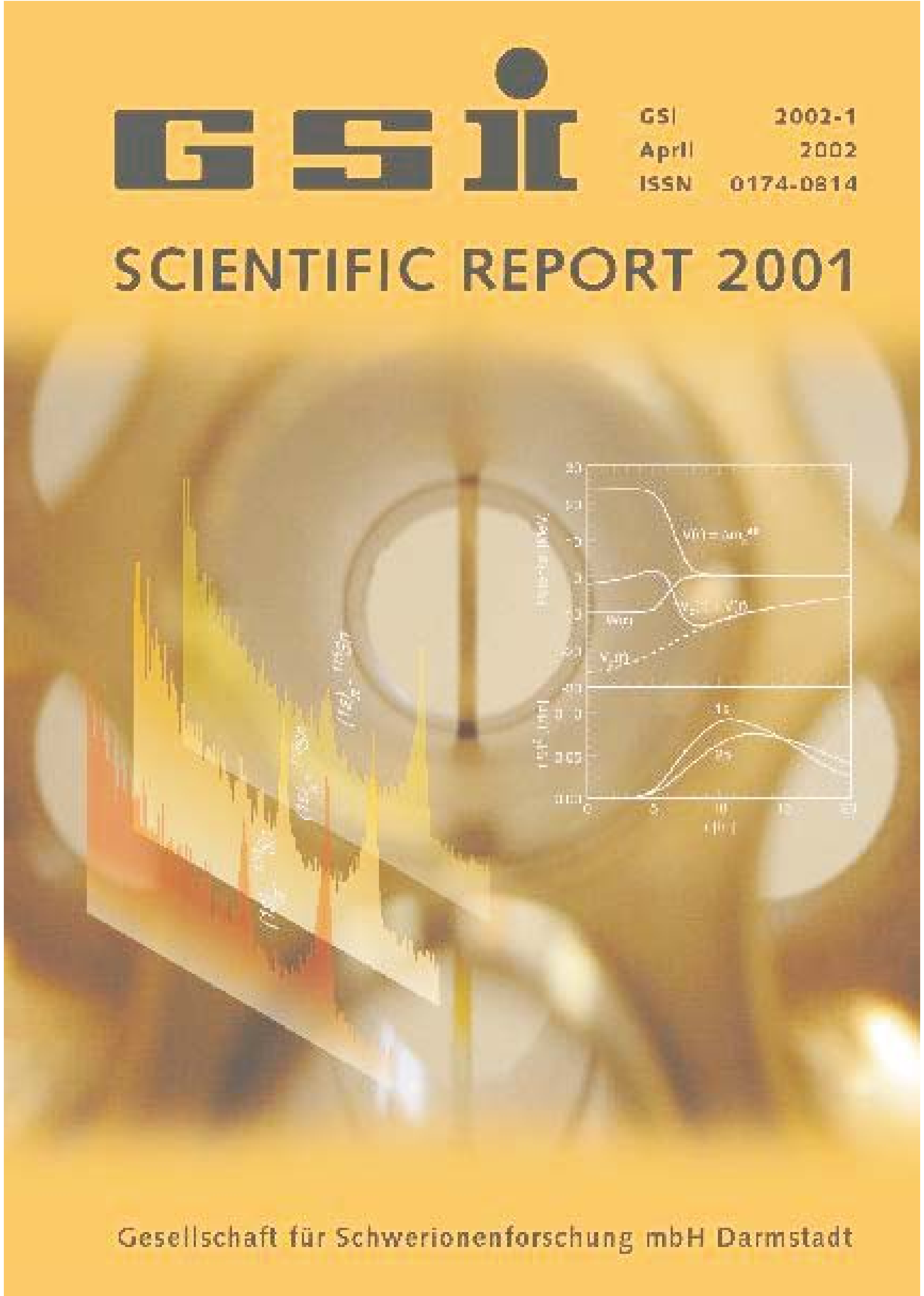
Recent results from experiments with pionic Sn atoms

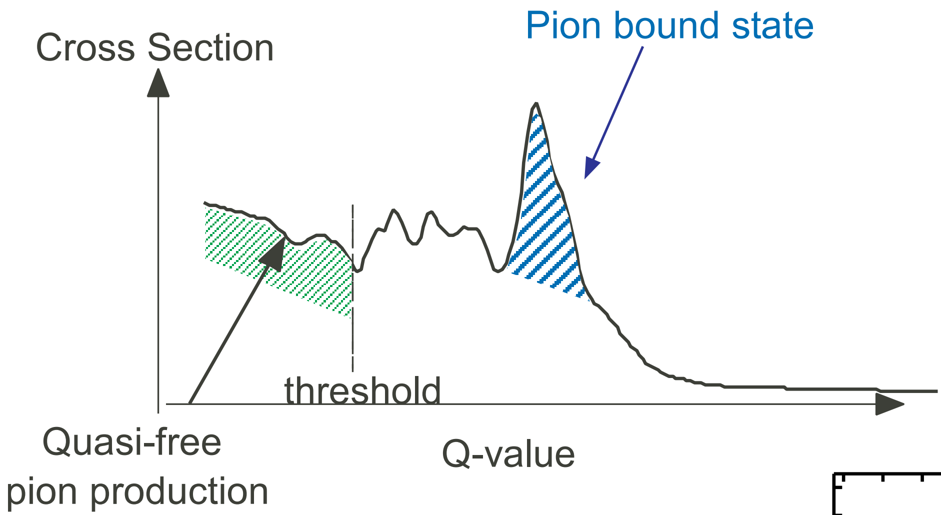
- *<u>High precision</u> spectroscopy with the FRS* -

