Study of neutron-rich hypernuclei by the (π-,K+) reaction at J-PARC

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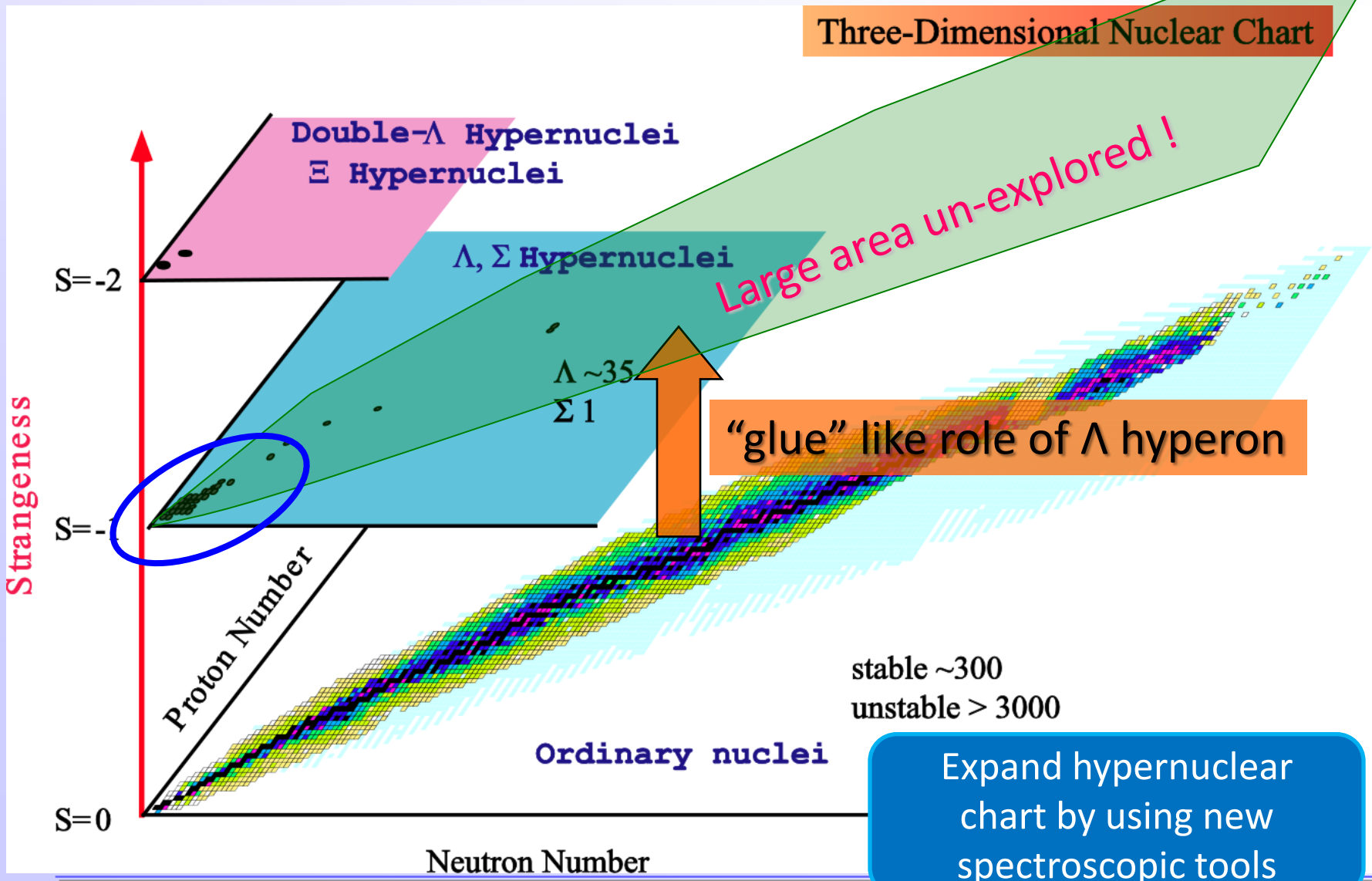
For J-PARC E10 Collaboration

