High resolution spectroscopy of Ξ hypernuclei with Active Fiber Target

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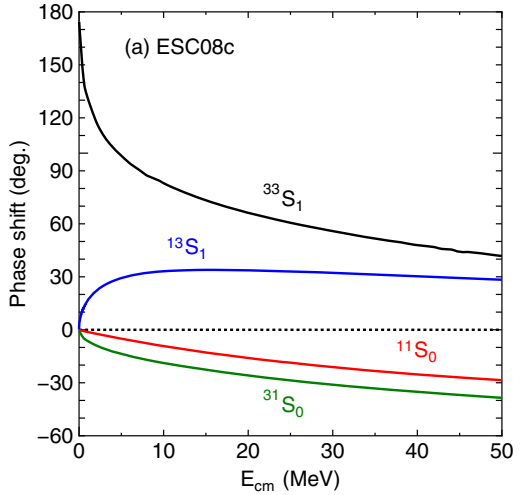
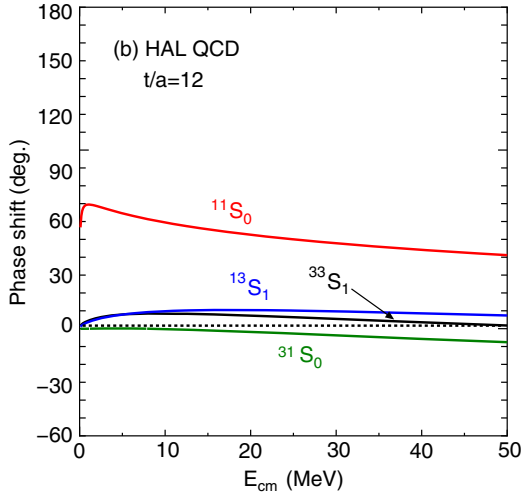
for the J-PARC E70 collaboration

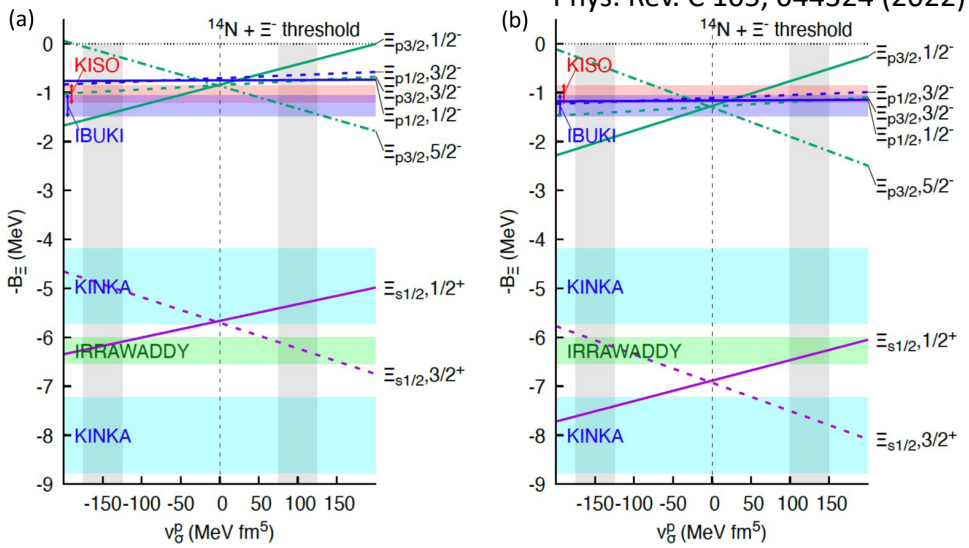
ΞN interaction

Hiyama-san's talk on Mon.
PhysRevLett.124.092501 (2020)

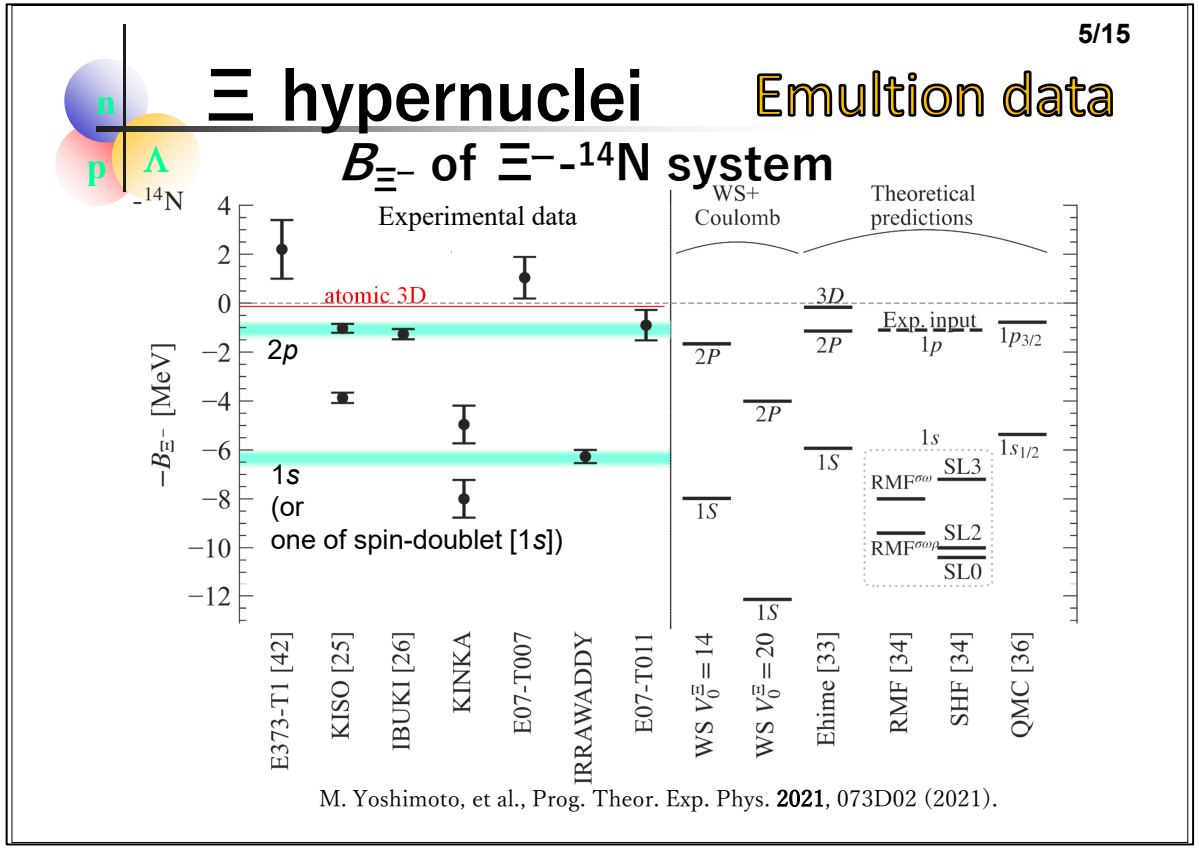




Tanimura-san's talk on Mon.
Phys. Rev. C 105, 044324 (2022)



