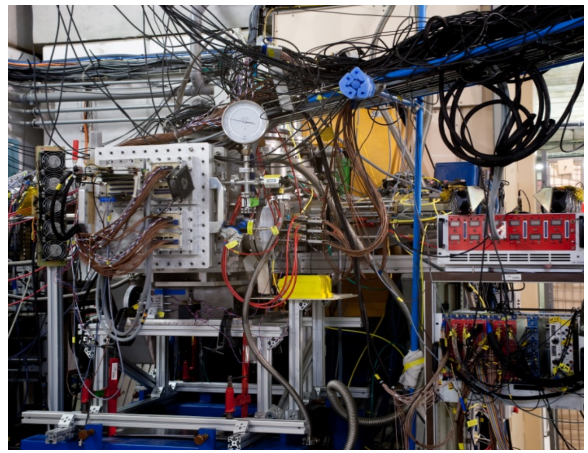
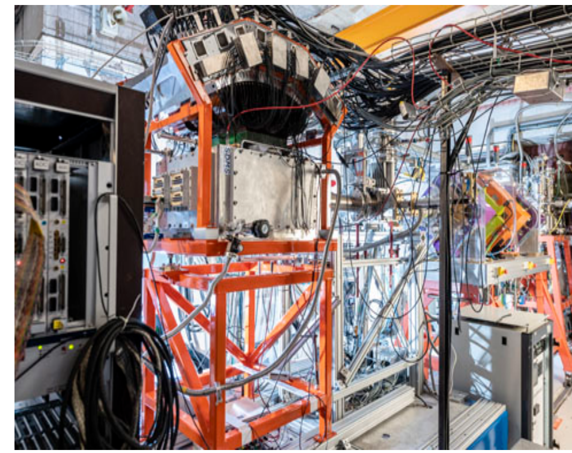
DE LA RECHERCHE À L'INDUSTRIE

ISGMR measurements in unstable nuclei using MAYA and ACTAR



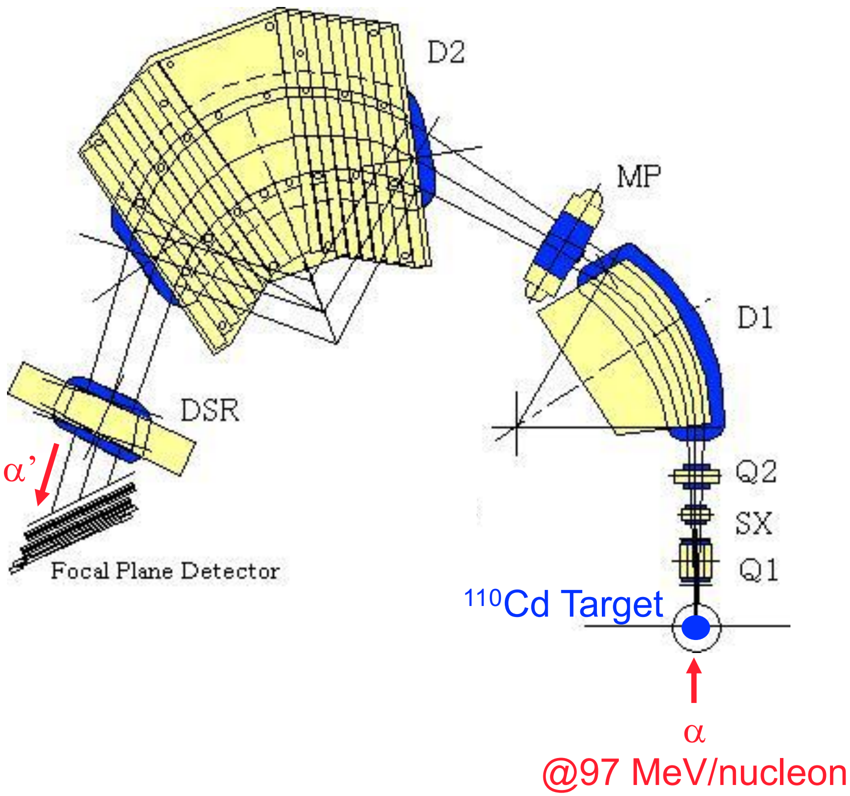


laboratoire commun CEA/DSM CNRS/IN2P3

Marine VANDEBROUCK (CEA Irfu/DPhN)

RESANET GMR Workshop
November 2020

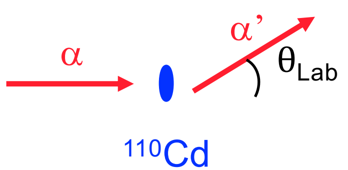
ISGMR measurement in stable nuclei



Magnetic spectrometer “Grand Raiden” @RCNP, Osaka University

✓ **Which reaction ?**

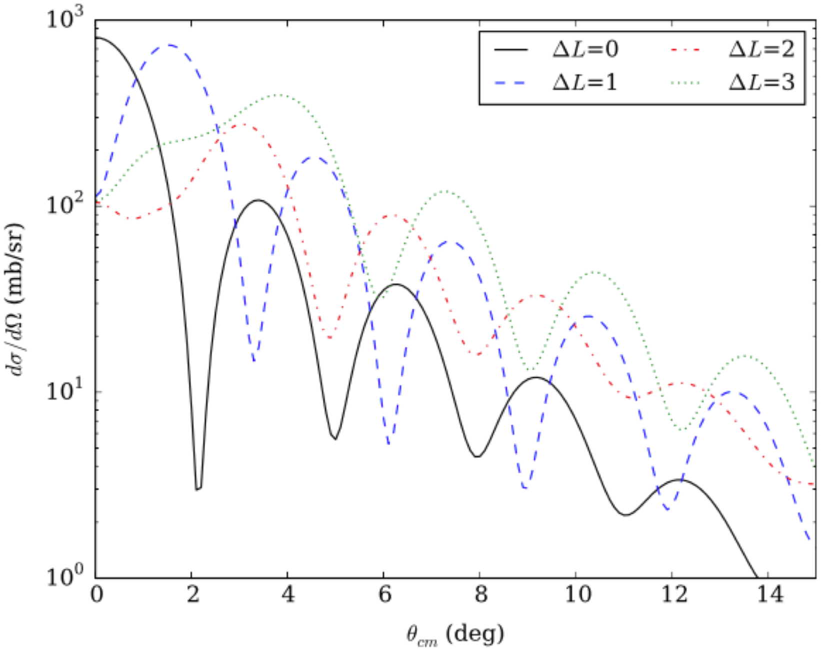
Inelastic scattering of isoscalar particles at 35–100 MeV/nucleon



Measurement of $E_{\alpha'}$ and θ_{Lab}
+ missing mass analysis ➡ $E^*(^{110}Cd)$

ISGMR measurement in stable nuclei

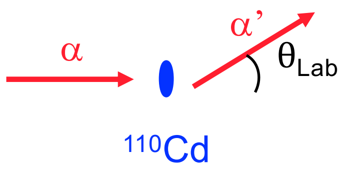
$^{110}Cd(\alpha,\alpha')^{110}Cd^*$, E_α = 97 MeV/nucleon, $E^*(^{110}Cd)$ = 15.5 MeV



