Analysis status of the J-PARC E15 experiment (a search for deeply-bound Kaonic nuclear state)

Y.Sada (Kyoto-Univ, RIKEN)

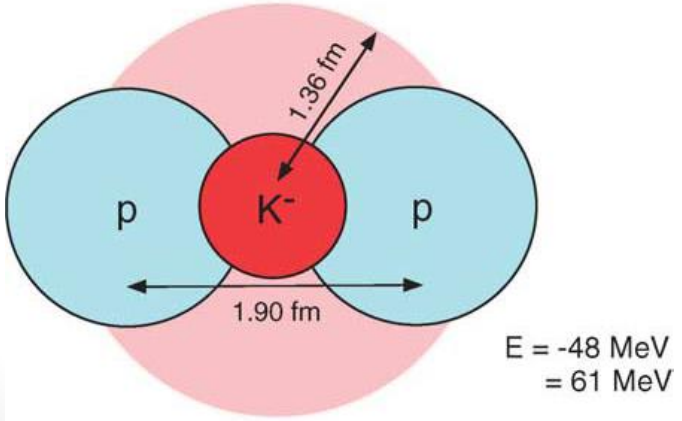
for the J-PARC E15 collaboration

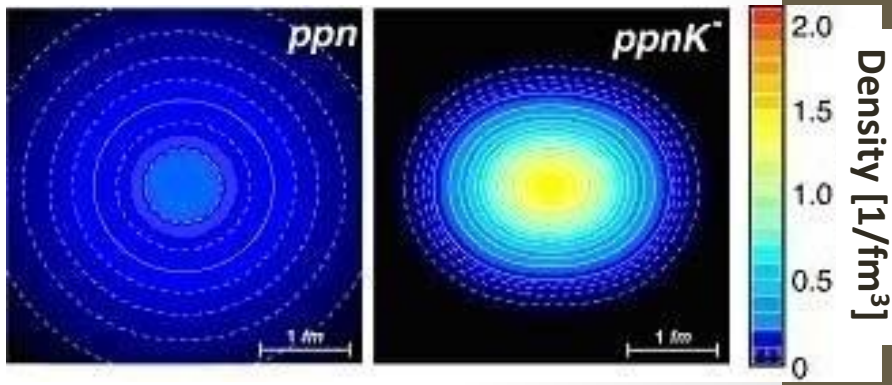
Contents

- Introduction
  - Kaon in nuclei
  - Theoretical situation
  - Experimental situation
- J-PARC E15 experiment
  - Set up
  - Detector performance
- Preliminary result
  - Semi-inclusive ^{3}He(K^{-},n) missing mass
  - Exclusive ^{3}He(K^{-},Λpn)
- Summary

K^- in Nucleus

- K^{bar}-N interaction
  - Kaonic-atom experiments (KpX@KEK, DEAR/SIDDHARTA@DAΦNE) clarified ***strongly*** **attractive K^{bar}-N interaction(I=0)**
  - What will happen when K^{bar} is embedded in nucleus?
    - K^{bar}-nucleus bound state?
    - high density?
  - Study of the simplest Kaonic nuclei($K^{bar}NN$) is important!





T.Yamazaki, A.Dote, Y.Akiaishi, PLB587, 167 (2004).

Current Theoretical situation

$K^{bar}NN$: the simplest K^{bar}-nuclear state

	Binding energy[MeV]	Width[MeV]
N. Barnea, A. Gal, E.Z. Liverts(2012)	16	41
A. Dote, T. Hyodo, W. Weise(2008,2009)	17-23	40-70
Y. Ikeda, H. Kamano, T. Sato(2010)	9-16	34-46

	Binding energy[MeV]	width[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

All studies predict existence of the $K^{bar}NN$

→ However, B.E. and Γ are controversial

Experimental situation

- FINUDA experiment @DAΦNE **=>positive?**
  - **Stopped K- @Light nuclei ->Λp invariant mass**
- DISTO experiment @SATARNE **=>positive?**
  - **p + p → (Λ + p) + K^+ @ 2.85GeV**
- HADES experiment @GSI **=>negative?**
  - **p + p → (Λ + p) + K^+ @ 3.5GeV**

And

- LEPS experiment **=>negative?**
  - **photon -induced reaction**

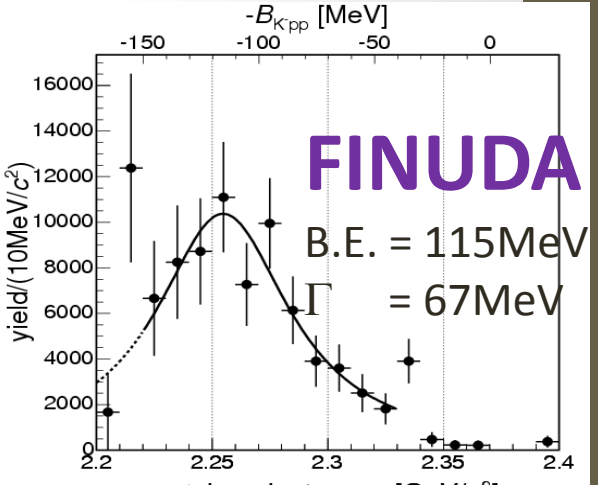
(Tokiyasu-san will talk @ 10:40)

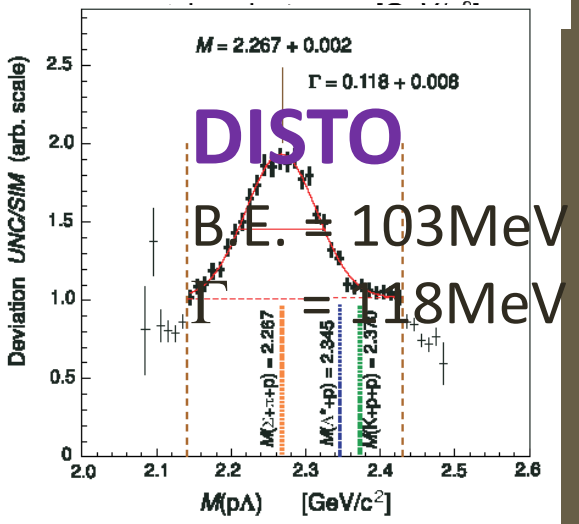
- J-PARC E27 experiment **=>positive?**
  - **d(π^+, K^+) @1.7GeV/c**

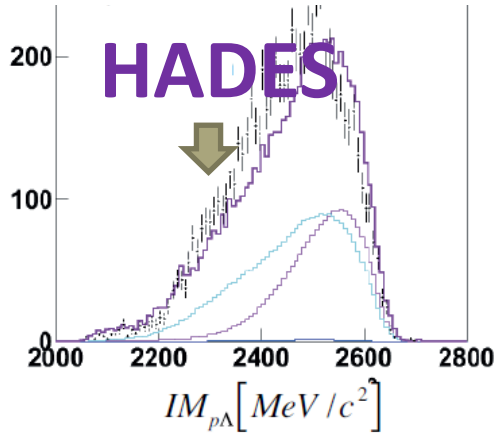
(Ekawa-san will talk @11:30)

Situation is not clear.

We need more studies of $K^{bar}NN$ in various reaction channels!!



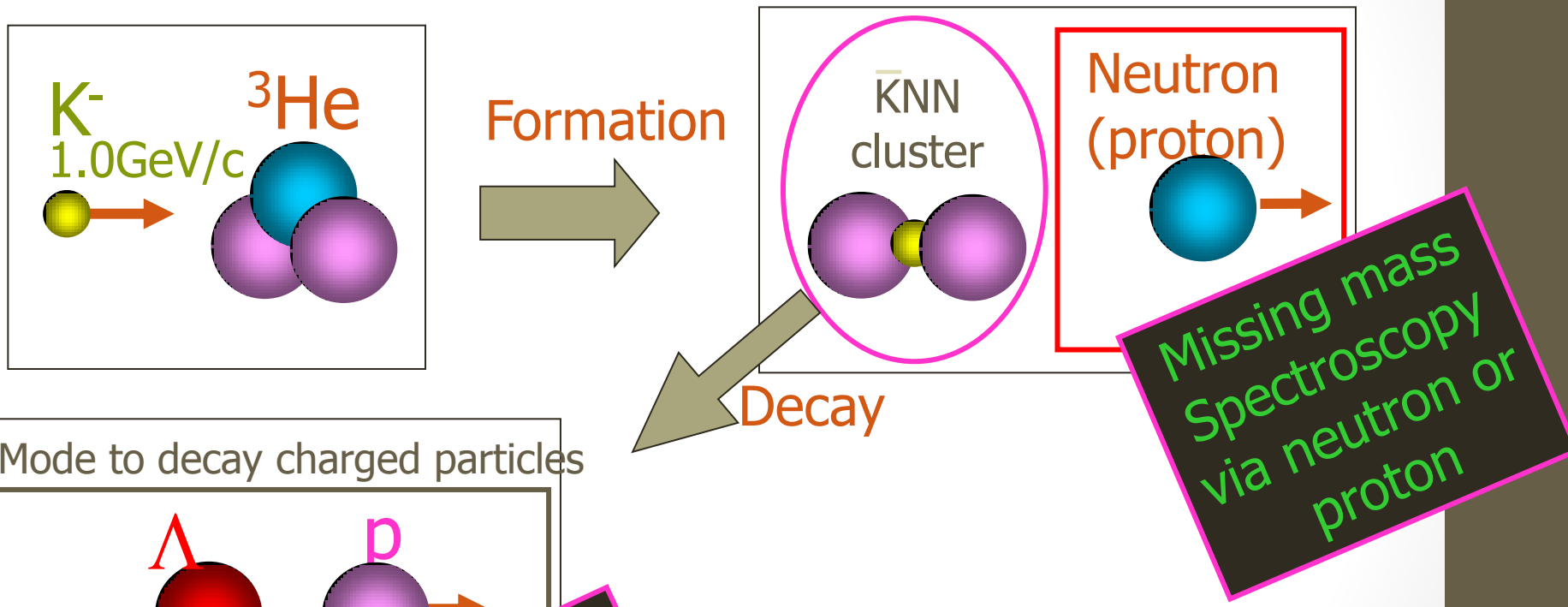




J-PARC E15 experiment

J-PARC E15 experiment

Experimental search for $K^{bar}NN$ bound states using in-flight (K^-, N) reaction on ^3He



