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

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For the J-PARC E15 collaboration

Hadron2013@Nara
Nov. 8, 2013

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Introduction

Motivation :
what will happen when anti-kaon is embedded in nucleus.

✔**Does the simplest Kaonic nuclei "K-pp" exist?**
✔**How much deeply bound ?**

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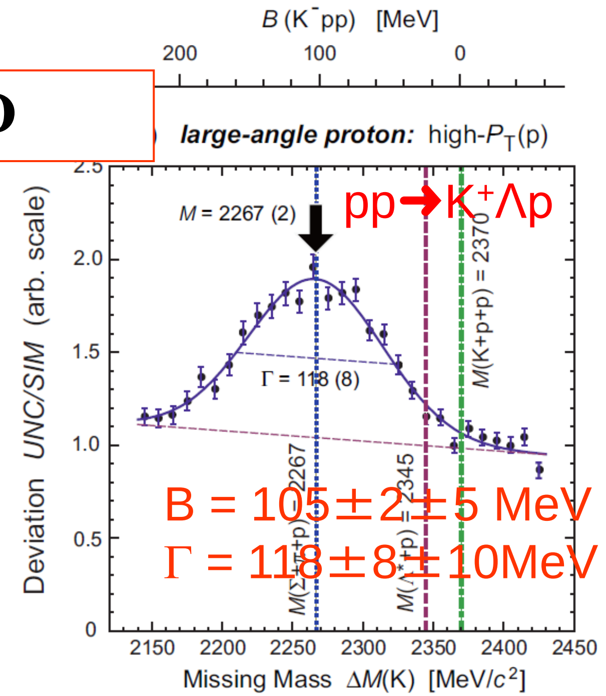
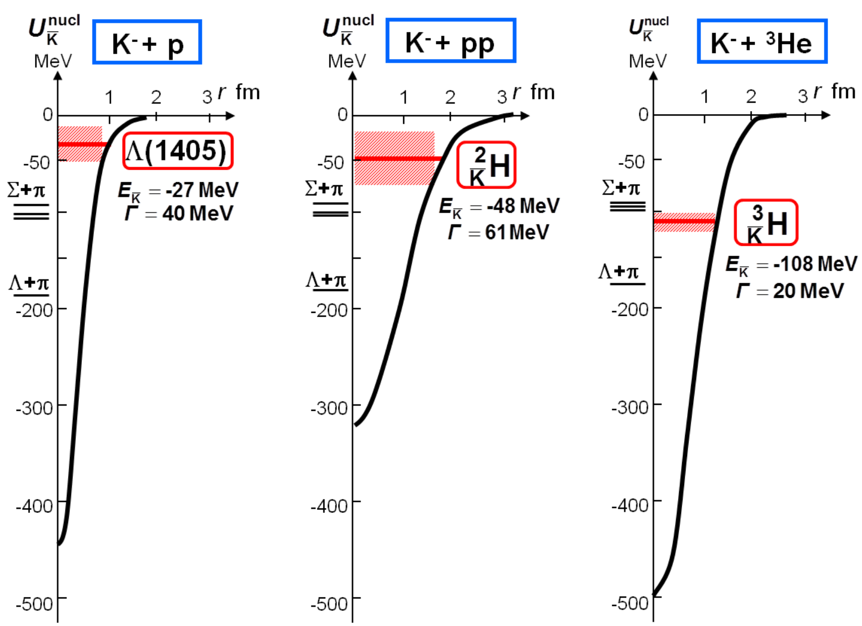


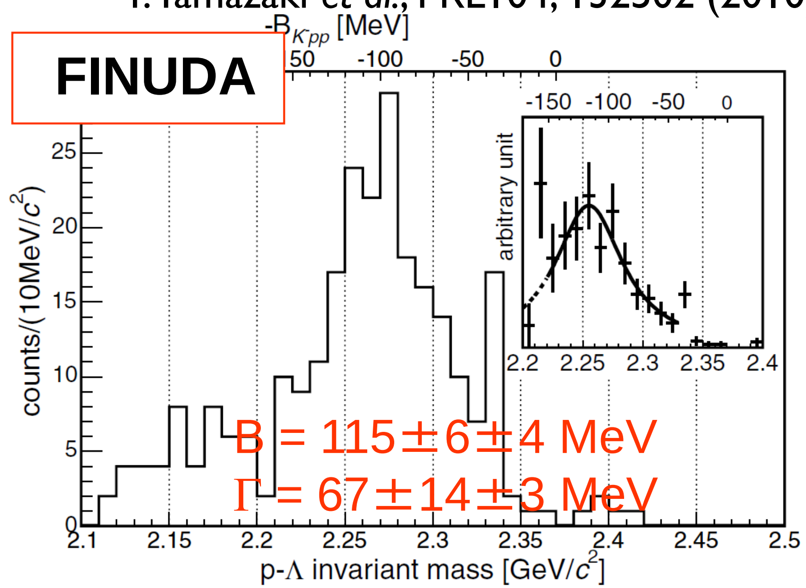
T.Yamazaki *et al.*, PRL104, 132502 (2010)



Y. Akaishi & T. Yamazaki, Phys. Rev. C65 (2002) 044005.

Y. Akaishi & T. Yamazaki, Phys. Lett. B535 (2002) 70.

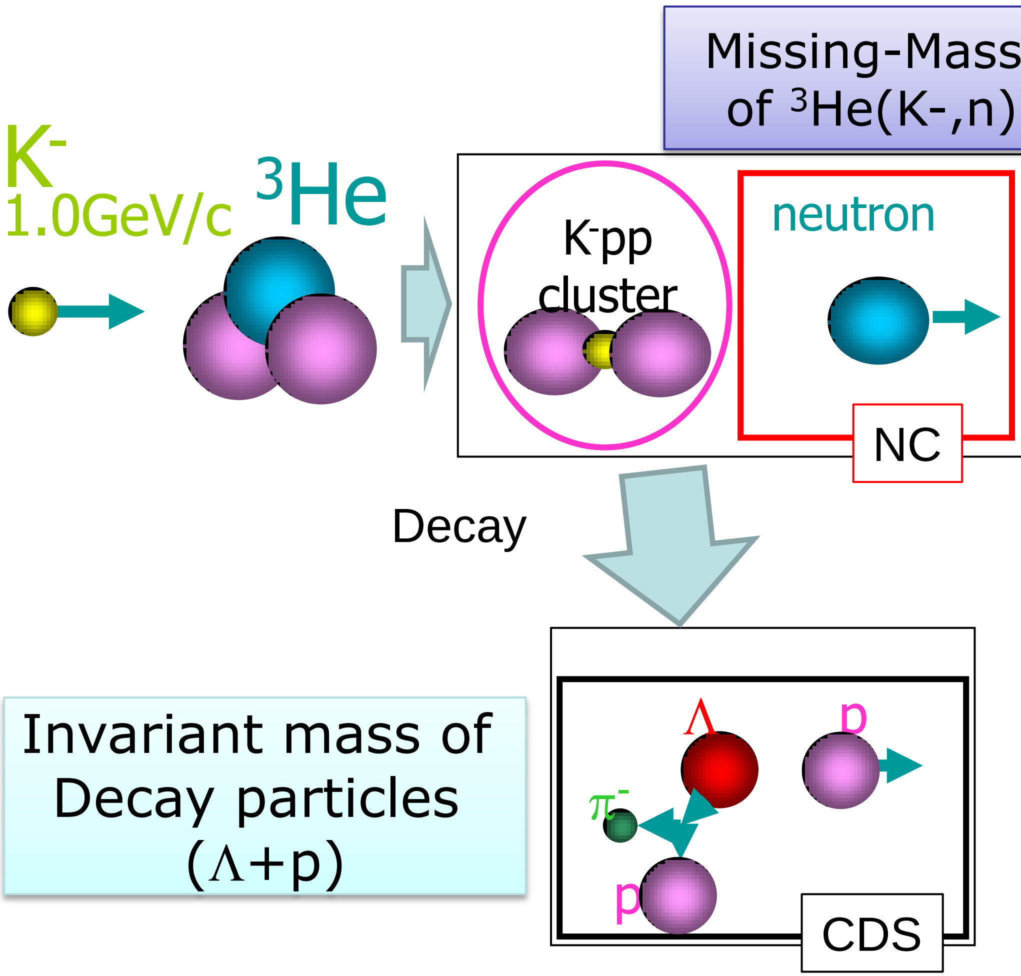
FINUDA



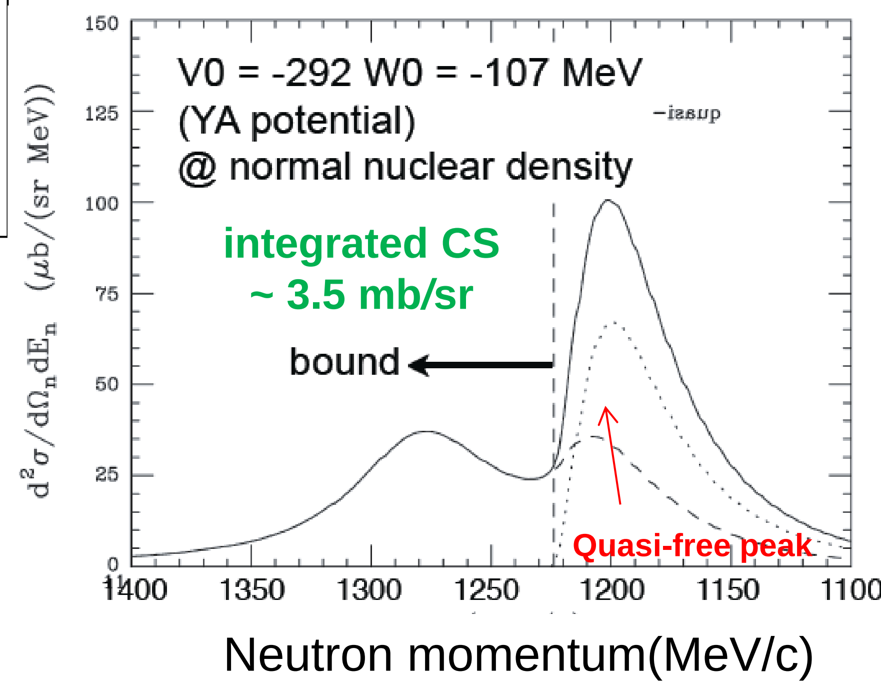
M.Agnello *et al.* , PRL 94, 212303 (2005)

J-PARC E15 Experiment

- **Search for K⁻pp bound state by using In-flight $^3He(K^-,n)$ Reaction.**
- **Measuring both I. M. and M. M. of "K⁻pp".**

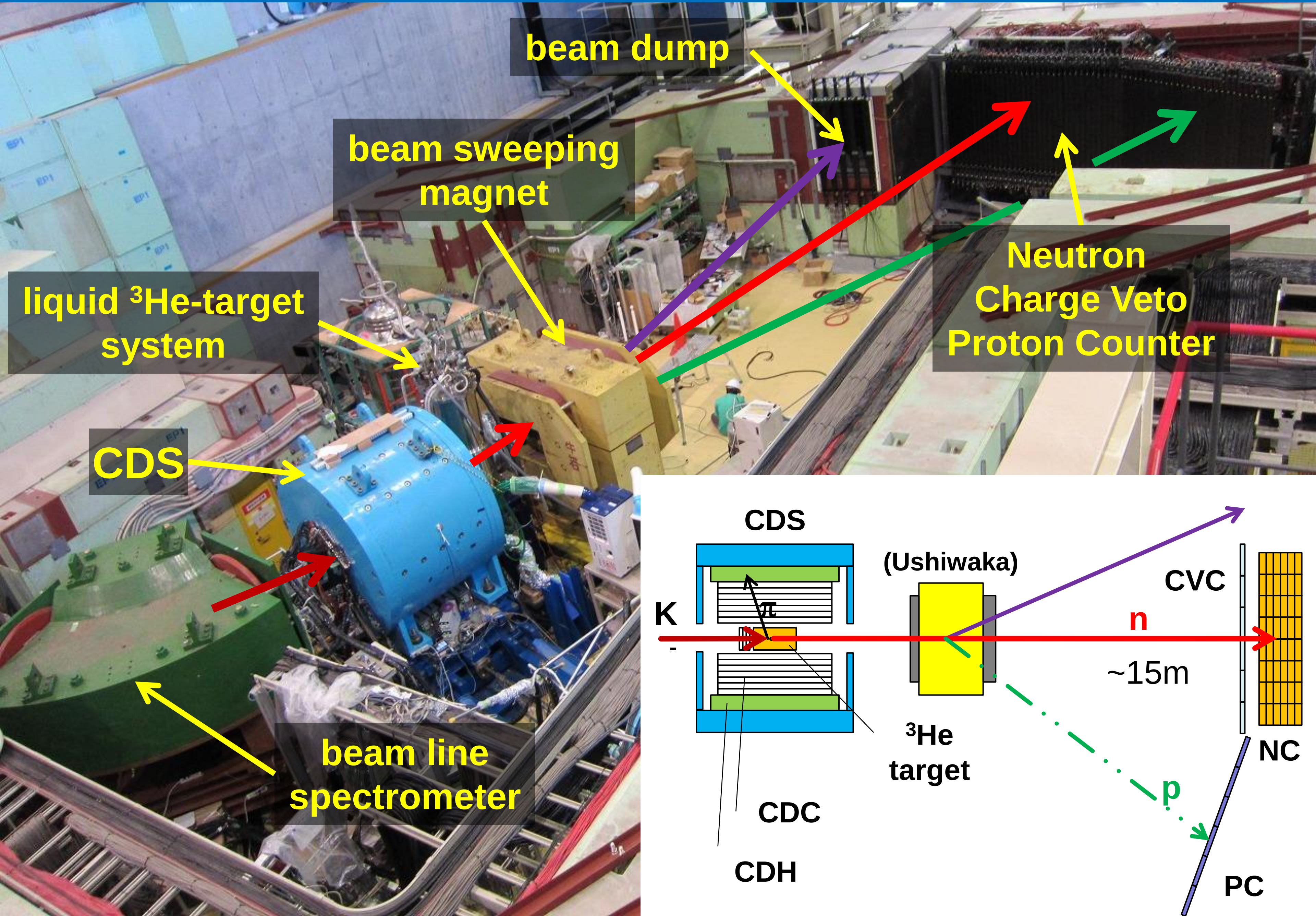


Theoretical calculation on $^3He(K^-,n)$
T. Koike and T. Harada, PLB652(2007)262



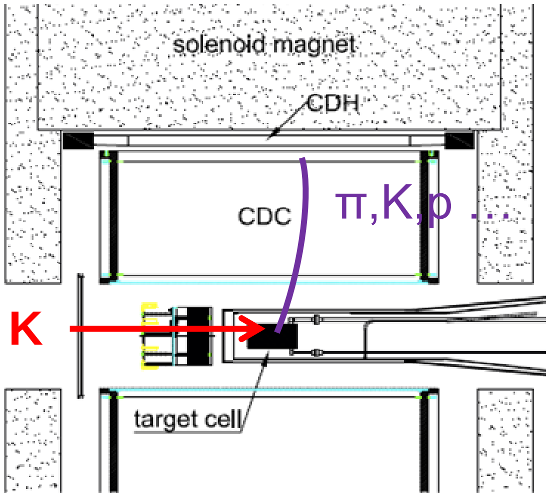
If right, we can measure the bound structure!

