Study of NN Correlations by polarised photons *

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PiP/TOF Gruppe, A2 Kollaboration

24th April 1998

- Correlations and 2N knockout
  - Introduction
  - Approaches for measurements
- Survey on completed experiments
  - Experimental setup
  - ^{6}Li,^{12}C,^{4}He Results
- The ^{4}He($\vec{\gamma}$,2N) experiment
  - Asymmetry and SRC
  - Production of polarised photons
  - Results
- Conclusion

*supported by DFG,DAAD,NATO

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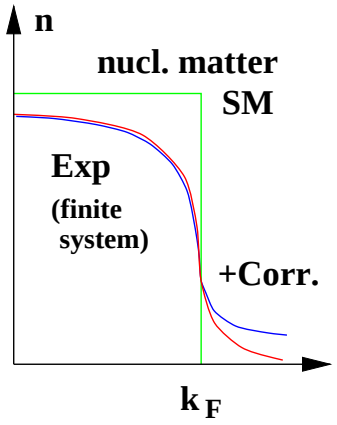
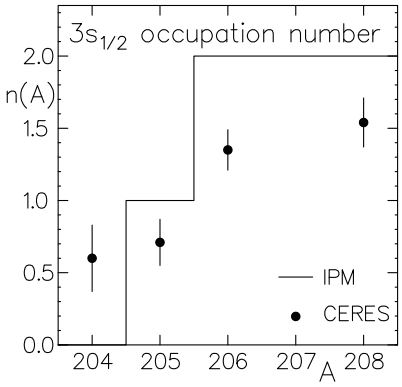
NN Correlations and Photo Absorption

Shell model

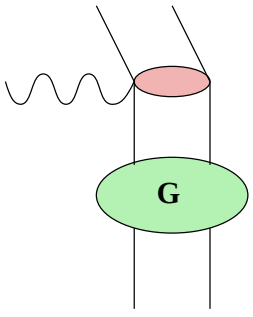
$$\sum V_{ij} = \sum V_i + V_{\rm res}$$
$$\rm IPM + Korr$$



CERES (P. Grabmayr)
Prog.Part.Nucl.Phys **29**(92)251



Approach via exclusive 2N emission



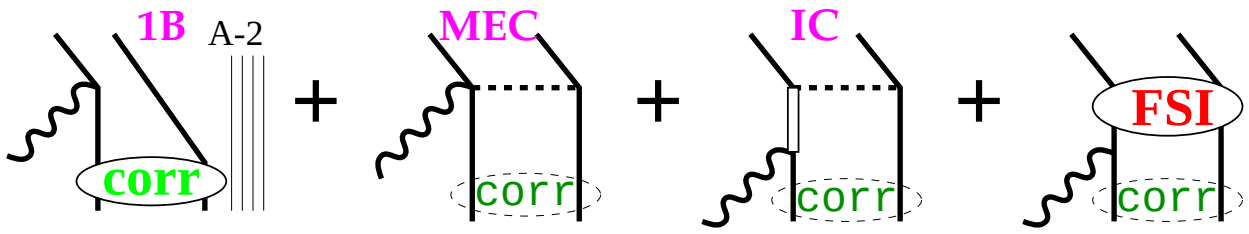
2B currents are sensitiv on SRC

$$\sigma \propto |< f|j_{[1]} + j_{[2]}|i >|^2$$
$$\sim F(P) S_{fi}(< p_r >)$$

$\rightarrow$ measurement of p_r, includes correlations

2N Knockout Measurements

Ground state correlations and competing processes

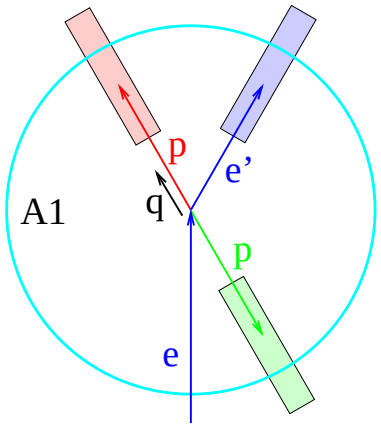


$(e, e'pp)$

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

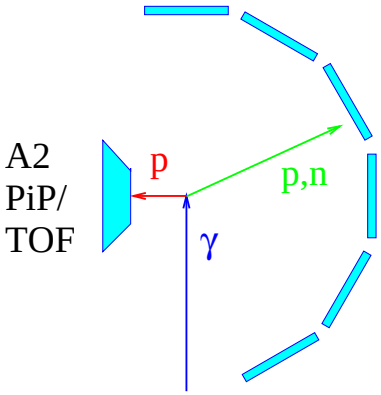
$\rightarrow$ direct approach to central SRC

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



(γ, np) & (γ, 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



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Survey of ^{6}Li, ^{12}C, ^{4}He, D

^{6}Li

- Absorption process understood in QD- and αd cluster model
  ^{6}Li(γ,np/pp)^{4}He exc./g.s. $\rightarrow$ 2N emitted from α/d cluster
- Data (g.s.) are well reproduced by calculations with Moscow potential Kukulin et al. NPA 513(90)332
  $\rightarrow$ Correlated WF dominated by tensor forces
- d-cluster in Li $\equiv$ deuteron (apart from Fermi motion)

