テトラニュートロンの探索
Tetra-neutron system

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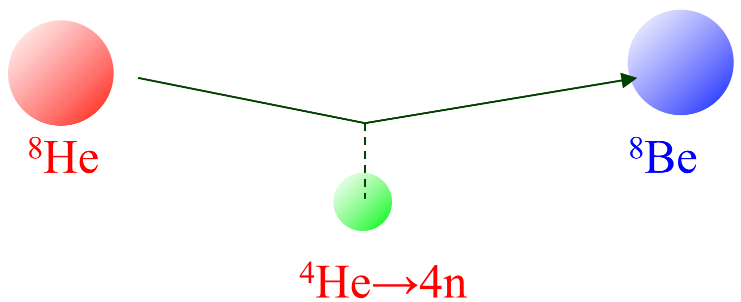
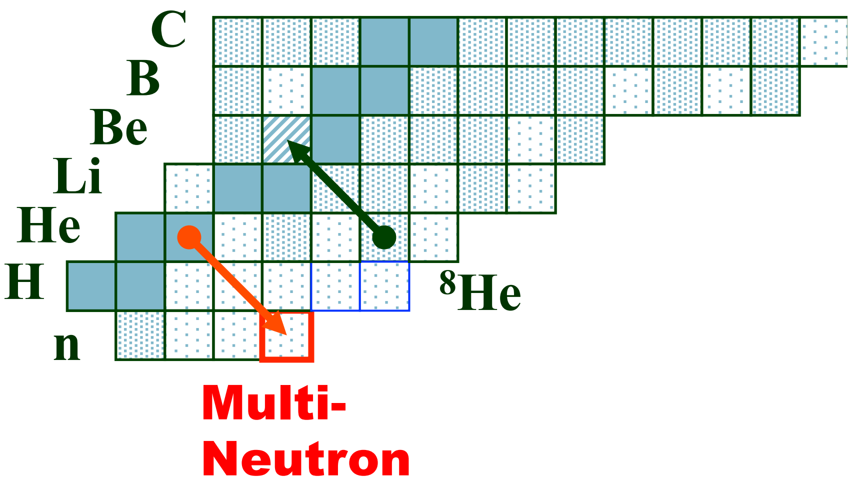
for SHARAQ Collaboration

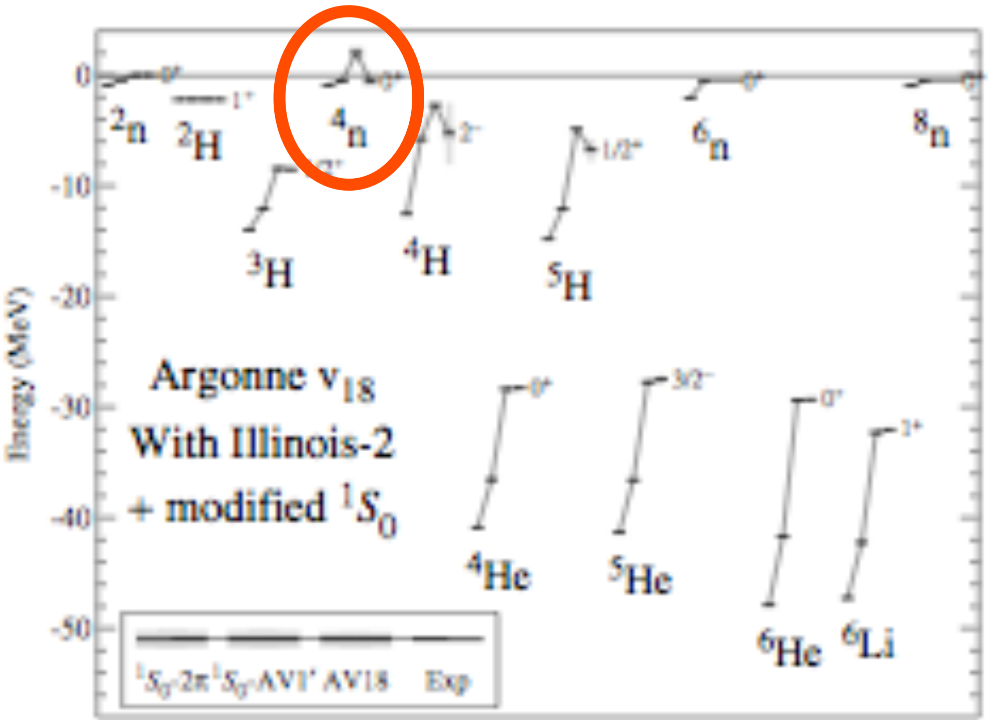
Tetra-neutron system produced by exothermic double-charge exchange reaction (NP1012-SHARAQ06)

See Poster of K. Kisamori



Recoil-less 4n system via DCX using internal energy of ^{8}He

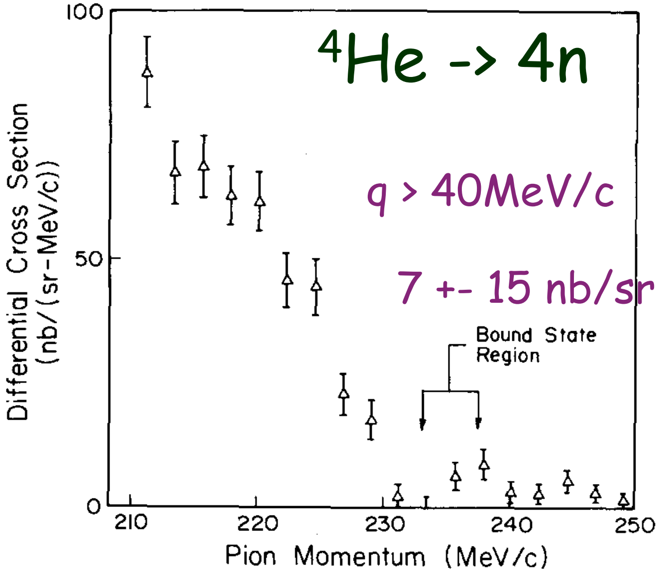


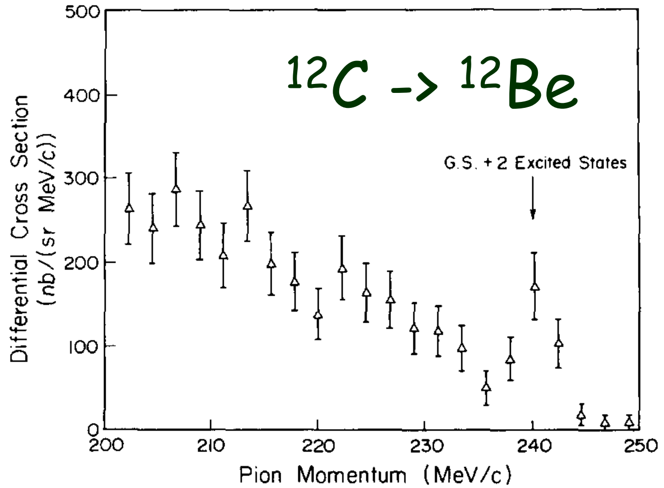


S.C. Pieper et al., PRL 90, 252501 (2003)

4n in breakup of ^{14}Be : Marques et al. PRC 65 (2002) 044006

(π^-,π^+) reaction @ 165 MeV; $\theta_{\pi+}$ = 0 degree





We have measured the momentum spectrum of π^+ produced at 0° by 165 MeV π^- on ^{4}He. A $\Delta P/P$ = 1% beam of 10^6 π^- per second was provided by the P^3 line of the Los Alamos Meson Physics Facility, and a cell of 910 mg/cm^2 liquid ^{4}He with windows of 18 mg/cm^2 Kapton served as the target [15]. An

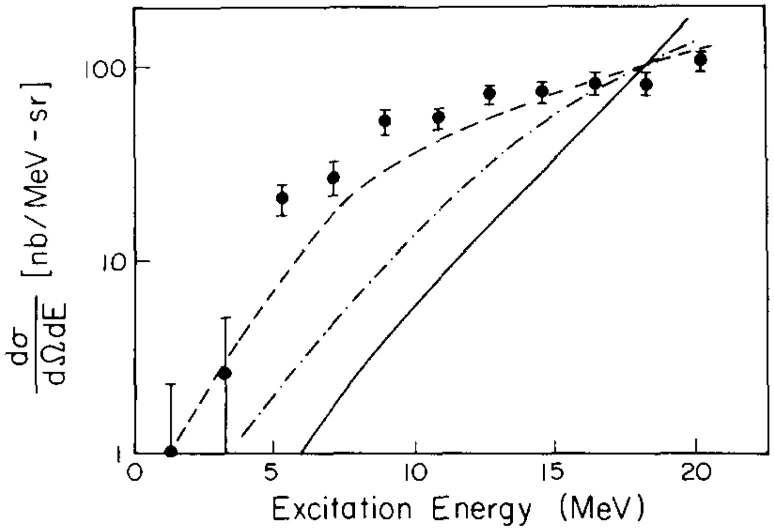
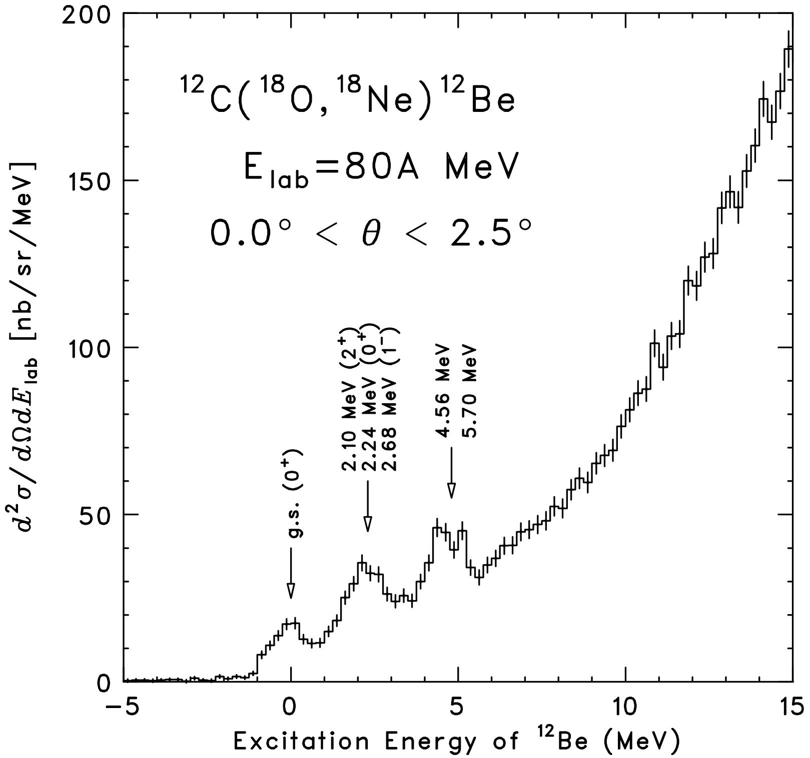


Fig. 3. The experimental results are plotted against the excitation of the final four-neutron state. The solid curve corresponds to the pure four-neutron phase space, while the dot–dashed and dashed curves are the four-neutron phase space curves with singlet state interactions in, respectively, one and both of the final state neutron pairs.