the completed K1.8BR spectrometer [Jun. 2012]



Cylindrical Detector System (CDS)

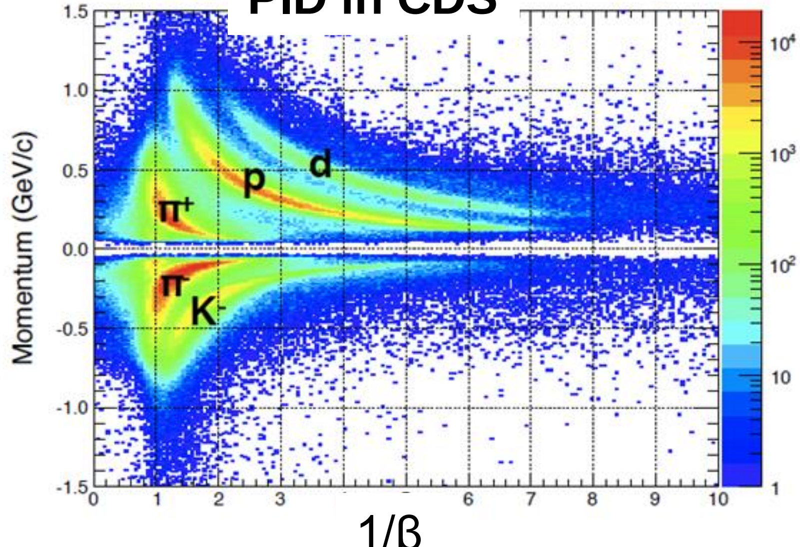
Cylindrical Detector System(CDS)



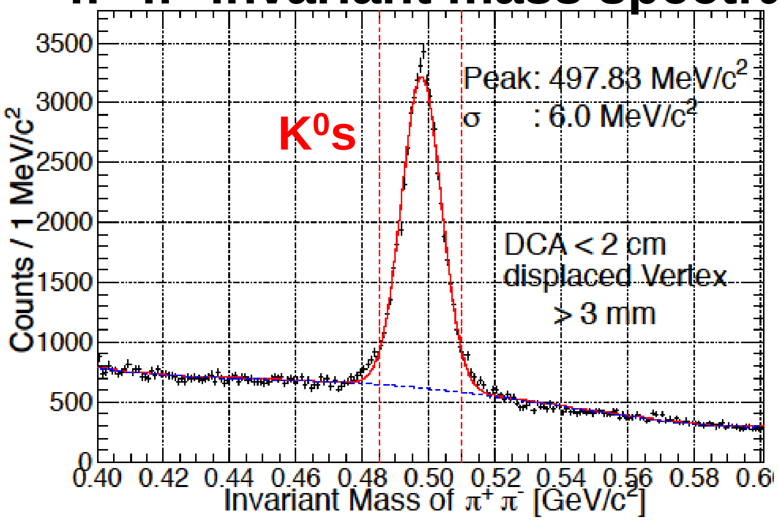
CDC:
 Drift Chamber
CDH:
 Hodoscope
Magnet: 0.7T

Cover 60% of the solid angle.

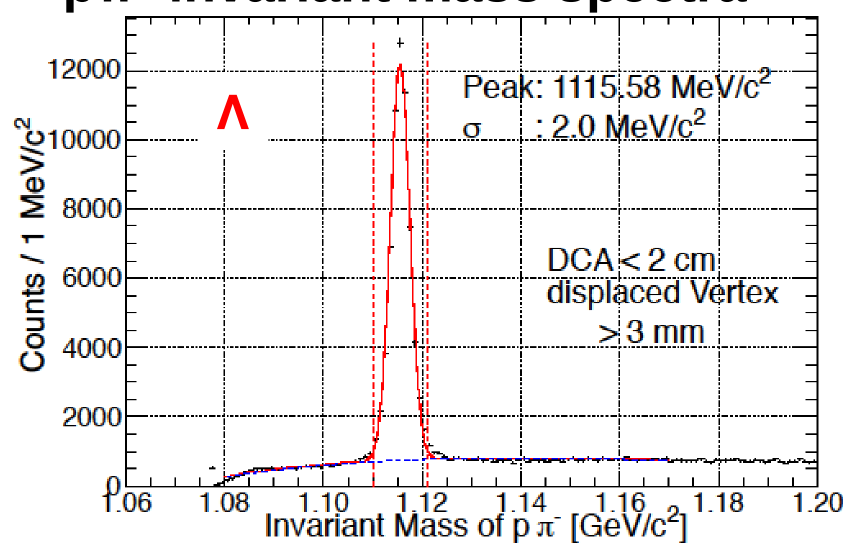
PID in CDS



π+π- invariant mass spectra

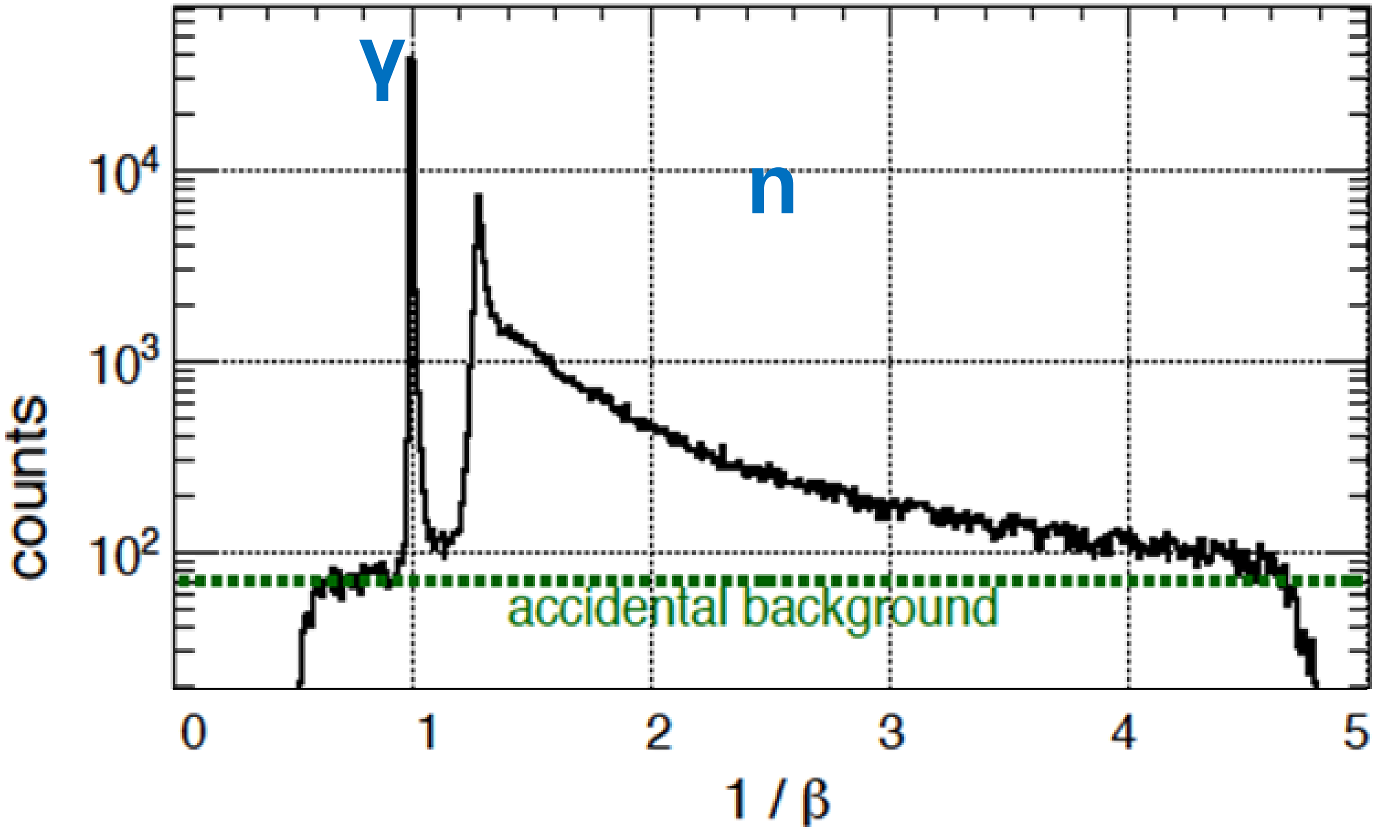


pπ- invariant mass spectra



Design performance was achieved!!

Forward neutral particle



- **Neutron Counter**
  - Neutron momentum is determined by TOF method.
  - **Good S/N of ~100**@QF neutron peak (Set threshold to 5 MeVee).
  - **σ_{TOF} ~ 160ps ➜ $\sigma_{M.M.}$ ~10 MeV/c^2 at the region of interest.**

J-PARC E15 1st stage physics run

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

period	Primary beam intensity	duration	Kaon on target
May, 2013	24kw (30Tppp, 6s cycle)	88 hours	4.0×10^9

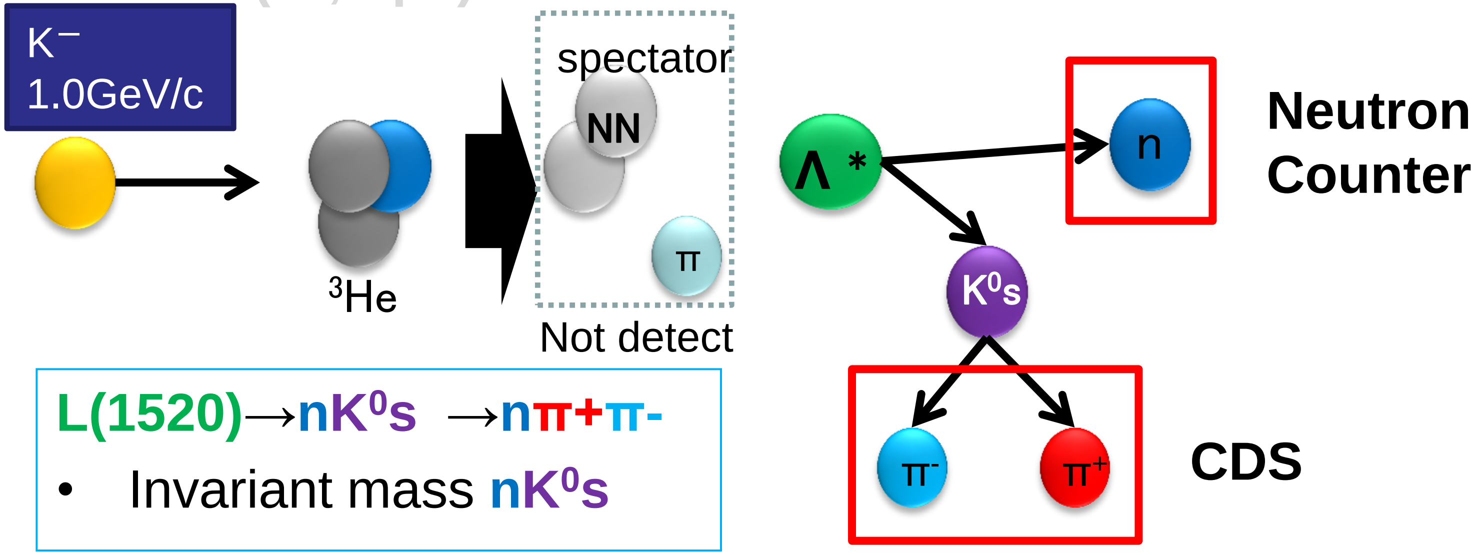
- **Preliminary result**
  1. Hyperon production study
     - Λ(1520) spectrum
  2. Semi-inclusive analysis
     - ^{3}He(K-,n) missing mass spectrum
  3. Exclusive analysis
     - ^{3}He(K-, Λpn) exclusive

Preliminary result : Hyperon production

Λ(1520) production

Semi – inclusive ^{3}He (K-, n) missing mass

Exclusive ^{3}He (K-, Λpn)

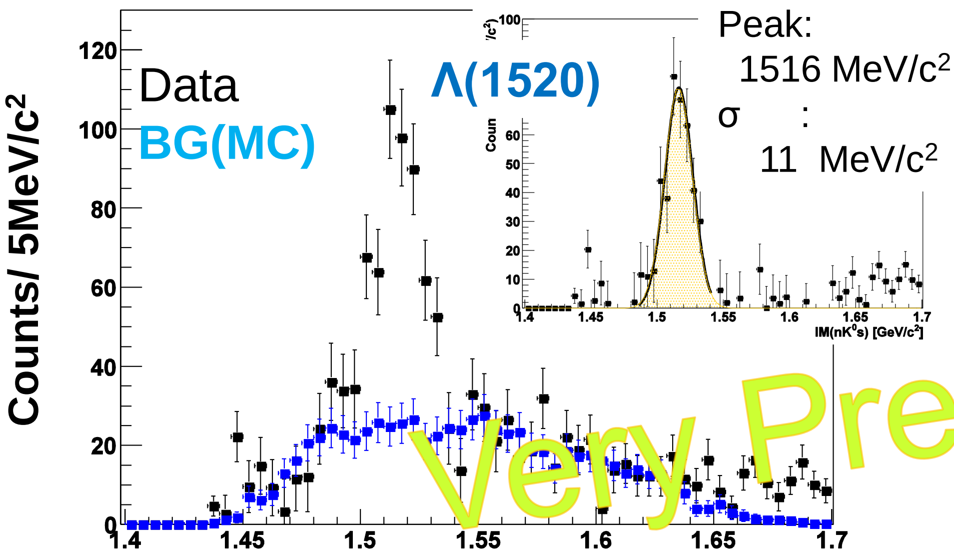


☑Hyperon production on nuclear target provides the important information on the **Y*N interaction**.

