Kaon L-T experiment at Jefferson Lab

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NSERC CRSNG

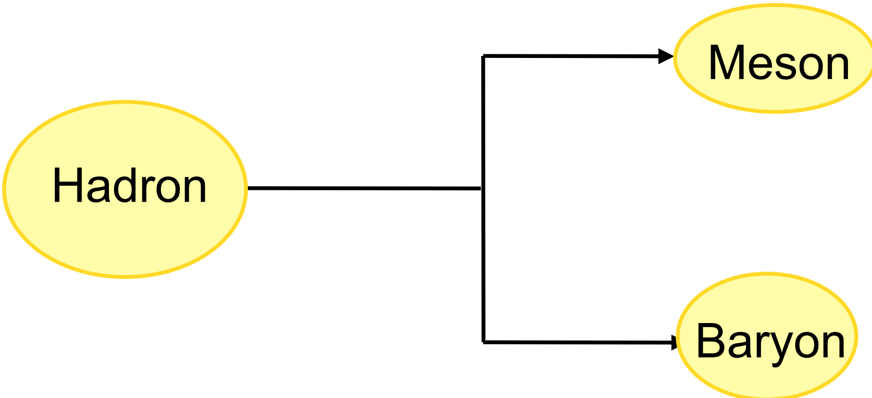
University of Regina

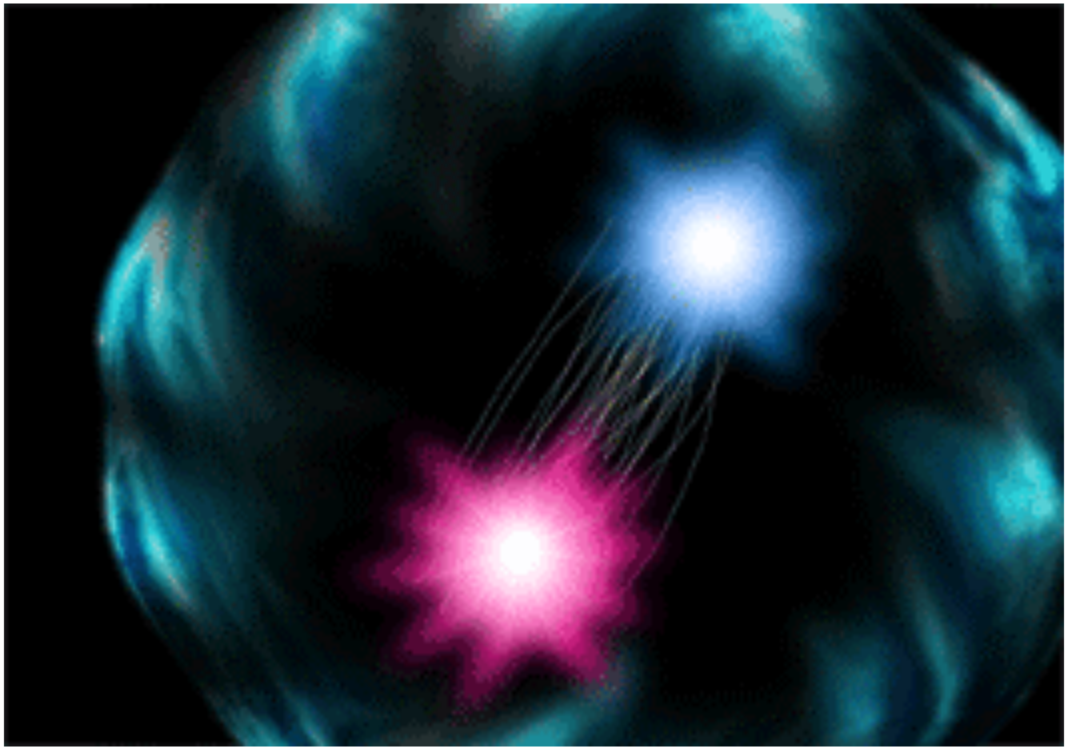
Jefferson Lab
Thomas Jefferson National Accelerator Facility

Scientific Motivation

- How does Quantum Chromodynamics (QCD) work in the confinement regime?
- How precisely does QCD predict hadronic structure?
- What are the form factors for strangeness mesons?

Inside Hadrons

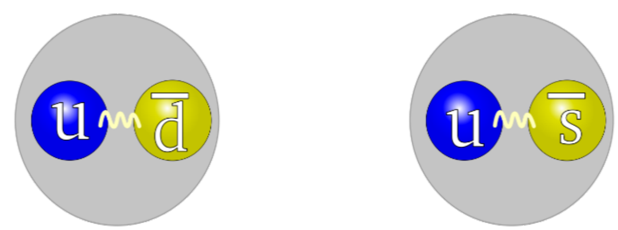




Pion's structure is determined by two valence quarks, and the quark-gluon sea.

Mesons are valence quark-antiquark states

Baryons are valence quark-quark-quark states



π^+ K^+

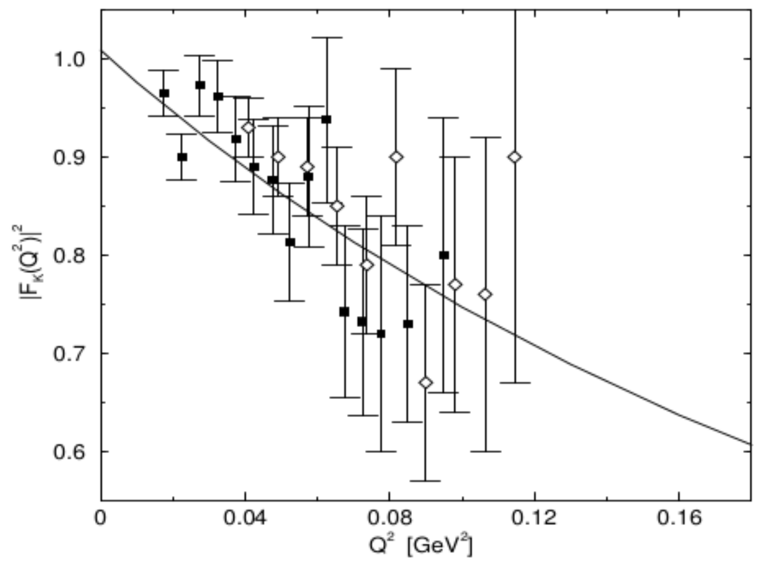
Meson Form Factor

Form factor: Elastic electron hadron scattering, eK → e'K'

Electromagnetic form factor can be calculated exactly at very large momentum transfer (small distances) with perturbative QCD

No "free" Pion and Kaon targets

Similar to π^+ form factor, elastic K^+ scattering from electrons used to measure charged kaon form factor at low Q^2 [Amendolia, et al., PL **B178** (1986) 435]



Can "kaon cloud" of the of the proton be used in the same way as the pion to extract kaon form factor via $p(e, e' K^+)\Lambda$?

