PRESPEC-AGATA at GSI

J. Gerl

GSI Darmstadt, Germany

presented at

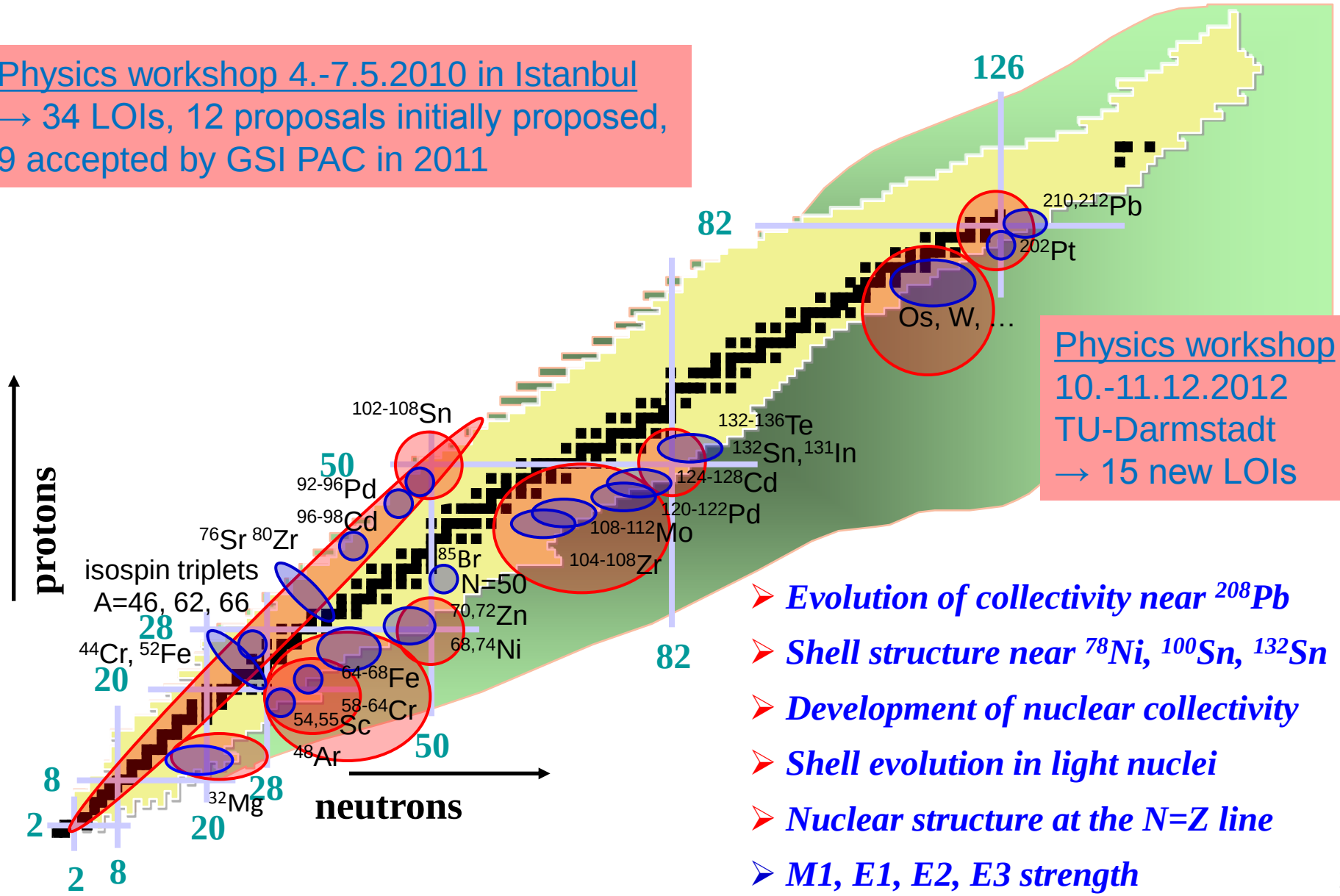
AGATA Week

September 11, 2018

Strasbourg, France

PRESPEC-AGATA Physics Campaign 2012-2014

Physics workshop 4.-7.5.2010 in Istanbul
→ 34 LOIs, 12 proposals initially proposed,
9 accepted by GSI PAC in 2011



Physics workshop
10.-11.12.2012
TU-Darmstadt
→ 15 new LOIs

- ***Evolution of collectivity near ^{208}Pb***
- ***Shell structure near ^{78}Ni, ^{100}Sn, ^{132}Sn***
- ***Development of nuclear collectivity***
- ***Shell evolution in light nuclei***
- ***Nuclear structure at the N=Z line***
- ***M1, E1, E2, E3 strength***

Status proposals and runs of 2012 and 2014

S424: Korten/Gerl

Performance commissioning (PRESPEC-AGATA)


S429: Rudolph / Podolyák / Gerl

Quadrantic evolution of collectivity around ^{208}Pb

S430: Wieland / Gorská

Pygmy Dipole Resonance in ^{64}Fe and the properties of neutron skin


S426: Pietralla / Rainovski / Gerl

Relativistic *M*1-Coulomb excitation of ^{85}Br

S433: Gadea / Gorská

Coulomb excitation of the band-terminating 12^+ yrast trap in ^{52}Fe

S428: Pietri

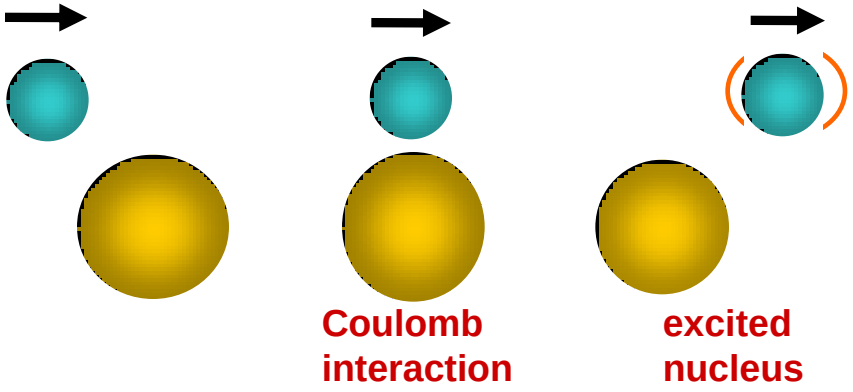
Shape evolution in neutron-rich Zr


S434: Recchia / Bentley

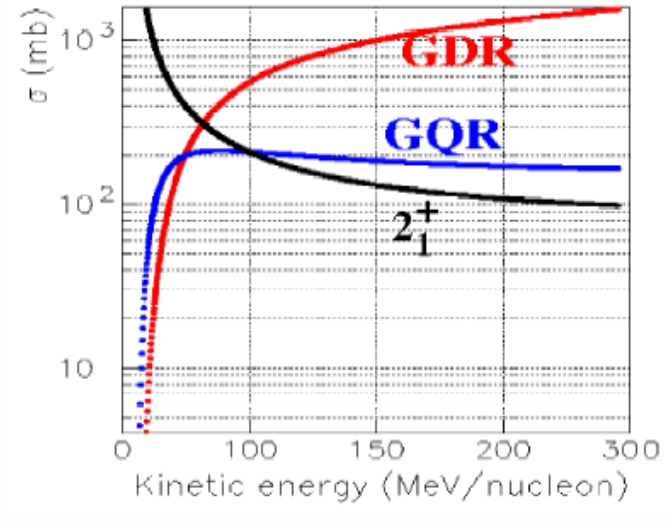
Transition rates and mirror energy differences in isobaric multiplets

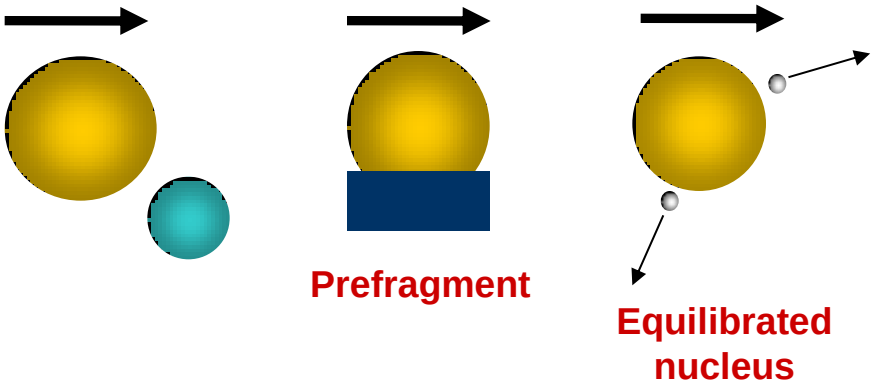
Analysis	Conferences	Publications

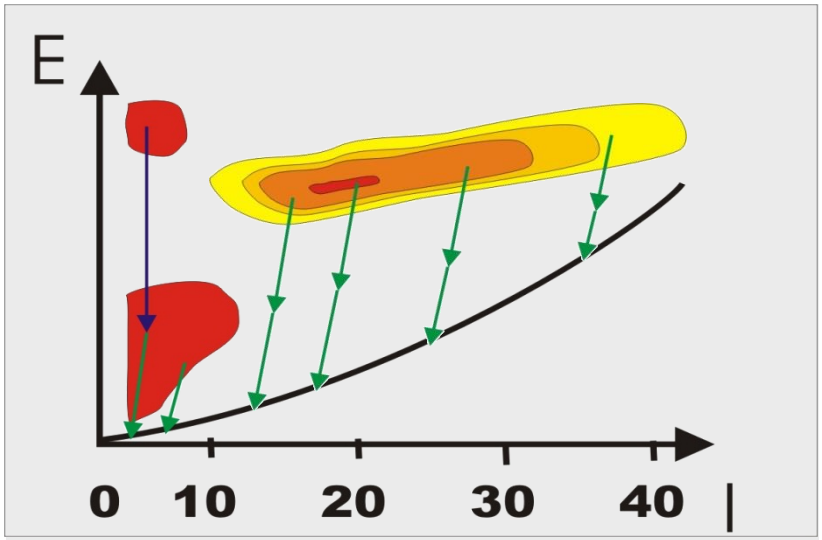
Relativistic Coulomb excitation / fragmentation



