

DIRECT MEASUREMENT OF THE $^{12}\text{C}+^{12}\text{C}$ FUSION REACTION

X.D. Tang^{1,2}

On behalf of the Carbon Fusion Experiment (CARFUSE) Collaboration

¹Institute of Modern Physics, CAS, China

*²Joint Department for Nuclear Physics,
Lanzhou University and Institute of Modern Physics, CAS, China*



INPC 2025

May 25-30, 2025
DCC, Daejeon, Korea

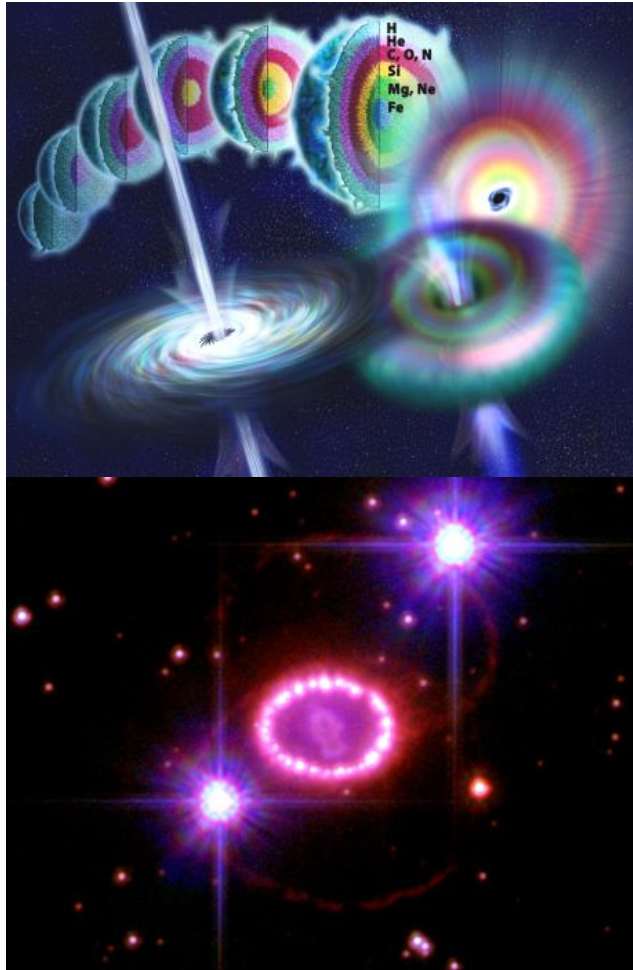


CARbon FUSion Experiment (CARFUSE) @LEAF, IMP

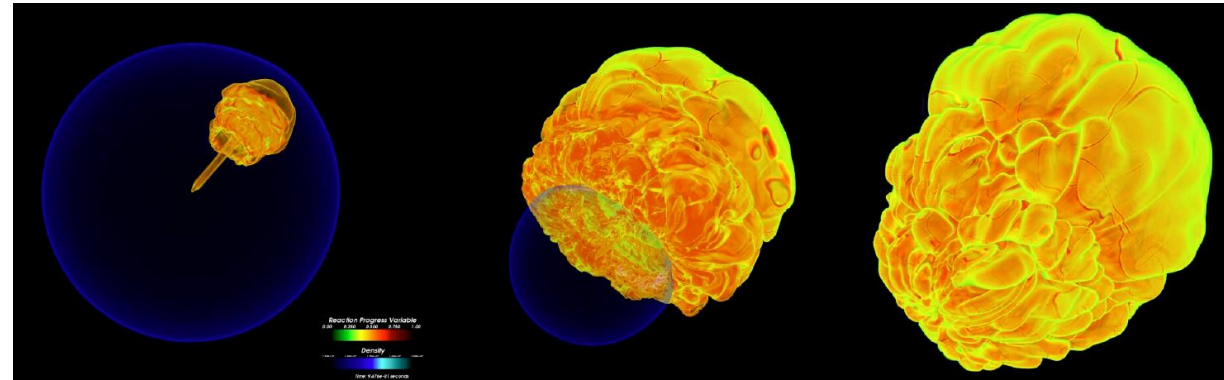


Carbon burning in the universe

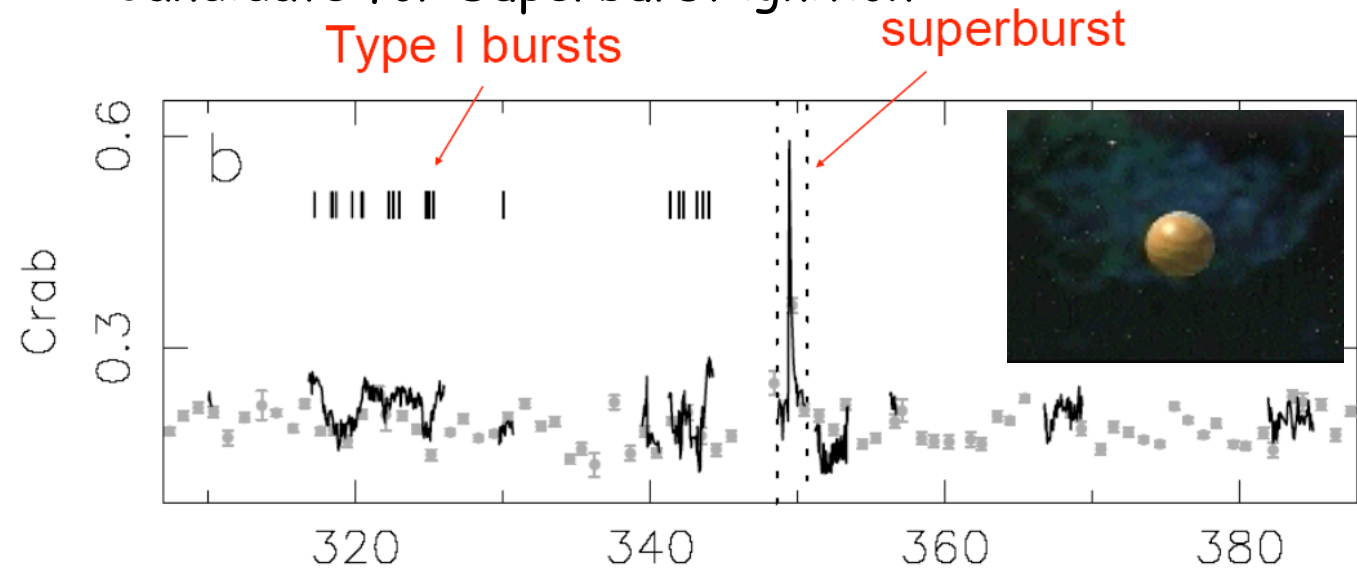
Nucleosynthesis in massive stars



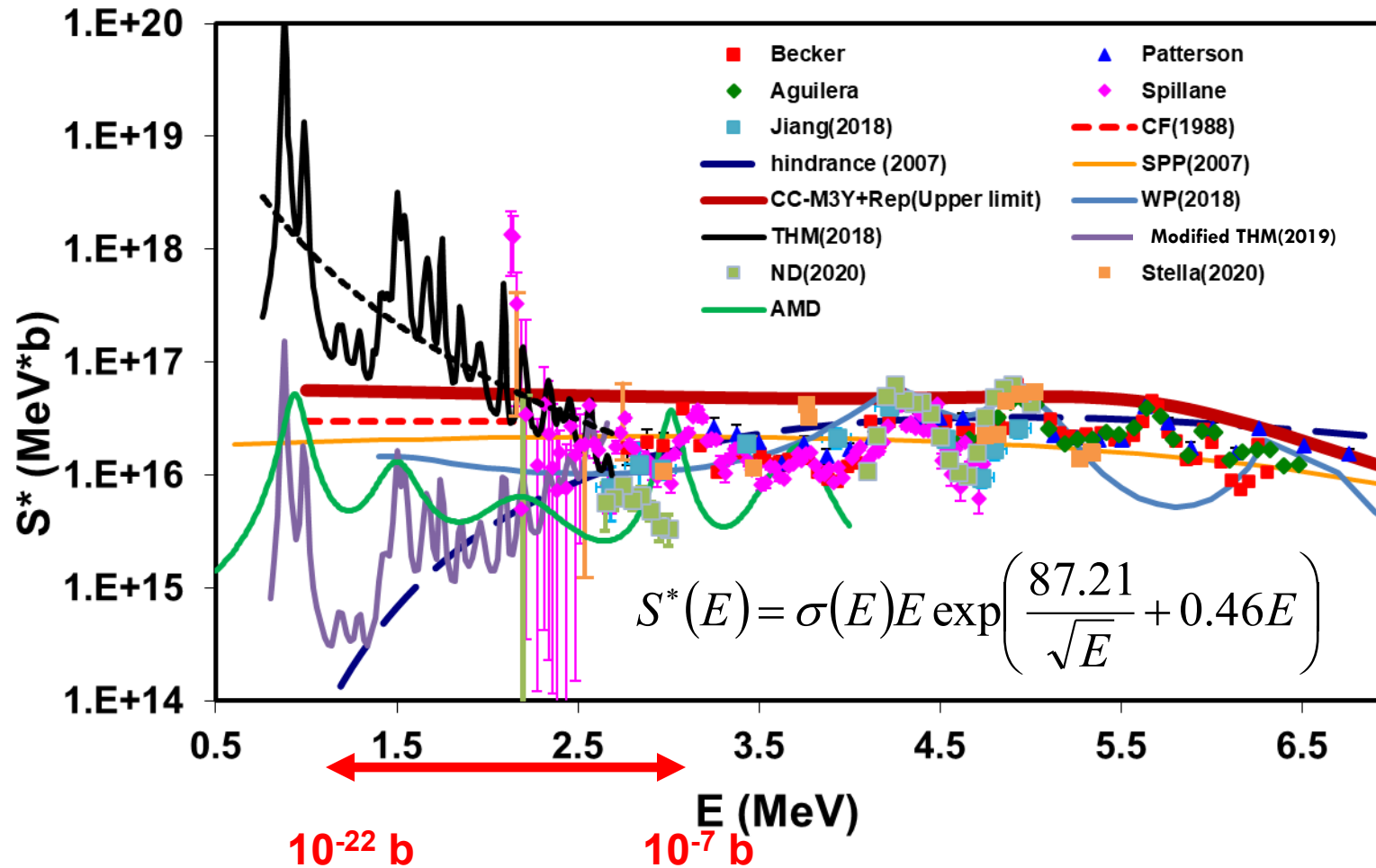
Ignition conditions in type Ia supernovae



