Kaon Electromagnetic Form Factor

Presented
by

VIJAY KUMAR

Co- author

G. M. Huber, T. Horn, P. Markowitz, S. J. D. Kay, A. Usman, R. L. Trotta

Scientific Motivation

- What are the form factors for strange mesons?

- How to validate different models of meson structure (form factor)?

- Does the pole of kaon meson dominate the longitudinal cross-section?

- How do the Longitudinal and Transverse cross-sections depend on the Q^2 (i.e. Test for QCD factorization)?

Meson Form Factor

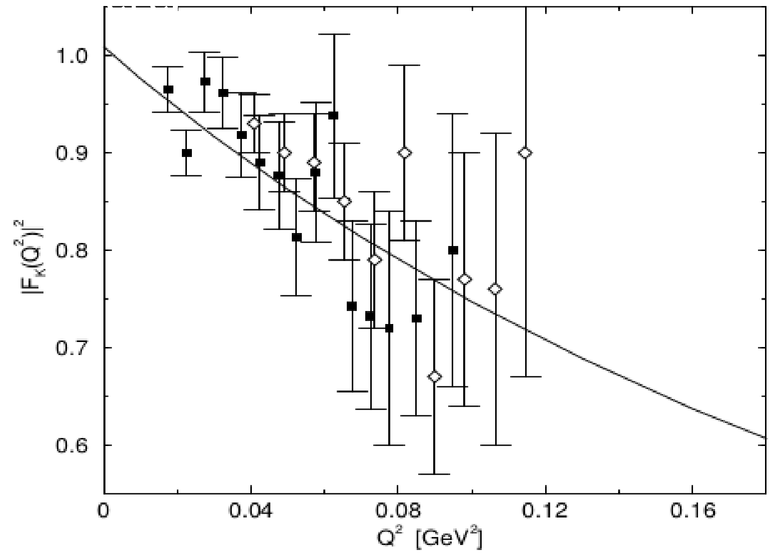
Form factor: Elastic electron hadron scattering, eK → e'K'

$$(p_1 + p_2)\, FK(Q^2) = < K(p_2)\, |J_\mu\, (0)|\, K(p_1) >$$

❖ Electromagnetic F_K, can be calculated exactly at very large momentum transfer Q^2, with perturbative QCD

Form factor

- Low, Q^2
- Moderate, Q^2 → JLab regime



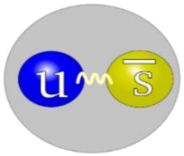
[Amendolia, et al., PL **B178** (1986) 435]

$\sqrt{< r^2_K >}$ = 0.53 ±0.05 fm

Meson Form Factor

For moderate Q^2 , the form factor remains a theoretical challenge

Clearest case for studying the effect in internal structure of hadron when replacing a lighter quark (d) with heavier one (s)

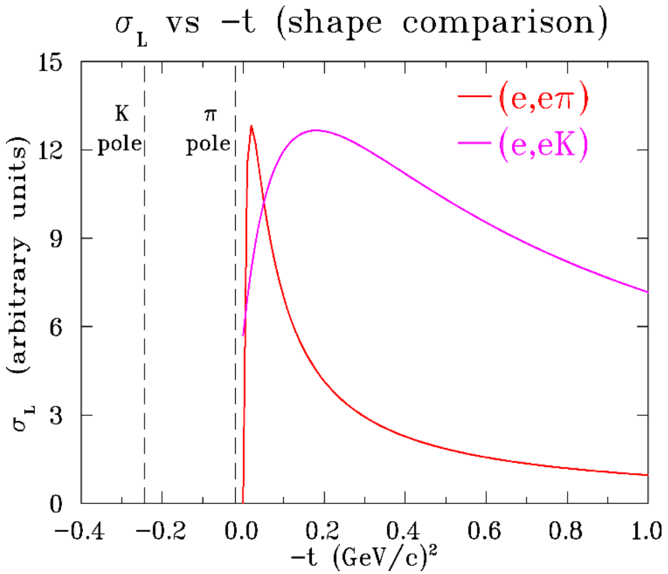


K^+

No "free" Kaon target

<u>Kaon cloud</u> of the proton be used in the same way as the pion to extract kaon form factor via p(e, e' K^+)Λ