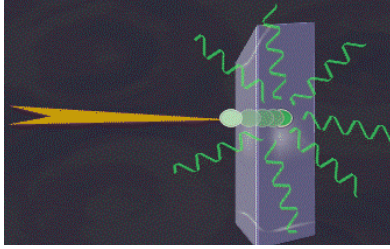
^{112}Sn →Au







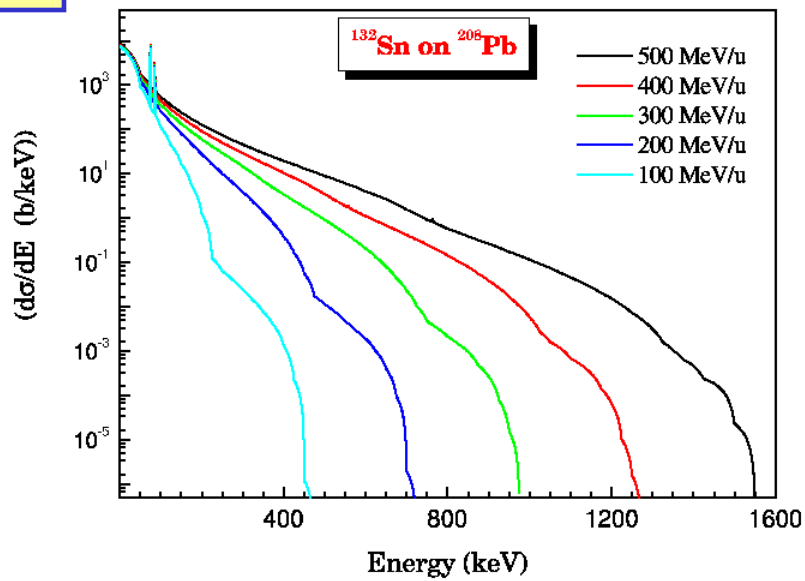
Atomic Background Radiation Bremsstrahlung

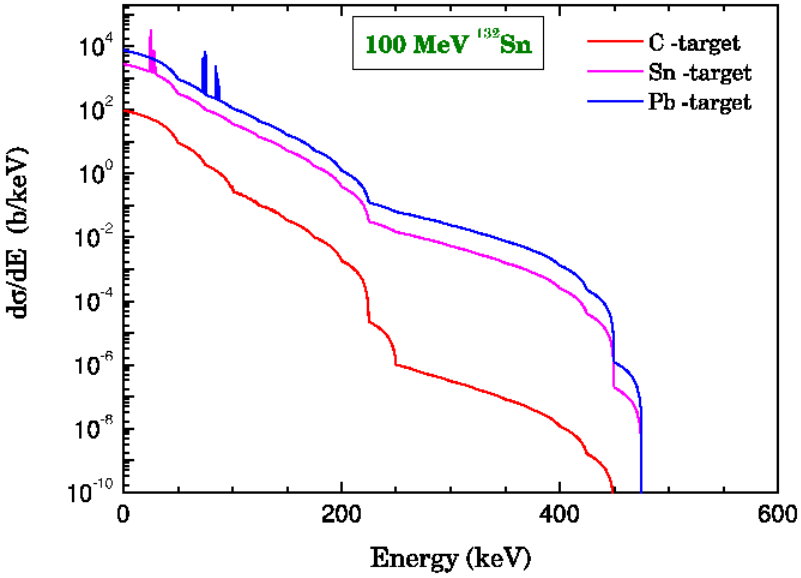


- Radiative electron capture (REC)
  capture of target electrons into bound states of the projectile:

- Primary Bremsstrahlung (PB)
  capture of target electrons into continuum states of the projectile:

- Secondary Bremsstrahlung (SB)
  Stopping of high energy electrons in the target:

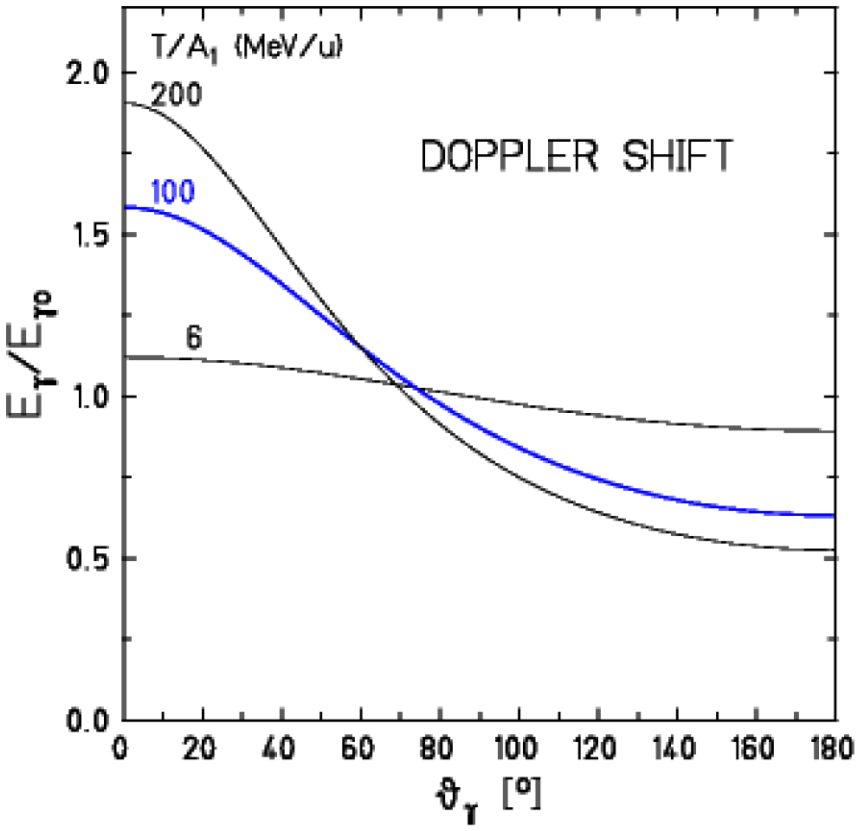




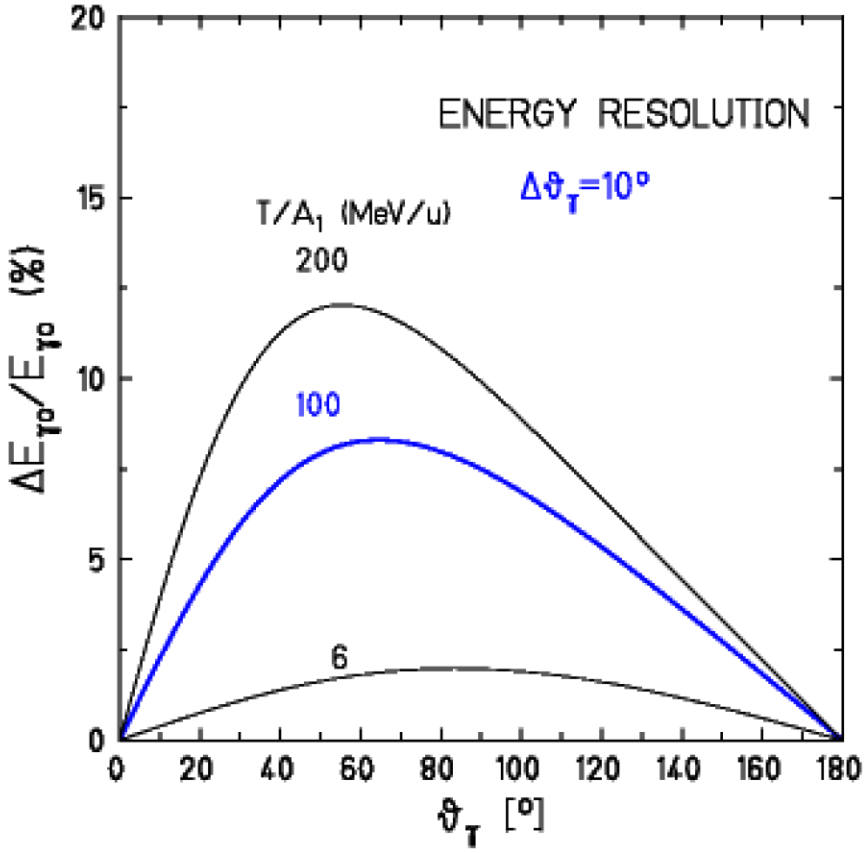
High granularity γ detector

Doppler Effect

Doppler shift



Doppler broadening



position sensitive γ detector

In-beam Spectroscopy

production

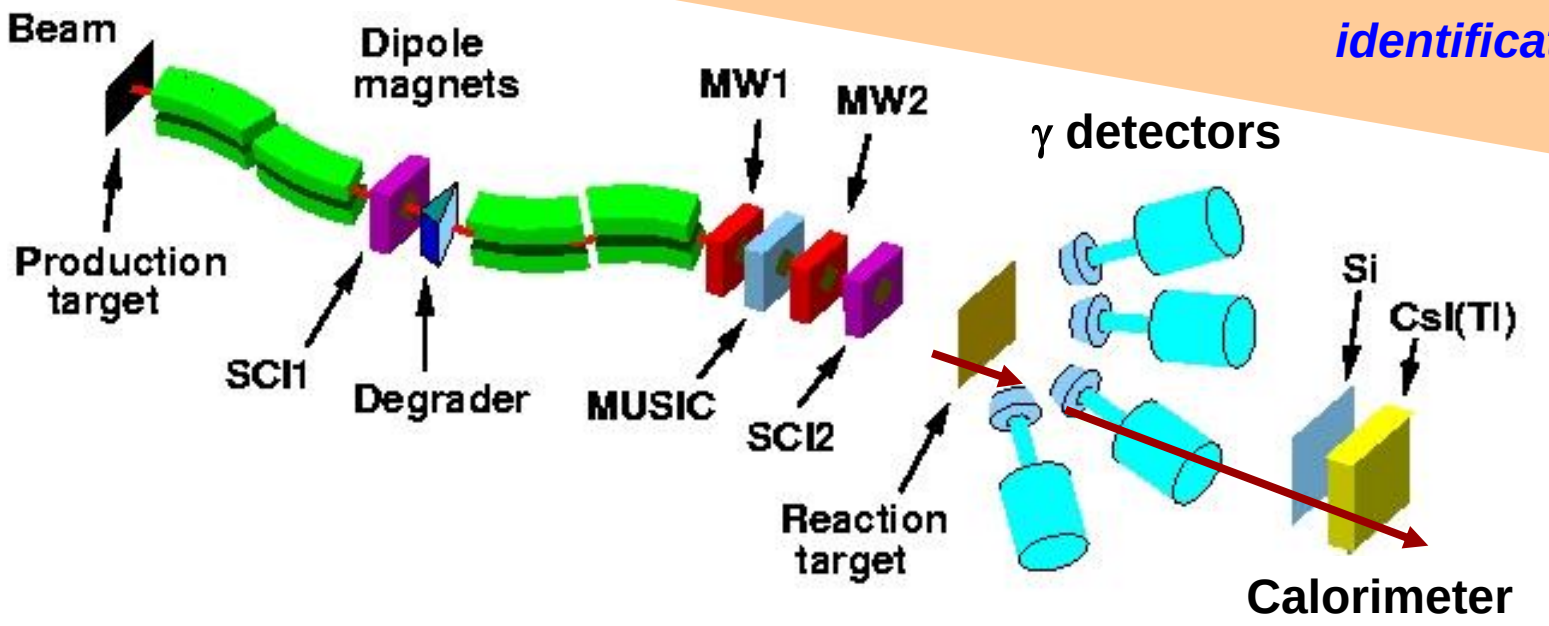
selection

identification

reaction

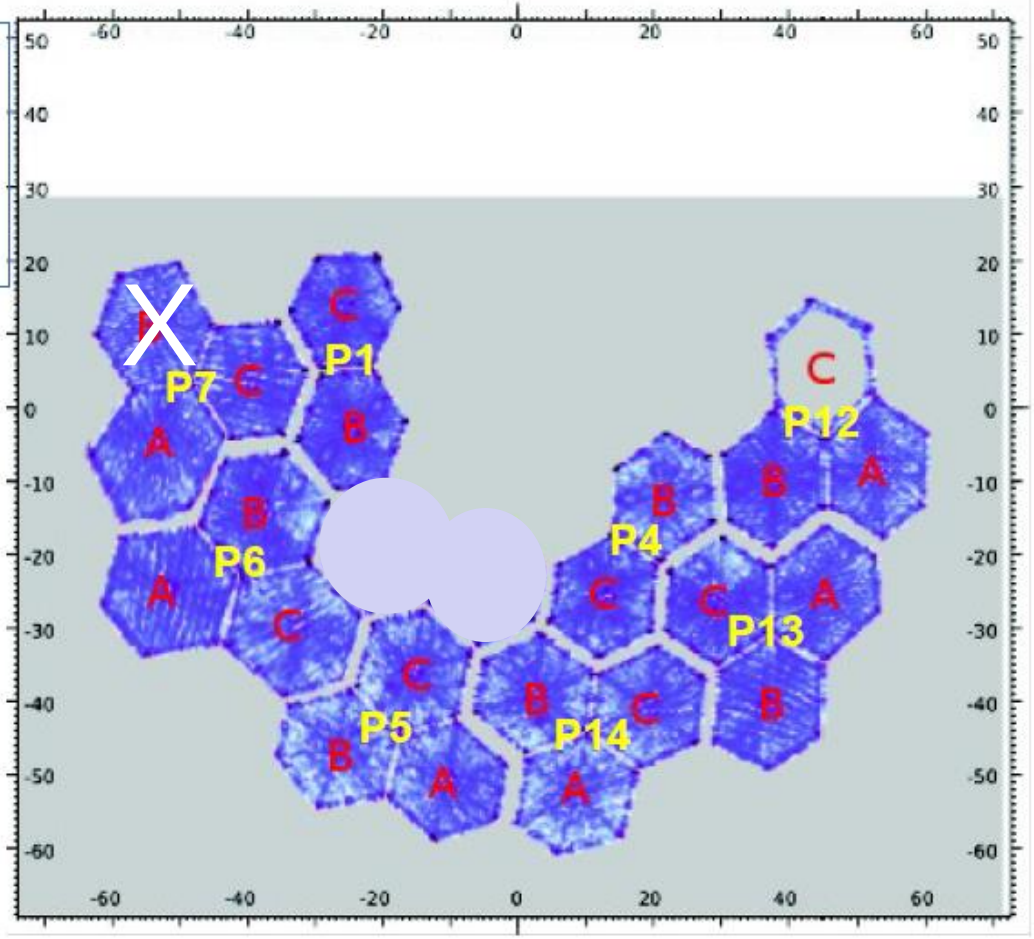
spectroscopy

identification



AGATA detector layout – Status 24-2-2014

Notes:
23 crystals
10 cry - beam R
12 cry - beam L



ADC01: B008, C006
ADC02: B012, C010
ADC03: B011, C008

ATC01: A008, B001, C003

ATC02: A003, B003, C005

ATC03: A002, B010, C001

ATC04: A007, B007, C007

ATC05: A004, B002, C004

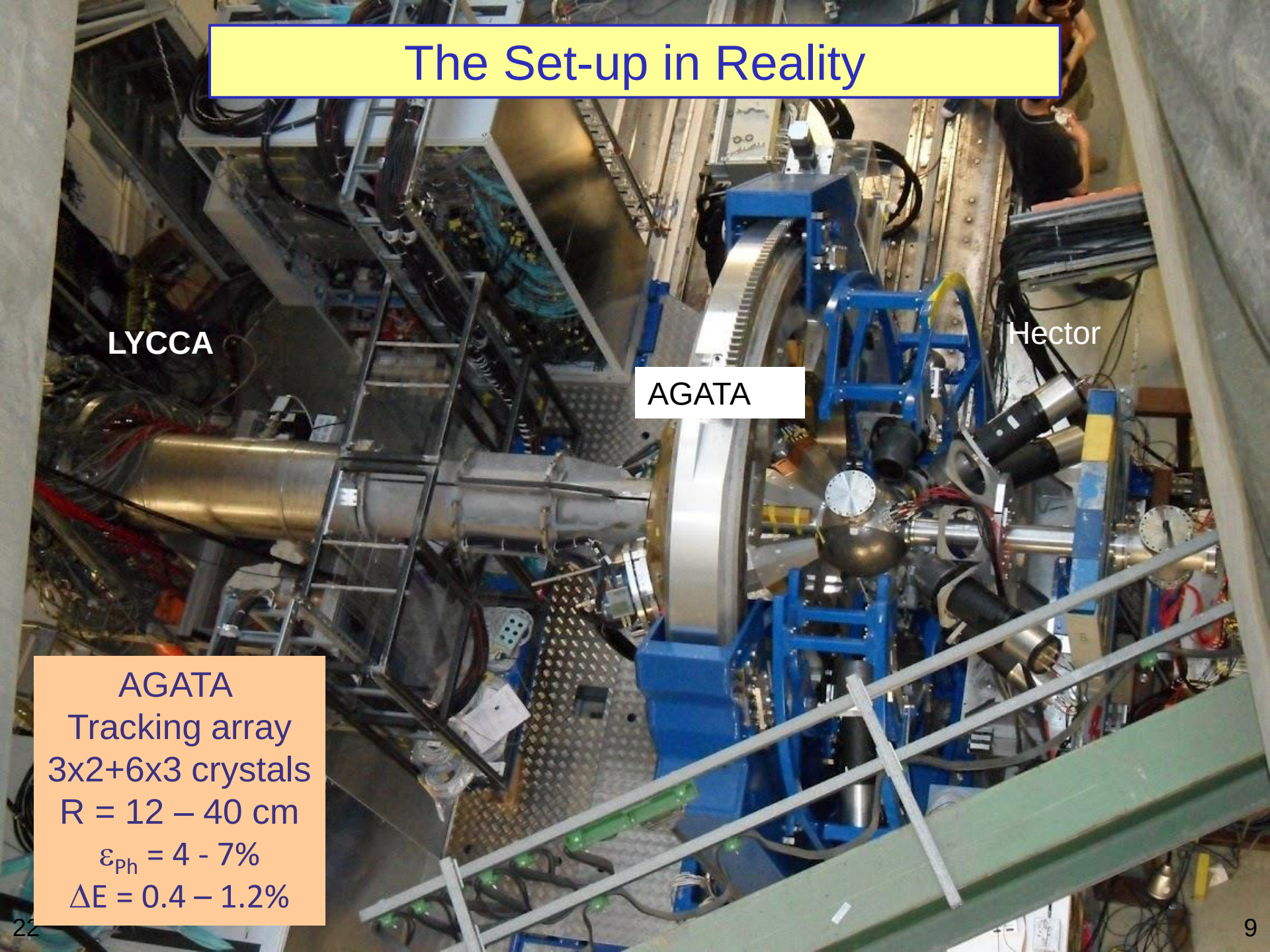
ATC06: A001, B004

P0 - ADC02
P1 - ADC03
P4 - ADC01

P12 – ATC06 (new mech. Adj.)
P13 – ATC03
P14 – ATC04 (new A007, B007, C007)

P5 – ATC05
P6 – ATC01 (new mech. Adj.)
P7 – ATC02

The Set-up in Reality



AGATA
Tracking array
3x2+6x3 crystals
R = 12 – 40 cm
ε_{Ph} = 4 - 7%
ΔE = 0.4 – 1.2%

Relativistic Coulex of n-rich Fe isotopes

Existence of Pygmy Dipole Strength or States especially in n-rich nuclei has an important

- impact on the **r-process nucleosynthesis**
- can be used for determination of **Nuclear symmetry energy***
- **can be used for Neutron skin thickness determination***

(Data on neutron rms radius constrain the isospin-asymmetric part of the Equation Of State of nuclear matter)

Note that:

Relation between neutron skin and neutron stars :

both are built on neutron rich nuclear matter

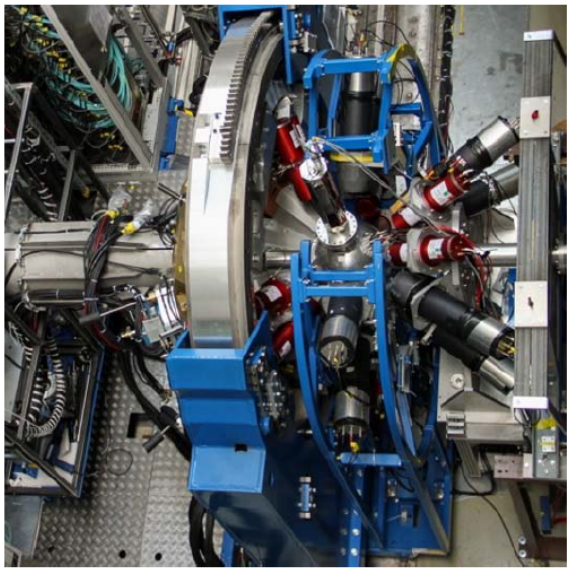
so that one-to-one correlations can be drawn

Relativistic coulomb excitation of ^{62,64}Fe was performed in GSI laboratory.

