Overview of the LEPS2/BGOegg experiment

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LEPS2/BGOegg collaboration

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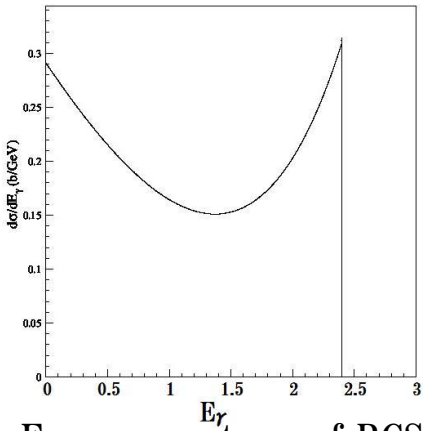
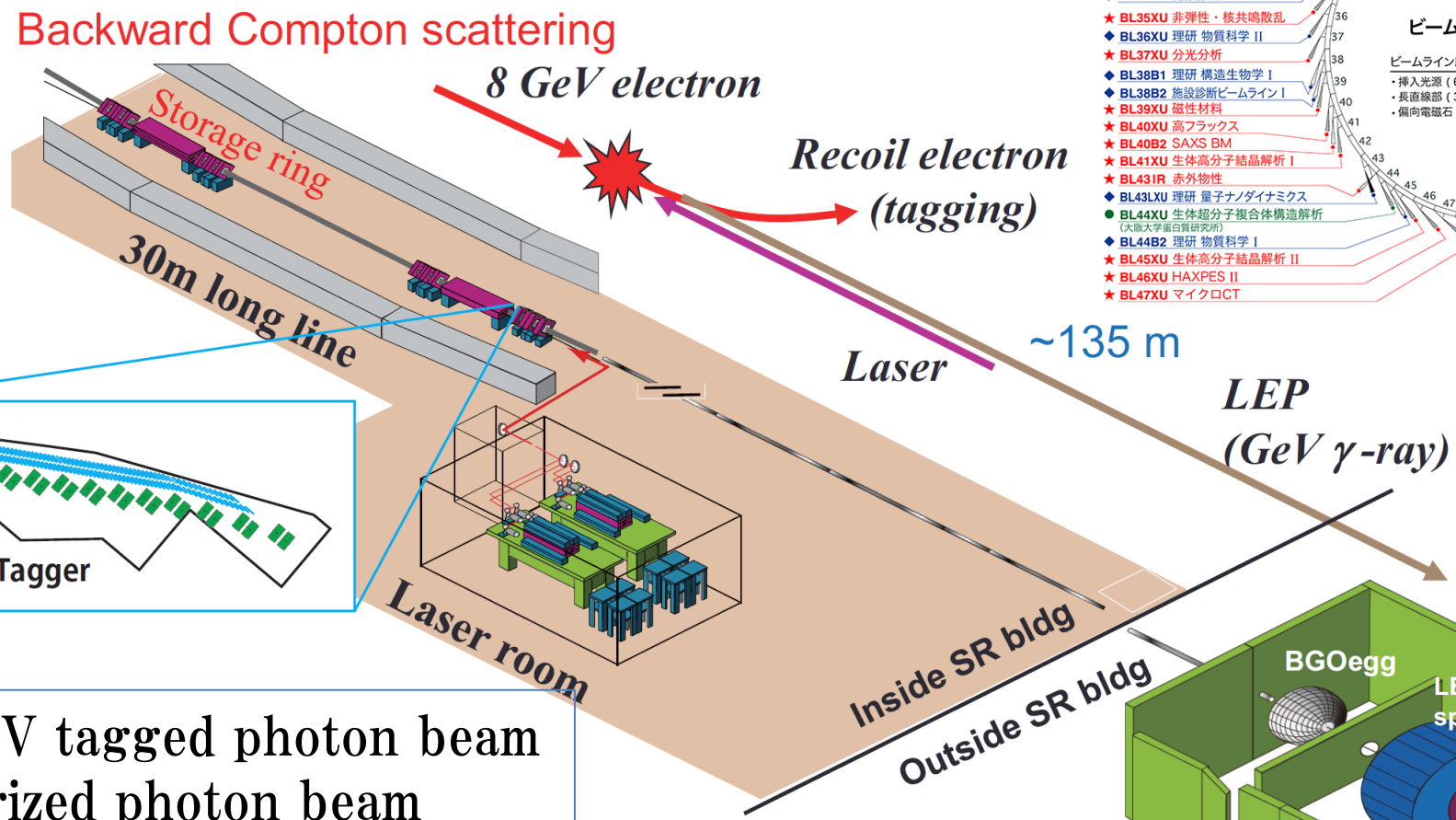
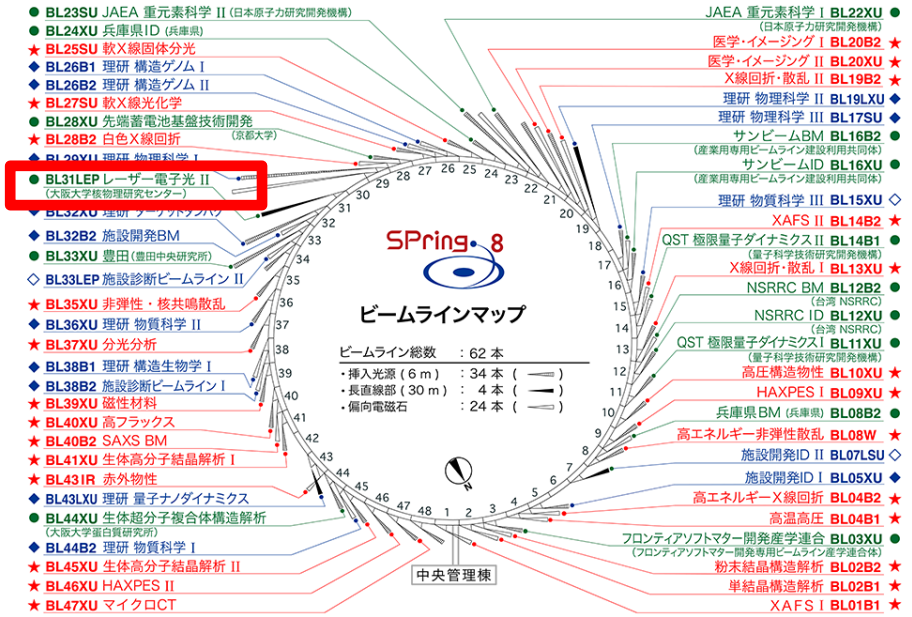
ELPH workshop C035

