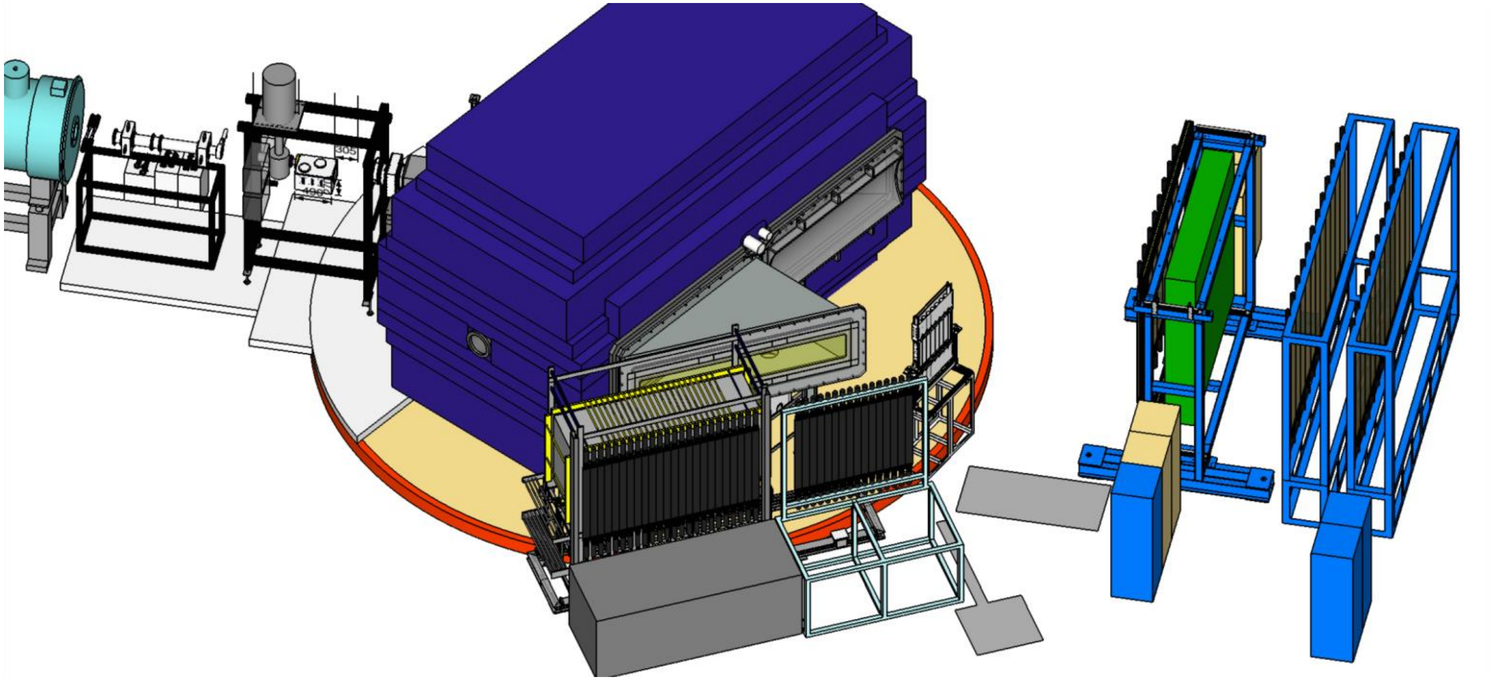
Low-energy dipole response of the halo nuclei $^{6,8}He$

SFB Workshop, 24.03.2021
C. Lehr



Dipole response of ^{6}He and ^{8}He

^{6}He

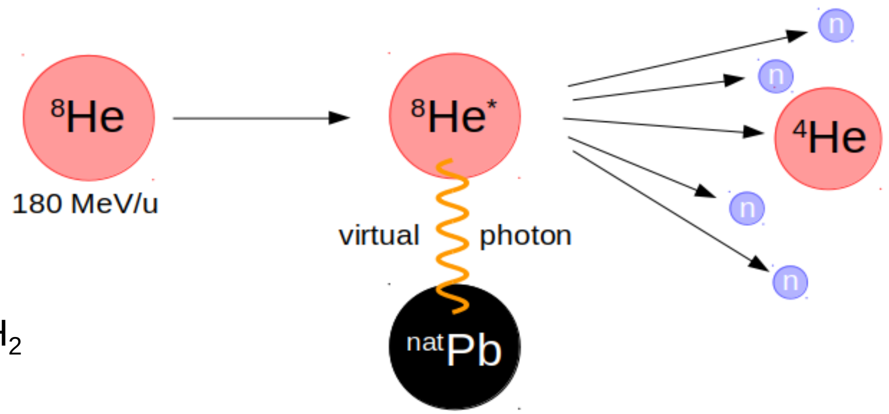
- Expand data from *Aumann et al., Phys. Rev. C 59 (1999) 1252*
- Extend dipole-strength distribution up to 15 MeV

^{8}He

- Only 2n channel measured by *Meister et al., Nucl. Phys. A 700 (2002) 3*
- Reconstruction of ^{8}He 4n channel possible for the first time with NeuLAND and NEBULA