J.E. Ungar et al., PLB 144 (1987) 333

Double charge exchange (DCX) reaction of HI



^{12}C -> ^{12}Be

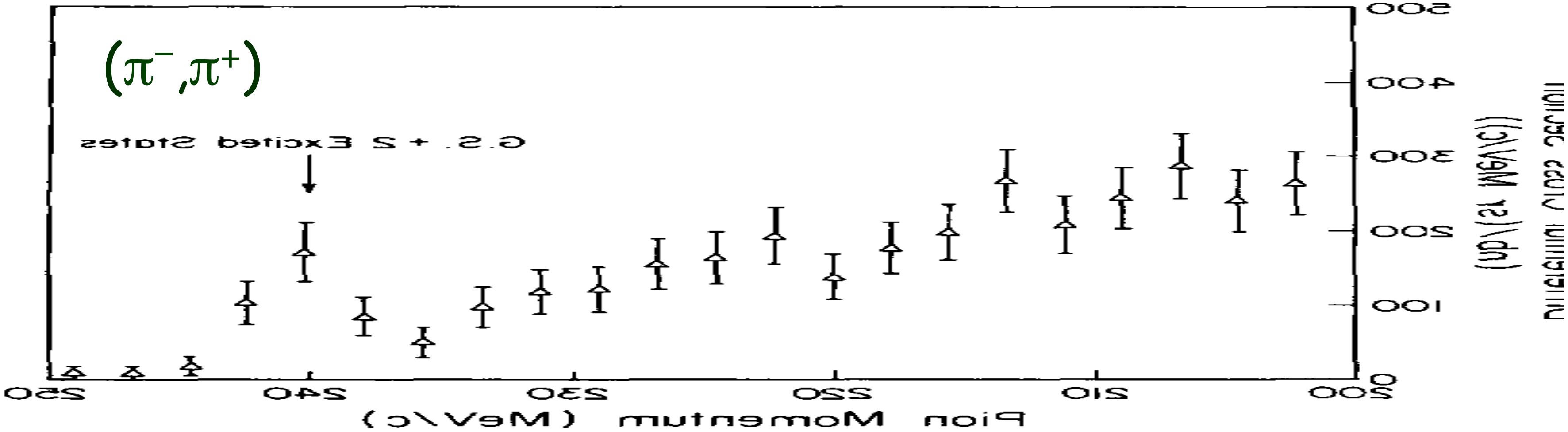
Stable ^{18}O beam (80A MeV)

(Takaki et al.)

~70nb/sr (Gnd)

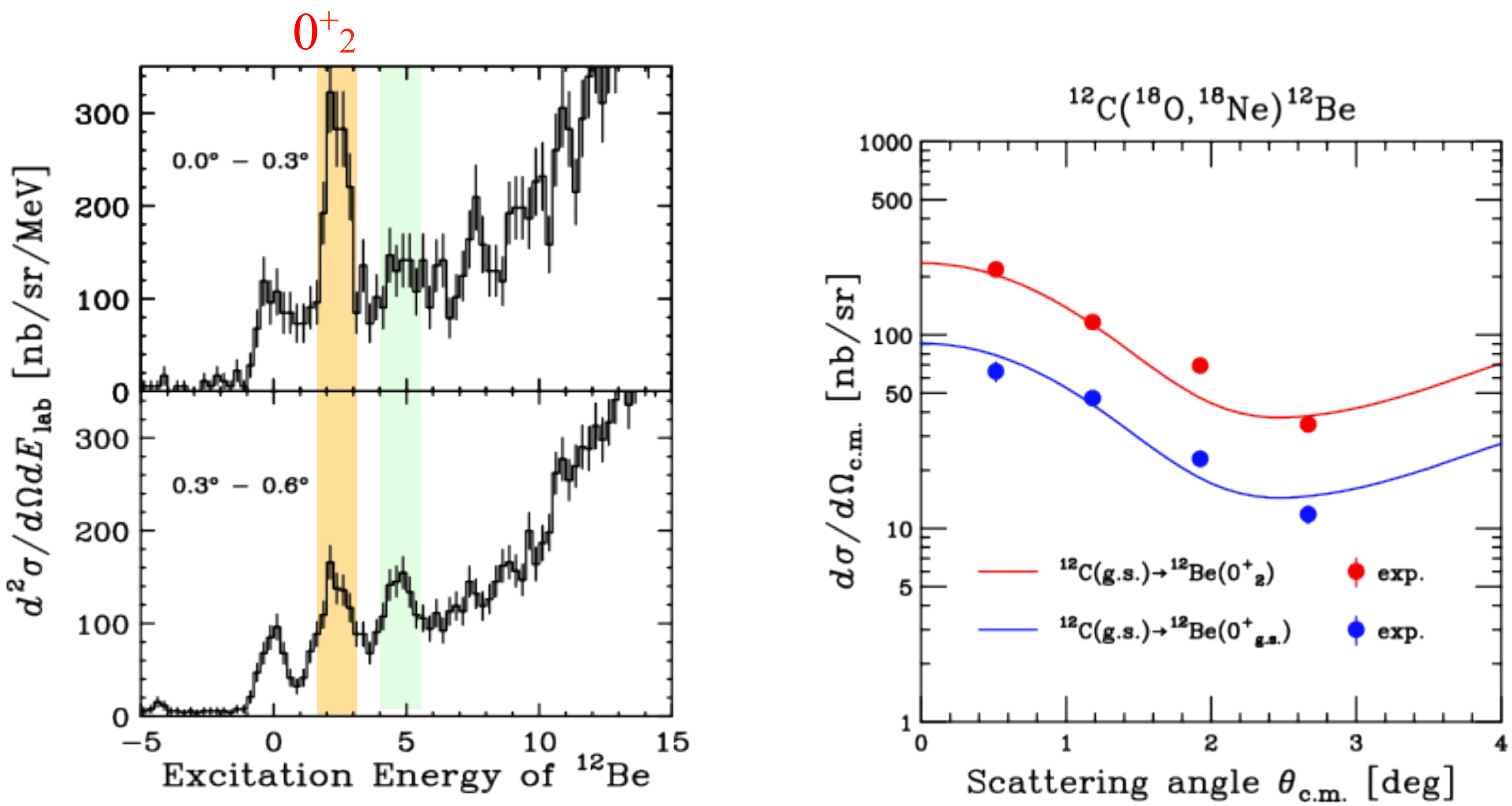
~200nb/sr (~2MeV)

HI DCX reaction can be used for spectroscopy for exotic nuclei (q is not so small >80 MeV/c)

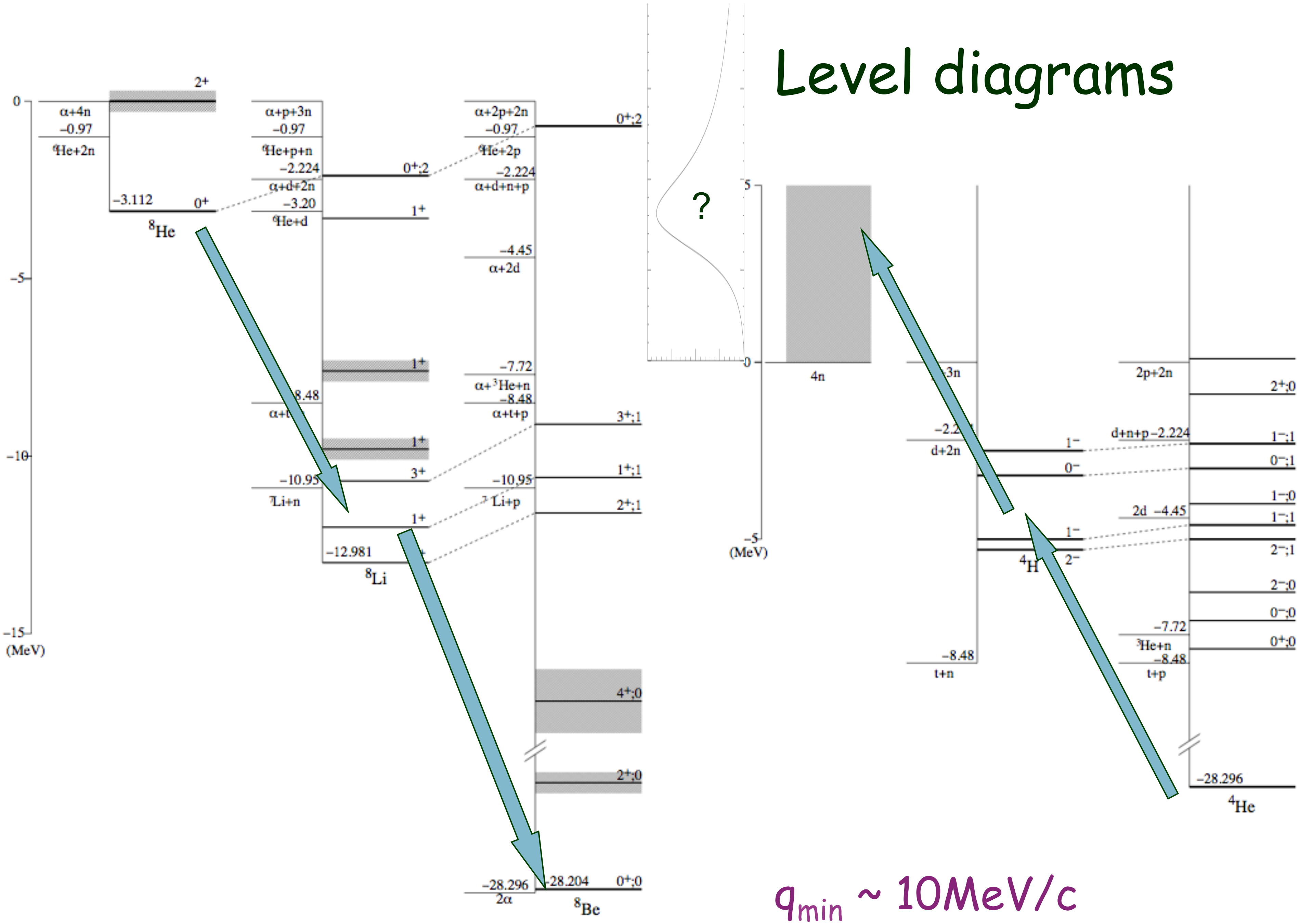


$^{12}C(^{18}O,^{18}Ne)^{12}Be$ @ 80A MeV [RCNP]

