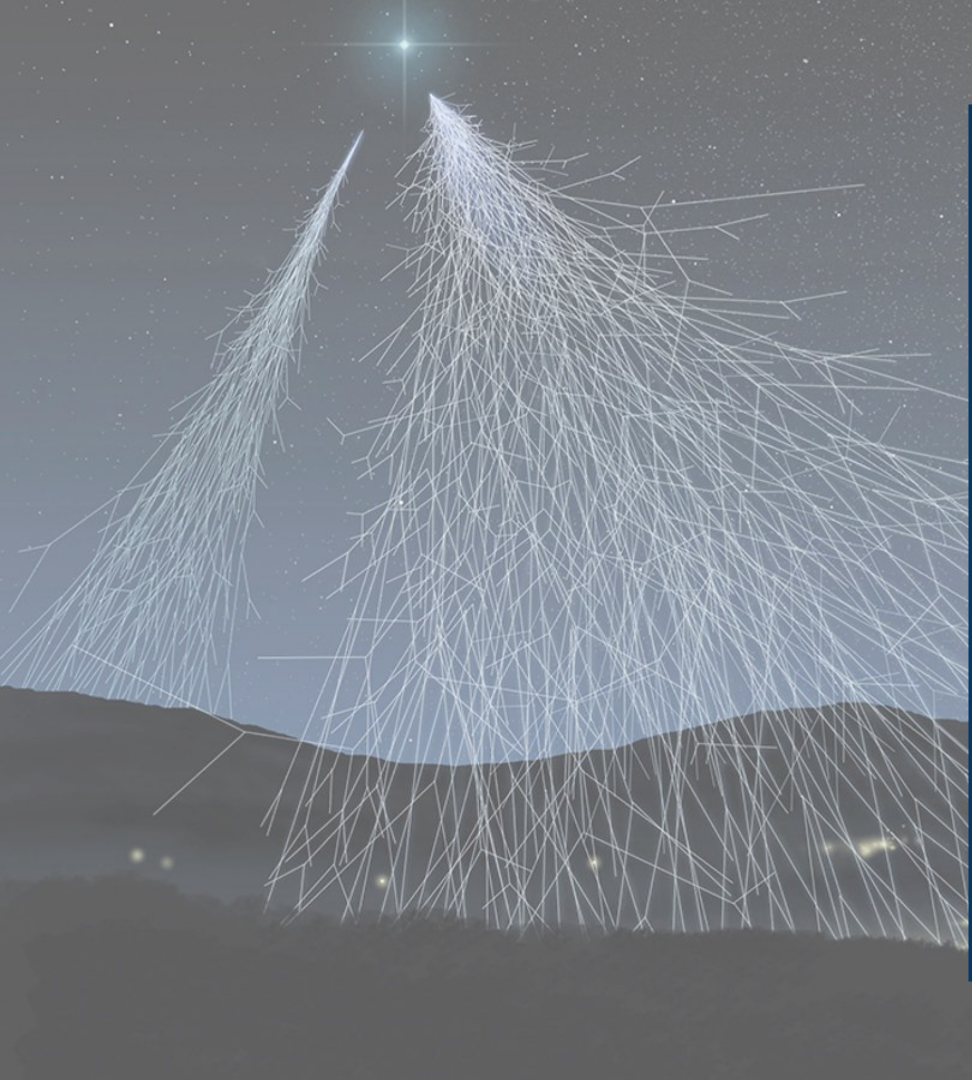

Analysis of High-Energy (p,p') data on $^{10,11}B$ for the PANDORA Project

ANDREEA GAVRILESCU

YOUNG RESEARCHERS AND YOUNG ENGINEERS DAYS 2025

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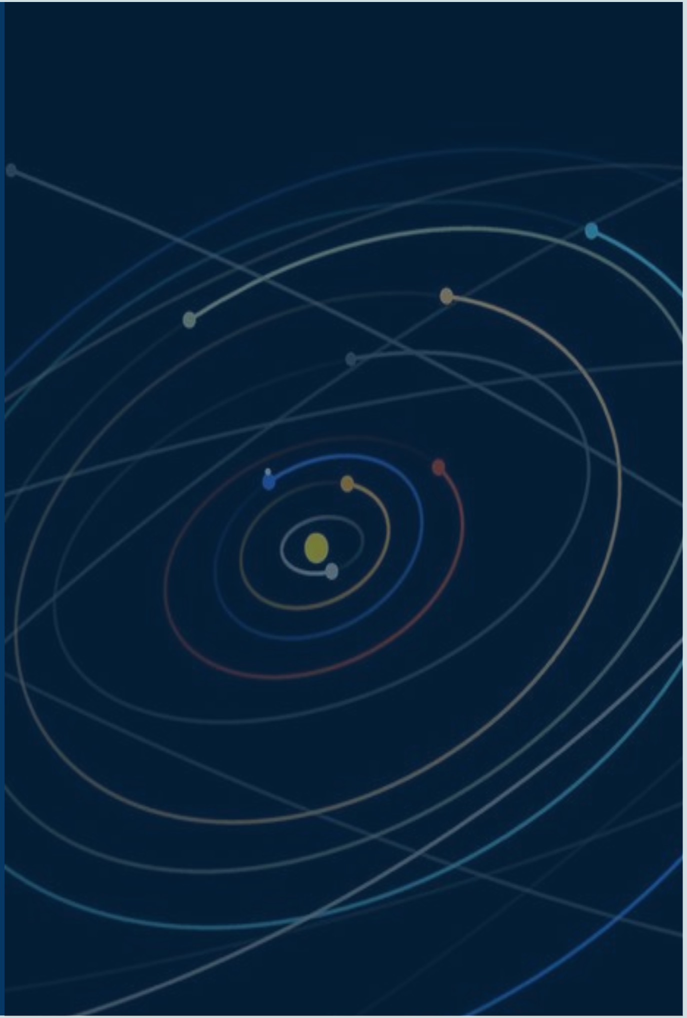

INTRODUCTION

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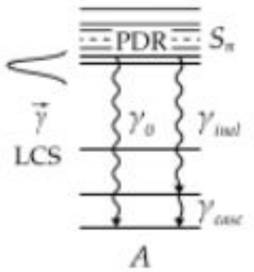
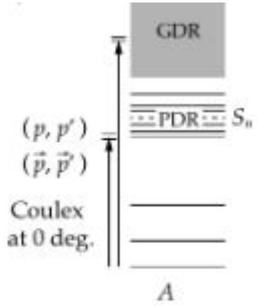


REAL PHOTONS



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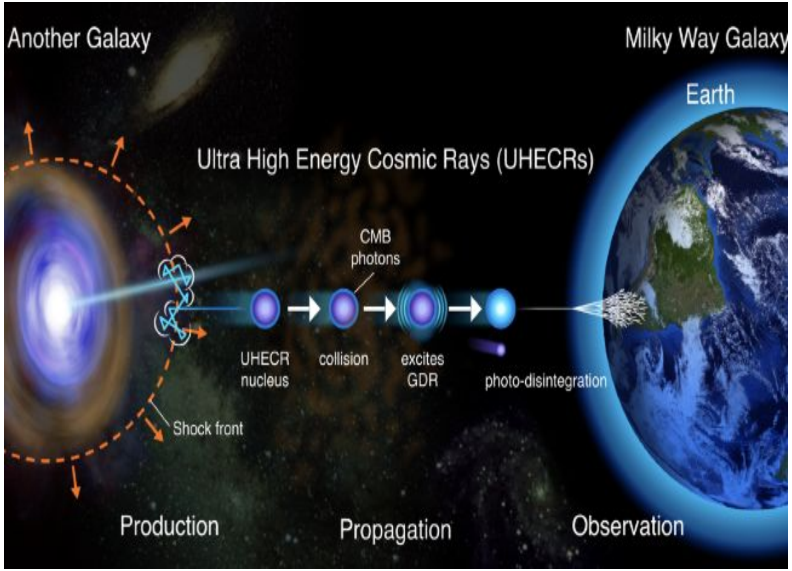
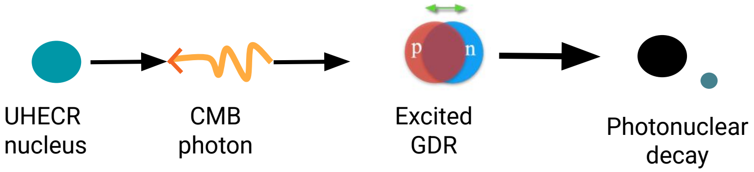


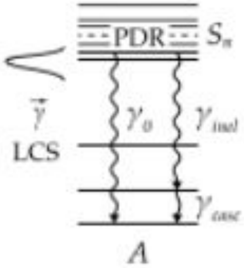


PANDORA
Photo-Absorption of Nuclei and Decay Observation for Reactions in Astrophysics

INTRODUCTION

- What is the PANDORA Project?

- photoabsorption cross-sections
- **p, n, α** and **γ** decay branching ratios
- stable nuclei A<60



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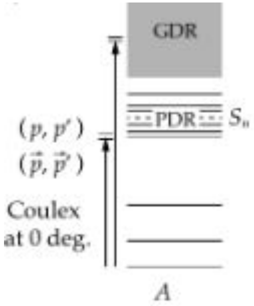

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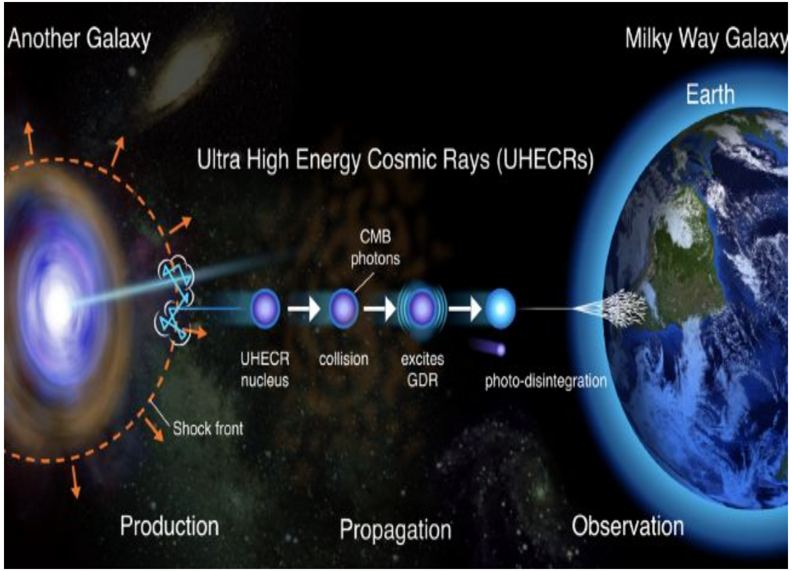

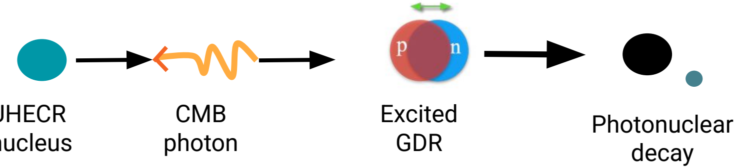

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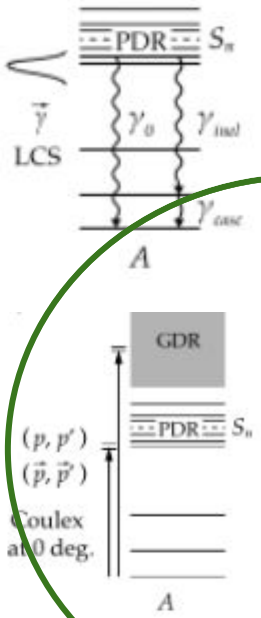

