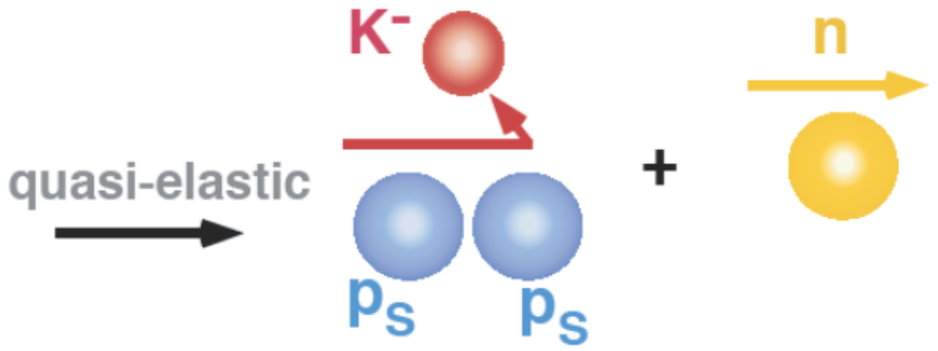


Search for Deeply-bound K-pp States in ^{3}He(K^{-} , Λp)n Reaction - Recent Results from J-PARC E15 Experiment

H. Outa

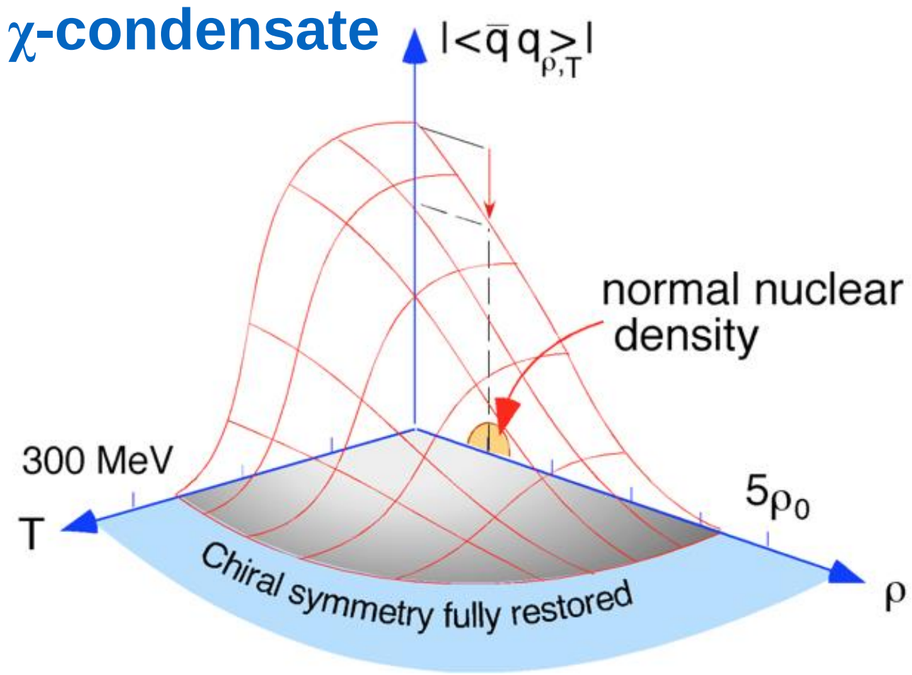
for E15 collaboration

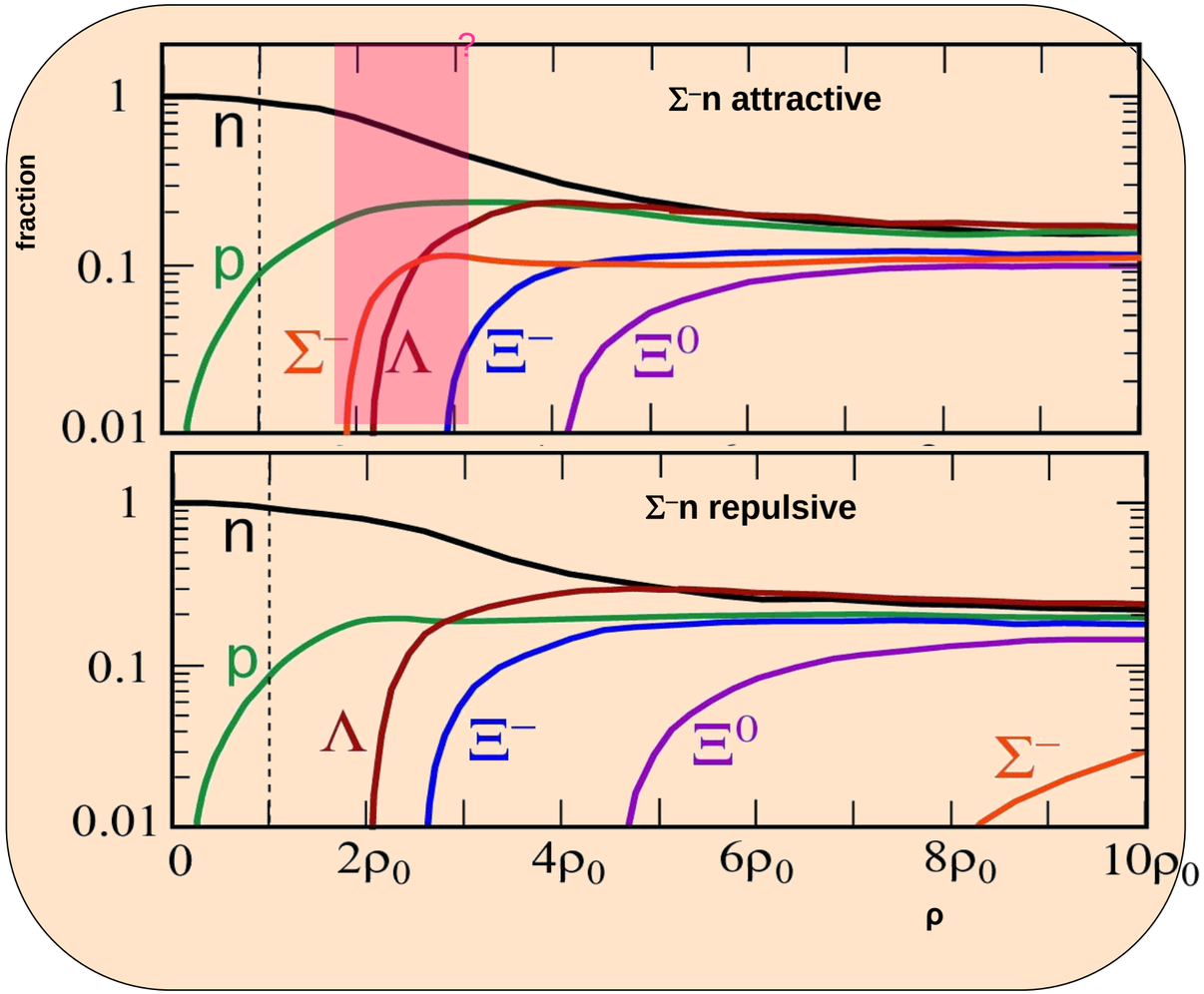
Objectives

Hadron masses and χ-symmetry

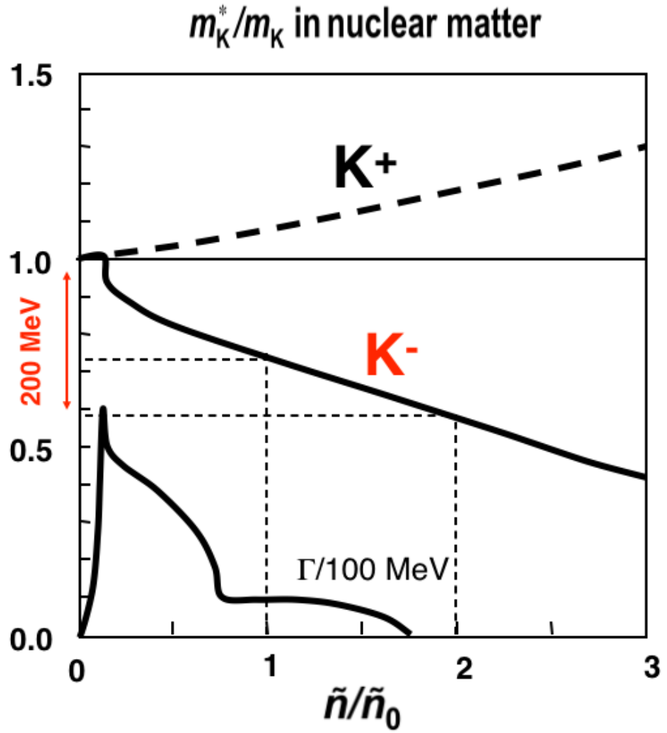
Key questions :

- Can kaon be a member of nuclei?
- Kaon properties change in nuclear media?
- Kaon condensation in neutron star ?





