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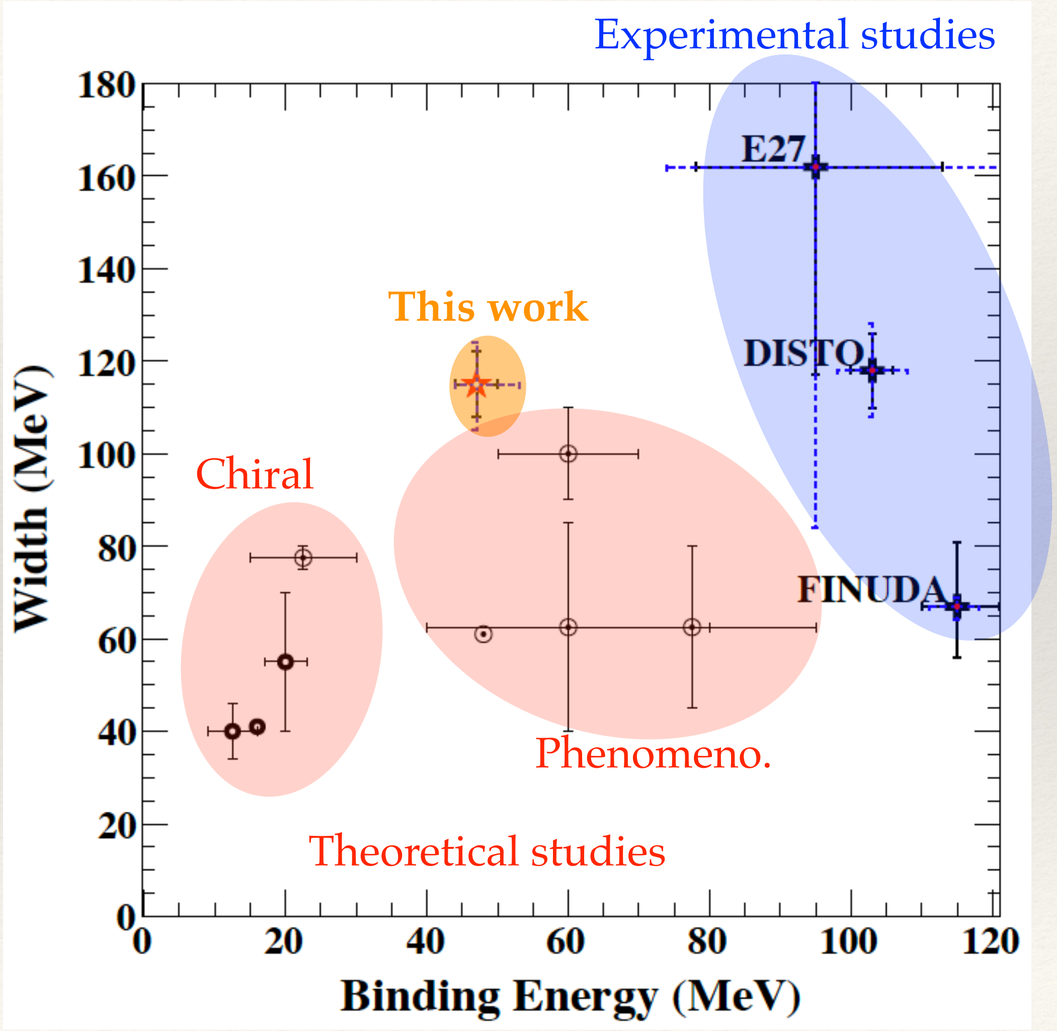
INPC2019 @ Glasgow

Result of KbarNN search via exclusive (K^-, n) reaction at J-PARC

Takumi Yamaga, RIKEN
For the E15 collaboration

Investigations of KbarNN

- The simplest kaonic nucleus.
  - A quasi-bound state of anti-kaon and nucleus
- Information of KbarN interaction below the threshold
  - B.E. & Γ
- Our recent result agree with theoretical expectation.
  - Further understanding of the KbarN interaction

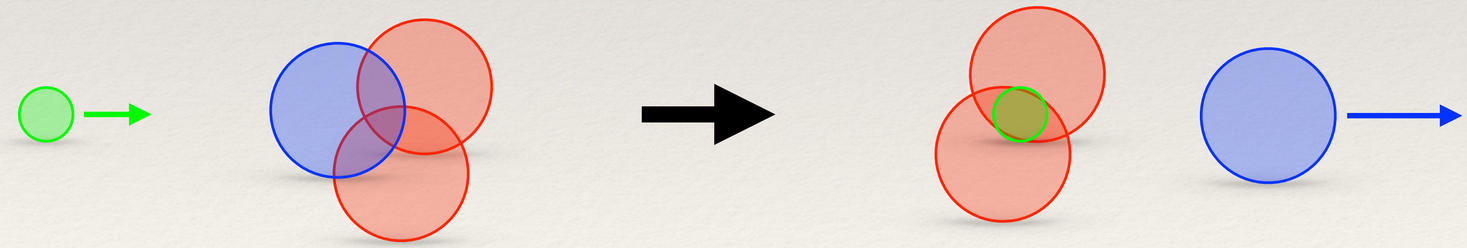


J-PARC E15 experiment

In-flight (K-, n) reaction to generate KbarNN bound state

$$p_K = 1 \text{ GeV}/c$$

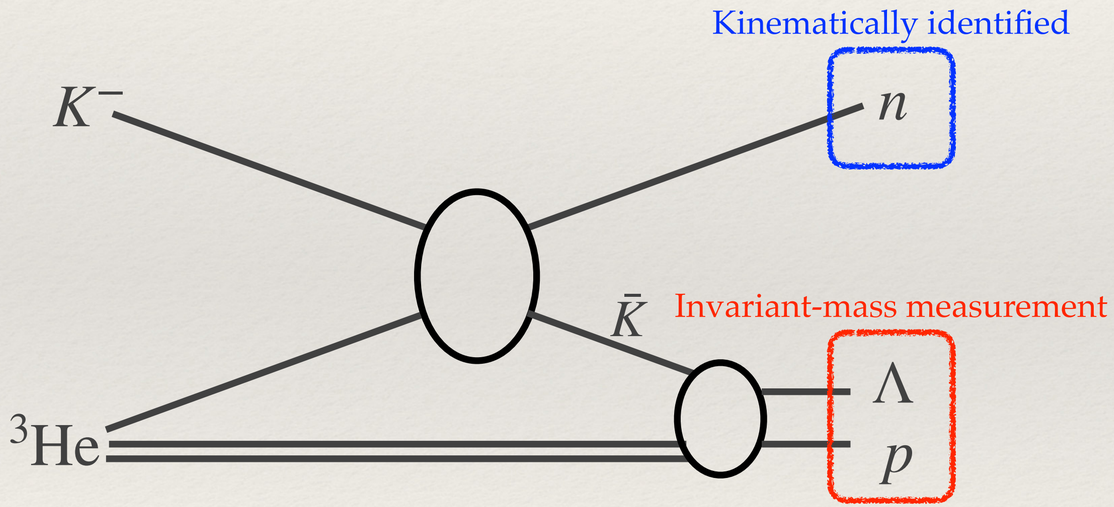
$$K^- + {}^3\text{He} \rightarrow K^- pp + n$$