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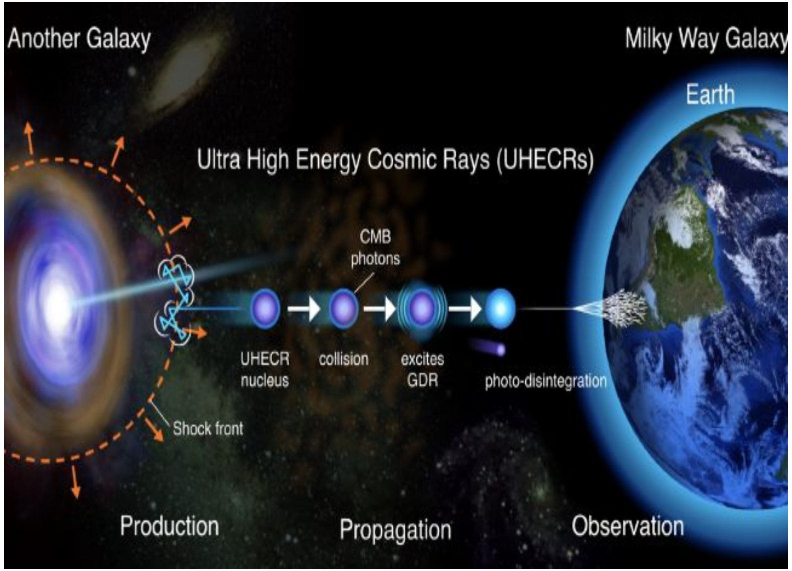

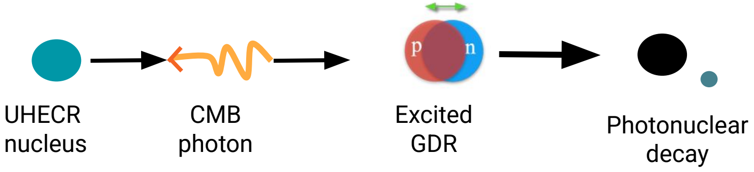

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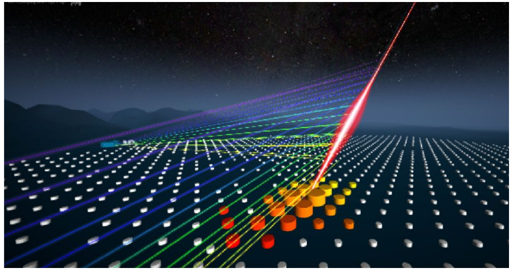
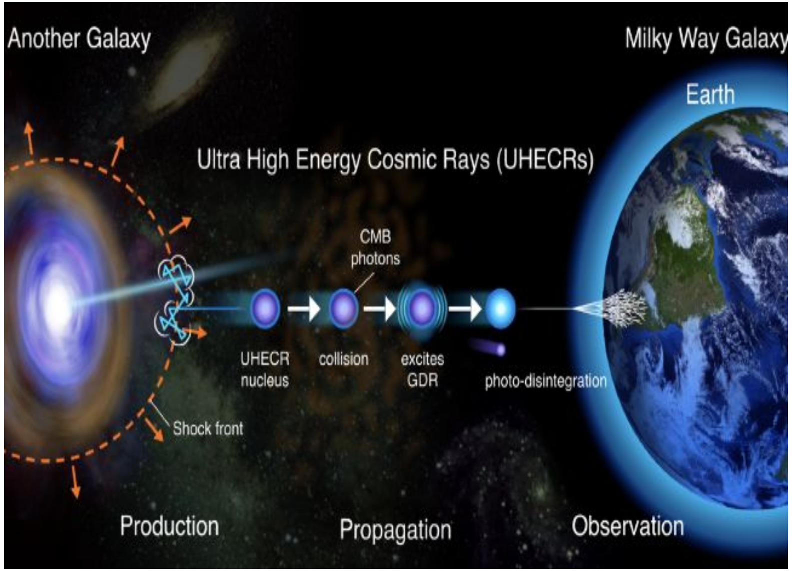
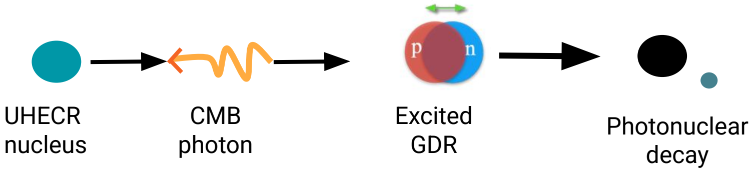
INTRODUCTION

- Short history



Telescope array
Pierre Auger Observatories





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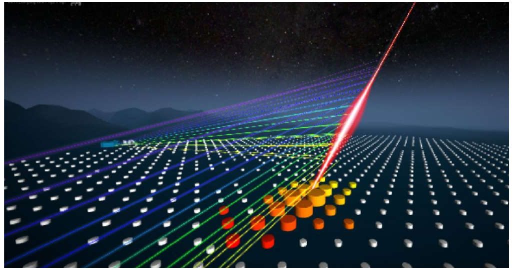

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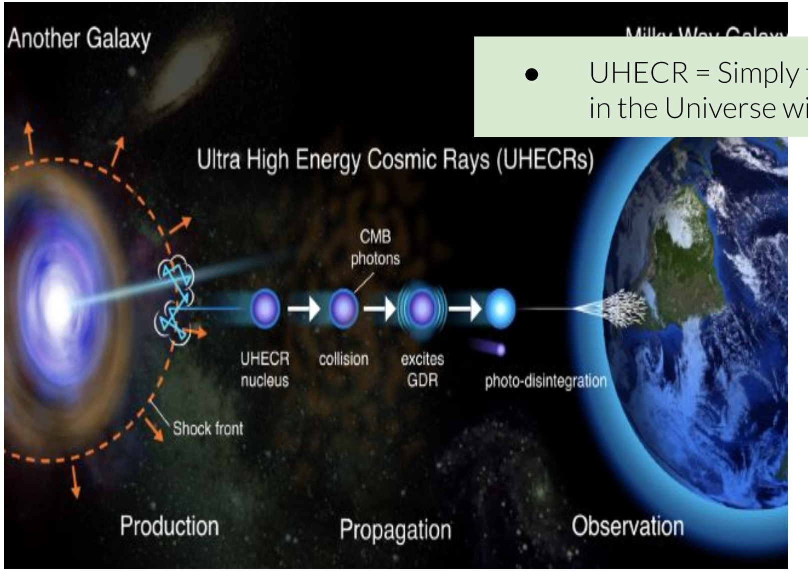
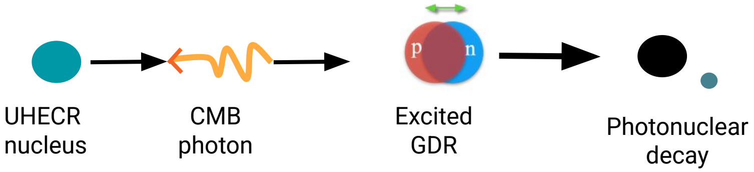


- UHECR = Simply the most energetic particles known in the Universe with energies above< 10^{18} eV



INTRODUCTION

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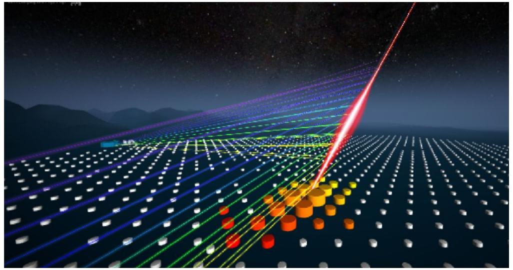

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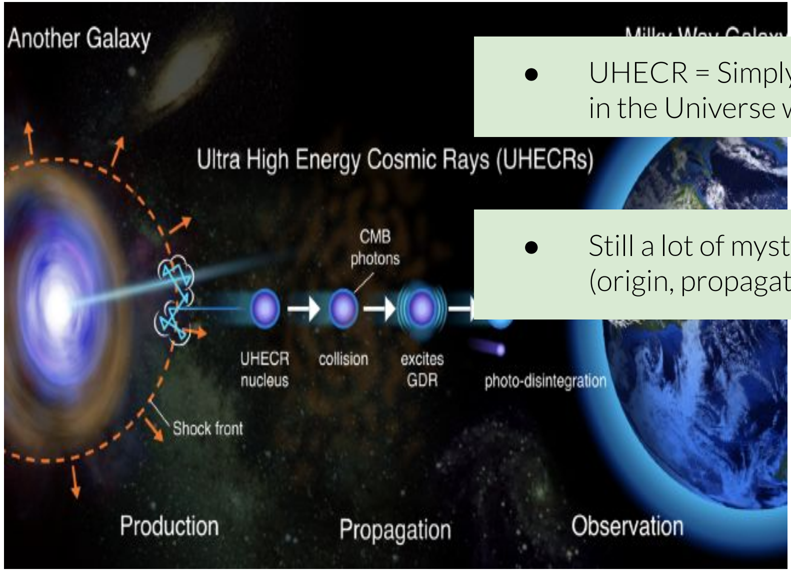
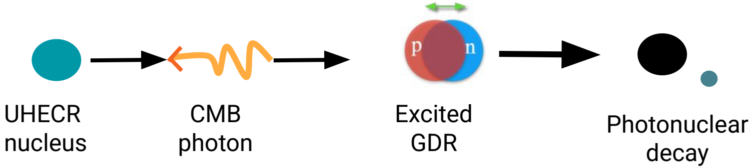


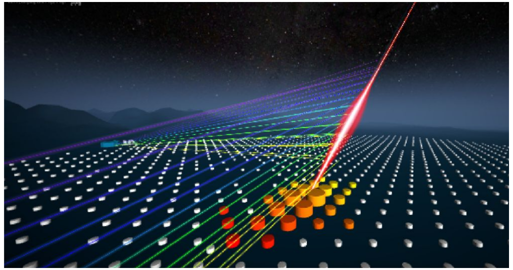
- UHECR = Simply the most energetic particles known in the Universe with energies above< 10^{18} eV

- Still a lot of mysteries associated with this topic (origin, propagation and composition)



