

Coulomb-excitation of the exotic nuclei ^{94}Kr and ^{96}Kr

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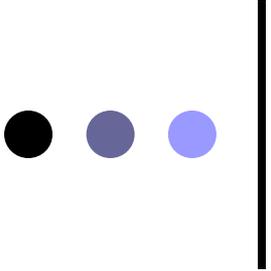
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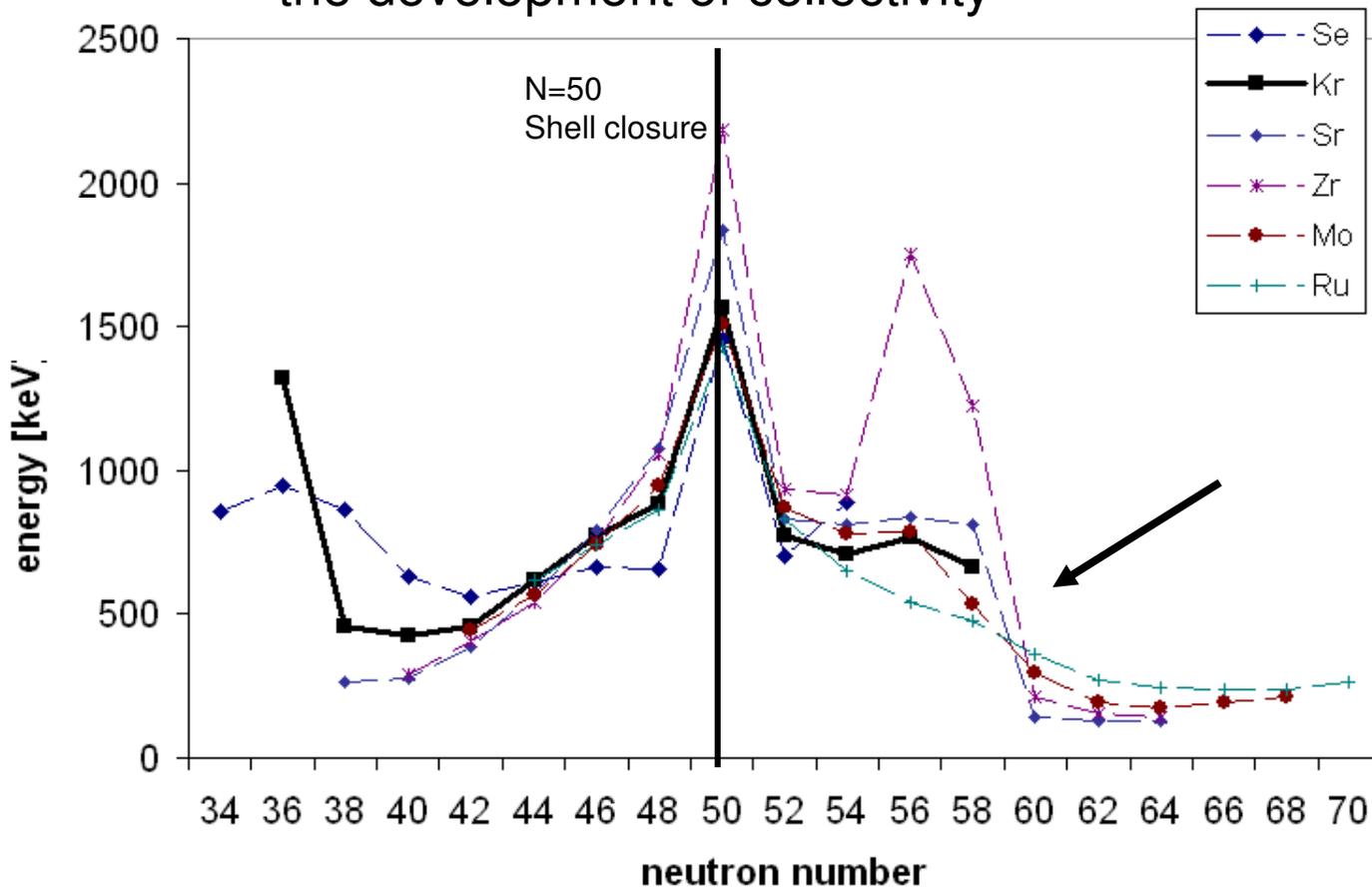


Outline

1. Introduction and motivation
2. Experimental setup and data analysis
3. Experiment on ^{94}Kr
4. Experiment on ^{96}Kr
5. Conclusion and outlook

Introduction

- A~100 mass region is well suited for understanding the development of collectivity

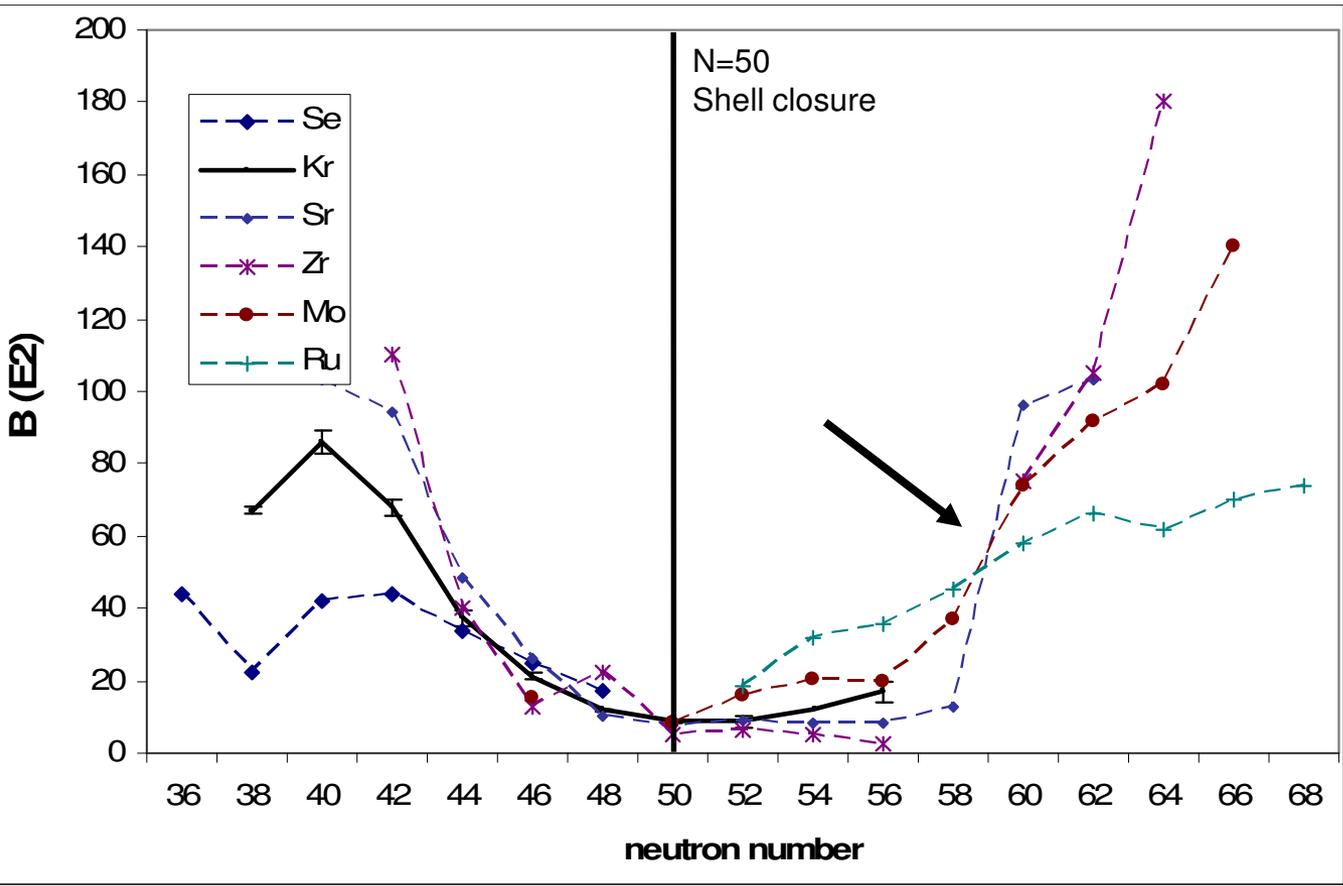




Interpretation: correlated occupation of Nilsson states:

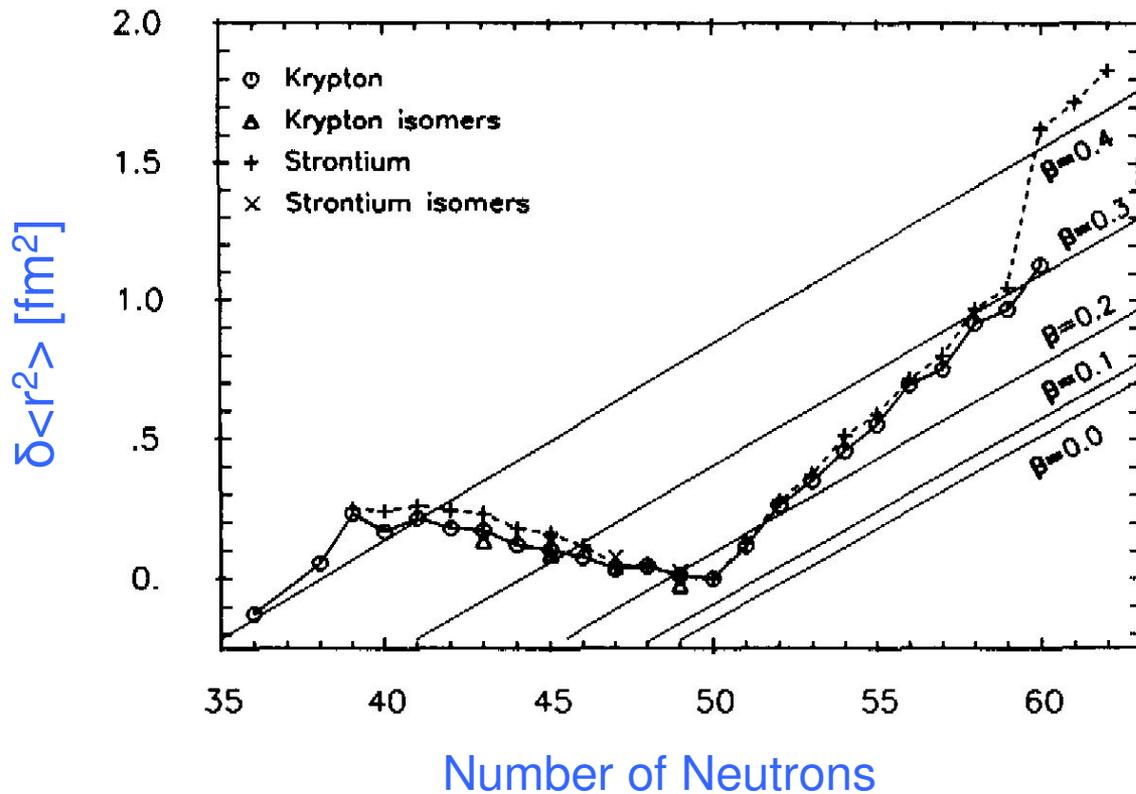
$$\pi g_{9/2} \leftrightarrow \nu h_{11/2} \quad (1,2)$$