We can observe every parincles
(both the **"Formation"** and
"Decay" of $K^{bar}NN$ bound state)

J-PARC/ K1.8BR


Harbin
Jilin
Liaoning
North Korea
Pyongyang
Seoul
South Korea
Sea of Japan
Japan
Sapporo
Aomori
Akita
Morioka
Sendai
Niigata
Nagano
Kanazawa
Tottori
Matsue
Tokyo
Chiba
Nagoya
Osaka
Shizuoka
Busan
Hiroshima
Tsu
Fukuoka
Matsuyama
Saga
Oita
Nagasaki
Kumamoto
East
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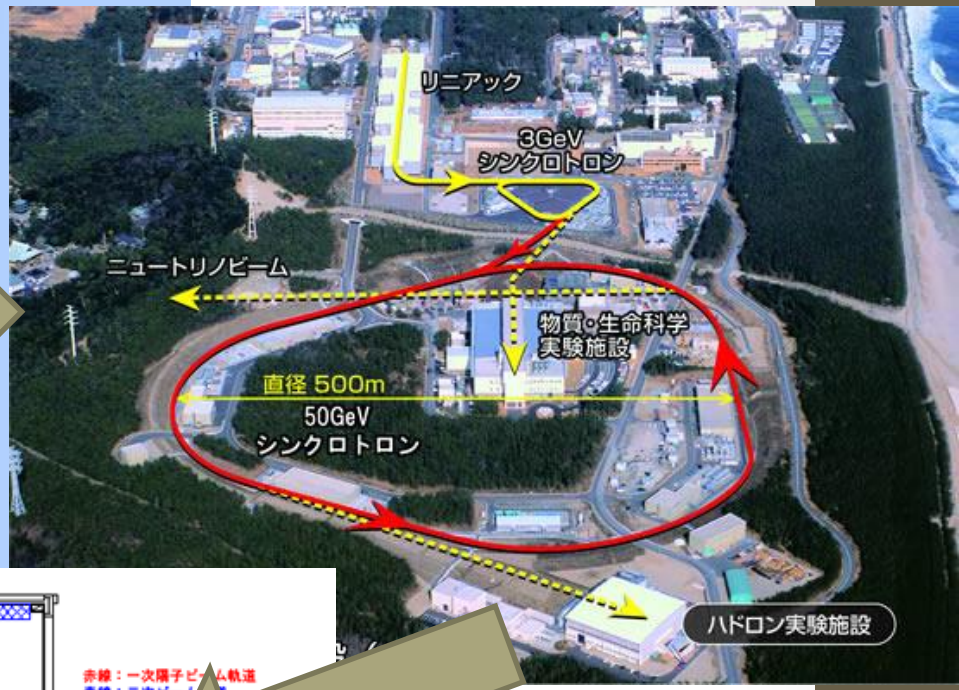
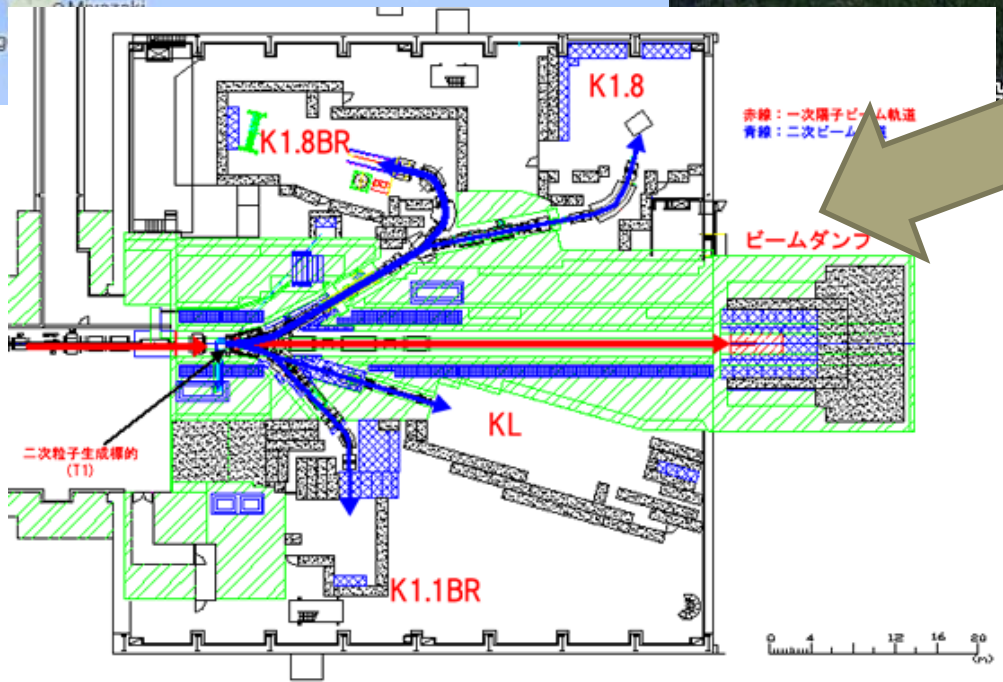
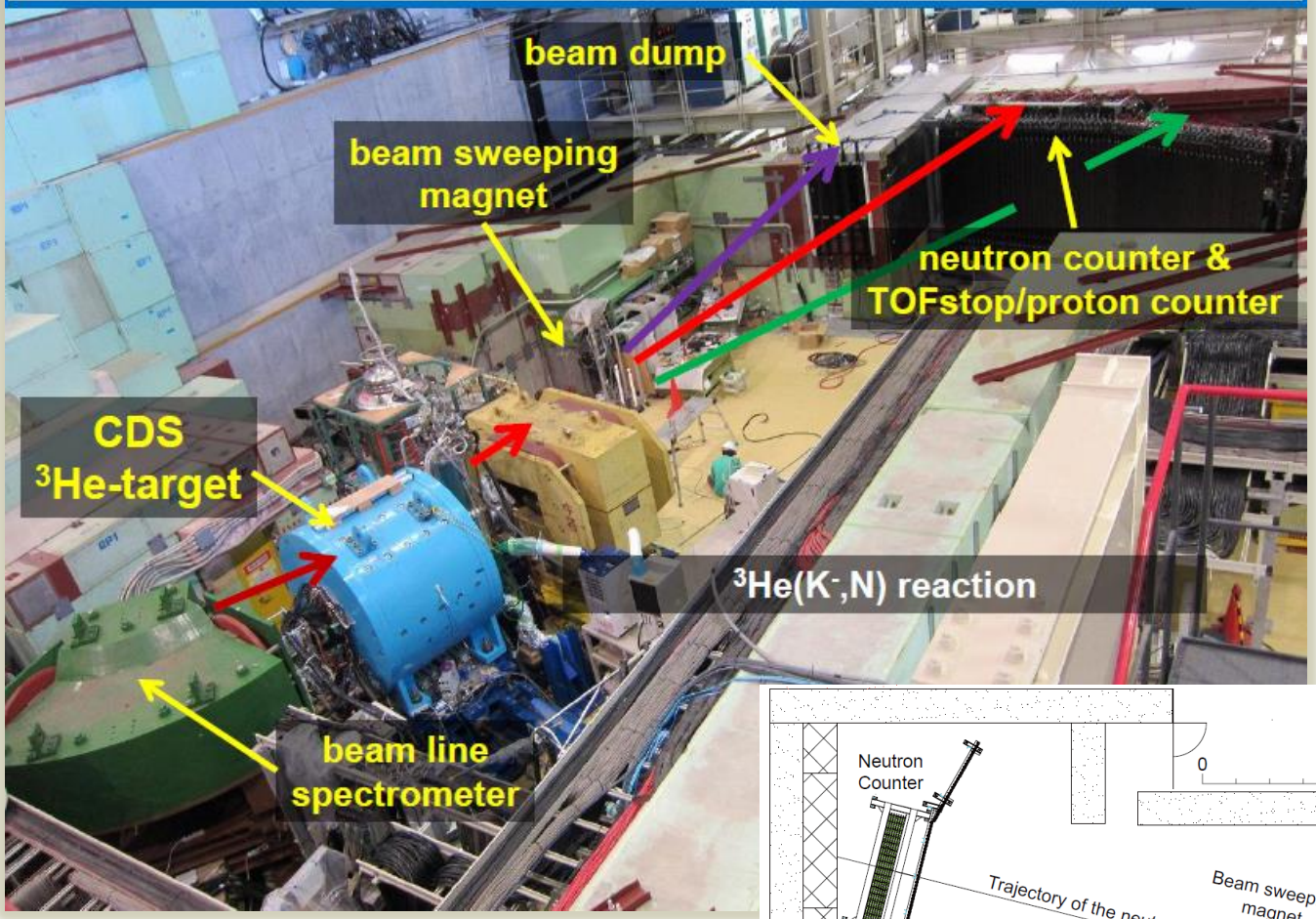
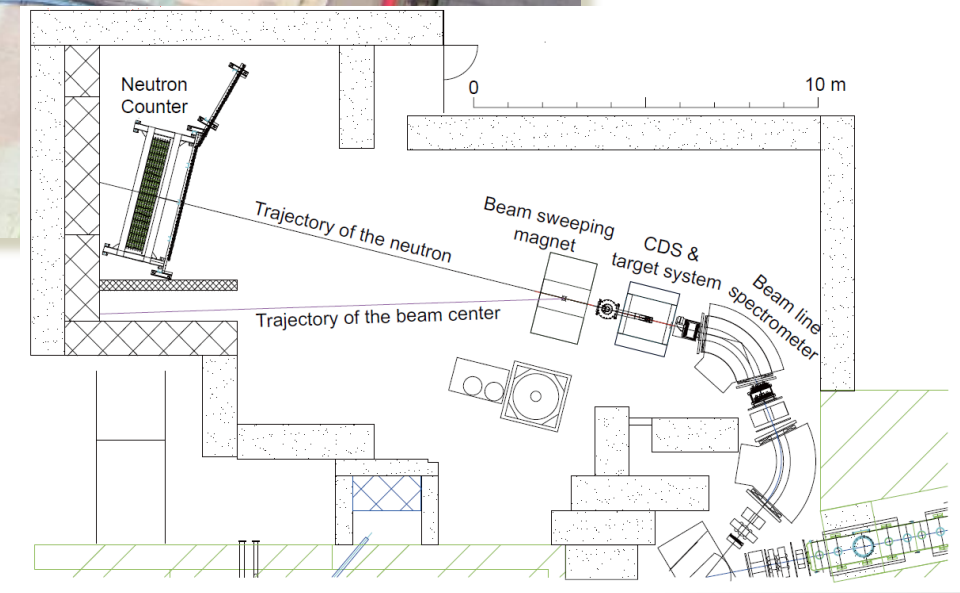

