

UNIVERSITY
of York

Systematic measurement of nucleon removal cross sections in the vicinity of doubly magic ^{78}Ni

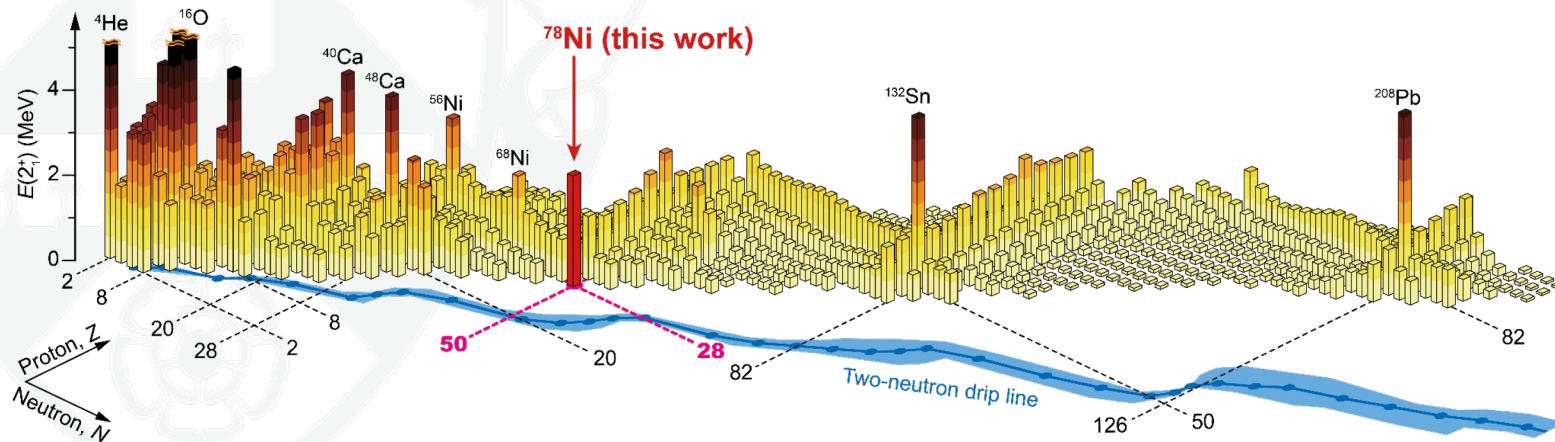
Hiroyuki Takahashi, Daiki Nishimura, Daisuke Suzuki,
Ryo Taniuchi and Serge Franchoo for RIBF181 collaboration

Tokyo City University, RIKEN Nishina Center, University of York, and IJCLab

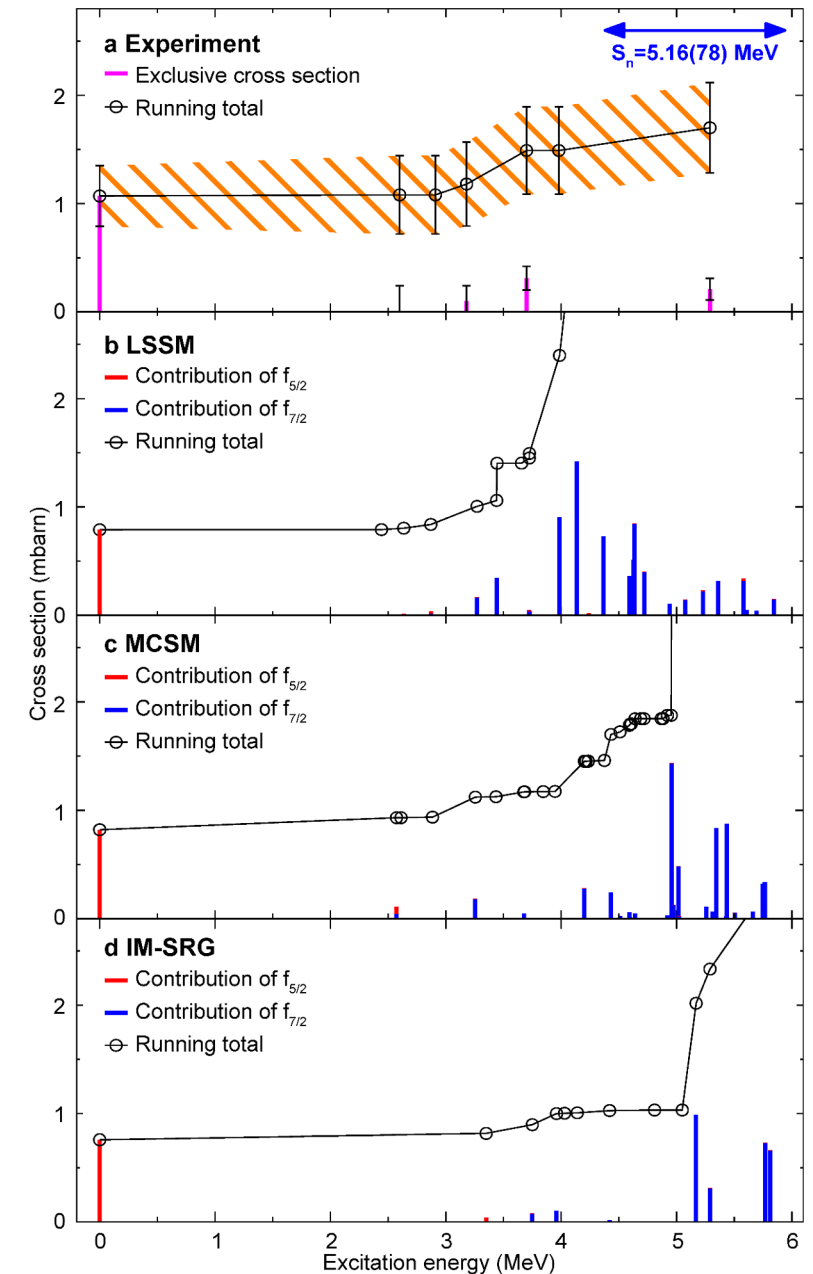
The doubly magic ^{78}Ni

In the previous study, the excitation energy of ^{78}Ni confirmed the magicity of ^{78}Ni (and suggested its shape coexistence).

The exclusive $^{79}\text{Cu}(p,2p)^{78}\text{Ni}$ cross sections seem to have consistent results between measurement and DWIA calculations with several nuclear structure models.

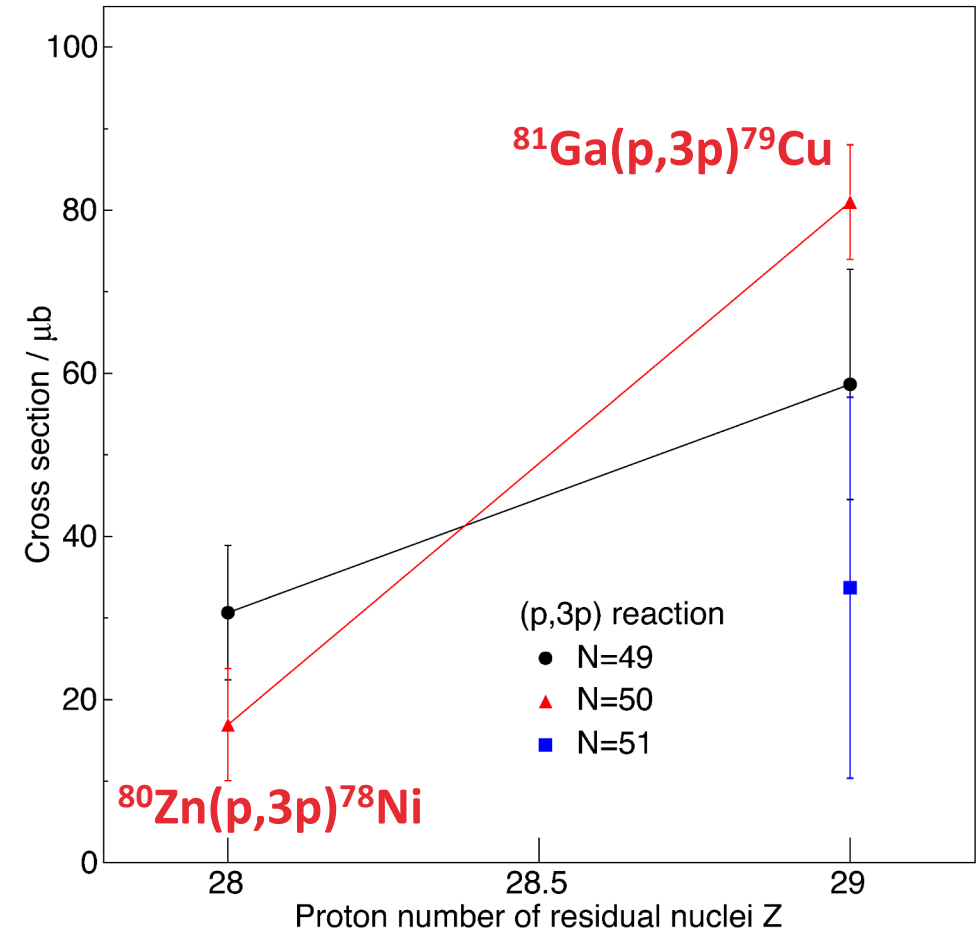
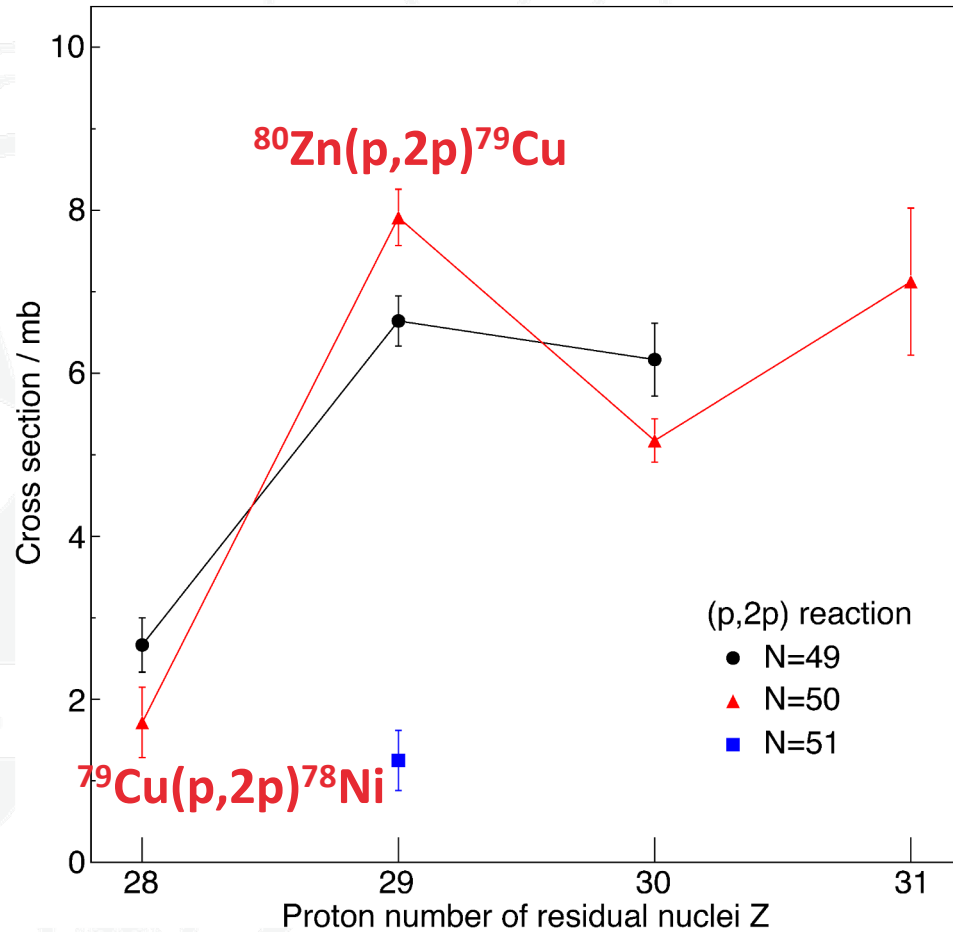


