

# Results of the AGATA campaign in Legnaro

## *UPDATE*

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# Outline

LNL  
2010-11



GSI  
2012-14



GANIL  
2015-

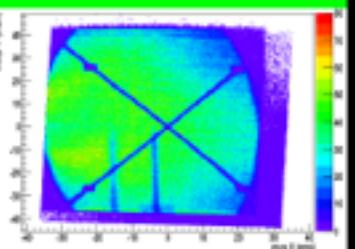
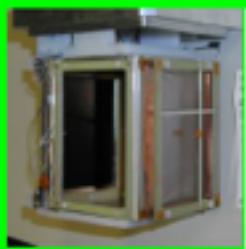


- AGATA demonstration phase
  - Legnaro Demonstration: 2009
  - Physics Campaign: 2010-11
- AGATA construction phase
  - GSI Physics Campaign
  - GANIL Physics Campaign

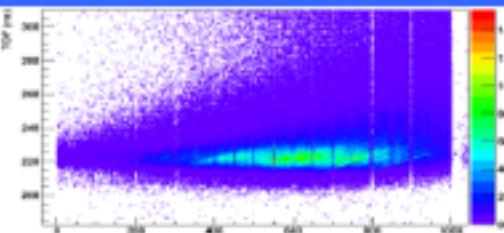


# PRISMA: Tracking Magnetic Spectrometer

MCP Start Det.: X,Y & T<sub>I</sub>



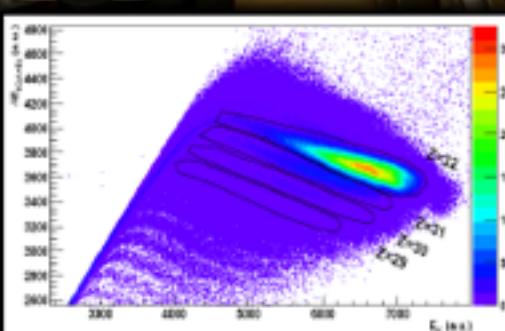
MWPPAC X,Y & T<sub>F</sub>



10 sect.



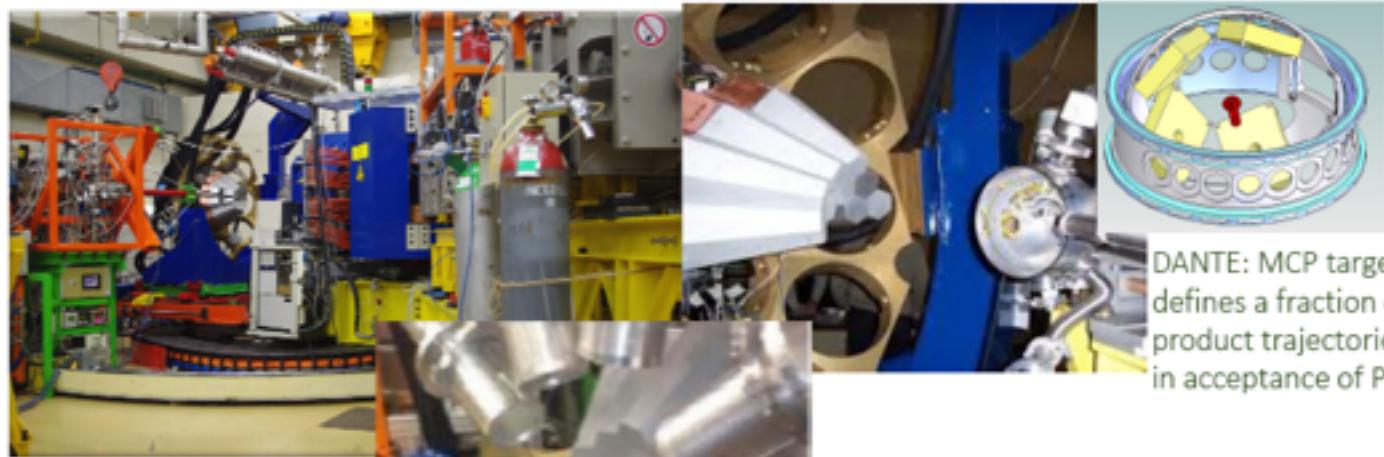
- Large acceptance  $\Omega = 80 \text{ msr}$
- $\Delta Z/Z \approx 1/60$  (Measured) IC
- Energy  $\Delta A/A \approx 1/190$  (Measured)
- Acceptance  $\pm 20\%$
- Max.  $B_p = 1.2 \text{ T.m.}$



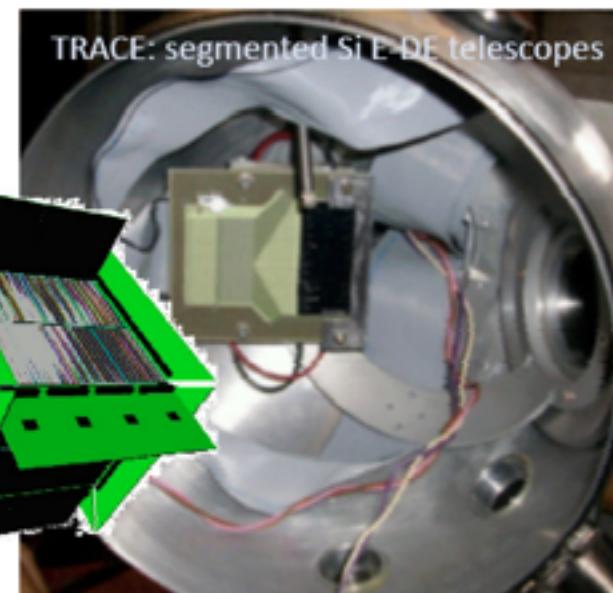
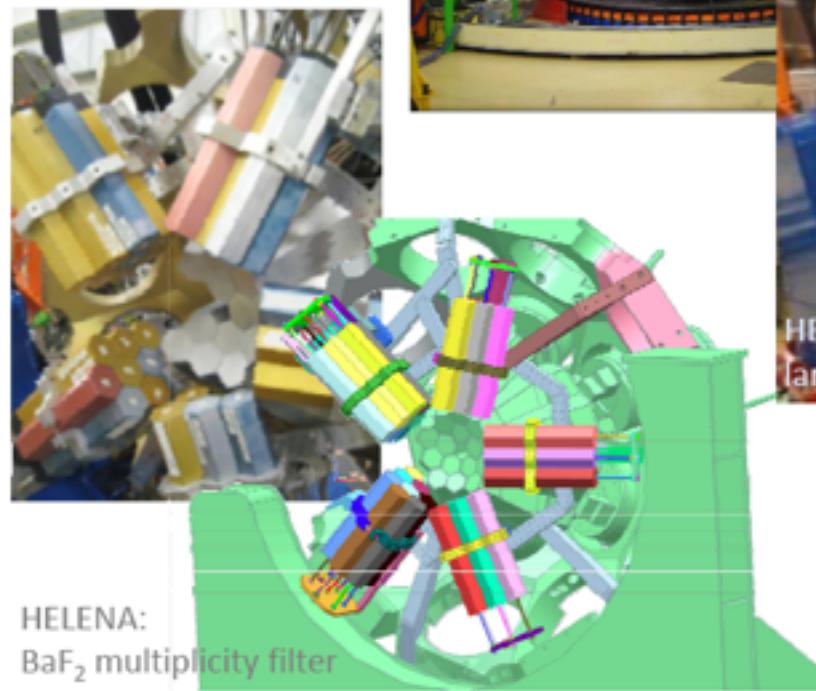
Ionisation Chamber  $\Delta E - E$

