AGATA at FAIR

Kathrin Wimmer

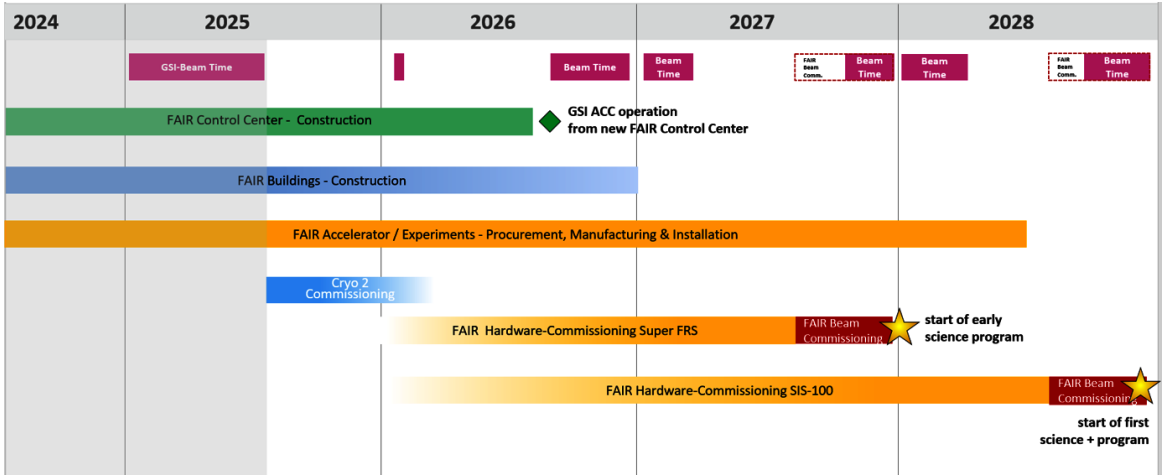
GSI Helmholtzzentrum für Schwerionenforschung

17. September 2025

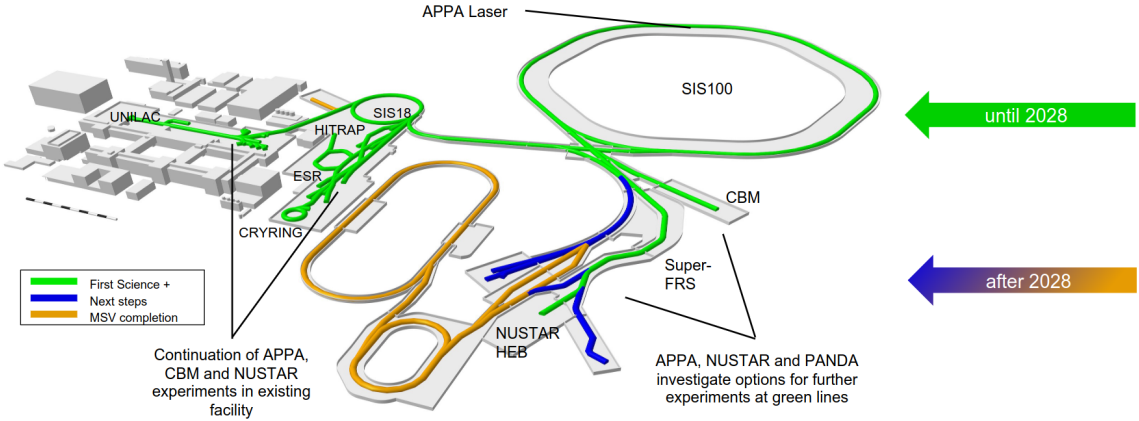
European Research Council
Established by the European Commission

FAIR construction

FAIR timeline



The FAIR timeline



- End of 2028 “First Science”: NUSTAR experiments with SIS100 beams at Super-FRS
- S-FRS provides secondary beams to R^3B, Super-FRS EC, and DESPEC
- Continue experiments at GSI (SHE at UNILAC, ESR, CRYRING)
- AGATA to be installed at the low-energy (LE) branch of Super-FRS

Magnet installation in the SIS100 tunnel

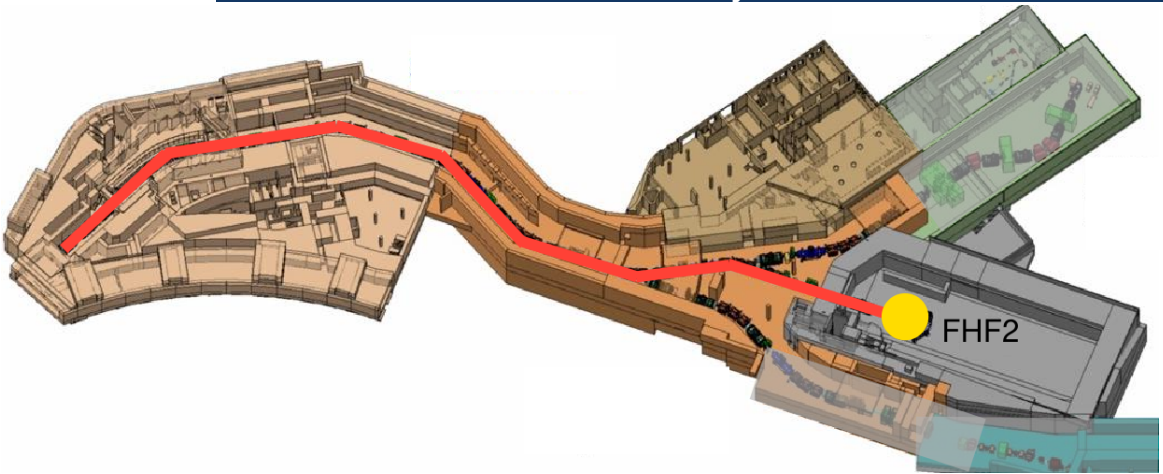
NUSTAR experimental areas

Installation in S-FRS target area

FRS tunnel

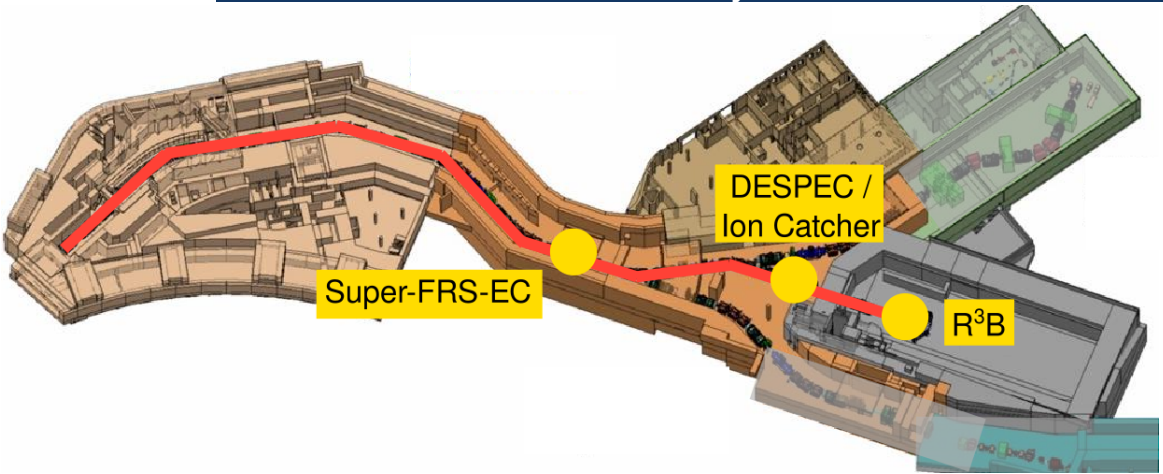
GSI/FAIR, Zeitrausch, https://www.gsi.de/medien-news/mediathek/bilderdatenbank

The NUSTAR timeline for early and first science



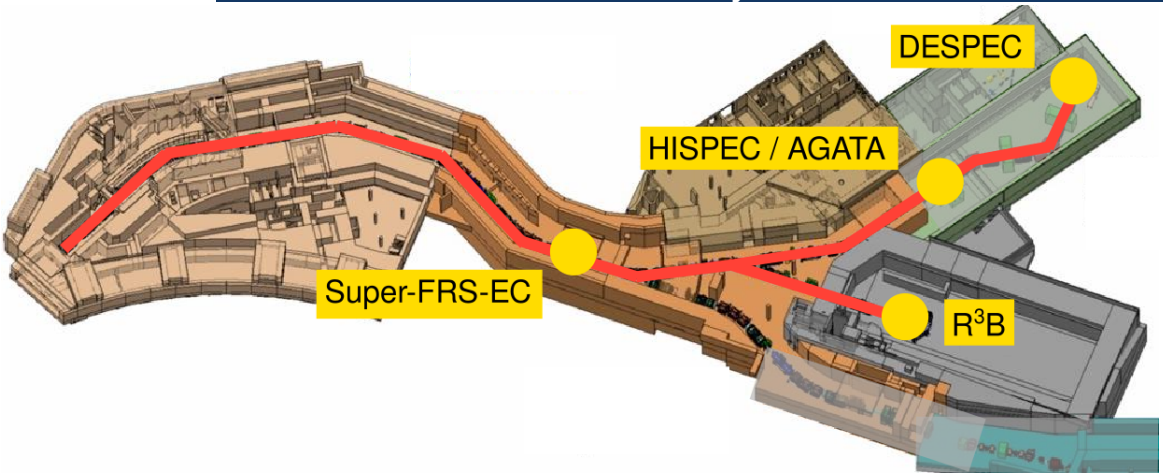
- Commissioning of Super-FRS and NUSTAR startup at FHF2 in Q4 2027
- Early (SIS18) and First Science (SIS100) experiments on one beam-line to HEC
- Funding decision on FS++ (including Low Energy Branch) aimed for in 2026, operation 2030+

The NUSTAR timeline for early and first science



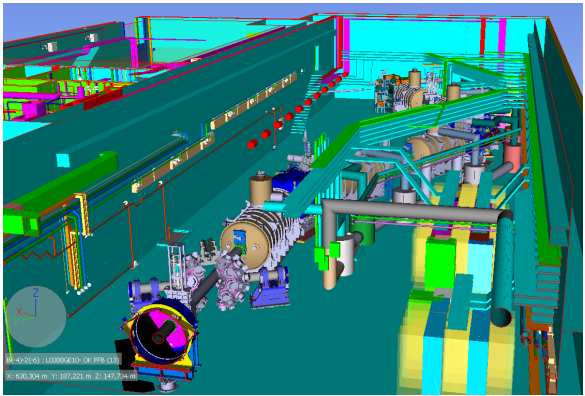
- Commissioning of Super-FRS and NUSTAR startup at FHF2 in Q4 2027
- Early (SIS18) and First Science (SIS100) experiments on one beam-line to HEC
- Funding decision on FS++ (including Low Energy Branch) aimed for in 2026, operation 2030+

The NUSTAR timeline for early and first science



- Commissioning of Super-FRS and NUSTAR startup at FHF2 in Q4 2027
- Early (SIS18) and First Science (SIS100) experiments on one beam-line to HEC
- Funding decision on FS++ (including Low Energy Branch) aimed for in 2026, operation 2030+