^{12}C

- Understanding of reaction mechanisms from comparison with Oset's code
- separation of direct 2N absorption possible
- pp channel weak (possible fed by dominating (γ,np) and FSI induced charge exchange current)

^{4}He

- basically 1S states $\rightarrow$ barely shell mixing
- high density, few nucleons $\rightarrow$ SRC $\nearrow$ FSI $\searrow$
- photon asymmetry (lin. $\vec{\gamma}$) $\rightarrow$ SRC $\nearrow$ FSI $\searrow$

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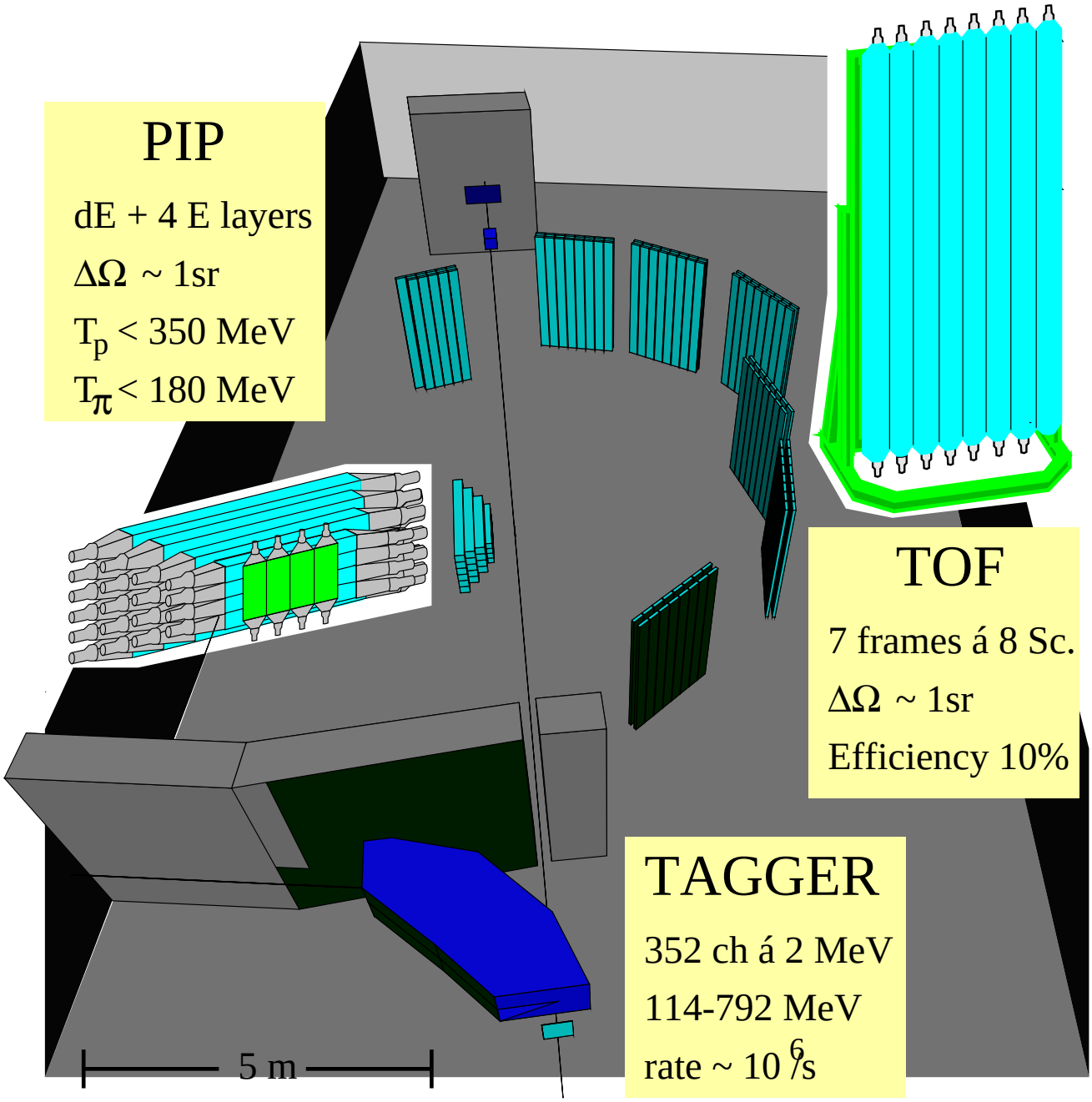
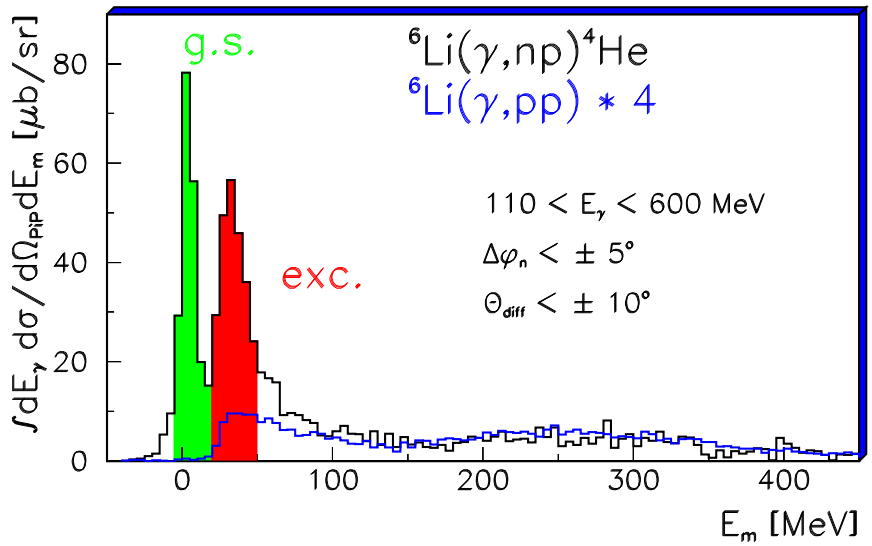
Experimental Setup