U. Garg and G. Colò, Part. And Nucl. Phys. 101 (2018)

✓ **Which reaction ?**

Inelastic scattering of isoscalar particles at 35–100 MeV/nucleon



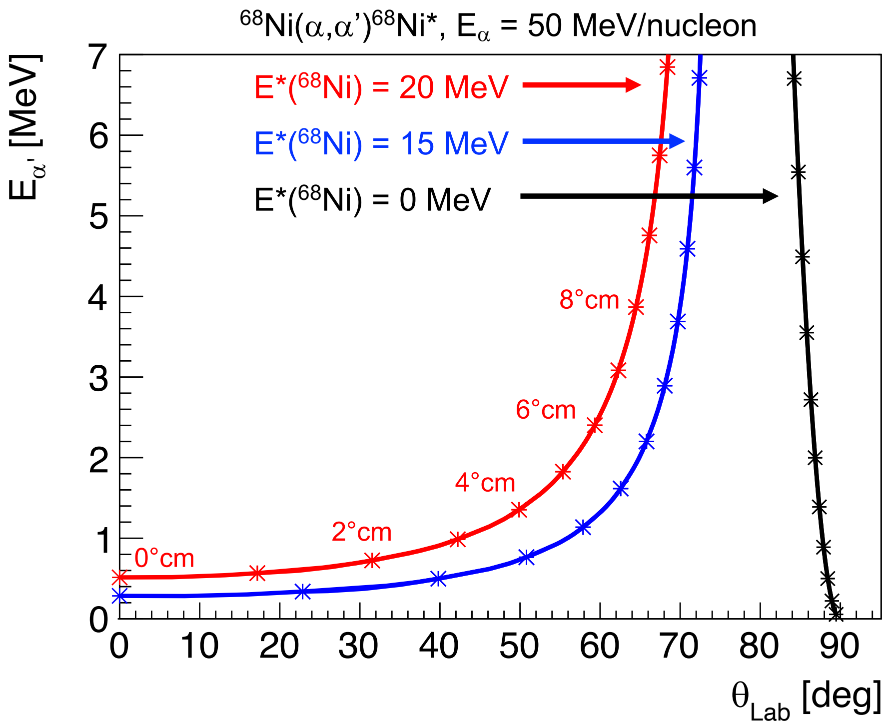
Measurement of $E_{\alpha'}$ and θ_{Lab}
+ missing mass analysis ➡ $E^*(^{110}Cd)$

✓ **How to identify the ISGMR, i.e. L = 0 strength ?**

Angular distribution at small angles in the center-of-mass

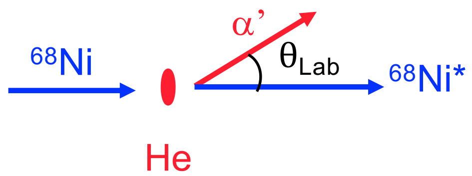
Introduction

ISGMR measurement in unstable nuclei, what is the difficulty ?



✓ **Which reaction ?**

Inelastic scattering of isoscalar particles at 35–100 MeV/nucleon **in inverse kinematics**

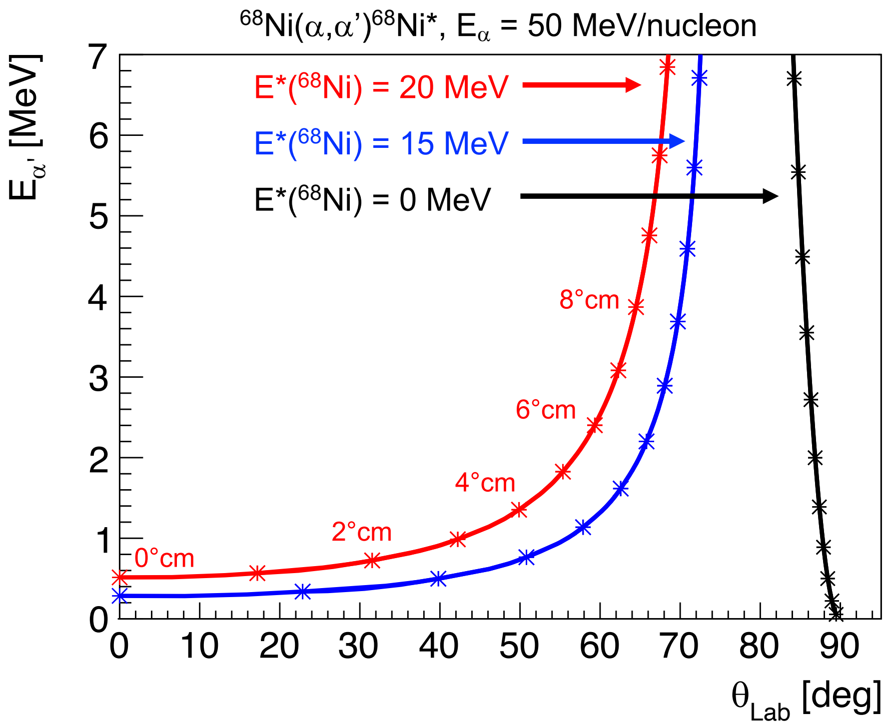


Measurement of $E_{\alpha'}$ and θ_{Lab}
+ missing mass analysis ➡ E*(^{68}Ni)

✓ **How to identify the ISGMR, i.e. L = 0 strength ?**

Angular distribution at small angles in the center-of-mass
➡ **low detection threshold**

ISGMR measurement in unstable nuclei, what is the difficulty ?



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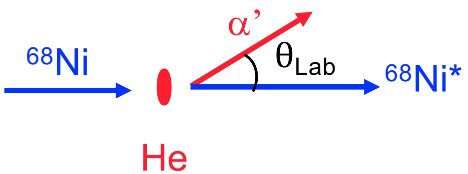


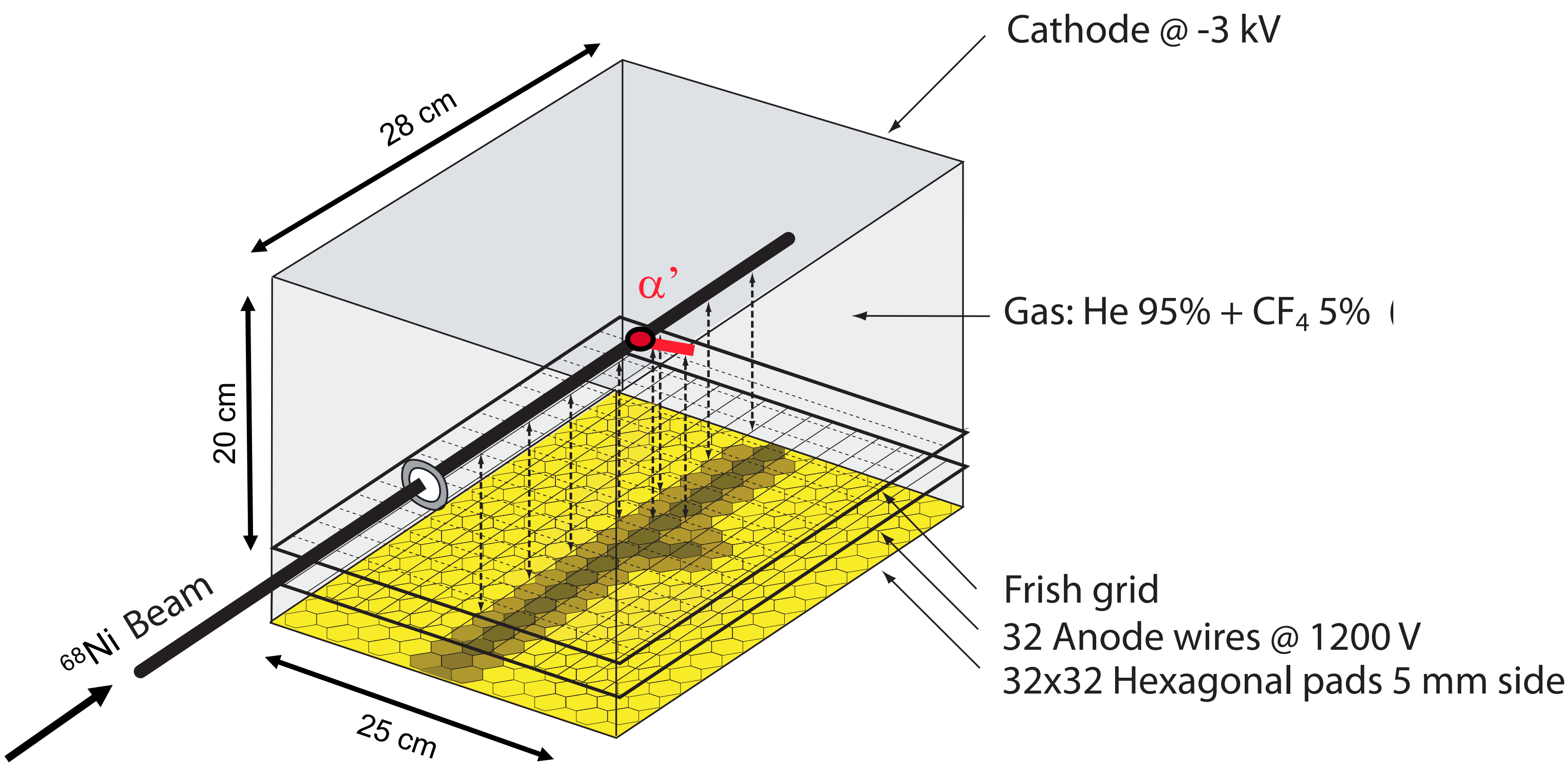
Measurement of $E_{\alpha'}$ and θ_{Lab}
\+ missing mass analysis ➡ E*(^{68}Ni)