リニアック
3GeV
シンクロトロン
ニュートリノビーム
物質・生命科学
実験施設
直径 500m
50GeV
シンクロトロン
ハドロン実験施設


K1.8
K1.8BR
ビームダンプ
KL
二次粒子生成標的
(T1)
K1.1BR

J-PARC K1.8BR beam line[Jun. 2012]

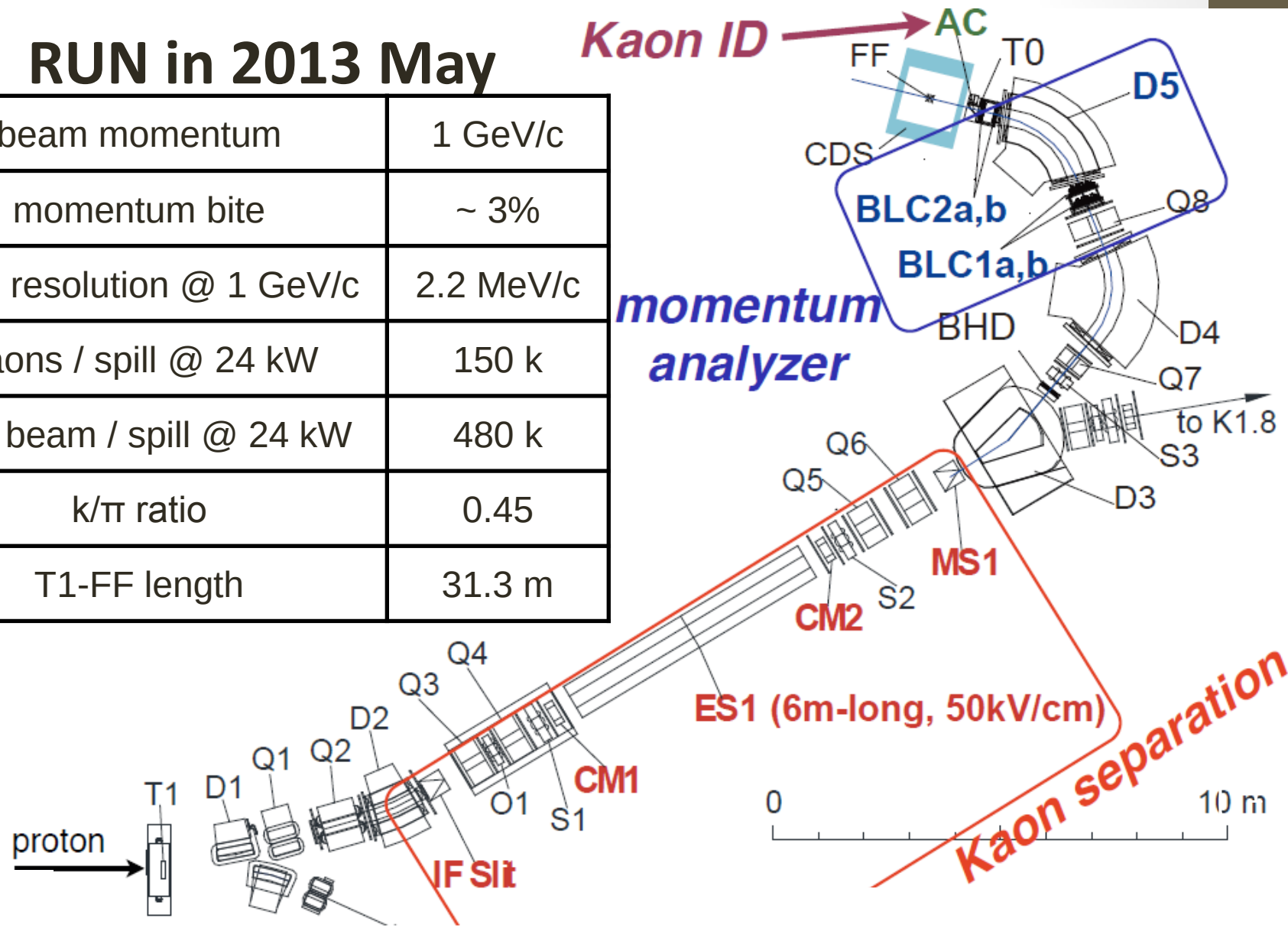




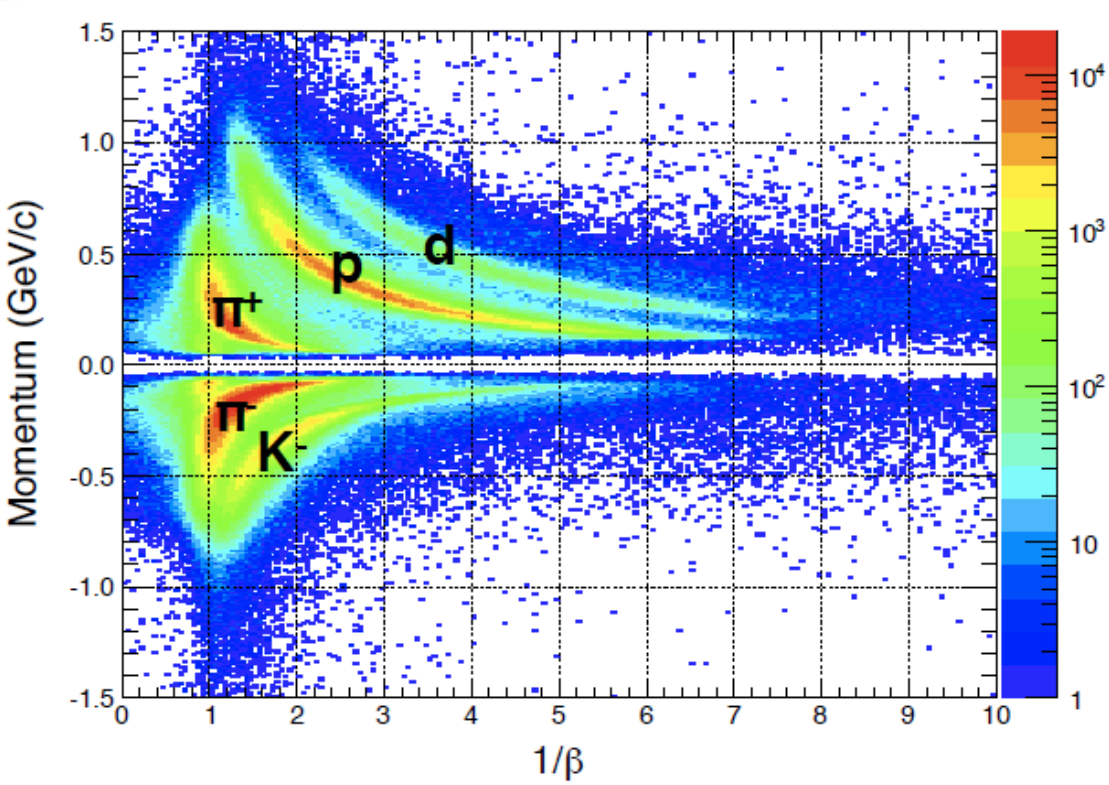
Kaon-Beam Spectrometer

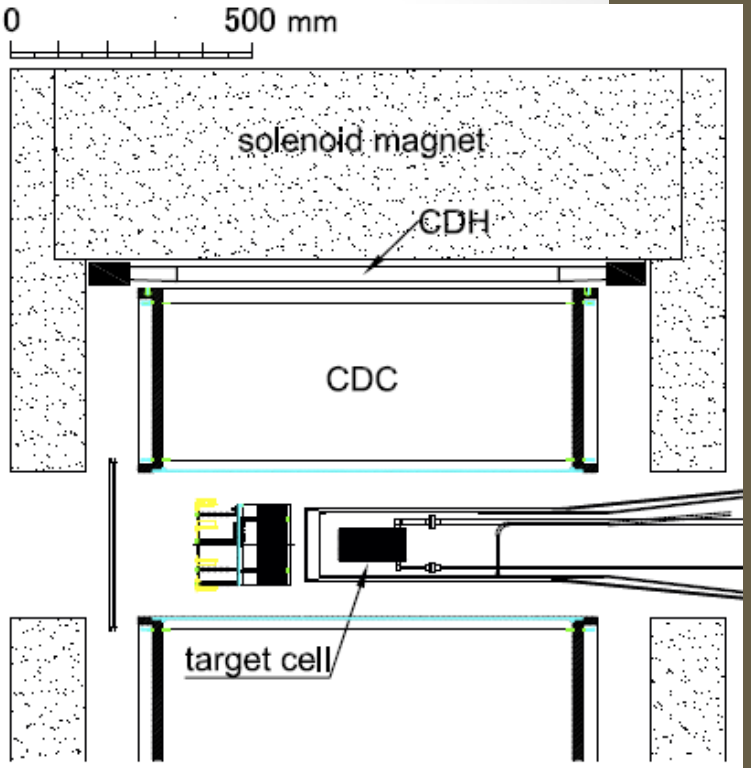
RUN in 2013 May

