22-Nov.-2012

J-PARC Hadron Facility and Strangeness Nuclear Physics

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Kyoto University

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- J-PARC Hadron Facility
- Strangeness Nuclear Physics program at J-PARC
  - on-going experiments
    - E19, E27,
    - ..., E15, E10, E13, E05
- Summary

J-PARC Facility (KEK/JAEA)

South to North

Linac

3 GeV Synchrotron

Neutrino Beams (to Kamioka)

50 GeV Synchrotron

Materials and Life Experimental Facility

Hadron Exp. Facility

CY2007 Beams
JFY2008 Beams
JFY2009 Beams

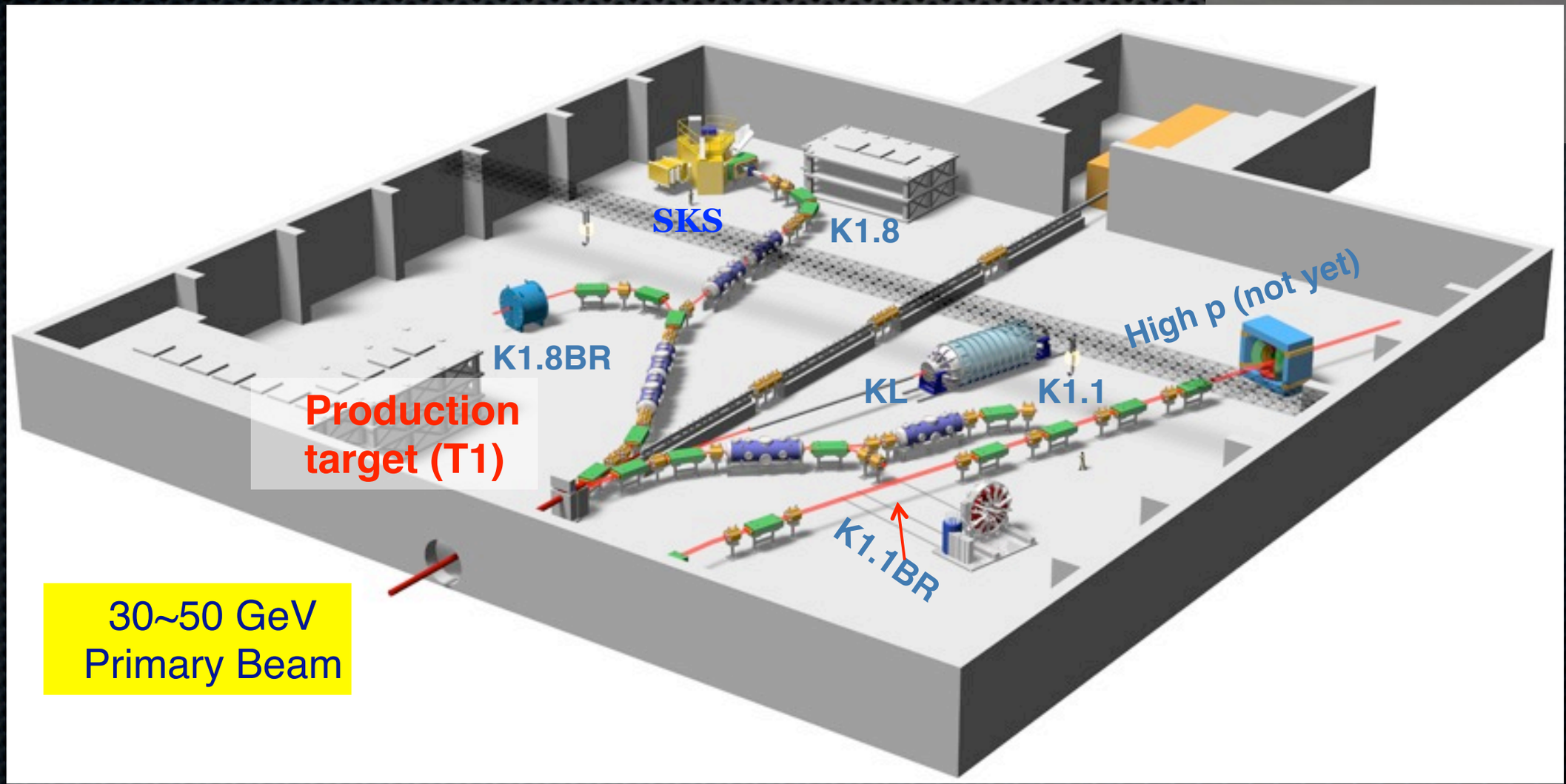
Photo in July of 2009

Hadron Experimental Hall

World highest intensity Kaon beams !

First beam in Feb. 2009

60m x 56m



Hadron Experimental Hall

60m x 56m
Completed in
June, 2007

Hadron Area in the Fall of 2009

K1.8 Area; SKS

KL Area

Primary Beam

KL Beam

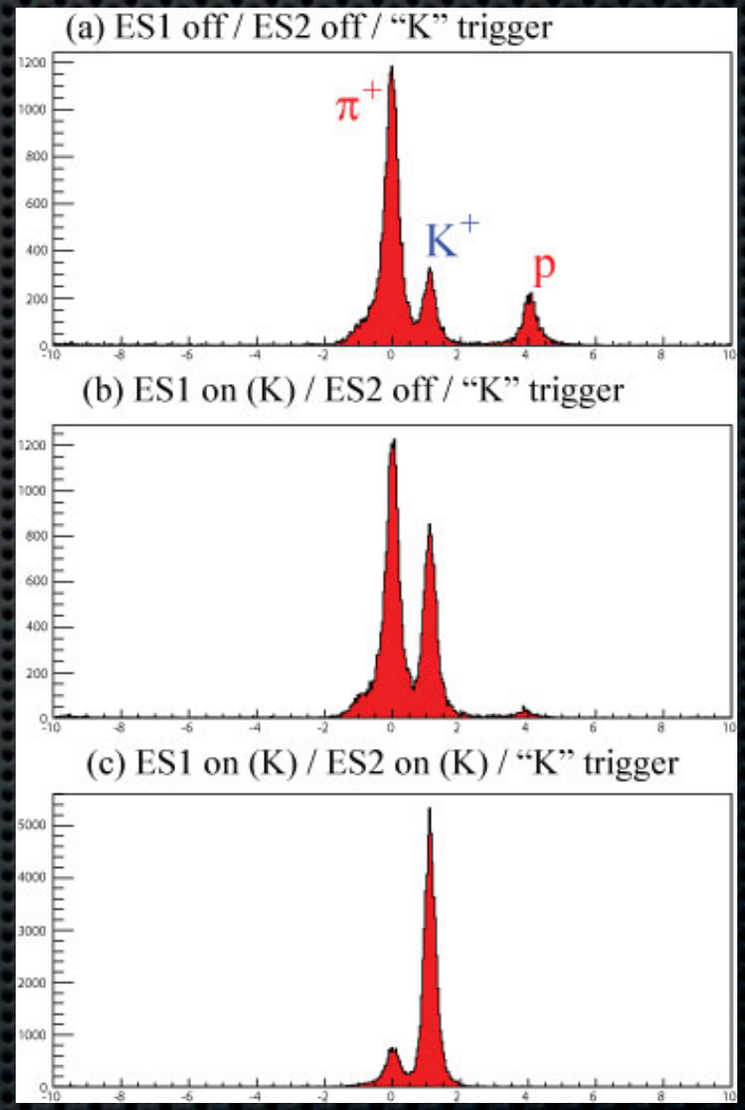
K1.8

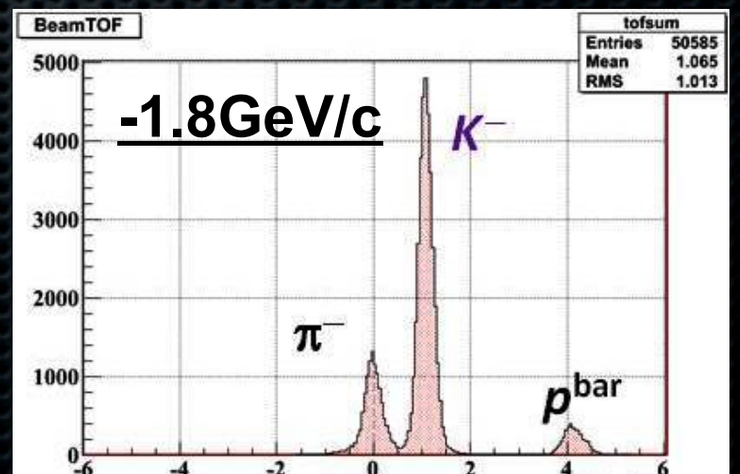
K1.8BR

Beam commissioning at Hadron Hall

In Winter 2009-10 at K1.8

- Good K/π ratio !!
  - Double-stage Electro-Static separator system works well.
- Beam intensity and time structure should be improved.
  - 3 - 5 kW on target
  - ~30% instantaneous duty





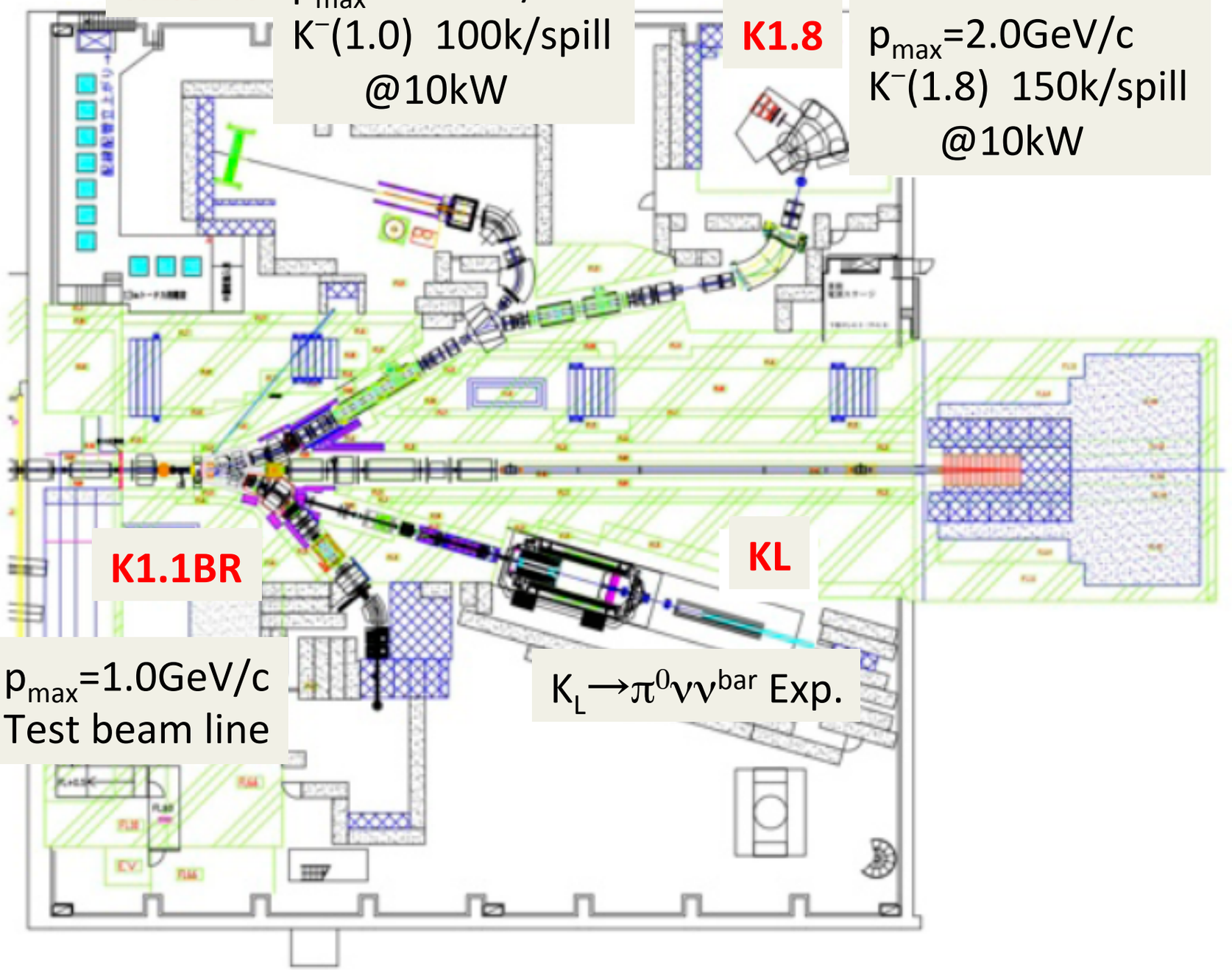
Successful data taking of E19 in Oct. - Nov. 2010

using pion beam

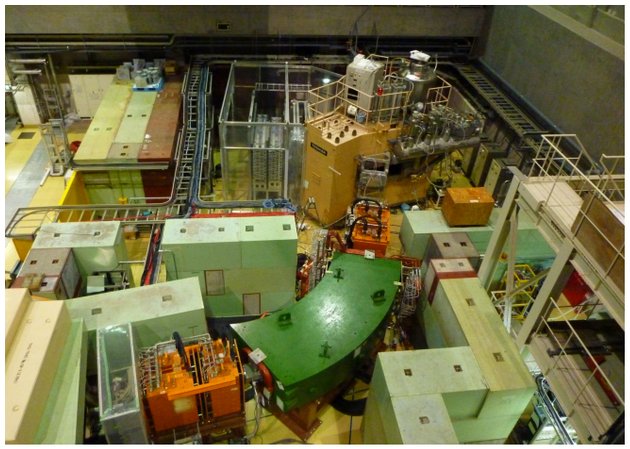
~272 hours

- ~40 people from KEK, Kyoto, Tohoku, Tokyo, Nara WU, Osaka, JAEA, UNM, INFN, Torino, Seoul, ITEP, JINR