# Ancillary Devices

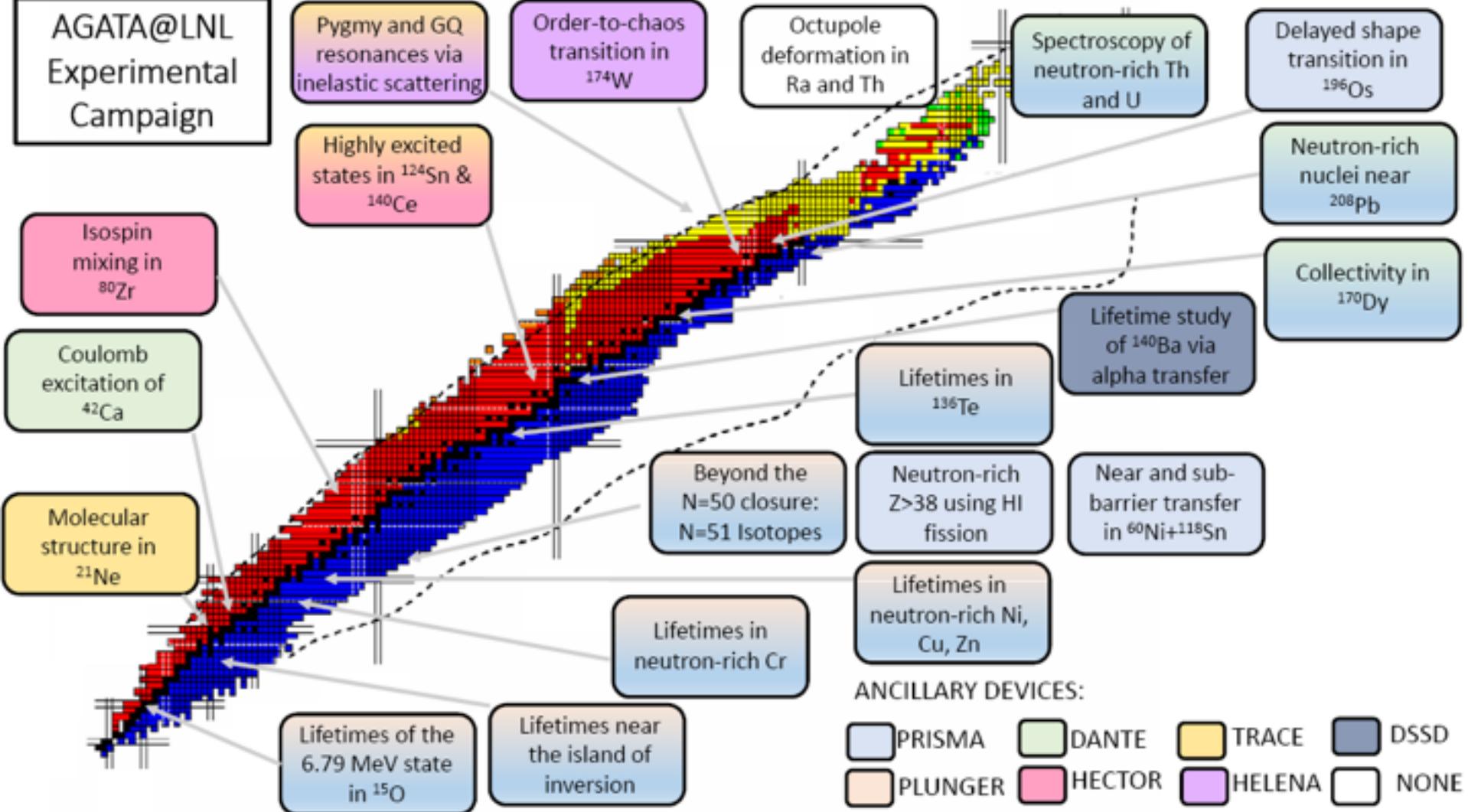
PRISMA: magnetic spectrometer with trajectory reconstruction to identify reaction products



DANTE: MCP target array defines a fraction of product trajectories not in acceptance of PRISMA