INTRODUCTION

• Short history



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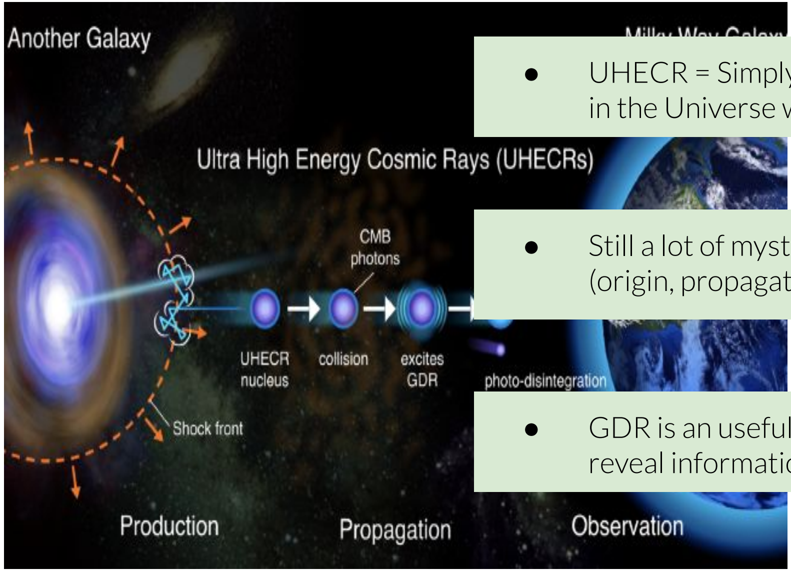
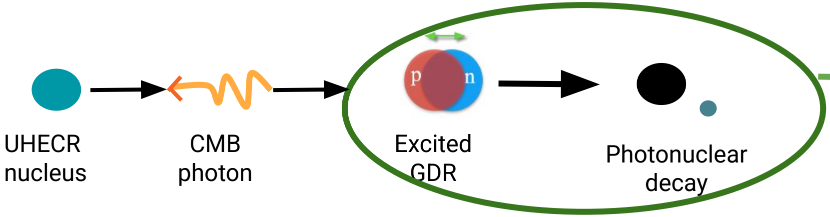
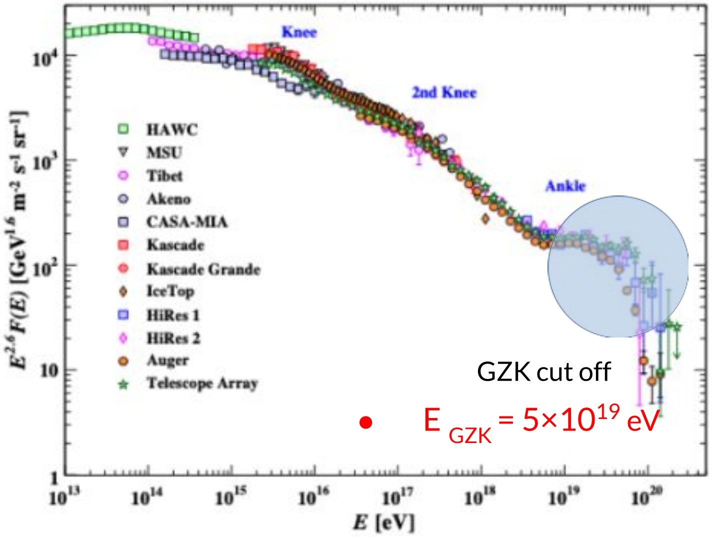


- UHECR = Simply the most energetic particles known in the Universe with energies above< 10^{18} eV
- Still a lot of mysteries associated with this topic (origin, propagation and composition)
- GDR is an useful tool in this case because it can reveal information related to photonuclear reactions



Energy loss & mass loss

MOTIVATION



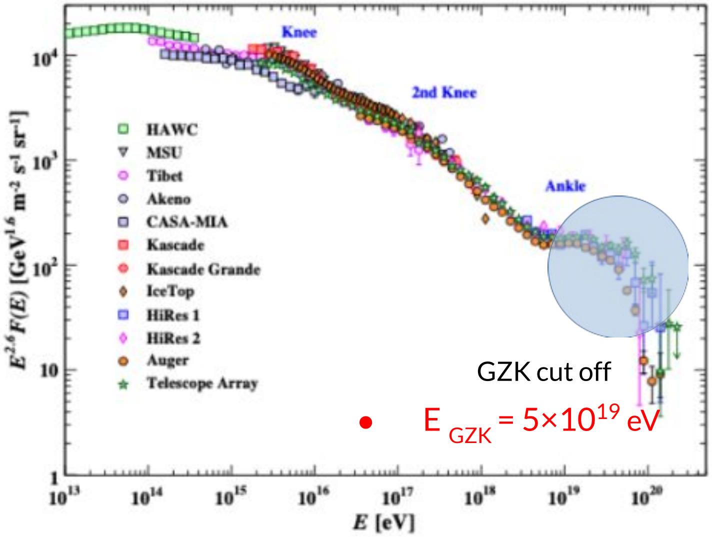
- $E_{GZK} = 5\times10^{19}$ eV

* 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)

- Try to understand their behaviour

- Why is this region so relevant?

MOTIVATION



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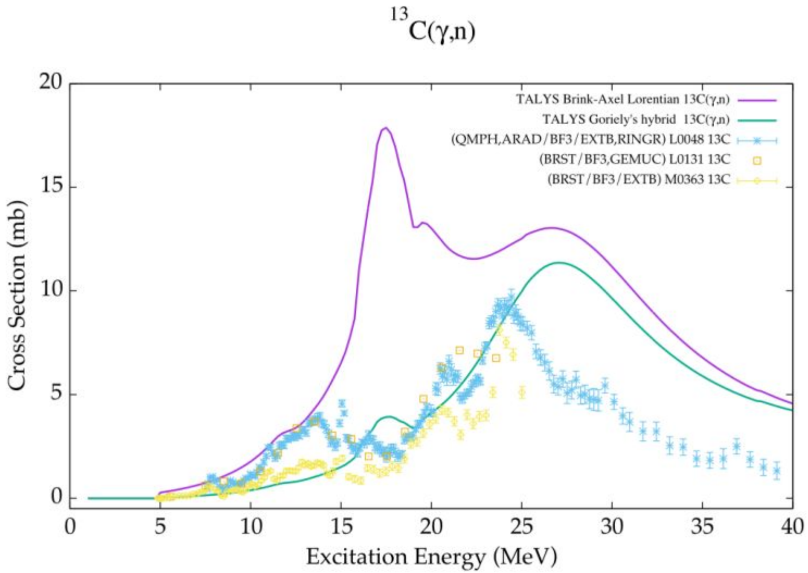
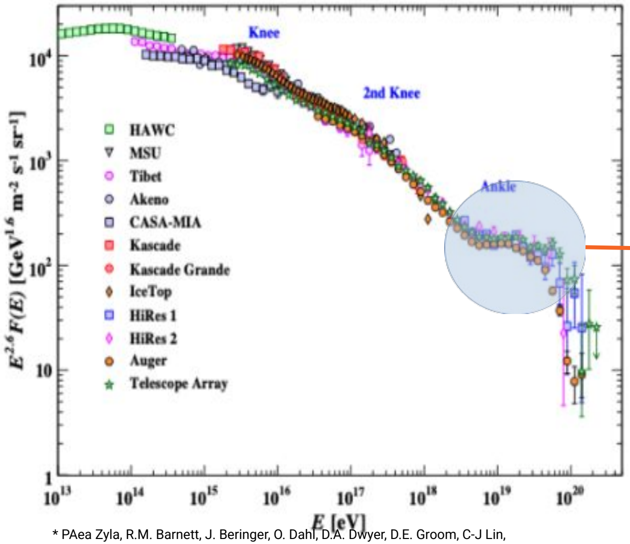
- We don't have enough data
- And the data we do have is inconsistent, incomplete



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

- Try to understand their behaviour
- Why is this region so relevant?

WHY DO WE WANT TO MEASURE LIGHT NUCLEI AND WHY ^{10}B and ^{11}B ?



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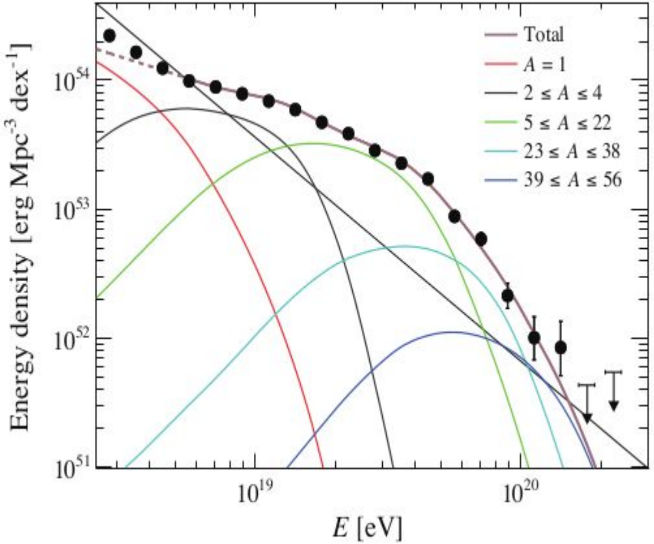

A. Tamii et al. Pandora project for the study of photonuclear reactions below A=60. The European Physical Journal A, 59 (2023) 101140

Light nuclei can explain the detection of cosmic rays with energies above the limit

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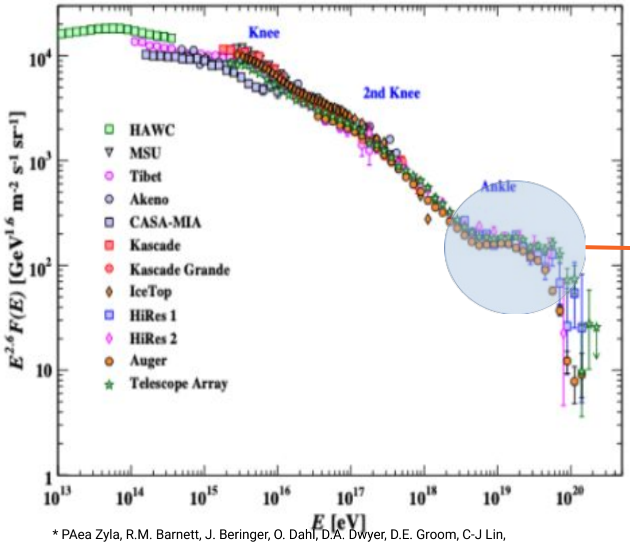

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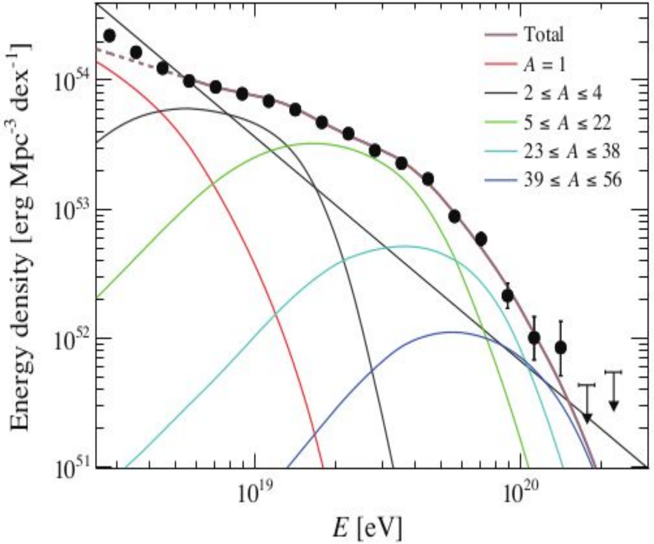

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Light nuclei can explain the detection of cosmic rays with energies above the limit

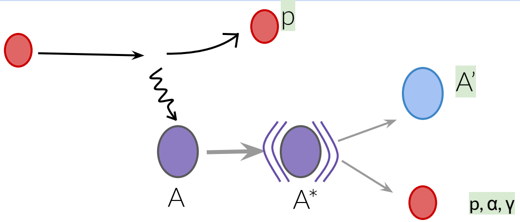
^{10}B and ^{11}B give the main contribution for this mass composition

