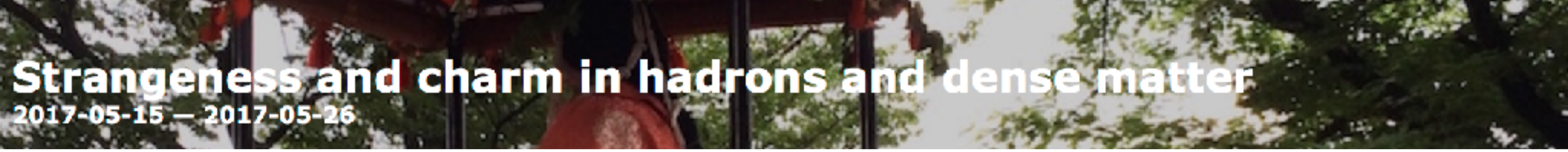
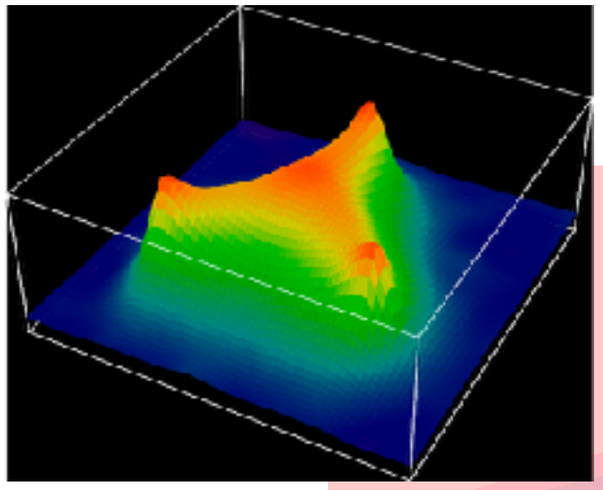


E15 Experiment at J-PARC

M. Iwasaki
RIKEN / TokyoTech
for E15 collaboration

To understand Hadrons / Nuclei based on QCD

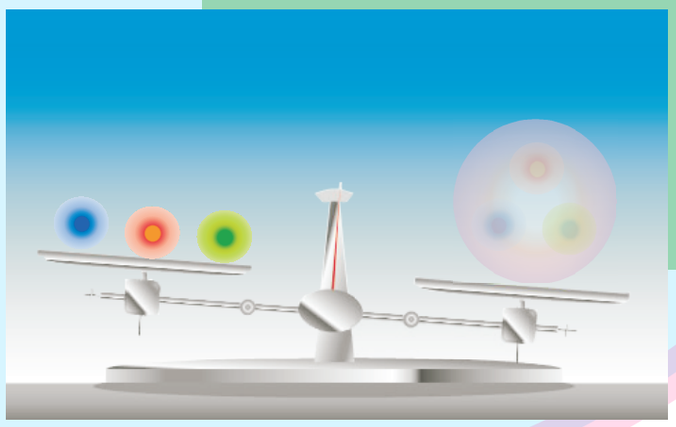


internal structure

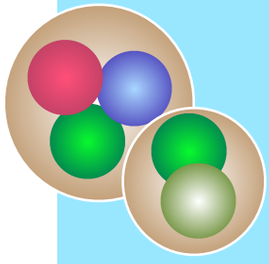
Shape

mass generation

Chiral symmetry



form of existence



Color symmetry

Hadrons

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

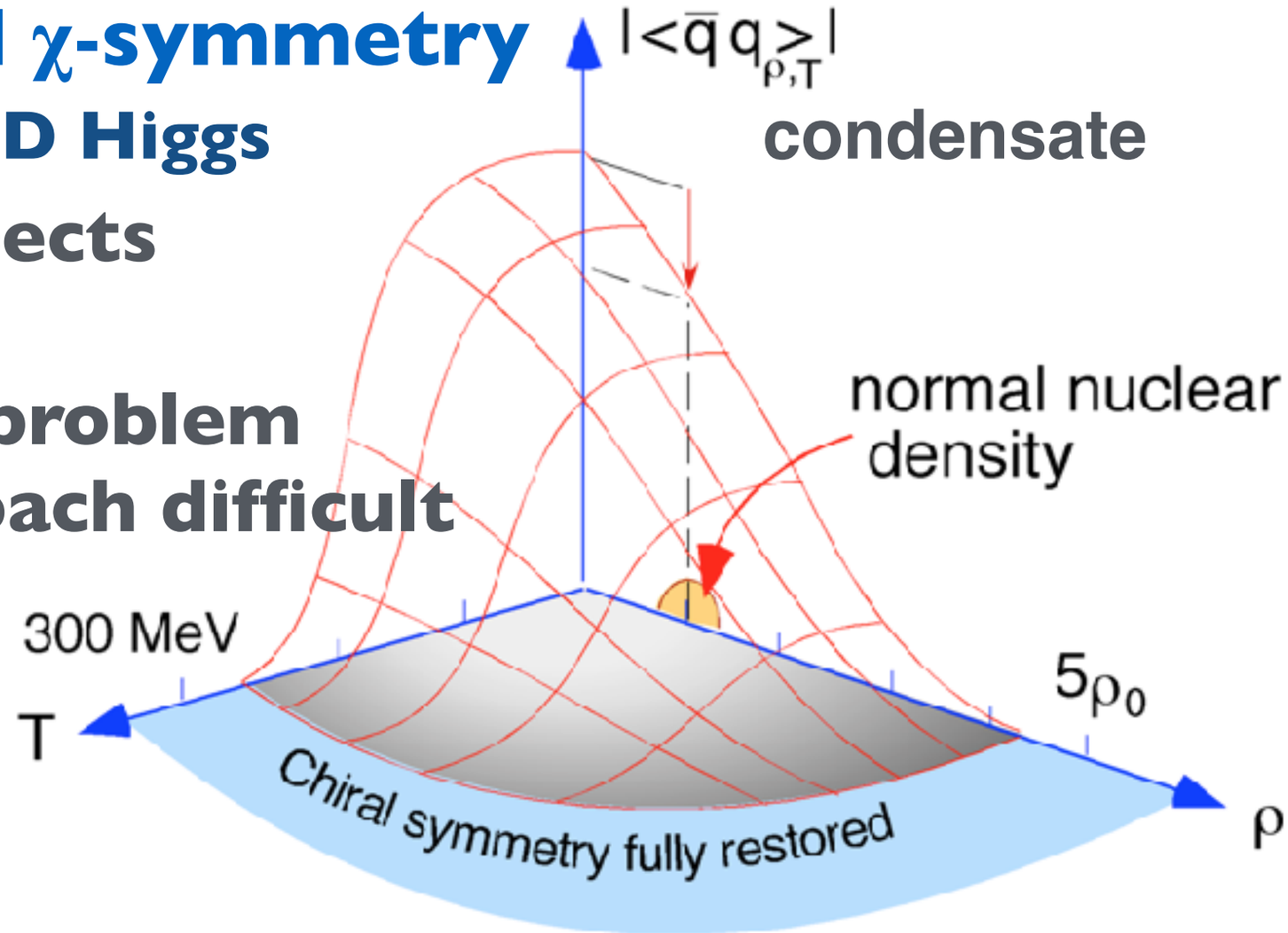
<q̄q> as QCD Higgs

Non-perturbative aspects

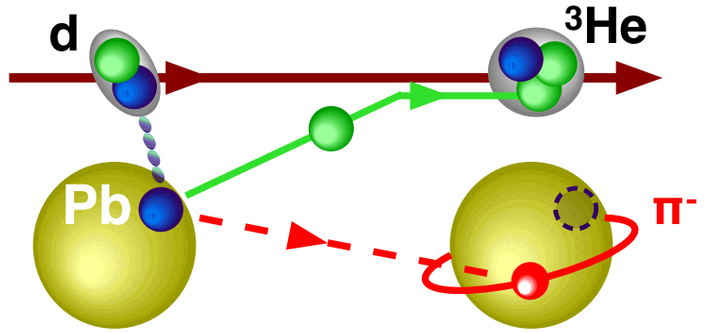
@ energy < Λ_{QCD}

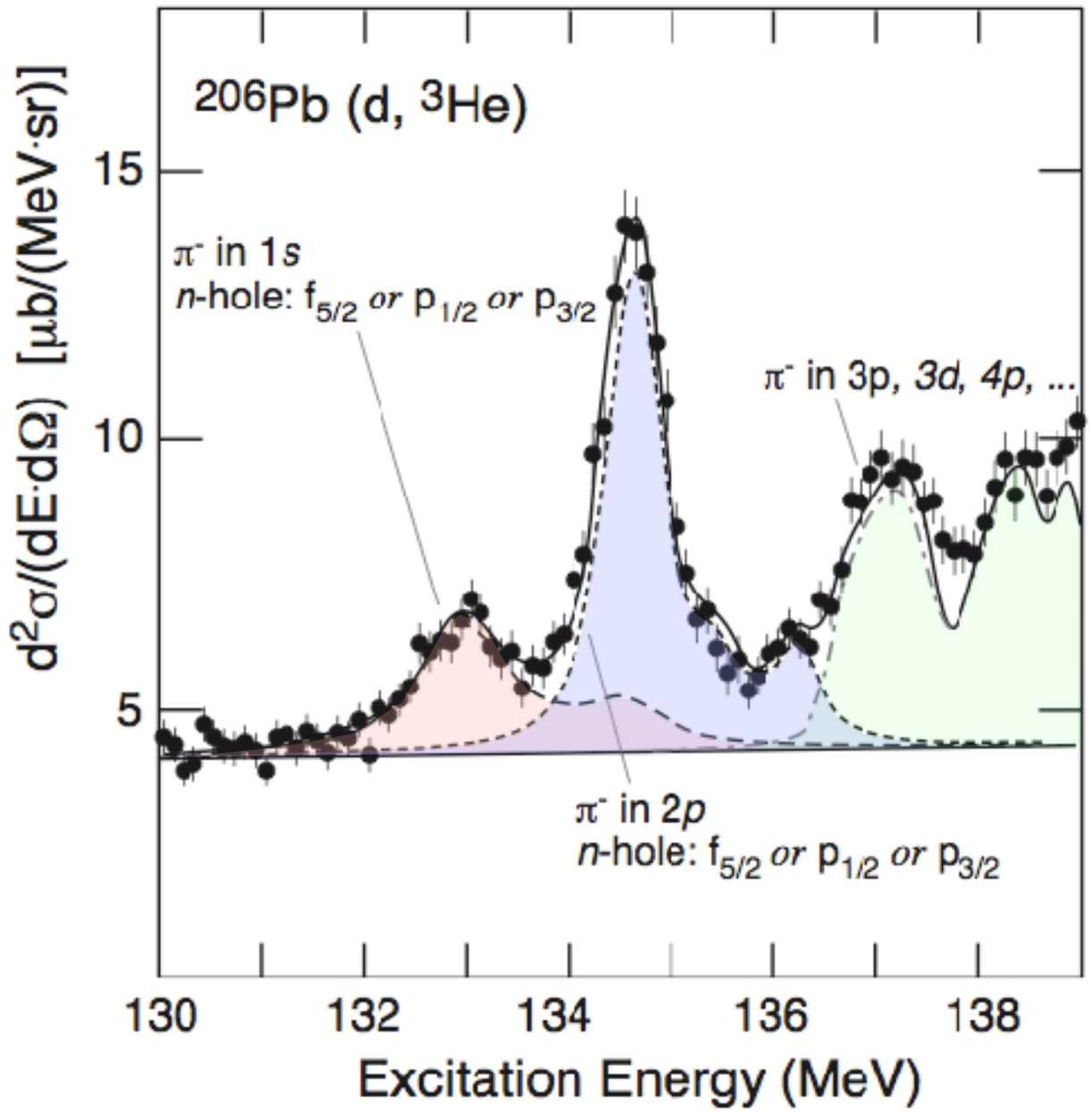
Finite density → sign problem

Lattice-QCD approach difficult

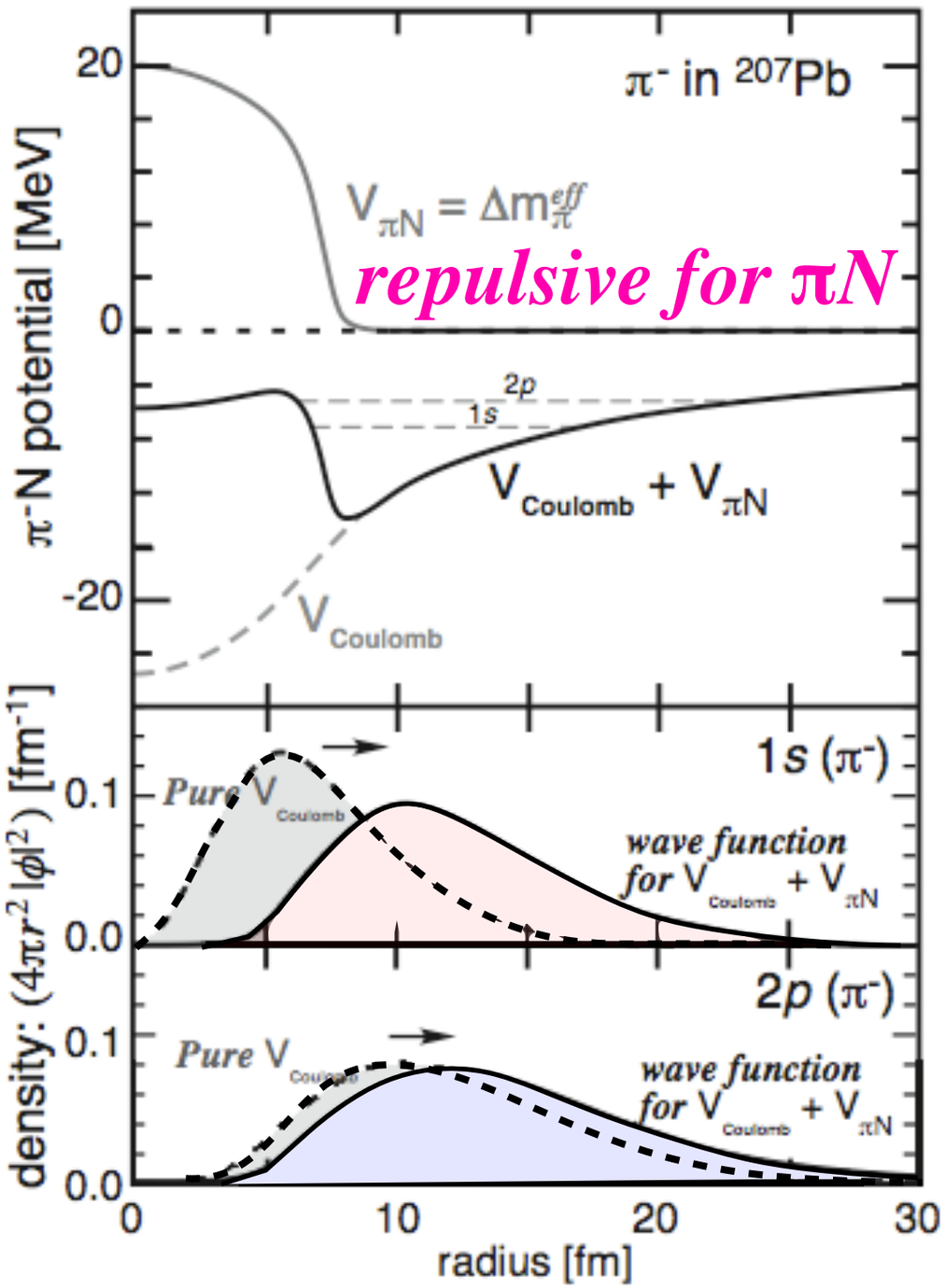


Can meson form a nuclear bound state?



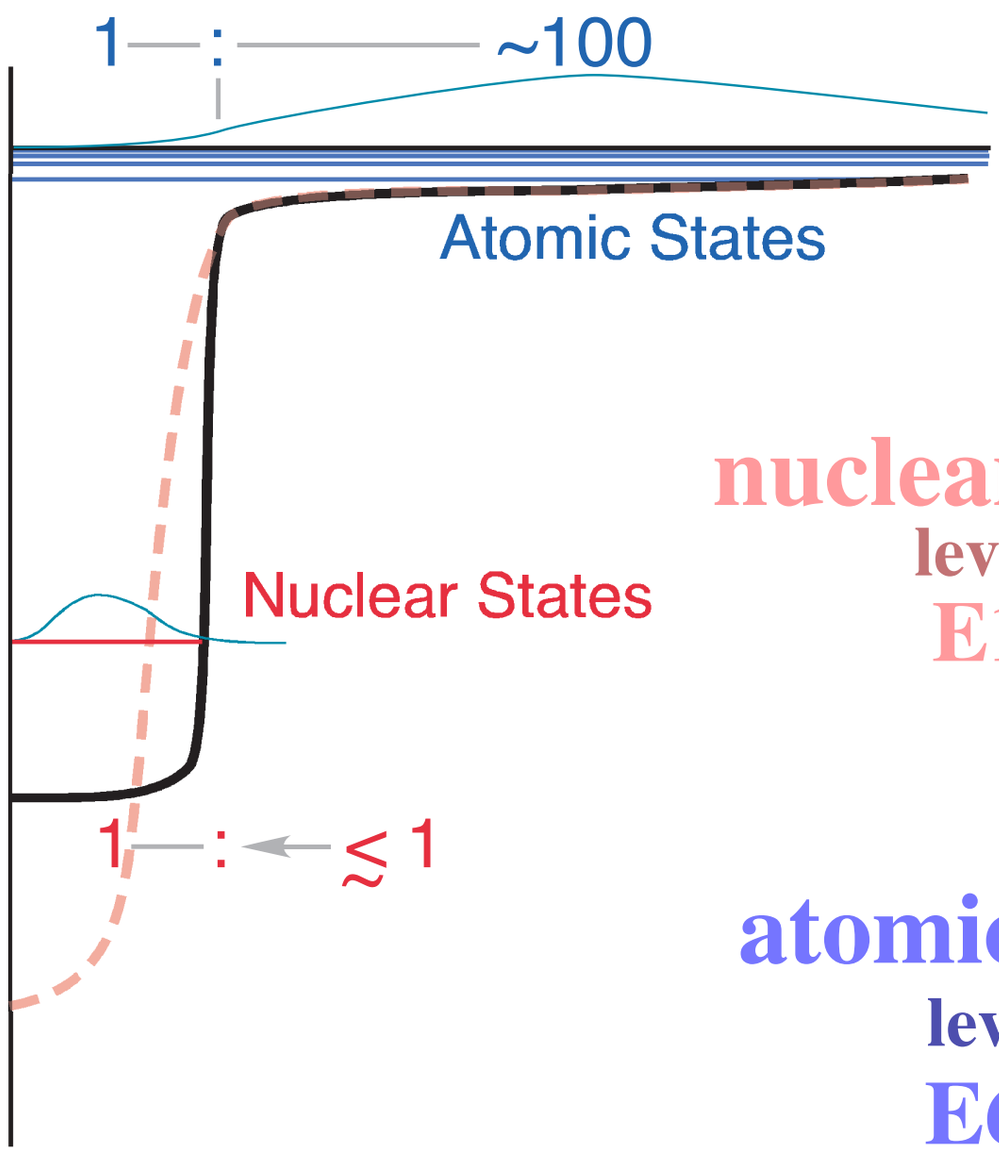


π atom

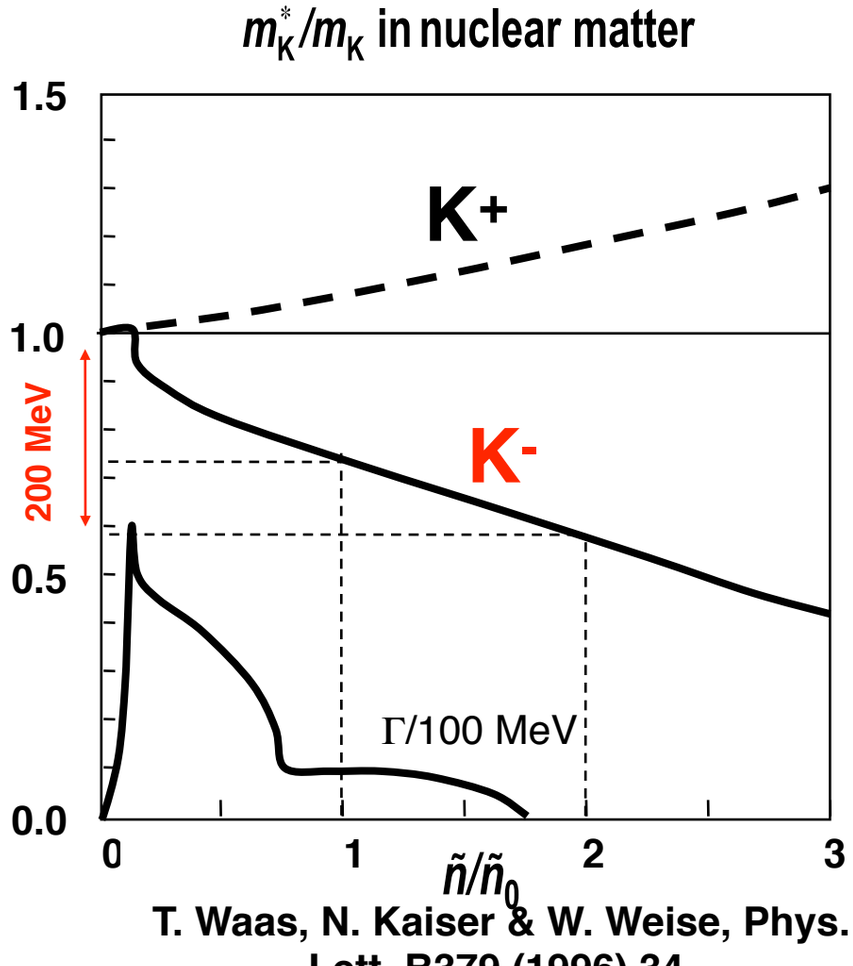


Yes, for Coulomb assisted hybrid-bound states

Study of $\bar{K}N$ interaction



strongly attractive in I=0 channel



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

nuclear states

level energy and decay width

E15: ^{3}He(K$^-$, n) missing & invariant mass

K @ 1 GeV/*c*

atomic states

level shift and absorption width

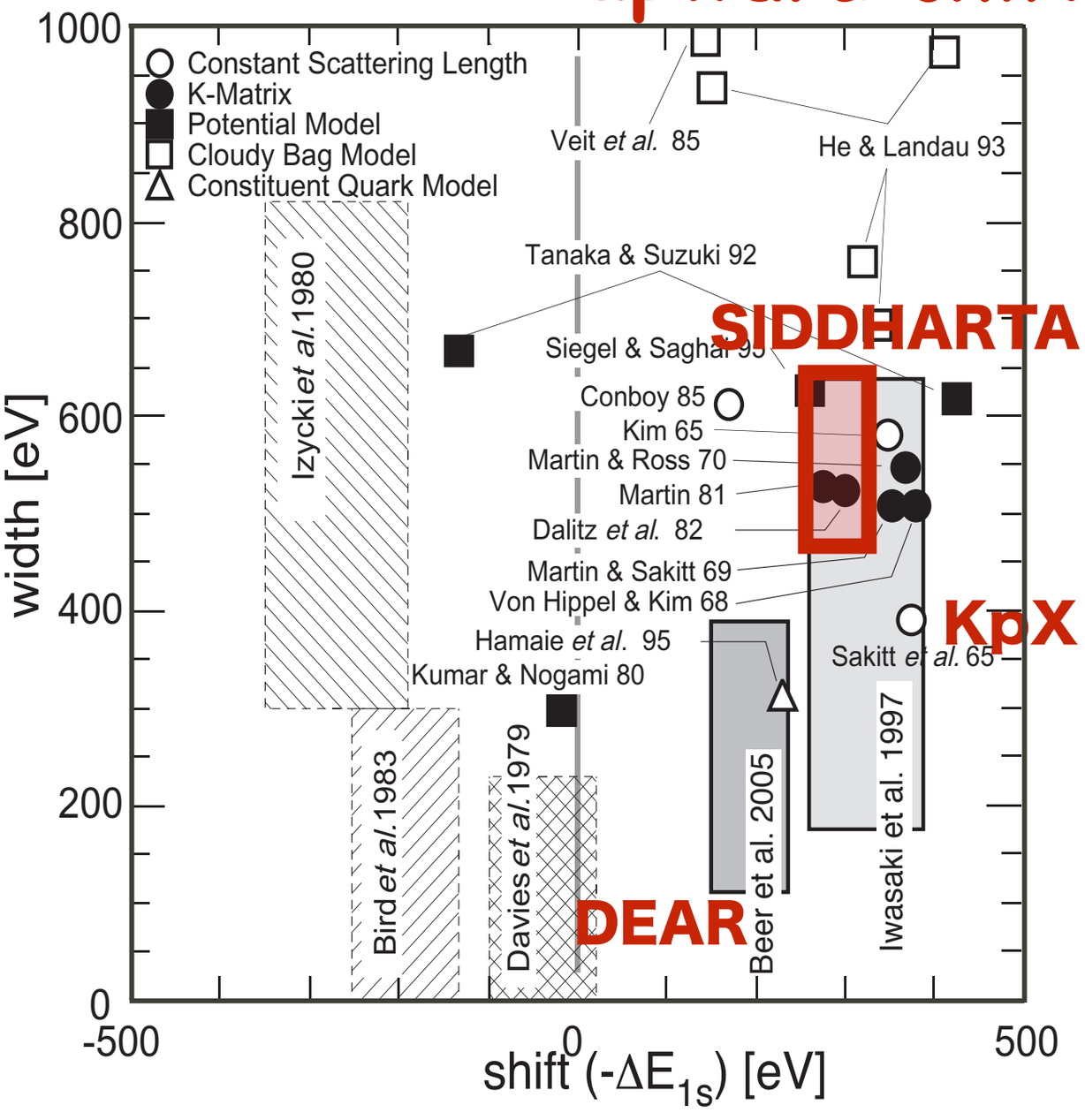
E62: K$^-$ ^{3}He 3*d* - 2*p* x-ray w/TES

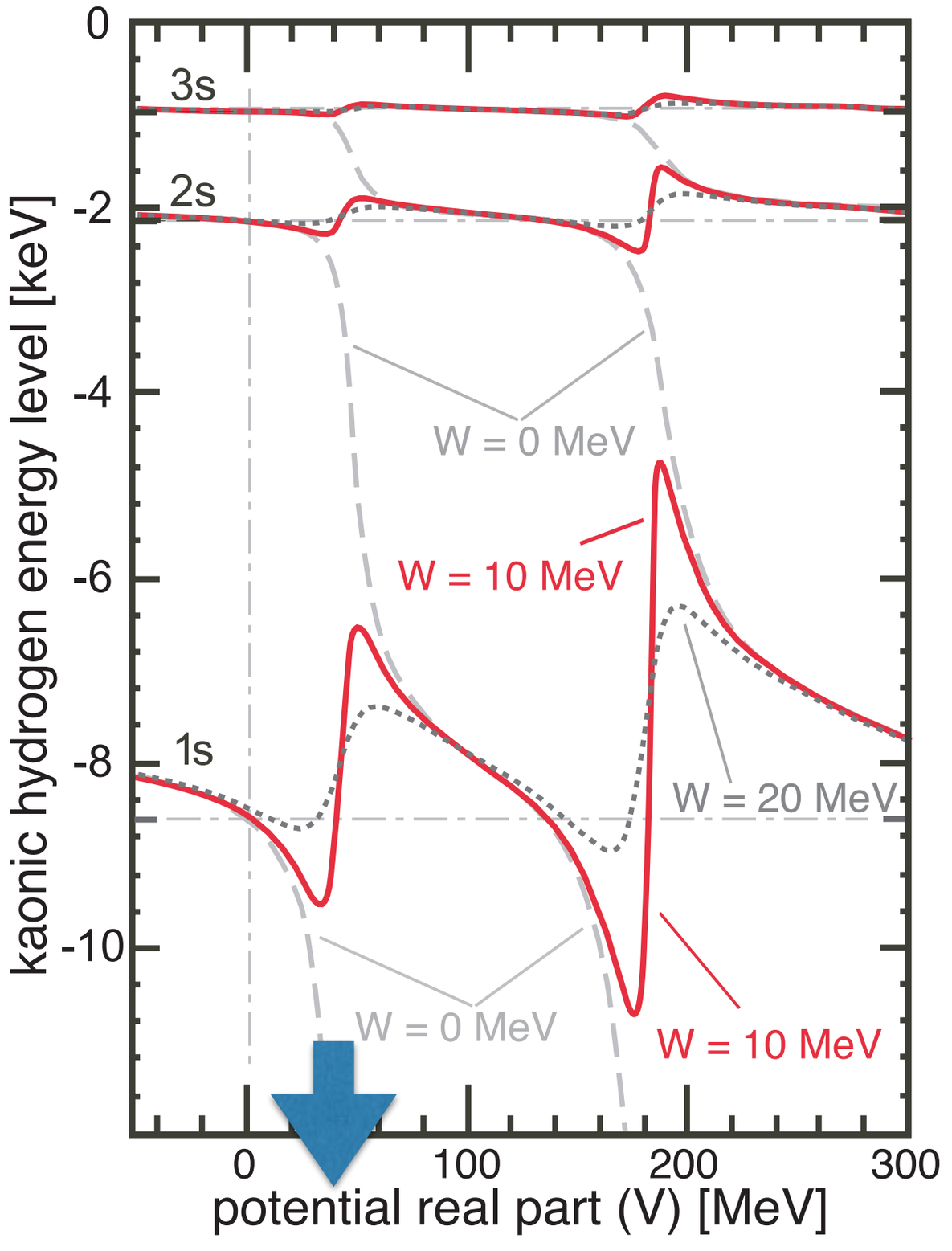
K at rest

Atomic study = very attractive

bound state?

upward shift





$\Lambda(1405)$ 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 ???