beam momentum	1 GeV/c
momentum bite	~ 3%
mom resolution @ 1 GeV/c	2.2 MeV/c
Kaons / 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: pID

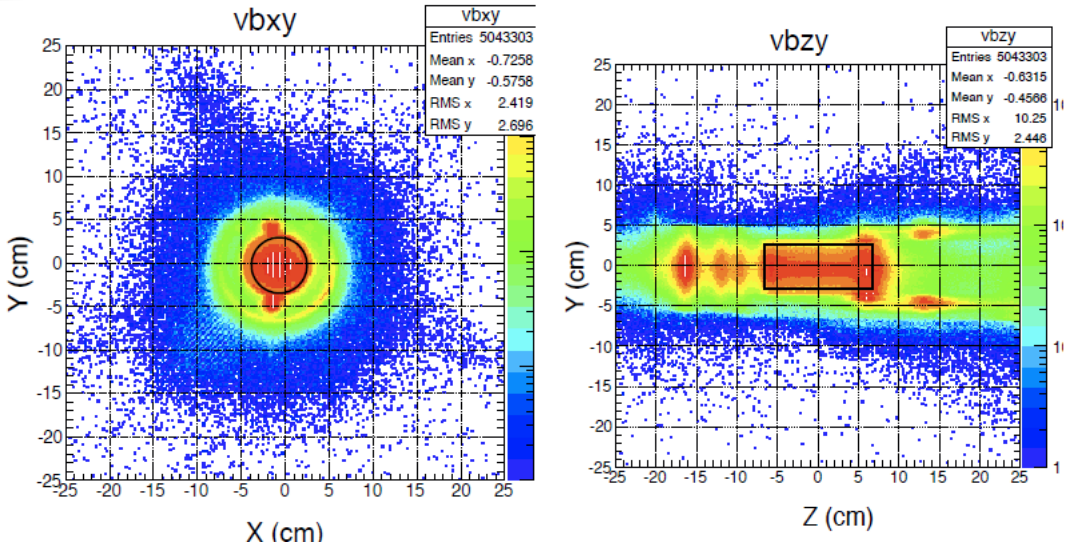




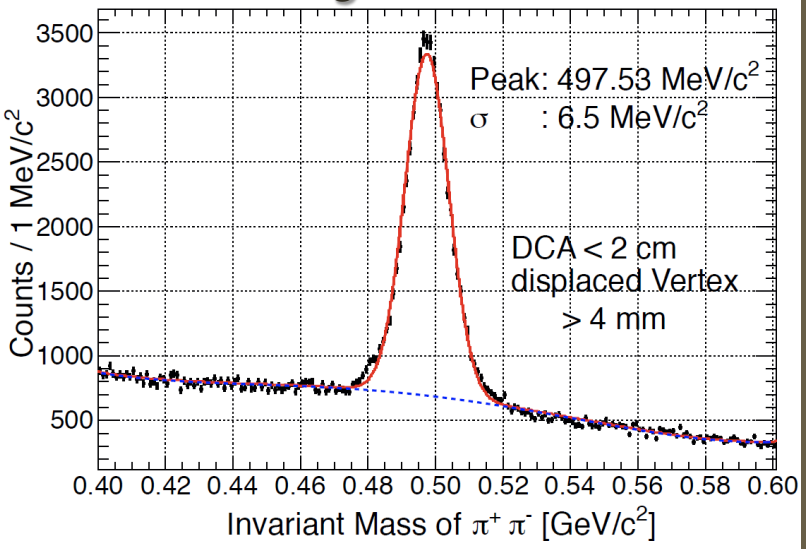
- CDC (15 layers, 1816ch) + CDH (36 seg) + 0.7T
  - solid angle: 60% of 4π
- **π/K/p/d are clearly separated**

