Search for the $K^{-}pp$ bound state via the ^{3}He(K^{-},n) reaction at 1 GeV/c

- Introduction
- J-PARC E15 experiment
- Latest result on ^{3}He(K^{-},n)

Tadashi Hashimoto for the J-PARC E15 collaboration

The J-PARC E15 collaboration

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Anti-kaon nucleon interaction at low energy

- **Kaon:**
  - The lightest hadron which contains a strange quark

$$K^+ = u\bar{s},\ K^0 = d\bar{s},\ \overline{K}^0 = \bar{d}s,\ K^- = \bar{u}s,$$

Kbar: Anti-Kaon

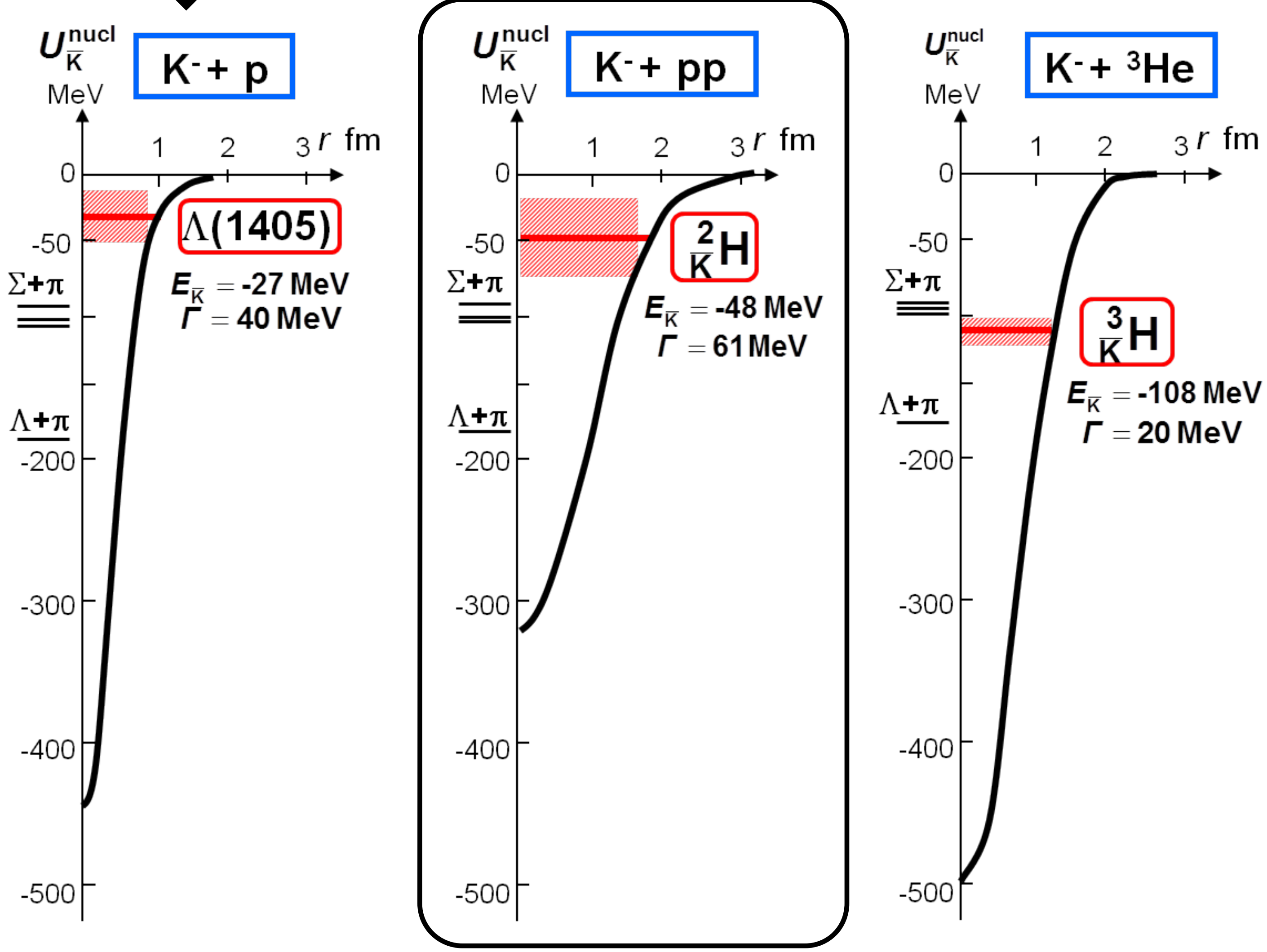
- **KbarN: Attractive in isospin=0**
  - Kaonic hydrogen X-ray measurements
  - Low-energy scattering experiments
- **Existence of Λ(1405) below the K^-p threshold**
  - Difficult to explain by a simple 3-quark state.
  - K-p quasi-bound state? Kp-πΣ two-pole structure?
- **Open question: how strong attraction??**

Kaonic nuclear bound state

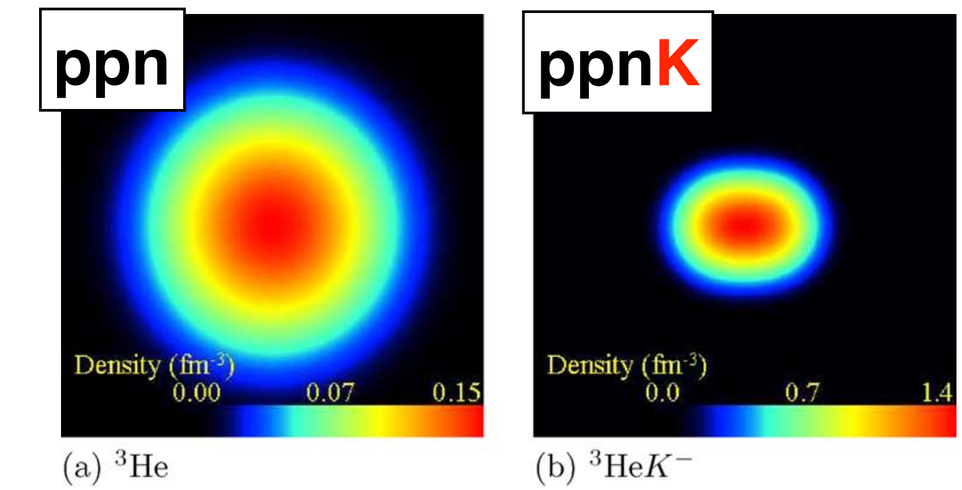
What will happen when anti-kaon is embedded in nucleus?

Assumption !

1.Y. Akaishi and T. Yamazaki. *Phys. Rev. C* **65,** 044005 (2002).
2.T. Yamazaki and Y. Akaishi. *Physics Letters B* **535,** 70–76 (2002).

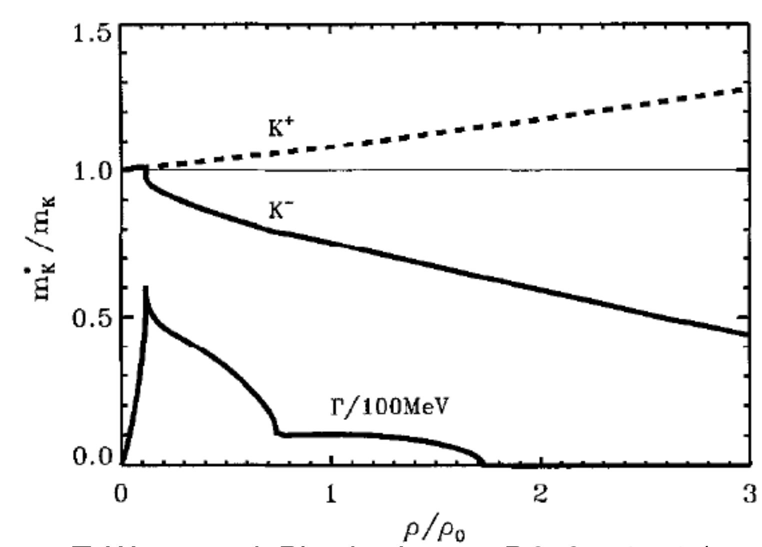


dense nuclei are predicted



A. Dote, H. Horiuchi, Y. Akaishi and T. Yamazaki, Phys. Lett. B 590 (2004) 51

Kaon in nuclear medium?



1.T. Waas *et al. Physics Letters B* **379,** 34–38 (1996).

K^-pp : $[K^{bar}(NN)_{I=1}]_{I=1/2}$

the lightest kaonic nucleus

$K^{-}pp$ few-body calculations

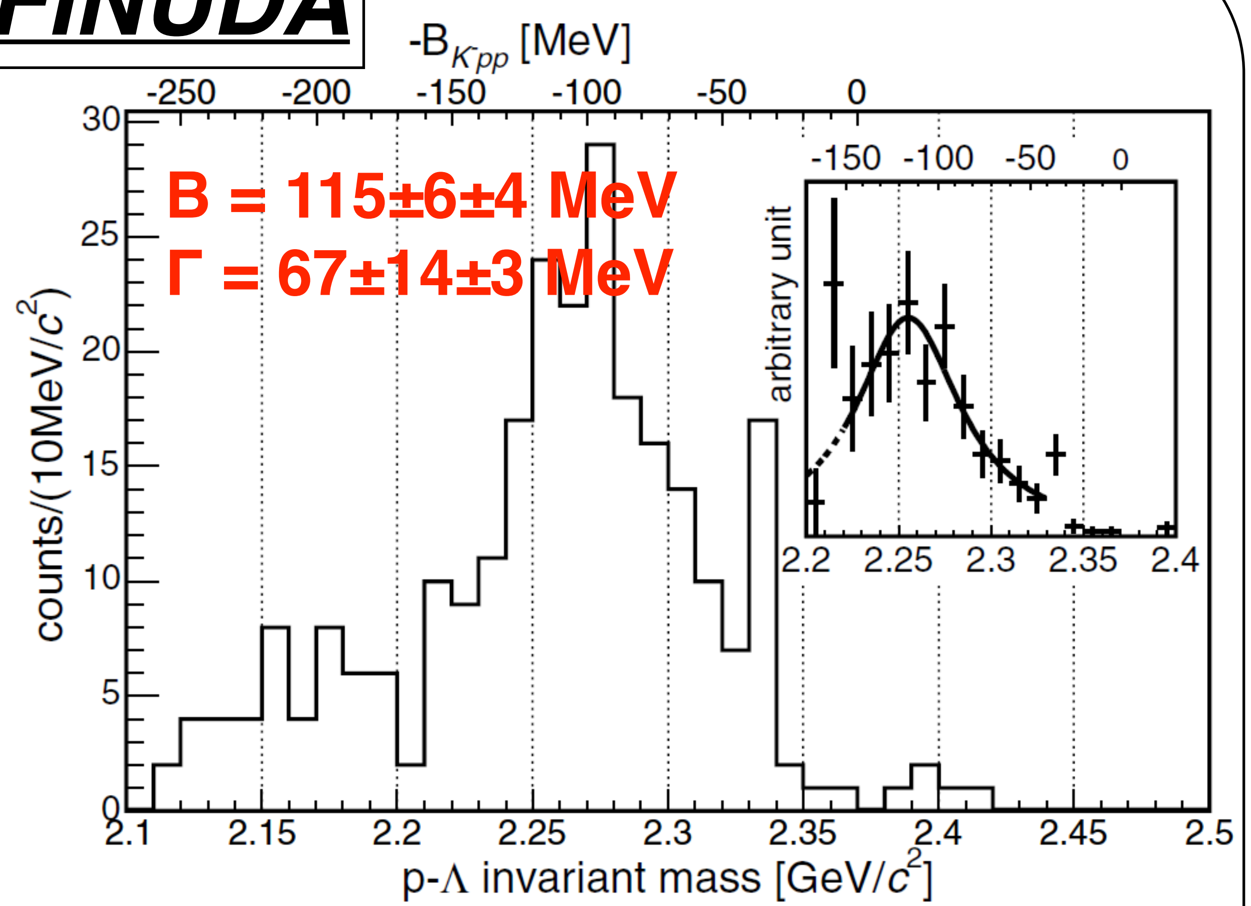
Λ(1405) ansatz	Method	B.E.[MeV]	Γ[MeV]
T. Yamazaki, Y. Akaishi(2002)	var.	48	61
N.V. Shevchenko, A. Gal, J. Mares(2007)	Fad.	50-70	90-110
Y. Ikeda, T. Sato (2007,2009)	Fad.	60-95	45-80
S. Wycech, A.M. Green (2009)	var.	40-80	40-85
S. Maeda, Y. Akaishi, T. Yamazaki (2013)	Fad.	51.5	61