The kaon pole is further away from the kinematically allowed region



In the Born term model F_K , appears as

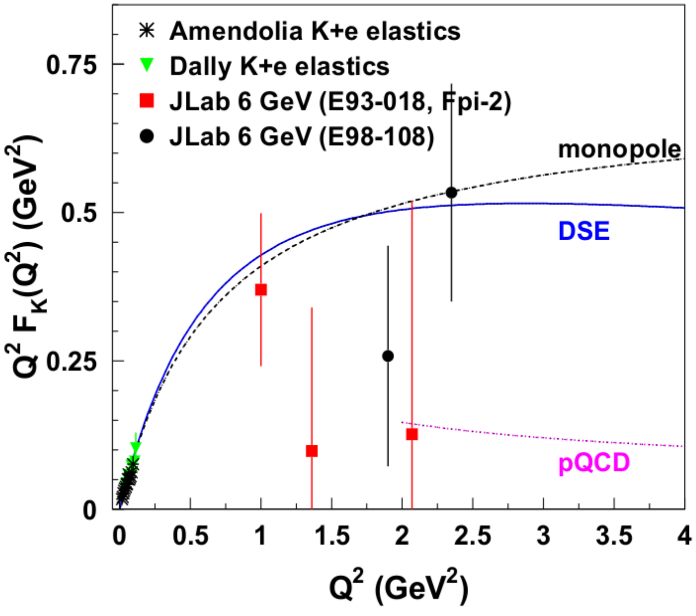
$$\frac{d\sigma_L}{dt} \propto \frac{-tQ^2}{(t-m_K^2)} \, g_{K\Lambda N}^2(t) \, F_K^2(Q^2,t)$$

Experimental Determination of Form Factor

- Model is required to extract the Form factor from longitudinal cross-section
- First measurement of F_K well above the resonance region
- Measure form factor to Q^2=3 GeV^2 with good overlap with elastic scattering data.
- Previous JLab studies lead us to expect that we can extract K^+ form factor from $-t$<0.8 GeV^2 σ_L data