$(\langle r^2_K \rangle)^{1/2} = 0.58 \pm 0.04$ fm

System of Reactions

E01-004,Fπ-2

$$e^- + p \rightarrow e'^- + \pi^+ + n$$ 2003

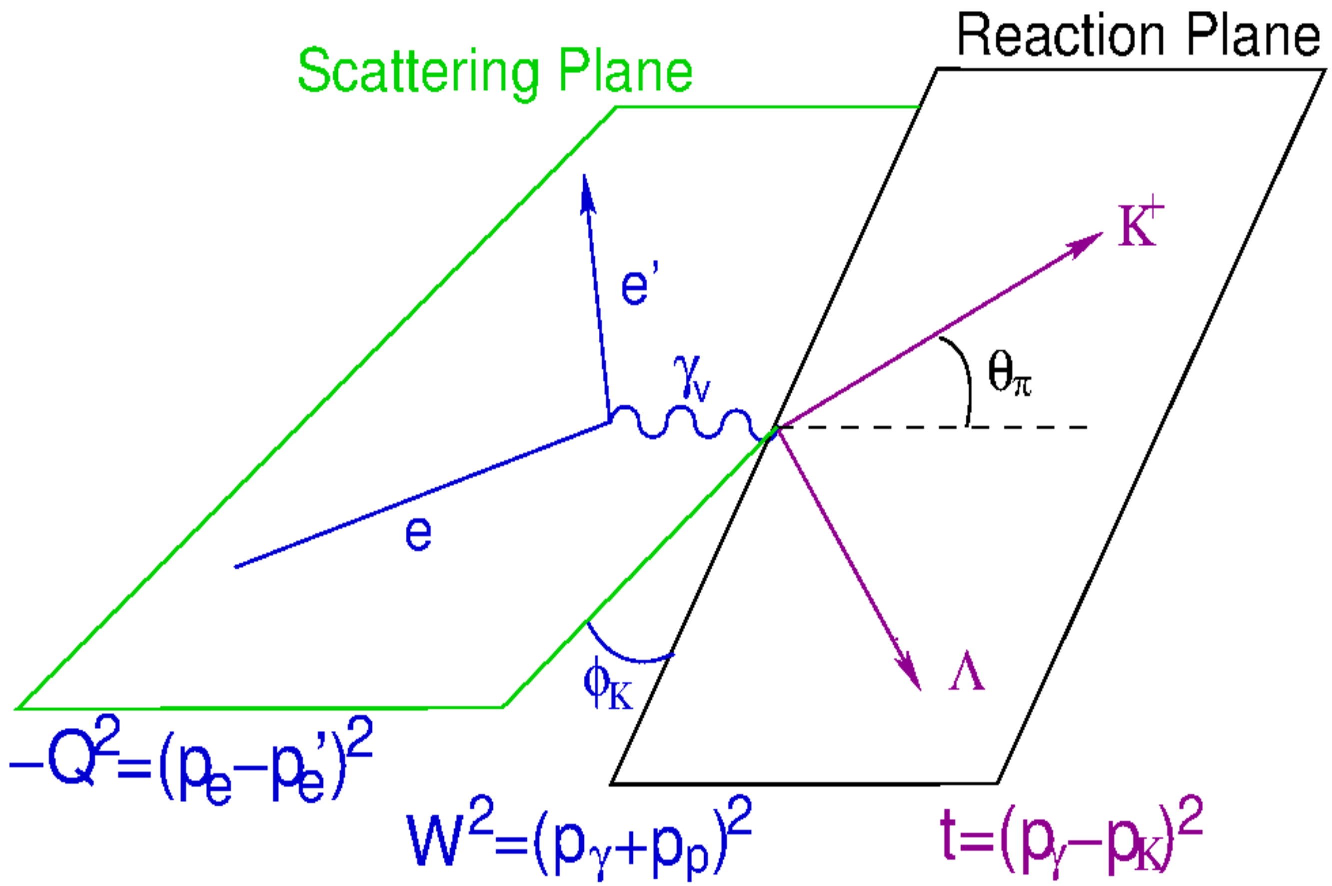
E12-09-011, Kaon L-T

$$e^- + p \rightarrow e'^- + K^+ + (\Lambda \; or \; \Sigma^0)$$

Λ, Σ^0(uds)

$M_\Lambda = 1115.68 \mathrm{MeV}^2/c^2$
$M_{\Sigma 0} = 1192.64 \mathrm{MeV}^2/c^2$

Reaction and scattering planes



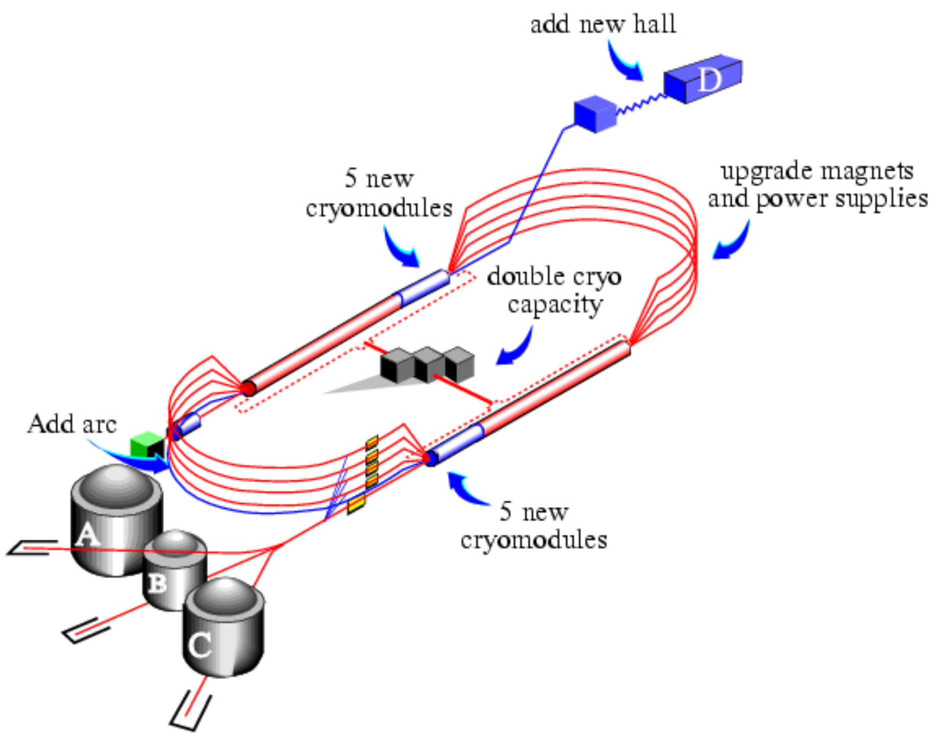
Missing energy, $E_m = E_e - E_{e'} - E(K^+)$

Missing momentum, $\vec{P}_m = \vec{q} - \vec{p}(K^+)$

Jefferson Lab

Accelerator: Continuous Electron Beam Accelerator Facility (CEBAF)

Two superconducting Linear Accelerators provide an intense high energy electron beam