chiral & energy dependent	Method	B.E.[MeV]	Γ[MeV]
N. Barnea, A. Gal, E.Z. Liverts(2012)	var.	16	41
A. Dote, T. Hyodo, W. Weise(2008,09)	var.	17-23	40-70
Y. Ikeda, H. Kamano, T. Sato(2010)	Fad.	9-16	34-46

- **All calculations agree on the existence of the bound state**
- **Model of the $K^{bar}N$ interaction makes large difference**

Claims of K⁻pp candidates

FINUDA



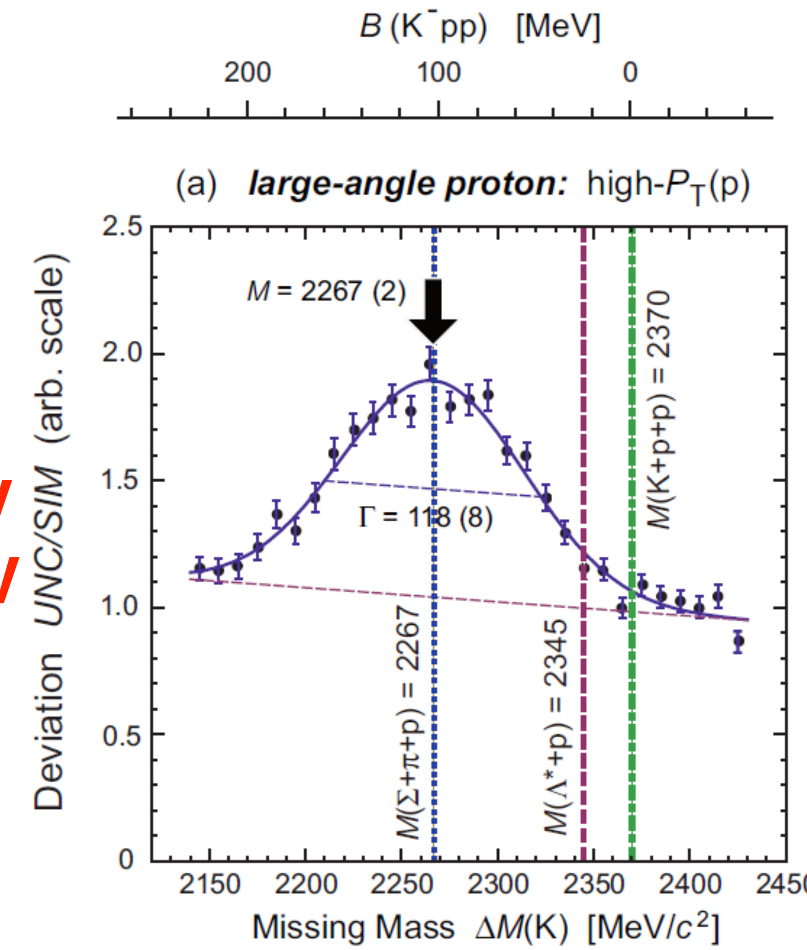
1.M. Agnello *et al. Phys. Rev. Lett.* **94,** 212303 (2005).

back-to-back Λp pair
from stopped K⁻ on ^{6}Li, ^{7}Li, ^{12}C

DISTO

@T_p=2.85 GeV

B = 105±2±5 MeV
Γ = 118±8±10MeV

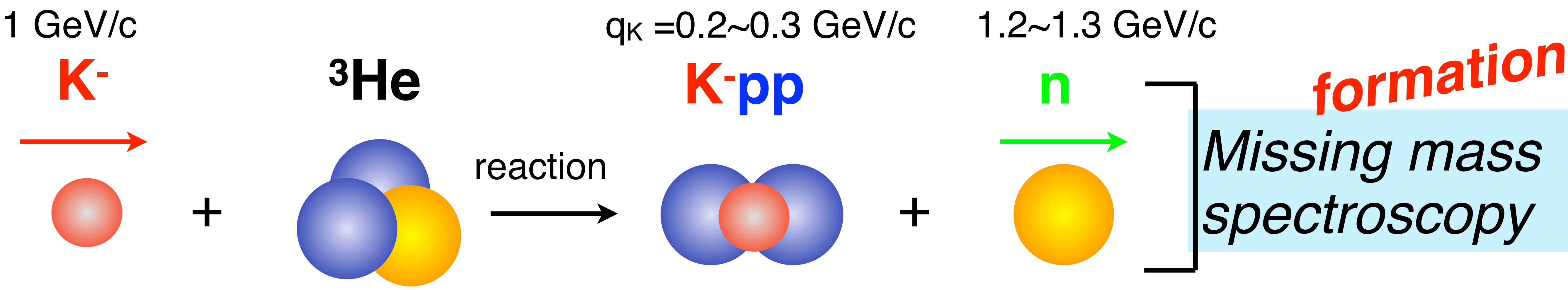


T. Yamazaki *et al. Phys. Rev. Lett.* **104,** 132502 (2010).
P. Kienle *et al. Eur. Phys. J. A* **48,** 183 (2012).

Exclusive pp→("K⁻pp"K⁺)→ΛpK⁺ channel

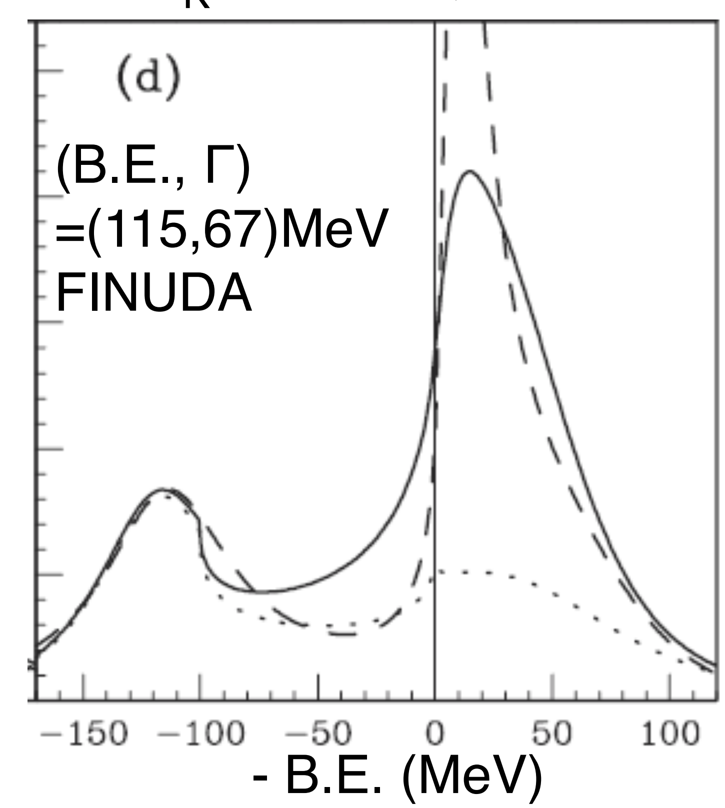
Deeper than any theories. Interpretations are still arguable…

J-PARC E15 1st stage physics run



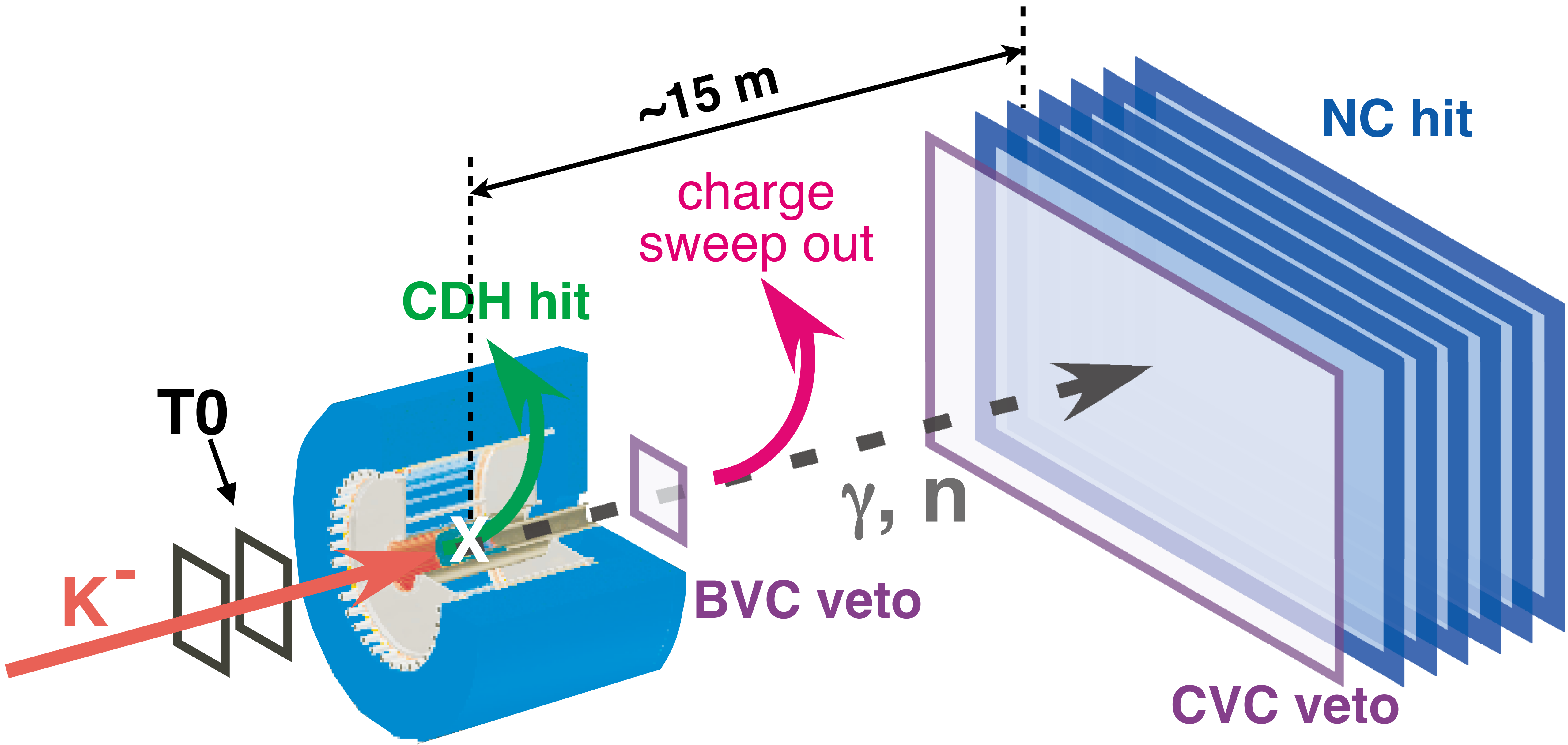
- **Kaon-induced simple reaction**
- **Focus on the formation channel**
  - ^{3}He(K$^-$,n)X semi-inclusive analysis
  - ^{3}He(K$^-$,p)X semi-inclusive analysis
  - Hint of exclusive ^{3}He(K$^-$,Λp)n events
- **First physics data taking in May, 2013**
  - 24 kW x 4 days, ~ 5 x 10^9 kaons on ^{3}He
  - < 1% of full proposal (270 kW x 40 days)

