Future perspective on kaonic nuclear study

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for E15 collaboration

A subject for discussion: J-PARC E15

Key questions :

- Can kaon (boson) be a member of nuclei?
- Kaon properties change in nuclear media?

Hadron masses and χ-symmetry

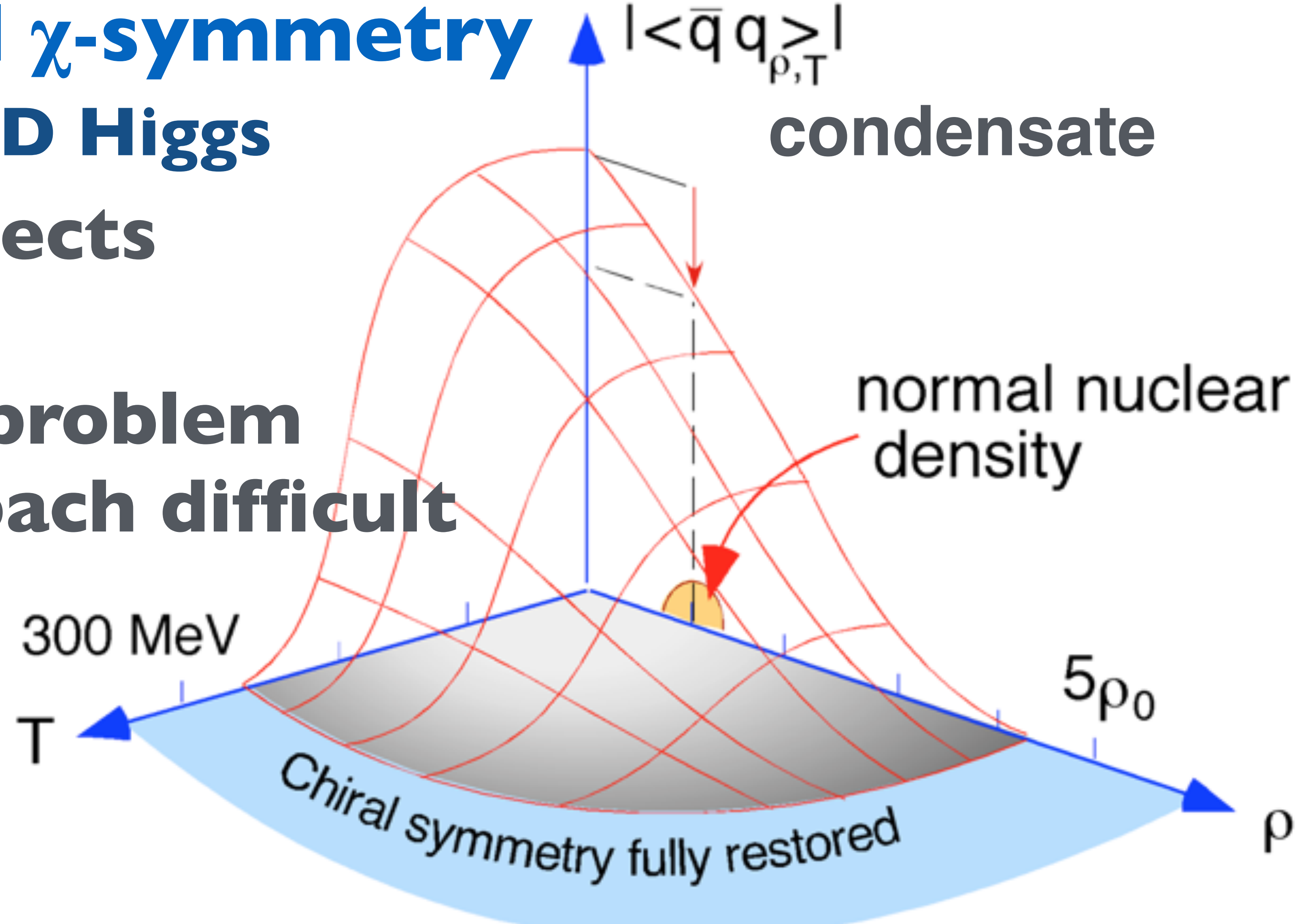
$<\bar{q}q>$ as QCD Higgs

Non-perturbative aspects

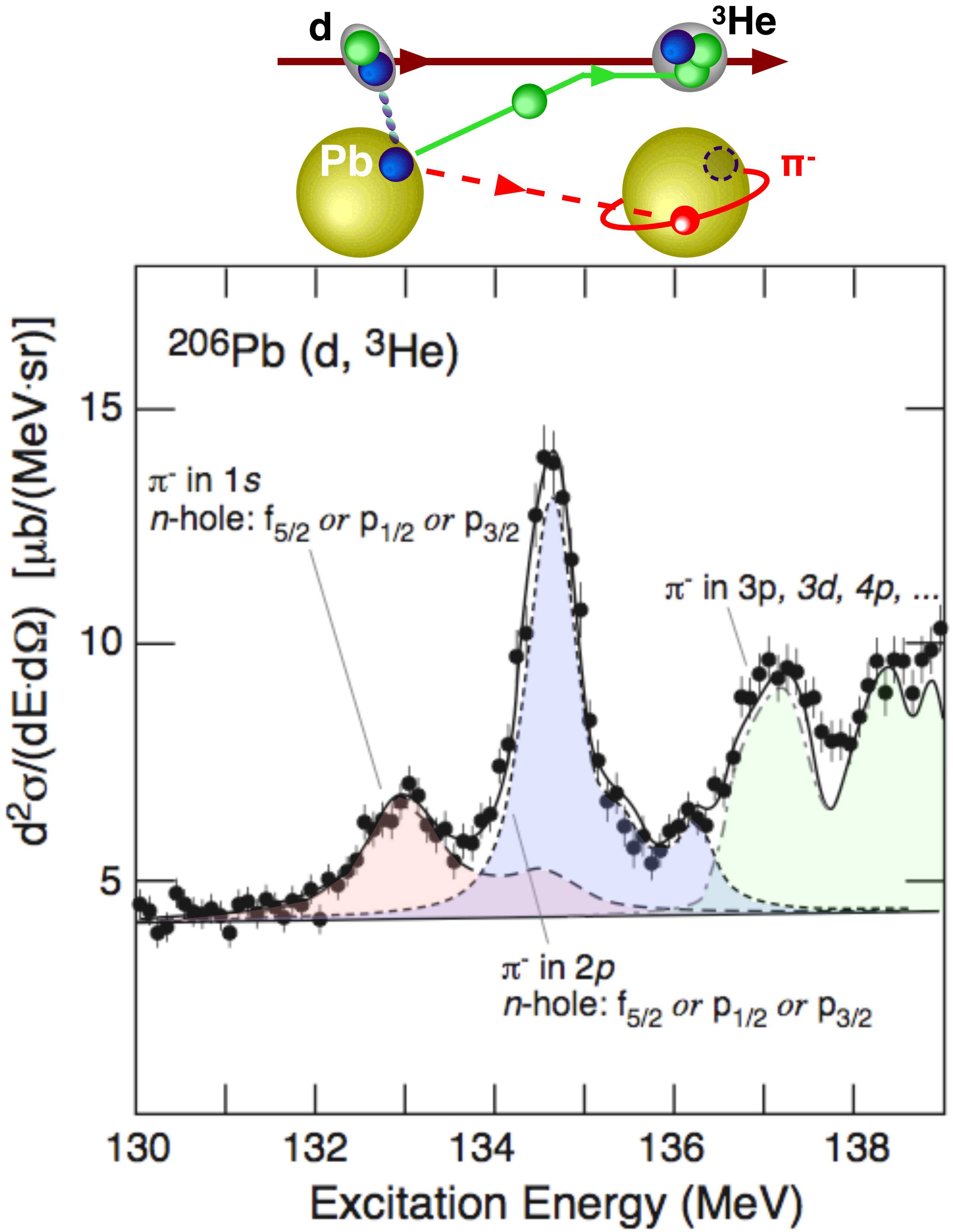
@ energy < Λ_{QCD}

Finite density → sign problem

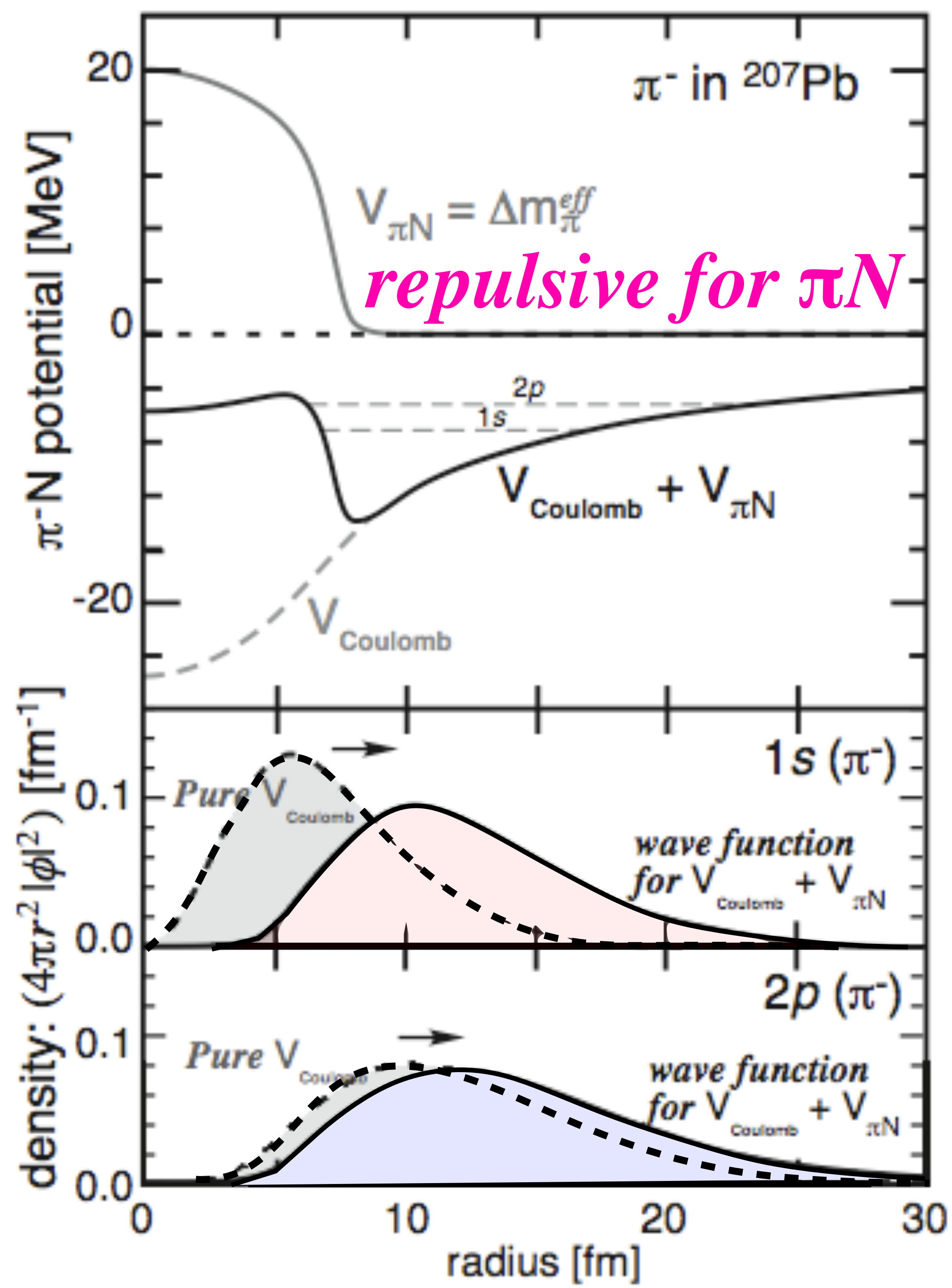
Lattice-QCD approach difficult



Can meson form a nuclear bound state?

