For 20th PAC meeting

16.7.2015

Kapon Physics at K1.8BR

E15 / E31 / E17 / P57

to study $K^{bar}N$ interaction

M.Iwasaki

Kaon Physics @ K1.8BR

- **E15** ($K^{bar}NN$ bound-state search) *M. Iwasaki*
  - **$K^{bar}N$ interaction below threshold (I=0 dominant)**
  - **new information on the building block of hadron**
- **E31** ($\Lambda(1405)$ measurement) *H. Noumi*
  - **$K^{bar}N$ induced $\Lambda(1405)$, spectral study of $\Lambda(1405)$ formation**
- **E17** (K^--^{3}He / ^{4}He atom measurement (***2p***)) *S. Okada*
  - **$K^{bar}N$ interaction at threshold energy**
- **P57** (K^-d atom measurement (***1s***)) *J. Zmeskal*
  - **isospin dependence of $K^{bar}N$ interaction at threshold energy**

Study $K^{bar}N$ interaction complimentary

- with different channels & processes

- sensitive in different energy region & isospin

to provide new insight of QCD

For 20th PAC meeting

16.7.2015

E15 St.R. of Calibration Run

$^3He(K^-,NX^{\pm})$: $d(K^-,NX^{\pm})$, $p(K^-,NX^{\pm})$

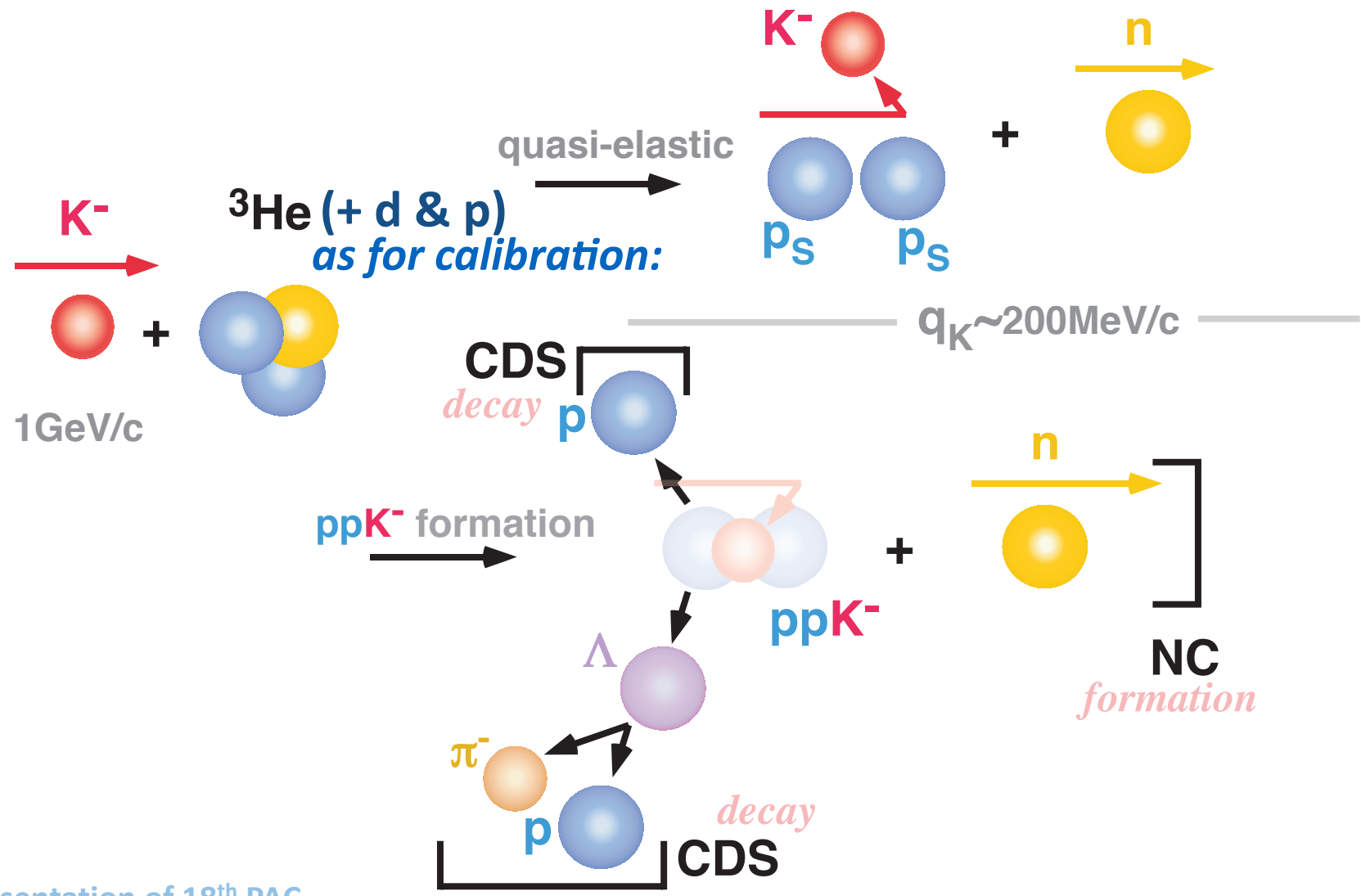
& 2nd stage request

M.Iwasaki

for the E15 Collaboration

E15: "K⁻pp" search via ^{3}He(K⁻,n) @p_K=1GeV/c

for efficient "ppK" formation { *without 2NA background*
Formation & Decay { *Y decay can be rejected*



Calibration Run with H2/D2 @ Run#62

objective:

1) compare spectral functions of different targets

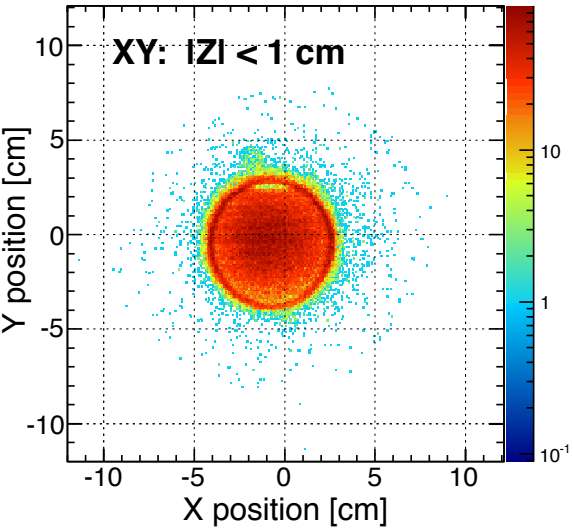
2) define efficiency of NC

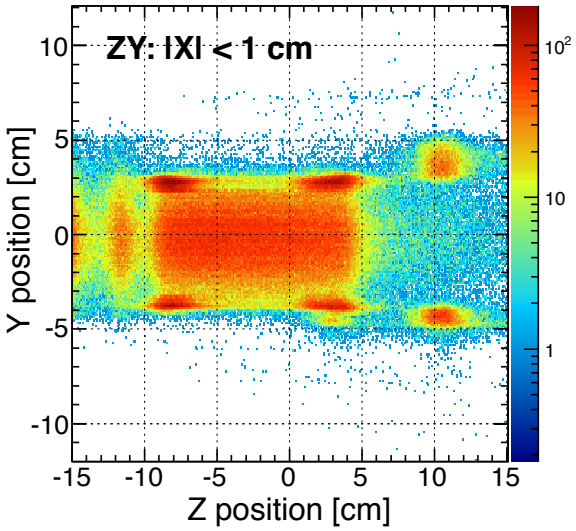
3) understand the response function of NC / PC

4) pilot run for E31 → Noumi's presentation

Spectrometer Performances

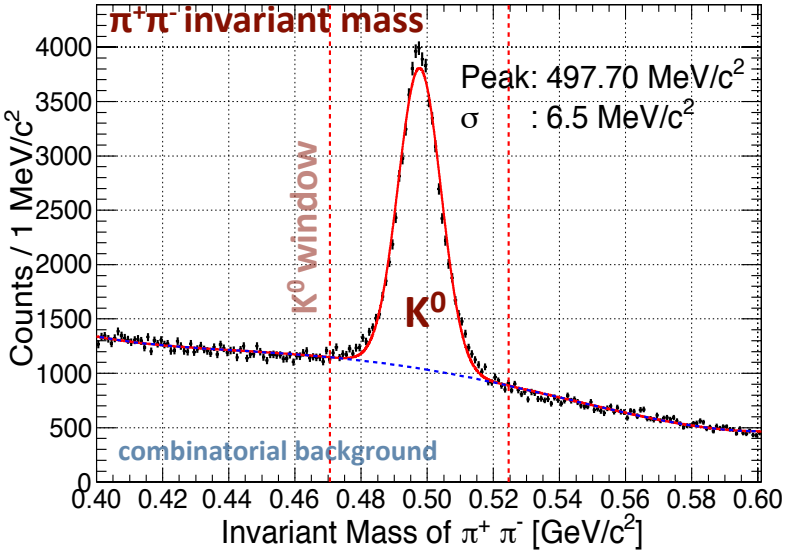
- **Event-vertex reconstruction (for fiducial event selection)**