R.Taniuchi *et al.*, Nature **569**,53-58 (2019).



Decreases in inclusive cross sections at Z=28

Ryo Taniuchi, PhD Thesis, University of Tokyo

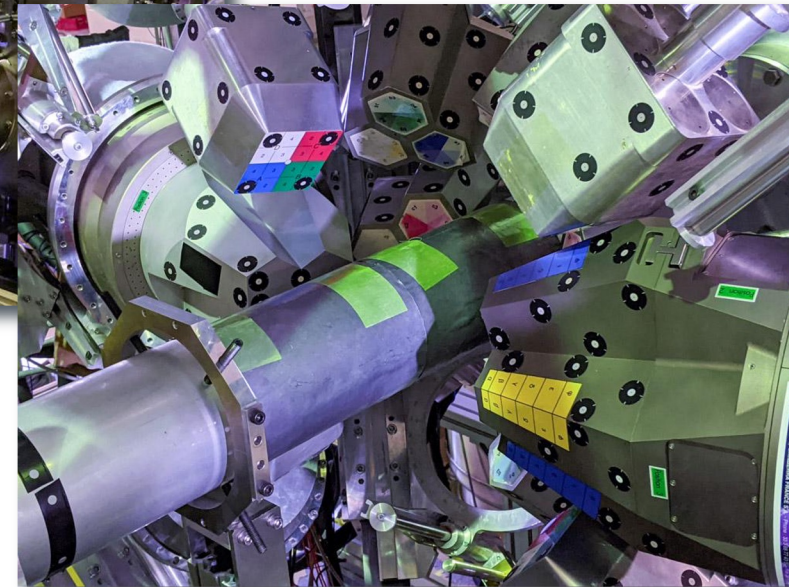
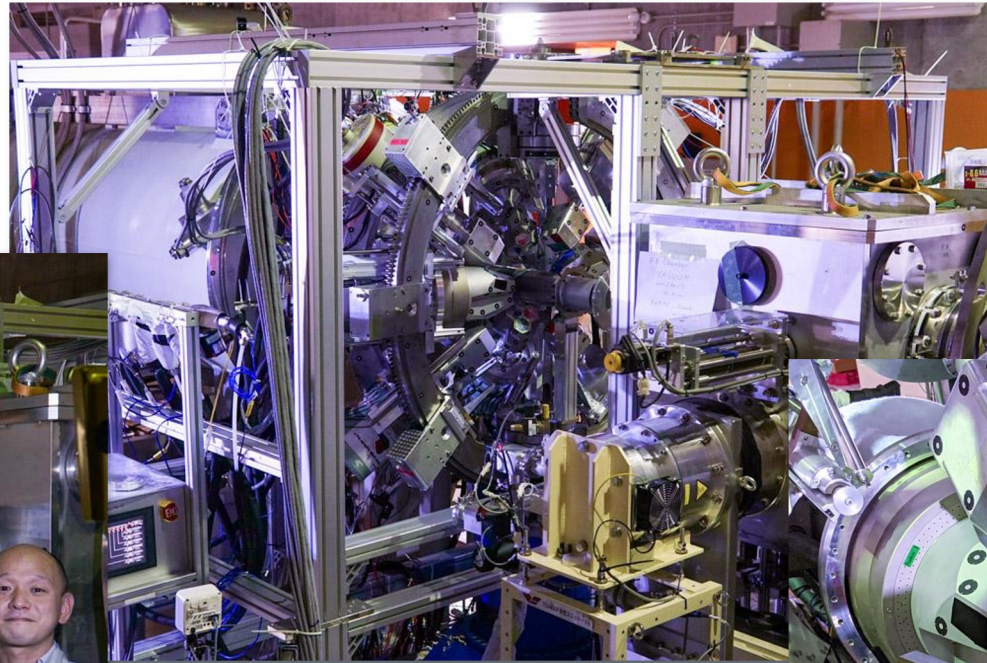


We need more dedicated measurement for cross sections around ^{78}Ni region

The RIBF181 experiment

“Gamma-ray spectroscopy in the vicinity of double-magic ^{78}Ni ”

Performed in Apr 2021 at RIBF/RIKEN under the **HiCARI** campaign

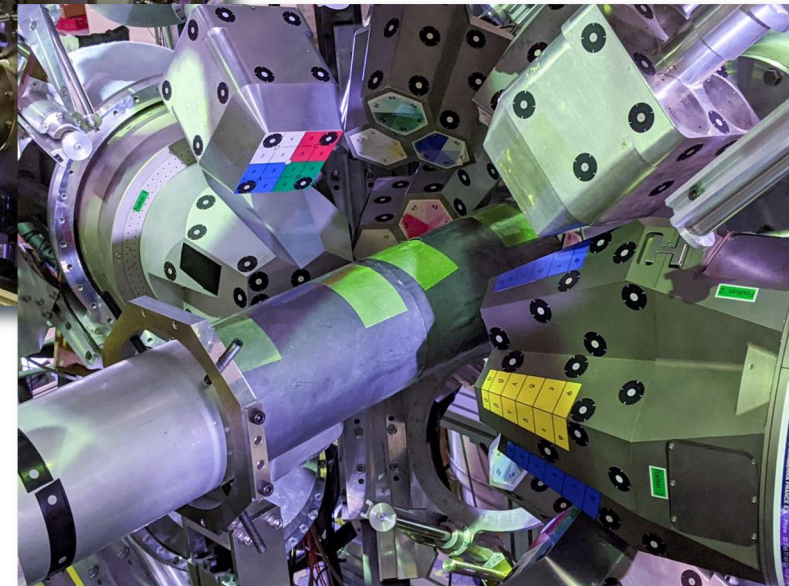
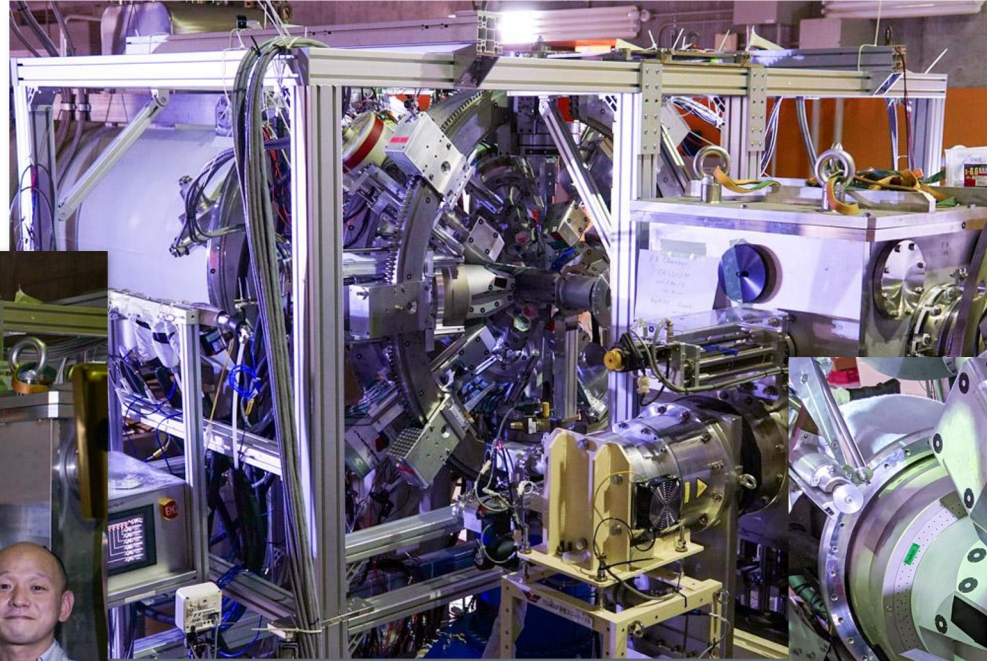


The RIBF181 experiment

“Gamma-ray spectroscopy in the vicinity of double-magic ^{78}Ni ”