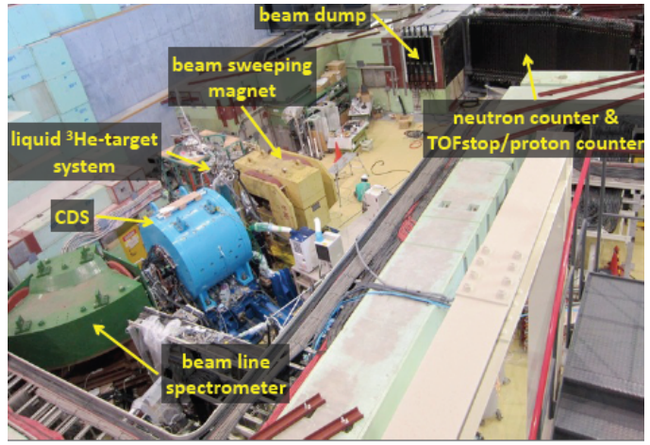
Hadron Hall in 2013



K1.8 & SKS



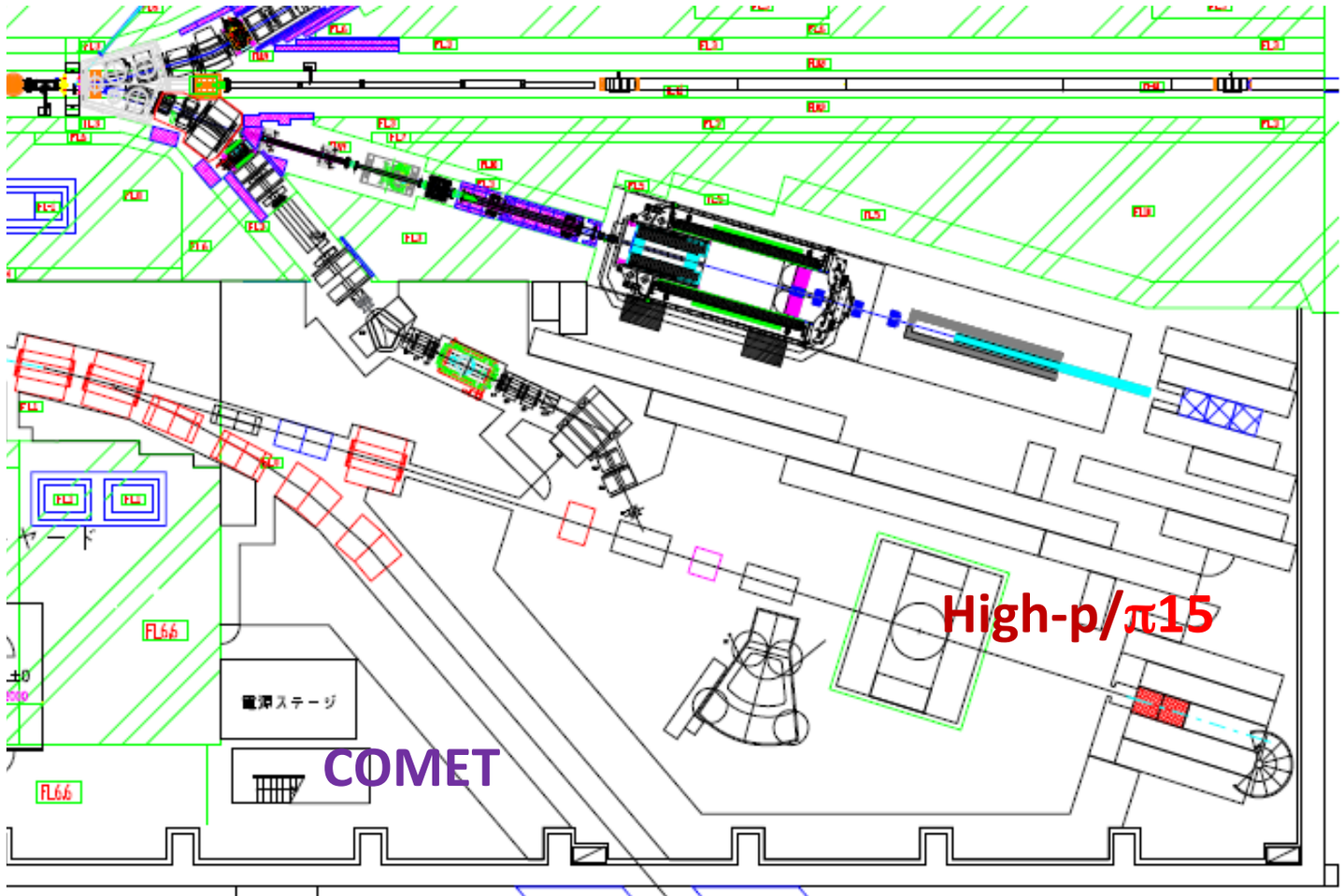
K1.8BR & CDS, nTOF



New beam lines

KEK is requesting to construct new primary beam lines in the south area with the highest priority.

In the earliest case, beam lines will be constructed during 2013—2015.



Experiments at K1.1 can be carried out from Feb. 2014 to June 2015 before the construction.

Experiments at K1.1 and High-p /p15 can be carried out alternatively after the construction, by switching the setup annually or bi-annually.

primary p beam —30GeV
secondary (un-separated) beam —15GeV/c

Future Extension

High-resolution (~100keV)
spectroscopy of Λ hypernuclei
by the ($\pi^{\pm}$,K^{+}) reactions

medium-/heavy- Λ hypernuclei

neutron-rich Λ hypernuclei

HIHR

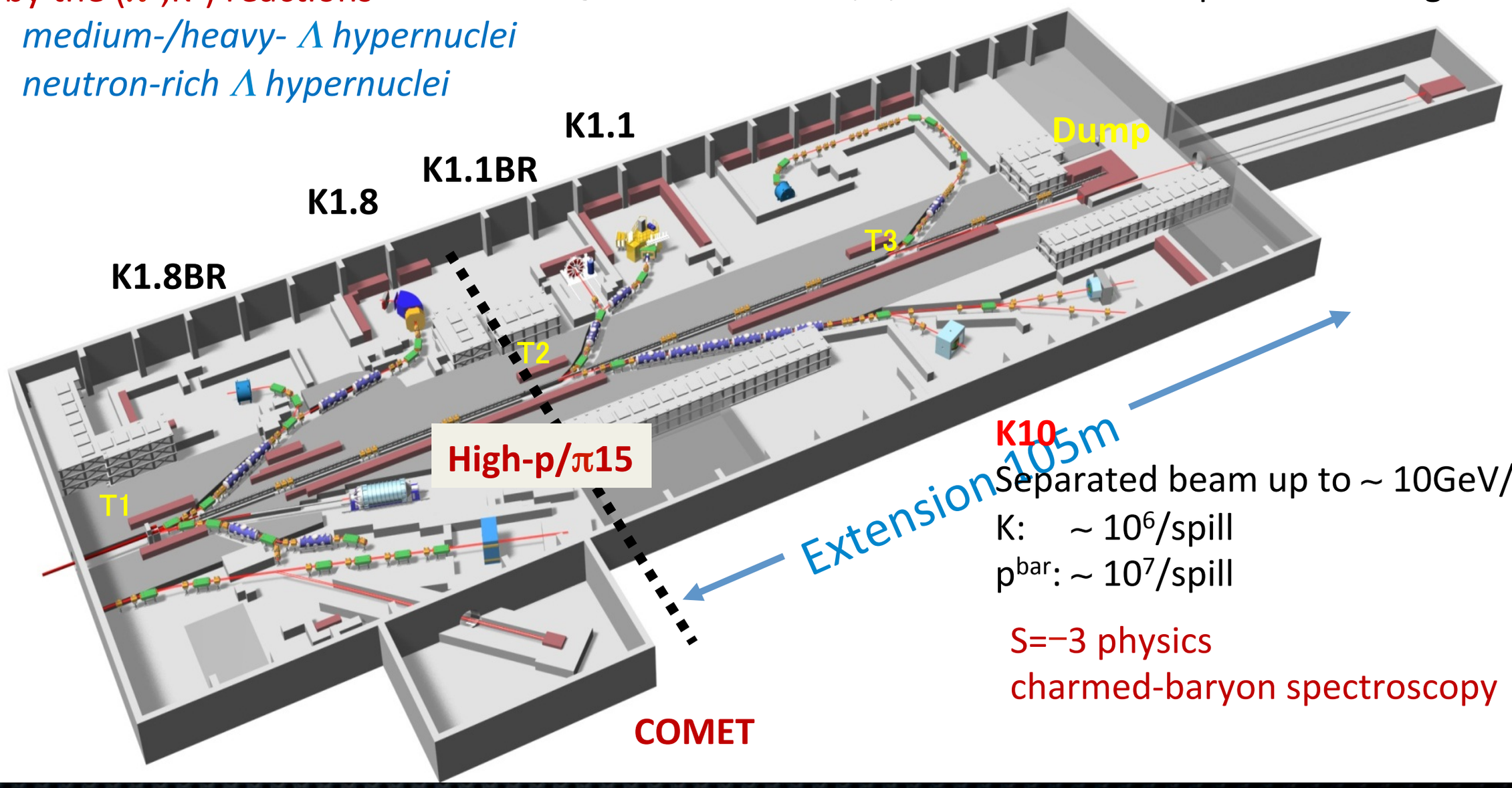
π beam up to 2GeV/c

High-intensity ~10^9/spill

High-resolution Δp/p ~10^{-5}

KL

5°production angle



K10

Separated beam up to ~ 10GeV/c

K: ~ 10^6/spill

p^{bar}: ~ 10^7/spill

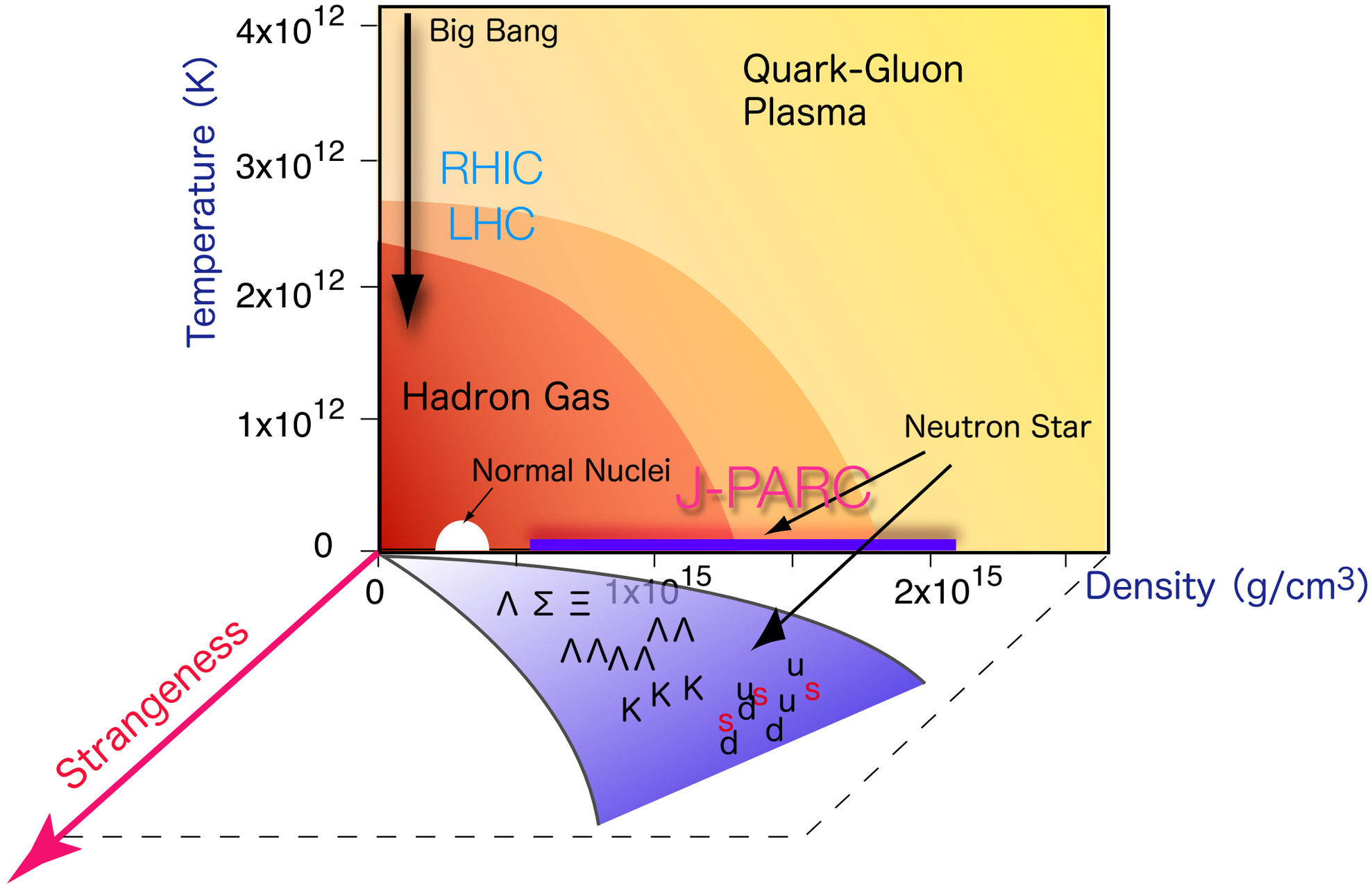
S=−3 physics

charmed-baryon spectroscopy

SNP Program at J-PARC

World Facilities in the 21st Century

Role of strangeness in dense matter



SNP Program Schedule

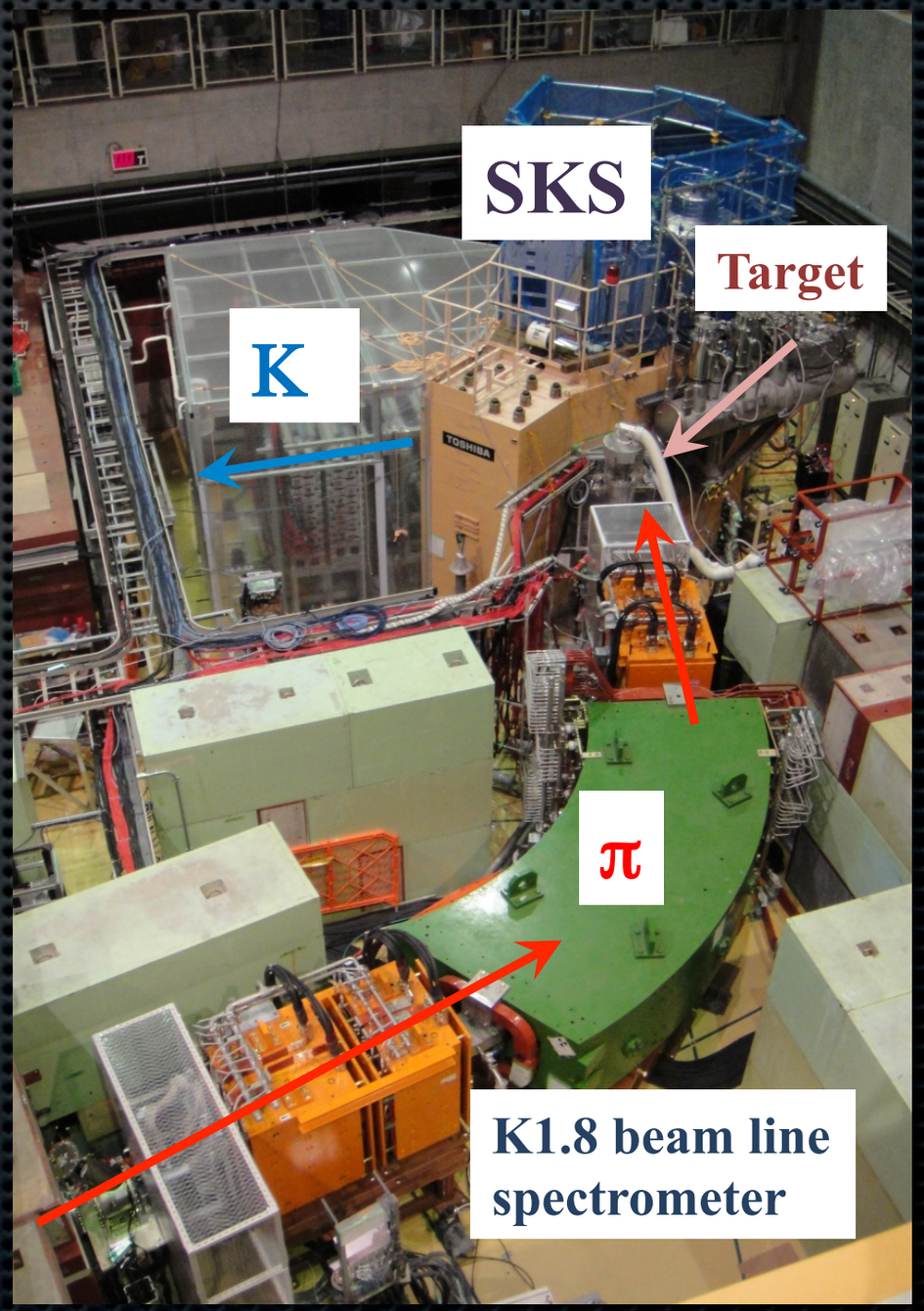
- 2010: Oct.-Nov.
  - E19: Penta-quark search in $\pi^- p \rightarrow K^- X$ at 1.92 GeV/c
    - *First physics data taking in Hadron Hall*
- 2012: Feb. , *after the Earthquake*
  - E19: $\pi^- p \rightarrow K^- X$ at 2 GeV/c
- 2012: June
  - E27: $d(\pi^+, K^+)$ for $K^- pp$, *a pilot run* 5 kW / 270 kW

