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S515 EXPERIMENT ANALYSIS STATUS

R3B Collaboration meeting
08.11.2023-10.11.2023
Mainz, Germany

S515 EXPERIMENT ANALYSIS STATUS

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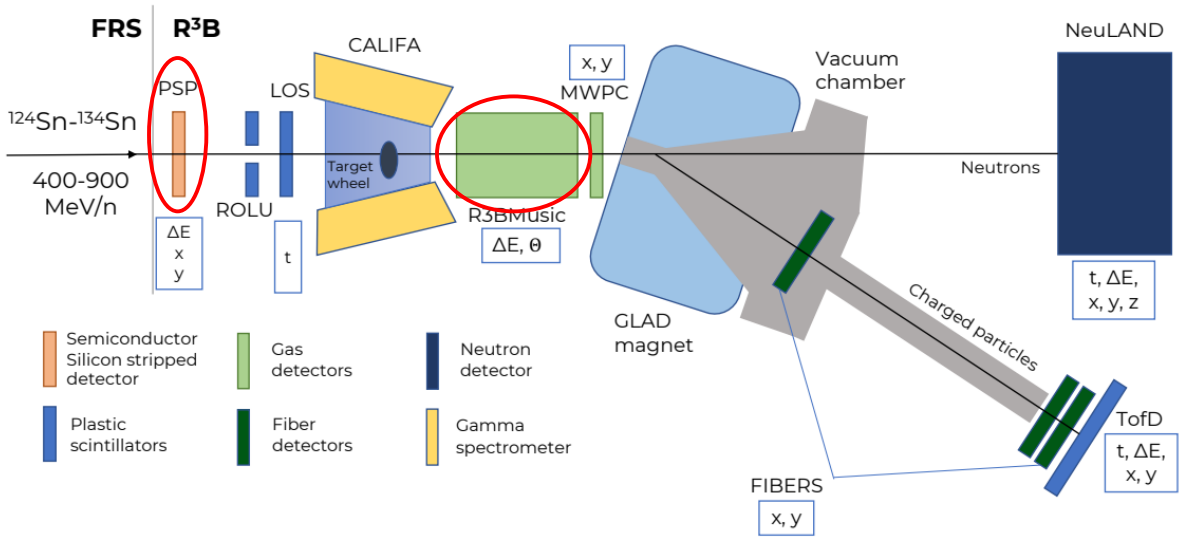
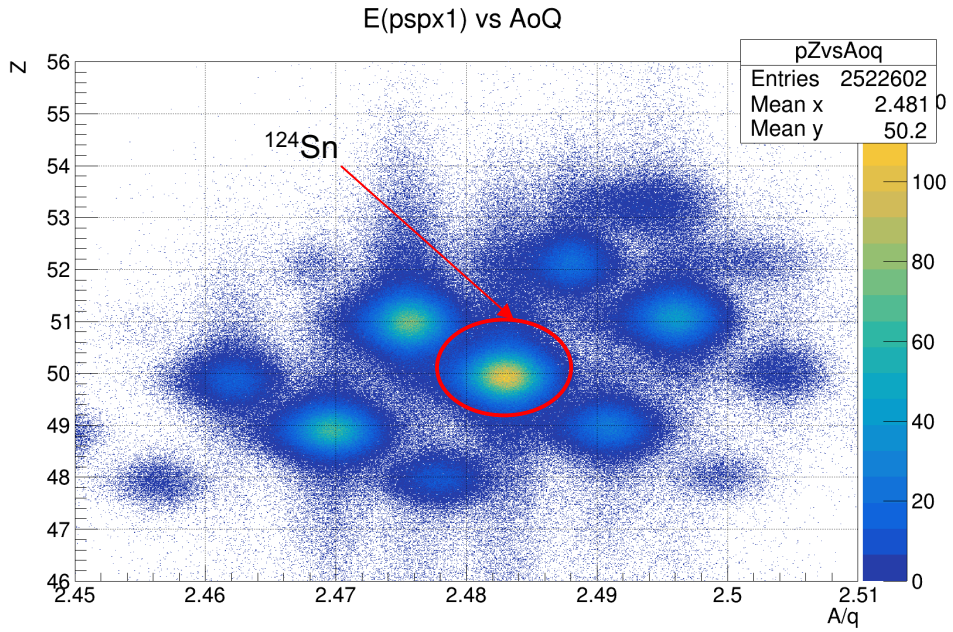
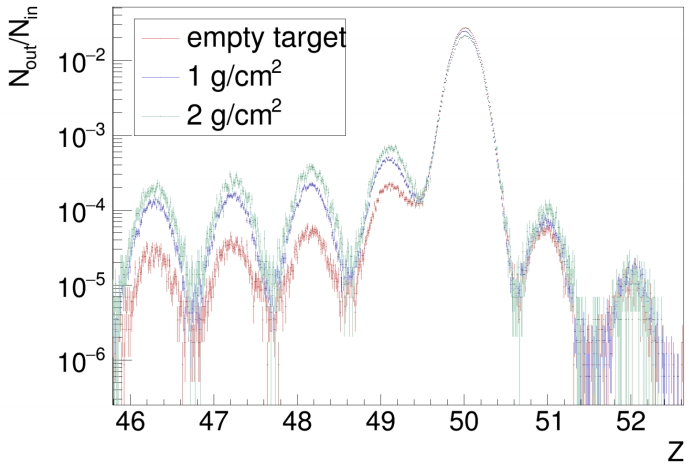
The experiment took place at GSI, April-May, 2021
Analysed reaction: $^{124}Sn+^{12}C$





Beam		Energy [Mev/u]	
primary	**secondary**	**primary**	**secondary**
^{136}Xe	**^{124}Sn**	**1080**	**904**
^{136}Xe	**^{124}Sn**	**620**	**405**
^{238}U	**^{134}Sn**	**1000**	**872**
^{238}U	**^{132}Sn**	**750**	**678**



- 2σ cut on incoming
- Observation of charge increase (Z=51)

- 1.GT resonance
- 2.Δ resonance

- Z=52 contamination

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1. GT resonance

- One of the components of quasi-elastic NN collision
- Collective excitation
- A spin-isospin flip of a nucleon
- Not included in the theory

2. Δ resonance

- Excitation of a nucleon to Δ and its decay to nucleon+pion

$$\pi^+ + n- > \Delta^+ - > \pi^0 + p$$
$$\pi^0 + n- > \Delta^0 - > \pi^- + p$$

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$^{112,\ 124}$Sn (@1 GeV/u)

1. GT resonance

- One of the components of quasi-elastic NN collision
- Collective excitation
- A spin-isospin flip of a nucleon
- Not included in the theory

2. Δ resonance

- Excitation of a nucleon to Δ and its decay to nucleon+pion

$$\pi^+ + n- > \Delta^+ - > \pi^0 + p$$
$$\pi^0 + n- > \Delta^0 - > \pi^- + p$$

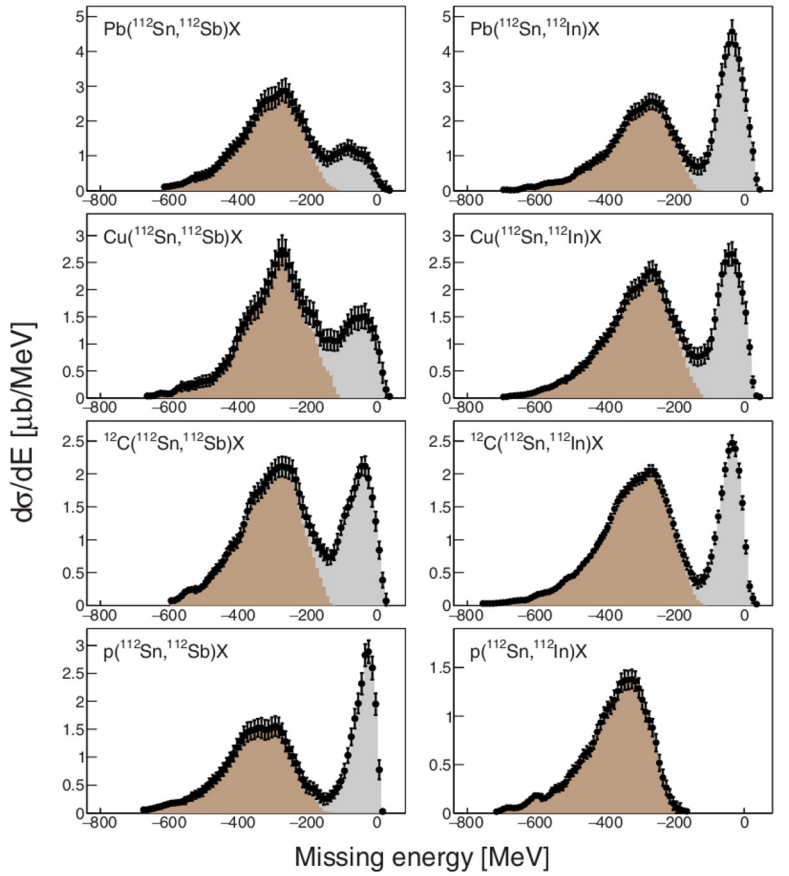

FIG. 3. Missing-energy spectra obtained from the Pb, Cu, ^{12}C, and proton targets for the single isobaric charge-exchange reactions (^{112}Sn, ^{112}Sb) and (^{112}Sn, ^{112}In). The quasielastic and inelastic contributions are displayed with gray and brown histograms, respectively.

