Photonpolarisation and asymmetry in the ^{4}He ($\vec{\gamma}$,np) reaction *

F.A. Natter
PiP/TOF group: Edinburgh, Glasgow, Tübingen
A2 collaboration Mainz

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- Introduction:
  Asymmetry and SRC
- Polarized bremsstrahlung
  - Kinematics and cross section
  - Experimental effects
  - Realistic modelling and results
- Asymmetry of the
  ^{4}He($\vec{\gamma}$,np) reaction
- Summary

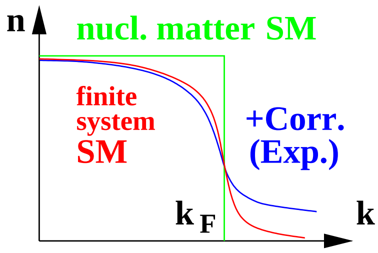
*supported by DFG(Schwerpunkt/Graduiertenkolleg),DAAD,NATO

SRC and Asymmetry

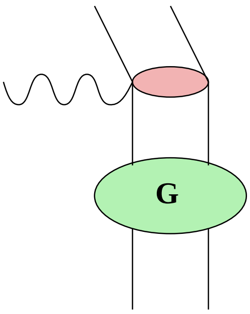
Shell model

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

IPM+Korr



Approach via exclusive 2N emission



2B currents are sensitiv on SRC

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

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

$\rightarrow$ measurement of p_r, includes correlations

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

Jastrow Correlation:

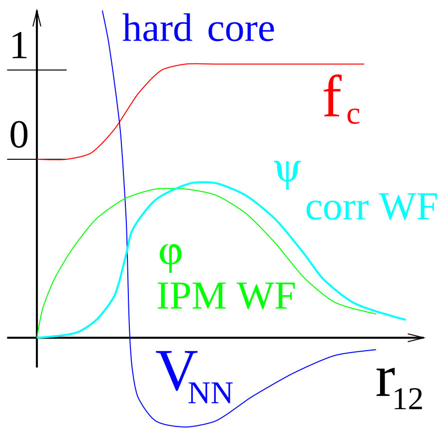
$$\psi_{12} = \phi_1 \phi_2 f_c(r_{12})$$

Direct photo absorption:

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

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

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



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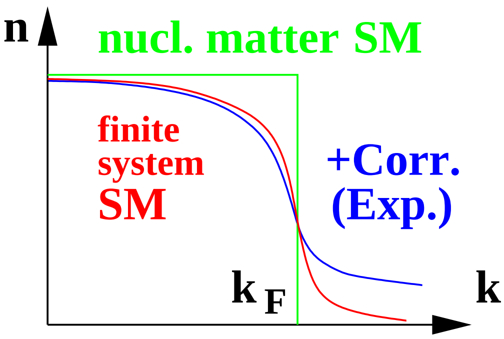

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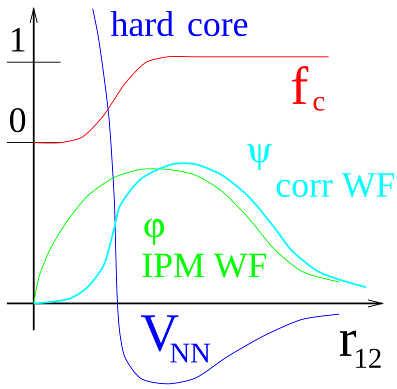

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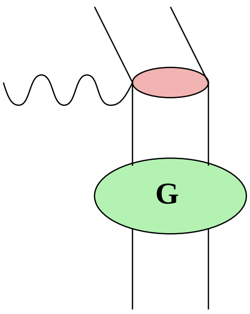