Analyzed modes

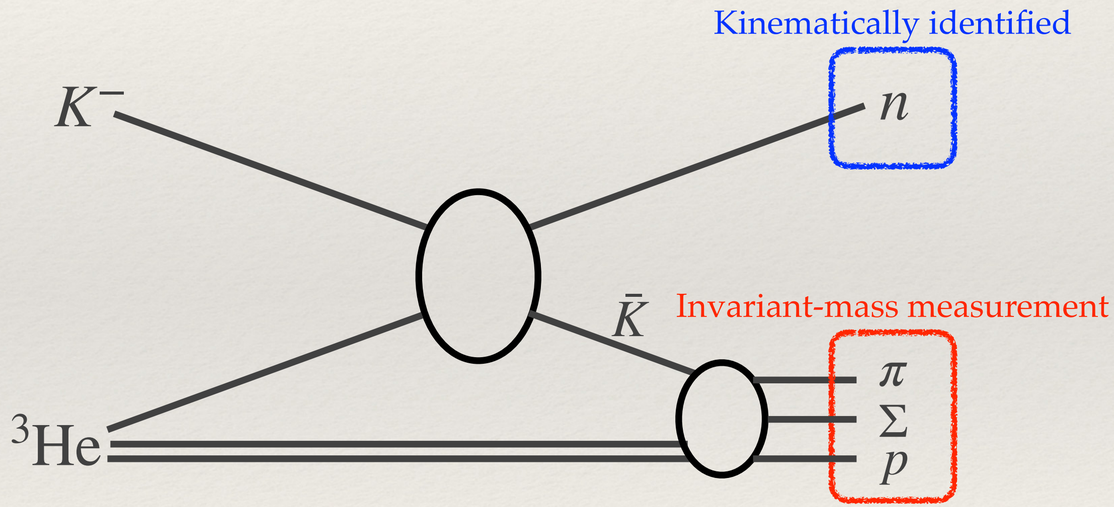
Measured exclusive channels

$$K^- + {}^3\mathrm{He} \rightarrow \Lambda p + n$$



Detected particles : $pp\pi^-$

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

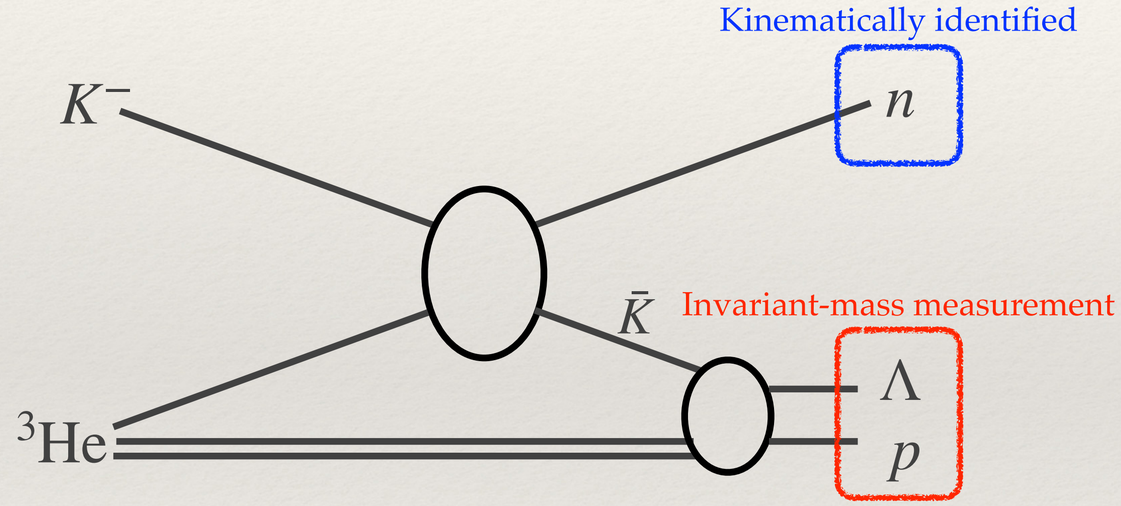


Detected particles : $np\pi^+\pi^-$

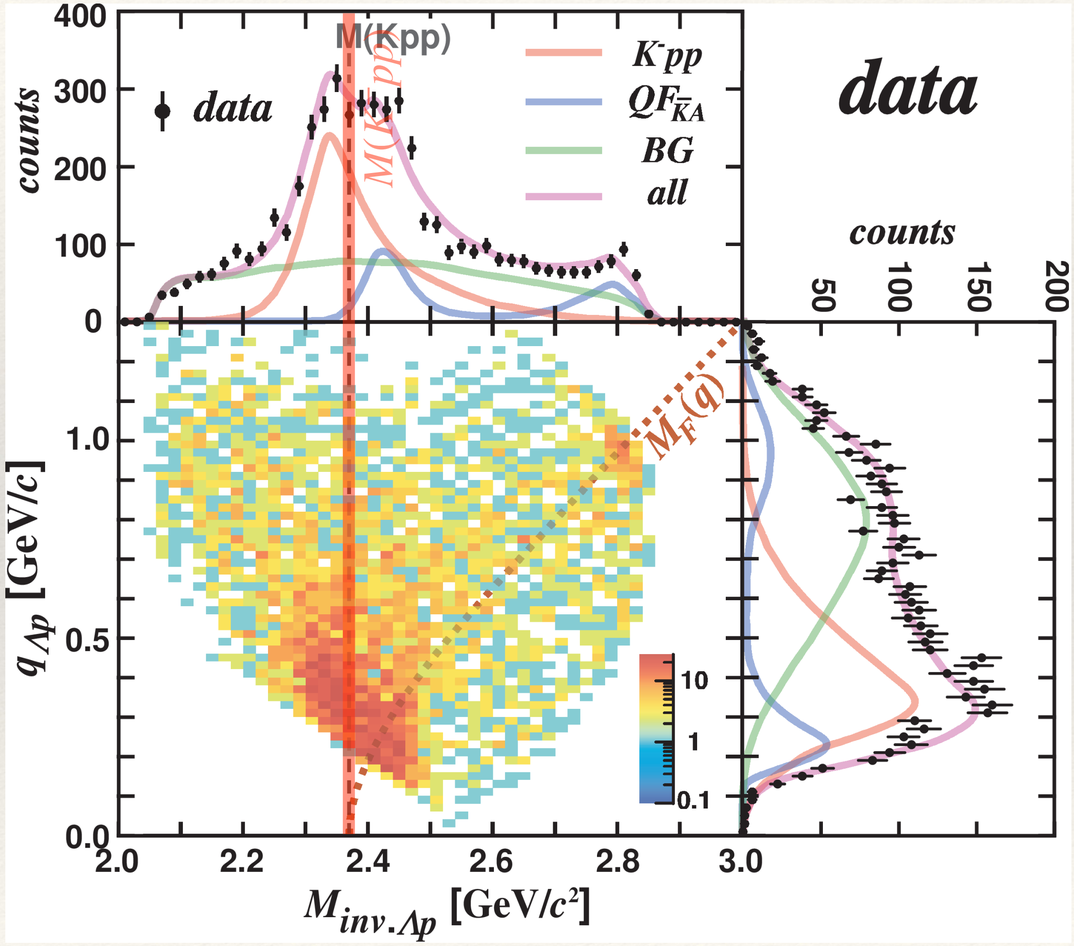
! Neutral particle detection by CDS

Result of Λpn analysis

$$K^- + {}^3\mathrm{He} \rightarrow \Lambda p + n$$

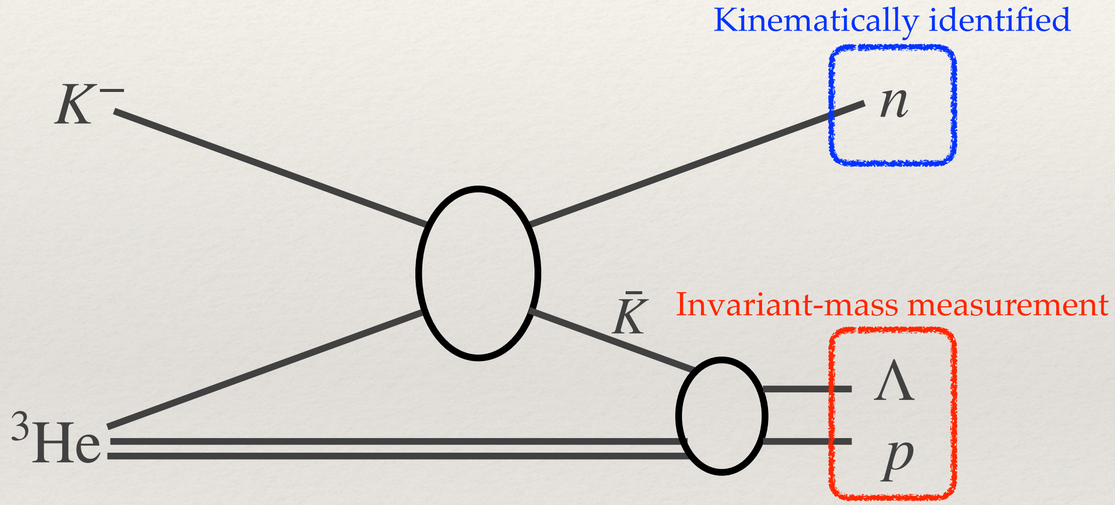


- Decomposed into 3 components
  - Well reproduced



Result of Λpn analysis

