Particle identification of RI beam in Sn region with the SAMURAI spectrometer

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Many slides are taken from a presentation by J. Yasuda in EMIS2015, May 15, 2015

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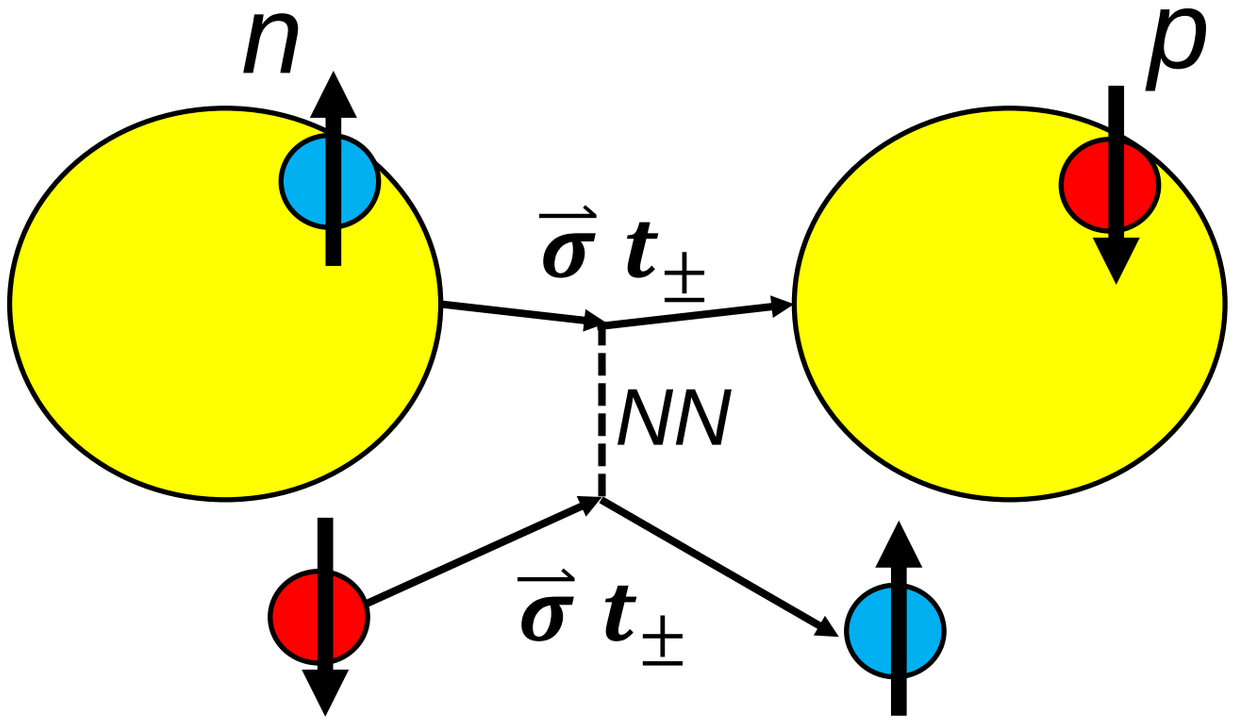
Outline

- Background of 132Sn(p,n) study
- Experimental setup for 132Sn(p,n) reaction at 250 MeV/u
- Particle identification (PID) analysis by SAMURAI
- How charge state appears in the PID plot
- Future prospects and ideas

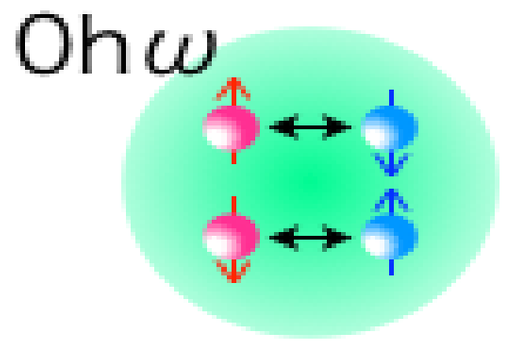
Charge-Exchange (CE) reactions

ΔT=1, ΔS=1,ΔL=0 induced by $\vec{\sigma}\, t_{\pm}$

strength : **B(GT)**



(p,n), (^{3}He,t), (n,p), (t,^{3}He), …

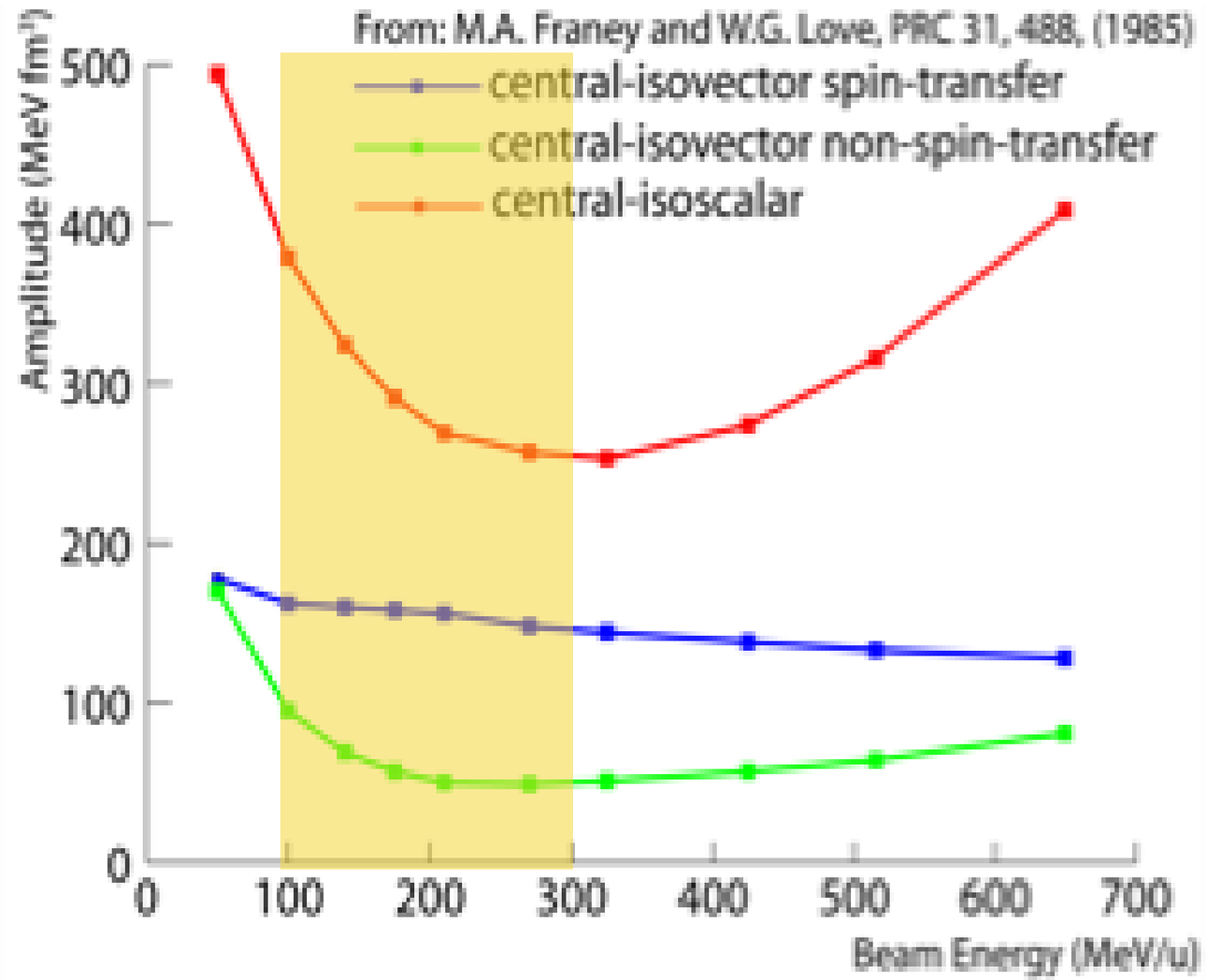


GTR

(Δn=0)

Cannot access by β-decay

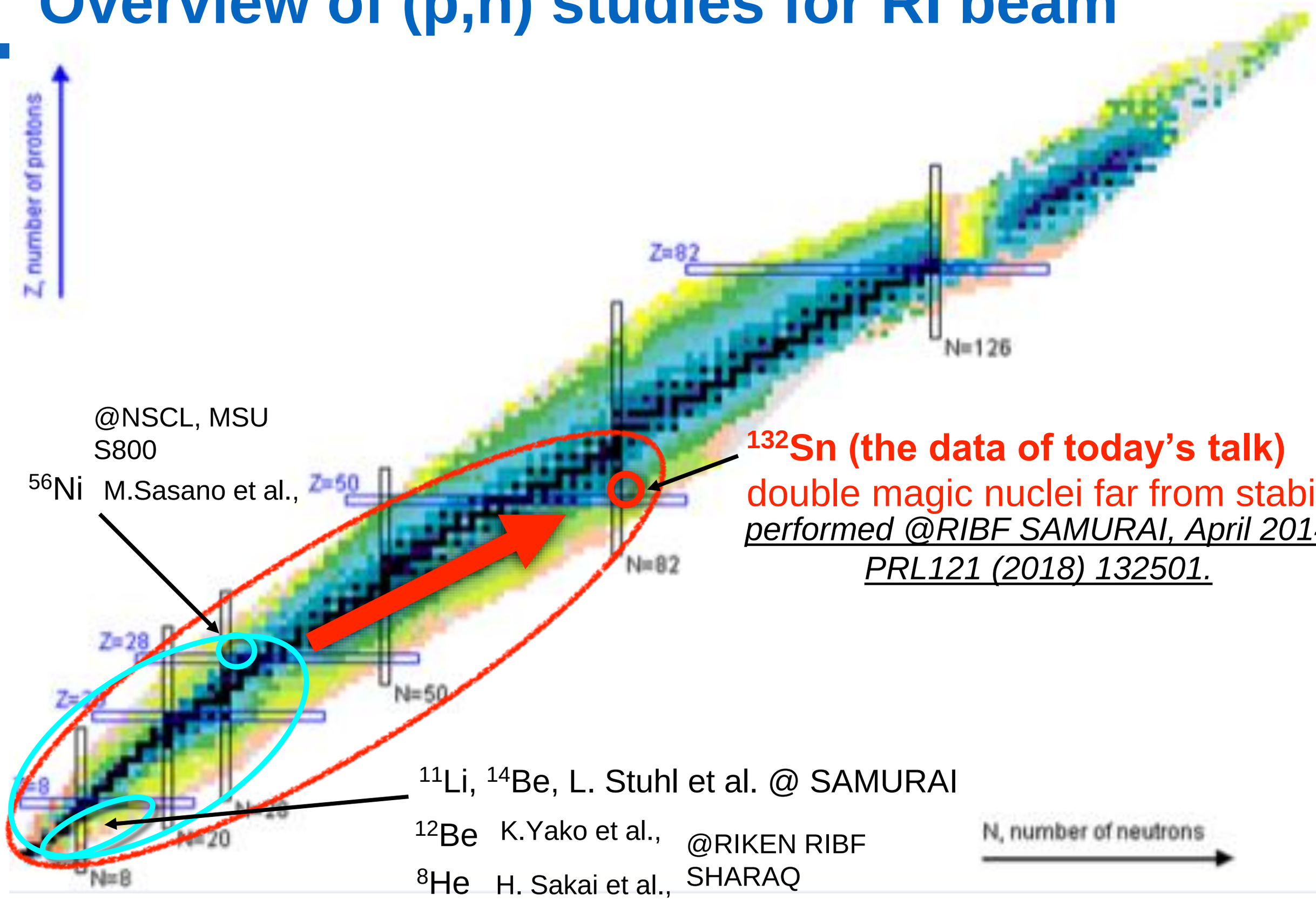
Charge exchange reactions



$$\frac{d\sigma}{d\Omega}(q=0) = \hat{\sigma} B(GT)$$

Need to handle RI beams with intermediate energies from 100 to 300 MeV

Overview of (p,n) studies for RI beam



@NSCL, MSU
S800
^{56}Ni M.Sasano et al.,

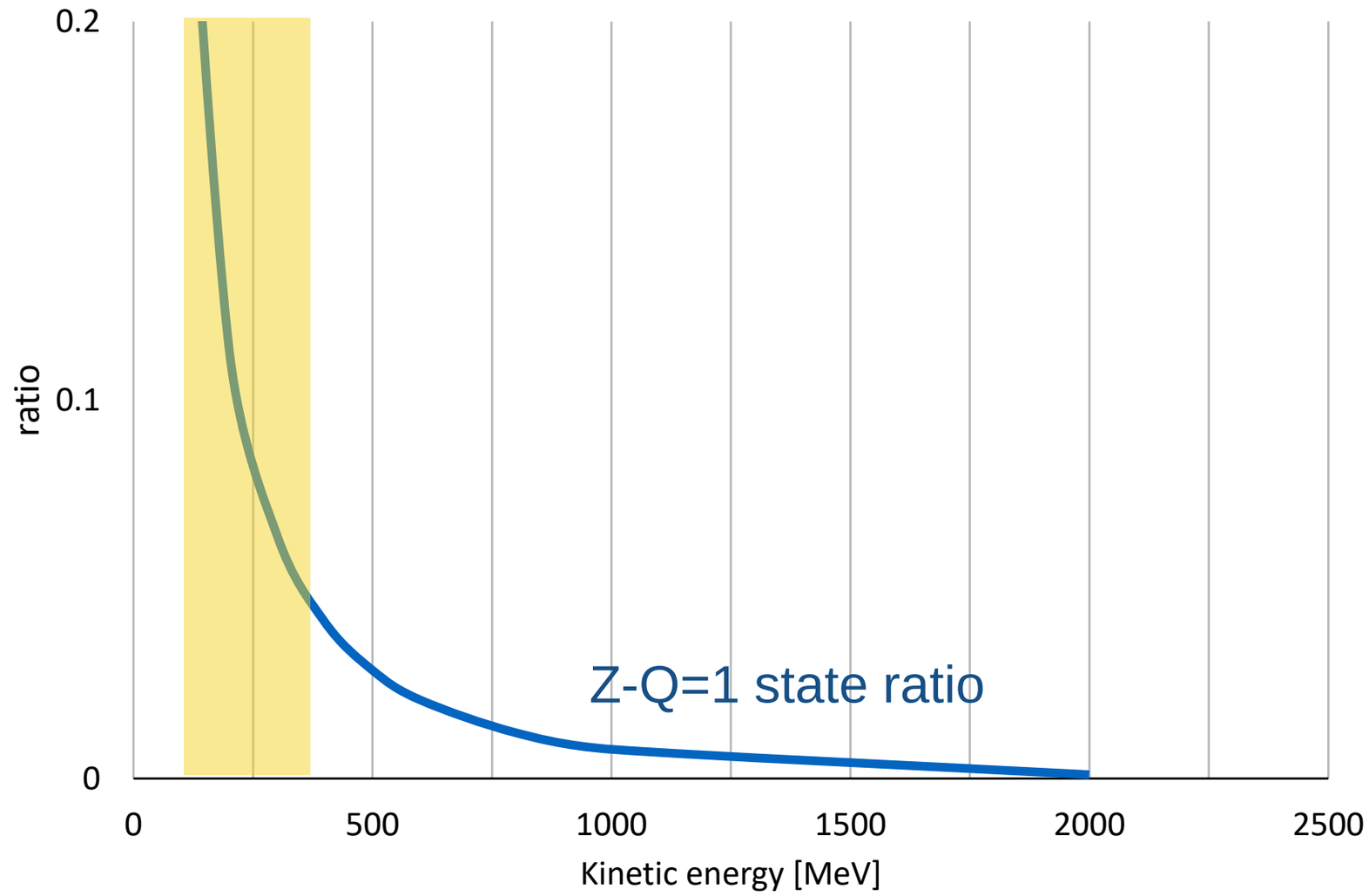
^{132}Sn (the data of today's talk)
double magic nuclei far from stability
performed @RIBF SAMURAI, April 2014
PRL121 (2018) 132501.

^{11}Li, ^{14}Be, L. Stuhl et al. @ SAMURAI

^{12}Be K.Yako et al., @RIKEN RIBF

^{8}He H. Sakai et al., SHARAQ

Charge state population for Sn beams

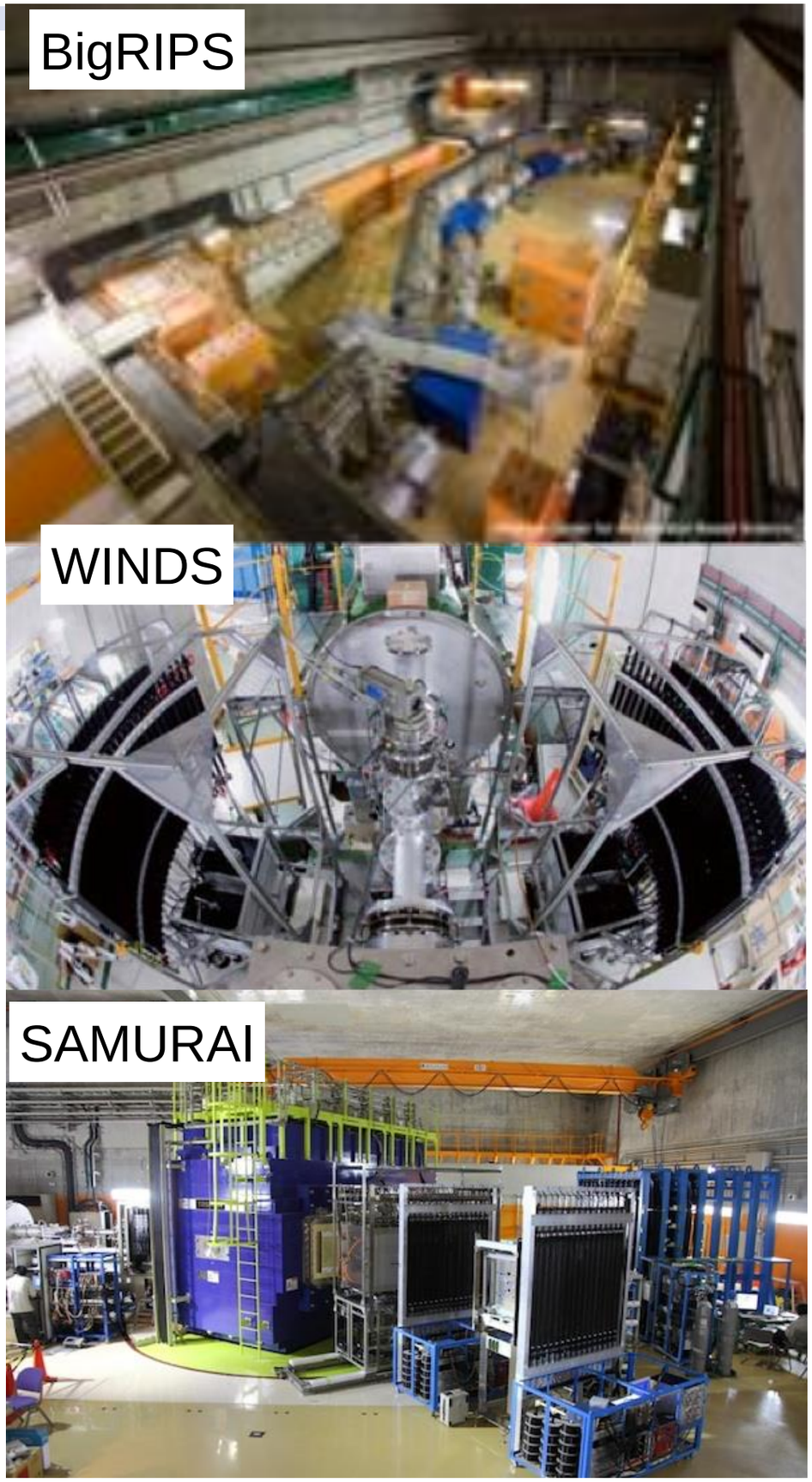


(p,n) measurement with WINDS + SAMURAI

- **Beam**
  - High Intensity : >10^4 pps
  - Intermediate kinetic energy : 200~300 MeV/u
    - **can access to far from the stability line**

