

Dipole Excitations and Parity Assignments in ^{48}Ca

V. Derya^{1*}, J. Endres¹, M. N. Harakeh^{2,3}, G. Rusev⁴, D. Savran^{5,6},
A. P. Tonchev⁴, H. J. Wörtche², and A. Zilges¹

¹*Institut für Kernphysik, Universität zu Köln, Germany*

²*KVI, Rijksuniversiteit Groningen, The Netherlands*

³*GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany*

⁴*Duke University, Durham, USA*

⁵*ExtreMe Matter Institute EMMI and Research Division, GSI, Darmstadt, Germany*

⁶*Frankfurt Institute for Advanced Studies FIAS, Frankfurt a.M., Germany*

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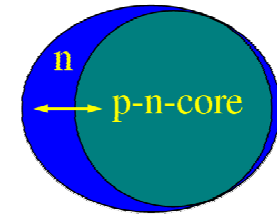
*Member of the Bonn-Cologne Graduate School of Physics and Astronomy

Outline

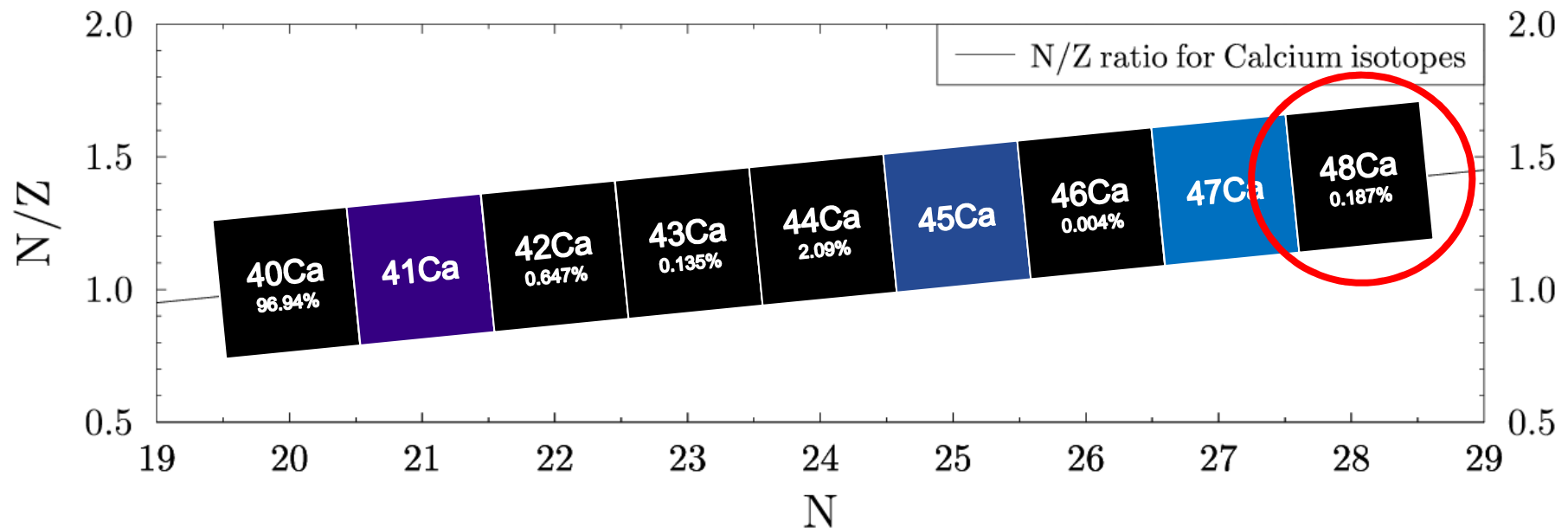
- Motivation
- (γ, γ') at TU Darmstadt
- $(\alpha, \alpha'\gamma)$ at KVI in Groningen
- Parity Measurement at HI γ S
- Summary

Motivation

- Low-lying electric dipole strength below the neutron threshold in ^{48}Ca
 \Leftrightarrow Pygmy Dipole Resonance (PDR)