Candidate for Superburst ignition



Uncertain cross section at stellar energies



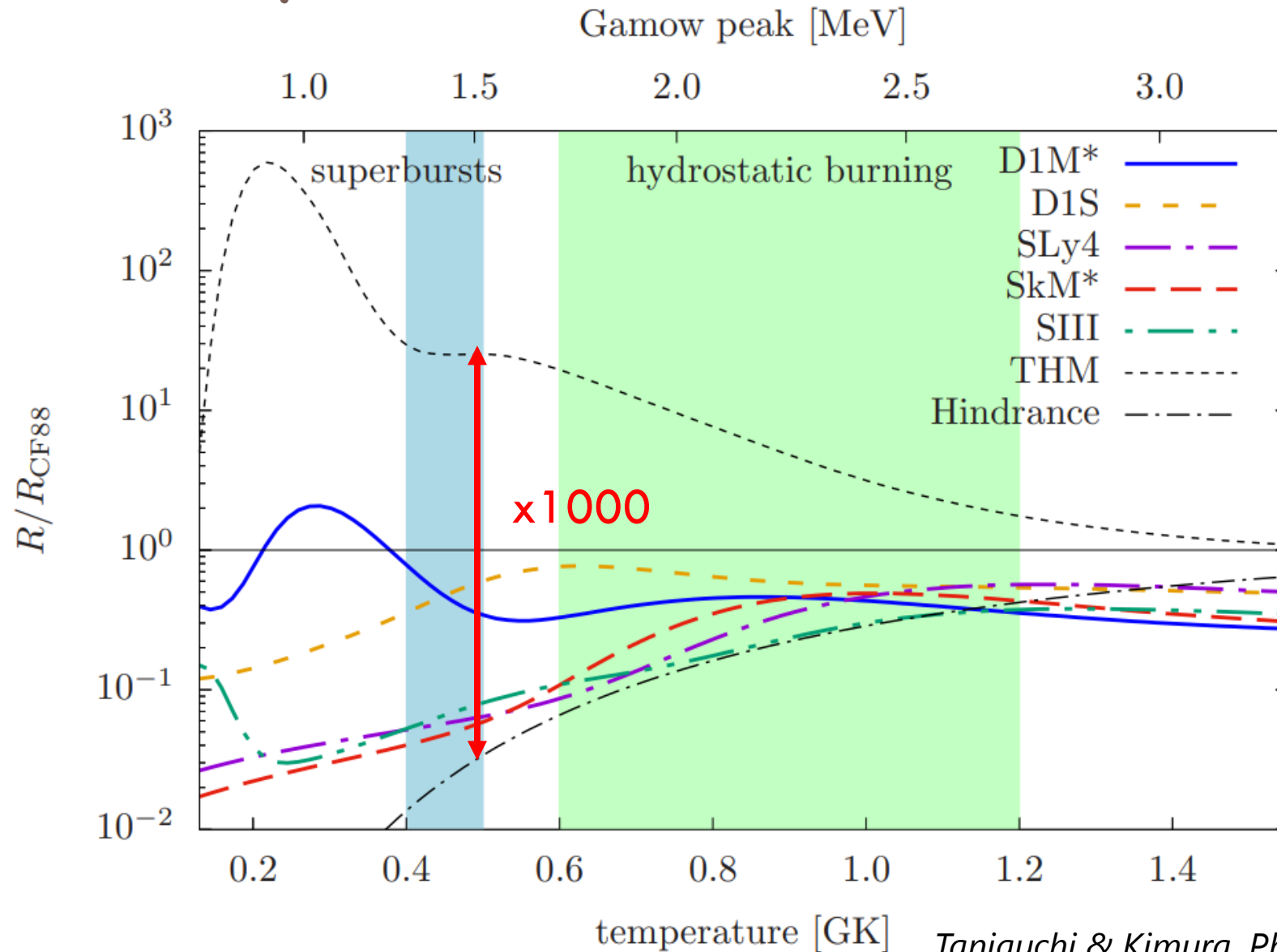
- Large difference between THM and Hindrance \rightarrow Highly uncertain rate
- INDIRECT: Corrected THM exhibits a trend similar to Hindrance by replacing PWIA with DWIA
- Unknown resonances: Need better selection ($T=0, J^\pi=0^+, 2^+$)

$^{12}\text{C}(^{12}\text{C}, \text{p})^{23}\text{Na}$ (Q=2.24 MeV)
 $^{12}\text{C}(^{12}\text{C}, \alpha)^{20}\text{Ne}$ (Q=4.62 MeV)
 $^{12}\text{C}(^{12}\text{C}, \text{n})^{23}\text{Mg}$ (Q=-2.62 MeV)
 $^{12}\text{C}(^{12}\text{C}, ^8\text{Be})^{16}\text{O}$ (Q=-0.20 MeV)

1. Beck, Mukhamedzhanov and Tang, Eur. Phys. J. A (2020) 56:87
2. Mukhamedzhanov, Eur. Phys. J. A (2022) 58:71
3. Tang & Ru, EPJ Web of Conferences 260, 01002 (2022)

4. Adsley et al., PRL(2022)
5. Nan et al., PLB(2025)

Uncertainty in the reaction rate



Related talks in INPC

□ Parallel Session: 6 Nuclear Astrophysics:

- Room 4: 1F #101 (May 29, 4:30 PM - 6:30 PM)

