Photonpolarisation and Asymmetry in the ^{4}He ($\vec{\gamma}$,np) Reaction [*]

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13.10.1999

- Introduction:
  - Short range correlations (SRC)
  - Experimental setup @ MAMI
  - Results of selected measurements
- Polarized bremsstrahlung
  - Kinematics and cross section
  - Experimental effects
  - Realistic modelling and results
- Asymmetry of the ^{4}He($\vec{\gamma}$,np) reaction
- Summary

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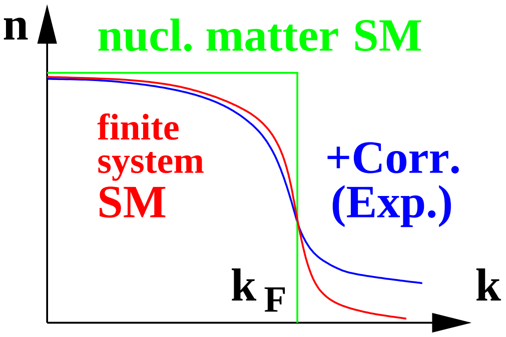
[*] supported by DFG(Schwerpunkt/Graduiertenkolleg),DAAD,NATO

SRC and Asymmetry

Shell model

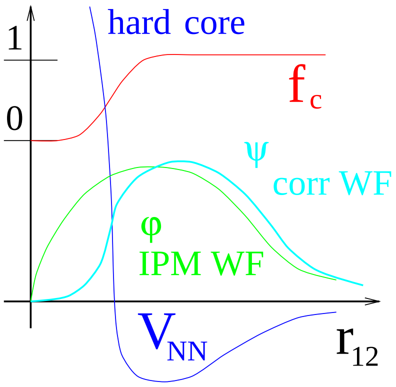
$$\sum V_{ij} = \sum V_i + V_{\mathrm{res}}$$

IPM+Korr

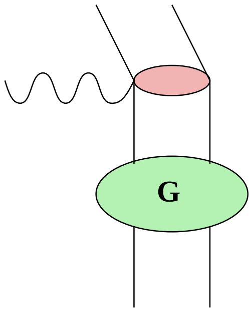


Jastrow Correlation:

$$\psi_{12} = \phi_1 \phi_2 f_c(r_{12})$$



Approach via exclusive 2N emission



2B currents are sensitiv on SRC

$$\sigma \quad \propto \quad | < f | j_{[1]} + j_{[2]} | i > |^2$$

$$\sim \quad F(P) S_{fi}(< p_r >)$$

→ measurement of p_r, includes correlations

Photon asymmetry: $\Sigma = \frac{1}{P_\gamma} \frac{\sigma_{||} - \sigma_\perp}{\sigma_{||} + \sigma_\perp}$ $\qquad \sigma_{||,\perp} = \sigma_0 (1 \pm P_\gamma \Sigma)$

Direct photo absorption:

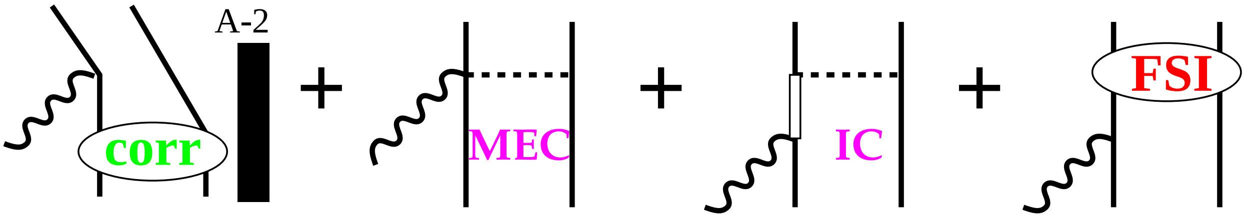
$$\sigma_0 \quad = | \textstyle\sum_{\text{1B,MEC,IC}} J(f)|^2$$

$$\sigma_0 \Sigma = | \textstyle\sum_{\text{interference}} J(\pm f)|^2$$

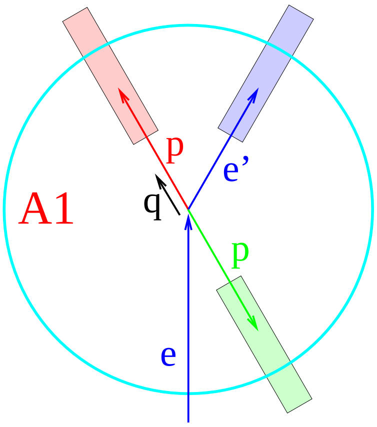
Ryckebusch: Phys. Lett. B383 (96)
Boato, Giannini: J. Phys. G15 (89)
Add. evidence:
Boffi: Nucl. Phys. A564 (93)