@ P_K=1GeV/c, θ_{lab}=0°



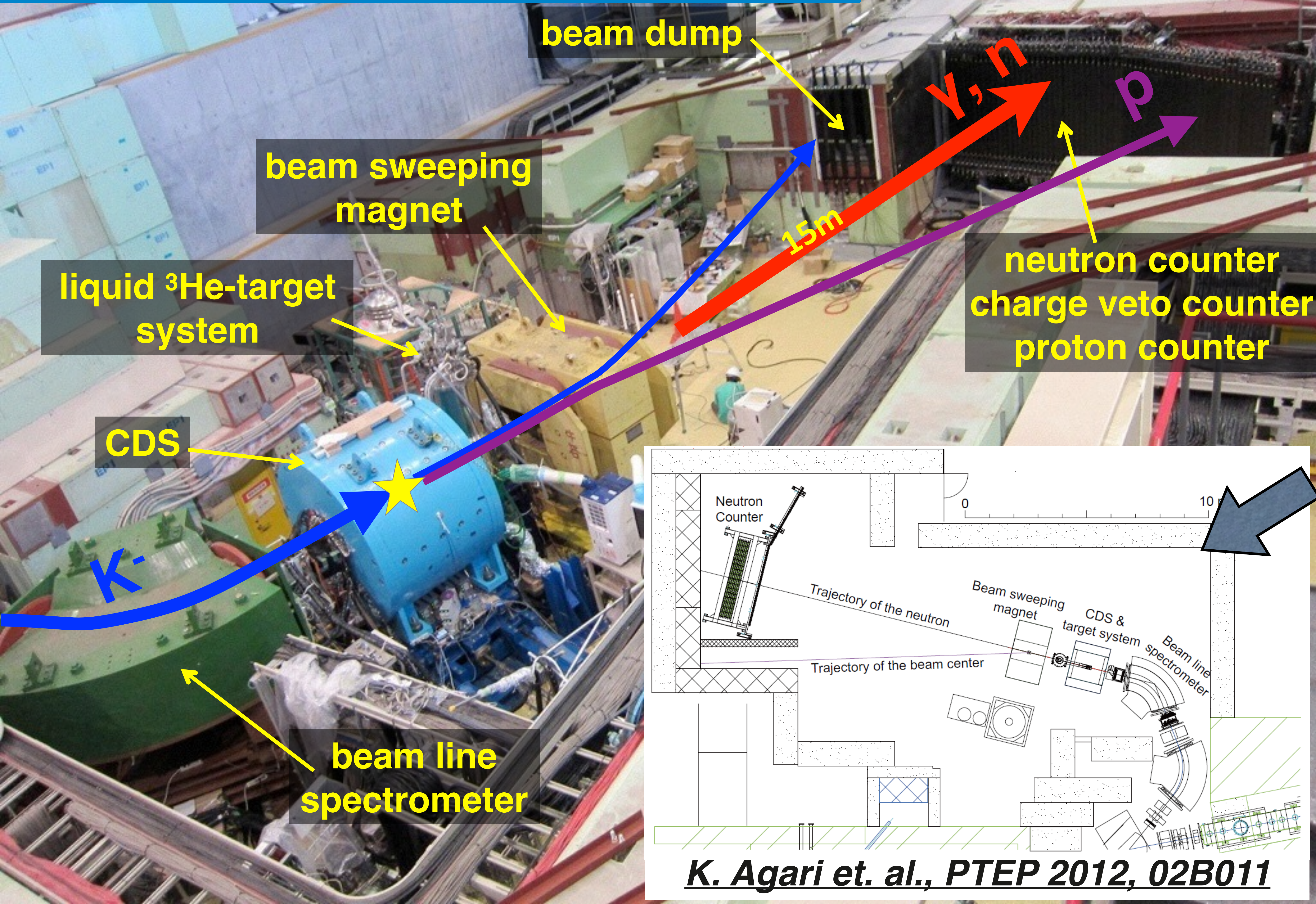
T. Koike and T. Harada. *Physics Letters B* **652,** 262–268 (2007).
T. Koike and T. Harada. *Phys. Rev. C* **80,** 055208 (2009).

Principle of the $^3He(K^-,n)$ measurement



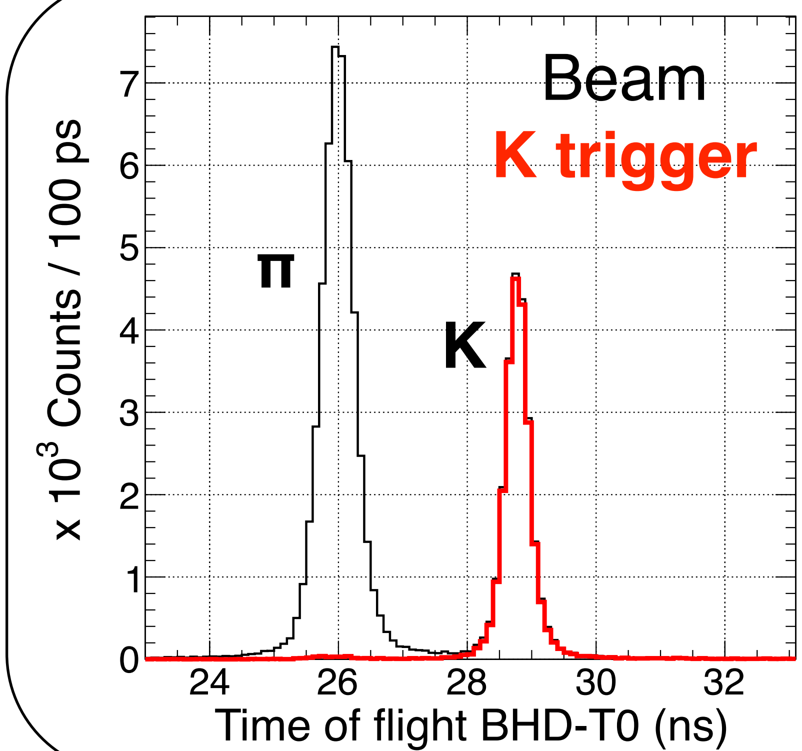
- **Kaon beam analysis :**
  select single-beam events & reconstruct beam momentum
- **Neutron analysis:**
  T0-NC TOF with vertex information provided by the CDS

