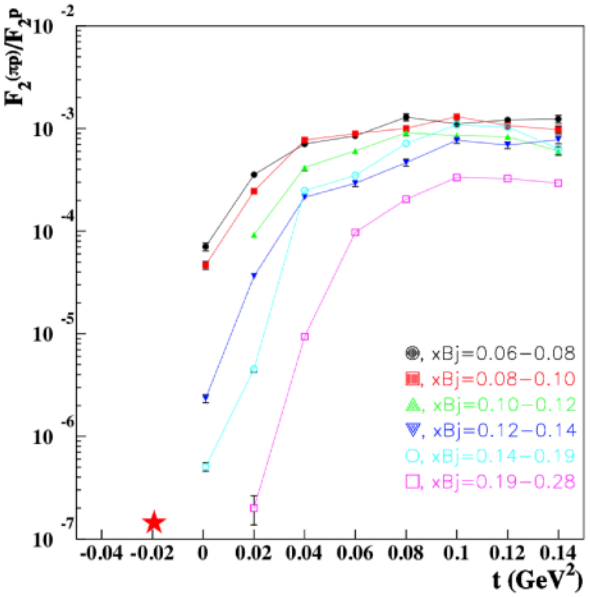


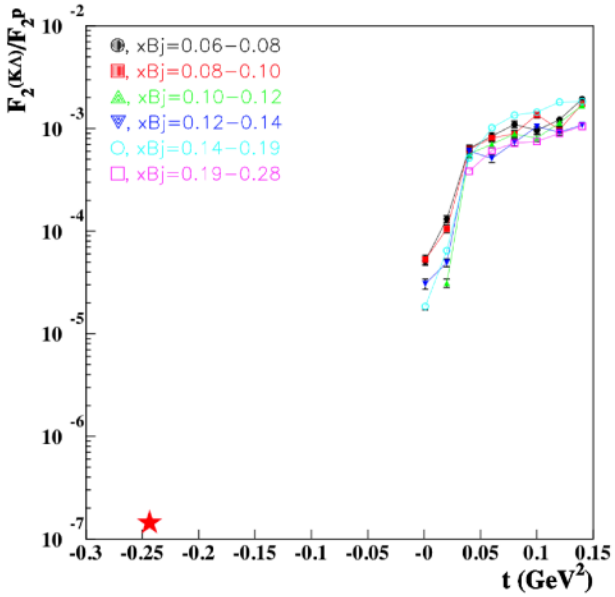




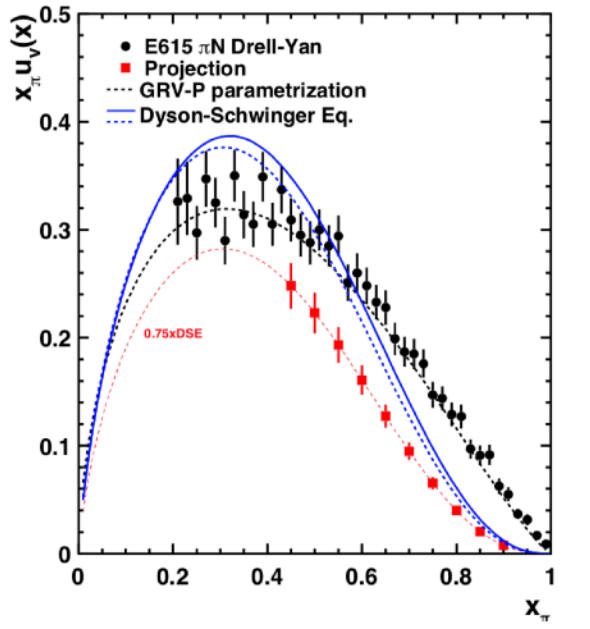


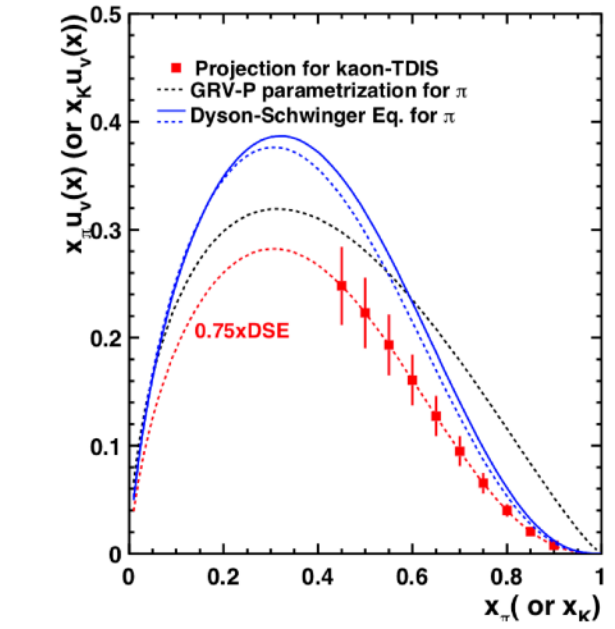
Projected Results





- Kinematical mapping of SF (e.g. t, x_{Bj})
- Low momentum reach for recoiling hadrons essential to obtain shape of curve
- K less sensitive to x_{Bj}





- Projected valence quark distributions
- Valuable insight for kaon in almost non-existent data set to study QCD models

Summary

- Light mesons building blocks of universe in addition to nucleon
  - important to know structure

- Understanding meson structure will provide more complete nucleon picture e.g.
  - What is mesonic content of nucleon? How does it affect SF/PDF?
  - Kaon TDIS provides access to sea/glue of nucleon - necessary to combine with valence quark info for PDF evolution

- C12-15-006A kaon TDIS run group proposal accepted PAC45 2017
- Simulations on-going - collaboration have been focussing on RTPC → mTPC, but several updated studies should be performed imminently for kaon TDIS since switching to mTPC e.g.:
  - optimisation of mTPC location for protons/pions detection efficiency
  - optimisation/improvements in dE/dx of mTPC for PID
  - achievable proton and pion momentum resolutions

- Kaon TDIS runs simultaneously and should not affect pion TDIS
- Optimisations to mTPC hopefully improve both pion/kaon TDIS
- Kaon TDIS useful background info for pion TDIS/theoretical models