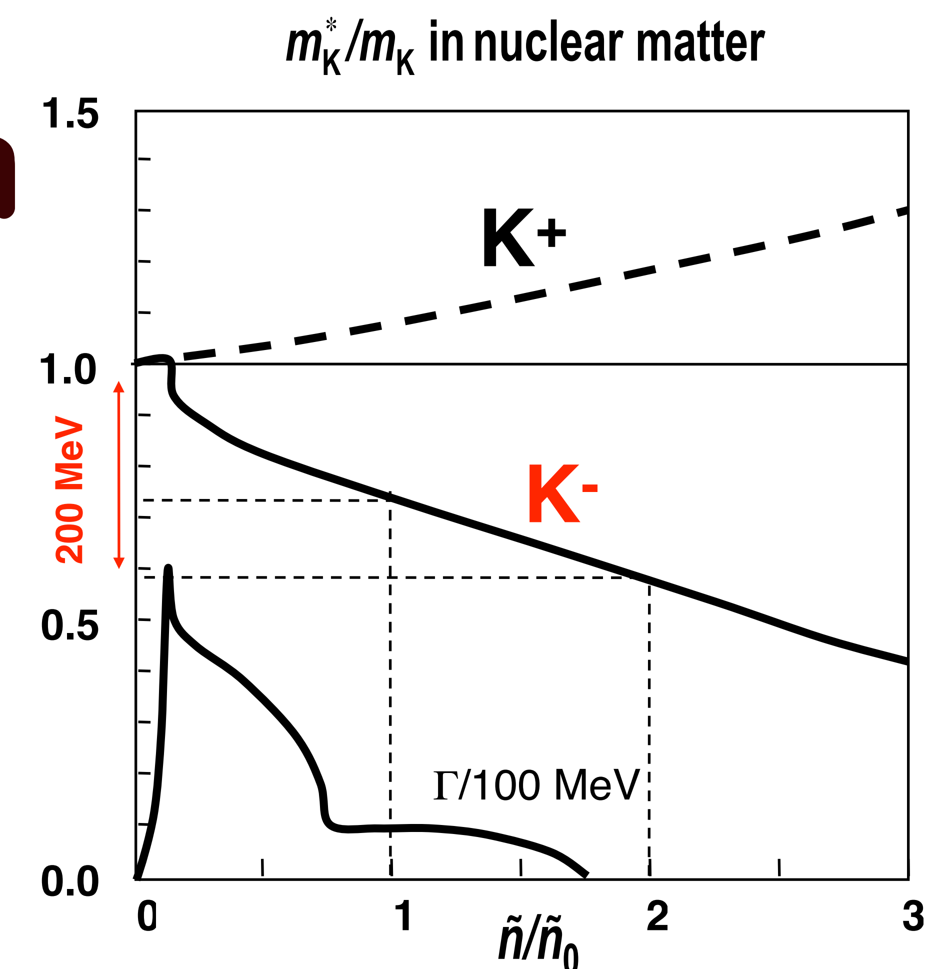


π atom

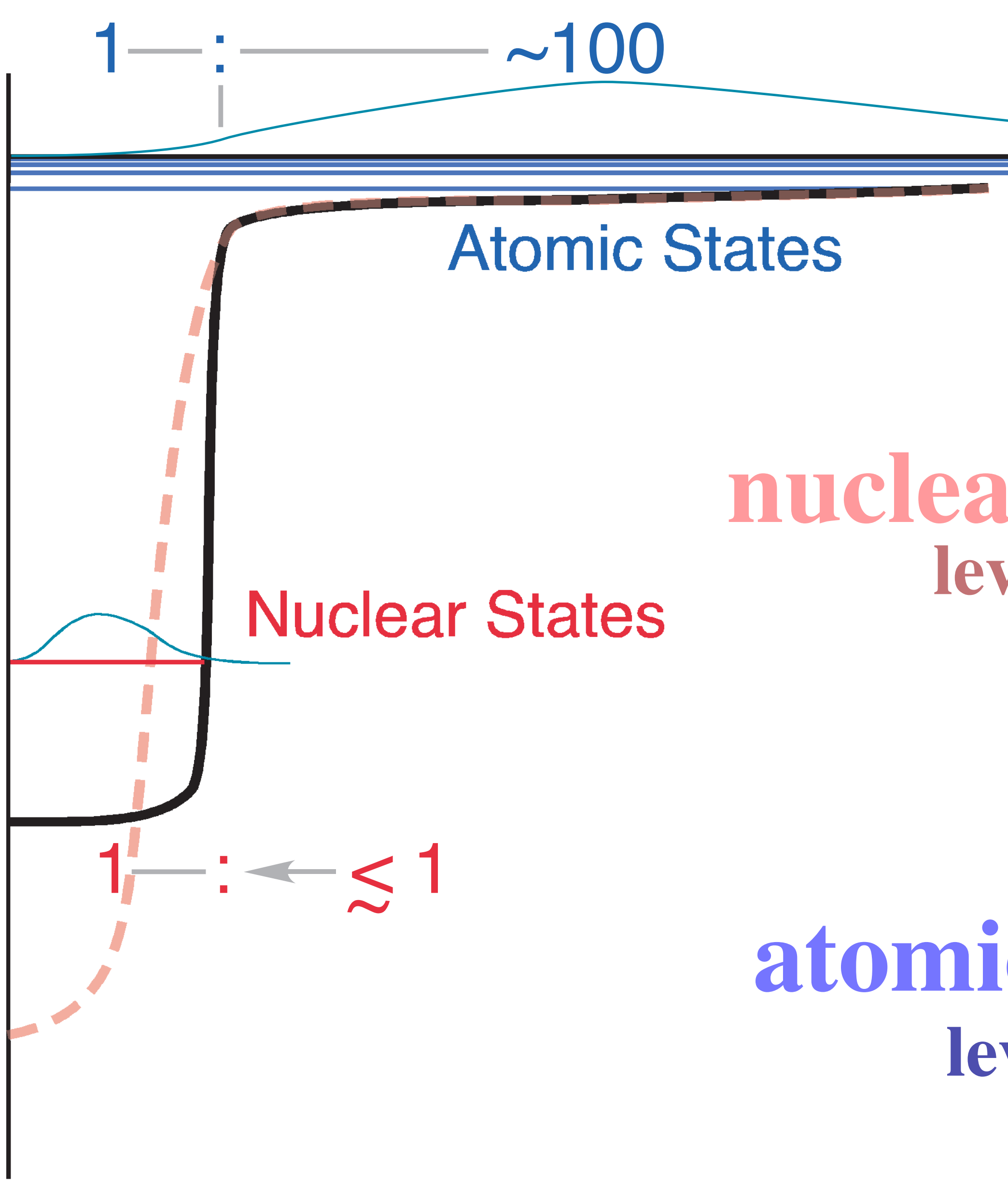


Yes, for Coulomb assisted hybrid-bound states

Study of $\bar{K}N$ interaction



T. Waas, N. Kaiser & W. Weise, Phys. Lett. B379 (1996) 34.



nuclear states

level energy and decay width

K @ 1 GeV/*c*

atomic states

level shift and absorption width

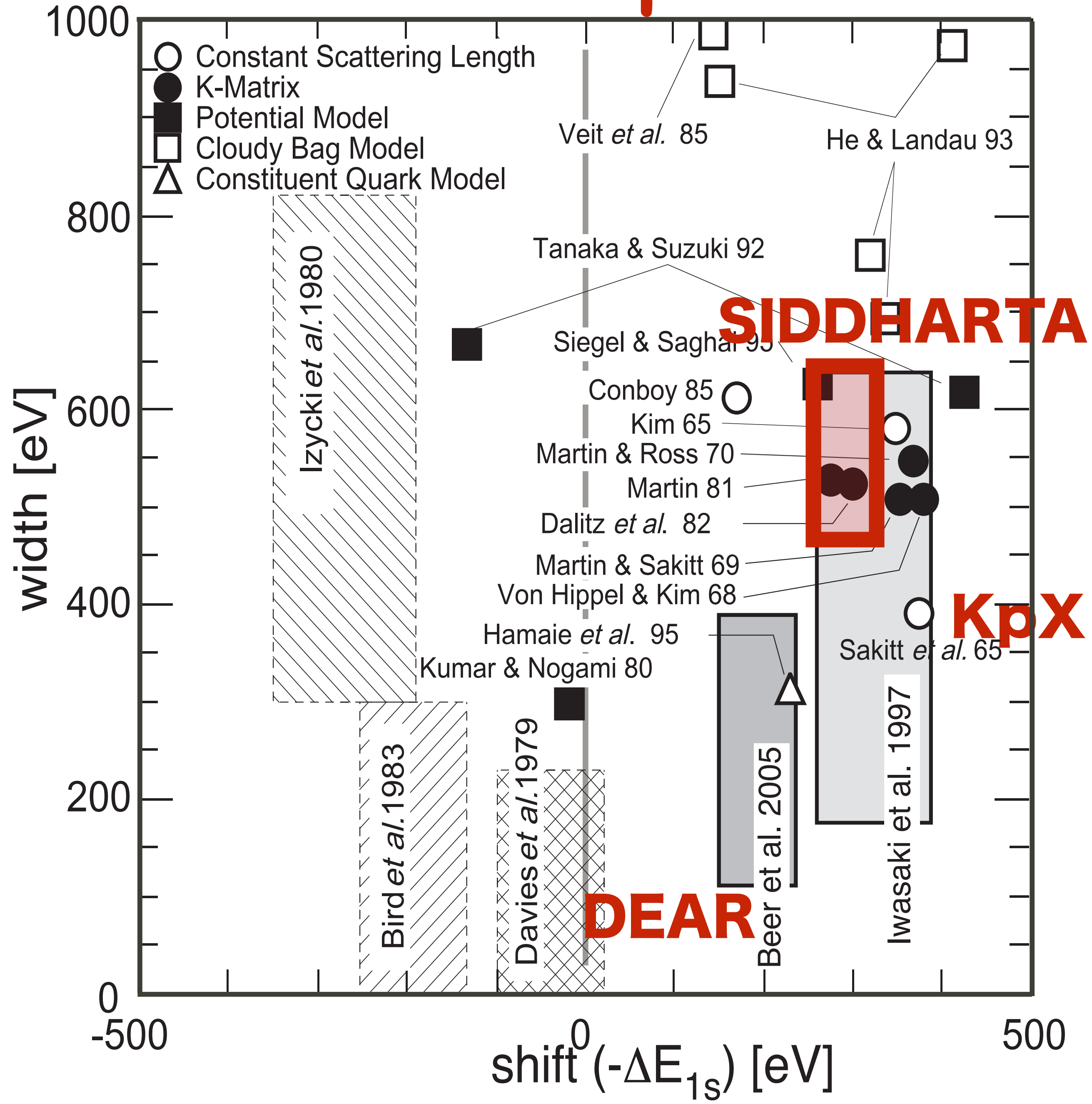
K at rest

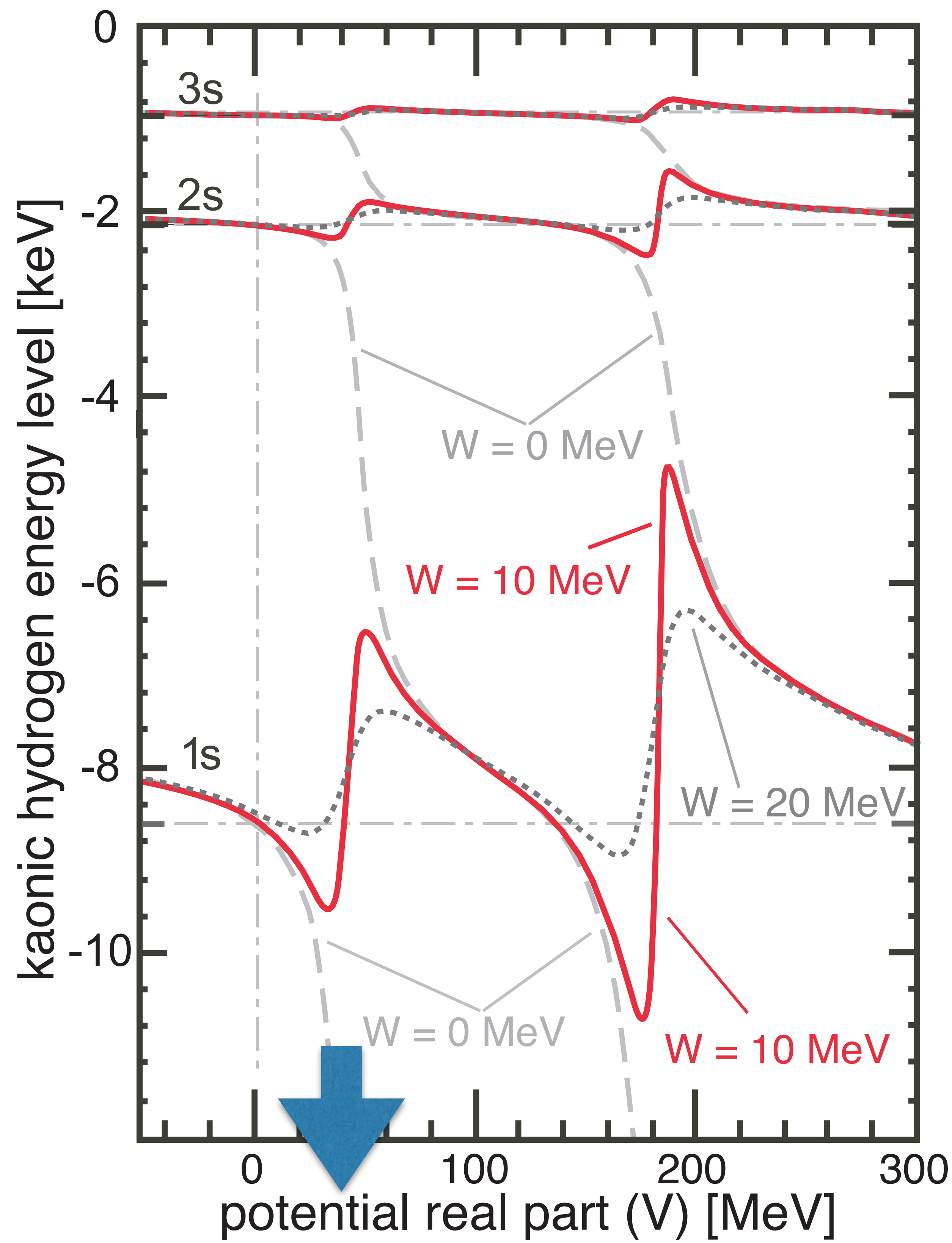
strongly attractive in I=0 channel

Atomic study = very attractive

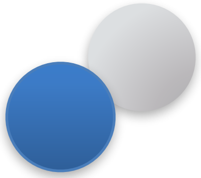
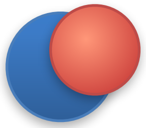
bound state?

upward shift





$\Lambda(1405)$ as $\bar{K}N$ bound state

	Nucleus	Hyper nucleus	Kaonic nucleus ???
			
Bound state	deuteron	Not bound	

$\Lambda(1405)$ as $\bar{K}N$ bound state

$\Lambda(1405)\ 1/2^-$

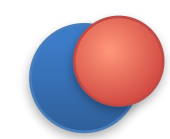
$I(J^P) = 0(\frac{1}{2}^-)$

The nature of the $\Lambda(1405)$ has been a puzzle for decades: three-quark state or hybrid; two poles or one. We cannot here survey the rather extensive literature. See, for example, CIEPLY 10, KISSLINGER 11, SEKIHARA 11, and SHEVCHENKO 12A for discussions and earlier references.

It seems to be the universal opinion of the chiral-unitary community that there are two poles in the 1400-MeV region. ZYCHOR 08 presents experimental evidence against the two-pole model, but this is disputed by GENG 07A. See also REVAI 09, which finds little basis for choosing between one- and two-pole models; and IKEDA 12, which favors the two-pole model.

A single, ordinary three-quark $\Lambda(1405)$ fits nicely into a $J^P = 1/2^-$ SU(4) $\overline{4}$ multiplet, whose other members are the $\Lambda_c(2595)^+$, $\Xi_c(2790)^+$, and $\Xi_c(2790)^0$; see Fig. 1 of our note on "Charmed Baryons."

Kaonic nucleus ???



$\Lambda(1405)$ MASS

PRODUCTION EXPERIMENTS

VALUE (MeV)	*EVTS*	*DOCUMENT ID*	*TECN*	*COMMENT*
$1405.1^{+1.3}_{-1.0}$ OUR AVERAGE				

$\Lambda(1405)$ as $\bar{K}N$ bound state

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	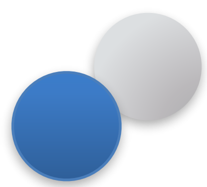		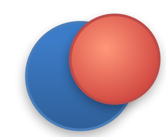
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$\Lambda(1405)$ as $\bar{K}N$ bound state

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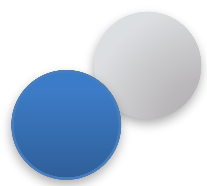
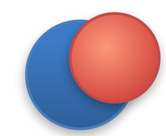
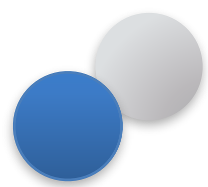
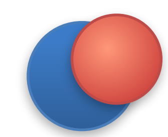
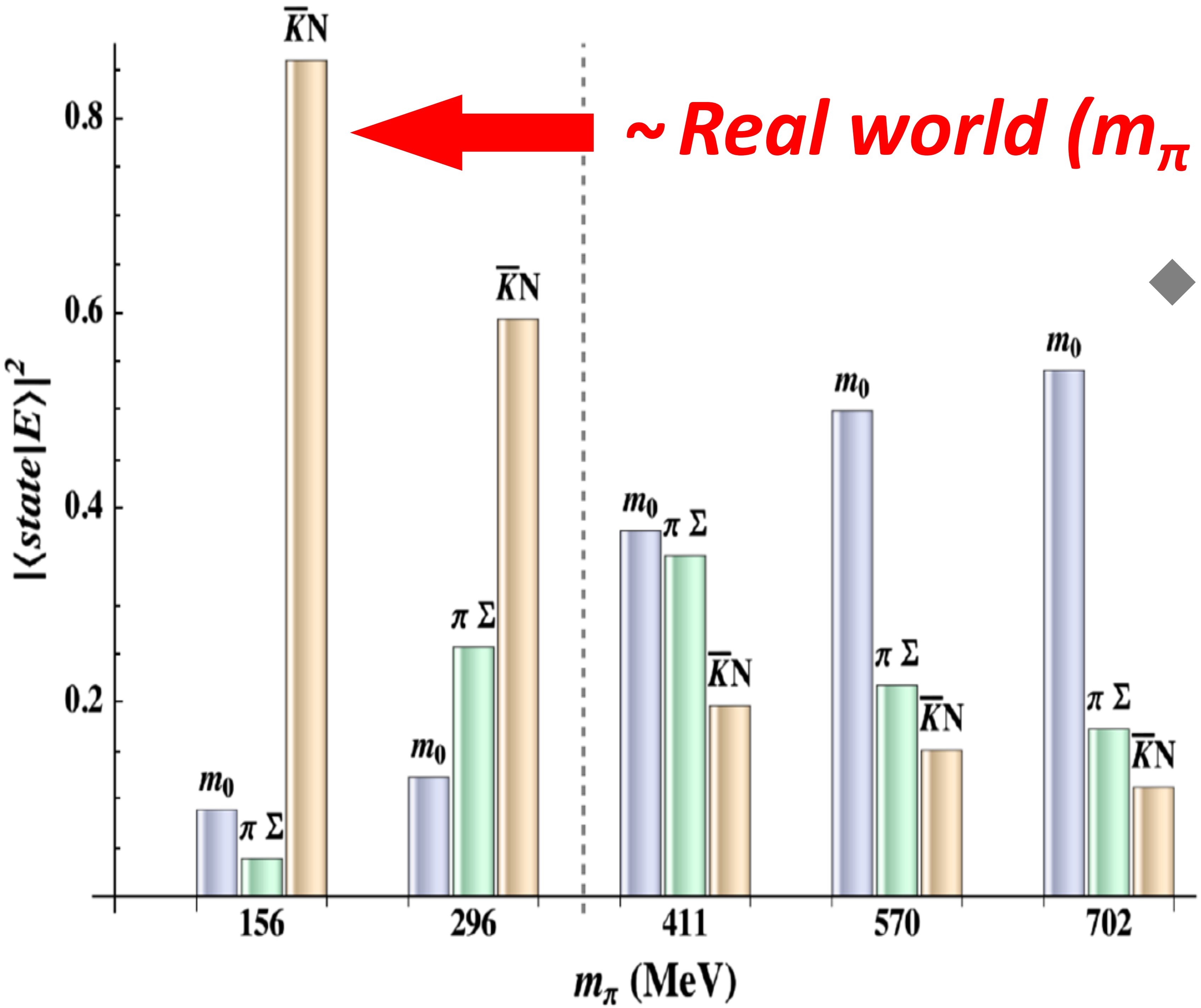
			
Bound state	deuteron	Not bound	$\Lambda(1405)$?
B.E.	~ 2 MeV	$-$	~ 27 MeV

$\Lambda(1405)$ as $\bar{K}N$ bound state

	Nucleus	Hyper nucleus	Kaonic nucleus
			
Bound state	deuteron	Not bound	$\Lambda(1405)$?
B.E.	~ 2 MeV	$-$	~ 27 MeV

$\bar{K}N$ >> 2MeV @ NN !!

$\Lambda(1405)$ structure from Lattice QCD calculation

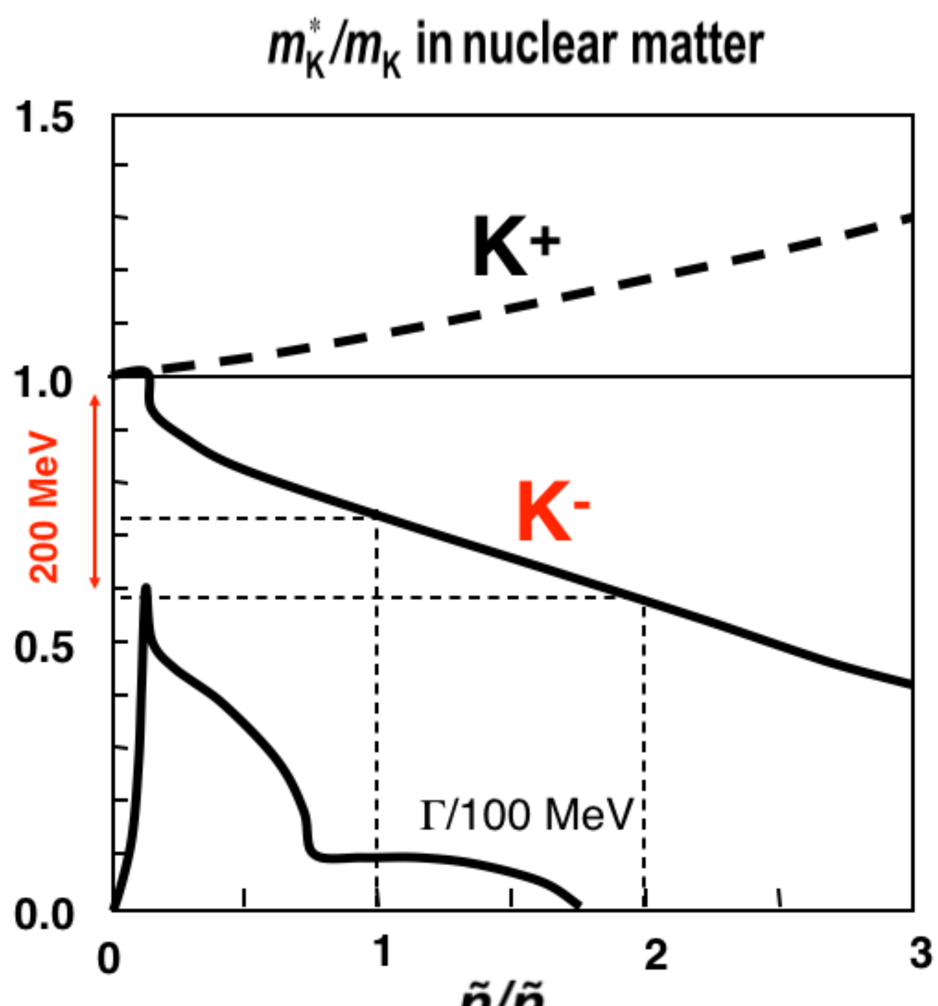


~Real world (m_π = 140 MeV/c^2)

