中性子過剰核の電気双極子応答と核物質の状態方程式

梅野 泰宏

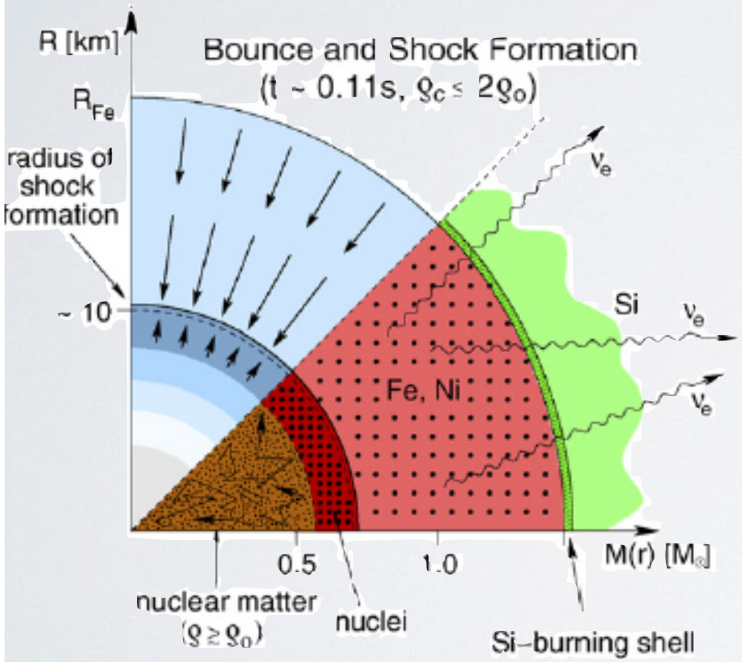
東京工業大学

状態方程式と天体現象

$$\frac{E}{A}(\rho,\delta) = \frac{E}{A}(\rho,0) + E_{sym}(\rho)\,\delta^2 + O\left(\delta^4\right)$$

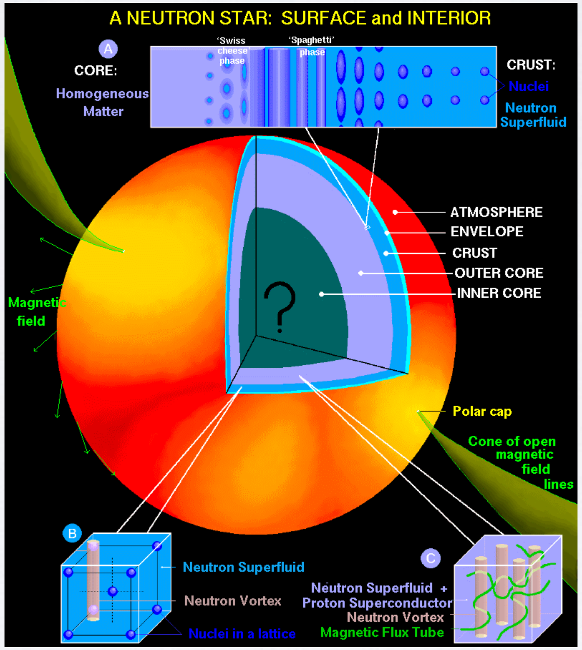
$$\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p} \simeq \frac{N-Z}{A}$$

Core collapse supernovae



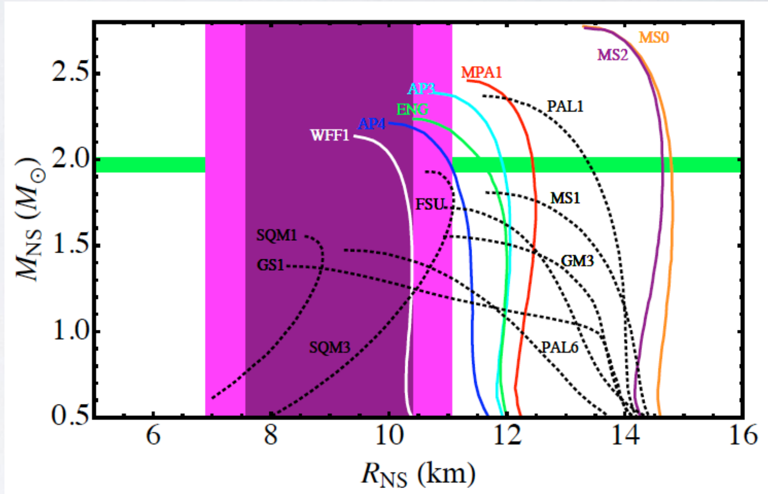
H.-Th. Janka et al., Phys. Rep. 442, 38 (2007)

Neutron star structure



http://www.astroscu.unam.mx/neutrones/NS-Picture/NStar/NStar_l.gif

Neutron star R vs Mass



S. Guillot et al., arXiv, 1302.0023

核物質の状態方程式

$$\frac{E}{A}(\rho,\delta) = \frac{E}{A}(\rho,0) + E_{sym}(\rho)\,\delta^2 + O\left(\delta^4\right)$$

$$\frac{E}{A}(\rho,0) = \frac{E}{A}(\rho_0) + \frac{K_\infty}{2}x^2 + \ldots$$

$$E_{sym}(\rho) = J + Lx + \frac{K_{sym}}{2}x^2 + \ldots$$

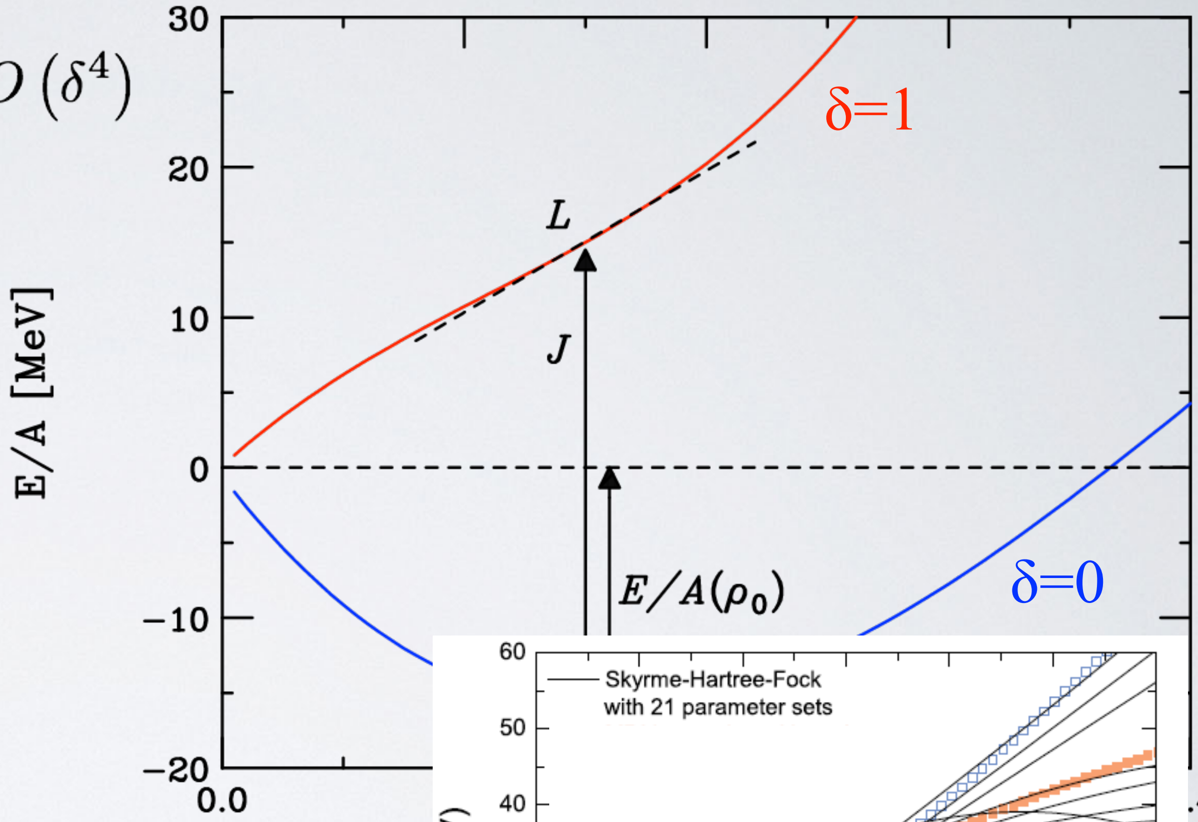
$$\delta = \frac{\rho_n - \rho_p}{\rho_n + \rho_p} \simeq \frac{N-Z}{A},\quad x = \frac{\rho - \rho_0}{3\rho_0}$$