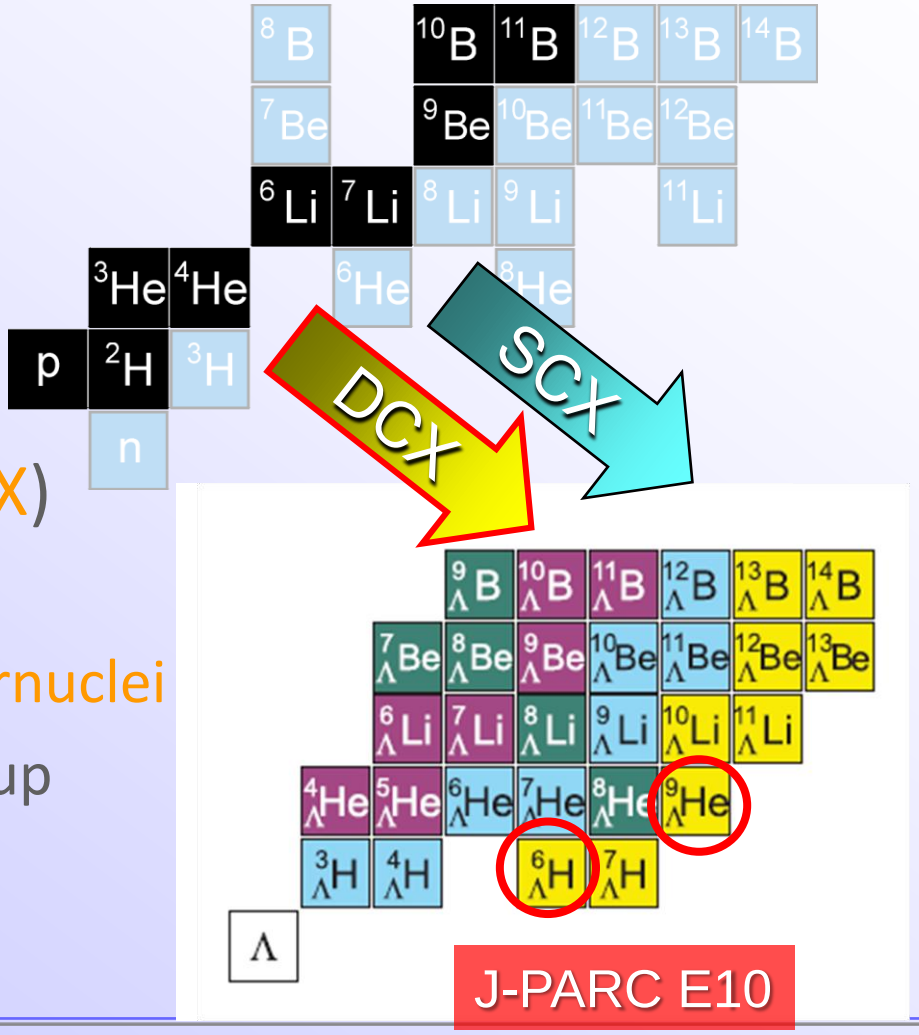
Nuclear Chart with Strangeness



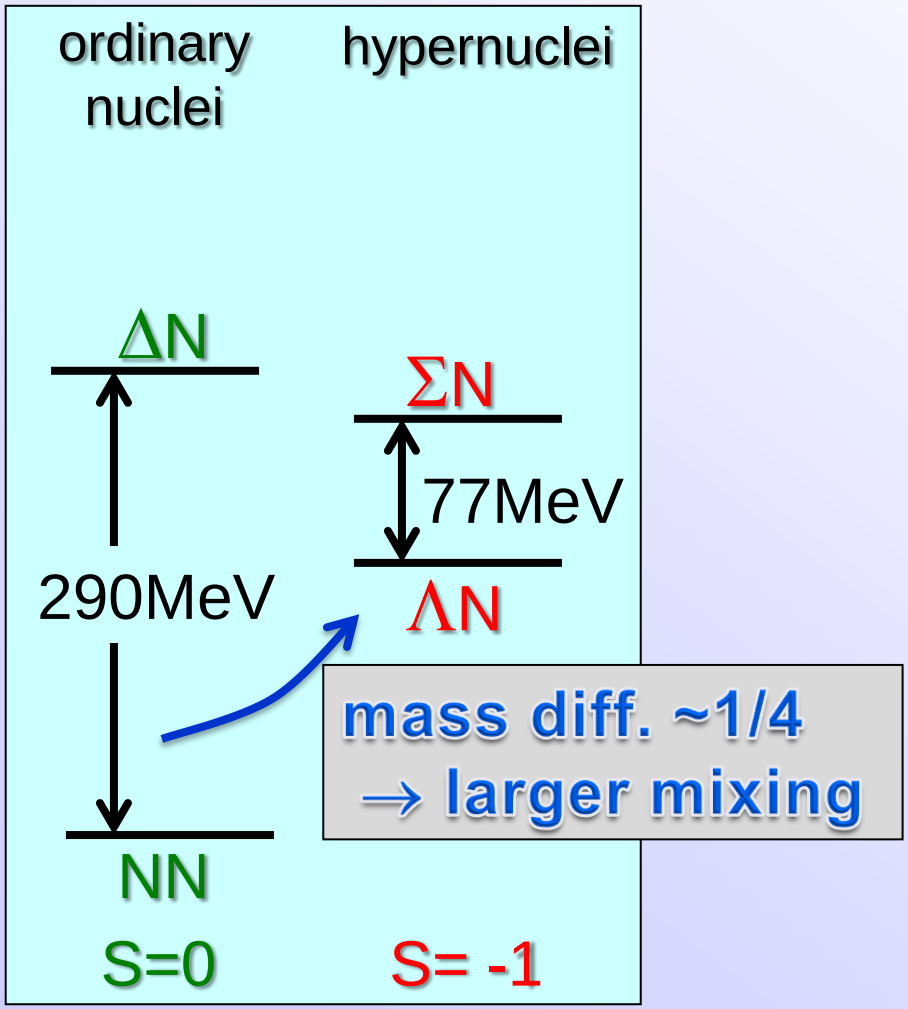
Expand hypernuclear chart by using new spectroscopic tools

Production Reactions

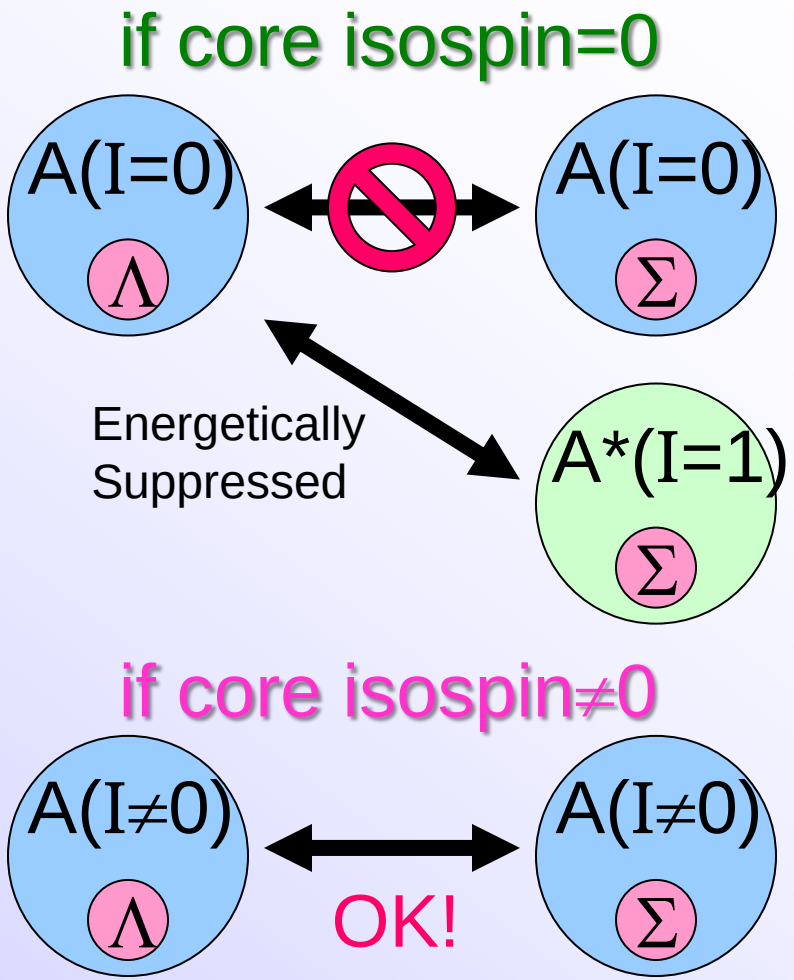
- Missing-mass spectroscopy
  - Non CX reactions (NCX)
    - $(\pi^+,K^+),(K^-,\pi^-)$
  - Single CX reactions (SCX)
    - $(e,e'K^+)$
      - thin target available
  - Double CX reactions (DCX)
    - (π^-,K^+), (K^-,π^+)
    - access neutron-rich hypernuclei
    - possible with existing setup
    - very low cross section !
      - roughly 1/1000 of NCX



