

Development of energy degraded RI beams
at RIBF
(approved at last NP-PAC)

Toshiyuki Sumikama
Tokyo University of Science
Co-spokesperson: Eiji Ideguchi, CNS

Collaborators

- ❖ T. Sumikama
Tokyo University of Science
- ❖ E. Ideguchi, S. Shimoura, H. Miya, S. Go,
K. Kisamori, M. Takaki, S. Michimasa
CNS, University of Tokyo
- ❖ N. Aoi, N. Inabe, T. Ohnishi, N. Fukuda, H. Takeda,
D. Kameda, T. Kubo
RIKEN Nishina Center
- ❖ M.P. Carpenter
Argonne National Laboratory

Outline

- Typical experiment using energy degraded beam around 5 MeV/u
- Optimization of energy degraders
- New optics
- Estimation of beam time

Energy degraded beam experiment

- Nuclear reaction at 2 - 10 MeV/u
e.g. Fusion-evaporation reaction and Multiple Coulomb excitation

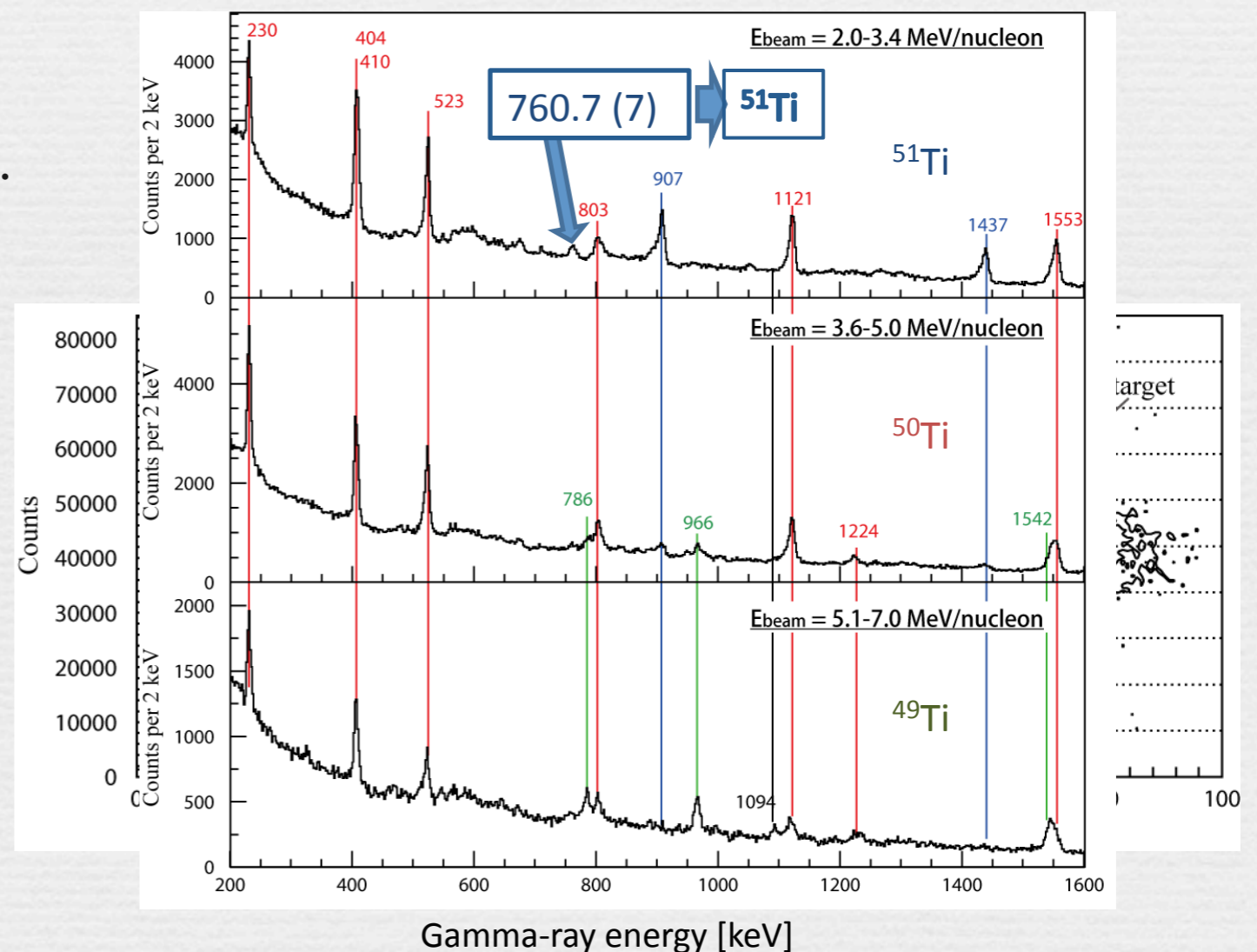
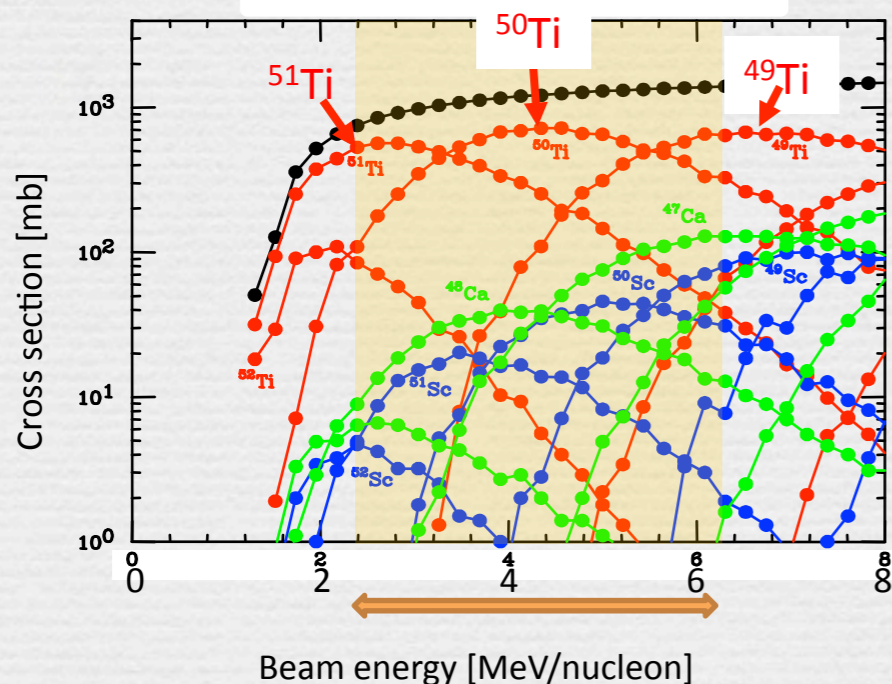
- Experiment performed at RIPS, RIKEN.