VGL Regge model

$$F_K(Q^2) = \frac{1}{1 + \frac{Q^2}{\Lambda_K^{\,2}}}$$



For VGL/Regge calculation, assume Λ^2_K=0.67 GeV^2, and Λ^2_{K*}=1.5 GeV^2,

Reaction and Scattering Planes

E12-09-011, Kaon L-T

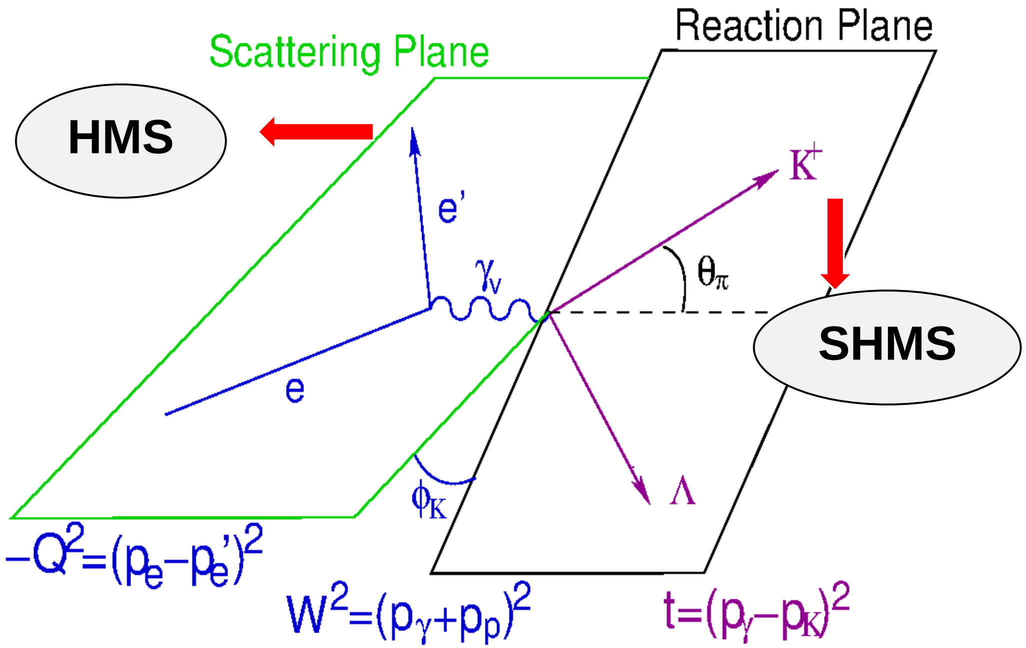
Completely exclusive reaction

$$e^- + p \rightarrow e'^- + K^+ + \Sigma^0$$

$M_{\Sigma 0}$ = 1192.64 MeV²/c²

$$e^- + p \rightarrow e'^- + K^+ + \Lambda$$

M_{Λ} = 1115.68MeV²/c²



Missing mass equation

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

Rosenbluth Separation Technique

Rosenbluth separation technique is required;

Measurement of cross-section at least two values of ε, while fixing the values of W, Q^2 and –t

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

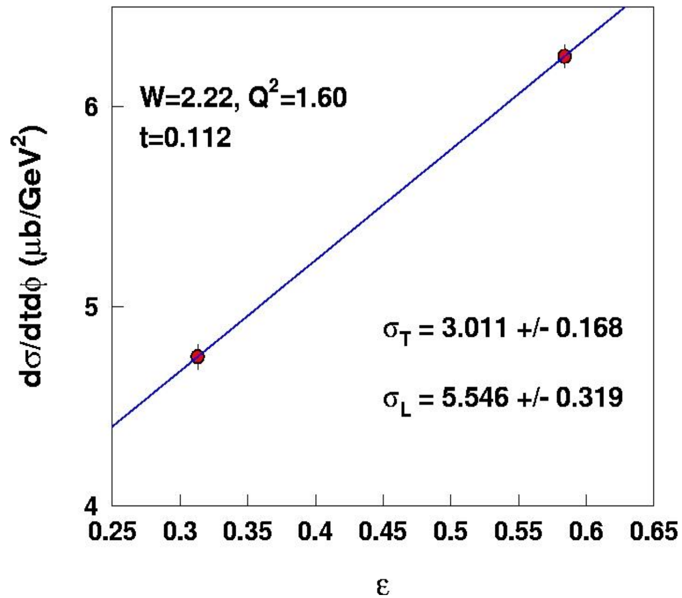
Virtual-photon polarization:

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

L/T Separation example

❖ For parallel kinematics

$$2\pi\frac{d\sigma}{dt\,d\phi}=\varepsilon\frac{d\sigma_L}{dt}+\frac{d\sigma_T}{dt}$$



Kaon LT Data Collected

E12-09-011 experiment ran in Hall C at Jefferson Lab over the fall 2018 and spring 2019

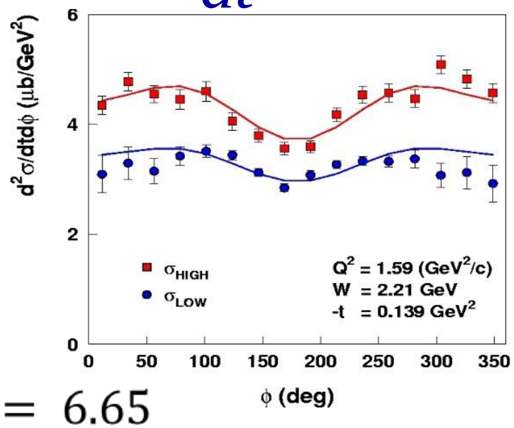
E (GeV)	Q^2 (GeV^2)	W (GeV)	$x = Q^2 / 2m_p (E - E')$	$\varepsilon_{High} / \varepsilon_{Low}$
10.6/8.2	5.5	3.02	0.40	0.53/0.18
10.6/8.2	4.4	2.74	0.40	0.72/0.48
10.6/8.2	3.0	3.14	0.25	0.67/0.39
10.6/6.2	3.0	2.32	0.40	0.88/0.57
10.6/6.2	2.115	2.95	0.21	0.79/0.25
4.9/3.8	0.5	2.40	0.09	0.70/0.45