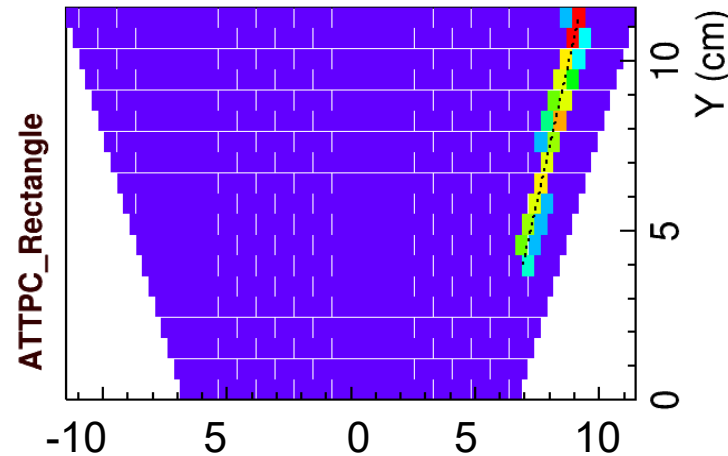
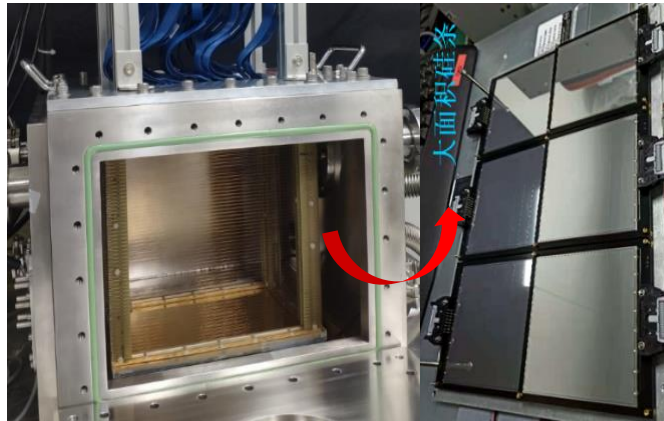
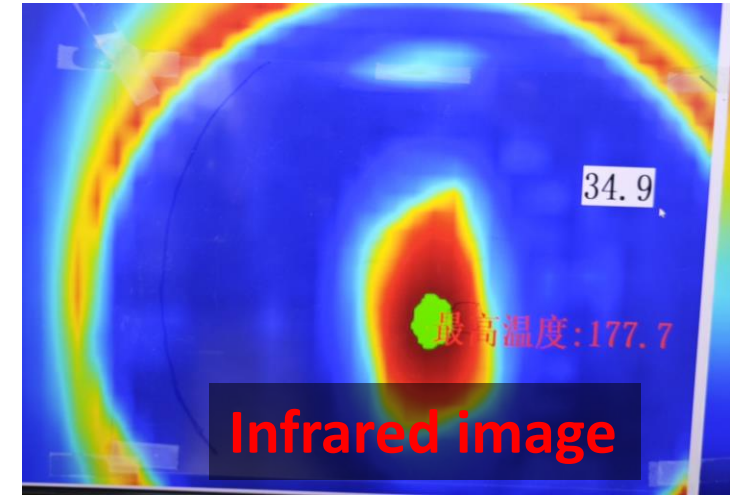
- ❖ Towards a new direct measurement of the $12\text{C}+12\text{C}$ process deep underground by LUNA, FERRARO, Federico
- ❖ Impacts of molecular resonances on astronuclear reactions, TANIGUCHI, Yasutaka

□ Parallel Session: 5 New Facilities and Instrumentation:

- Room 1: 2F Grand Ballroom #201-202 (May 29, 11:00 AM - 1:00 PM)