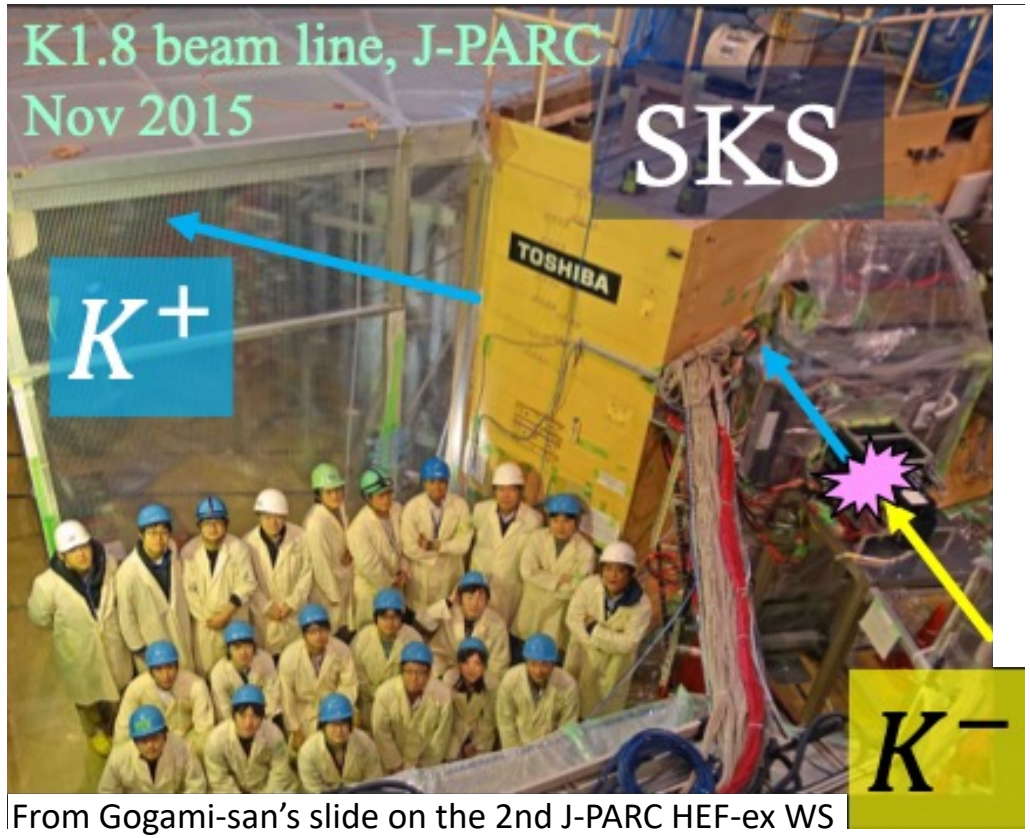
Nakazawa-san's talk on Mon.



Experimental data is still scarce and
ΞN scattering experiment is little difficult …
Spectroscopy of Ξ hypernuclei is important.

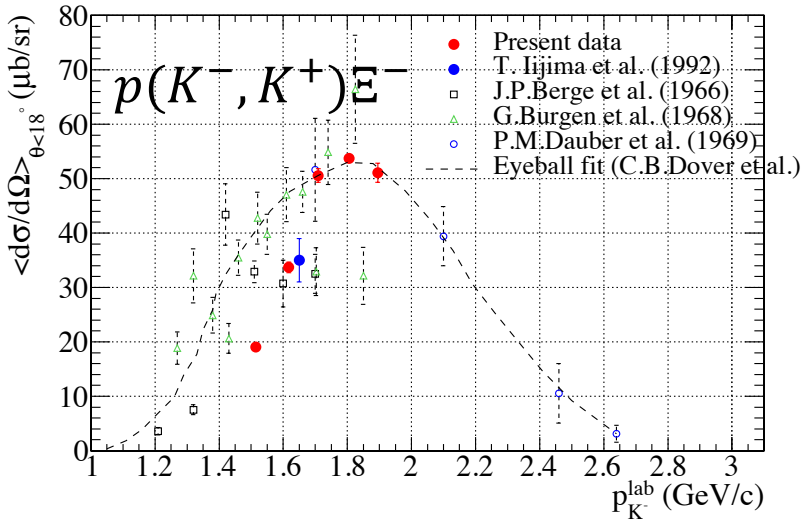
J-PARC E05

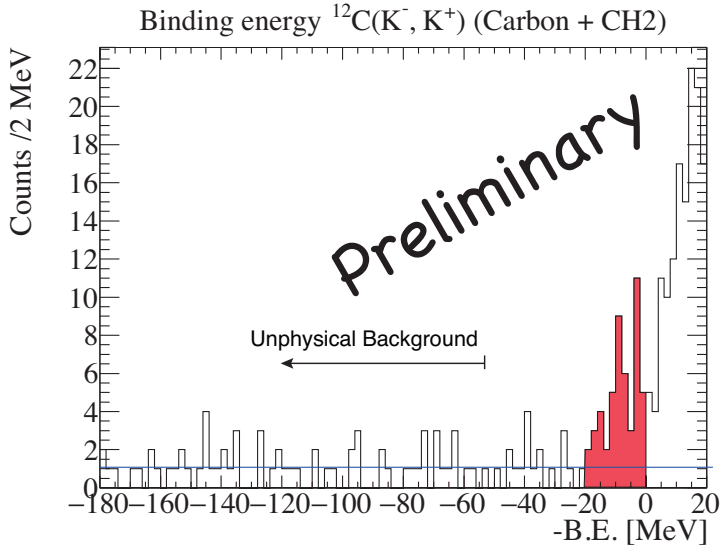
One of the Day-1 experiment at the J-PARC Hadron Hall



From Gogami-san's slide on the 2nd J-PARC HEF-ex WS

AIP Conference Prceedings 2130, 020015 (2019)