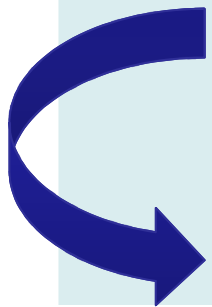


- Dependence on N/Z ratio in the Calcium chain



Probes for Scattering Experiments

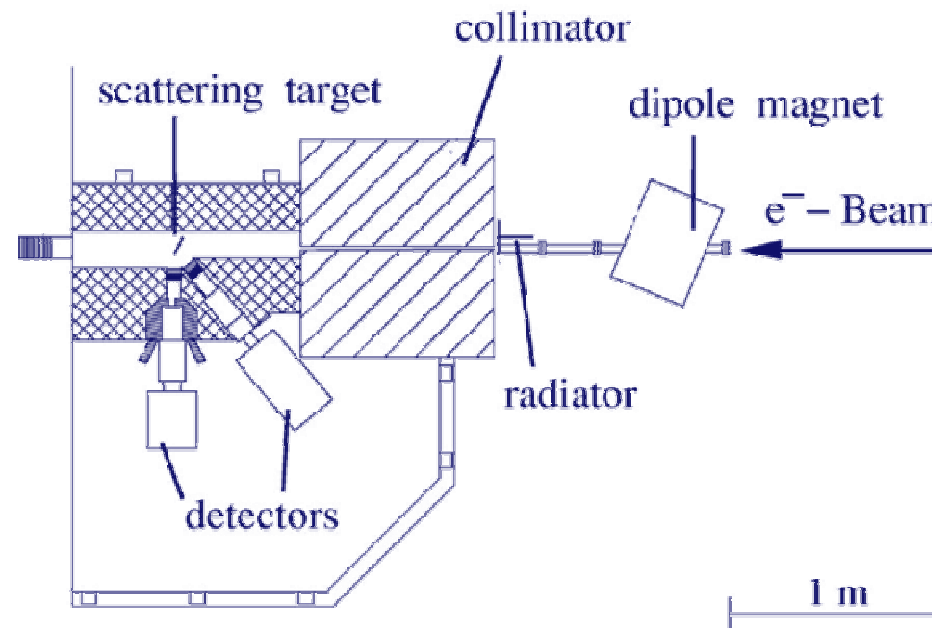
- Photons: electromagnetic interaction
 - Transition energy, spin, transition strength
- α particles: strong interaction (isoscalar) (and electromagnetic)
 - Excitation energy, scattering cross section
- Polarized photons: electromagnetic interaction
 - Parity



Insight into the structure of the (dipole) excitations

(γ, γ') at S-DALINAC

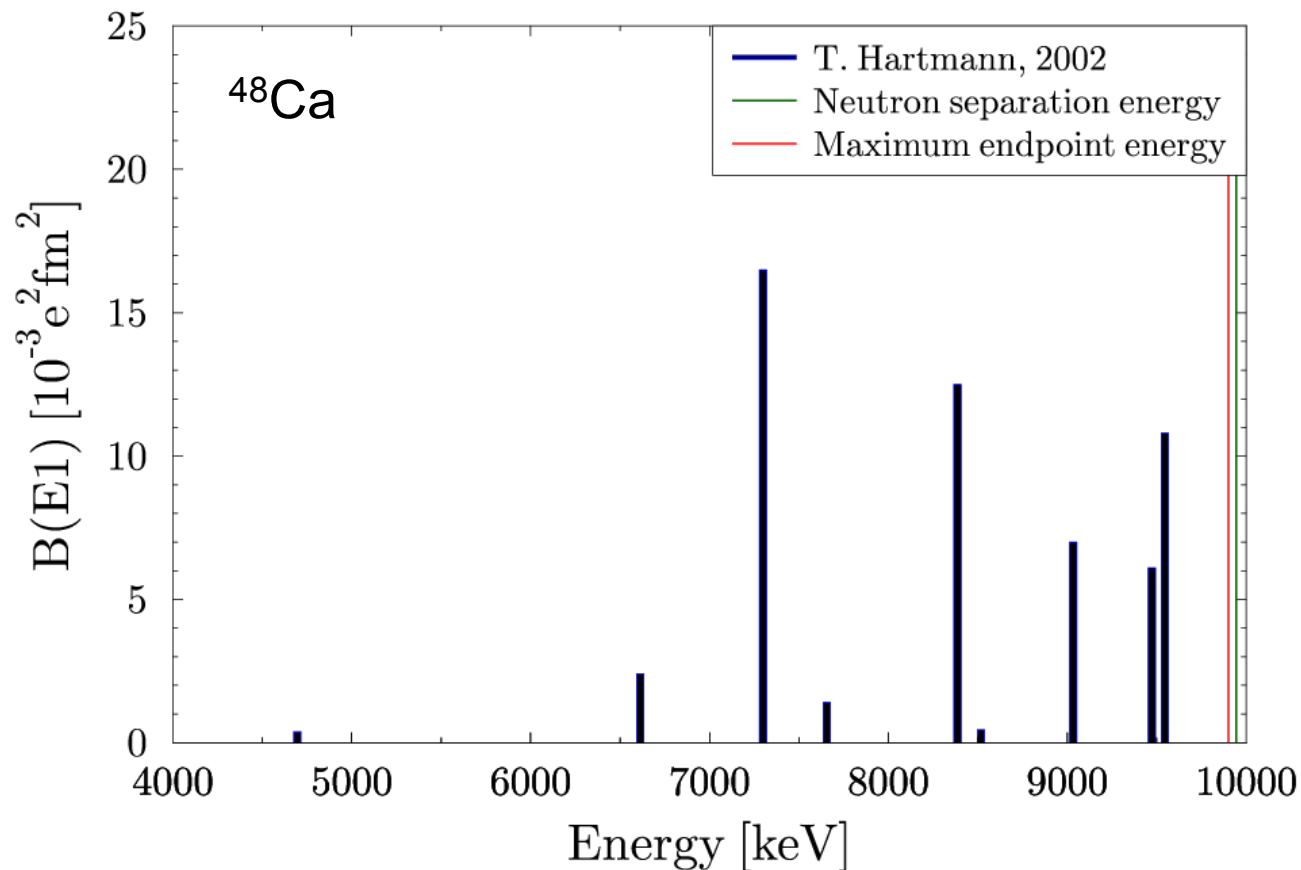
- Real photon scattering
- Bremsstrahlung source: mono-energetic electron beam stopped in a copper target
- Two HPGe detectors at 90° and 130°