K.Itahashi for S236 collaboration



Nuclear reaction

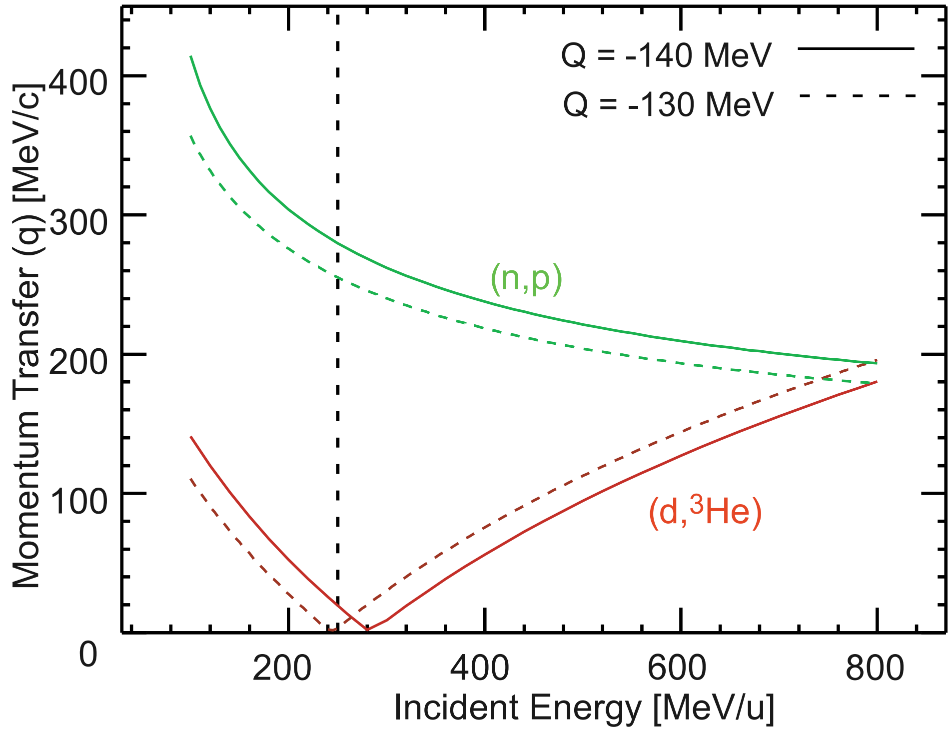
Direct population of deeply bound states



(d,^{3}He) reaction:
Formed state is coupling with a neutron hole

1996 pionic 2p state in ^{207}Pb
1998 pionic 1s state in ^{206}Pb

Proper choice of incident energy leads to small momentum transfer to enhance the bound state formation.