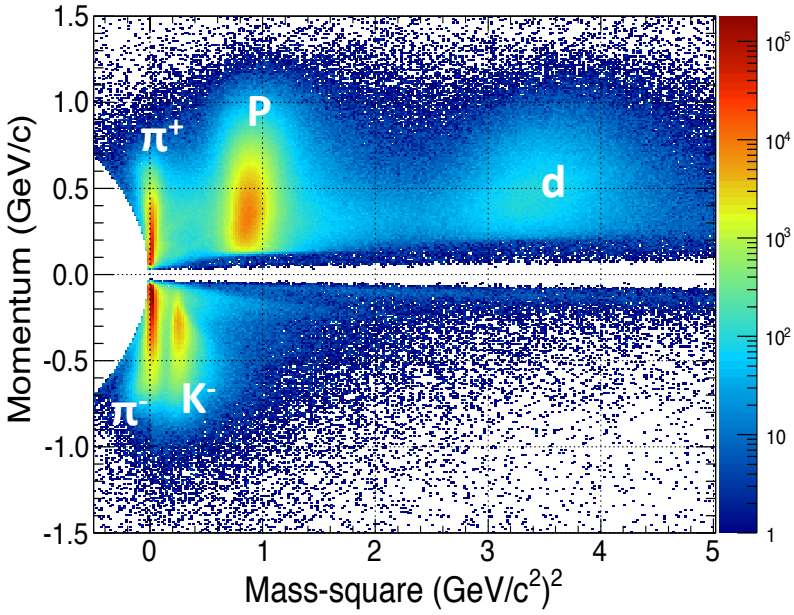


vertex between tracks of initial K^- & charged particle in CDS

- **$K^0_S \rightarrow \pi^+\pi^-$ (CDS calibration)**

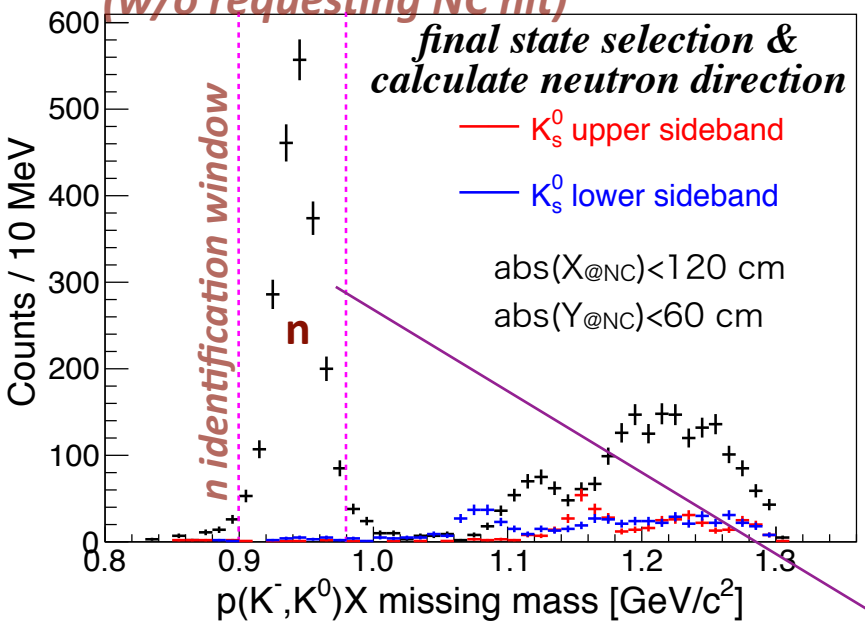


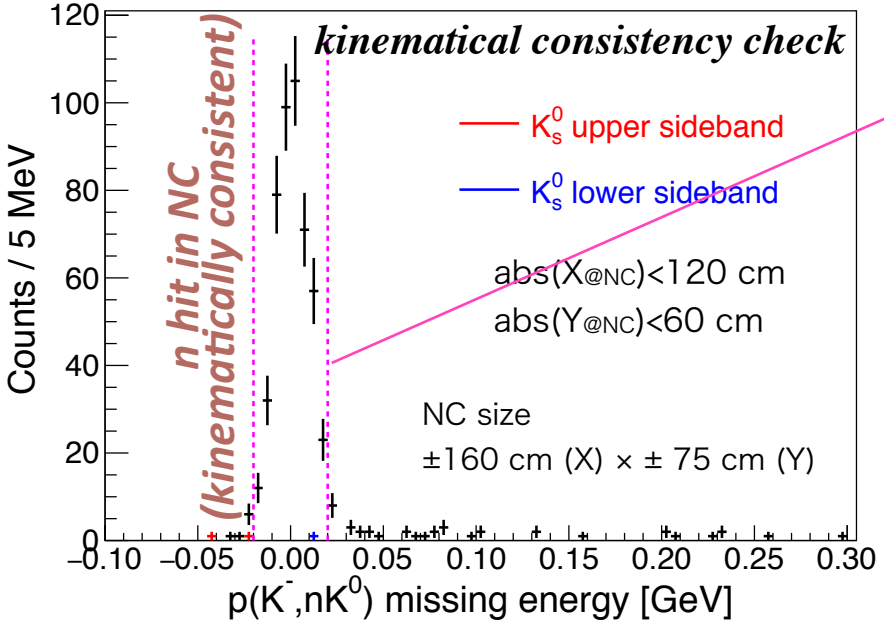
- **PID with CDS**



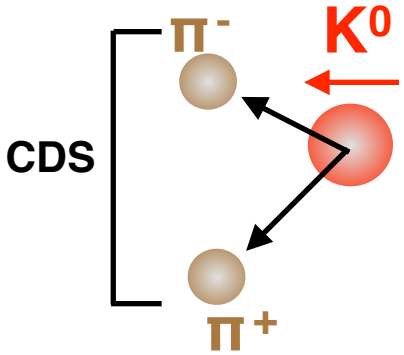
NC Efficiency Evaluation using $p(K^-,K^0_S)n$

(w/o requesting NC hit)





"neutron direction" can be calculated by incoming K⁻ & K⁰ decay



n (we know where to go)

check whether hit in NC

$$\frac{N^{K^0_s}_{neutron} - N^{sideband}_{neutron}}{\left(N^{K^0_s}_{missN} - N^{sideband}_{missN}\right) \times R_{onNC} \times \epsilon^{BVC\&CVC}_{overveto}}$$

