Proton elastic scattering

for the study of weakly bound nuclei

with SAMURAI

Contents

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SAMURAI work shop
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Elastic Scattering of Protons with RI beams (ESPRI) project

Collaborators

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NIRS
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Motivation

Nuclear size and density distribution

- Fundamental properties of nuclei
- Inputs and/or guidelines to describe the nuclear reactions and structures

	Stable nuclei	Unstable nuclei
Charge radius (Matter radius)	Muonic atom	Isotope shift (Interaction cross section)
Charge distribution	Electron scattering	
Neutron distribution	Proton elastic scattering	
	Charge distribution / radius ●Charge radii are proportional to $A^{1/3}$ ●The diffuseness is independent of A, Neutron distribution ●Approximately equal to the proton distribution	Matter radius ● Matter radii have Isospin dependence. ●Skins arise from differences betwreen S_p and S_n. ●Halo is caused by the loosely bound nucleon(s).

Concerning the density distribution, experimetal data is rare !!

Elastic scattering of Protons with RI beams

Stable nuclei

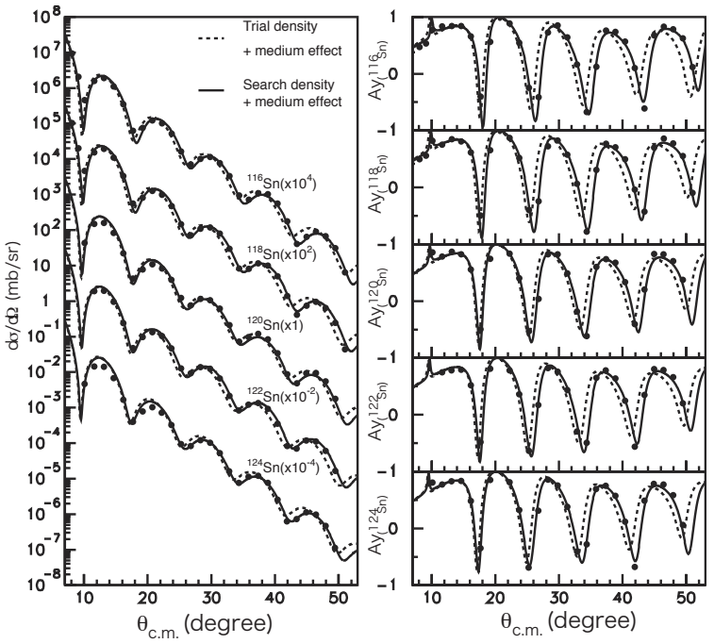
Sakaguchi Group

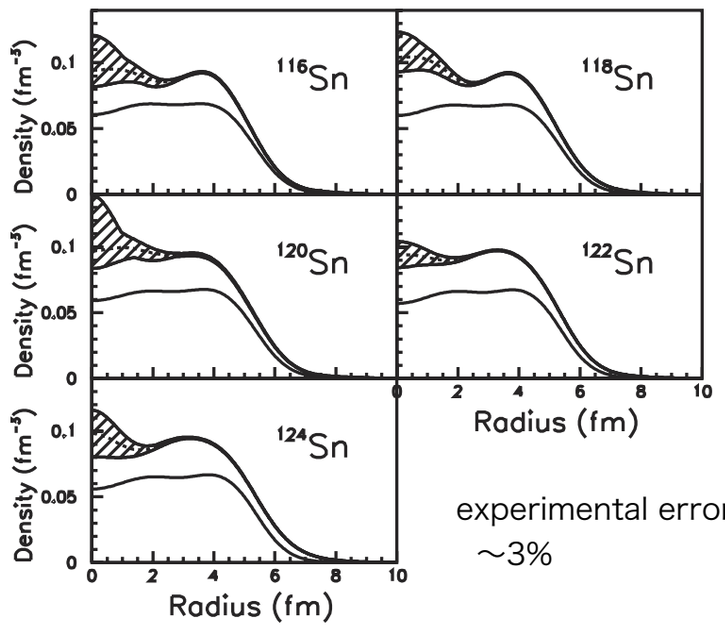
Polarized proton elastic scattering at 300MeV

⇒They have succeeded in extracting neutron density distributions of Sn, Pb isotopes systematically.

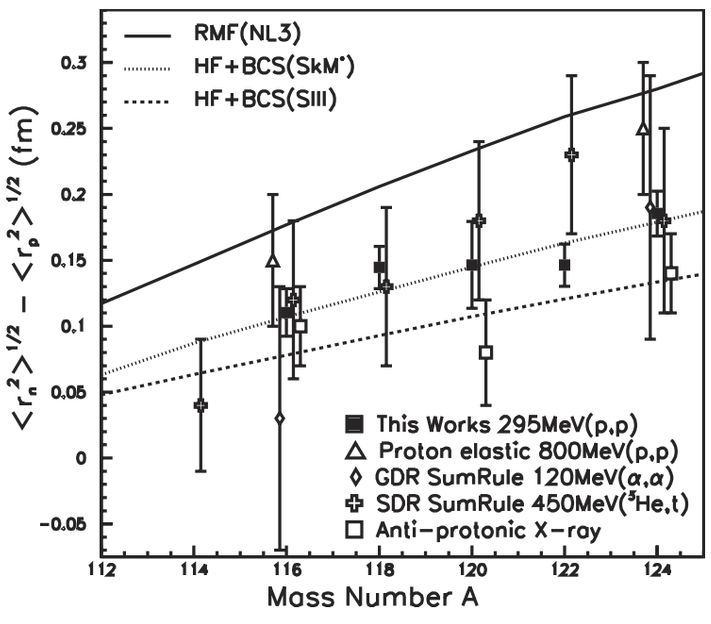
Sn

S.Terashima et al., Phys. Rev. C 77, 024317 (2008)