- Recent Lattice QCD supports,

$$\Lambda(1405) = p - K^{-}$$
$$= (uud)\text{-}(\bar{u}s)$$

Search for Kaonic nuclear states



T. Waas, N. Kaiser & W. Weise, Phys. Lett. B379 (1996) 34.

strongly attractive in I=0 channel

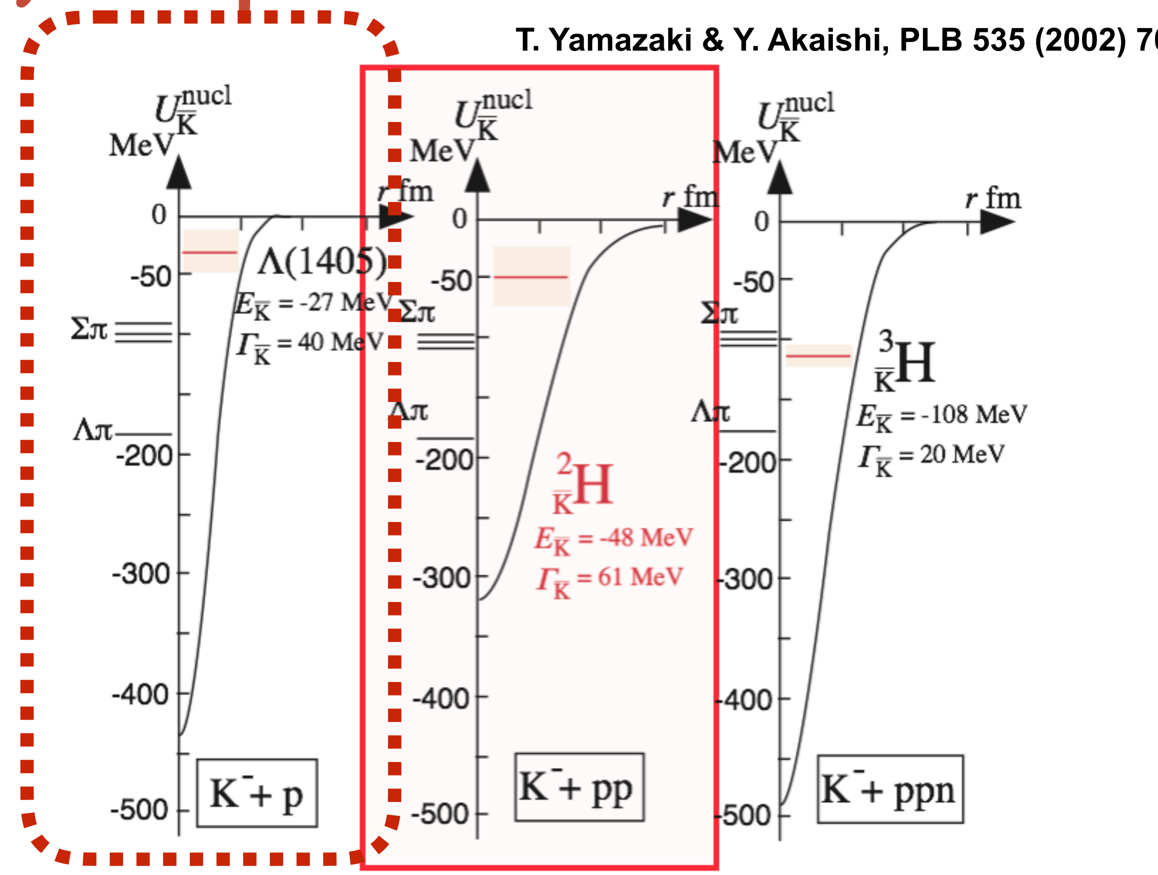
nuclear state search

- **simplest system** *K^-pp*

^{3}He(K^-, n) @ 1 GeV/*c*

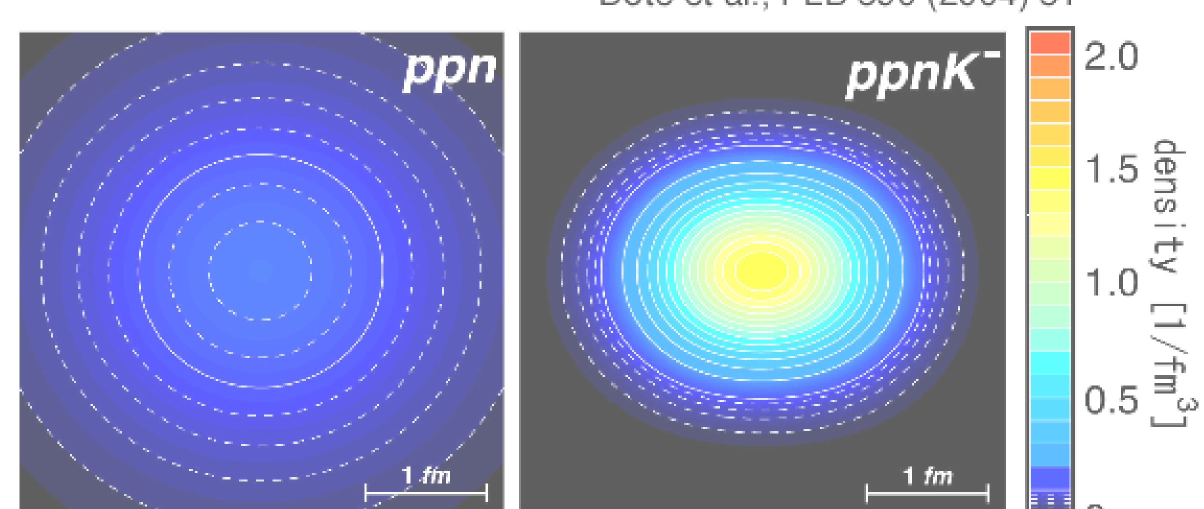
Λ(1405) = K^-p bound state ?

T. Yamazaki & Y. Akaishi, PLB 535 (2002) 70



B_K ~ 50 MeV!

Dote et al., PLB 590 (2004) 51



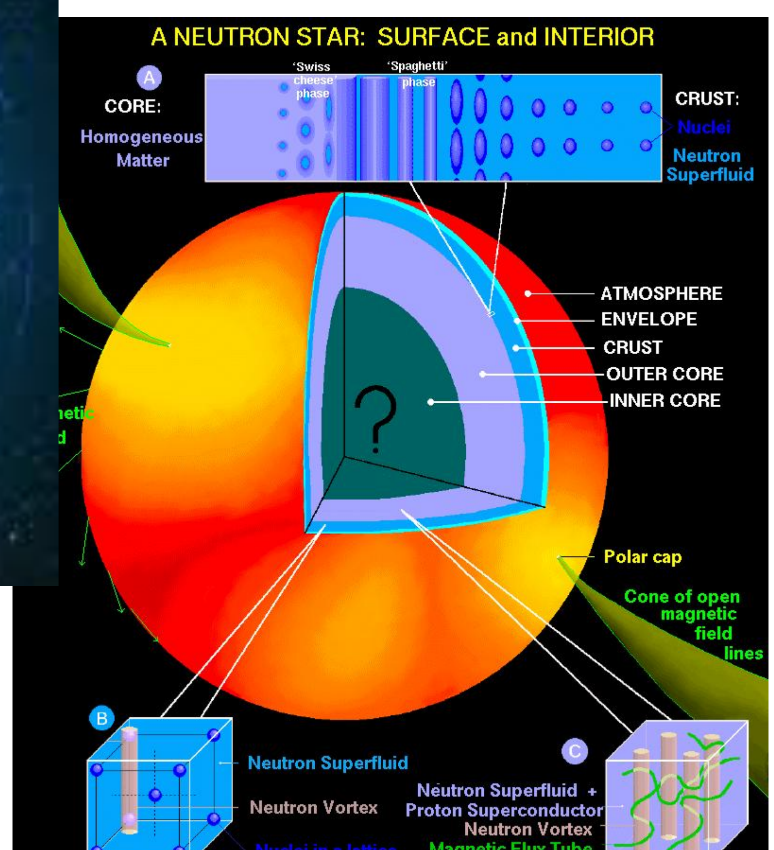
formation of high density matter?

Particle fraction in dense nuclear matter – a possibility –

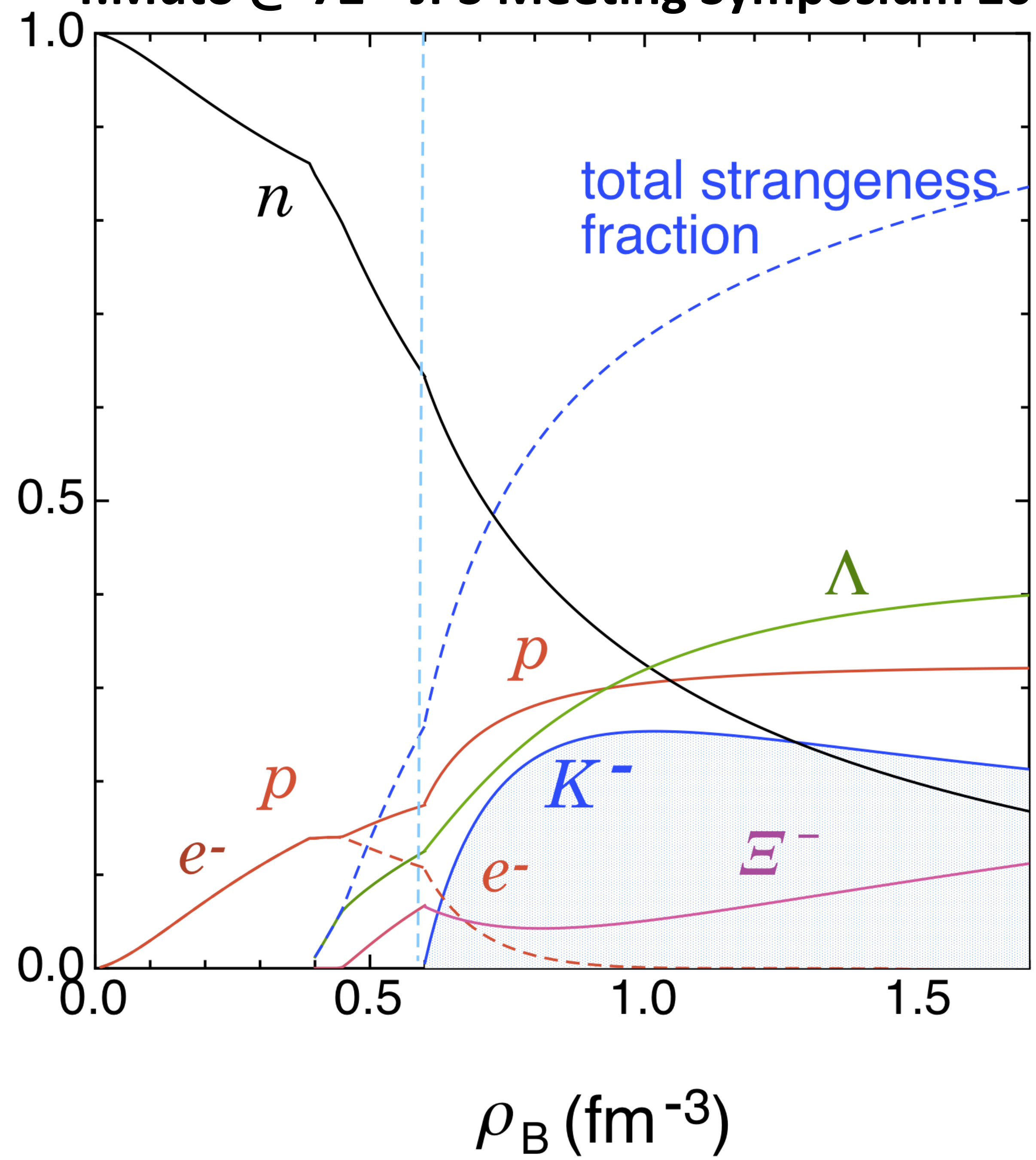
Does kaon can be born spontaneously in star matter?

EOS might be too soft…

http://pl.wikipedia.org/wiki/Gwiazda_neutronowa#mediaviewer/File:Chandra-crab.jpg



T.Muto @ 72th JPS Meeting Symposium 2017

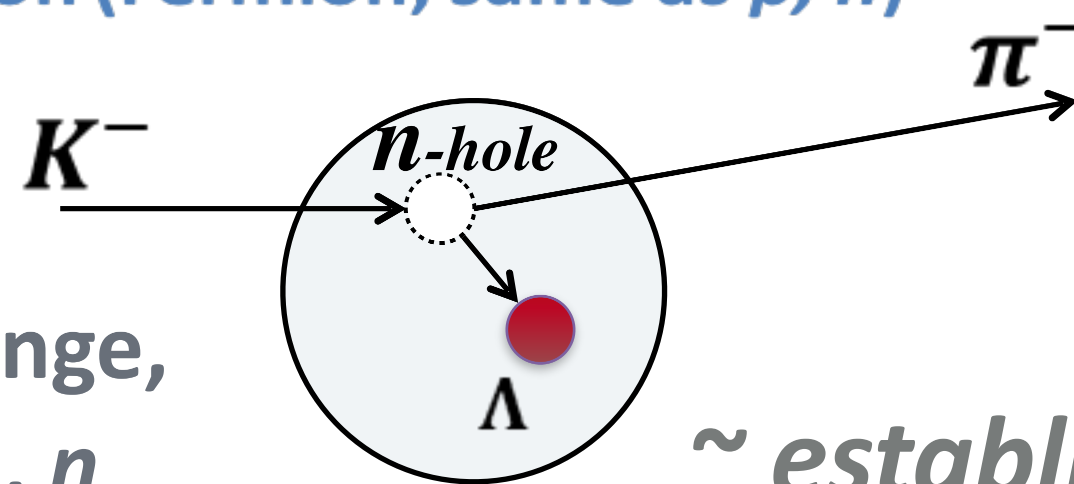


Can "boson" be a constituent of "matter"?

Hyper-nucleus

Λ : 3-quark baryon (Fermion, same as *p, n*)

$$K^- + n \rightarrow \Lambda + \pi^-$$
$(\bar{u}s)$ (udd) (uds) $(\bar{u}d)$



existence might not that strange, because it is Fermion like *p, n*

~ established

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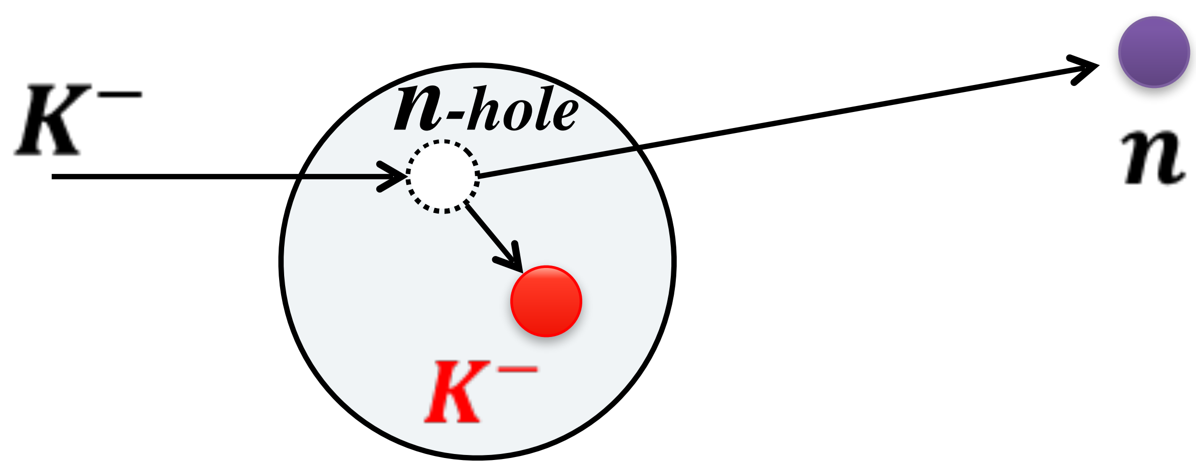
anti Kaon-nucleus

New Paradigm

Can anti-quark $\bar{u}$ "survive" in a nucleus?



K : $(\bar{u}s)$ meson (Boson, like *π, but strongly attractive*)

$$K^- + n \rightarrow K^- + n$$
$(\bar{u}s)$ (udd) $(\bar{u}s)$ (udd)

Can we make "meson" as a member of "nuclear matter"?

E15 1^{st}

Published E15[1st] data

PTEP

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

^{3}He(K$^-$, n) — semi-inclusive

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
M. Cargnelli[8], S. Choi[4], C. Curceanu[9], S. Enomoto[2], D. Faso[6,7], H. Fuj
Y. Fujiwara[1], T. Fukuda[11], C. Guaraldo[9], R. S. Hayano[1], T. Hiraiwa[2], M
M. Iliescu[9], K. Inoue[13], Y. Ishiguro[10], T. Ishikawa[1], S. Ishimoto[12], K. I
M. Iwai[12], M. Iwasaki[14,15], Y. Kato[14], S. Kawasaki[13], P. Kienle[16,‡], H.
J. Marton[8], Y. Matsuda[17], Y. Mizoi[11], O. Morra[6], T. Nagae[10], H. Noum
H. Ohnishi[14,2], S. Okada[14], H. Outa[14], K. Piscicchia[9], M. Poli Lener[9],
A. Romero Vidal[9], Y. Sada[10], A. Sakaguchi[13], F. Sakuma[14], M. Sato[14],
M. Sekimoto[12], H. Shi[9], D. Sirghi[9,5], F. Sirghi[9,5], S. Suzuki[12], T. Suzuk
H. Tatsuno[1], M. Tokuda[15], D. Tomono[10], A. Toyoda[12], K. Tsukada[18],
O. Vazquez Doce[9,19], E. Widmann[8], T. Yamaga[13], T. Yamazaki[1,14], H.
Q. Zhang[14], J. Zmeskal[8]