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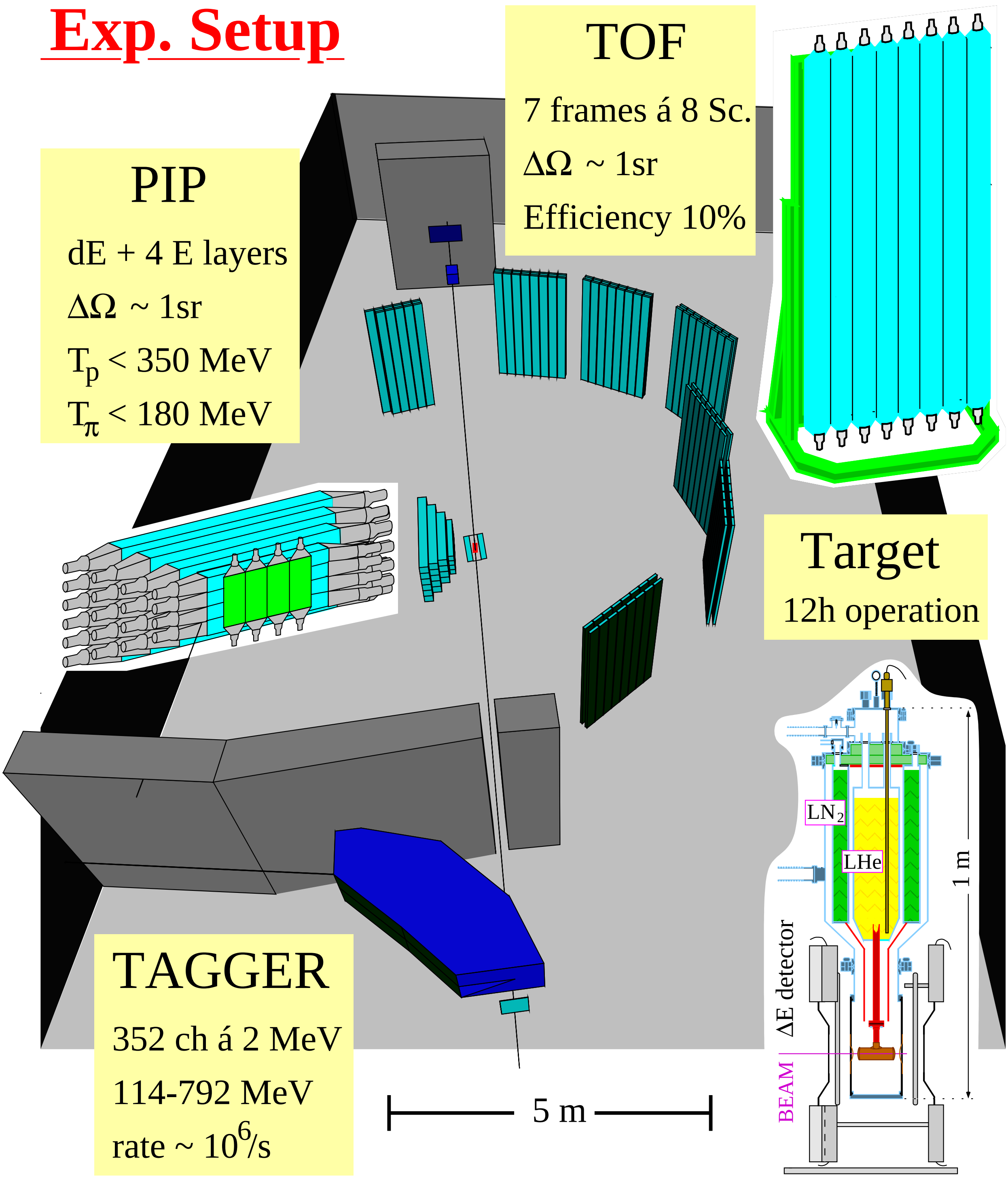
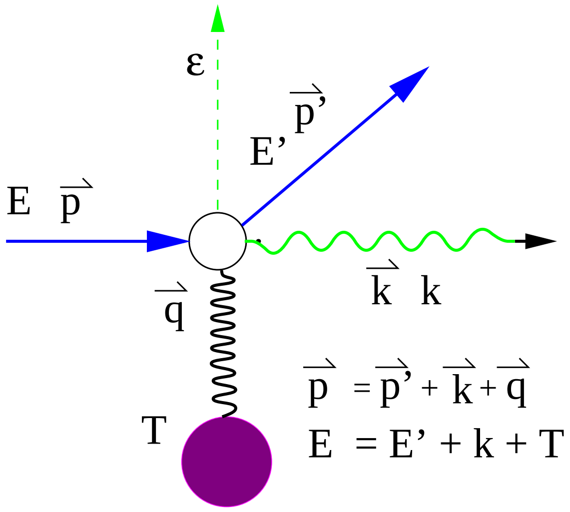
Exp. Setup