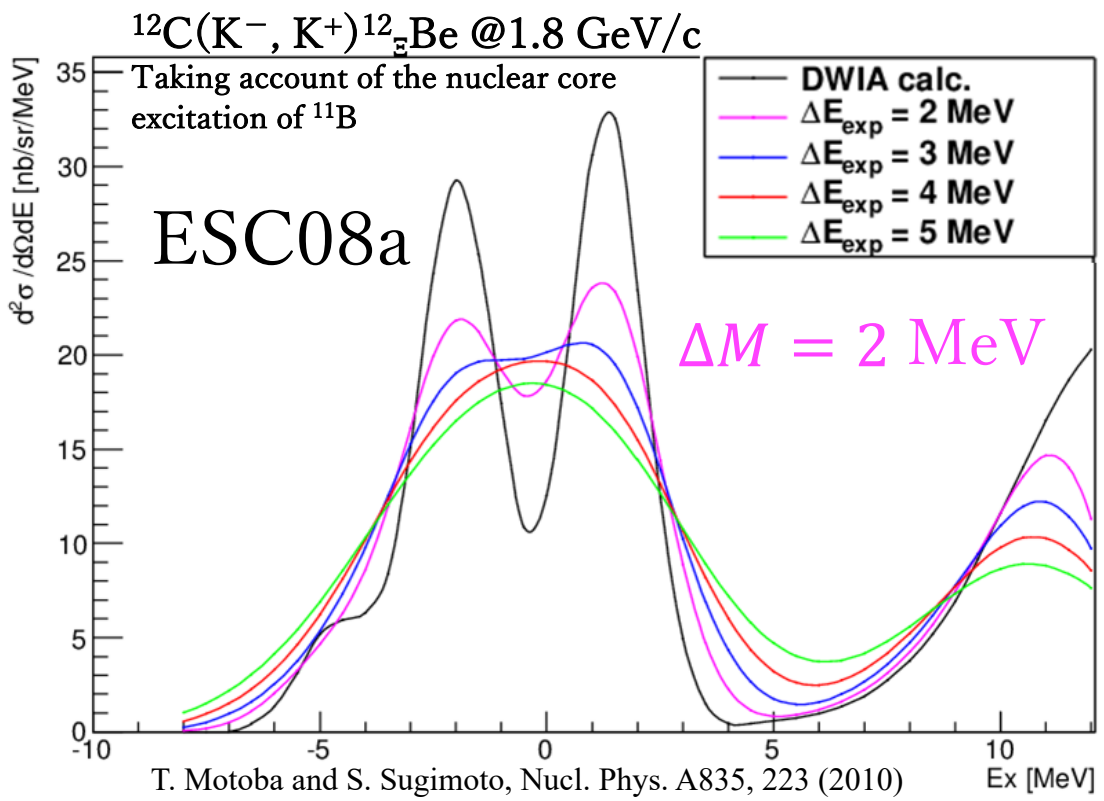


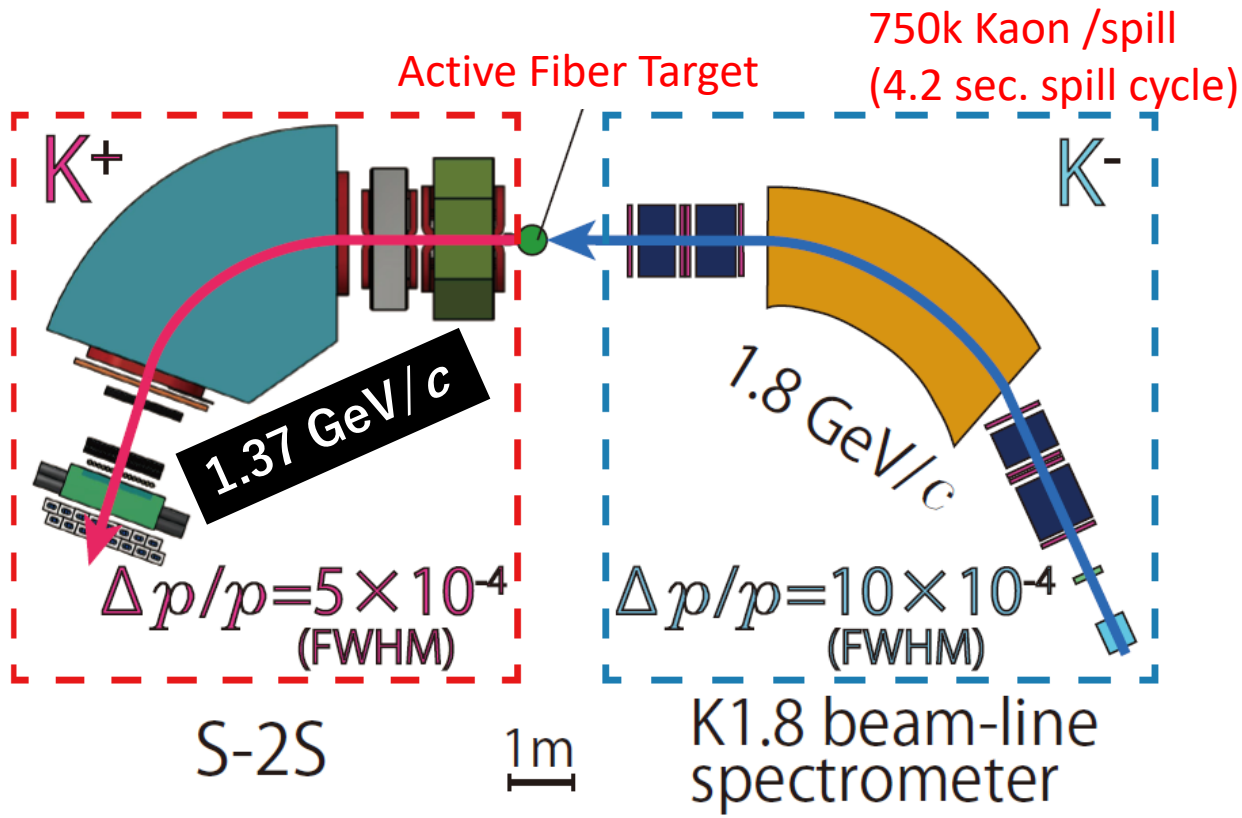


Resolution improved (= 6 MeV_{FWHM}), but not enough

J-PARC E70

High resolution missing-mass spectroscopy via the (K^-, K^+) reaction
→ Measurement of the binding energy and width of Ξ hypernucleus





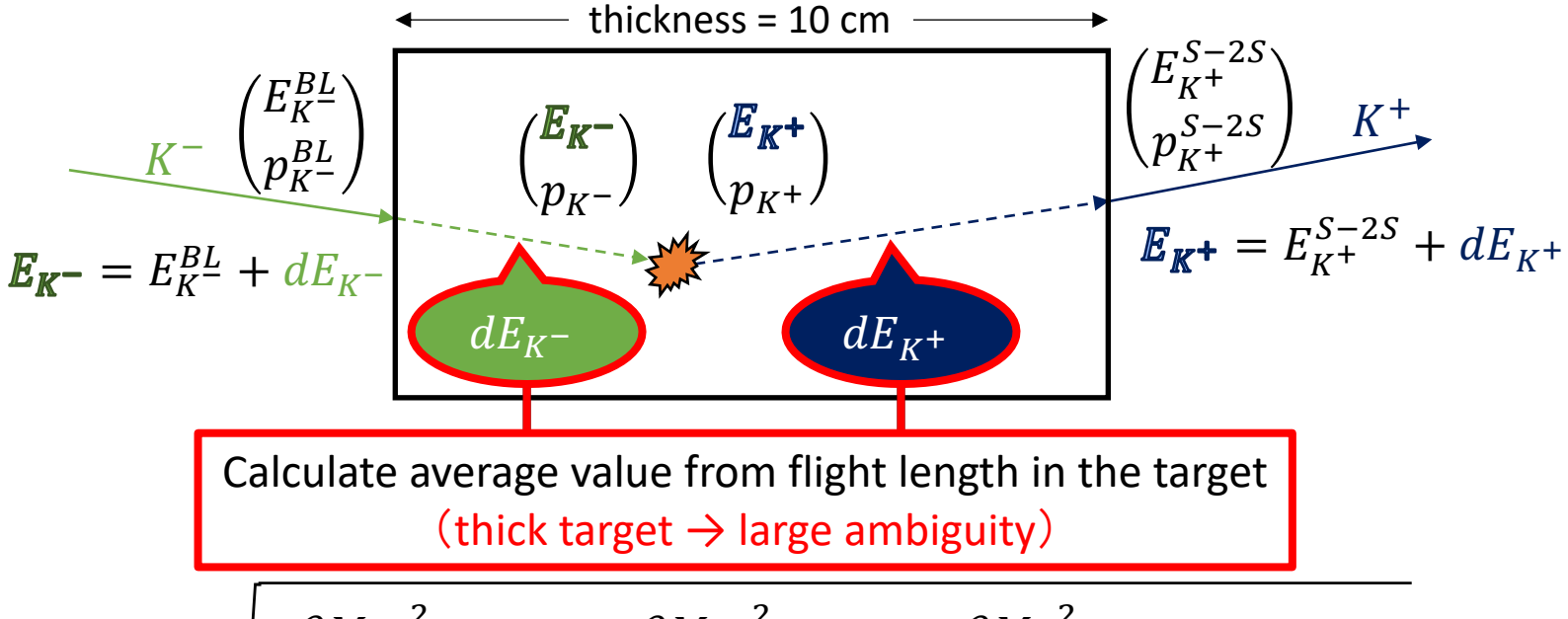
Separation of peaks with a good resolution of ~ 2 MeV (FWHM)
Statistics of Ξ hypernuclei > 100

