B01公募研究

HypTPCを用いた少数系K中間子クラスター K^-pp, K^-pppの研究

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2021/06/14, 19

第6回クラスター階層領域研究会

Introduction

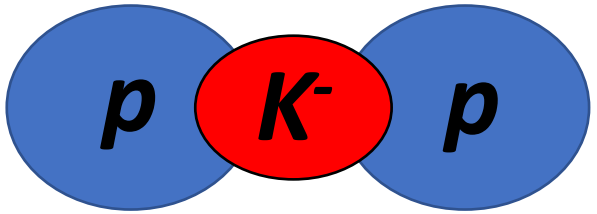
Λ(1405)

- Λ(1405) is assigned as an excited three quark baryon (u, d, s) with I = 0 and $J^P = (1/2)^-$ in the constituent quark model.
- However, the observed mass is smaller about 80 MeV than the theoretical prediction.

- $\bar{K}N$ bound state(?) two pole state(?)

- Many body system called as Kaonic nuclei is expected.
  Ex: K^-pp, K^-K^-pp, etc…

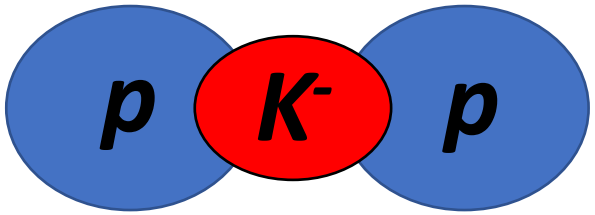
K^-pp bound state



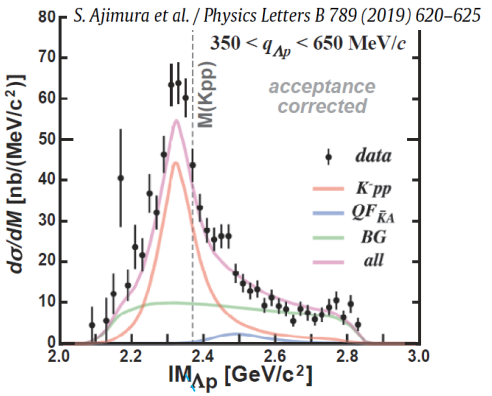
- It is expected to be the simplest kaonic nuclei.
- $\bar{K}NN$, Total charge:+1, I = ½, $J^P = 0^-$.
- The bound state was expected due to the $\bar{K}$N strong interaction, which is strongly attractive in I = 0.

- It has a rich information such as the $\bar{K}$N strong interaction in sub-threshold region and behavior of Λ(1405) in many body system.
- It makes high density (?)

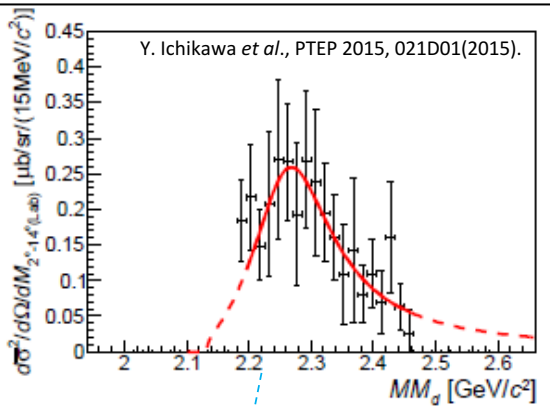
K^-pp



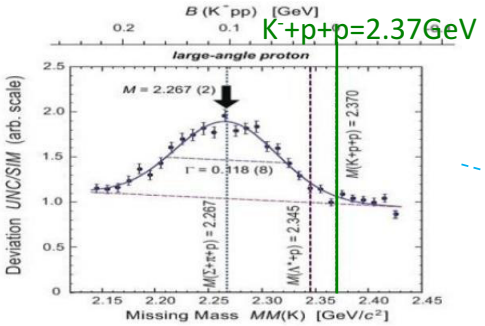
J-PARC E15: $^3He(K^-, \Lambda p)n$



J-PARC E27: $d(\pi^+, K^+)\Sigma^0 p$

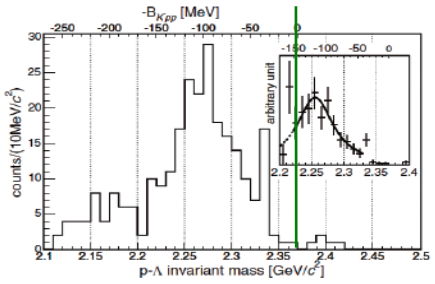


DISTO: $p(p, K^+)\Lambda p$

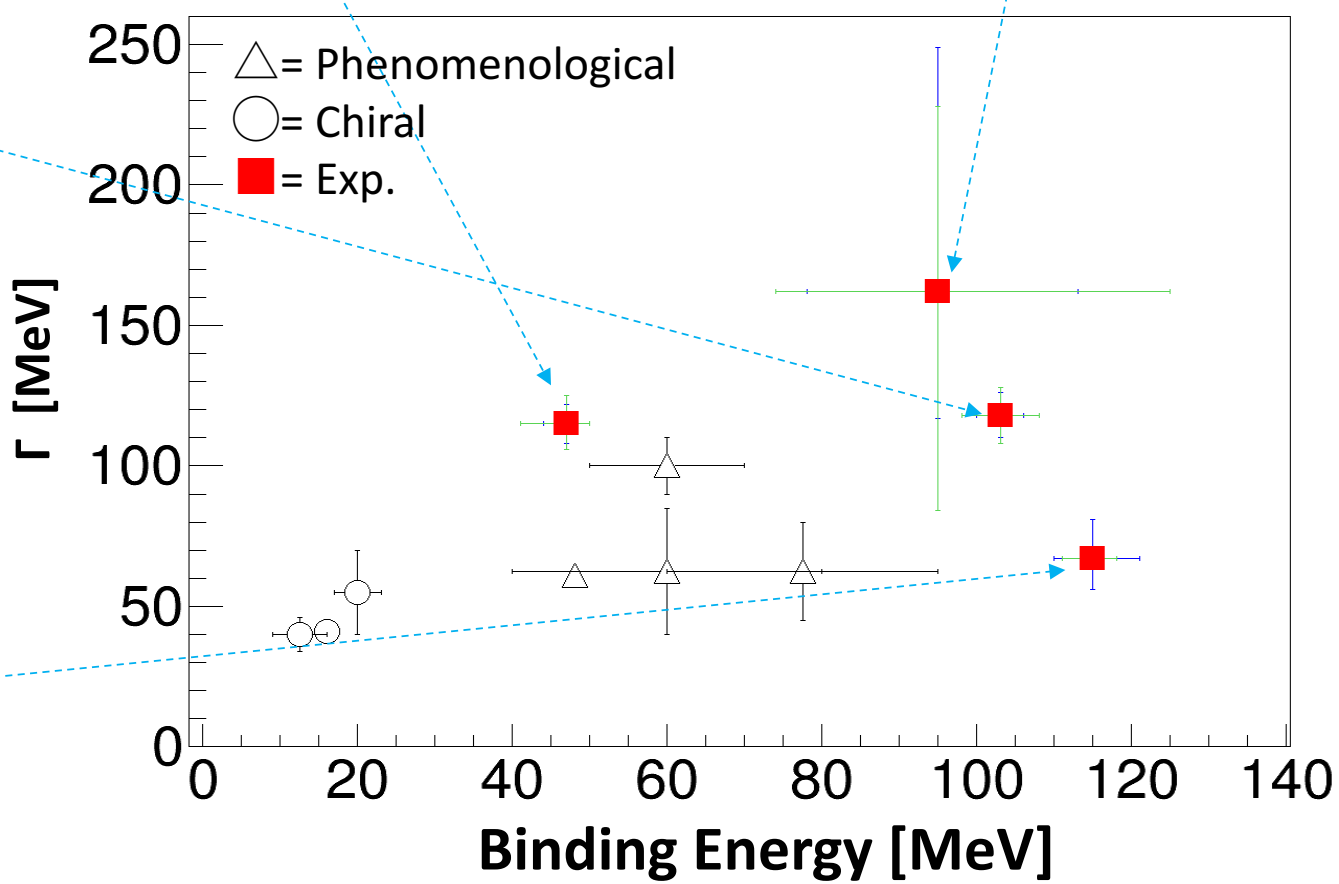


T.Yamazaki *et al.*, PRL 104, 132502 (2010)

FINUDA: stopped K^-



M.Agnello *et al.*, PRL 94, 212303 (2005)



Structure of K^-pp

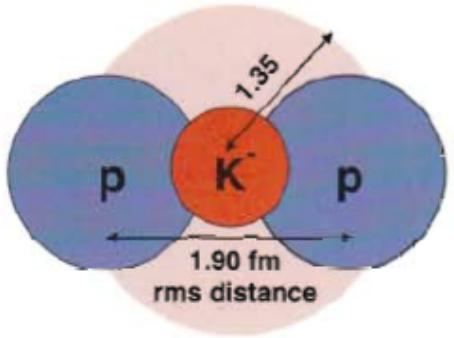
(Theoretical study)

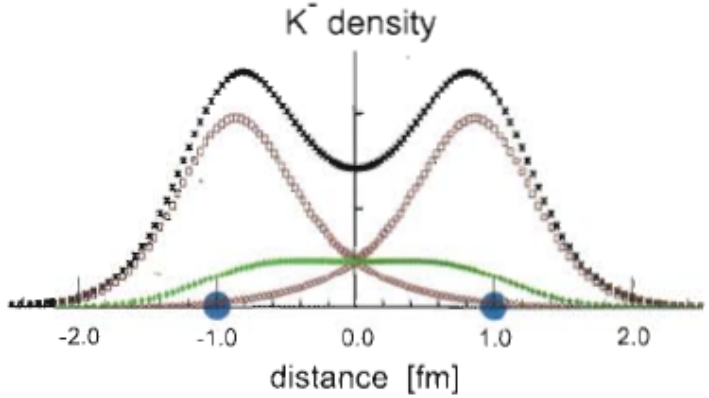
赤石さんのスライドより

2002

Phys. Lett. B **535** (2002) 70

K^-–(pp)



