Current Status

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Current Status

- Chapter.1 Introduction check is finished.
  - Introduce some theoritial calculation.
- Chapter.4 Disscussion is being written.
  - Comparison with theoriticcal calculation.
    Calculation by K. Miyagawa et. el.
    Dyamical Coupled Chanel(DCC), H. Kamano et. el.
  - Fit assuming the 2-step reaction.
    I have not written document yet.
    Responce function will be updated by Kawasaki.
    $\Rightarrow$ Fitting will be revaised.
- Chapter.2 Expermental setup and Chapter.3 Analysis have not arrenged.

Table of Content

- Introduction
  - Discovery of $\Lambda(1405)$
  - $\bar{K}N$ interaction
  - Tow pole structure of the $\Lambda(1405)$
  - Recent experimental status of the $\Lambda(1405)$
  - Recent theoritial status of the $\Lambda(1405)$
  - $d(K^{-}, n)$ reaction
  - The J-PARC E31 experiment
- Discussion
  - Spectra
    - Qualitative properties of obtained spectra
    - Comparison with theoritical calculation
    - Fit assuming the 2-step reaction

Discovery of the $\Lambda(1405)$

$\Lambda(1405)$(PDG)

$S = -1, J^P = (\frac{1}{2})^-$

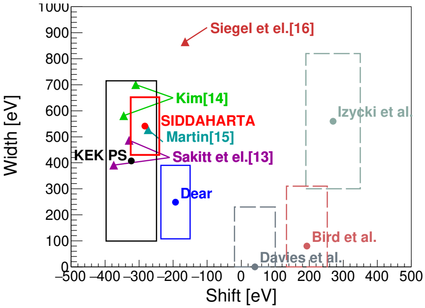
$m = 1405.1^{+1.3}_{-1.0} MeV/c$

$\Gamma = 50.5 \pm 2.0 MeV/c$

$\Rightarrow$ $\Lambda(1405)$ was analyzied as a $\bar{K}N$ bound state.

1959 R. H. Dalitz and F. taun was predicted.
1961 The candidate was discoveried in $K^- p \rightarrow \pi\pi\pi\Sigma$ at the LRL.
There are ambiguity of π.
1985 The high statics data was reported with 4.2 GeV/c K^- beam by R. J. Hemingway.
$\Rightarrow$ $\pi^+\Sigma^-$ spectrum was used first analysis by the R. H. Dalitz.

$\bar{K}N$ interaction (Kaonic hydrogen puzzle)



Deser-Trueman formula

$$\Delta E_1^s - \frac{i}{2}\Gamma_1 = -2\alpha^3 \mu_c^2 a_{K^-p}$$

1960's-1980's

1980 M. Izycki et al.,
Z. Phys. A 297, 11

1979 J. D. Davies et al.,
Phys. Lett. B **83**, 55

1983 P. M. Bird et al.,
Nucl. Phys. A **404**, 482

Improve by usage of gasses target

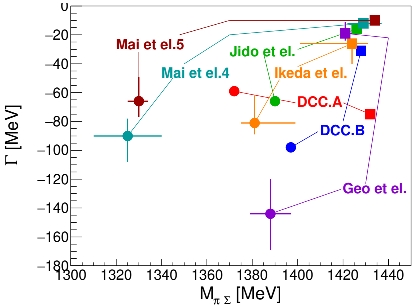
1997 M. Iwasaki et el., Phys. Rev. Lett. **78**, 3067 **KEK PS**
2005 G. Beer et el., Phys. Rev. Lett. **94**, 212302 **Dear**
2011 M. Bazzi et el., Phys. Lett. B **704**, 113 **SHIDDARTA**
$\Rightarrow$ Using as $\bar{K}N$ Constraint

Recent theoritial status

D. Jido et el. suggested tow pole state, $\bar{K}N$(higher) and $\pi\Sigma$(lower).

Nucl. Phys. A 725, 181 (2003).

$\Rightarrow$ Similar method and result were come out.



NLO w/ Constraint by SHIDDARTA.