E. Ideguchi et al., EPJA 25 429(2005).
M. Niikura et al., EPJA 42, 271 (2009).

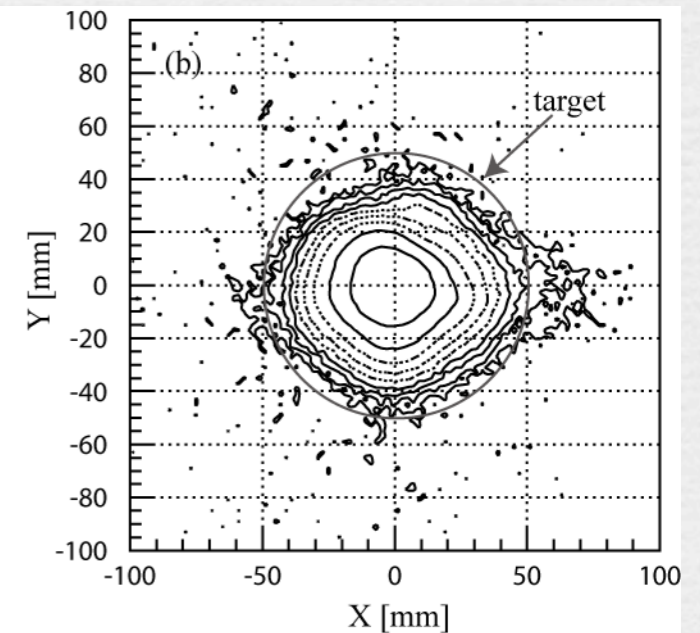
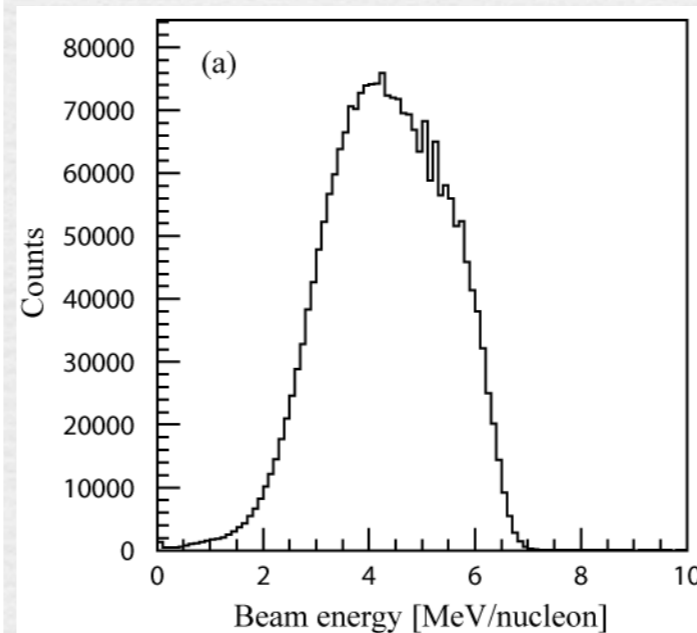
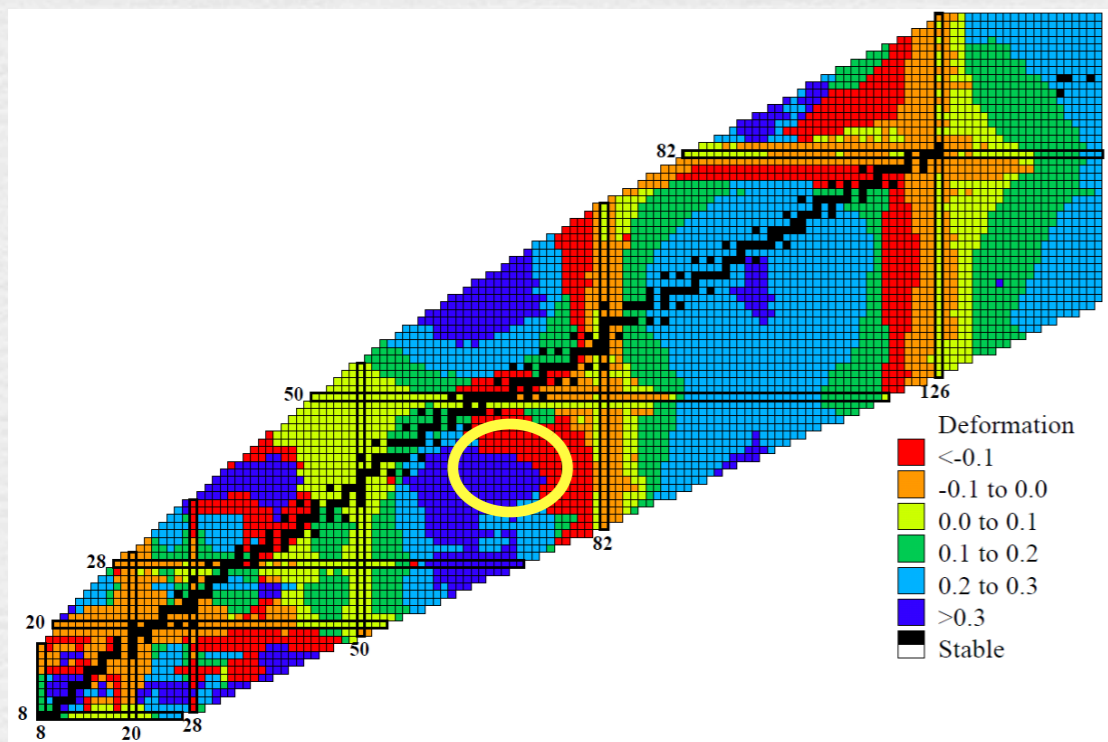
Using the broadened beam energy, excitation function was deduced to identify the evaporation channels.

Calculated excitation function (CASCADE)



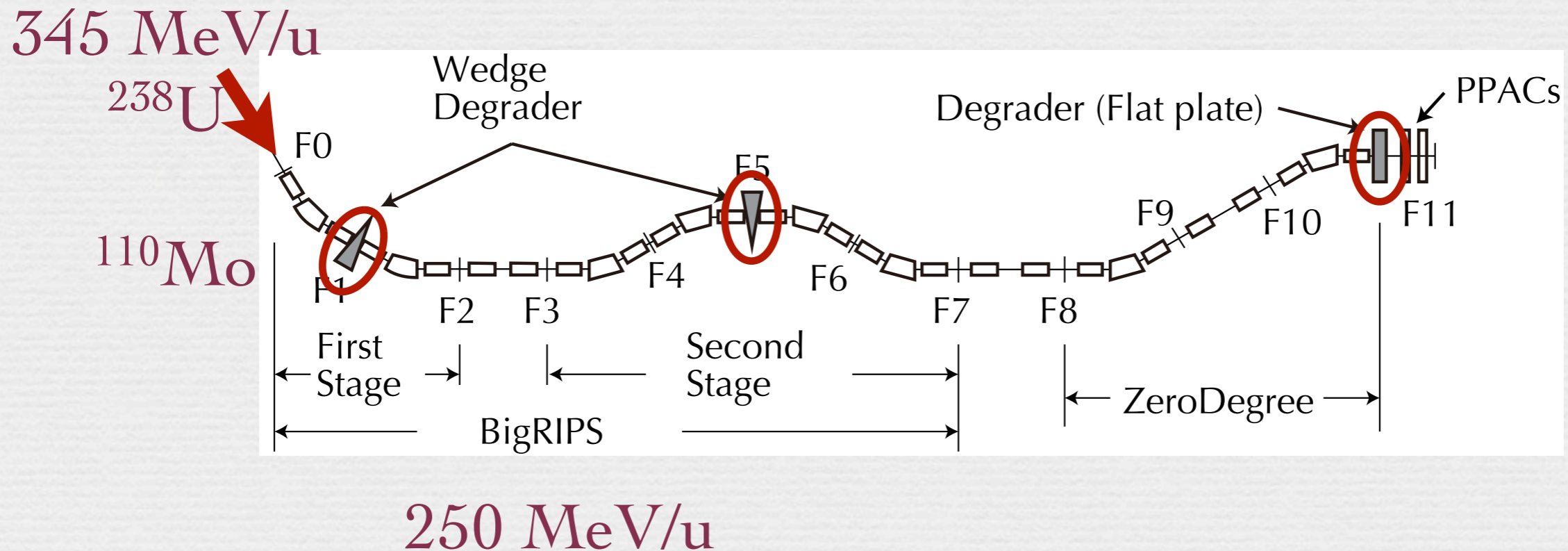
Requirement for degraded beam

- Requirement for energy degraded beam
 $E = 2 - 10 \text{ MeV/u}$
Beam spot size: $50 \text{ mm}\phi$
- Development of energy degraded beam.
Objective: ^{110}Mo
(neutron rich isotopes with $Z \sim 40$)



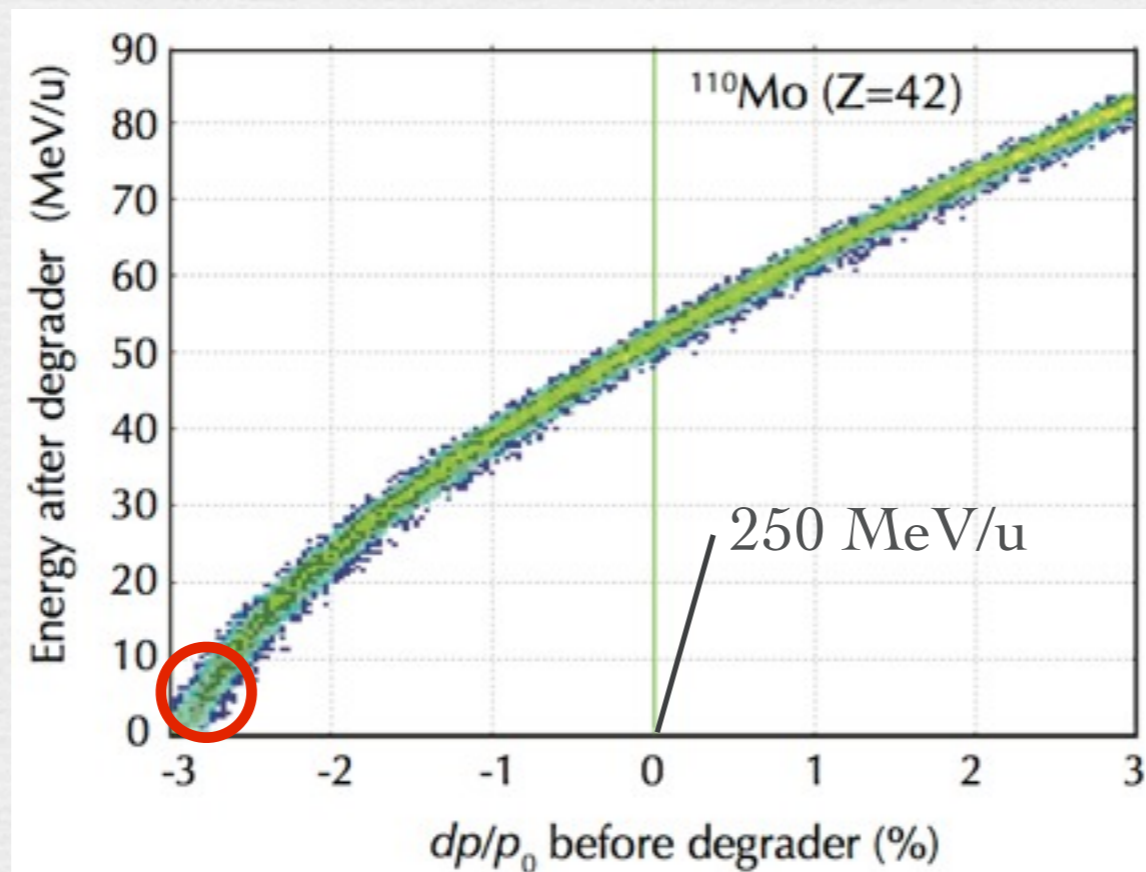
Optimization of energy degraders

- RI beam energy is degraded down to 5 MeV/u by using three energy degraders (Aluminum) at F1, F5 and F11.
- Degradation at F1; For RI beam separation
 - $d = 1.5 \text{ g/cm}^2$, ($d/R = 0.325$)
 - 250 MeV/u