J.L. Rodrıguez-Sanchez et al. Phys. Rev. C, 106(1):014618, 2022.

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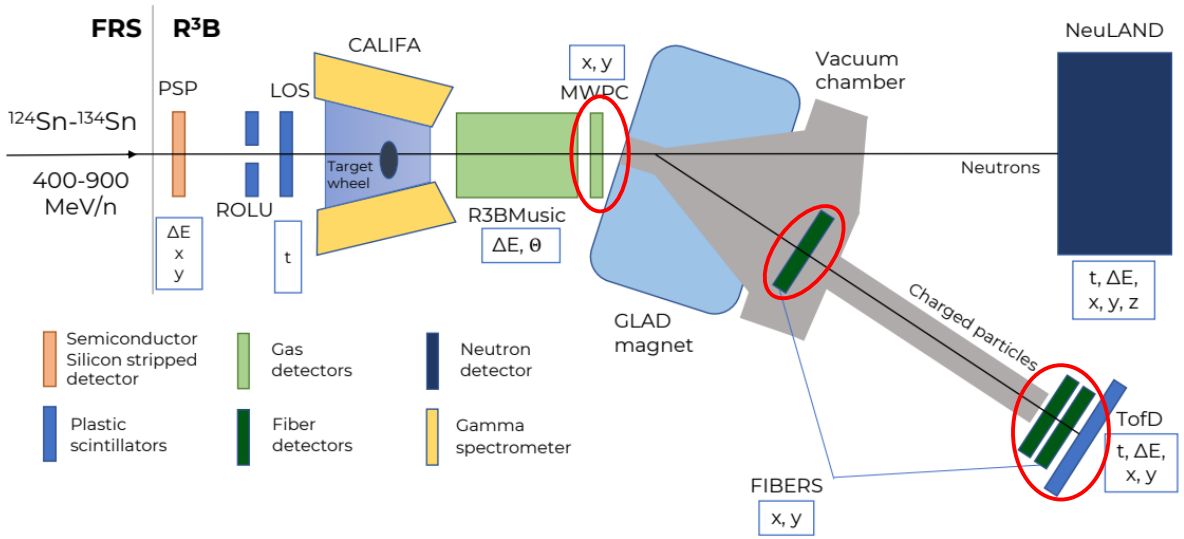
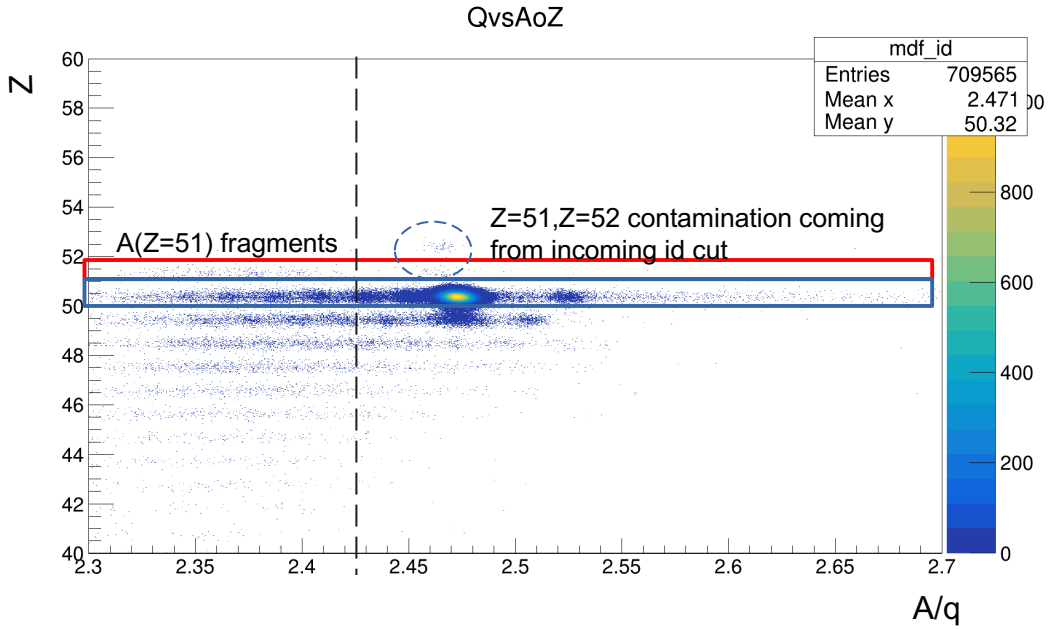
TRACKING ANALYSIS



- mwpc(x,y)
- fi10(x)
- fi11(x)
- ~~fi12(y)~~
- TofD(y)

C_{lost}(fi11→fi12) ≈ 16.5%
C_{lost}(fi11→tofd) ≈ 0.02%

→Missing signals from 16 channels. this causes a lost of events when using Fi12 in the analysis
→Fi12 was excluded, TofD y position was used



- A/q (^{124}Sn) = 2.48
- there is a slight shift in A/q value. It is ~2.473 for ^{124}Sn

- A/q (^{124}Sb) = 2.43,
- ~30 events is observed at A/Q value around ~2.42

- A/q (^{123}Sb) = 2.41
- ~75 events around ~2.4

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MISSING ENERGY ANALYSIS

→ One needs to compare the velocities of the same A with different charges. For instance, ^{124}Sn and ^{124}Sb

→ Statistics of Z=51 fragments are very low, a rough graphical cut was made around AoQ value corresponding to ^{123}Sb

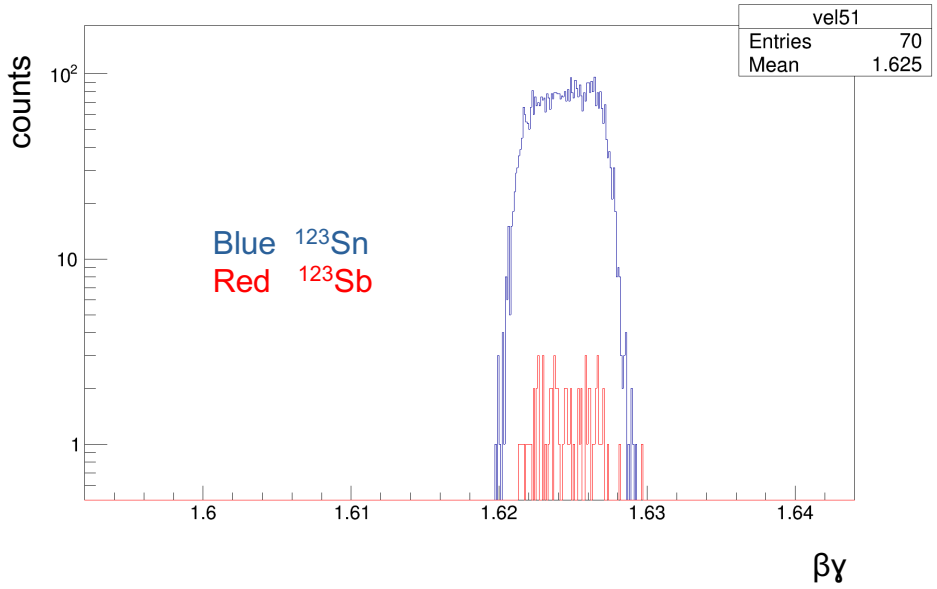
→ *Frs_beta* was used to calculate ToF in a tracking routine

ToF = FlightPath/Frs_beta/speed_of_light

β = FlightPath/ToF/speed_of_light

$\beta\gamma \approx$ AoQ/PoQ/AMU

→ One can try to extract velocity from *FlightPath* calculated by mdf, and ToF from LOS-TofD



