PANDORAプロジェクト状況報告

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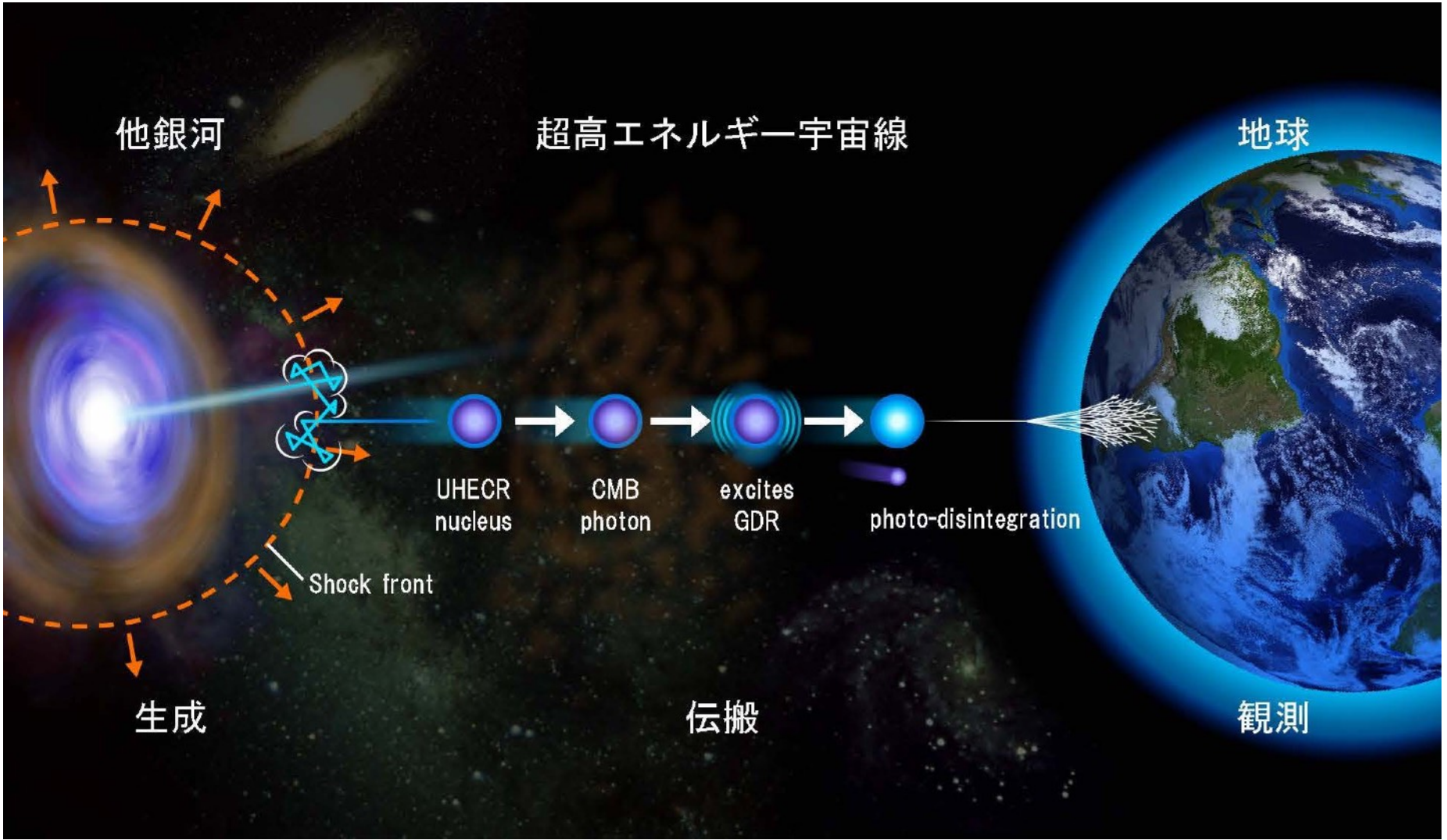
Research Center for Nuclear Physics (RCNP)
Osaka University, Japan

