# Analysis of High-Energy (p,p') data on $^{12}C$ for the PANDORA Project


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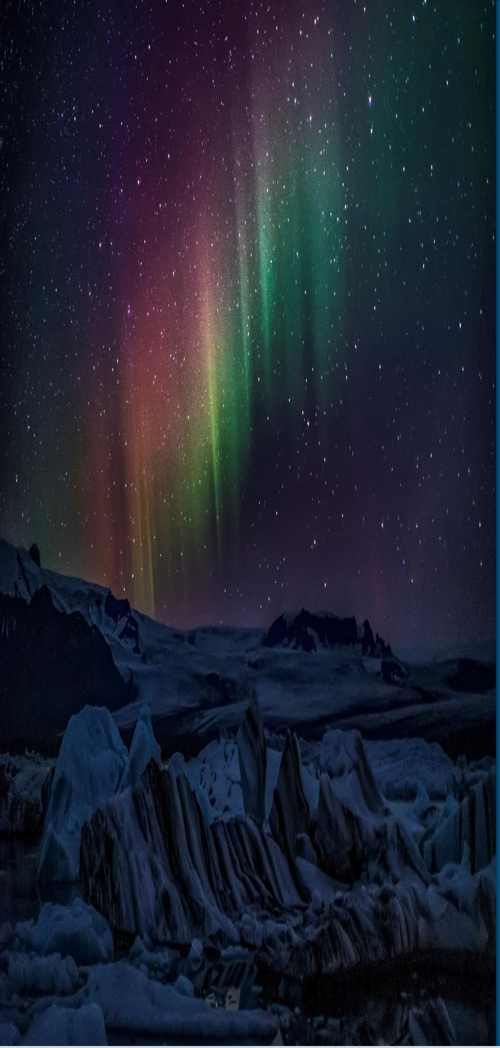
Gamma Driven Experiments Department



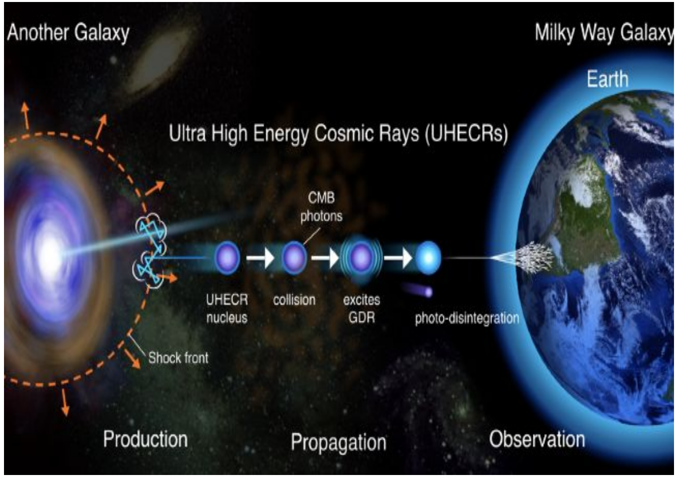
# Overview

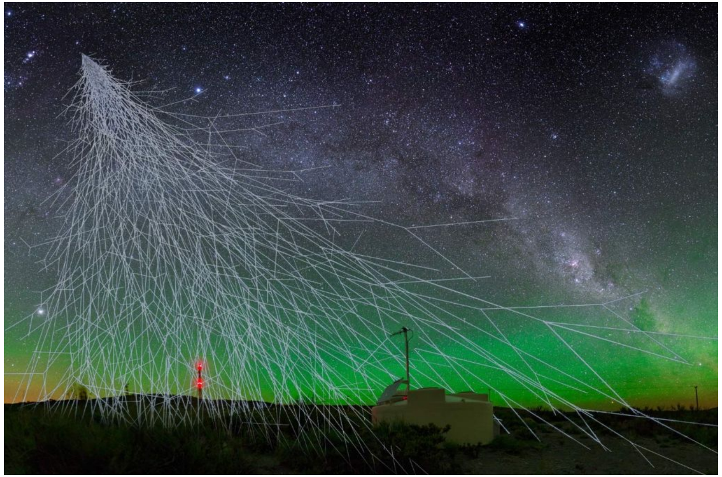
- What is the PANDORA Project?
- Motivation
- Experimental setup
- $^{12}$C(p,p’) measurements
- Summary
- Future prospects

Photo-Absorption of Nuclei and Decay Observation for Reactions in Astrophysics

# What is the PANDORA Project?

The purpose of the PANDORA collaboration lies in investigating the photo-disintegration and energy loss processes of nuclei with mass below A=56.