✓ **How to identify the ISGMR, i.e. L = 0 strength ?**

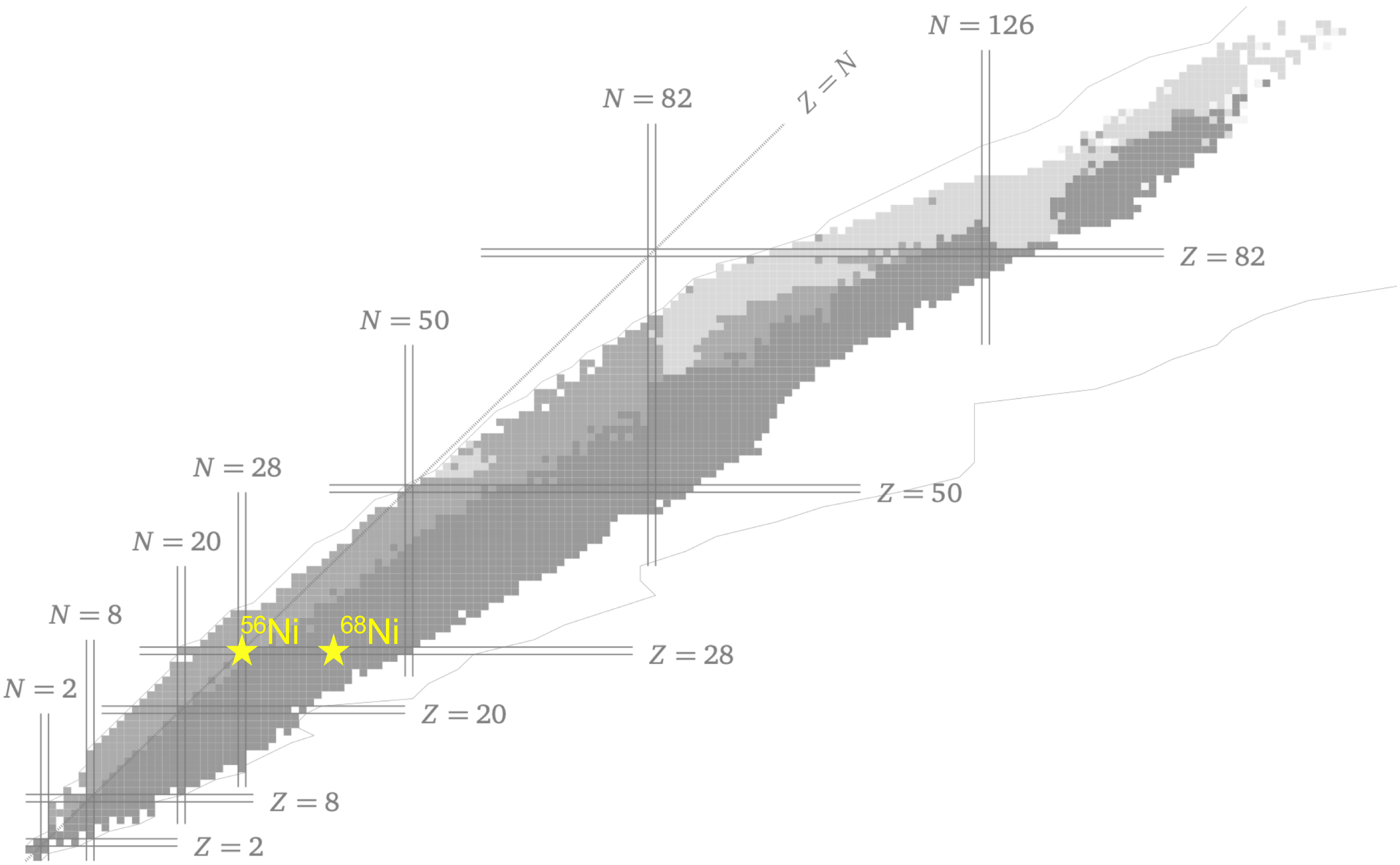
Angular distribution at small angles in the center-of-mass

➡ **low detection threshold**

The active target MAYA at GANIL



ISGMR results in unstable nuclei with MAYA



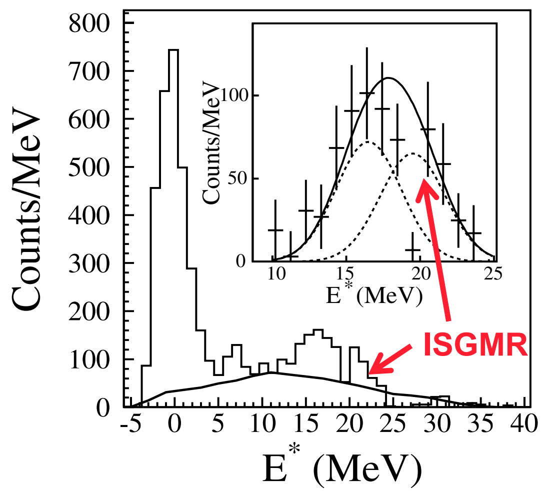
ISGMR results in unstable nuclei with MAYA