Statistics vs Resolution

Statistics

The production cross section of the Ξ hypernucleus is very small (several tens of nb/sr)
→ High intensity beam & thick target are needed

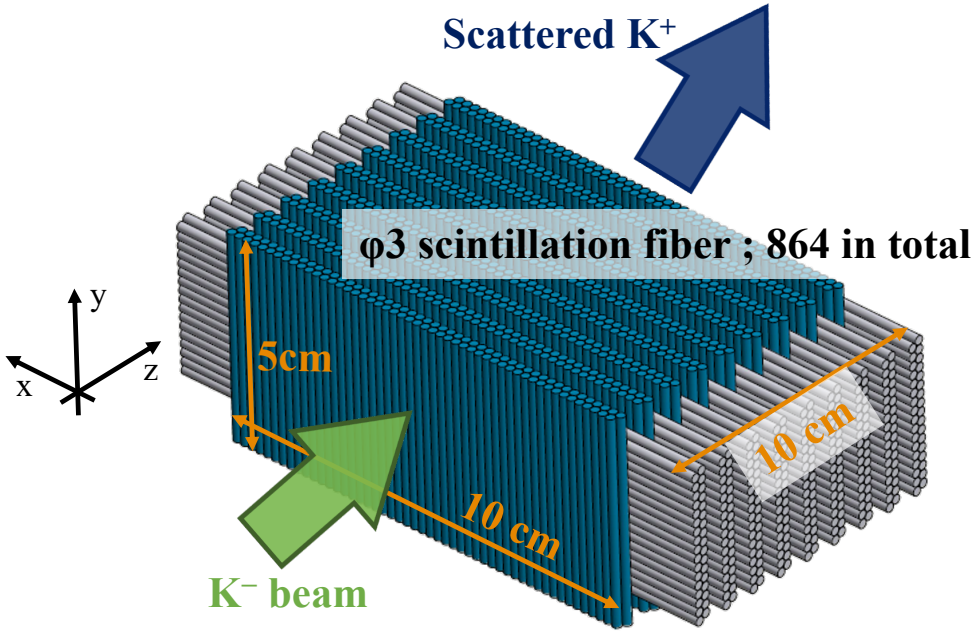
Resolution

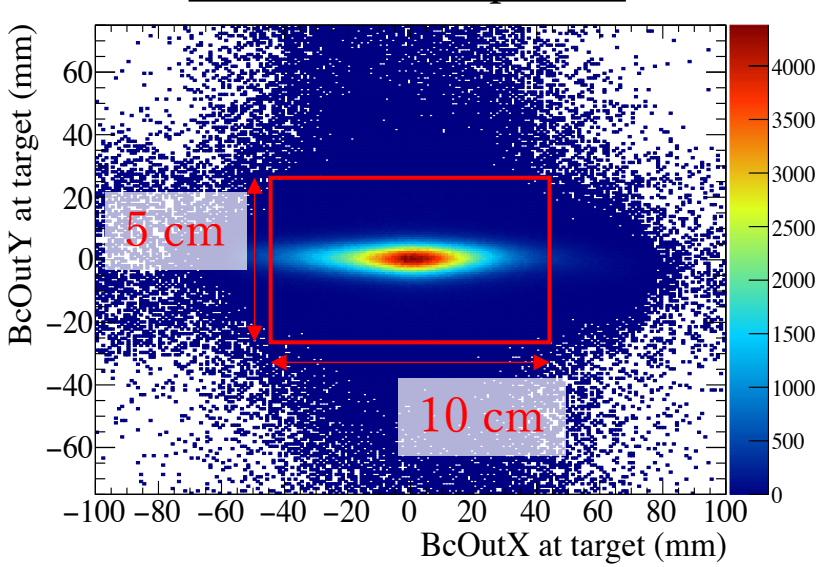


$$\Delta M = \sqrt{\left(\frac{\partial M}{\partial p_{K^-}}\right)^2 \Delta p_{K^-}^2 + \left(\frac{\partial M}{\partial p_{K^+}}\right)^2 \Delta p_{K^+}^2 + \left(\frac{\partial M}{\partial \theta}\right)^2 \Delta\theta^2 + \left(E_{strag}\right)^2}$$

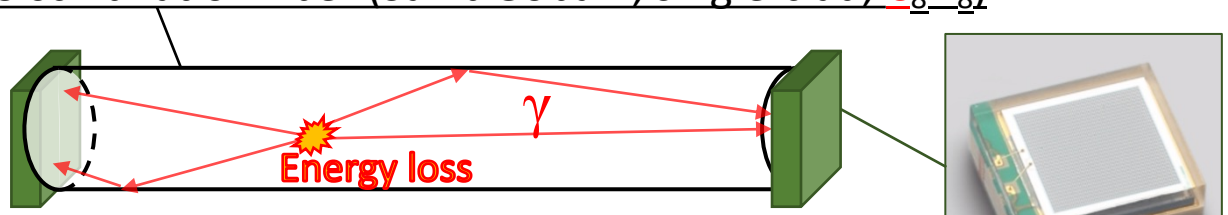
Directly measure $dE_{K^\pm}$ event by event = Active target

Active Fiber Target (AFT)





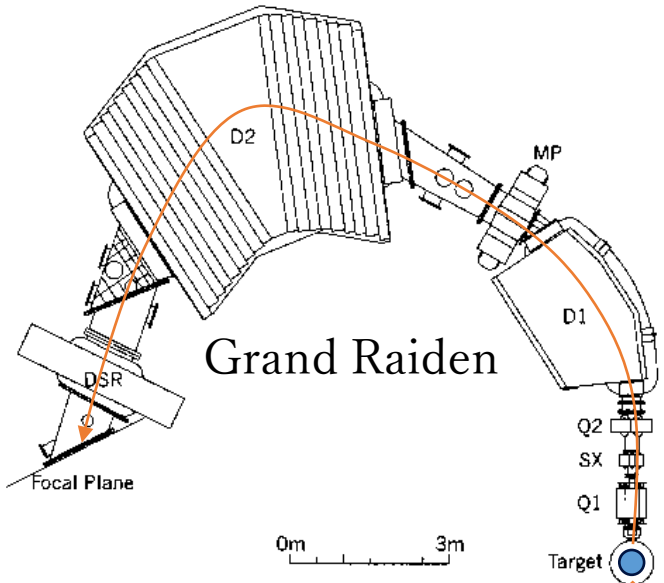
Φ3 scintillation fiber (Saint-Gobain, single-clad, C_8H_8)



