

# LASER-SPECTROSCOPY EXPERIMENTS AT ANL

A01 & A03

# AGENDA

- 1** Collinear Laser Spectroscopy
- 2** A03: Neutron-Rich Medium Mass Nuclei
- 3** A01: Boron-8, a Proton-Halo Nucleus?
- 4** Summary

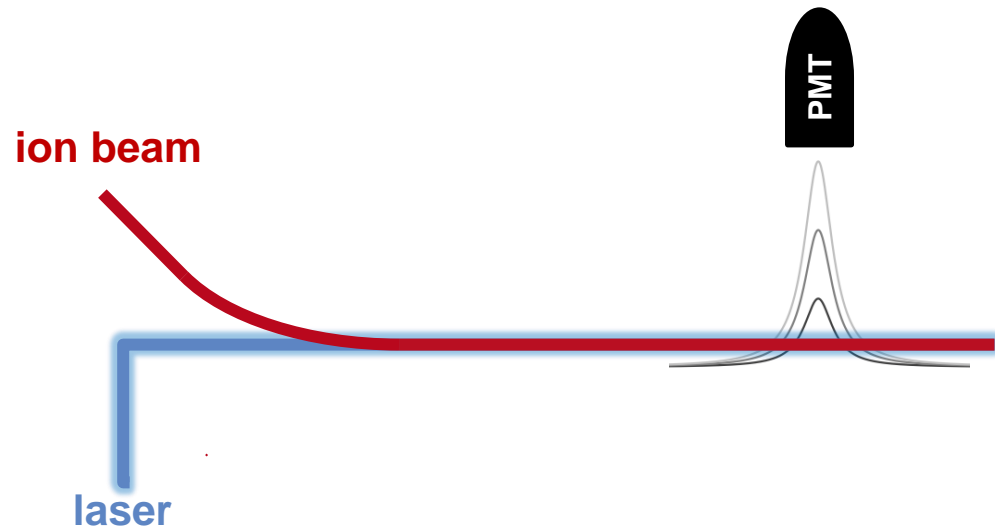




SHORT REMINDER

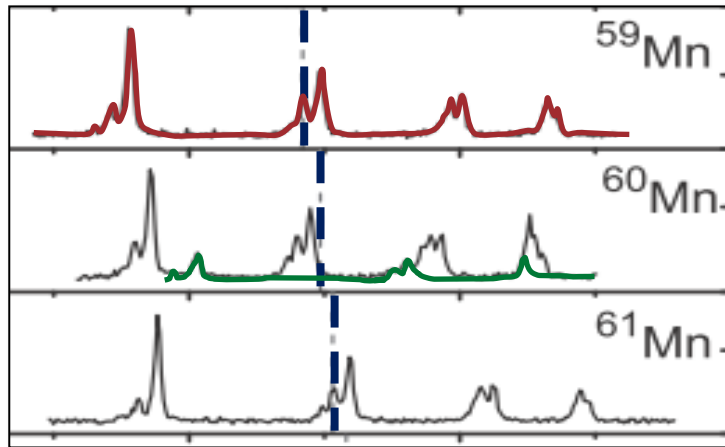
# COLLINEAR LASER SPECTROSCOPY

# COLLINEAR LASER SPECTROSCOPY



- low velocity beams (~30keV)
- atomic structure → nuclear properties
- compare across isotopic chain

PRL C 94, 054321 (2016)



hyperfine structure

isomers

isotope shift

## Observables:

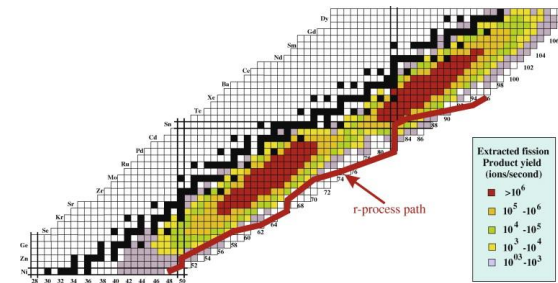
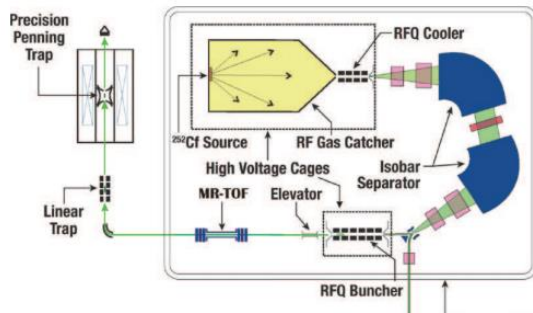
- ▶ nuclear moments
- ▶ nuclear spins
- ▶ nuclear charge radii





AO3: ELECTROMAGNETIC STRUCTURE OF MEDIUM-MASS NUCLEI

# LASER SPECTROSCOPY ON NEUTRON-RICH MEDIUM MASS NUCLEI



Savard, NIM B 266, (2008)

# CARIBU

- ▶ spontaneous fission of  $^{252}\text{Cf}$
- ▶ neutron-rich isotopes between  $A=70-170$

## ACCEPTED PROPOSALS:

Renewal: Collinear Laser Spectroscopy of Neutron-rich Transition Metals at CARIBU

Palladium, Ruthenium

Collinear Laser Spectroscopy of Neutron-rich Uranium-Fission Fragments at NuCARIBU