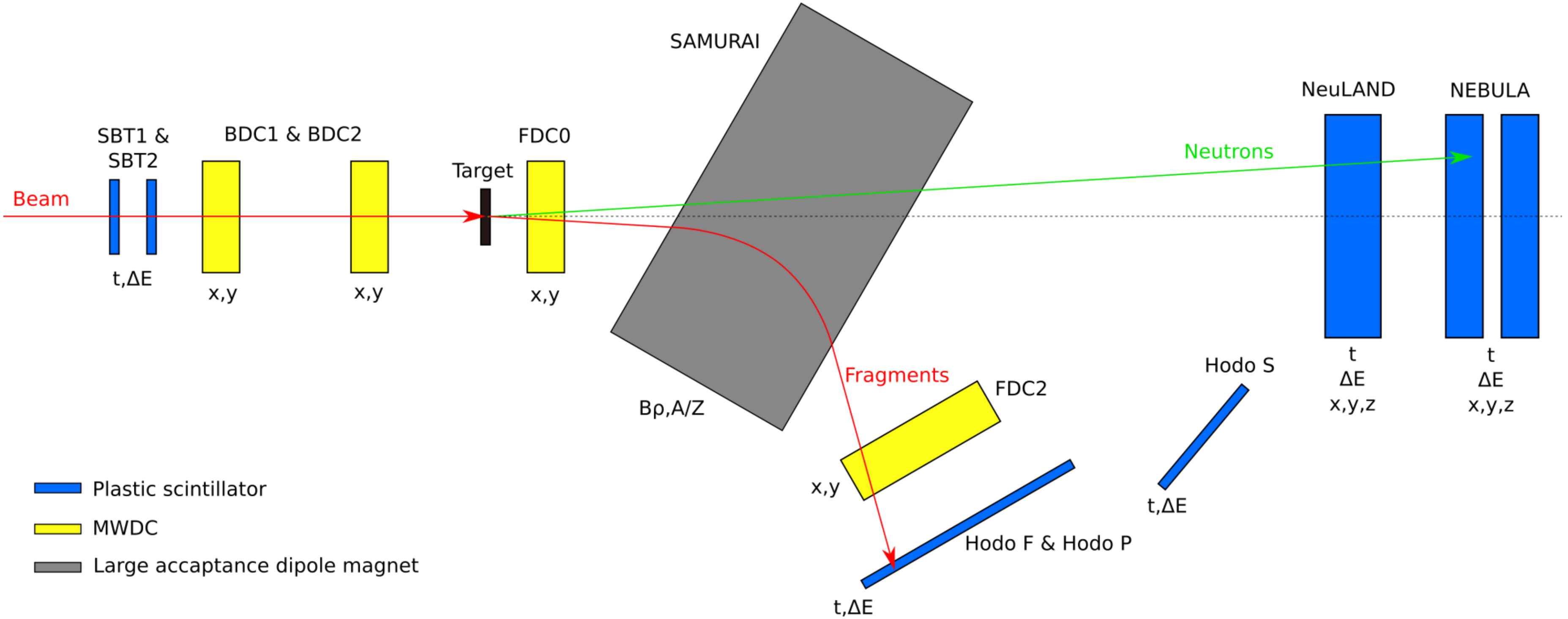
Experiment

- Carried out July 2017 at SAMURAI at RIBF
- ^{18}O primary beam @ 220 AMeV
- ^{6}He and ^{8}He secondary beams @ 185 AMeV
- Beam rate ~100 kHz for both settings
- Series of targets with increasing Z: Pb, Sn, Ti, C, CH_2



SAMURAI setup

- Versatile setup for reaction measurements in inverse kinematics
- Kinematically complete measurement
- Superconducting dipole (up to Bρ = 7.08 Tm)
- NeuLAND and NEBULA for neutron detection
- Arranged in 3 separate walls
- 88 cm of plastic scintillator in total



Neutron detectors

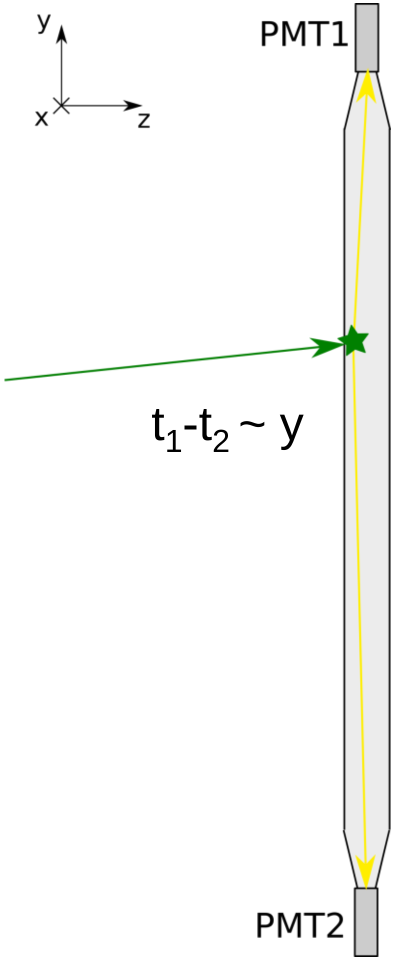
NeuLAND demonstrator:

- 400 plastic scintillator bars arranged in 4 double planes
- Horizontal and vertical
- 5 x 5 x 250 cm

NEBULA

- 120 plastic scintillator bars arranged in 4 planes in 2 separate walls
- All vertical
- 12 x 12 x 180 cm