2N Knockout Measurements

Ground state correlations and competing processes



$(e, e'pp)$

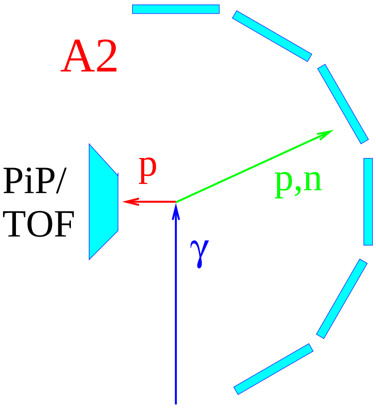


- superparallel kinematics:
  MEC=0, IC=0 for σ_L

→ direct approach to central SRC

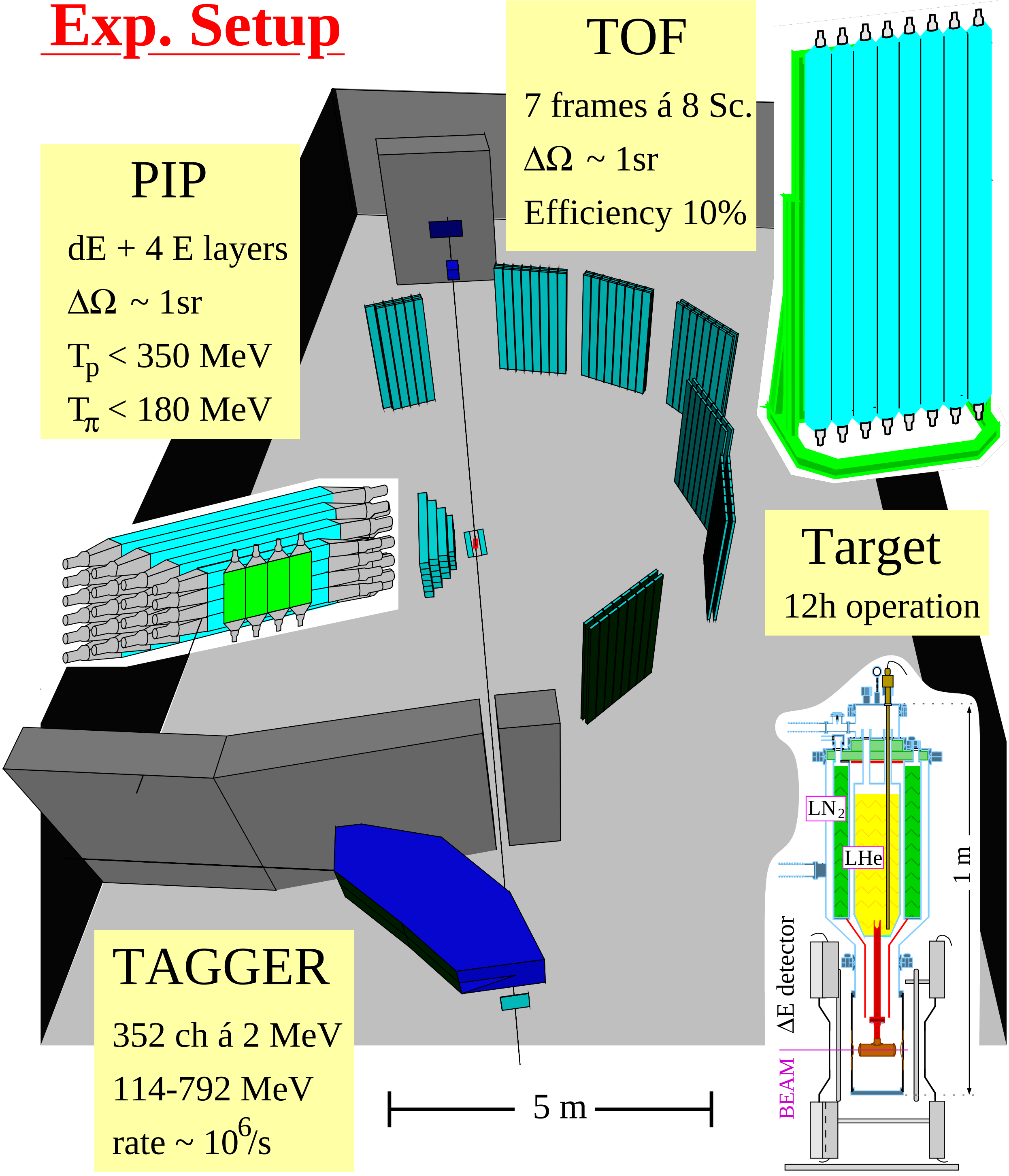
But: Fermi motion of pair: $\vec{q} \neq \vec{p}_N$
Xsec very small

$(\gamma, np/pp)$



- Coincident measurement over wide angle and E_γ range
- Real (transversal) photons sensitive on larger tensor SRC
- MEC/IC might be separated via kinematics and isospin (Daniel Knödler, Tübingen, Diss. 99)

Exp. Setup



PIP

dE + 4 E layers

$\Delta\Omega \sim 1$sr

$T_p < 350$ MeV

$T_\pi < 180$ MeV

TOF

7 frames á 8 Sc.