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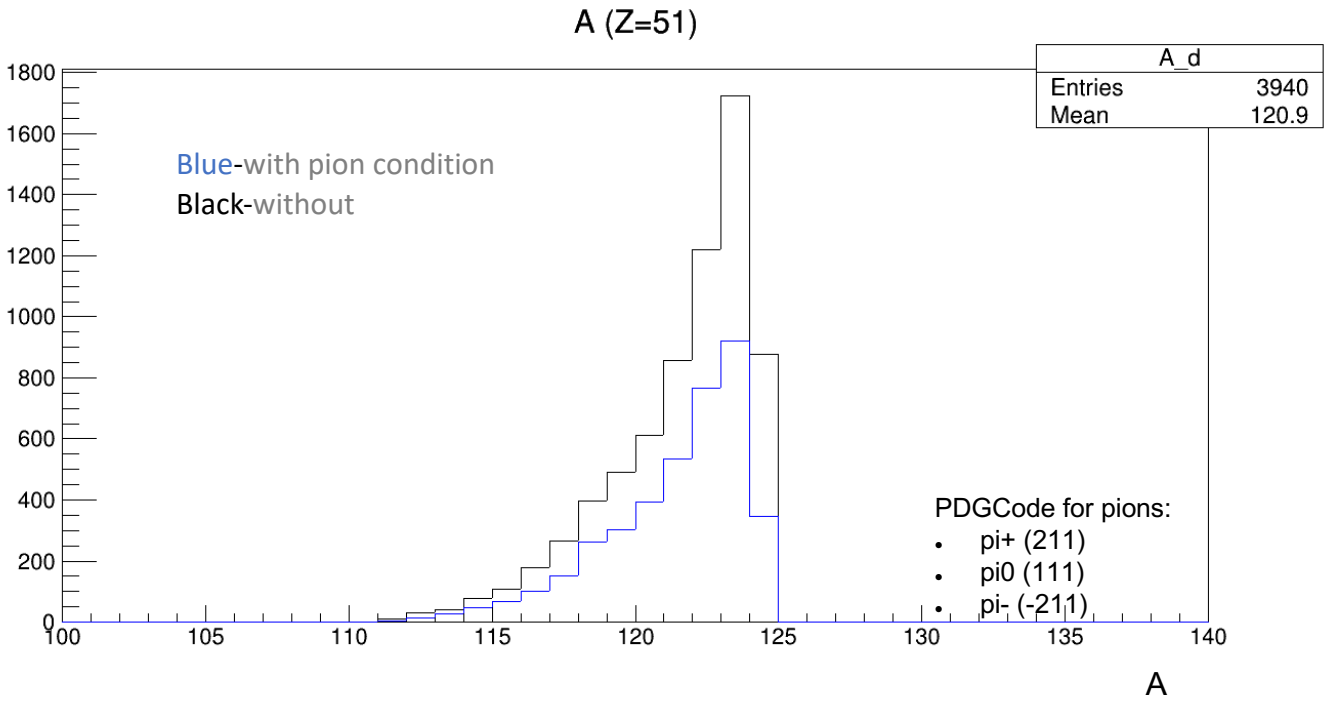
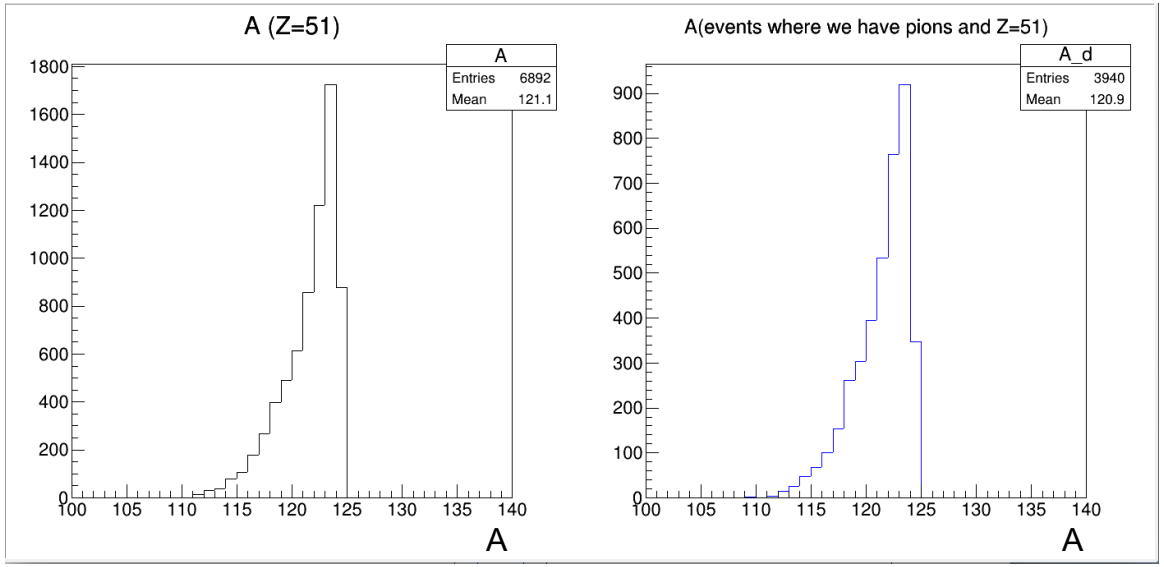
SIMULATION. INCL ROOT ANALYSIS

$^{124}Sn+^{12}C$ file produced and provided by Martina
#Entries 941268





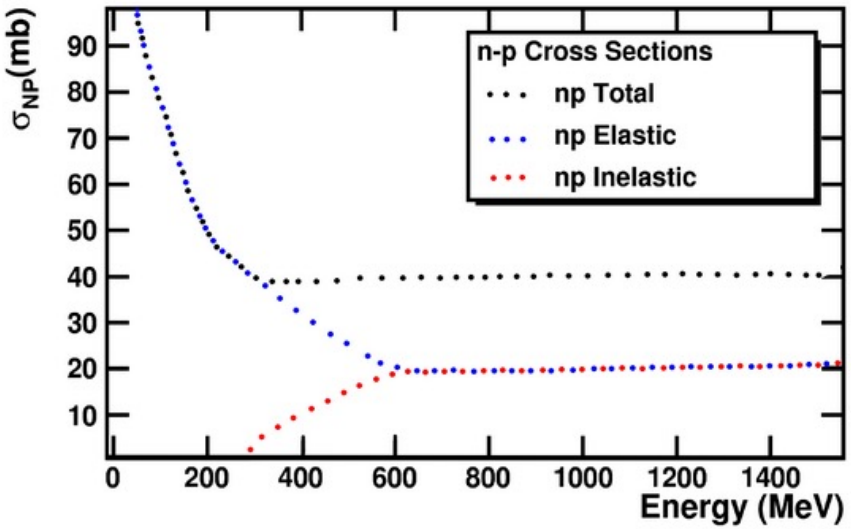
- A=123 is pronounced one

- Number of total events with Z=51 **6892**
- Number of events with Z=51 with pions in the final state **3940**

- R~0.57 (~50-50%)

SIMULATION. INCL ROOT ANALYSIS

*Plot by Jose Luis



$\sigma_{np(el)}/\sigma_{np(tot)} = \sigma_{np(inel)}/\sigma_{np(tot)}$ for E_N>600 MeV

- E_{beam} 900 AMeV
- E_{beam} 400 AMeV

→ Analysis of low beam energy 400AMeV 124Sn runs

INCL data:

σ_R=2482 mb
N = 941268
$N_{Z=51}$= 6892

$\sigma_{z=51} = (\sigma_R * N_{Z=51})/N \approx 18$ mb

Exp data:

$\sigma_{z=51} \approx 15(1)$ mb

SIMULATION. INCL ROOT ANALYSIS.CHARGE-EXCHANGE CROSS SECTION

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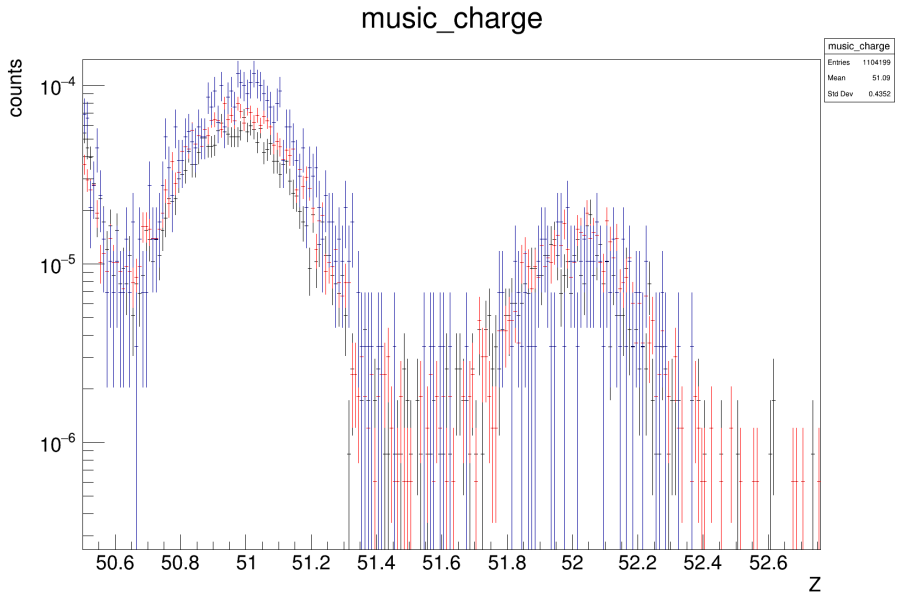
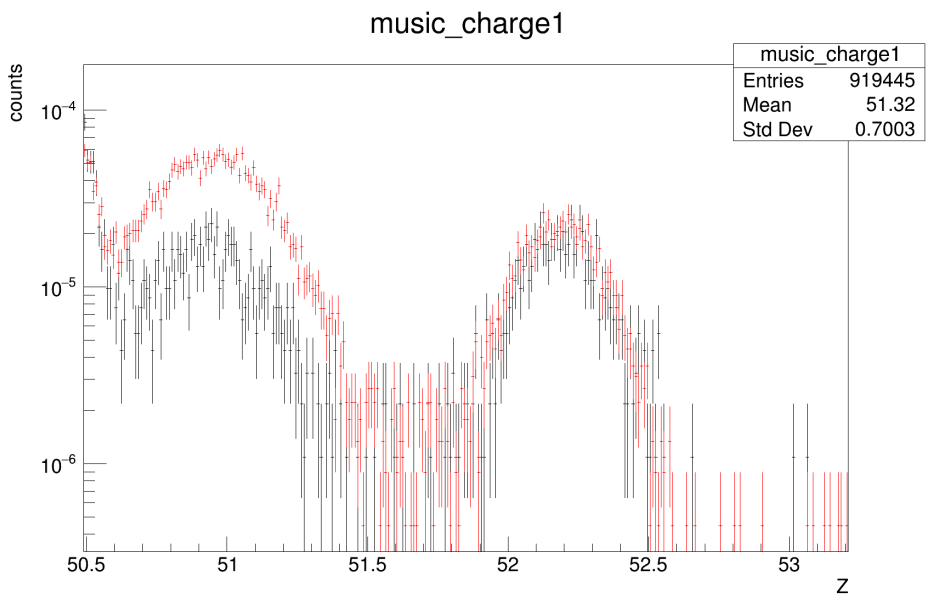
$^{124}Sn+^{12}C$ (900 AMeV)



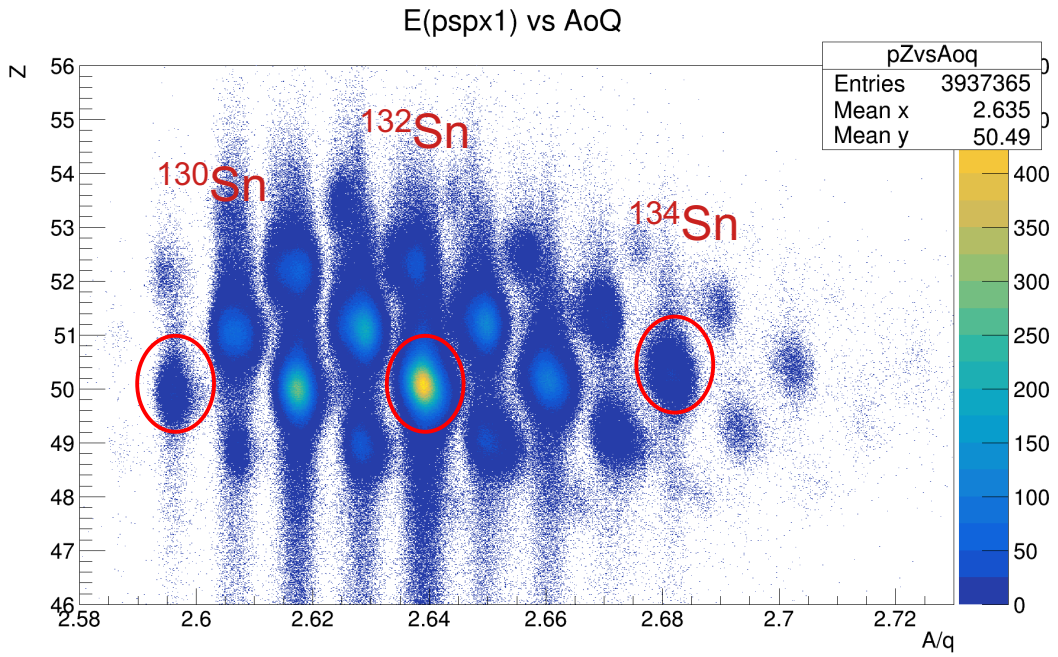
$^{132}Sn+^{12}C$ (675 AMeV)

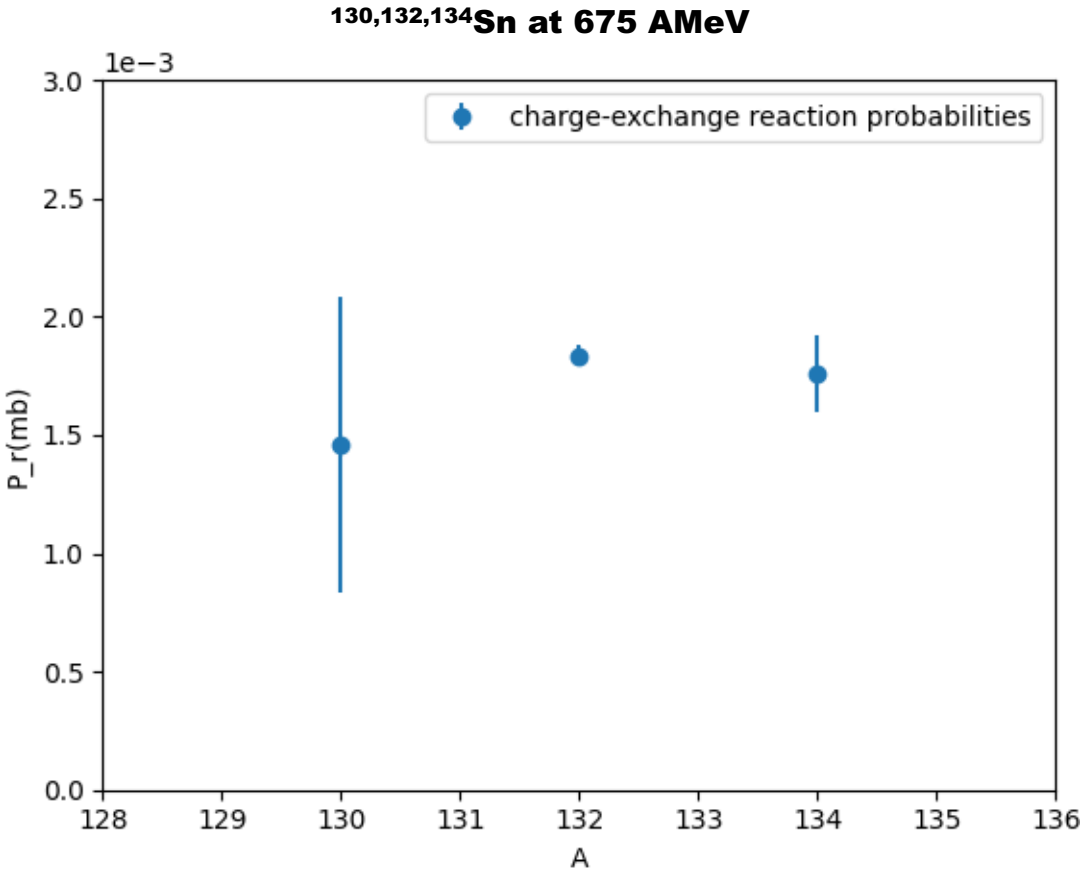


A	$\sigma_{\Delta Z=+1}$[mb]	$\Delta\sigma_{\Delta Z=+1}$[mb]
^{124}Sn (900 AMeV)	15.06	1.35
^{132}Sn (675 AMeV)	40.79	1.05

PRELIMINARY

SIMULATION. INCL ROOT ANALYSIS. CHARGE-EXCHANGE CROSS SECTION





For ^{130}Sn, ^{134}Sn selection a graphical cut was used
For ^{132}Sn selection 2σ elliptical cut was used

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Z=51 ANALYSIS CONCLUSION

→ Low statistics in $^{124}Sn+^{12}C$ @900AMeV

→ Ratio of inelastic and elastic cross sections is 50-50 % starting E_N>600 MeV

→ Ratio of two contribution from INCL simulation is ~1/2

→ Cross section values given by INCL and obtained from data is comparable (18mb and 15mb respectively)

→ Analysis of 400AMeV ^{124}Sn since at that energy elastic σ_{NP} is higher, GT might be slightly enhanced

→ Charge-exchange probabilities of $^{130,132,134}Sn$ at 675MeV are compatible in the range of error bars

→ Try to extract a velocity using FlightPath from mdf tracking and ToF from LOS-TofD

This charge-exchange cross section is necessary to derive the final neutron removal cross section.