Cerium, Neodymium

# nuCARIBU

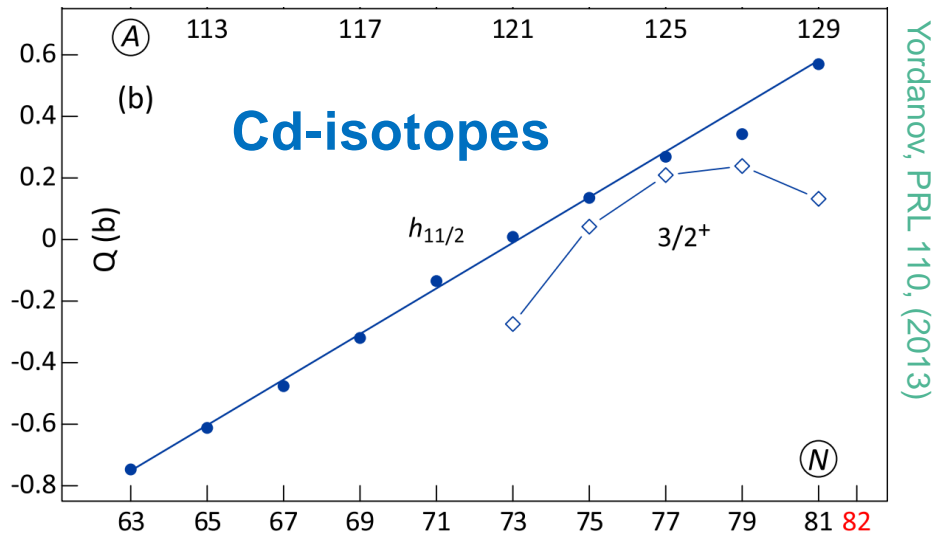
- ▶ neutron-induced fission on uranium
- ▶ neutron-rich isotopes between  $A=70-160$
- ▶ production peaks at slightly lower masses





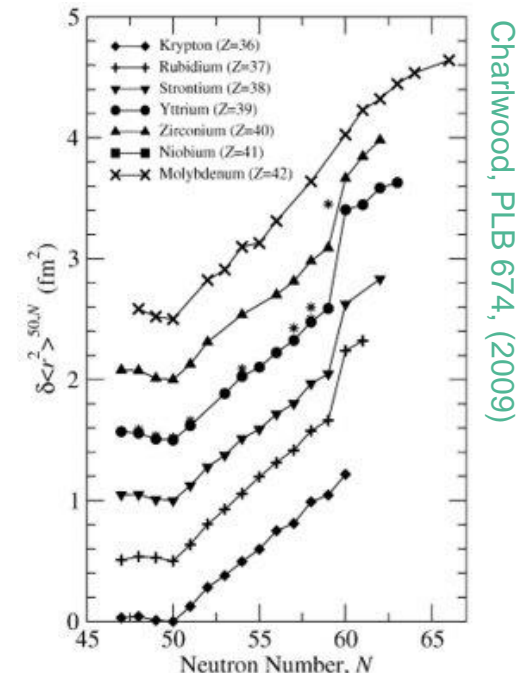
# THE PALLADIUM ISOTOPIC CHAIN

- ▶ nuclear QP moments near proton shell closure:
  - ▶ Cd (Z=48): unexpected simple linear behavior
  - ▶ predicted by particle-hole excitations from nuclear shell model



# THE RUTHENIUM ISOTOPIC CHAIN

- ▶ sudden deformation at N=60
  - expand to Z = 44
- ▶ triaxiality in  $^{108,110,112}\text{Ru}$ ?