$\Lambda(1405)$?

~27 MeV

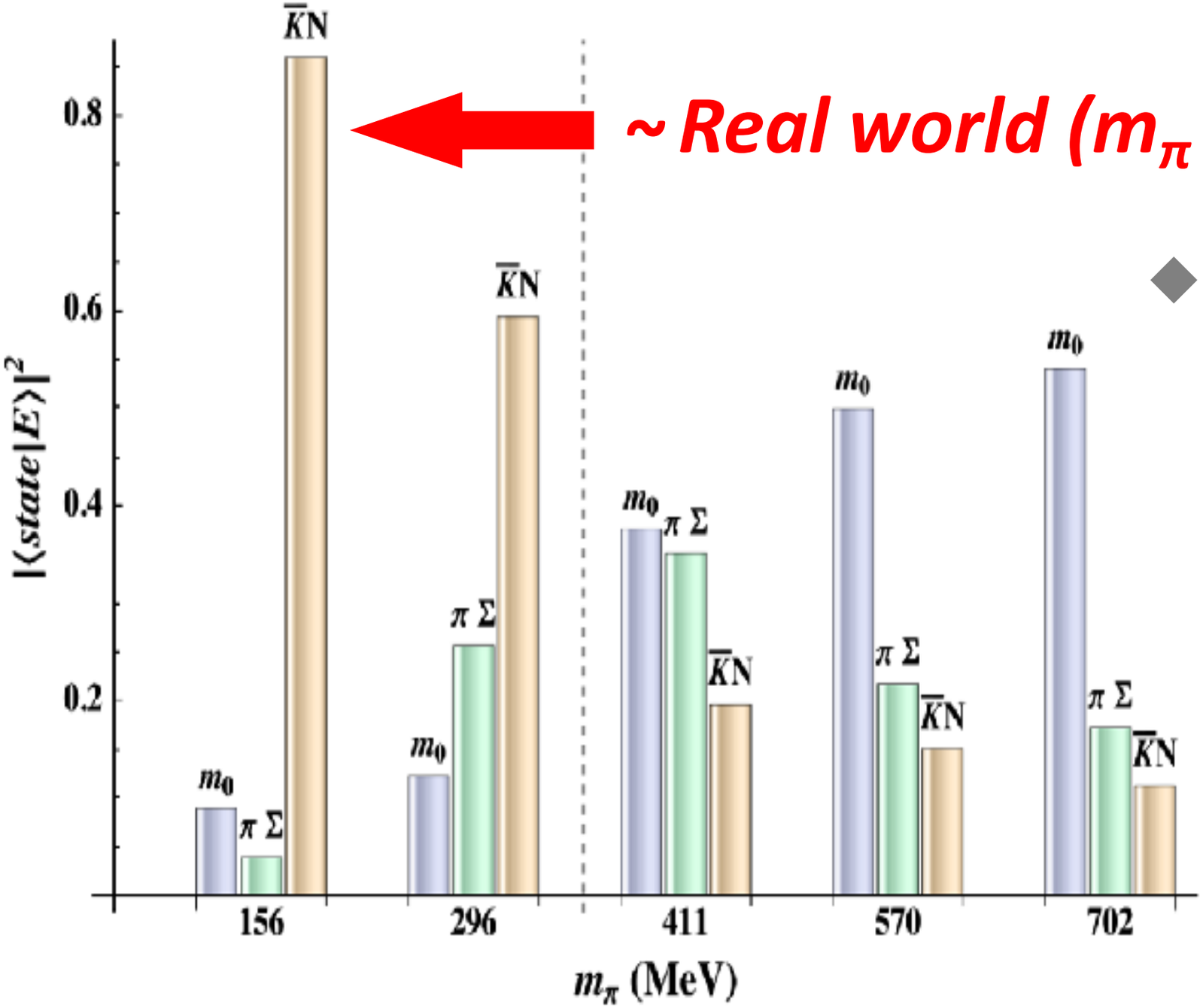
$\bar{K}N$ >> 2MeV @ NN !!

$\Lambda(1405)$ MASS

PRODUCTION EXPERIMENTS

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

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



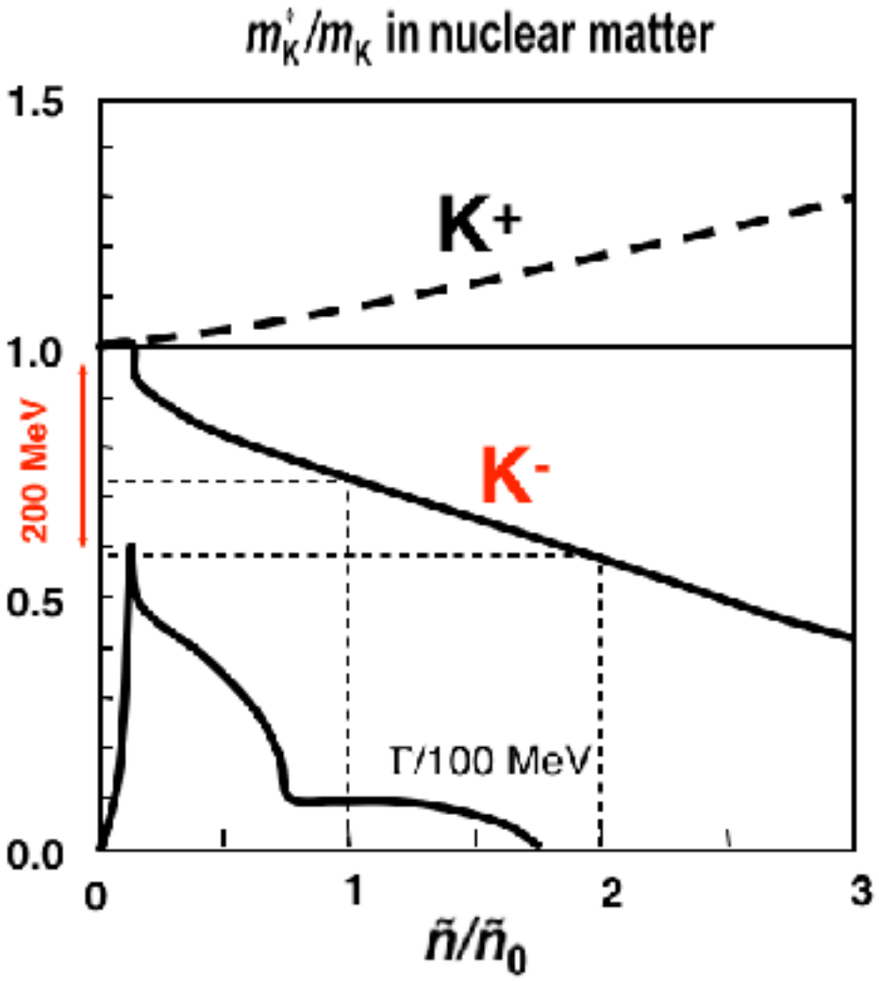
~ Real world (m_π = 140 MeV/c^2)

- **Recent Lattice QCD supports,**

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

$$= (uud)\text{-}(\bar{u}s)$$

Search for Kaonic nuclear states

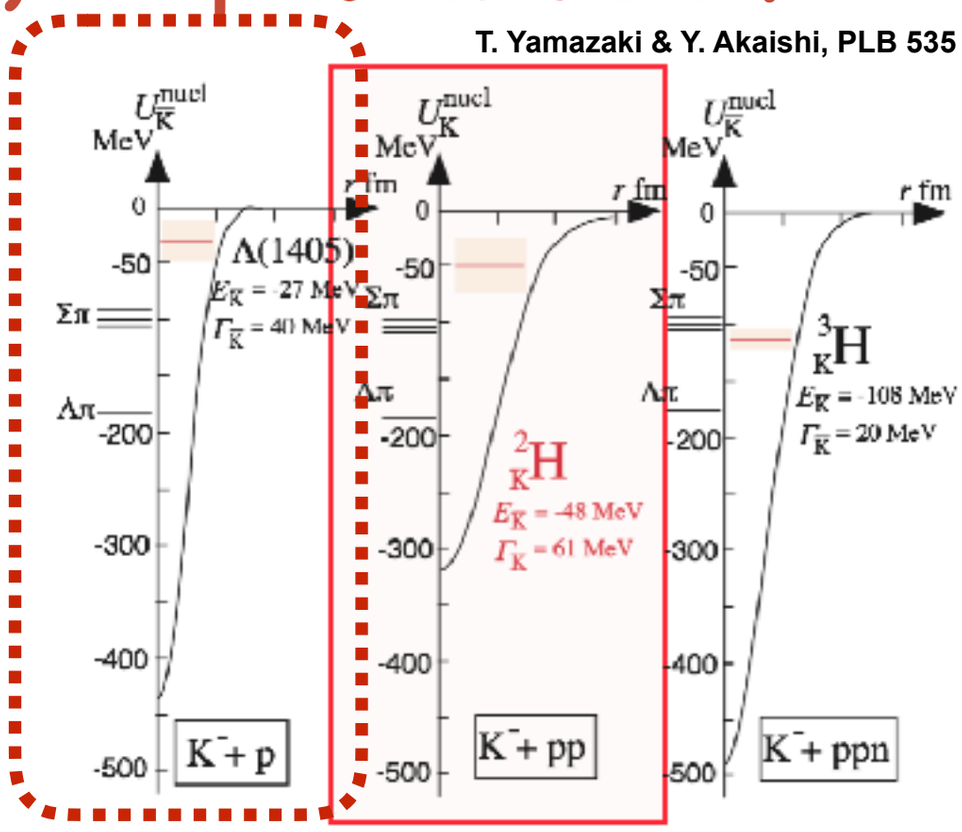


T. Waas, N. Kaiser & W. Weise, Phys. Lett. B379 (1996) 34.

strongly attractive in I=0 channel

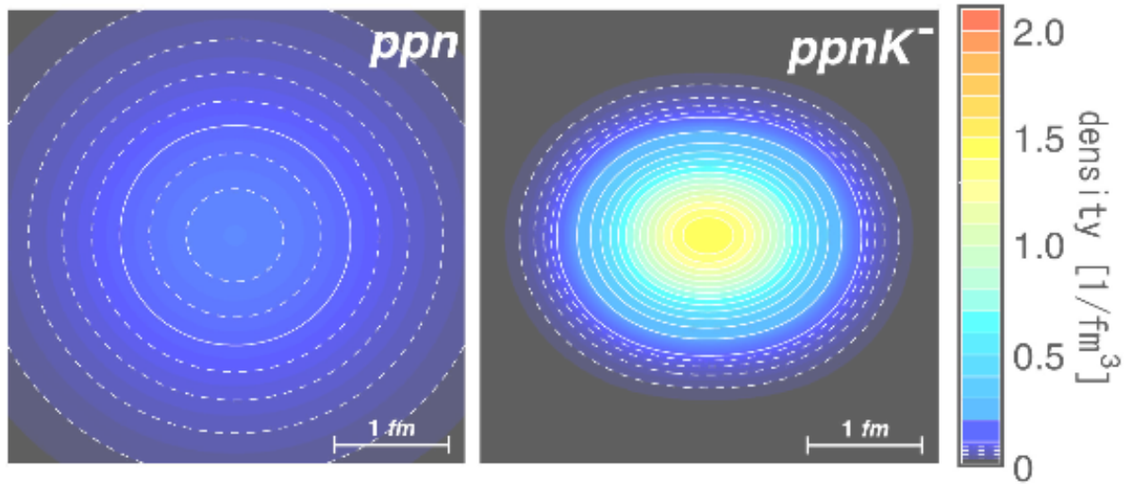
Λ(1405) = K^-p bound state ?

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



$B_{\bar{K}}$ ~ 50 MeV!

Dote et al., PLB 590 (2004) 51



formation of high density matter?

nuclear state search

- simplest system K^-pp

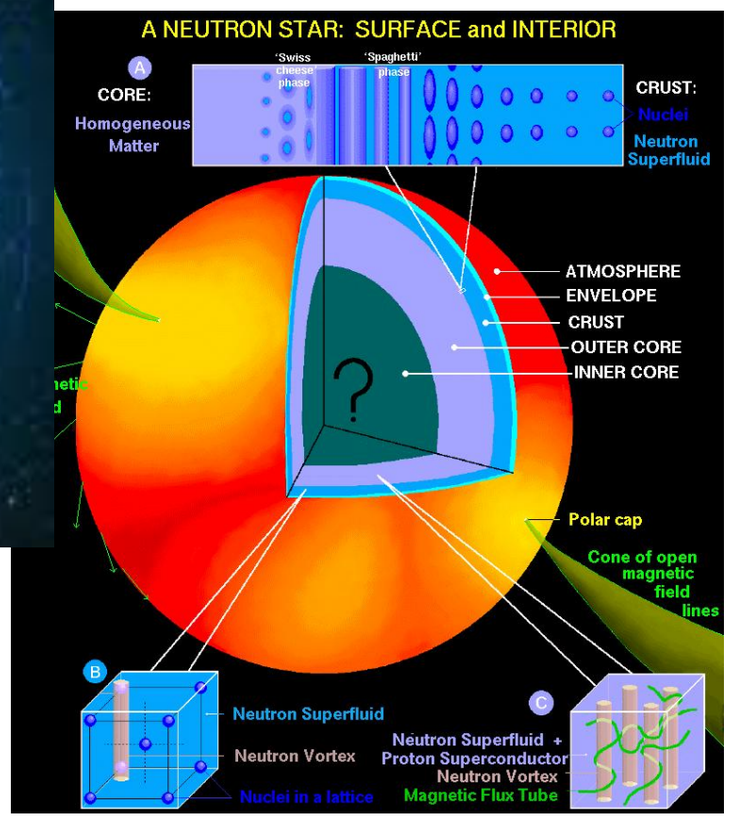
^{3}He(K^-, n) @ 1 GeV/c

Particle fraction in dense nuclear matter – a possibility –

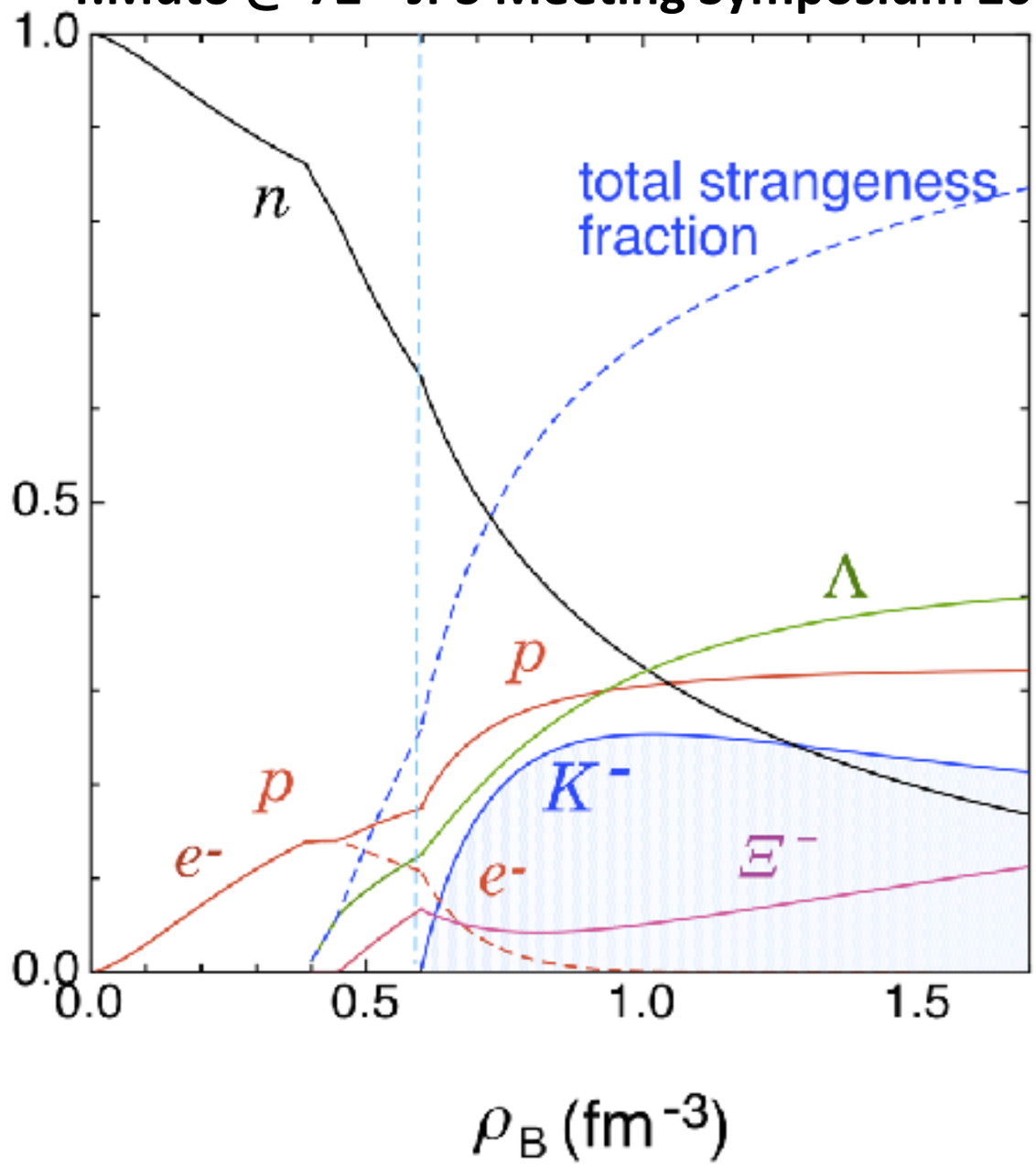
Does kaon can be born spontaneously in star matter?

EOS might be too soft…

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



T.Muto @ 72th JPS Meeting Symposium 2017

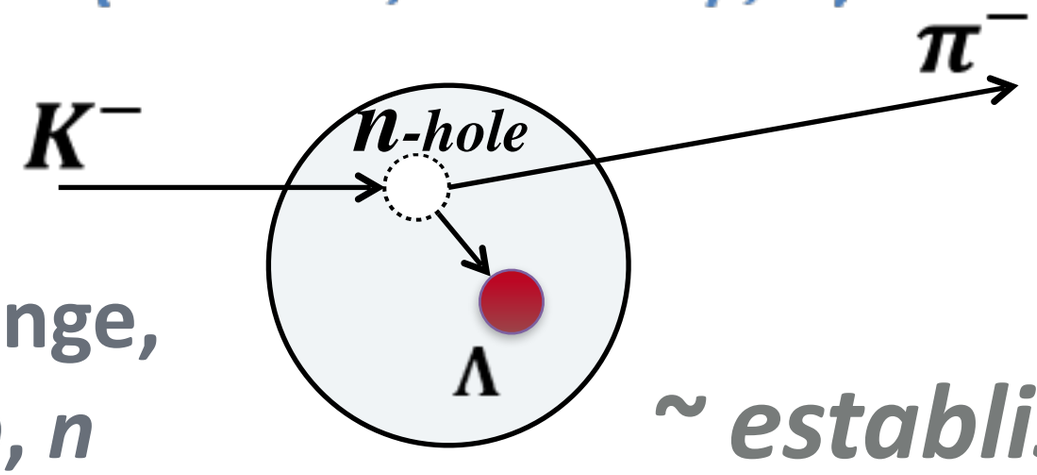


Can “boson” be a constituent of “matter”?

Hyper-nucleus

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

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



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

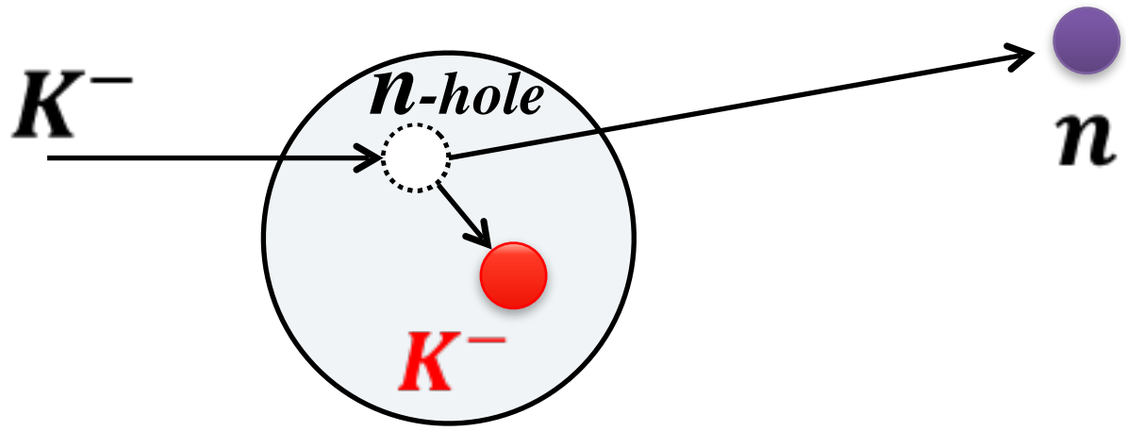
~ established

---

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*)

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

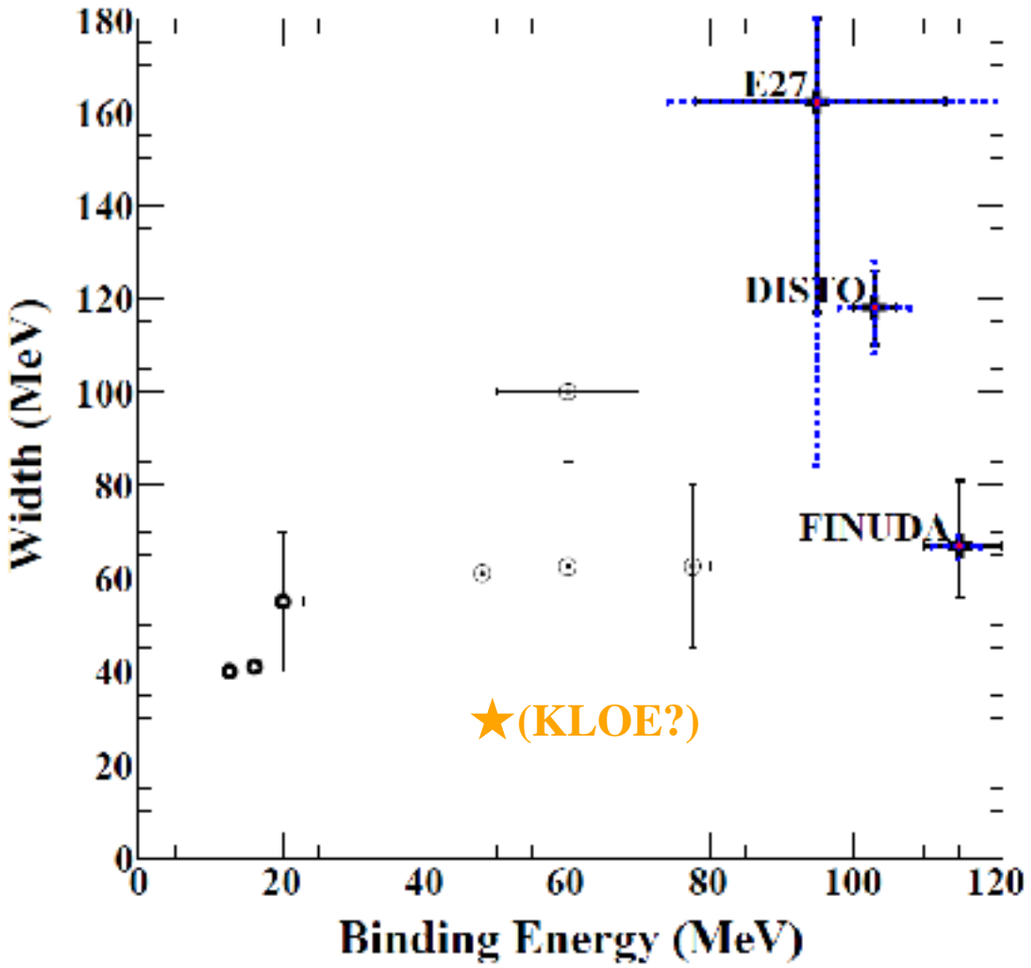
Can we make “meson” as a
member of “nuclear matter”?

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
    $pp \to \Lambda p K^+$

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

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

    HADES
    $pp \to \Lambda p K^+$
    $N^* \to \Lambda K^+$?

    FINUDA ?