# AGATA@LNL Experimental Campaign

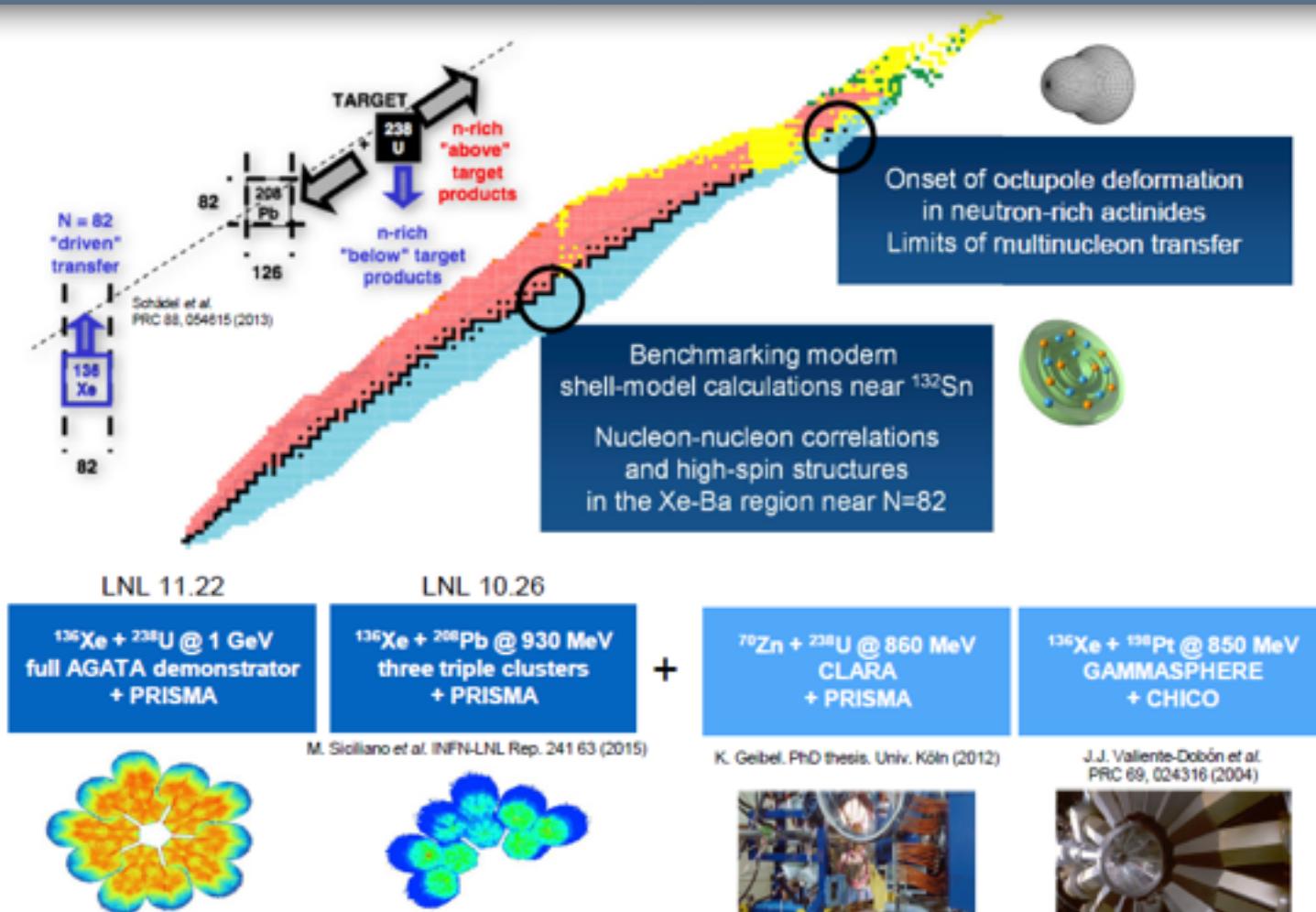


20 approved exp with a total of 142 days (about 3500 hours) appro

F. Recchia, Oct 7<sup>th</sup> 2016

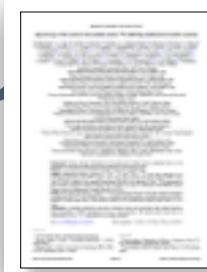
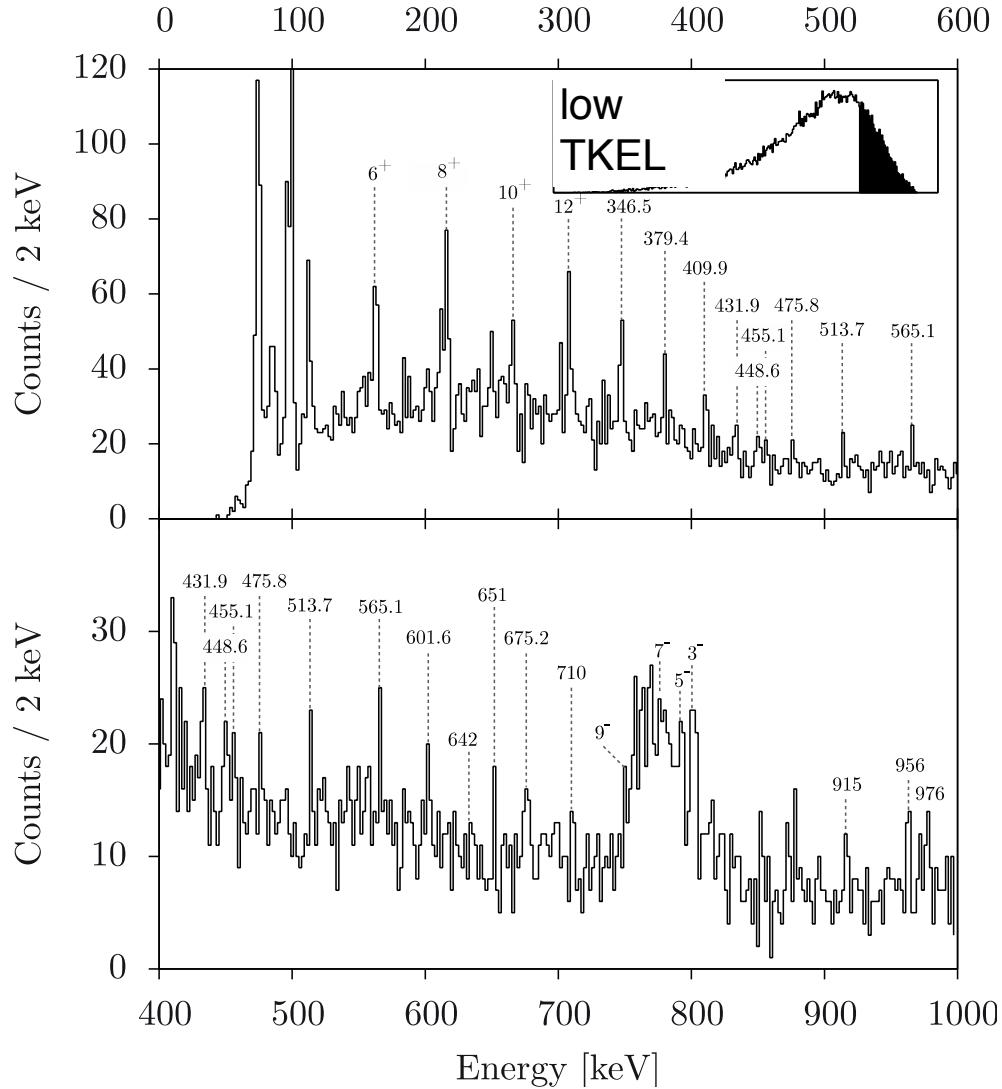
# Spectroscopy of Light and Heavy Transfer Products in Multinucleon-Transfer Reactions

A. Vogt, B. Birkenbach, P. Reiter, M. Siciliano, J.J. Valiente-Dobón,  
C. Wheldon, L. Corradi, S. Szilner, T. Mijatovic *et al.*



# Spectroscopy of $^{240}\text{U}$

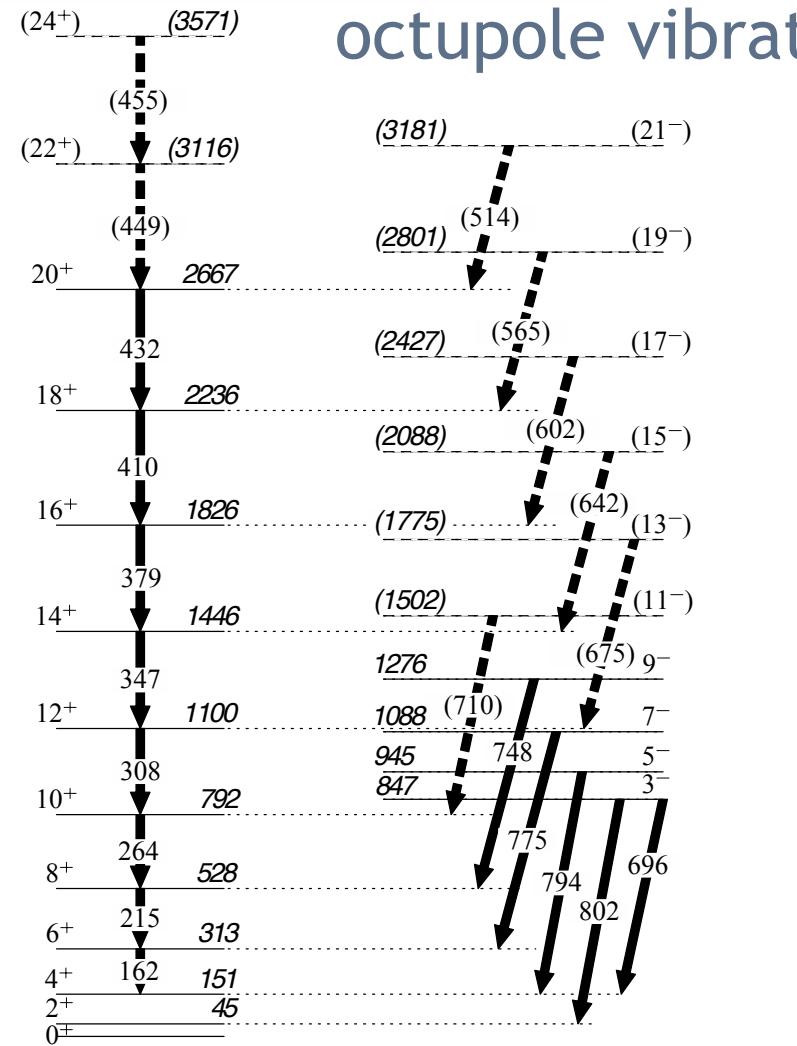
U 234  $2.46 \times 10^6 \text{ a}$  U 235  $7.04 \times 10^6 \text{ a}$  U 236  $24.10 \text{ d}$  U 237  $6.75 \text{ d}$  U 238  $4.47 \times 10^6 \text{ a}$  U 239  $23.5 \text{ min}$  U 240  $14.1 \text{ h}$  U 242  $16.8 \text{ min}$