Y. Ikeda, et el.,

Nucl. Phys. A **881**, 98 (2012)

Z.-H. Guo and J. Oller,

Phys. Rev. C **87**, 3, 035202 (2013)

Filltering by CLAS data

M. Mai and U.-G. Meiβner

Eur. Phys. J. A **51**, 3, 30

DCC method

H. Kamano et el.

Phys. Rev. C**92**, 025205 (2015)

$d(K^-, n)$ reaction and J-PARC E31

Using bubble chamber at the CERN by Braun [1].

- 686-848 MeV/c K^- beam.
- Wide angle of n was measured.

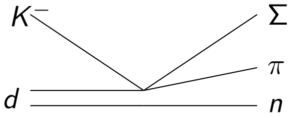
$\Rightarrow$ Diag.(a) is considered to be dominant.

J-PARC E31 experiment

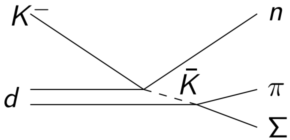
- 1.0 GeV/c K^- beam.
- Super-forward neutron was measured.

$\Rightarrow$ Diag.(b) is considered to be dominant.

[1] O. Braun et el., Nucl. Phys. B **129**, 1 (1977).



(a) 1-step reaction



(b) 2-step reaction

$d(K^-, n)$ reaction and J-PARC E31

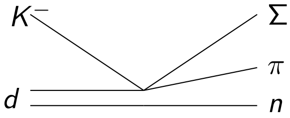
K. Miyagawa calculation

- $K^- p \to \bar{K}N$: PWA (Gopal et. el.[1])
- $\bar{K}N \to \pi\Sigma$: Several Ch-U analysis.

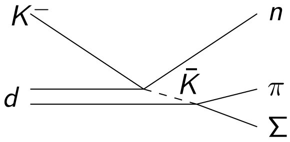
Model	Pole1	Pole2
ORB	$1426 - 16i$	$1390 - 66i$
Ohnishi	$1429 - 15i$	$1344 - 49i$
TW1	$1433 - 25i$	$1371 - 54i$

DCC (H. Kamano et. el.[2])

- Fitting all $\bar{K}N$ scattering data.
- There are two parameter-set (Model.A and .B)



(a) 1-step reaction

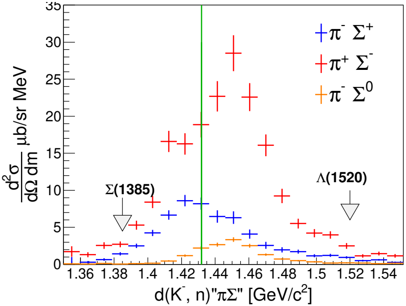


(b) 2-step reaction

[1] K. Miyagawa and J. Haidenbauer, Phys. Rev. C **85**, 065201 (2012).

[2] H. Kamano et el., Phys. ReV. C**94**, 065205 (2016).

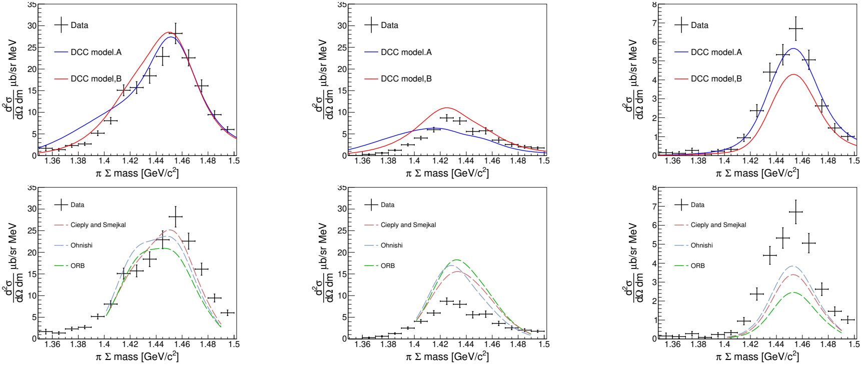
Spectra



There are almost no structure
around $\Sigma(1385)(I = 1, P\text{-wave})$ and $\Lambda(1520)(I = 0, D\text{-wave})$.

The difference of $\pi^+\Sigma^-$ and $\pi^-\Sigma^+$ spectra.
$\Rightarrow$ The interference term of $I = 0$ and $I = 1$.