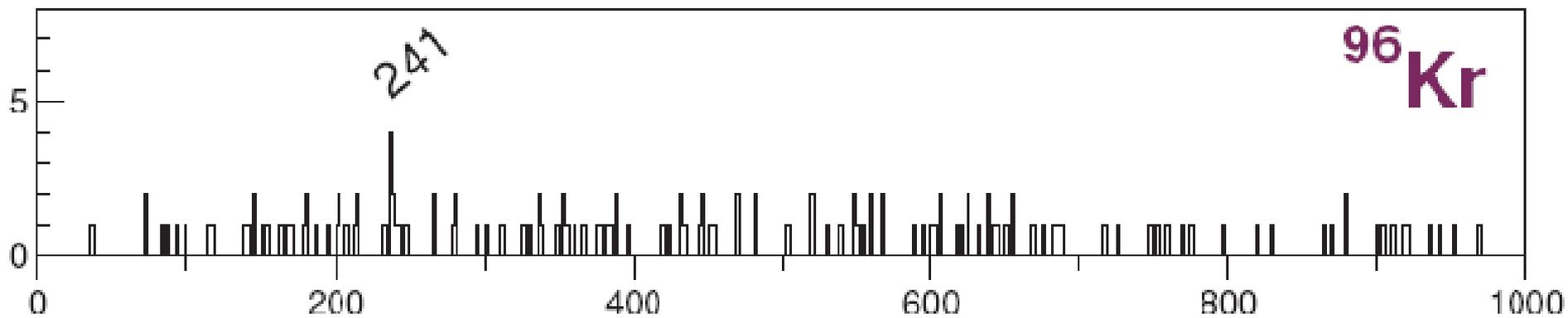
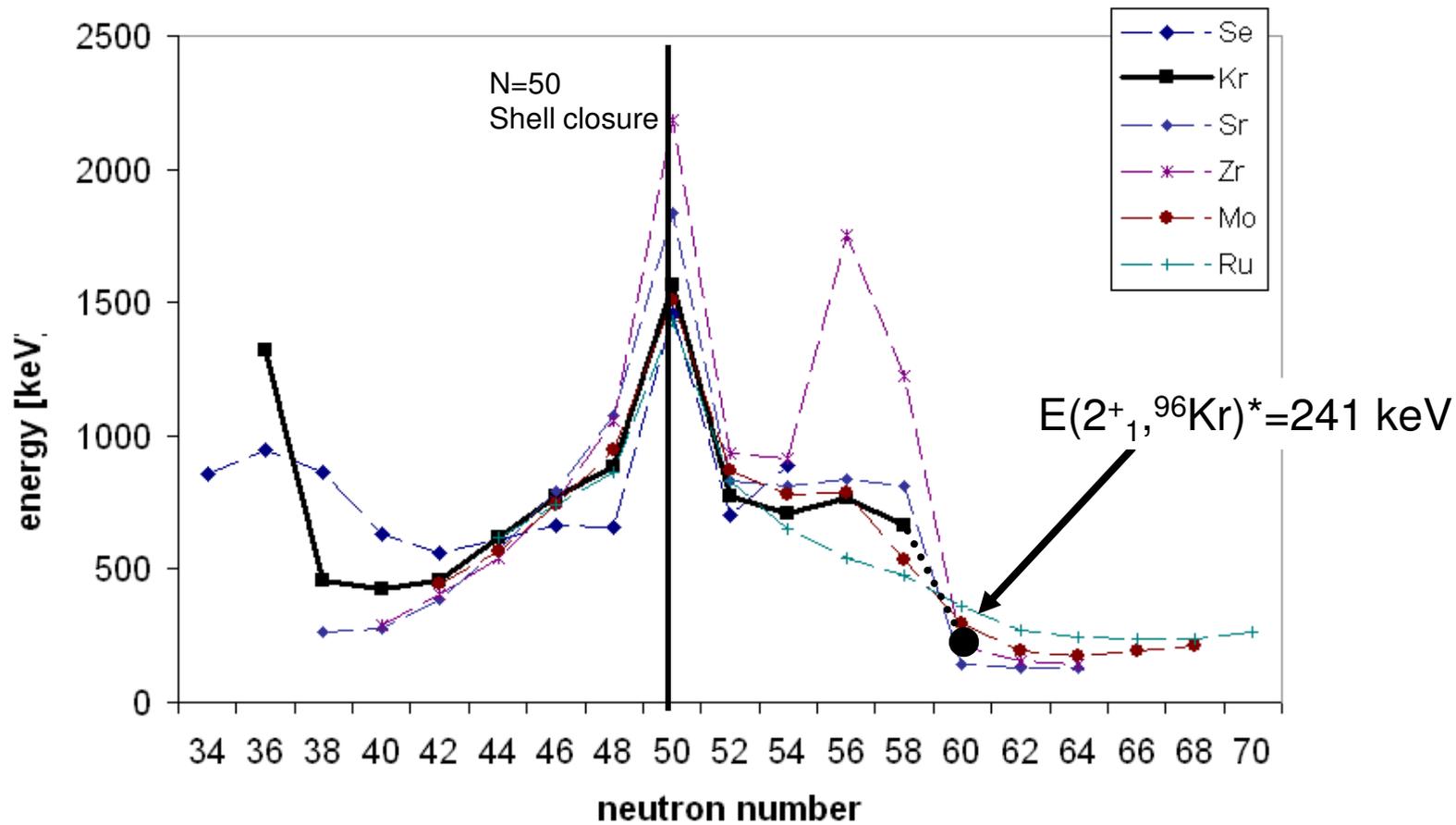
krypton-isotopes: $Z=36 \rightarrow$ reduced pn-interaction ?



- 1: A. Kumar, M.R. Guyne, *Phys. Rev. C* 32(1985)2116;
- 2: W. Urban et al., *Nucl. Phys. A* 689 (2001) 605

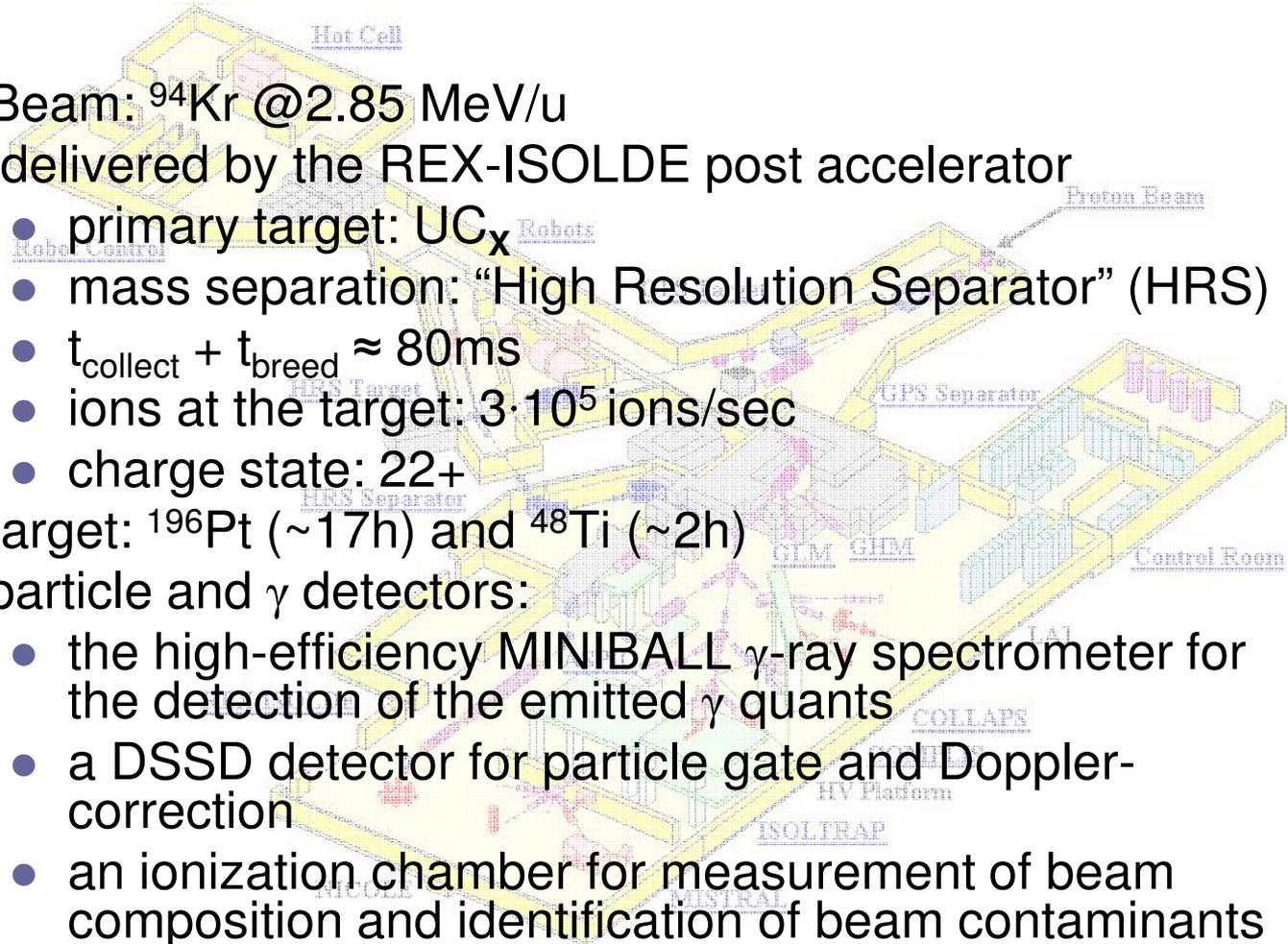
Mean-Square Charge Radii





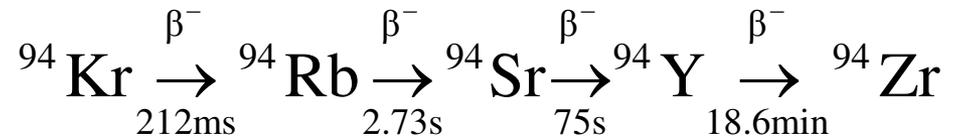
Setup of the experiment on ^{94}Kr

- Beam: ^{94}Kr @2.85 MeV/u delivered by the REX-ISOLDE post accelerator
 - primary target: UC_x
 - mass separation: “High Resolution Separator” (HRS)
 - $t_{\text{collect}} + t_{\text{breed}} \approx 80\text{ms}$
 - ions at the target: $3 \cdot 10^5$ ions/sec
 - charge state: $22+$
- target: ^{196}Pt ($\sim 17\text{h}$) and ^{48}Ti ($\sim 2\text{h}$)
- particle and γ detectors:
 - the high-efficiency MINIBALL γ -ray spectrometer for the detection of the emitted γ quants
 - a DSSD detector for particle gate and Doppler-correction
 - an ionization chamber for measurement of beam composition and identification of beam contaminants