TOF
7 frames á 8 Sc.
ΔΩ ~ 1sr
Efficiency 10%
PIP
dE + 4 E layers
ΔΩ ~ 1sr
T_p < 350 MeV
T_π < 180 MeV
Target
12h operation
LN2
LHe
1 m
ΔE detector
BEAM
TAGGER
352 ch á 2 MeV
114-792 MeV
rate ~ 10^6/s
5 m

Bremsstrahlungs Process



Kinematics:

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

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

Cross section:

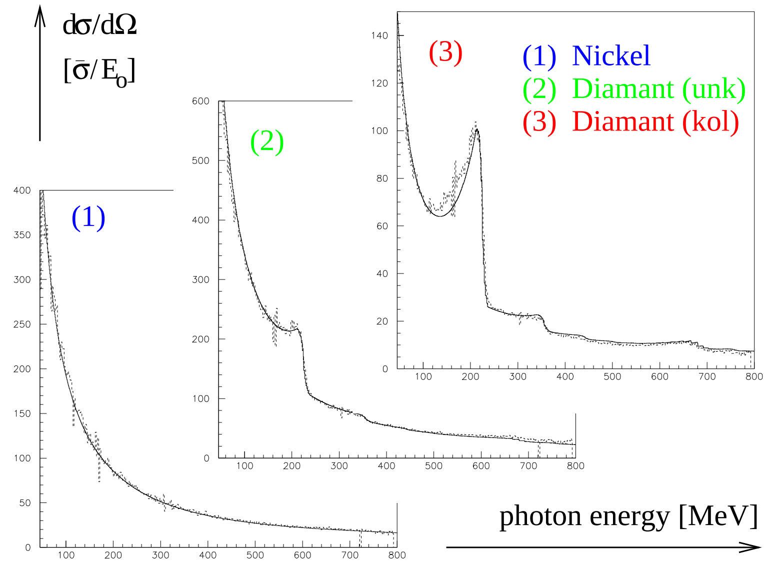
$\sigma \sim \frac{1}{k}\cos^2\phi$

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

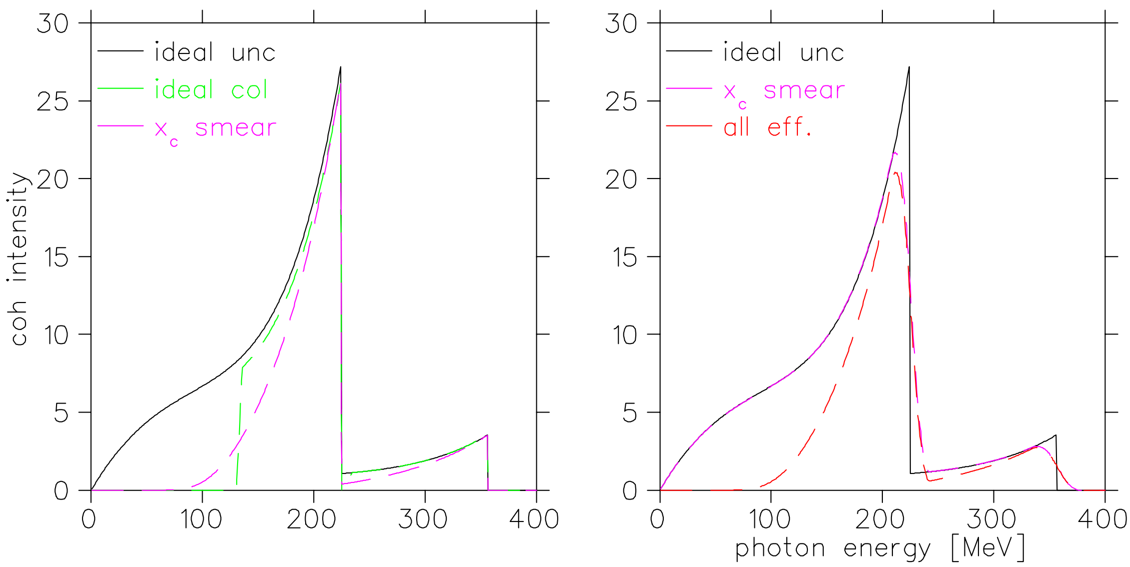
in $x_c < x < x_d$

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