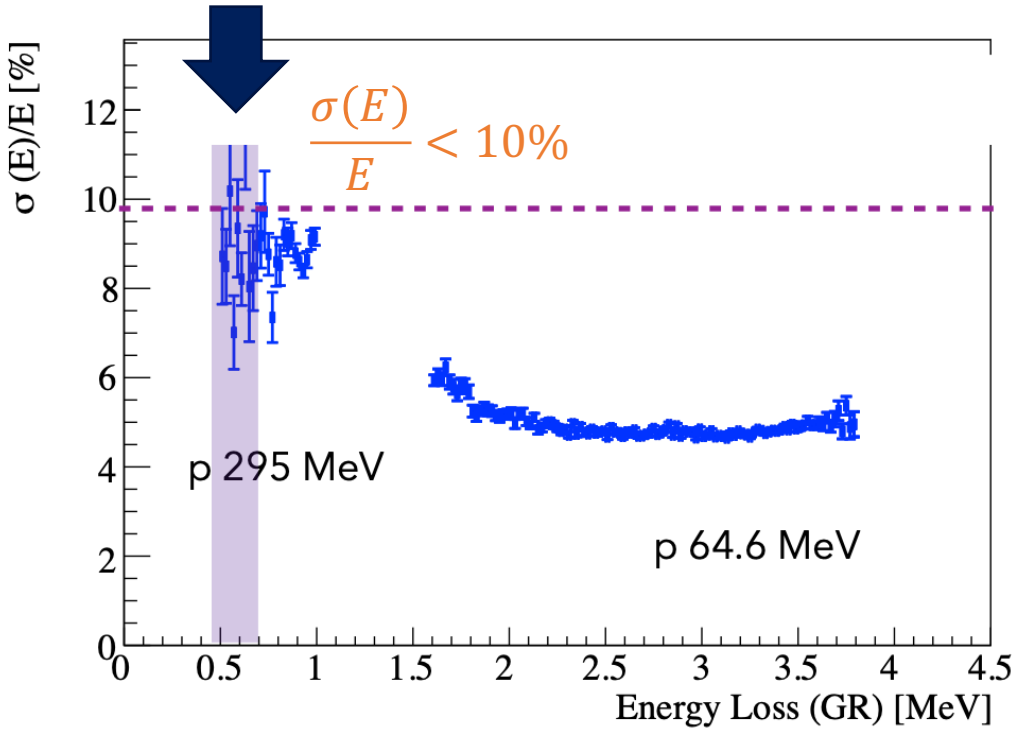
MPPC (S13360-3075PE)
Both edge reading : ~ 1800 ch
→ Read-out by VME-EASIROC

