Search for deeply bound Kaonic nuclear states via ^{3}He(K$^-$, n) reaction at J-PARC

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on behalf of E15 collaboration

Outline

- Introduction:
  Physics motivation & current status
- Our approach:
  E15@J-PARC
- Summary & outlook

Beginning of the story ...

Particle Data Group, 2013th edition

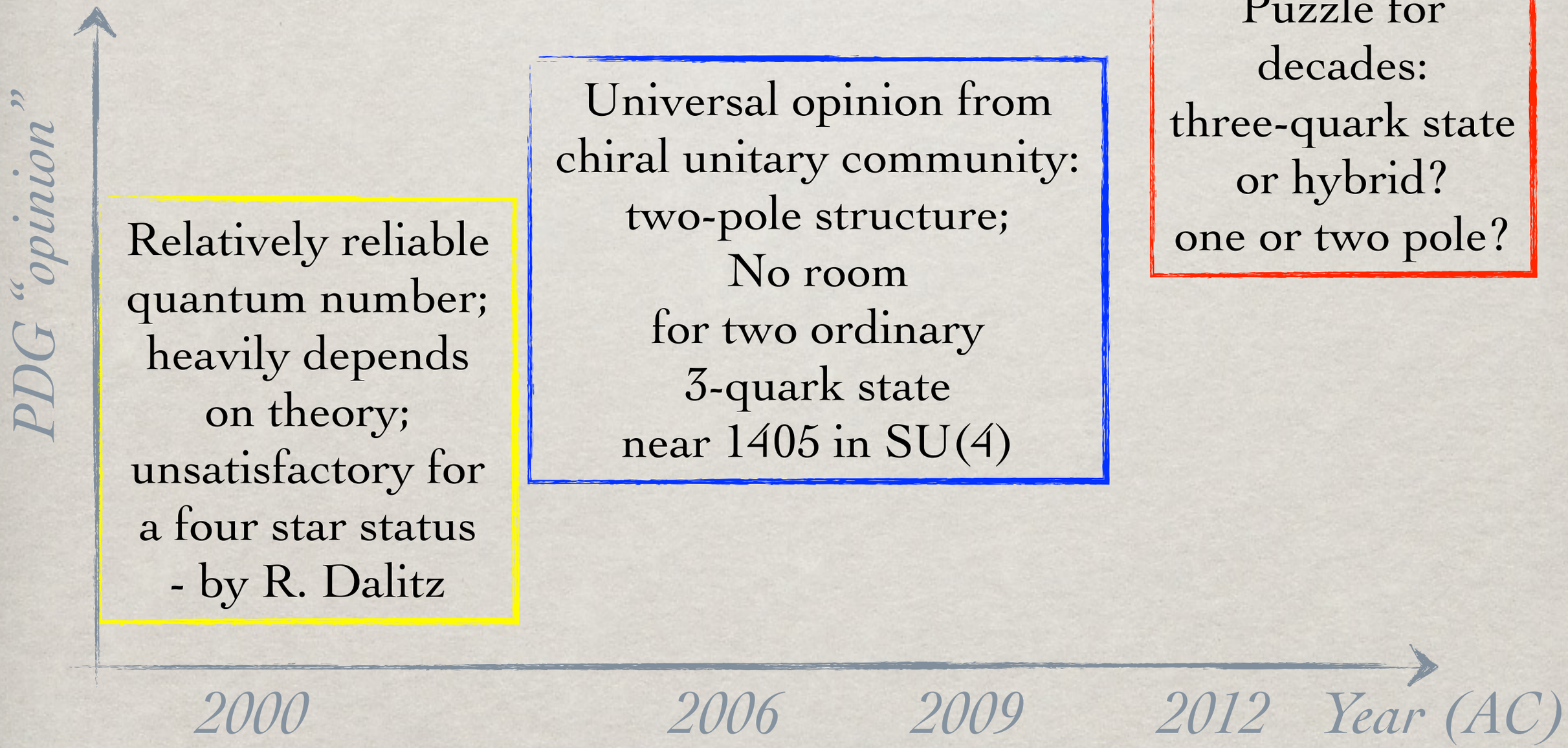
$\Lambda(1405)\ 1/2^-$ $I(J^P) = 0(\frac{1}{2}^-)$ Status: ****

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, and SEKIHARA 11, for discussions and earlier references.

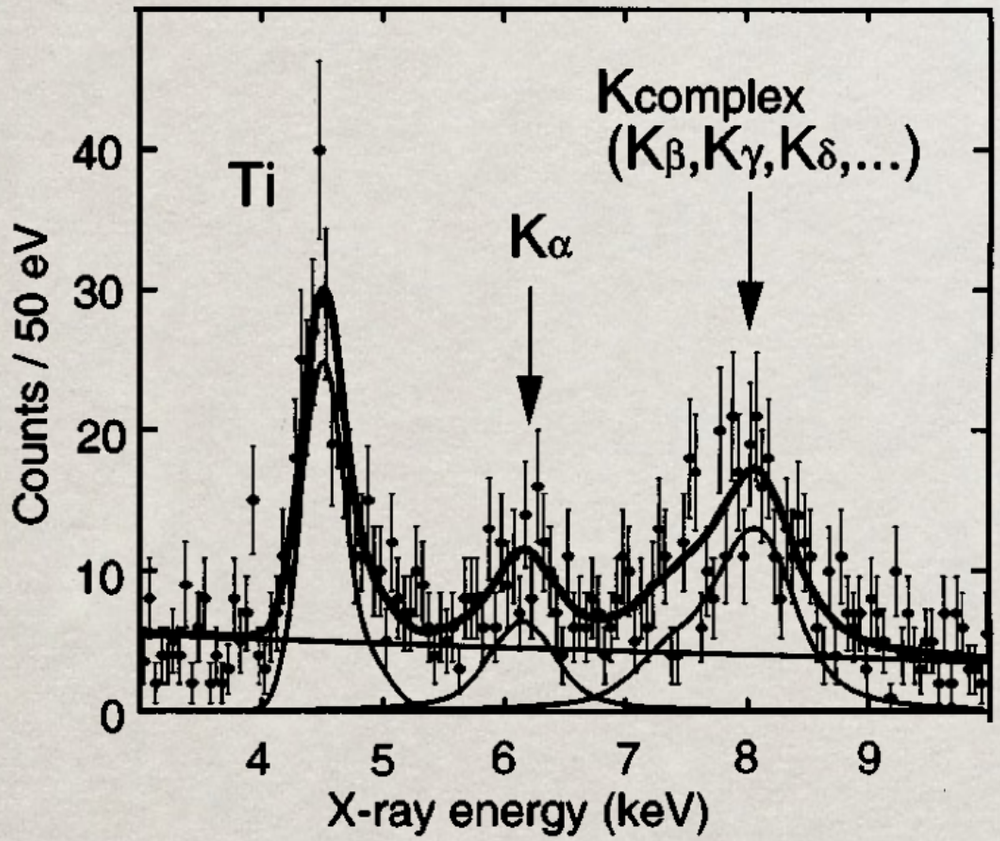
It seems to be the universal opinion of the chiral-unitary community that there are two poles in the 1400-MeV region. ZYCHOR 08 presents experimental evidence against the two-pole model, but this is disputed by GENG 07A. See also REVAI 09, which finds little basis for choosing between one- and two-pole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

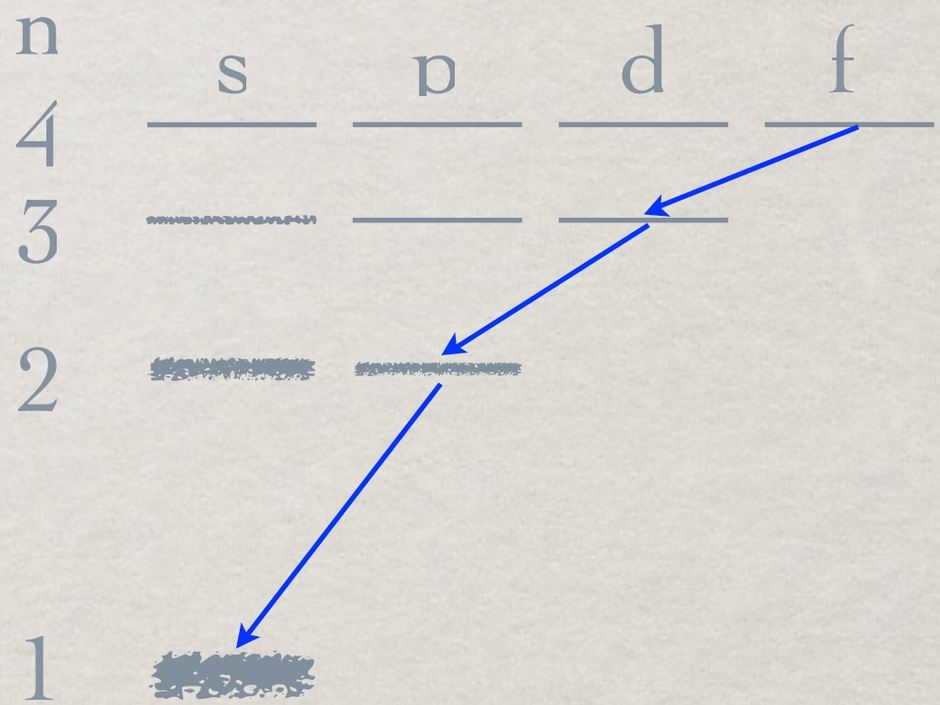
A single, ordinary three-quark $\Lambda(1405)$ fits nicely into a $J^P = 1/2^-$ SU(4) $\overline{4}$ multiplet, whose other members are the $\Lambda_c(2595)^+$, $\Xi_c(2790)^+$, and $\Xi_c(2790)^0$; see Fig. 1 of our note on "Charmed Baryons."