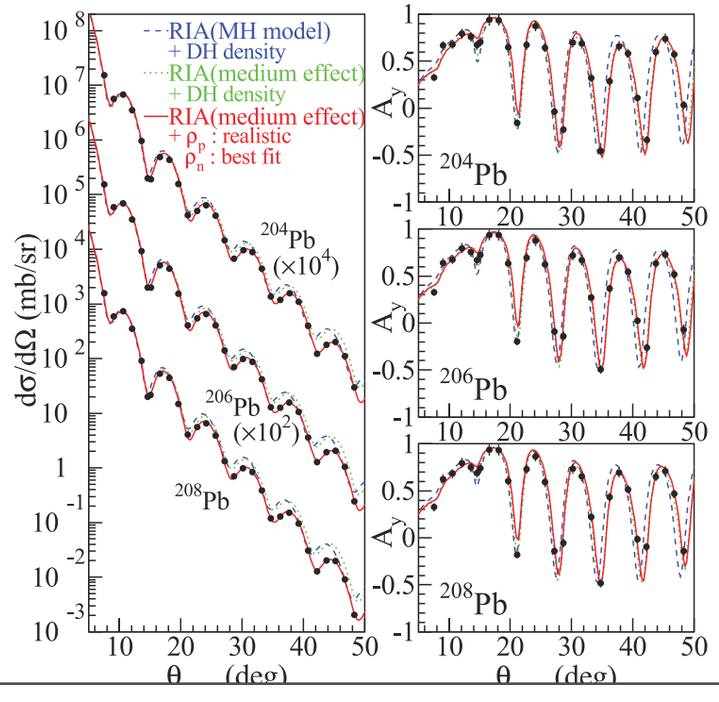


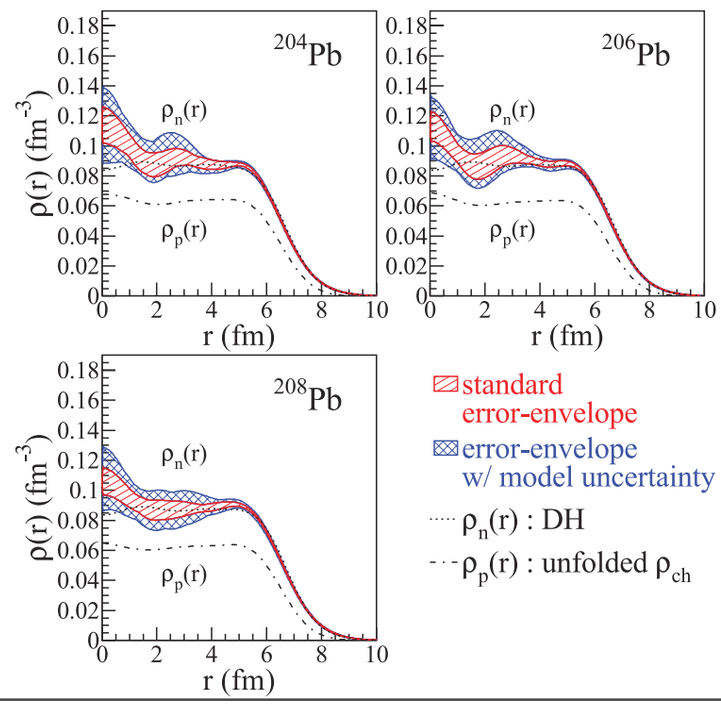
experimental error
～3%



Pb

J.Zenihiro et al., Phys. Rev. C 82, 044611 (2010)