Rosenbluth Separation Technique

❖ For non parallel kinematics

The interference terms (LT & TT) will be separated out from the non parallel data (i.e. detected K^+ not parallel to virtual photon momentum)

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



Low epsilon:

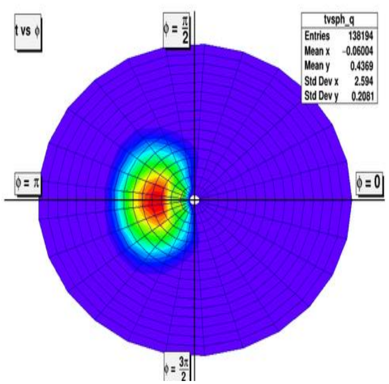
$E_b = 10.6\ GeV \qquad Q^2 = 3.0\ GeV^2 \qquad W = 3.14\ GeV$

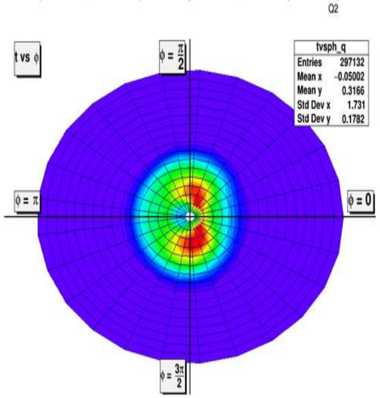
$x = 0.25$

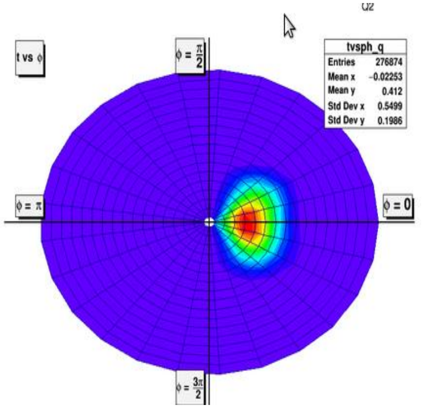
$\boldsymbol{\theta}_{SHMS} = 12.42$ (Left)

$\boldsymbol{\theta}_{SHMS} = 9.42$ (Center)

$\boldsymbol{\theta}_{SHMS} = 6.65$ (Right)







