The search for the η'-mesic nuclei in the LEPS2/BGOegg experiment

N. Tomida (RCNP, Osaka Univ.)

2018/Nov/13

QNP2018, Tsukuba

η'-nucleus optical potential

$$U(r) = (V_0 + iW_0) \times \frac{\rho(r)}{\rho_0}$$

$V_0 = \Delta m_{\eta'}(\rho_0)$: η' mass shift

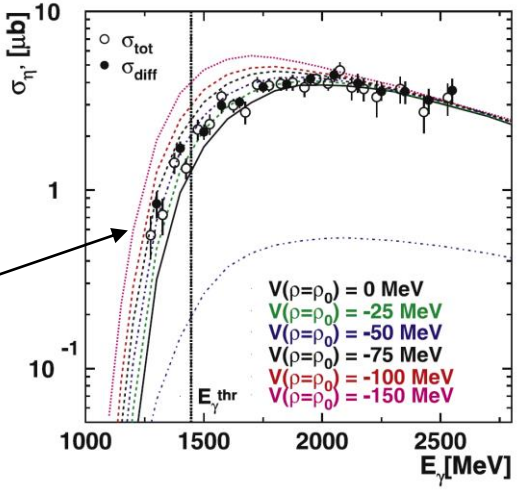
$W_0 = -\Gamma(\rho_0)/2$: η' absorption

Theory

- NJL model : V_0 = 150 MeV
  (PRC 74 (2006) 045203)
- linear sigma model : V_0 = 80 MeV
  (PRC 88 (2013) 064906)
- QMC model : V_0 = 37 MeV
  (PLB 634 (2006) 368)

Experiment

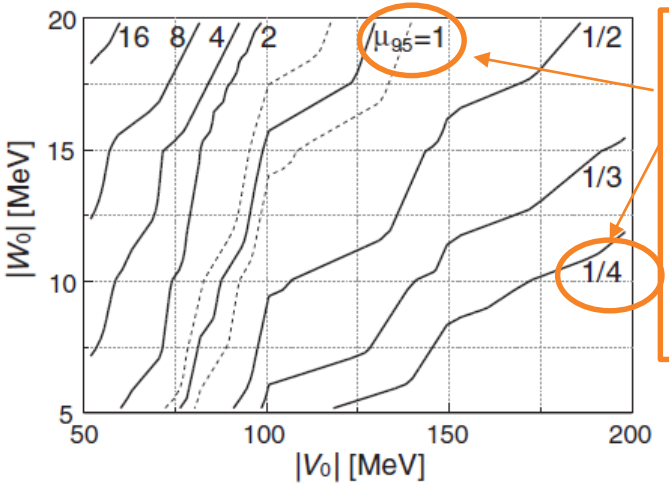
- CB-ELSA
  $\gamma^{12}C \rightarrow \eta' X$ (PLB 727(2013)417)
  unbound



Comparison with theoretical calculation

$V_0 = 39 \pm 7(stat) \pm 15(syst)$ MeV

- GSI no PID
  $p^{12}C \rightarrow d X$ (PRL 117(2016)202501)



Depending on the scale of the theoretical cross section calculation

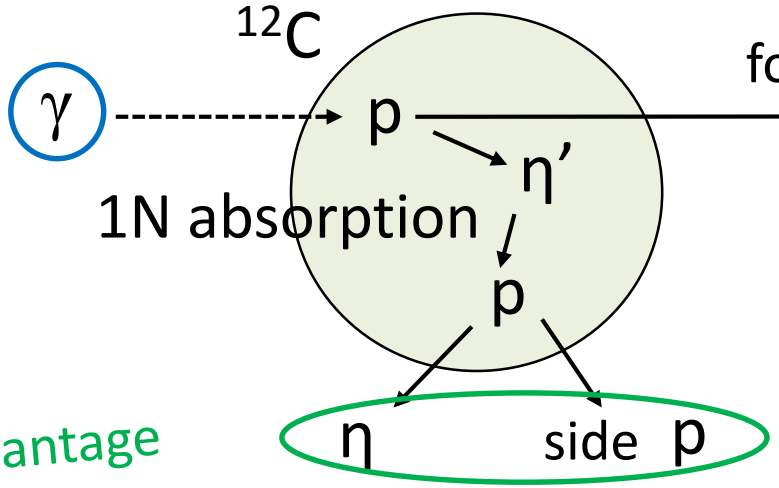
(pn->dη' cross section is not known)