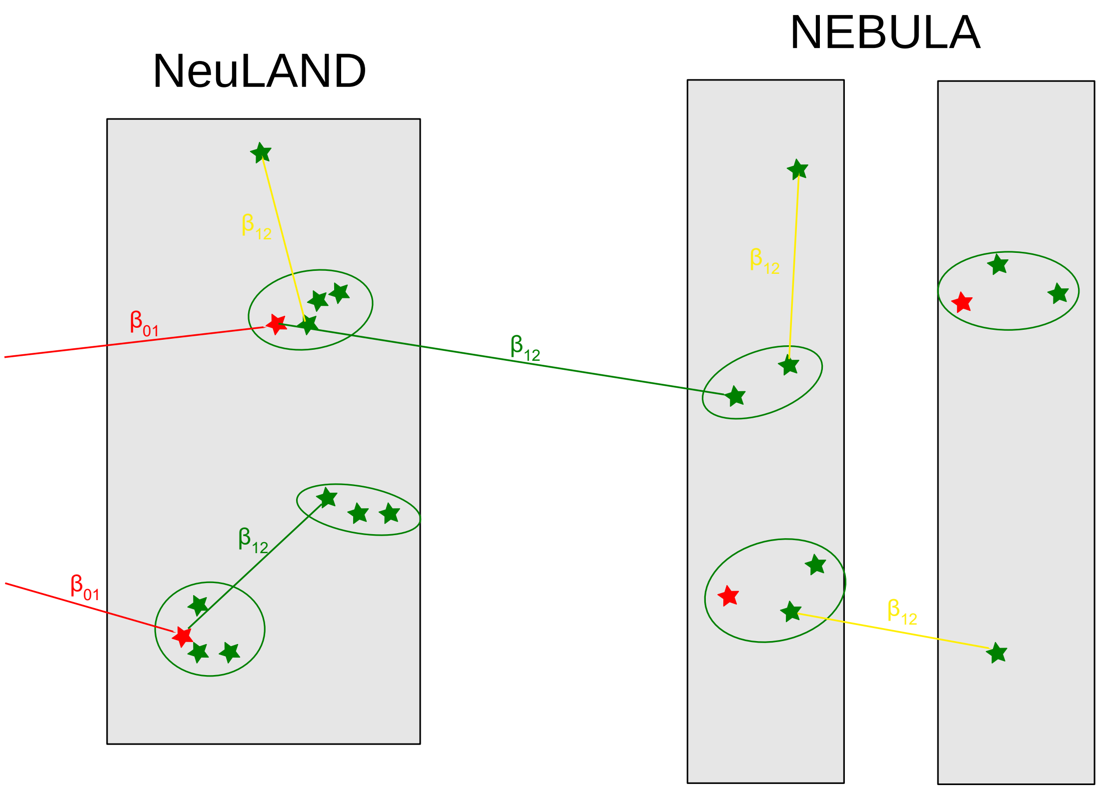
4n detection possible for the first time



Neutron reconstruction

Reconstruction algorithm

1. Apply ToF and Q cuts
2. Cluster algorithm:
   $|t_1\text{-}t_2| < 1.33\text{ns}$, $|\mathbf{x}_1\text{-}\mathbf{x}_2| < 180\text{mm}$ (NeuLAND)
   $|t_1\text{-}t_2| < 2.0\text{ns}$, $|\mathbf{x}_1\text{-}\mathbf{x}_2| < 300\text{mm}$ (NEBULA)
3. Identify gamma cross talk:
   $1/\beta_{12} \approx 1$
4. Identify cross talk from scattered neutrons: $\beta_{12} < \beta_{01}$
5. Apply veto condition



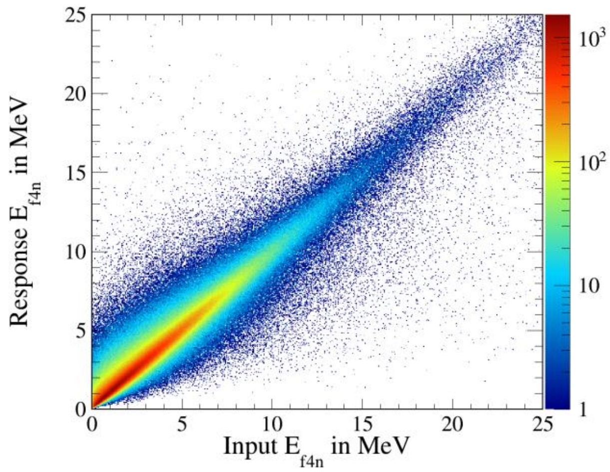
Different-wall cross talk treated according to *T. Nakamura, Y. Kondo, NIM B 376 (2016) 156–161*