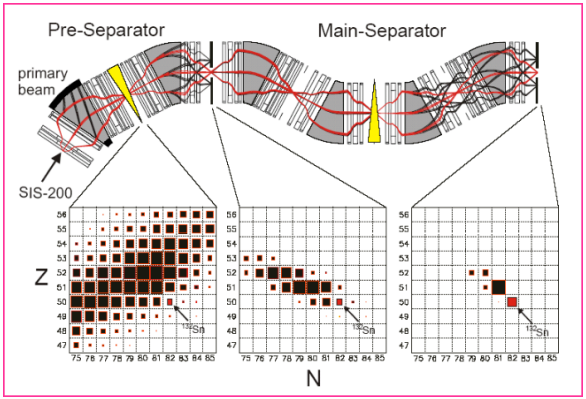
Low-energy cave

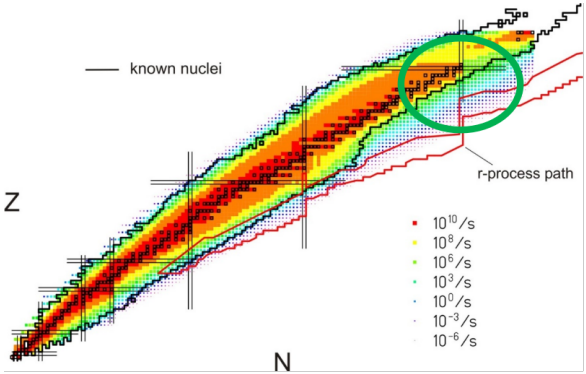


- Low-energy cave
- Building completed, but installation of infrastructure awaits funding decision
- Operation currently planned for First Science++ phase from 2030+

H. Albers, P. Hofmann

Super Fragment-Separator



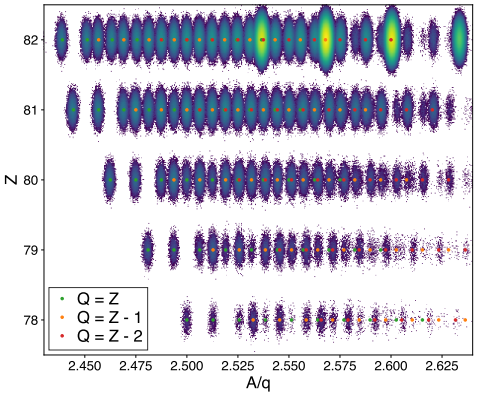


- Two stage separation and identification
- Large reach for many radioactive beams
- Typical required intensities for in-beam spectroscopy 10-100 pps

- $B\rho - \Delta E - TOF$ method

$$\frac{dE}{dx} = \frac{4\pi e^4 Z^2}{m_e v^2} Nz \left[ln\left(\frac{2m_e v^2}{I}\right) - ln(1-\beta^2) - \beta^2 \right]$$

$$\frac{A}{Q} = \frac{B\rho}{\beta\gamma}\frac{c}{m_u} \quad \text{with} \quad TOF = \frac{L}{\beta c}$$



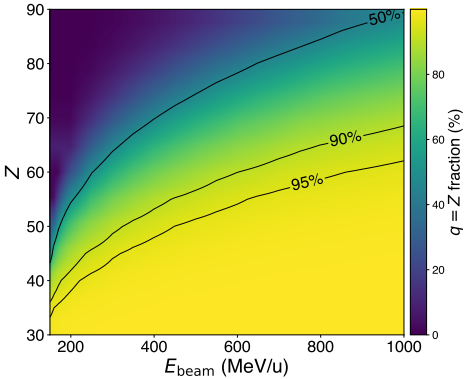
- Challenge: separation of charge states
- Increase in primary beam intensity and transmission
- Competitive intensities throughout the periodic table

Super Fragment-Separator

- $B\rho - \Delta E - TOF$ method

$$\frac{dE}{dx} = \frac{4\pi e^4 Z^2}{m_e v^2} Nz \left[ln\left(\frac{2m_e v^2}{I}\right) - ln(1-\beta^2) - \beta^2 \right]$$

$$\frac{A}{Q} = \frac{B\rho}{\beta\gamma}\frac{c}{m_u} \quad \text{with} \quad TOF = \frac{L}{\beta c}$$



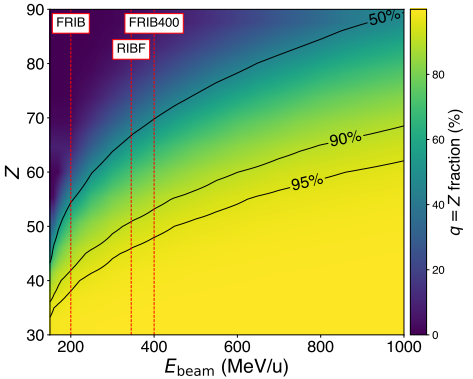
- Challenge: separation of charge states
  → Benefit from high beam energy
- Increase in primary beam intensity and transmission
- Competitive intensities throughout the periodic table

Super Fragment-Separator

- $B\rho - \Delta E - TOF$ method

$$\frac{dE}{dx} = \frac{4\pi e^4 Z^2}{m_e v^2} Nz \left[ln\left(\frac{2m_e v^2}{I}\right) - ln(1-\beta^2) - \beta^2 \right]$$

$$\frac{A}{Q} = \frac{B\rho}{\beta\gamma}\frac{c}{m_u} \quad \text{with} \quad TOF = \frac{L}{\beta c}$$



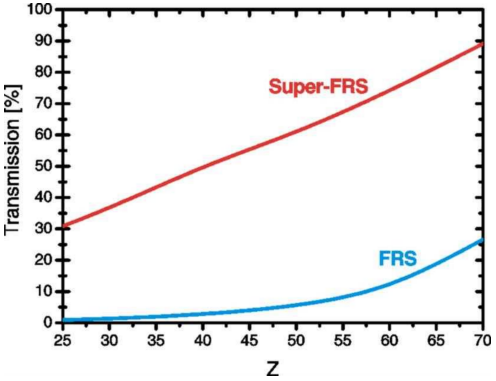
- Challenge: separation of charge states
  → Benefit from high beam energy
- Increase in primary beam intensity and transmission
- Competitive intensities throughout the periodic table

Super Fragment-Separator

- $B\rho - \Delta E - TOF$ method

$$\frac{dE}{dx} = \frac{4\pi e^4 Z^2}{m_e v^2} Nz \left[ln\left(\frac{2m_e v^2}{I}\right) - ln(1-\beta^2) - \beta^2 \right]$$

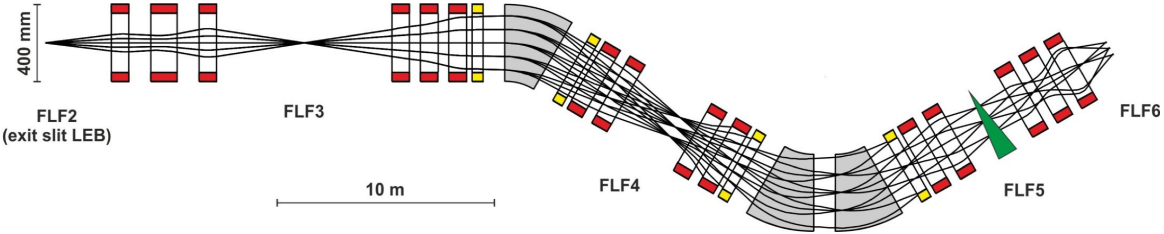
$$\frac{A}{Q} = \frac{B\rho}{\beta\gamma}\frac{c}{m_u} \quad \text{with} \quad TOF = \frac{L}{\beta c}$$



- Challenge: separation of charge states
  → Benefit from high beam energy
- Increase in primary beam intensity and transmission
- Competitive intensities throughout the periodic table

Facility	U intensity per spill
Phase 0 at GSI	$2 \cdot 10^9$
Early Science	$8 \cdot 10^9$
First Science SIS100	$2 \cdot 10^{10}$
Final full intensity with SIS100	$3 \cdot 10^{11}$

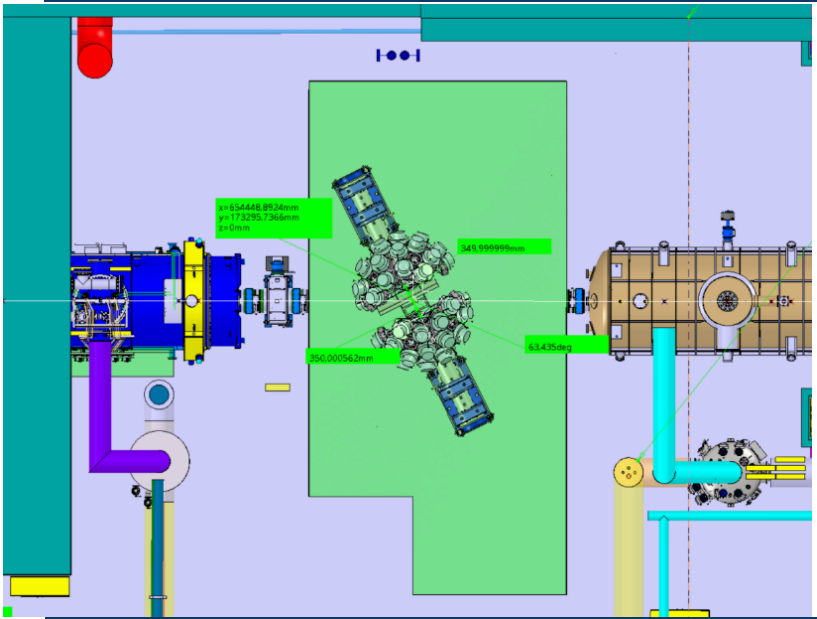
Low-Energy Buncher



Conceptual design with flexible operation

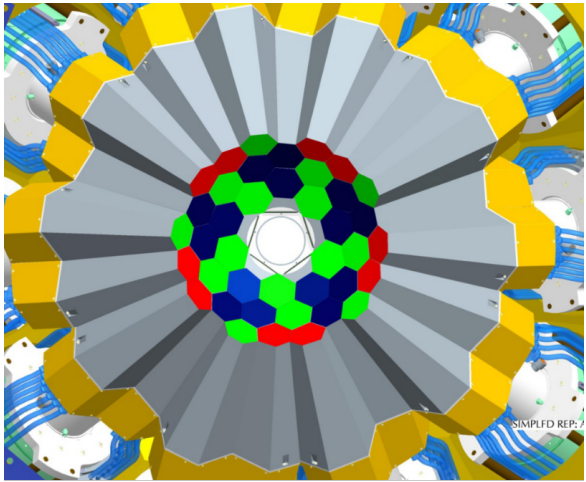
- Secondary target at FLF3
- Large experimental area, about 7 m along the beam line at FLF3
- Large acceptance spectrometer
- 3 dipole magnets with 30° deflection angle, maximum rigidity 7 Tm (about 300 *A*MeV depending on the species)
- High-resolution / energy buncher mode
- Dispersion matching (main-separator and energy buncher)
- Intermediate focus at focal plane FLF4, LYCCA for particle identification