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

$$I_{\text{exp}} = \int_{MS} ds \int_{BD} d^2 t_b \, w(\vec{t}_b) \otimes w(\vec{t}_m(s)) \times \int_{BS} d^2 r_e \, w(\vec{r}_e) \, I_{\text{coh}}(\theta_0, \alpha_0, \vec{t}_e) \Big|_{r_c > |\vec{r}^{\,c}_{\gamma}|}$$

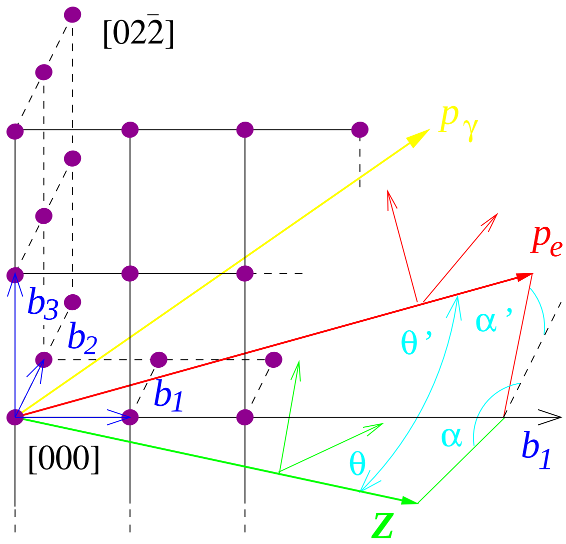


Monte Carlo Simulation (MCB)

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

Brems process

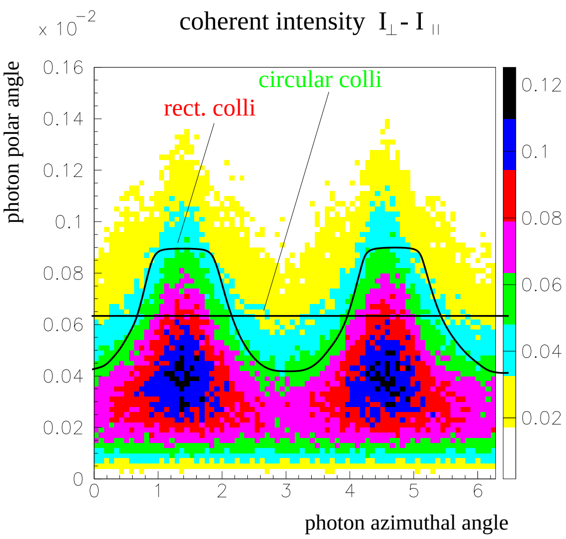
$\theta_0, \alpha_0 \xrightarrow{\vec{p}e} \theta_e, \alpha_e$
calc intensity $I^{\text{coh,inc}}$
photon $\longrightarrow$ lab sys
check collimation