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THE TOTAL REACTION CROSS SECTION CALCULATION

$^{124}Sn+^{12}C$

- Incoming number of ^{124}Sn particles **I^e, I^t**

→ elliptical 2σ cut on AoQ from FRS and Z from PSP

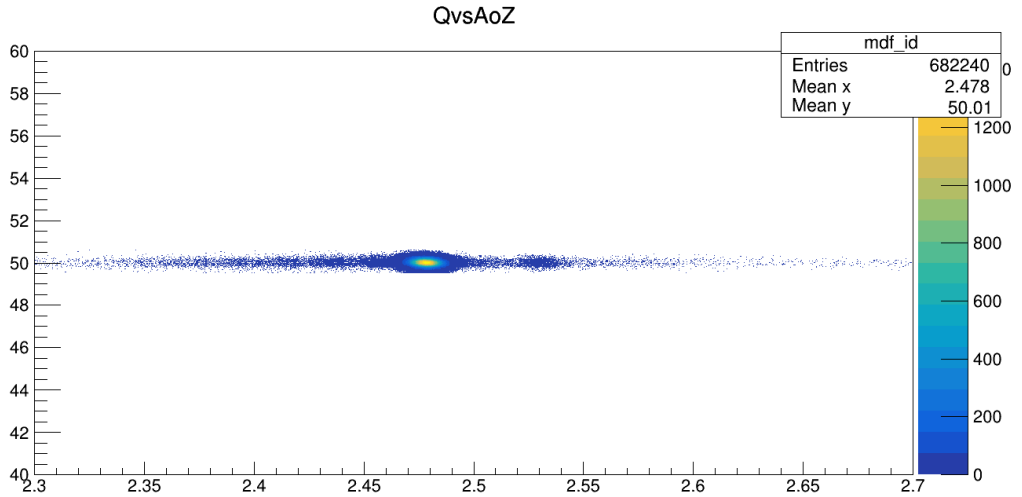
- Unreacted number of particles (Z=50, N=74) **U^e, U^t**

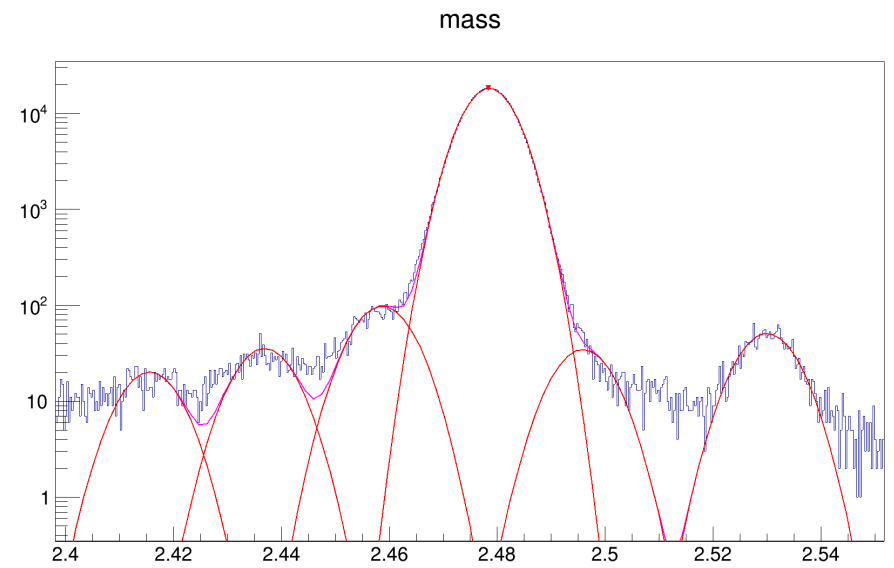
→ cut on Z=50
→ projection on AoQ
→ sum of several gaussians with fixed σ
→ integral of AoQ=2.48

$$\sigma_R = -\frac{1}{T}\ln\left(\frac{U^t}{I^t}\frac{I^e}{U^e}\right)$$
$$= -\frac{1}{T}\ln\left(\frac{1-P^t}{1-P^e}\right)$$

σ_R = 2405 +/- 42 mb

***no correction is included**





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THE TOTAL CHARGE-CHANGING CROSS SECTION CALCULATION

$^{124}Sn+^{12}C$

- Incoming number of ^{124}Sn particles **I^e, I^t**

→ elliptical 2σ cut on AoQ from FRS and Z from PSP

- Unreacted number of particles (Z=50, N=74 || N≠74) **U^e, U^t**

→ sum of several gaussians with fixed σ on charge spectra from MUSIC

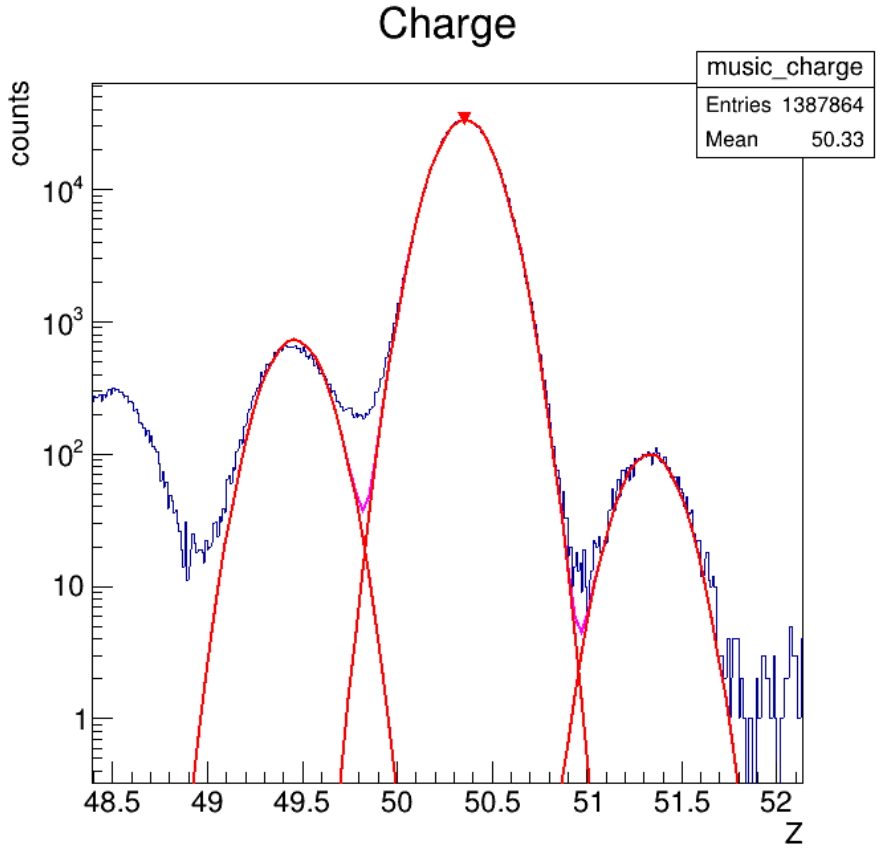
→ integral of Z=50

$$\sigma_{\Delta Z} = -\frac{1}{T}\ln\left[e^{-\sigma_R T}P^e_{\Delta Z} - P^t_{\Delta Z} + 1\right]$$

$\sigma_{\Delta Z}$ = 2162 +/- 37 mb

$$\sigma_{CE} = -\frac{1}{T}\ln\left[e^{-\sigma_R T}e^{\sigma_{\Delta Z} T}P^e_{CE} - e^{\sigma_{\Delta Z} T}P^t_{CE} + 1\right]$$