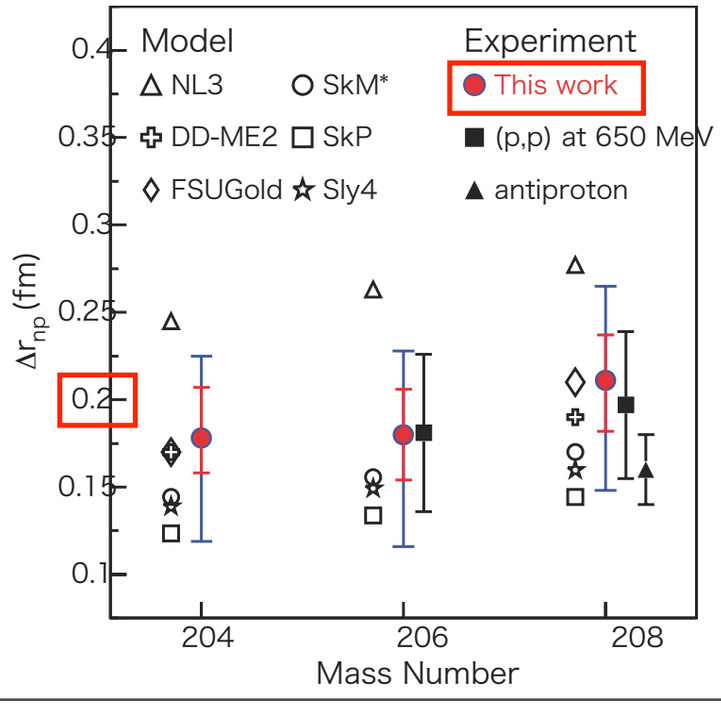


standard error-envelope

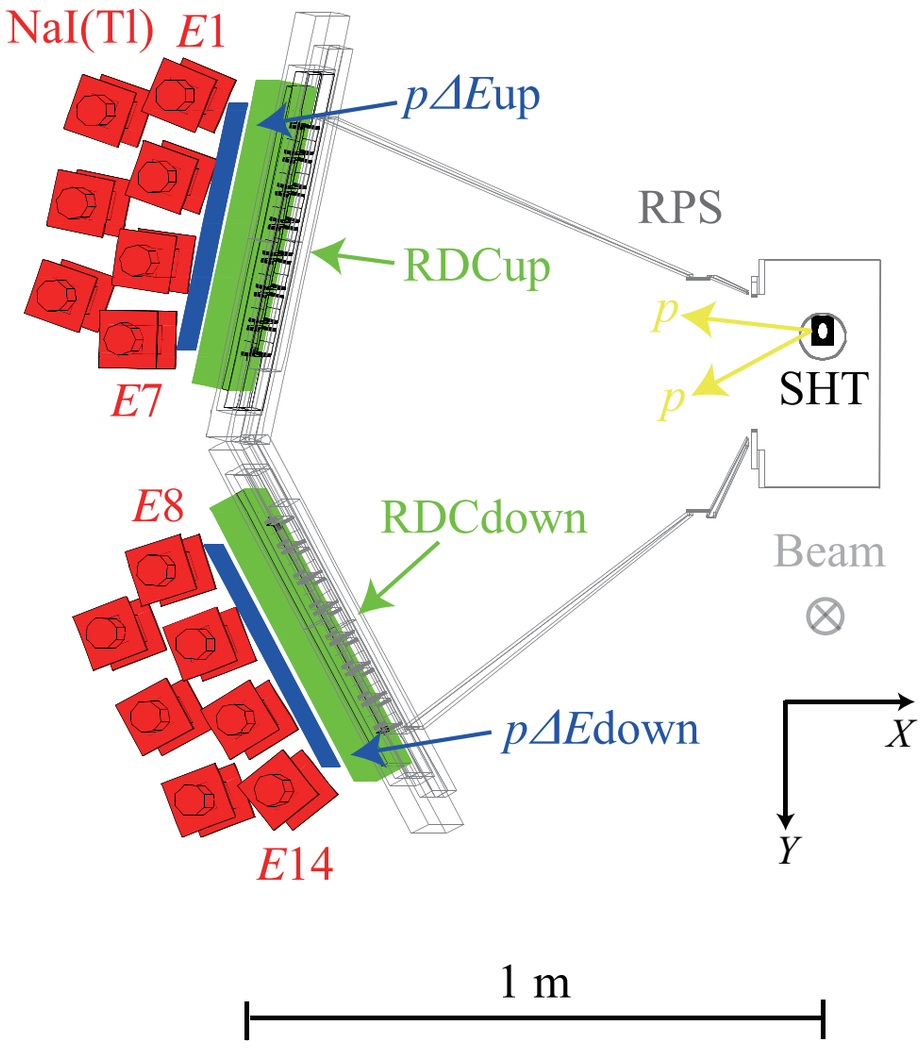
error-envelope w/ model uncertainty

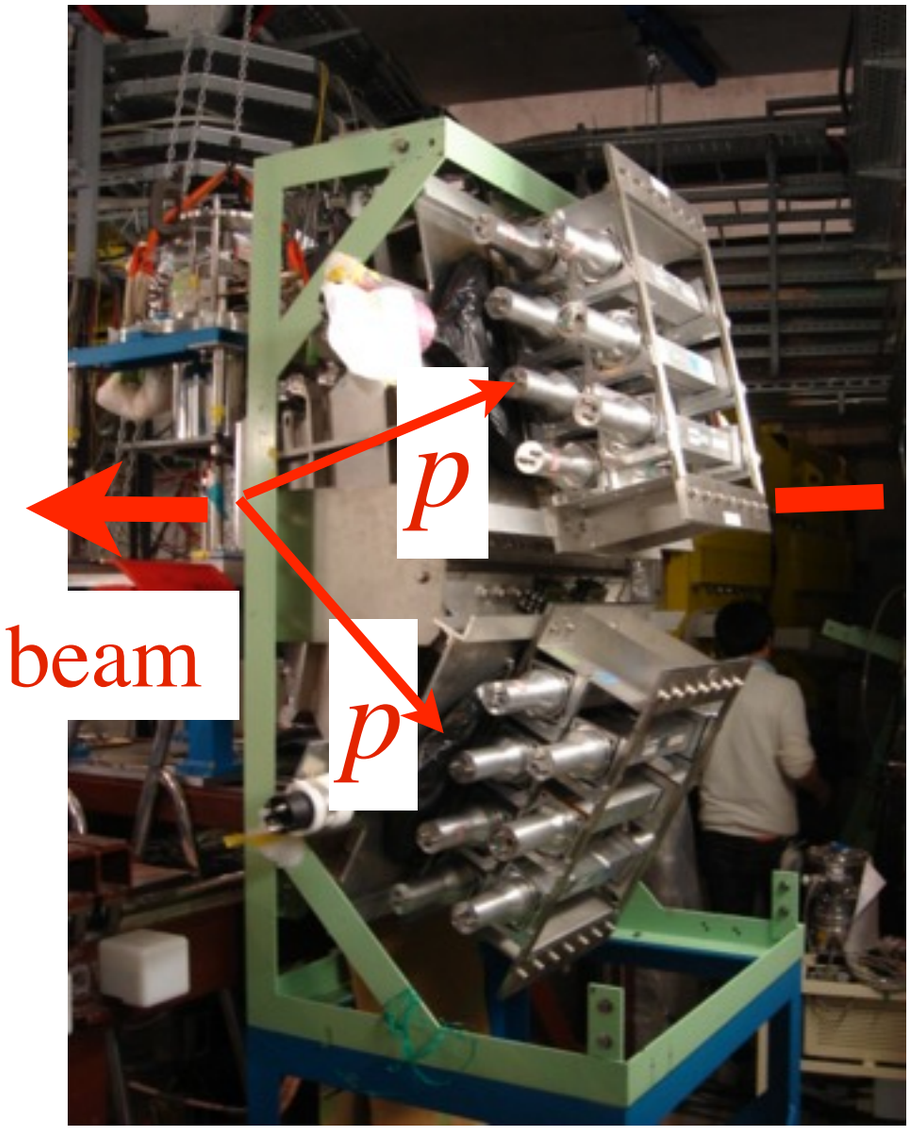
$\rho_n(r)$: DH

$\rho_p(r)$: unfolded ρ_{ch}



Recoil Proton Spectrometer (RPS)





	Solid H_2 (SHT)	RDC	$p\Delta E$	E
material	Para H_2	Ar+C_2H_6	Plastic	NaI(Tl)
effective area	ϕ 30 mm	436 x 436 mm^2	440 x 440 mm^2	431.8 x 45.72 mm^2
thickness	1 mm	69.4 mm	2.53 / 3.09 mm	50.8 mm
Resolution		500 μm	TOF : 0.1 nsec	0.3 %(80 MeV)

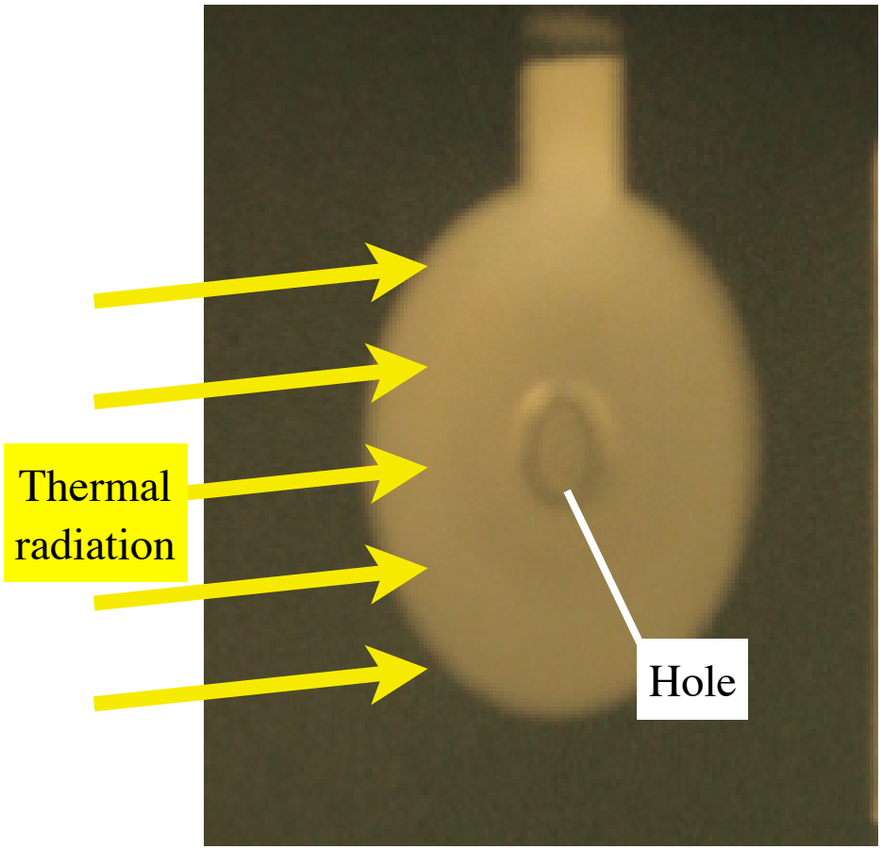
Para Solid Hydrogen Target (*p*-SHT)