- ❖ Commissioning and operation of LEAF with high intensity heavy ion beams, YANG, Yao

High Intensity+Time Projection Chamber



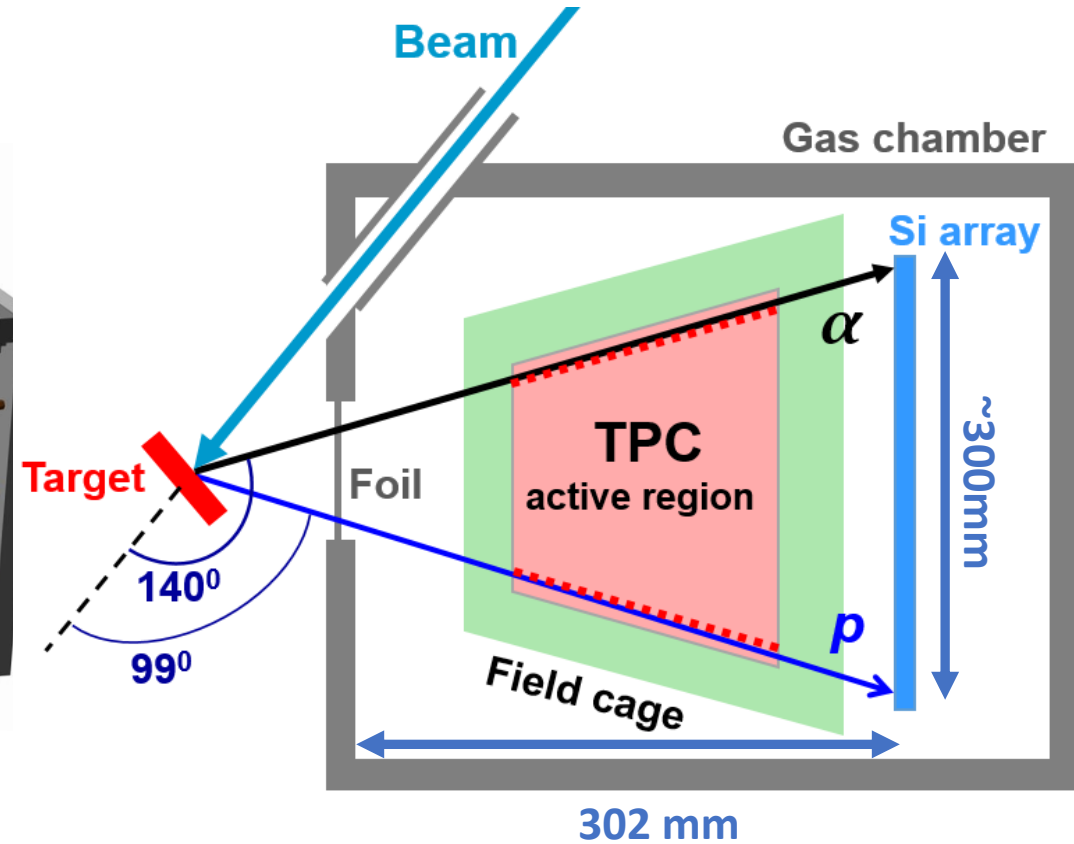
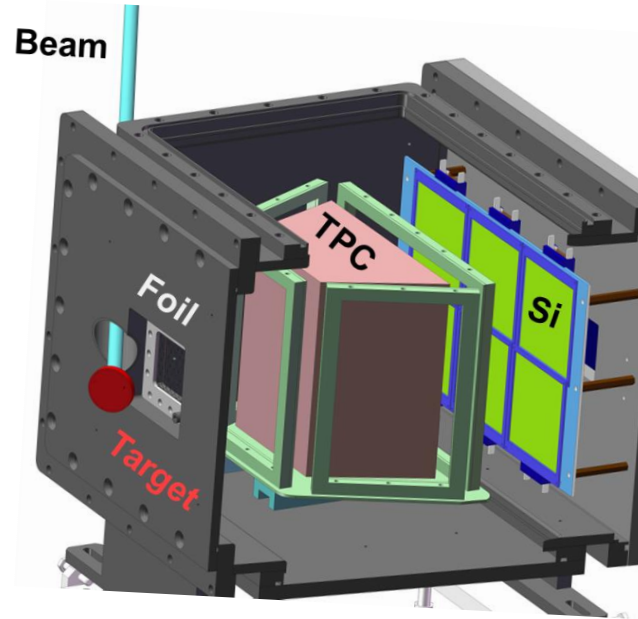
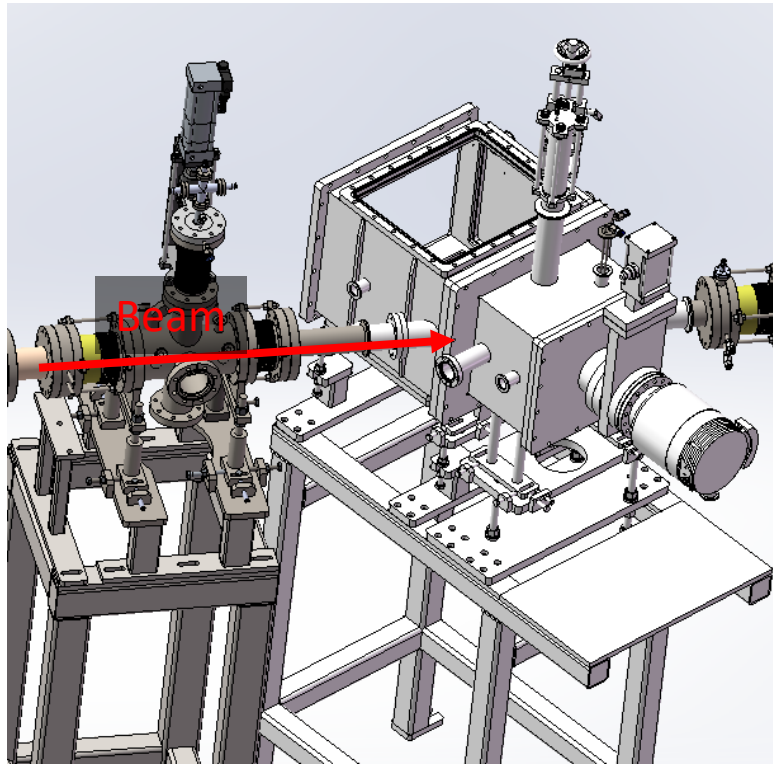
- **LINAC:** High Intensity beam up to 200 pA (**Spillane: 40pA**)
- **TPC:** Ultra sensitive tracking detector
- **Complementary** to LUNA-MV and other experiments