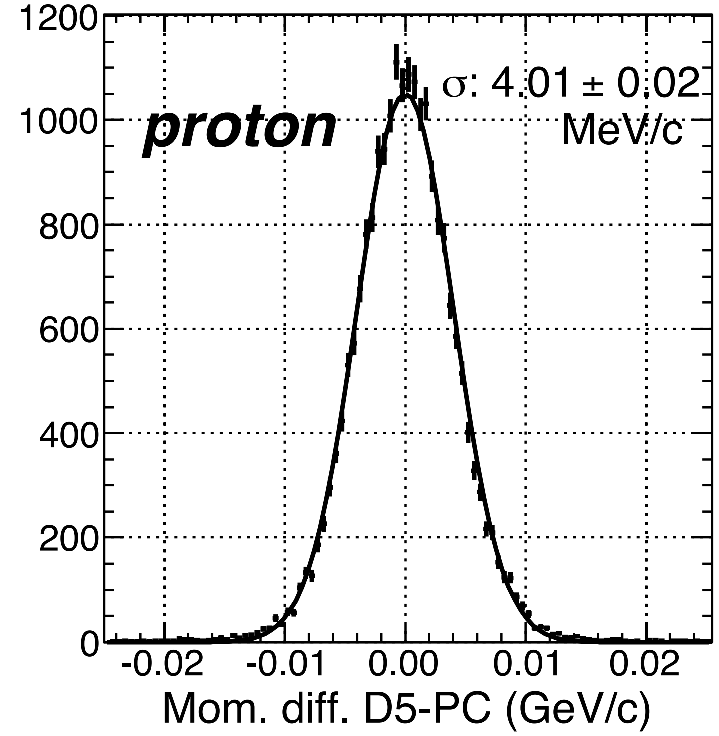
J-PARC K1.8BR spectrometer



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

Basic performances





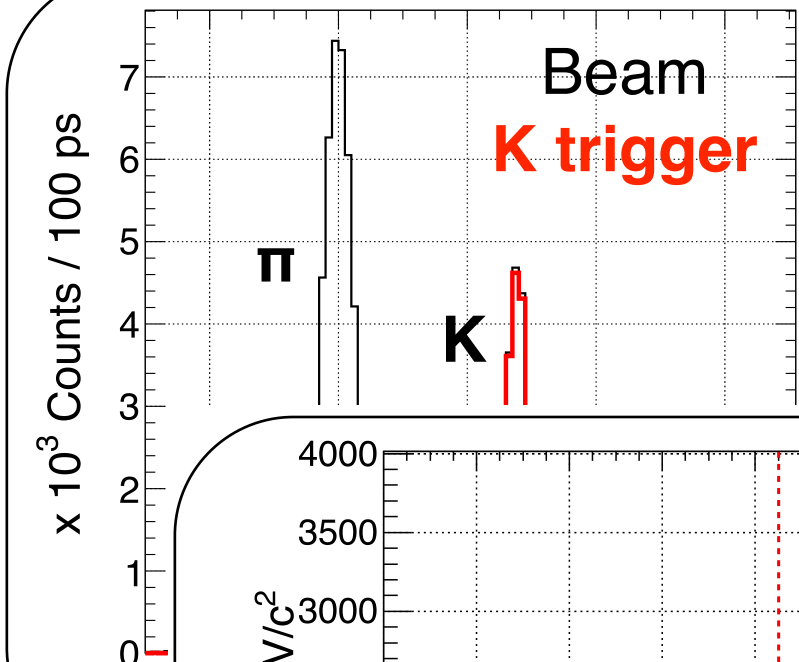
@ 24 kW

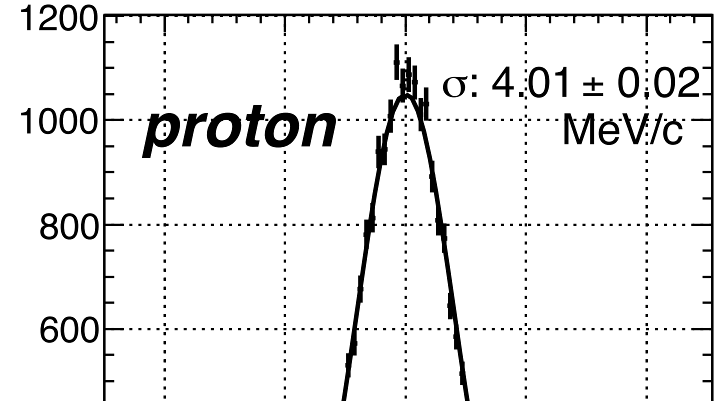
kaon/spill : 150k

K/π ratio : 0.45

σ_{beam} ~ 2 MeV/c
@ 1 GeV/c

Basic performances





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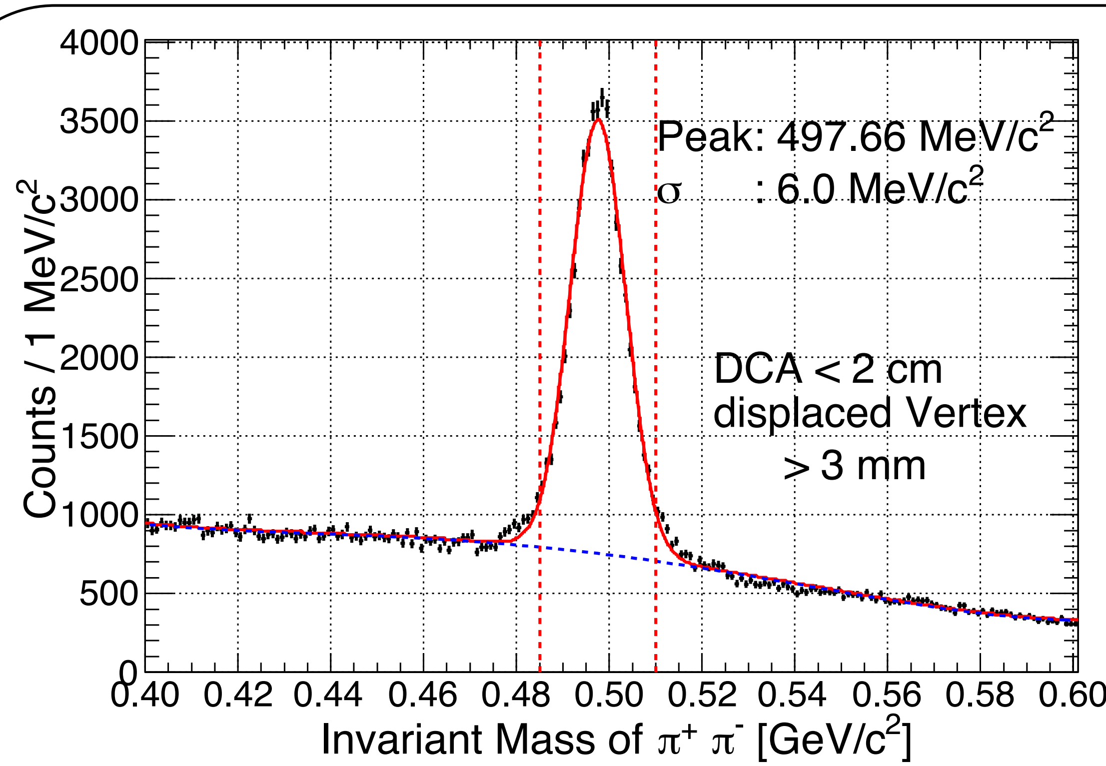

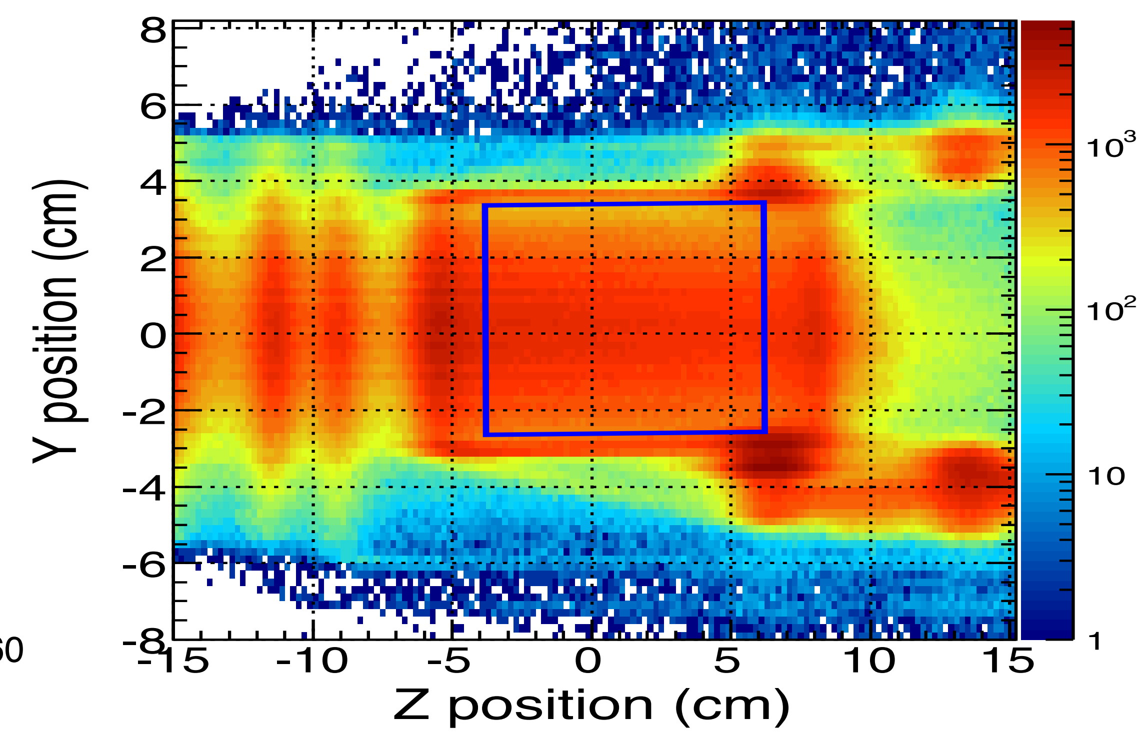

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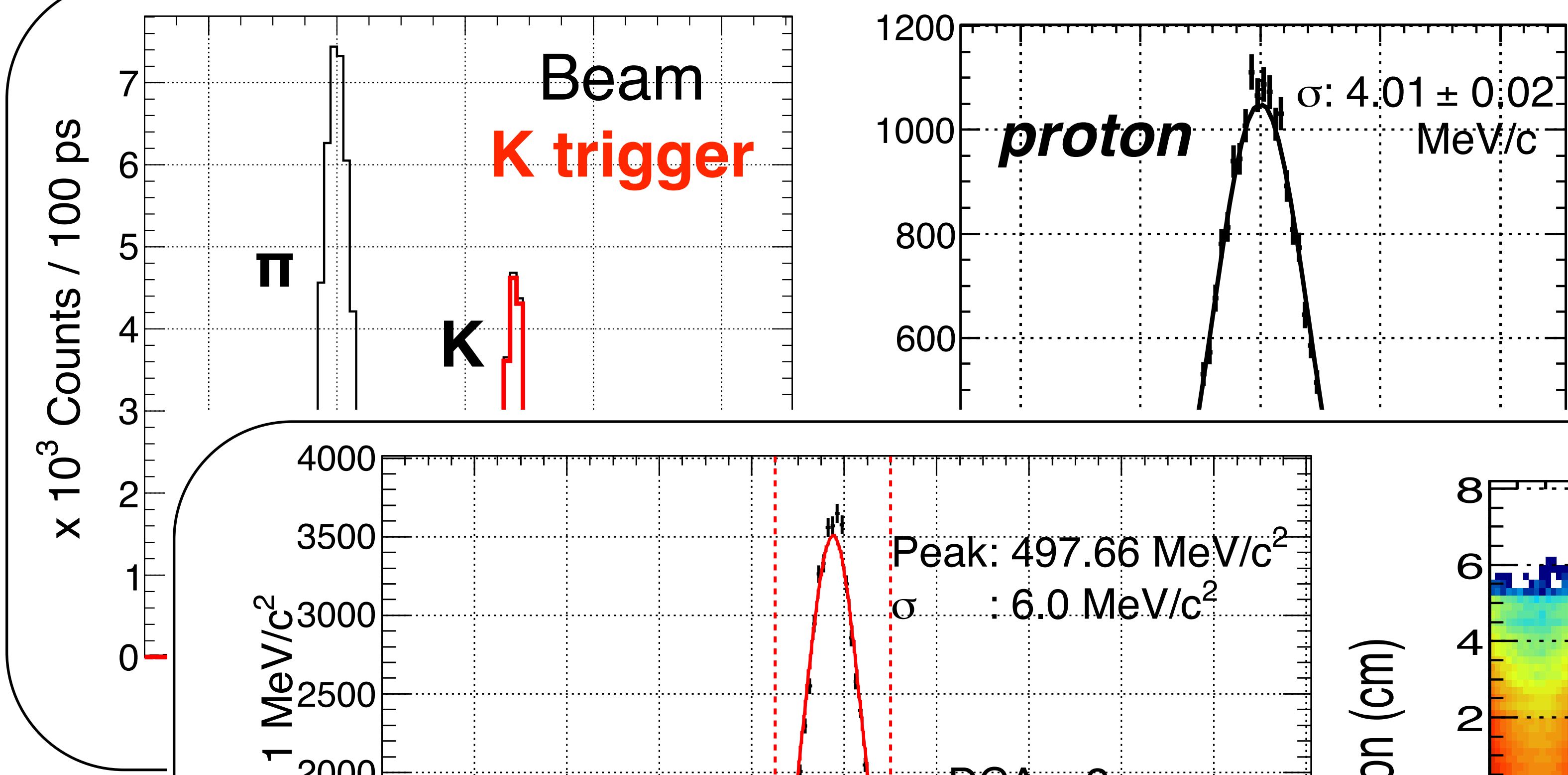