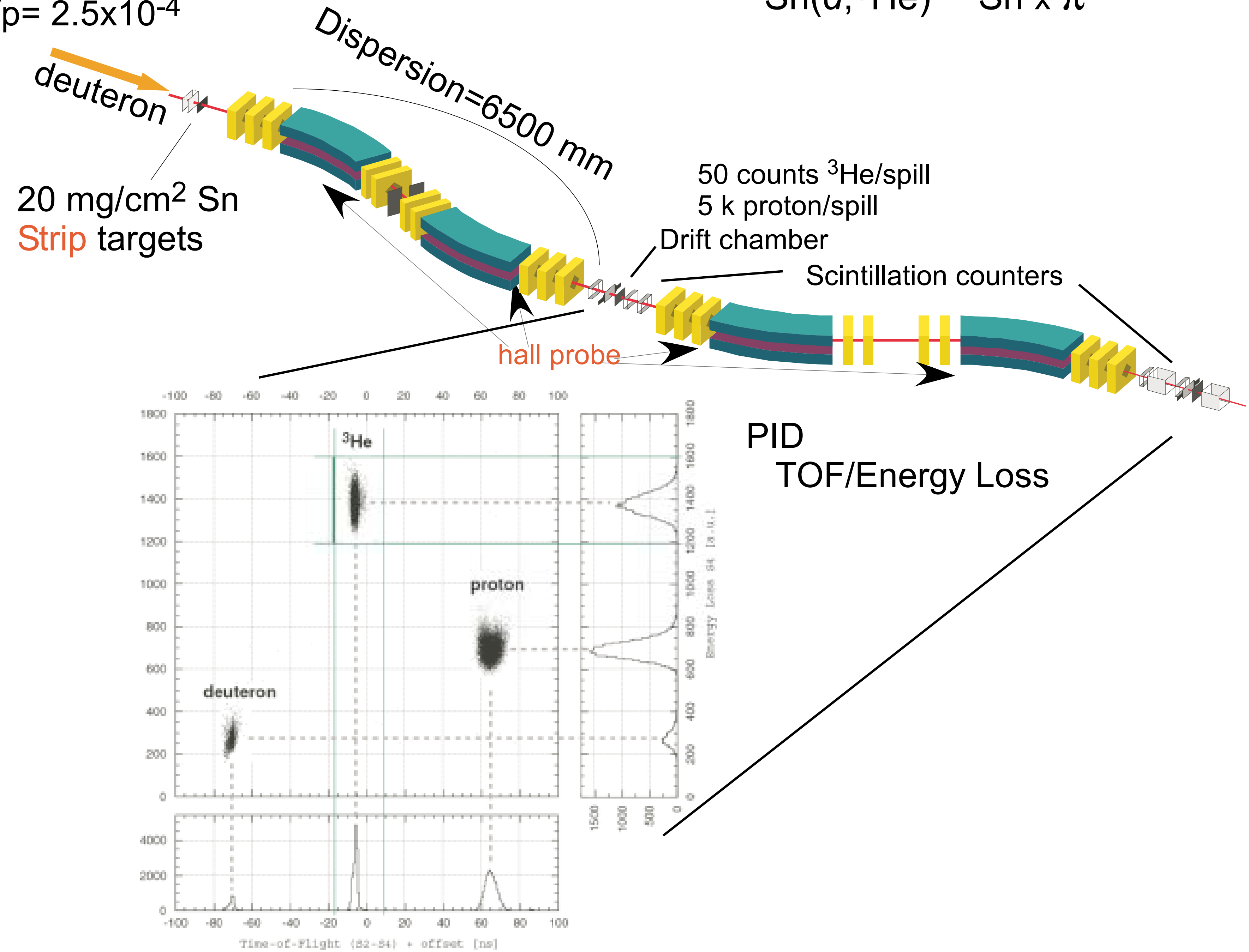
Experimental Principle and Method

$^{A}Sn(d,{}^{3}He)^{A-1}Sn \times \pi^{-}$

T_d= 503.388 MeV

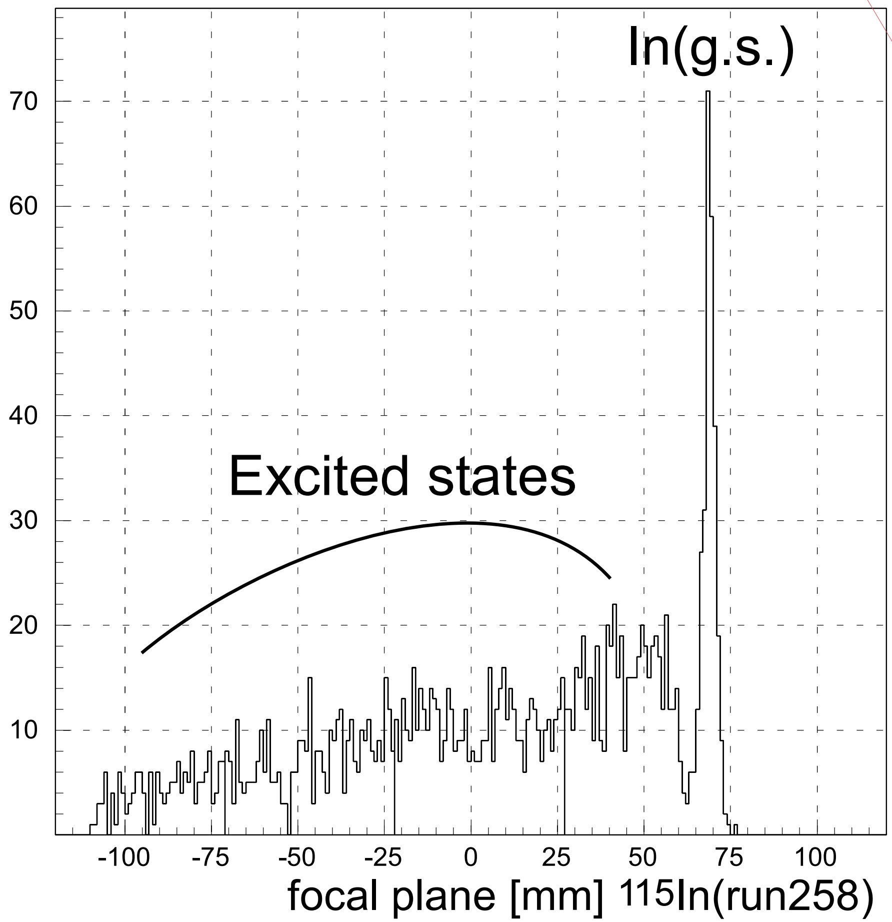