AGATA at FLF3



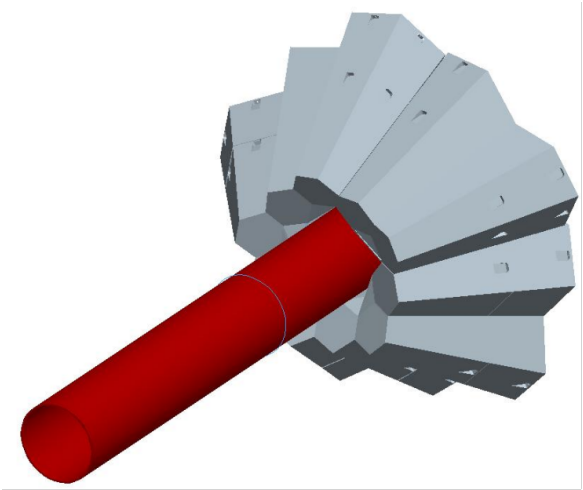
AGATA at FLF3

- Beam rates 100 Hz to 100 kHz
- Beam spot size at secondary target $\sim 2 - 3$ cm
- Typical target size 8×8 cm^2
- Fast secondary particles are created
  $\rightarrow$ Could damage most forward detectors
  or lead to dead-time
- Consider acceptance of spectrometer for several beam species
- Exit of target chamber 120 mm beam pipe
- Diameter pentagon 160 mm
- Use doubles at most forward angles around a pentagon
- Need five double cryostats (existing)



AGATA at FLF3

Double cryostats with a 120 mm beam pipe



Science program

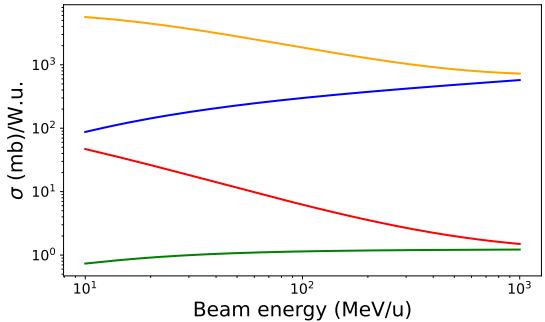
Relativistic Coulomb excitation

- Alder-Winther relativistic Coulomb excitation

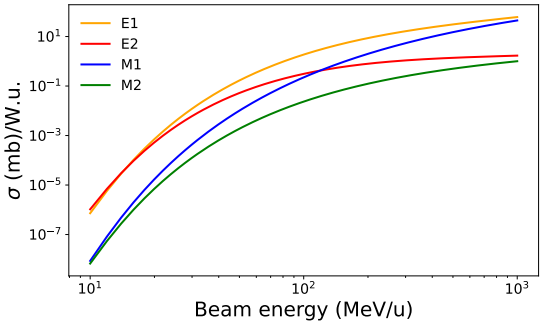
A. Winther and K. Alder, Nucl. Phys. A **319** (1979) 518.

- Direct one-step process, cross section proportional to $B(E2)$ value
- Excitation cross section depends on beam energy
- Higher cross section for low-lying states with lower beam energy, no strong beam energy dependence
- Highly excited states favored with high beam energy

Excitation energy 1 MeV:

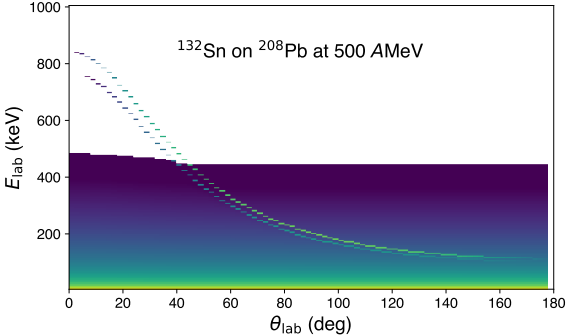


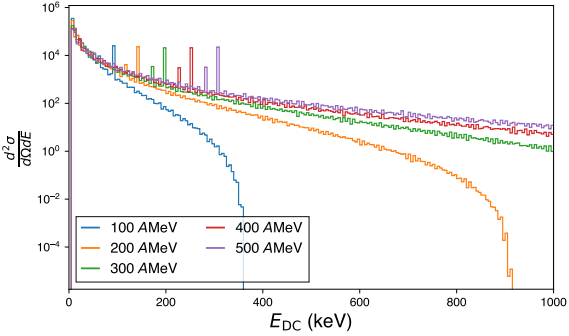
Excitation energy 20 MeV:



calculator https://github.com/wimmer-k/Coulex

Atomic background



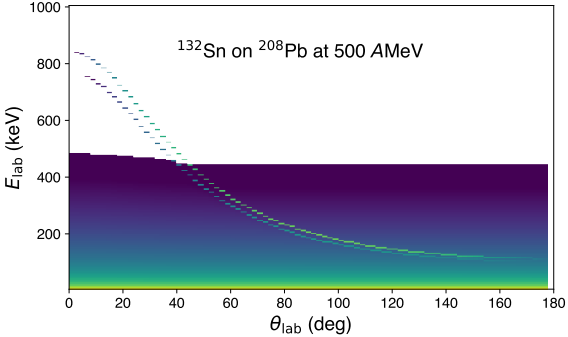


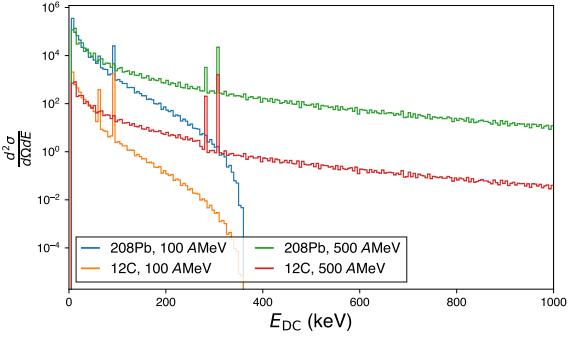
- Background from atomic processes
- Radiative electron capture $\sigma \sim Z_p^2 Z_t$, discrete energy spectrum $E_{K,REC} = (\gamma - 1)mc^2 + E_K$
- Primary Bremsstrahlung $\sigma \sim Z_p^2 Z_t$, continuous energy distribution, isotropic
- Secondary Bremsstrahlung $\sigma \sim Z_p^2 Z_t^2$
- Large cross sections, can dominate the spectrum

calculator https://github.com/wimmer-k/Coulex

- Need shielding of detectors

Atomic background



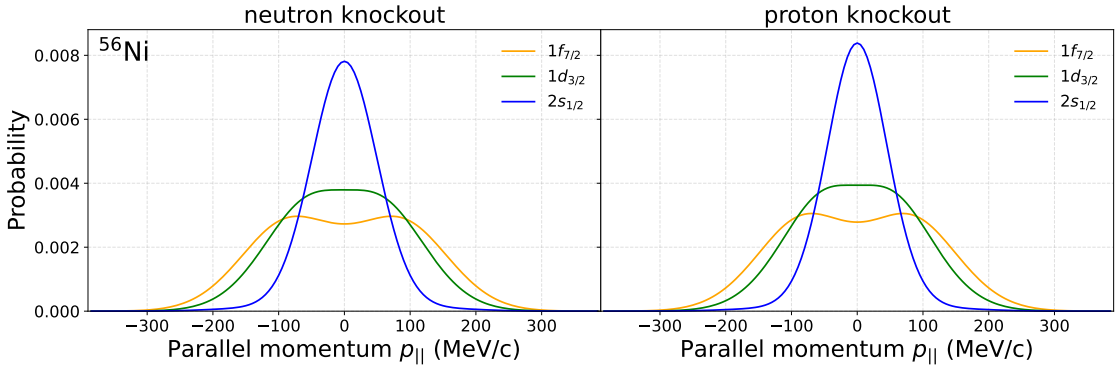


- Background from atomic processes
- Radiative electron capture $\sigma \sim Z_{\mathrm{p}}^2 Z_{\mathrm{t}}$, discrete energy spectrum $E_{K,\mathrm{REC}} = (\gamma - 1)mc^2 + E_K$
- Primary Bremsstrahlung $\sigma \sim Z_{\mathrm{p}}^2 Z_{\mathrm{t}}$, continuous energy distribution, isotropic
- Secondary Bremsstrahlung $\sigma \sim Z_{\mathrm{p}}^2 Z_{\mathrm{t}}^2$
- Large cross sections, can dominate the spectrum
- Need shielding of detectors

calculator https://github.com/wimmer-k/Coulex

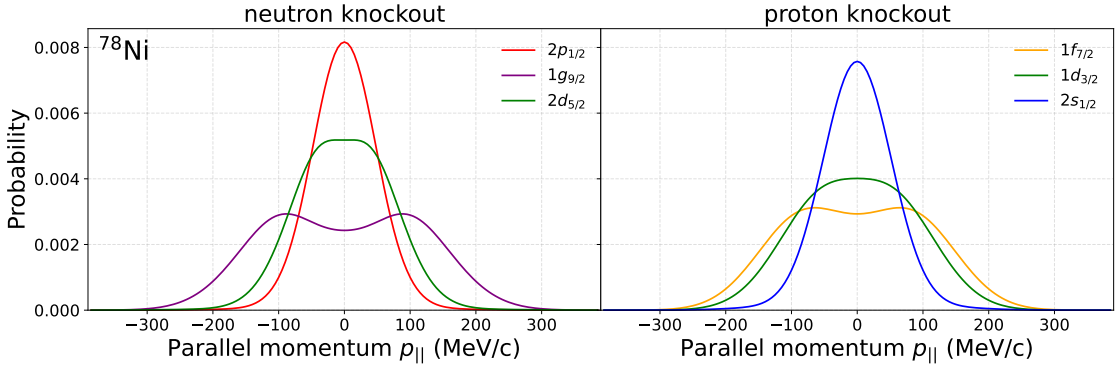
Knockout reactions and momentum distributions

- Width and shape of the parallel momentum distribution indicate the orbital from which the nucleon was removed
- Exclusive cross sections for spectroscopic factors and occupations
- Shell evolution and new magic numbers



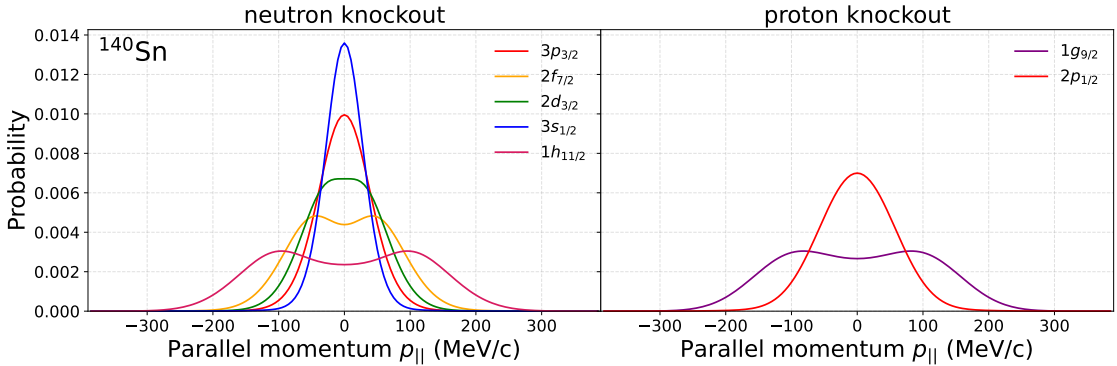
Knockout reactions and momentum distributions

- Width and shape of the parallel momentum distribution indicate the orbital from which the nucleon was removed
- Exclusive cross sections for spectroscopic factors and occupations
- Shell evolution and new magic numbers