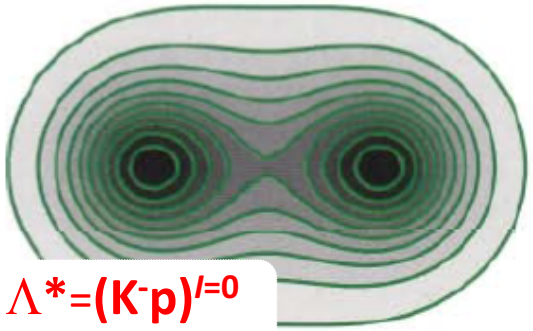


2007

Phys. Rev. C **76** (2007) 045201

(K^-p)–p

Λ*-p structure

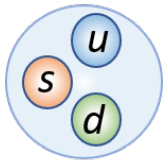


Λ*=(K^-p)$^{I=0}$ unit

with a few % covalent part

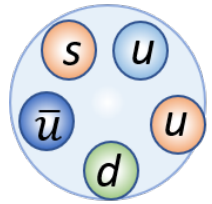
Hierarchical structure

Λ(1405)

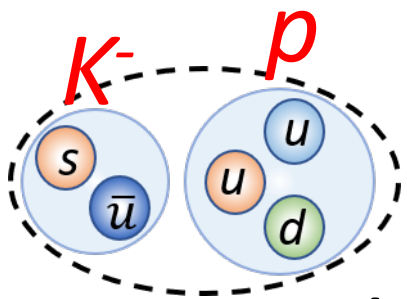


3 quarks

Λ(1405) = Λ*



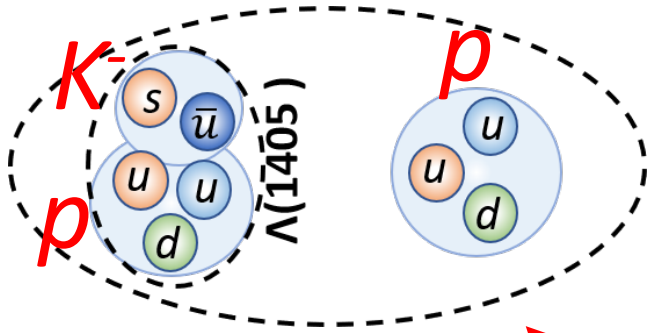
5 quarks



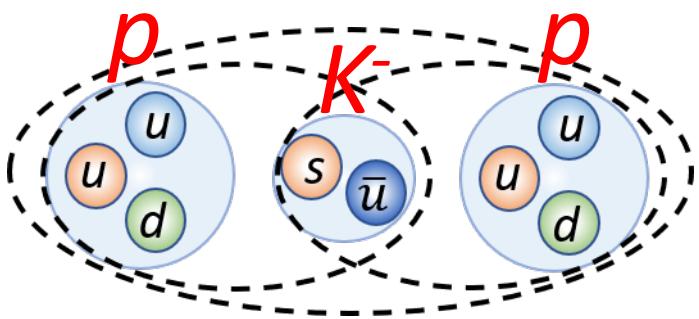
Meson – Baryon molecule

Λ(1405) = $\bar{K}N$ + (πΣ +…)

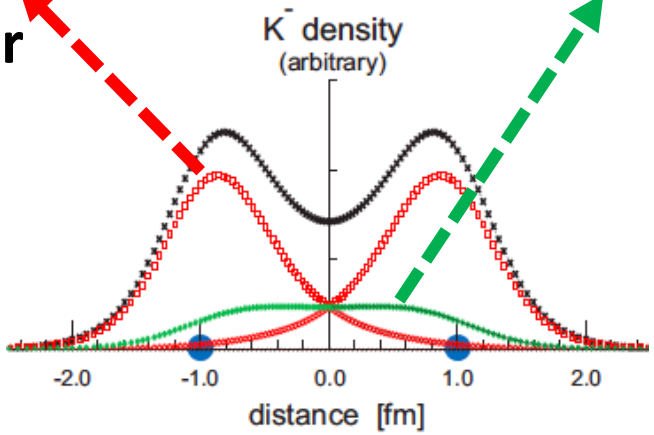
K⁻pp



Λ(1405)-Cluster

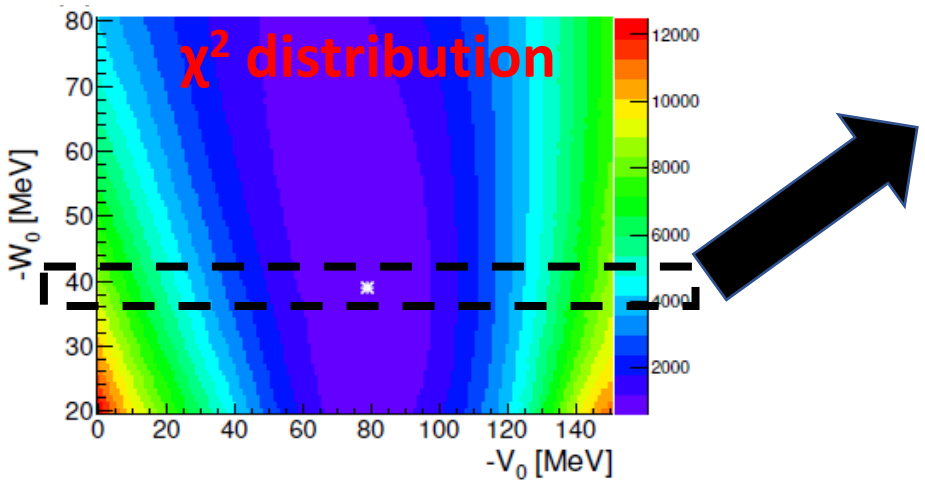


Field picture

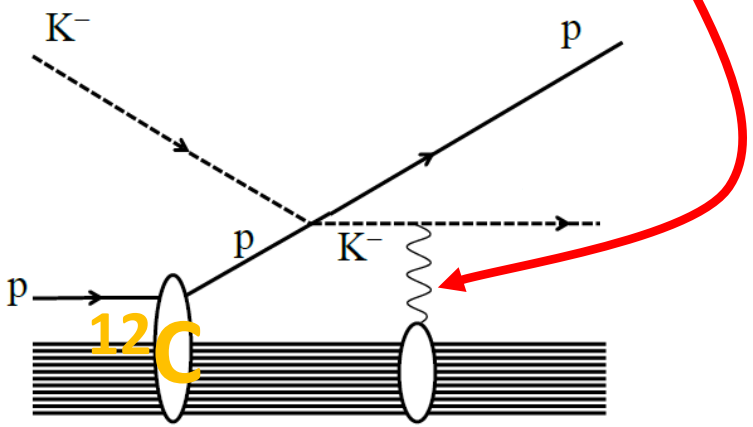


J-PARC E05byproduct: $^{12}C(K^-, p)$

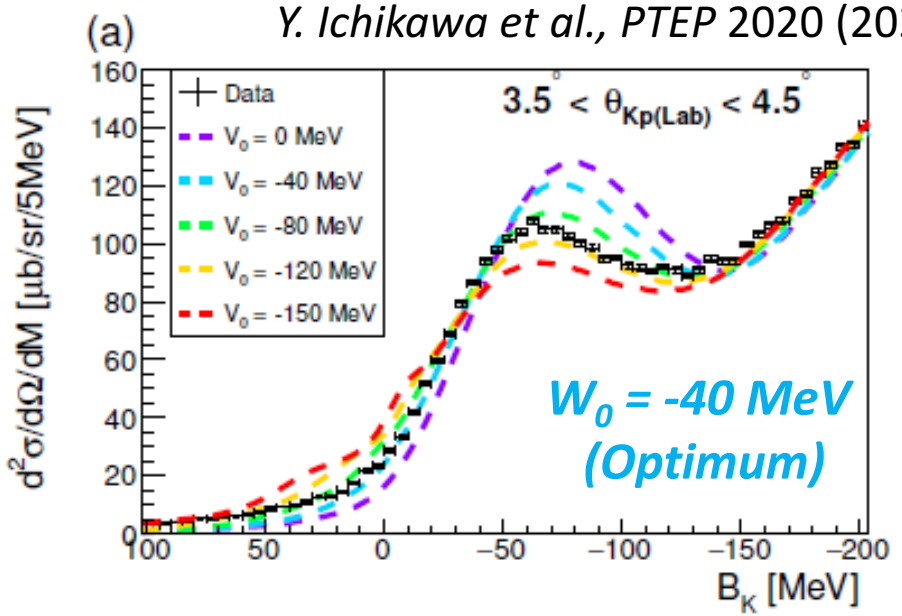
Optimum: (V_0, W_0) = (-80, -40) MeV!
Corresponding to shallow potential

