experiments with photons at Mainz

NN interaction at short distances

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Deutsche
Forschungsgemeinschaft
DFG

nuclear structure & NN interaction

nuclear
many body
systems:

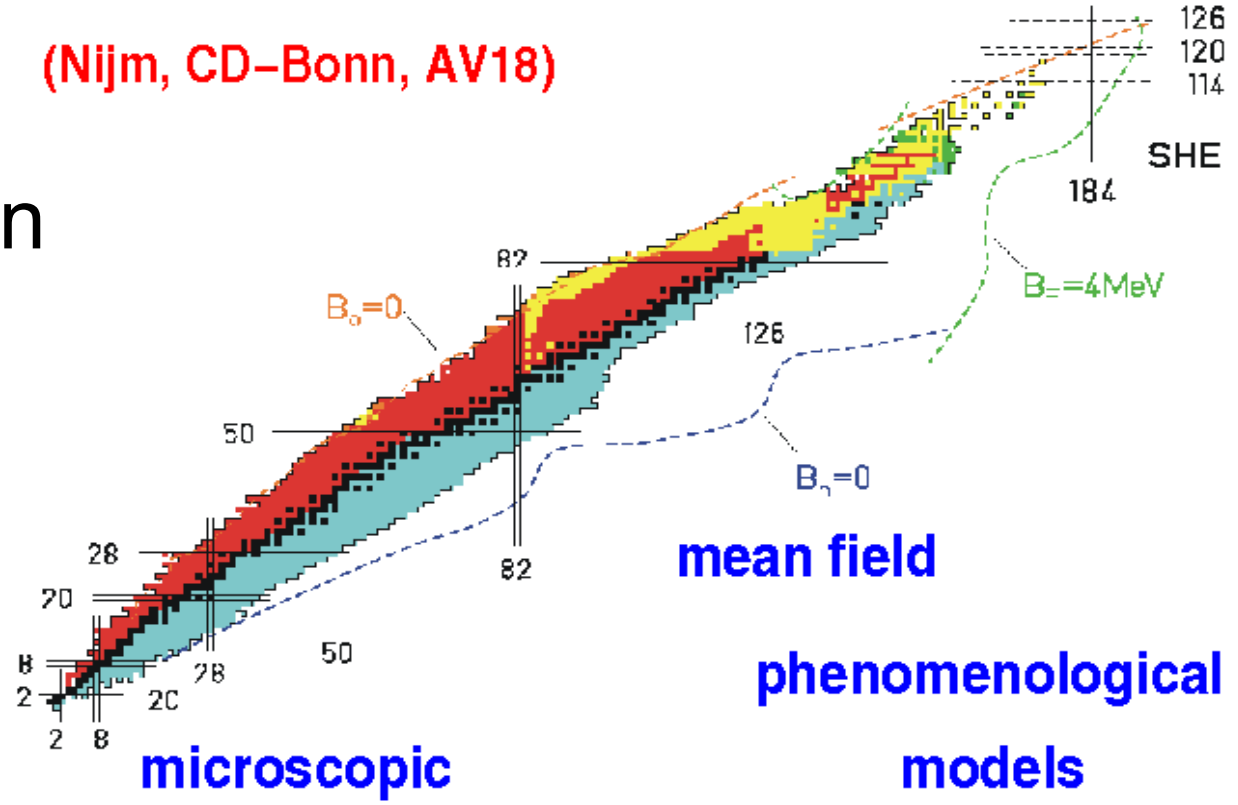
Schrödinger equation

$$H\Psi = E\Psi$$

Nucleon–nucleon Interaction

(Nijm, CD–Bonn, AV18)

neutron stars

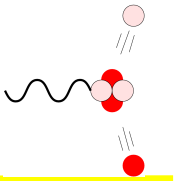


mean field

phenomenological models

microscopic

NN potentials

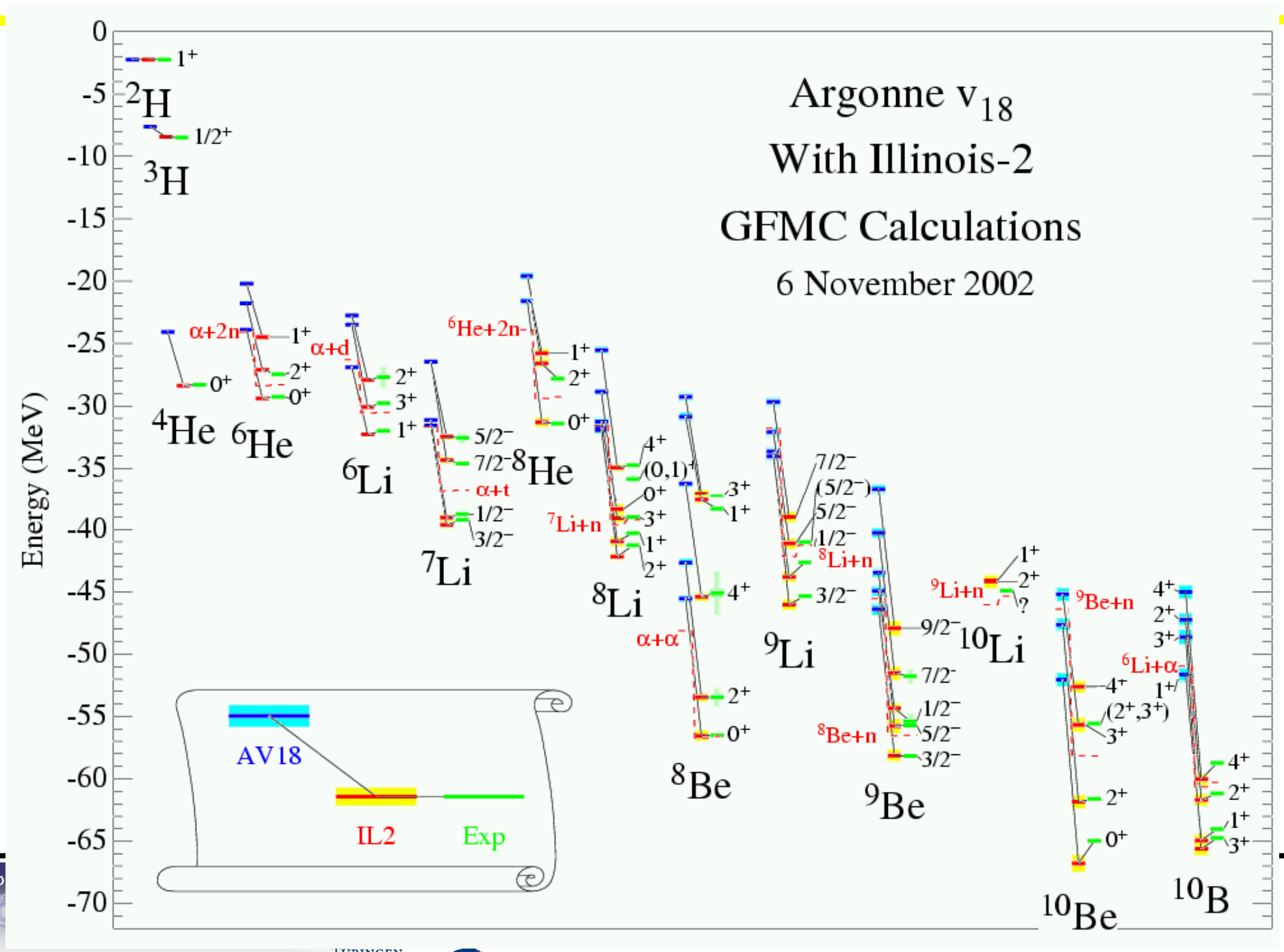


choose NN potential
define system
minimize through variation (+GFMC)

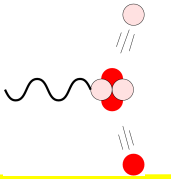
$$E_V = \frac{\langle \psi_V | H | \psi_V \rangle}{\langle \psi_V | \psi_V \rangle} \geq E_o$$

Potenzial/MeV	^{3}H	^{4}He	3Body	^{3}H	^{4}He
Experiment	8.48	28.40		8.48	28.40
Nijm 1	7.74	24.98			
CD-Bonn	8.01	26.26	TM	8.48	28.40
AV18	7.6	24.01	U/IX	8.48	28.50

nuclear structure & NN interaction



Outline



- Introduction
- Some experimental details
- real and virtual photon induced 2N emission
- momentum distributions
- neutron electric form factor
- summary

- 20 years of neutron detector TOF

  (blueprints to Bonn, COSY, J.Rapaport ff.)

NN correlations

H. Müther: exp(S) method

$$|\Psi>=\exp\left(\sum_{n=1}^{A}\hat{S}_n\right)|\Phi> \qquad (1)$$

$$\hat{S}_n=\frac{1}{n!^2}\sum_{\nu_i\rho_i}<\rho_1\ldots\rho_n|S_n|\nu_1\ldots\nu_n>a^\dagger_{\rho_1}\ldots a^\dagger_{\rho_n}a_{\nu_n}\ldots a_{\nu_1} \qquad (2)$$

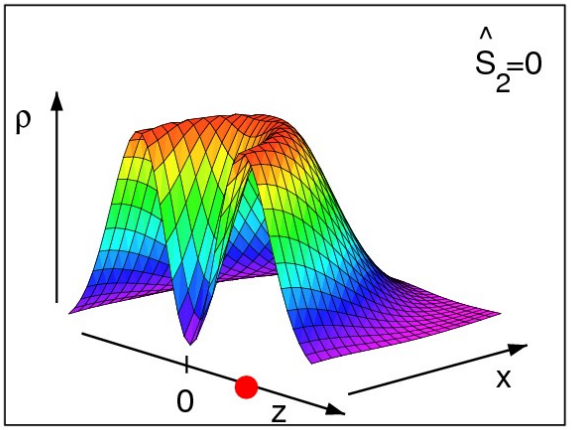
with n=1&2 ; ρ_i unoccupied and ν_i occupied states

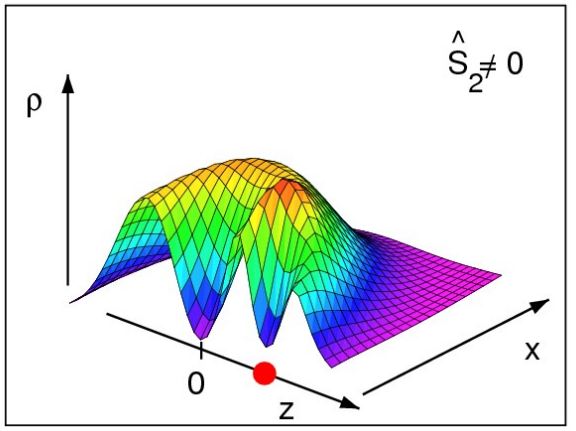
$$\begin{aligned}\psi_1|\nu_1> &= |\nu_1>+\hat{S}_1|\nu_1>\\ \psi_2|\nu_1\nu_2> &= \mathcal{A}\,\psi_1|\nu_1>\psi_1|\nu_2>+\hat{S}_2|\nu_1\nu_2> \qquad (3)\end{aligned}$$

$$\left|<\vec{r}_1\vec{r}_2|\psi_2|p_{1/2},p_{1/2}\,J=0,T=1>\right|^2$$

^{16}O

$(p_{1/2})^{-2}$





$(\hat{S}_2=0)$ $(\hat{S}_2\neq 0)$

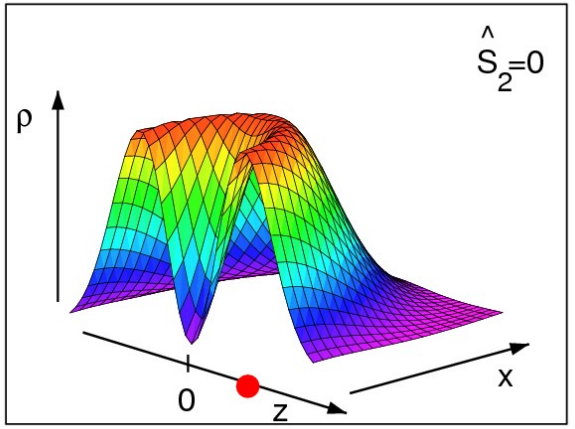
$\vec{r}_1=(x_1=0,y_1=0,z_1=2\ \text{fm})\ (x_2>0,y_2=0)$