Z.C.Zhang+ NIMA(2021)

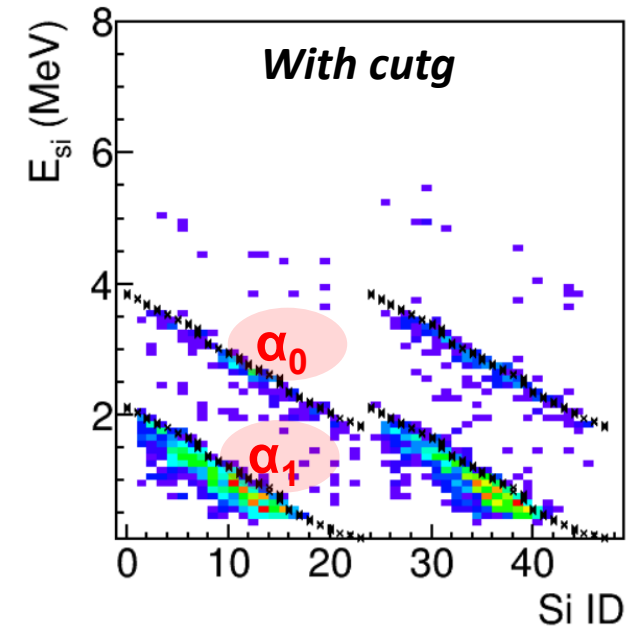
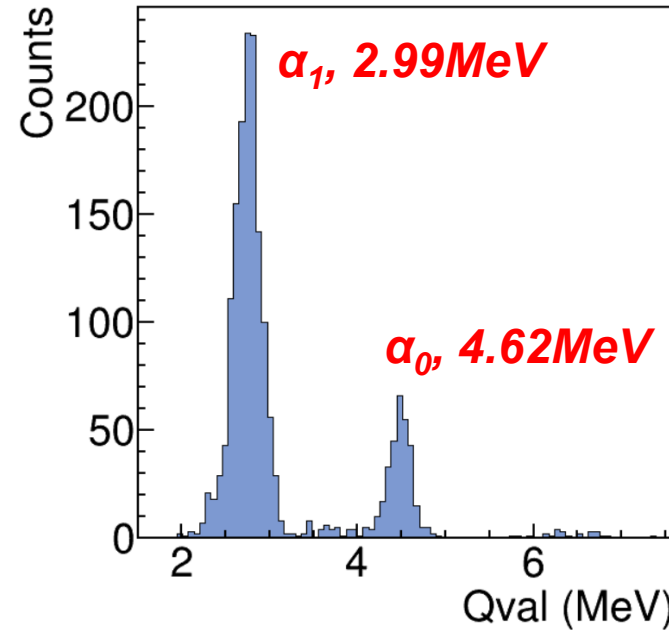
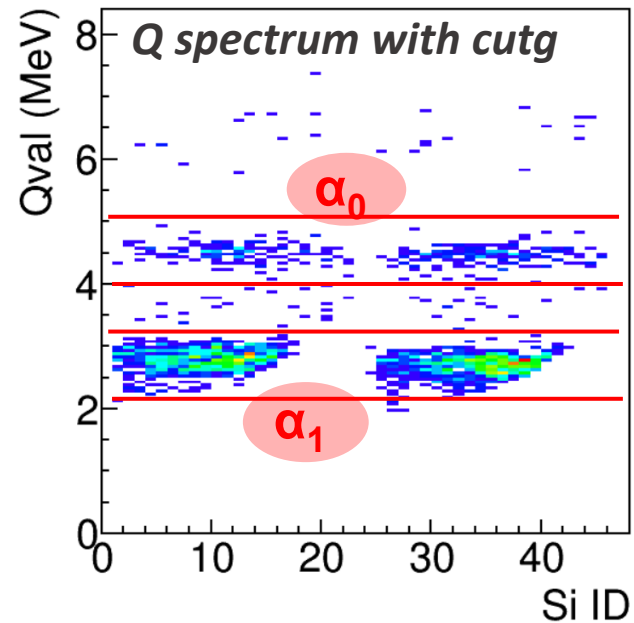
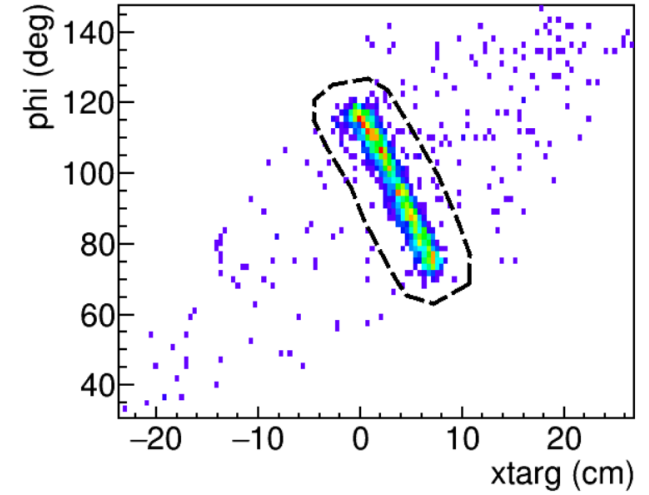
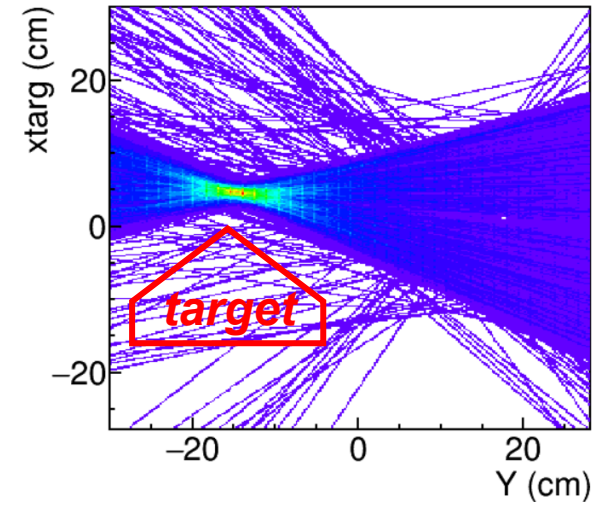
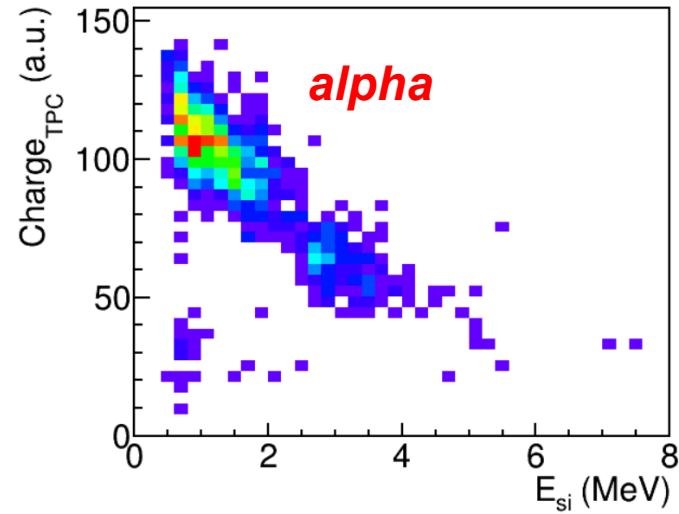
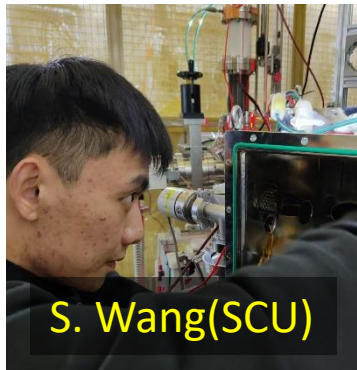
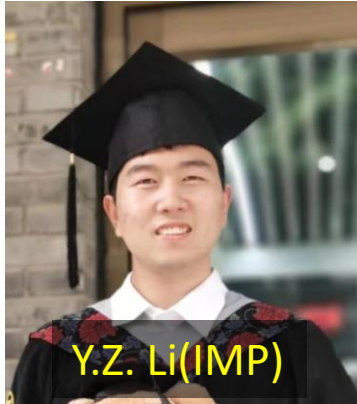
Doi: 10.1016/j.nima.2021.165740