- **Neutron detection**
  - WINDS(Wide angle Inverse kinematics Neutron Detectors for SHARAQ) : 73 scintillators
    - **cover wide angular range**

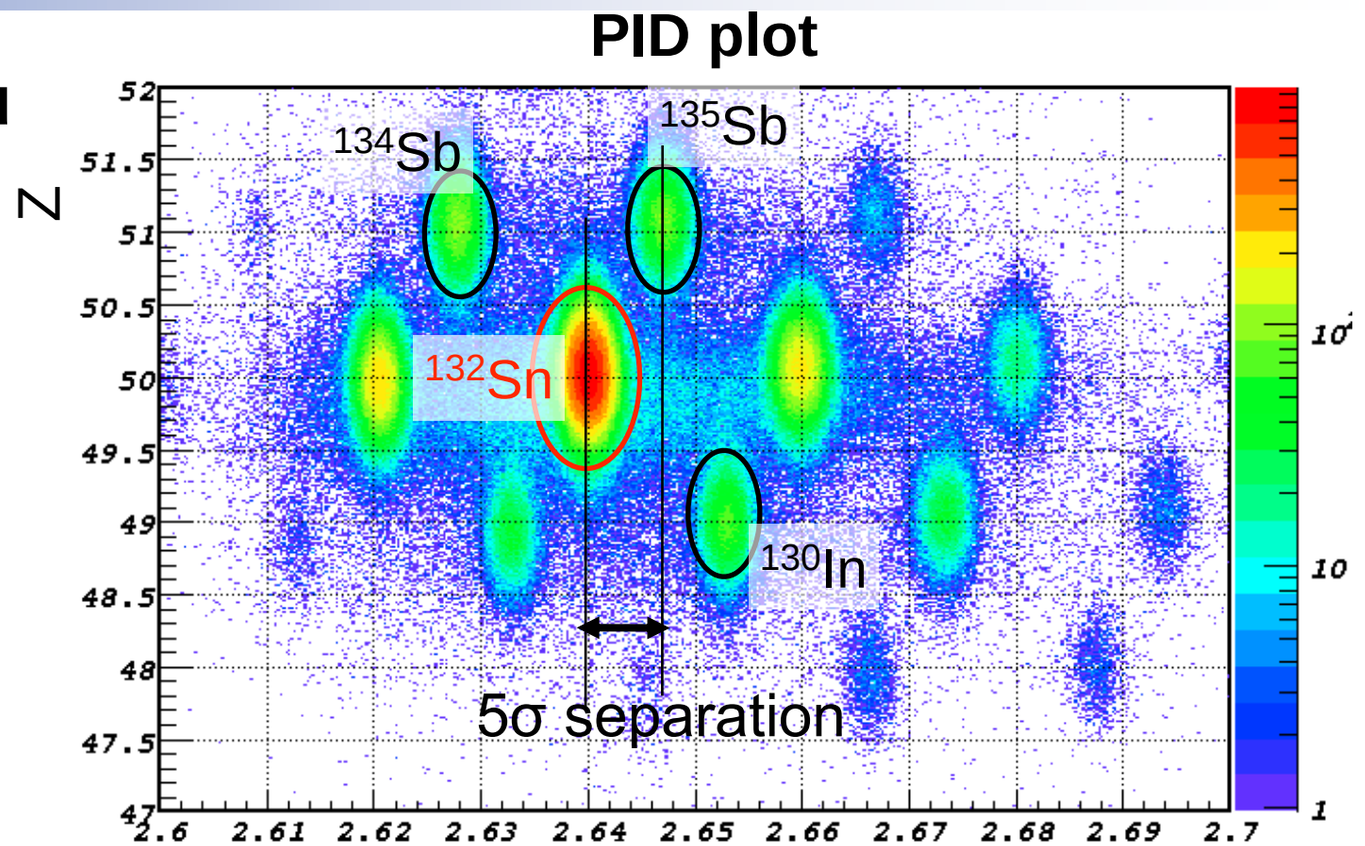
- **Residue tag**
  - SAMURAI
  - Large acceptance
    - **measure all decay particle in one setting**

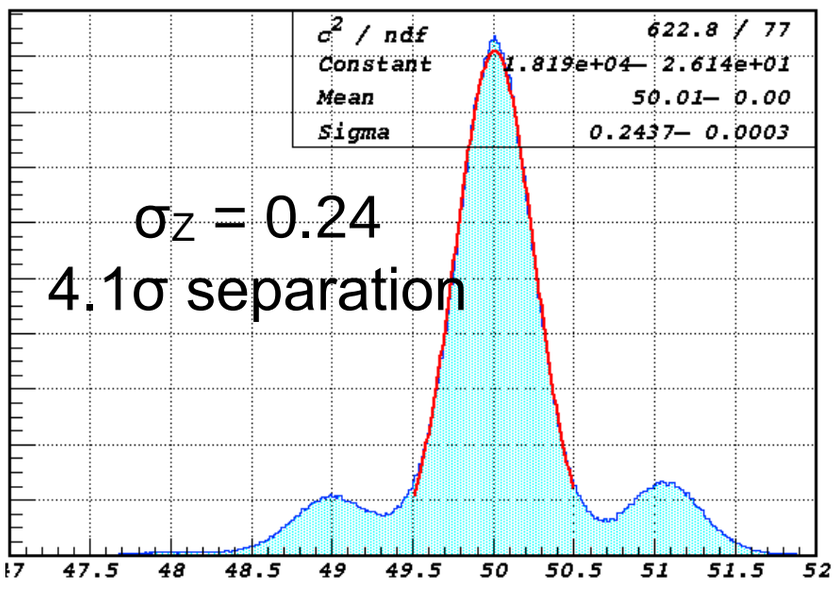


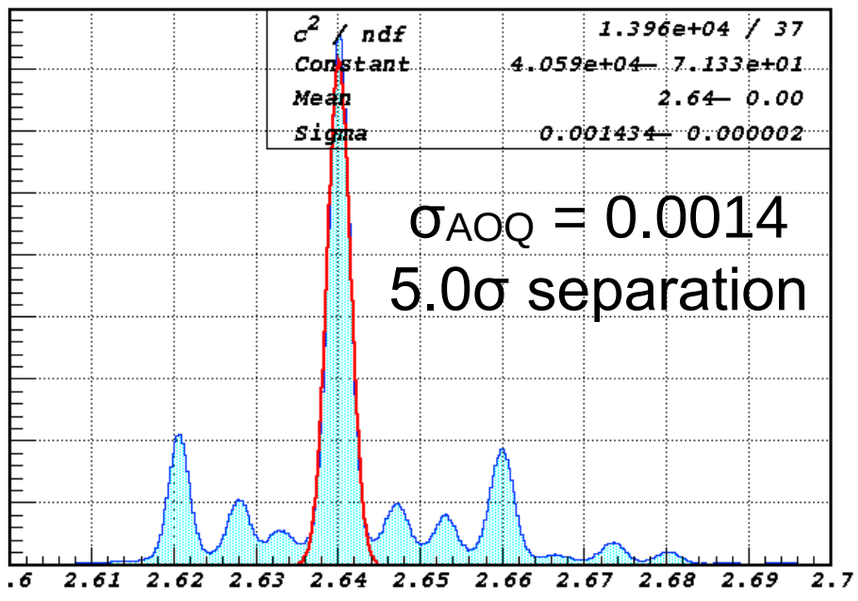
^{132}Sn beam production

- **Beam energy after F7: 270 MeV/u**
- **Total beam Intensity**
  - 1.4 x 10^4 pps
- **PID by BigRIPS**
  - σ_Z = 0.24
  - $\sigma_{A/Q}$ = 0.0014
- **Purity**
  - ^{132}Sn : 40%

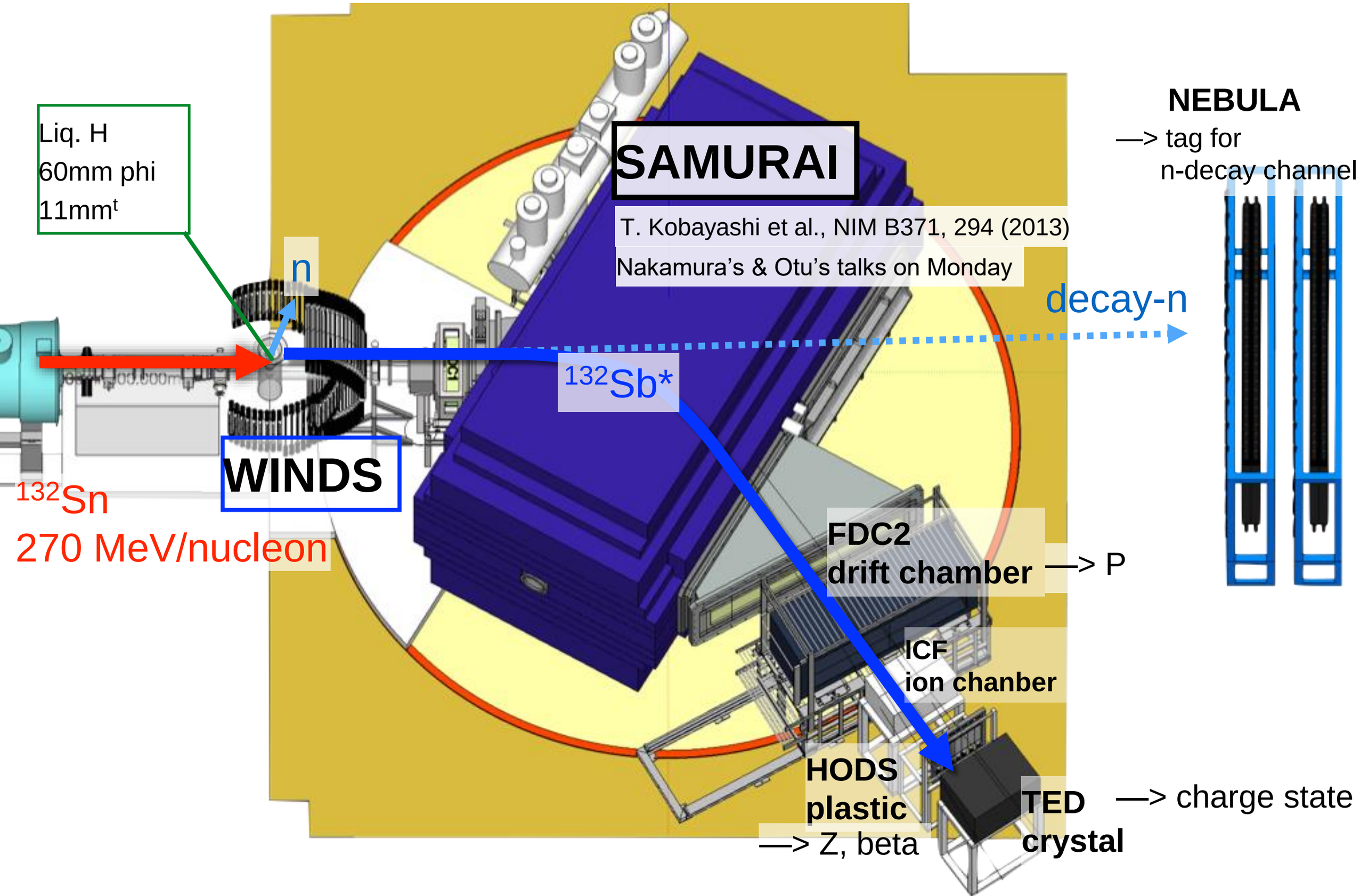
	purity [%]
132Sn	40.11
133Sn	9.47
131Sn	9.50
135Sb	3.88
134Sb	4.28
130in	3.24
129In	1.96