ΛN-ΣN Mixing in Λ Hypernuclei



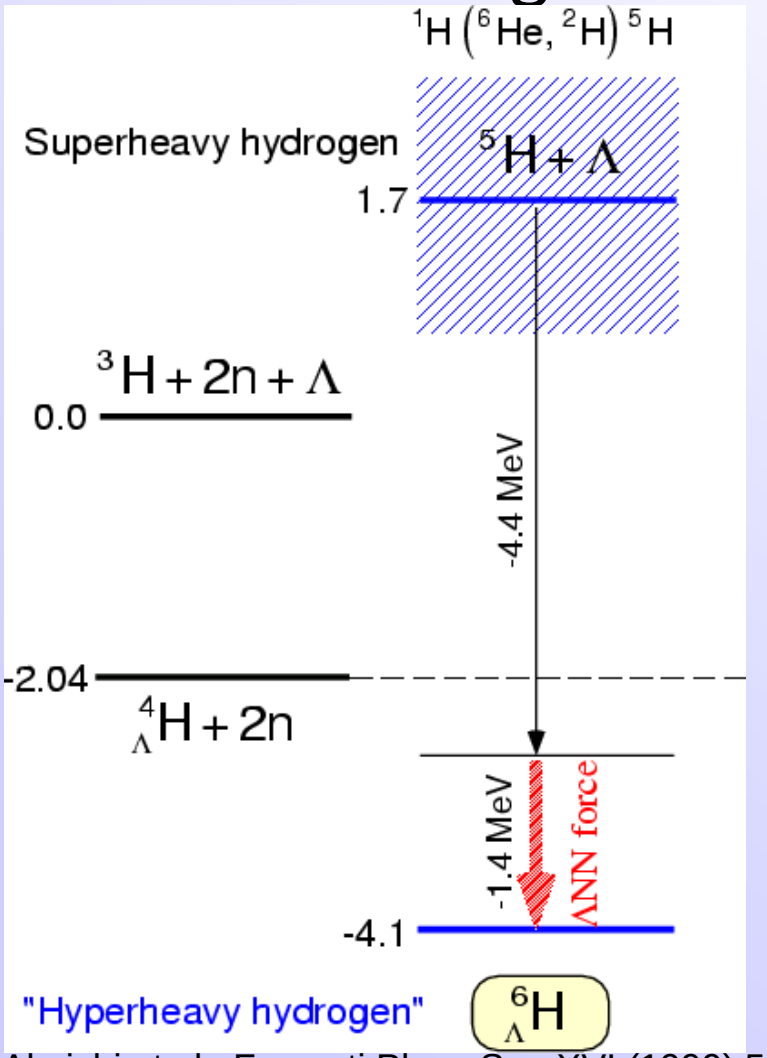
mass diff. ~1/4
→ larger mixing



Important neutron rich hypernuclei (large isospin)

Mixing in Neutron-rich Hypernuclei

- ΛN-ΣN mixing effect is important



Coherent ΛN-ΣN mixing
originally introduced to explain A=3-5 hypernuclei

Normal ΣN interaction

B_Λ ~ 4.4 MeV

Coherent ΛN-ΣN mixing effect

B_Λ ~ 4.4 + 1.4 MeV

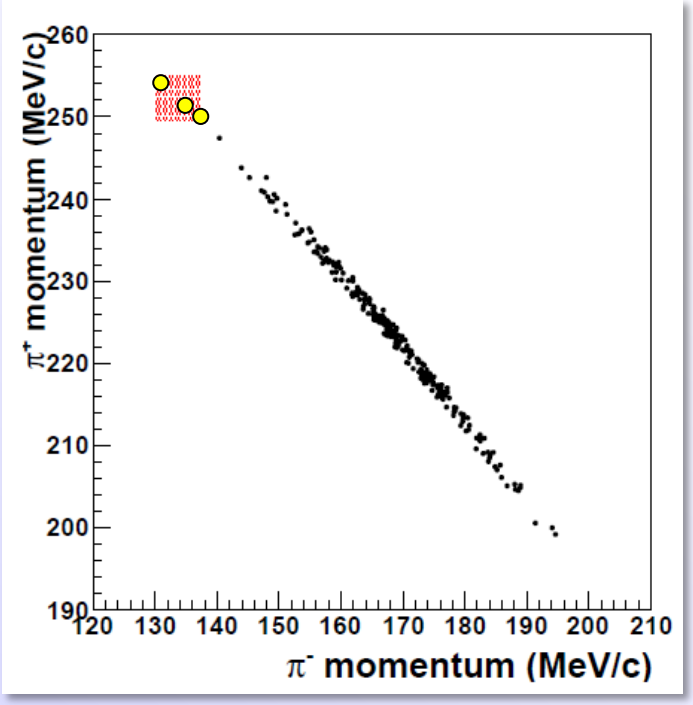
Precise measurement of B.E.