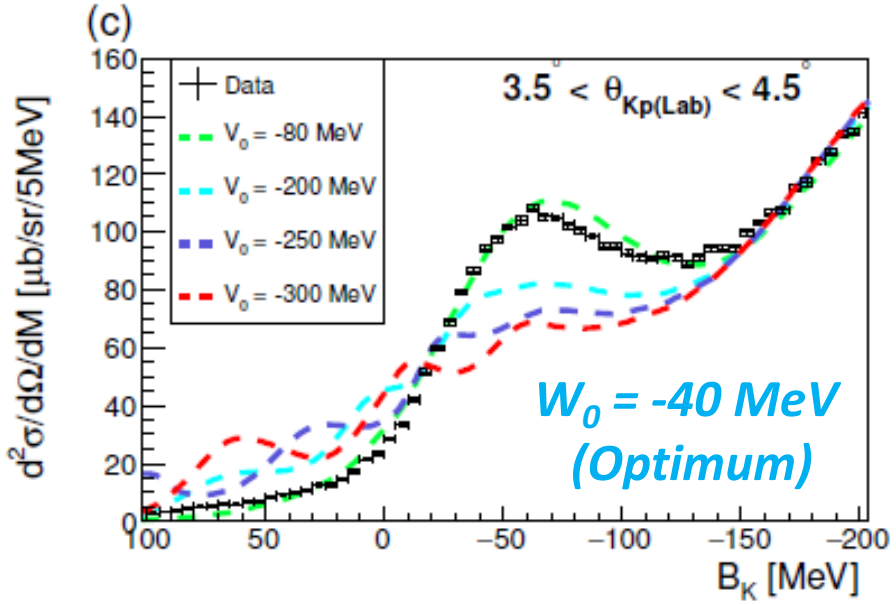


$$U(r,E) = (V_0 + iW_0 f_{\mathrm{phase}}(E))\frac{\rho(r)}{\rho(0)} \ ,$$



Y. Ichikawa et al., PTEP 2020 (2020) 12, 123D01

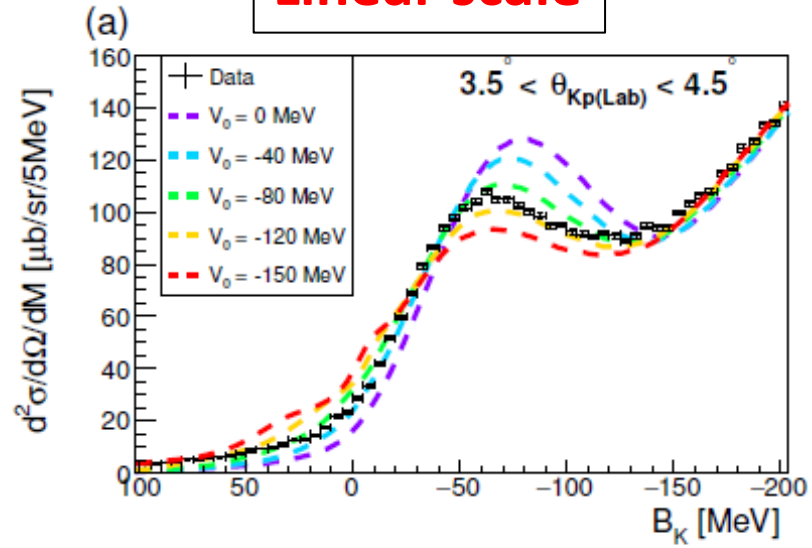




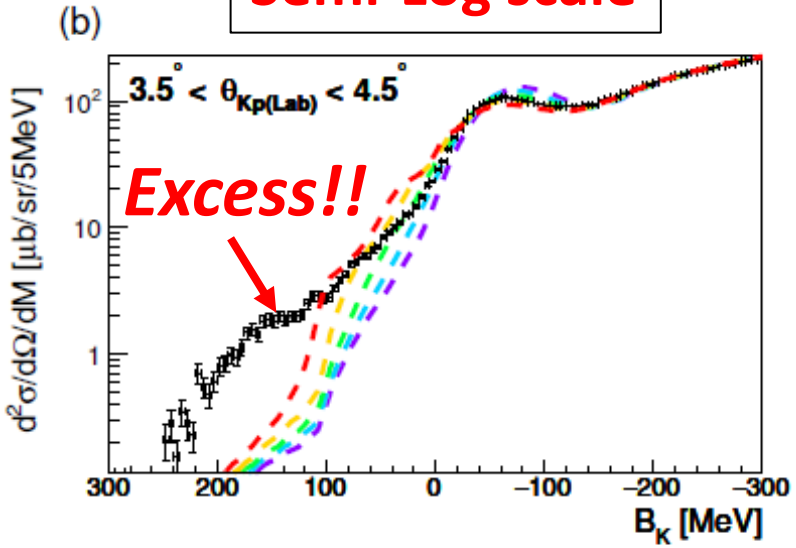
Event Excess

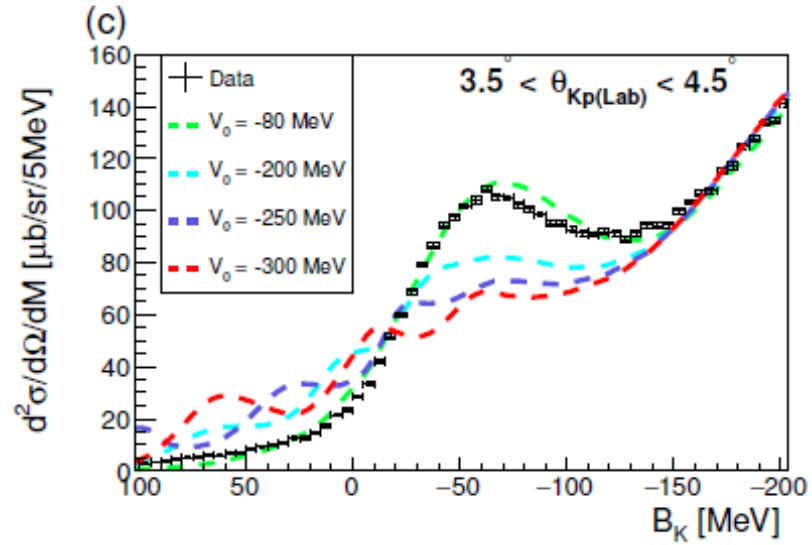
Y. Ichikawa et al., PTEP 2020 (2020) 12, 123D01