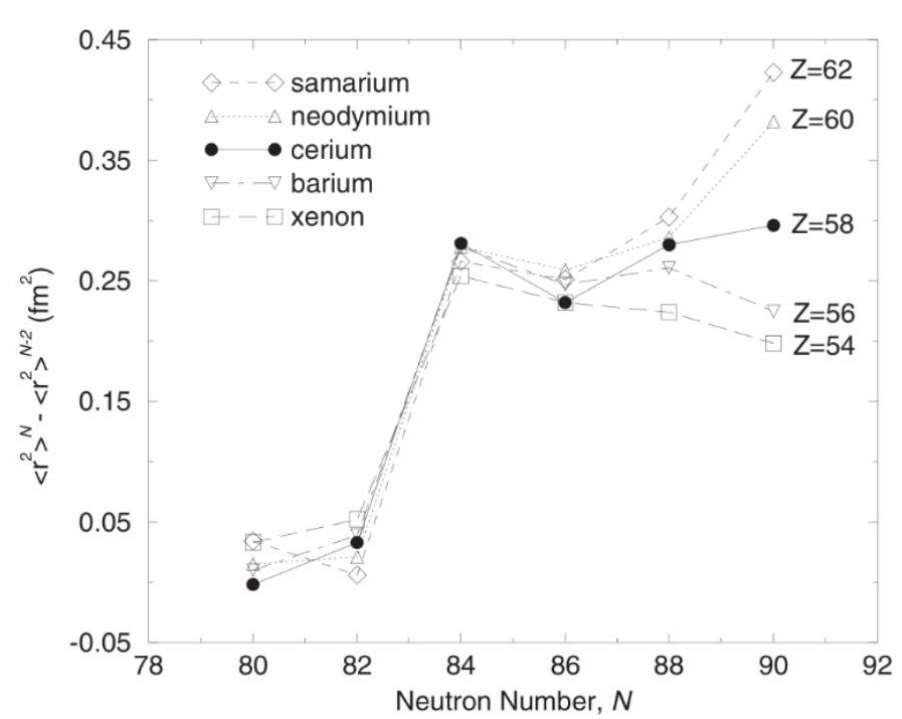


# NUCLEAR DEFORMATIONS IN Ce AND Nd

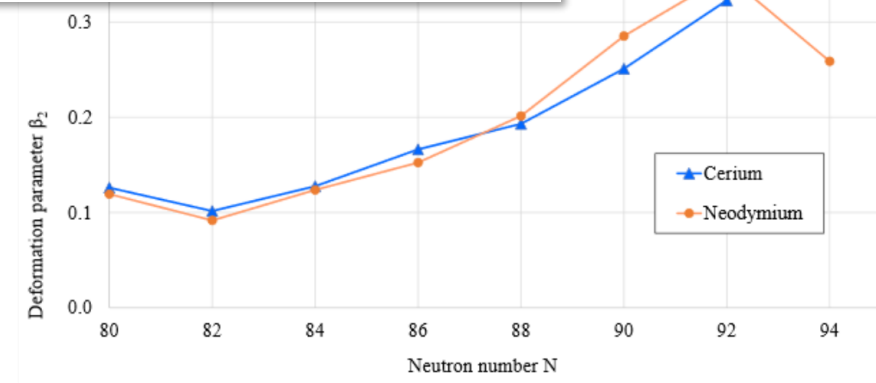
- ▶ Ce (Z=58): strong increase in qp deformation
- ▶ Nd (Z=60): decrease in qp deformation

$$\delta\langle r^2 \rangle = \delta\langle r^2 \rangle_{\text{sph}} + \frac{5}{4\pi} \langle r^2 \rangle_{\text{sph}} \sum_i \delta\langle \beta_i^2 \rangle$$

- ▶ inverted trend in  $\delta\langle r^2 \rangle$  expected



Cheal, JPG 29 2479, (2003)