estimated by MC
~ 0.9 @ H_2
~ 0.6 @ ^{3}He

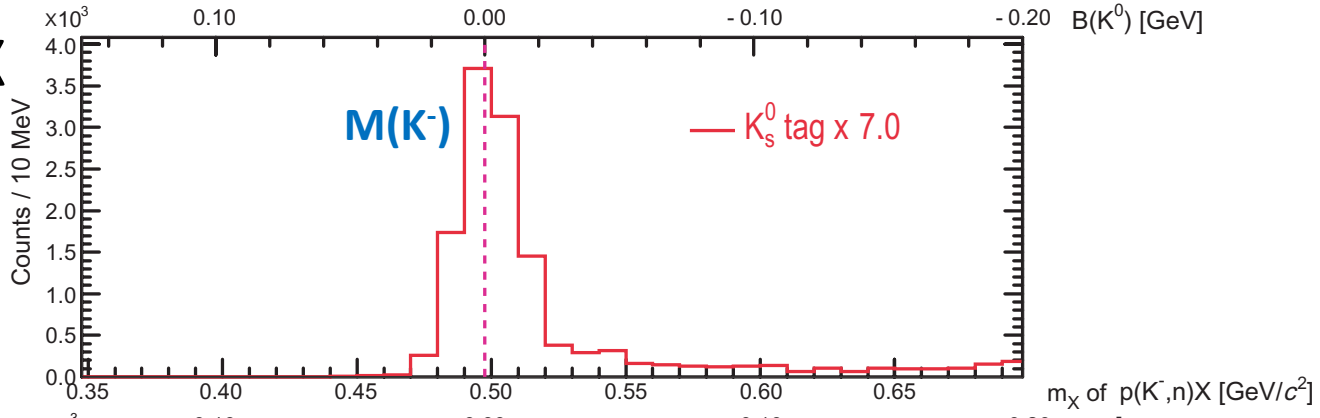
~ 0.9

NC detection efficiency can be evaluated at the precision of ~1%

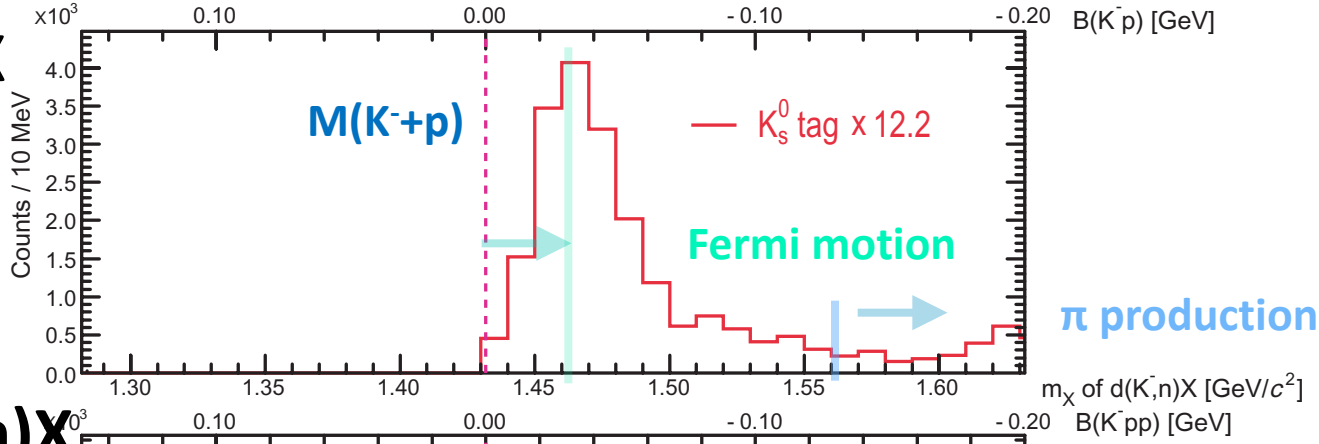
c.f.) 23 ± 4% @ ^{3}He target

Spectra of (K^-,nK^0) events on p/d/^{3}He

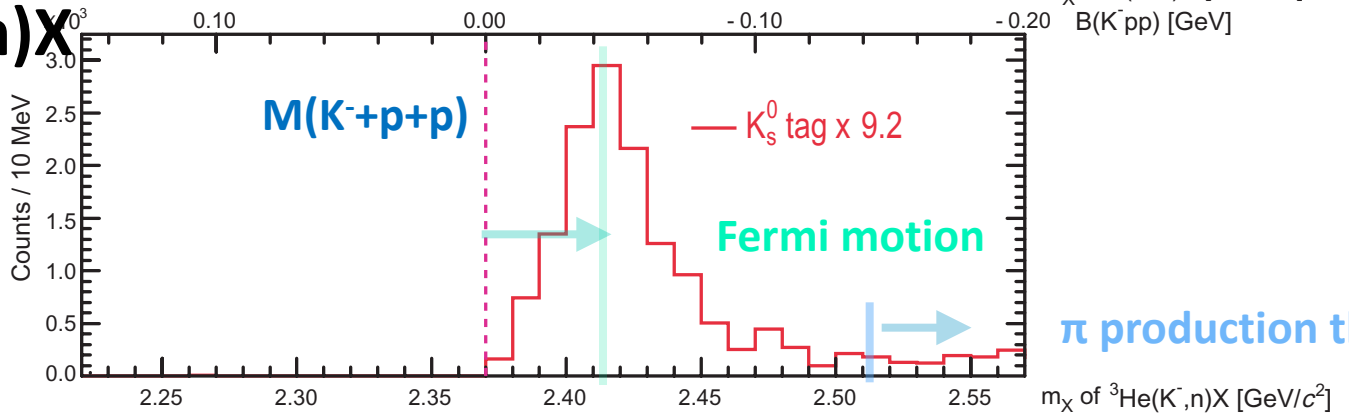
p(K^-,n)X



d(K^-,n)X

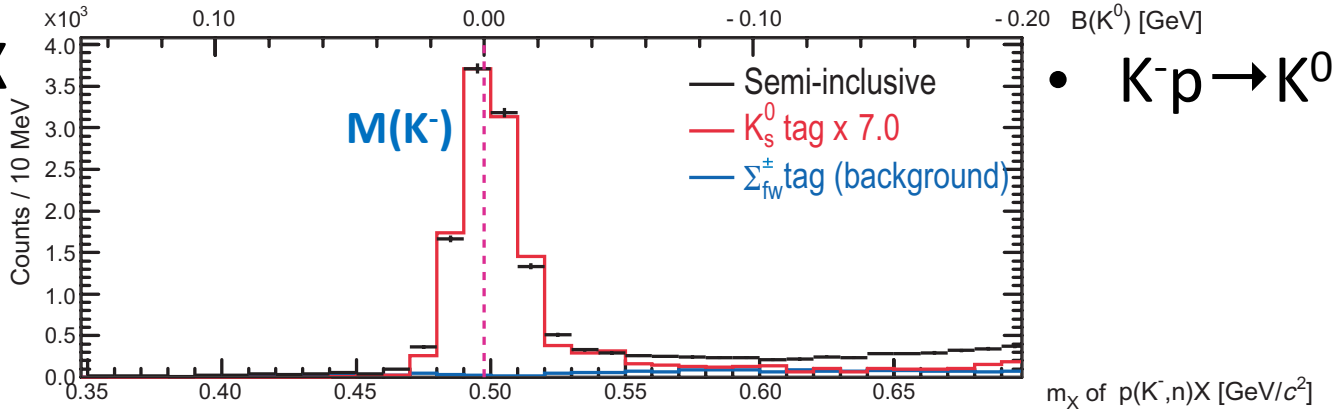


^{3}He(K^-,n)X



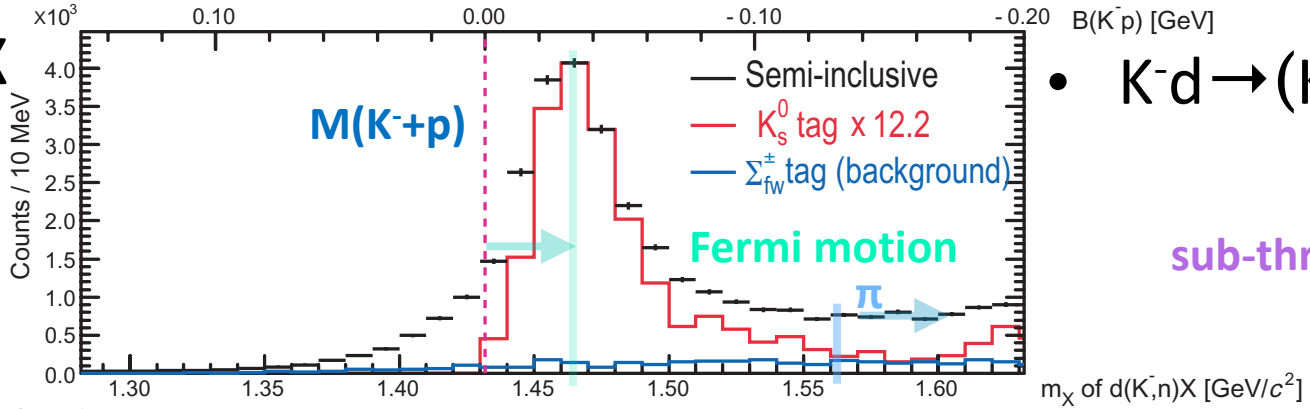
Spectra of (K^-,nK^0) events on p/d/^{3}He

p(K^-,n)X



- $K^- p \rightarrow K^0 + n_{fw}$

d(K^-,n)X



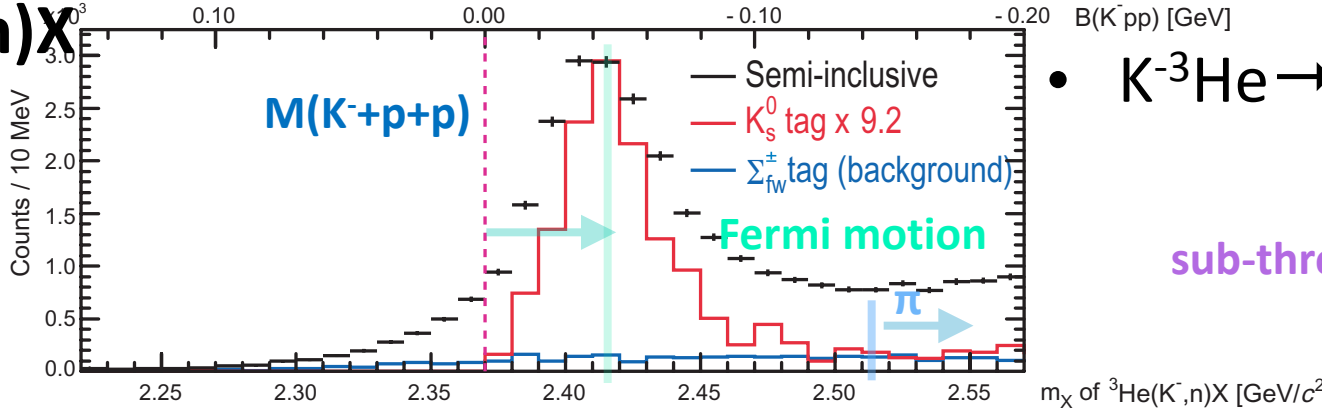
- $K^- d \rightarrow (K^- p) + n_{fw}$

  Y^*

  sub-threshold excess!

  cf. E31

^{3}He(K^-,n)X



- $K^- {}^3He \rightarrow (K^- pp) + n_{fw}$

  Y^*N

  sub-threshold excess!

Calibration Run

Very successful

Progress in E15 Analysis

1) semi-inclusive data → publication

2) $\Lambda p + n_{mis}$ data → preparation on publication

3) other channels → more data needed

Formation vs Decay

Formation channel

semi-inclusive

$K^- + {}^3He \rightarrow n + X\ (\theta_n=0)$

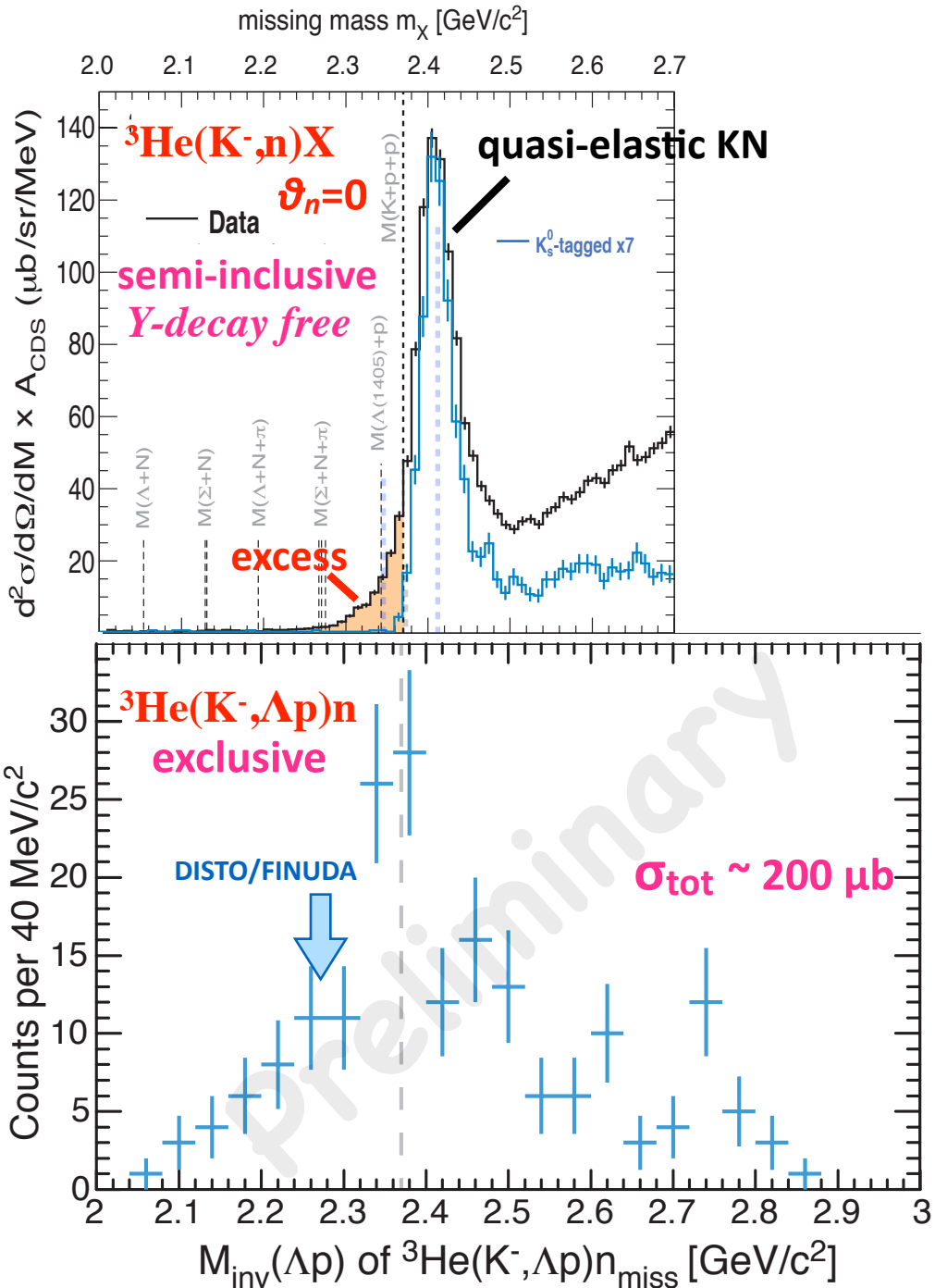
- excess below threshold
  background-free
- contribution from
  Λ(1405)n + p_S (2NA)
  may exist

Decay channel

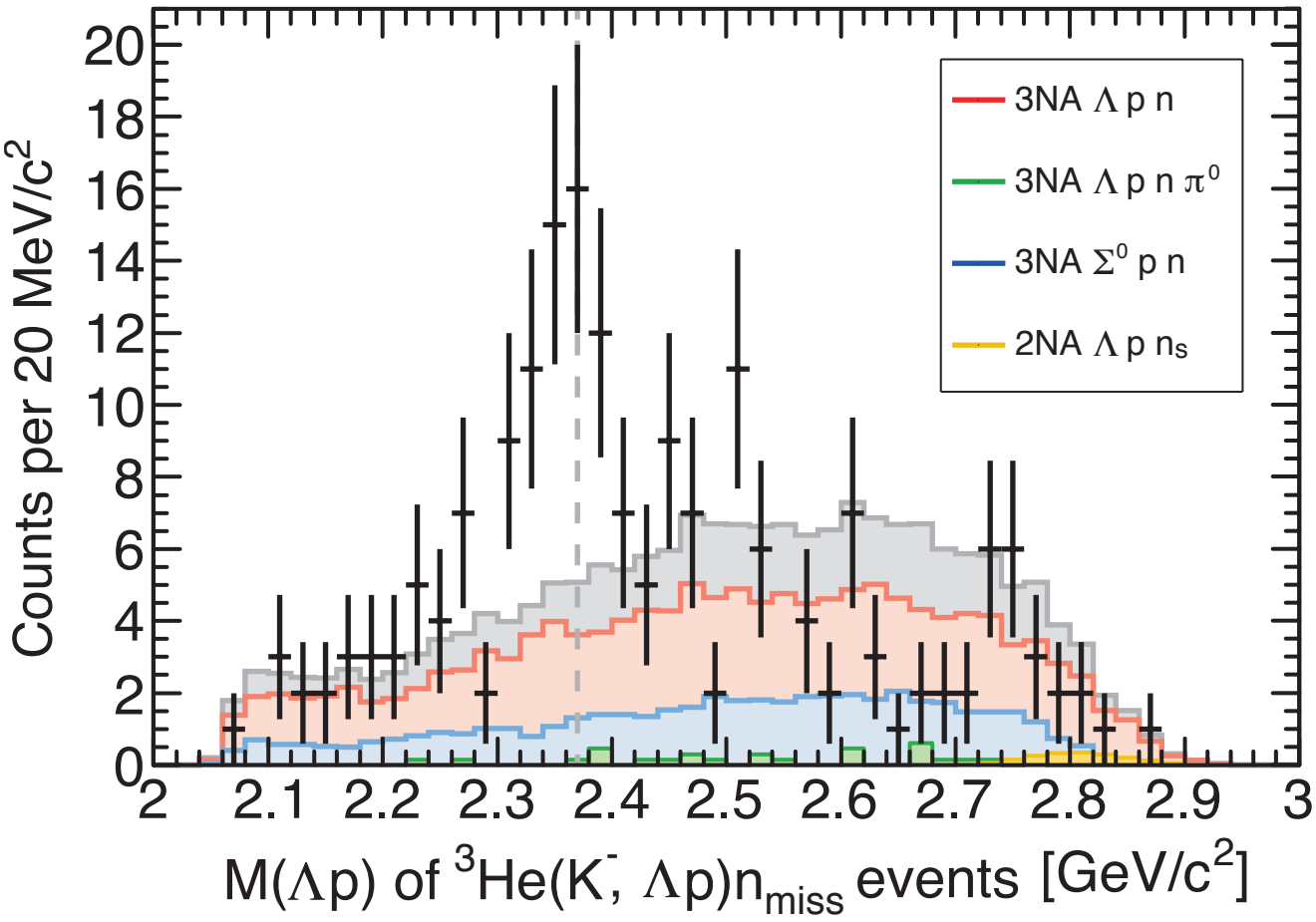
exclusive

$K^- + {}^3He \rightarrow \Lambda + p + n_{mis.}$

- excess exist near threshold
- cannot be Λ(1405)n + p_S (2NA), because F.S.= Λpn
- contamination Σ^0 < 20%



