# Identification of the $2^+_{ms}$ mixed-symmetry state in $^{52}$Ti using the alpha transfer reaction

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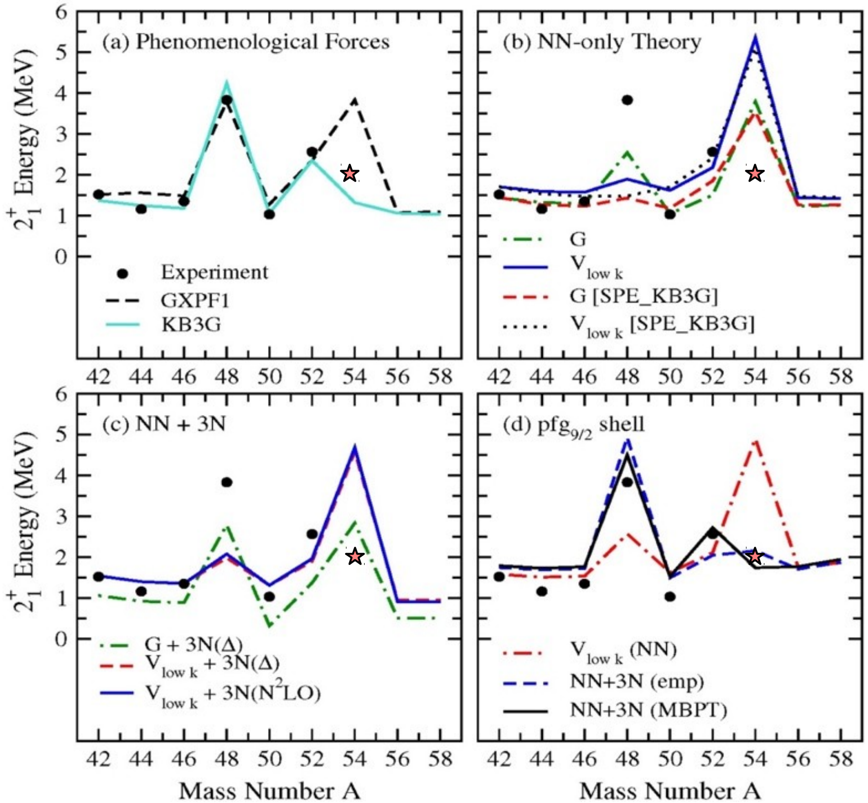
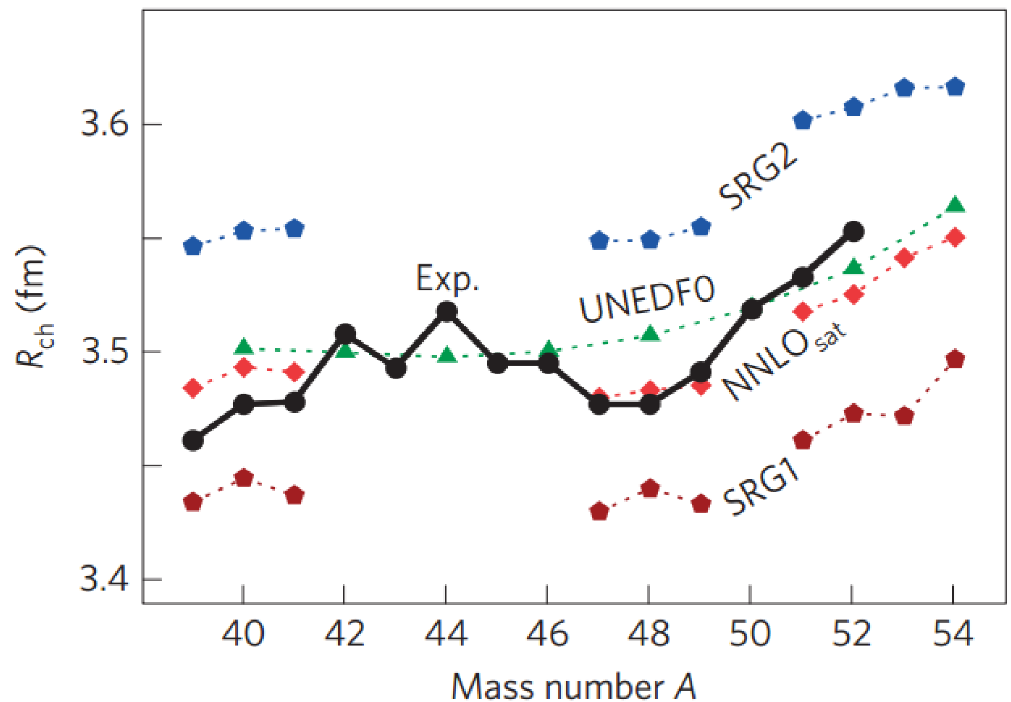
# Out lines

- Brief Introduction
- Experimental set up
- Some Preliminary Results
- Conclusion.

# Neutron-Rich $^{48}$Ca doubly magic nucleus




R. F. Garcia Ruiz et.al (2016) Nature.

3N forces essential to understand doubly magic 48Ca and also determine gaps at N=32 and N=34
J.D. Holt et al., Phys. Rev. C 90, 024312 (2014)

# Introduction

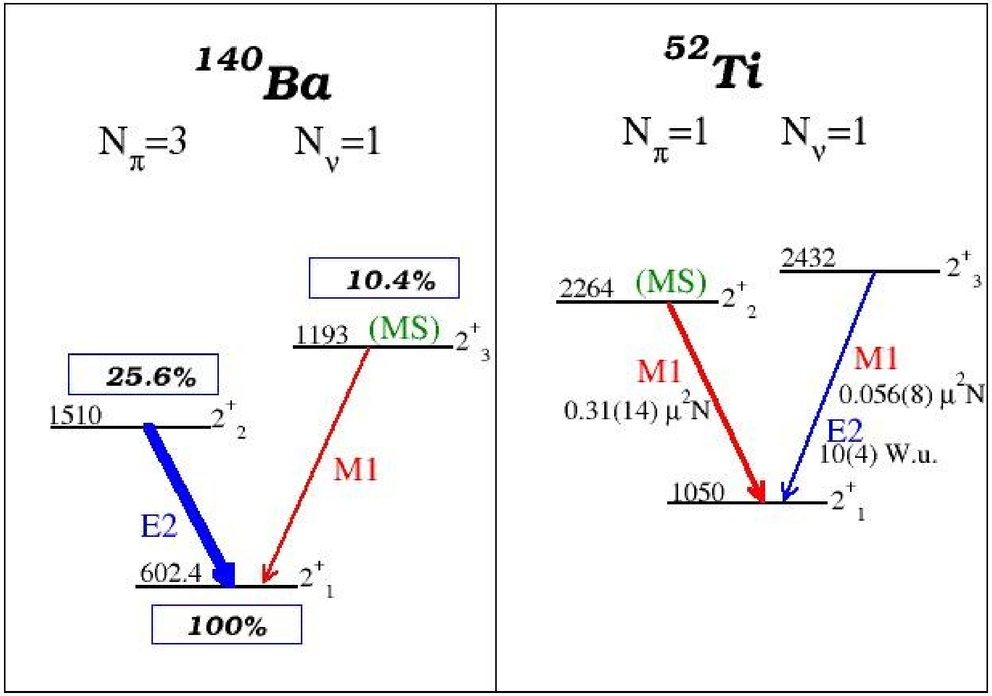
- In spherical even-even nuclei the quadrupole interaction leads to so called proton-neutron mixed symmetry (MS) states. Coupling of $2^+$ proton and $2^+$ neutron states. The wave functions:

| | |
|---|---|
| $^{50}$Ti<br>$\|2_1^+\rangle = \|2\pi_{j=2}\ 2\nu_{j=o}\rangle \equiv 2_\pi^+$ | $^{52}$Ti $\alpha^2 + \beta^2 = 1$<br>$\|2_1^+\rangle = \alpha\|2_\pi^+\rangle + \beta\|2_\nu^+\rangle$<br>$\|2_{ms}^+\rangle = -\beta\|2_\pi^+\rangle + \alpha\|2_\nu^+\rangle$ |
| $^{48}$Ca | $^{50}$Ca<br>$\|2_1^+\rangle = \|2\nu_{j=2}\ 2\pi_{j=o}\rangle \equiv 2_\nu^+$ |

- The MS state are sensitivity to the underlying sub shell closure and their part of residual interaction. it used to specify the microscopic structure of shell closure. **G. Rainoviski et. al. PRL (2006).**

# Mixed Symmetry State

- Strong M1 decay to the fully symmetric state $2^+_1$ and weak collective decay strength to the ground state E2 transition.
- IBM-2, predict the cross section from alpha-transfer into MS state.