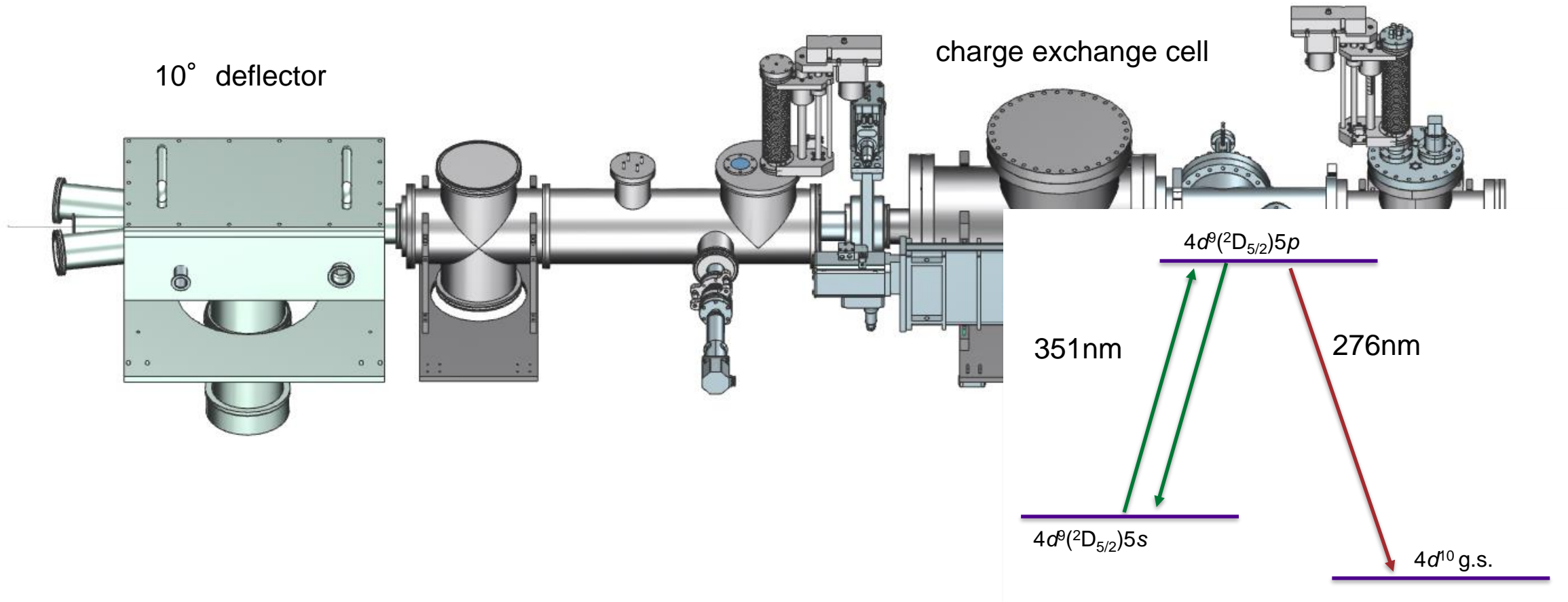


<https://www.nndc.bnl.gov/nudat3/>





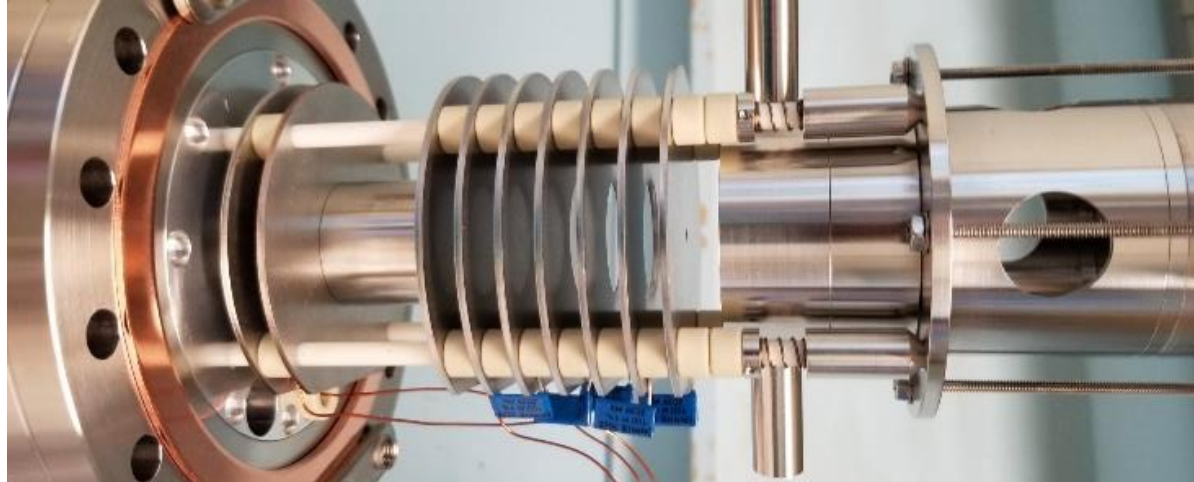
# TRIGA



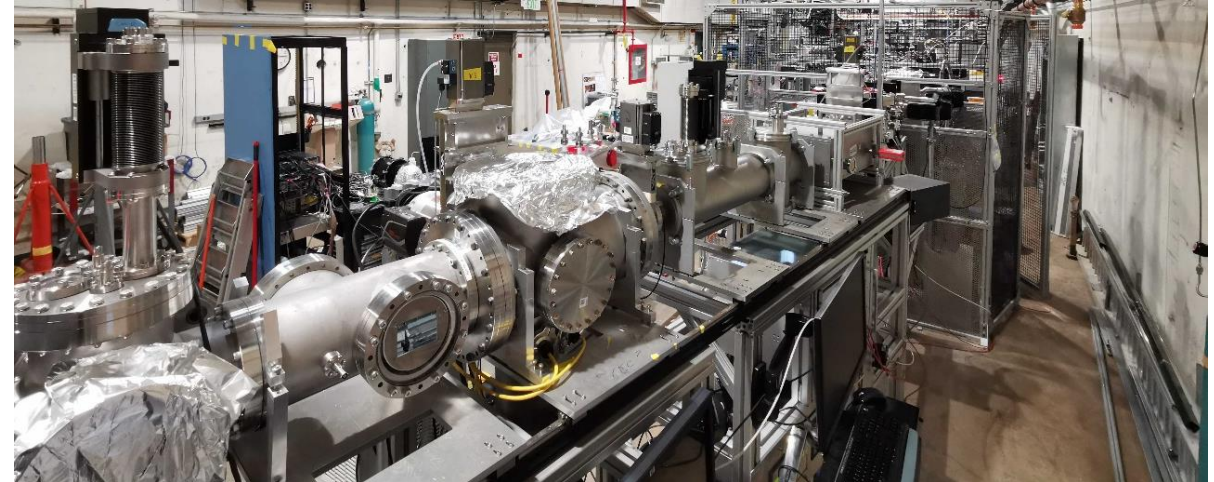


# STATUS

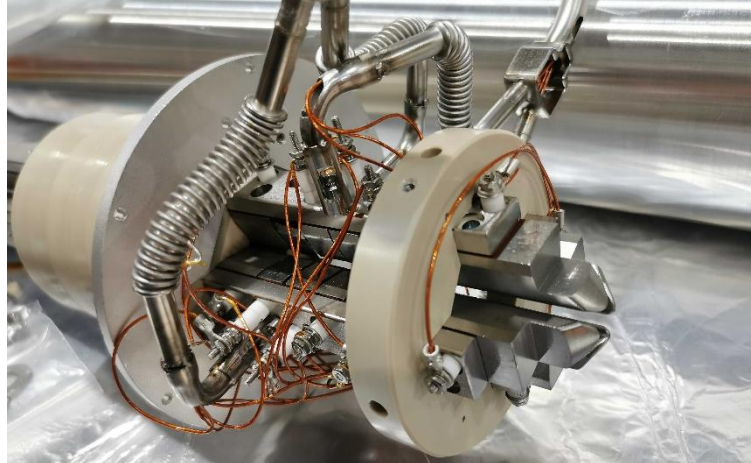
offline source



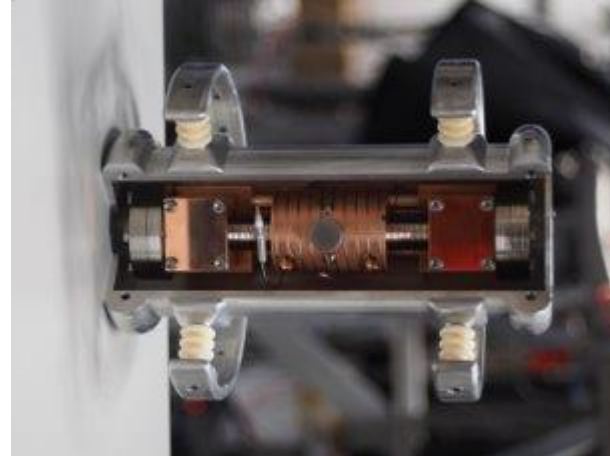
TRIGA beamline



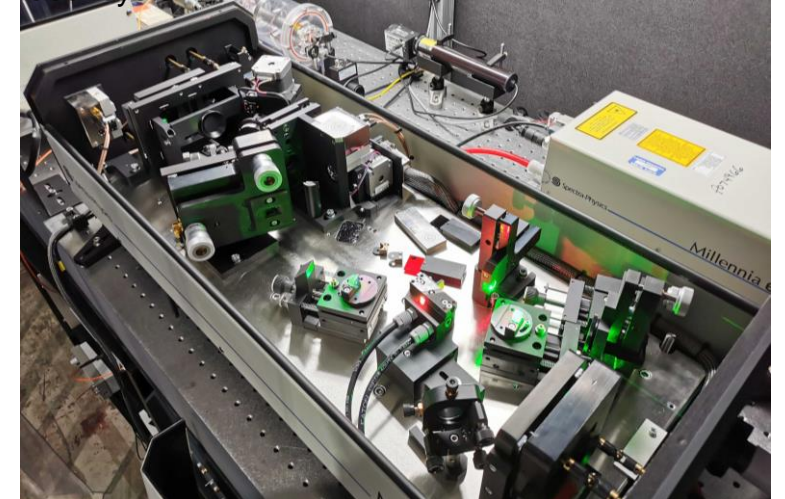
cooler-buncher