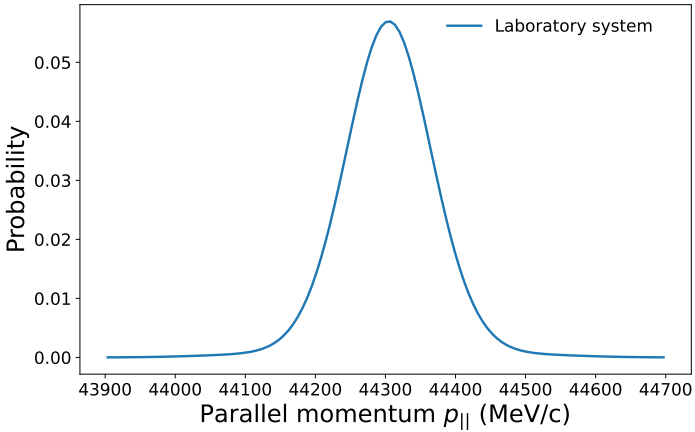
Knockout reactions and momentum distributions

- Width and shape of the parallel momentum distribution indicate the orbital from which the nucleon was removed
- Exclusive cross sections for spectroscopic factors and occupations
- Shell evolution and new magic numbers



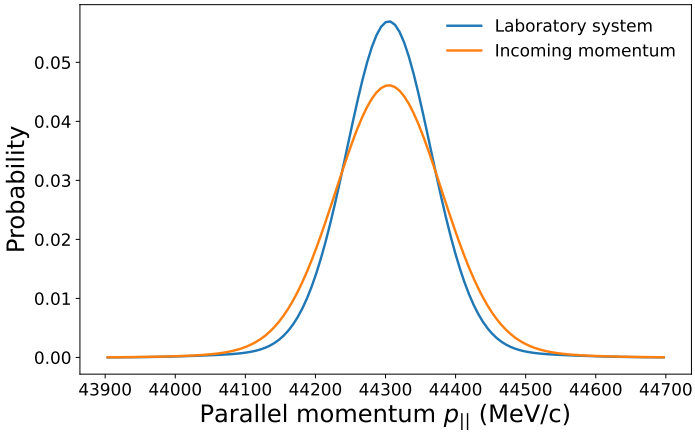
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



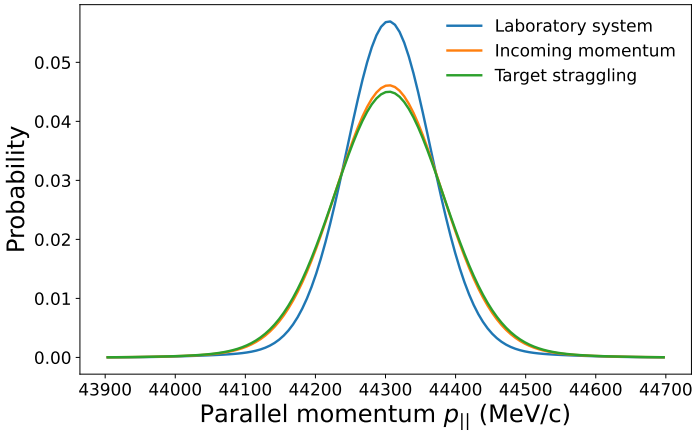
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



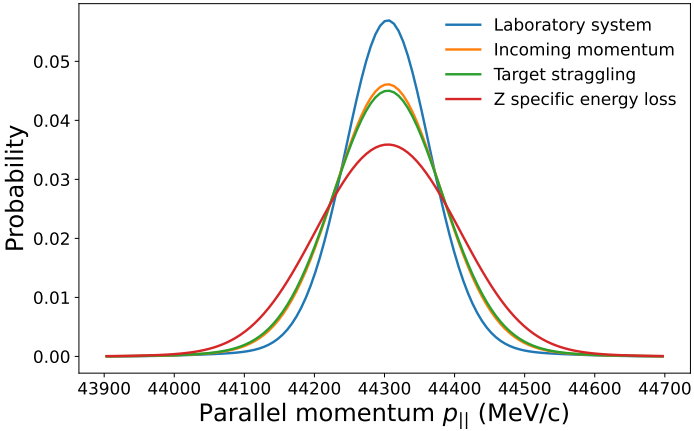
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



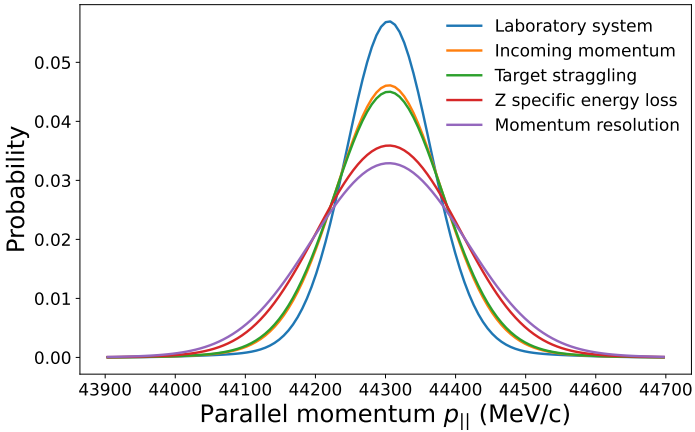
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



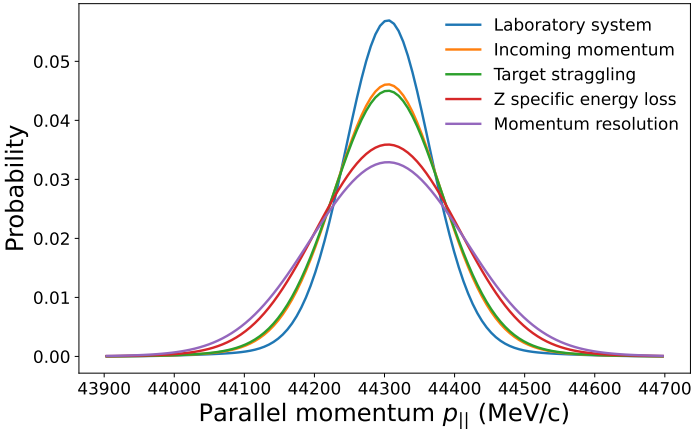
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions:
  Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



- Momentum resolution is setup and experiment specific
- Importance of these contributions depend on beam energy, target thickness, and proton number

Setups and secondary devices

Resolving power of spectrometer behind secondary target:

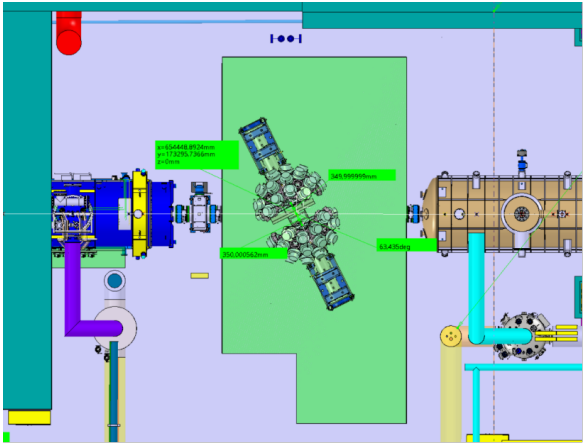
- Z resolution by $\Delta E - E$
- Mass and A/q resolution including charge states
- $B\rho$ acceptance and momentum resolution ($\Delta p/p \sim 1/1000$)
- Total kinetic energy measurement, or transmission to stopped beam experiments

Secondary targets:

- Beam line tracking detectors around the target for Doppler correction and scattering angle measurements
- Plunger for lifetime measurements
- Liquid hydrogen target for quasi-free knockout and inelastic scattering
- Active target with vertex reconstruction for lifetime and cross section measurements

Summary

- FAIR civil construction is finished
- Installation of accelerator modules and infrastructure is ongoing
- On the path toward early and first science experiments

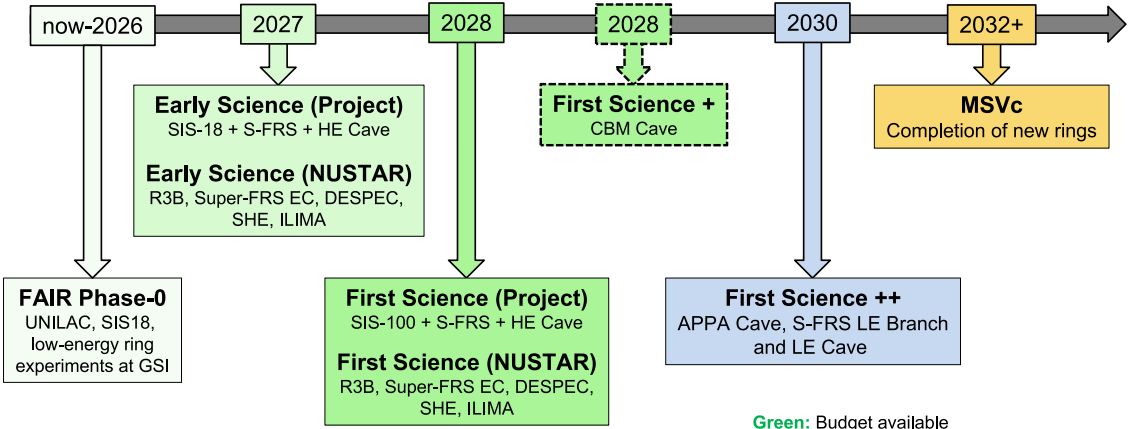


- Low-energy branch including spectrometer now under discussion
- Workshop and discussion with other NUSTAR sub-collaborations at the NUSTAR meeting in Prague
- AGATA needs the low-energy branch and spectrometer and vice-versa

Thank you for your attention

Backup

The FAIR timeline



– Timeline dependent on Council decisions and timely delivery of SIS100 quadrupoles
– Additional funding needed in 2026 for continuation of skilled workforce

Green: Budget available
Green: Budget decision expected soon
Blue: Civil construction complete
Orange: Significant additional investment required

Courtesy Helena Albers

- AGATA to be installed at the low-energy (LE) branch of Super-FRS

Coulomb excitation

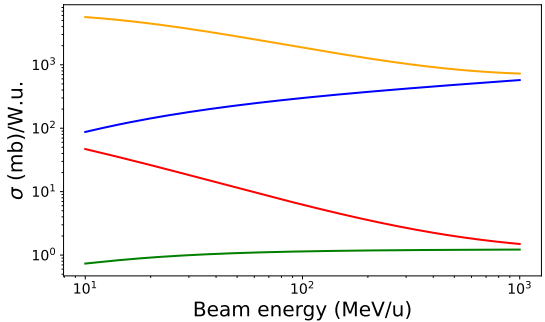
Relativistic Coulomb excitation

- Alder-Winther relativistic Coulomb excitation

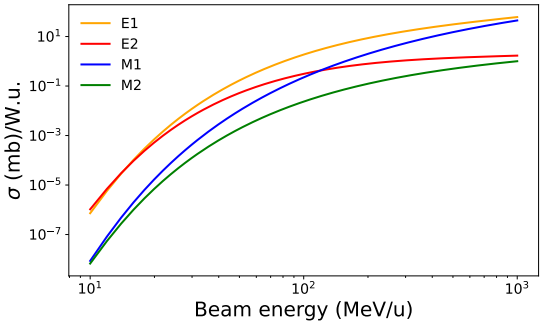
A. Winther and K. Alder, Nucl. Phys. A **319** (1979) 518.