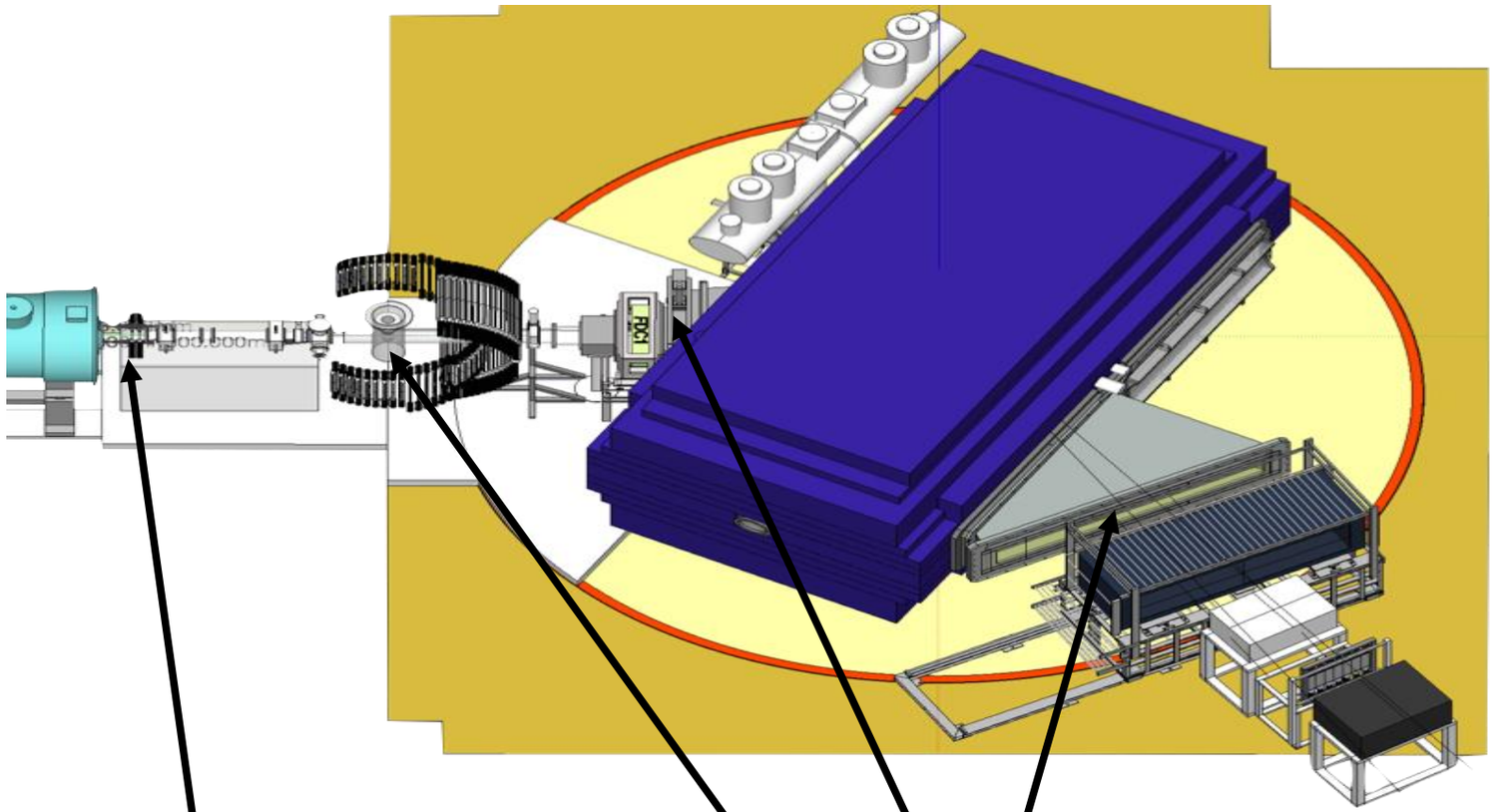


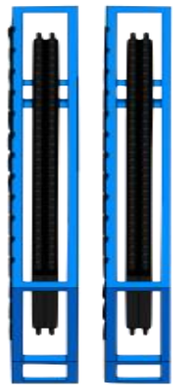


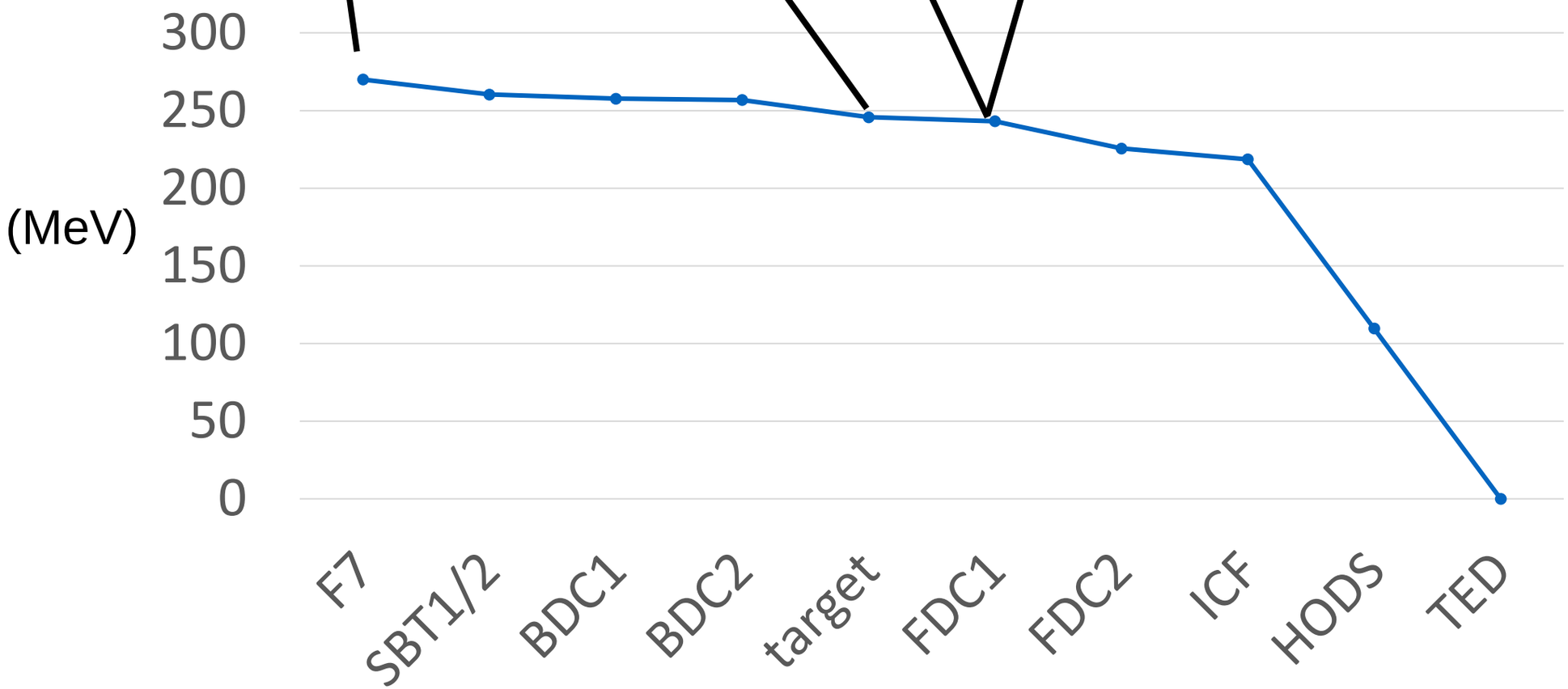
Experimental setup



Damping of beam energies

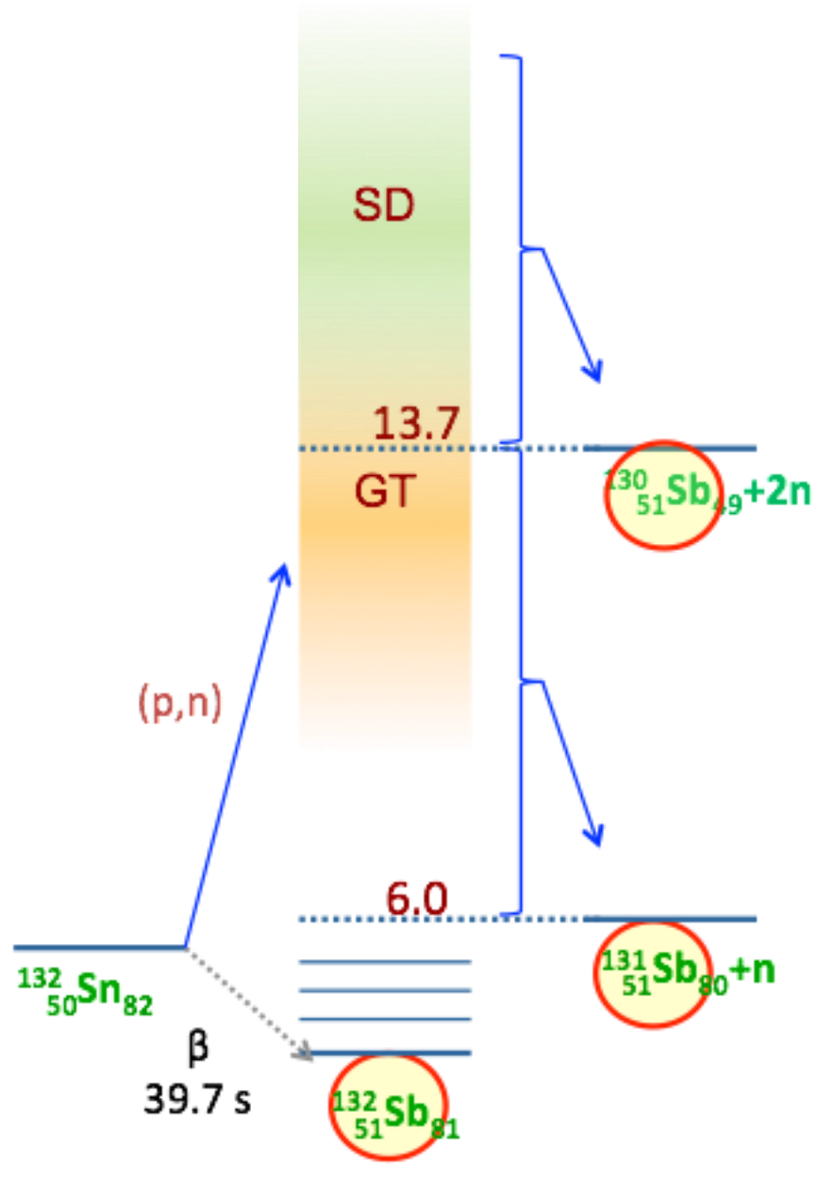






Requirements on SAMURAI

- **Large acceptance**
  - all decay channel with multi-nucleon emission can be measured in one setting
    - momentum spread ~2%
- **Good PID resolution for heavy residue**
  - 5σ separation for A & Z in order to improve S/N



TOF analysis

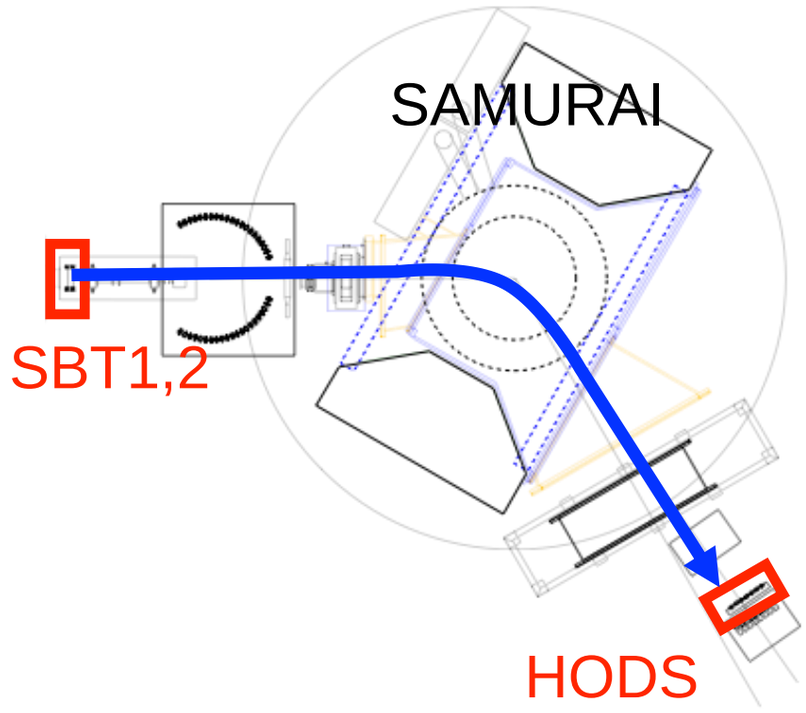
- **Plastic counter HODS & SBT1,2**
  - HODS : 6 plastic scintillation with size of 450 x 100 x 5 mm^3
  - SBT1,2 : 130 x 130 x 5 mm^3
  - FPL ~12.5 m
  - Resolution estimation
    - Empty cell & beam trigger

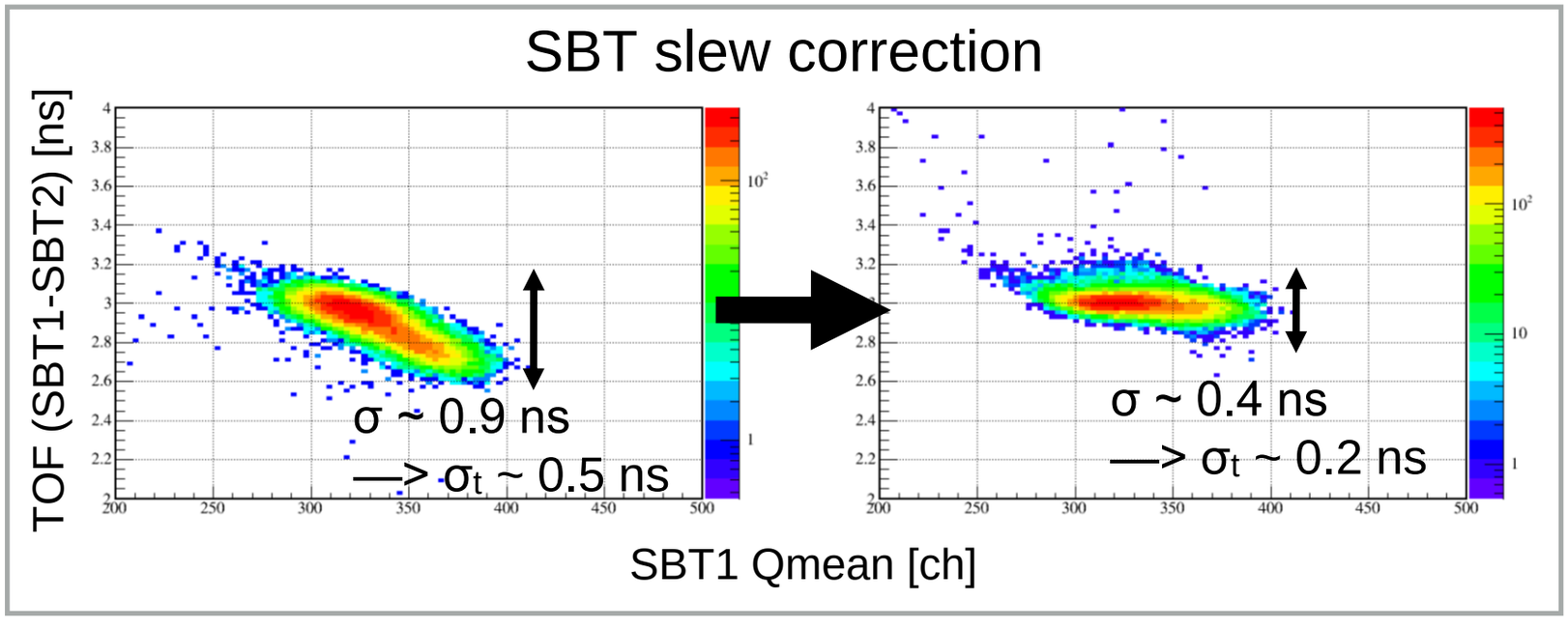
    → SBT1,2 timing resolution (average of SBT1,2)

    → σ_t = 17ps (w/ slew correction)

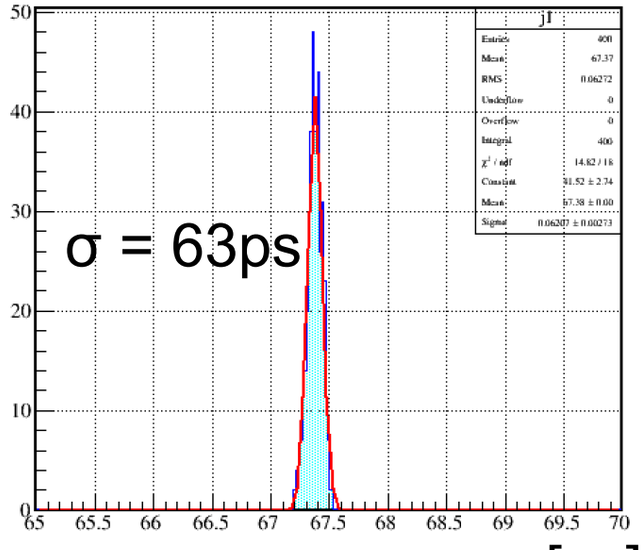
    <—> σ_t = 46 ps (w/o slew correction)

    → TOF (SBT1,2-HODS) : σ = 63ps





TOF(SBT1,2—HODS)
@ Empty cel & Beam trigger



Momentum analysis

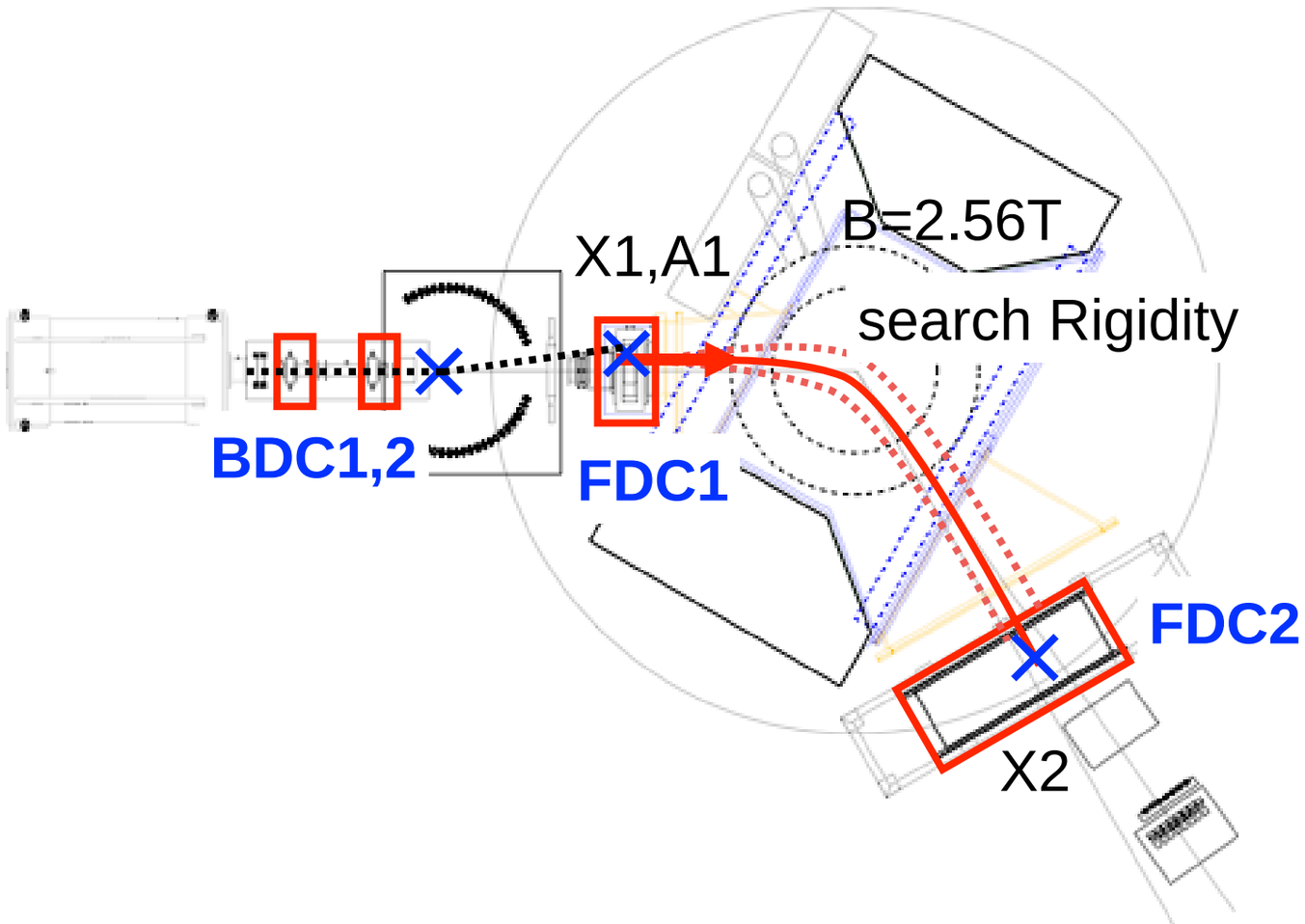
- **Input parameter**
  - Upstream vector (X1, A1), Magnetic Field, Downstream position (X2)
  - **A1 was derived by using 3 tracking detectors**

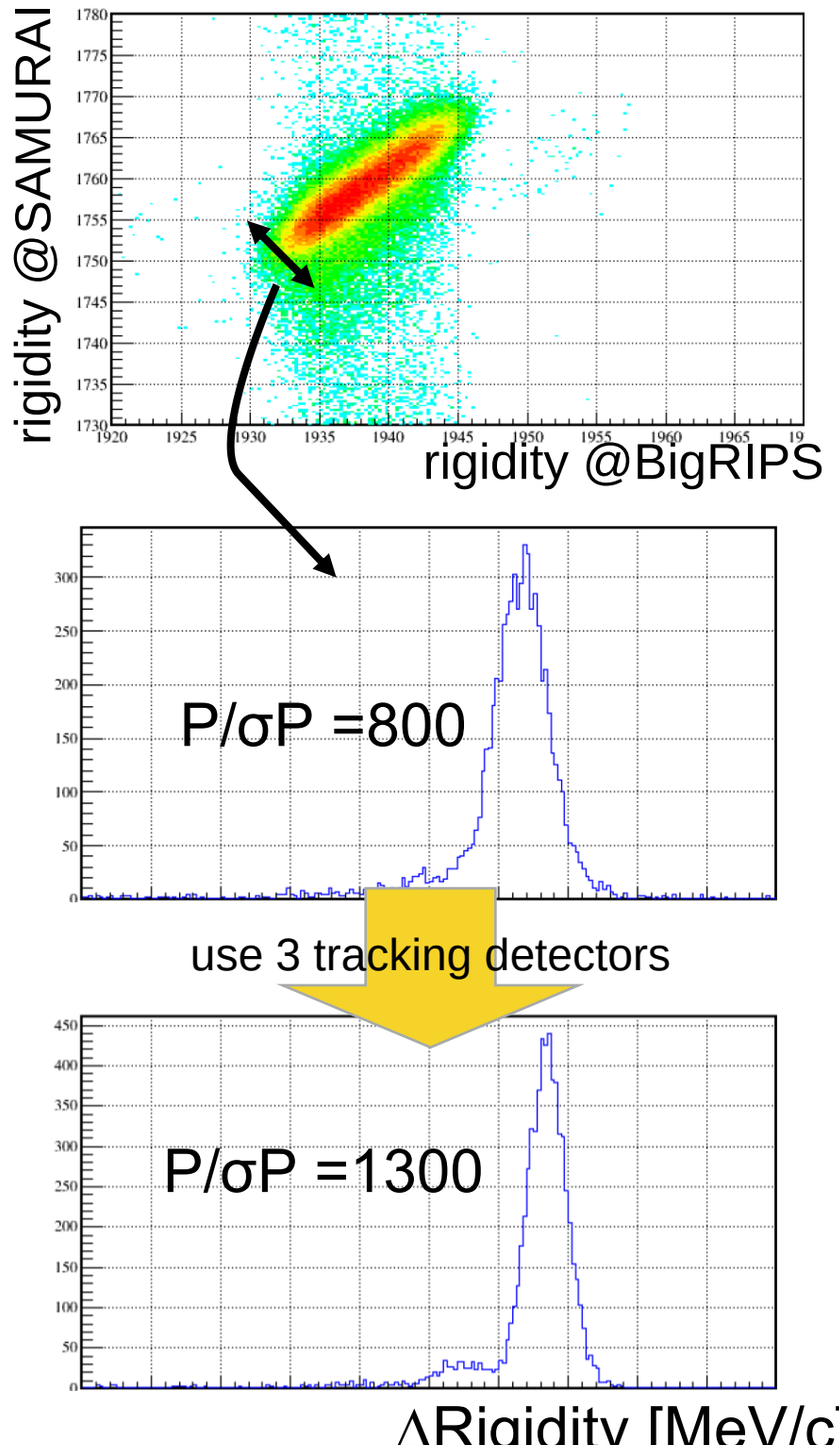
    High angular resolution σA ~0.3 mrad