Hall-C Instrumentation

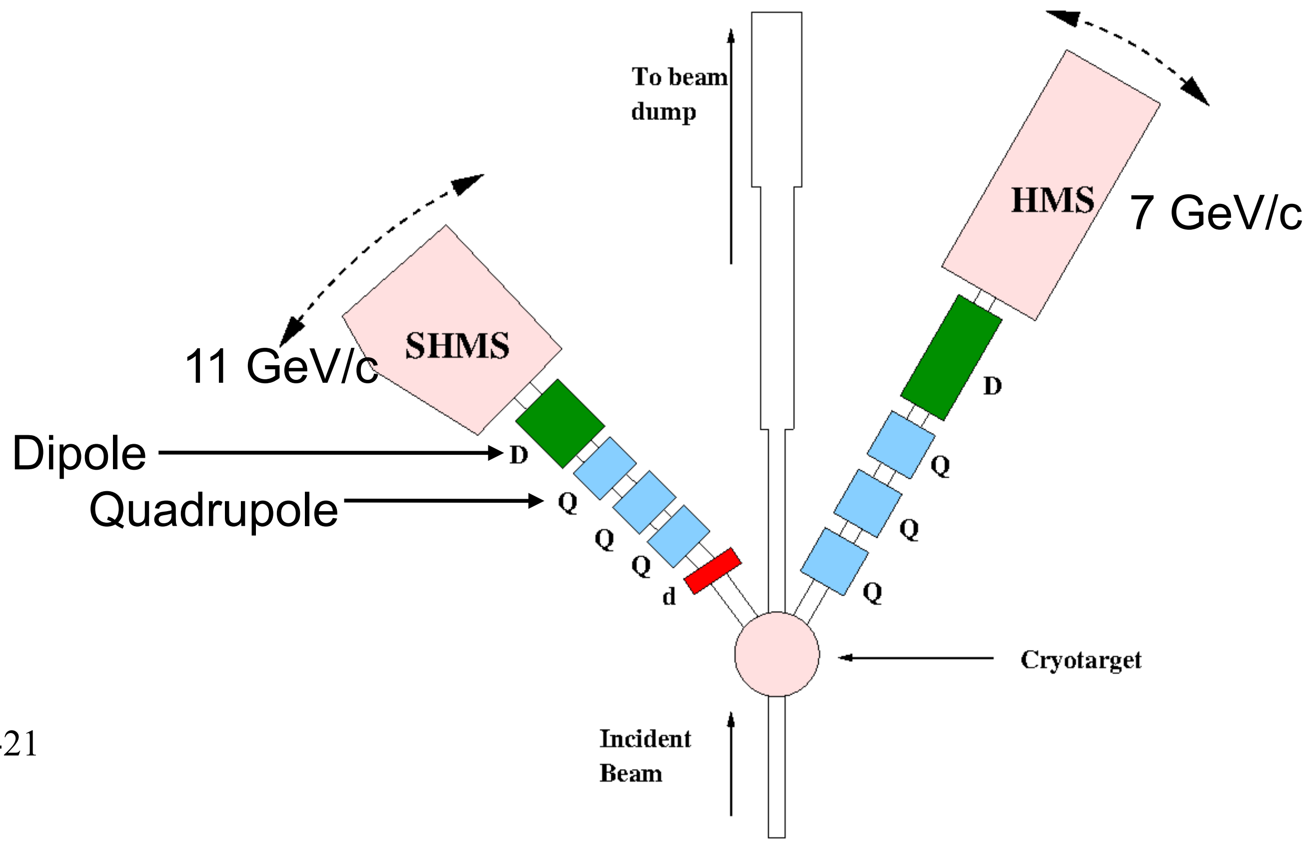
Super High Momentum Spectrometer (SHMS) for Kaon detection

High Momentum Spectrometer (HMS) for Electron detection

Dipole is used to select particles of specific momentum range

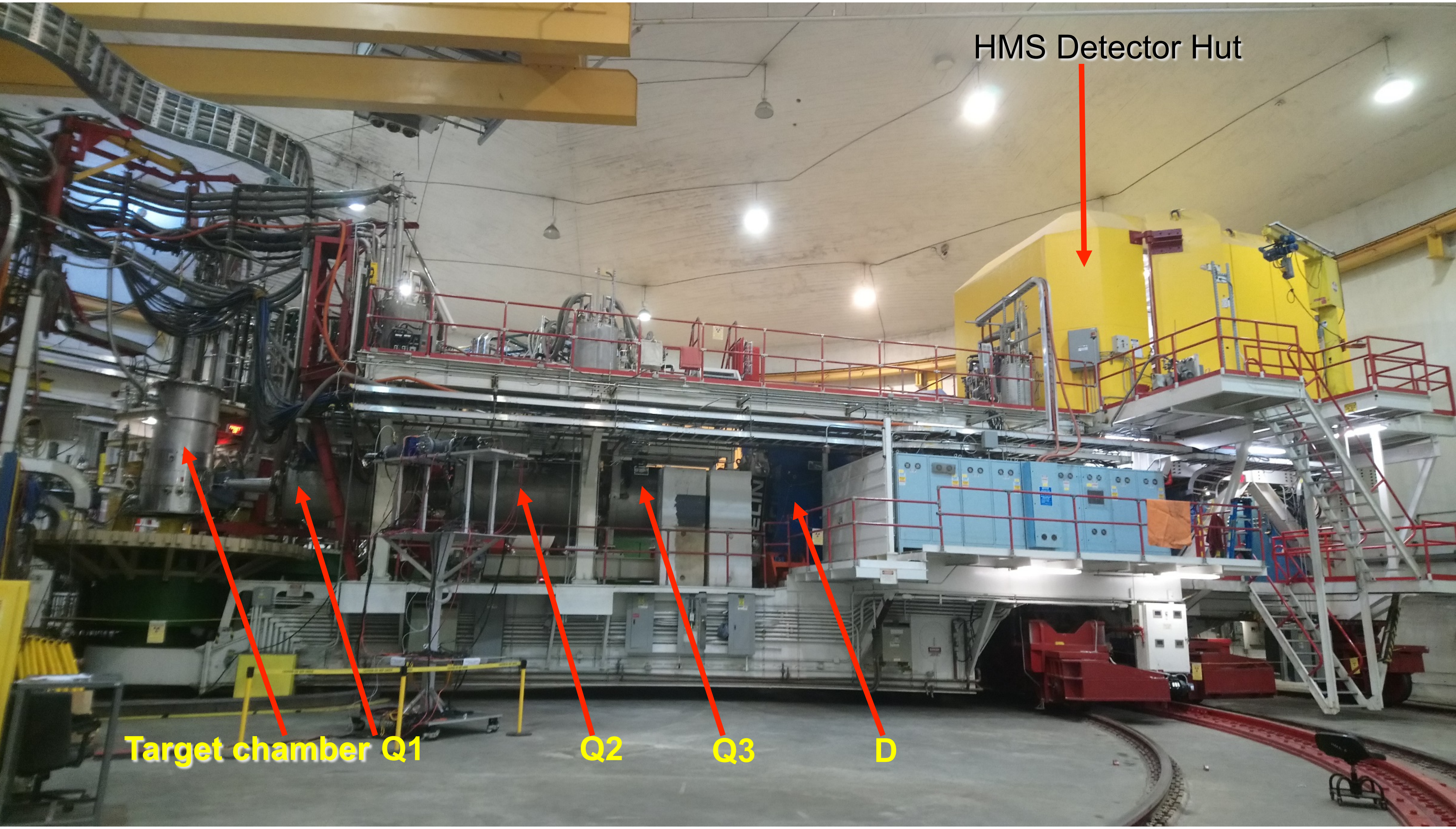
Kaon angles between 5.5 – 40 deg
Kaon momenta between 0.5 – 11 GeV/c