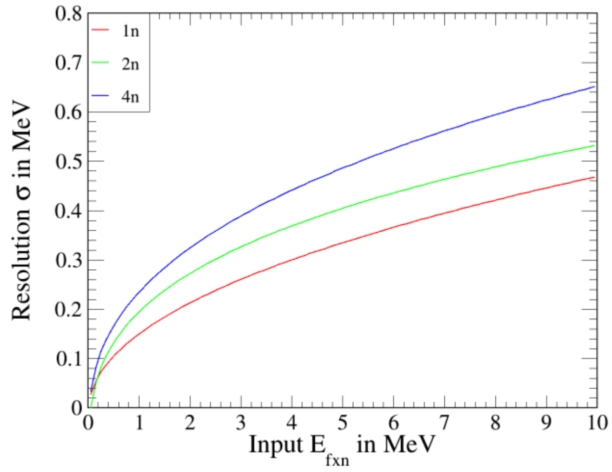
4n Efficiency & Response

TECHNISCHE UNIVERSITÄT DARMSTADT

Performance of reconstruction algorithm

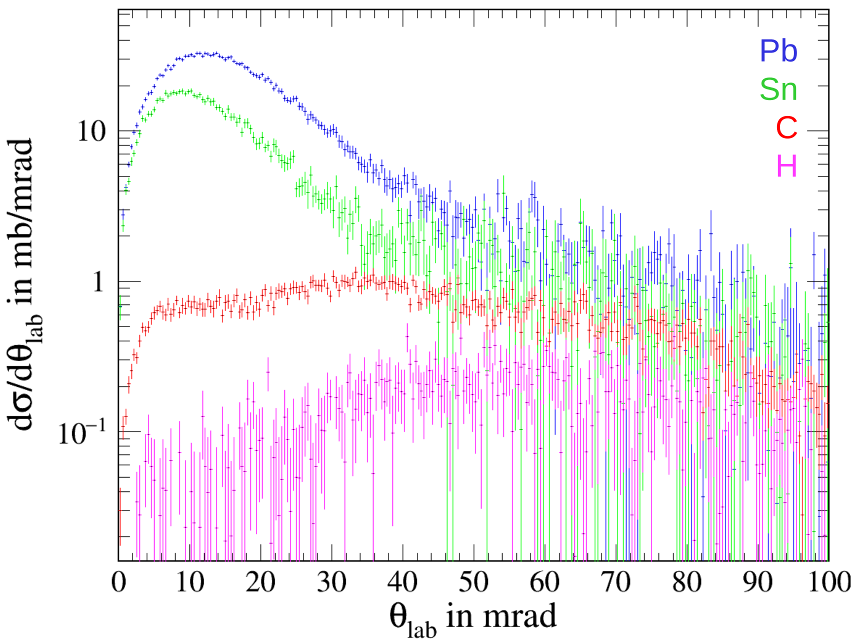
- Geant4 simulation of full experiment setup including neutron detector and fragment momentum resolutions
- Reproducing hit multiplicity, hit distribution, light output and ToF of neutron response in NeuLAND and NEBULA
- Algorithm applied to experiment and simulation data in the same way
- **Performance 2n:**
  Total efficiency: ~12% at 1 MeV
  Cross-talk contribution: ~3% at 1 MeV
- **Performance 4n:**
  Total efficiency: ~1.2% at 1 MeV
  Cross-talk contribution: ~20% at 1 MeV