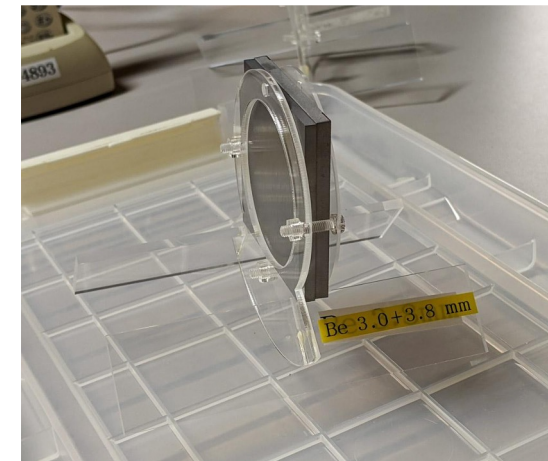
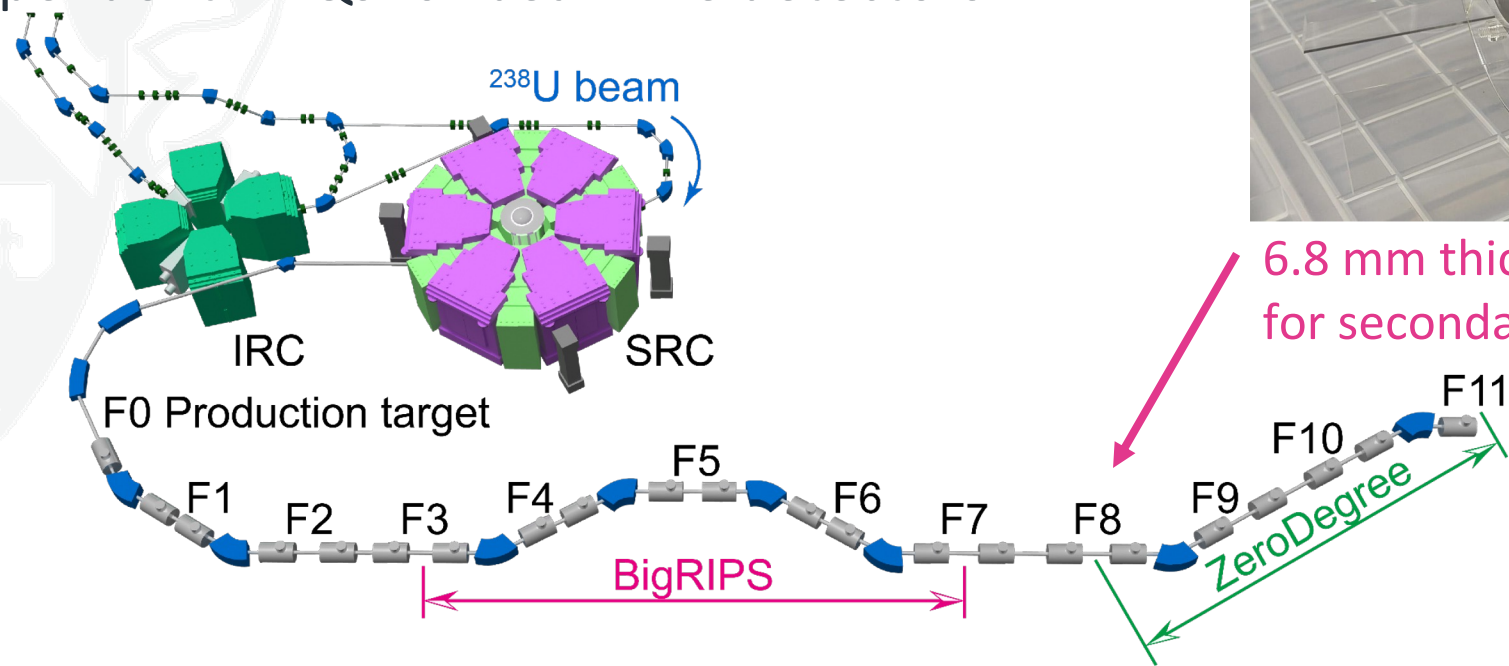
Performed in Apr 2021 at RIBF/RIKEN under the **HiCARI** campaign

Hiroyuki
Takahashi



Experimental setup

- **Primary beam:** 90 p nA ^{238}U at 345 MeV/nucleon for 7 days
- **Secondary beam:**
 - 50 kHz (total) at ~ 250 MeV/nucleon
 - ^{80}Zn -centred cocktail beam ($N = 49\text{-}51$ transmitted)
 - Momentum distribution is restricted to $\pm 2.5\%$
- **ZeroDegree** was centred to transmit (-1p) channels
- Two independent DAQs for beamline detectors

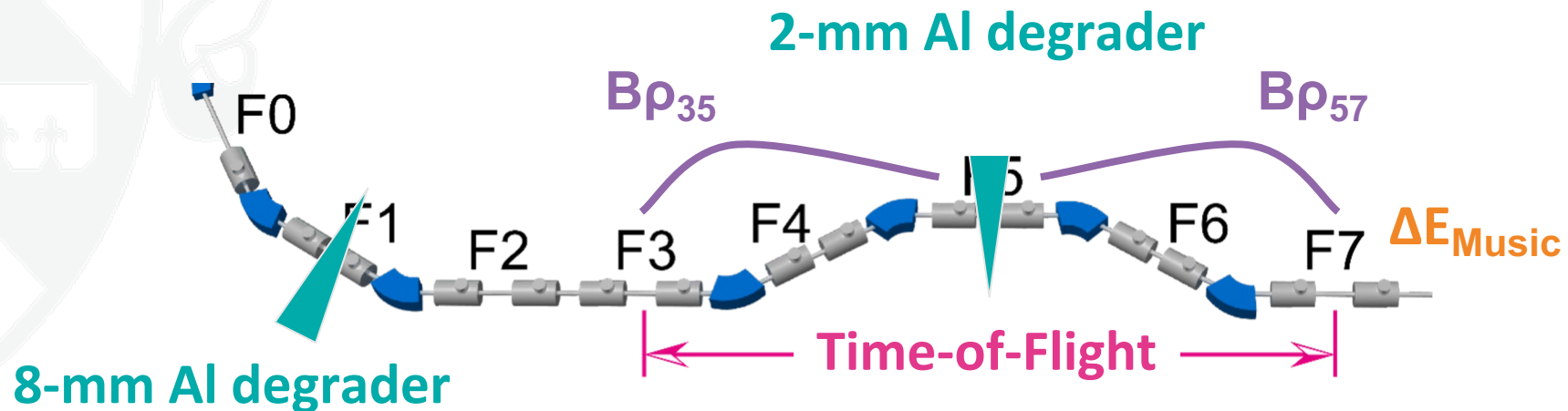


6.8 mm thick Be target for secondary reactions

High-rate beam reconstruction in BigRIPS

Brho-ToF- ΔE method was applied to secondary beam identification event-by-event.

- **Brho**: Ion trajectories with 6 double-PPACs
 - **ToF**: Time-of-flight between F3-F7
 - **ΔE** : MUSIC at F7 with a fast SA (shaping time=0.5 us)
- ΔE_{Music} suffers from pile-up hits

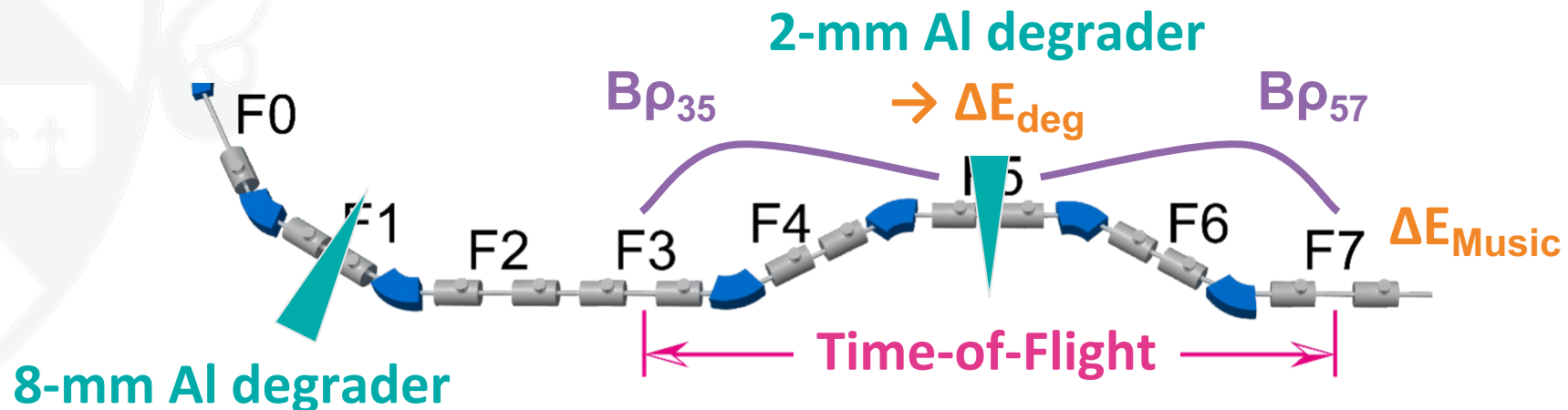


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 - ΔE_{Music} suffers from pile-up hits
 - Energy loss at the degrader at F5 ΔE_{deg} is also calculated from **Bp change**