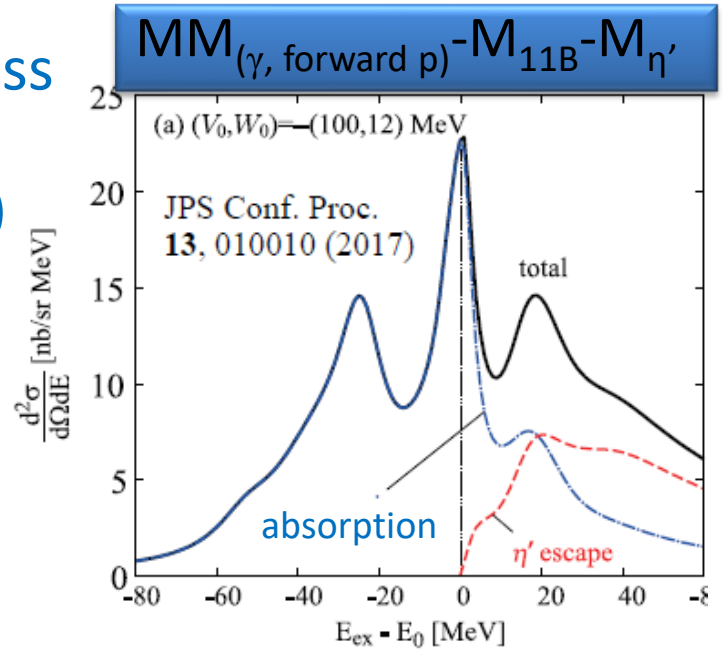
Upper limit

What we do

- η'-mesic nuclei search by MM(γ,p) @LEPS2 using BGOegg

- γ + ^{12}C -> η'⊗^{11}B + p





Advantage

- Tag decay product =

back-to-back ηp pair from 1N absorption of **bound (stopped) η'**

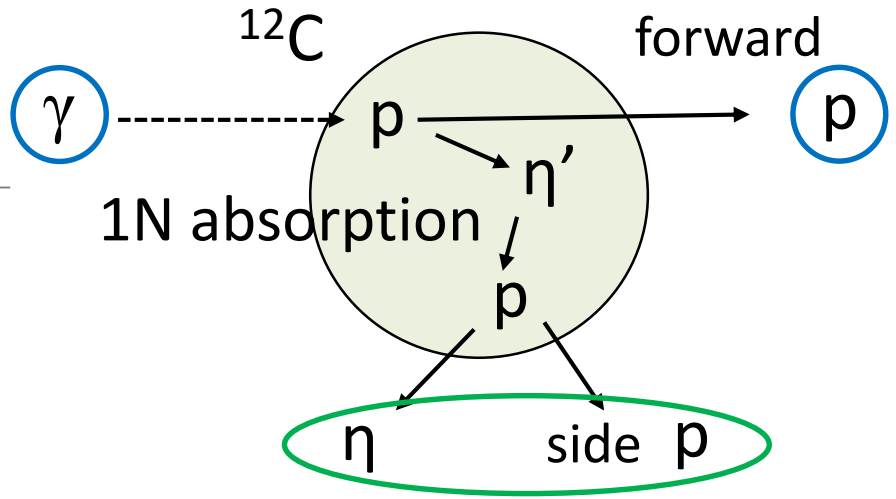
- MM resolution : 12~30 MeV => Cannot see "peak structures"

=> Compare yield below threshold with the theoretical calculation

- Data taken in 2015 (8.0x10^{12} photons)
- Blind analysis [mask : -100 < $MM_{(\gamma, \text{forward p})}$-$M_{11B}$-$M_{\eta'}$ < 100 MeV]