Angles between 10.5 – 90 deg
Momenta between 0.5 – 7 GeV/c



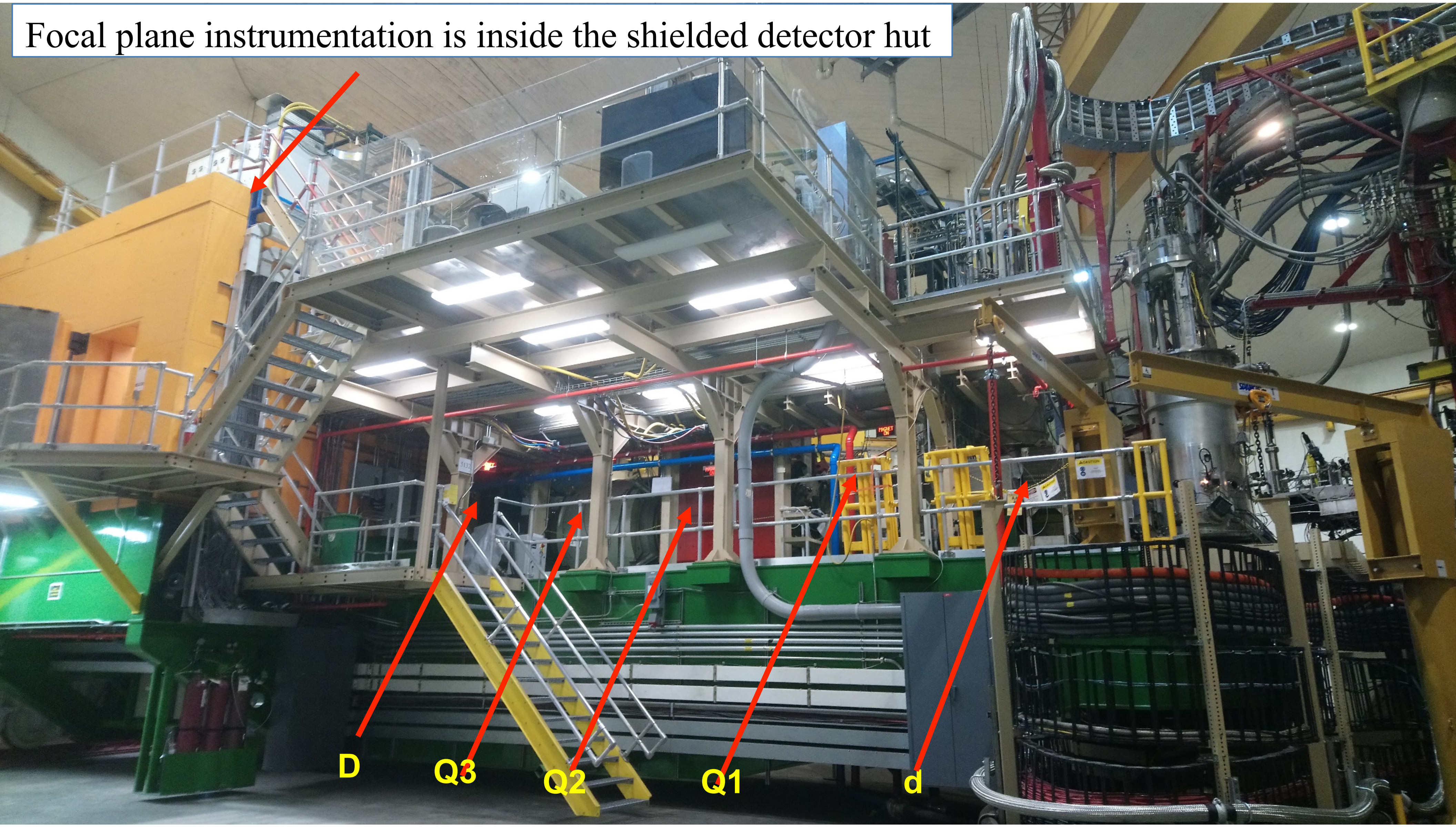
High Momentum Spectrometer (HMS)

Inside Hall-C view

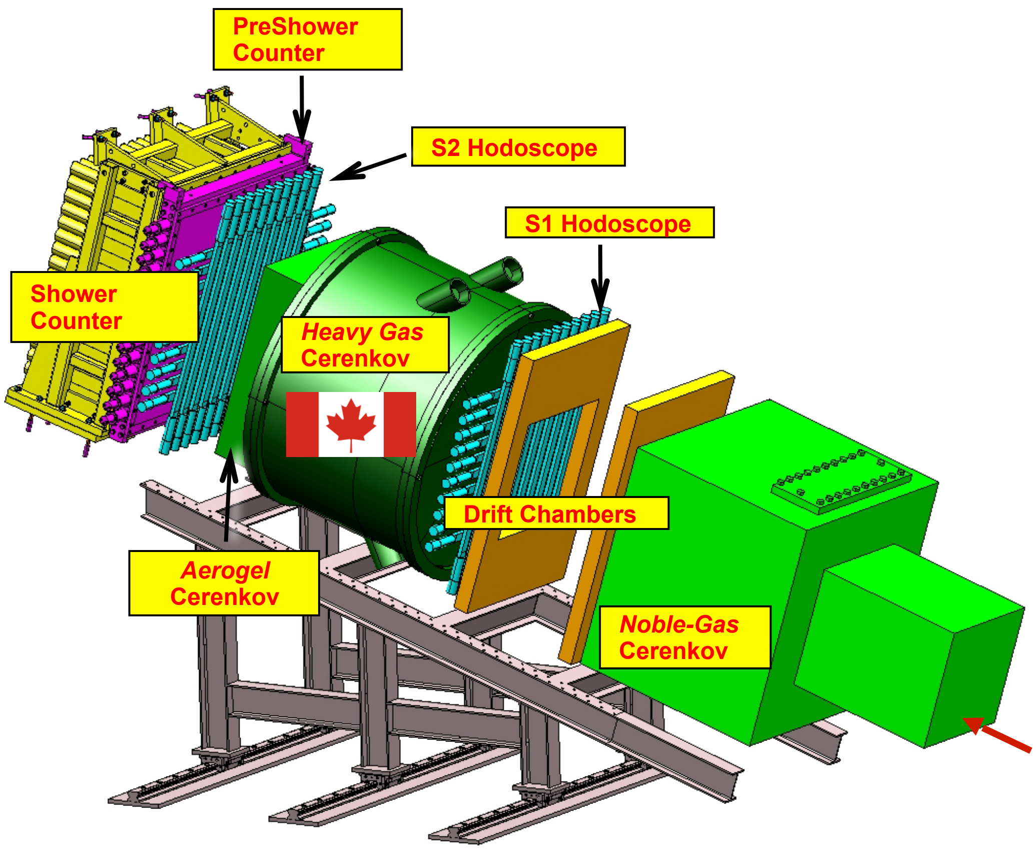


Super High Momentum Spectrometer (SHMS)