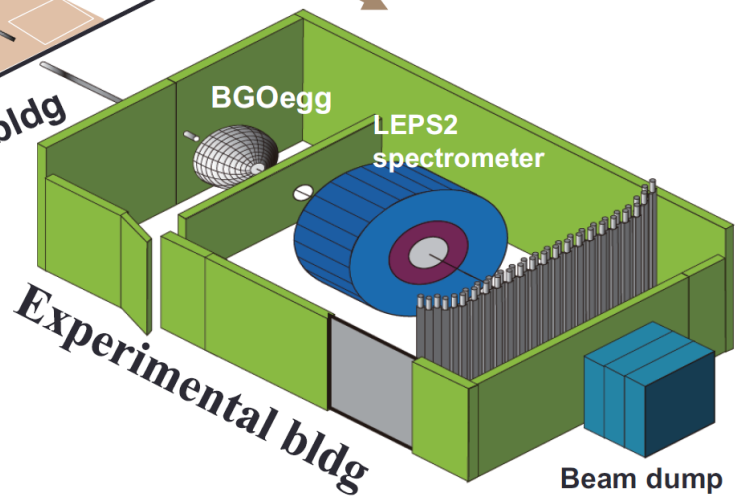
LEPS2 beamline @ SPring-8



Energy spectrum of BCS

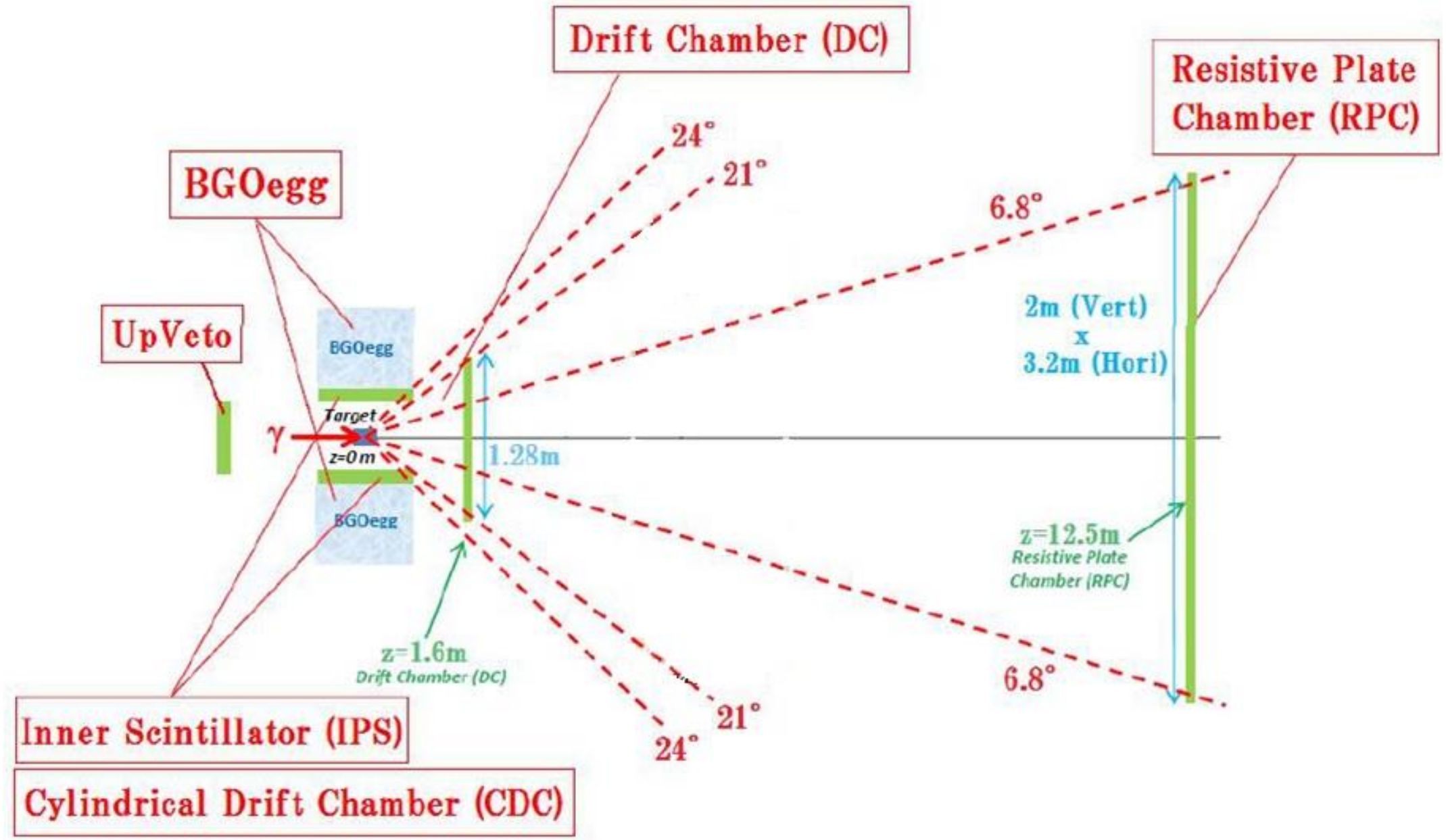




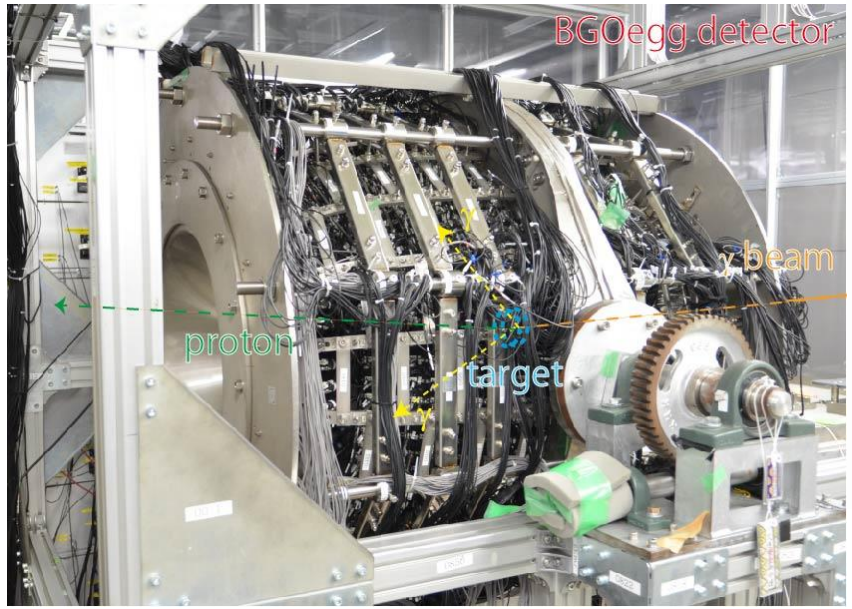


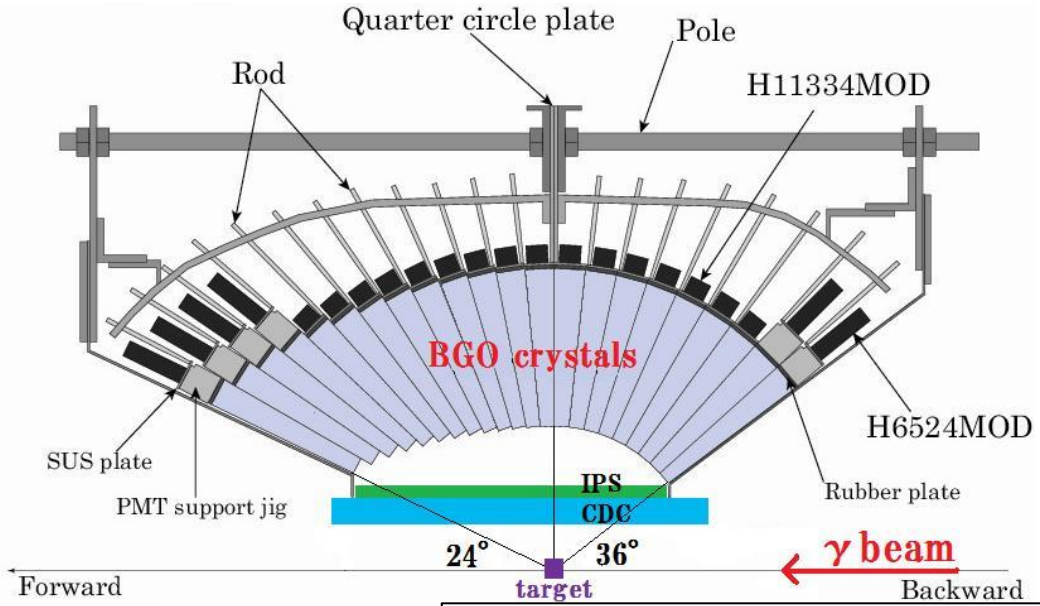
- 1.3 – 2.4 GeV tagged photon beam
- highly polarized photon beam
- ～2 Mcps beam intensity

LEPS2/BGOegg experiment Phase-I (2014～2016)



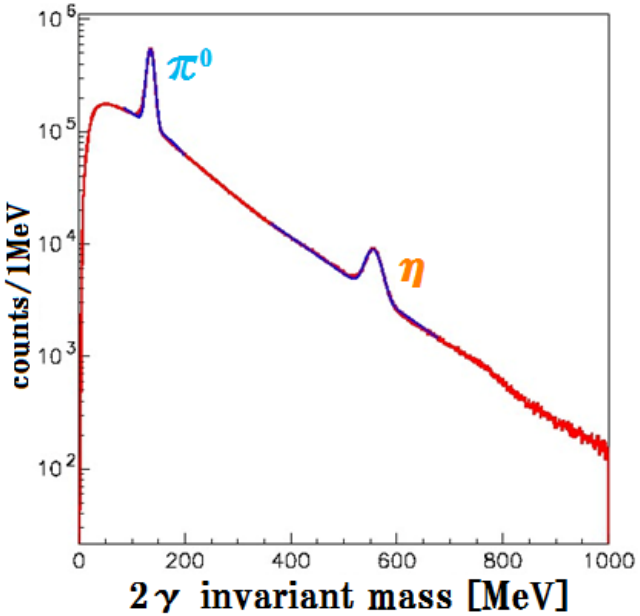
BGOegg calorimeter





Liquid H_2 target (2014B/2015B/2016A)
Nuclear target (C) (2015A/2016A)

- 1320 BGO crystals
- polar angle : 24° ~ 144°
  azimutial angle : 360°
- homogenious
- no housing material
- energy resolution : 1.38% @ 1GeV
- position resolution : 3.1mm @ 1GeV



σ_π = 6.7 MeV

σ_η = 14.4 MeV

Physics subjects

1. Spectroscopy of light baryon resonances
   - single meson photoproduction
     ($\gamma p \to \pi^0 p$ / ηp / $\eta' p$ / ωp)

2. Search for the evidence of exiotic hadron structures
   - photoproduction of scalar mesons
     ($\gamma p \to f_0(980) p$ / $a_0(980) p$)

3. Study of hadron properties in nuclear medium
   - Search for η' mesic nuclei
   - Direct measurement of in-medium η'mass spectrum

