

A Search for Deeply Bound Kaonic Nuclear States at J-PARC

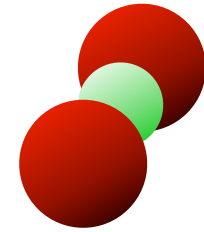
- Introduction
- J-PARC E15 1st stage physics run
- Forward particle spectrum
- Summary

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Tokyo Institute of Technology
for E15 collaborations

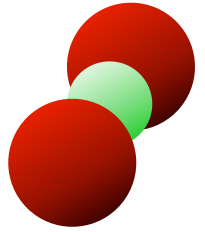
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Kaonic nuclei



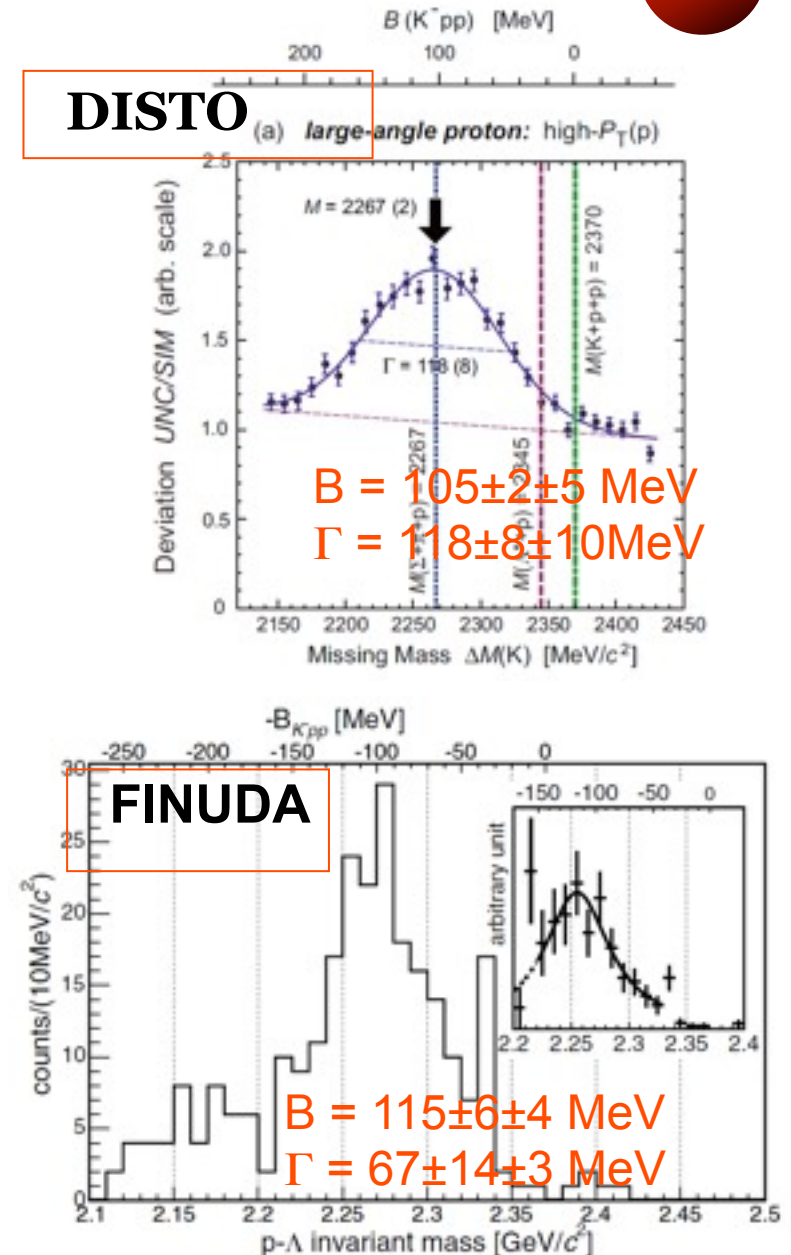
- Kaonic nucleus is a bound state of nucleus and anti-Kaon ($\bar{K}NN$, $\bar{K}NNN$, $\bar{K}\bar{K}NN$, ...)
- Interaction between proton and anti-Kaon is strongly attractive
 - high density?
 - $\Lambda(1405) \Leftrightarrow \bar{K}N$? $\Sigma\pi$?
 - chiral symmetry

The simplest kaonic nuclei $\bar{K}NN$



chiral & energy dependent	B.E.[MeV]	Γ [MeV]
N. Barnea, A. Gal, E.Z. Liverts(2012)	16	41
A. Dote, T. Hyodo, W. Weise(2008,09)	17-23	40-70
Y. Ikeda, H. Kamano, T. Sato(2010)	9-16	34-46
$\Lambda(1405)$ ansatz	B.E.[MeV]	Γ [MeV]
T. Yamazaki, Y. Akaishi(2002)	48	61
N.V. Shevchenko, A. Gal, J. Mares(2007)	50-70	90-110
Y. Ikeda, T. Sato (2007,2009)	60-95	45-80
S. Wycech, A.M. Green (2009)	40-80	40-85

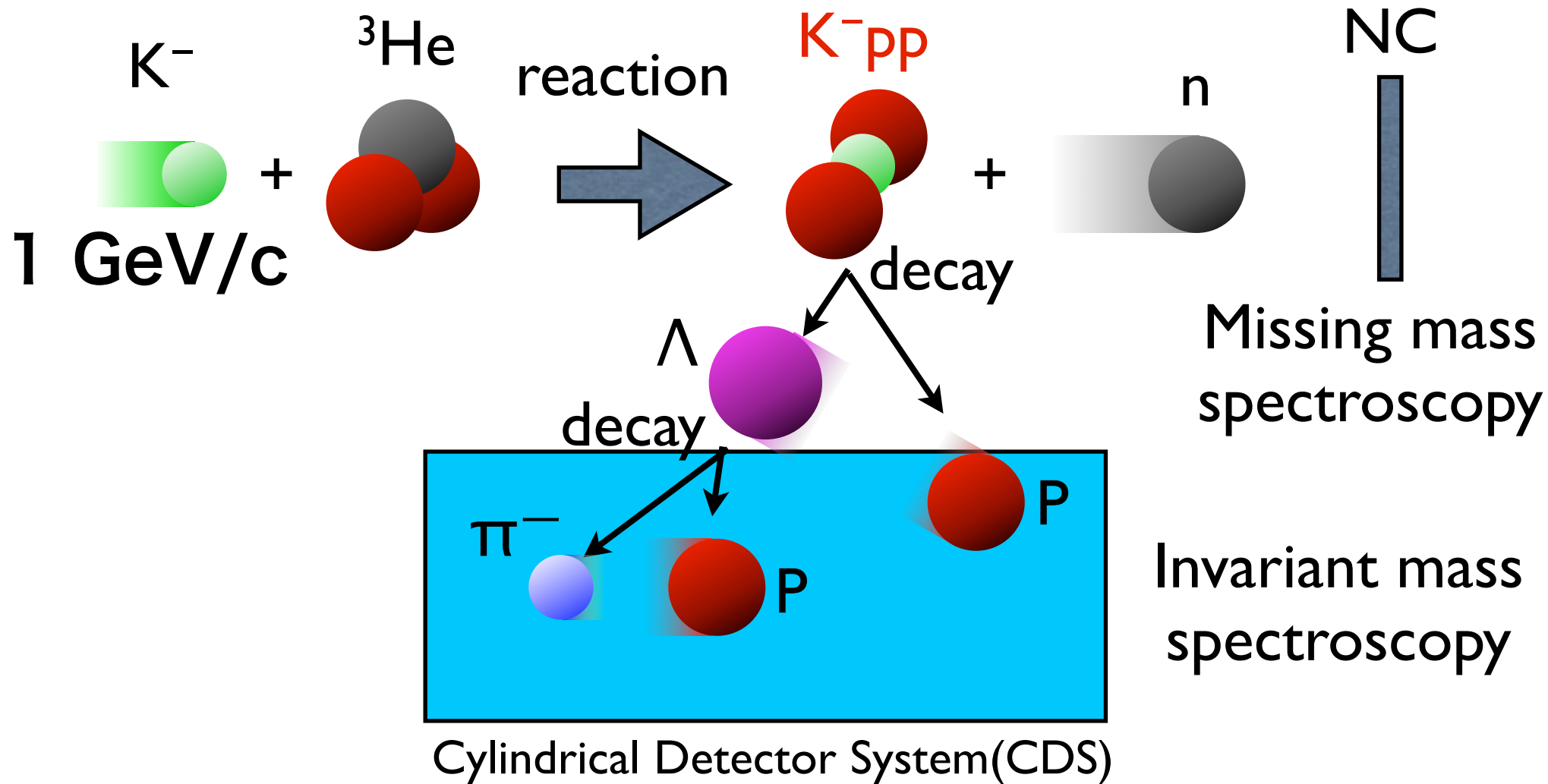
- Many theoretical calculations
- Little experimental information
- bound or not? B.E. and width?