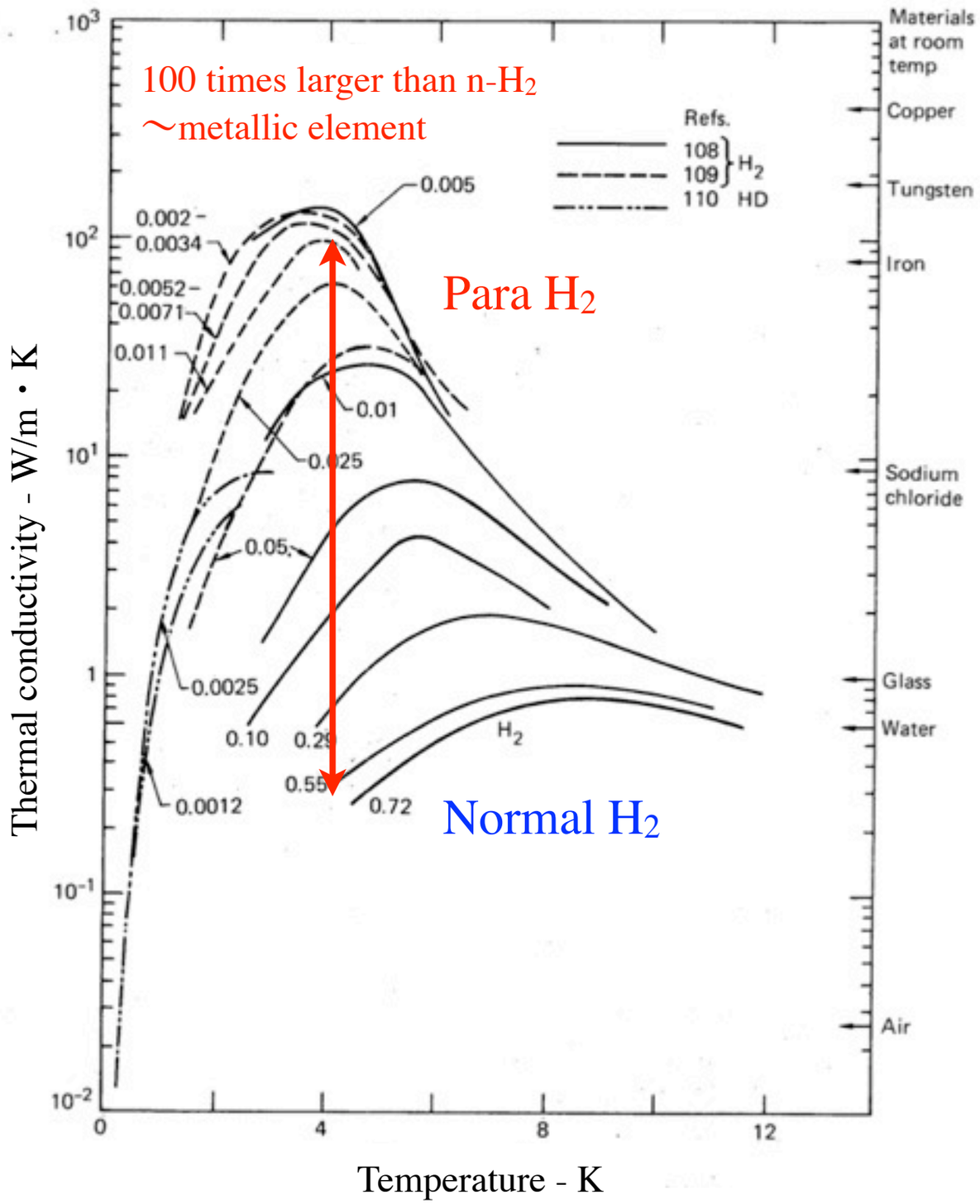
Ortho/Para H_2

H_2 molecular
Nuclear spin of two protons

Para H_2 : singlet (S=0, J=0,2,4,...)
Ortho H_2 : Triplet (S=1, J=1,3,5,...)