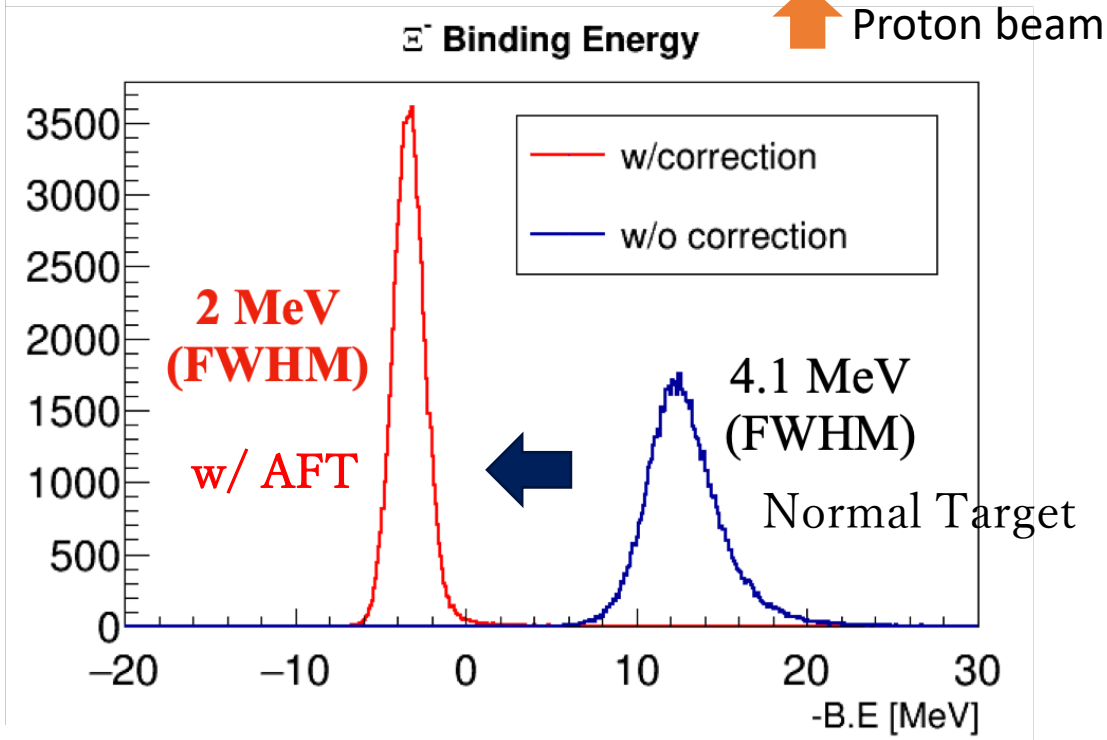
Resolution evaluation

- RCNP, Osaka Univ. in 2017
- Using one fiber

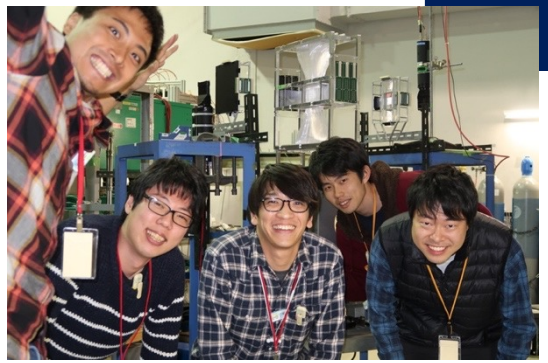


Energy loss of K± @ 1.8 GeV/c ~ 0.6 MeV

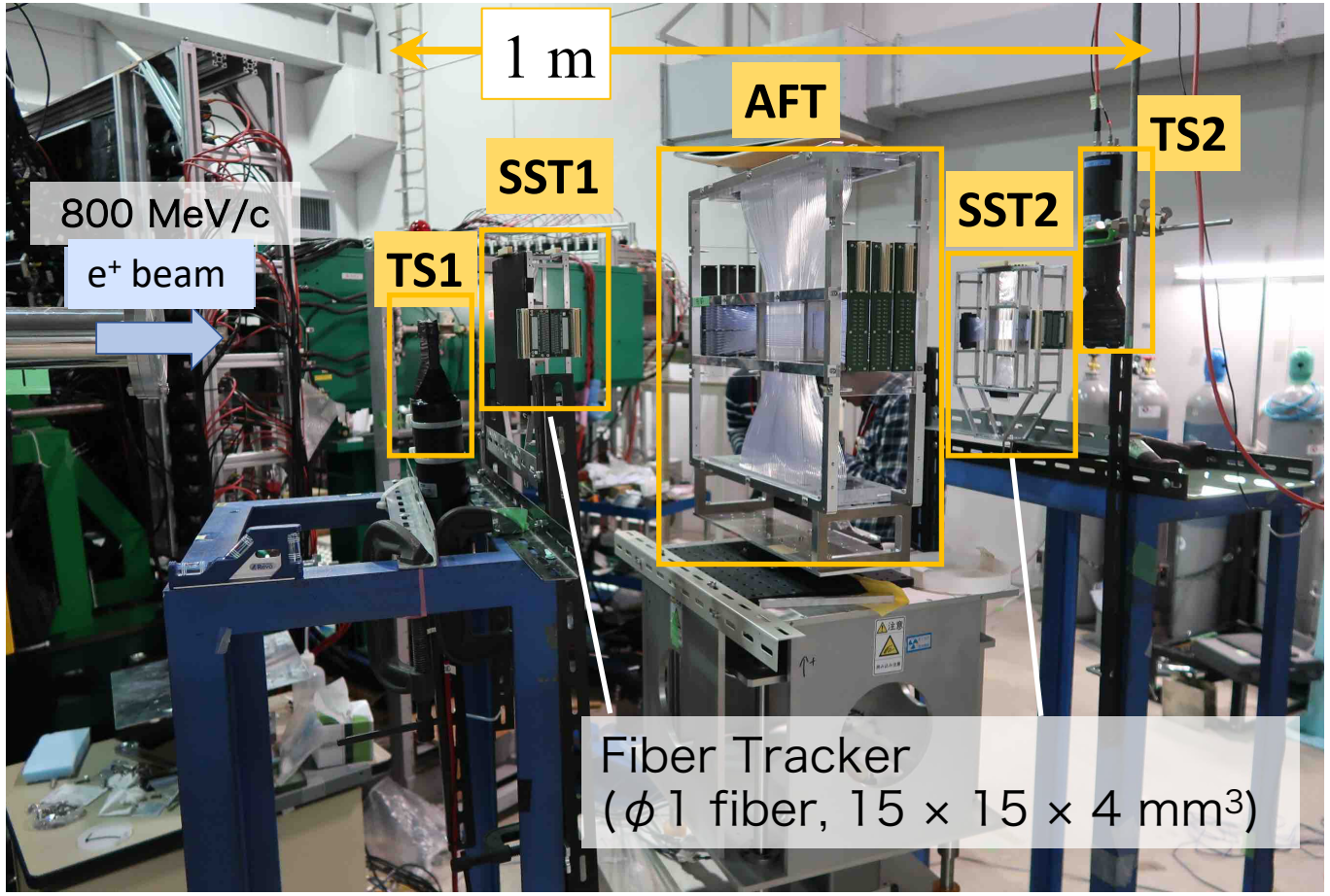


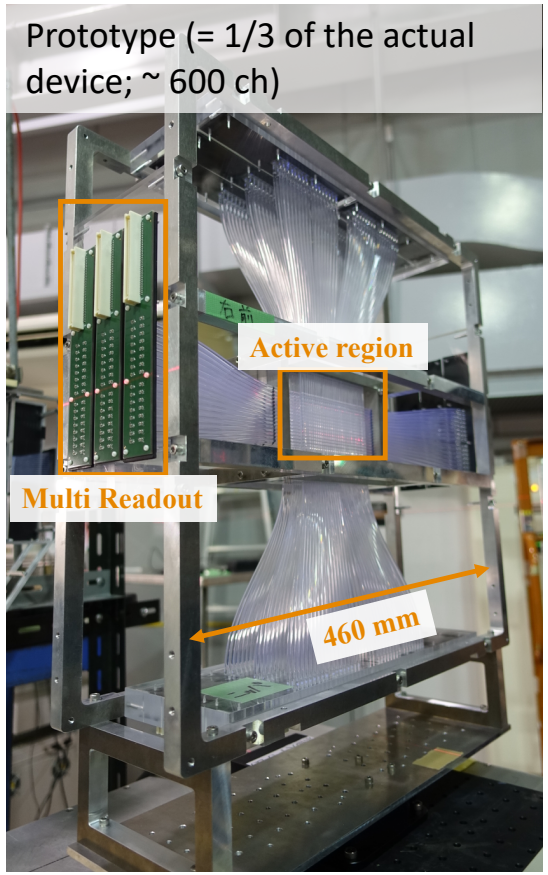


Multi channel read-out test



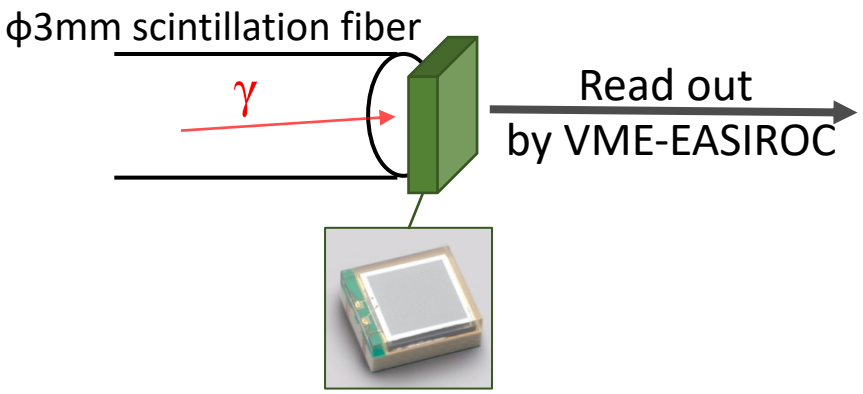
ELPH in 2019