I_d=1.5 x 10^{11}/spill

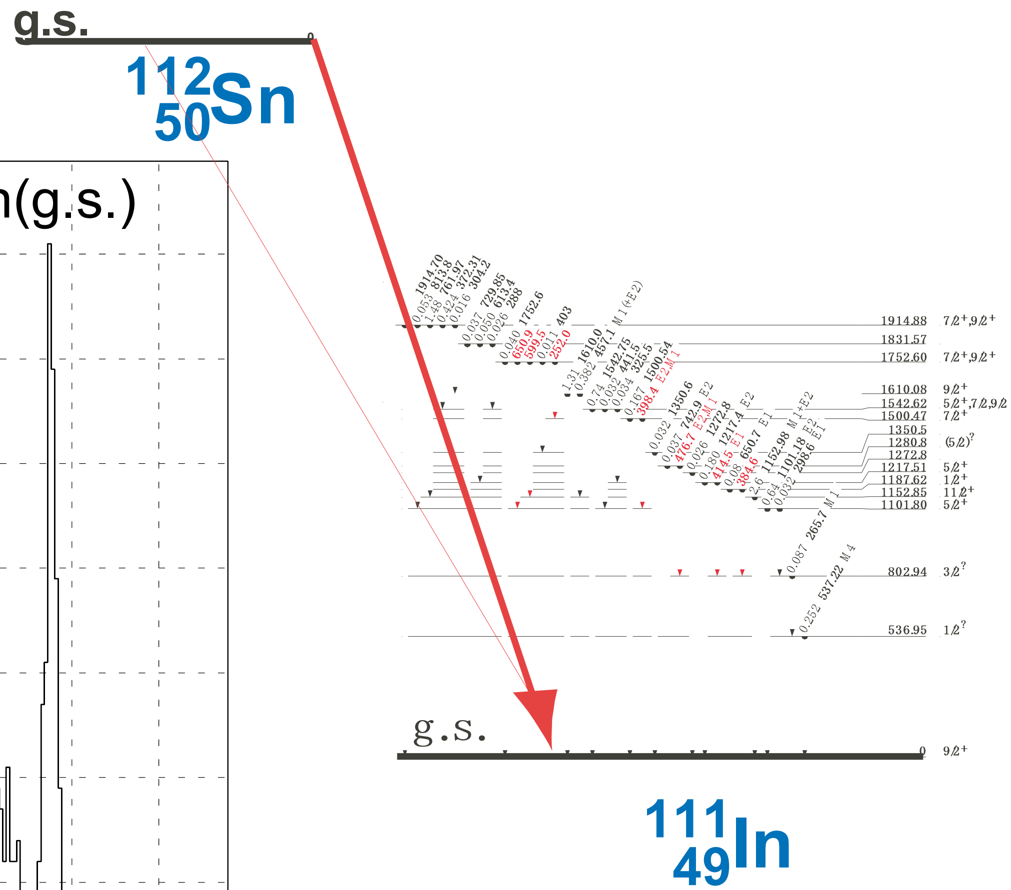
$\Delta p/p$= 2.5×10^{-4}



Calibration measurements

$^{A}Sn(d,^{3}He)^{A-1}In$(g.s.) measurement.