Search for Kaonic nuclear states



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

strongly attractive in I=0 channel

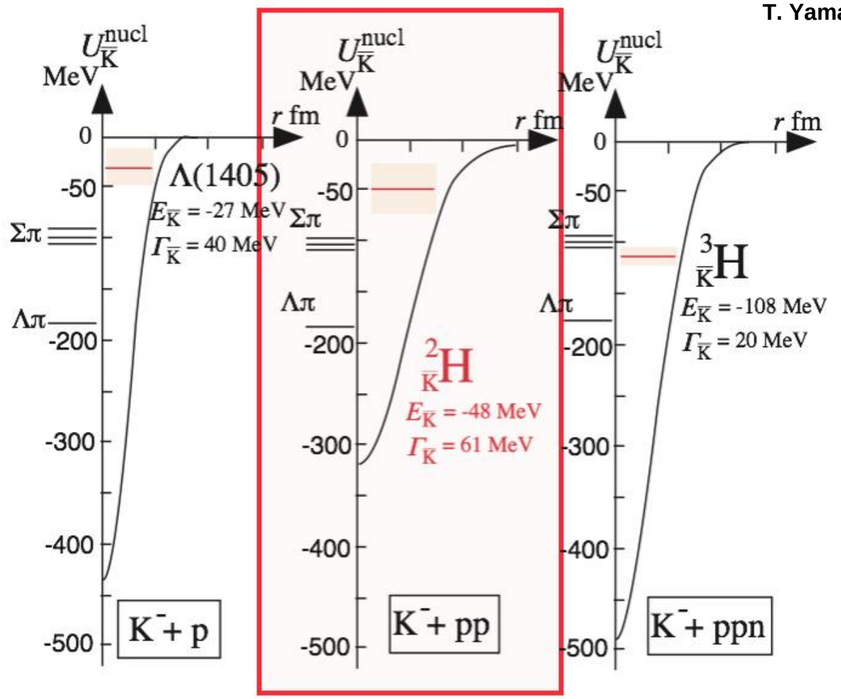
nuclear state search

K⁻pp • simplest system

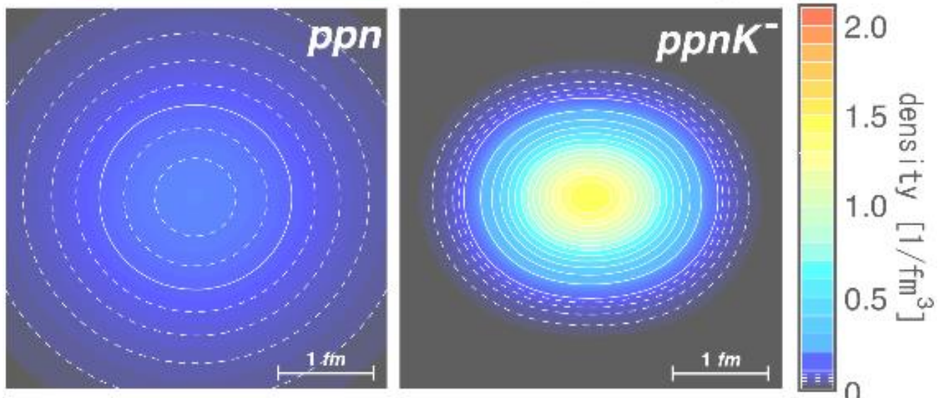
^{3}He(K$^-$, n) @ 1 GeV/*c*

assuming Λ(1405) = K⁻p bound state …

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



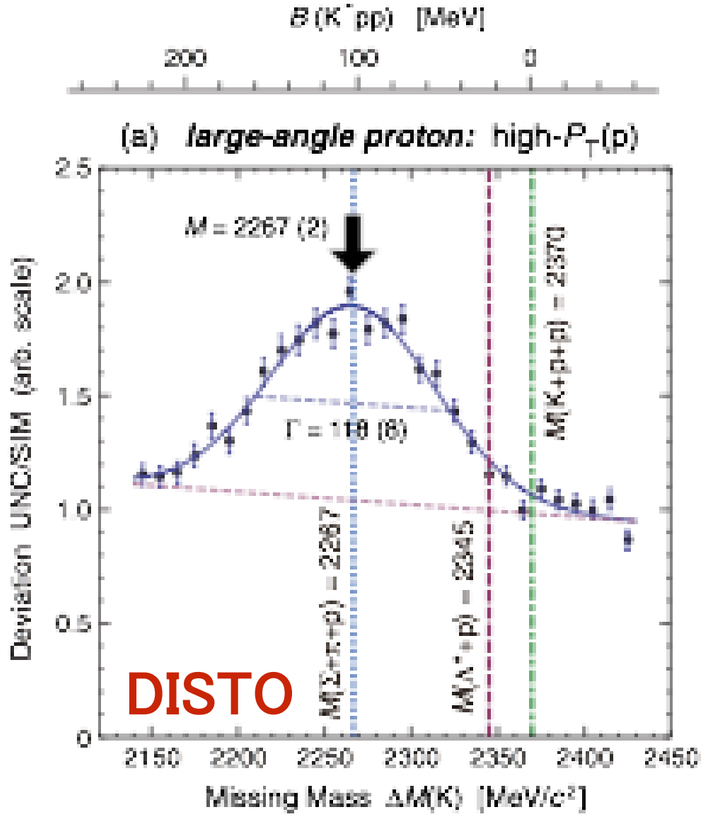
590 (2004) 51

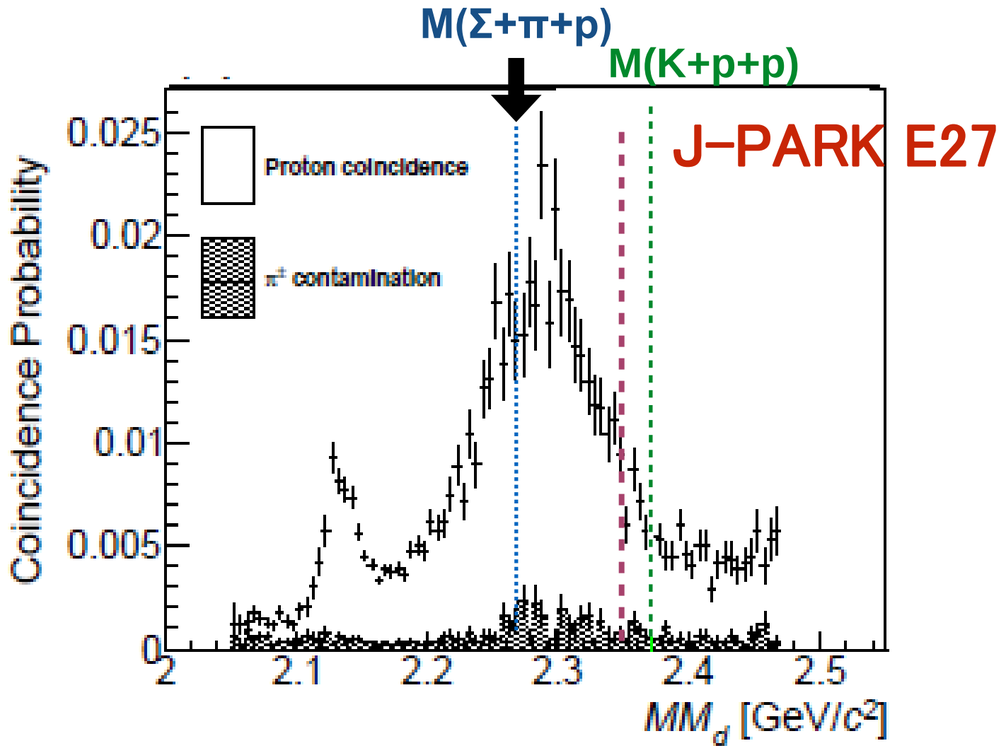


formation of high density matter?

Present “Kpp" Candidates @ B_K~100 MeV

very deep ??





Many objections exist, though…

why no threshold ($\Sigma\pi p$) effect seen?

why no quasi-elastic K seen?