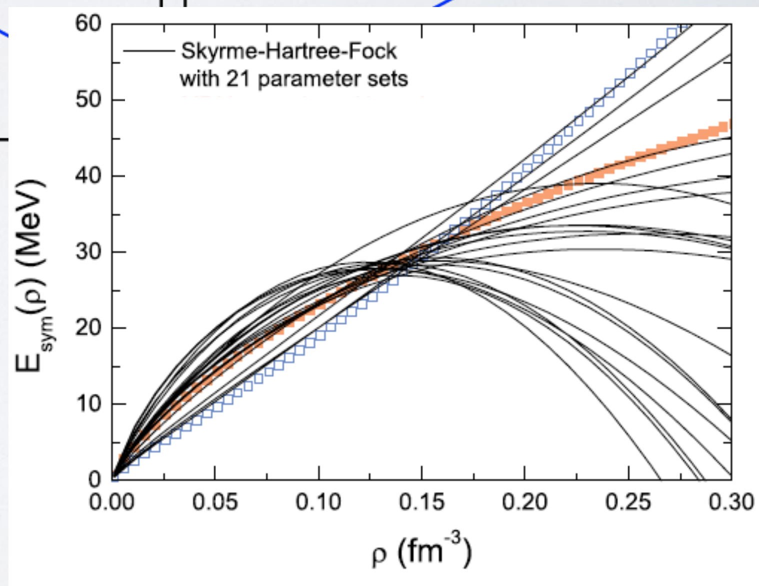
$$\frac{E}{A}(\rho_0) \sim 16\ \mathrm{MeV}$$