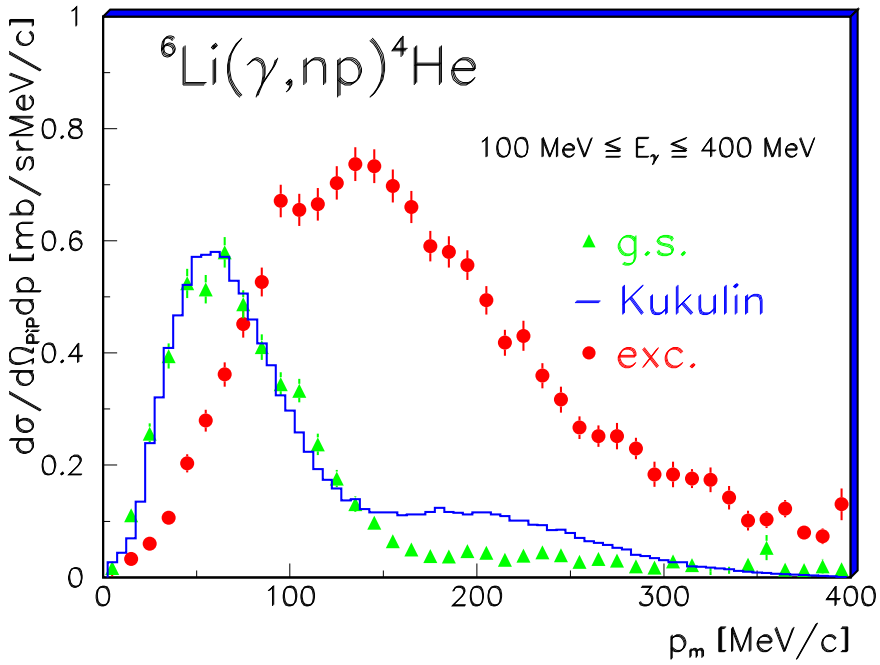


+ ToF system unique
+ High energy and momentum resolution

Tagger: S.J. Hall NIM A301(91)230
PiP : I. MacGregor et al., NIMA 382(96)479
ToF : P. Grabmayr, NIMA 402 (98) 85-94

^{6}Li: α-d Cluster Structure





$$\vec{p}_{\,2m} = \vec{p}_{\,A-2} = \vec{p}_{\,\gamma} - \vec{p}_{\,p} - \vec{p}_{\,n} \overset{\text{PWIA}}{=} -\vec{p}_{\,d}$$

$$\vec{E}_{\,2m} = E_\gamma - T_p - T_n$$

P. Grabmayr et al., Phys. Lett. B 370 (96) 17

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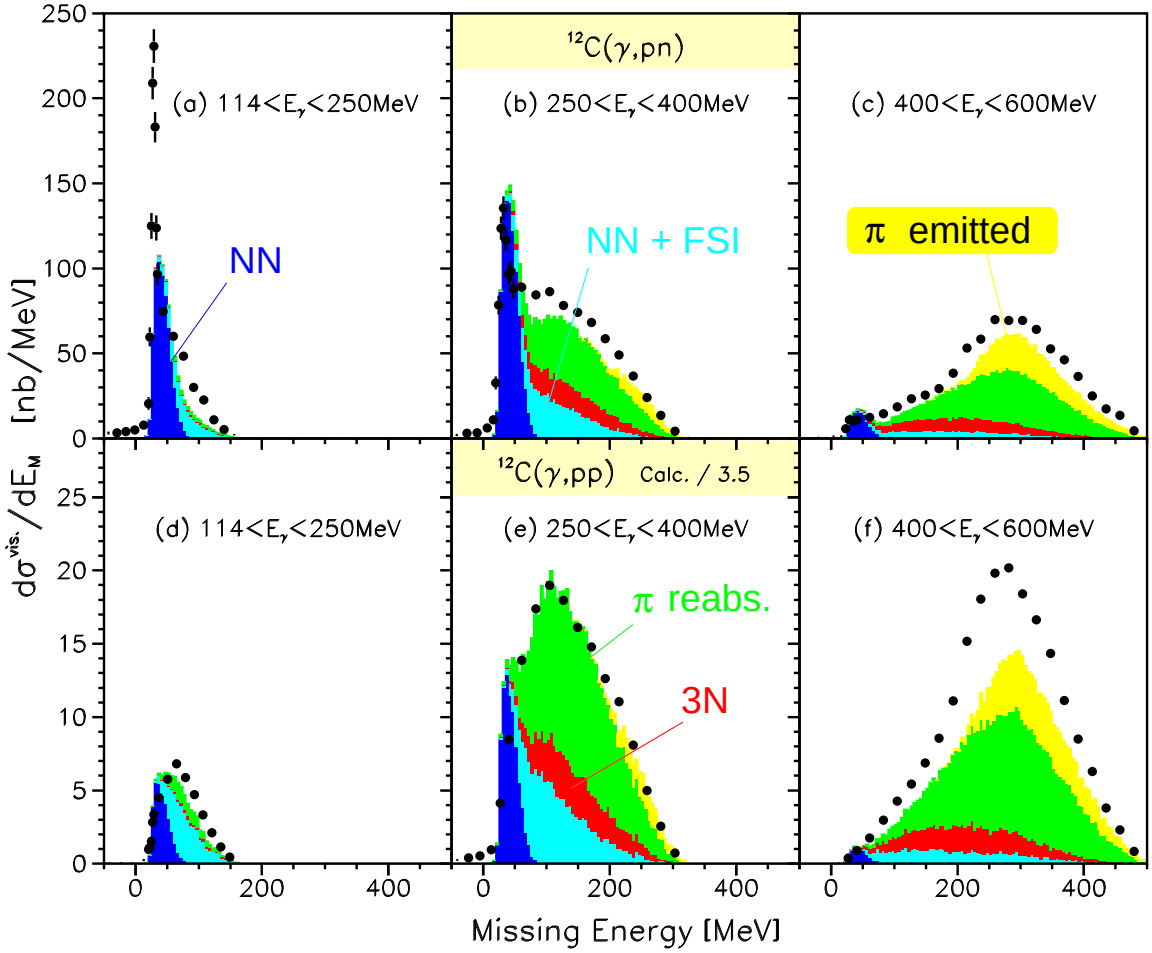
^{12}C: Reaction Mechanisms