- Direct one-step process, cross section proportional to $B(E2)$ value
- Excitation cross section depends on beam energy
- Higher cross section for low-lying states with lower beam energy, no strong beam energy dependence
- Highly excited states favored with high beam energy

Excitation energy 1 MeV:

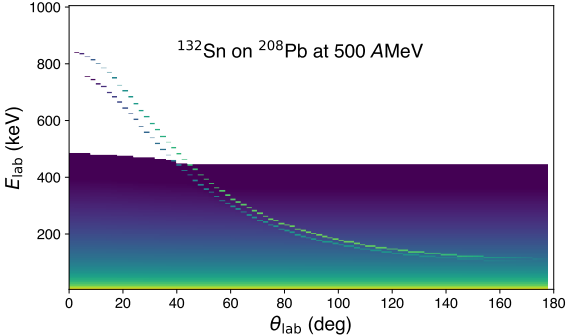


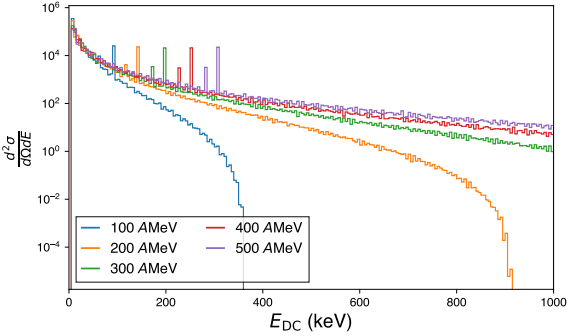
Excitation energy 20 MeV:



calculator https://github.com/wimmer-k/Coulex

Atomic background

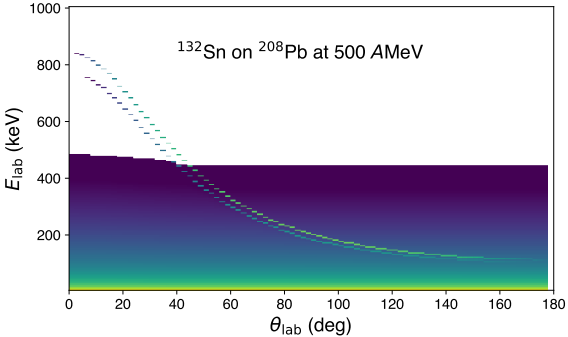


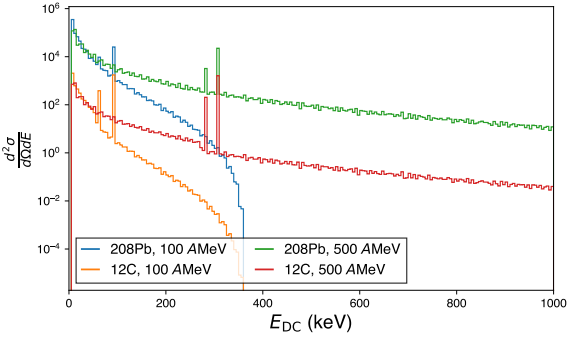


- Background from atomic processes
- Radiative electron capture $\sigma \sim Z_p^2 Z_t$, discrete energy spectrum $E_{K,\mathrm{REC}} = (\gamma - 1)mc^2 + E_K$
- Primary Bremsstrahlung $\sigma \sim Z_p^2 Z_t$, continuous energy distribution, isotropic
- Secondary Bremsstrahlung $\sigma \sim Z_p^2 Z_t^2$
- Large cross sections, can dominate the spectrum

calculator https://github.com/wimmer-k/Coulex

Atomic background



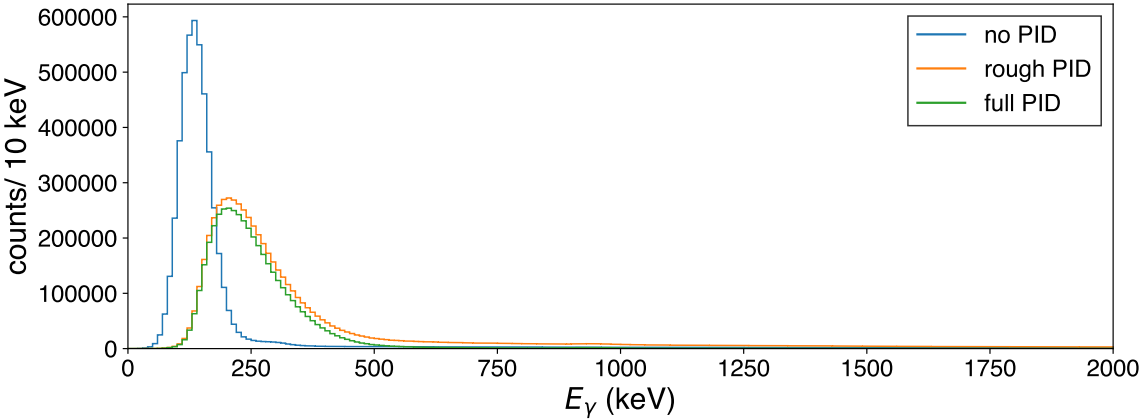


- Background from atomic processes
- Radiative electron capture $\sigma \sim Z_p^2 Z_t$, discrete energy spectrum $E_{K,\mathrm{REC}} = (\gamma - 1)mc^2 + E_K$
- Primary Bremsstrahlung $\sigma \sim Z_p^2 Z_t$, continuous energy distribution, isotropic
- Secondary Bremsstrahlung $\sigma \sim Z_p^2 Z_t^2$
- Large cross sections, can dominate the spectrum

calculator https://github.com/wimmer-k/Coulex

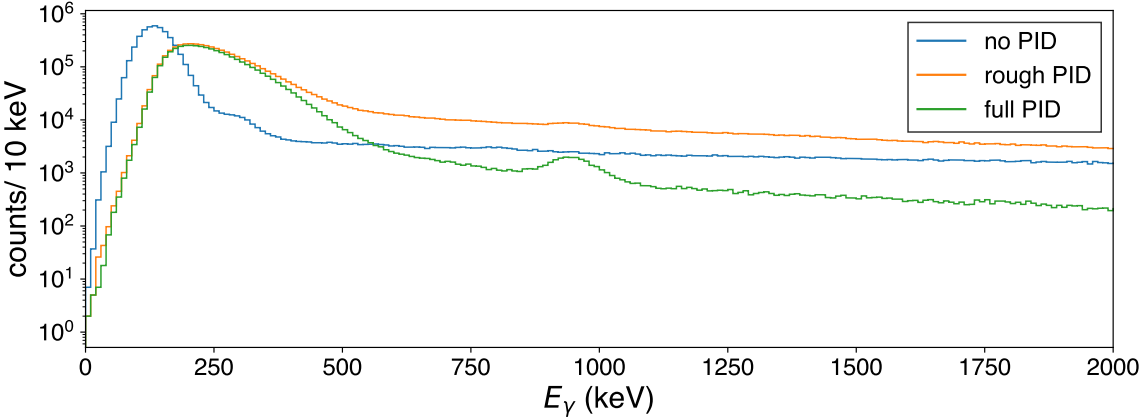
Outgoing particle identification

- Inelastic scattering is identified by the detection of the γ ray with appropriate energy
- Example: ^{62}Zn at 150 *A*MeV with DALI2^{+} NaI array
- Particle identification is strictly not needed
- Velocity measurement after target could be beneficial



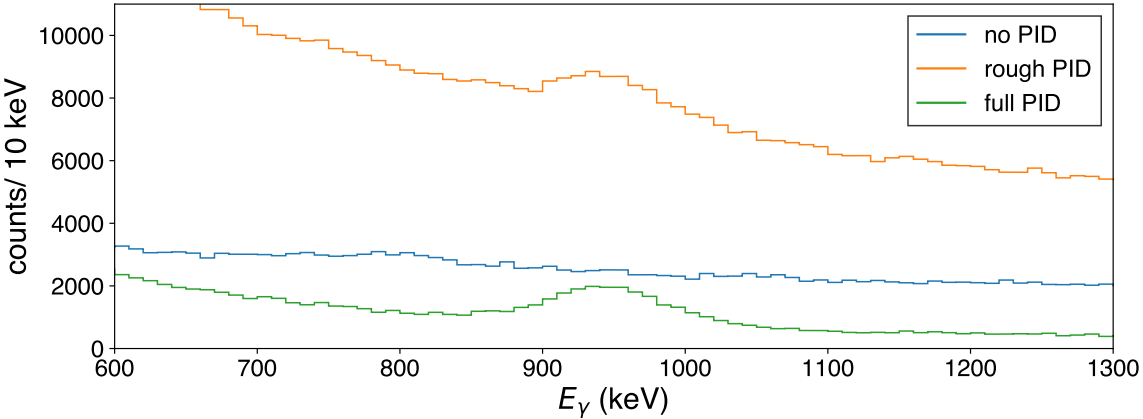
Outgoing particle identification

- Inelastic scattering is identified by the detection of the γ ray with appropriate energy
- Example: ^{62}Zn at 150 *A*MeV with DALI2^{+} NaI array
- Particle identification is strictly not needed
- Velocity measurement after target could be beneficial



Outgoing particle identification

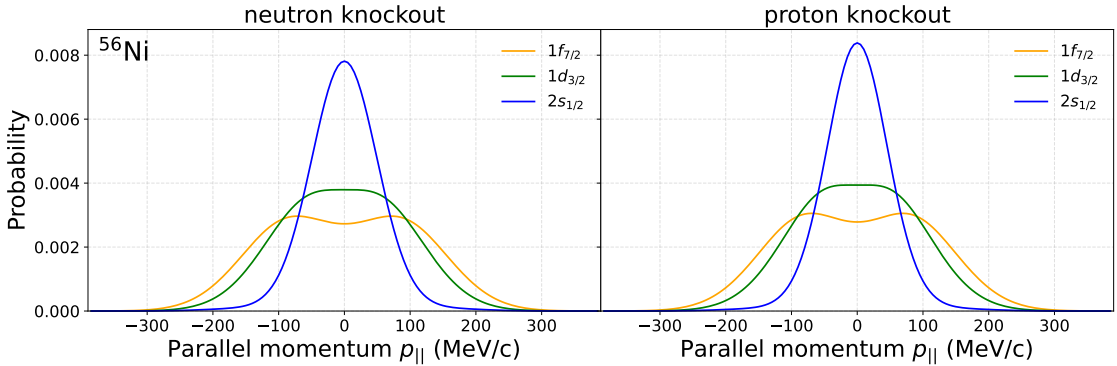
- Inelastic scattering is identified by the detection of the γ ray with appropriate energy
- Example: ^{62}Zn at 150 *A*MeV with DALI2^{+} NaI array
- Particle identification is strictly not needed
- Velocity measurement after target could be beneficial