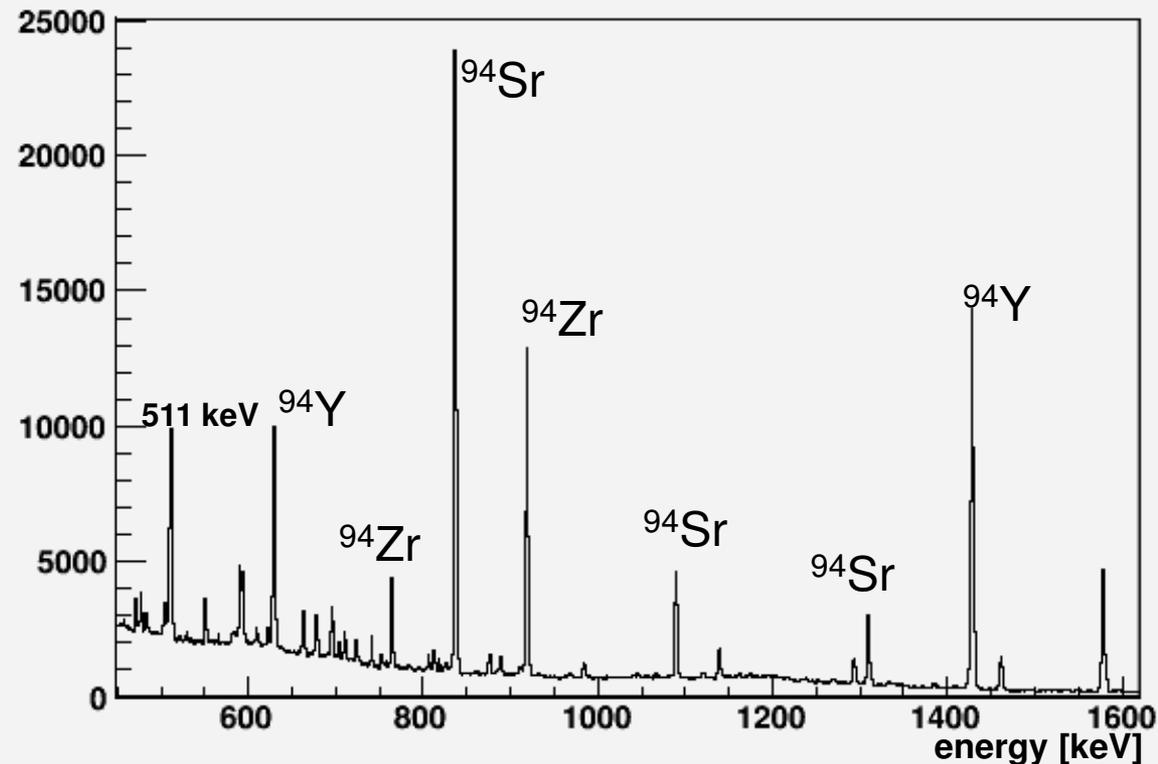


MINIBALL γ -ray spectrometer

- o Consisting of 8 MINIBALL cluster detectors with 18 segments per cluster
- o Energy and efficiency calibration performed using a ^{152}Eu source

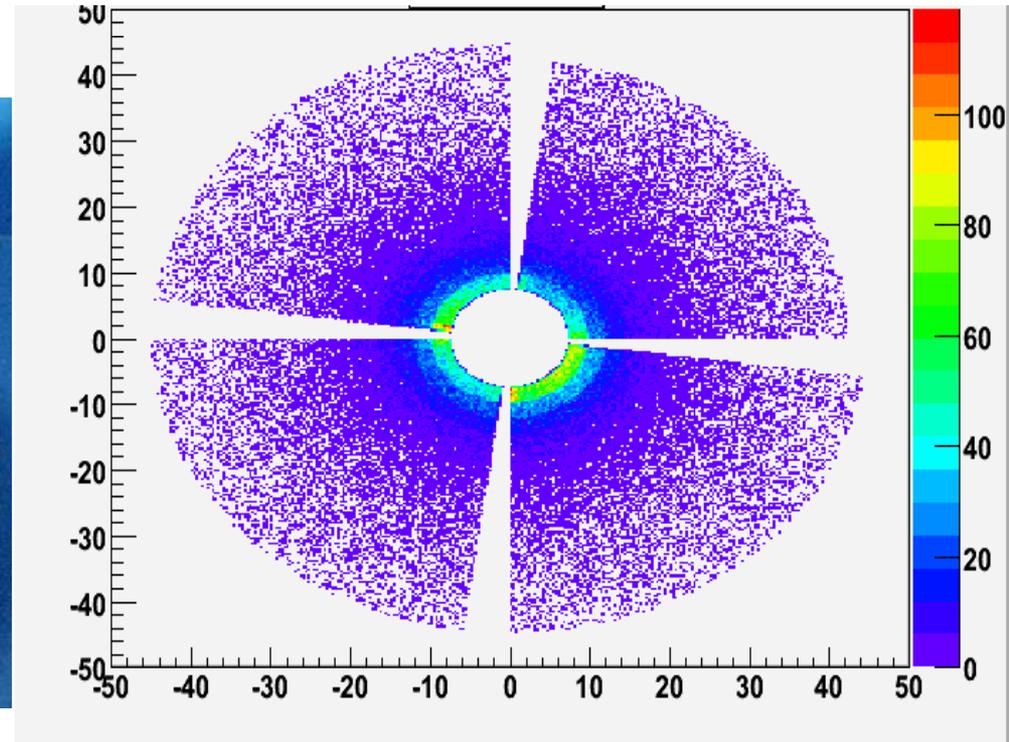
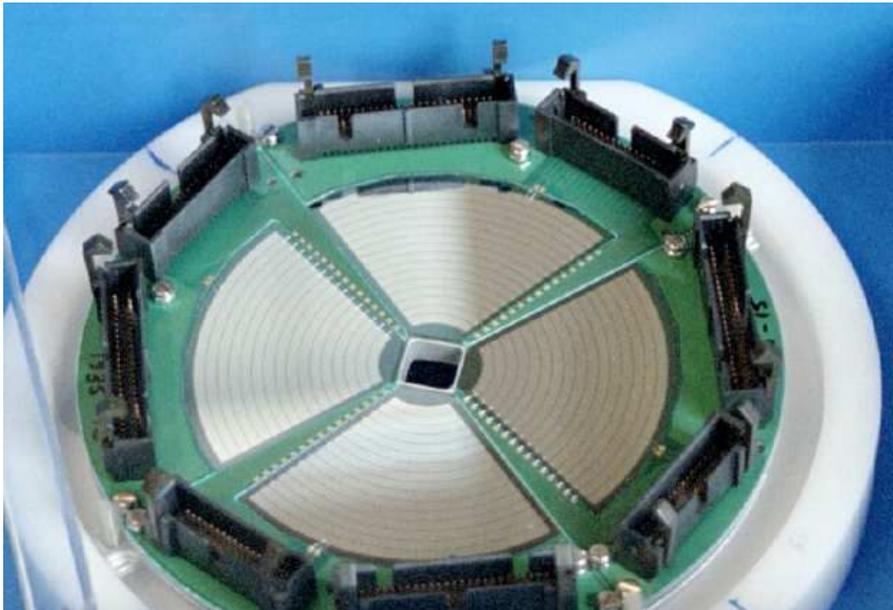


Online γ -spectrum with 268 MeV ${}^{94}\text{Kr}$ beam on ${}^{196}\text{Pt}$ target

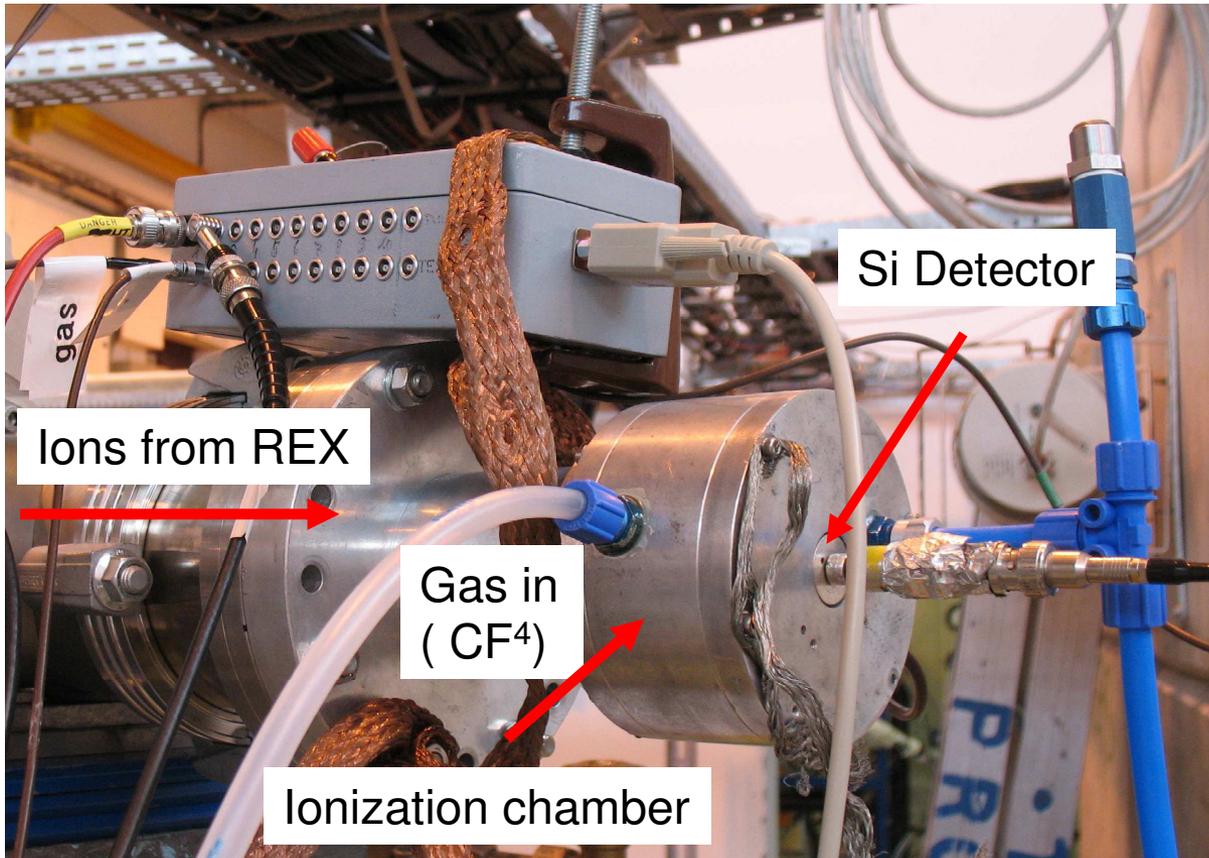


Double sided silicon strip detector (DSSD)

- Consisting of four quadrants
 - 16 annular strips per quadrant at the front
 - 24 radiant segments per quadrant the back
 - total area: 50cm² (93% active)
 - calibration performed using a quad-alpha source