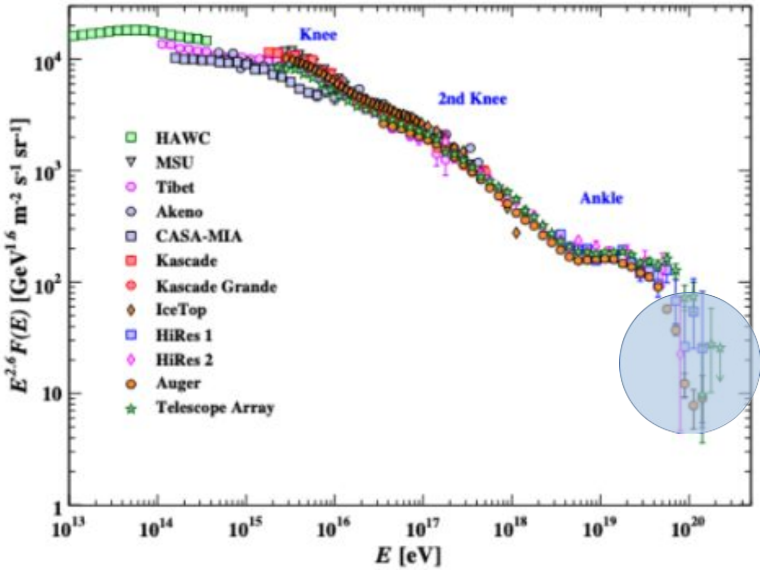


Pierre Auger Observatory
Telescope Array

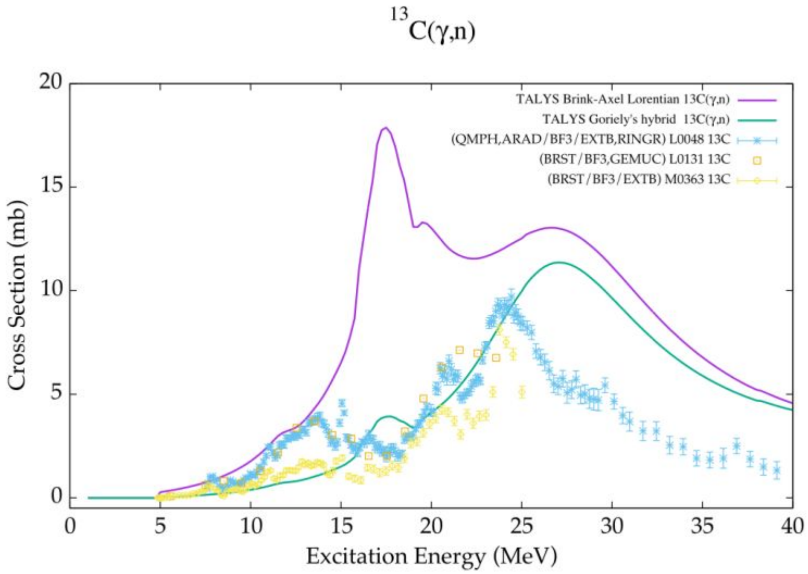
# Motivation

- We don’t have enough data.
- And the data we do have is inconsistent, incomplete.



