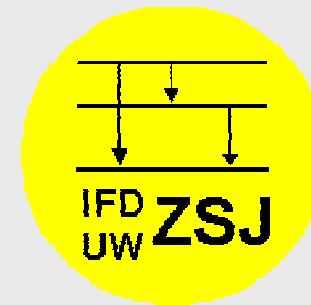


# O przemianie $\beta$ $^8\text{He}$



Marek Pfützner



Seminarium Struktury Jądra Atomowego,  
6 maja 2009

# Plan

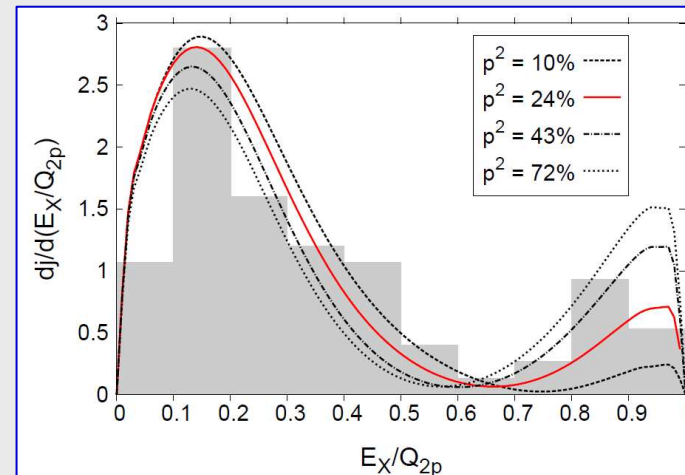
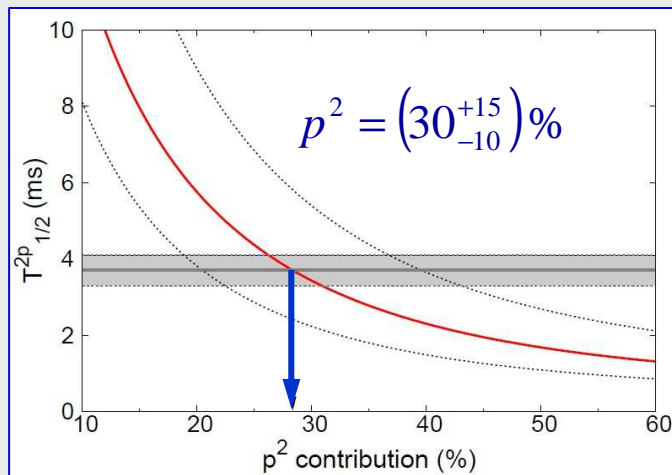


- Plany dalszych badań prom.  $2p$
- Ulepszanie OTPC
- Przypadek  $^8\text{He}$
- Opóźniona emisja deuteronu przez jądra z neutronowym halo
- Przemiana  $\beta$   $^8\text{He}$
- Kilka zarejestrowanych zdarzeń (jeszcze ciepłych!)

# Emisja 2p i struktura jądrowa

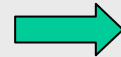
- 2p radioactivity offers more observables than 1p emission (correlations!)

Better test of nuclear models



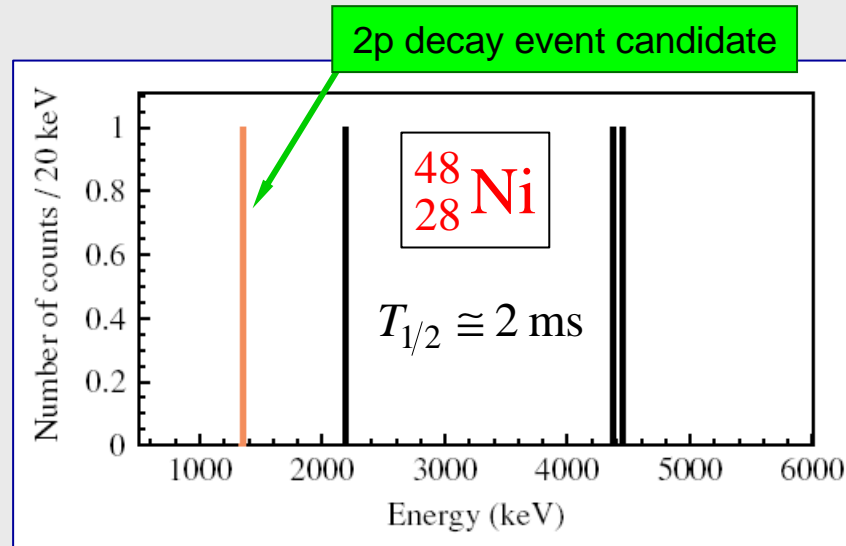
- 3-body model consistently reproduces all observables for  $^{45}\text{Fe}$  which evidently depend on the initial state of two protons.
- Perhaps one can separate the 3-body decay dynamics from the correct description of the detailed structure of the decaying nucleus?

probability of 2p in a state of given  $l$



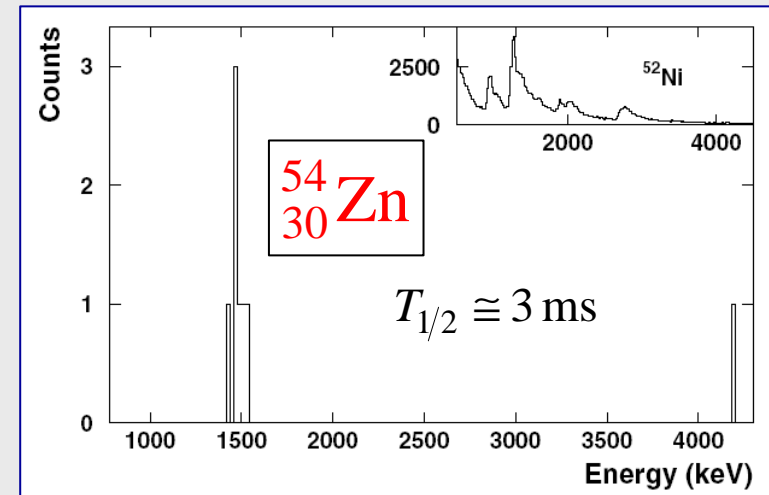
3-body decay with correct FS and Coulomb interactions

# Planowane eksperymenty



**GANIL:** fragmentation of  $^{58}\text{Ni}$  beam @ 75 MeV/u  
4  $^{48}\text{Ni}$  ions implanted in a Si strip detector  
C. Dossat et al., PRC 72 (2005) 054315

- 2p branching possibly small ( $\approx 25\%$ )
- closed shell!
- good estimate of x-sec.  
6 atoms/day @ 30 pA

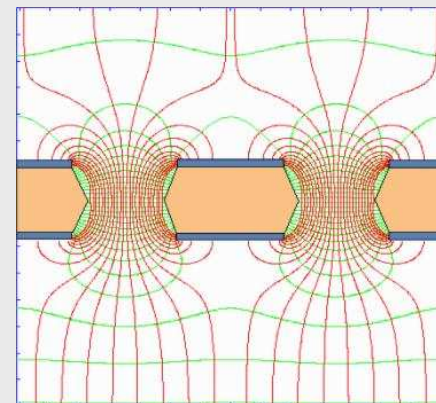
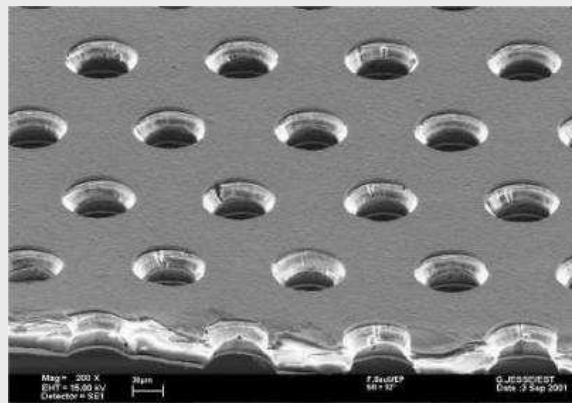
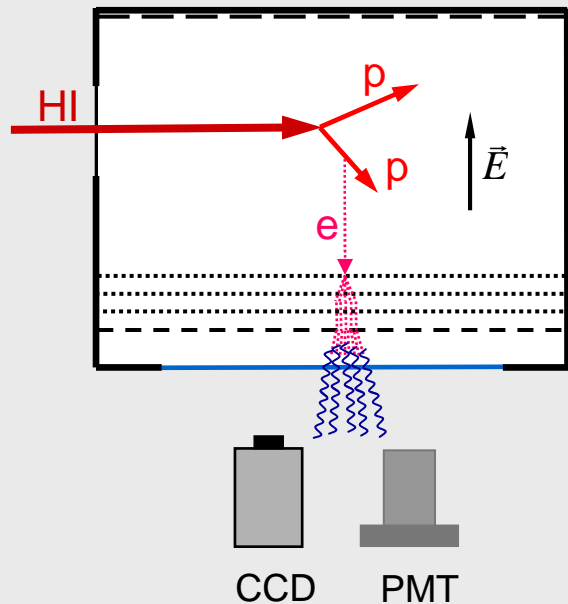


**GANIL:** fragmentation of  $^{58}\text{Ni}$  beam @ 75 MeV/u  
8  $^{54}\text{Zn}$  ions implanted in a Si strip detector  
B. Blank et al., PRL 94 (2005) 232501

- known to be 2p emitter ( $b(2p) \approx 90\%$ )
- probably dominated by  $p^2$

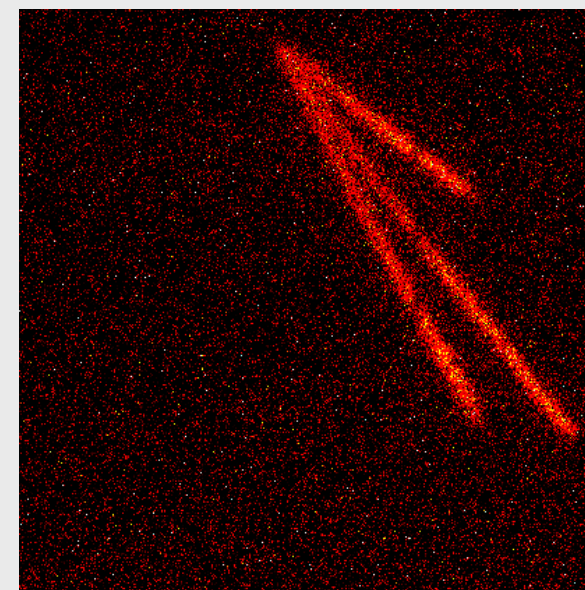
NSCL experiment soon

# Ulepszona OTPC



- 'Natural' geometry (implantation perpendicular to field lines):
  - increased efficiency
  - no ion-induced sparks
  - no diffusion problem

- First amplification stage replaced by 3 GEM foils:
  - lower voltages
  - less sparking
  - larger amplification
  - larger dynamic range

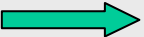


W. Dominik, seminarium SJA, 19.11.2008 → <http://zsj.fuw.edu.pl/>

α tracks recorded 22.04.09

# Potrzeba testów

- The new OTPC version needs testing with real charged-particle decays.
- An ideal case: combine a test with a real physics experiment

Our choice   ${}^8\text{He}$

${}^8\text{He}$  – a nucleus with the **largest neutron/proton ratio** among particle-stable ones, attracts lot of interest, mainly due to possible 4-neutron halo.