PTEP

Prog. Theor. Exp. Phys. **2016**, 051D01 (11 pages)
DOI: 10.1093/ptep/ptw040

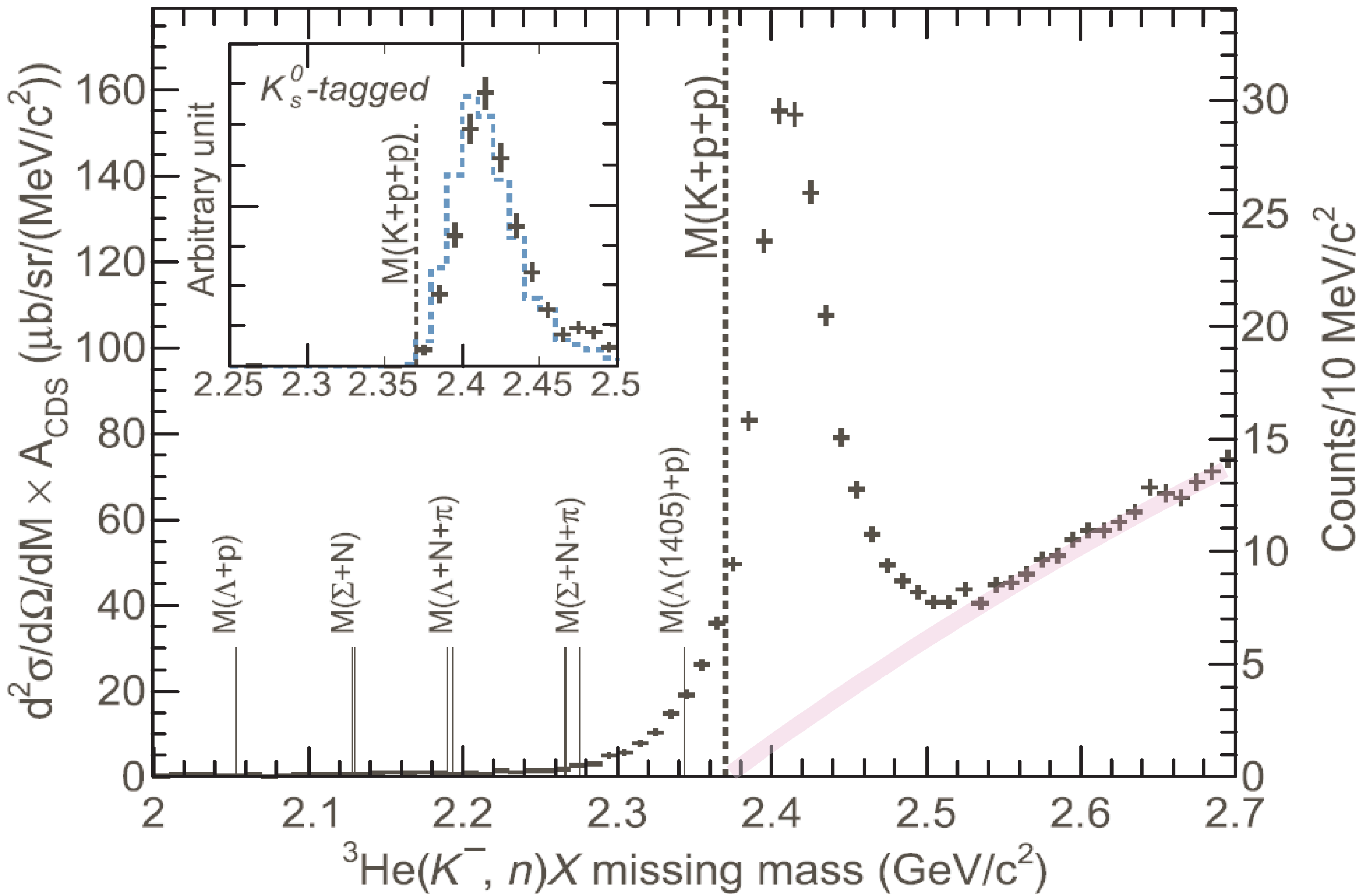
^{3}He(K$^-$, Λp) n — exclusive

Letter

Structure near the $K^- + p + p$ threshold in the in-flight $^3\mathrm{He}(K^-, \Lambda p)n$ reaction

J-PARC E15 Collaboration
Y. Sada[1,*], S. Ajimura[1], M. Bazzi[2], G. Beer[3], H. Bhang[4], M. Bragadireanu[5], P. Buehler[6], L. Busso[7,9], M. Cargnelli[6], S. Choi[4], C. Curceanu[2], S. Enomoto[8], D. Faso[7,9], H. Fujioka[10], Y. Fujiwara[11], T. Fukuda[12], C. Guaraldo[2], T. Hashimoto[13], R. S. Hayano[11], T. Hiraiwa[1], M. Iio[8], M. Iliescu[2], K. Inoue[1], Y. Ishiguro[10], T. Ishikawa[11], S. Ishimoto[8], T. Ishiwatari[6], K. Itahashi[13], M. Iwai[8], M. Iwasaki[13,14], Y. Kato[13], S. Kawasaki[15], P. Kienle[†,16], H. Kou[14], Y. Ma[13], J. Marton[6], Y. Matsuda[17], Y. Mizoi[12], O. Morra[7], T. Nagae[10], H. Noumi[1], H. Ohnishi[13,1], S. Okada[13], H. Outa[13], K. Piscicchia[2], A. Romero Vidal[2], A. Sakaguchi[15], F. Sakuma[13], M. Sato[13], A. Scordo[2], M. Sekimoto[8], H. Shi[2], D. Sirghi[2,5], F. Sirghi[2,5], K. Suzuki[6], S. Suzuki[8], T. Suzuki[11], K. Tanida[18], H. Tatsuno[19], M. Tokuda[14], D. Tomono[1], A. Toyoda[8], K. Tsukada[20], O. Vazquez Doce[2,21], E. Widmann[6], B. K. Wuenschek[6], T. Yamaga[15], T. Yamazaki[11,13], H. Yim[22], Q. Zhang[13], and J. Zmeskal[6]

$^3He(K^-, n_{NC})X$ — semi-inclusive

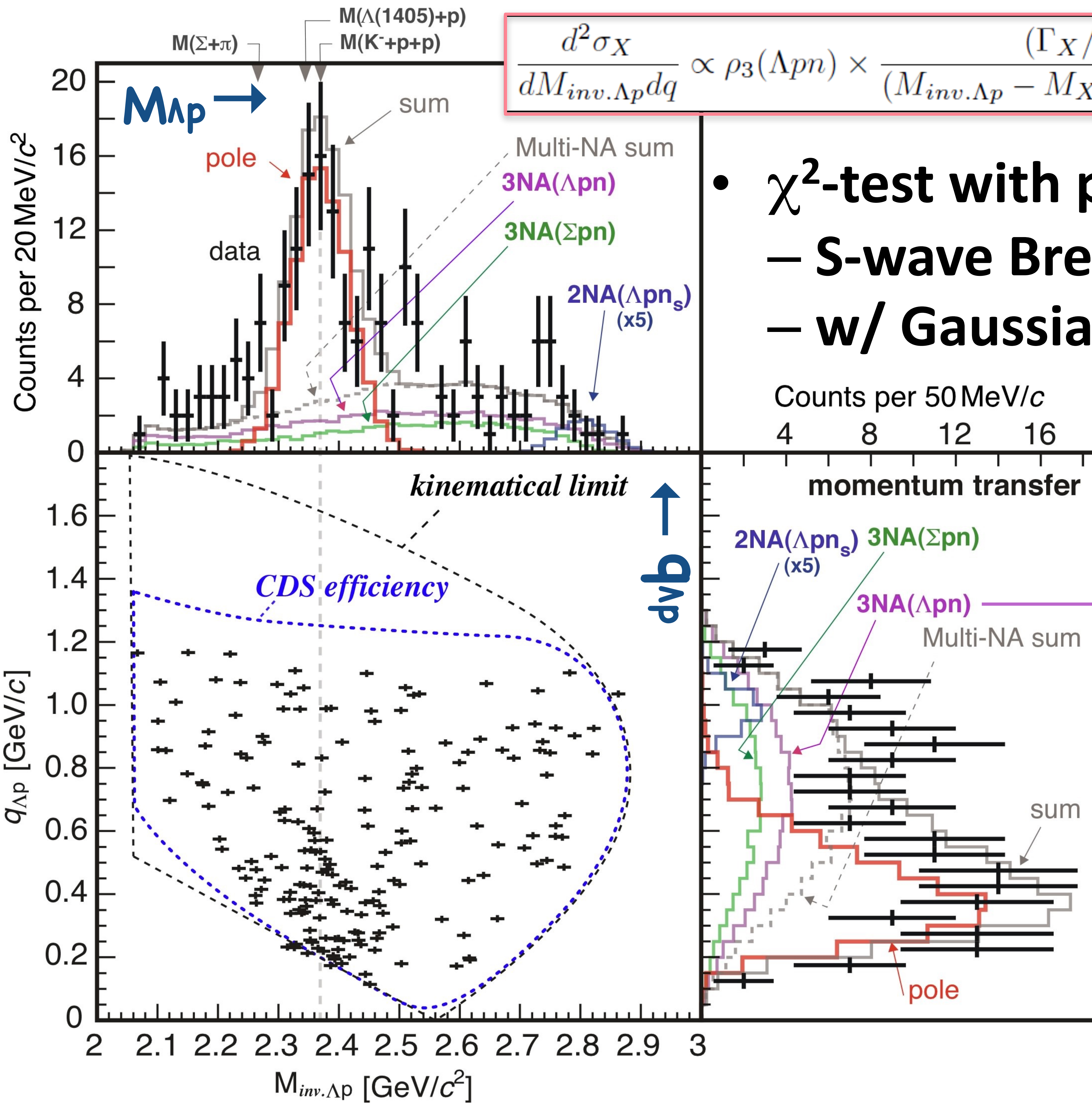


E15 1st result

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

$$\frac{d^2\sigma_X}{dM_{inv.\Lambda p}\,dq} \propto \rho_3(\Lambda pn) \times \frac{(\Gamma_X/2)^2}{(M_{inv.\Lambda p} - M_X)^2 + (\Gamma_X/2)^2} \times |\exp(-q^2/2Q_X^2)|^2,$$

- χ^2-test with pole & 3NA(Ypn)
  - S-wave Breit-Wigner pole
  - w/ Gaussian form-factor



$$\frac{d^2\sigma_{3NA(\Lambda pn)}}{dT_n^{CM}\,d\cos\theta_n^{CM}} \propto \rho_3(\Lambda pn)$$

B(X) ~ 15 MeV

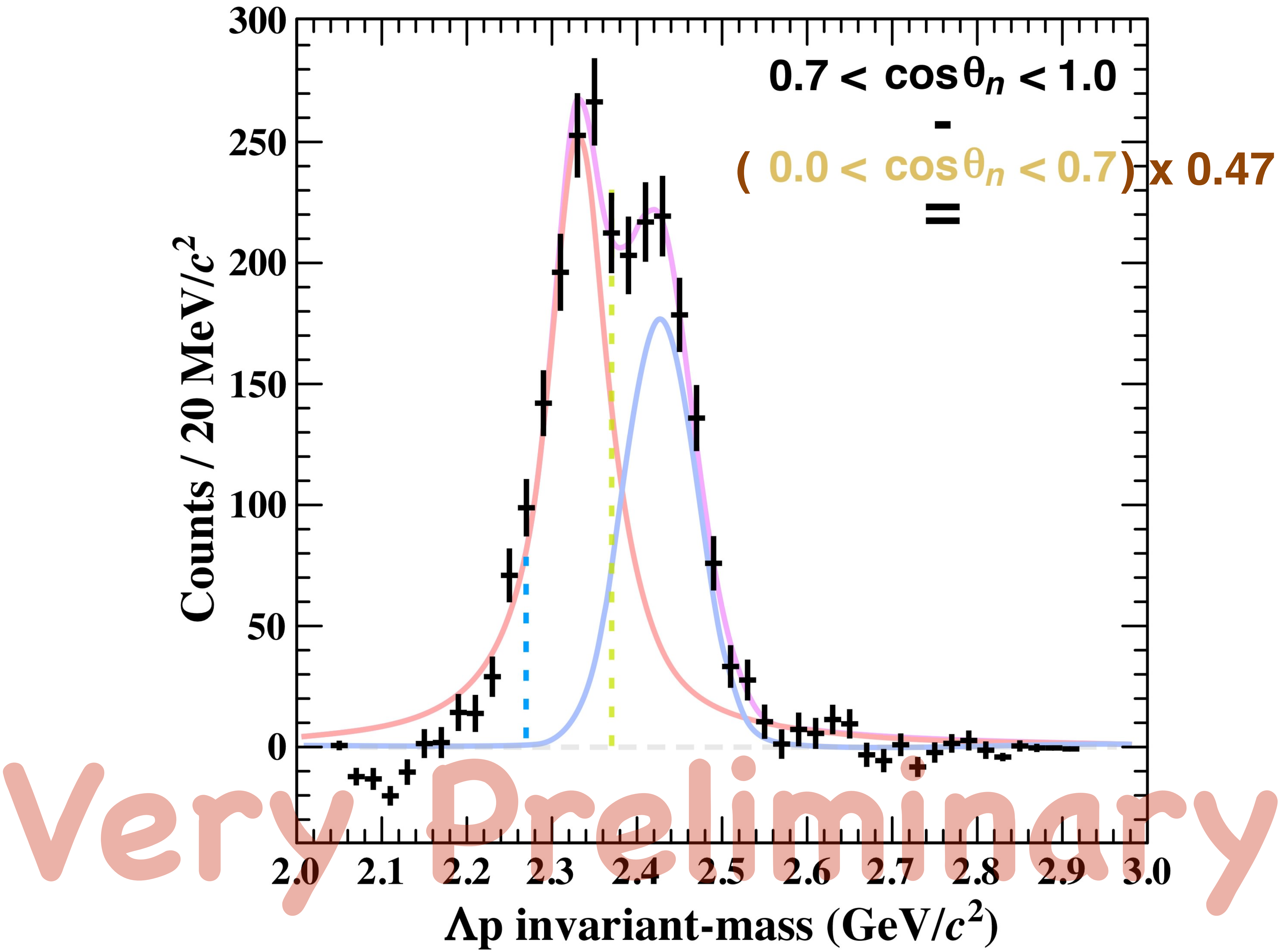
Γ(X) ~ 110 MeV

Q(X) ~ 400 MeV/c

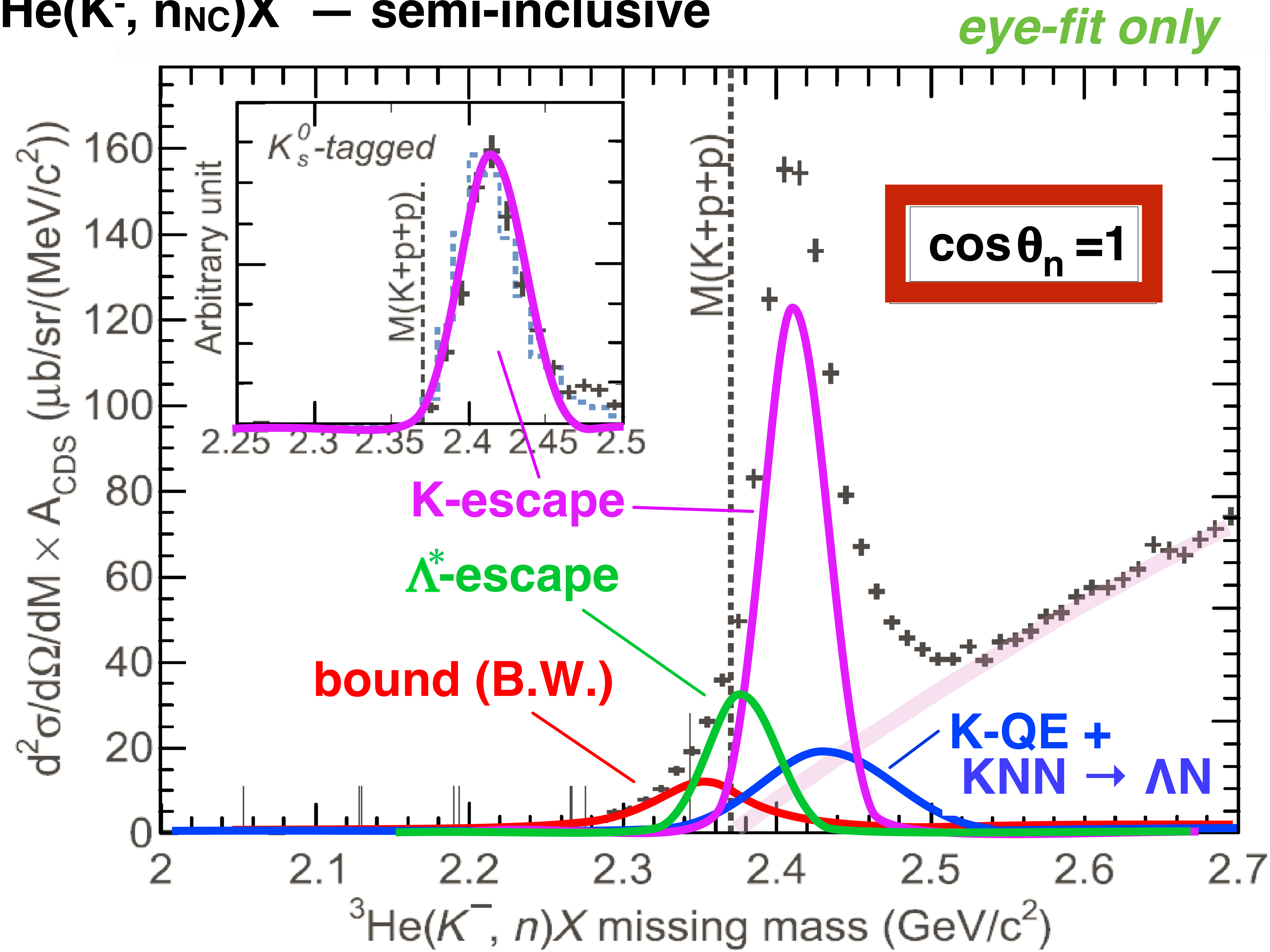
E15 2^{nd}

~ 30 times for Λpn channel

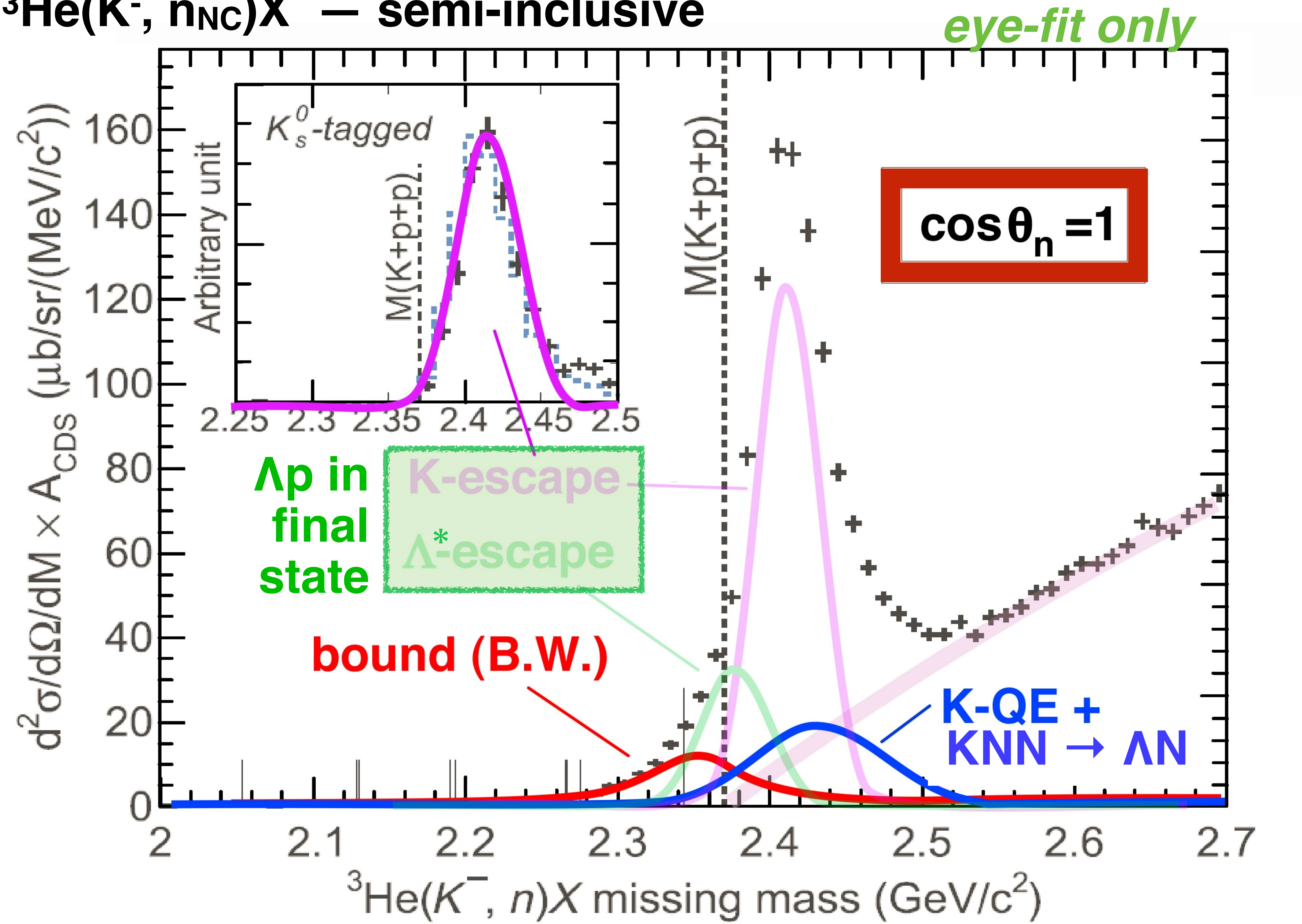
fit with Bright-Wigner + Gaussian



$^3He(K^-, n_{NC})X$ — semi-inclusive



$^{3}He(K^{-}, n_{NC})X$ — semi-inclusive



^{3}He(K^-, Λp)n @ p_K=1GeV/c consist from

1) peak in unbound region (above M(Kpp))