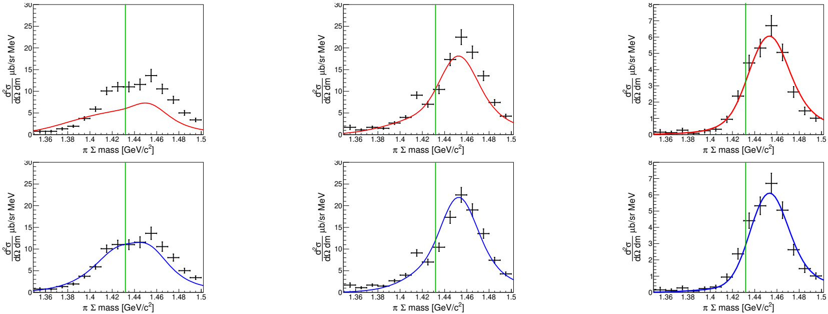
Comparison with Theoritiacl Calc



No fitting parameter

$\Rightarrow$ DCC corresponds all spectra

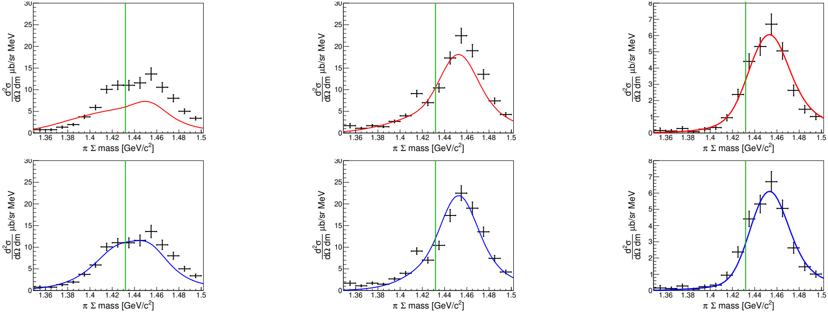
Fitting with Scaleing Parameter



	Scale $I=0$	Scale $I=1$	χ^2/NDF
Model.A	0.562 ± 0.015	1.070 ± 0.040	$691/42 = 16.4$
Model.B	0.721 ± 0.016	1.423 ± 0.055	$220/42 = 5.25$

	pole1($\bar{K}$)	pole2($\pi\Sigma$)
Model.A	$1437 - 75i$	$1372 - 56i$
Model.B	$1428 - 31i$	$1397 - 98i$

Fitting with Scaleing Parameter

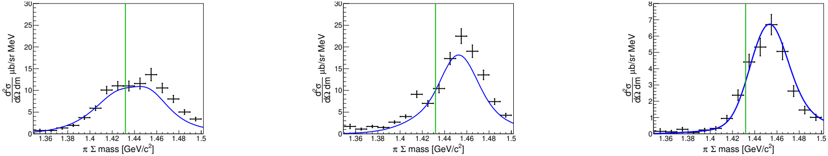


$\Rightarrow$ Model.A not corresponds due to wide width of pole.1.

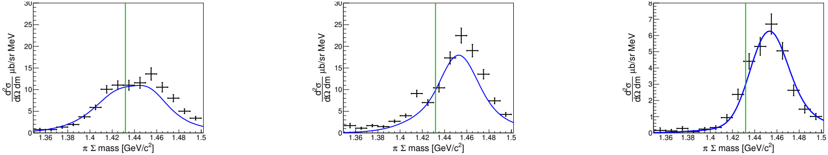
	pole1($\bar{K}N$)	pole2($\pi\Sigma$)
Model.A	$1437 - 75i$	$1372 - 56i$
Model.B	$1428 - 31i$	$1397 - 98i$

Fit with interference term

Fix $I = 1$strength by $\pi^{-}\Sigma^{0}$ spectra



All parameters are simultaneously fitted



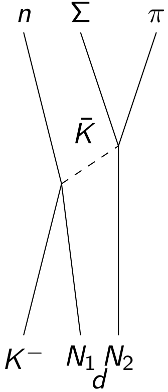
	Scale $I = 0$	Scale $I = 1$	interfer	χ^2/NDF
Fix $I = 1$	0.682 ± 0.017	1.570 ± 0.058	0.811 ± 0.030	$184/41 = 4.48$
All fit	0.686 ± 0.017	1.462 ± 0.059	0.828 ± 0.030	$187/41 = 4.56$

Fit is improved.