$\sigma_{\Delta Z=+1}$ = 15.07 +/- 1.35 mb



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THE TOTAL NEUTRON-REMOVAL CROSS SECTION CALCULATION

$^{124}Sn+^{12}C$

- Incoming number of ^{124}Sn particles $\mathbf{I^e}$, $\mathbf{I^t}$

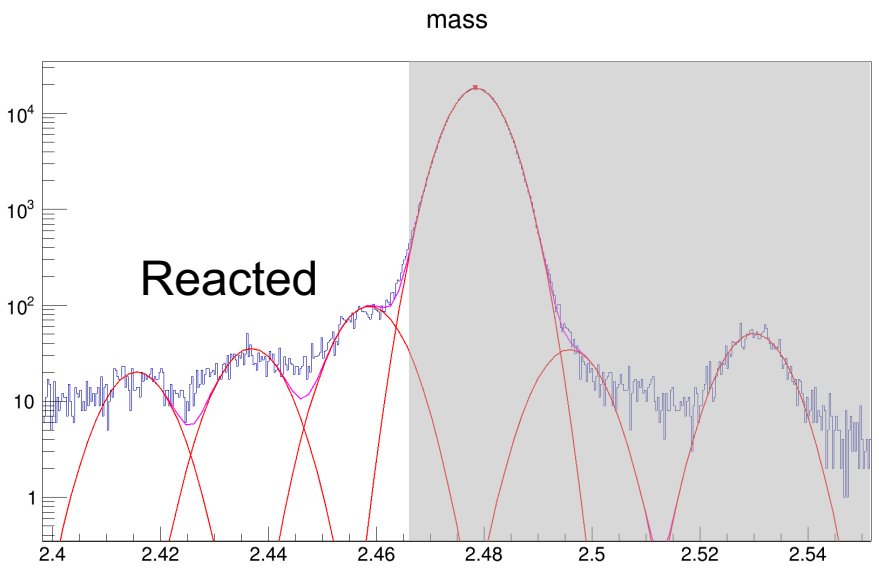
→ elliptical 2σ cut on AoQ from FRS and Z from PSP

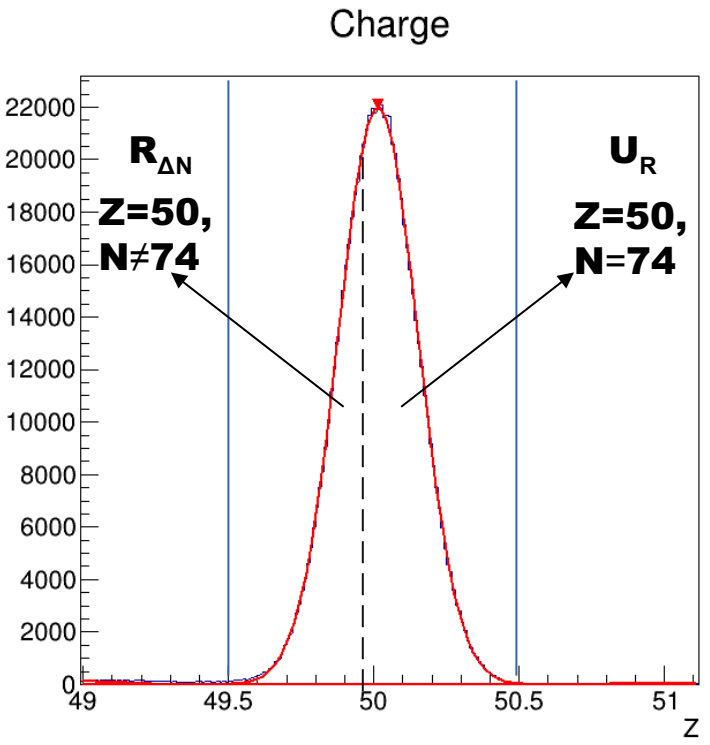
1. Reacted number of particles (Z=50, N≠74) $\mathbf{R^e}$, $\mathbf{R^t}$

→ gate on Z=50
→ projection on AoQ
→ sum of several gaussians with fixed σ
→ integral of A-1, A-2, ...A-n

2. $\mathbf{R_{\Delta N}=U_{\Delta Z}- U_R}$
   $\mathbf{U_{\Delta Z}}$ (Z=50, N=74 || N≠74)
   $\mathbf{U_R}$ (Z=50, N=74)

3. $\mathbf{\sigma_{\Delta N} = \sigma_R - \sigma_{\Delta Z}}$





$U_{\Delta Z}$ (Z=50, N=74 || N≠74)

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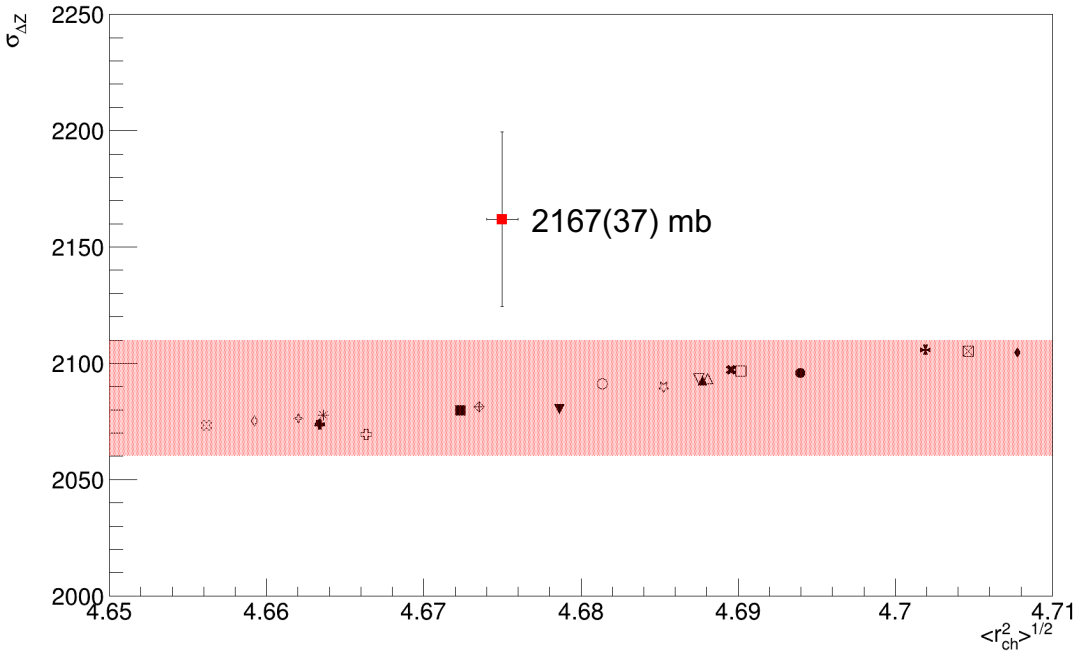
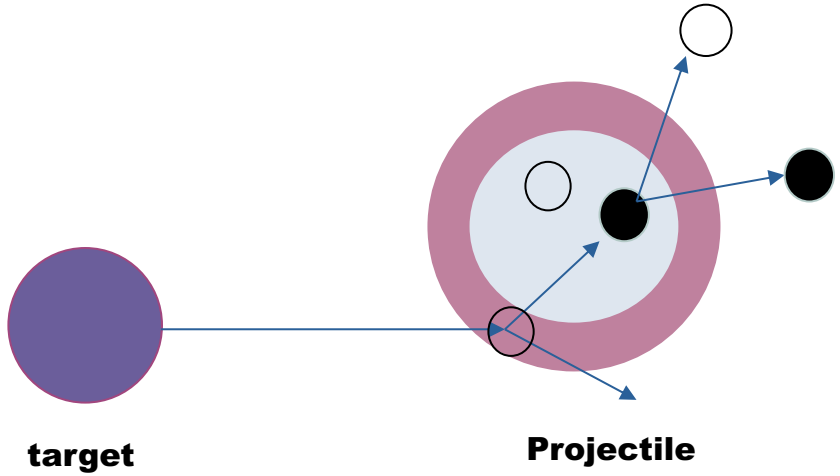
COMPARISON WITH THEORY

^{124}Sn+^{12}C @ 900AMeV





- Two step process, which is not considered in theory
- Proton was removed from the projectile in the result of an interaction with projectile's neutron

***An analysis with 2 g/cm^2 thickness needs to be done, tracked data are not produced yet**

Exp. σ_R [mb]	Theor. σ_R [mb] min.value	Theor. σ_R [mb] max.value	INCL
2405 (42)	2506	2563	2482

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SUMMARY & OUTLOOK

Preliminary σ_R , $\sigma_{\Delta Z}$, $\sigma_{\Delta Z=+1}$ were calculated
The method how to calculate $\sigma_{\Delta N}$ is discussed

→ Continue charge-exchange analysis
→ Analyze other tin isotopes at different energies (tracking, cross section calculations)

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THANK YOU FOR YOUR ATTENTION!