r-EMU Informal Meeting, Aug 8, 2020 by Zoom

PANDORA Project

A<60 核の光核反応の理解が目的

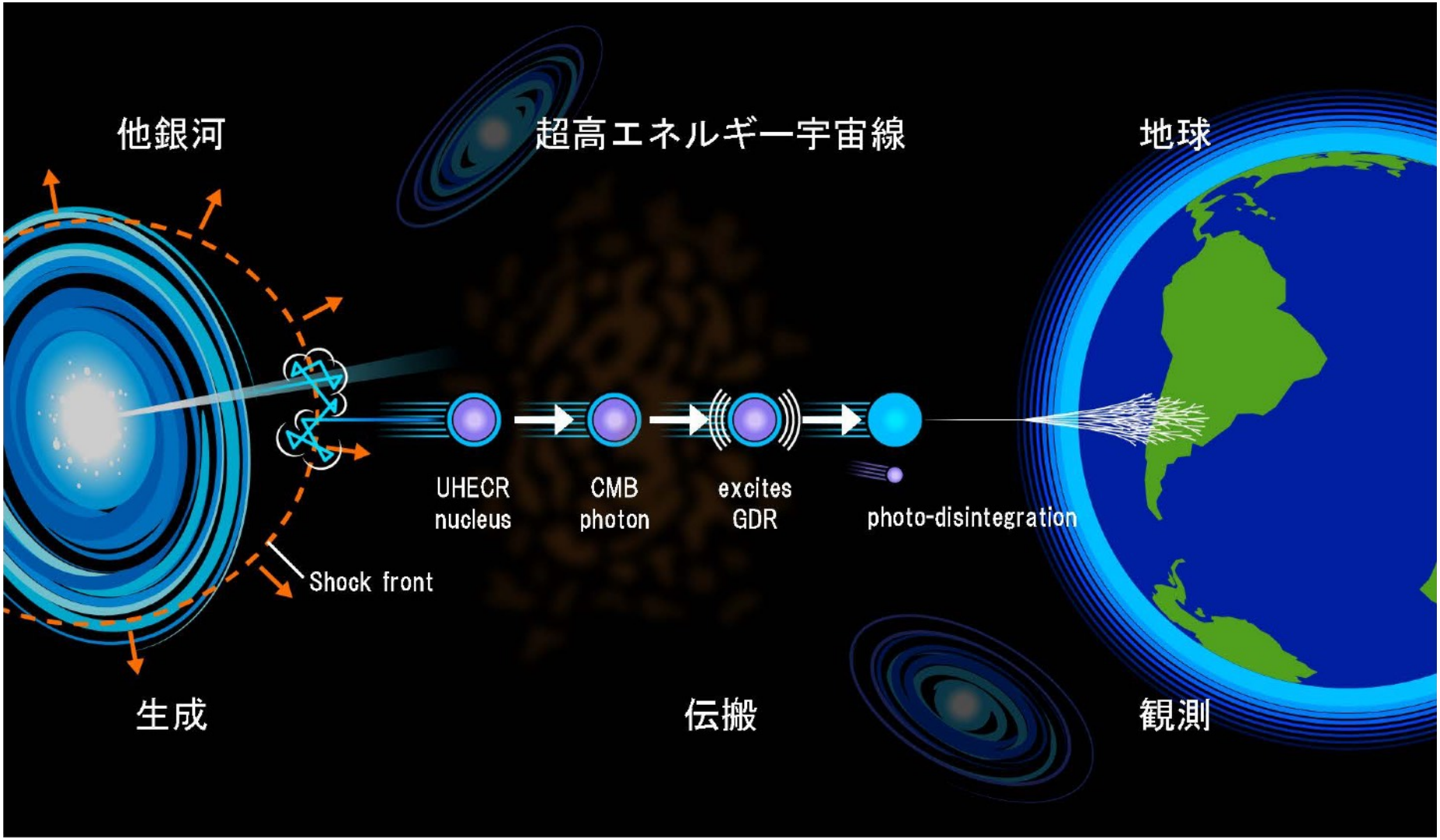
主目的の1つは超高エネルギー宇宙線のエネルギー質量減衰機構の定量的記述



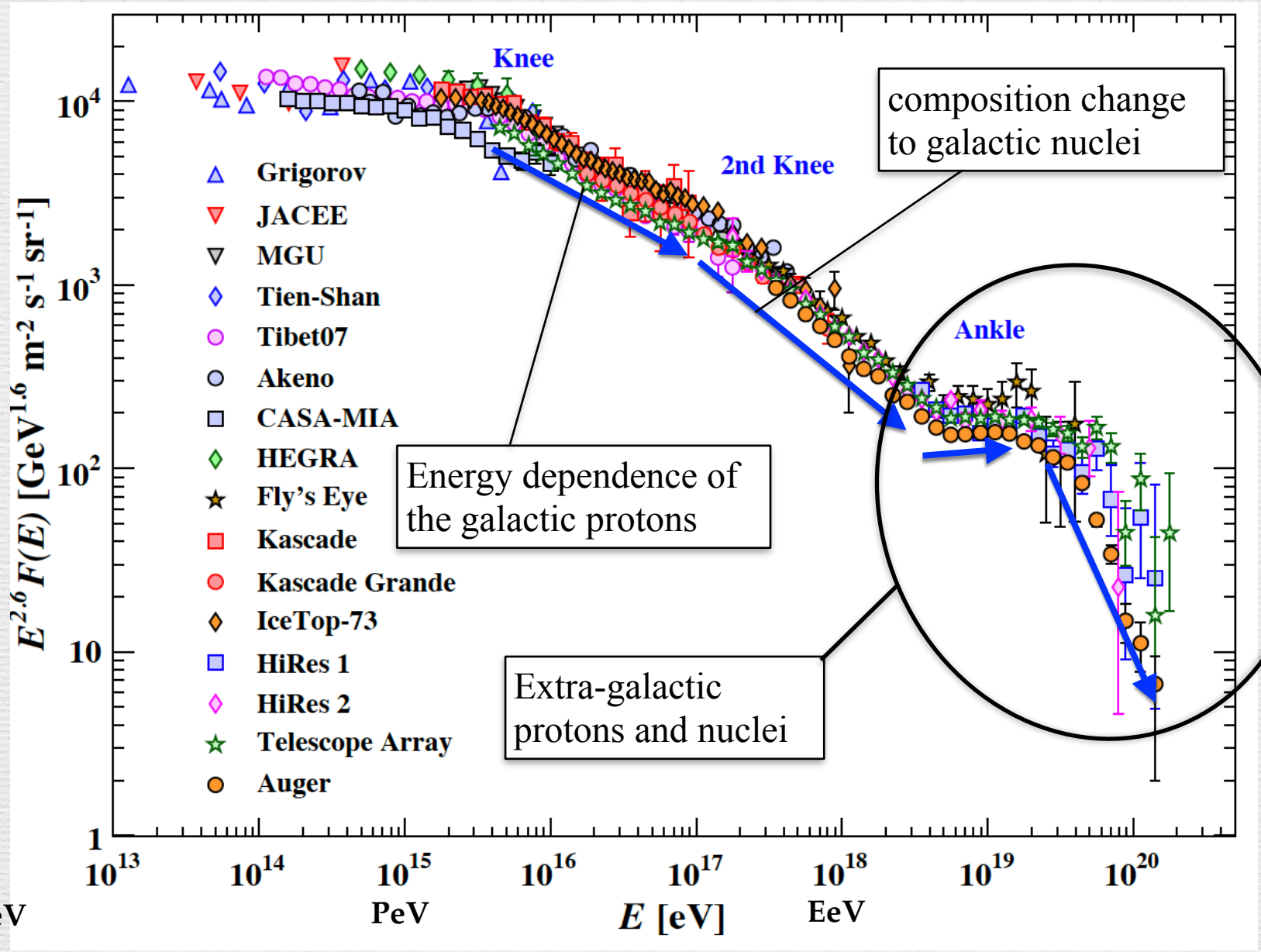
PANDORA Project

A<60 核の光核反応の理解が目的

主目的の1つは超高エネルギー宇宙線のエネルギー質量減衰機構の定量的記述



Ultra-High-Energy Cosmic Rays (UHECRs) [PDG2018]



Extragalactic Propagation of UHECR Nuclei

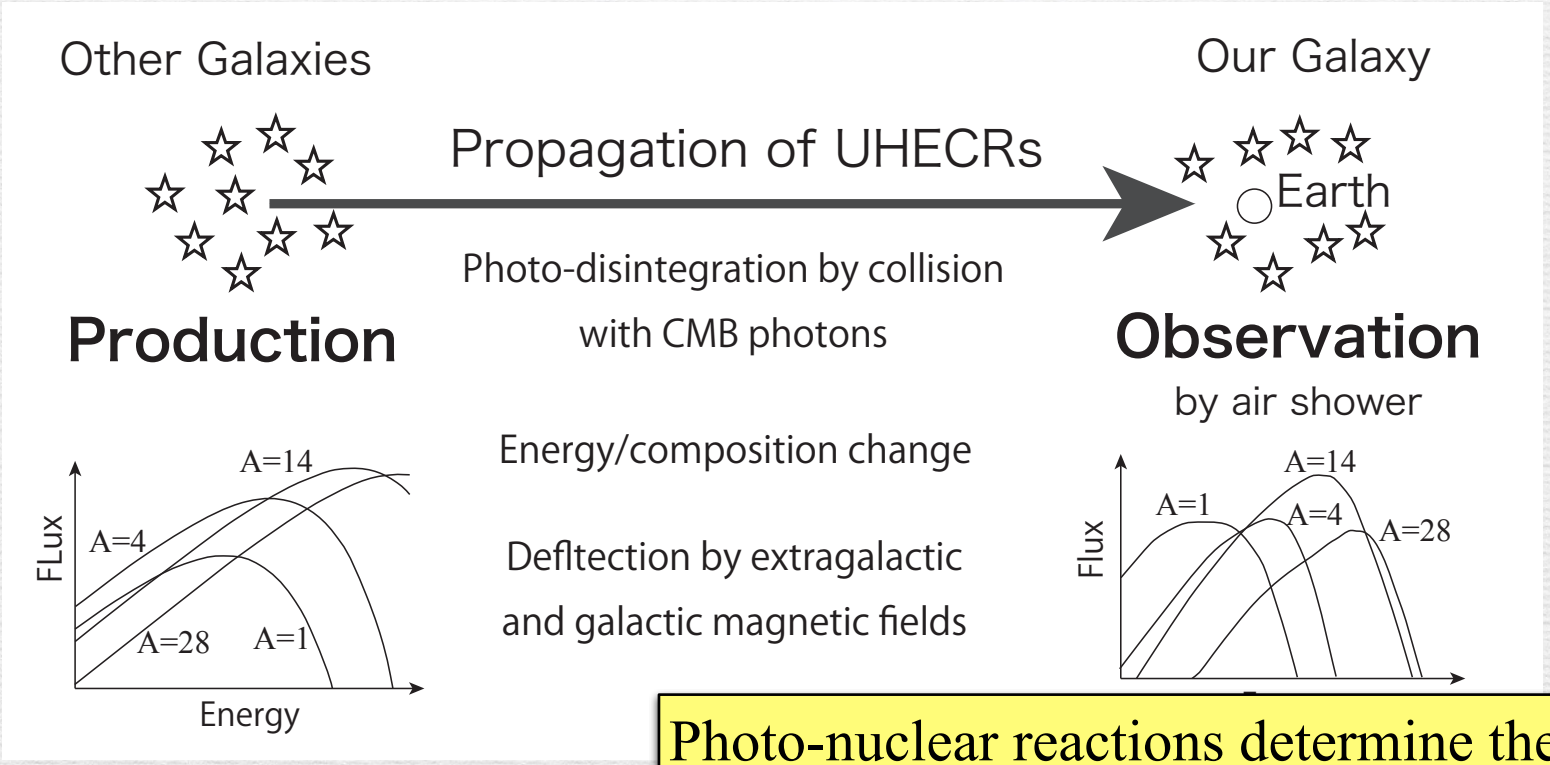
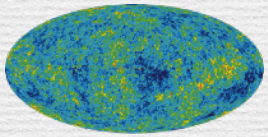


Photo-nuclear reactions determine the allowed travel distance of UHECRs nuclei and their composition/energy modification in extra-galactic propagation.