$$K^- + {}^3\mathrm{He} \rightarrow \Lambda p + n$$

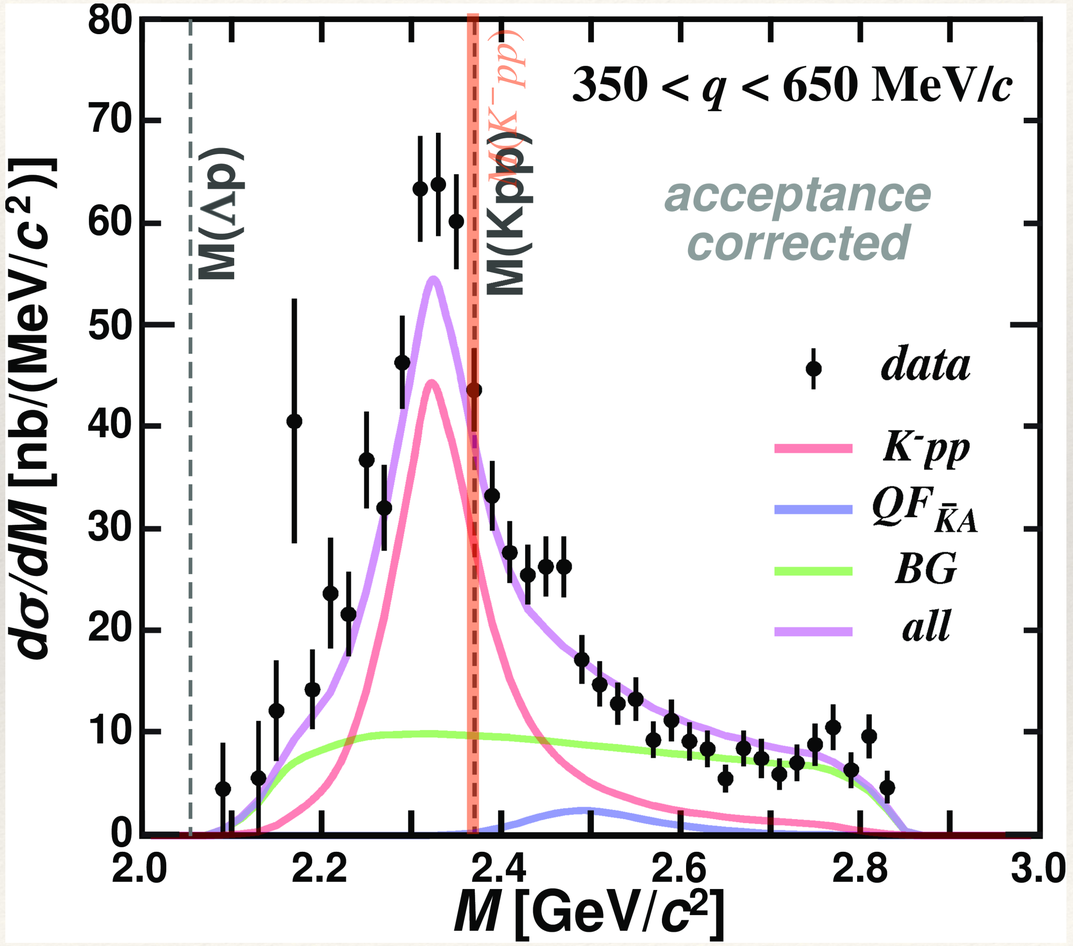


- Observation of KbarNN

$$B.E. = 47 \pm 3(\mathrm{stat.})^{+3}_{-6}(\mathrm{syst.})\ \mathrm{MeV}$$

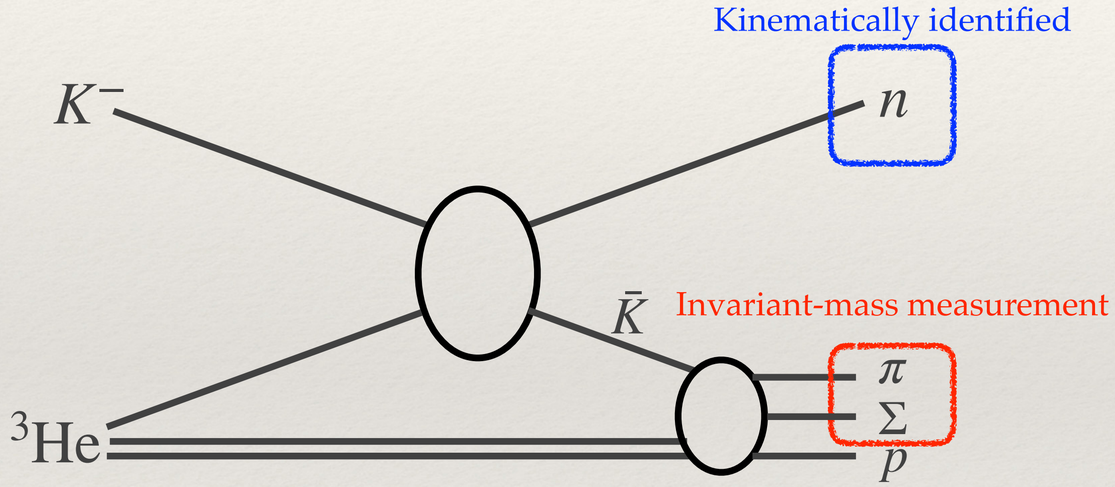
$$\Gamma = 115 \pm 7(\mathrm{stat.})^{+10}_{-20}(\mathrm{syst.})\ \mathrm{MeV}$$

Physics Letters B 789 (2019) 620

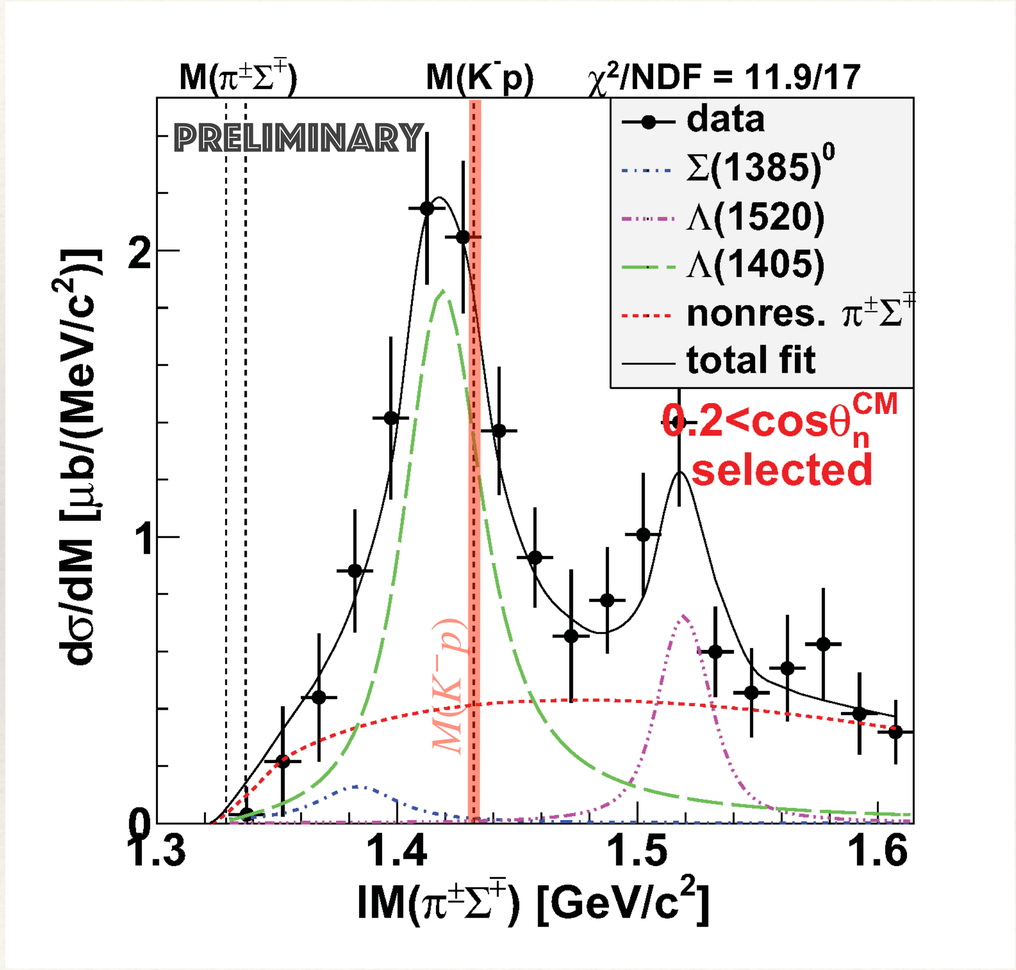


Result of πΣpn analysis

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

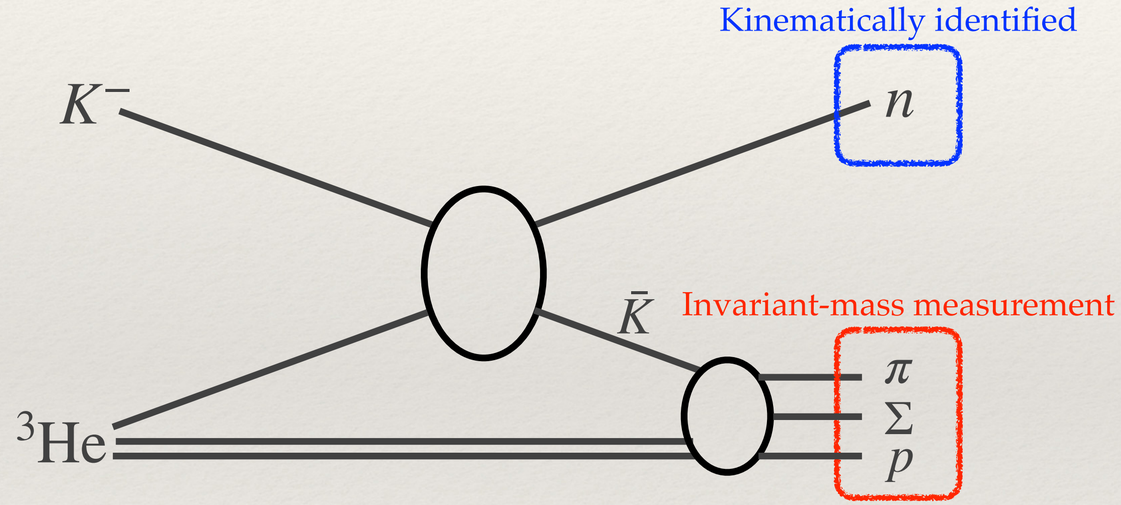


- Y* production clearly observed
  - Λ*-prod. is much larger than Σ*-prod.