→ Estimation of mixing effect

Y. Akaishi et al. Frascati Phys. Ser. XVI (1999) 59

Past studies of neutron-rich Λ hypernuclei

- Experiments with (stopped-K^- ,π^+) reaction
  - KEK-PS in 1996 and FINUDA/DAFNE in 2006
    - Only upper-limits of branching ratio were obtained
  - New result from FINUDA/DAΦNE
    - ^{6}Li(stopped-K^-,π^+) reaction
      - saw also weak decay kinematics
    - 3 events of candidate of $^6_\Lambda$H
  - Interesting , need more events
- Experiment with (π^-,K^+) reaction
  - KEK-521 produced $^{10}_\Lambda$Li



M. Agnello et al., FINUDA Collaboration, Phys. Rev. Lett. 108 (2012) 042501

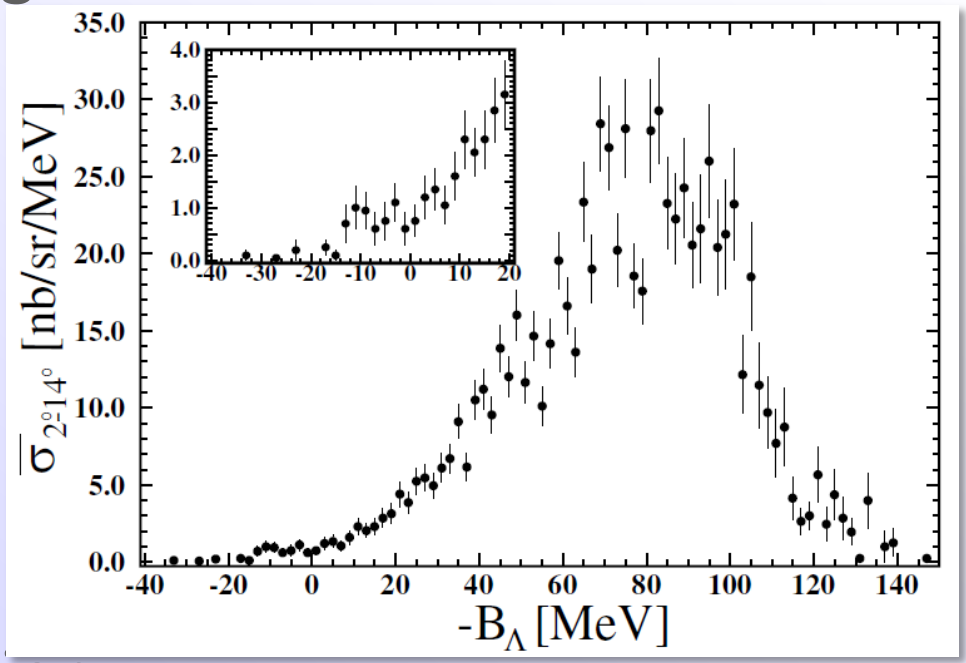
KEK-PS-E521 experiment

- Pilot experiment to produce n-rich Λ hypernuclei

  P.K.Saha et al. PRL **94** (2005) 052501.

  – DCX reaction with ^{10}B target

    • $^{10}B(\pi^-,K^+)^{10}_{\Lambda}Li$



- Experimental condition

  – Pion beam momentum

    • **1.2** GeV/c → **11.3** nb/sr

    • 1.05 GeV/c → 5.8 nb/sr

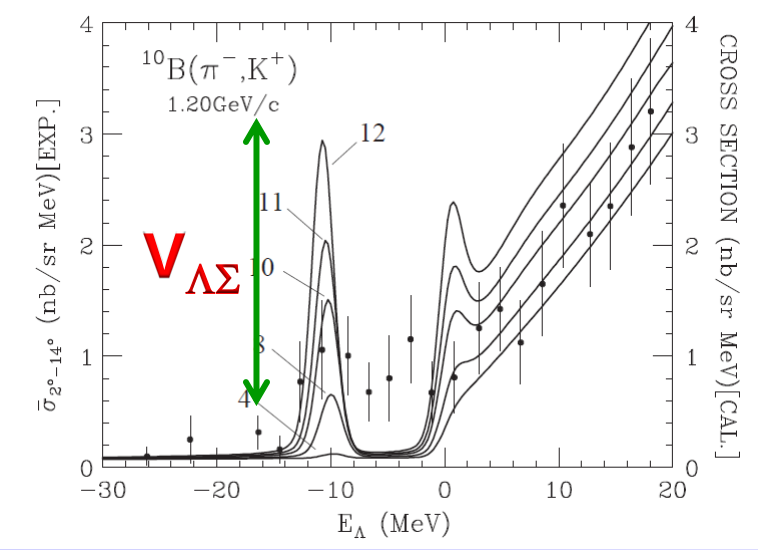
  – 47 events in Λ bound region

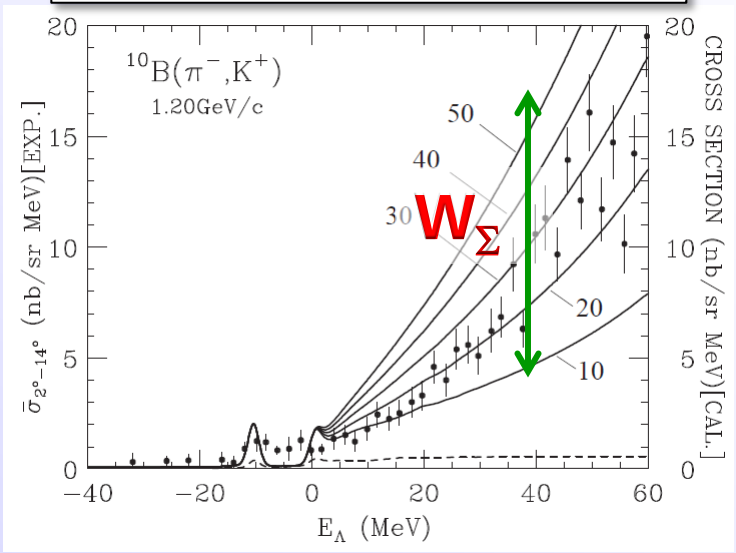
- Proposed experiment is base on this reaction

DCX reaction mechanism

- ΛN-ΣN coupled channel calculation for the DCX reaction by Harada et al.
- Spectrum is sensitive to mixing interaction $V_{\Lambda\Sigma}$ and Σ-N interaction W_Σ

T. Harada et al., Phys Rev **C79** (2009) 014603.





- Bound region → $V_{\Lambda\Sigma}$
- Continuum region → W_Σ

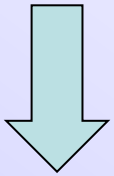
More yield is necessary to make detailed discussions