Cylindrical Detector System: Tracking

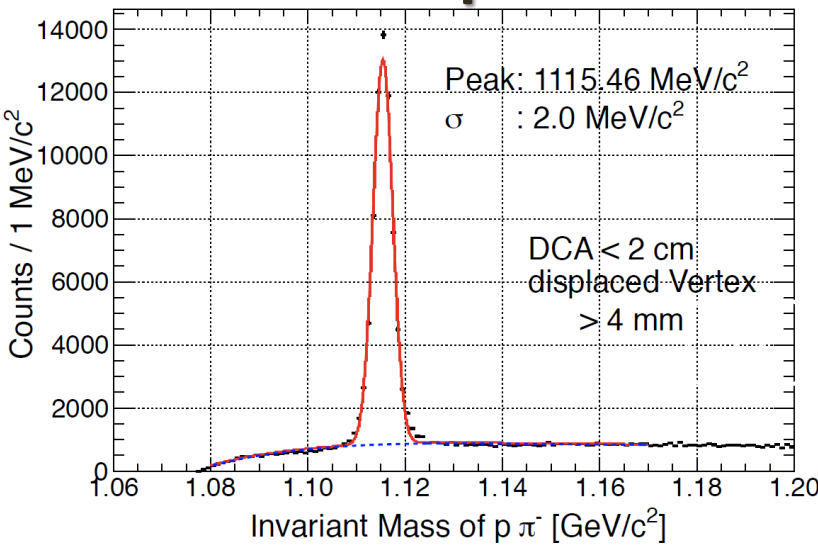
target image



$K^0_S \rightarrow \pi^+\pi^-$



$\Lambda \rightarrow p\pi^-$

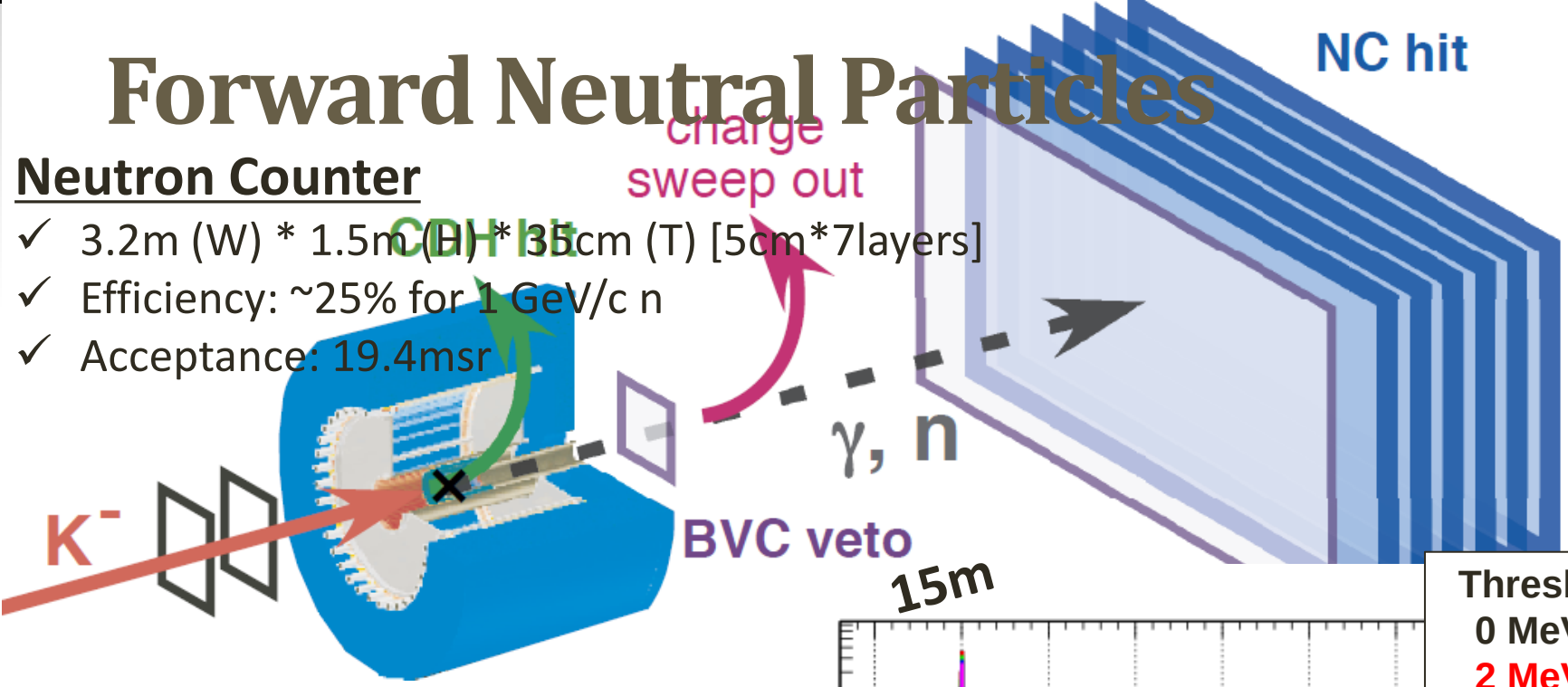


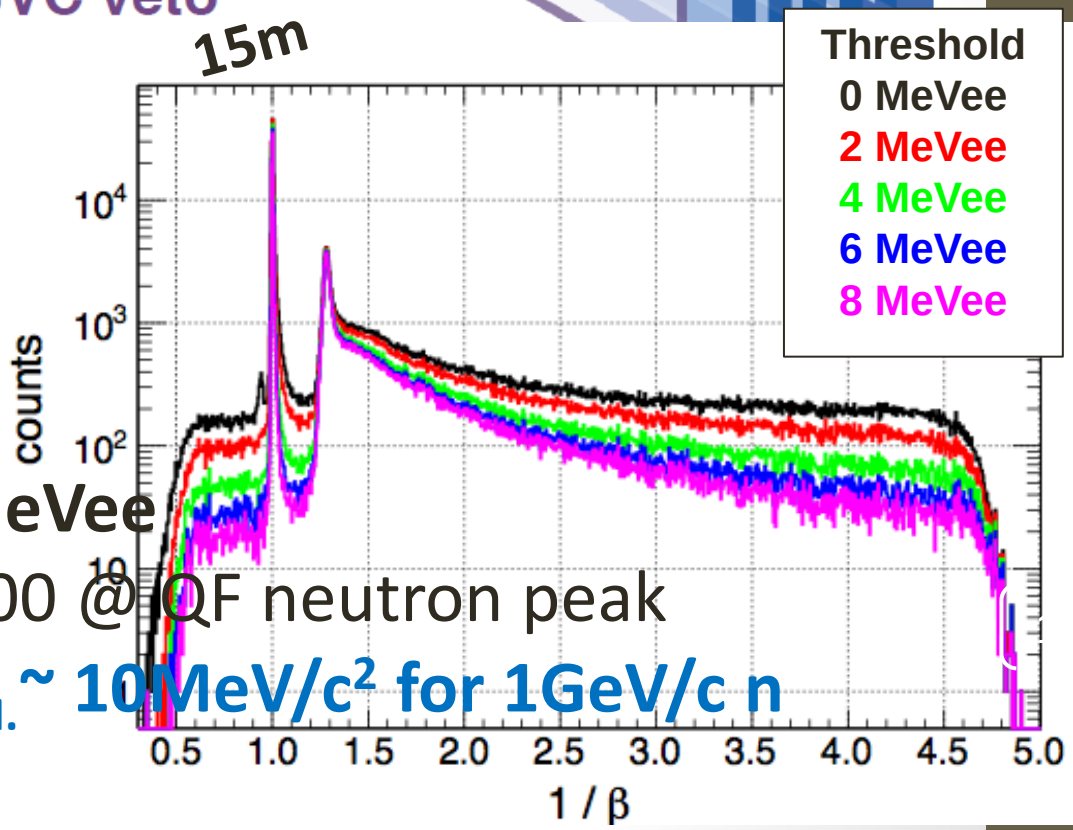
- Designed performance was achieved
  - K^0/Λ are reproduced by the MC
- **Resolution for $K^{bar}NN \rightarrow \Lambda p$ reconstruction: ~10MeV/c²**

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





- ✓ **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

1st Stage Physics Run

Jun.2006	**proposed and approved @ 1st PAC**
Feb 2009	first beam transportation to K1.8BR
Mar.11 2011	the earthquake
May 2012	completion of spectrometer construction
May 2013	**1st physics run**
May.23 2013	the accident (run was stopped)

1st physics run	
duration	Kaon on target
88 hours	4.0×10^9

- Accumulated data in the 1st stage physics run
  - ~1% of original proposal

From 1st physics data

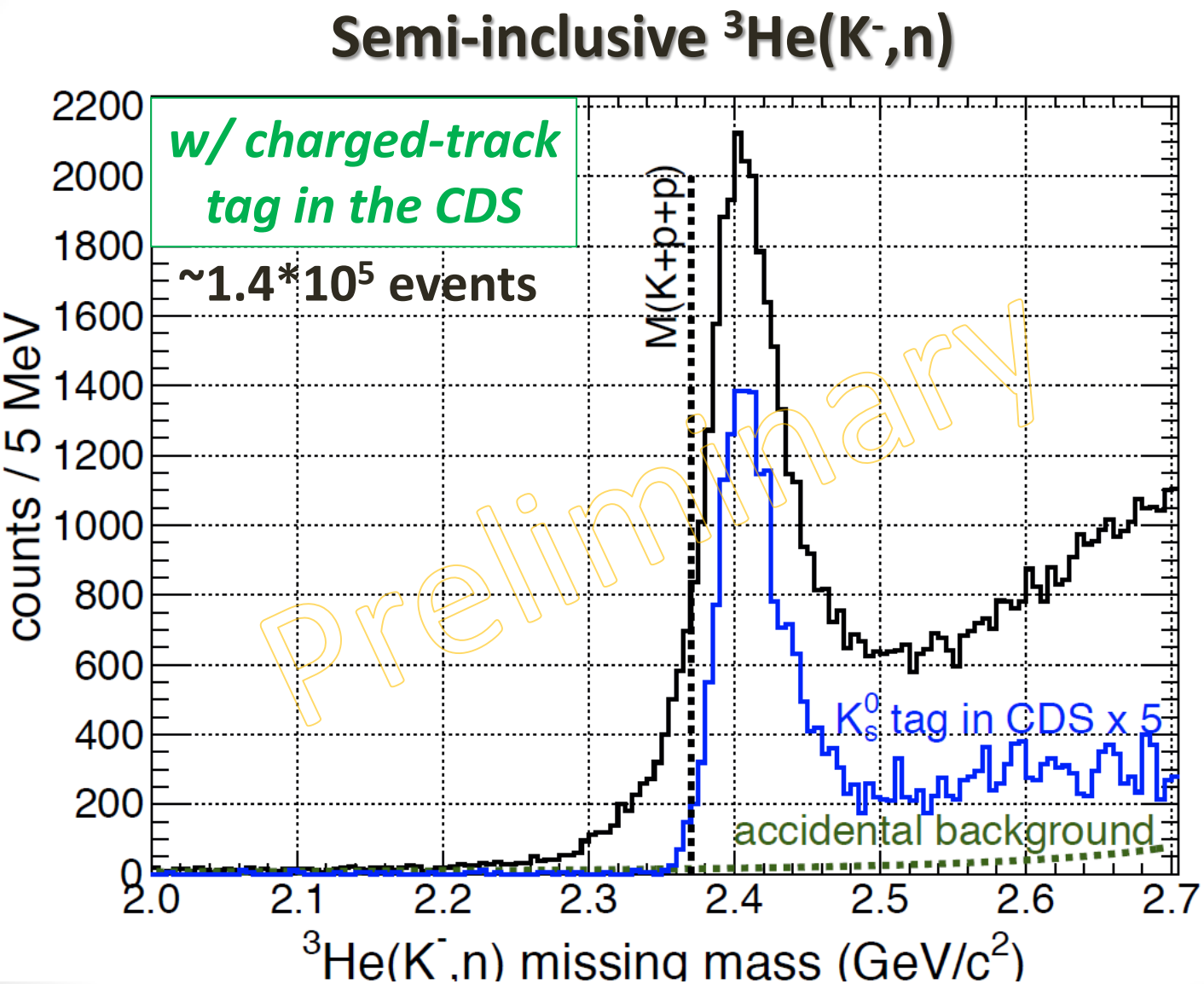
- semi-inclusive analysis
  - **^{3}He(K^-, n) missing mass**
- exclusive analysis
  - **^{3}He(K^-, Λpn) exclusive**