T. Hartmann *et al.*, Phys. Rev. C **65** (2002) 034301

B(E1) Strength Distribution

- Exhaustion of the E1 Energy Weighted Sum Rule:
 ^{48}Ca : 0.33(4)%



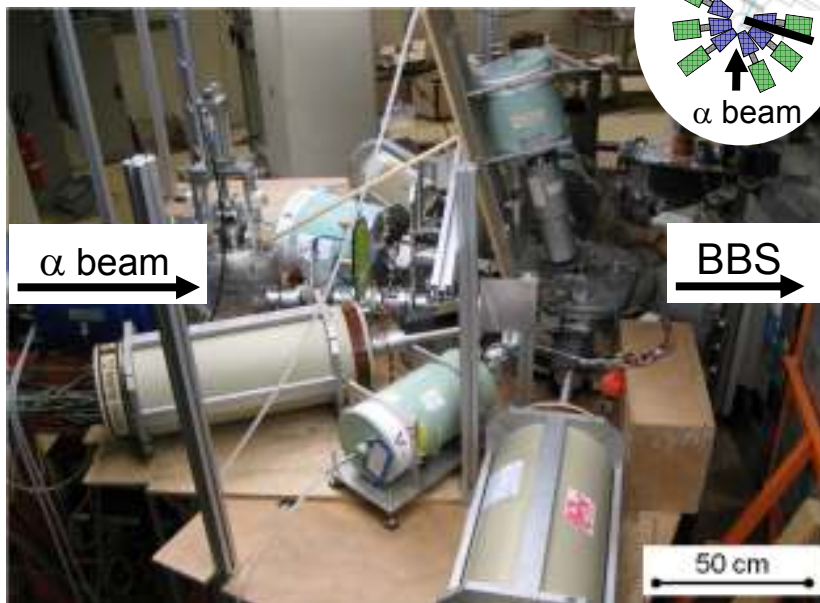
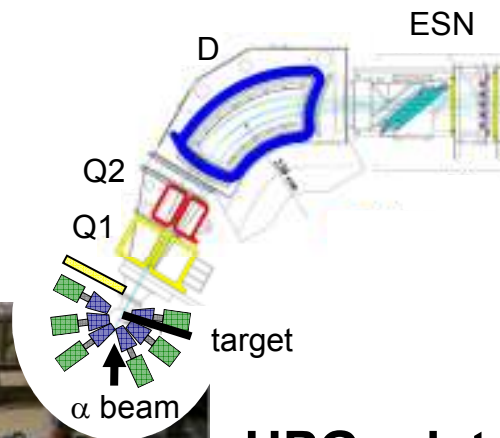
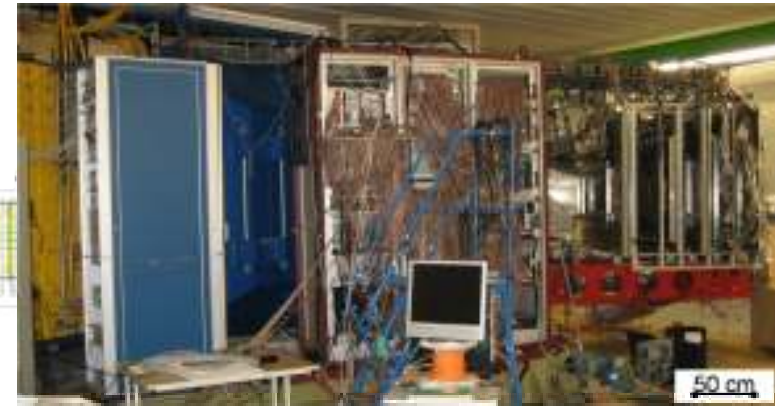
- T. Hartmann *et al.*, Phys. Rev. C **65** (2002) 034301
- T. Hartmann *et al.*, Phys. Rev. Lett. **93** (2004) 192501

$(\alpha, \alpha'\gamma)$ at KVI

- Reaction: ${}^{48}_{20}\text{Ca}_{28}(\alpha, \alpha'\gamma)$
- Beam energy of 136 MeV
 - particle current ≈ 0.4 pA
- Performed at *KVI*
(Groningen, The Netherlands)