Thanks to my analysis colleagues:
Ivana Lihtar, Andrea Horvat, Martina Feijoo Fontan, Jose Luis Rodrigues, Igor Gasparic, Valerii Panin, Dominic Rossi

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BACKUP SLIDES

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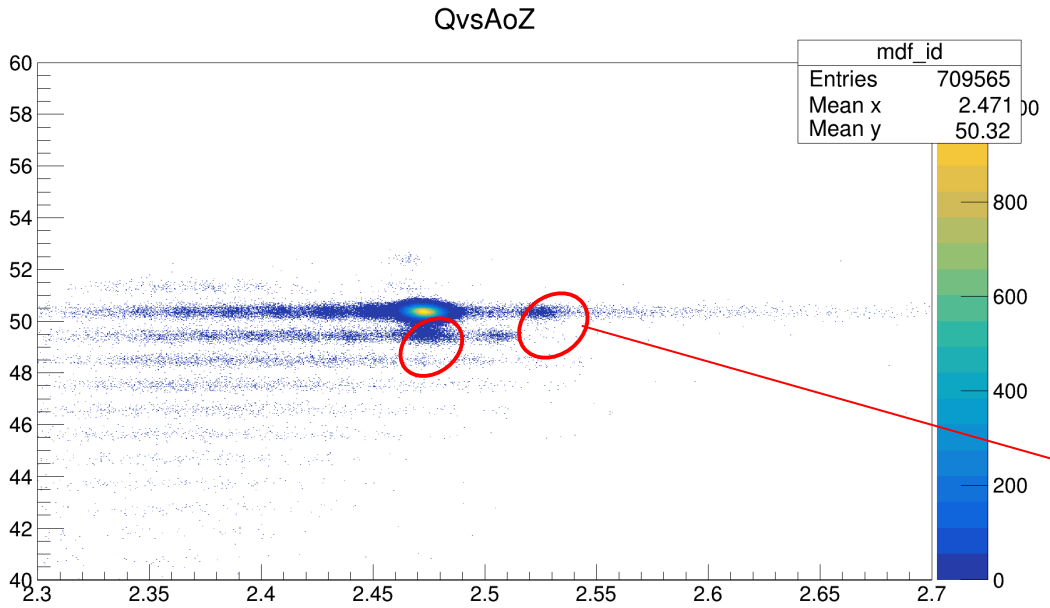
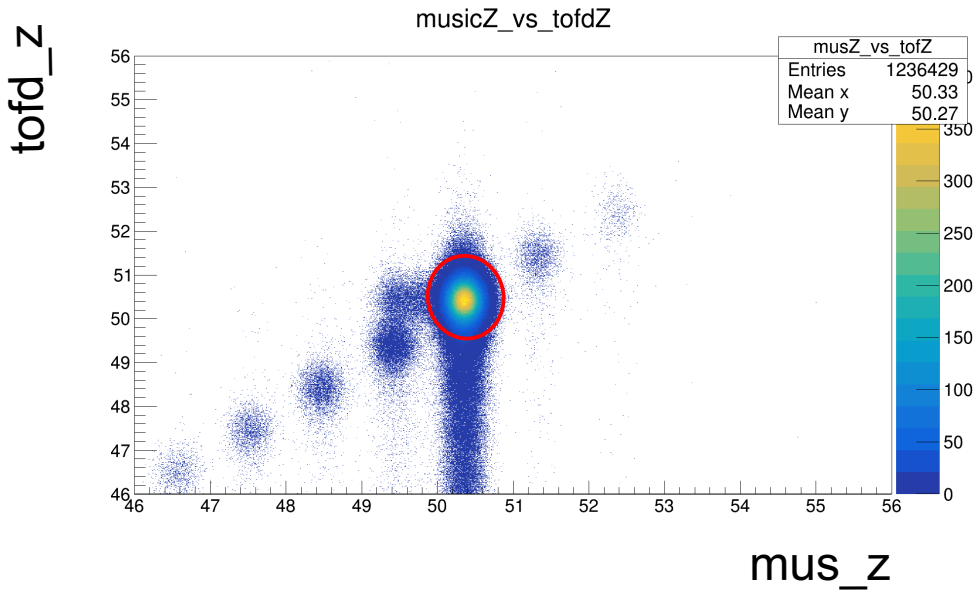
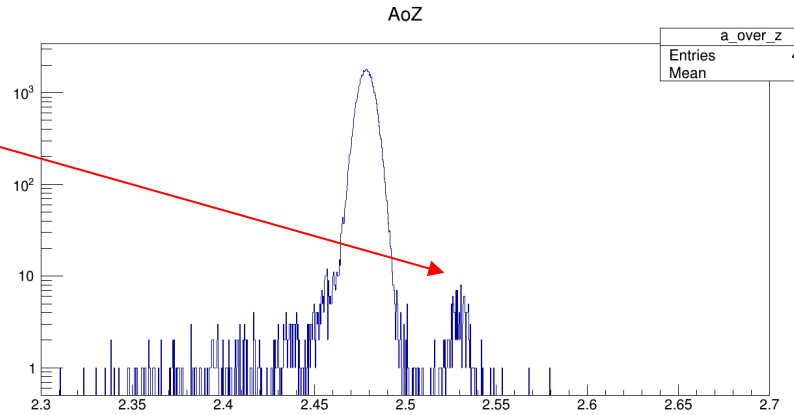
CHARGE STATES 49+

1.Z=50(psp)→Z=50(music) →Z=49(glad)







A fraction of particles leaves the detector with additional n electrons and enters the magnet with the charge Q = Z − n.