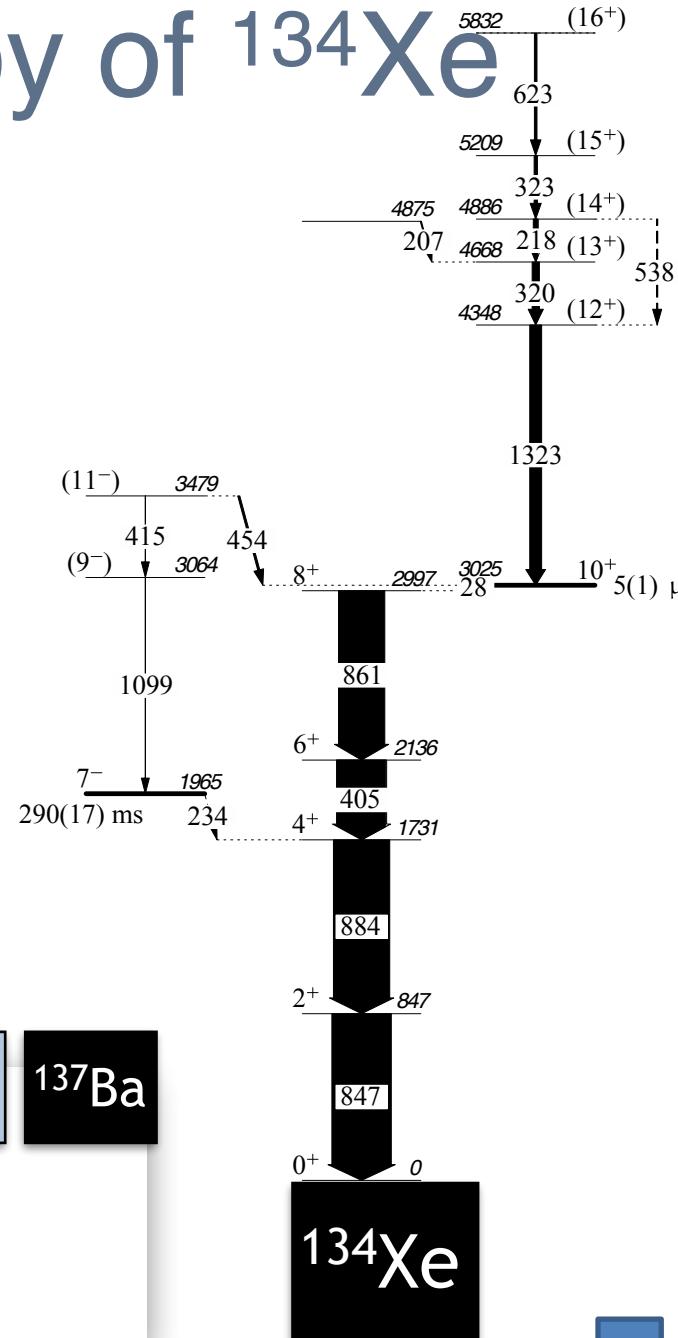
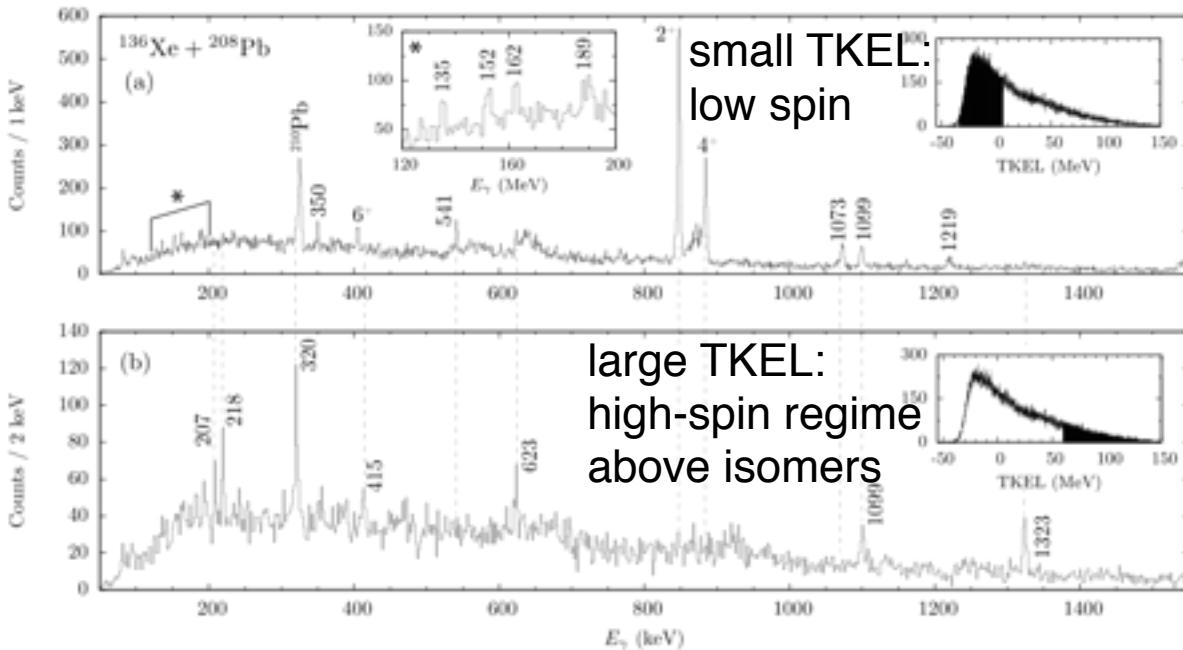
PHYSICAL REVIEW C™

B. Birkenbach *et al.*  
PRC 92, 044319

(2015)  
High-spin structure of  
 $^{134}\text{Xe}$



# High-Spin Spectroscopy of $^{134}\text{Xe}$



- Previously no information on structure beyond the  $7^-$  and  $10^+$  states
- Constrain excitation energies via Total Kinetic Energy Loss (TKEL)



A. Vogt *et al.*  
 PRC 93, 054325  
 (2016)  
 High-spin structure of  
 $^{134}\text{Xe}$

PHYSICAL REVIEW C™

Current work:  
 High-spin structure of  
 $^{135}\text{Xe}$  and  $^{137}\text{Ba}$   
 To be submitted to  
 PRC

$^{135}\text{Xe}$

$^{137}\text{Ba}$

$^{134}\text{Xe}$

# LNL experiment 09.08 (Oct 2011)

## Coulomb-Excitation of $^{136}\text{Xe}$ and $\alpha$ -transfer to $^{140}\text{Ba}$

(C. Stahl, J. Leske, D. Bazacco, E. Farnea, A. Gadea, A. Gottardo, P. R. John, C. Michelagnoli, N. Pietralla, M. Reese, J. J. Valiente-Dobon et al.)