Preliminary Result

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

Exclusive ^{3}He(K-,Λpn)

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

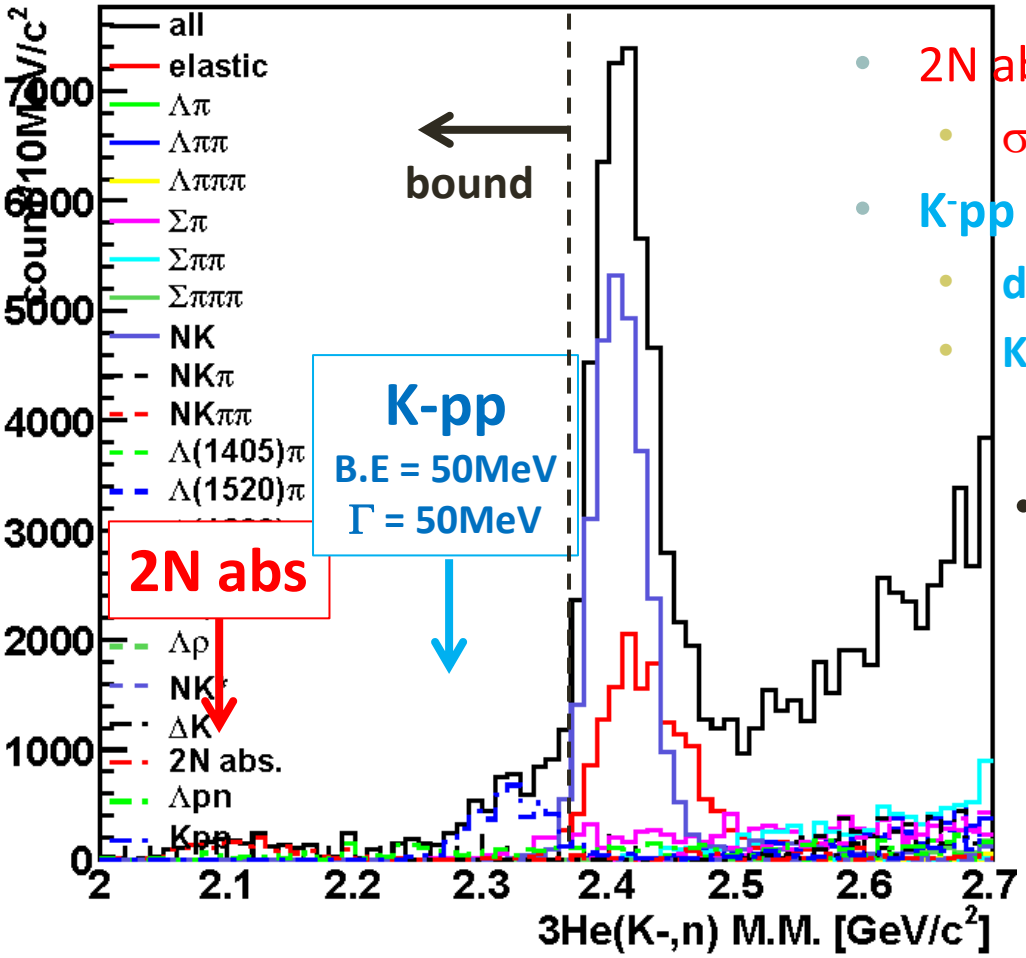


Spectrum from MC(geant4)

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

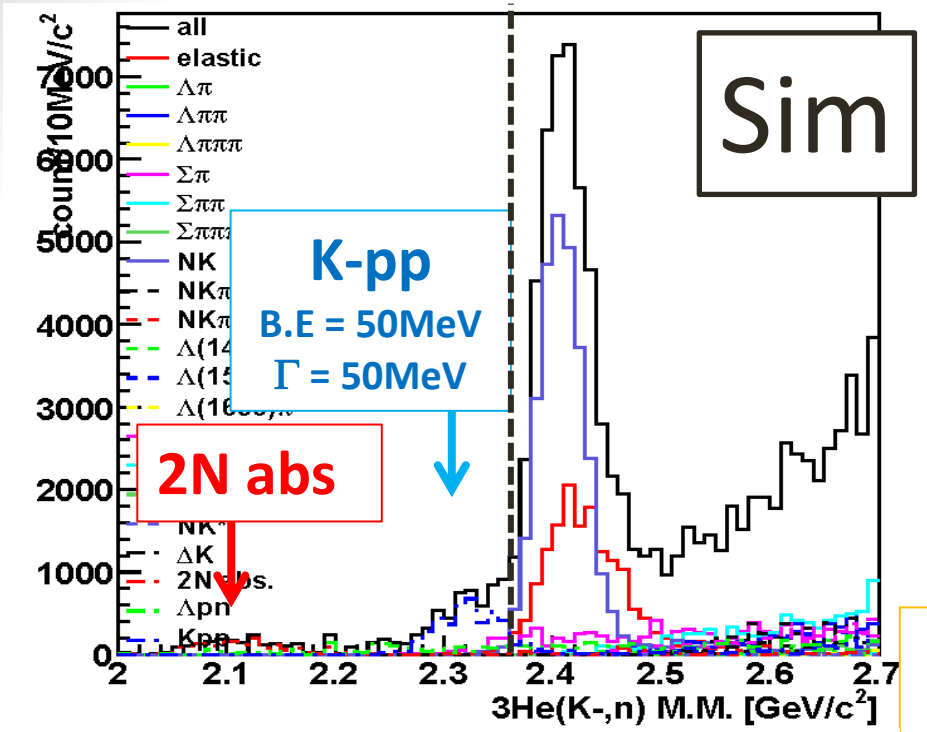
Known K$^-$N interactions are considered from data of past experiments [CERN-HERA-83-02]

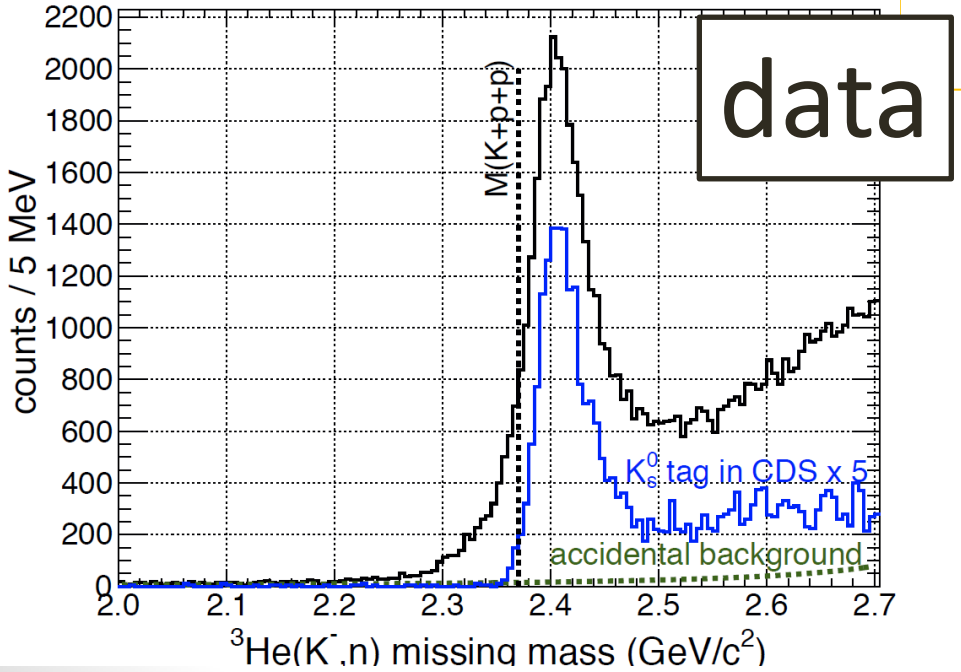
Simple assumptions: $\sigma_{tot} = 2*\sigma_{K-p} + \sigma_{K-n}$



- 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^0p(25%), πΣp(50%)**

- **for one-nucleon induced reactions, almost background is free in bound region**





