Proton elastic scattering at the 300MeV/u and investigation of nucleon density distributions

RIKEN Nishina Center

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Motivation by using (p,p$^{(\prime)}$)

- Study for nucleon density distributions.

  ⇒ Elastic scattering

- Spectroscopy of bound and unbound states

  from light to heavy nuclei.

  ⇒ Inelastic scattering

- [Study of deformed nuclei

  ⇒ Coupled channel between elastic and inelastic scattering??]

Missing Mass Method via Proton scattering

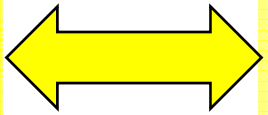
- We can observe both bound and unbound state energy to detect directly recoil proton from hydrogen target. H(HI.p) HI: Heavy Ion [beam]
- Non-selectivity of proton probe for inelastic channel

(isoscalar[ΔT=0],isovector[ΔT=1],spin-flip[ΔS=0],non-spin-flip[ΔS=1])

Merit and Demerit

Recoil-particle measurement

○Good angular resolutions
○Absolute excited energy
×Poor energy resolution
×Poor statistics(Thin Target)
○Wide dynamic range
for excited energy
-bound state and unbound state-



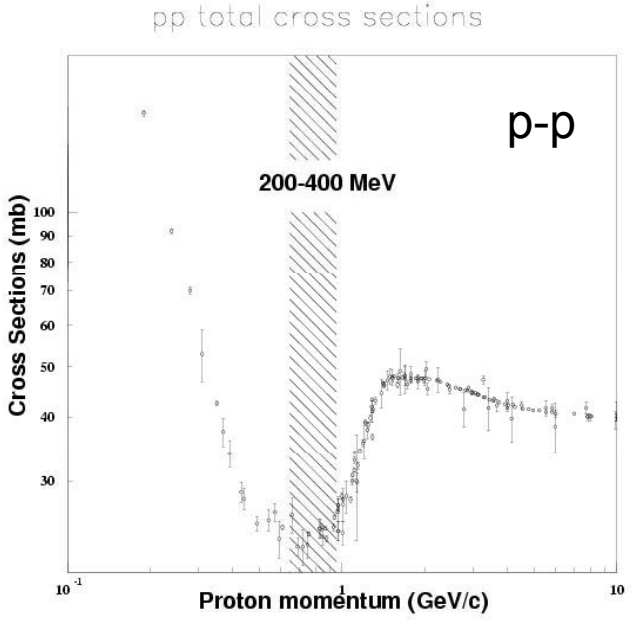
Gamma spectroscopy

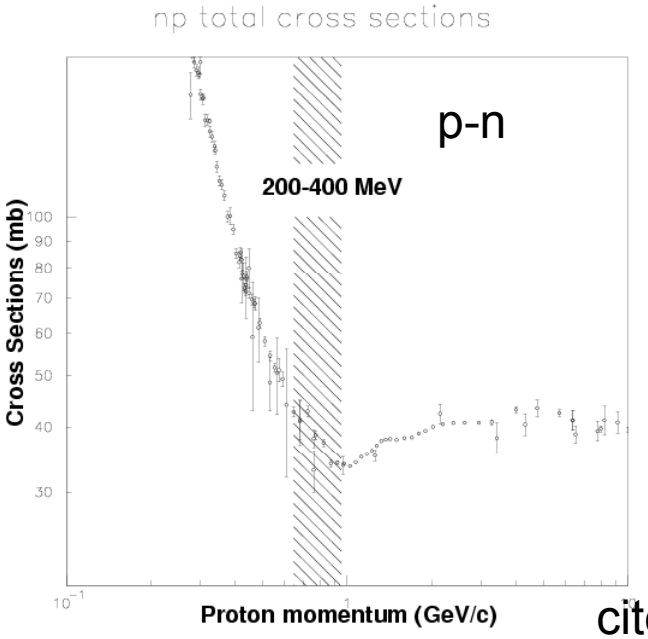
×Poor angular resolution
△Relative excited energy
○Good energy resolution
○Good statistics
△Up to neutron [proton]
separation energy
-bound state-

Proton probe
at the intermediate energy

- Intermediate energy (~several hundred MeV) proton is a good probe to extract nuclear structure information

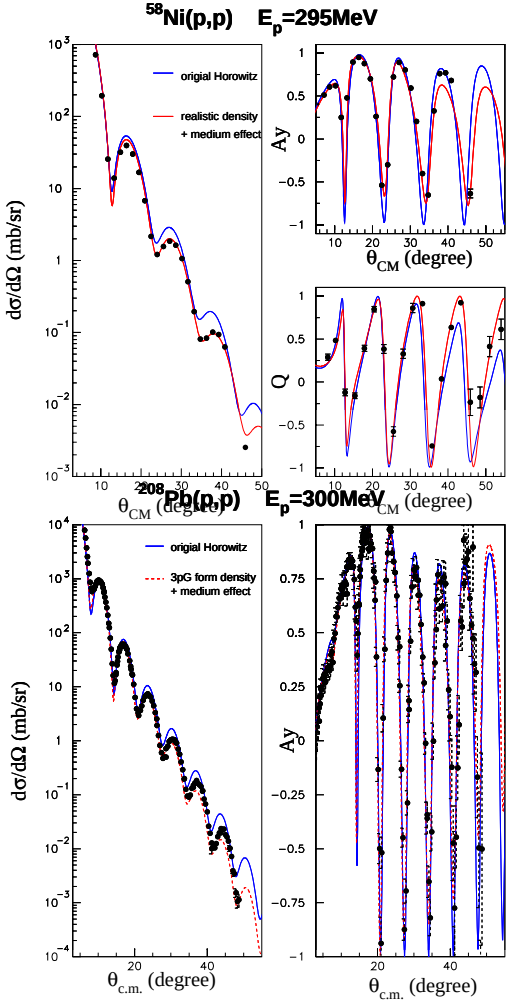
  because of its long (~2 fm) mean free path in the nuclear