SNP Program Schedule

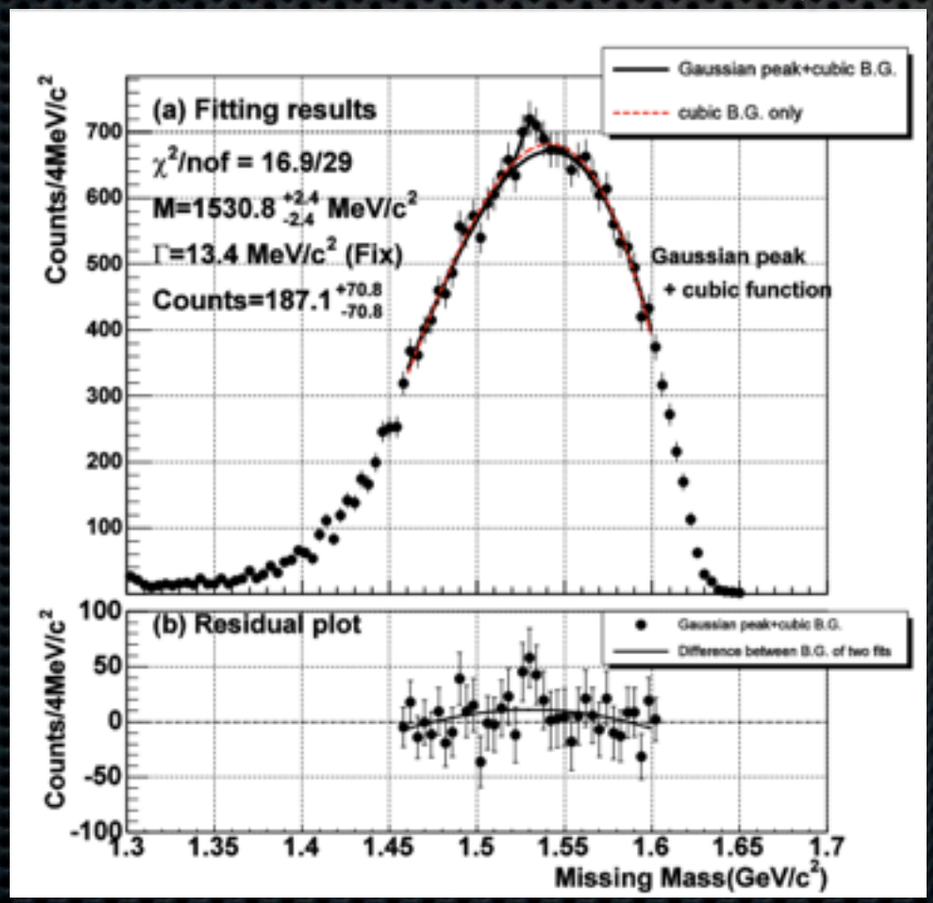
- In near future...
- 2012: Dec. 10 kW
  - E10: $(\pi^-,K^+)^6_\Lambda H$
- 2013: March - June > 10 kW
  - E15: $^3He(K^-,n)$ for *K^-pp*
  - E13: Hypernuclear γ-ray spectroscopy; $^4_\Lambda He$, $^{19}_\Lambda F$
  - E05: Ξ hypernuclei; $^{12}C(K^-,K^+)$

High-resolution search for Θ^+ in $\pi^- p \to K^- X$ reaction: E19 M. Naruki et al.

- $\pi^- p \to K^- \Theta^+$ at 1.92 GeV/c
  - SKS Spectrometer at K1.8
    - ΔE=13.4 MeV → 1.4 MeV



KEK PS E522: K. Miwa et al., PLB635 (2006) 72.

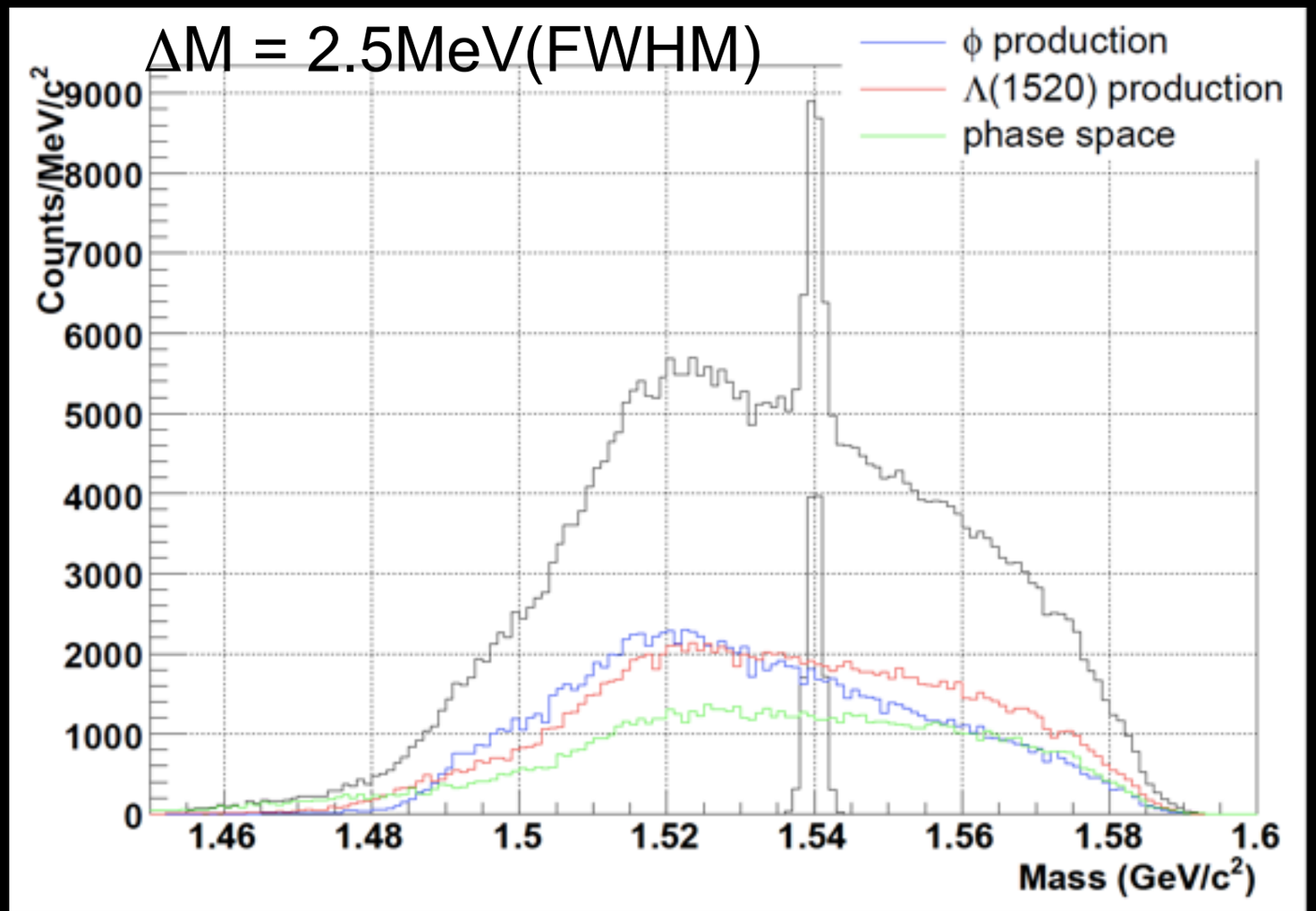


S/N=2.5 σ

dσ/dΩ=1.9μb/sr, if true.

Expected Missing Mass Spectrum

assuming $d\sigma/d\Omega$ = 1.9μb/sr (lab)



we aim to;

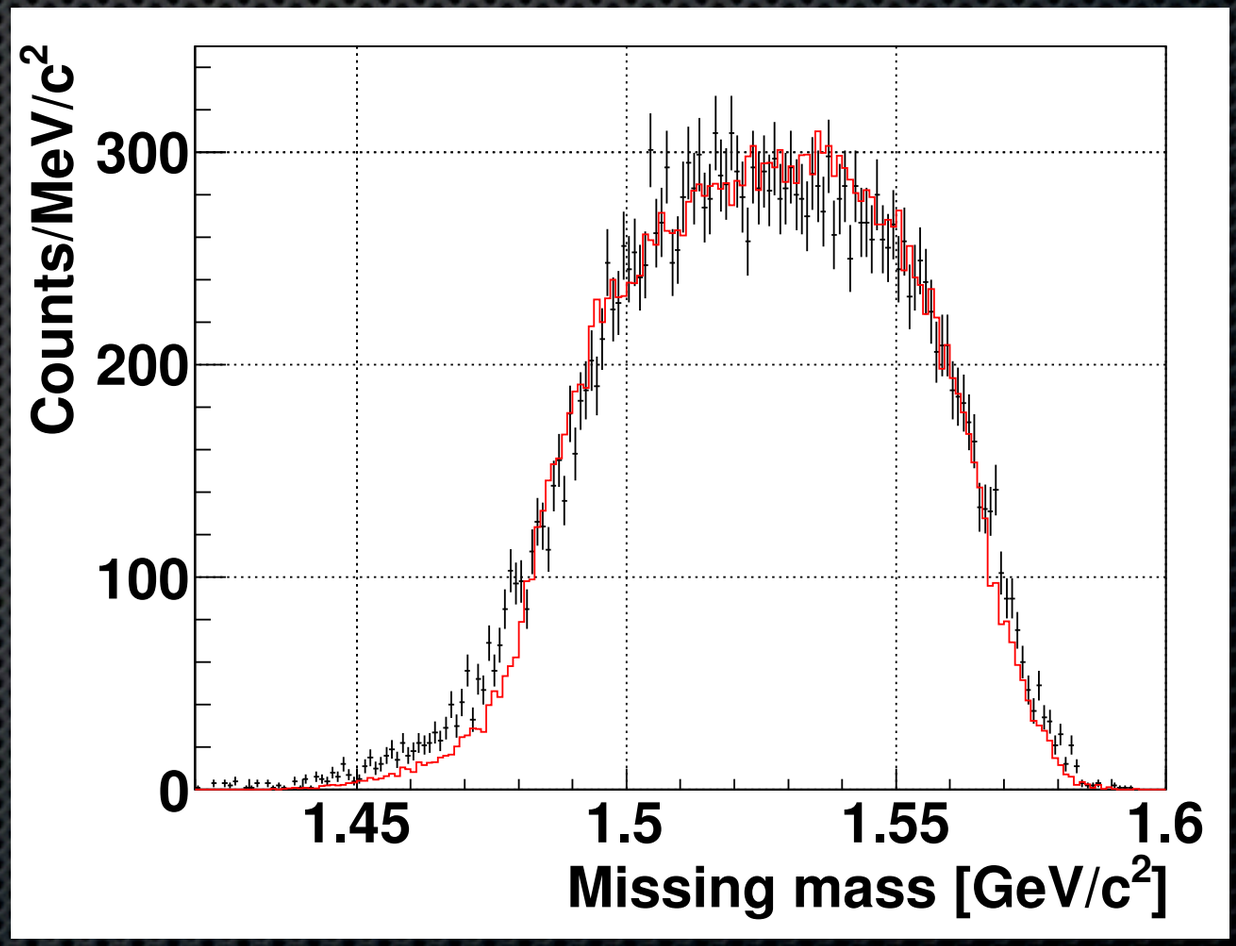
- confirm Θ^+ with high statistics
- study momentum dependence of cross section

Background sources

φ	$\phi n \rightarrow K^+K^-n$	30.0±8.0 μb
Λ	$\Lambda(1520)K^0 \rightarrow K^-K^0p$	20.8±5.0 μb
phase space	K^-KN	26 μb

Result of the 1st run

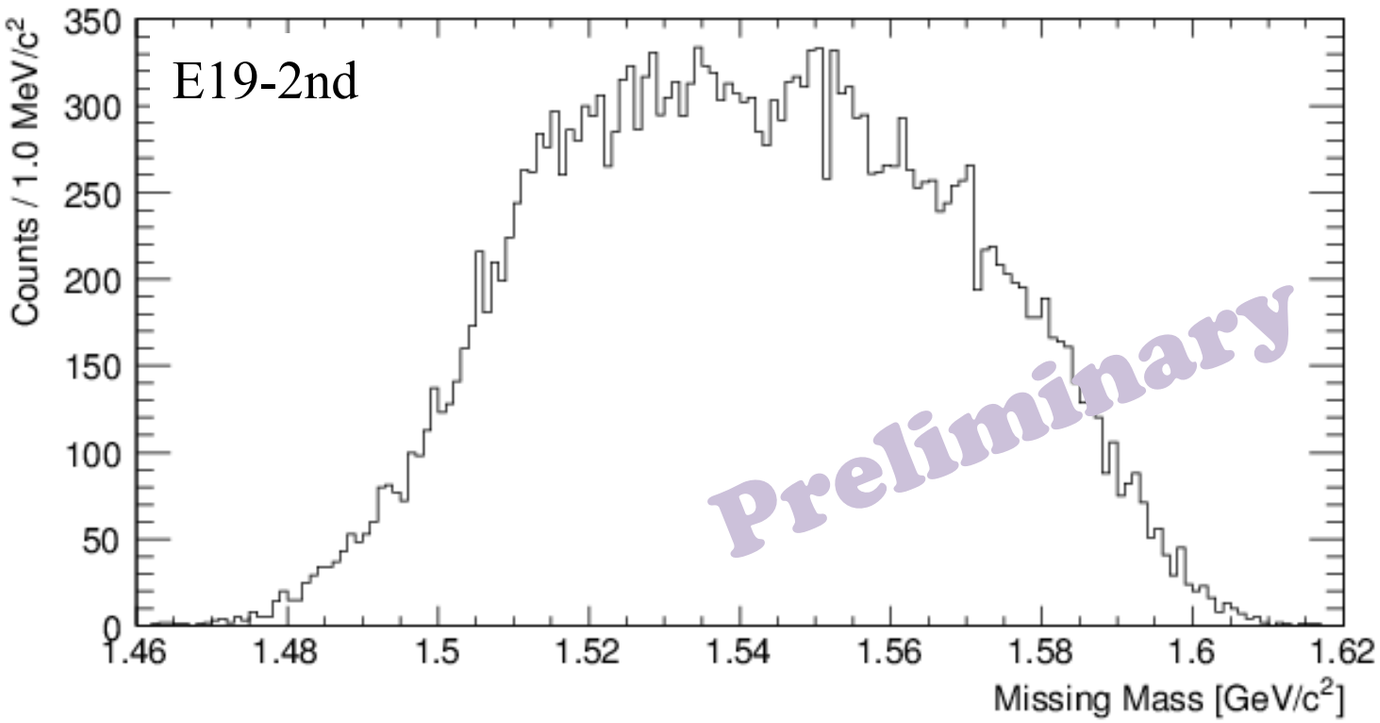
- $\pi^- p \rightarrow K^- X$ at 1.92 GeV/c
  - 7.8×10^{10} π^- in total
  - $\Delta E = 1.4$ MeV $_{FWHM}$
  - No prominent peak structure !
  - 2nd data taking at 2 GeV/c completed.