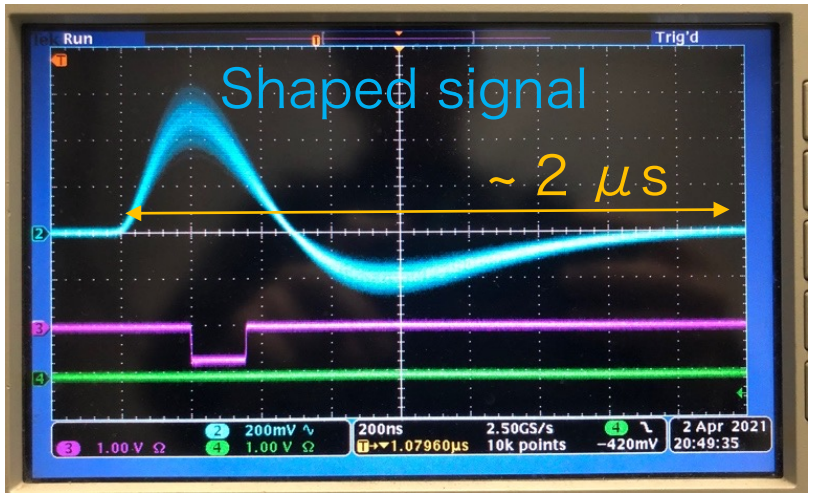


Detection efficieny > 95%

Deterioration of ADC resolution by pile-up

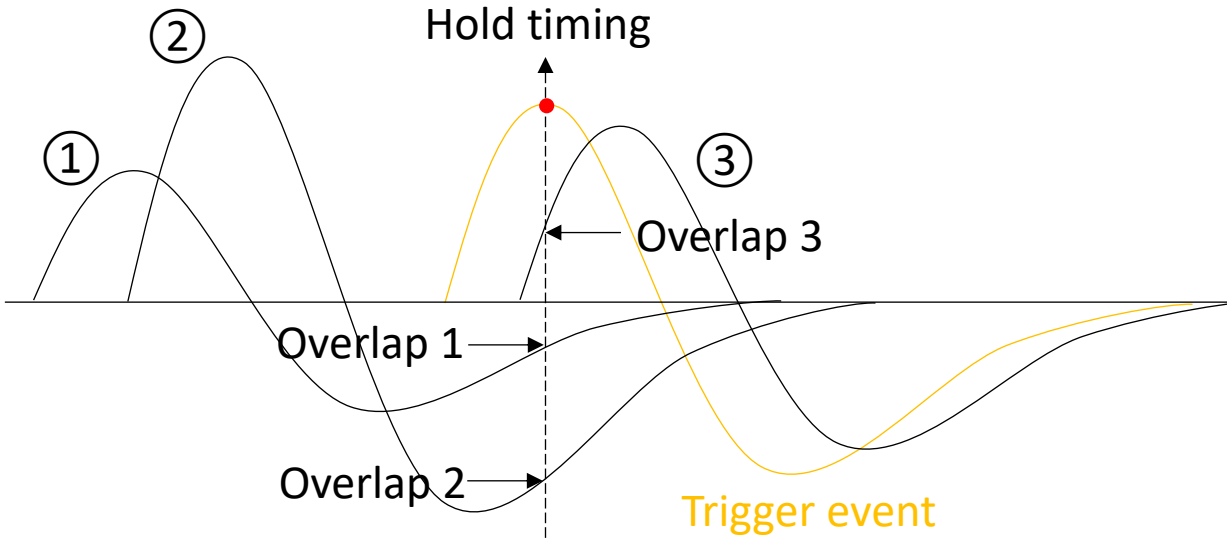


MPPC (S13360-3075PE)



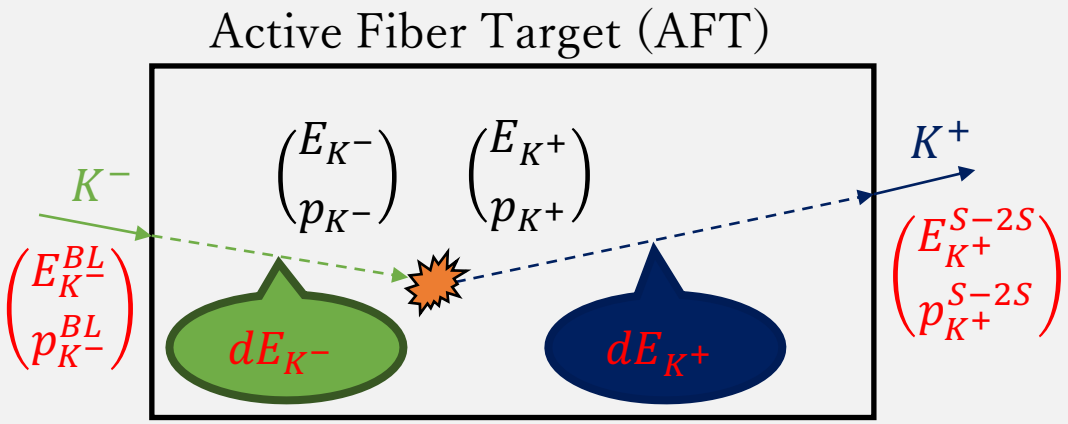
- VME-EASIROC has long recovery time of $2\,\mu s$
- This causes pile-up due to nearby events under high beam rate.
- As a result, ADC resolution will be poor.