For the last 10 years, the NNDC Data Base shows:

→ **113** papers on  ${}^8\text{He}$ ,

to be compared with → **36** on  ${}^{45}\text{Fe}$ ,

and... → **901** on  ${}^{208}\text{Pb}$

# Recent highlights

Most recent highlights on  $^8\text{He}$ ,

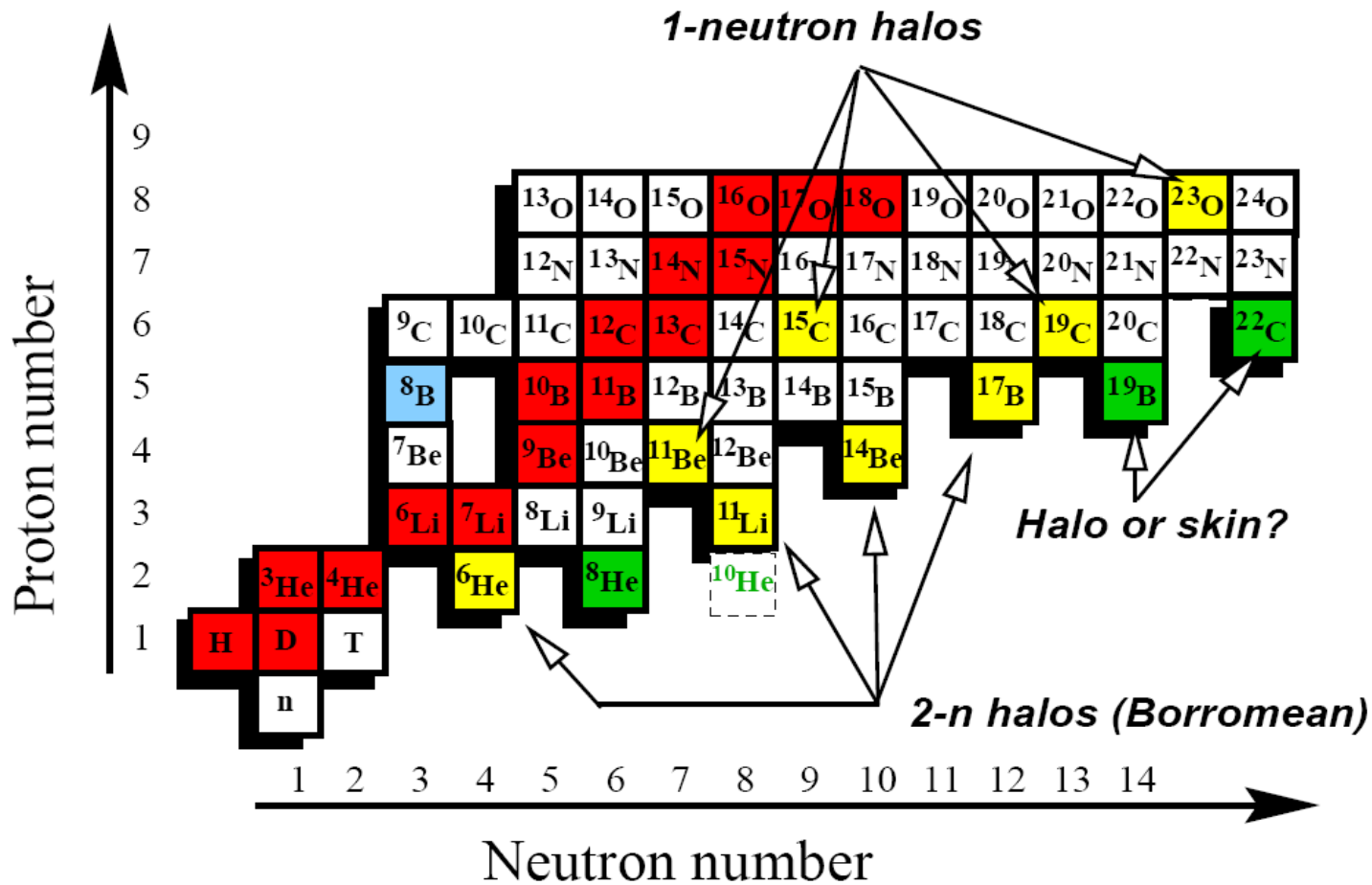
- ⇒ P. Mueller et al., Phys. Rev. Lett. 99 (2007) 252501 – „Nuclear Charge Radius of  $^8\text{He}$ ”
- ⇒ V.L. Ryjkov et al., Phys. Rev. Lett. 101 (2008) 012501 – „Direct Mass Measurement of the Four-Neutron Halo Nuclide  $^8\text{He}$ ”
- ⇒ M.S. Golovkov et al., Phys. Lett. B 672 (2009) 22 – „The  $^8\text{He}$  and  $^{10}\text{He}$  spectra studied in the (t,p) reaction”
- ⇒ K. Hagino et al., Phys. Rev. C 77 (2008) 054317 – „Strong dineutron correlation in  $^8\text{He}$  and  $^{18}\text{C}$ ”

(first three were presented at ENAM'08 conference)

➤ Halo status not clear, somewhere between skin and halo?  
Jim Al.-Khalili: „[...]  $^8\text{He}$ ] is akin to a mouse with the skin of an elephant”

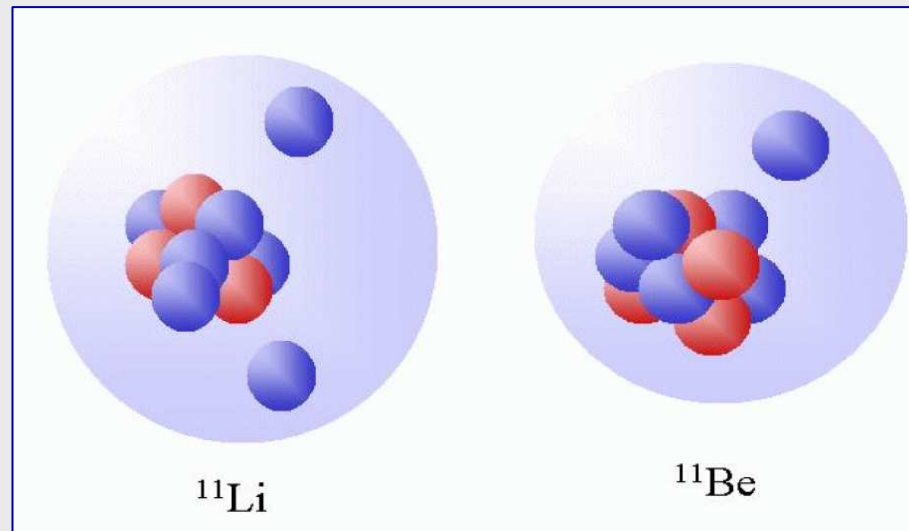
➤ Many unknowns in the  $\beta$ - decay of  $^8\text{He}$  !

# Halo neutronowe





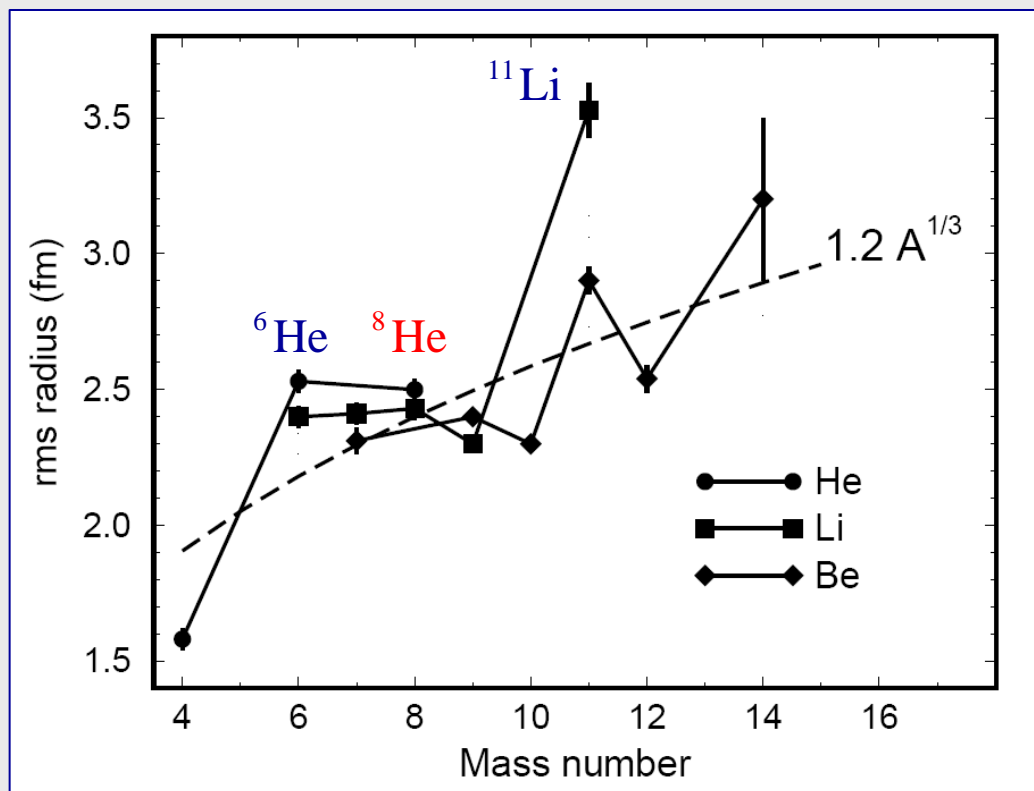
# Ważne własności halo



**Klasteryzacja:** wewnętrzne stopnie swobody rdzenia nie są sprzężone z ruchem zewnętrznych neutronów, funkcja falowa układu daje się z dobrym przybliżeniem przedstawić jako :  $\Psi_A \approx \phi(\text{core}) \cdot \psi(\text{halo})$

**Przestrzenna rozciągłość:** ponad 50% gęstości ff neutronów halo znajduje się poza zasięgiem potencjału jądrowego

# Promienie lekkich jąder

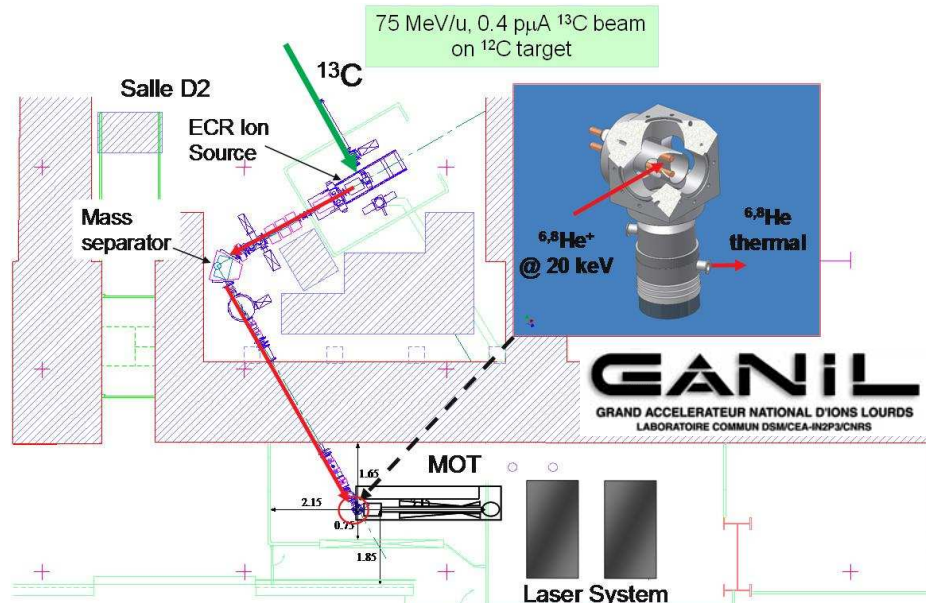


Średnie promienie kwadratowe jąder wydedukowane z pomiarów całkowitego przekroju czynnego na reakcję. Znaczny wzrost w stosunku do gładkiej zależności  $\propto A^{1/3}$  jest uważany za przejaw halo neutronowego.