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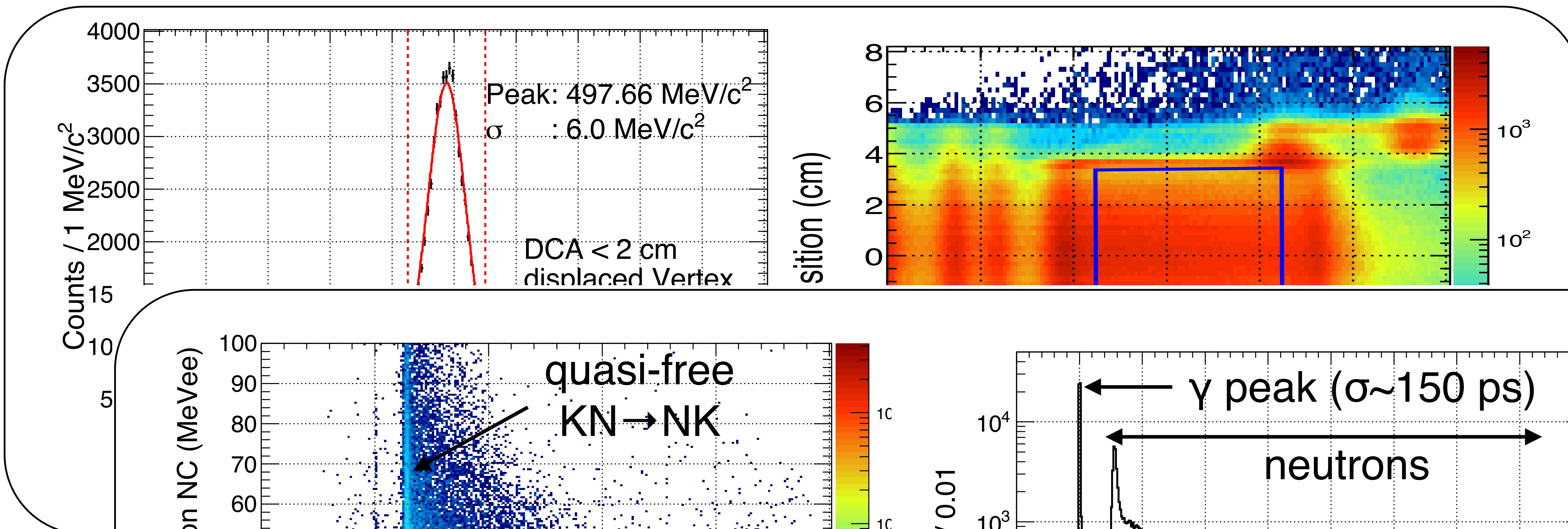
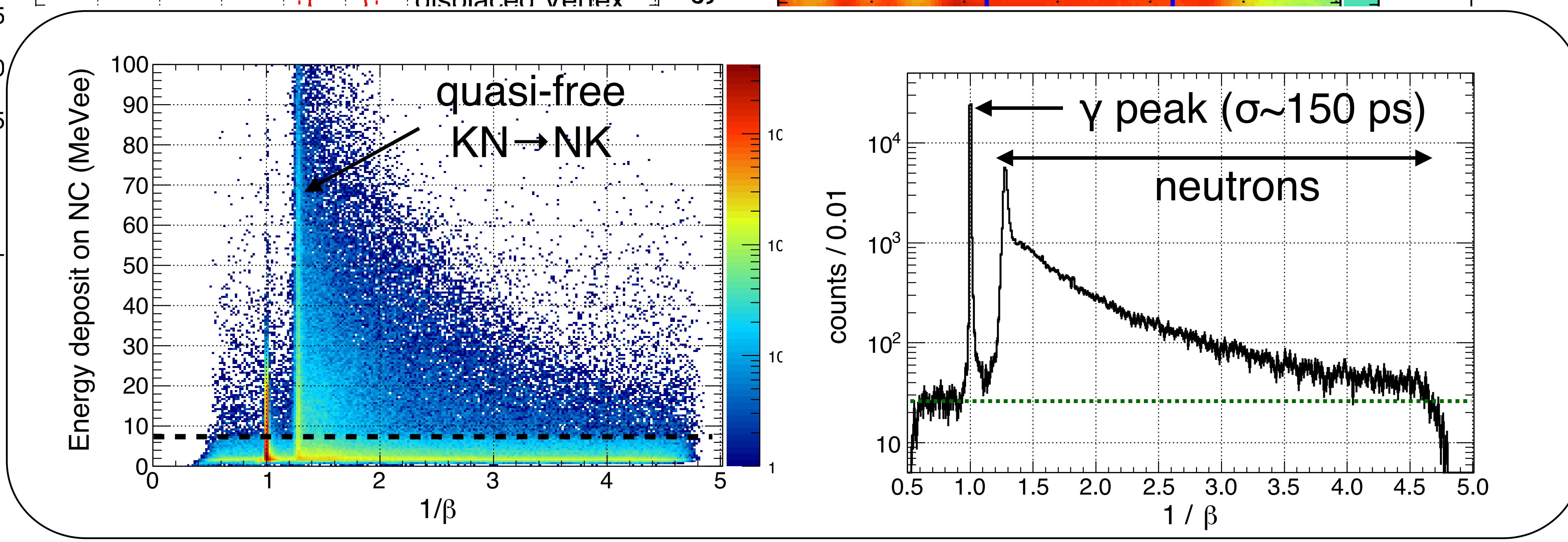
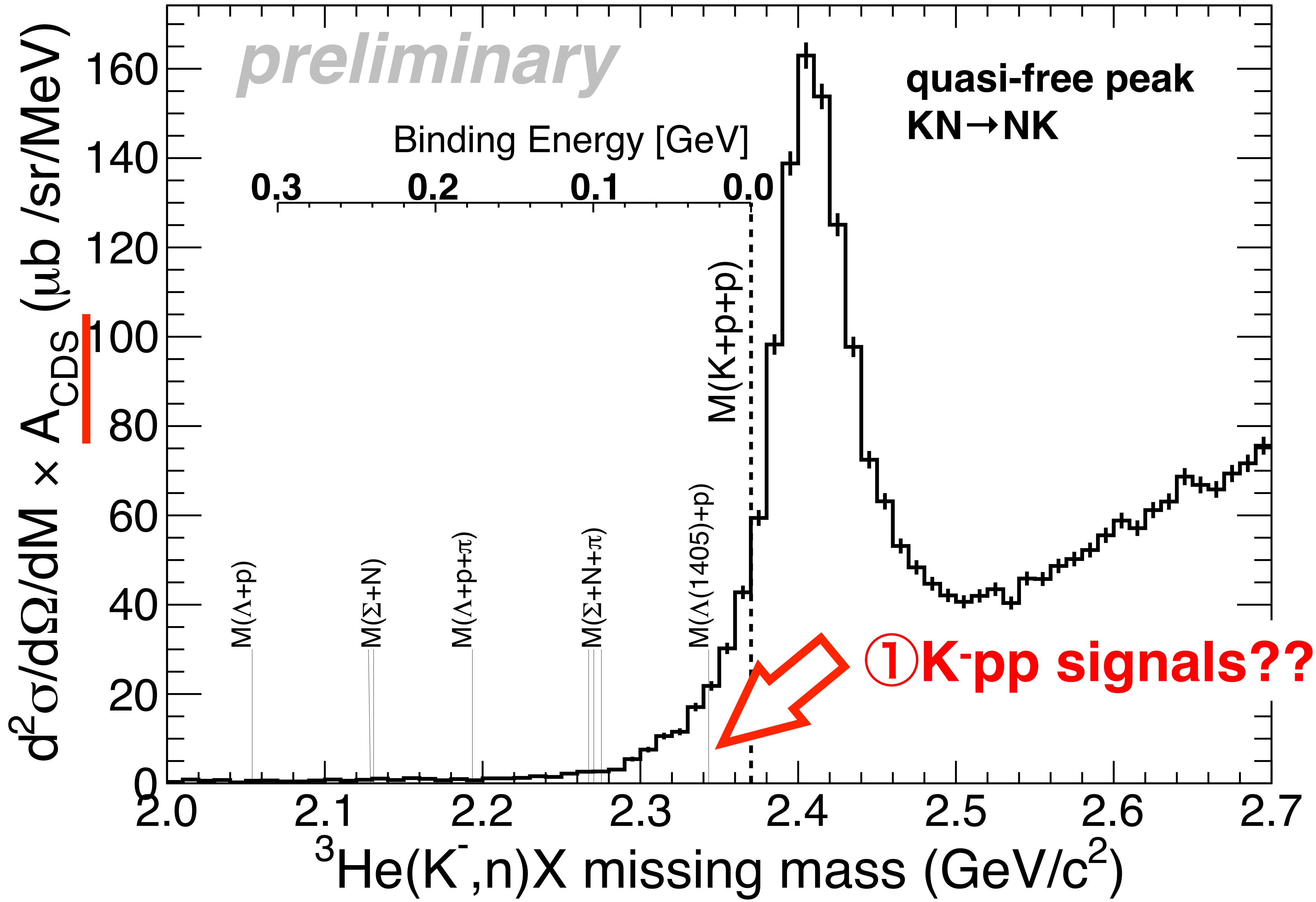