Experimental set-up

BRIEF OVERVIEW OF THE EXPERIMENT

Virtual Photons and high-resolution magnetic spectrometers + ancillaries

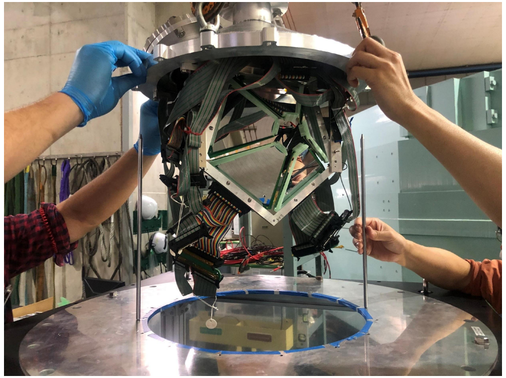
$^{10}B(p,p')^{10}B$
$^{11}B(p,p')^{11}B$



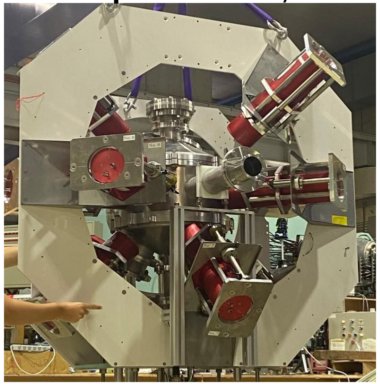
Coulex at 0 deg at RCNP, Osaka in JAPAN

Photo-absorbtion:
(p,p')@392MeV

p, α decays:
SAKRA Array

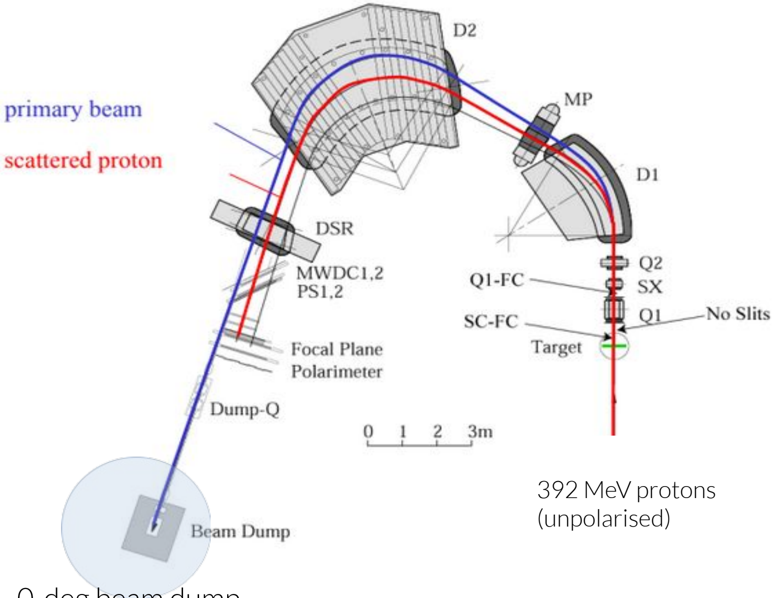


γ decay :
Scylla Array



RCNP - Grand Raiden (GR) magnetic spectrometer

0-deg mode

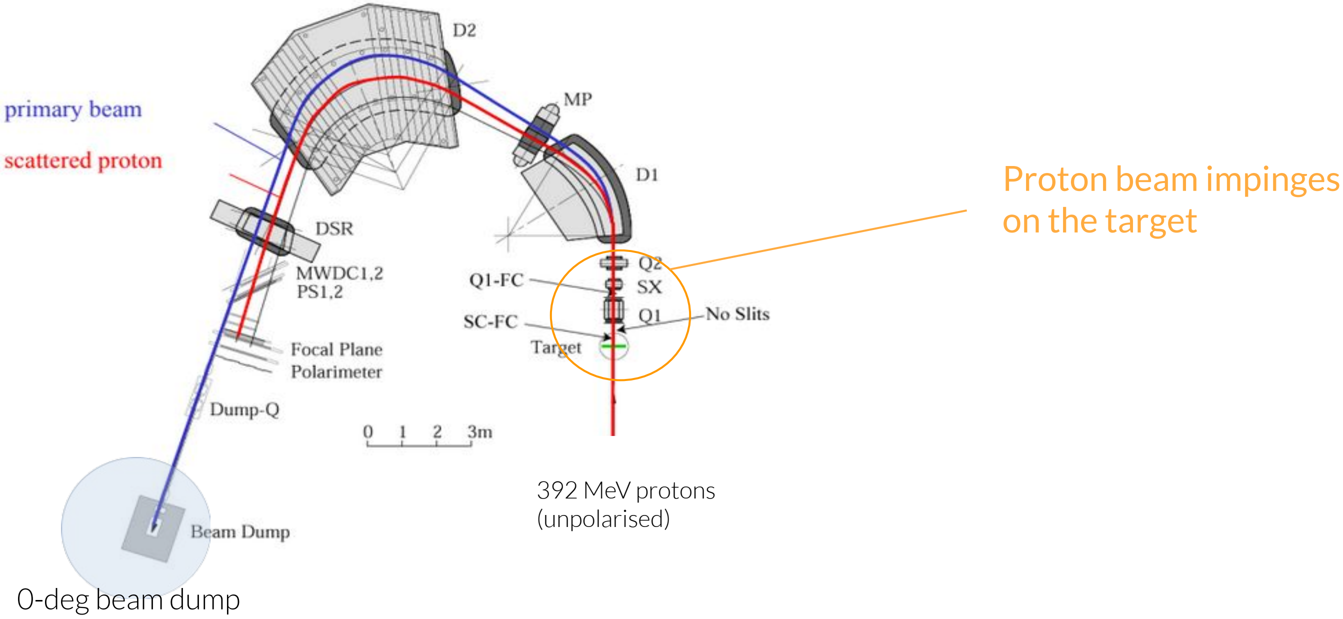


392 MeV protons
(unpolarised)

0-deg beam dump

Grand Raiden Transportation modes

0-deg mode

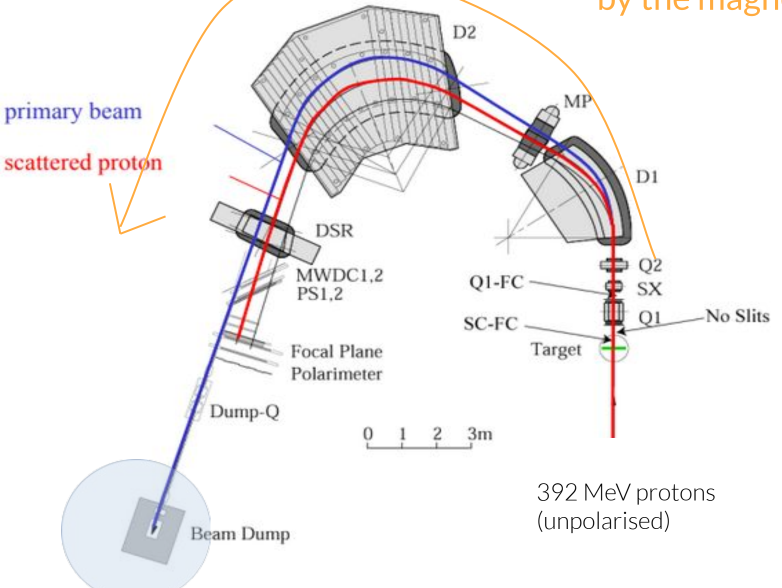


- Ability to deduce the excitation energy of the target nucleus with sufficient resolution

Grand Raiden Transportation modes

0-deg mode

Ejectiles are momentum analysed by the magnetic spectrometer



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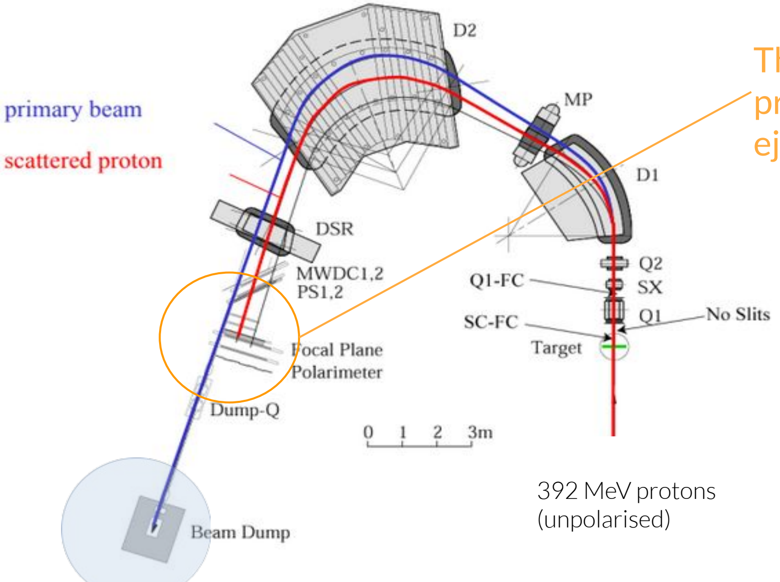


The focal-detectors are used to provide information about the ejectiles

392 MeV protons (unpolarised)

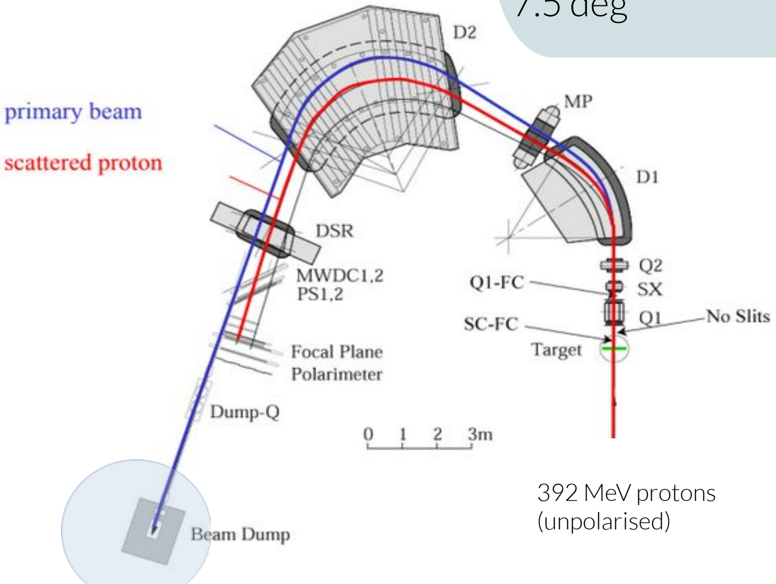
0-deg beam dump

- Ability to deduce the excitation energy of the target nucleus with sufficient resolution