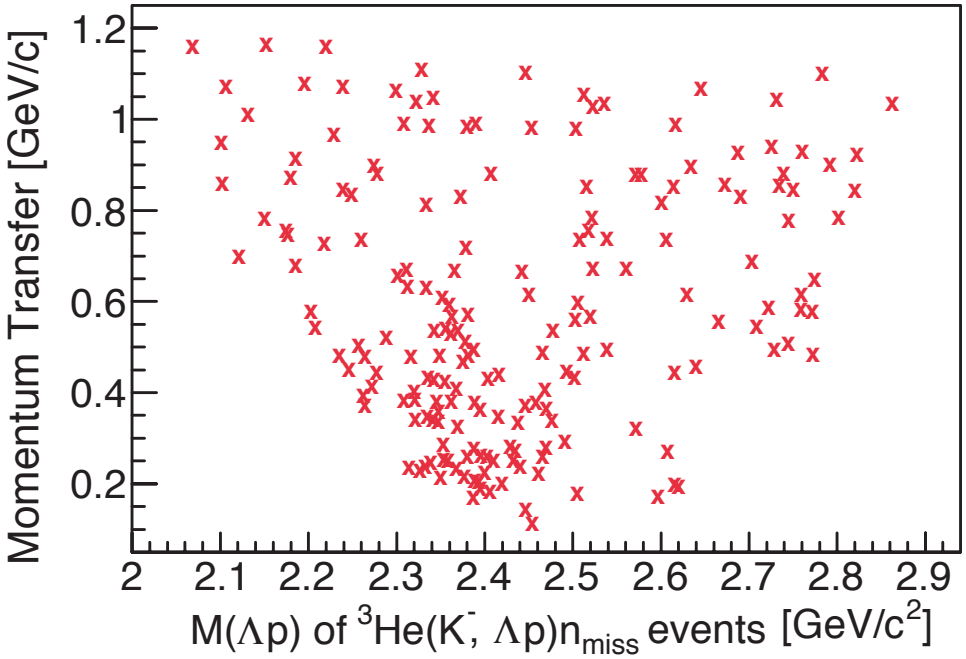
Exclusive ^{3}He(K$^-$,Λp)n$_{mis}$ by 3NA



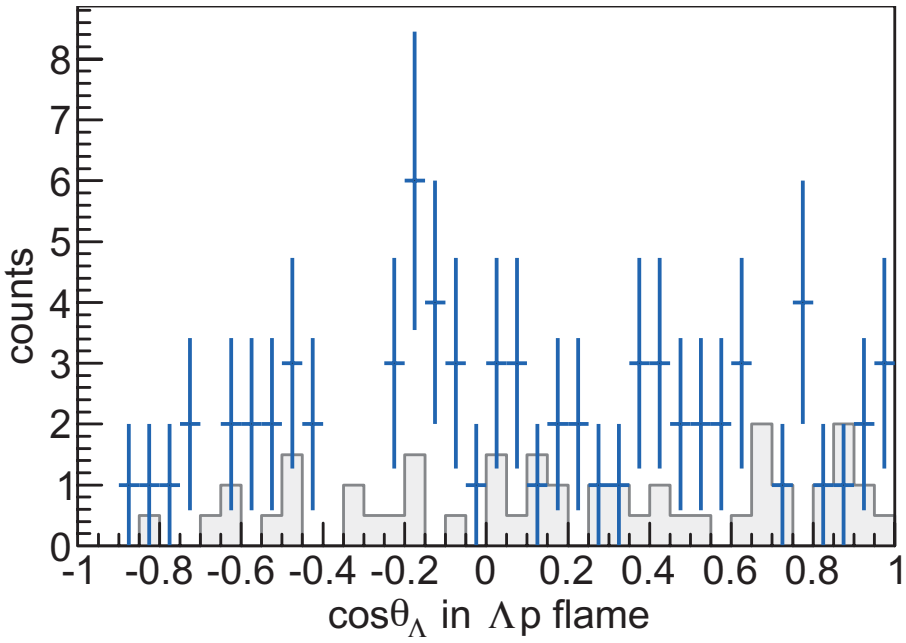
- The spectrum CANNOT be reproduced only by 3NA
- Clear structure is seen around KNN threshold
  - ***NOT explained by any 2-step reactions, such as Λ*N→Λp***

Kinematics of the Structure

Mom. Trans vs. IM(Λp)



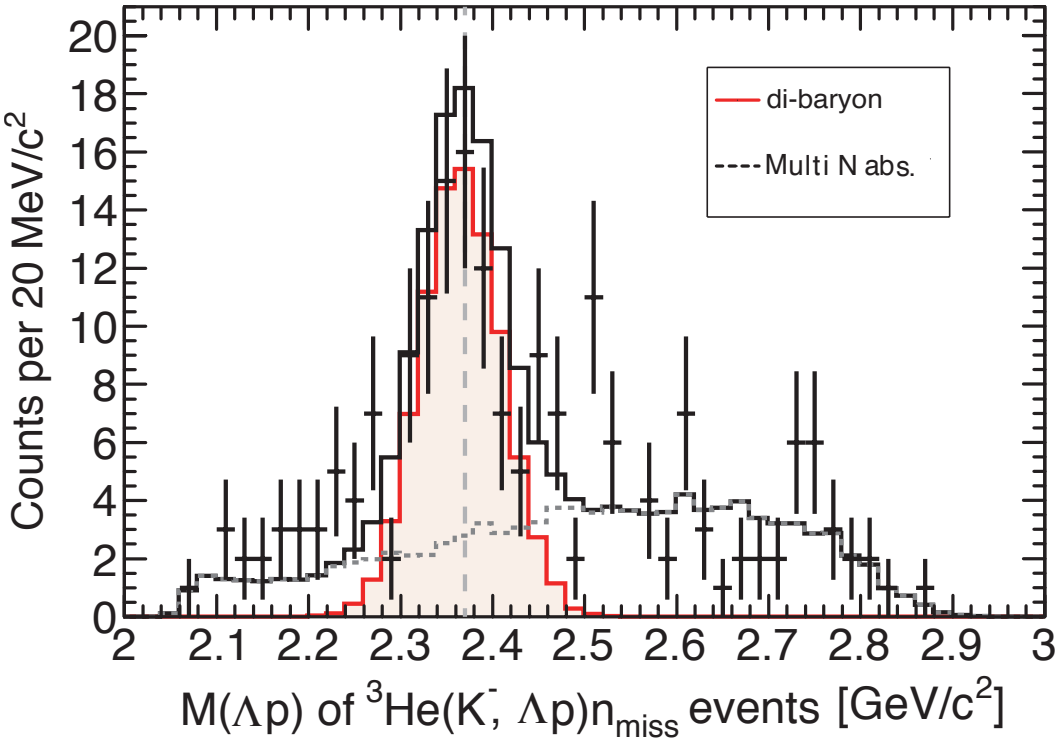
Λp decay-angle in CM

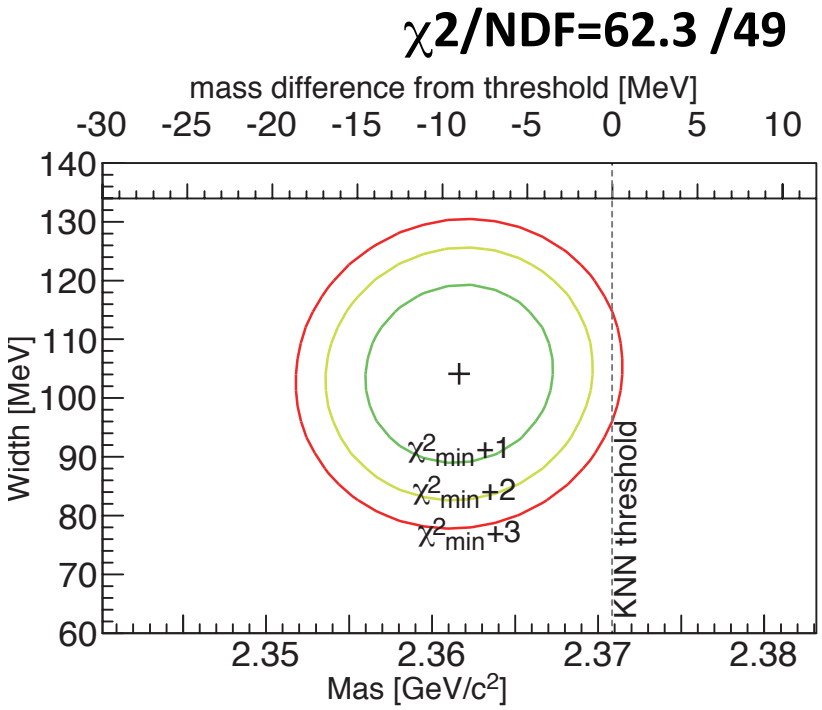


cosθ$_Λ$ = 1 relative to the Λp frame

- low-momentum transfer is enhanced
- isotropic decay

Assuming Breit-Wigner





- χ^2-test with Breit-Wigner and 3NA backgrounds
  - assume isotropic Λp decay as a function of mass and width