$\bar{K}N$ interaction: $\Lambda(1405)$



$\bar{K}N$ interaction: Kaonic atom

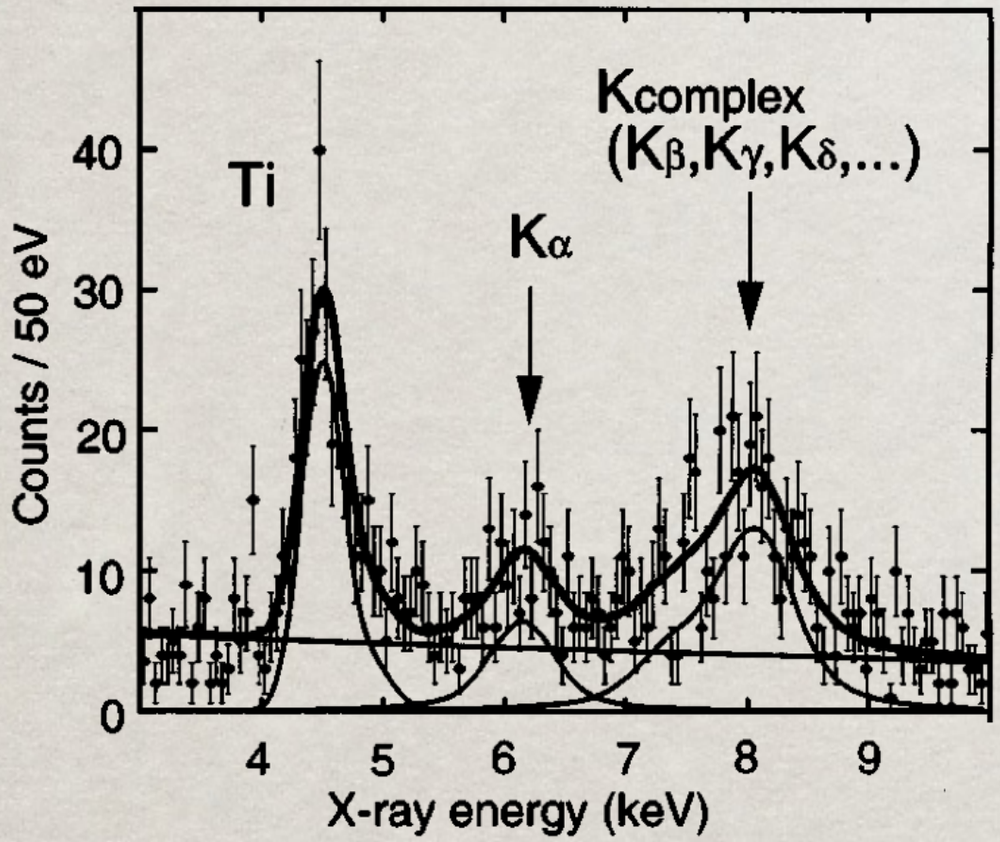


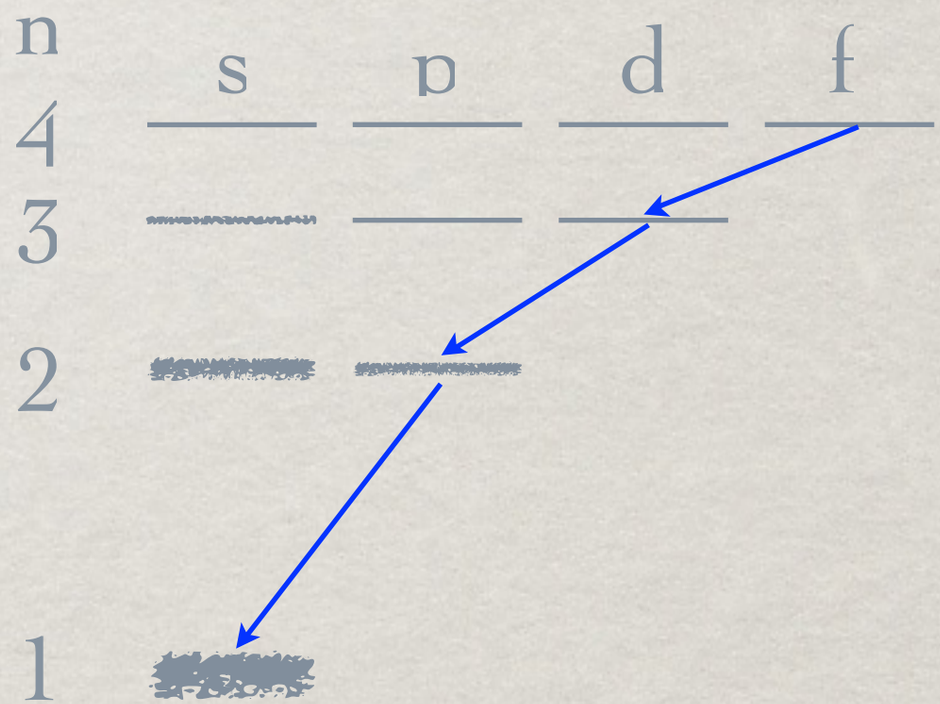


Re(V)=-50~-200 MeV

M. Iwasaki, *et al.*, Phys. Rev. Lett. 78, 3067

$\bar{K}N$ interaction: Kaonic atom



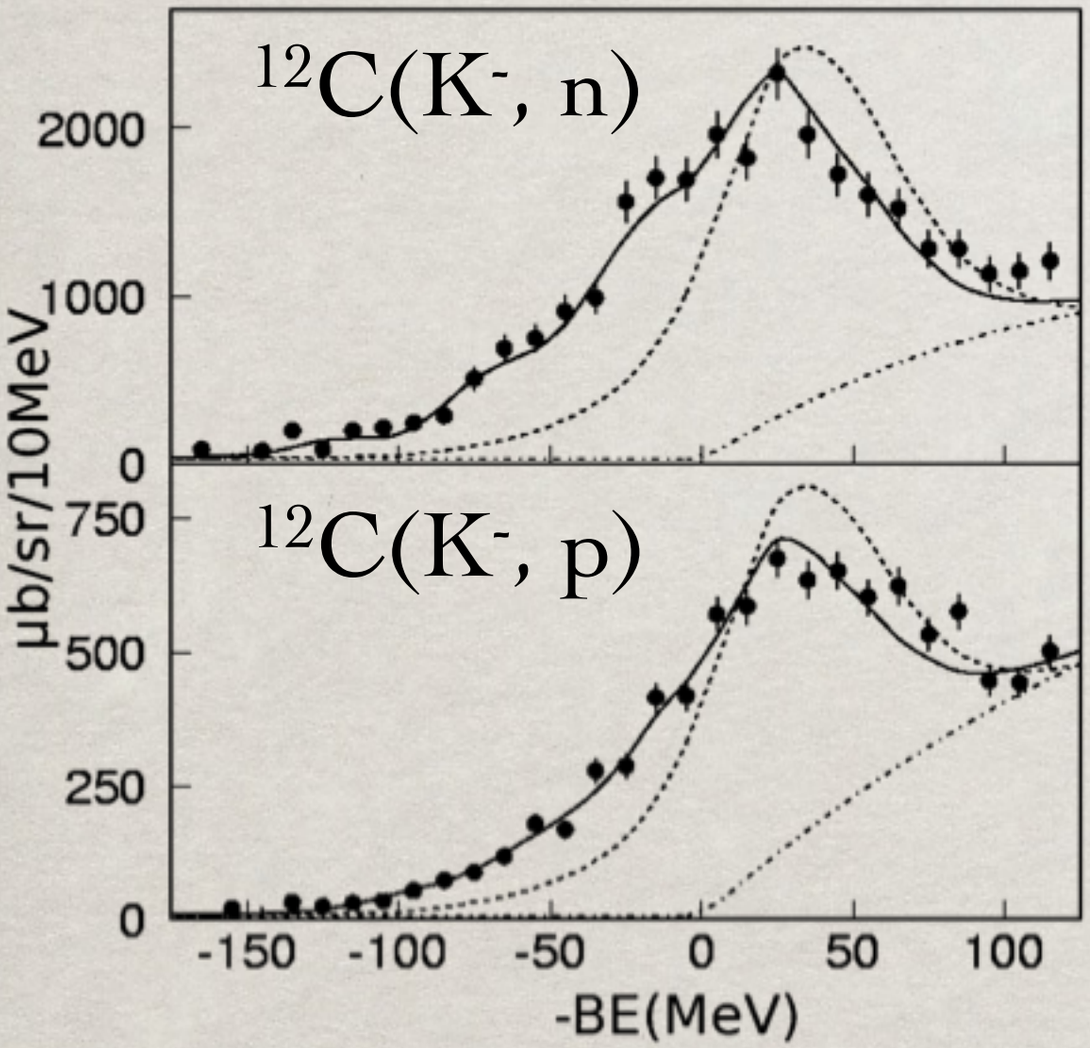


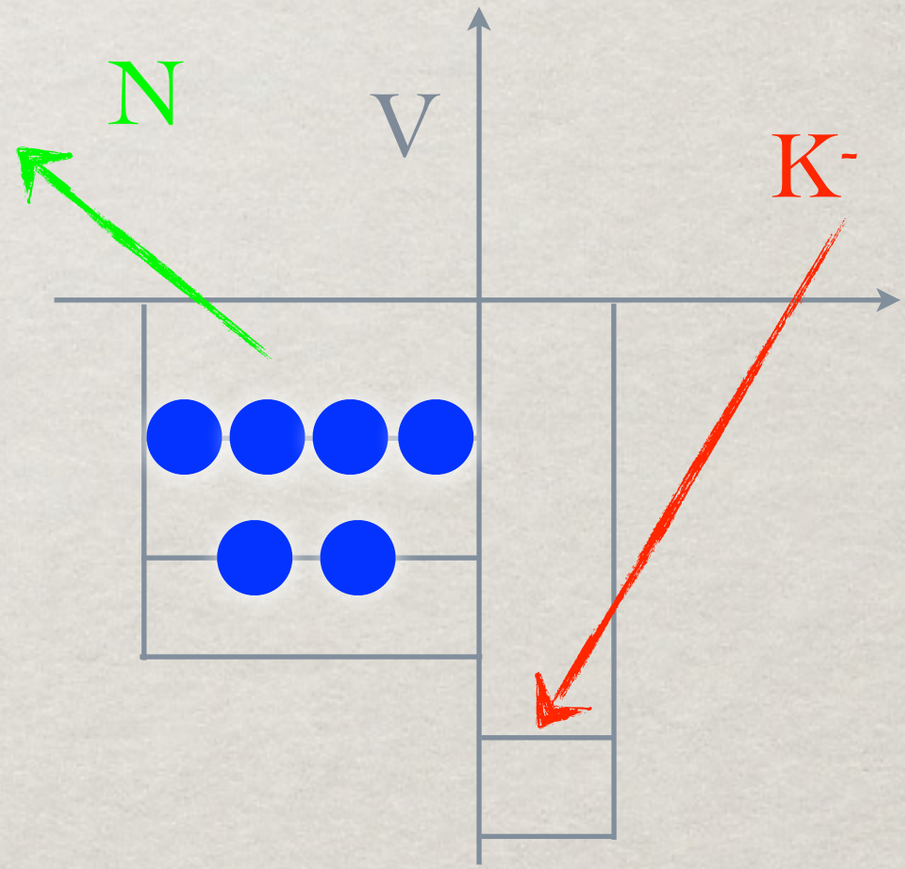
Re(V)=-50~-200 MeV

Density dependence;
Peripheral information.