K. Shirotori et al., PRL 109 (2012) 132002.

Preliminary result of E19-2nd run

Missing Mass : p (π^-, K^-) *X* @ p_π = 2.0 GeV/c



- Analysis parameters were not finally tuned yet.
- No clear peak structure was observed.
- Efficiency evaluation is on-going.
- Tentative expected sensitivity ~ 0.3 μb/sr.

By M. Moritsu@HYP2012

Search for K^-pp in the $d(\pi^+,K^+)$ reaction

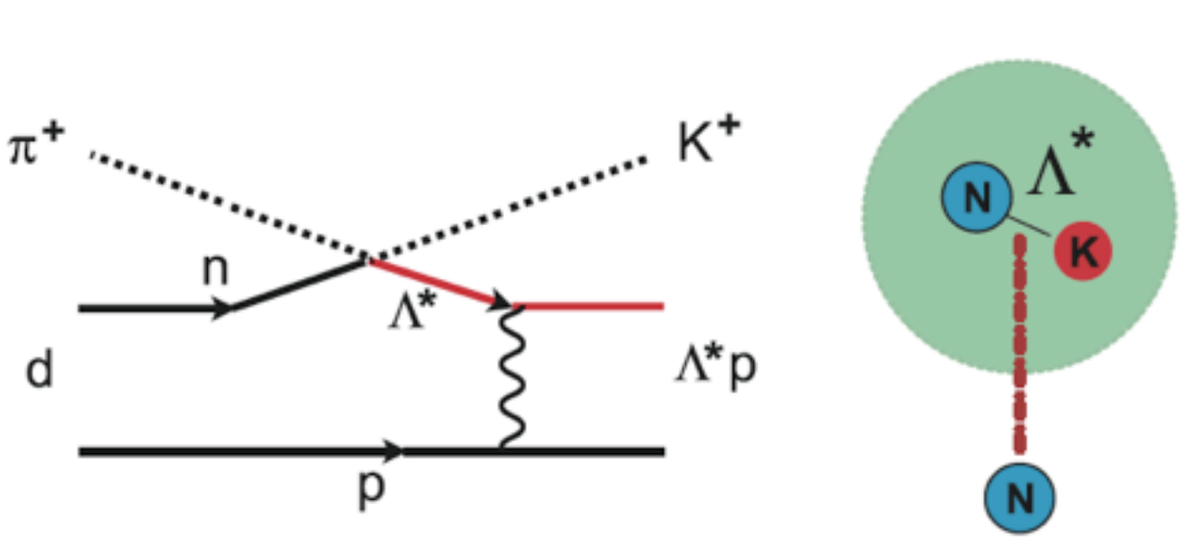
E27

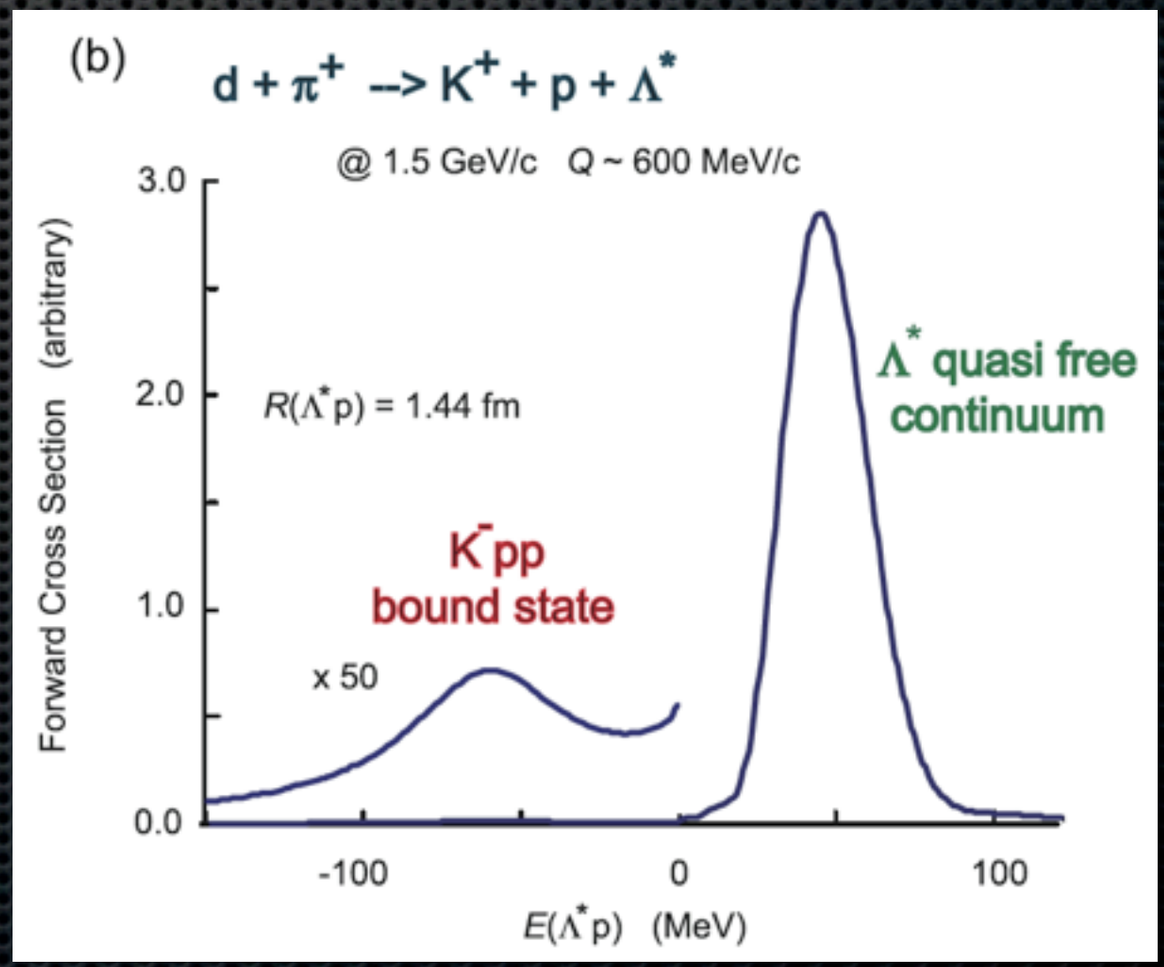
T. Nagae et al.

π^+ + "n" --> "Λ^*" + K^+

"Λ^*" + "p" --> bound K^-pp ***minor***

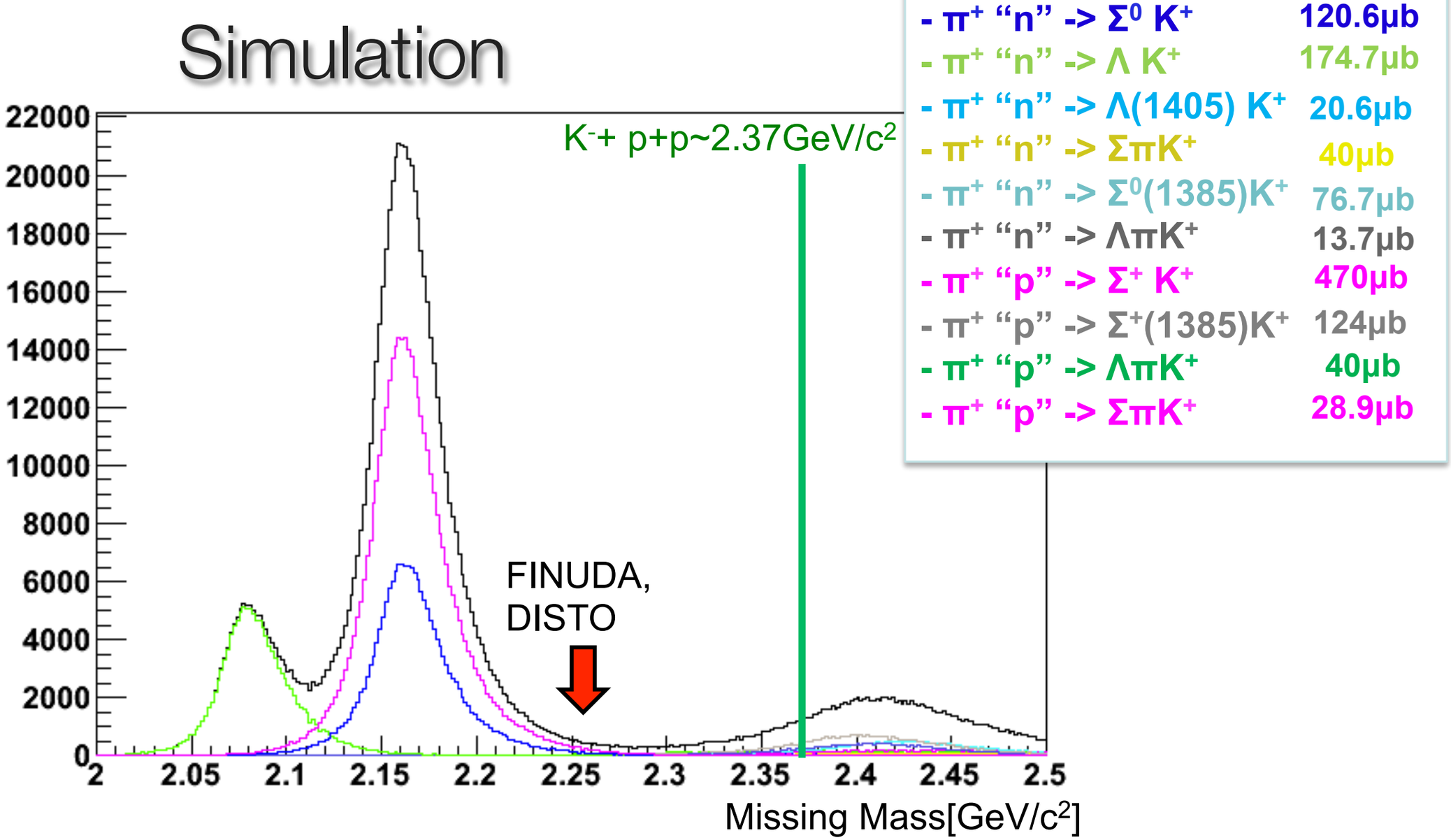
--> quasi-free Λ^* ***dominant***



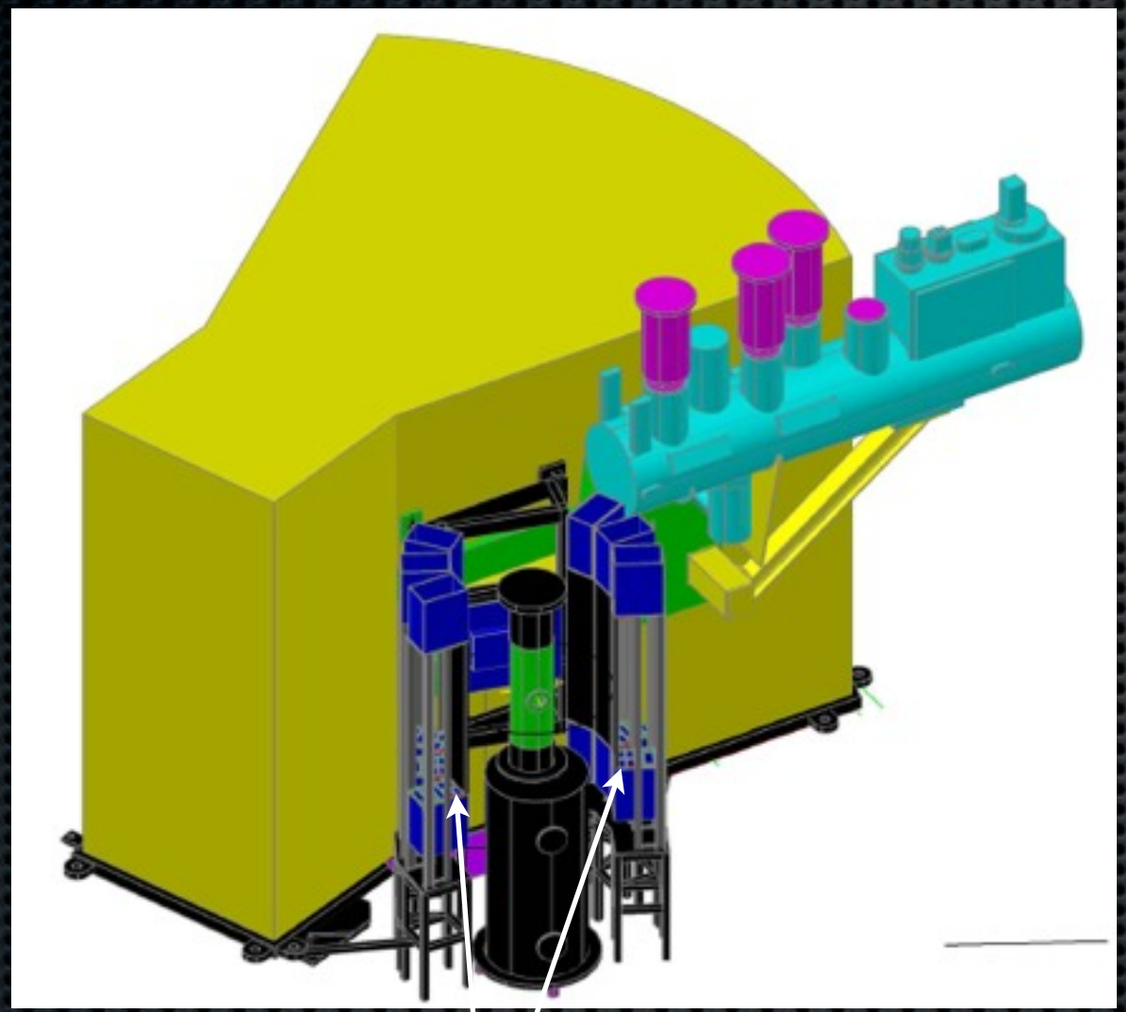


Yamazaki & Akaishi, Phys. Rev. C76 (2007) 045201.