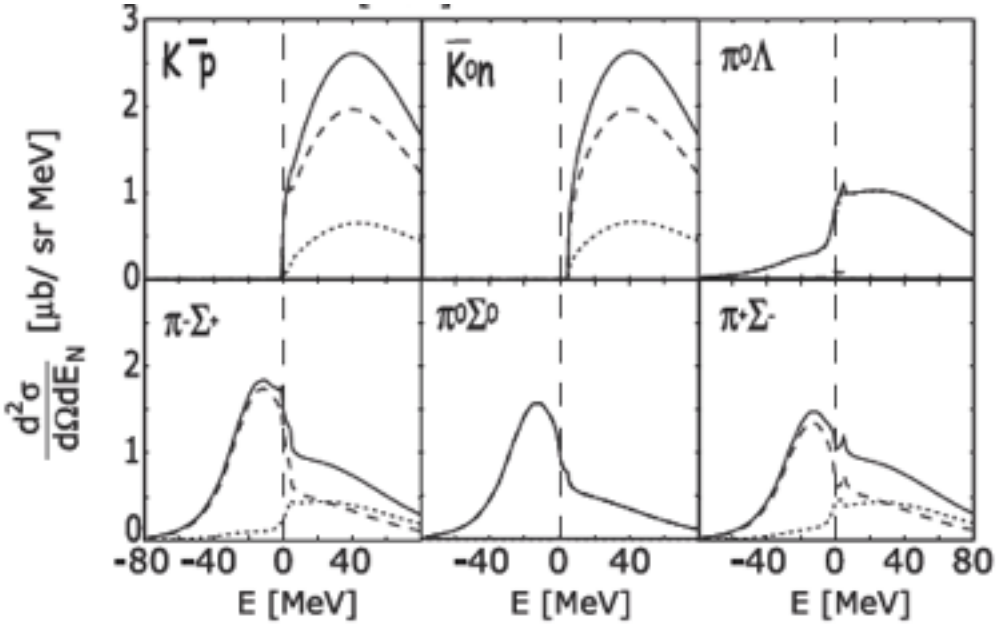
Compilation of other final states

"KNN" → $p\Sigma^0$

"KNN" → $p\pi^{\pm}\Sigma^{\mp}$

"KNN" → Λp (w/ n in NC)