M. Iwasaki, *et al.*, Phys. Rev. Lett. 78, 3067

$\bar{K}N$ interaction: KEK-E548



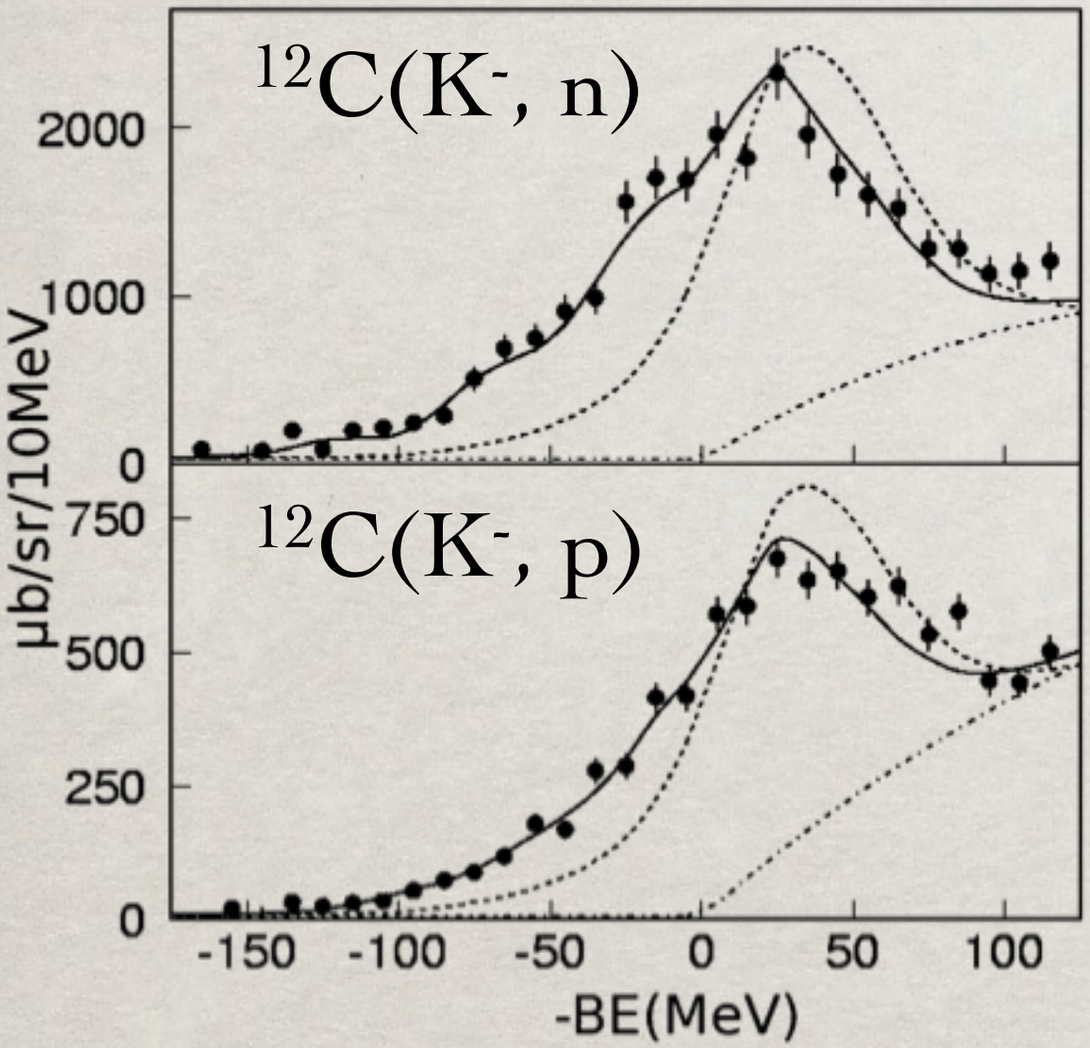


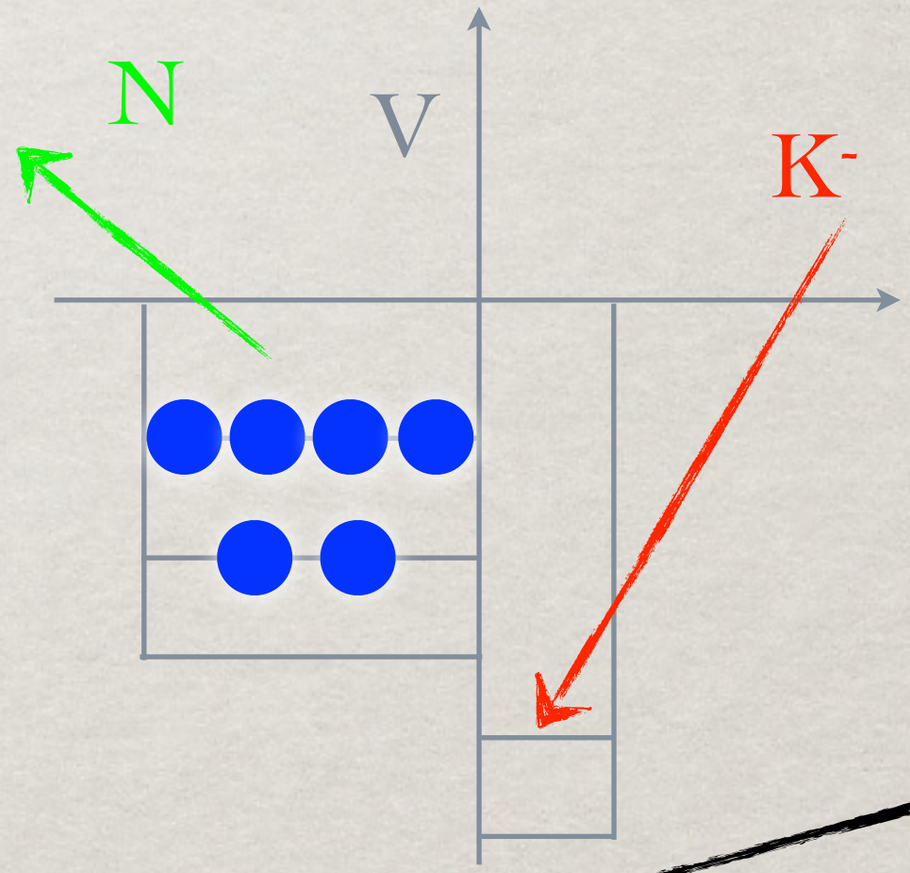
Re(V)=-160~-190MeV

Im(V)=-40~-50MeV

T. Kishimoto, *et al.*, Prog. Theor. Phys. 118, 181

$\bar{K}N$ interaction: KEK-E548





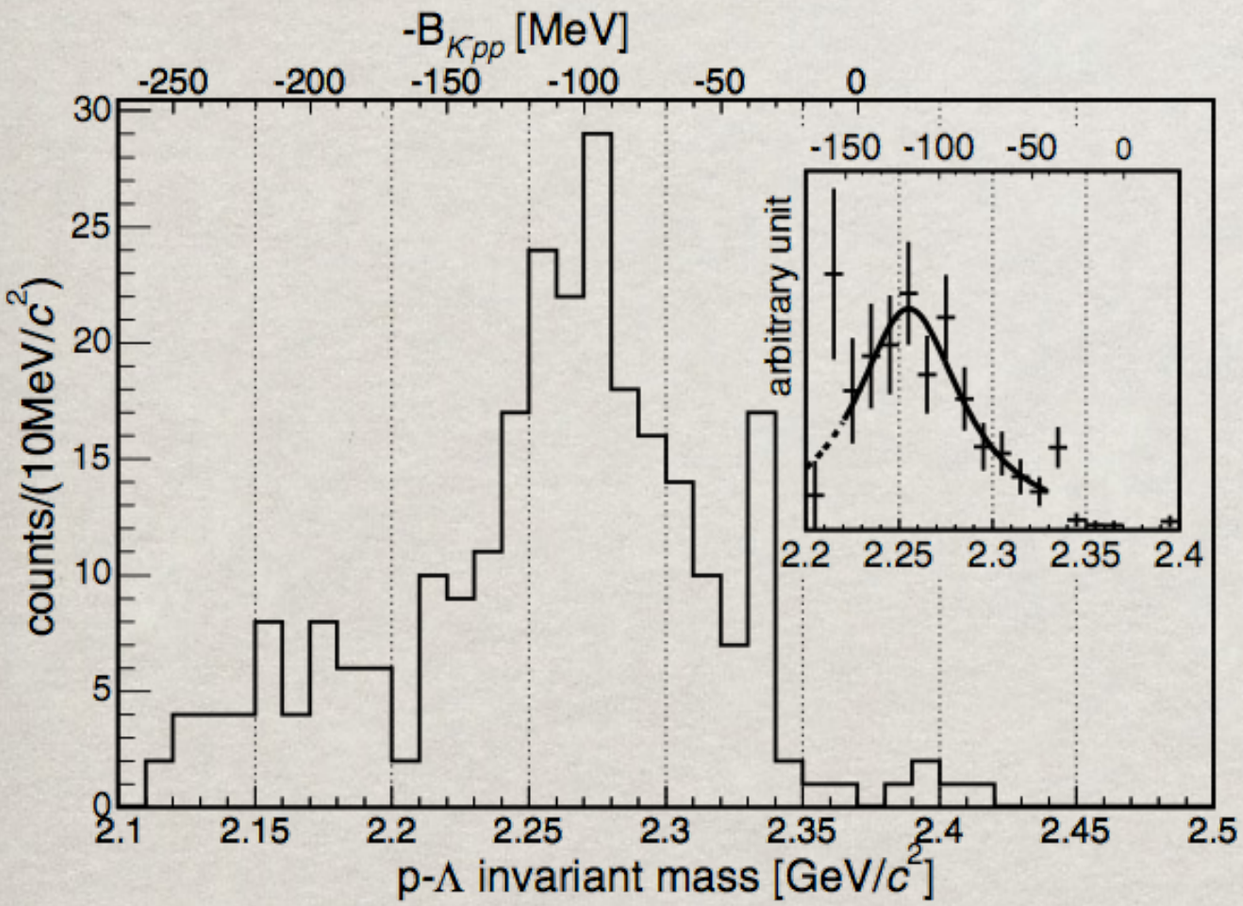
Re(V)=-160~-190MeV

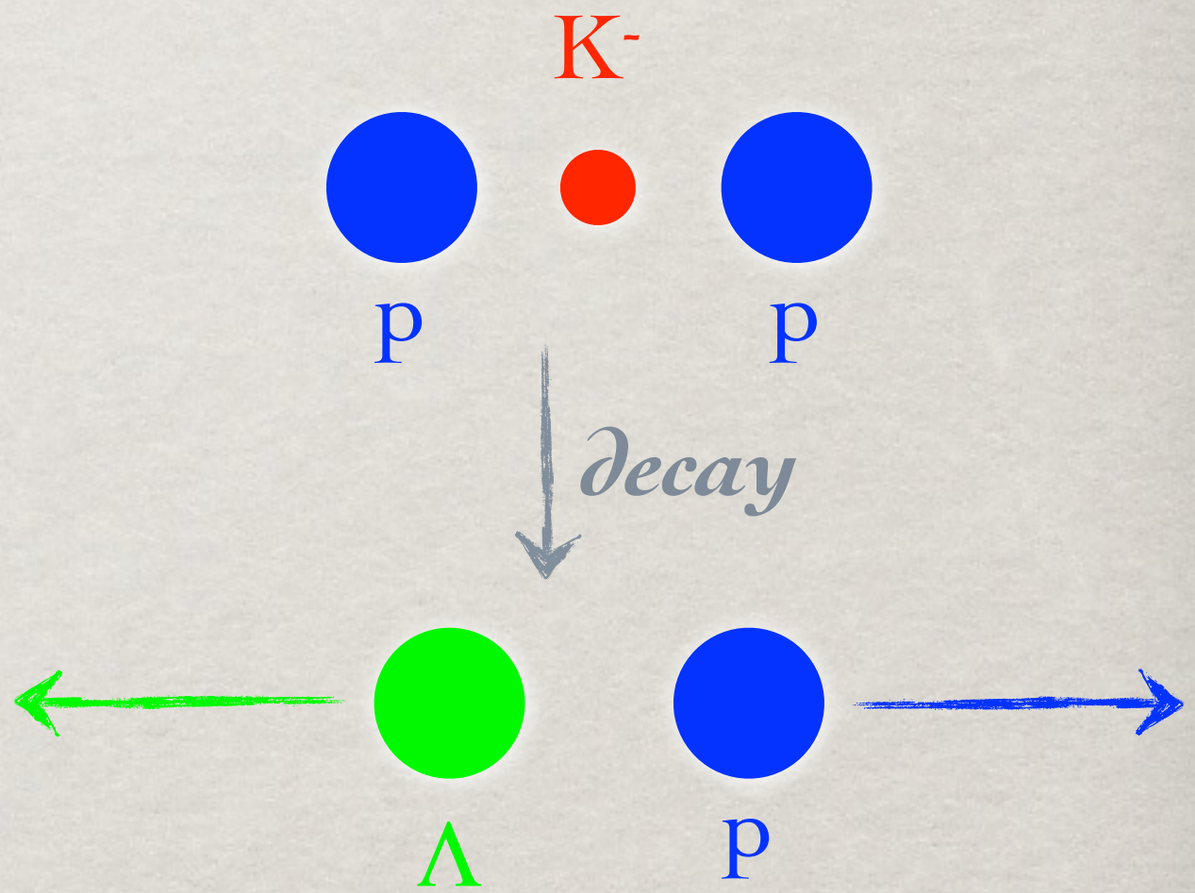
Im(V)=-40~-50MeV

Σ-channel;
Final state interaction

T. Kishimoto, *et al.*, Prog. Theor. Phys. 118, 181

$\overline{K}N$ interaction: FINUDA experiment



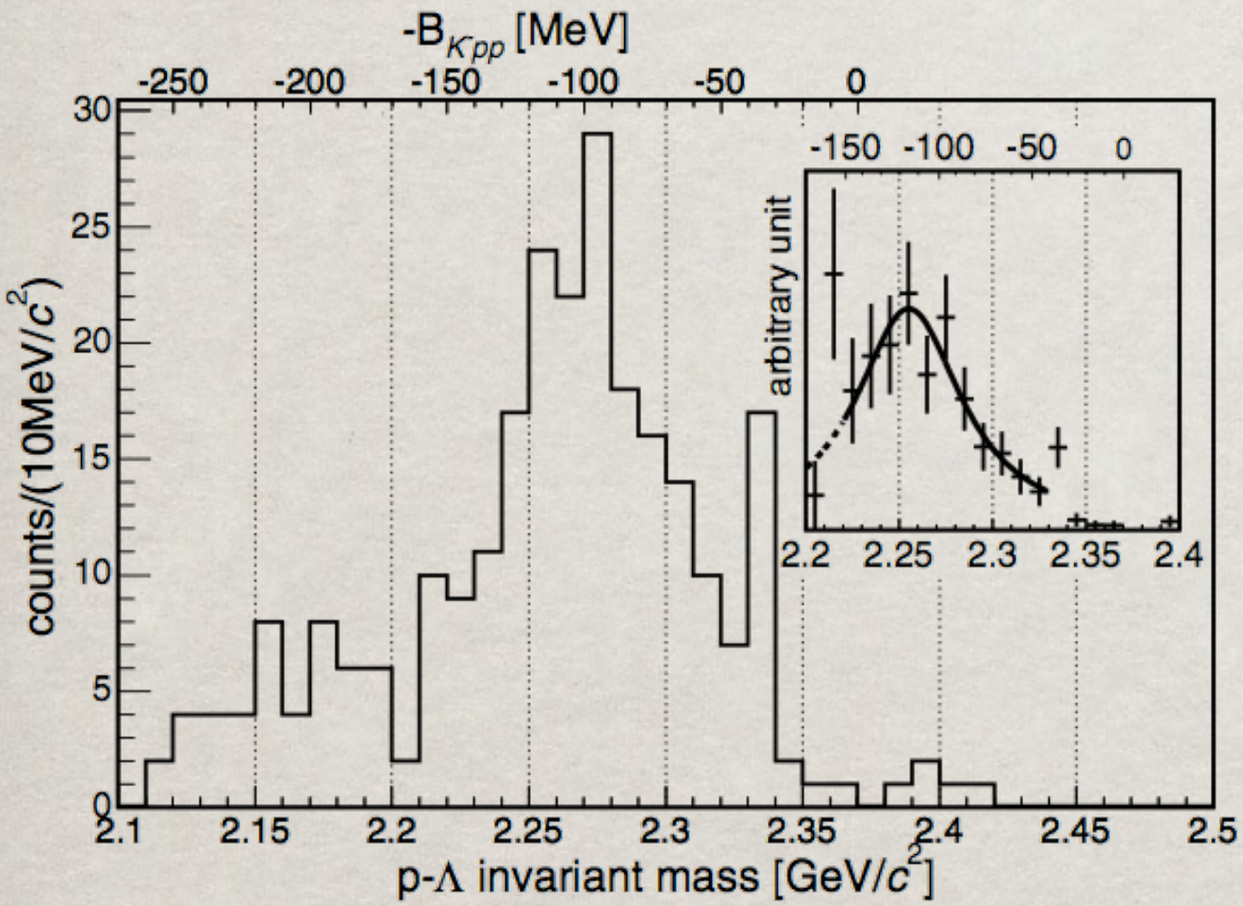


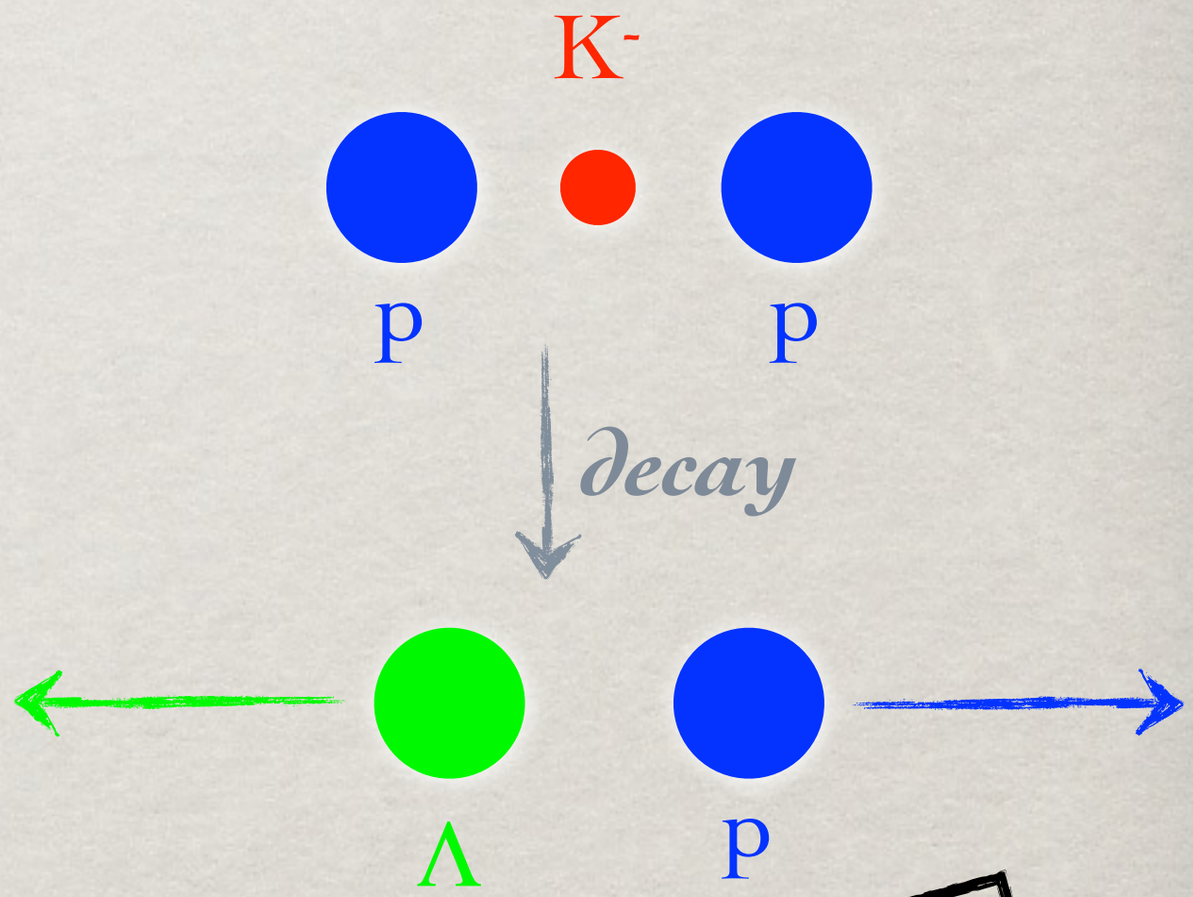
B_k=115MeV

Width=67MeV

M. Agnello, *et al.*, Phys. Rev. Lett. 94, 212303