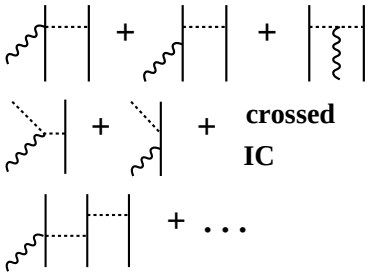


2N absorption (+ FSI)

QFπ production (emit/reabs)

3N absorption

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



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

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

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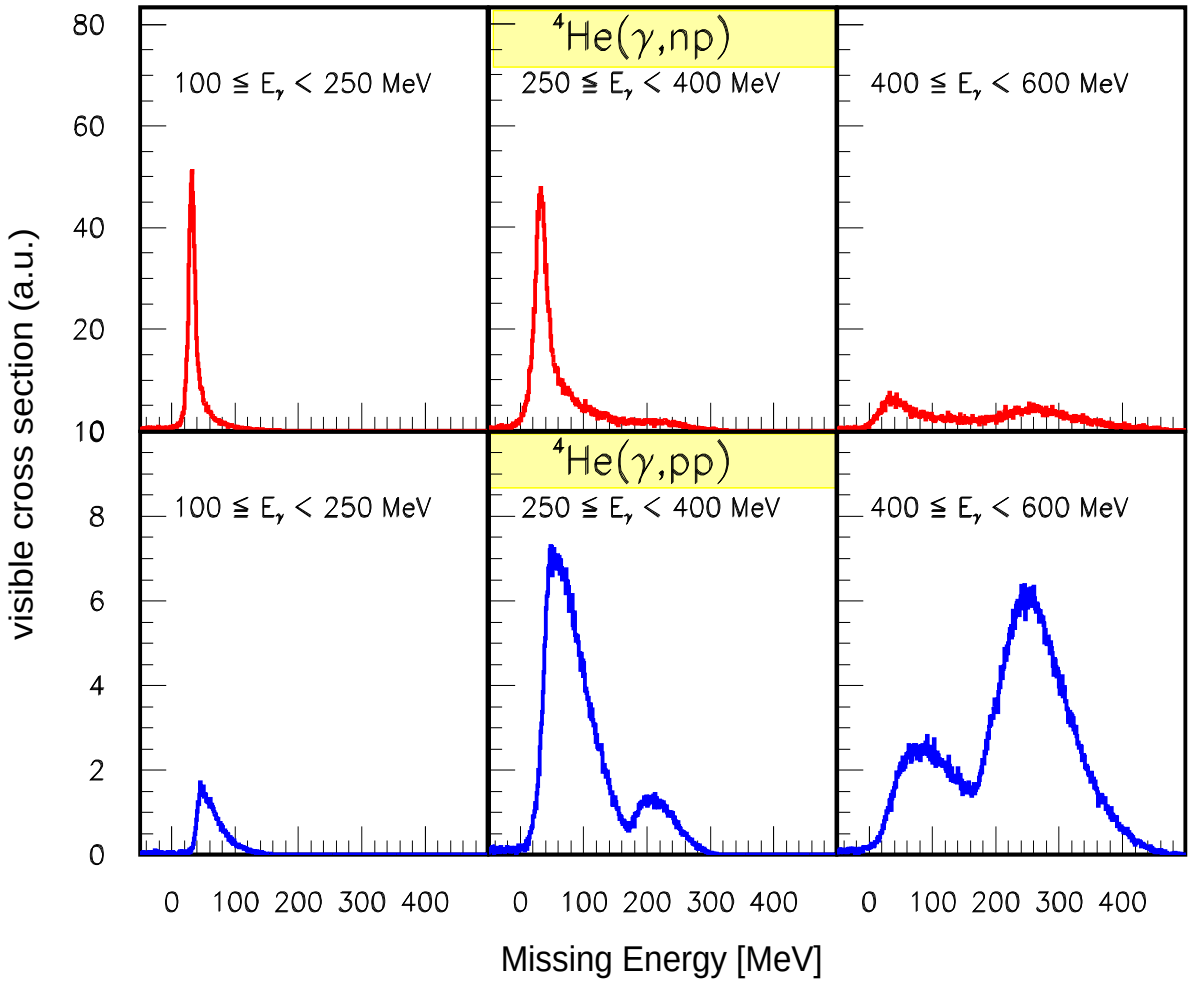
^{4}He Missing Energy Distribution