Almost same result fix $I = 1$ or not.

Fitting assuming the 2-step reaction

This reaction was explaned by K. Miyagawa [3].



$$
\begin{aligned}
\frac{d\sigma}{dMd\Omega} &= \int T_{K^-p\to\bar{K}N}\Phi_d(q_N2)G_0\,T_{\bar{K}N\to\pi\Sigma}dq \\
f_{res}(M_{\pi\Sigma}) &= \left|\int T_{\bar{K}N\to\bar{K}N}G_0\Phi_d(q_{N2})\right| \\
G_0(q_1,q_2) &= \frac{1}{q_0^q-\mathbf{q}^2+i\epsilon}
\end{aligned}
$$

: Green Function of the $\bar{K}$

$T_{K^-p\to\bar{K}N}$: Data from Gopal et. el. [1]

$\Phi(q_{N2})$: Wave-function of deuteron [2]

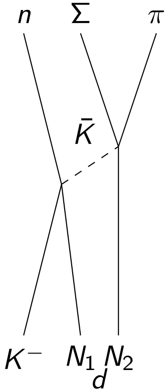
[1] G. P. Gopal et al., Nucl. Phys. B **119**, 362 (1977).

[2] R. Machleidt, Phys. Rev. C**63**, 024001 (2001).

[3] K. Miyagawa and J. Haidenbauer, Phys. Rev. C **85**, 065201 (2012).

Fitting assuming the 2-step reaction

This reaction was explaned by K. Miyagawa [3].



$$\frac{d\sigma}{dMd\Omega} = \int T_{K^-p\to\bar{K}N}\Phi_d(q_N2)G_0T_{\bar{K}N\to\pi\Sigma}dq$$

$$f_{res}(M_{\pi\Sigma}) = \left|\int T_{\bar{K}N\to\bar{K}N}G_0\Phi_d(q_{N2})\right|$$

- I use Noumi's f_{res}.
- f_{res} will be updated by Kawasaki.

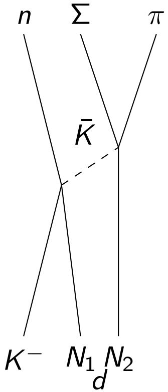
$\Rightarrow$ The fitting will be updated.

[1] G. P. Gopal et al., Nucl. Phys. B **119**, 362 (1977).

[2] R. Machleidt, Phys. Rev. C**63**, 024001 (2001).

[3] K. Miyagawa and J. Haidenbauer, Phys. Rev. C **85**, 065201 (2012).

Fitting assuming the 2-step reaction



$$\frac{d\sigma}{dMd\Omega} = \int T_{K^-p\to\bar{K}N}\Phi_d(q_N2)G_0\,T_{\bar{K}N\to\pi\Sigma}dq$$

$$T_{\bar{K}N\to\pi\Sigma} = \frac{e^{i\delta}}{\sqrt{k_1}}\frac{\sqrt{\mathbf{Im}A - \frac{1}{2}|A|^2\mathbf{Im}Rk^2}}{1 - iAk_2 + \frac{1}{2}ARk_2^2}$$

$$T_{\bar{K}N\to\bar{K}N} = \frac{A}{1 - iAk_2 + \frac{1}{2}ARk_2^2}$$

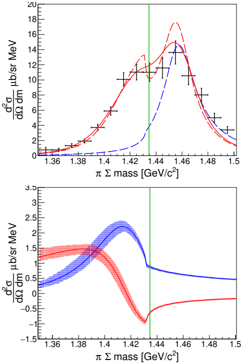
$$\Rightarrow \text{(Pole position)} : 1 - iAk_2 + \frac{1}{2}ARk_2^2 = 0$$

This fitting 2-complex, A & R param and scaling factor.