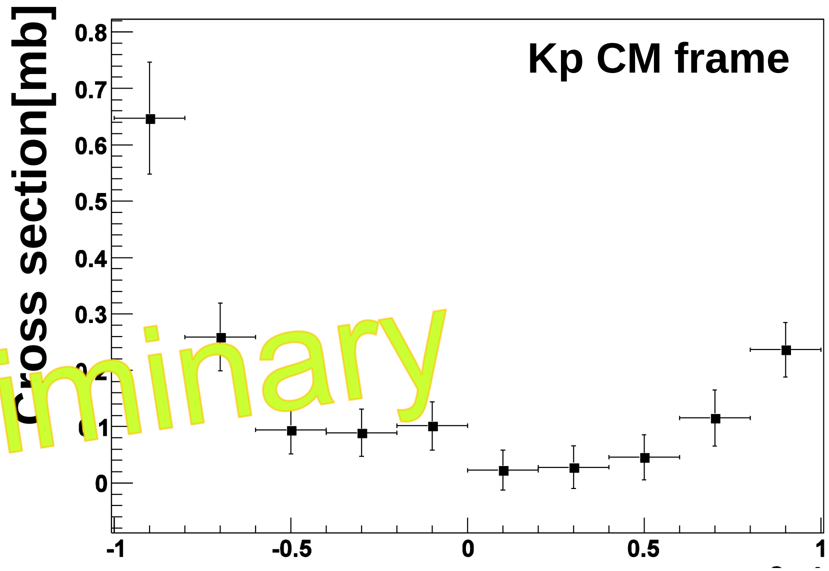
☑There are **no data** using **nuclear target** and **this energy region (K$^-$:1GeV/c)**.

Preliminary result : Hyperon production

Λ(1520) production



Invariant Mass of nK^0s [GeV/c^2]



Angular distribution of L1520[cosΘ]

☑**Λ(1520) peak is clear seen.**

BG: $Kp\to n\pi K^0 s$(non-resonant reaction)

☑Peak position is consistent with PDG.

☑Cross section .

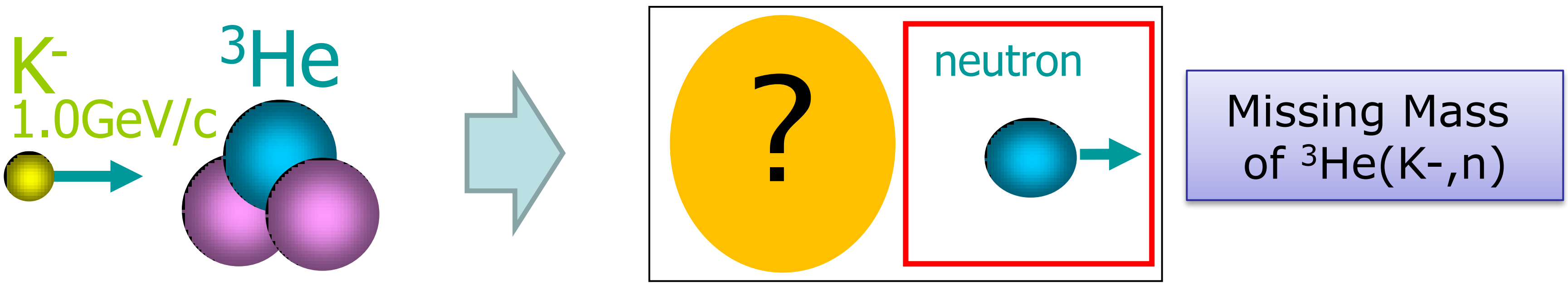
・**Consistent with old data at the same order level.**

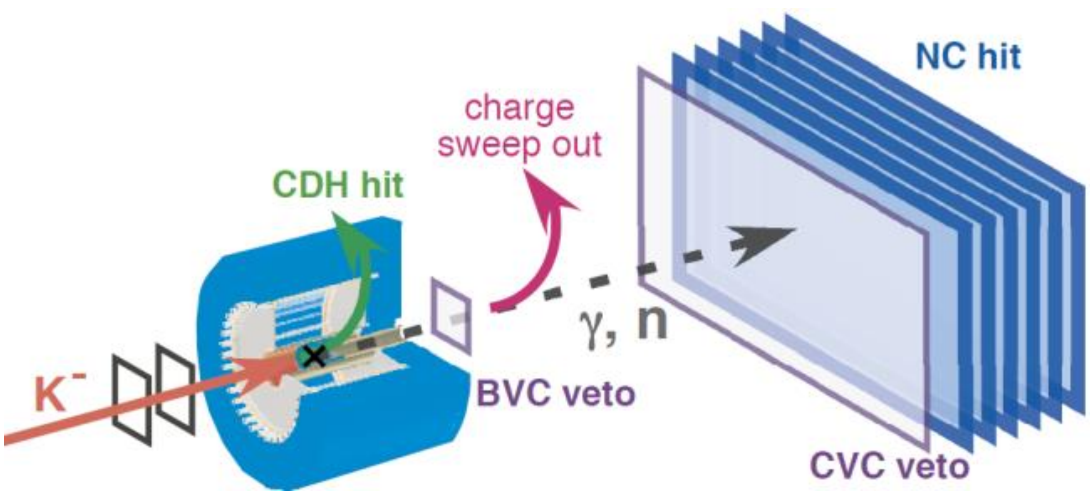
・**Study of other decay channels is in progress.**

Preliminary result :

Semi – inclusive ^{3}He(K-, n) missing mass

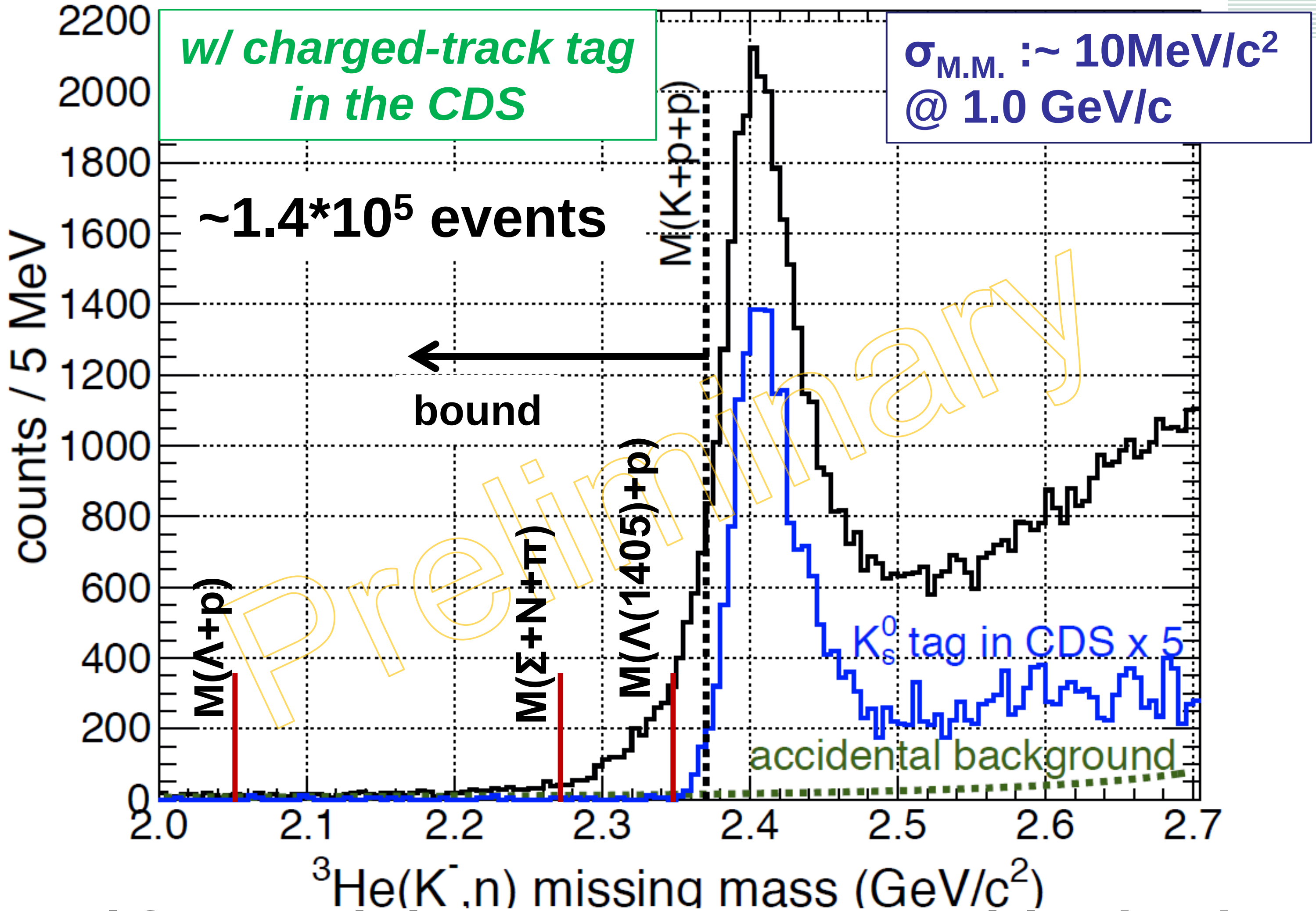
Exclusive ^{3}He (K-, Λpn)





“Semi-” : require at least 1 charged track in the CDS.

Semi-Inclusive ^{3}He(K$^-$,n)



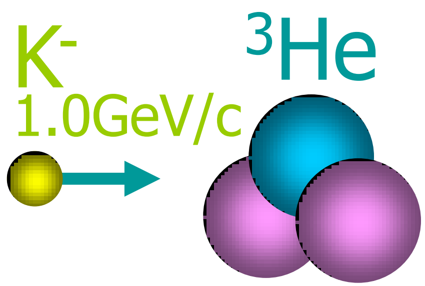
☑Quasi free peak (K-n→K-n & K-p→K0n) is clearly seen.

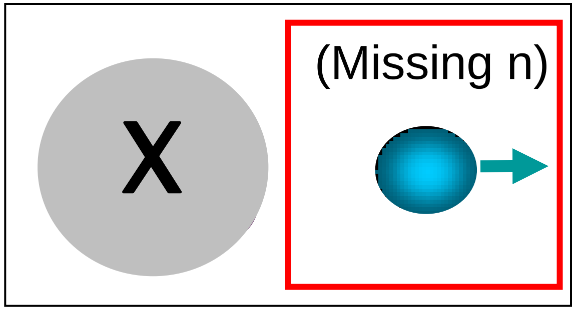
☑**The excess in the K-bound region is very interesting,** it's hard to explain by detector resolution.

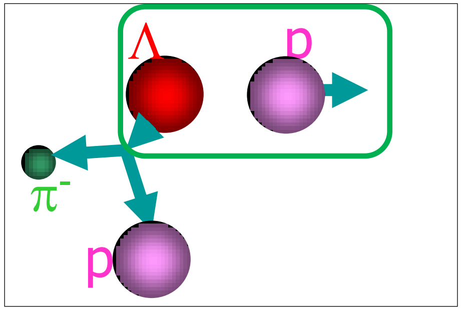
Preliminary result :

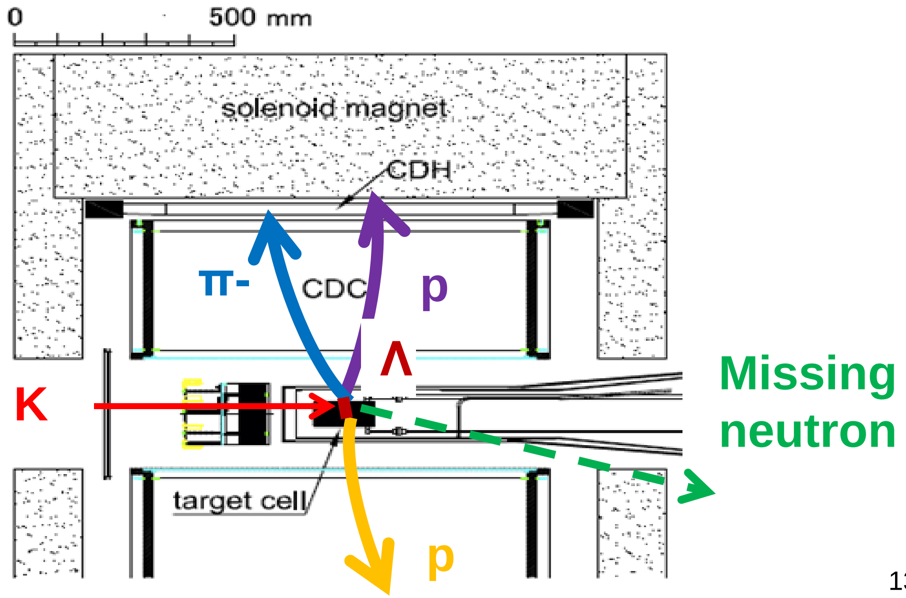
Semi – inclusive ^3He (K-, n) missing mass

Exclusive ^3He (K-, Λpn)