Big-Bite Spectrometer @ 5°

- QQD magnet spectrometer



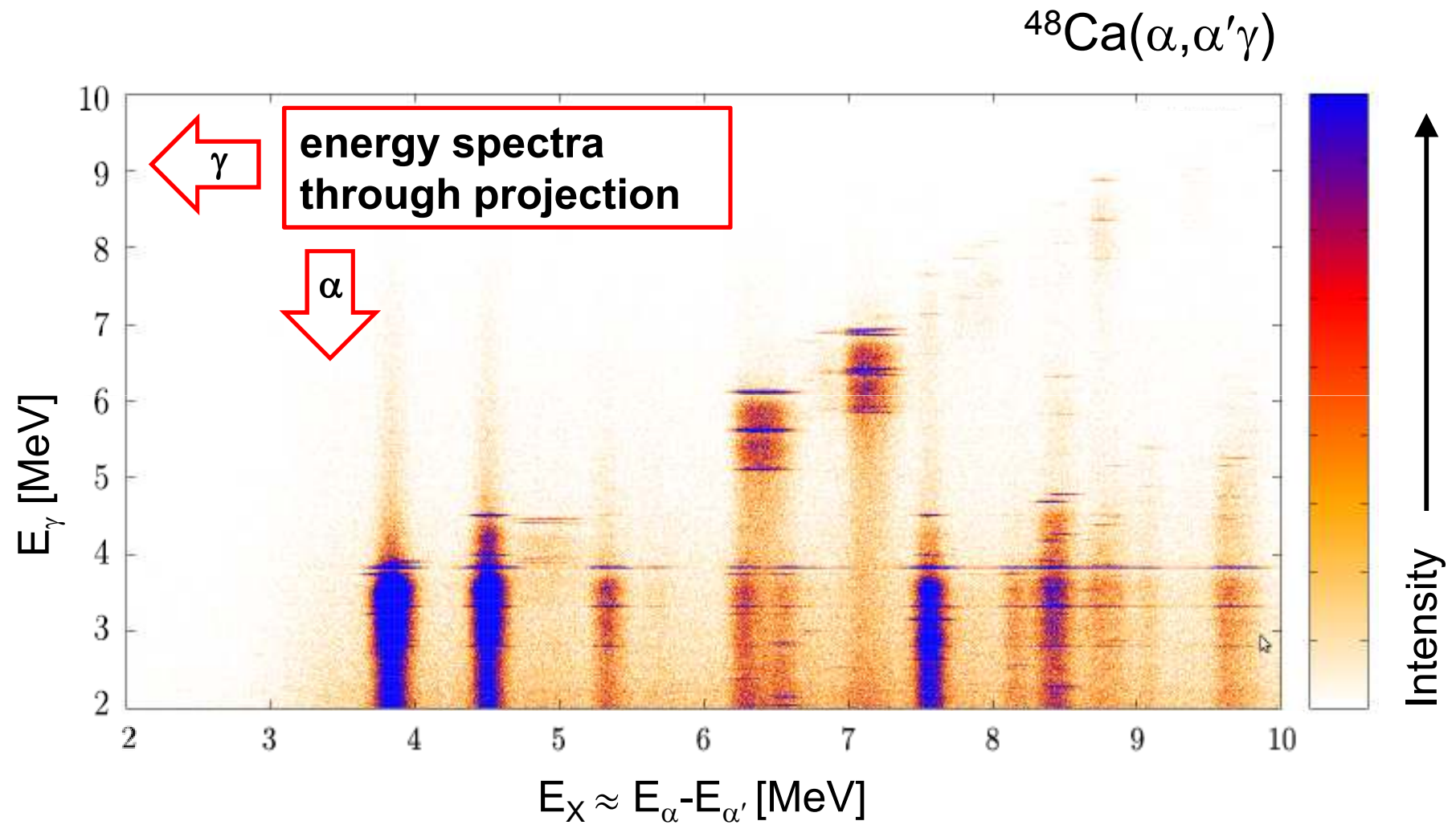
HPGe-detector array for γ spectroscopy

- 6 HPGe detectors

Target

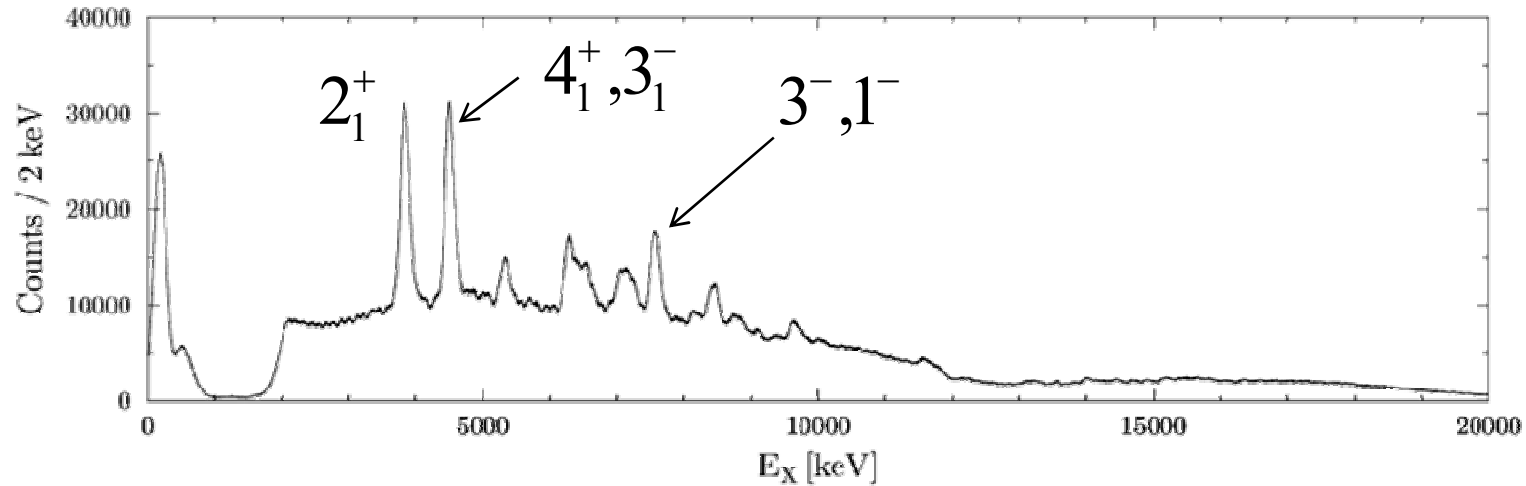
- 1.7 mg/cm²
- 99% enriched in ${}^{48}\text{Ca}$