$$J \sim 32\ \mathrm{MeV}$$

B. Tsang et al. PRC 86, 015803 (2012).

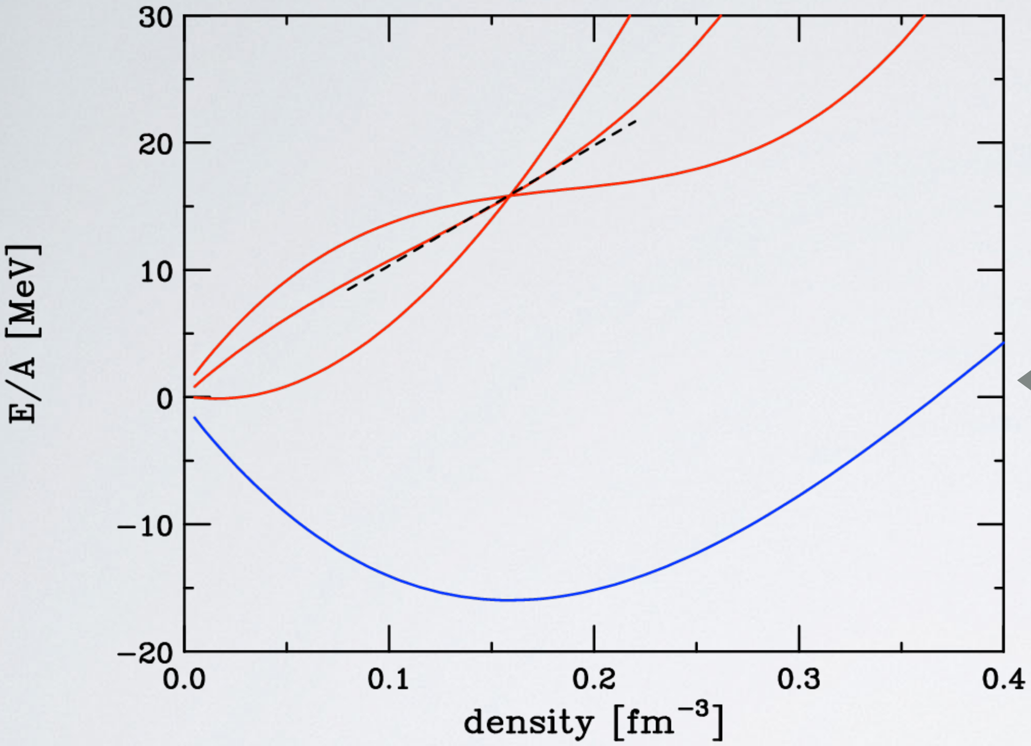
- L: 不定性が大きい

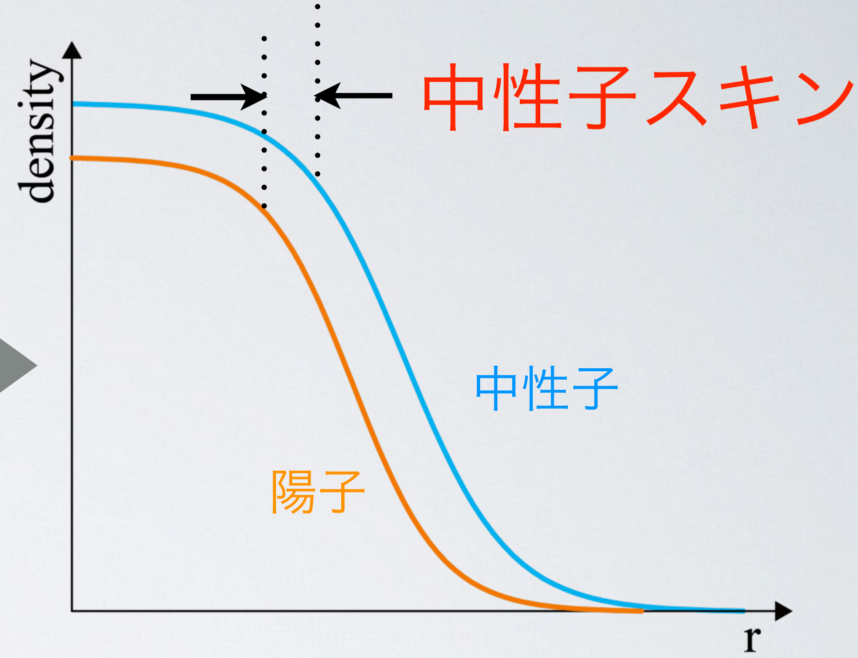




L. W. Chen et al. PRC72, 064309

対称エネルギーの密度依存性と中性子スキン

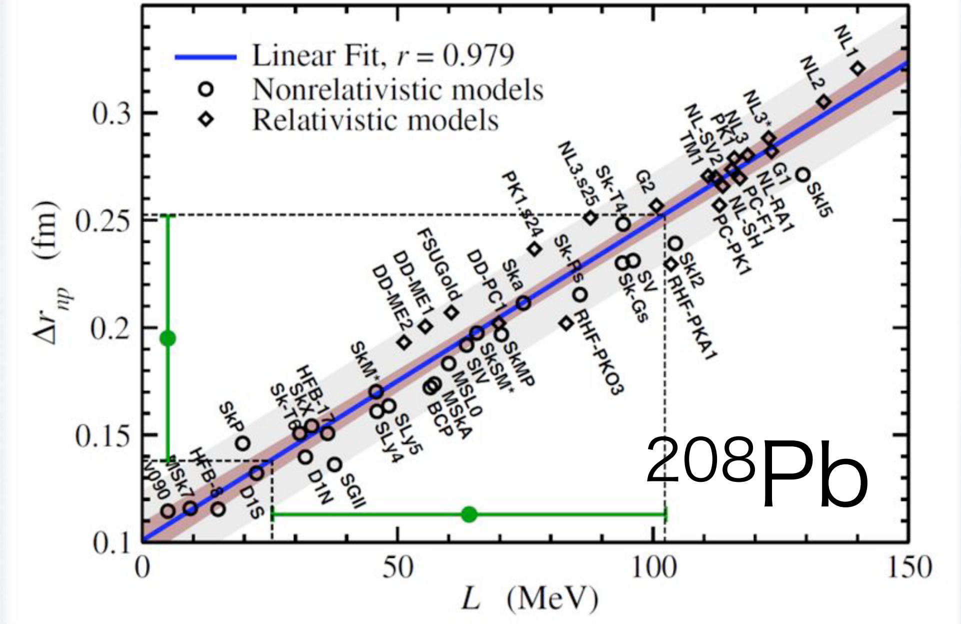




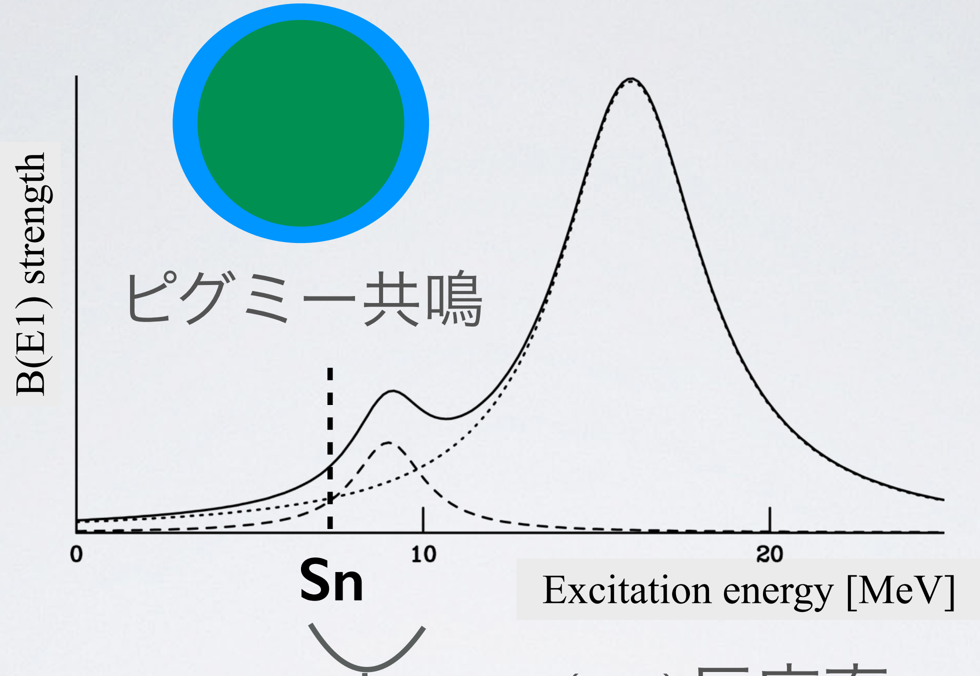
Large *L* → Small Esym in low-ρ

→ Thick *n*-skin

Roca-Maza et al., PRL 106, 252501



中性子過剰核のE1応答



(n,γ)反応率→ r-process

- ピグミー共鳴(PDR)
  - Ex~10 MeV, ~5% of EWSR
- 巨大双極子共鳴
  - Ex~15 MeV, ~100% of EWSR

中性子スキン、

対称エネルギーの

密度依存性

J. Piekarewicz, EPJA 50, 25 (2014).

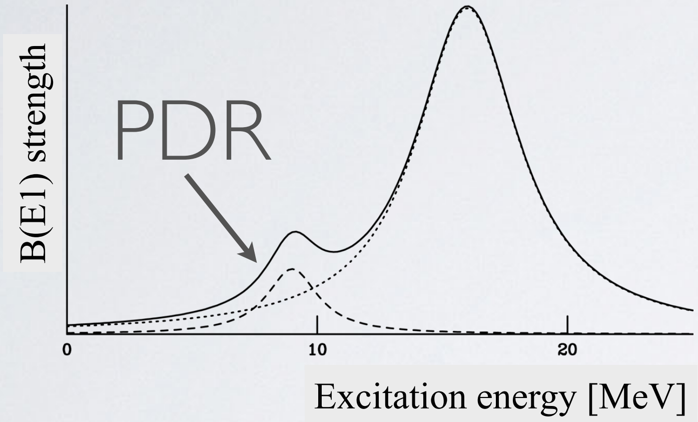
E1応答-対称エネルギー-スキン厚

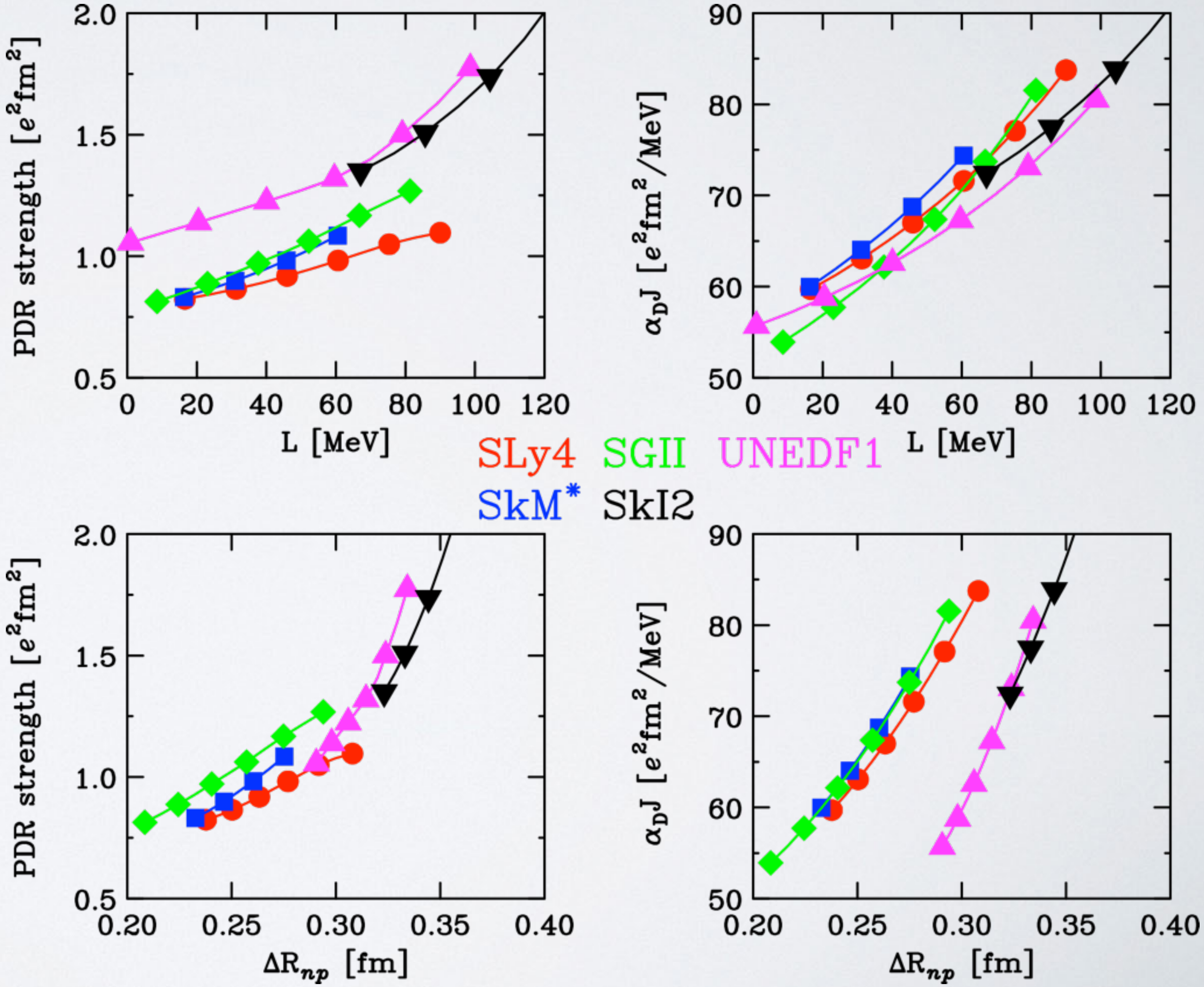
$$\frac{E}{A}(\rho,\delta) = \frac{E}{A}(\rho,0) + E_{sym}(\rho)\,\delta^2 + O\left(\delta^4\right)$$