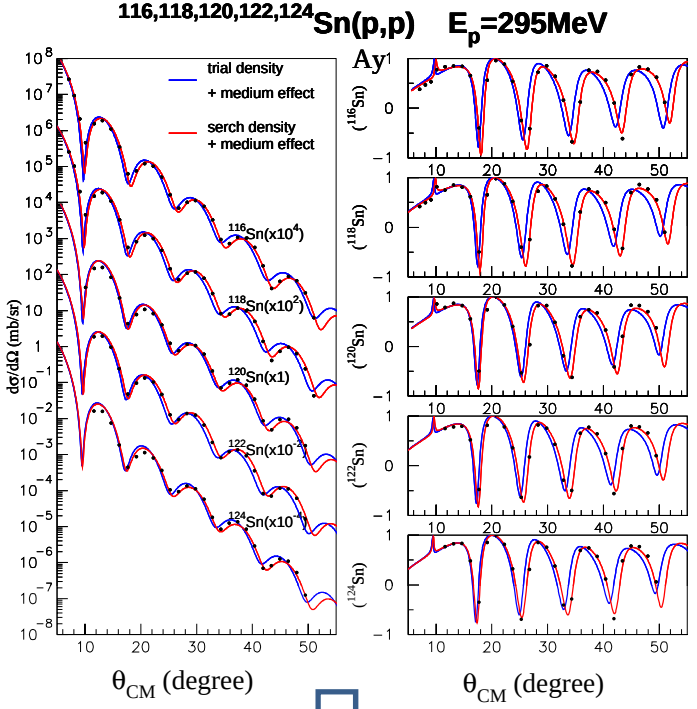
cited by PDG

Elastic scattering of stable nuclei at the intermediate energy



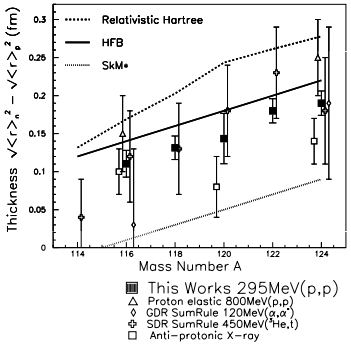
^{58}Ni

^{208}Pb

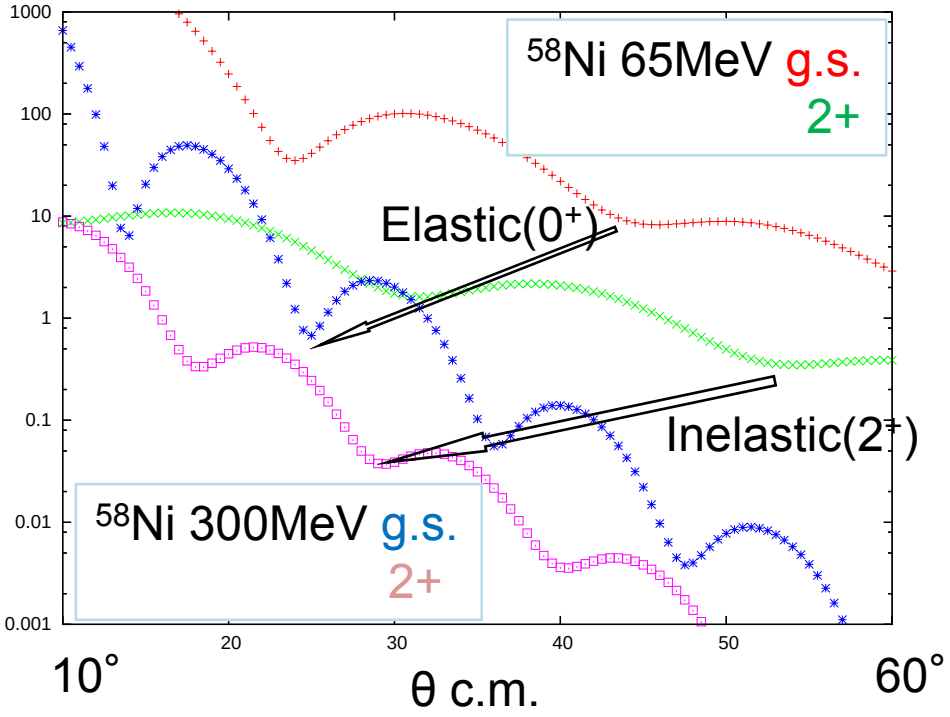


isotope Sn

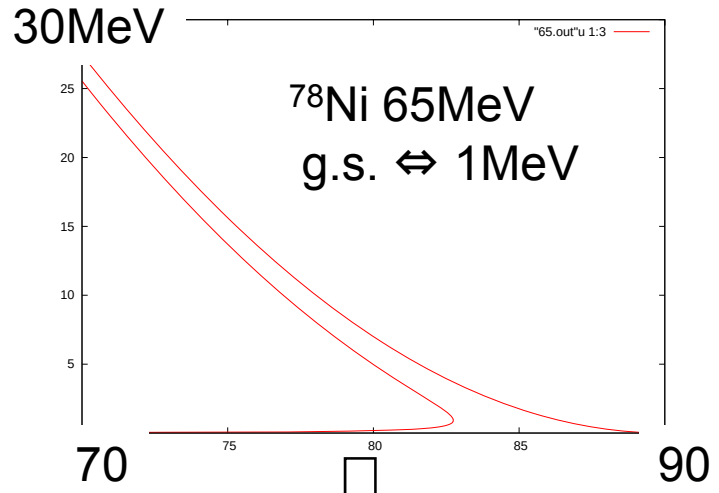
Radius and thicknesses

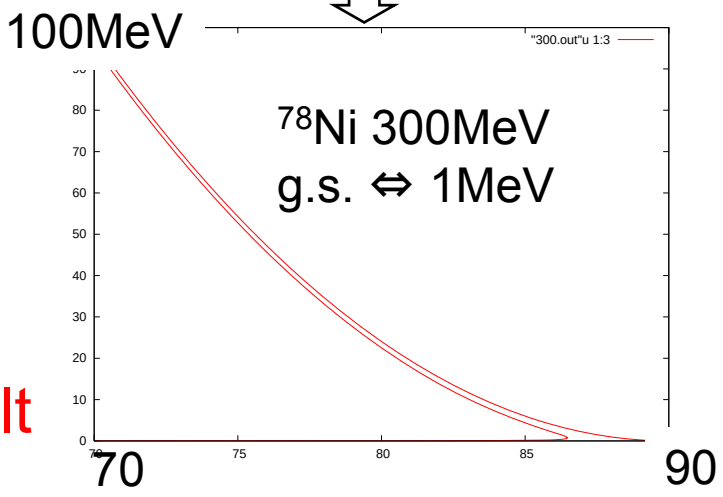


Elastic and inelastic scattering at the intermediate energy



By ECIS with Global potential





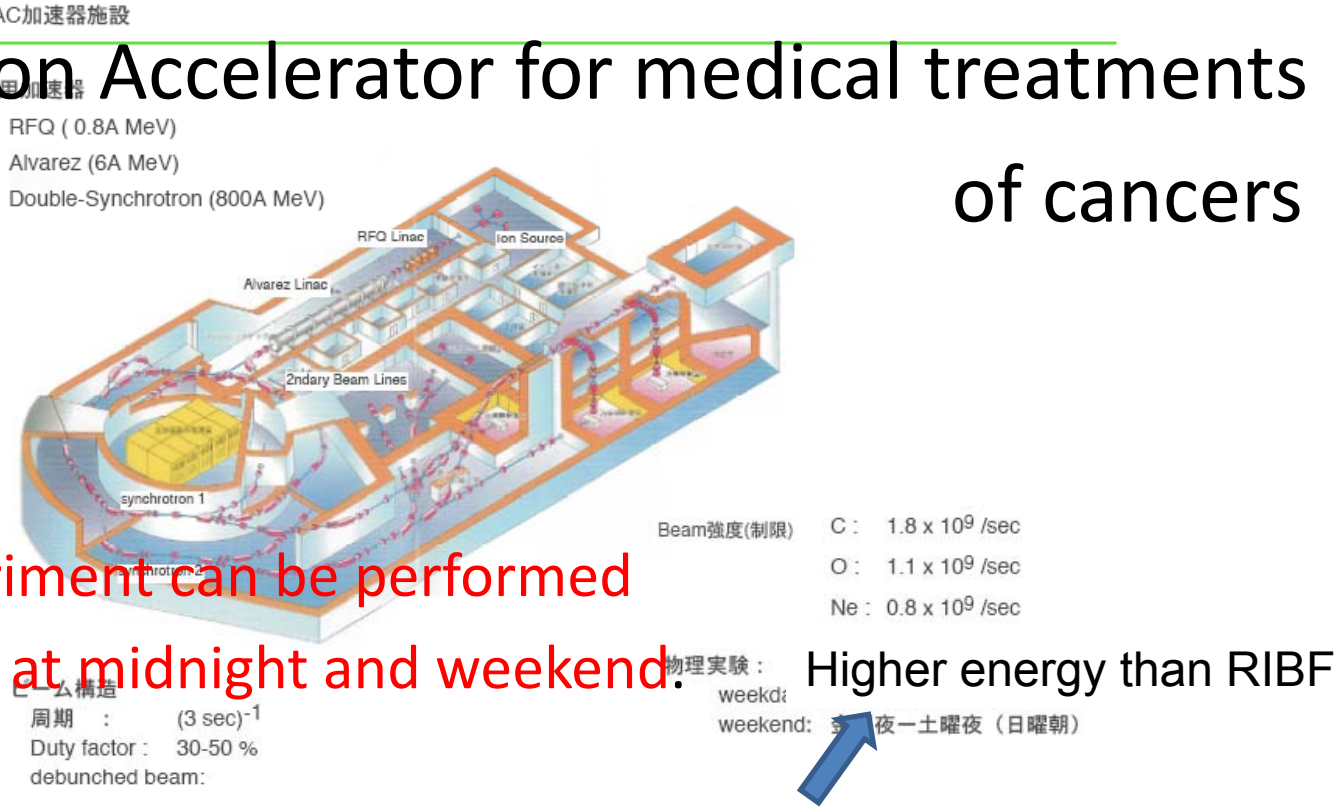
Higher Incident Energy

Cross section ⇒ smaller

Kinematics Condition ⇒ more difficult

HIMAC
[Heavy Ion Medical Accelerator in Chiba]

Synchrotron Accelerator for medical treatments of cancers



Physics experiment can be performed only at midnight and weekend.

