Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

SANDA
Supplying Accurate Nuclear Data for energy and non-energy Applications

HORIZON2020

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C²TN

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

nTOF

D2.10

Report on the measurement of double-differential charged-particle emission cross sections at the CERN n_TOF facility in the neutron energy range from 20 MeV to 200 MeV

R. Beyer, M. Dietz, A. Junghans, R. Nolte, E. Pirovano, P. Vaz

DDX experiment at CERN n_TOF

Objective: proof of principle experiment, measurement above 100 MeV of double differential cross sections of (n,cp) reactions at CERN n_TOF

➤ **Task 1.4**: Detectors for non-energy application

- D1.8: submitted 28-Feb-2022
- Development of charged particle telescope for measurements at n_TOF with high energy neutrons

➤ **Subtask 2.6.2**: Measurement of cross sections relevant for hadron therapy

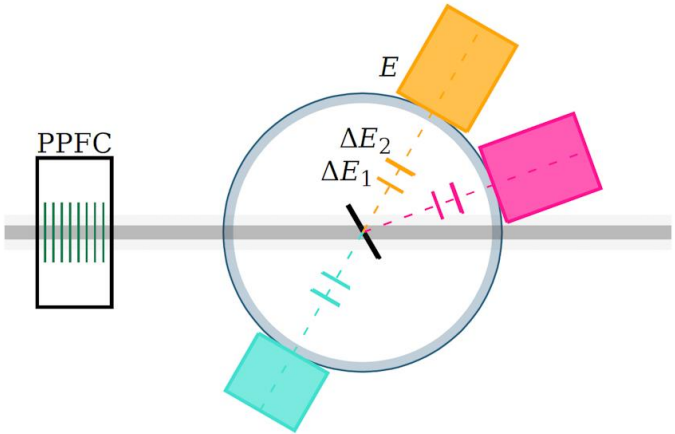
- D2.10: pending – report submitted to WGL
- Construction of dedicated setup and measurement of the double differential cross section of C(n,cp) between 20 and 200 MeV

Project overview

- Development of an experimental setup for charged particle detection
  - Δ*E*-Δ*E*-*E* technique for particle identification
    (n,p) (n,d) (n,t) (n,α) (n,^{3}He)
  - FC (^{235}U) as neutron monitor

- Proof of principle experiment at CERN n_TOF on carbon
  - Focus on energy range 100-200 MeV,
    overlap region for statistical and INC models

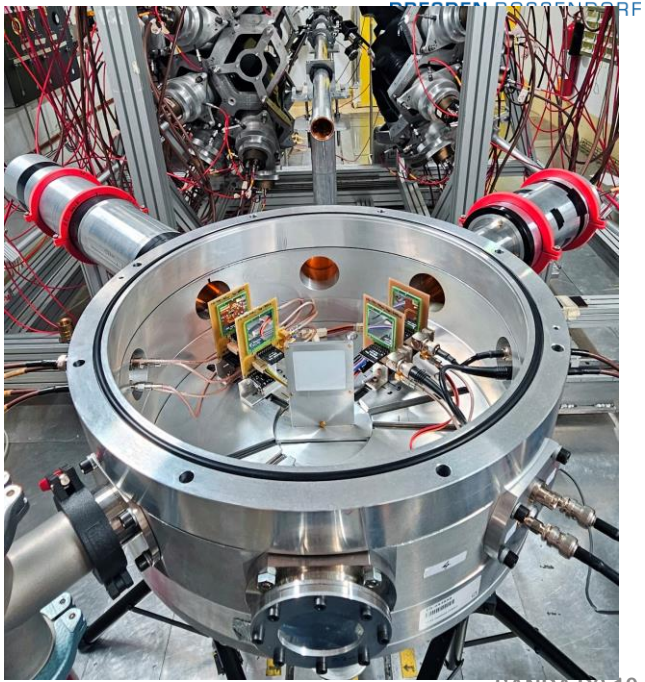
- FC was already used at n_TOF,
  but not the telescopes
- Concerns: interaction with the γ-flash,
  energy resolution, particle identification,
  construction of the vacuum chamber



Status in February 2022

- End - Task 1.4 (detector development)
  Begin - Subtask 2.6.2 (cross section measurement)
- Report D 1.8 submitted on 28-02-2022

- Detectors selected based on MC simulations
- Pre-existing vacuum chamber adapted to host 2 telescopes at ±45 degrees
- Test at PTB with protons and alpha beams <5 MeV, extrapolation for expected performance at higher energies
- Submission of INTC Letter Of Intent for beamtime at n_TOF for tests
- Beamtime planned for May 2022, November 2022