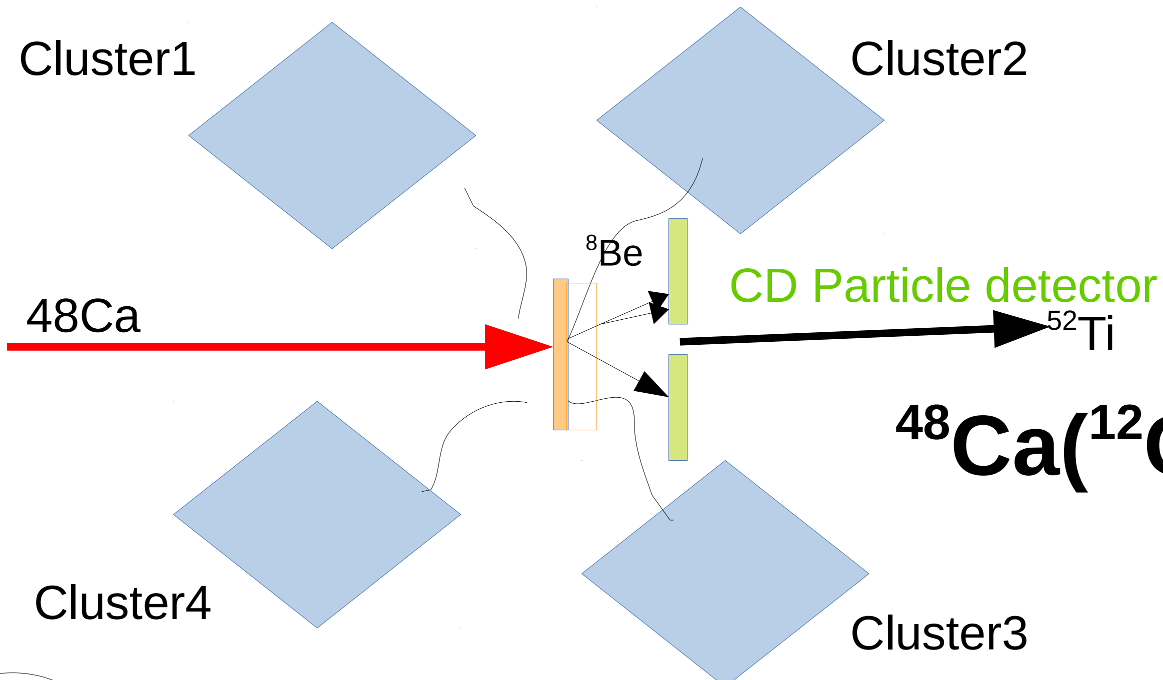

$$\frac{\sigma(\mathbf{2}^+_{\mathbf{ms}})}{\sigma(\mathbf{2}^+_{\mathbf{1}})} = \frac{(\mathbf{N}_\pi - \mathbf{N}_\nu)}{\mathbf{2}\sqrt{(\mathbf{N}_\nu + \mathbf{1})(\mathbf{N}_\pi + \mathbf{1})}}$$

$$\sigma\,(\mathbf{ms}) \simeq (\mathbf{N}_\pi - \mathbf{N}_\nu) \simeq \mathbf{0}$$

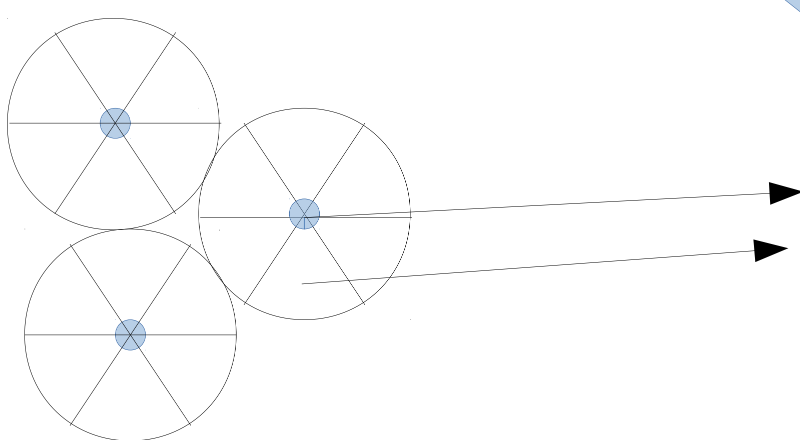
C. Stahl et al. Phys. Rev. C (2015)

# Experimental Set up

- Gamma-spectroscopy on $^{52}$Ti has been performed using inverse kinematics to populate the states.
- MINIBALL germanium array at the Maier-Leibnitz-Laboratory in Munich.



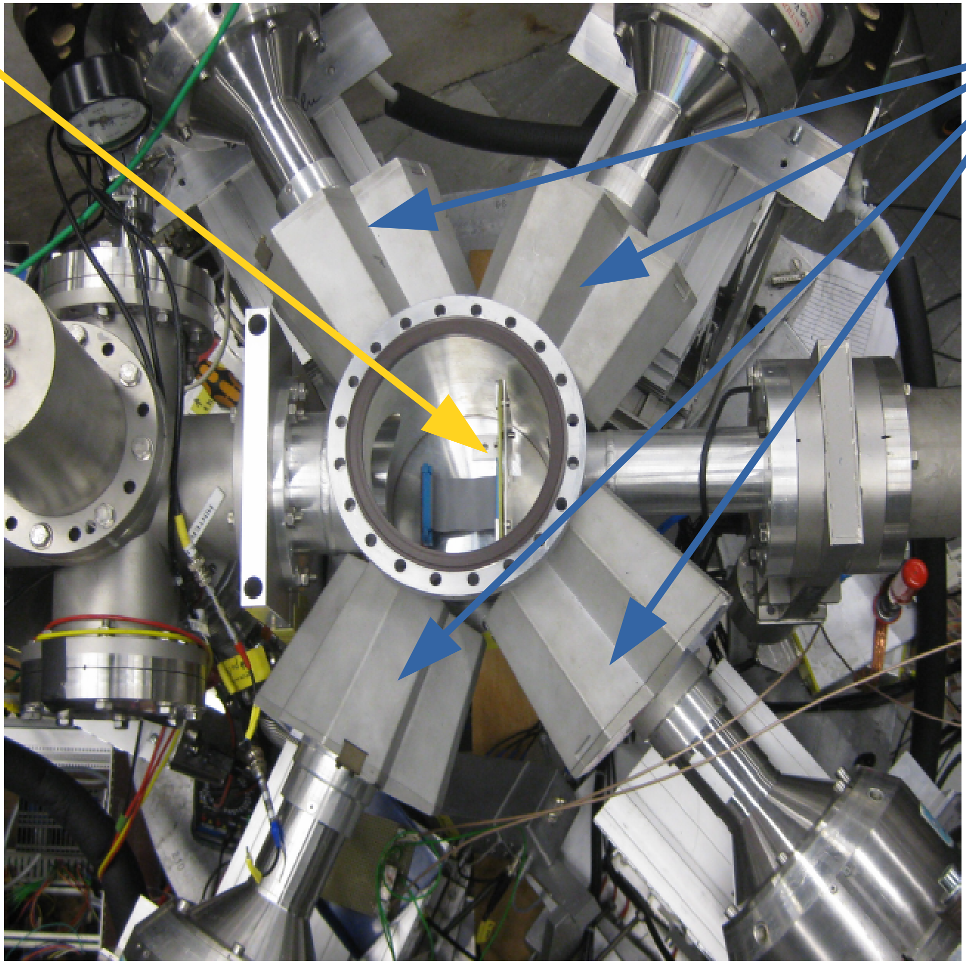

**$^{48}$Ca($^{12}$C,$^{8}$Be)$^{52}$Ti**



Mini ball setup
4 Ge cluster detectors
3 Crystal(Core)
6 Segments

Total 72 detectors !