Knockout reactions and momentum distributions

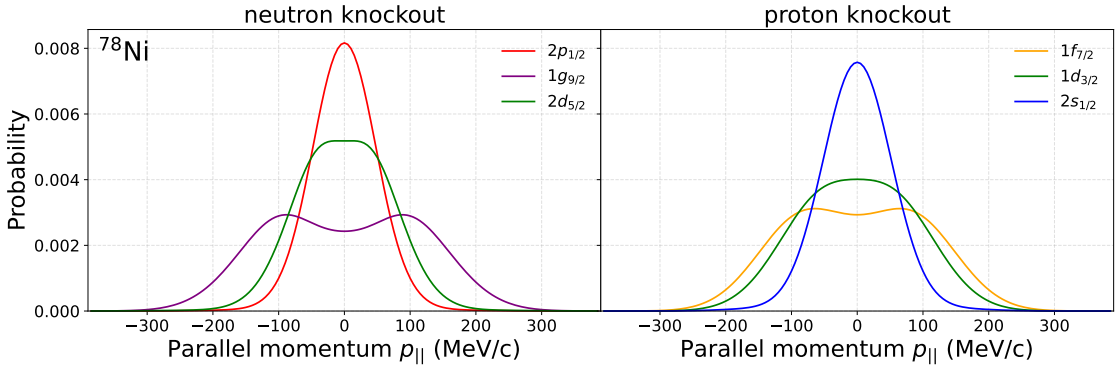
Momentum distributions

- Width and shape of the parallel momentum distribution indicate the orbital from which the nucleon was removed
- Exclusive cross sections for spectroscopic factors and occupations



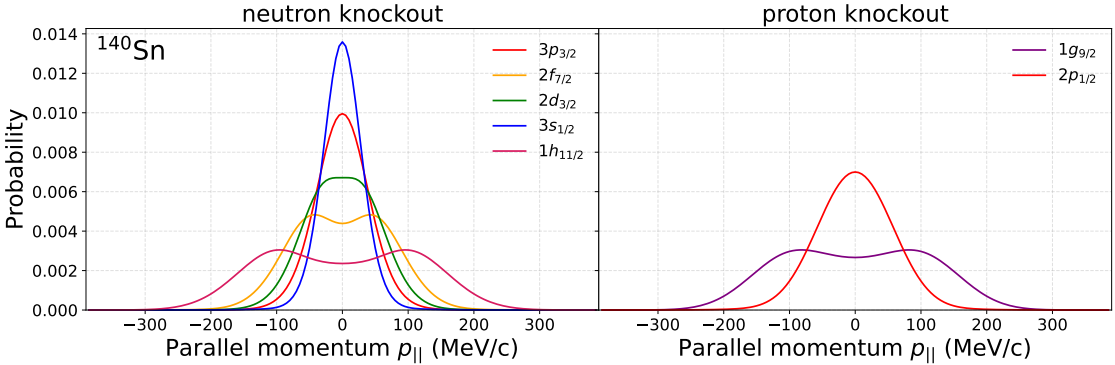
Momentum distributions

- Width and shape of the parallel momentum distribution indicate the orbital from which the nucleon was removed
- Exclusive cross sections for spectroscopic factors and occupations



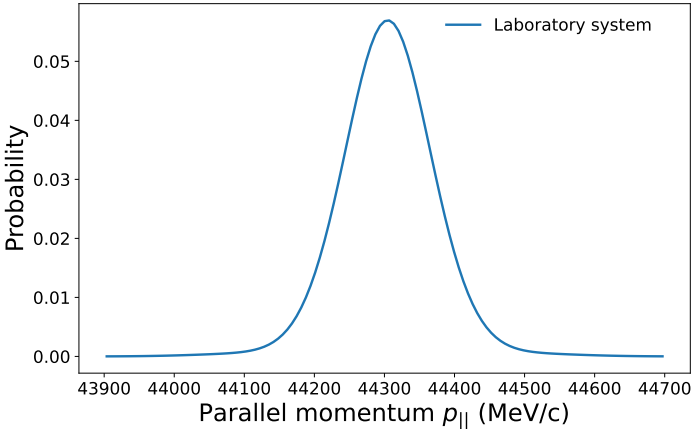
Momentum distributions

- Width and shape of the parallel momentum distribution indicate the orbital from which the nucleon was removed
- Exclusive cross sections for spectroscopic factors and occupations



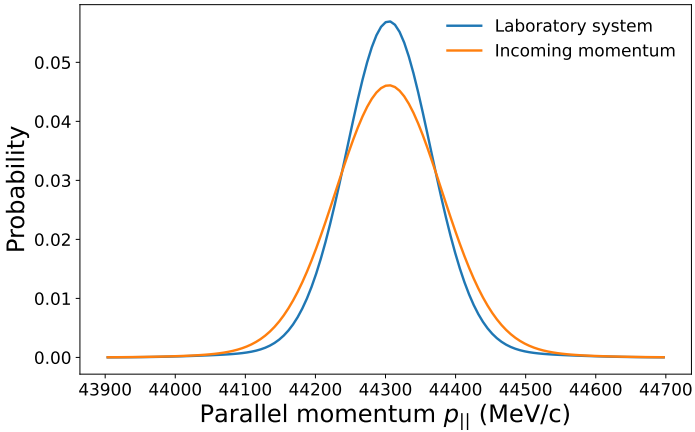
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



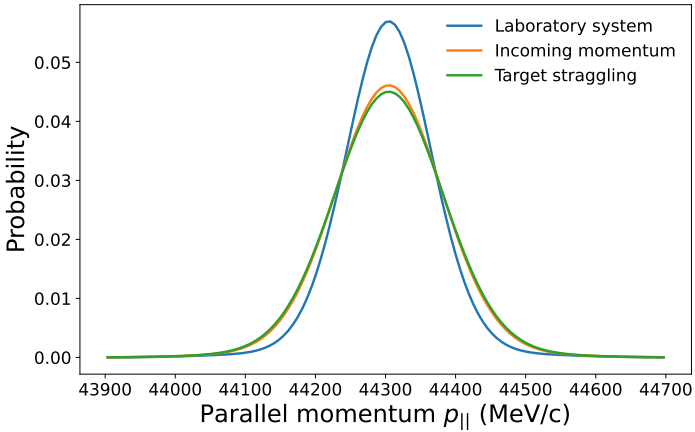
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



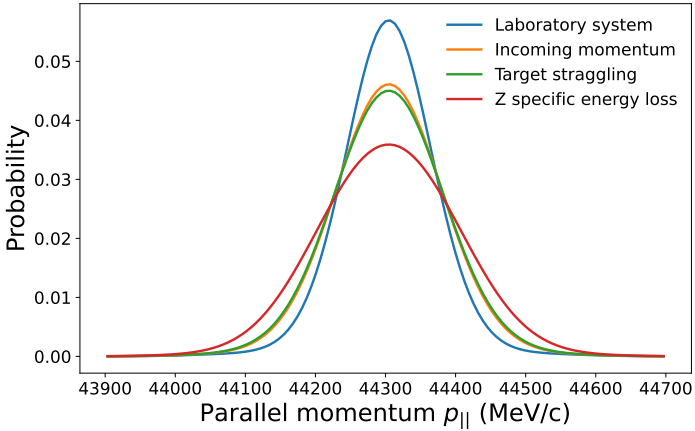
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



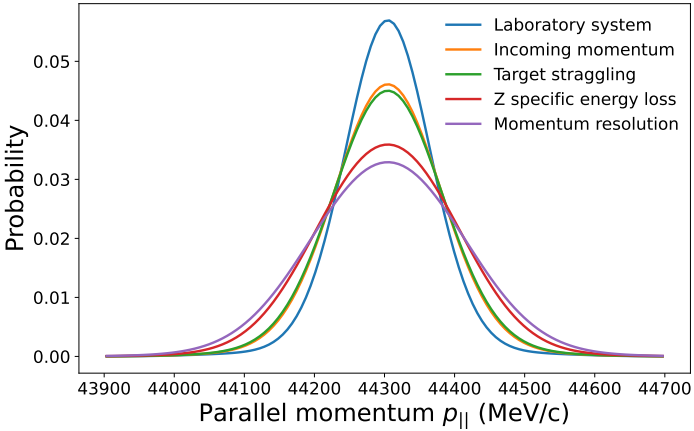
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



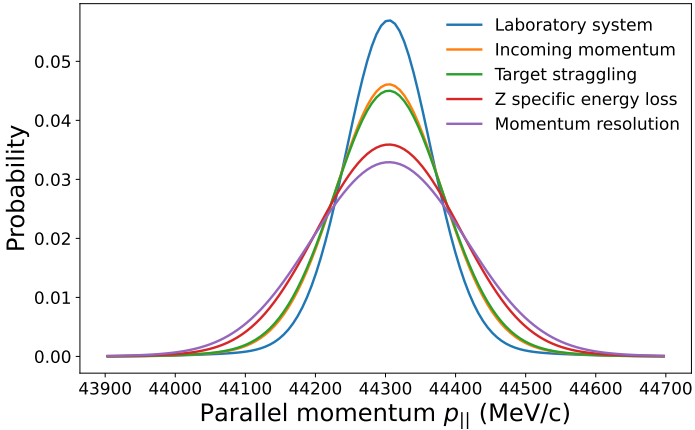
Momentum resolution

- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions:
  Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



Momentum resolution

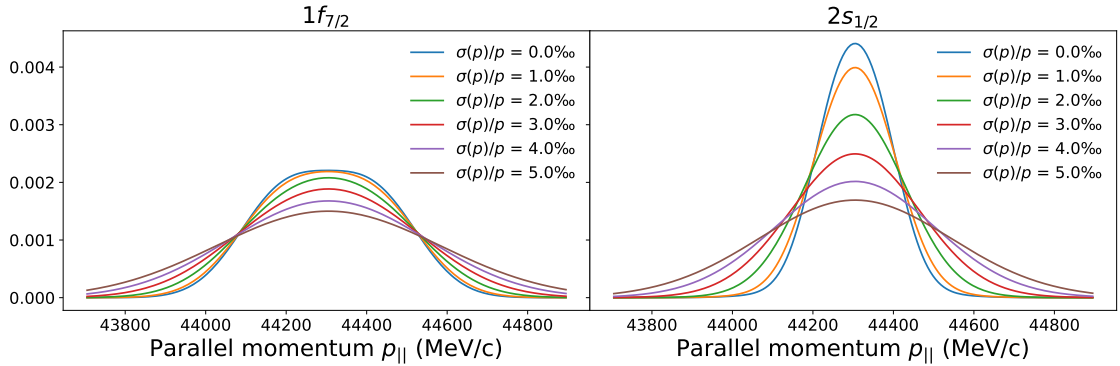
- Theoretical distributions need to be transformed into the laboratory system
- Folding with incoming momentum distribution or resolution
- Energy straggling in the target
- For proton knockout reactions: Z dependent energy loss depending on where the reaction happens
  $\rightarrow$ Folding with rectangular distribution
- Momentum resolution of spectrometer behind secondary target



- Momentum resolution is setup and experiment specific
- Importance of these contributions depend on beam energy, target thickness, and proton number

Momentum resolution

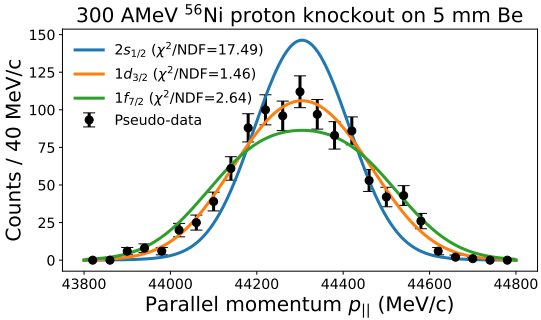
- 300 *A*MeV ^{56}Ni beam, one-proton knockout