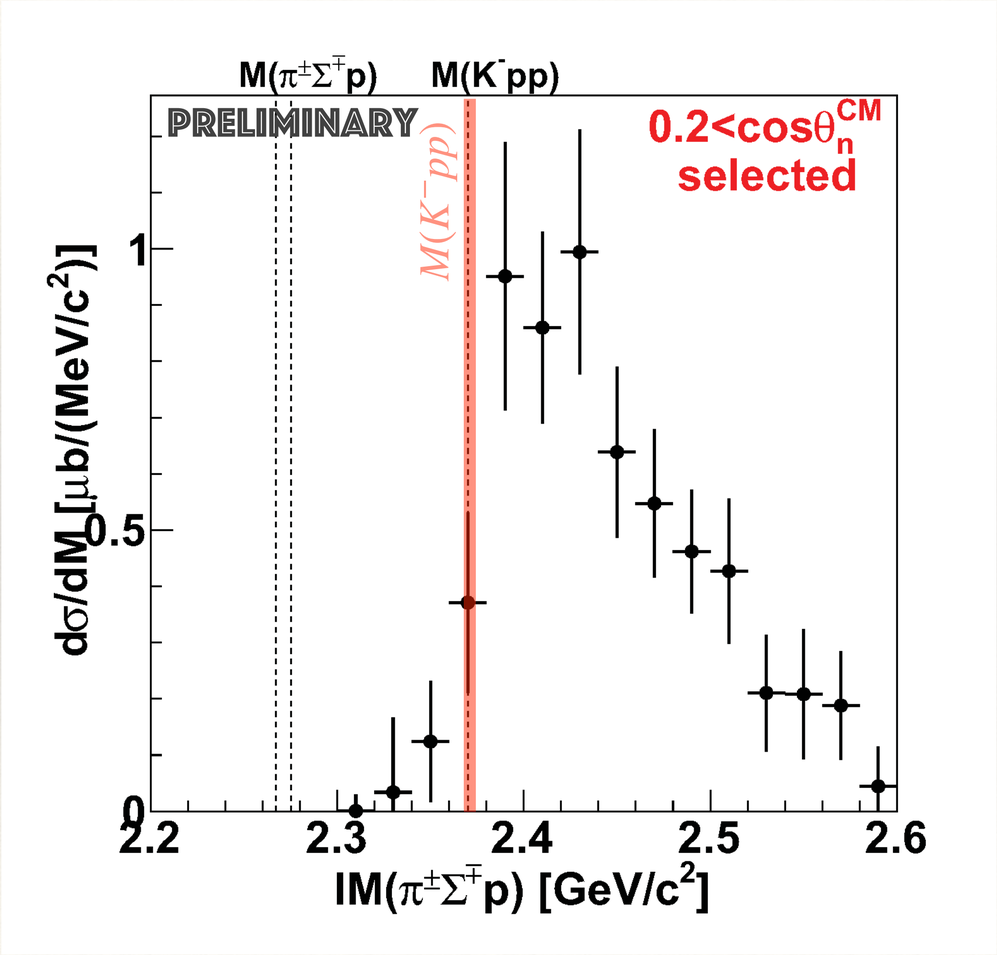


Result of πΣpn analysis

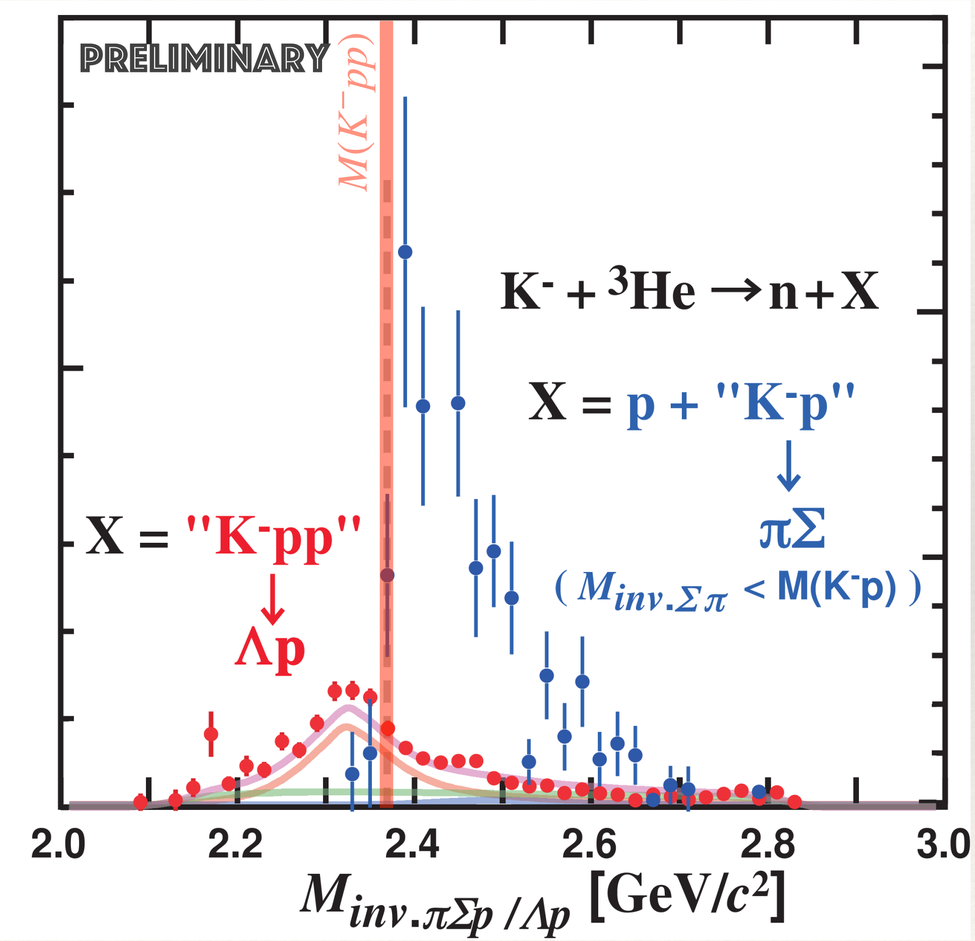
$$K^- + {}^3\mathrm{He} \rightarrow \pi\Sigma p + n$$

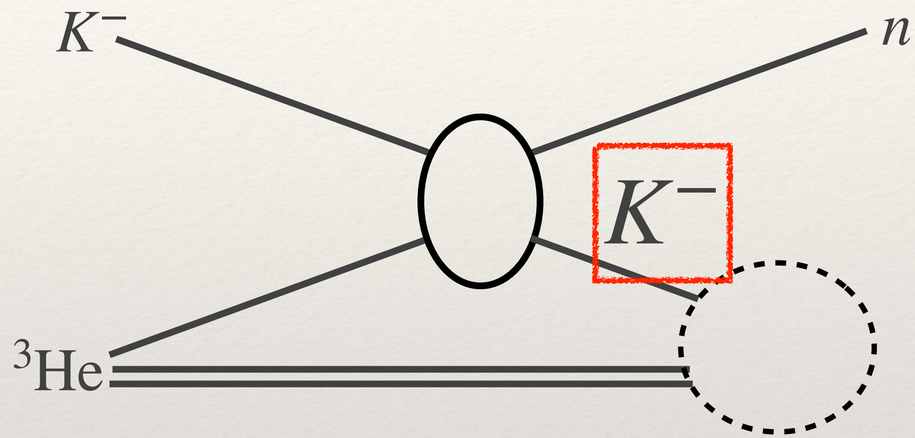


- Almost events are above threshold.
  - QF-Y* production does not make any structure below the threshold.



Comparison between Λpn & πΣpn

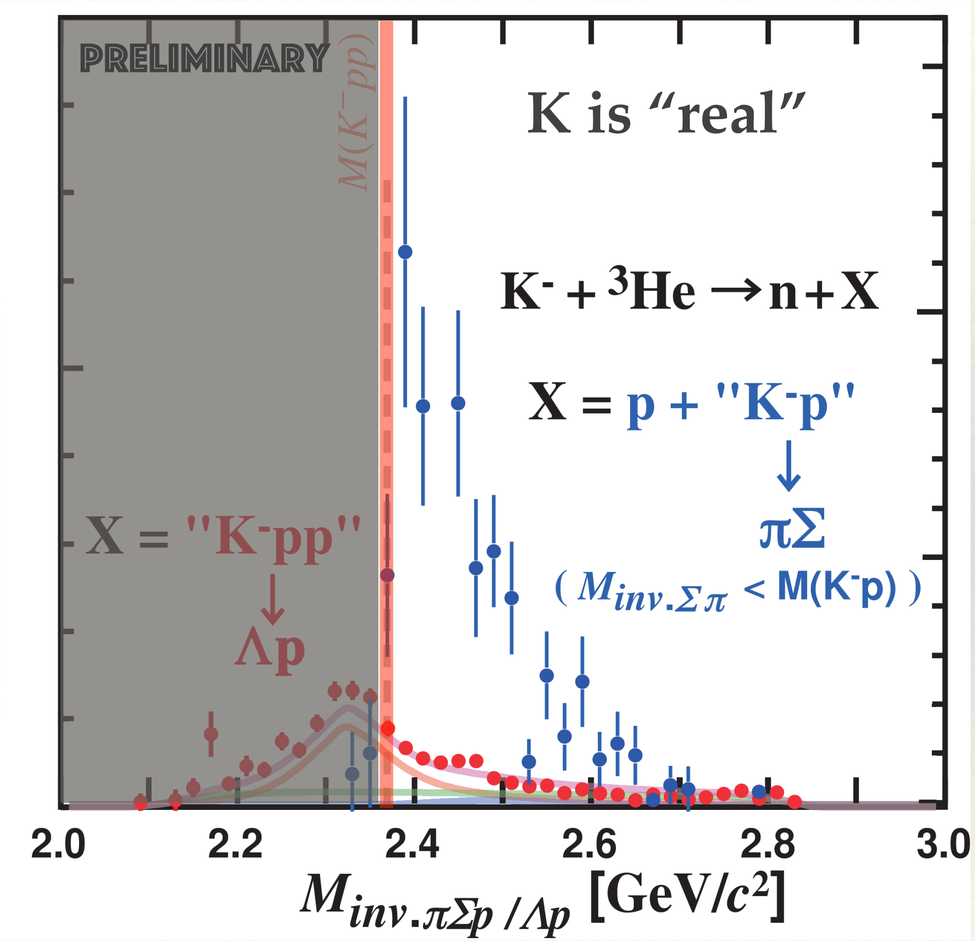




Above the threshold (real-K)