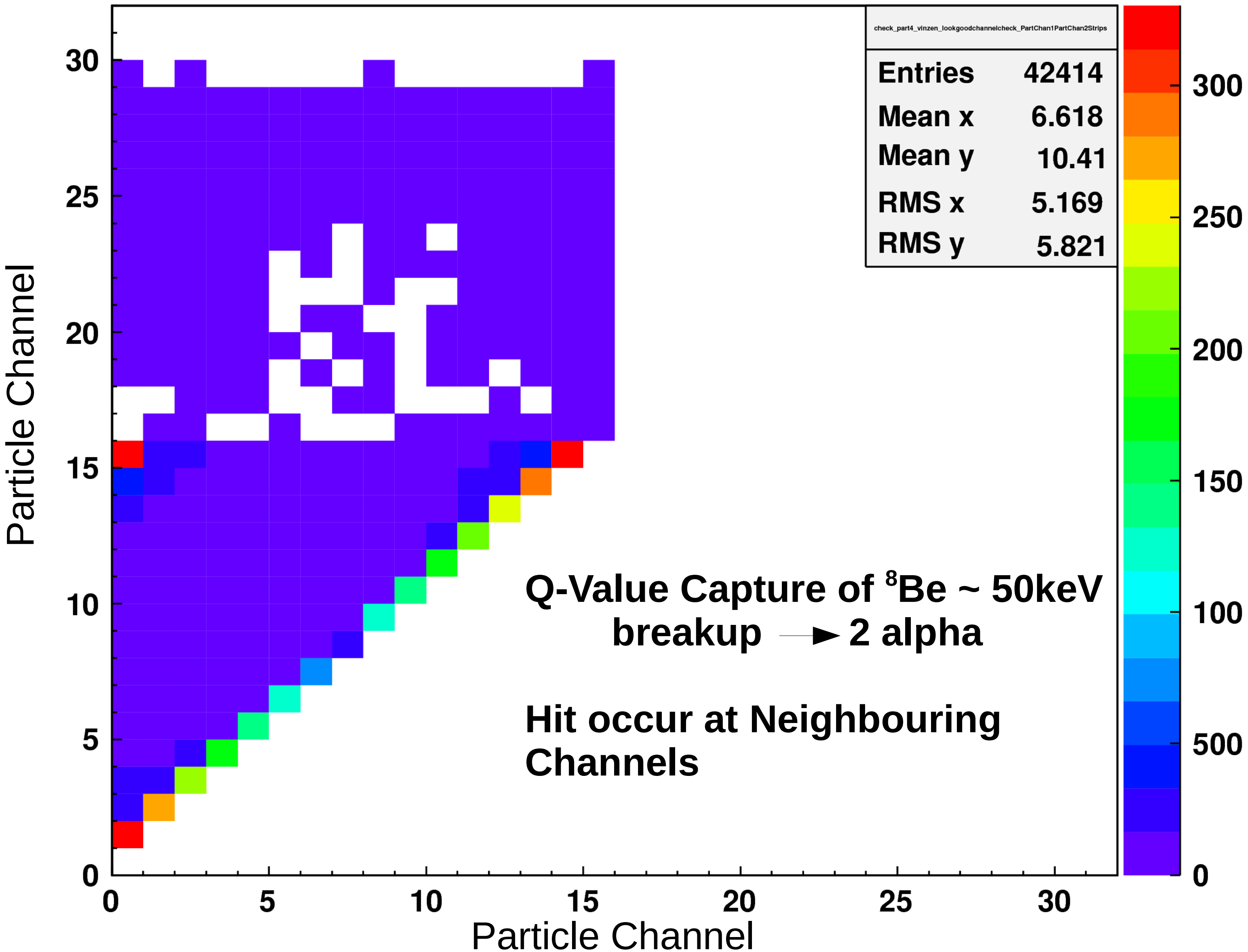
# Experimental Set up



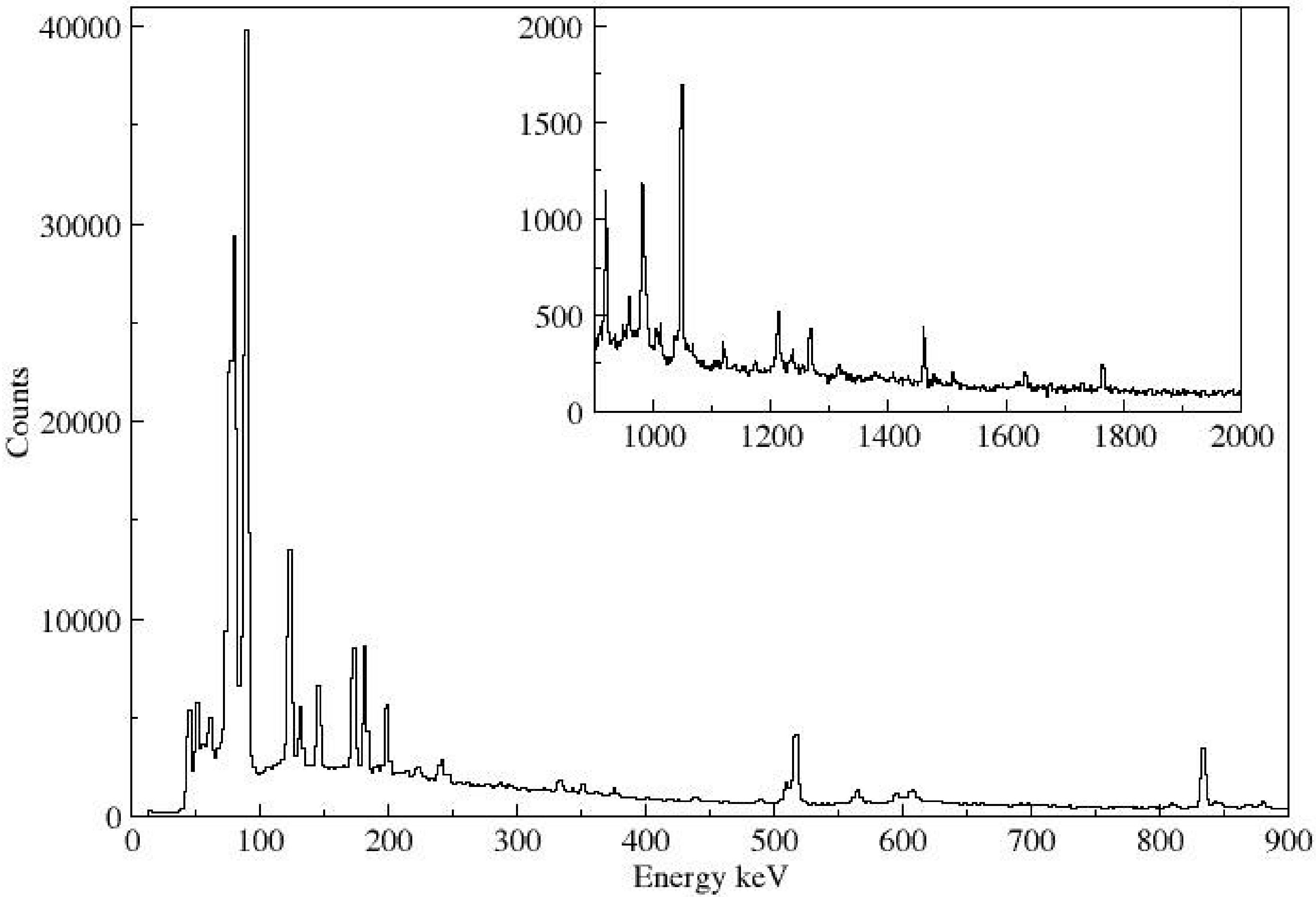

**$^{48}Ca(^{12}C,^{8}Be)^{52}Ti$**

High-resolution **Miniball Ge detector array**. Before