Optimization of energy degraders

- Two degrader mode (degraders at F1 & F11)
flat plate degrader at F11



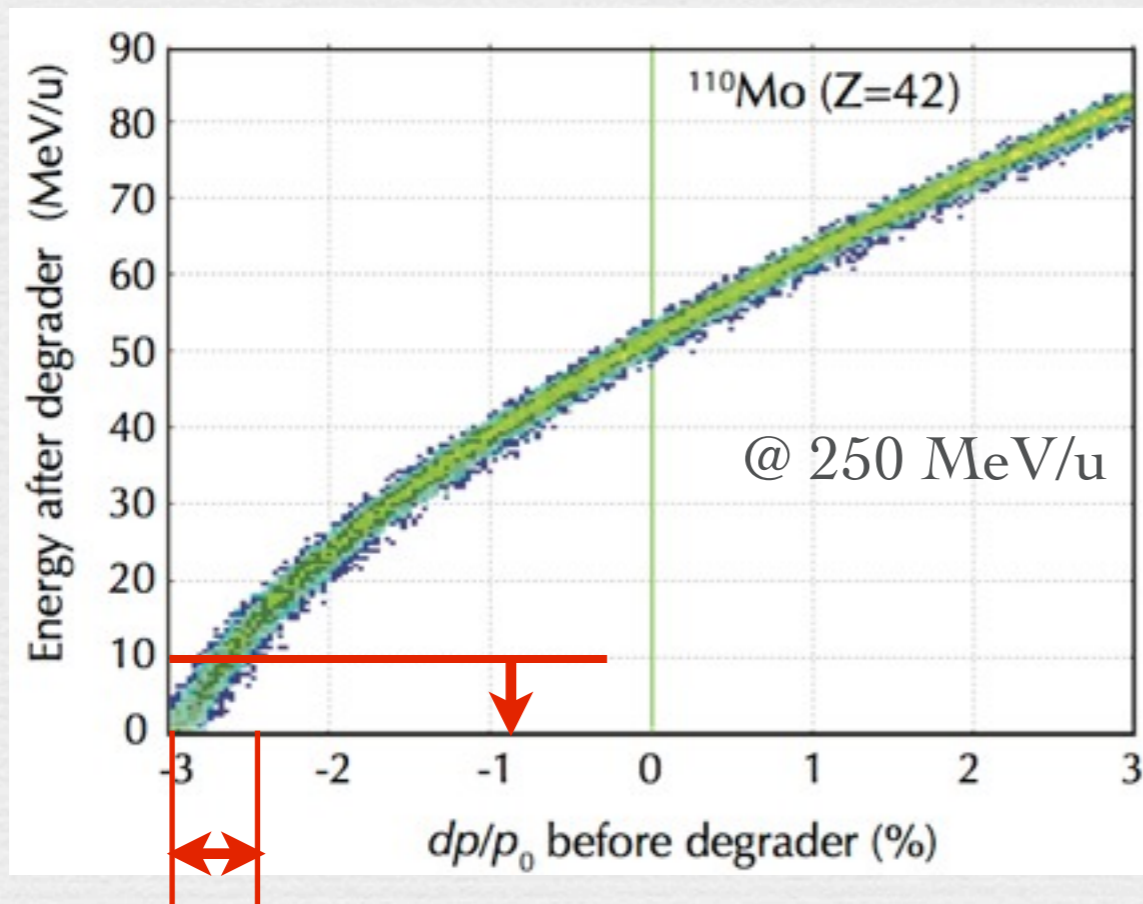
LISE++ simulation
(ATIMA 2.1)

Energy straggling
1 MeV/u : ATIMA 2.1
3 MeV/u : Guillemaud-Muller

Momentum acceptance: 6 %

Optimization of energy degraders

- Two degraders mode
flat plate degrader at F11



Effective momentum range

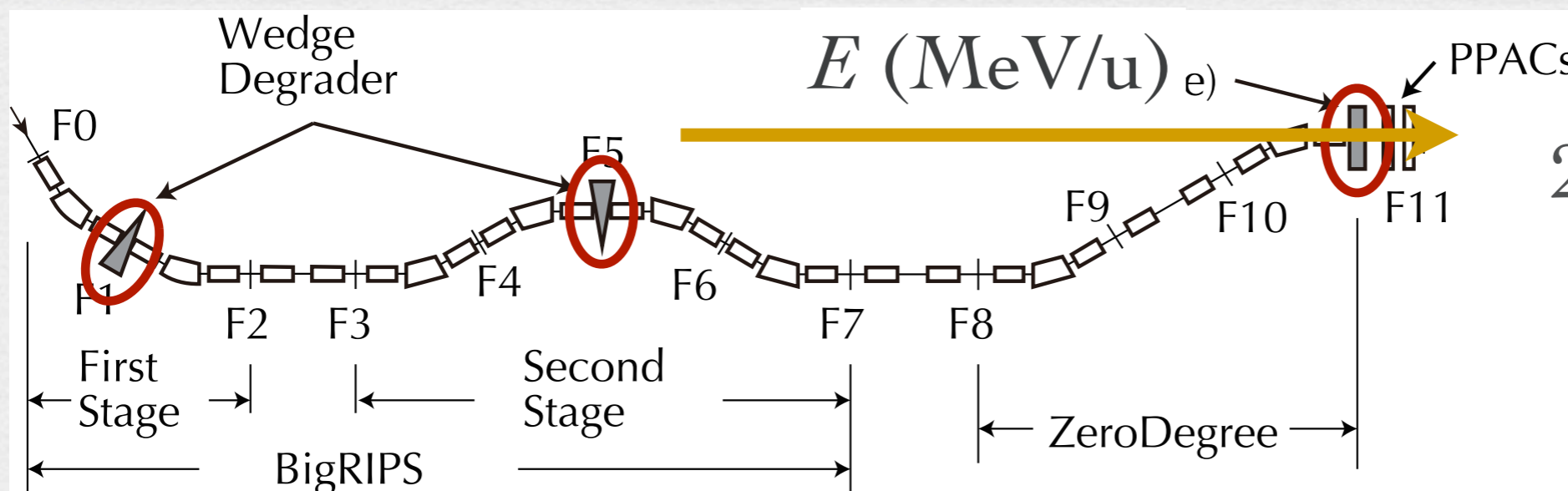
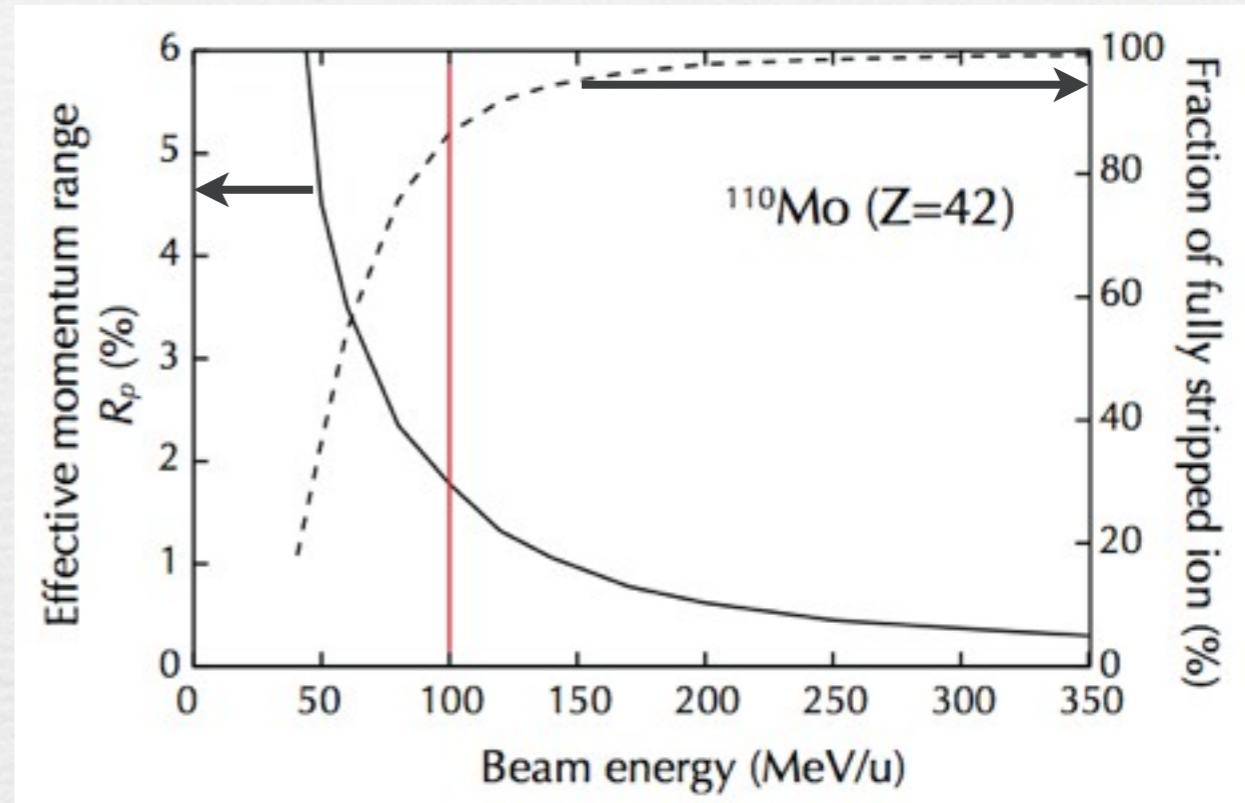
Transmission

$$= \frac{^{110}\text{Mo within acceptance}}{^{110}\text{Mo separated at 1st stage}}$$
$$= 5 \%$$