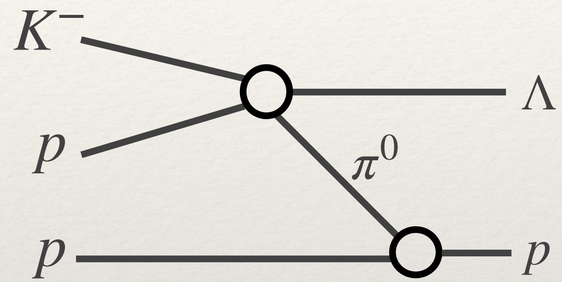
Below the threshold (virtual-K)

Comparison between Λpn & πΣpn



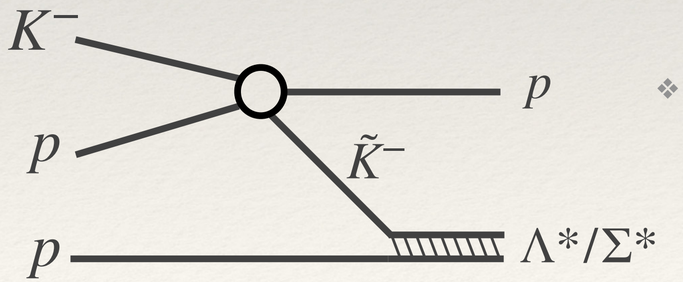
Above the threshold (real-K)

$K^- + {}^3\mathrm{He} \rightarrow \Lambda p + n$



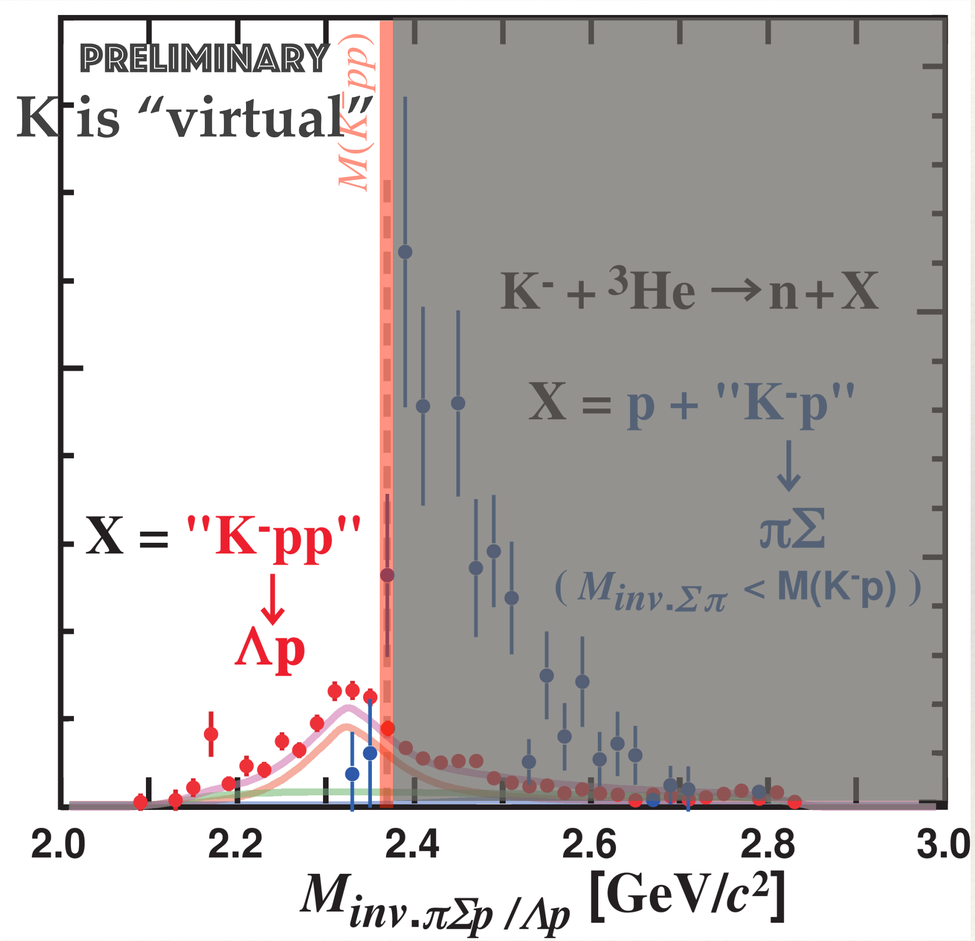
- Much smaller than mesonic mode
  - Pion absorption is necessary.

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



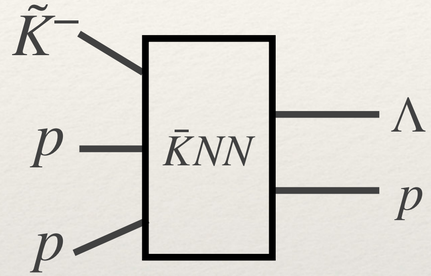
- Enhancement by Y* production
  - Λ* >> Σ* was observed.

Comparison between Λpn & πΣpn



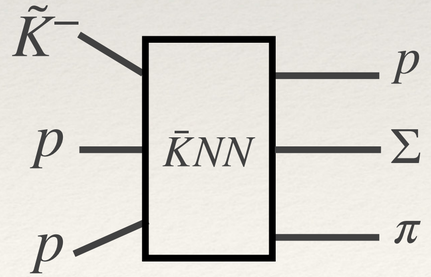
Below the threshold (virtual-K)

$$K^- + {}^3\mathrm{He} \rightarrow \Lambda p + n$$



- Enhancement of KbarNN production
  - Σ* contribution should be small.
    - From the result of mesonic mode

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



- Much smaller than non-mesonic mode
  - Due to phase space limitation
- Y* production should be small.

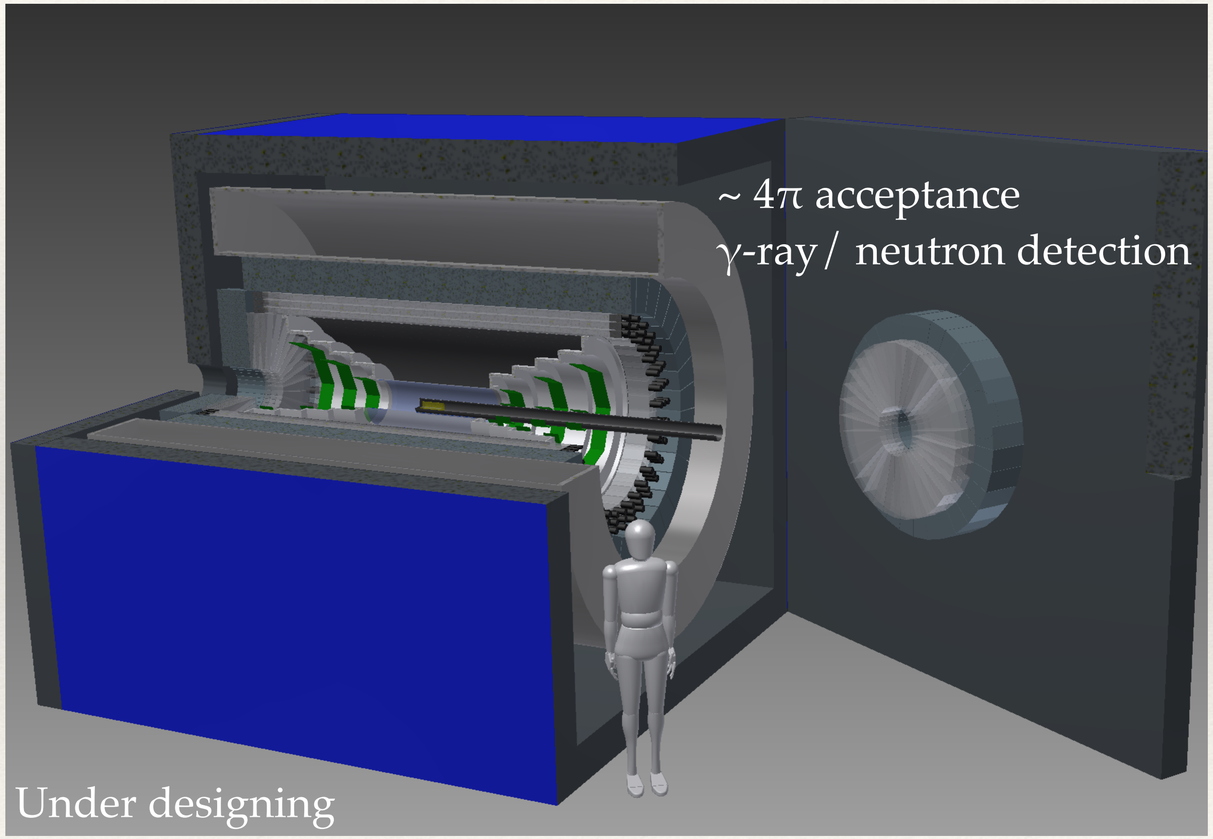
Conclusion

- We have been performed experiment with (K-, n) reaction.
  - In Λpn channel
    - We observed Clear signal from KbarNN.
      - $B.E. = 47 \pm 3(\mathrm{stat.})^{+3}_{-6}(\mathrm{syst.})$ MeV
      - $\Gamma = 115 \pm 7(\mathrm{stat.})^{+10}_{-20}(\mathrm{syst.})$ MeV
  - In $\pi\Sigma$pn channel
    - We observed Y* production in 3He(K-, n) reaction at first time in IM($\pi\Sigma$) spectrum.
      - Y* is produced by on-shell scatted kaon in the first (K^-, n) reaction.
    - KbarNN signal cannot be distinguished due to small phase space even if it's the main decay mode.
- Our results make further understanding about KbarN interaction and kaonic nuclei.
  - Theoretical calculations are desired to develop the understanding.