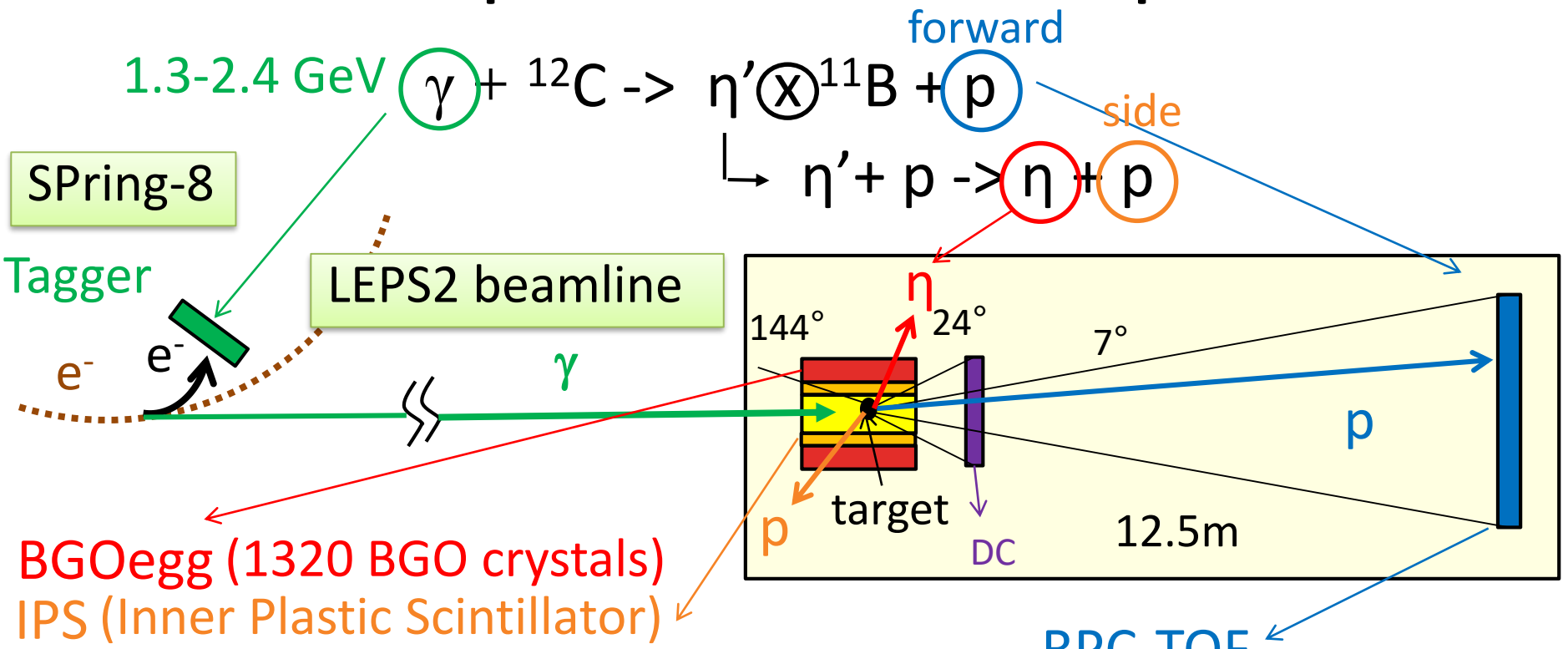
Contents

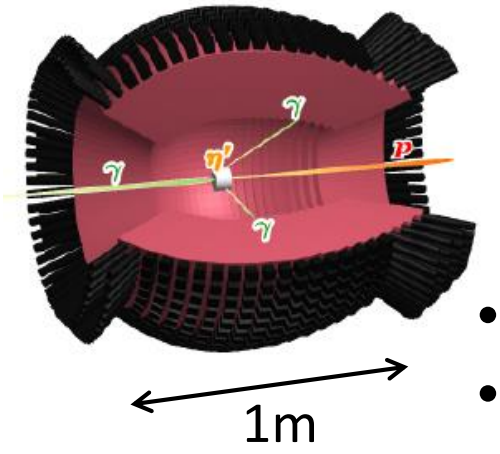
- η'-nucleus optical potential
- What we do



- Experimental set up
- η, side p selection cuts
  - Particle identification cuts
  - Kinematical cuts
    - Signal selection cuts <= from QMD signal simulation
    - BG reduction cut <= η angle
- Expected yield
  - Quasi-free η' data used for normalization of cross section
- 1/3-data (signal region masked)
- Summary

