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

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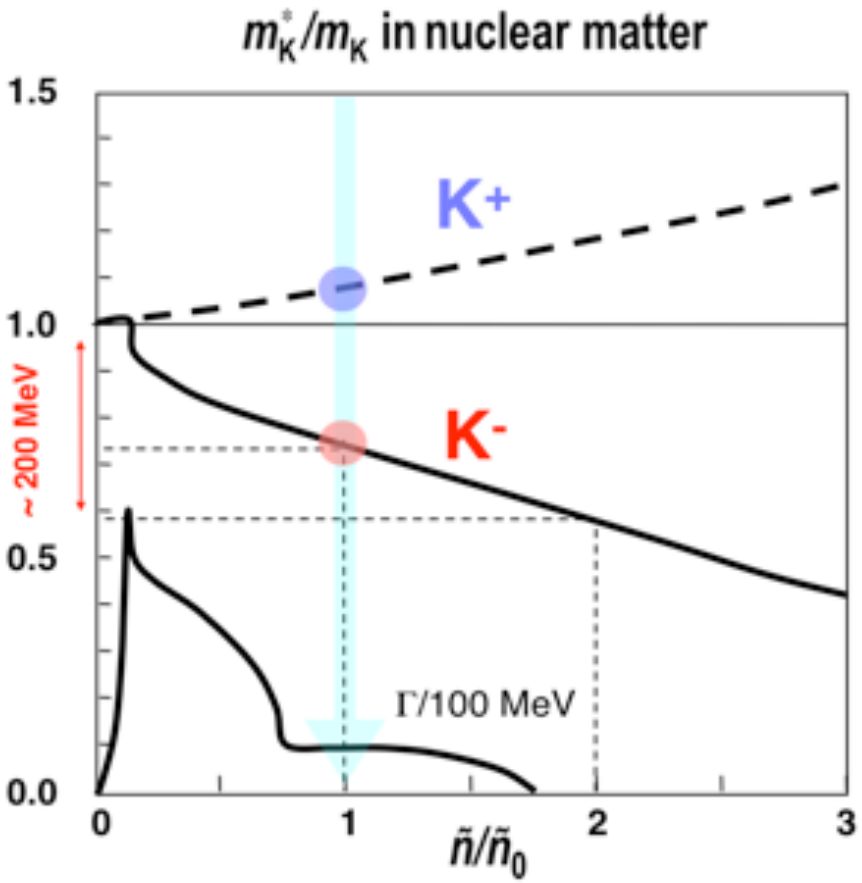
for the E15 collaboration

- Introduction
- The J-PARC E15 experiment
- Preliminary results of 1st physics run
- Summary

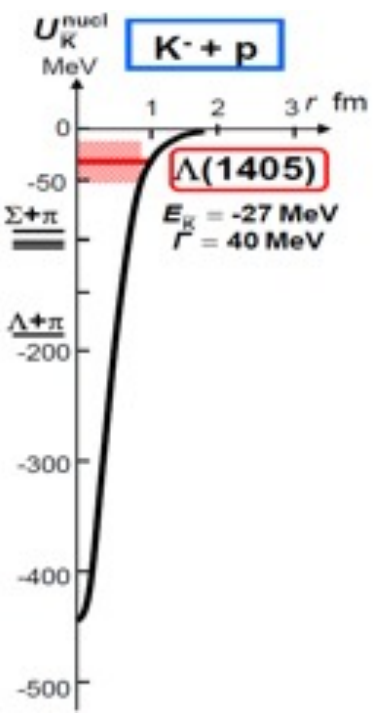
Embedding K⁻ in nucleus

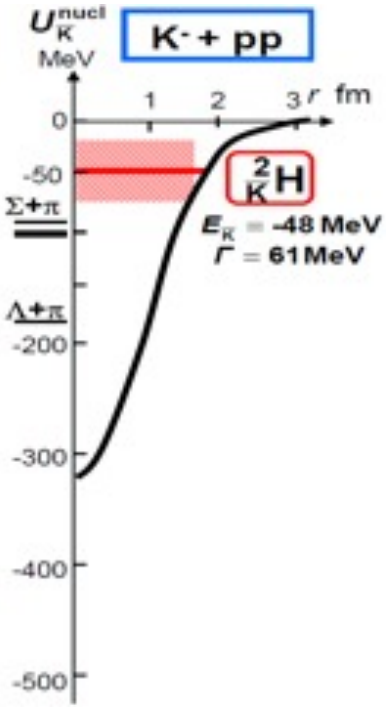
Motivation of J-PARC E15

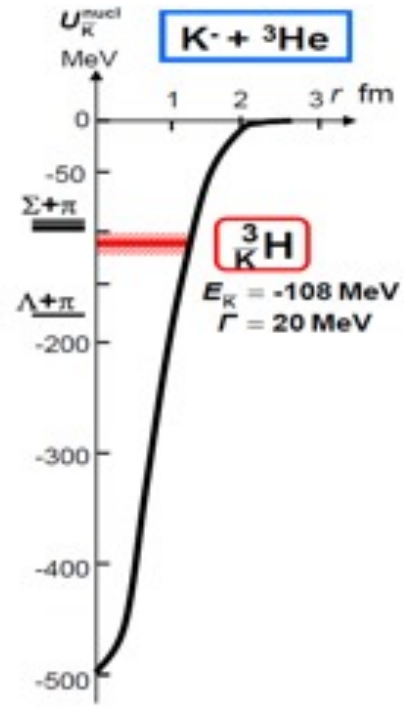
- understand KN interaction below threshold
- K mass modification / high density matter?



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







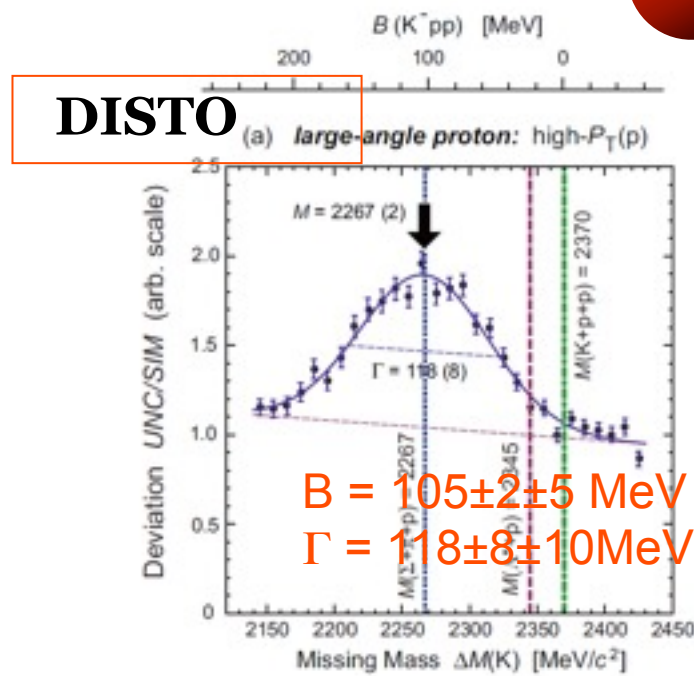
Y.Akaishi & T.Yamazaki, PLB535, 70(2002).