- same features as ^{12}C
- FSI reduced compared to ^{12}C
- direct 2N absorption stronger with respect to inelastic processes

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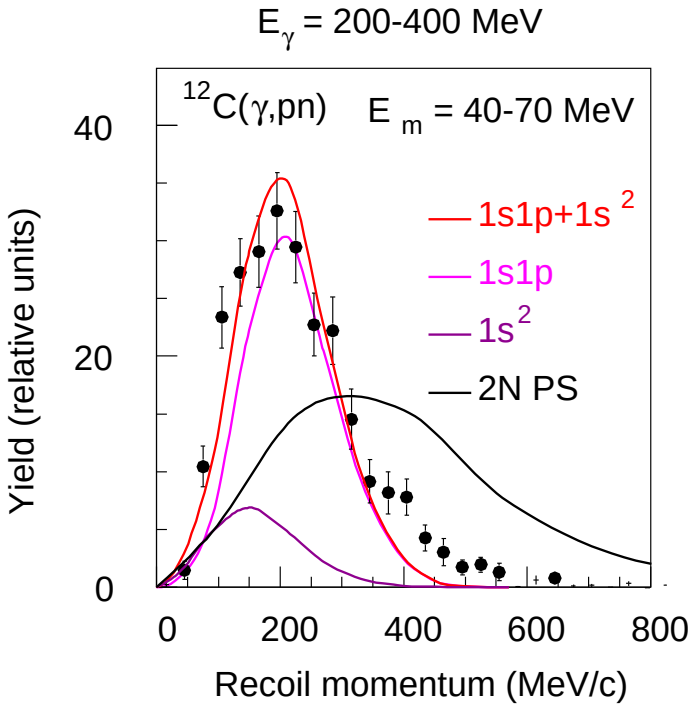
preliminary !!

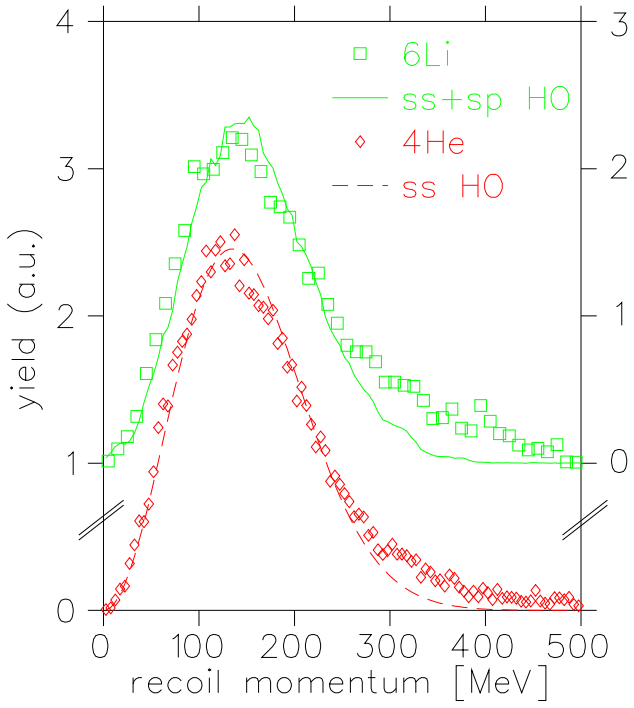
Pair Momentum Distributions



HO momentum distribution fits data →

Spectator model applicable

$P_{\mathrm{NN}} = -p_{\mathrm{rec}}$



Separation $\sigma \propto F(P)S_{fi}$ possible

^{4}He and ^{6}Li exc. same pair momentum distribution

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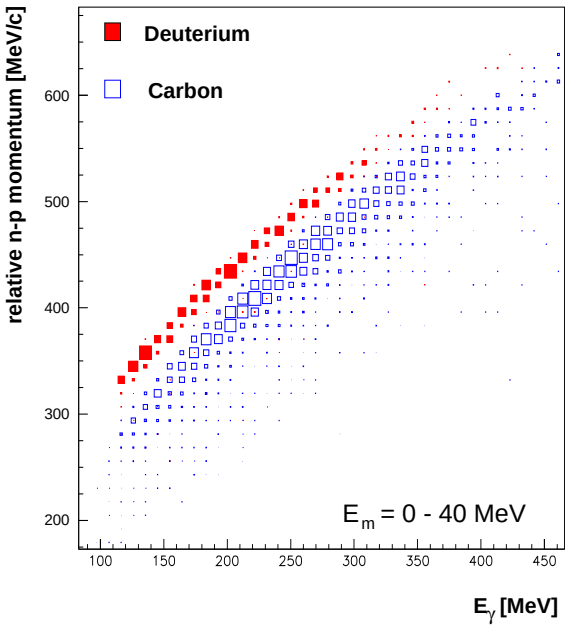
NN Relative Momenta