Single meson photoproduction

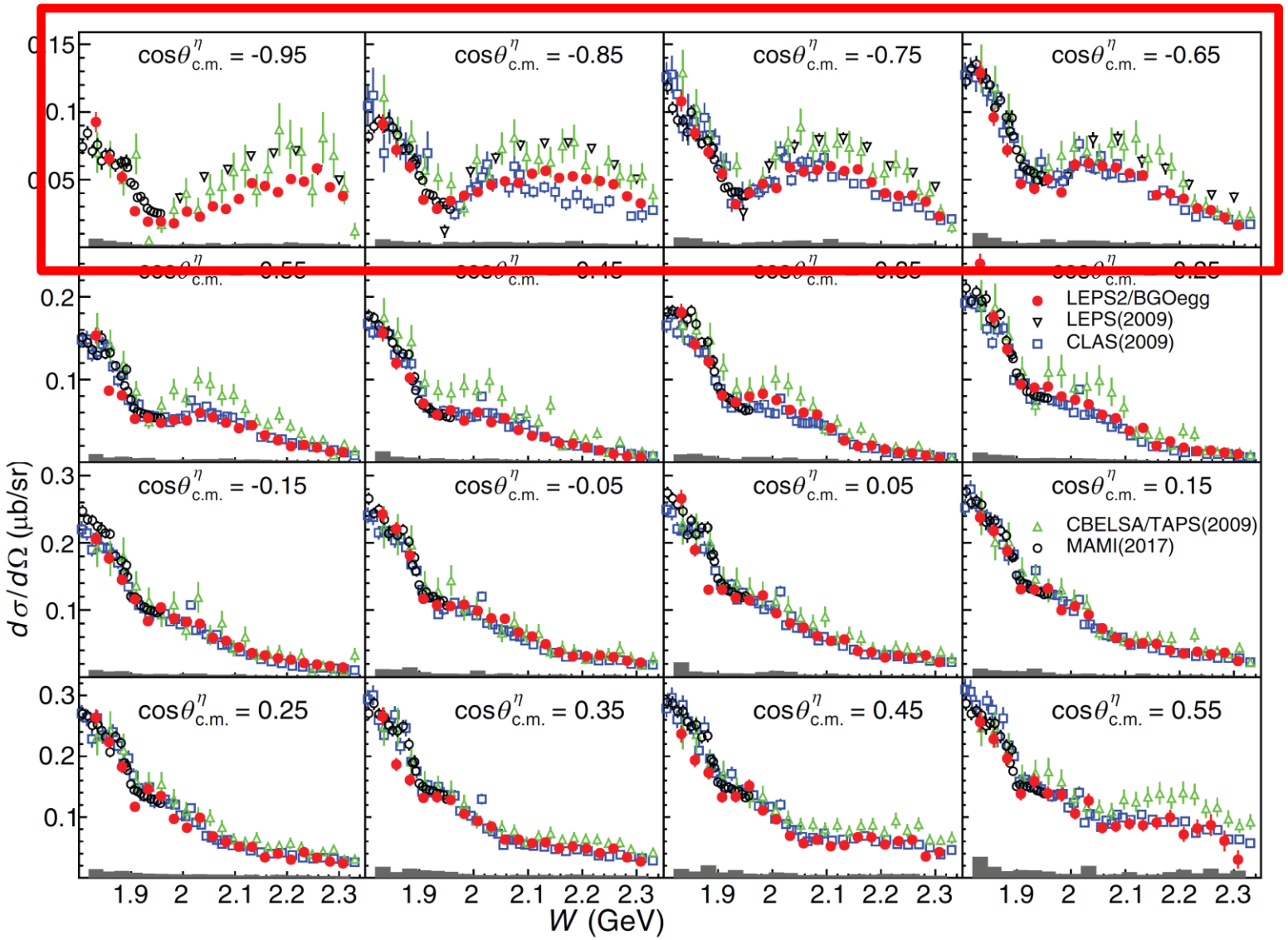
- $\gamma p \to \pi^0 p$ (PRC**100** (2019) 055202)
  - $I = 1 \Rightarrow$ Both $N^*(I = 1/2)$ and $\Delta^*(I = 3/2)$ contribute in the s-channel.
  - High precision data can be obtained thanks to a large cross section.

- $\gamma p \to \eta p$ (PRC**106** (2022) 035201)
  - $I = 0 \Rightarrow$ Only the contribution from $N^*(I = 1/2)$.
  - Possible to investigate the coupling of N^* with $s\bar{s}$.

- $\gamma p \to \eta' p$
  - Important to explore high mass resonances

- $\gamma p \to \omega p$ (PRC**102** (2020) 025201)
  - Couples to N^* with the different spin states.
  - Spin information is studied with spin-density matrix elements.

Differential cross section of $\gamma p \to \eta p$



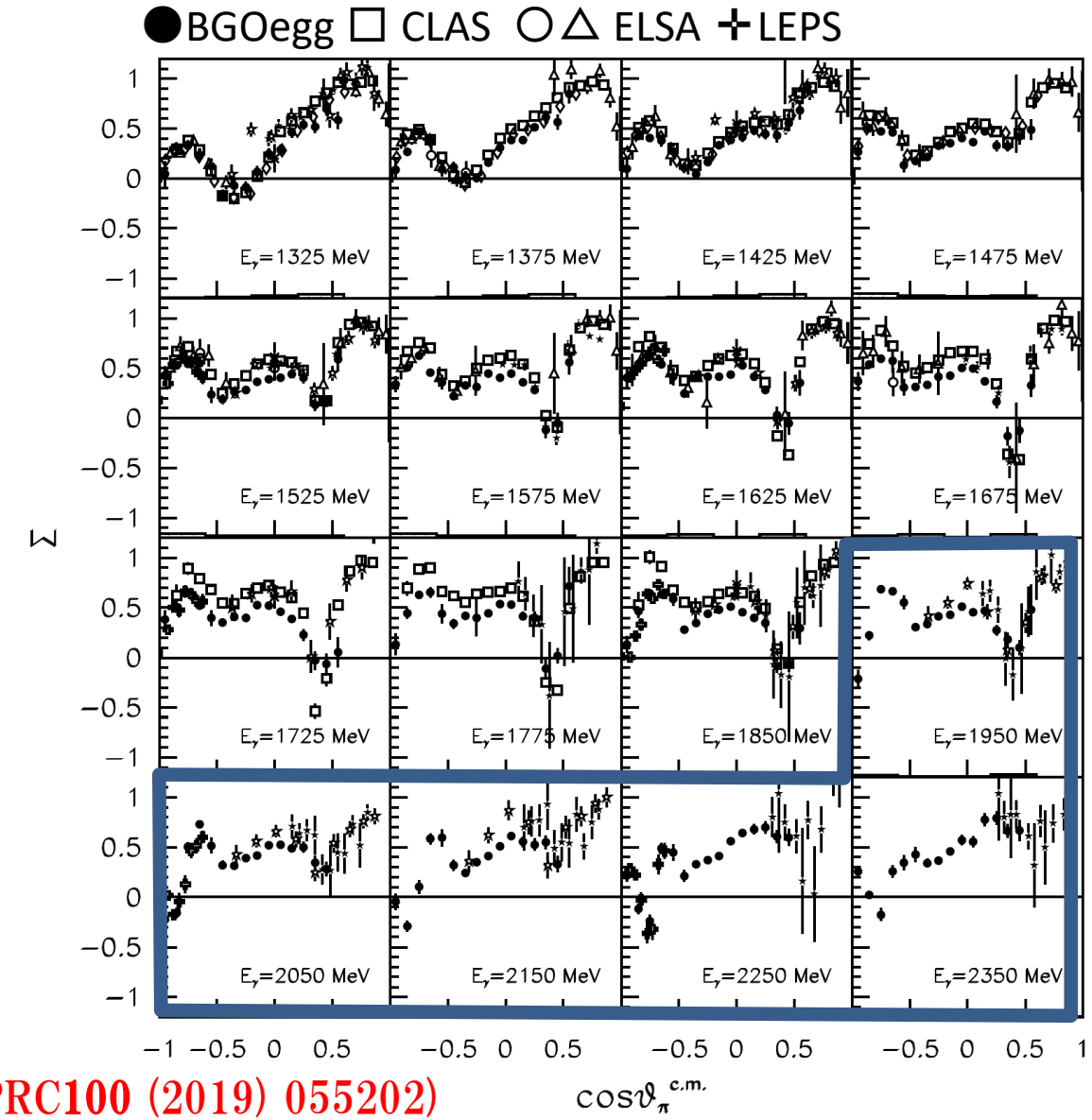
(PRC106 (2022) 035201)

- Providing precise data up to extremely backward angles.
- A clear bump structure is seen at higher energies at backward angles.
- The shape and peak position of the bump structure strongly depends on polar angles.