Grand Raiden Transportation modes

Laboratory angular range from 0 deg to 7.5 deg

0-deg mode



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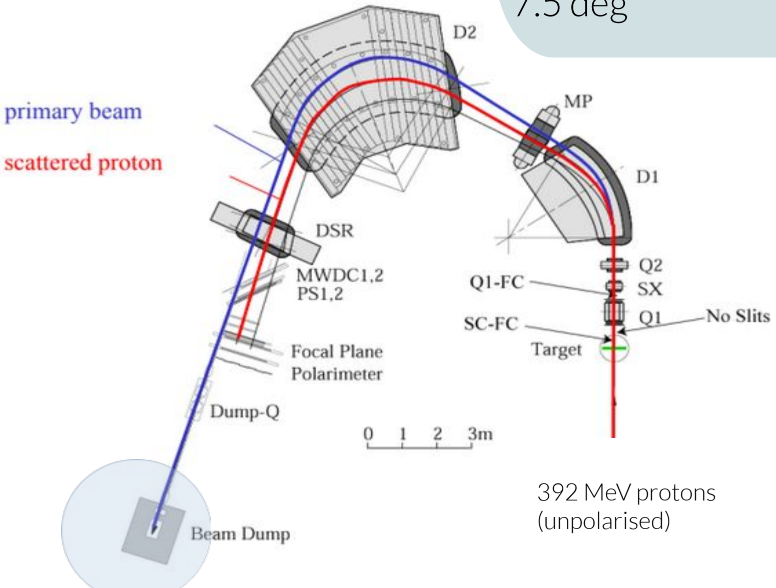

392 MeV protons (unpolarised)

0-deg beam dump

charged particle decay and gamma-ray decay coincidence

- Ability to deduce the excitation energy of the target nucleus with sufficient resolution

Grand Raiden Transportation modes

0-deg mode

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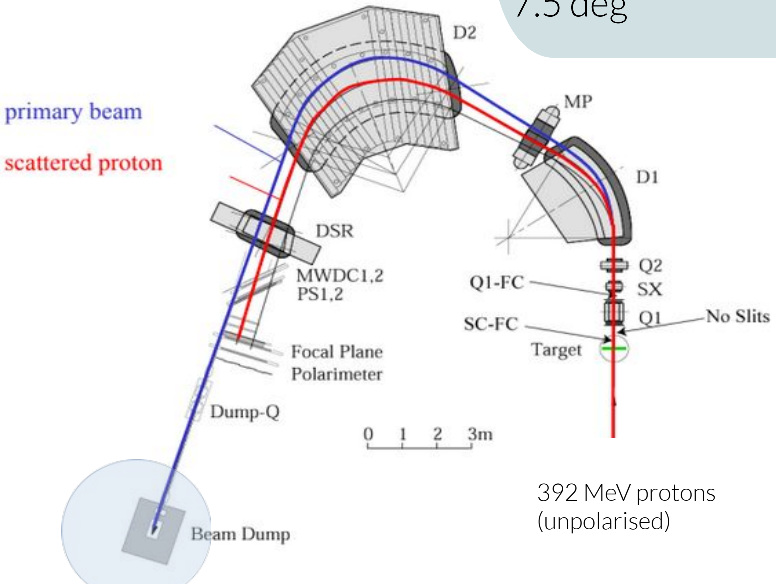
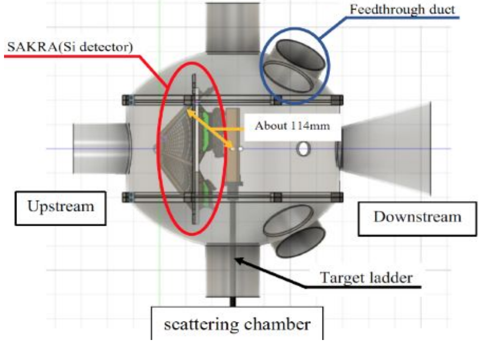


392 MeV protons (unpolarised)

0-deg beam dump

- Ability to deduce the excitation energy of the target nucleus with sufficient resolution

SAKRA Array for particle identification



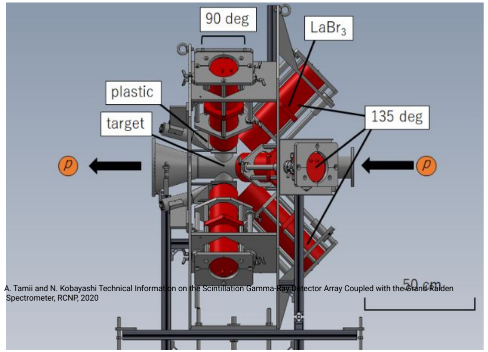
Spectrometer, RCNP, 2020

- For this experiment the original SAKRA configuration was used
- 10 double-sided silicon stip detectors (DSSSDs)
- Thickness of 500µm&100µm of the MMM
- 160 ch front side
- 80 ch rear side

charged particle decay and gamma-ray decay coincidence

SCγlla Array

- 8 large volume $LaBr_3$ detectors
- ^{60}Co and ^{137}Cs sources used for testing the signal
- FWHM ~21 keV

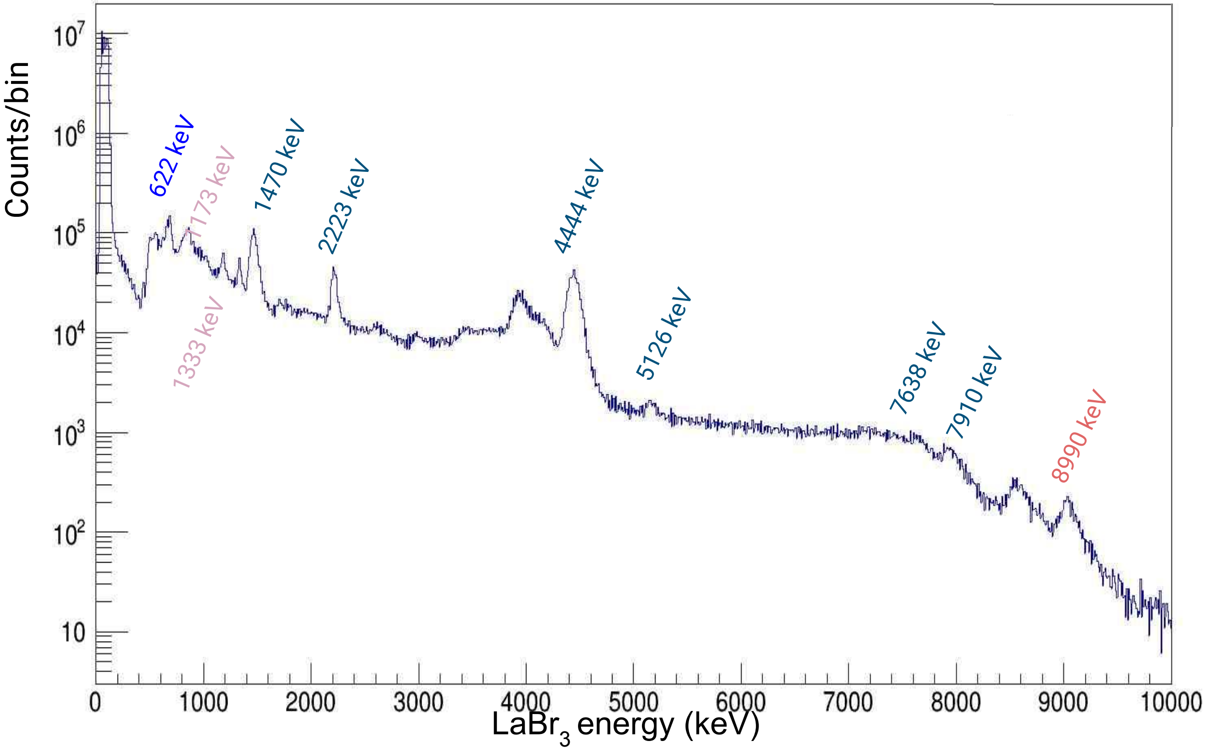


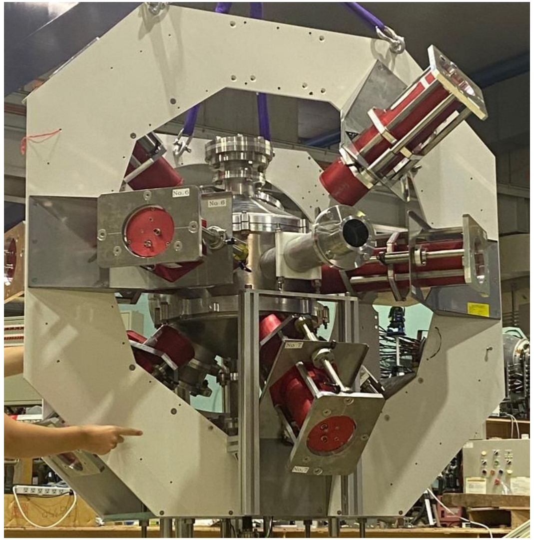
A. Tamii and N. Kobayashi Technical Information on the Scintillation Gamma-Ray Detector Array Coupled with the Grand Raiden Spectrometer, RCNP, 2020

Results from the first PANDORA experiment (E563)

Calibration of $LaBr_3$ detectors

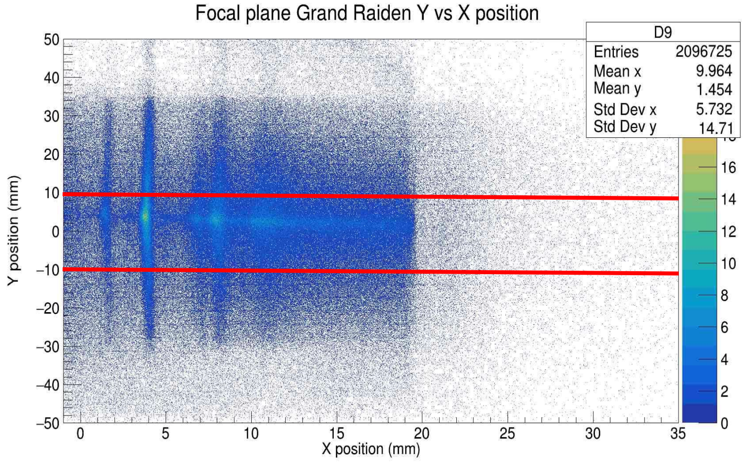
$LaBr_3$ with $^{60}Co + ^{137}Cs + ^{241}Am/Be\text{-}Ni$ source run

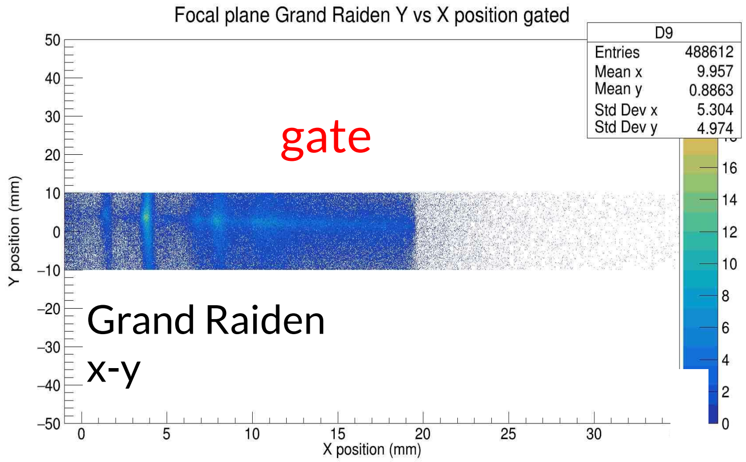




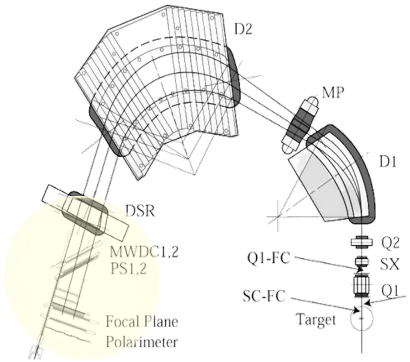
- The $LaBr_3$:Ce detectors placed on the scattering chamber