$\Delta\Omega \sim 1$sr

Efficiency 10%

Target

12h operation

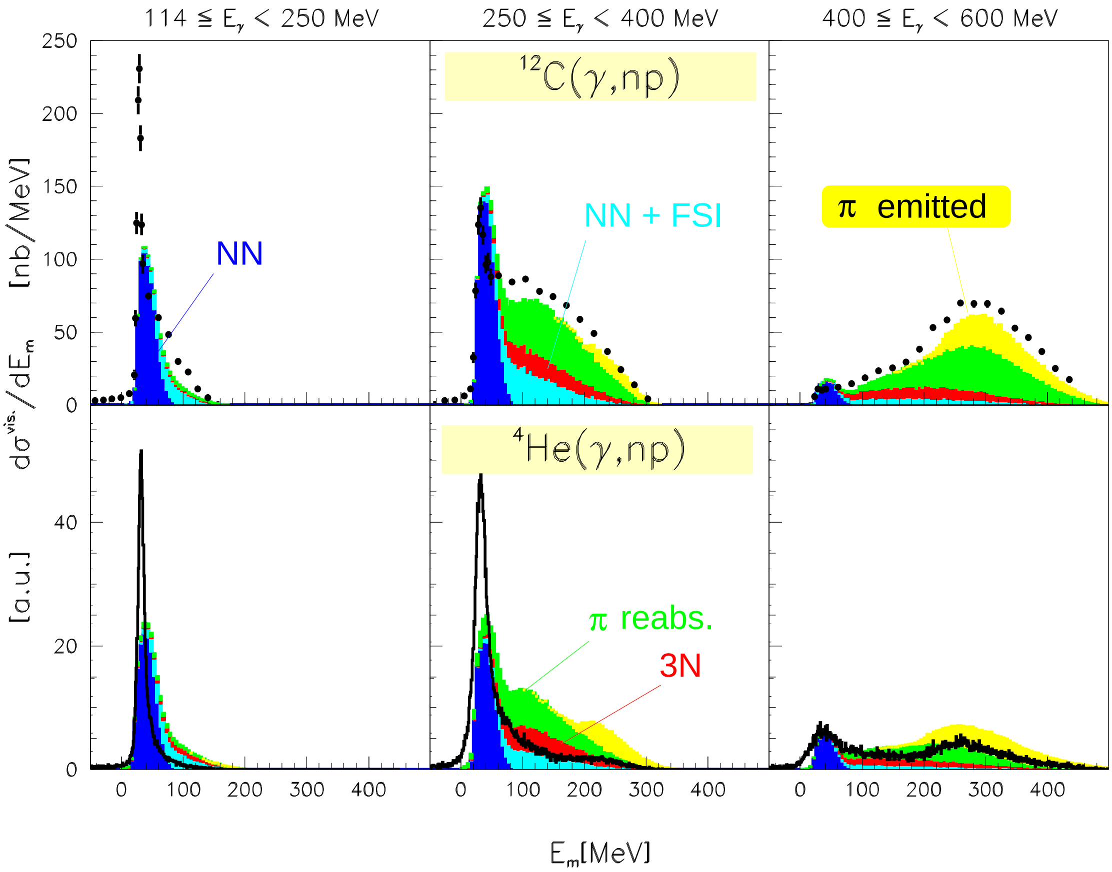
TAGGER

352 ch á 2 MeV

114-792 MeV

rate ~ 10^6/s

Reaction Mechanisms: ^{12}C, ^{4}He

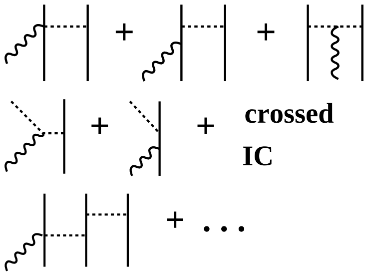


2N absorption (+ FSI)

QFπ production (emit/reabs)

3N absorption

> E_{2m} used to enhance direct 2N absorption



$$\sigma_{\text{tot}} = -\frac{1}{k}\int d^3r\; \rho(r)\,\mathrm{Im}\Pi(k,\rho)$$

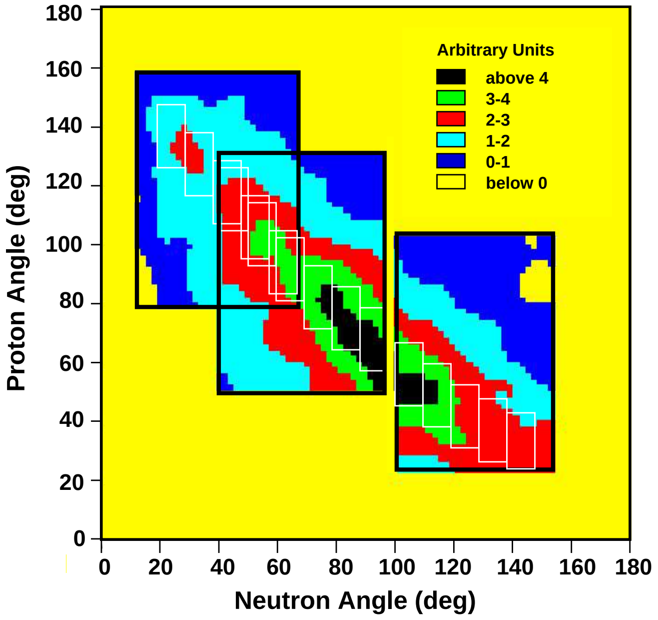
Carrasco,Oset NPA **536** (92) 445

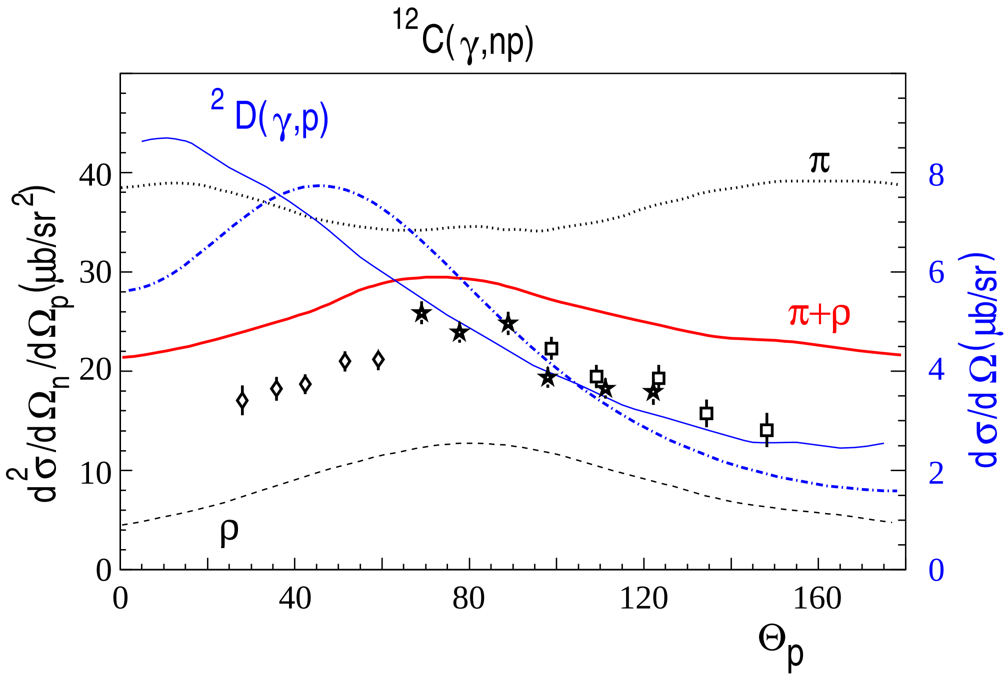
T. Lamparter et. al. ,Z. Phys. A **355** (96) 1; T. Hehl, Prog. Part. Nucl. Phys. **34** (95) 385