operating at the MLL (Munich), it was operational at REX-ISOLDE at Cern for over 10 years.

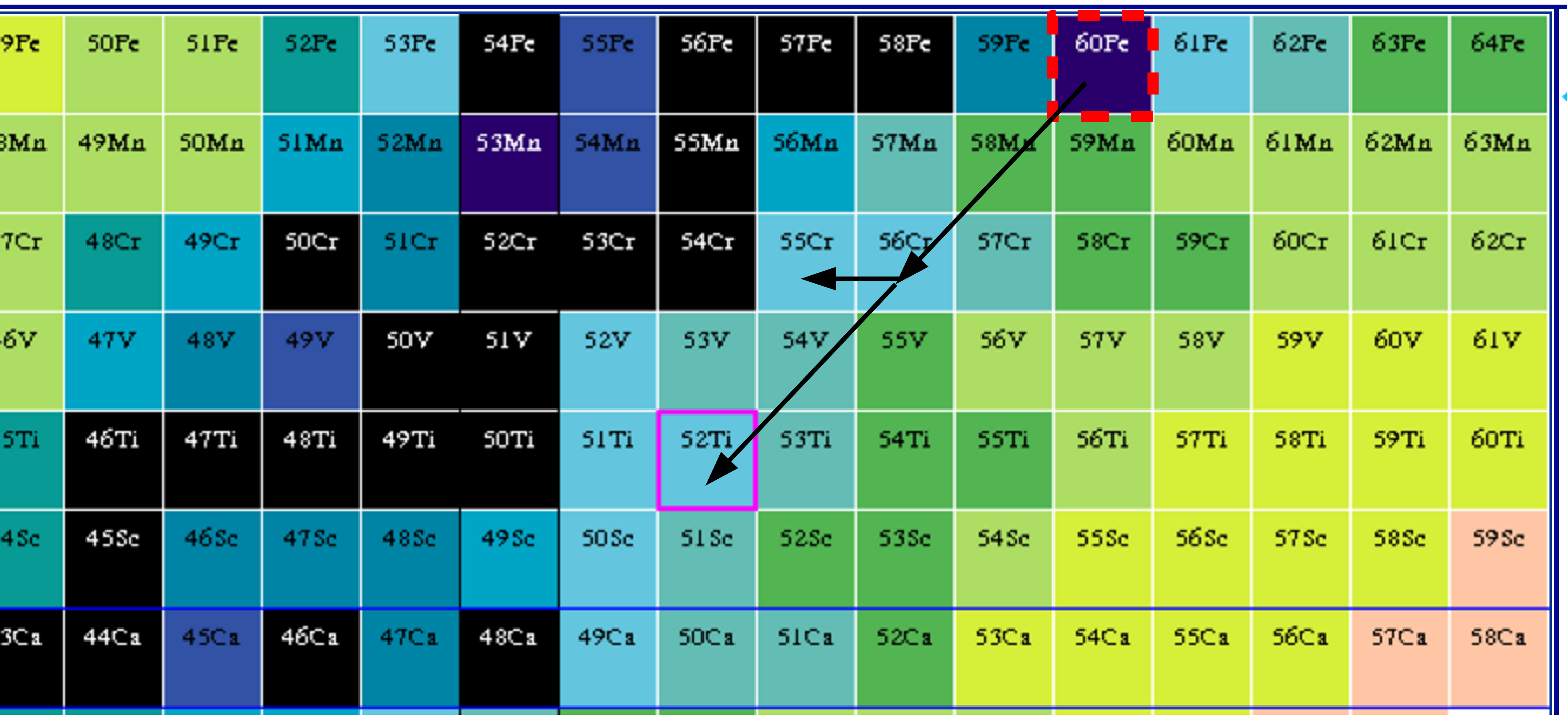
# Particle Channel Vs Channel in CD Particle Detector