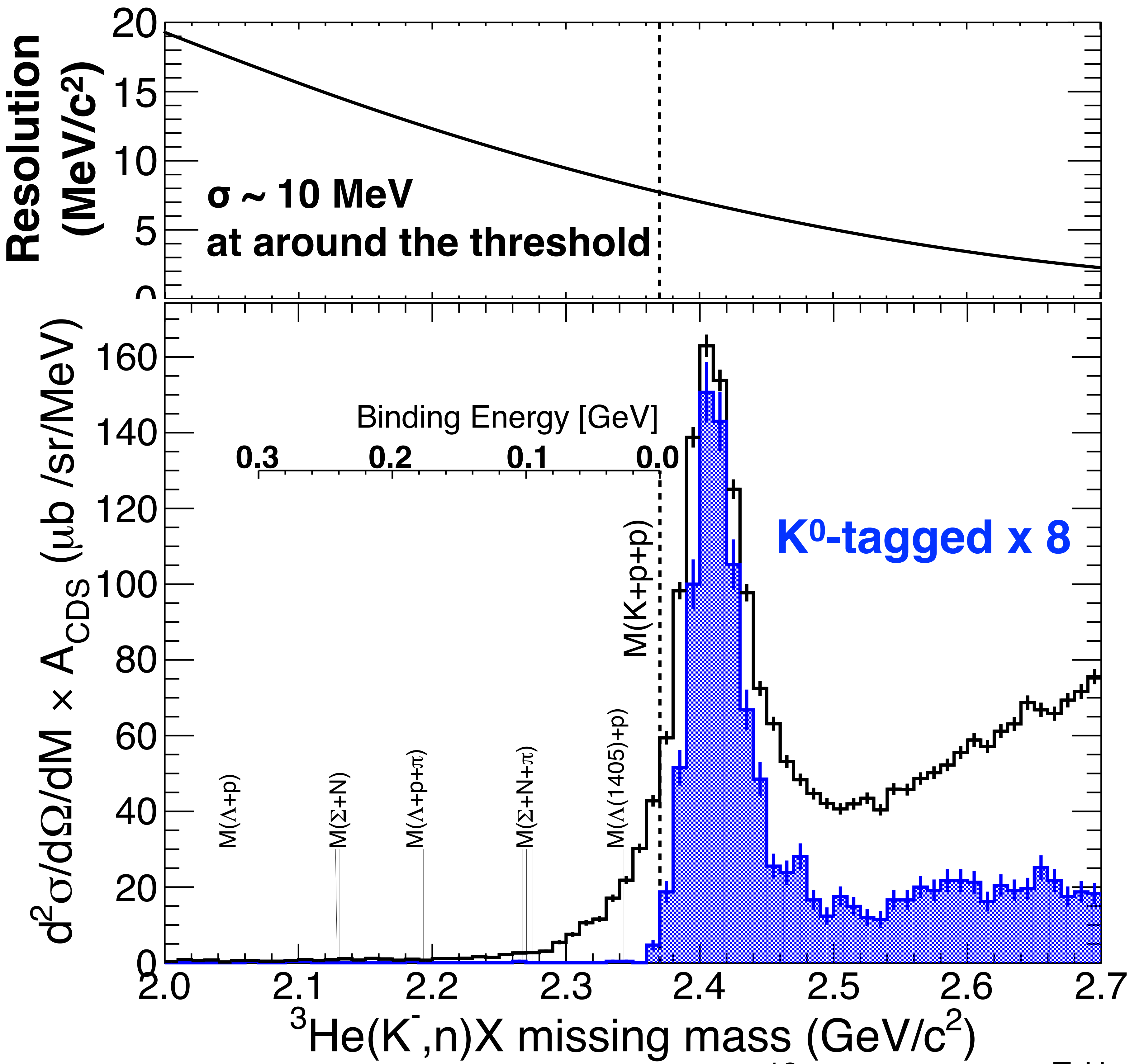


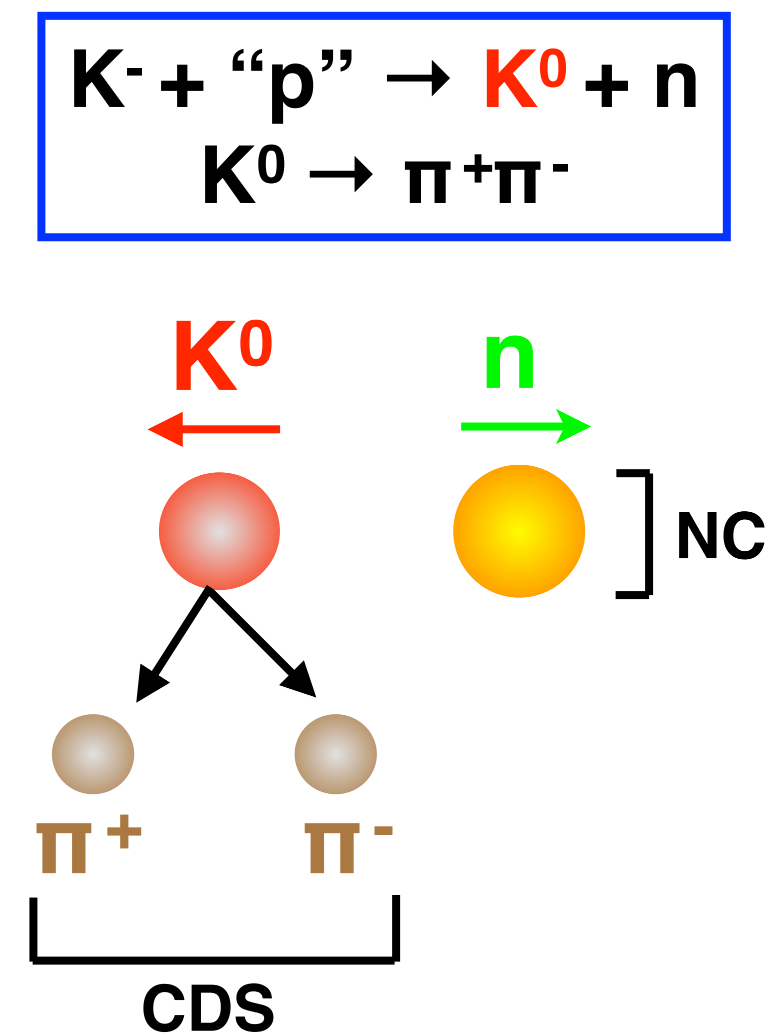
Semi-inclusive spectrum

θ^lab = 0° @ p_K = 1 GeV/c
biased by the request of charged track(s) in the CDS



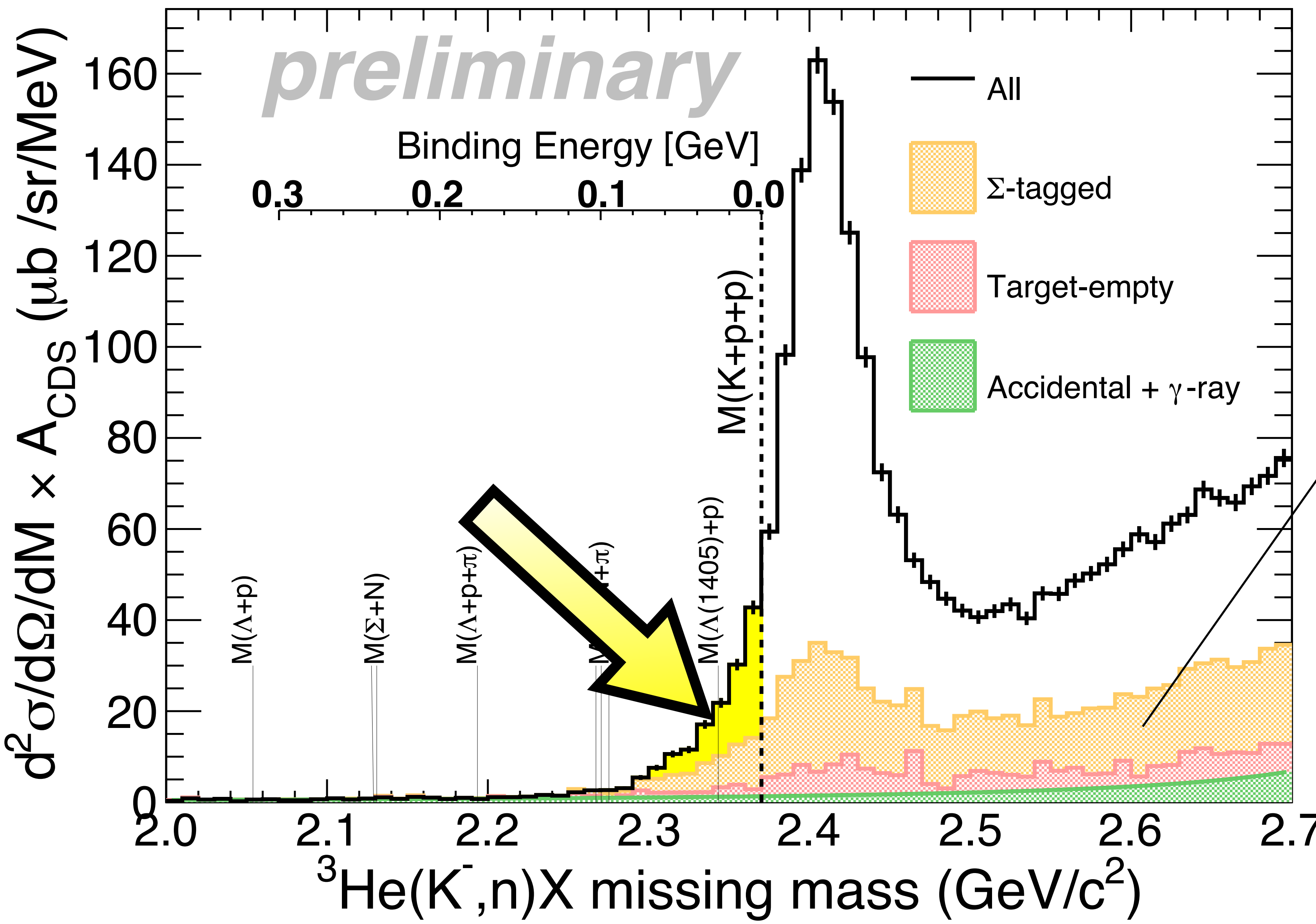
Missing-mass resolution

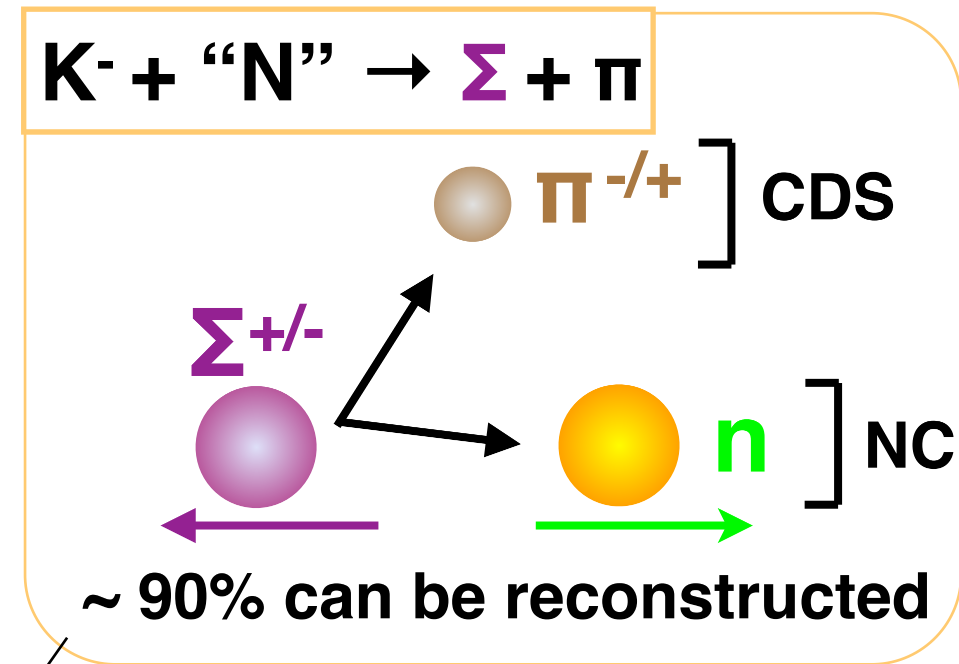


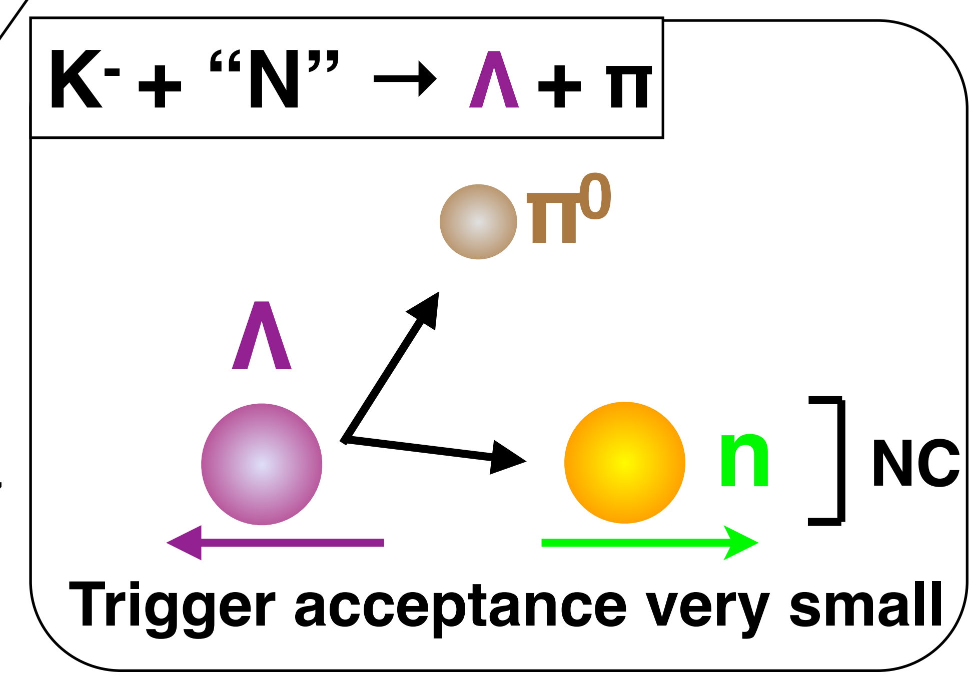


The tail is not due to the detector resolution

Background evaluation



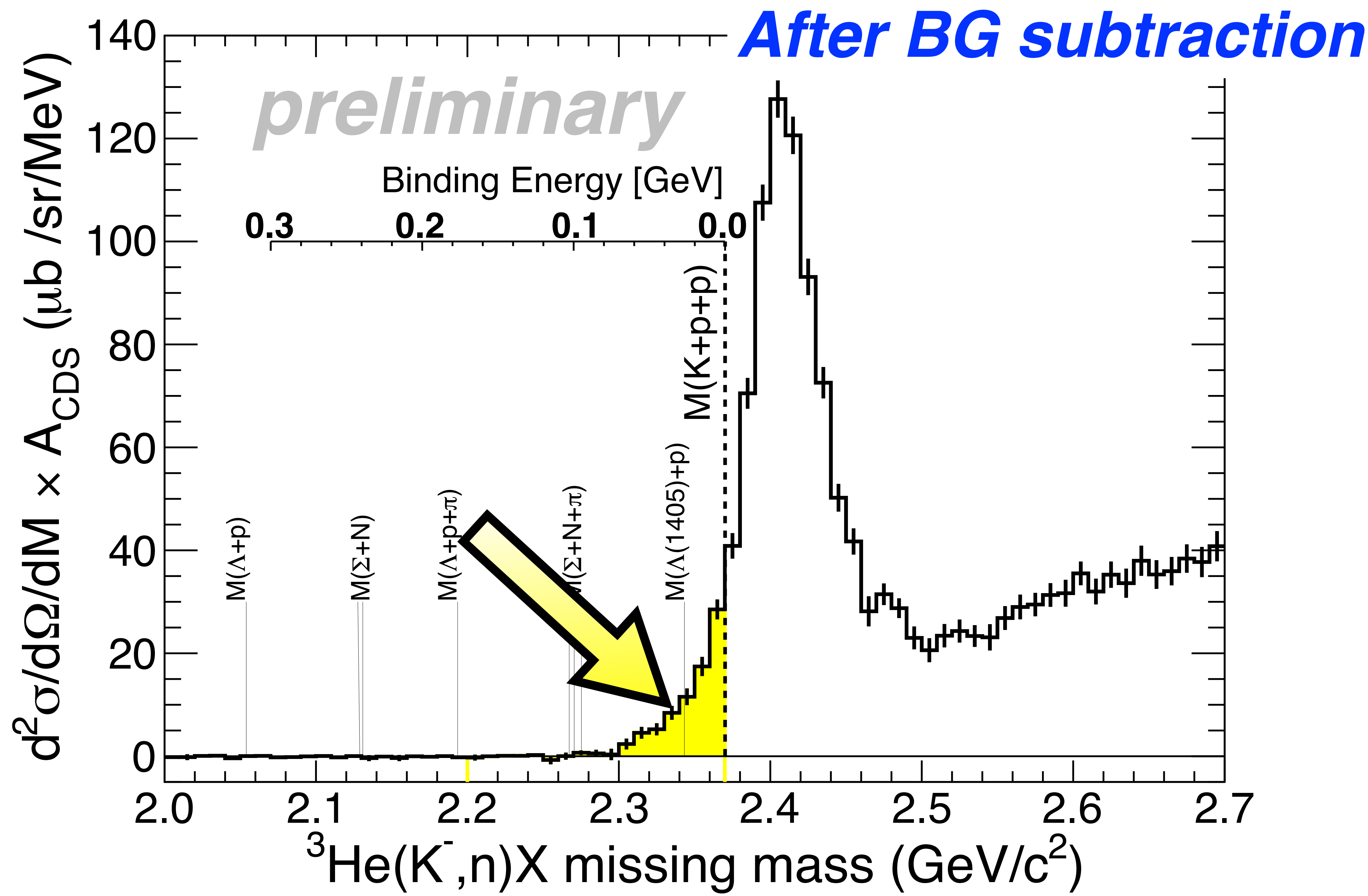