Time-gate & "good_fit" gate (preliminary results ^{12}C calibration)





We use the focal plane information to discriminate between different types of particles taking into account their deflected trajectories



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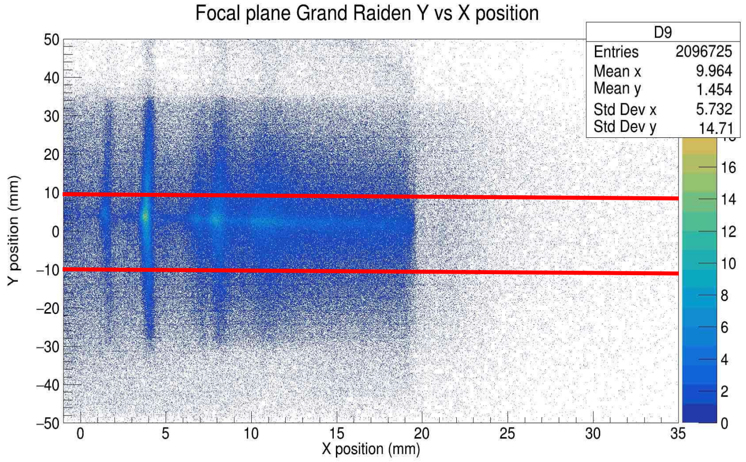

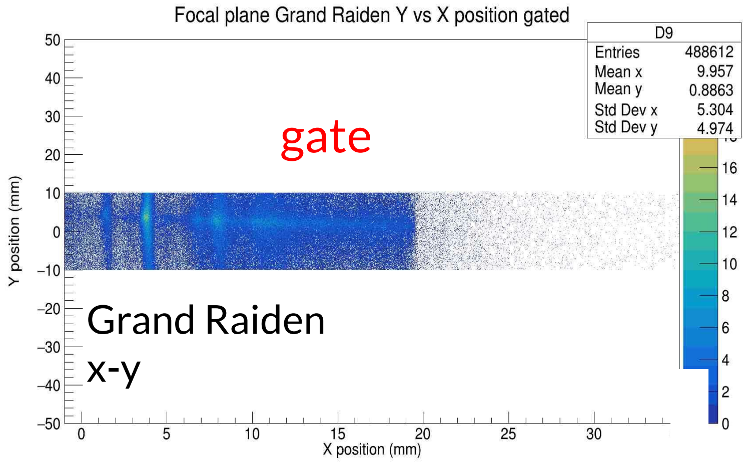

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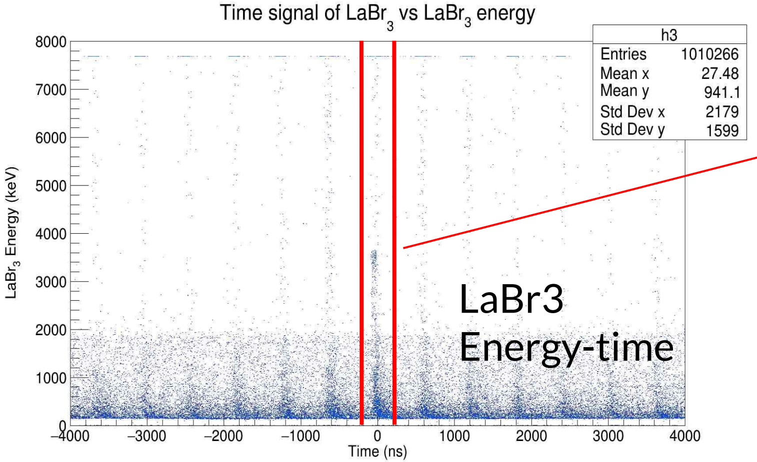
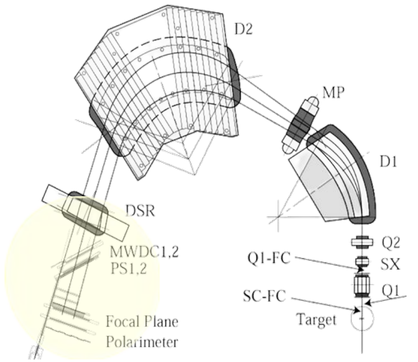
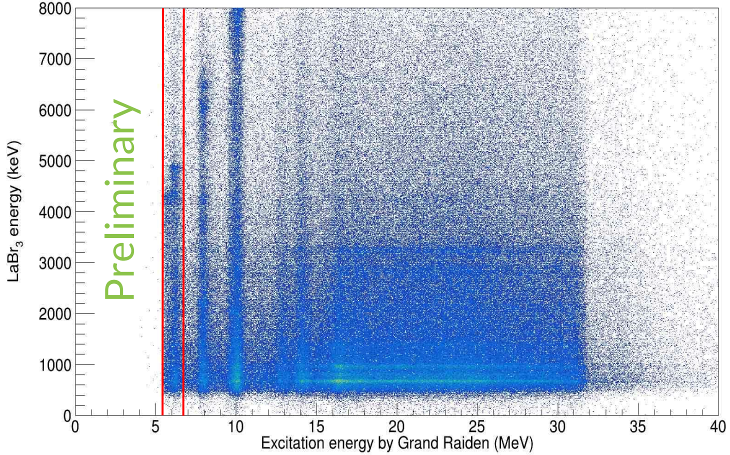


Real coincidence

We use the TDC signal and consider this to be the real coincidence so we gate using this information in order to select good events



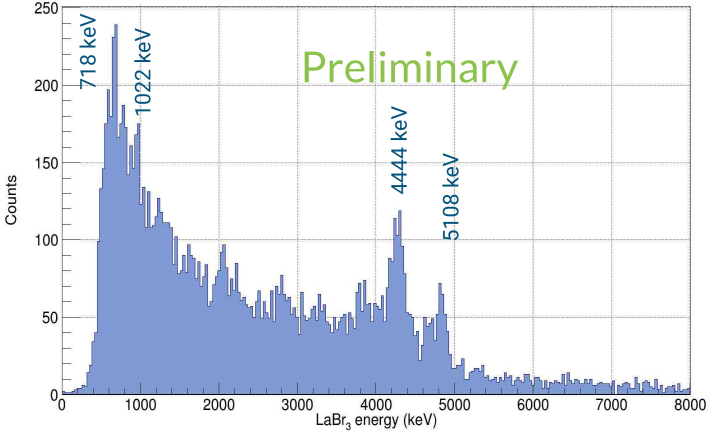
Grand Raiden Excitation Energy versus LaBr3 gamma decay coincidences for ^{10}B