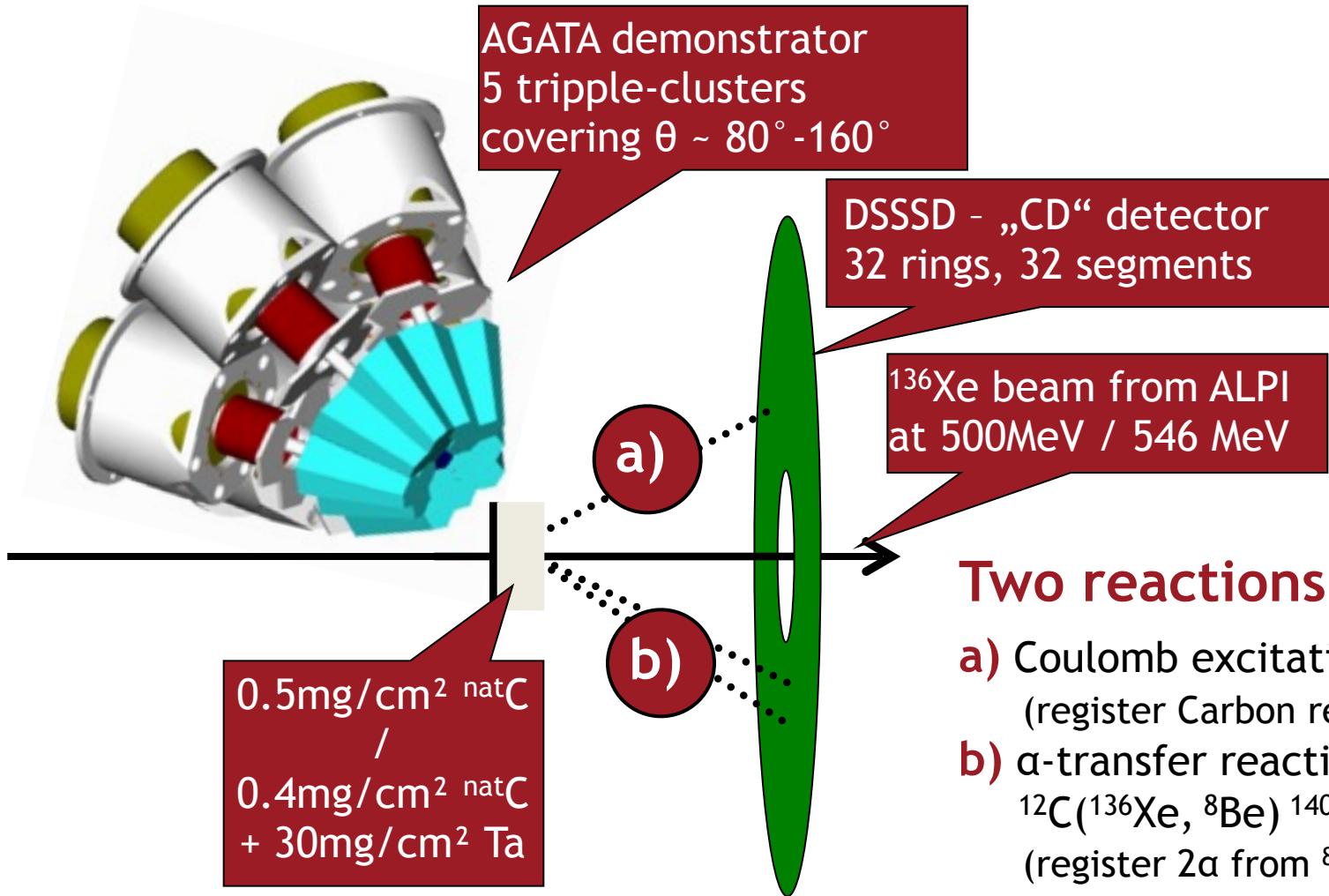
### Motivations for the experiment:

- Population of the  $2_{1,\text{ms}}^+$  Mixed-Symmetry State (MSS) in  $^{140}\text{Ba}$ 
  - $\alpha$ -transfer intensity: New experimental signature for MSSs?  
(C. E. Alonso et al., PRC 78 (2008) 017301)
- Benchmark the continuous-angle Doppler-Shift Attenuation Method (caDSAM)
  - test case  $^{136}\text{Xe}$ , take advantage of AGATAs position resolution  
(C. Stahl, PhD thesis, TU Darmstadt, 2015)

Supported under grants  
05P09RDFN4 & 05P12RDFN8



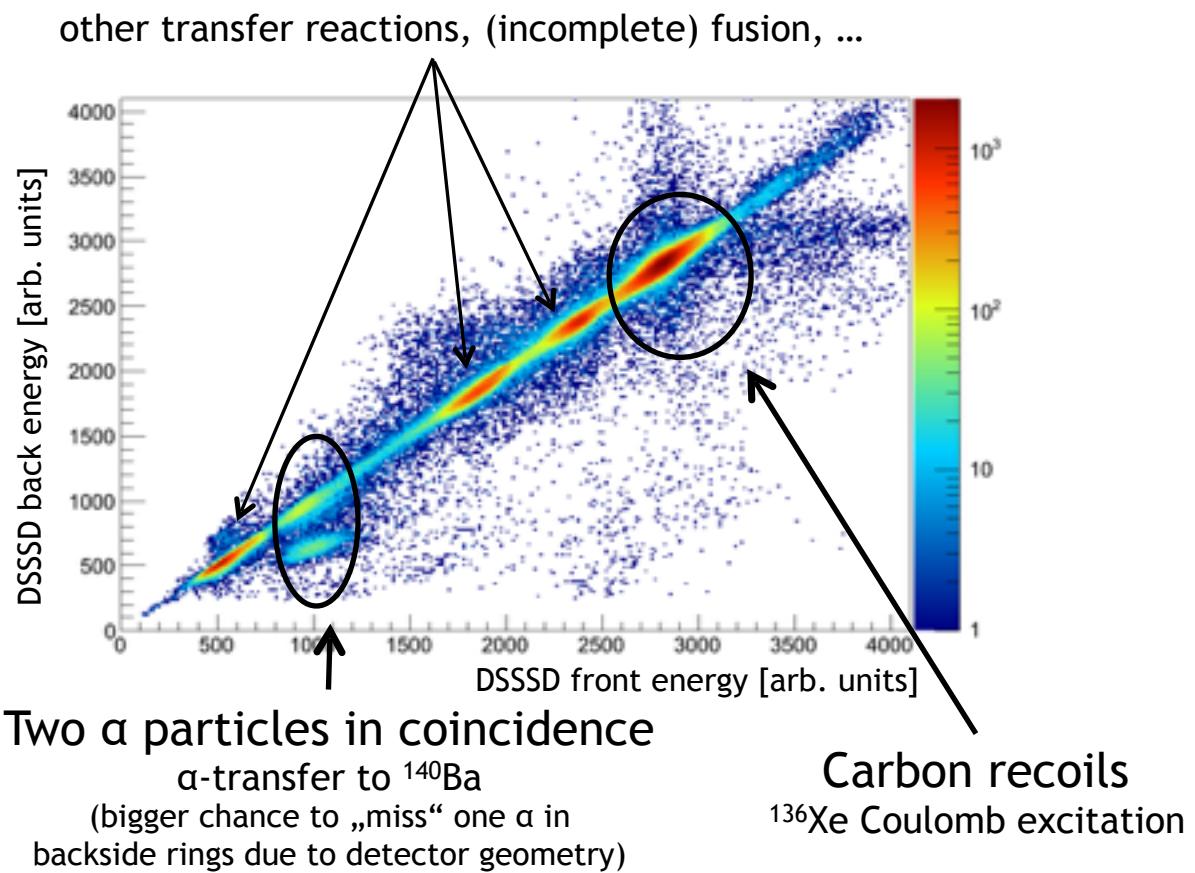
# LNL experiment 09.08 (Oct 2011)