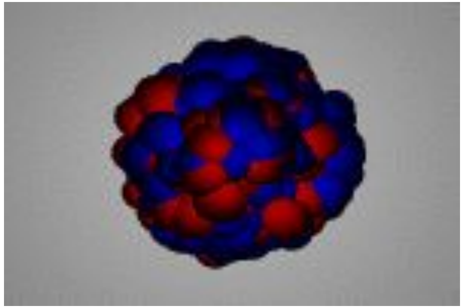

* PAea Zyla, R.M. Barnett, J. Beringer, O. Dahl, D.A. Dwyer, D.E. Groom, C-J Lin, K.S. Lugovsky, E. Pianori, et al., Review of particle physics. Progress of Theoretical and Experimental Physics, 8(2020)

- Origin?
- How these energetic particles get accelerated?
- Started collecting data about their composition



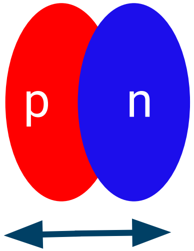

*Otuka, N., et al. "Towards a more complete and accurate experimental nuclear reaction data library (EXFOR) (2014): 272-276.

# Physical motivation



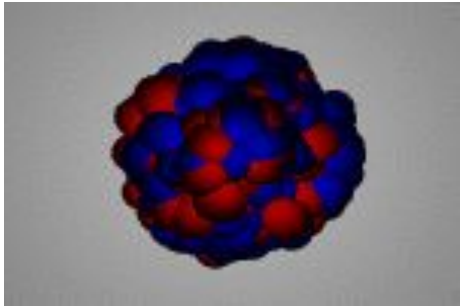
- IsoVector Giant Dipole Resonance (IVGDR)

What is it?




1. Reduces transition probability B(E1)
2. Dipole polarisability
3. Gamma strength function

# Physical motivation



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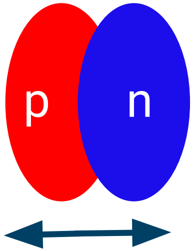
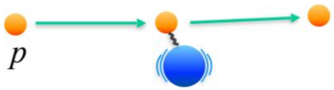



What methods do excite it?

1. Real photons


2. Virtual photons



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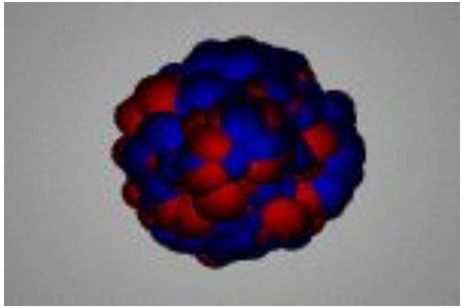


- IsoVector Giant Dipole Resonance (IVGDR)

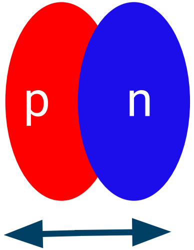
Where?

ELI-NP
Bucharest

RCNP
Osaka

iThemba LABS
Cape Town

What is it?

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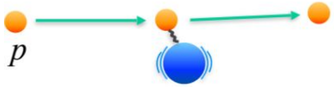
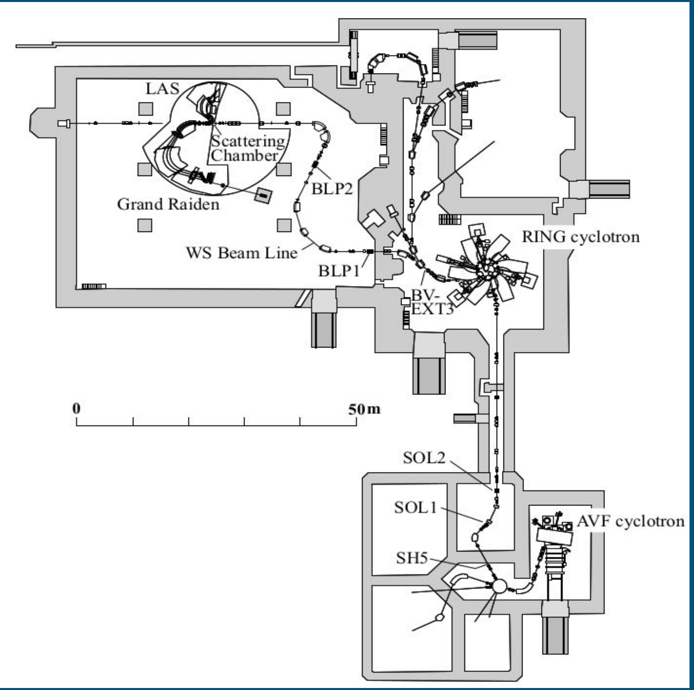