2005

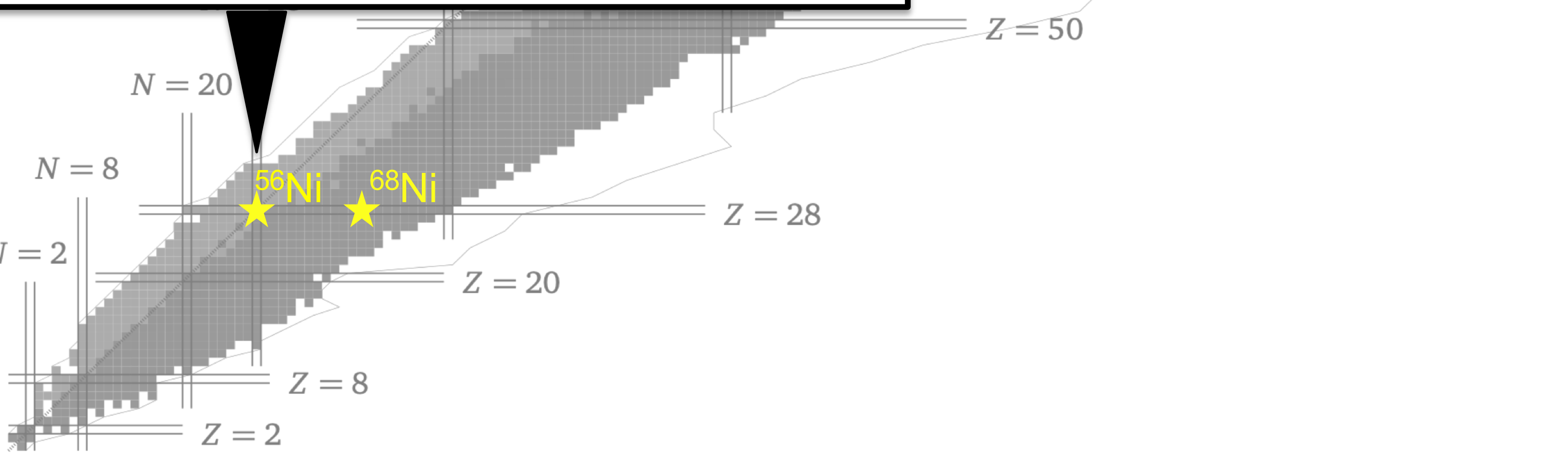
^{56}Ni

$^{56}Ni + d \rightarrow d' + {}^{56}Ni^*$
50 MeV/nucleon
SPEG + MAYA @GANIL

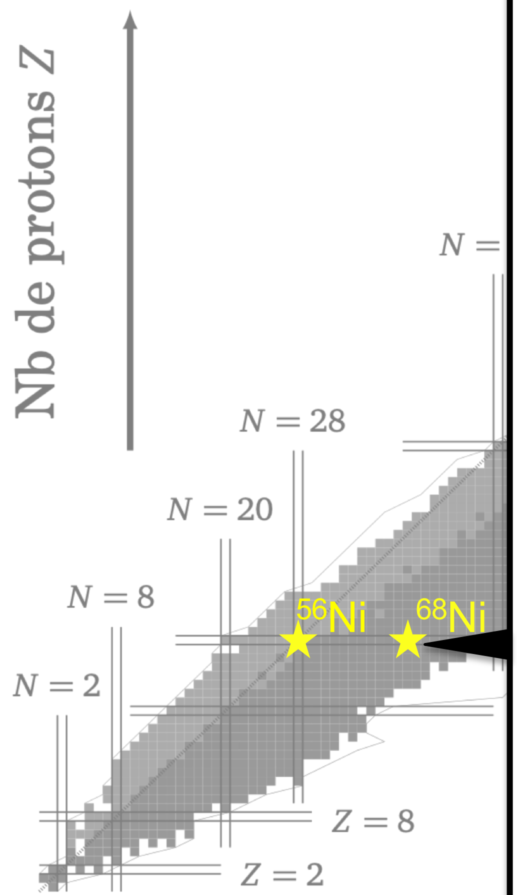
$E^*(^{56}Ni)_{ISGMR}$ = 19.3 ± 0.5 MeV
$EWSR(^{56}Ni)_{ISGMR}$ = 136 ± 27 %



C. Monrozeau *et al.*, Phys. Rev. Lett. 100, 042501 (2008)



ISGMR results in unstable nuclei with MAYA



2010

^{68}Ni

$^{68}Ni + d \rightarrow d' + {}^{68}Ni^*$

$^{68}Ni + \alpha \rightarrow \alpha' + {}^{68}Ni^*$

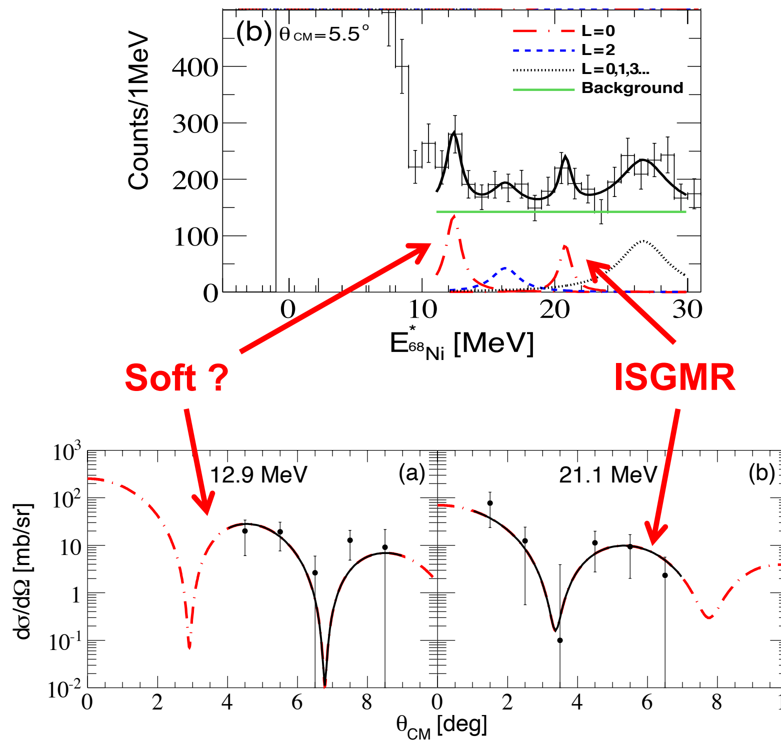
50 MeV/nucleon

LISE + MAYA @GANIL

$E^*(^{68}Ni)_{ISGMR}$ = 20.9 ± 1.0 MeV (d,d')

$E^*(^{68}Ni)_{ISGMR}$ = 21.1 ± 1.9 MeV (α,α')