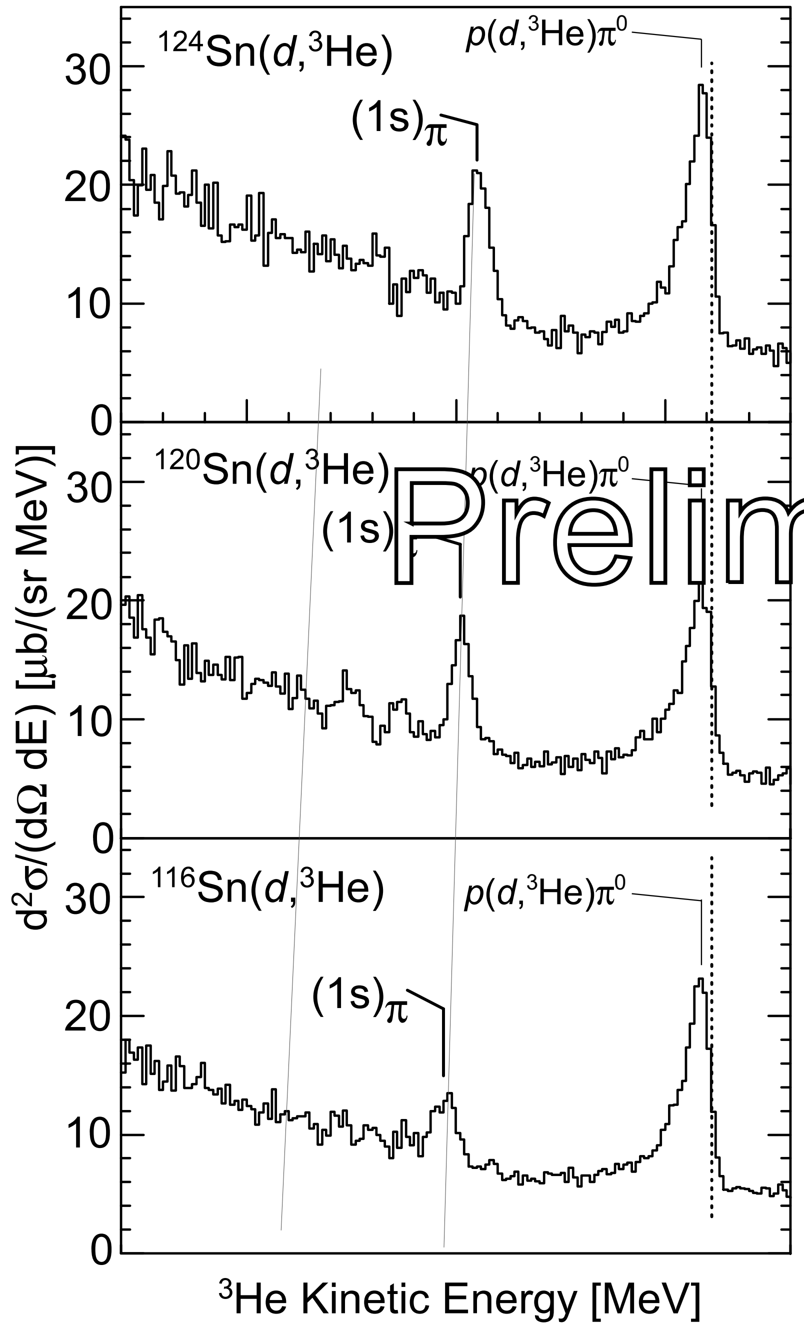


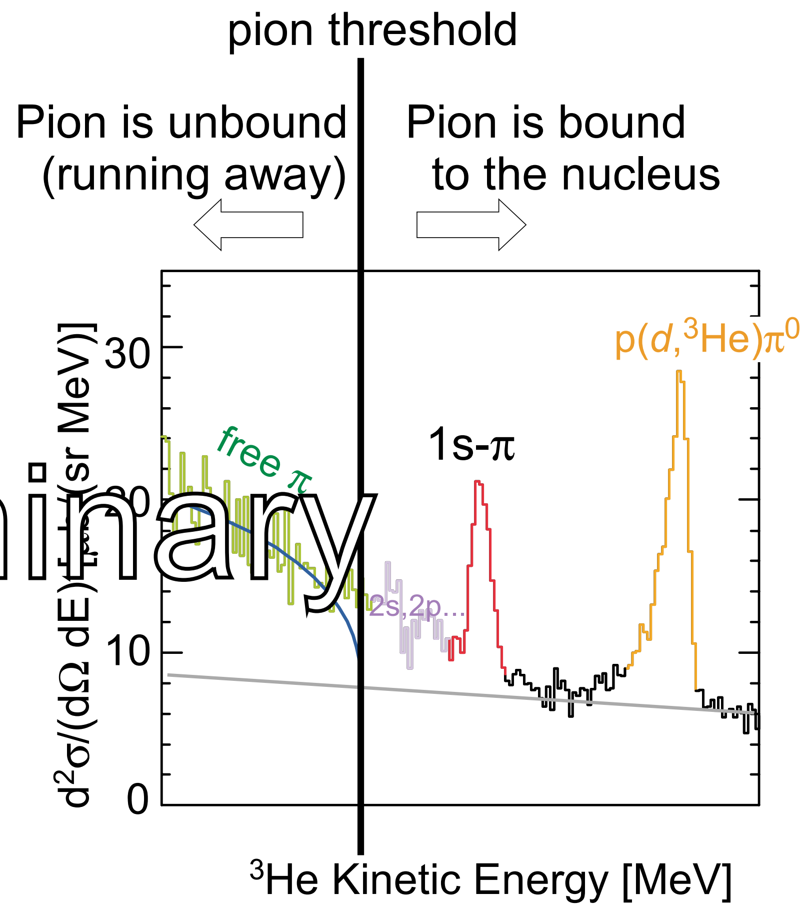


Direct measurement of overall resolution.