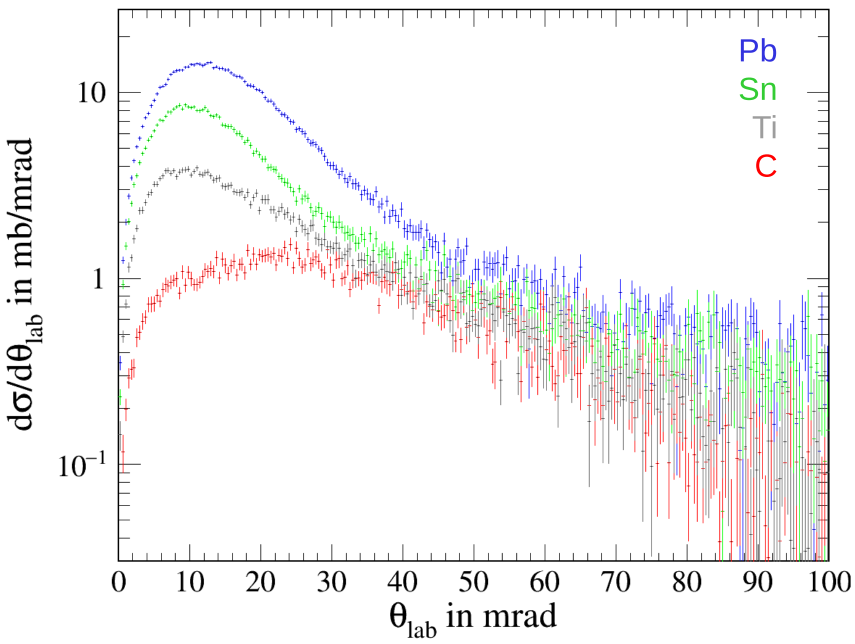


Nuclear contribution – Scattering angles

$^{6}He \rightarrow {}^{4}He + 2n$



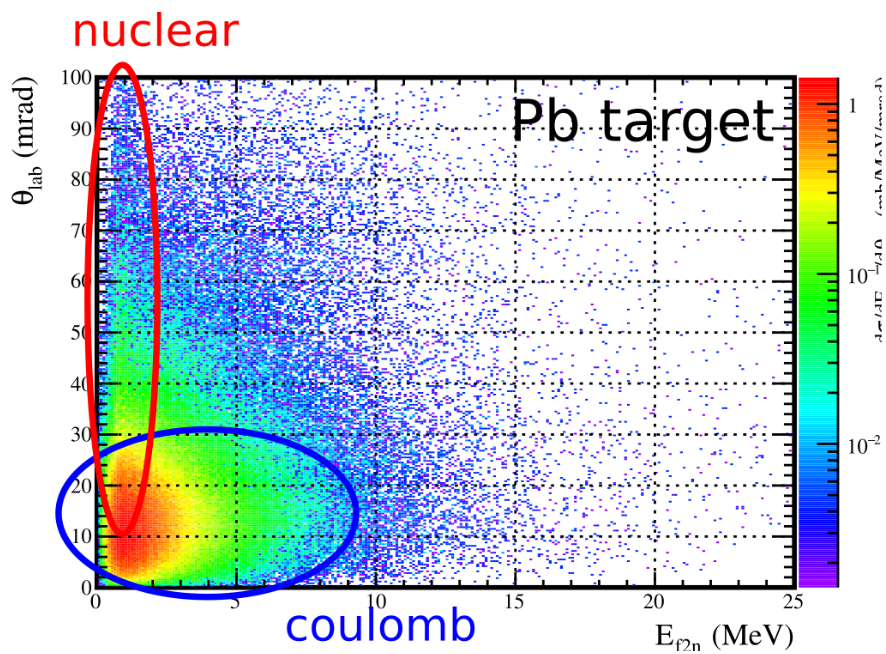
$^{8}He \rightarrow {}^{6}He + 2n$

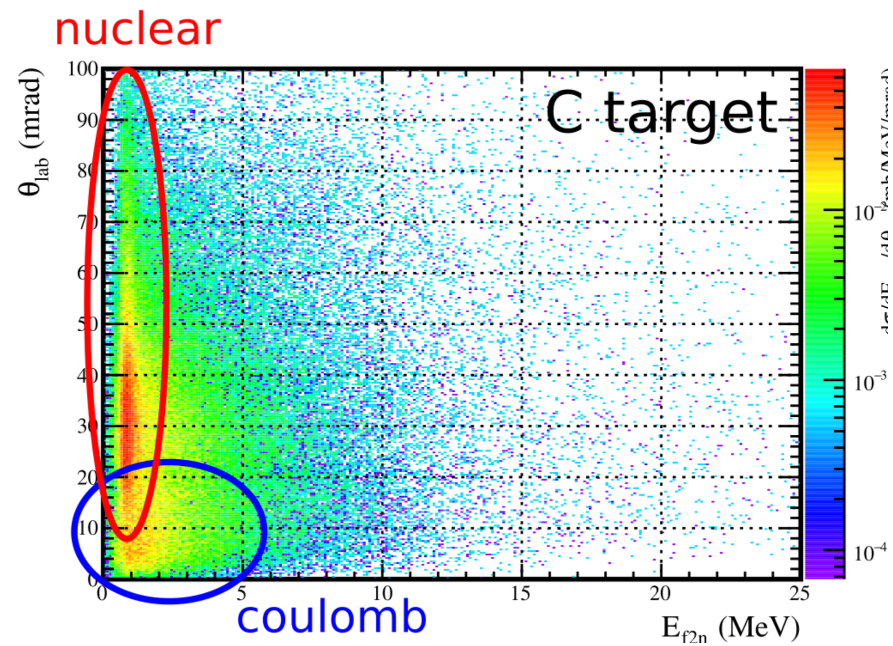


Nuclear contribution – Scattering angles

TECHNISCHE
UNIVERSITÄT
DARMSTADT

$^{6}He \rightarrow ^{4}He + 2n$





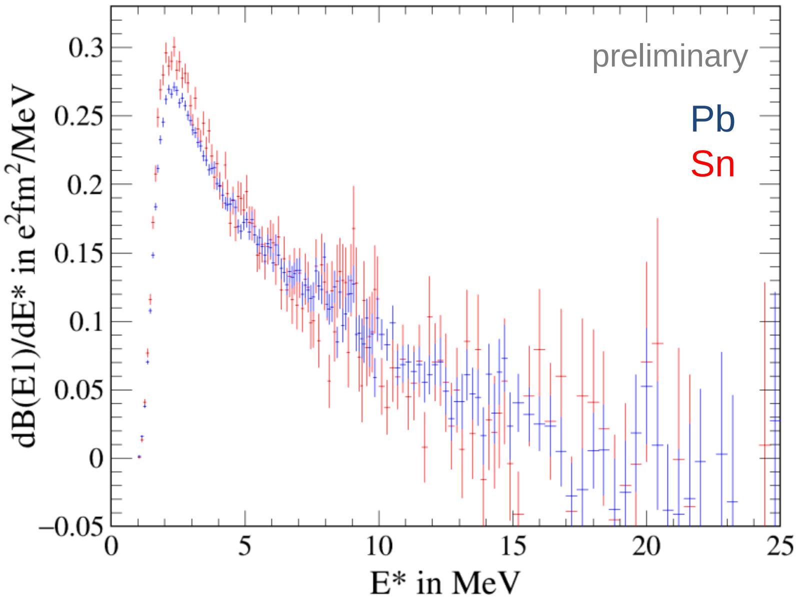
Nuclear contribution – Scale parameter

TECHNISCHE UNIVERSITÄT DARMSTADT

Scale parameter Γ for subtraction of nuclear contribution

- Determined from fit of B(E1) of Sn target to Pb target
- $\Gamma \propto A^{1/3}$