# Prompt Gamma Ray Spectra from MINIBALL

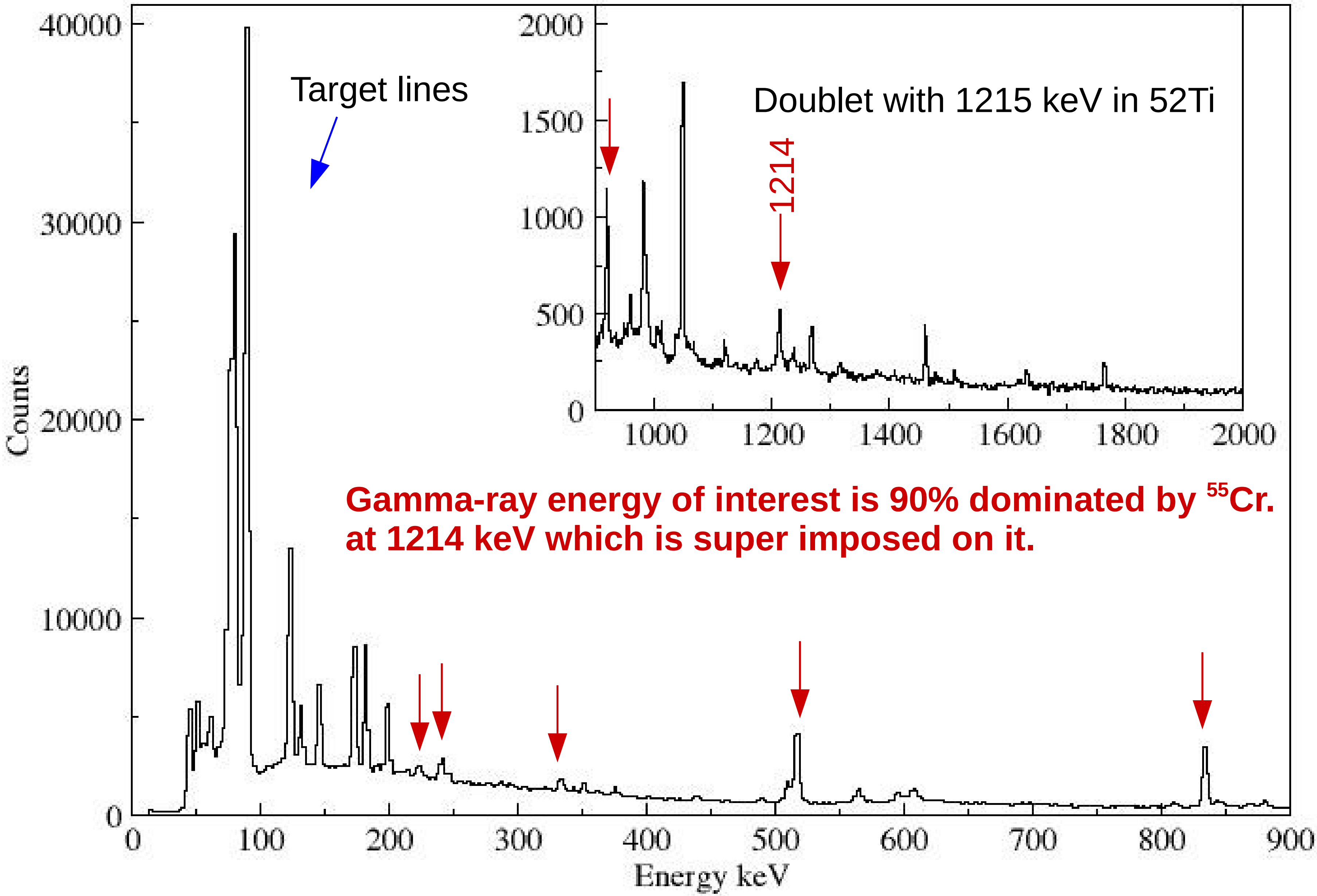


# Chart of Nuclei and Possible reaction Channels

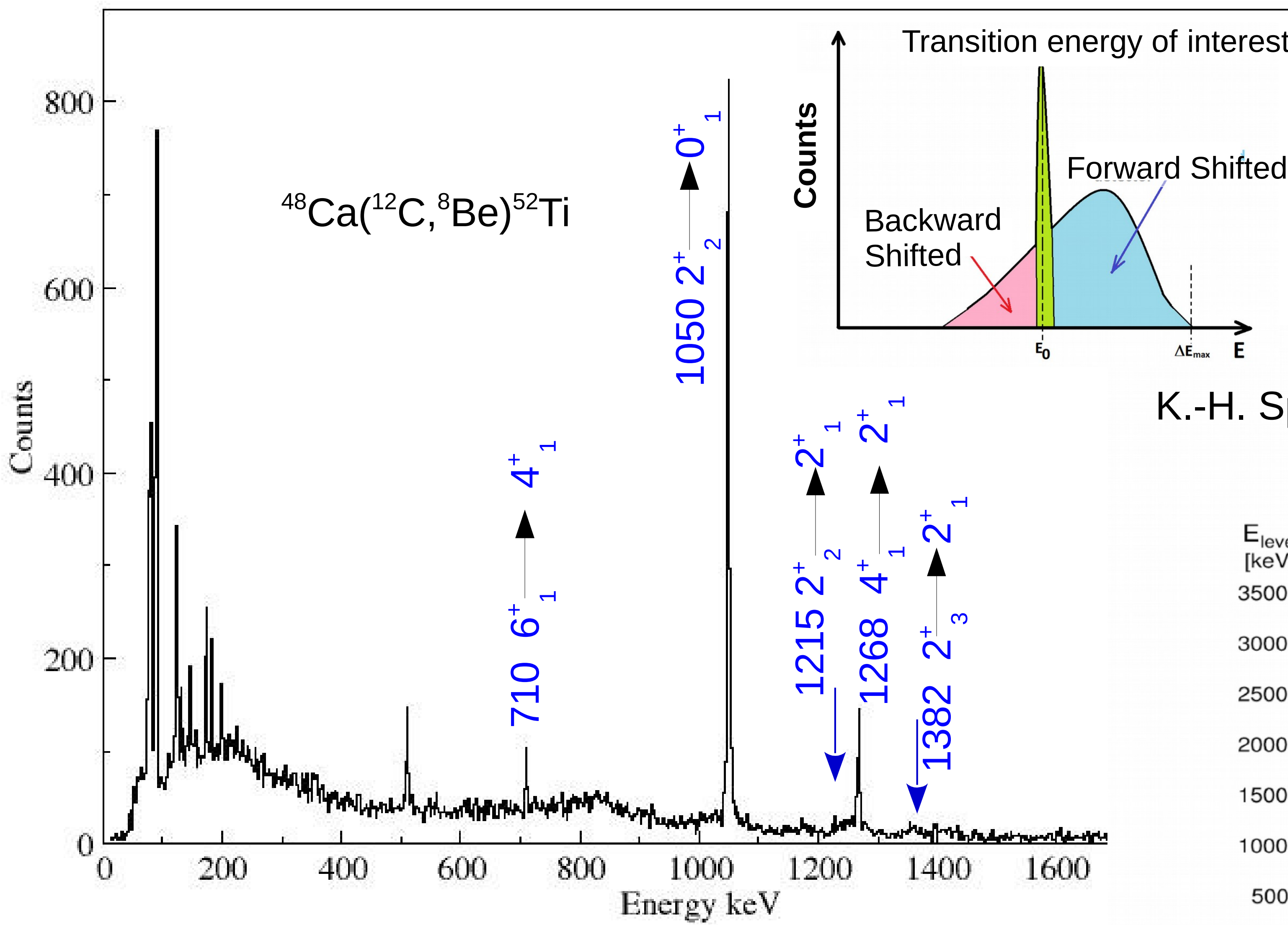


# Inspecting the Gamma-ray

## $^{48}Ca(^{12}C,\alpha n)^{55}Cr$

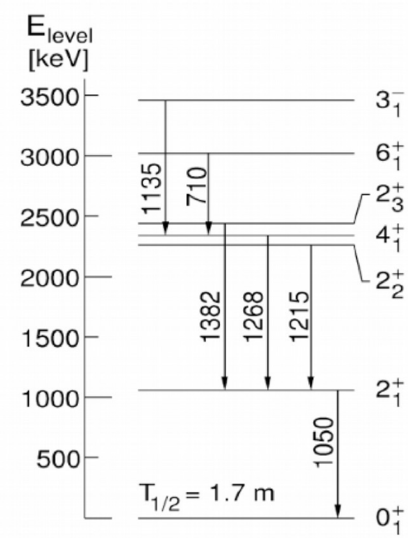