Inside Hall-C view



SHMS Focal Plane Detector System



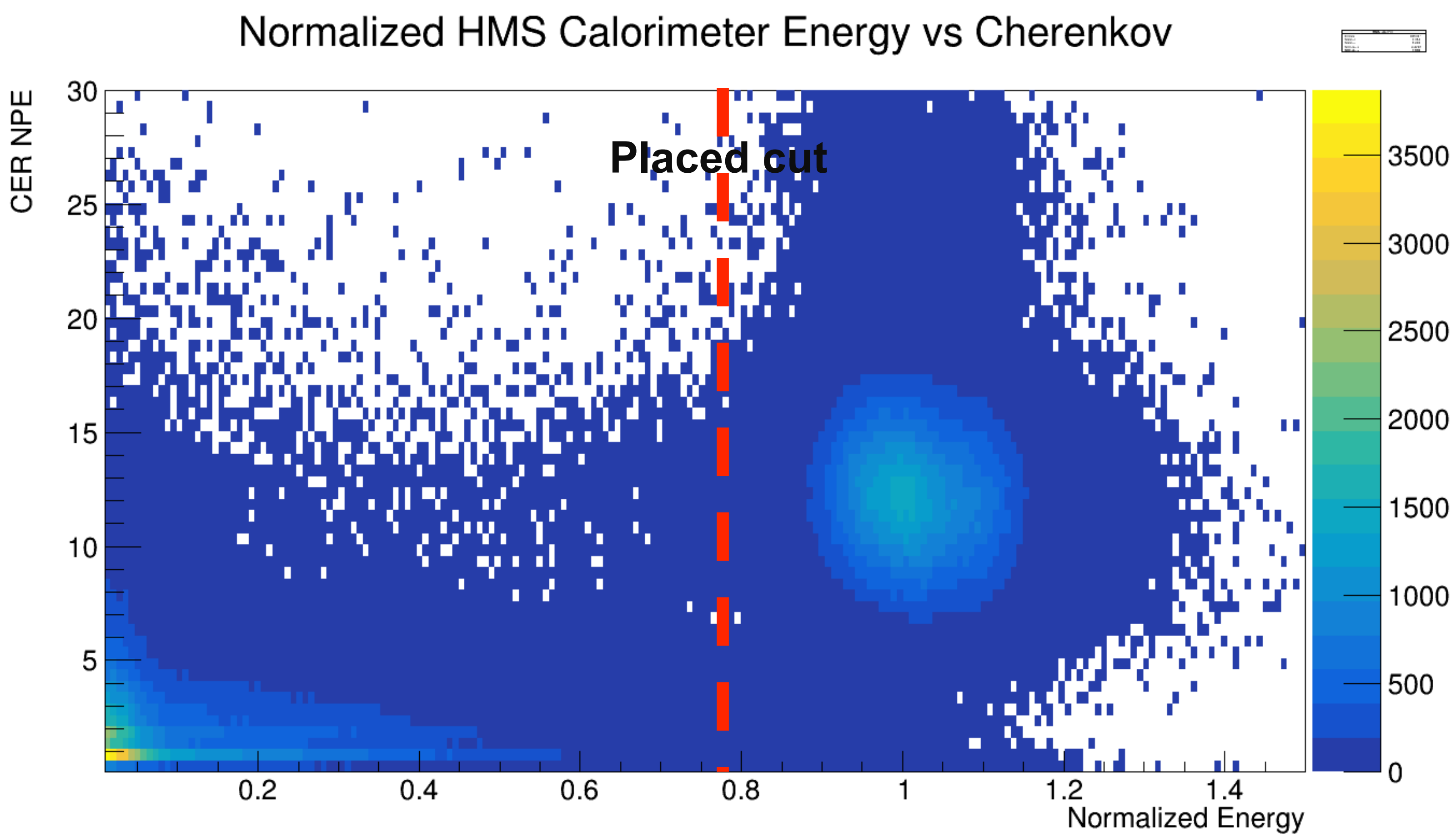
DETECTOR	PURPOSE	NOTES
S1XY, S2XY Hodoscopes	Lowest-level Trigger. Time reference	
Drift Chambers	Momentum Measurement. Tracking.	5mm max. drift 300 micron resolution
Noble-Gas Cerenkov	Particle ID, Trigger. $e^{\pm}/\pi^{\pm}$ at high momentum (replace by vacuum at low p)	Vary Ar/Ne mixture to set index at $\pi^{\pm}$ threshold.
Heavy-Gas Cerenkov	Particle ID, Trigger. $\pi^{\pm}/K^{\pm}$ discrimination	C_4F_8O – Vary pressure to set index at $K^{\pm}$ threshold
Aerogel Cerenkov	Particle ID, K+/p discrimination	n= 1.011,1.015,1.03,1.05
Preshower / Shower Counters	Particle ID, Trigger. Electron tag	