    <—> σA~0.8 mrad (just use 1 tracking chamber)

Resolution : P/σP = 1300

<—> P/σP = 800 (just use 1 tracking chamber for ini. p)

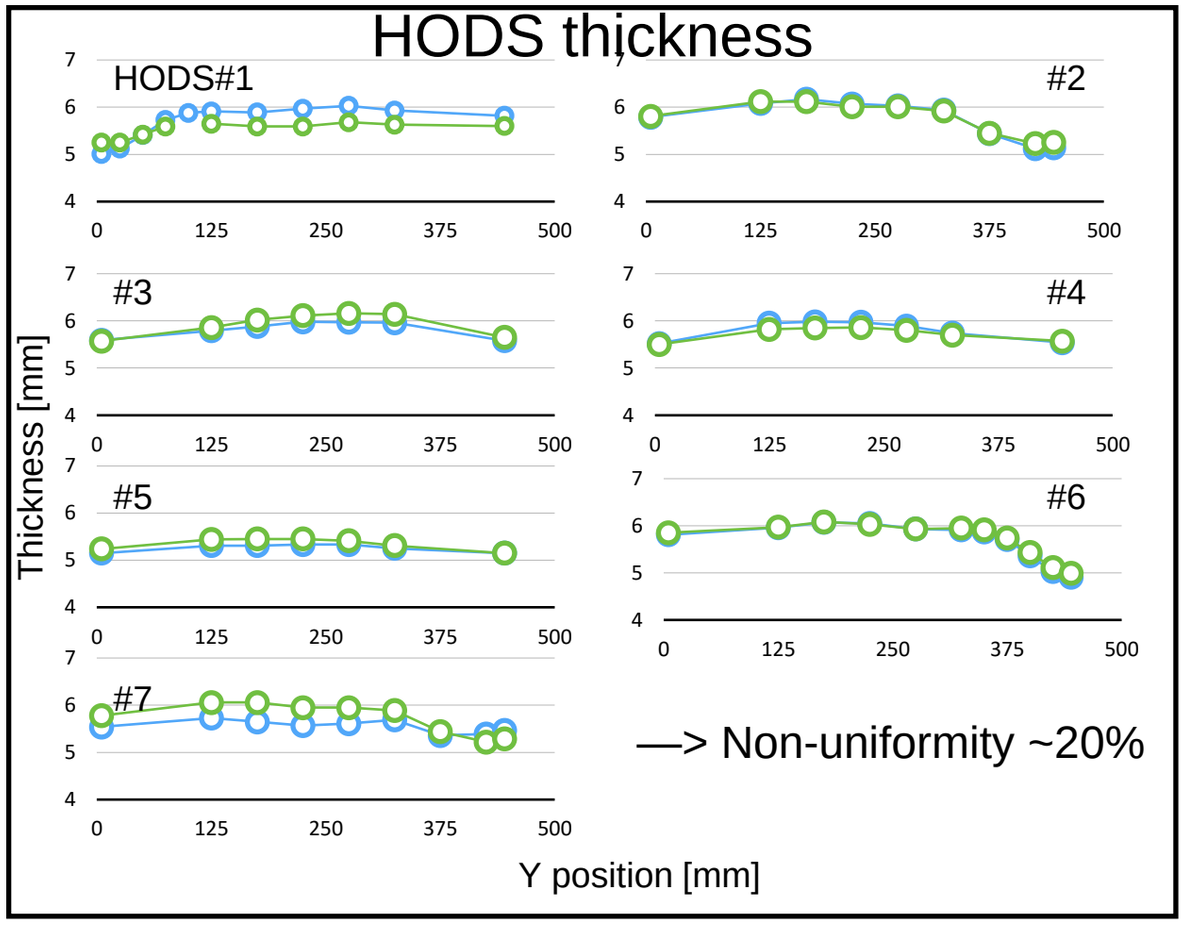


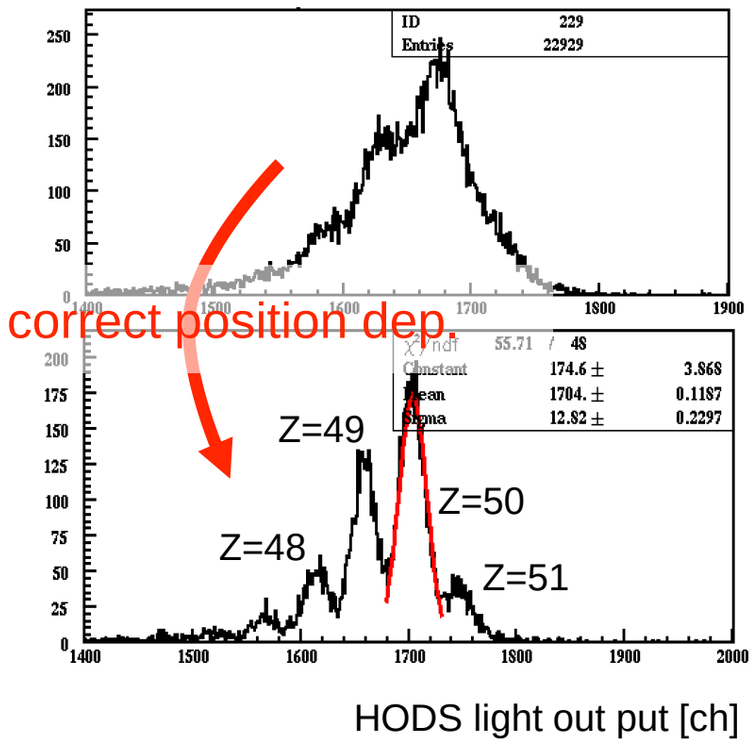


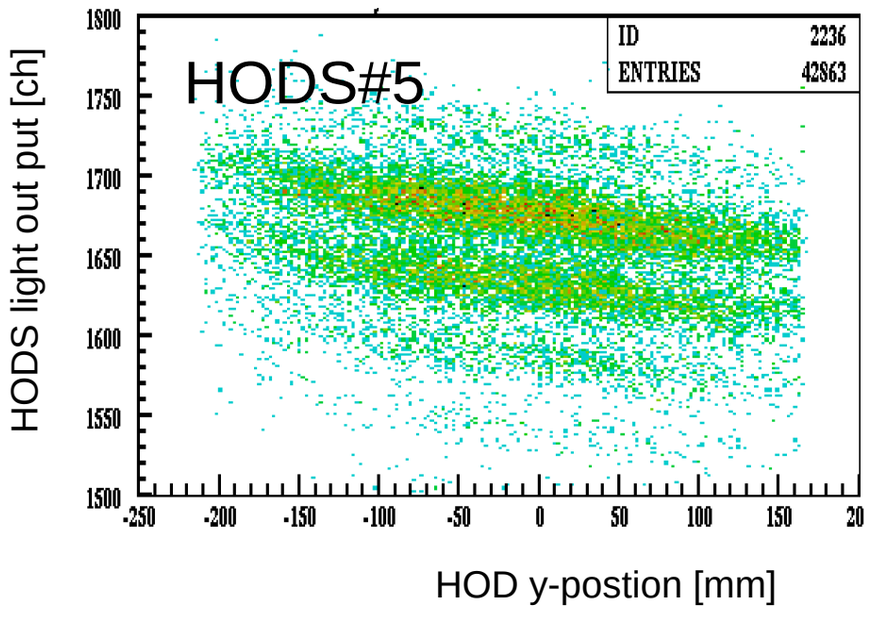
ΔE analysis

- **Energy loss at plastic scintillator HODS**
  - HODS thickness : ~ 6 mm
    - Non-uniformity ~ 20%
    - Energy loss ~ 6000 MeV
  - Correct position dependence by using FDC2 tracking information

→ **Resolution : $\sigma_{\Delta E}/\Delta E$ = 0.4%**







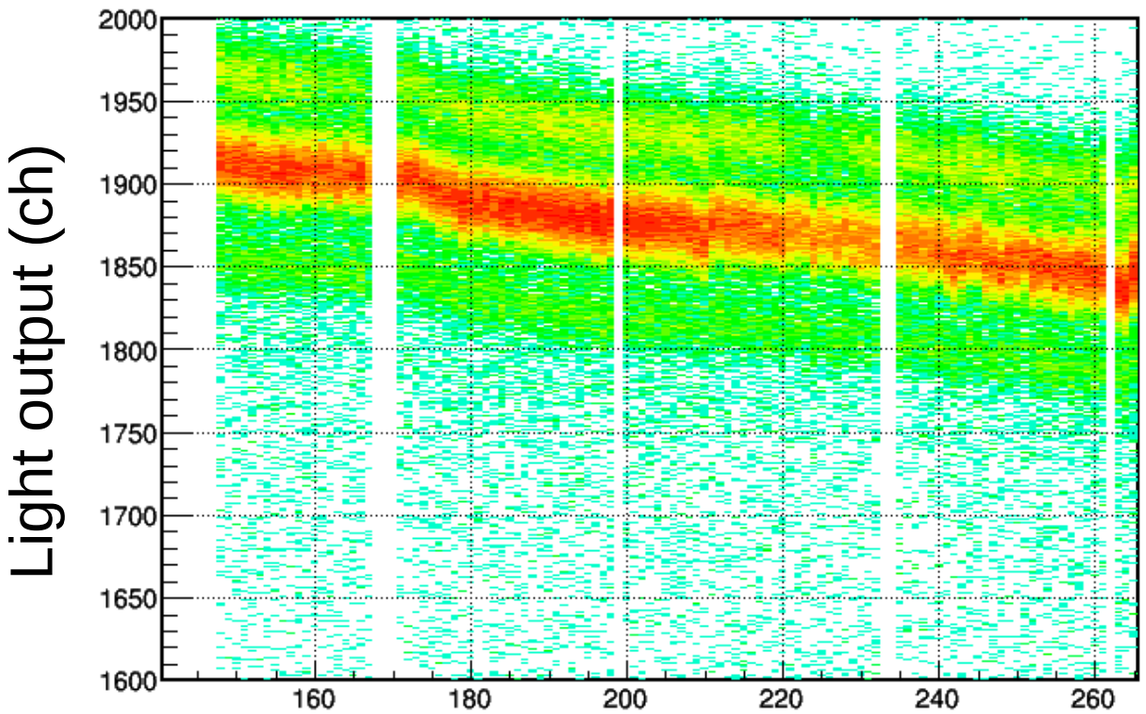
Stability of dE counter (plastic scintillator)

- **Gain attenuation**
  - **especially for beam hit bar**
  - **Normalization parameter for ΔE has been corrected for each RUN**