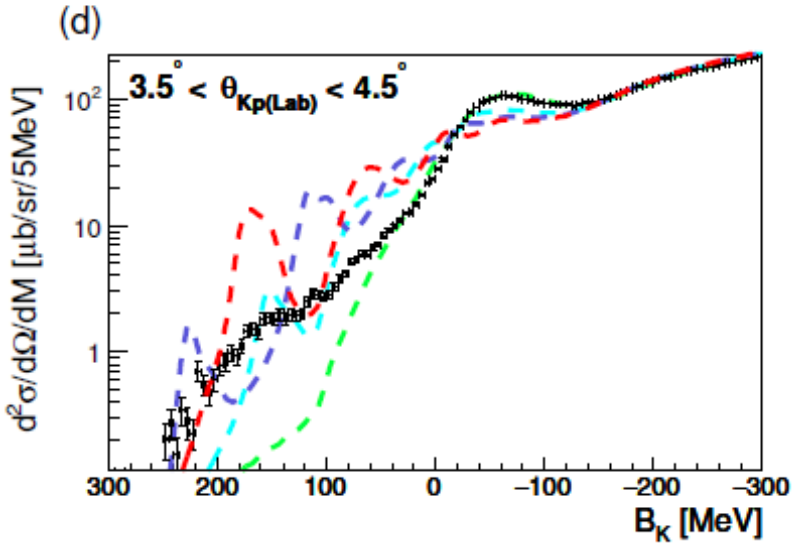
Linear scale



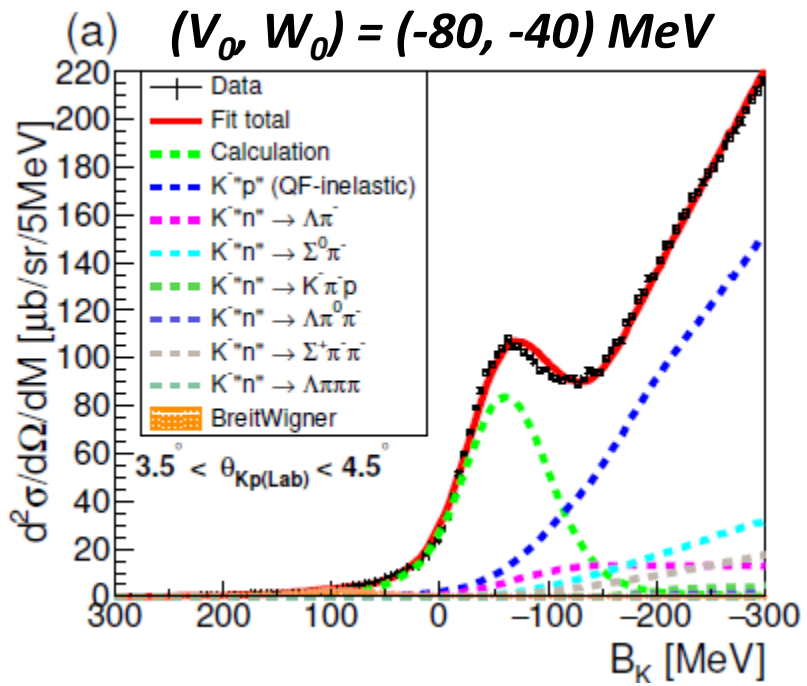
Semi-Log scale

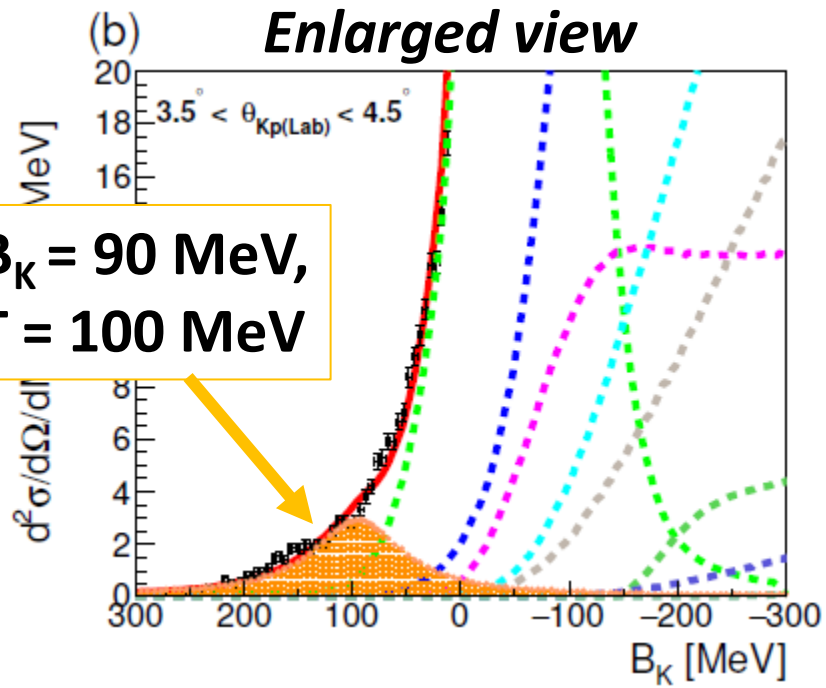


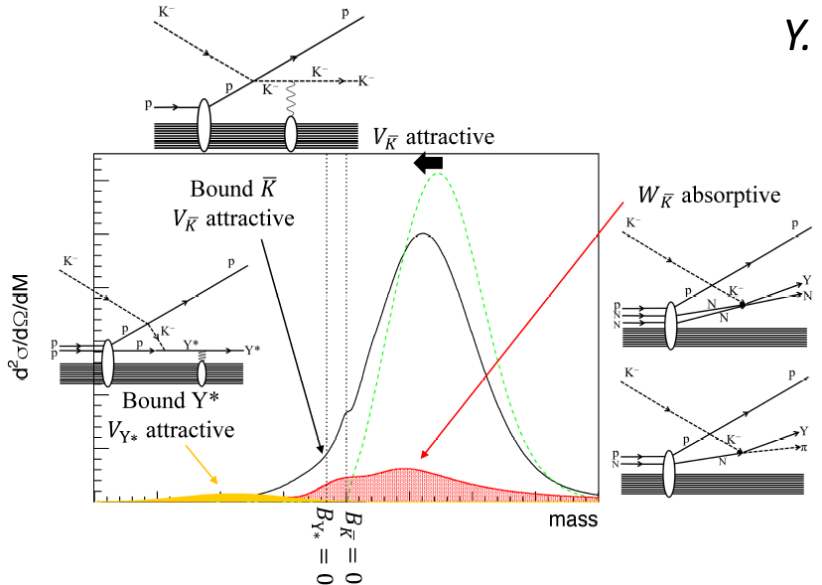




Event Excess: Fitted by BW (Y-nucleus?)*





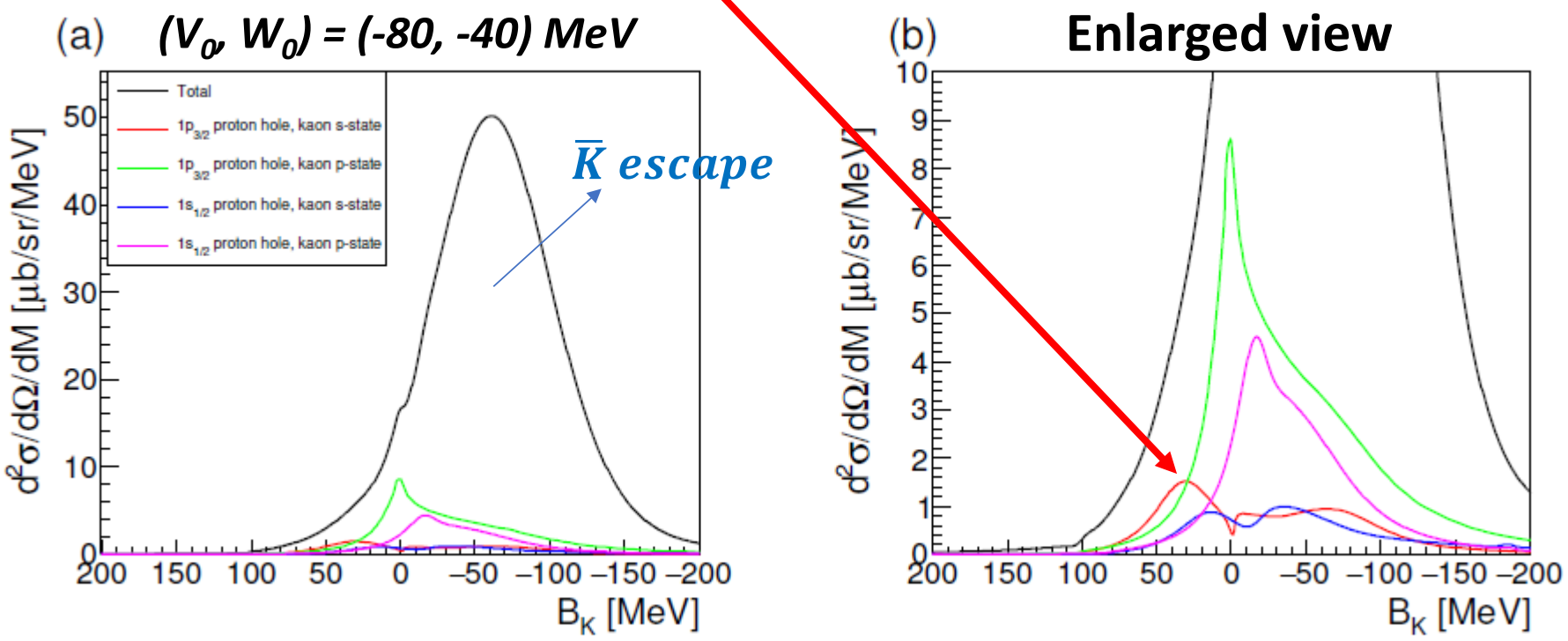


Y. Ichikawa et al., PTEP 2020 (2020) 12, 123D01

Kaonic nuclear state (Decomposed theoretical spectrum)

proton-hole: $1p_{3/2}$, $\bar{K}$: s-state

Kaonic nuclear state: B_K = 31 MeV, Γ = 53 MeV



Discussion: Relationship with kaonic-atom X-rays

$V_K^{(1)}$: 1N absorption term
derived by IHW NLO
chiral K^-N scattering amplitude

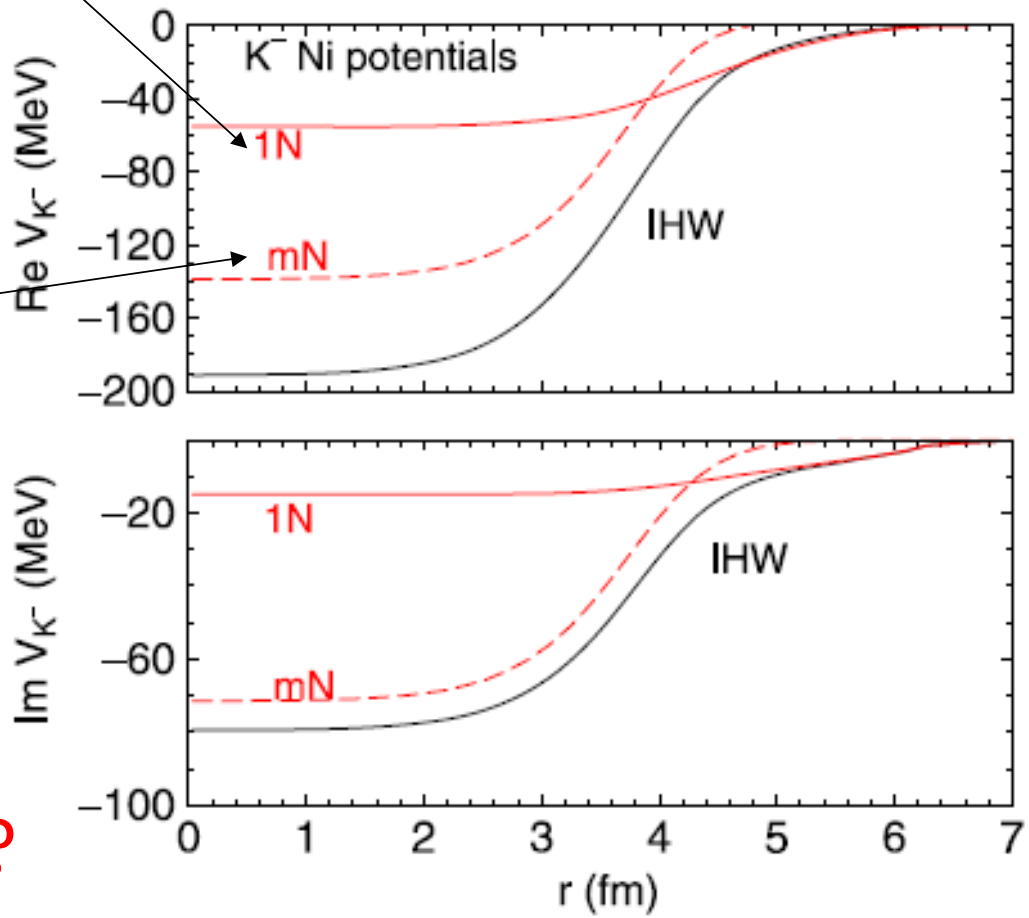
$V_K^{(2)}$: mN absorption term
Phenomenological potential
(fitted by X-ray data)

For the deep $V_K^{(2)}$ potential,
Y* doorway process as
K^-"p"→Y*, Y*"N"→ YN
should play an important role!!

$V_K^{(2)}$ corresponding to V_{Y^*}?