$\overline{K}N$ interaction: FINUDA experiment



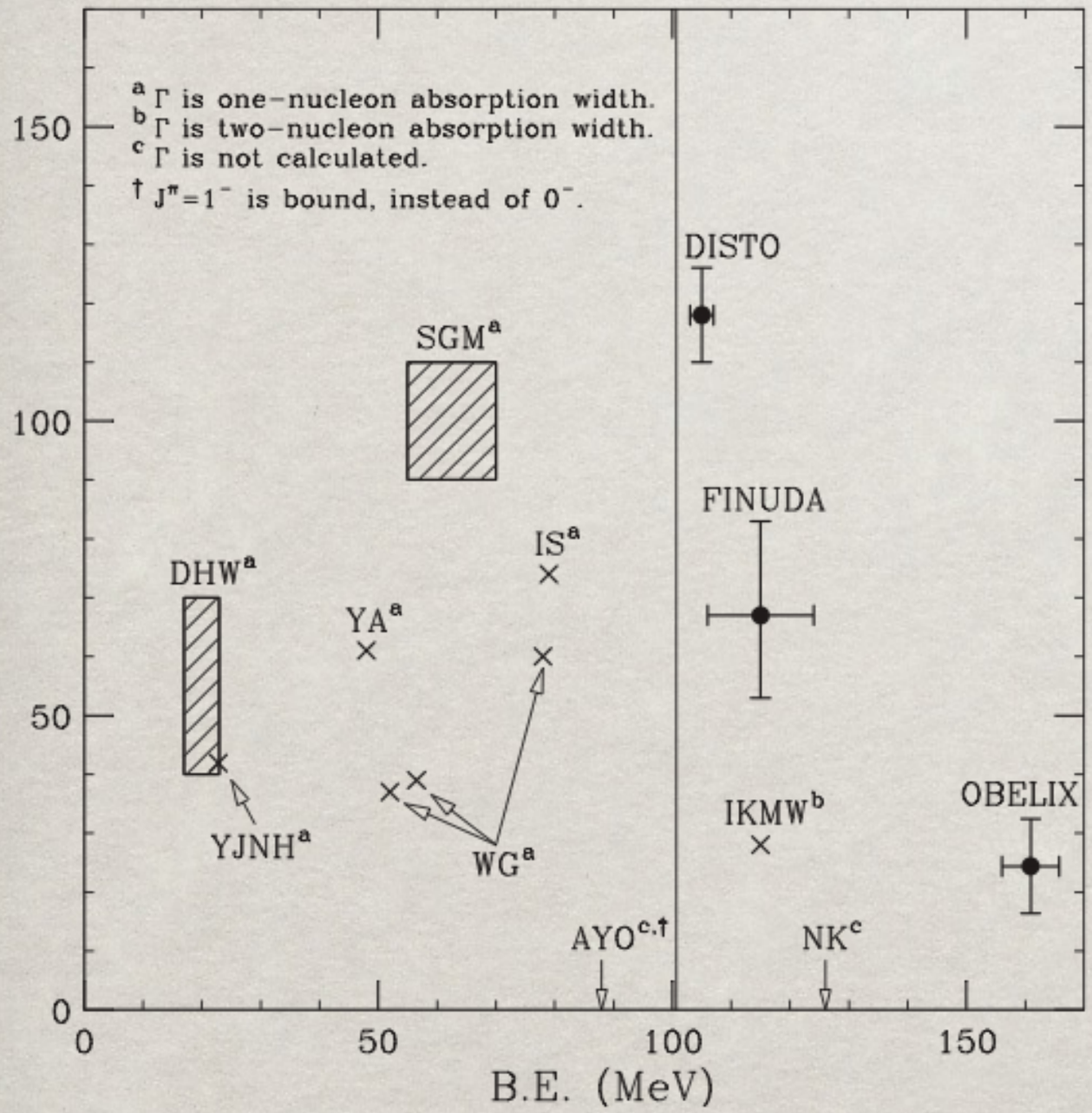


B_k=115MeV
Width=67MeV

Σ-channel;
Final state interaction

M. Agnello, *et al.*, Phys. Rev. Lett. 94, 212303

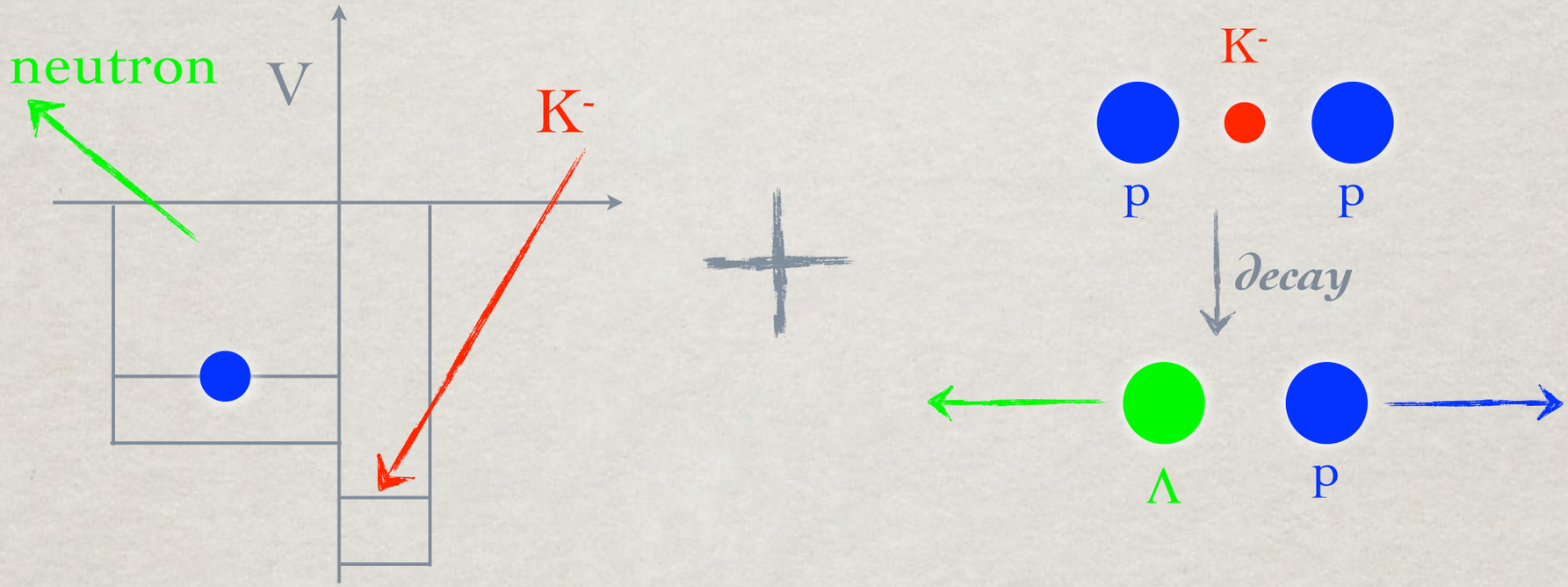
$\bar{K}N$ interaction: summary

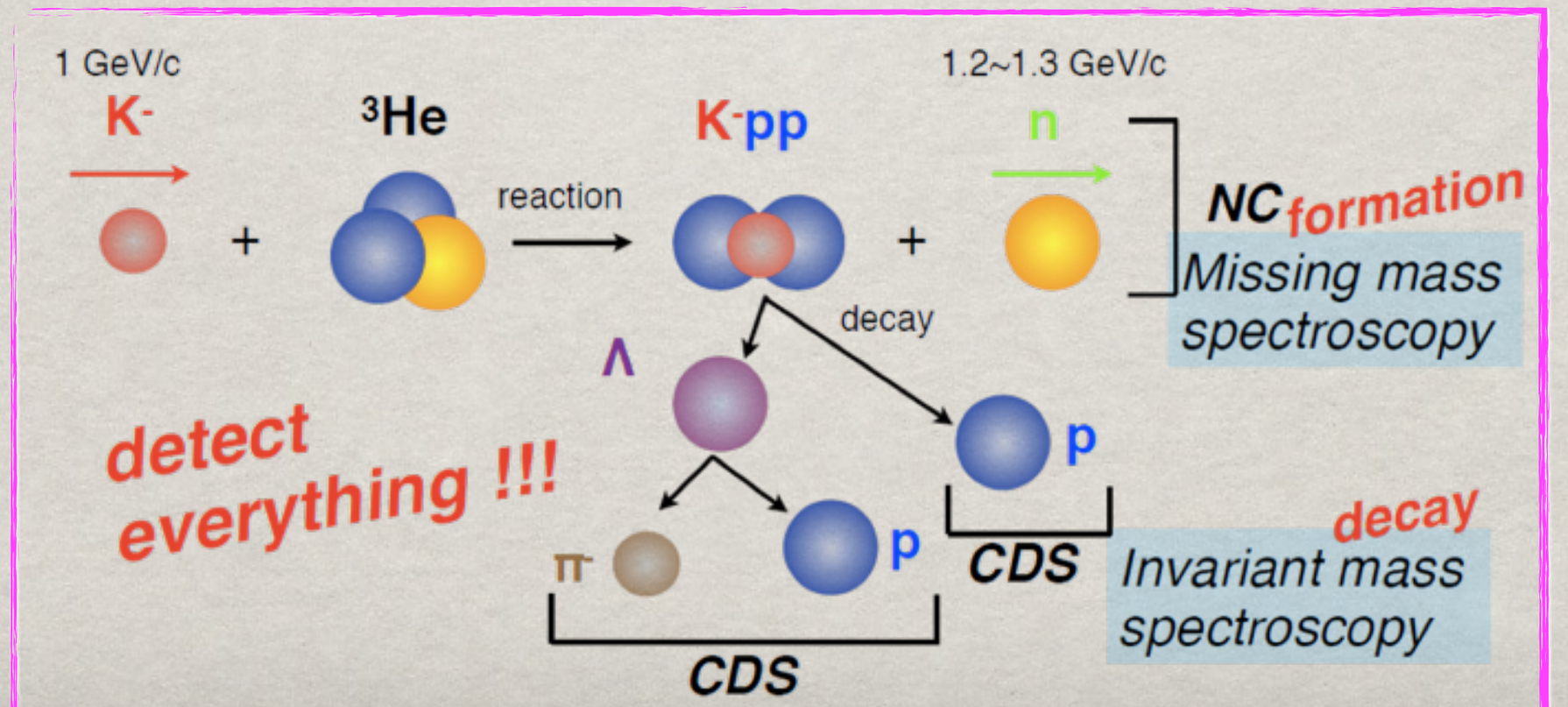


- Akaishi, Yamazaki [AY]
  - ATMs with phenomenological model
- Dote, Hyodo, Wise [DHW]
  - Variational with chiral-SU(3) model
- Ikeda, Sato [IS]
  - Faddeev with Chiral-SU(3) model
- Shevchenko, Gal, Mares [SGM]
  - Faddeev with phenomenological model
- Wycech, Green [YG]
  - Variational with phenomenological model
- Arai, Yasui, Oka [AYO]
  - Λ^* model

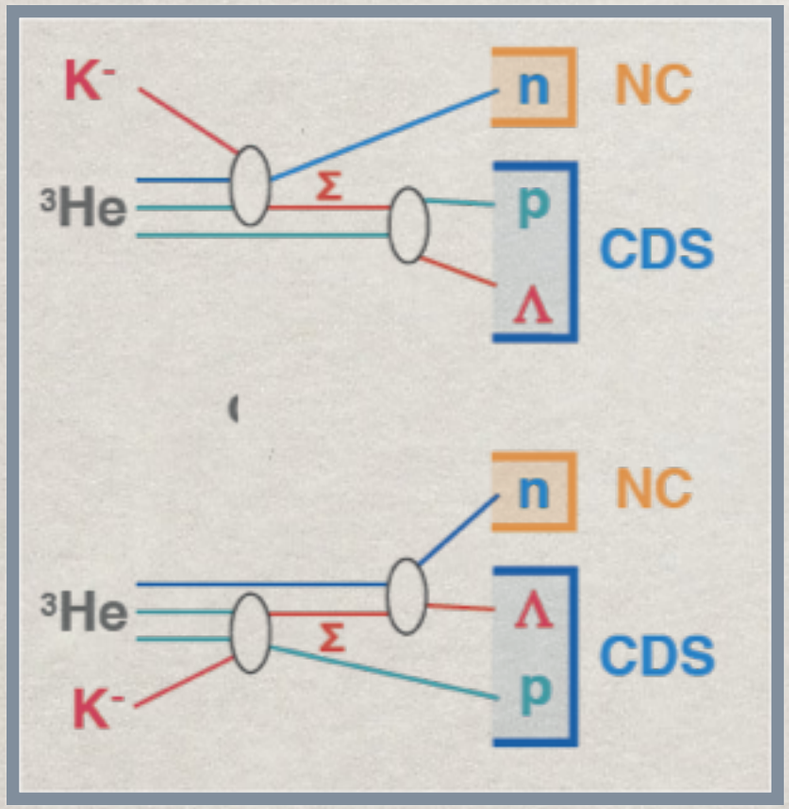
T. Koike, *et al.*, Phys. Rev. C 80, 055208