Acceptance
E: 2 - 10 MeV/u
Beam spot: 50 mm ϕ

Optimization of energy degraders

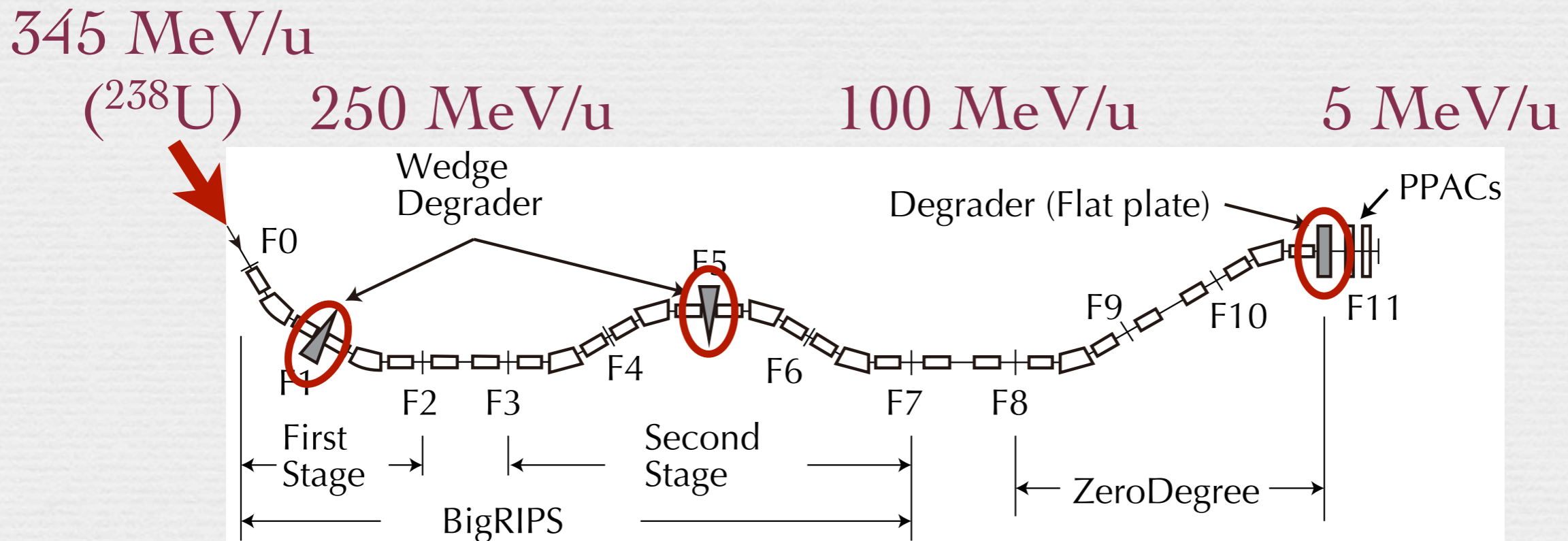
- 2nd degrader is used to degrade the beam energy
- 100 MeV/u
after 2nd degrader
19 % transmission



Optimization of energy degraders

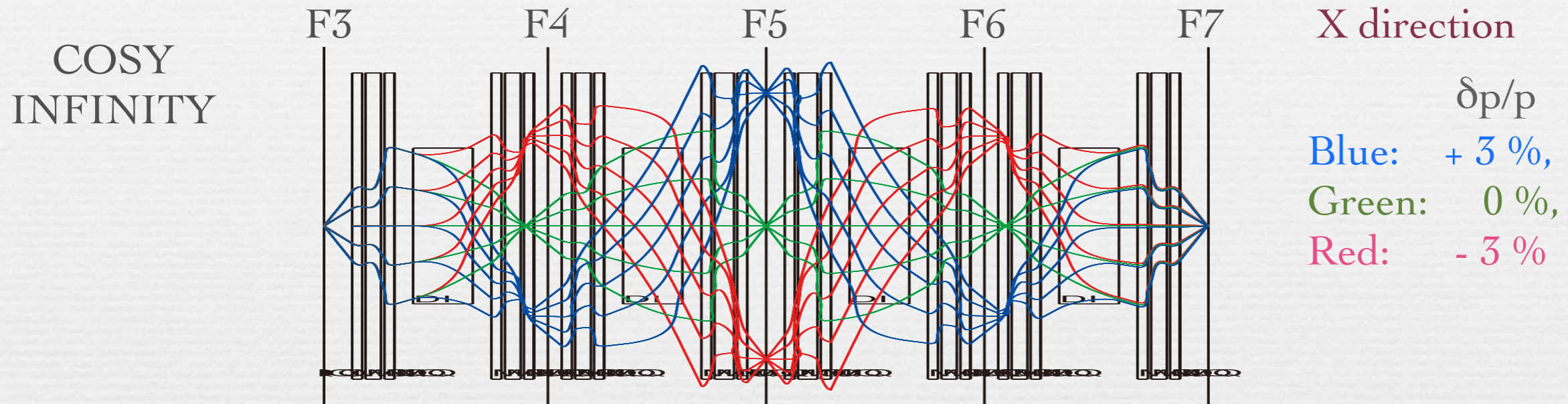
- Wedge-shaped degrader at F5
 - 100 MeV/u after F5 degrader
 - ρ spread from $\pm 3\%$ to $\pm 1.2\%$
 - New optics mode is designed to achieve achromatic condition.