# Gamma Spectra for 2 Particle hit

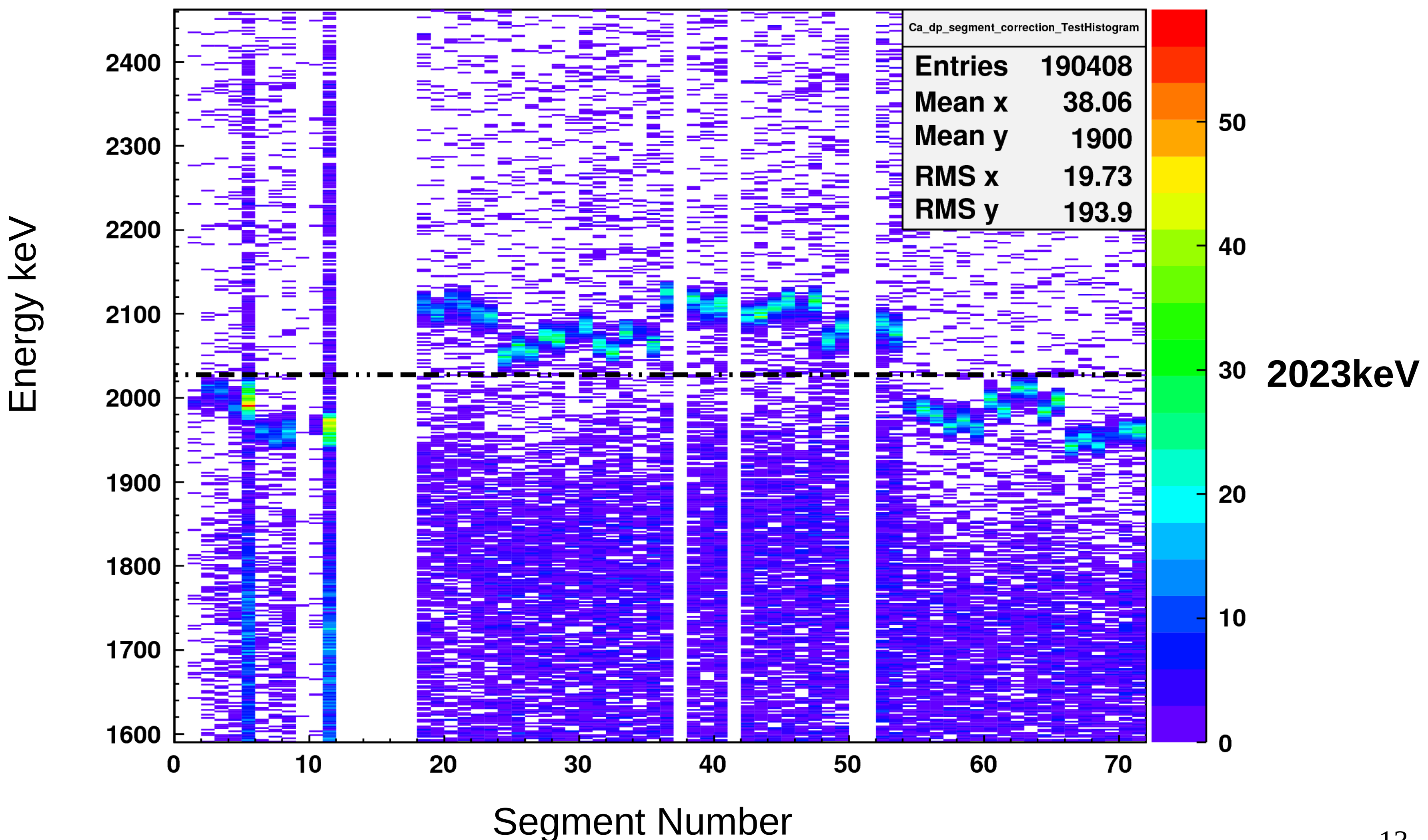



| | |
|---|---|
| 0+ | 1.7 min |
| $2_1$+ | 3.60 ps |
| $2_2$+ | 39 fs |
| $2_3$+ | 3.3 fs |
| 4+ | 25 ps |

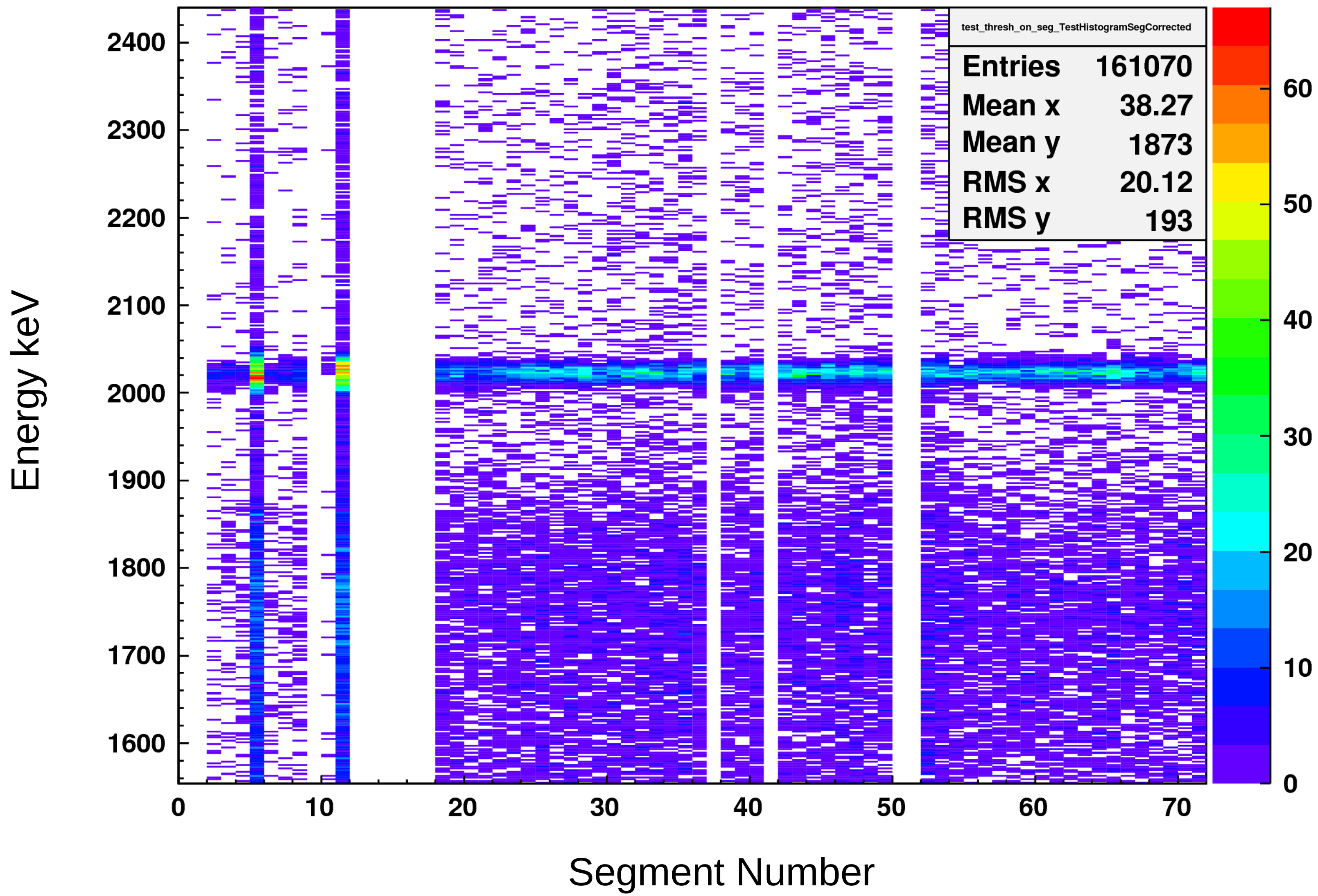
K.-H. Speidel *et al.* (2006)



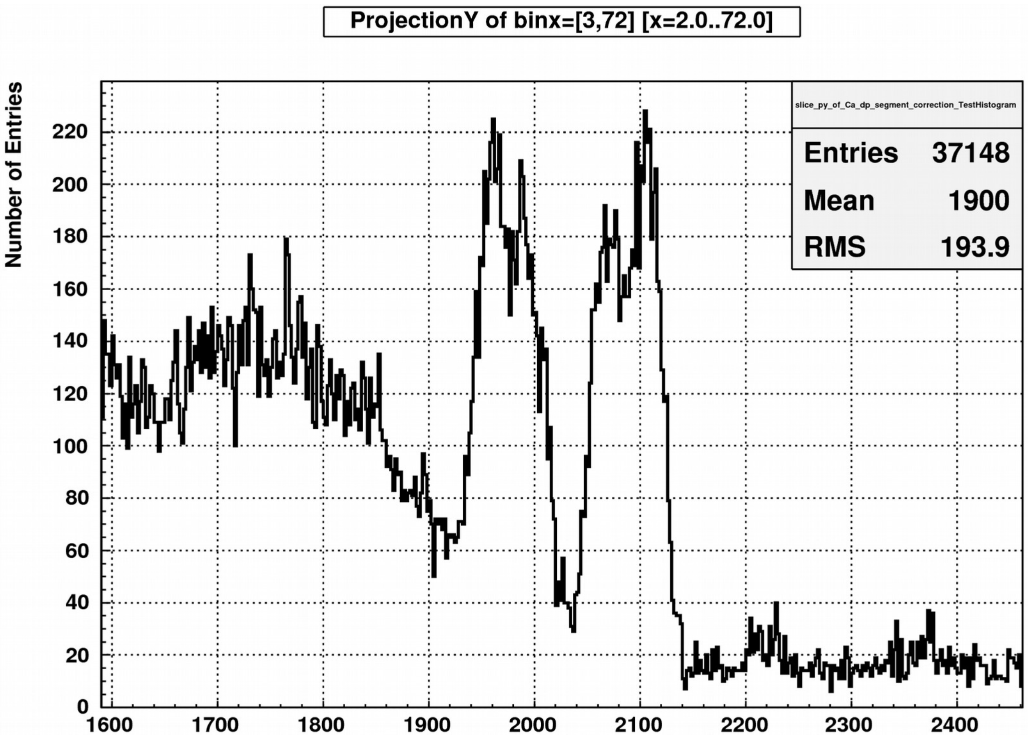
# $^{48}Ca(d,p)^{49}Ca$
# No Doppler Shift Correction