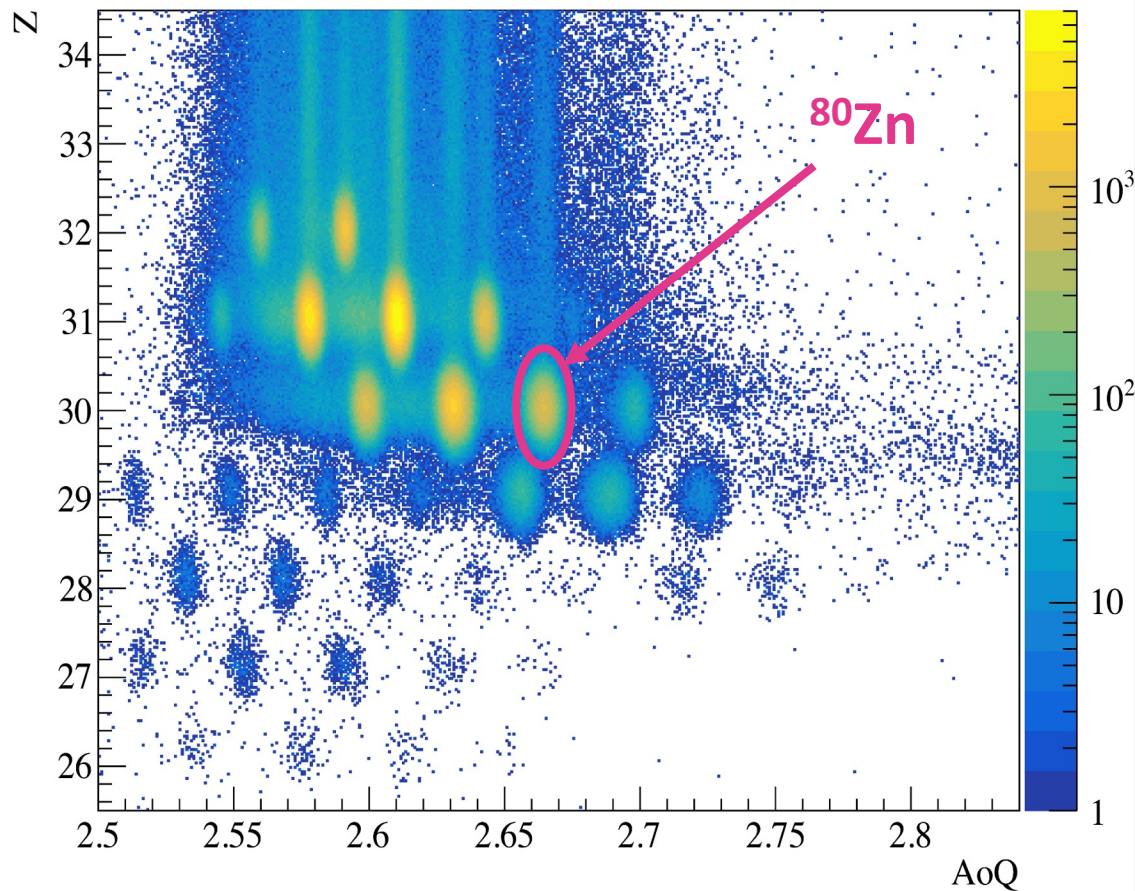
Y. Shimizu *et al.*, J. Phys. Soc. Jpn. **87**, 014203 (2018); N. Fukuda *et al.*, J. Phys. Soc. Jpn. **87**, 014202 (2018).



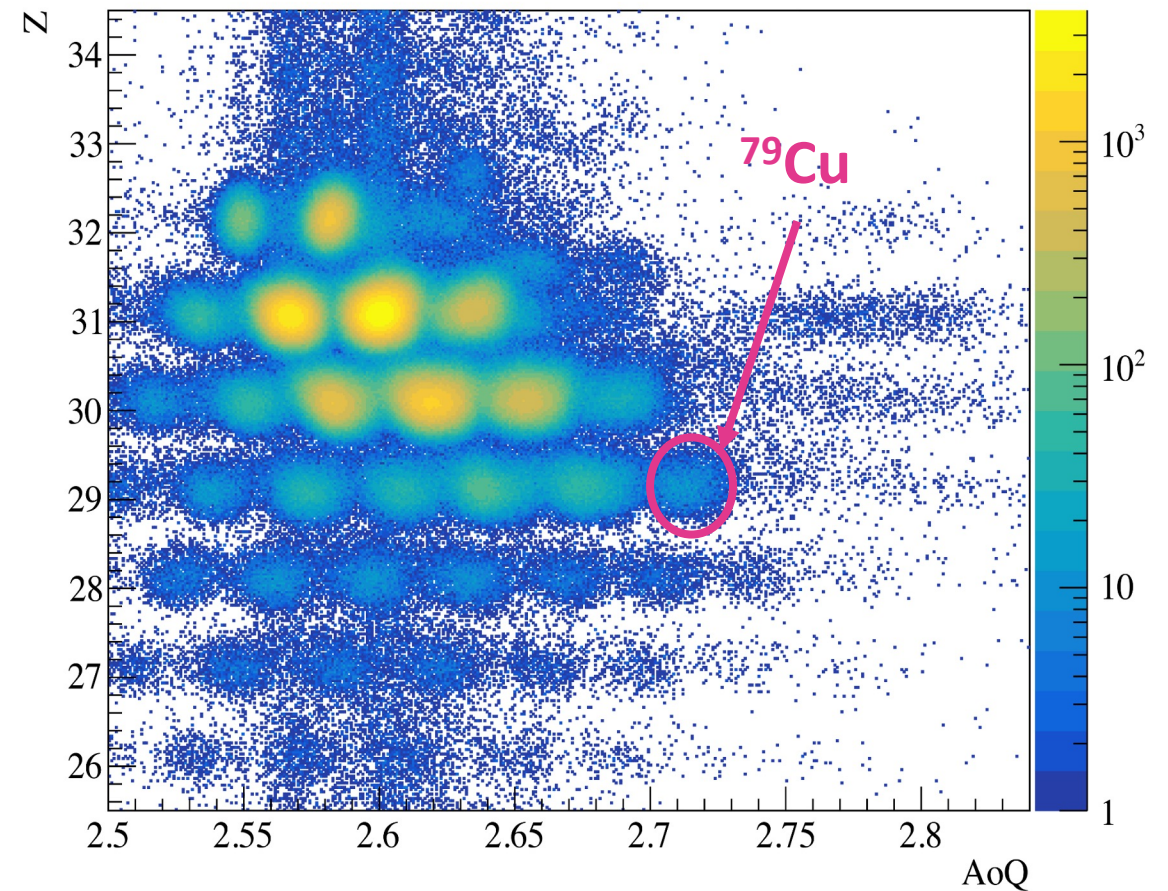
Particle identification plots

Beam rate of $^{80}\text{Zn} = 2 \text{ kHz}$, $^{79}\text{Cu} = 40 \text{ Hz}$. 7-8 times higher than the previous experiment.

PID in BigRIPS with Gamma triggers

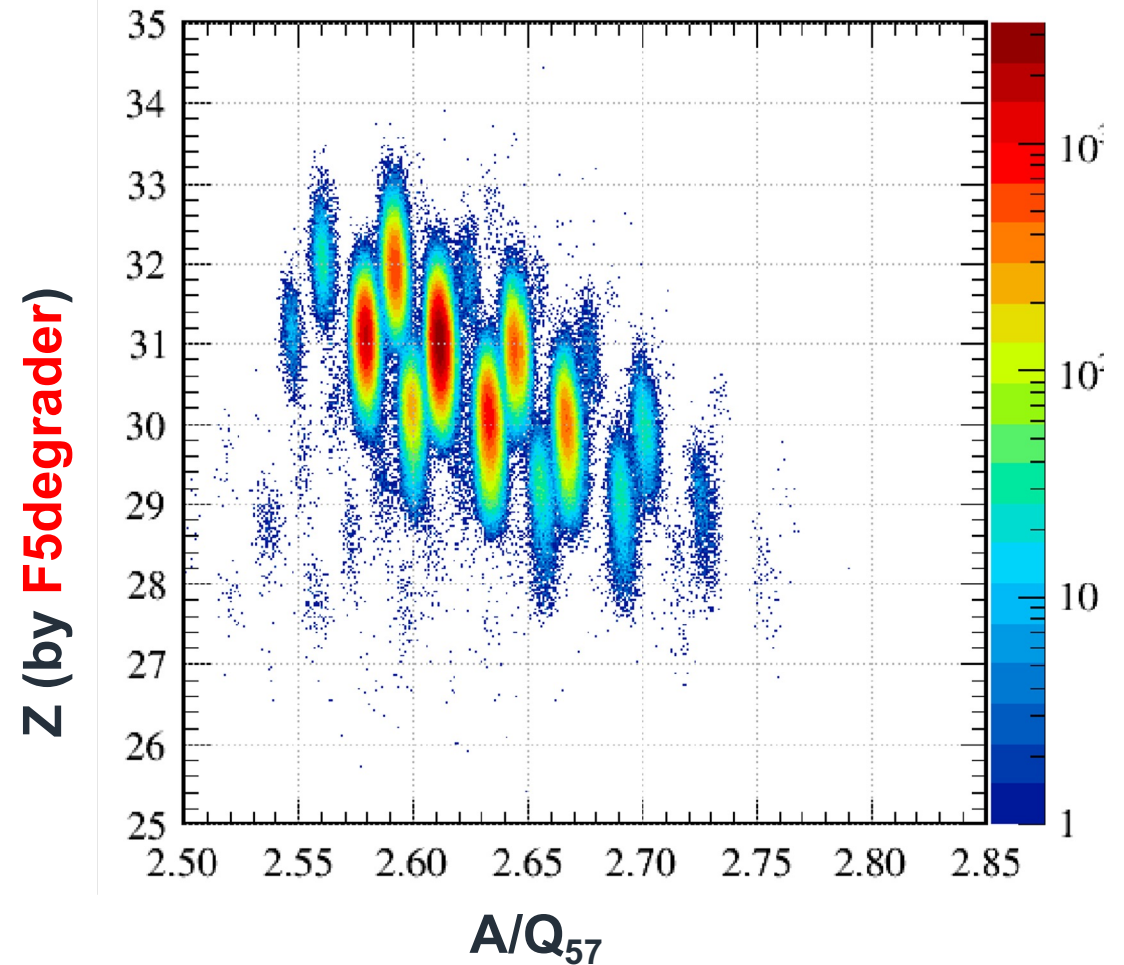
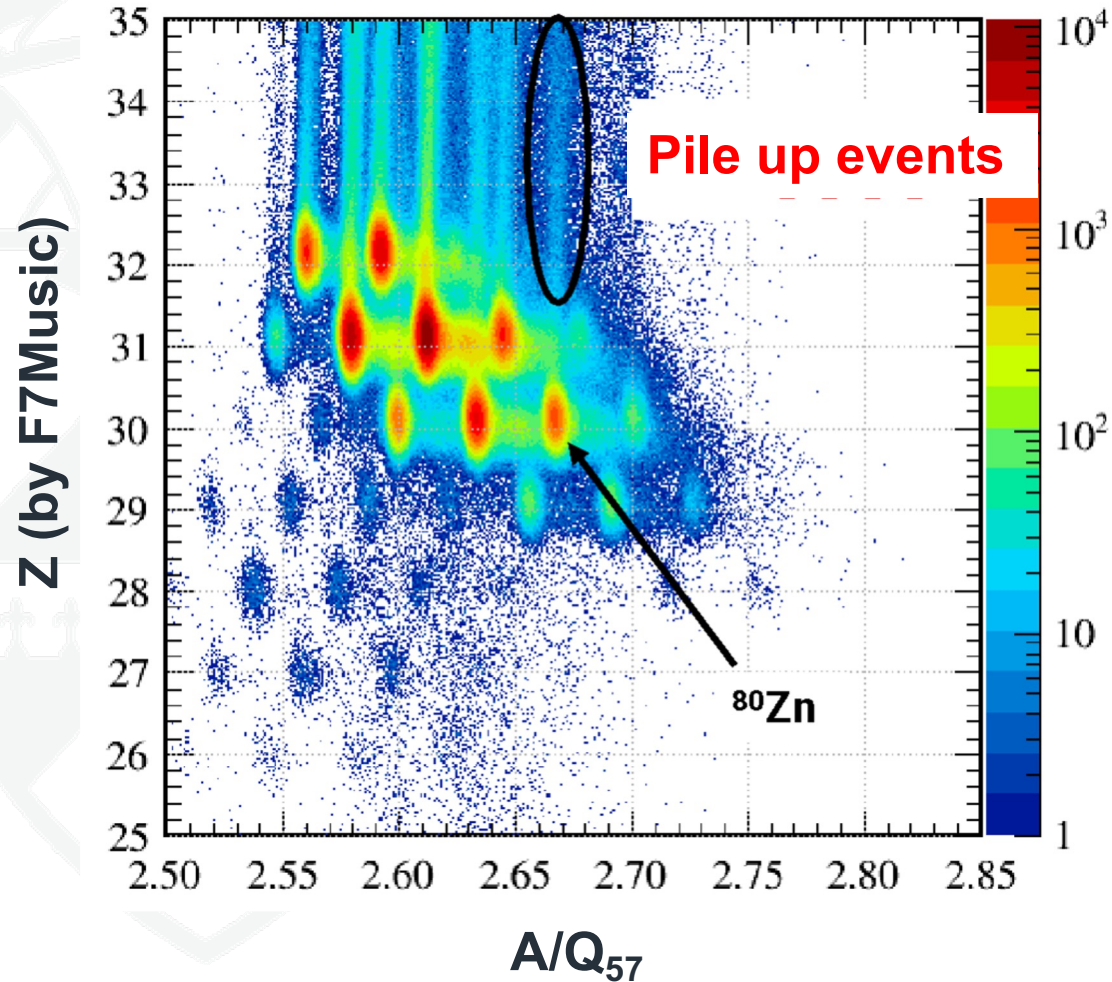