Situation of K^-pp bound state

- **Theoretical calc.**

  Bound state exists

  KbarN 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

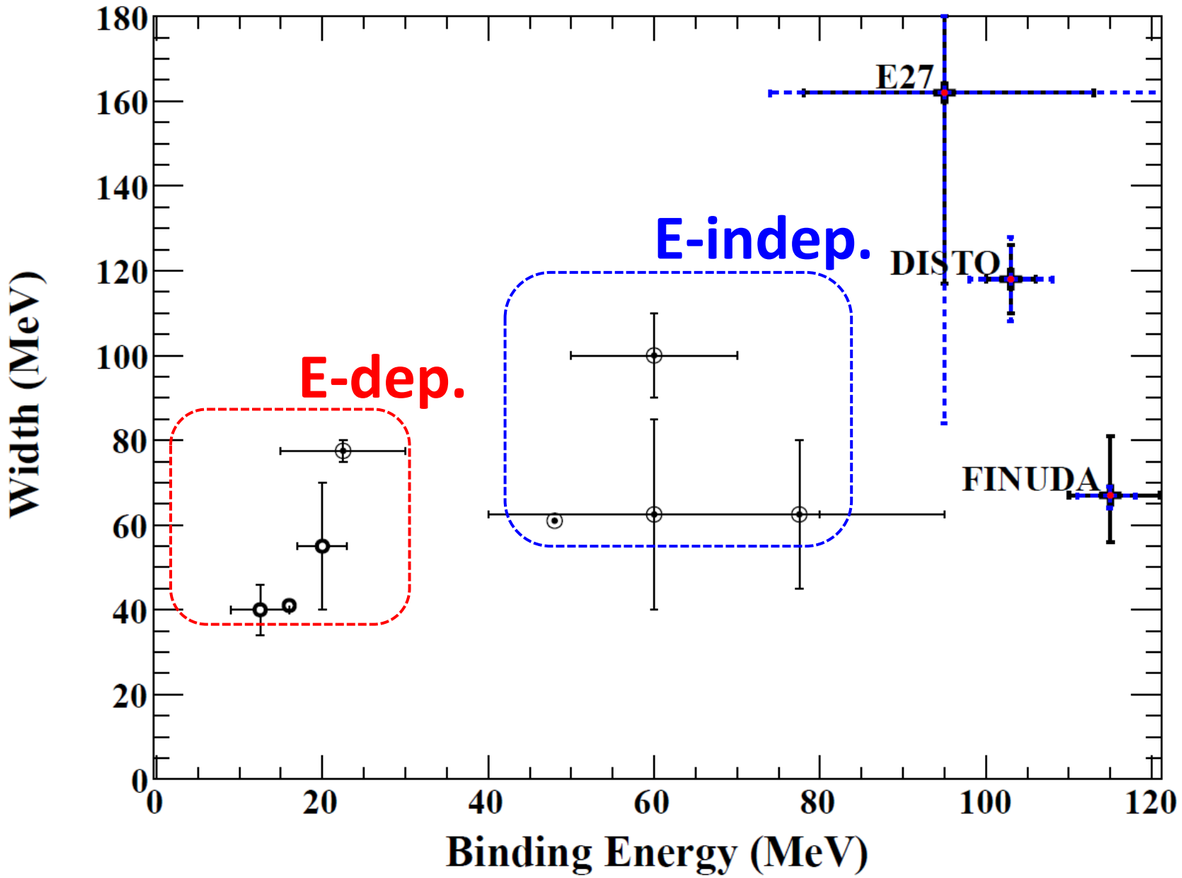
  $(stopped\ K^-, \Lambda p)$

  LEPS

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

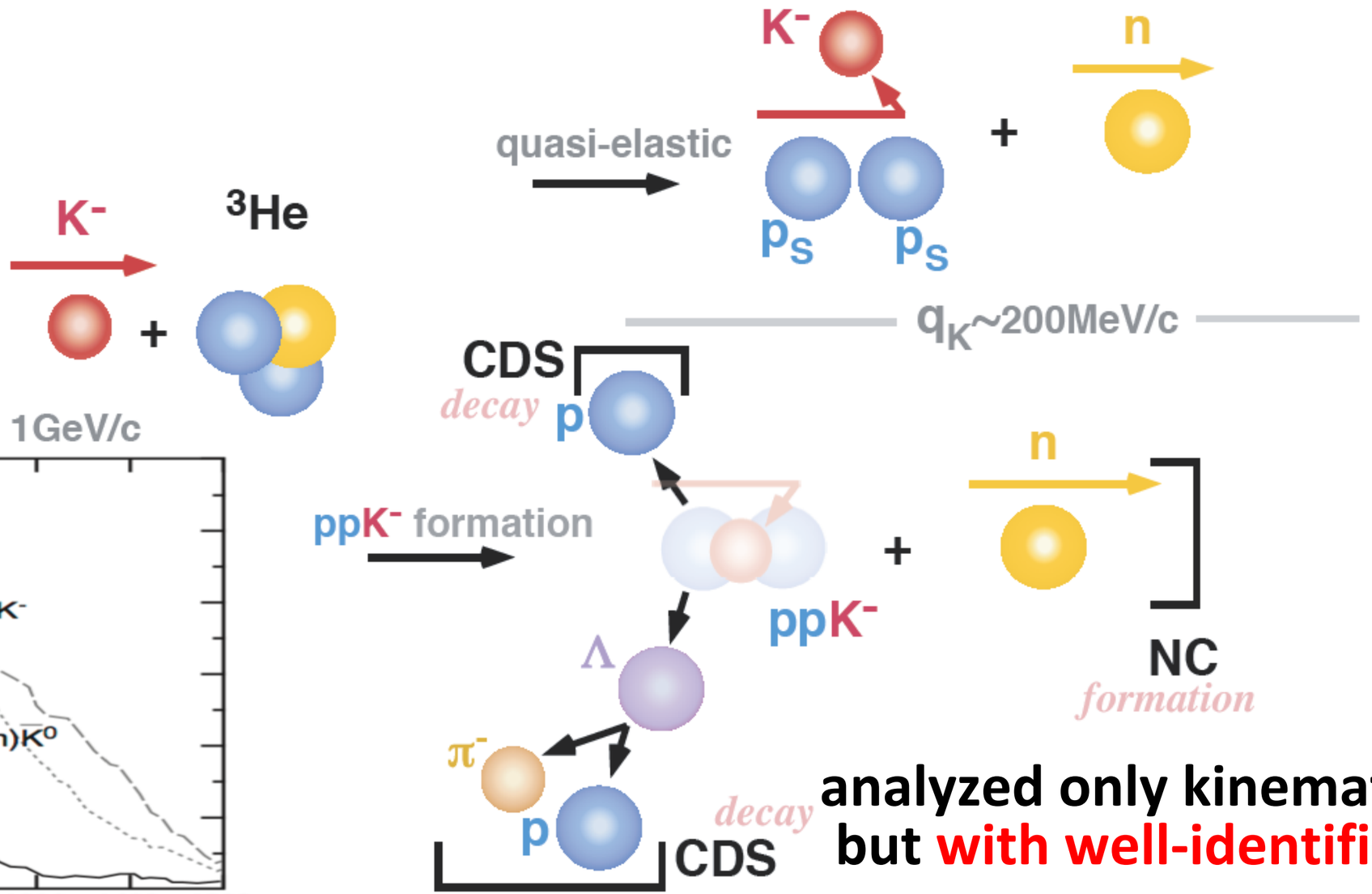
  HADES

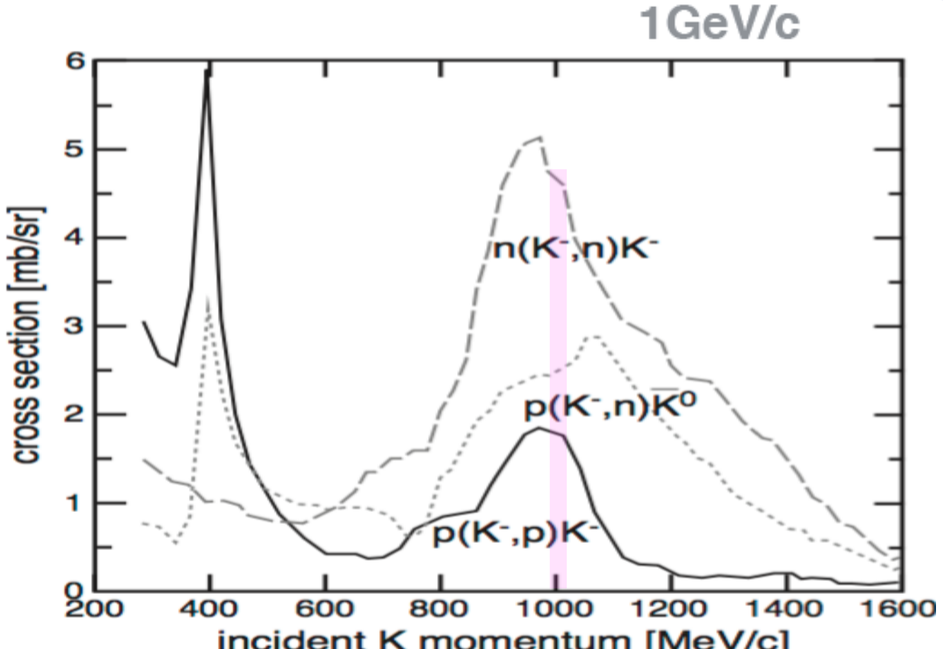
  $pp \to \Lambda p K^+$



"K⁻pp" search via ^{3}He(K⁻,n) @p_K=1GeV/c

for efficient "ppK" formation $q_K \sim 200$ MeV/c





analyzed only kinematically
but with well-identified FS

Published E15[1st] data

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

Letter

^{3}He(K$^-$, n) — semi-inclusive

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. Bragadire anu
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 Ler er[9],
A. Romero Vidal[9], Y. Sada[10], A. Sakaguchi[13], F. Sakuma[14], M. Sa o[14],
M. Sekimoto[12], H. Shi[9], D. Sirghi[9,5], F. Sirghi[9,5], S. Suzuki[12], T. S uzuk
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]

Only 3 days!
(suspended by the earthquake)

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

Letter

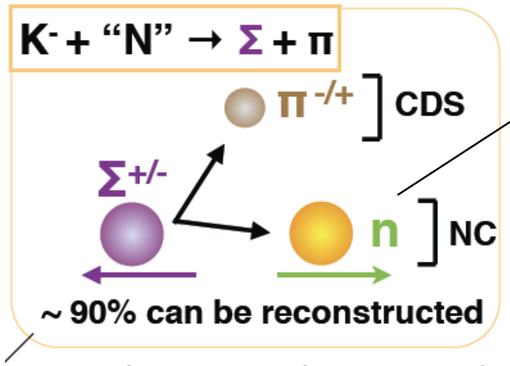
^{3}He(K$^-$, Λp) n — exclusive

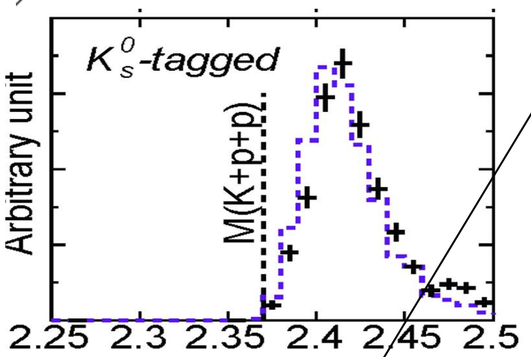
Structure near the $K^- + p + p$ threshold in the in-flight $^3\mathrm{He}(K^-, \Lambda p)n$ reaction

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]

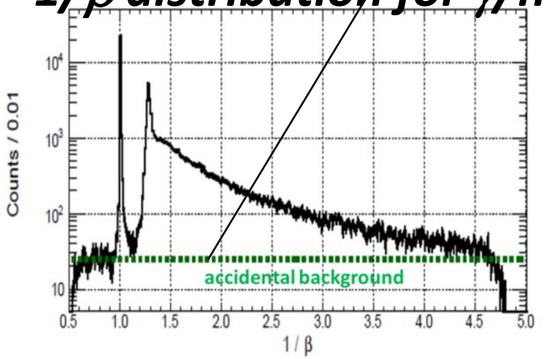
with new data!

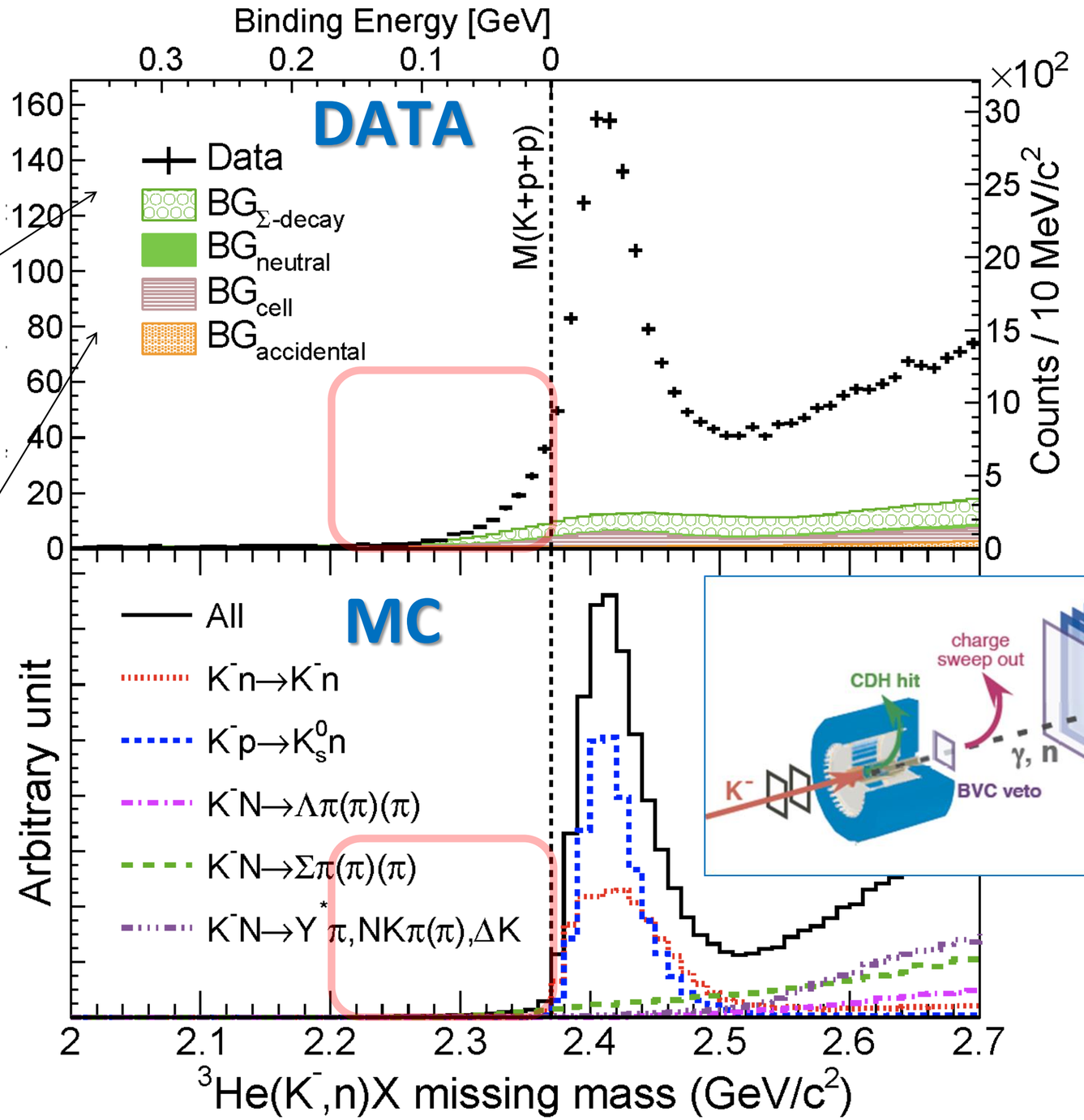
E15
^{3}He(K$^-$,n)X





1/β distribution for γ/n





Improving statistics via E15^{2nd} data

What is the structure found in E15^{1st} data?