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J-PARC E15 experiment

A search for the simplest kaonic nucleus K^-pp



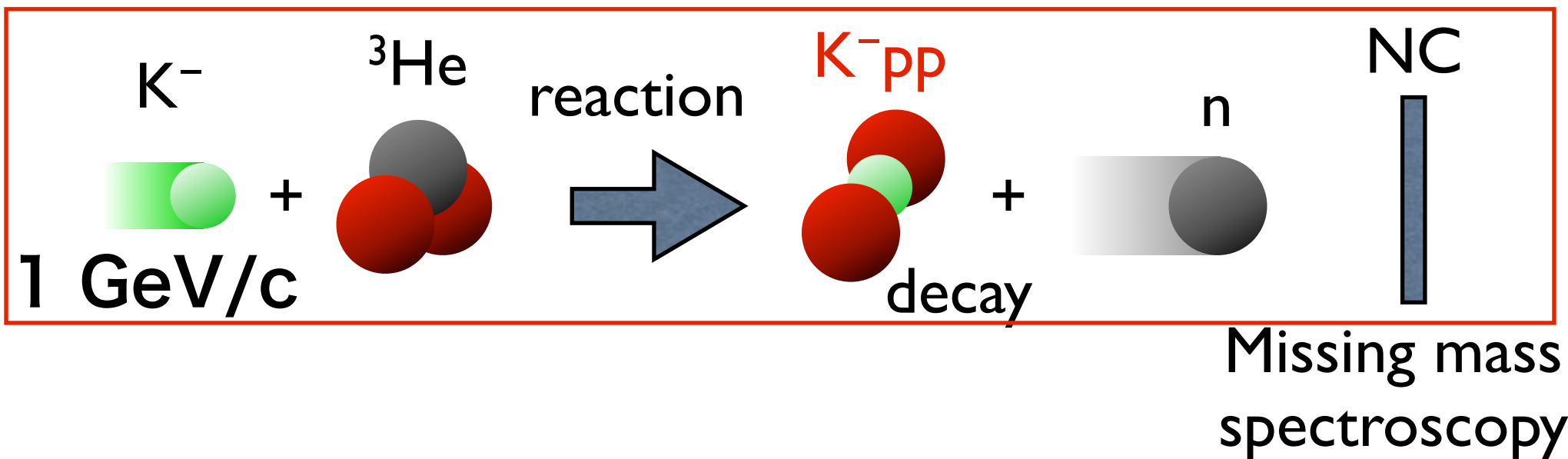
everything detected!

Low background !

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J-PARC E15 experiment

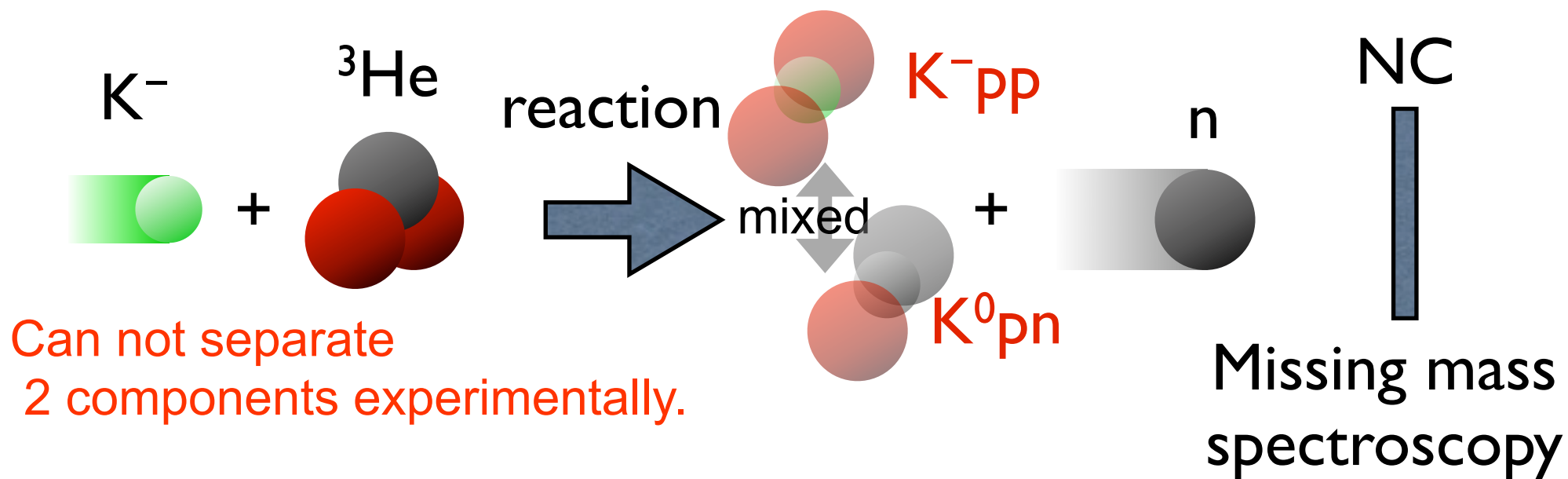
A search for the simplest kaonic nucleus K^-pp



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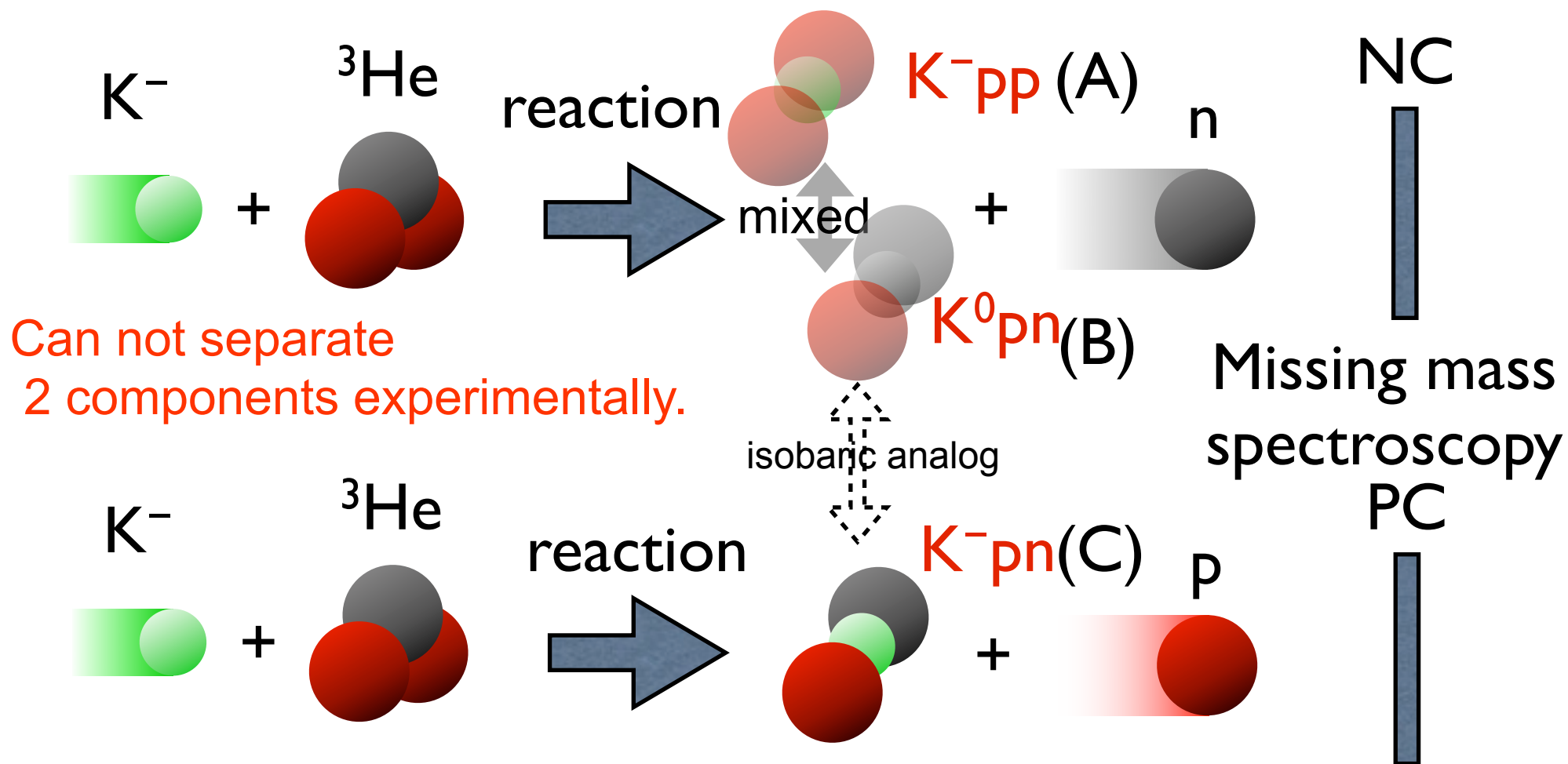
J-PARC E15 experiment