^{62,64}Fe beam at circa 73% of speed of light was produced (**400-440AMeV**).

The exotic beam was brought to collide with **High Z thick target** (Pb for ^{64}Fe and Au for ^{62}Fe and ^{64}Fe) and the gamma emission of the projectile after the collision was measured.

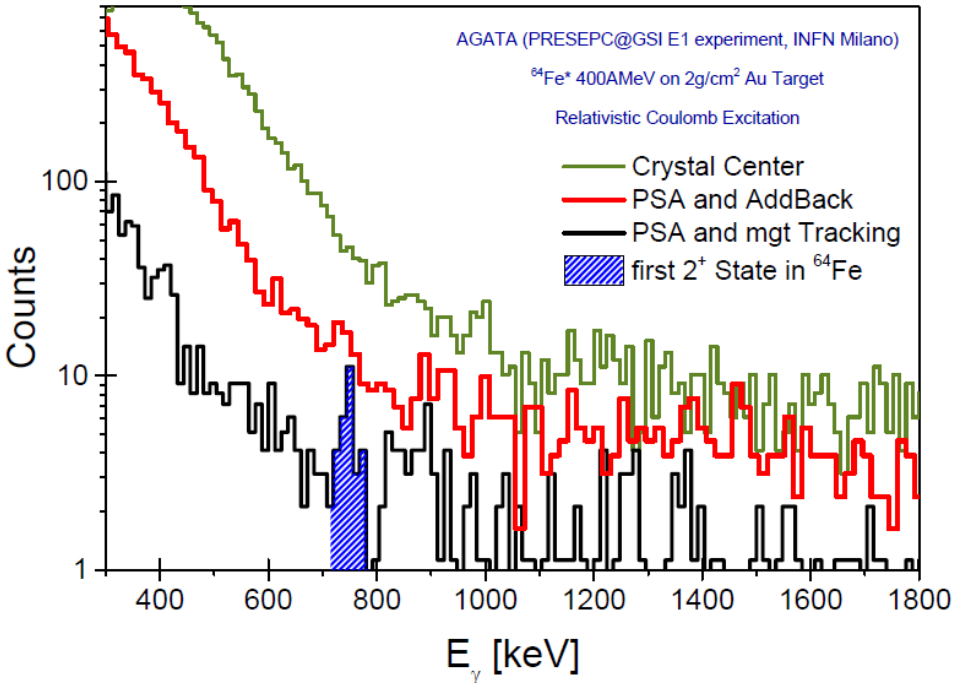
The experiment was performed in 2012 (test **1,5** days) and 2014 (**3** days) during the PreSPEC-AGATA campaign with very low beam current



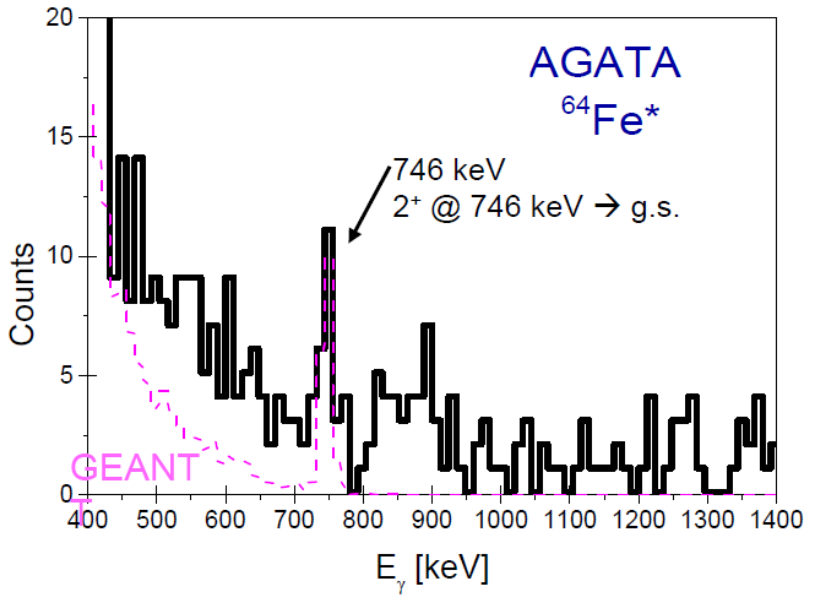
AGATA	From 15° to 60°
HECTOR	22°, 68°, 95°, 142°

courtesy O. Wieland et al.

PSA and Tracking at v/c = 0.73



Measurement of known 2^+ states (needed to «calibrate» E1 strength) proofs that AGATA & Prespec PSA+Tracking setup works very well at E_beam=440AMeV !!!!

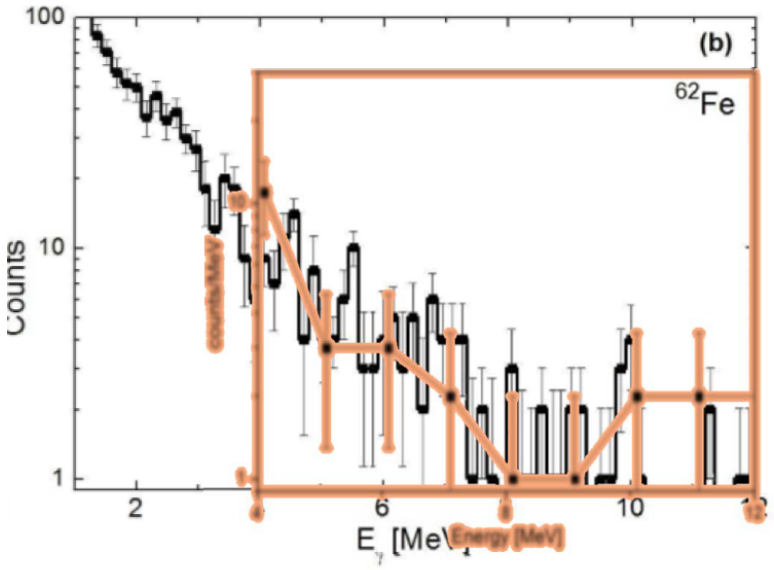


2g Gold Target & Beta 0.73* !
E2 Yield as expected !
Angular distribution measured in AGATA confirms multipole characters in the experiment of the peaks.
(*note: experiment favours E1 excitation)

courtesy O. Wieland et al.

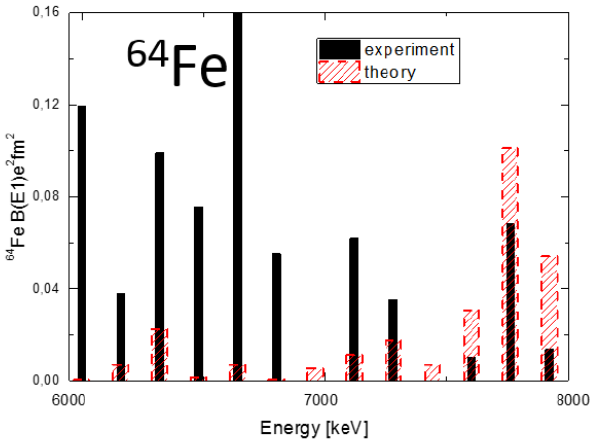
γ spectra at very high energies

Structure appear in the region of 6-8 MeV



LaBr3:Ce spectra

QPM
1p1h + 2p2h +3p3h
Wood Saxon
three-phonon QPM



*These experimental results provide, **for the first time**, information on high energy gamma ray transitions 6-8MeV in very **exotic** nuclei.*
*The Region around Sn,Sp is of paramount interest for nuclear astrophysics and (preliminary) the **E1 scaling law looks universal** !*