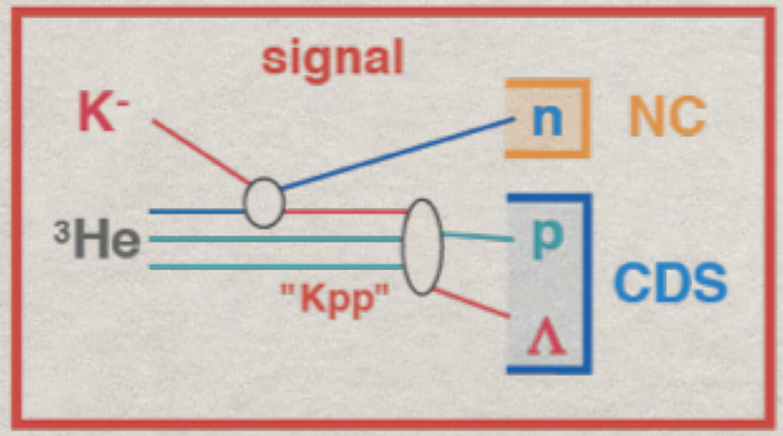
E15@J-PARC: The idea

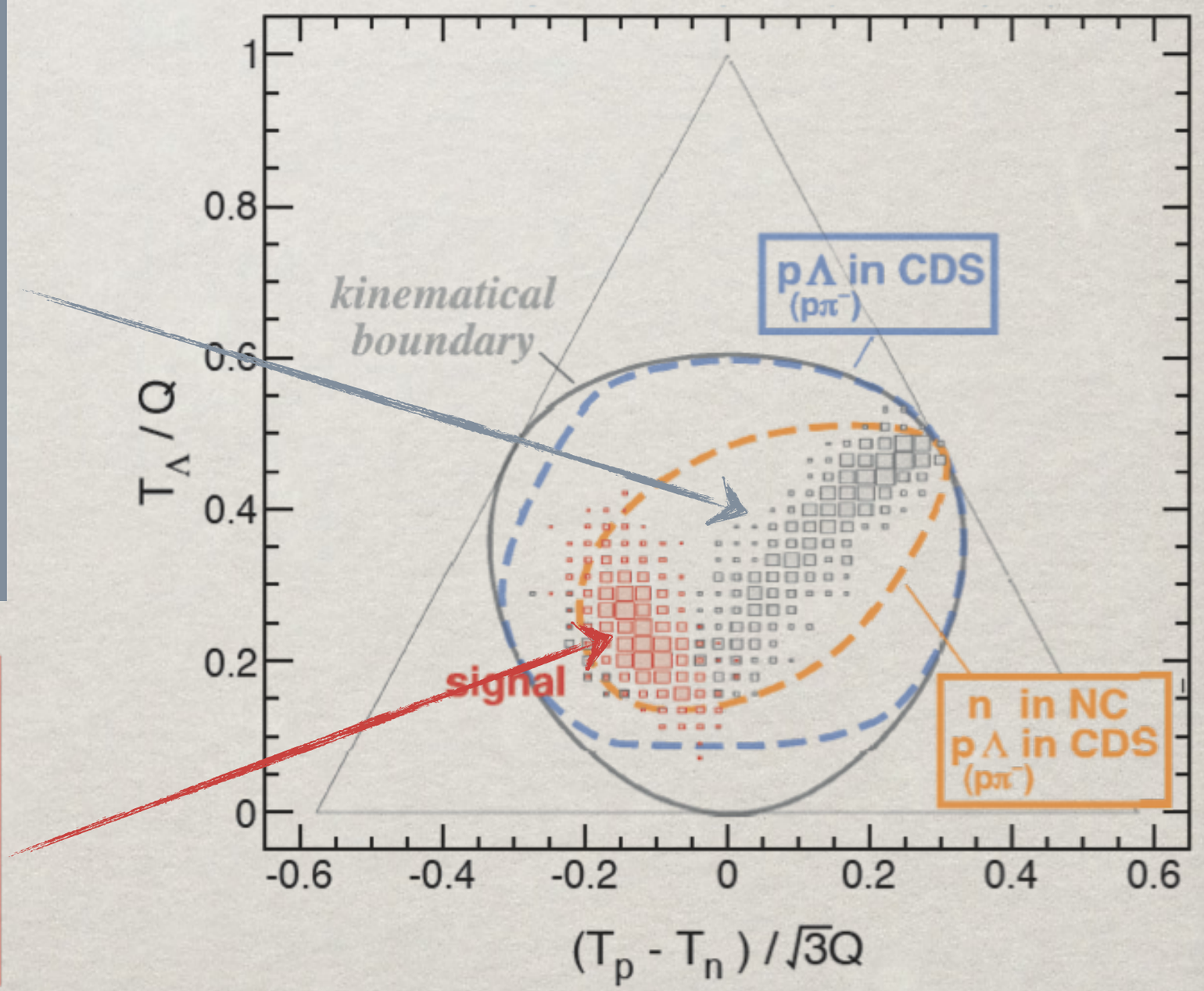




E15@J-PARC: Dalitz plot

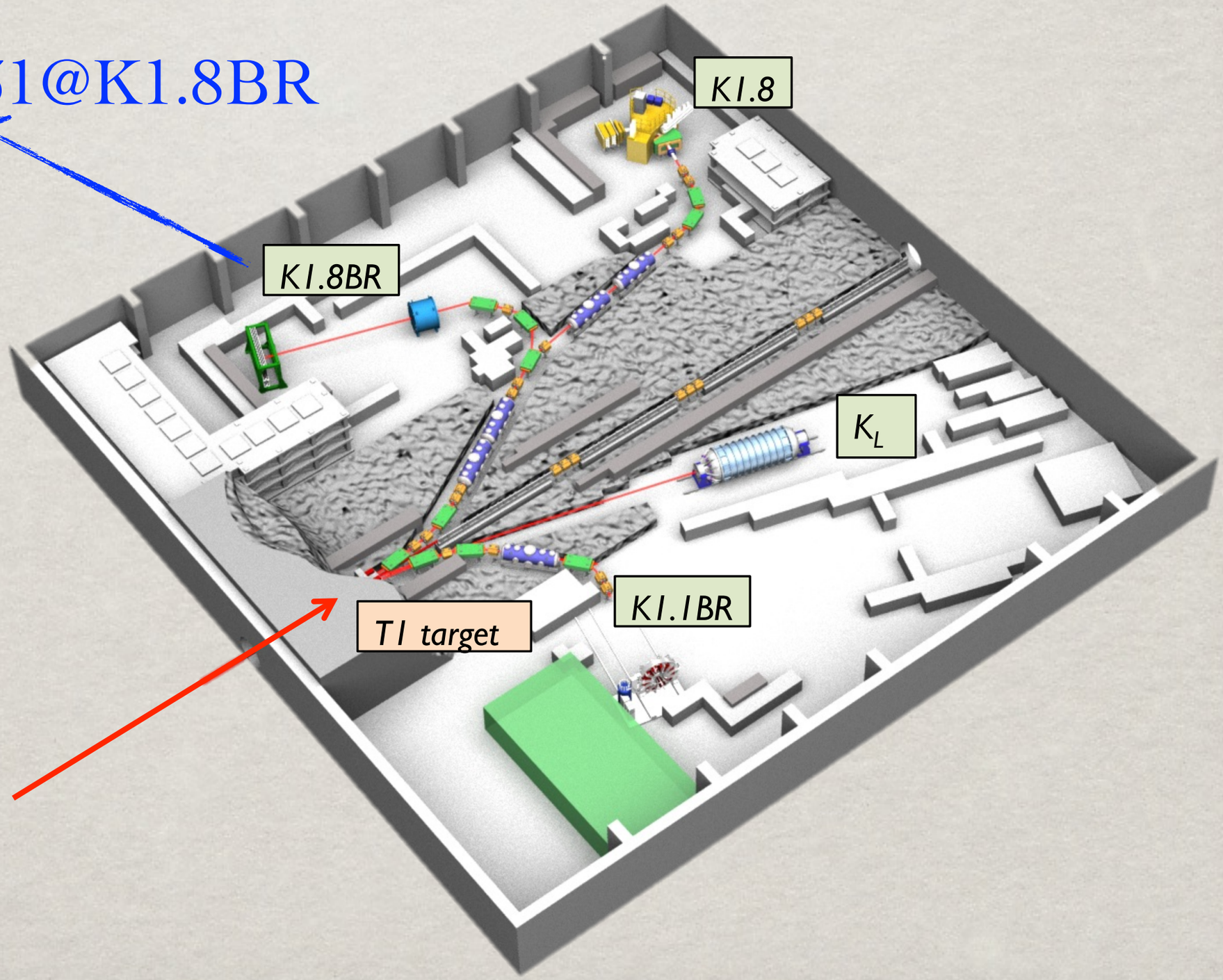






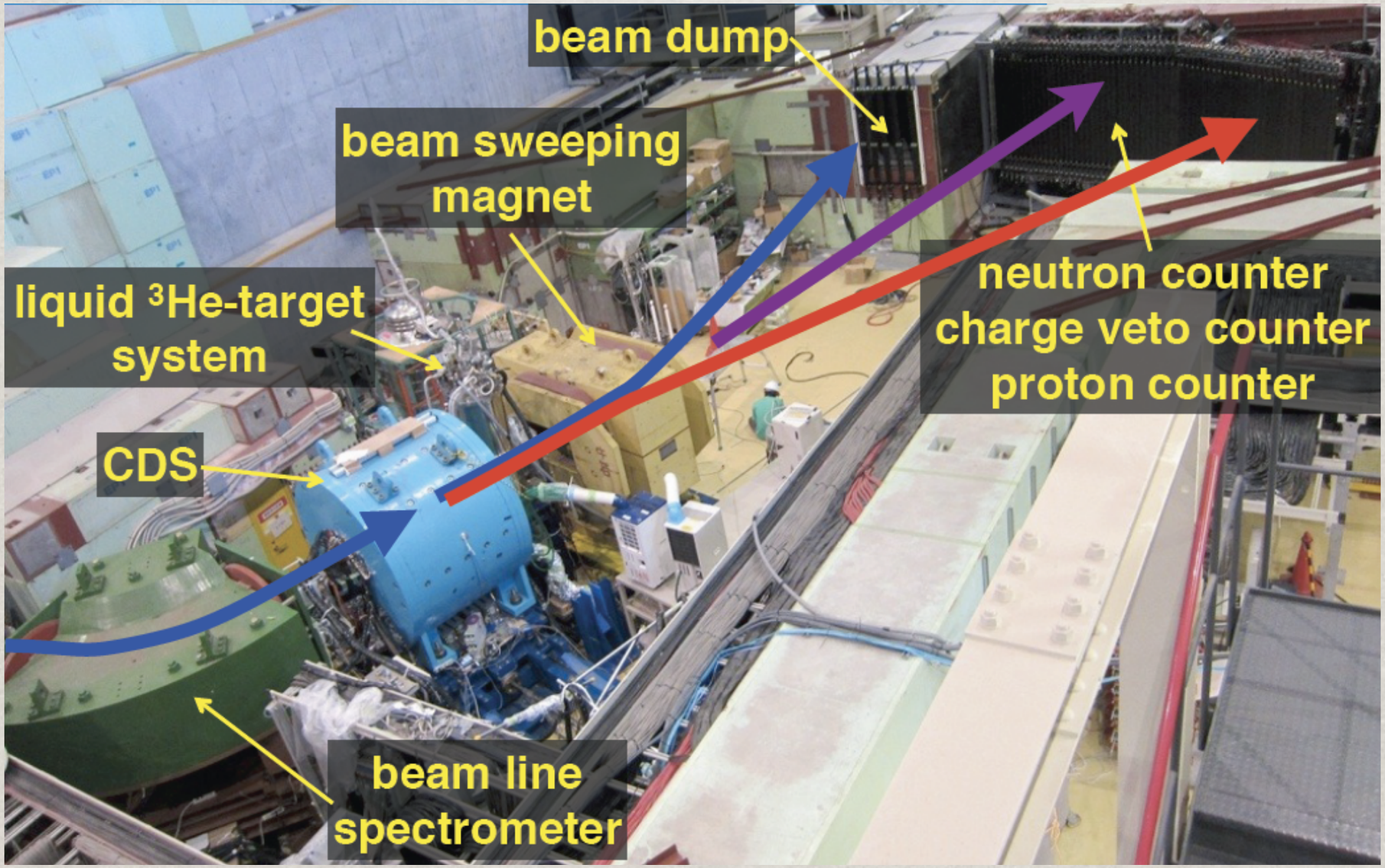
E15@J-PARC: Experimental setup

E15/E17/E31@K1.8BR



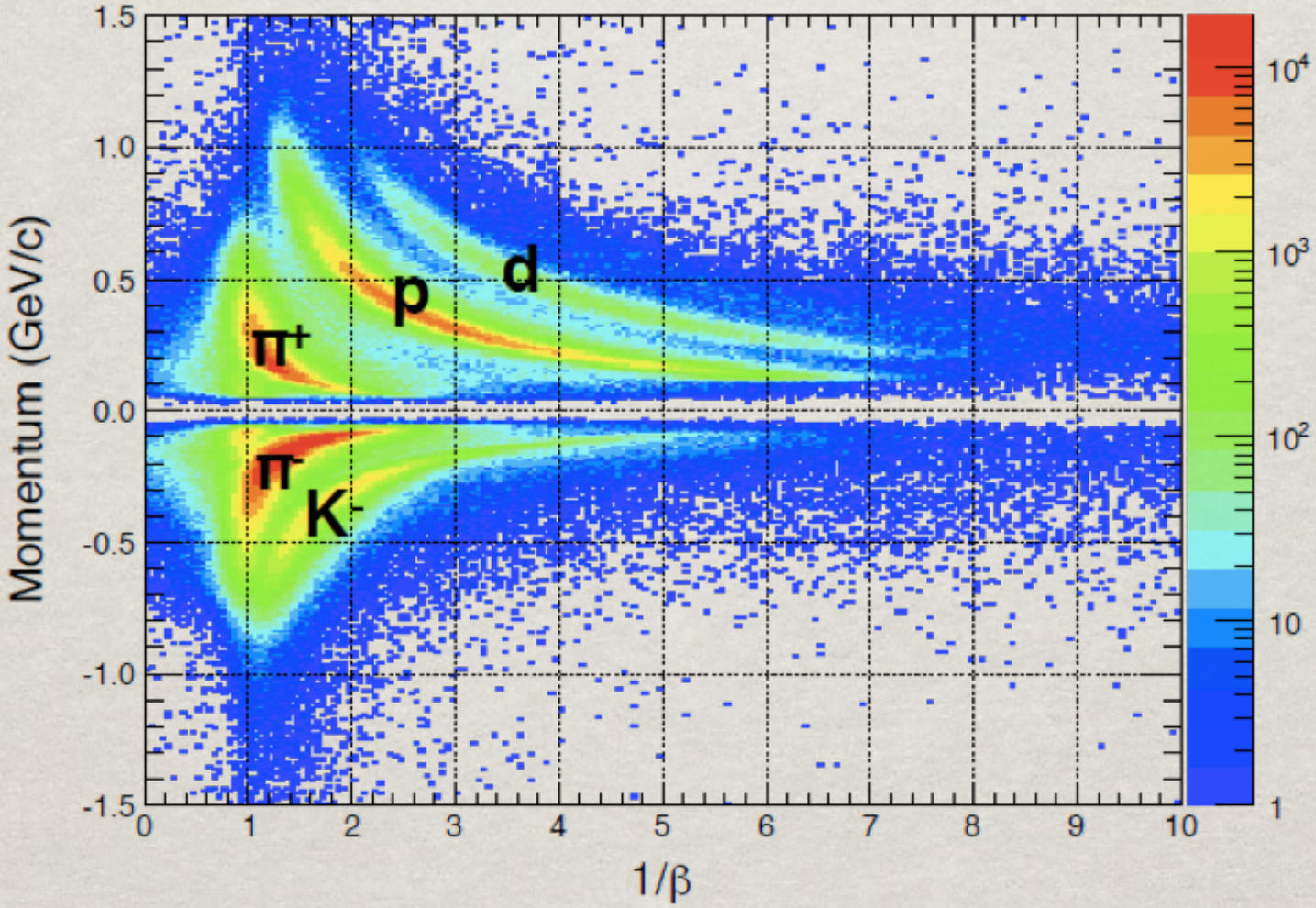
E15@J-PARC: Experimental setup

4×10^9 K^- on target (1% of original proposal)