Further investigation

- To establish KbarNN,
  - Σp decay mode
    - Need γ-ray detection
  - Spin-Parity
    - Need more careful discussion…
- Beyond KbarNN,
  - KbarNNN / KbarNNNN / ….
    - Need large acceptance
    - Need neutron detection

New CDS



Thank you for your attention

J-PARC E15 collaboration

S. Ajimura[1], H. Asano[2], G. Beer[3], C. Berucci[4], H. Bhang[5], M. Bragadireanu[6], P. Buehler[4], L. Busso[7,8], M. Cargnelli[4], S. Choi[5], C. Curceanu[9], S. Enomoto[10], H. Fujioka[11], Y. Fujiwara[12], T. Fukuda[13], C. Guaraldo[9], T. Hashimoto[14], R. S. Hayano[12], T. Hiraiwa[1], M. Iio[10], M. Iliescu[9], K. Inoue[1], Y. Ishiguro[15], T. Ishikawa[12], S. Ishimoto[10], K. Itahashi[2], M. Iwasaki[2,11],* K. Kanno[12], K. Kato[15], Y. Kato[2], S. Kawasaki[1], P. Kienle[16],† H. Kou[11], Y. Ma[2], J. Marton[4], Y. Matsuda[12], Y. Mizoi[13], O. Morra[7], T. Nagae[15], H. Noumi[1], H. Ohnishi[17,2], S. Okada[2], H. Outa[2], K. Piscicchia[9], Y. Sada[1], A. Sakaguchi[1], F. Sakuma[2],‡ M. Sato[10], A. Scordo[9], M. Sekimoto[10], H. Shi[9], K. Shirotori[1], D. Sirghi[9,6], F. Sirghi[9,6], K. Suzuki[4], S. Suzuki[10], T. Suzuki[12], K. Tanida[14], H. Tatsuno[18], M. Tokuda[11], D. Tomono[1], A. Toyoda[10], K. Tsukada[17], O. Vazquez Doce[9,16], E. Widmann[4], T. Yamaga[2,1],§ T. Yamazaki[12,2], Q. Zhang[2], and J. Zmeskal[4]

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[18] *Lund University, Lund, 221 00, Sweden*

Backup

Theoretical studies

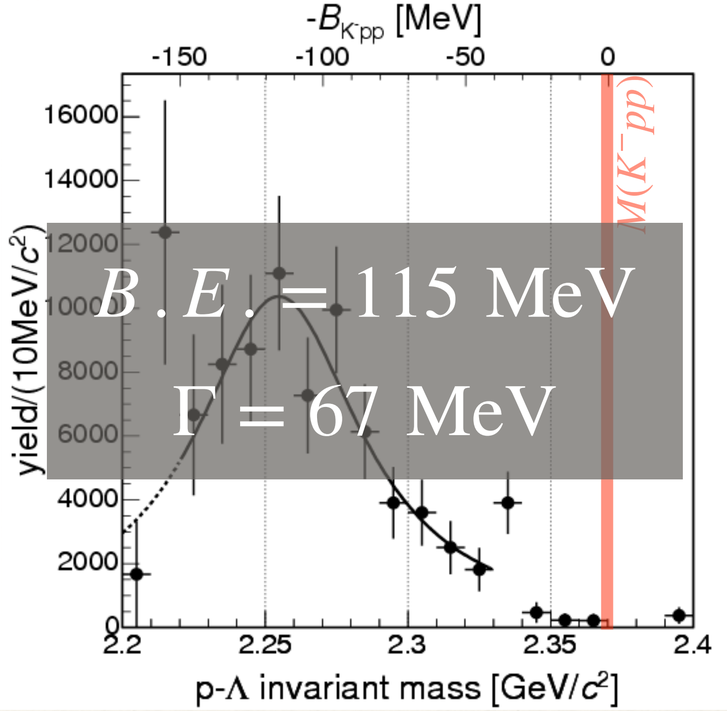
From F. Sakuma NFQCD2018 slide

KbarN interaction	**Chiral SU(3)**			**Phenomenological**			
Method	Variational		Faddeev	Variational		Faddeev	
	Barnea, Gal, Liverts	Dote, Hyodo, Weise	Ikeda, Kamano, Sato	Yamazaki, Akaishi	Wyceck, Green	Shevchenko, Gal, Mares	Ikeda, Sato
B.E. (MeV)	16	17 - 23	9 - 16	48	40 - 80	50 - 70	60 - 95
Width (MeV)	41	40 - 70	34 - 46	61	40 - 85	90 - 110	45 - 80