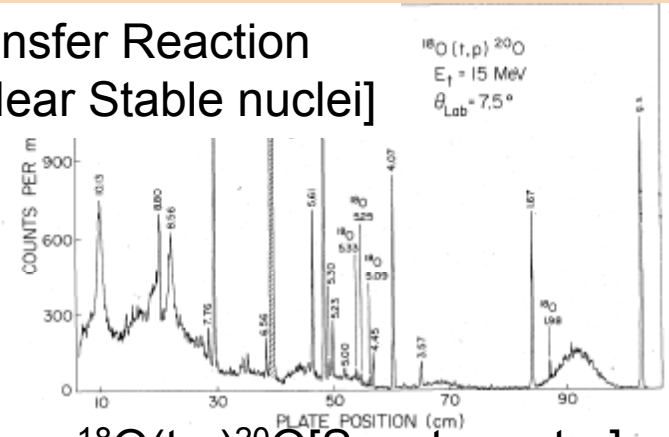
Higher energy than RIBF

- Low Intensity(<~10^9/sec) and High energy(~800MeV/A)

$^{22}Ne \Rightarrow {}^{20}O$ at 300MeV/u

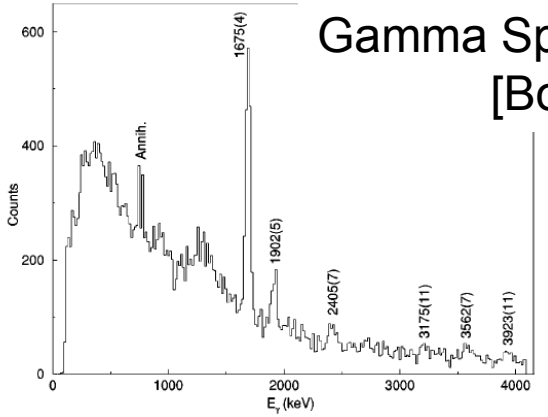
Other Experiment (^{20}O)

Transfer Reaction
[Near Stable nuclei]



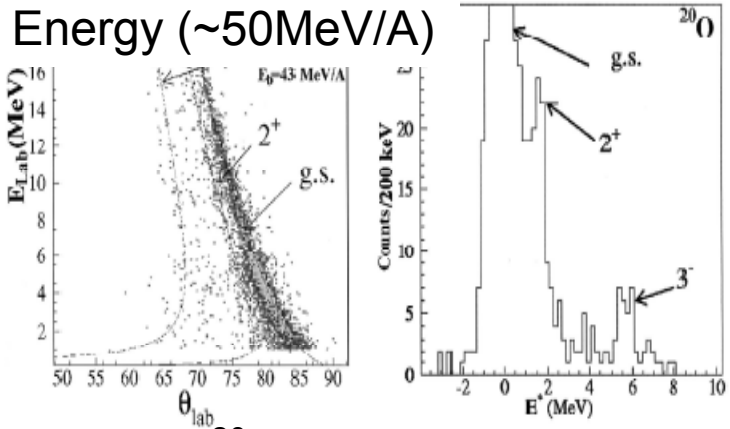
^{18}O(t,p)^{20}O[Spectrometer]
PRC20 (‘79)1673-

Gamma Spectroscopy
[Bound State]

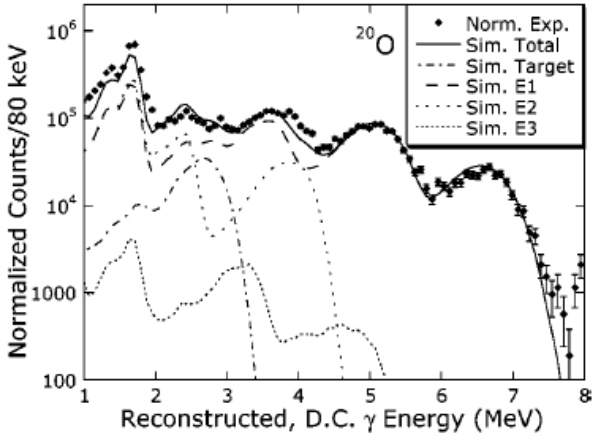


Single Fragmentation[Ge]
PRC69(‘04)034312

Lower Energy (~50MeV/A)

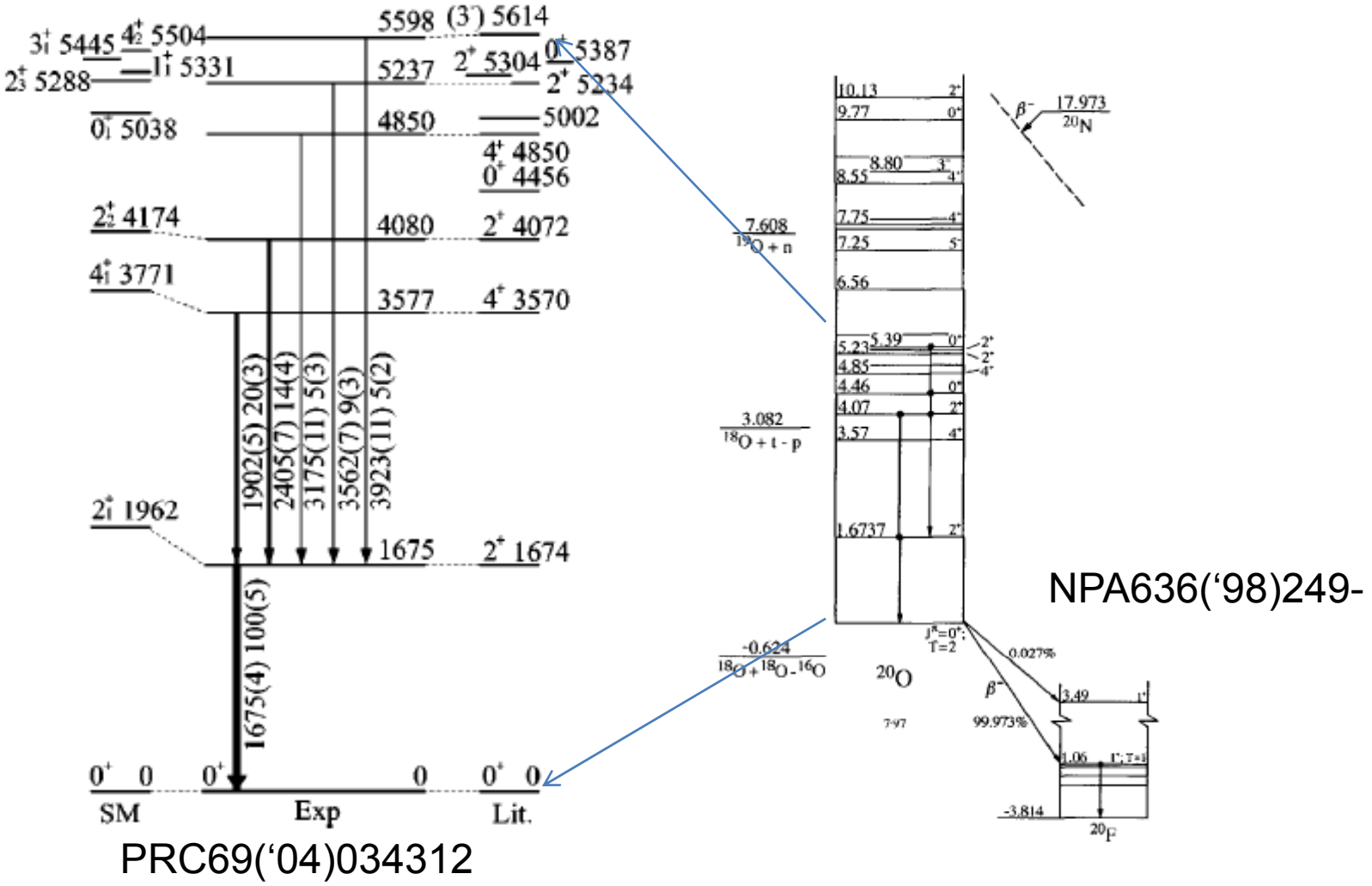


CH_2(^{20}O,p)[Si-Si(Li)-CsI]
MUST PLB490(‘00)45-

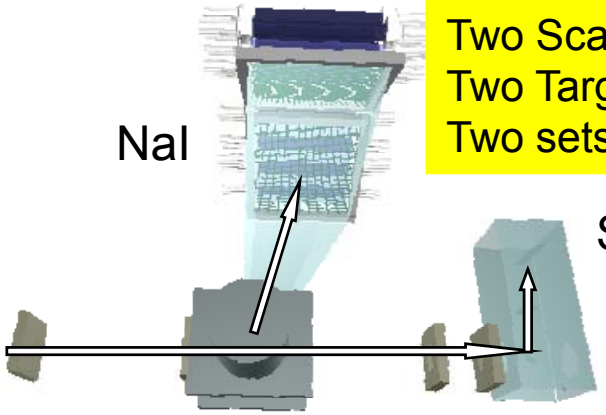


Coulomb Excitation[BaF]
PRC67(‘03)064309

Levels of ^{20}O

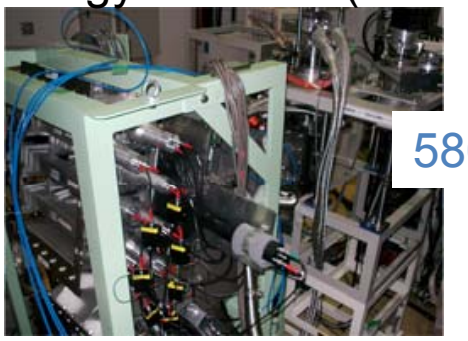


ESPRI Detectors
[Elastic Scattering of Protons with RI beam]