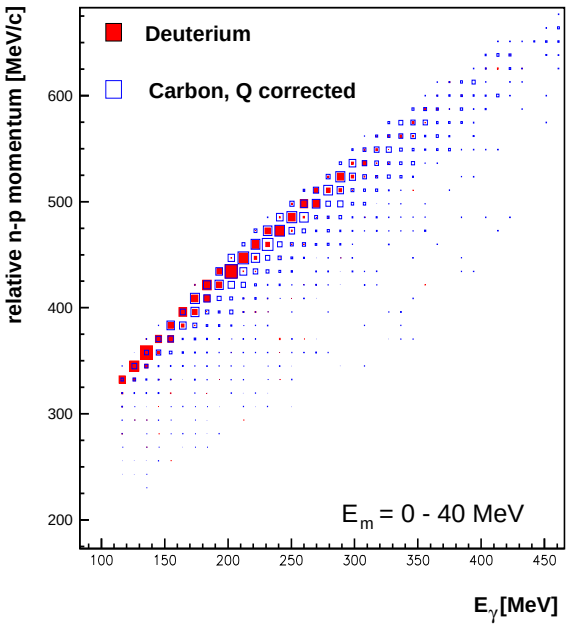
Final: $\vec{p}\,'_{\text{rel}} = (\vec{p}\,'_p - \vec{p}\,'_n)/2$ 'Perpendicular' kinematics

Initial: $\vec{p}_{\text{rel}} = \vec{p}\,'_{\text{rel}} \pm \vec{q}\,/2$ $\rightarrow \vec{p}_{\text{rel}} \approx \vec{p}\,'_{\text{rel}}$



np COM system:
kin. relation: $p_{\text{rel}}(E_\gamma)$

Q values differ $\rightarrow$
not comparable



eventwise Q value
corrected via E_{2m}

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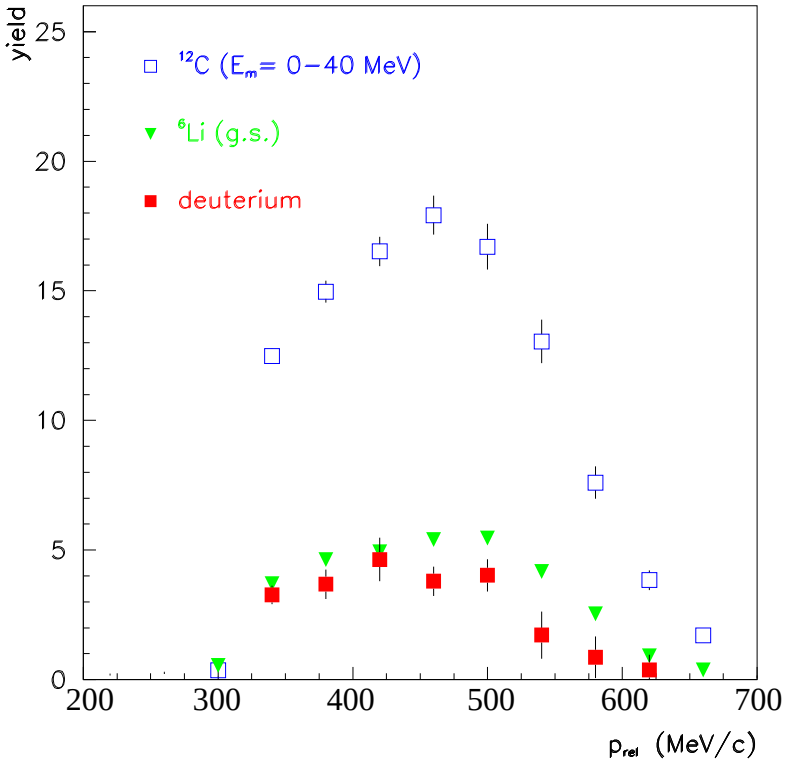
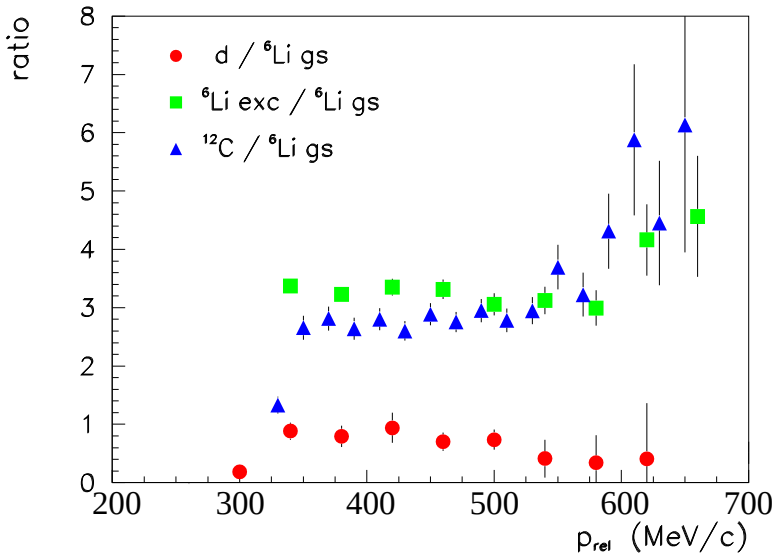
Relative Momentum Distributions