Cosmic Microwave Background (CMB)

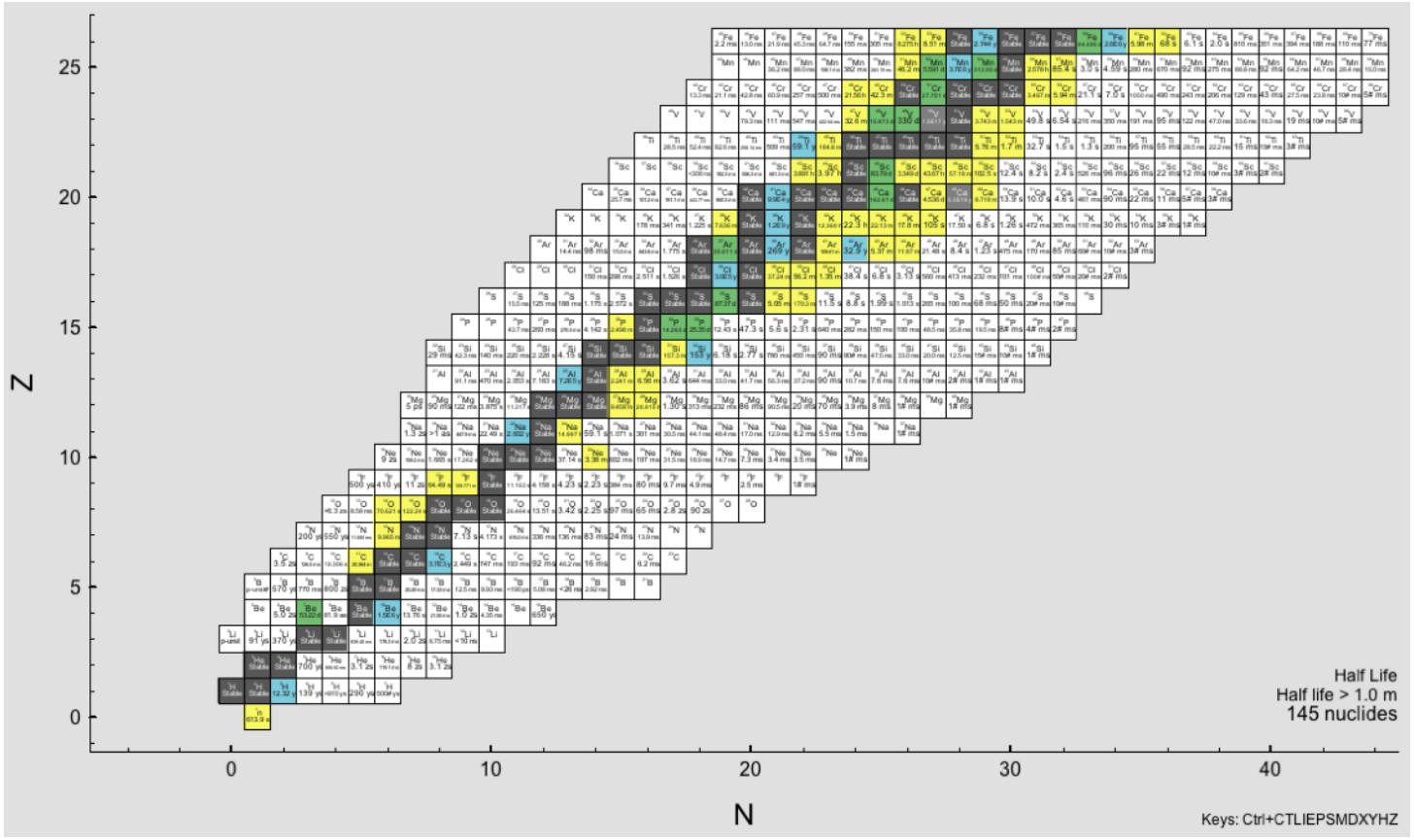
WMAP

T=2.73 K



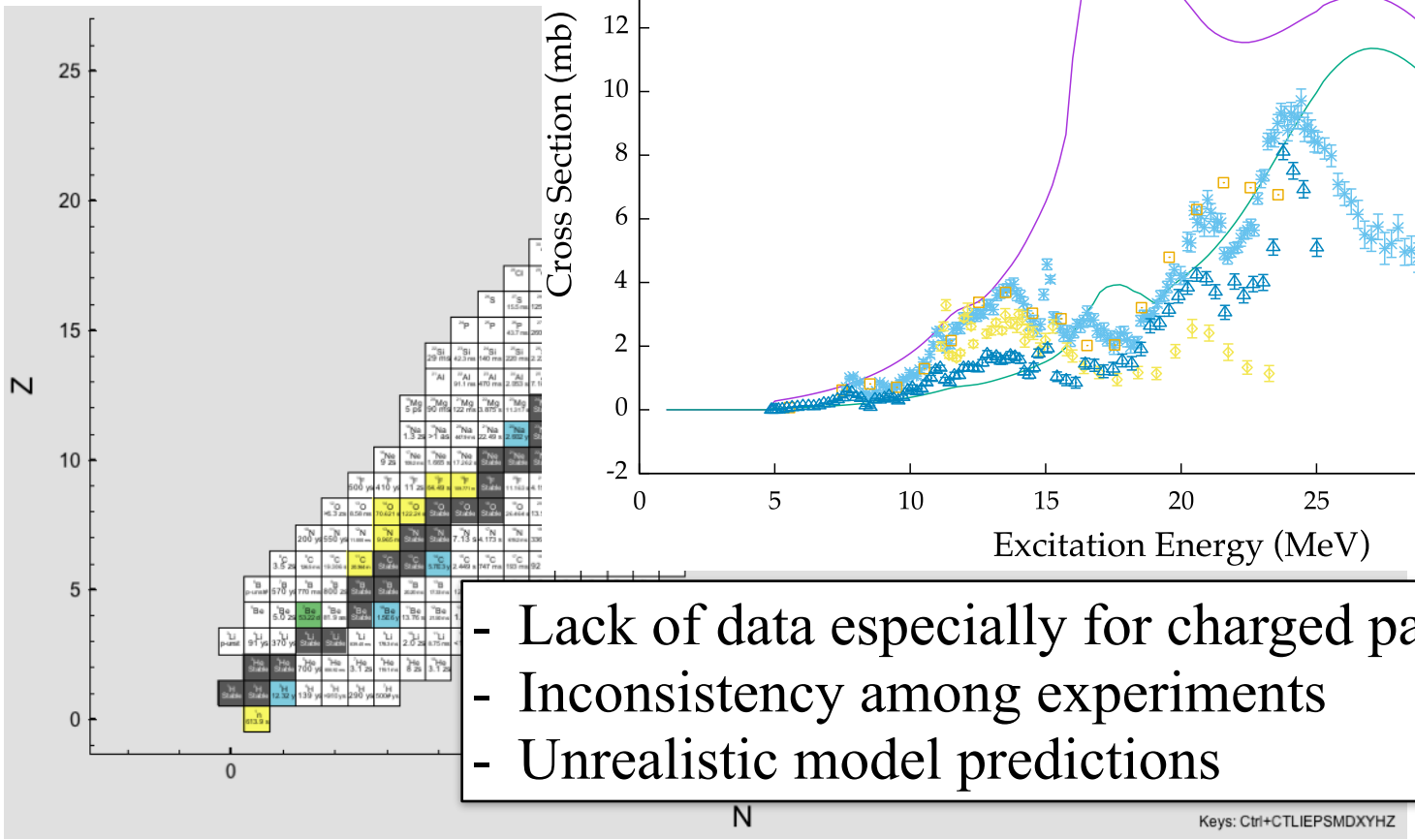
Systematic Measurement on Photo-Absorption C.S. and n,p,α,γ decays for light to A~56 stable nuclei