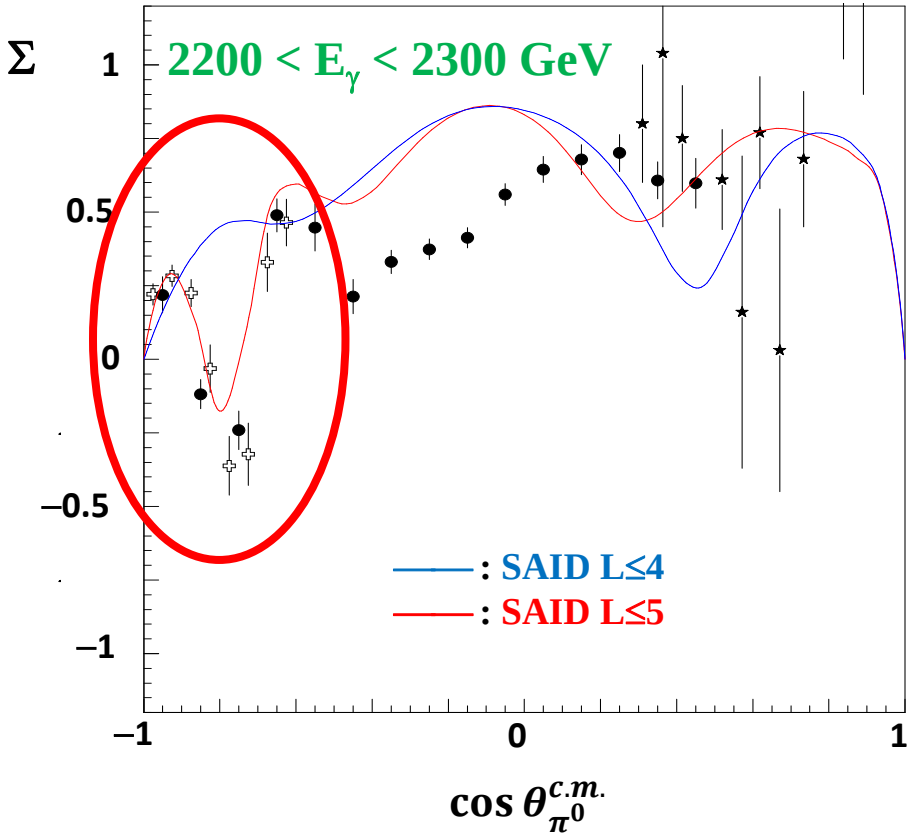
→ Possibly indicating contributions from high-spin resonances?

Photon beam asymmetry of $\gamma p \rightarrow \pi^0 p$

- Study for resonances with higher angular momentum (N^*,Δ^*).
  - Study of the interference of multipole amplitudes using **photon beam asymmetry.**



(PRC100 (2019) 055202)

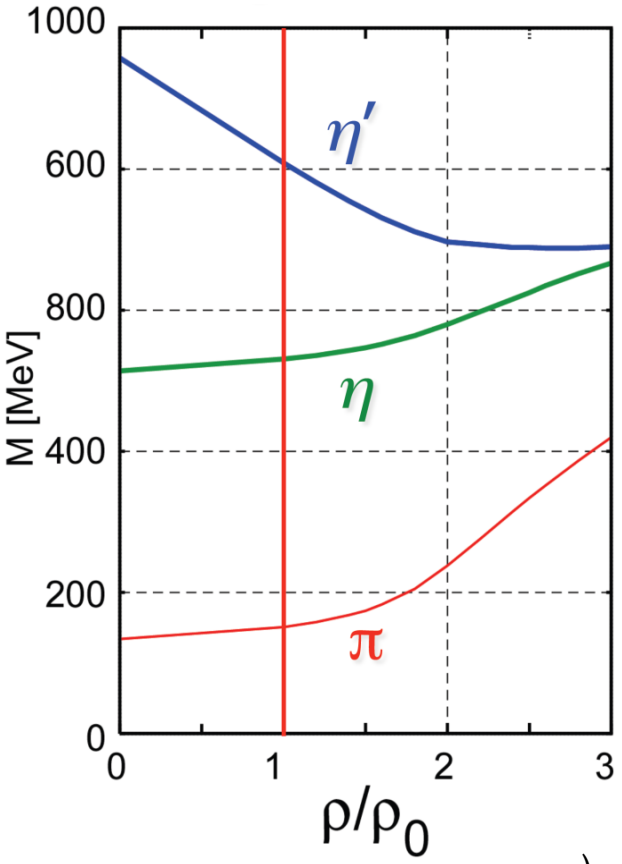


- The existing PWA models deviate from our data at higher energies.
- The backward structure dip structure comes from a higher multipole amplitude which corresponds to high spin resonances (J^P=9/2$^+$).

In-medium η' property

- η' mass in nuclear medium
  - η' meson has larger mass than other pseudo scalar mesons due to $U_A(1)$ anomaly effect.
    → The mass of η' is expected to decrease at the nuclear density.
  - Predicted mass reduction varies in the range of 40-150 MeV depending on how to construct effective Lagrangian.

  -> Need experimental information

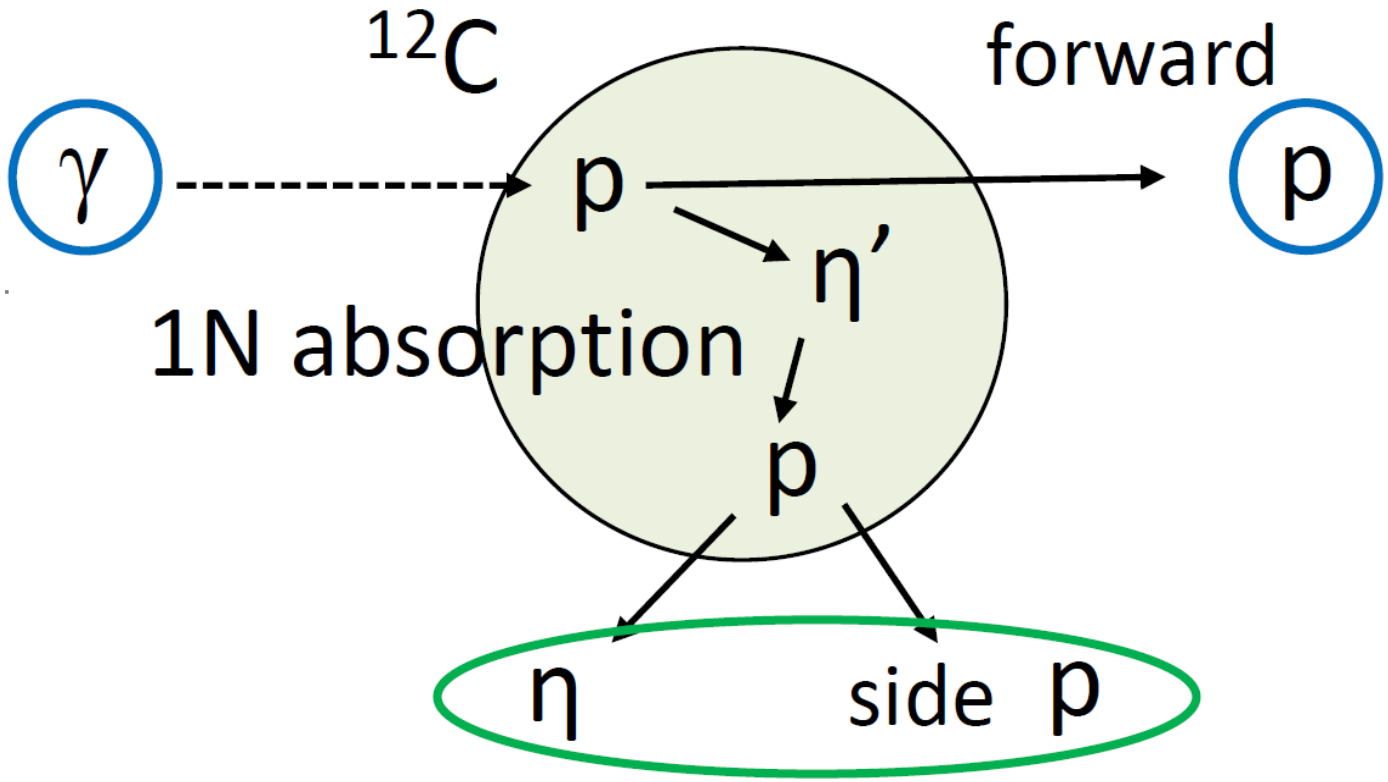


(based on NJL model + KMT interaction)
Nagahiro et al., PRC74, 045203(2006)

- Two different method were adopted to measure in-medium η' mass in the BGOegg exp.