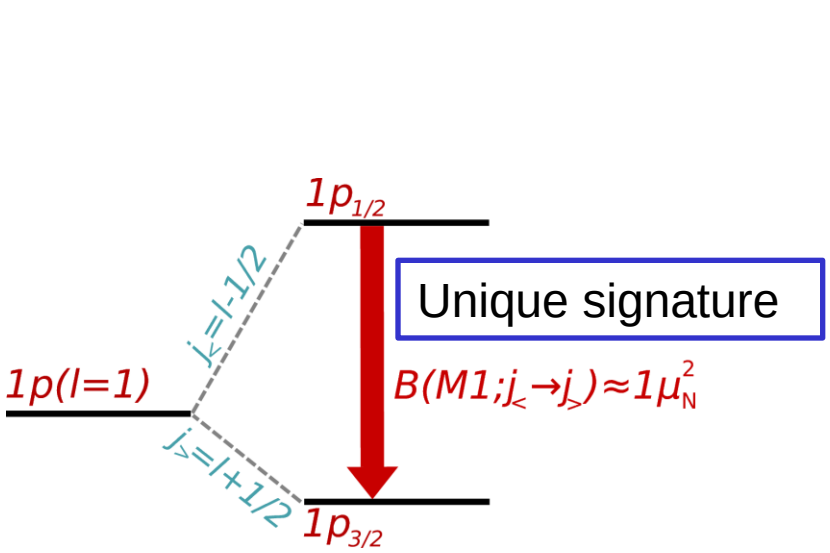
ready for publication in 2018

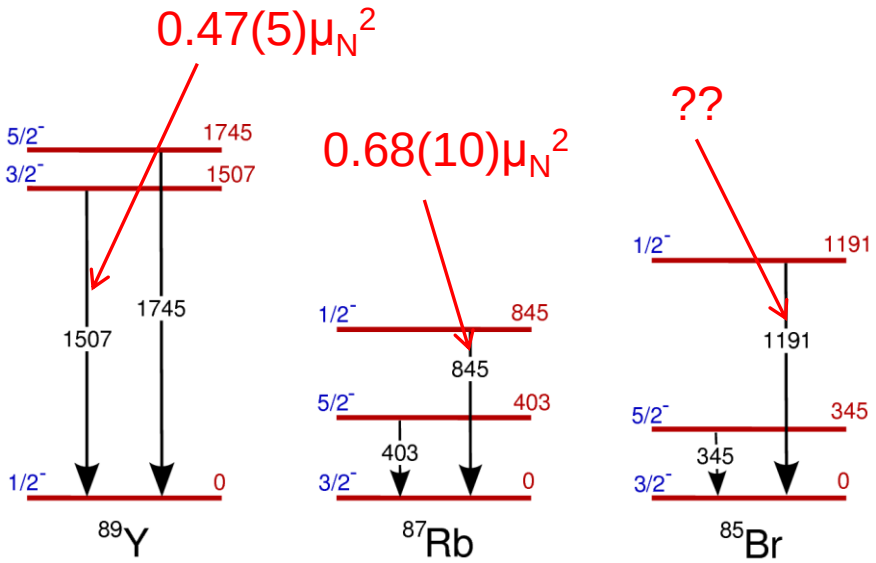
courtesy O. Wieland et al.

Evolution of the proton SPE towards ^{78}Ni

Confirm that the $1/2^-$ state (1191 keV) in ^{85}Br is the $\pi p_{1/2}$ state!

➡ Observe the spin-orbit splitting by a strong spin-flip M1 transition

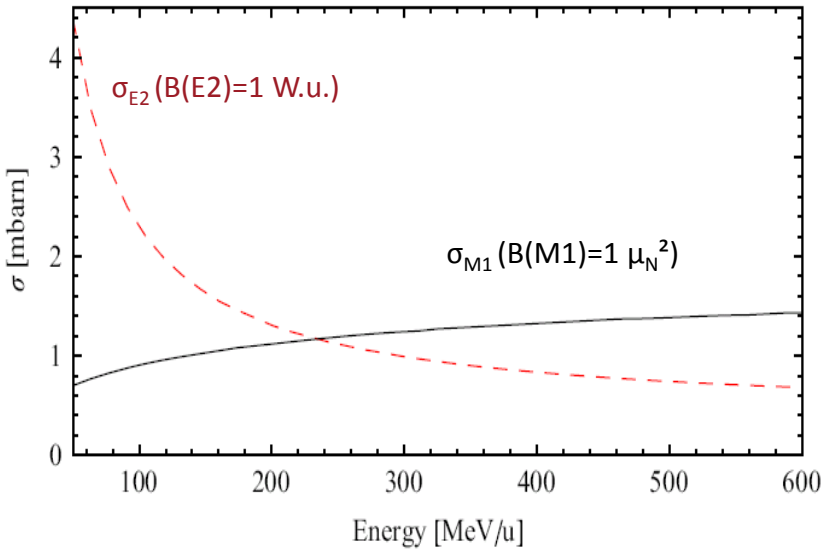


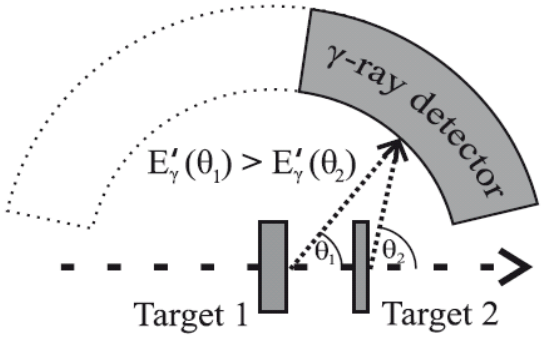


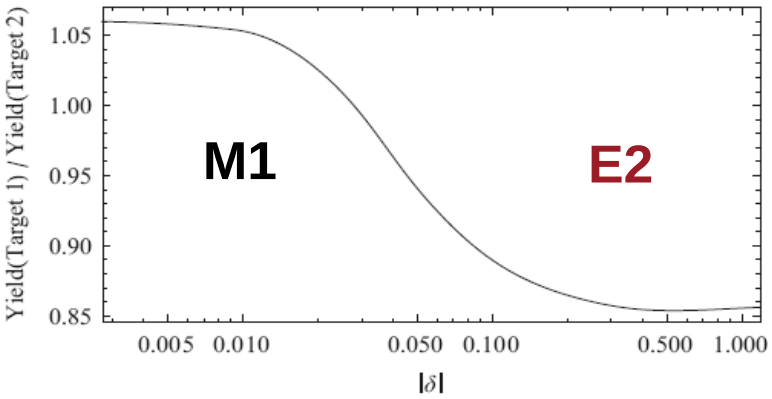
courtesy M. Lettmann

Experimental method

Measure the multipole mixing ratio



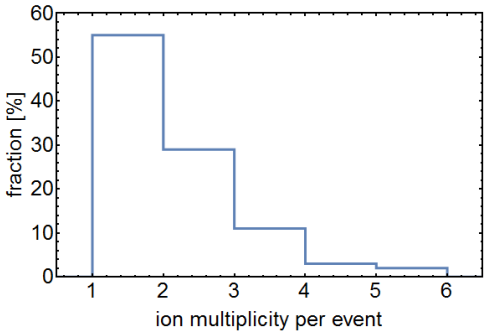




-Use two targets to vary beam energy
-Use high beam intensity to get the yield

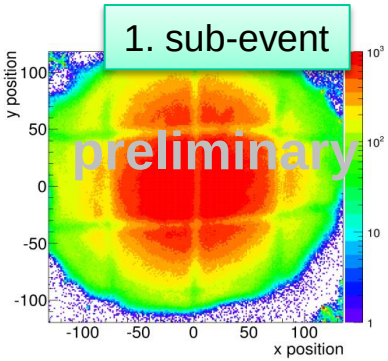
courtesy M. Lettmann

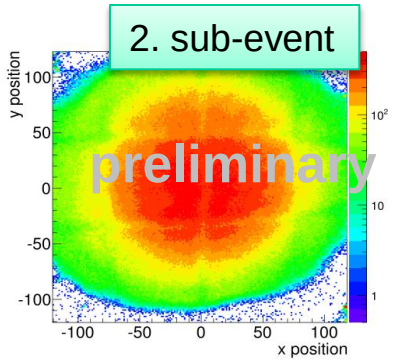
Analysis progress

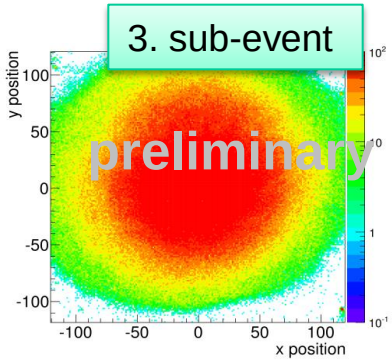


1. Disentangle multiple particle events using ID and position information to increase number of events
2. Redo AGATA analysis