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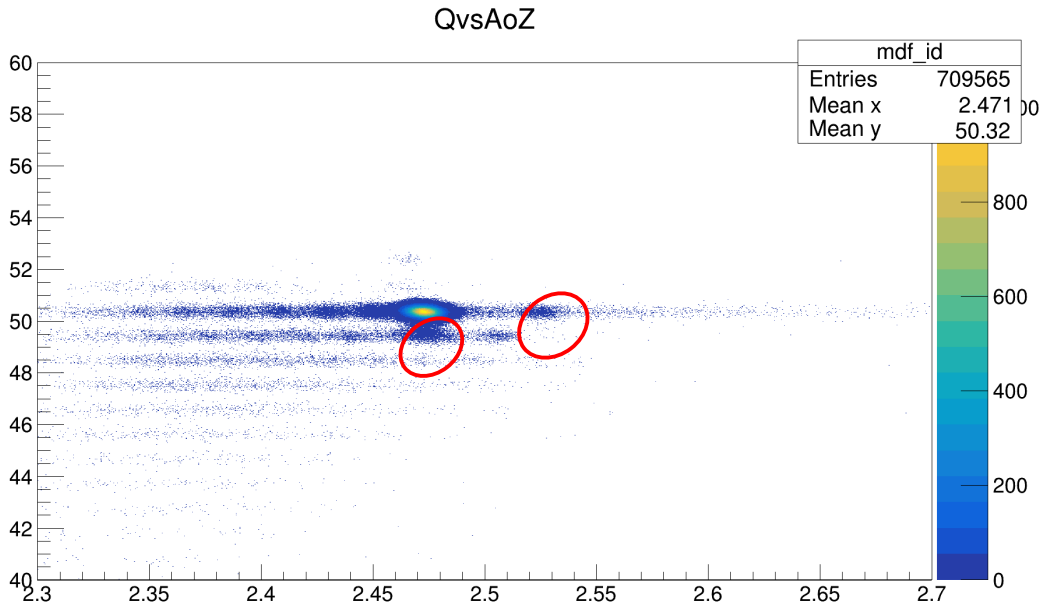
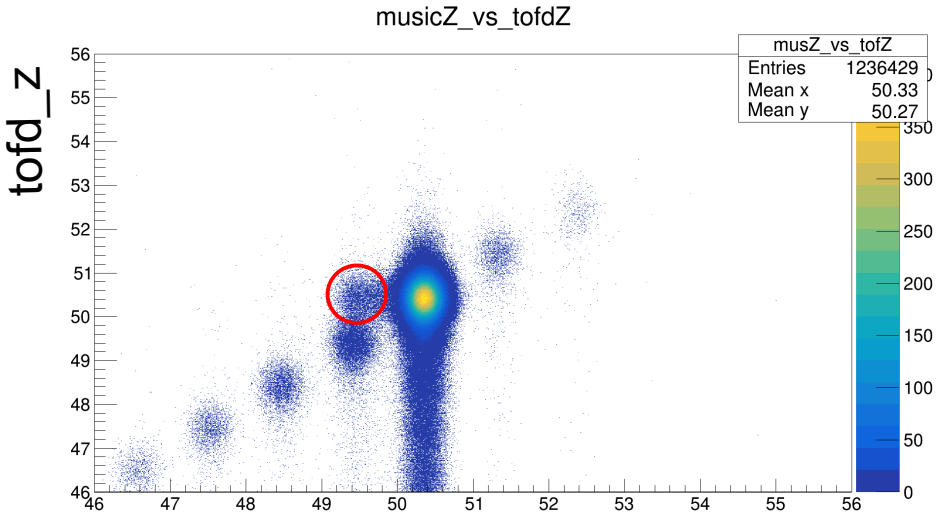
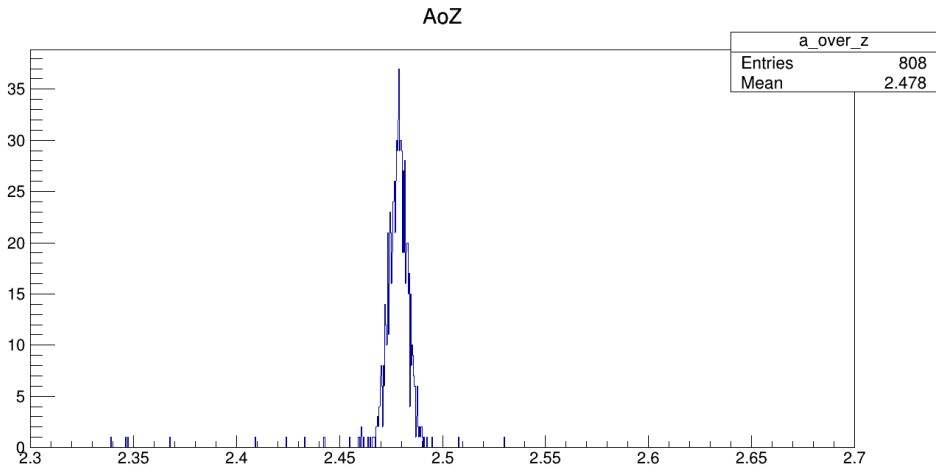
CHARGE STATES 49+

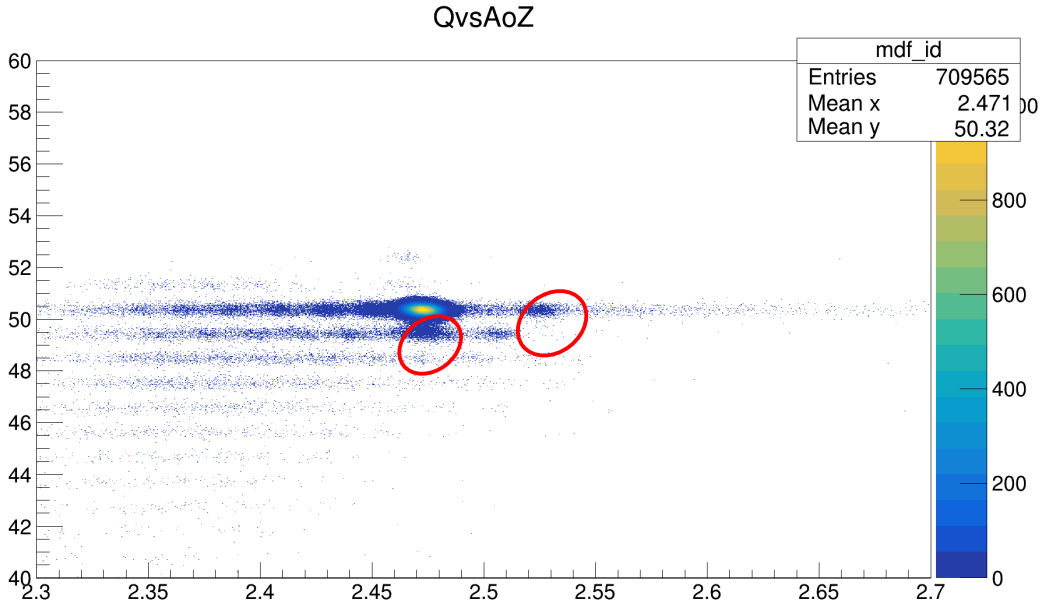
2.Z=50(psp)→Z=49(music)→Z=50(glad)

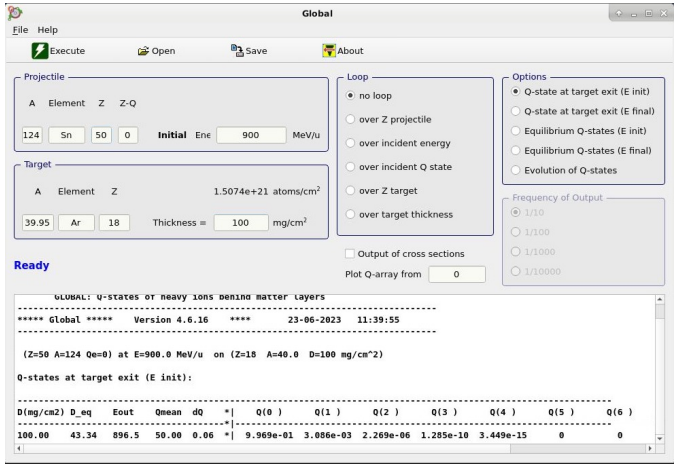


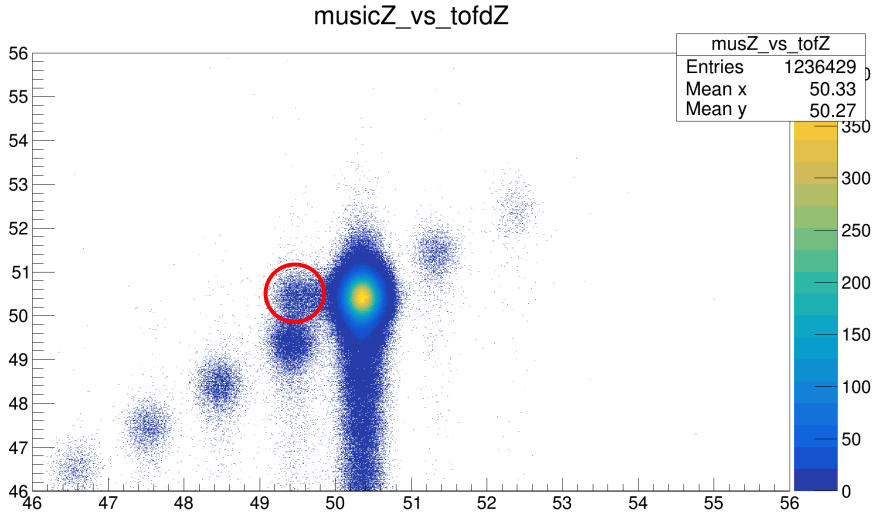


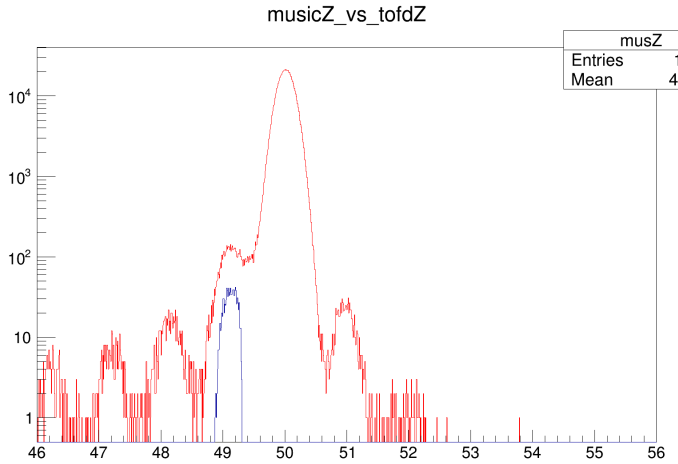


CHARGE STATES 49+









$N_{cs}/N_{Z=50}$ ~0.16%

CALCULATION. EQUATIONS DERIVATION

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