QF = K back-scattering (QE) × internal conversion (IC)

2) peak in bound region (below M(Kpp))

nuclear bound state

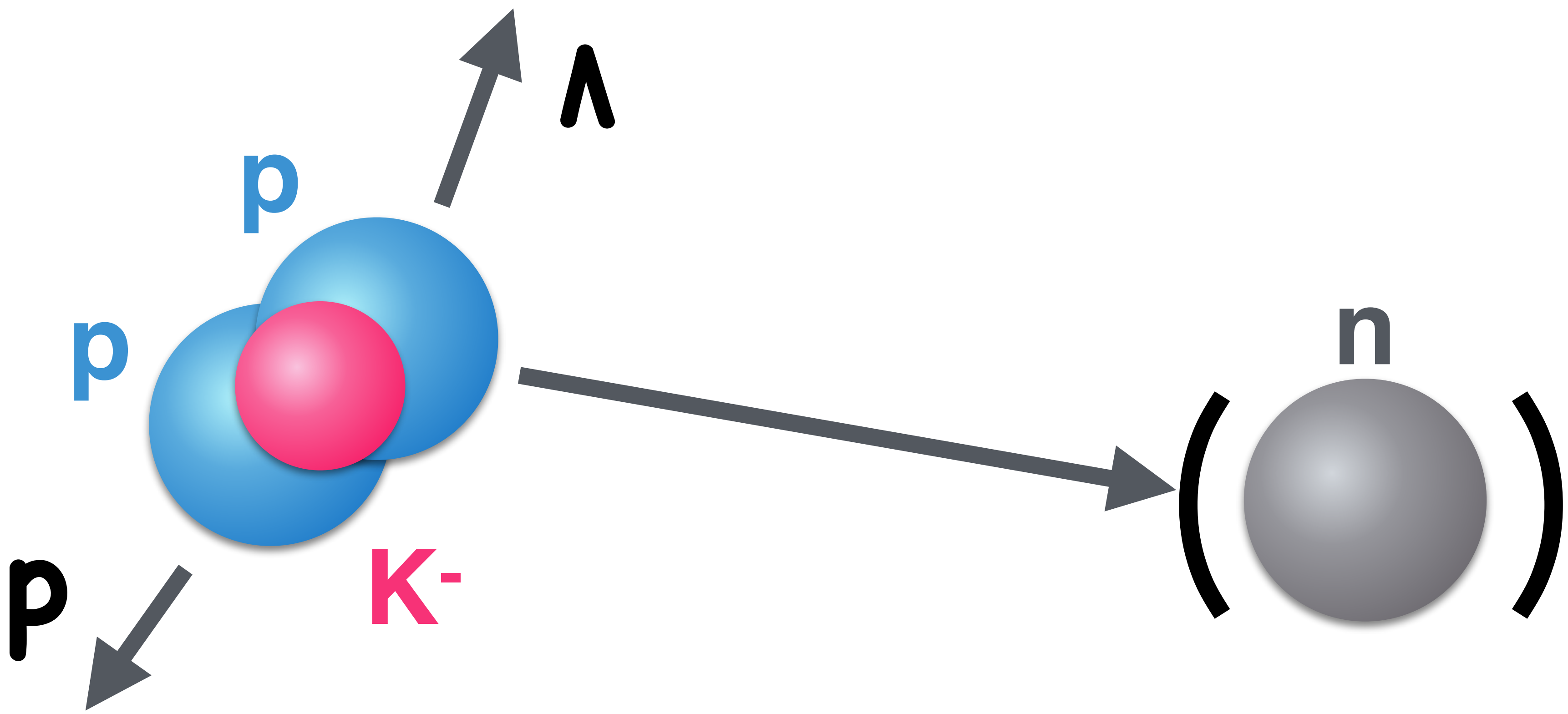
unlike baryonic resonance, this is associated with QF = QE + IC ... cf. nuclear formation

one can pull out the constituent particles, Kpp

K^-pp compose the resonance

E15: $^3He(K^-, \Lambda p)n$ comparison with E31: $d(K^-, n\pi^\pm\pi^\mp)$

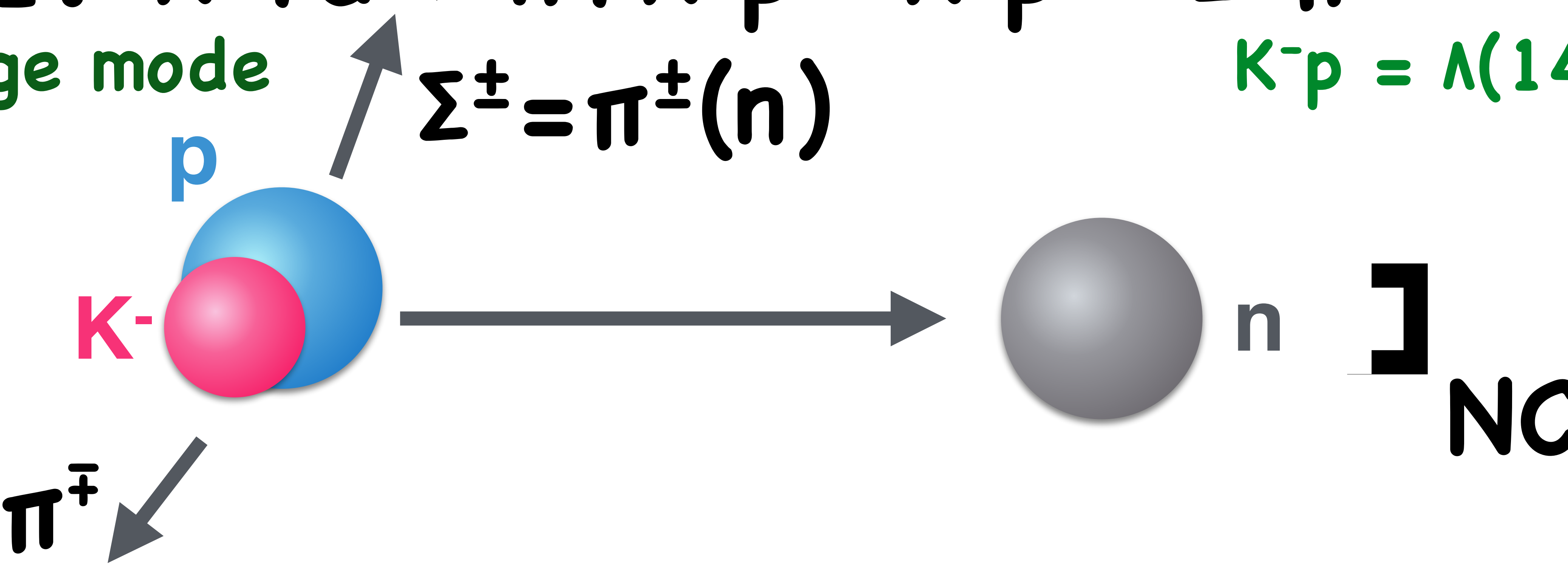
E15: $K^- + {}^3He \rightarrow n + K^-pp$ $\quad K^-pp \rightarrow \Lambda p$

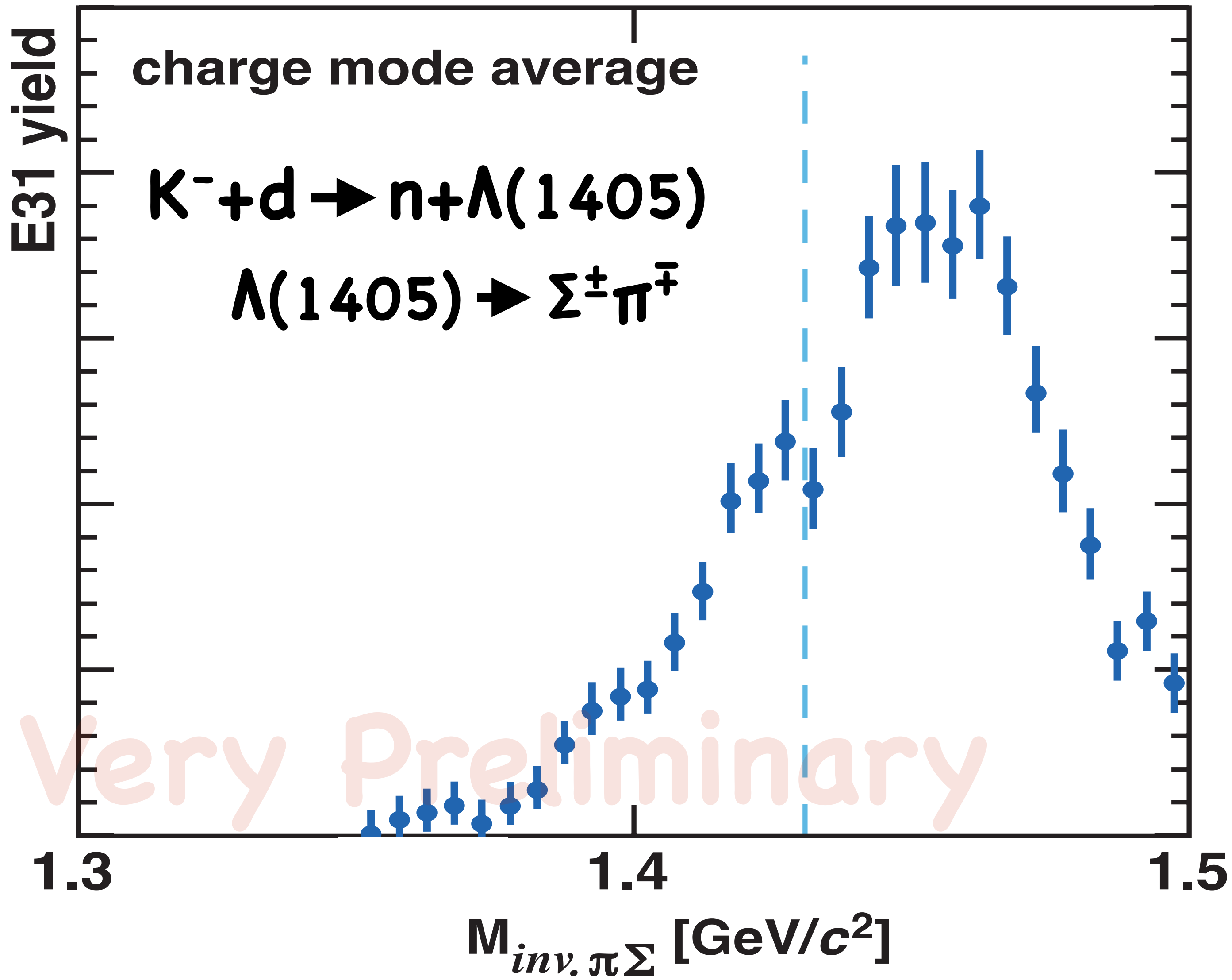


E31: $K^- + d \rightarrow n + K^-p$ $\quad K^-p \rightarrow \Sigma^\pm \pi^\mp$

charge mode

$K^-p = \Lambda(1405)$



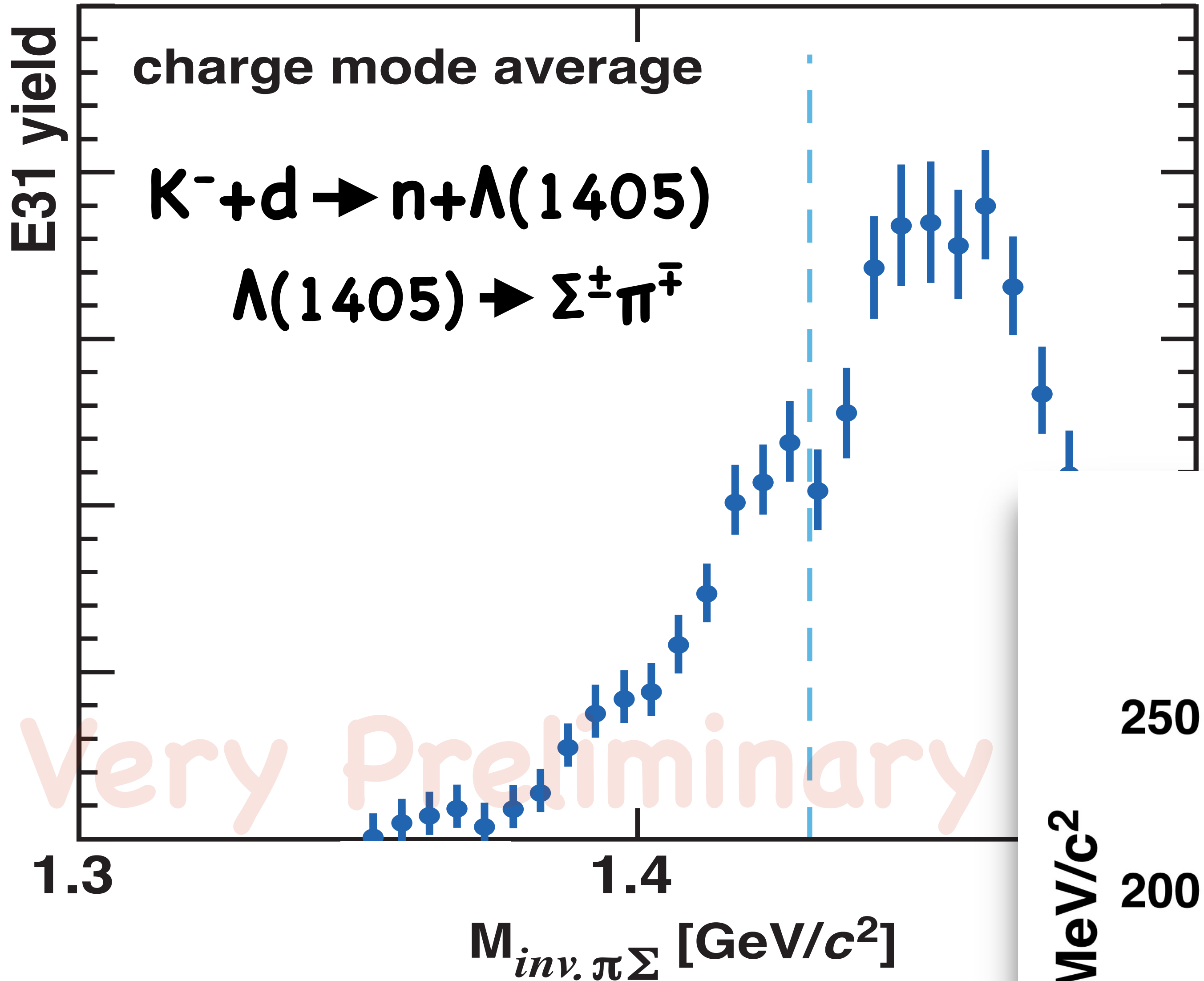


MENU2016 Kawasaki et al.,

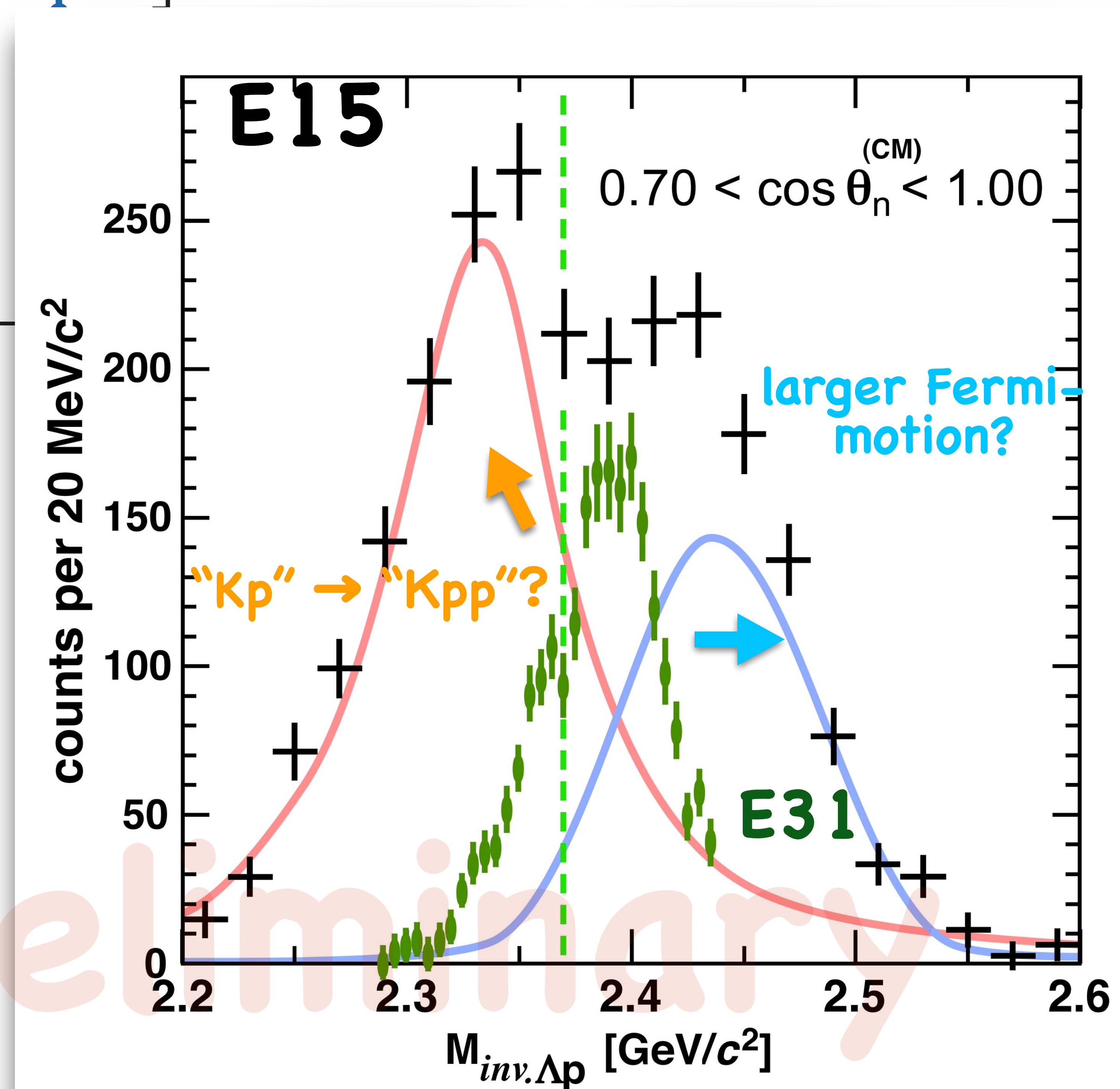
E31:

$K^{-}+d \rightarrow n+\Lambda(1405)$

$\Lambda(1405) \rightarrow \Sigma^{\pm}\pi^{\mp}$



MENU2016 Kawasaki et al.,



E31:

$K^- + d \to n + \Lambda(1405)$

$\Lambda(1405) \to \Sigma^{\pm}\pi^{\mp}$

E15 & E31

1) unbound region (above M(Kpp) / M(Kp))

$$QF = \left(\begin{array}{c} \text{K back-scattering (QE)} \\ \times \\ \text{conversion (C)} \end{array} \right)$$

non-resonant

2) bound region (below M(Kpp) / M(Kp))

nuclear bound state

$B_{Kpp} > B_{Kp}$

$\Gamma_{Kpp} >> \Gamma_{Kp}$

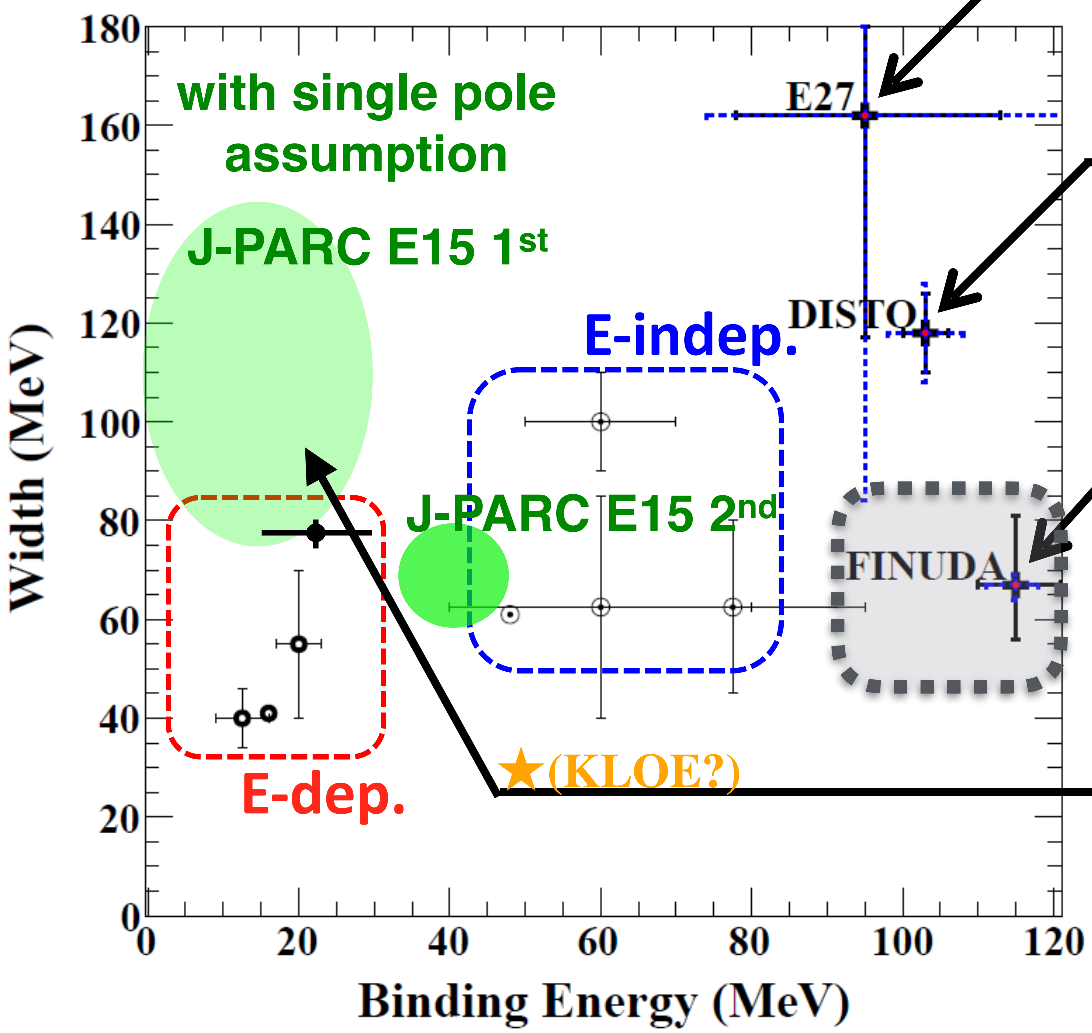
Kpp major decay = YN

Recent status of $K^{-}pp$ bound state

- **Recent results**
  - **Theoretical calc.**

    $\bar{K}N$ interaction model

    E-dep. / E-indep.



  - **Experiments**

Reports structure / ***NO** structure*

J-PARC E27
$d(\pi^{+}, K^{+})X$

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

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

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

LEPS
$p(\gamma, \pi^{-}K^{+})X$

HADES
$pp \rightarrow \Lambda p K^{+}$
$N^{*} \rightarrow \Lambda K^{+}$?

FINUDA ?

Experimental studies on $K^{-}pp$ — *a personal view*

J-PARC E15 experiment

- — lowest momentum transfer, achievable
- — well identified final state
- — less background expected

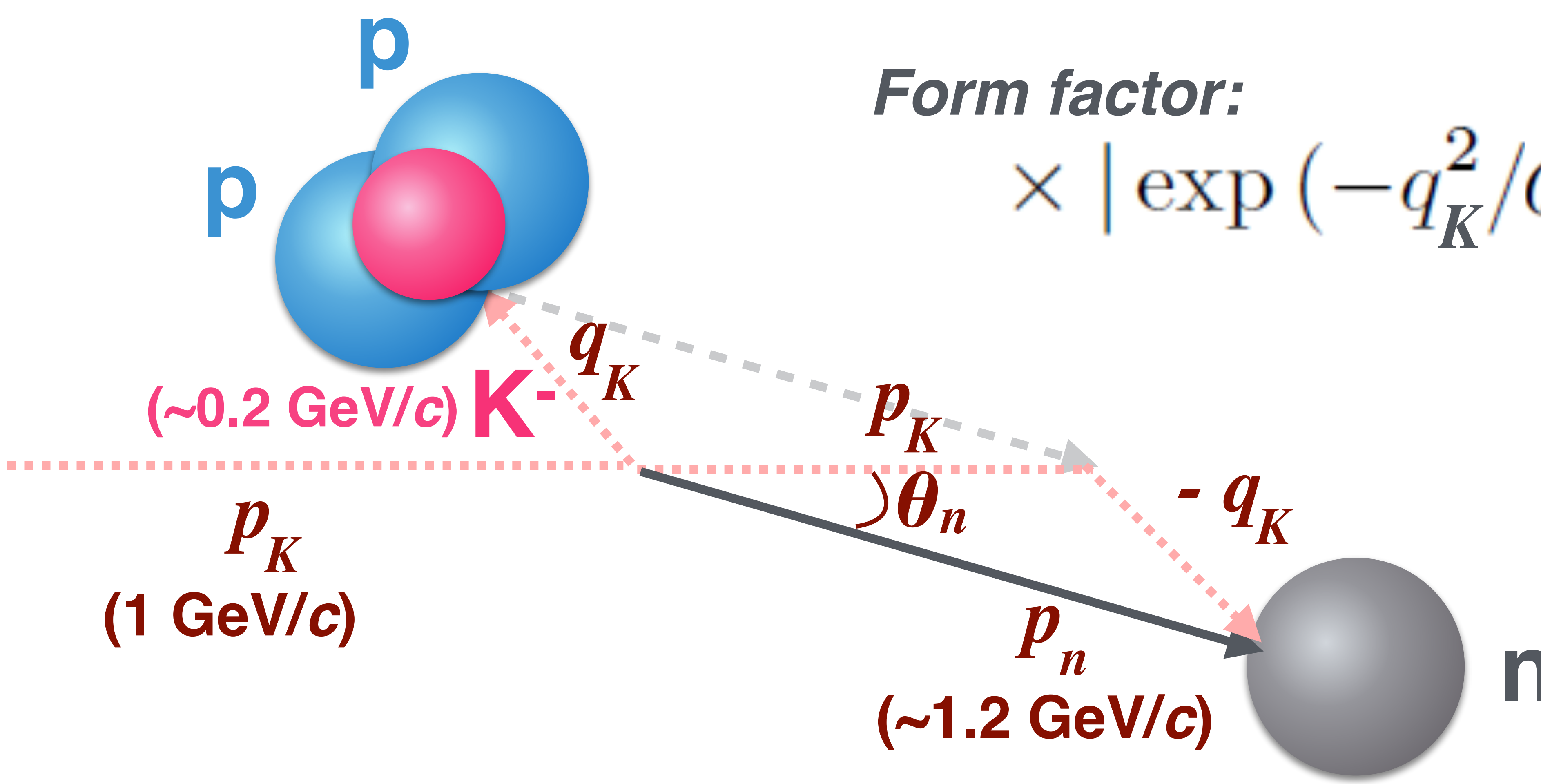
non-strange channel → $K^{+}\Lambda(Y) \gg K^{+}K^{-}N$

Experiment	Reaction	final state	projectile	q (MeV/c)	B.G.	statistics	Q.F.	Results
FINUDA	X (K^- at-rest, Λ p) Y	Λp + X	K^-	N. A.	2NA	insufficient	?	~ 100?
KLOE	^{4}He (K^- at-rest, Σ^0 p) X	Σ^0p + X	K^-	N. A.	2NA	?	?	~ 50??
DISTO	p p→K^+ Λ p (T_p = 2.85 GeV)	(Λ p) + K^+ p + (K^+ Λ) ?	p	300-400	N*(1710) →K^+ Λ	huge w/ K^+ Λ	No	~ 100?
HADES	p p→K^+ Λ p (T_p = 3.50 GeV)	p + Λ + K^+ N*(1710)	p	500-700	K^+ Λ	Null	Null	Null
LEPS	p (γ, π^- K^+) X	N.A.	γ	300-600	small σ	Null	Null	Null
J-PARC E27	d (π^+,K^+) X (= Λp / Σ^0 p)	Λp / Σ^0p	π^+	500-700	K^+ Λ(Σ^0)	insufficient w/ K^+ Y	No	~ 100?
J-PARC E15	^{3}He(K^-, Λp) n	Λp + n	K^-	200-300	—	good	Yes	40 ~ 50?

$^3He(K^-, \Lambda p)n$:
How to extract size information?

momentum transfer q_K & $\cos\theta_n$

$$q_K = p_K - p_n \quad (\sim 200\,\mathrm{MeV}/c)$$



Form factor:

$$\times \left|\exp\left(-q_K^2/Q_X^2\right)\right|^2,$$

$$Q_X = \frac{\hbar}{R}$$

$$q_K^2 = p_K^2 + p_n^2 - 2\,p_K\,p_n \cos\theta_n$$

$\bar{\mathrm{K}}\mathrm{N} \rightarrow$ **Y*(~1700)** $\rightarrow \bar{\mathrm{K}}\mathrm{N}$

$$f(\mathbf{p}_\mathrm{K}, \mathbf{p}_\mathrm{n}) \propto \langle f|\, V\, |i\rangle + \langle f|\, V \frac{1}{E - H_0 + i\epsilon} V\, |i\rangle + \ldots$$

$\bar{\mathrm{K}}\mathrm{N_s N_s} \rightarrow$ **"K⁻pp" S-wave resonance?**

$$f_0(\mathbf{p}_\mathrm{K}, \mathbf{p}_\mathrm{n}) \propto \left\langle \exp\left(-i\frac{\mathbf{p}_\mathrm{n}\cdot\mathbf{x}'}{\hbar}\right)\exp\left(-\frac{\mathbf{x}'^2}{2{R_\mathrm{Kpp}}^2}\right)\middle|\, V\, \middle|\exp\left(i\frac{\mathbf{p}_\mathrm{K}\cdot\mathbf{x}}{\hbar}\right)\exp\left(-\frac{\mathbf{x}^2}{2{R_\mathrm{He}}^2}\right)\right\rangle$$

$$\frac{V_0}{4\pi}\delta(\mathbf{x}' - \mathbf{x})$$

PWIA

$$\begin{aligned}
&\propto \frac{V_0}{4\pi}\int d^3x \exp\left(-i\frac{(\mathbf{p}_\mathrm{K} - \mathbf{p}_\mathrm{n})\cdot\mathbf{x}}{\hbar}\right)\exp\left(-\left(\frac{1}{{R_\mathrm{Kpp}}^2} + \frac{1}{{R_\mathrm{He}}^2}\right)\frac{\mathbf{x}^2}{2}\right) \\
&= \frac{V_0}{4\pi}\int d^3x \exp\left(i\,\mathbf{k}\cdot\mathbf{x}\right)\exp\left(-\frac{\mathbf{x}^2}{2R^2}\right), \qquad R = R_\mathrm{Kpp}\left(1 + \left(\frac{R_\mathrm{Kpp}}{R_\mathrm{He}}\right)^2\right)^{-1/2} \\
&= \sqrt{\frac{\pi}{2}}V_0 R^3 \exp\left(-\frac{R^2k^2}{2}\right)
\end{aligned}$$

$$\frac{d\sigma_0}{d\Omega} \propto |f_0(q)|^2 \propto \exp\left(-\frac{R^2q^2}{\hbar^2}\right) = \exp\left(-\frac{q^2}{Q^2}\right), \qquad Q = \frac{\hbar}{R}$$

what we assumed in E15^{1st}

existence of a pole in : $K^- + {}^3He \rightarrow \Lambda + p + n_{mis.}$

$$\frac{d^2\sigma_X}{dM_{inv.\Lambda p}dq} \propto \rho_3(\Lambda pn) \times \frac{(\Gamma_X/2)^2}{(M_{inv.\Lambda p} - M_X)^2 + (\Gamma_X/2)^2}$$

$$\times \left|\exp\left(-q_K^2/Q_X^2\right)\right|^2,$$

q is reaching as large as ~800 MeV/c!

large Q_x (~400MeV/c) implies

realization of compact state

WHAT WE WISH TO HAVE?

spin / parity

WHAT'S NEXT?

$\bar{K}N \to$ Y*(~1700) $\to \bar{K}N$ $f(\mathbf{p_K}, \mathbf{p_n}) \propto \langle f|\, V\, |i\rangle + \langle f|\, V \frac{1}{E - H_0 + i\epsilon} V\, |i\rangle + \ldots$

$\bar{K}N_sN_s \to$ “K^-pp” S-wave resonance?

$$f_0(\mathbf{p_K}, \mathbf{p_n}) \propto \left\langle \exp\left(-i\frac{\mathbf{p_n}\cdot\mathbf{x}'}{\hbar}\right)\exp\left(-\frac{\mathbf{x}'^2}{2{R_{\rm Kpp}}^2}\right)\middle| V \middle| \exp\left(i\frac{\mathbf{p_K}\cdot\mathbf{x}}{\hbar}\right)\exp\left(-\frac{\mathbf{x}^2}{2{R_{\rm He}}^2}\right)\right\rangle$$

$$\frac{V_0}{4\pi}\delta(\mathbf{x}'-\mathbf{x})$$ PWIA

$$\propto \frac{V_0}{4\pi}\int d^3x \exp\left(-i\frac{(\mathbf{p_K}-\mathbf{p_n})\cdot\mathbf{x}}{\hbar}\right)\exp\left(-\left(\frac{1}{{R_{\rm Kpp}}^2}+\frac{1}{{R_{\rm He}}^2}\right)\frac{\mathbf{x}^2}{2}\right)$$

$$= \frac{V_0}{4\pi}\int d^3x \exp\left(i\,\mathbf{k}\cdot\mathbf{x}\right)\exp\left(-\frac{\mathbf{x}^2}{2R^2}\right), \quad R = R_{\rm Kpp}\left(1+\left(\frac{R_{\rm Kpp}}{R_{\rm He}}\right)^2\right)^{-1/2}$$

$$= \sqrt{\frac{\pi}{2}}V_0R^3\exp\left(-\frac{R^2k^2}{2}\right)$$

$$\frac{d\sigma_0}{d\Omega} \propto |f_0(q)|^2 \propto \exp\left(-\frac{R^2q^2}{\hbar^2}\right) = \exp\left(-\frac{q^2}{Q^2}\right),$$

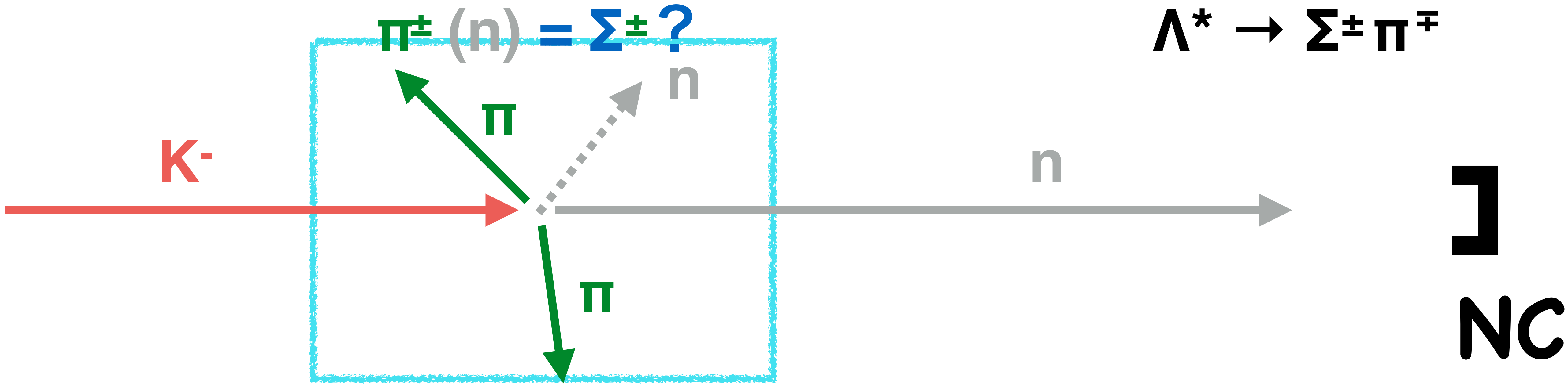
$$Q = \frac{\hbar}{R}$$

Theoretical calculation!