Experimental set up

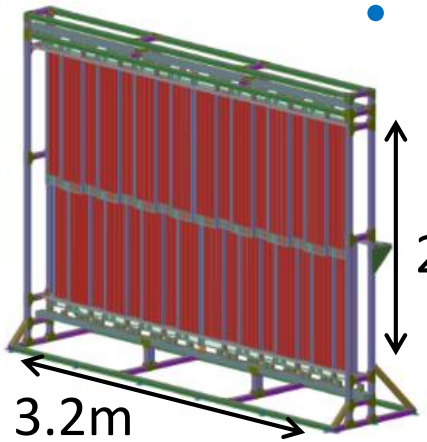




- η -> 2γ (br=39%)
- Side proton
(50 MeV<E_{kin}<250 MeV)

- η' -> 2γ (normalization)
- ηπ^0 (BG study)

RPC-TOF

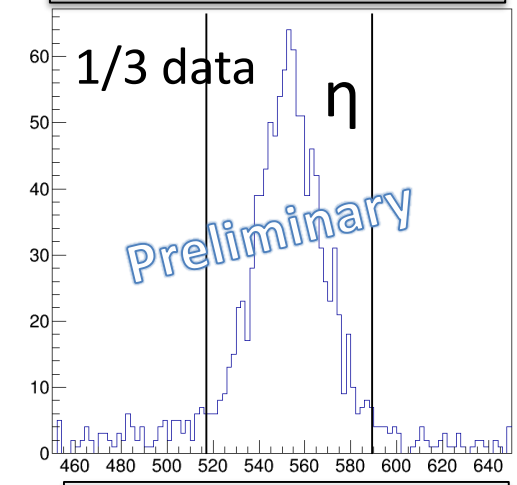


- Forward proton energy

η and side proton selection cuts

Particle identification cut

2γ invariant mass

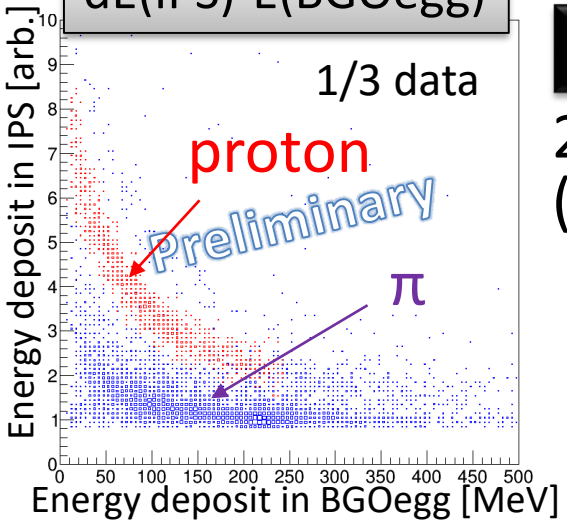


η

Few combinatorial BG

=> Multi π BG is strongly suppressed

dE(IPS)-E(BGOegg)



side proton

2 protons (forward, side)

=> BG from primary reactions is suppressed

Kinematical cut

Remaining BG :
reaction emitting
η + side p + forward p

- γpp->ηpp
- γp->πηp, πp->πp
  ηp->ηp
  πpn->pn
- γp->ππp, πp->ηp

Signal selection cut

Select signal kinematics

- η'(stop)p->ηp

BG reduction cut

from BG data

Signal selection cut

QMD (Quantum Molecular Dynamics)

γC->ηX

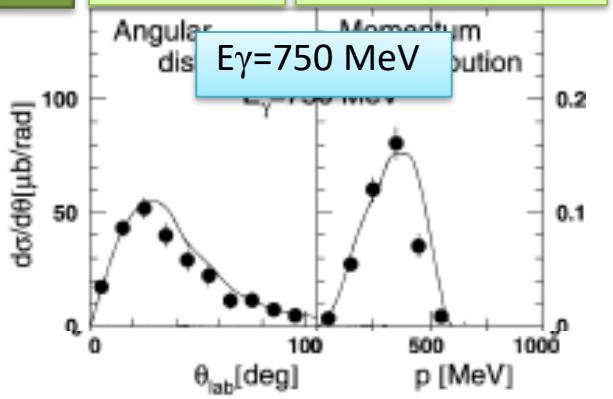
η angle | η momentum

- η, p interaction with nuclei

  experimental data reproduced well
  (PLB 639 (2006) 429)