original aim of E15



J. Yamagata-Sekihara et. al., Phys. Rev. C 80, 045204 (2009)

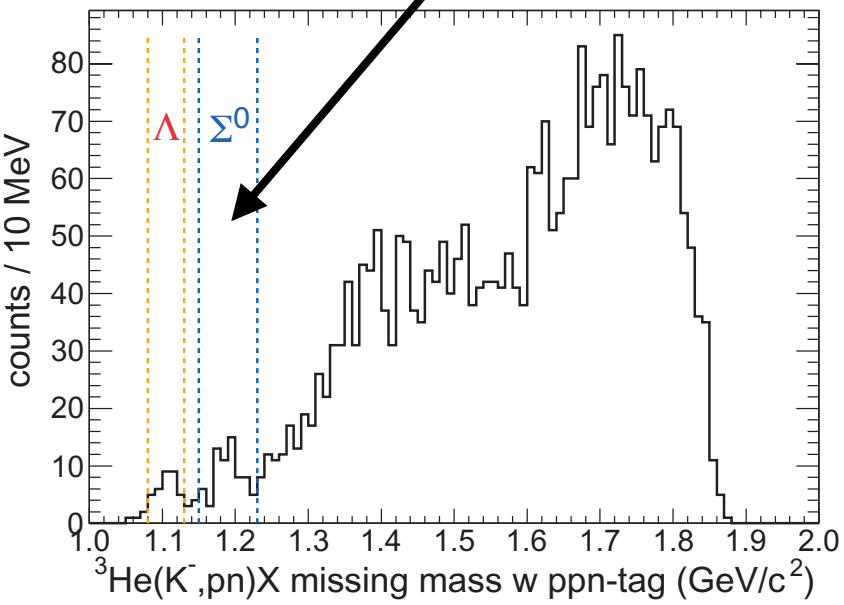
$p\Sigma^0$ final state

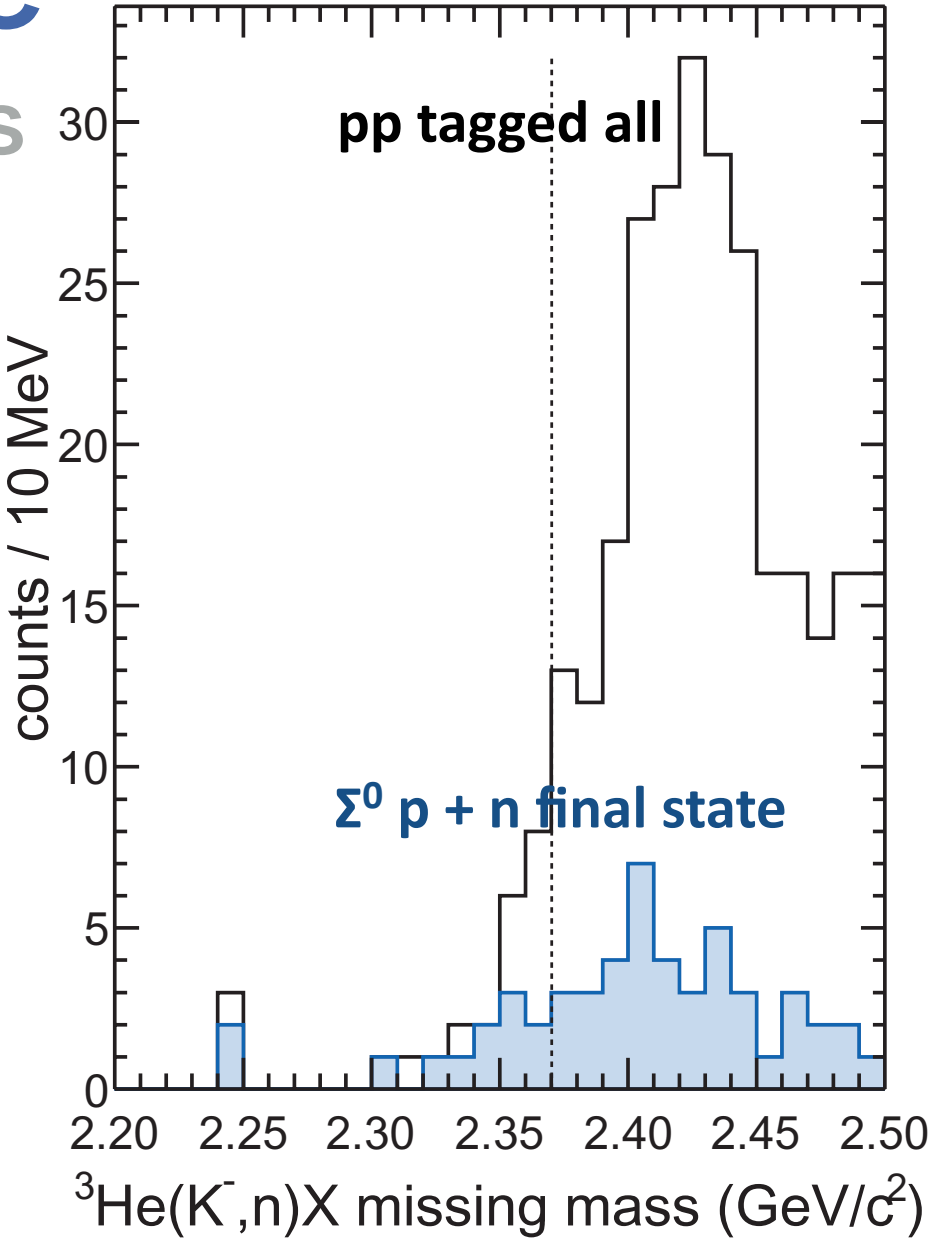
in ppn tagged events

$$K^- + {}^3He \rightarrow \Sigma^0 + p + n$$

$$\Sigma^0 \rightarrow \Lambda\gamma \rightarrow p + \pi$$

CDS
NC





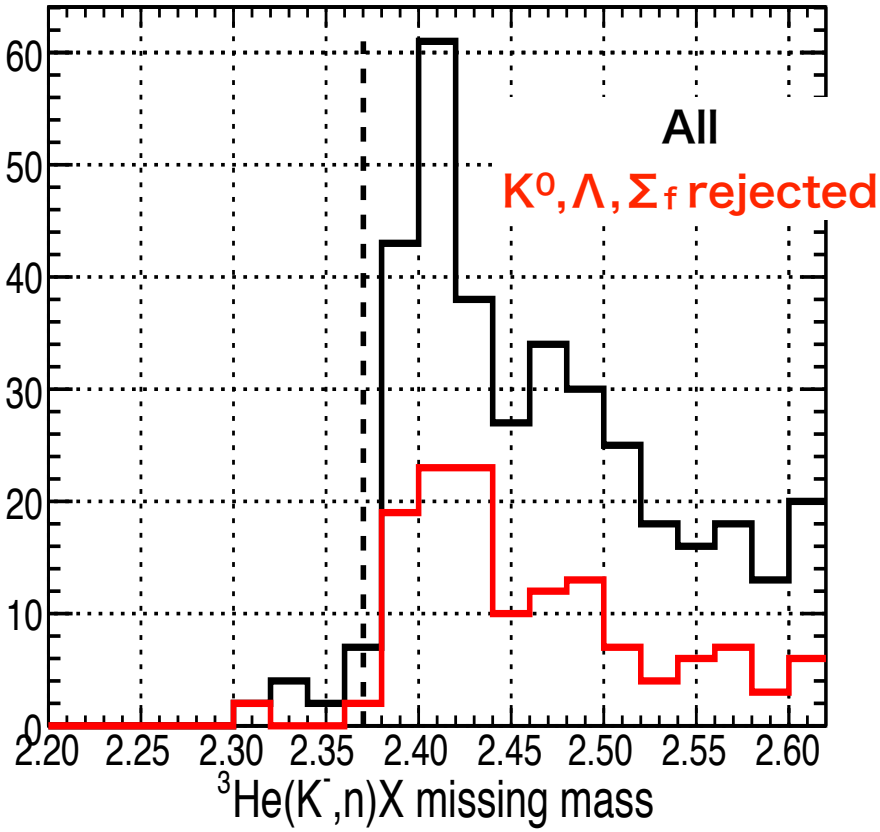
$p\pi^{\pm}\Sigma^{\mp}$ final state

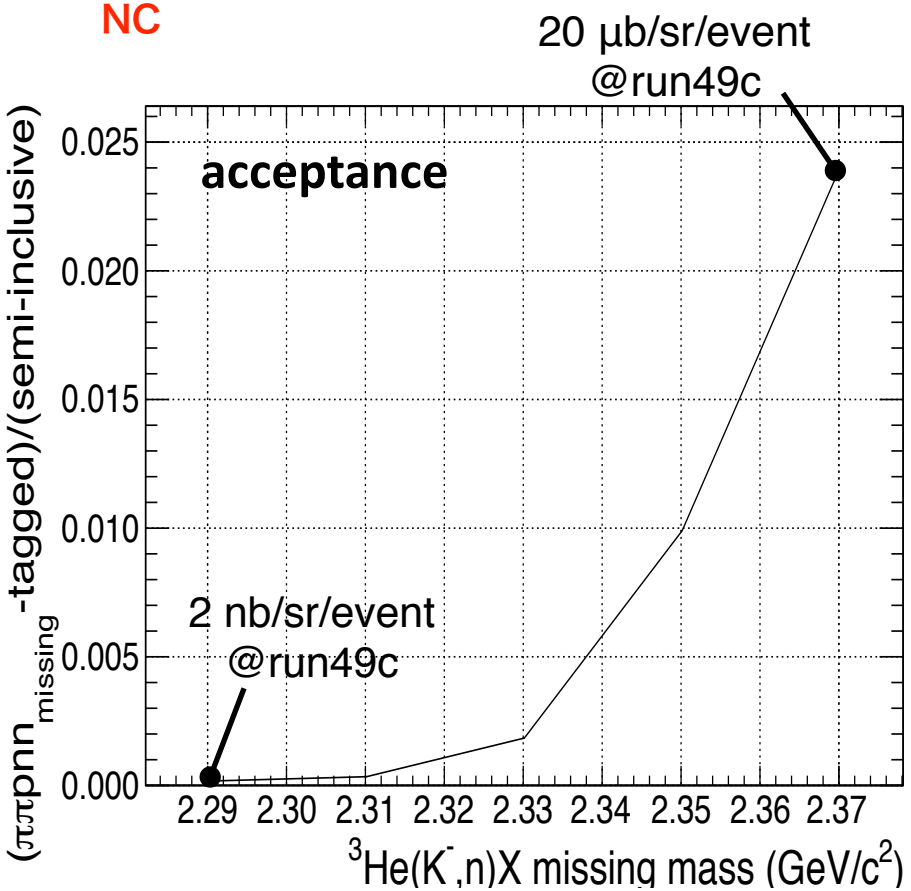
in $\pi\pi$pn tagged events

$$K^- + {}^3He \rightarrow \Sigma + \pi + p + n$$ CDS

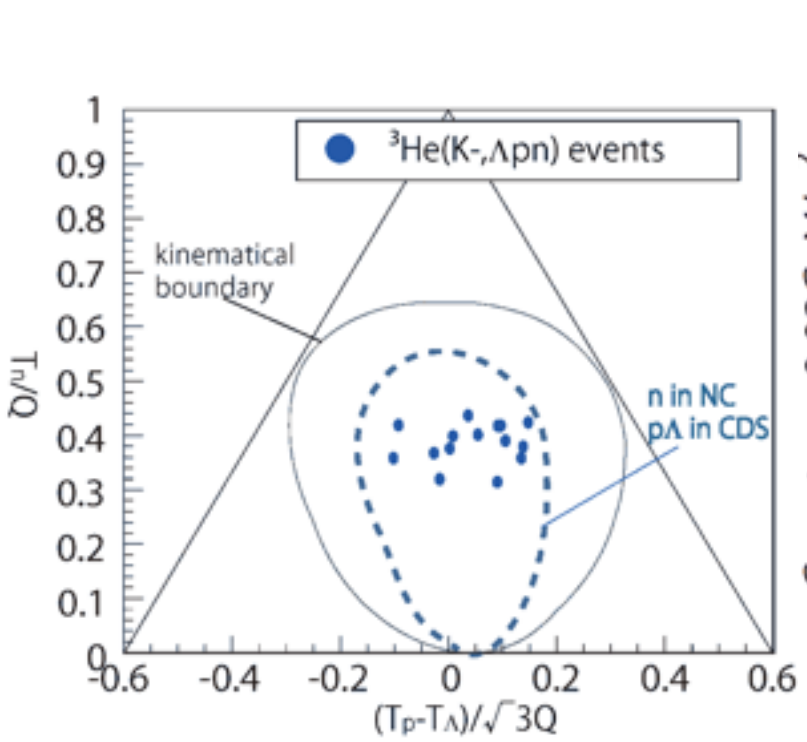
NC

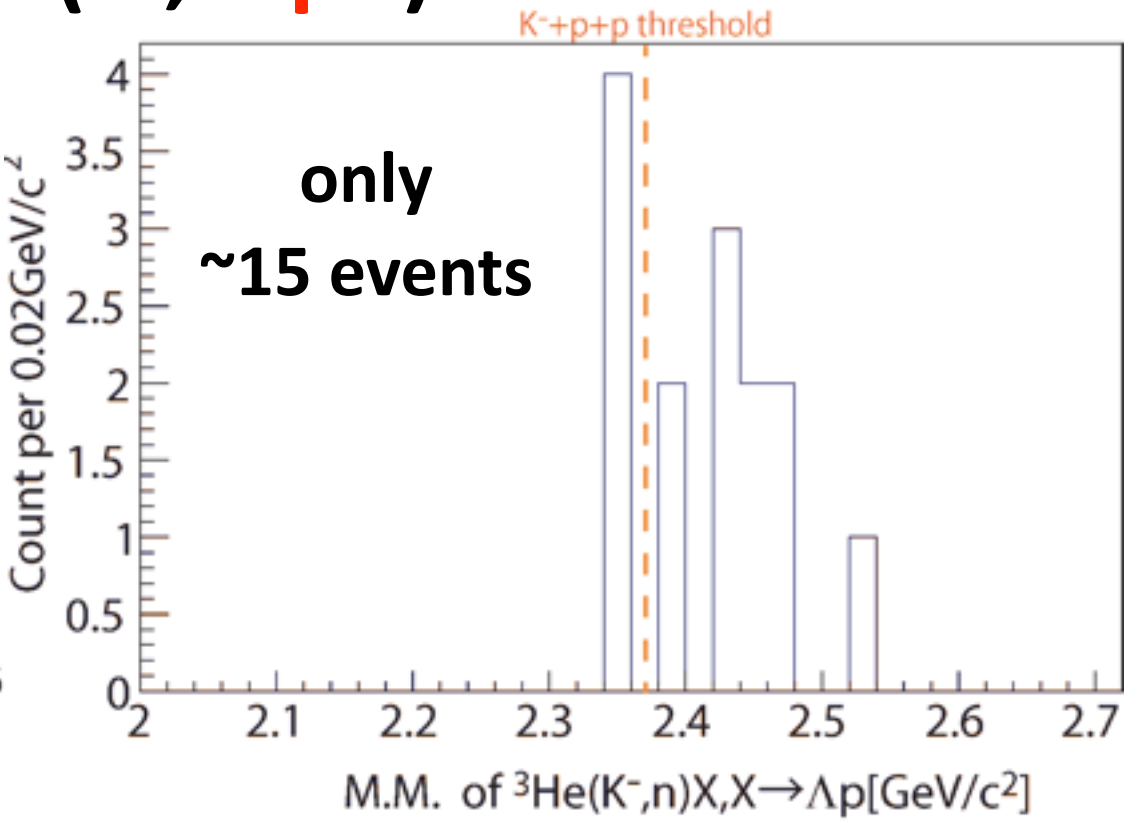
$$\Sigma \rightarrow n + \pi$$





Kinematically-complete measurement of ^{3}He(K$^-$, Λpn)





- Minimum momentum transfer of the ^{3}He(K$^-$,n) reaction
  → would enhance the S-1 di-baryon production
- **x100 beam time is required**

Simply need more data for other decay channel / full kinematic

x 10 **x 100**

E15 2nd stage

May, 2013 (Run#49c)	24 kW (30 Tppp, 6s)	140 k/spill	88 h	5.1×10^9

x10

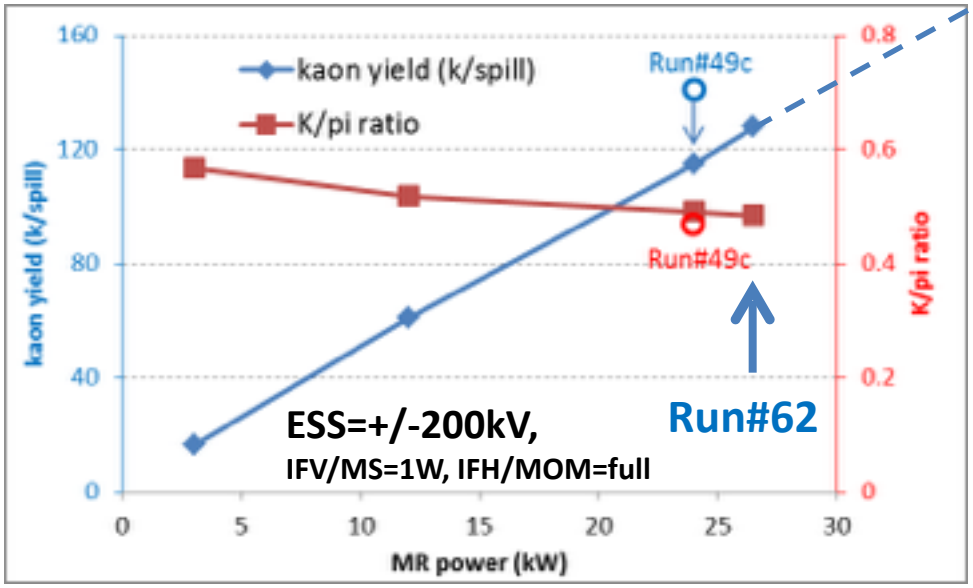
E15 2nd: 50×10^9 kaons on target

The goal of the E15 2nd

1. confirm the spectral shape of the Λp invariant-mass by the exclusive measurement of $^3He(K^-, \Lambda p)n_{mis.}$
2. explore the neutron spectrum at $\theta_{lab}=0$ with aid of kinematically complete measurement of $^3He(K^-, \Lambda pn)$
3. extend study on other channel, like $^3He(K^-, \Sigma\pi pn)$

➢ to extract more information on the $K^{bar}N$ interaction

New Measurement of 1.0 GeV/c K^- Yield @ Run#62



40kW
200k/spill K-
autumn 2015?

50kW
250k/spill K-
2016???

Run#49c (24kW)	*140 k/spill*	*0.45*	*450k/spill*
Run#62 (24kW)	*110 k/spill*	*0.48*	*340k/spill*
(26.5kW)	*130 k/spill*	*0.47*	*400k/spill*
40kW	*200 k/spill?*	*0.45?*	*650k/spill?*
50kW	*250 k/spill?*	*0.45?*	*800k/spill?*
100kW	*500 k/spill?*	*0.45?*	*1.6M/spill?*

Updated Beam-Time Request for E15-2nd

	Exp. Target	Primary-beam intensity	Secondary-kaon intensity	Duration	Kaons on target (w/ tgt selection)
May, 2013 (Run#49c)	E15^{1st} (done) ^{3}He	*24 kW (30 Tppp, 6s)*	*140 k/spill*	*88 h*	*5.3 x 10^9*
Apr-May, 2015 (Run#62)	calibration (done) H_2	*26.5 kW (33 Tppp, 6s)*	*130 k/spill*	*73 h*	*3.7 x 10^9*
Apr-May, 2015 (Run#62)	calibration (done) D_2	*26.5 kW (33 Tppp, 6s)*	*130 k/spill*	*53 h*	*2.8 x 10^9*
Autumn, 2015	E15^{2nd} ***^{3}He***	***40 kW (50 Tppp, 6s)***	***200k/spill***	***26d***	***50x10^9***

** production target: Au 50% loss, spill length: 2s, spill duty factor: 35~45%, K/pi ratio: ~1/2*

** ~70% of beam kaons hit the fiducial volume of ^{3}He target*

We wish to perform

E15 2nd Physics-Run

in autumn 2015

Summary

- **Beam-time request for E15^{2nd}**
  - 31 days with 40kW [=50*10^{9} K^{-} on target]
    - including commissioning, ^{4}He-refill time, acc/exp-eff.(0.9)
  - the results would provide fruitful information on K^{bar}N interaction
- **Analysis status of E15^{1st}**
  - Semi-inclusive ^{3}He(K^{-},n)X: **PTEP(2015)061D01**
  - Exclusive ^{3}He(K^{-},Λp)n: paper in preparation
- **Calibration with D2/H2 targets @ Run#62**
  - Analysis is going on
    - (detailed) spectrometer performances
    - elementary N(K^{-},N)X reactions for ^{3}He(K^{-},N) analysis