# Experimental setup

# Overview of the RCNP facility




* proton beam at 392 MeV

* WS-course, GRAF beam-line

* Grand Raiden at 4.5 deg

* Silicon detector array (SAKRA)

* Targets: $^{12}$C (1 mg/cm$^2$), $^{13}$C (1.6 mg/cm$^2$), blank-frame

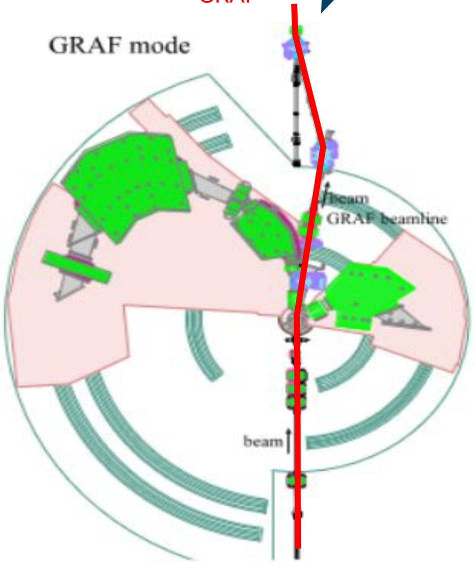

First experiments within the PANDORA Project

# The Grand-Raiden Spectrometer (GR)

Downstream

Beam dump

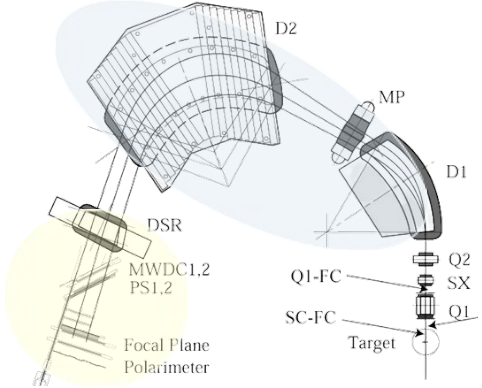
GRAF



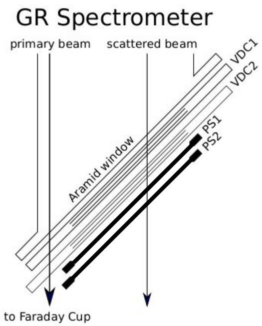

Upstream

p beam ;
392 MeV;
~1nA;

P. von Neumann-Cosel, A. Tamii, Eur. Phys. J. A 55, 110 (2019)




Equipped with several magnets (dipole, quadrupole and sextupole magnet) for scattered proton deflection

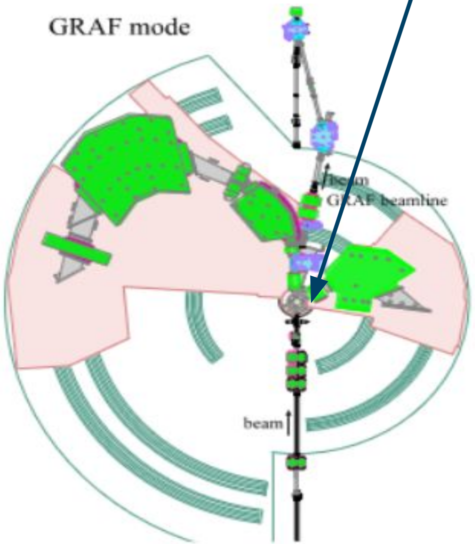



The focal plane (FP) detector consists of two multi-wire drift chambers (VDCs) and two 10mm-thick plastic scintillators