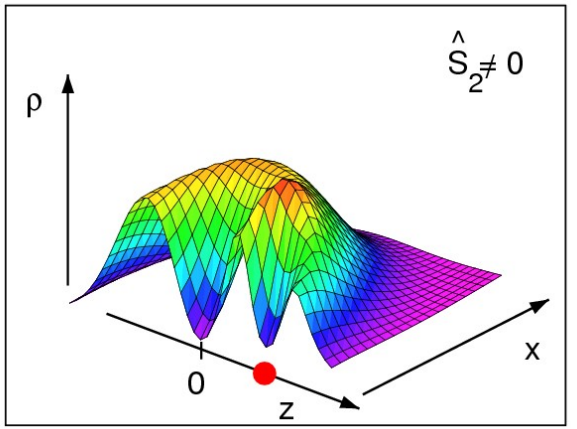
NN correlations

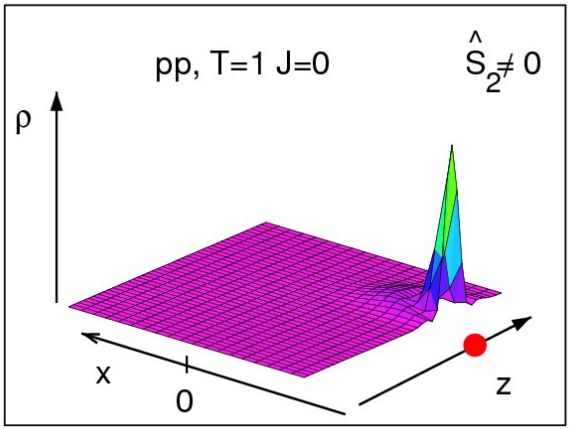
H. Müther: exp(S) method

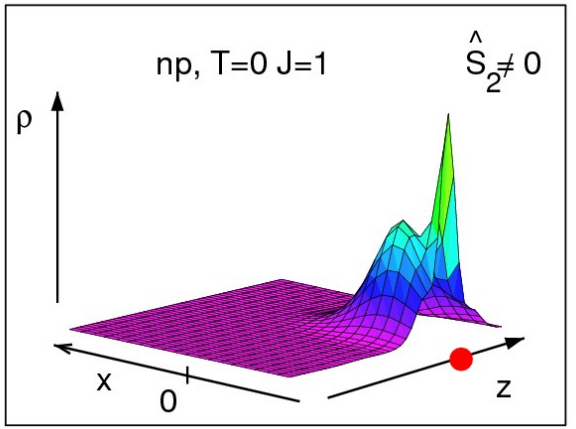
^{16}O

$(p_{1/2})^{-2}$









NN correlations

H. Müther: exp(S) method

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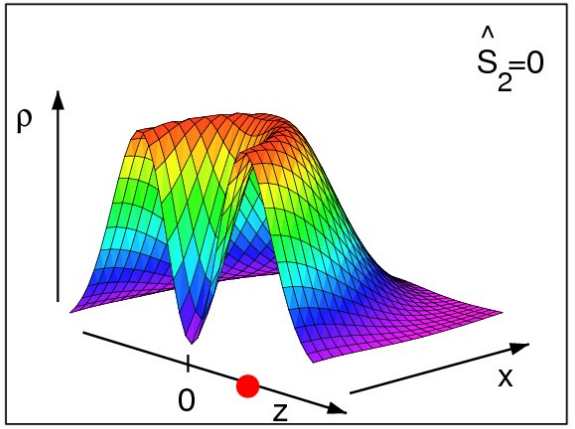
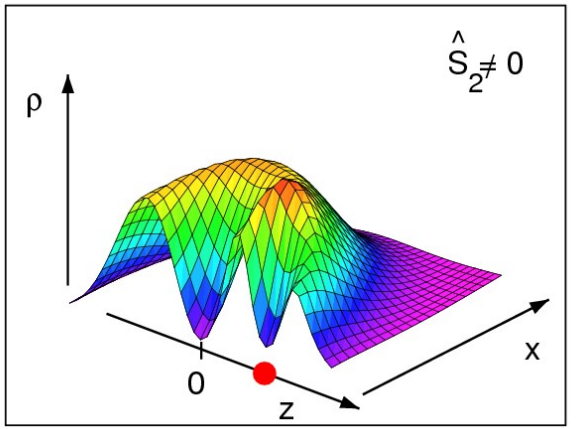
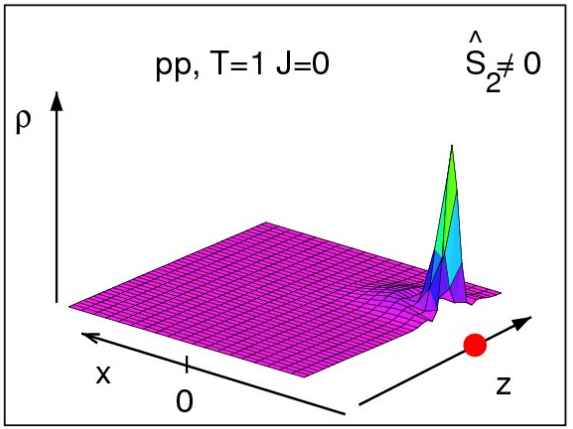
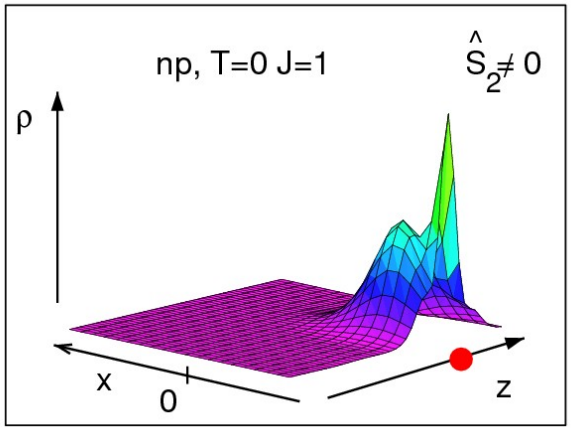
$(p_{1/2})^{-2}$





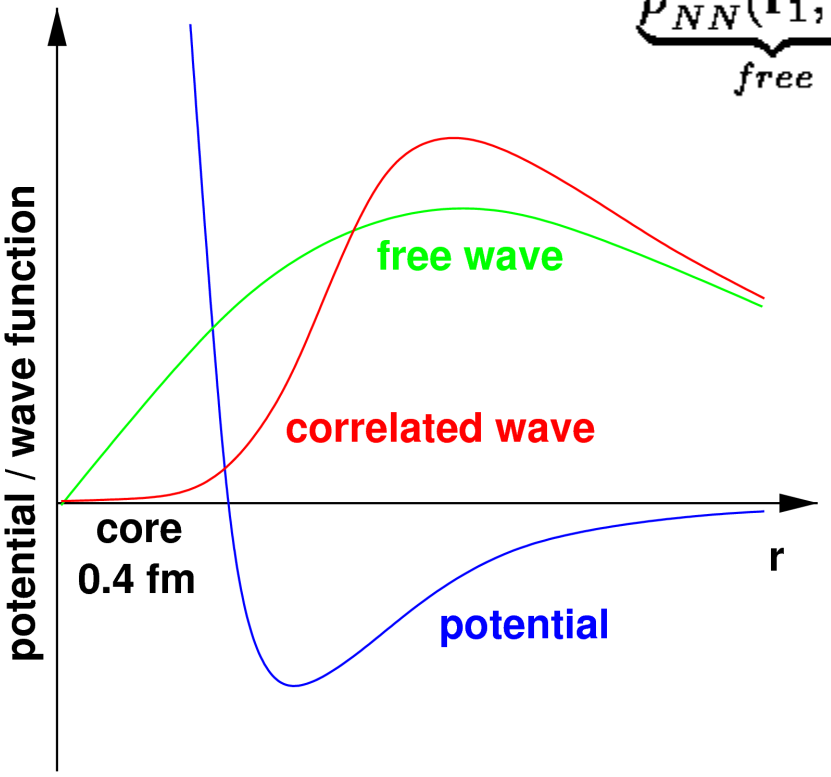




NN correlations

- 3 body forces
- NN correlations
- in medium effects

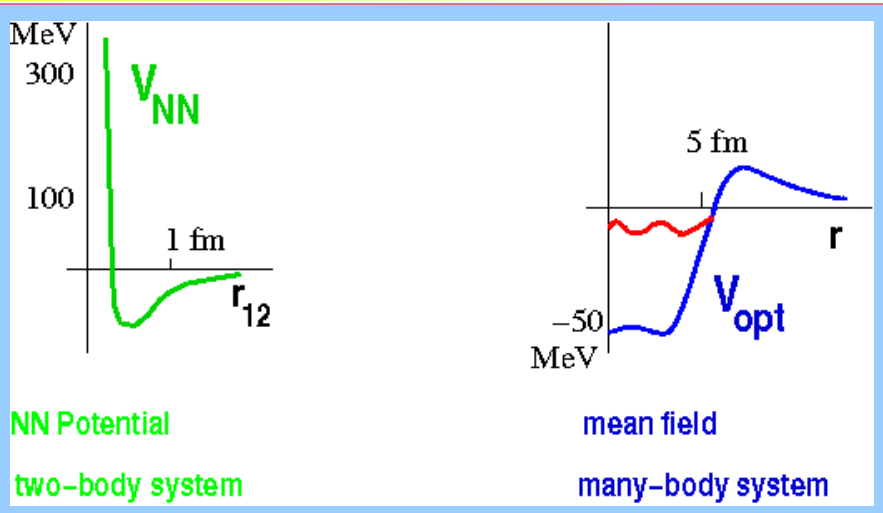
$$\underbrace{\rho^{f}_{NN}(\mathbf{r_1},\mathbf{r_2})}_{free} = \tfrac{1}{2}[\rho_N(\mathbf{r_1})\cdot\rho_N(\mathbf{r_2}) - \underbrace{\rho_N(\mathbf{r_1}|\mathbf{r_2})\cdot\rho_N(\mathbf{r_2}|\mathbf{r_1})}_{e.g.\,Pauli-correlations}]$$



Dynamic Correlations

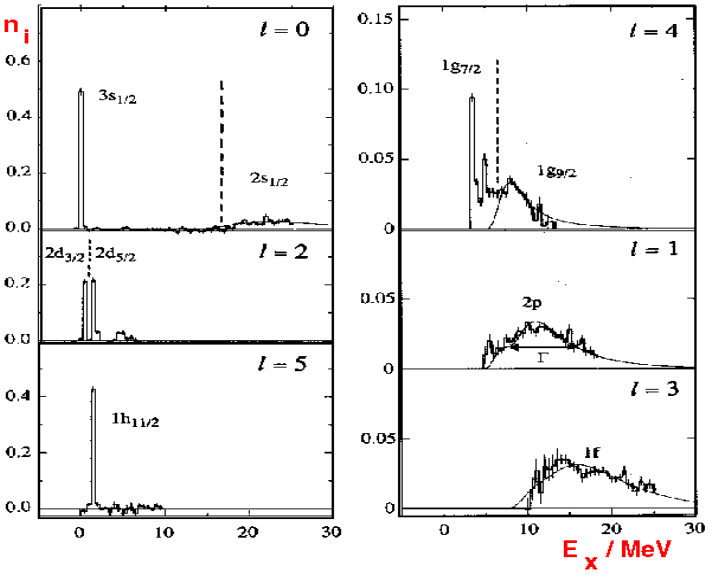
$$\underbrace{C_{dyn}(\mathbf{r_1},\mathbf{r_2})}_{\text{dynamic}} = \underbrace{\rho_{NN}}_{\text{genuine}} - \underbrace{\rho^{f}_{NN}}_{\text{free}}$$

from few body to heavier nuclei



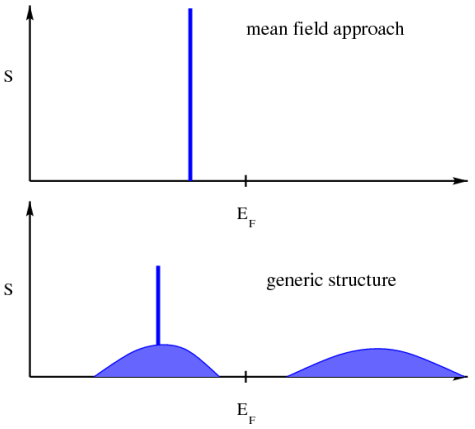
Pauli principle requires
larger distance between nucleons