● data

— QMD



Signal simulation with T. Maruyama

- $\gamma + {}^{12}C \rightarrow N^* + {}^{10}Be + p$
  - $N^* \rightarrow \eta p$

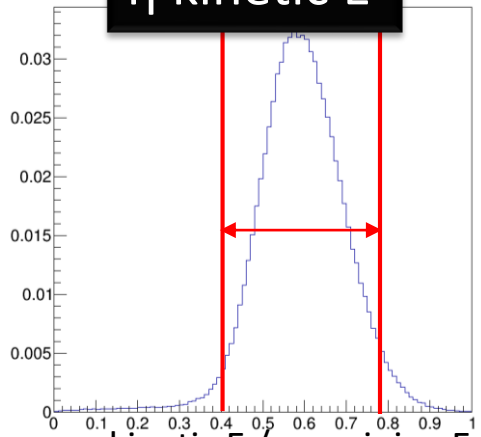
Input : γ, forward p momentum => MM(γ,p)
Remaining momentum is shared by $N^* + {}^{10}Be$ system

=> N* almost at rest => back-to-back ηp

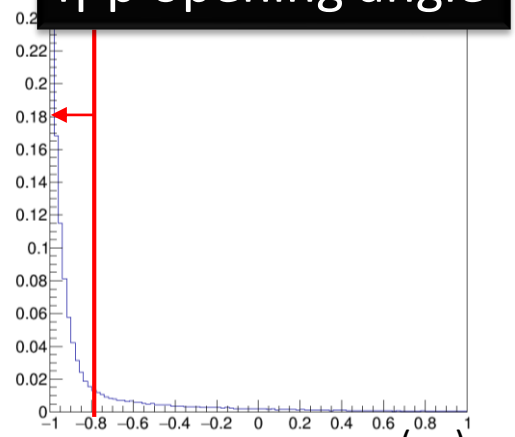
Signal selection cut

- η, p kinetic energy
- ηp opening angle
- ηp invariant mass

η kinetic E



η-p opening angle



ηp escape rate from nuclei

- ~33% (both η,p escape)

Using ratio to “remaining energy”

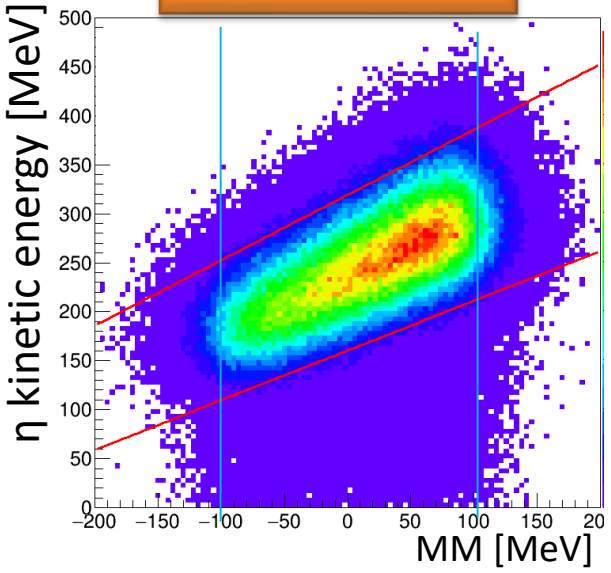
side forward

$\gamma + {}^{12}C \rightarrow \eta + p + X + p$

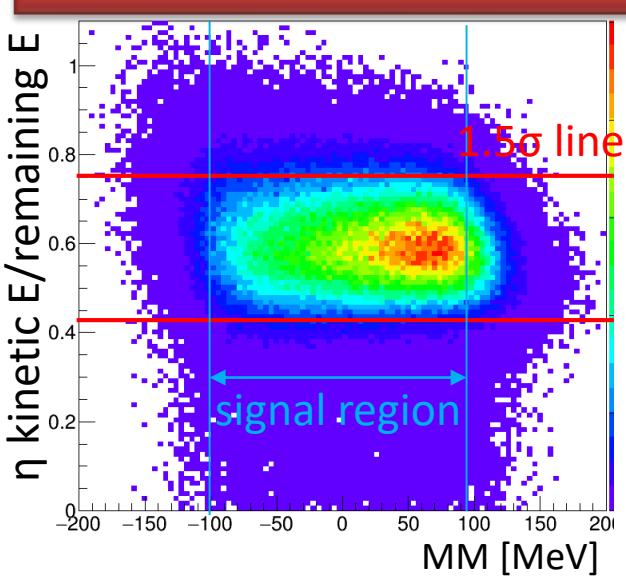
remaining E = $E_\gamma + m_{12C} - m_\eta - m_{side\ p} - m_{10Be} - E_{forward\ p}$