A search for the simplest kaonic nucleus K^-pp



J-PARC E15 experiment

A search for the simplest kaonic nucleus K^-pp

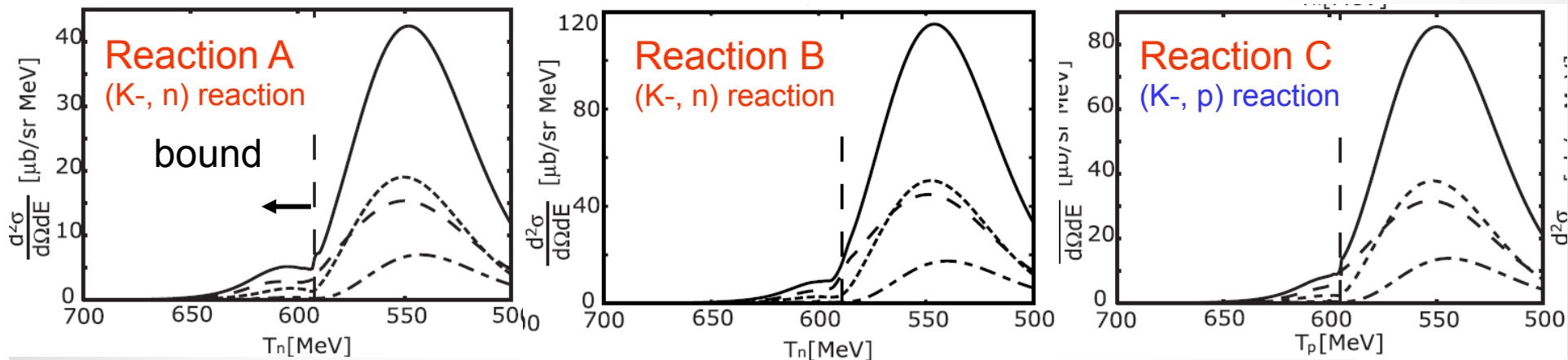
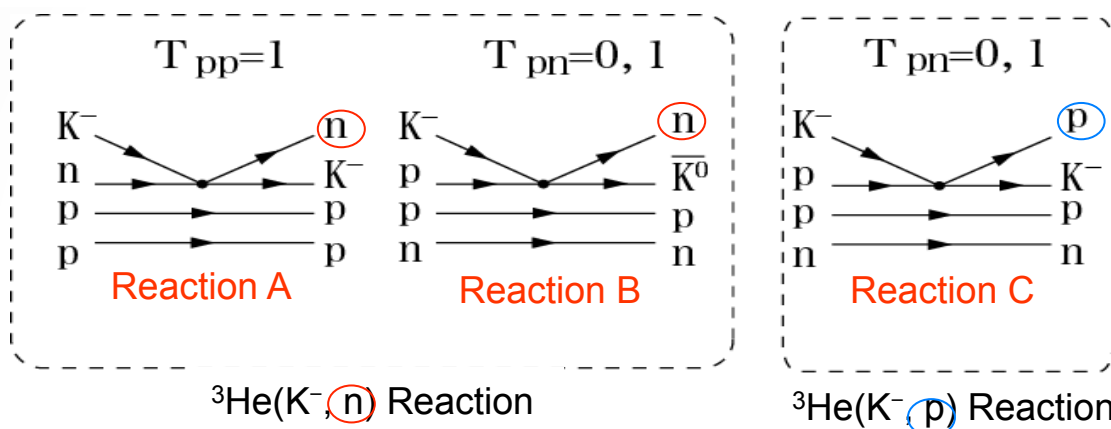


To compare with both ${}^3\text{He}(K^-, n/p)$ reactions,
 We can get the information of isospin dependence of reactions.

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Theoretical calculation on ${}^3\text{He}(K^-, p/n)$

Calculation of $(K^-, n/p)\bar{K}NN$ missing mass spectrum



J. Yamagata-Sekihara, D. Jido, H. Nagahiro, and S. Hirenzaki.,
 Phys. Rev. C80, 045204 (2009)

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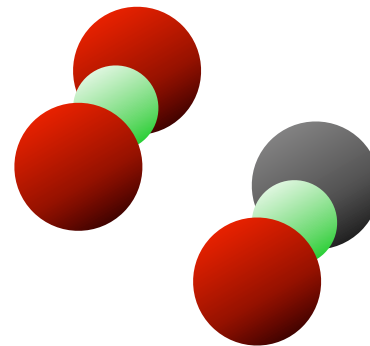
J-PARC E15 1st stage physics run

- Accumulated data
 - w/ liquid helium-3 target: ~1% of original proposal

period	primary beam intensity	duration	Kaons on target
March, 2013	14.5 kW (18 Tppp, 6s cycle)	30 hours	0.9×10^9
May, 2013	24 kW (30 Tppp, 6s cycle)	88 hours	4.0×10^9

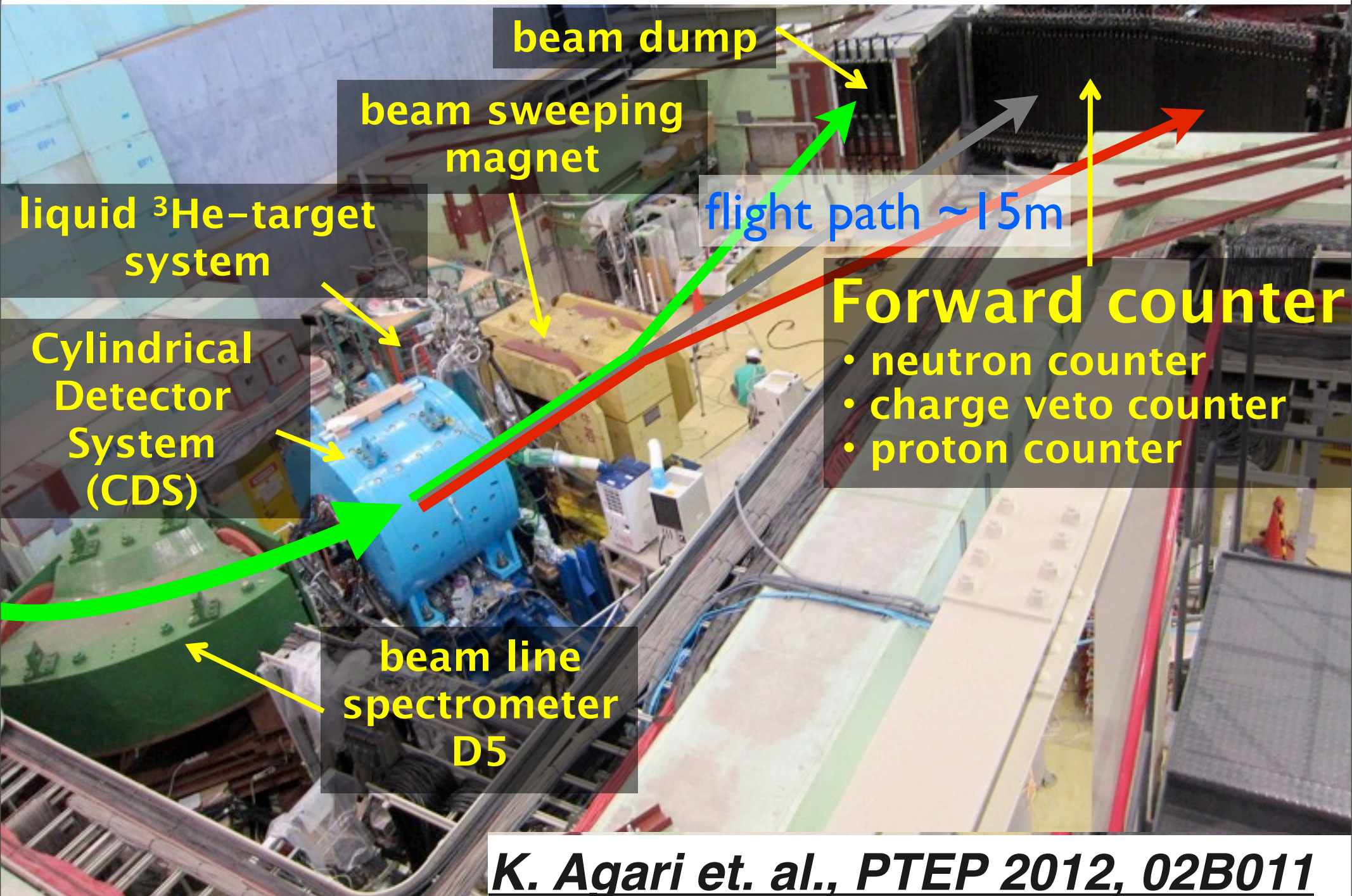
production target: Au 50% loss, spill length: ~2s, spill duty factor: ~45%

- In total, 5×10^9 K- on target
- empty target run, beam-through run, pion scattering run ...
- Expected physics output
 - ${}^3\text{He}(K^-, n)$, [& $\Lambda p n$]
 - ${}^3\text{He}(K^-, p)$, [${}^3\text{He}(K^-, d)$]
 - multi-nucleon absorption, hyperon production etc...

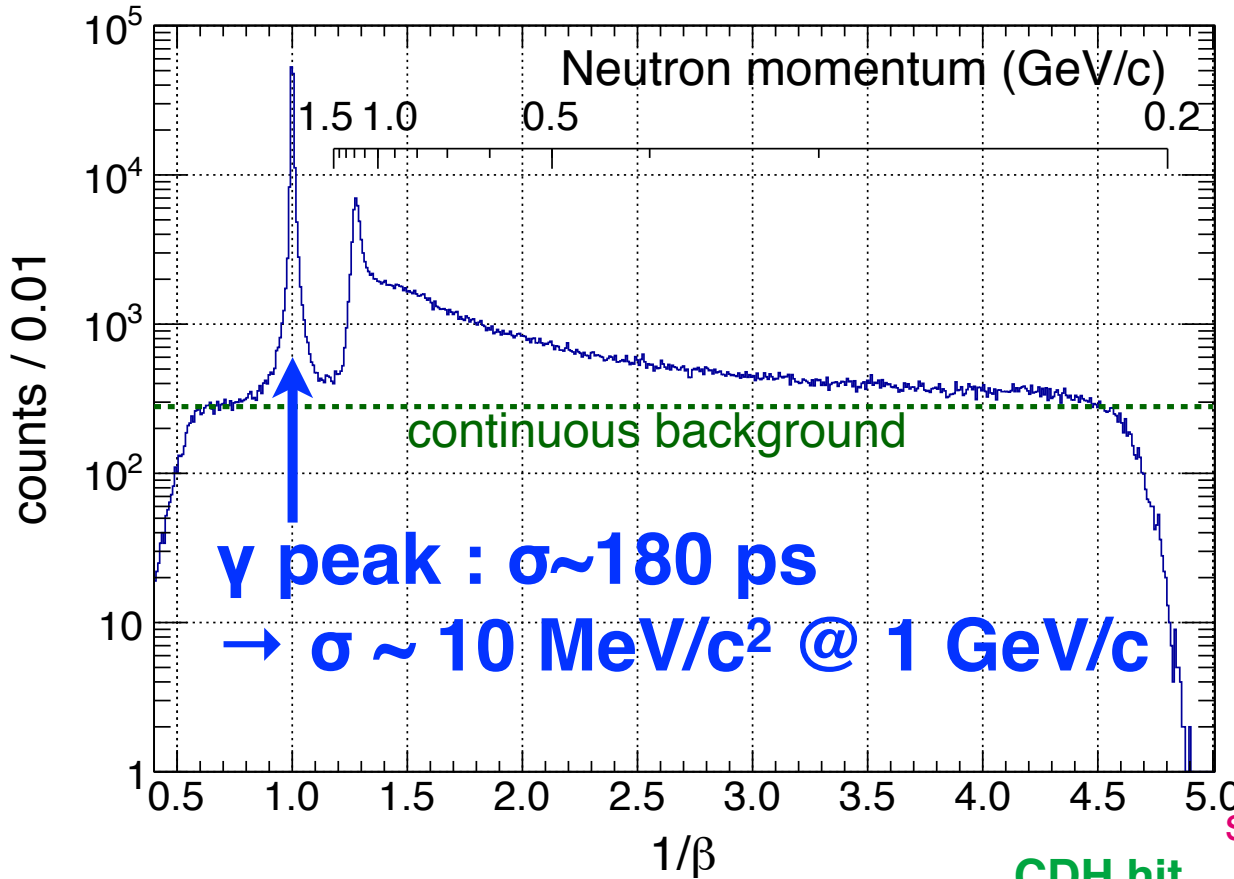


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the J-PARC K1.8BR spectrometer