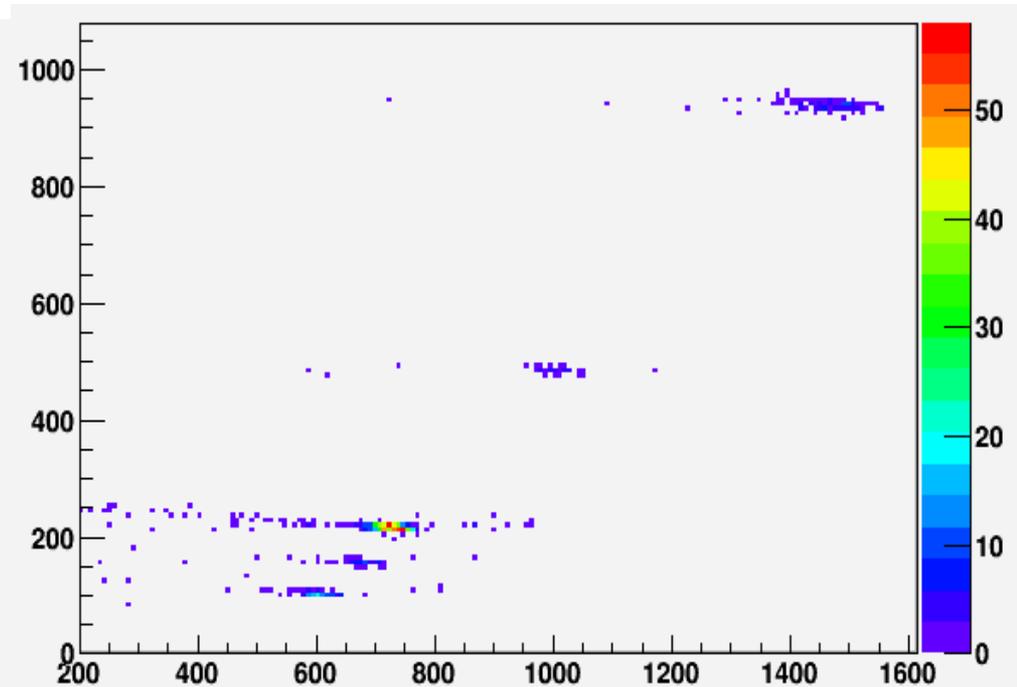
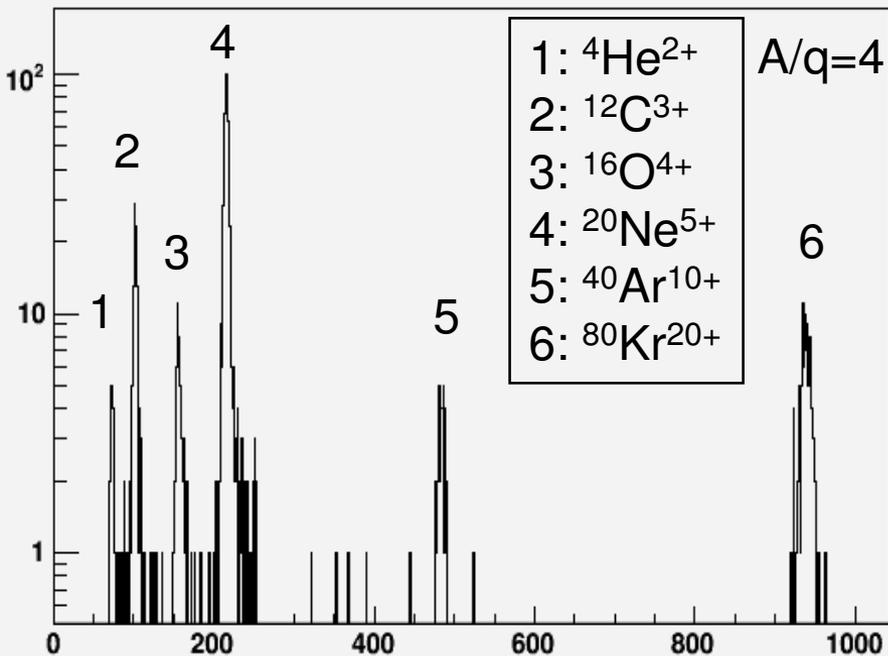


Ionization chamber



Ionization chamber

- Calibration (using a stable beam) is difficult:
 - Detector-response not linear to dE and E
 - dE, E depending on Z, A, Q (stripping on Mylar-Foile!)
 - working on simulations...



Identification of ^{94}Kr beam components

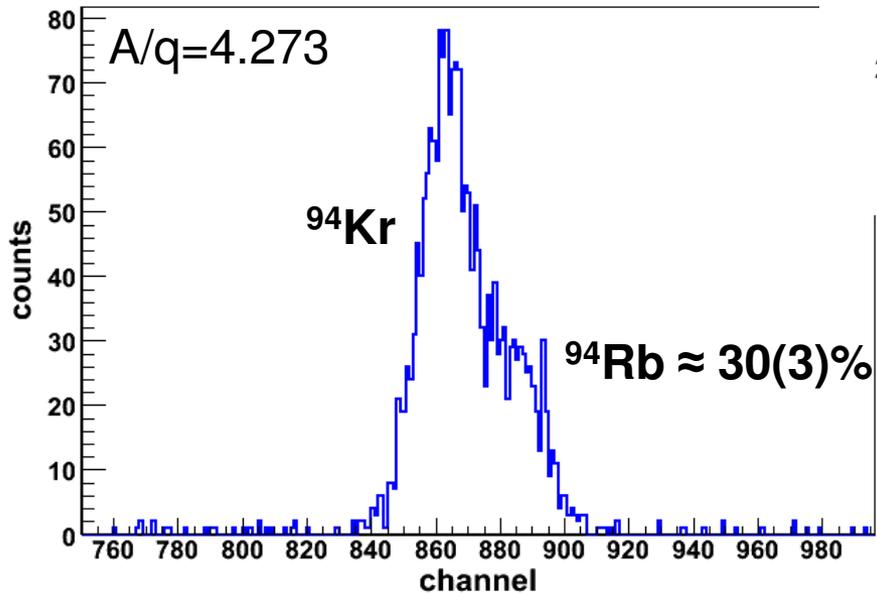
$T_{1/2} (^{94}\text{Kr}) = 212 \text{ ms}$

$t_{\text{collect}} + t_{\text{breed}} \approx 80 \text{ ms}$

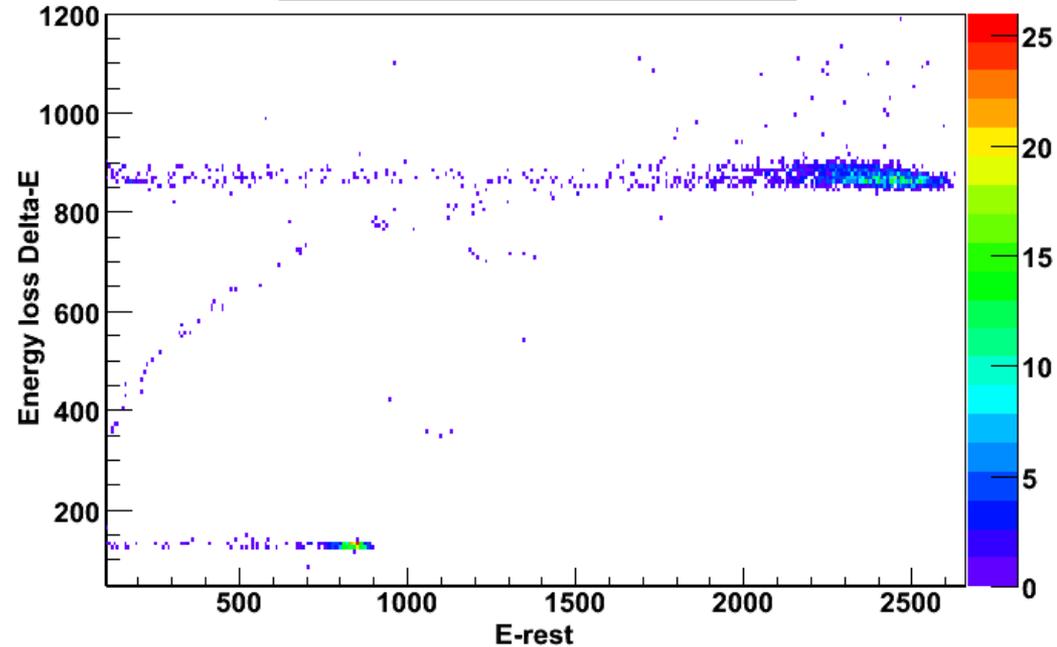
Radioactive decay law:

$\rightarrow \sim 24\%$ of ^{94}Kr decays to ^{94}Rb

Ion chamber: Energy loss

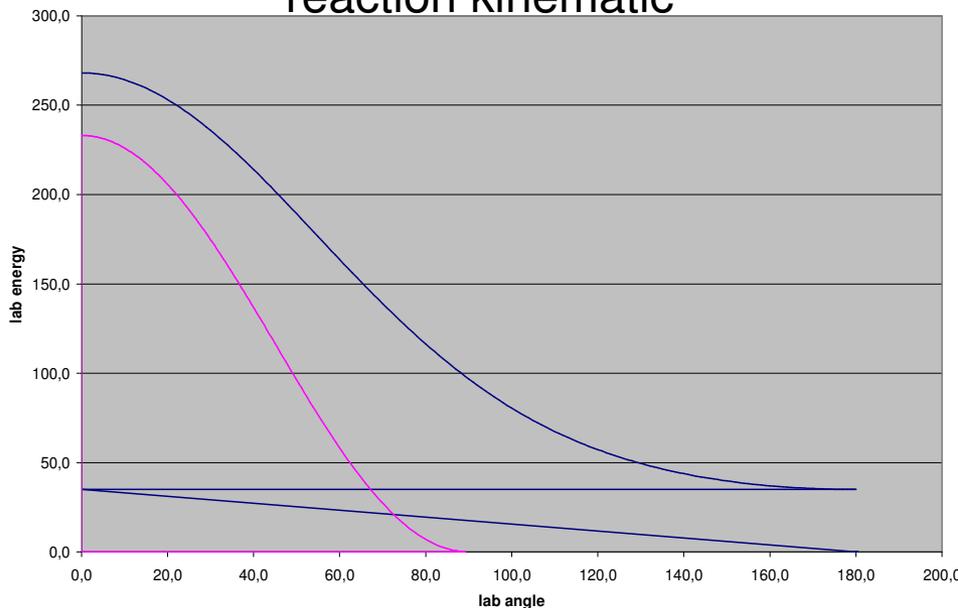


Ion Chamber: Delta-E vs E-rest

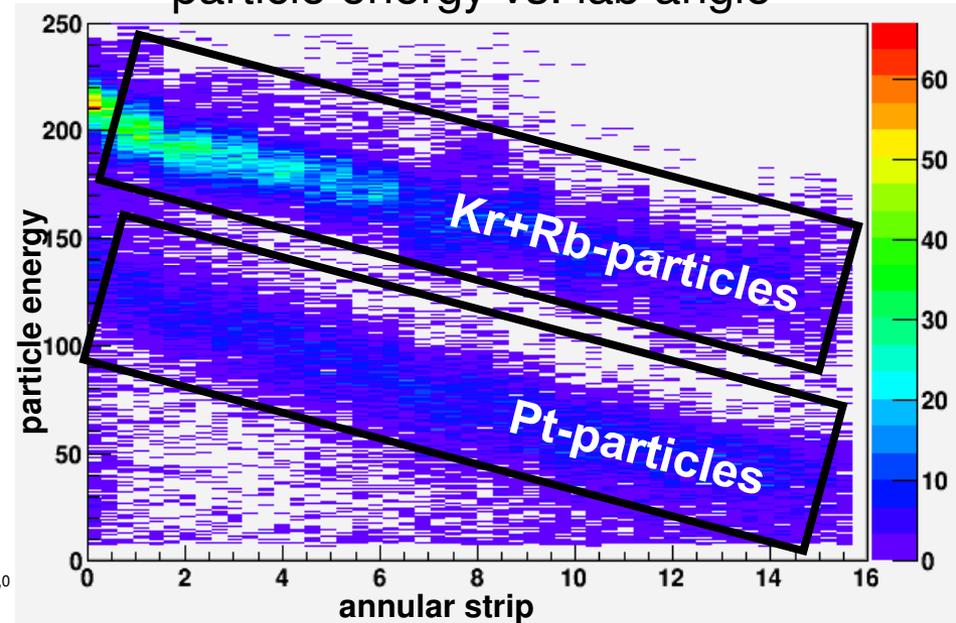


Particle gated γ -spectra of ^{94}Kr particles on ^{196}Pt

Catkin* calculation of the reaction kinematic



Experimentally determined particle energy vs. lab angle



γ peaks caused by Coulex reaction appear Doppler shifted in the γ spectrum, because the Coulomb excited ions emit their γ probably in flight.