Fragments in ZeroDegree with Gamma triggers

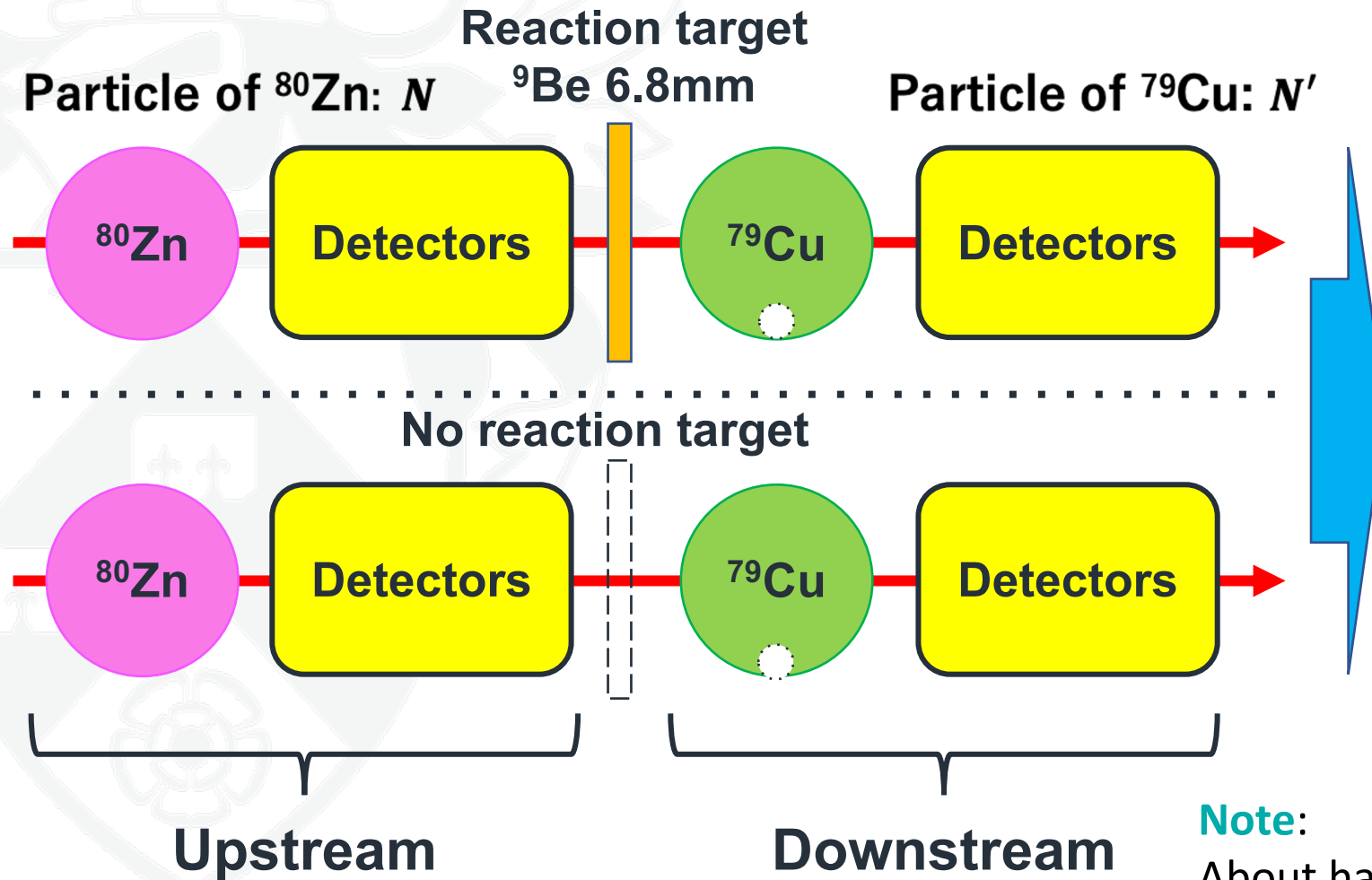


Pile-up hits in Music detector for Z reconstruction

An example shown for the Z reconstruction without using the MUSIC detector



Contributions from other materials along beamline



1 proton removal cross section σ_{-1p}

$$\sigma_{-1p} = \frac{\frac{N'_{in}}{N_{in}} - \frac{N'_{none}}{N_{none}}}{{}^9\text{Be} [\text{unit}/\text{cm}^2]}$$

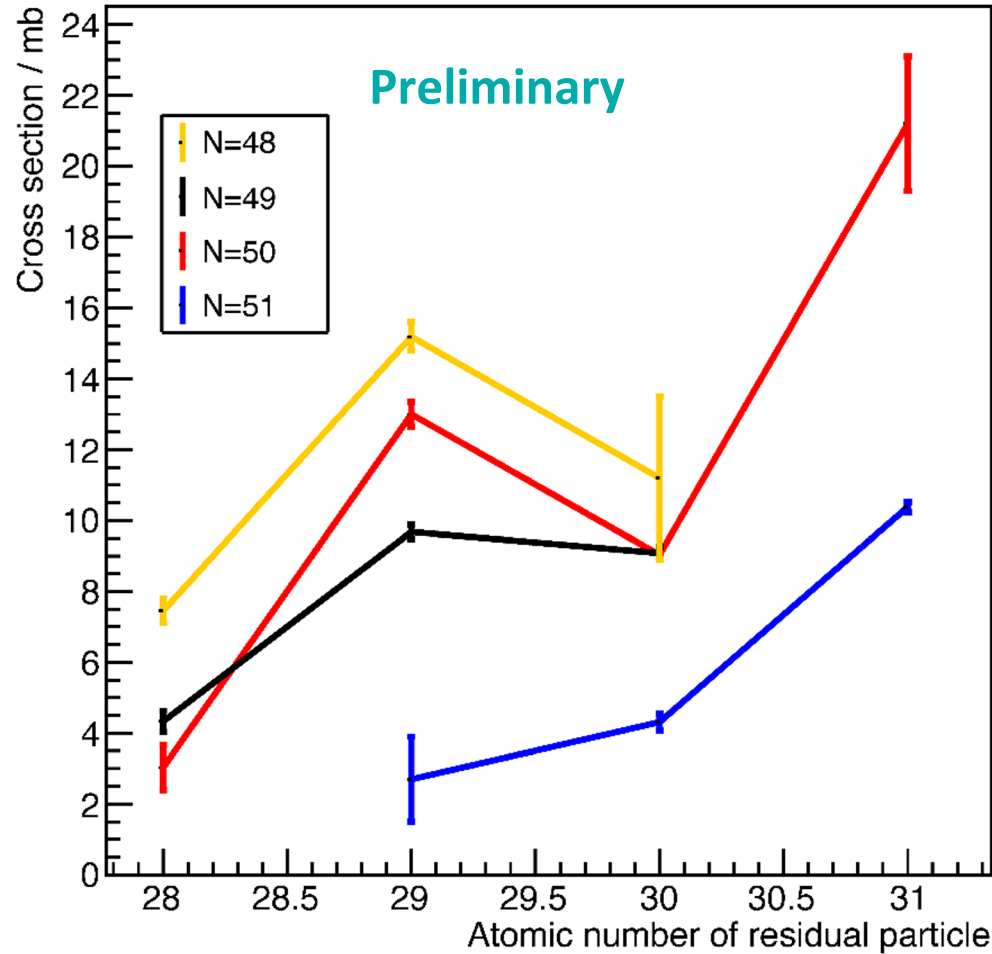
[mb]
(= 10^{-27} cm²)