Supporting materials

Calibration Run with H2/D2 @ RUN#62

- Calibration run for E15 was successfully accomplished
  - To evaluate
    - (detailed) spectrometer performances
    - elementary N(K^-,N)X reactions for ^{3}He(K^-,N) analysis

	Exp. Target	Primary-beam intensity	Secondary-kaon intensity	Duration	Kaons on target (w/ tgt selection)
May, 2013 (Run#49c)	*^{3}He*	*24 kW (30 Tppp, 6s)*	*140 k/spill*	*88 h*	*5.3 x 10^9*
Apr-May, 2015 (Run#62)	***H_2***	***26.5 kW (33 Tppp, 6s)***	***130 k/spill***	***73 h***	***3.7 x 10^9***
Apr-May, 2015 (Run#62)	***D_2***	***26.5 kW (33 Tppp, 6s)***	***130 k/spill***	***53 h***	***2.8 x 10^9***

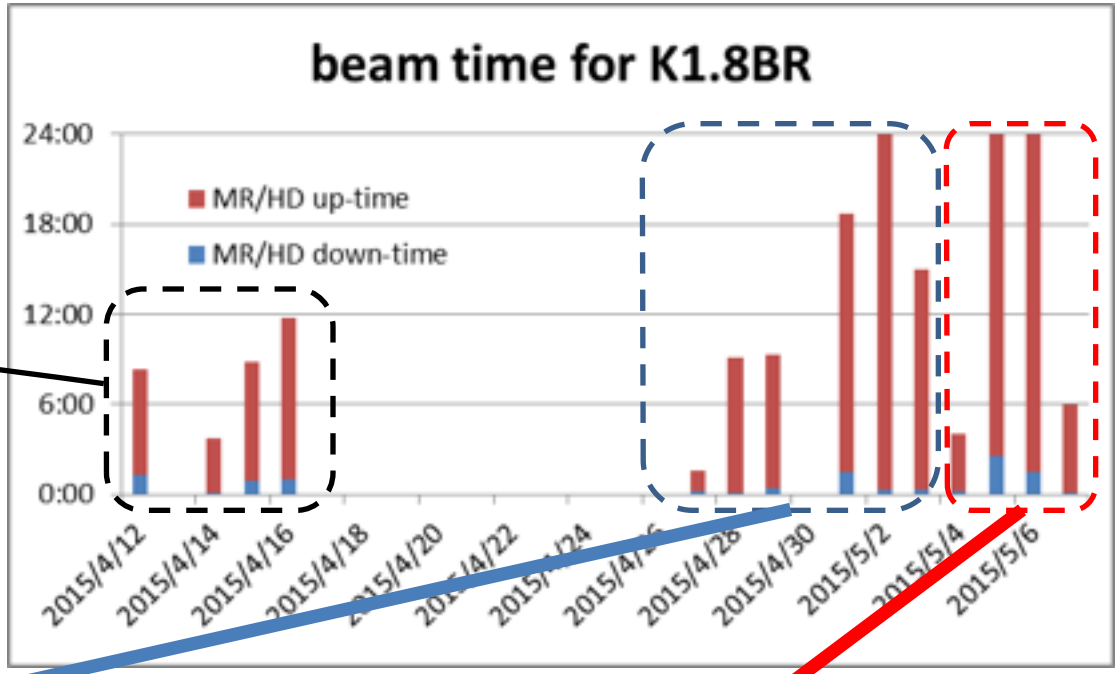
** production target: Au 50% loss, spill length: 2s, spill duty factor: 35~45%, K/pi ratio: ~1/2*

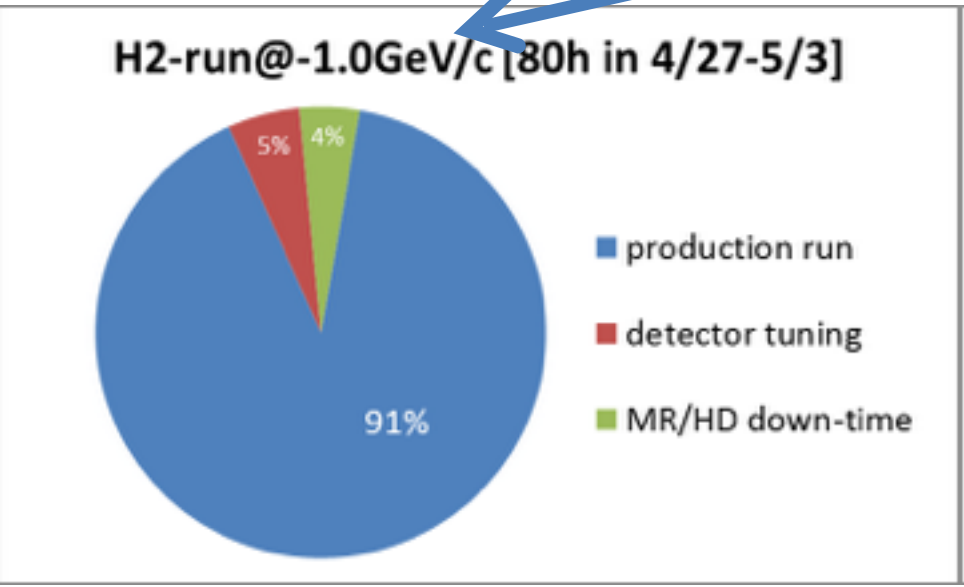
** ~70% of beam kaons hit the fiducial volume of ^{3}He target*

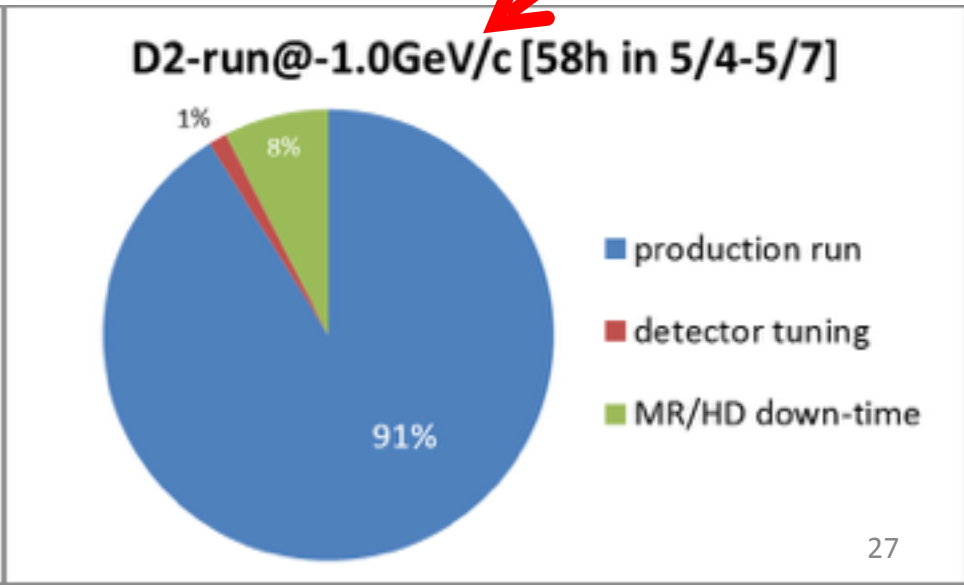
Execution Summary Beam-time @ RUN#62

Commissioning run

- Beam-line tuning
  - 7.0h
- -0.9GeV/c K w/ H2
  - 2.6h
- -1.1GeV/c K w/ H2
  - 6.4h
- -1.0GeV/c K
  - 8.3h







Publication(s) from the E15 1st

Semi-inclusive ^{3}He(K$^-$,n)X

T.Hashimoto et al.,
PTEP(2015)061D01

PTEP

Prog. Theor. Exp. Phys. 2015, 061D01 (11 pages)
DOI: 10.1093/ptep/ptv076

Letter

Search for the deeply bound $K^- pp$ state from the semi-inclusive forward-neutron spectrum in the in-flight K^- reaction on helium-3

J-PARC E15 Collaboration

T. Hashimoto[1,*,†], S. Ajimura[2], G. Beer[3], H. Bhang[4], M. Bragadireanu[5], L. Busso[6,7], M. Cargnelli[8], S. Choi[4], C. Curceanu[9], S. Enomoto[2], D. Faso[6,7], H. Fujioka[10], Y. Fujiwara[1], T. Fukuda[11], C. Guaraldo[9], R. S. Hayano[1], T. Hiraiwa[2], M. Iio[12], M. Iliescu[9], K. Inoue[13], Y. Ishiguro[10], T. Ishikawa[1], S. Ishimoto[12], K. Itahashi[14], M. Iwai[12], M. Iwasaki[14,15], Y. Kato[14], S. Kawasaki[13], P. Kienle[16,‡], H. Kou[15], Y. Ma[14], J. Marton[8], Y. Matsuda[17], Y. Mizoi[11], O. Morra[6], T. Nagae[10], H. Noumi[2],

Exclusive ^{3}He(K$^-$,Λp)n

Y.Sada et al.,
paper in preparation

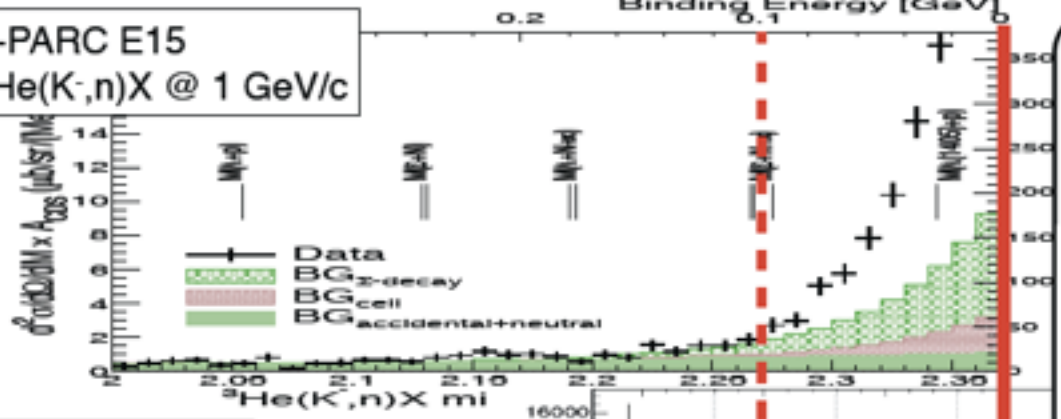
PTEP

Prog. Theor. Exp. Phys. 2015, 00000 (11 pages)
DOI: 10.1093/ptep/0000000000

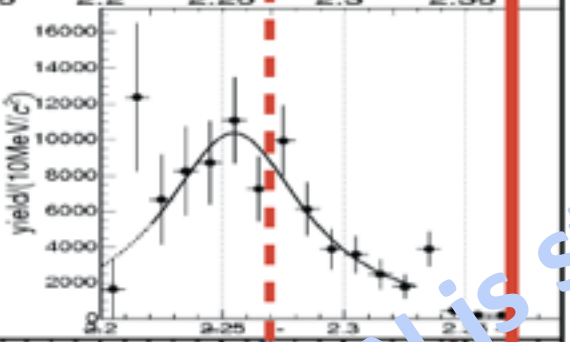
Search for S=-1 di-baryonic state on $K^- pp$ threshold