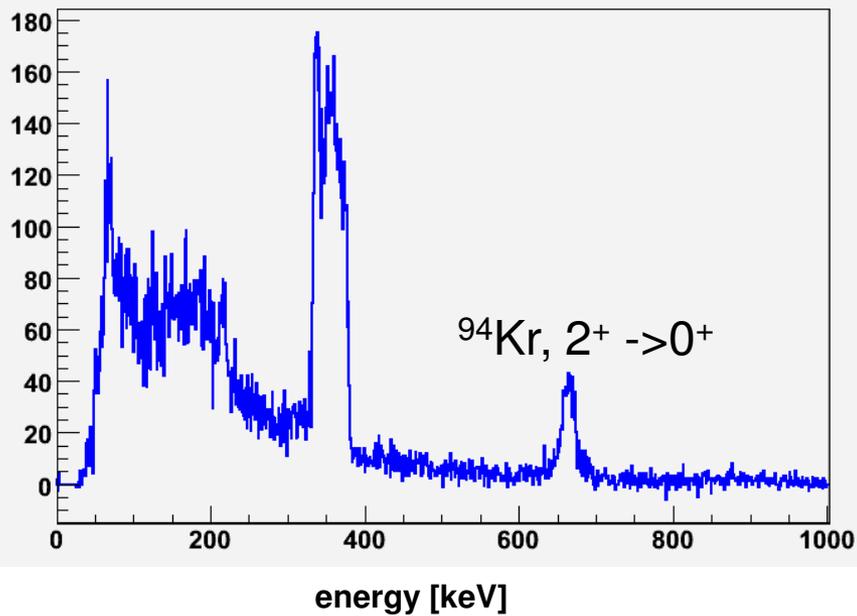
By setting a particle gate, the Doppler shifted γ peaks can be corrected.

$$E_{\gamma} = E_0 \left(1 + \frac{v}{c} \cdot \cos(\vartheta) \right)$$

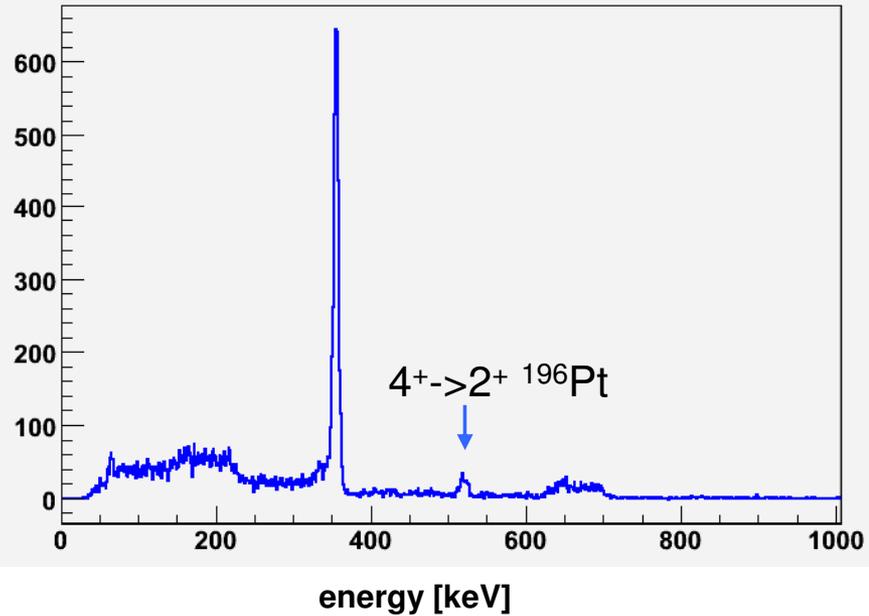
*: catkin2.02, W.N. Catford (1998,2005)

Particle gated γ -spectra of ^{94}Kr particles on ^{196}Pt

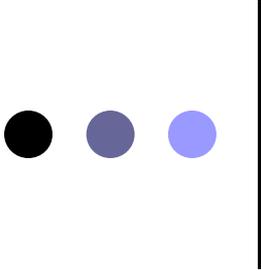
Particle gate on Kr-region
Doppler-correction for A=94



Particle gate on Pt-region
Doppler-correction for A=196



$$f = \left(1 - \left(\frac{2 \cdot E_P}{A} \right) \right)^{-1/2} \cdot \left(1 - \sqrt{\left(\frac{2 \cdot E_P}{A} \right)} \cdot \sin \vartheta_P \cdot \sin \vartheta_\gamma \cdot \cos(\varphi_P - \varphi_\gamma) + \cos \vartheta_P \cdot \cos \vartheta_\gamma \right)$$



Determination of the absolute transition strength

- Using the computer code CLX* by Ower et al, based upon the Coulex theory of Winther and de Boer**

$$\sigma_P = \frac{\epsilon_T}{\epsilon_T} \cdot \frac{N_P}{N_T} \cdot \frac{b_T}{b_T} \cdot \frac{W_T}{W_T} \cdot \sigma_T$$

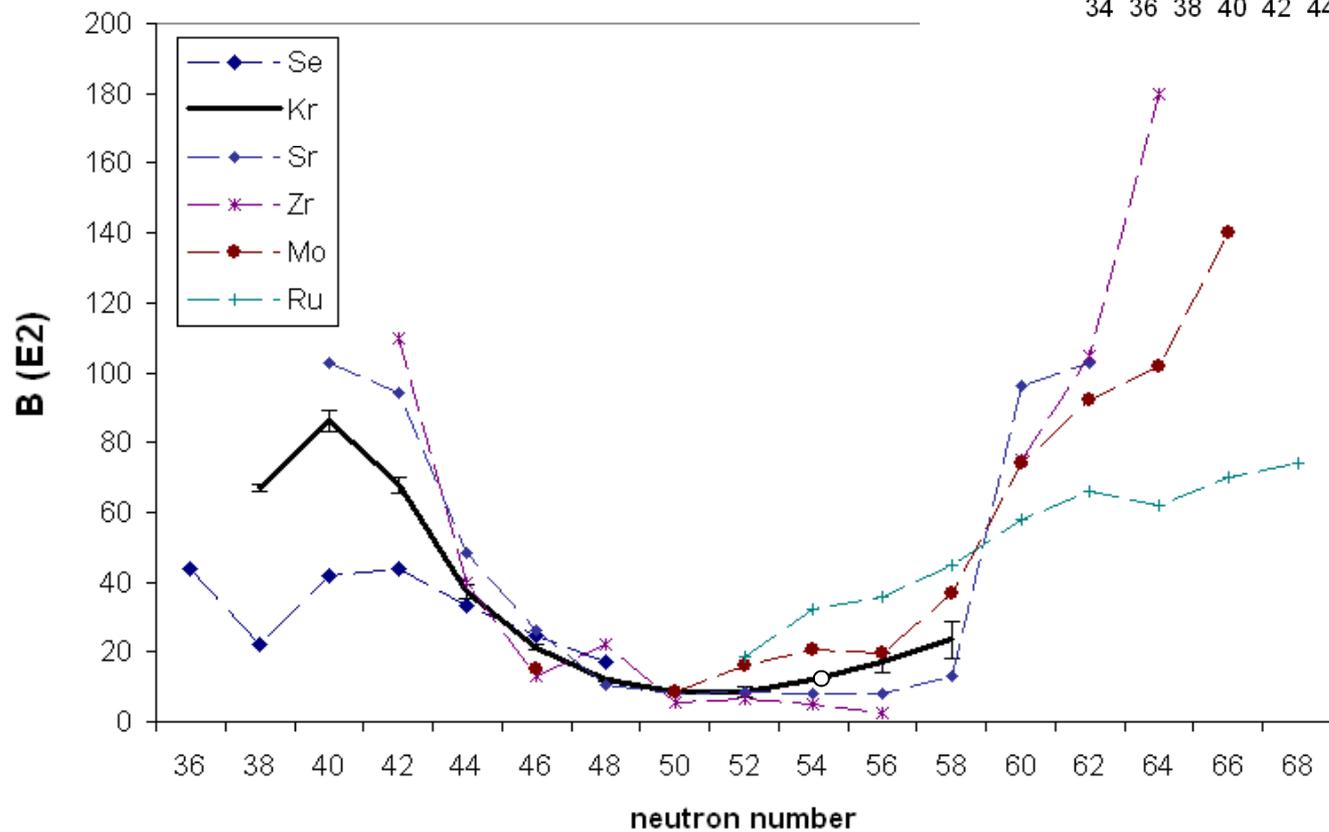
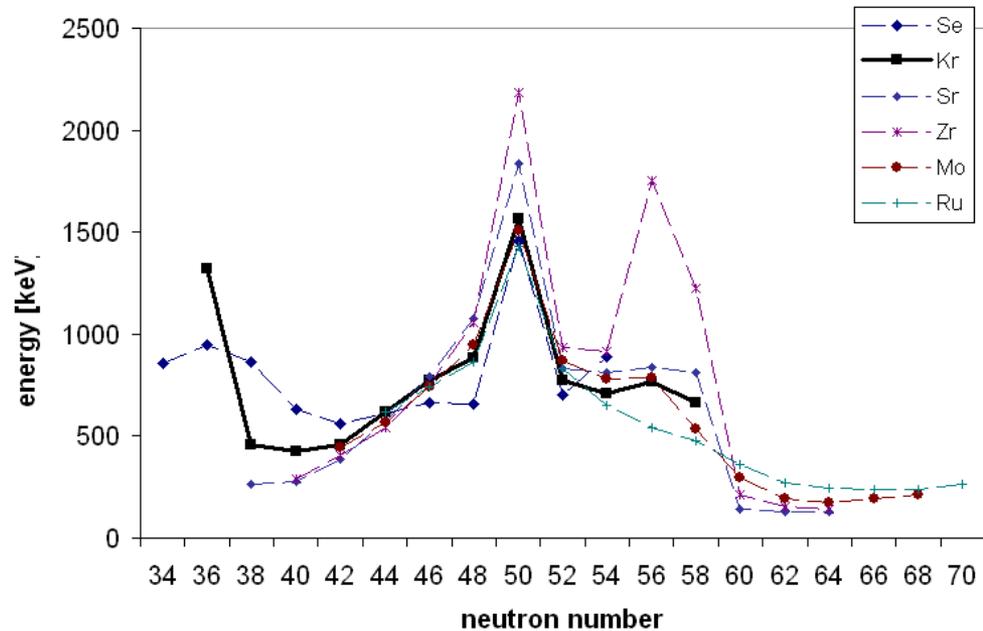
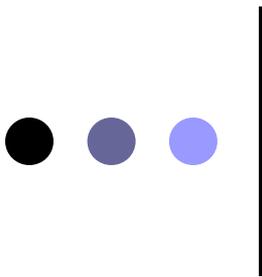
- $\sigma_{P,T} \sim B(E2; 2^+_{1} \rightarrow 0^+_{1})_{P,T}$
- $^{196}\text{Pt}: B(E2; 2^+_{1} \rightarrow 0^+_{1}) = 40.6(2) \text{ W.u.}$