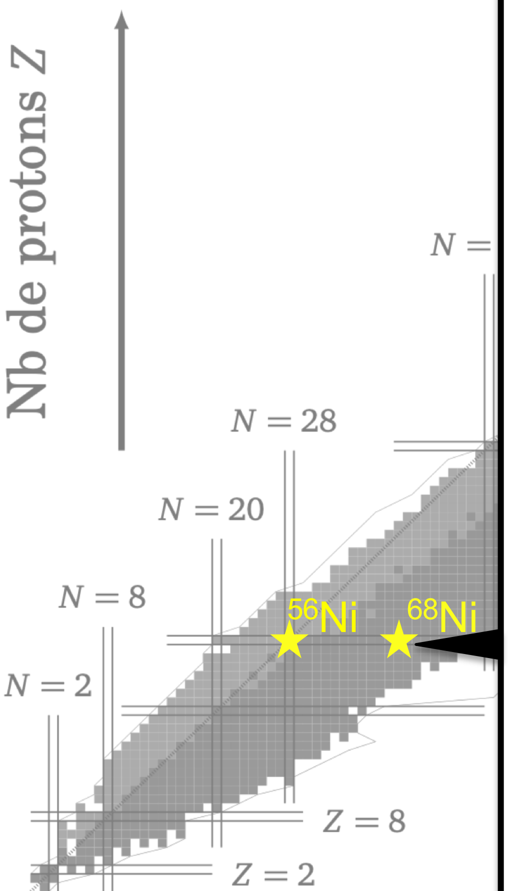
No extracted EWSR



M. Vandebrouck *et al.*, Phys. Rev. Lett. 113, 032504 (2014)

M. Vandebrouck *et al.*, Phys. Rev. C. 92, 024316 (2015)

ISGMR results in unstable nuclei with MAYA

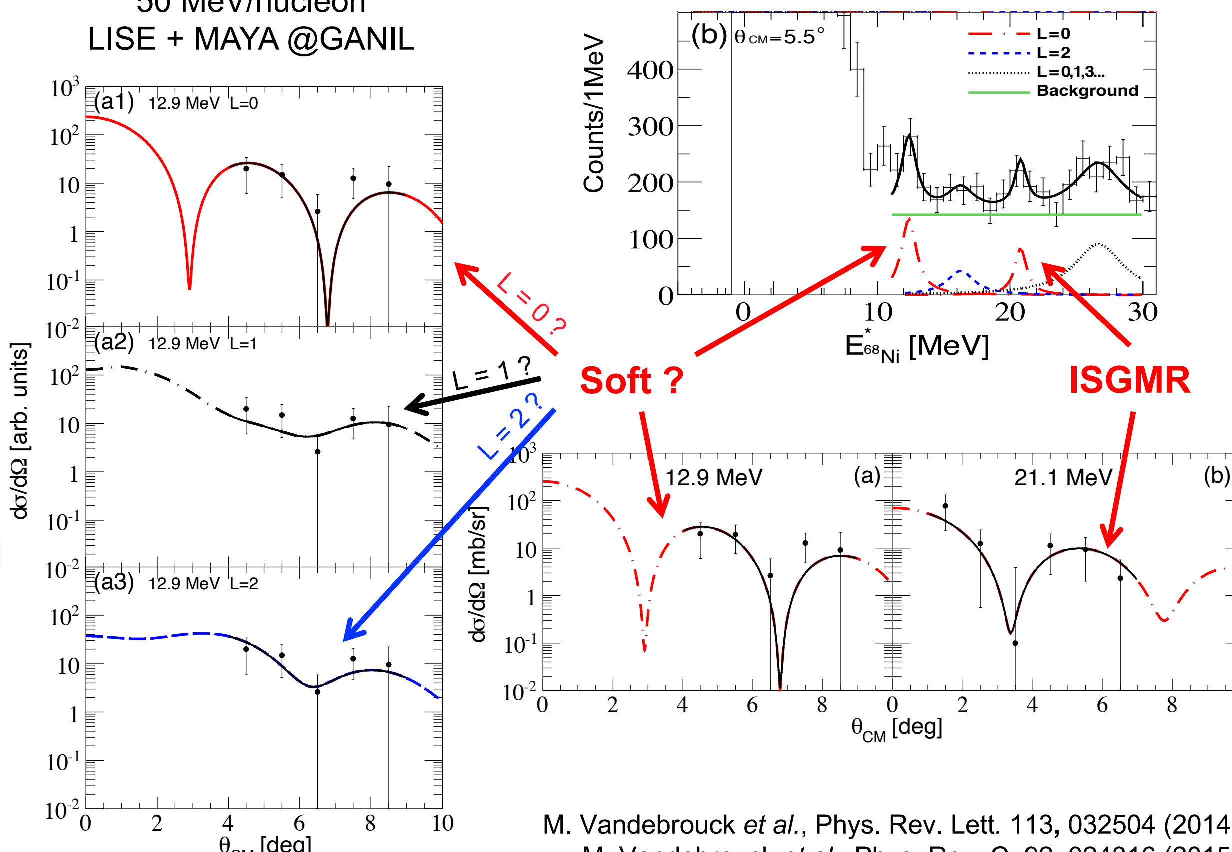


2010

^{68}Ni

^{68}Ni + d → d’ + ^{68}Ni*
^{68}Ni + α → α’ + ^{68}Ni*
50 MeV/nucleon
LISE + MAYA @GANIL

E*(^{68}Ni)$_{ISGMR}$ = 20.9 ± 1.0 MeV (d,d’)
E*(^{68}Ni)$_{ISGMR}$ = 21.1 ± 1.9 MeV (α,α’)
No extracted EWSR



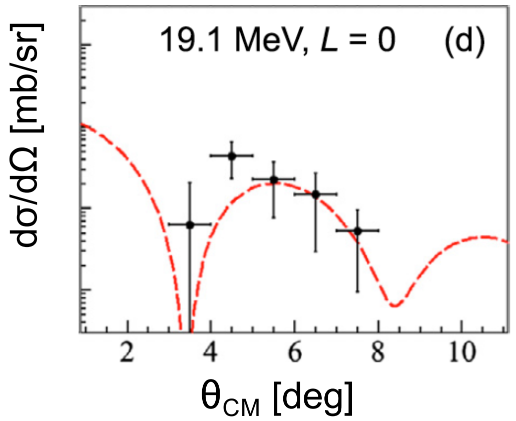
M. Vandebrouck *et al.*, Phys. Rev. Lett. 113, 032504 (2014)
M. Vandebrouck *et al.*, Phys. Rev. C. 92, 024316 (2015)

ISGMR results in unstable nuclei with MAYA

2011

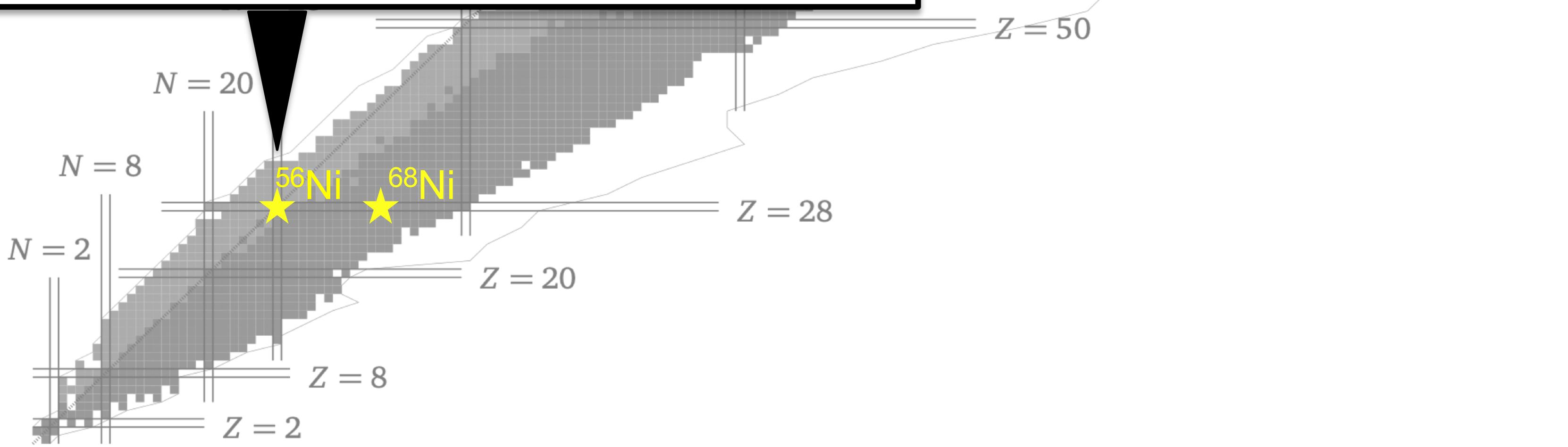
^{56}Ni

$^{56}Ni + \alpha \rightarrow \alpha' + ^{56}Ni^*$
50 MeV/nucleon
LISE + MAYA @GANIL