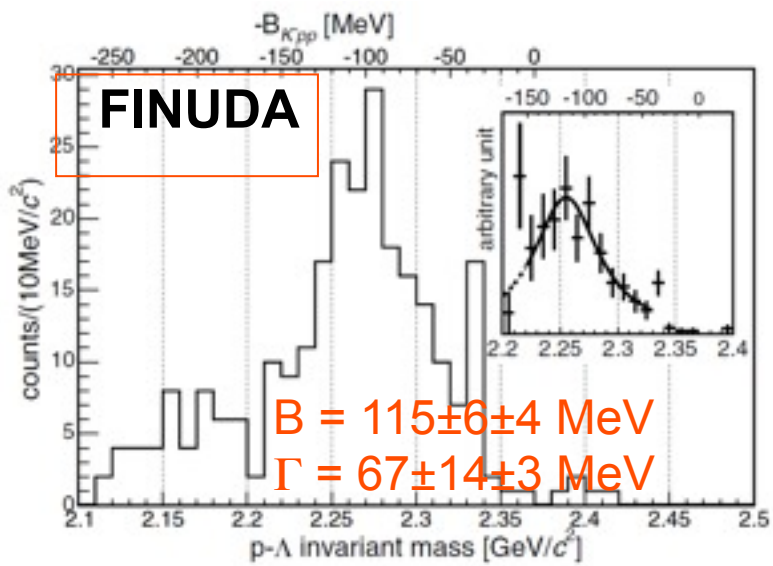
The simplest kaonic nuclei $\bar{K}NN$

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

Λ(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

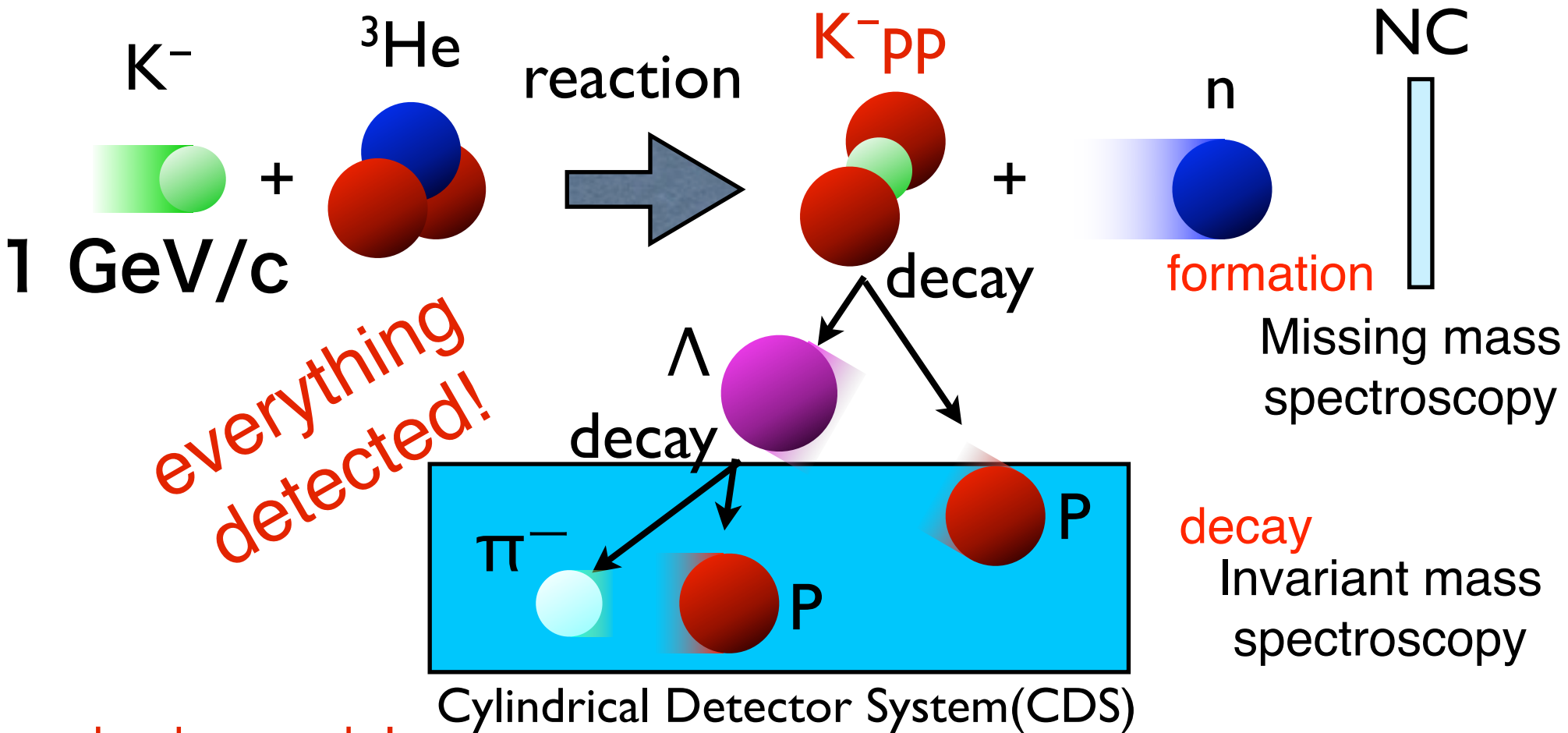
- **Many theoretical calculations**
- **Little experimental information**
- **bound or not? B.E. and width?**





Experimental principle

A search for the simplest kaonic nucleus K^-pp using ^3He(in-flight K^-,n) reaction



Low background !

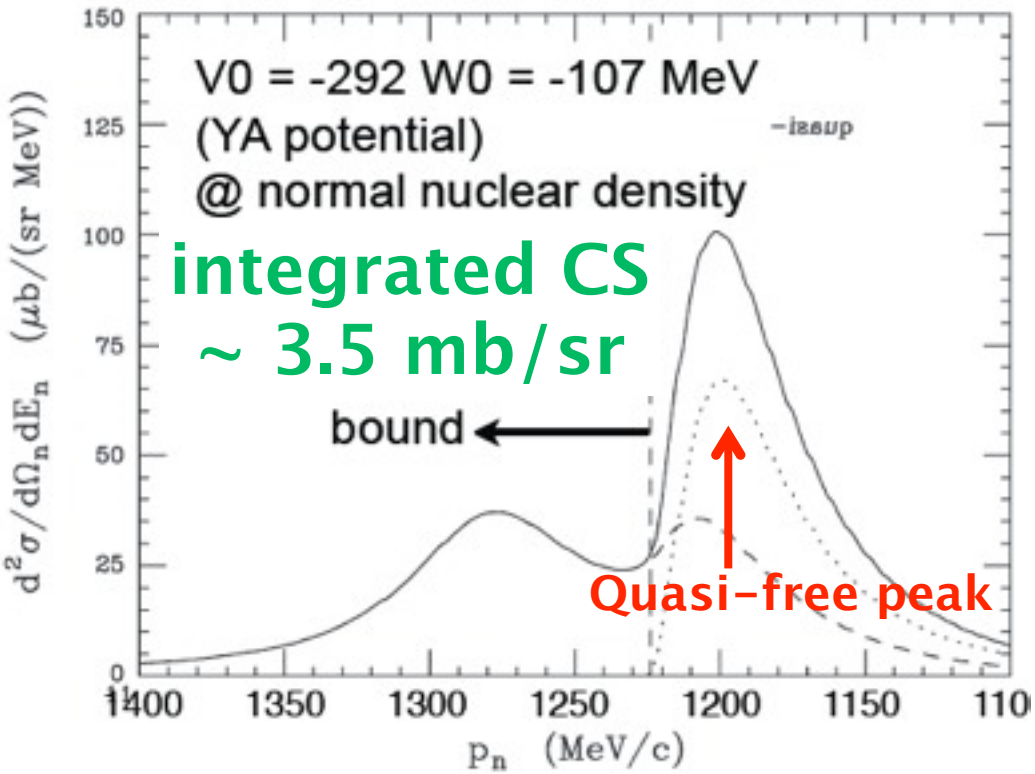
- two-nucleon absorption
- hyperon decays

} CAN be discriminated kinematically

Theoretical calculation

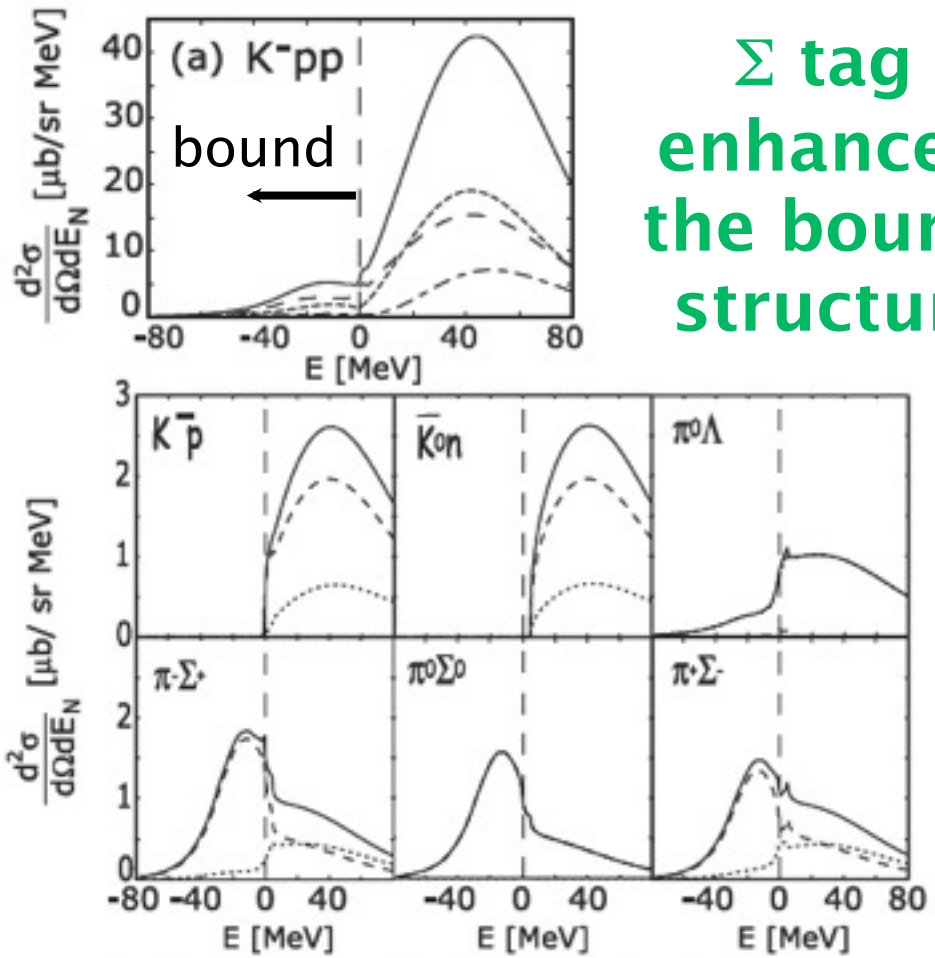
Calculated formation-spectra for ^{3}He(in-flight K-,n)

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



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

If right, we can measure the bound structure!