# LNL experiment 09.08 (Oct 2011)

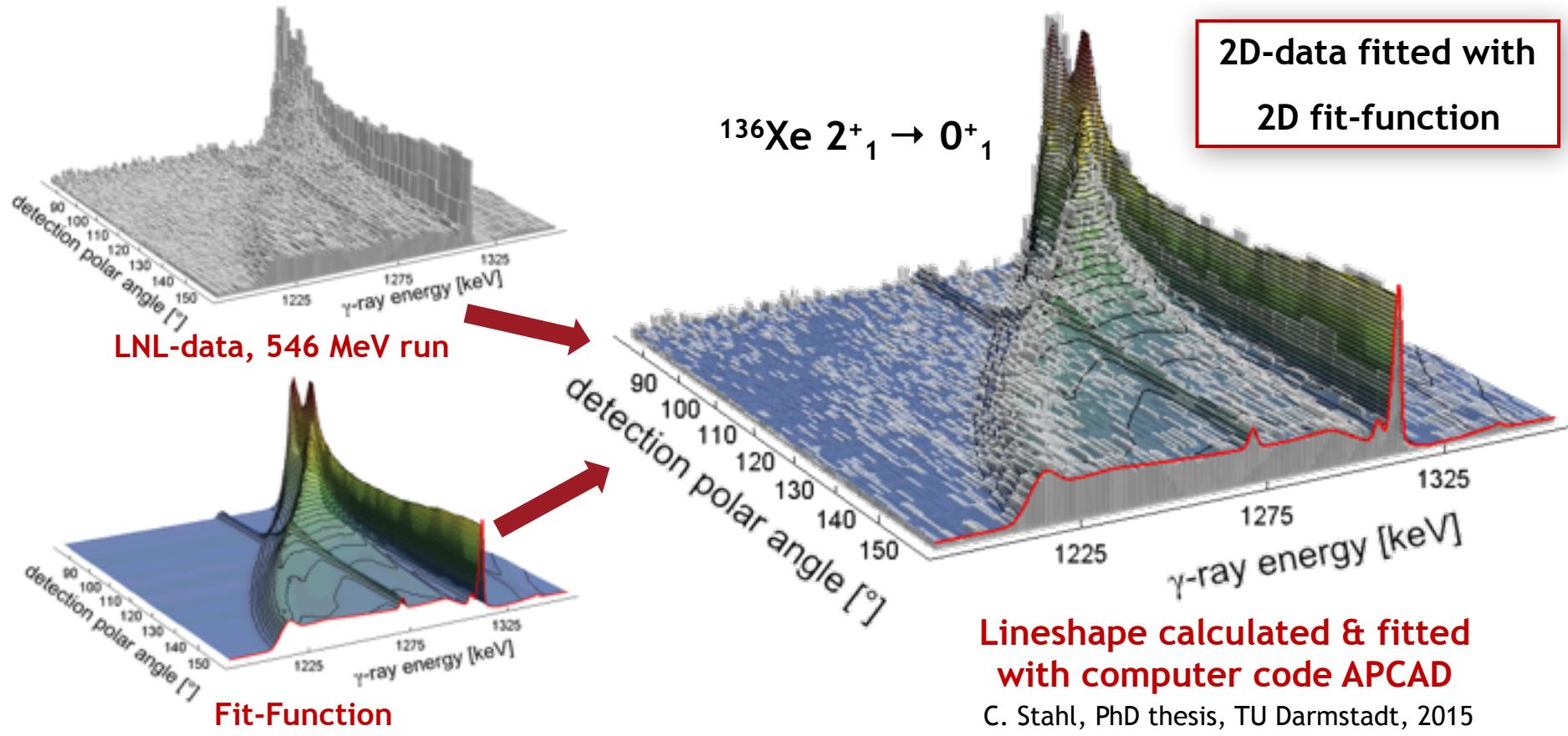
## Reaction identification from DSSSD spectra

Fig:  
546 MeV beam energy,  
DSAM - target,  
inner DSSSD-ring



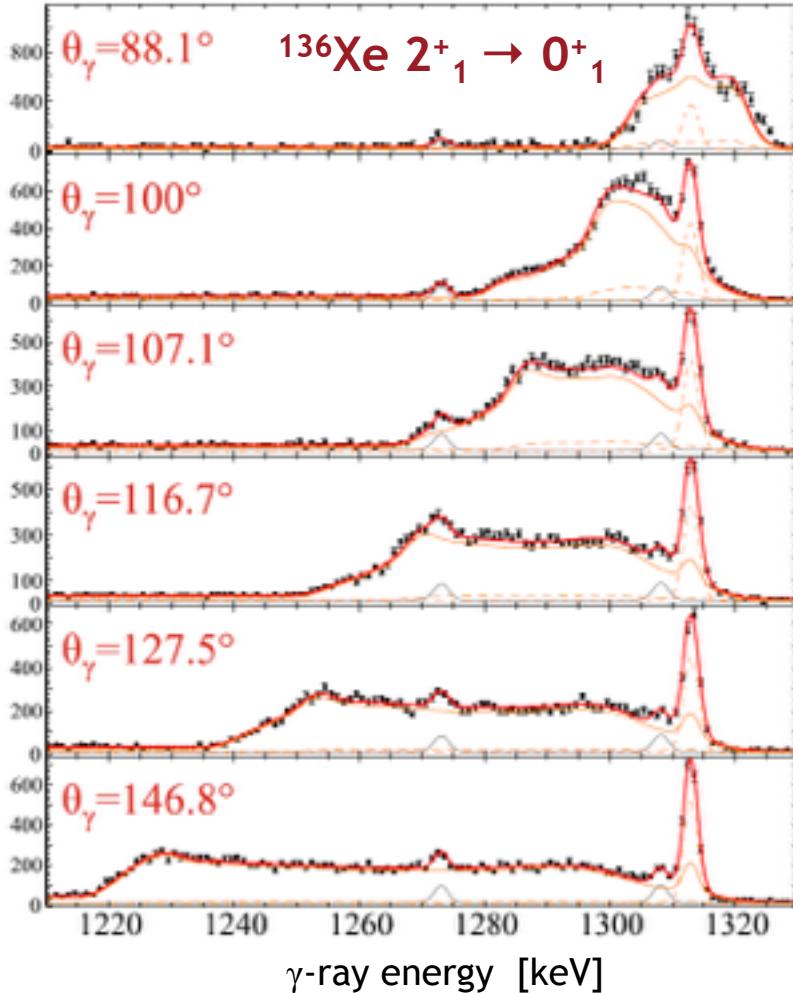
# caDSAM lifetime measurement in $^{136}\text{Xe}$

Beautiful data for test of the continuous angle DSA method!