- Angular distribution is consistent with two-step GT transition for Gnd and 2-MeV peaks



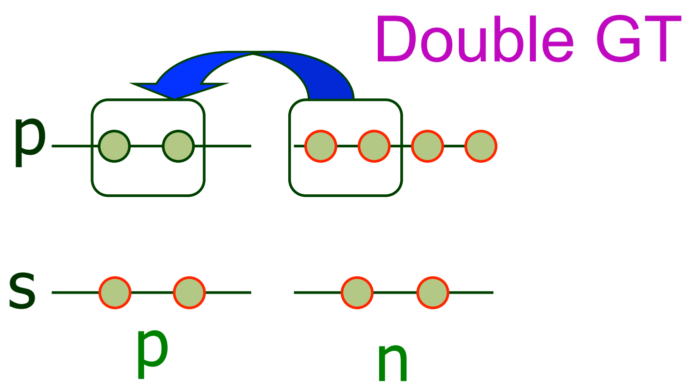
Level diagrams



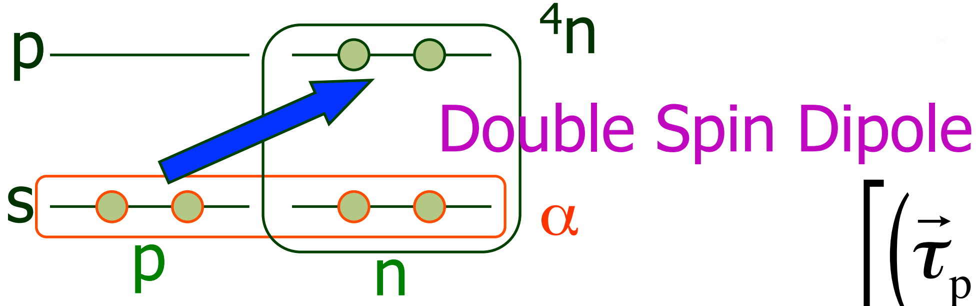
$q_{min} \sim 10 MeV/c$

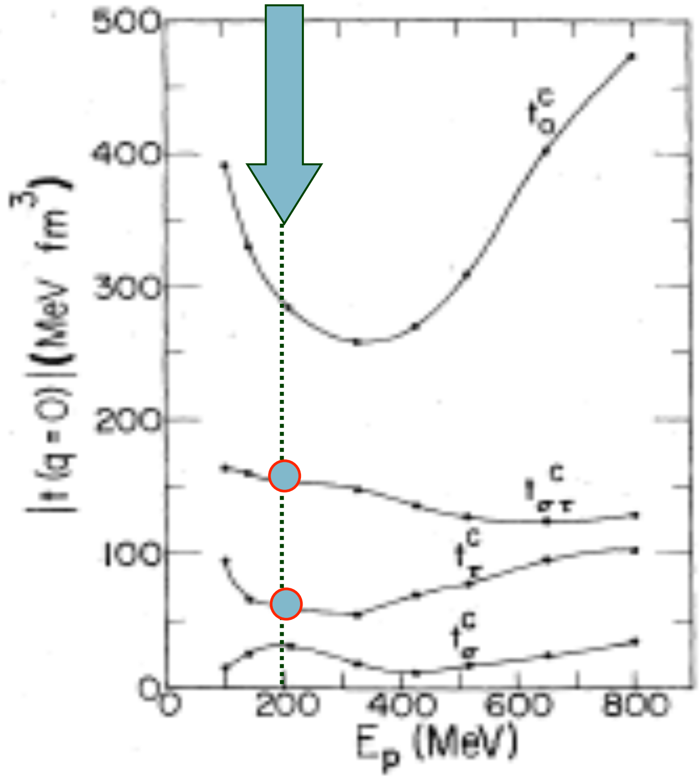
Reaction Mechanism

^{8}He → ^{8}Be



^{4}He → 4n

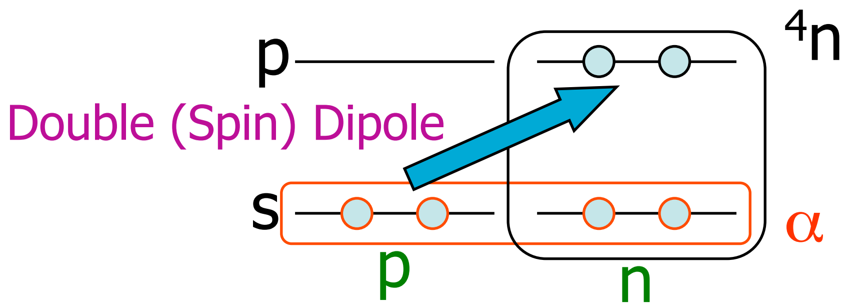


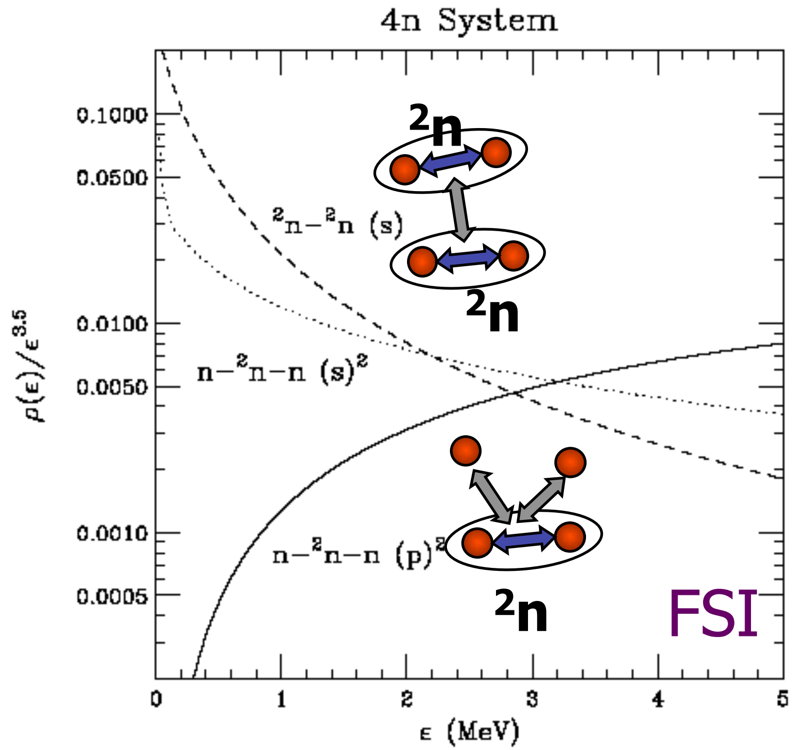


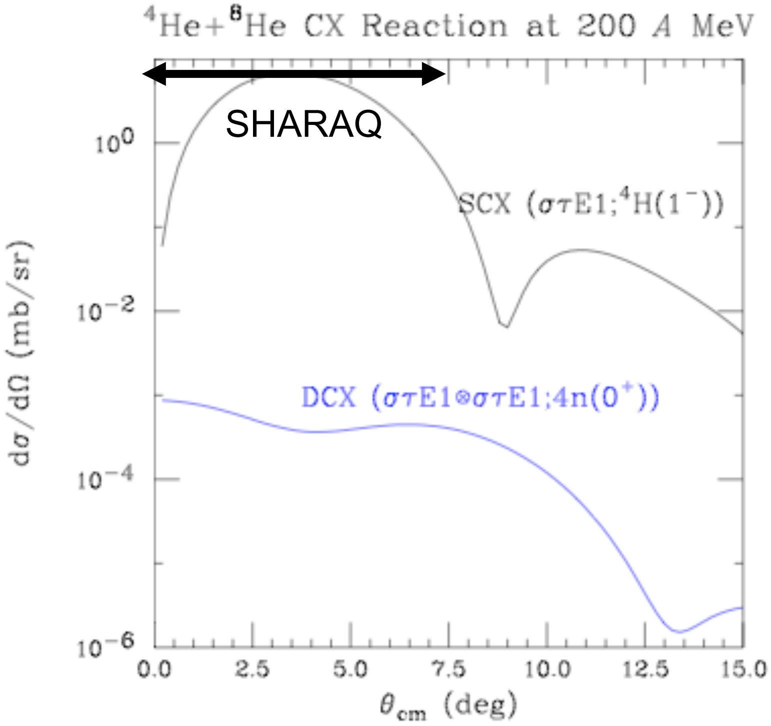
$$\left[\left(\vec{\tau}_{\mathrm{p}}\cdot\vec{\tau}_{\mathrm{t}}\right)\left(\vec{\sigma}_{\mathrm{p}}\cdot\vec{\sigma}_{\mathrm{t}}\right)r_{\mathrm{t}}Y_{1}\left(\hat{r}_{\mathrm{t}}\right)\right]^{2}$$