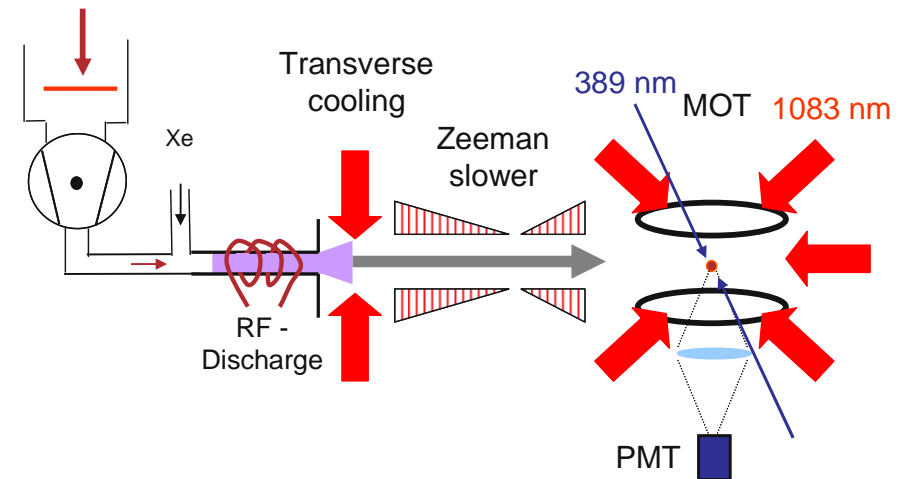
# $6,8\text{He}$ - Technique: Magneto-Optical Trap

Courtesy of P. Mueller



$\sim 1 \times 10^8$   $^6\text{He}^+/\text{s}$   
 $\sim 5 \times 10^5$   $^8\text{He}^+/\text{s}$

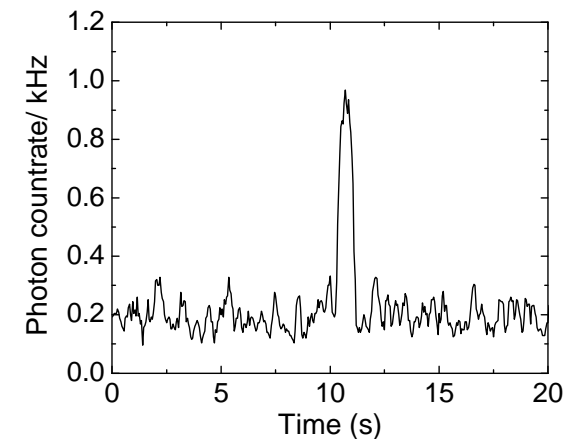
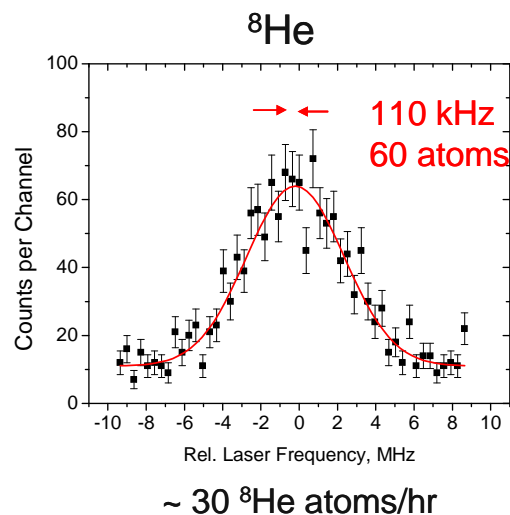
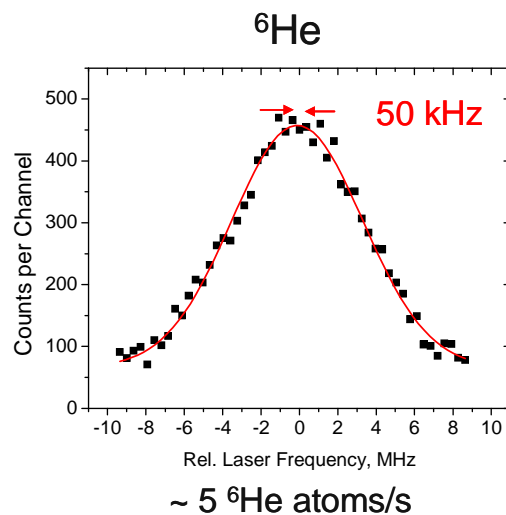
## Atom Trap Setup



Source  
 $5 \times 10^7$  He-6/s,  
 $1 \times 10^5$  He-8/s

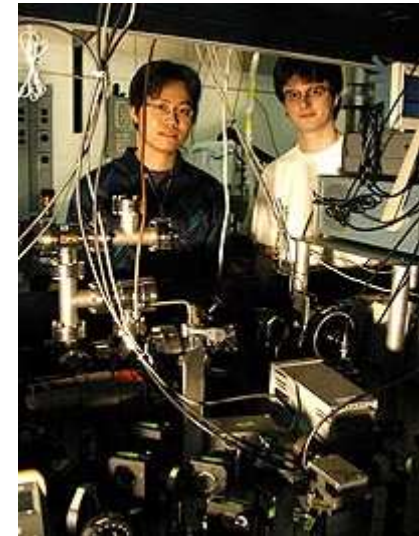
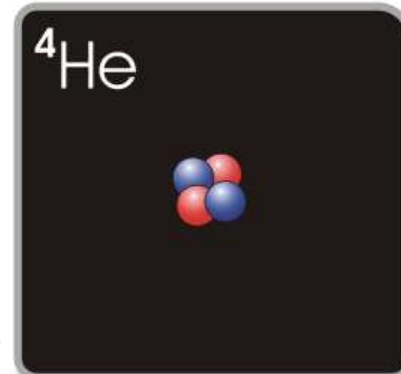
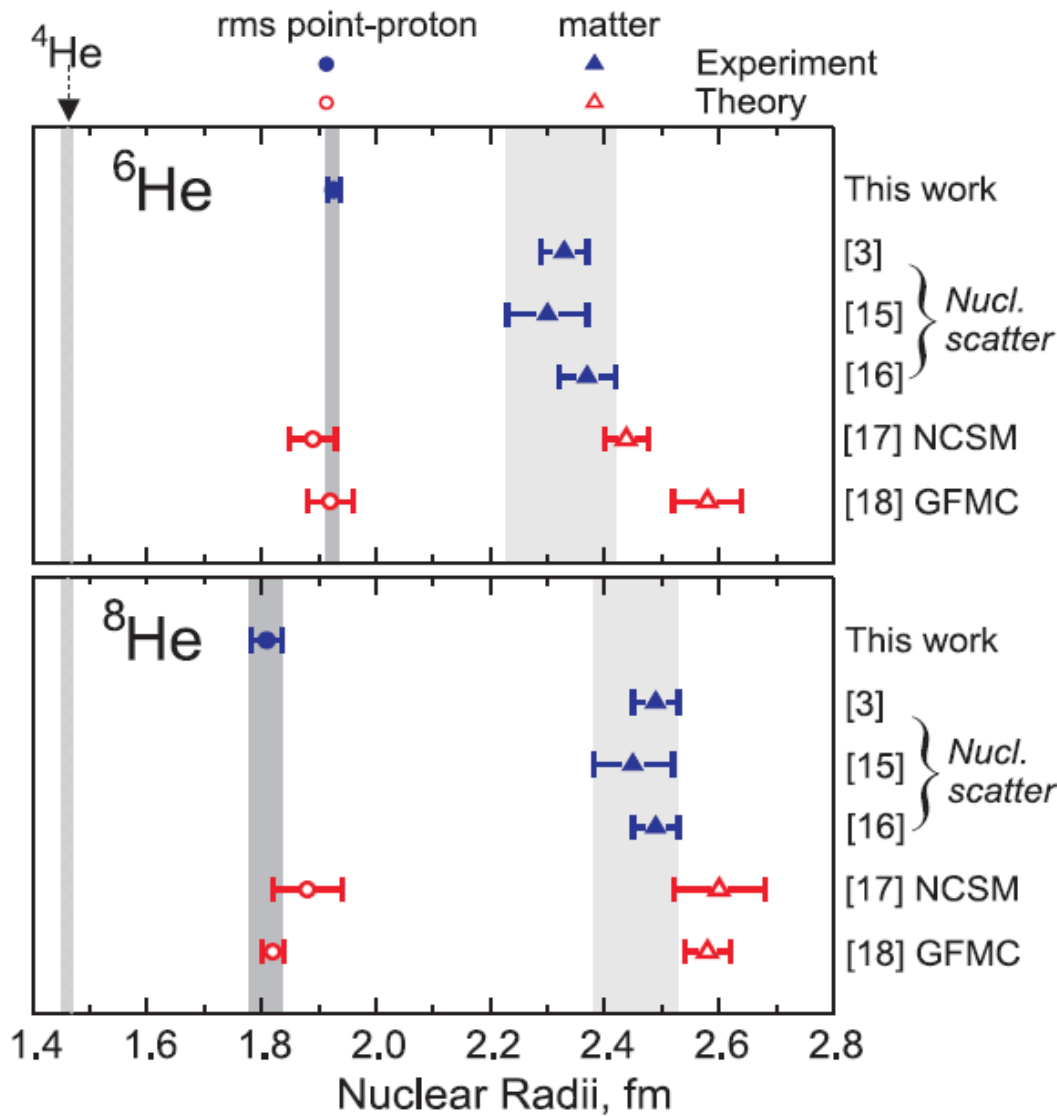
Capture efficiency  
 $1 \times 10^{-7}$

Trap  
 $\sim 5$  He-6/s,  
 $\sim 30$  He-8/hr

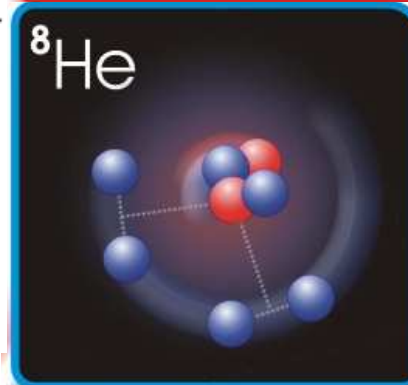
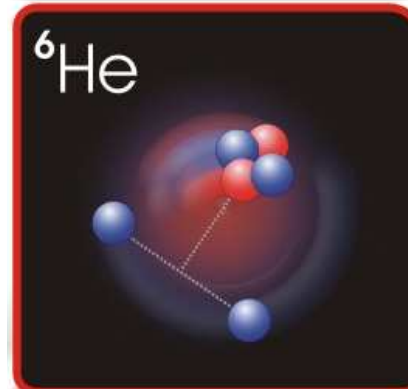


# ${}^6, {}^8\text{He}$ - Charge Radii (presented at ENAM'08)

Courtesy of P. Mueller



P. Mueller  
L.-B. Wang



L.-B. Wang et al., PRL  
93, 142501 (2004).

P. Mueller et al.,  
PRL 99, 252501 (2007).

# Pomiar masy ${}^8\text{He}$

PRL 101, 012501 (2008)