Yield

corrected for different solid angle acceptance



Ratio

with respect to ^{6}Li g.s. yield

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Polarised Measurements

Photon asymmetry Σ (SRC sensitive observable):

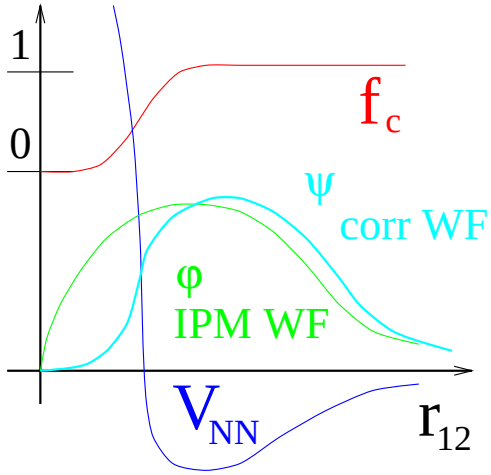
$\Sigma = \frac{1}{P_\gamma}\frac{\sigma_{\parallel}-\sigma_{\perp}}{\sigma_{\parallel}+\sigma_{\perp}}$ with $\sigma_{\parallel,\perp} = \sigma_0(1 \pm P_\gamma \Sigma)$

Jastrow Correlation:

$$\Psi(1,A) = \prod_{i<j}\sum_{S,T} f_{ST}(r_{ij})\Lambda_{ST}\,\Phi(1,A)$$

emitted NN only (central):

$$\Psi(1,A) = \Phi(3,A)\psi_{12} = \Phi(3,A)\phi_1\phi_2 f_c(r_{12})$$



Direct photo absorption:

factorized Xsec in QD and zero range approximation:

(Jan Ryckebusch, Phys. Lett. B383 (96); Boato/Giannini J. Phys. G15 (89))

$$\sigma_0 \sim \left| J_{1B}^{S,C}(f) + J_{MEC}(f) + J_{\Delta}^{(non)res} \right|^2$$

$$\sigma_0\Sigma \sim \left| J_{1B}^{C}(f) + j_{MEC}(f) - J_{\Delta}^{(non)res} \right|^2$$

Additional support:

Boffi et. al., Nucl. Phys. A **564** (1993) 473 : $^{16}O(\gamma, pn)^{14}N$

A. Buchmann, Leidemann Nucl. Phys. A 443 (85) 726 : $\sigma, \Sigma\{d(\gamma,p)n\}$

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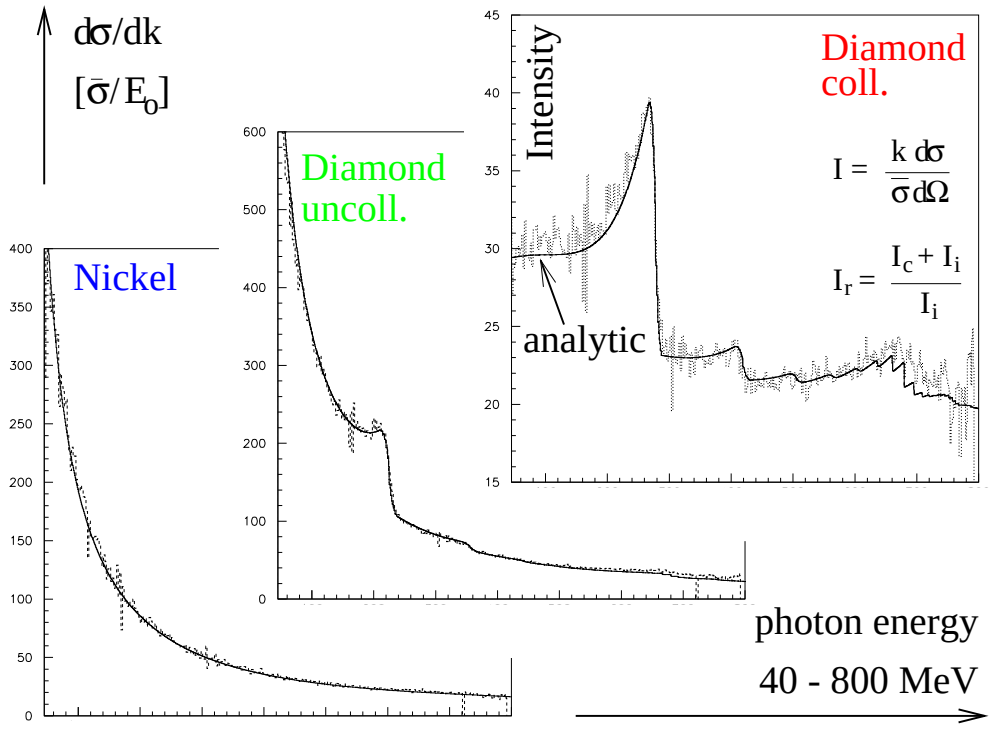
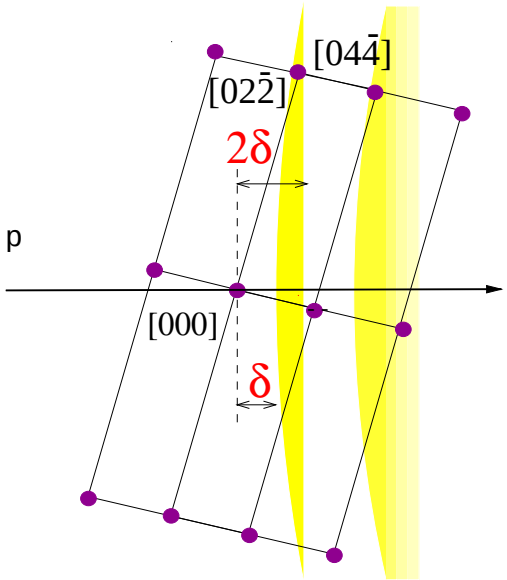
Bremsstrahlung (experimental)