Experimental Results

April-May 2001





Rotation of targets

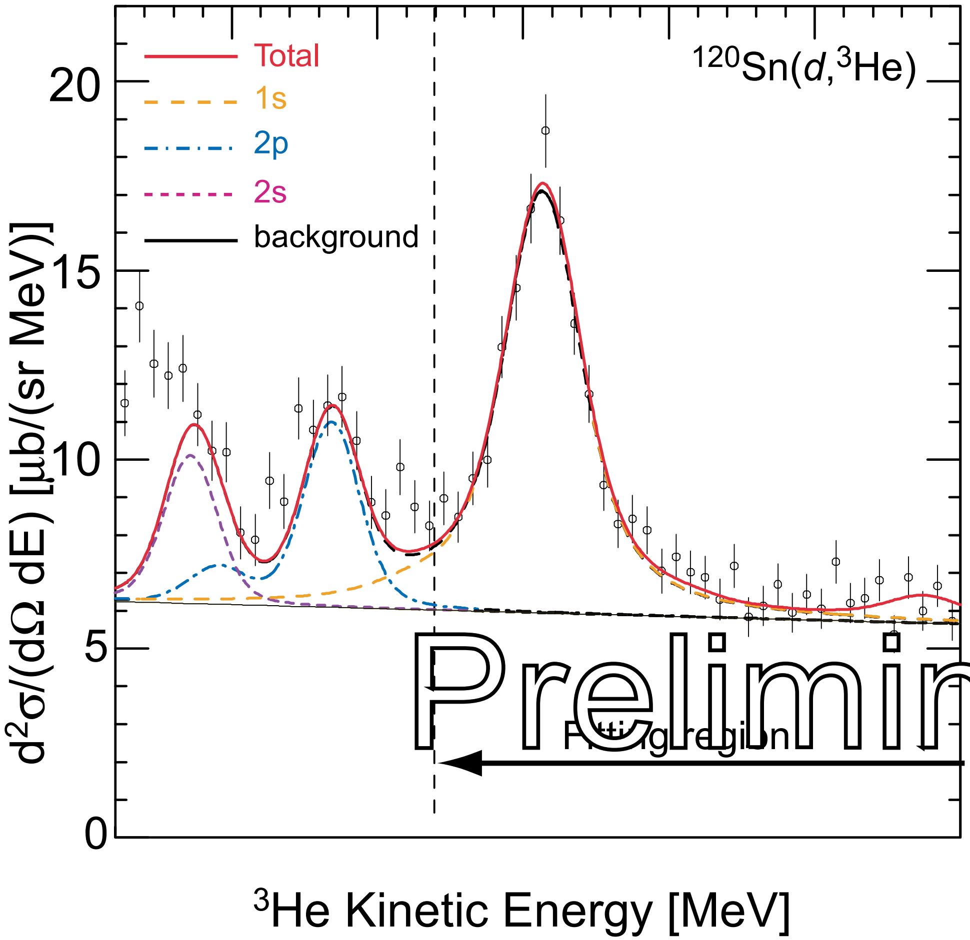
^{124}Sn ➡ CH_2 ➡ ^{120}Sn ➡ CH_2 ➡ ^{116}Sn ➡ CH_2

2 hrs. 2 hrs. 2 hrs.

First precise measurement of isotope shift in deeply bound pionic atoms.

K. Suzuki et al. *submitted to* PRL

Spectral Decomposition



2001 Spring

B.E.		stat.	syst.	[MeV] total
115Sn	3.906			
119Sn	3.820			
123Sn	3.744			
Width		**stat.**	**syst.**	**total**
115Sn	0.441			
119Sn	0.326			
123Sn	0.341			