Experimental studies on K^-pp

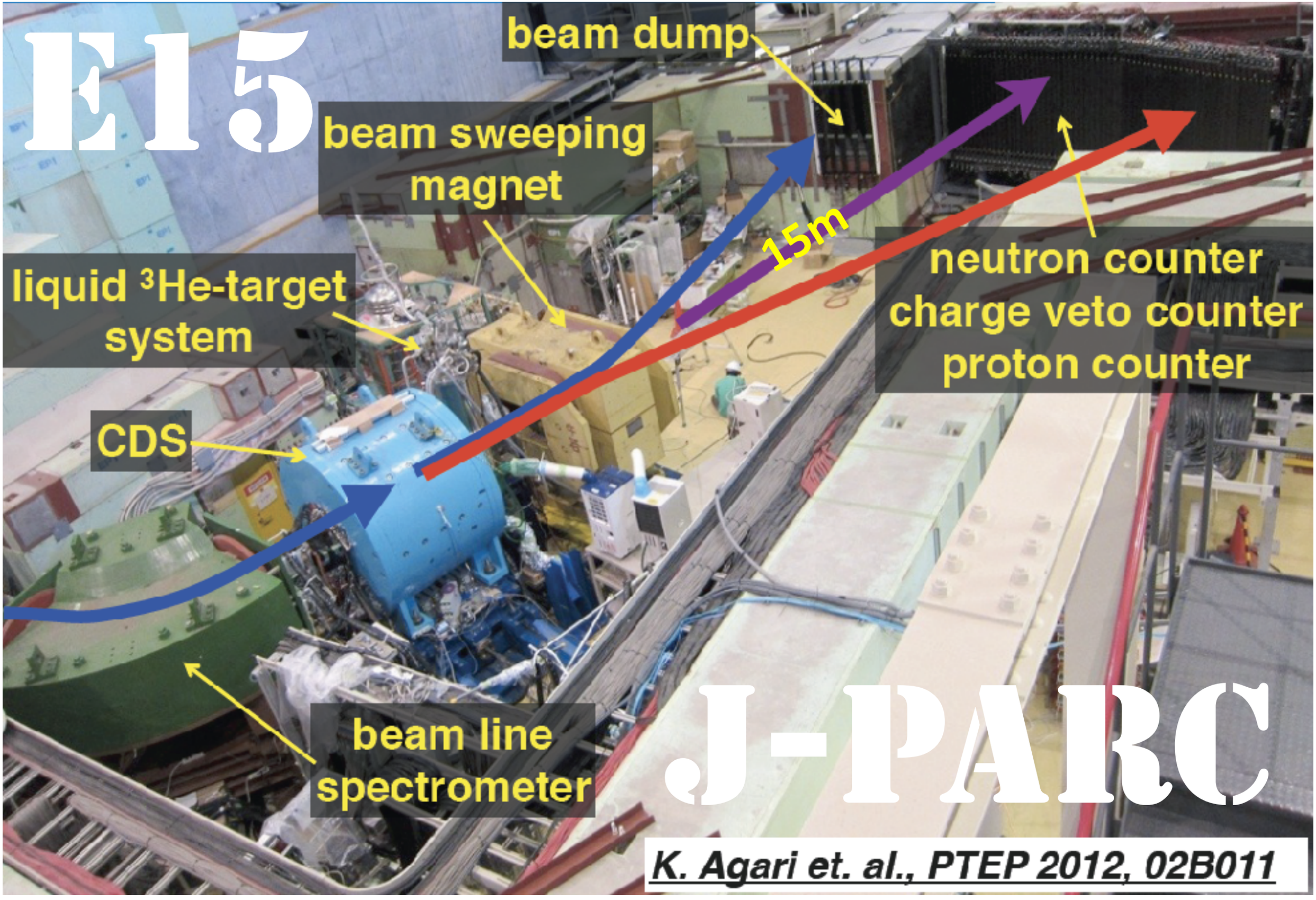
J-PARC E15 experiment

— lowest momentum transfer, achievable

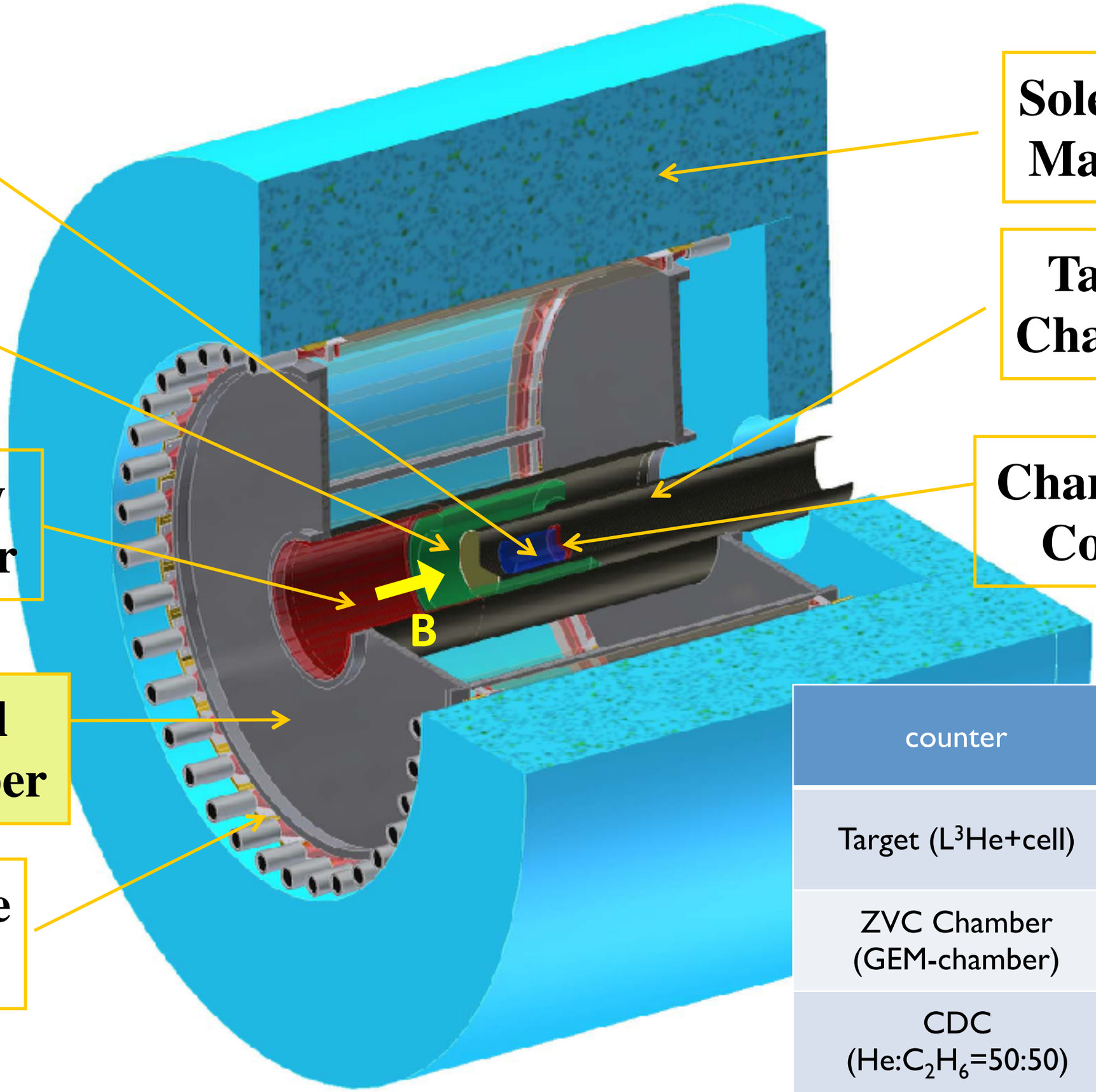
— well identified final state

— less background expected

Experiment	Reaction	Momentum transfer q_K (MeV/c)	final state	Background & misc.	Results
FINUDA	X (K^- at-rest, Λ p) X	N. A.	Λp + X	2NA	~ 100?
KLOE	^{4}He (K^- at-rest, Σ^0 p) X	N. A.	Σ^0p + X	2NA	~ 50??
DISTO	p p→K^+ Λ p (T_p = 2.85 GeV)	300-400	Λp + K^+ p + (K^+ Λ) ?	N*→K^+ Λ	~ 100?
HADES	p p→K^+ Λ p (T_p = 3.50 GeV)	500-700	p + Λ + K^+	large q_K	Null
LEPS	p (γ, π^- K^+) X	300-600	N.A.	small σ	Null
J-PARC E27	d (π^+, K^+) X (= Λp / Σ^0 p)	500-700	Λp / Σ^0p	multi-π	~ 100?
J-PARC E15	^{3}He(K^-, Λp) n	200-300 (~ p_F)	Λp + n	—	


E15
beam dump
beam sweeping magnet
liquid ³He-target system
15m
neutron counter
charge veto counter
proton counter
CDS
beam line spectrometer
J-PARC
K. Agari et. al., PTEP 2012, 02B011

CDS overview



liq. ^{3}He Target

Z-Vertex Chamber

Kaon Decay Veto Counter

Cylindrical Drift Chamber

Hodoscope Counter

Solenoid Magnet

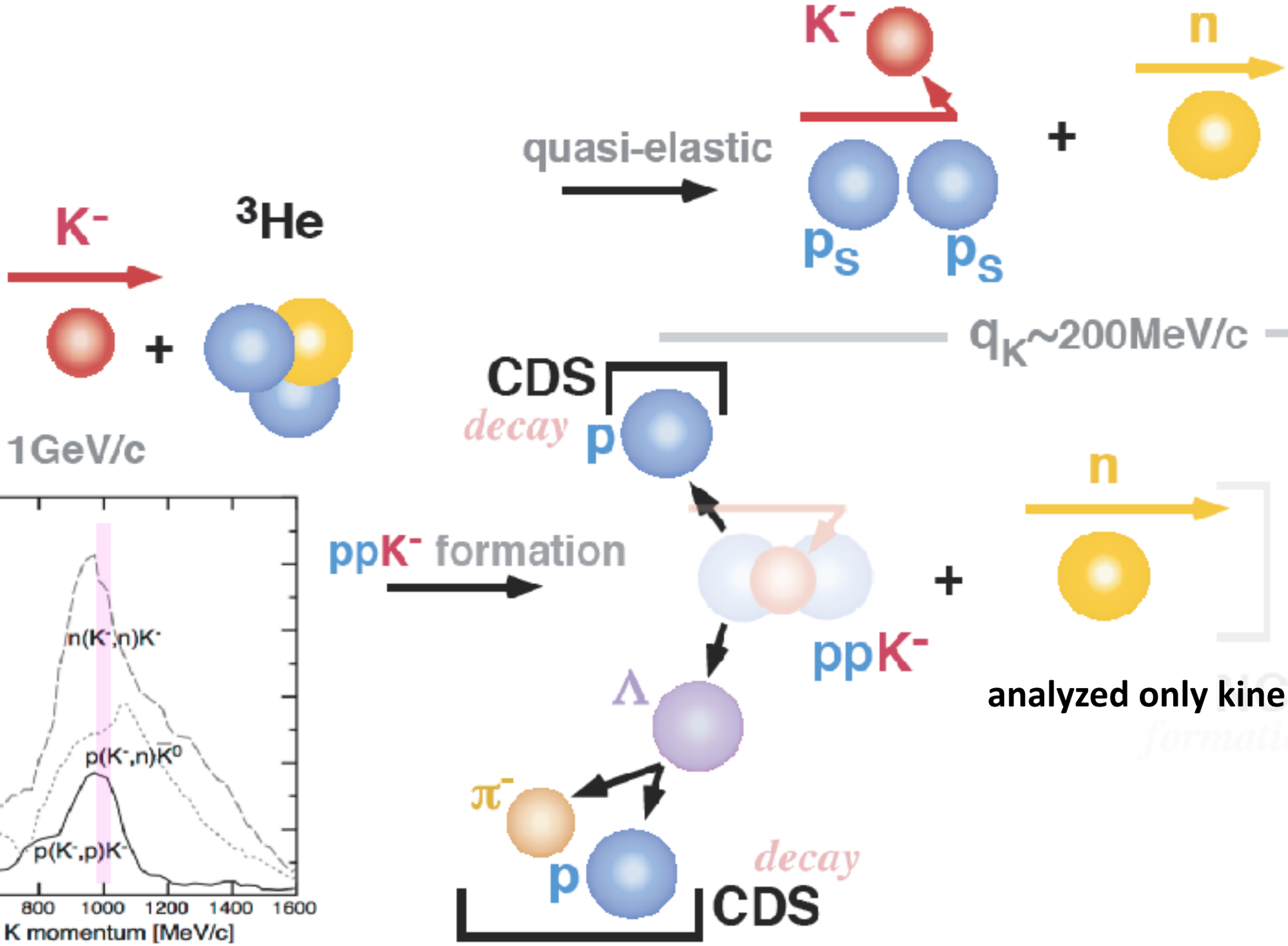
Target Chamber

Charge Veto Counter

counter	Rad. Length
Target (L^{3}He+cell)	0.0155
ZVC Chamber (GEM-chamber)	0.0027
CDC (He:C_2H_6=50:50)	0.0048

"K^-pp" search via $^3He(K^-,n)$ @p_K=1GeV/c

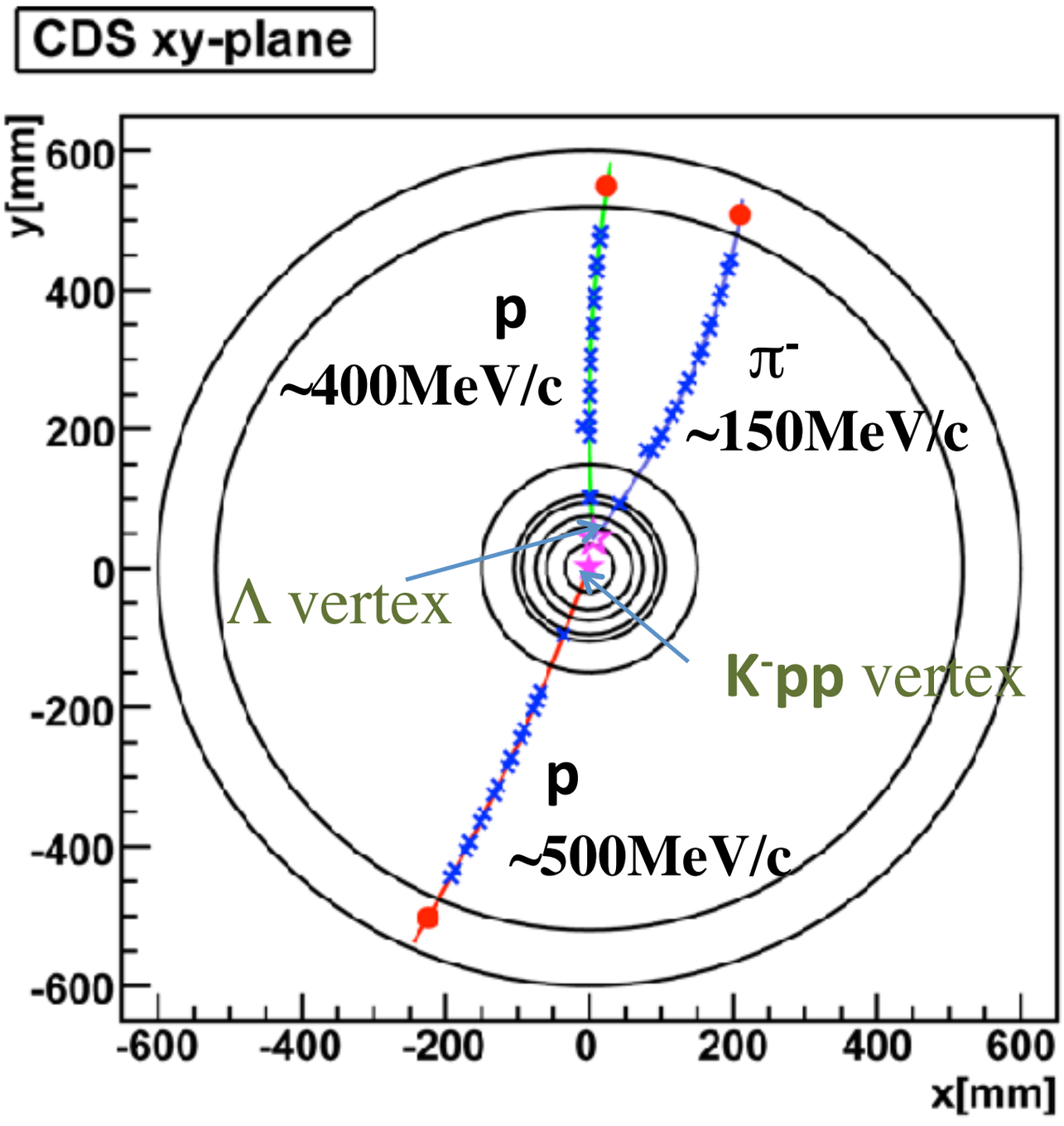
for efficient "ppK" formation $q_K = p_n - p_K$ (~ 200MeV/c)

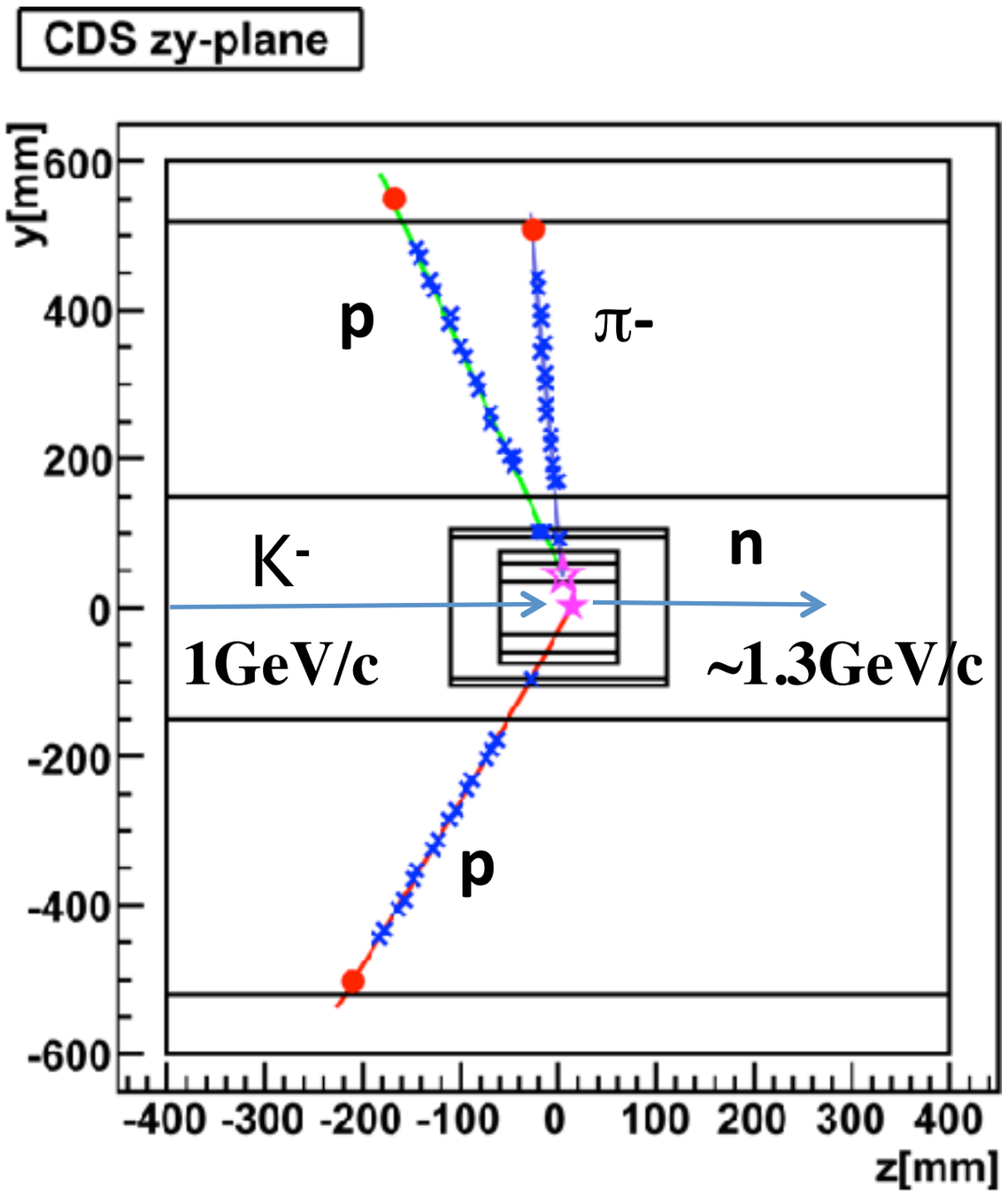


analyzed only kinematically

K^-pp event display

- **with forward neutron**





E15 1st

... 3 days

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[5], M. Cargnelli[8], S. Choi[4], C. Curceanu[9], S. Enomoto[2], D. Faso[6,7], H. Fuj[ijioka][10], Y. Fujiwara[1], T. Fukuda[11], C. Guaraldo[9], R. S. Hayano[1], T. Hiraiwa[2], N[oumi][1], M. Iliescu[9], K. Inoue[13], Y. Ishiguro[10], T. Ishikawa[1], S. Ishimoto[12], K. I[shiwatari][6], M. Iwai[12], M. Iwasaki[14,15], Y. Kato[14], S. Kawasaki[13], P. Kienle[16,‡], H. [Kou][14], J. Marton[8], Y. Matsuda[17], Y. Mizoi[11], O. Morra[6], T. Nagae[10], H. Noum[i][1], 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[i][11], 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. [Yim][22], 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

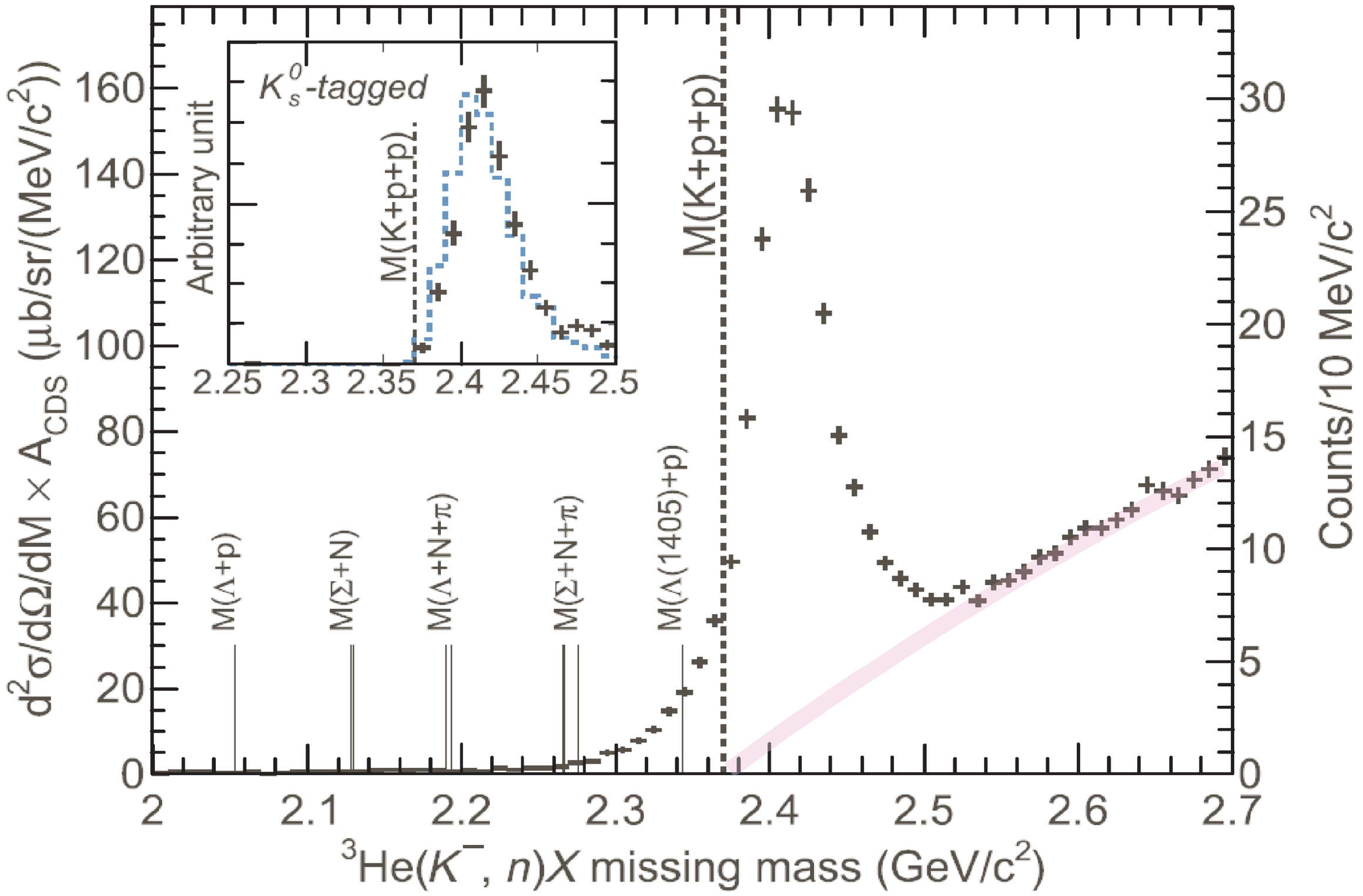
Letter

Structure near the $K^- + p + p$ threshold in the in-flight ^{3}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]

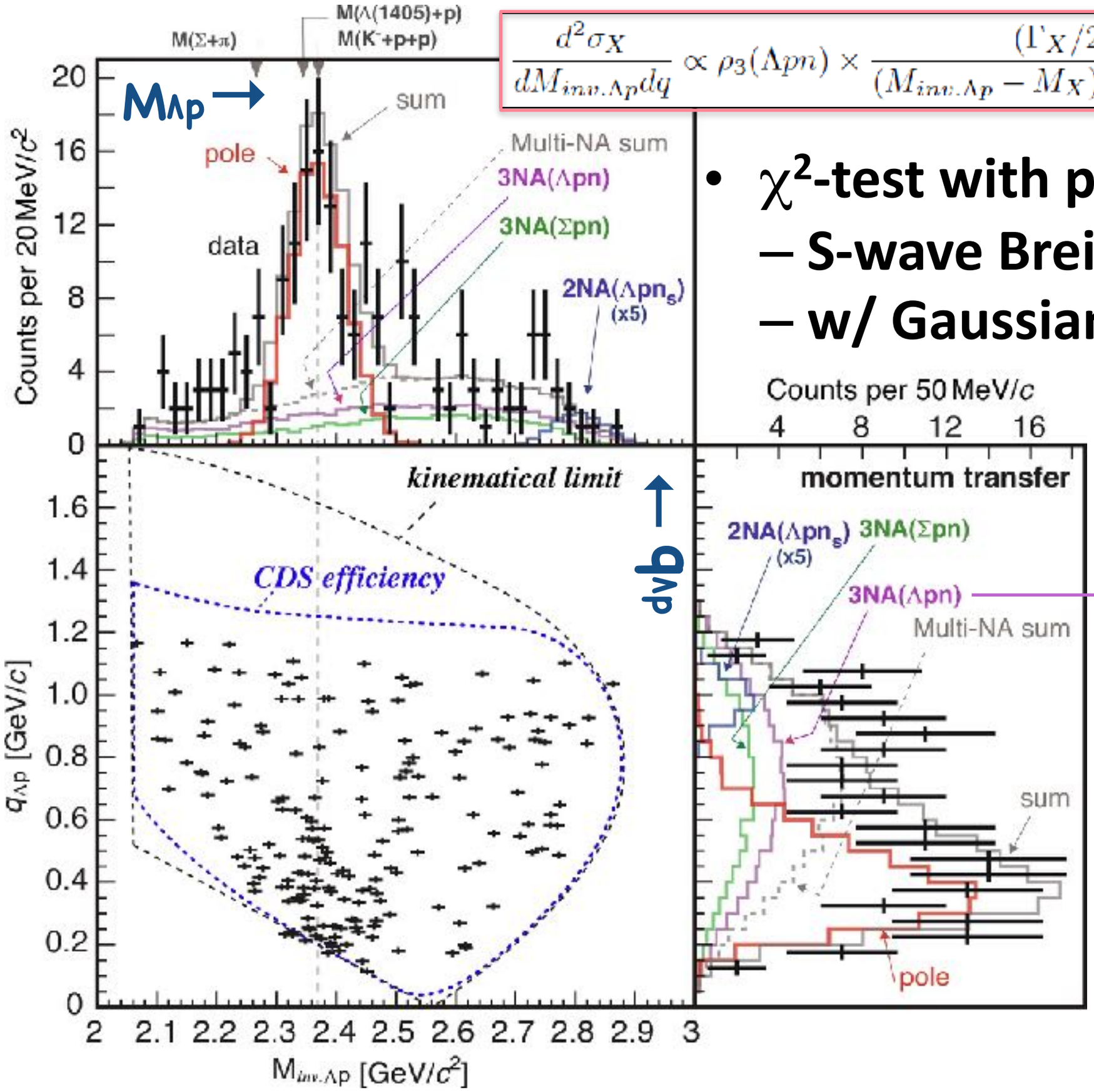
$^3He(K^-, n_{NC})X$ — semi-inclusive



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

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

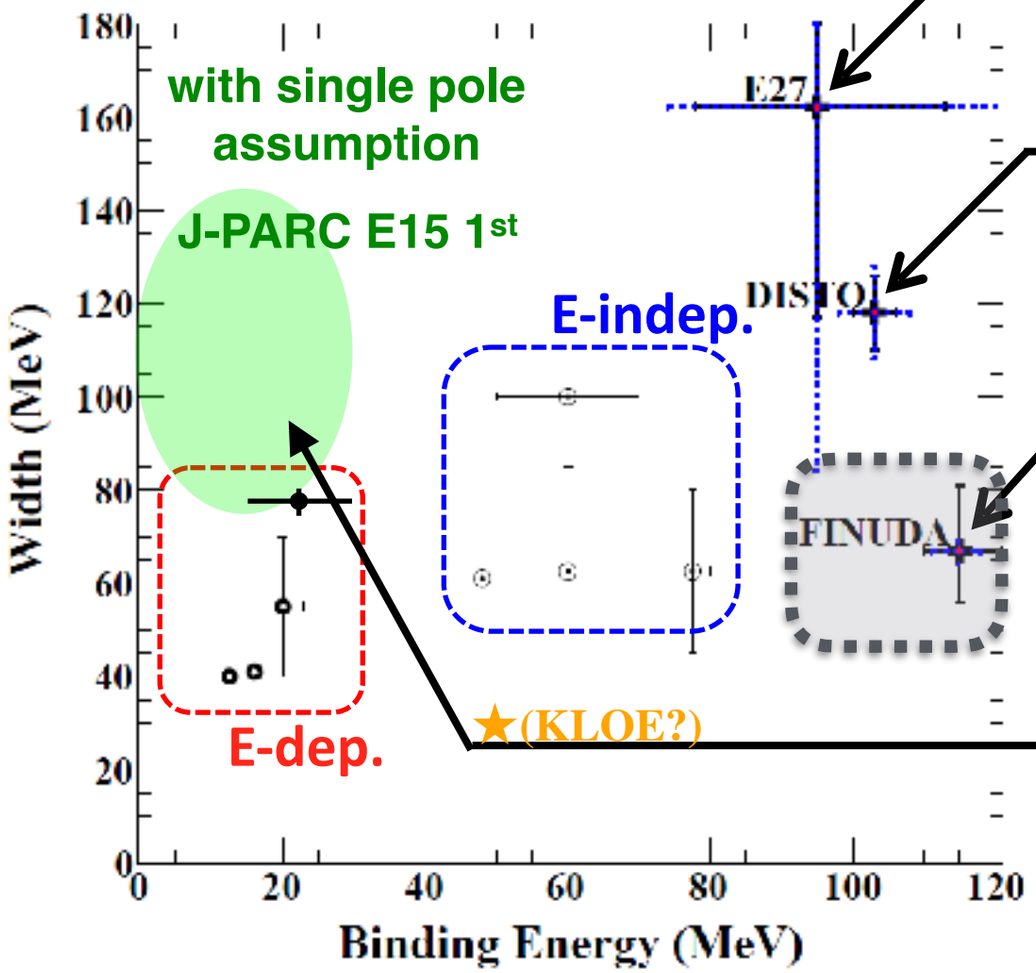
B(X) ~ 15 MeV
Γ(X) ~ 110 MeV
Q(X) ~ 400 MeV/c

Recent status of K^-pp bound state

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

$\bar{K}N$ interaction model

E-dep. / E-indep.