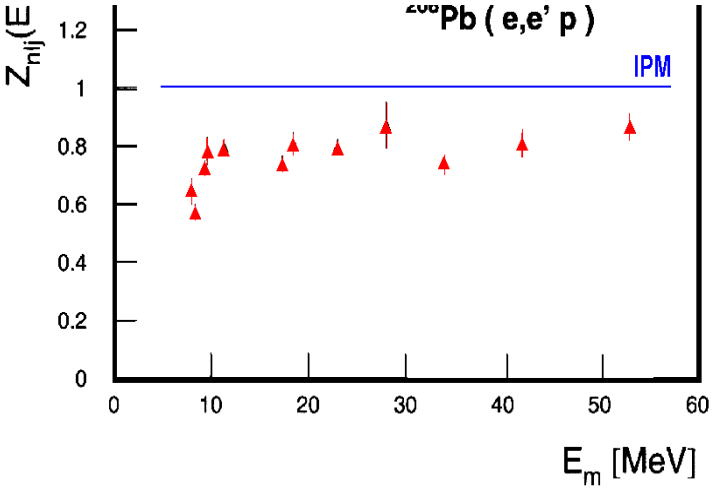
NIKHEF (25 years)



cartoon:

spectral function

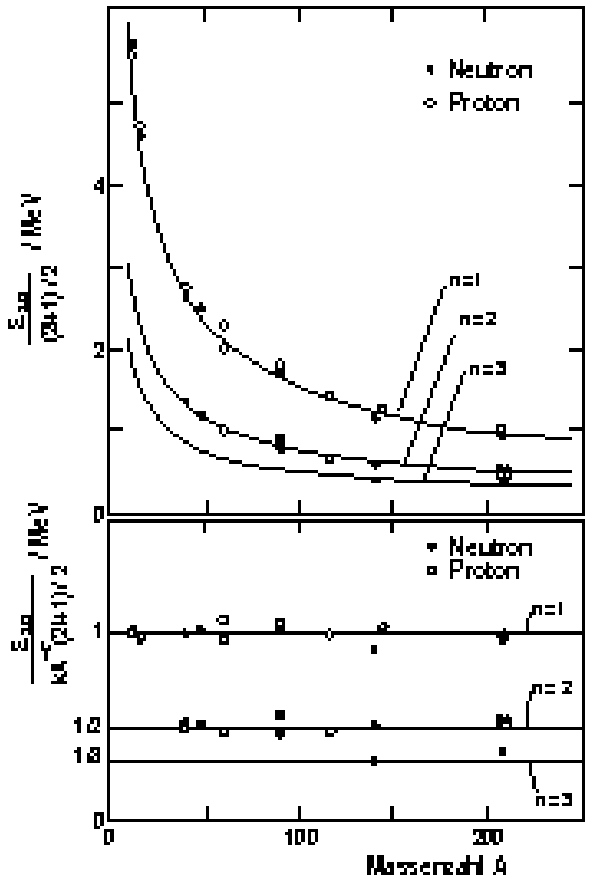


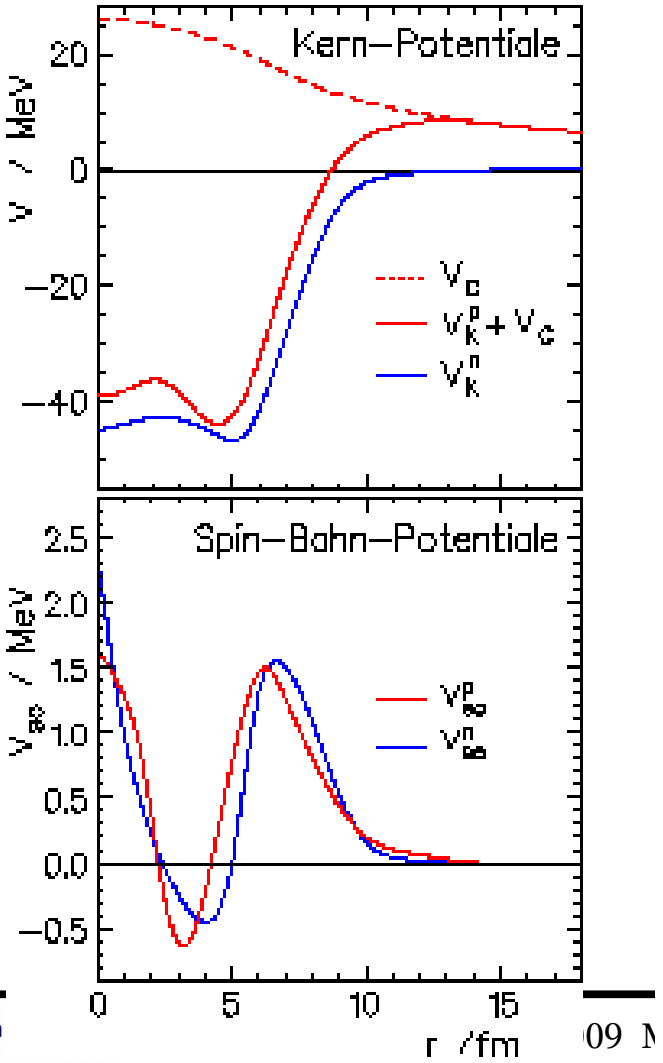


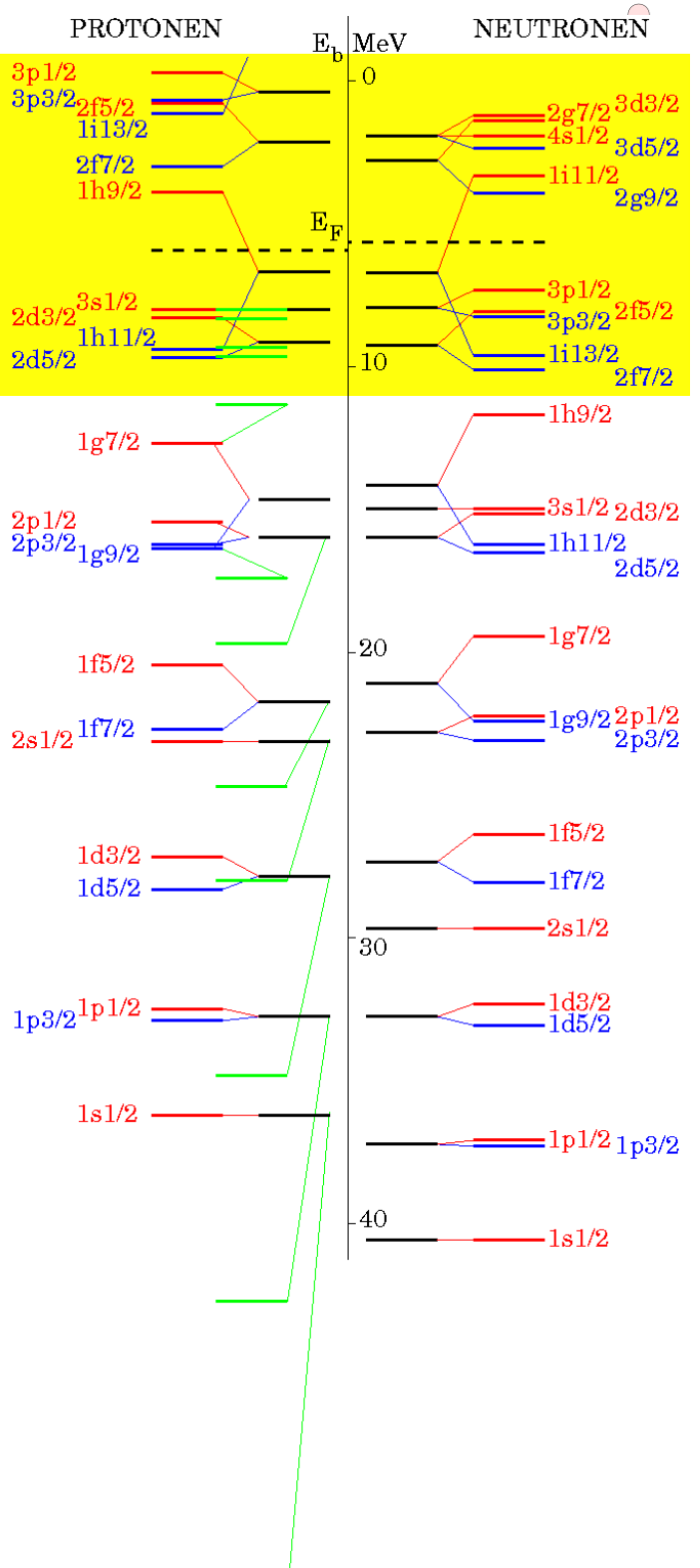
single particle properties

$$V_{so} = \boldsymbol{l}.\boldsymbol{s}\ \frac{d}{dr} V_N$$

^{208}Pb







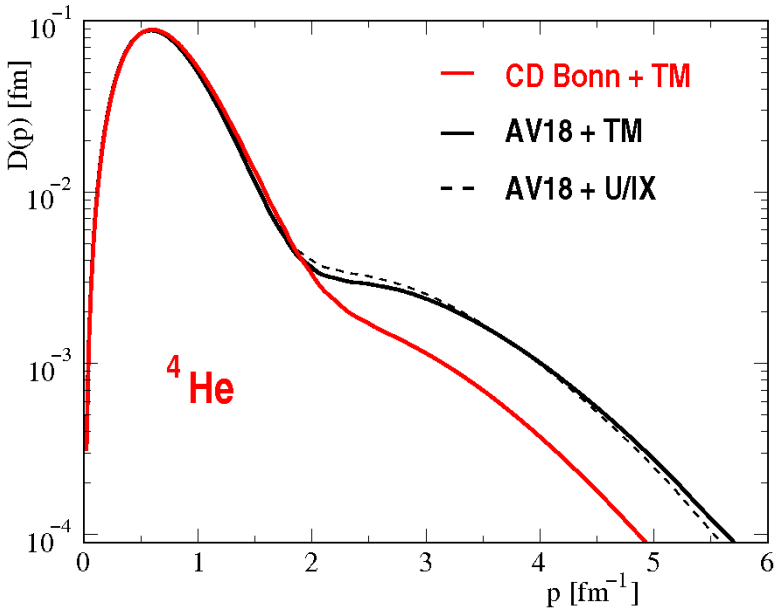
momentum distributions

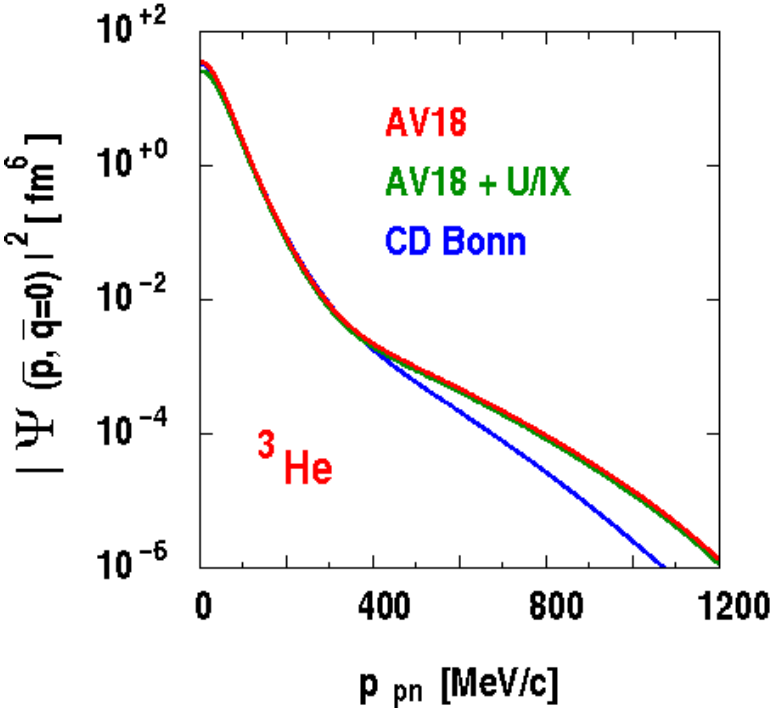
H.Müther for nuclear matter

R.Schivilla, RB.Wiringa etal
PRL 98 (07) 132501

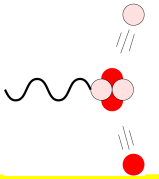
Glöckle,J. Golak etal

MeV	CDB	AV18	Nijm1
E_{HF}	4.64	30.34	12.08
E_{Corr}	-17.11	-15.85	-15.82
$V_{\pi HF}$	16.7	15.8	15.0
$V_{\pi Corr}$	–2.30	-40.35	-28.98
T	36.23	47.07	39.26