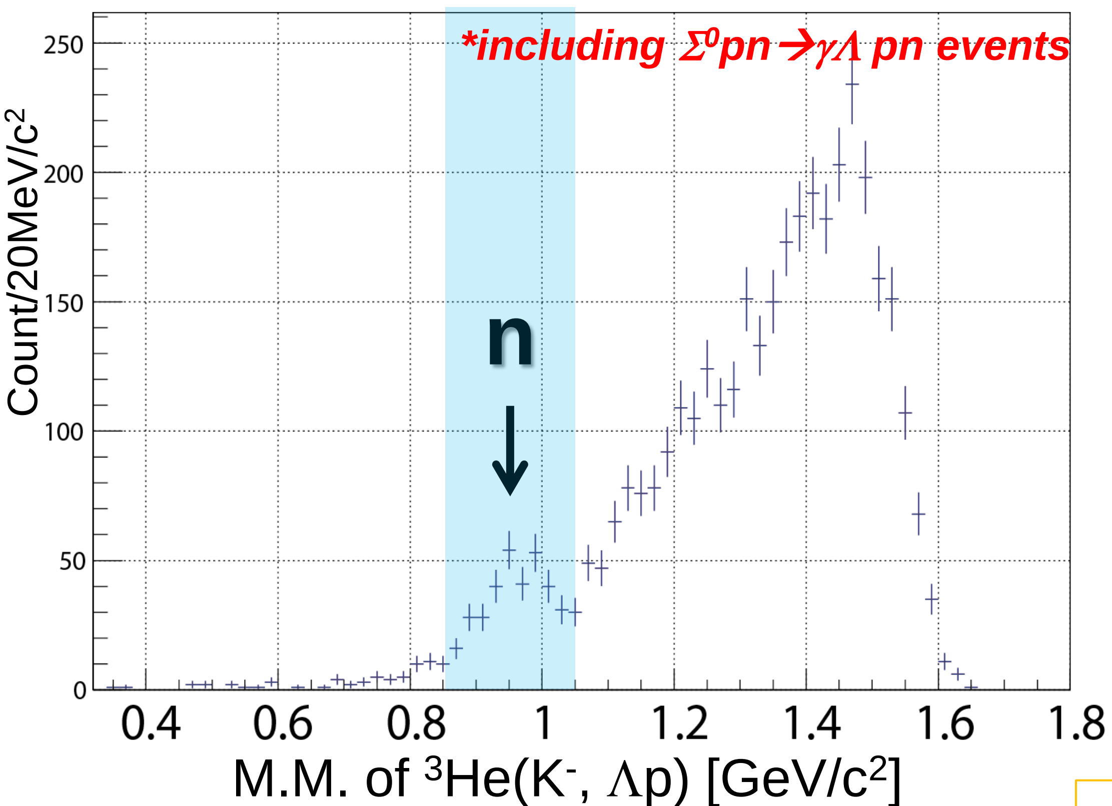


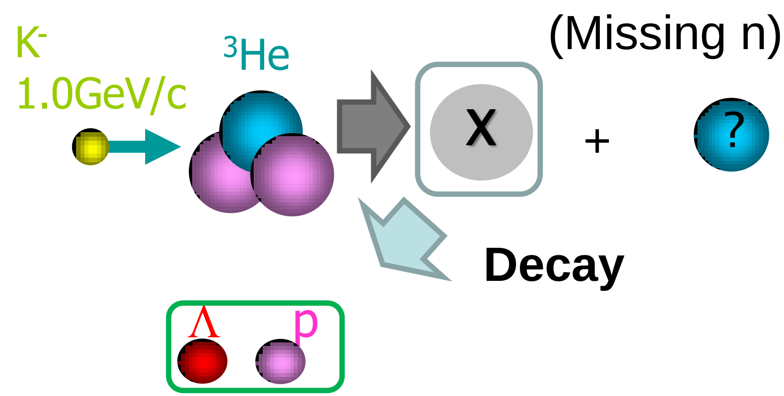






Missing Mass of ^{3}He(K$^-$, Λp)



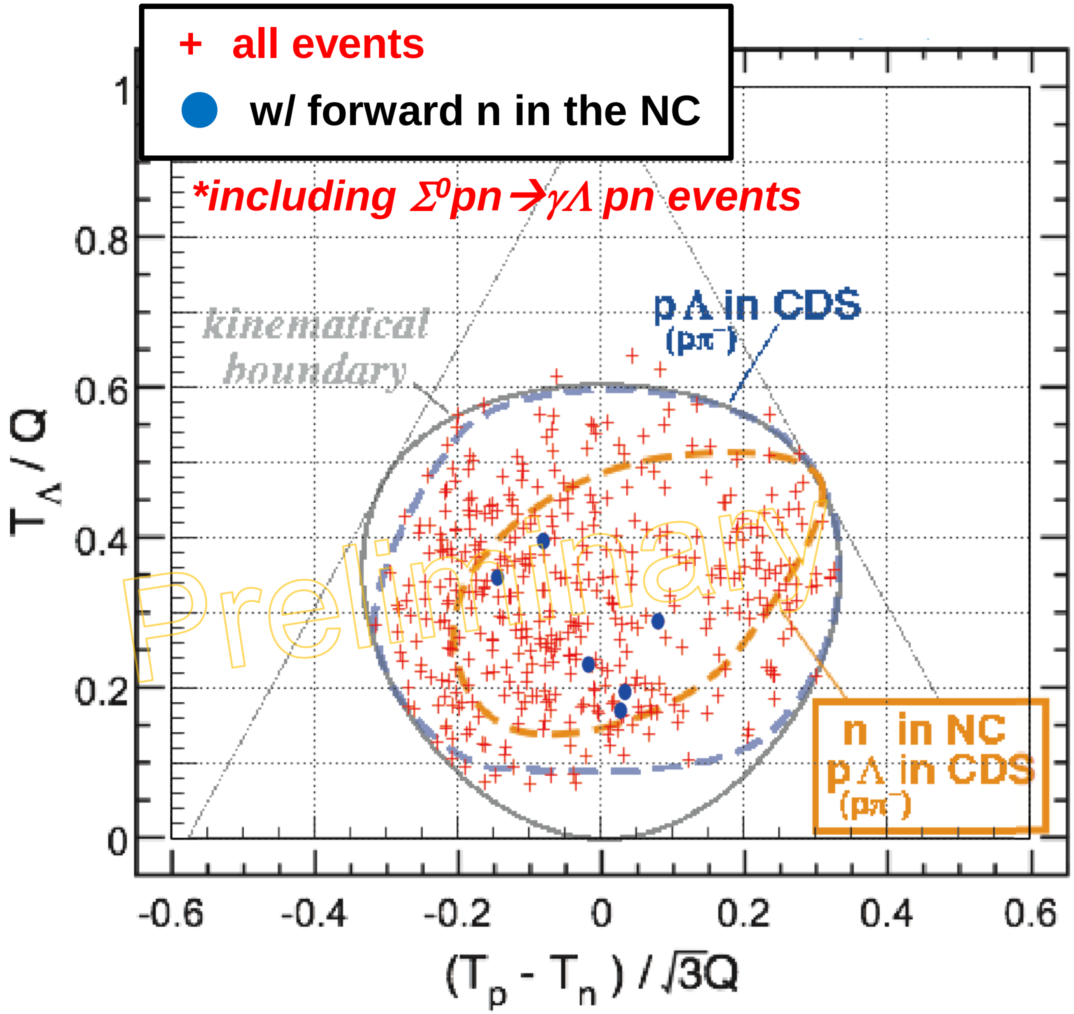


M. M. of ^{3}He (K-, Λp) [GeV/c^2]

- **Missing neutron** **can be identified.**
- **Num. of Λpn (n missing) is ~400 events.**

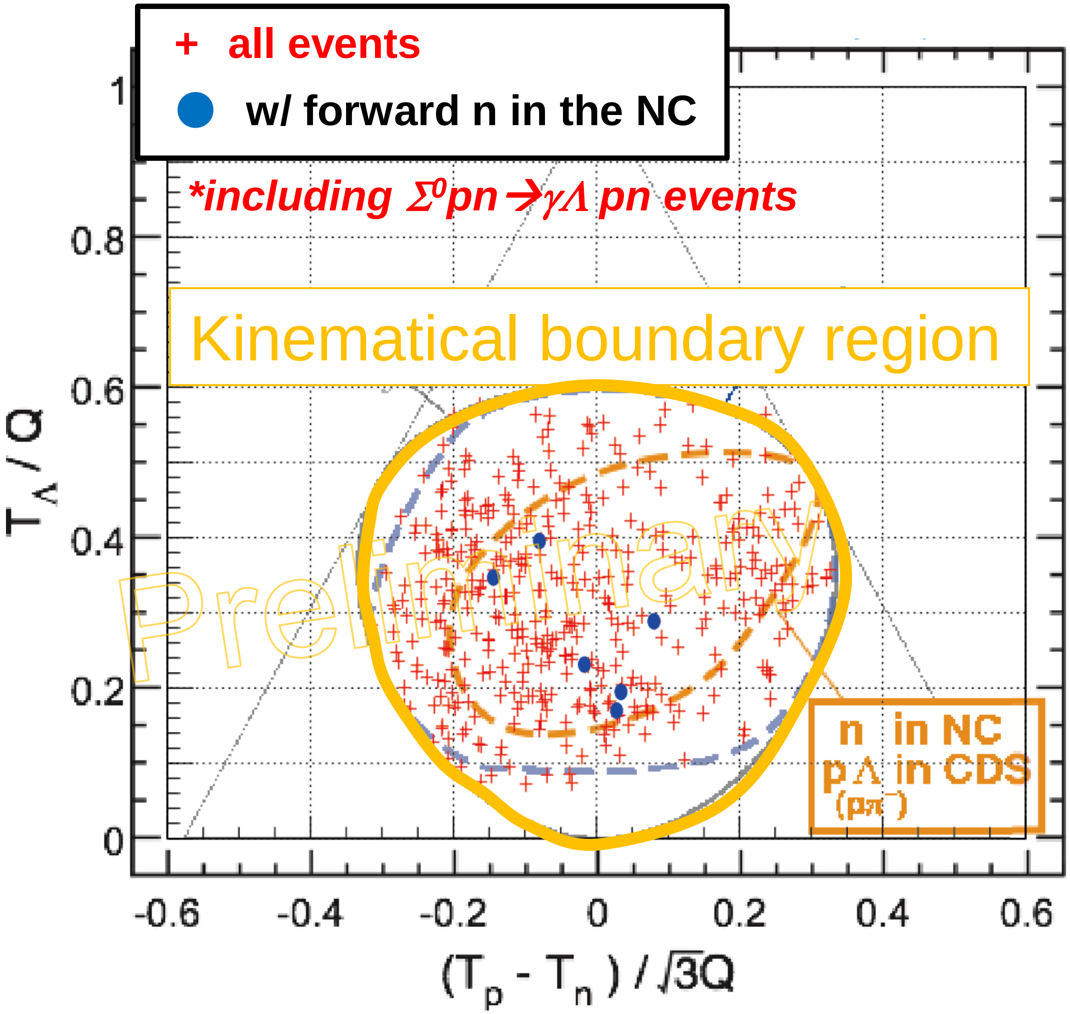
To study the origin of Λpn events,
Let check Dalitz-plot in the next slide.

$^3He(K^-, \Lambda pn)$ Result :Dalitz plot of Λpn



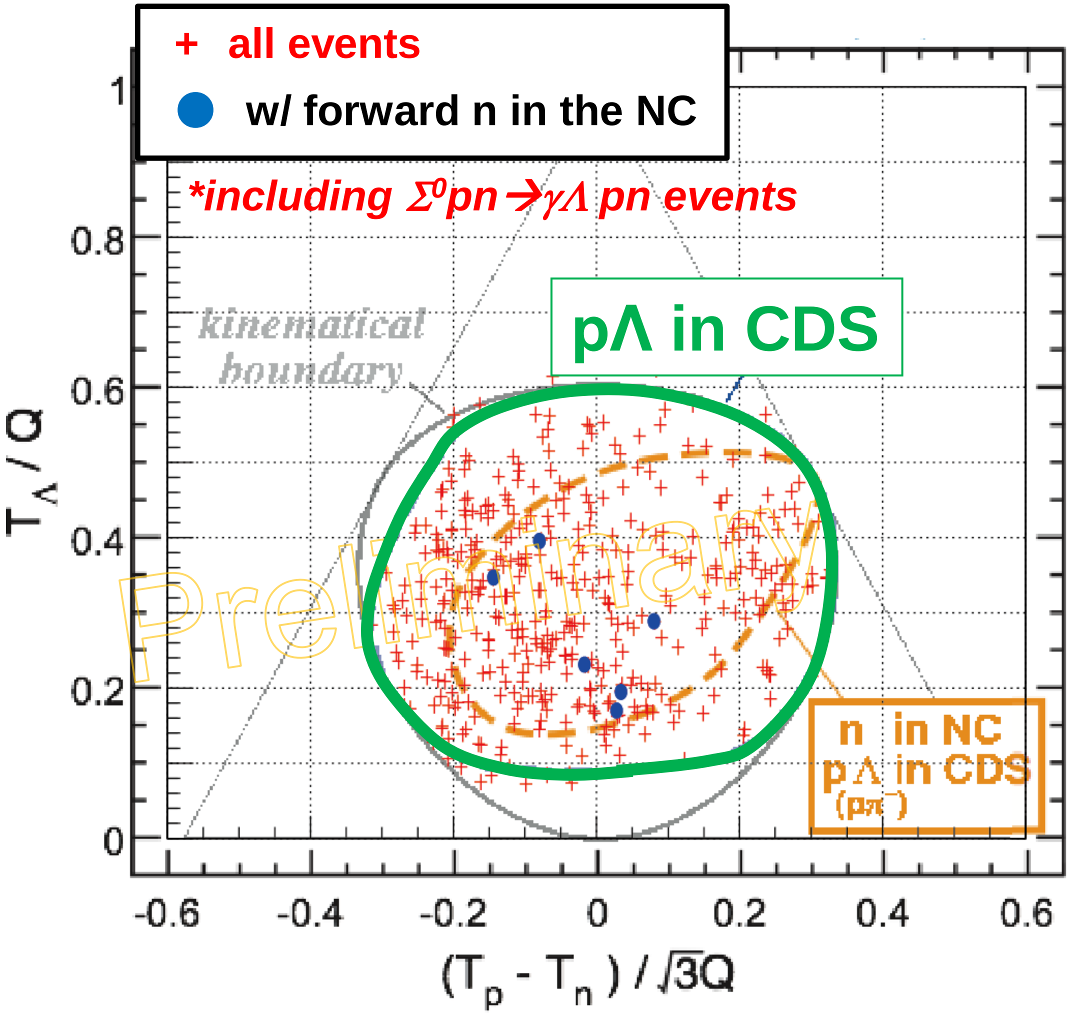
Selected **neutron missing** mass peak.

^{3}He(K^-, Λpn) Result :Dalitz plot of Λpn



Selected **neutron missing** mass peak.