$$E_{sym}(\rho) = J + Lx + \frac{K_{sym}}{2}x^2 + \ldots$$

T. Inakura, private communication

^{52}CaのRPA計算



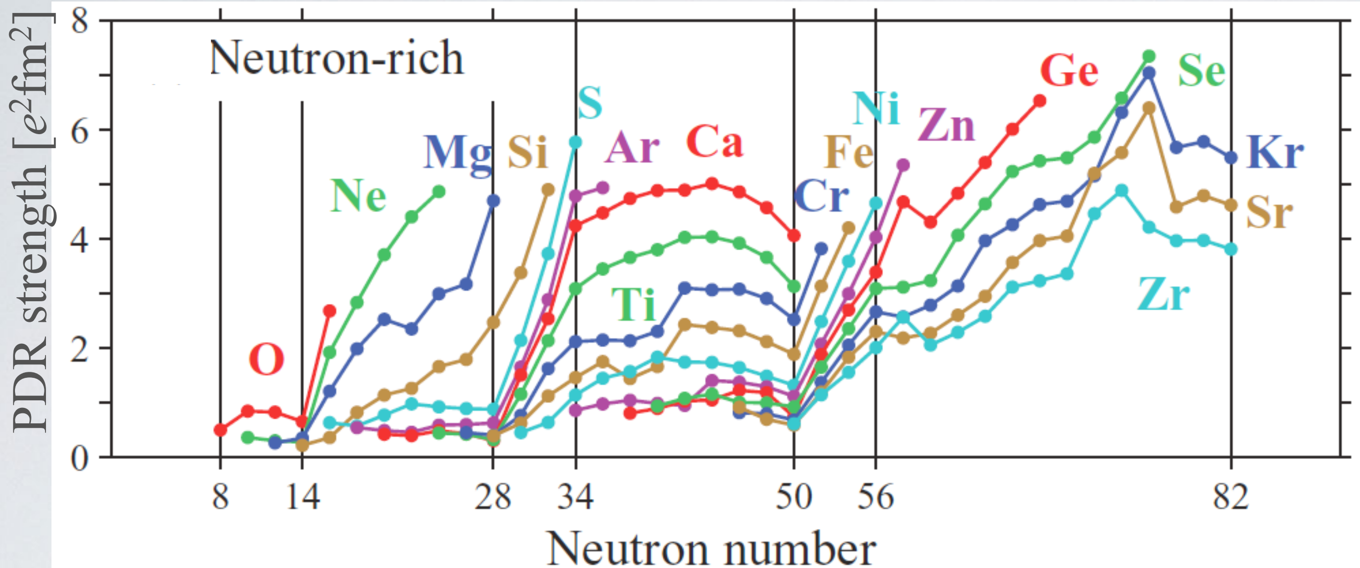


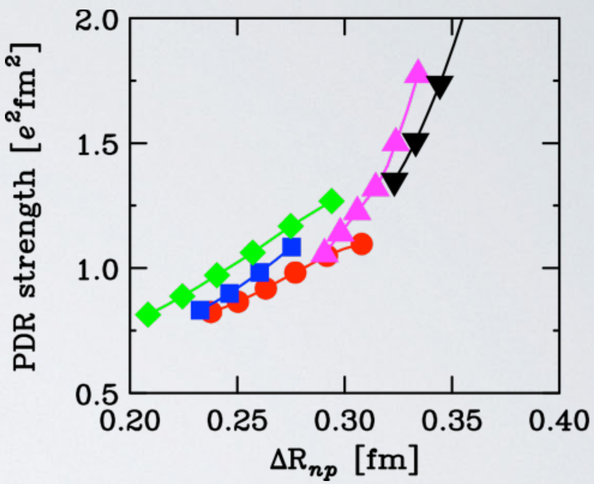
- PDR強度
- 双極子分極度 α_D

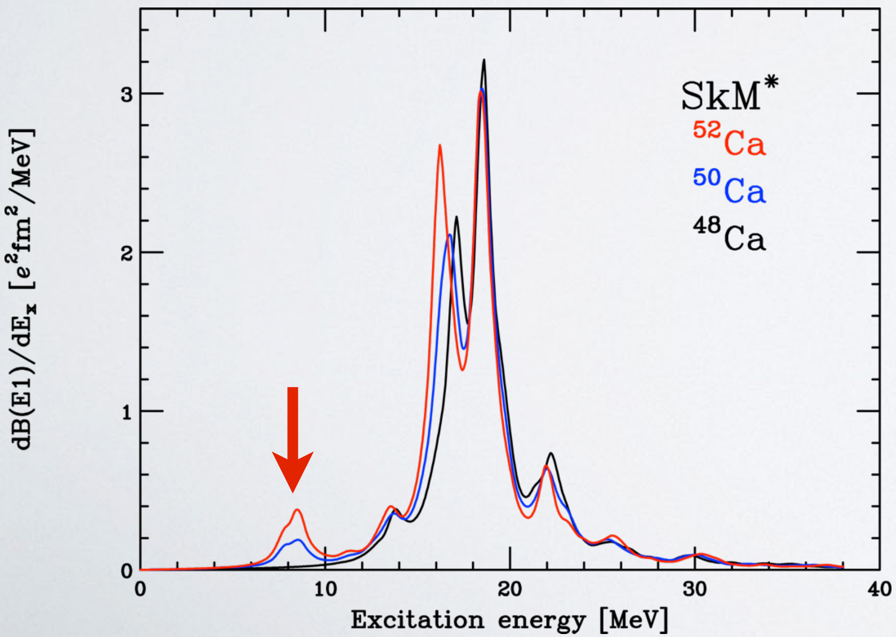
$$\alpha_D = \frac{8\pi}{9}\int \frac{dB(E1)}{\omega}$$

PDR強度の同位体依存性

- 48-54Ca: 急激なPDR強度の増大 T. Inakura et al., PRC84, 021302 (2011)