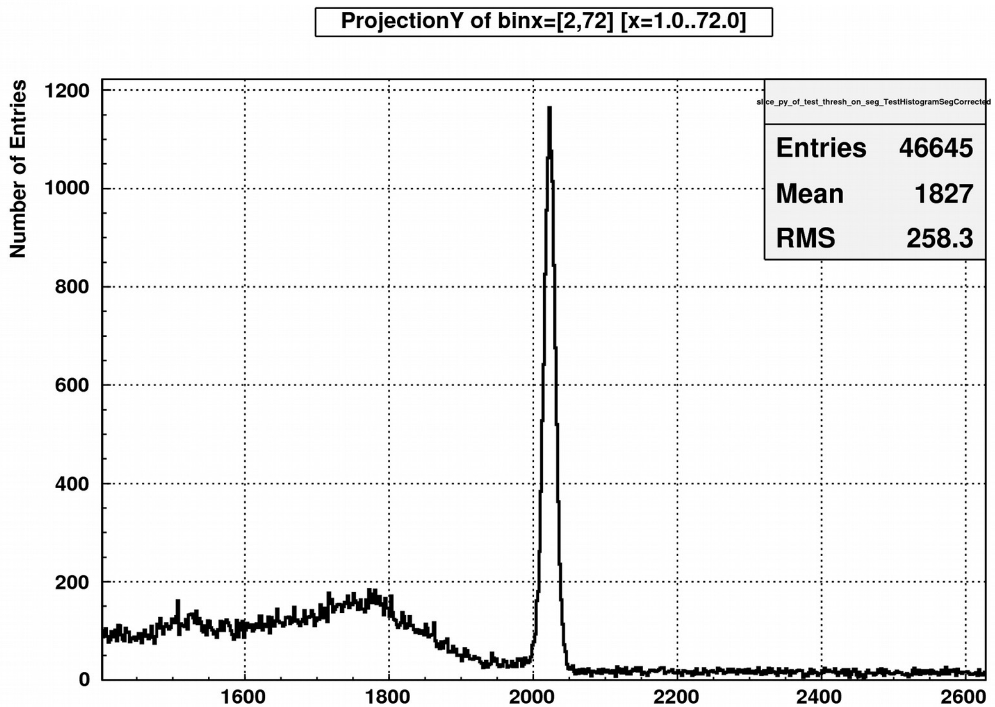


# $^{48}Ca(d,p)^{49}Ca$
# Doppler Correction at the Segments



# $^{48}Ca(d,p)^{49}Ca$
# Projections after Doppler Correction

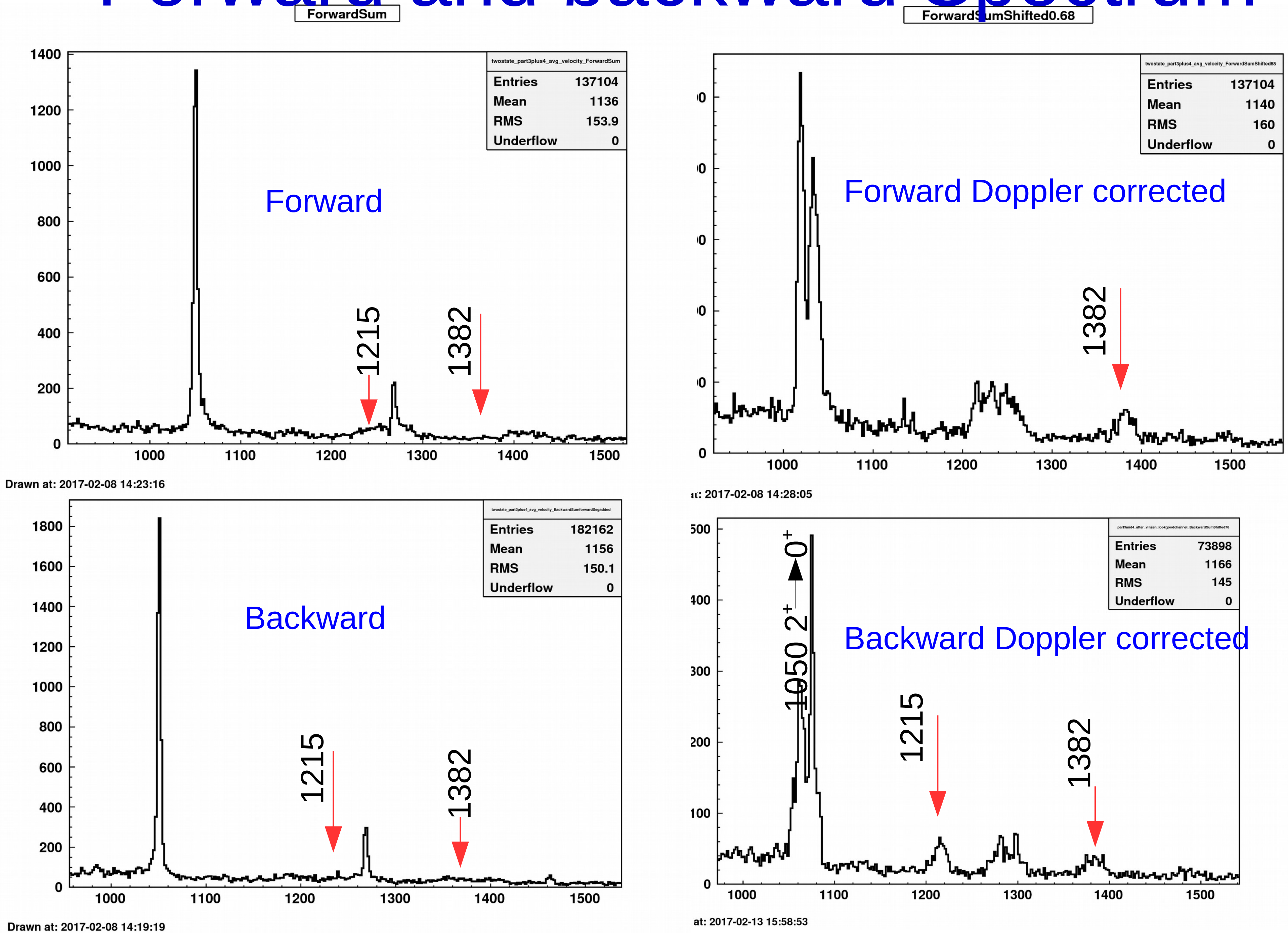


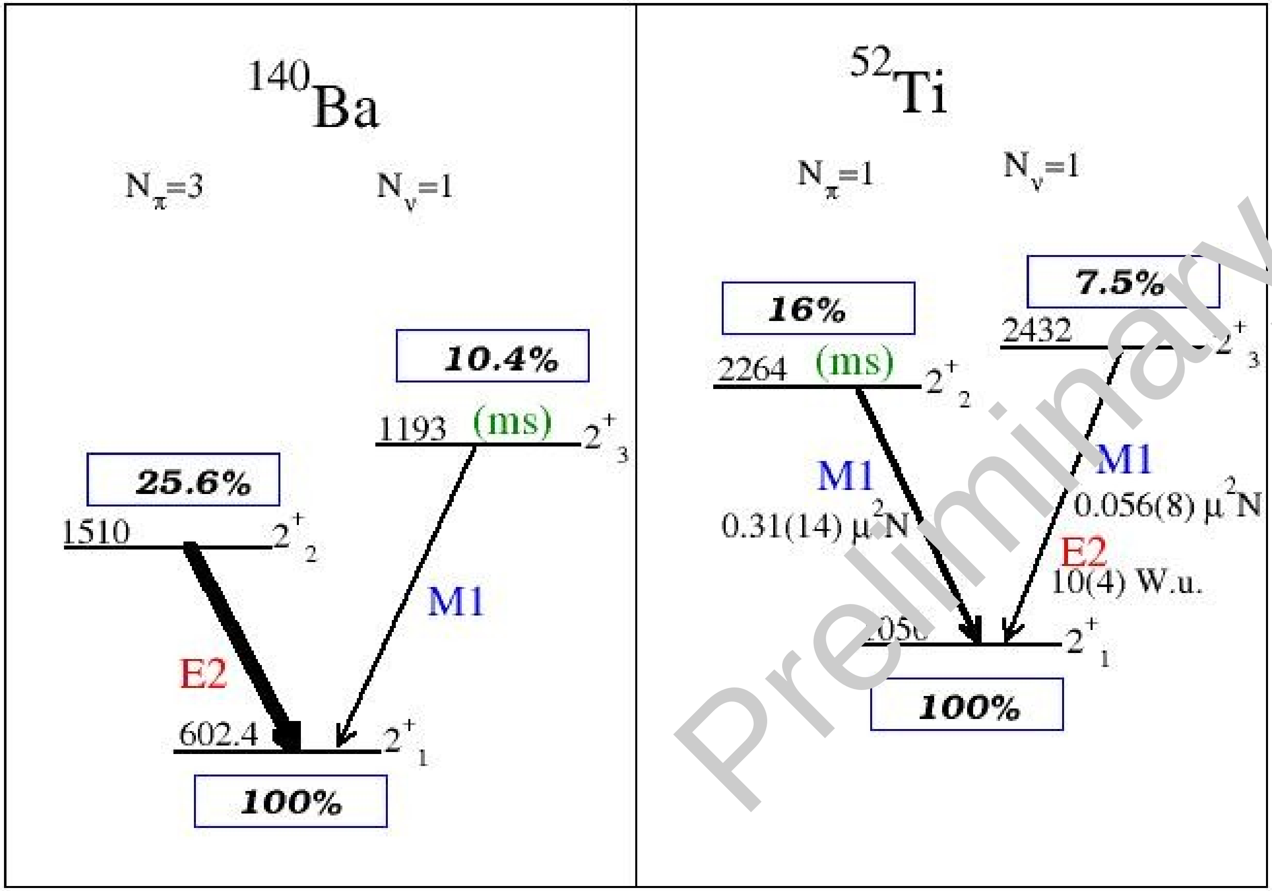

**At Core level: FWHM ~ 30keV at 2023keV Gamma-ray**

**Segment level: Improve FWHM ~ 20keV**

# Forward and backward Spectrum

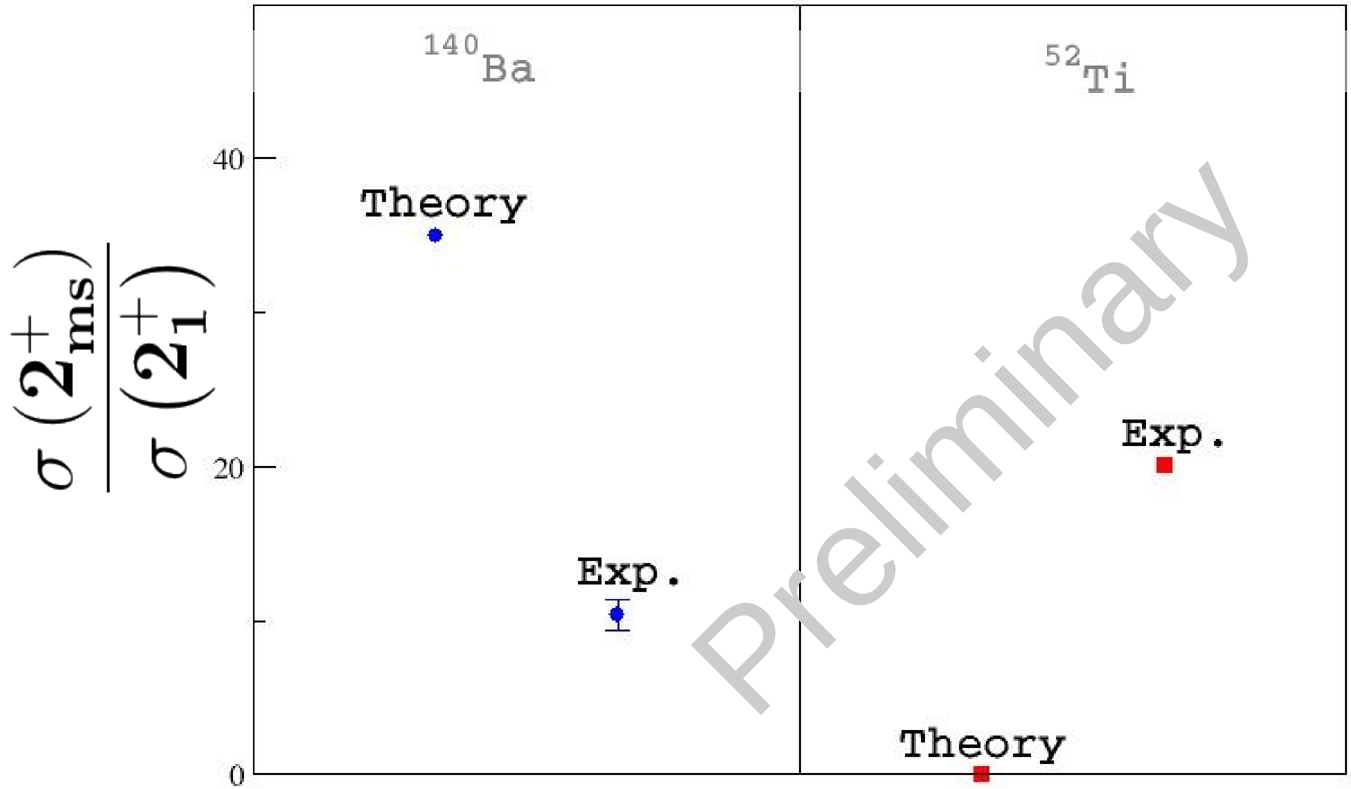


# Relative cross-Section of MS state to $2^+_1$ after alpha transfer




$$\frac{\sigma(2^+_{ms})}{\sigma(2^+_1)} = \frac{(N_\pi - N_\nu)}{2\sqrt{(N_\nu + 1)(N_\pi + 1)}}$$

# Conclusion




- There is unexpected large population of MS state in $^{52}$Ti, even stronger in $^{140}$Ba experimentally.
- Challenging our understanding of MS state and how they are populated in alpha transfer.
- Discrepancy between the theory and our understanding to the MS state.
- Fundamental information can be achieved on the size of valance shell in neutron-rich $^{48}$Ca which may indicate change in shell evolution.

# Thanks to My Collaborator

- Dennis Muecher
- Vinzenz Bildstein
- Maier-Leibnitz-Laboratory in Munich.

**Thanks for your time!**