$$dp/p \quad \pm 3\% \quad \longrightarrow \quad \pm 1.2\%$$

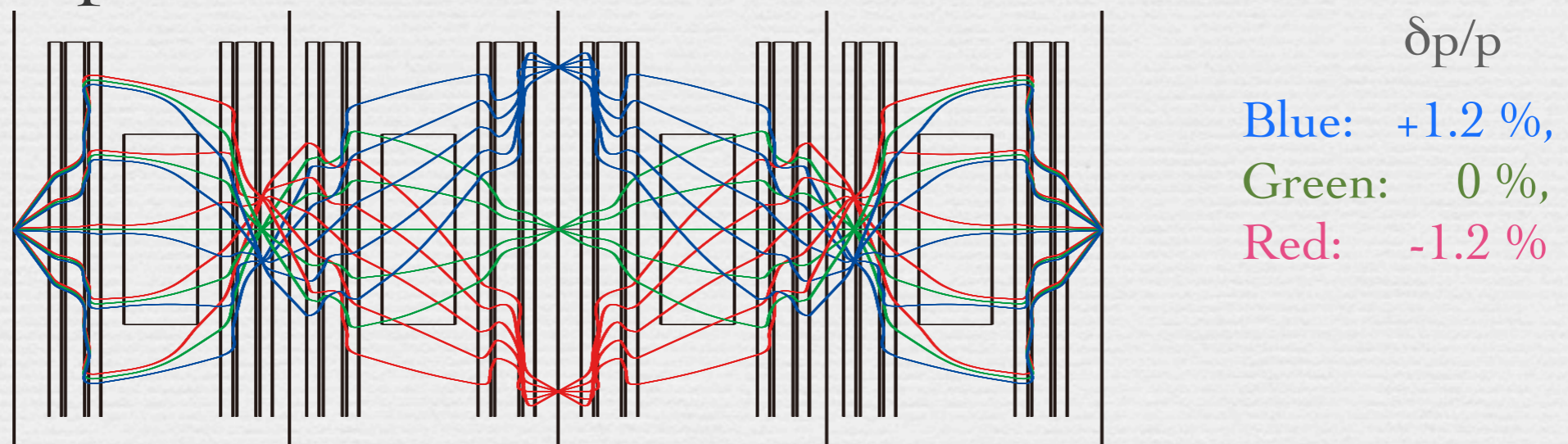


New optics mode @ 2nd stage of BigRIPS

Standard optics mode

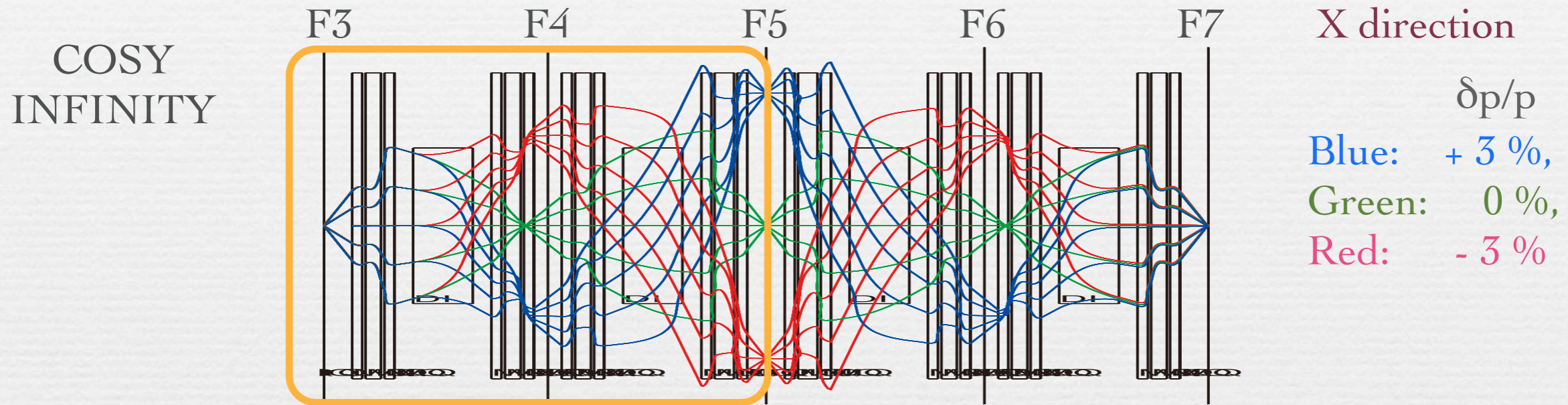


New optics mode



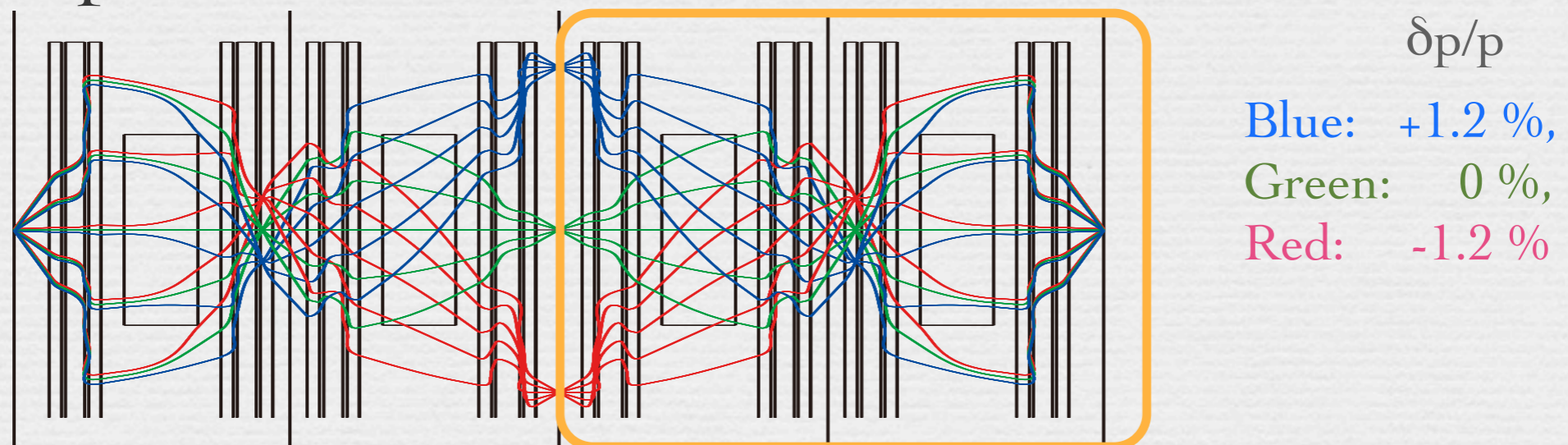
New optics mode @ 2nd stage of BigRIPS

Standard optics mode



$$\delta p/p \pm 3\% \longrightarrow \pm 1.2\%$$

New optics mode



Energy degraded beam @ final focal plane

Simulation of energy and beam spot size at F11

LISE++

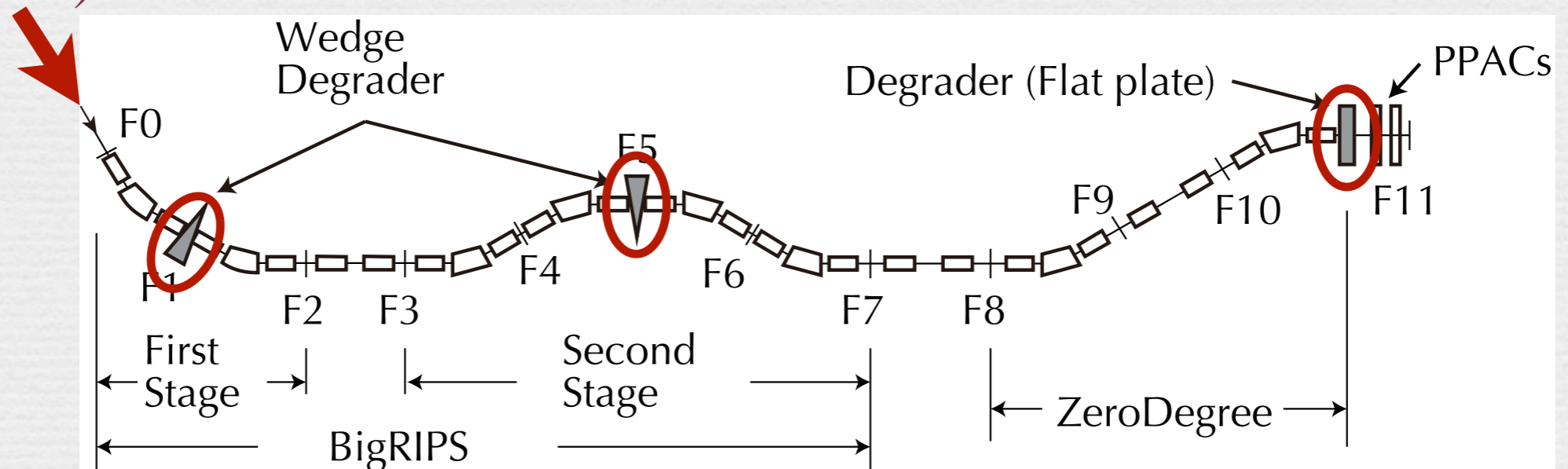
$$dp/p \quad \pm 3 \% \quad \pm 1.2 \%$$