→ $^{94}\text{Kr}: B(E2; 2^+_{1} \rightarrow 0^+_{1}) = 23.5(52) \text{ W.u.}$

$\tau = 7.3(16) \text{ ps}$

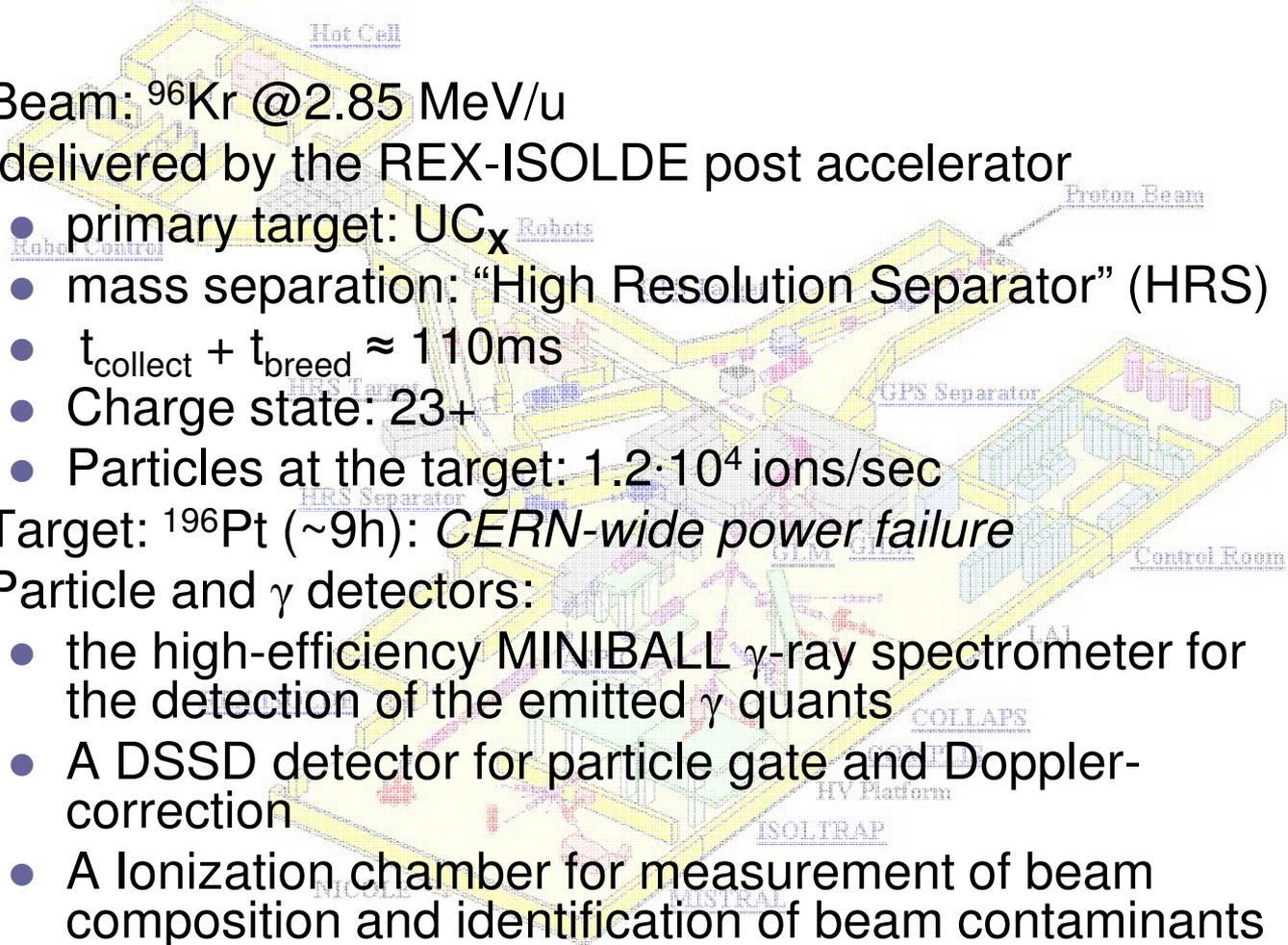
*: H. Ower, computer code CLX

** : A. Winther and J. de Boer, *Coulomb Excitation*, (Academic, New York, 1965)



Setup of the experiment on ^{96}Kr

- Beam: ^{96}Kr @2.85 MeV/u delivered by the REX-ISOLDE post accelerator
 - primary target: UC_x
 - mass separation: “High Resolution Separator” (HRS)
 - $t_{\text{collect}} + t_{\text{breed}} \approx 110\text{ms}$
 - Charge state: $23+$
 - Particles at the target: $1.2 \cdot 10^4$ ions/sec
- Target: ^{196}Pt ($\sim 9\text{h}$): *CERN-wide power failure*
- Particle and γ detectors:
 - the high-efficiency MINIBALL γ -ray spectrometer for the detection of the emitted γ quants
 - A DSSD detector for particle gate and Doppler-correction
 - A Ionization chamber for measurement of beam composition and identification of beam contaminants



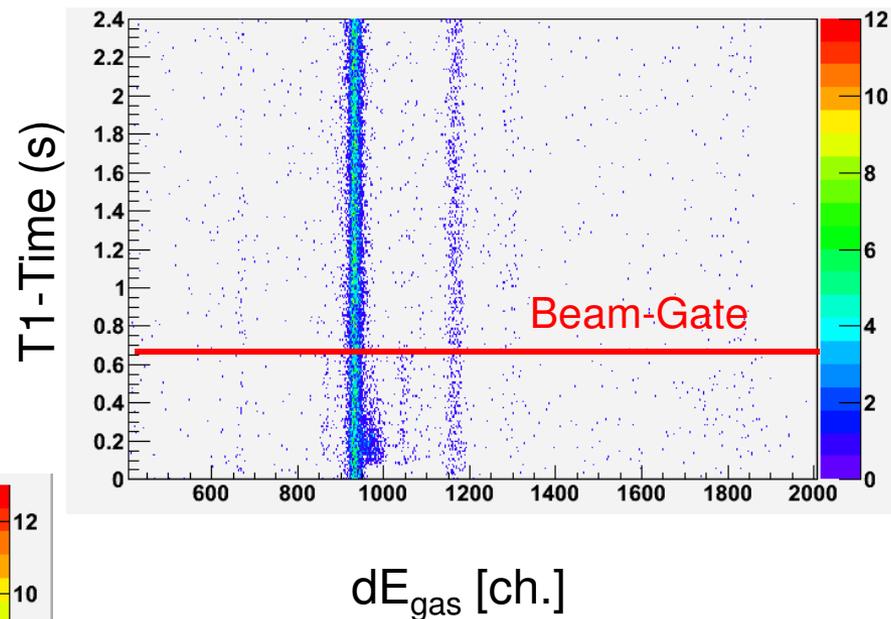
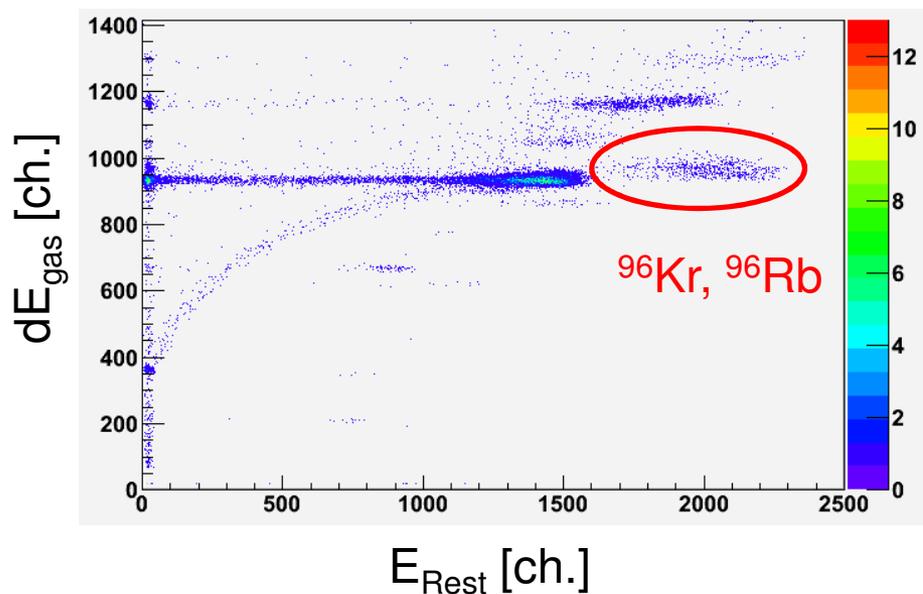
Identification of ^{96}Kr beam components

$T_{1/2} (^{96}\text{Kr}) \approx 80 \text{ ms}$

$t_{\text{collect}} + t_{\text{breed}} \approx 110 \text{ ms}$

Radioactive decay law:

→ ~62% of ^{96}Kr decays to ^{96}Rb



$A/q=4.174$

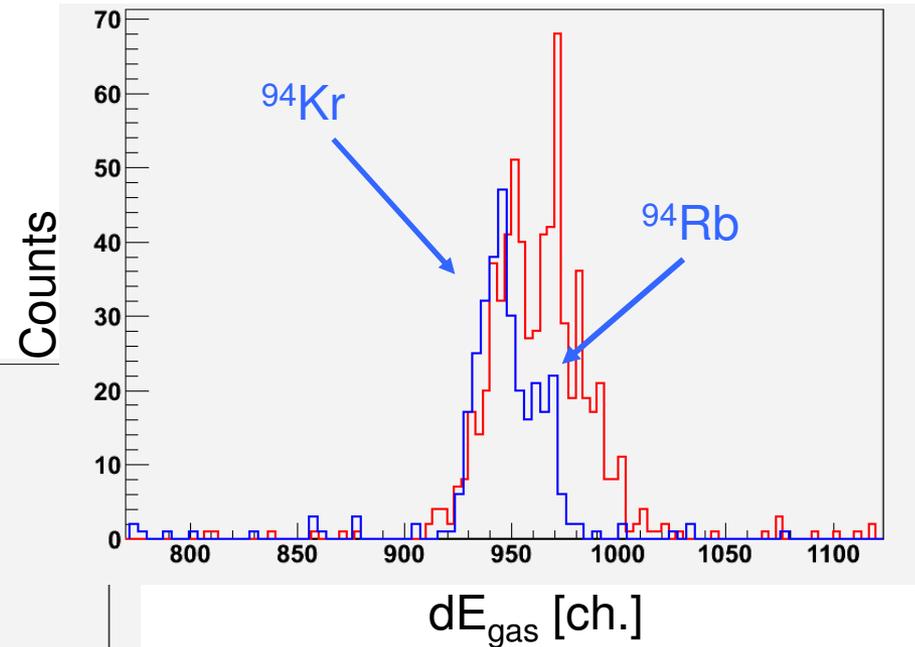
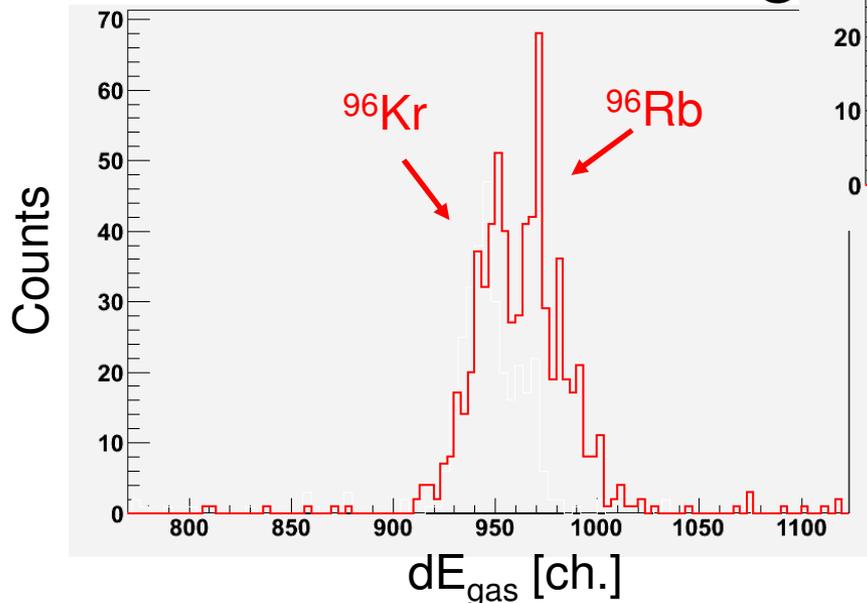
Separation of ^{96}Kr from decay products