# caDSAM lifetime measurement in $^{136}\text{Xe}$

Counts per keV



6 out of 35  
simultaneously  
fitted angular bins

$$\tau_{2_1^+} = 524.3^{+2.2}_{-1.4} \text{(stat)}^{+26.6}_{-23.1} \text{(sys)} \text{ fs}$$

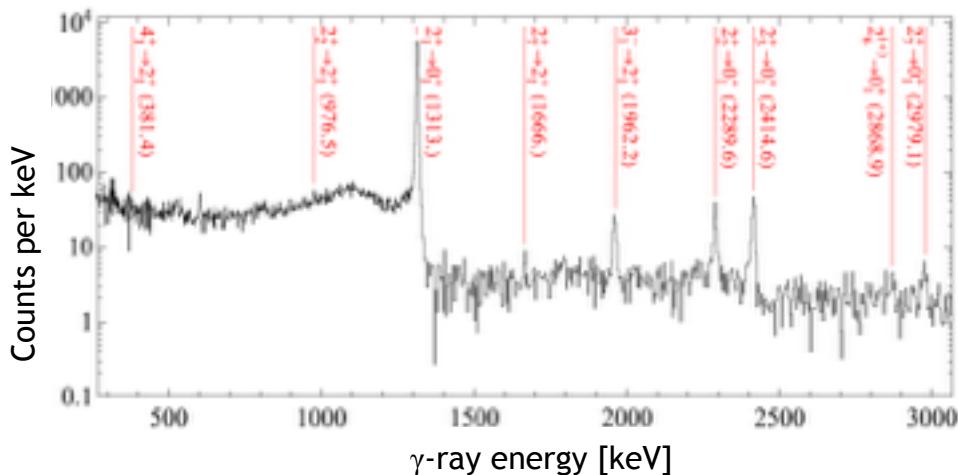
ENSDF: 519 (20) fs

$$\tau_{3_1^-} = 43.8 \pm 1.6 \text{(stat)}^{+1.7}_{-1.8} \text{(sys)} \text{ fs}$$

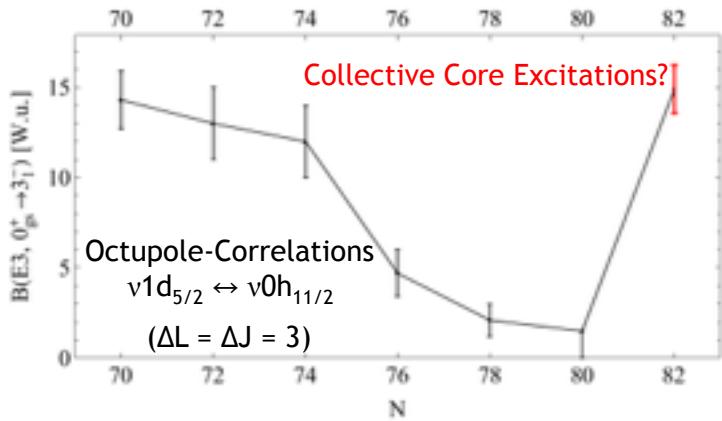
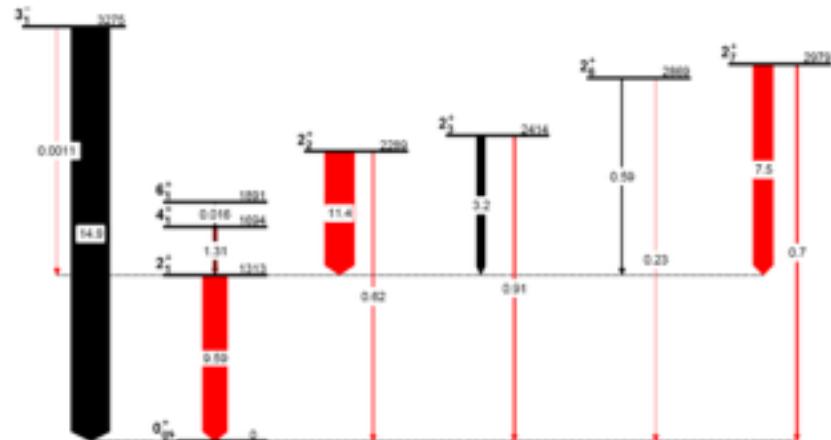
ENSDF: unbekannt

Systematic errors: Stopping-Power, (Feeding)

# Coulomb-Excitation of $^{136}\text{Xe}$



„Safe Coulex“ data: 500 MeV beam energy, scattering angle cut

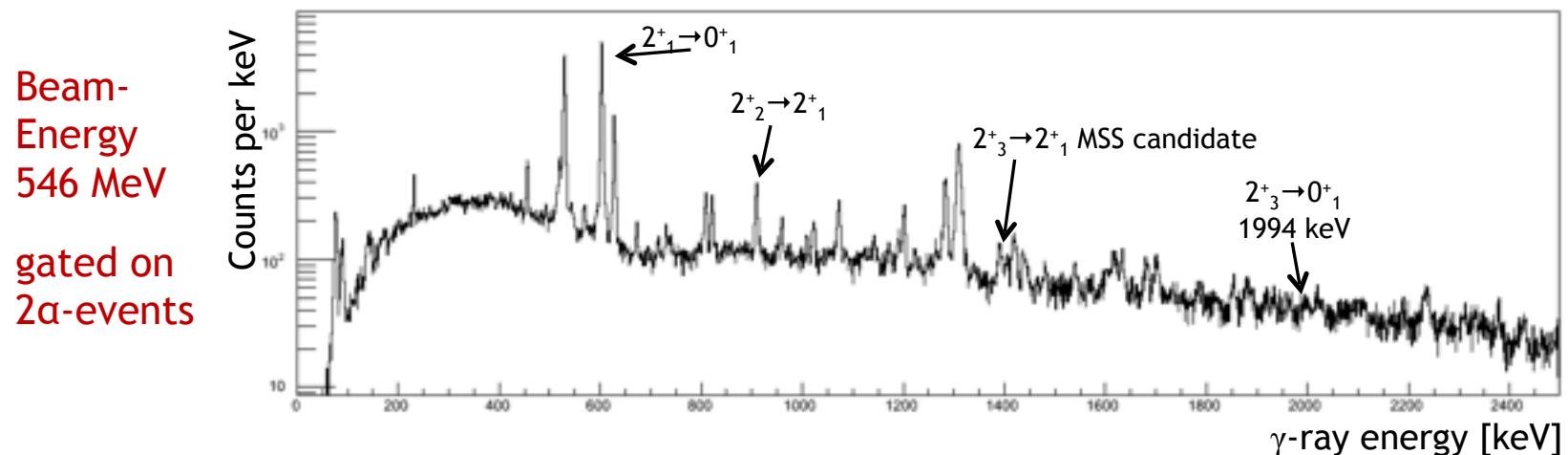


Observed sudden „Jump“ of  $B(E3)$  strengths in Xe isotopes at N=82  
 Competition between single-particle and collective structures?

124-134Xe: Mueller *et al.*, PRC 73, 014316 (2006)

# $\alpha$ -transfer to $^{140}\text{Ba}$

Can the  $\alpha$ -transfer population cross-section serve as a unique signature for Mixed-Symmetry States (MSS)?

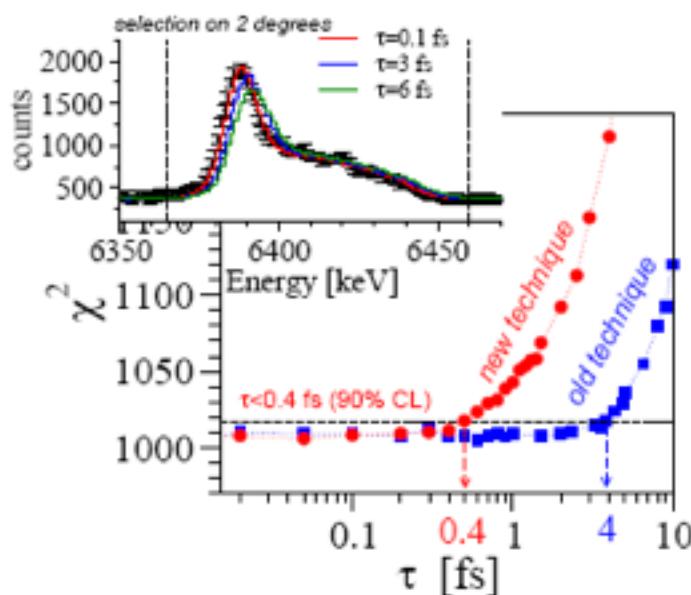
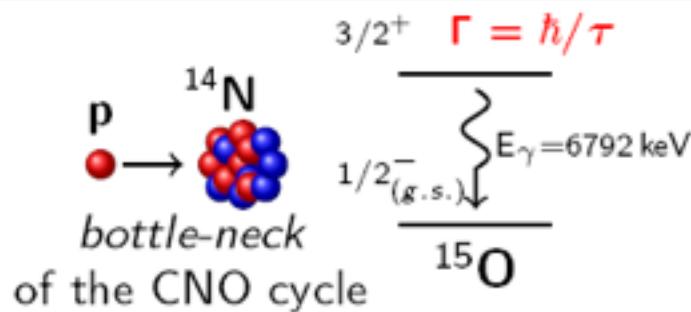


Answer: NO.