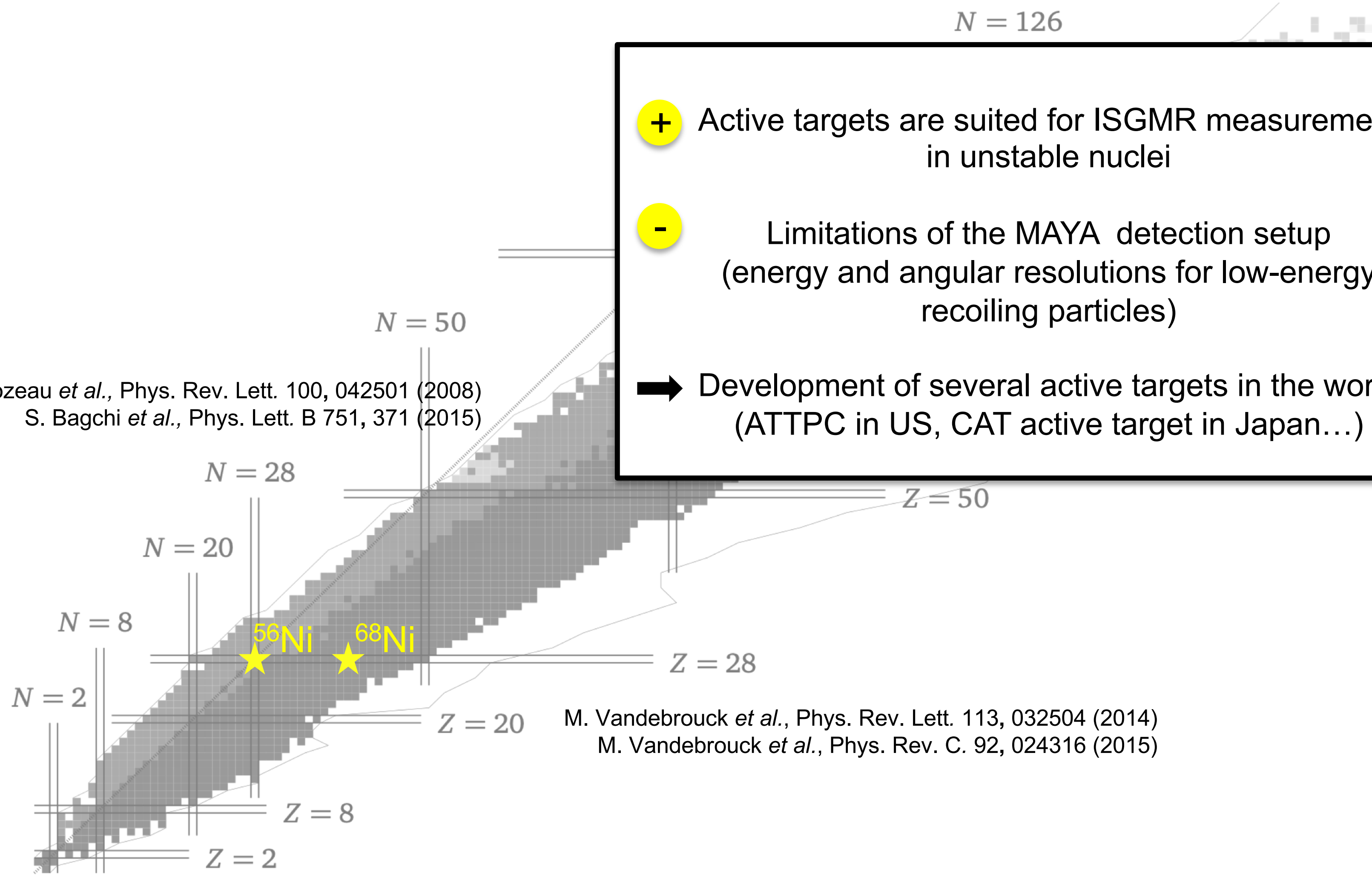


$E^*(^{56}Ni)_{ISGMR}$ = 19.1 ± 0.5 MeV
$EWSR(^{56}Ni)_{ISGMR}$ = 240 ± 120 %

S. Bagchi *et al.*, Phys. Lett. B 751, 371 (2015)



ISGMR results in unstable nuclei with MAYA



C. Monrozeau *et al.*, Phys. Rev. Lett. 100, 042501 (2008)
S. Bagchi *et al.*, Phys. Lett. B 751, 371 (2015)

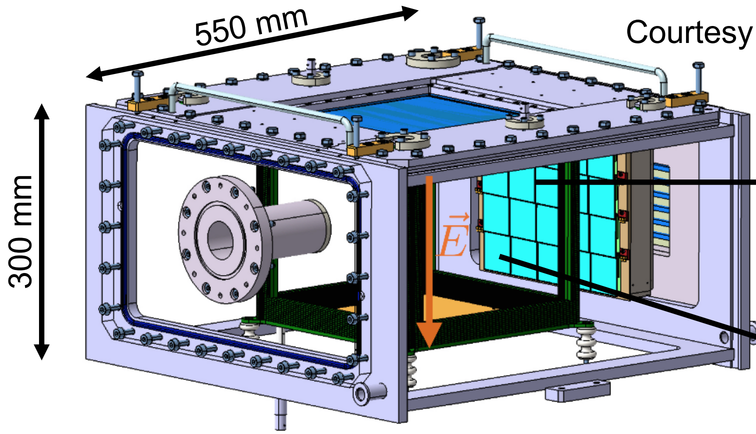
\+ Active targets are suited for ISGMR measurement in unstable nuclei

\- Limitations of the MAYA detection setup (energy and angular resolutions for low-energy recoiling particles)

➡ Development of several active targets in the world (ATTPC in US, CAT active target in Japan…)

M. Vandebrouck *et al.*, Phys. Rev. Lett. 113, 032504 (2014)
M. Vandebrouck *et al.*, Phys. Rev. C. 92, 024316 (2015)

The ACTAR TPC at GANIL

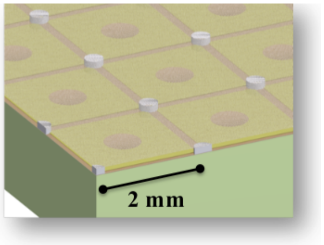


Courtesy T. Roger

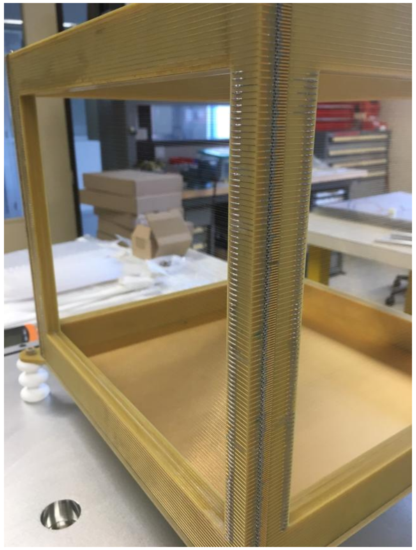
✓ Amplification region

- Micromegas gas amplifier
- Pad plane : 128x128 square pads of 2x2 mm^2

(16 384 channels to read !)

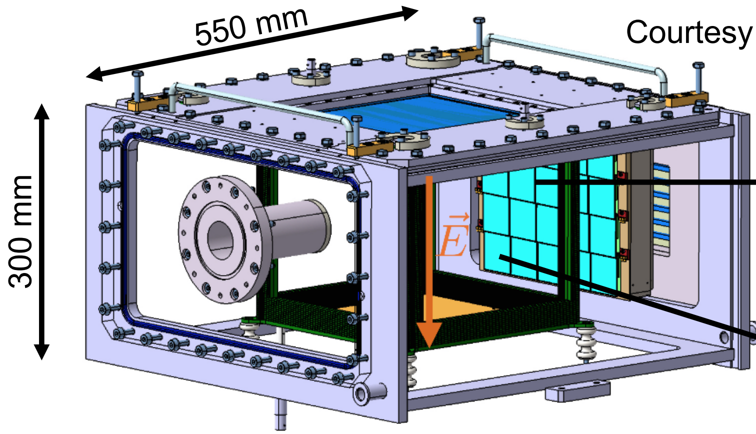


✓ Drift region



T. Roger *et al.*, NIMA 895, 126 (2018)
B. Mauss *et al*. NIMA 940, 498 (2019)

The ACTAR TPC at GANIL



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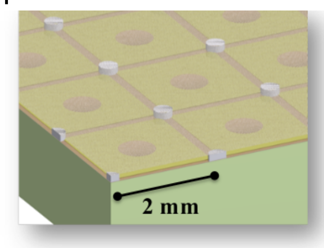


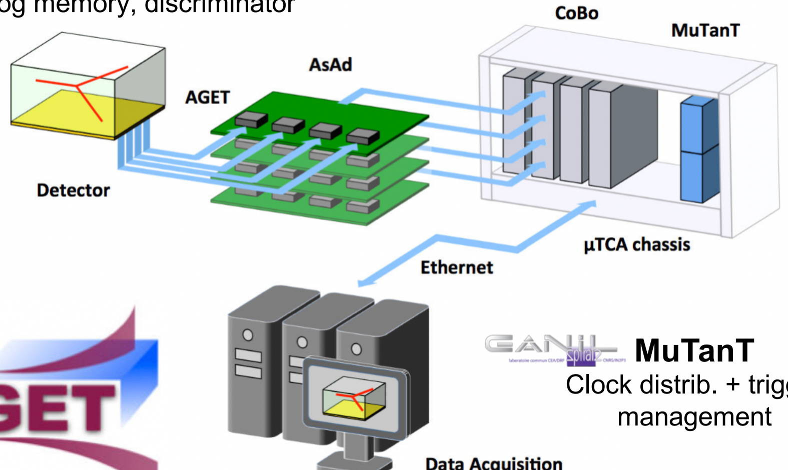
✓ Drift region

T. Roger *et al.*, NIMA 895, 126 (2018)
B. Mauss *et al*. NIMA 940, 498 (2019)

AGET
64 channels signal processing (CSA + shaper), analog memory, discriminator

ENBG **AsAd**
4 AGET chips + ADC

NSCL **CoBo**
4 AsAd boards digital data management



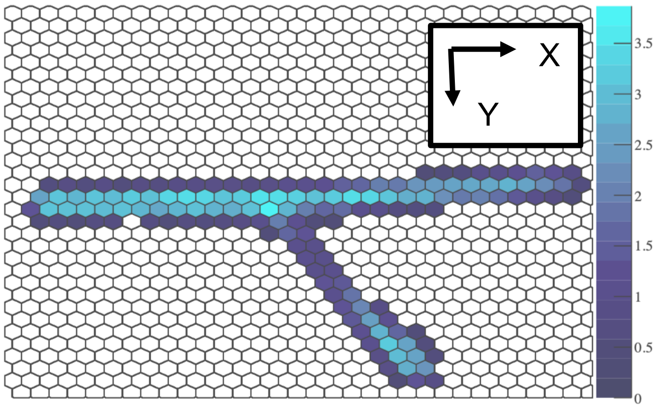
GET

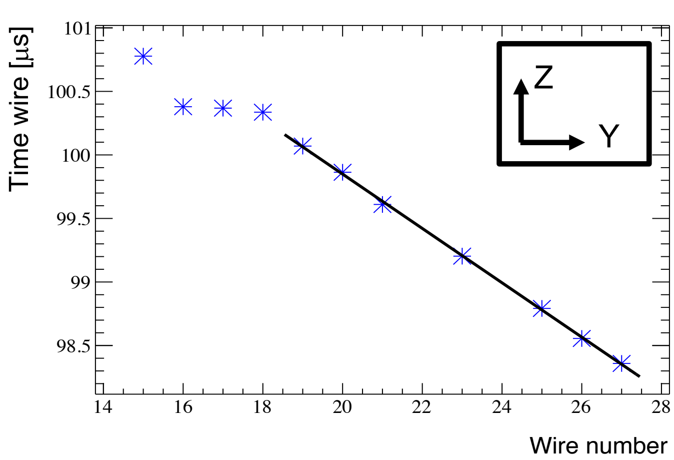
GANIL **MuTanT**
Clock distrib. + trigger management