Kinematic:

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

MAMI: $q_t/q_l \approx 10^3$



Cross section:

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

Main contrib:

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

$\rightarrow P_{\max}(220, 280, 350) = 68, 62, 51\%$

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

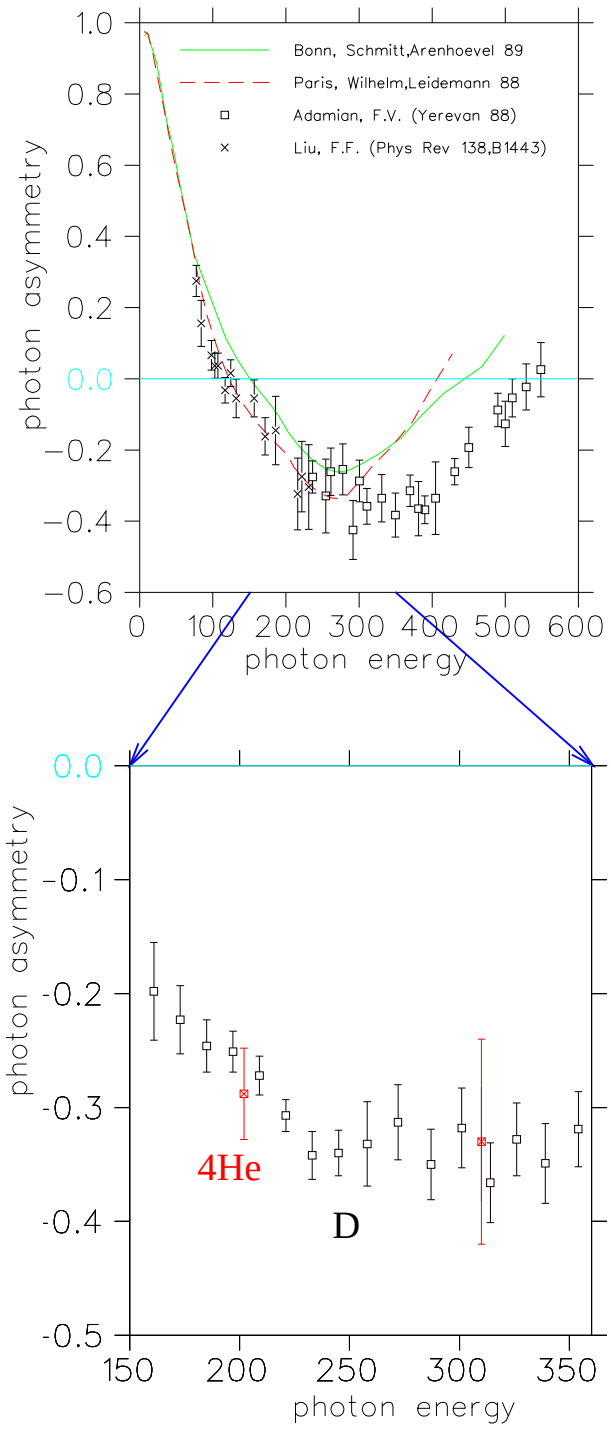
Low E_γ :

E1 dominant $\rightarrow \Sigma$ pos

$E_\gamma > \pi$ threshold :

M1 dominant $\rightarrow \Sigma$ neg
(N-Δ transition $\sim$ M1)

$(\theta_p = 90°)$



^{4}He $\sim$ D ?

(only subset of data !,
calibration not yet finished)

^{12}C : Σ smaller
FSI or medium
dependent SRC

$(50° < \theta_p < 130°)$

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preliminary !!

Summary

- reaction mechanisms understood (Oset)
  → direct 2N absorption separable
- Spectator model and factorization applicable
  Separation of center and relative motion
  → high relative momenta at present clearest sign of SRC
- pn channel: comparison with free deuteron (also polarized)
- Photon asymmetry measurements on ^{4}He and ^{12}C performed.
  (reliable data, high statistics and encouraging preliminary results)

Perspectives

- (e,e'pn) as missing reaction (targets: ^{3,4}He, ^{16}O)
  (theoretical evidence for stronger effects in pn than pp).
  → First test proved feasibility of experiment
- high energy resolution to extract state dependent SRC
- Comparison to latest calculations:
  (^{16}O: Müther, Tübingen; ^{4}He: Ryckebusch, Gent)

Real photon experiments are most competitive worldwide
(in collaboration with Scottish groups)
(e,e'pp) Mainz, supported by SFB
(e,e'pn) Mainz, supported by DFG Schwerpunkt

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