# The Grand-Raiden Spectrometer (GR)

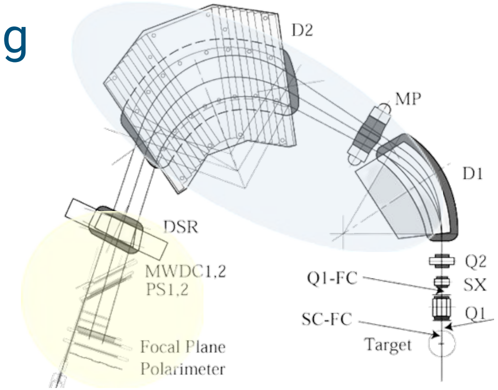
Downstream

Scattering chamber




Upstream

P. von Neumann-Cosel, A. Tamii, Eur. Phys. J. A 55, 110 (2019)

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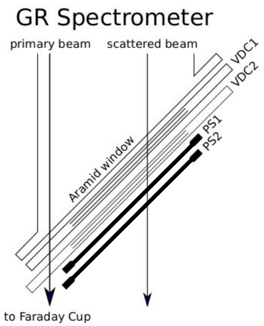


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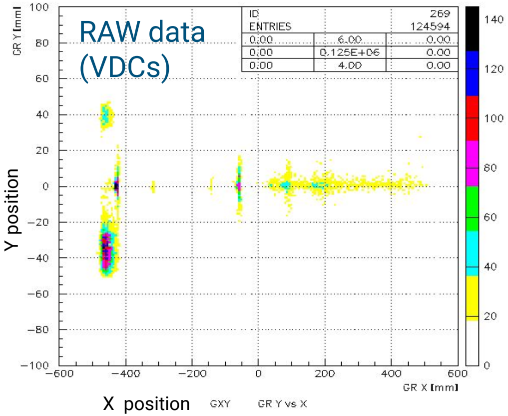
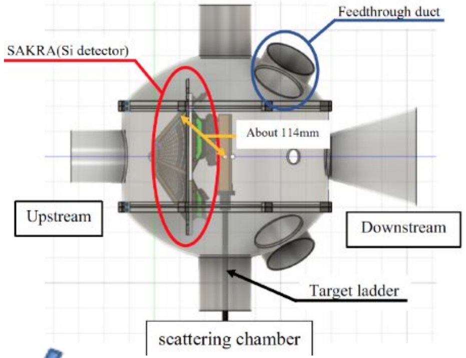
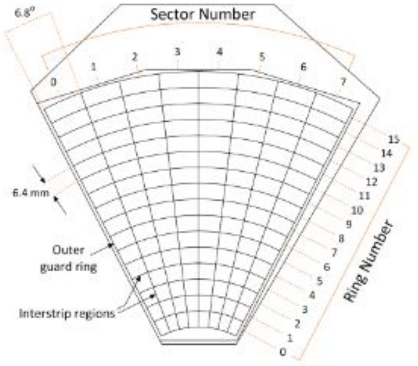


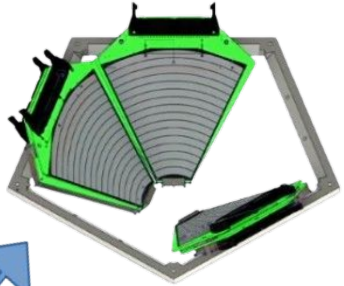



# SAKRA Array

**In the text experiment we only used 3 sets but in the final configuration for the real experiment there will be 5 sets in a lamp shade configuration**




Silicon detector array (SAKRA), 6 sets of DSSSDs (500μm-MMM) placed at a backward angle arranged in 3 telescopes



2 layers of silicon detectors are used for △E-E measurements for PID

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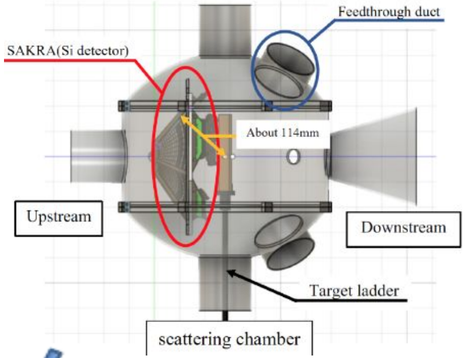