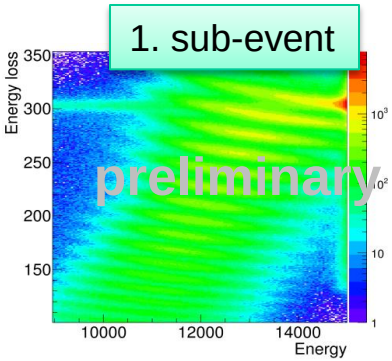
Combined position information

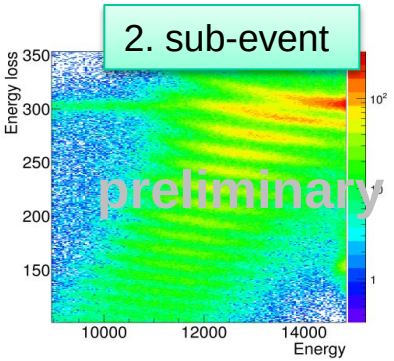


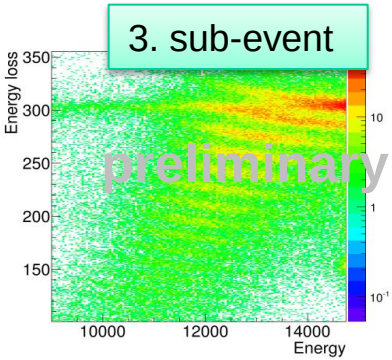




Particle identification

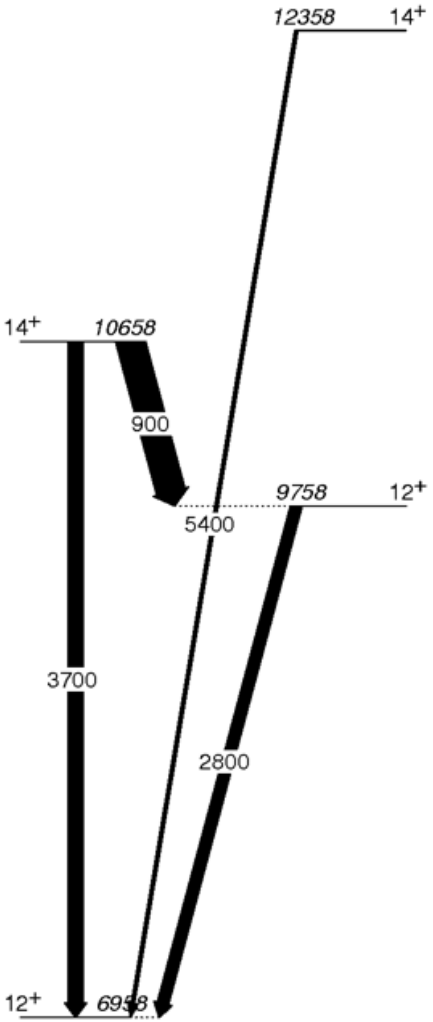


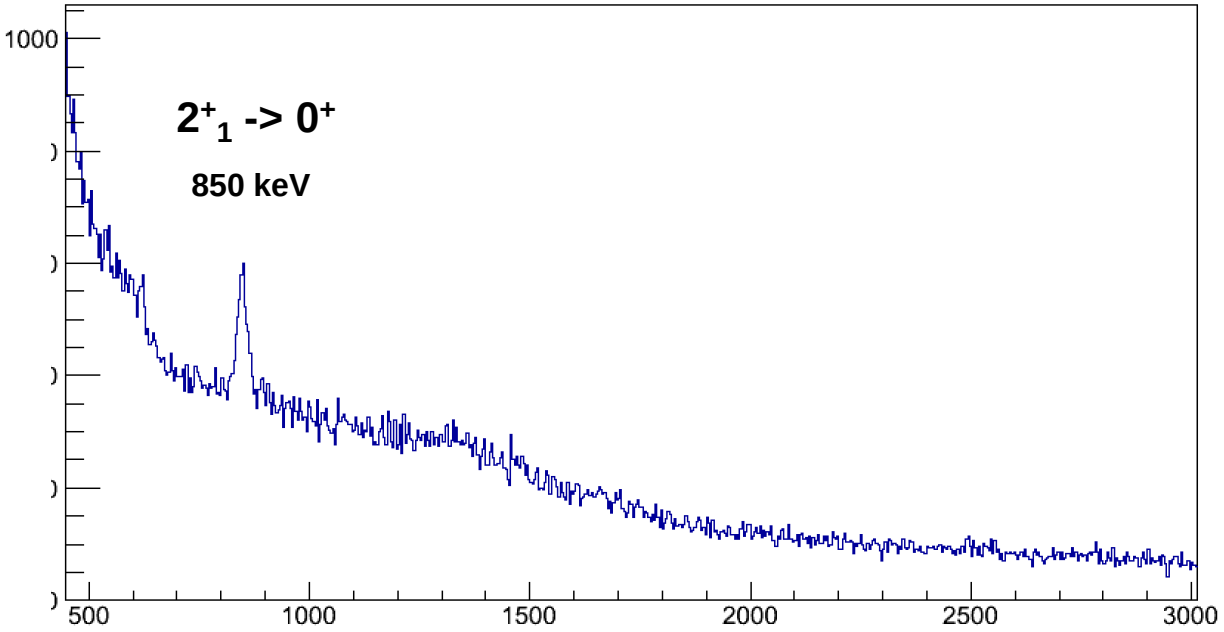


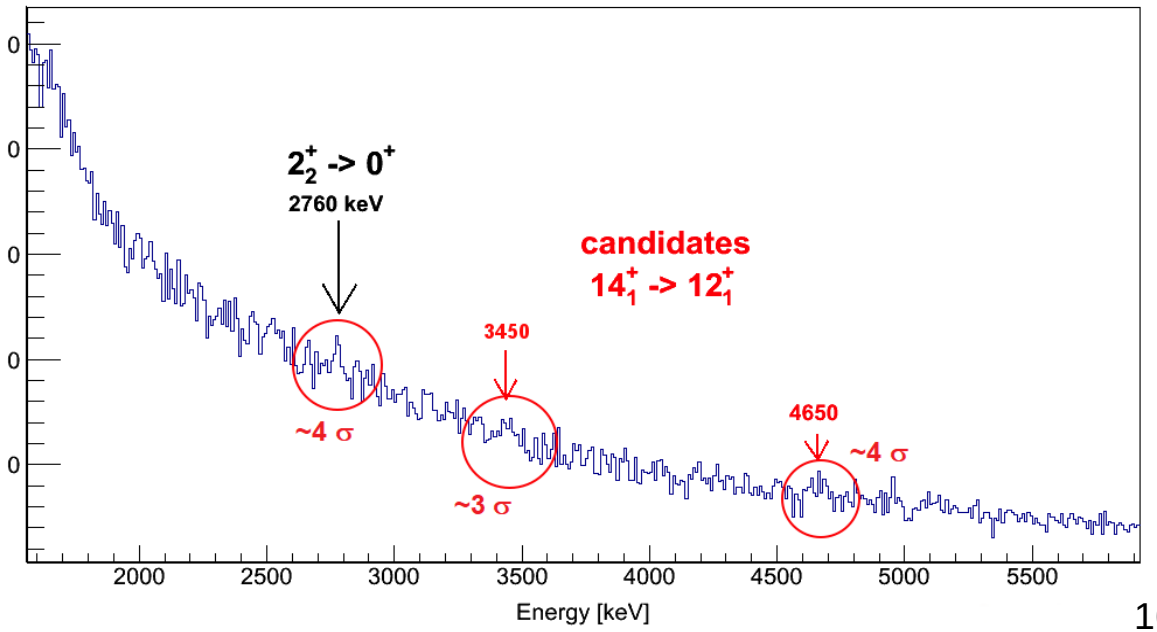


M. Lettmann

^{52}Fe Isomer Coulex transitions







Tayfun Hüyük

^{52}Fe Isomer Coulex Results

Isomeric ratio: 14%

Experimental cross sections

$I_i \rightarrow I_f$	E_γ [keV]	σ [mb]
$0^+ \rightarrow 2_1^+$	849.5(1.4)	79(5)
$0^+ \rightarrow 2_2^+$	2770[2760]	16(7)
$(12^+ \rightarrow 14^+)$	3450	29(19)
$(12^+ \rightarrow 14^+)$	4650	34(23)

Preliminary results

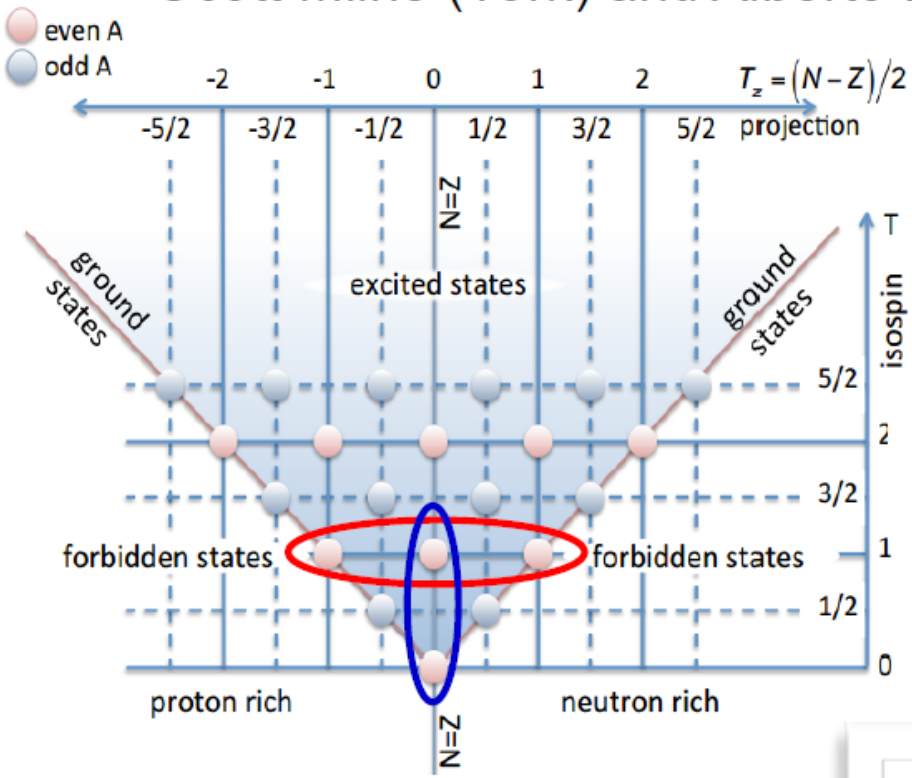
Interaction	I_i -> I_f [ħ]	ΔE [keV]	B(E2) [e^2fm^4]
KB3G	12^+ -> 14^+	4391	21.6
GXPF1A	12^+ -> 14^+	3753	34.3
Exp. candidate	(12^+ -> 14^+)	3450	350(230)
Exp. candidate	(12^+ -> 14^+)	4650	440(280)

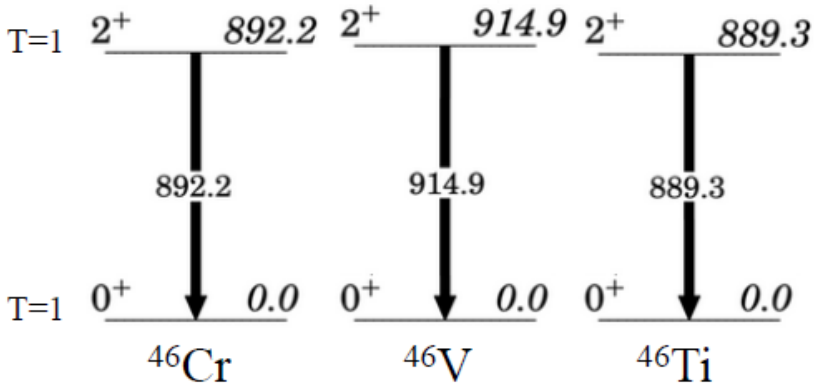
Strongly enhanced B(E2) compared to Large Scale Shell Model

Tayfun Hüyük

Isospin symmetry in the A=46 isobaric triplet

AGATA-PRESPEC Experiment, April 2014 - analysis by:
Scott Milne (York) and Alberto Boso (Padova)





B(E2) (e^2fm^4): **186(40)** **188(24)** **193(2)**

Literature values

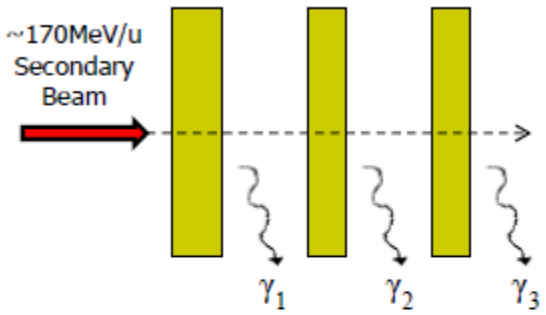
Test linearity of E2 matrix element with T_z - isospin selection rule

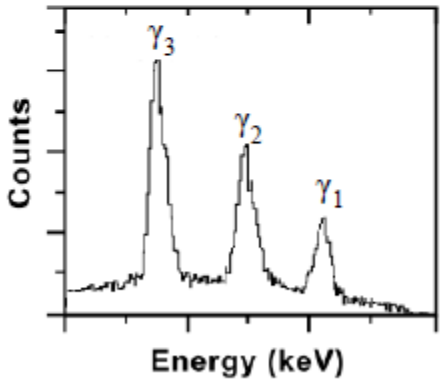
$$M_{tot} = M^{(0)} + \frac{T_z}{\sqrt{(2T+1)(T+1)T}} M^{(1)}$$

Alberto Boso, Mike Bentley et al.