J-PARC E10 Experiment

Production of ${}^{6}_{\Lambda}$H and ${}^{9}_{\Lambda}$He hypernuclei

Aim at Experiment

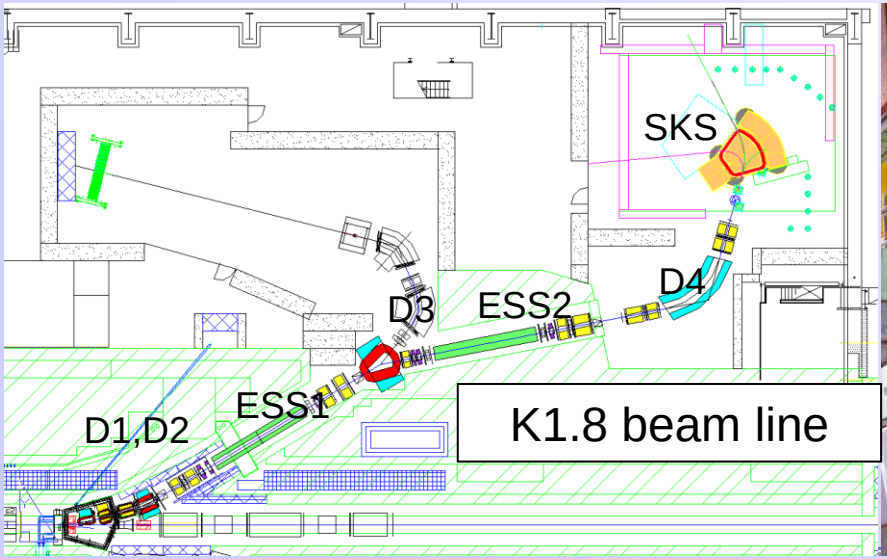
- Production of neutron-rich hypernuclei
  - higher statistics than previous experiments
- Information of Effect of ΛN-ΣN mixing in neutron-rich hypernuclei
  - precise measurement of binding energies

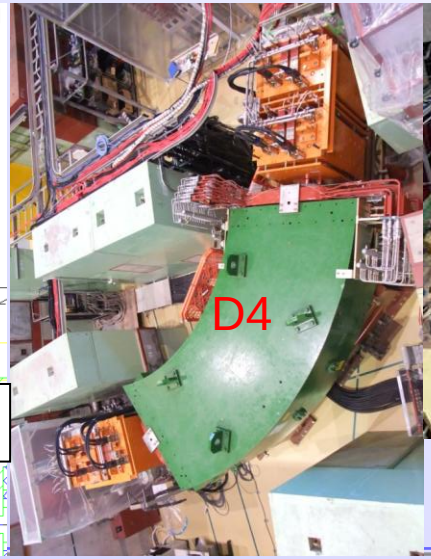


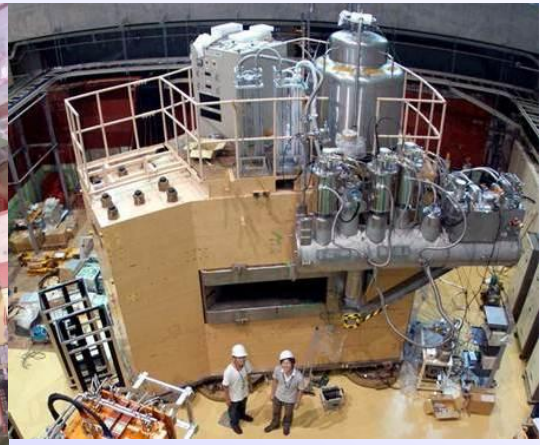
- Method
  - Missing-mass spectroscopy by (π^-, K^+) reaction
    - method has been established at KEK-PS E521

Experimental Setup

- K1.8 beam line
  - 1.2 GeV/c π^- beams
  - Good momentum resolution: $\Delta p/p \sim 3.3 \times 10^{-4}$
- Superconducting Kaon Spectrometer(SKS)
  - Good momentum resolution: $\Delta p/p \sim 1.0 \times 10^{-3}$
  - Large acceptance : $\Delta\Omega \sim 100$mSr







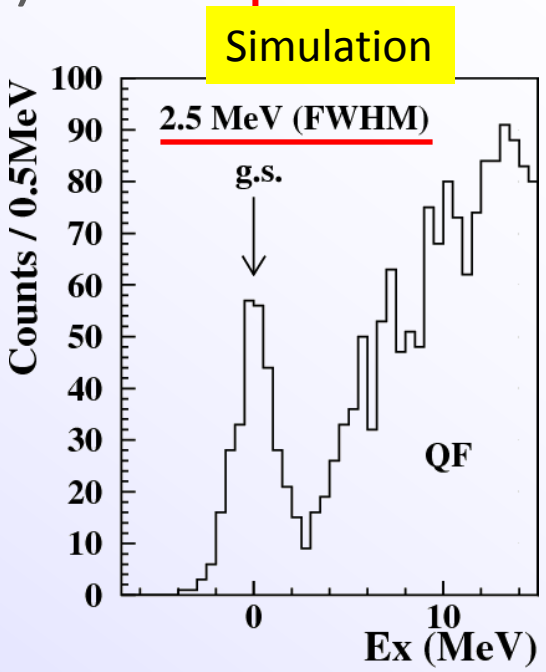
SKS

Yield estimation in E10 proposal

- $^{6}_{\Lambda}$H yields estimated under the run conditions
  - 3 weeks with 10M/spill (6 s acc. cycle) → 3 T pions

Parameters	Values
Pion beam momentum	1.2 GeV/c
Pion beam intensity	10M/spill
Total number of pions (6 s acc. cycle)	3T pions
Target thickness	/cm^2
DCX cross section (assumed)	10 nb/sr
SKS acceptance	100 msr
Spectrometer efficiency (due to K decay)	0.5
Analysis efficiency	0.5
Estimated $^{6}_{\Lambda}$H yield	265