PMT w/ booster will be help to solve this problem

Beam hit bar HODS#4

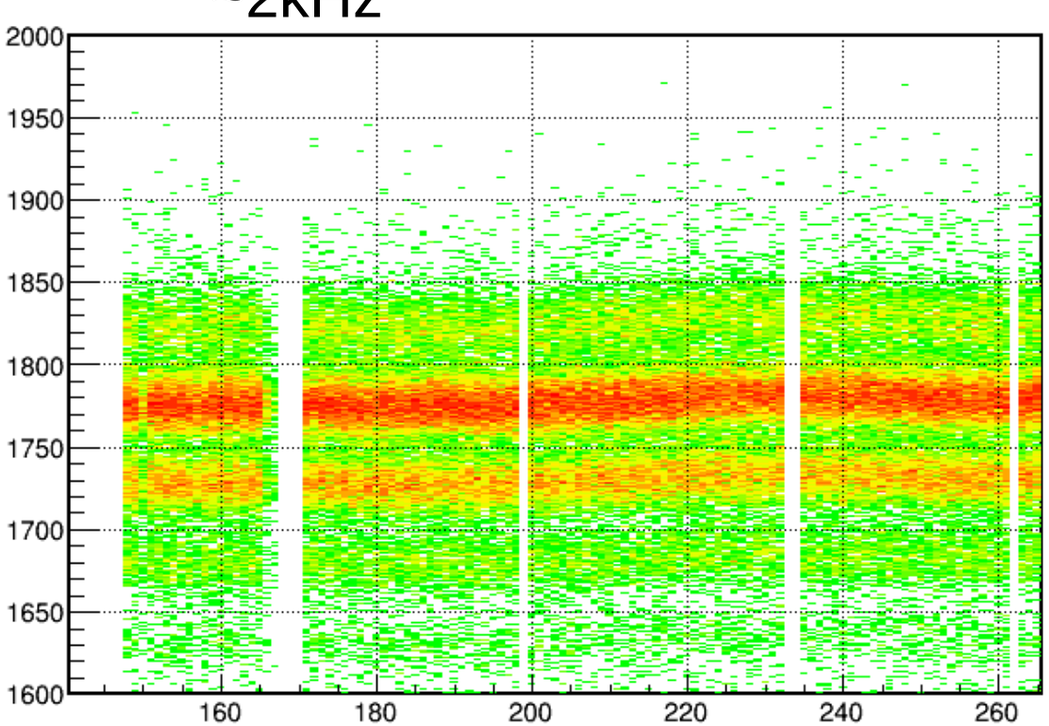
~20kHz



~40h

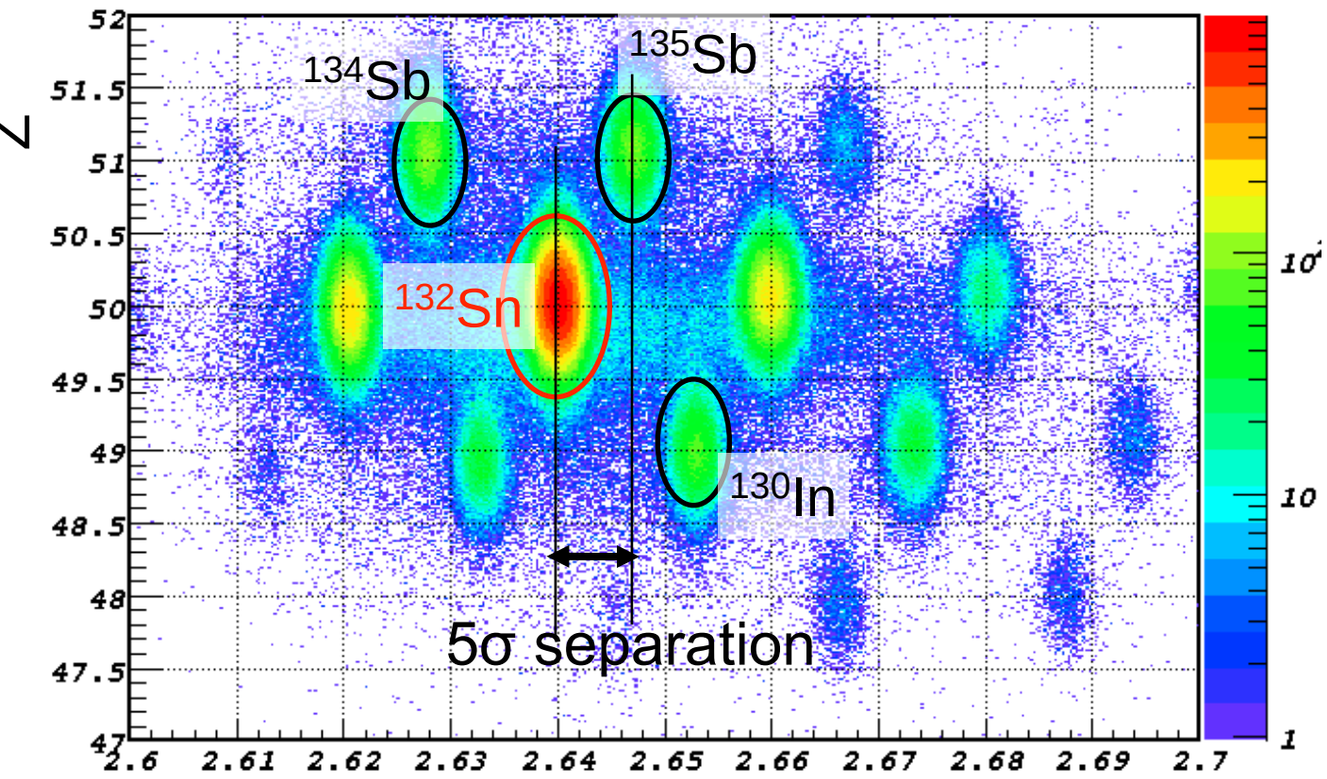
Fragment hit bar HODS#5

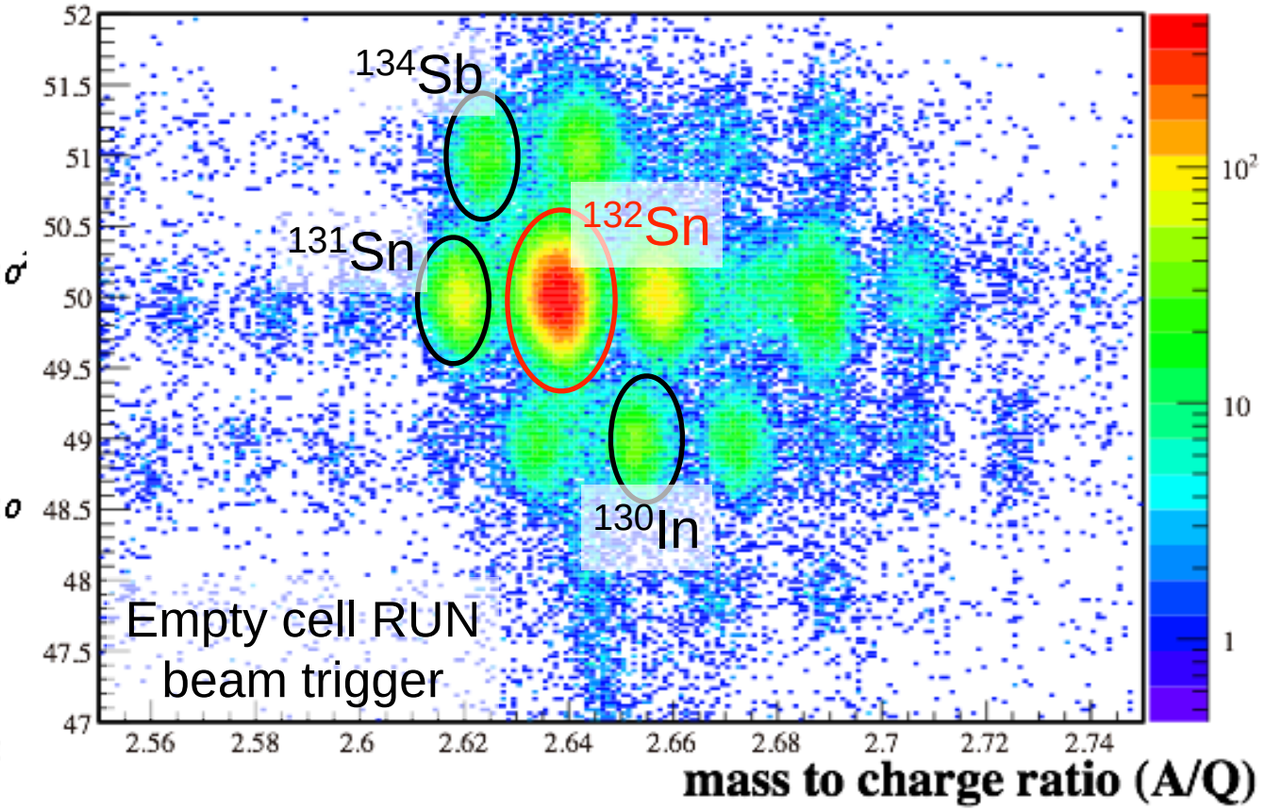
~2kHz

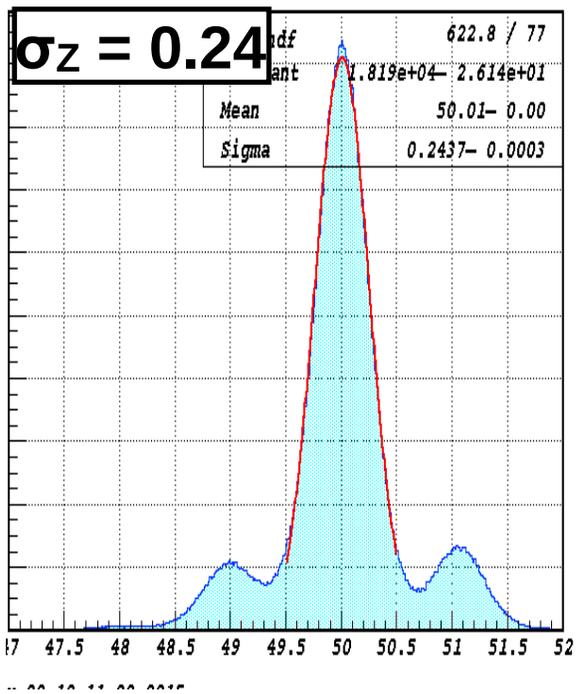


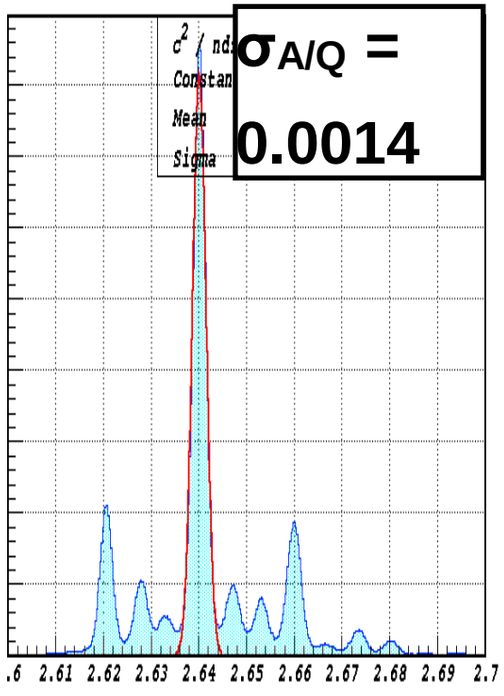
~40h

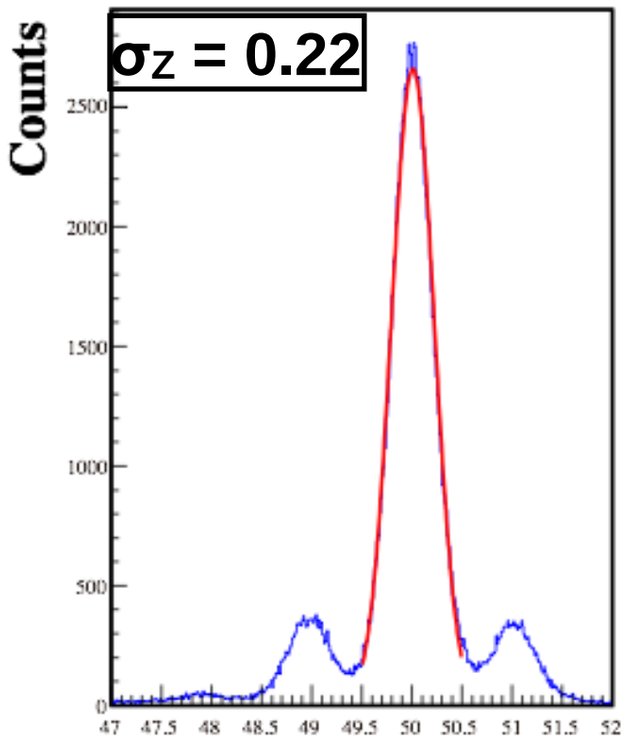
Comparison between BigRIPS and SAMURAI (unreacted events with empty cell)

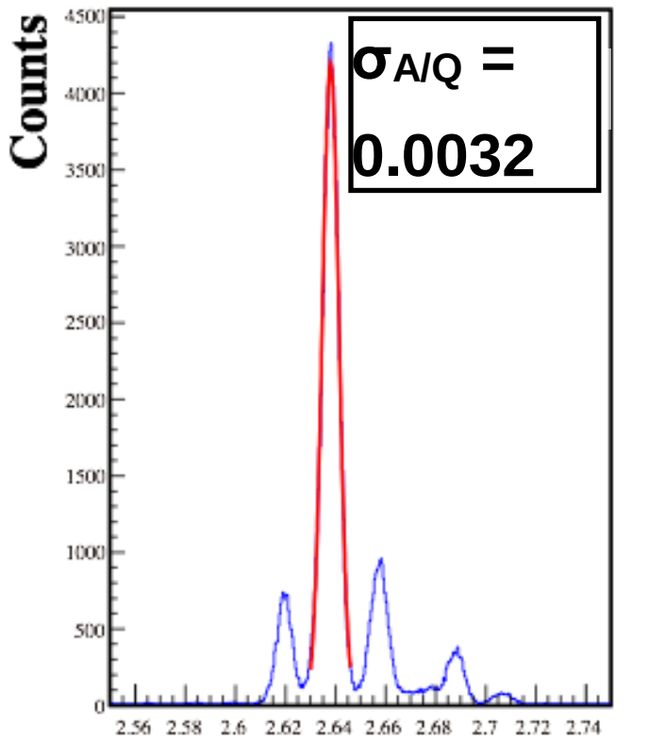




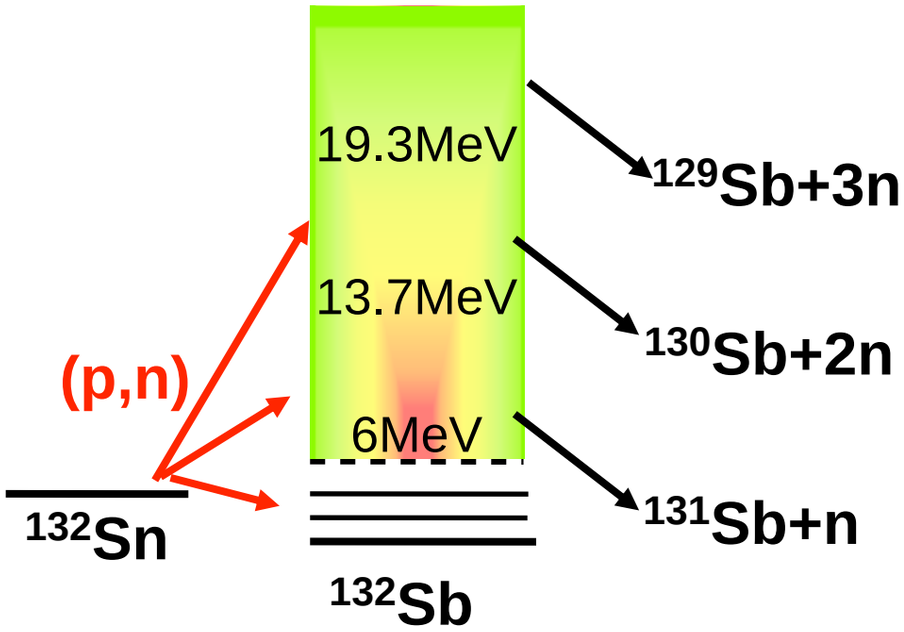


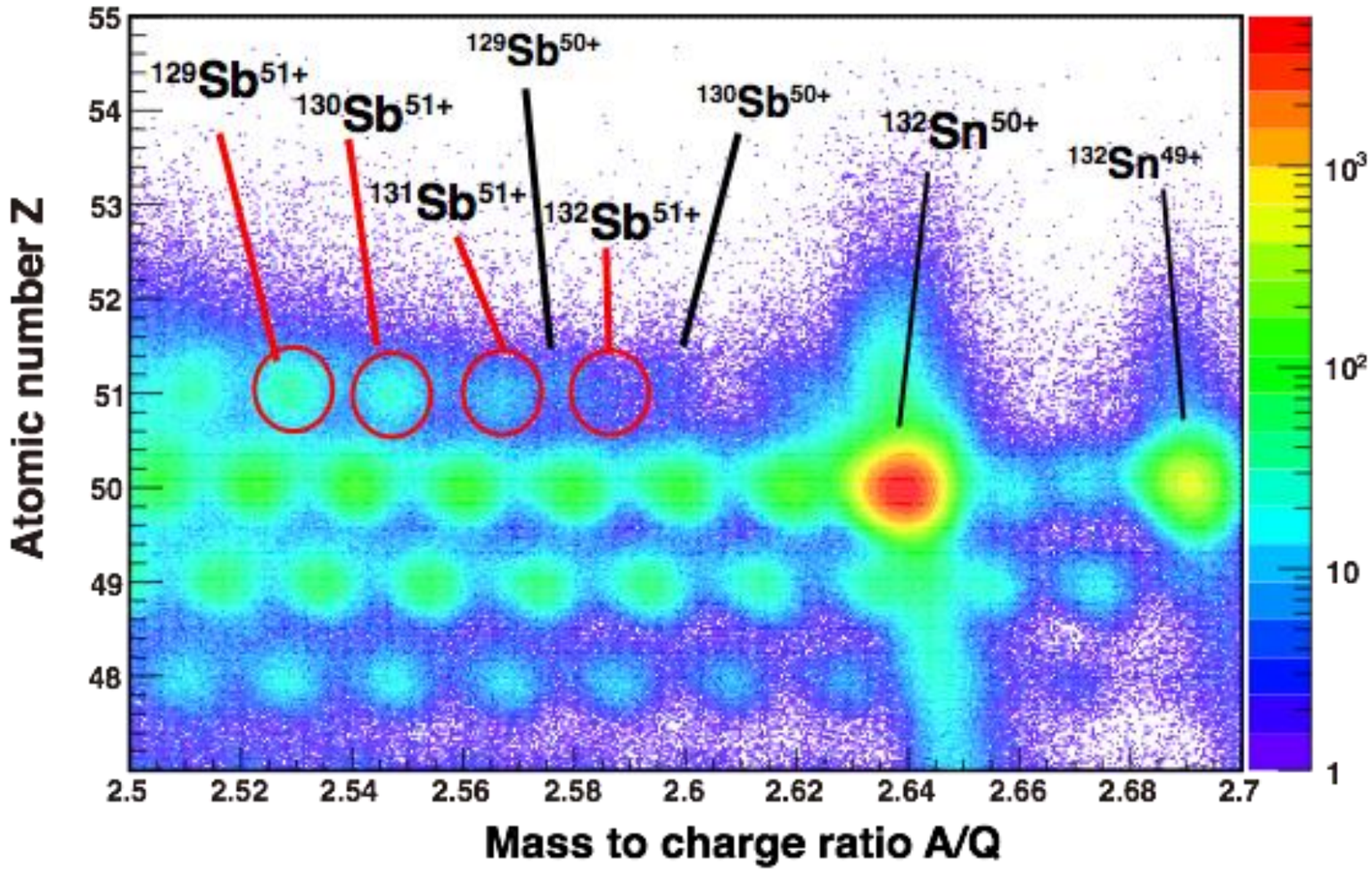






PID for (p,n) reaction residues





Z distribution

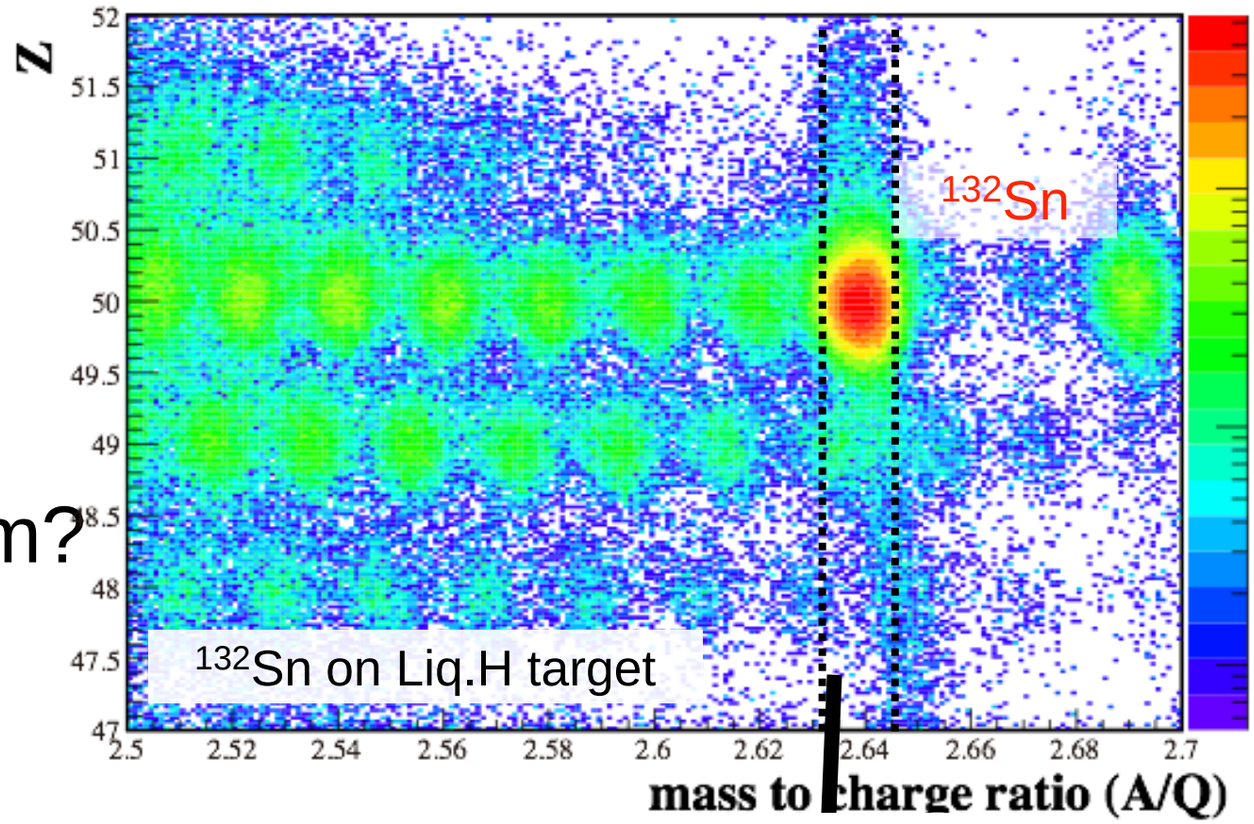
Tail component ~ 1%

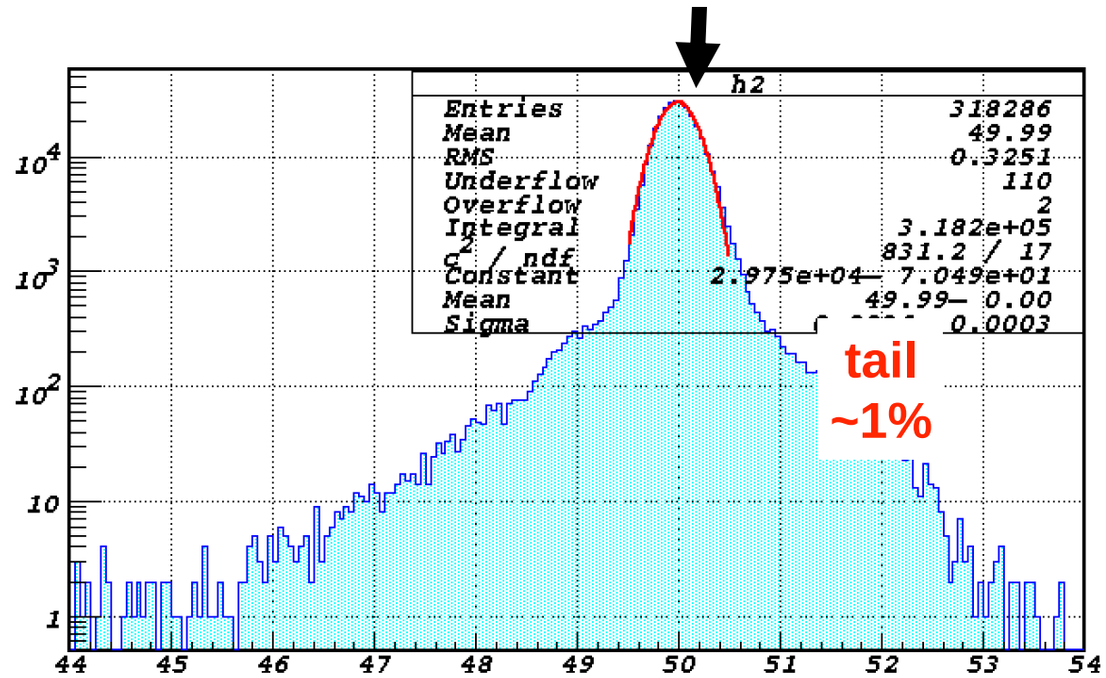
→

Detector response

or effect of charge state equilibrium?