E. Friedman, A. Gal / Nuclear Physics A 899 (2013) 60–75

$$V_{K^-} = V_{K^-}^{(1)} + V_{K^-}^{(2)}:$$

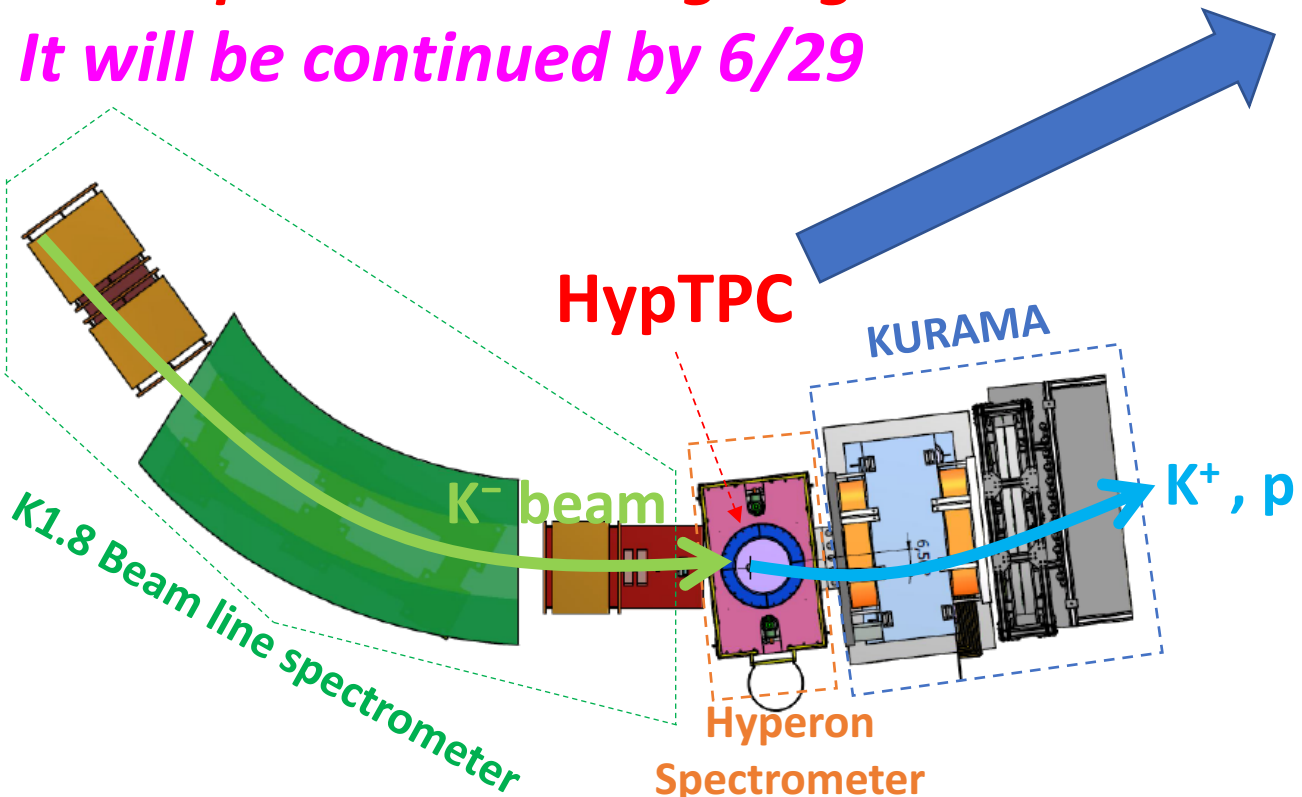


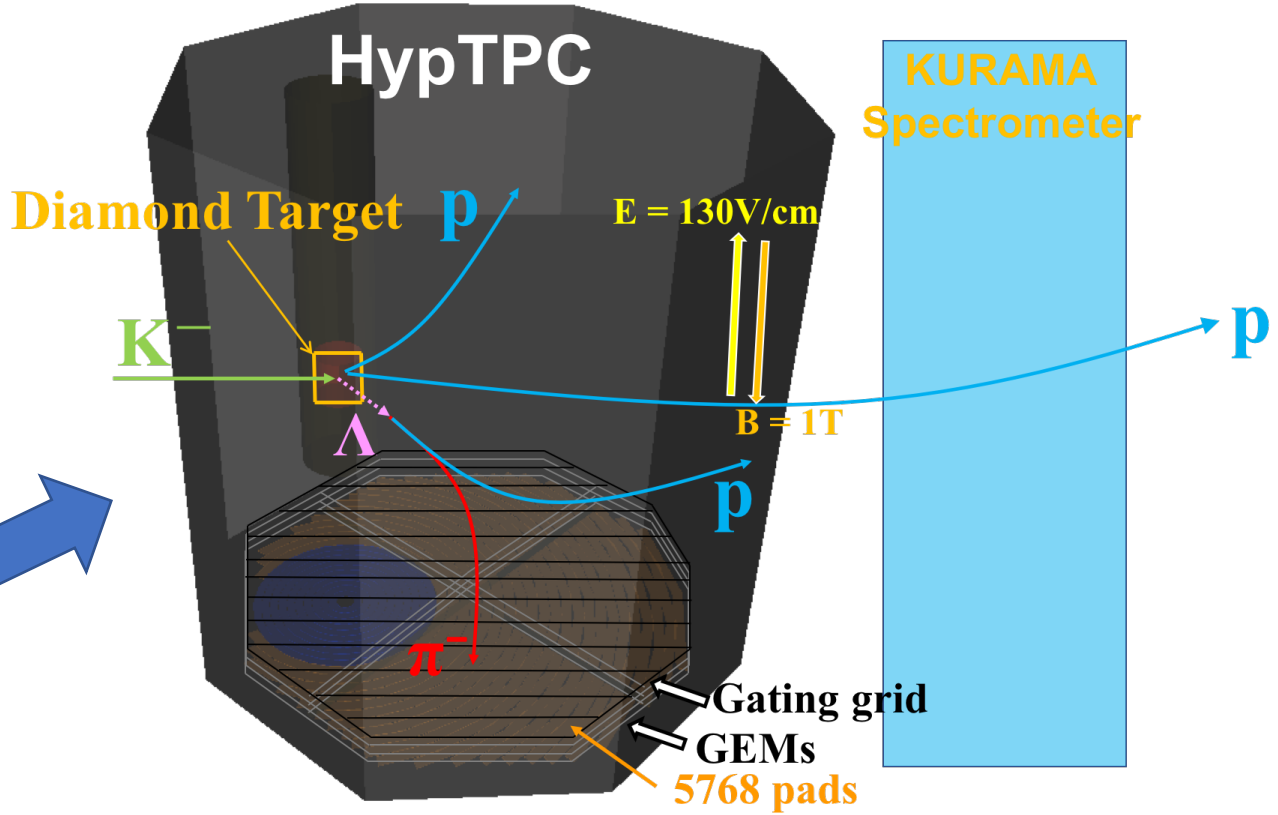
Study of K-cluster by using HypTPC (E42 byproducts)

Beyond E05 = E42 (H-dibaryon search)

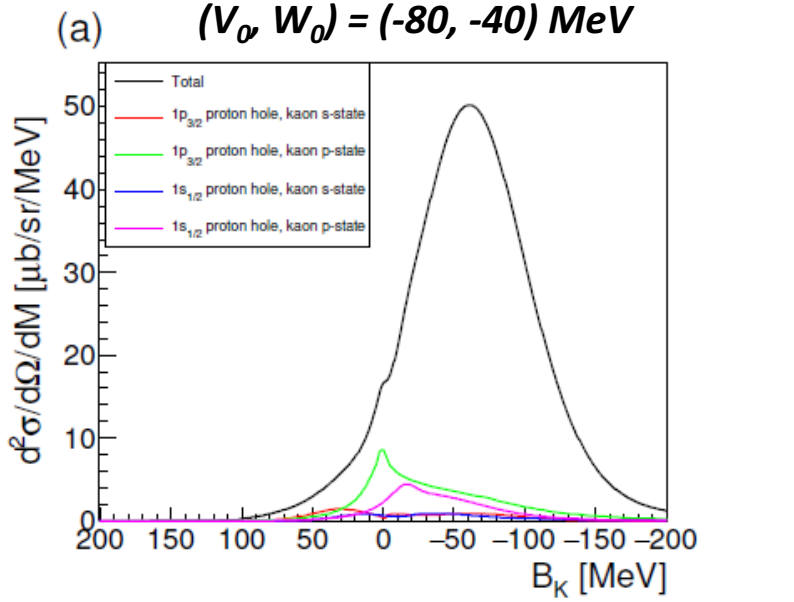
Outgoing proton: KURAMA
Decay particle: HypTPC
  Λp: measured by p, π^-, p
  Σπp: identified by $\pi^{\pm}\pi^{\pm}$p

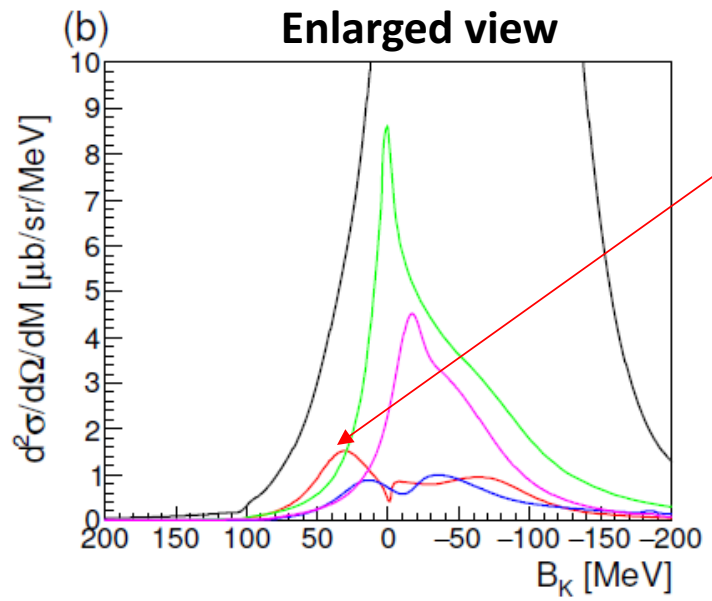
E42 experiment is on-going !!
It will be continued by 6/29