Multi-neutron system

$^4He(^8He,^8Be)^4n$



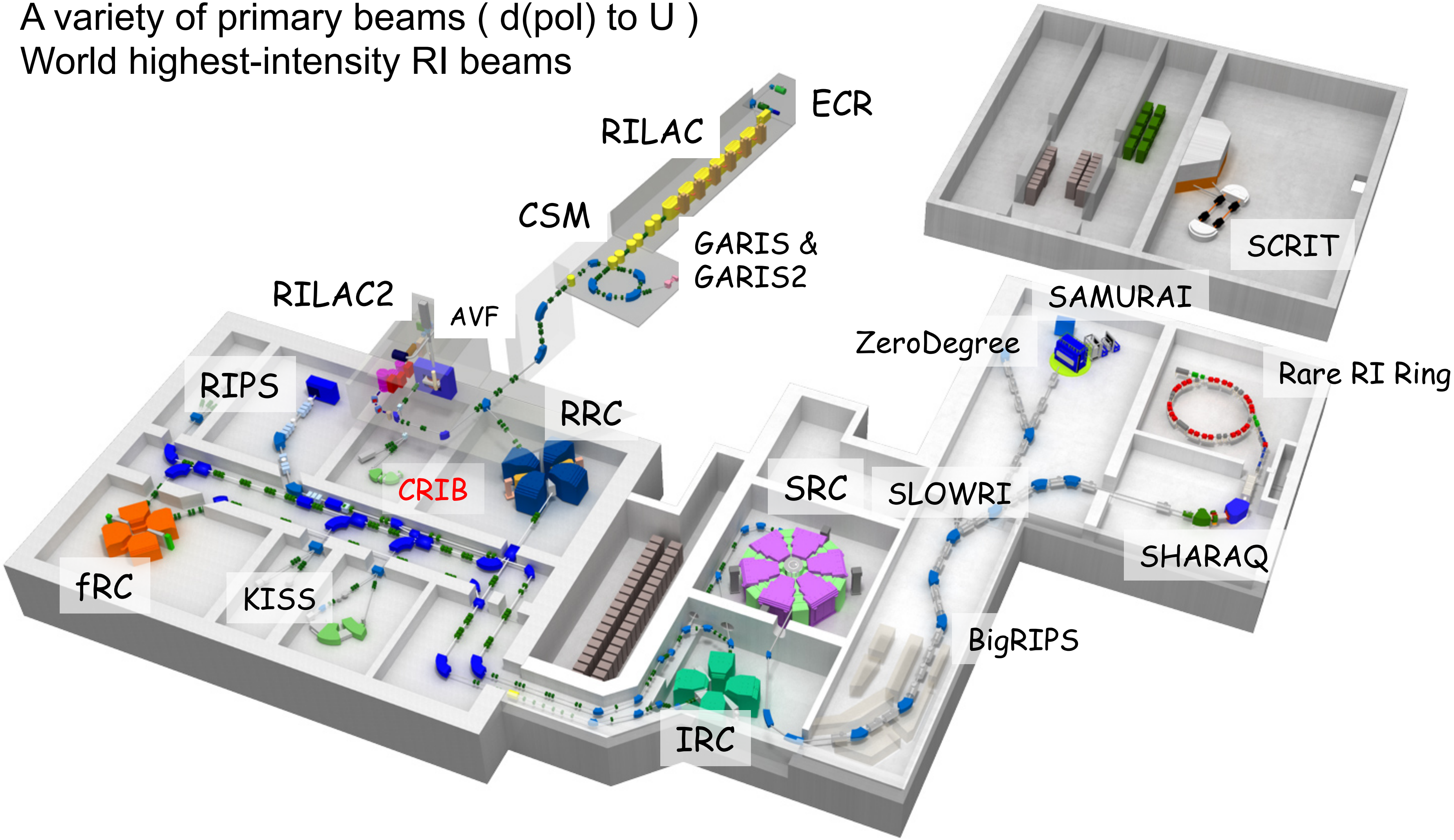




- Optical potential: Double Folding
  [PRC 82 (2010) 044612]
- Microscopic FF

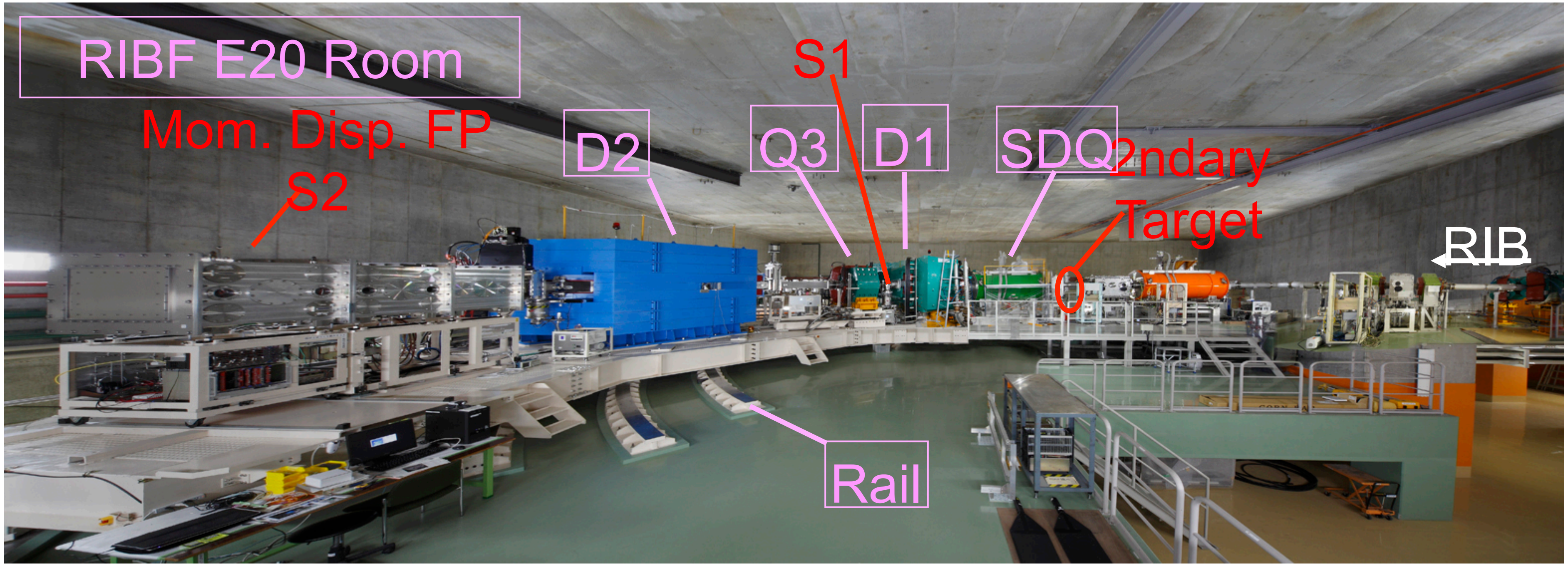
RI Beam Factory at RIKEN

3 injectors + cascade of 4 cyclotrons
⇒ several to 345 MeV/nucleon
A variety of primary beams (d(pol) to U)
World highest-intensity RI beams



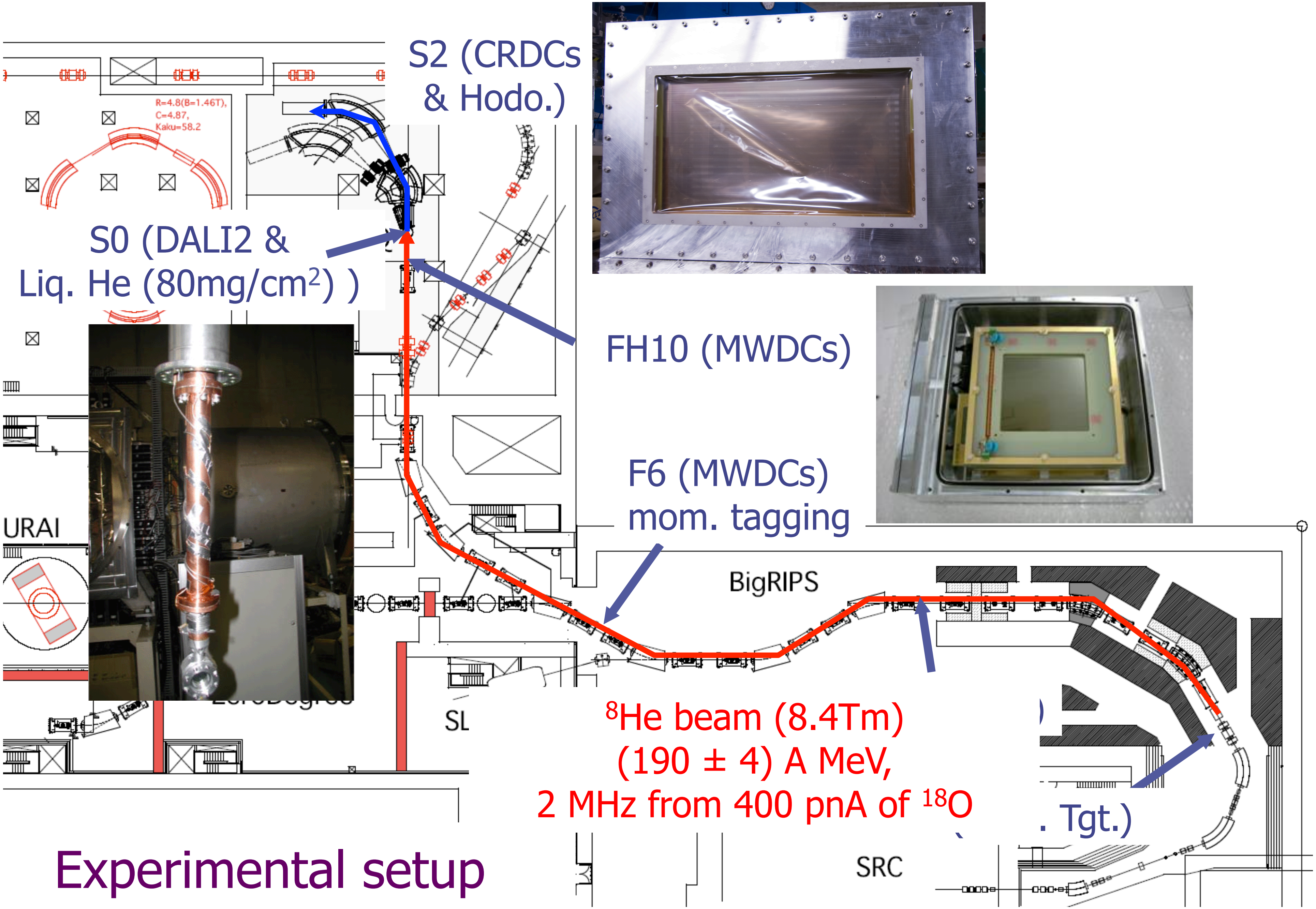
SHARAQ spectrometer

T. Uesaka et al.,
NIMB B **266** (2008) 4218.

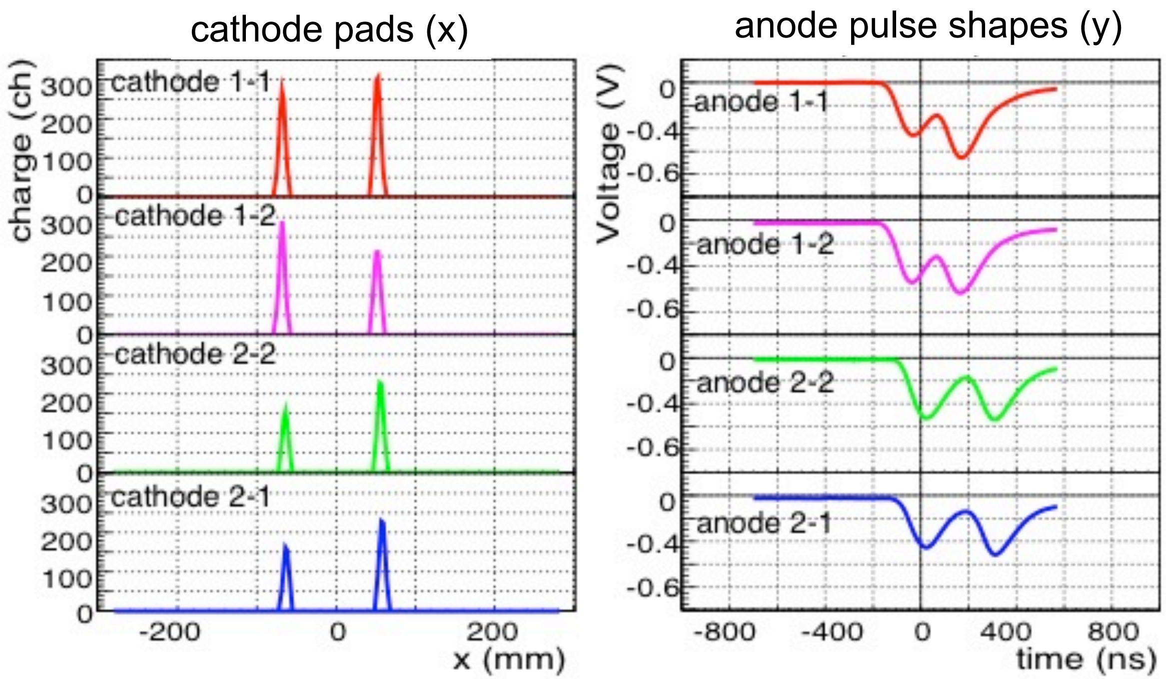


Maximum rigidity	**6.8 Tm**
Momentum resolution	**d*p*/*p* = 1/14700**
Angular resolution	**~ 1 mrad**
Momentum acceptance	**± 1%**
Angular acceptance	**~ 5 msr**