Reports structure / ***NO structure***

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

DISTO
$pp \to \Lambda pK^+$

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

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

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

HADES
$pp \to \Lambda pK^+$
$N^* \to \Lambda K^+$?

FINUDA ?

E15 2nd

3 weeks

~ 30 times for Apn channel

What is the structure found in E15[1st] data?

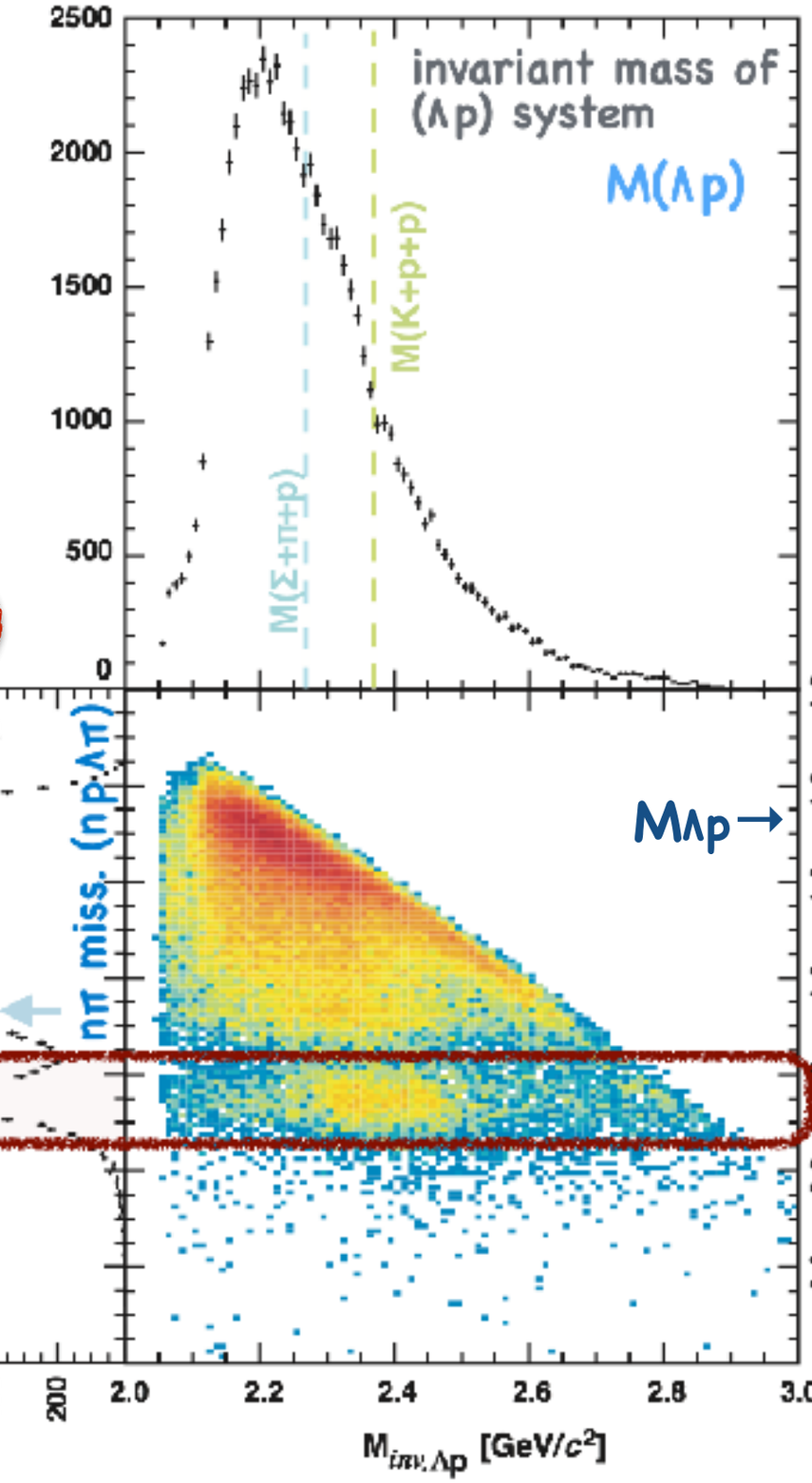
Improving statistics via E15[2nd] data

$K^- + {}^3He \rightarrow ? \rightarrow \Lambda + p + X$

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

$Y(=K^-pp) \rightarrow \Lambda + p$

$K^- + {}^3He \rightarrow \Lambda + p + X_{mis}\ (X_{mis}=n)$



~ 30 times more data for Λpn final state

Dalitz Plot of Λpn in equal manner

$T_n + T_p + T_\Lambda = Q$ Viviani's theorem on equilateral triangle

PRELIMINARY

2NA??

$K^- + \text{“}pn + p_s\text{”} \rightarrow \Lambda n + p_s$??

T_n/Q

T_p/Q

T_Λ/Q

$(T_p - T_\Lambda)/\sqrt{3}Q$

structure(s)

2NA

$K^- + \text{“}pp + n_s\text{”} \rightarrow \Lambda p + n_s$

Counts / 20 (MeV/c^2)

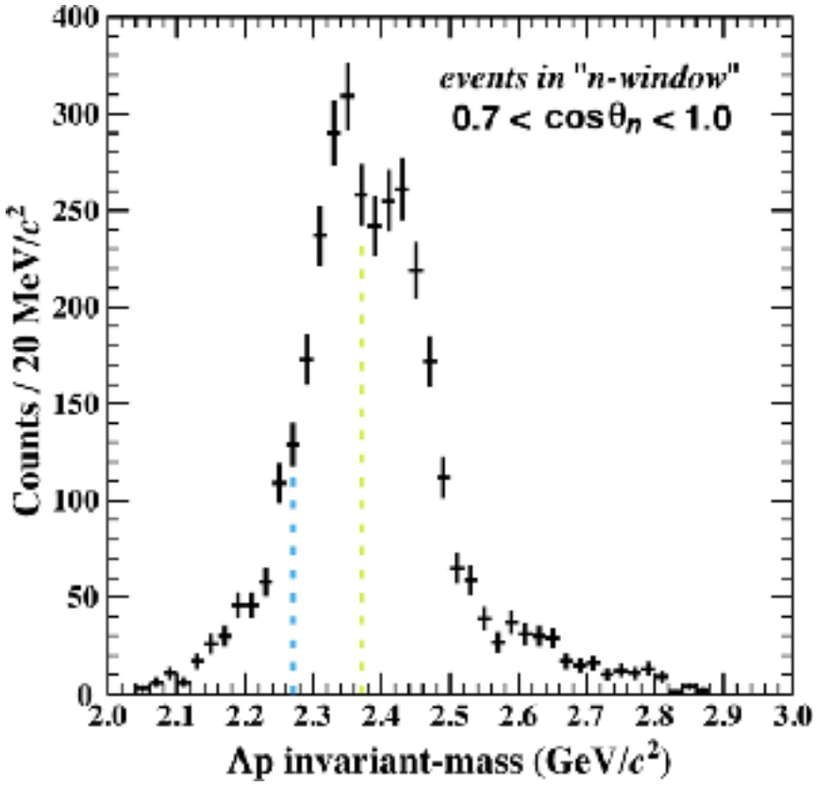
$M_{\Lambda p}$ ↓

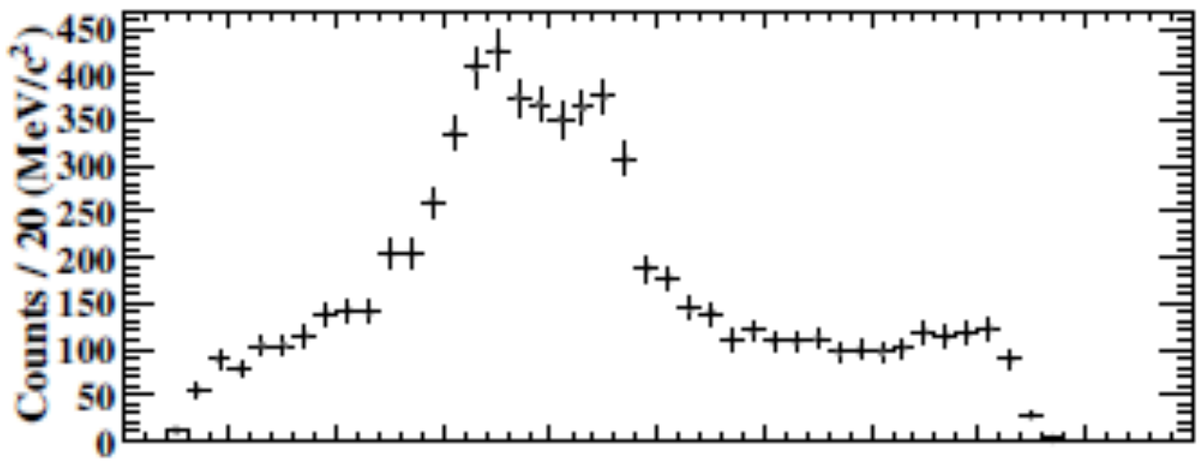
Λp invariant mass

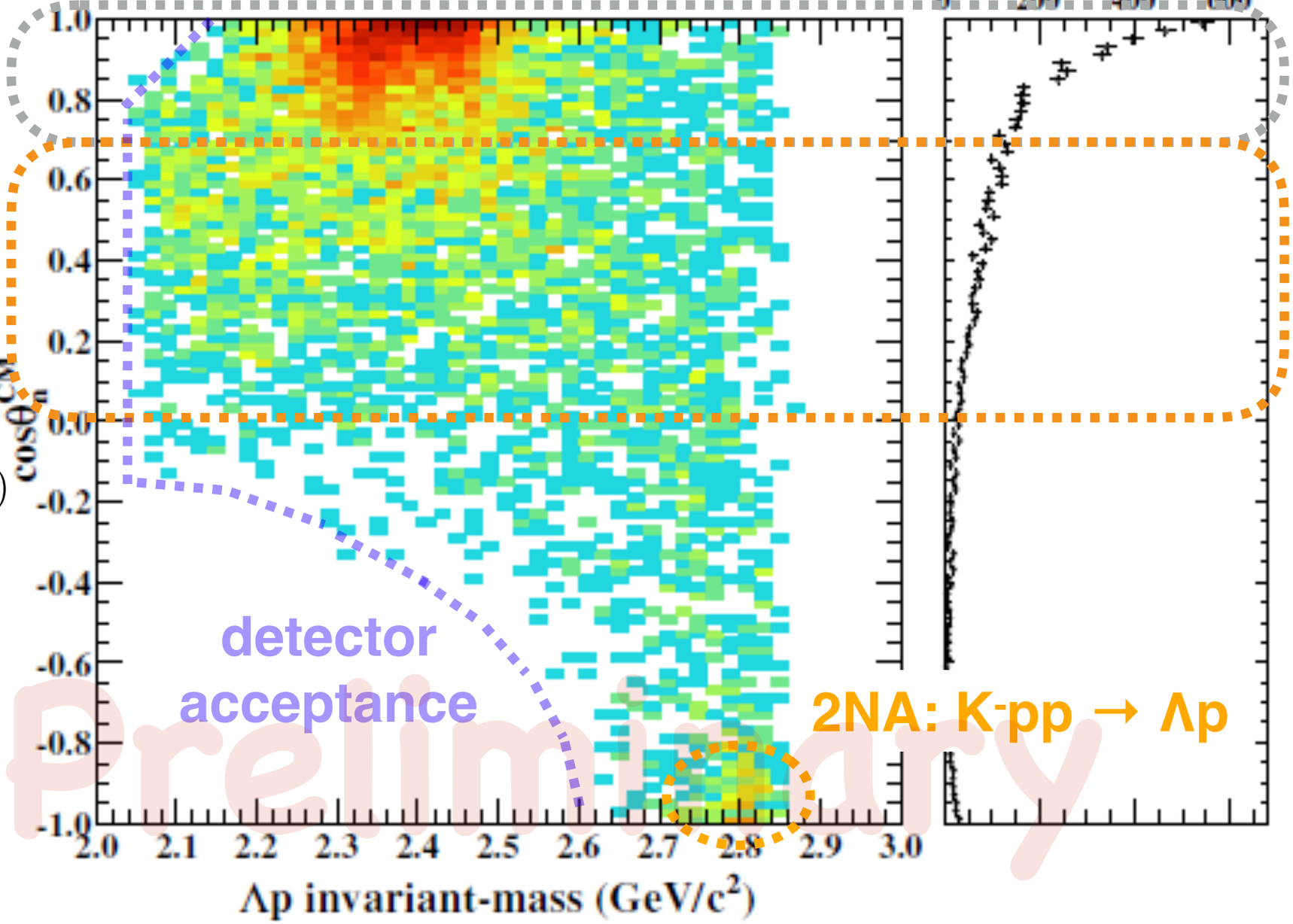
^{3}He(K^{-}, Λp)n:

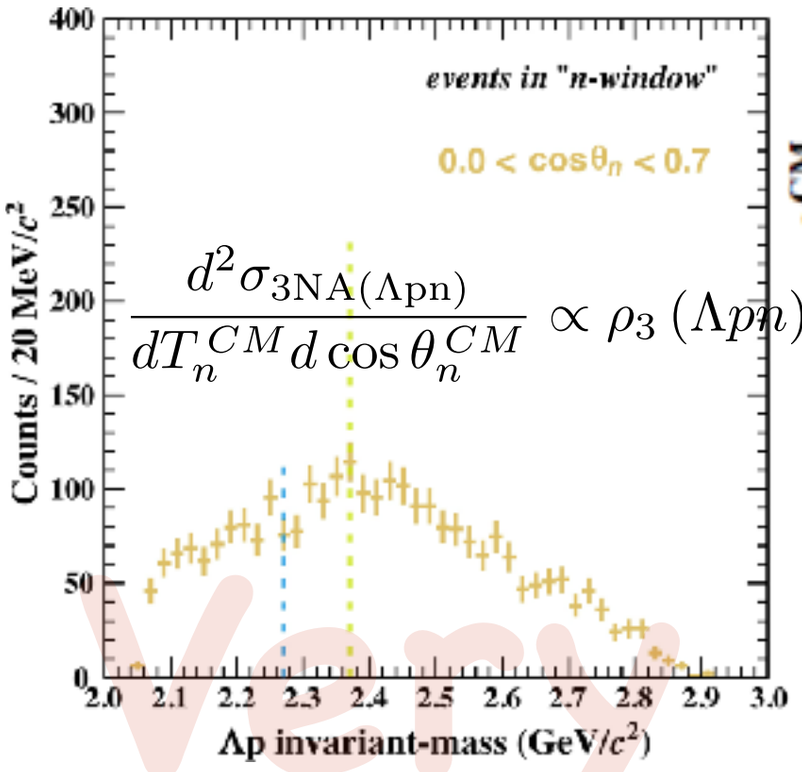
Angular Dependence of n in CM

^{3}He(K$^-$, Λp)n: Angular Dependence





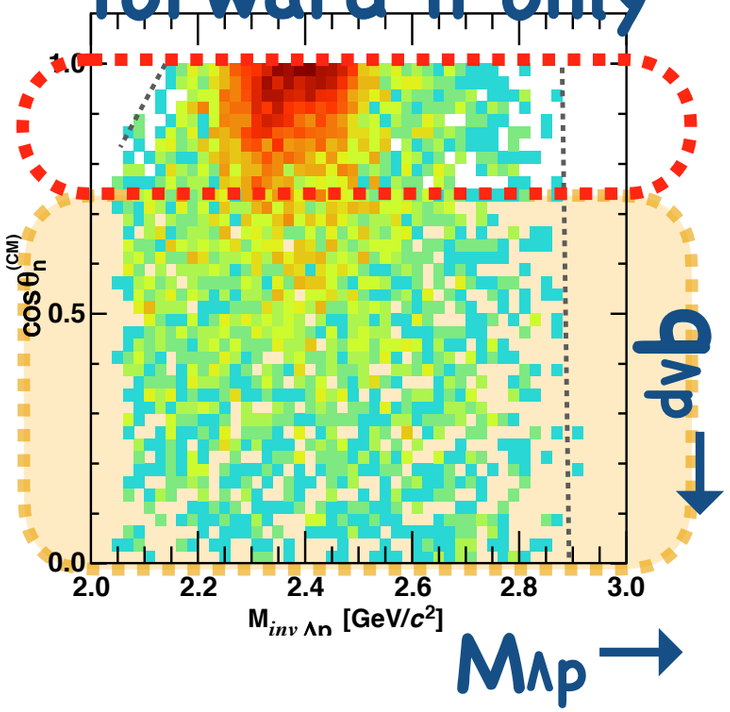


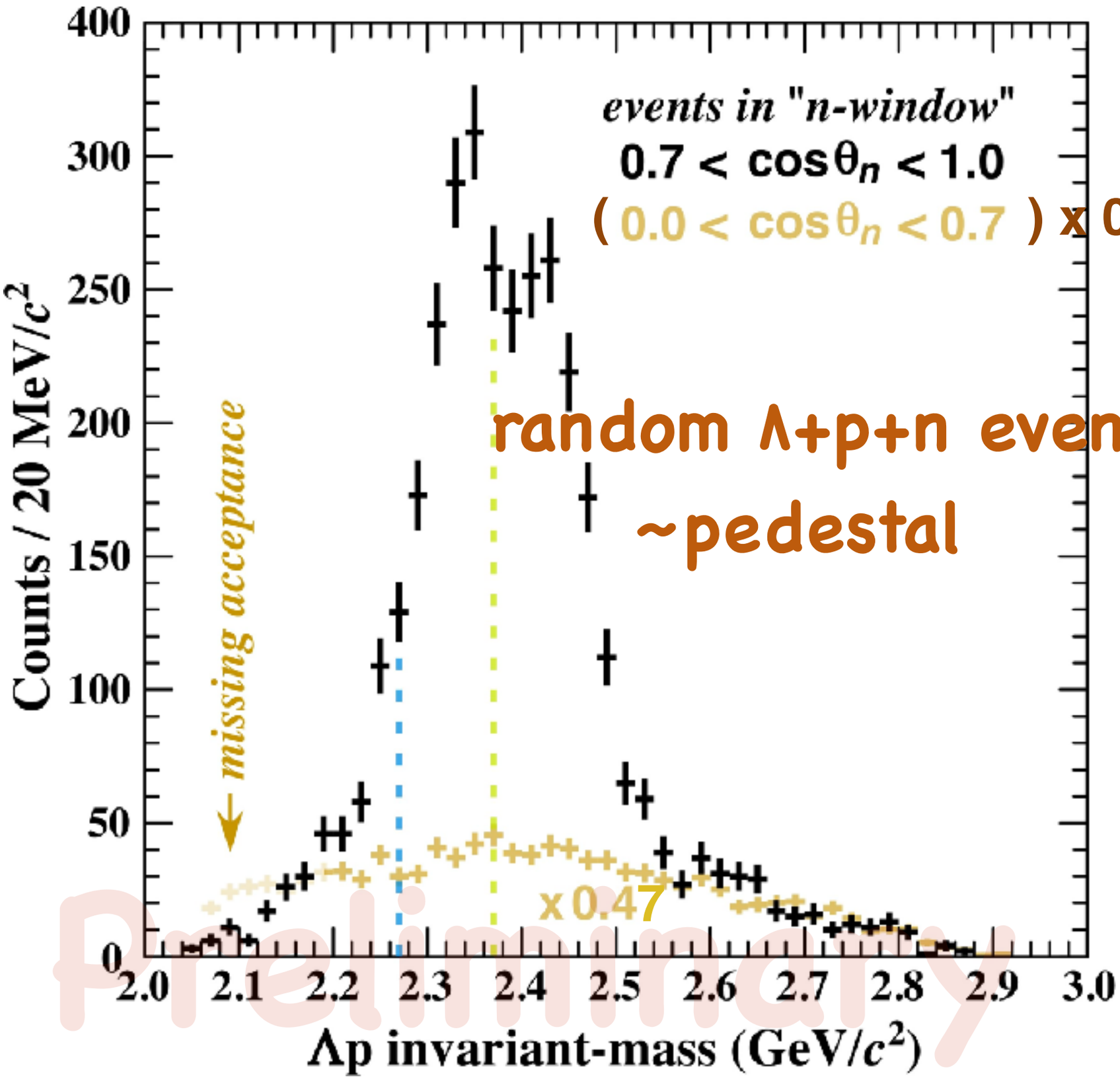


$$\frac{d^2\sigma_{3\mathrm{NA}(\Lambda \mathrm{pn})}}{dT_n^{CM} d\cos\theta_n^{CM}} \propto \rho_3\,(\Lambda pn)$$

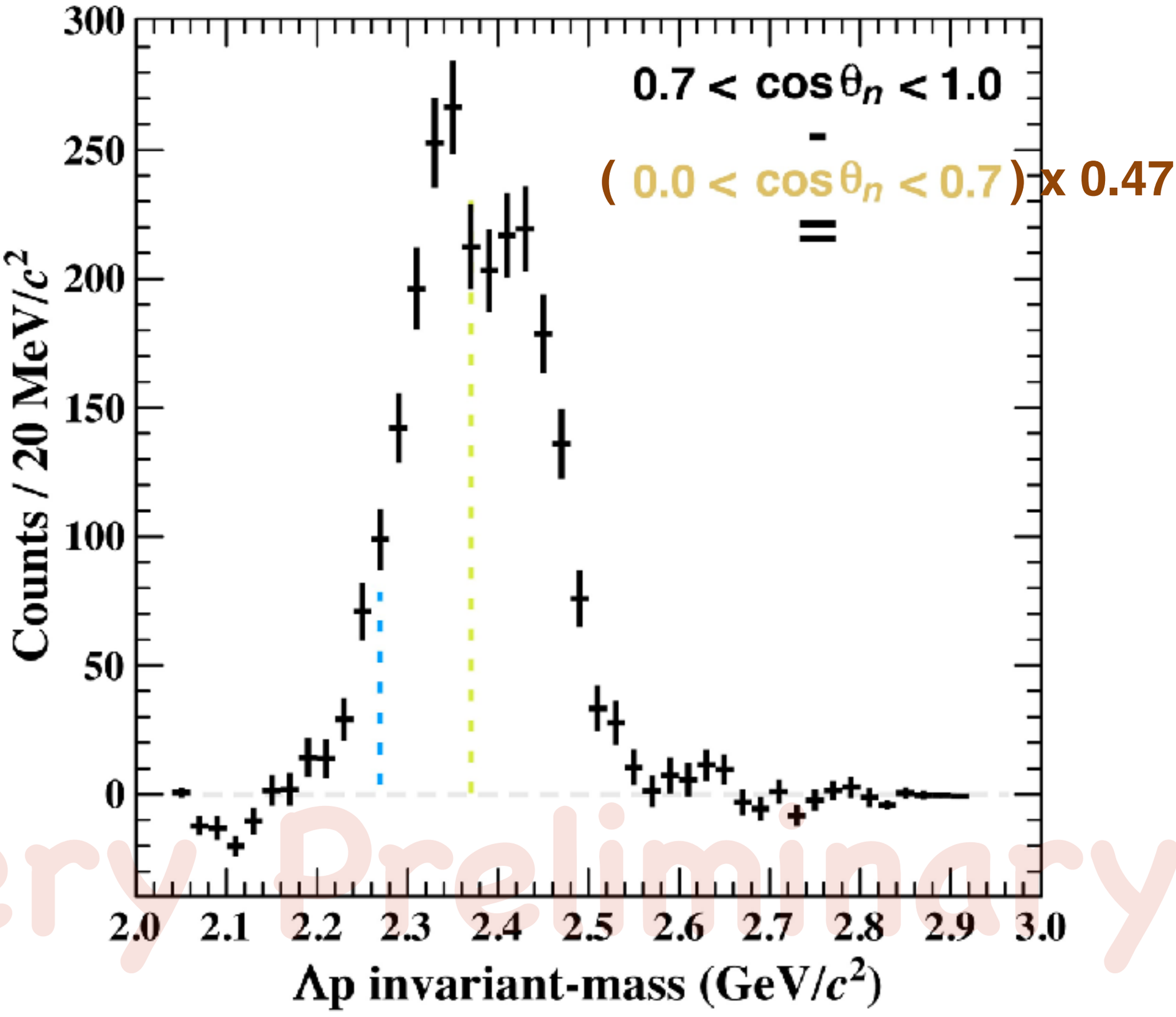
$K^-+{}^3He \rightarrow \Lambda+p+n$: randomly divided