Expected inclusive spectrum

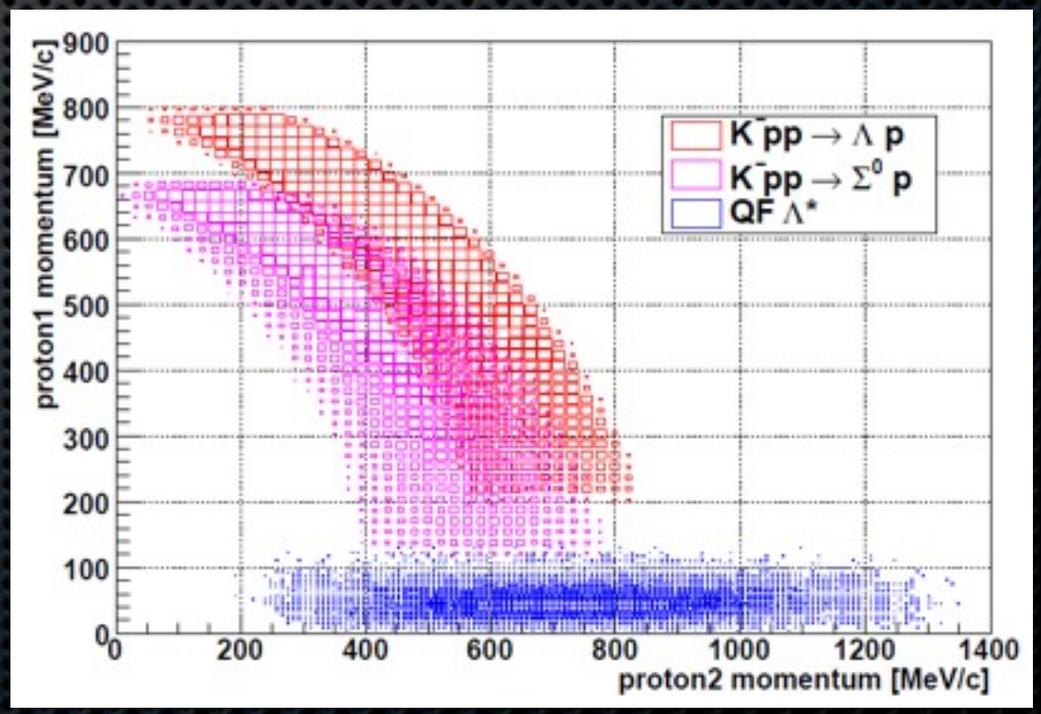


Proton tagging



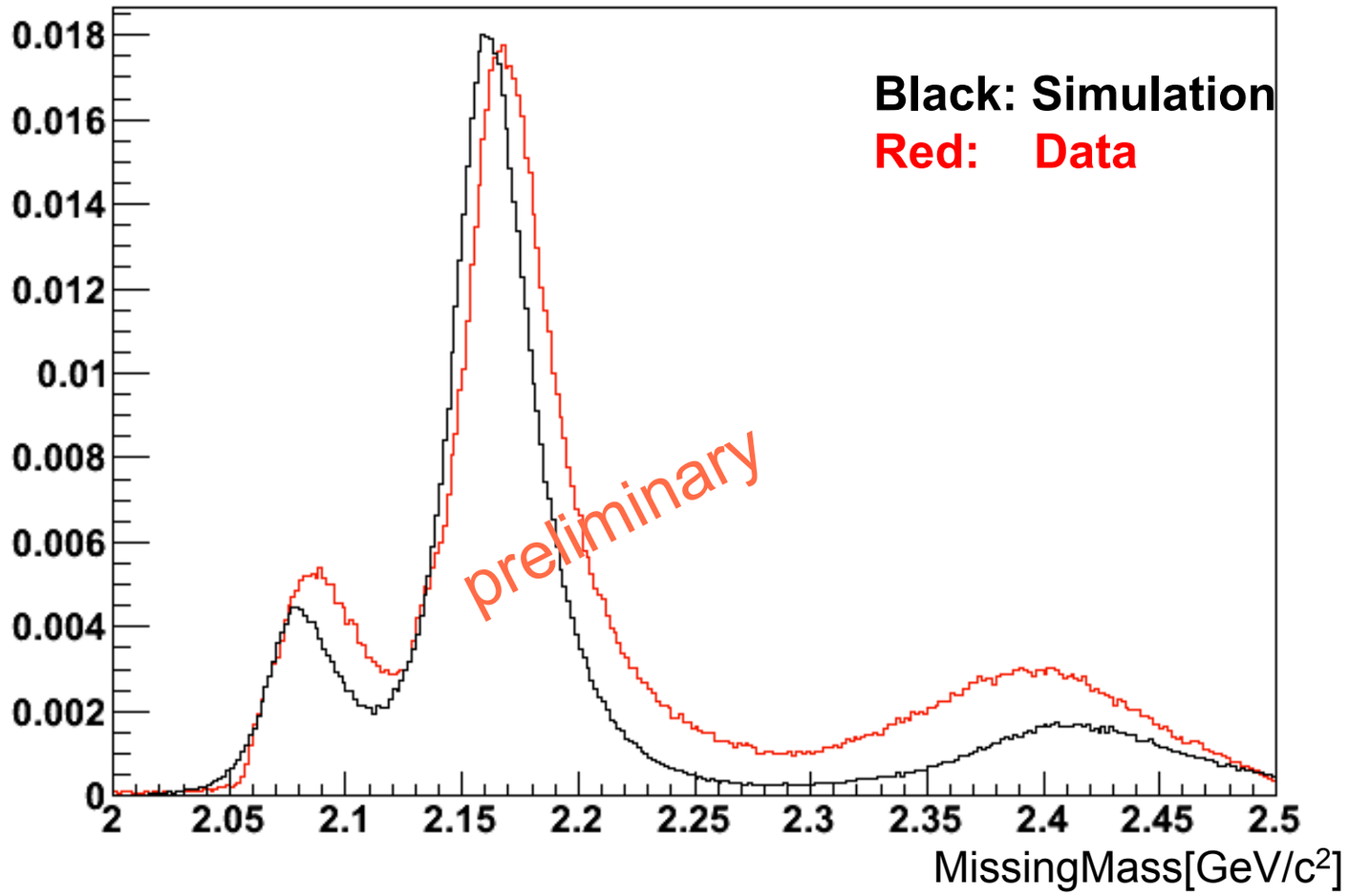
Range Counters

- Quasifree backgrounds
  - $\pi^+ d \rightarrow \Lambda + K^+ + p_s$
  - $\rightarrow \Sigma^0 + K^+ + p_s$
  - $\rightarrow \Sigma^+ + K^+ + n_s$
  - $\pi^+ d \rightarrow \Lambda + \pi + K^+ + N_s$
  - $\rightarrow \Sigma + \pi + K^+ + N_s$



$d(\pi^+,K^+)$ at 1.7 GeV/c

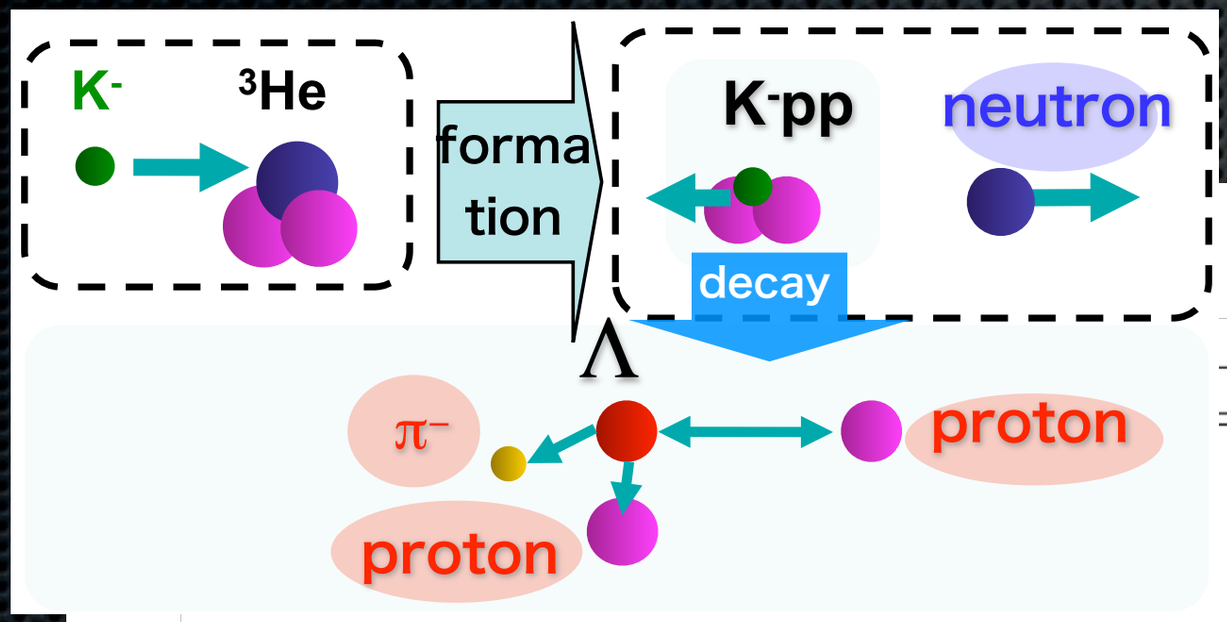
- Inclusive $d(\pi^+,K^+)$spectrum

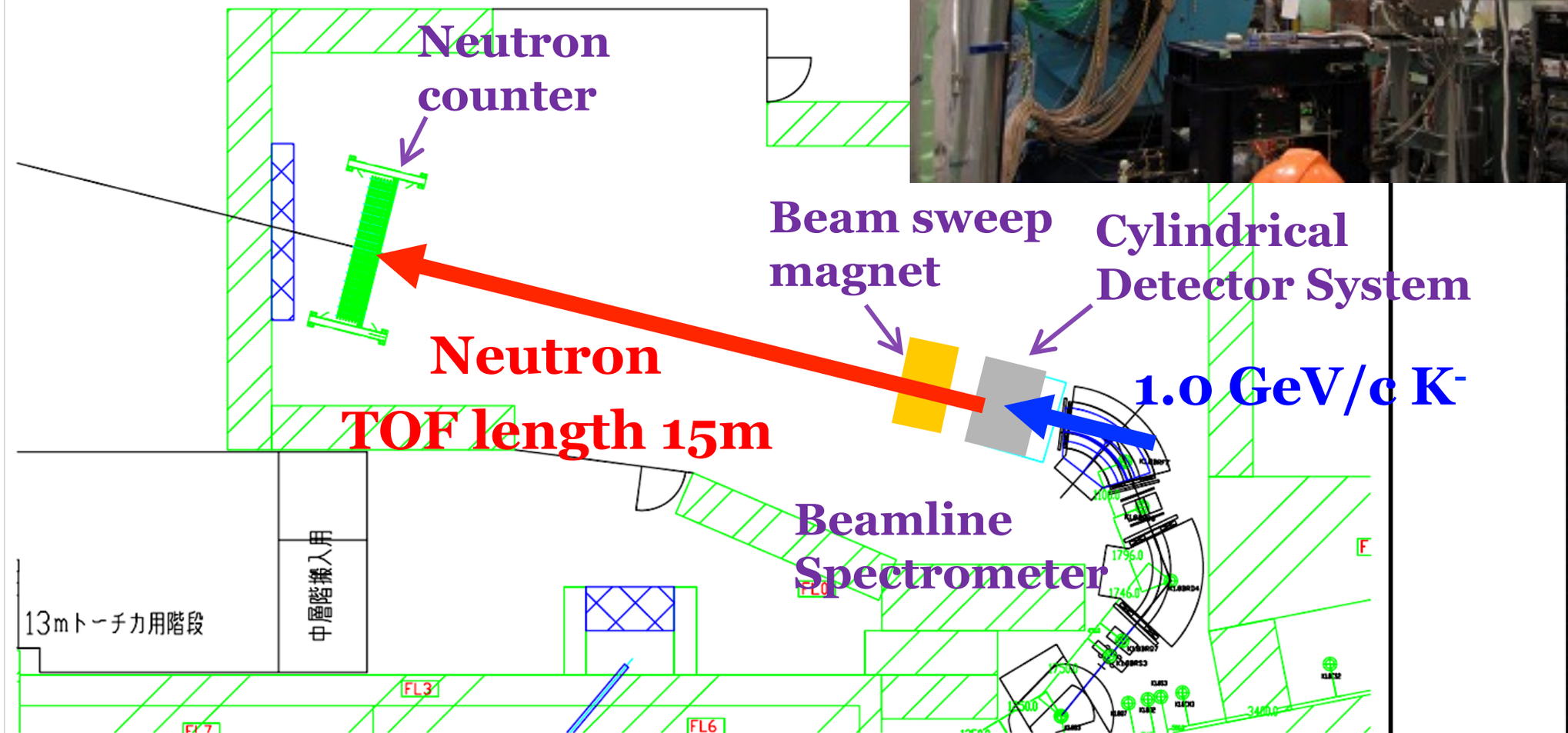


A Search for deeply-bound kaonic nuclear states by in-flight ^{3}He(K^{-},n) reaction at 1 GeV/c