Note:

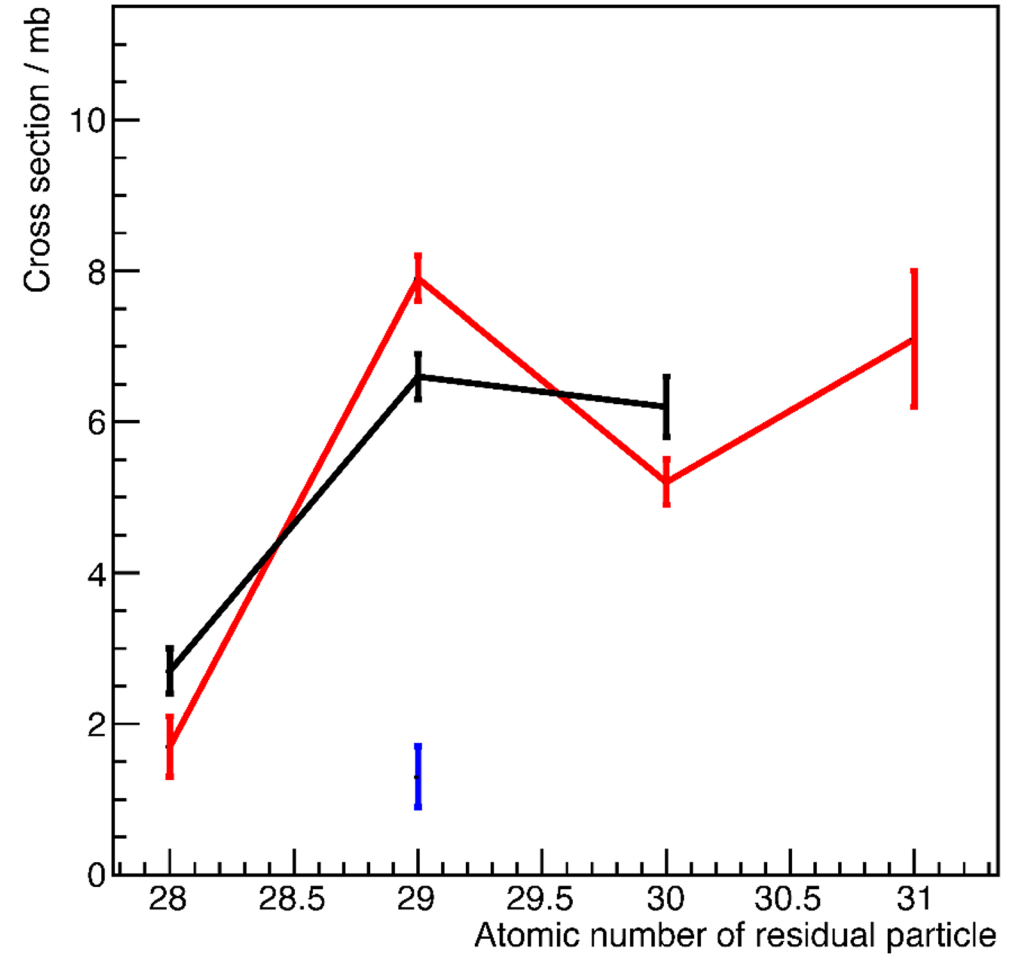
About half of the statistics analysed
Beam transmission in ZeroDegree to be corrected

Preliminary measured cross sections

-1p cross section in this study with Be target



(p,2p) cross section in previous study with LqH₂ target



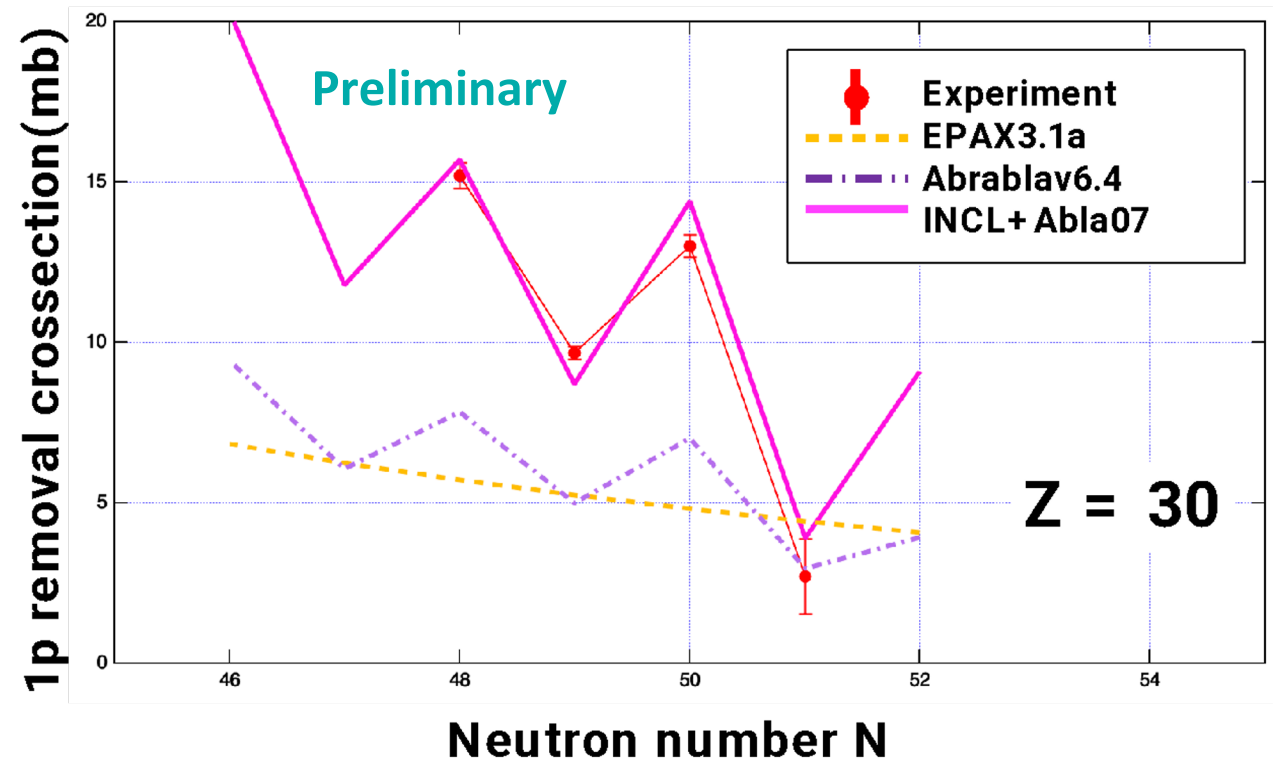
Comparison with phenom. calculations

EPAX: Phenomenological fit for fragmentation reactions

INCL (intra-nuclear cascade model): MC-Simulated 2N collisions

Abrasion-ablation: Ablation taken into account

INCL & Abrabla gives good agreement.
Odd-even staggering is well explained.
Neutron evaporation process would be affected by separation energy $S(n)$?

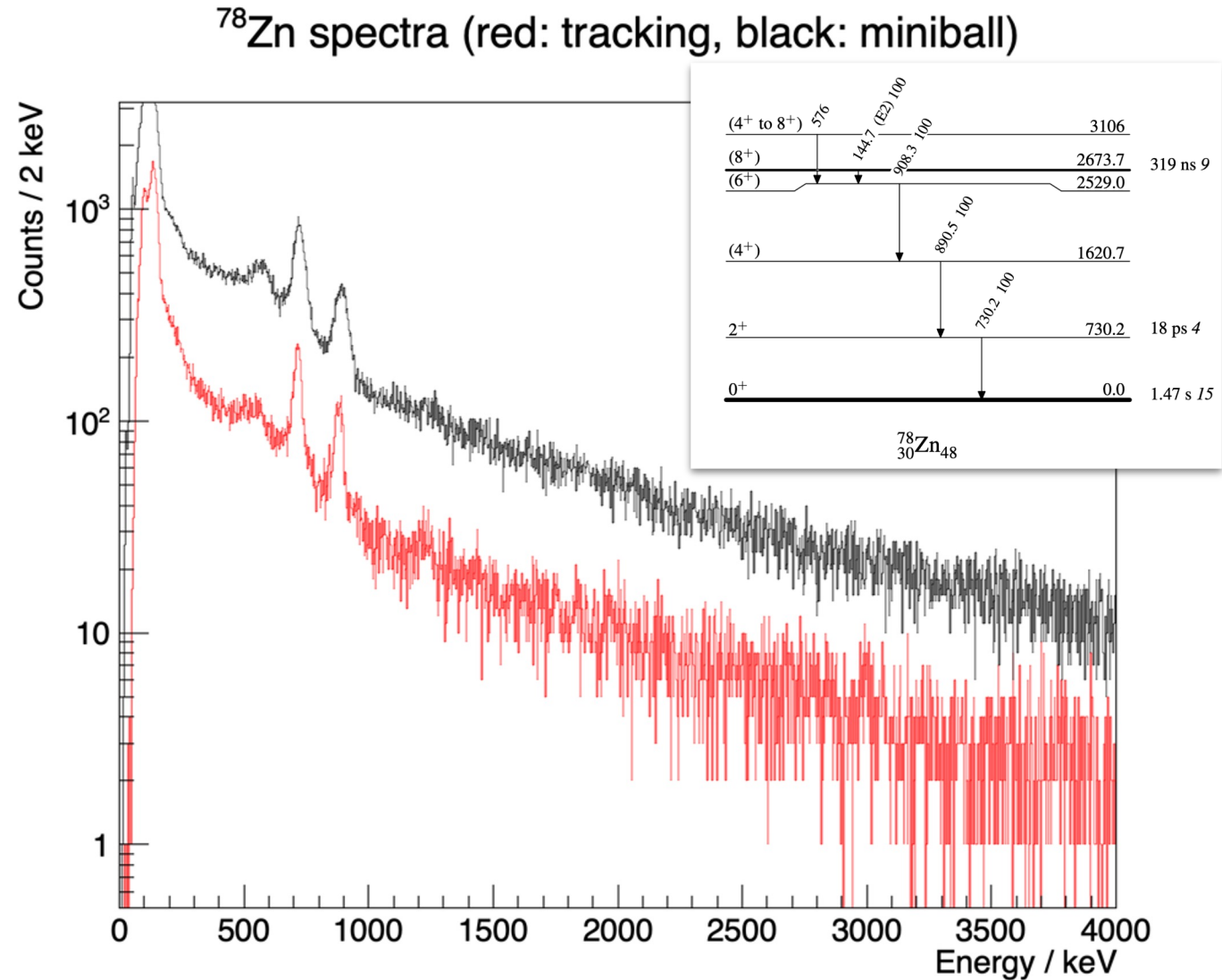


Summary

- A systematic measurement of (inclusive) cross sections in ^{78}Ni region has been performed at ~ 250 MeV/nucleon on Be target with BigRIPS/ZeroDegree.
- A (relatively) high-rate secondary beam could be reconstructed unambiguously.
- Preliminary analysis for $Z=29-32$ isotopes was performed. Consistent results with the previous study using (p,2p) reaction obtained including the sudden decrease in the cross section of $^{79}\text{Cu}(-1p)^{78}\text{Ni}$ is seen.
- Within several phenomenological fragmentation models, the Abrabla calculations reproduce the cross sections better than EPAX.