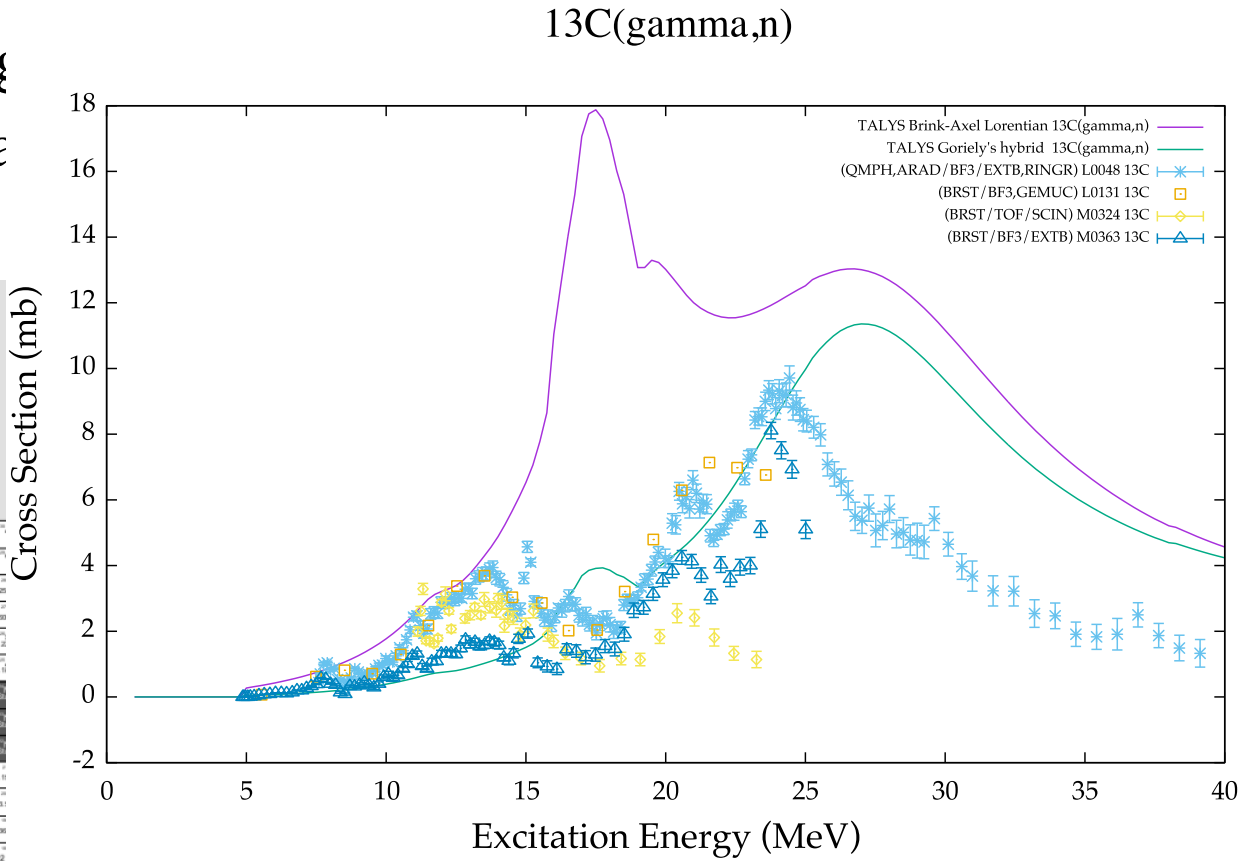
- photo-absorption (electric dipole) strength distribution
- n, p, α, γ decay branching ratios
- for stable nuclei from light to A~56



Systematic Measurement on Photo-Absorption C.S. and n,p,α,γ decays for light to A~56 stable nuclei

- E1 excitation streng
- n, p, α, γ decay bra
- from light to A~56

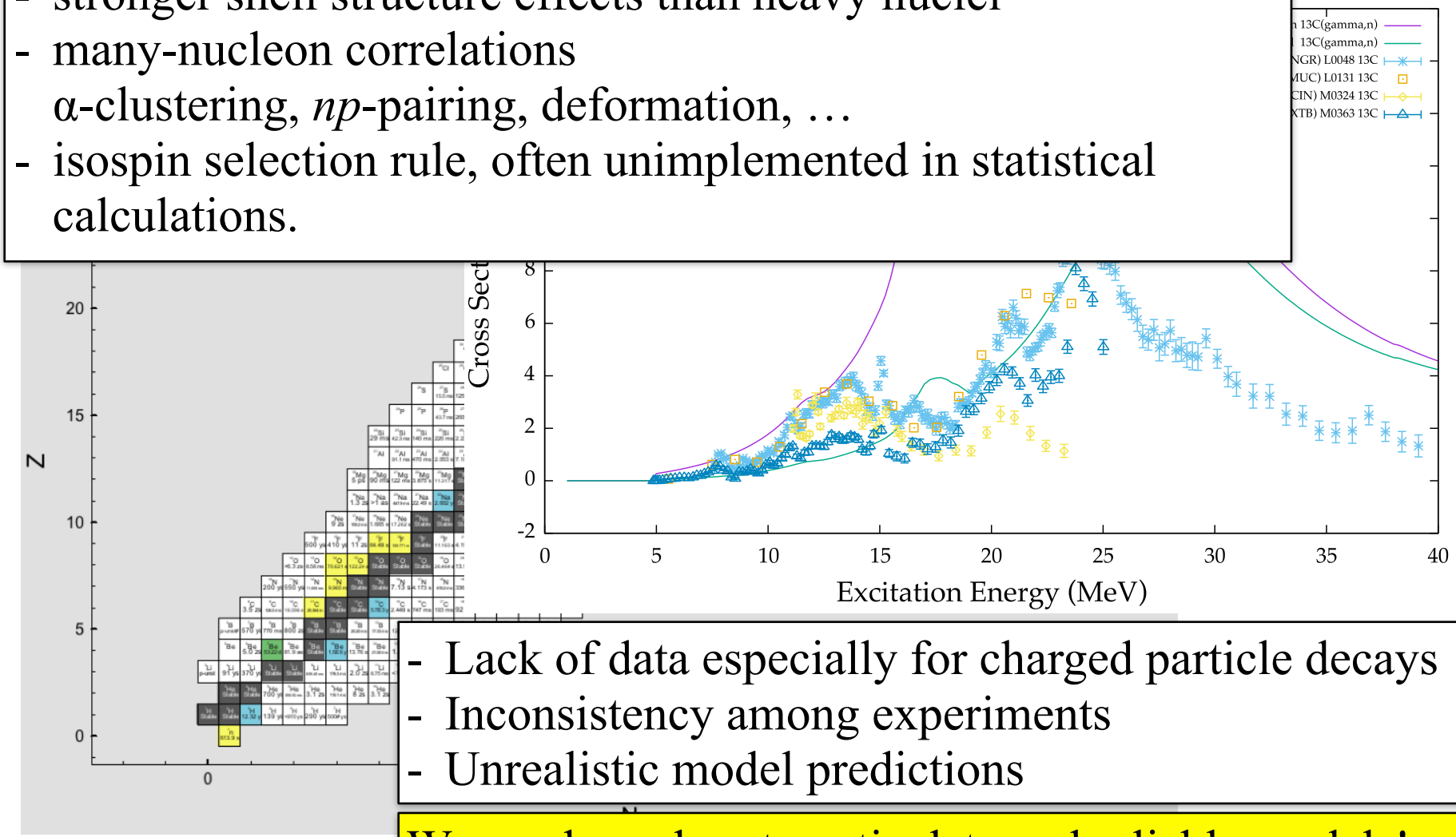




- Lack of data especially for charged particle decays
- Inconsistency among experiments
- Unrealistic model predictions

Systematic Measurement on Photo-Absorption C.S. and n,p,α,γ decays for light to A~56 stable nuclei

difficulties in theoretical modeling of light-medium mass nuclei
- stronger shell structure effects than heavy nuclei
- many-nucleon correlations
  α-clustering, *np*-pairing, deformation, …
- isospin selection rule, often unimplemented in statistical calculations.



- Lack of data especially for charged particle decays
- Inconsistency among experiments
- Unrealistic model predictions

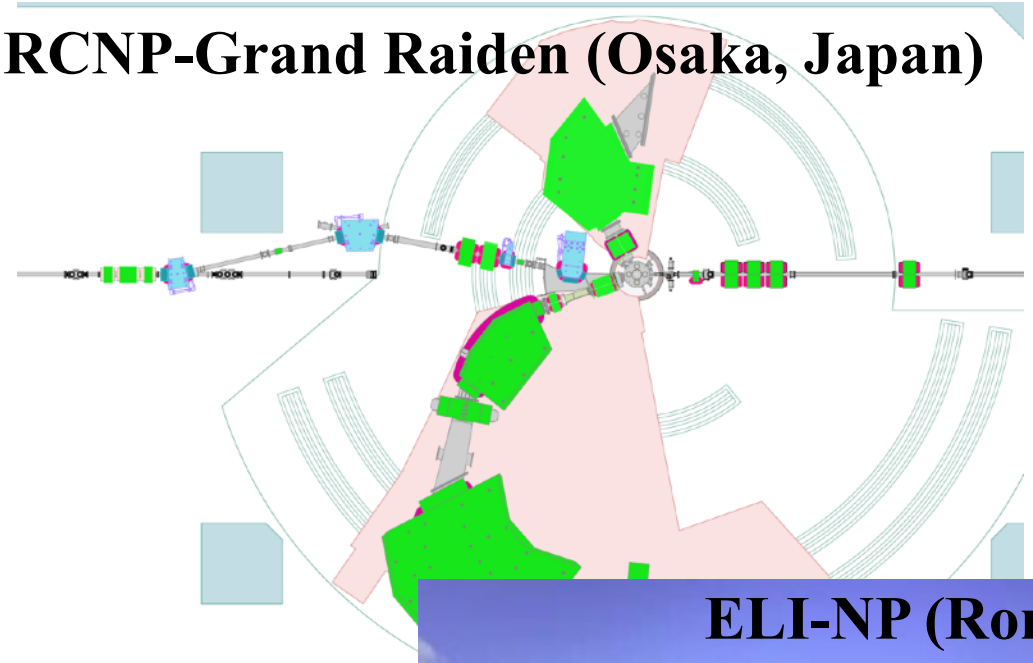
We need good systematic data and reliable models!