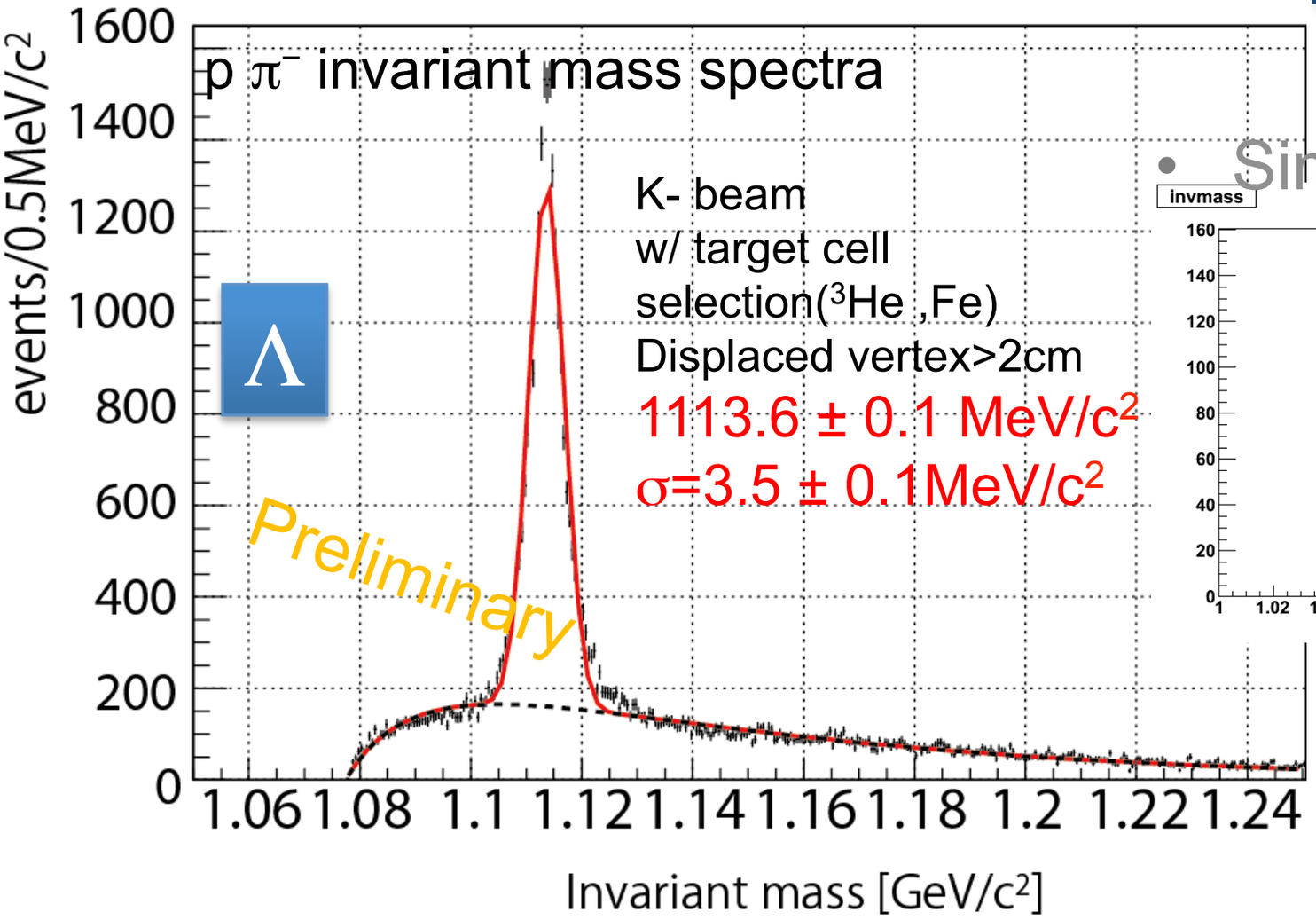
E15

M. Iwasaki et al.

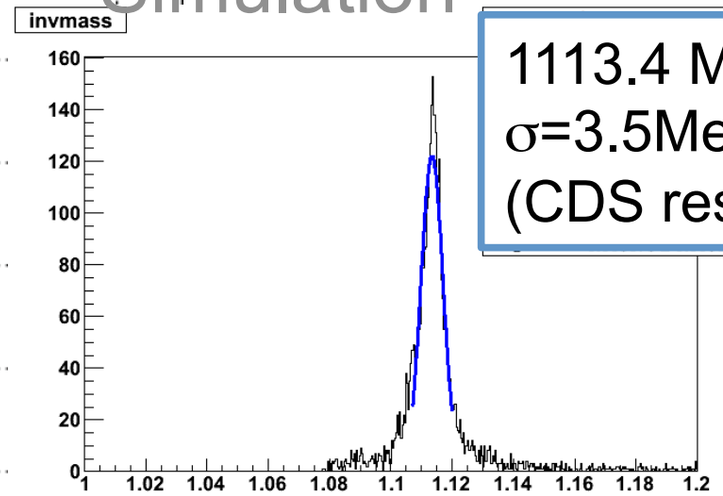




Invariant mass spectra

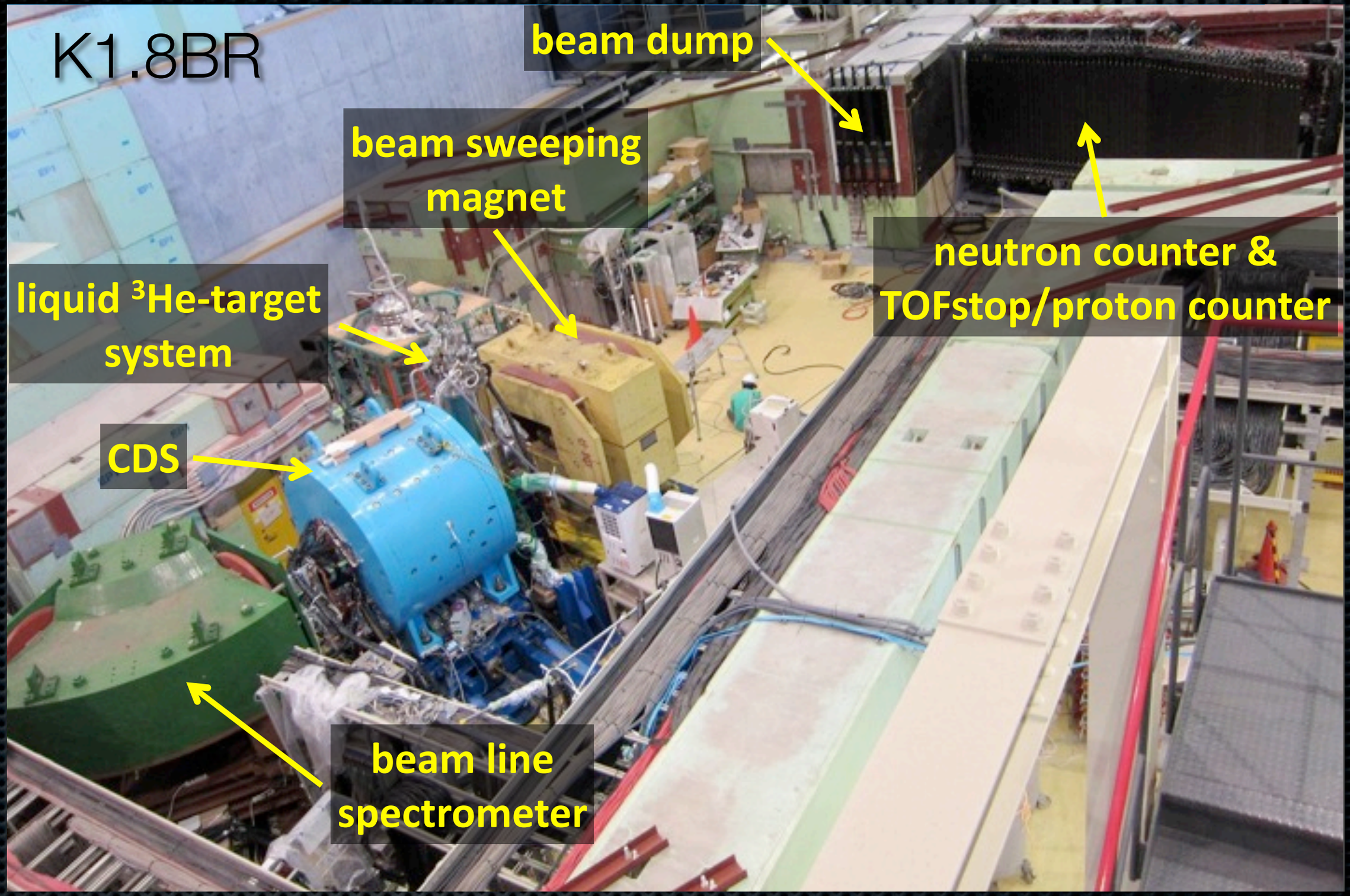


- Simulation



1113.4 MeV/c^2
σ=3.5MeV/c^2
(CDS resl.200μm)

By Y. Sada@HYP2012



- E15 is ready for data taking.

Neutron-rich Hypernuclei with (π^-,K^+) reaction

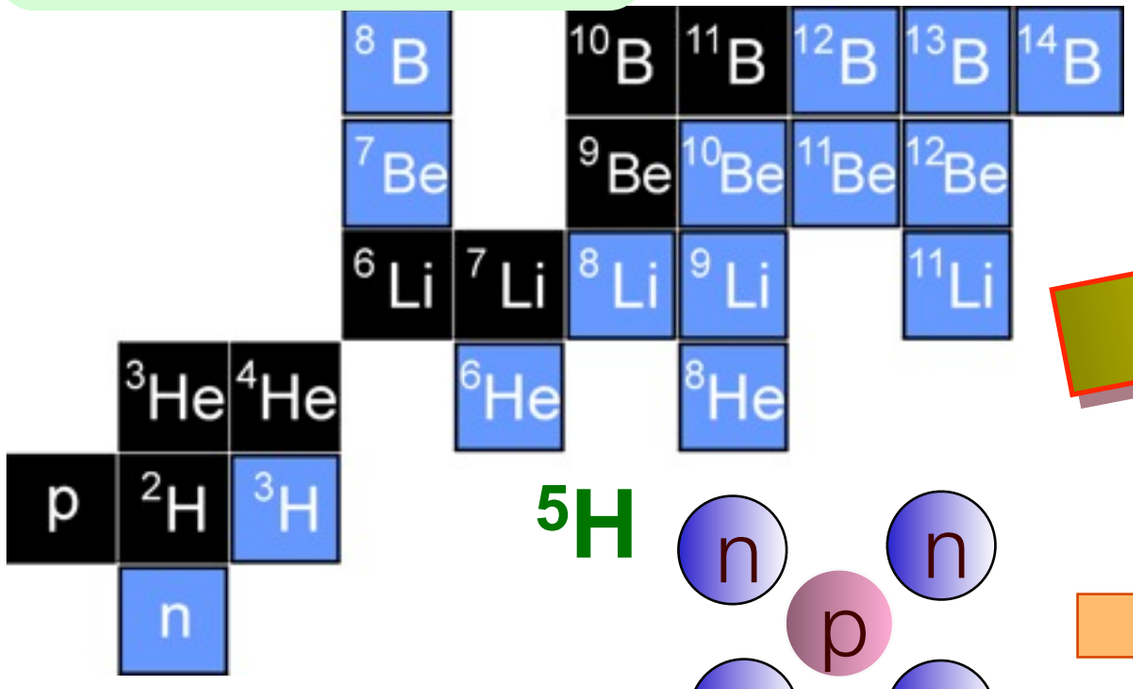
J-PARC E10
A. Sakaguchi et al.

NCX: (K^-,π^-), (π^+,K^+) reaction

SCX: $(e,e'K^+)$, (K^-,π^0), (π^-,K^0) reaction

DCX: (K^-,π^+), (π^-,K^+) reaction

ordinary nuclei



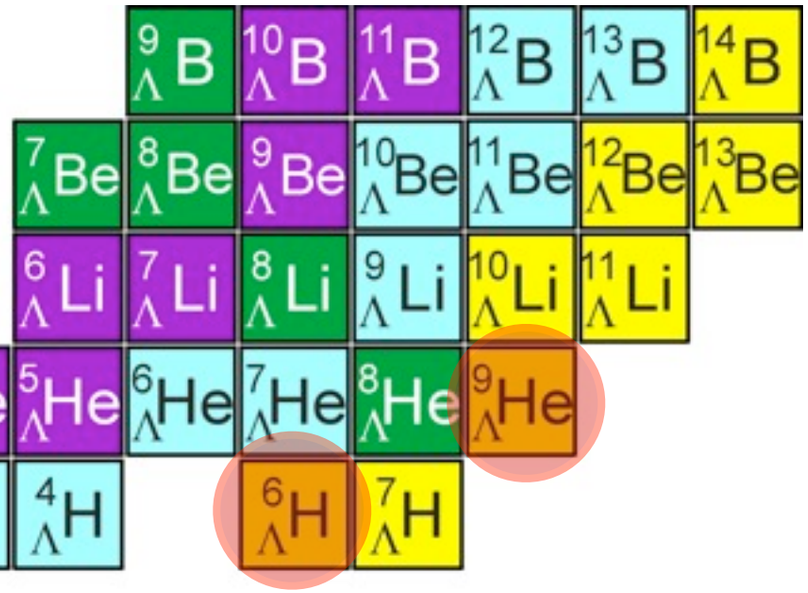
NCX

SCX

DCX

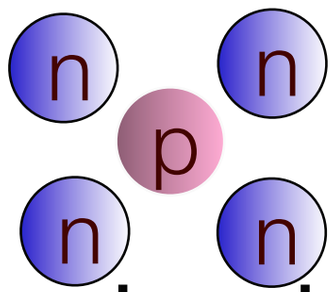
Λ

Λ-hypernuclei



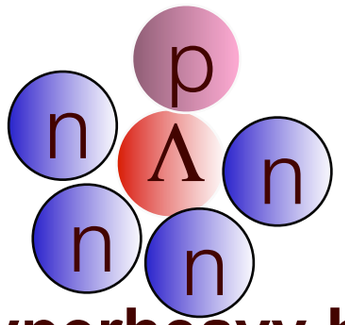
Akaishi:
Glue-like role of Λ
(B_Λ=4.4 MeV)
+
ΛNN coherent coupling (+1.4 MeV)

^{5}H



unbound

$^6_\Lambda$H



"Hyperheavy hydrogen": deeply bound

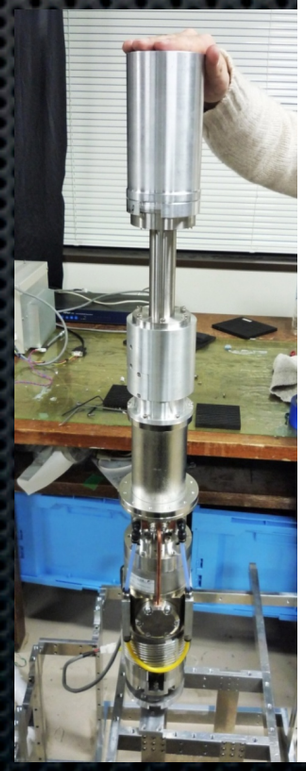
Gamma-ray Spectroscopy of Light Hypernuclei

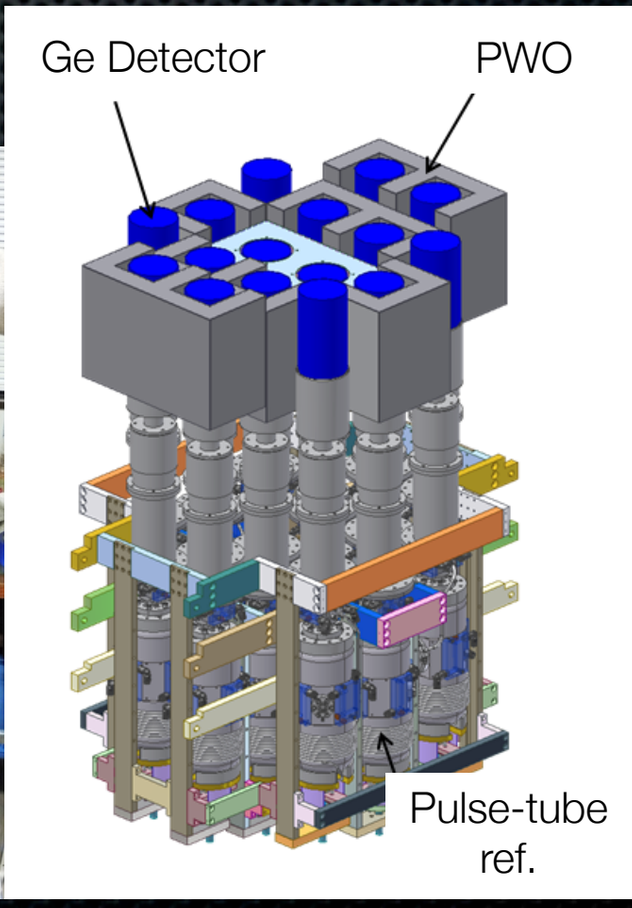
J-PARC E13
H. Tamura et al.