Σ tag enhances the bound structure

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

J-PARC E15 1st stage physics run

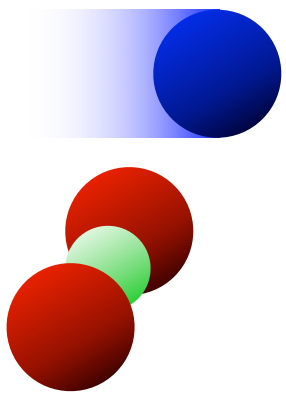
- Accumulated data
  - w/ liquid helium-3 target: ~1% of original proposal

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%

Preliminary results presented in this talk

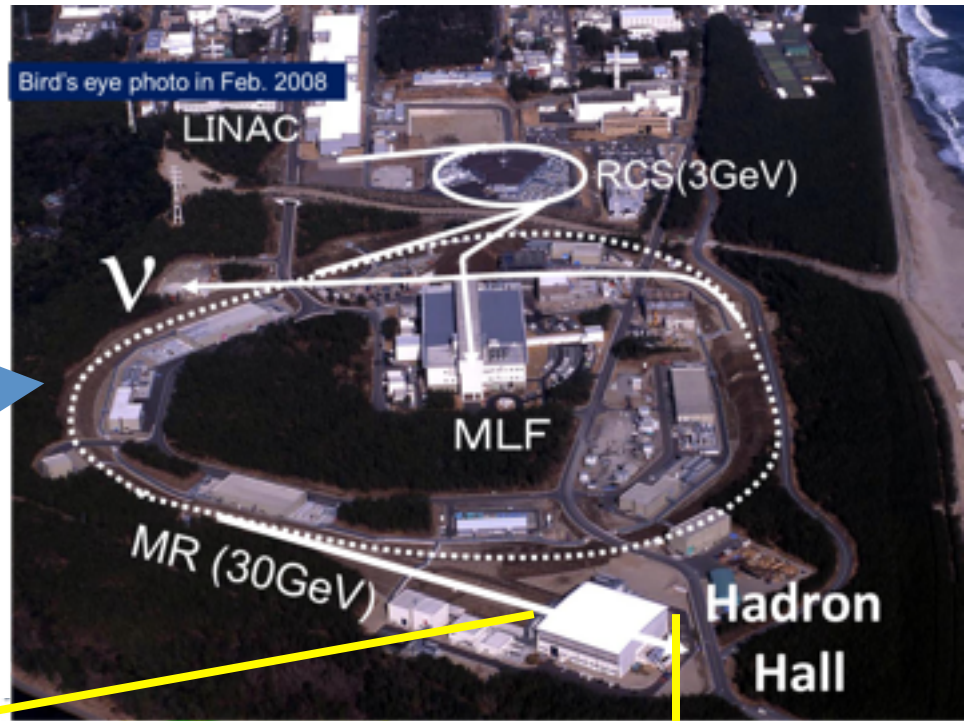
1. semi-Inclusive ^{3}He(K-,n)X spectrum
2. exclusive ^{3}He(K-,Λpn) spectrum



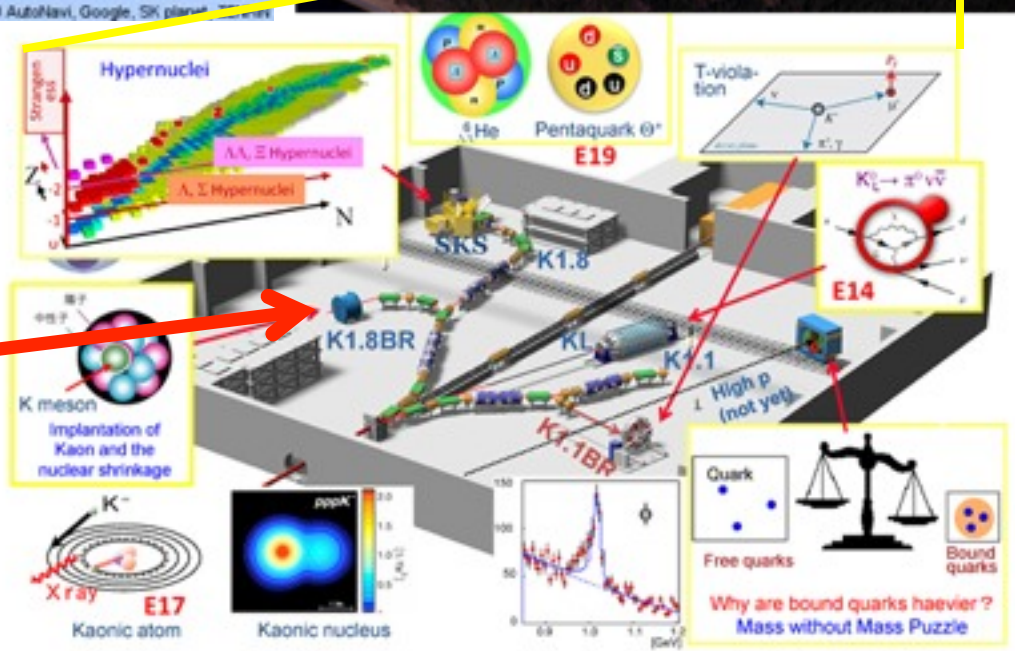
other expected physics

Inclusive 3He(K-, p)X spectrum in progress
3He(K-, n) Σ± π∓ p in progress

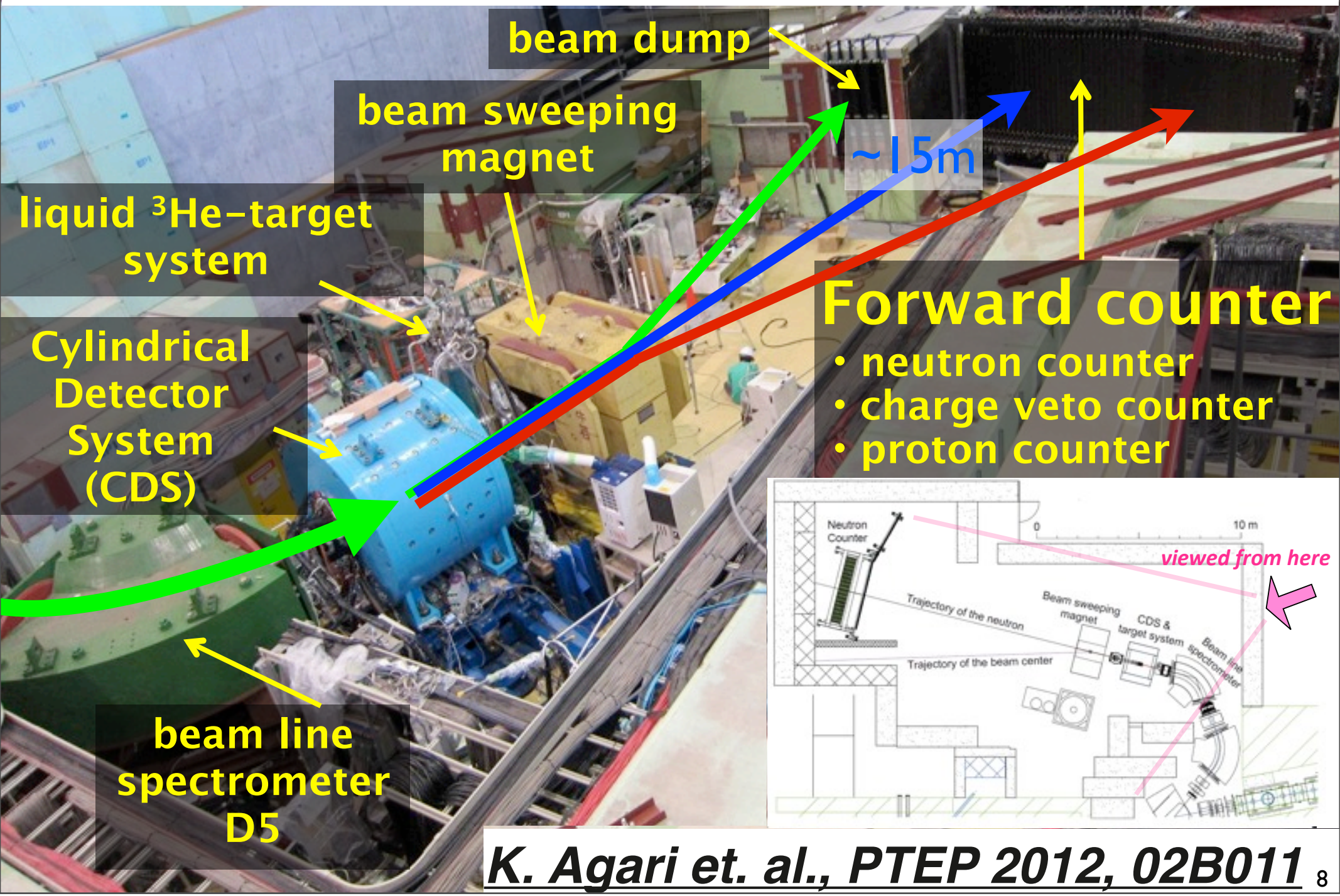
J-PARC (Japan Proton Accelerator Research Complex)



K1.8BR
E15/E17/E31



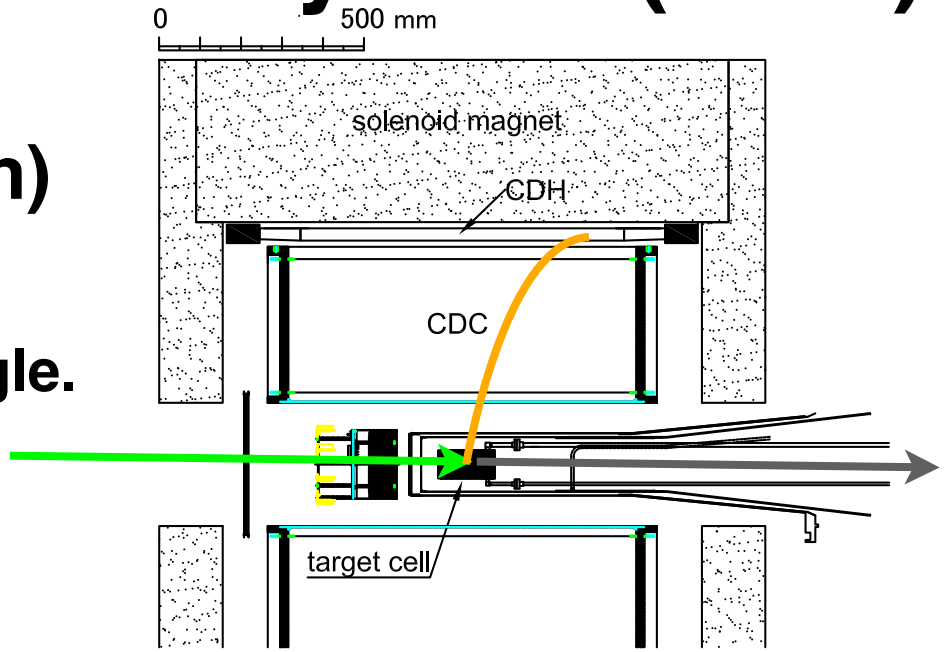
Experimental setup



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

Cylindrical Detector System (CDS)