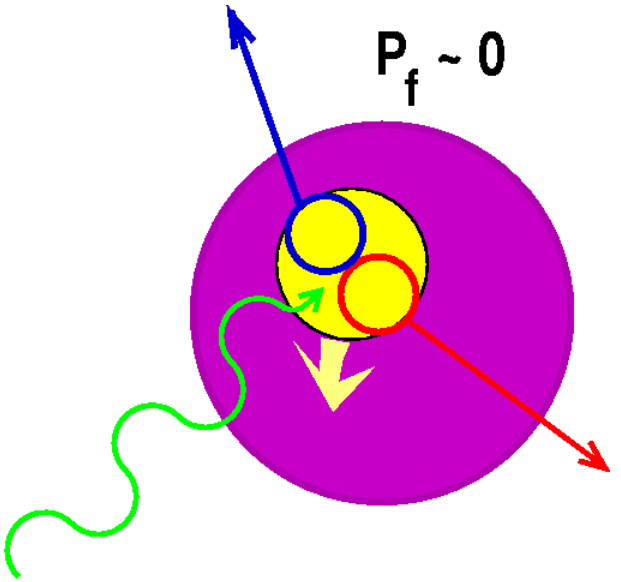
(e,e'N) and (e,e'NN)



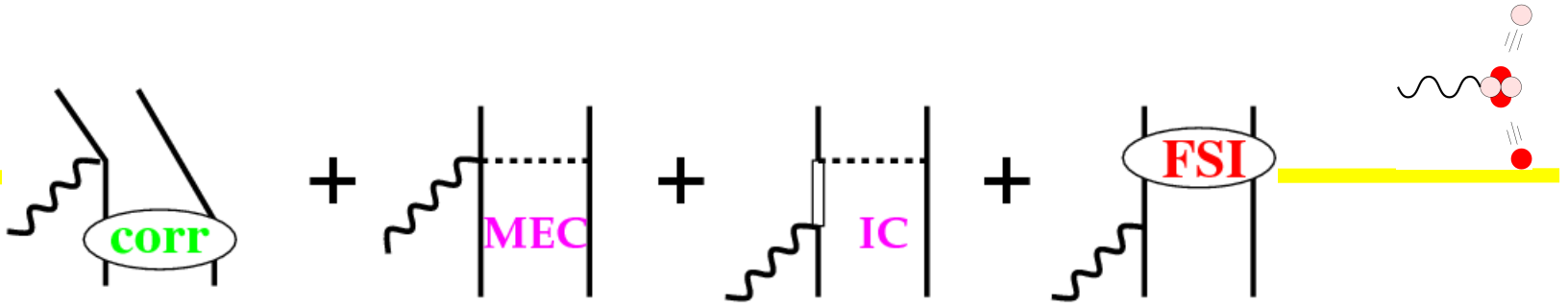
trivial correlations:
Pauli-principle, pairing, kinematical

(e,e'N) :
correlations at high excitation energy
D. Rohe @ Jlab

(e,e'NN):
correlations at low excitation energy
reduced background
use final states as spin/isospin filters



reactions



(e,e'pp)

MEC=0,IC=0 for σ_L

central correlations

but small σ

(e,e'pn)

IC=0 for σ_L

tensor correlations

but MEC

(γ,np)(γ,pp)

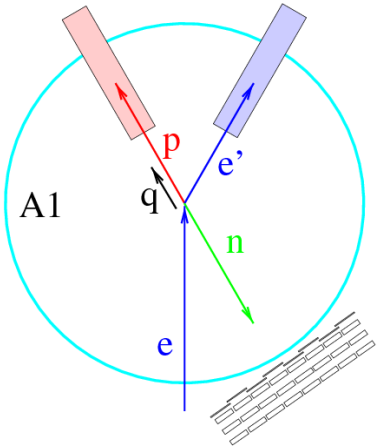
purely σ_T ;σ_{TT} for polarized γ

tensor correlations

MEC & IC separation

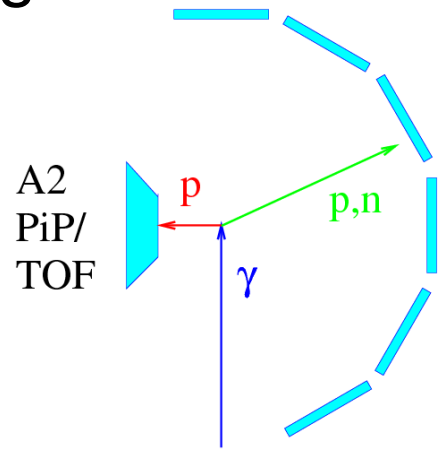
via kinematics and isospin

large kin. ranges

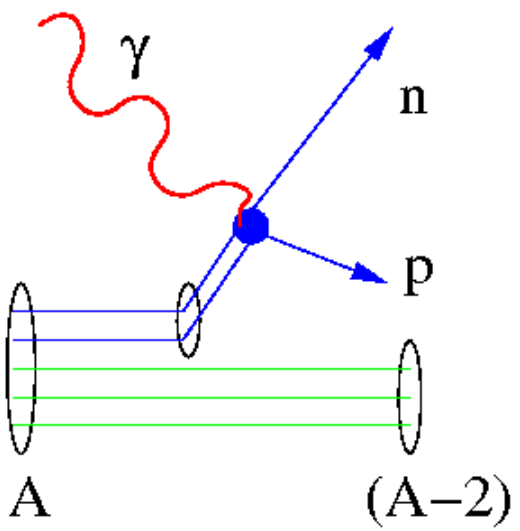


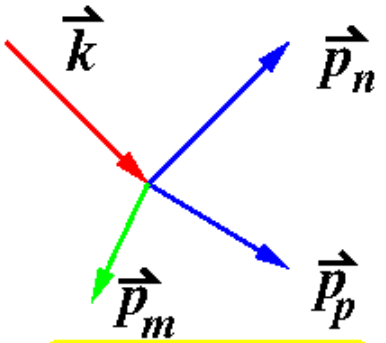
no Rosenbluth separation

super parallel kinematics



kinematics and observables





PWIA:

$$\vec{p}_m = -\vec{p}_{(qp)}$$

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

$$E_m = E_\gamma - T_p - T_n - T_R$$

$$\vec{p}_{rel} = (\vec{p}_p - \vec{p}_n)/2$$

- $\vec{p}^{\,pair}_{Fermi}$
- E_x in $(A-2)$
- rel. motion

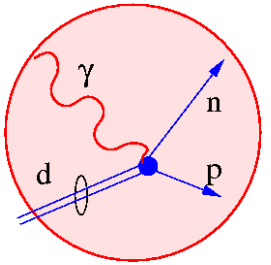
after !!!

Gottfried (1958) 50 years!
factorized model

$d\sigma \sim$

$F(p_m)\, S_{fi}(p_{rel})\, \delta(E_f - E_i) d^3p_n d^3p_p$

2h spectral function

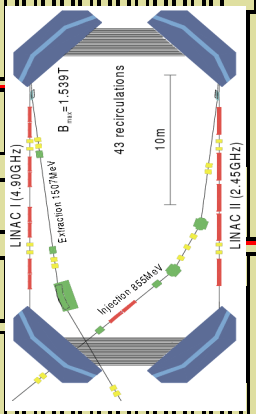


$\sigma \sim \Psi^*\Psi$ $\sigma(\gamma d)$

unfactorized models:
Ghent (JR), Pavia(CG)