→ Estimated the impact of this effect on missing mass resolution

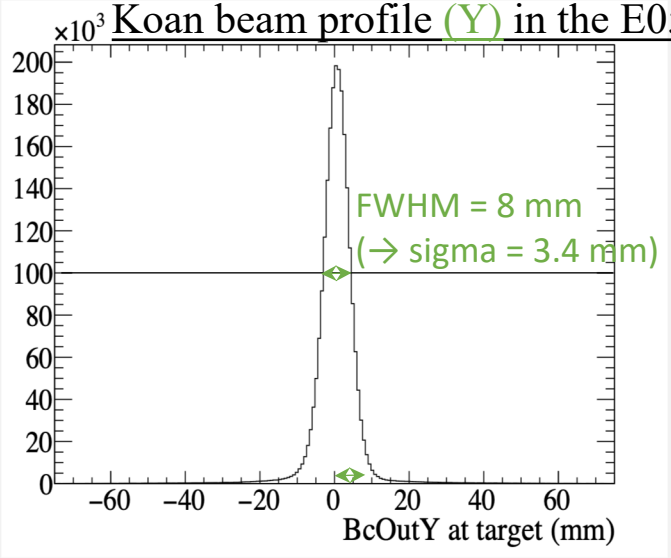


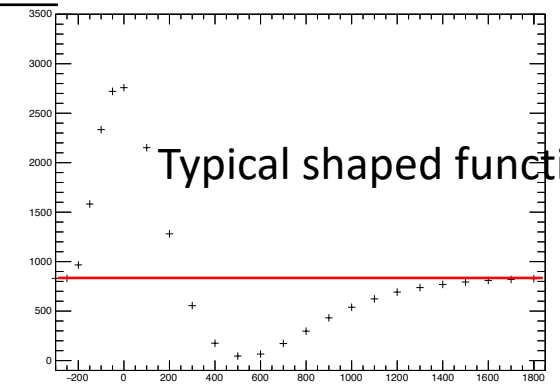
Simulation

① Geant4 simulation with AFT



② Pile-up event in MC simulation





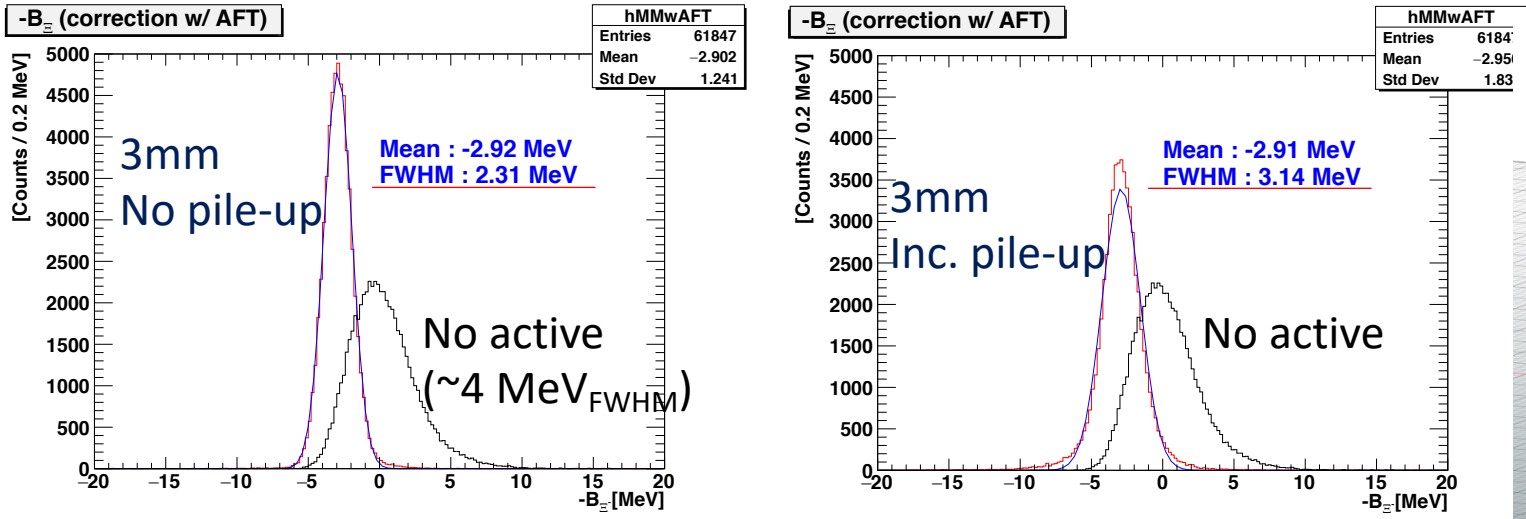
0.5 MHz in a center fiber
@2.5 M/spill (spill on = 2.0 sec)

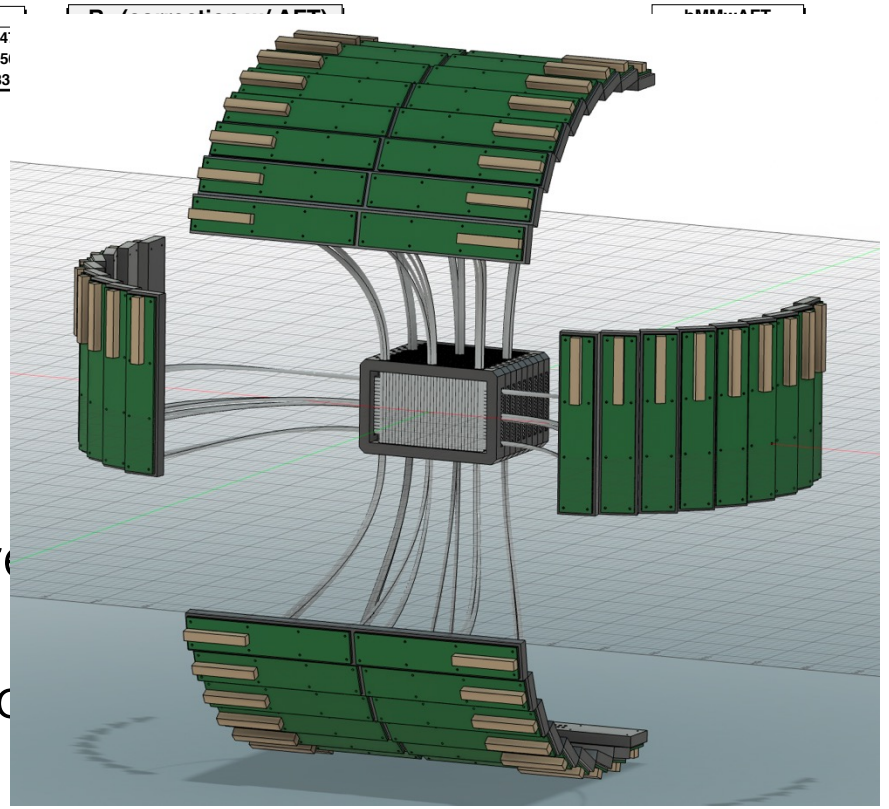
③ Calculate missing mass

$$M = \sqrt{(E_{K^-} + M_A - E_{K^+})^2 - p_{K^-}^2 - p_{K^+}^2 + 2p_{K^-}p_{K^+}cos\theta}$$

Results

[MeV]	input	No active	3mm No pile-up	3mm Inc. pile-up	TOT (20%)
Resolution （FWHM）	1.03	4.00	2.31	3.14	2.57





- Although the use of AFT improves resolution compare correction capability is small due to pile-up effects.
- Measurements made with TOT ensure that pile-up pro energy resolution is maintained at a moderate level

Final design is on going with a policy of using TOT (and ADC)

Preparation status & Schedule

Overall E70 from Gogami (Fri)

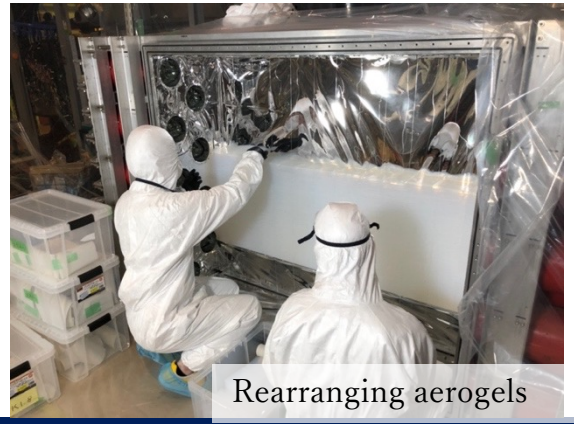
	~ May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. 2023 ~
AFT	R&D	Final design		Construction	Install at K1.8 Cabling		Signal & DAQ check	READY	
SDC in		Operatin test		Install at K1.8	Cabling	Signal & DAQ check			
S-2S	Installed								
SDC out	Installed	Cabling		Signal check					
TOF	R&D Mass-pro	Final check	Install at K1.8	Cabling					
AC									
WC									

Preparation status from Ebata (poster)

Commissioning run (2 weeks)

Final Tuning (1 - 2 months)

Physics Run (20 days)


Rearranging aerogels


Surveying SDC


Connecting PMT and scintillator


Cosmic ray test in IQBRC

Summary

ΞN interaction

- Information needed to build realistic Baryon-Baryon interaction
- Experimental information is still scarce (even with the results of the emulsion experiment)
- Spectroscopy information of Ξ hypernuclei is important

High resolution spectroscopy of Ξ hypernuclei (J-PARC E70)

- Missing-mass spectroscopy via the ^{12}C(K$^-$, K$^+$)$^{12}_{\Xi}$Be reaction
- Measurent of peak structures of the bound states will constrain to the ΞN interaction
- S-2S and AFT will allow measurements with a good missing-mass resolution $\Delta M \sim 2$ MeV

Active Fiber Target (AFT)

- Energy correction event by event
- AFT allows better resolution than normal target.
- R&D was finished and currently constructing

Schedule & Outlook

- We are aiming to be ready on this Dec.