K. Agari, *et al.*, PTEP 2012, 02B011

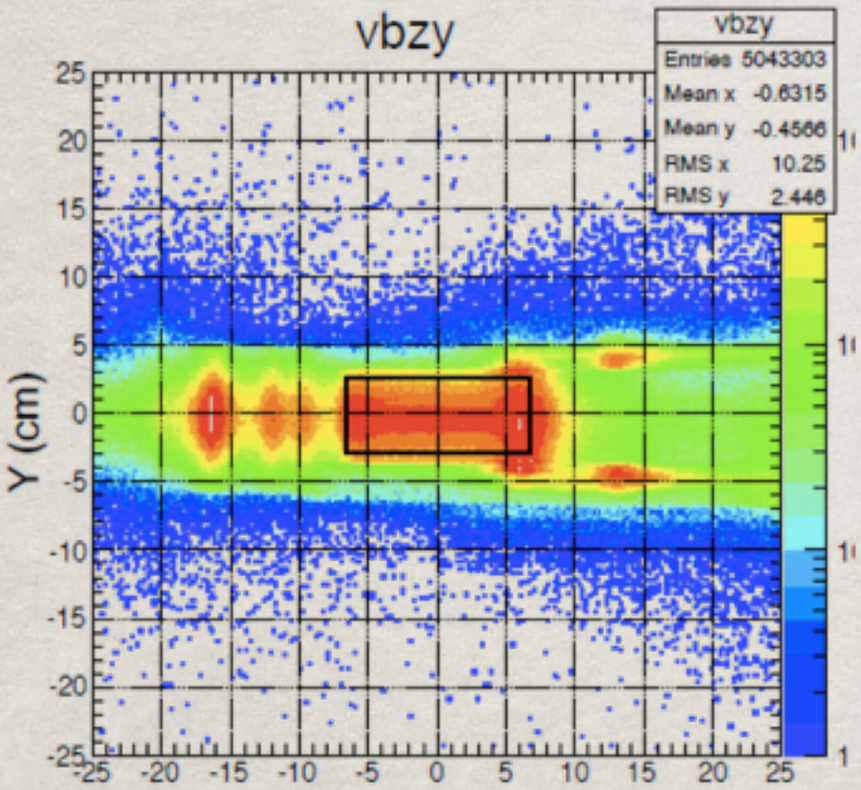
E15@J-PARC: Detector performance

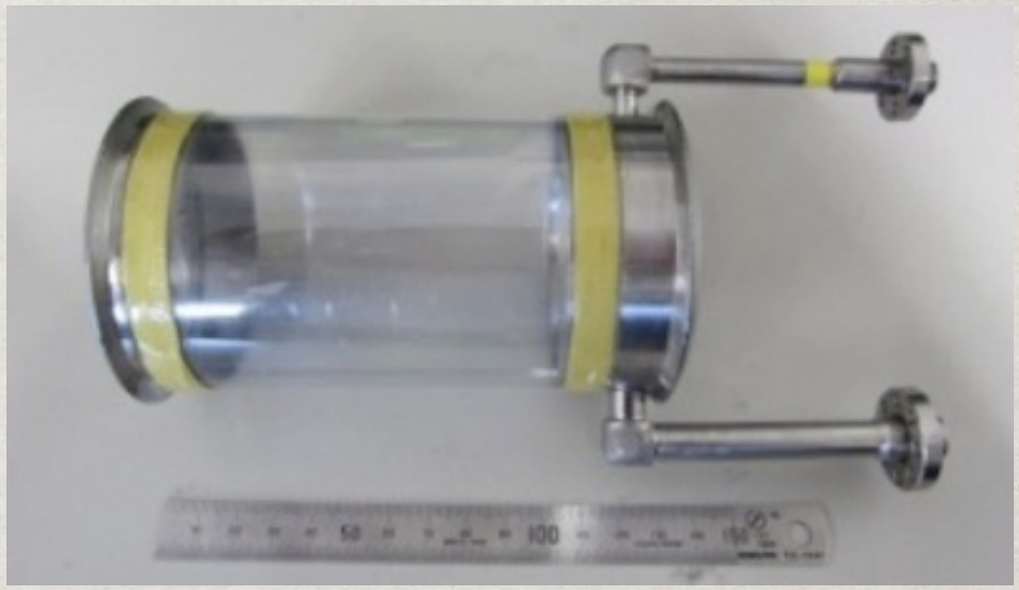


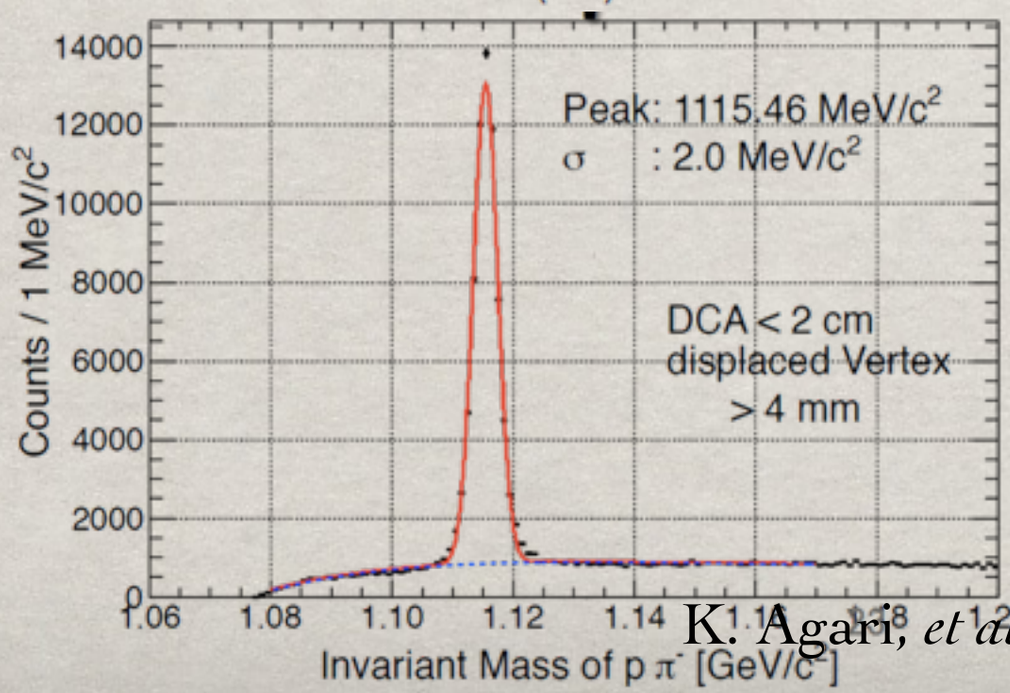
PID from Cylindrical Detection System
(15 layer, 1816 ch @ 0.7 T)
60% of 4pi solid angle

K. Agari, *et al.*, PTEP 2012, 02B011

E15@J-PARC: Detector performance



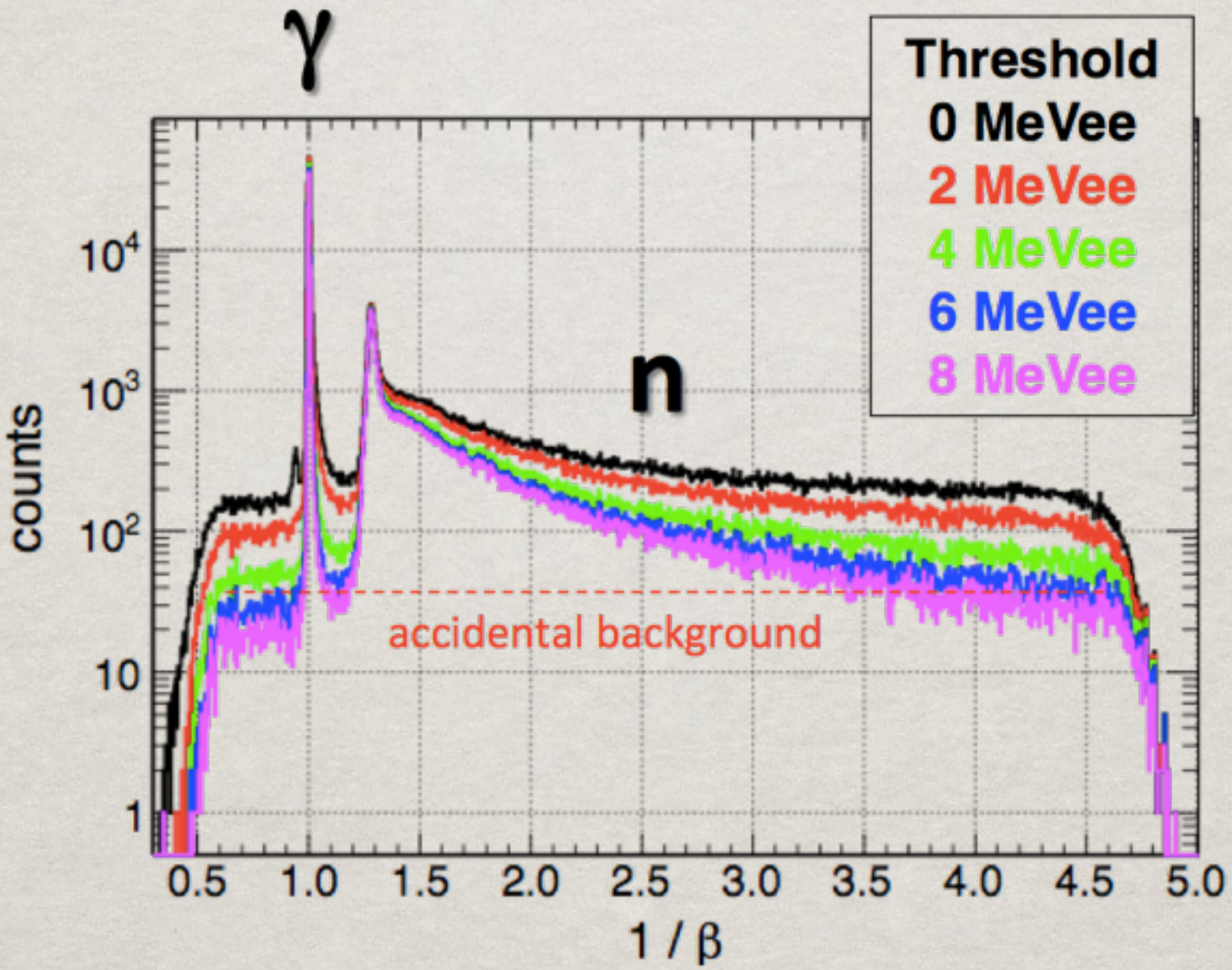




Designed resolution achieved!
(10 MeV/c^2 for K^-pp)