$\sigma \sim W_{\mu\nu} L^{\mu\nu}$ $J_1(q), J_2(q), J_\Delta(q)$

MAMI racetrack microtron



A4

A2

A3

RTM 2

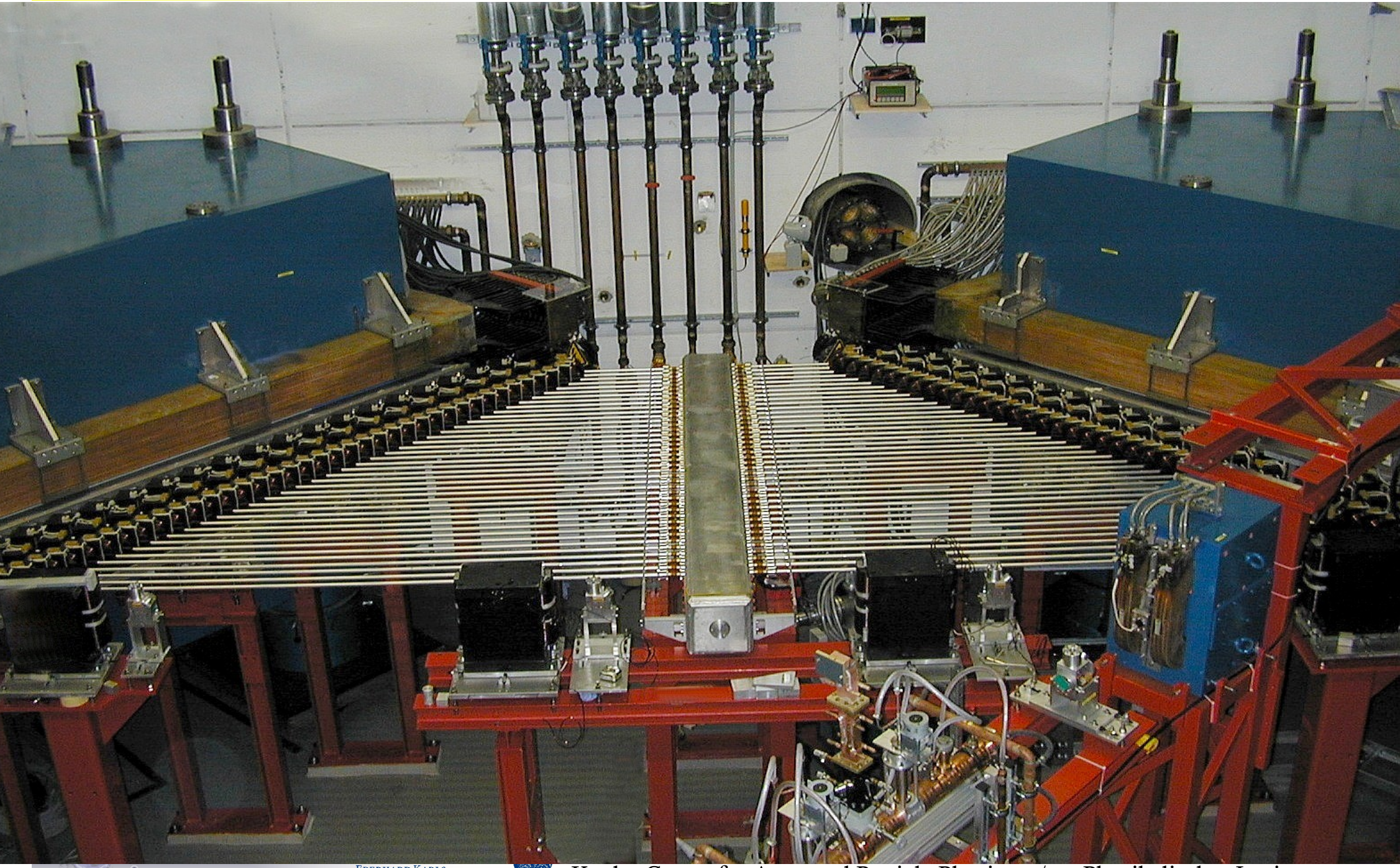
RTM 3

RTM 1

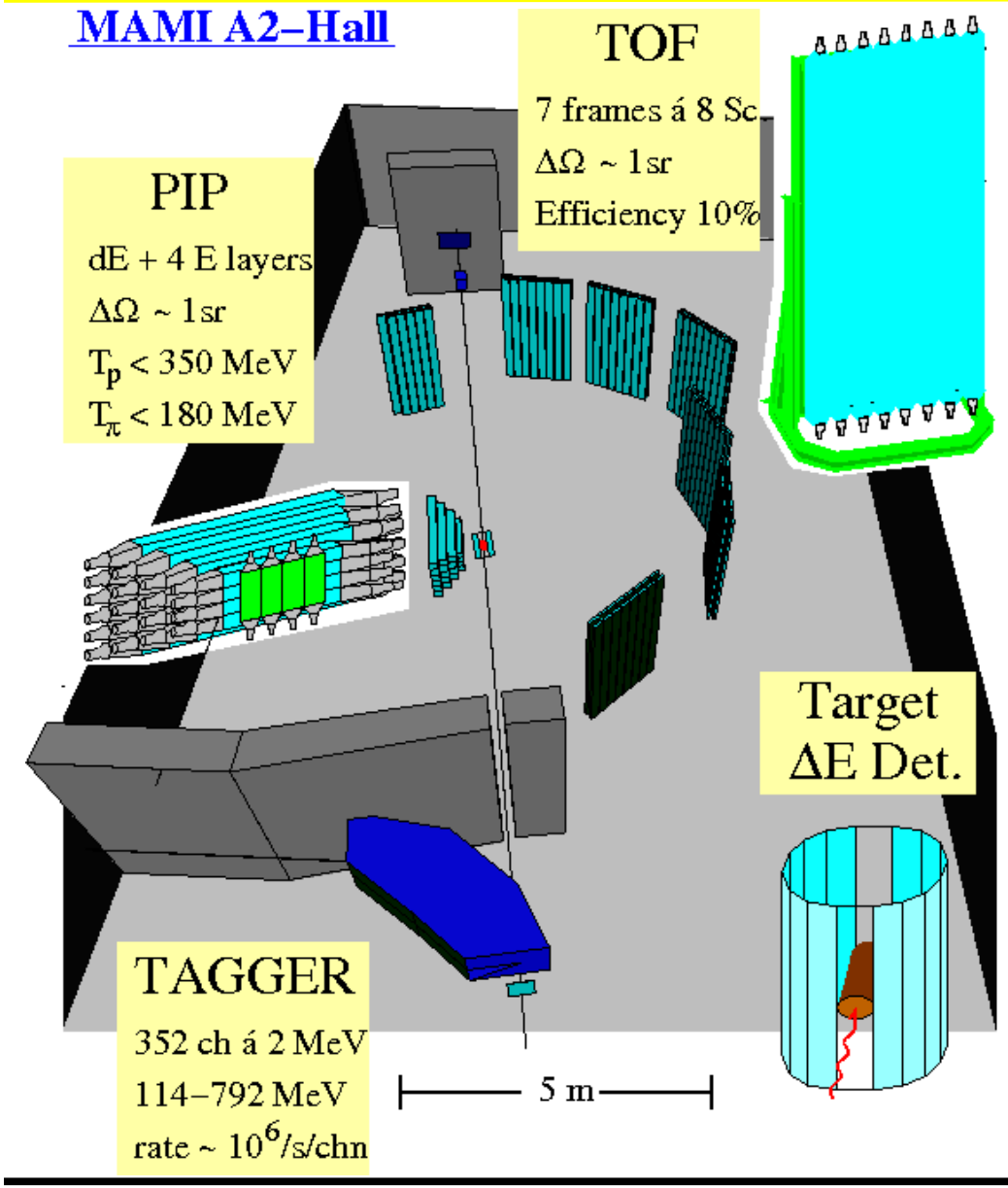
Spektrometerhalle

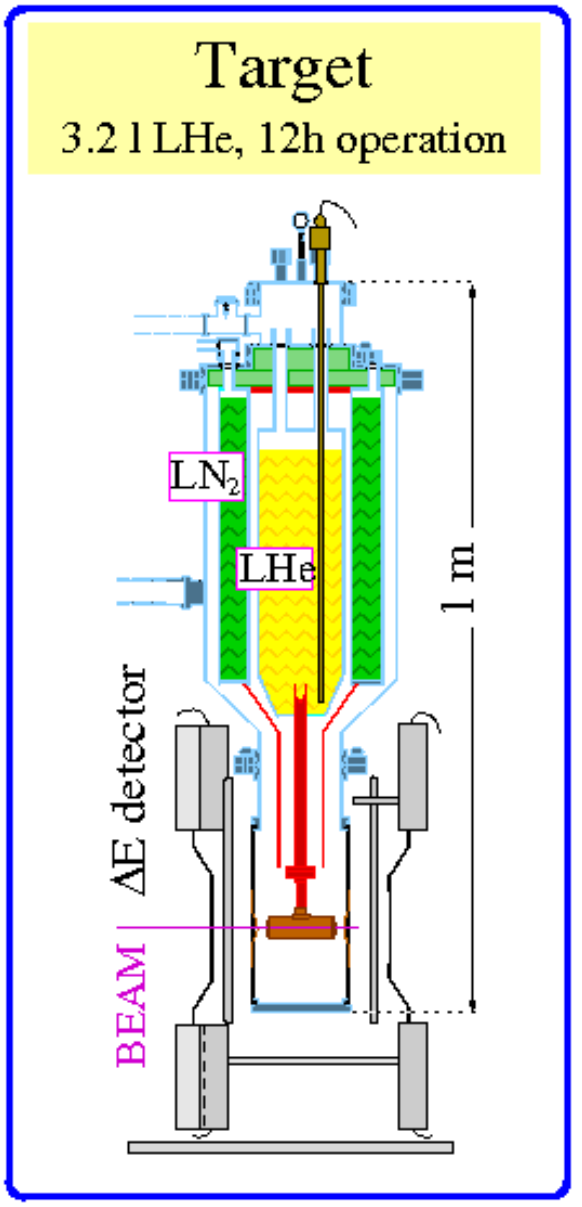
A1

HDSM 34 beam lines between DIP3 &DIP4

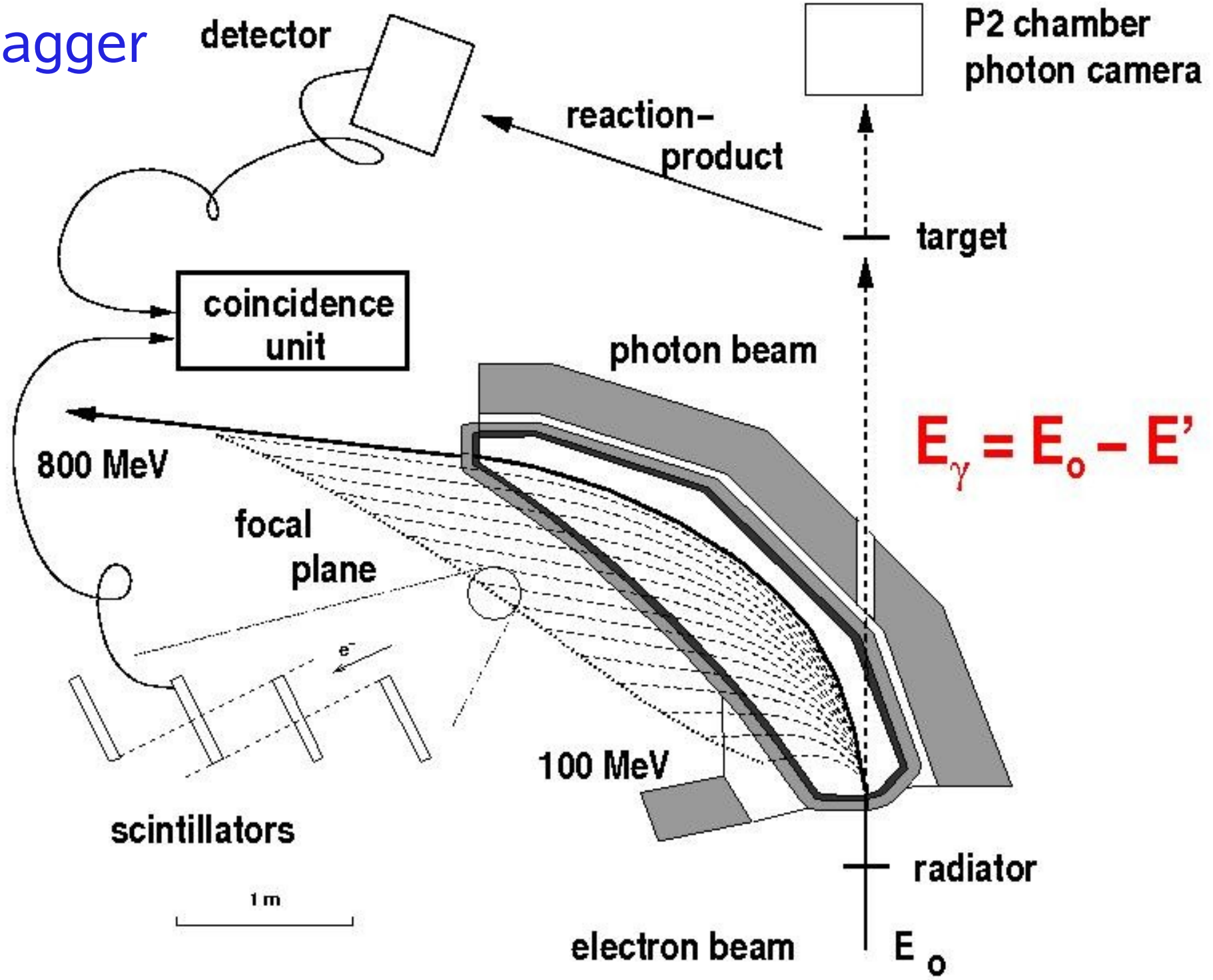


apparatus for real photons



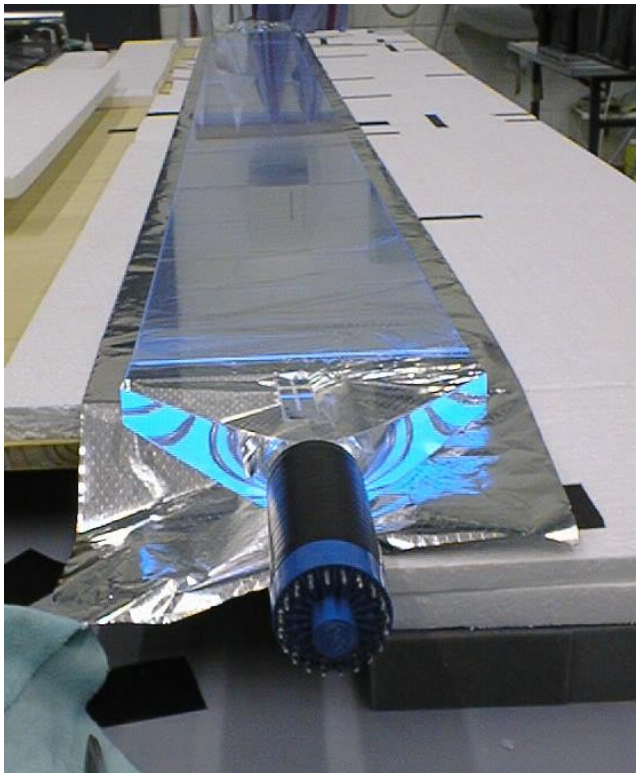


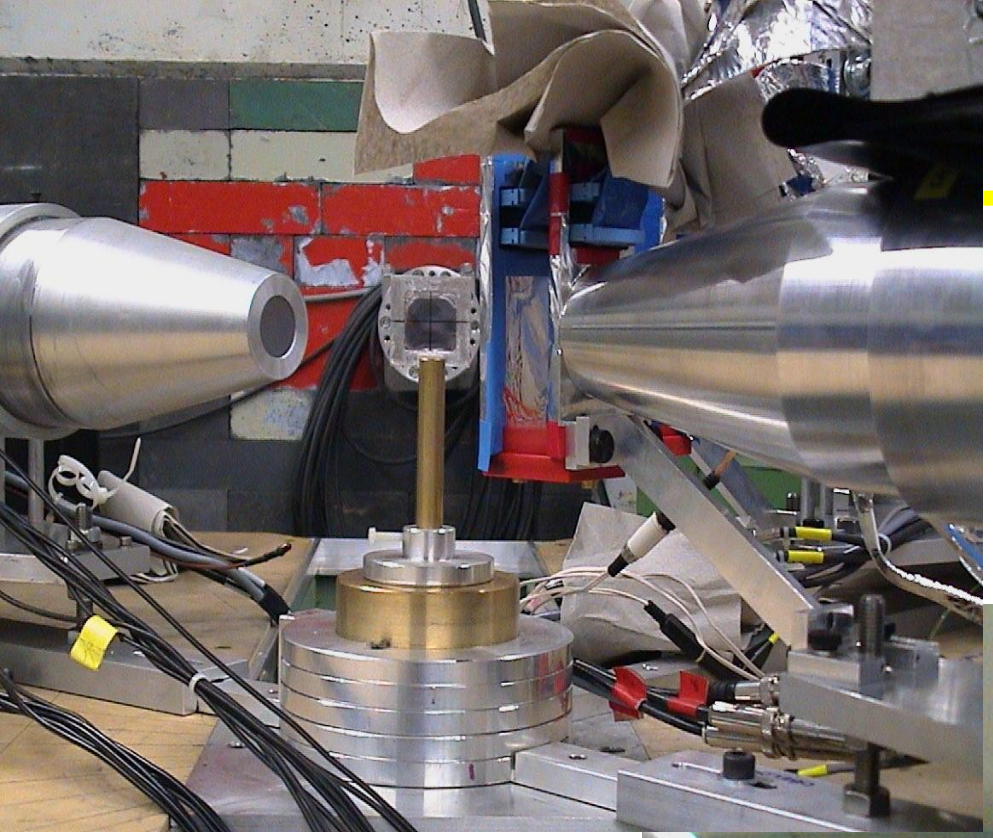
Tagger


detector
P2 chamber
photon camera
reaction-
product
target
coincidence
unit
photon beam
$E_\gamma = E_o - E'$
800 MeV
focal
plane
e⁻
100 MeV
scintillators
1 m
radiator
electron beam
E o