300 K (Normal H_2)
para : ortho = 1:3



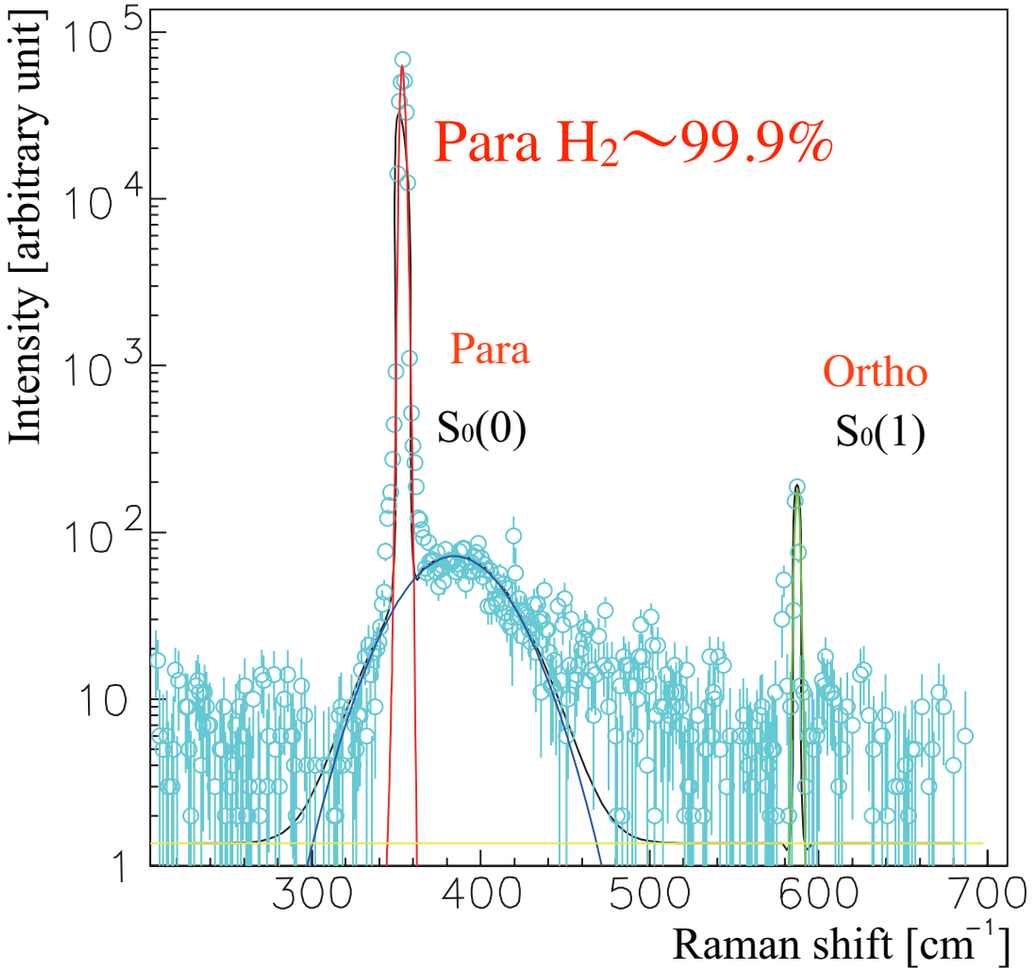


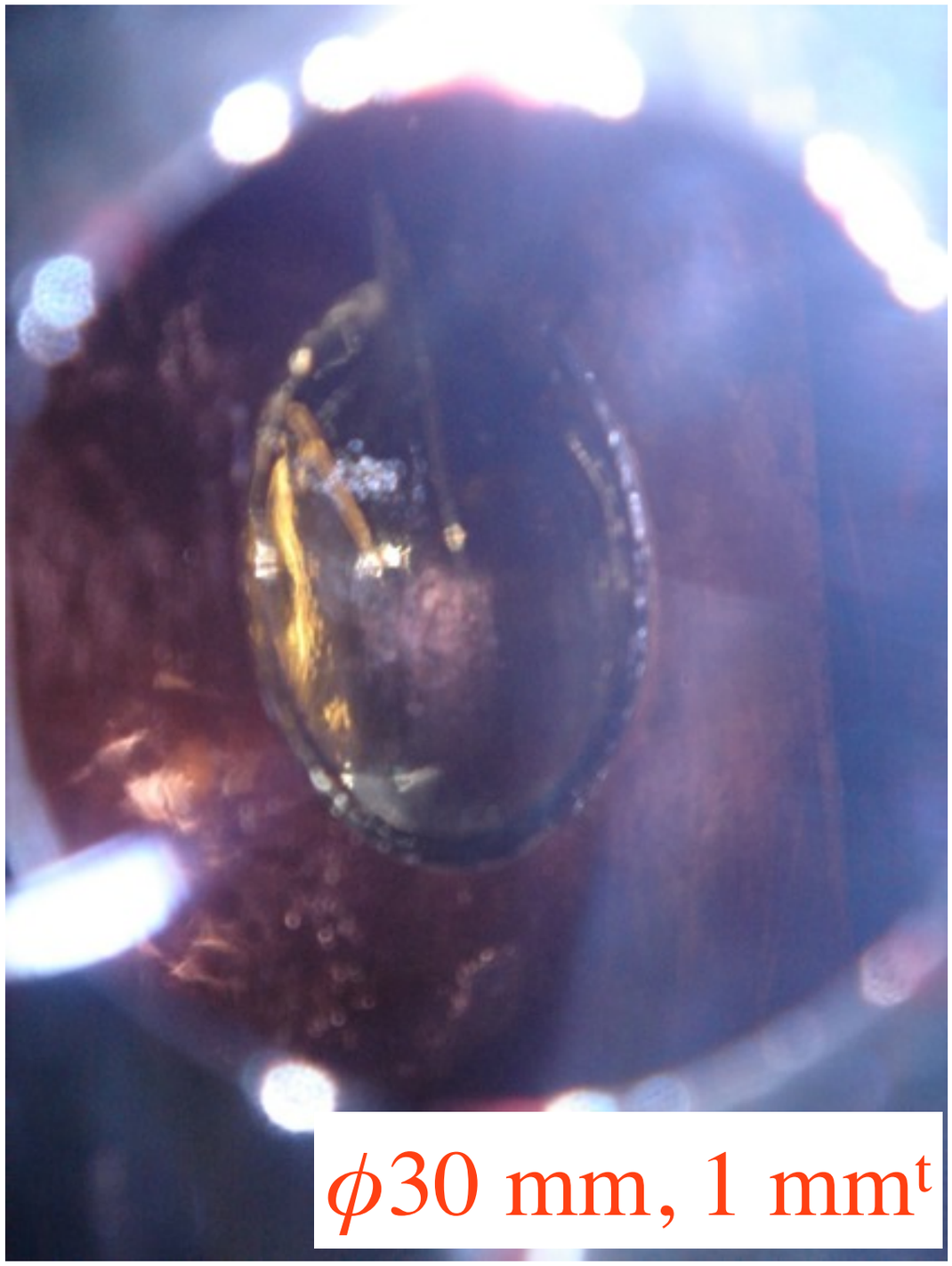
P.C.Souers, CRYOGENIC HYDROGEN DATA PERTINENT TO MAGNETIC FUSION ENERGY, Lawrence Livermore Laboratory Report UCRL-52628 (1979) Livermore California.
108 : R.W.Hill and B.Schneidmesser, Z.Physik. Chem. Neue Folge 16 (1958).
109 : R.G.Bohn and C.F.Mate, Phys. Rev. B 2 (1970) 2121.

Para Solid hydrogen target (*p*-SHT)

Para-H_2 concentration

Raman spectroscopy





Experiments of ESPRI

FY2006-2008: $^{9,10,11}C$

Heavy Ion Medical Accelerator in Chiba (HIMAC)
in National Institute of Radiological Science (NIRS)

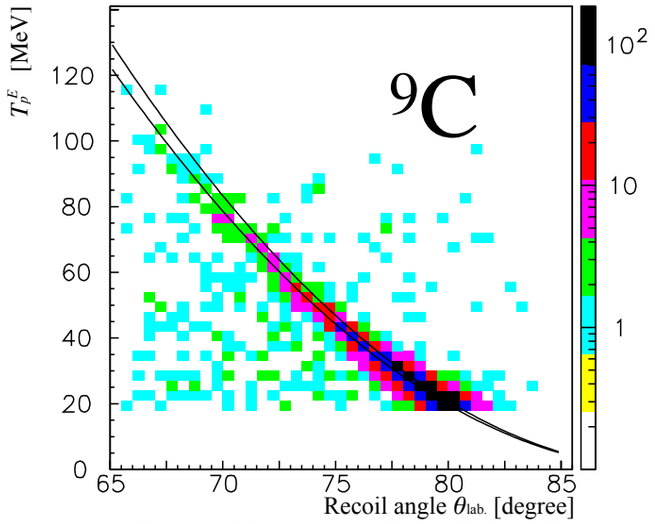
FY2009-2010: $^{66,70}Ni$

Gesellshaft für Schwerionenforschung (GSI)

Preliminary result

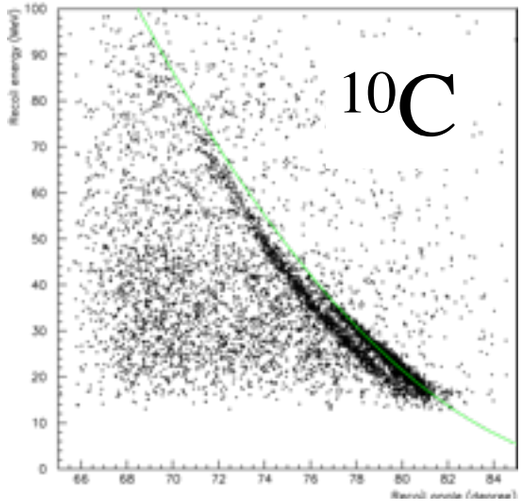
Kinematics correlation ($\theta_{\mathrm{lab.}}$ - E_p)

Recoil proton energy (MeV)



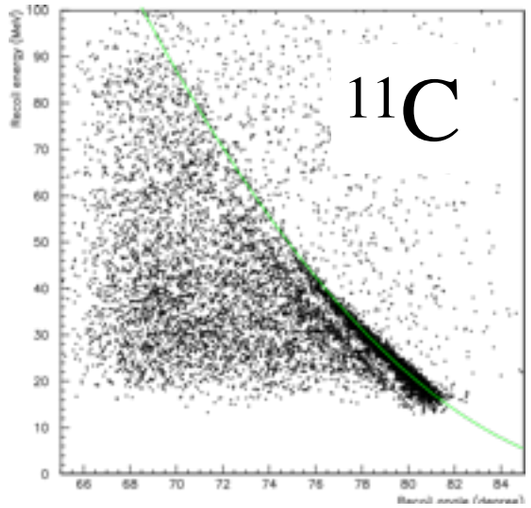
Recoil angle $\theta_{\mathrm{lab.}}$ [deg.]

Preliminary



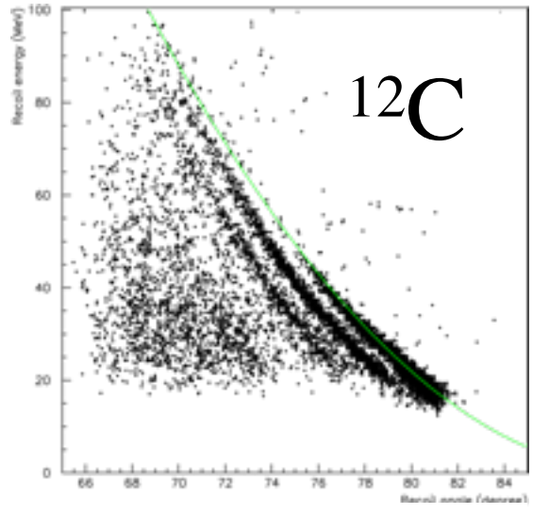
Recoil angle $\theta_{\mathrm{lab.}}$ [deg.]