Y. Sada[1], S. Ajimura[1], G. Beer[2], H. Bh[illegible], M. [illegible]agadireanu[4], P. Buehler[5], L. Busso[6,9], M. Cargnelli[5], S. Choi[3], C. C[illegible]eanu[4], S. Enomoto[8], D. Faso[6,9], H. Fujioka[10], Y. Fujiwara[11], T. Fu[illegible][12], [illegible] Guaraldo[7], T. Hashimoto[11], R. S. Hayano[11], T. Hiraiwa[1], [illegible] Ii[illegible], [illegible]escu[7], K. Inoue[13], Y. Ishiguro[10], T. Ishikawa[11], S. Ishimoto[illegible] T[illegible]shi[illegible]tari[5], K. Itahashi[14], M. Iwai[8], M. Iwasaki[15,14], Y. Kato[14], S. Kawa[illegible], P. [illegible][16], H. Kou[15], Y. Ma[14], J. Marton[5], Y. Matsuda[17], Y. M[illegible]oi[12], O. [illegible]orra[6], T. Nagae[10], H. Noumi[1], H. Ohnishi[14], S. Okada[14], H. Outa[illegible], F. Pisicchia[7], M. Poli Lener[7], A. Romero Vidal[7], A. Sakaguchi[13], F. Sakuma[14], M. Sato[14], A. Scordo[7], M. Sekimoto[8], H. Shi[18], D. Sirghi[18], F. Sirghi[18], K. Suzuki[18], S. Suzuki[8], T. Suzuki[11], K. Tanida[3],

J-PARC E15
^{3}He(K$^-$,n)X @ 1 GeV/c

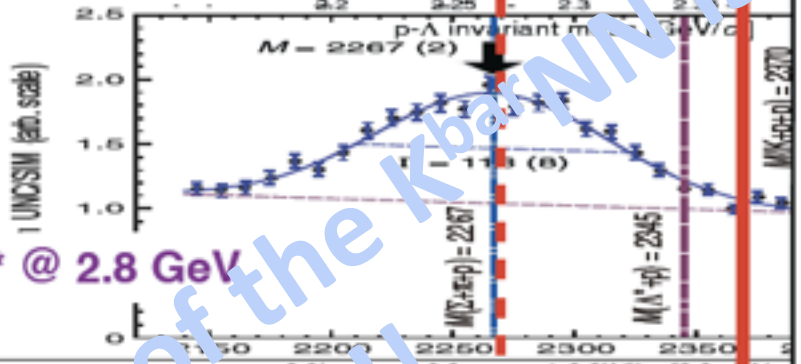


FINUDA
(stopped K$^-$, Λp)



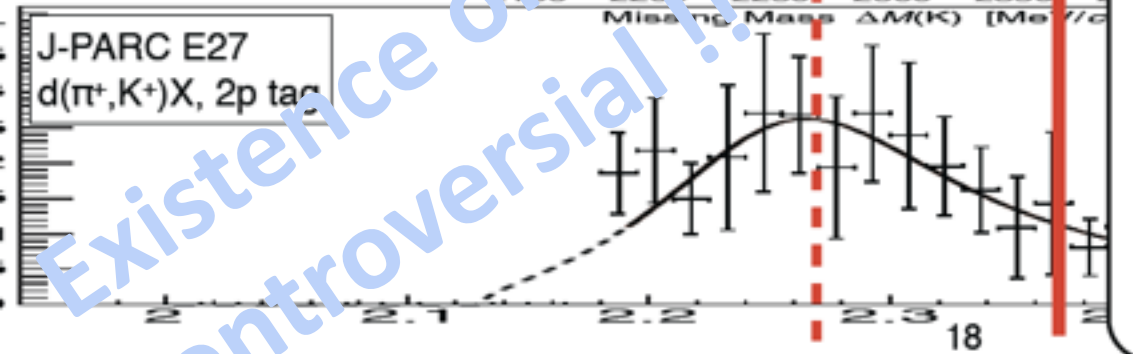
~ 0.1% of stopped K$^-$

DISTO
pp→ΛpK$^+$

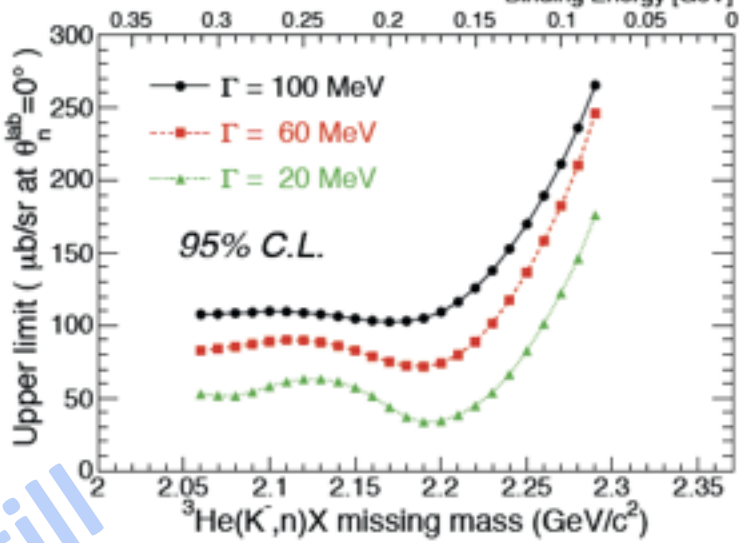


larger than Λ* @ 2.8 GeV

J-PARC E27
d(π$^+$,K$^+$)X, 2p tag



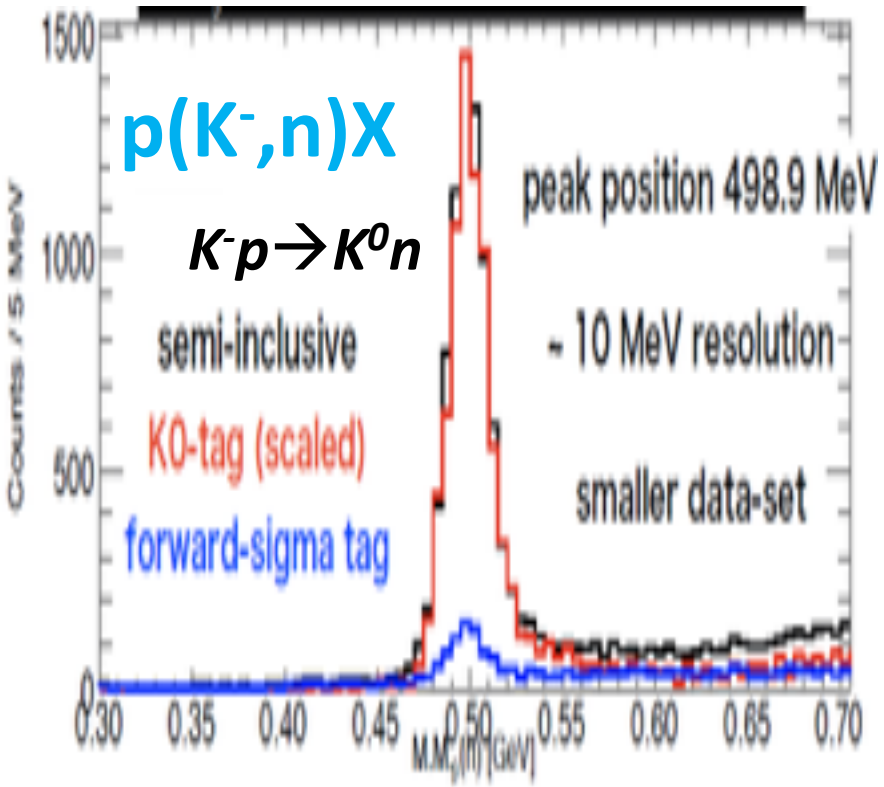
Existence of the K$^-$pnn is still controversial !!

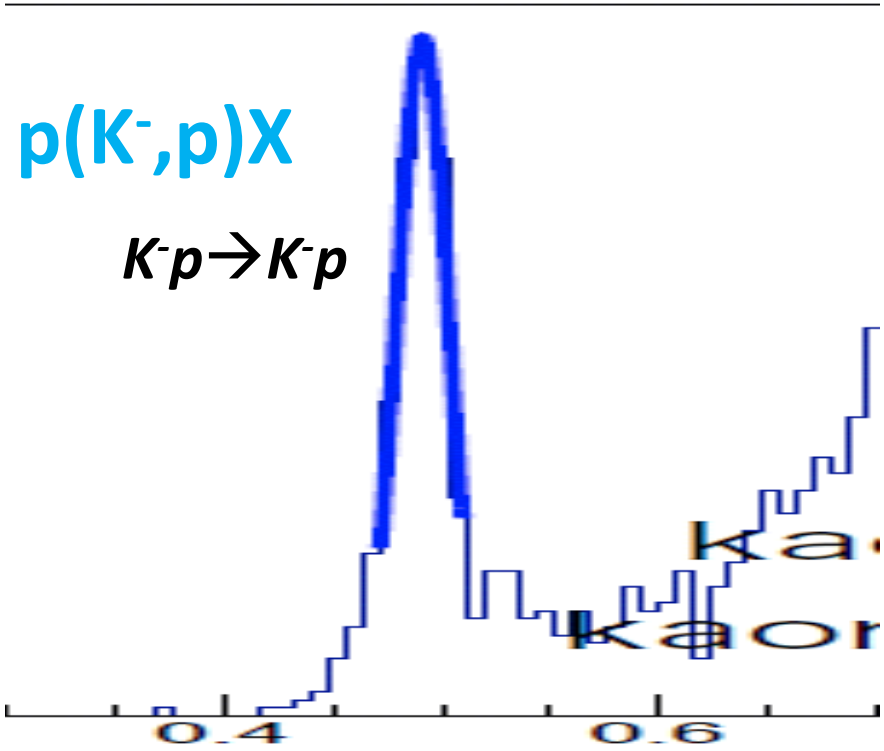


Assumptions
Intrinsic peak shape: Breit-Wigner
Decay mode: **K$^-$pp→Λp 100%** (isotropic decay)

- **J-PARC E15 (U.L.)**
  30 ~ 300 μb/sr @ 0 deg.
  0.5 - 5% of quasi-elastic
  smaller than usual hypernucleus sticking
- **LEPS (γ+d) (U.L.)**
  1.5-26% of γN→K$^+$π$^-$Y
- **HADES (pp @ 3.5 GeV)**
  0.7-4.2 μb (Λ* ~ 10 μb)

(K^-,p) Calibration with H2-target





- Calibration of (K^-,p) measurement has also been done
  - calibration for ^{3}He(K^-,p) analysis
- Analysis of ^{3}He(K^-,n/p) isospin-dependence is in progress

Approved Beam-time at 18th-PAC

Beam-time Plan @ K1.8BR

1 GeV/c K^- yield = 140 k/spill (=Run49c) *previously achieved value*

May, 2013 (Run#49c)	24 kW (30 Tppp, 6s)	140 k/spill	88 h	5.1 x 10^9

1. Commissioning run
   - **~1 day**
2. Calibration run with H2-target
   - **~4 days** → $p(K^-,K^0)n_{forward}$: ~5×10^3 *corrected*
3. E31 pilot run with D2-target
   - $14*10^9$ kaons on target = **~10 days**
4. E15 2nd-stage production run with ^{3}He-target
   - $50*10^9$ kaons on target = **~40 days**

--- Report from 18th PAC ---

"The beam request of the 2nd stage is reasonable and necessary to further study the K-pp system, and supports the beam request." 5

Thank you for attention!