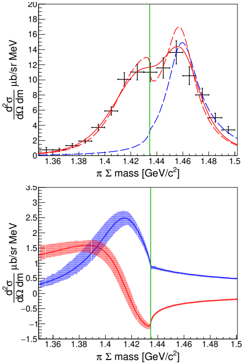
$\Rightarrow$ 5 parameters

Fitting result

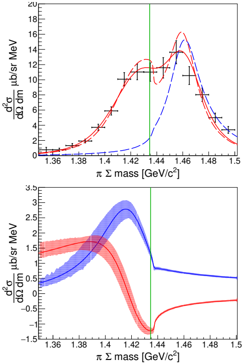
$K^- p$ threshold



$\bar{K} N$ threshold

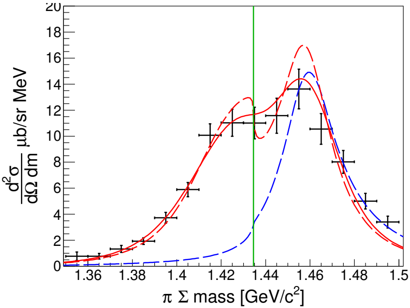


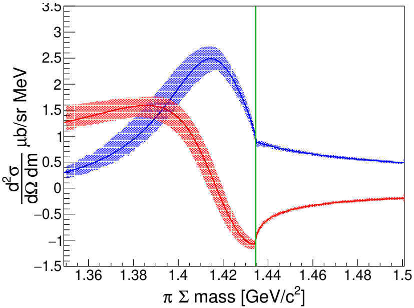
$K^0 n$ threshold



	A_{re}	A_{im}	R_{re}	R_{im}	M	Γ
$K^- p$	-0.95 ± 0.11	0.94 ± 0.16	-0.27 ± 0.40	0.52 ± 0.18	1417.6	30.3
$\bar{K} N$	-1.05 ± 0.12	0.86 ± 0.15	-0.22 ± 0.40	0.42 ± 0.16	1418.3	27.8
$K^0 n$	-1.13 ± 0.13	0.79 ± 0.15	-0.16 ± 0.40	0.33 ± 0.16	1419.3	25.9

Fitting result with $\bar{K}N = \frac{1}{2}(K^- p + K^0 n)$ threshold





$$Scale = 0.0372 \pm 0.0047$$

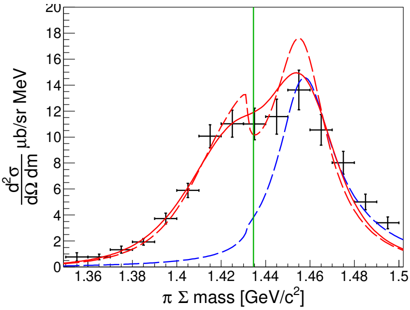
$$A = -1.05 \pm 0.12 + (0.86 \pm 0.15)i$$

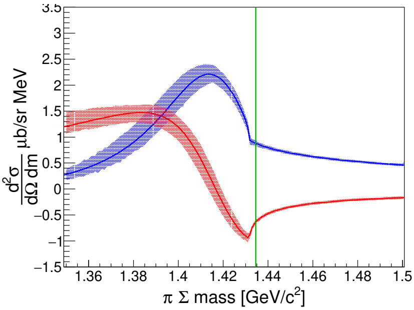
$$R = -0.22 \pm 0.40 - (0.42 \pm 0.16)i$$

$$M = 1418.3\text{MeV}$$

$$\Gamma = 27.8\text{MeV}$$

Fitting result with K^-p threshold





$$Scale = 0.0377 \pm 0.0042$$

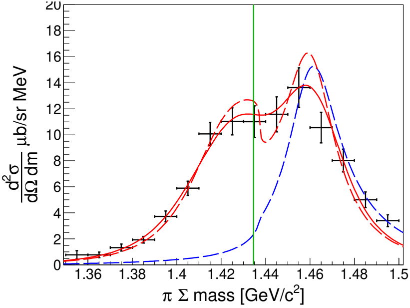
$$A = -0.95 \pm 0.11 + (0.94 \pm 0.16)i$$