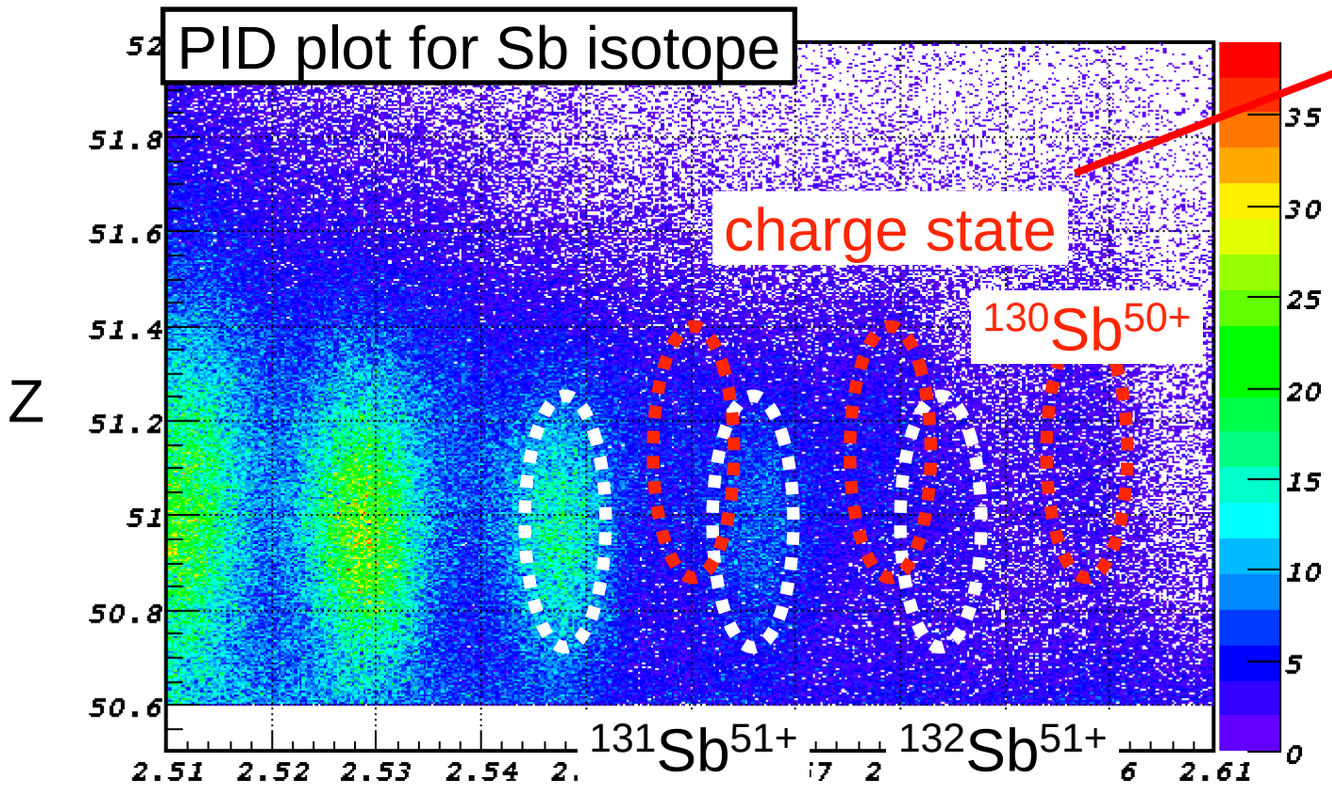
→ Not so significant for this case

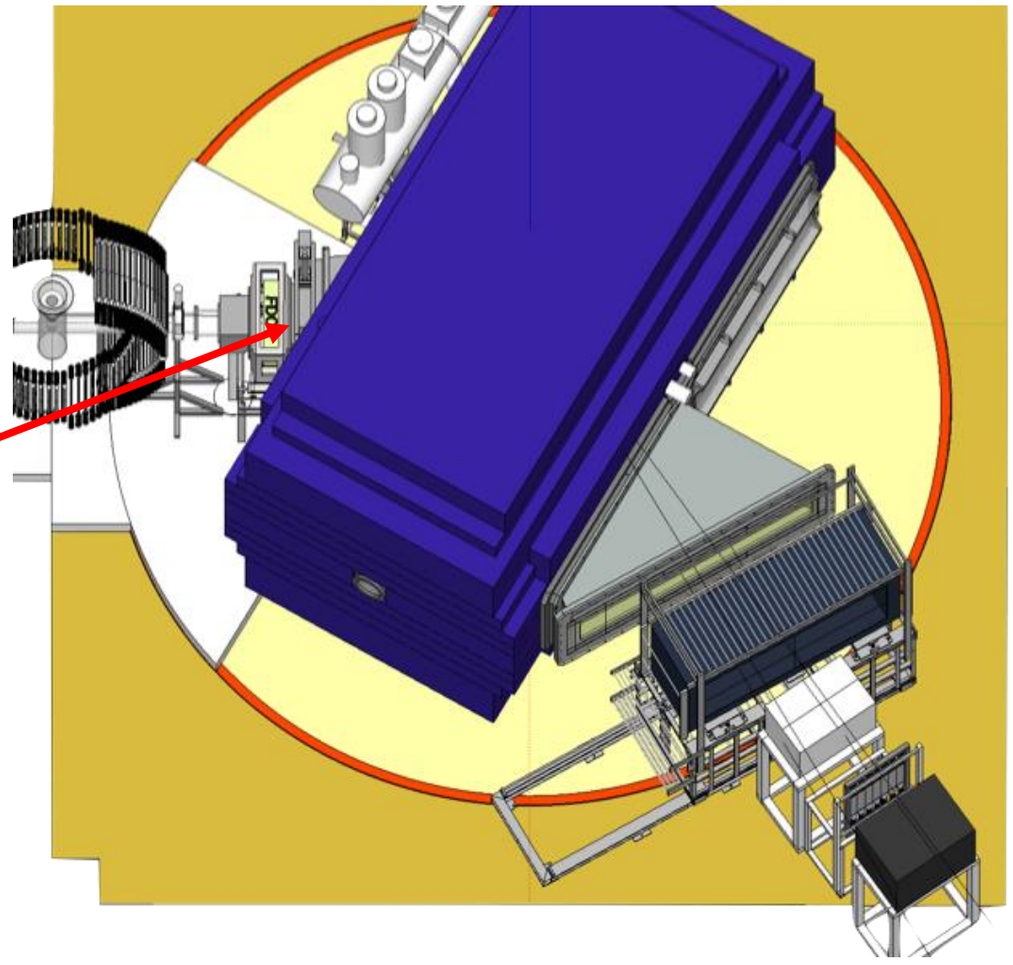




Charge states in PID

- **charge changing after F7**
  - Z>Q : ~10% (calculation by GLOBAL code)



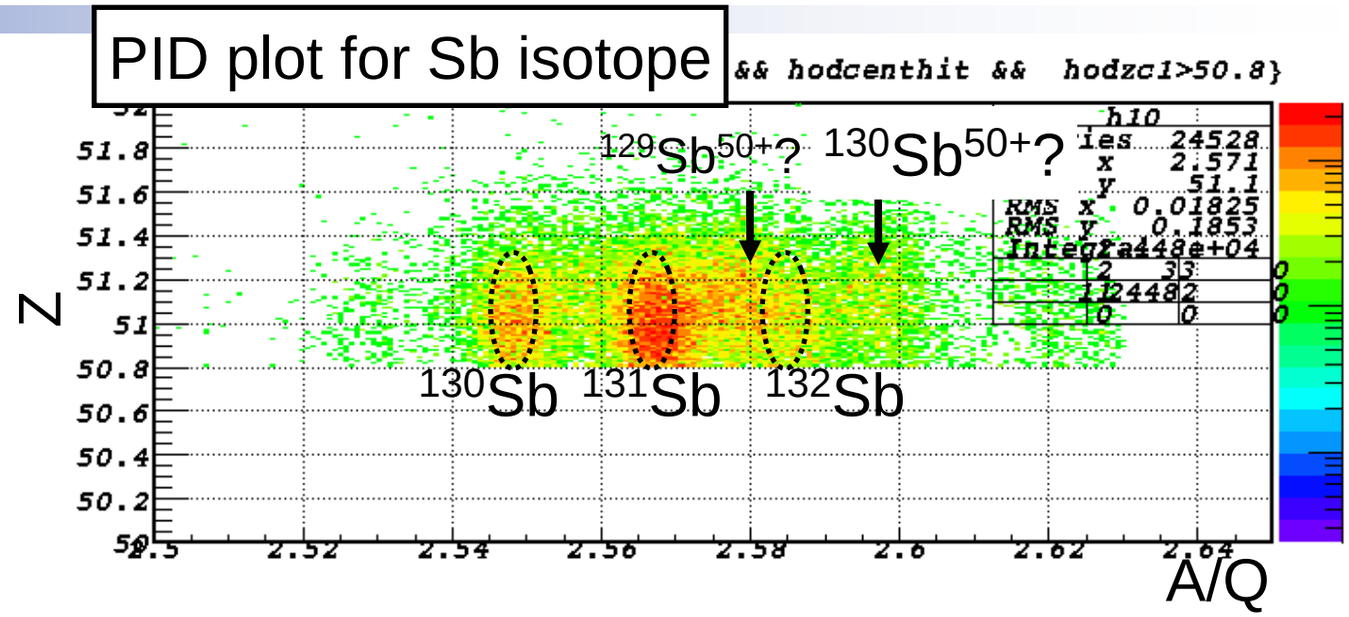


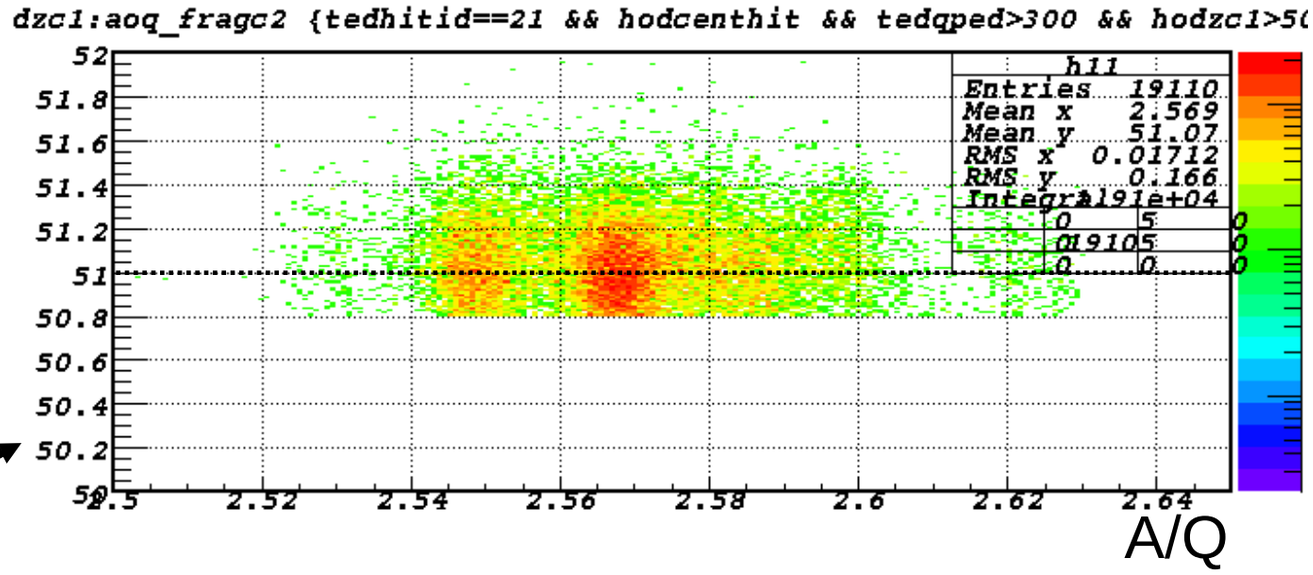
Charge state separation

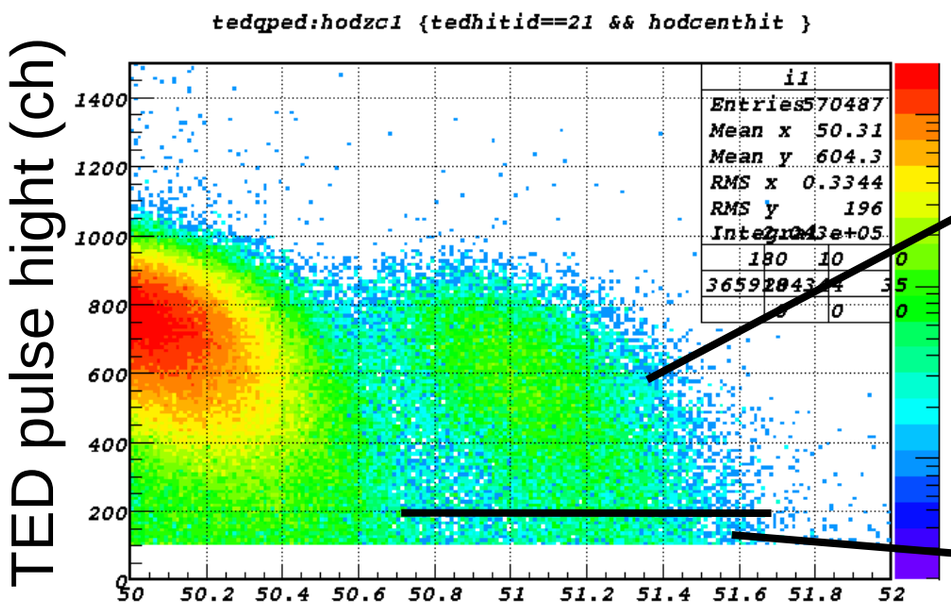
- **Charge state**
  - **$^{129}Sb^{50+}$: A/Q = 2.58**
  - **$^{130}Sb^{50+}$: A/Q = 2.6**
    - **AOQ($^{132}Sb^{51+}$)-AOQ($^{129}Sb^{50+}$)/σAQO ~ 2σ**

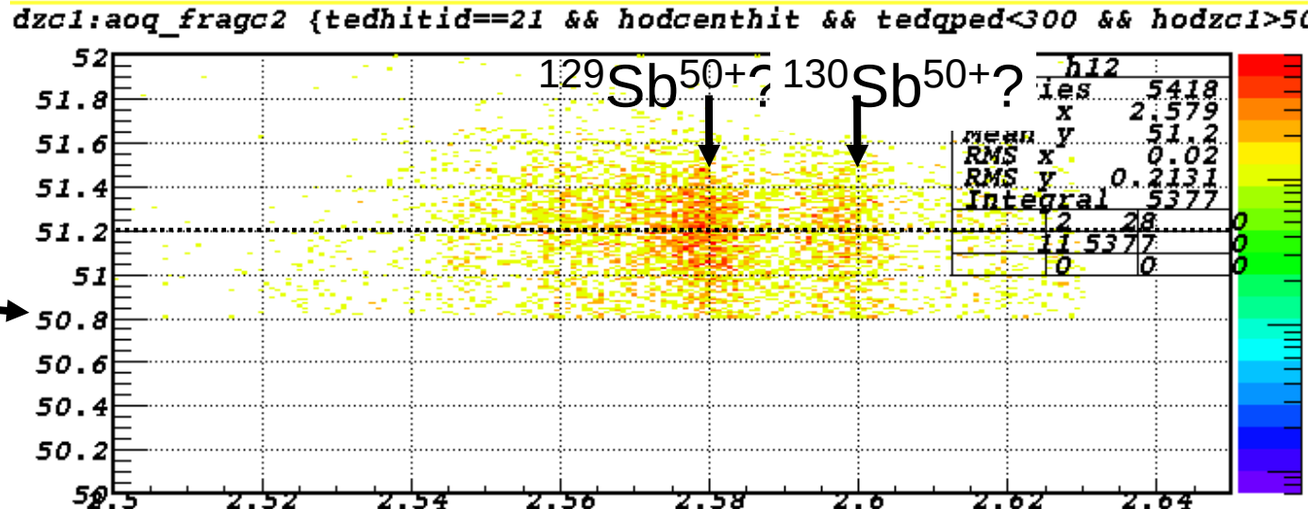
- **Coincidence with TED (id=21)**
  - **Select lower total energy region**
    - **A/Q =2.58,2.6 region are enhanced**