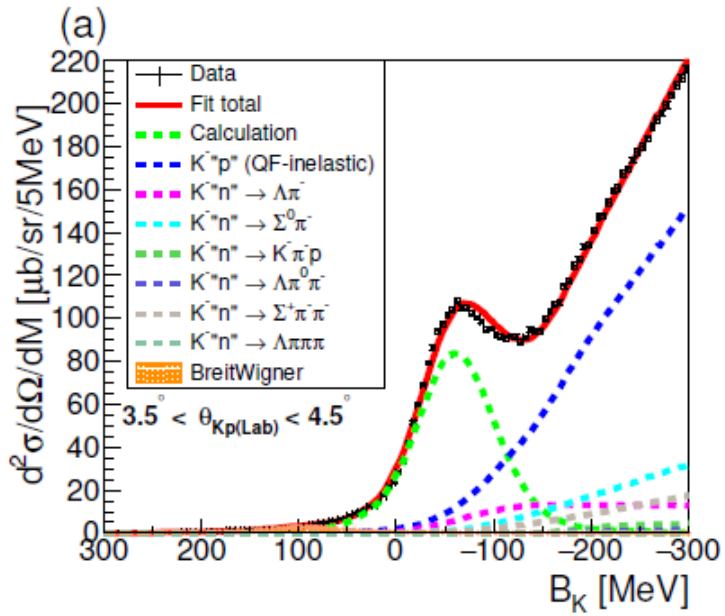


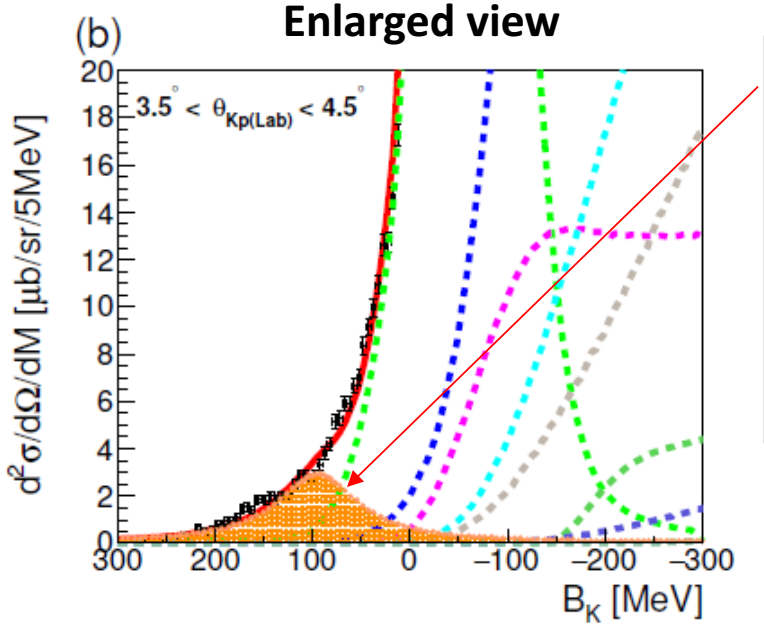
Exclusive measurement (Motivation)



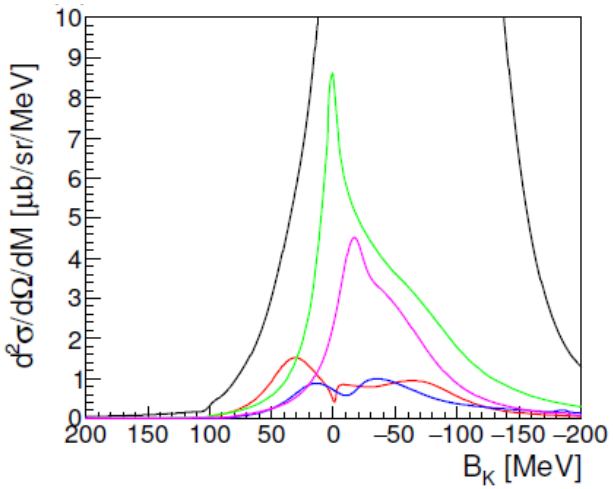


Motivation:
To observe the 1s state as a distinct peak!
Method:
$^{12}C(K^-, p)\Sigma\pi p$ measurement(?)





Motivation:
To observe the excess as a distinct peak!
Method:
$^{12}C(K^-, p)\Lambda p$ measurement(?)

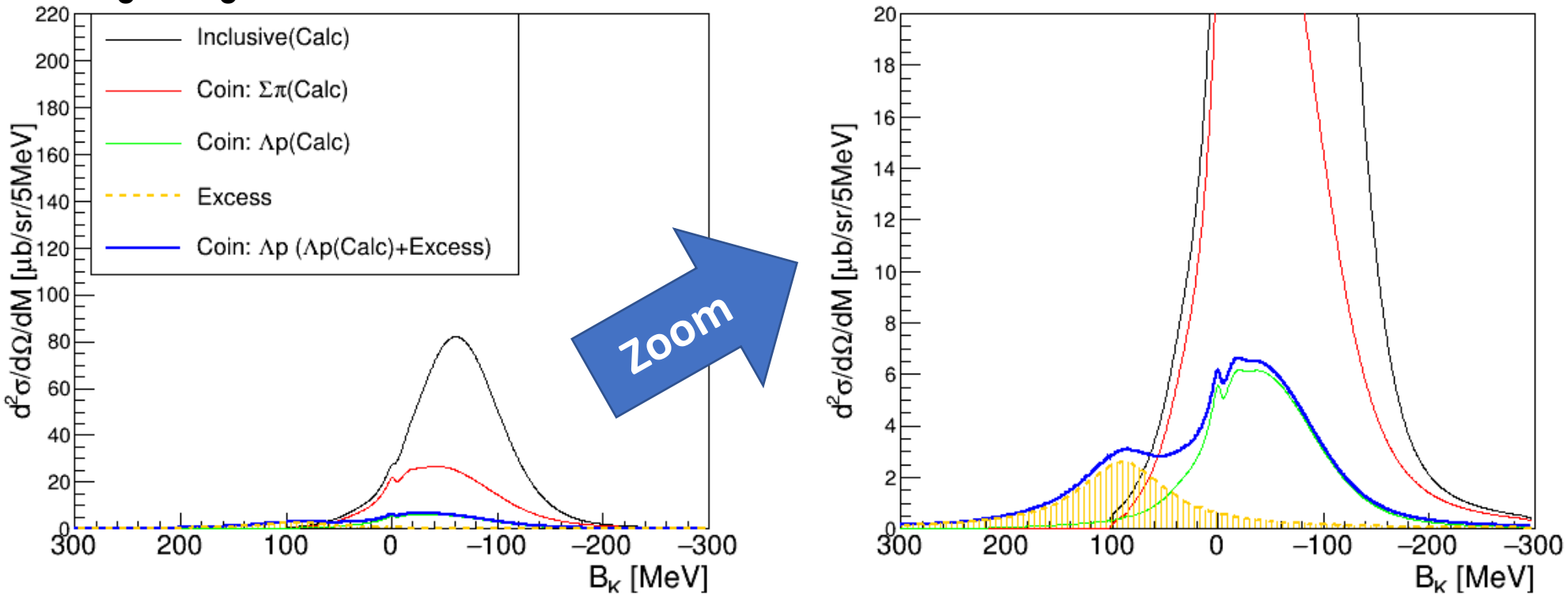


Conversion spectrum

Difficult to see the 1s peak by One body abs. (^{12}C(K$^-$, p)Σπ).
The one of the possible channel is ^{12}C(K$^-$, p)Σπp.

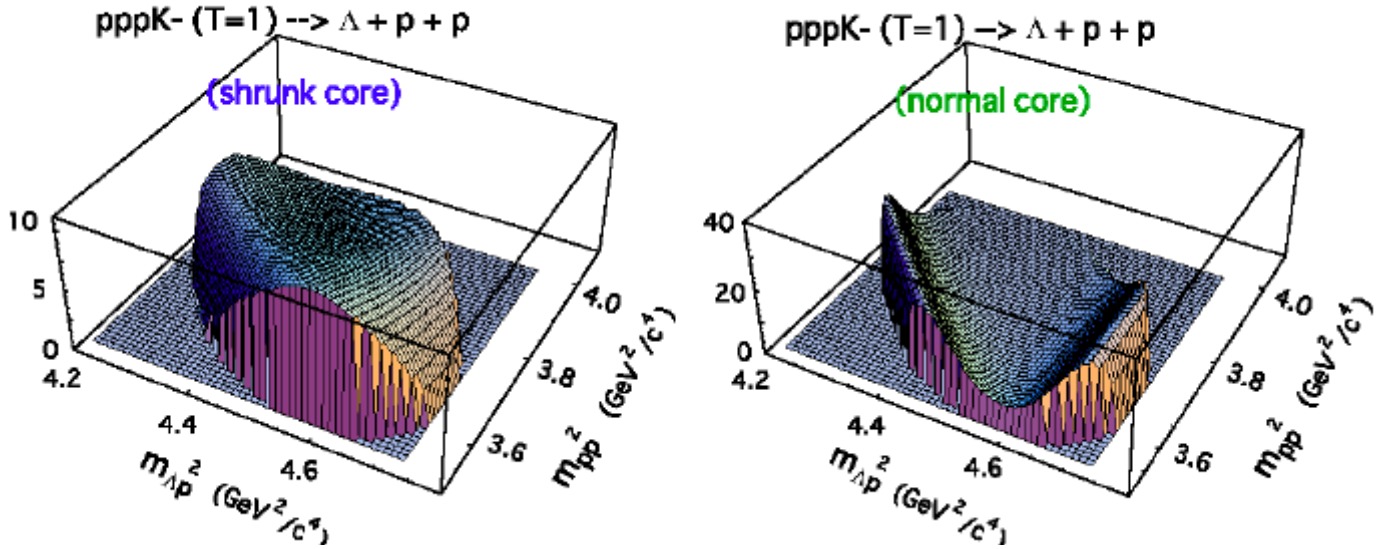
^{12}C(K$^-$, p)Λp probability is low.
→ Possibility to see the Y*-nucleus state.