new charge exchange cell



laser system



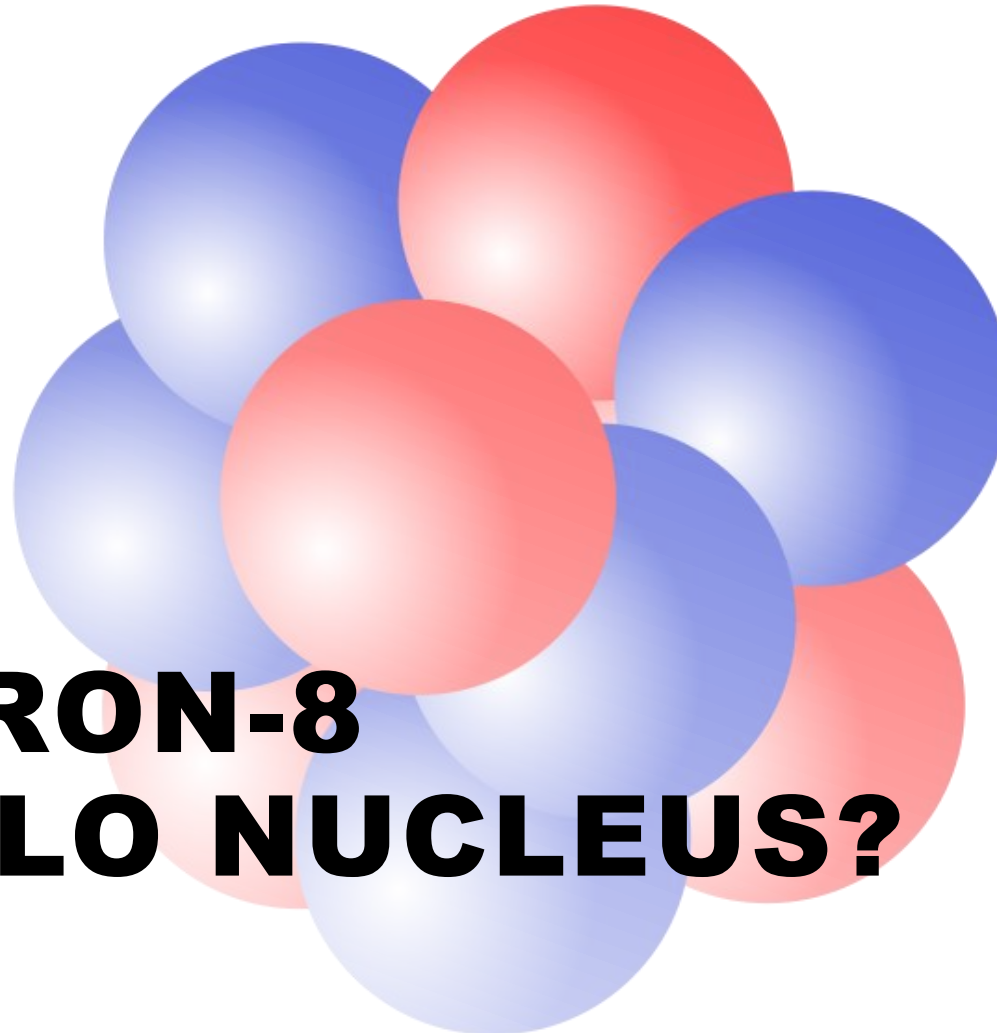
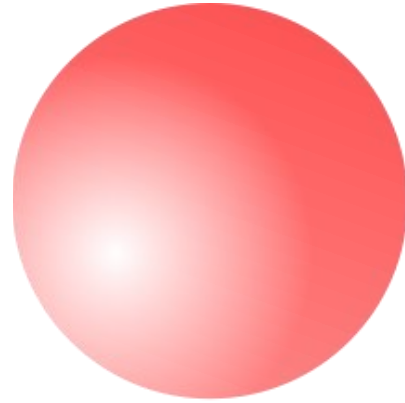




# NEXT STEPS

- ▶ October:
  - ▶ laser spectroscopy without CEC: Zr<sup>+</sup> offline
  - ▶ cooler-buncher commissioning
  - ▶ laser spectroscopy with CEC: Pd (Ru) offline
- ▶ November:
  - ▶ online beamtime Pd (Ru)