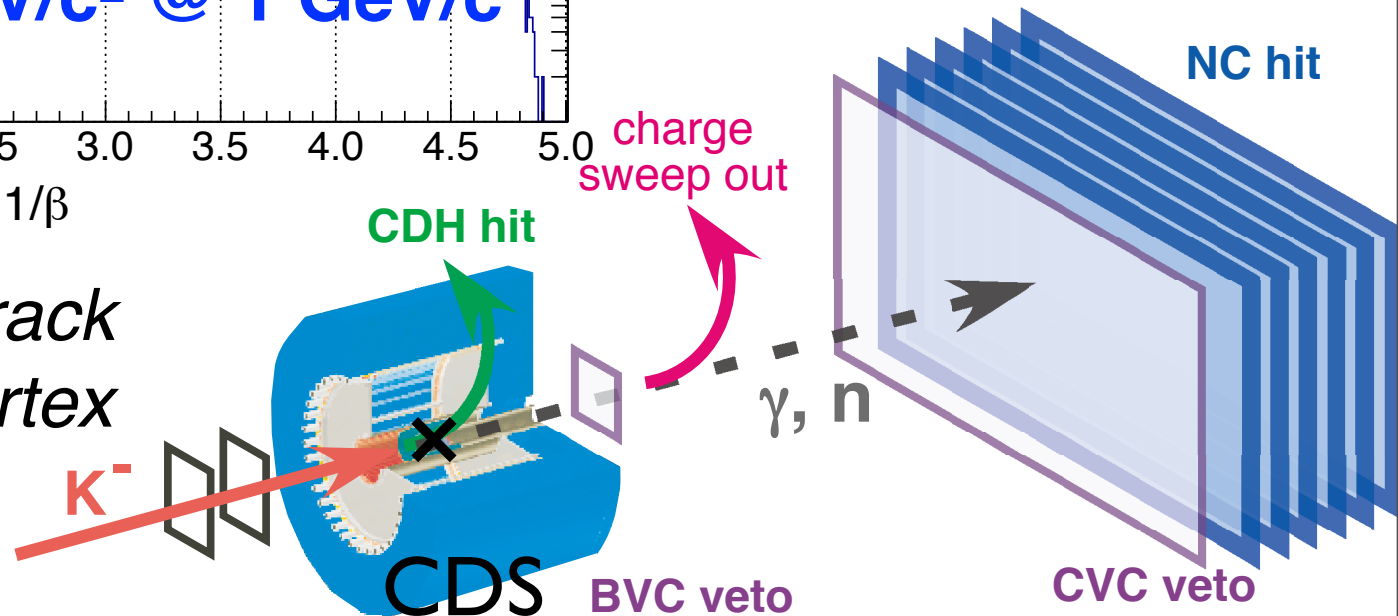


Forward neutral particle



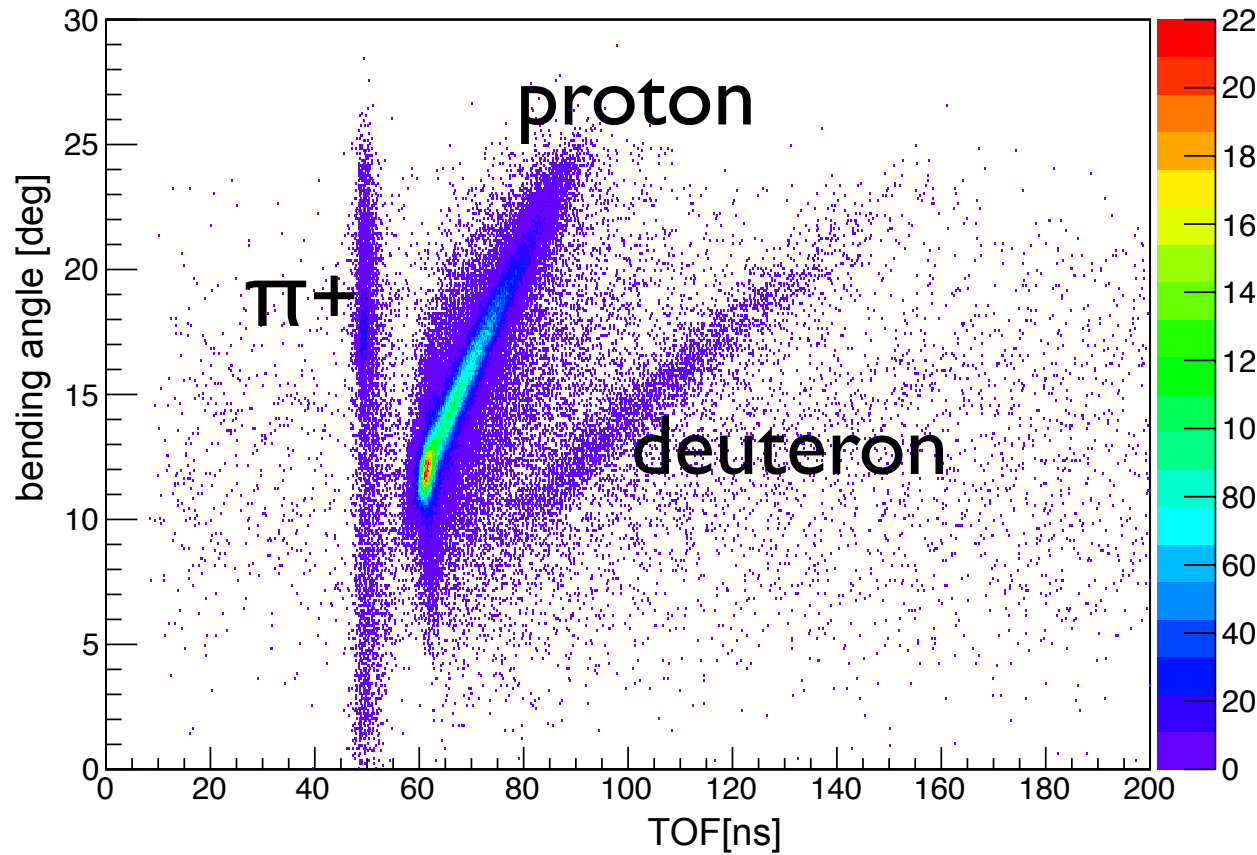
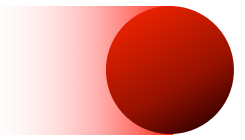
- **Neutron Counter**
 - W 3.2 m x H 1.5 m
 - T 5 cm x 7 layers
 - ~ 30% eff. @ 1 GeV/c
 - acceptance: 19.4 msr
 - ±6.2° (horizontal)
 - ±2.9° (vertical)

require 1 charged track to determine the vertex



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Forward Charged particle



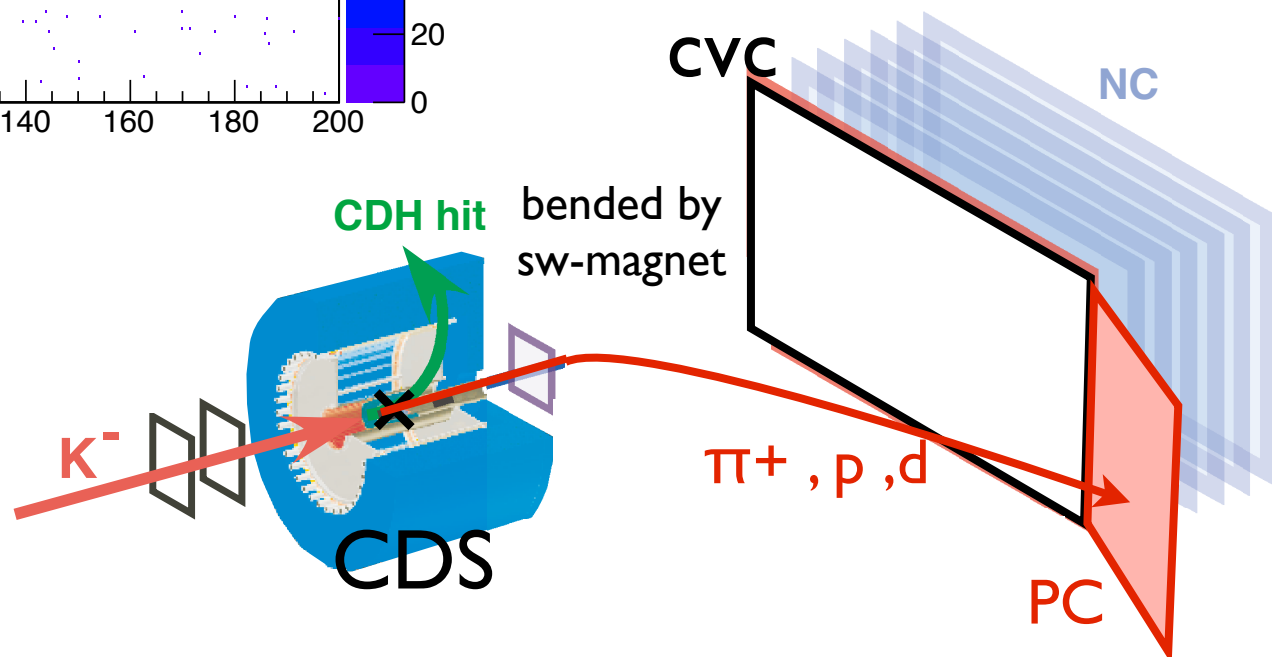
Bending Magnet

- used in KEK π^2 beam line
- aperture: 82cm(H)*40cm(V)
- pole length: 70cm
- 1.0T operation