PHYSICAL REVIEW LETTERS

week ending  
4 JULY 2008

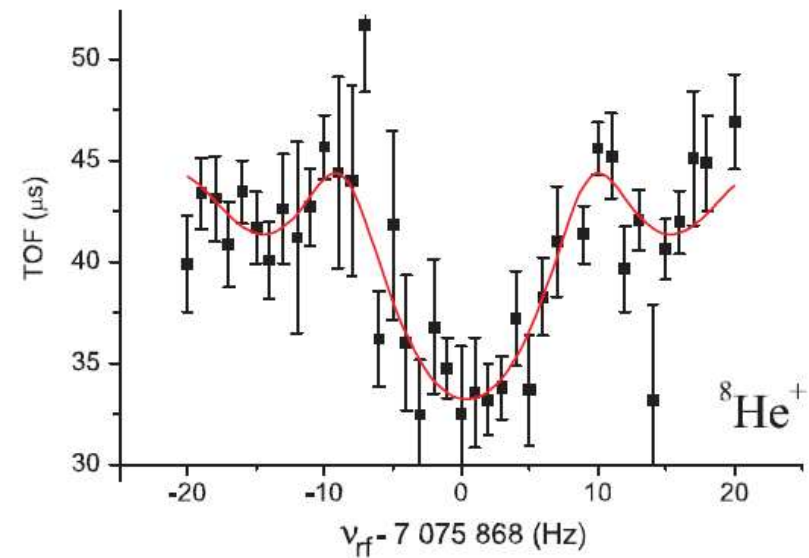
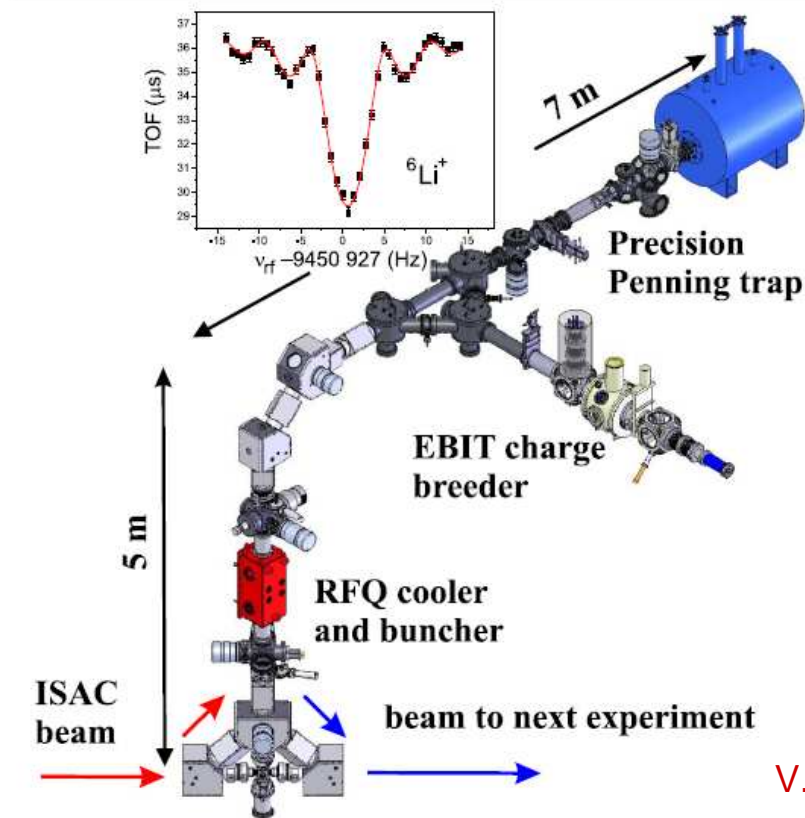
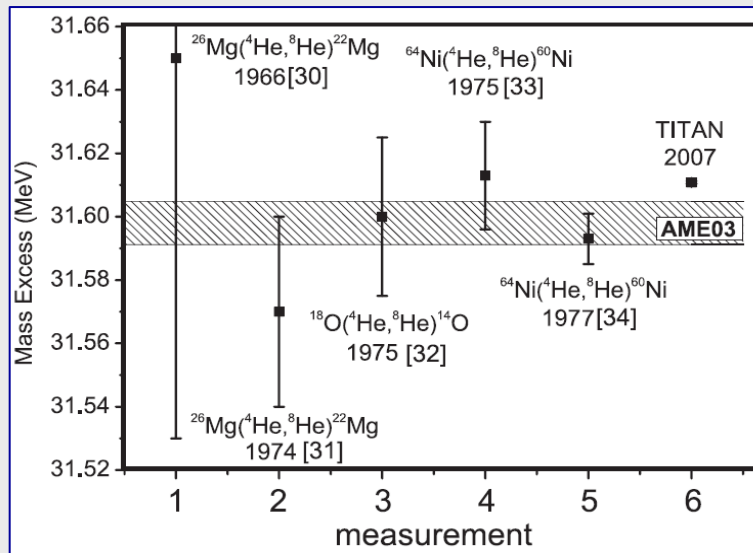
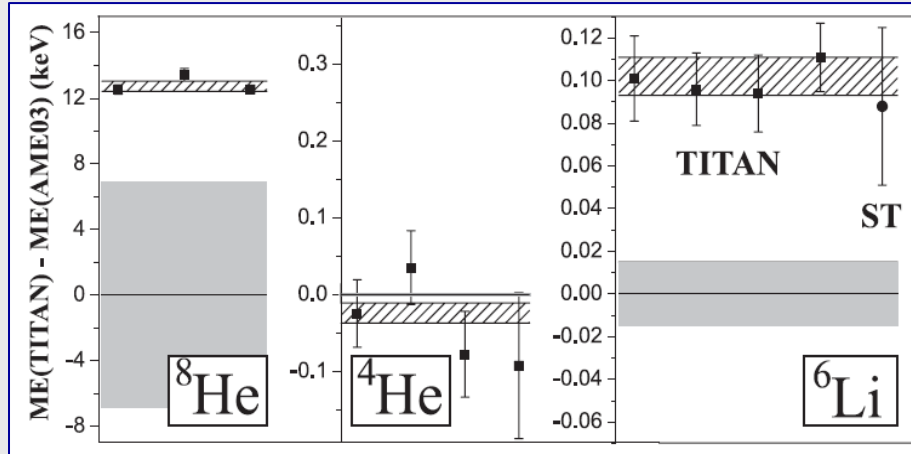


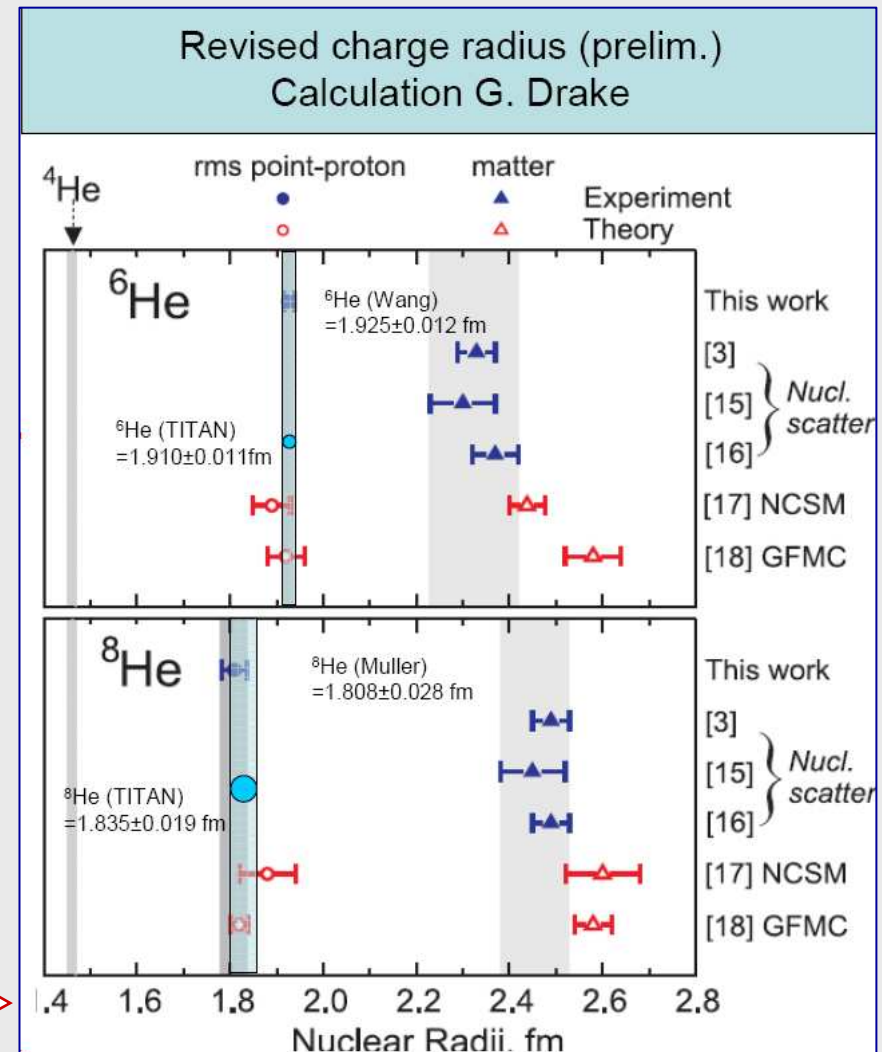
FIG. 2 (color online). Time-of-flight resonances recorded for  ${}^8\text{He}^+$ . The solid line is a fit of the theoretical curve [21] to the data.

V.L. Ryjkov et al., Phys. Rev. Lett. 101 (2008) 012501

# Masa $^8\text{He}$



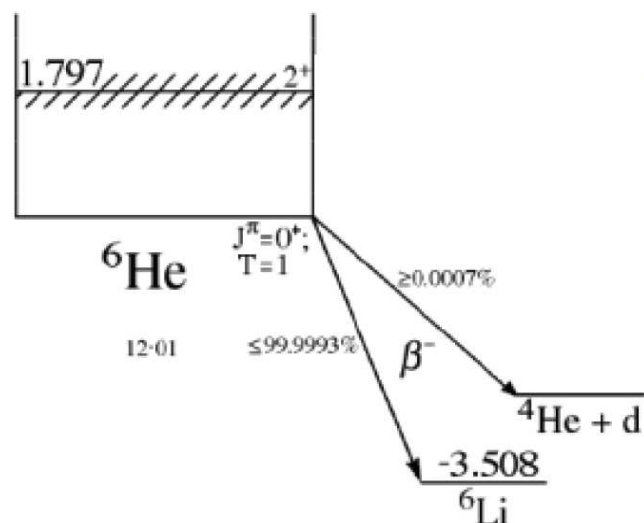
**Masa  $^8\text{He}$  większa o 13 keV!**



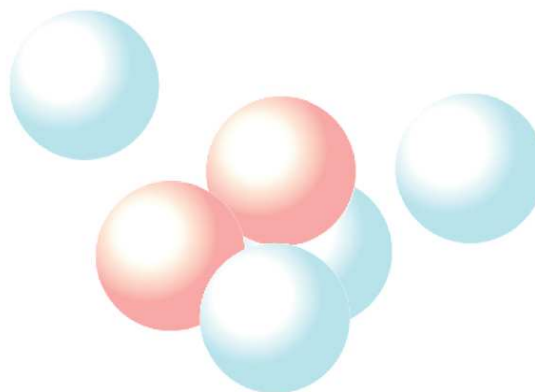
Z prezentacji J. Dillinga na ENAM'08  $\Rightarrow$

# Przemiana $\beta$ ${}^6\text{He}$

## The deuteron-emission channel in ${}^6\text{He}$



- $\beta$ -decay to g.s.  ${}^6\text{Li}$   
 $Q_\beta=3.508\text{MeV}$  ;  $T_{1/2}=806,7\text{ms}$
- $\beta$ -delayed  $\alpha + d$  emission ;  $Q=2\text{MeV}$   
 $B.R.$  of the order  $10^{-6}$



K. Riisager et al.  
ISOLDE (1990)  
branching ratio  
 **$B.R. = (2.8 \pm 0.5) \times 10^{-6}$**

M.J.G. Borge et al.  
ISOLDE (1993)  
 **$B.R. = (7.6 \pm 0.6) \times 10^{-6}$**

D. Anthony et al.  
TRIUMF (2006)  
 **$B.R. = (1.8 \pm 0.9) \times 10^{-6}$**

Louvain-la-Neuve (2005)

**$B.R. = 1.65(10) \times 10^{-6}$**

$(E_d > 350 \text{ keV})$

Z prezentacji Jeroena Büschera na ENAM'08

D. Smirnov et al., NIM A 547 (2005) 480



# Opóźniona emisja $d$ z ${}^6\text{He}$

Outline

$\beta$ -decay of halo nuclei

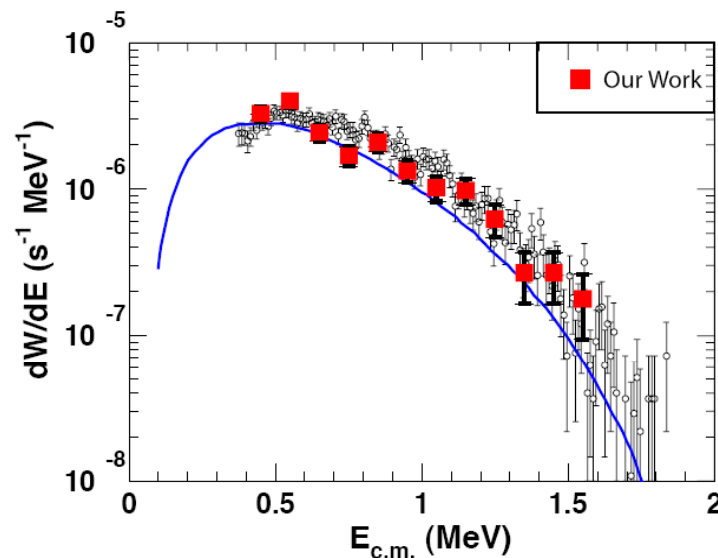
Implantation-decay in a DSSSD

${}^6\text{He}$

${}^{11}\text{Li}$

Summary

## Results and Discussion



[<sup>a</sup> D. Anthony et al., Phys.Rev.C 65, 034310 (2002) ]