E. C. Pollacco *et al.*, NIMA 887, 81 (2018)

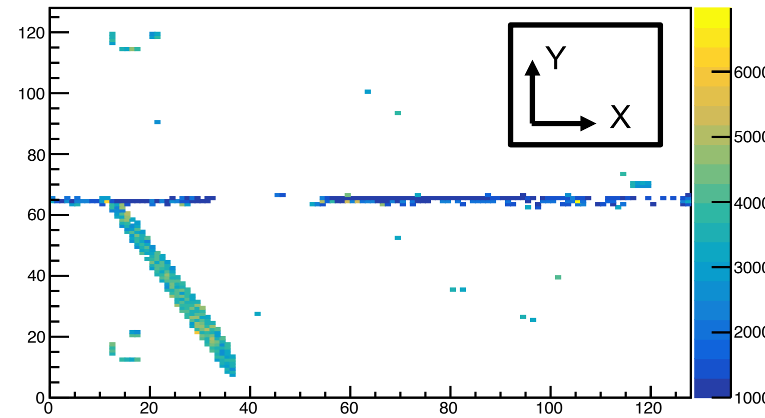
Typical events with MAYA vs ACTAR TPC

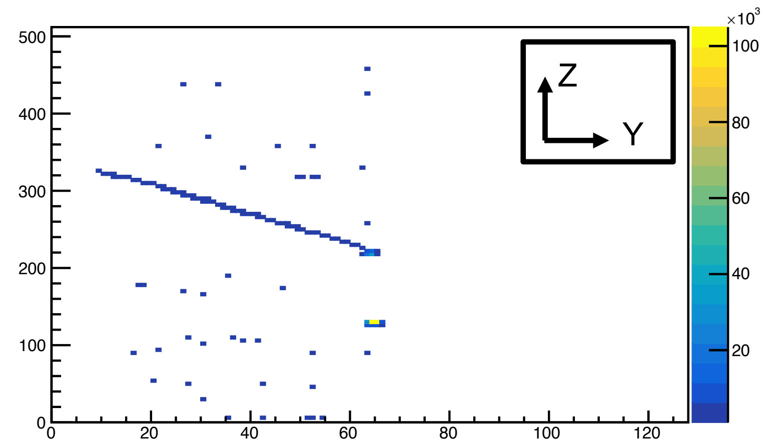
MAYA





actar TPC





ISGMR measurement in unstable nuclei with ACTAR TPC

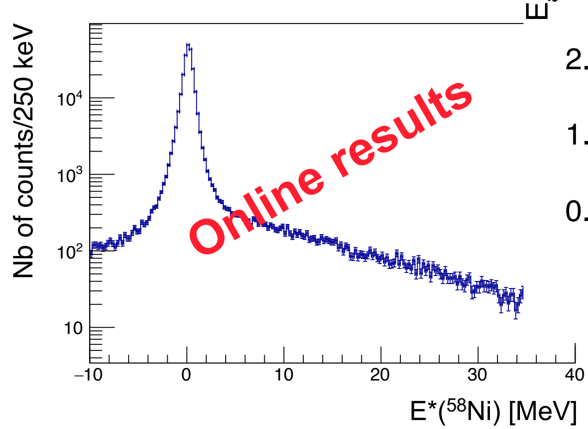
May 2019 ^{58}Ni

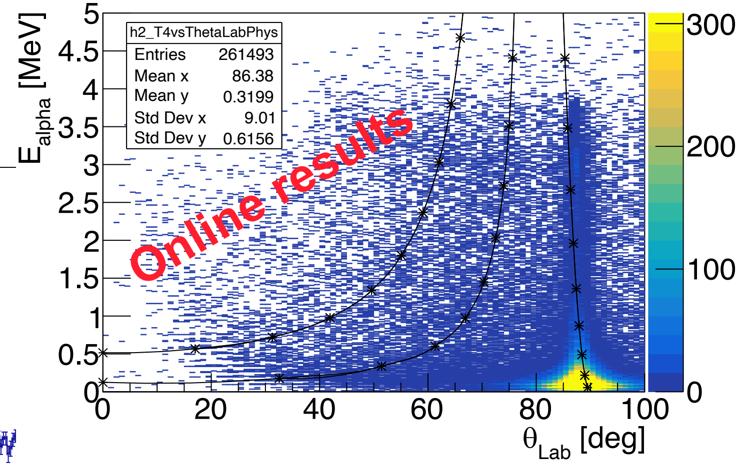
KU LEUVEN

Anchor point experiment

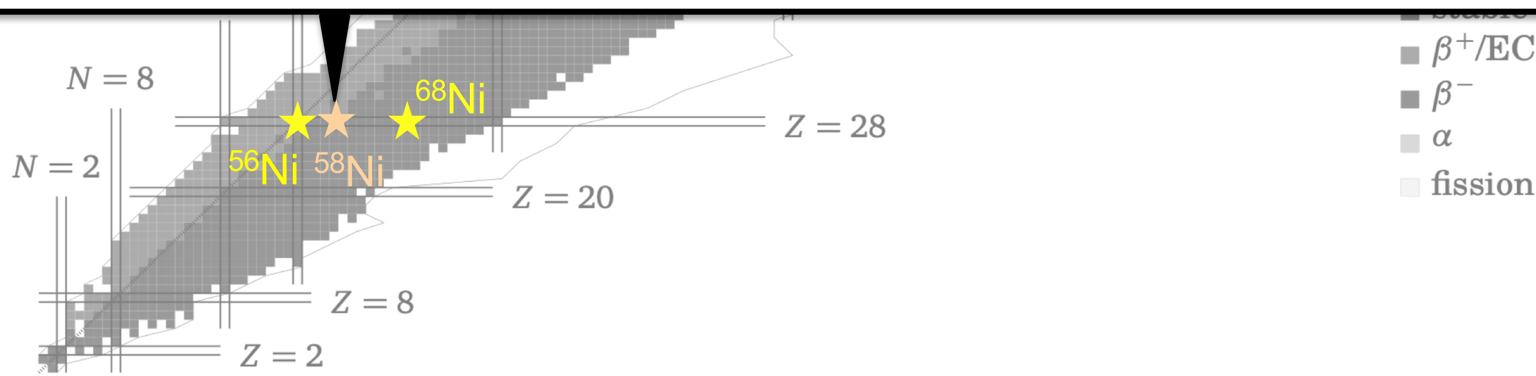
$^{58}Ni + \alpha \rightarrow \alpha' + {}^{58}Ni^*$
(inverse kinematics)
50 MeV/nucleon
LISE + ACTAR TPC @GANIL

To be compared with results in direct kinematics
(Y. W. Lui *et al*. PRC 73, 014314 (2006)
B.K. Nayak *et al*. PLB 637 (2006))