$T_{1/2} (^{96}\text{Kr}) \approx 80 \text{ ms}$

$t_{\text{collect}} + t_{\text{breed}} \approx 110 \text{ ms}$

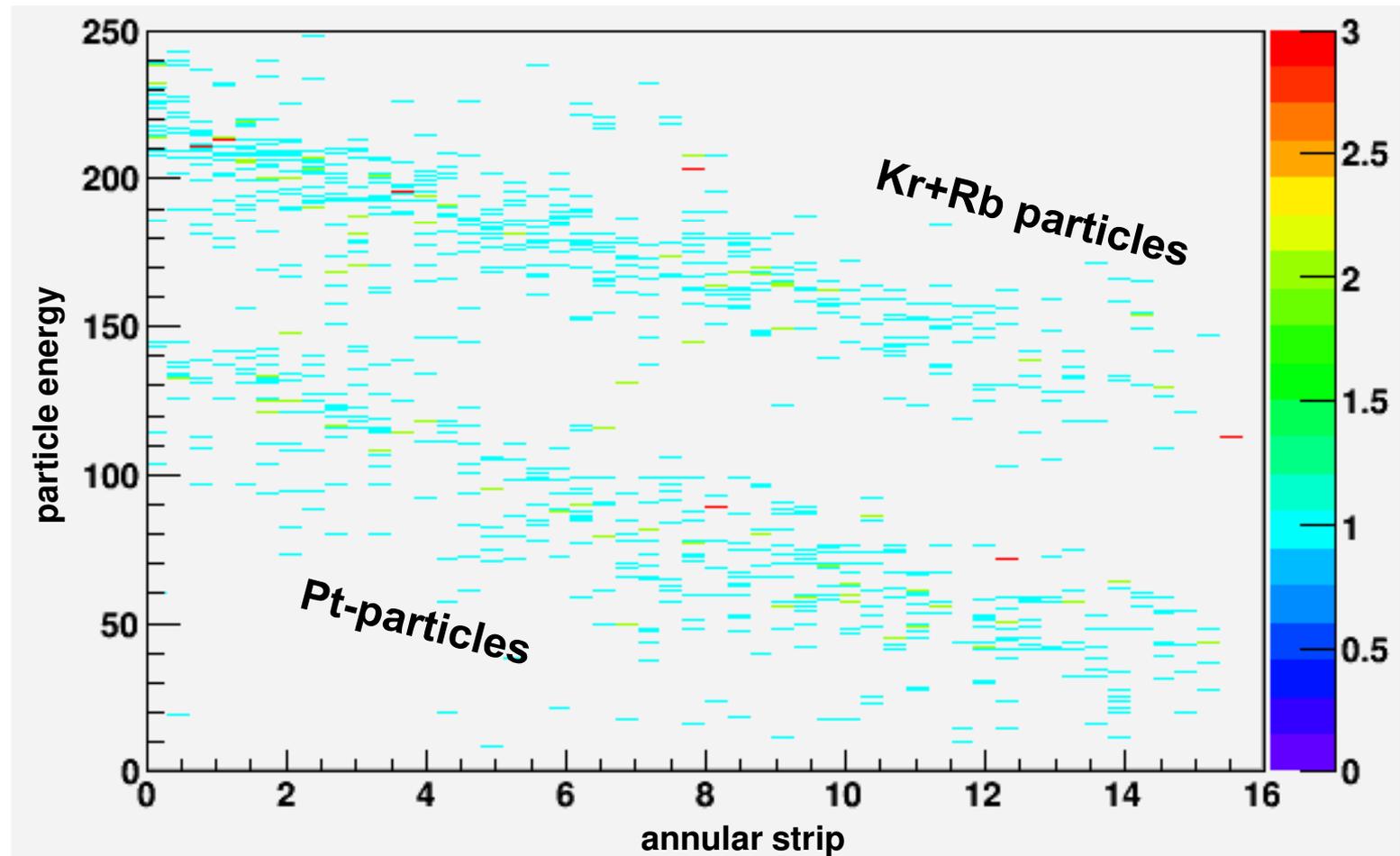
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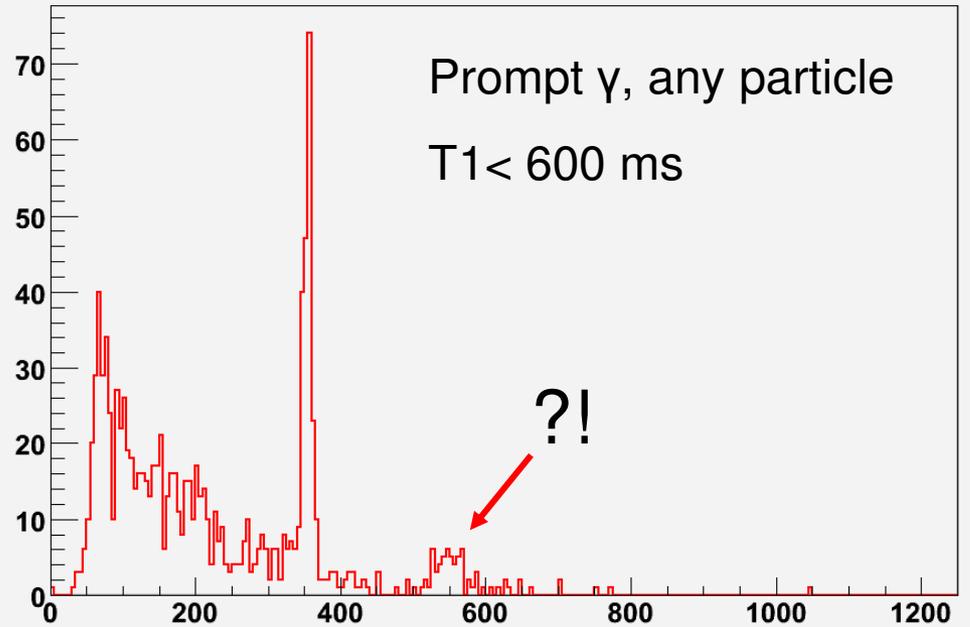
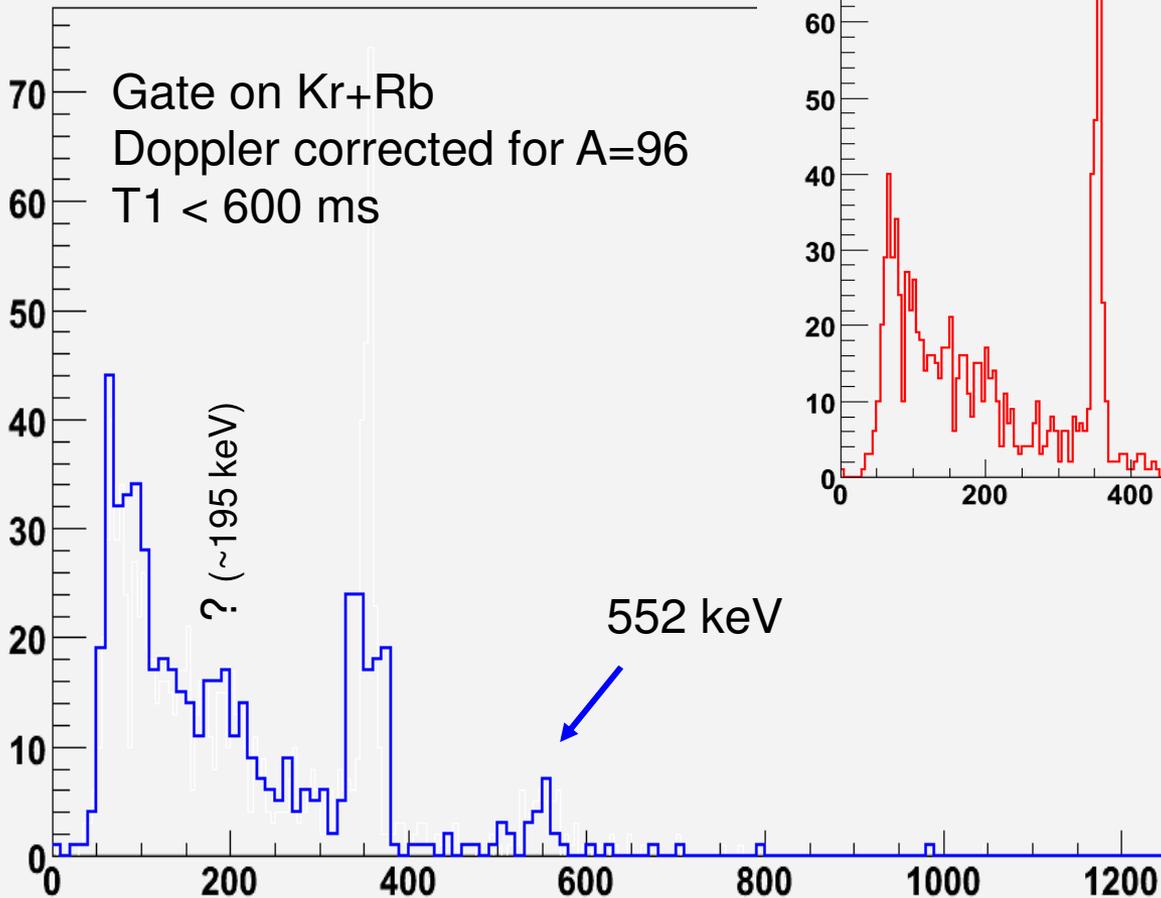


Particle gated γ -spectra of ^{96}Kr particles on ^{196}Pt

Experimentally determined particle energy vs. lab angle

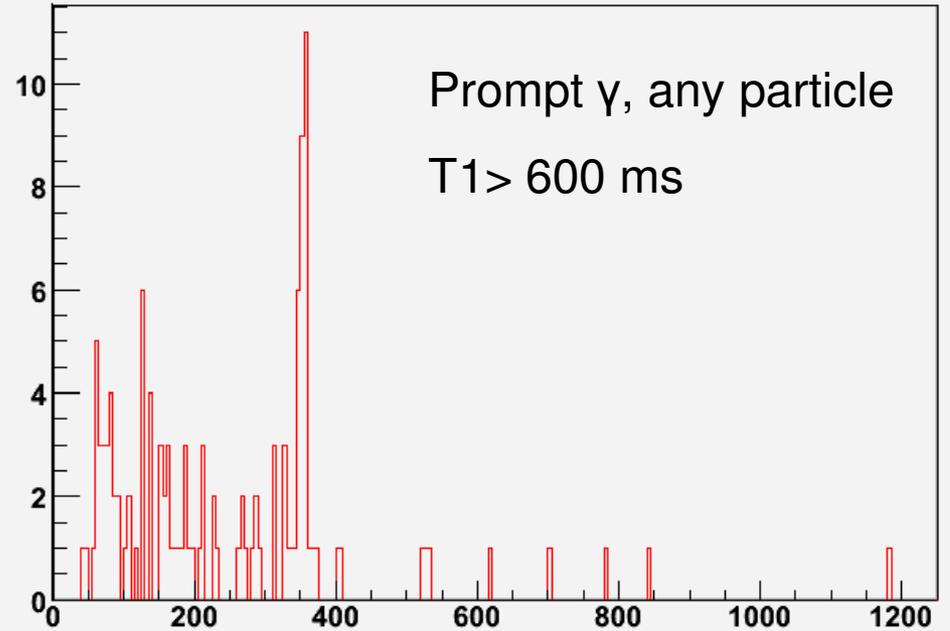
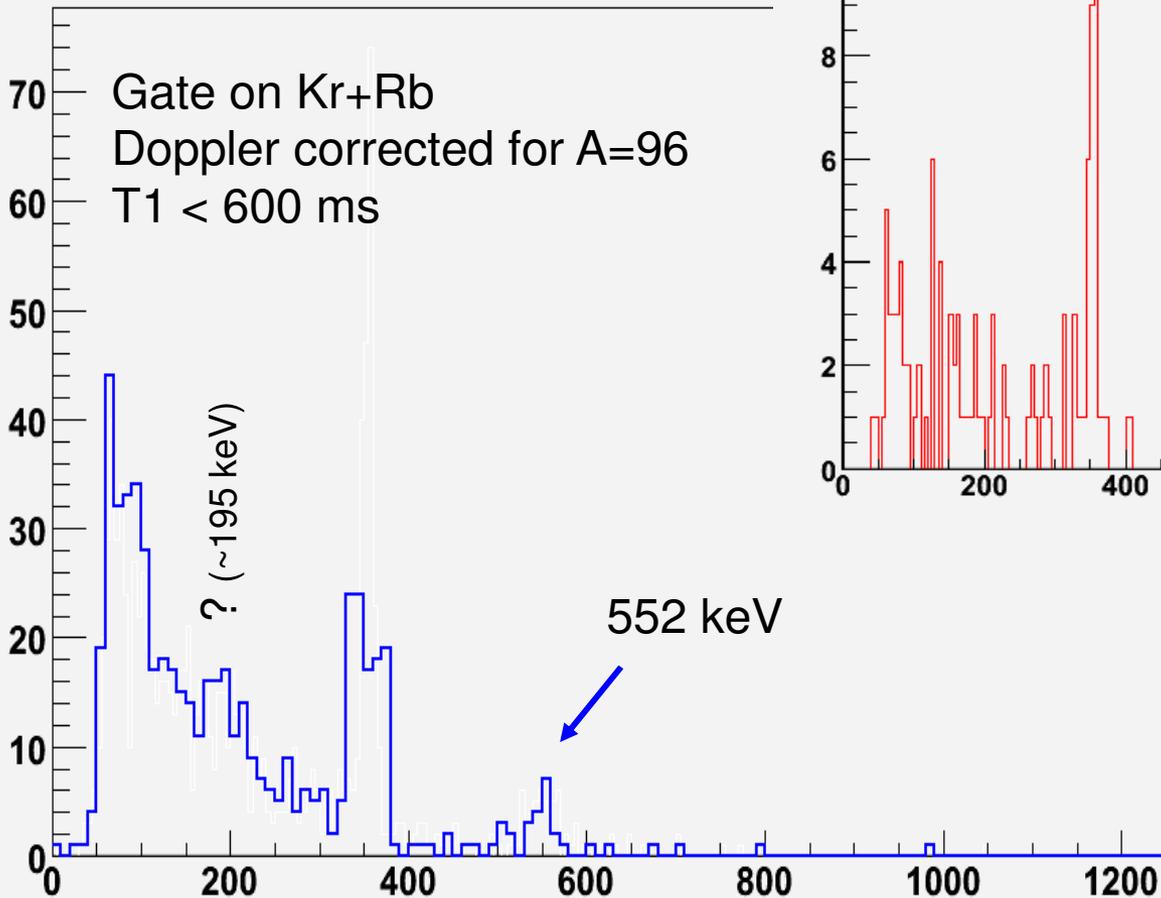