E15^{1st} E15^{2nd}

3 days → 3 weeks w/ higher priority to Λp in CDS

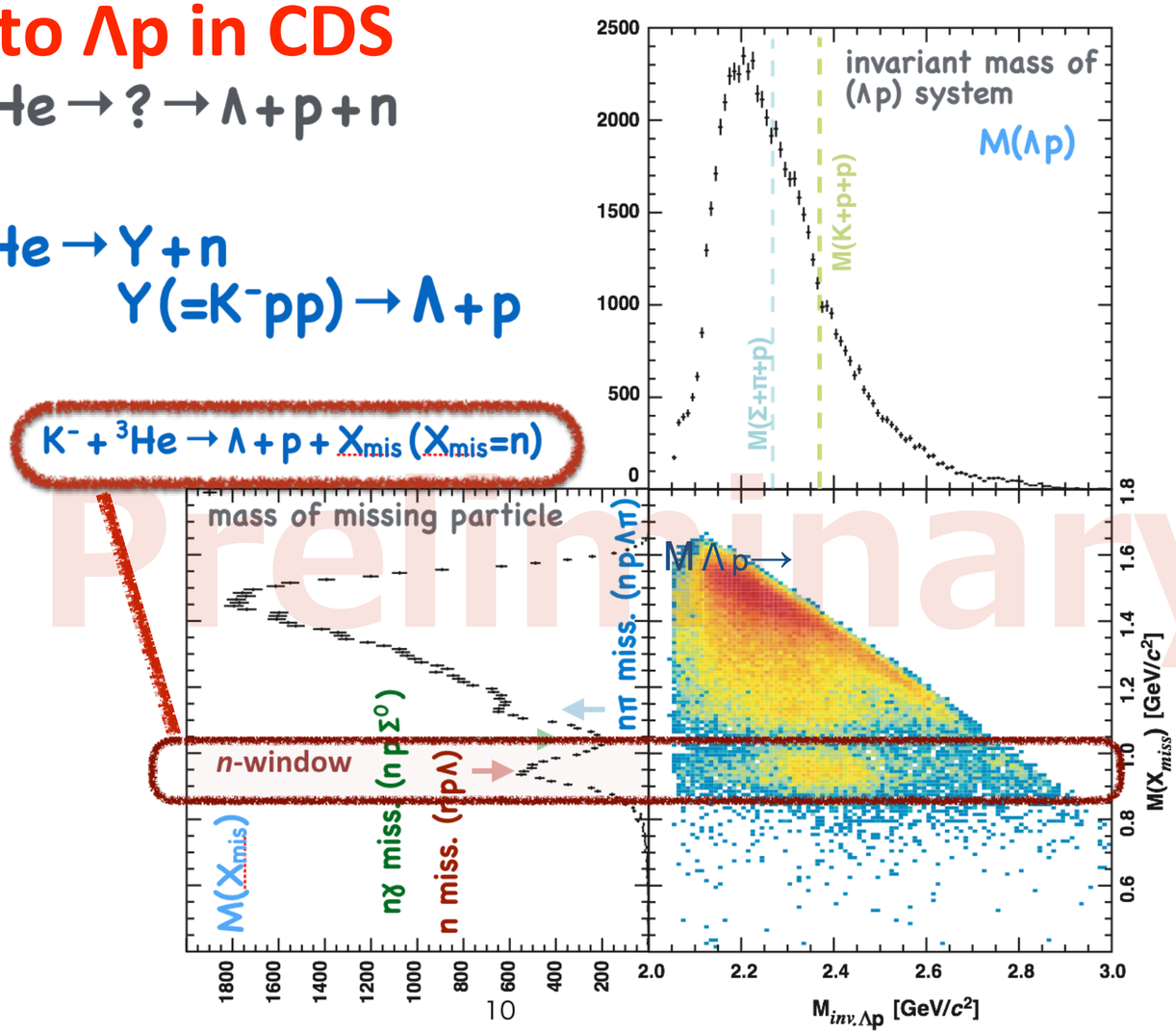
$K^- + {}^3He \rightarrow ? \rightarrow \Lambda + p + n$

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

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

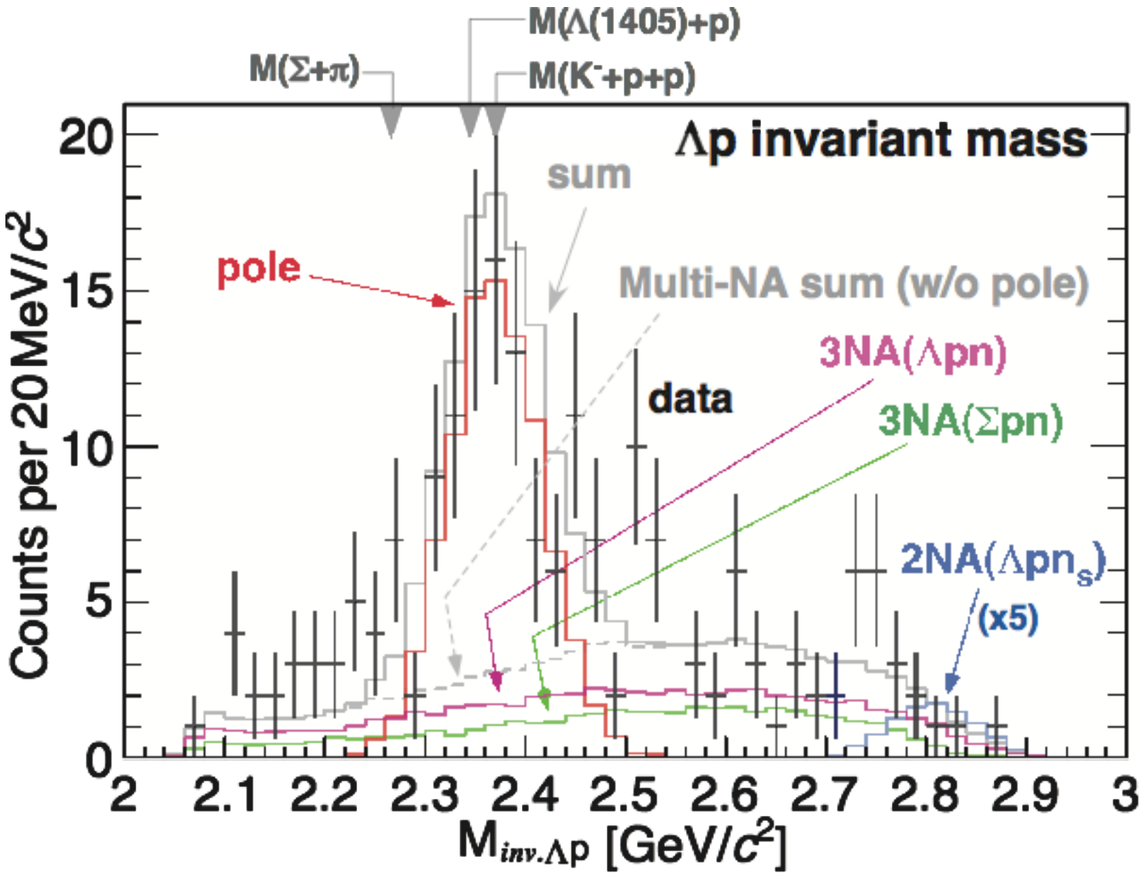
~ 6 times more data for forward neutron

~ 30 times more data for Λpn final state



E15[1st] and E15[2nd] spectra consistent?

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



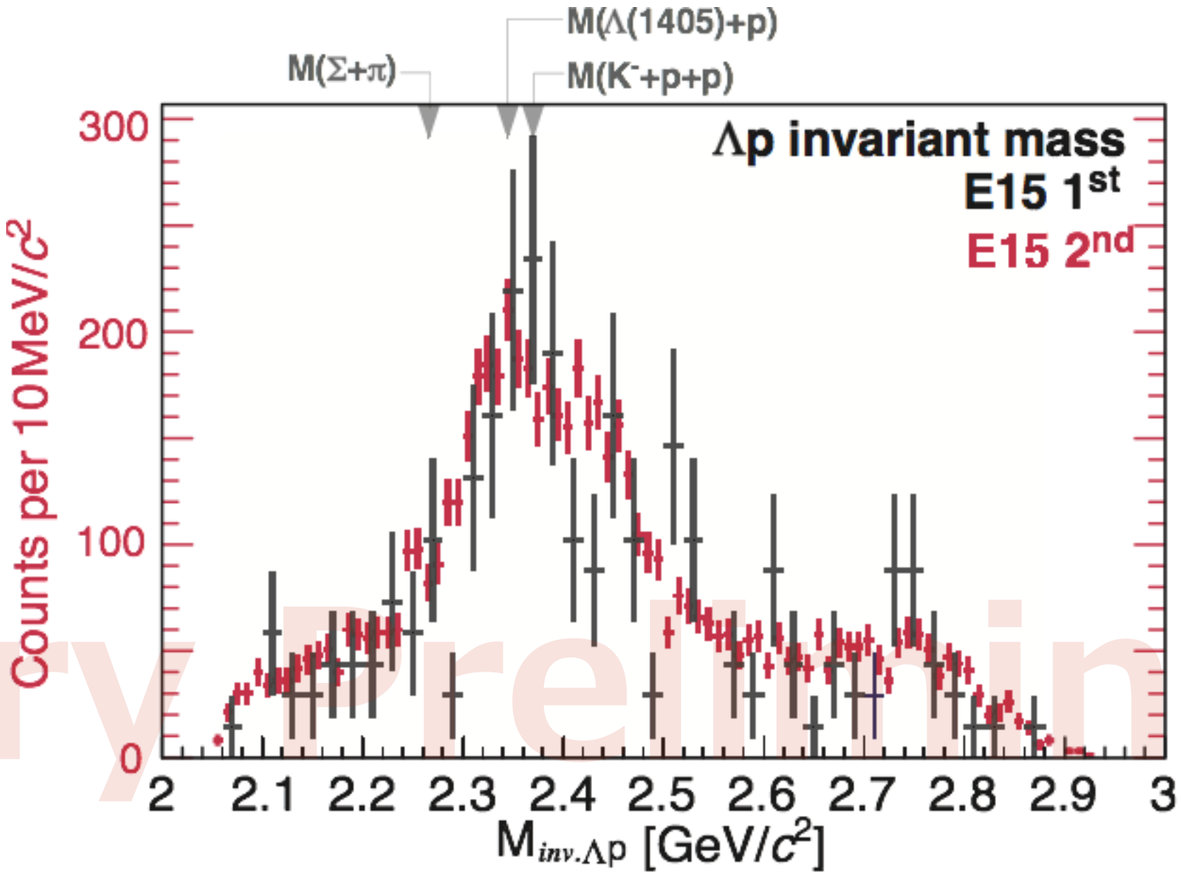
PTEP(2016) fit
w/ "single" peak

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

MΛp⟶

E15[1st] and E15[2nd] spectra consistent?

YES! They are consistent!