Experimental studies :: Stopped K-

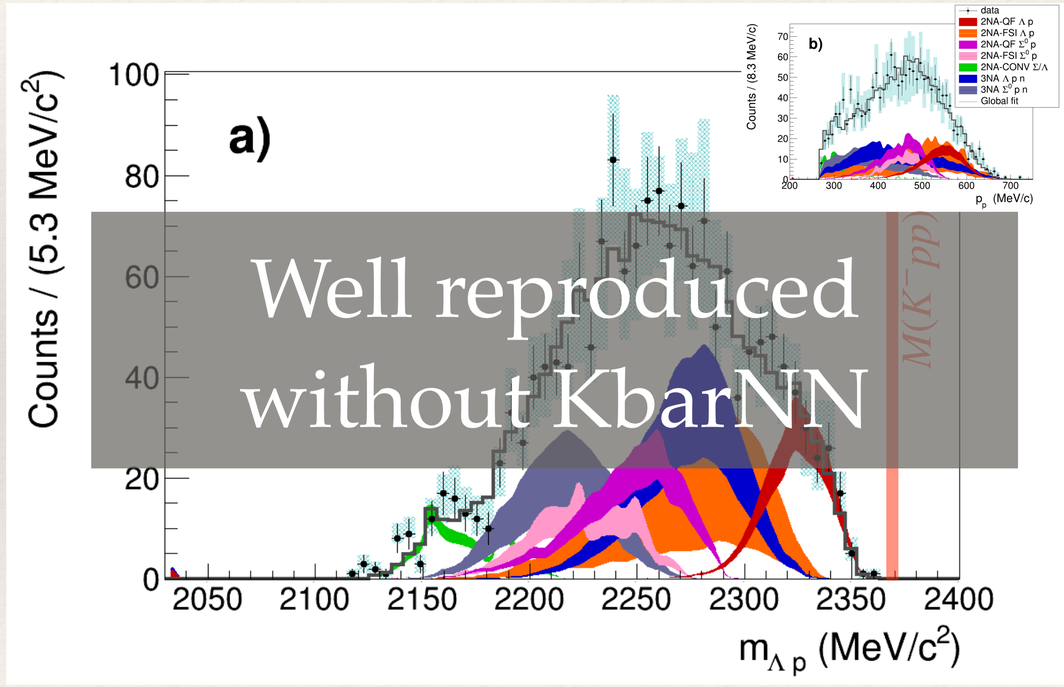
$A(\mathit{stopped}\ K^-, \Lambda p)$

FINUDA@DAΦNE



PRL94(2005) 132502

AMADEUS@DAΦNE



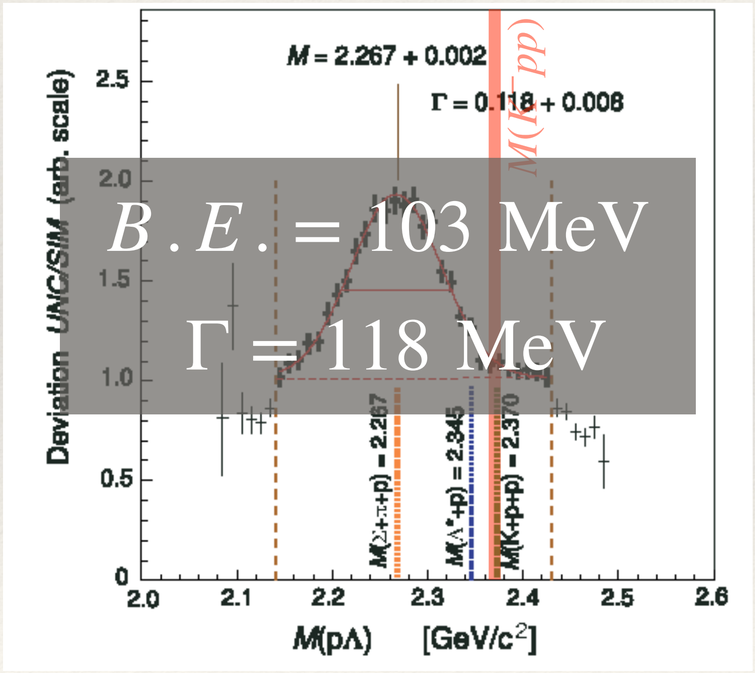
arXiv:1809.07212

Experimental studies :: pp collison

$$p + p \rightarrow \Lambda p + K^{+}$$

@ 2.85 GeV

DISTO@SATURNE



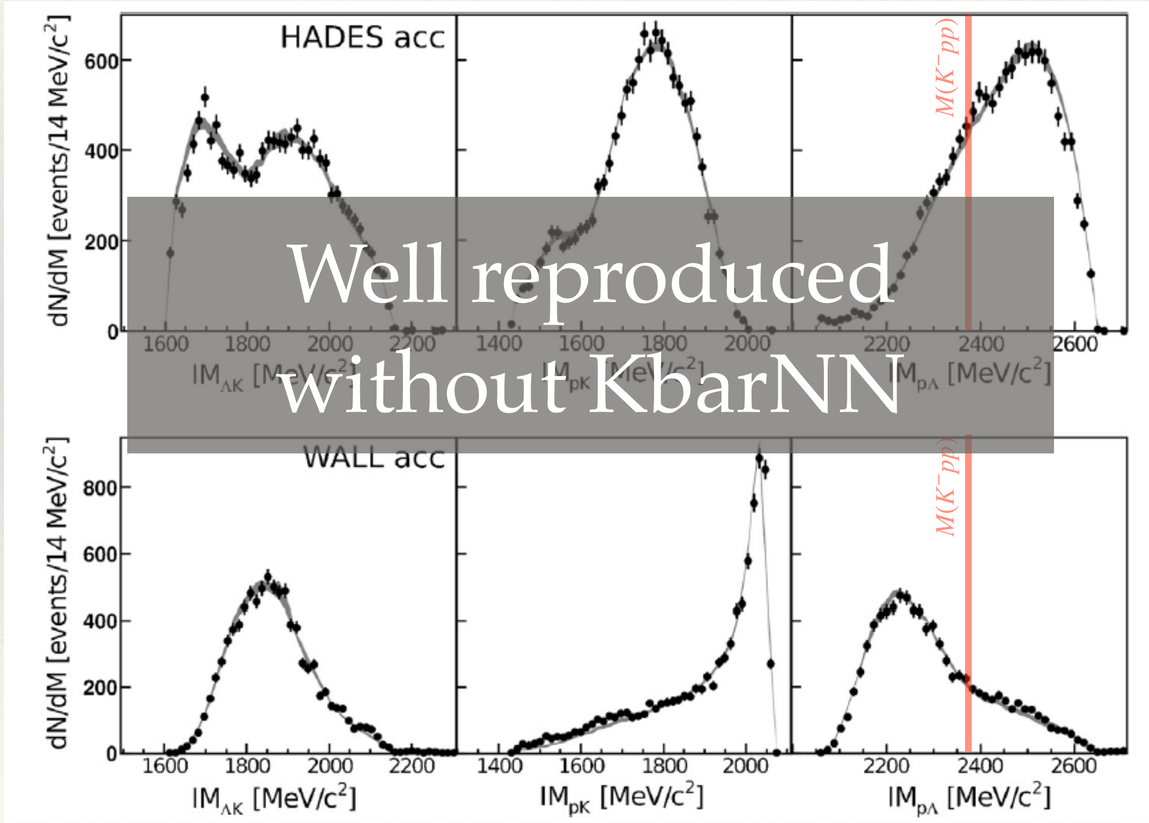
$B.E. = 103$ MeV

$\Gamma = 118$ MeV

PRL104(2010) 132502

@ 3.5 GeV

HADES@GSI



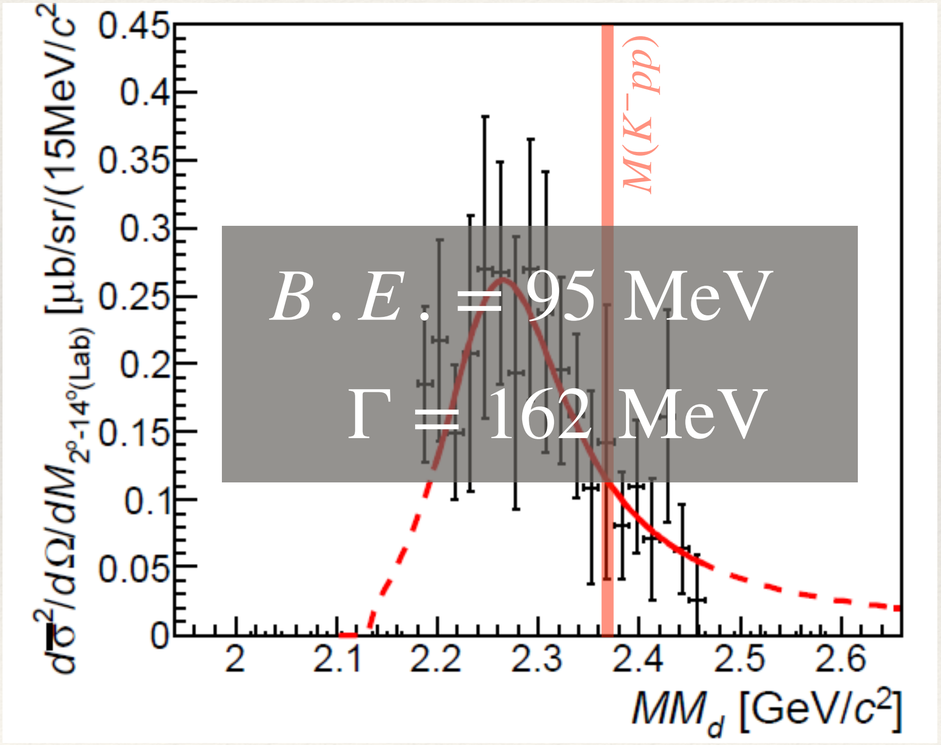
Well reproduced without KbarNN

PLB742(2015) 242

Experimental studies :: (π^-, K^+) & $(\gamma, K^+\pi^-)$ reactions

$$d(\pi^-, K^+)Yp$$