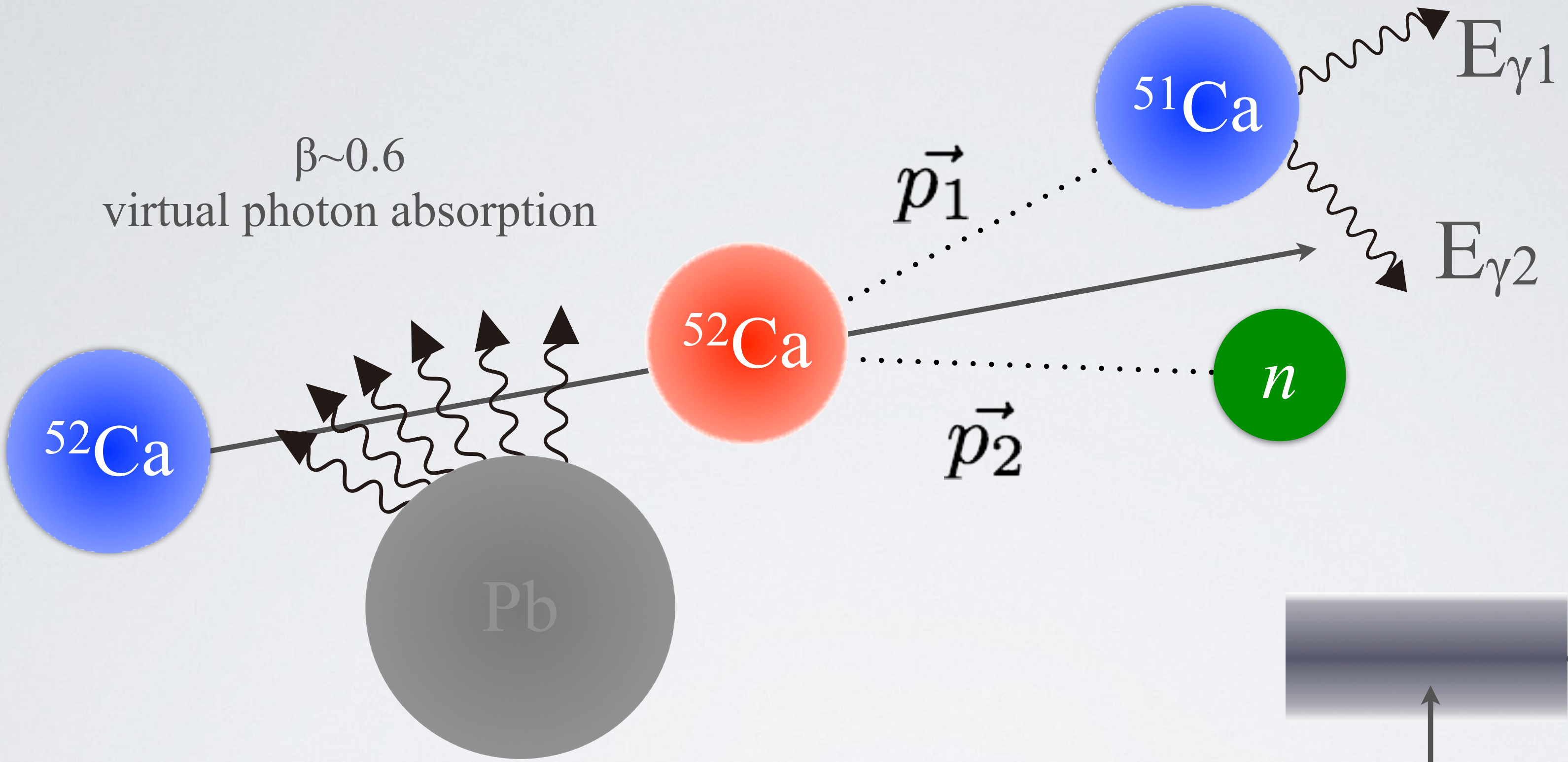


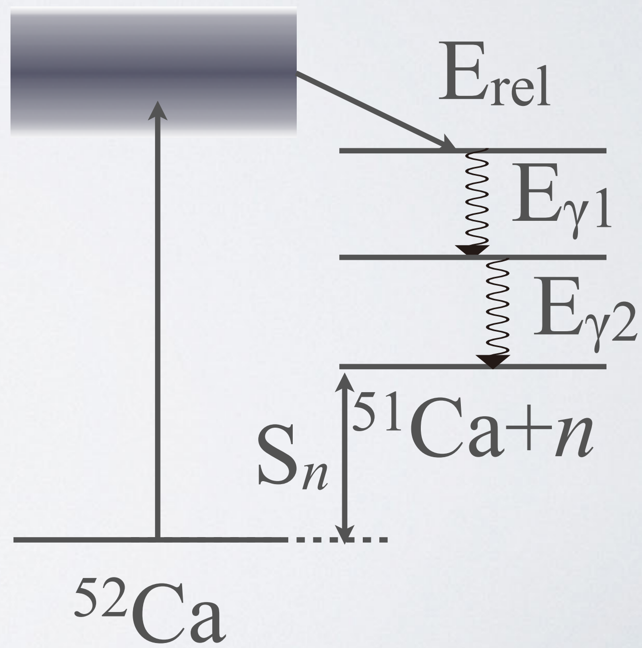


48-52CaのE1応答測定
→PDRの進化
→2p軌道におけるスキンの進化
→Lの制限

SAMURAIで実験

クーロン励起と不変質量法

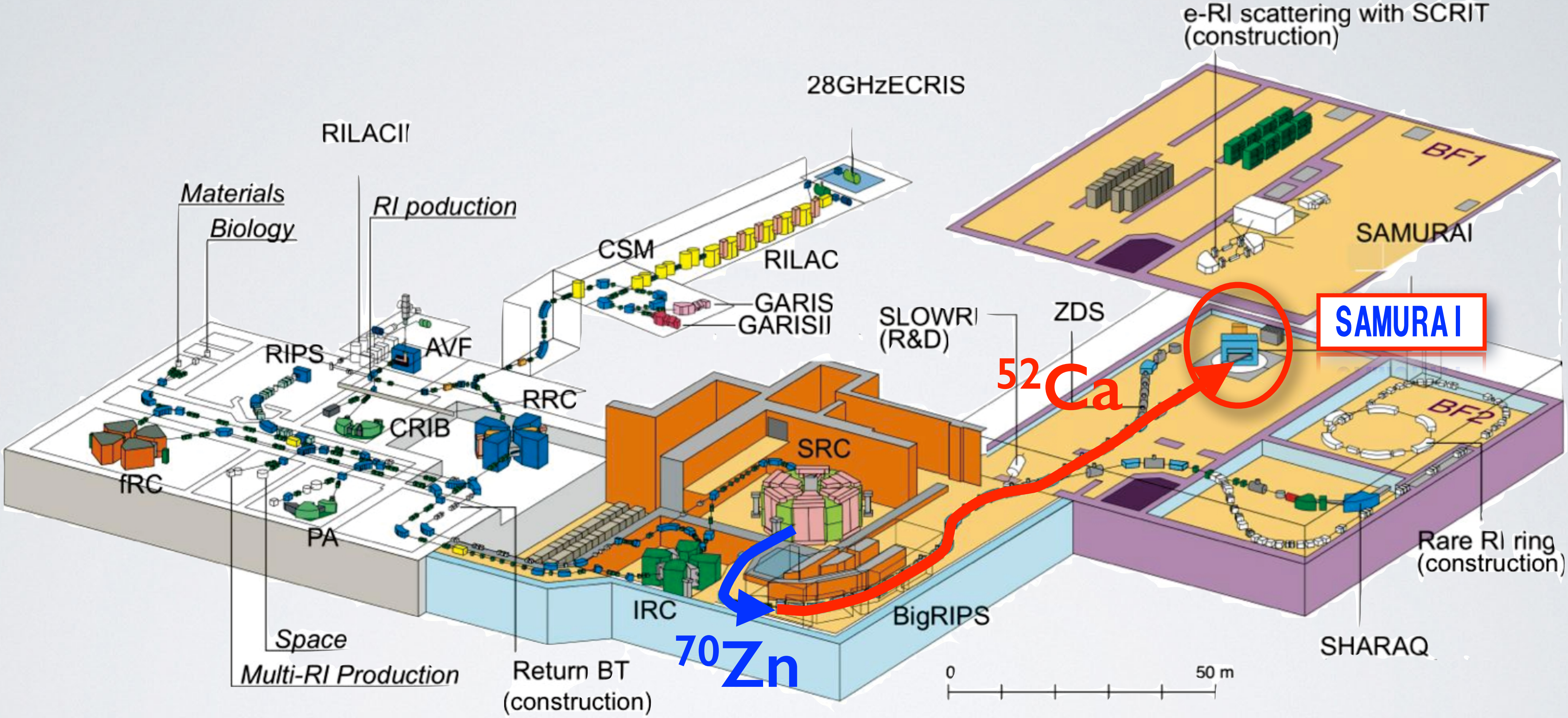




$$E_{rel} = \sqrt{\left(\sum E_i\right)^2 + \left(\sum \vec{p_i}\right)^2} - (m_{^{51}Ca} + m_n)$$