Proton Counter

- w 2.7 m x H1.5 m
- T 3cm
- 27 seg

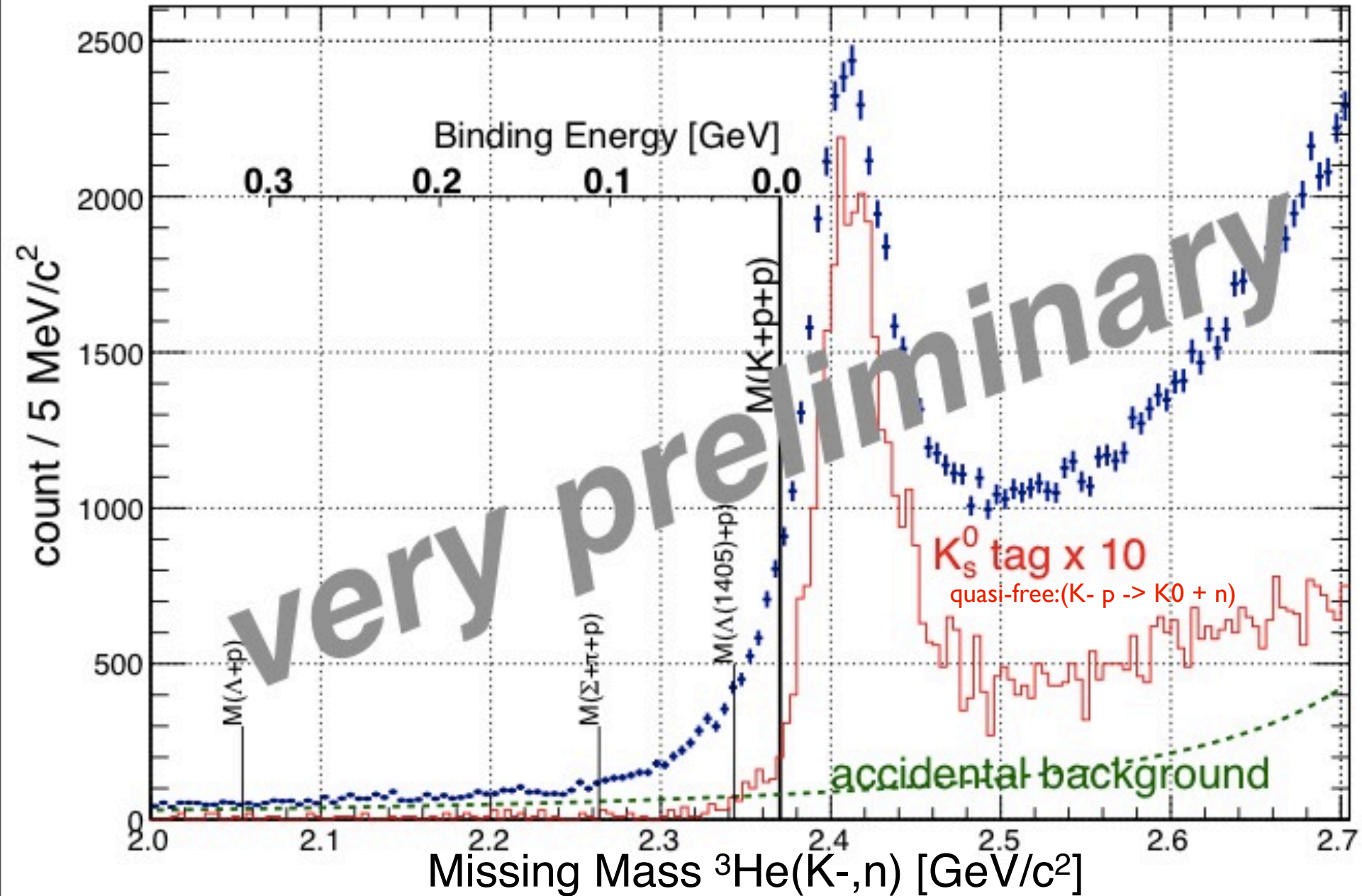
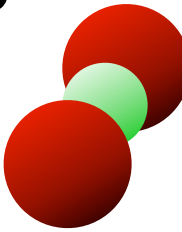
require 1 charged track to determine the vertex



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Inclusive neutron spectrum at forward angle

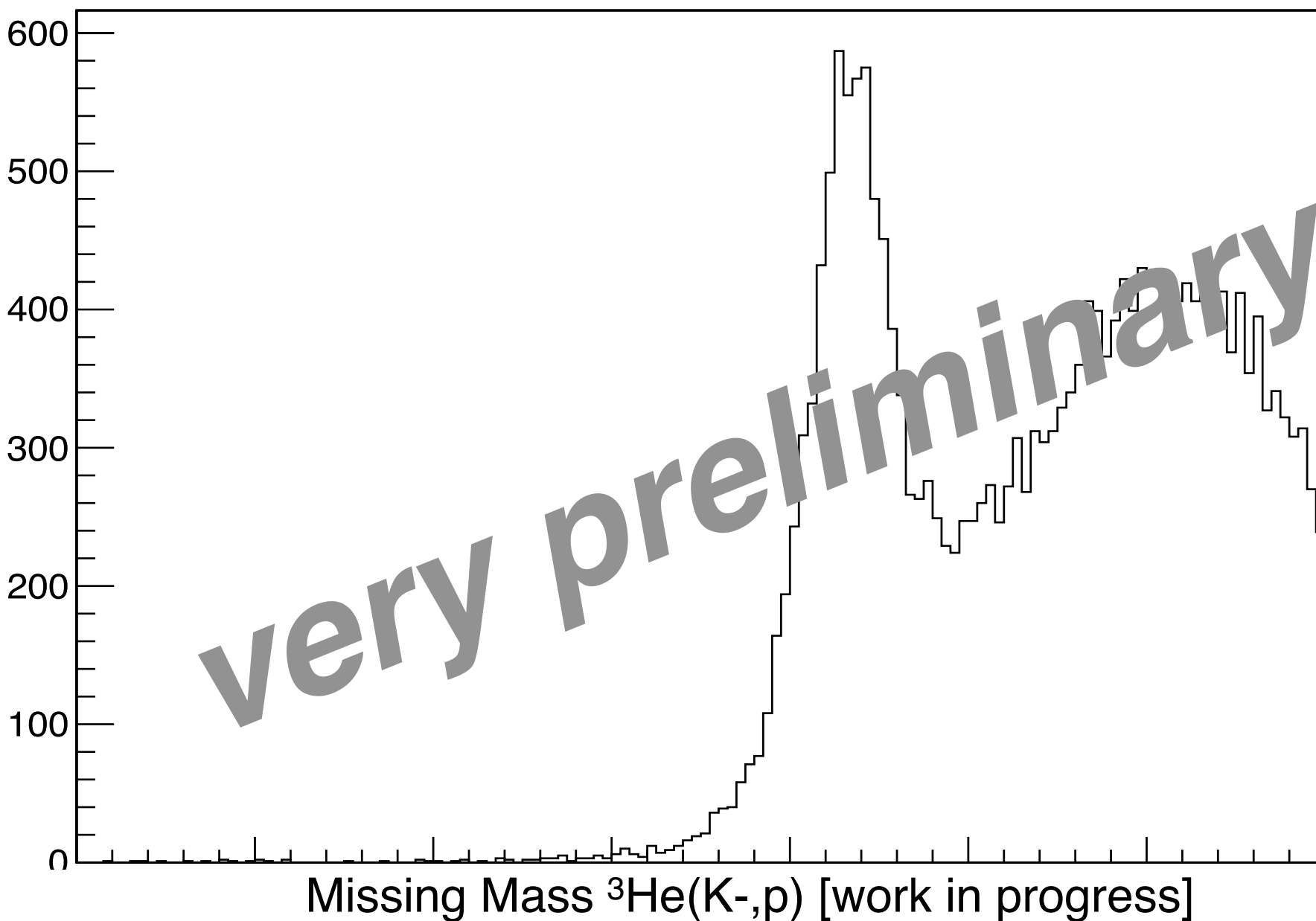
presented by hashimoto INPC2013@Firenze



quasi-free reaction (K-p \rightarrow K0 n) has been clearly seen in the spectra

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Inclusive proton spectrum at forward angle



quasi-free reaction ($K^-p \rightarrow K^- p$) has been clearly seen in the spectra

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Summary

- We have performed J-PARC E15 1st stage physics run to search for the K^-pp bound state.
 - **$\sim 5 \times 10^9$ kaons were irradiated on ^3He**
 - **Missing mass spectra for (K^-, n) reaction on ^3He has been presented**
 - **also missing mass spectra for (K^-, p) reaction on ^3He are presented in first time.**
 - **in both case, quasi-free reaction. i.e. $(K^- p \rightarrow K^0 n$ or $K^- p \rightarrow K^- p$ reaction on ^3He nucleus) were clearly identified.**
- Further analysis results will appear soon !!
 - hunt small "K-pp" signal by reducing background, tagging decay particle etc...
 - $\Lambda p n$ daliz plot, hyperon production