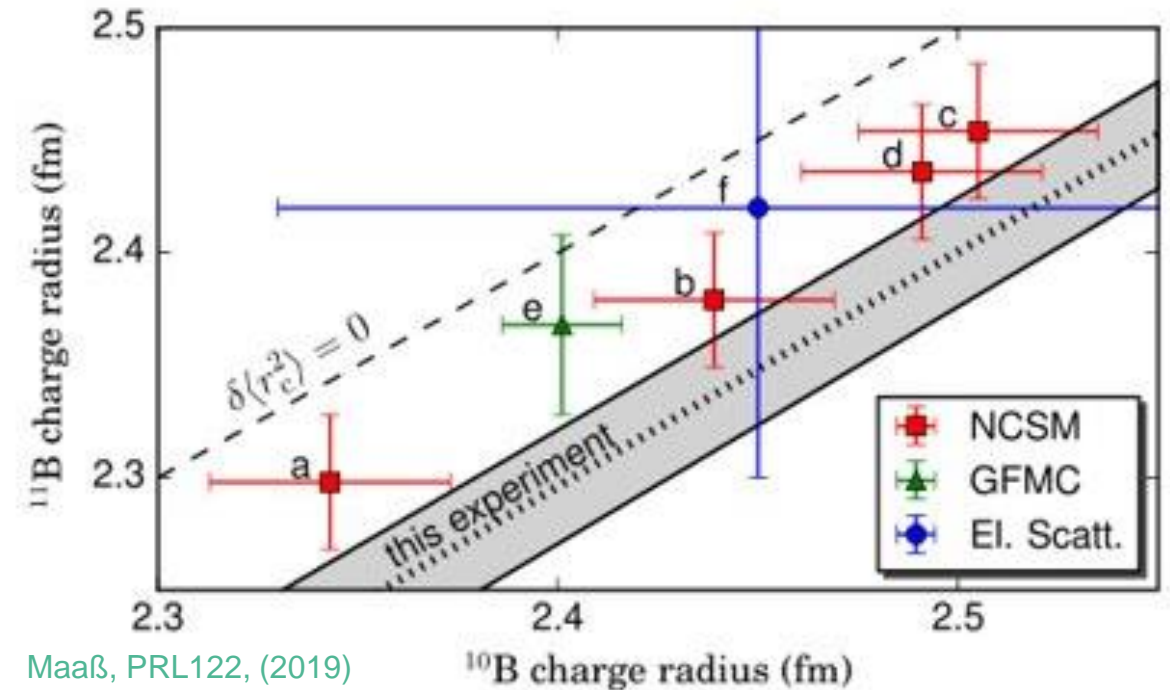
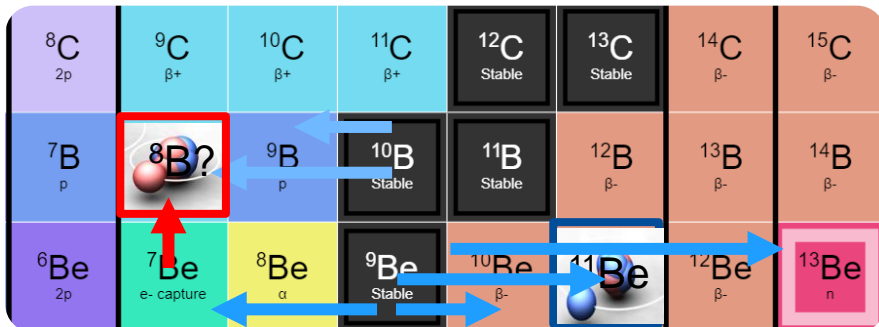
**A01: PRECISION STRUCTURE OF LIGHT NUCLEI**

# **TOWARDS BORON-8 A PROTON-HALO NUCLEUS?**



# GOAL

- ▶ electromagnetic observables of light nuclei
- ▶ test ab initio calculations
  - ✓ done for He, Li, Be<sup>+</sup>
- ▶ charge radius of <sup>8</sup>B
  - ? proton halo nucleus



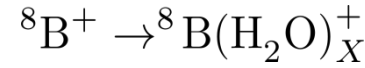
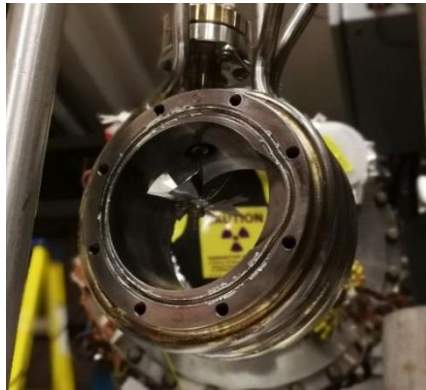
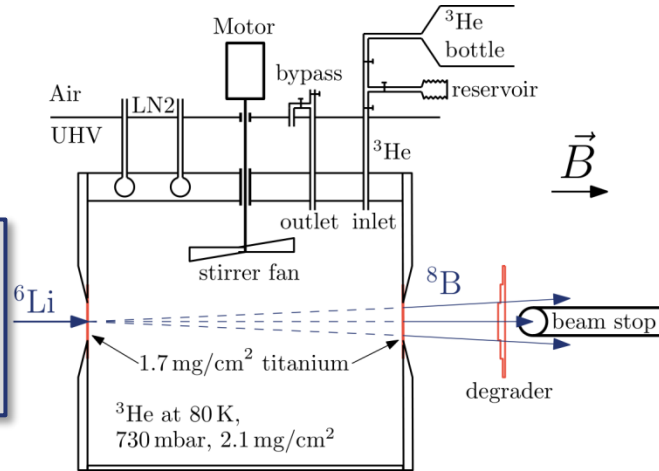
Maaß, PRL122, (2019)