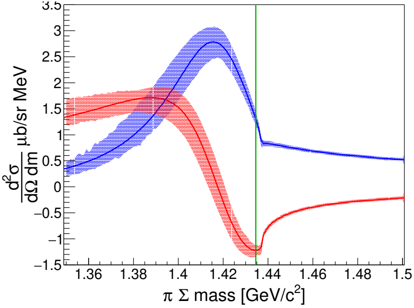
$$R = -0.27 \pm 0.40 - (0.52 \pm 0.18)i$$

$$M = 1417.6\text{MeV}$$

$$\Gamma = 30.3\text{MeV}$$

Fitting result with $K^0 n$ threshold





$$Scale = 0.0367 \pm 0.0053$$

$$A = -1.13 \pm 0.13 + (0.79 \pm 0.15)i$$

$$R = -0.16 \pm 0.40 - (0.33 \pm 0.16)i$$

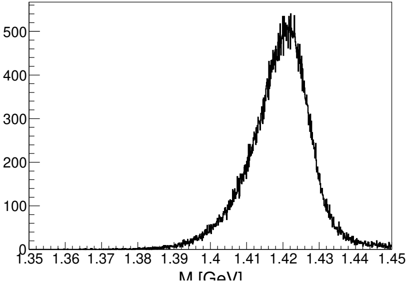
$$M = 1419.3\text{MeV}$$

$$\Gamma = 25.9\text{MeV}$$

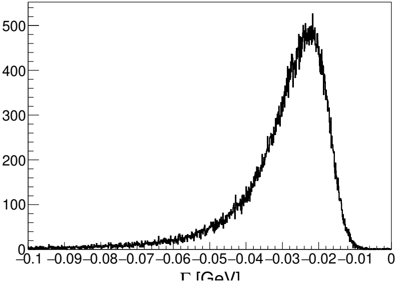
Pole parameter of $\Lambda(1405)$ ($\bar{K}N$ threshold)

Distribution is distorted due to threshold effect.
$\Rightarrow$ Distribution is produced by Gausian random ($N = 100,000$).

Mass

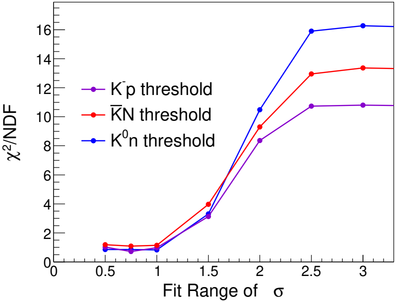


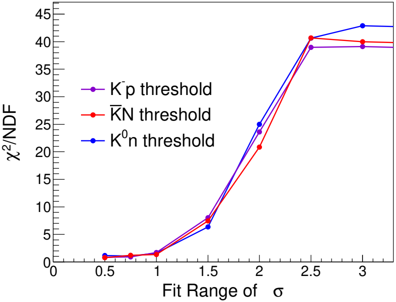
Width



Errors of mass and width are estimated using these distrbution.
$\Rightarrow$ Tail component should be not included.
$\Rightarrow$ Fit range shold be determined w/o arbitrariness.

Fitting range is defined by height of histogram.
ex) $1\sigma \sim 1/\sqrt{e}, 2\sigma \sim 1/2e$





$\Rightarrow 1\sigma$ saturates χ^2/NDF.

Summary

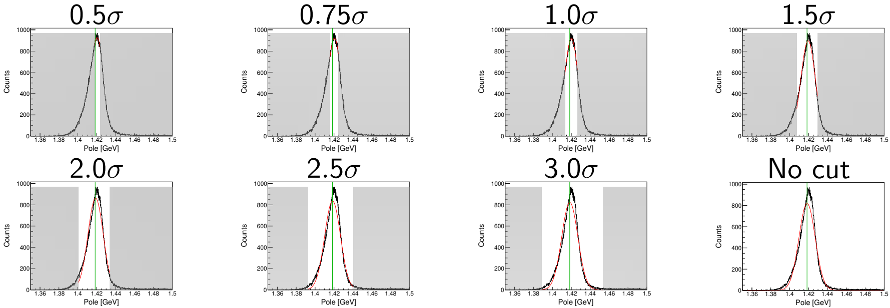
- I should write Doctor thesis.
  Check of Chapter.1 Introduction is finished.
  I'm writing Chapter.4 Discussion.
- I disscuss comparison w/ theoritiacl calc. and
  fit assuming the 2-step reaction.
  $\Rightarrow f_{res}(M_{\pi\Sigma})$ will be modified and fit is reavaied.