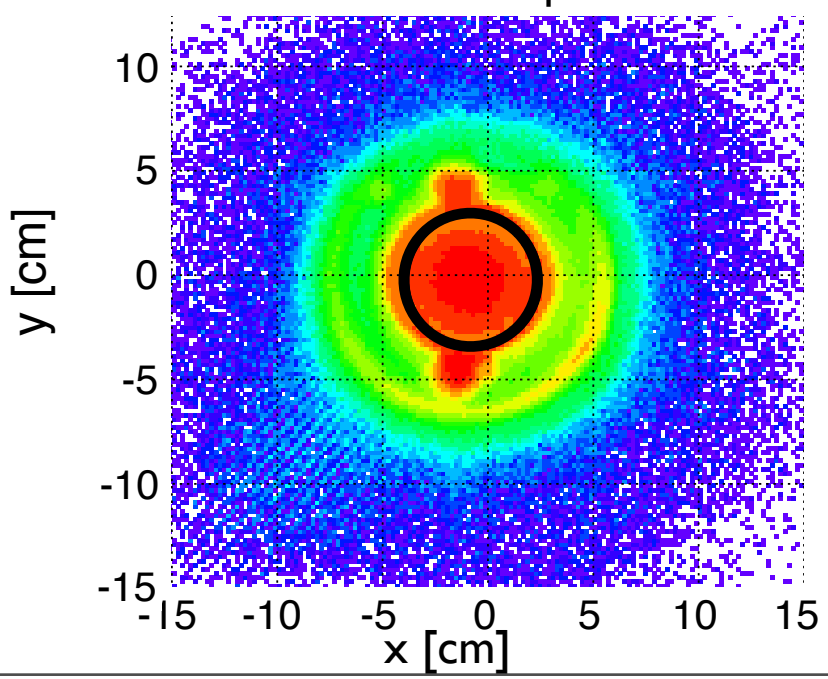
- CDC (15 layers 1816 ch)
- CDH (36 seg)
  - cover 60% of the solid angle.