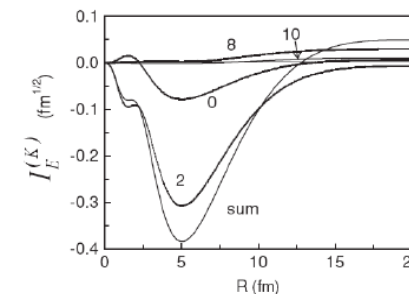
[<sup>b</sup> E.M. Tursunov et al., Phys.Rev.C 74, 014303 (2006) ]

$$\text{B.R.} = 1.65(10) \times 10^{-6}$$

good agreement with

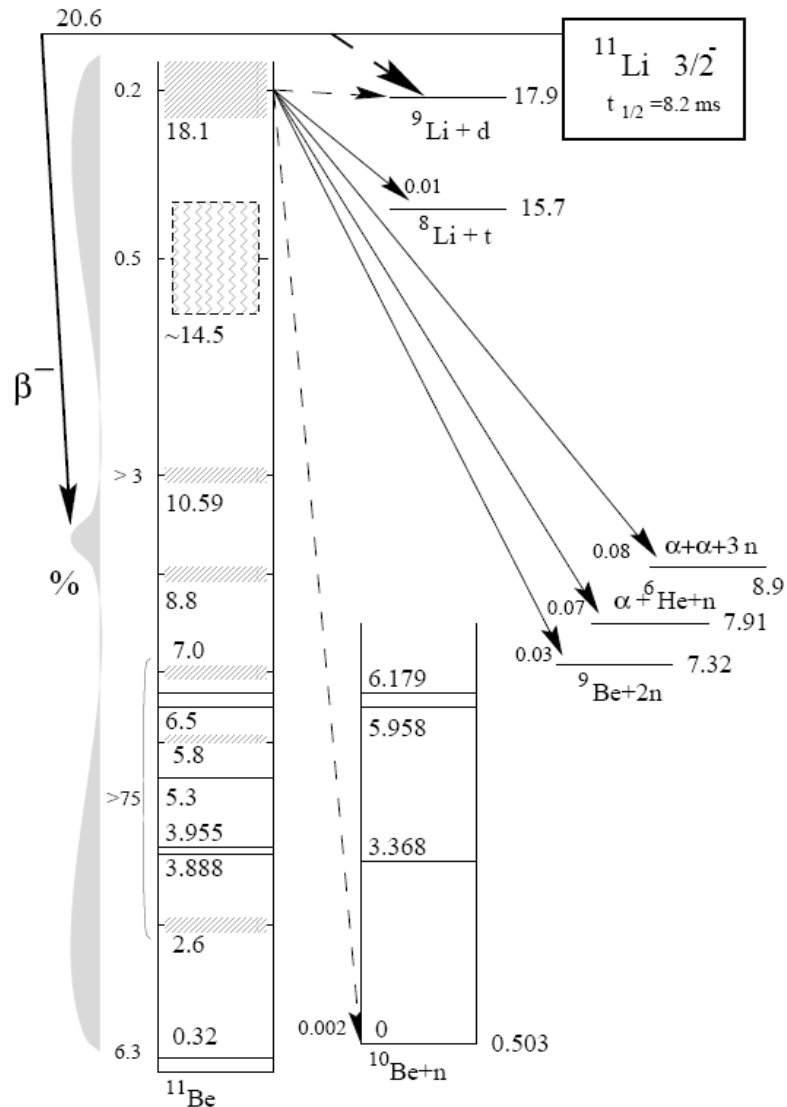
$$\text{B.R.} = 1.8(9) \times 10^{-6} \text{ }^a$$

- quenching due to a cancellation between the internal and halo parts in the Gamow-Teller matrix element <sup>b</sup>

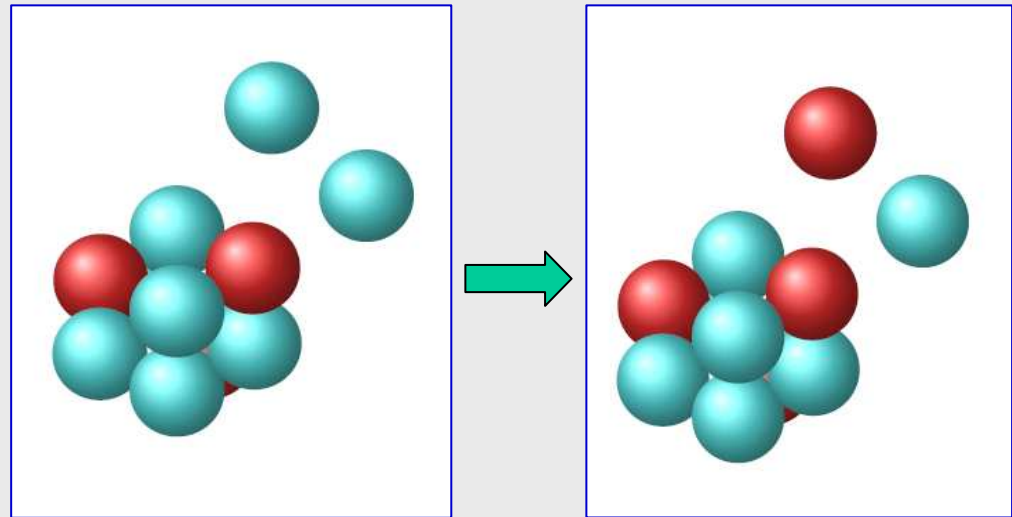


- sensitivity of the initial  ${}^6\text{He}$  wave function up to very large distances (30fm)<sup>b</sup>

# Opóźniona emisja $d$ z $^{11}\text{Li}$



K. Riisager et al., NPA 616 (1997) 169c

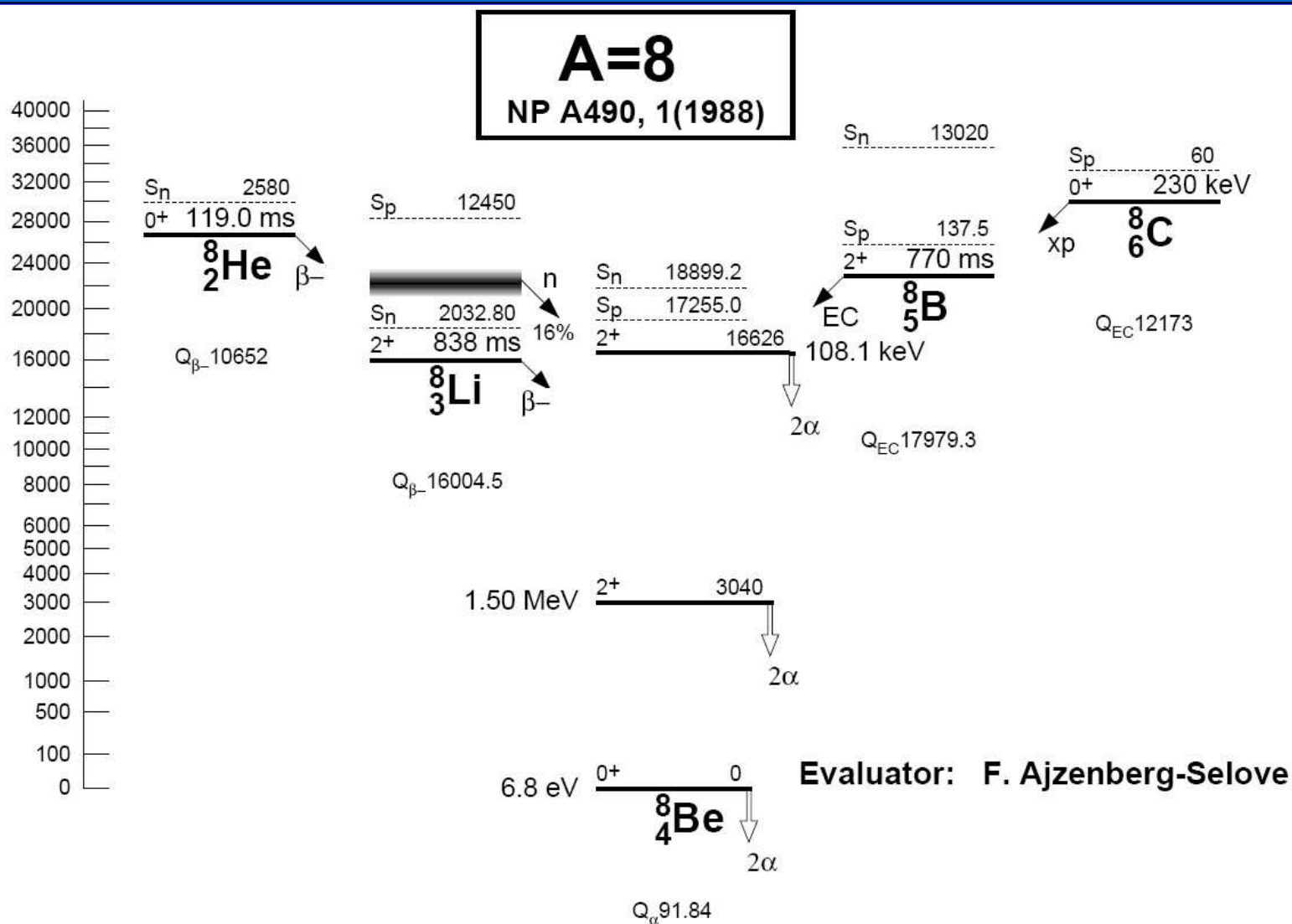


$B.R. = 1.30(13) \times 10^{-4}$   
 "large" value only possible  
 if core has a small contribution  
 $\Rightarrow$  decay essentially in the halo

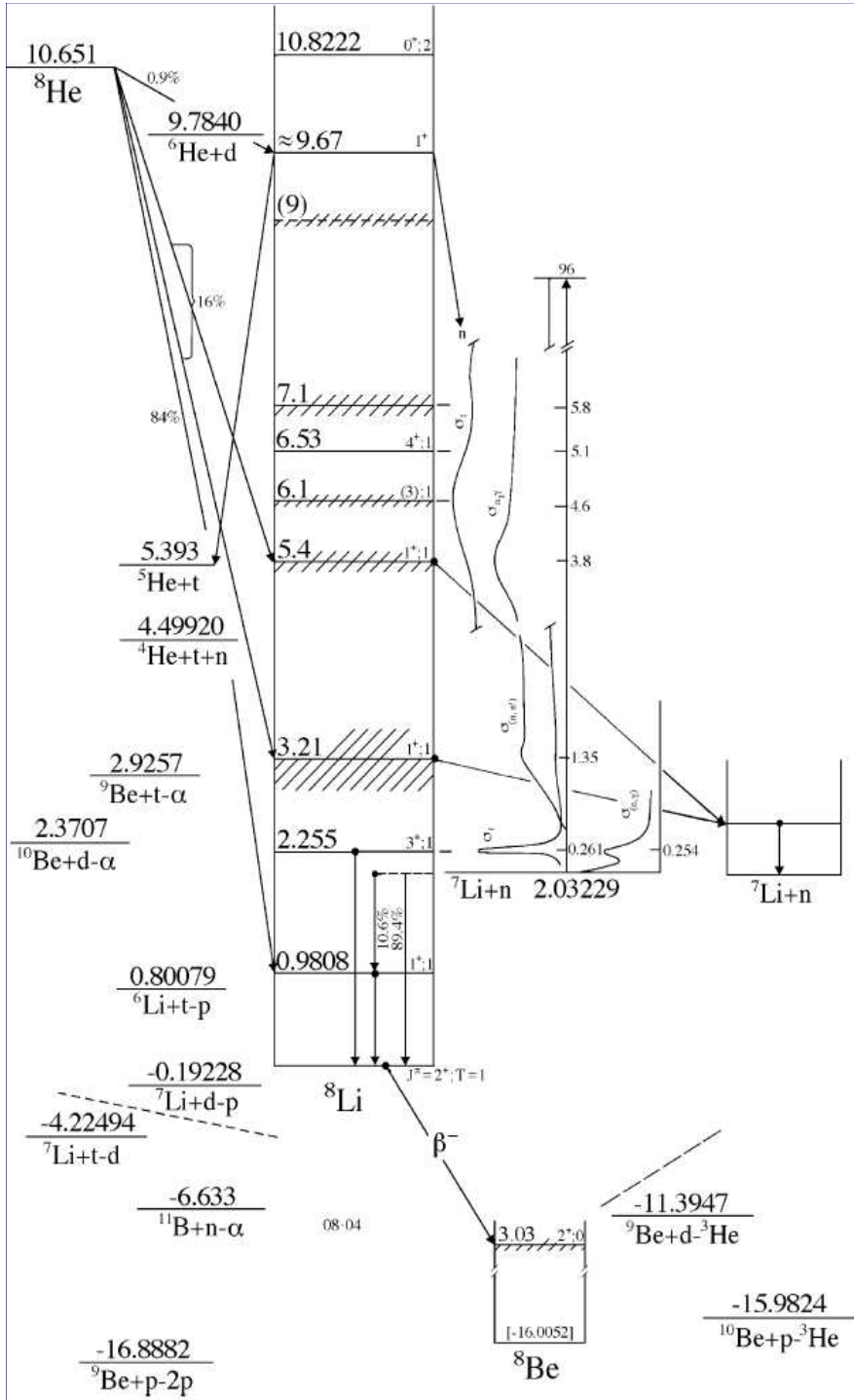
**Jeroen Büscher na ENAM'08**

R. Raabe et al., PRL 101 (2008) 212501

# Izobary A = 8



# Przemiana $\beta$ $^8\text{He}$



Ostatni (?!) eksperyment poświęcony przemianie  $\beta$   $^8\text{He}$ :

ISOLDE (1992)