neutron detection

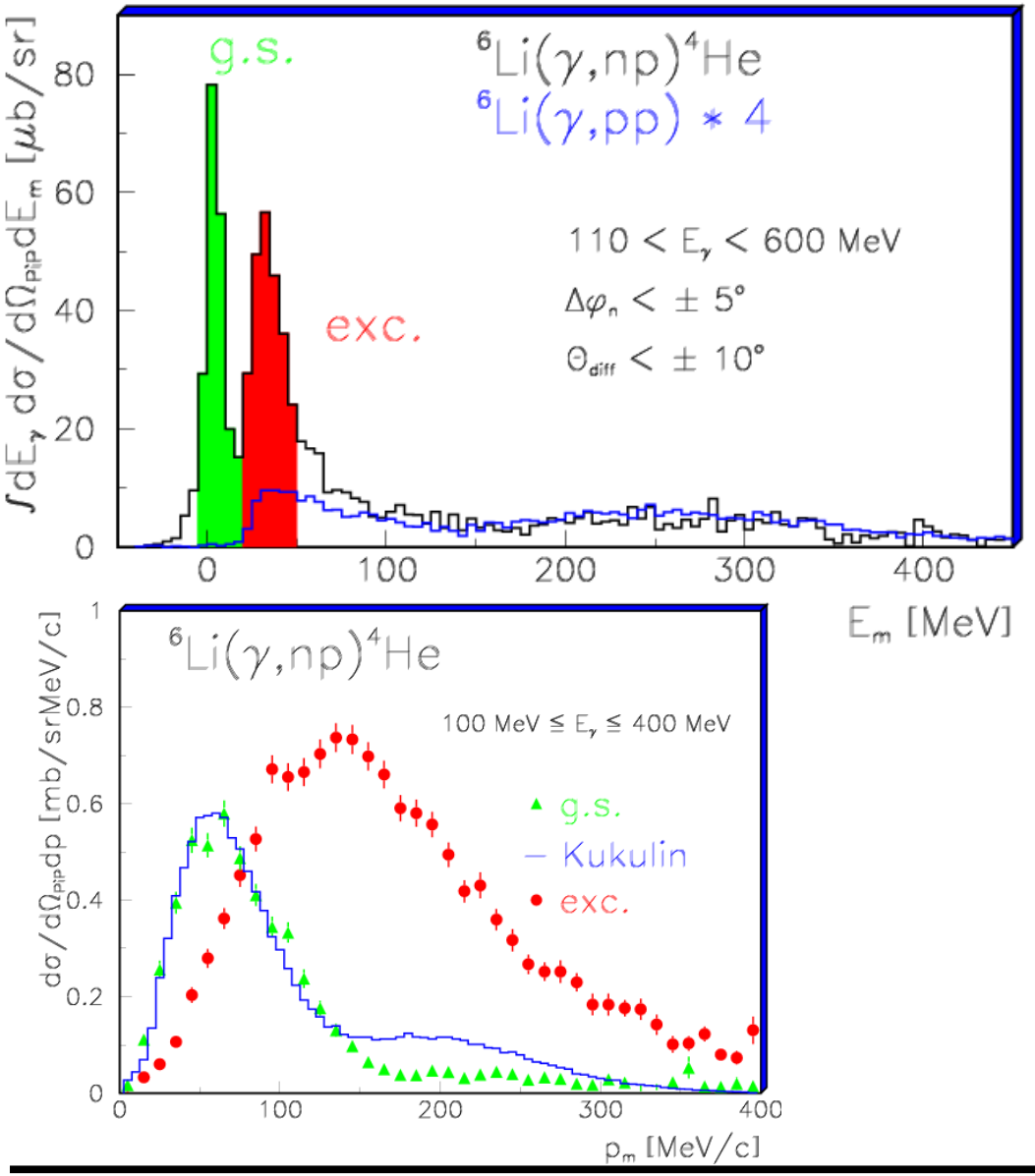
Ne110: 10(50) x 200 x 3000 mm^3

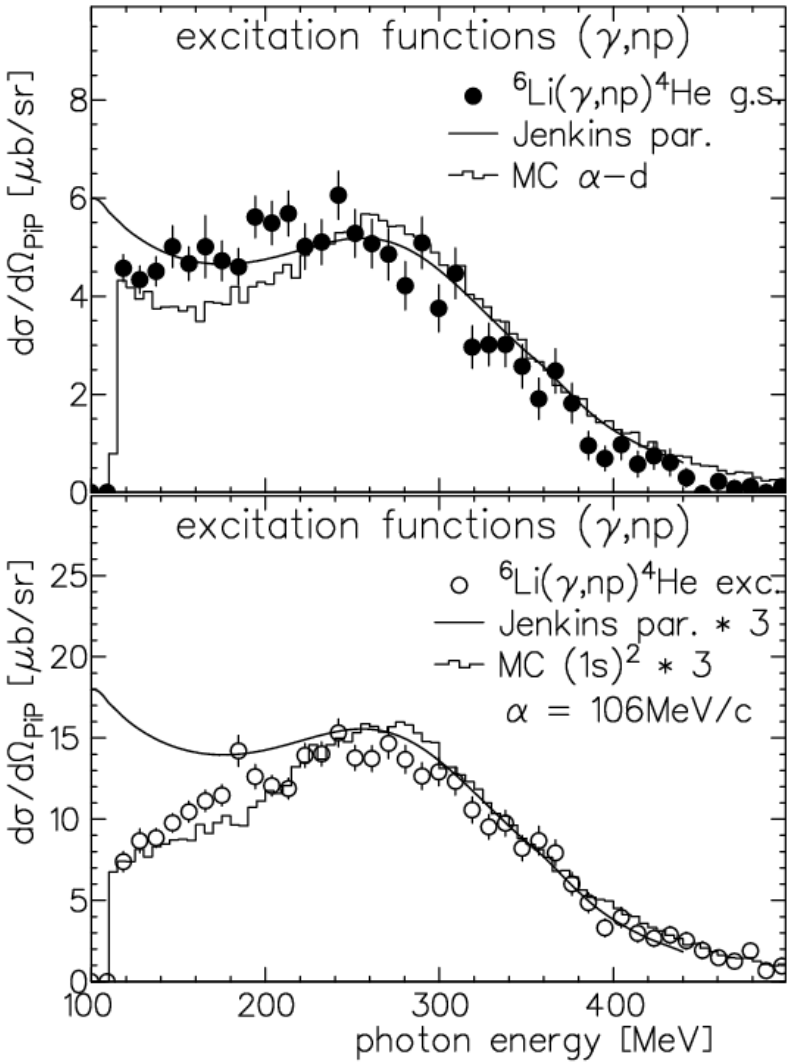





Wanges 20t

^{6}Li for d+α

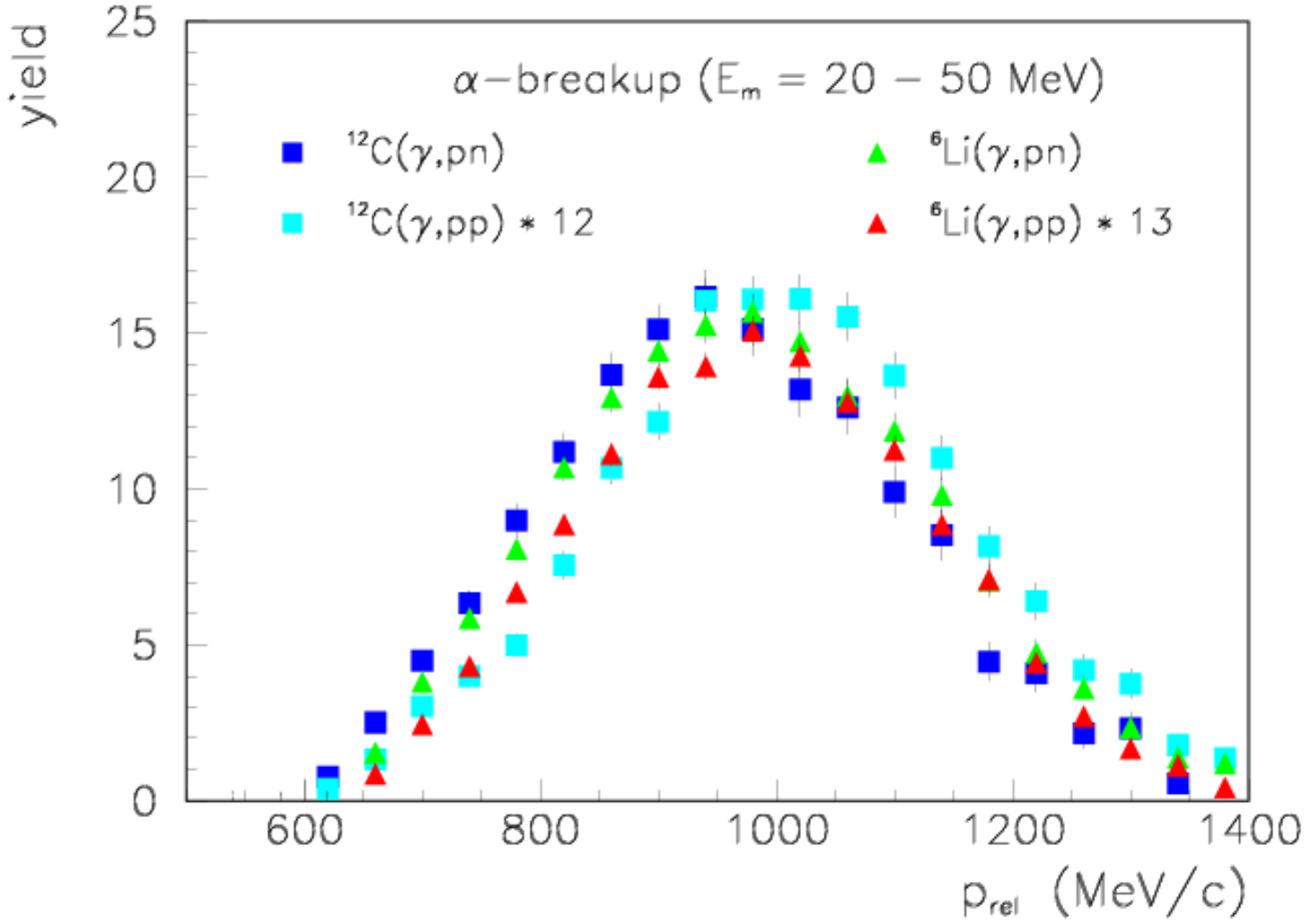




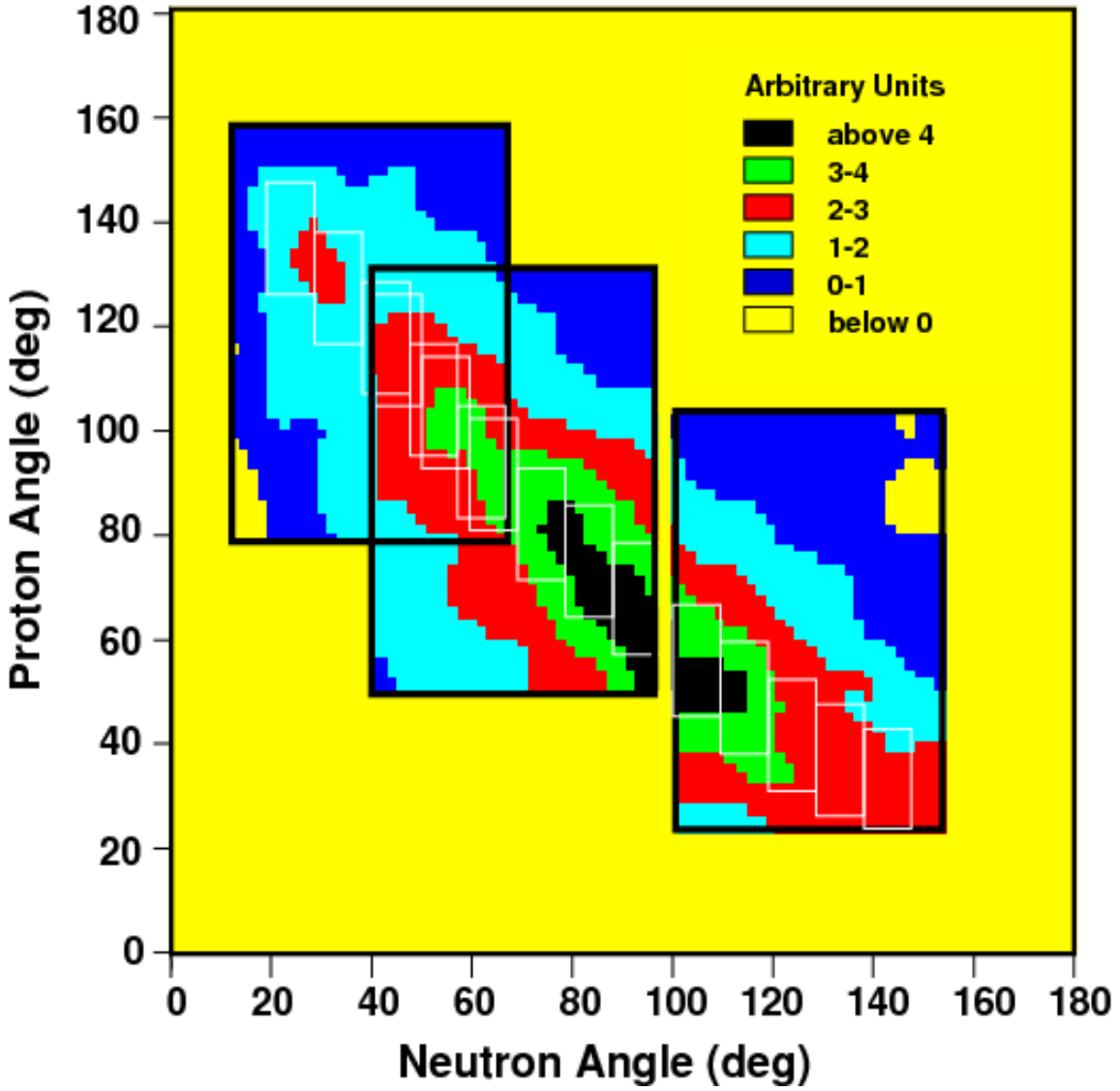
PG, Phys. Lett. B370 (96) 17

^{6}Li vs ^{12}C

breackup of α-cluster



angular distribution

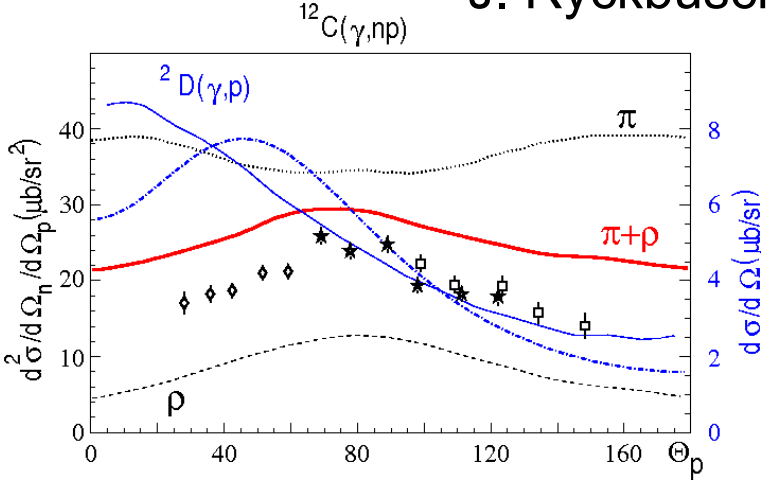


T. Yau etal, EPJA 1 (98) 241