CNS 銀杏 ICHOR

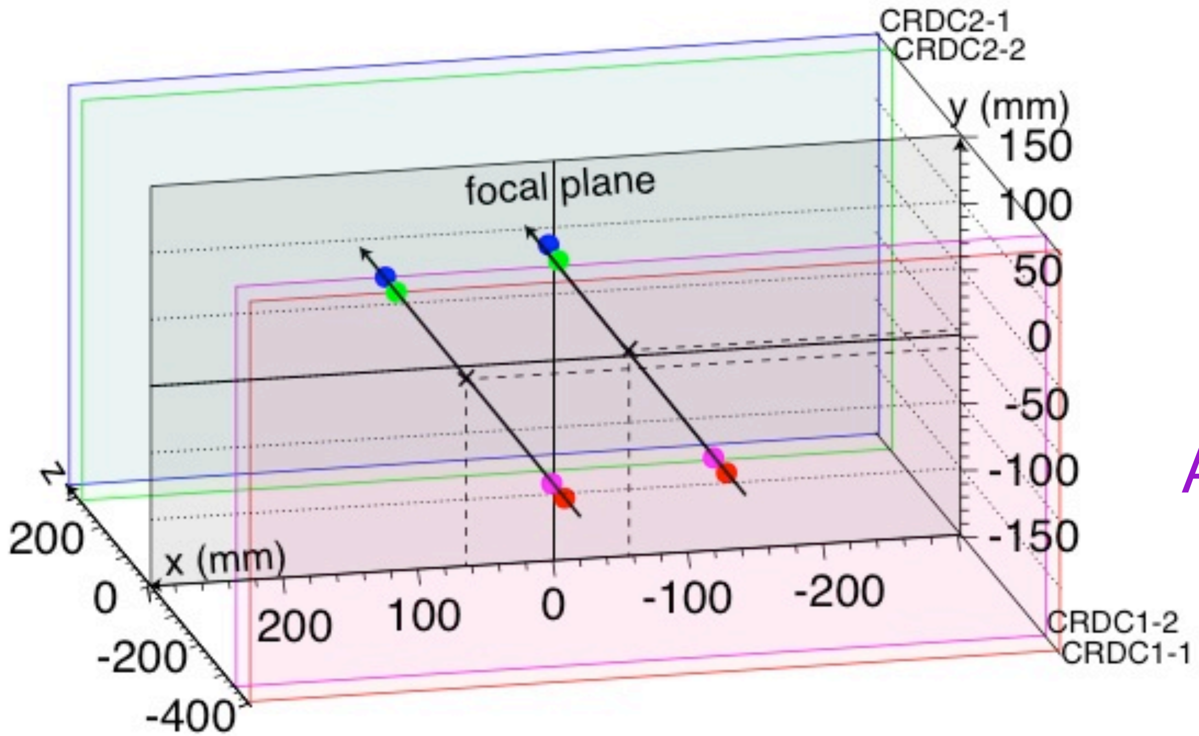


Experimental setup



Display of 2α event at SHARAQ focal plane (S2)

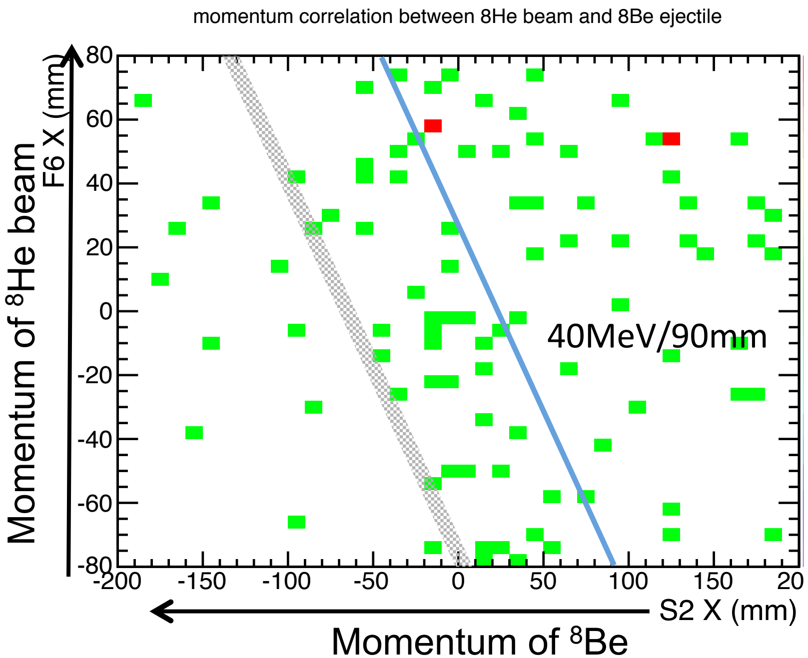
$^{4}He(^{8}He,^{8}Be(\rightarrow 2\alpha))4n$ @ 190 A MeV

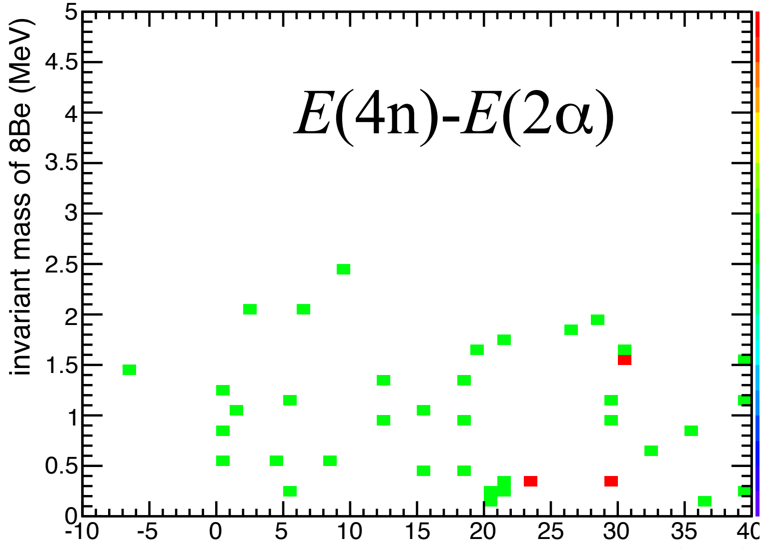


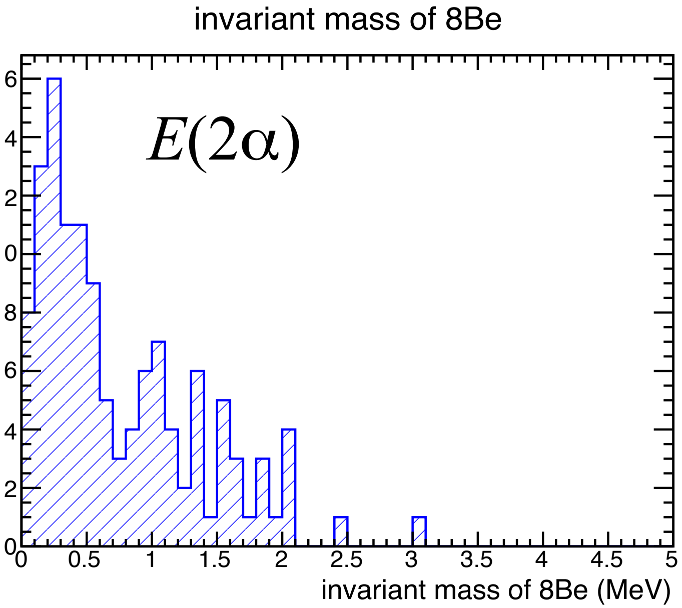
Several hundreds of 2α were accumulated

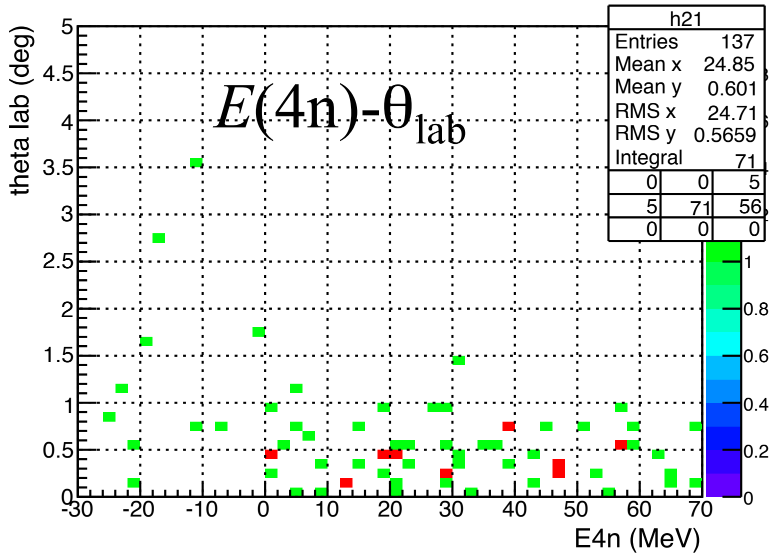
Analysis is in progress

Preliminary data (absolute scale has systematic error)