PANDORA Project

Photo-**A**bsorption of **N**uclei and **D**ecay **O**bservation for **R**eactions in **A**strophysics

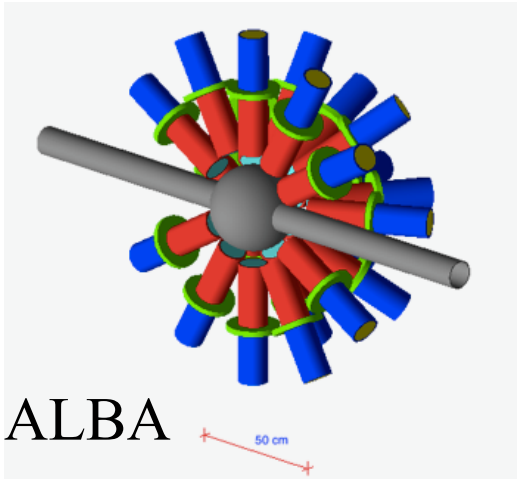
Joint project among three experimental facilities with nuclear theories and astrophysical simulations

RCNP-Grand Raiden (Osaka, Japan)

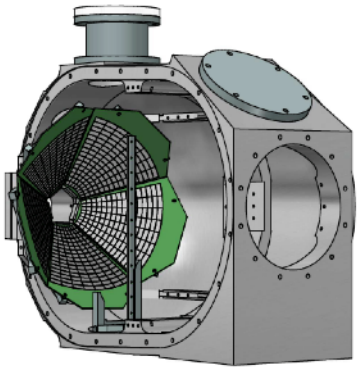


ELI-NP (Romania)

iThemba LABS South Africa



CAKE



decay charge particle detector array

complementary experimental techniques

Photo-disintegration Pass of ^{56}Fe

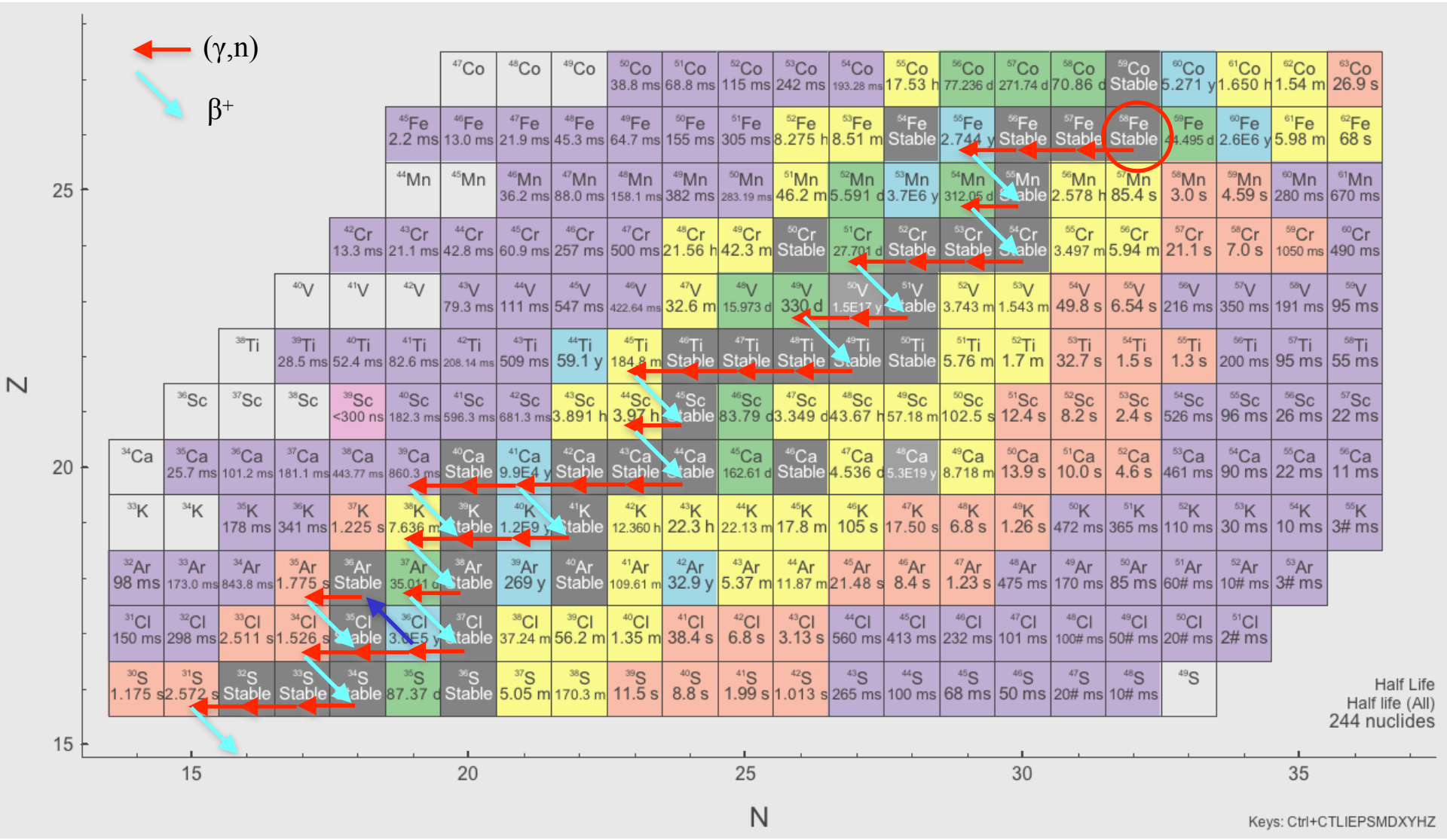
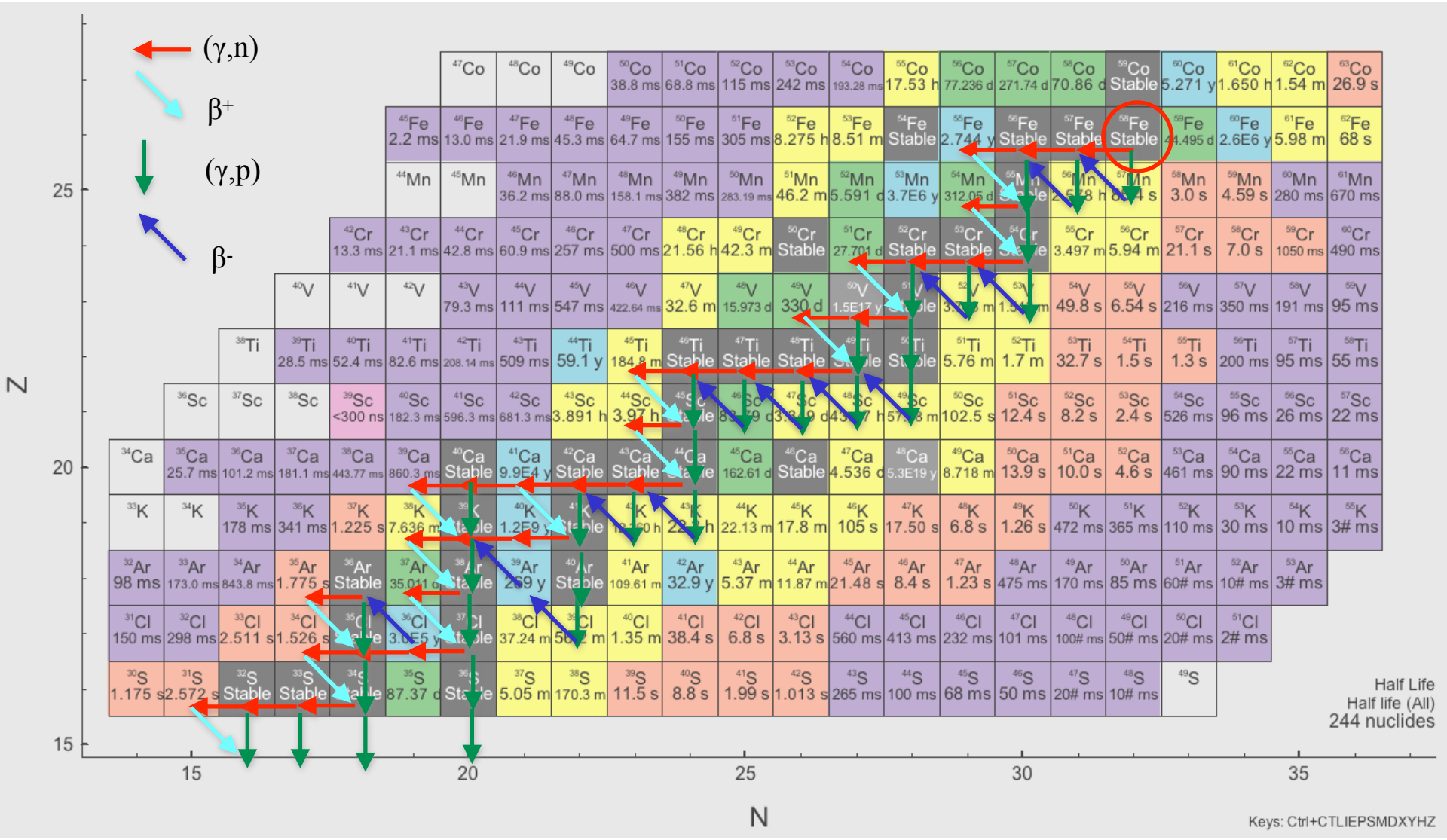