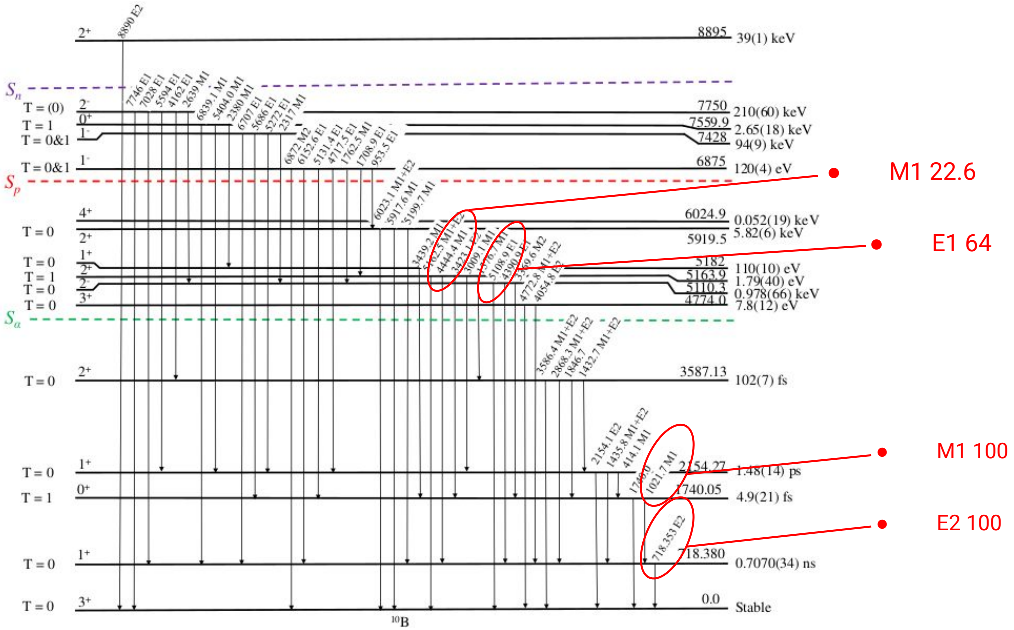


GR 4.5 degrees

High gain

Excitation energy range 5.6 to 6.5 MeV





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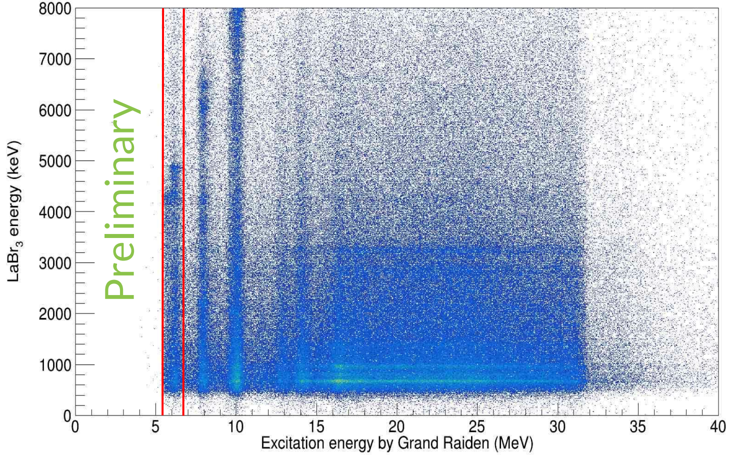
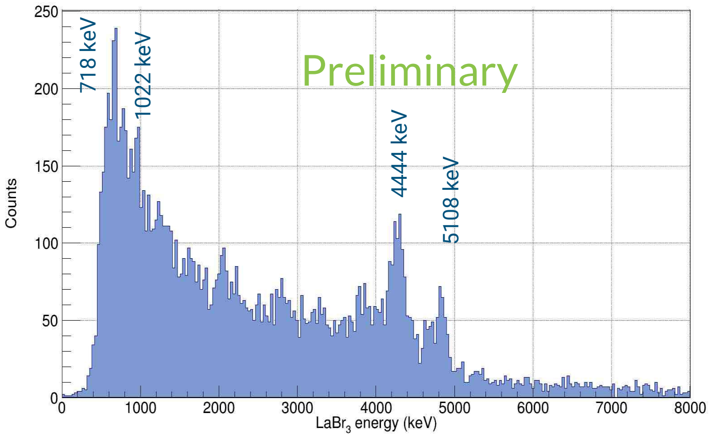
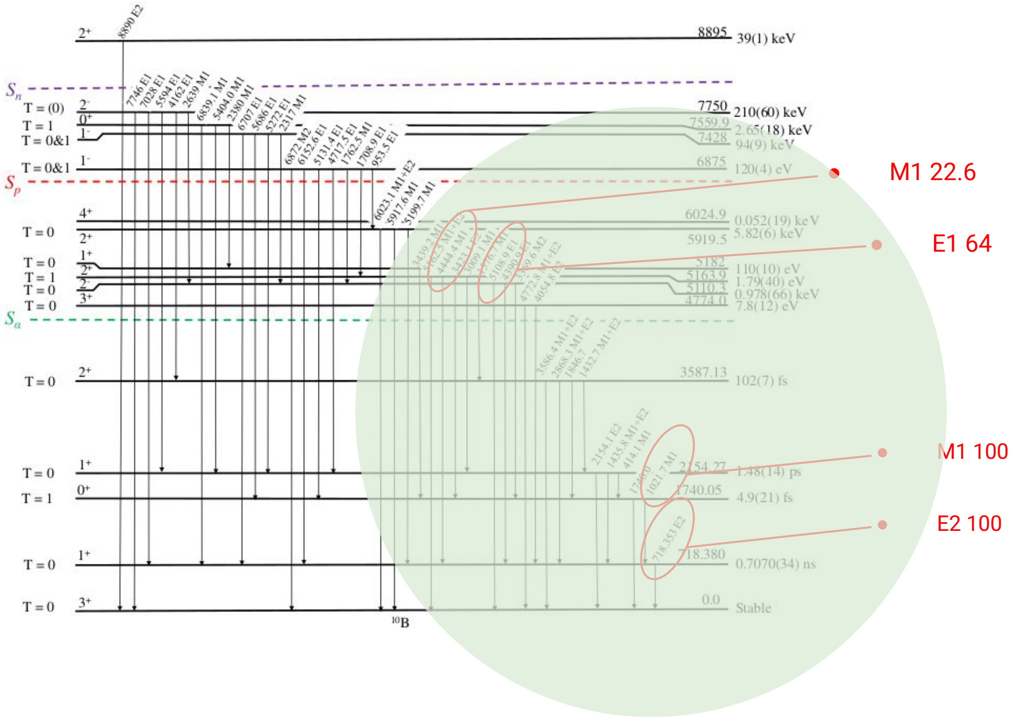
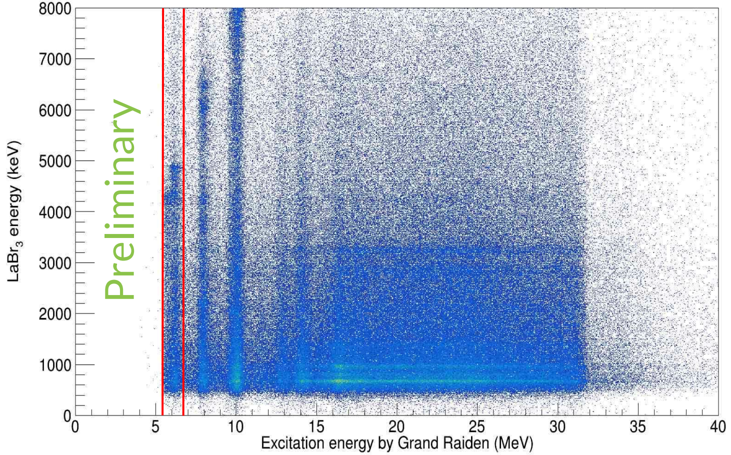






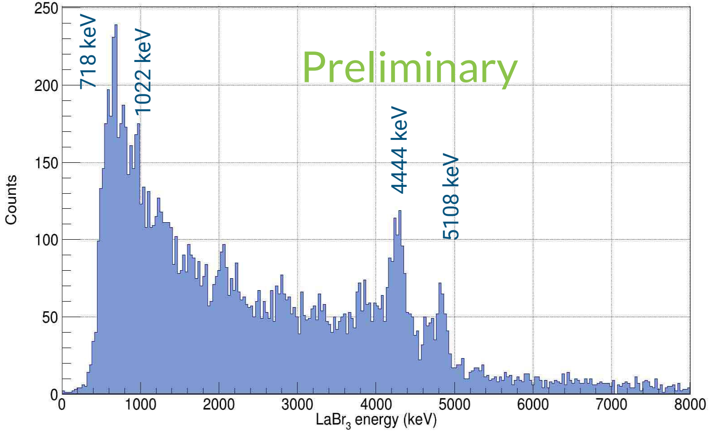
Grand Raiden Excitation Energy versus LaBr3 gamma decay coincidences for ^{10}B

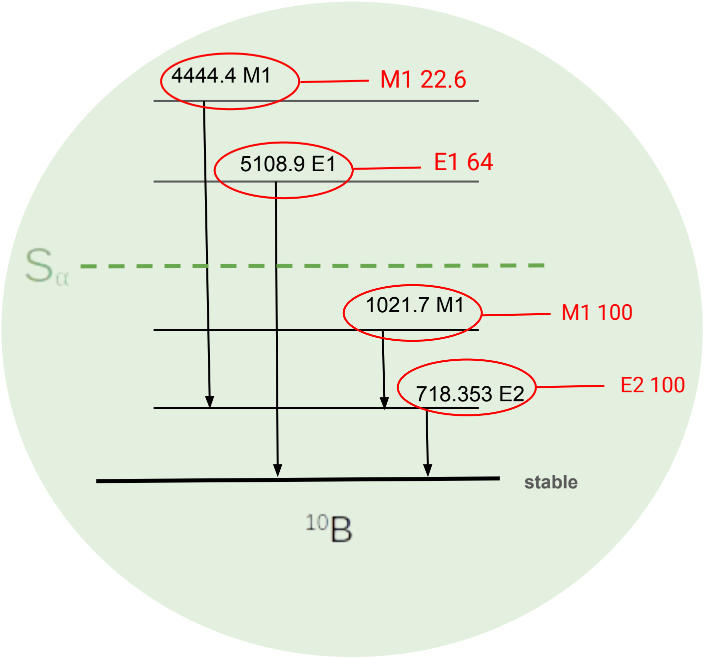


GR 4.5 degrees

High gain

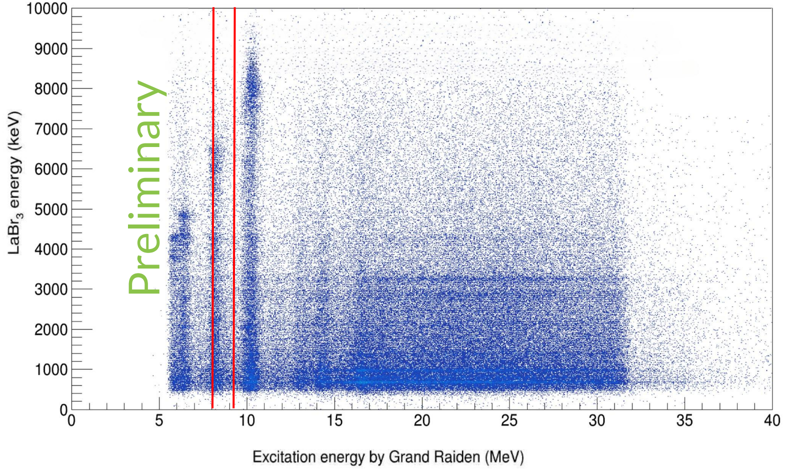
Excitation energy range 5.6 to 6.5 MeV

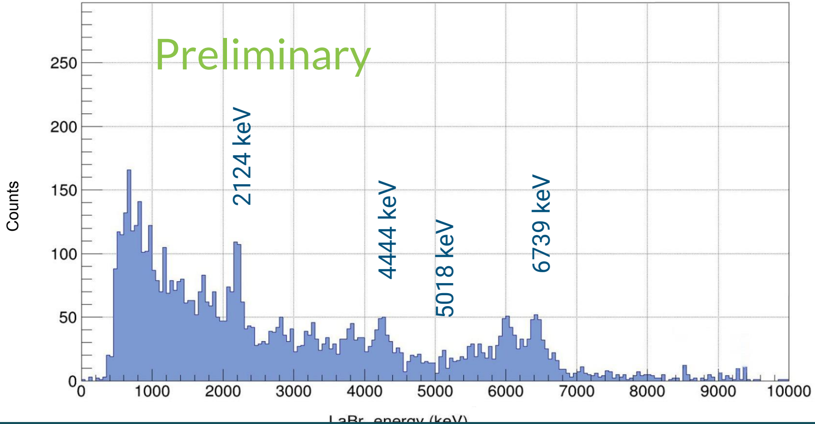


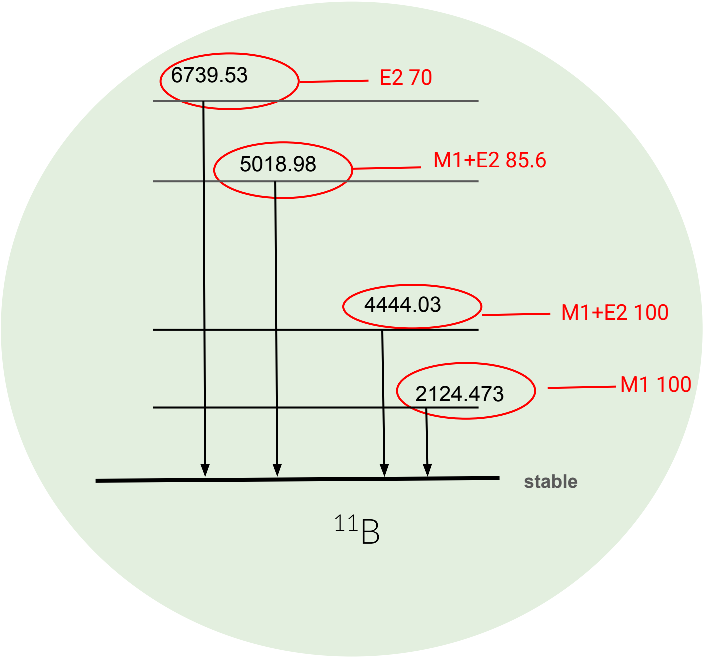


Grand Raiden Excitation Energy versus LaBr3 gamma decay coincidences for ^{11}B

GR 4.5 degrees High gain Excitation energy range 8 to 8.5 MeV





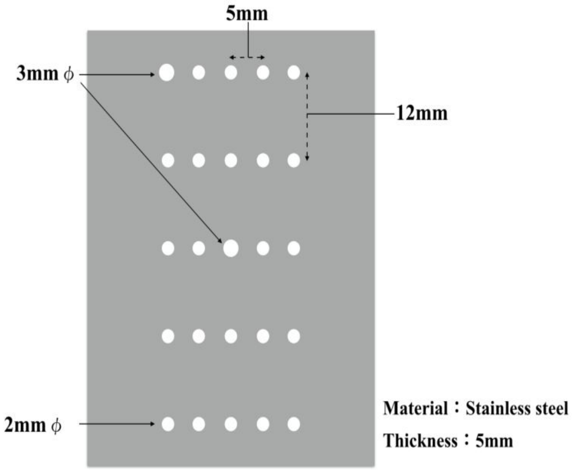


- Will be able to distinguish the continuum states following background subtraction.