Angular Distribution

T.T.-H. Yau
PhD thesis 1996,
Eur. Phys. J.
A1 (98) 241

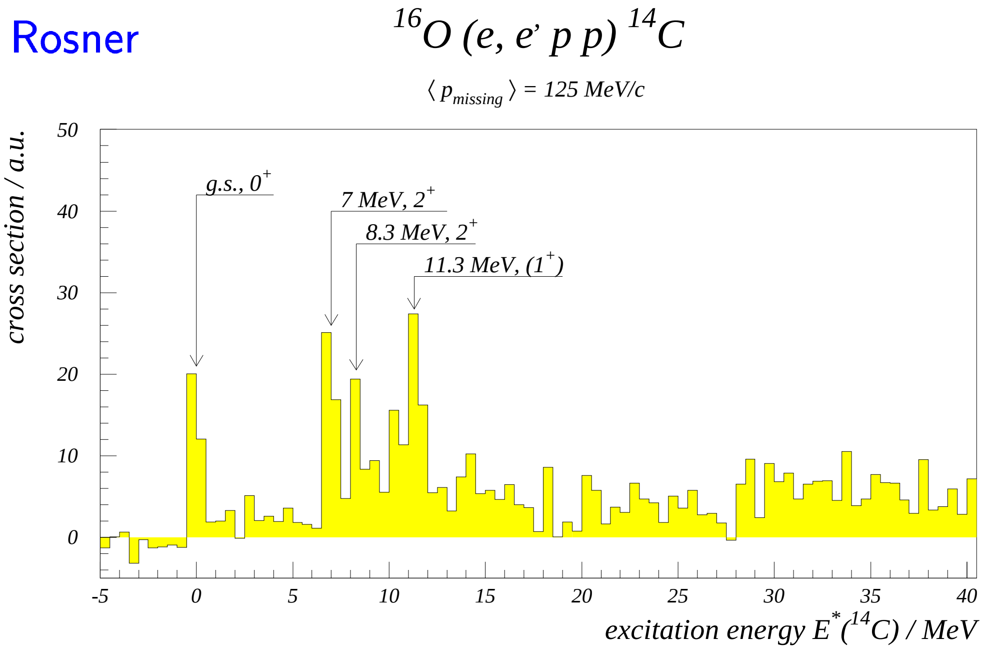
$120 < E_\gamma < 150$
$20 < E_m < 70$ MeV





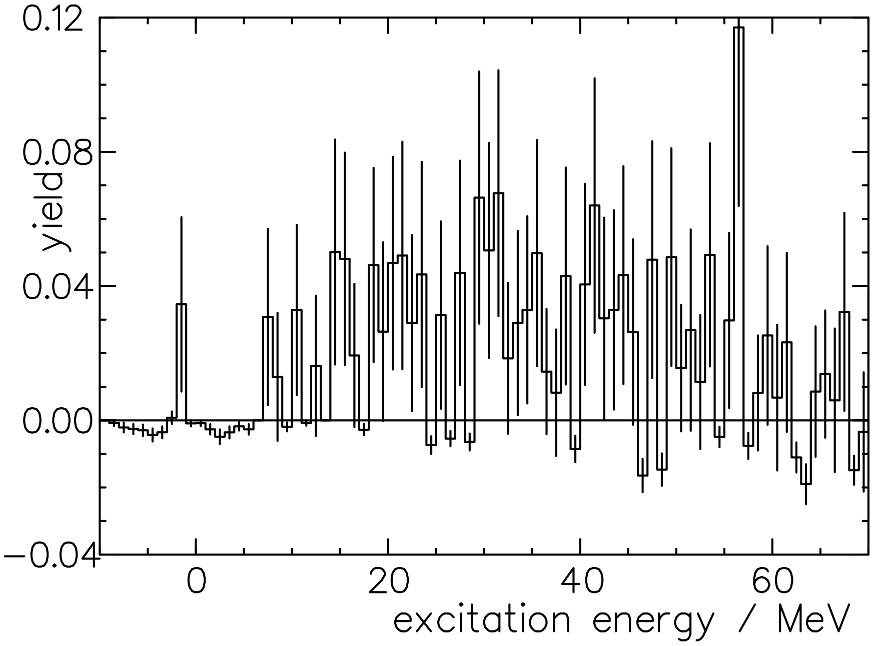
Missing Energy ^{16}O

A1: G. Rosner

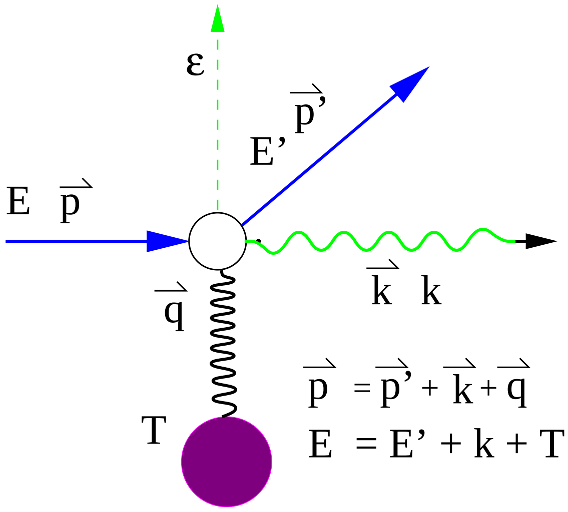


A2: Ge + Si-strip detectors

$100 < E_\gamma < 200$ MeV



Bremsstrahlung Process



$$\vec{p} = \vec{p}' + \vec{k} + \vec{q}$$
$$E = E' + k + T$$

Kinematics:

$\delta = q_l^{\min}(E_\gamma) < q < 2\delta$

$q_t/q_l \approx 10^3 \rightarrow$ pancake

Cross section:

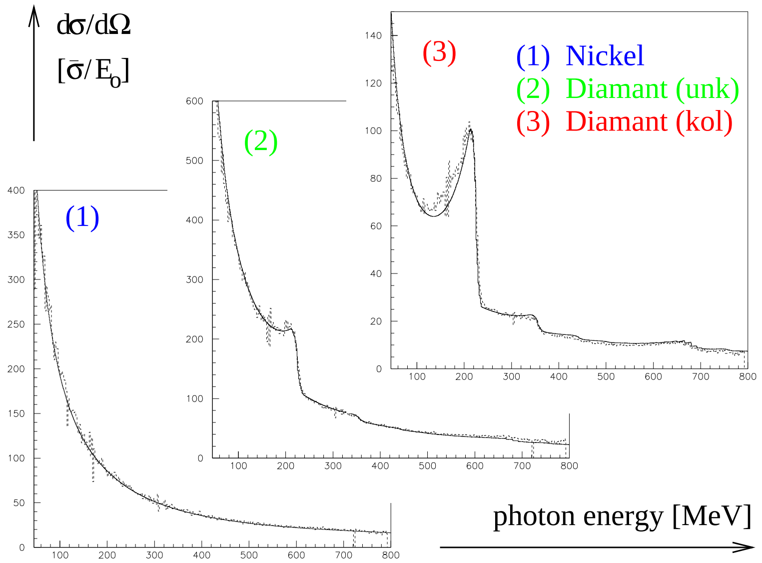
$\sigma \sim \frac{1}{k}\cos^2\phi$

main contribution:

$\vec{E} \parallel \vec{\epsilon} \in (\vec{p}, \vec{q})$ plane

Lattice radiator (diamond) and Bragg condition $\vec{q} = \vec{g}$

$\rightsquigarrow$ additional coherent (polarized) intensity: $I = \frac{k}{\bar{\sigma}}\frac{d\sigma}{dk}$



Collimation:

incoherent:

gets reduced

coherent:

not affected

in $x_c < x < x_d$

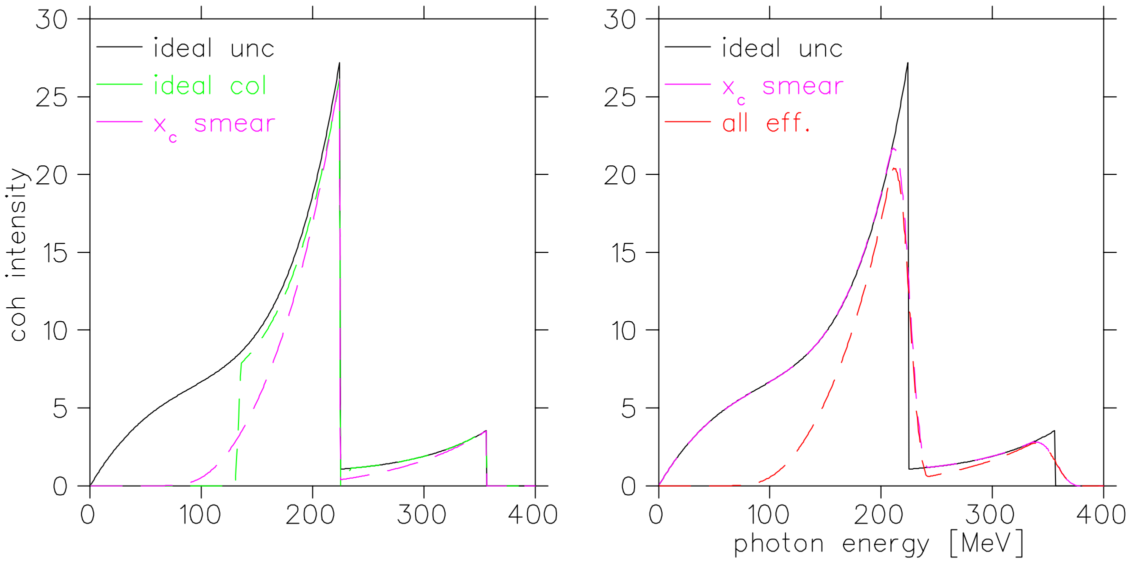
$x_d, x_c \leftarrow \vartheta_c, \vec{g}$

Experimental Effects

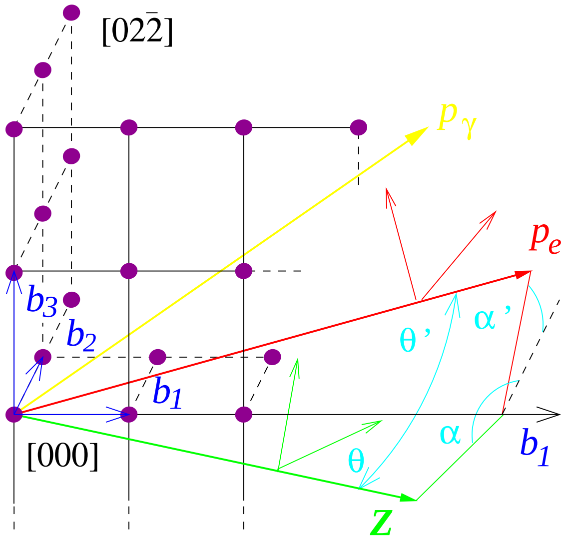
source		effect	influence
temperature	→	Debye Waller factor	$I_{\text{coh}}/I_{\text{inc}}$
BS : beam spot size	→	"fuzzy" collimator	x_c
BD: beam divergence	→	+ variation of θ, α	x_d
MS : multiple scattering	→	increases *BD*	x_d

$$I_{\text{exp}} = \int_{MS} ds \int_{BD} d^2 t_b \; w(\vec{t}_b) \otimes w(\vec{t}_m(s))$$

$$\times \int_{BS} d^2 r_e \; w(\vec{r}_e) \; I_{\text{coh}}(\theta_0, \alpha_0, \vec{t}_e)\Big|_{r_c > |\vec{r}^{\,c}_{\gamma}|}$$



Monte Carlo Simulation (MCB)



Parmeters:

ES (E_0), *BS* ($\vec{r}_e$), *BD*($\vec{t}_b$),
MS ($\vec{t}_m(s)$) distr.
radiator properties