Very Challenging to operate



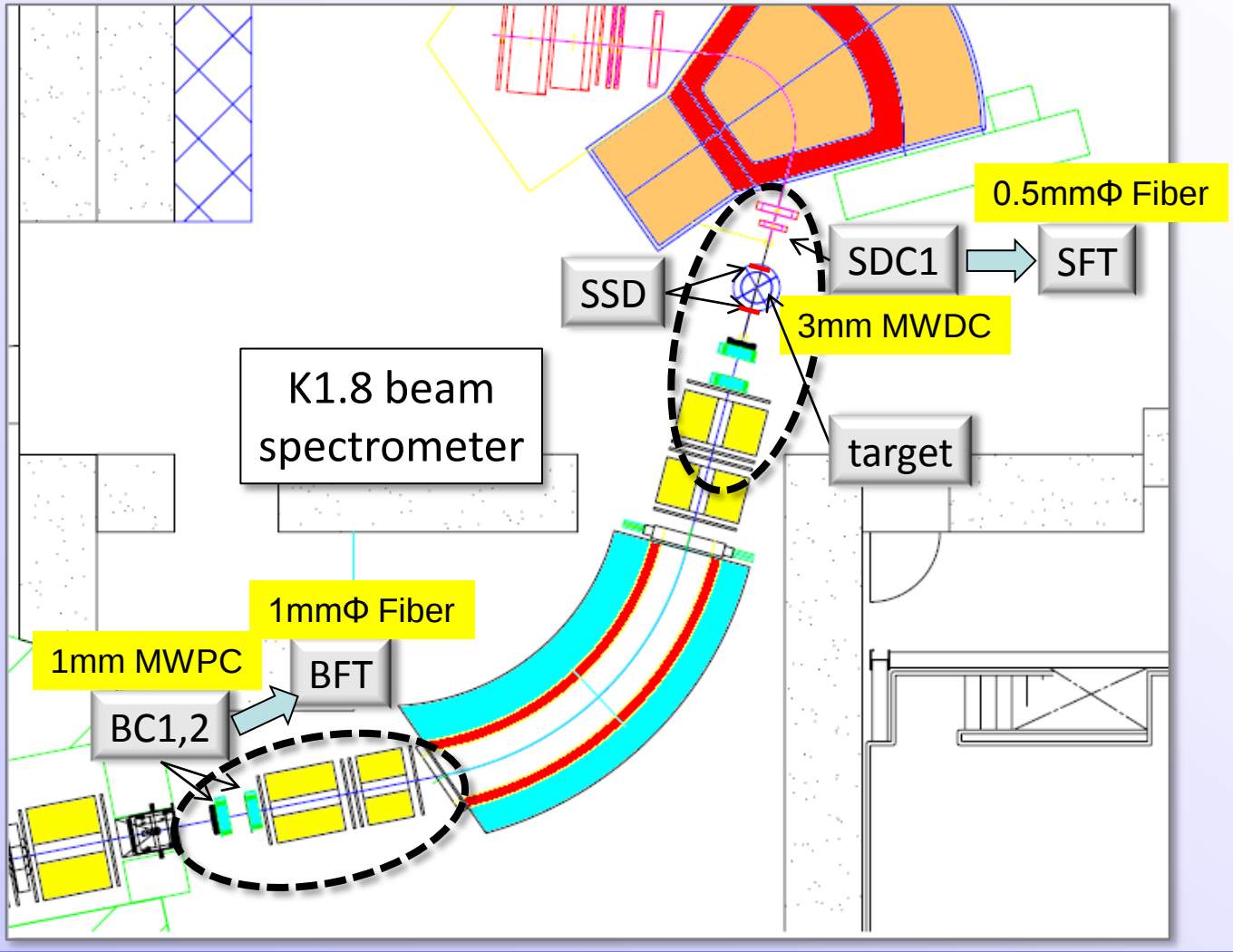
  - Yields is roughly 6 times larger than previous KEK E521