345 MeV/u

(²³⁸U) 250 MeV/u

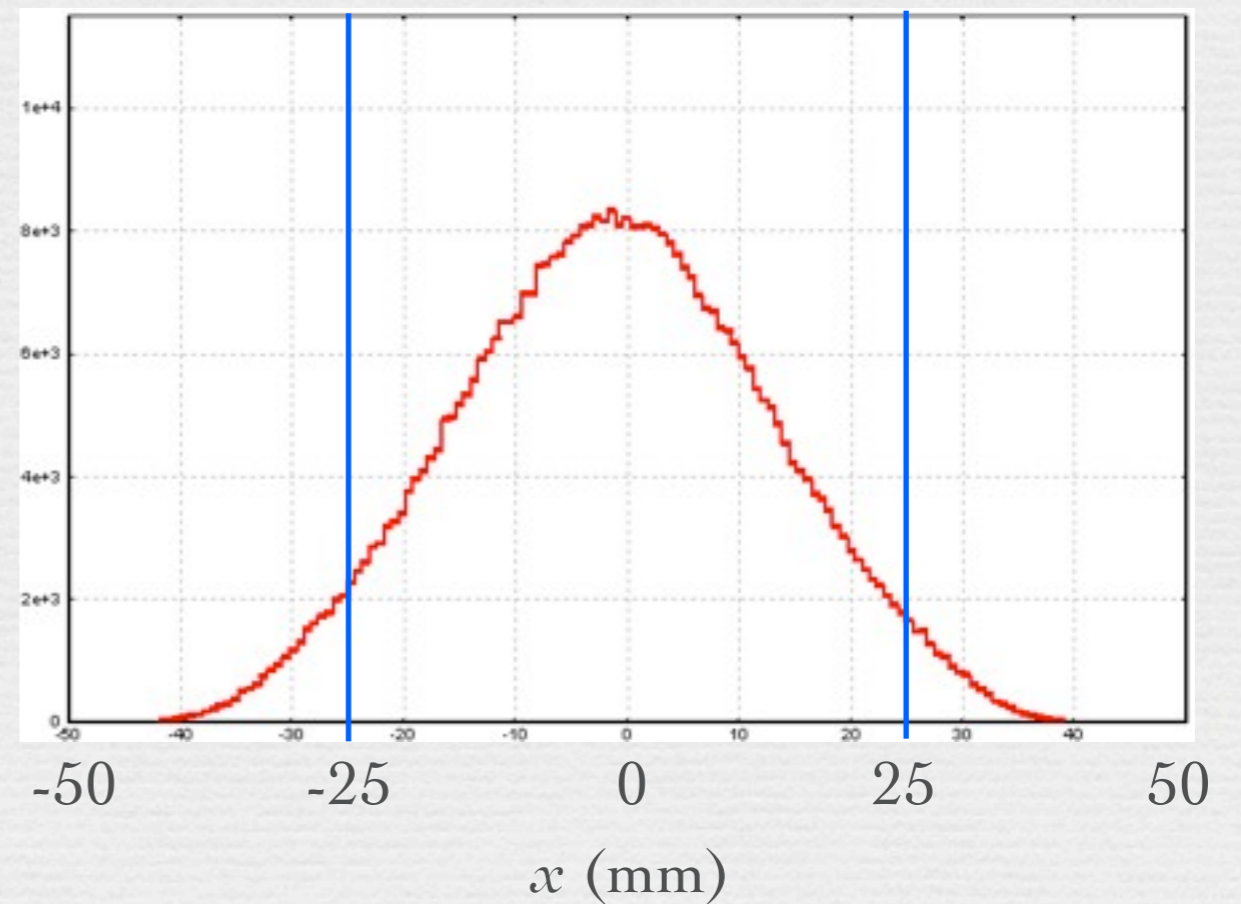
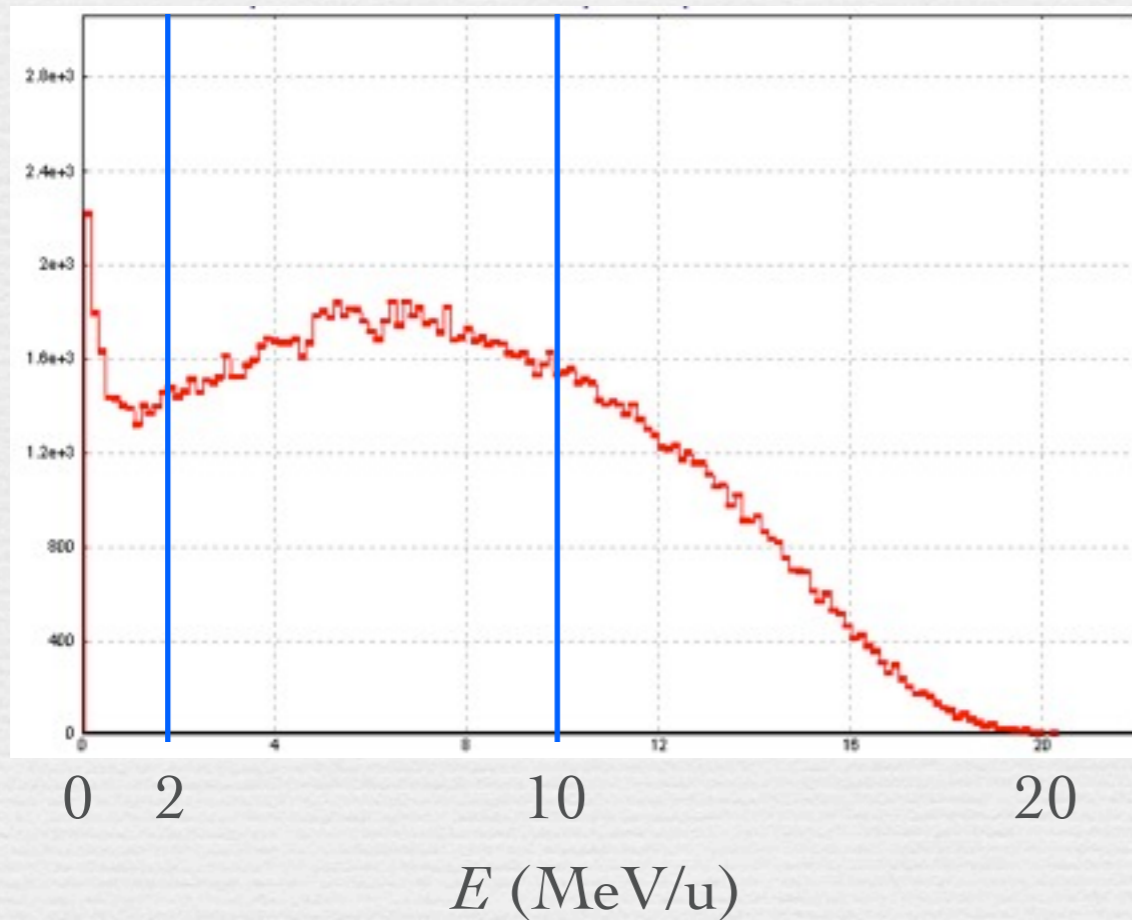
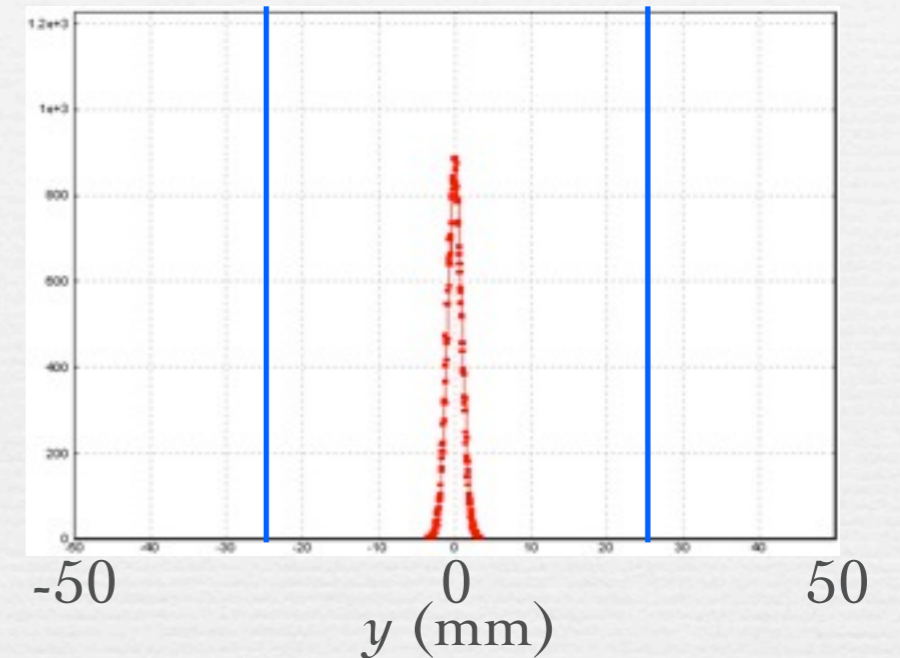
100 MeV/u