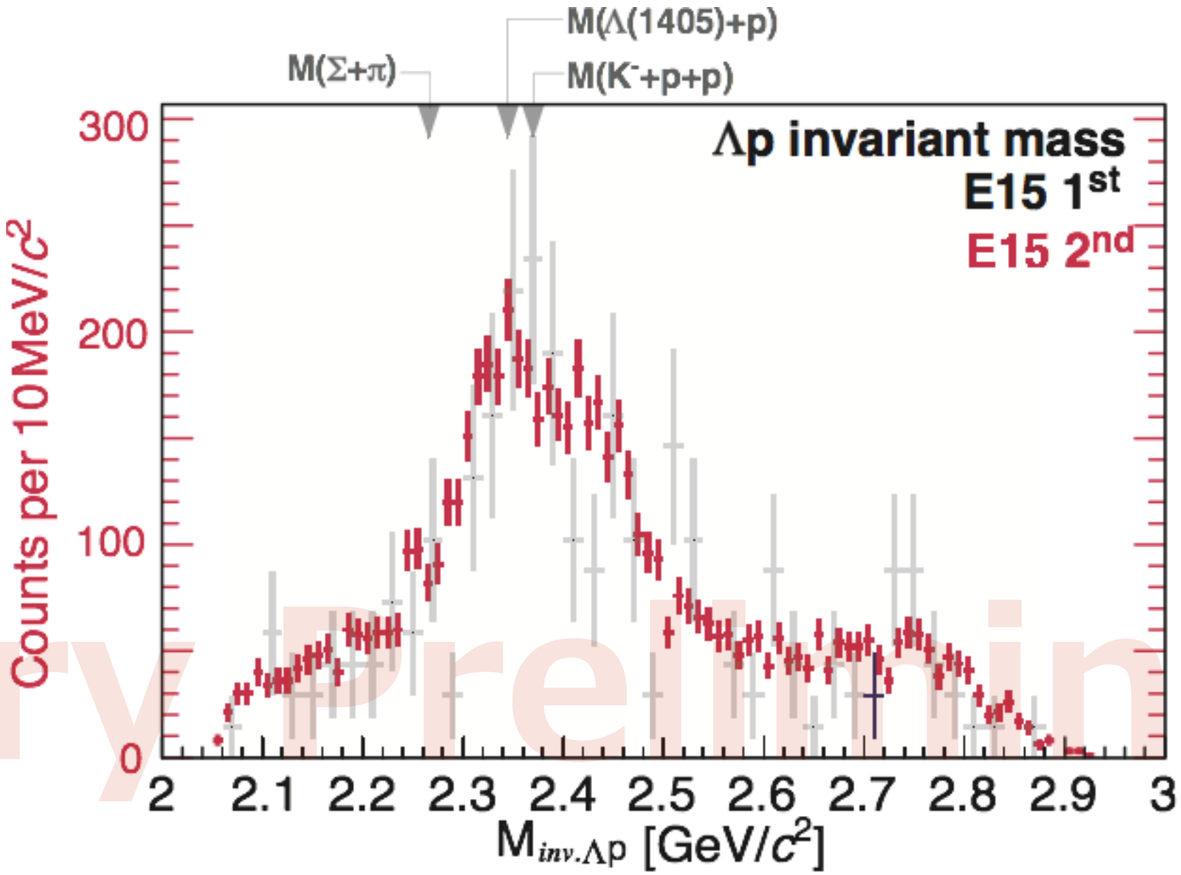


MΛp⟶

E15[1st] and E15[2nd] spectra consistent?

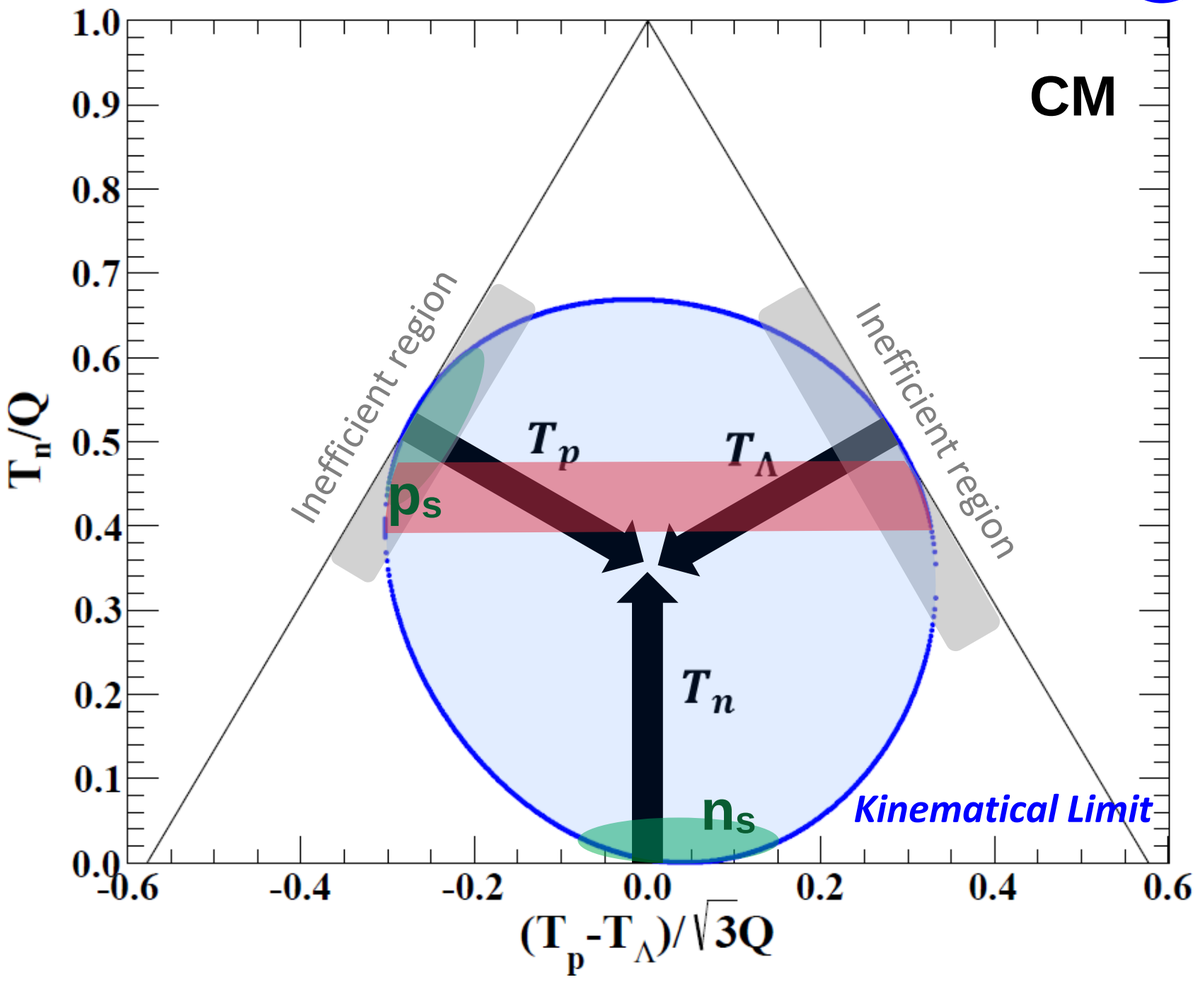
YES! They are consistent!

E15[2nd] spectrum does not allow single pole assumption



MΛp⟶

Dalitz Plot of Λpn



kinematical limit

K^-pp formation

flat for point-like 3NA

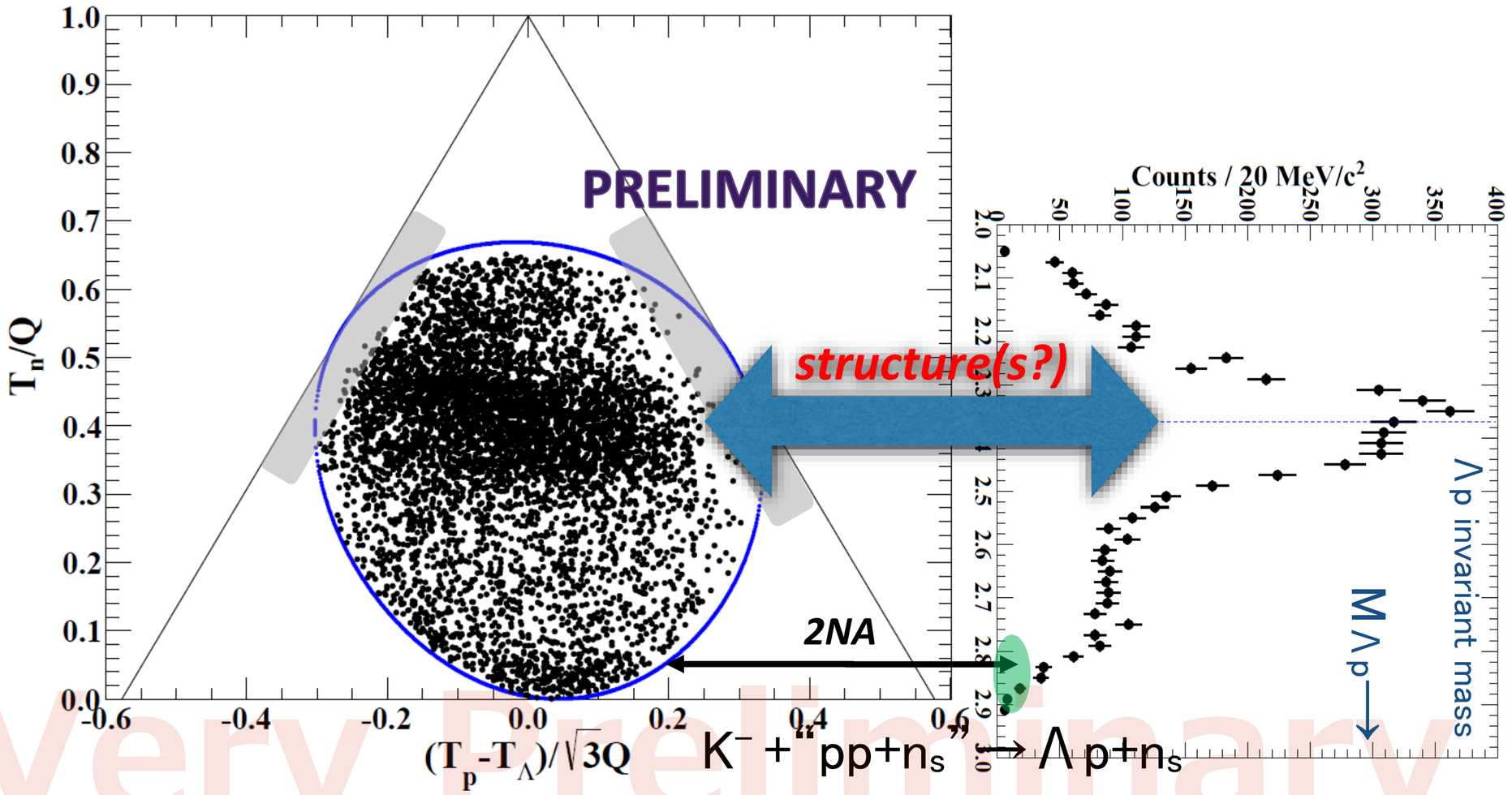
Is ^{3}He point-like?