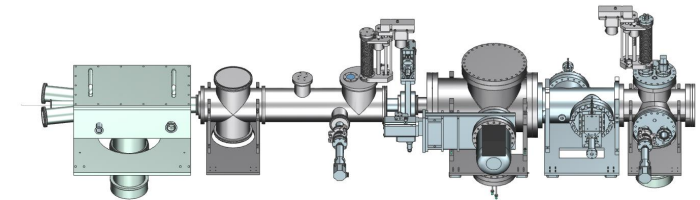
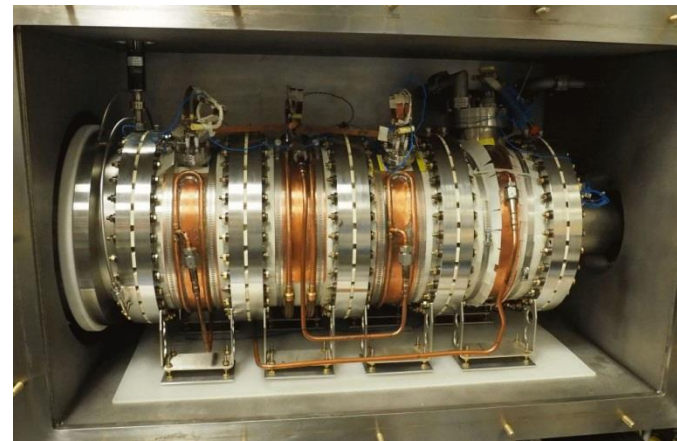
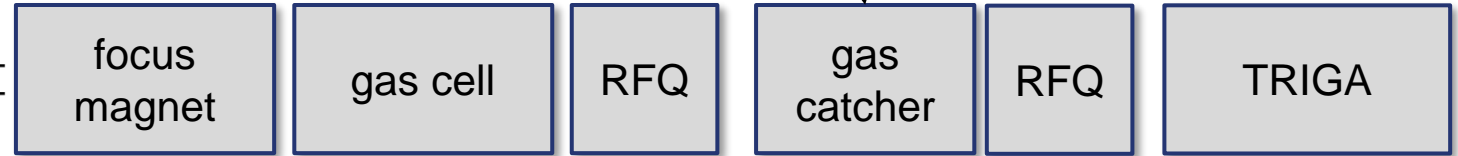
# SETUP

ATLAS

${}^6\text{Li}$ - beam  
41 MeV  
450 pA

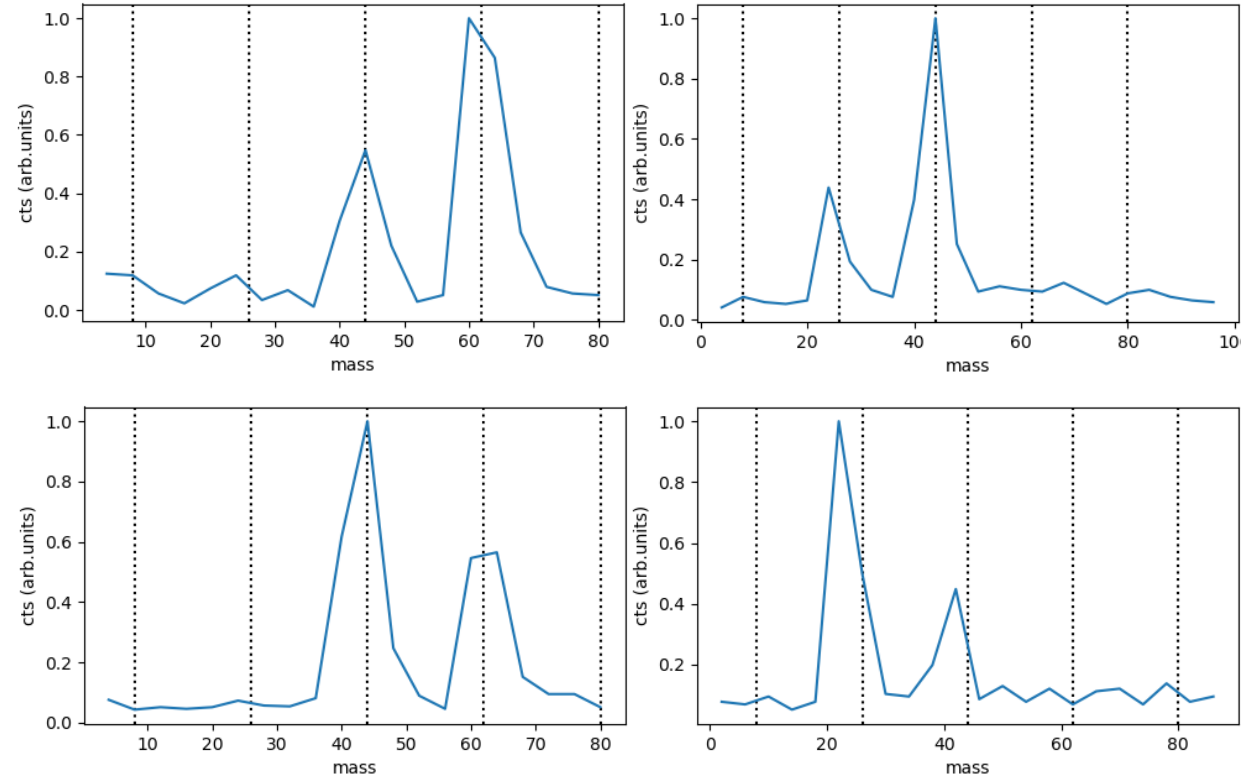
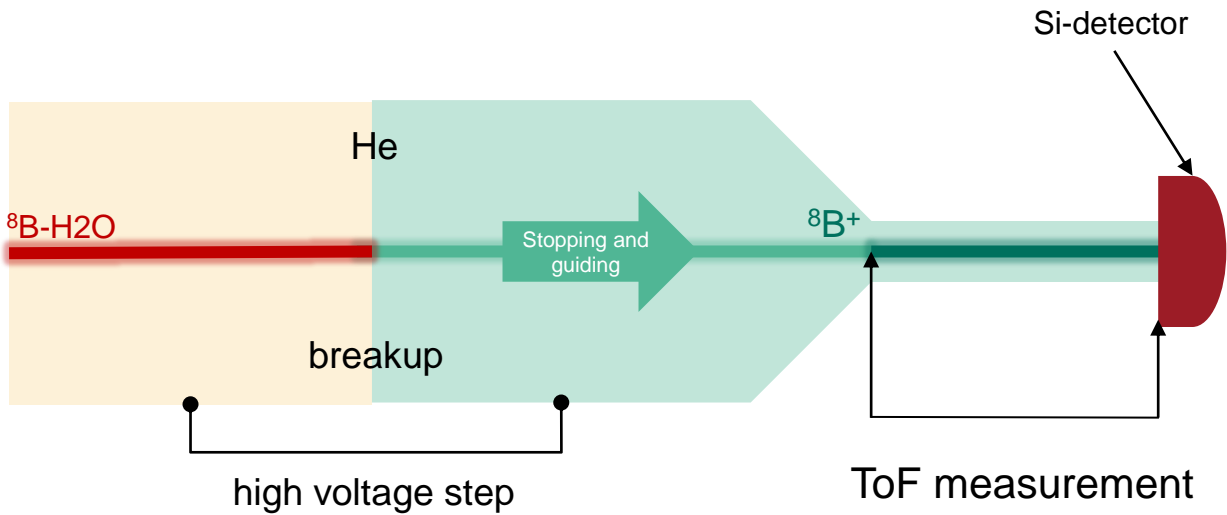