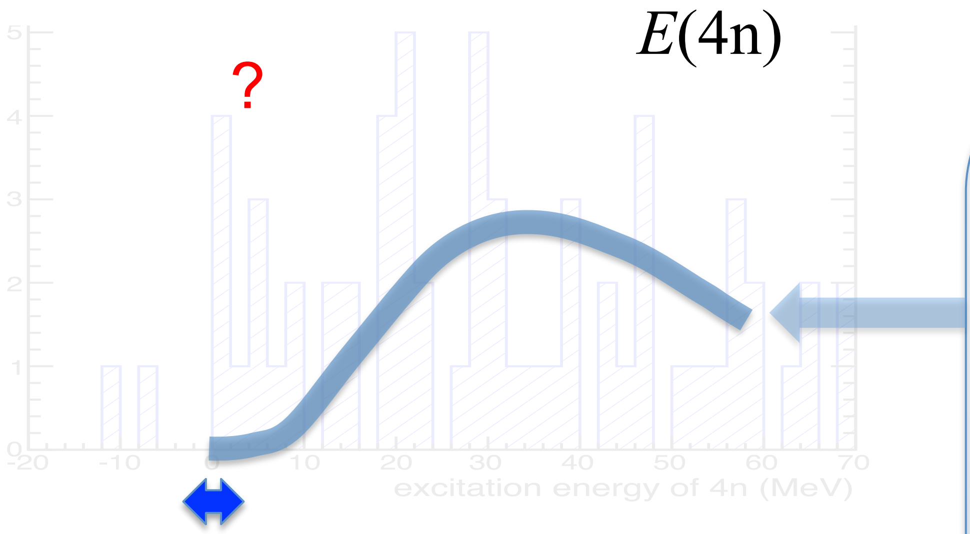








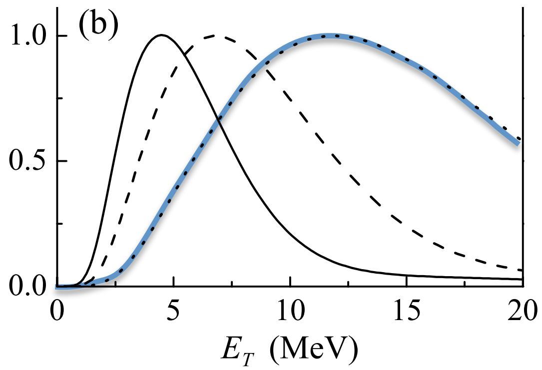
Preliminary missing mass data & discussion

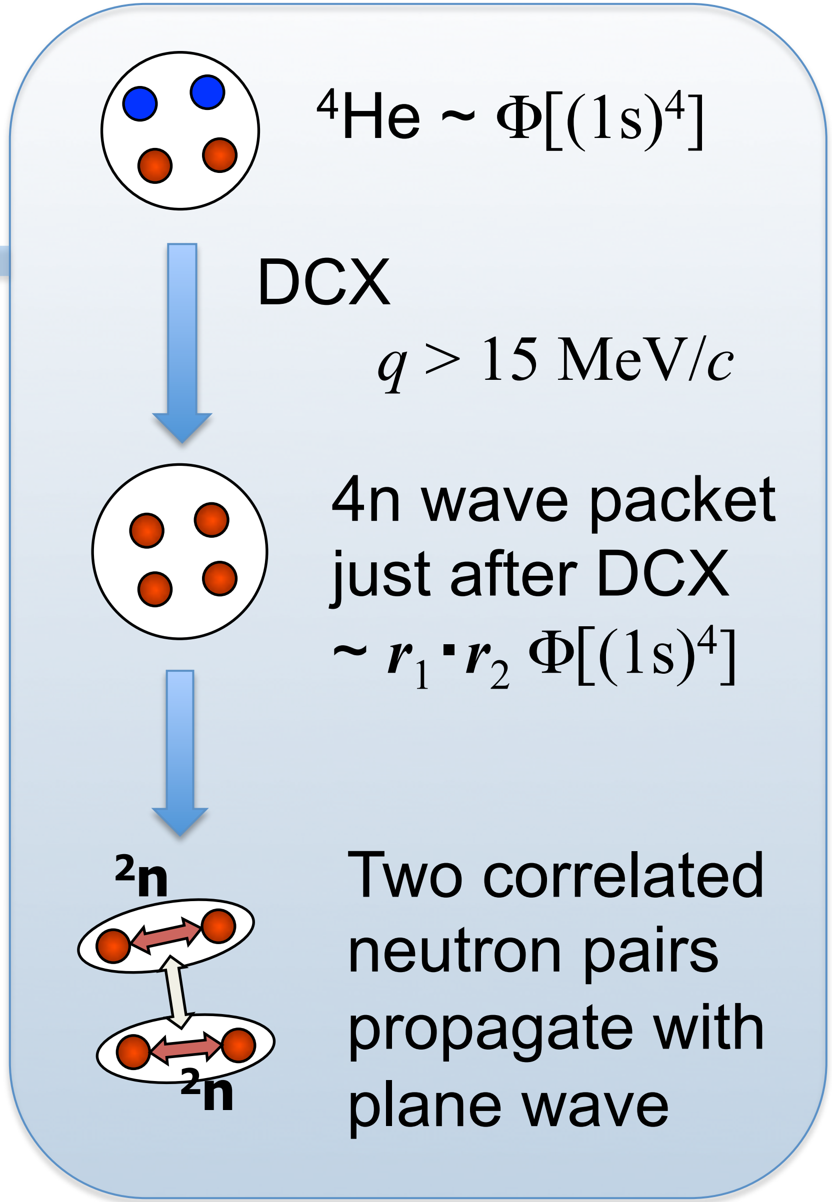


Continuum spectrum from Gaussian wave packet with n-n FSI

Fig. 2(b) of L.V. Grigorenko, N.K. Timofeyuk, M.V. Zhukov, Eur. Phys. J. A 19, 187-201 (2004)

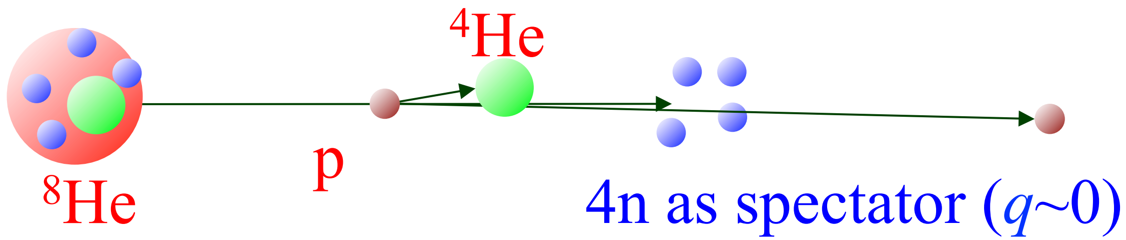
source size=8.9fm 7.3fm 5.6fm

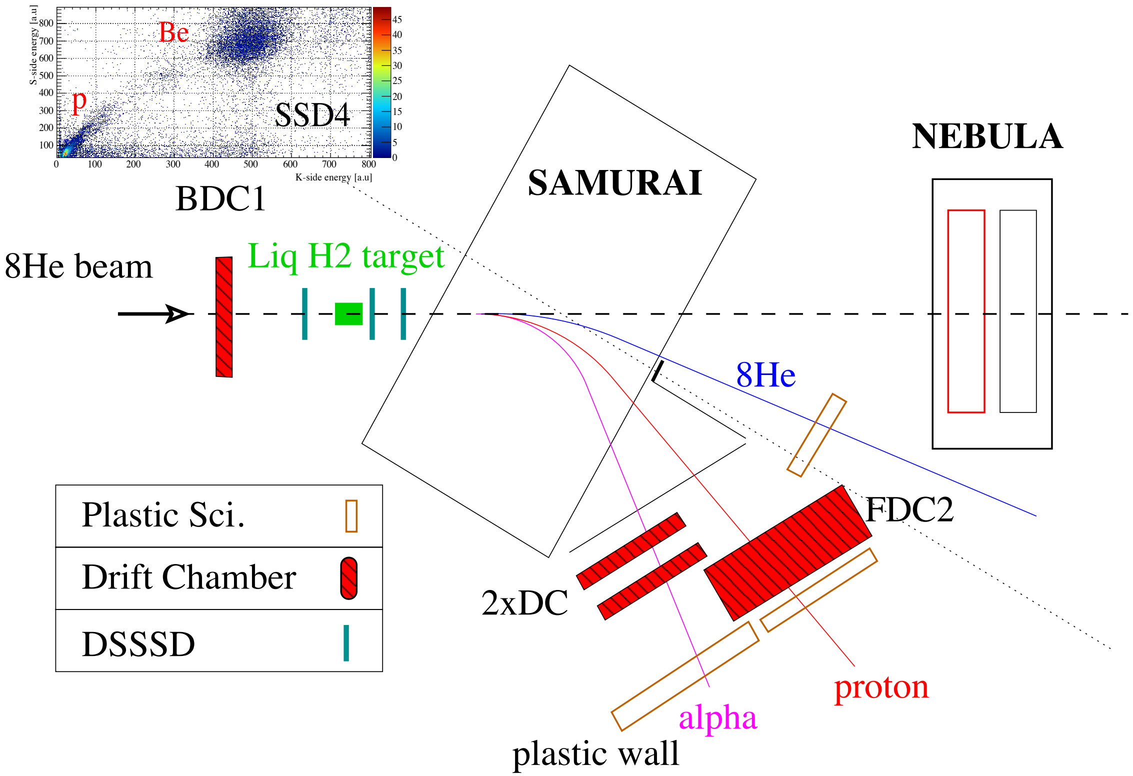


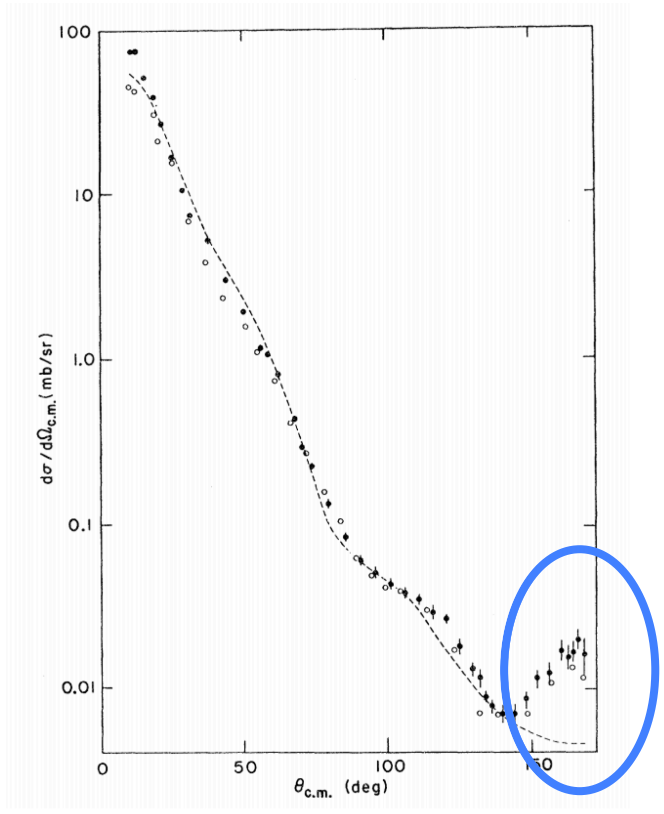


Investigation of the 4n system at SAMURAI by measuring (p,pα) quasi-free scattering at large momentum transfer in complete kinematics