Challenge for High rate beam operation

Upgrade of tracking detector

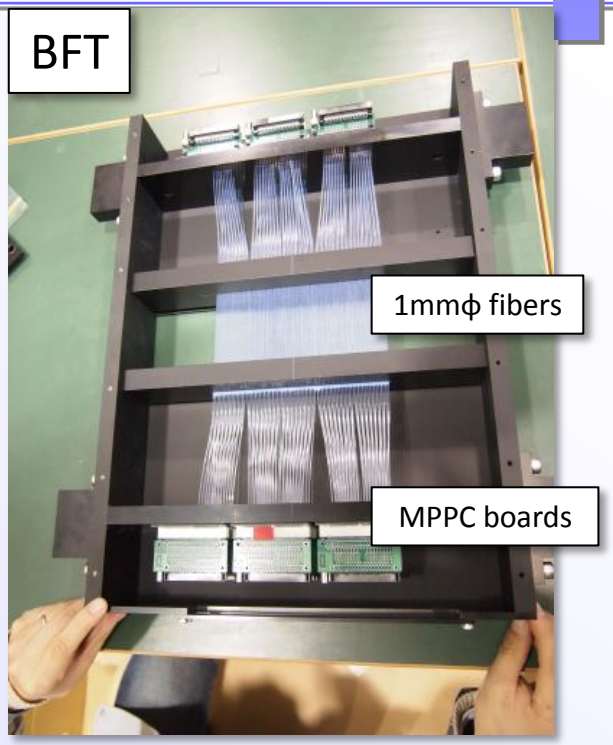
Upgrades for higher beam intensity

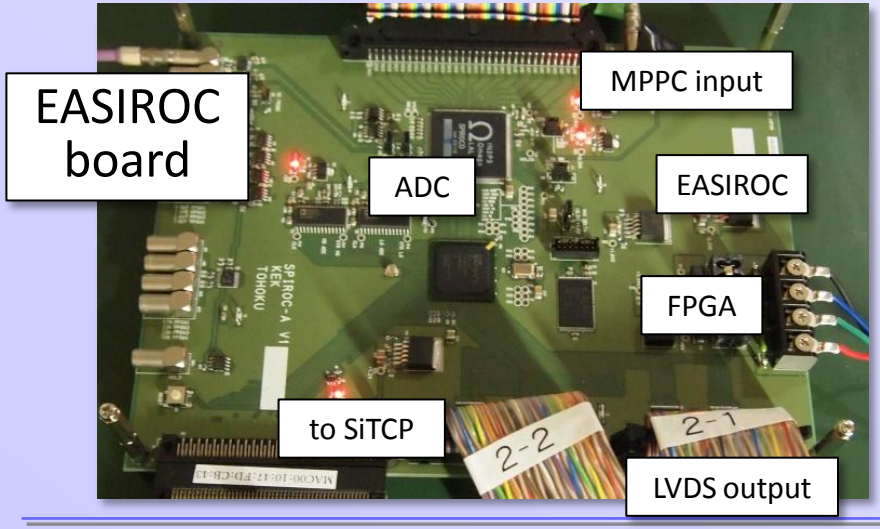
- Detectors in K1.8 beam spectrometer

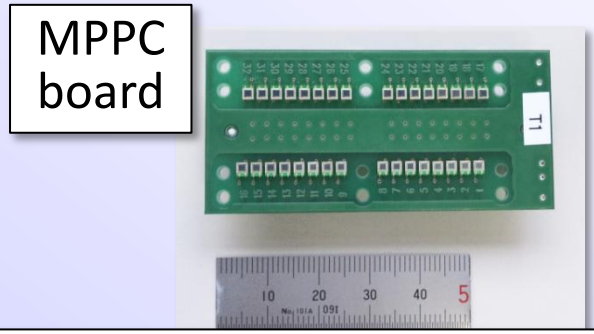


BFT design

- BFT (beam fiber tracker) design
  - 1mm ϕ scintillating fibers
    - 2 layers staggered by 0.5mm
    - 160 × 2 = 320 fibers
  - Read out by MPPC+EASIROC
    - Flexible and easy to handle



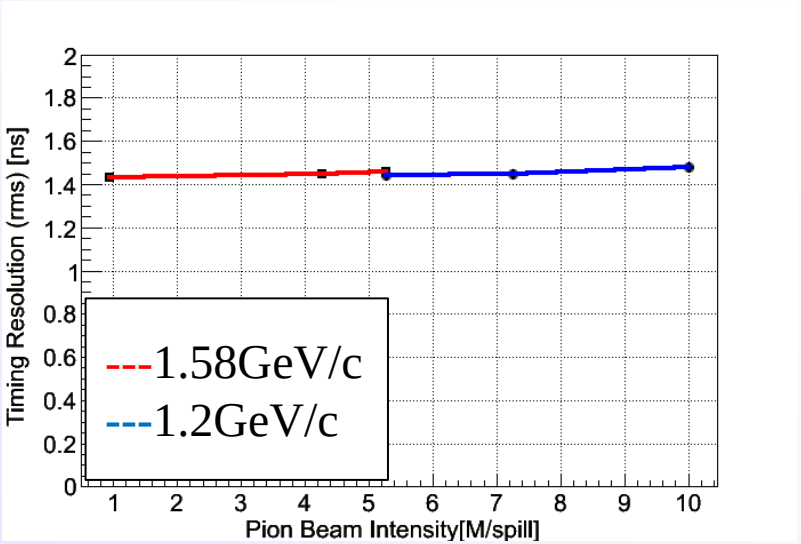


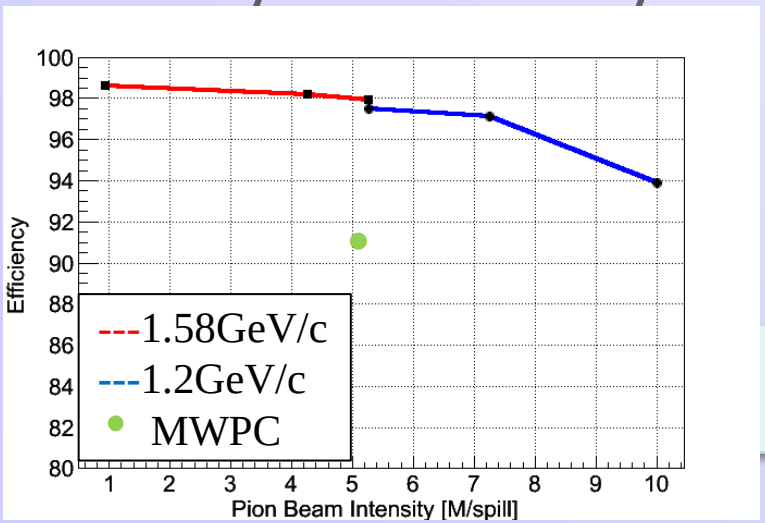


Developed by K. Miwa , R. Honda (Tohoku Univ.)
S. Hasegawa(JAEA)

BFT high-rate beam study in June

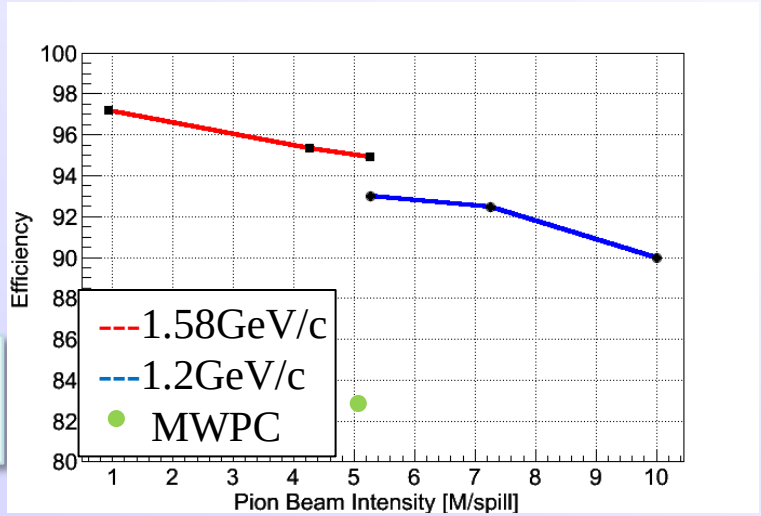
- Timing resolution
  - **1.5ns (rms)** w/o corrections
  - Better than current MWPCs
    - MWPC encoder: 10 ns
    - Drift time spread: 30 ns
- Analysis efficiency