Photo-disintegration Pass of ^{56}Fe

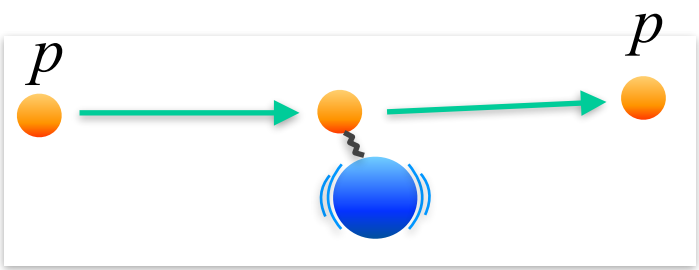


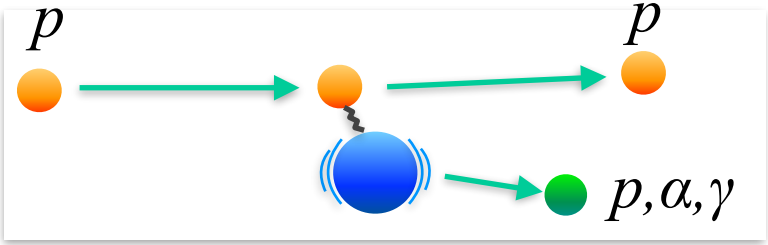
(γ,xn), (γ,α) reactions also take place.
Several unstable nuclei also contribute.

Probing Photo-Nuclear Response of Nuclei

Virtual photo excitation by proton scattering

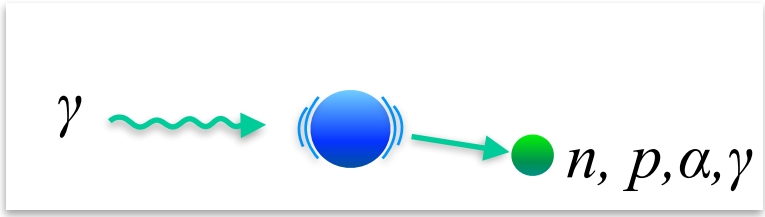
- Missing mass method
  with proton Coulomb excitation
- better for total strength
  and strength distribution
  higher cross sections
  also applicable for p,α,γ decays





Real photo excitation

- Gamma-beam by laser-Compton
  scattering with an electron beam
- individual decay channels
  better for absolute normalization
  applicable also for *n* and *xn* decays in addition to p,α,γ



Experiment combining three complementary facilities

Virtual Photon Exp.

RCNP 2021-

Total strength distribution up 32 MeV

γ-decay

multipole decomp. analysis (ang. dep. and polarization transfer)

iThemba LABS 2020-

Total strength distribution up 24 MeV

p,α,γ-decays

multipole decomp. analysis (ang. dep.)

Real Photon Exp.

ELI-NP 2023-

absolute c.s.

model independent separation of E1 and M1

n,p,α,γ-decays up to 20 MeV

Experiment combining three complementary facilities

Virtual Photon Exp.

RCNP 2021-

Total strength distribution up 32 MeV

γ-decay

multipole decomp. analysis (ang. dep. and polarization transfer)

iThemba LABS 2020-

Beam time approved for the first cases: ^{12}C, ^{27}Al

σ_{abs} and *p*,α,γ decays

Total strength distribution up 24 MeV

p,α,γ-decays

multipole decomp. analysis (ang. dep.)

Real Photon Exp.

Good systematic data
Consistency among three facilities
Reference target: ^{27}Al.

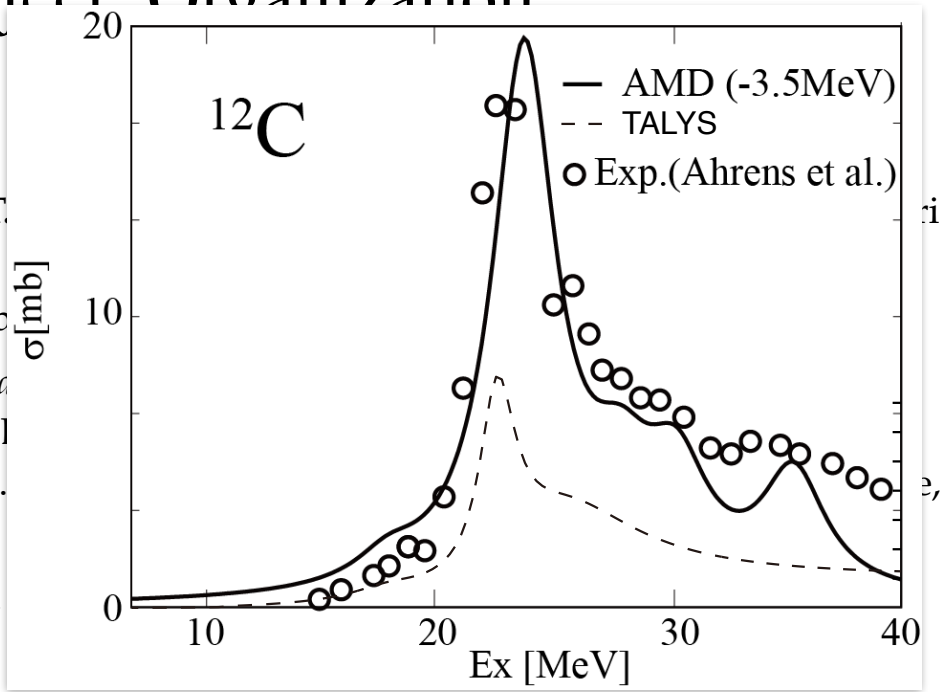
ELI-NP 2023-

absolute c.s.

model independent separation of E1 and M1

n,p,α,γ-decays up to 20 MeV

PANDORA Project: Organization



Nuclear Experiments

RCNP

Osaka Univ.

A. Tamii, N. Kobayashi, T. ...ri

ELI-NP

ELI-NP

P.-A. Söderström, D. Balab...

iThemba LABS

iThemba LABS, Witswatersla...

L. Pellegri, R. Neveling, F.I... Wiedeking, P. Adsley, L.M... A. Netshiya ...e,

TU-Darmstadt — P. von Neumann-Cosel, N.