5 MeV/u



Energy degraded beam @ final focal plane

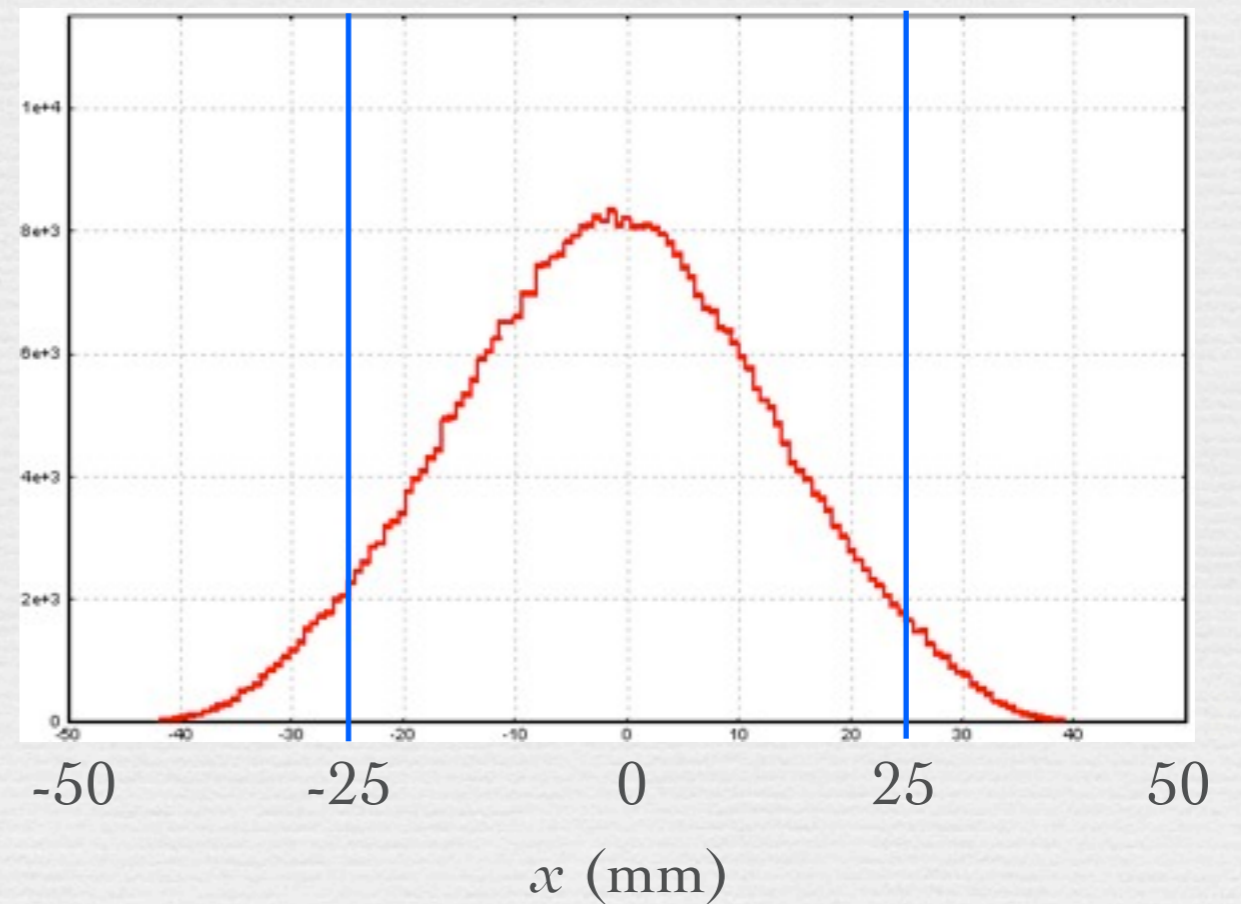
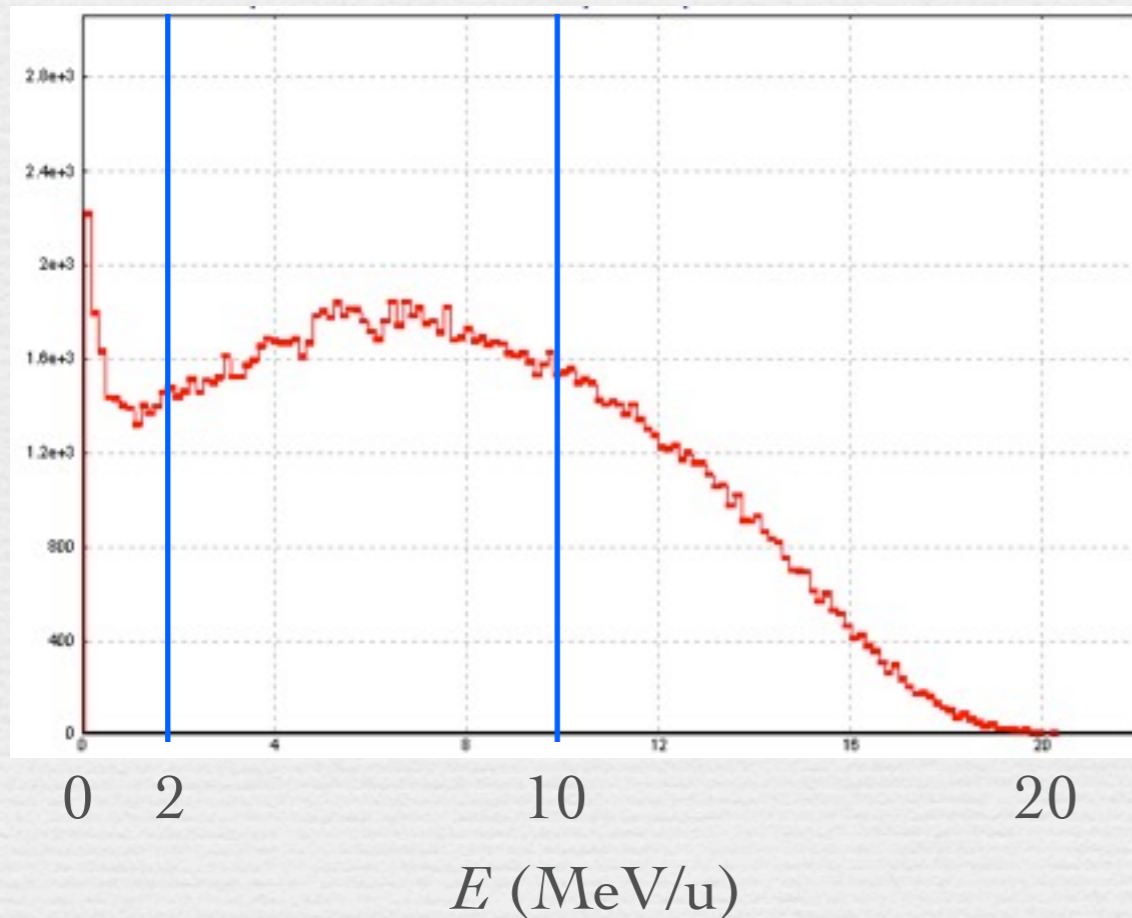
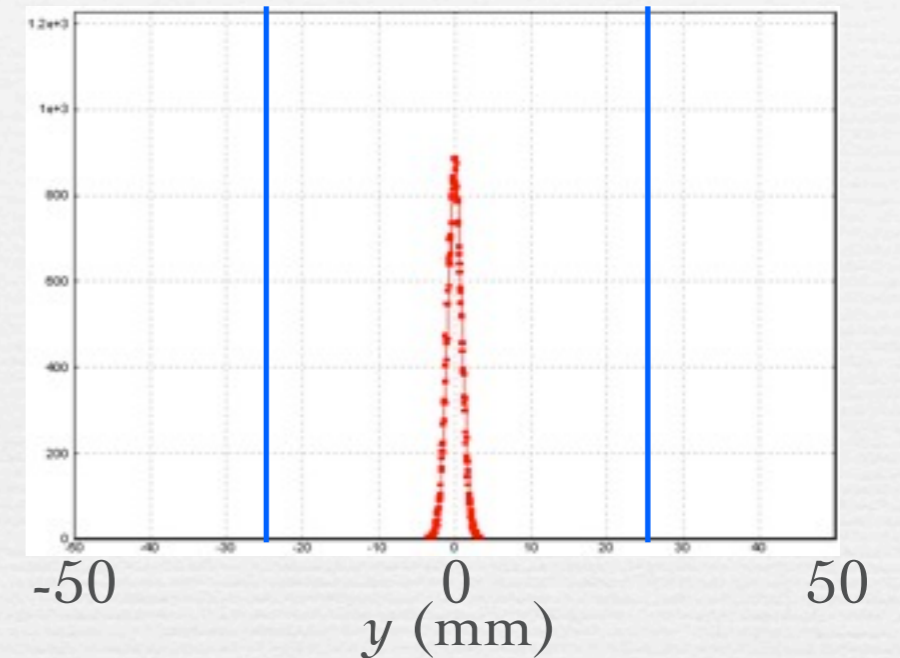
- Total transmission is 46 %.



Energy degraded beam @ final focal plane

☛ Total transmission is 46 %.

Degraders	Optics	Transmission
F1, F11	Standard	5%
F1, F5, F11	Standard	19%
F1, F5, F11	New	46%



Collaboration

- ❧ Kickoff Meeting mainly by Japanese Users
Mini-workshop of E-degraded RI beams at RIBF
Tomorrow 10:00 - RIBF 2F Conference Hall
After lunch - RIBF 2F Meeting Room (203)
- ❧ Japan, Europe & USA
- ❧ Clover Array for stopped & E-degraded RI beam
M. Carpenter (ANL) & E. Ideguchi (CNS)
- ❧ Hopefully; EURICA
- ❧ Collaboration Name (To be discussed on this Wed.)
SRIC: Slowed down RI beam Collaboration at RIBF
EDRIC: Energy Degraded RI beam Collaboration at RIBF
SRIB: Slowed down RI Beam at RIBF
- ❧ Please send an e-mail if you want to join this project.
sumikama@ph.noda.tus.ac.jp

E degraded RI beam campaign with EURICA

- This winter: beam time for development (hopefully)
- Possible campaign of energy degraded RI beam with EURICA

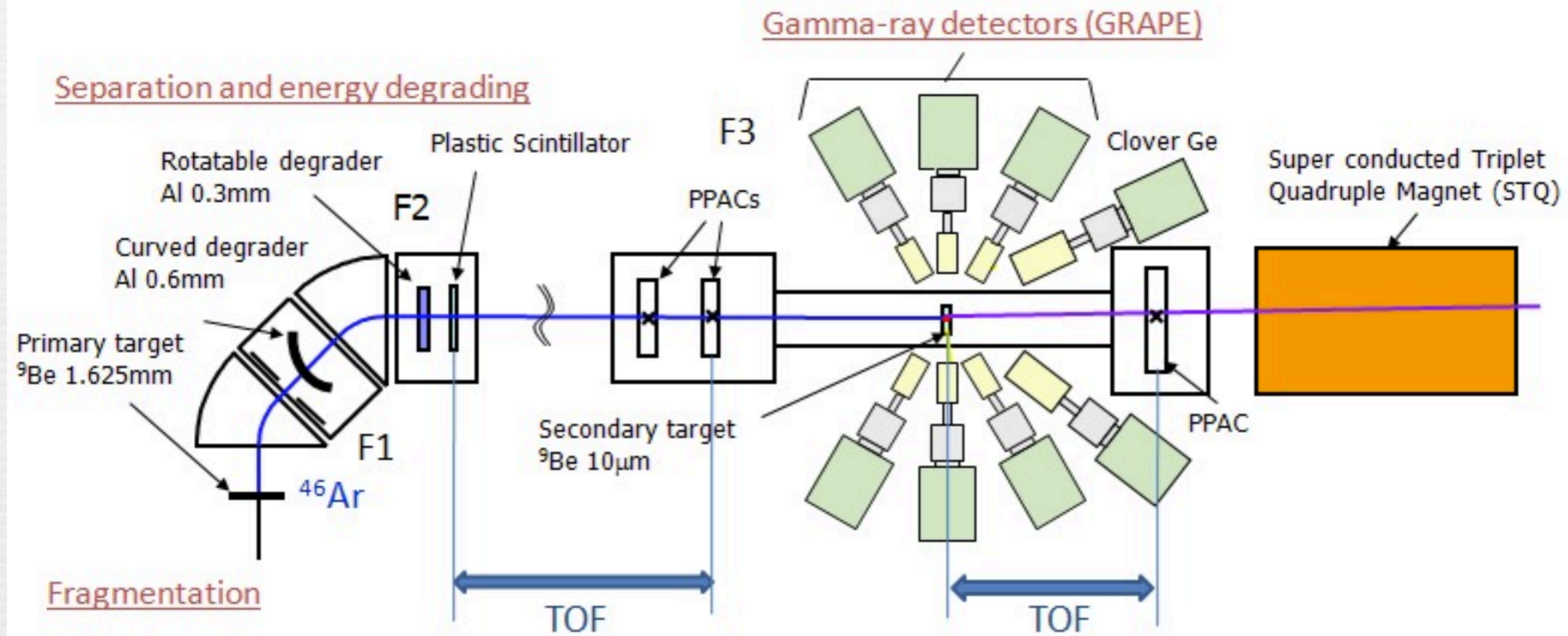
Thank you for your attention

Experimental Setup

RIPS in RIKEN (E6 cave)