M. Borge et al., NP A 560 (1993) 664

► Obserwacja kanału:



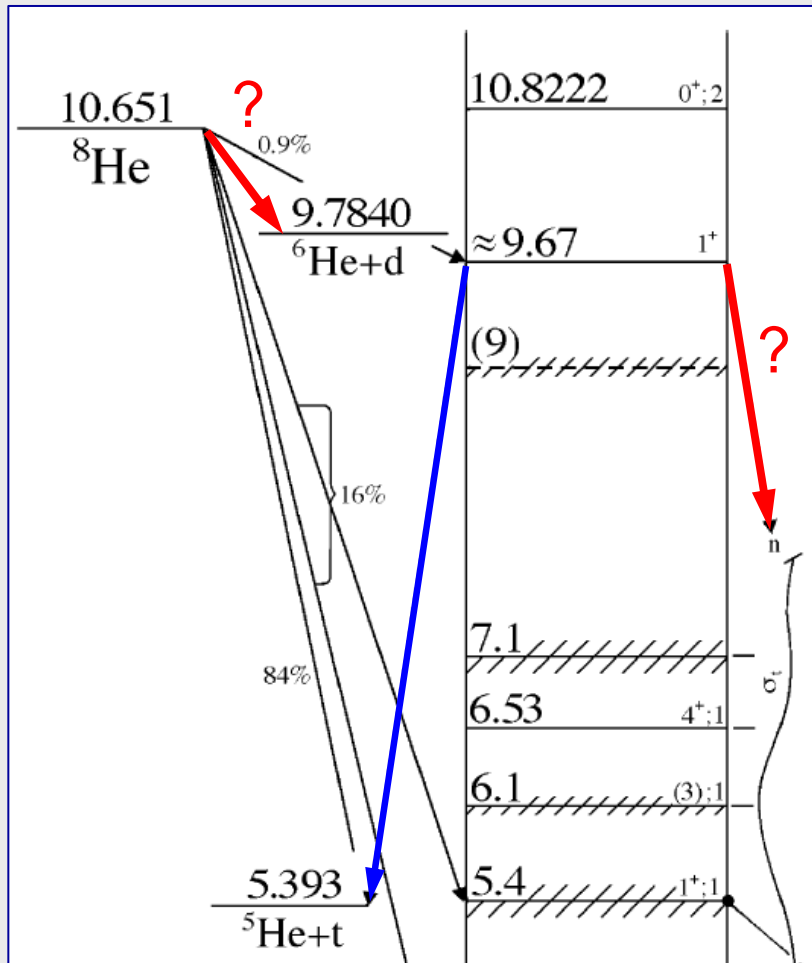
Zmierzone rozgałęzienie:

$$(8.0 \pm 0.5) \times 10^{-3}$$

$$\rightarrow B_{GT} \geq 5.2, \log ft = 2.9 !$$

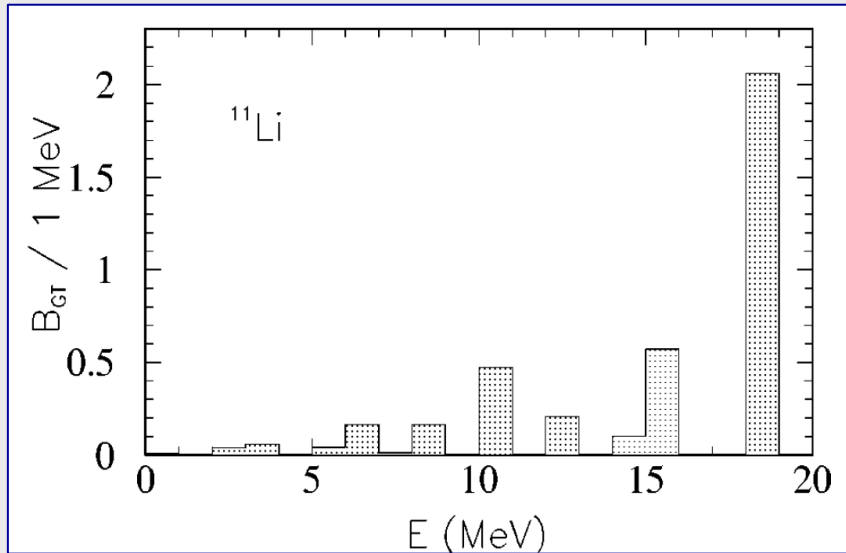
D.R. Tilley et al., NP A 747 (2004) 155

# Pytania



- Jakie naprawdę jest zasilanie stanu 9.67 MeV ?
- Czy mamy szansę zaobserwować przejście z emisją deuteronu? Jeśli tak, to czy powie nam to coś o strukturze halo w tym jądrze?

# Rozkład nasilenia GT



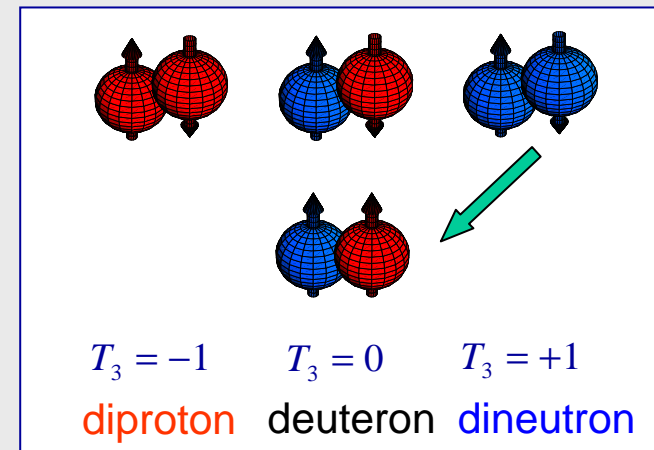
Modele przewidują, że w <sup>8</sup>Li również występuje rezonans *halo-analogowy* przy energii ok. 9 MeV, zasilany w rozpadzie β <sup>8</sup>He, dla którego wartość B<sub>GT</sub> jest rzędu 10.

L.V. Grigorenko et al., NP A607 (1996) 277

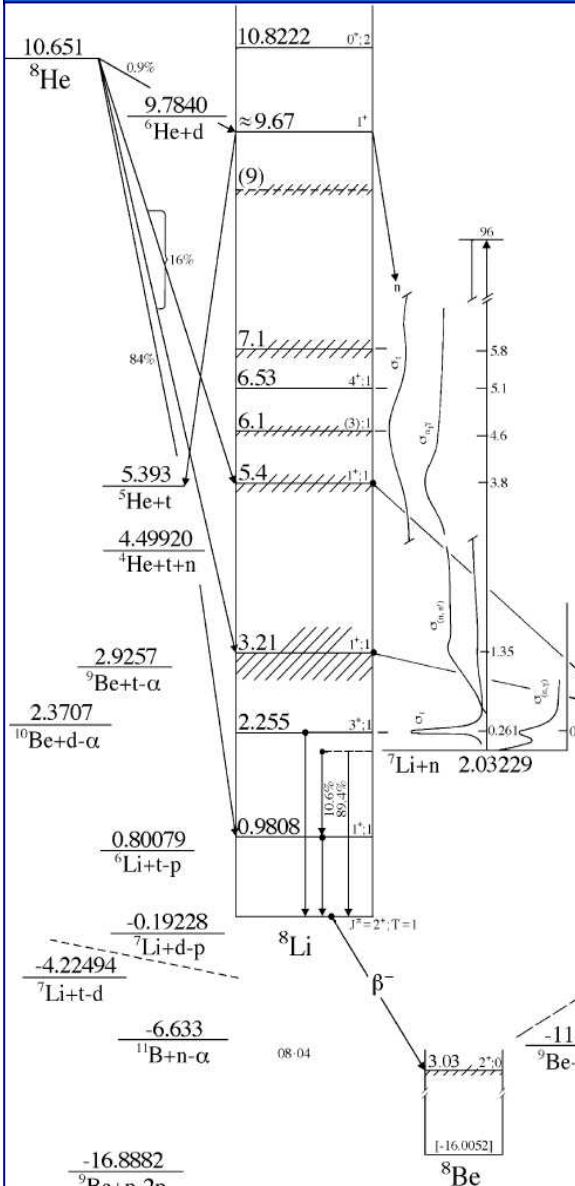
Koncepcja stanu *halo-analogowego*

M. Zhukov et al., PRC 52 (1995) 2641

W grubym przybliżeniu, dwa neutrony halo ( $T^h = 1, T_3 = 1$ ) przechodzą do stanu  $T^h = 1, T_3 = 0$  w jądrze końcowym.



# Kanały z cząstkami naładowanymi



84 % ?

$$E_\alpha = 1.5 \text{ MeV}, R \approx 4 \text{ cm}$$



16 % ?

$$E_{\text{Li}} \leq 1 \text{ MeV}, R \leq 2.8 \text{ cm}$$



$\approx 1$  % ?

$$E_t \leq 3 \text{ MeV}, R \leq 27 \text{ cm}$$

$$E_\alpha \leq 2.5 \text{ MeV}, R \leq 7 \text{ cm}$$



???

$$E_d \leq 0.6 \text{ MeV}, R \leq 4 \text{ cm}$$

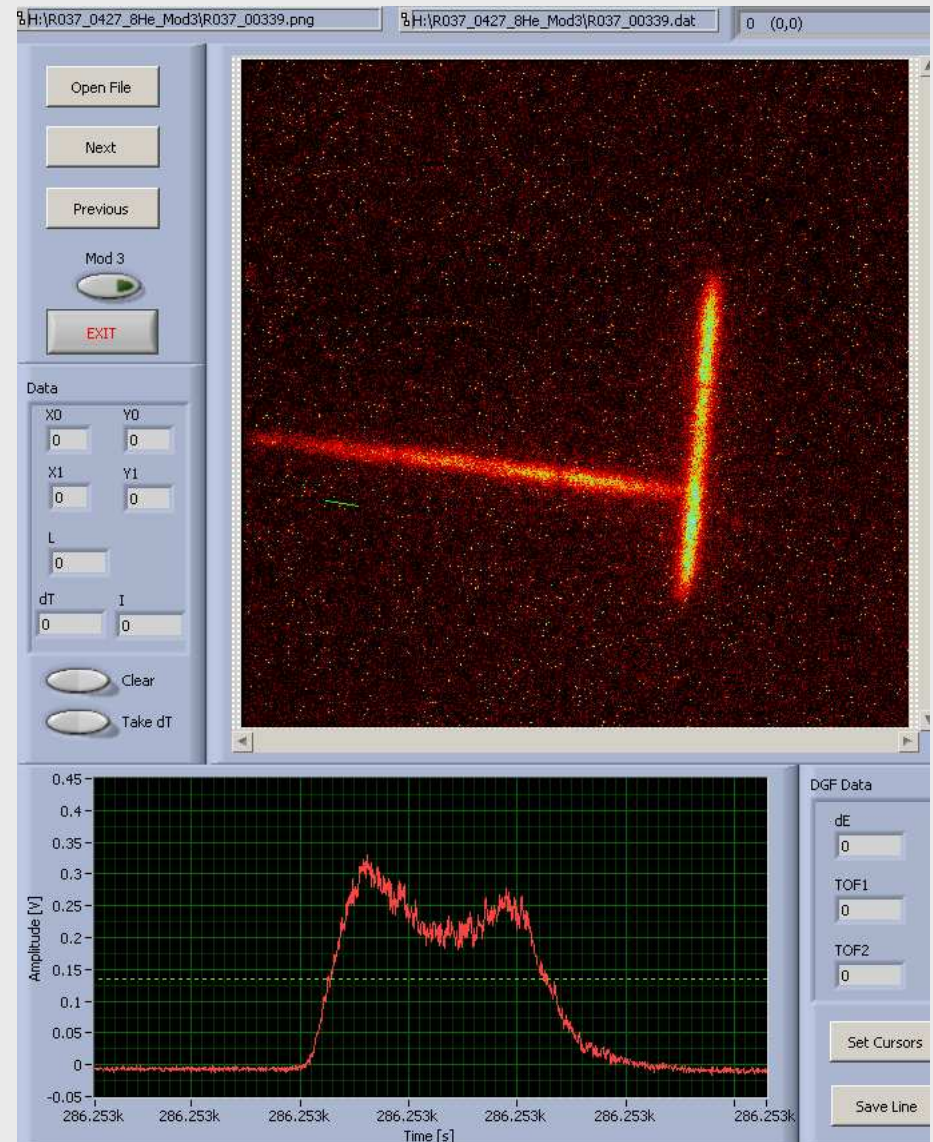
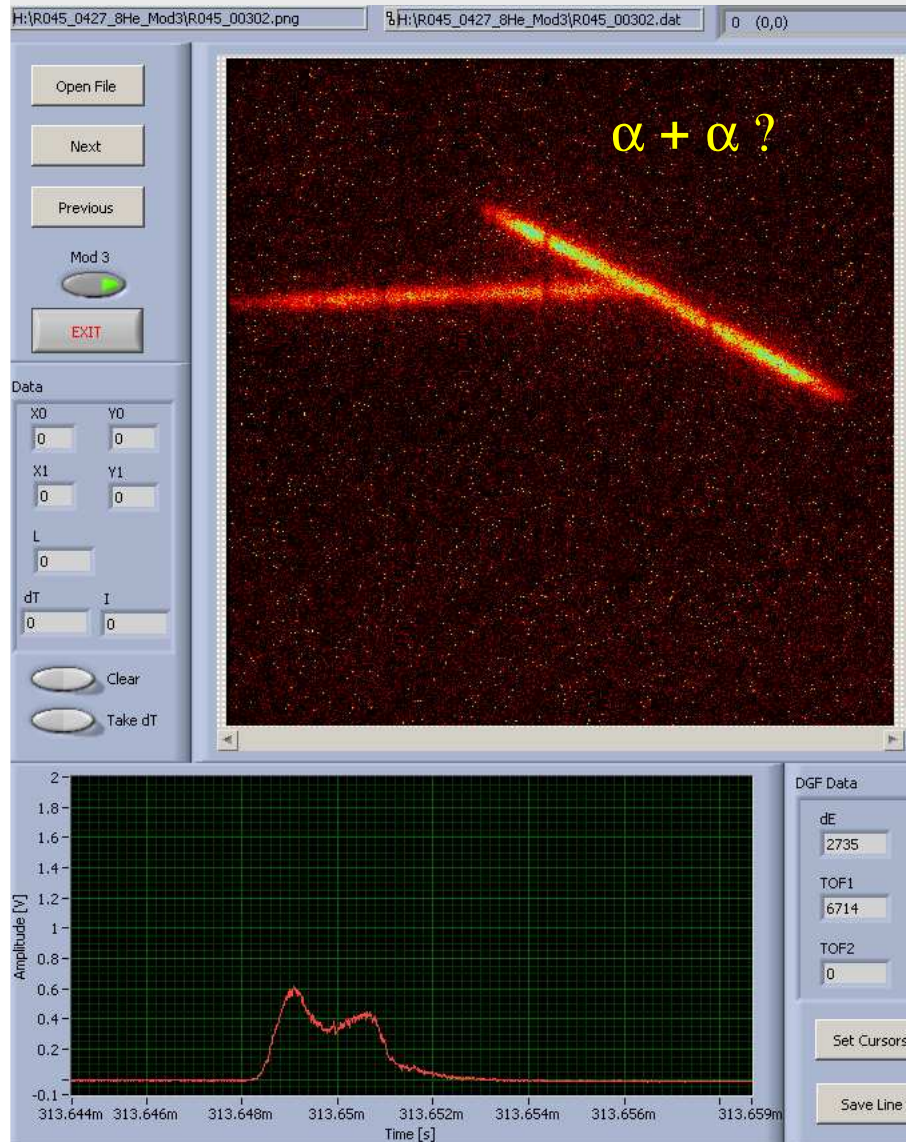
$$E_{\text{He}} \leq 0.2 \text{ MeV}, R \leq 1 \text{ cm}$$