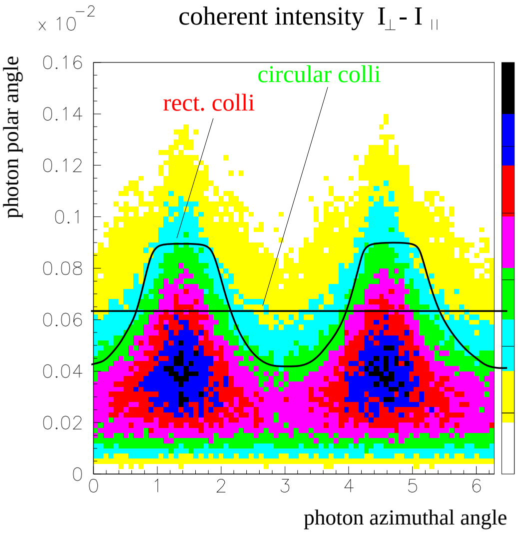
Brems process

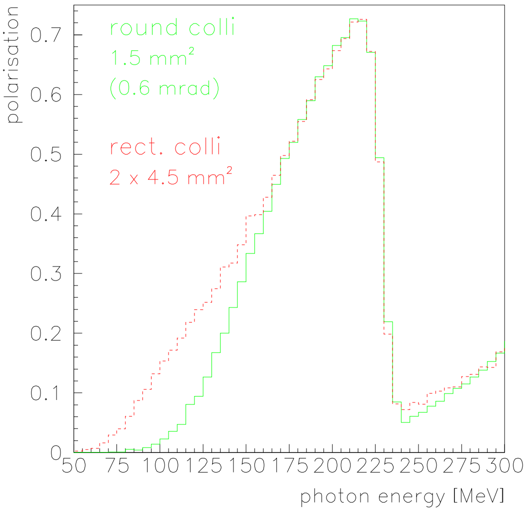
$\theta_0, \alpha_0 \xrightarrow{\vec{p}_e} \theta_e, \alpha_e$
calc intensity $I^{\text{coh,inc}}$
photon ⟶ lab sys
check collimation

→Advantage: 'precise', evaluation of each event

Rectangular collimator

same total collimated cross section (tagging efficiency)





Approximative Analytical Calculation (ANB)

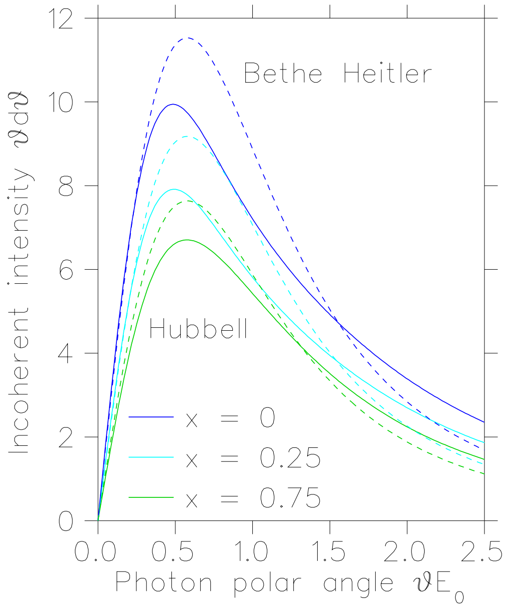
Approximations

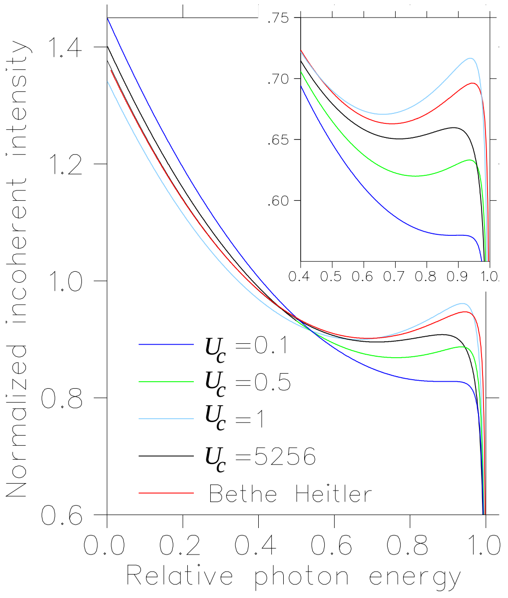
- 2d transversal distributions $\longrightarrow$ spherical symmetrical
- mean multiple scattering distribution: $\bar{\sigma}_m$ (Moliére therory)
- 'total' electron divergence (ED): $\sigma^2_{ED} = \bar{\sigma}^2_m + \sigma^2_{BD}$

$$\Rightarrow \quad I^{\text{inc}/\text{coh}}_{\text{exp}} = \int_{6\text{ fold}} \longrightarrow \int_{\vartheta_c} w(\vartheta_C) I^{\text{inc}} \;\Big/\; C_{ED}\bar{I}^{\text{coh}}$$

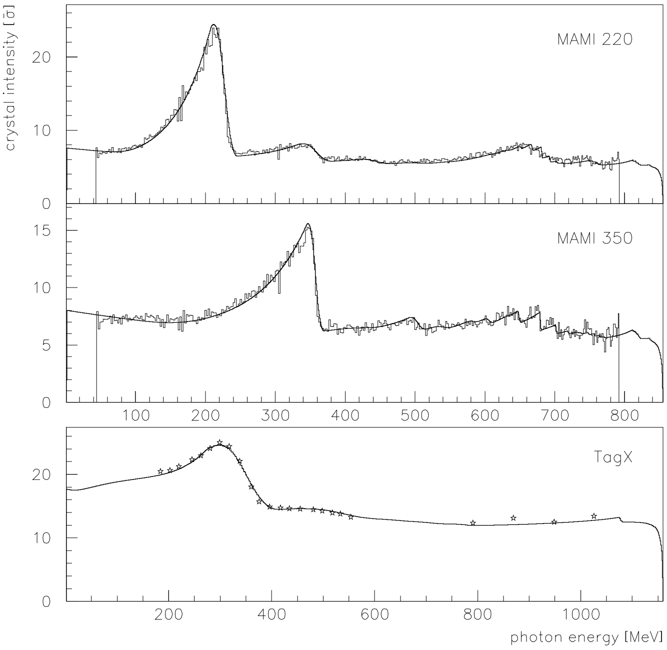
Improvements (ANB,MCB ↔ Göttingen)