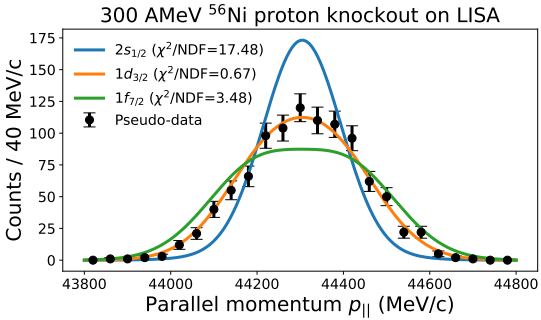


- $\Delta p/p$ resolving power of $1/1000$ or better desired

Active target

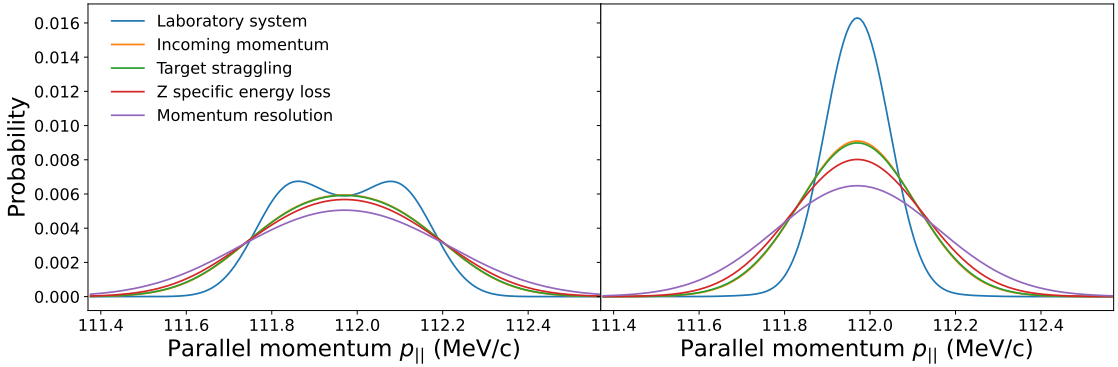
- 300 *A*MeV ^{56}Ni beam with $\sigma(p)/p = 1/1000$ for both incoming and outgoing beams
- Statistical uncertainties for 1000 counts





Heavier nuclei

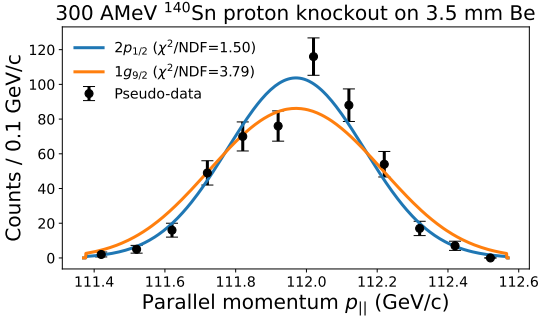
- 300 *A*MeV ^{140}Sn beam with $\sigma(p)/p = 1/1000$ for both incoming and outgoing beams
- Pseudo data for $2p_{1/2}$ knockout
- Statistical uncertainties for 500 counts

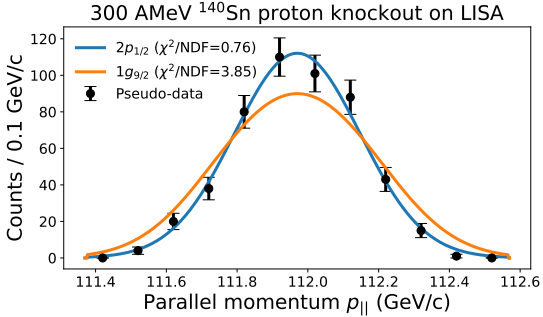


- In-beam spectroscopy in Sn region feasible

Heavier nuclei

- 300 *A*MeV ^{140}Sn beam with $\sigma(p)/p = 1/1000$ for both incoming and outgoing beams
- Pseudo data for $2p_{1/2}$ knockout
- Statistical uncertainties for 500 counts



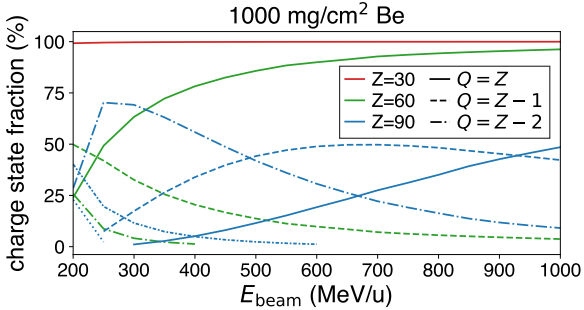


- In-beam spectroscopy in Sn region feasible

Charge states

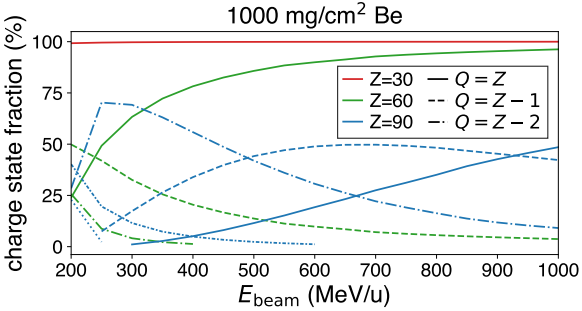
Charge states

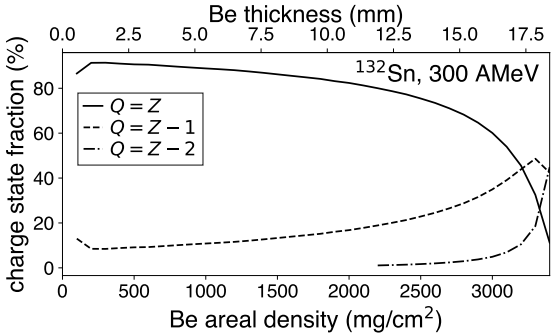
- Charge state distribution after the target strongly depends on beam energy and proton number
- Fully stripped ions only dominating for $Z \lesssim 50$
- Charge states have different transmissions and might be lost in spectrometer
- For light materials, thick targets can still be used
- Coulomb excitation on heavy targets requires larger acceptance
- Pb region very challenging, but could focus on one charge state and optimize for that



Charge states

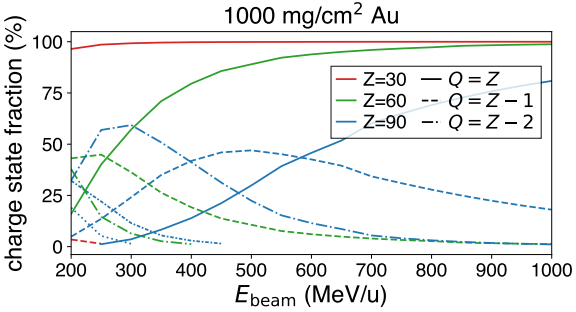
- Charge state distribution after the target strongly depends on beam energy and proton number
- Fully stripped ions only dominating for $Z \lesssim 50$
- Charge states have different transmissions and might be lost in spectrometer
- For light materials, thick targets can still be used
- Coulomb excitation on heavy targets requires larger acceptance
- Pb region very challenging, but could focus on one charge state and optimize for that

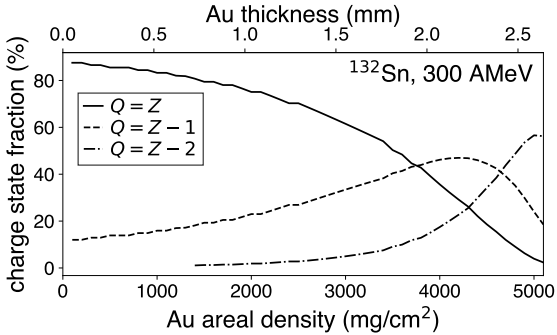




Charge states

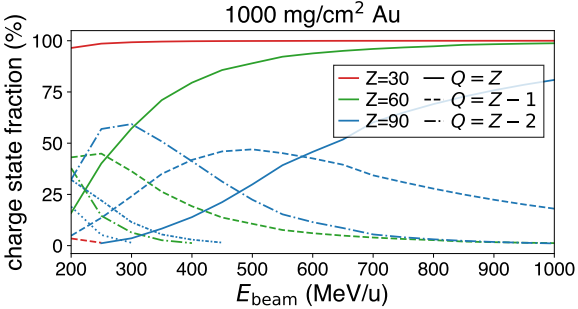
- Charge state distribution after the target strongly depends on beam energy and proton number
- Fully stripped ions only dominating for $Z \lesssim 50$
- Charge states have different transmissions and might be lost in spectrometer
- For light materials, thick targets can still be used
- Coulomb excitation on heavy targets requires larger acceptance
- Pb region very challenging, but could focus on one charge state and optimize for that

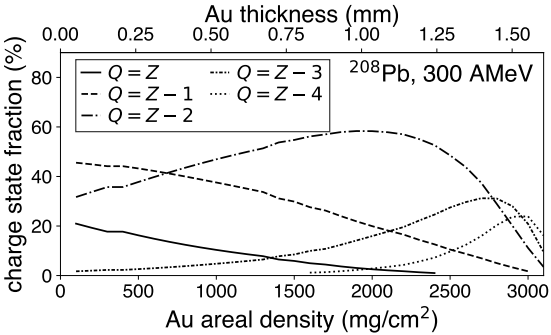




Charge states

- Charge state distribution after the target strongly depends on beam energy and proton number
- Fully stripped ions only dominating for $Z \lesssim 50$
- Charge states have different transmissions and might be lost in spectrometer
- For light materials, thick targets can still be used
- Coulomb excitation on heavy targets requires larger acceptance
- Pb region very challenging, but could focus on one charge state and optimize for that

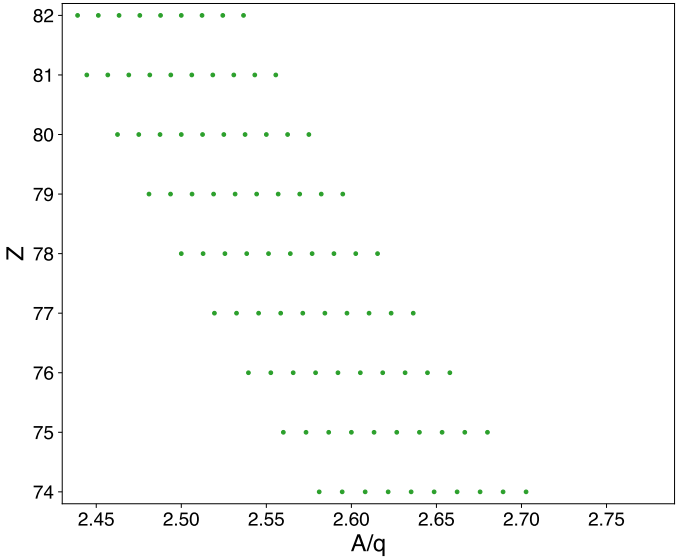




Charge states

- Charge states can lead to contaminations in particle identification
- Example: ^{208}Pb fragmentation
- Isotopes of interest overlap with less exotic isotopes in smaller charge states
- Realistic charge state distribution and fragmentation cross sections
- A/q resolution of $1/1000$ assumed