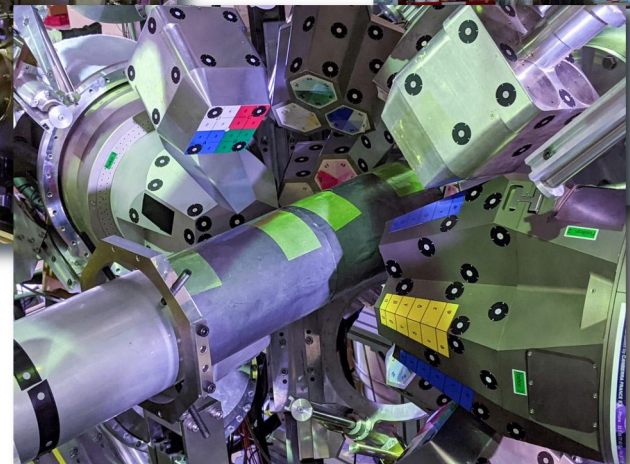
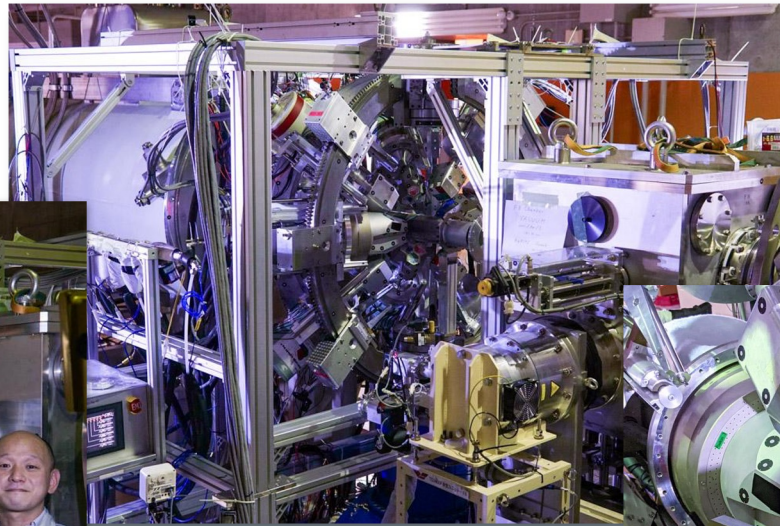
Future outlooks

- Full statistics of the data and more reaction channels to be analysed
- Comparison with other reaction calculations such as the Eikonal theory will be performed
- Gamma-ray spectra of HiCARI array also being investigated



Local and core members of the RIBF181 experiment

R. Taniuchi, S. Franchoo, D. Suzuki, N. Aoi, H. Baba, F. Browne, C. M. Campbell, S. Chen, R. Crane, H. L. Crawford, H. de Witte, P. Doornenbal, C. Fransen, N. Fukuda, H. Hess, E. Ideguchi, S. Iwazaki, J. Kim, A. Kohda, T. Koike, T. Koiwai, B. Mauss, R. Mizuno, B. Moon, M. Niikura, D. Nishimura, T. Parry, M. Petri, P. Reiter, H. Sakurai, Y. Shimizu, H. Suzuki, H. Takahashi, H. Takeda, S. Thiel, K. Wimmer, Y. Yamamoto, and M. Yoshimoto

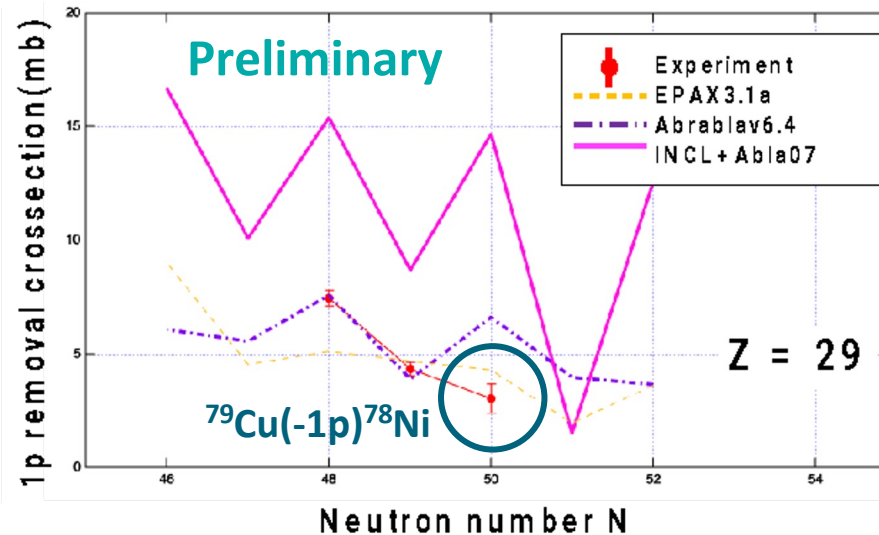
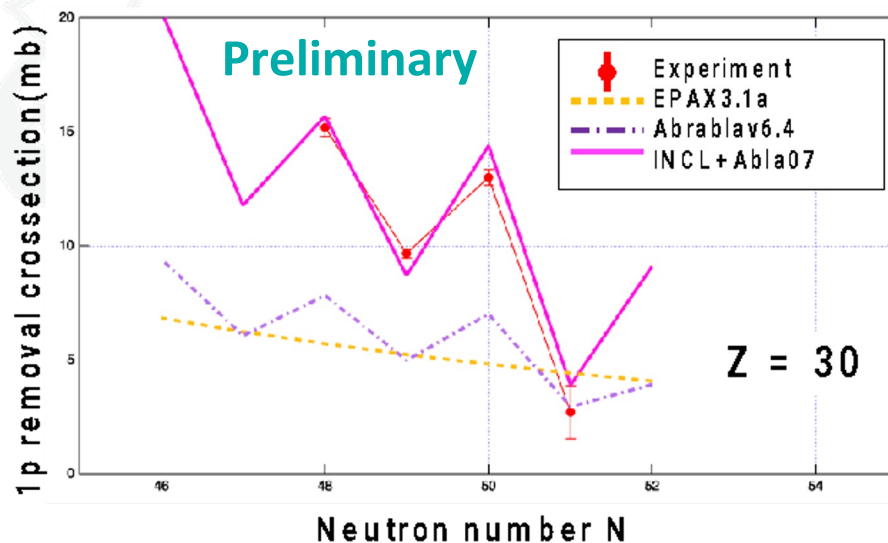
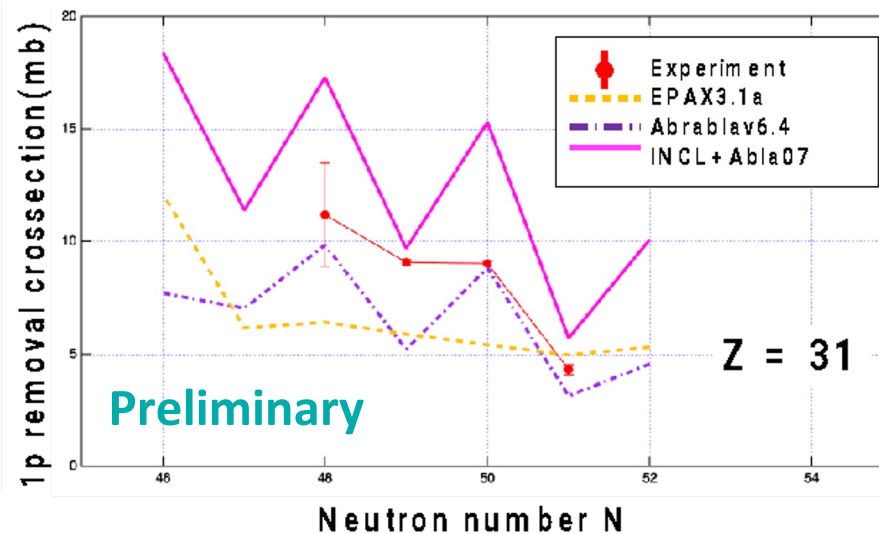
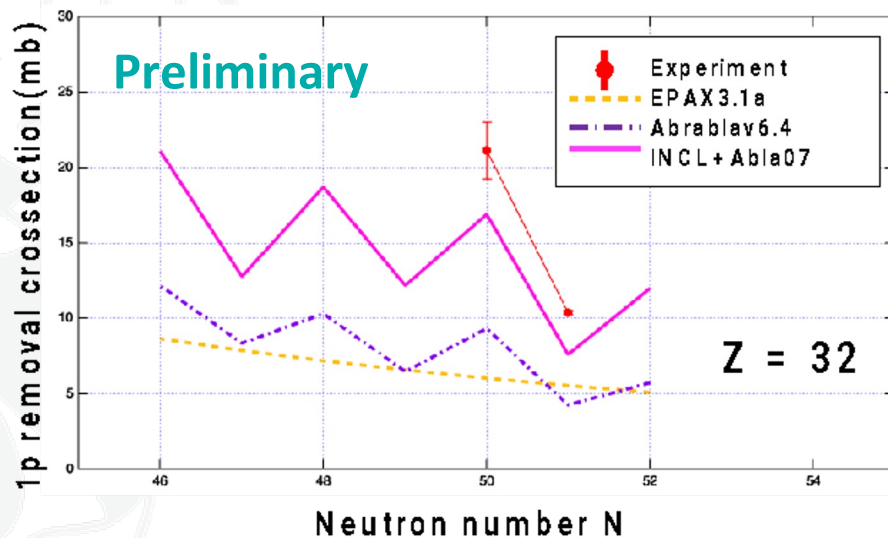