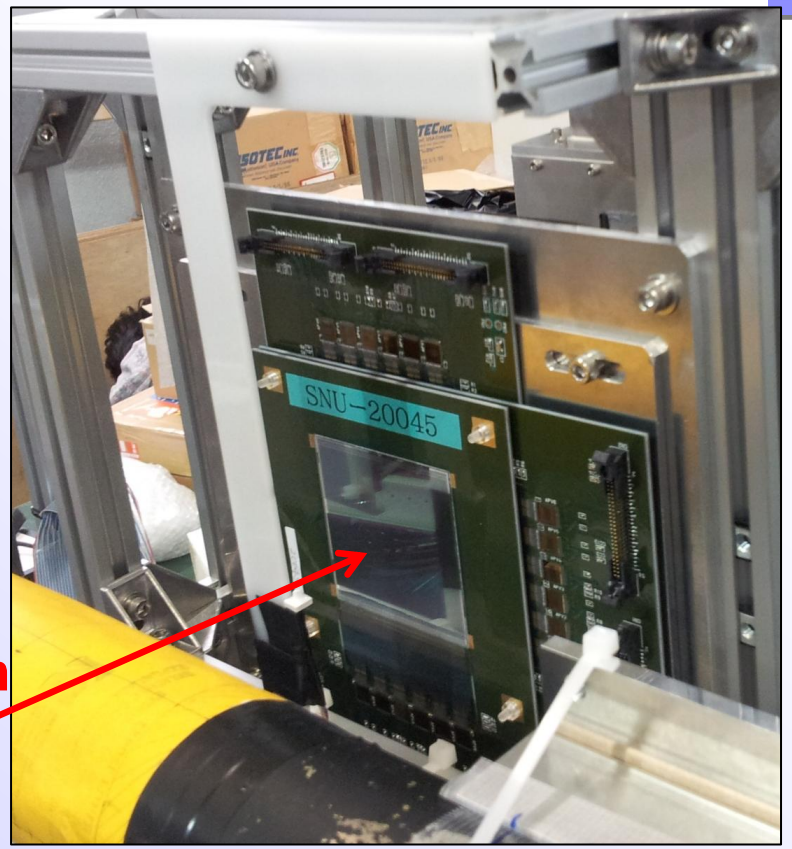
Request Single Hit

Efficiency ≥ 90%



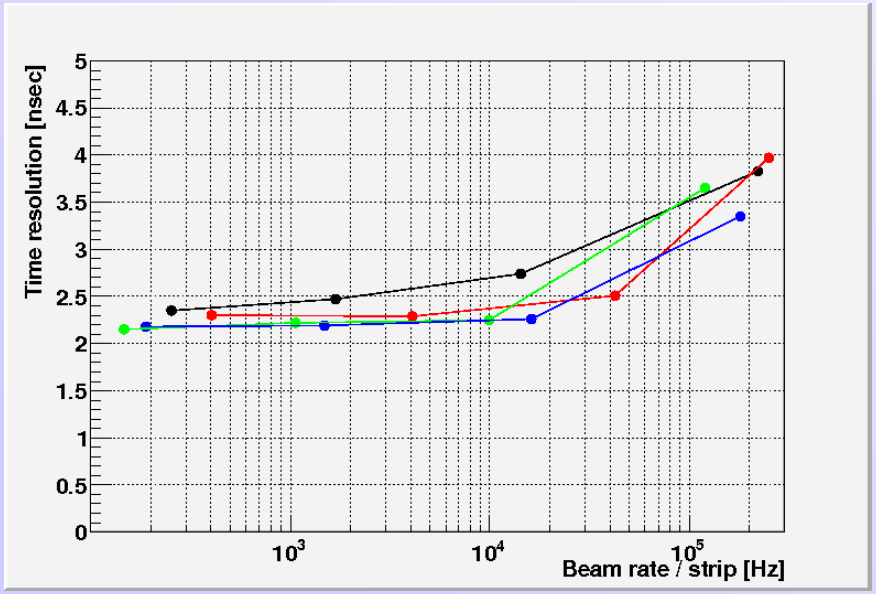
SSD design

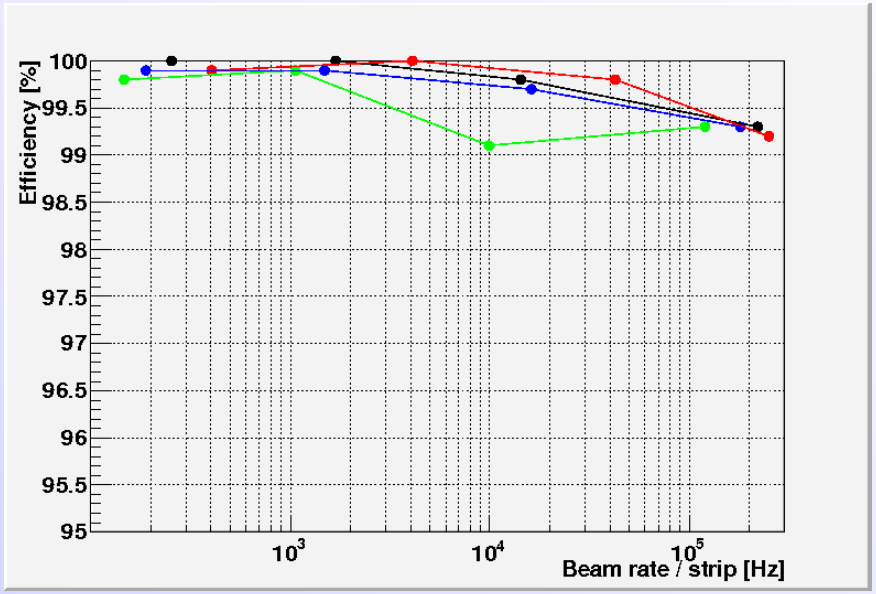
- vertex SSD design
  - **80μm** pitch
  - 6cm×6cm×300mm
  - APV 25 chip
  - Serial Data transfer
  - Accept **10^5** Hz/strip
    - Typical K1.8 beam 5×10^5 hits/mm/(10M beam)
    - 2 s beam spill, duty factor 25% → work at 10M/spill beam



SSD high-rate beam study

- Performance Study at J-PARC and RCNP
  - Timing resolution: about **4ns**
  - S/N ratio for MIP: about 20
  - Zero-suppression: data size → 2%
  - Efficiency : more than **99%**





Summary

- E10 aims to produce neutron-rich Λ hypernuclei, ${}^{6}_{\Lambda}\mathrm{H}$ and ${}^{9}_{\Lambda}\mathrm{He}$, close to the neutron drip-line.
- We may obtain information of Λ-N interaction in the extreme condition.
- We studied new detector(Fiber Tracker and Silicon Strip Detecor) under high rate beam. We got result of enough efficiency for high rate.