Predicted: MSS has 1/3 of population of  $2^+_1$   
(C. E. Alonso *et al.*, PRC 78 (2008) 017301)

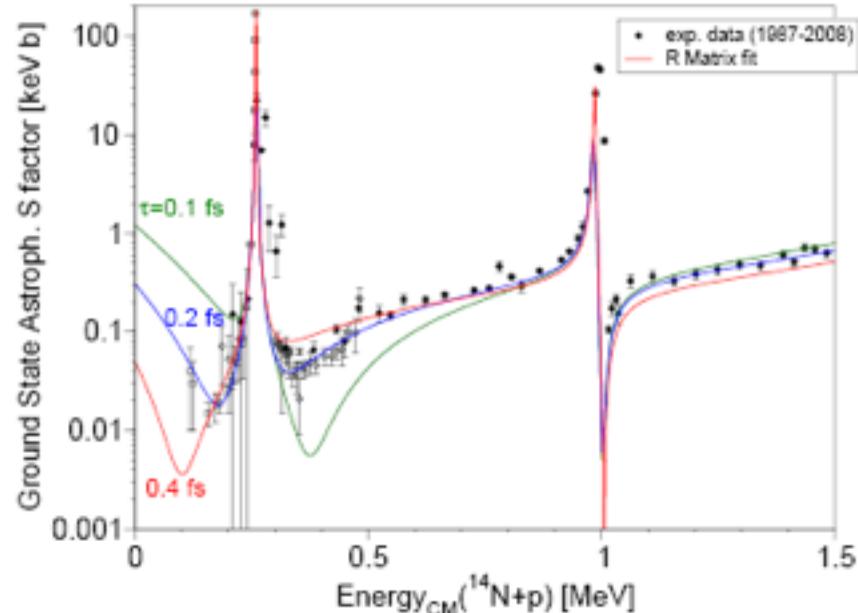
Observed: MSS has 10.4(10)% of  $2^+_1$  population BUT  $2^+_2$  has 25.6(19)%...  
(C. Stahl *et al.*, PRC 92, (2015) 044324)

# H-burning in stars: new constraint for the CNO rate via a pioneering sub-femtosecond lifetime measurement



Determination of  $\tau$  via  
lineshape analysis over a  
**continuous angular distribution**

$\Gamma$  dominates  $\sigma(p + ^{14}\text{N})$  at stellar energies  
E.G. Adelberger et al., RMP83 (2011) 195



**First firm lower limit on  $S_{GS}(0)$**

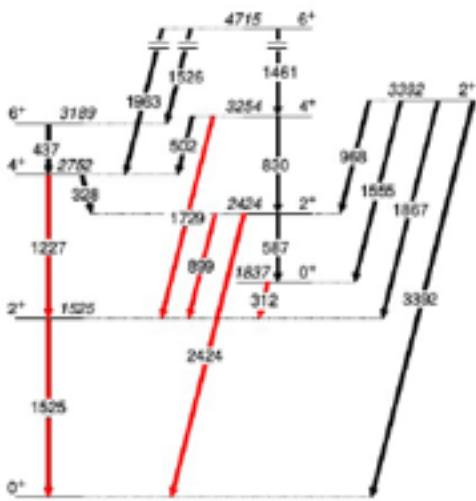
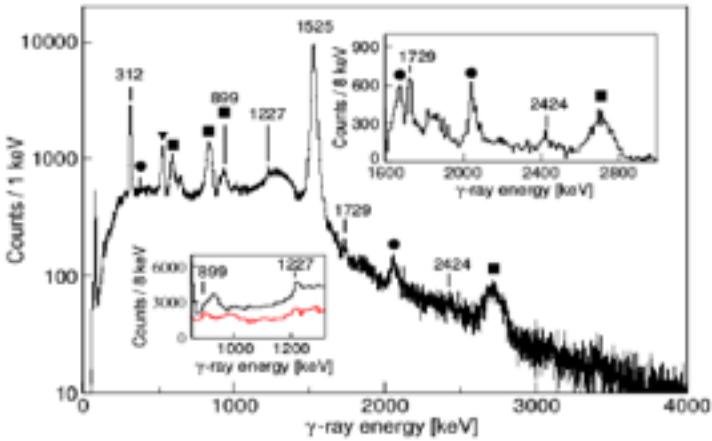
CM, PhD Thesis, 2013; CM et al., submitted to PLB

Impact on: Solar composition problem,  
Evolution of massive stars,  
Age of globular clusters

C. Michelagnoli et al.

# Coulomb excitation of $^{42}\text{Ca}$

- Beam:  $^{42}\text{Ca}$ , 170 MeV
- Targets:
  - $^{208}\text{Pb}$ , 1 mg/cm<sup>2</sup>
  - $^{197}\text{Au}$ , 1 mg/cm<sup>2</sup>
- AGATA: 3 triple clusters
- DANTE: 3 MCP detectors, 100-144°



- 0<sup>+</sup>, 2<sup>+</sup> and 4<sup>+</sup> states in GSB and SDB
- the quadrupole deformation parameters of the 0<sup>+</sup> and 2<sup>+</sup>
- the results were compared with SM and BMF calculations
- spherical GS shape
- $\beta=0.43(2)$  and  $\beta=0.45(2)$ , for 0<sub>2<sup>+</sup></sub> and 2<sub>2<sup>+</sup></sub> - SD character
- non-axial character of SD bands in the A ~ 40 mass region

# *Many other interesting publications*

- *Population of the 2<sub>+</sub> mixed symmetry state of  $^{140}\text{Ba}$  with the  $\alpha$ -transfer reaction*  
Stahl et al., PRC 92, 044324 (2015)
- *High-spin structure in  $^{40}\text{K}$*   
Söderström et al., PRC 86, 054320 (2012)
- *Global properties of K hindrance probed by the  $\gamma$  decay of the warm rotating  $^{174}\text{W}$  nucleus*  
Vandone et al., PRC 88, 034312 (2013)
- *Lifetime measurements in neutron-rich  $^{63,65}\text{Co}$  isotopes using the AGATA demonstrator*  
Modamio et al., PRC 88, 044326 (2013)
- *Transition probabilities in neutron-rich  $^{84,86}\text{Se}$*   
Litzinger et al., PRC 92, 064322 (2015)
- *Pair neutron transfer in  $^{60}\text{Ni} + ^{116}\text{Sn}$  probed via  $\gamma$ -particle coincidences*  
Montanari et al., PRC 93, 054623 (2016)
- *Pygmy dipole resonance in Ce 140 via inelastic scattering of  $^{17}\text{O}$*   
Krzysiek, M et al PRC 93 (2016)044330

*Several publications are currently under review...*



# Concluding remarks:

- Importance of a range of ancillary detectors for stable beams operations.
- Productive in publications - but it takes some time on a new device.
- AGATA: A successful European collaboration