$$E_x = E_{rel} + S_n + \sum E_{\gamma i}$$

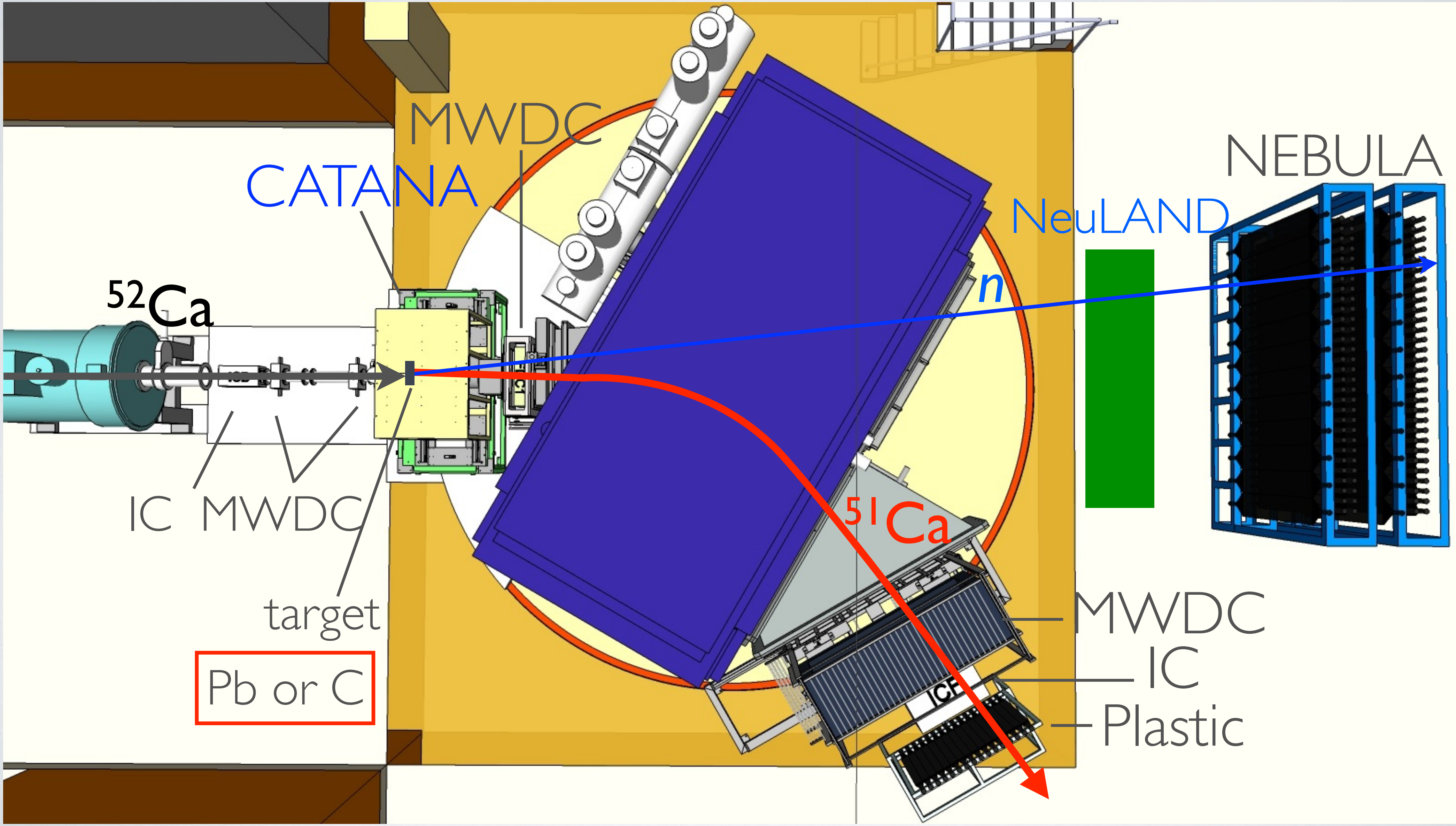
理研仁科センター



1次ビーム^{70}Zn@ 345 MeV/nucleon

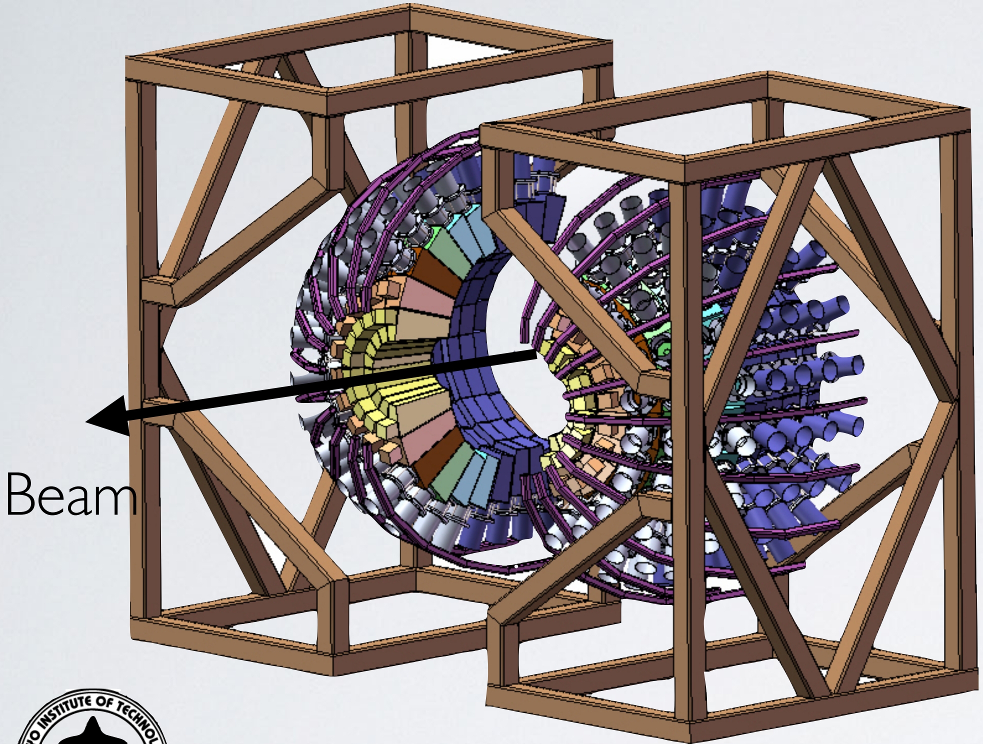
→ 2次ビーム ^{48,50,52}Ca(10^2~10^4 cps)

SAMURAI



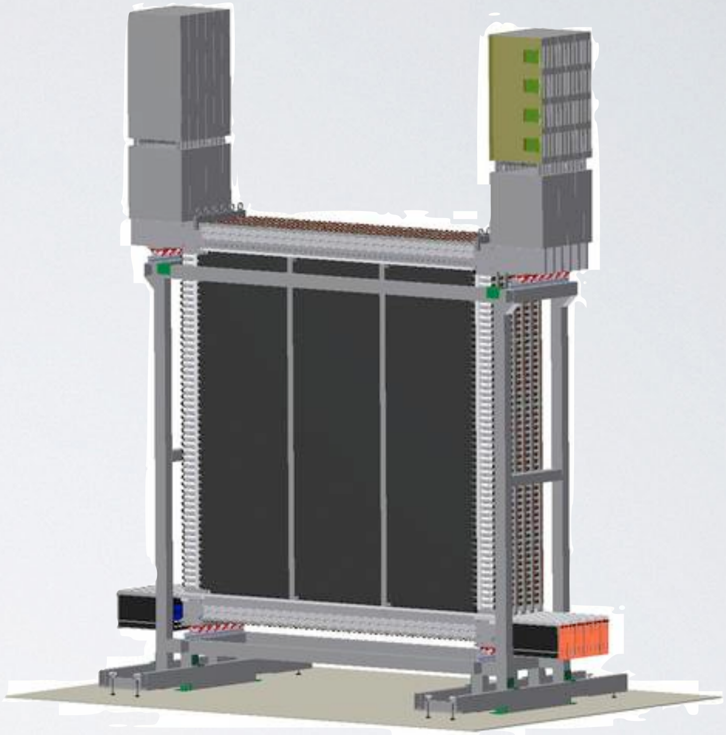
MWDC
CATANA
NEBULA
NeuLAND
52Ca
n
IC MWDC
51Ca
target
MWDC
IC
Plastic
Pb or C

追加される検出器



CATANA

- 200 CsI(Na) detectors
- thickness: 9.5 ~ 15 cm
- Photo peak efficiency
  - 56% for 1 Me
- 2015年夏完成予定



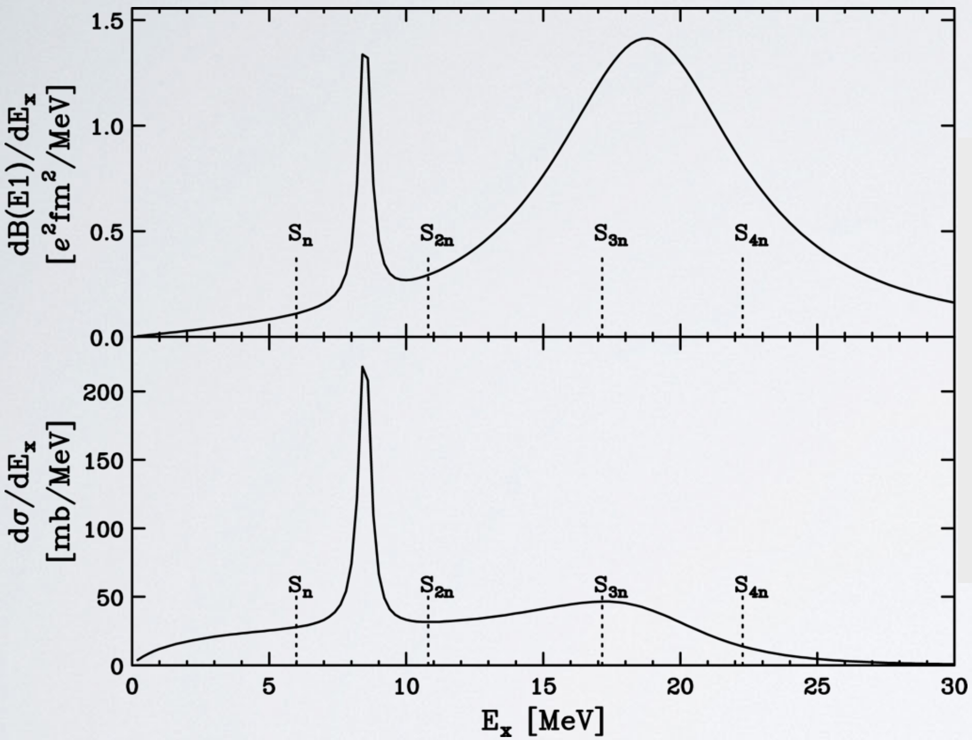
NeuLAND

- 400 plastic scintillator bar
  - 5 x 5 x 250 cm^3
- one neutron detection efficiency with NEBULA
- Commission: October, 2014@GSI