Search for η'-nucleus bound state

- **Missing mass spectroscopy of C(γ, p)**

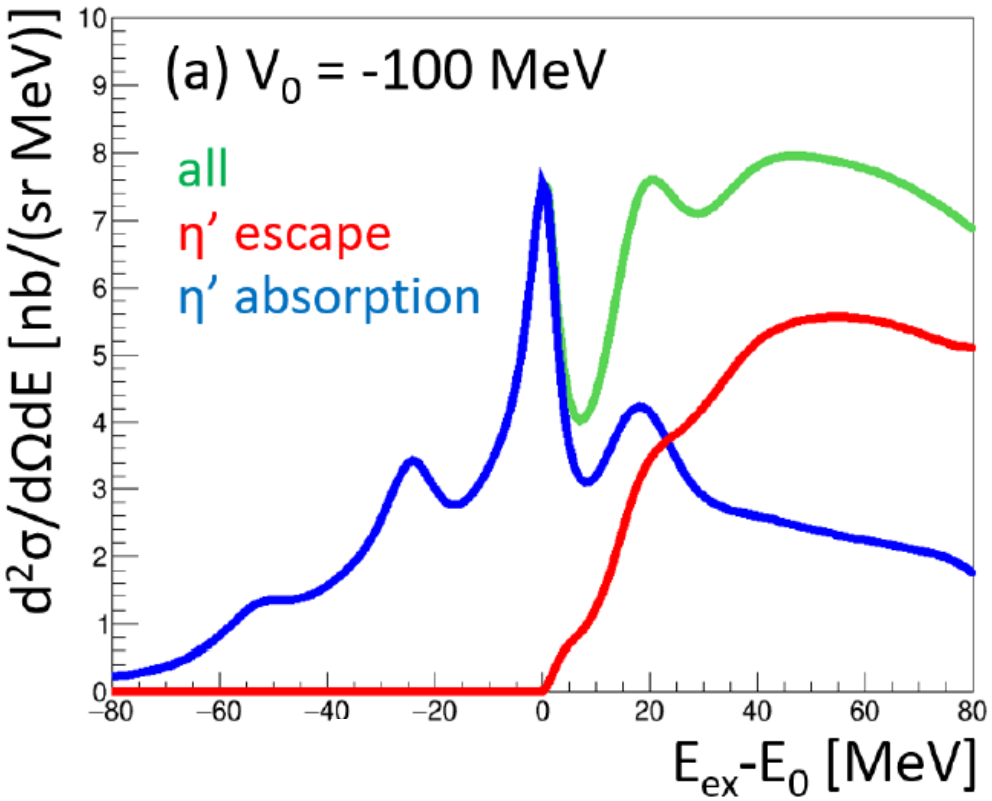


- **Tag back-to-back ηp from $\eta' p$ absorption process**

η'-nucleus optical potential PRL 94 (2005) 232503

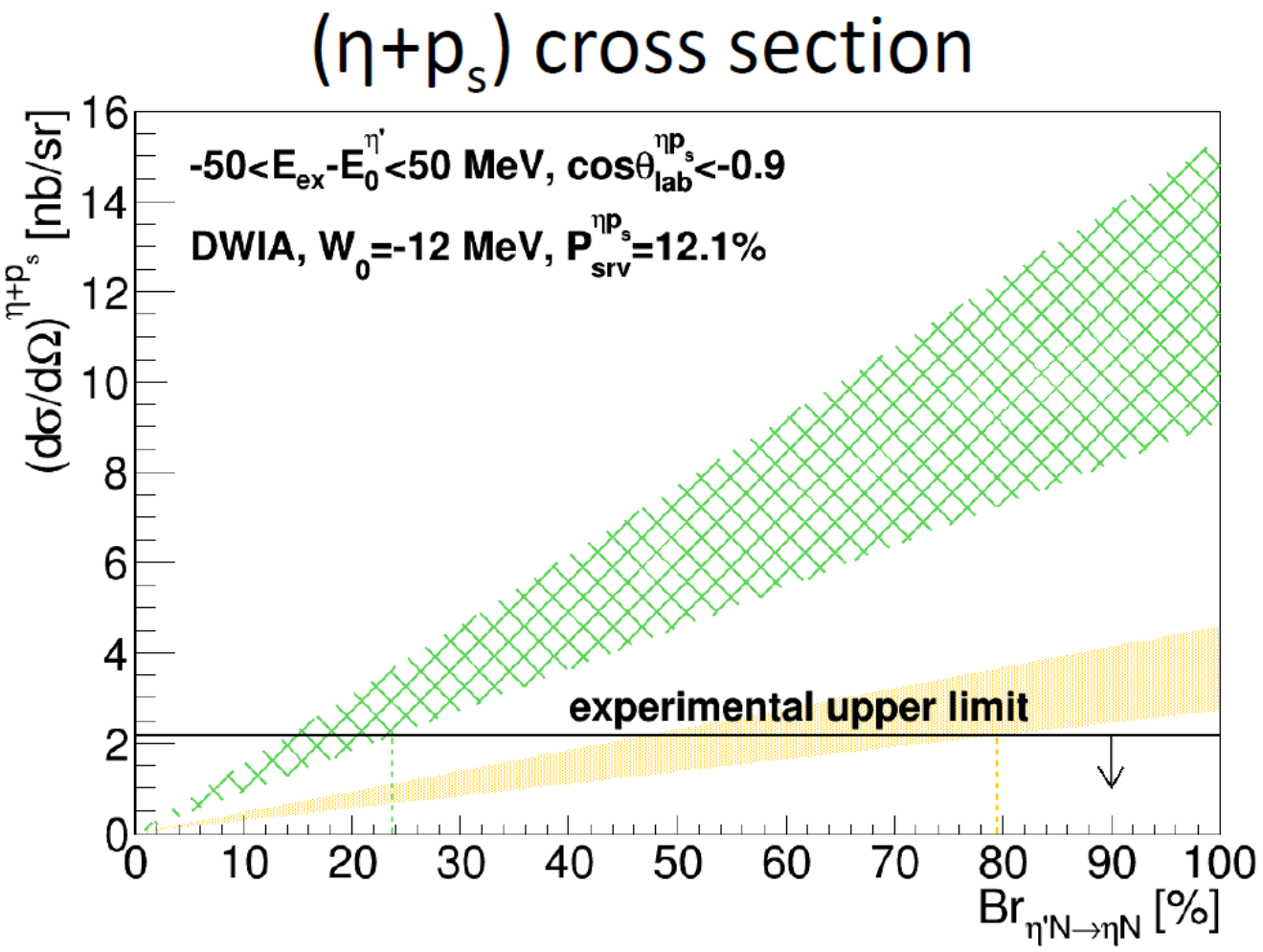
- U(r) = (V_0+iW_0) x ρ(r)/$ρ_0$
- V_0 = Δm($ρ_0$) : mass shift at the normal nuclear density
- W_0 = -Γ ($ρ_0$)/2 : width at the normal nuclear density

- If mass shift is large and absorption is small, η'-nucleus bound state may be formed



Search for η'-nucleus bound state

(PRL **124** (2020) 202501)



DWIA V_0=-100 MeV

DWIA V_0=-20 MeV

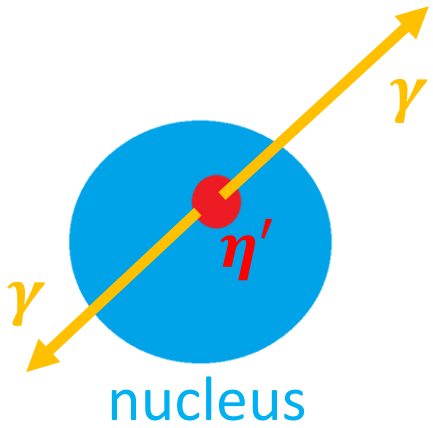
- No signals indicating bound states were observed.
- Our results indicate small $Br_{\eta' N \to \eta N}$ and/or shallow V_0.
- New analysis including two nucleon absorption is on-going.

Direct measurement of in-medium η' mass spectrum

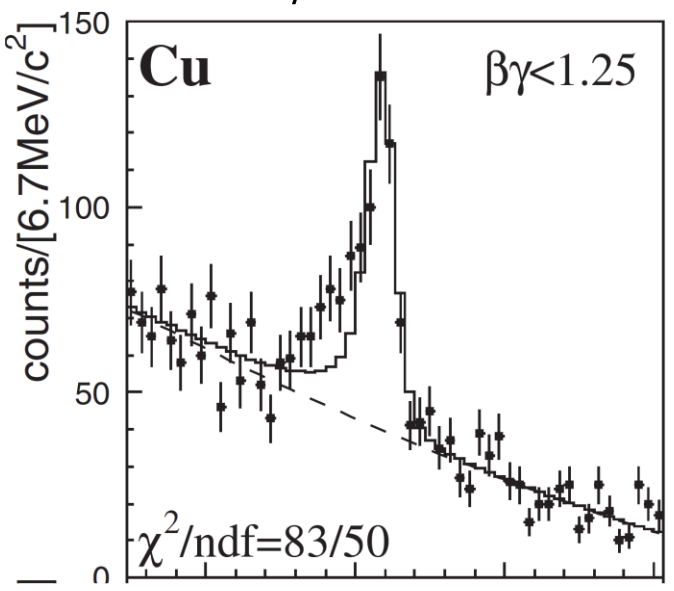
- Line shape analysis
  - A direct measurement of mass spectra with invariant mass distribution
  - No experimental data for η'

- $\eta' \to \gamma\gamma$ mode
  - No final state interaction
  - No radiative tail in the spectrum

- High mass resolution is required.