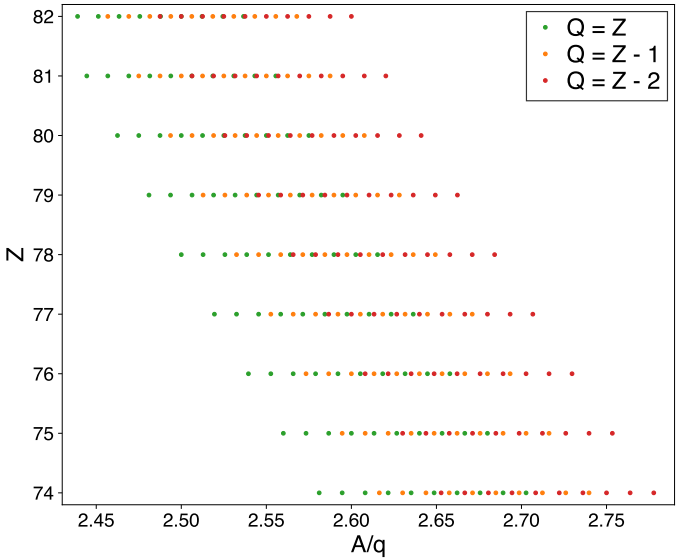
A	q	A/q	$\Delta(A/q)/(A/q)$
207	81	2.55555	
205	80	2.56250	$2.72 \cdot 10^{-3}$
204	80	2.55000	$2.17 \cdot 10^{-3}$
202	79	2.55696	$0.55 \cdot 10^{-3}$



Charge states

- Charge states can lead to contaminations in particle identification
- Example: ^{208}Pb fragmentation
- Isotopes of interest overlap with less exotic isotopes in smaller charge states
- Realistic charge state distribution and fragmentation cross sections
- A/q resolution of $1/1000$ assumed

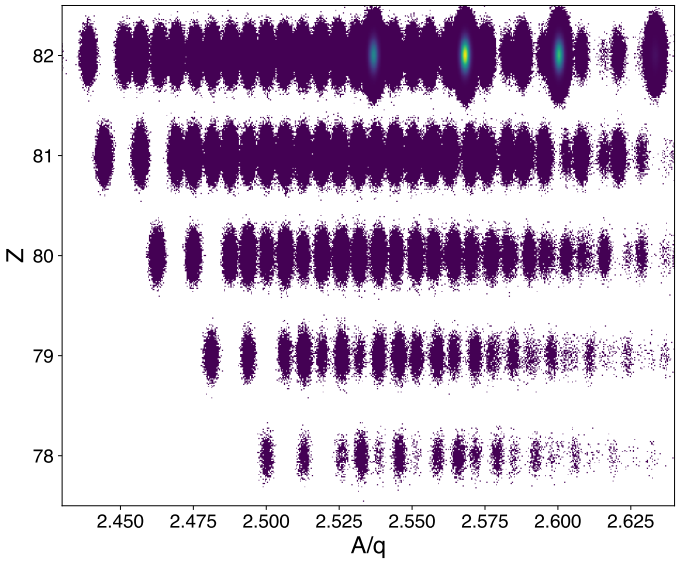
A	q	A/q	$\Delta(A/q)/(A/q)$
207	81	2.55555	
205	80	2.56250	$2.72 \cdot 10^{-3}$
204	80	2.55000	$2.17 \cdot 10^{-3}$
202	79	2.55696	$0.55 \cdot 10^{-3}$



Charge states

- Charge states can lead to contaminations in particle identification
- Example: ^{208}Pb fragmentation
- Isotopes of interest overlap with less exotic isotopes in smaller charge states
- Realistic charge state distribution and fragmentation cross sections
- A/q resolution of $1/1000$ assumed

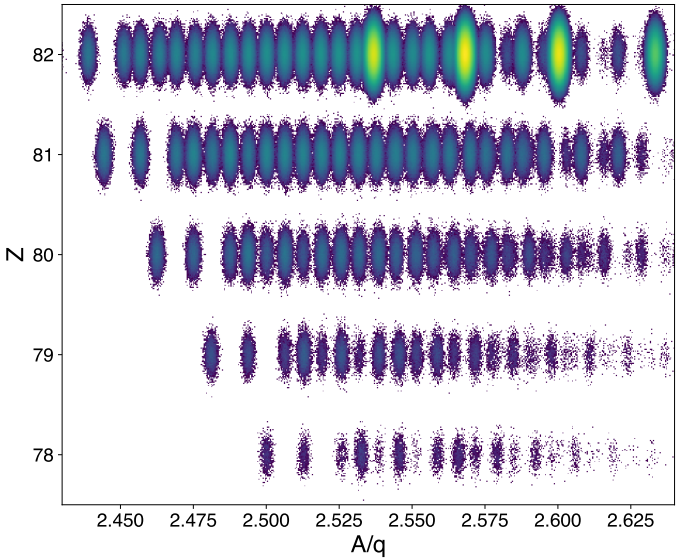
A	q	A/q	$\Delta(A/q)/(A/q)$
207	81	2.55555	
205	80	2.56250	$2.72 \cdot 10^{-3}$
204	80	2.55000	$2.17 \cdot 10^{-3}$
202	79	2.55696	$0.55 \cdot 10^{-3}$



Charge states

- Charge states can lead to contaminations in particle identification
- Example: ^{208}Pb fragmentation
- Isotopes of interest overlap with less exotic isotopes in smaller charge states
- Realistic charge state distribution and fragmentation cross sections
- A/q resolution of $1/1000$ assumed

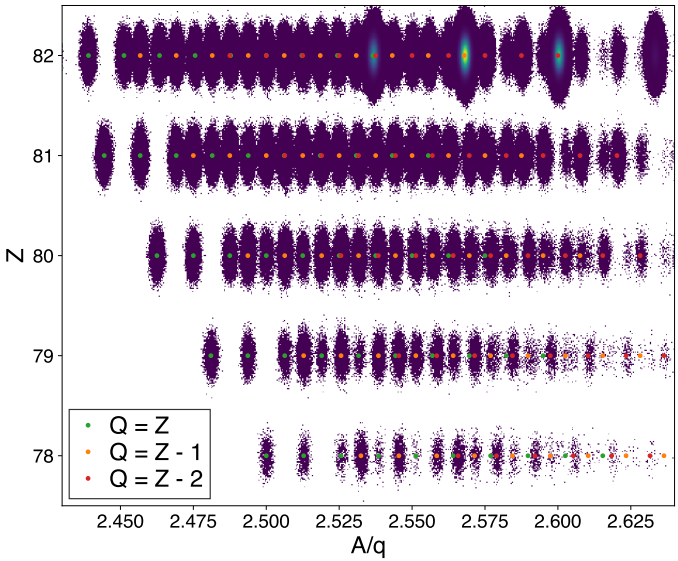
A	q	A/q	$\Delta(A/q)/(A/q)$
207	81	2.55555	
205	80	2.56250	$2.72 \cdot 10^{-3}$
204	80	2.55000	$2.17 \cdot 10^{-3}$
202	79	2.55696	$0.55 \cdot 10^{-3}$



Charge states

- Charge states can lead to contaminations in particle identification
- Example: ^{208}Pb fragmentation
- Isotopes of interest overlap with less exotic isotopes in smaller charge states
- Realistic charge state distribution and fragmentation cross sections
- A/q resolution of $1/1000$ assumed

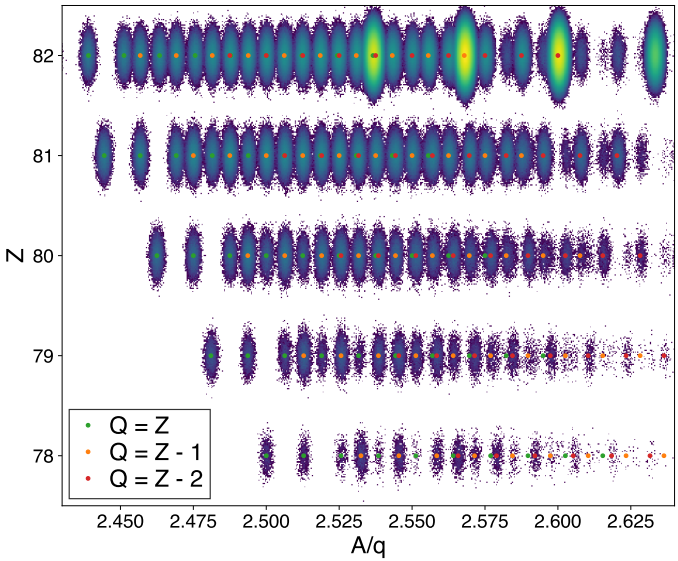
A	q	A/q	$\Delta(A/q)/(A/q)$
207	81	2.55555	
205	80	2.56250	$2.72 \cdot 10^{-3}$
204	80	2.55000	$2.17 \cdot 10^{-3}$
202	79	2.55696	$0.55 \cdot 10^{-3}$



Charge states

- Charge states can lead to contaminations in particle identification
- Example: ^{208}Pb fragmentation
- Isotopes of interest overlap with less exotic isotopes in smaller charge states
- Realistic charge state distribution and fragmentation cross sections
- A/q resolution of $1/1000$ assumed

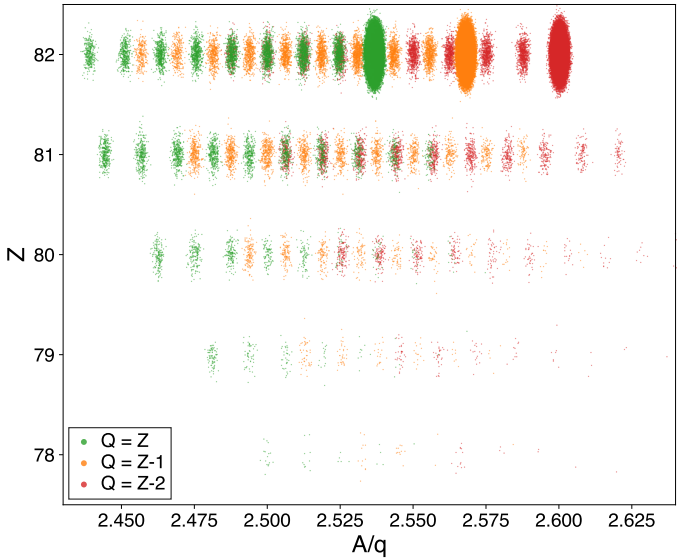
A	q	A/q	$\Delta(A/q)/(A/q)$
207	81	2.55555	
205	80	2.56250	$2.72 \cdot 10^{-3}$
204	80	2.55000	$2.17 \cdot 10^{-3}$
202	79	2.55696	$0.55 \cdot 10^{-3}$



Charge states

- Charge states can lead to contaminations in particle identification
- Example: ^{208}Pb fragmentation
- Isotopes of interest overlap with less exotic isotopes in smaller charge states
- Realistic charge state distribution and fragmentation cross sections
- A/q resolution of $1/1000$ assumed

A	q	A/q	$\Delta(A/q)/(A/q)$
207	81	2.55555	
205	80	2.56250	$2.72 \cdot 10^{-3}$
204	80	2.55000	$2.17 \cdot 10^{-3}$
202	79	2.55696	$0.55 \cdot 10^{-3}$



Summary

- summary