= Available energy for η, side p kinetic energy

η kinetic E



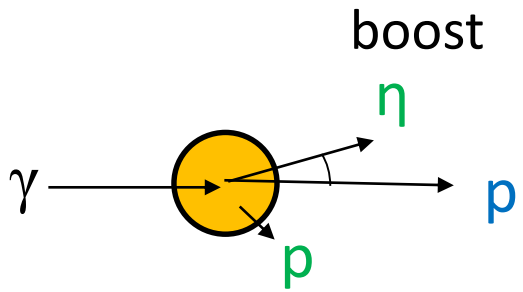
η kinetic E / remaining E



Selection becomes independent on MM

BG reduction cut

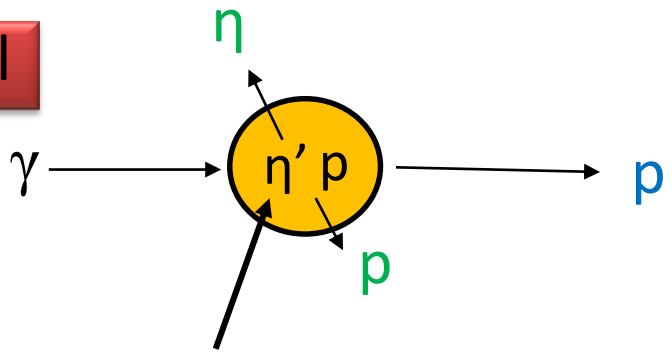
BG



- γpp->ηpp
- γp->πηp, πp->πp or ηp->ηp
- γp->ππp, πp->ηp

- all cases : forward peak η

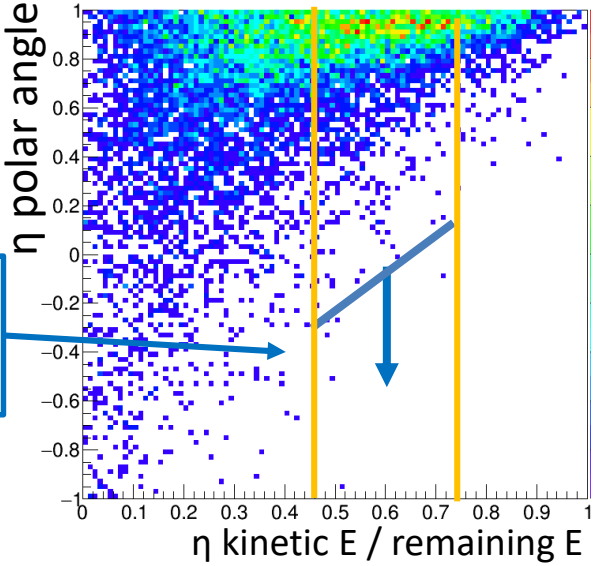
signal



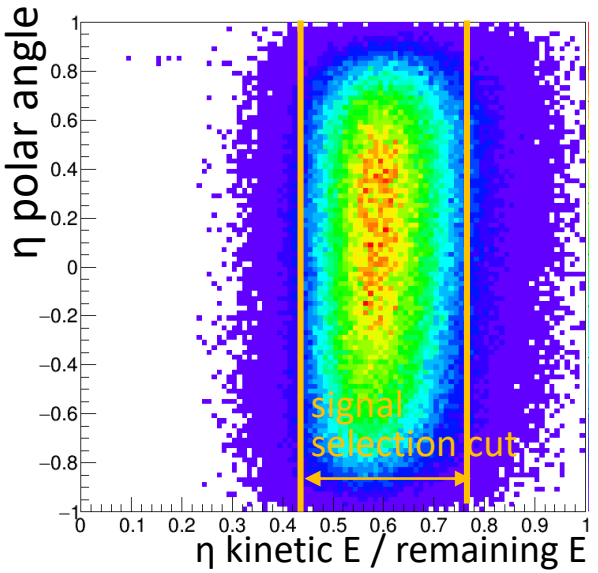
- from **η' at rest**
- isotropic η angle distribution

γC->π^0ηpX data

backward η selection



QMD signal sim.