forward n only

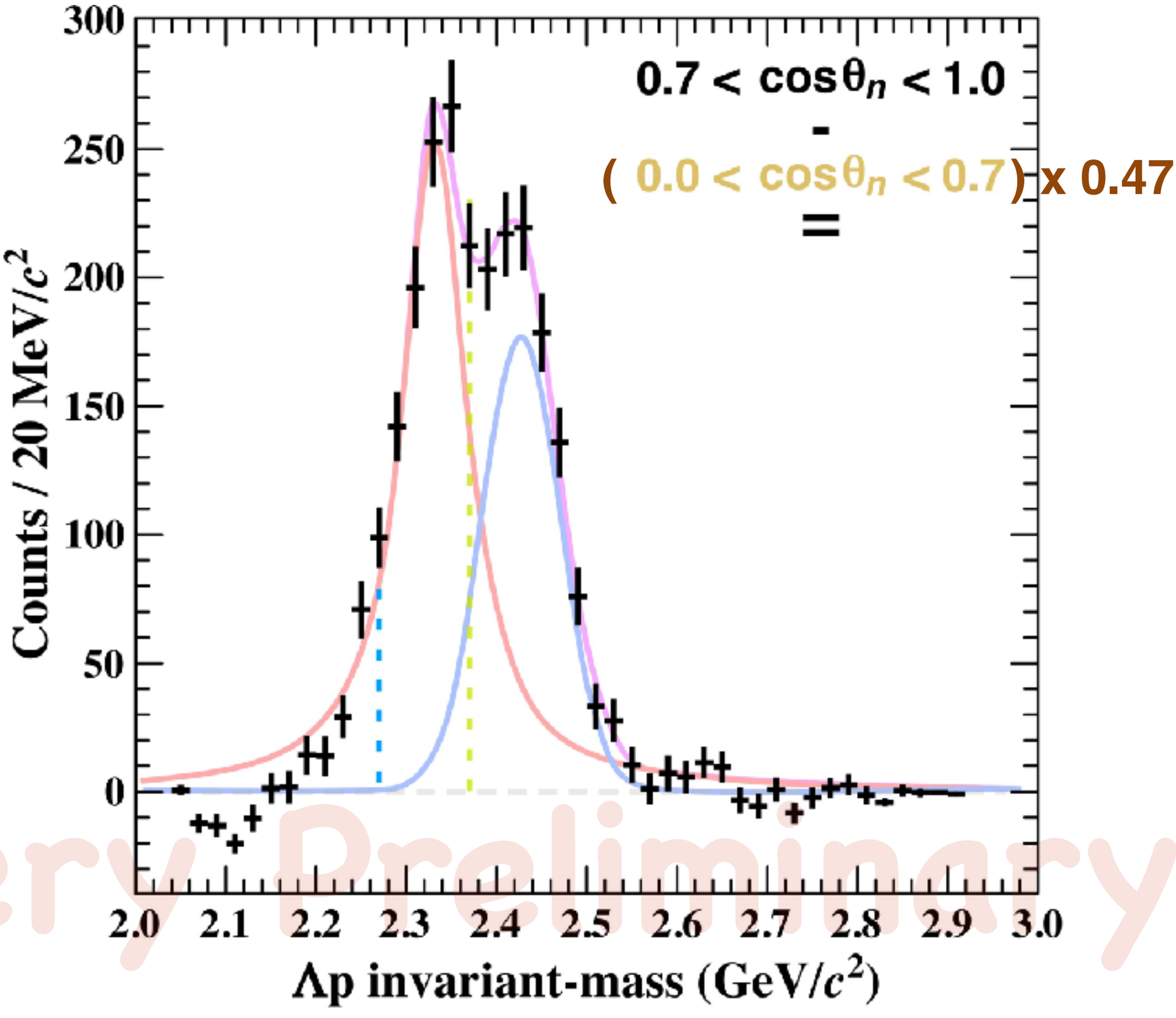




random Λ+p+n event subtraction



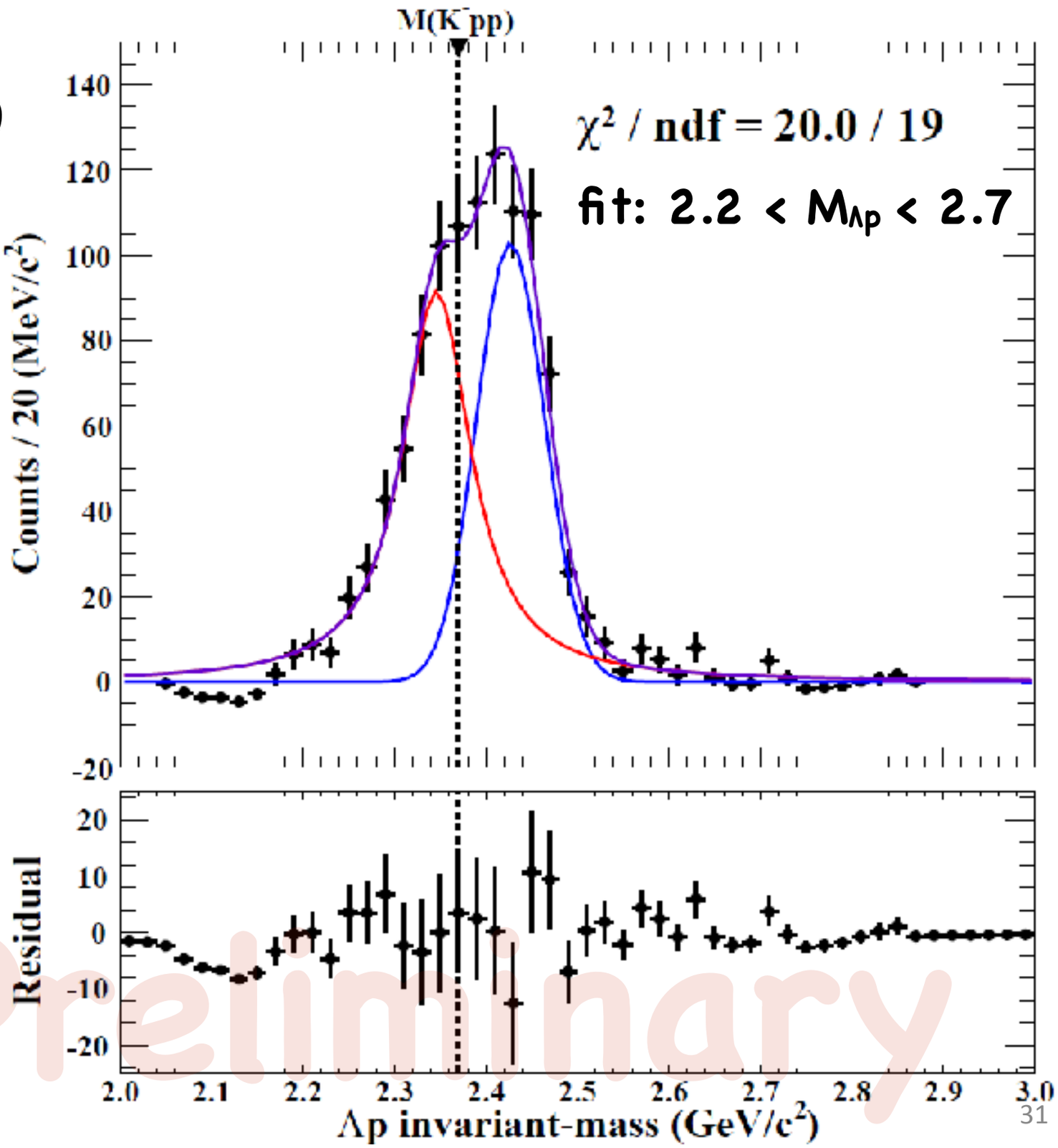
fit with Bright-Wigner + Gaussian



fit with Bright-Wigner + Gaussian

$\cos\theta_n$ slice

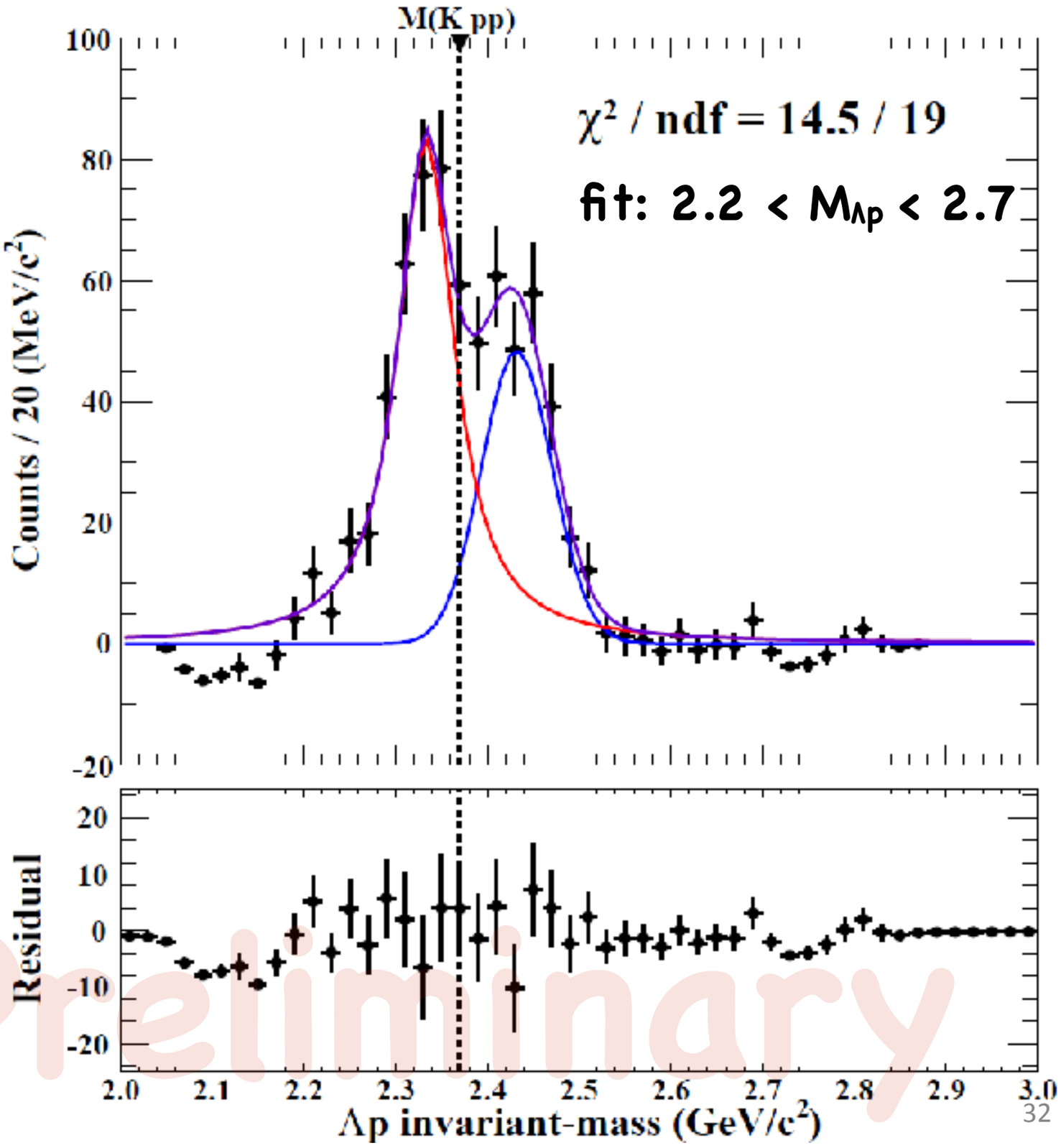
$0.95 < \cos\theta_n < 1.00$



fit with Bright-Wigner + Gaussian

$\cos\theta_n$ slice

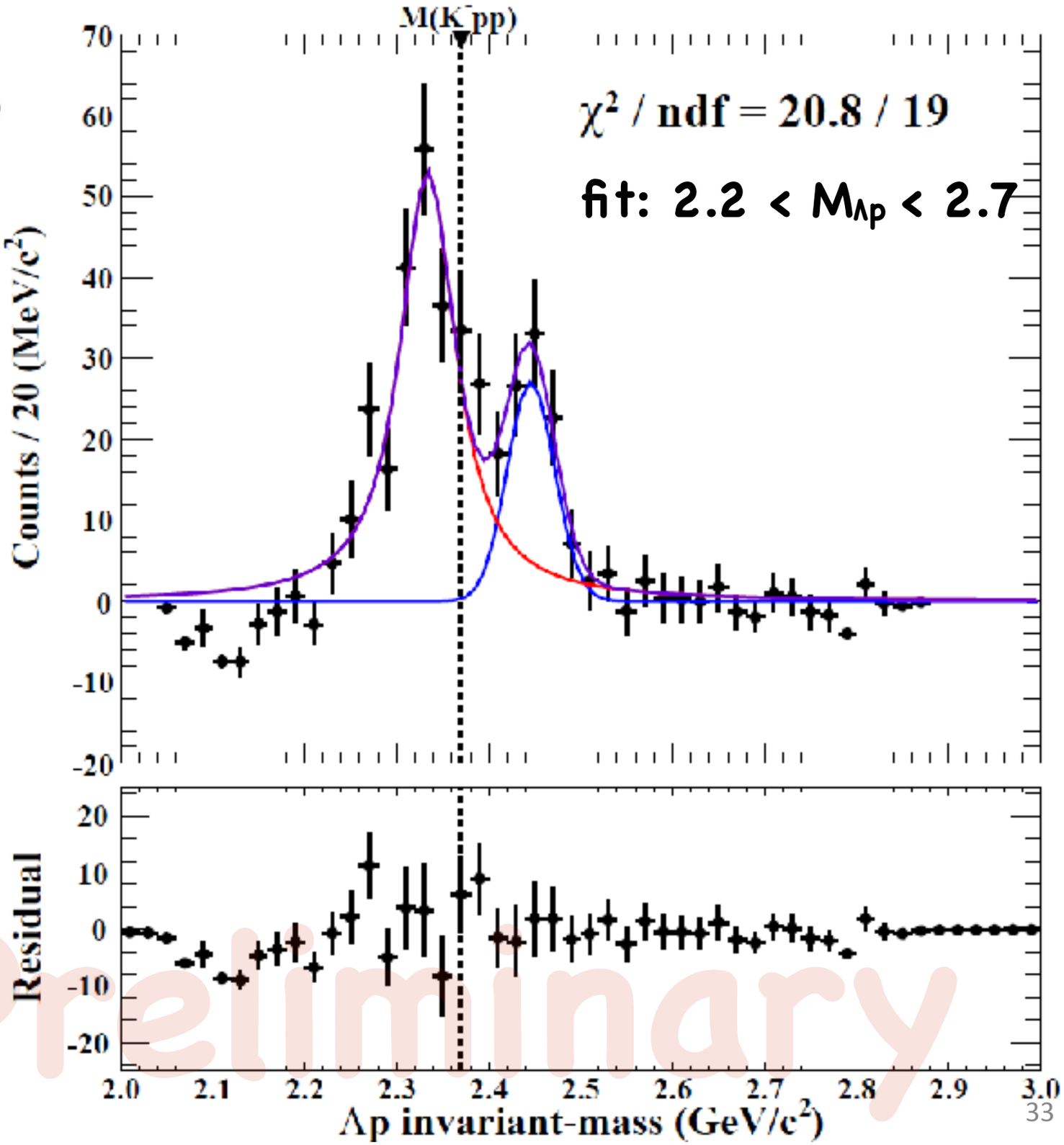
$0.90 < \cos\theta_n < 0.95$



fit with Bright-Wigner + Gaussian

$\cos\theta_n$ slice

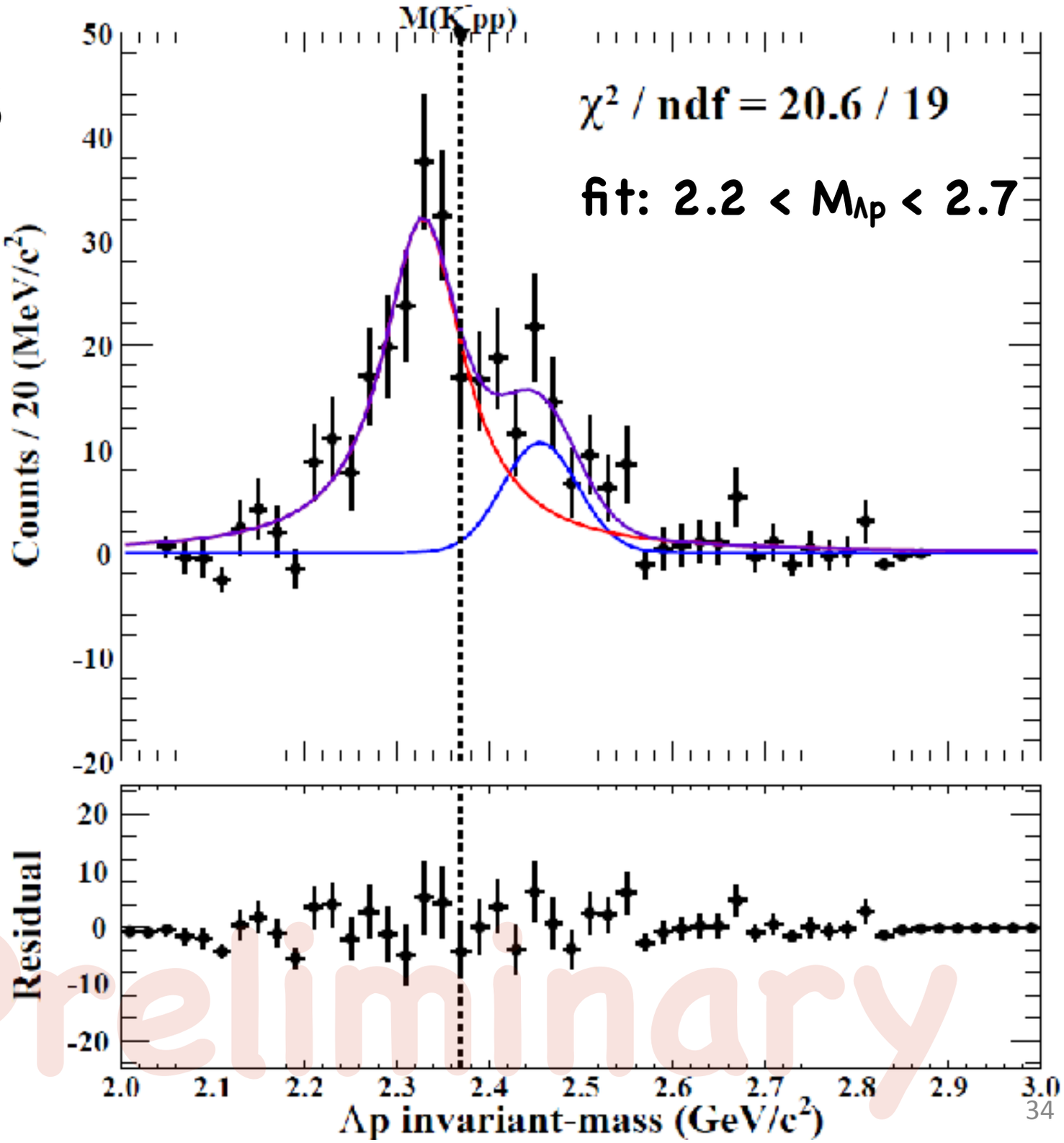
$0.85 < \cos\theta_n < 0.90$



fit with Bright-Wigner + Gaussian

$\cos\theta_n$ slice

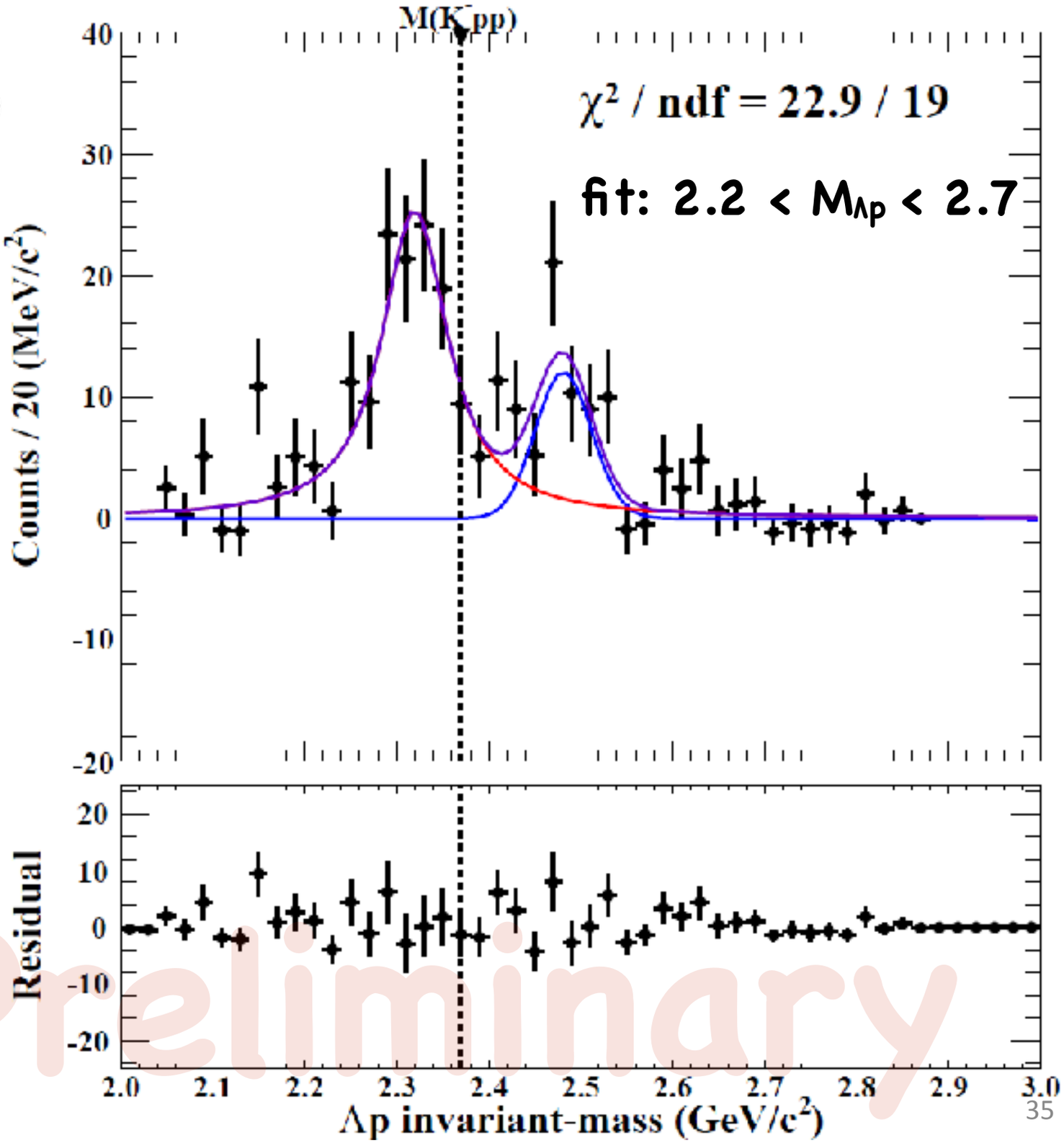
$0.80 < \cos\theta_n < 0.85$



fit with Bright-Wigner + Gaussian

$\cos\theta_n$ slice

$0.75 < \cos\theta_n < 0.80$

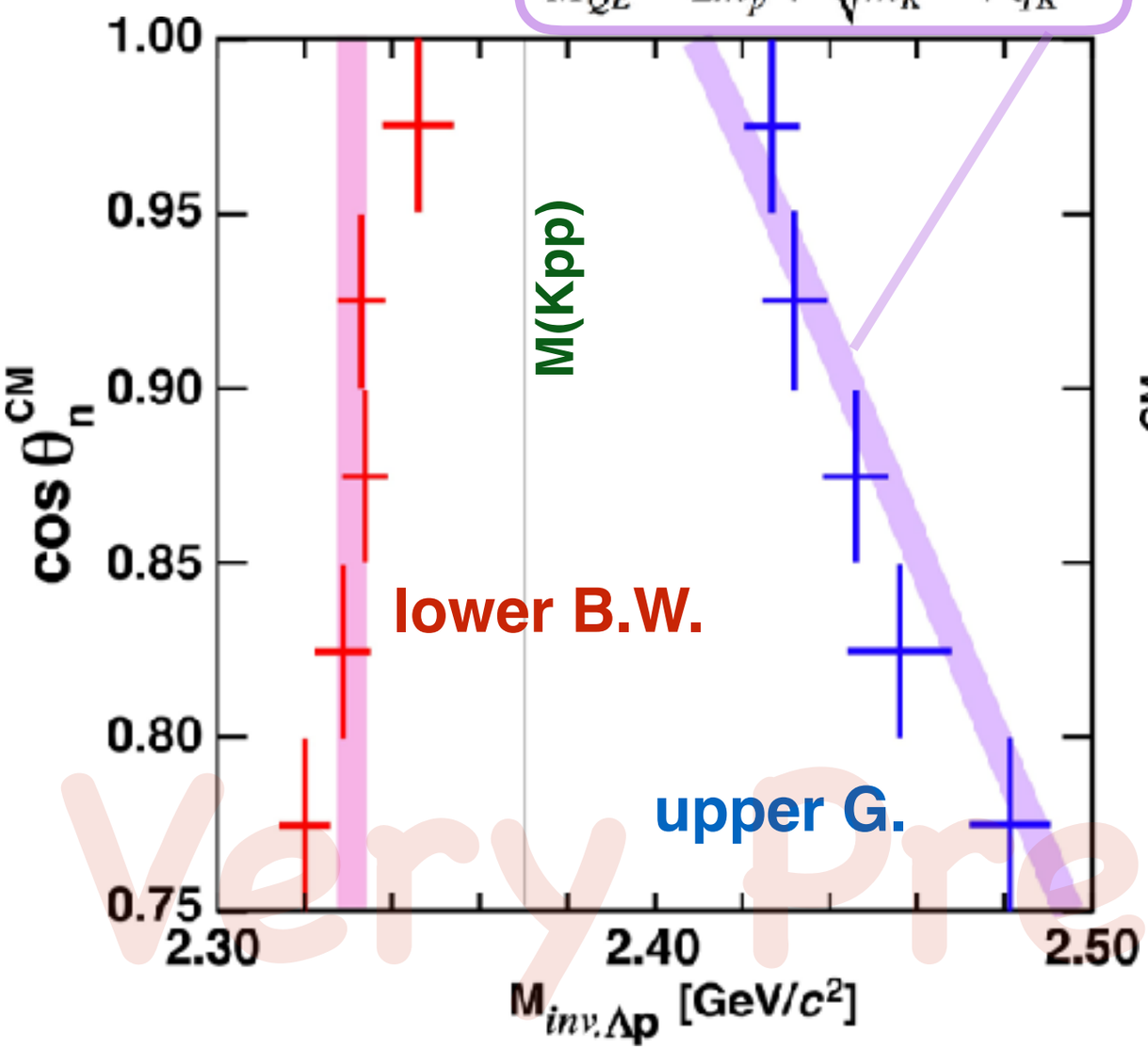


fit with Bright-Wigner + Gaussian by slicing $\cos\theta_n$

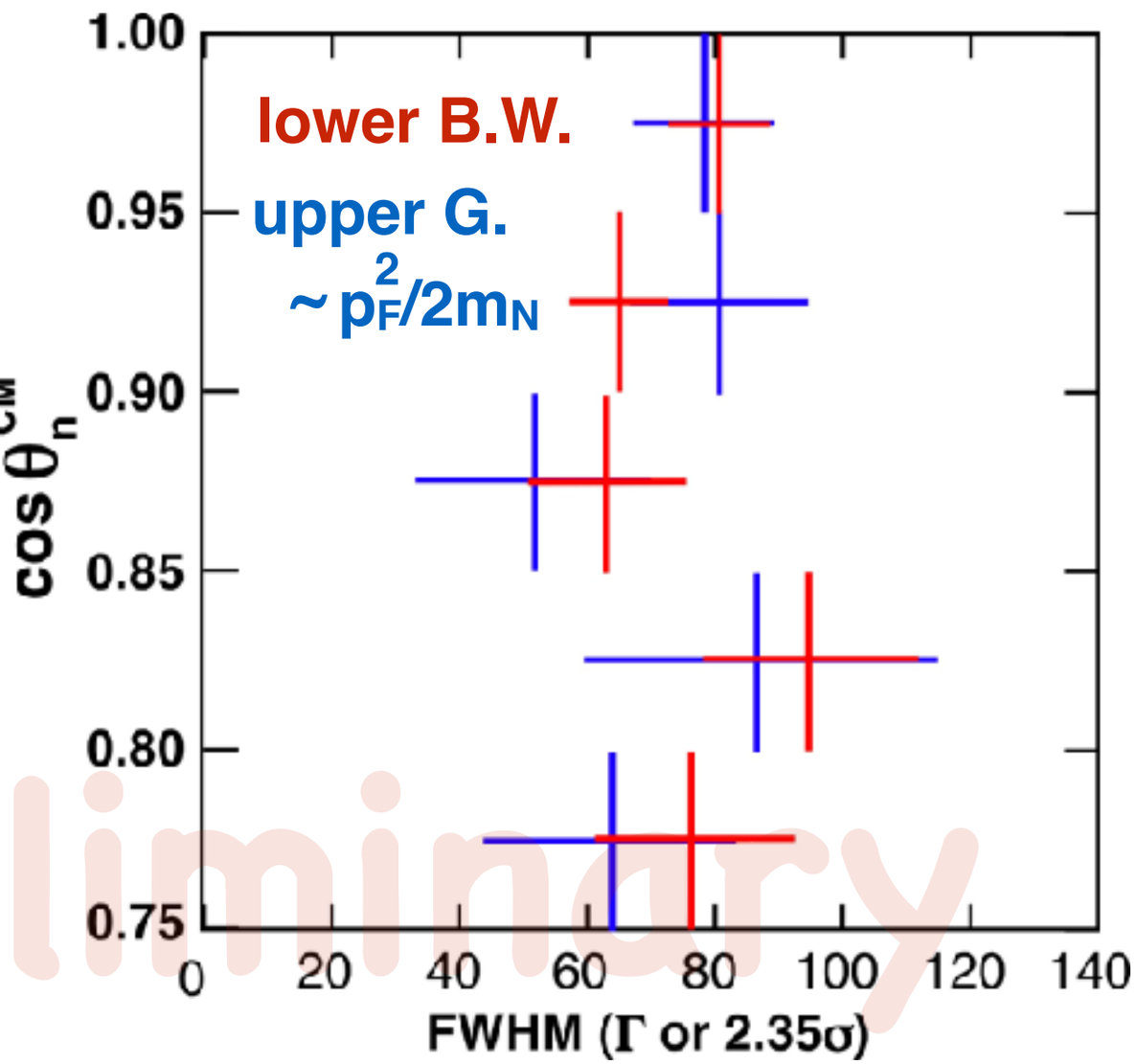
upper peak shift by recoil kaon energy !!