2NA process

with spectator

n_s / p_s

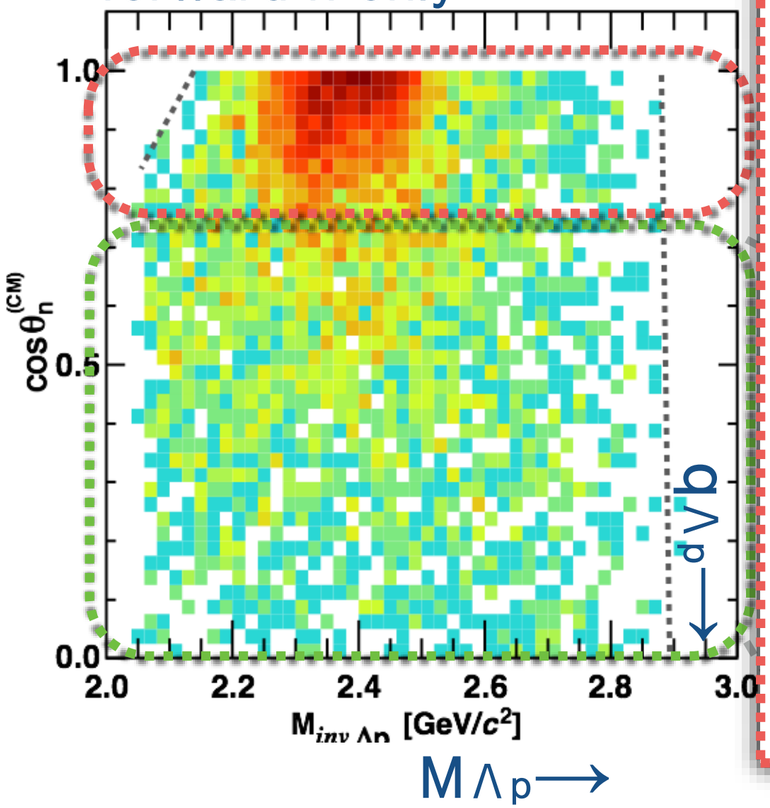
Dalitz Plot of Λpn

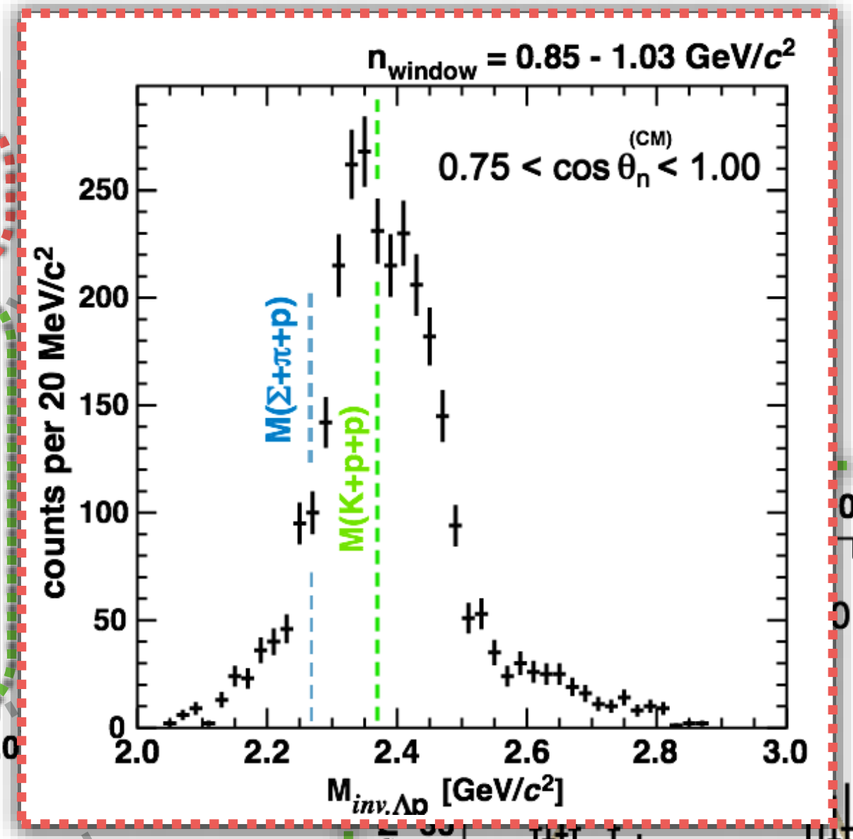


^{3}He(K^{-}, Λp)n:
Angular Dependence of n in CM

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

forward n only





distribute uniformly over Dalitz

"point like reaction?"

^{3}He(K^{-}, Λp)n:
Angular Dependence of n in CM

in more detail
as a clue to understand

^{3}He(K^-, Λp)n:
Angular Dependence of n in CM

two components exist?

if that is the case,

bound region :
forward peaking

weakly depend to cos θ

unbound region :
very forward peaking

bit strongly depend to cos θ

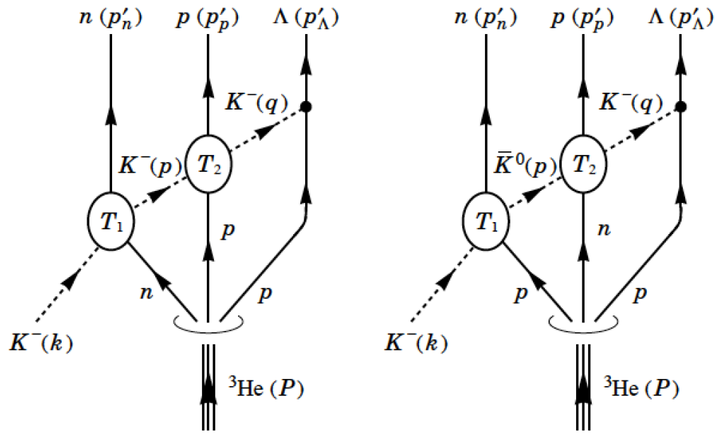
lower Q_K preferred

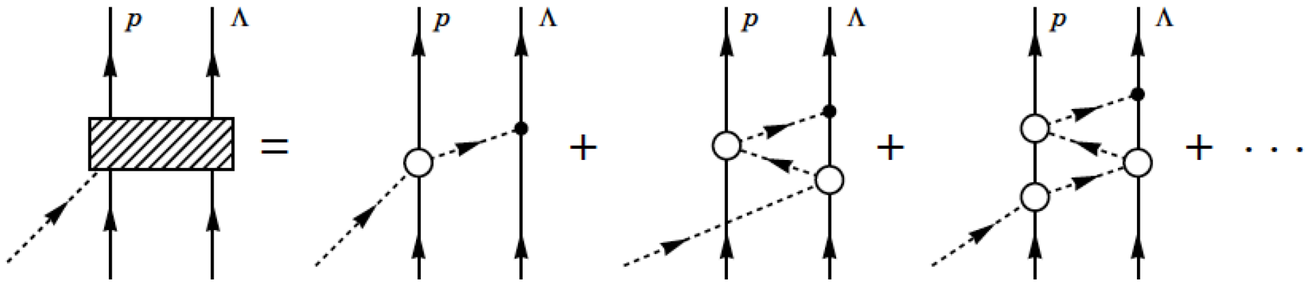
^{3}He(K^-, Λp)n:

Not like semi-inclusive spectrum,
“quasi-free K” excluded by the final state: Λpn,
but still need to ask …

ructure can be explained with quasi-elastic K scatterin

through uncorrelated Λ(1405)p channel





PTEP
Prog. Theor. Exp. Phys. **2013**, 00000 (27 pages)
DOI: 10.1093/ptep/0000000000

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

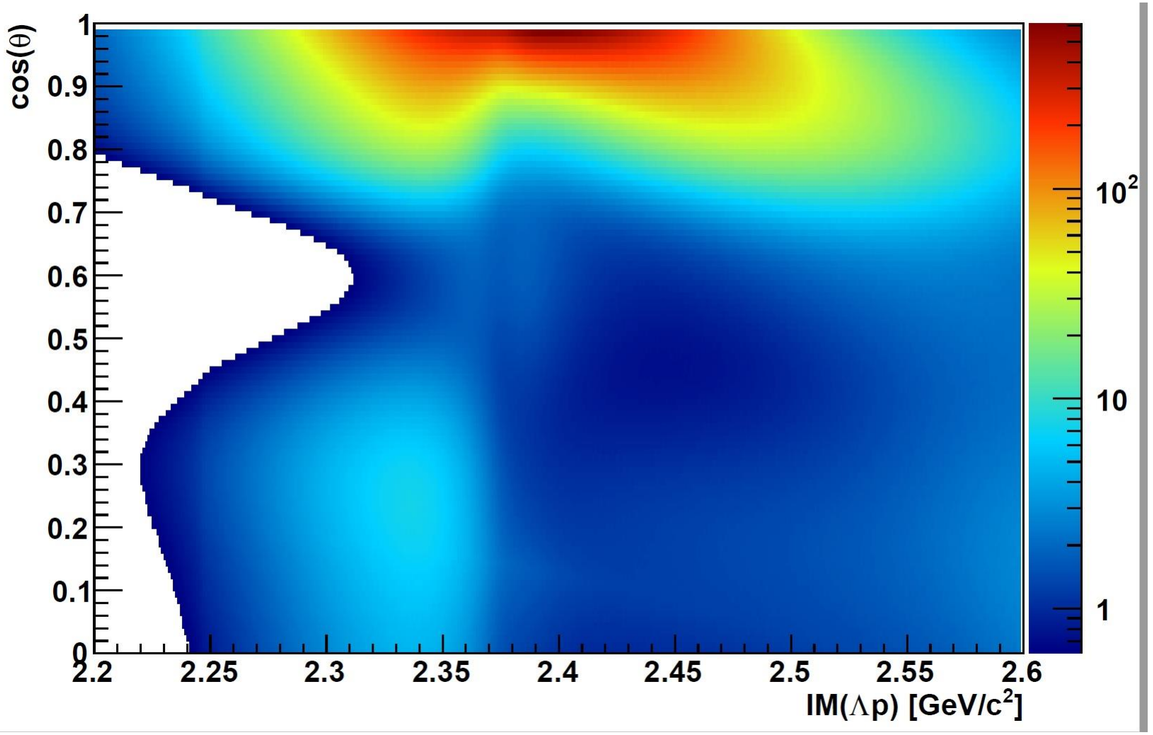
Takayasu Sekihara[1,*], Eulogio Oset[2], and Angels Ramos[3]