Preliminary



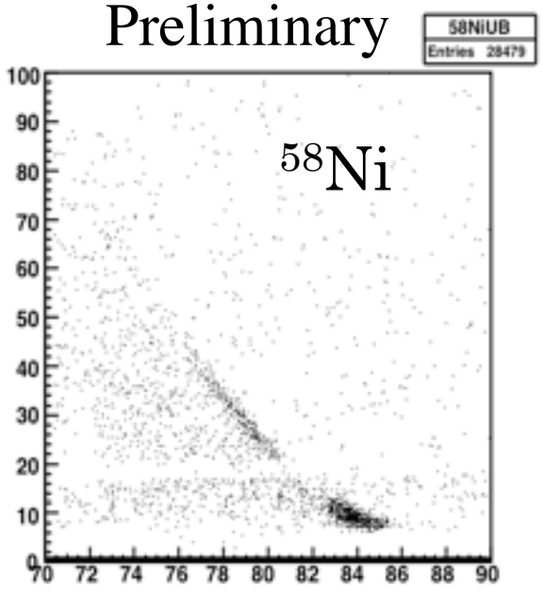
Recoil angle $\theta_{\mathrm{lab.}}$ [deg.]

Preliminary



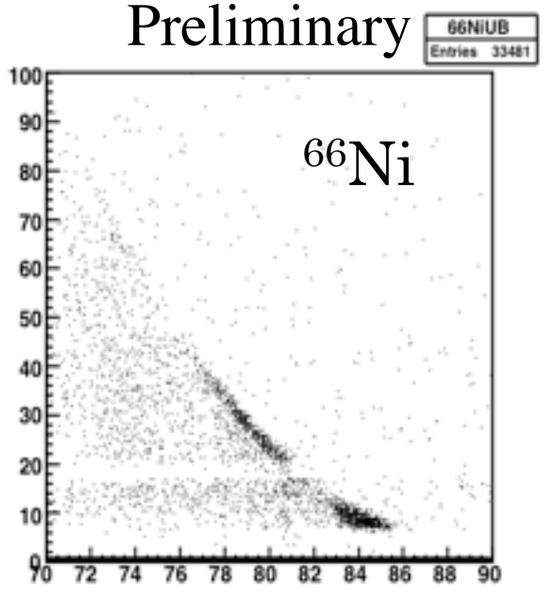
Recoil angle $\theta_{\mathrm{lab.}}$ [deg.]

Preliminary



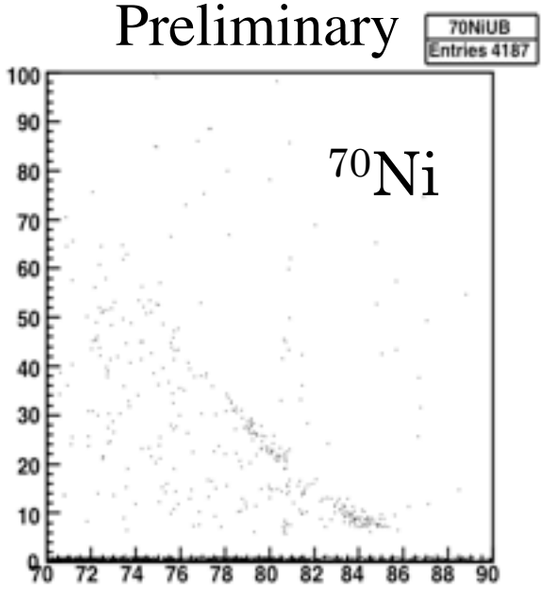
Recoil angle $\theta_{\mathrm{lab.}}$ [deg.]

Preliminary



Recoil angle $\theta_{\mathrm{lab.}}$ [deg.]

Preliminary



Recoil angle $\theta_{\mathrm{lab.}}$ [deg.]