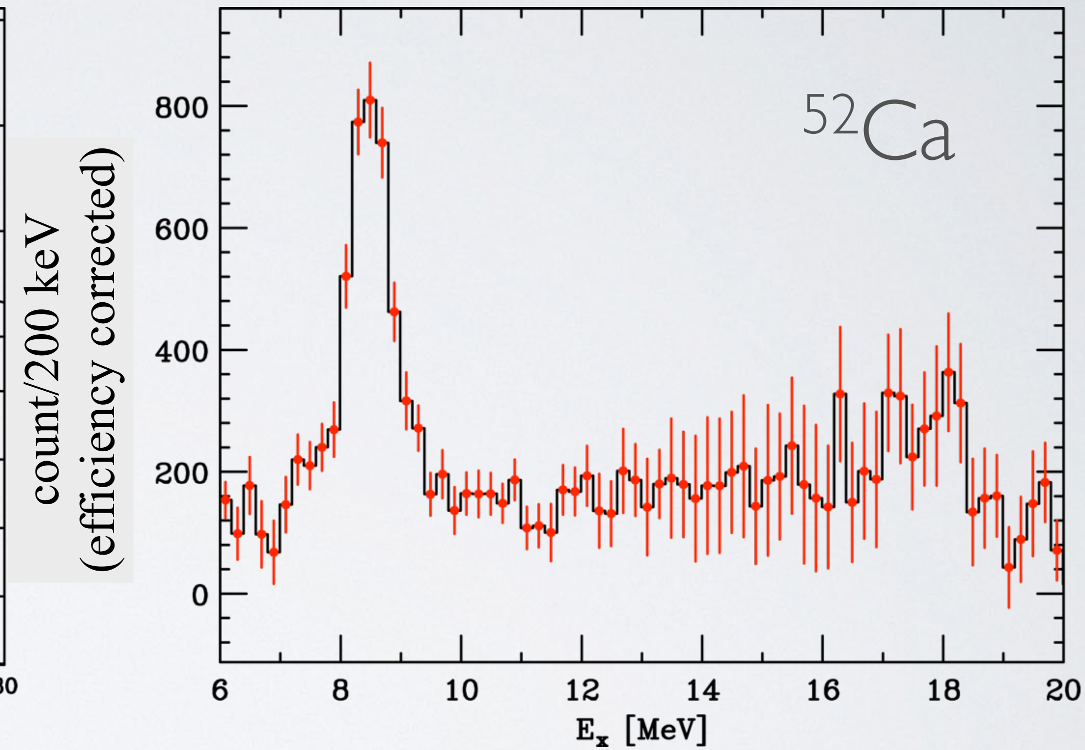
実験は2015年夏以降を予定

励起エネルギーの再構成

- B(E1)分布: PDR + GDR



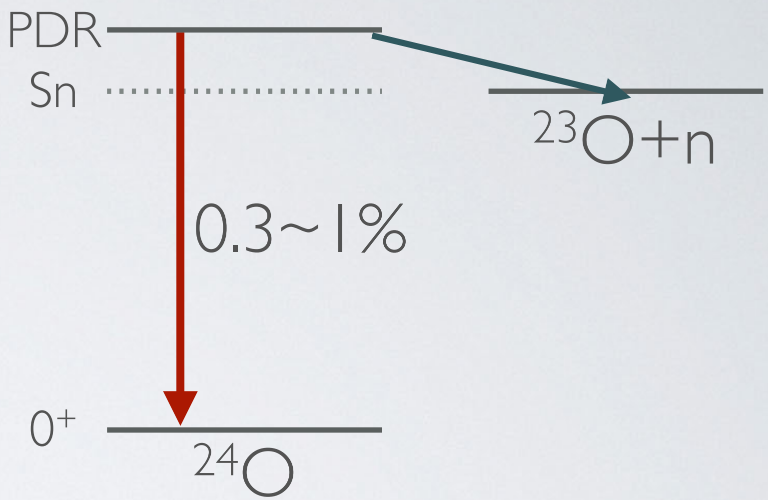
Simulation



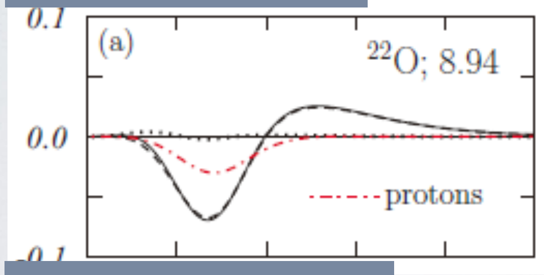
- 検出器の分解能を含んでいる

γ spectroscopy for PDR

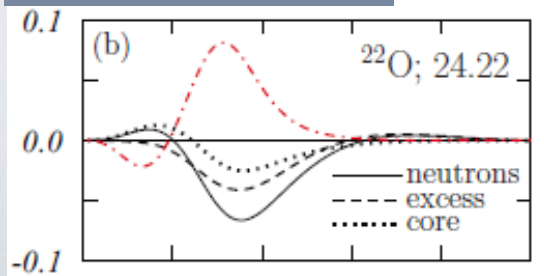
- ^{20,22,24}O: (α,α'γ) and Coulex: H. Baba
- ^{70,72}Ni: Coulex: O. Wieland
- ^{124,128,132}Sn: (α,α'γ): T. Aumann