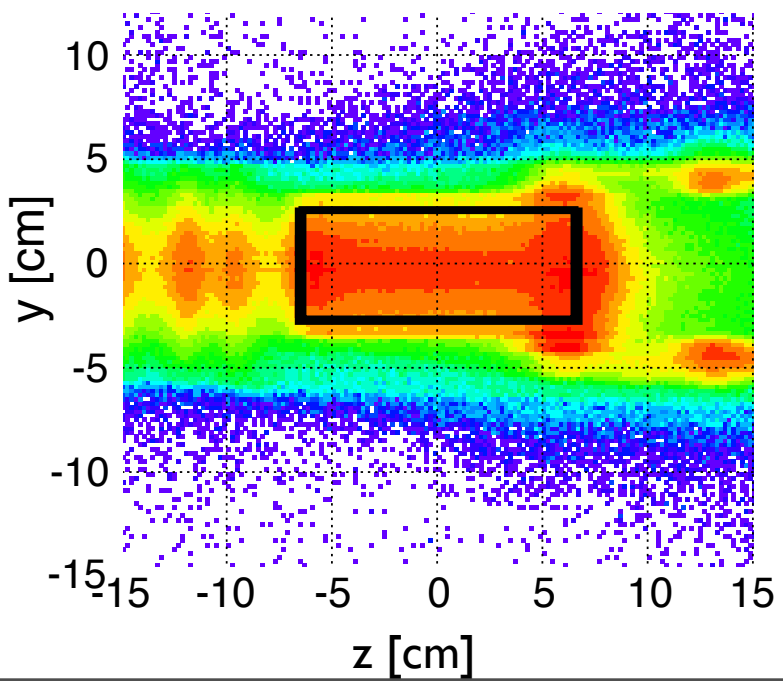
Event Vertex

vertex distribution between incoming K & a charged particle in CDS

viewed from upstream



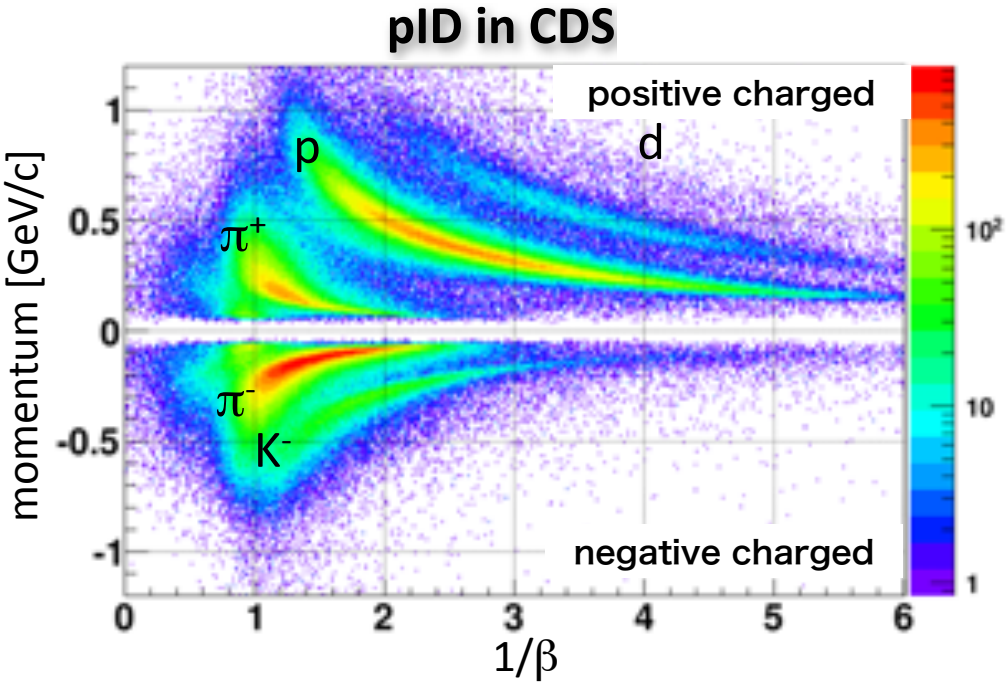
side view

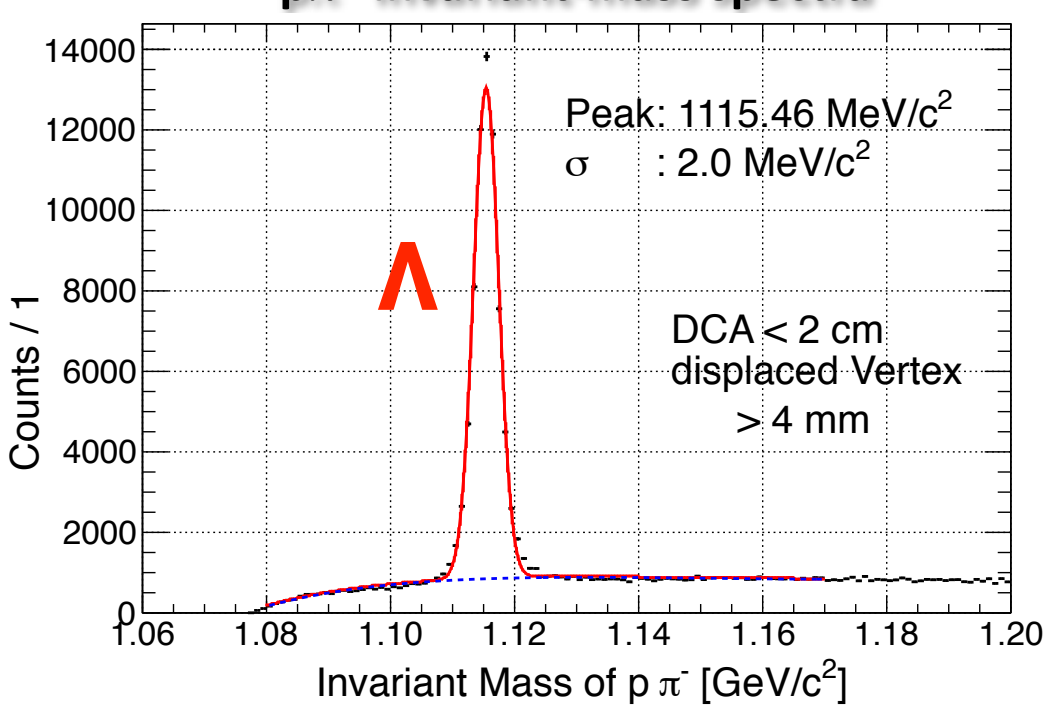


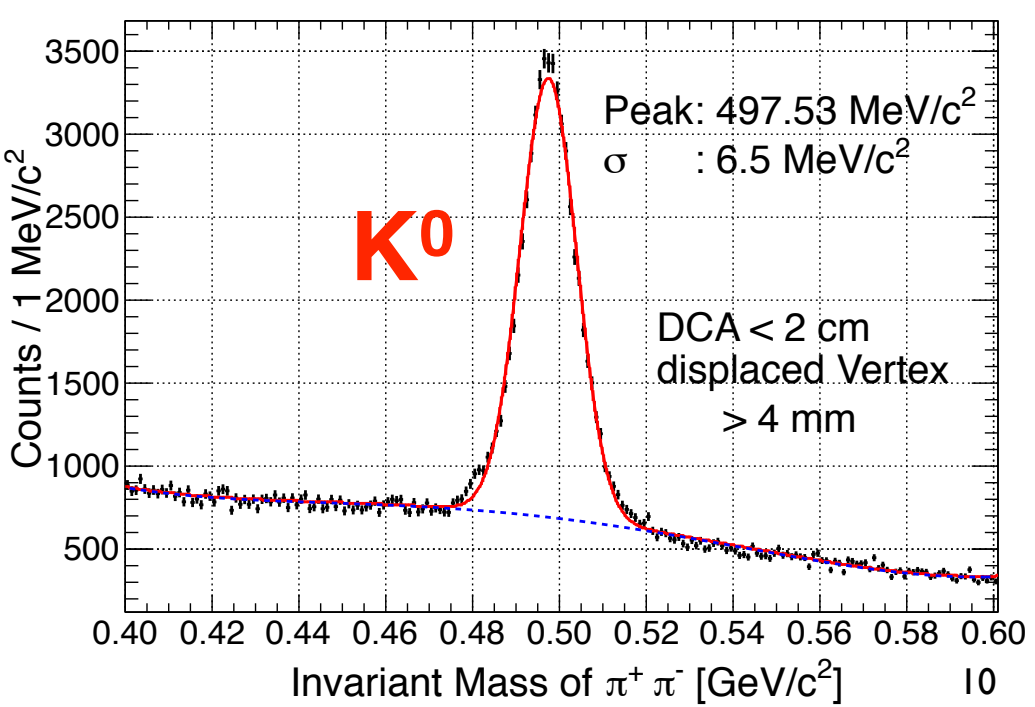
Cylindrical Detector System (CDS)

Design performance was achieved

- Particle ID is successfully done
- Λ and K0 peaks are clearly seen
- Vertex resolution:~ 2mm in x & y, ~ 5mm in z
- ~ 10 MeV/c^2 resolution for Λp invariant mass

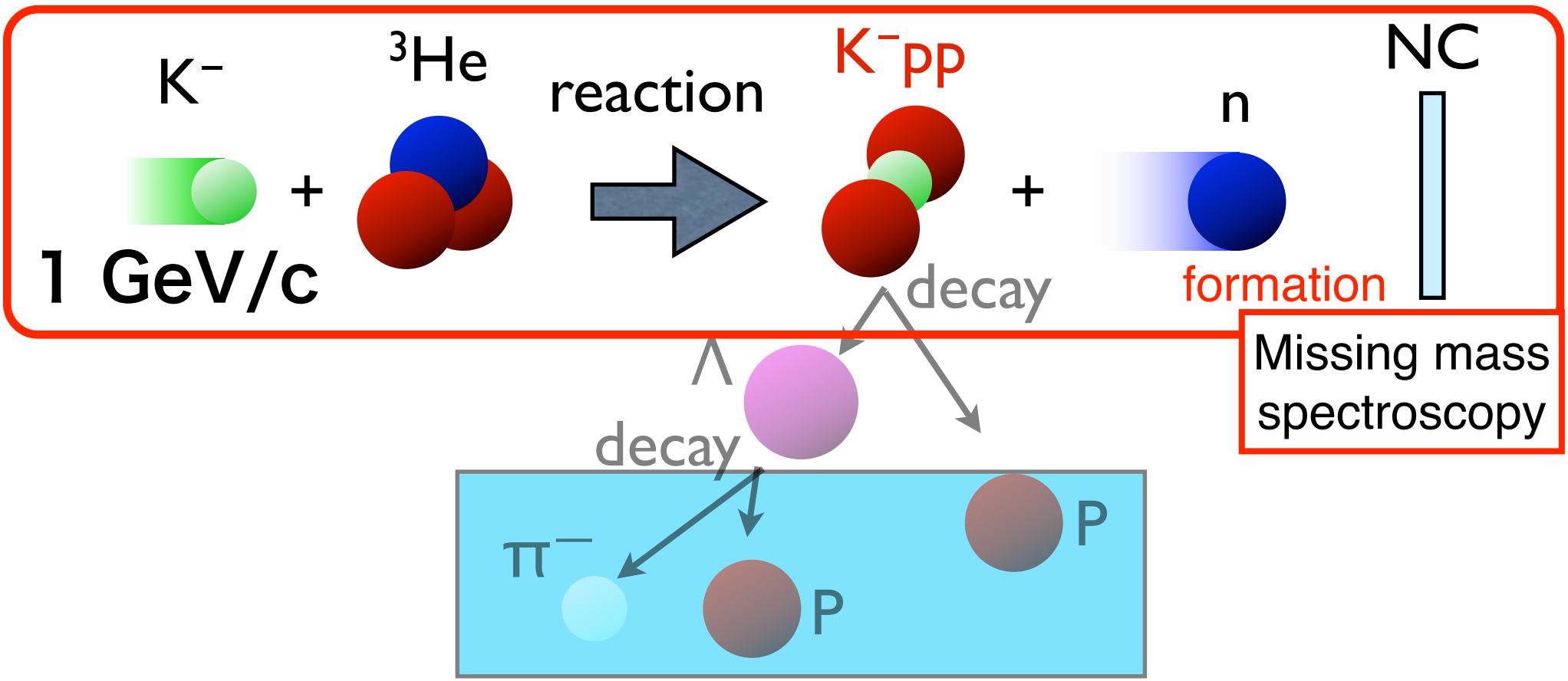






Forward neutral particles

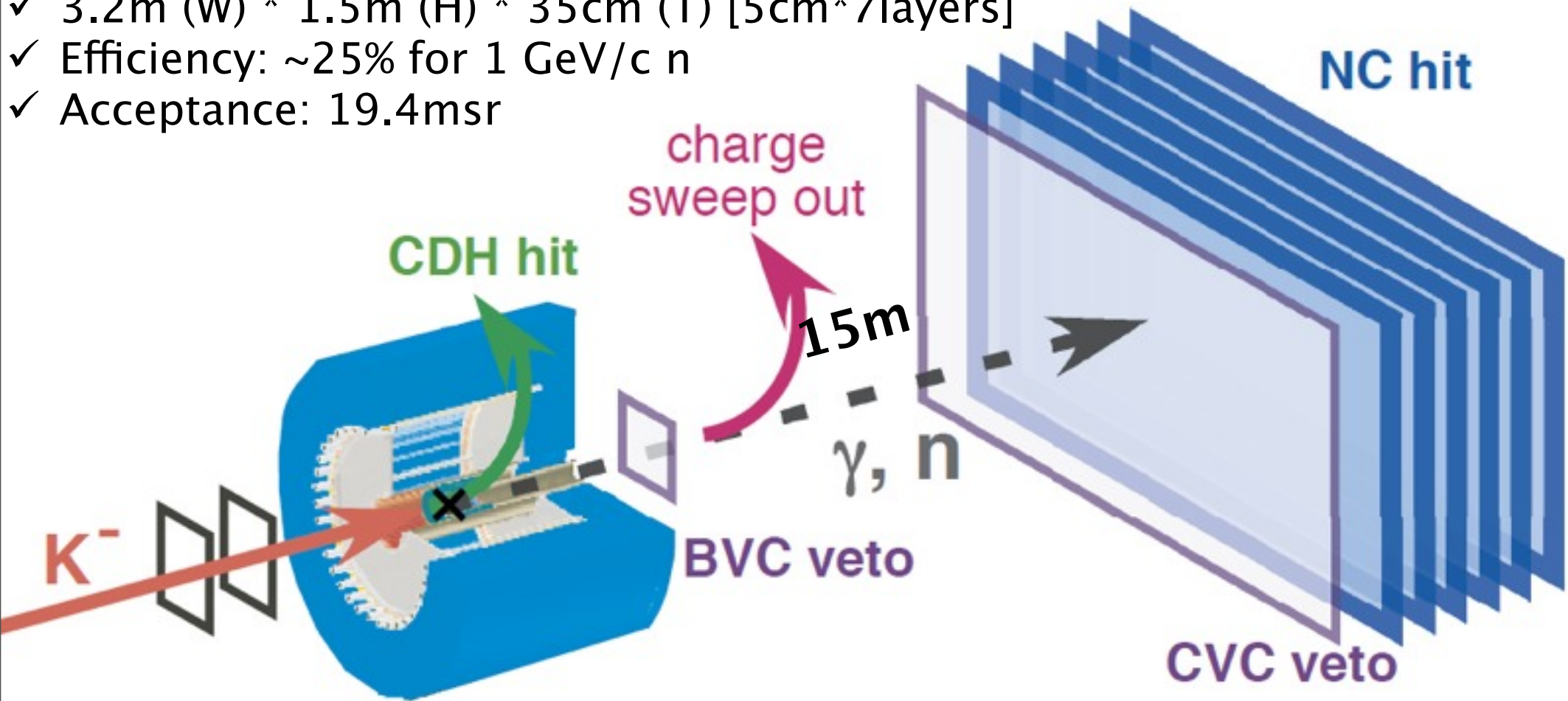
A search for the simplest kaonic nucleus K^-pp using ^{3}He(in-flight K^-,n) reaction