▶ **TED information is useful to separate Charge state**

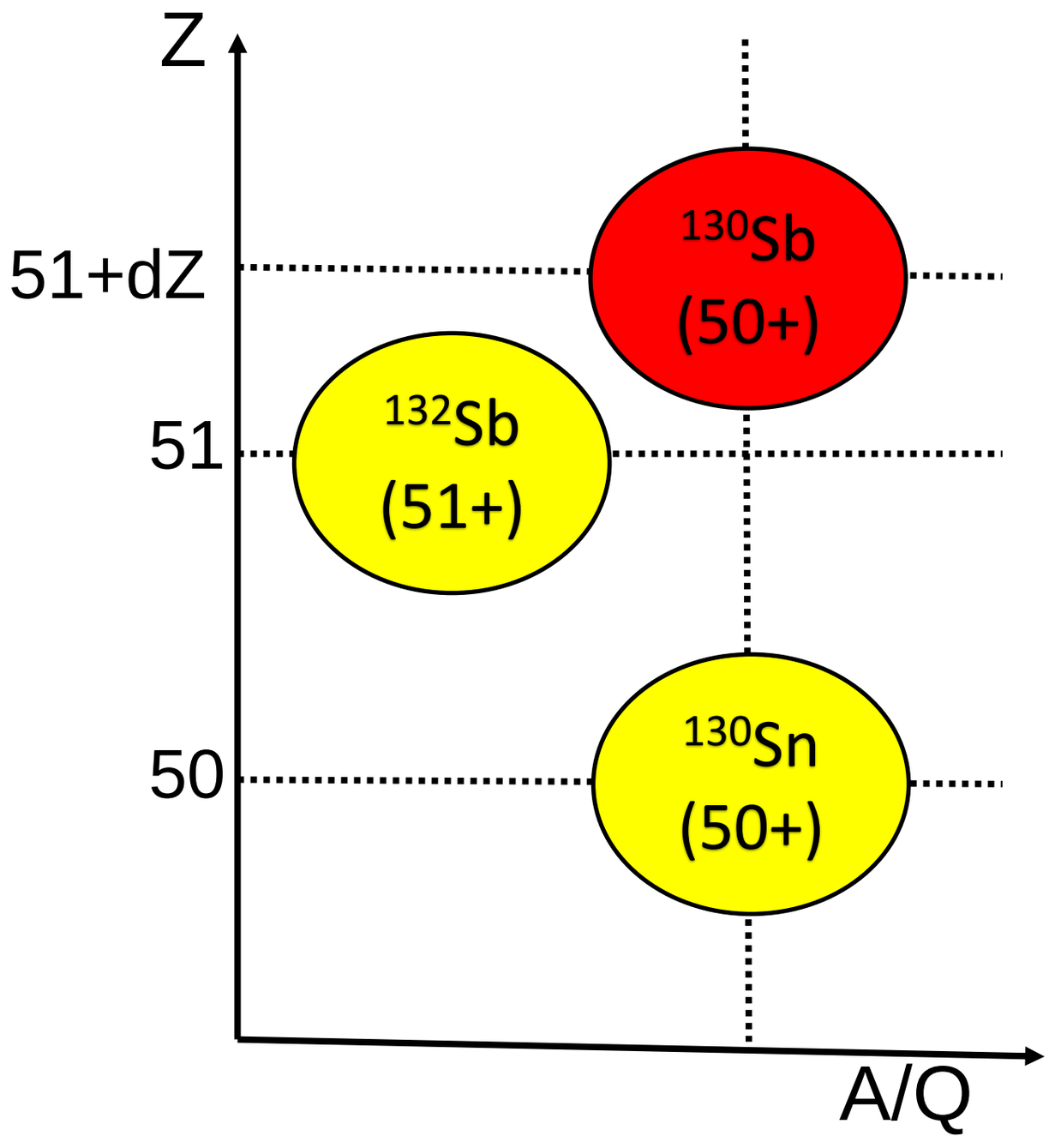






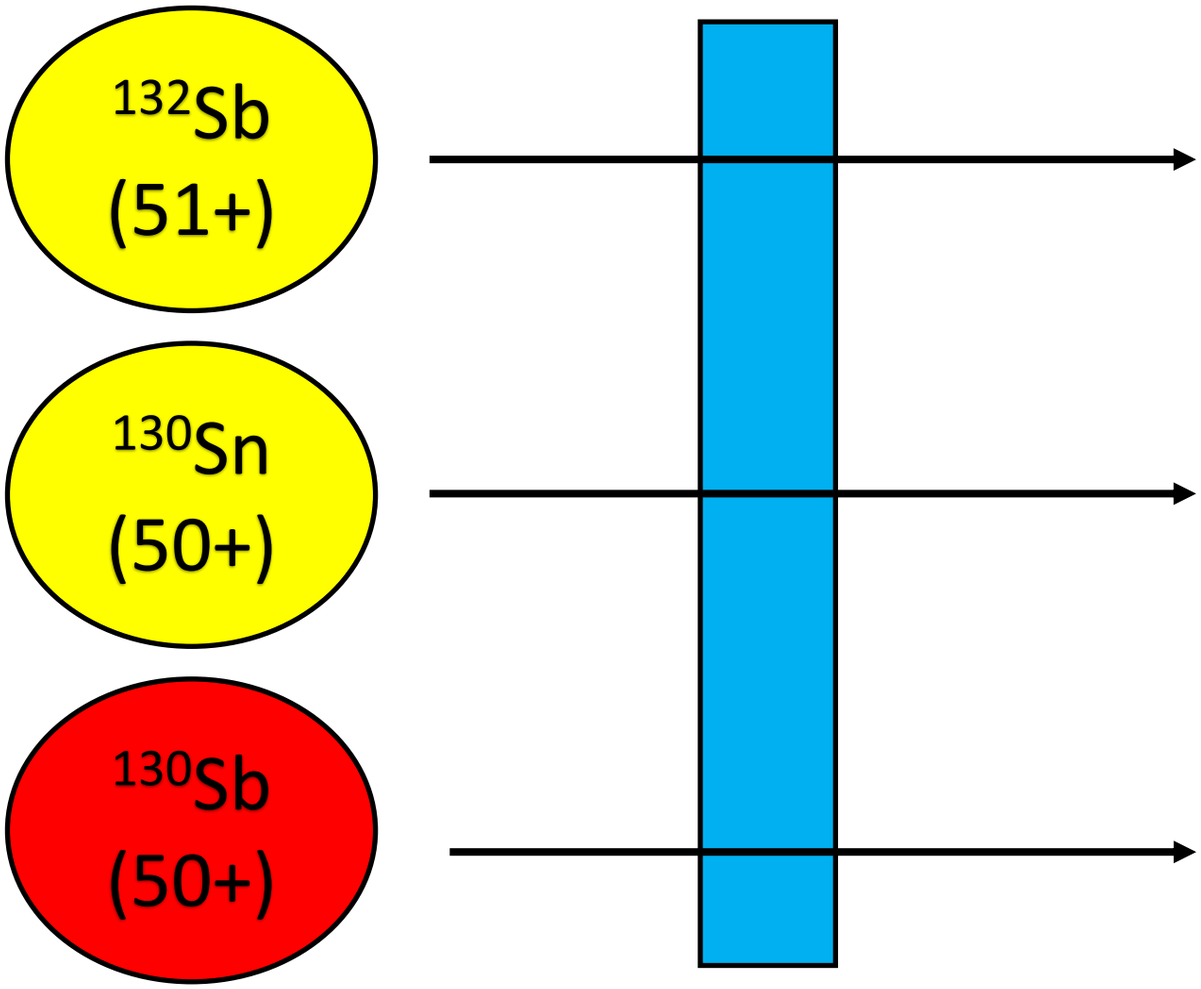


Pattern of charge states in PID for Sn region



Energy losses in HODS

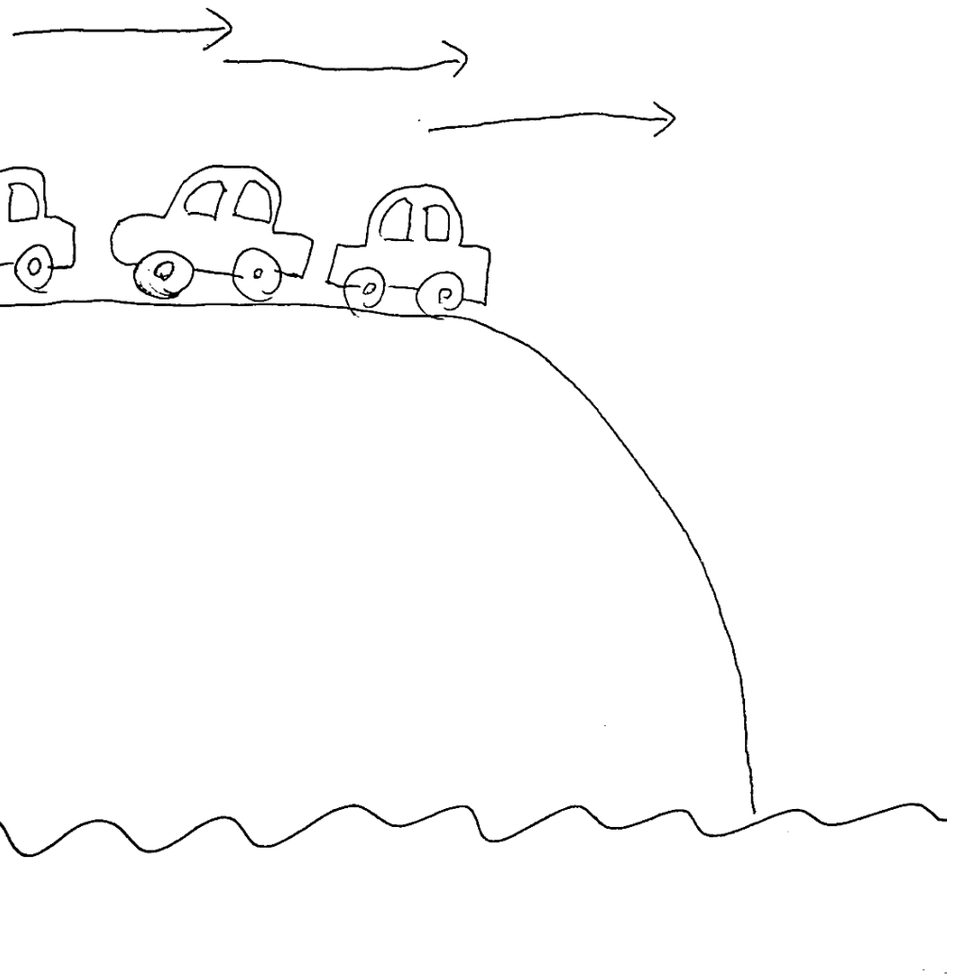
6 mm
→ ~50% energy loss
→ Close to Bragg peak



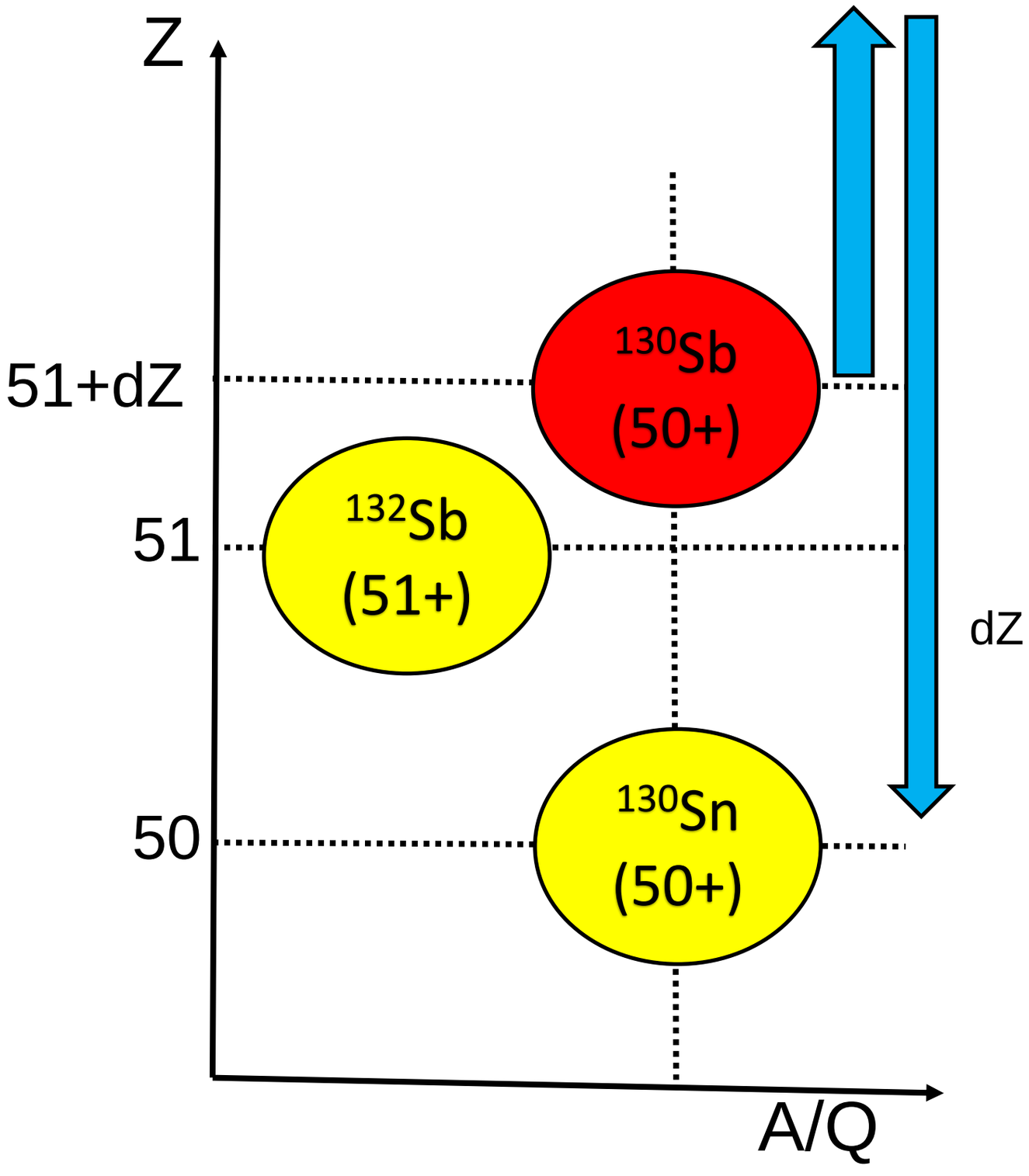
@ the same rigidity
(5.54081 Tm)