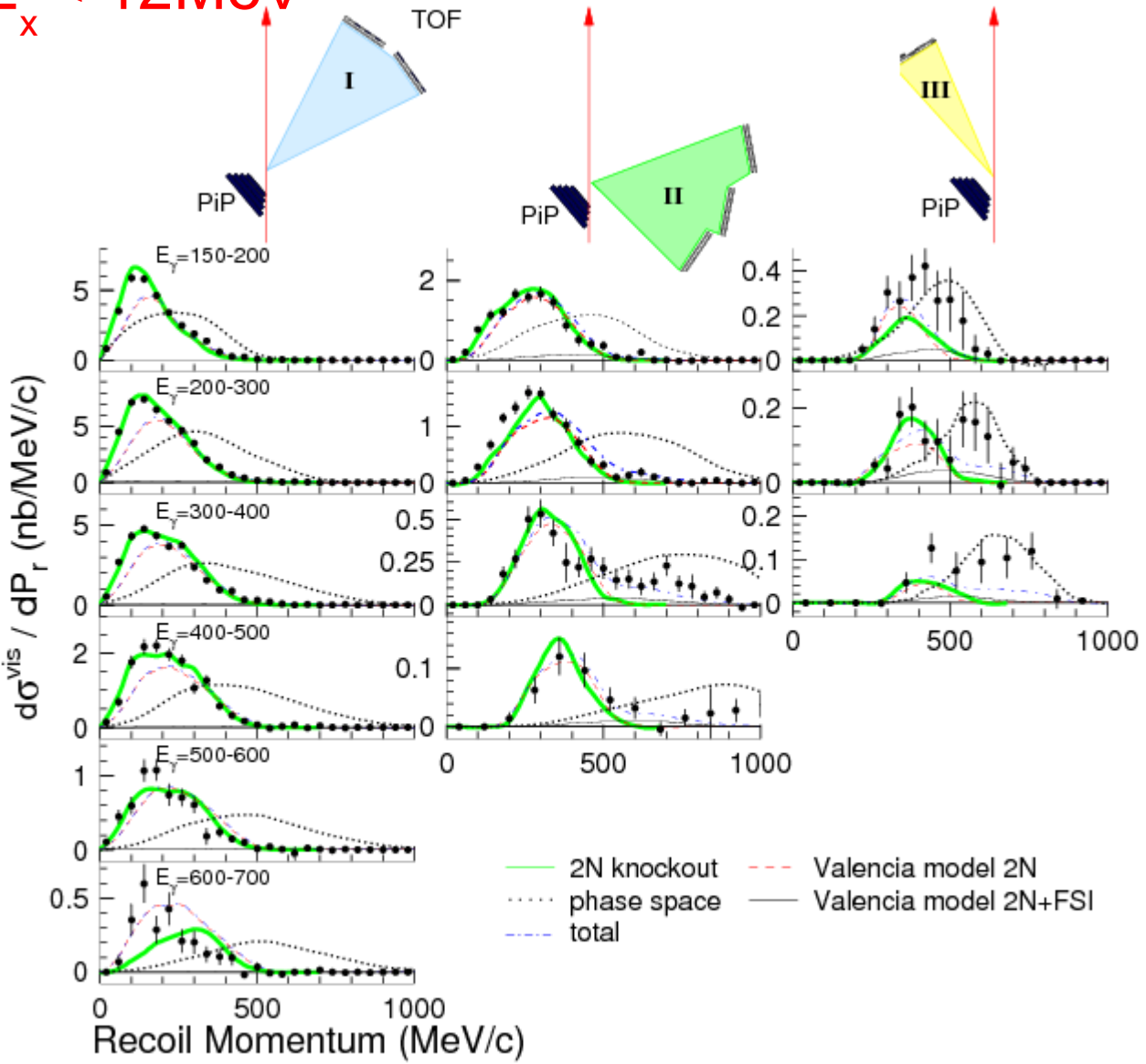
$120 < E_\gamma < 150$ MeV

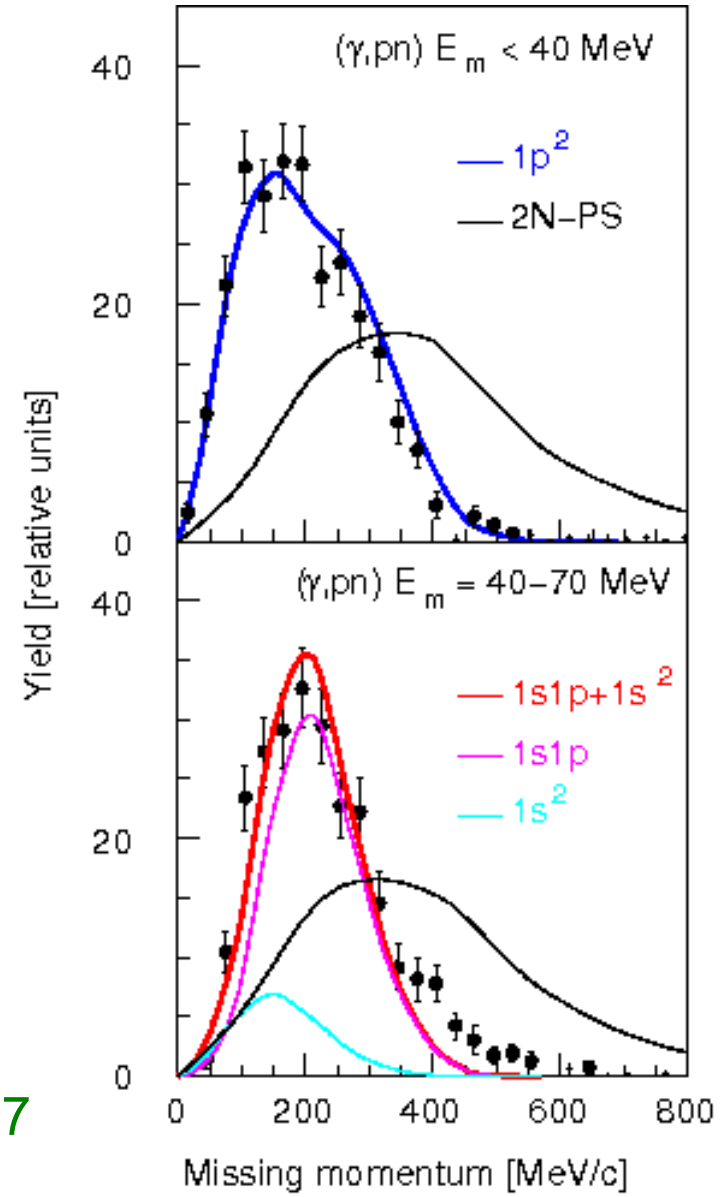
$20 < E_m < 70$ MeV

J. Ryckbusch



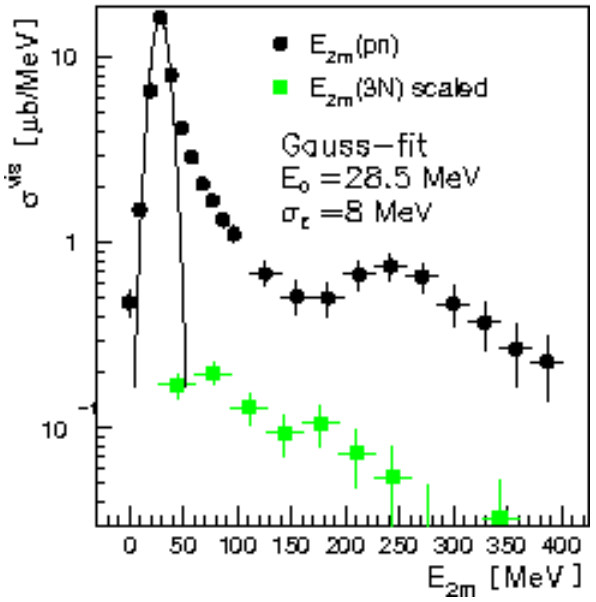
E_x < 12MeV

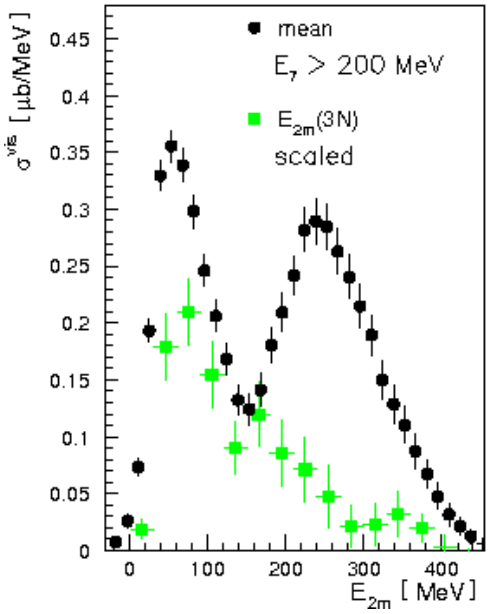




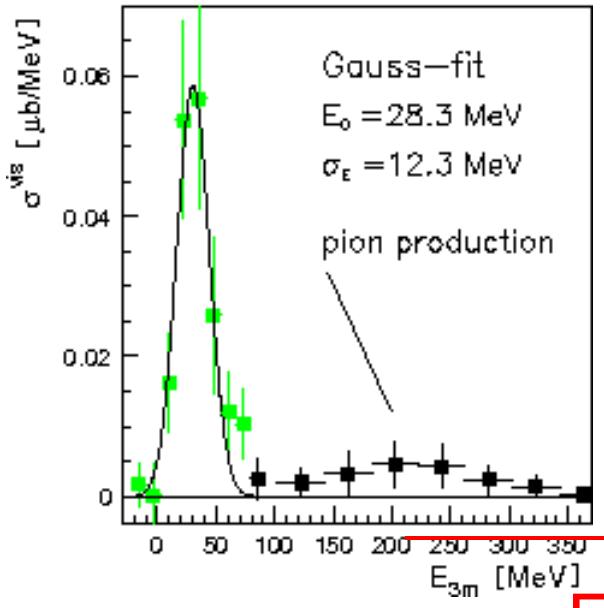
P.D. Harty etal, Phys.Lett. B380(96)247

^{4}He(γ,np) , ^{4}He(γ,pp) and ^{4}He(γ,nnp)





E_{2m}



E_{3m}