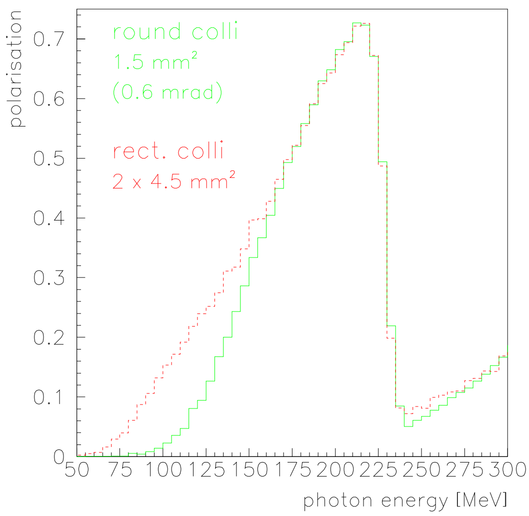


$\rightarrow$Advantage: 'precise', evaluation of each event

Rectangular collimator

same total collimated cross section (tagging efficiency)





PiP TOF

Approximative Analytical Calculation (ANB)

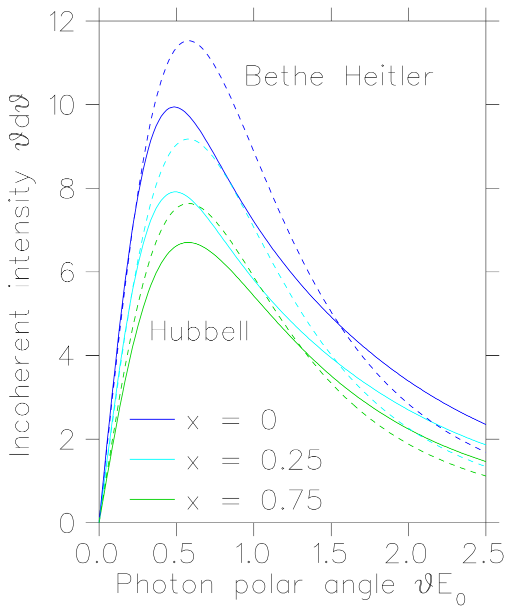
Approximations

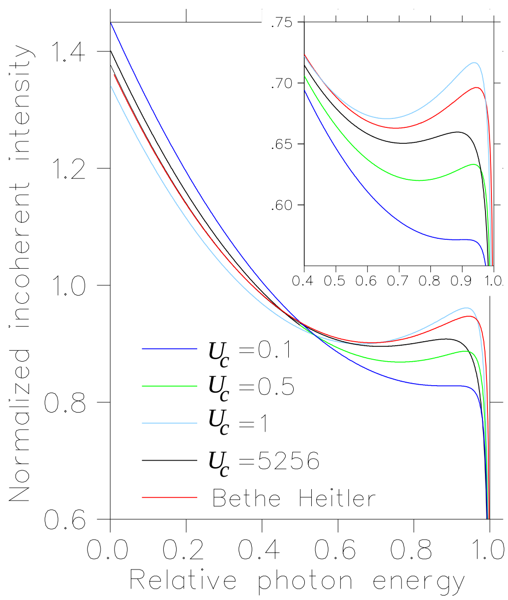
- 2d transversal distributions $\longrightarrow$ spherical symmetrical
- mean multiple scattering distribution: $\bar{\sigma}_m$ (Moliére therory)
- 'total' electron divergence (ED): $\sigma^2_{ED} = \bar{\sigma}^2_m + \sigma^2_{BD}$

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

Improvements (ANB,MCB $\leftrightarrow$ 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