# Nowa wersja OTPC w Dubnej

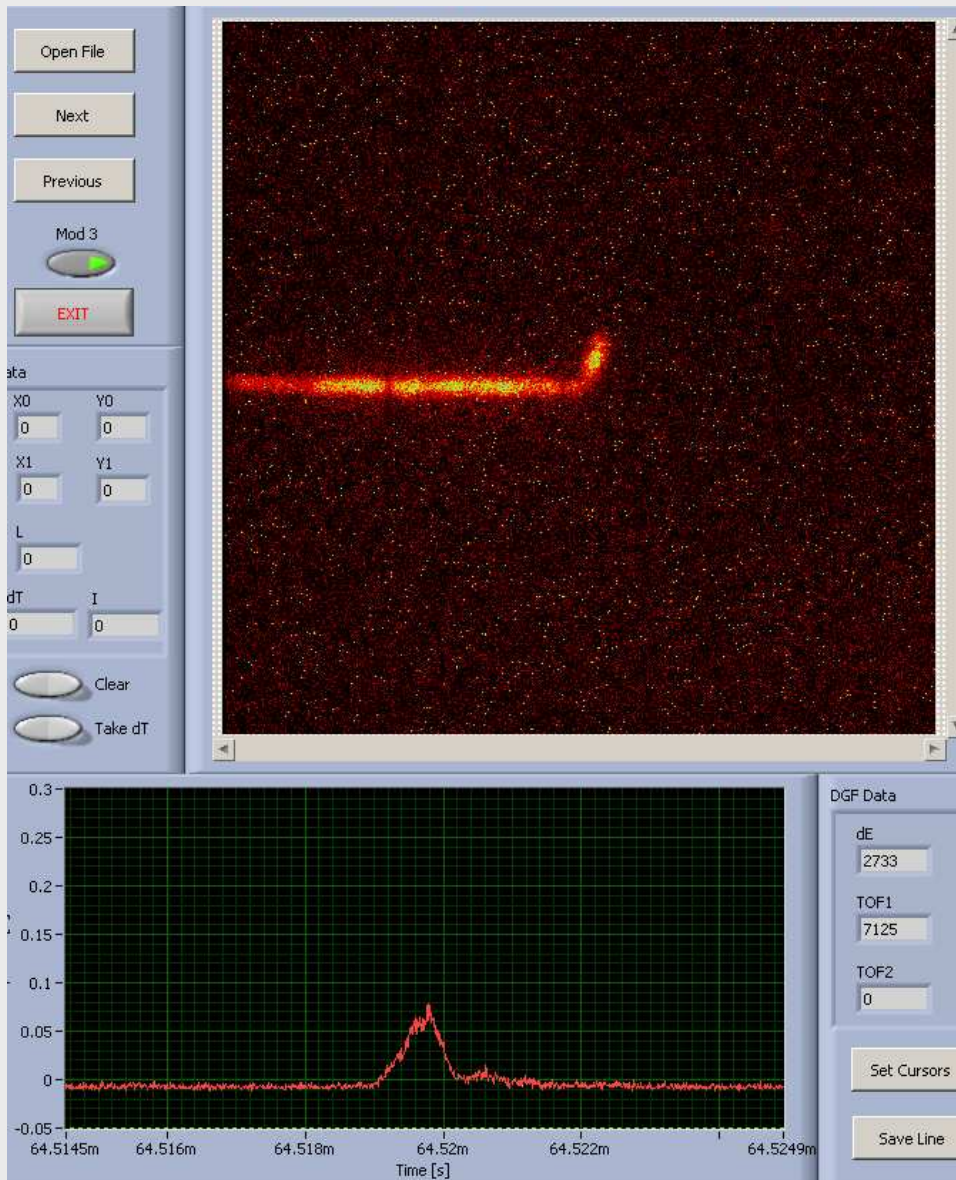




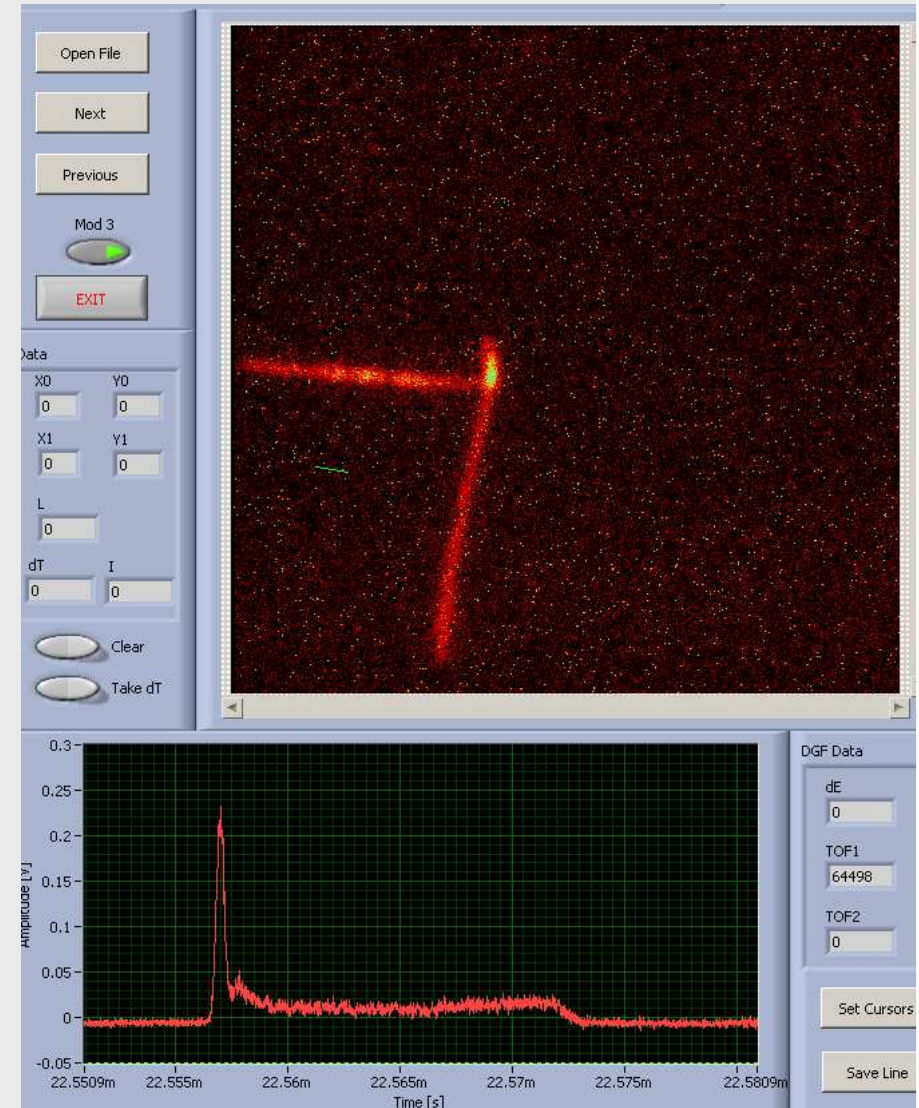
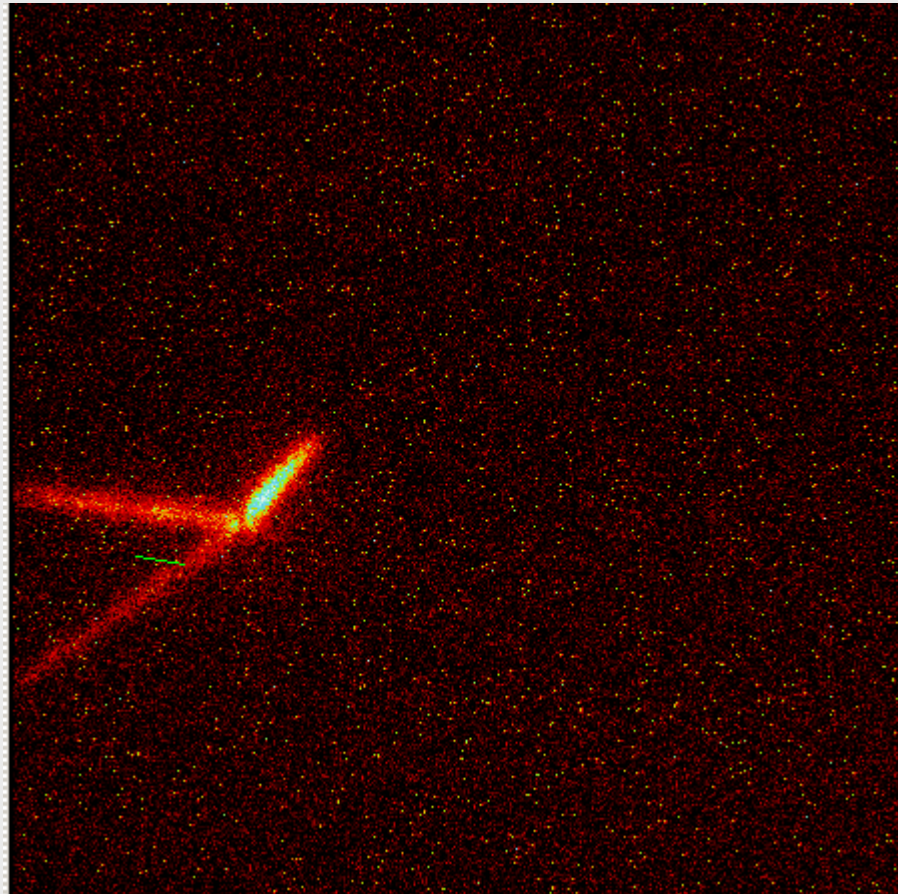
# Przykłady zdarzeń (i)