^{3}He(K$^-$, Λpn) Result :Dalitz plot of Λpn

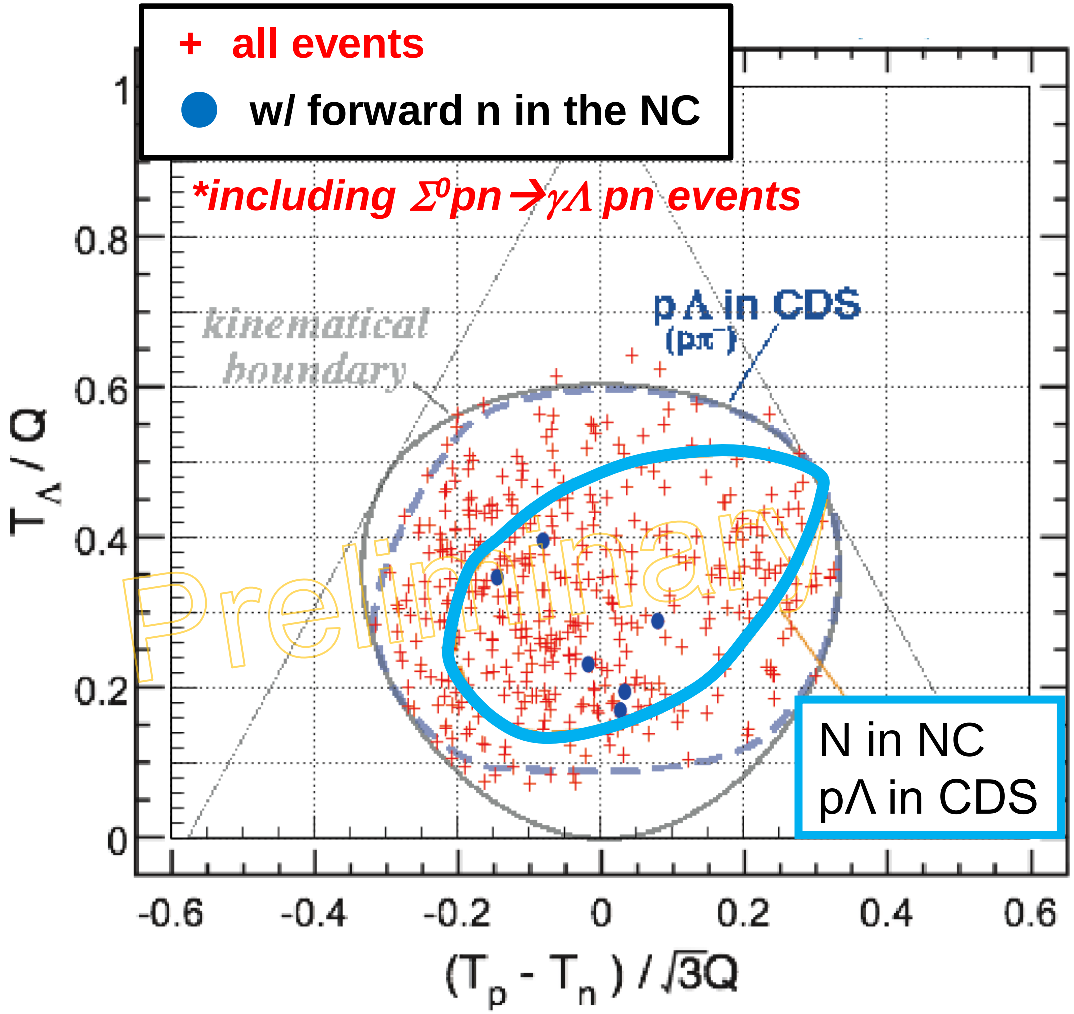


Selected **neutron missing** mass peak.

- Events are scattered widely in phase space.
- Multi-N absorption processes exist.

☑**It seems 3N-abs(Λpn) exists**

^{3}He(K$^-$, Λpn) Result :Dalitz plot of Λpn



Selected **neutron missing** mass peak.

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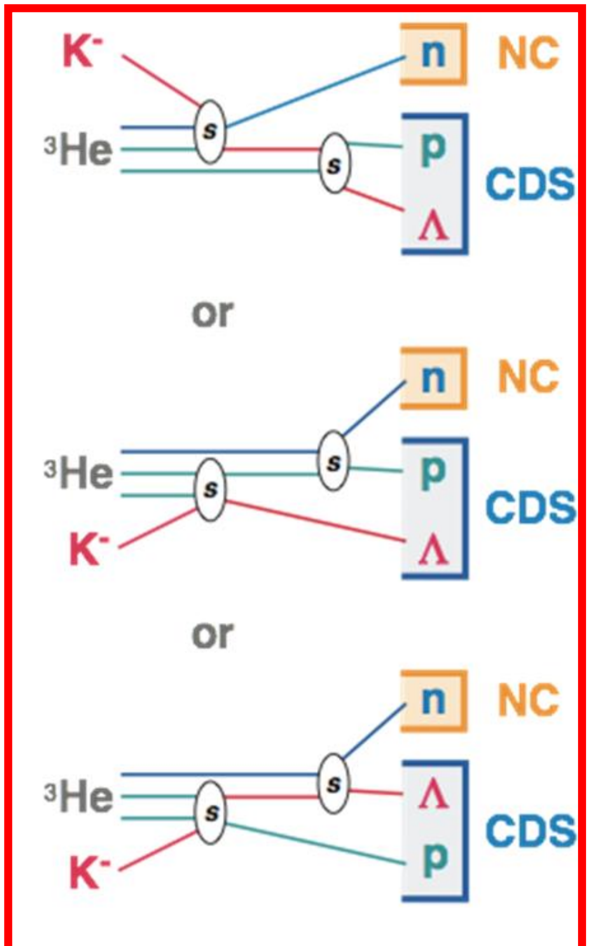
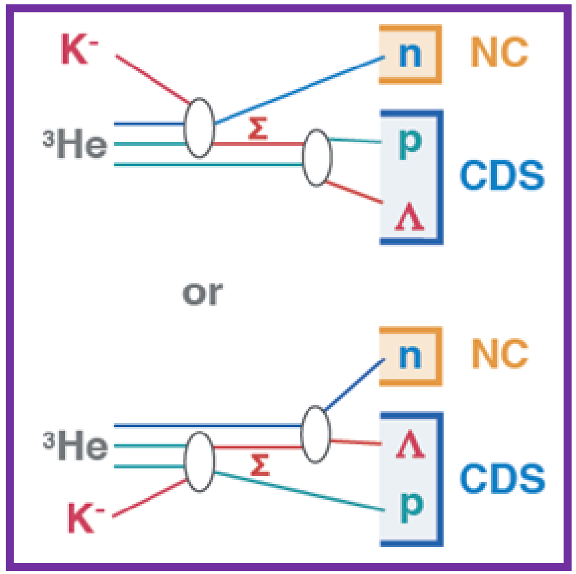
- **"Λpn" w/ forward n in the NC are a few events.**

☑We would like to carry out high statistical experiments !

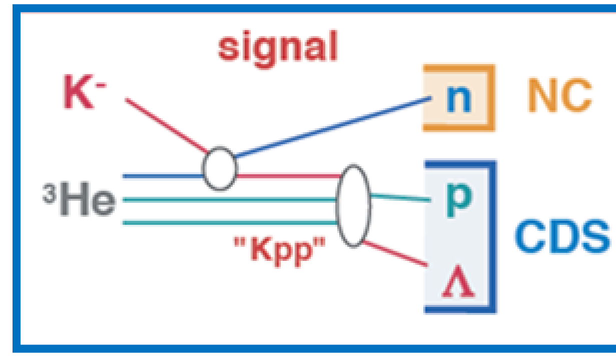
2N-abs



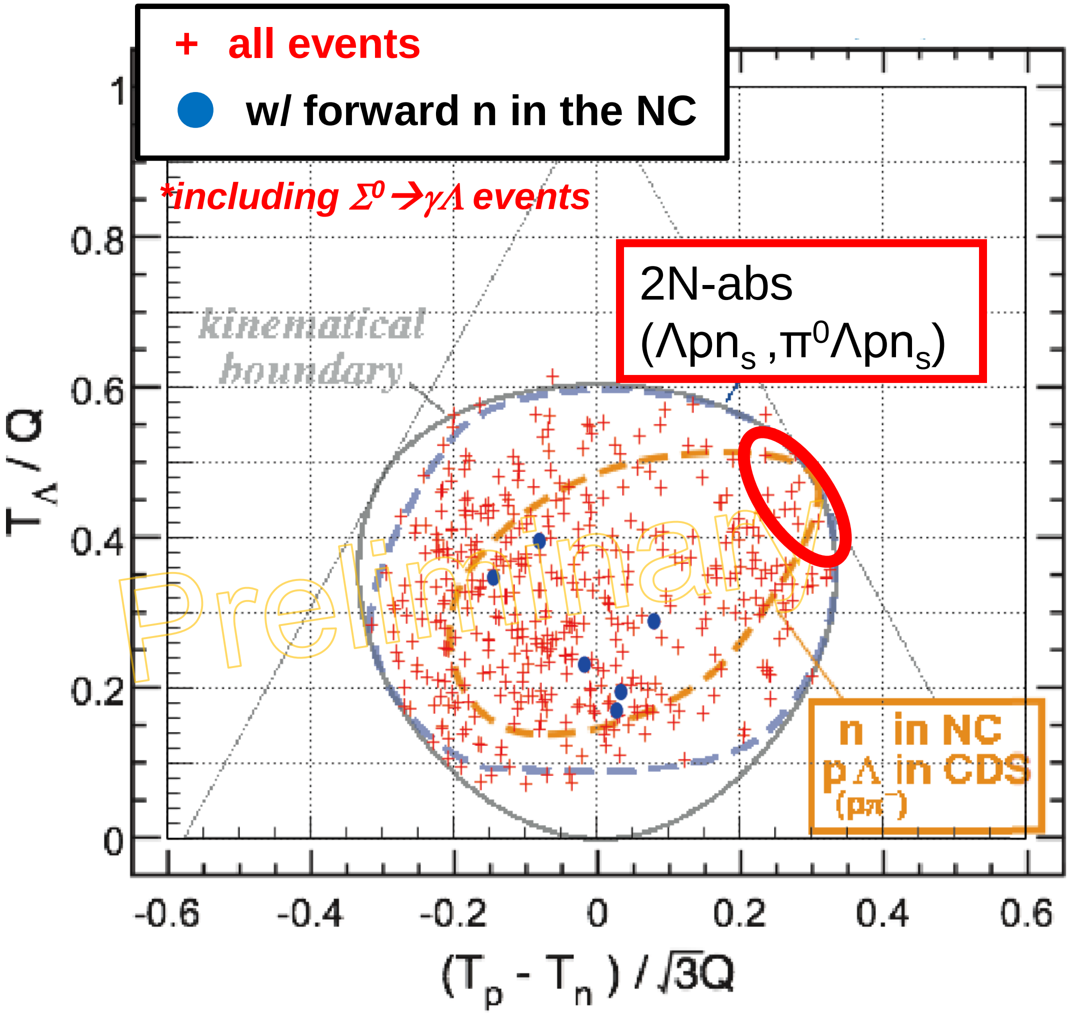
Σ-Λ conversion (2step)



Kpp



^{3}He(K$^-$, Λpn) Result :Dalitz plot of Λpn



Selected **neutron missing** mass peak.

- Events are scattered widely in phase space.
- Multi-N absorption processes exist.

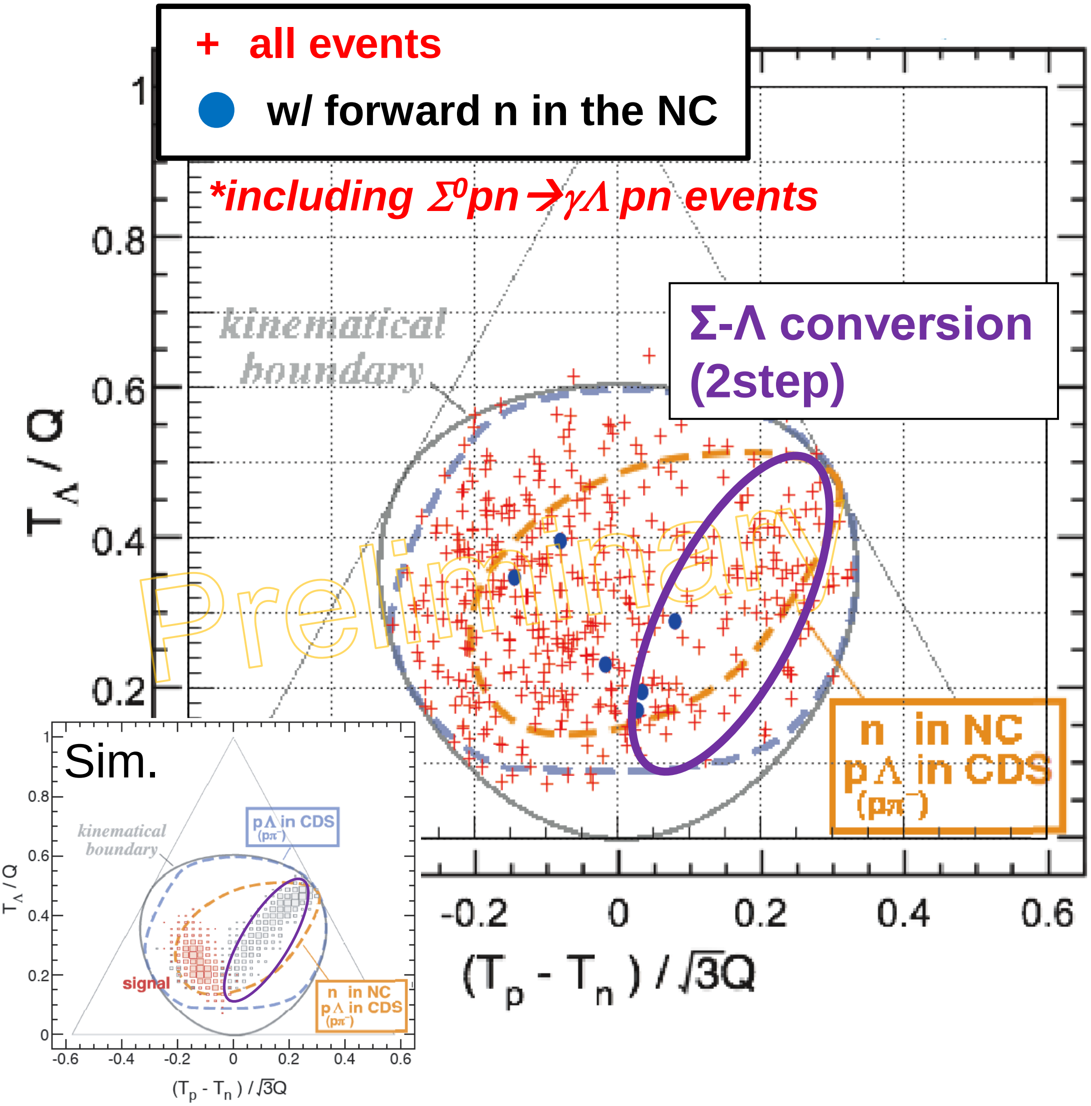
☑It seems 3N-abs(Λpn) exists

☑2N-abs is very weak.

- **“Λpn” w/ forward n in the NC are a few events.**

☑We would like to carry out high statistical experiments !

^{3}He(K$^-$, Λpn) Result :Dalitz plot of Λpn



Selected **neutron missing** mass peak.

- Events are scattered widely in phase space.
- Multi-N absorption processes exist.