K. Agari, *et al.*, PTEP 2012, 02B011

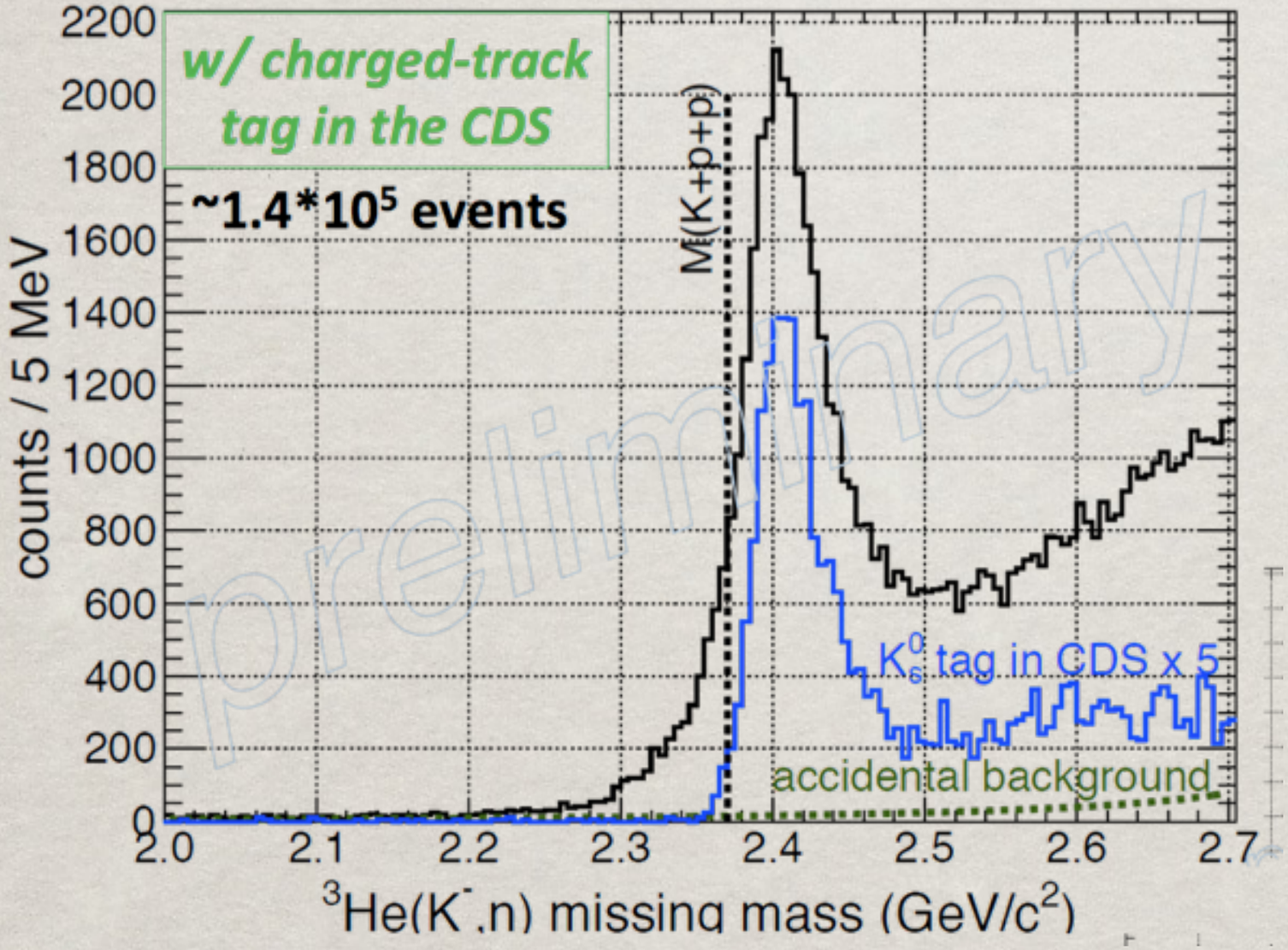
E15@J-PARC: Detector performance

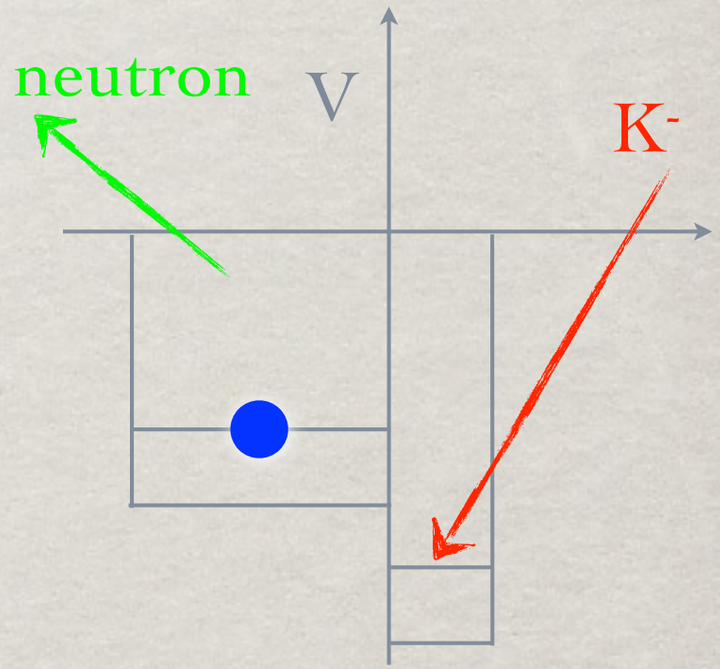


Time resolution ~160ps:
10 MeV/c^2 for 1GeV/c neutron

K. Agari, *et al.*, PTEP 2012, 02B011

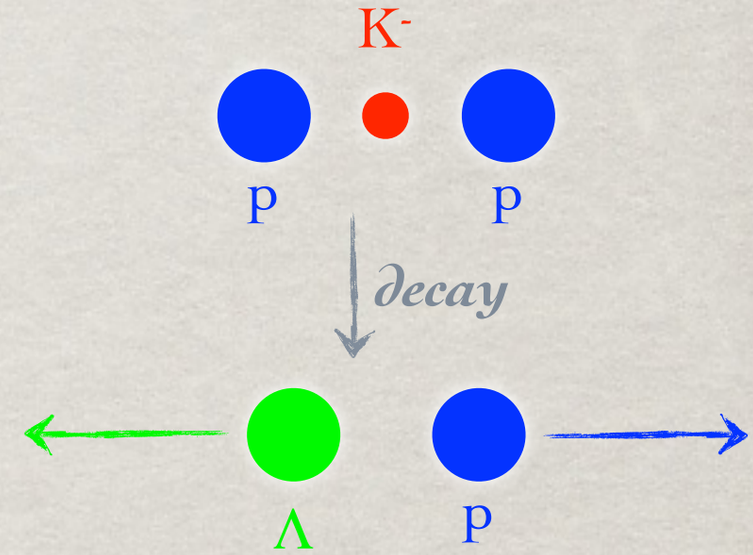
E15@J-PARC: Preliminary results





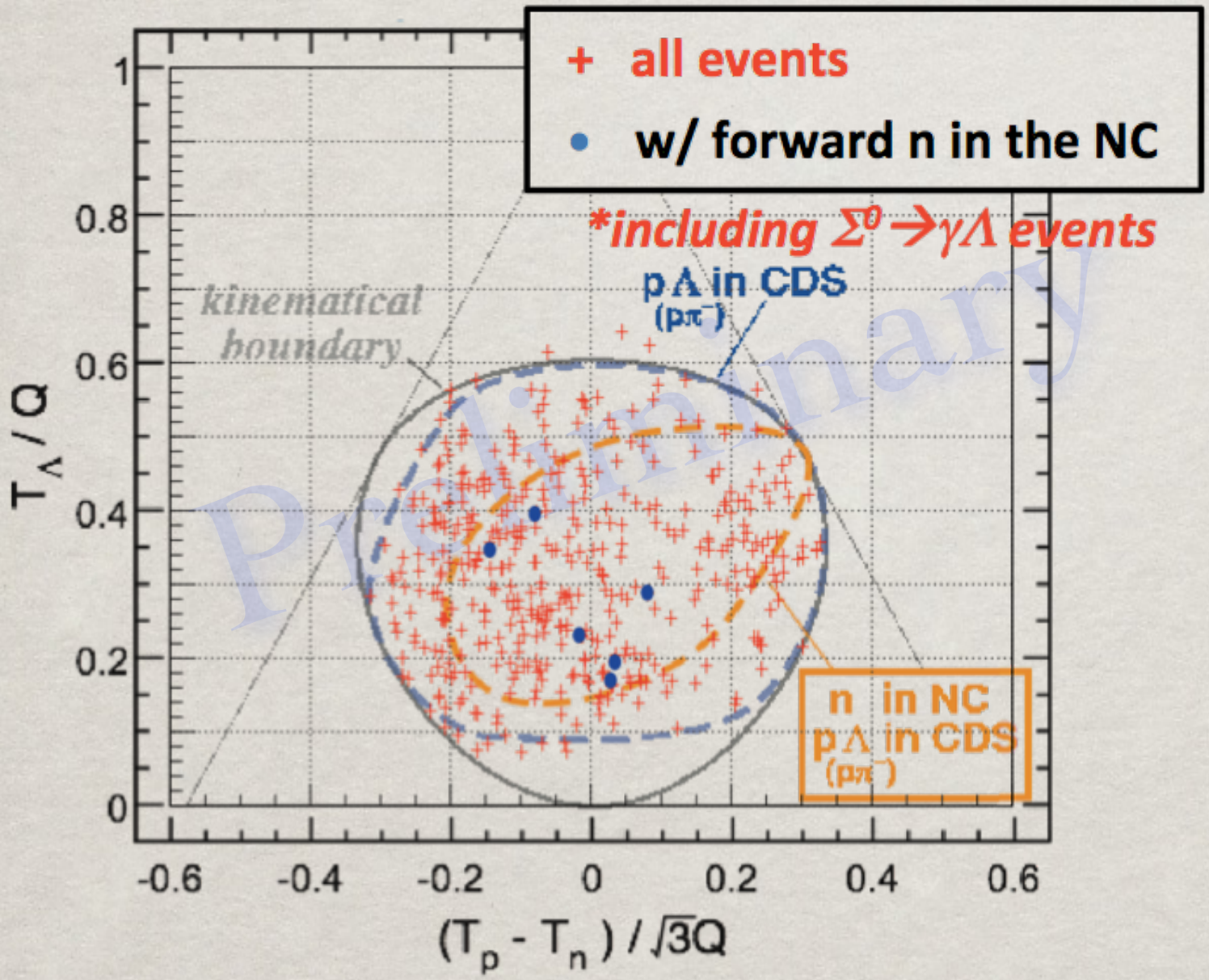
- Semi inclusive ^{3}He(K$^-$, n);
- Interesting structure below K$^-$pp threshold.

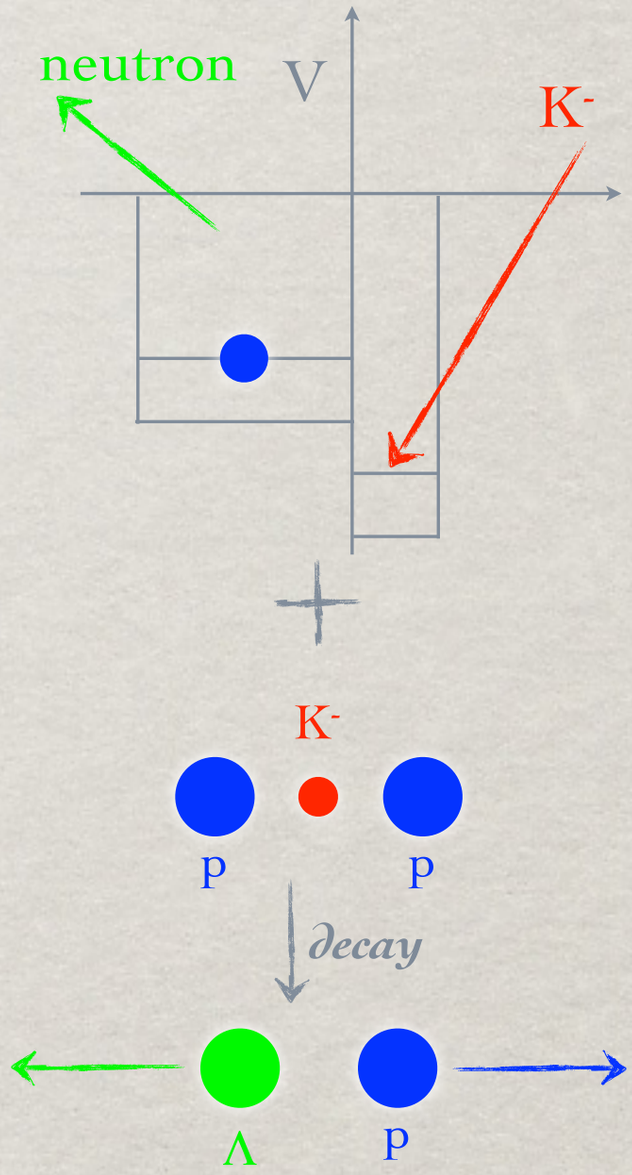
E15@J-PARC: Preliminary results



- Inclusive $^{3}He(K^{-}, \Lambda p)$;
- Interesting structure below $K^{-}pp$ threshold.

E15@J-PARC: Preliminary results





- Exclusive $^{3}He(K^{-}, \Lambda pn)$;
- opening angle of Λp under investigation

Summary & outlook

1. E15 experiment has been carried out at J-PARC K1.8BR beam line
2. Data taking for 1st Physics run finished successfully (4×10^9 K^- on target)
3. Data analysis is promising though still under going
4. More statistics is necessary...

Thank you for your attention!

S. Ajimura[a], G. Beer[b], H. Bhang[c], M. Bragadireanu[e], P. Buehler[f], L. Busso[g,h], M. Cargnelli[f], S. Choi[c], C. Curceanu[d], S. Enomoto[i], D. Faso[g,h], H. Fujioka[j], Y. Fujiwara[k], T. Fukuda[l], C. Guaraldo[d], T. Hashimoto[k], R. S. Hayano[k], T. Hiraiwa[a], M. Iio[o], M. Iliescu[d], K. Inoue[i], Y. Ishiguro[j], T. Ishikawa[k], S. Ishimoto[o], T. Ishiwatari[f], K. Itahashi[n], M. Iwai[o], M. Iwasaki[m,n*], Y. Kato[n], S. Kawasaki[i], P. Kienle[p], H. Kou[m], Y. Ma[n], J. Marton[f], Y. Matsuda[q], Y. Mizoi[l], O. Morra[g], T. Nagae[j$], H. Noumi[a], H. Ohnishi[n], S. Okada[n], H. Outa[n], K. Piscicchia[d], M. Poli Lener[d], A. Romero Vidal[d], Y. Sada[j], A. Sakaguchi[i], F. Sakuma[n], M. Sato[n], A. Scordo[d], M. Sekimoto[o], H. Shi[k], D. Sirghi[d,e], F. Sirghi[d,e], K. Suzuki[f], S. Suzuki[o], T. Suzuki[k], K. Tanida[c], H. Tatsuno[d], M. Tokuda[m], D. Tomono[n], A. Toyoda[o], K. Tsukada[r], O. Vazquez Doce[d,s], E. Widmann[f], B. K. Weunschek[f], T. Yamaga[i], T. Yamazaki[k,n], H. Yim[t], Q. Zhang[n], and J. Zmeskal[f]