# Przykłady zdarzeń (ii)

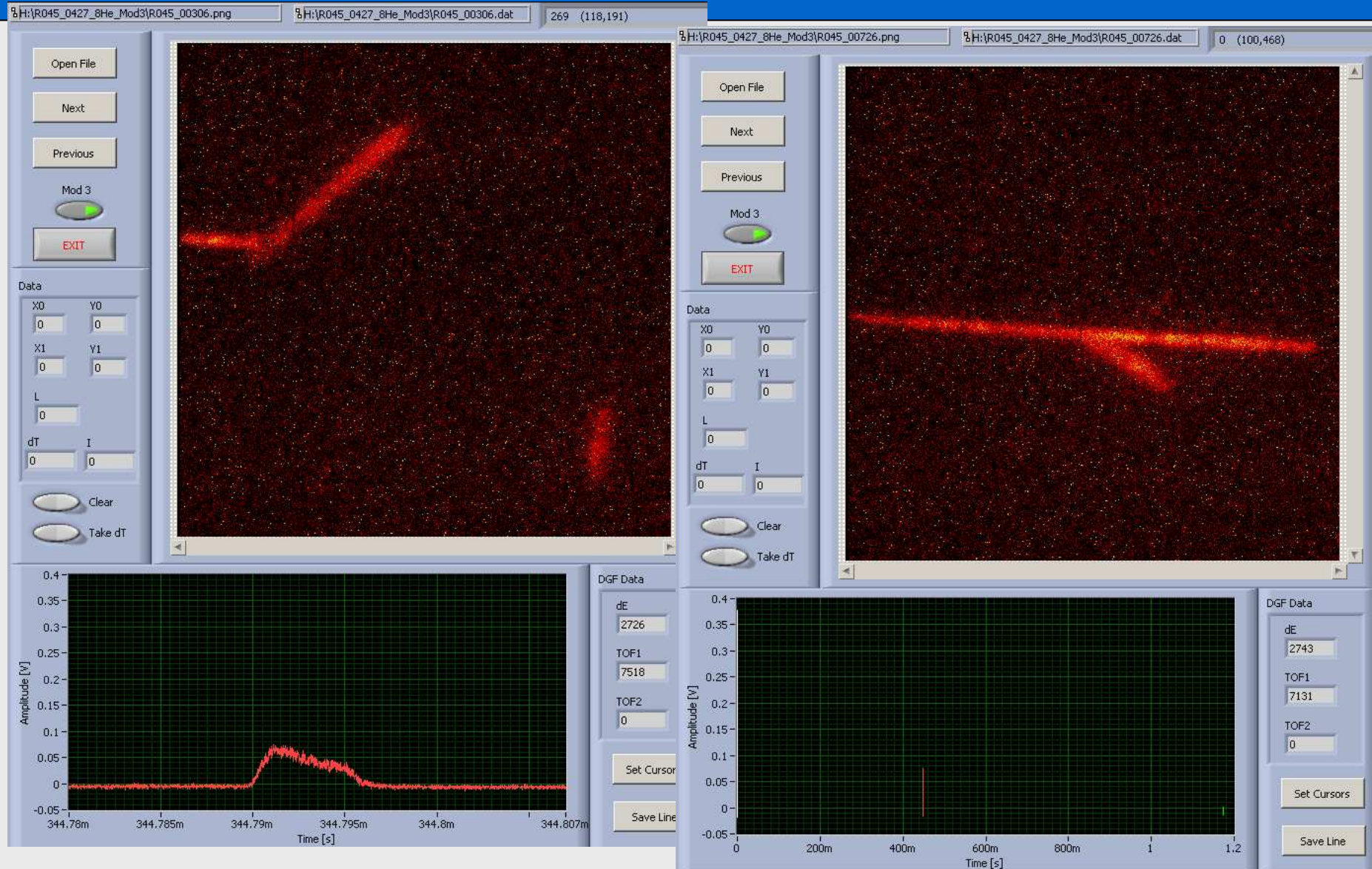


# Przykłady zdarzeń (iii)

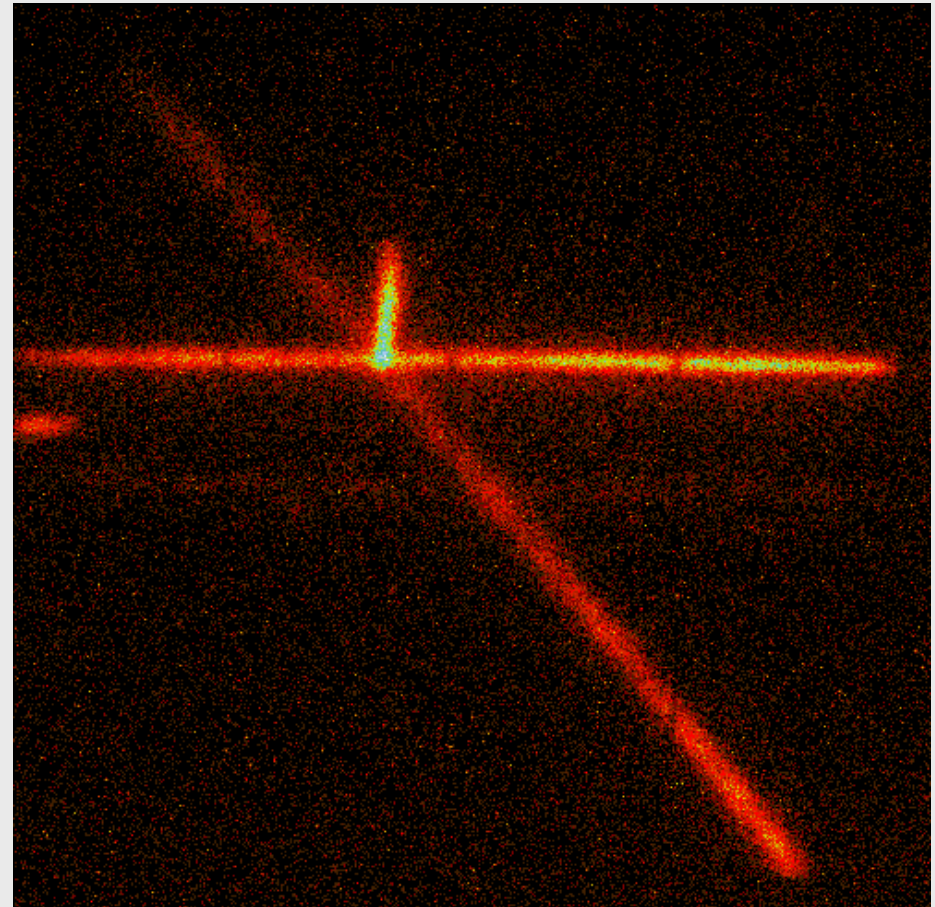
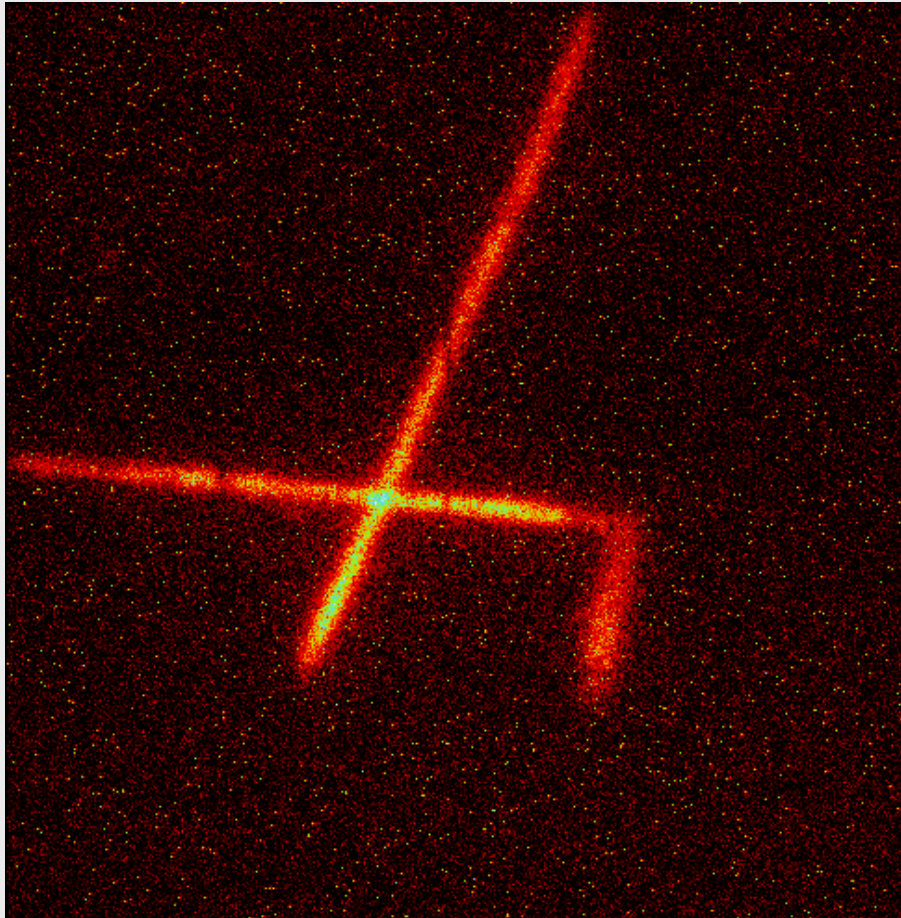


?

# Przykłady zdarzeń (iv)



???



!!!

**НОЛЬ**

**МОЖНО**

**ПОЛУЧИТЬ**

**И НА**

**ВЫКЛЮЧЕННОЙ**

**АППАРАТУРЕ**

# Collaboration

## **Dubna 2009 Experiment:**

### *University of Warsaw*

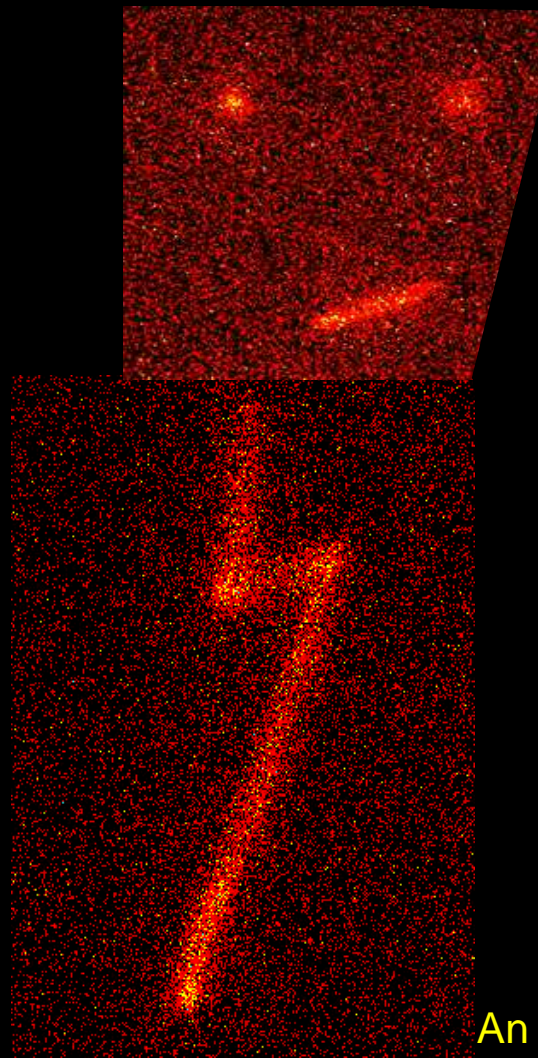
- H. Czyrkowski
- W. Dominik
- Z. Janas
- S. Mianowski
- K. Miernik
- M. P.

### *Joint Institute for Nuclear Research*

- A. Fomichev
- M. Golovkov
- L. Grigorenko
- A. Rodin
- S. Stepantsov
- R. Slepnev
- G. M. Ter-Akopian
- R. Wolski



Dziękuję za uwagę!



An OTPC little man