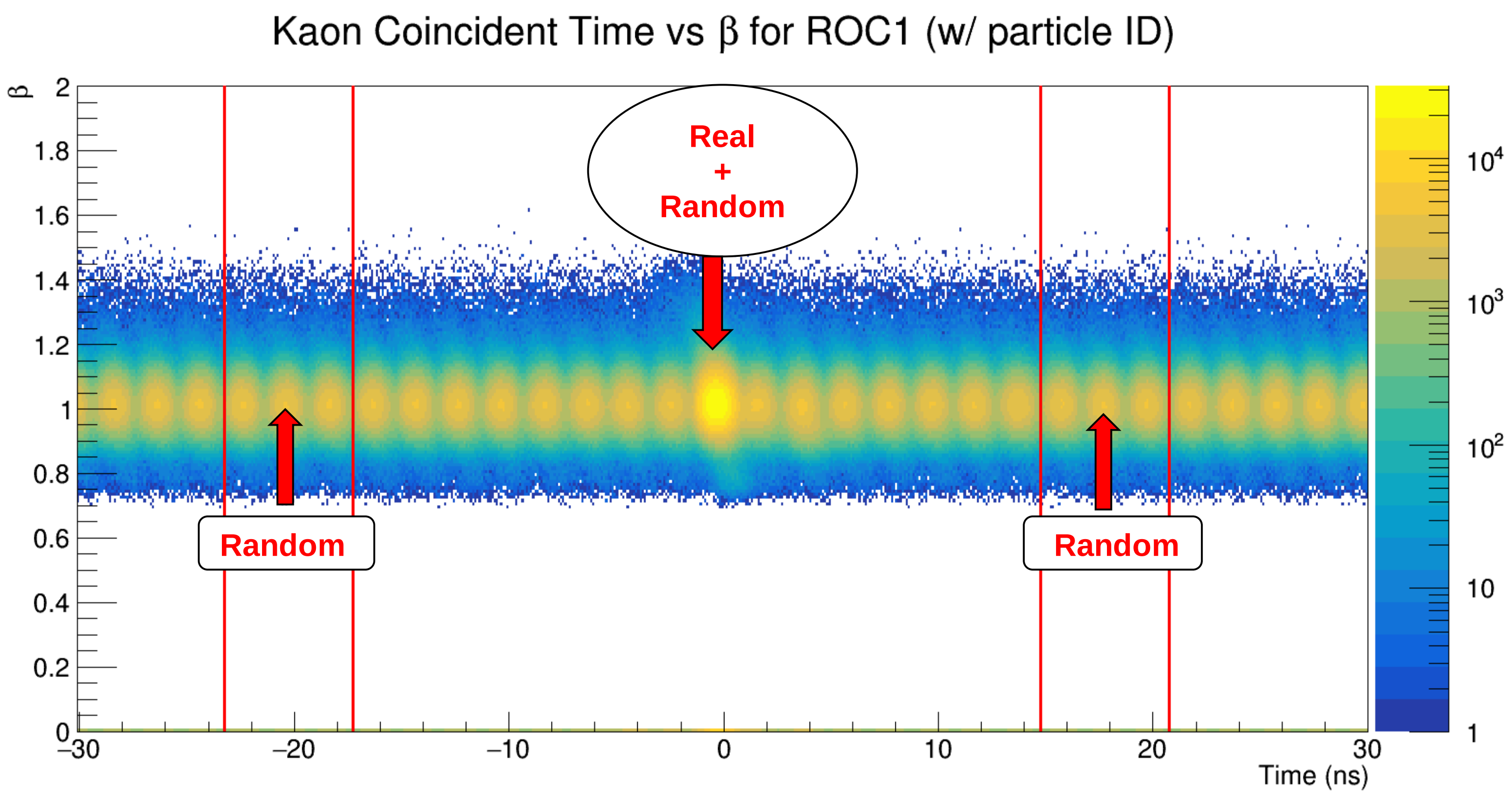
Subtraction of Random Coincidence

$E_b = 4.9\ GeV$ $Q^2 = 0.5\ GeV^2$

$w = 2.40\ GeV$ $x = 0.09$

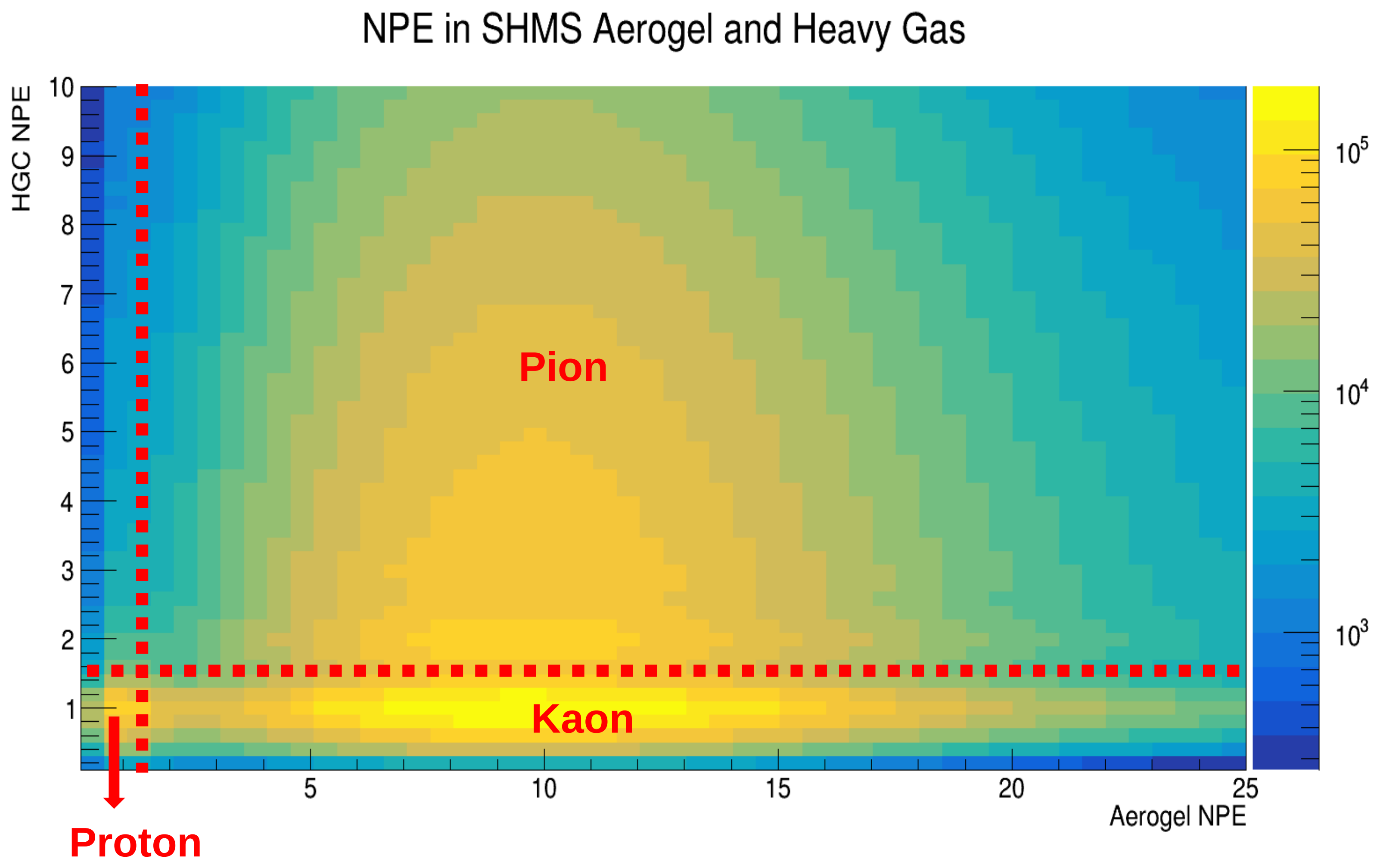