S. Paschalis (TUD) for SAMURAI collab.

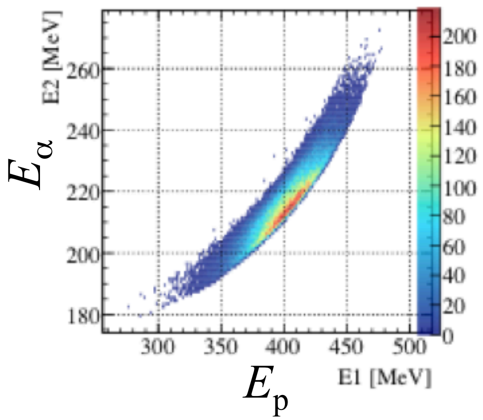


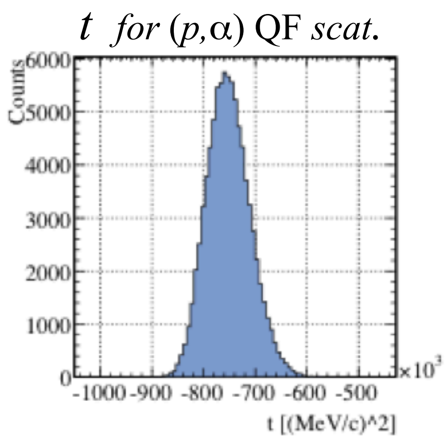


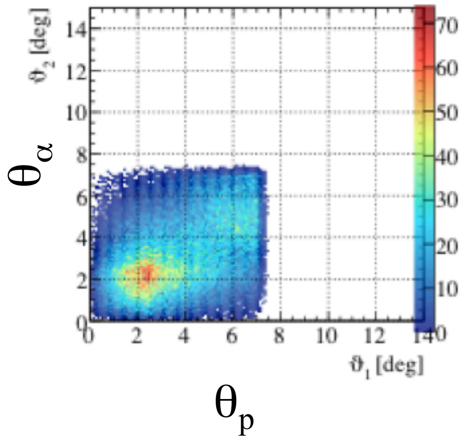


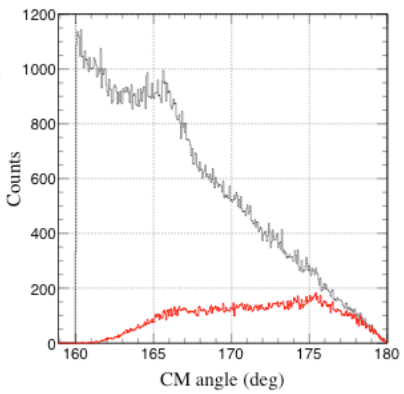
p-⁴He elastic differential cross section at 156 MeV.

Simulation



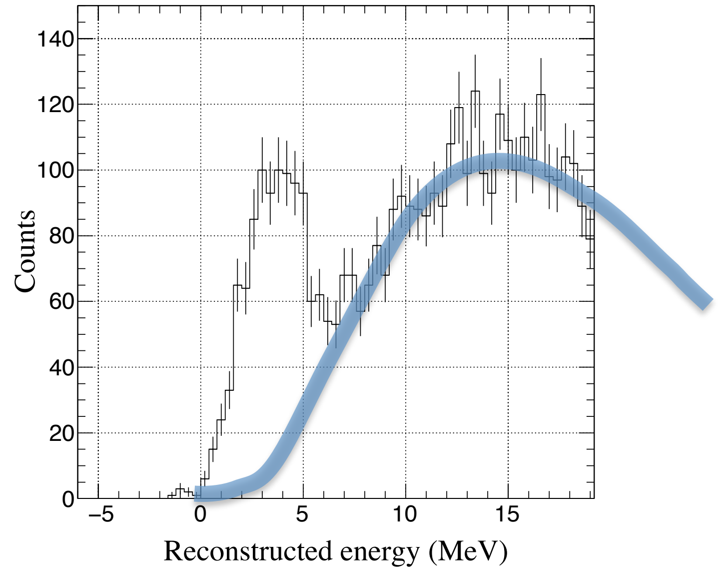






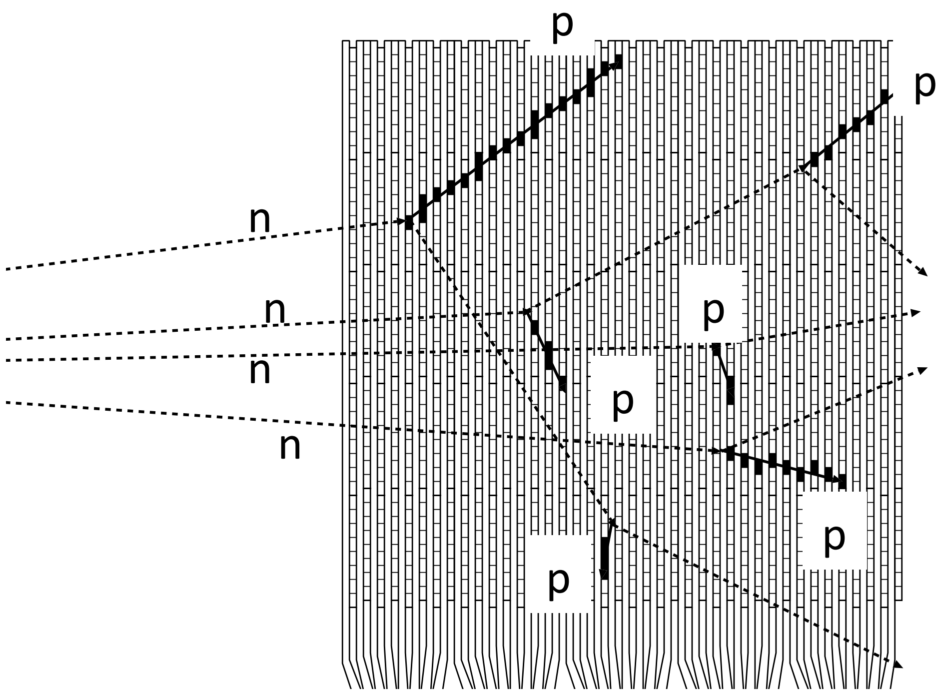
7deg^H×2.5deg^V

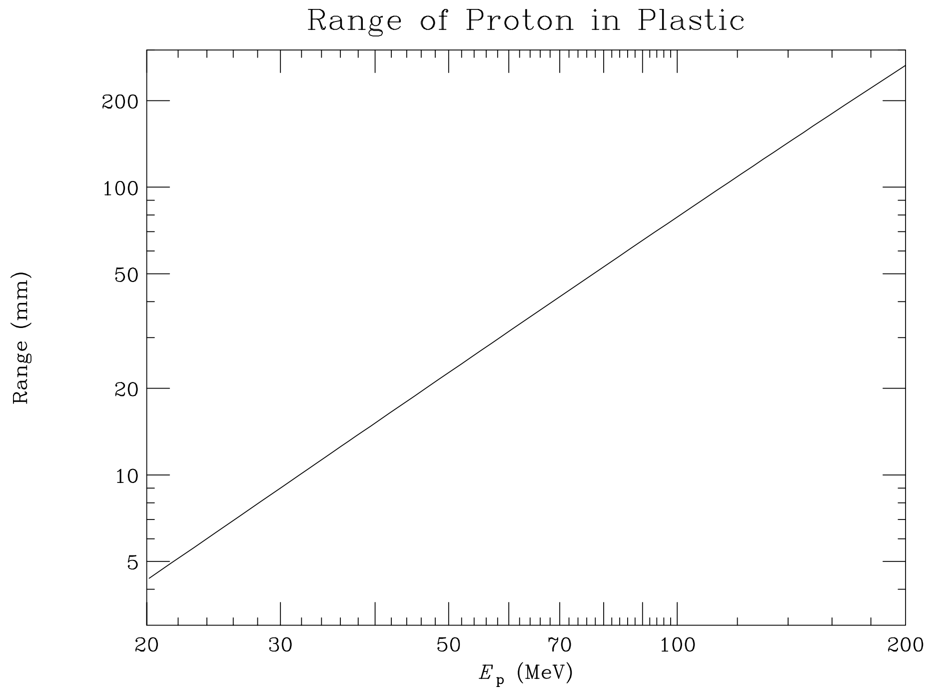
Expected Mass spectrum



Reconstructed energy spectrum for an assumed resonance at 3.5 MeV with a width of 3.5 MeV plus a broad contribution of 70% non-resonant background
(4n source size is much larger than that in DCX)