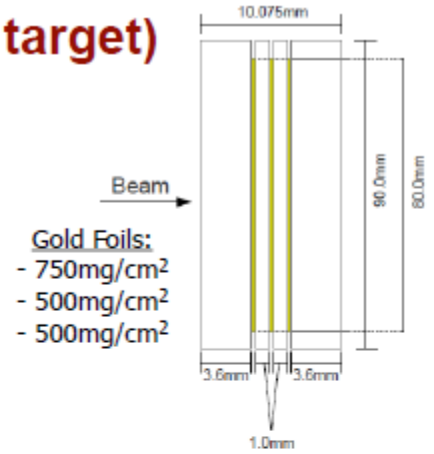
Triple DSAM at relativistic energies

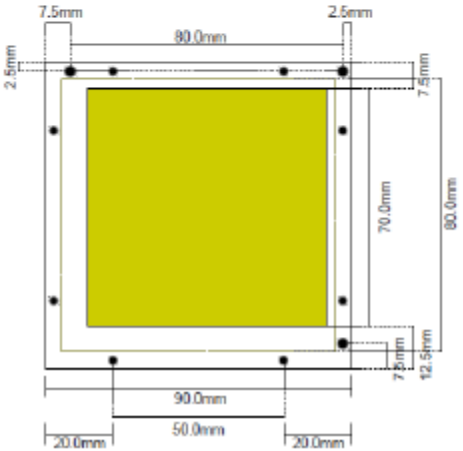
Triple Gold Foil (stretched target)



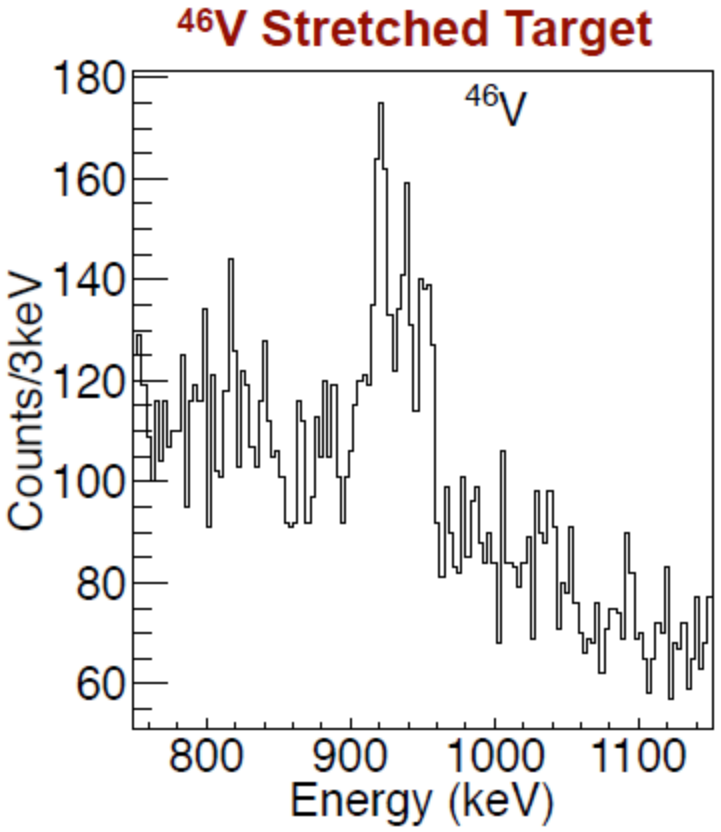


Doppler Shift: $E_{exp} = E_{cor}\frac{\sqrt{(1-\beta^2)}}{[1-\beta Cos(\theta_{dop})]}$





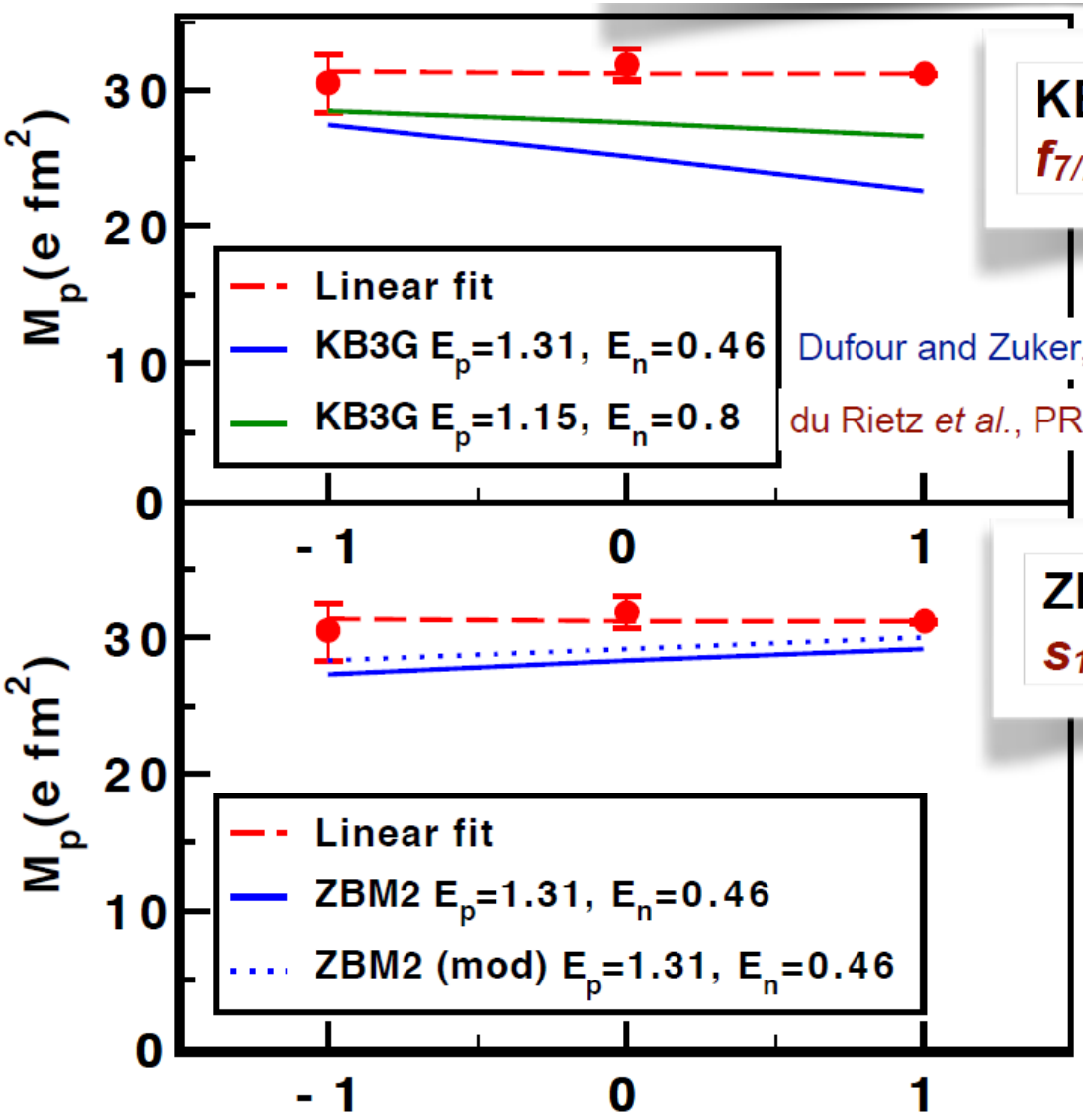
A=46 multiplet



Only possible with ultra-high position resolution of AGATA

Alberto Boso, Mike Bentley et al.