- Hubbells xsec: better Z, x, ϑ_c dependence — JAP 30/7(59)981
- e^- contrib. more exact: Z, x, E_B dependent — Mathew, Owens NIM 111(73)157





Results

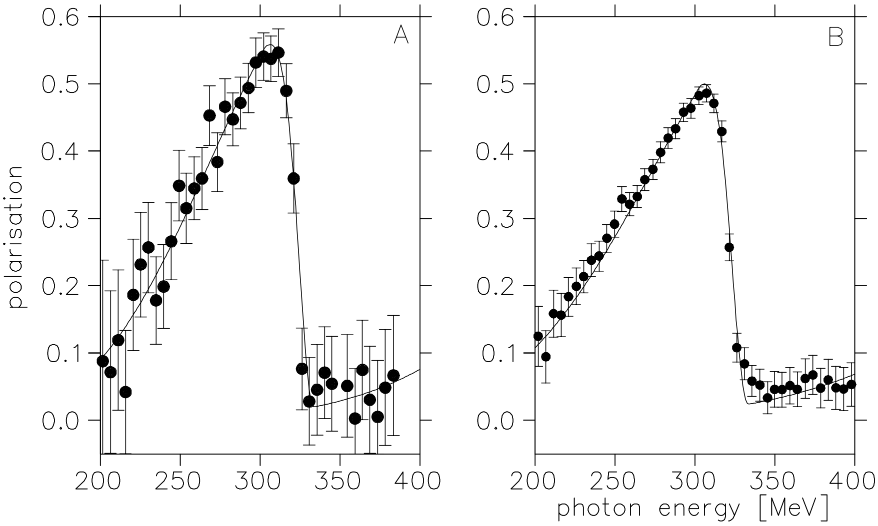


^{4}He($\vec{\gamma}$,2N) @ MAMI:

Diamond-yield compared to total crystal intensity for $k_d = 220, 350$ MeV

TagX @ Tokio:

1.2 GeV, $k_d = 350$ MeV



$\underline{^4\text{He}(\gamma,\pi^0)}$

@ MAMI/TAPS

P_γ completely transferred to azimuthal asym. of π^0 mesons:

$P_\gamma \propto \mathcal{A}^{\pi^0}(\epsilon_{\parallel,\perp})$

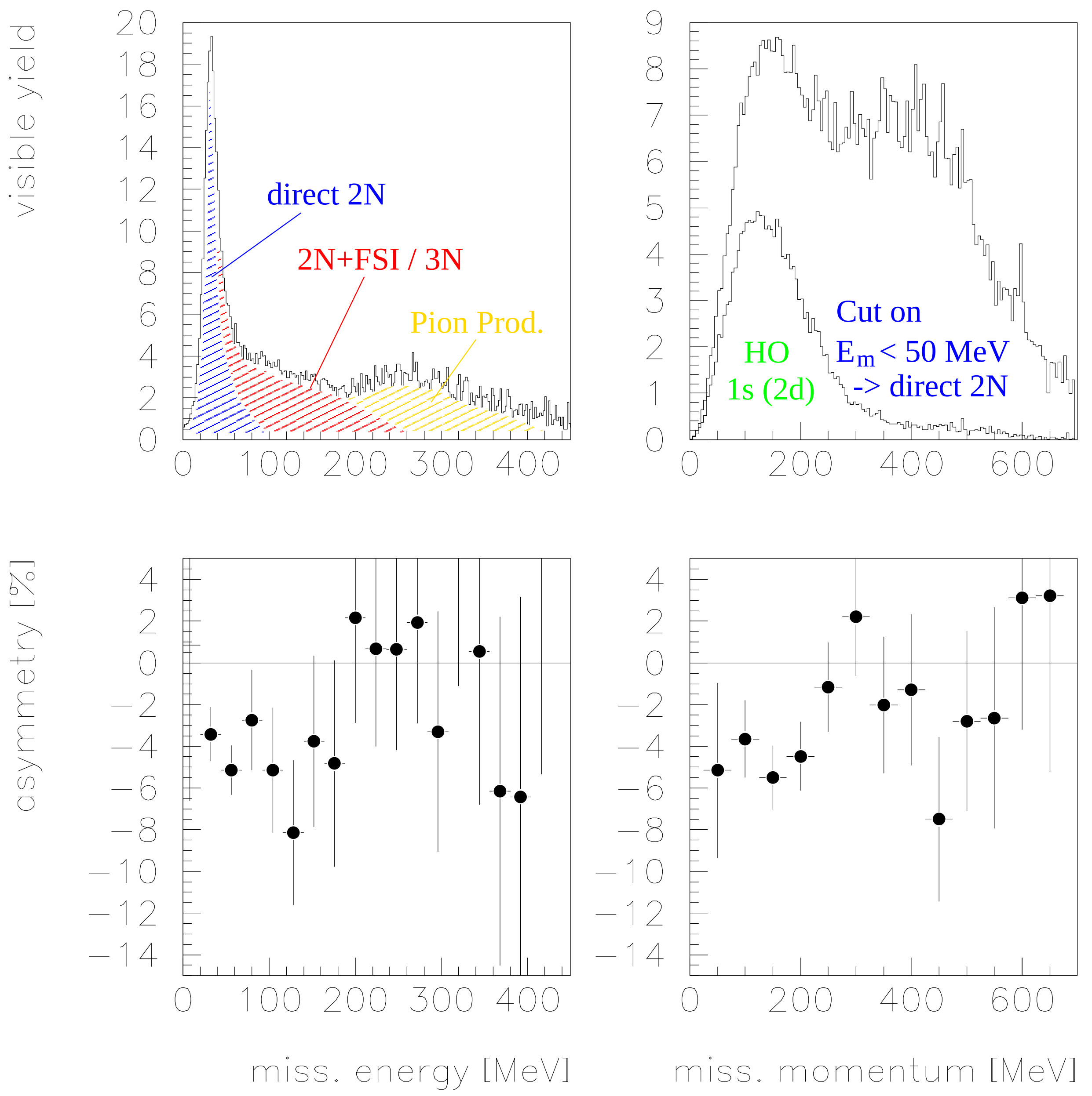
$\longrightarrow$ ANB calc. for 2 colli angles: $\vartheta_c^{A,B} = 0.5, 0.7$ mrad