Particle gated γ -spectra

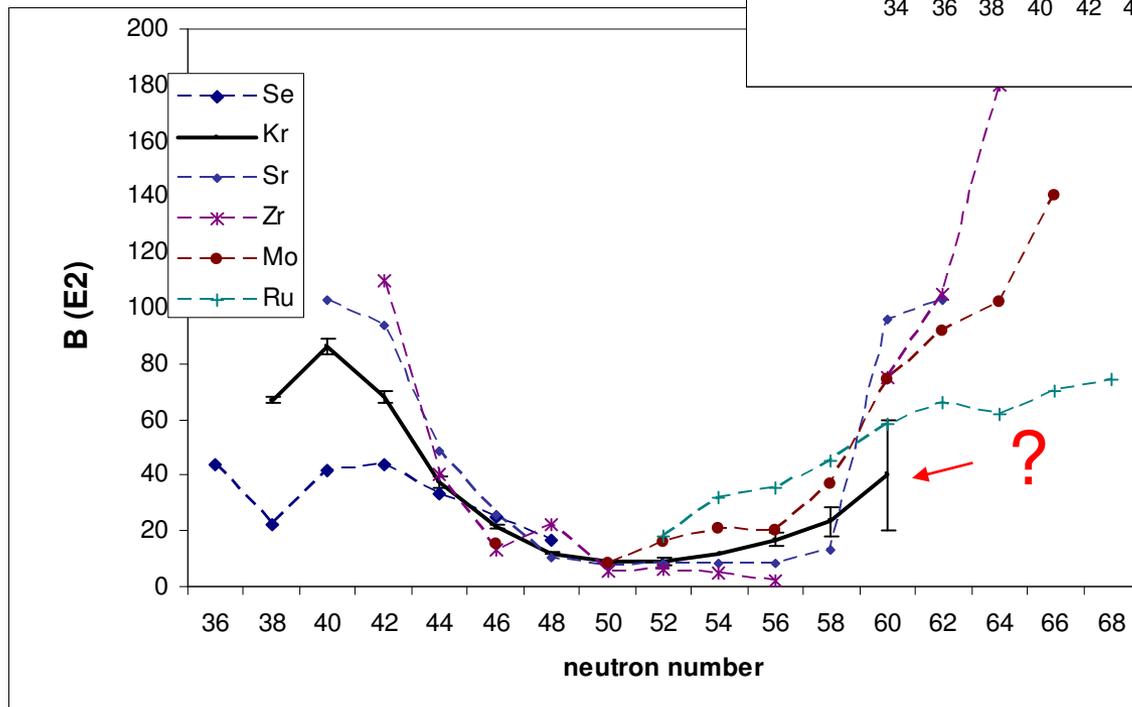
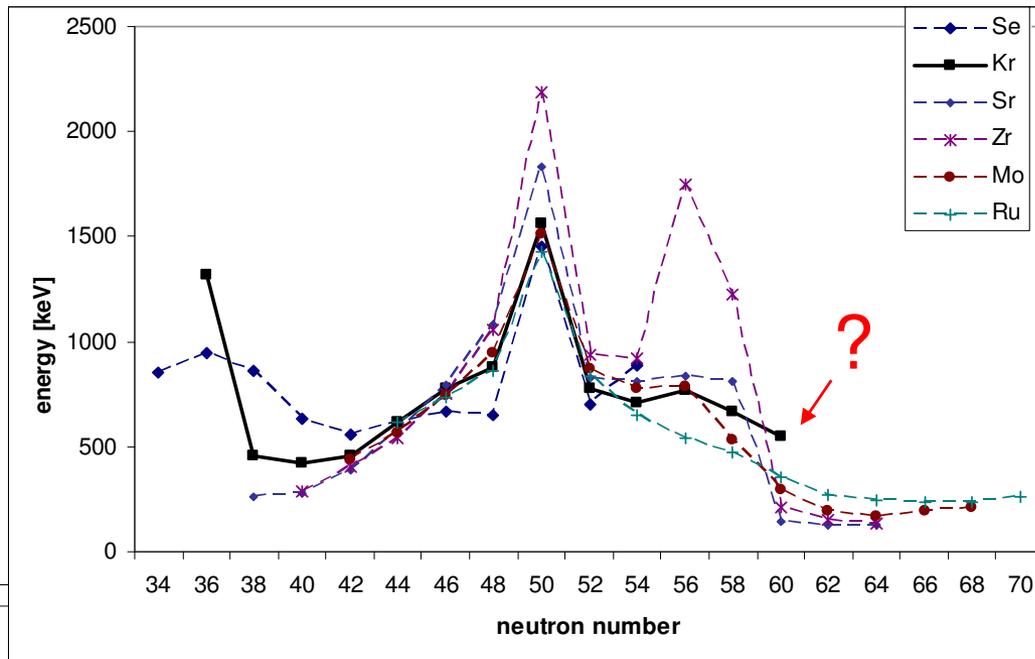
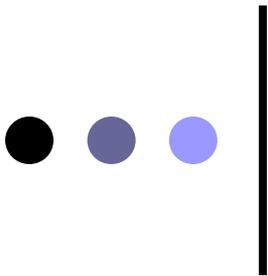


Keep in mind:
 $4^+ \rightarrow 2^+$ ^{196}Pt : 521 keV

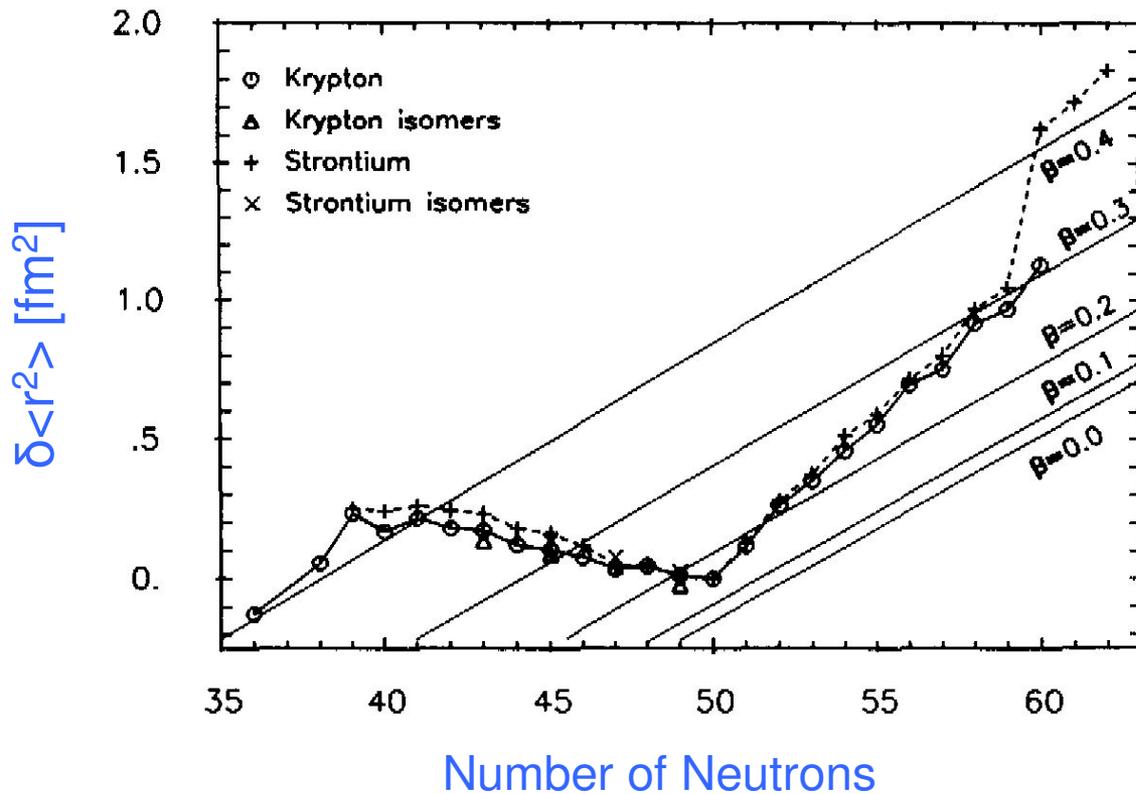
Particle gated γ -spectra

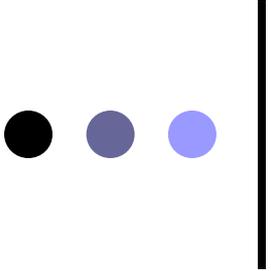


Keep in mind:
 $4^+ \rightarrow 2^+$ ^{196}Pt : 521 keV



Mean-Square Charge Radii





Conclusion and Outlook

- We determined a $B(E2; 2^+_{1} \rightarrow 0^+_{1})$ value of 23.5(52) W.u. for ^{94}Kr , which results in a lifetime of the 2^+_{1} state of $\tau = 7.3(16)$ ps.
- An ionization chamber was used to measure the beam composition and to identify several contaminants, especially for the ^{96}Kr beam
- Our data on ^{96}Kr do not confirm the previously known value of $E(2^+_{1})$ so far. In contrast, we have some evidence for a 2^+_{1} -state at about 552 keV.
→ Continuation of the experiment needed, maybe using a different charge state ($23+ \rightarrow 22+$) to reduce the charge breeding and charge collecting time