peak position

$M_{QE} = 2m_p + \sqrt{m_K{}^2 + q_K{}^2}$

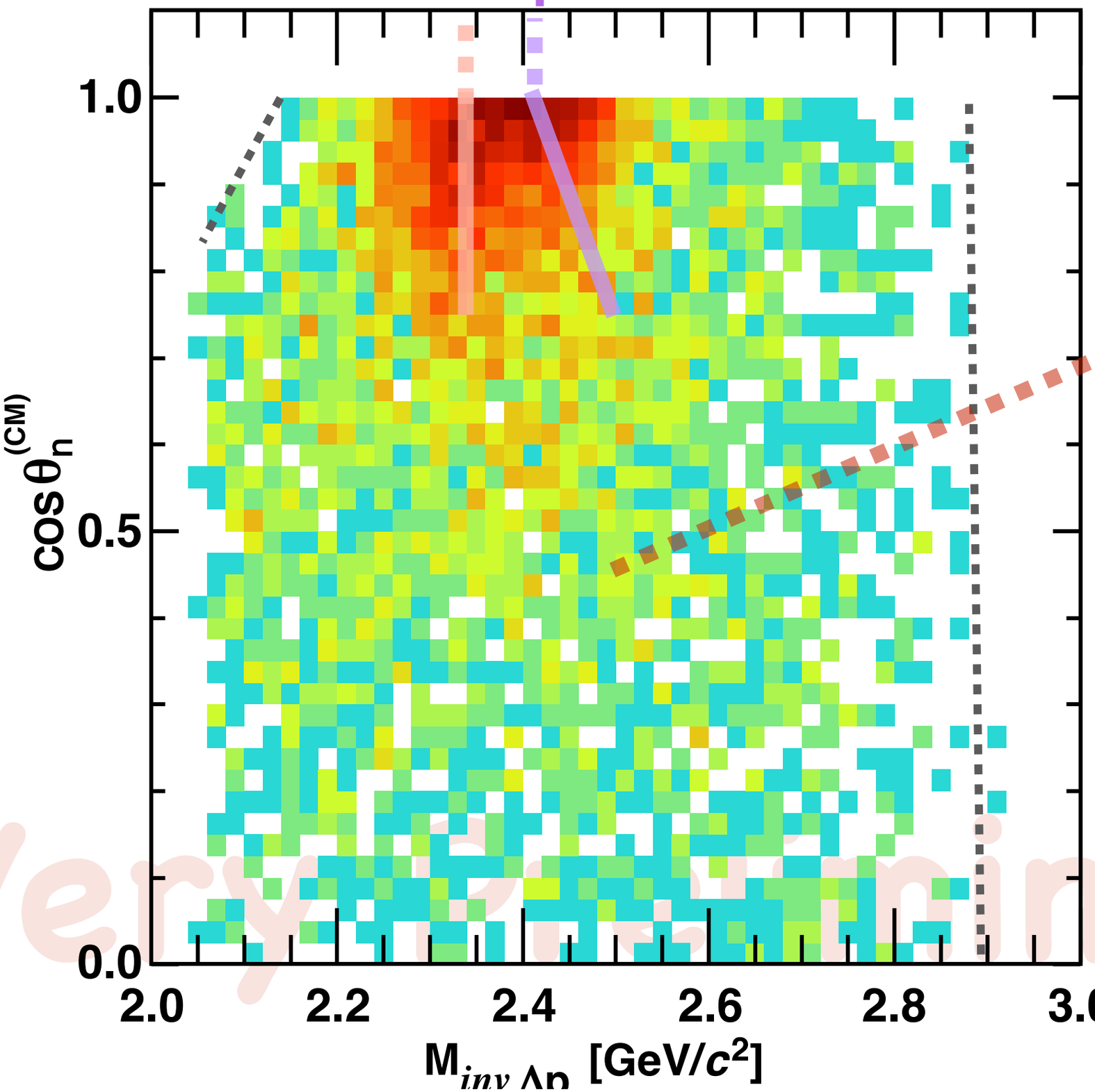


width



^{3}He(K$^-$, Λp)n: Angular Dependence

nuclear bound state quasi-elastic + internal conv.

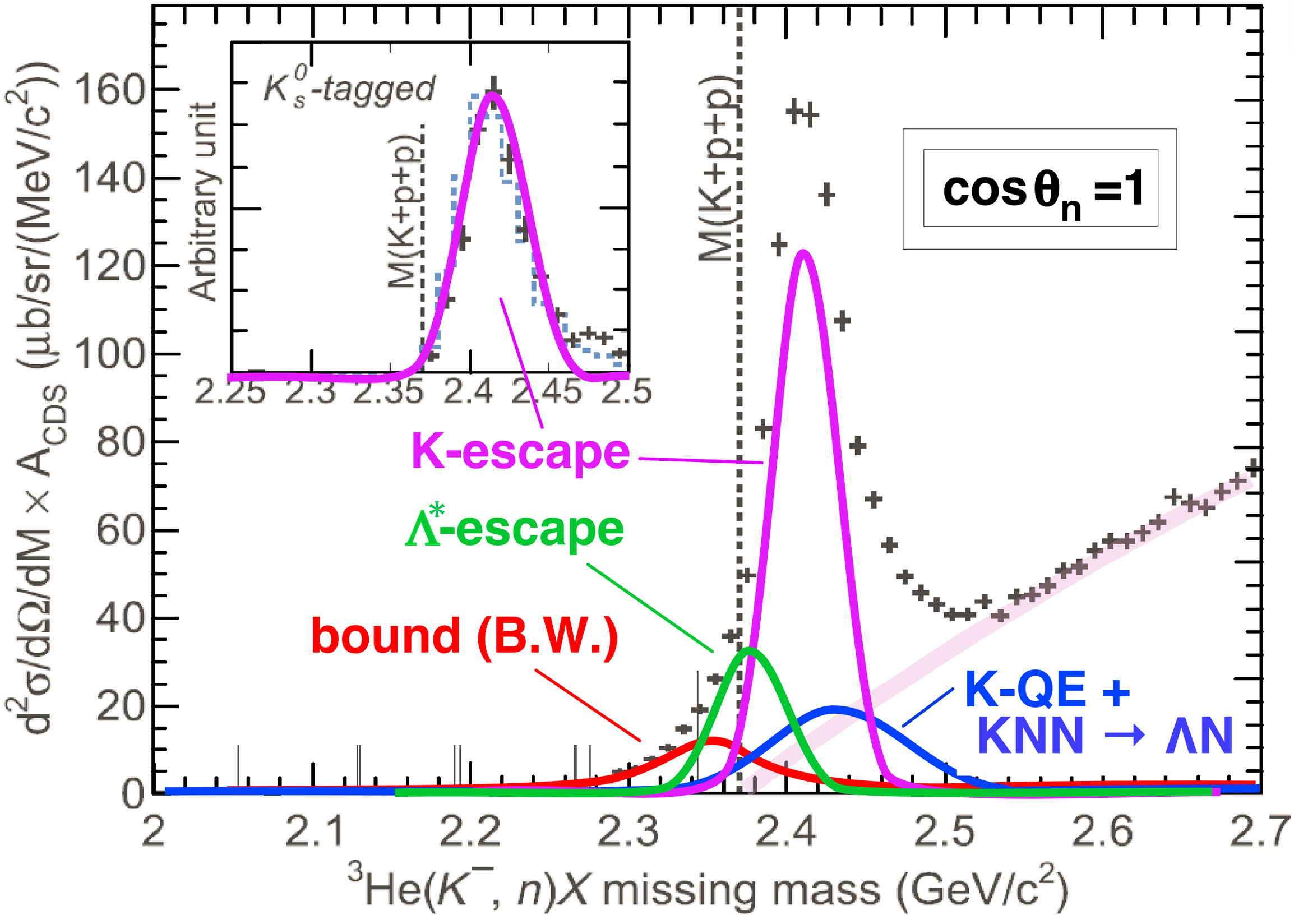


3N phase space?

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

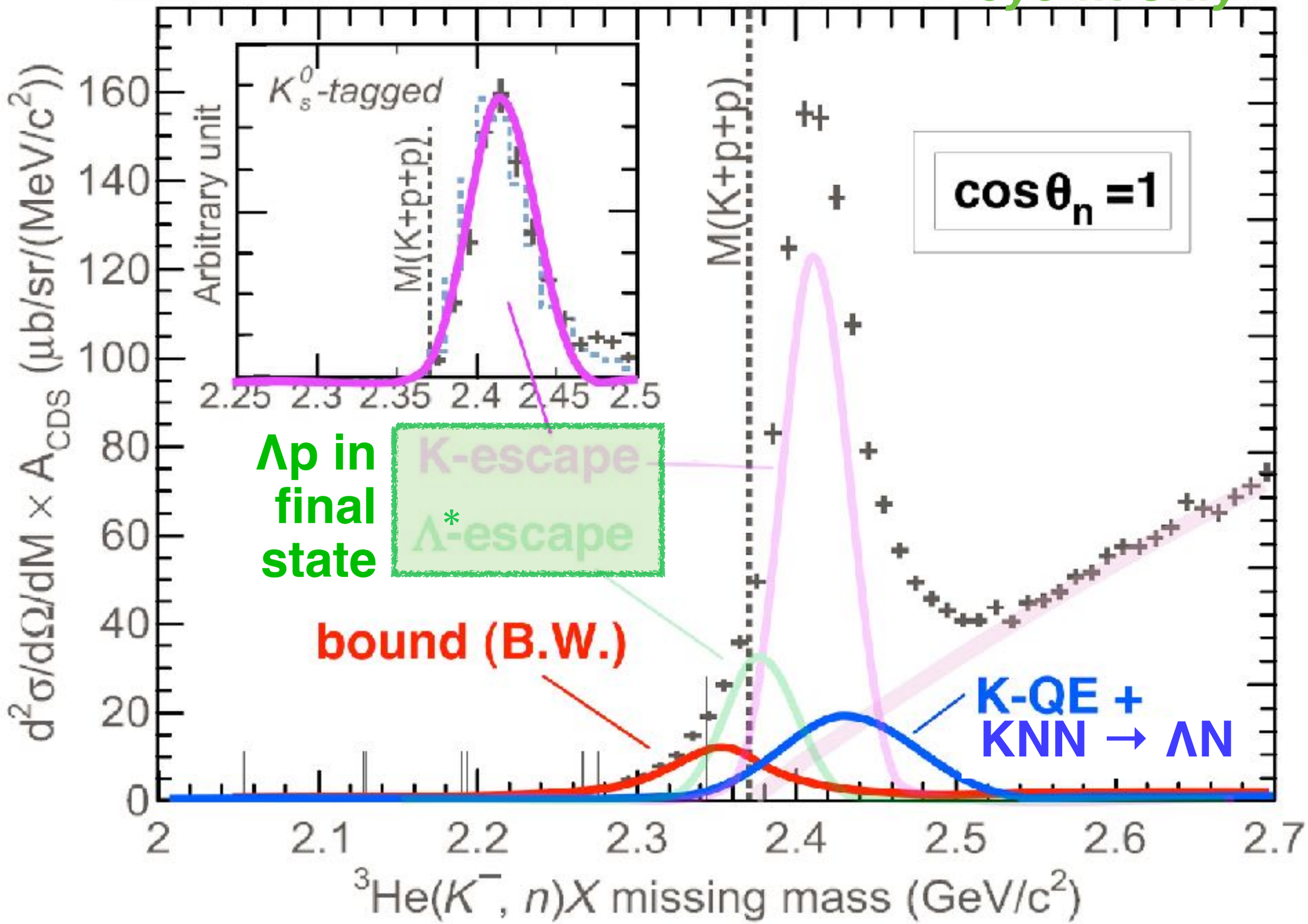
^{3}He(K^-, n_{NC})X — semi-inclusive

eye-fit only

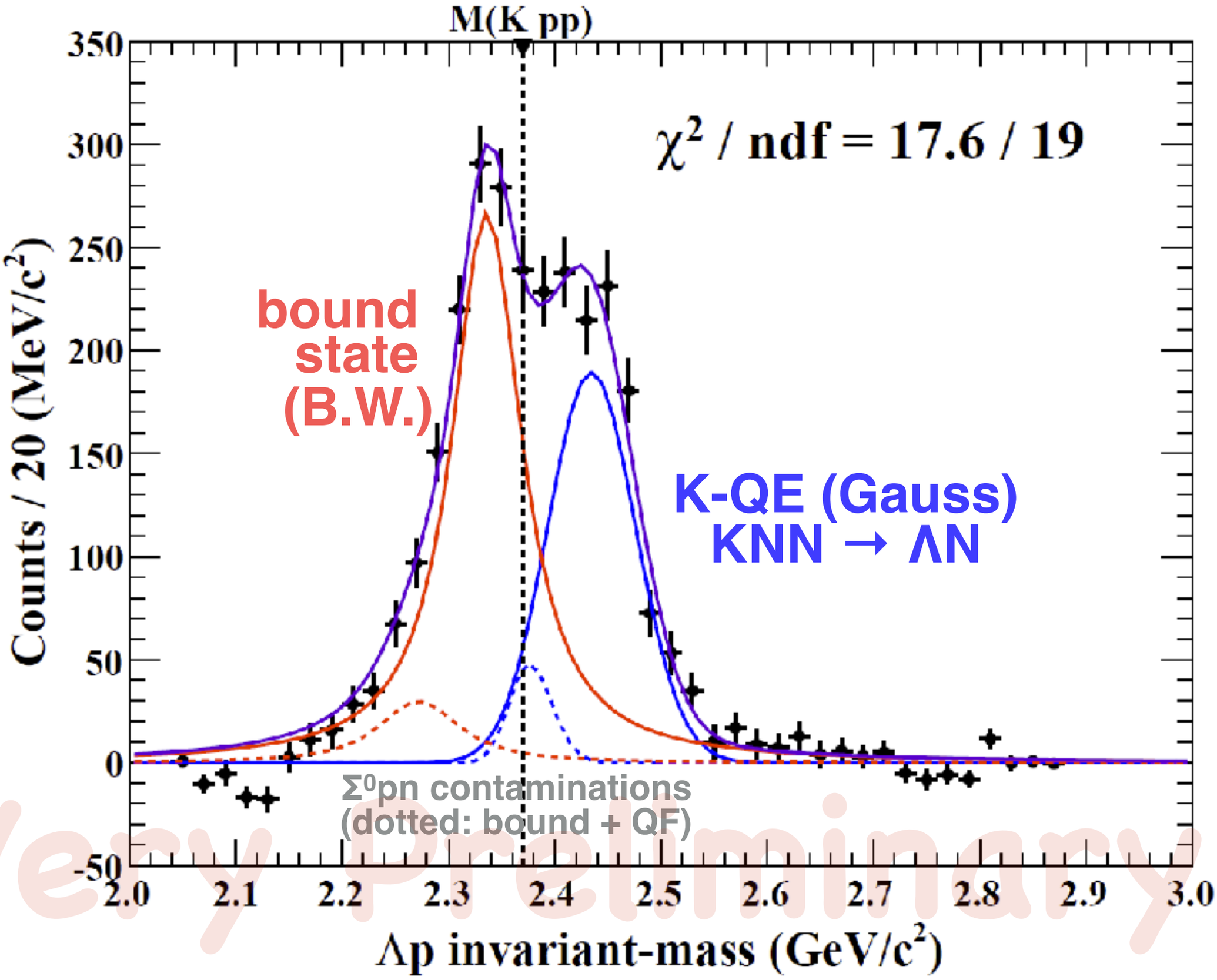


$^3He(K^-, n_{NC})X$ — semi-inclusive

eye-fit only

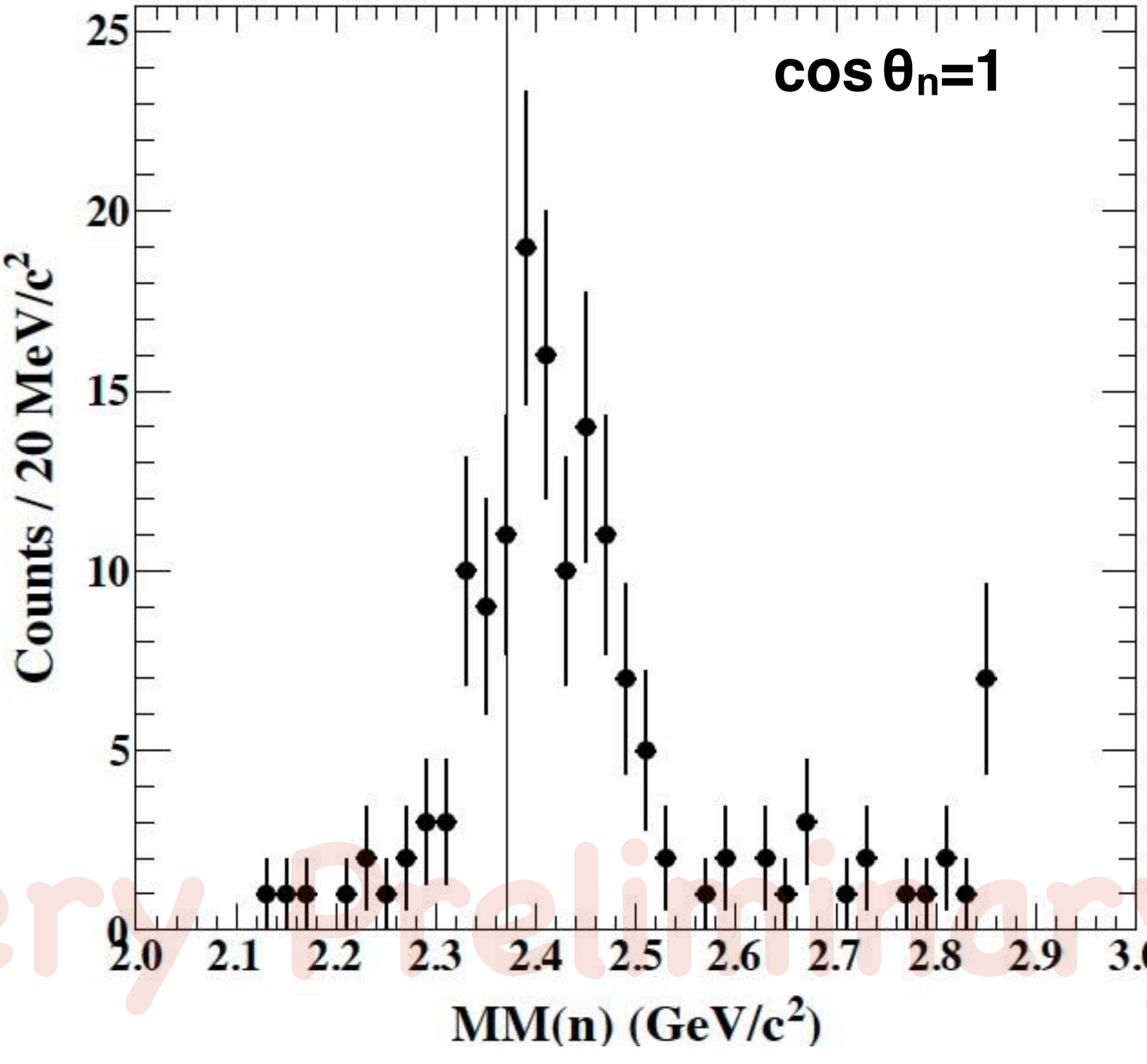


^{3}He(K^{-}, Λp)n



$^3He(K^-, \Lambda_{CDS}\, n_{NC})\, p$

very forward n



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

1) flat distribution proportional to phase space ?

- kaon total-energy ~randomly divided into Λ+p+n
- point-like 3NA reaction??

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

- peak shift: $M_{\Lambda p}^{QF} \sim 2m_p + m_K + q^2/2m_K$

quasi-elastic K scattering x internal conversion

$q^2/2m$ simply consumed as Λp kinetic energy!

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

- no peak shift: $M_{\Lambda p}^{Kpp} \sim 2m_p + m_K - B_{Kpp}$

nuclear bound state

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

1) flat distribution proportional to phase space ?

single-step 3NA internal conversion?

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

K back-scattering (QE)

QF = x

internal conversion (IC)

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

nuclear bound state

unlike baryonic resonance, this is associated with QF = QE + IC

one can pull out the constituent particles, Kpp

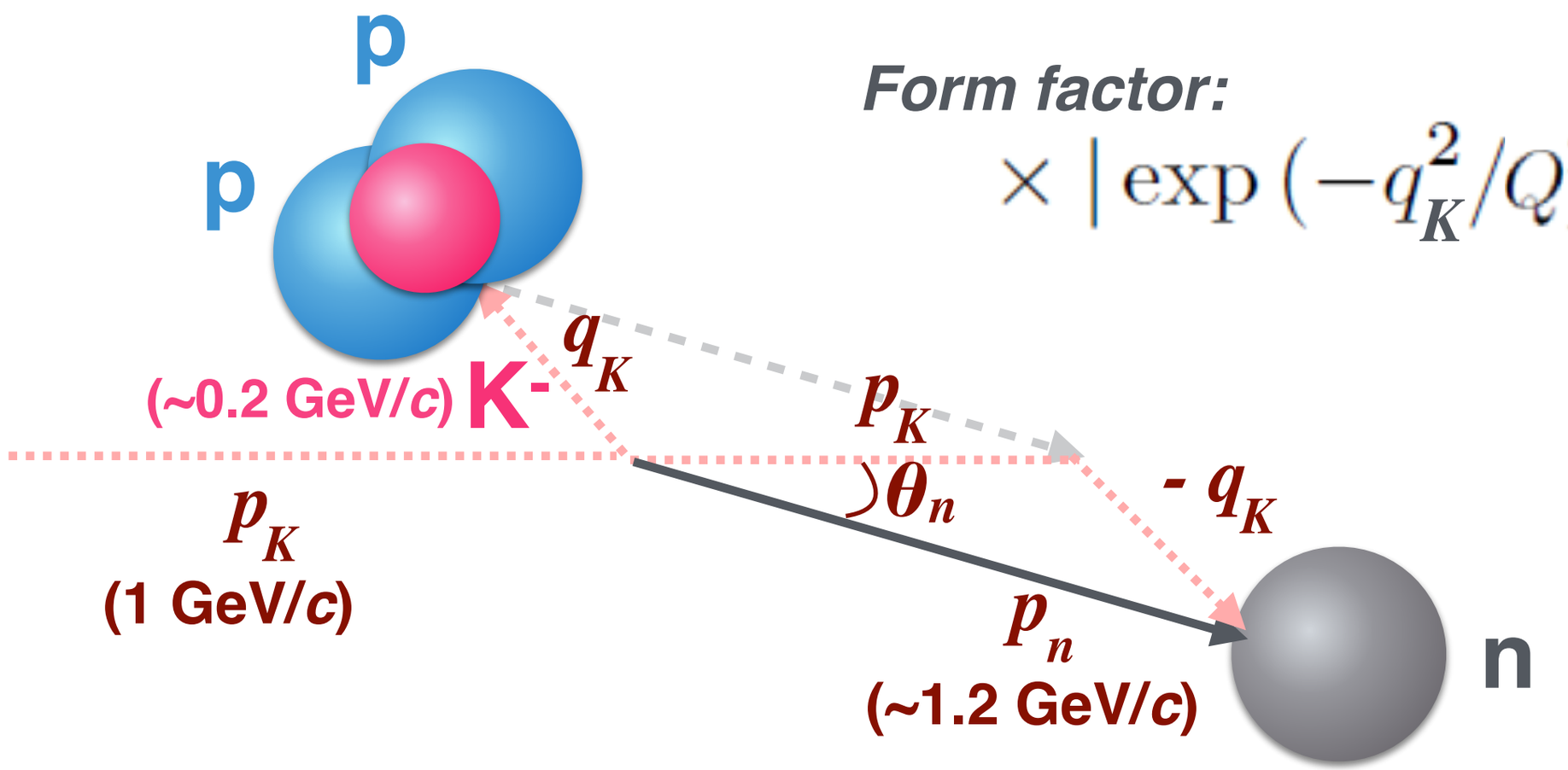
K^-pp compose the resonance

^{3}He(K^{-}, Λp)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:

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

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

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

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

$\bar{K}N_sN_s \rightarrow$ **"K$^-$pp" S-wave resonance?**

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

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

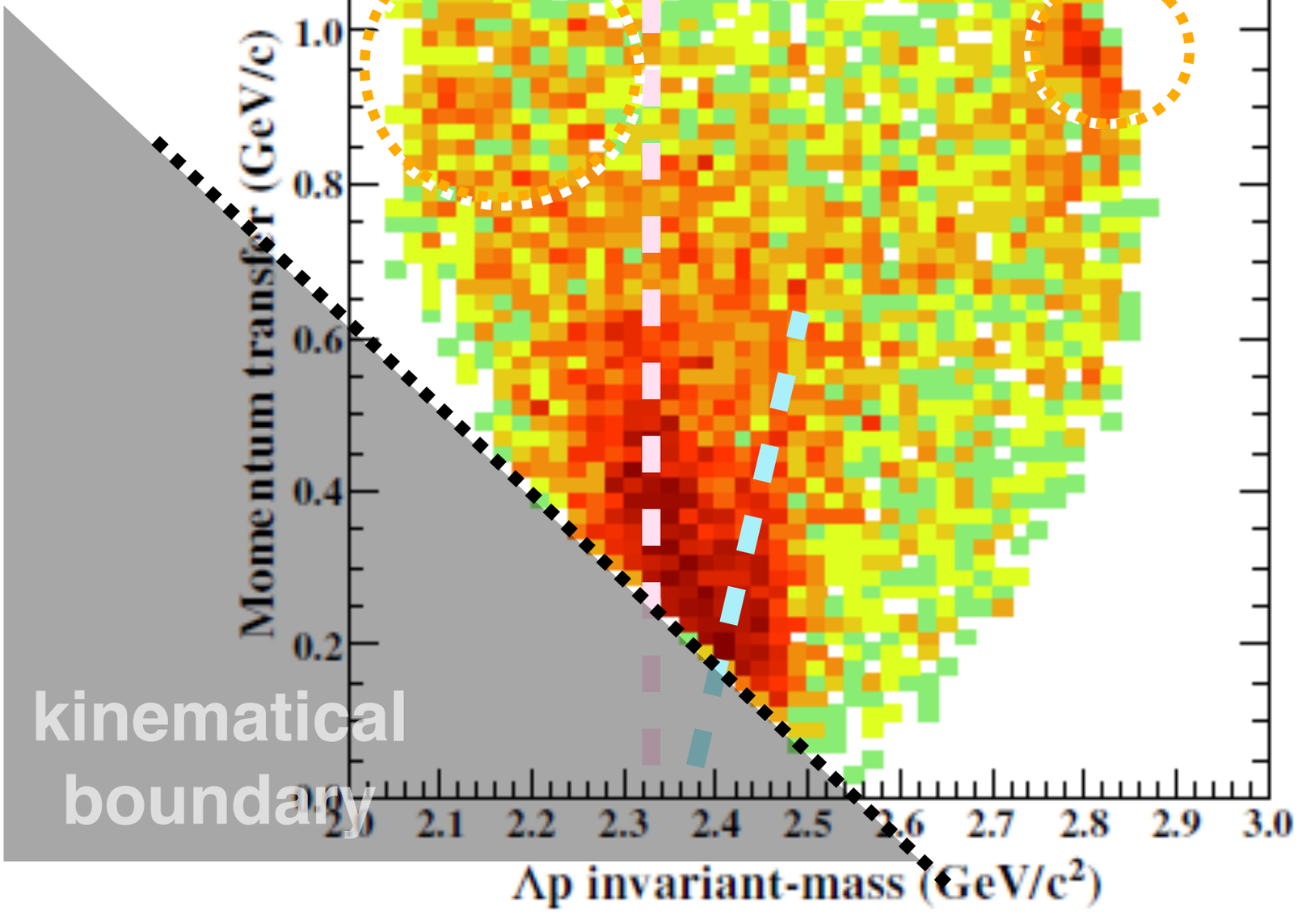
$$\propto \quad \frac{V_0}{4\pi}\int d^3x \exp\left(-i\,\frac{(\mathbf{p_K}-\mathbf{p_n})\cdot\mathbf{x}}{\hbar}\right)\exp\left(-\left(\frac{1}{{R_{\mathrm{Kpp}}}^2}+\frac{1}{{R_{\mathrm{He}}}^2}\right)\frac{\mathbf{x}^2}{2}\right)$$

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

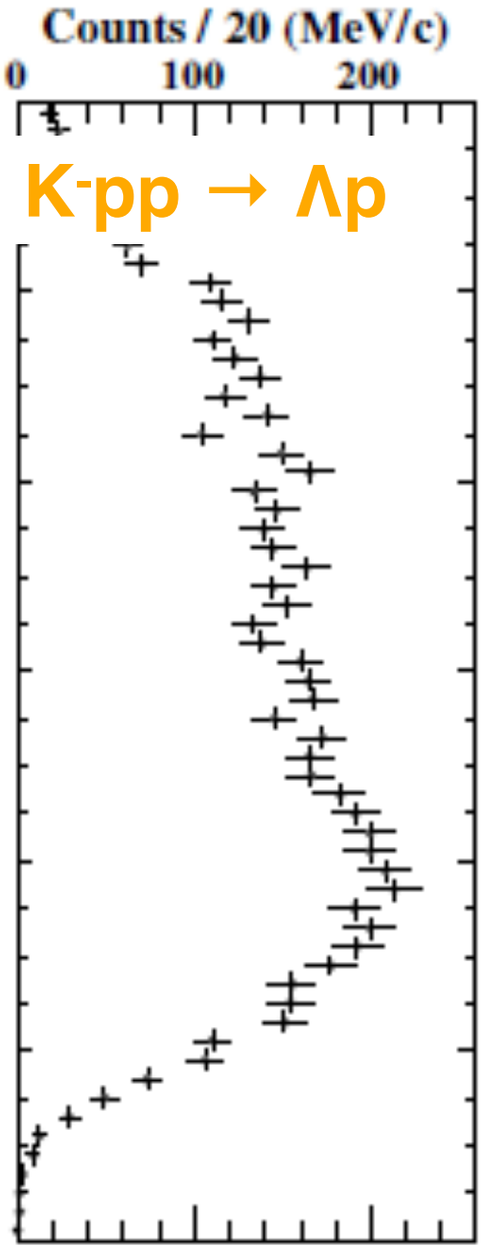
$$= \quad \sqrt{\frac{\pi}{2}}V_0R^3\exp\left(-\frac{R^2k^2}{2}\right)$$

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

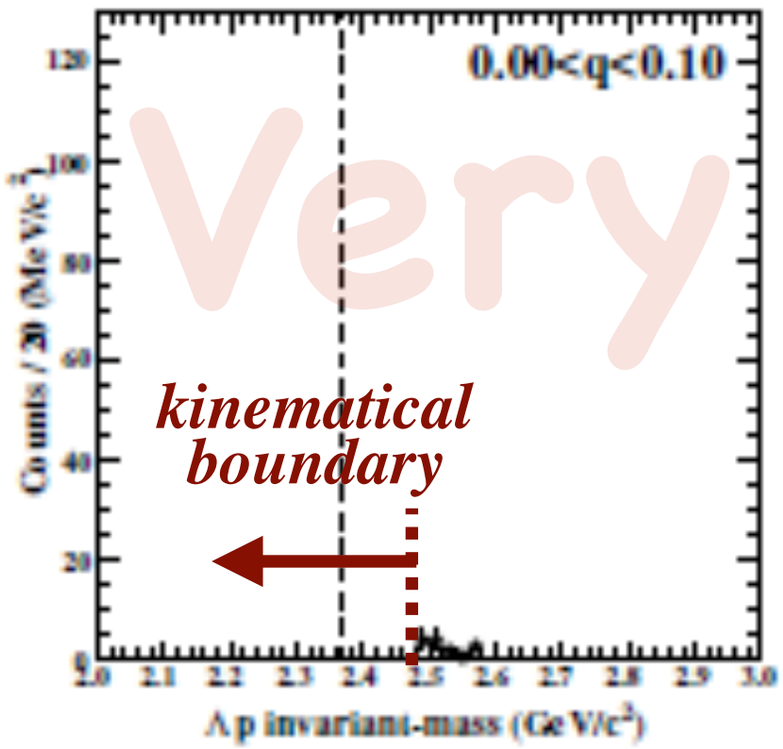
2NA: $K^-pn \rightarrow \Lambda n$?

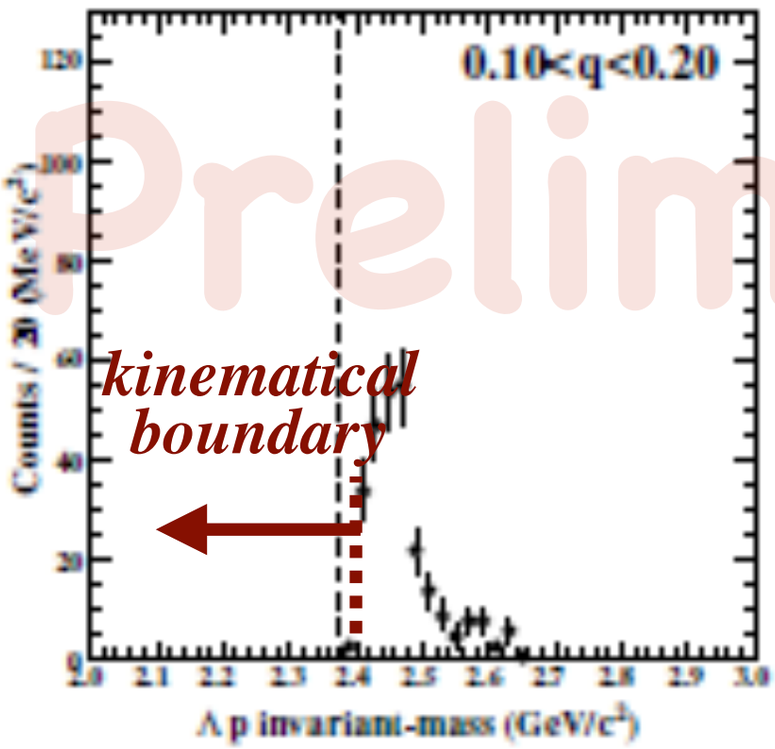


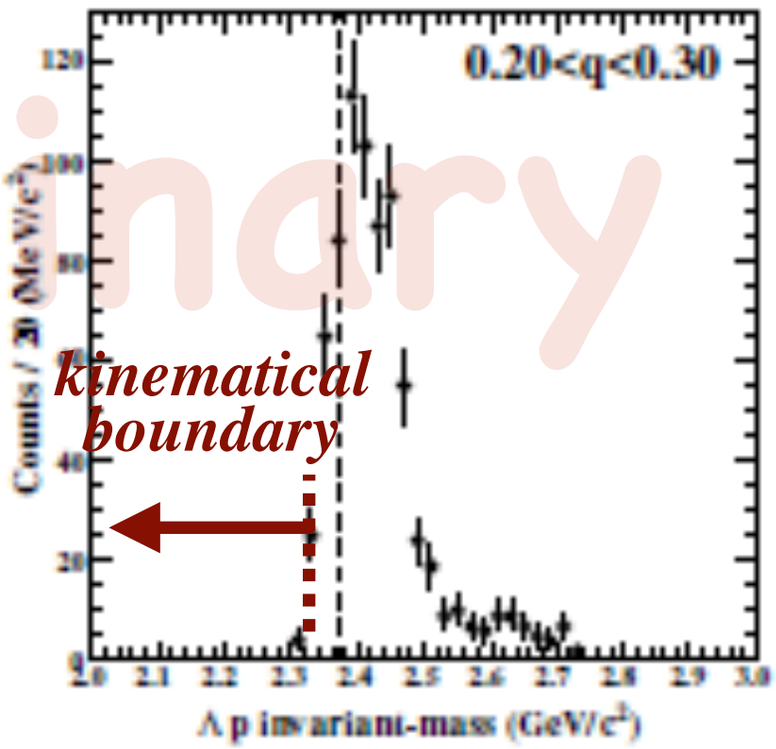
2NA: $K^-pp \rightarrow \Lambda p$

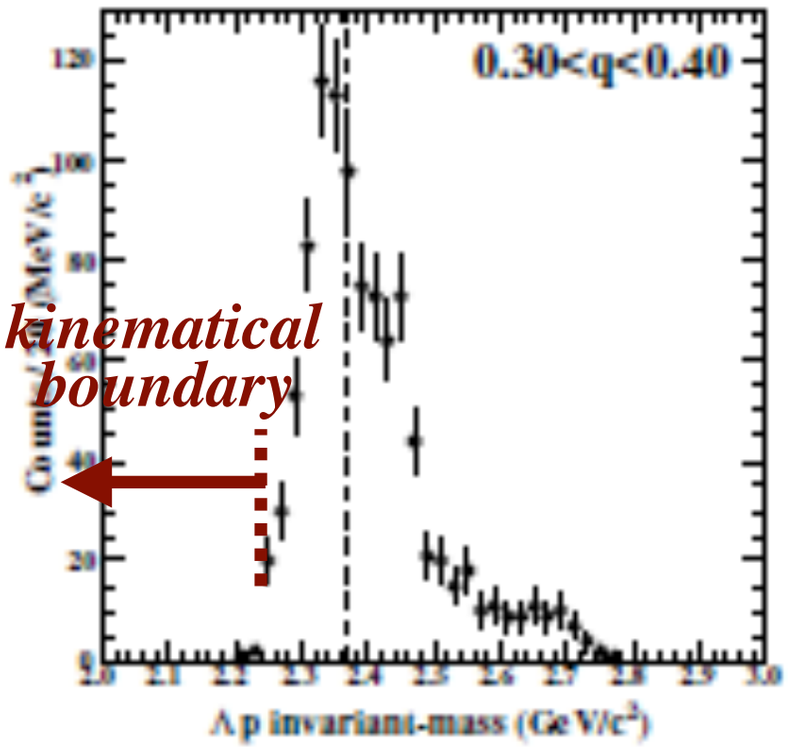


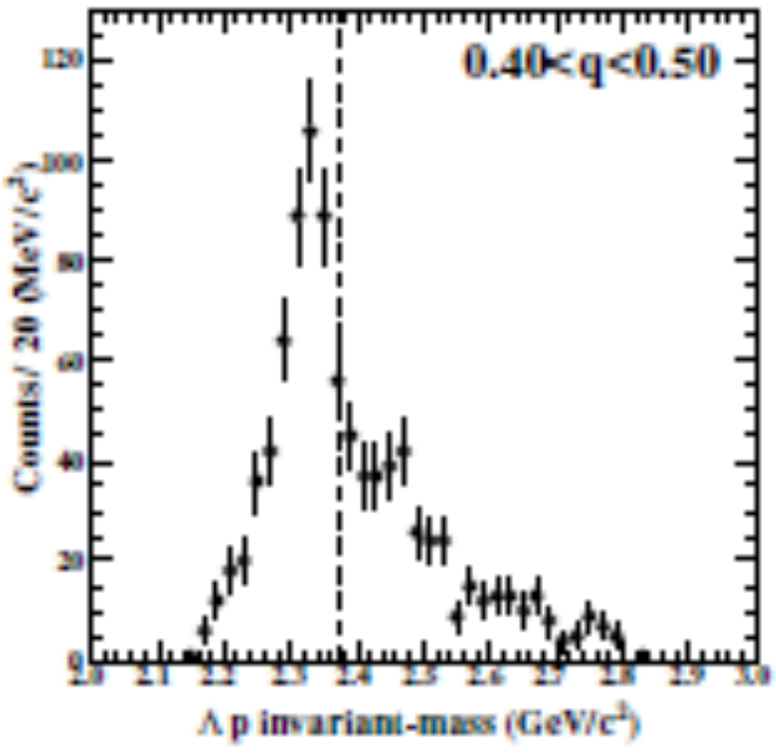
q_K slice by 100 MeV/c

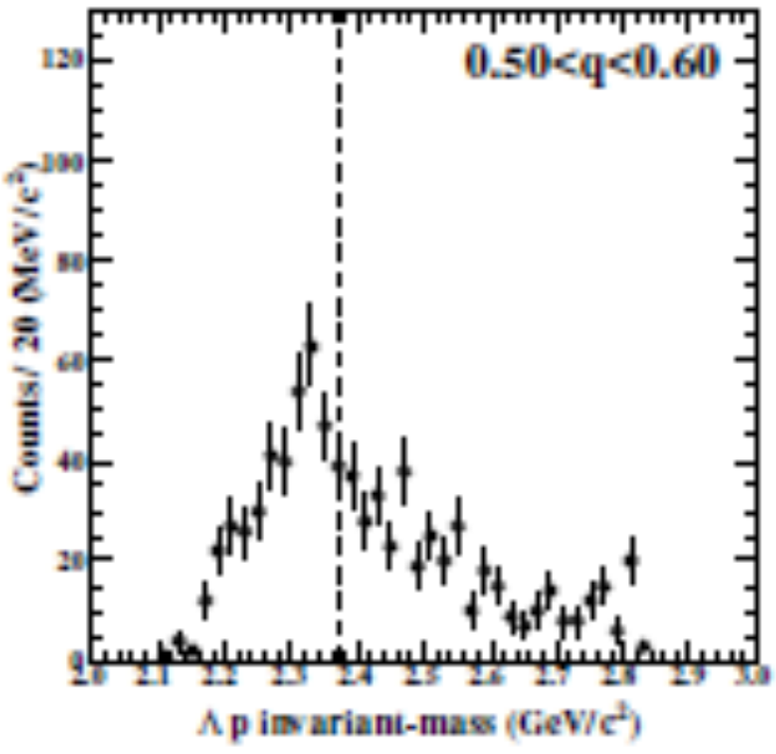












what we assumed in E15[1st]

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

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

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

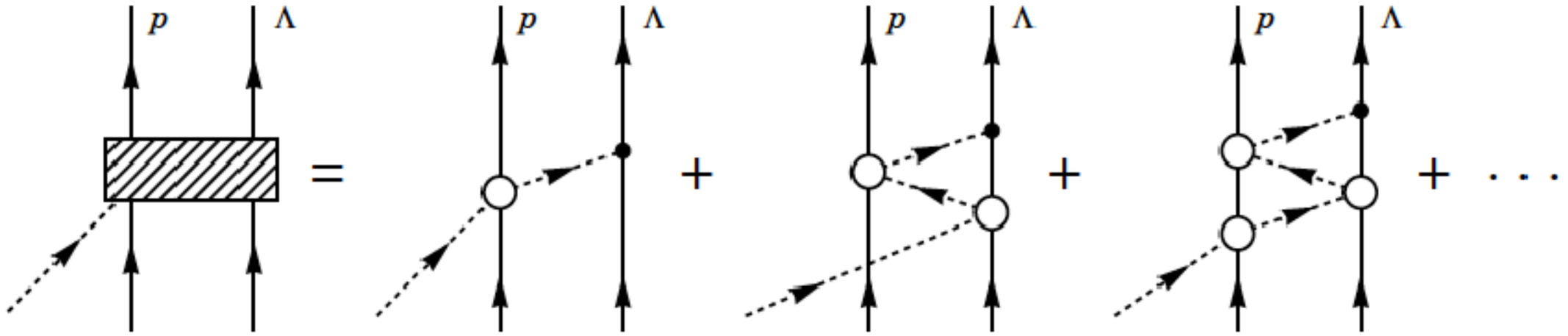
q is reaching as large as ~800 MeV/c!

large Q_x (~400MeV/c) implies
realization of compact state

^{3}He(K^{-}, Λp)n:
a theoretical prediction
based on the E15 1st run

^{3}He(K$^-$, Λp)n:

Structure can be explained with quasi-elastic K scattering & Kpp @ x-UM?



Sekihara Oset Ramos

PTEP

Prog. Theor. Exp. Phys. 2016, 123D03 (27 pages)
DOI: 10.1093/ptep/ptw166

On the structure observed in the in-flight ^{3}He(K^-, Λp)n reaction at J-PARC

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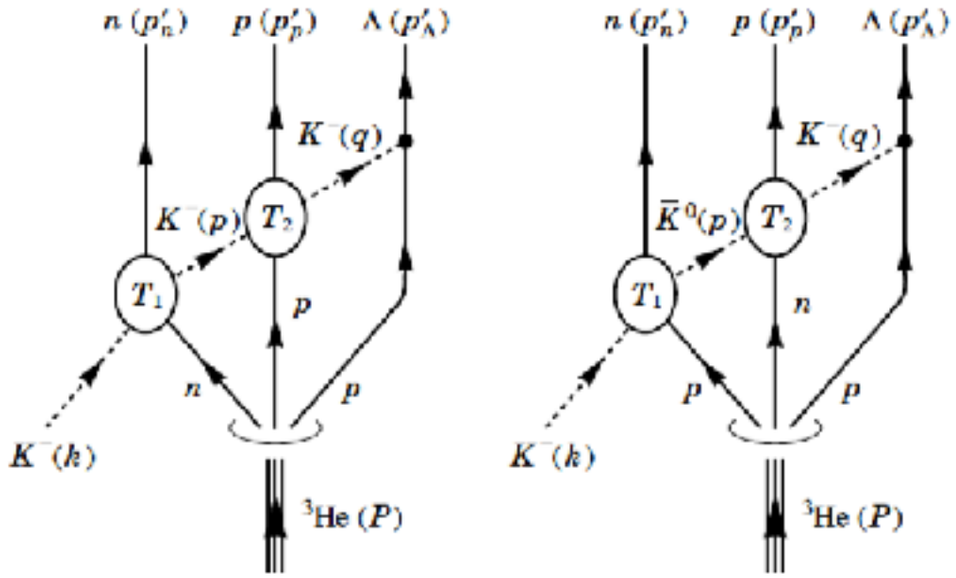
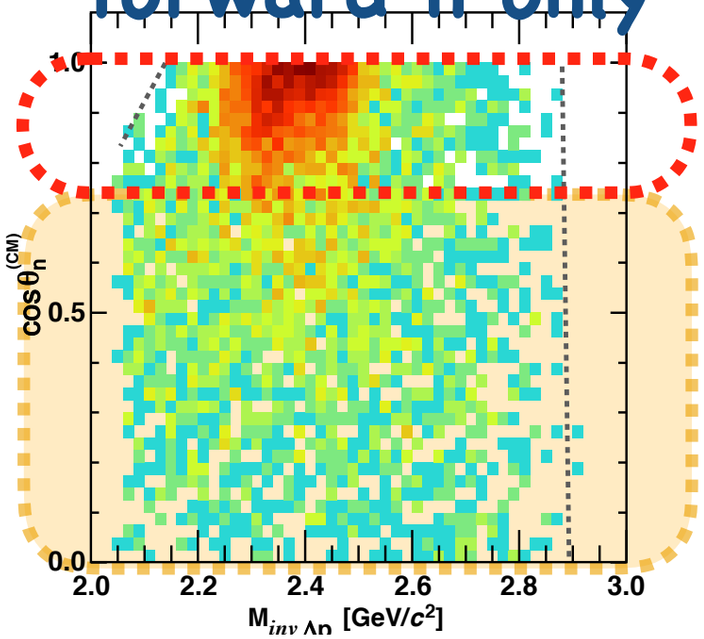
Received July 11, 2016; Revised October 7, 2016; Accepted October 15, 2016; Published December 30, 2016



Qualitatively consistent with S.O.R.

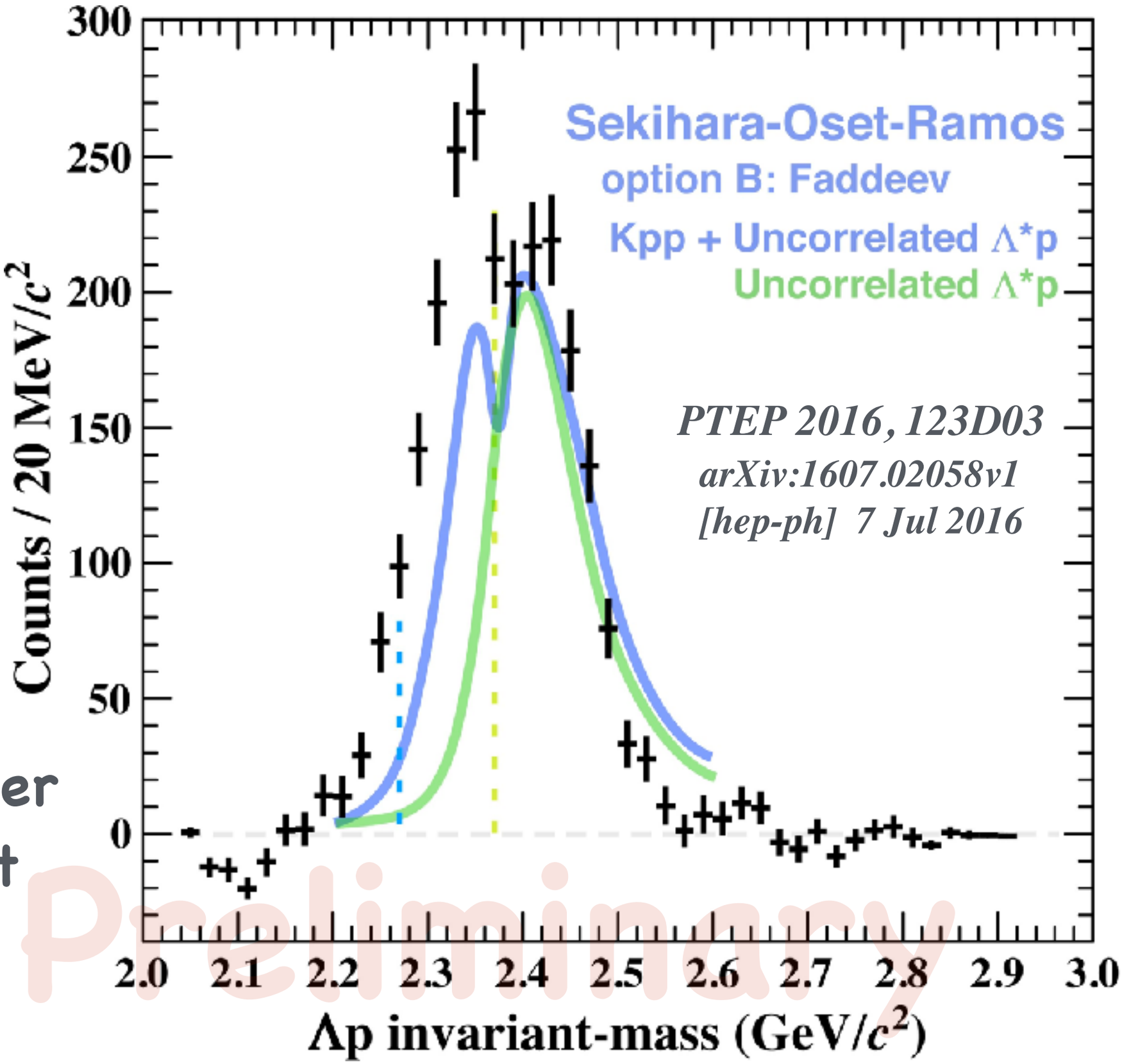
forward n only



QE + "Kpp"