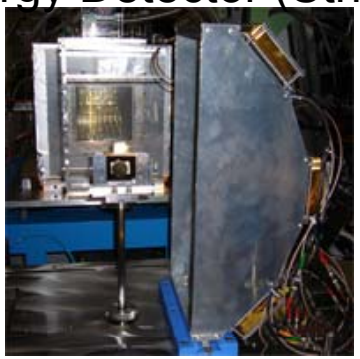
Two Scattering Cambers
Two Targets
Two sets of Detectors

High Energy Detector (DC+NaI)



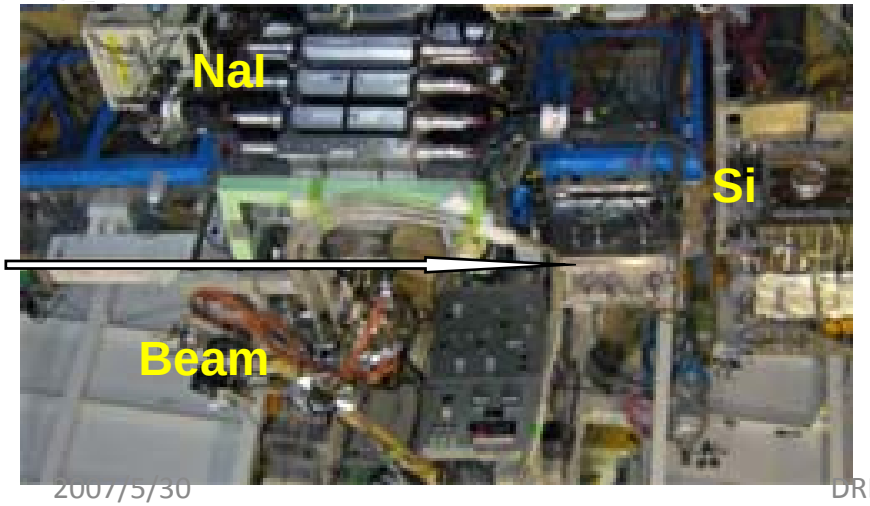
580 mrad(φ)

Low Energy Detector (Strip-Si+SiLIi)



700 mrad(φ)

Experimental Setup at HIMAC



-Measurement- Event-by-event
HI: PI, Position, Angle, Energy
Recoil: PI, Angle, Energy—
(Optional: Scattered HI: PI, Angle)

Requirement of Detectors

[except parts of nuclei(ex. ^{6,8}He, ^{11}Li, ^{9}Be, ^{8,9}B, ^{9}C)]

- High rate beam counting detector at F1 for beam energy measurements

  Scintillation Fiber Detector[SFD]

- Good angular resolution + Low intense RI beam

  Thin Solid Hydrogen Target[SHT]

- Beam and Recoil particle tracking…..

  Drift chamber x(2+2) [BDCs, RDCs]

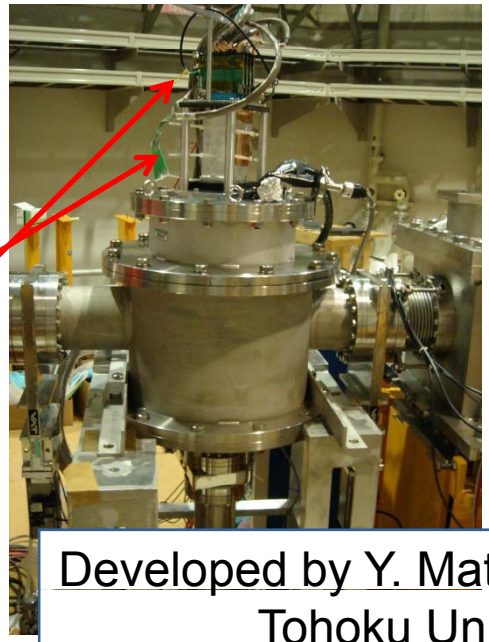
- Total Energy scintillators

  NaI(Tl) x 14

Scintillation Fiber Detector [SFD]

- High rate position detector

  50[h]x2[w]x2[t] mm^3 x 60 segments



Developed by Y. Matsuda
Tohoku Univ.[JPN]

- Readout

MAPMT[H8500:64ch]+PreAmpDiscri[ASD chip] + Multihit TDC

Succeeded measuring the momentum of

light nuclei(^{20}O,^{9}C) under 2MHz at HIMAC

Solid Hydrogen Target [SHT]

Merit

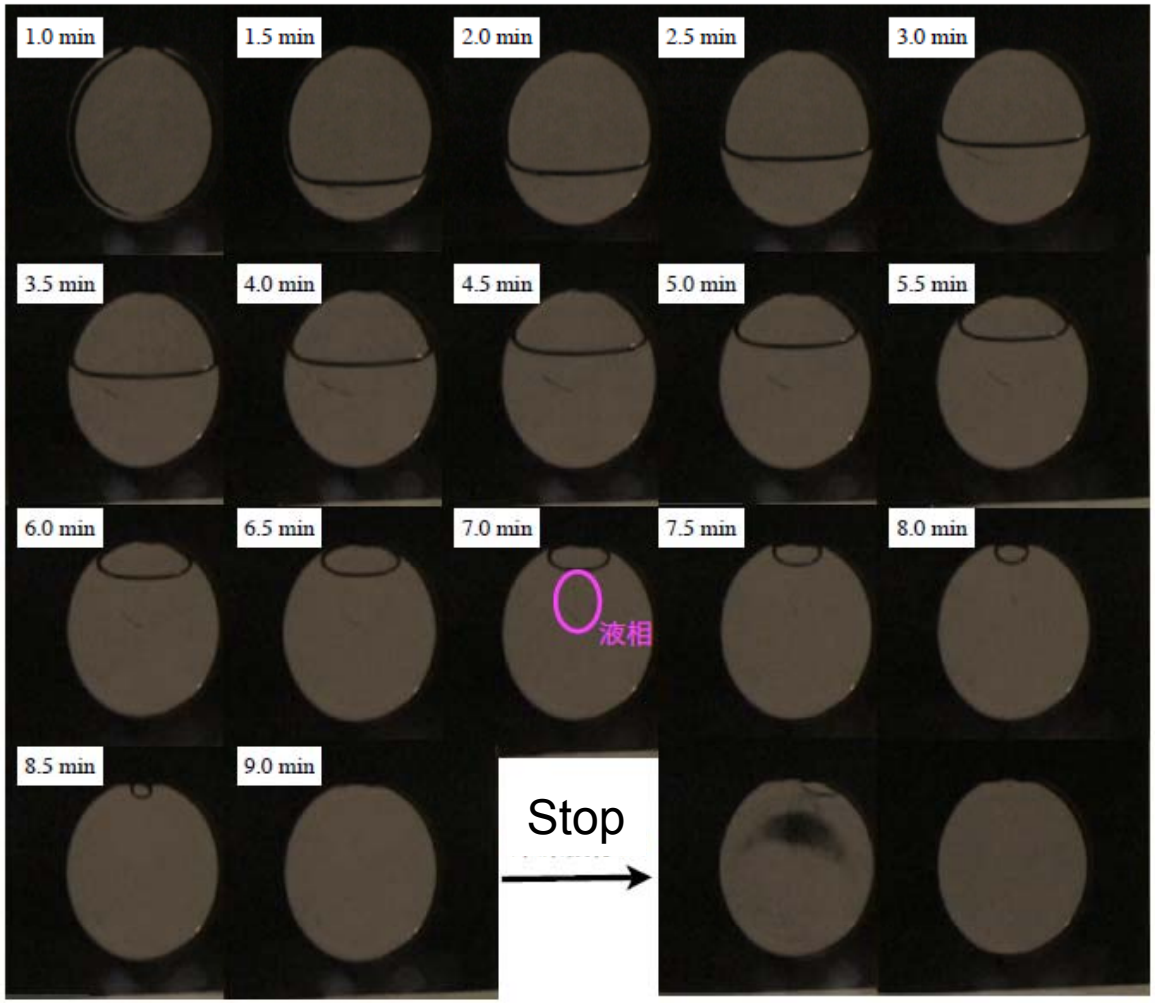
- Low multiple scattering
  (ex. ~1/10 CH_2)
- Low Background
  (only window material)
  S/N ≫10