$\boldsymbol{\theta}_{SHMS} = 6.0\ (right)$ $I = 16$ uA

$t_{coin} = t_{HMS} - t_{SHMS}$



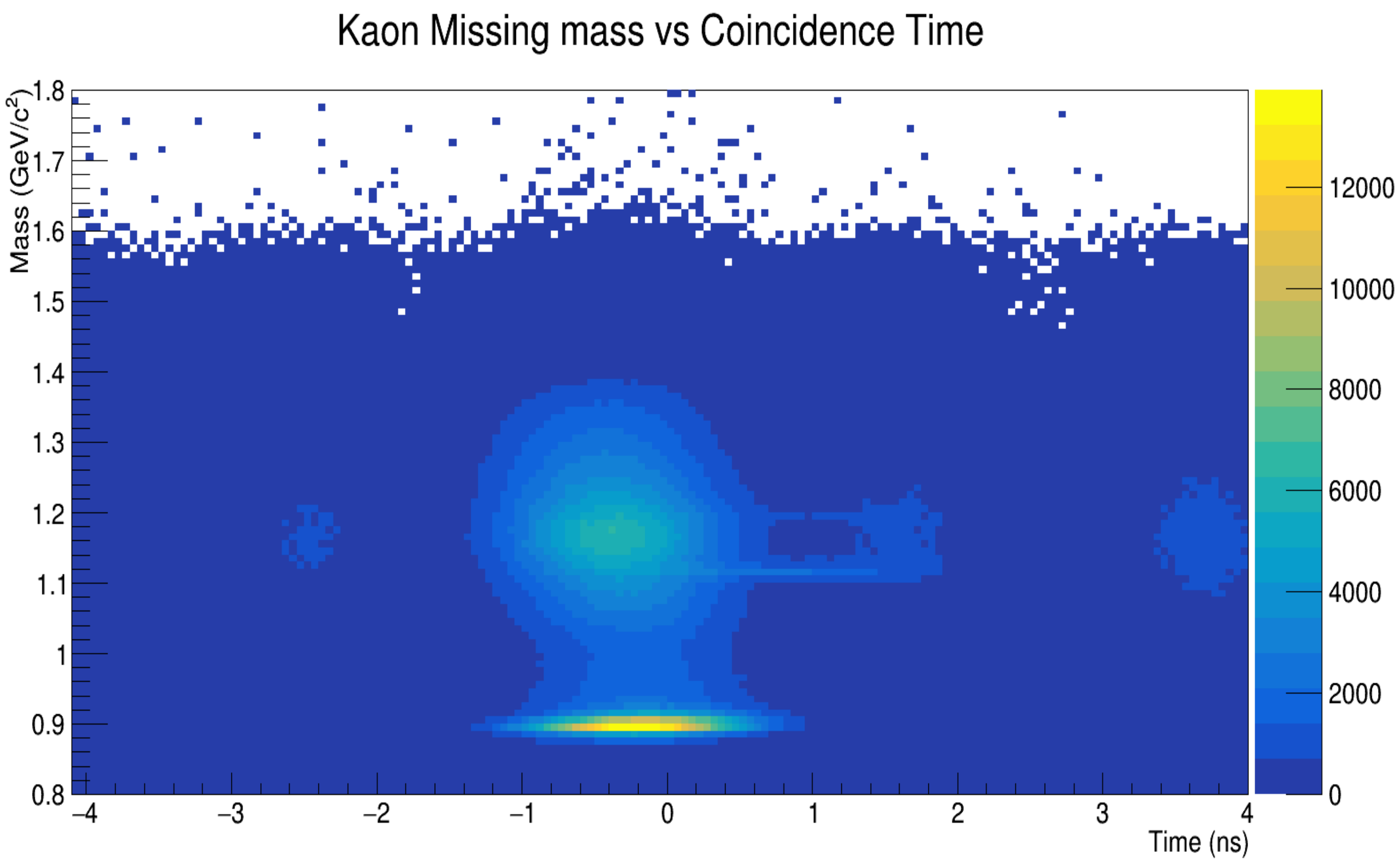
Particle Identification (PID)