- ΛN interaction in sd-shell hypernuclei
  - $^{19}_{\Lambda}$F: easiest in sd-shell
- Charge Symmetry Breaking
  - $^{4}_{\Lambda}$He - $^{4}_{\Lambda}$H
- Spin-flip B(M1) measurement for g_{Λ} in nuclei
  - ^{7}Li(K^-,$\pi^-\gamma$)$^{7}_{\Lambda}$Li at 1.5 GeV/c: M1($3/2^+ \rightarrow 1/2^+$)

Ge x32; ε~6% at 1 MeV
→ γ-γ coincidence

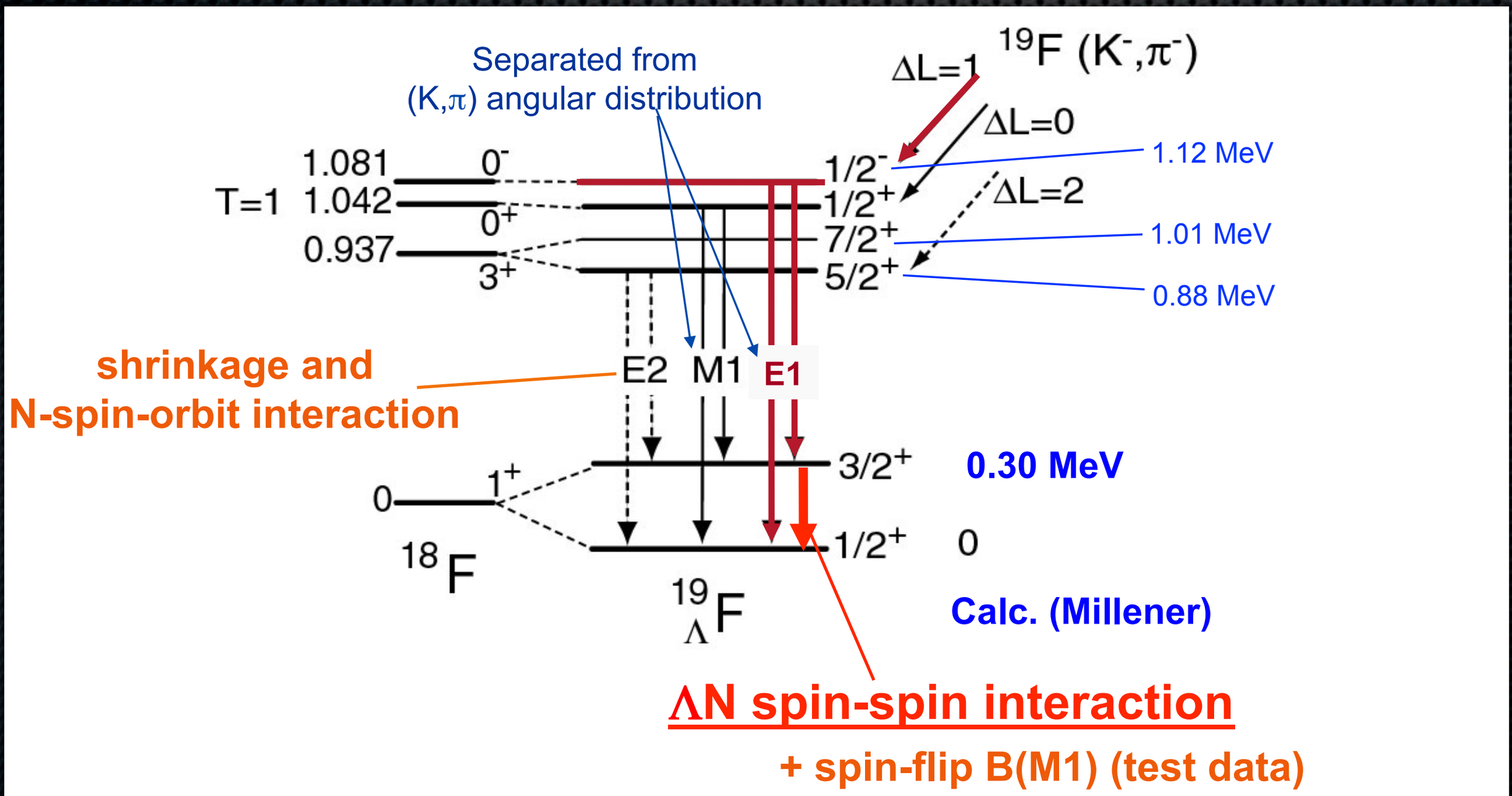
Hyperball-J





$^{19}_{\Lambda}$F Spectroscopy

- The first study on sd-shell hypernuclei

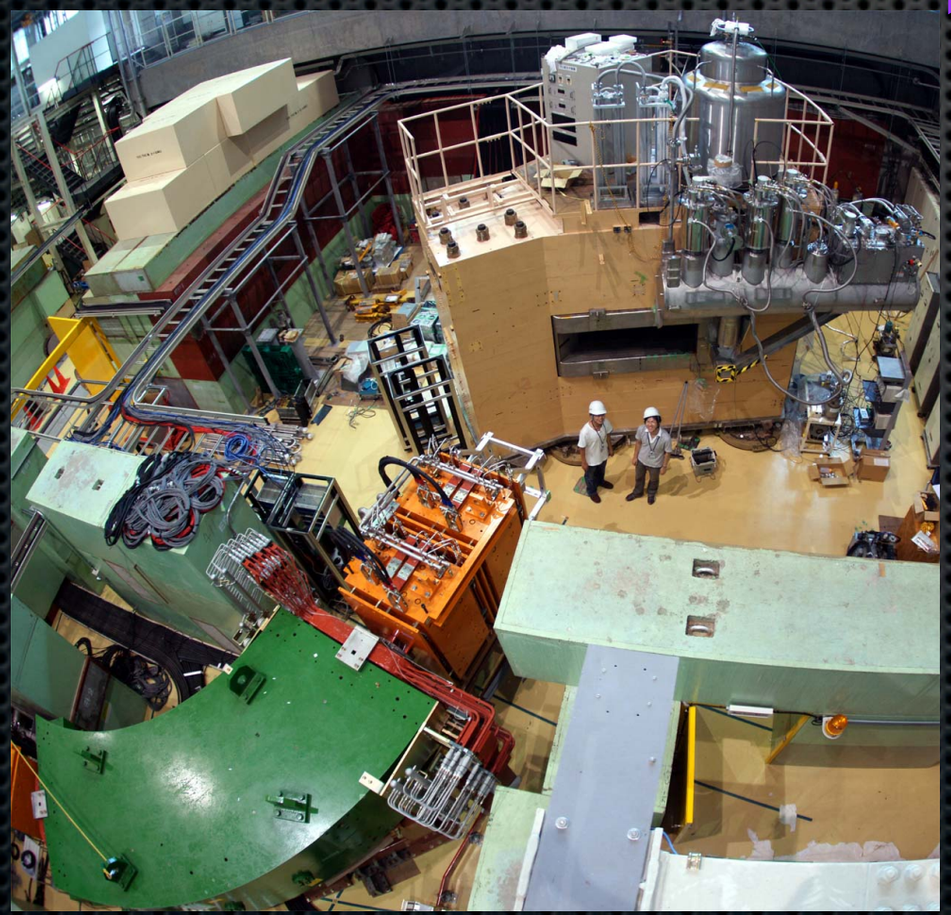


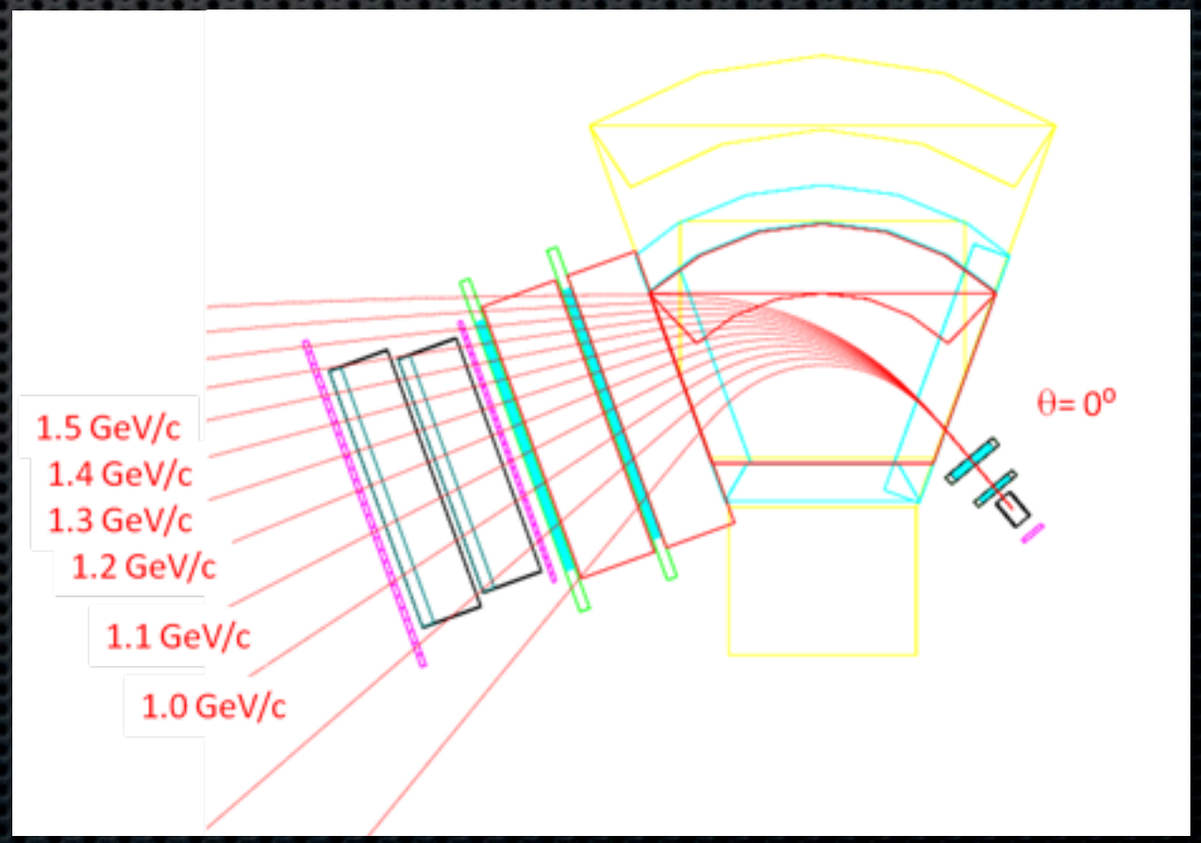
Spectroscopic Study of Ξ-Hypernucleus, $^{12}_{\Xi}$Be, via the ^{12}C(K^-,K^+) Reaction

J-PARC E05
T. Nagae et al.

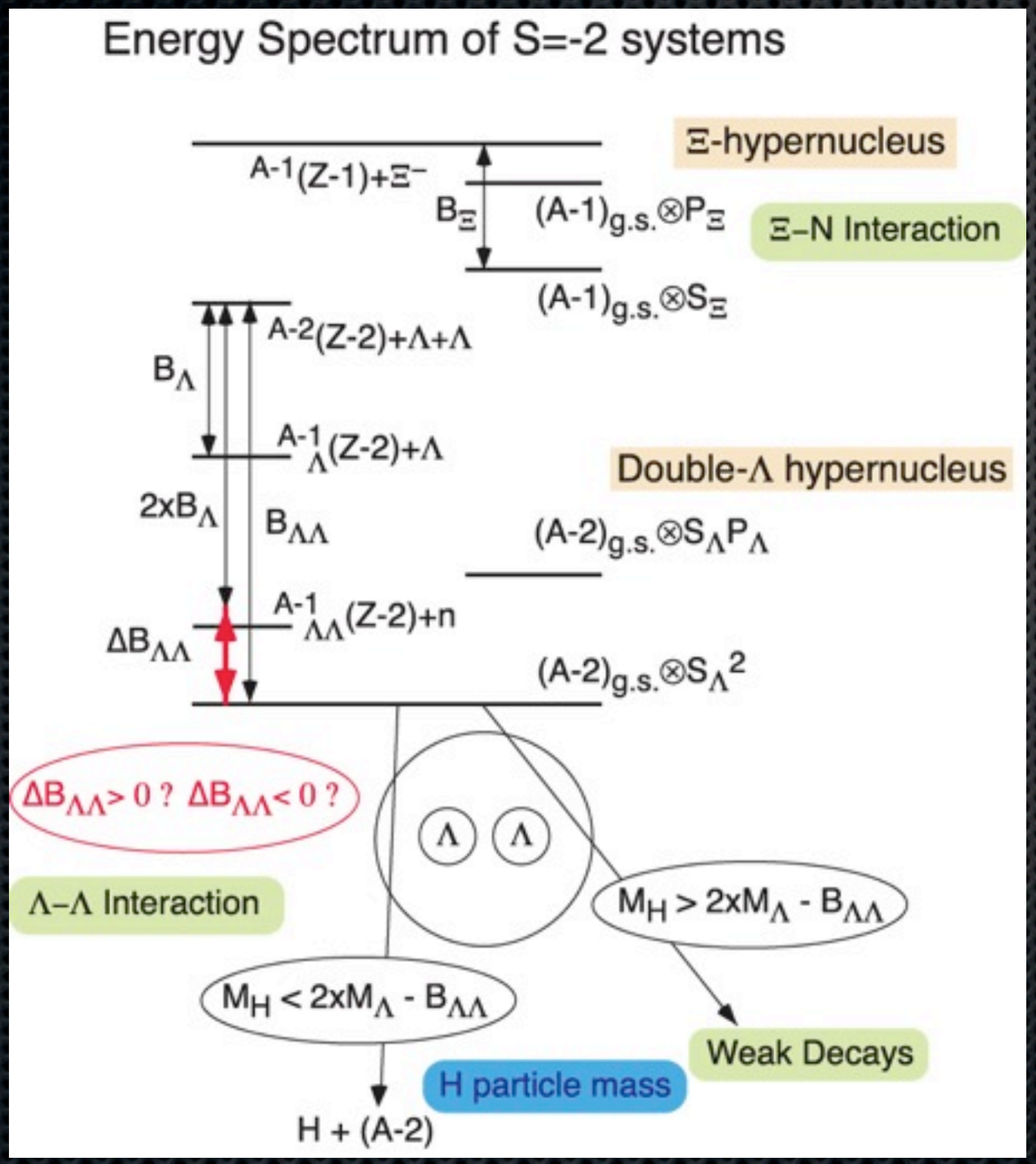
- Discovery of Ξ-hypernuclei
- Measurement of Ξ-nucleus potential depth and width