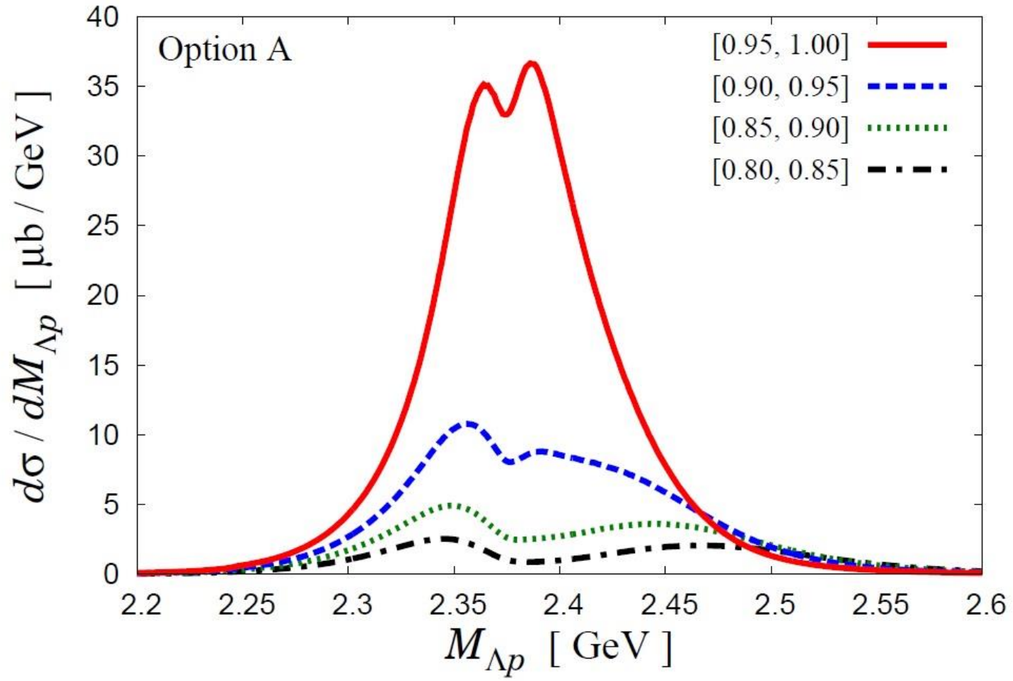
[1]*Advanced Science Research Center, Japan Atomic Energy Agency, Shirakata, Tokai, Ibaraki, 319-1195, Japan*
[2]*Departamento de Física Teórica and IFIC, Centro Mixto Universidad de Valencia-CSIC, Institutos de Investigación de Paterna, Aptdo. 22085, 46071 Valencia, Spain*
[3]*Departament de Física Quàntica i Astrofísica and Institut de Ciències del Cosmos, Universitat de Barcelona, Martí i Franquès 1, 08028 Barcelona, Spain*
[*]*E-mail: sekihara@post.j-parc.jp*

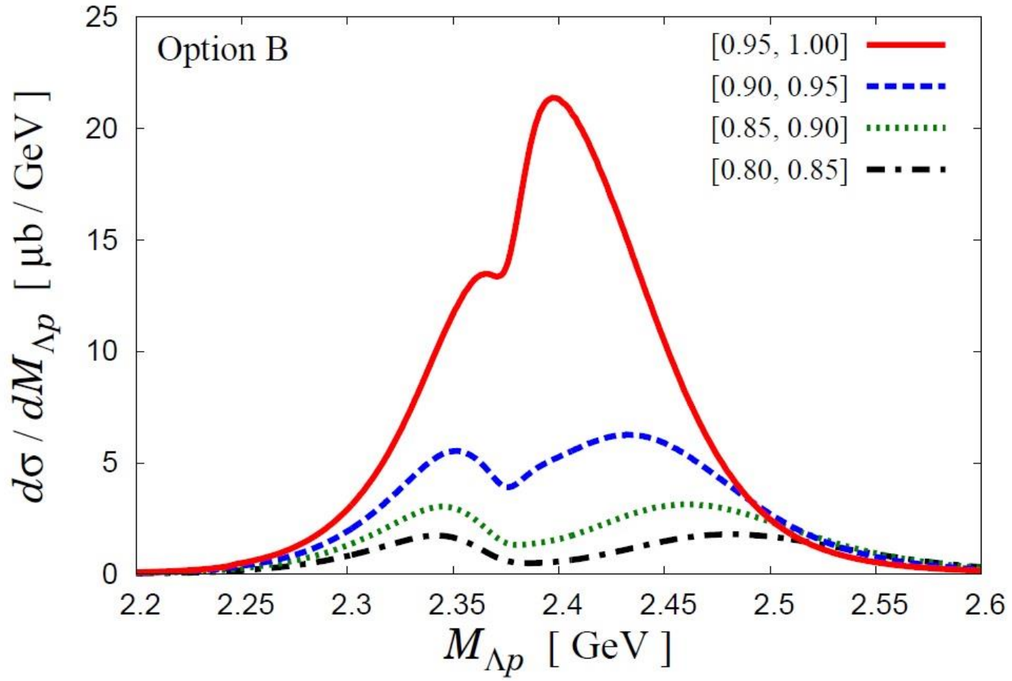
Sekihara, Oset, Ramos

Sekihara's calculation with QF-K and K-pp explains well the E15 $\cos\theta_{cm}$ distributions

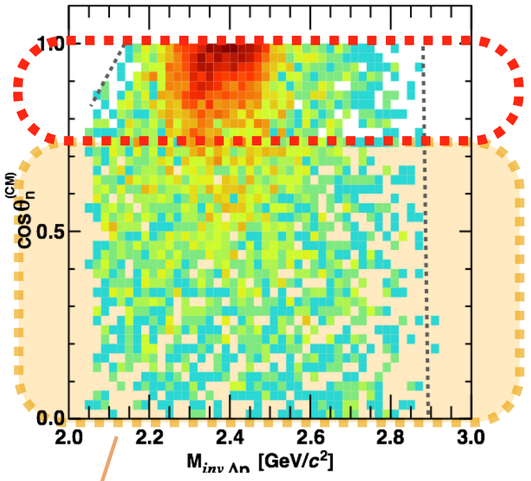
But…

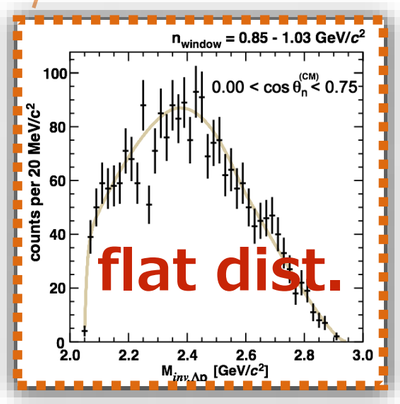




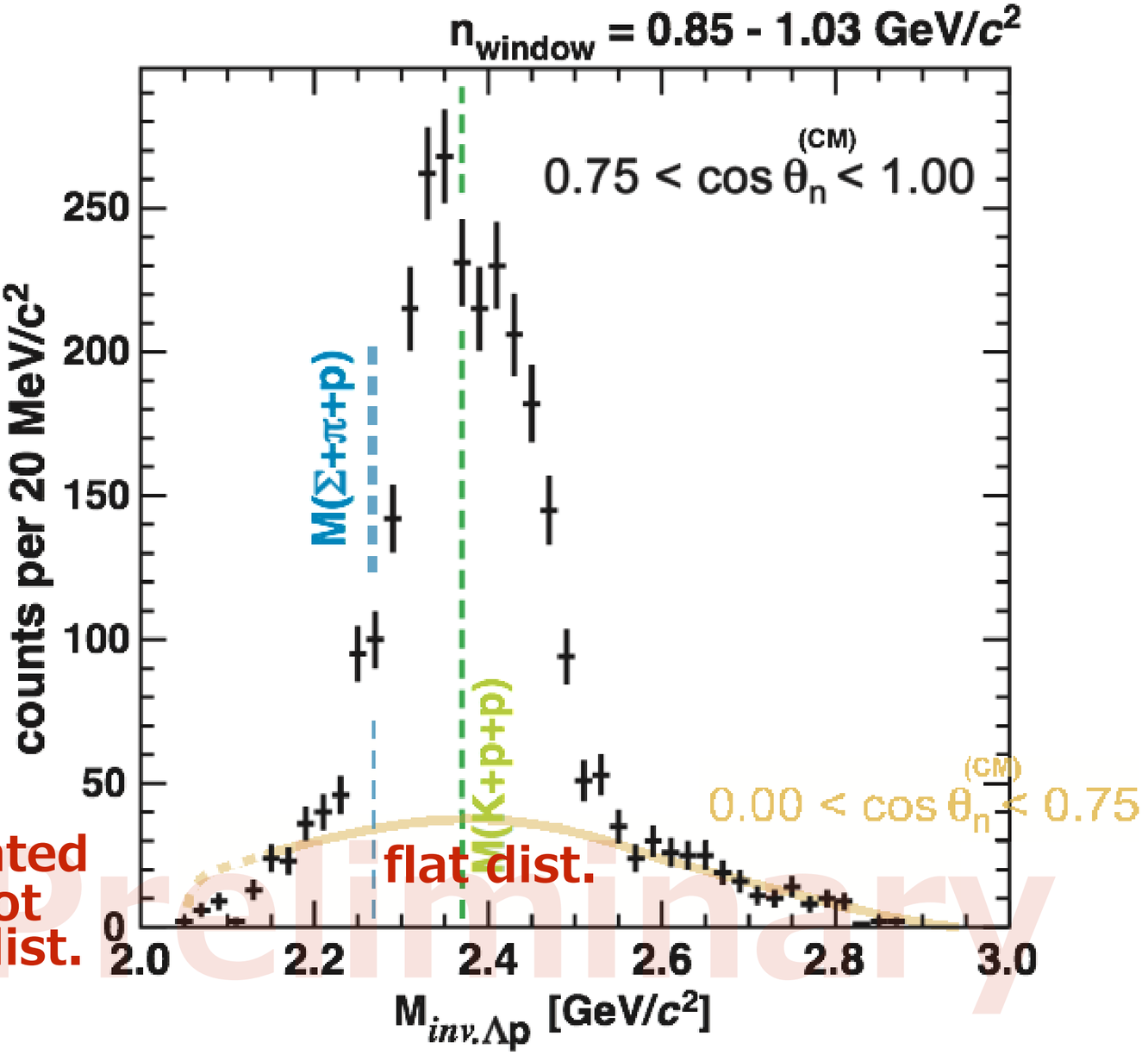


^{3}He(K^-, Λp)n:



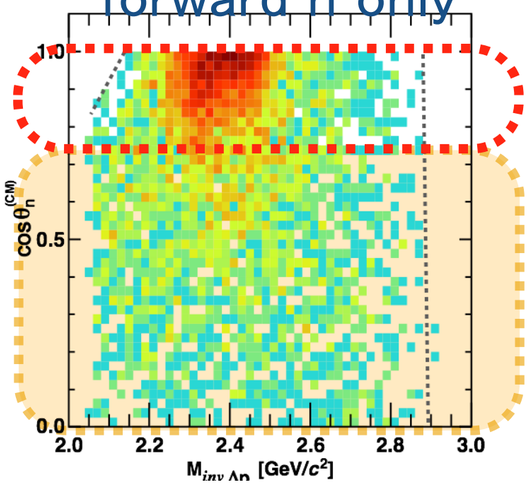


assuming uncorrelated
Λ*p channel do not
interfere with flat dist.