Forward neutral particles

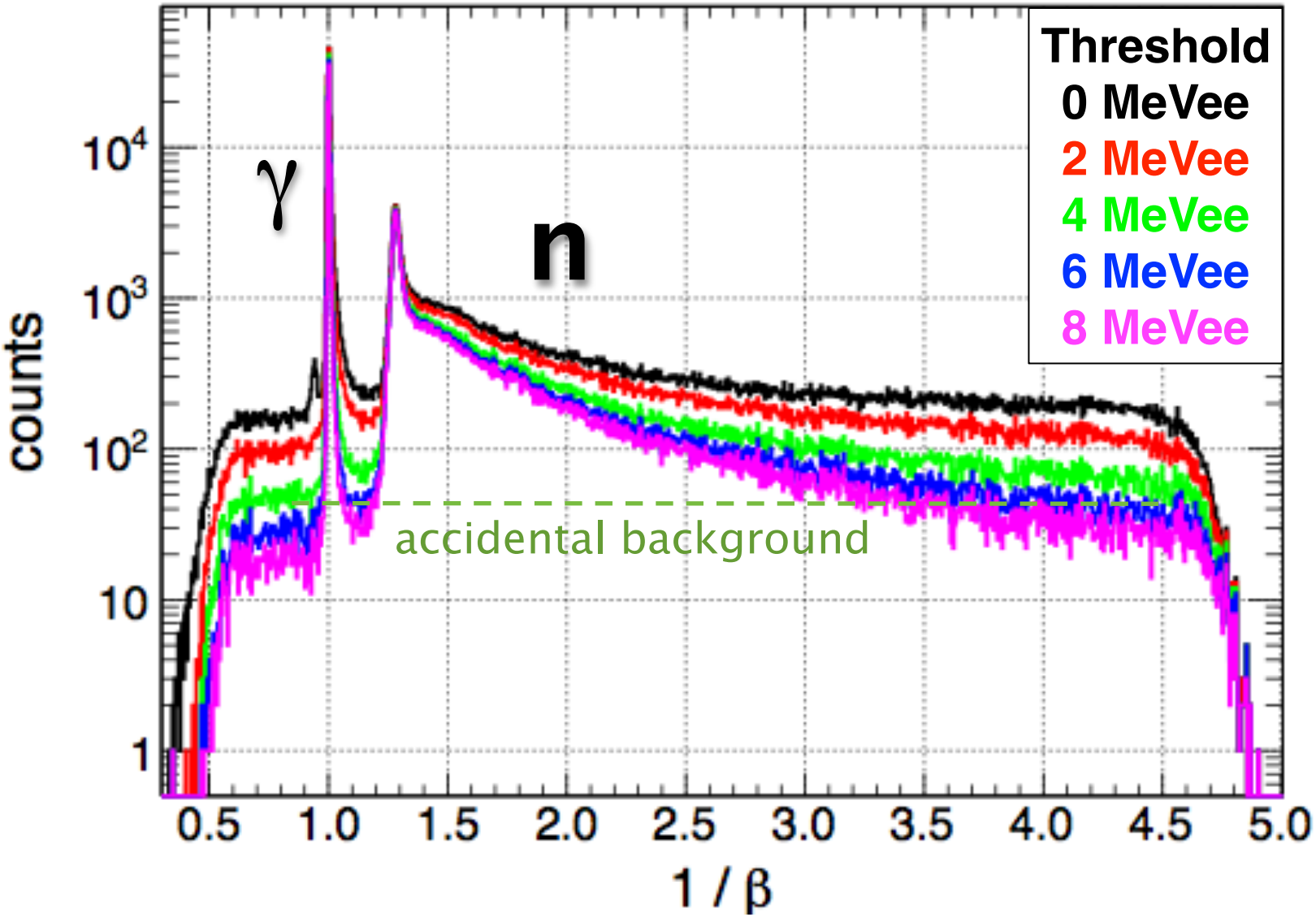
Neutron Counter

- ✓ 3.2m (W) * 1.5m (H) * 35cm (T) [5cm*7layers]
- ✓ Efficiency: ~25% for 1 GeV/c n
- ✓ Acceptance: 19.4msr



- Neutron momentum is determined by TOF method
- require at least 1 track in CDC to reconstruct the reaction vertex→ flight length

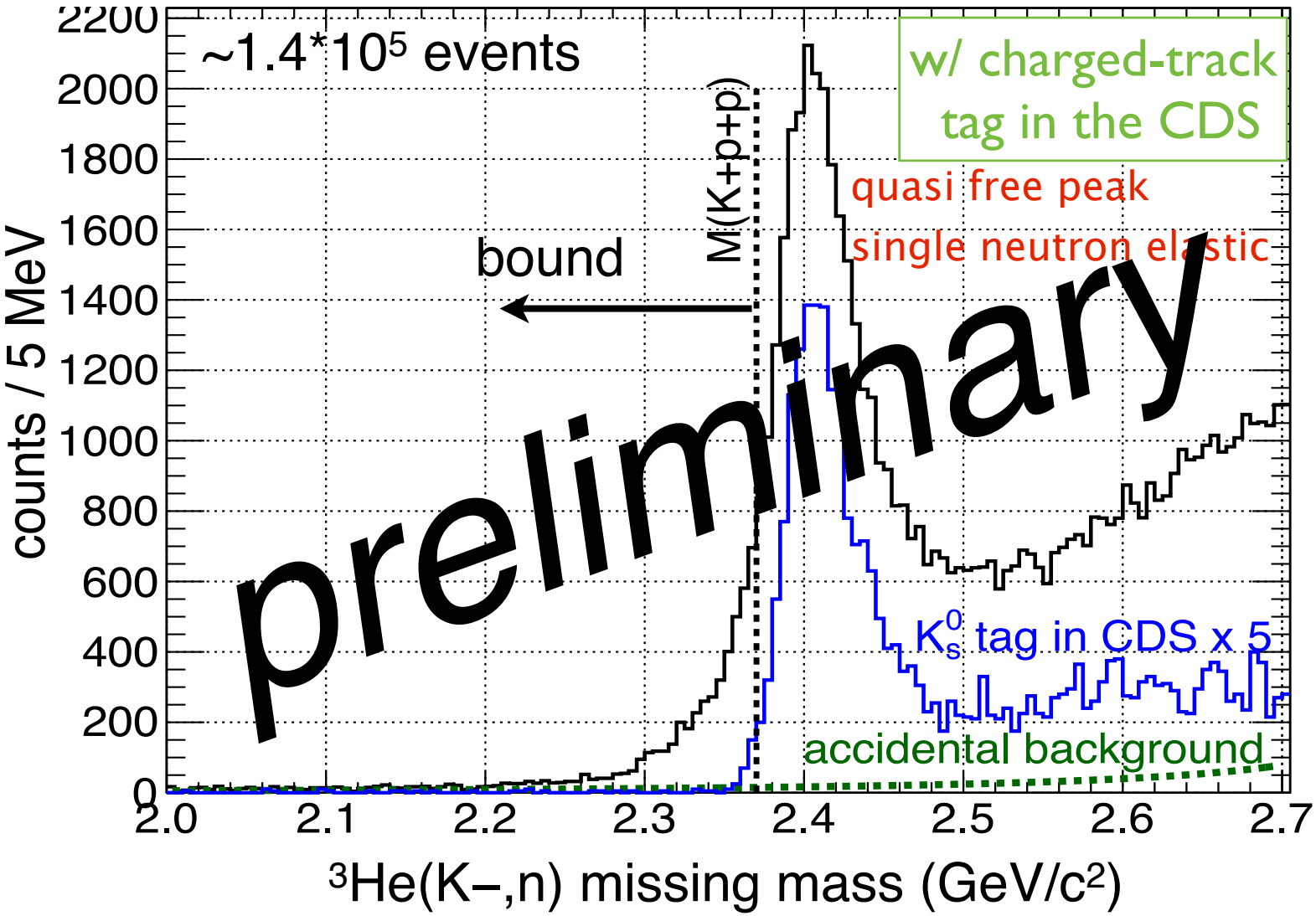
Forward neutral particles



- ✓ **Set threshold to 5 MeVee**
- ✓ good S/N ratio of ~100% @ QF neutron peak
- ✓ σ_{TOF} ~ 160ps → $\sigma_{M.M.}$~ 10MeV/c² for 1GeV/c n

Preliminary Result 1: ^{3}He(K-,n)