Nuclear Theory

AMD — **M. Kimura, Y. Taniguchi**, H. Motoki — **Antisymmetrized Molecular Dynamics**

NRFT — **E. Litovinova**, P. Ring, H. Wibowo — **Nuclear Relativistic Field Theory**

TALYS — **S. Goriely**, E. Khan

UHECR Theory

Propagation — **D. Allard**, B. Baret, I. Deloncle, J. Kiener, E. Parizot, V. Tatischeff

Production — **S. Nagataki**, J. Oliver, H. Haoning

NC Neutrino Detection

M. Sakuda, M.S. Reen, Y. Koshio,

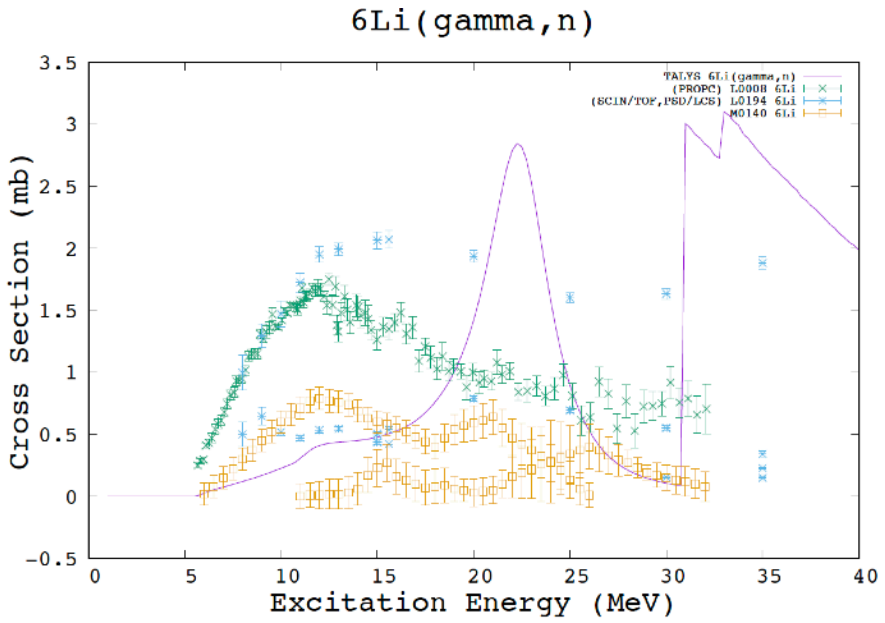
進捗状況

- ELI-NP LoI 提出 2020年1月
- PANDORA Collaboration Workshop 開催: 2020.6.30-7.1
- 日本物理学会シンポジウム「軽中重核の電弱励起・崩壊と宇宙物理」2020.9.17
- 光核反応のデータが、超高エネルギー宇宙線伝搬過程の計算に与える影響についてのStudy: 理研木戸氏、およびフランスグループ
- 核理論計算: AMD(木村G)、RPA(稲倉)、RNFT(Litovinova-G)
- New SUBARU: ^{6,7}Li(γ,xn)実験: 2021年7月
- iThemba 実験: 2021年6-7月頃になるか?
- RCNPへのプロポーザル提出 2021年1-2月?
- ELI-NPの実験は2023年に開始できるのか(???)

日本物理学会シンポジウム2020.9.17

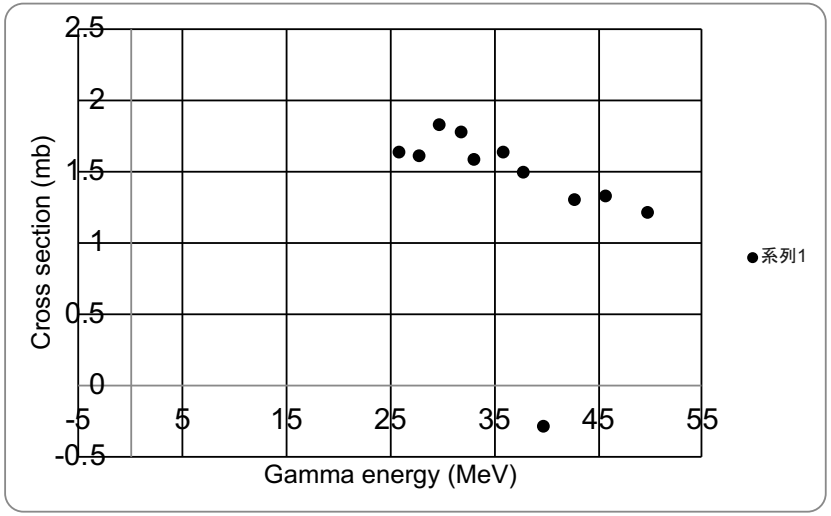
1	21535F	(姓) 須田 (姓ふりがな) 利美	(名) すだ (名ふりがな) としみ	Toshimi Suda	(和文) 東北大学電子光理学研究センター (英文) ELPH, Tohoku University	(和文) 趣旨説明・問題提起 (英文) Motivation and key questions	10
2	30895A	(姓) 民井 (姓ふりがな) たみい	(名) 淳 (名ふりがな) あつし	Atsushi Tamii	(和文) 大阪大学核物理研究センター (英文) RCNP, Osaka Univ.	(和文) 軽中重核の電気励起と崩壊測定計画: PANDORA (英文) Measurement of electric excitation and decay of light-intermediate mass nuclei: PANDORA	25
3	31015H	(姓) 垰 (姓ふりがな) さこ	(名) 隆志 (名ふりがな) たかし	Takashi Sako	(和文) 東大宇宙線研 (英文) ICRR, Univ. of Tokyo	(和文) テレスコープアレイ実験による超高エネルギー宇宙線原子核組成研究の進展 (英文) Progress on Ultra-High Energy Cosmic Ray mass composition analysis by the Telescope Array experiment	25
4	47757H	(姓) 木戸 (姓ふりがな) きど	(名) 英治 (名ふりがな) えいじ	Eiji Kido	(和文) 理研 (英文) RIKEN	(和文) 超高エネルギー宇宙線の伝搬と光核反応 (英文) Propagation of ultra-high energy cosmic rays and photo-nuclear reactions	25
5	54177D	(姓) 木村 (姓ふりがな) きむら	(名) 真明 (名ふりがな) まさあき	Masaaki Kimura	(和文) 北海道大学 (英文) Hokkaido Univ.	(和文) 反対称化分子動力学による光核励起断面積の理論計算 (英文) Photo-nuclear excitation cross section calculated by antisymmetrized molecular dynamics	25
6	16926B	(姓) 宇都宮 (姓ふりがな) うつのみや	(名) 弘章 (名ふりがな) ひろあき	Hiroaki Utsunomiya	(和文) 甲南大学 (英文) Konan Univ.	(和文) レーザーコンプトン散乱ガンマ線が拓く原子核・宇宙核物理 (英文) Laser Compton-scattered gamma rays for nuclear physics and astrophysics	
7	41484J	(姓) 稲倉 (姓ふりがな) いなくら	(名) 恒法 (名ふりがな) つねのり	Tsunenori Inakura	(和文) 東工大先導原研 (英文) LANE, Tokyo Tech	(和文) 平均場近似による光吸収断面積の系統的記述と問題点 (英文) Current status of systematic mean-field calculation of photoabsorption cross section	
8	30961J	(姓) 小汐 (姓ふりがな) こしお	(名) 由介 (名ふりがな) ゆうすけ	Yusuke Koshio	(和文) 岡山大学 (英文) Okayama Univ.	(和文) 中性カレントニュートリノ検出計画 (英文) Neutral current neutrino detection	
9	34366F	(姓) 宇都野 (姓ふりがな) うつの	(名) 穣 (名ふりがな) ゆたか	Yutaka Utsuno	(和文) 原子力機構 (英文) JAEA	(和文) 大規模殻模型計算によるE1応答 (英文) Large-scale shell-model calculations of E1 responses	25