Triple DSAM results



KB3G interaction in $f_{7/2}p_{3/2}f_{5/2}p_{1/2}$ space

Dufour and Zuker, PRC **54**, 1641 (1996)

du Rietz *et al.*, PRL **93**,222501(2004) (from A=51 mirrors)

ZBM2 interaction in $s_{1/2}d_{3/2}f_{7/2}p_{3/2}$ space

A.Boso, S.A.Milne, M.A.Bentley, F.Recchia *et al. in preparation 2018*

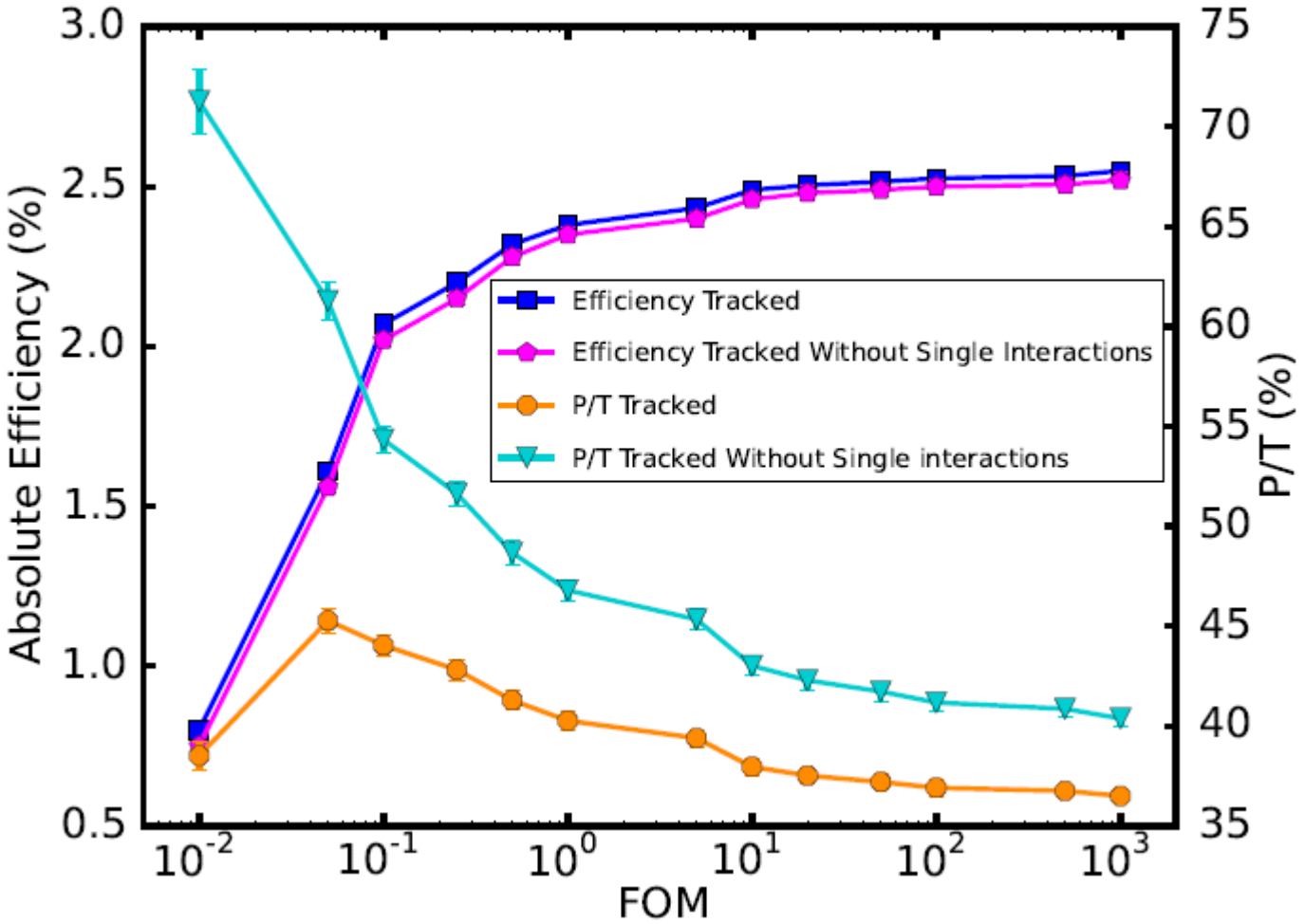
No evidence for non-linear behaviour with T_z

Conclusions

- The PRESPEC-AGATA campaign at GSI in 2012-2014 could run only a limited experimental programme
- Data analysis is very complex and time consuming
- Novel experimental methods emerge from the combination of relativistic beams and AGATA
- Analysis is still ongoing
- Physics results are popping up one after the other


Was a Great Collaboration

AGATA Efficiency versus P/T

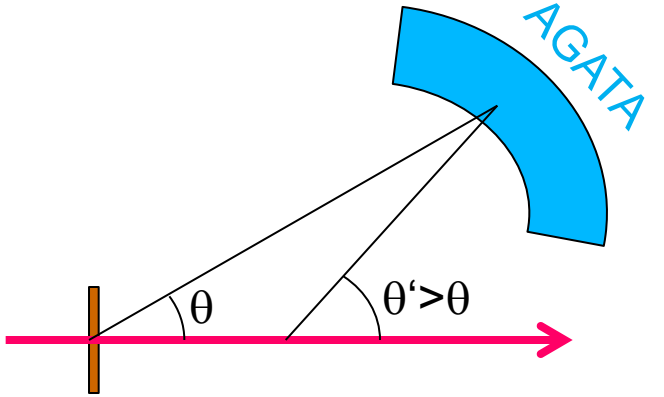


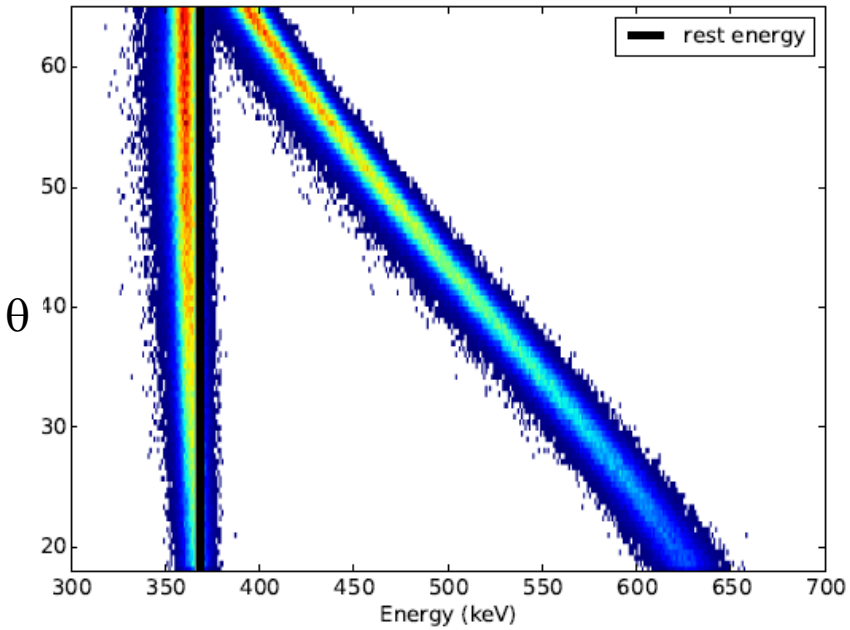
^{60}Co at nominal position

Natasa Lalovic et al. NIM A806 (2016) 258-266

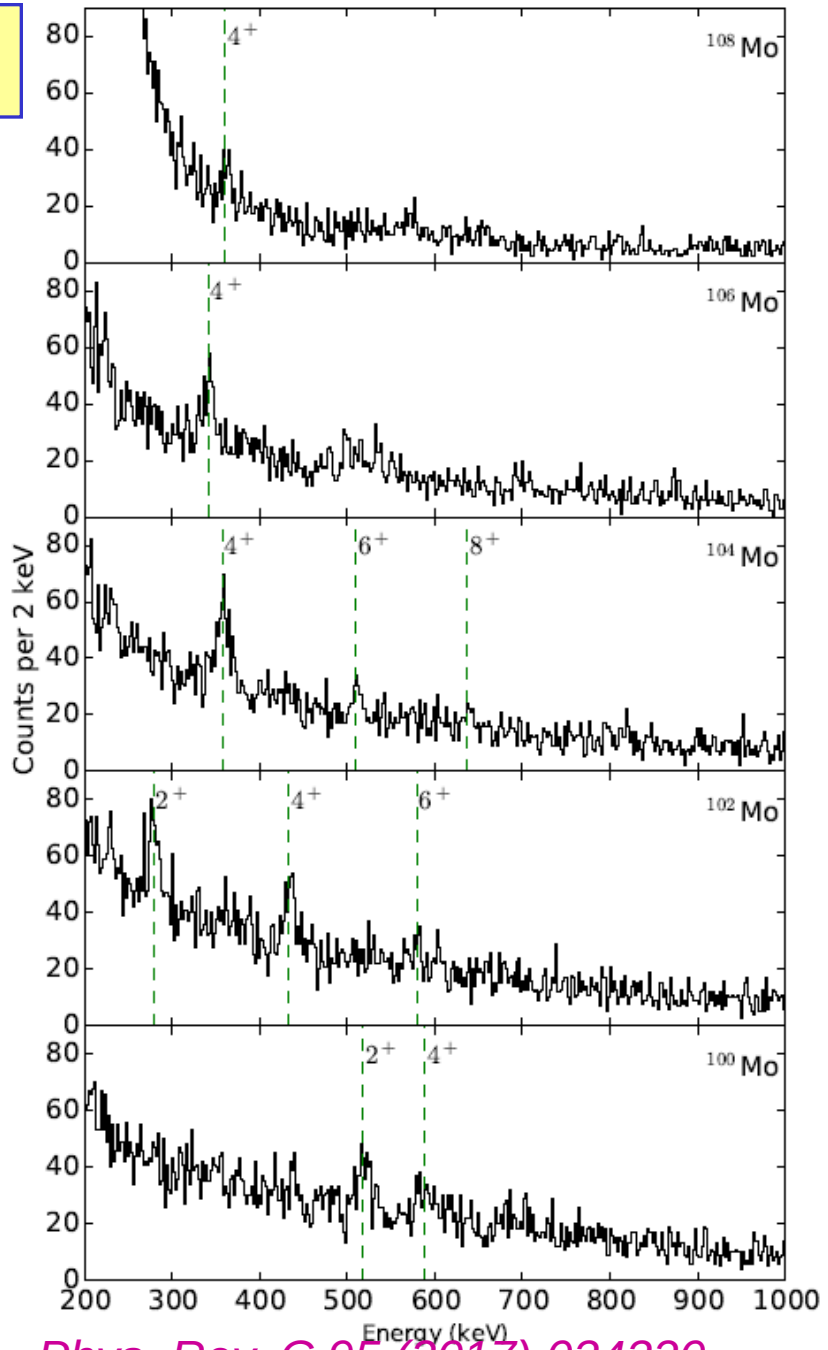
Lifetimes from decay position

Triaxiality in heavy Mo isotopes





Only possible with relativistic beams



Damian Ralet et al., Phys. Rev. C 95 (2017) 034320