Nuclear reaction: ${}^9\text{Be}({}^{46}\text{Ar}, xn){}^{55-x}\text{Ti}$

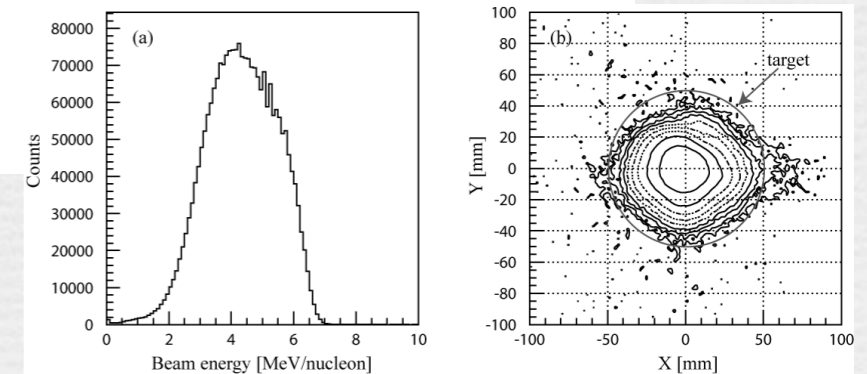
Separation and energy degrading



Fragmentation

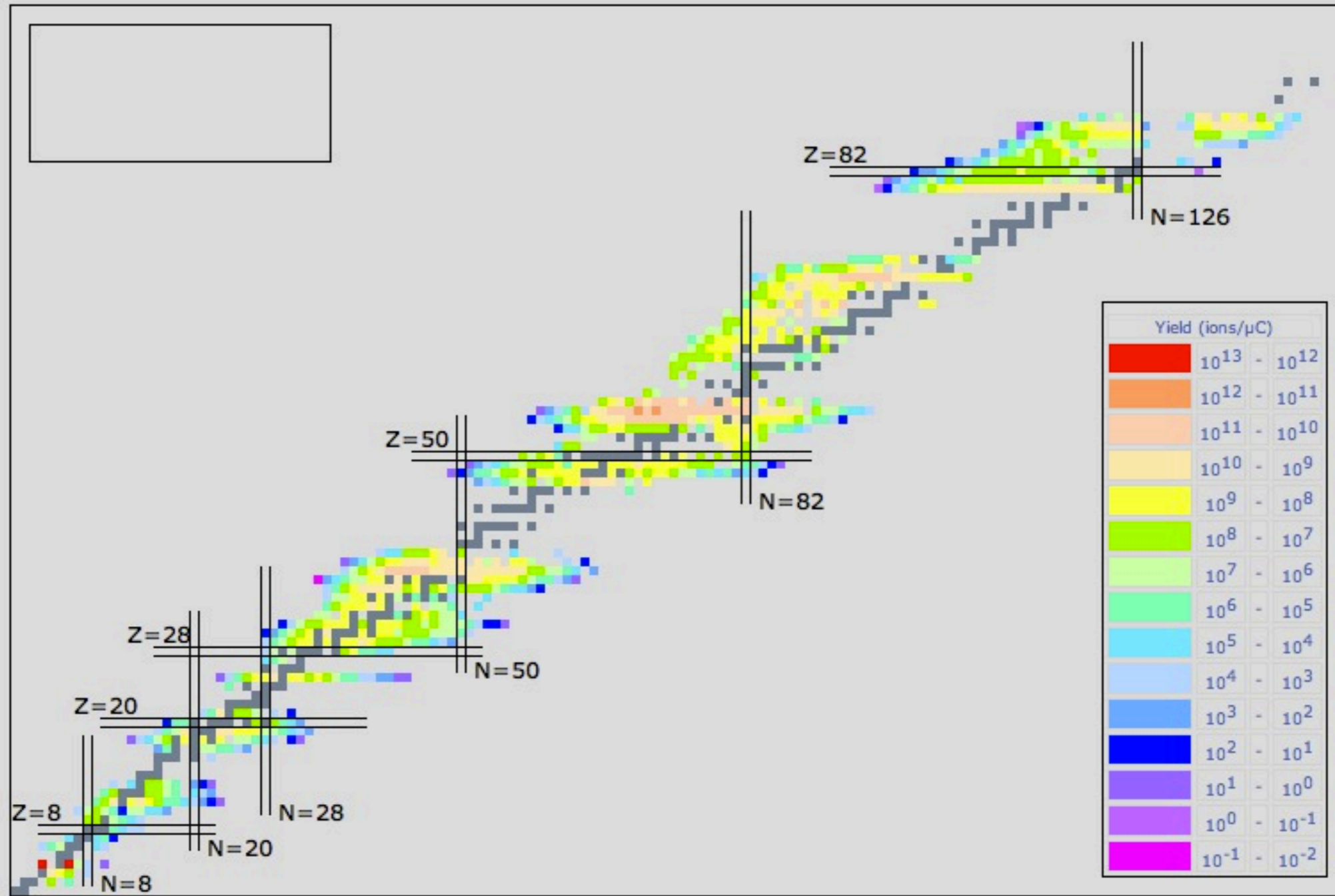
${}^{48}\text{Ca}$ primary beam
63.4 A MeV

Measurement of beam energy and position



Courtesy of Ideguchi-san

Nuclear chart for ISOLDE



Estimation of beam time

- BigRIPS tuning for ^{110}Mo and optics tuning of standard optics mode
 - 1 day
- Study of new optics mode
 - 5 hours
- Degraded beam study with standard optics
 - 7 hours
- Degraded beam study with new optics
 - 12 hours
- Total
 - 2 days

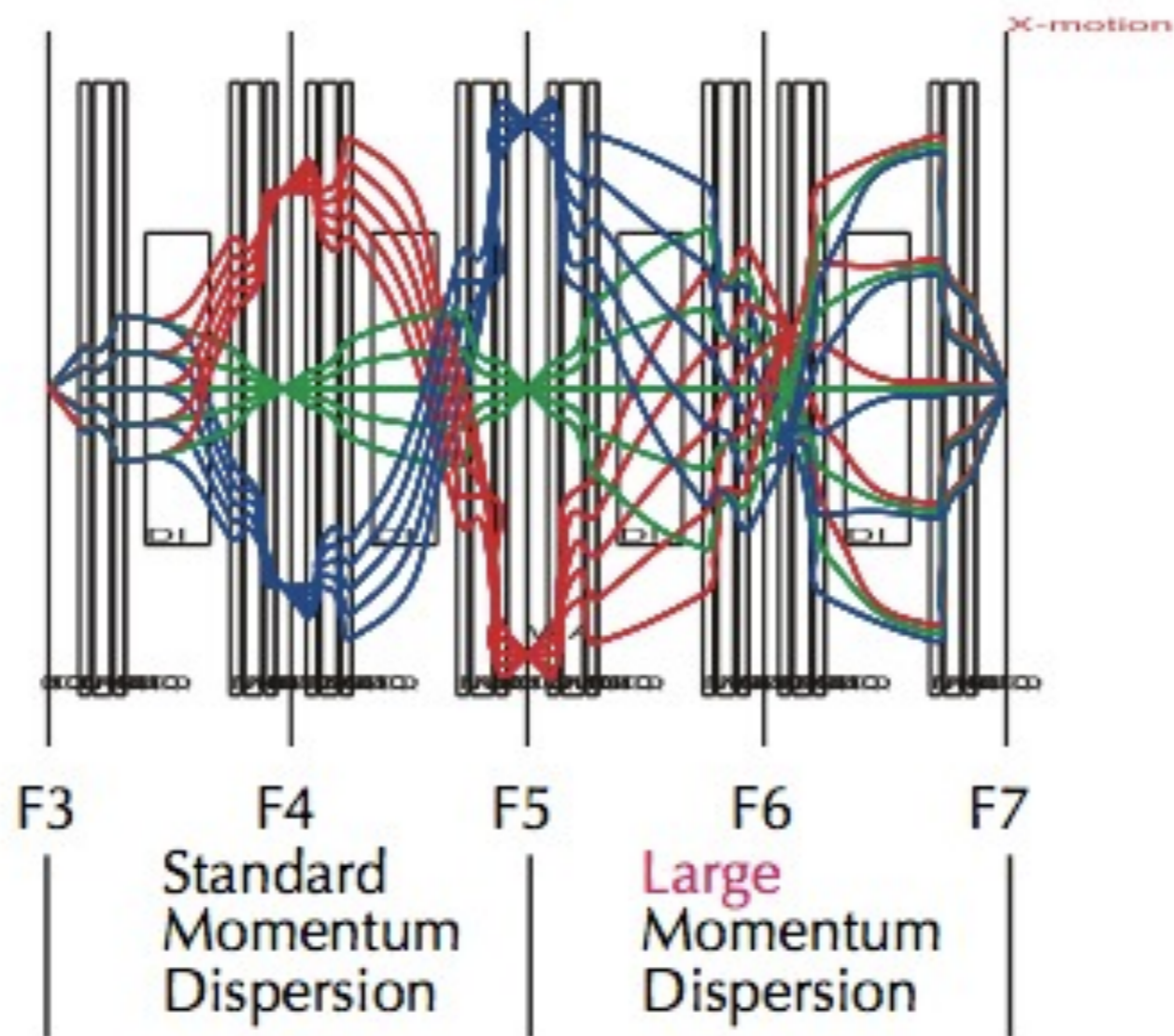
(b)

Degrader

$\pm 3\%$



$\pm 1.2\%$



F3

F4

F5

F6

F7

Standard
Momentum
Dispersion

Large
Momentum
Dispersion

Acromatic

Dispersive

Acromatic