☑It seems 3N-abs(Λpn) exists

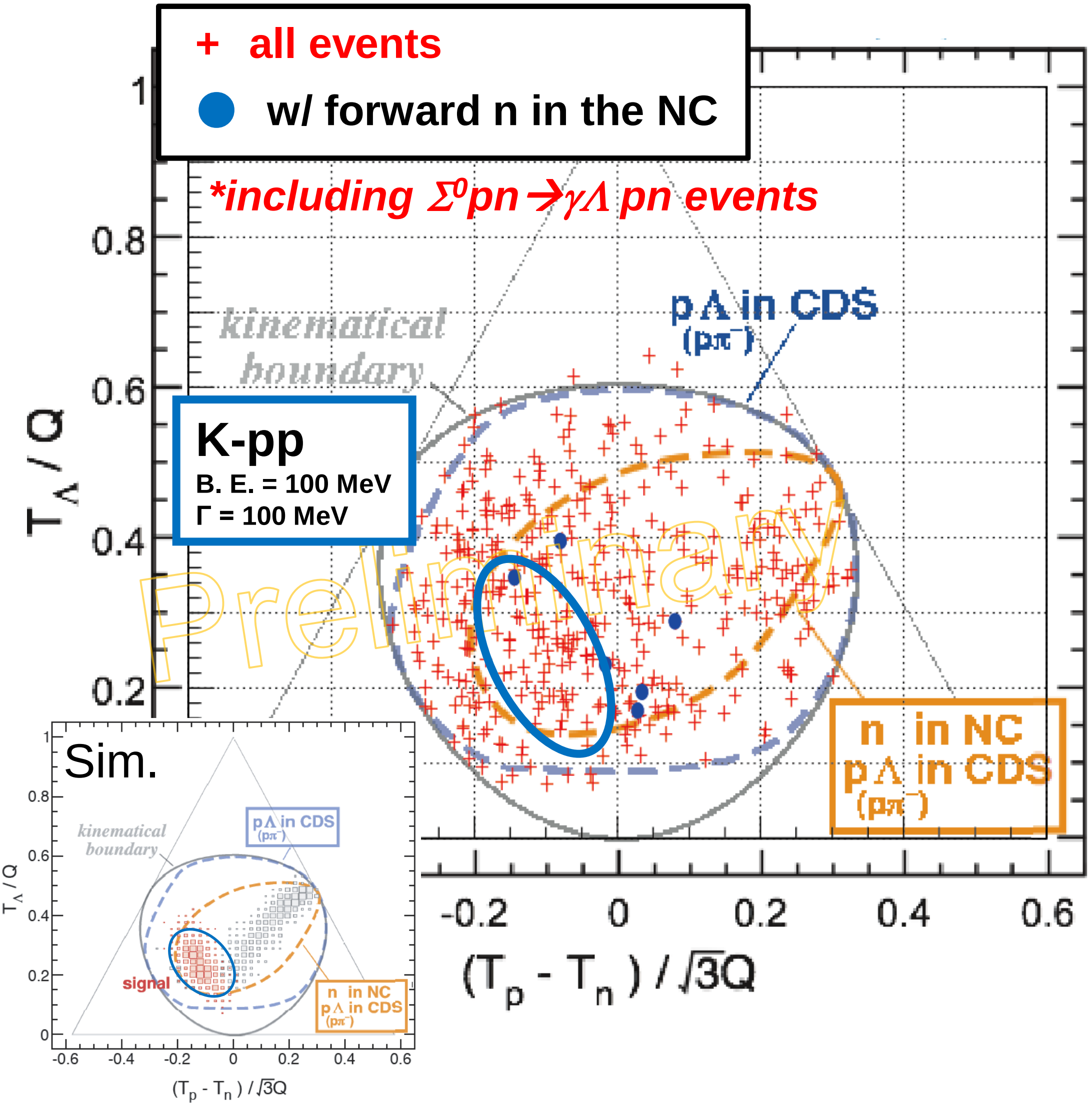
☑2N-abs is almost nothing.

☑ **can not see Σ-Λ conversion line?**

- **"Λpn" w/ forward n in the NC is a few events.**

☑We would like to carry out high statistical experiments !

^{3}He(K$^-$, Λpn) Result :Dalitz plot of Λpn



Selected **neutron missing** mass peak.

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☑It seems 3N-abs(Λpn) exists

☑2N-abs is almost nothing.

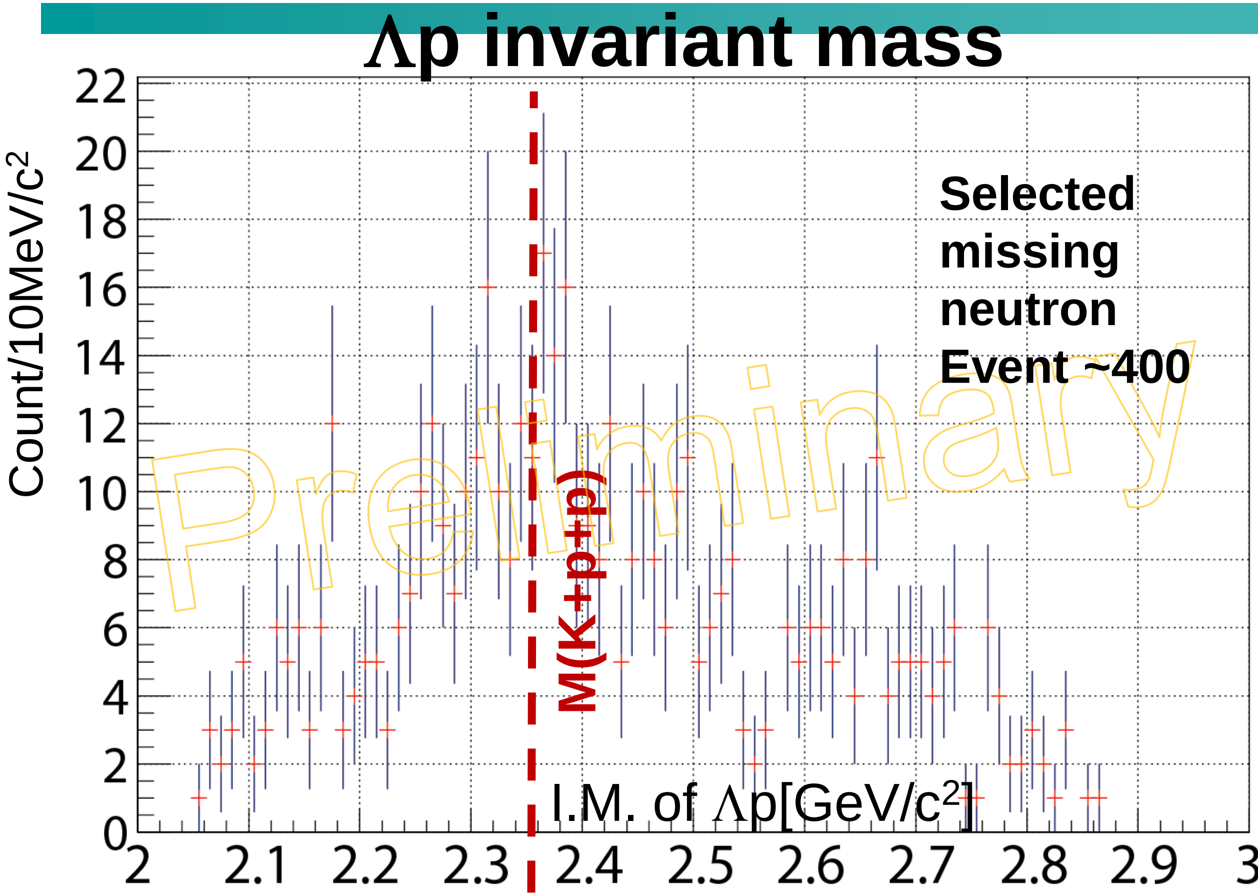
☑ can not see Σ-Λ conversion line?

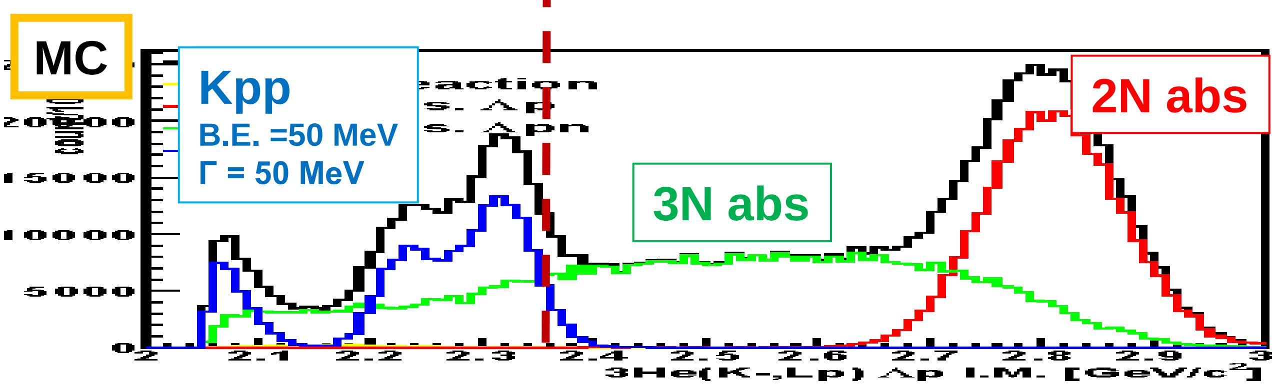
- **"Λpn" w/ forward n in the NC is a few events.**

☑We would like to carry out high statistical experiments !

Finally, will be confirmed in I. M. of Λp w/ missing n.

^{3}He(K$^-$, Λpn) Result





It seems that

- ☑2N abs is very weak.
- ☑**3N abs may be dominant.**
- ☑careful studies are in progress.

Summary

- **We have performed 1st physics run of the J-PARC E15 experiment to search for deeply-bound K-pp state**.
  - ✓~4 x 10^9 kaons were irradiated on ^{3}He.
  - ✓^{3}He (K^-, n): ~1.4 x 10^5 events

- **We presented preliminary results.**
  - ✓Hyperon production(Λ(1520)) spectrum
  - ✓Semi inclusive 3He(K-,n) spectrum
  - ✓Exclusive 3He(K-, Λpn) spectrum

J-PARC E15 collaboration

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(*) Spokesperson
($) Co-Spokesperson

Thank you for your attention !

1: Semi-Inclusive ^{3}He(K$^-$,n)

Expected spectrum from MC (Geant4)

- Known K$^-$N interactions are considered from babble chamber data [CERN-HERA-83-02]

Simple assumptions: $\sigma_{tot} = 2*\sigma_{K\text{-}p} + \sigma_{K\text{-}n}$

for one-nucleon induced reactions,

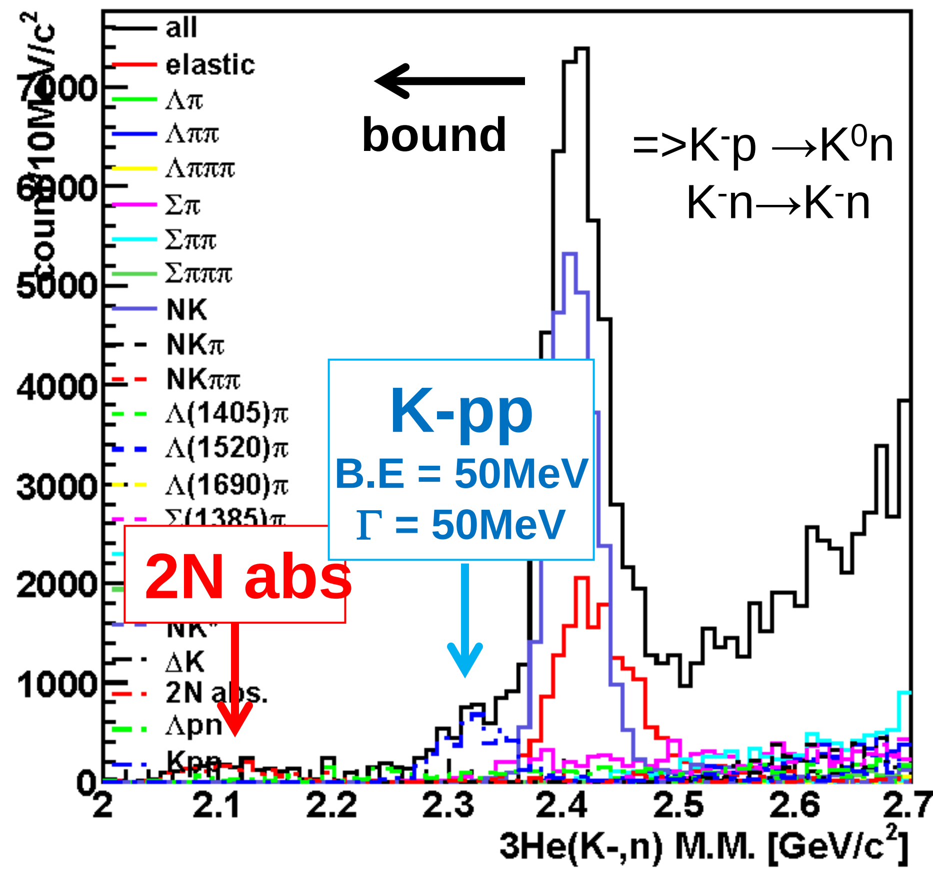
almost background free

- 2N abs.: K$^-$ ^{3}He → Λ n p_s
  - σ/dΩ=1mb/sr,
- **K$^-$pp prod.: K$^-$ ^{3}He → K$^-$pp n**
  - **dσ/dΩ=1mb/sr**
  - **K$^-$pp → Λp(25%), Σ^{0}p(25%), πΣp(50%)**

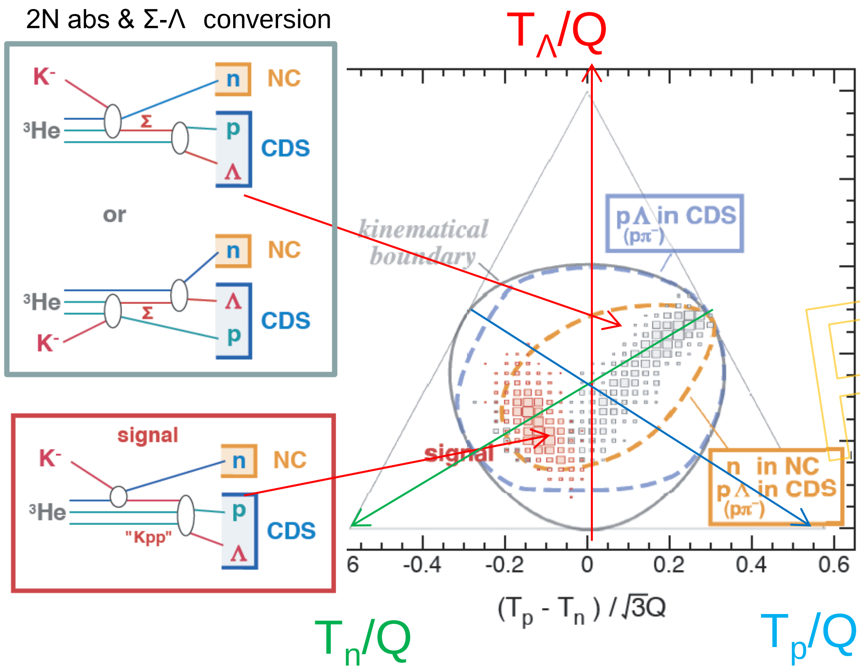
⇒ if cross section is over ~1 mb/sr,

We have sensitivity of signal.