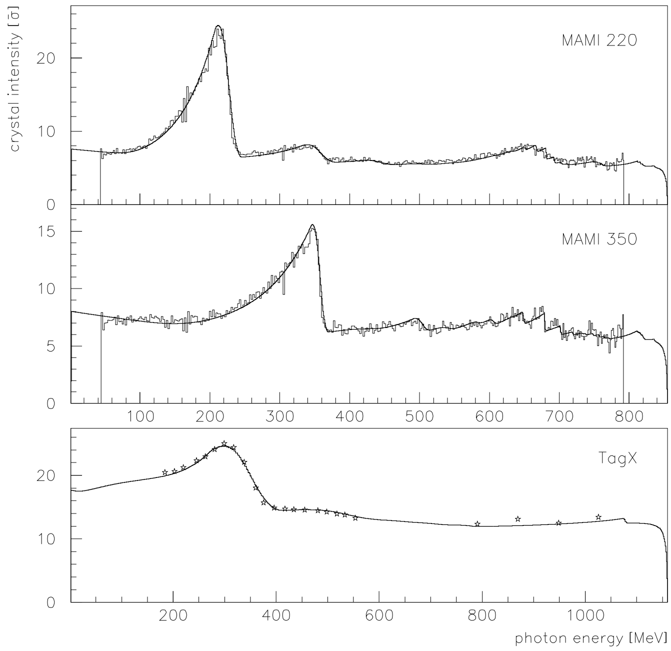
Results

^{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

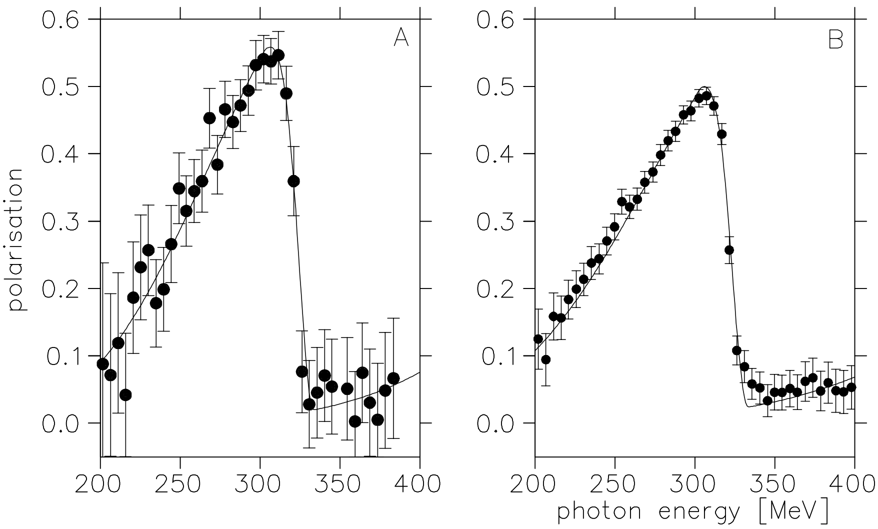


^{4}He(γ, π^0)