E15 collaborator

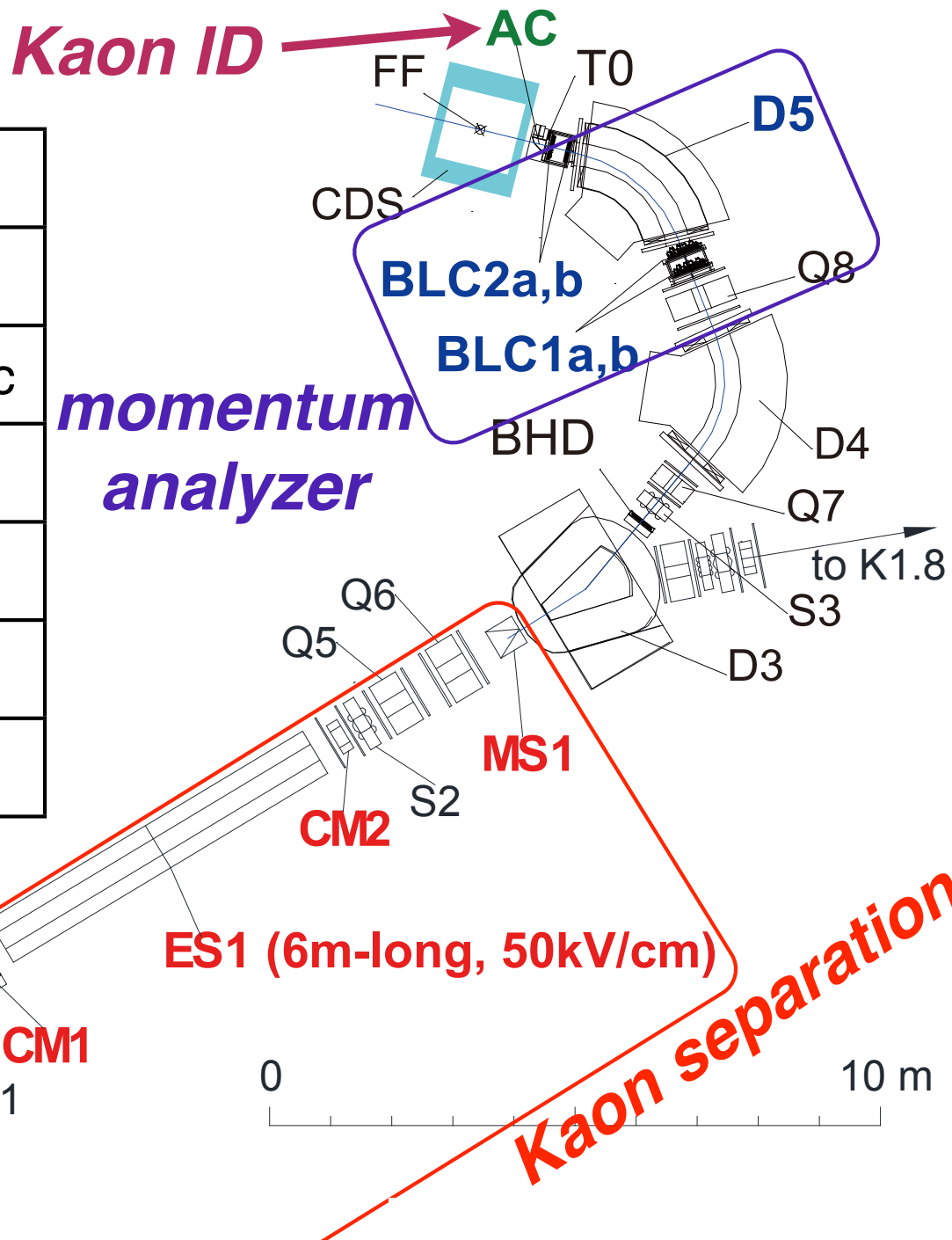
S. Ajimura^a, G. Beer^b, H. Bhang^c, M. Bragadireanu^d, P. Buehler^e, L. Busso^{f,g},
M. Cargnelli^e, S. Choi^c, C. Curceanu^h, S. Enomotoⁱ, D. Faso^{f,g}, H. Fujioka^j, Y. Fujiwara^k,
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Y. Matsuda^q, Y. Mizoi^l, O. Morra^f, T. Nagae^{j†}, H. Noumi^a, H. Ohnishi^m, S. Okada^m,
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K. Suzuki^e, S. Suzukiⁿ, T. Suzuki^k, K. Tanida^c, H. Tatsuno^h, M. Tokuda^o, D. Tomono^m,
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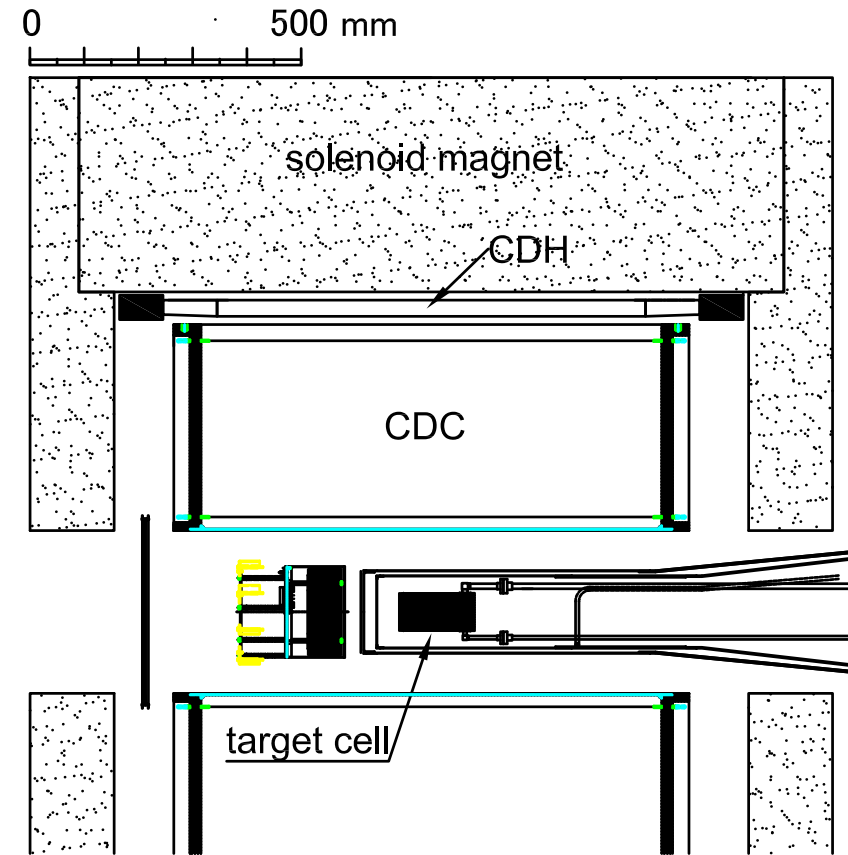
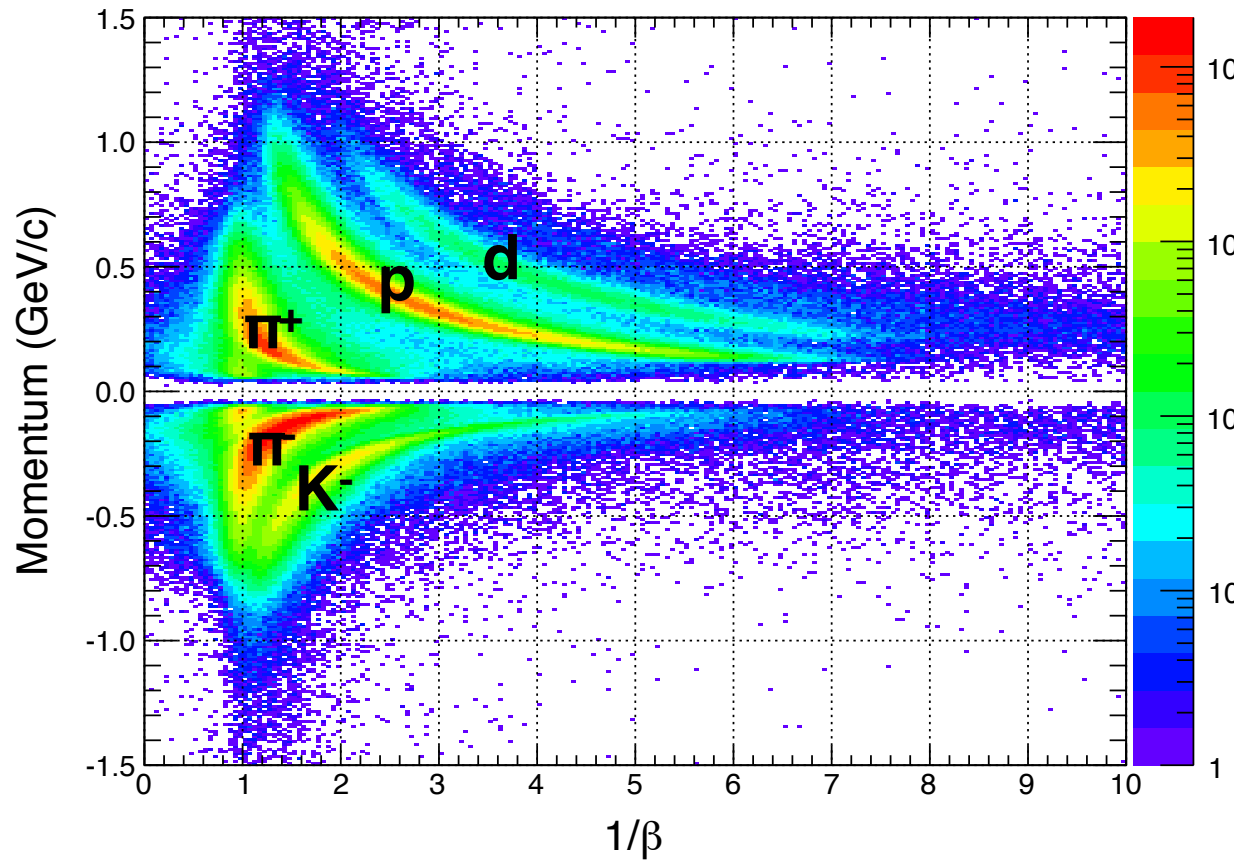
*Thank you
for your attention !*