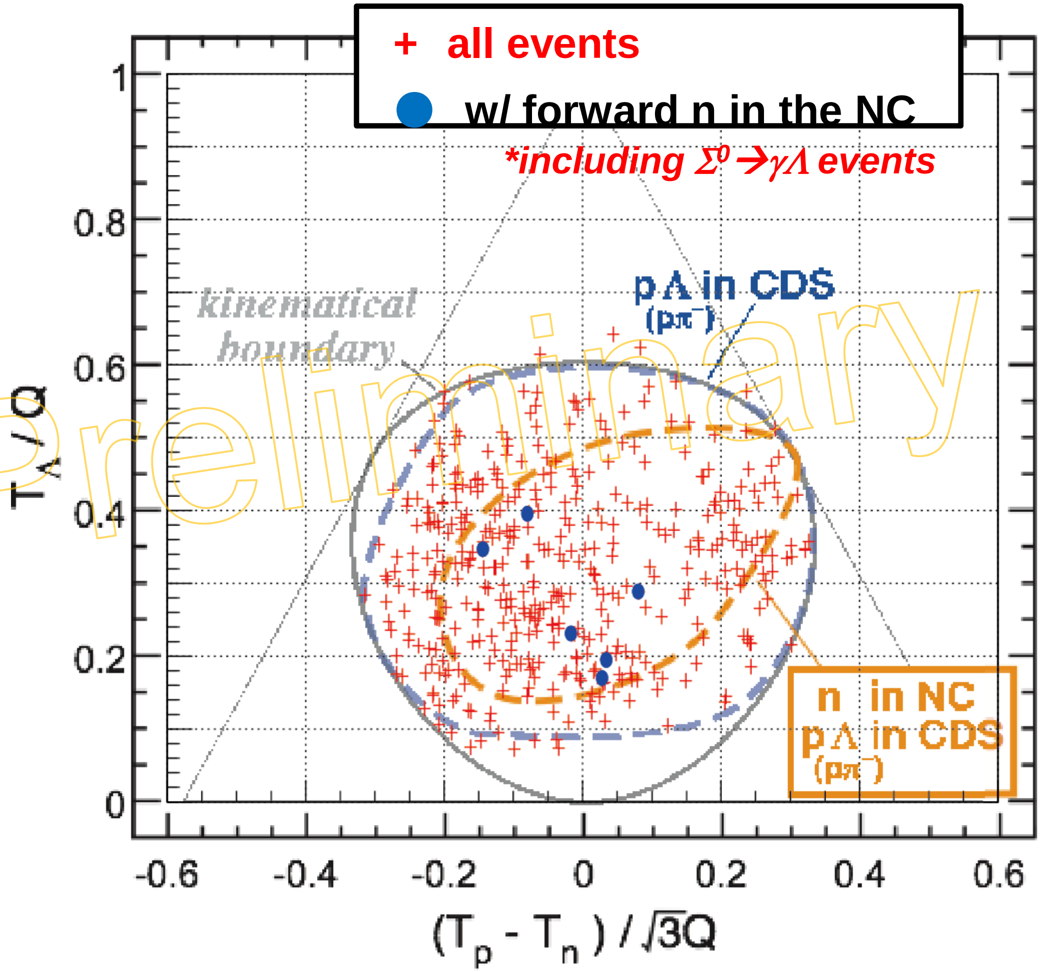
^{3}He(K$^-$,n) M.M. spectrum w/ 1-charged tag in the



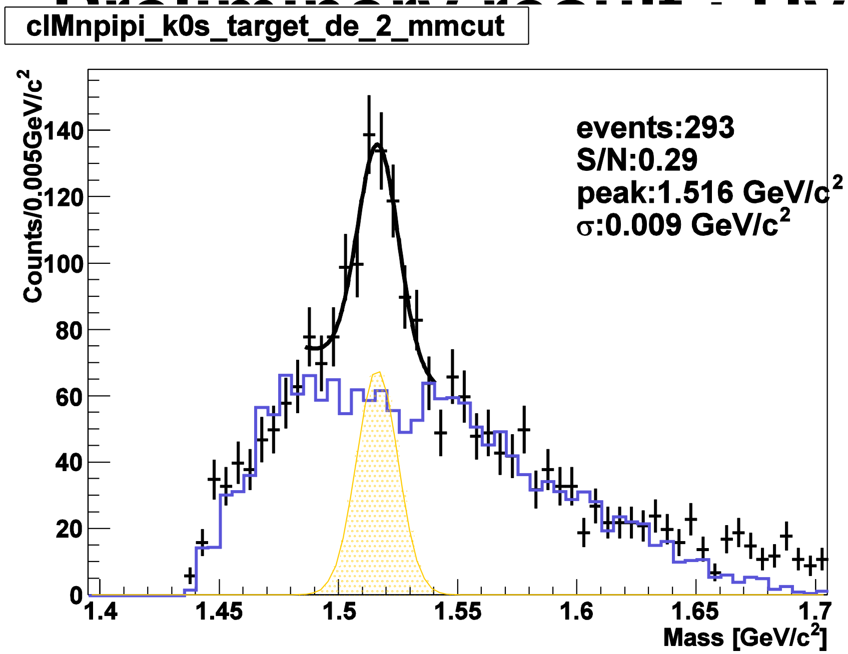
Dalitz plot



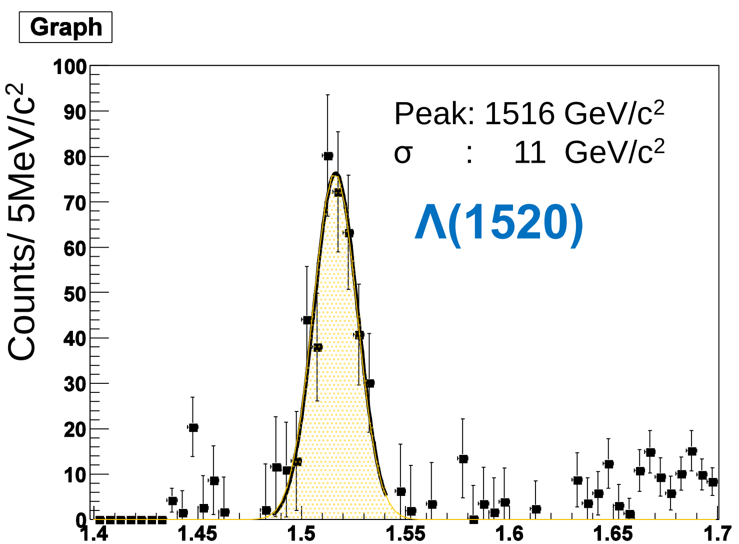
Dalitz plot of Λpn



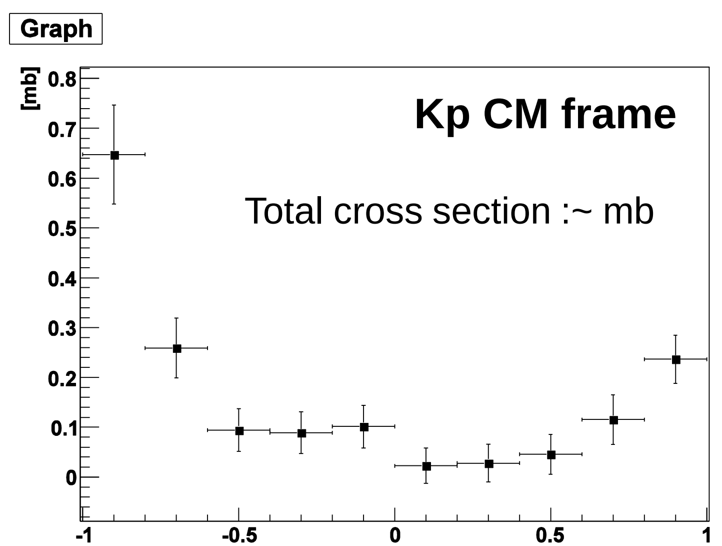
Preliminary result : Hyperon production



- Λ(1520) peak is clear seen.
- Peak position is consistent with PDG.
  - Combination of CDS & NC performance is good.
- Cross section
  - consistent with old data at the same order level.



Invariant Mass of nK^0s [GeV/c^2]



Angular distribution of L1520[cosΘ]