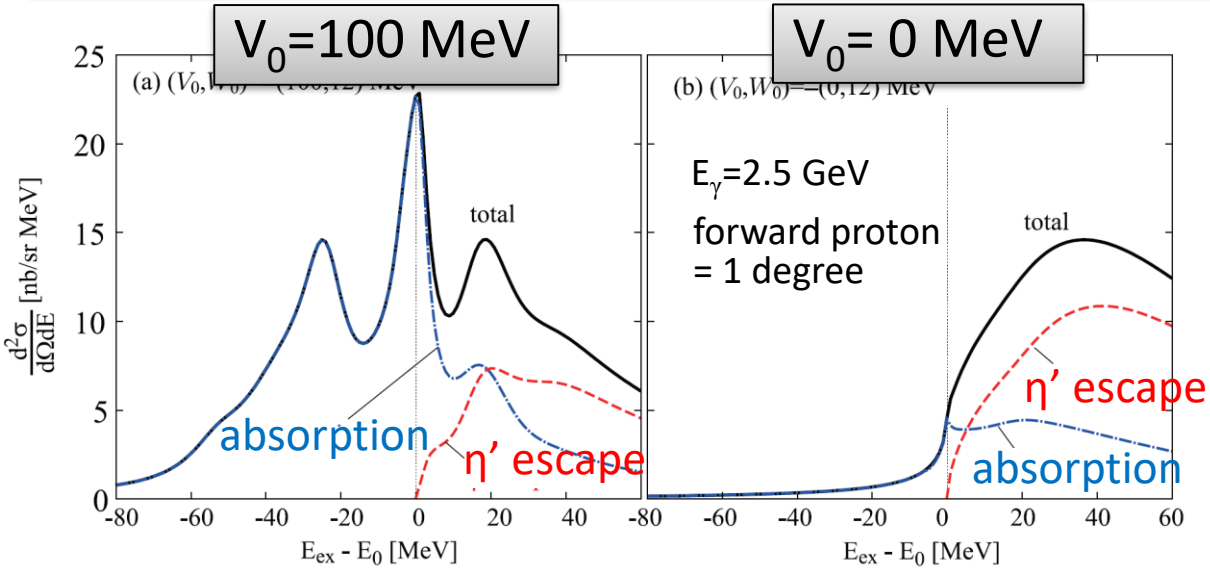
Yield estimation

Nucl. Phys. A 435 (1985) 727

- Calculation using Green's function method (by H. Nagahiro)
  - Normalized by γp->η'p cross section (⇔GSI exp.)

  => Still absolute value of the cross section is not so reliable
- The spectra is separated to absorption and η' escape (quasi-free)
  - absorption { 1N absorption η'N -> πN, KΛ, KΣ, ηN Measure
    2N absorption η'NN -> NN

- Normalize the cross section by η' escape event
- Obtain information of ηp branch (including η,p escape rate from nuclei) from absorption events @ $0<E_{ex}-E_0<60$ MeV



JPS Conf. Proc.
13, 010010 (2017)

V_0 = 100, 50, 20, 0 MeV
W_0 = 12 MeV

Calculation up to $L_{\eta'}=7$
($E_{ex}-E_0$ < 60 MeV)

η’ escape (quasi-free) events

- 2015 same data set
- γ + C -> η’ + X + p

  BGOegg 2γ (br=2%)

Expected yield

1/3-data

Summary

- We search for η' bound state via missing mass spectroscopy of $^{12}C(\gamma, p)X$ using BGOegg @ LEPS2
- We tag back-to-back ηp pair from 1N absorption of bound η'
- The yield is estimated by using Green's function method
- We normalize the cross section using η' escape events
- We obtain info of ηp branch using ηp events @ 0<MM<60 MeV
- We defined signal selection cut condition using QMD signal simulation
- We also define BG reduction cut (backward η selection cut) to remove remaining BG
- MM dependence of BG events are being studied using 1/3-data
- After fixing all cuts, we will open the box