Incident Particles through SHMS magnet optics

p(e,e'K$^+$) Λ,Σ^0 Event Selection

Electron selection in HMS

$Eb = 10.599\ GeV,\ Q^2 = 3.0$, W = 3.14, ε = 0.6668

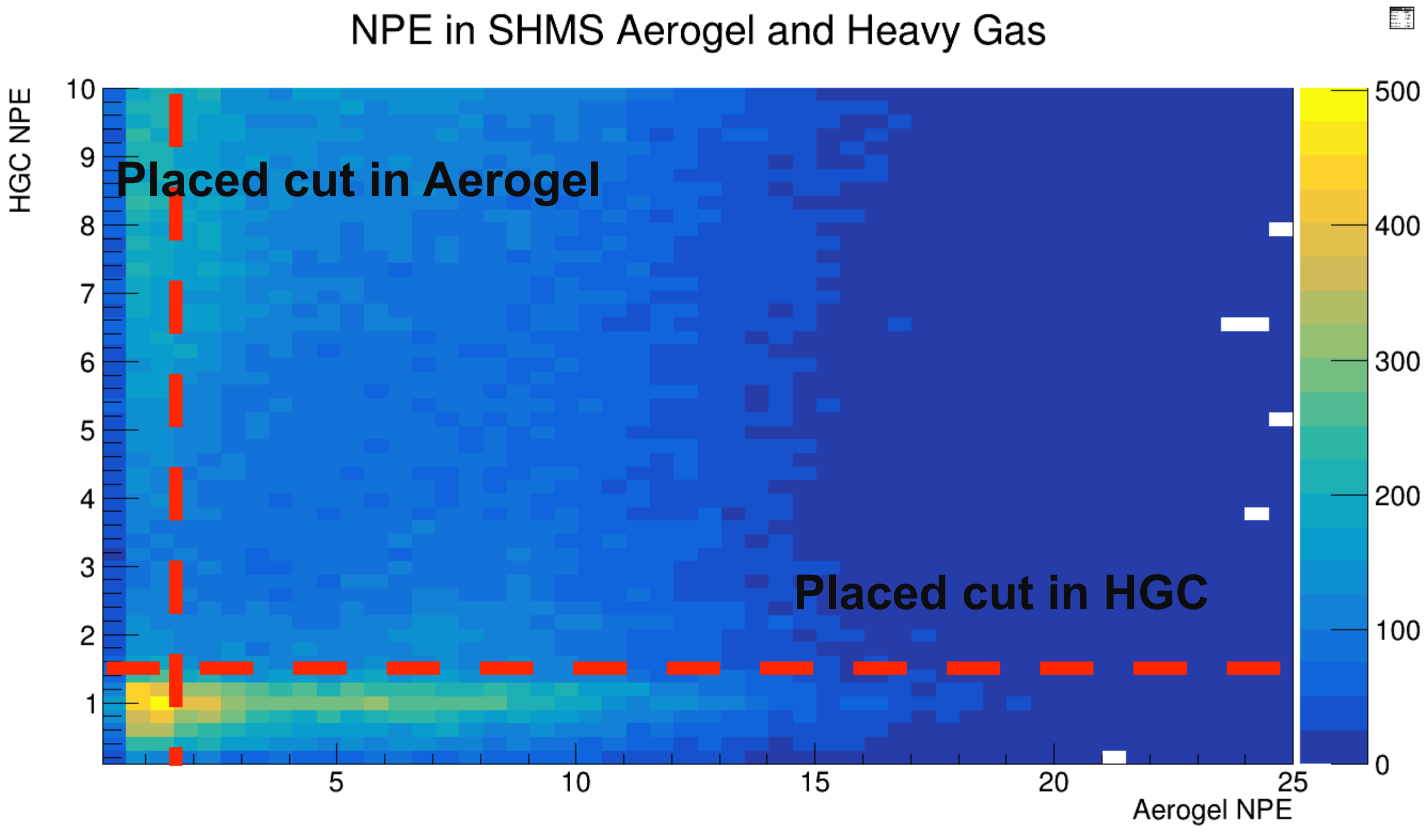


HMS with negative polarity and the central momentum = 4.204 GeV/c

p(e,e' K$^+$) Λ,Σ^0 Event Selection

Kaon selection in SHMS

$Eb = 10.599\ GeV,\ Q^2 = 3.0$, W = 3.14, ε = 0.6668

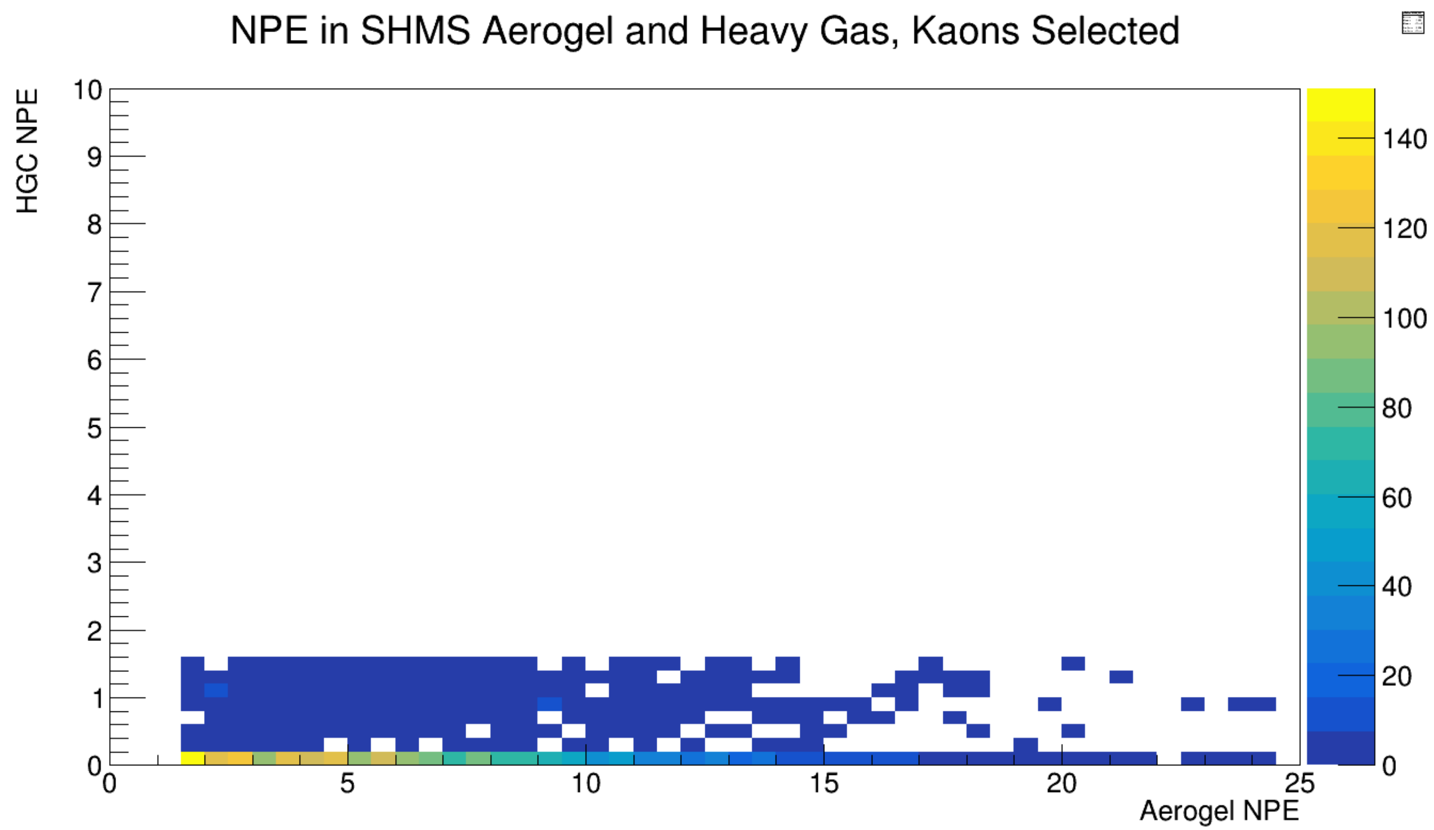