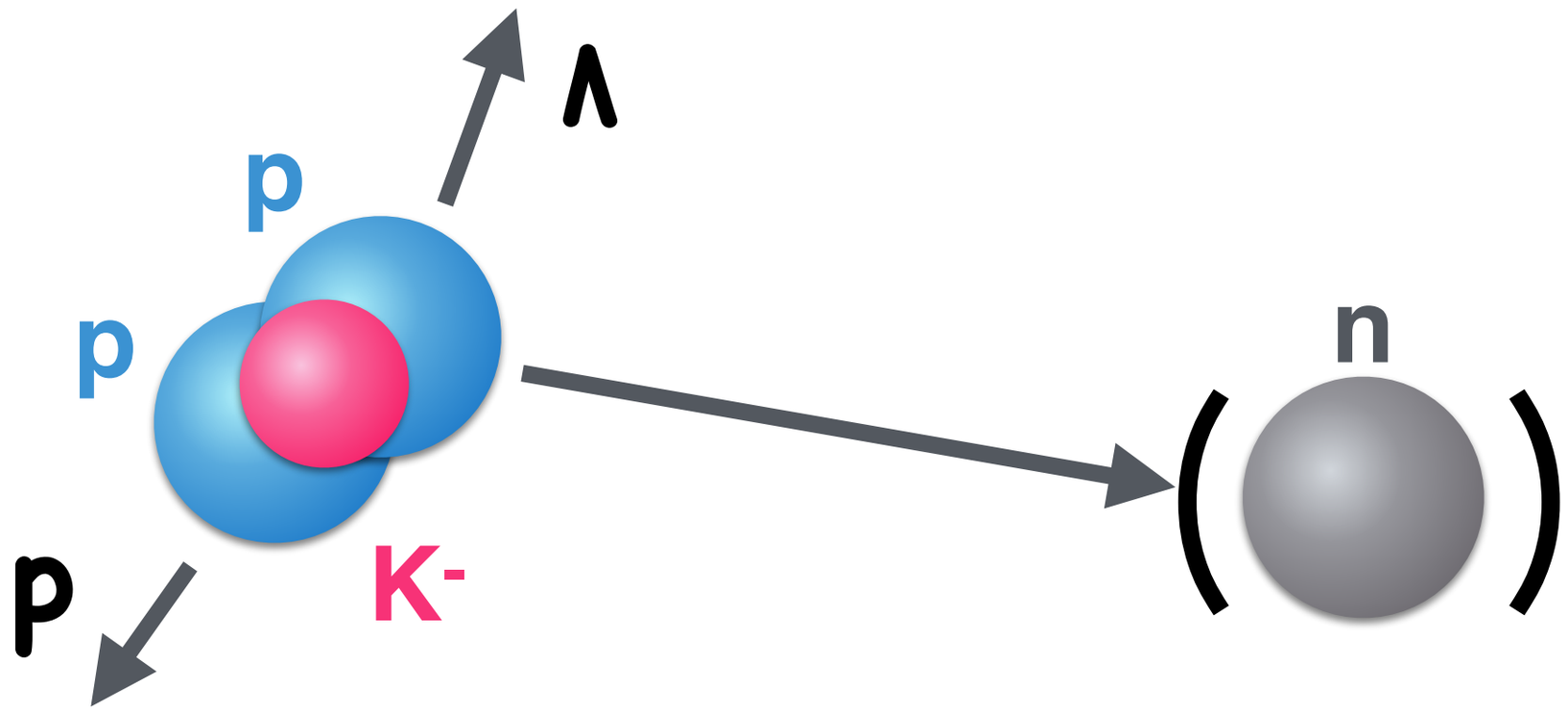
K multiple scattering

qualitatively rather good agreement



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

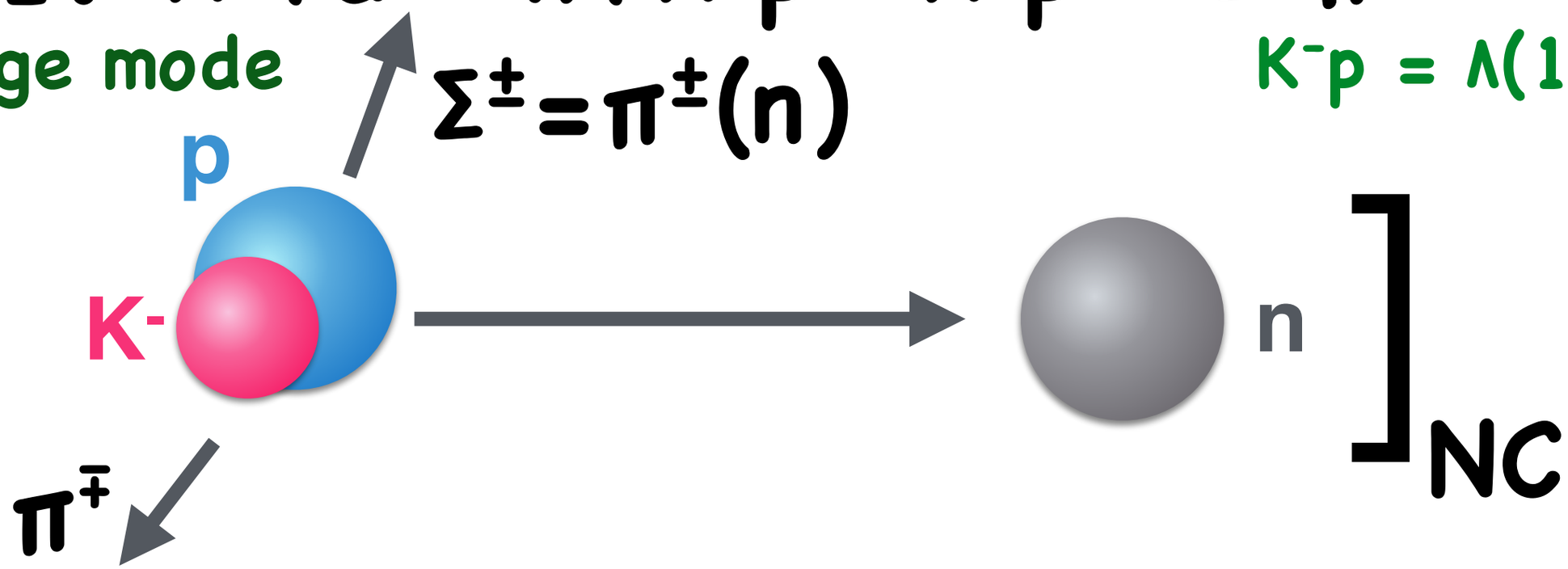
E15: $K^- + {}^3He \rightarrow n + K^-pp$ $\quad K^-pp \rightarrow \Lambda p$

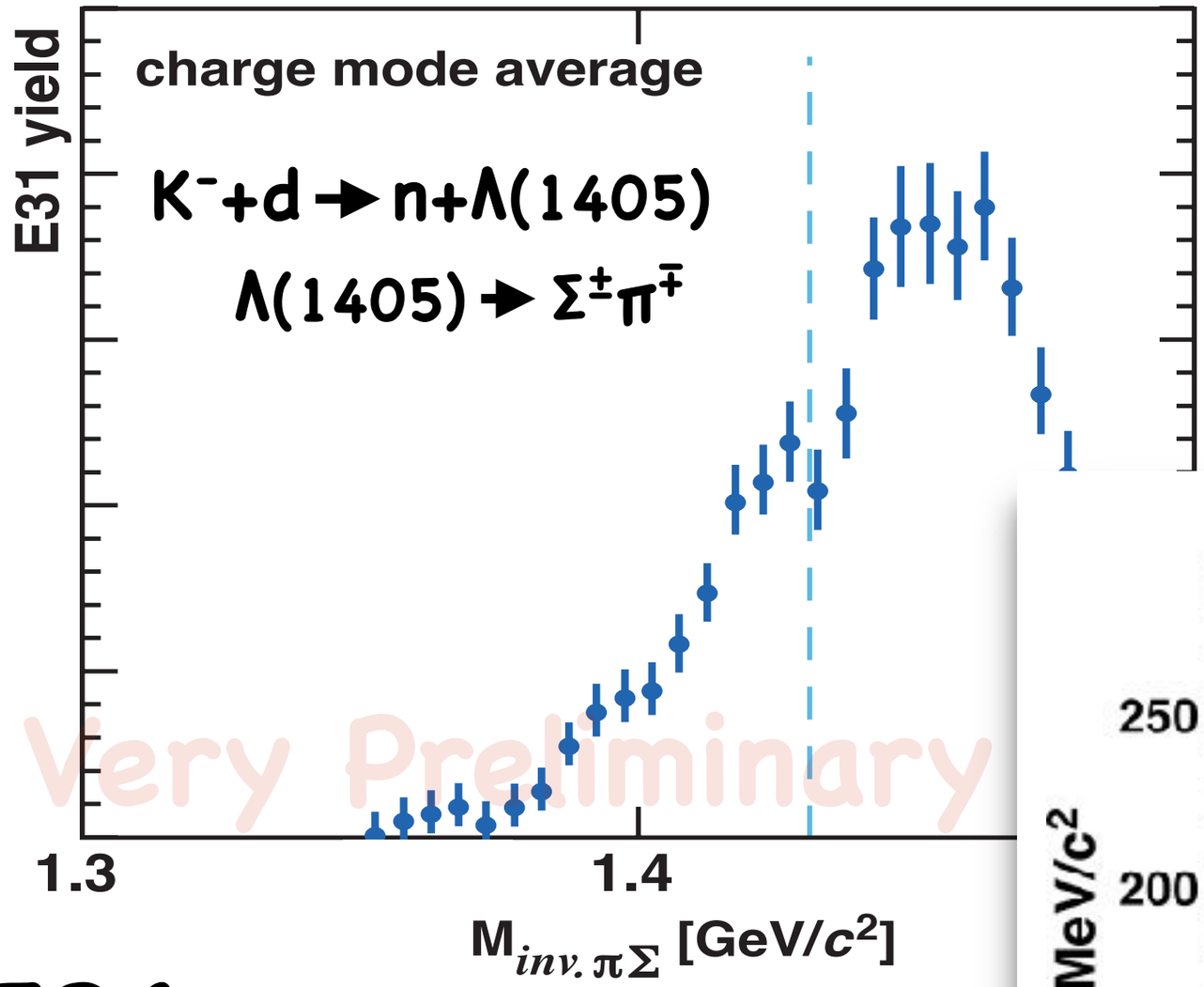


E31: $K^- + d \rightarrow n + K^-p$ $\quad K^-p \rightarrow \Sigma^{\pm}\pi^{\mp}$

charge mode

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



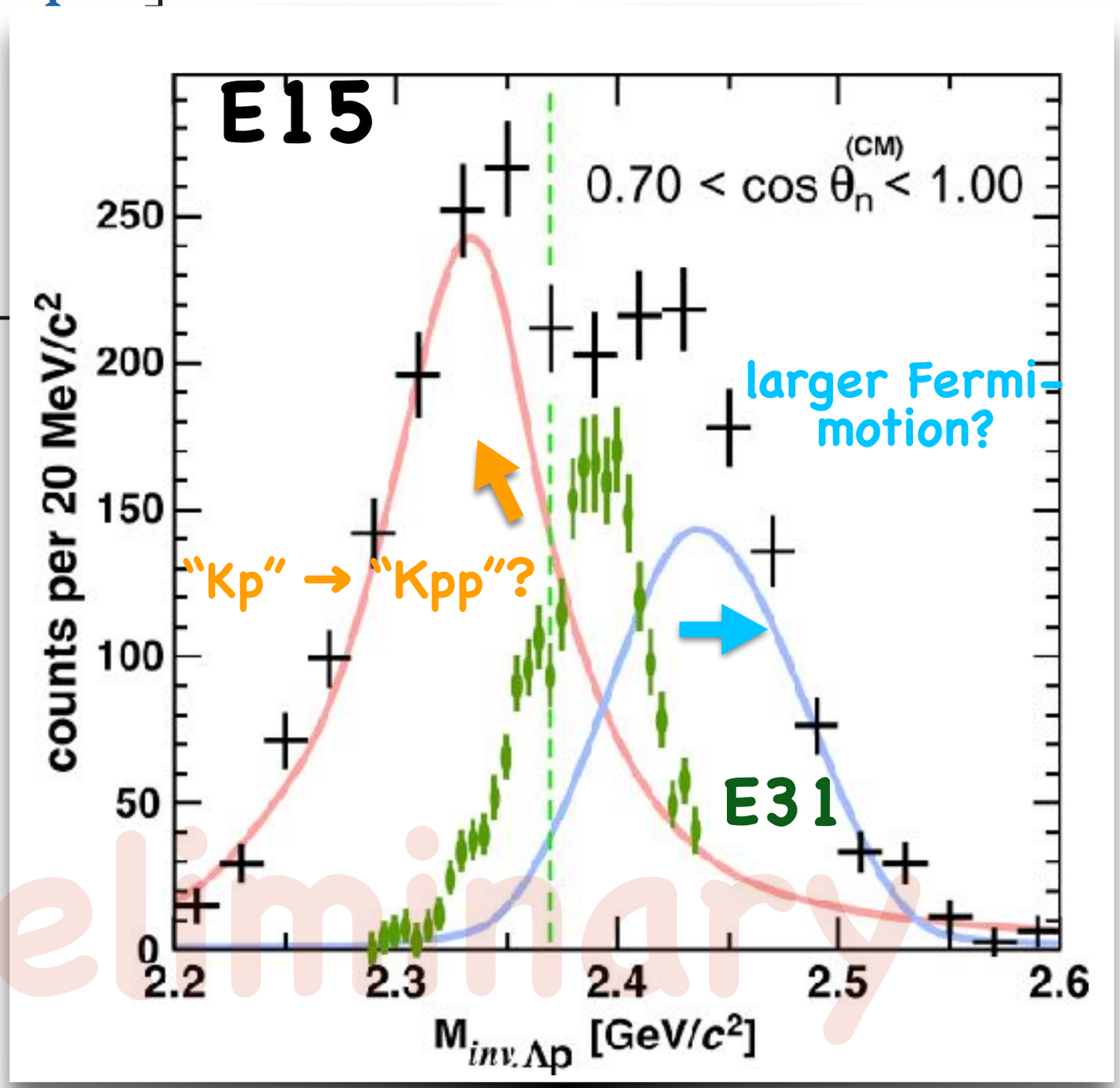


MENU2016 Kawasaki et al.,

E31:

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

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



E15 & E31

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

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

non-resonant

2) bound region (below M(Kpp))

nuclear bound state

$B_{Kpp} > B_{Kp}$

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

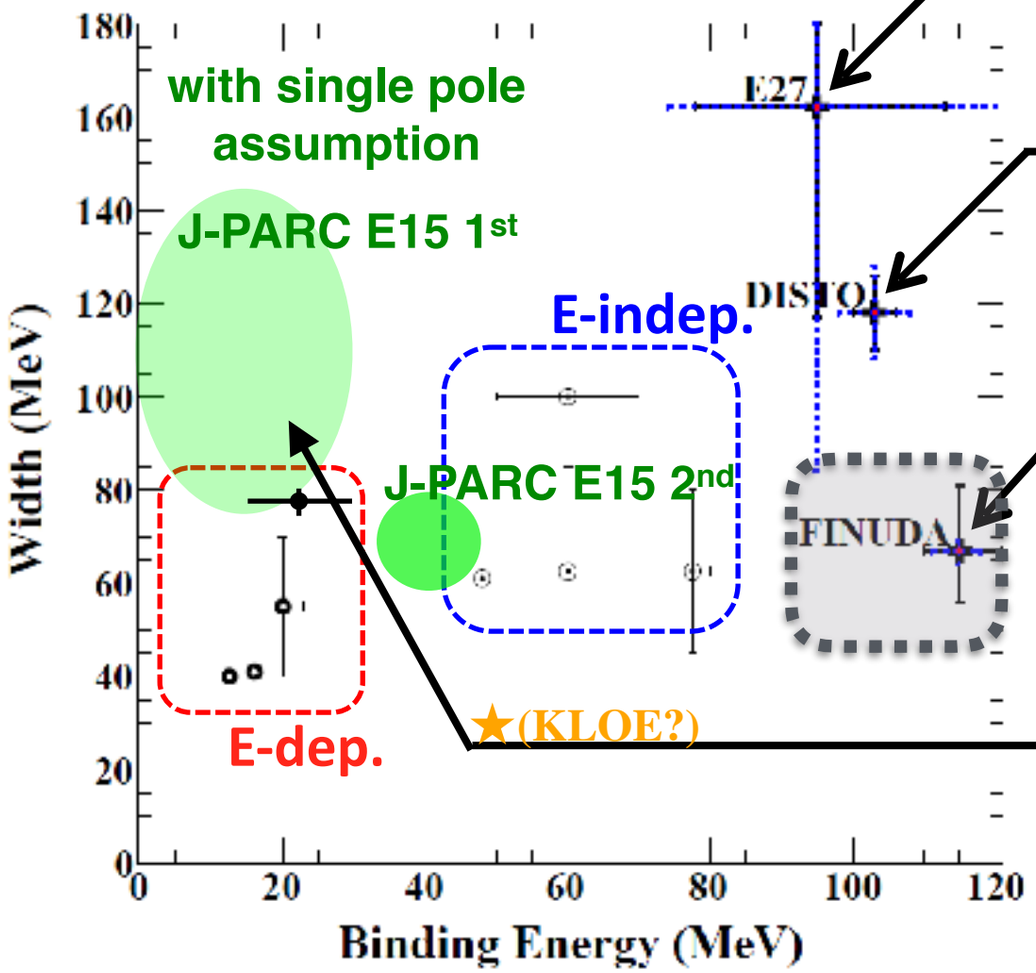
Kpp major decay = YN

Recent status of K^-pp bound state

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

$\bar{K}N$ interaction model

E-dep. / E-indep.



Reports structure / ***NO structure***

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

DISTO
$pp \to \Lambda pK^+$

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

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

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

HADES
$pp \to \Lambda pK^+$
$N^* \to \Lambda K^+$?

FINUDA ?

WHAT WE WISH TO HAVE?

spin / parity

WHAT'S NEXT?

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

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

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

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

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

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

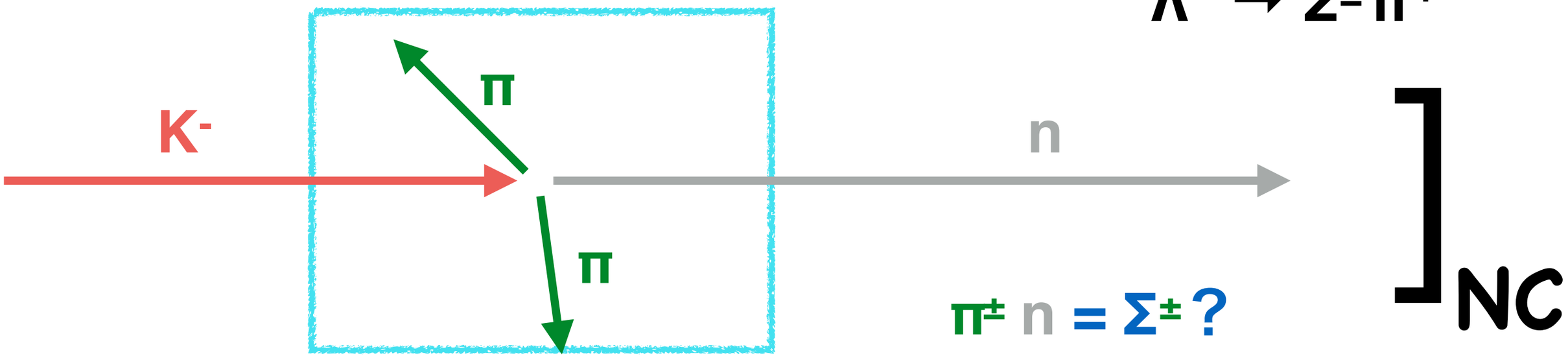
$$= \sqrt{\frac{\pi}{2}} V_0 R^3 \exp\left(-\frac{R^2k^2}{2}\right)$$

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

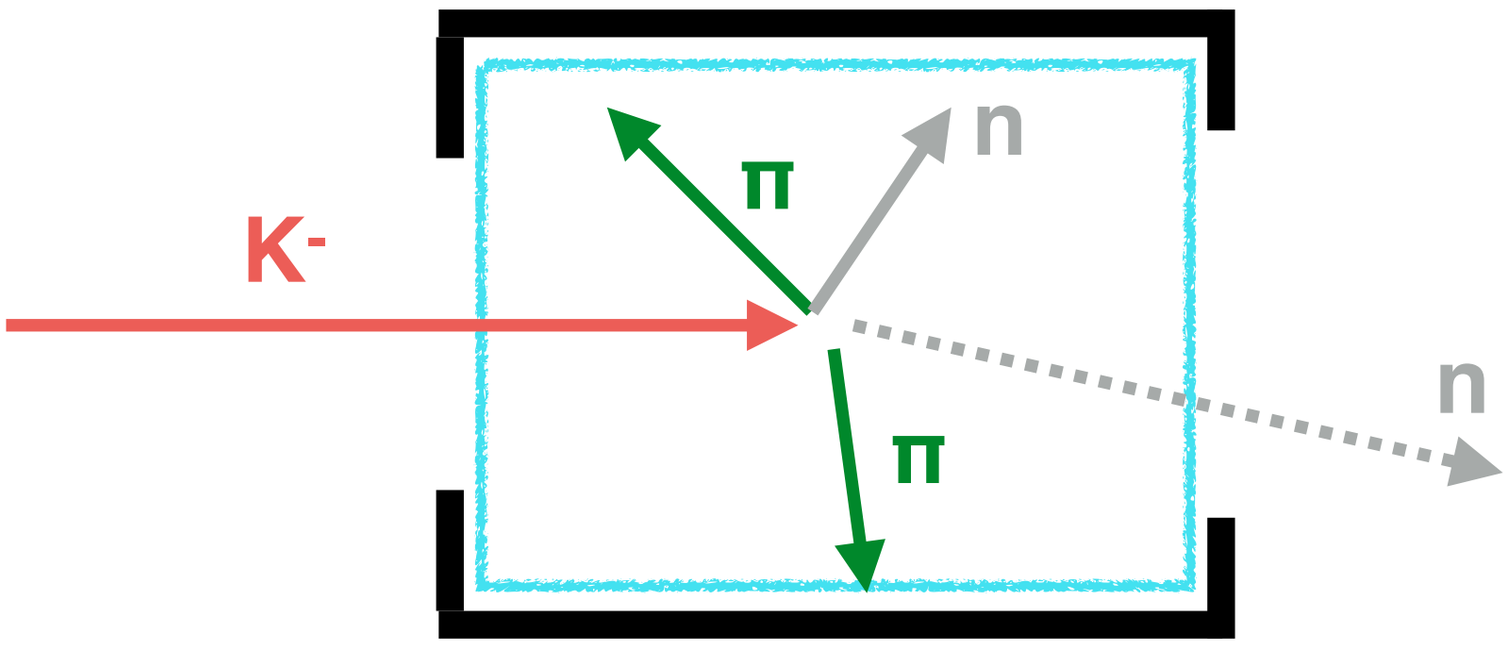
present E31 ($\cos\theta_n = 1$)

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

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



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



q dependence of Λ* production

by checking

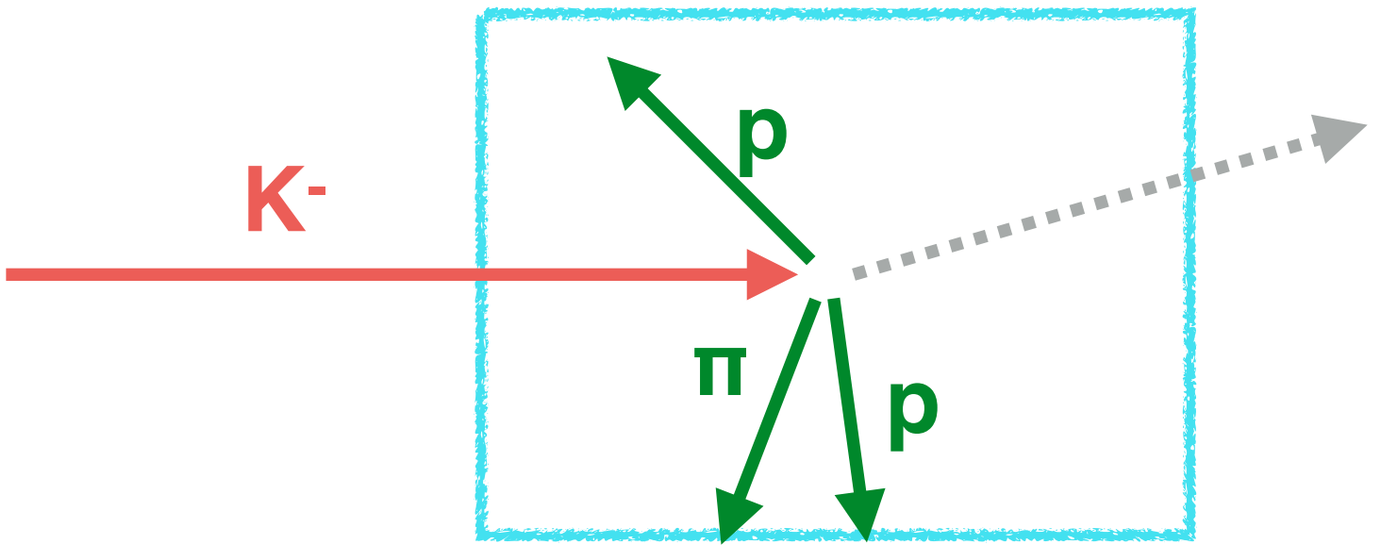
$\pi^{\pm}$ n = $\Sigma^{\pm}$

directory

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

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

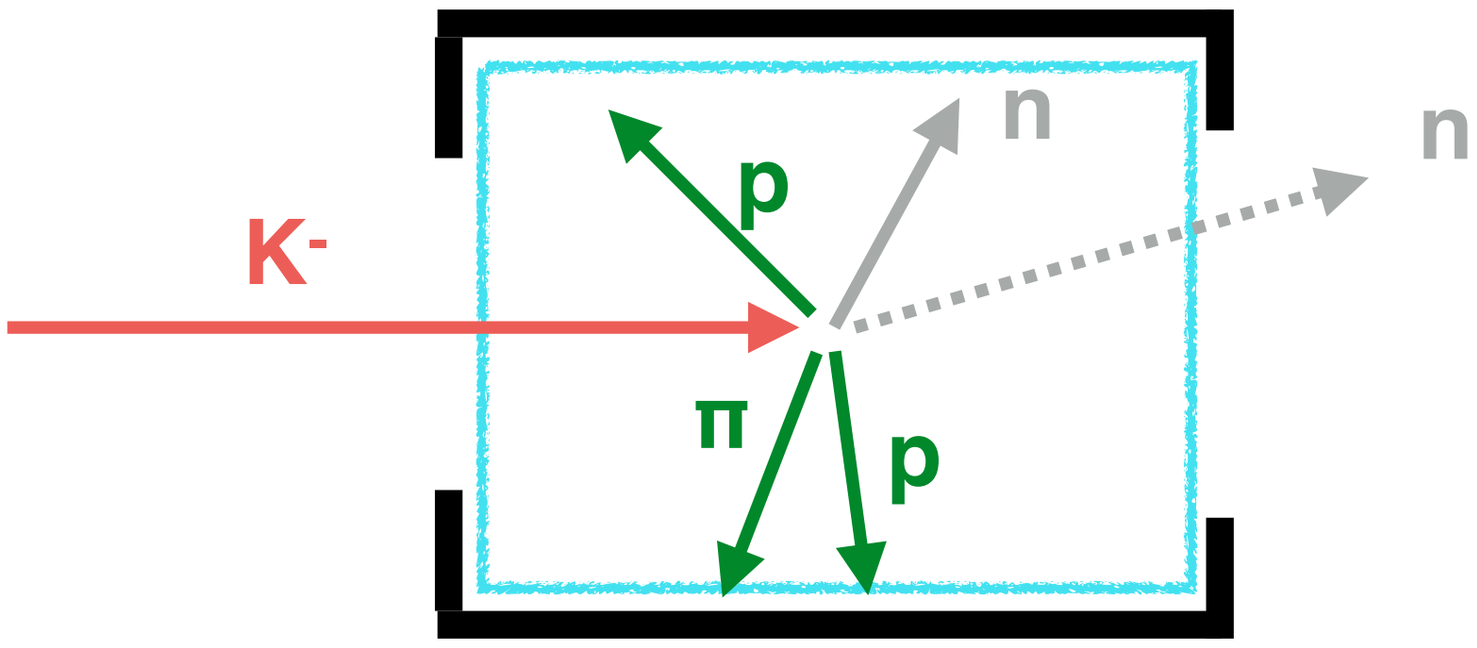
$K\, pp \rightarrow \Lambda\, p$



$\pi^- p = \Lambda$?

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

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



“ Kppn ” nuclei?

Summary

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

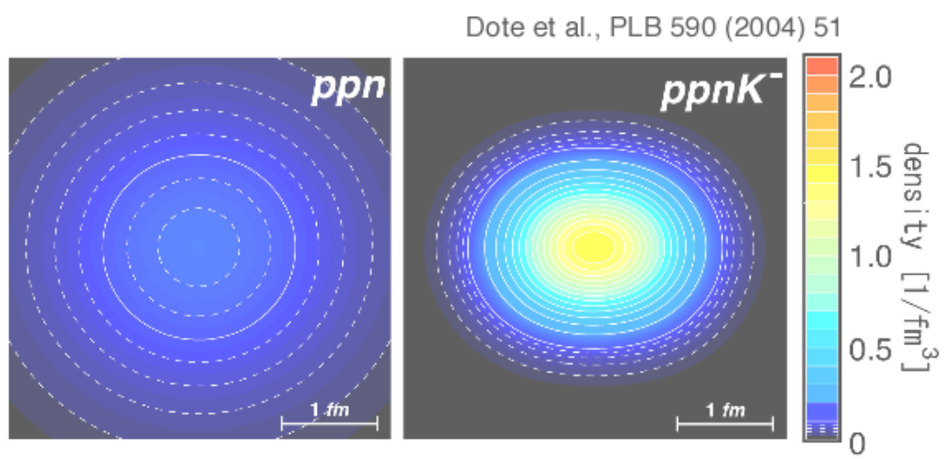
convincing Kpp signal

compact deep nuclear bound system ?

angular distribution analysis spin / parity / size

confirmation (independent) analysis

are in progress



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