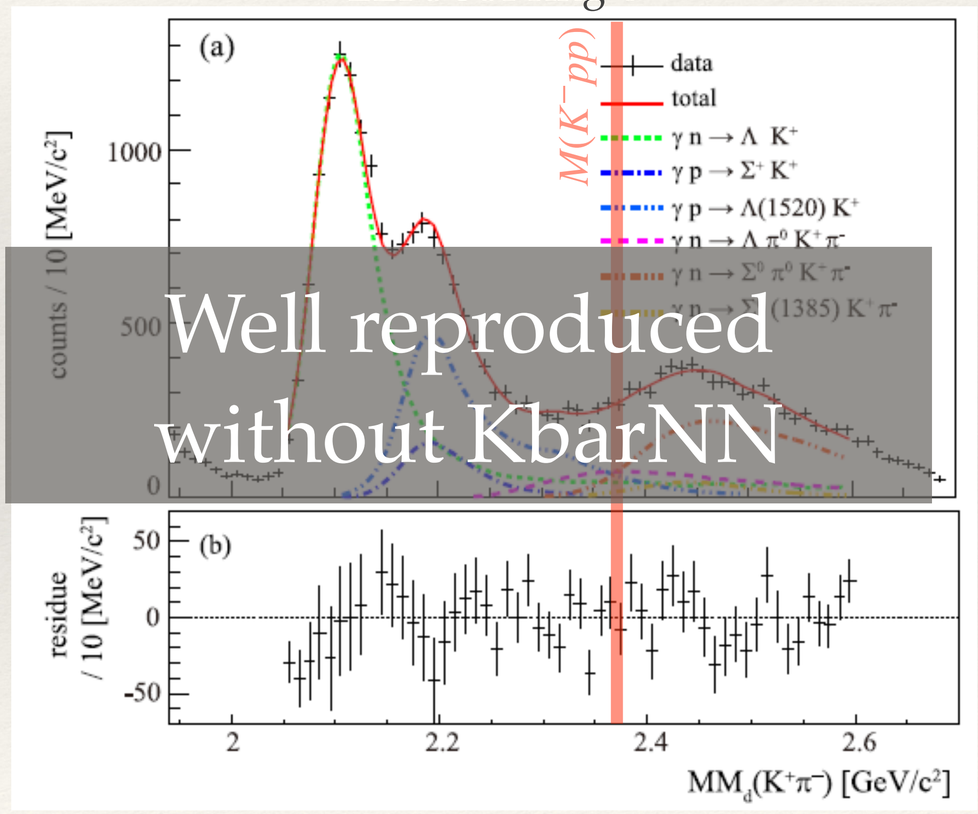
E27@J-PARC



PTEP(2015) 021D01

$$d(\gamma, \pi^- K^+)X$$

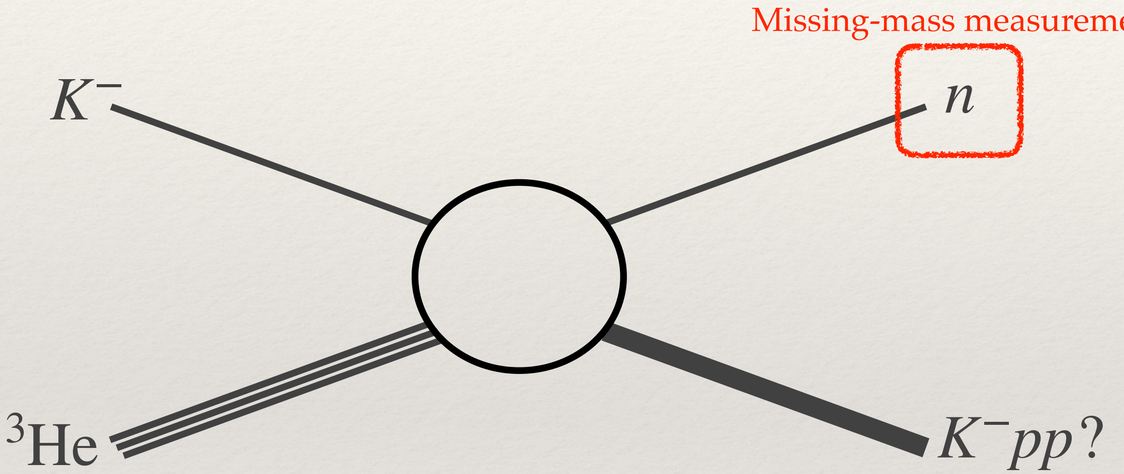
LEPS@SPring-8



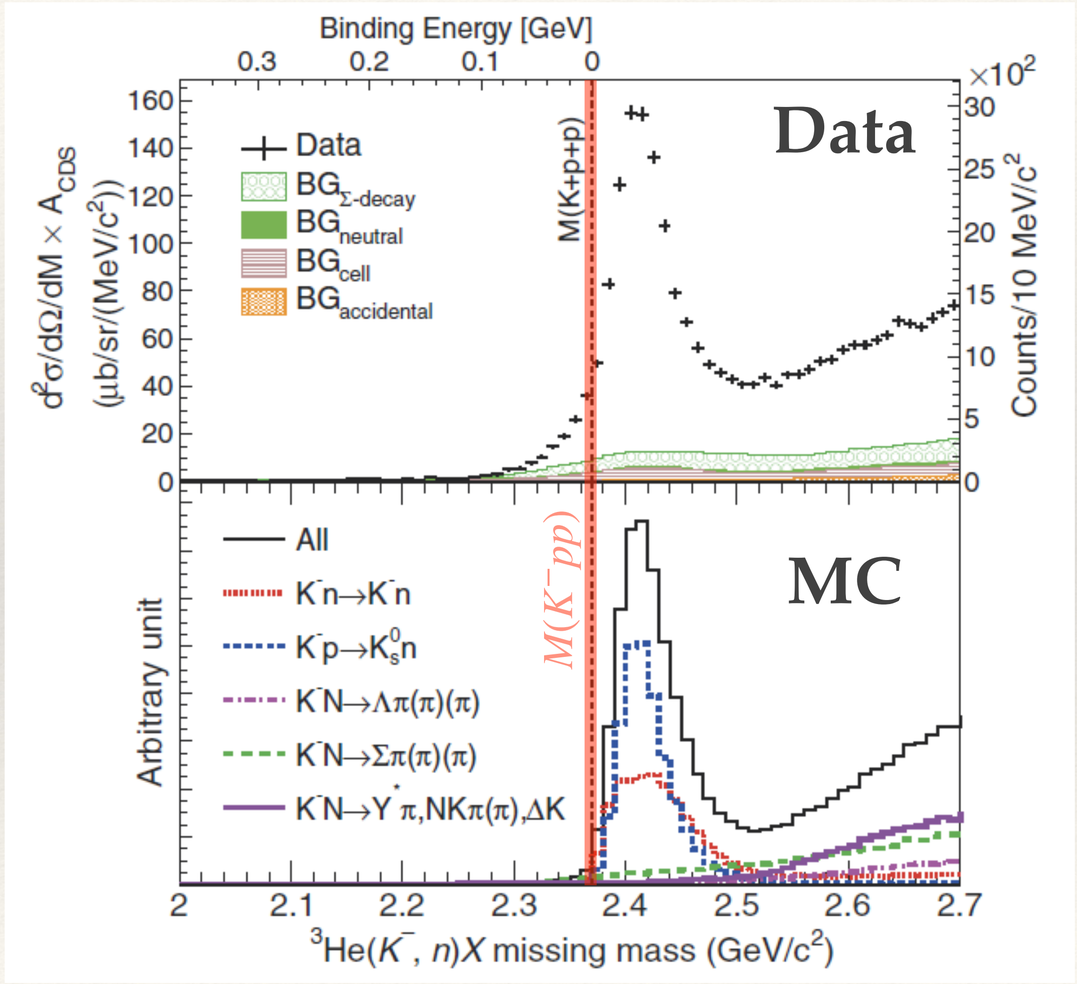
PLB 728 (2014) 616

Results of E15 - 1st

Semi-inclusive analysis of $^3\mathrm{He}(K^-, n)$



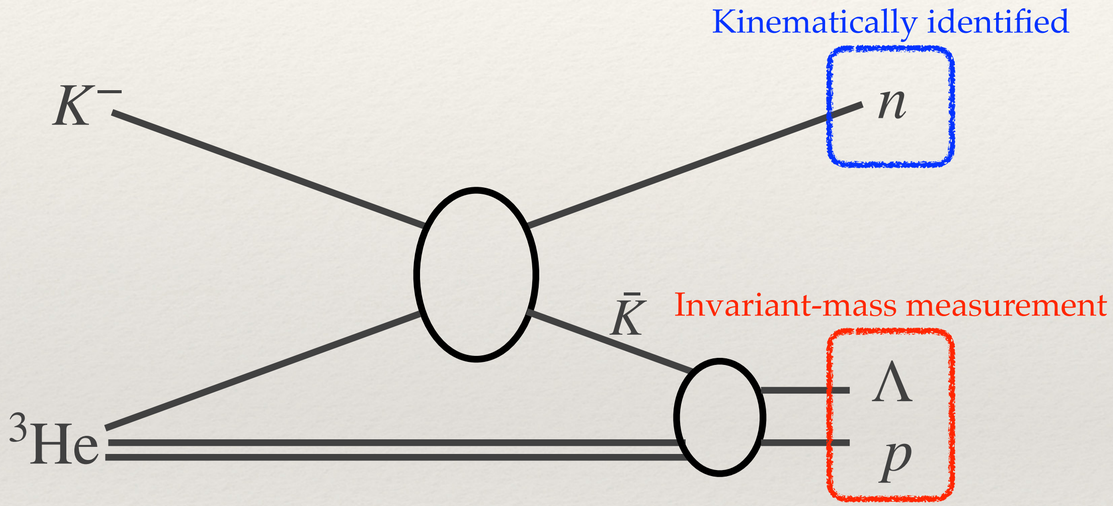
- Strong QF peak above M(Kpp)
- No clear peak below M(Kpp)



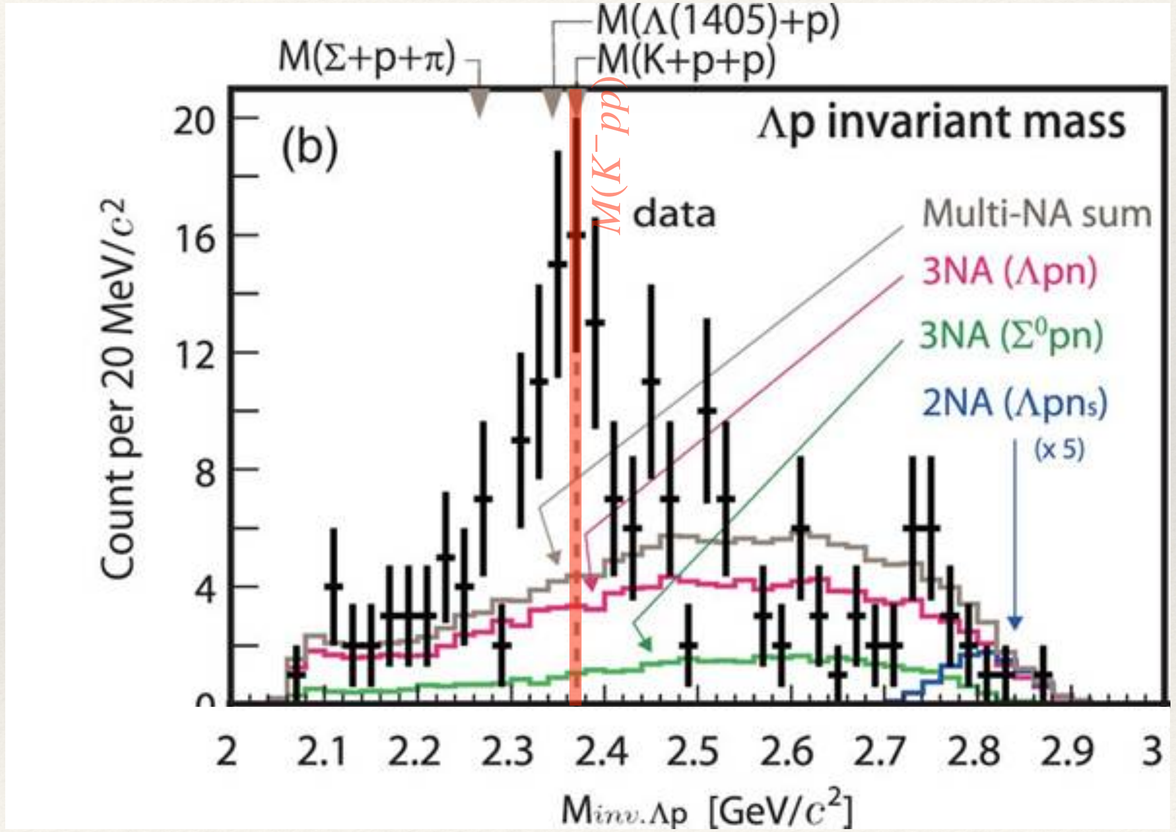
PTEP (2015) 061D01

Results of E15 - 1st

Exclusive analysis of $^3\mathrm{He}(K^-, \Lambda p)n$



- Peak around M(Kpp)
  - B.E. ~ 15 MeV
  - Width ~ 110 MeV



PTEP (2016) 051D01

E15 experiment