SHMS with positive polarity and the central momentum = 6.053 GeV/c

p(e,e' K^+)Λ,Σ^0 Event Selection

Kaon selection in SHMS

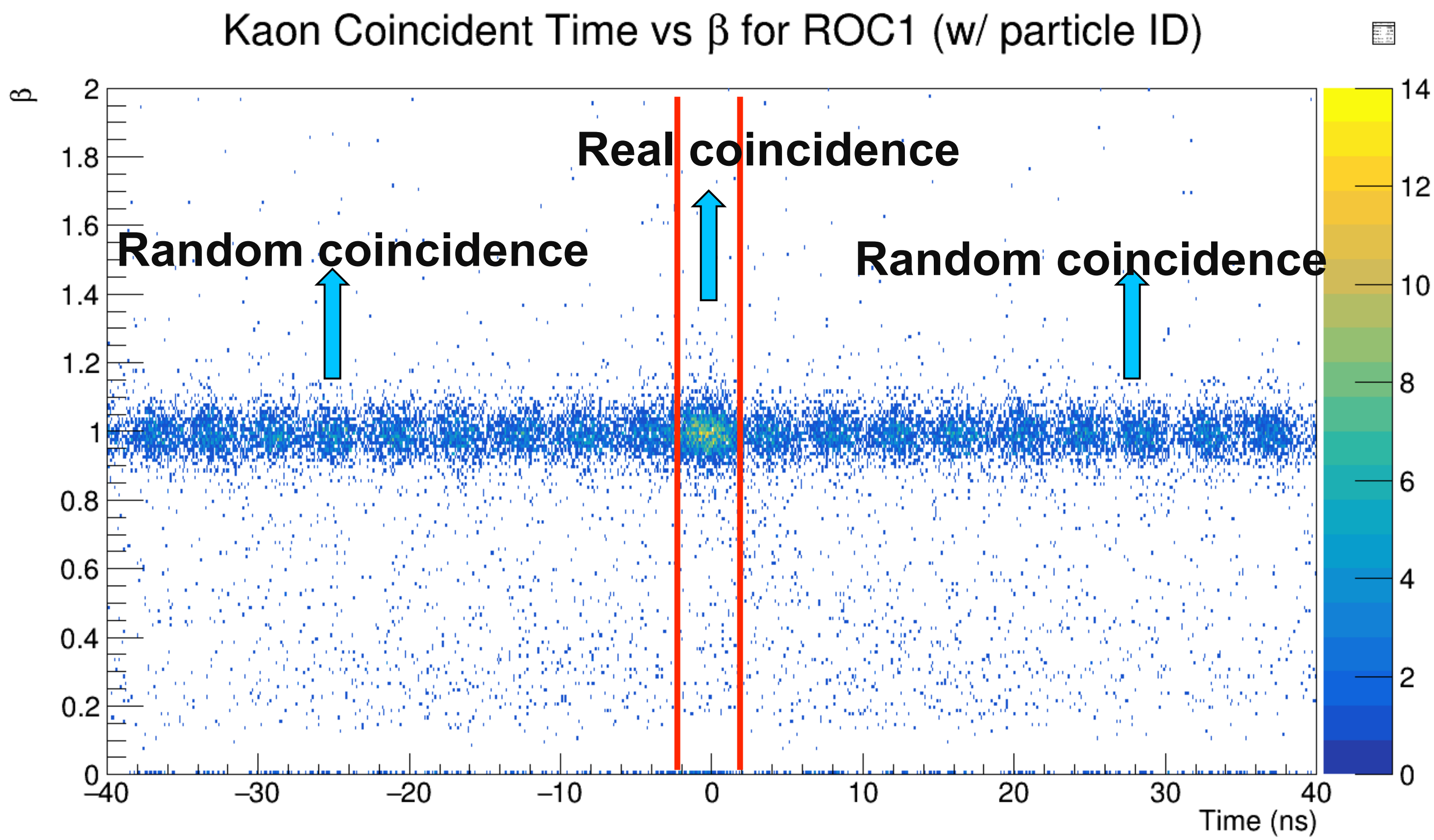
$Eb = 10.599\ GeV,\ Q^2 = 3.0$, W = 3.14, ε = 0.6668



Background subtraction

$Eb = 10.599\ GeV,\ Q^2 = 3.0$, W = 3.14, ε = 0.6668

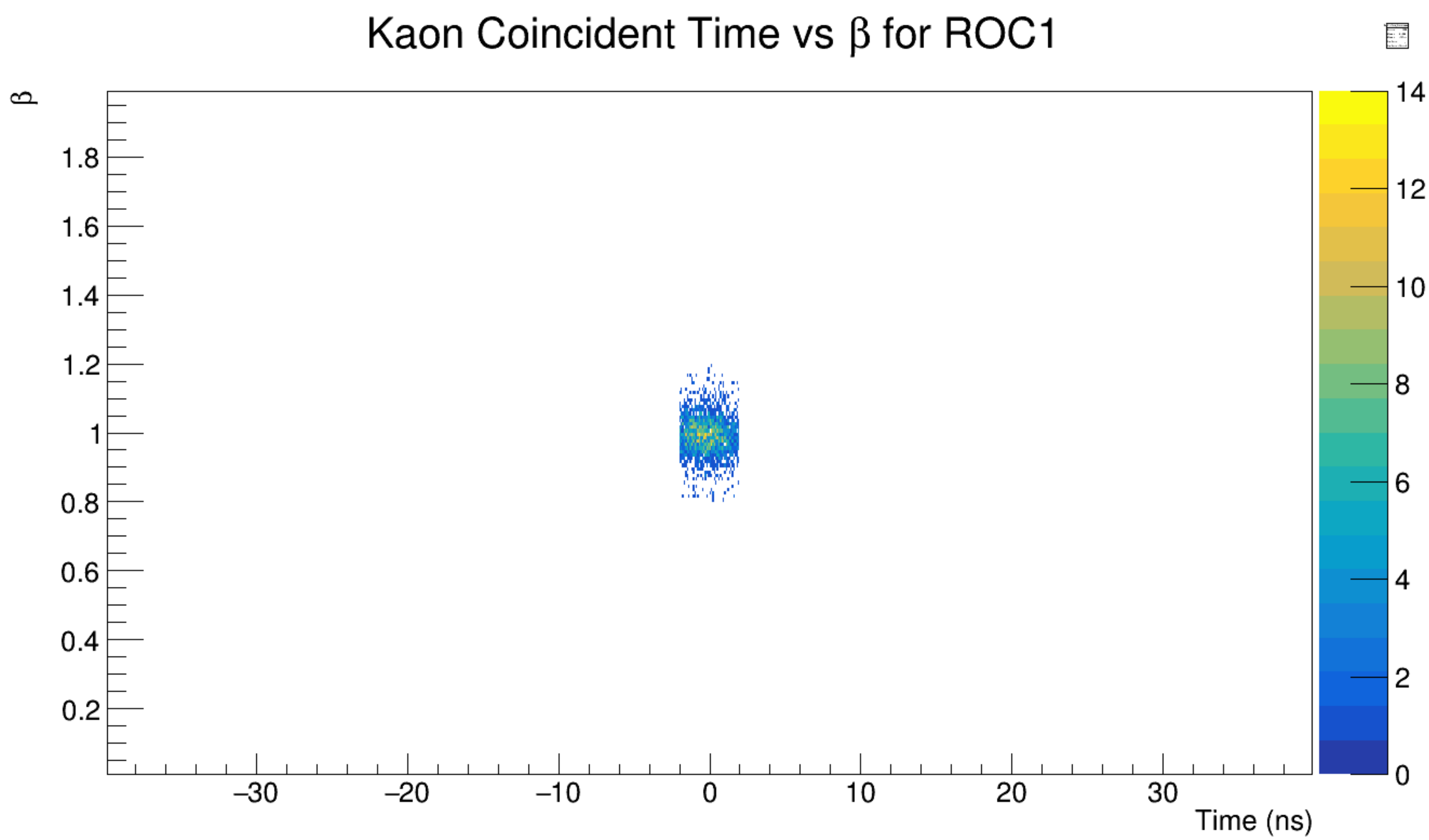
Random Background Subtraction



These data have real coincidence and random coincidence of Kaon in SHMS and electron in HMS