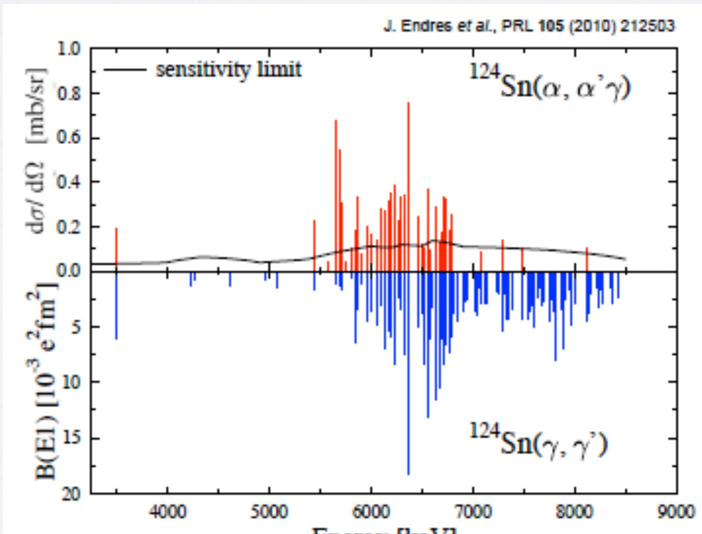
^{22}O PDR: IS



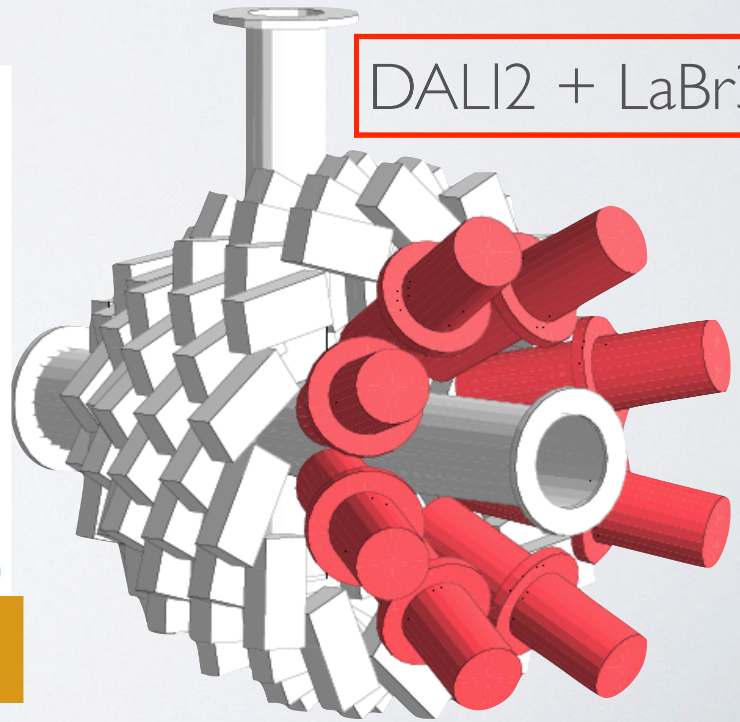
^{22}O GDR: IV



G. Co' et al., PRC 87,034305 (2013).

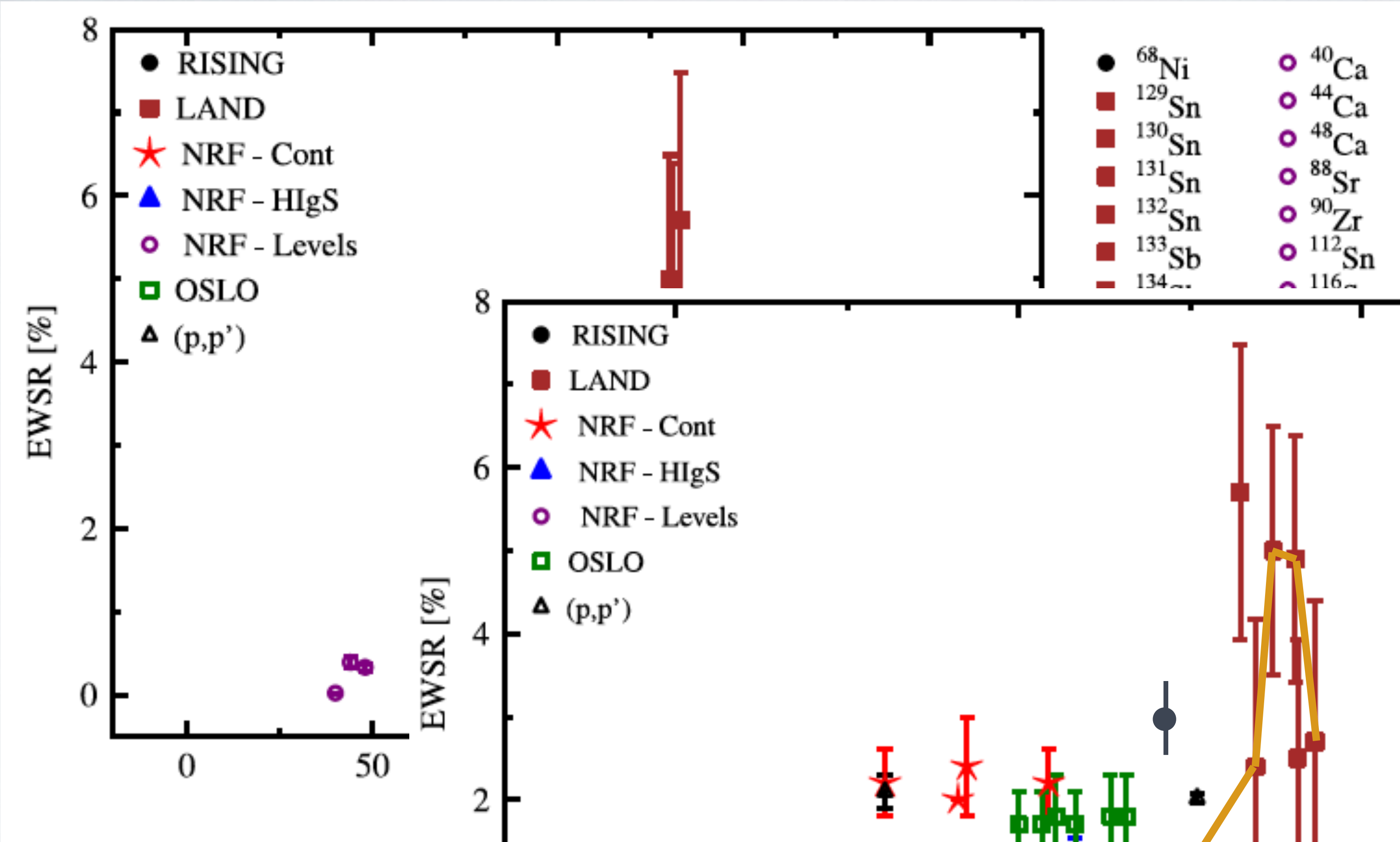


実験は2014年秋？

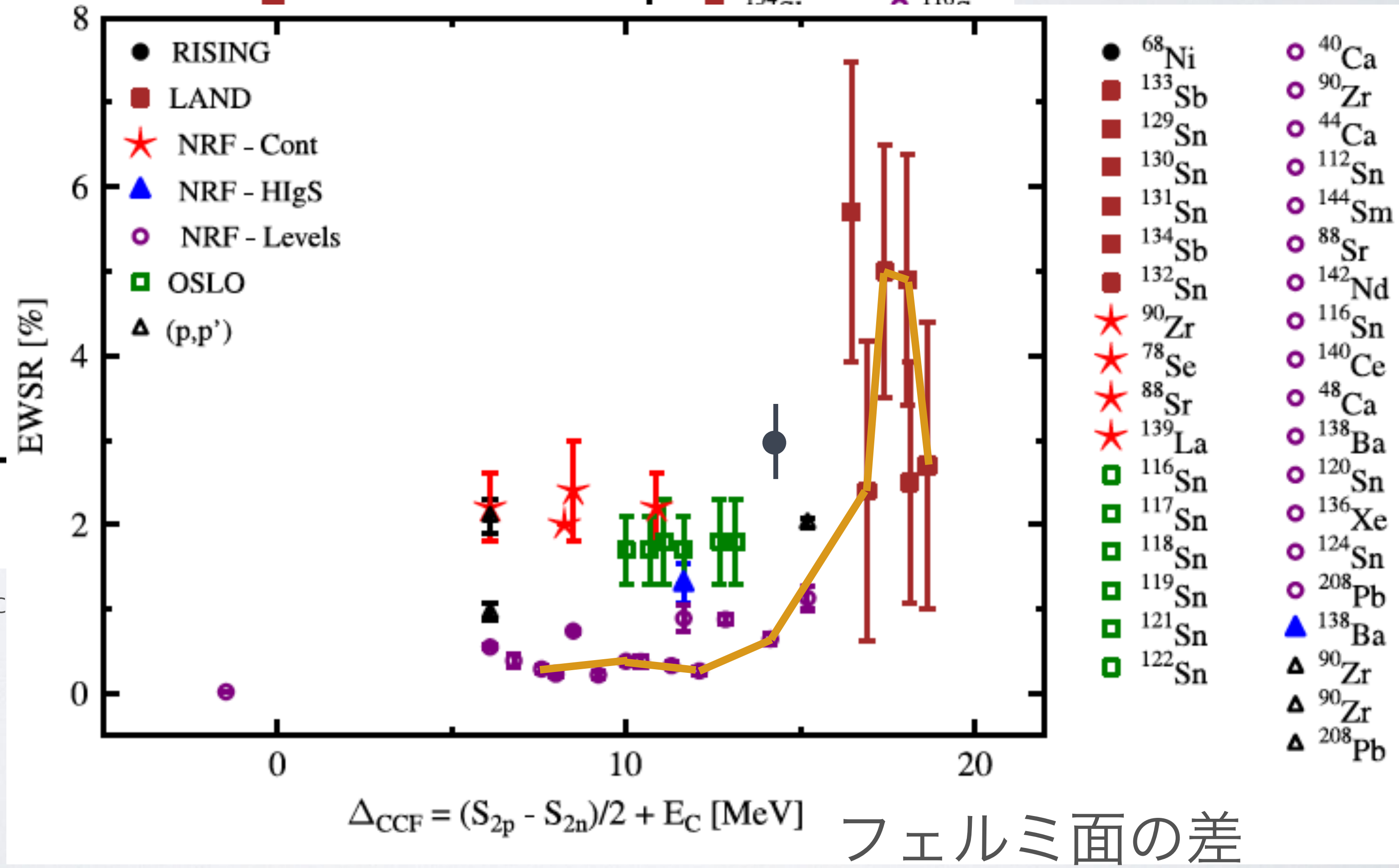


DALI2 + LaBr3

PDRの現状



D. Savran et al., Prog. Part. Nuc



まとめと今後の展望

- ^{48,50,52}CaのE1応答測定 → PDRの進化、skin厚、EOS
  - SAMURAI + CATANA + NeuLAND
  - 7日間のビームタイムを獲得 → 2015年
- γ線分光によるPDR測定実験

- Isovector とIsoscaler成分
- 系統的測定
  - Ca, Ni, Sn同位体