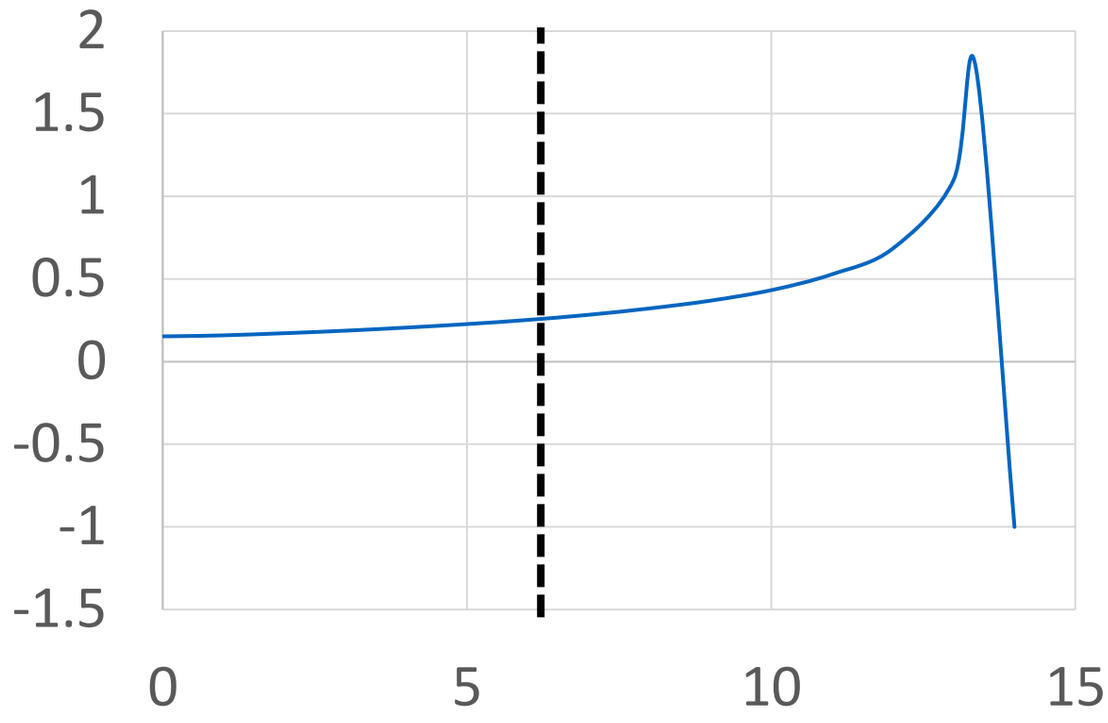
Rebel w/o a cause:
The Chicken Race



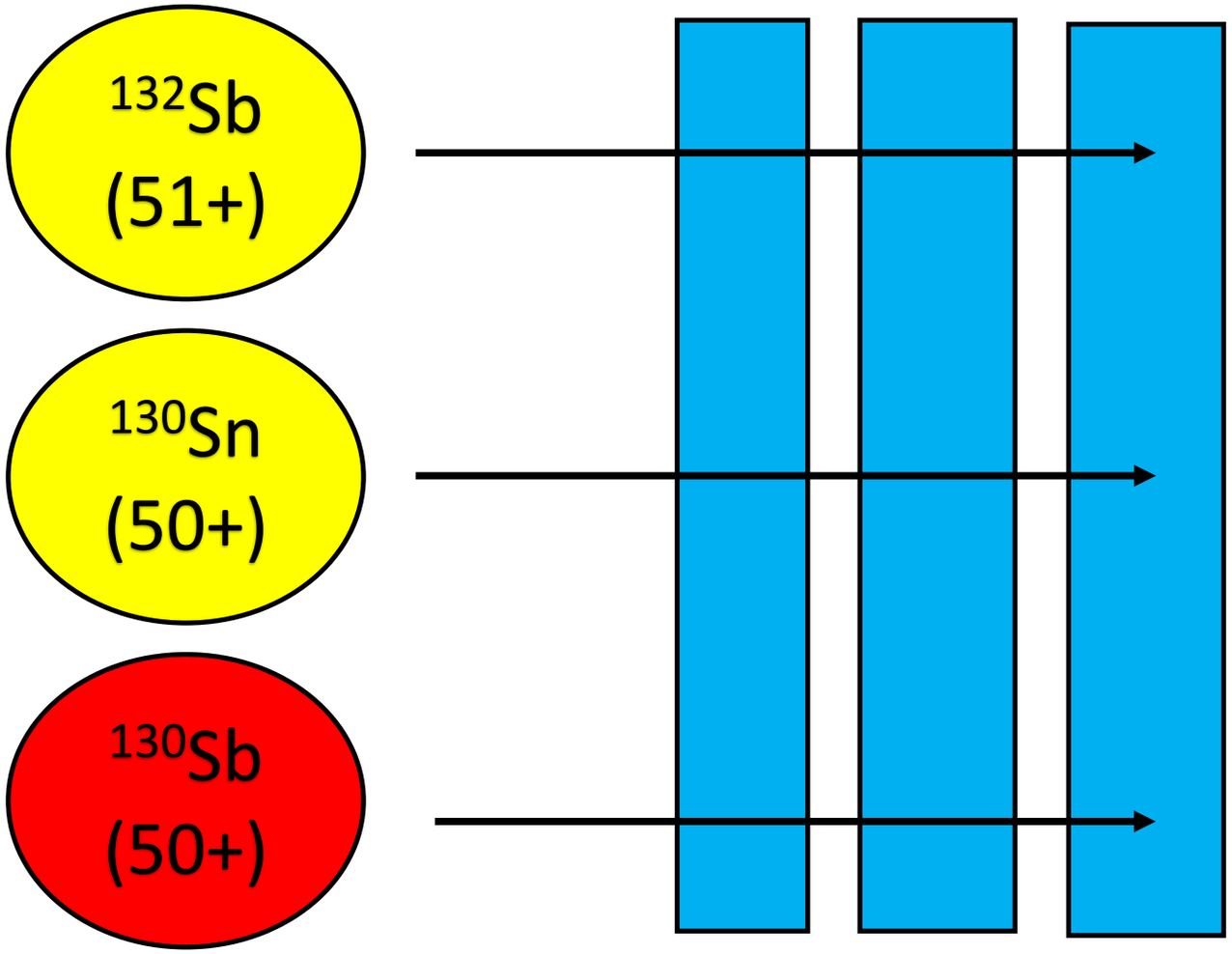


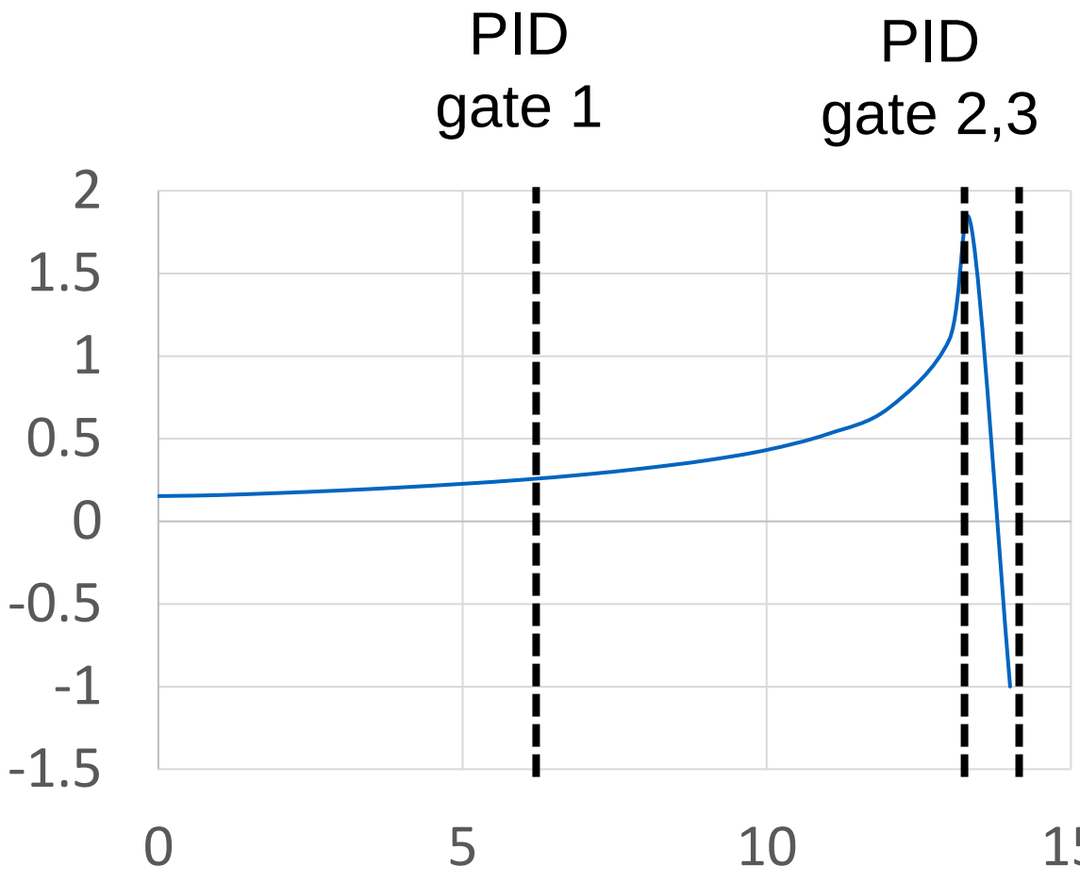
As a function of thickness





Better setup is…



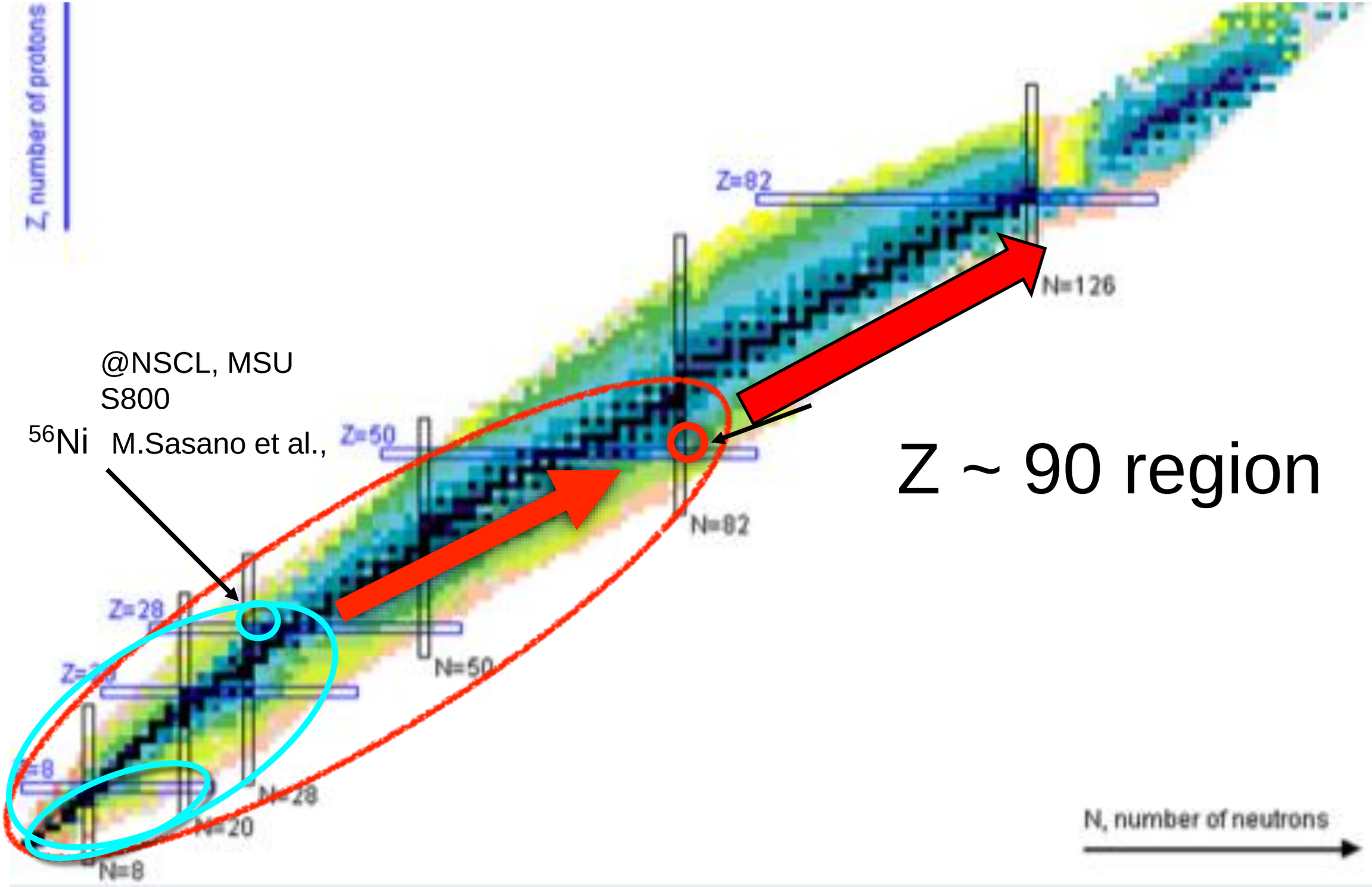


Thickness of HODS plastic scintillat
(mm)

@ the same rigidity
(5.54081 Tm)

Uniformity of thickness must be controlled

Future plan…



@NSCL, MSU
S800
^{56}Ni M.Sasano et al.,

Z ~ 90 region

Difficulties in Z~90 region @ 250 MeV/u

- **A/Q separation is more difficult**
  - **→ Improve position and time resolution of detectors for rigidity and tof analysis**

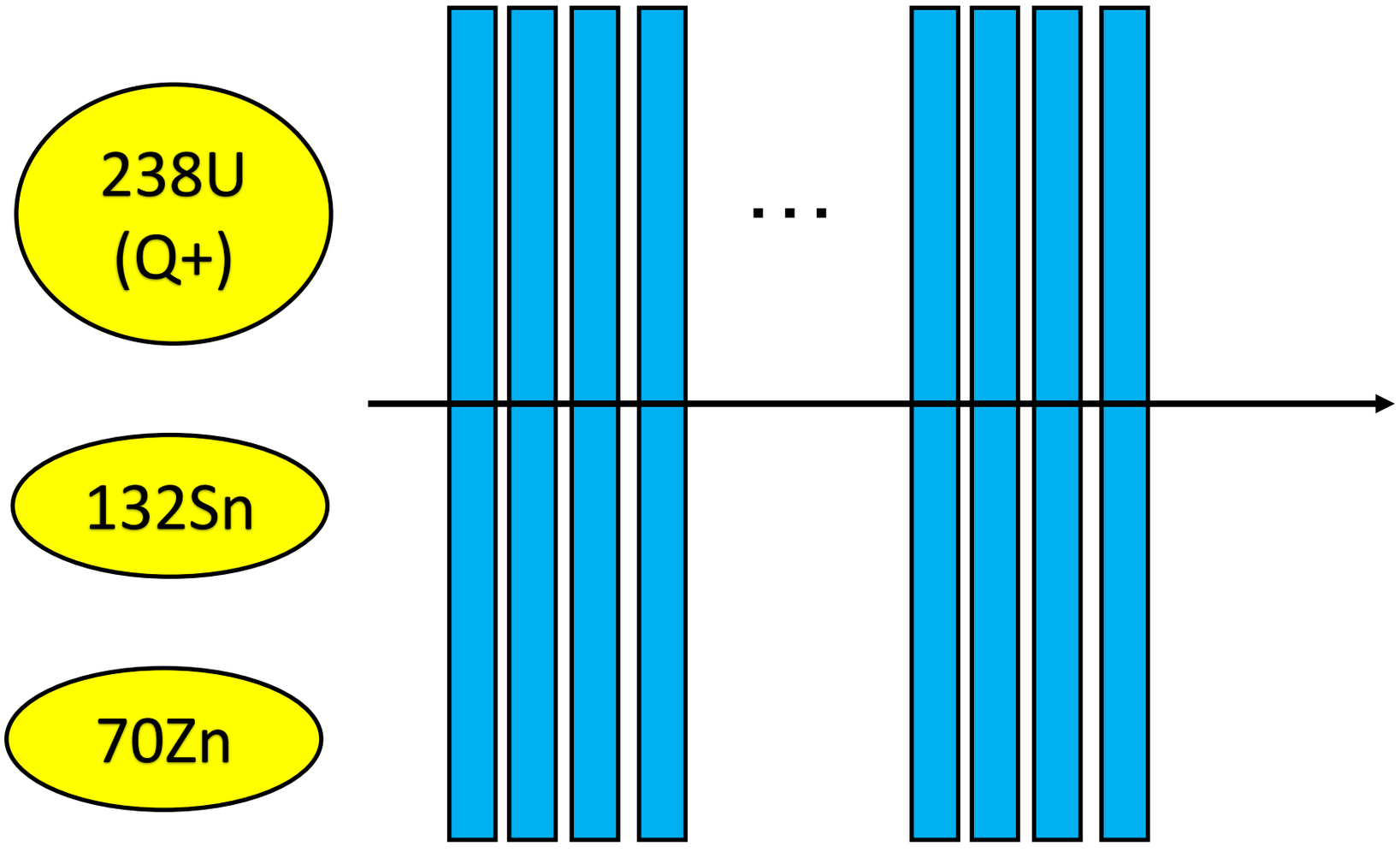
- **Short stopping range :**
  - **12.2 mm (CH2) ←→ 20.4 mm (CH2)**
  - **→ Minimize the material thicknesses**
    Smaller reaction loss

- **Large dE/dX**
  - **→ uniformity of the material thicknesses is required**

- **Charge state is dominant :**
  - **Q = Z – 1 is the main component**
  - **broader energy loss distribution**
  - **→ Measure Bragg curve itself**

- **Fission also occurs**
  - **→ Energy losses for Z ~ 30 to 50 region must be covered**
    Higher granularity to detect two fragments

Range counter



Si / SiC detectors

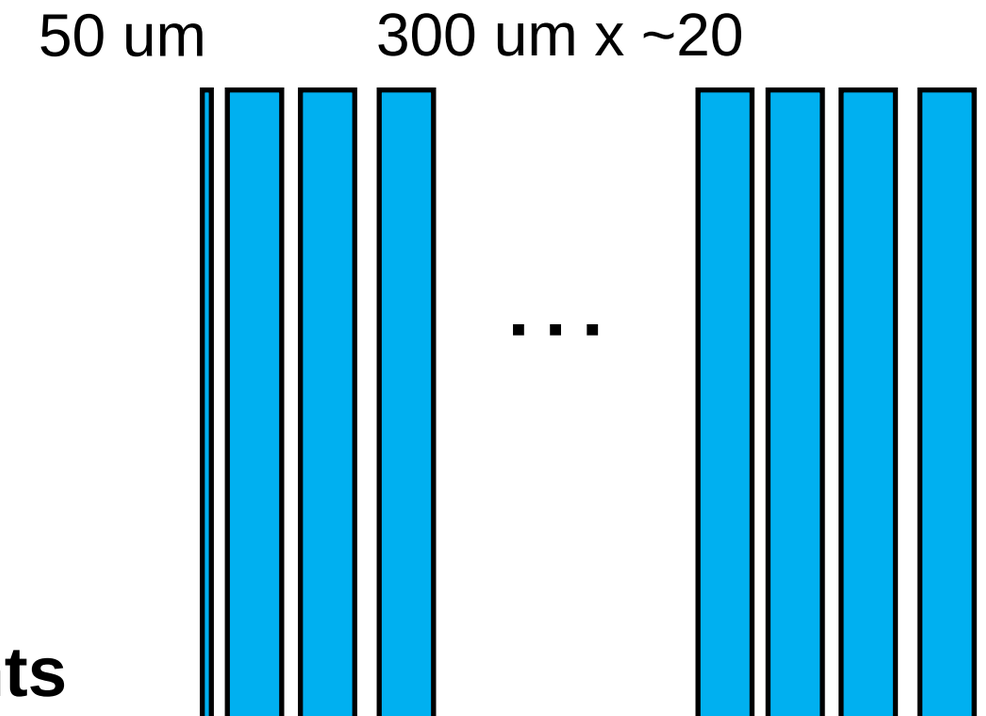
- **Uniformity of Si wafer : ~ several 0.1%**

- **Strip detectors : 100 um strip size**
  → dX ~ 30 um in sigma
  Higher position and angular resolutions

- **Thin (~50 um) layers for timing measurements**

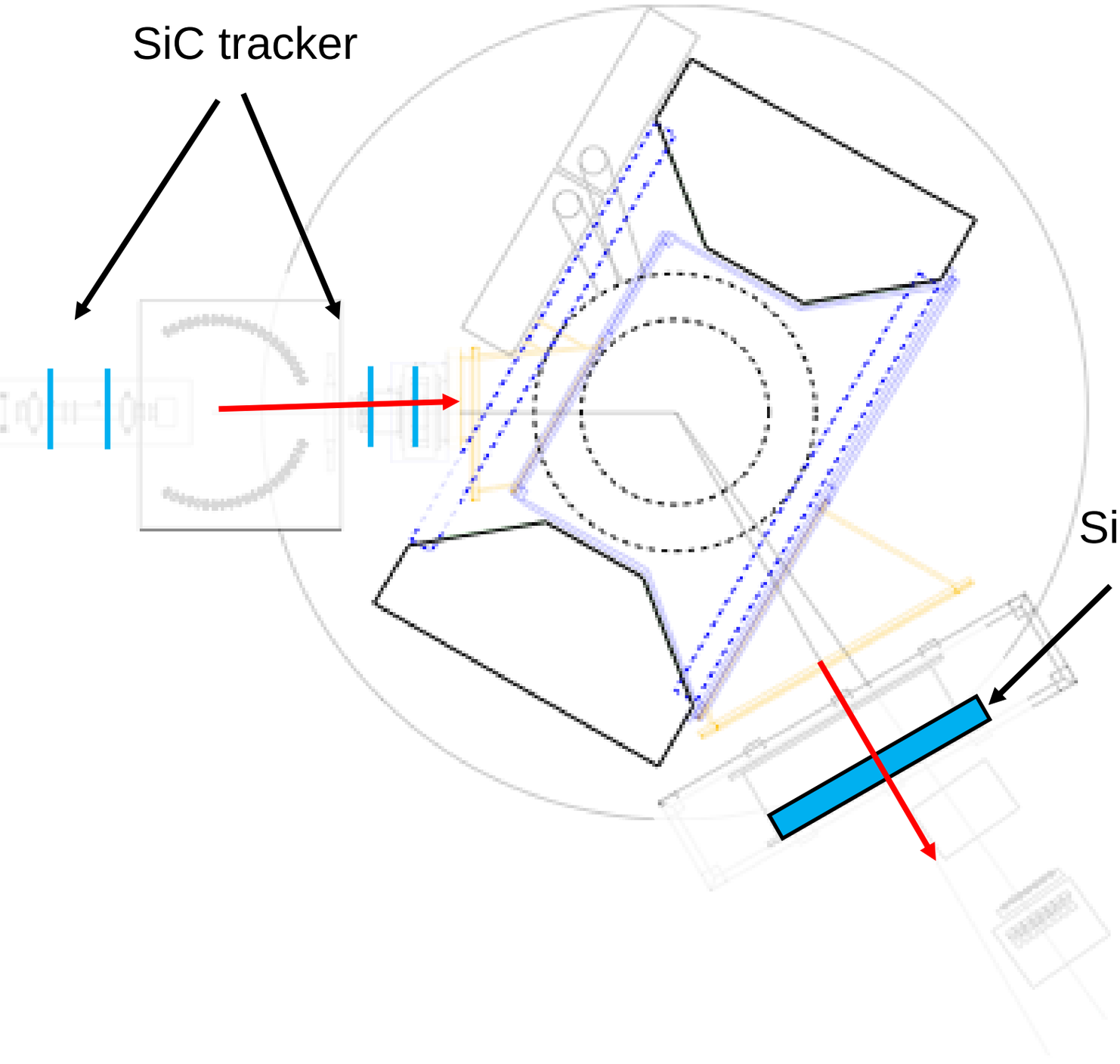
- **Signal amplifications with electronics**
  → Multi gain preamplifier

- **Si wafer size available in market : 300/450(?) phi**

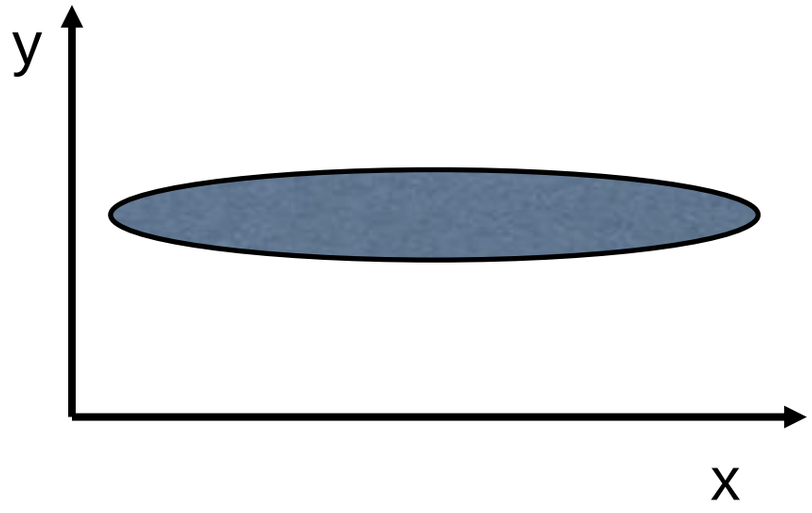


Weak point : radiation damage
→ SiC: stronger radiation hardicity (wafer size : 150 phi)
Higher granularity

Possible setup



- Vertical parallel
- Horizontal focus transport



Summary

- **PID plot is made for reaction residues from the 132Sn(p,n) reaction at 250 MeV/u using the SAMURAI spectrometer**

- **~10% goes to charge states (Q<Z).**

- **Position of the charge state moves as a function of the HODS plastic scintillator → Range counter**

- **Ultimate (?) solution: Si/SiC TOF/tracker/range counters**

Thank you very much!