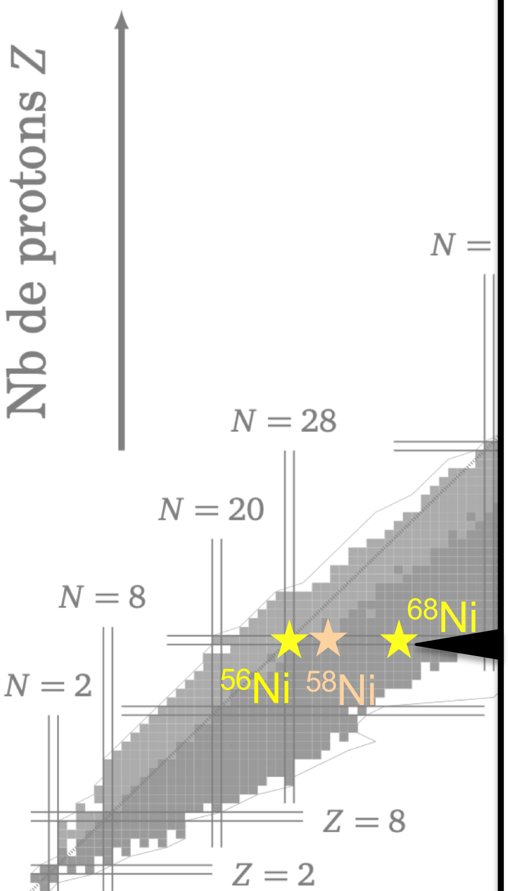




Resolution of the elastic peak :
~ 1 MeV FWHM (~ 3 MeV with MAYA)



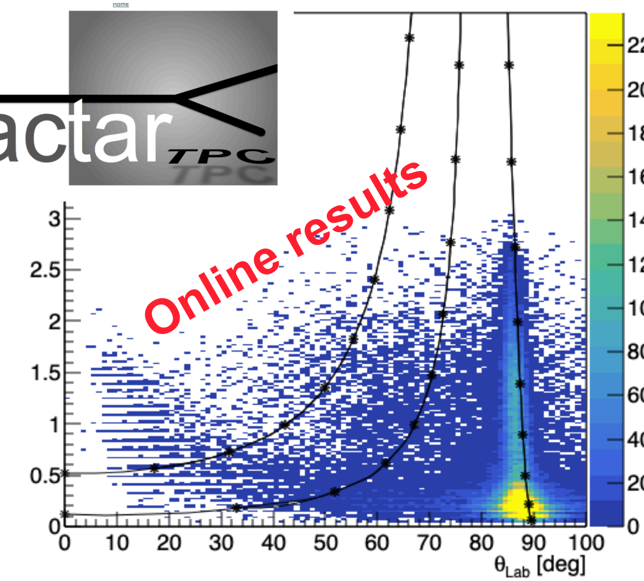
ISGMR measurement in unstable nuclei with ACTAR TPC

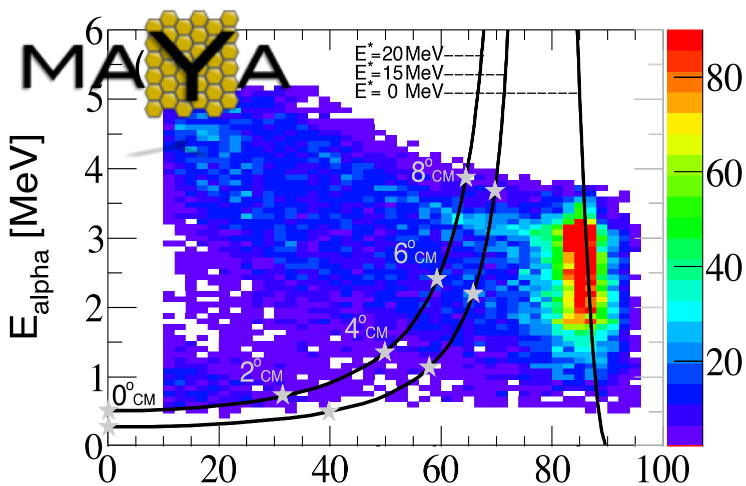


July 2019 ^{68}Ni

KU LEUVEN

^{68}Ni + α → α' + ^{68}Ni*
50 MeV/nucleon
LISE + ACTAR TPC @GANIL





Energy threshold :
~ 100 keV (600 keV with MAYA)

Ongoing analysis by A. Arokiaraj (KU Leuven)

✓ Clustering

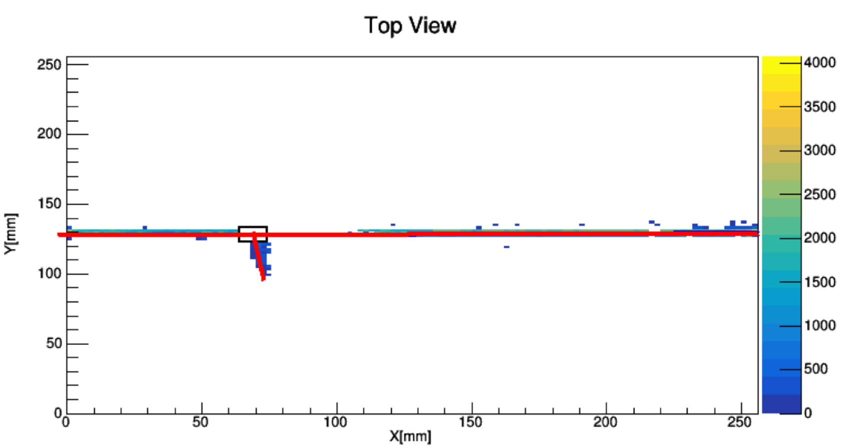
Use of a machine-learning tool : DBSCAN, a density-based clustering algorithm

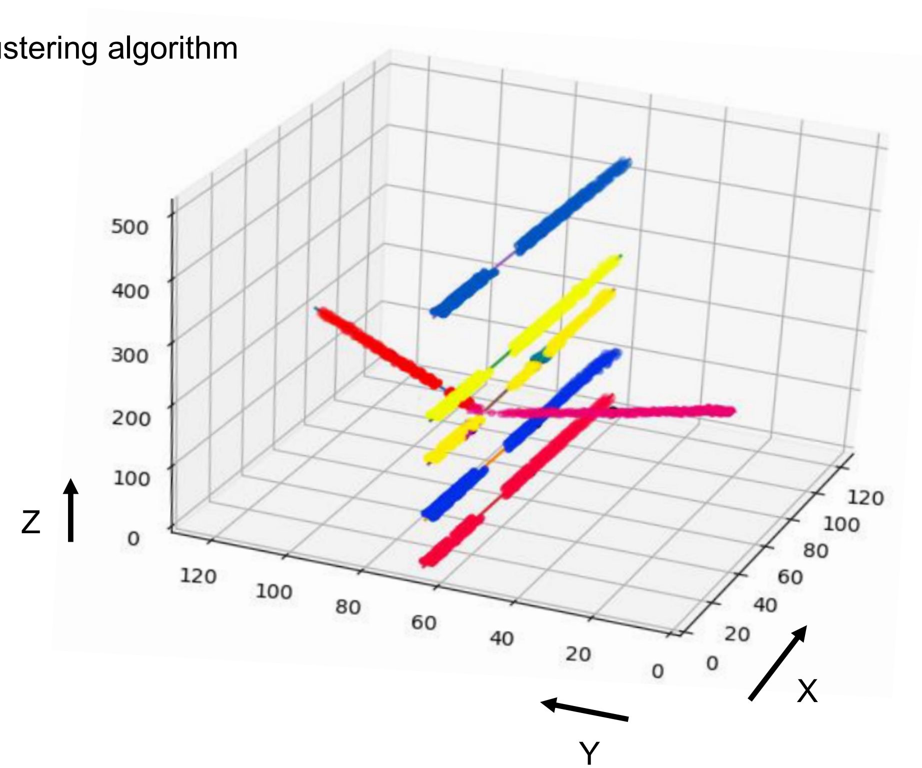
E. Schubert *et al.* ACM Trans. On Database Syst. 42 (2017)

✓ Merging of the clusters

Based on distance + angle between 2 clusters

✓ Fitting





Courtesy A. Arokiaraj

Conclusion

- ✓ Active targets are particularly suited for ISGMR measurements in unstable nuclei
- ✓ Other opportunity : experiments using storage rings (see N. Kalantar talk)

In the future…

- ✓ Data analysis ^{58}Ni(α,α')^{58}Ni* and ^{68}Ni(α,α')^{68}Ni experiments with ACTAR
- ✓ ^{70}Ni (α,α')^{70}Ni* with ATTPC at MSU

- ✓ Study of ISGMR isotopic – isotonic chains
- ✓ Study of soft modes in ^{36}S and ^{34}Si (see O. Sorlin talk)