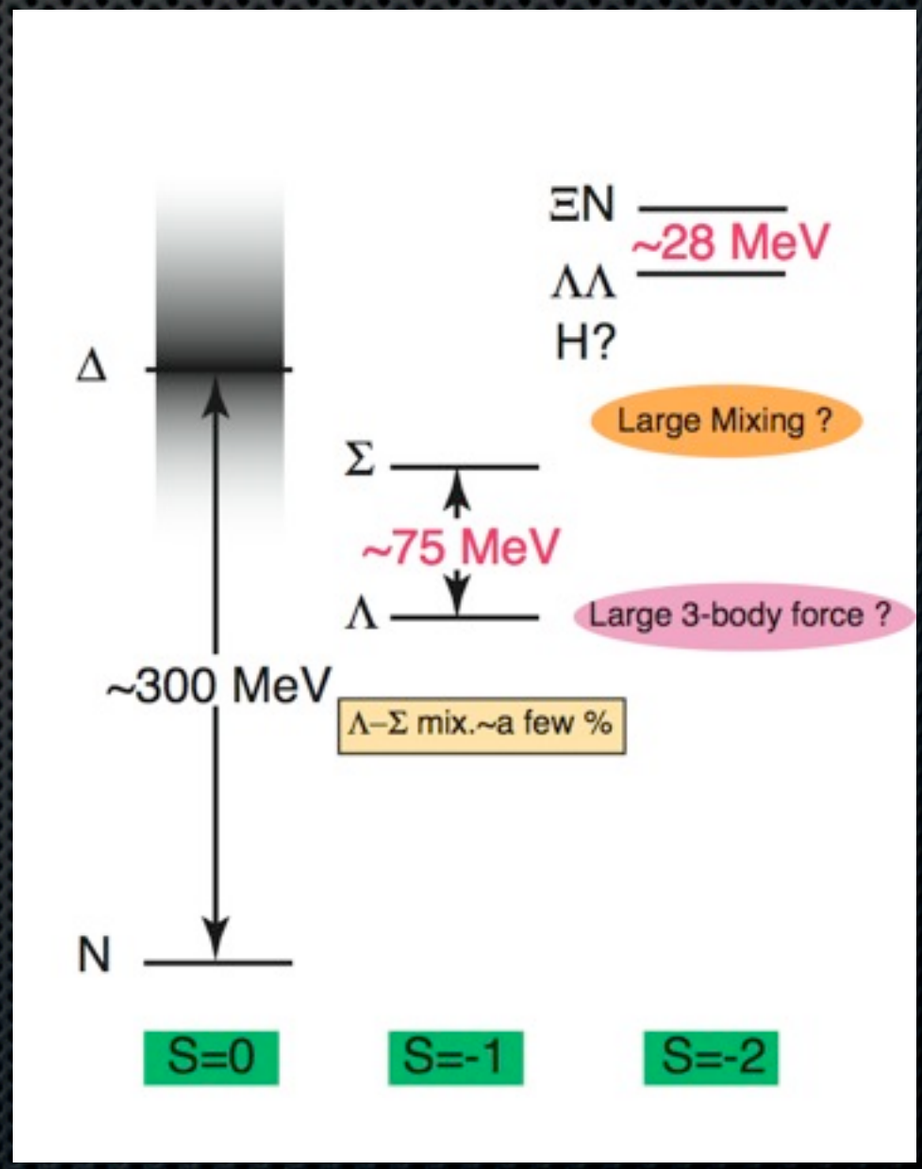
of $^{12}_{\Xi}$Be S=-1 → S=-2 (Multi-Strangeness System)





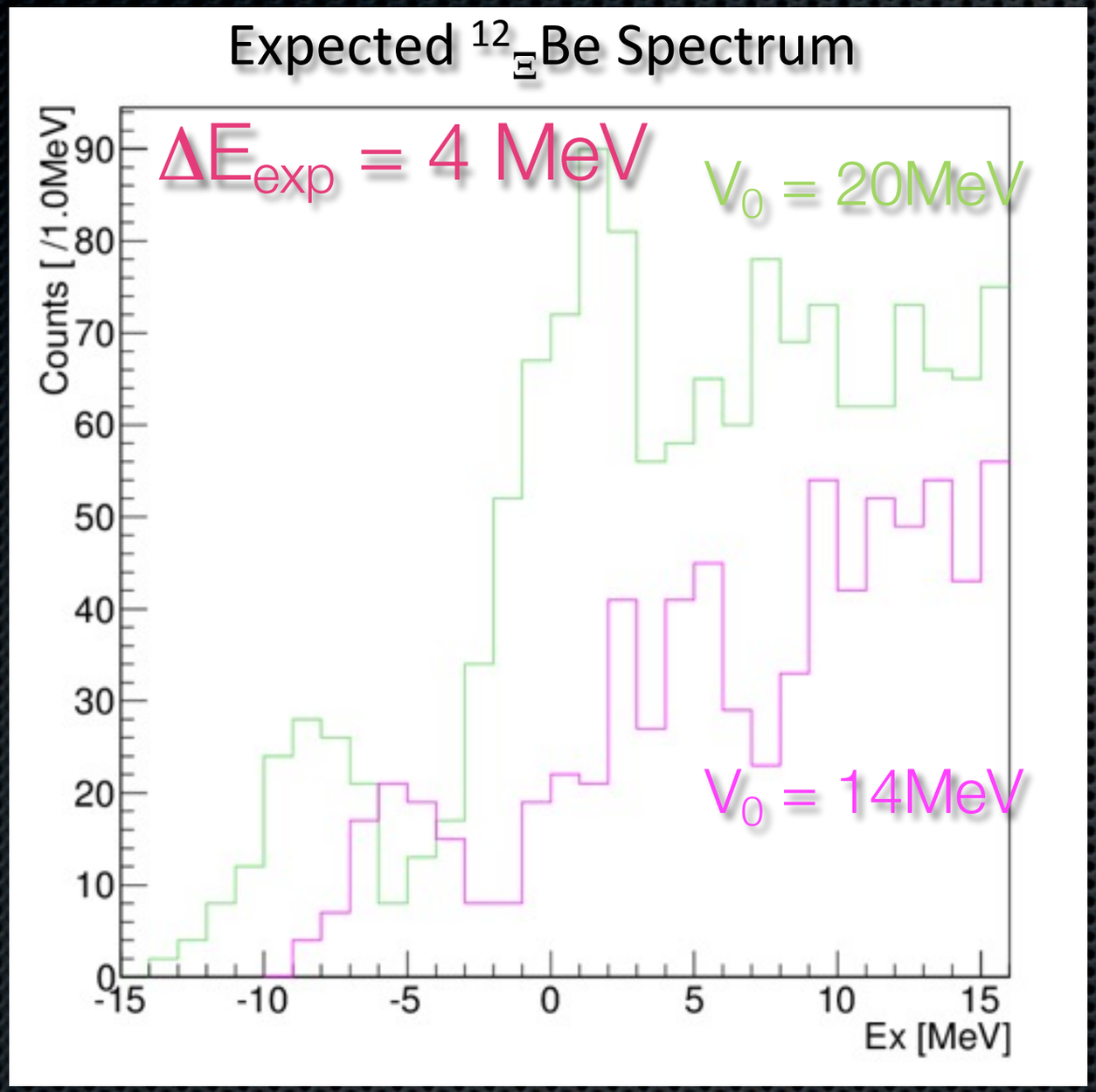
S=-2 World


Energy Spectrum of S=-2 systems
Ξ-hypernucleus
A-1(Z-1)+Ξ⁻
BΞ
(A-1)g.s.⊗PΞ
Ξ–N Interaction
(A-1)g.s.⊗SΞ
A-2(Z-2)+Λ+Λ
BΛ
A-1Λ(Z-2)+Λ
Double-Λ hypernucleus
2xBΛ
BΛΛ
(A-2)g.s.⊗SΛPΛ
A-1ΛΛ(Z-2)+n
ΔBΛΛ
(A-2)g.s.⊗SΛ2
ΔBΛΛ> 0 ? ΔBΛΛ< 0 ?
Λ Λ
Λ–Λ Interaction
MH > 2xMΛ - BΛΛ
MH < 2xMΛ - BΛΛ
Weak Decays
H particle mass
H + (A-2)


ΞN
~28 MeV
ΛΛ
H?
Large Mixing ?
Δ
Σ
~75 MeV
Λ
Large 3-body force ?
~300 MeV
Λ–Σ mix.~a few %
N
S=0
S=-1
S=-2

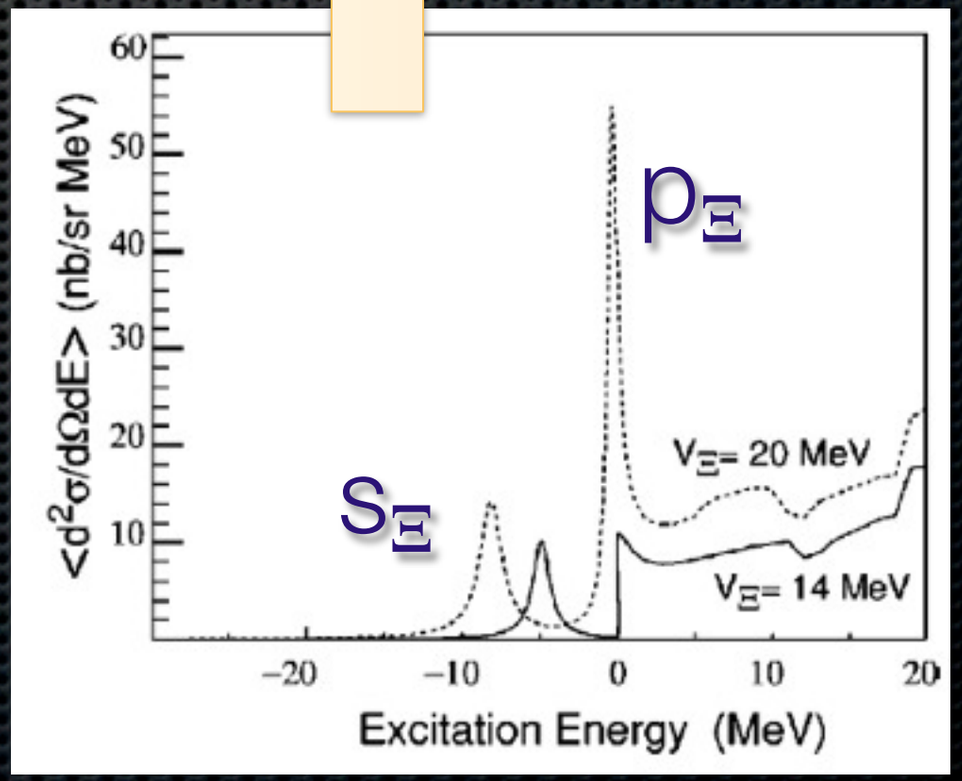
E05 (@30 kW) : Expected Spectrum

in case of W.S. potential



✓**can identify bound state.**

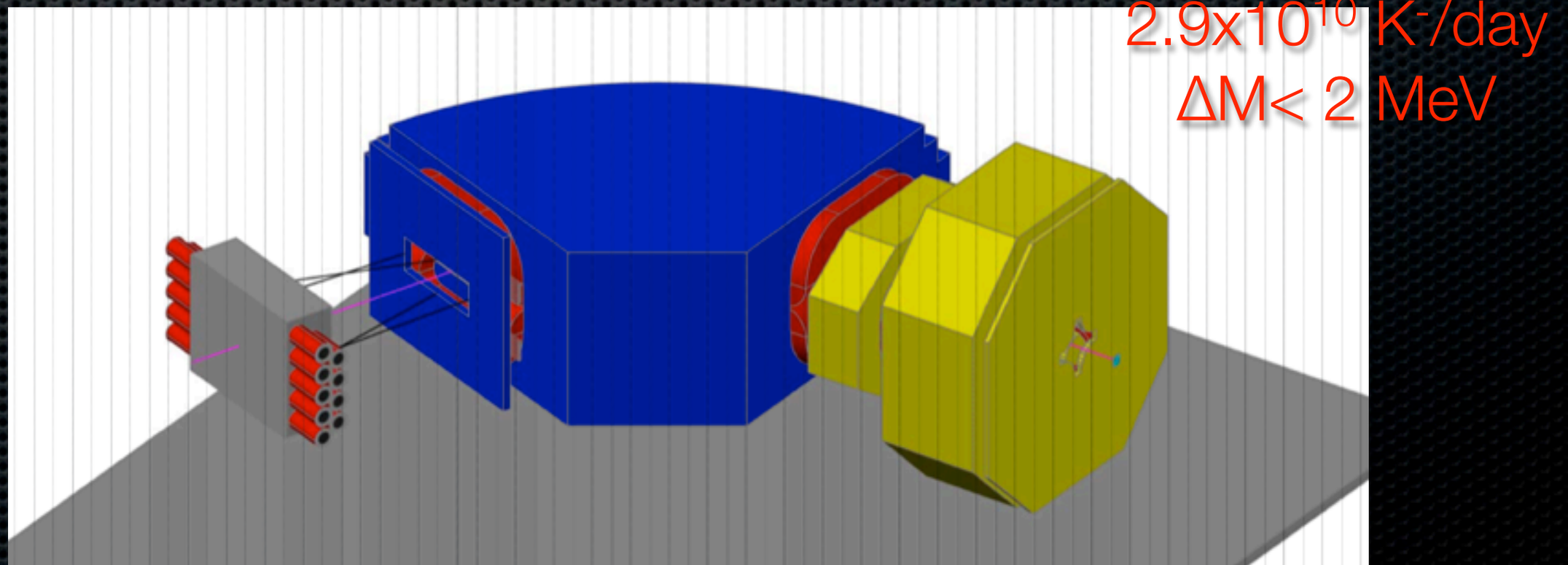
DWIA spectra from
P.Khaustov et al.,
PRC 61 (2000) 054603



simple peak structure

E05 Phase 2 with S-2S

- Grant-In-Aid for Specially promoted research: 2011 – 2015
- 60 msr, Δp/p=0.05% → ΔM=1.5 MeV
- Construction of S-2S(QQD): ~3 years
  - Installation in 2014
- Data taking in 2015 with > 150 kW !!



Summary

- J-PARC Beam recovery after the eqrthquake: Feb. 2012
- Day-1 Experiments; data-taking in progress
  - E19: penta-quark search; 2nd run completed.
  - E27: K-pp search in d(π^+,K^+); pilot run finished.
  - E10: Neutron-rich hypernuclei
  - E15: K^-pp search in ^{3}He(K^-,n) reaction
  - E13: Hypernuclear gamma-ray spectroscopy
  - E05: Ξ hypernuclei
  - etc.