Detector setup

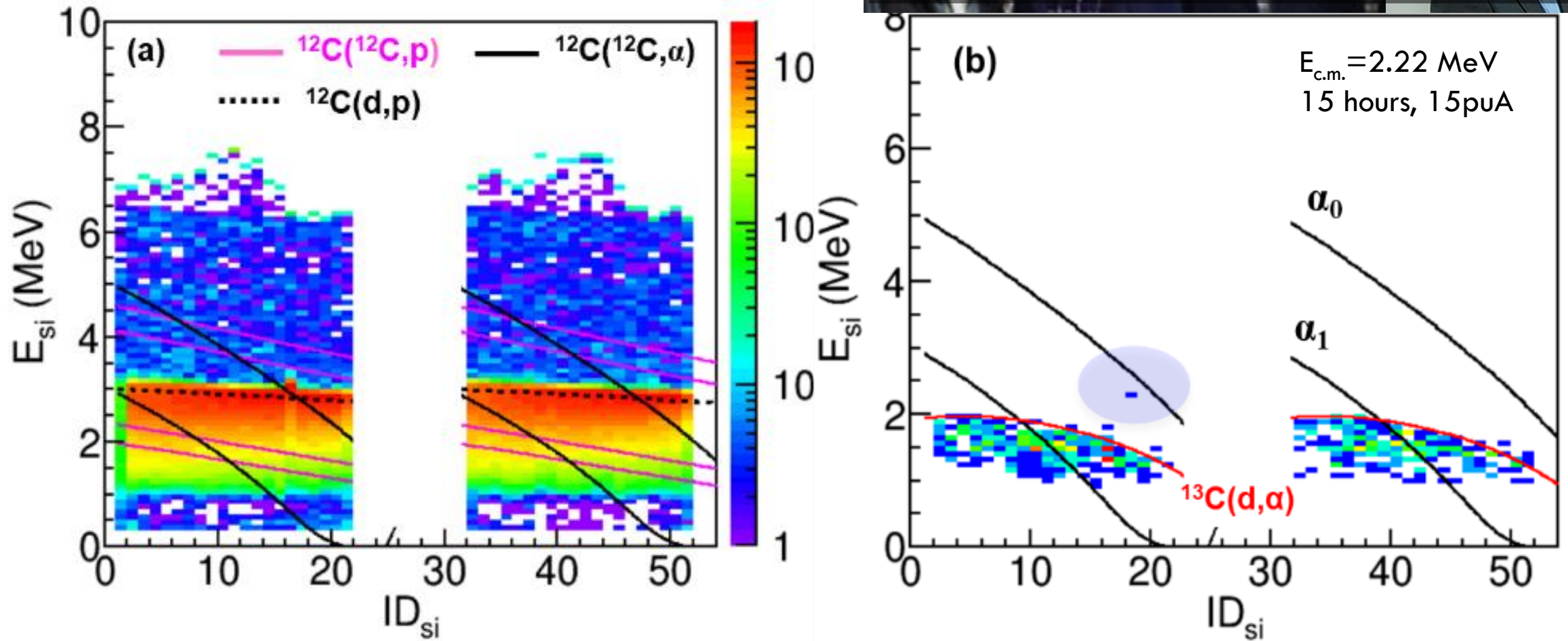
Time Projection Chamber (TPC) + Si array $\left\{ \begin{array}{l} \text{Background suppression via tracking} \\ \text{Particle identification} \end{array} \right.$



Analysis: $E_{\text{cm}}=2.72\text{MeV}$ with Graphite (5N)

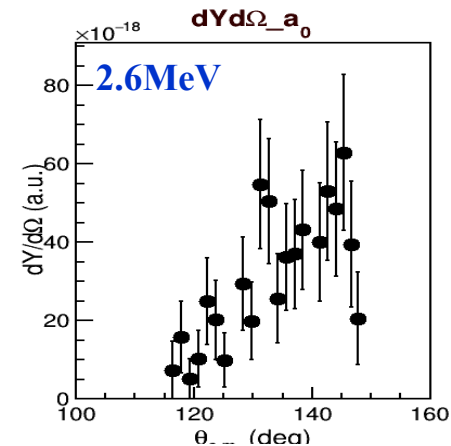
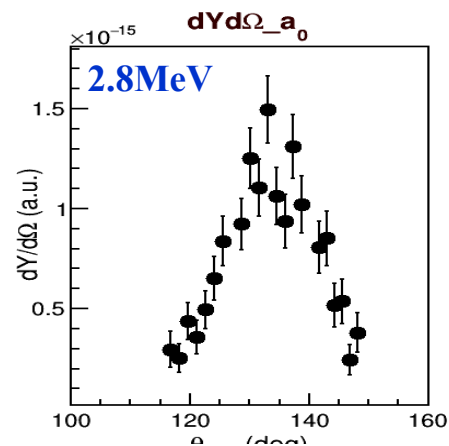
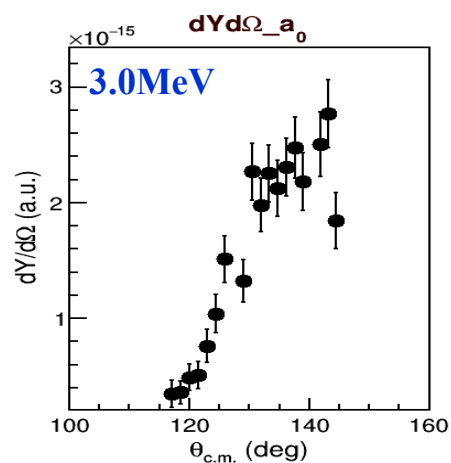