There remains a statistically significant excess

What is the origin of the excess?

naively understood with attractive & absorptive potential



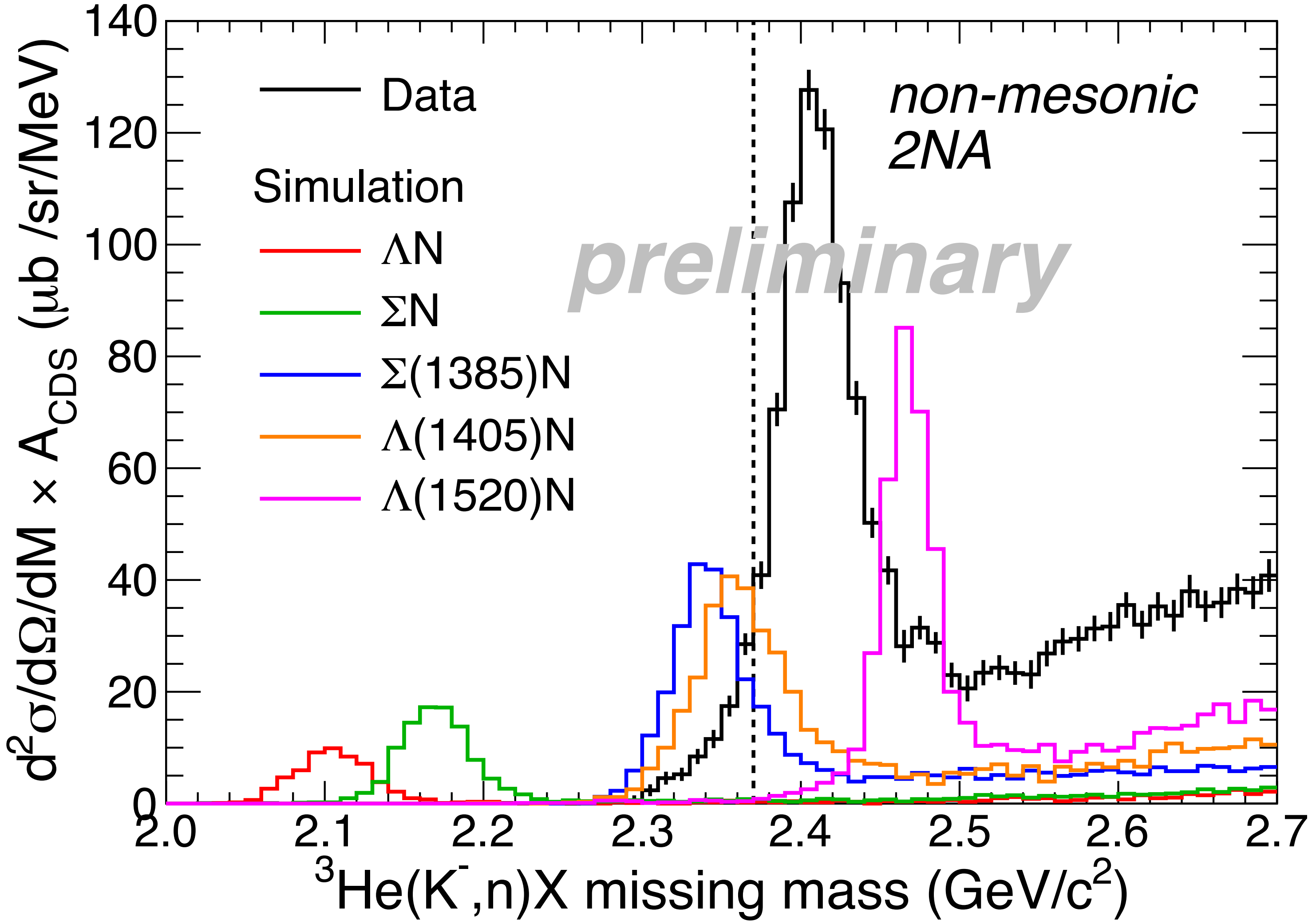
What is the origin of the excess?

naively understood with attractive & absorptive potential

other possibilities are…

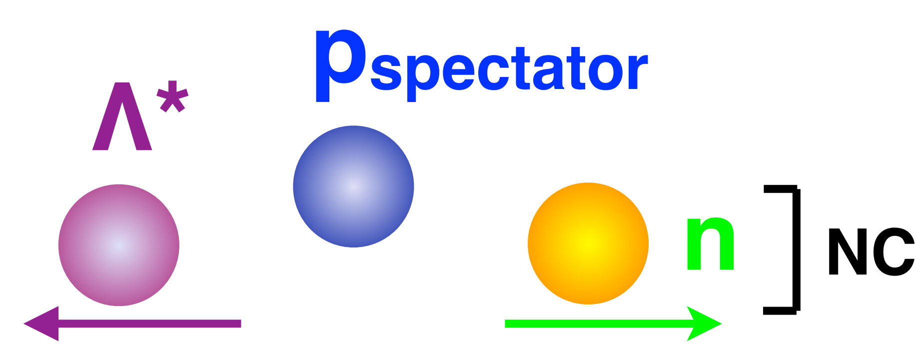
1. non-mesonic two-nucleon absorption: Λ(1405)n branch

- rather large cross-section ~ 5 mb/sr needed
- somehow suppressed Λ(1520)n branch < 2 mb/sr