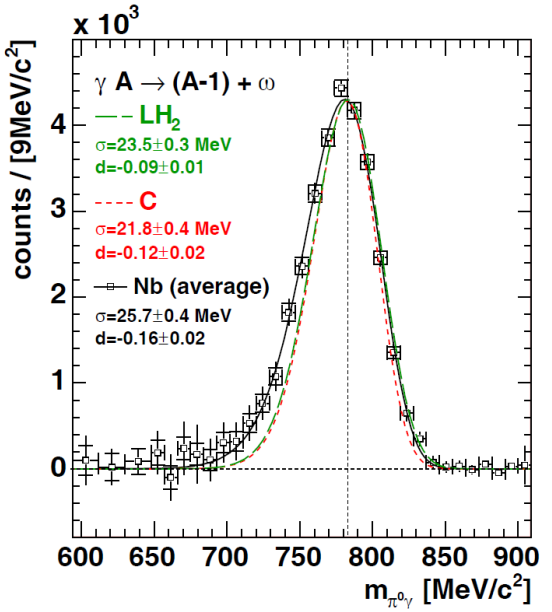


$\phi \to e^+e^-$



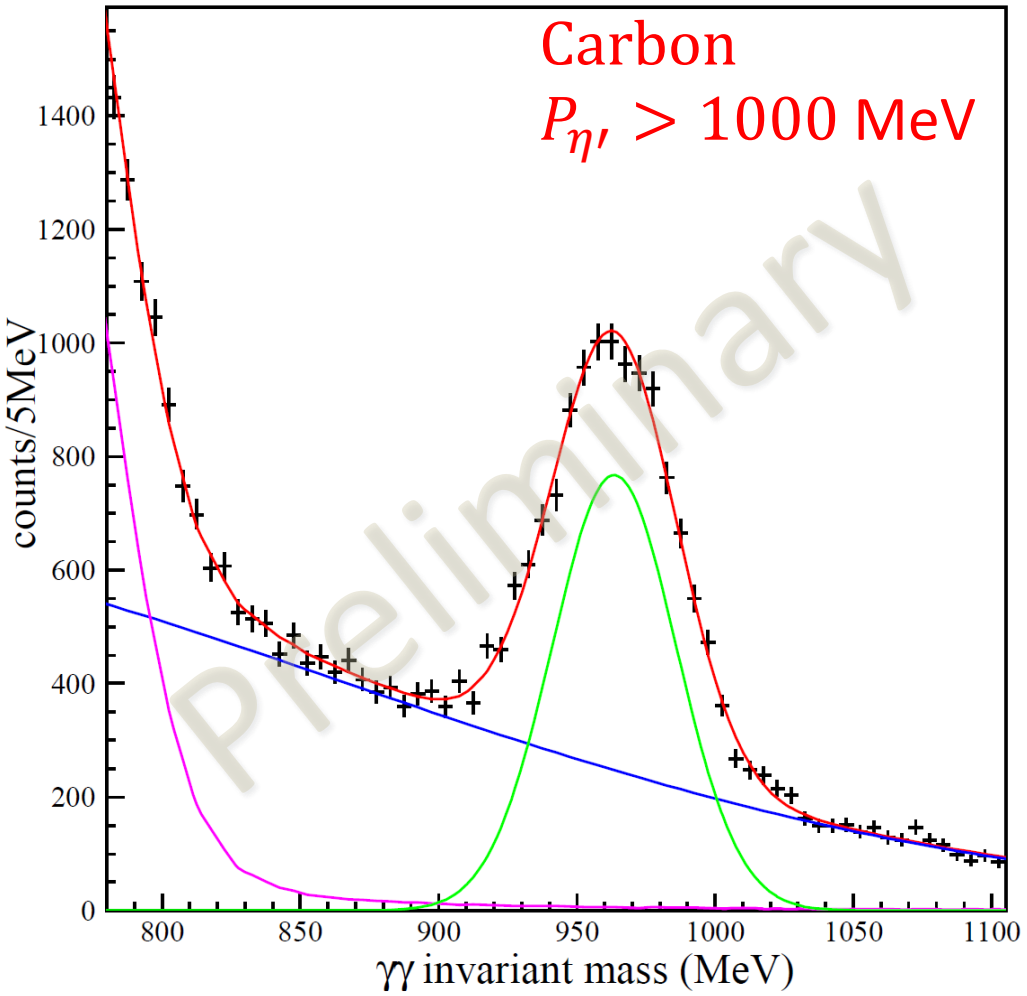
R.Muto et al. PRL98, 042501(2007)

$\omega \to \pi^0\gamma$

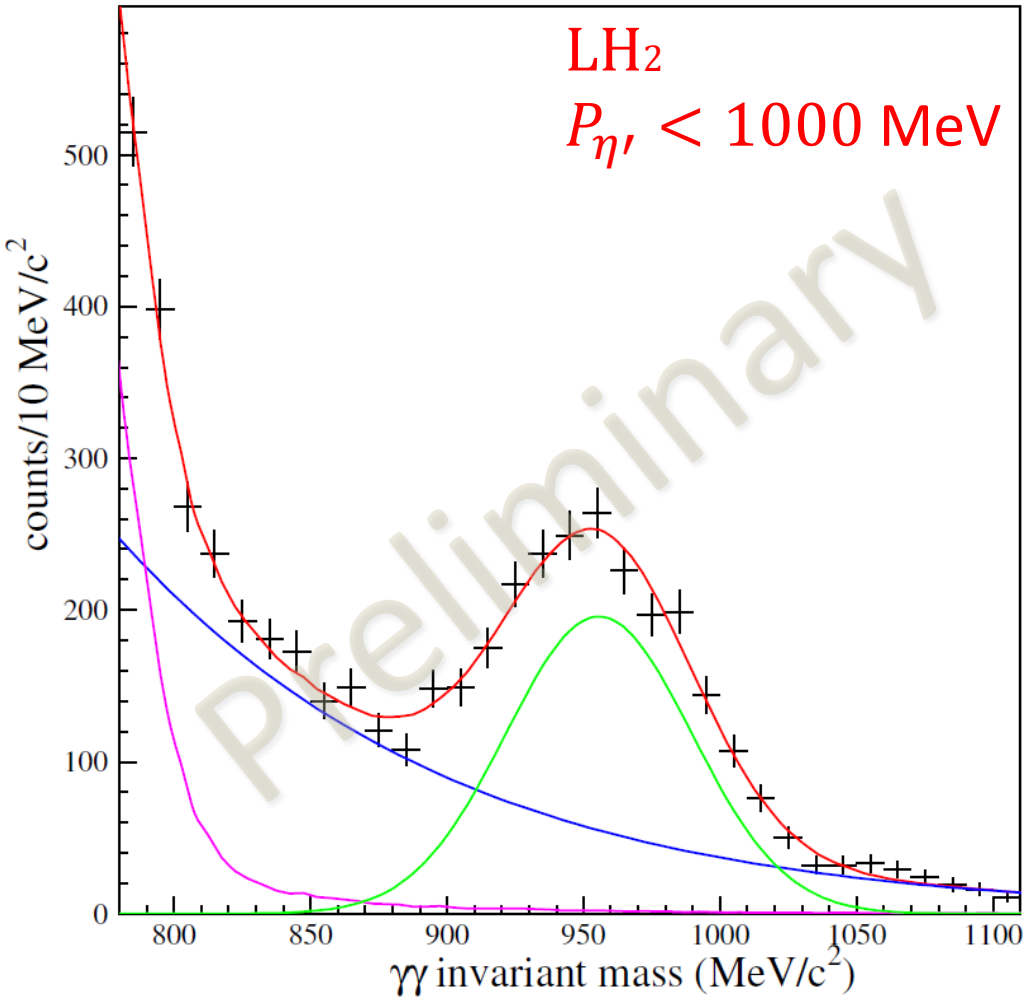


M.Thiel et al. Eur.Phys.J.A49, 132(2013)