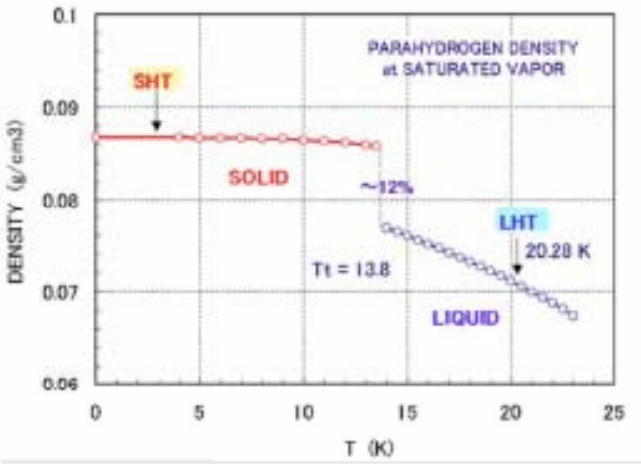
⇒ Lower Intensity RI beam

Demerit

- Technical limit of thickness
  ~1mm+4umMylar thickness??
  [⇒Recoil angle resolution]

Solid Hydrogen Target [SHT]

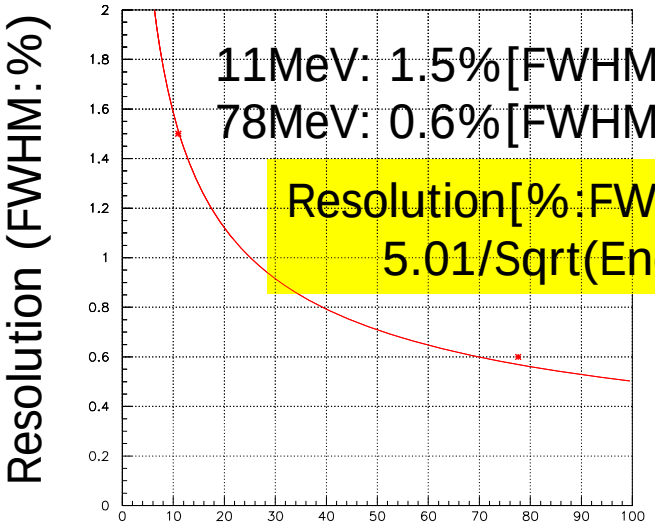


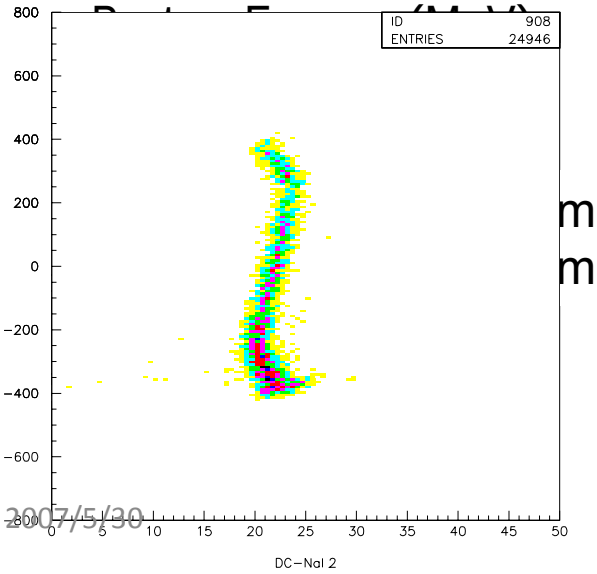


Stable density of SHT
for temperature

RPS-NaI[Tl]

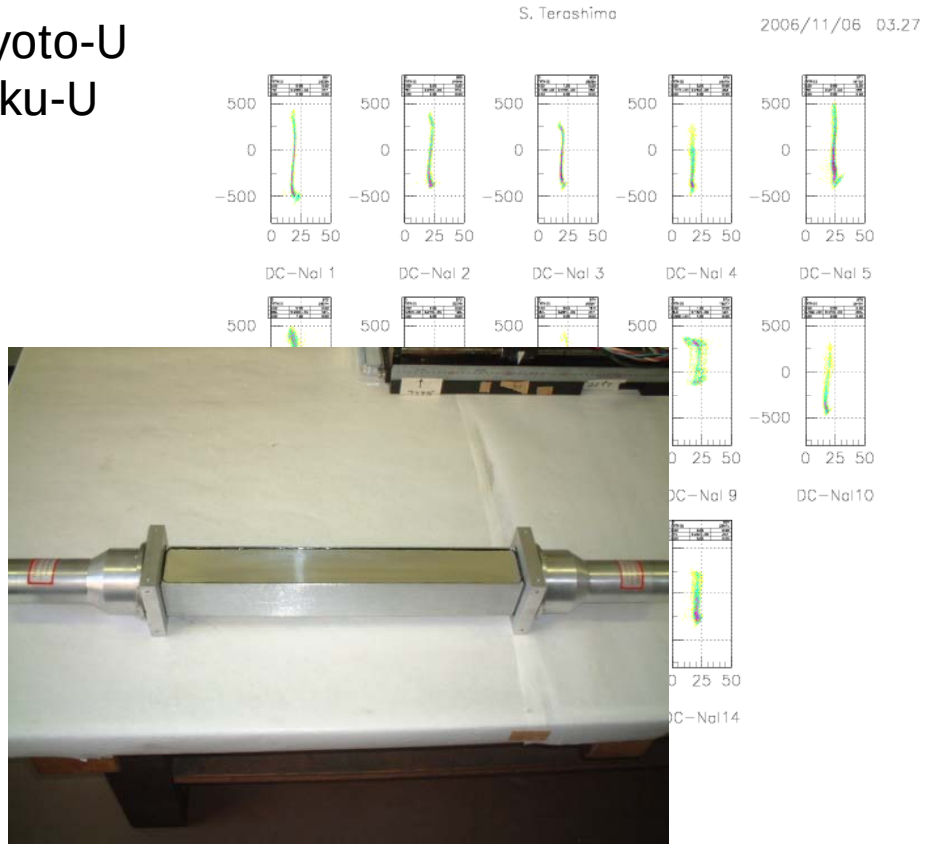
NaI resolution for Proton





ms]

ms with corr]