α - γ coincidence matrix

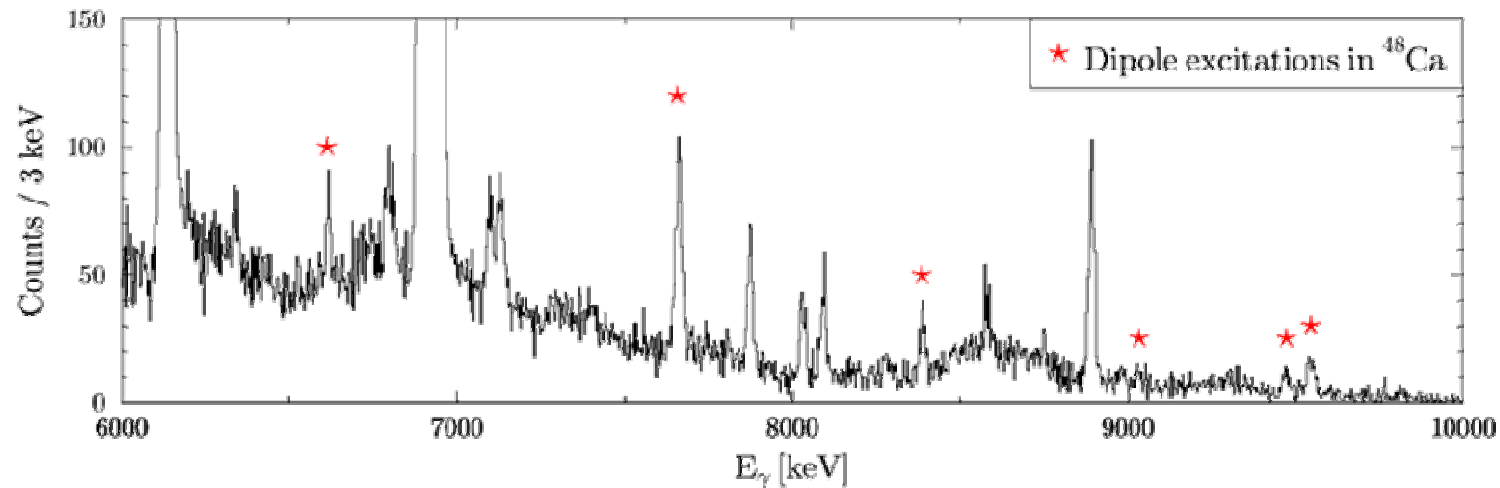


Energy Spectra

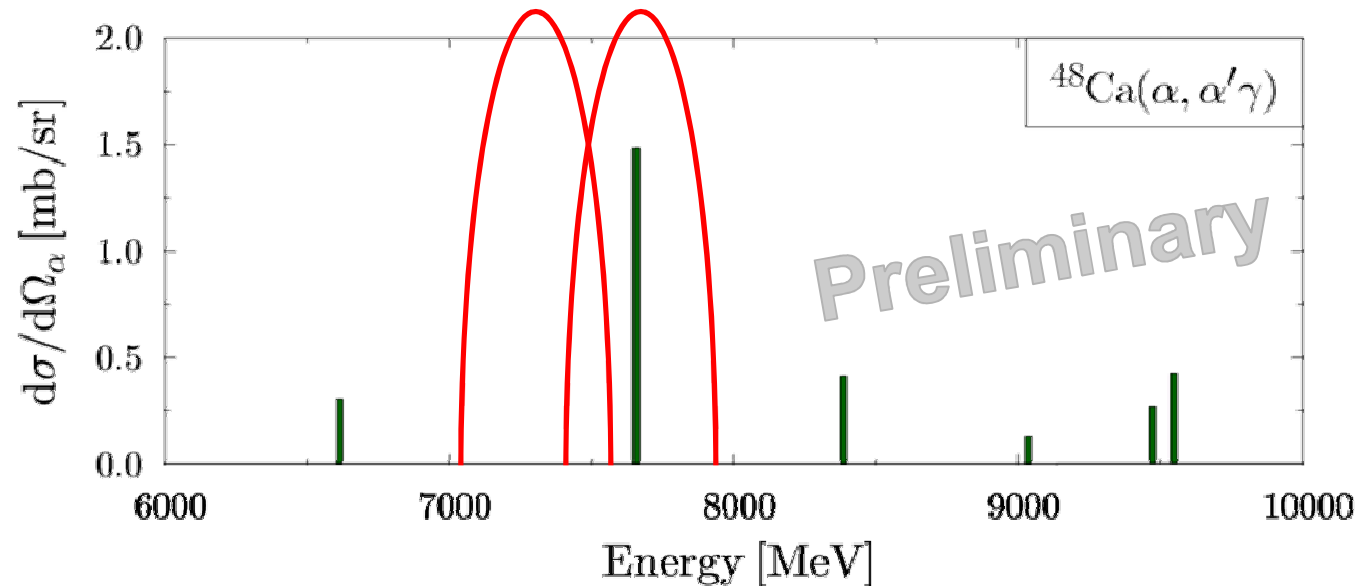
α spectrum



γ spectrum with gate on $E_X \approx E_\gamma$



$(\alpha, \alpha'\gamma)$ and (γ, γ') in ^{48}Ca



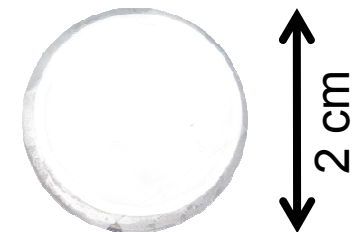
- Strongest state in (γ, γ') at 7.3 MeV is missing in $(\alpha, \alpha'\gamma)$

Parity Measurement at HI γ S



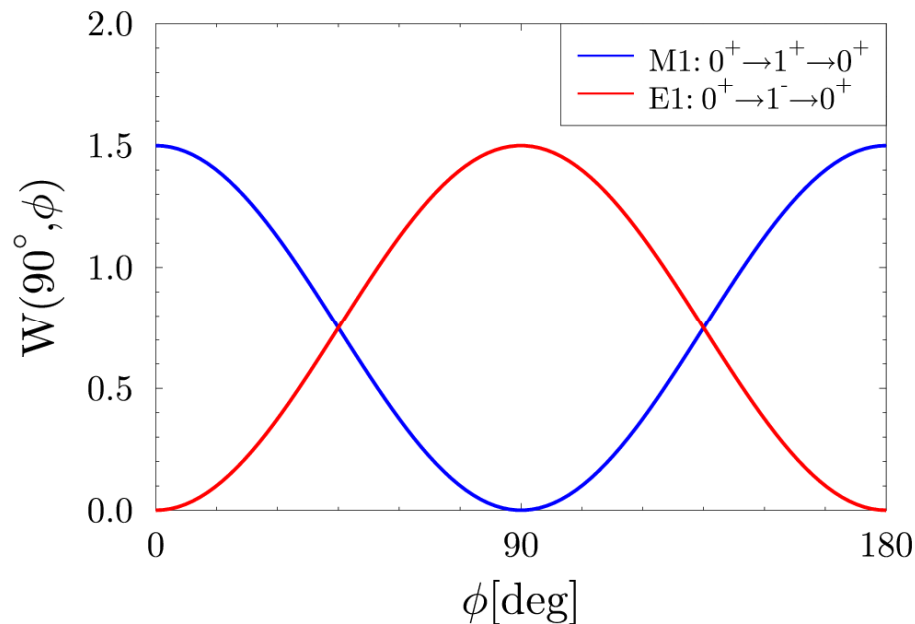
direction of polarization

- High Intensity γ -Ray Source (HI γ S) at the Duke Free Electron Laser Laboratory (DFELL)
- 100% linear polarized and nearly mono-energetic intense γ -ray beam ($I_\gamma \sim 10^7$ photons/sec)
- Six HPGe detectors:
 - One for beam monitoring
 - One at backward angle
 - Four at $\theta = 90^\circ$ in the horizontal and vertical plane
- Target: ^{48}Ca
 - Amount: 1 g



Parity Measurement

- Angular distribution W in the $\theta = 90^\circ$ plane for the azimuthal angle ϕ with respect to the polarization plane



$$\begin{aligned}\varepsilon &= q \frac{W(90^\circ, 0^\circ) - W(90^\circ, 90^\circ)}{W(90^\circ, 0^\circ) + W(90^\circ, 90^\circ)} \\ &= q \begin{cases} +1, & \text{for } J^\pi = 1^+ \\ -1, & \text{for } J^\pi = 1^- \end{cases}\end{aligned}$$

q : experimental sensitivity

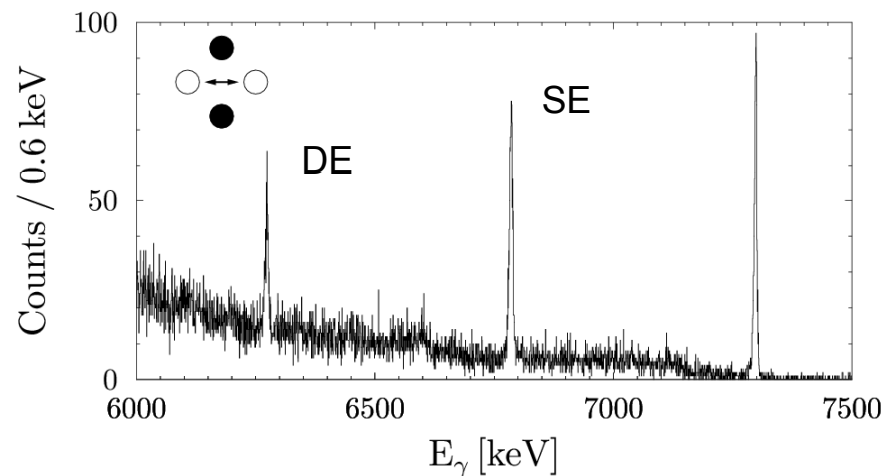
- Experimental asymmetry
 \Rightarrow Parity determination