Spectral fit



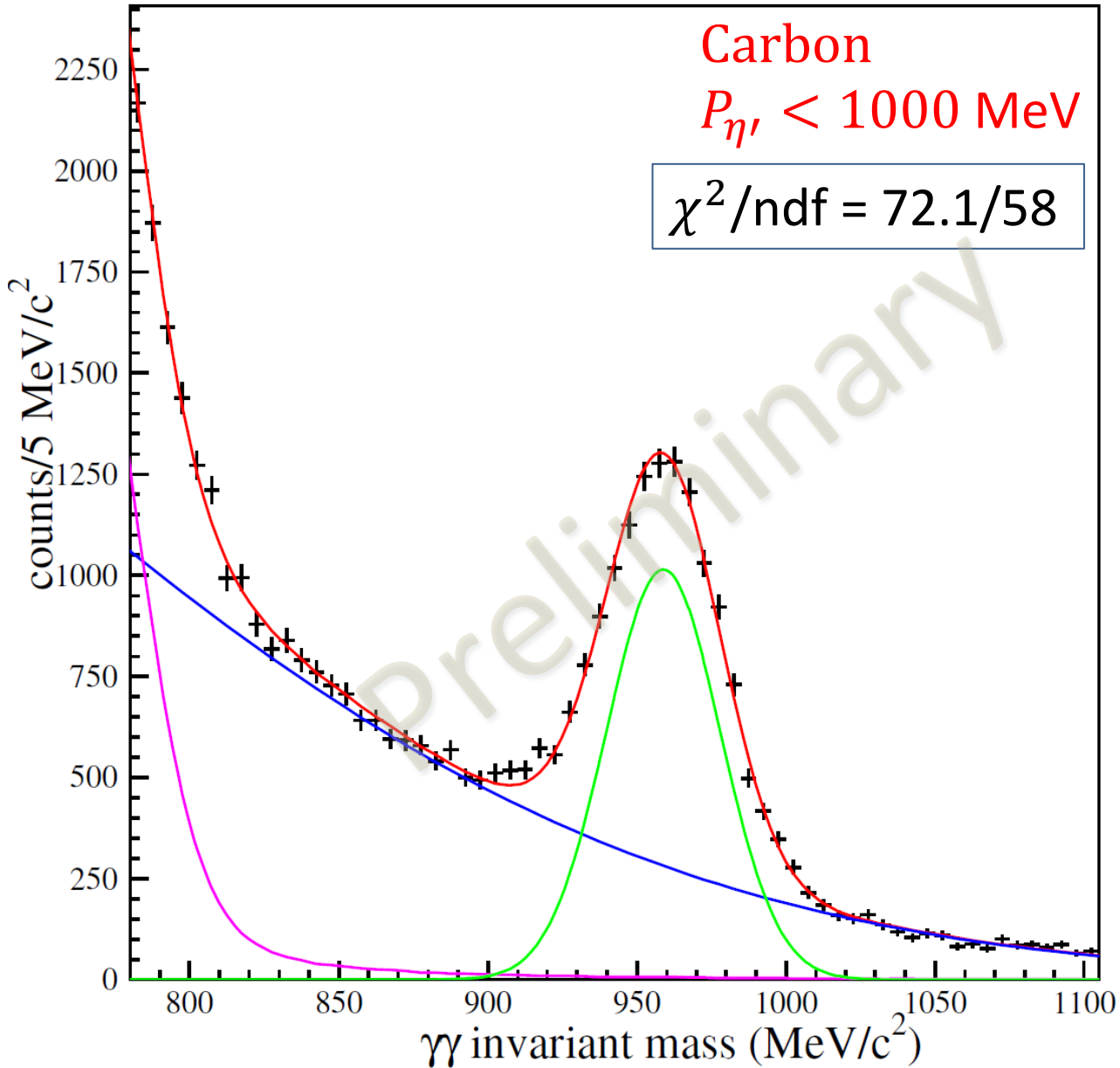
χ^2/ndf = 60.1/58

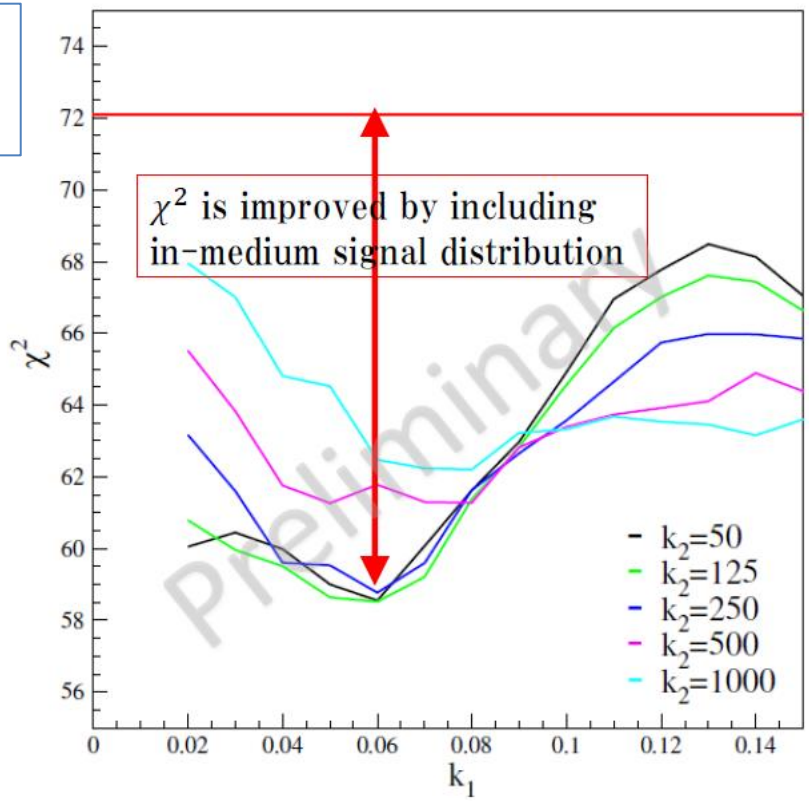


χ^2/ndf = 26.0/26

Spectral fit

$$m_{\eta'}(\rho) = m_0(1 - k_1\frac{\rho}{\rho_0})$$
$$\Gamma_{\eta'}(\rho) = \Gamma_0(1 + k_2\frac{\rho}{\rho_0})$$



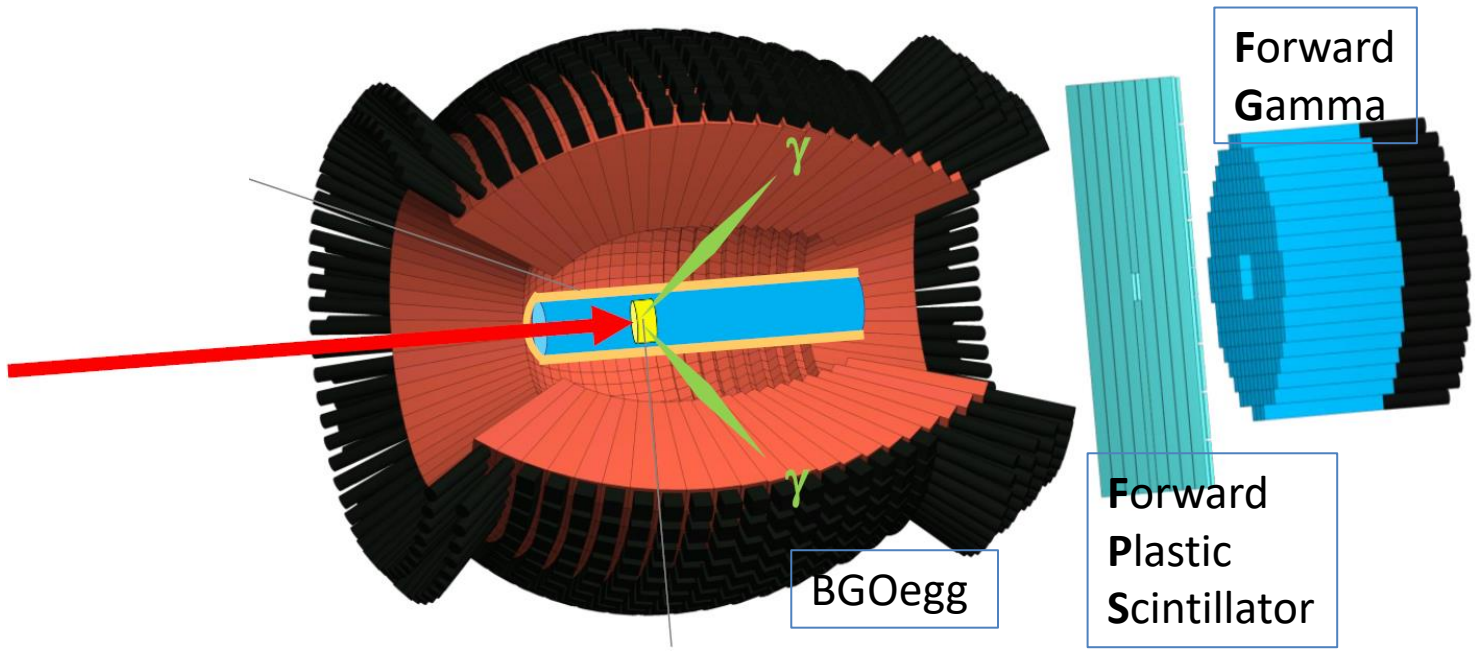


- Worse χ^2 comes from some enhancement in the mass region under the quasi-free η' peak.
- Statistically $\sim 3.7\sigma$ deviation
- This deviation could not be explained by known sources.