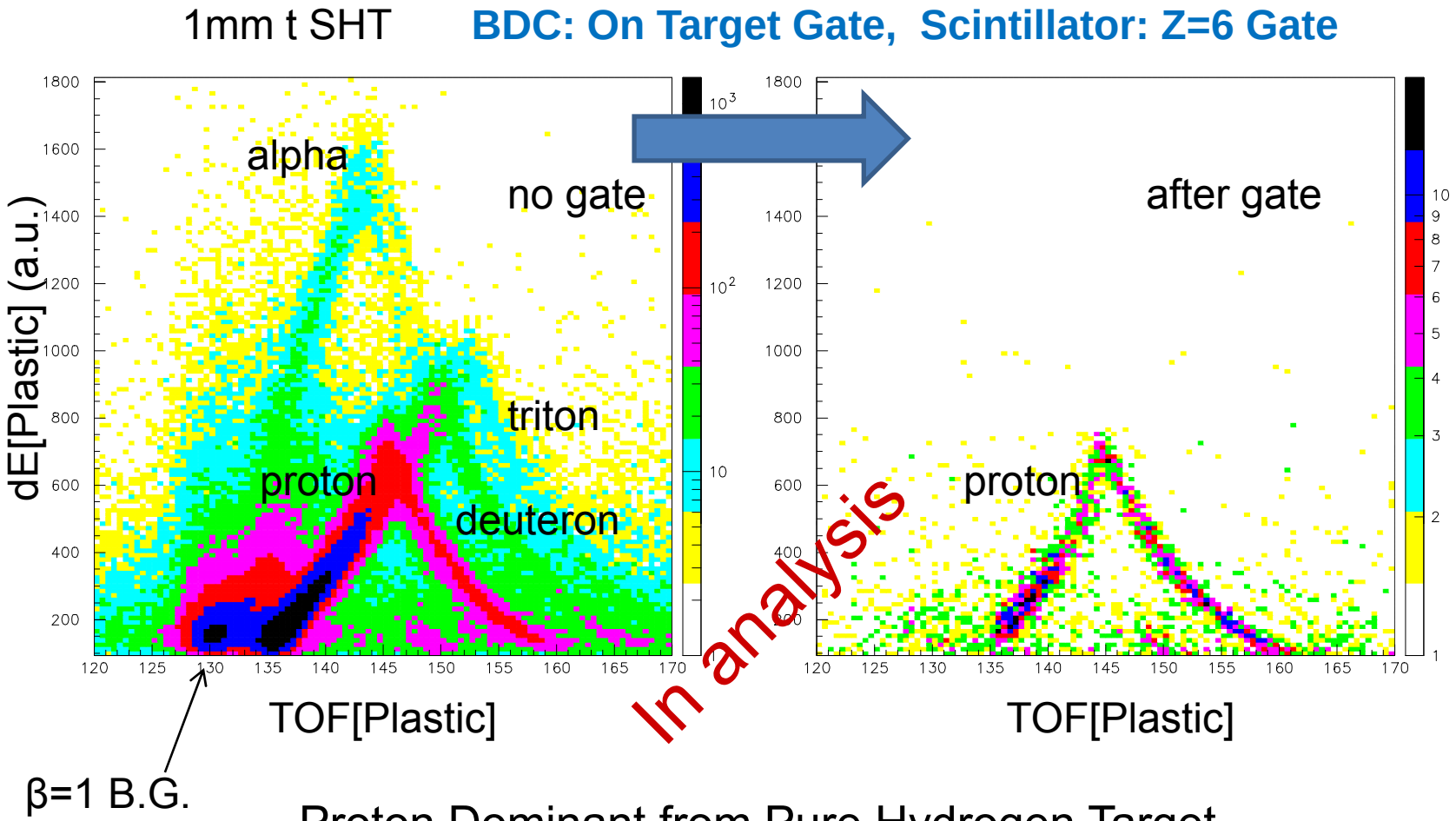
Total energy counter for high energy proton
2 x 2 x 18 inch NaI(Tl)

Experimental Results [Preliminary]