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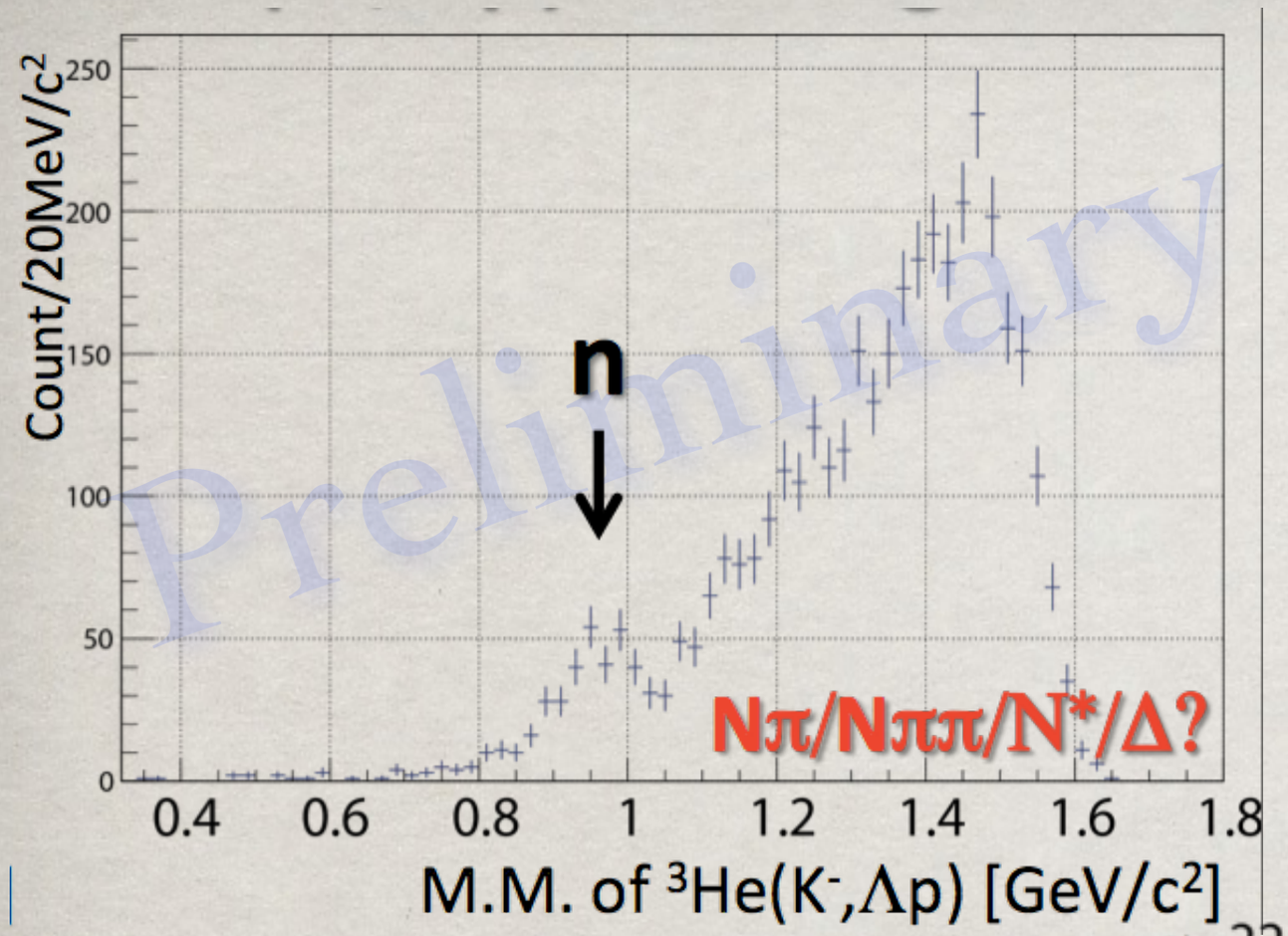
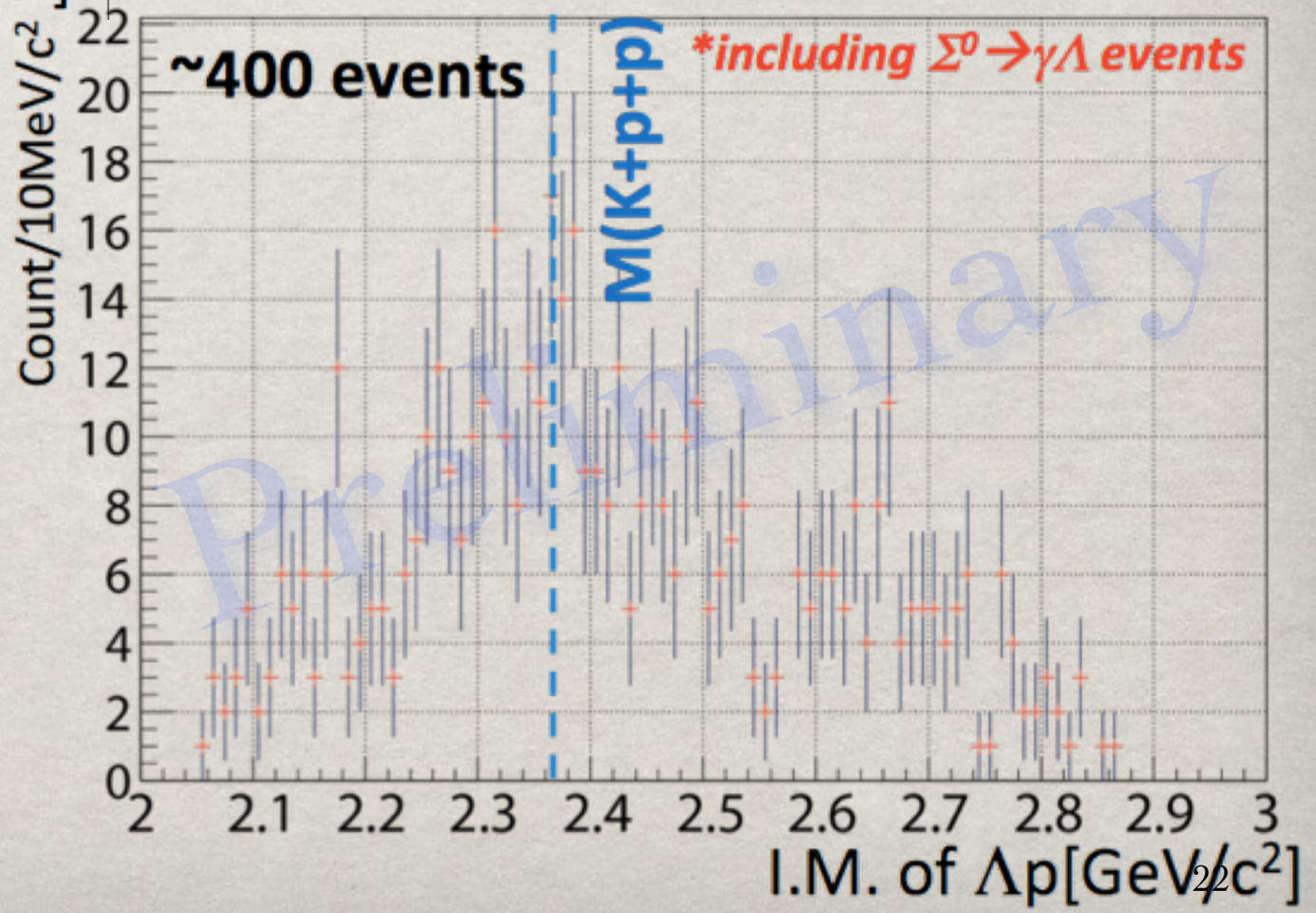
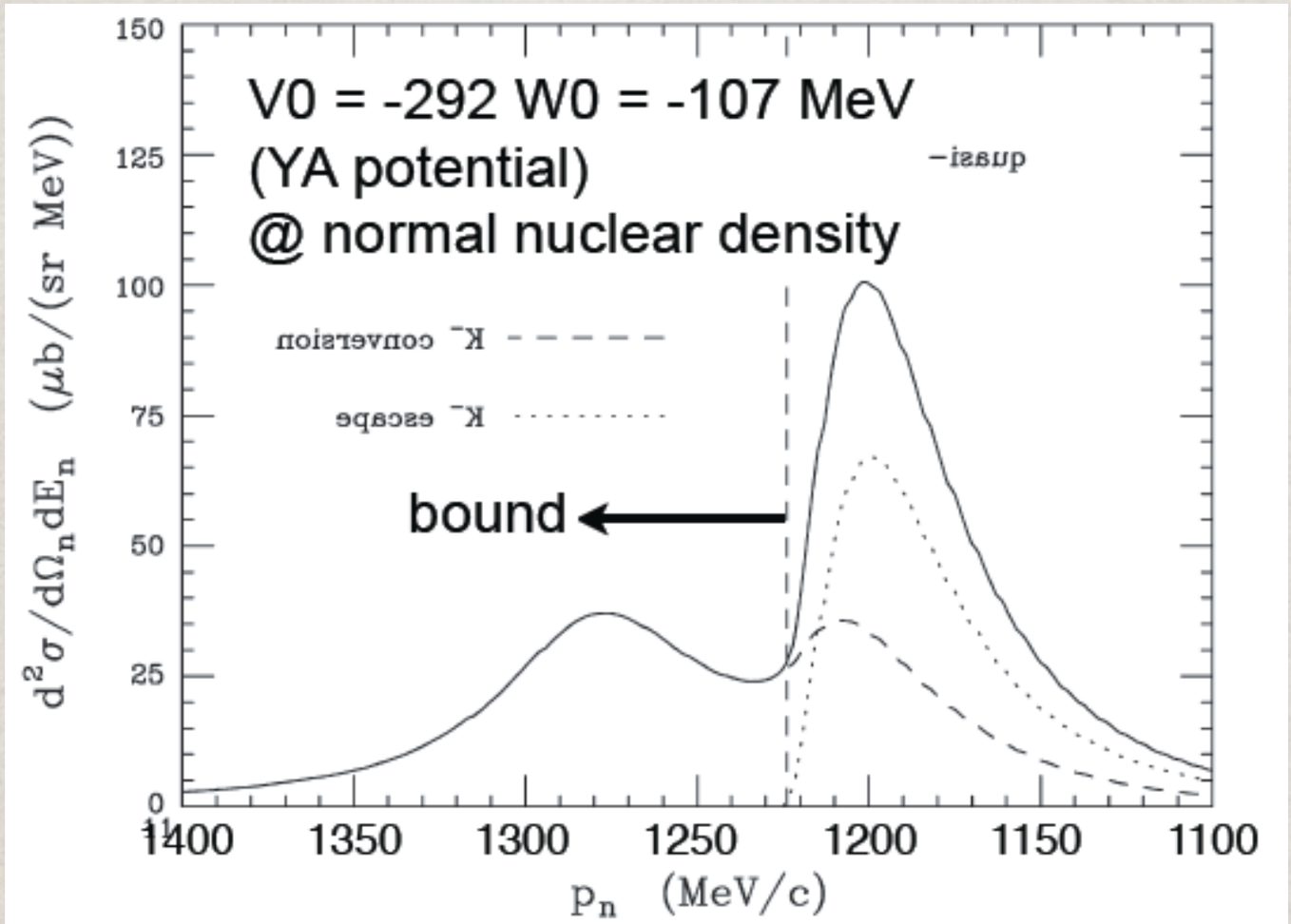
(*) Spokesperson
($) Co-Spokesperson


Count/20MeV/c²
n
Nπ/Nππ/N*/Δ?
M.M. of ³He(K⁻,Λp) [GeV/c²]
Preliminary


Count/10MeV/c²
~400 events
M(K+p+p)
*including Σ⁰→γΛ events
I.M. of Λp[GeV/c²]
Preliminary



T.Koike and T.Harada. , PLB652 (2007) 262

$\bar{K}N$ interaction: $\Lambda(1405)$ Ansatz

What if $\Lambda(1405)$ is bound state of K^-p?
(B_K=27 MeV, Width=40 MeV)
formation of deeply bound state?

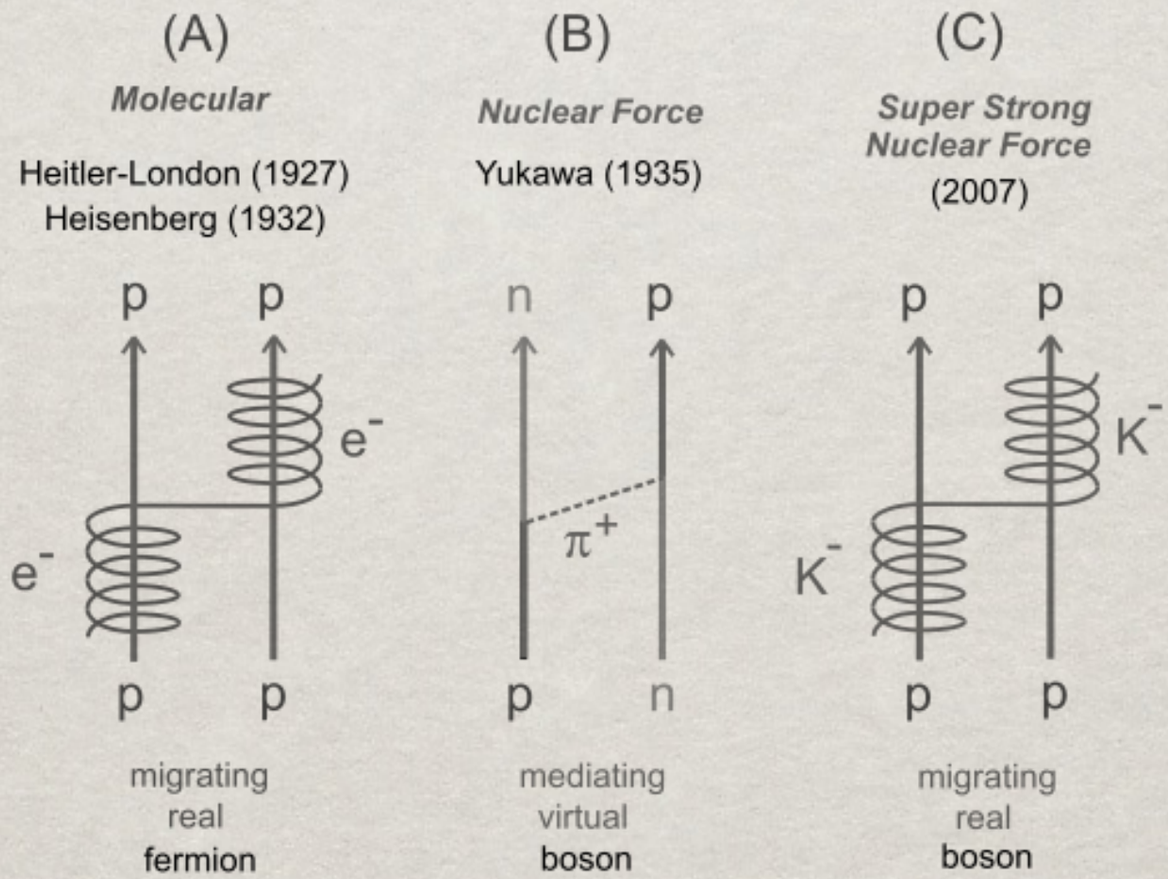


Fig. 5. Summary of the three different interaction schemes for nuclear forces. (A) The Heitler-London-Heisenberg model. (B) The Yukawa interaction. (C) The super strong nuclear force by the $\bar{K}$ covalency.

T. Yamazaki, *et al.*, Proc. Jpn. Acad., Ser. B 83, 144