Another result with HOPG @ $E_{c.m.}=2.2\text{MeV}$

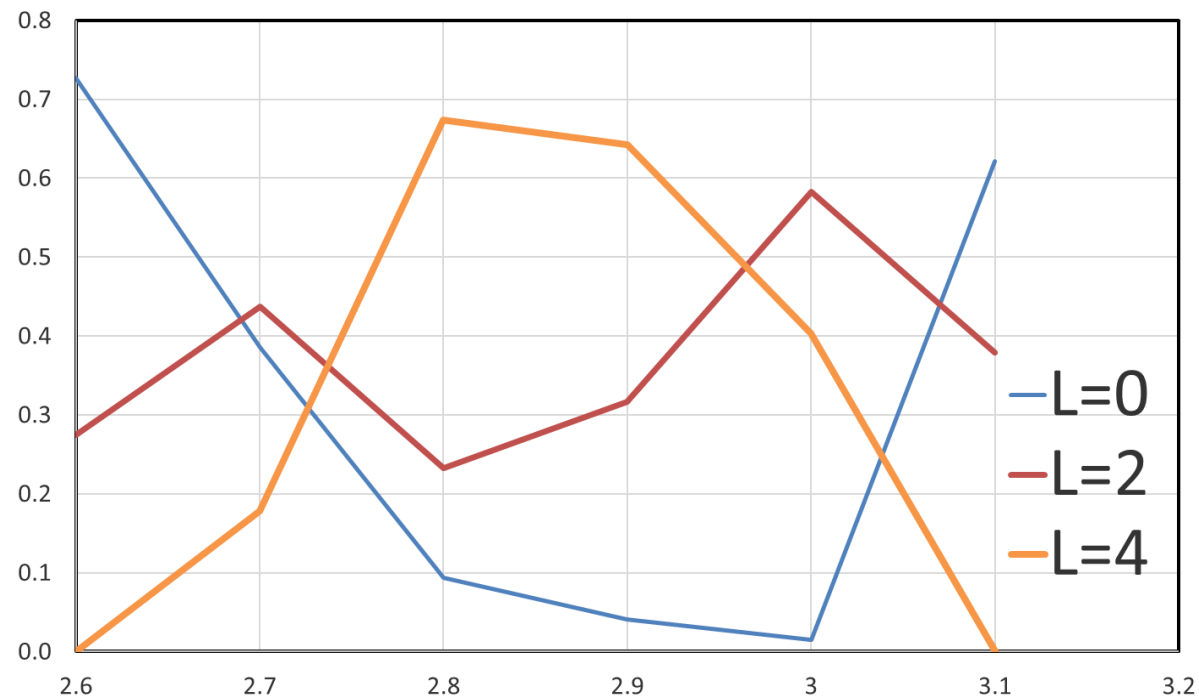
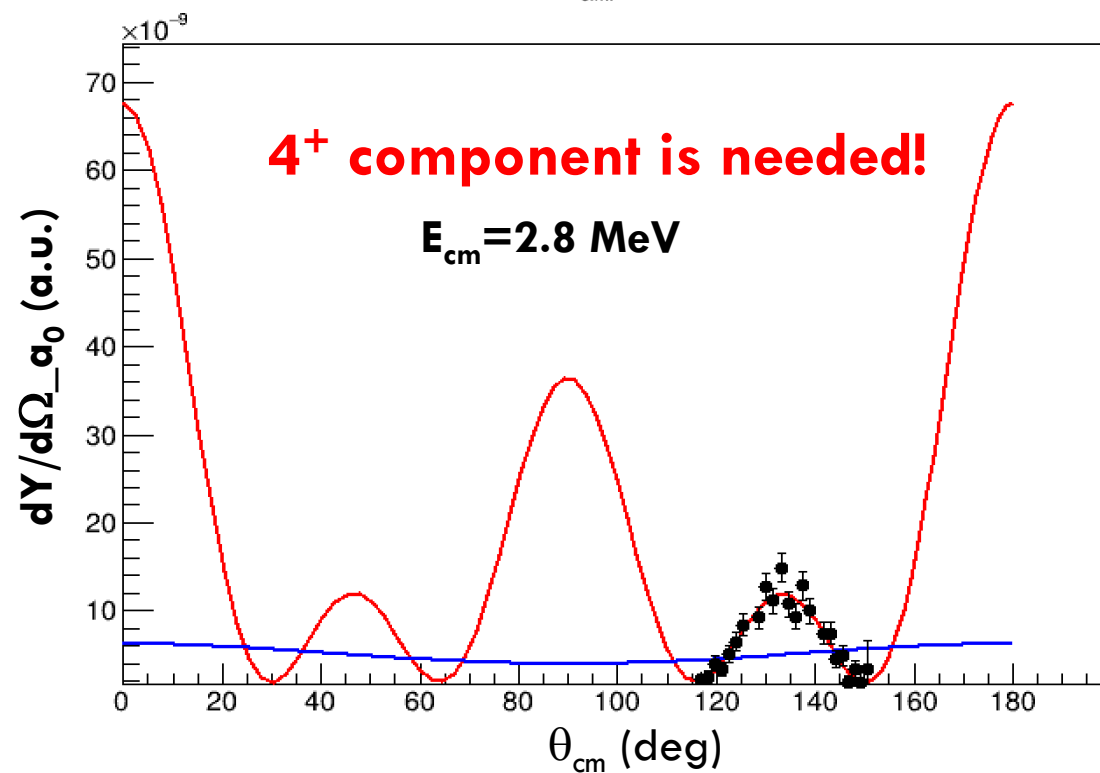


Clear identification with cuts in the energy loss and tracks in TPC

Determination of J^π of $E_{\text{cm}}=2.76$ (MeV)



Contribution of difference spin



Summary

- Direct measurement of $^{12}\text{C}+^{12}\text{C}$
 - First direct measurement of a_0 below 2.5 MeV indicates the deficits of the THM/mTHM results
 - New reaction rate $\sim \text{CF88}/3$
 - $4^+ @ E_{\text{c.m.}} = 2.76 \text{ MeV}$ and level density will help theory (eg. AMD) to provide a more reliable prediction
- Indirect (THM, $^{24}\text{Mg}(\alpha, \alpha')$) + Direct measurements will provide best extrapolation
Collaboration will end up with better science!