FYI 1998 Autumn

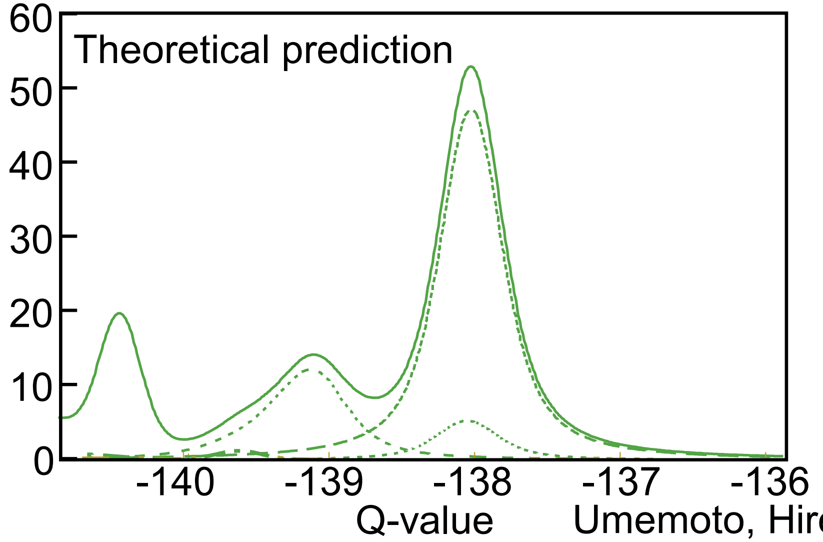
^{207}Pb

$B_{1s} = 6.762 \pm 0.061$

$\Gamma_{1s} = 0.764 ^{+0.171}_{-0.154}$

$B_{2p} = 5.110 \pm 0.045$

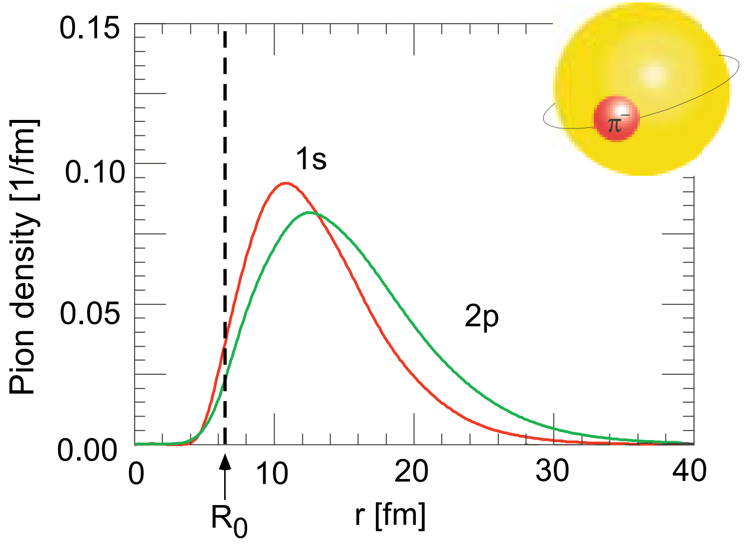
$\Gamma_{2p} = 0.321 ^{+0.060}_{-0.062}$

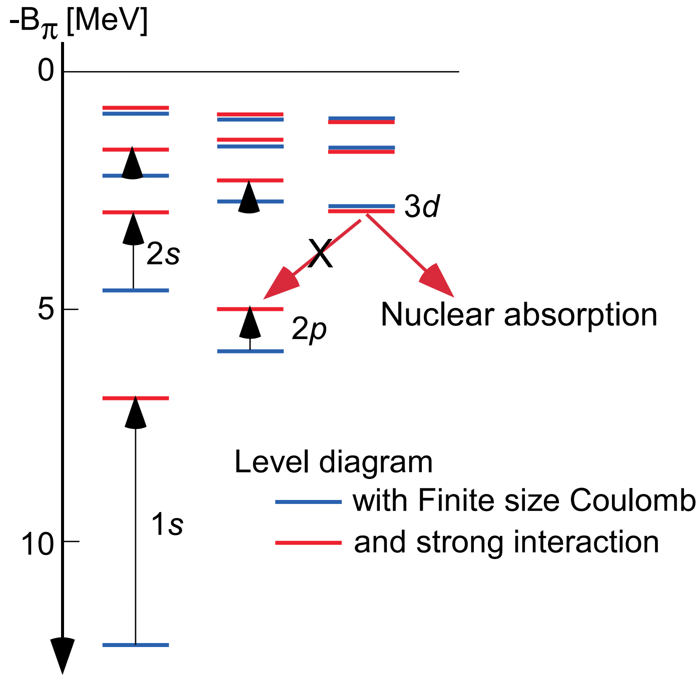


Umemoto, Hirenzaki

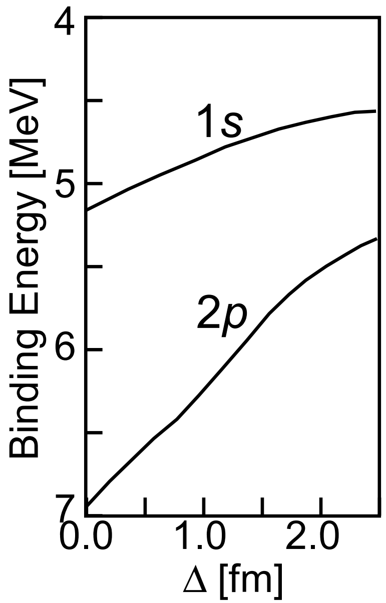
What are intersting in pionic Sn nuclei?

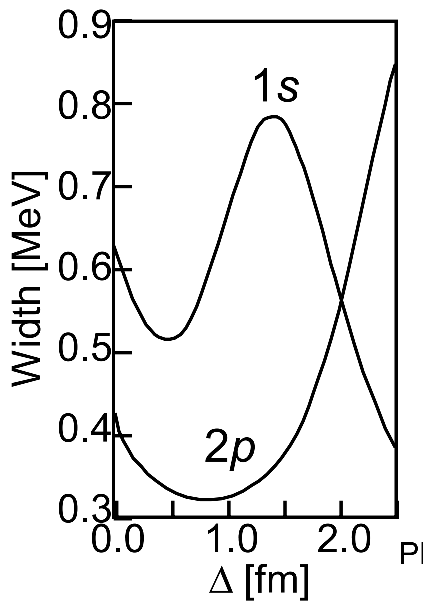
1. Pionic 1*s* Sn atoms have never been observed by anybody.