RPS parts

^{20}O ~300MeV/A [2006 Aug.] up to 2.0fm^{-1}

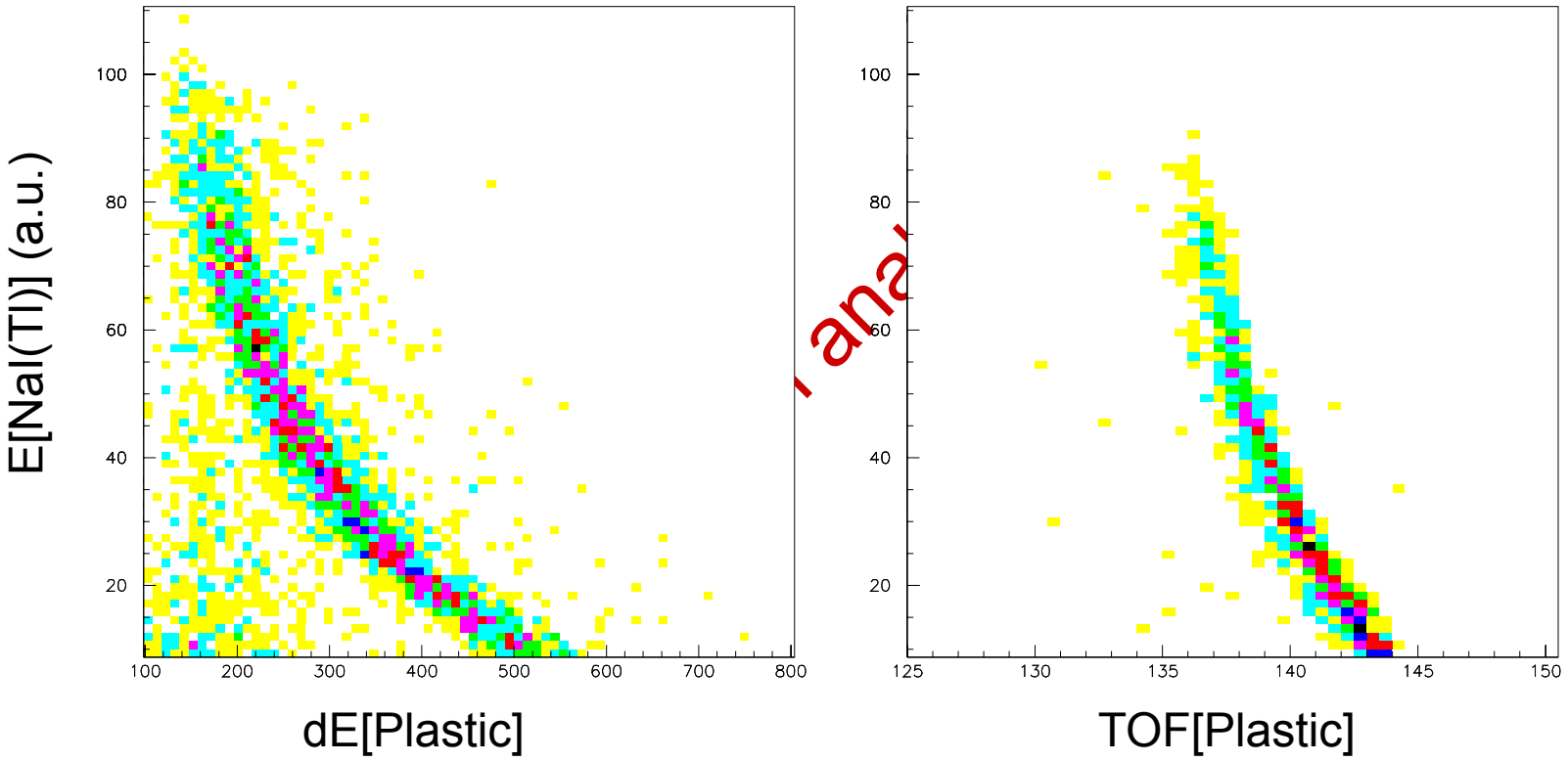
Recoil PI



Proton Dominant from Pure Hydrogen Target

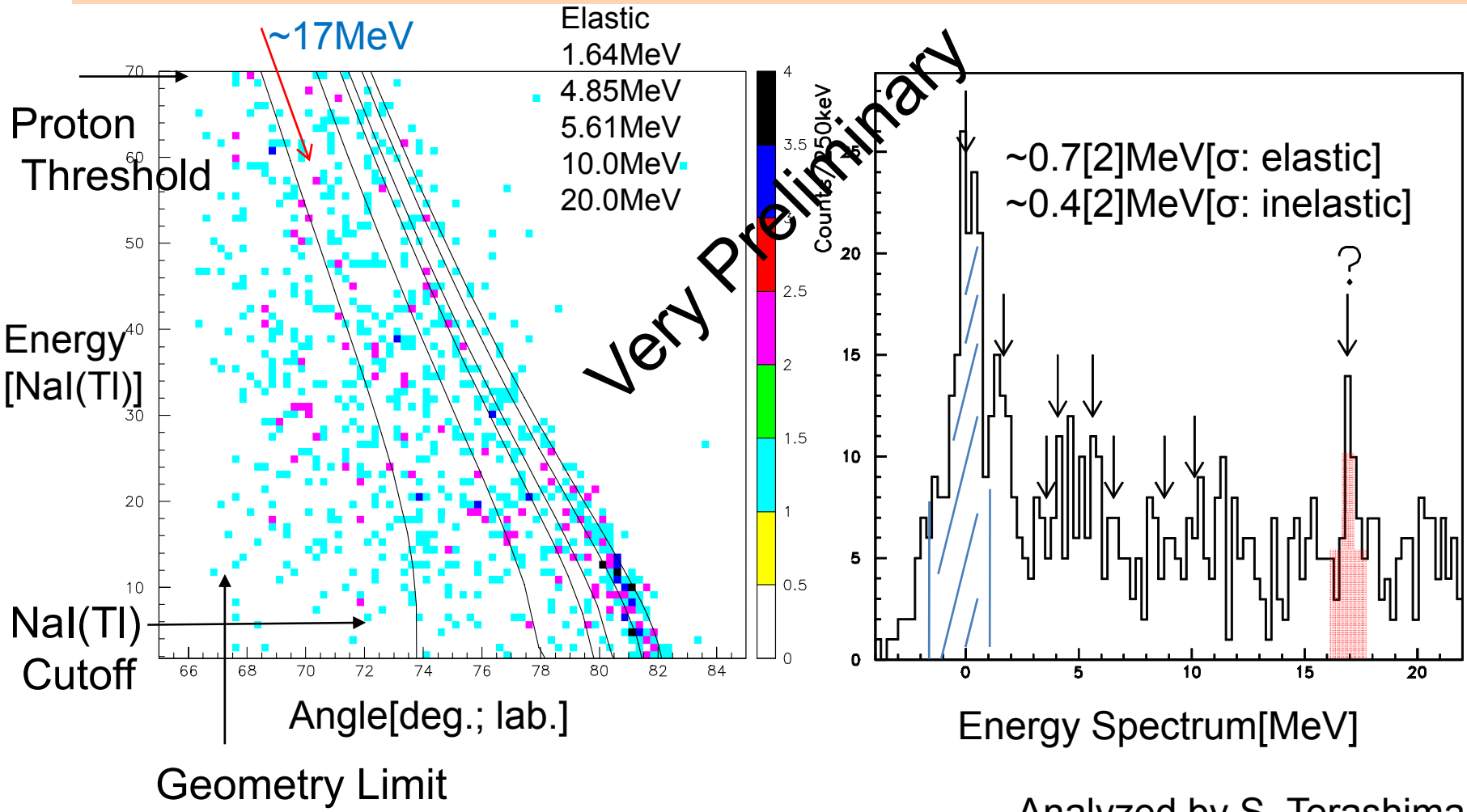
Recoil PI

1mm t SHT **BDC: On Target Gate, Scintillator: Z=6 Gate**



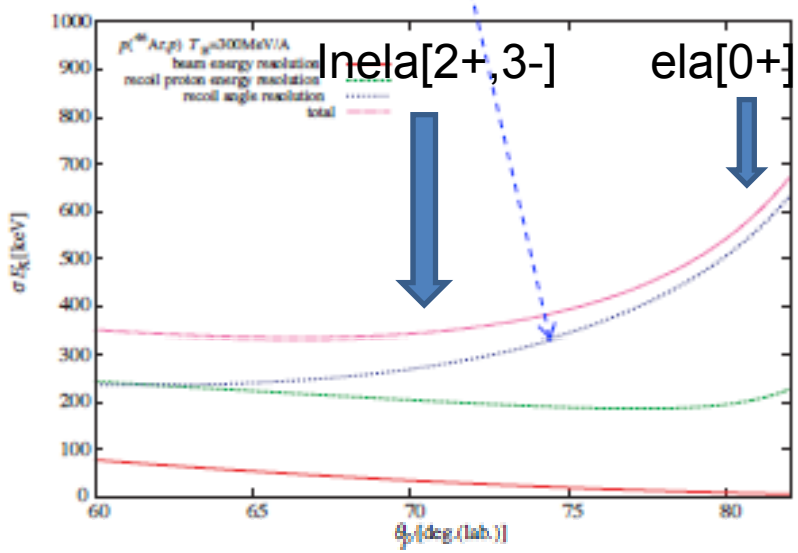
Proton Dominant from Pure Hydrogen Target

^{20}O Results [Preliminary]



Analyzed by S. Terashima

Resolution estimation

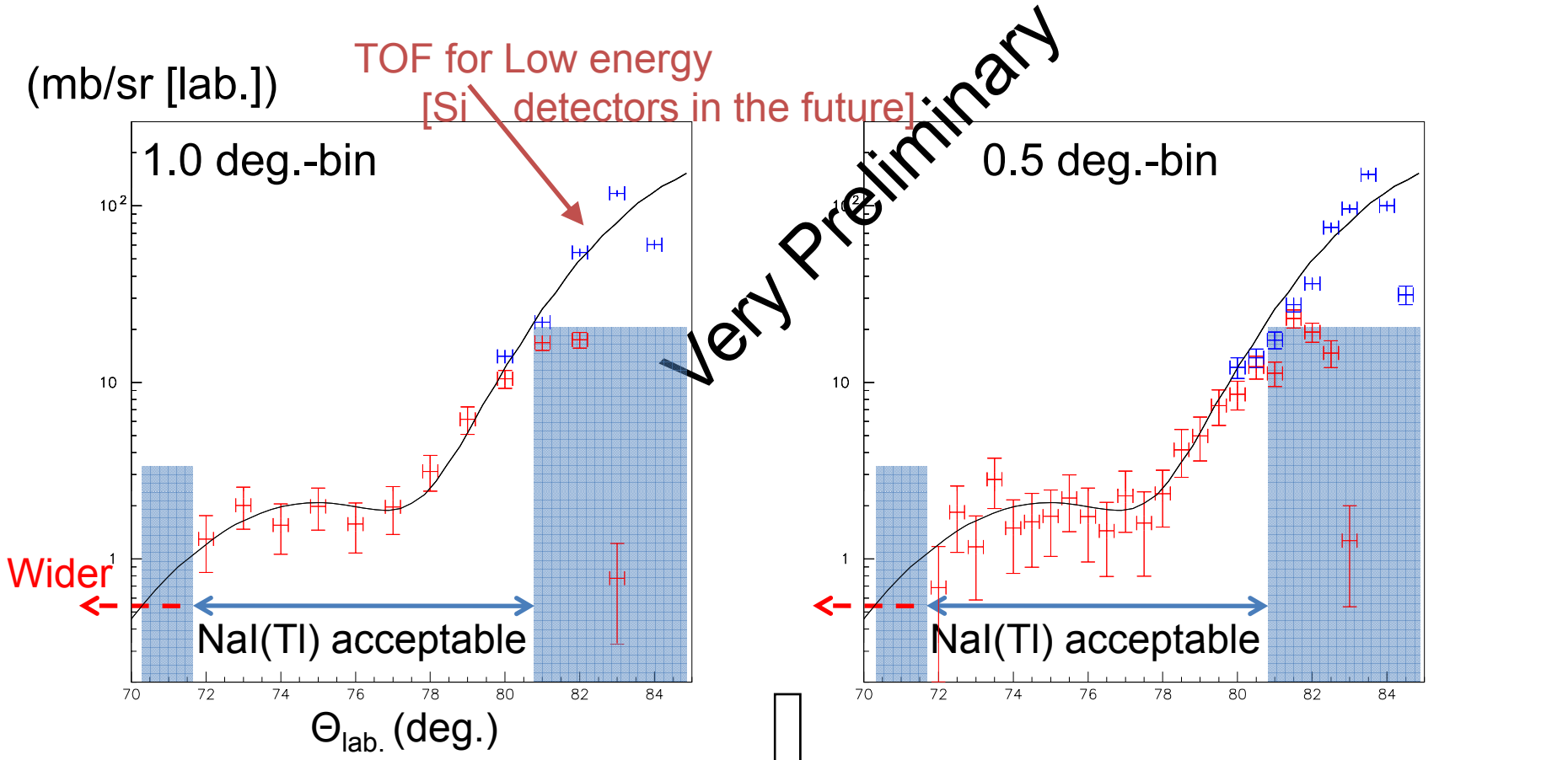


Low momentum transfer region (~1fm^{-1}) ⇒ Target multiple scattering dominant

High momentum transfer region (~2fm^{-1}) ⇒ Calorimeter energy resolution dominant