- **Tail structure may suggest exotic state??**

=>Need more studies

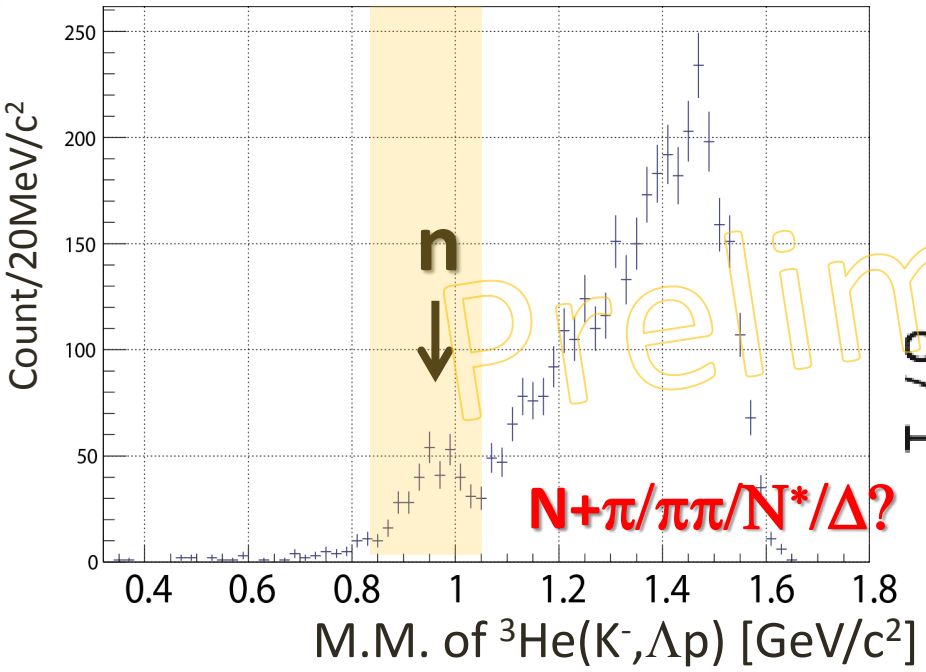
Preliminary Result

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

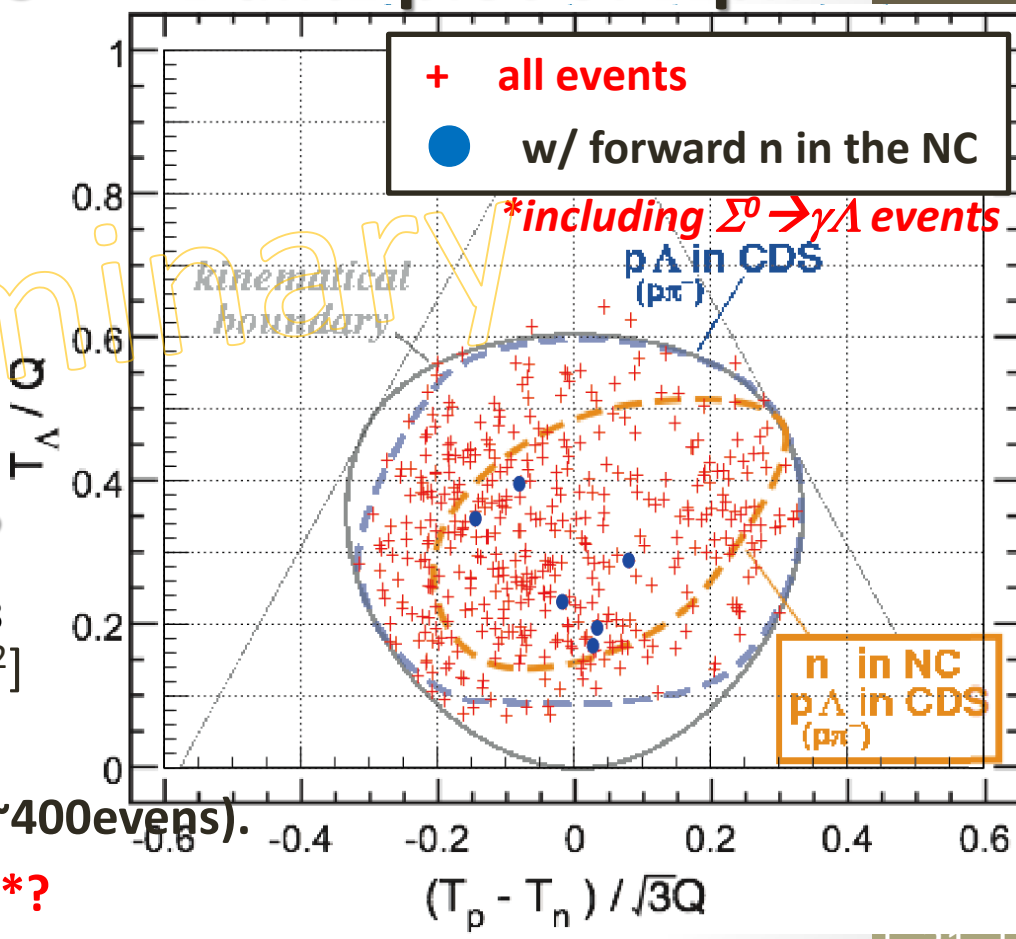
Exclusive ^{3}He(K-,Λpn)

^{3}He(K$^-$,Λpn) Result

^{3}He(K$^-$,Λp) missing mass



Dalitz plot of Λpn



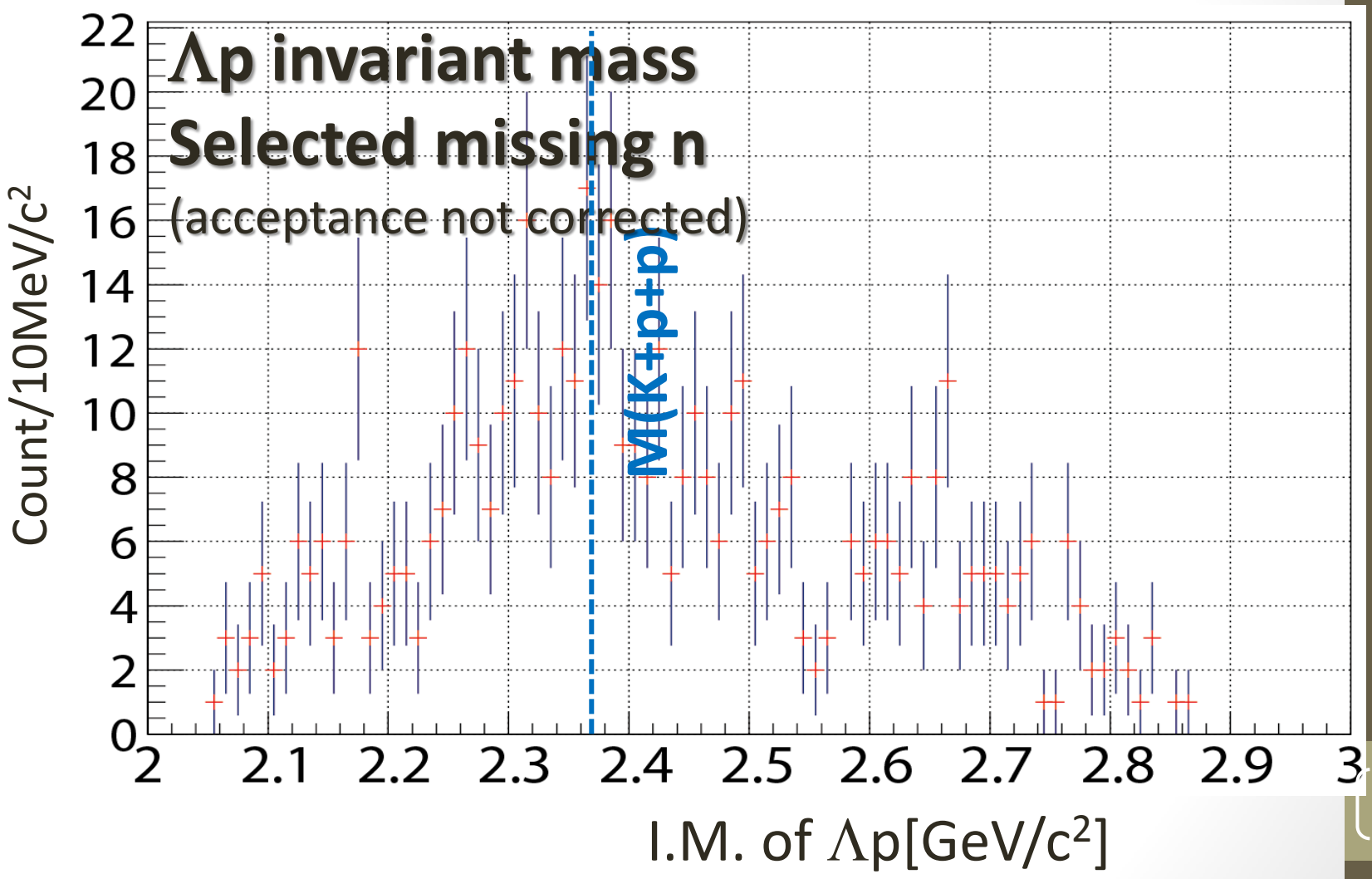
In Λp evens , Λpn events are minority (~400evens).

=>main evens are Λp + N+π?/N+ππ?/N*?