Plane at RIBF

1. Weakly bound systems

Neutron rich : ^{6,8}He, ^{9,11}Li, ^{12,14}Be

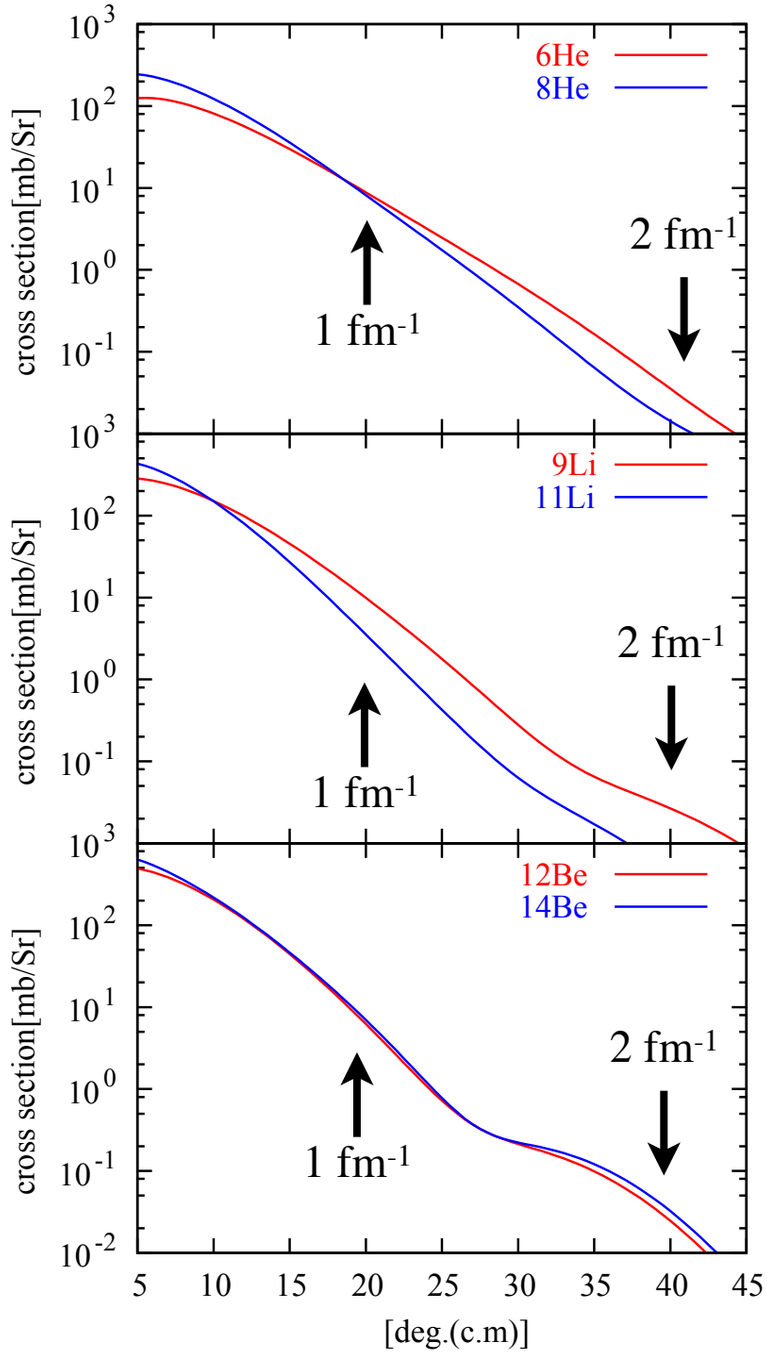
Proton rich : A～10

2. Modification of shell structure

A=30～50

3. Asymmetric nuclear matter

A=70～100

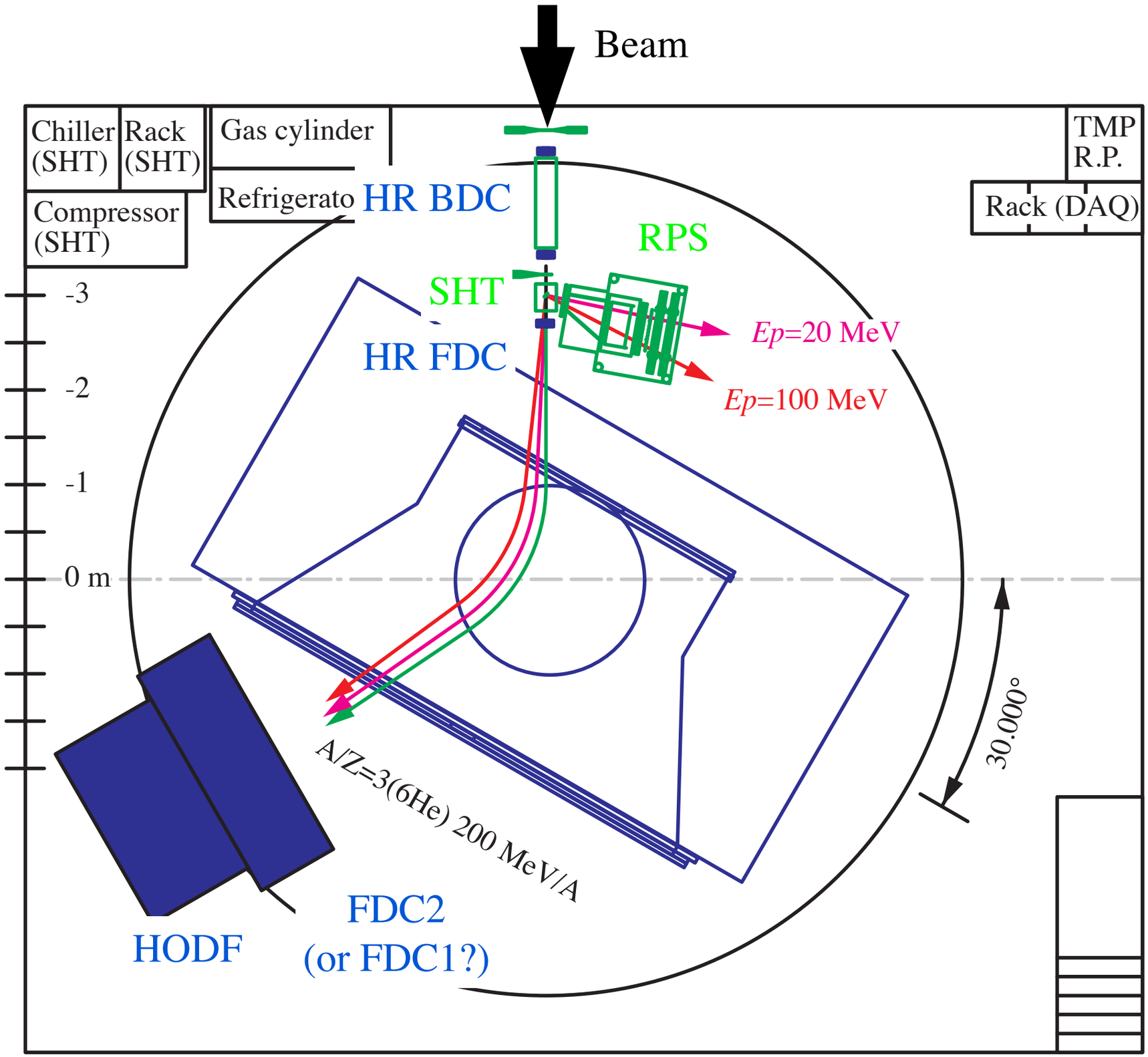


Combination with SAMURAI

	Sn	S_2n	E_x (1st)
^{6}He	1.87	**0.97**	1.80
^{8}He	2.57	**2.14**	3.10
^{11}Li	0.33	**0.30**	-
^{14}Be	1.85	**1.26**	-
^{9}Li	4.06	6.10	**2.69**
^{12}Be	3.17	3.67	**2.10**

Data: NNDC

Experimental setup



Detectors(we need)