(V_0, W_0) = (-80, -40) MeV ***Calculated by J. Yamagata-Sekihara.***

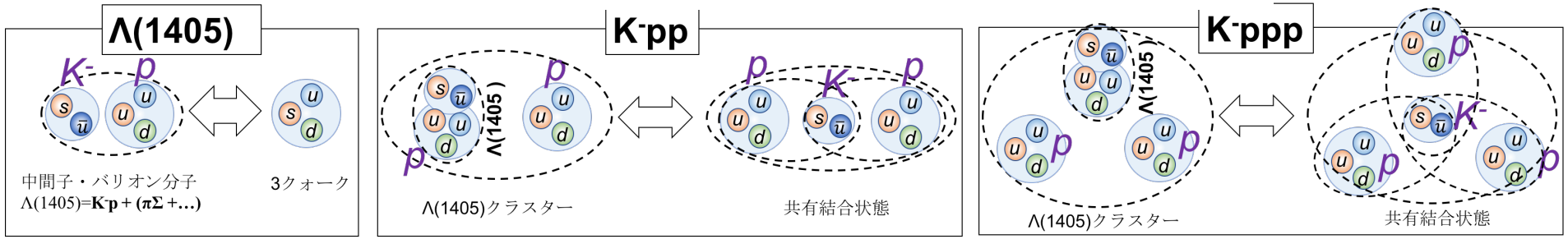


K^-pp, K^-ppp search

K^-pp: Λp invariant mass, K^-ppp: Λppp invariant mass by selecting $^{12}C(K^-, p)$ reaction. (fragment production)

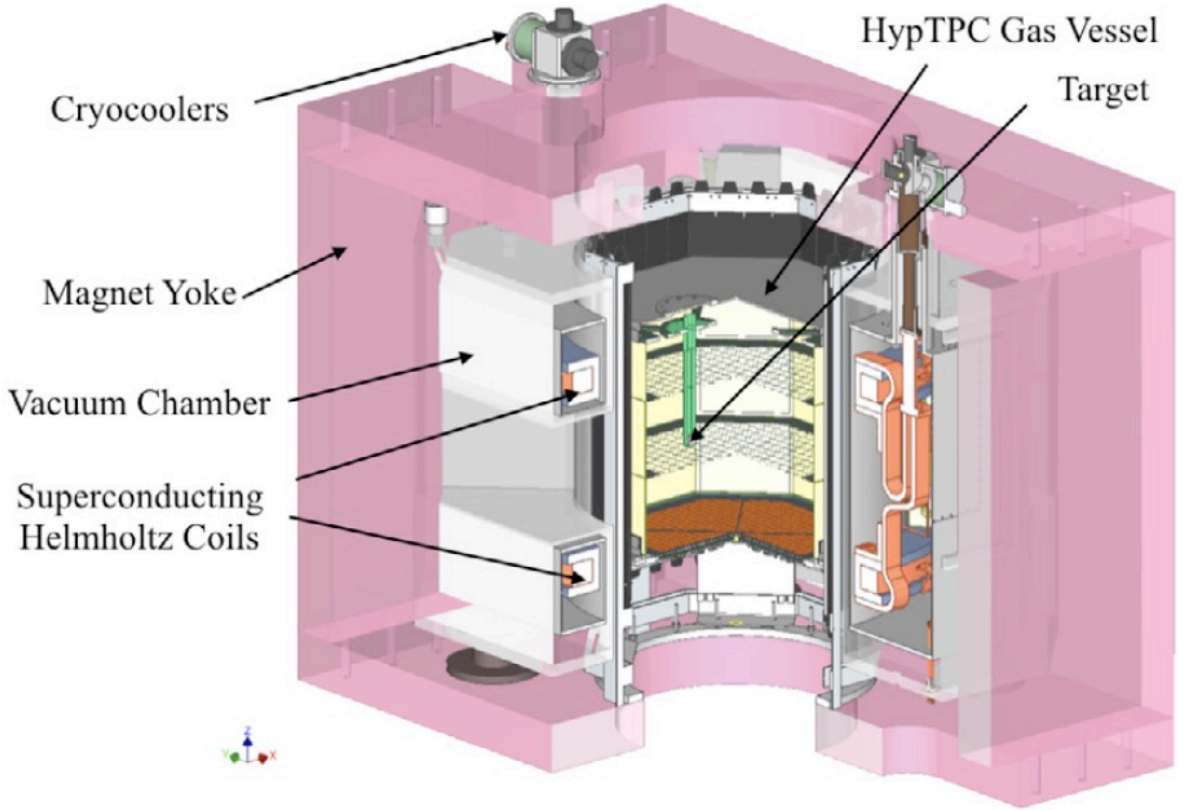


P. Kienle et al. / Physics Letters B 632 (2006) 187–191



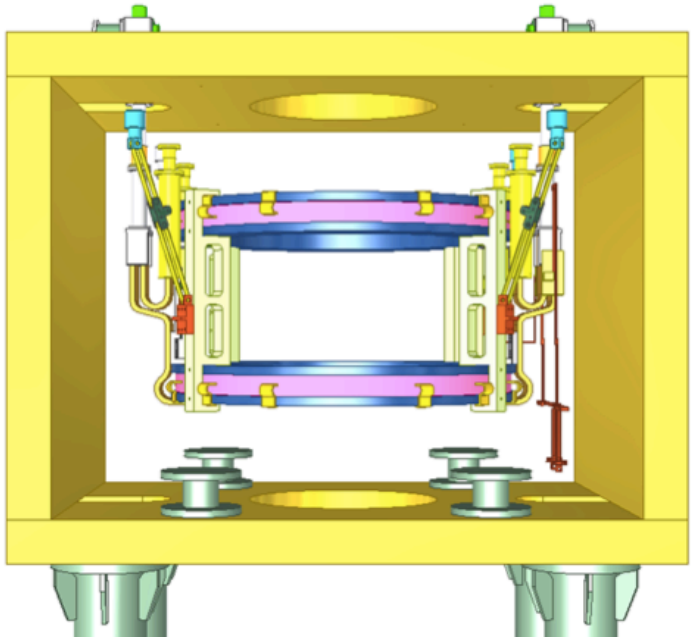
Hyperon Spectrometer (HS)

- Superconducting Helmholtz Magnet
- Time Projection Chamber "HypTPC" (*Main detector*)
- Time of Flight Detector "HTOF"



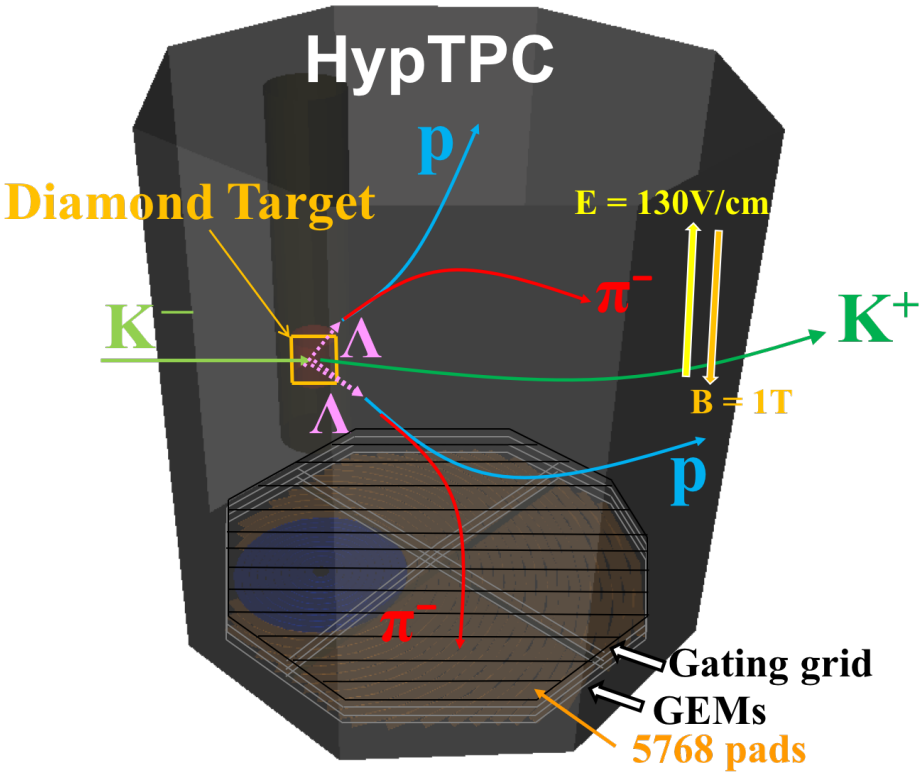
Superconducting Helmholtz Magnet

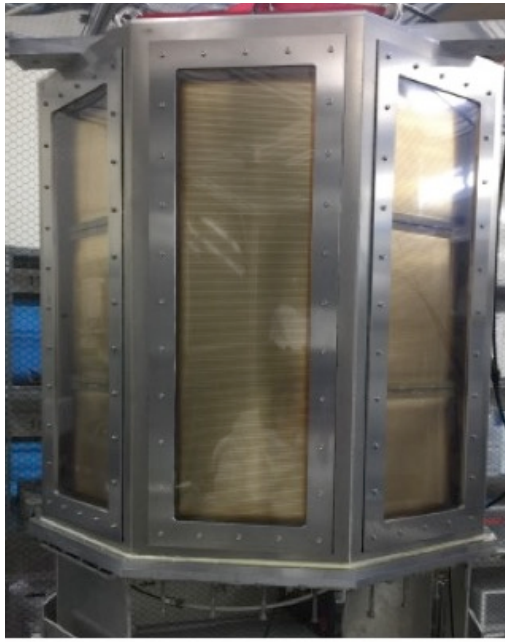
- Helmholz type, design maximum magnetic field : 1.5 T
- Conduction cooling with 2 GM cryocoolers
- Coil diameter : 1.0m
- Field uniformity : Br/By<1% in TPC volume
  to achieve the good momentum resolution