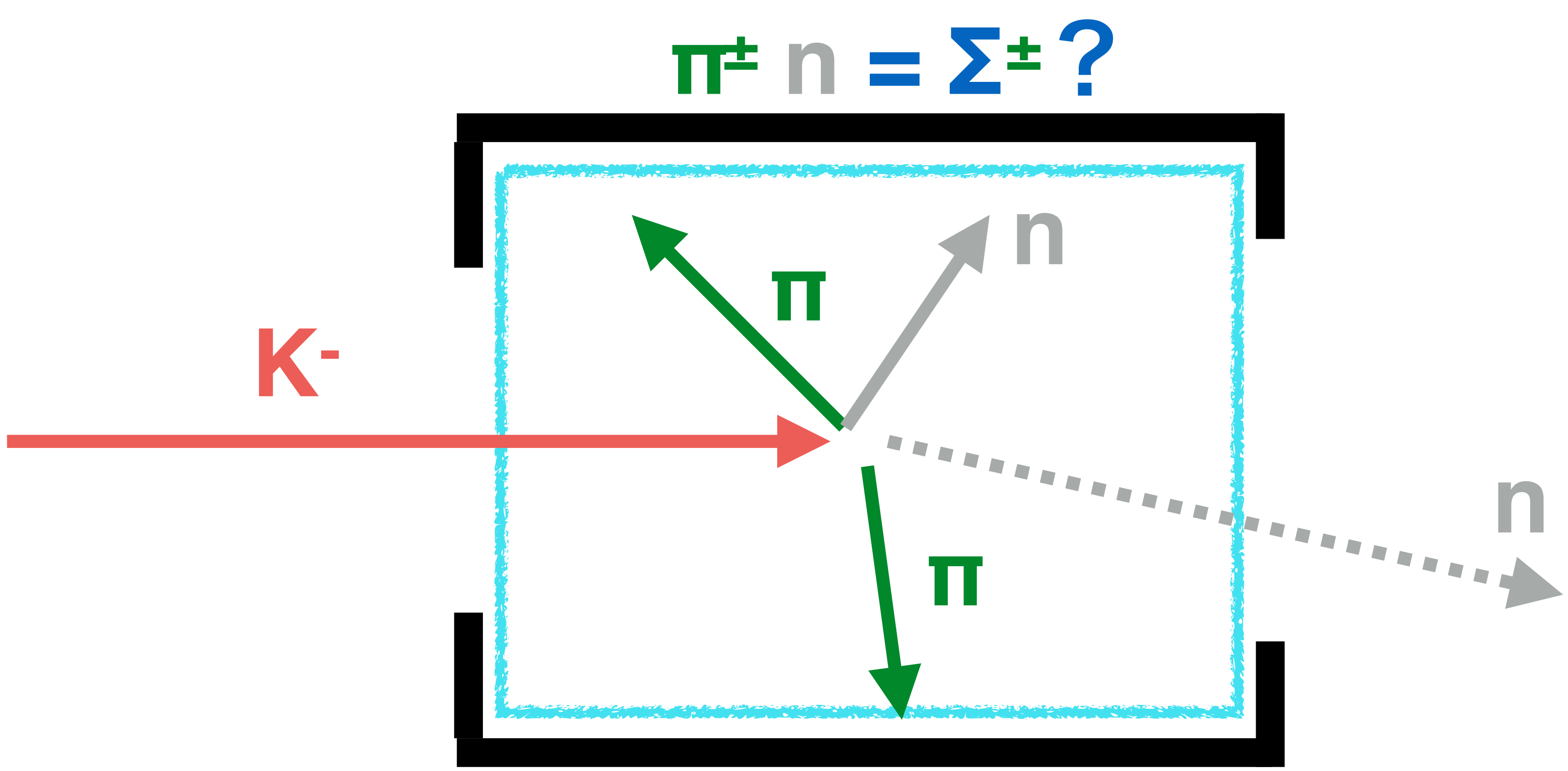
present E31 ($\cos\theta_n = 1$)

$K^- d \rightarrow \Lambda^* n$

$\Lambda^* \rightarrow \Sigma^\pm \pi^\mp$



signal @ E15 = $\cos\theta_n = 0.75 \sim 1$



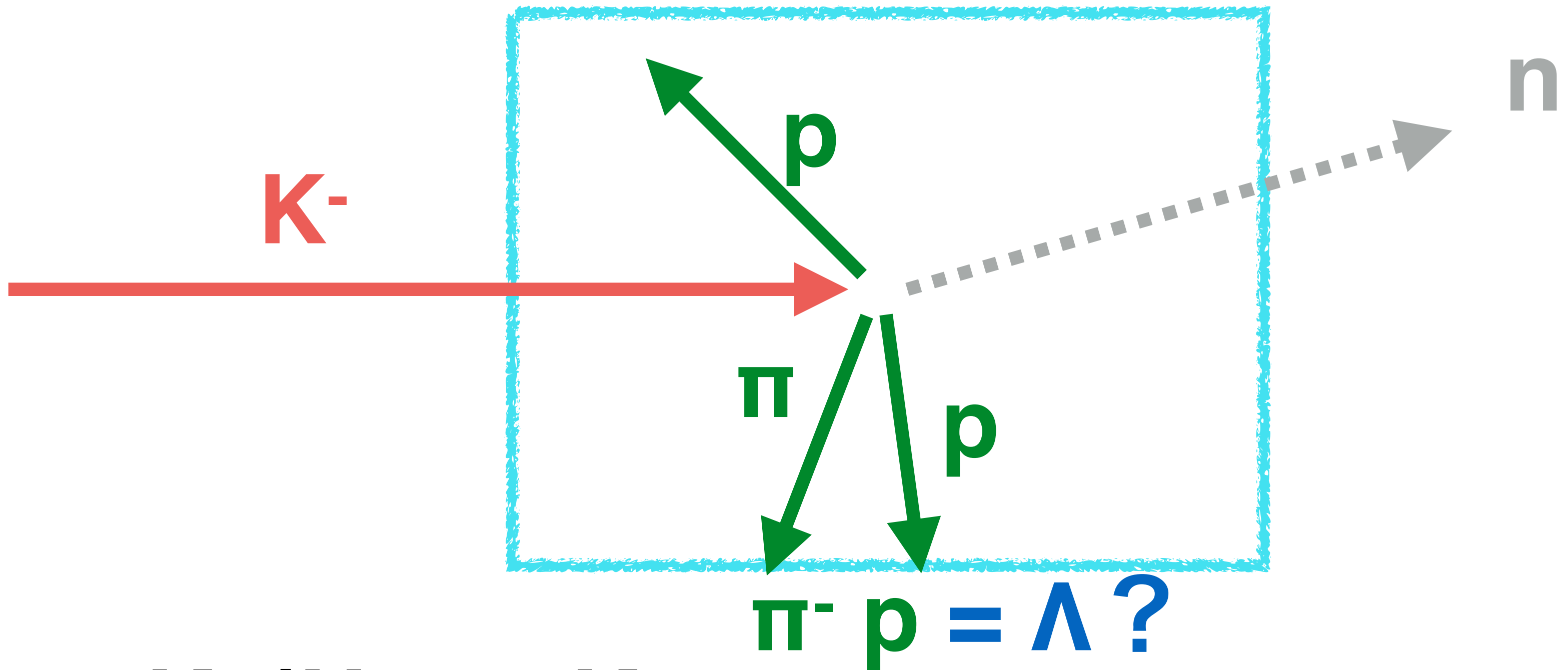
q dependence of Λ^* production

by checking
$\pi^\pm n = \Sigma^\pm$
directory

E15 ($\cos\theta_n = 0.75 \sim 1$)

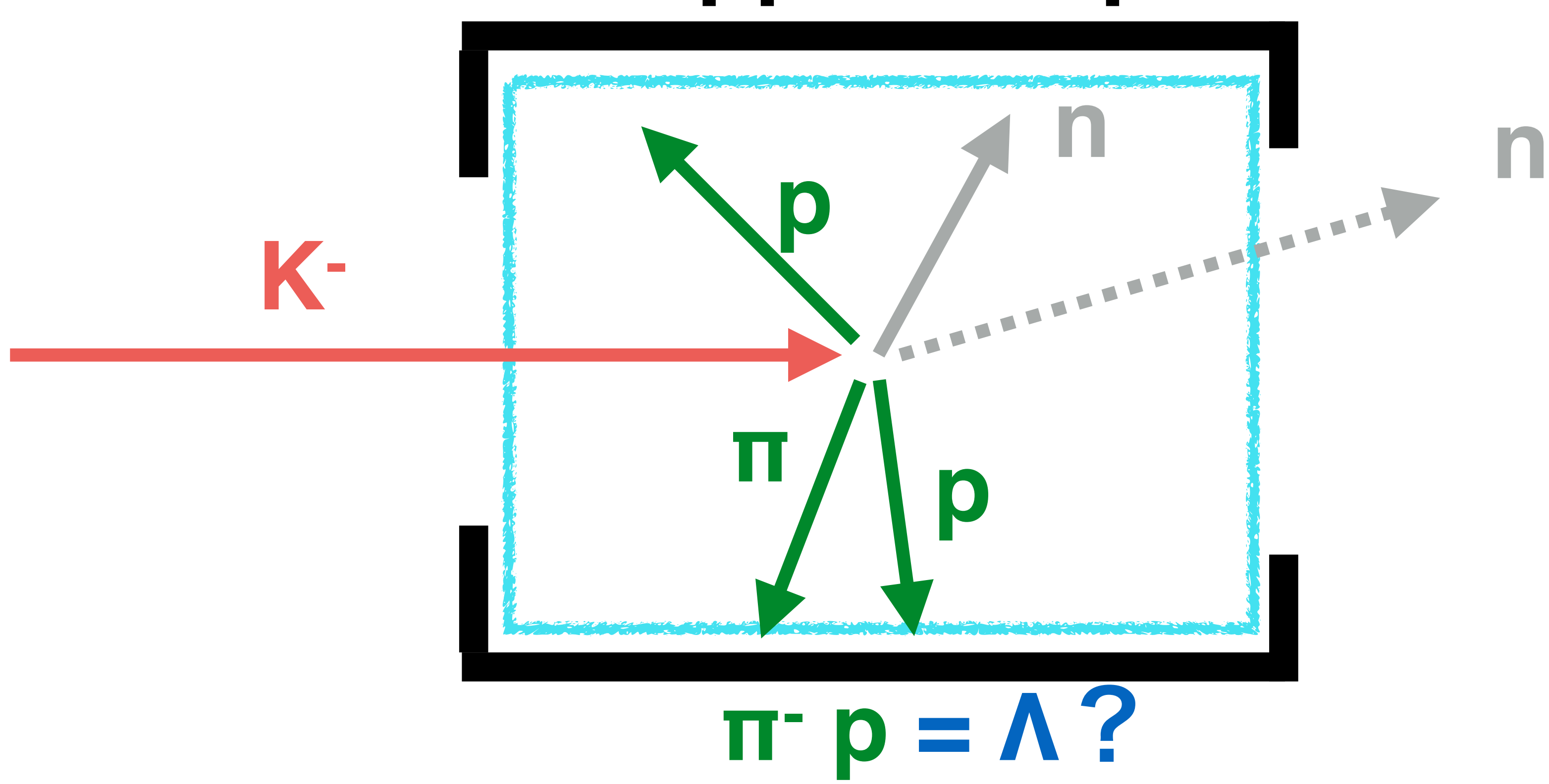
$K^- \, {}^3He \rightarrow K \, n$

$K \, pp \rightarrow \Lambda \, p$

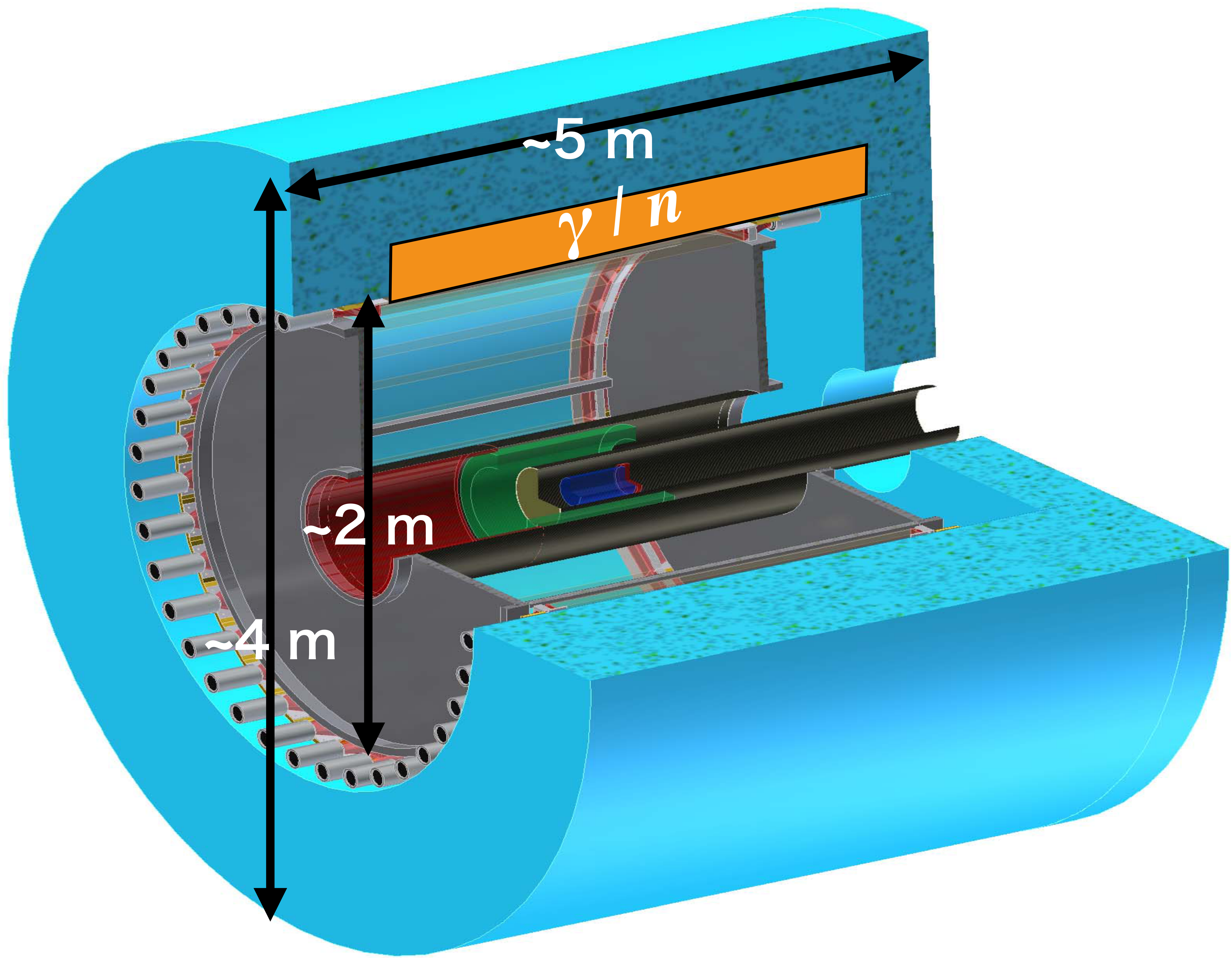


$K^- \, {}^4He \rightarrow K \, n$

$K \, ppn \rightarrow \Lambda \, pn$



" Kppn " nuclei?