- -BPC
- -BDC
- -FDC 1or2
- -HODF

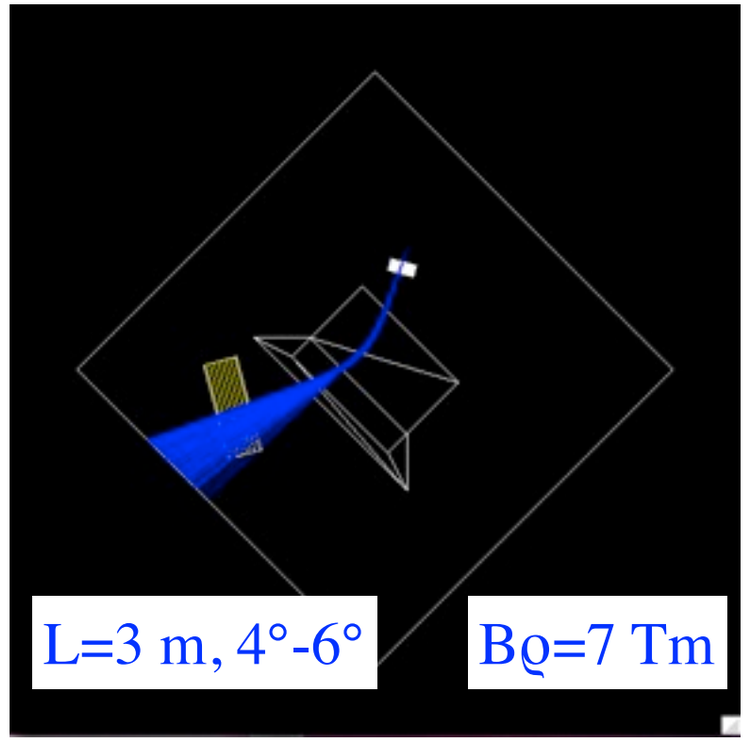
Requests/questions

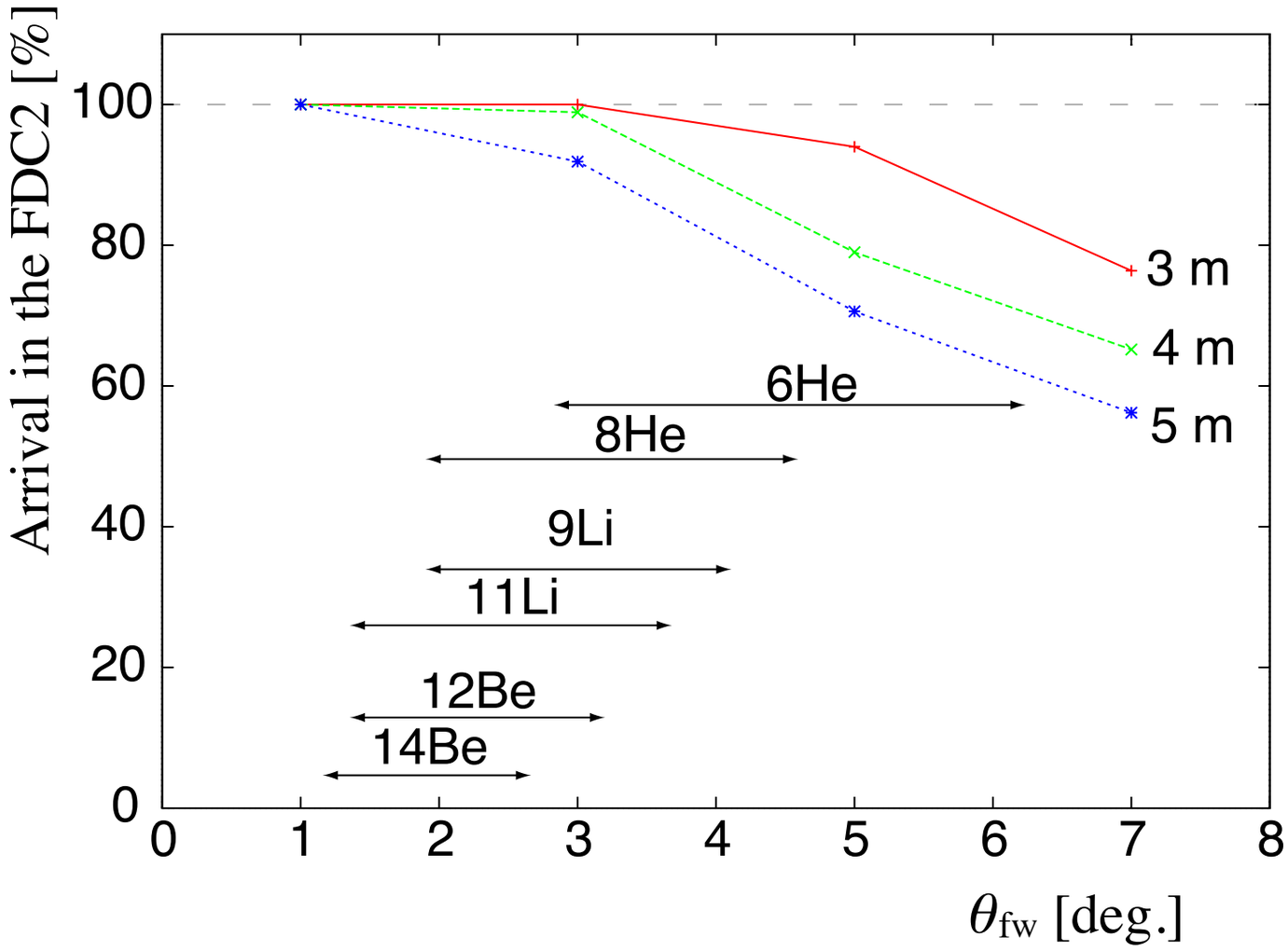
1. Placement of our equipments near the RPS.
2. Short distance between the RPS and SAMURAI

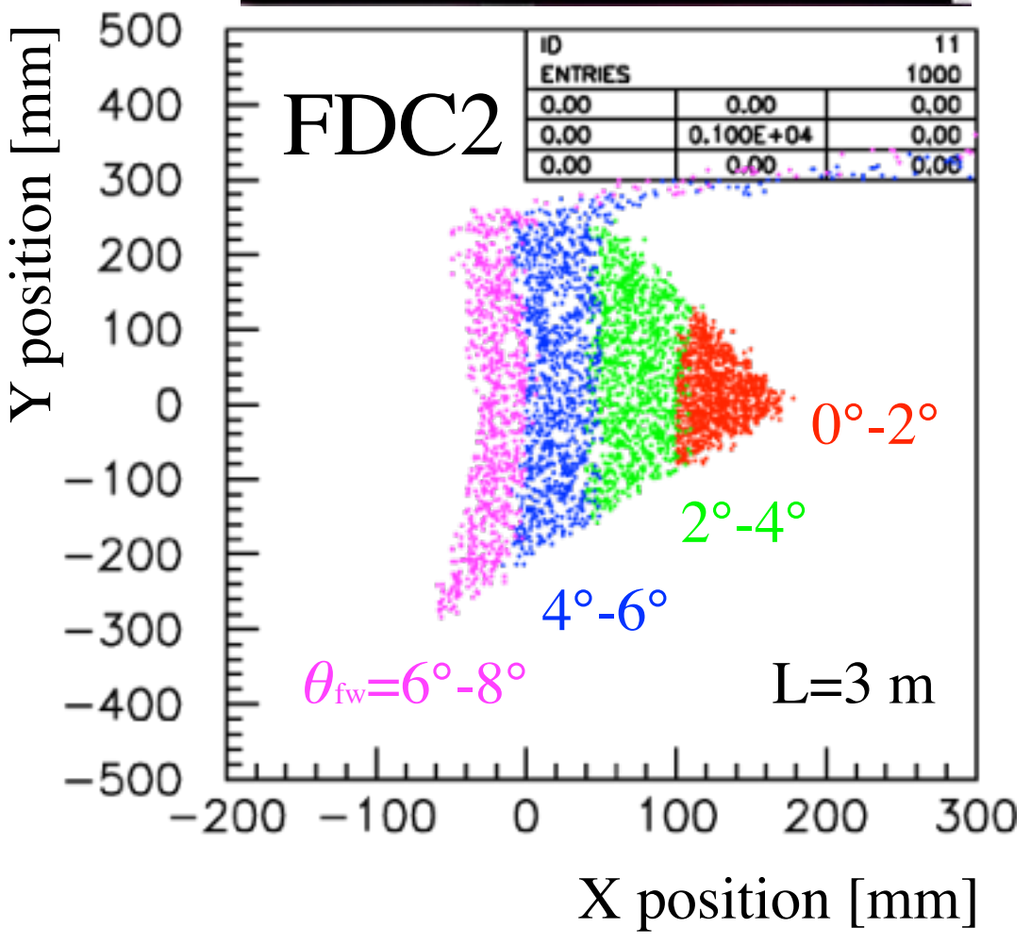
Experimental setup

		^{6}He	^{14}Be
q [fm-1]	T_p [MeV]	θ_{fw} [deg.]	θ_{fw} [deg.]
1	20	2.9	1.2
2.2	100	**6.2**	2.6

Field map(TOSCA):
Sato san
Program(GEANT4):
Isobe san







Summary

- We planed a project: Elastic scattering of protons with RI beams (ESPRI).

- We have developed a recoil proton spectrometer (RPS).
  - Experiments: ^{9,10,11}C (HIMAC), ^{66,70}Ni (GSI)
  - The RPS will be ready in FY2011 (RIBF).

- I propose measurements of proton elastic scattering on the neutron rich nuclei:
  ^{6,8}He, ^{9,11}Li ^{12,14}Be.
  - Momentum transfer: 1 fm^{-1} to 2 fm^{-1}
  - High statistics

- We request followings:
  - short distance between the RPS and SAMURAI (< 4 m).
  - Machine time (Beam energy: 200 MeV/A, beam intensity: 0.2 Mcps)

^{6,8}He, ^{11}Li,^{14}Be: 1 day × 4 nuclei = 4 days
^{9}Li,^{12}Be: 5 day × 2 nuclei = 10 days
Primary beam ^{18}O run = 1day
Background run = 1day
Circuit adjustment = 1day

Total 17 days

-Equipments:
BPC, BDC, FDC, HODOF, circuits, cable,....