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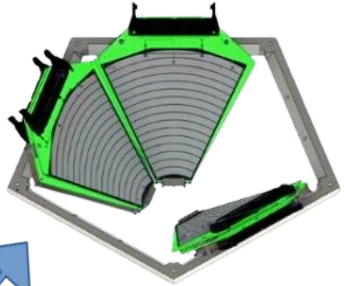
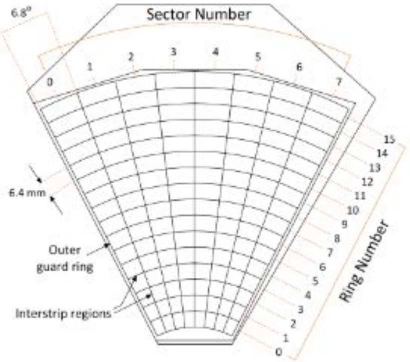
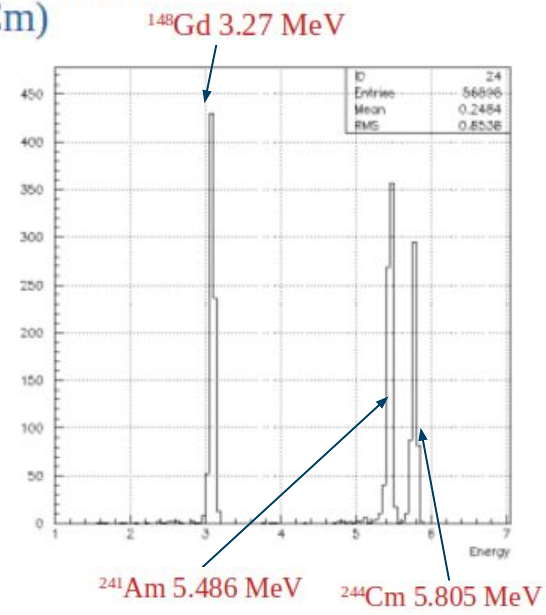





*Source data: mixed 3-alpha sources ( $^{148}$Gd, $^{241}$Am, $^{244}$Cm)

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# The GR analysis

# Data obtained in the GR focal plane

Y gate

**“Good events”**

- **We want to select events that have done 0 deg elastic scattering and that are properly reconstructed in the trajectory of the spectrometer**

- **We know that the events of interest are located from -10 to 10 mm in the vertical position**

- **In this θ vs X position we need a θ correction depending on the angle**

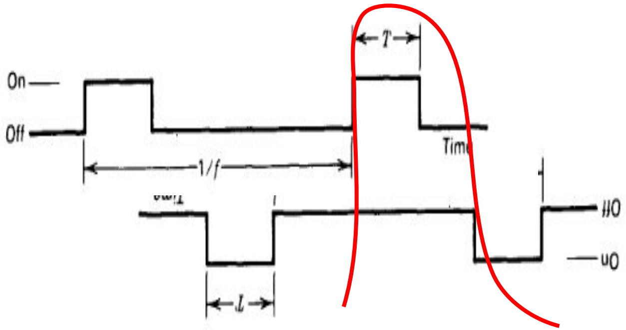
X position (mm)

# Data obtained in the Plastic Scintillators

RAW ToF uncorrected

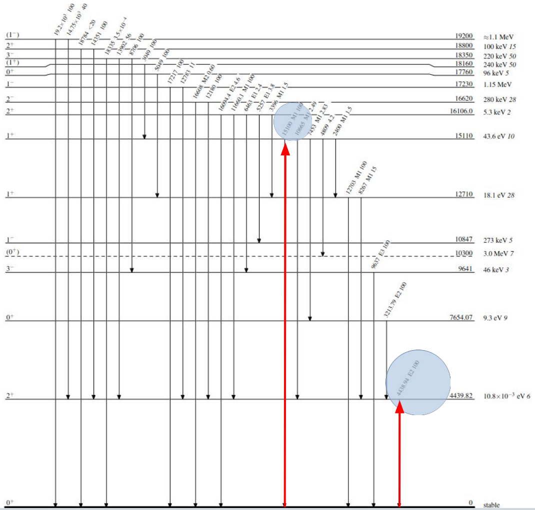
Ungated events

- If we gate the two structures we see in ToF vs energy loss in PS1 in the FP where the effect of the Y gate can be seen we have good events left



# X position energy calibration

X position



Excitation energy (MeV)

**Linear calibration:**
**E=0.0285*x+16.6**

The Grand Raiden spectrometer was calibrated using known peaks from $^{12}C$ in the x focal plane.