The selection of kaon is done using Heavy-Gas Cerenkov and Aerogel Cerenkov detectors



Missing Mass Reconstruction

Missing mass $$M_{miss} = [(E_b + m_p - E_{e'} - E_{K^+})^2 - (\overrightarrow{P_e} - \overrightarrow{p_{e'}} - \overrightarrow{p_{K^+}})^2]^{\frac{1}{2}}$$



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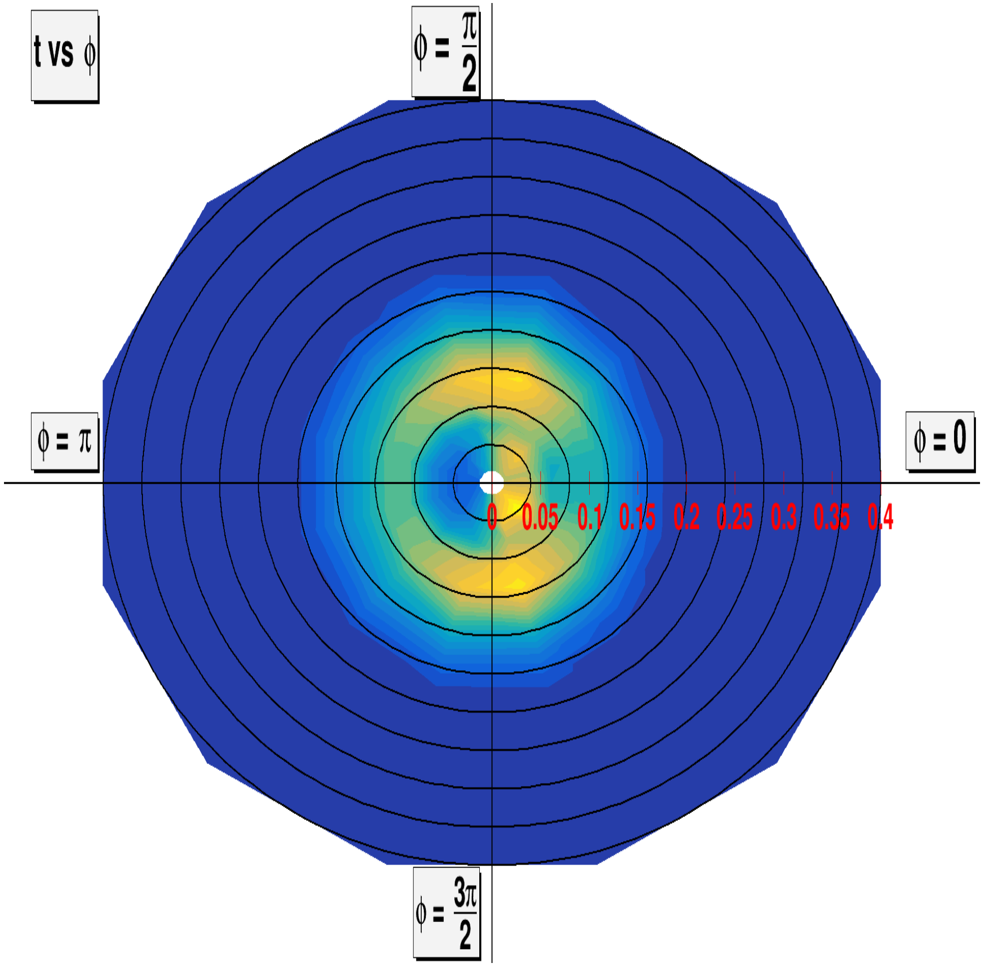