Kaon beam quality at J-PARC K1.8BR

beam momentum	1 GeV/c
momentum bite	~ 3%
mom resolution @ 1 GeV/c	2.2 MeV/c
kaon / spill @ 24 kW	150 k
total beam / spill @ 24 kW	480 k
k/ π ratio	0.45
T1-FF length	31.3 m

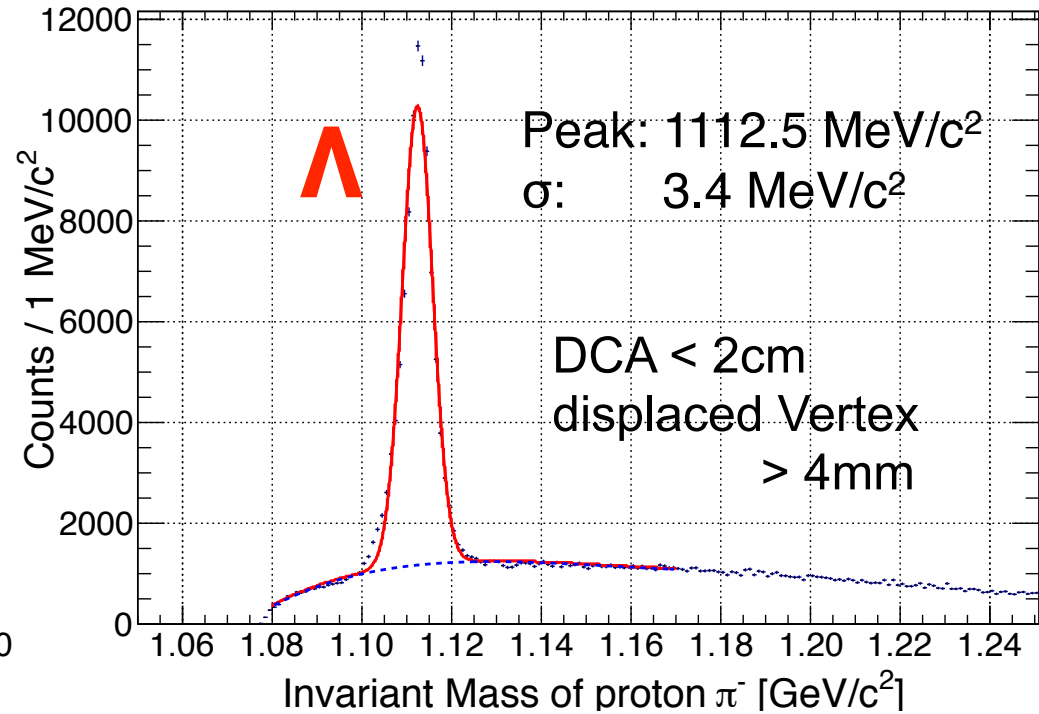
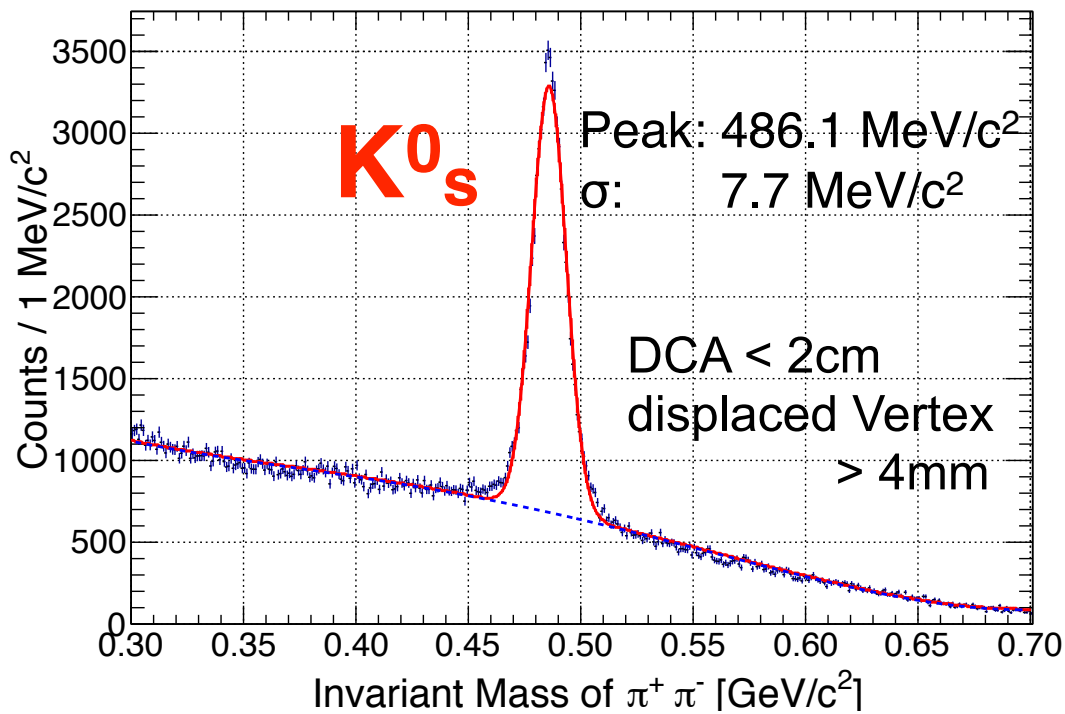


Cylindrical Detector System



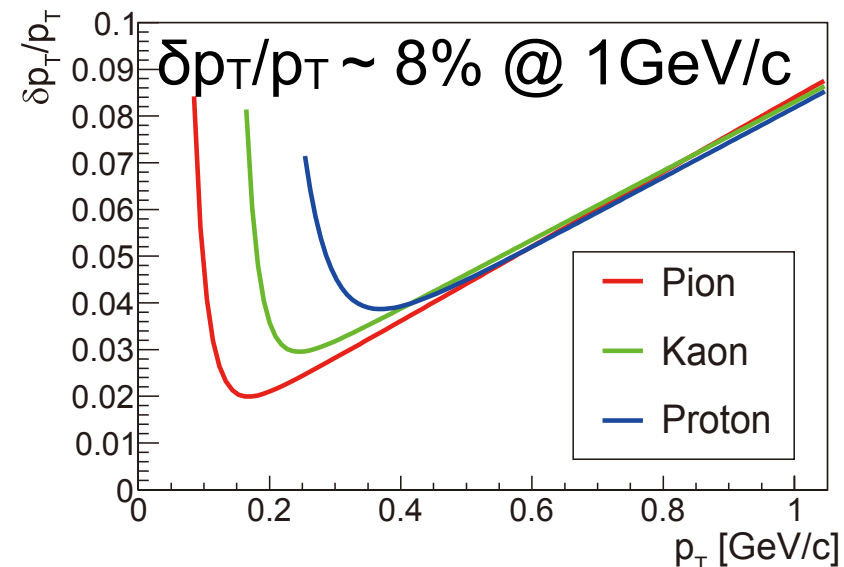
- **CDC (15 layers 1816 ch) + CDH (36 seg)**
 - cover 60% of solid angle.
 - **particle ID successfully done.**
 - **Kaon elastic event, deuterons are seen.**