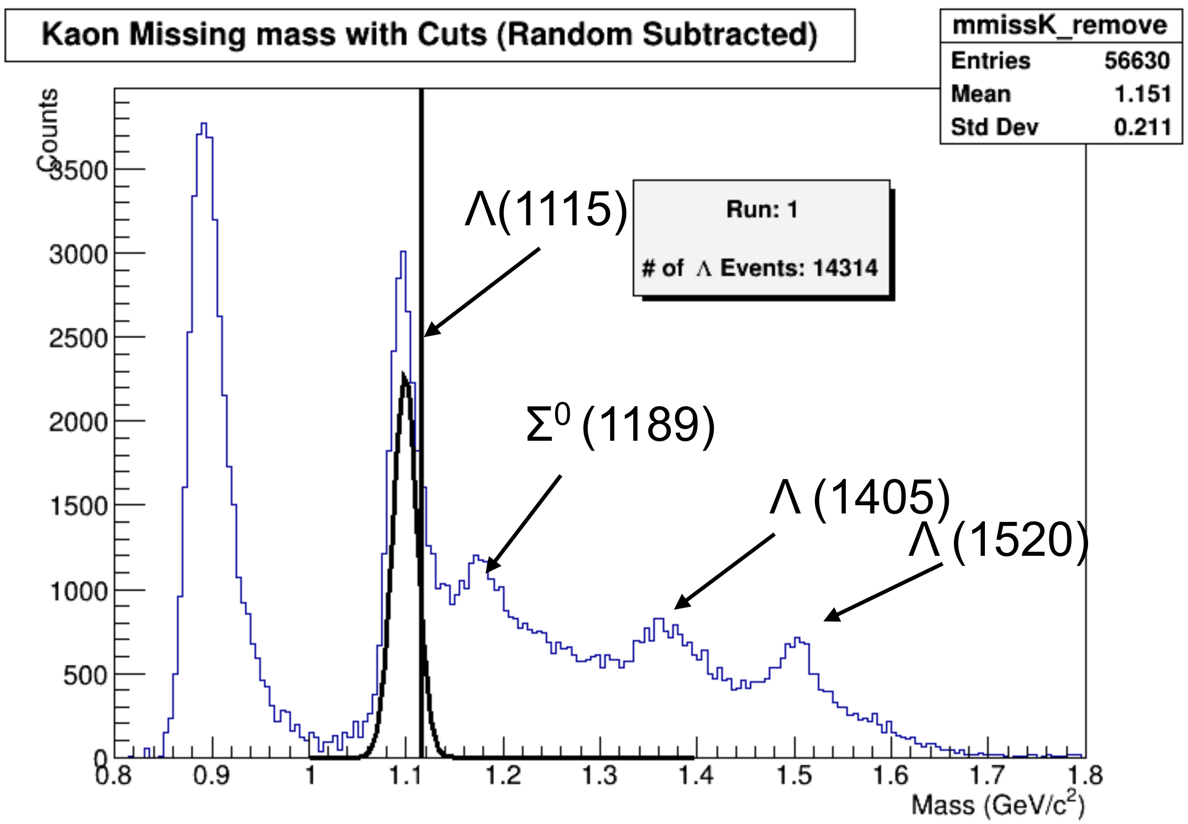
Background subtraction

$Eb = 10.599\ GeV,\ Q^2 = 3.0$, W = 3.14, ε = 0.6668



Missing mass reconstruction

$Eb = 10.599\ GeV,\ Q^2 = 3.0$, W = 3.14, ε = 0.6668



$$M_{miss} = [(Eb + m_p - E_{e'} - E_{K+})^2 - (\vec{p}_{e^-} - \vec{p}_{e'} - \vec{p}_{K+})^2]^{1/2}$$

Measuring dσ_L/dt

Physical cross-section

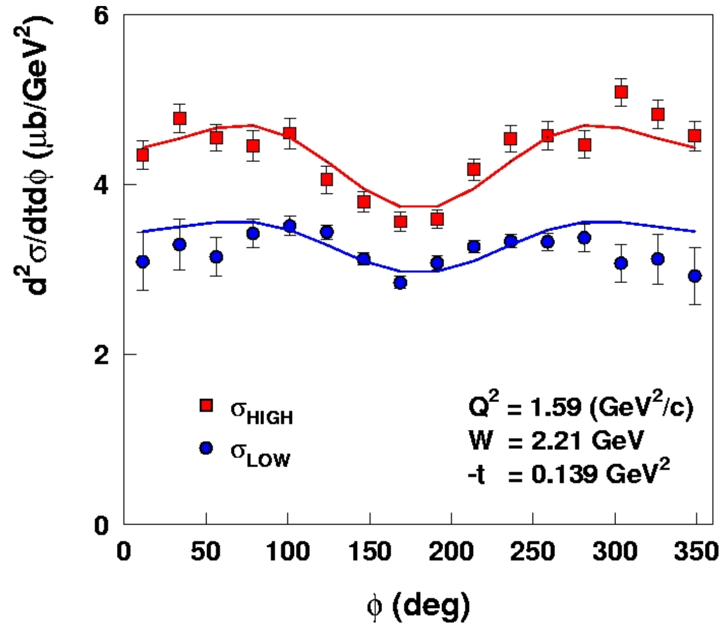
$$2\pi \frac{d\sigma}{dt\,d\phi} = \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_T}{dt} + \sqrt{2\varepsilon(\varepsilon+1)}\frac{d\sigma_{LT}}{dt}\cos\phi + \varepsilon\frac{d\sigma_{TT}}{dt}\cos 2\phi$$

Virtual-photon polarization:

$$\varepsilon = \left(1 + 2\frac{(E_e - E_{e'})^2 + Q^2}{Q^2}\tan^2\frac{\theta_{e'}}{2}\right)^{-1}$$

We have to measure in non-parallel kinematics to access the interference terms (i.e. detected K^+ not parallel to virtual photon momentum, LT and TT must also be determined).

Rosenbluth separation required to isolate σ_L
- Measure cross-section at fixed (W,Q^2,-t) at two beam energies
- Simultaneous fit at two ϵ values to determine σ_L ,σ_T ,and interference tems



Kaon L-T Current Status

Setting	Low Є data with beam energy (GeV)	High Є data with beam energy(GeV)
$Q^2 = 0.50$ $W = 2.40$	0.4515 $E_b = 3.835$ Done	0.6979 $E_b = 4.933$ Done
$Q^2 = 2.1$ $W = 2.95$	0.3099 $E_b = 6.430$ No	0.7864 $E_b = 10.588$ Done
$Q^2 = 3.0$ $W = 2.32$	0.6108 $E_b = 6.430$ No	0.8791 $E_b = 10.588$ Done
$Q^2 = 3.0$ $W = 3.14$	0.4460 $E_b = 8.534$ No	0.6668 $E_b = 10.588$ Done
$Q^2 = 4.4$ $W = 2.74$	0.5259 $E_b = 8.534$ No	0.7148 $E_b = 10.588$ Done
$Q^2 = 5.5$ $W = 3.02$	0.2330 $E_b = 8.534$ No	0.5291 $E_b = 10.588$ Done

Thank you

Summary and outlook

Want to measure the form factor

New experiment in progress

Data taking to be completed soon