Direct measurement of multi-neutrons
Multi-neutron tracker



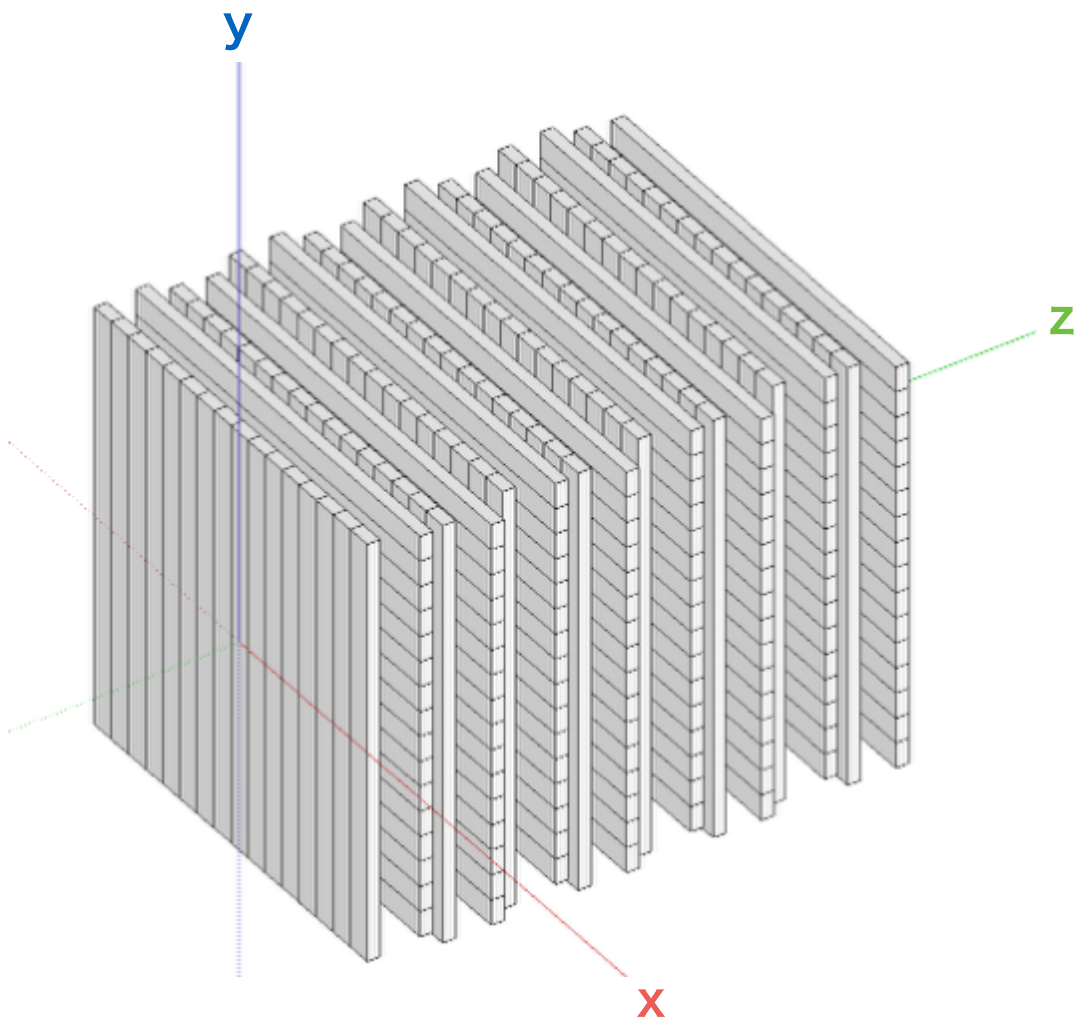


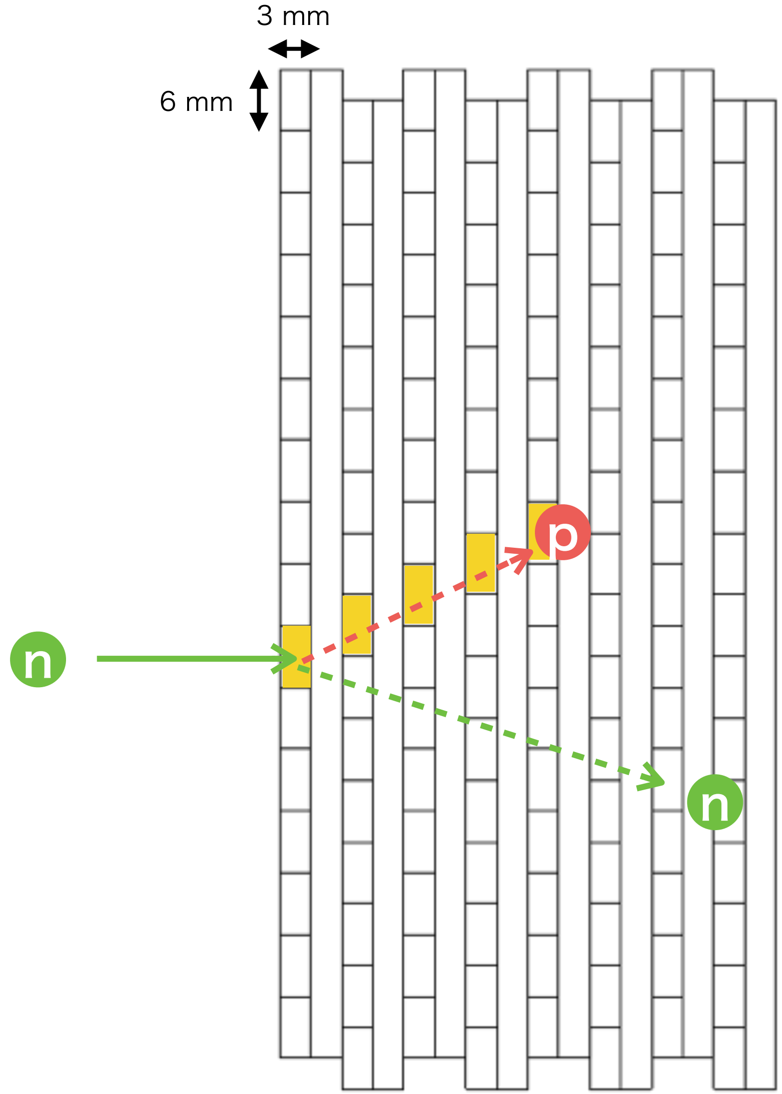
Range of proton above 30 MeV > 9mm

Tracking of recoil protons -> identification of cross talk from a single neutron

Present design

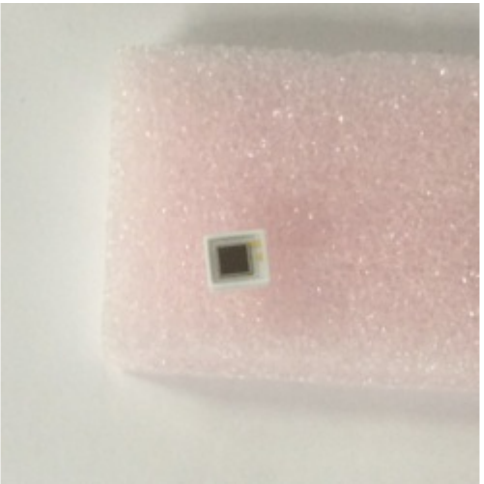
X-Y-X'-Y'-X-Y-X'-Y'- … with gap or X-T-Y-T-X'-T-Y'-T- …

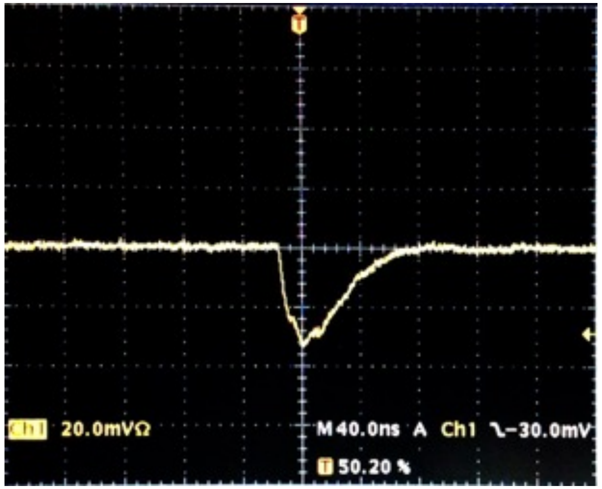


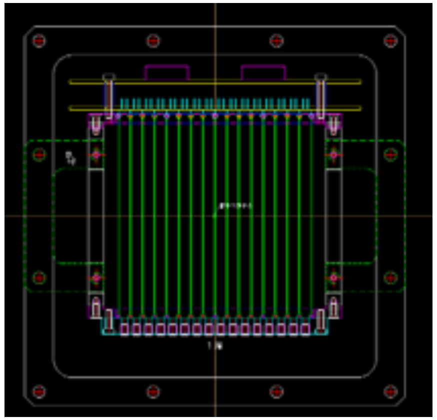
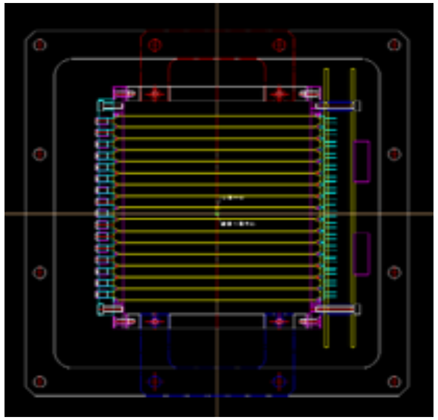
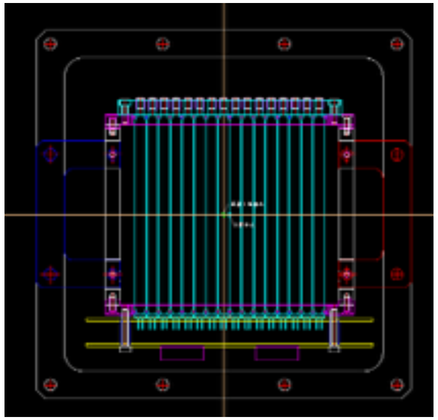
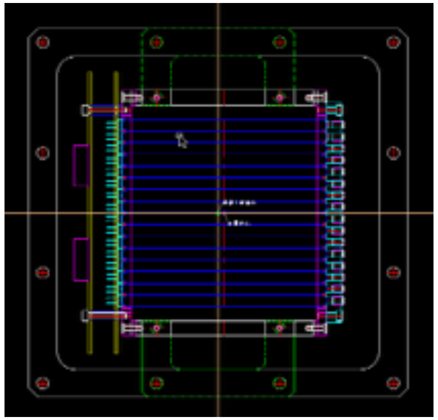


Prototype module (micro-hodoscope)

- $3^{t}\times 6^{w}\times 100^{l}$ mm^3 plastic scintillator (BC408) × 16
- MPPC (S12572) for sensing scintillation
- Supporting frame for Four micro-hodoscopes

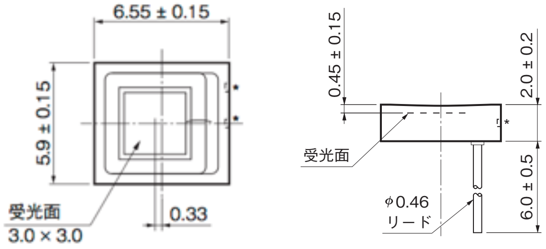




MPPC（Multi-Pixel Photon Counter）

シンチレーション光の読み出しに使用するMPPC（S12572-050C）について



特徴

- 高い増幅率
- 優れた時間分解能
- 小スペース
- 磁場の影響を受けない
- 低電圧で動作

構成

受光面サイズ	3 × 3 mm
ピクセルピッチ	50 μm
ピクセル数	3600
窓材屈折率	1.59

電気的および光学的特性

感度波長範囲	320 ~ 900 nm
最大感度波長	450 nm
検出効率	35 %
時間分解能	250 ps
端子間容量	320 pF
増幅率	1.25×10^6

Readout (under consideration)

Hit / Charge / Timing

- TDC (V1290) from “pulse-width over threshold” or “QTC” signal
    - Delay-line readout may be used (if “timing planes” are introduced)
- Timing plane without segmentation (100×100 mm^2) for better timing resolution