Semi-inclusive ^{3}He(K$^-$,n) $\sigma_{M.M.}$~ 10MeV/c^2 @ 1GeV/c

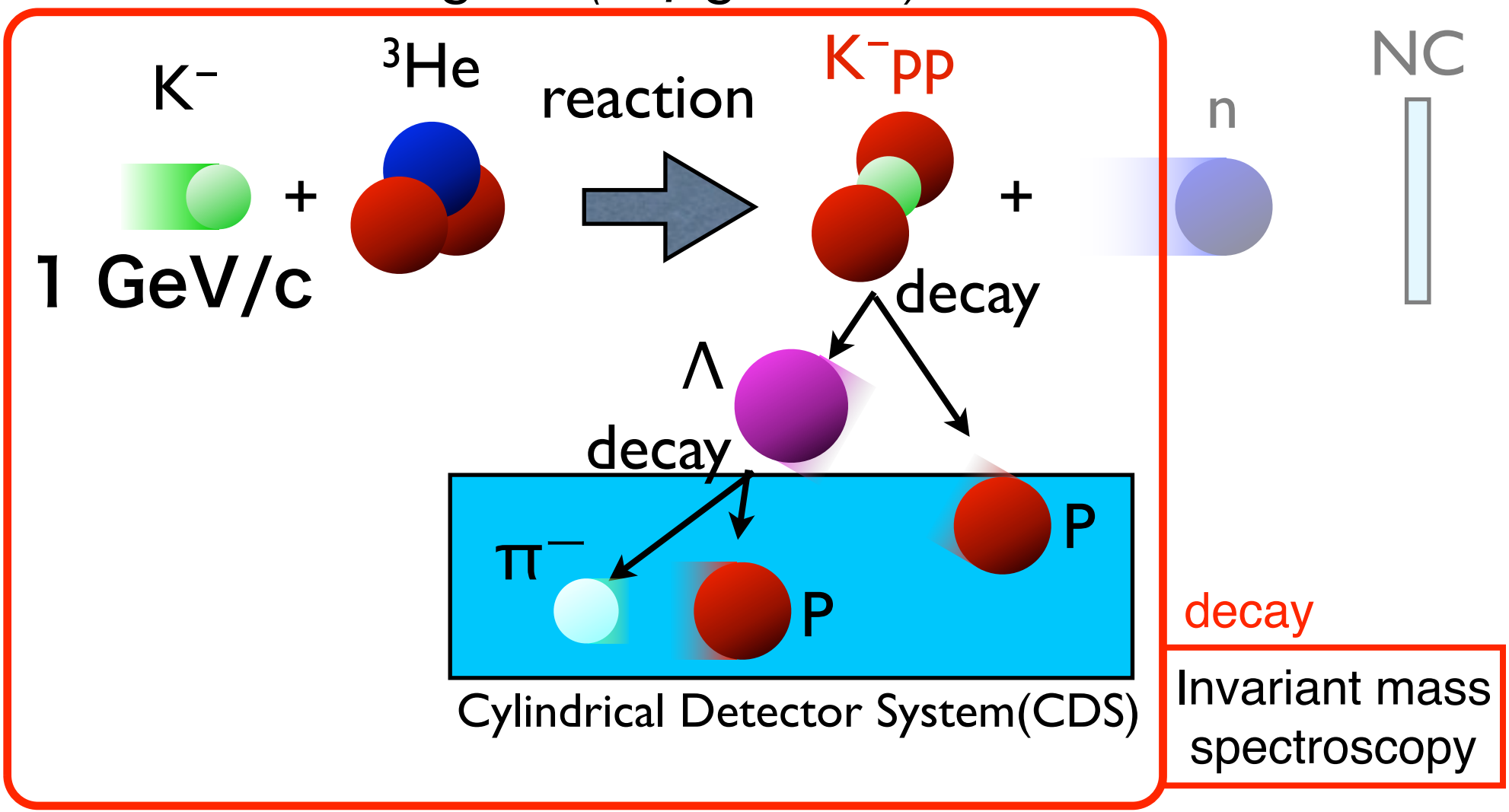


Quasi free peak (K−n→K−n & K−p→K0n) is clearly seen

The tail structure is very interesting, because tail component is not seen in K0 tagged spectrum (K−p→K0n)

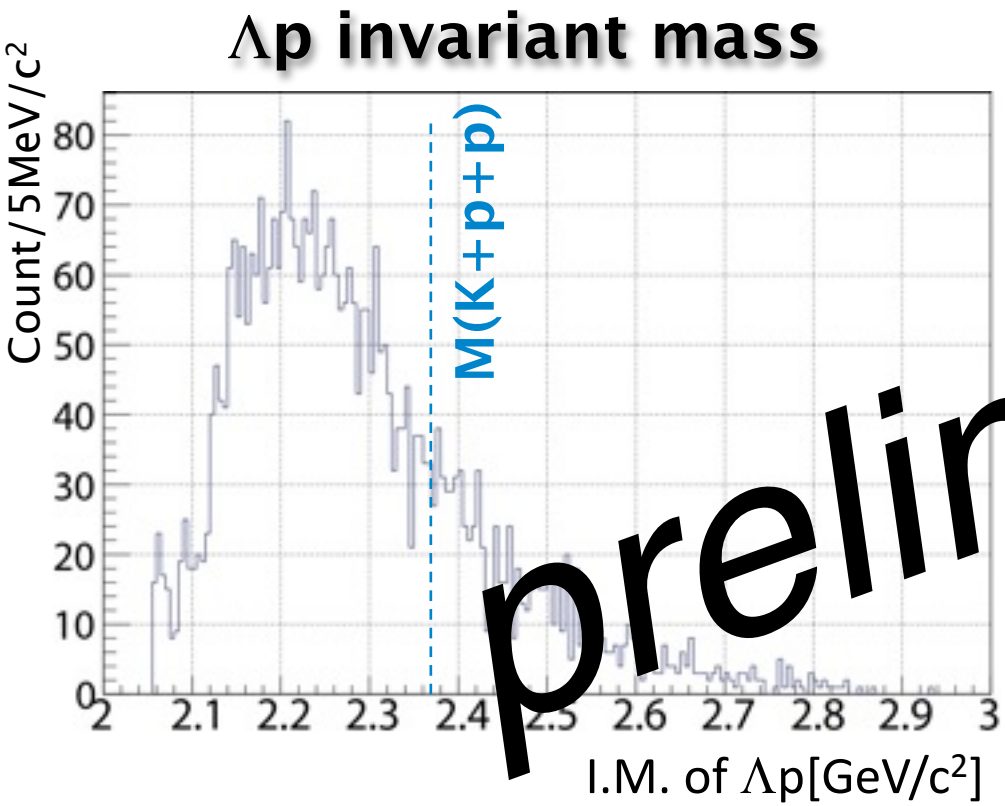
Λp event in CDS

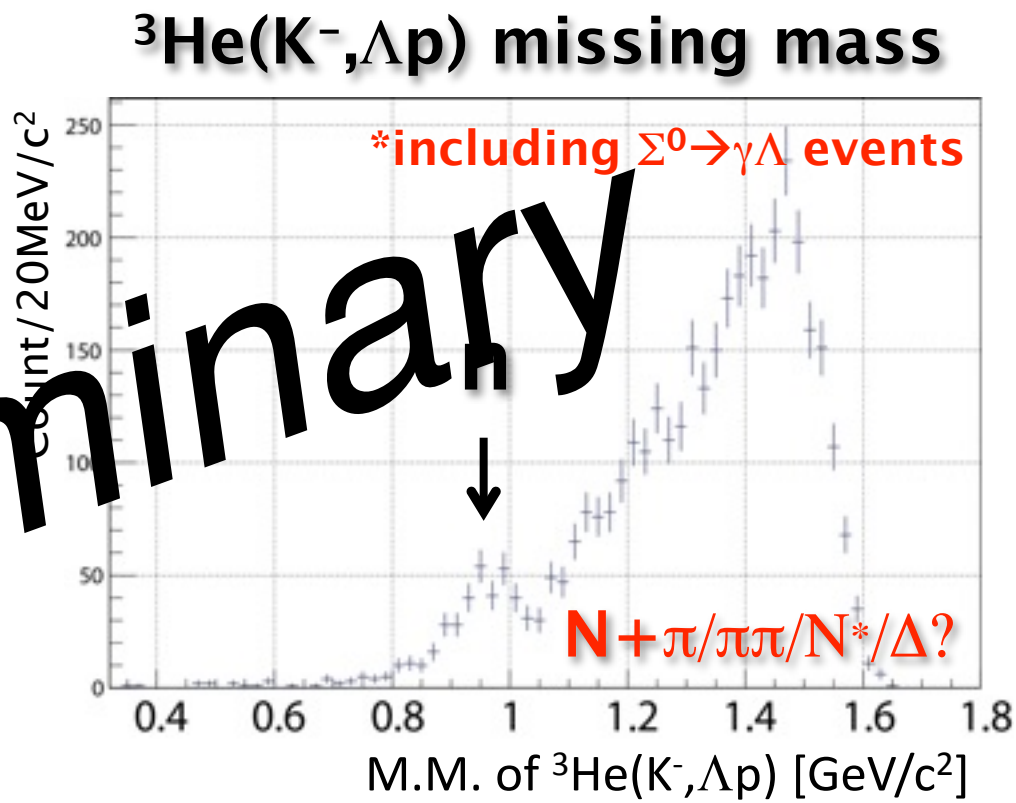
A search for the simplest kaonic nucleus K^-pp using ^{3}He(in-flight K^-,n) reaction



Preliminary Result2: ^{3}He(K-,Λp)

~ 3000 ppπ- events are detected in CDS





I.M. of Λp

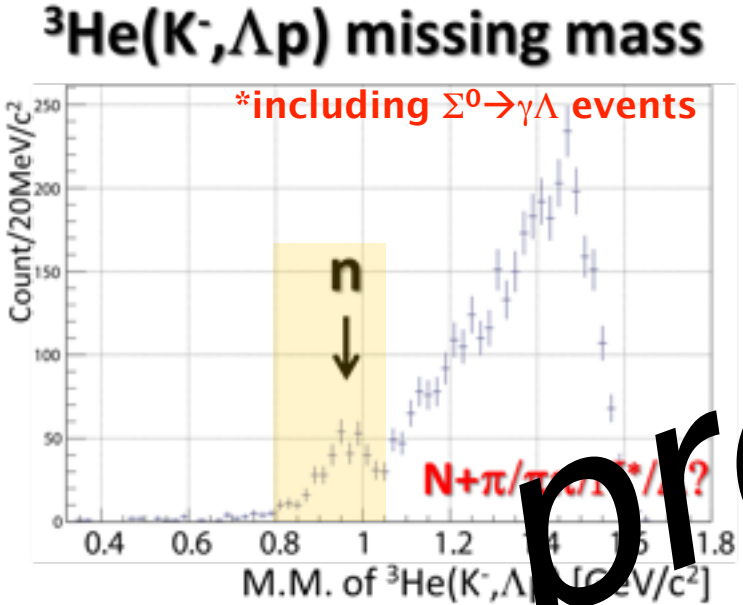
spectrum shape is NOT understood yet.