molecular breakup





# MOLECULAR BREAKUP



- breakup of mass 60 → mass 26
- ? further breakup happening
- ? no catching of low masses possible

# OUTLOOK

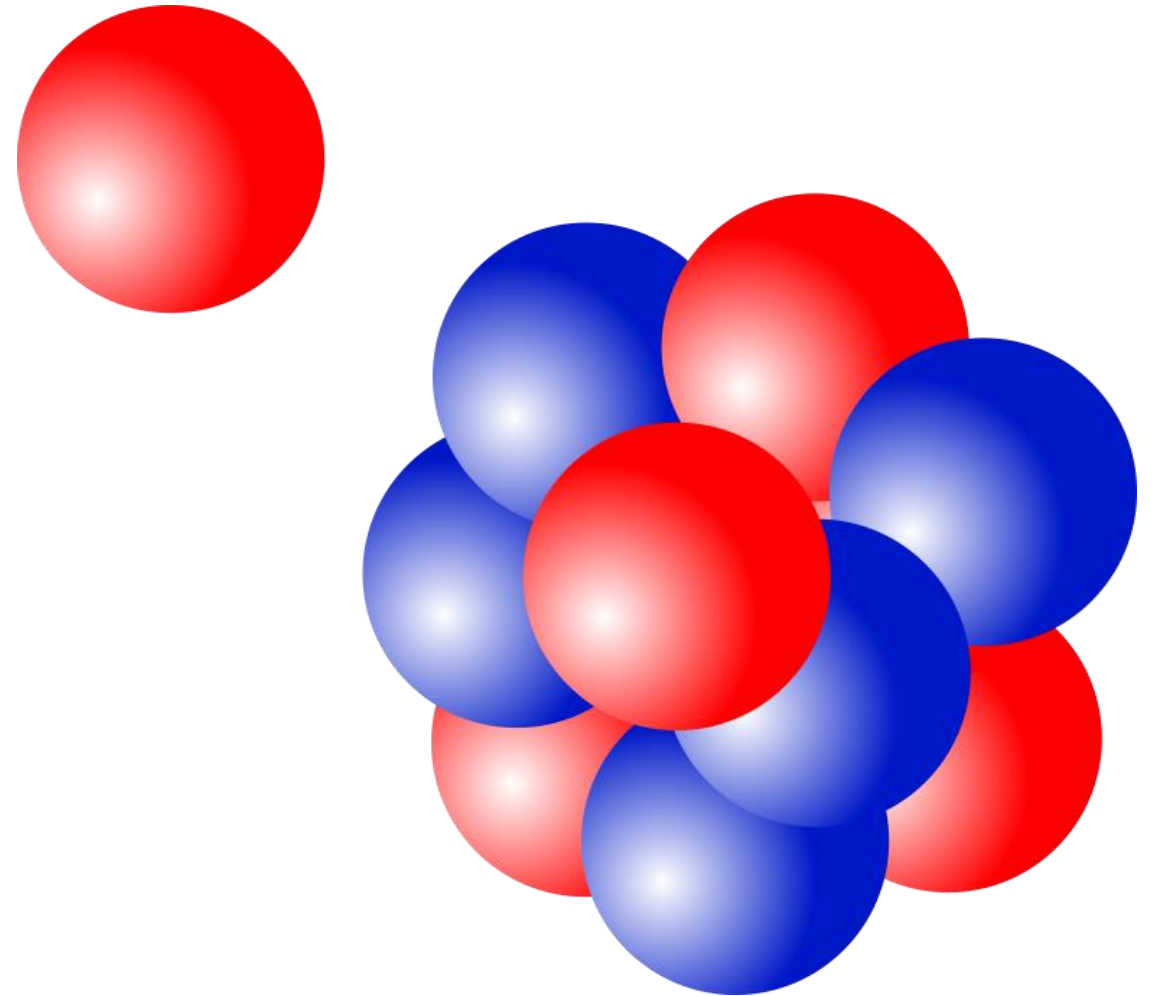


## continuous beam

- ▶ implement Wienfilter
- ▶ mass measurement without the need of catching ions

## bunched beam

- ▶ change buncher for light masses
  
- ▶ higher production rates at FRIB





# SUMMARY

## A03:

- ▶ experimental setup commissioned and ready
- ▶ upcoming beamtime on Pd in November

## A01:

- ▶ first evidence of molecular breakup
- ▶ further investigations needed

# THANKYOU