2. Pionic atoms are sensitive to the nuclear density parameters





PLB249(1990)Toki et al.

Pionic atom Binding energy and width vary largely if neutron skin exists

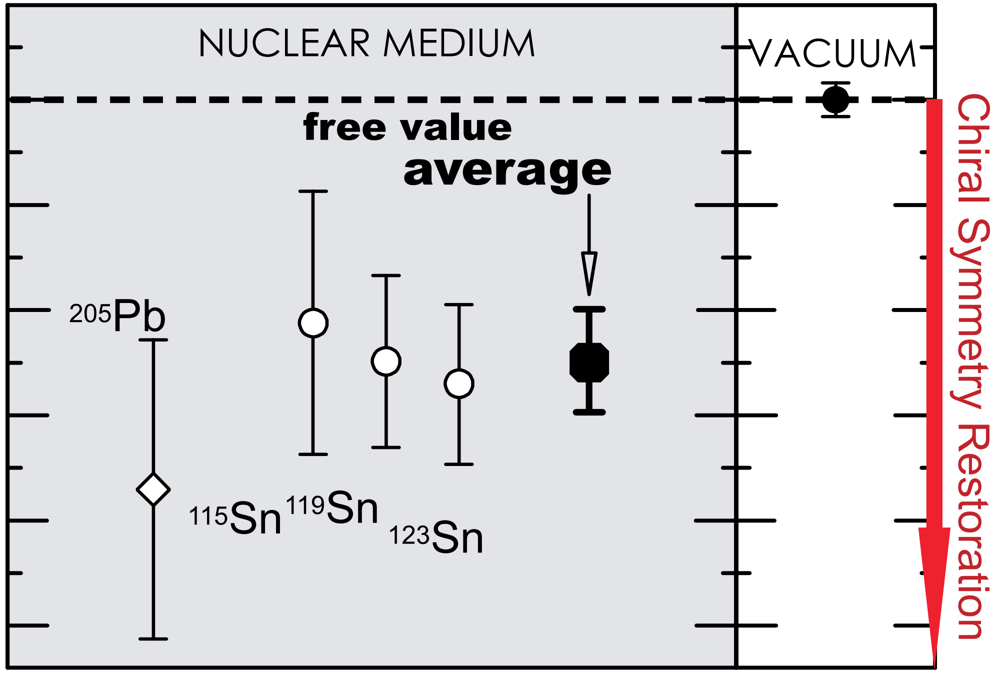
3. Real pion is located inside nuclear matter.

In-medium properties of pion can be measured.

$U_{opt}(r) = \ldots +V_s(r)$ [Local (s-wave) part]

$$V_s(r) \propto b_0\rho(r) + b_1\Delta\rho(r) + \varepsilon_2 B_0\rho^2(r)$$

Isoscalar Isovector

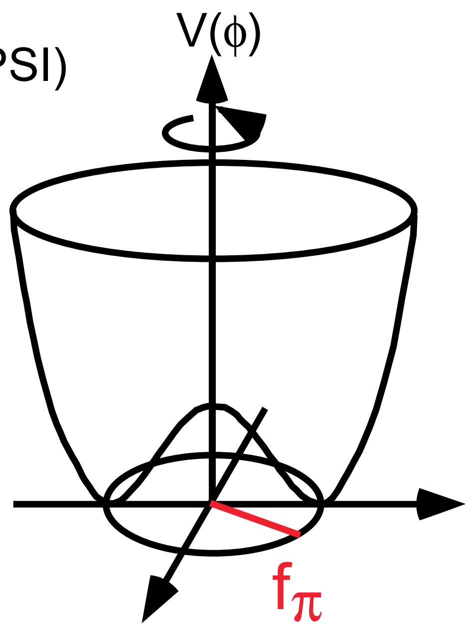


Pionic ^{123}Sn, ^{119}Sn, ^{115}Sn

Unknown isovector part interaction.

in-medium b_0, b_1 values

free b_0, b_1 values (Pionic H precise measurement at PSI)



$$b_1 f_\pi^2 = b_1(\rho) f_\pi^*(\rho)^2$$

Pionic atoms have sensitivity
to the chiral symmetry.

Summary

We performed a high precision measurement of the excitation spectrum of 1*s* pionic Sn atoms at ~ 140 MeV above the ground state. B_π and Γ_π are respectively determined with accuracy of < 30 keV and < 90 keV.

The binding energies and widths are related to the optical potential of π-N interaction and also to the proton and neutron density distributions.

Pionic atoms are used as probes to measure the fundamental symmetry of the vacuum.

In order to clarify the property modification of the bound meson and the vacuum, it is effective to perform systematic observation of meson bound states.

S236 Collaboration

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