@ MAMI/TAPS

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

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



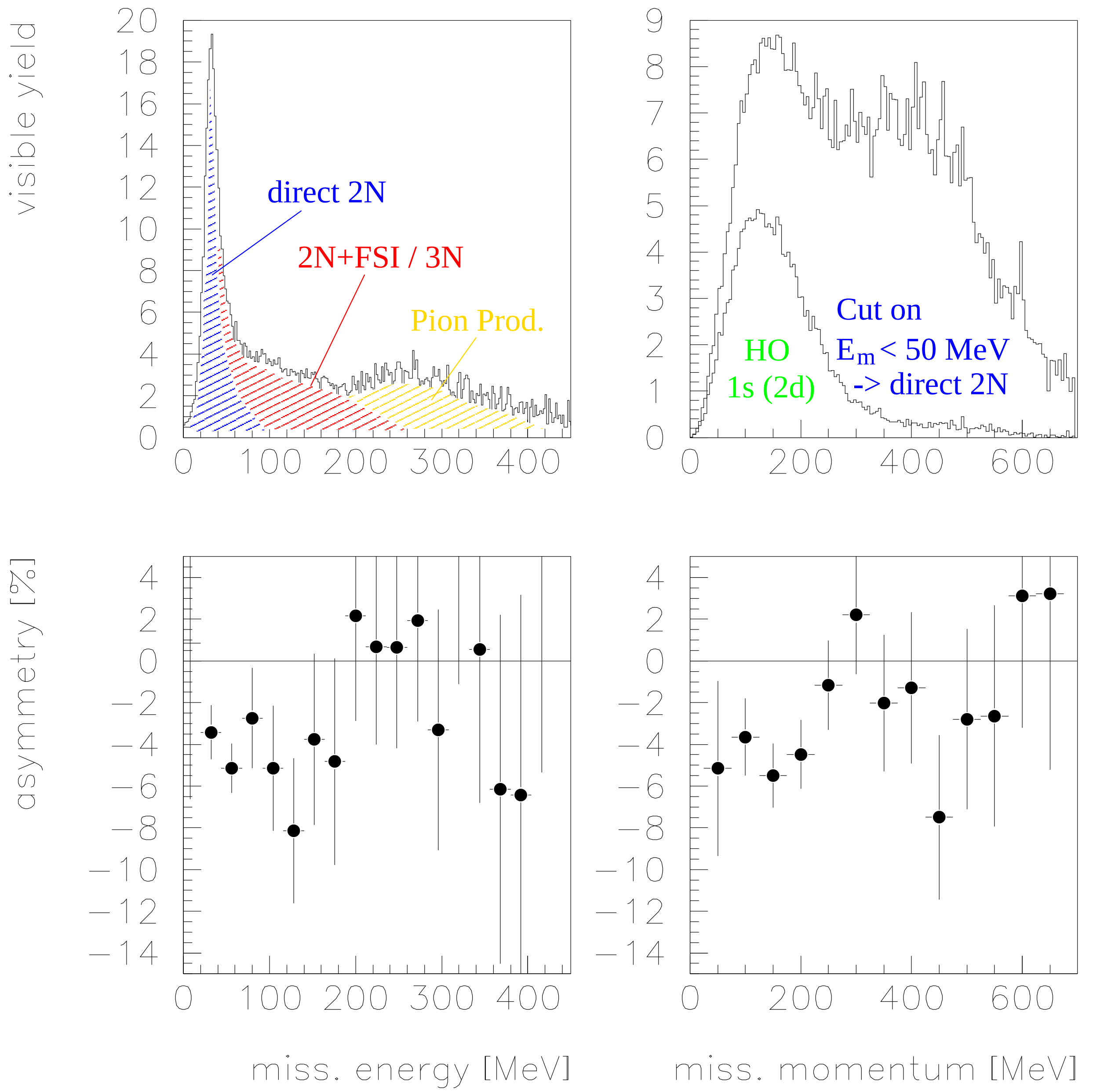
⟶ ANB calc. for 2 colli angles: $\vartheta_c^{A,B} = 0.5, 0.7$ mrad

PiP TOF

Polarisation ^{4}He

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

$E_{2m} = E_\gamma - T_p - T_n - T_{\text{rec}}$ $\qquad$ $\vec{p}_m = \vec{k}_\gamma - \vec{p}_p - \vec{p}_n$



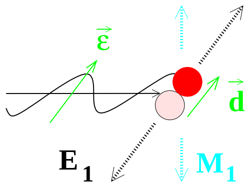
preliminary !!

x

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

Low E_γ :