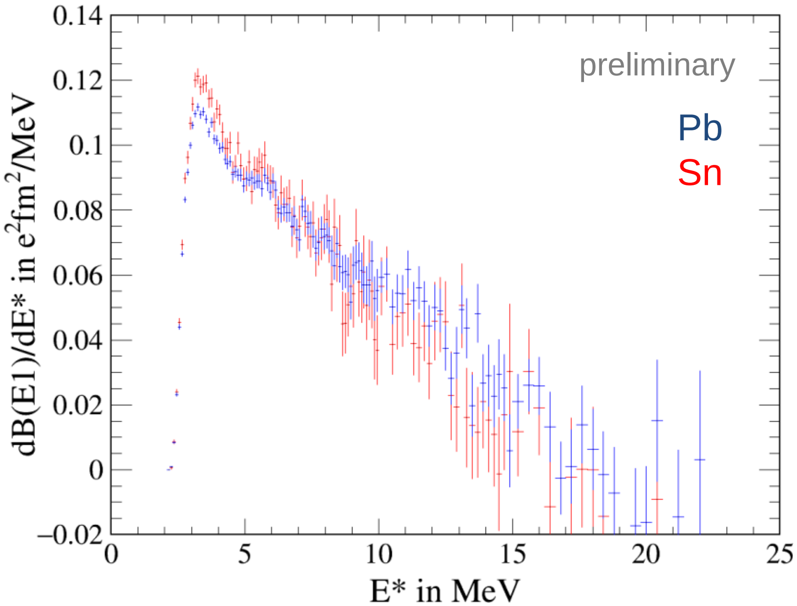
$^{6}He \rightarrow {}^{4}He + 2n$



Γ_{Pb}=1.71 +- 0.02

Γ_{Sn}=1.51 +- 0.01

$^{8}He \rightarrow {}^{6}He + 2n$

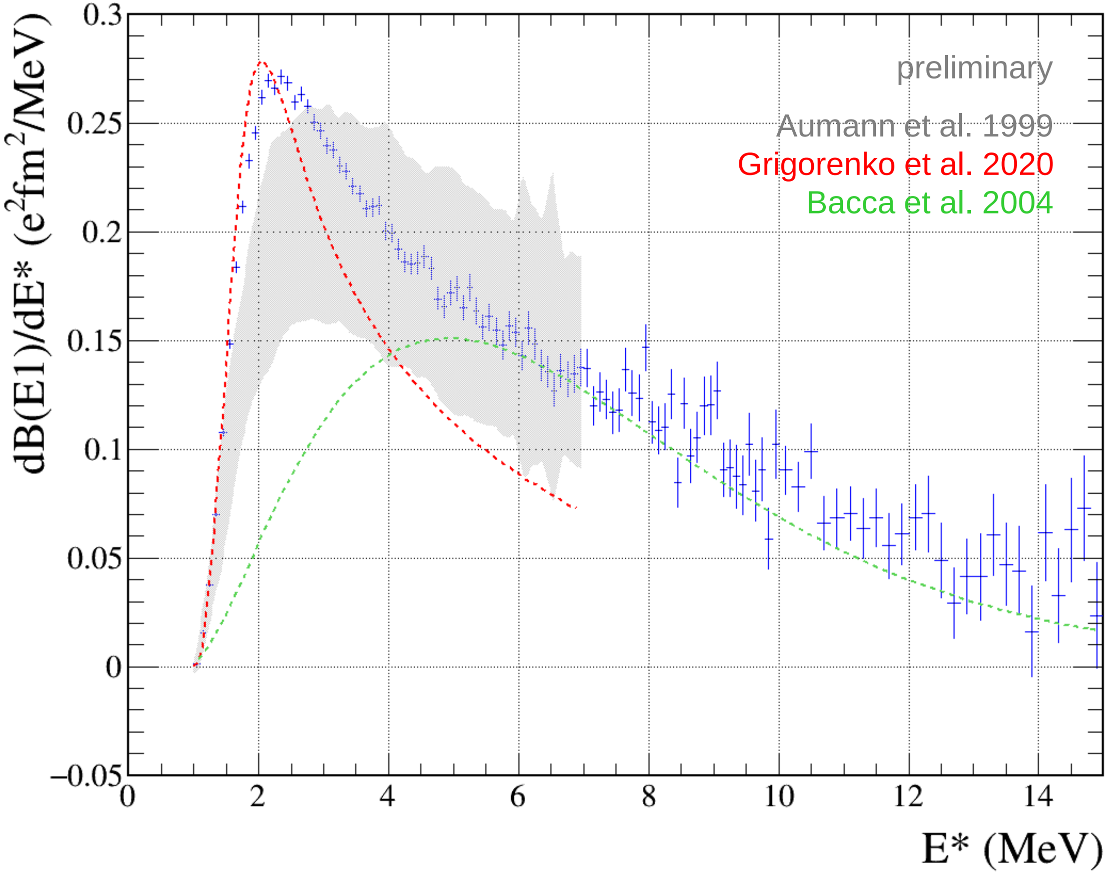


Γ_{Pb}=1.90 +- 0.01

Γ_{Sn}=1.65 +- 0.01

$^6He \rightarrow {}^4He + 2n$ Pb Coulomb

TECHNISCHE UNIVERSITÄT DARMSTADT

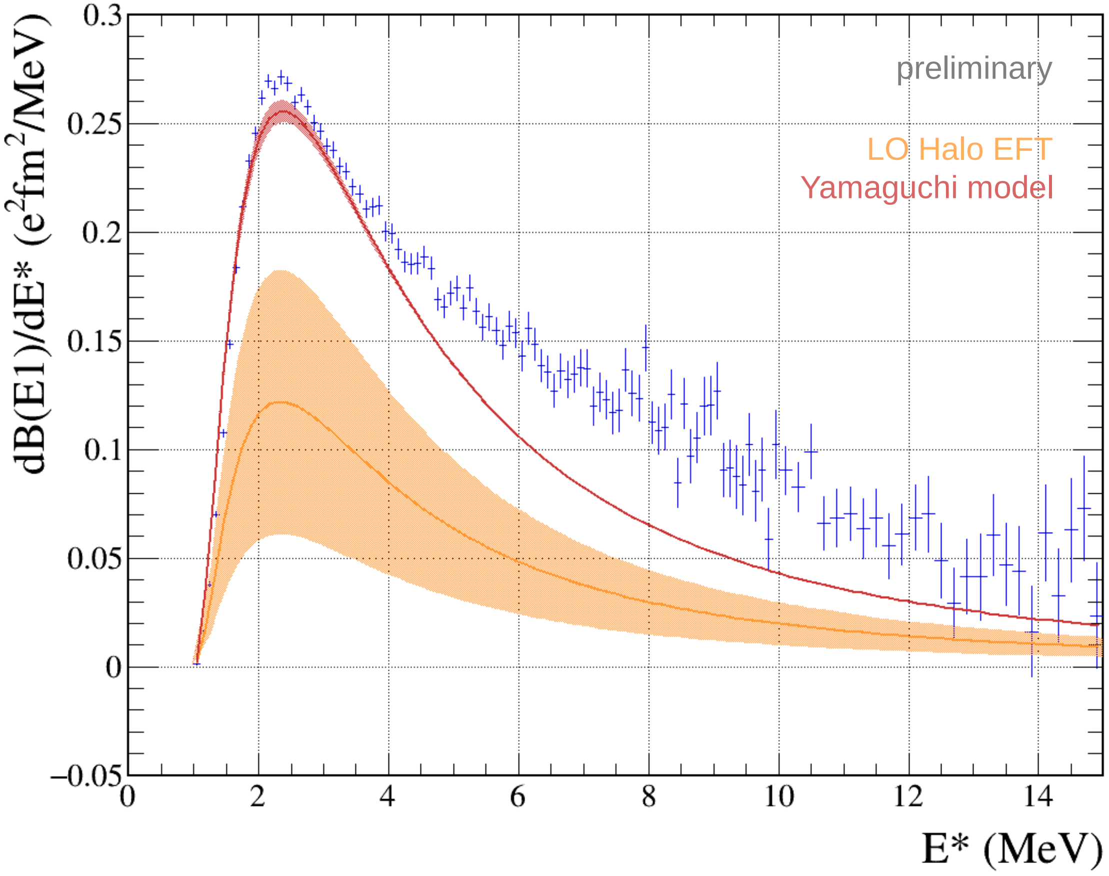


preliminary

Pb target	∑B(E1) (e²fm²)
E*<5 MeV	0.79±0.08
E*<10 MeV	1.42±0.15
E*<15 MeV	1.71±0.19

$^6He \rightarrow {}^4He + 2n$ Pb Coulomb

TECHNISCHE UNIVERSITÄT DARMSTADT



Halo EFT calculations
by M. Göbel

preliminary

Pb target	∑B(E1) (e^2fm^2)
E*<5 MeV	0.79±0.08
E*<10 MeV	1.42±0.15
E*<15 MeV	1.71±0.19

$^6He \rightarrow {}^4He + 2n$

TECHNISCHE UNIVERSITÄT DARMSTADT

- Energy weighted cluster sum rule exhausted at 7.47 MeV

preliminary