$$\varepsilon = \frac{I(\parallel) - I(\perp)}{I(\parallel) + I(\perp)}$$

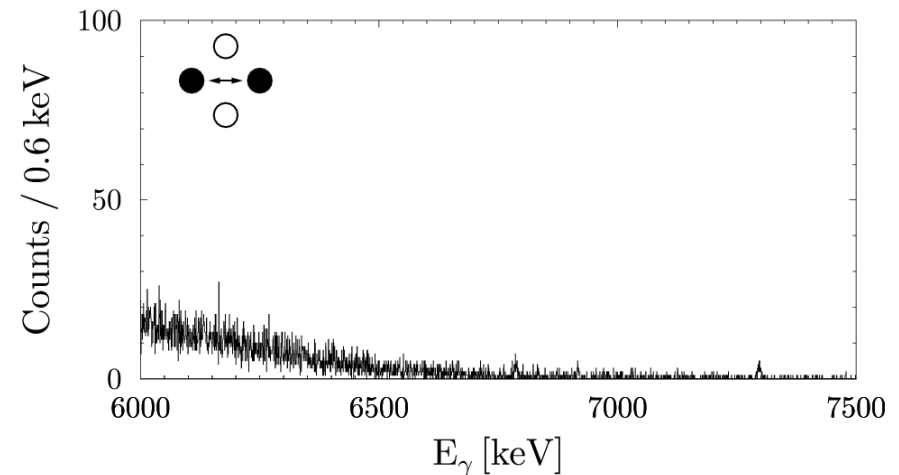
The state at 7.298 MeV

- γ -ray beam energy of 7.3 MeV
- Measured for 1.5 h

γ spectrum of the vertical detectors



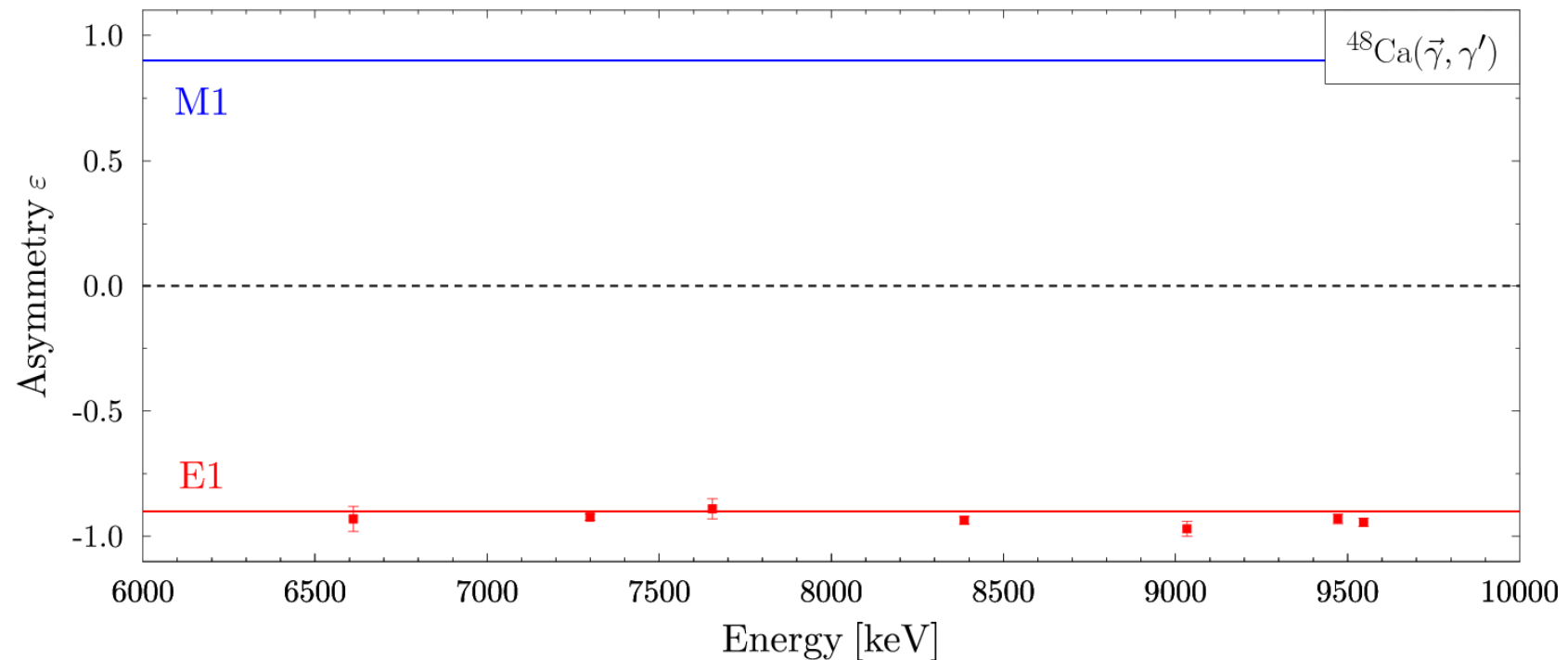
γ spectrum of the horizontal detectors



- Experimental asymmetry: $\varepsilon = -0.923(13)$
- State has negative parity

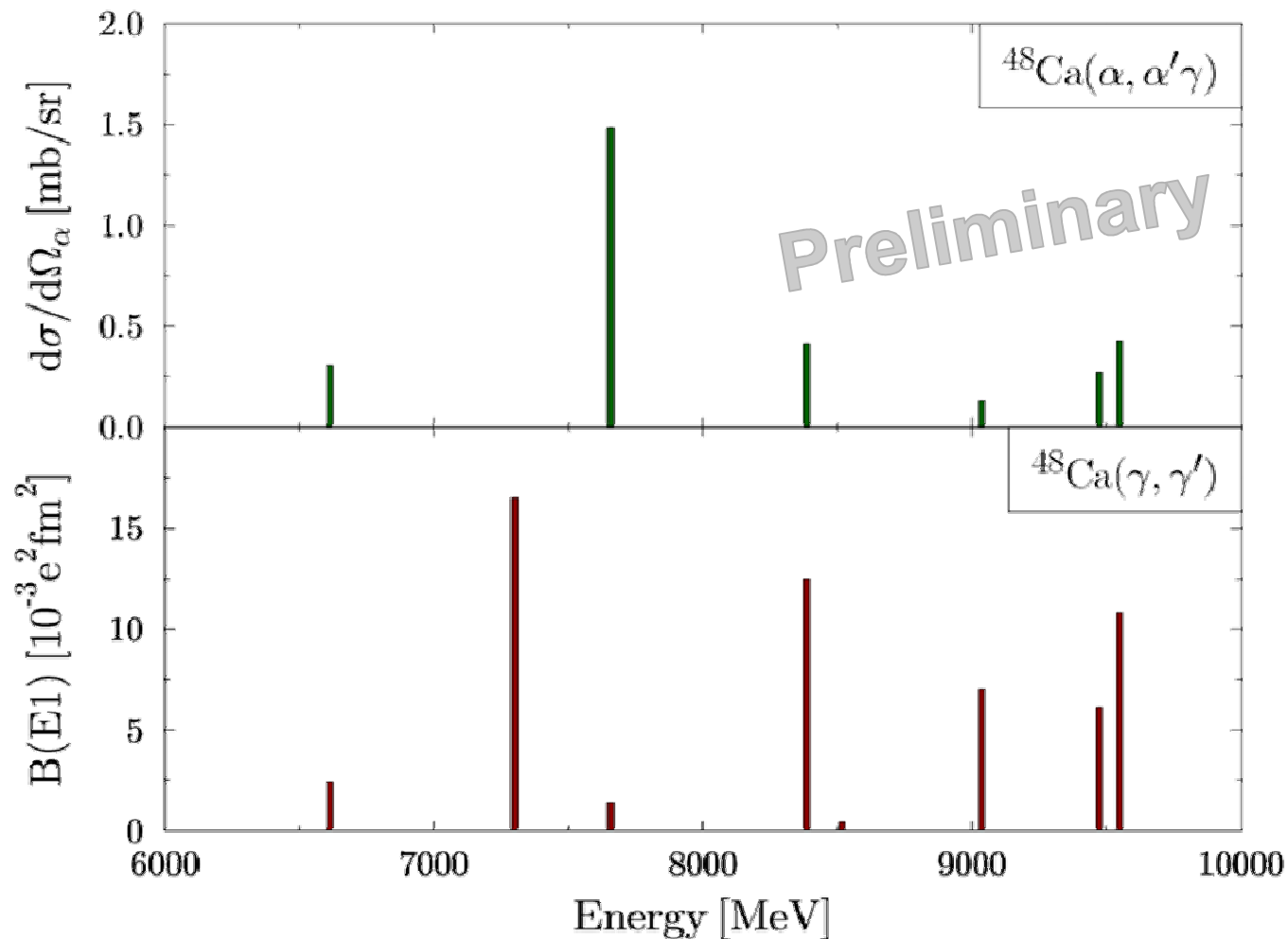
Parity Assignments in ^{48}Ca

- γ -ray beam energies between 6.6 and 9.51 MeV
- 7 dipole excitations were observed



➔ The excited $J=1$ states have **negative** parity

$(\alpha, \alpha'\gamma)$ and (γ, γ') in ^{48}Ca



- Strong structural difference from the neighboring $J^\pi=1^-$ states

Summary

- Dipole excitations in ^{48}Ca have been measured with three different experimental methods
- The three complementary probes were used to get a deeper insight into the structure of the $J=1$ states
- Parity of the state excited by photons but not excited by α particles could be determined as negative
- Parity measurement confirms the assumption of negative parity for all measured $J=1$ states

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