# SAKRA Analysis

# Effects of the gate in GR

Without GR conditions

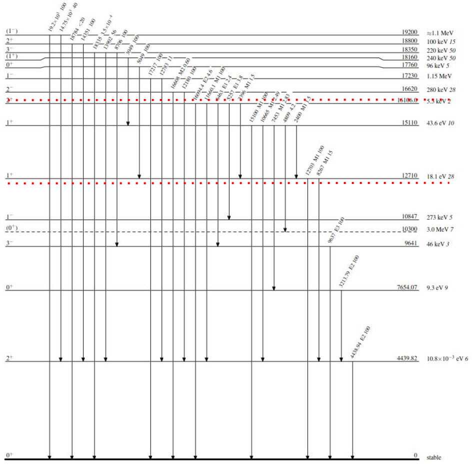
With PID and Y gate

We can correlate the events and can use the GR to select the good events in SAKRA

# ΔE − E measurements for particle identification

TOF measurements between SAKRA and RF signal

Low energy particles stop in the ΔE detector




$^{12}C$

We check again if the assumed gated can separate the proton and alphas.

This shows that you can use ToF to select p structures and α-like structures

# Conclusions:

1. The text experiment was a successful and this opened the way of the first PANDORA experiment
2. In this test experiment we assessed the TOF and $\Delta E - E$ were used for particle experiments and  the results are conclusive
3. We read and understand the data from all the experimental detectors : GR, focal place detectors, ToF detectors, Multi-wire trackers and SAKRA.
4. Full Pandora Experiment on $^{10}$B, $^{11}$B, $^{12}$C, $^{13}$C and $^{27}$Al was performed in October 2023.
5. We want to propose for another experiment at the RCNP to analyze other nuclei

AT et al, NIMA605, 326 (2009) published

# Thank you!

***PANDORA Project for the study of photonuclear reactions below A=56***

**A. Tamii, L. Pellegri, P.-A. Söderström, D. Allard, S. Goriely, T. Inakura, E. Khan, E. Kido, M. Kimura, E. Litvinova, S. Nagataki, P. von Neumann-Cosel, N. Pietralla, N. Shimizu, N. Tsoneva, Y. Utsuno, S. Adachi, P. Adsley, A. Bahini, D. Balabanski, B. Baret, J. A. C. Bekker, S. D. Binda, E. Boicu, A. Bracco, I. Brandherm, M. Brezeanu, J. W. Brummer, F. Camera, F. C. L. Crespi, R. Dalal, L. M. Donaldson, Y. Fujikawa, T. Furuno, H. Haoning, R. Higuchi, Y. Honda, A. Gavrilescu, A. Inoue, J. Isaak, H. Jivan, P. Jones, S. Jongile, O. Just, T. Kawabata, T. Khumalo, J. Kiener, J. Kleemann, N. Kobayashi, Y. Koshio, A. Kuşoğlu, K. C. W. Li, K. L. Malatji, R. E. Molaeng, H. Motoki, M. Murata, A. A. Netshiya, R. Neveling, R. Niina, S. Okamoto, S. Ota, O. Papst, E. Parizot, T. Petruse, M. S. Reen, P. Ring, K. Sakanashi, E. Sideras-Haddad, S. Siem, M. Spall, T. Suda, T. Sudo, Y. Taniguchi, V. Tatischeff, H. Utsunomiya, H. Wang, V. Werner, H. Wibowo, M. Wiedeking, O. Wieland, Y. Xu, and Z. H. Yang**