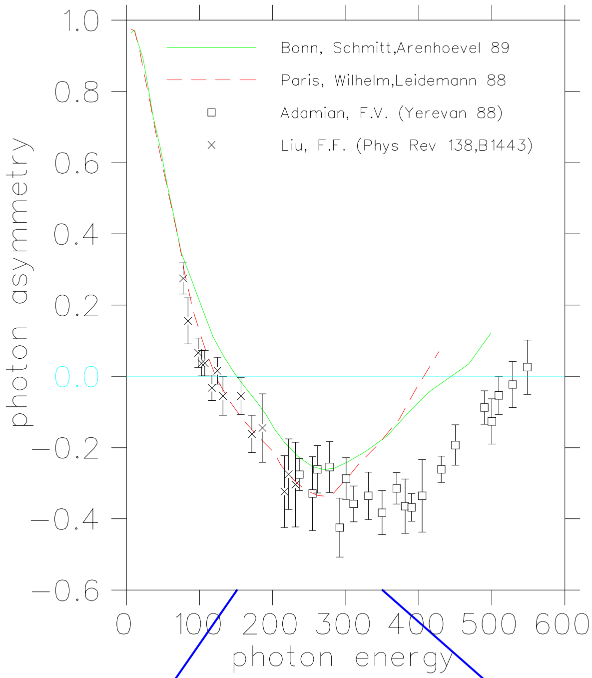
E1 dominant $\rightarrow$ Σ pos



E_γ > π threshold :

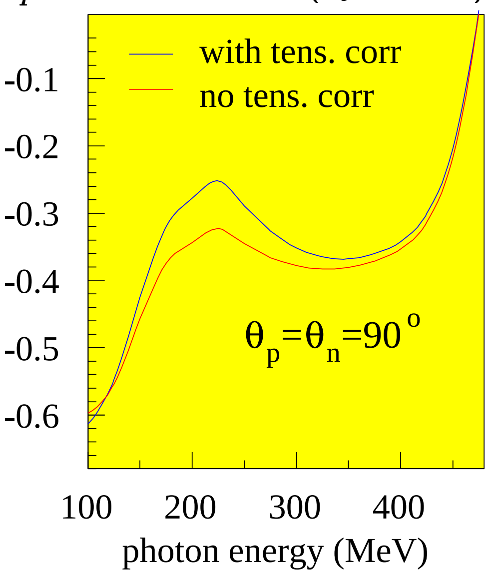
Δ excitation $\rightsquigarrow$

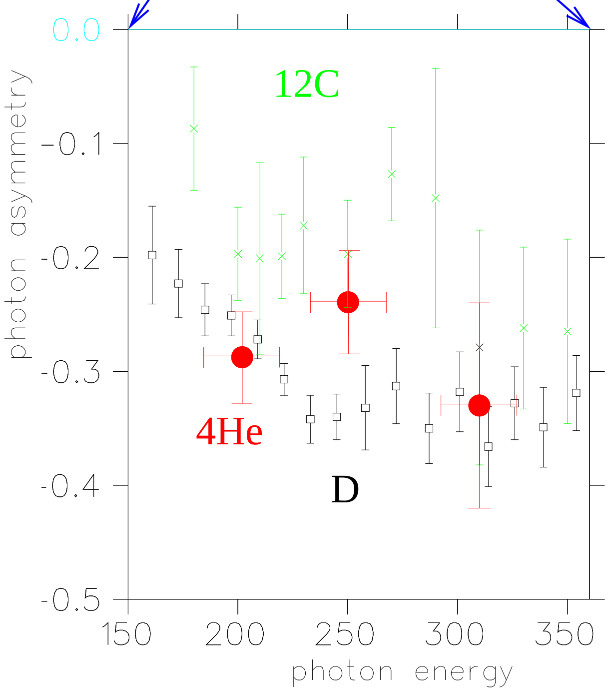
M1 dominant $\rightarrow$ Σ neg



^{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’
  $\rightarrow |P_{\text{MCB}} - P_{\text{ANB}}| \lesssim 2\%$, ANB $\approx$ 200 faster

- reliable prediction of the polarisation over a wide photon energy range, with systematic error less than 3%
  $\rightarrow$ small contribution from photon polarisation to systematic error of asymmetries

- Promising results from the asymmetry measurement of ^{4}He ($\vec{\gamma}$,np)
  $\rightarrow$ Additional information on SRC
  from ^{4}He($\vec{\gamma}$,pp)
  $\Rightarrow$ comparison with theory essential