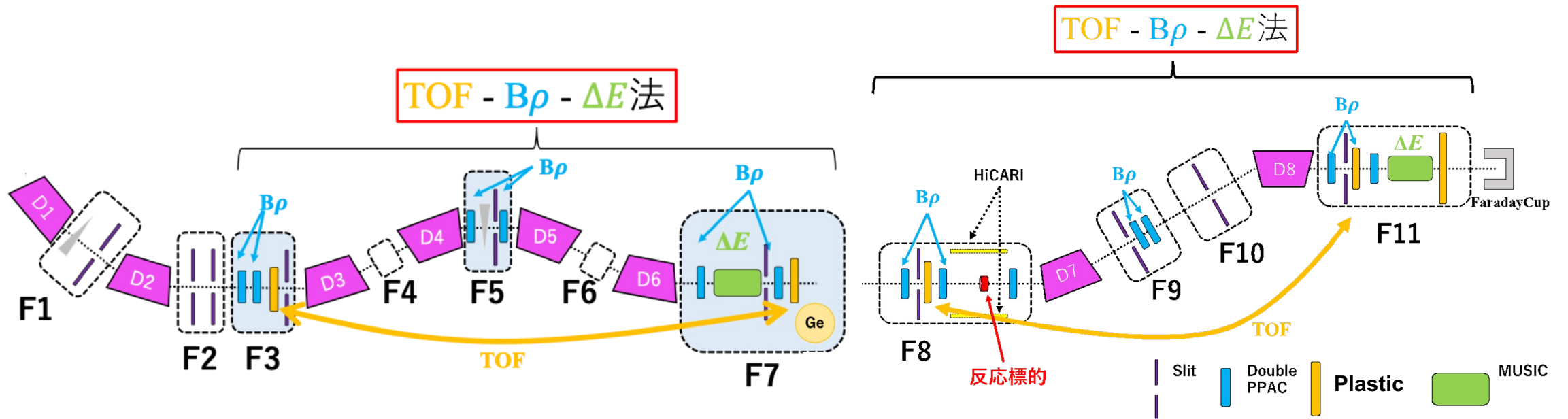
Preliminary results with a part of the data

Note:
About half of the
statistics analysed

Beam transmission in
ZeroDegree to be
corrected



Detectors set up



Beam @F7
 ^{80}Zn 250 MeV/u
 Total 50kHz



Beam @F11
 ^{79}Cu 210 MeV/u
 Total 25k Hz

ビーム設定

表 2.4 本実験における BigRIPS のビームライン設定

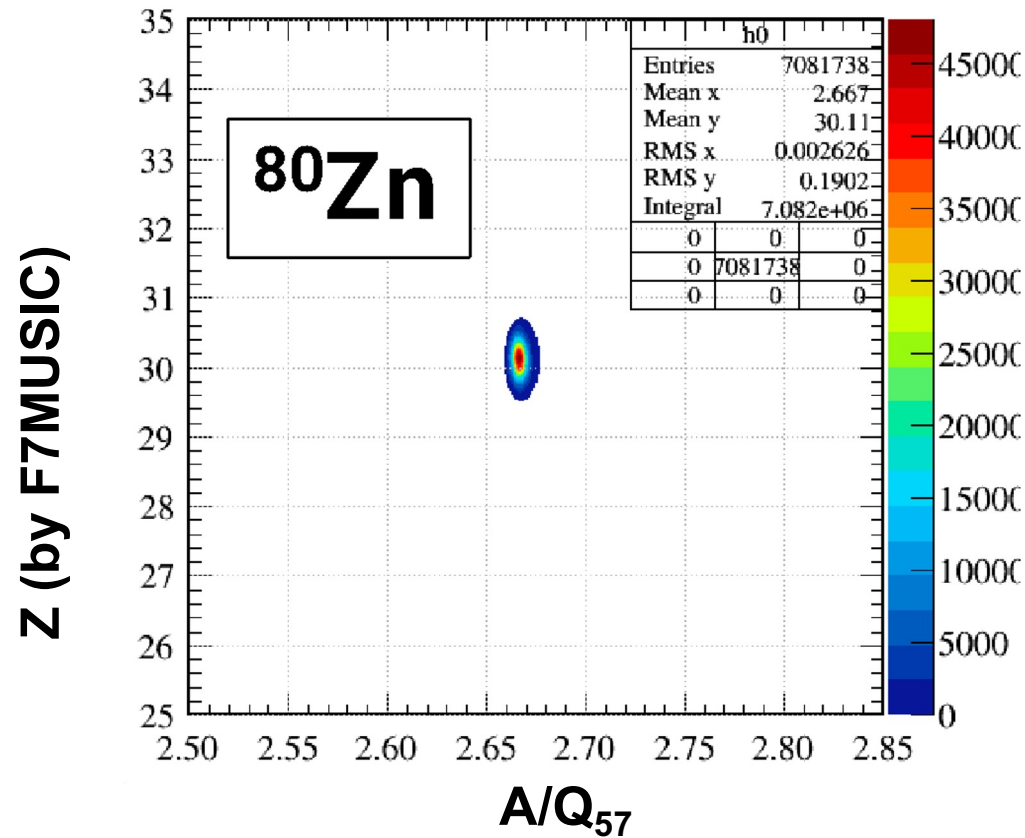
名称	設定
核種	^{80}Zn
F0 生成標的 Be	4 mm
F1 Wedge 型ディグレーダー Al	8 mm 7.3129 mrad
F5 Wedge 型ディグレーダー Al	2.0 mm 1.60 mrad
Slit	F1 L: 42.80 mm,R: 64.20 mm
	F2 L: 7.00 mm,R: 12.00 mm
	F5 L:110.00 mm,R: 63.40 mm
	F7 L:110.00 mm,R:110.00 mm
Brho	D1 7.8470 Tm
	D2 6.986 Tm
	D3 6.963 Tm
	D4 6.963 Tm
	D5 6.707 Tm
	D6 6.707 Tm
ビーム強度	F3 約 63 kHz
	F7 約 50 kHz

19

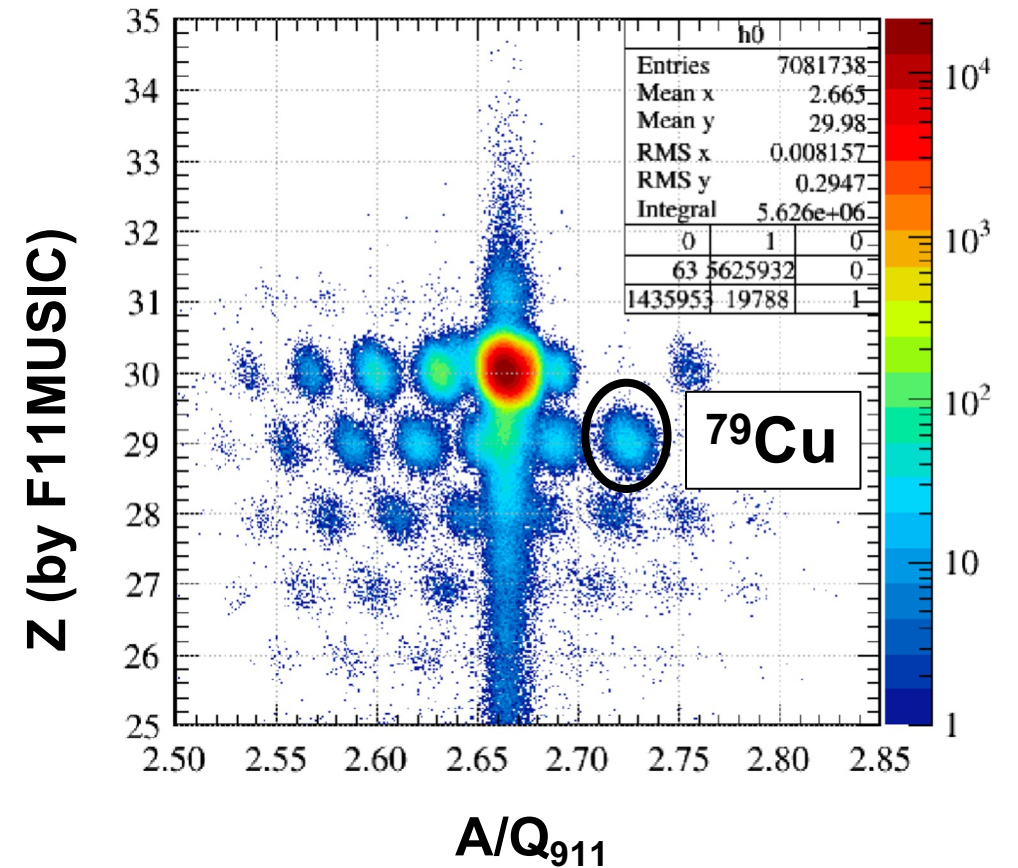
表 2.5 本実験における ZDS のビームライン設定

名称	Target in	Target out
核種	^{79}Cu	
反応標的 Be	6.8 mm	
Slit	F9 L: 120.00 mm,R: 120.00 mm	
	F10 L: 120.00 mm,R: 120.00 mm	
Brho	D7 6.015 Tm	6.724 Tm
	D8 6.006 Tm	6.717 Tm
ビーム強度	F11 約 24 kHz	約 34 kHz

Measurement of 1-proton removal cross section



Before Reaction target



After Reaction target