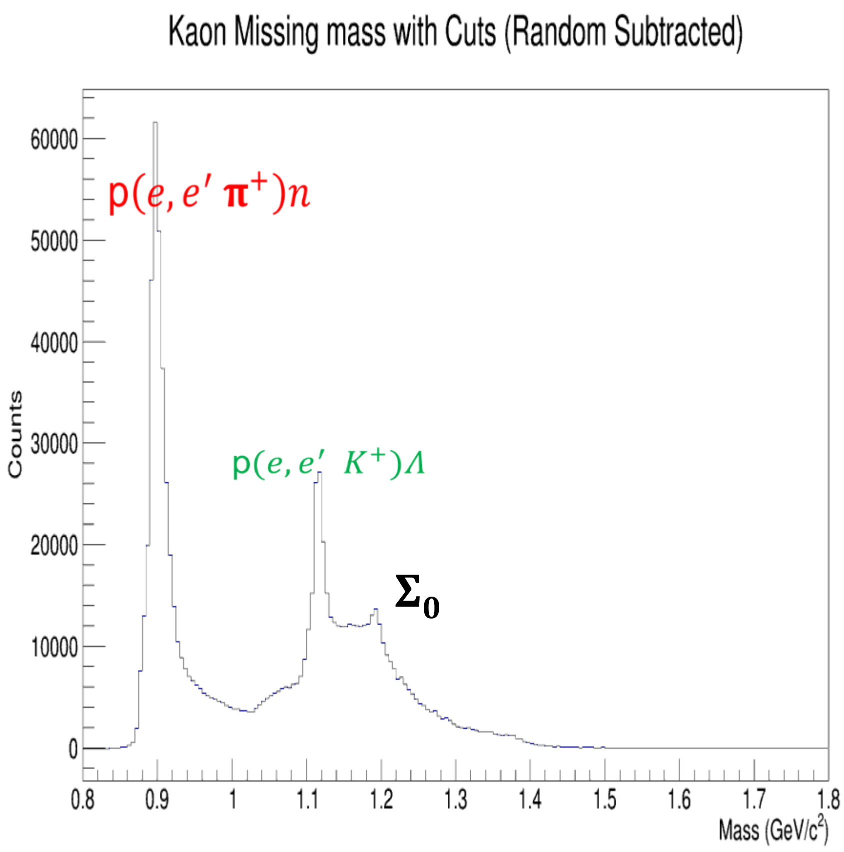

Future Perspective

- We are preparing for comprehensive particle identification (PID) analysis.
- Systematic studies on cryotarget boiling, deadtime, luminosity dependence, e-p elastic scattering to determine the reliability of data.
- Very precise measurement (separation) of the longitudinal cross-section.
- Checking that data will allow for the extraction of form factor of kaon.
- Study for the QCD factorization.

Thank you

Thanks to CINP for travel award