Fit result

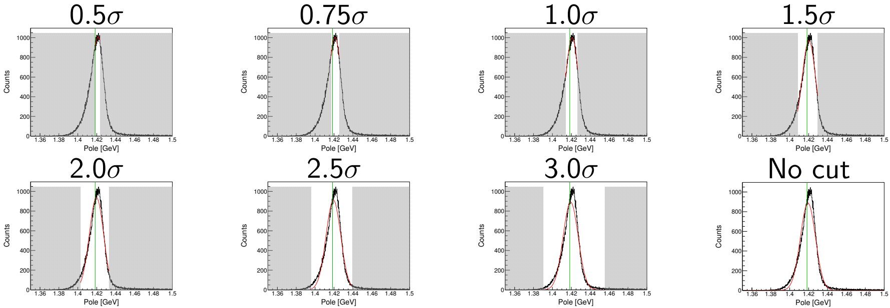
$$\text{My fit} = 1418.3^{+9.2}_{-4.1}(\text{fit})^{+1.0}_{-1.3}(\text{syst.}) - 27.8^{+11.8}_{-2.8}(\text{fit})^{+2.3}_{-2.1}(\text{syst.})i[MeV]$$

Back up

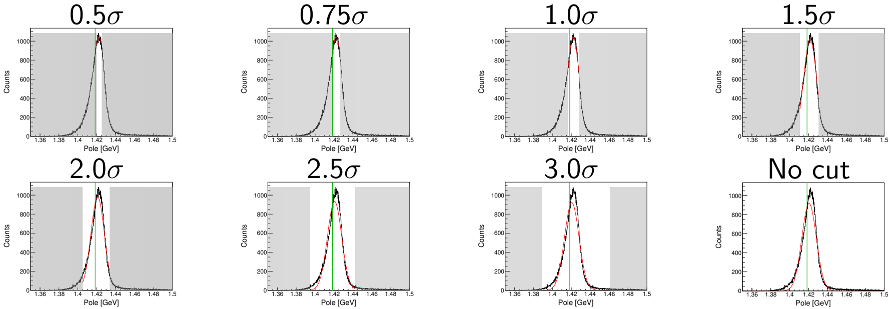
$\Lambda(1405)$ mass fitting with $K^- p$ threshold



$\Lambda(1405)$ mass fitting with $\bar{K}N$ threshold

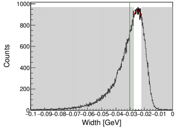


$\Lambda(1405)$ mass fitting with $K^0 n$ threshold

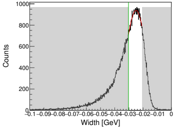


$\Lambda(1405)$ width fitting with K^-p threshold

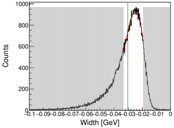
0.5σ



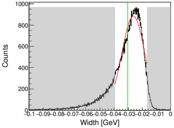
0.75σ



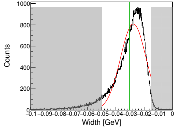
1.0σ



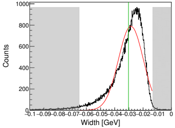
1.5σ



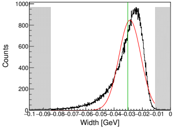
2.0σ



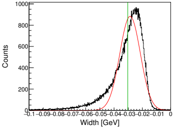
2.5σ



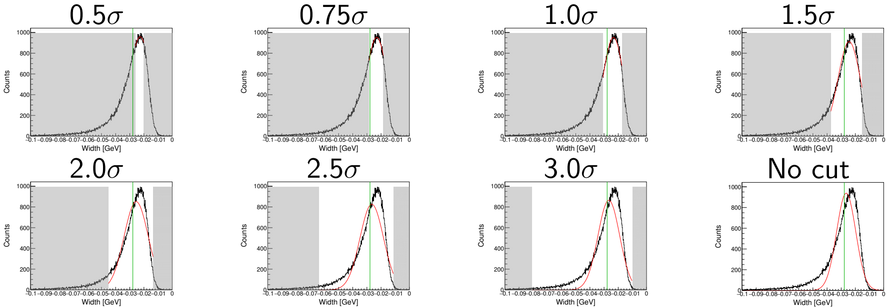
3.0σ



No cut



Λ(1405) width fitting with $\bar{K}N$ threshold



$\Lambda(1405)$ width fitting with $K^0 n$ threshold