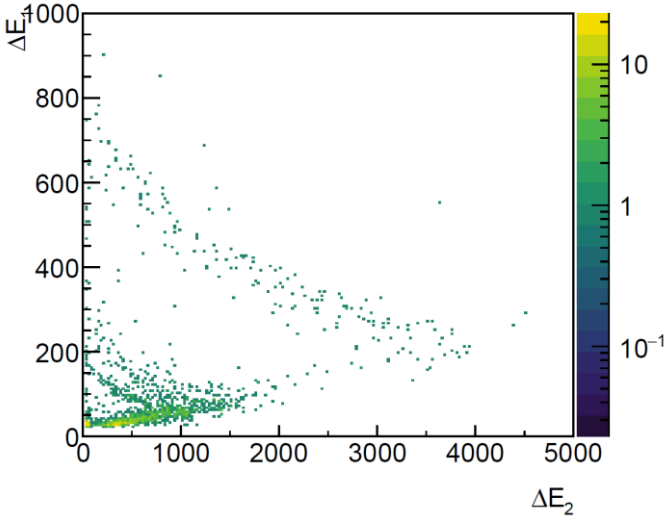


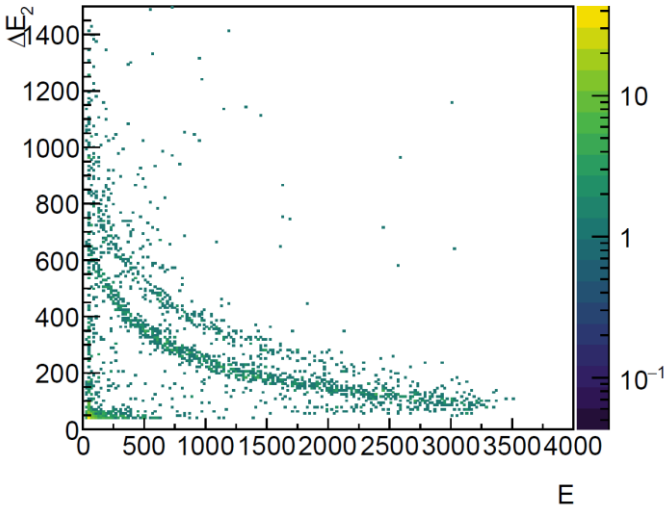
Feb 2022 – Feb 2023

- May-2022: First detector test at n_TOF
- Nov-2022: Second detector test at n_TOF
- γ-flash issue (ringing) under control, particle identification possible up to 200 MeV

- Jan-2023: Submission of INTC proposal for C(n,cp)
- Requested 30×10^{17} protons ~ 30 days of beamtime

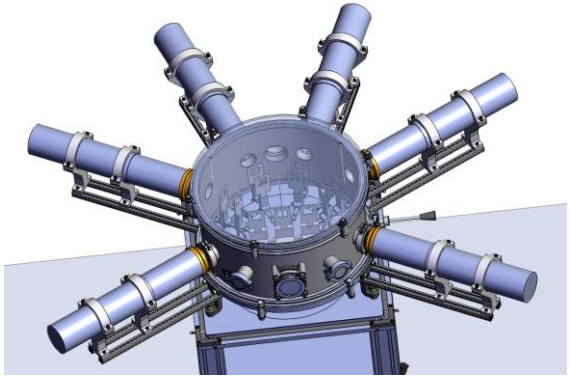
- Feb-2023: Technical design and construction of dedicated vacuum chamber by PTB Department “Scientific Instrumentation”
- Estimated delivery date: August 2023
- All on time!





Feb 2023 – today

- Issue: end of postdoc contract in February 2023, new colleague started in May 2024
- Construction of vacuum chamber also suffered under this. Real delivery date: November 2023



- Beamtime of 30 days was not realistic
- Proof-of-principle beamtime had to be reassessed
- Objectives still the same: proof of principle of Δ*E*-*E* method, provide data on C(n,cp) to test statistical / INC models
- But while managing resources

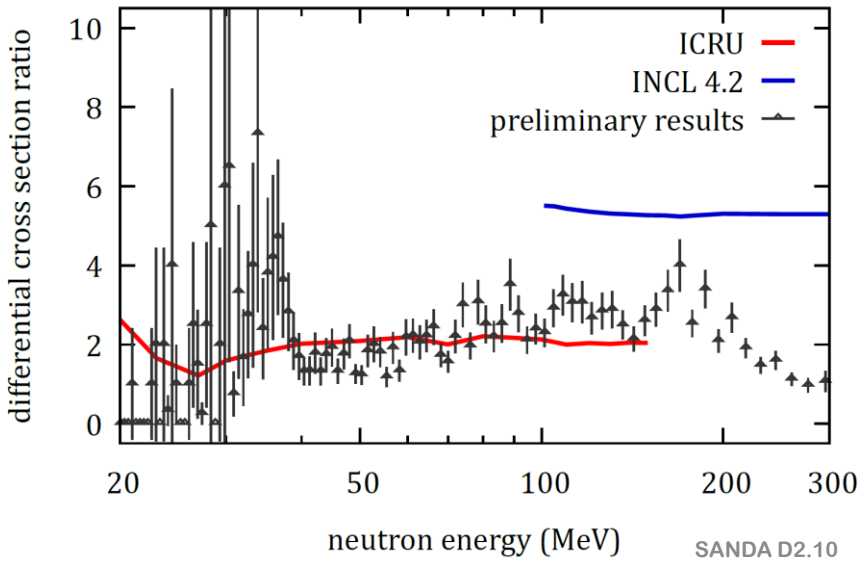
- Sep-2023: C(n,cp) beamtime at n_TOF for proton/deuteron emission ratio
- Analysis and report (just submitted)

Results of “exploratory beamtime”

Objective: ratio of proton emission / deuteron emission at 45 degrees

- Measurements at 45 degrees possible with existing setup
- Neutron flux measurement not necessary
  → simpler setup / data analysis
- Emission rate of p & d at forward angles is high
  → only a few days of beamtime were necessary
- Investigation ICRU / INLC discrepancy
  in the energy region where they overlap
  → $\sigma_{(n,p)}$ similar but $\sigma_{(n,d)}$ factor 3 discrepant

- “Full” DDX planned for October 2024



Summary & outlook

Included in the report D2.10:

- Detector tests: May 2022, November 2022
- Construction of chamber for measurements at n_TOF
- Application to INTC for beamtime for C(n,cp) DDX (30×10^{17} protons)
- Preliminary results on proton emission / deuteron emission at 45 deg.

Dissemination

- ANIMMA 2023 + proceedings
  M. Dietz et al., EPJ Web of Conferences 288, 01003 (2023)
- Results on DDX of C (beamtime of 2024) in peer-reviewed journal and EXFOR, if quality will be sufficient