- $\sqrt{\langle r_{c,2n}^2 \rangle} = 3.35 \pm 0.08$ fm $\quad \sqrt{\langle r_c^2 \rangle} = 1.12 \pm 0.03$ fm

*H. Esbensen et al., PRC **76**, 024302 (2007)*

- $\sqrt{\langle r_{c,2n}^2 \rangle} = 3.71 \pm 0.07$ fm

*G. Papadimitriou et al., PRC **84**, 051304 (2011)*

- $\sqrt{\langle r_c^2 \rangle} = 1.14$ fm

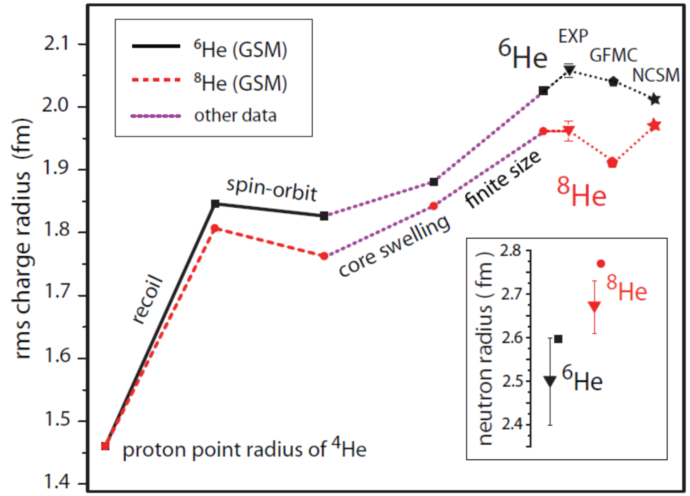


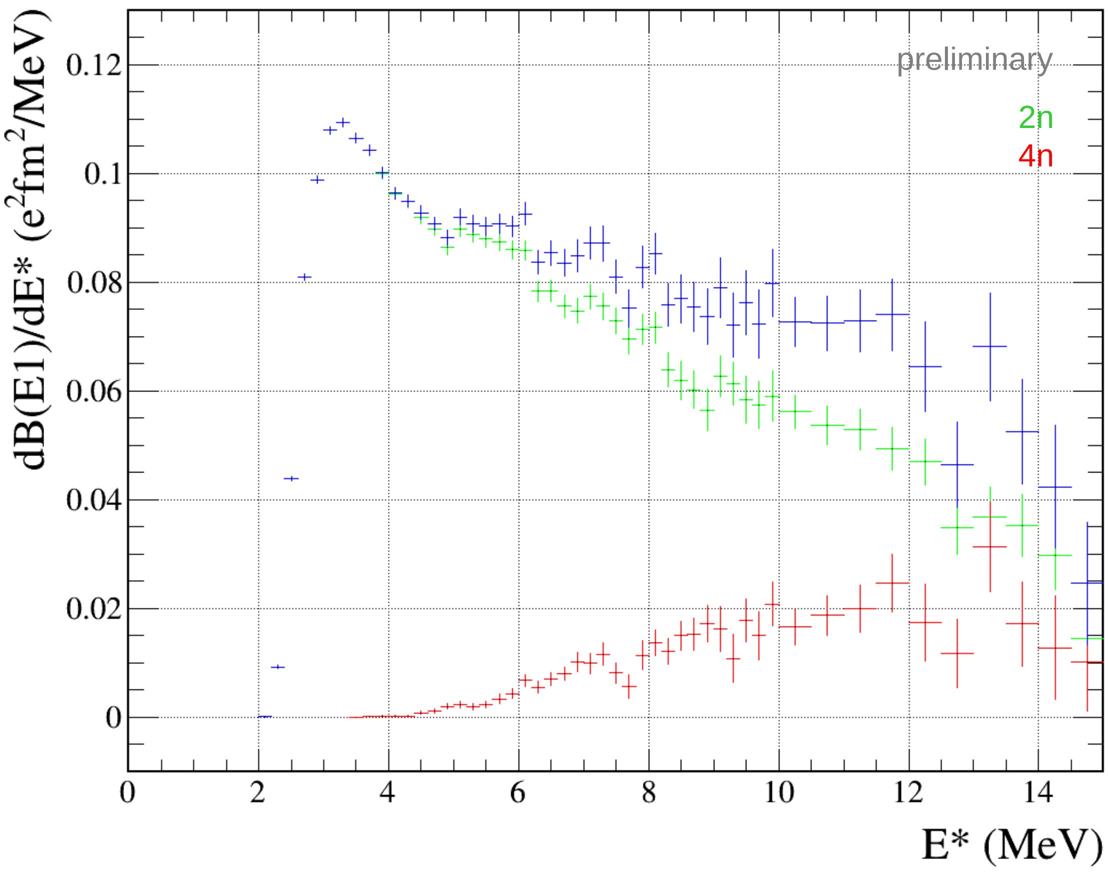
FIG. 4. (Color online) Different contributions to the charge radius of ^{6}He (solid line, squares) and ^{8}He (dashed line, dots) calculated in the GSM. The core swelling contribution is taken from GFMC calculations of Ref. [22]. Recently revised experimental charge radii come from [7] (triangles). The NCSM [10] (stars) and GFMC [9] (pentagons) results are marked for comparison. The inset shows GSM rms neutron radii compared to experimental results [34].