BGOegg Phase-II project

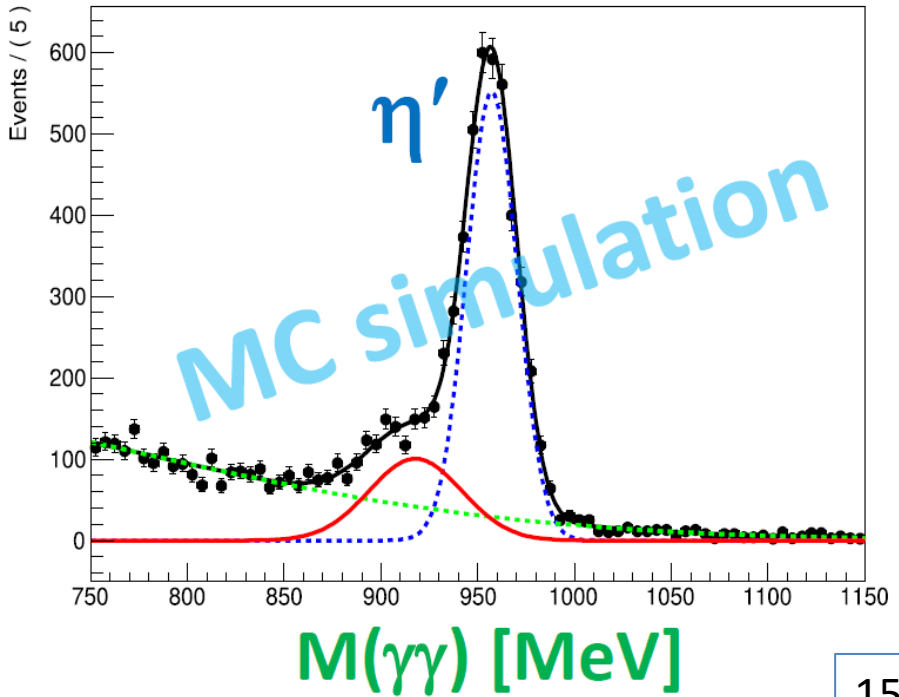
To confirm the result of in-medium signal
in the C target data with high statistics & small BG.

- Forward PWO calorimeter (FG)
  - reduction of multi-meson BG
  (～1/8 with existing FG / ～1/40 by further upgrade)
- Cu target
  - larger nuclear radius (x1.8)
  - more target nucleons (x1.8)
  - better mass resolution (x0.6)
- larger photon beam intensity by pulse laser (～5Mcps)

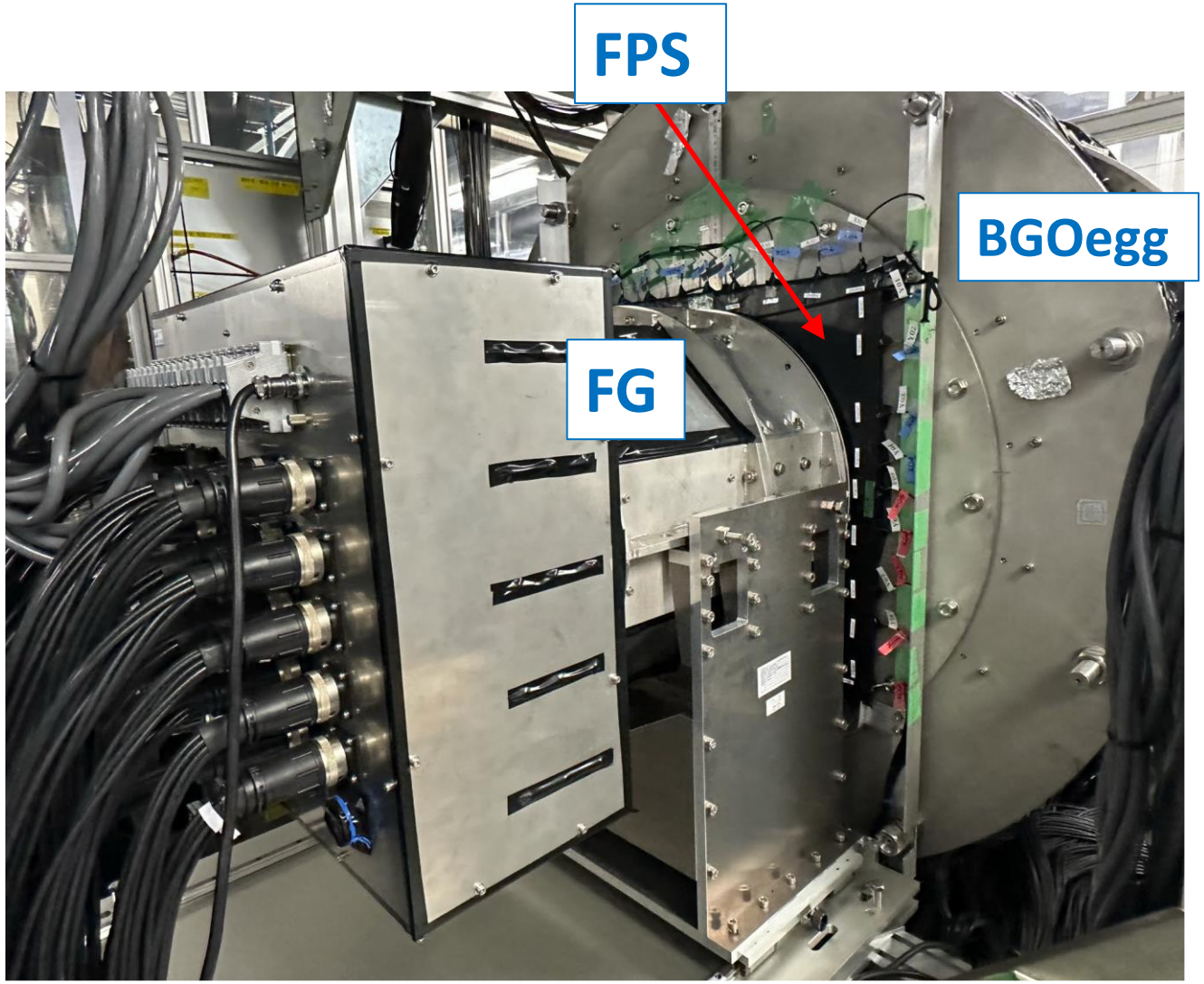


Expected spectrum based on
the result of C target data

Cu target : P(γγ)<600 MeV/c



BGOegg Phase-II project

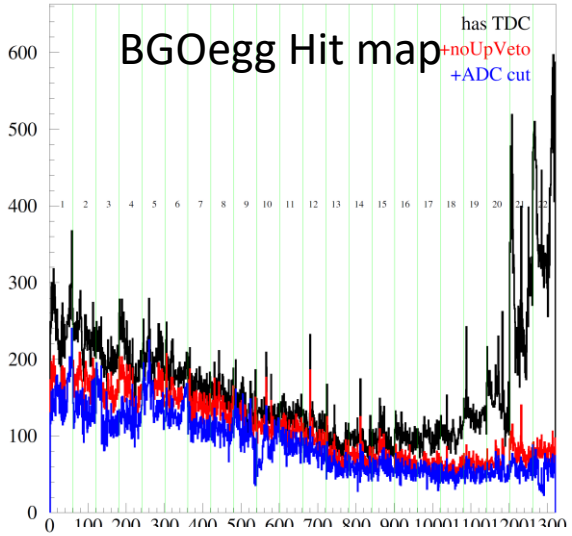


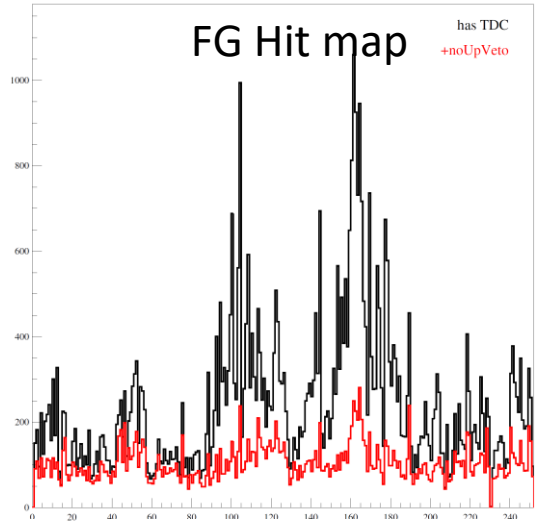
- Status of BGOegg Phase-II exp.
  - Upgrage of BGOegg system
  - Installation of FG / FPS
  - DAQ upgrade

  → Jan. 2023 : Commissioning run

- 2023FY : Physics run start

The data of each detector was confirmed in the commissioning run





Summary

- We are performing a meson photoproduction experiment with a highly polarized photon beam at the SPring-8/LEPS2 beamline. The hadron spectroscopy is performed with high-resolution electro-magnetic calorimeter BGOegg.

- The LEPS2/BGOegg experiment (Phase-I) has successfully obtained physics results on
  - light-baryon spectroscopy
  - scalar meson photoproduction
  - in-medium properties of η' mesons.

- The Phase-II project is on-going with high-intensity photon beam and upgrade detector systems. The flagship physics topic is to measure the in-medium η' mass spectrum with small background and high statistics.