Sieve slit data

Scattering angle calibration

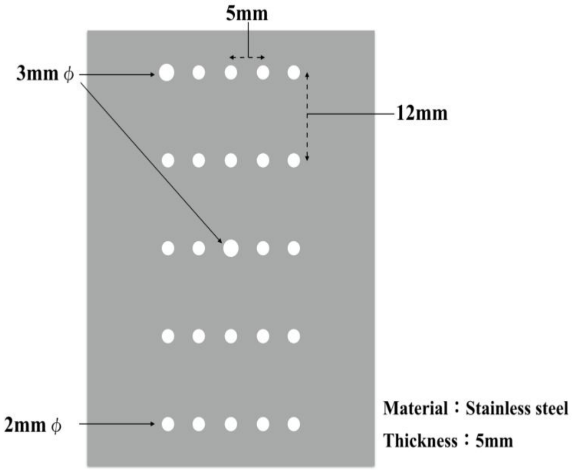
Sieve Slit Data p + ^{63}Cu elastic scattering reaction angles → angular distributions



- 5x5 matrix
- Position: at the entrance of the GR, 585 mm downstream of the target.
- Trajectory at the focal plane → scattering angle at target
- Reconstruction of **ϴ** target and **Φ** target by a multidimensional analysis where we need some parameters: **ϴ** focal plane, **Φ** focal plane, **X** focal plane, **Y** focal plane.

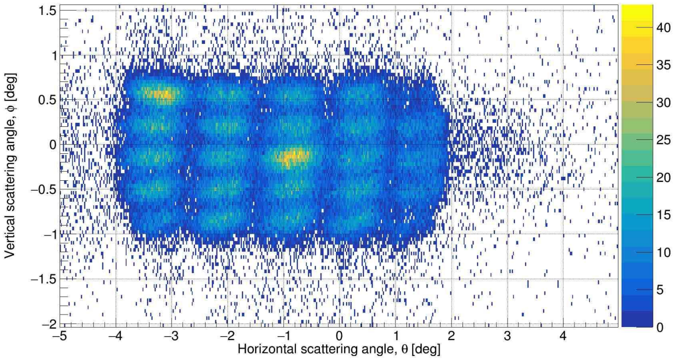
Sieve Slit Data p + ^{63}Cu elastic scattering

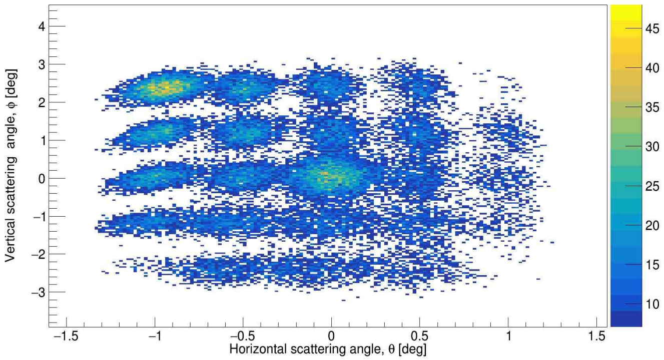
reaction angles → angular distributions



- 5x5 matrix
- Position: at the entrance of the GR, 585 mm downstream of the target.
- Trajectory at the focal plane → scattering angle at target
- Reconstruction of Θ target and Φ target by a multidimensional analysis where we need some parameters: Θ focal plane, Φ focal plane, X focal plane, Y focal plane.

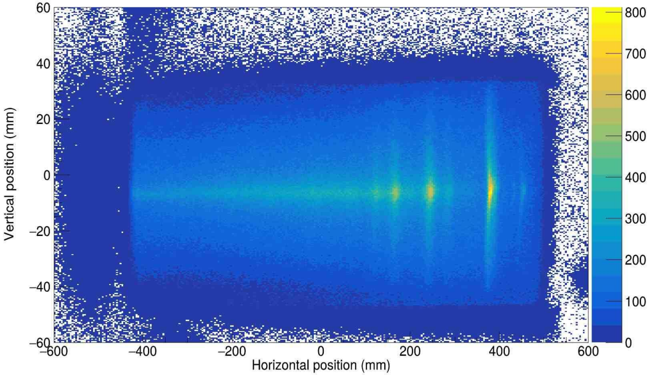
→ Corrected scattering angle

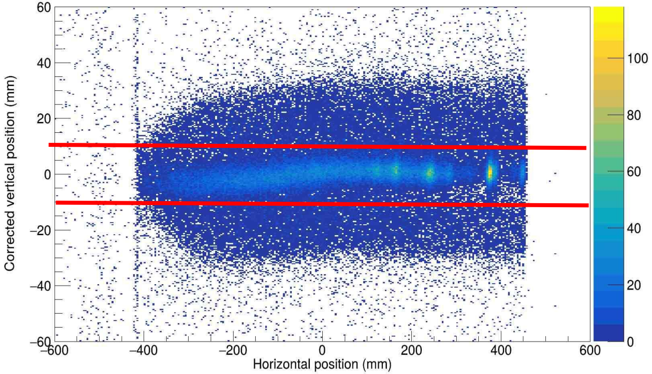




- The final mapping of the sieve slit data of one of the calibration runs from the focal to the target angles.

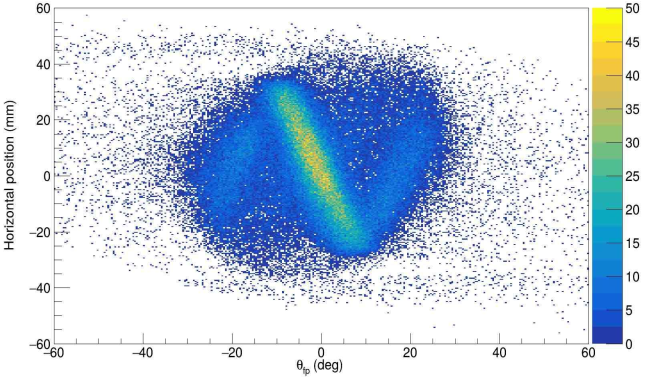
Background subtraction procedure

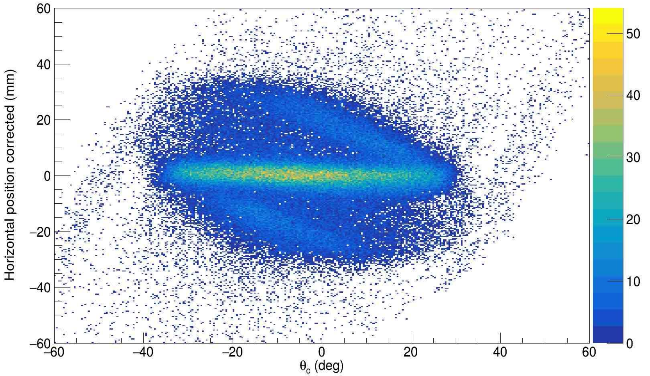




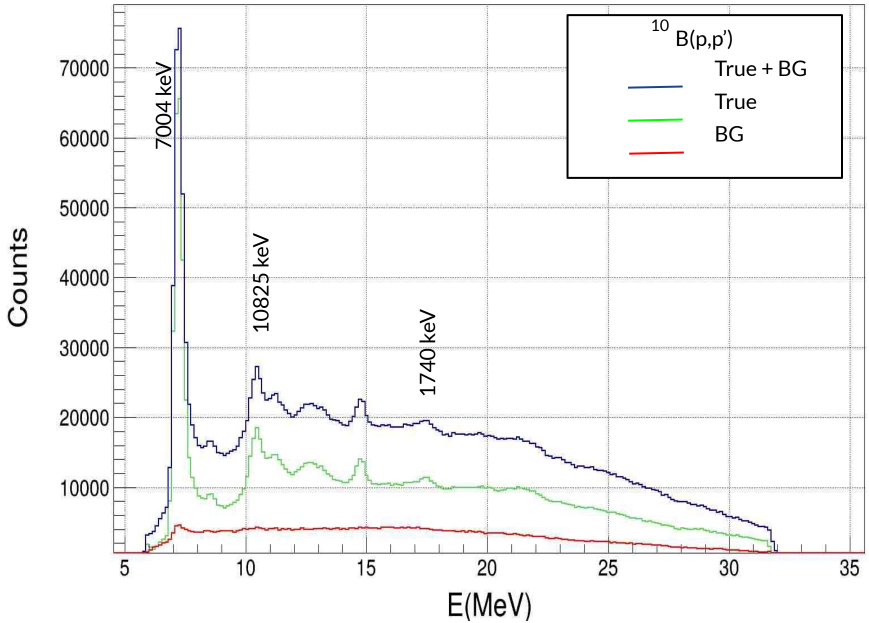
- Get background free spectra
- Don't have a 'safe' y region to select
- All good events are centered
- Restore the focusing condition

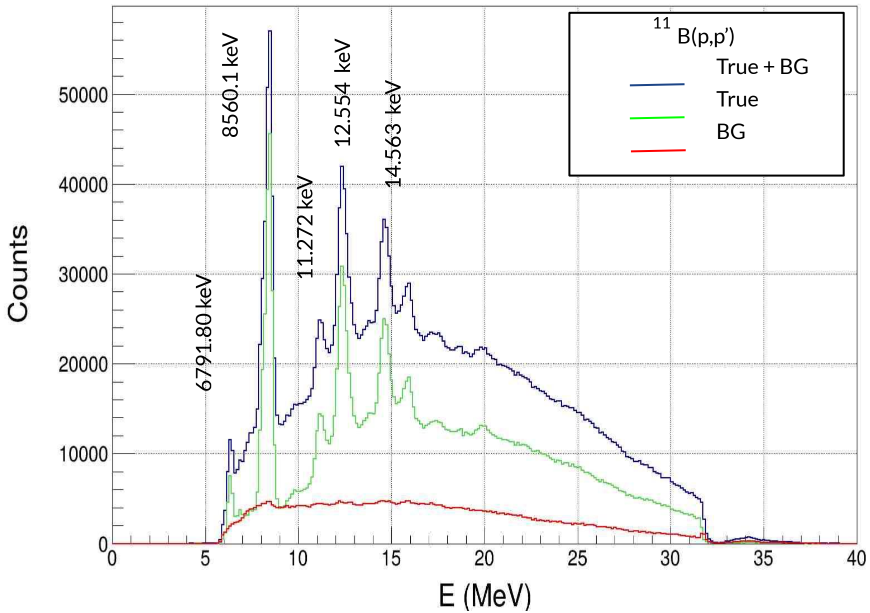
Restoration of the focusing condition with an theta angle dependant — rotation matrix





Preliminary background subtraction





Future tasks:

- Finish the background subtraction for the other conditions
- Multipole Decomposition Analysis (MDA)
- Separate EM dipole and quadrupole excitations

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- Finish the background subtraction for the other conditions
- Multipole Decomposition Analysis (MDA)
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Conclusions:

- We proposed another experiment at RCNP where we will measure other light nuclei : ^{16}O, $^{24,26}Mg$, ^{40}Ca and ^{56}Fe
- Preliminary results look promising
- The mapping of the the sieve slit data was achieved. However we had some difficulties for phi angle separation in some of the runs.
- The background subtraction for 0 deg looks promising

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

Questions?