^{4}He Asymmetry

Asymmetry A: $\sigma_{\|,\perp} = \sigma_0(1 \pm P_\gamma \Sigma) = \sigma_0 \pm A$

$E_{2m} = E_\gamma - T_p - T_n - T_{\text{rec}}$

$\vec{p}_m = \vec{k}_\gamma - \vec{p}_p - \vec{p}_n$

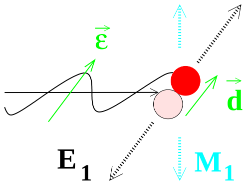


preliminary !!

^{4}He/^{12}C/D Photon Asymmetry in Comparison

Low E_γ :

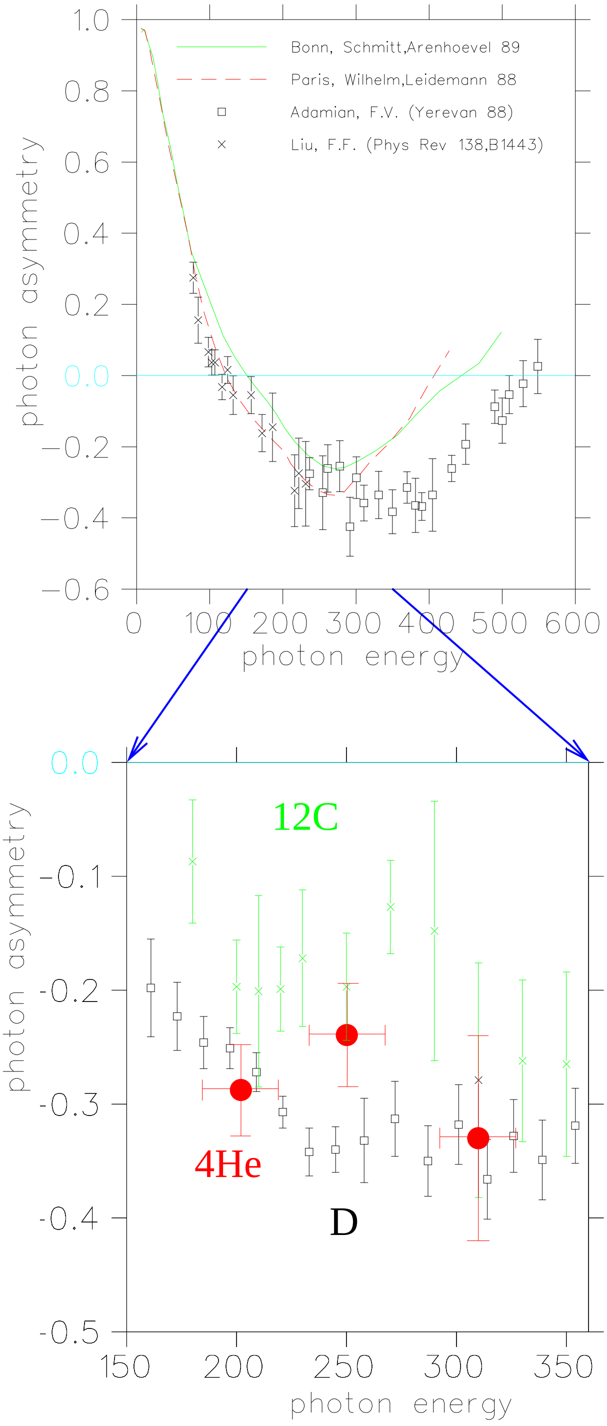
E1 dominant $\rightarrow$ Σ pos



$E_\gamma > \pi$ threshold :

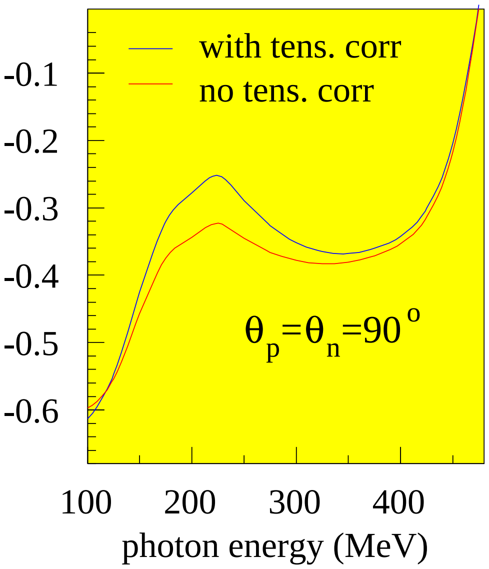
Δ excitation $\rightsquigarrow$

M1 dominant $\rightarrow$ Σ neg



^{12}C(γ,pn)^{10}B (p-shell)^2

$\theta_p = \theta_n = 90^\circ$ (Ryckebusch)



preliminary !!

Summary

- improved bremsstrahl description
  for different radiators and collimators due to
  the use of Hubbells cross section and
  a more exact calculation of the electron contribution.
- two codes:
  ANB approximative but fast
  MCB slow but 'exact'
  $\rightarrow$ $|P_{\mathsf{MCB}} - P_{\mathsf{ANB}}| \lesssim 2\%$, ANB $\approx$ 200 faster
  $\rightarrow$ small contribution from photon polarisation
  to systematic error of asymmetries
- Promising results from the
  asymmetry measurement of ^{4}He ($\vec{\gamma}$,np)
  $\Rightarrow$ comparison with theory essential

Prospects

- Additional information on SRC from ^{4}He($\vec{\gamma}$,pp)
- Successful pilot experiment:
  high-resolution ^{16}O(γ,pp)
  $\rightarrow$ 2N knockout into discrete final states
- high-resolution (e,e'np) in A1
  with TOF and spectrometers