Beam spectrometer

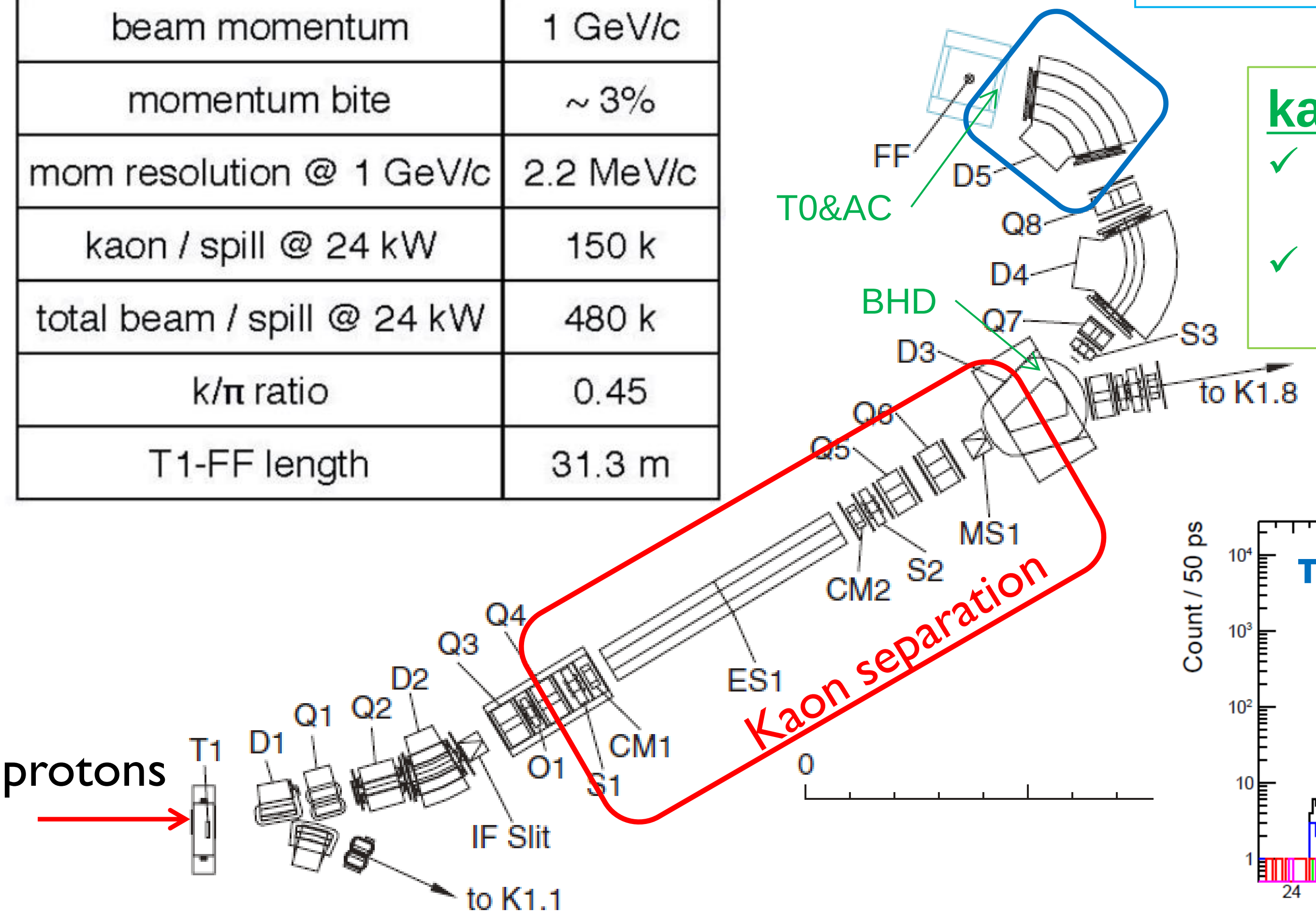
beam spectrometer @ K1.8BR beam line

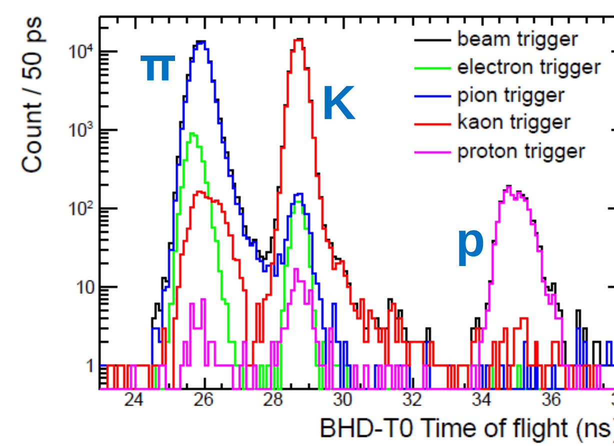
properties @ p_{K^-} = 1.0 GeV/c

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

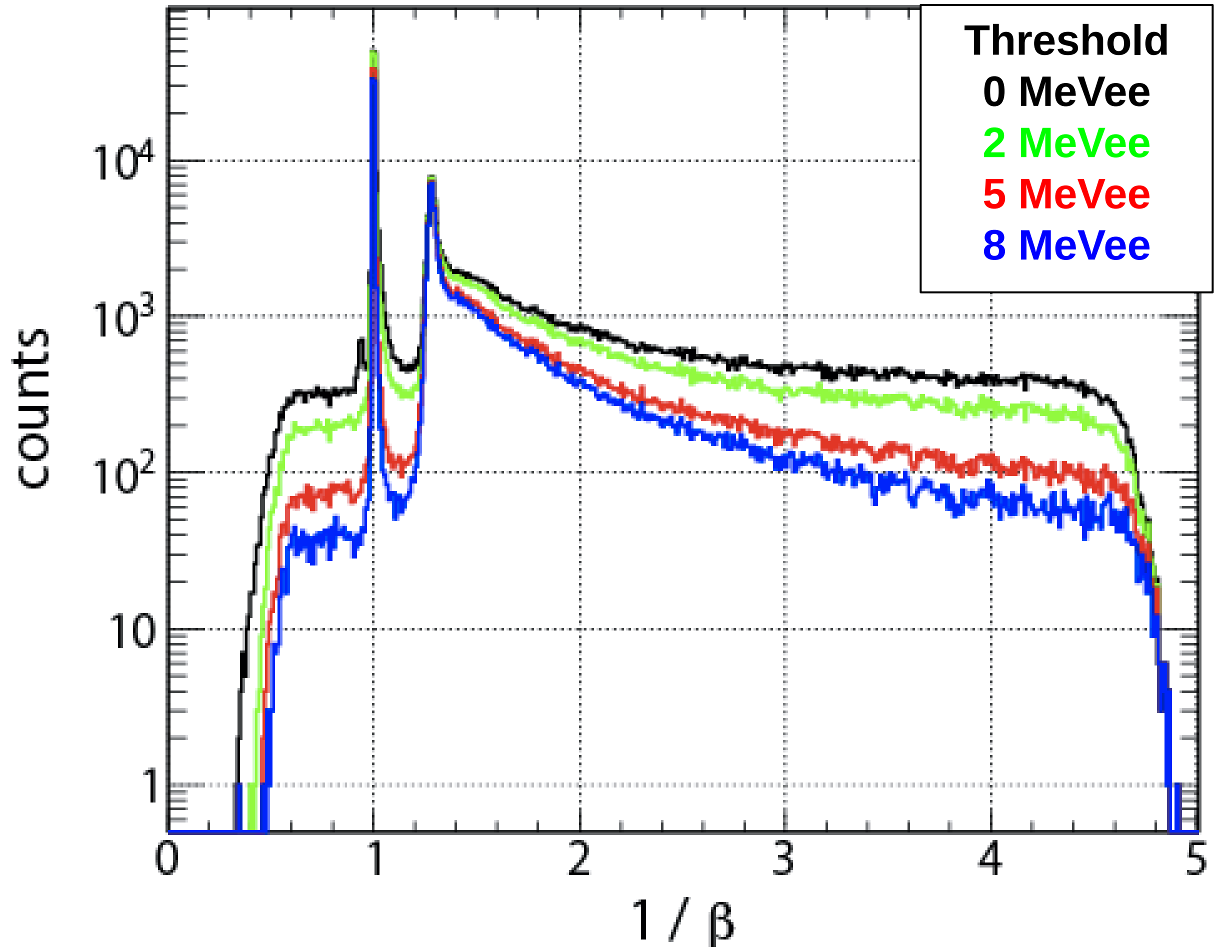
Momentum analyzer
Dipole and wire drift chambers

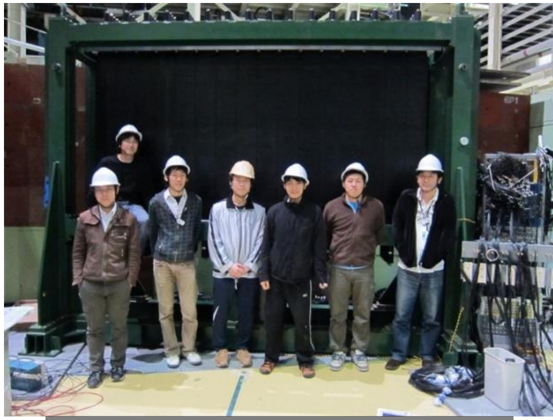
kaon identification
- ✓ Aerogel Cherenkov counter
- ✓ ToF(BHD-T0) Flight length=7.7m





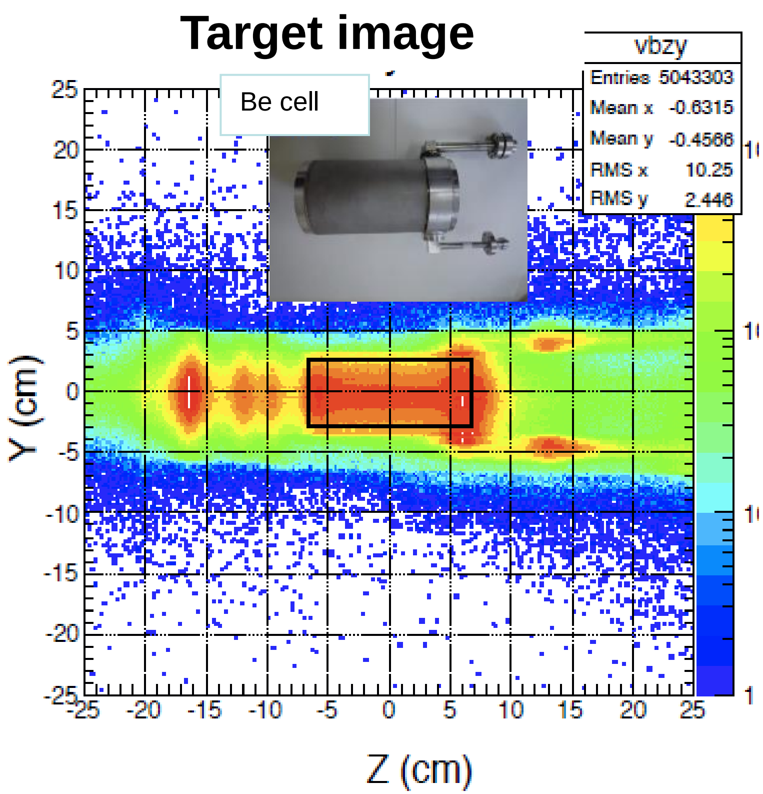
TOF(BHD-T0) @+1.0 GeV/*c*





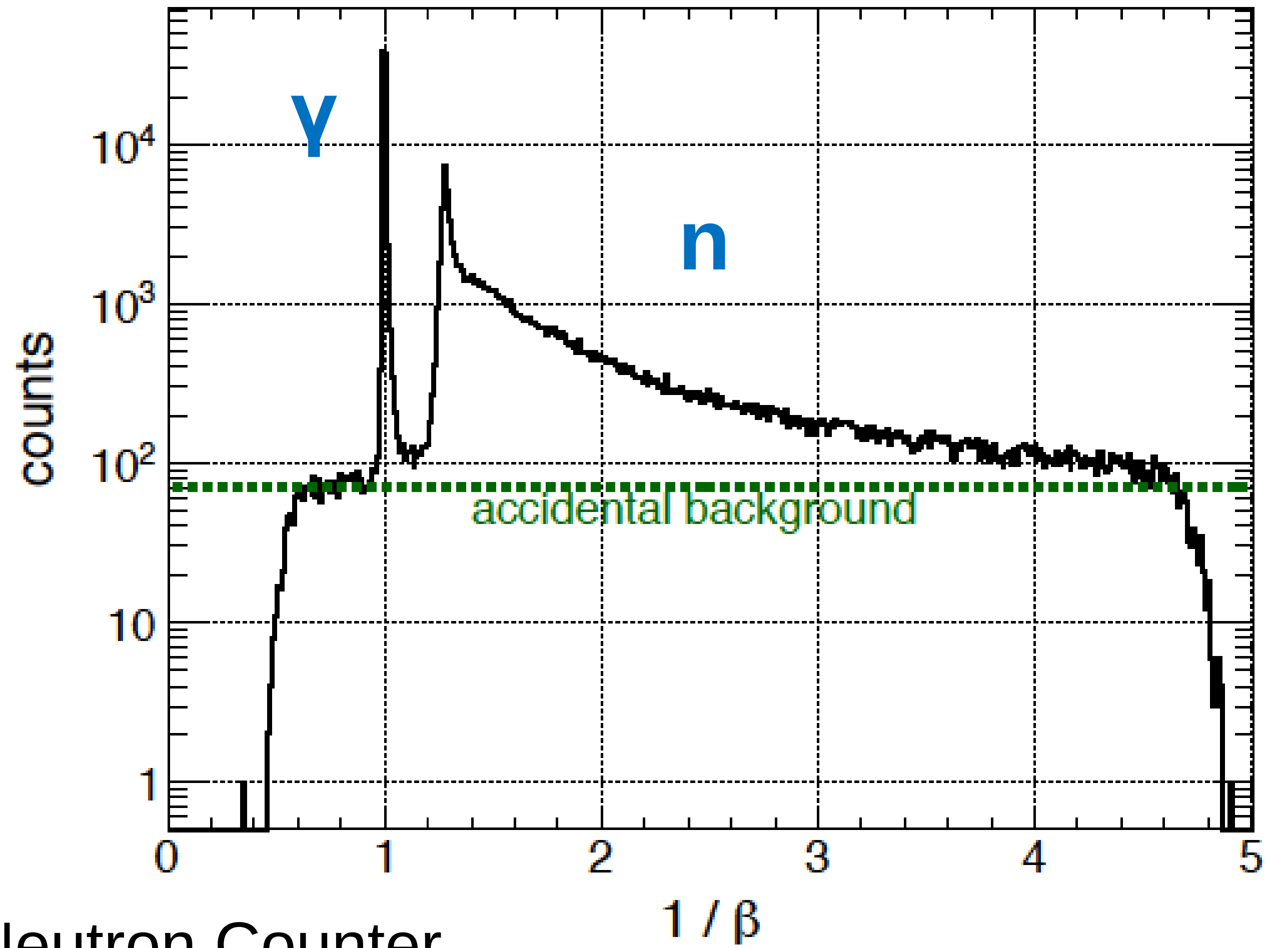
NC construction was completed in Apr. 2012

Cylindrical Detector System (CDS)

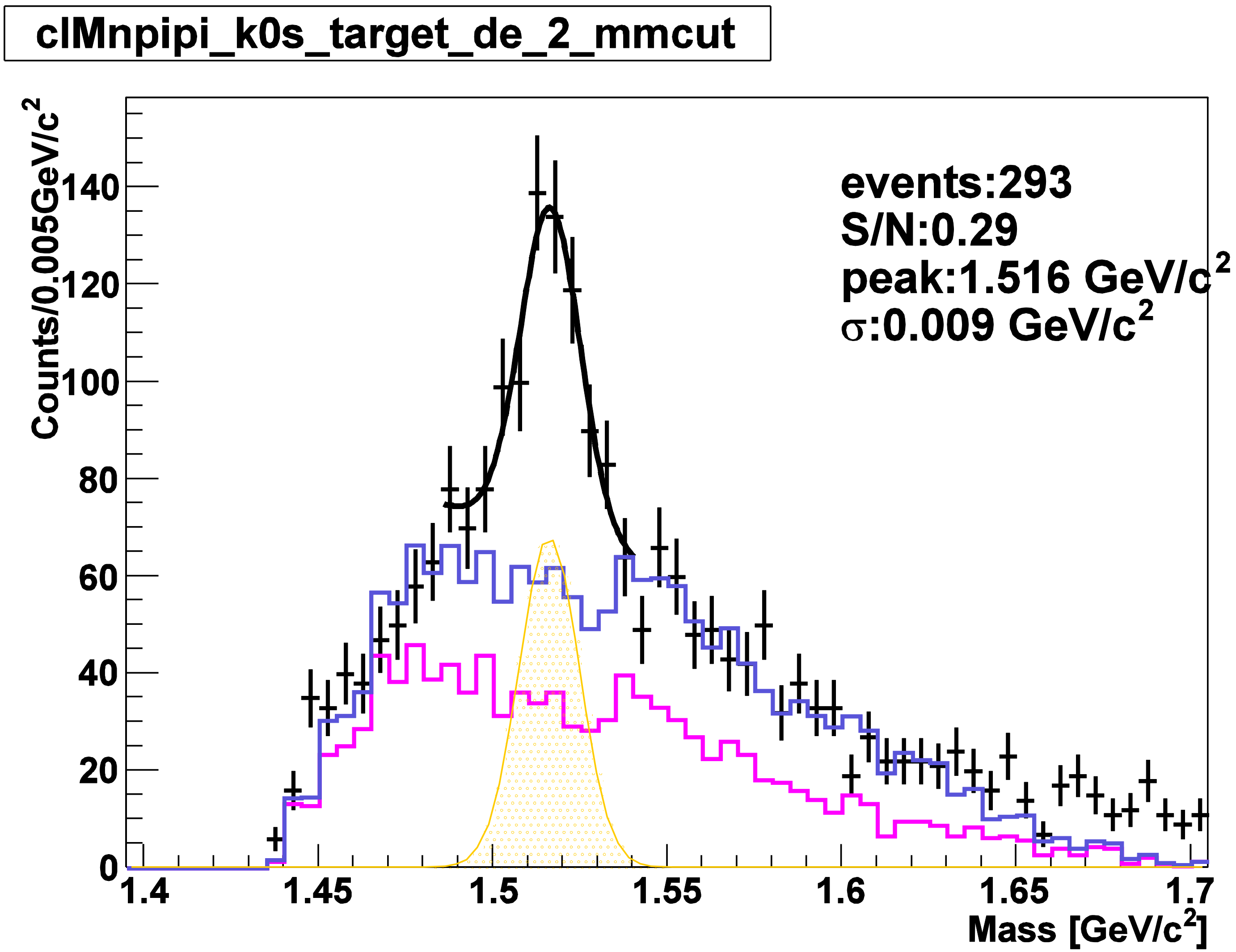


Design performance was achieved!!

Forward neutral particle



- Neutron Counter
  - Neutron momentum is determined by TOF method.
  - **Good S/N of ~100**@ QF neutron peak (Set threshold to 5 MeVee).
  - **σ_{TOF} ~ 160ps ➜ $\sigma_{M.M.}$ ~10 MeV/c^2 at the region of interest**.



clMnpipi_k0s_target_de_2_mmcut
Counts/0.005GeV/c2
0
20
40
60
80
100
120
140
events:293
S/N:0.29
peak:1.516 GeV/c2
σ:0.009 GeV/c2
1.4
1.45
1.5
1.55
1.6
1.65
1.7
Mass [GeV/c2]

2: Inclusive $^3He(K^-,\Lambda p)$

Expected (simplified) spectrum from MC (Geant4)

- Known K^-N interactions are considered from babble chamber data [CERN-HERA-83-02]
- Simple assumptions:
  - $\sigma_{tot} = 2*\sigma_{K\text{-}p} + \sigma_{K\text{-}n}$
  - 2N abs.: $K^- \, ^3He \rightarrow \Lambda \, p \, n_s$
    - $\sigma/d\Omega$=1mb/sr, (isotrop
  - 3N abs.: $K^- \, ^3He \rightarrow \Lambda \, p \, n$
    - $d\sigma/d\Omega$=1mb/sr (isotropic)
  - **K^-pp prod.: $K^- \, ^3He \rightarrow K^-pp \, n$**
    - **$d\sigma/d\Omega$=1mb/sr (isotropic)**
    - **$K^-pp \rightarrow \Lambda p(25\%), \Sigma^0 p(25\%), \pi\Sigma p(50\%)$**

K-pp
B.E = 50MeV
Γ = 50MeV