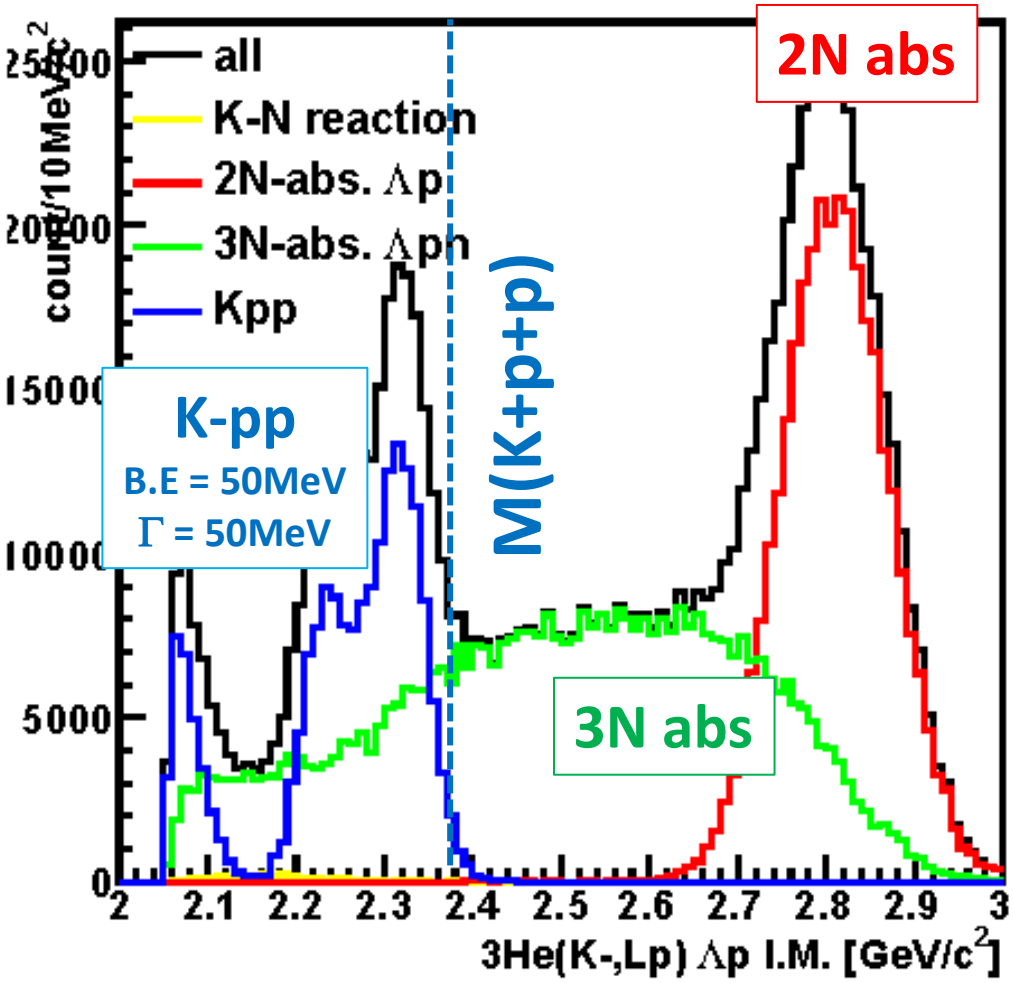
In Dalitz plot of Λpn, events are scattered widely in phase space

=>It seems 3N abs (or exotic state?) exists.

^{3}He(K^-,Λpn) Result :I.M of Λp



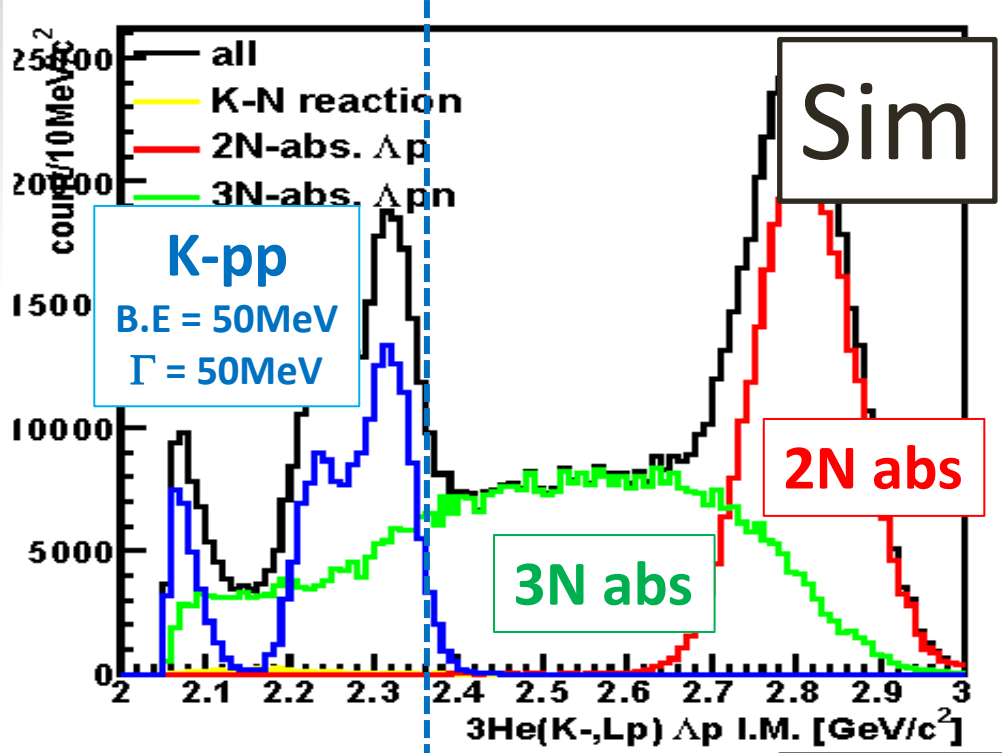
Spectrum from MC(geant4)
exclusive ^{3}He(K$^-$,Λpn) : I.M. of Λp

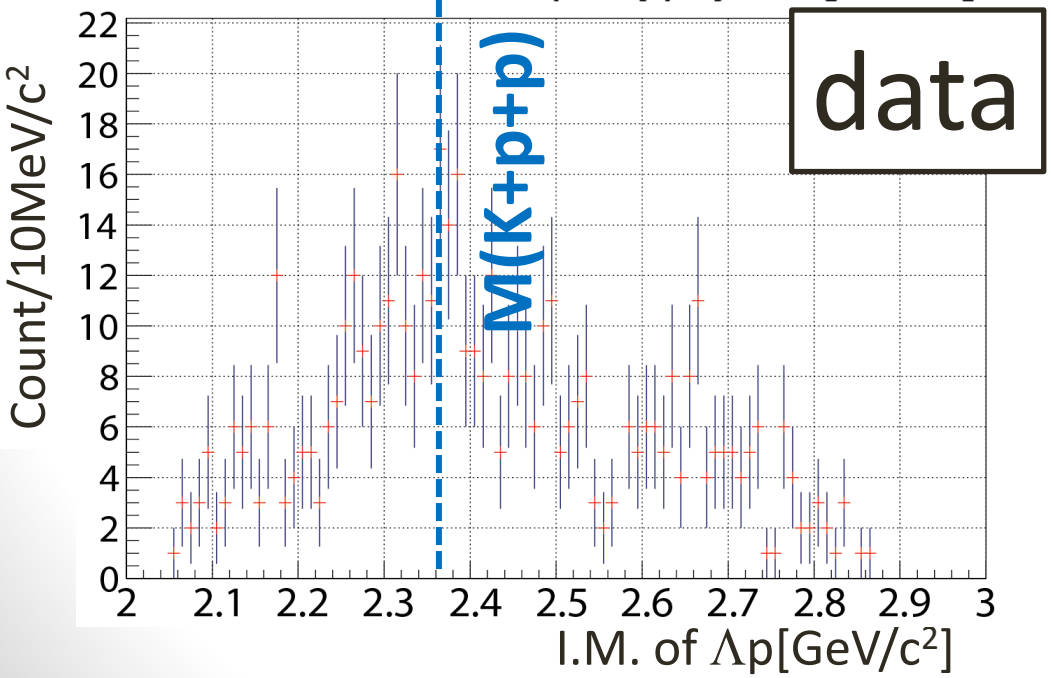


2N abs.: $K^- {}^3He \rightarrow \Lambda\ p\ n_s$
- $\sigma/d\Omega$=1mb/sr, isotropic

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%)**





From MC,2Nabs makes peak in high energy region

=>real data spectrum don't have the peak in high energy region.

It seems 3N abs (or exotic state?) is dominant.

Summary

- **We accumulated the data of 1st physics run of the J-PARC E15 experiment to search for the $K^{bar}NN$ bound-state**
  - ~$4*10^9$ kaons were incident on ^{3}He
- **We have got Preliminary result**
  - Semi- inclusive ^{3}He (K^-, n) missing mass
  - Exclusive ^{3}He(K^-,Λpn)
- **Further analyses are under way**
  - Finalization of the ^{3}He(K^-,n) spectrum
  - Detailed analysis of exclusive Λpn events or other final state (Σ mode?)
  - ^{3}He(K^-,p) and ^{3}He(K^-,d) spectra
  - Y* study

(About E15 exp. , Enomoto-san also will talk @"HADRON2013" in Nara(Nov. 8th))

J-PARC E15 collaboration

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