*Picture taken from G. Papadimitriou et al., PRC **84**, 051304 (2011)*

- **Charge radius of 6He mainly depends on core recoil due to correlations of the halo neutrons and core swelling**
- **Core swelling effect smaller than in 11Li (inert alpha core)**

$^{8}He \rightarrow {}^{6}He + 2n$ / $^{8}He \rightarrow {}^{4}He + 4n$

TECHNISCHE UNIVERSITÄT DARMSTADT



preliminary

Pb target	∑B(E1) (e^2fm^2)
E*<5 MeV	0.25±0.02
E*<10 MeV	0.66±0.07
E*<15 MeV	0.95±0.12

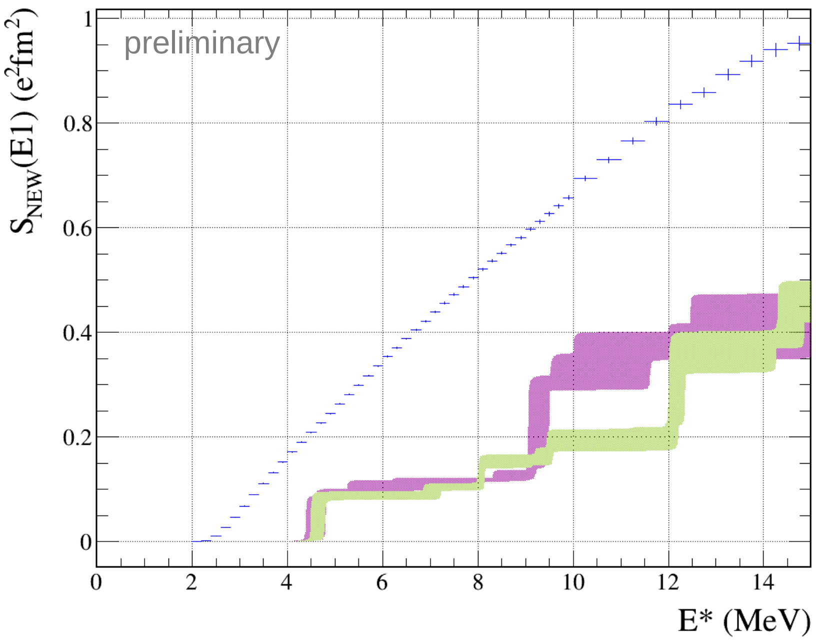
$^8He \rightarrow {}^6He + 2n$ / $^8He \rightarrow {}^4He + 4n$

TECHNISCHE UNIVERSITÄT DARMSTADT

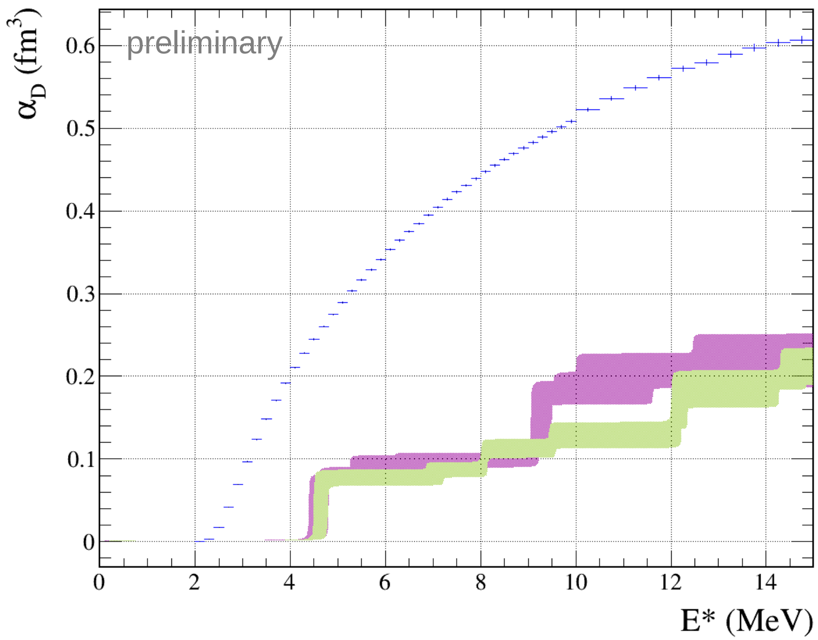
Coupled-cluster theory calculations
by F. Bonaiti and S. Bacca

Coupled-cluster approximation levels:
D/D/D
T-1/T-1/D

B(E1) running sum



Polarizability



Thank you for your attention!