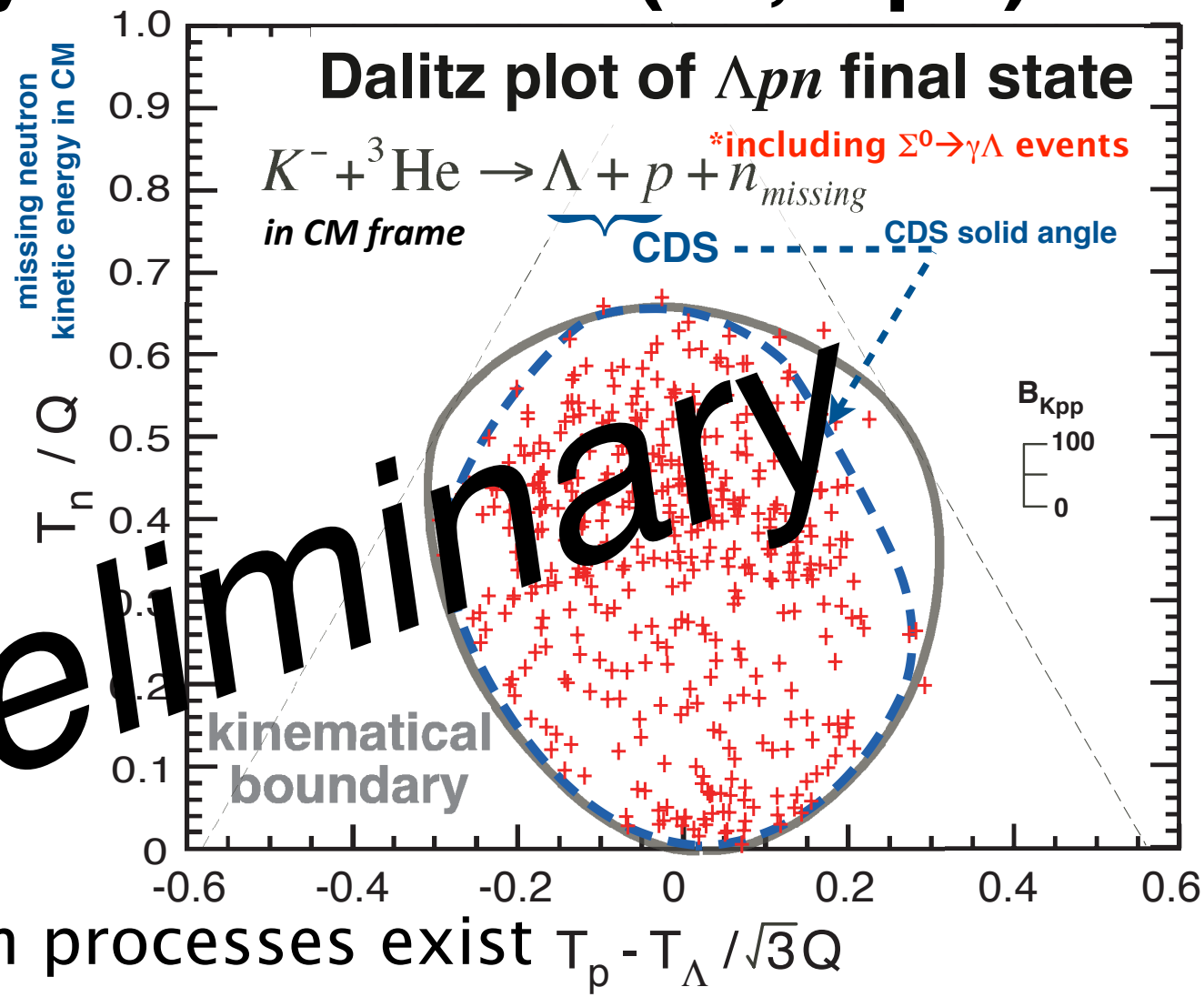
M.M. of ^{3}He(K$^-$,Λp)

neutron missing mass peak can be seen.

Preliminary Result2: ^{3}He(K-, Λpn)

Select neutron missing peak





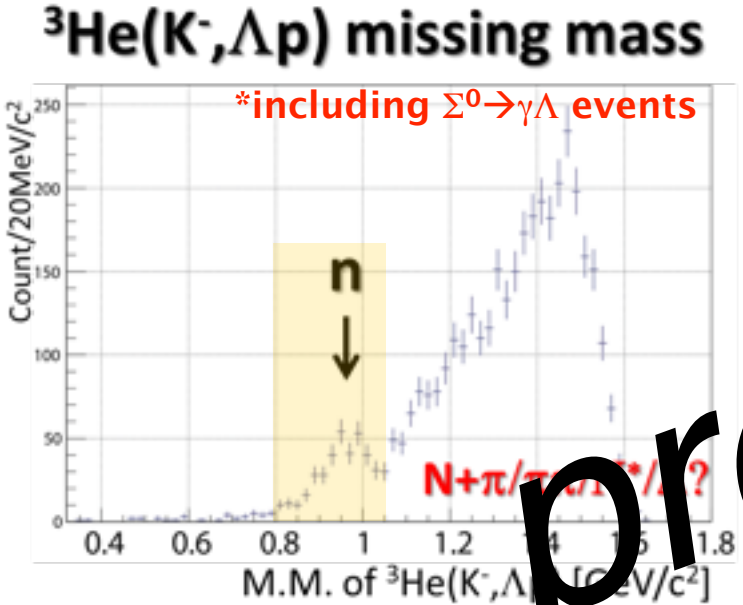
preliminary

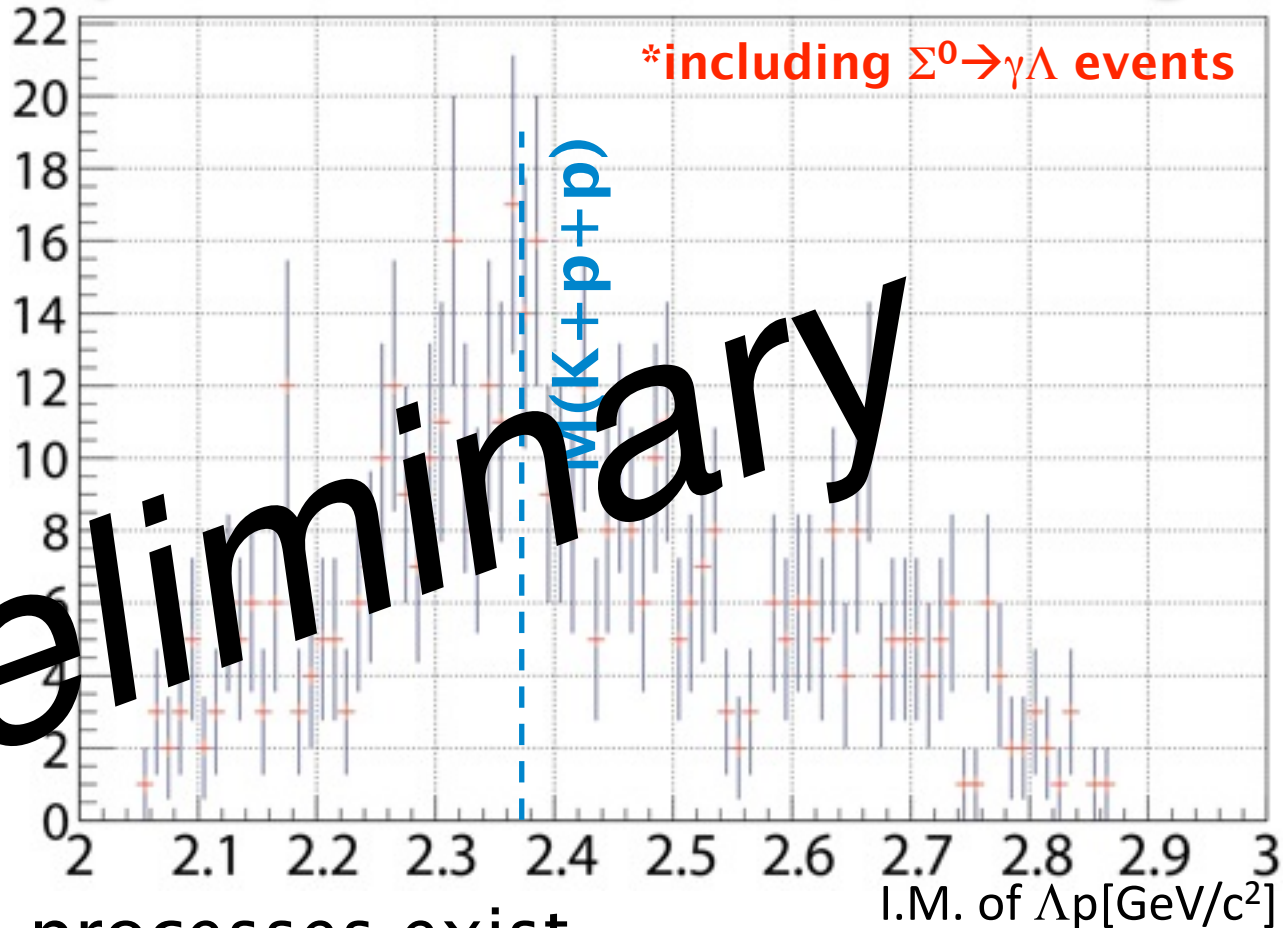
- multi-N absorption processes exist
- distribution as expected phase-space decay of Λpn???

Preliminary Result2: ^{3}He(K-, Λpn)

Λp invariant mass w/ missing n

Select neutron missing peak





preliminary

- multi-N absorption processes exist
- distribution as expected phase-space decay of Λpn???
- Spectrum shape is NOT understood yet.
- Further analysis is ongoing: Opening angle of Λp, Momentum/Angular dist., etc.

Summary

- **We have performed 1st physics run of the J-PARC E15 experiment to search for the K^-pp bound-state**
  - ~$4*10^9$ kaons were incident on ^{3}He
    - ^{3}He(K^-,n) : ~$1.4*10^5$ events
    - semi-Inclusive ^{3}He(K-,n)X spectrum presented
    - ^{3}He(K^-,Λp) : ~3,000 events with the CDS
    - exclusive 3He(K-, Λpn) spectrum presented
- **Further analyses will be reported soon**
  - Finalization of the ^{3}He(K^-,n) spectrum
  - Detailed analysis of exclusive Λpn events
  - Comparison of ^{3}He(K^-,n/p) spectra
  - …

The J-PARC E15 collaboration

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