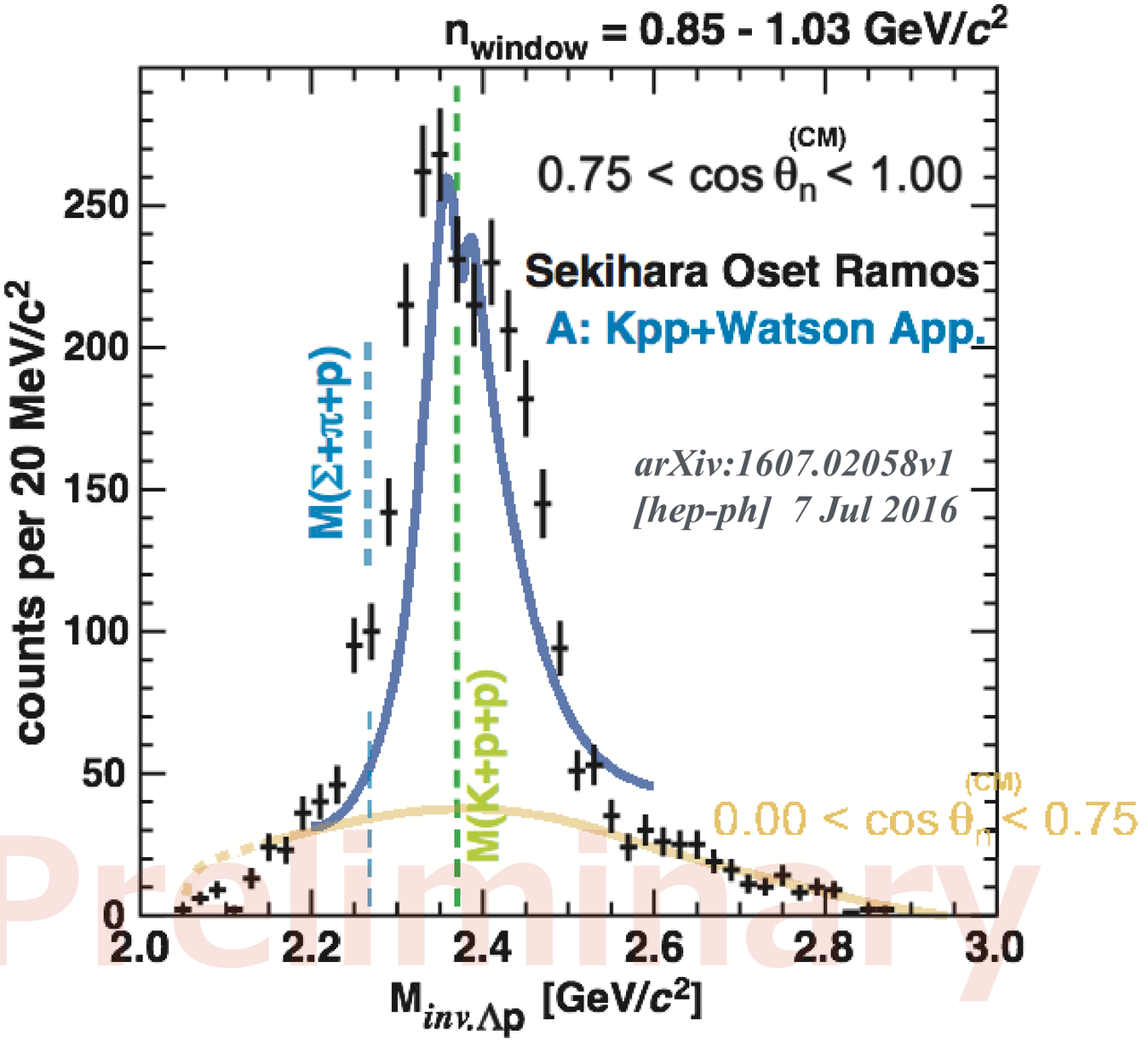
^{3}He(K^-, Λp)n: comparison

forward n only



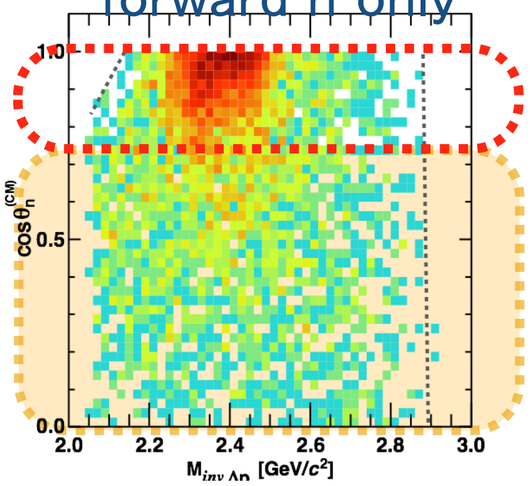
QE + “Kpp”

K multiple scattering



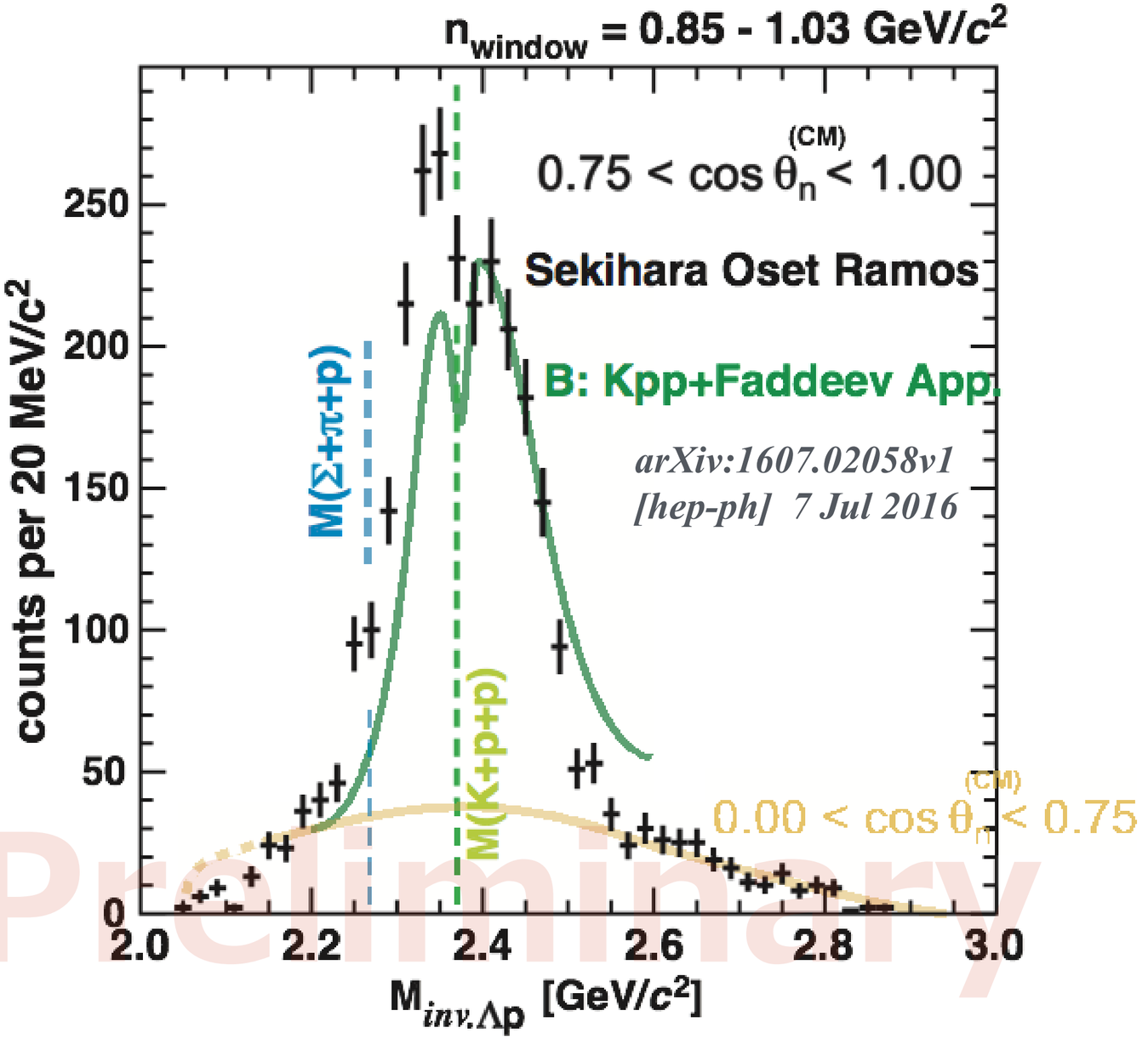
^{3}He(K^-, Λp)n: comparison

forward n only



QE + “Kpp”

K multiple scattering



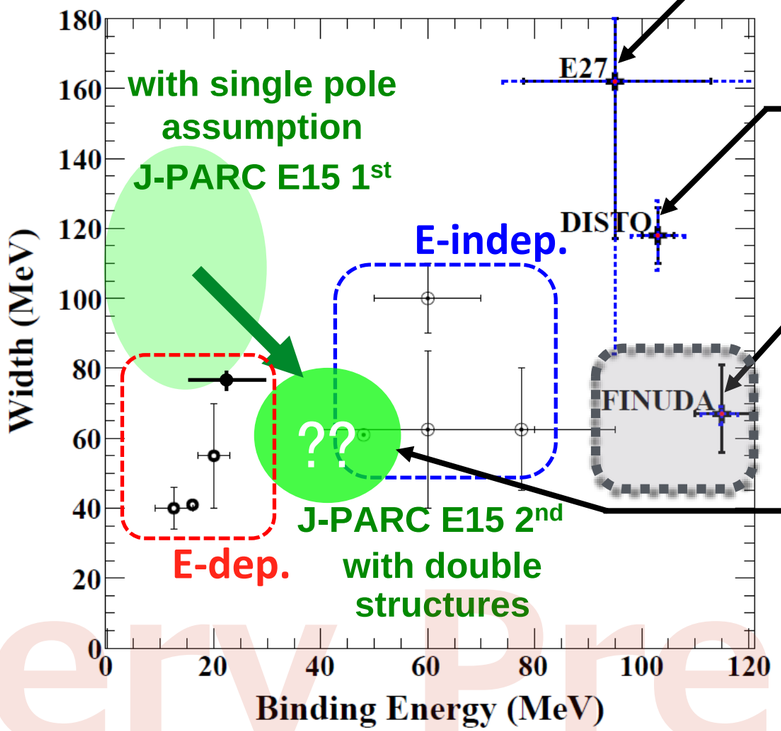
Recent status of K^-pp bound state

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

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

HADES
$pp \to \Lambda pK^+$

^{3}He(K$^-$, Λ p)n:

could be the first convincing data
… after a long journey …


University
of Victoria
British Columbia
Canada

大阪大学
OSAKA UNIVERSITY

THE UNIVERSITY OF TOKYO

서 울 대 학 교
SEOUL NATIONAL UNIVERSITY

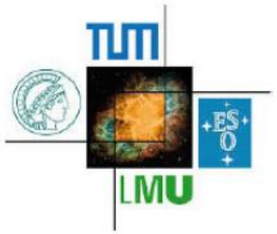
POLITECNICO
MILANO

CENTRO
FERMI
Museo Storico della Fisica e
Centro Studi e Ricerche Enrico Fermi

INFN
Istituto Nazionale
di Fisica Nucleare
Laboratori Nazionali di Frascati

RCNP

TOKYO INSTITUTE OF TECHNOLOGY
DEPARTMENT OF PHYSICS

KYOTO UNIVERSITY
KYOTO JAPAN
FOUNDED 1897

TUM
ESO
LMU

THANKS


IFIN-HH





KOREA INSTITUTE OF
RADIOLOGICAL & MEDICAL SCIENCES

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