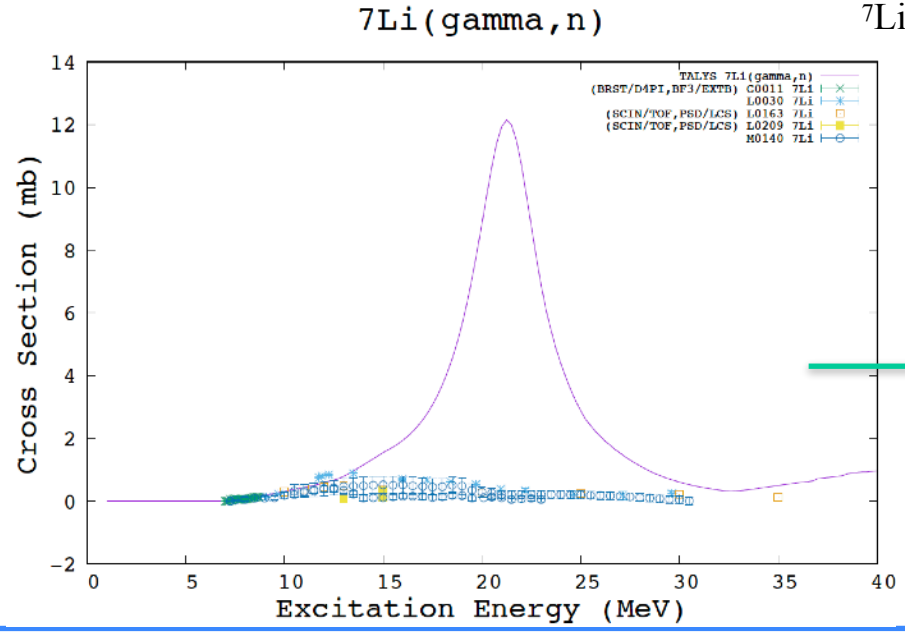
^{6,7}Li(γ,xn)実験 at New SUBARU-GACKO



NewSUBARU - Online Rough Analysis (γ,1n)

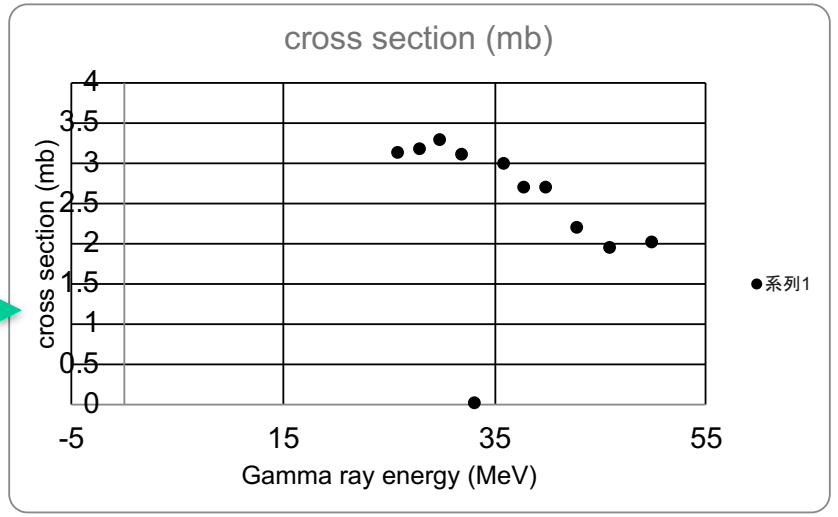
^{6}Li





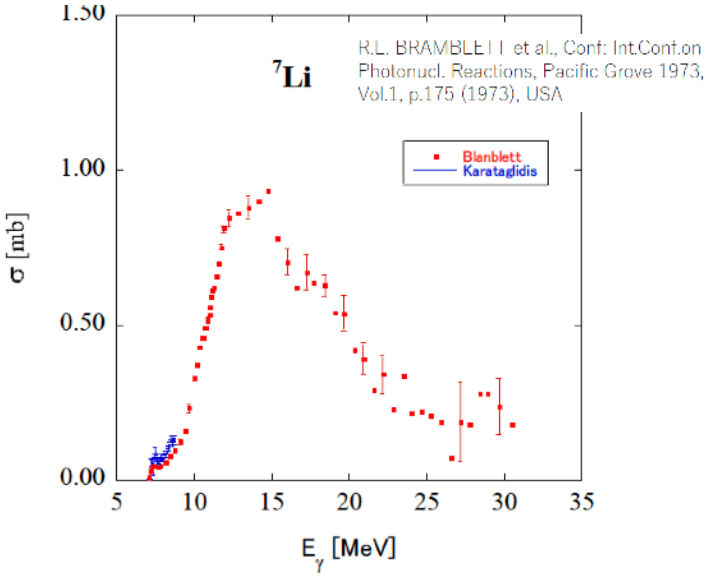
^{7}Liの断面積が全く違う(ずっと大きい)?

Nat$^{}$Li ^{7}Li 92.5%



Data analysis in progress

^{7}Li photo-nuclear cross sections (comparison)



^{Nat}Li(γ,abs) Ahrens et al., NP251, 479(1975)

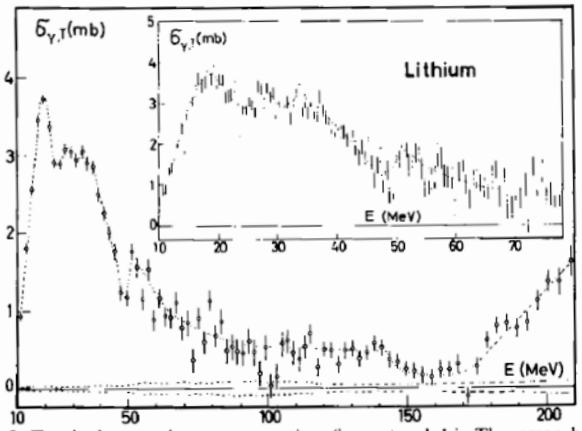


Fig. 2. Total photonuclear cross section for natural Li. The error bars indicate one standard deviation of counting statistics from the main spectrometer. The dashed lines along the abscissa indicate the uncertainty due to counting statistics in the normalizing spectrometer. Oscillations of the base line within this area are possible, the period of these oscillations, however, must not be smaller than 10% in photon energy. The dashed and dotted lines through the cross section values have been drawn to guide

W.A. Wurts et al., PRC 84, 044601 (2011)

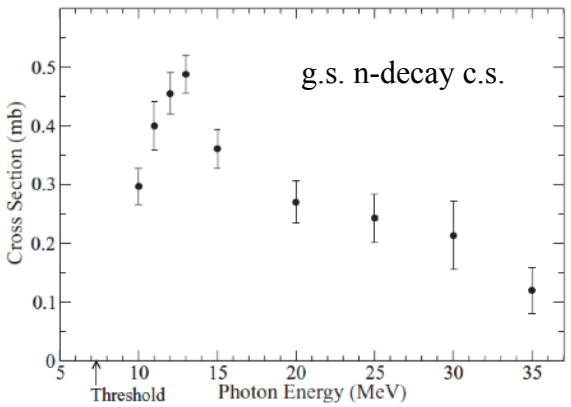
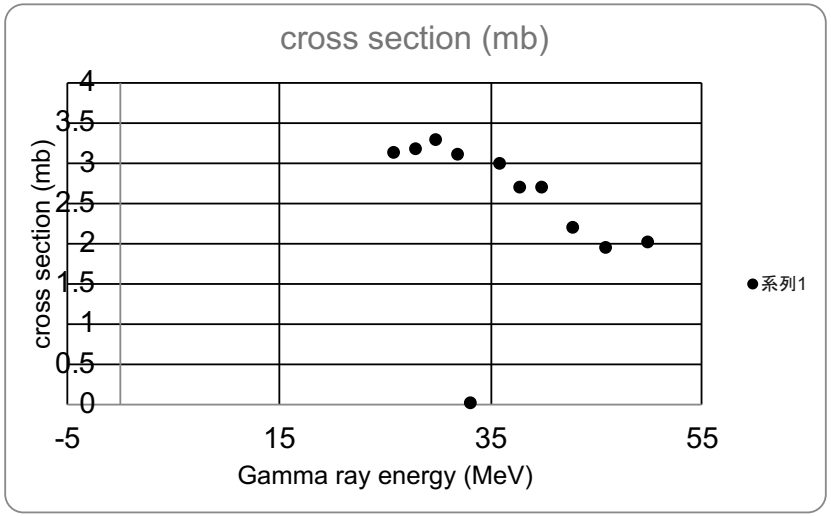


FIG. 4. The absolute cross section for $^{7}\mathrm{Li} + \gamma \rightarrow {}^{6}\mathrm{Li(g.s.)} + n$. Error bars represent both statistical and systematic uncertainties added in quadrature.

NewSUBARU - Online Rough Analysis (γ,1n) ^{Nat}Li ^{7}Li 92.5%



Data analysis in progress