~5 m
γ / n
~2 m
~4 m

Summary

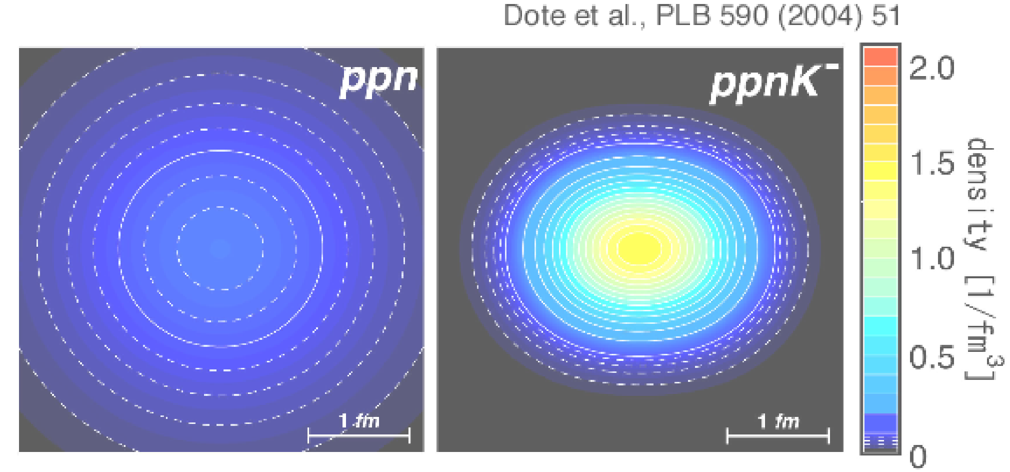
Why not improve detector?

for γ & n detect in CDS

spin / parity / branch / size / larger A

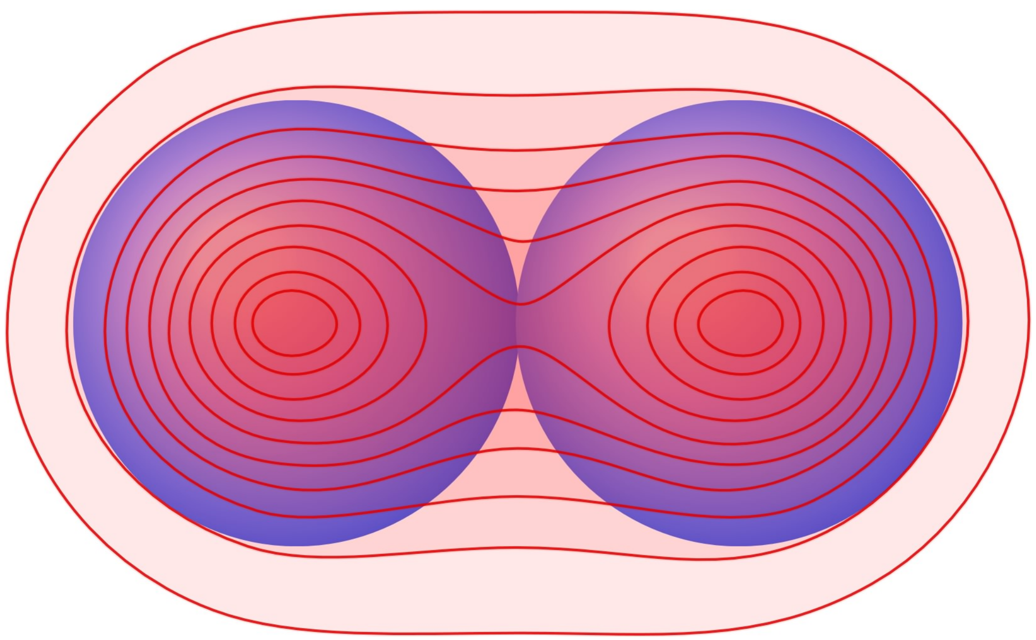
for high density matter study

Dote et al., PLB 590 (2004) 51

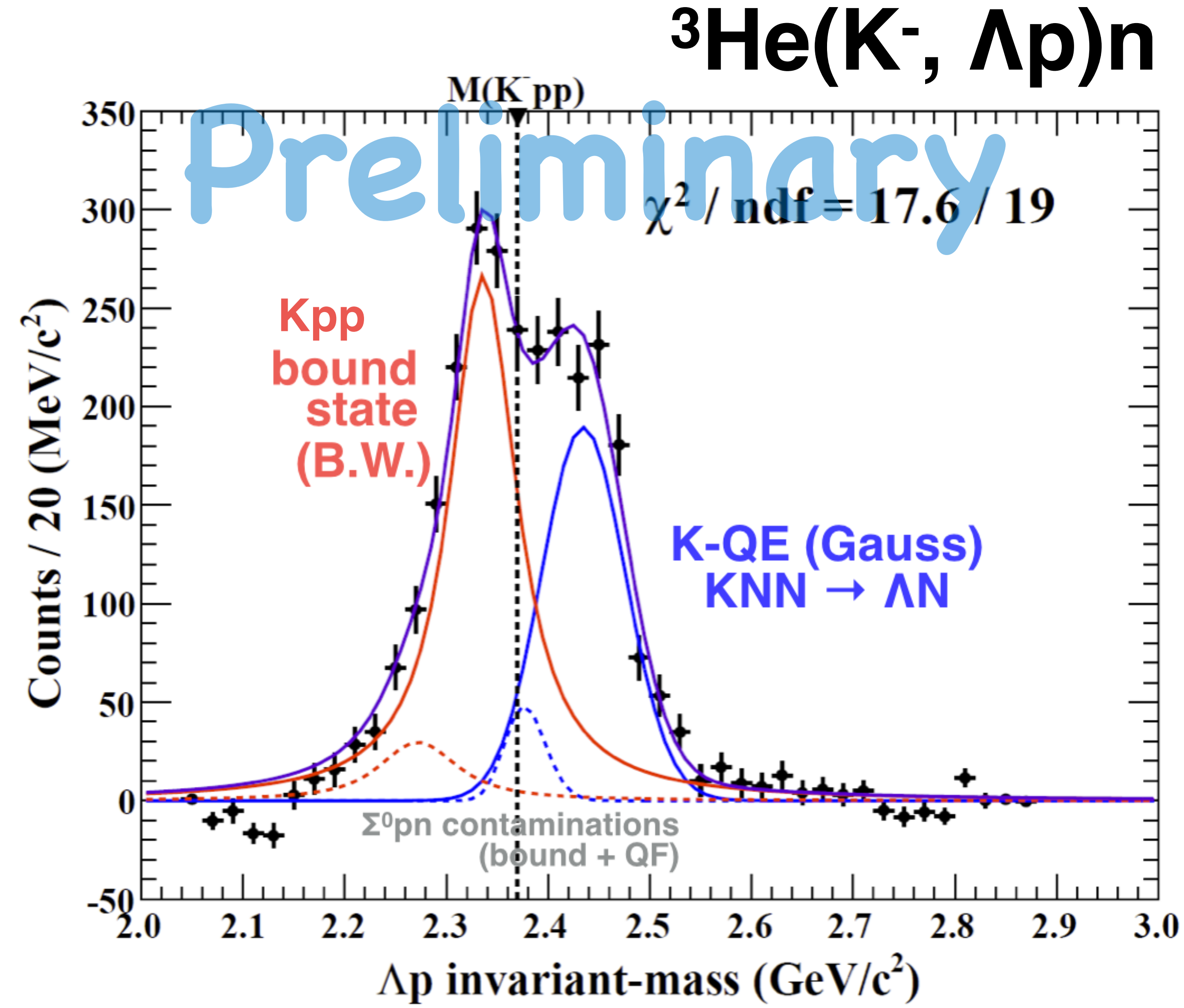


Strange Quark Matter?

success in K^-pp



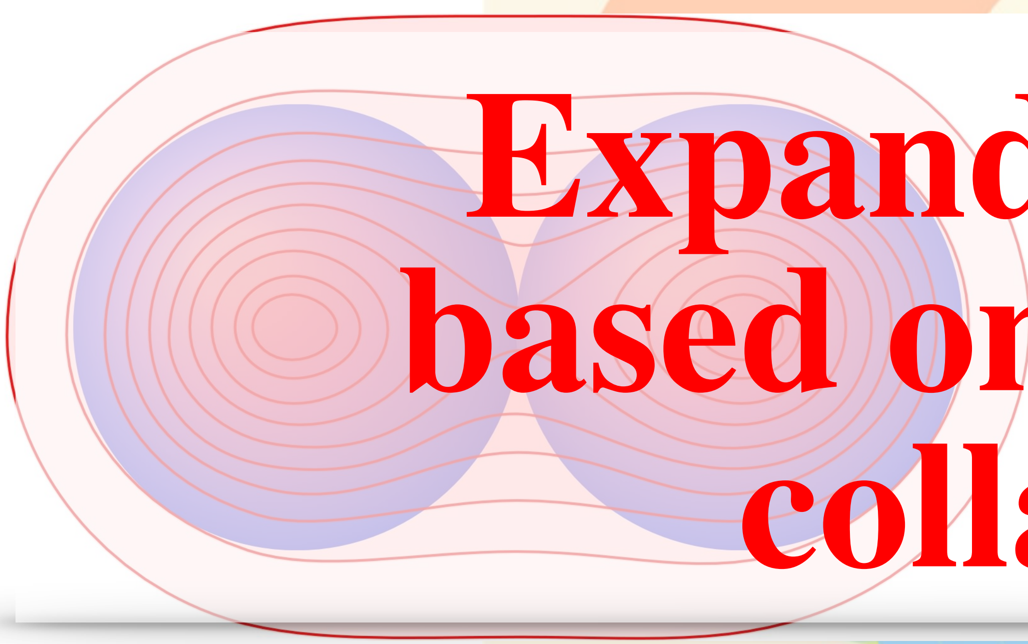
$\bar{K}N$ interaction

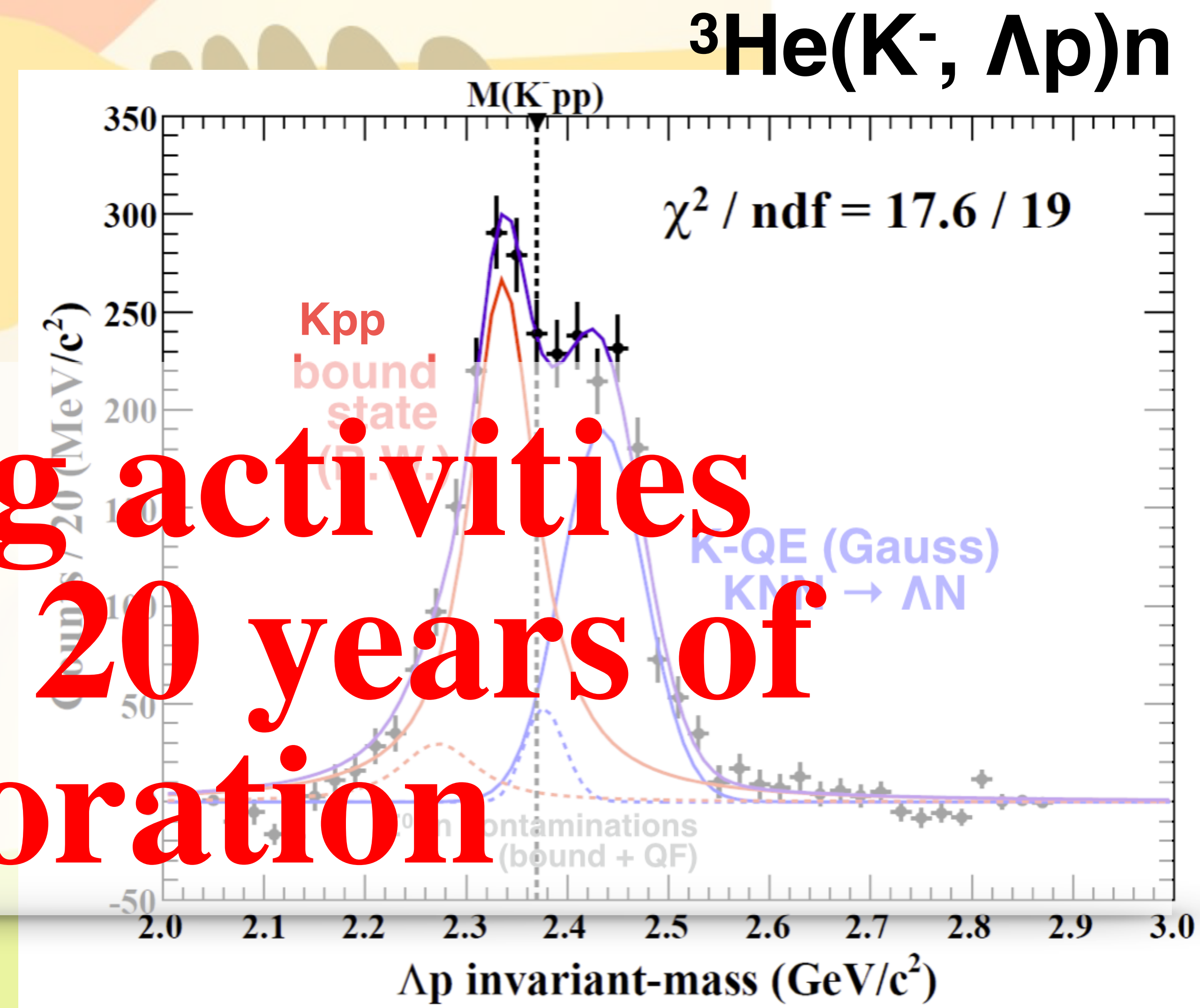


Kaonic Nuclei

Strange Quark Matter?

success in K^-pp





Expanding activities based on > 20 years of collaboration

$\bar{K}N$ interaction

Kaonic Nuclei

E15 collaboration

S. Ajimura, M. Bazzi, G. Beer, H. Bhang, M. Bragadireanu, P. Buehler, L. Busso, M. Cargnelli, S. Choi, C. Curceanu, S. Enomoto, D. Faso, H. Fujioka, Y. Fujiwara, T. Fukuda12, C. Guaraldo, T. Hashimoto, R. S. Hayano, T. Hiraiwa, M. Iio, M. Iliescu, K. Inoue, Y. Ishiguro, T. Ishikawa, S. Ishimoto, T. Ishiwatari, K. Itahashi, M. Iwai, M. Iwasaki, Y. Kato, S. Kawasaki, P. Kienle, H. Kou, Y. Ma, J. Marton, Y. Matsuda, Y. Mizoi1, O. Morra, T. Nagae, H. Noumi, H. Ohnishi, S. Okada, H. Outa, K. Piscicchia, A. Romero Vidal, Y. Sada, A. Sakaguchi, F. Sakuma, M. Sato, A. Scordo, M. Sekimoto, H. Shi, D. Sirghi, F. Sirghi, K. Suzuki, S. Suzuki, T. Suzuki, K. Tanida, H. Tatsuno, M. Tokuda, D. Tomono, A. Toyoda, K. Tsukada, O. Vazquez Doce, E. Widmann, B. K. Wuenschek, T. Yamaga, T. Yamazaki, H. Yim, Q. Zhang, and J. Zmeskal

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Showcasing example of Executive Program

— StrangeMatter —

Strangeness in the compact stars?

High precision experimental and theoretical studies of the strange matter nuclear interactions at low-energies

— Italy-Japan —

Catalina Curceanu

INFN Istituto Nazionale di Fisica Nucleare

REPVBBLICA ITALIANA

Masahiko Iwasaki

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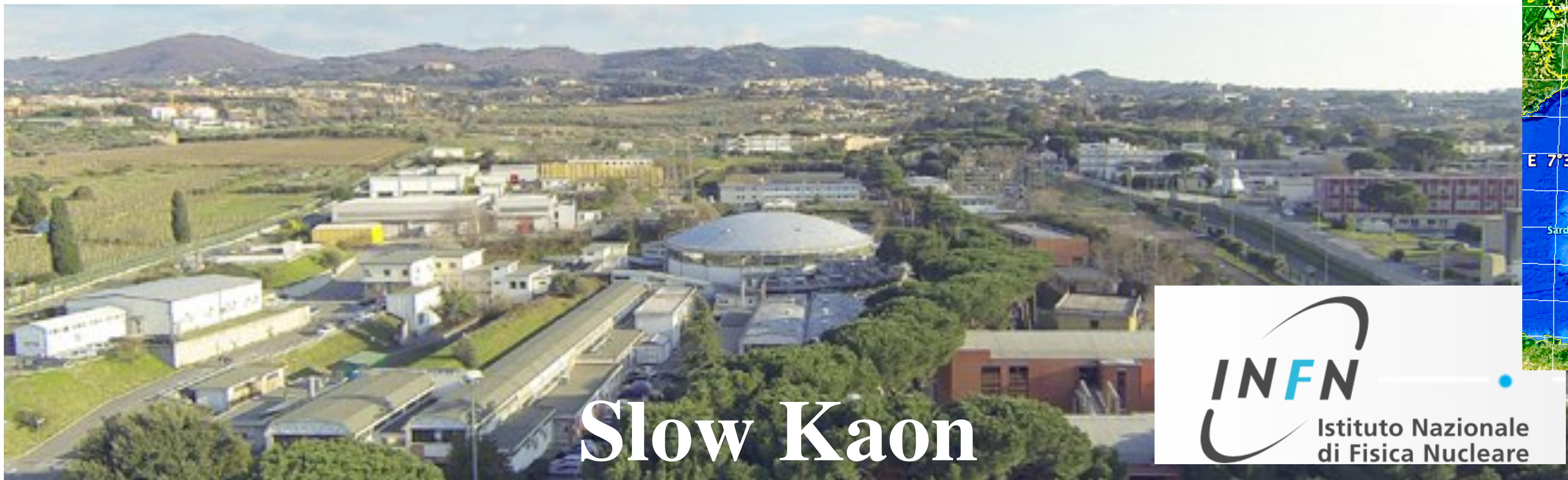
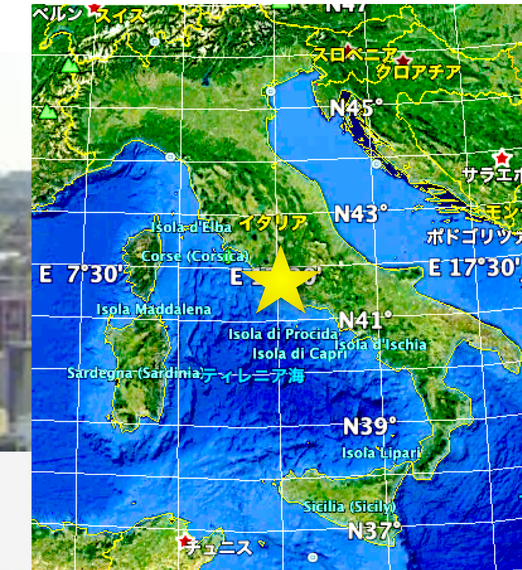
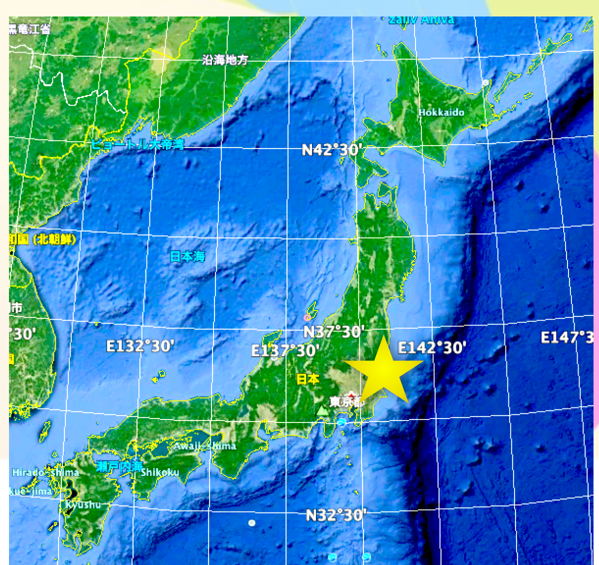
Ministero degli Affari Esteri e della Cooperazione Internazionale

2017.6.7


Slow Kaon
INFN
Istituto Nazionale
di Fisica Nucleare


N45°
N43°
E 7°30'
E 17°30'
N41°
N39°
N37°
Isola d'Elba
Corse (Corsica)
Isola Maddalena
Isola di Procida
Isola d'Ischia
Isola di Capri
Sardegna (Sardinia)
Isola Lipari
Sicilia (Sicily)


Hokkaido
N42°30'
N37°30'
E132°30'
E137°30'
E142°30'
N32°30'


J-PARC (KEK/JAEA)
Linac
South to North
3 GeV
Synchrotron
Neutrino
Beams (to
Kamioka)
Materials and Life
Science Experimental
Facility
50 GeV
Synchro
Hadron
Experiment
al Facility
J-PARC
Fast Kaon