⇒ Energy resolution will be better

Ground State [0^+] angular distributions



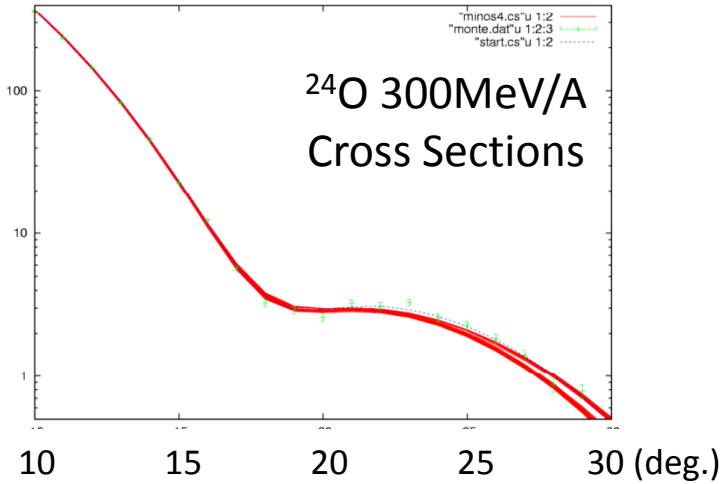
Calc. by ECIS with Global potential

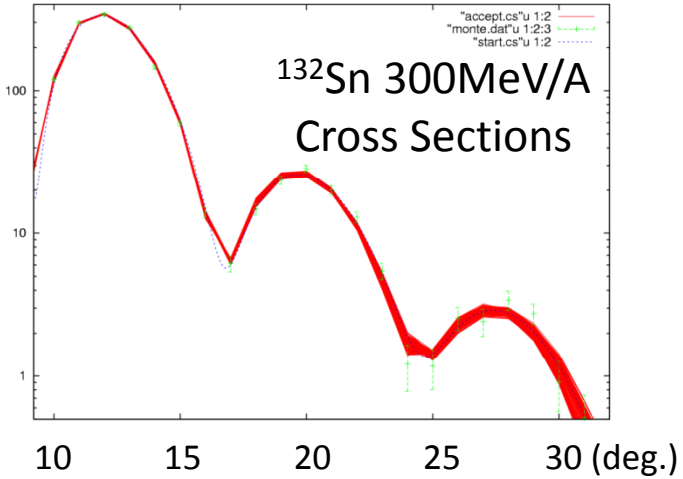
Analyzed by S. Terashima

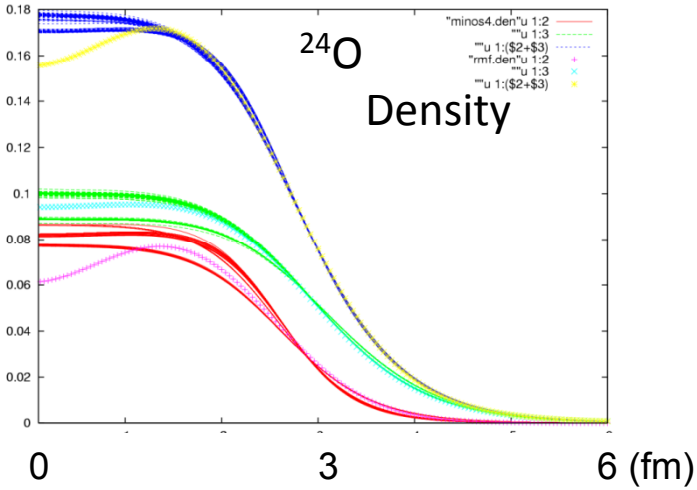
Need more statistics for nucleon density distributions

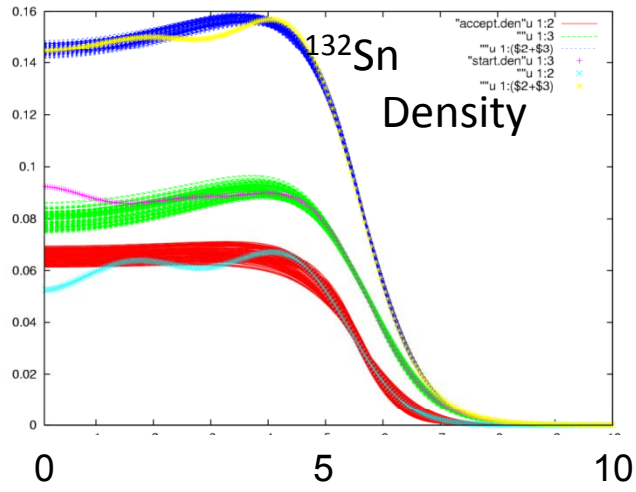
Simulation --Density Distribution--

Statistical error only(1mb/sr:10%[expectation at RIBF])
The shapes were assumed 3-parameter Fermi(Gauss) type.







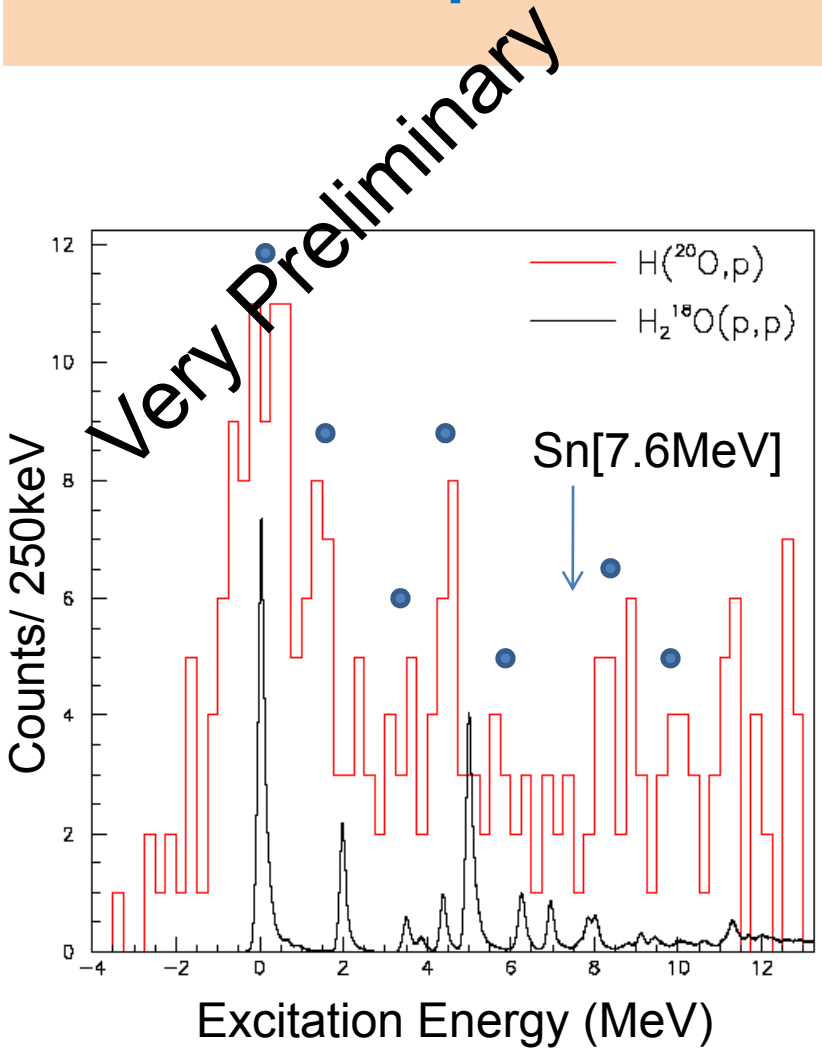


Need to $10^{4\text{-}5}$ pps
(At present)

Several 10^{3} pps
(In future)

Comparison of ^{18}O with ^{20}O

Momentum Transfer Region :1~2 fm^{-1}



^{18}O at RCNP 300MeV proton beam
: Enriched Ice Target(O18 Water)
resolution 200keV [FWHM]

^{20}O at HIMAC ~300MeV/u secondary beam
: Solid Hydrogen Target
--Good resolution cut--
~1-1.5MeV[FWHM]

ela:inela[^{18}O] = ela:inela[^{20}O] = ~1:2
⇒ almost background free
but more statistics

Next step : Level assignment and
absolute value of cross sections

Summary and Perspective

- We planed the proton scattering experiment at the 300MeV/u
- We succeeded measuring recoil protons of ^{20}O and ^{9}C elastic channels at HIMAC, and planed to measure the high statistics ^{20}O data.
- We will provide the cross section data of proton elastic scattering of unstable nuclei at RIBF.

Collaborators

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