Cylindrical Detector System

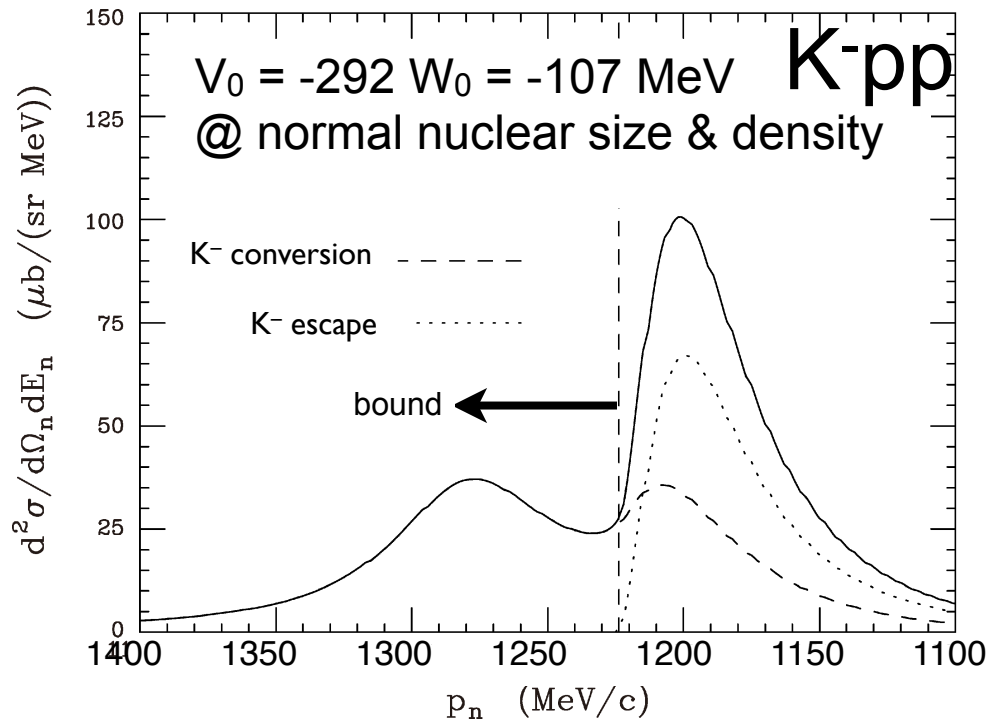


- **Design performance was achieved**

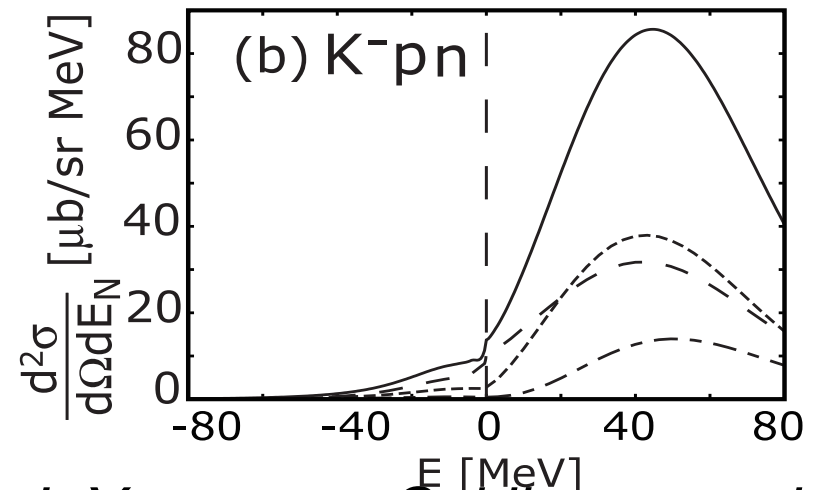
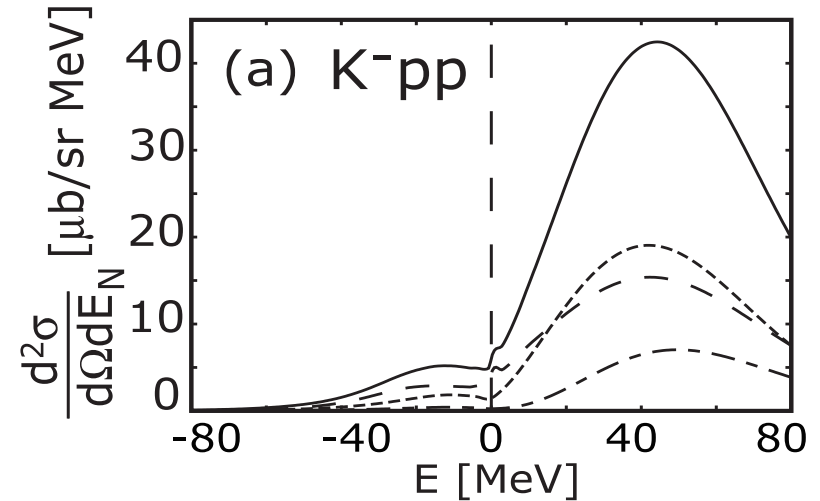
- Peak positions and widths are consistent with a simulation.
- Vertex resolution: xy ~ 2mm, z ~ 5mm
- ~ 10 MeV/c² resolution for Λp invariant mass



Theoretical calculation on ${}^3\text{He}(\text{K}^-, \text{N})$



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

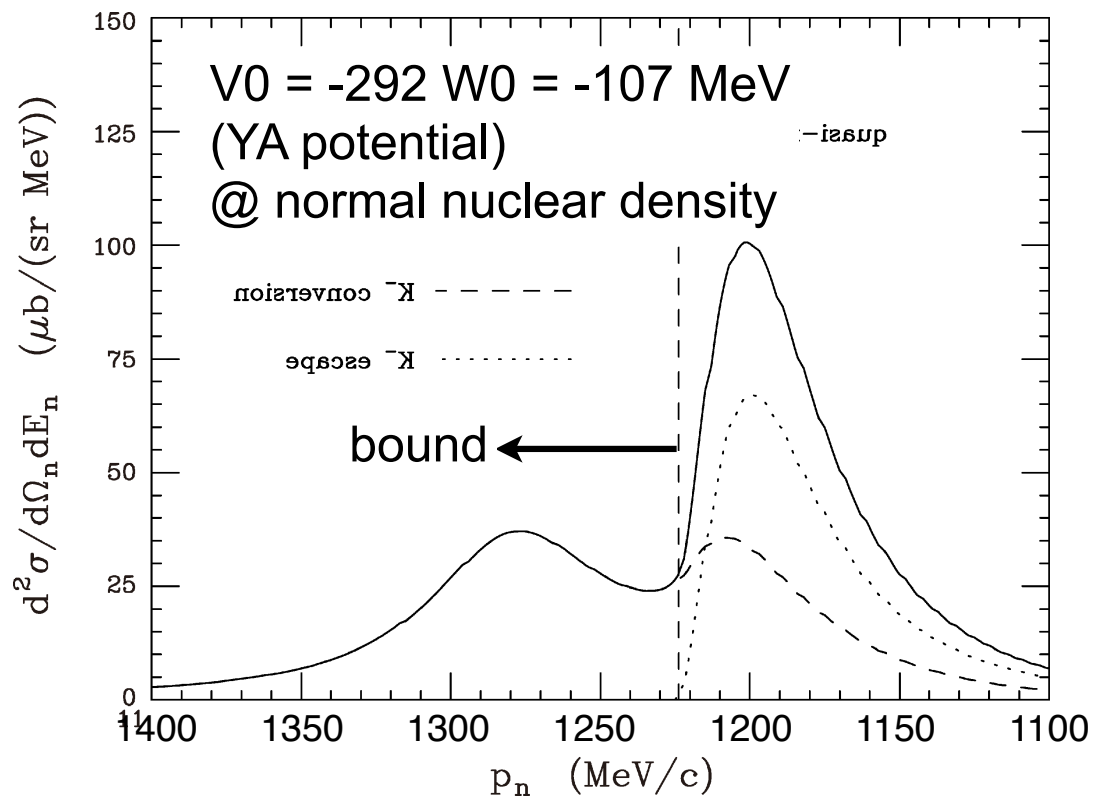


J. Yamagata-Sekihara et. al., Phys. Rev. C 80, 045204 (2009)

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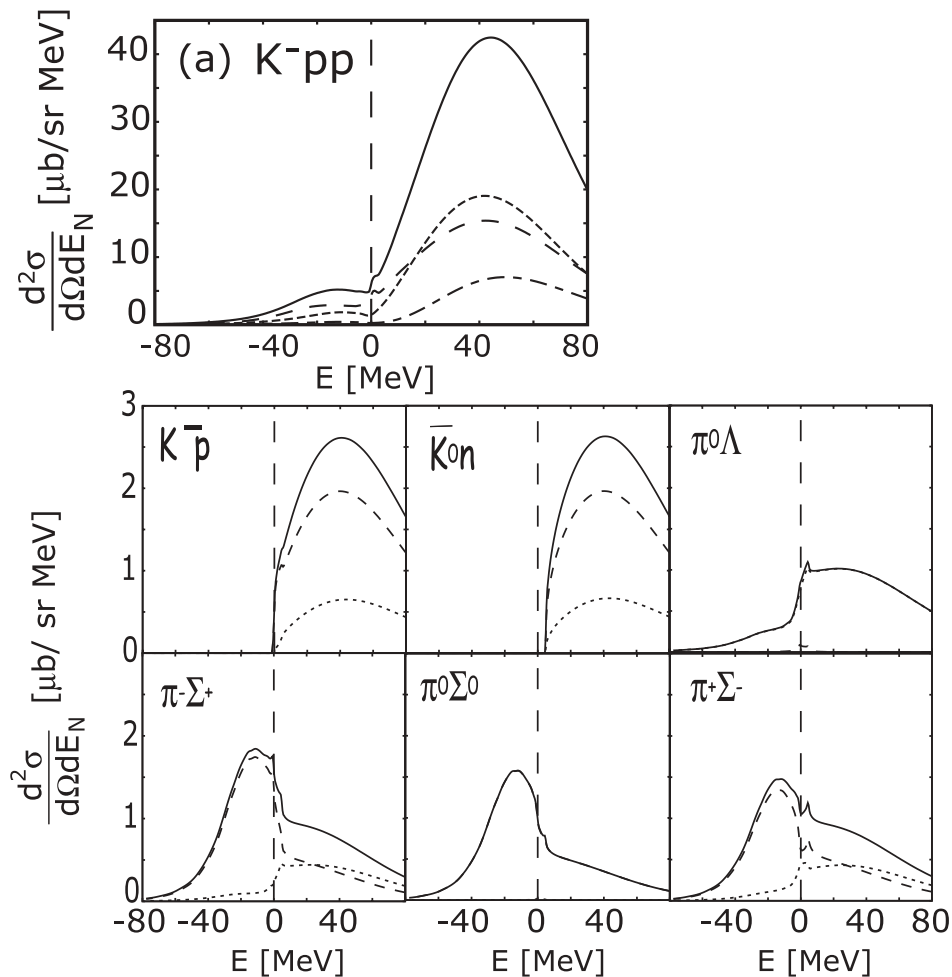
Theoretical calculation on ${}^3\text{He}(\text{K}^-, \text{n})$

$\text{K}^- + {}^3\text{He} \rightarrow \text{"K}^- \text{pp}" + \text{n}$ @ $P_{\text{K}}=1\text{GeV}/c$, $\theta=0^\circ$



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

**cross section
may be $> \text{mb}/\text{sr}$**



*J. Yamagata-Sekihara et al.,
Phys. Rev. C 80, 045204 (2009)*

**Σ tag may enhance the
structure in bound region.**