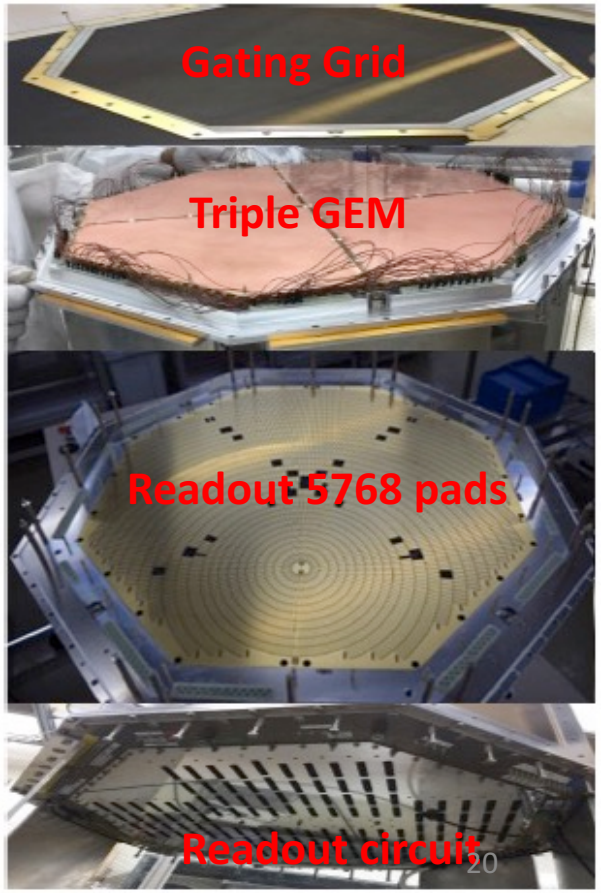


Time Projection Chamber "HypTPC"

- Octagonal prism field cage
- Inner target system → Large Acceptance
- Triple GEM layers
  (100 + 50 + 50 μm)
- 5768 readout pads
  - Inner(10 rows): 2.1-2.7 × 9 mm^2
  - Outer(22 rows): 2.3-2.4 × 12.5 mm^2
- Gating grid: ϕ50 μm, 1mm space
- Gas: P-10 (v_{max} ~ 5.3 cm /s)
- Gain ~ 10^4
- Position resolution < 300 μm
- Δp/p = 1-3% for π and p







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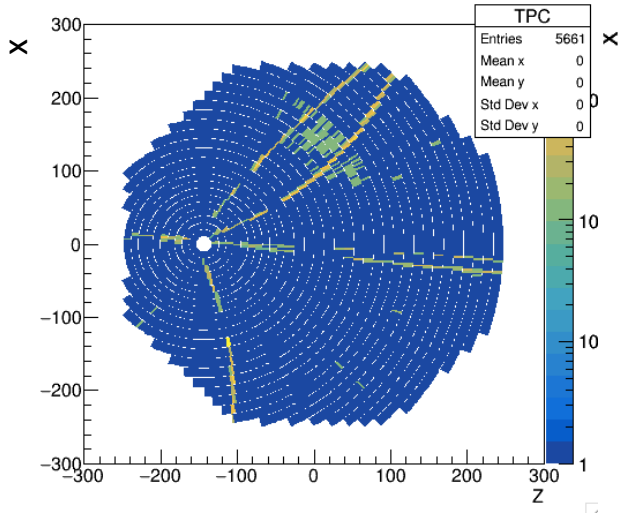
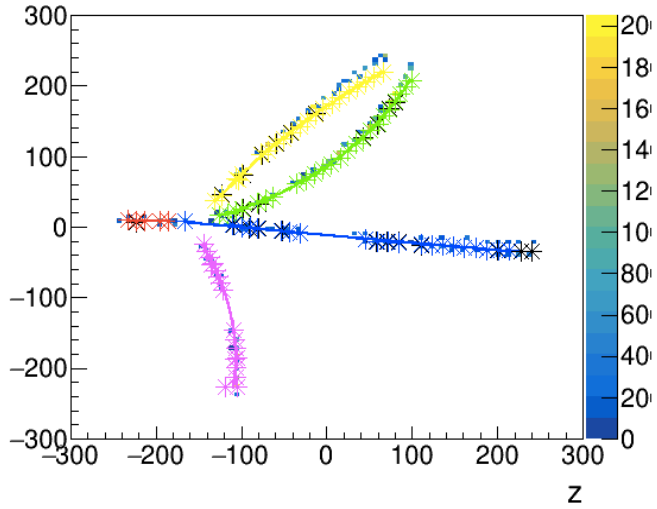
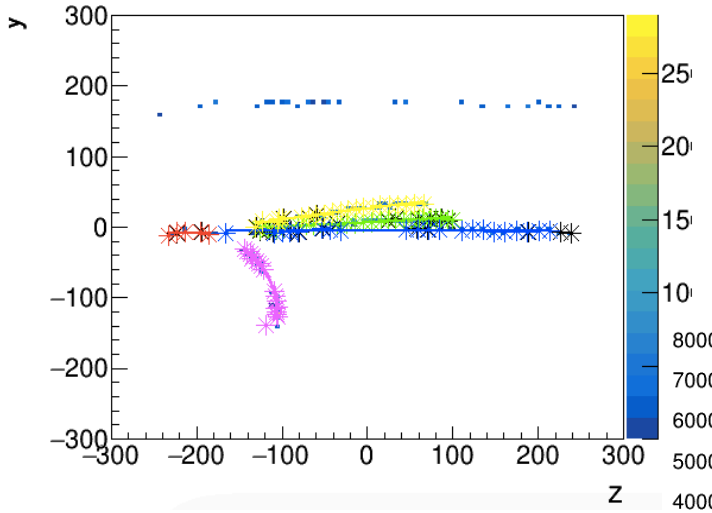
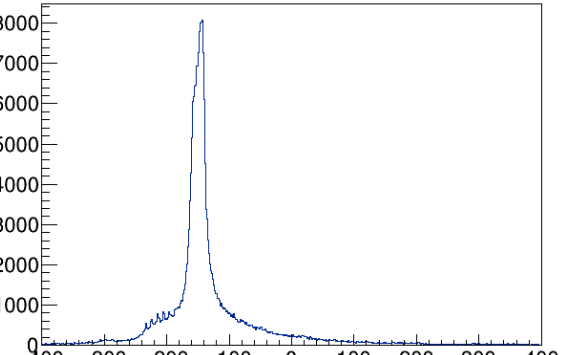
Online analysis of HypTPC [E42 data]

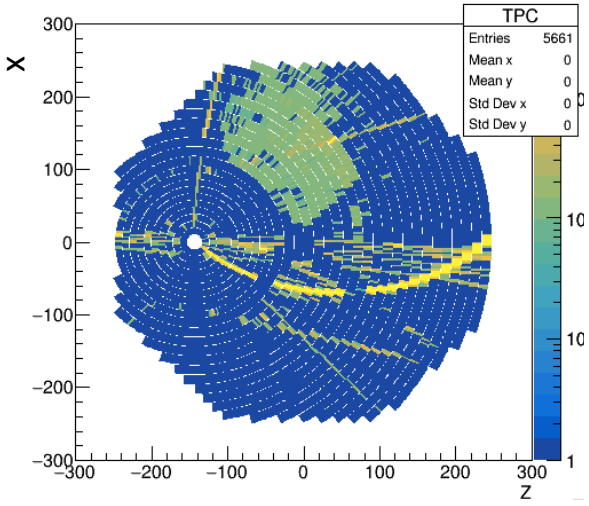


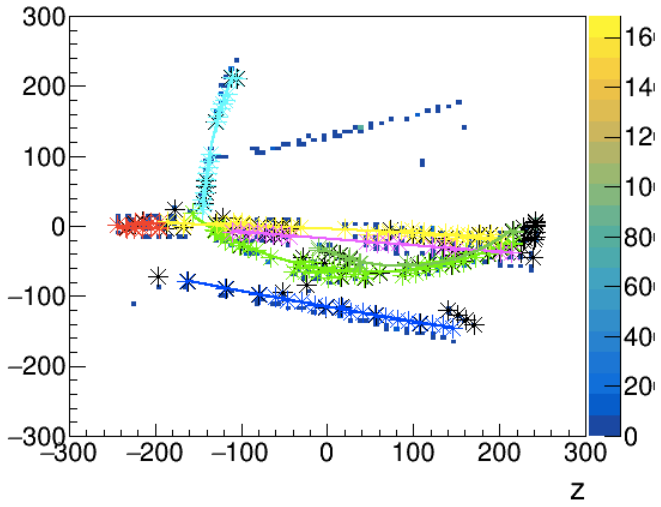


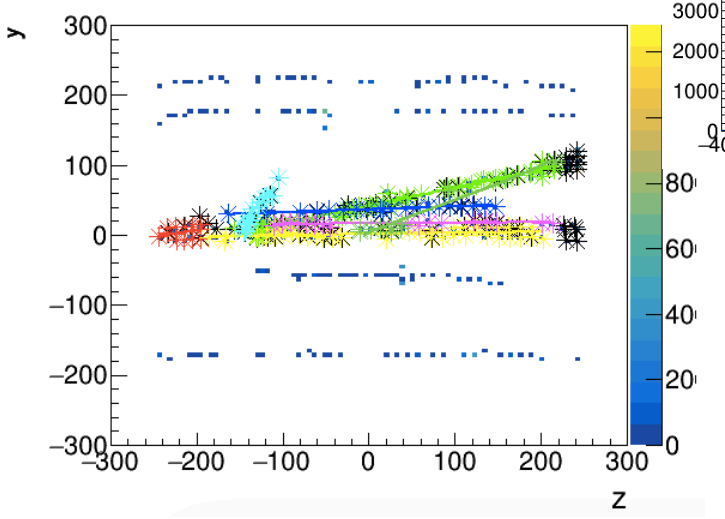


Vertex z distribution









Summary

- Beyond E05 byproduct $^{12}C(K^-, p)$ [Inclusive measurement]
  = E42 byproduct $^{12}C(K^-, p)$ [Exclusive measurement]
  - Decay charged particles are measured by HypTPC.
  - $^{12}C(K^-, p)\Lambda p$ reaction is promising to confirm E05 result.
  - K^-pp and K^-ppp will be searched by Λp and Λpp invariant mass spectroscopy, respectively.
    K^-ppp size may be possible to estimate by comparing Dalitz plot distribution.

- E42 experiment is on-going at J-PARC!!

Back up