20 mb/sr @ θ=0
B.W. with PDG mass&width

$$K^- + ^3\text{He} \rightarrow Y^{(*)} + \boxed{N} + N_s.$$



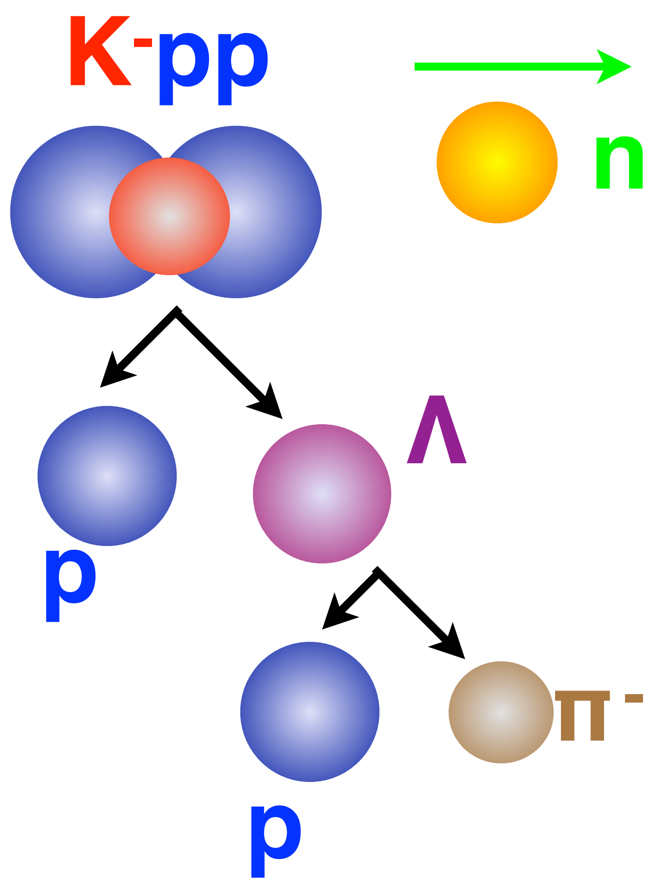
ΛN/ΣN branches are negligibly small

What is the origin of the excess?

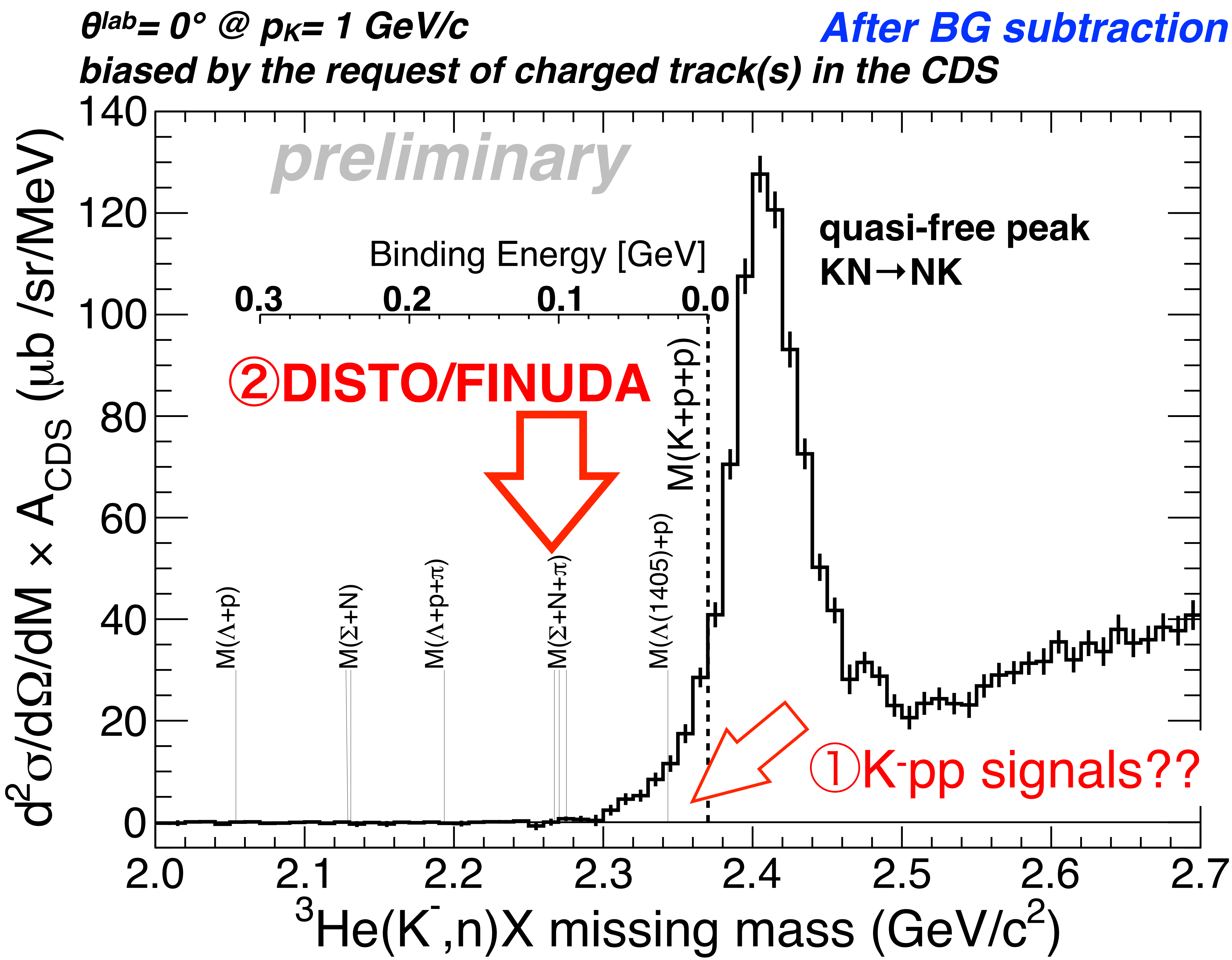
naively understood with attractive & absorptive potential

other possibilities are…

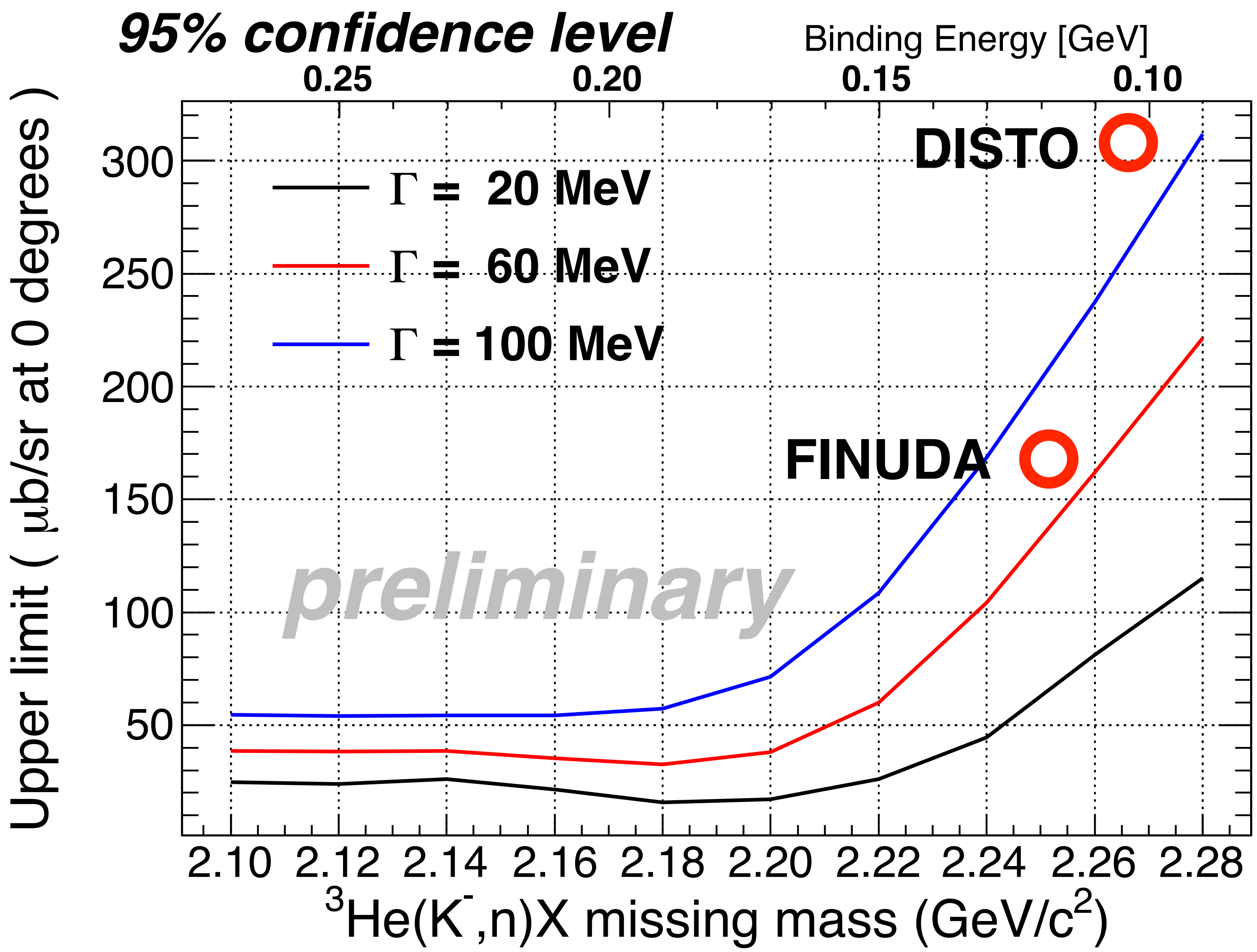
1. **non-mesonic two-nucleon absorption: Λ(1405)n branch**
   - rather large cross-section ~ 5 mb/sr needed
   - somehow suppressed Λ(1520)n branch < 2 mb/sr
2. **Loosely-bound K^-pp state**
   - The excess corresponds to 1~2 mb/sr
     - decay mode assumption: $K^-pp \rightarrow \Lambda p/\Sigma p/\pi\Sigma p$
   - cf.) Theory:
     - Pheno. pot.: a few mb/sr
       T. Koike and T. Harada. *Phys. Rev. C* **80,** 055208 (2009).
     - Chiral pot.: a few hundreds μb/sr
       J. Yamagata-Sekihara, *et. al.*, *Phys. Rev. C*, ***80***, 045204 (2009).



Semi-inclusive spectrum



Upper limits for deeply-bound states



200 ~ 300 μb/sr (θ_{lab}=0°) upper limits in the ^{3}He(K^-,n) reaction for FINUDA/DISTO peaks

	B.E. (MeV)	Γ (MeV)	95% C.L. (mb/sr)
FINUDA	115	67	~0.2
DISTO	103	118	~0.3

Conclusion

- **J-PARC E15 searches for the *"K^-pp"* bound state**
  - 1st physics data with 24 kW*4 day running (< 1% of full proposal)
  - All the detector subsystems are working well with the good performance as designed
- **$^3He(K^-,n)X$ spectrum was obtained for the first time**
  - Semi-inclusive condition
  - We observed a tail component in the K-bound region which is hard to be explained by ordinary processes
  - Deeply-bound state claimed by DISTO and FINUDA was not seen as a significant peak.
    Its upper limit was determined to be 0.2~0.3 mb/sr.
- **First publication is coming soon!**