MEC vs FSI

A. Natter, PhD Tübingen 2001, NPA690(2001)

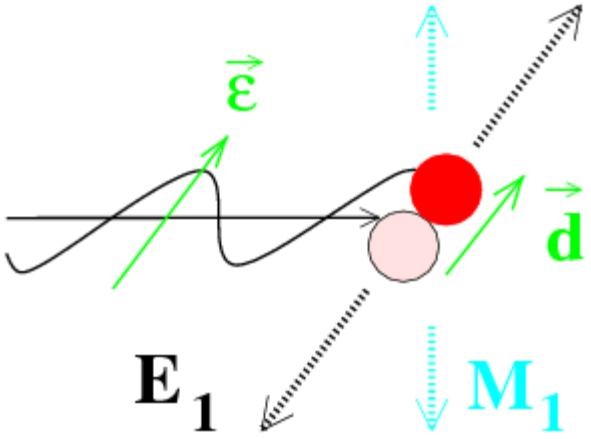
photon asymmetries

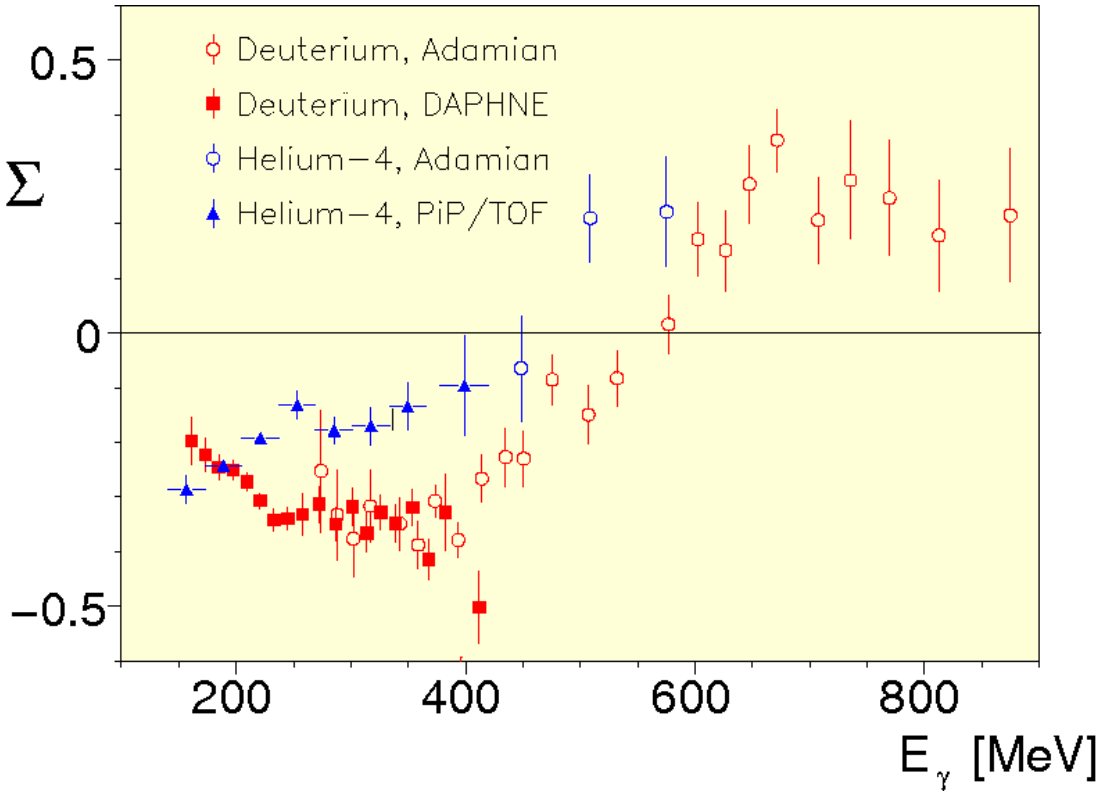
$$\Sigma = \frac{1}{P_\gamma} \times \frac{\sigma_\parallel - \sigma_\perp}{\sigma_\parallel + \sigma_\perp}$$

E1: Σ positive

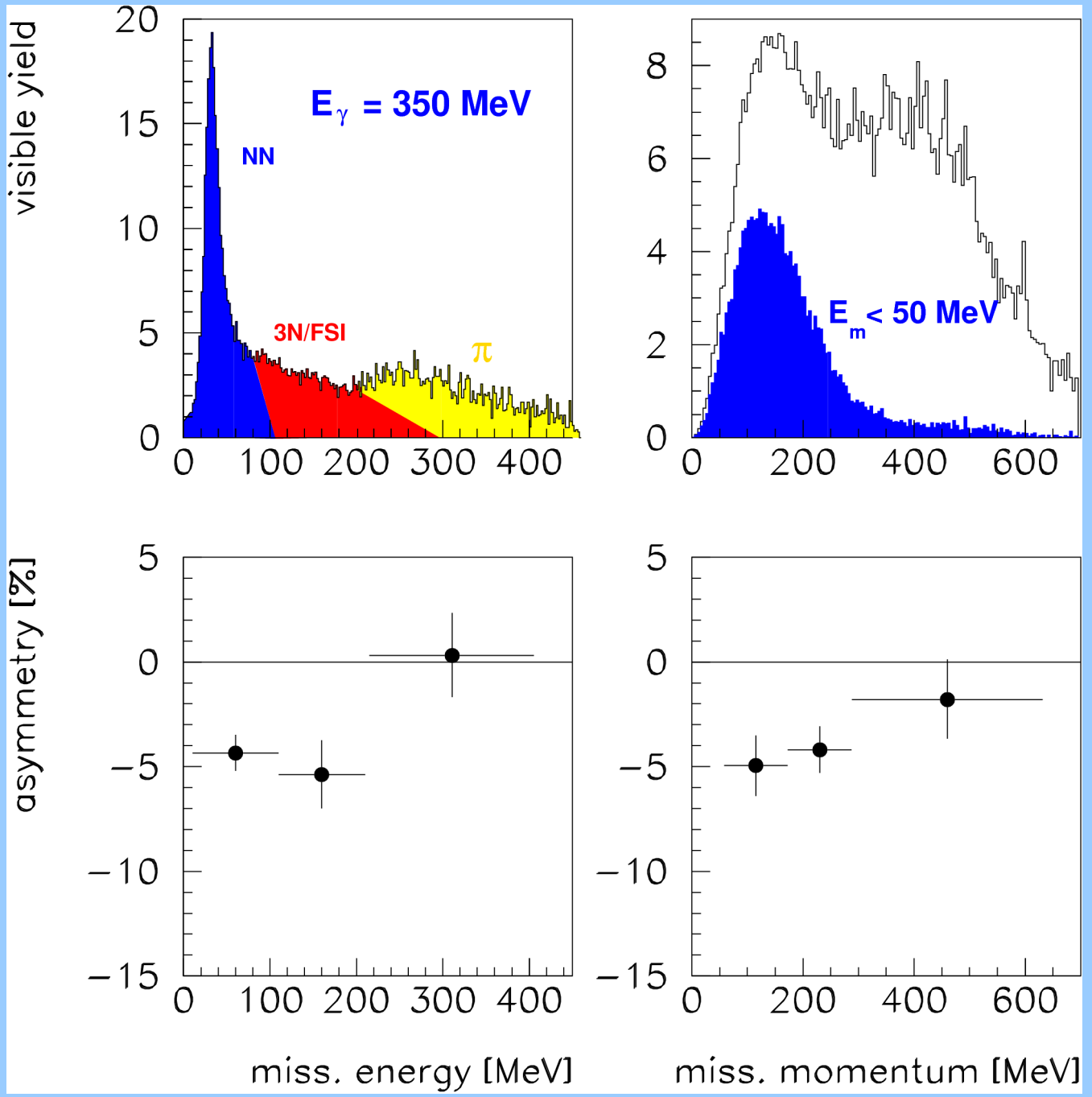
Adamian etal.

very low energies

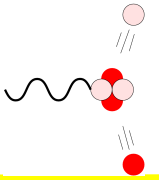




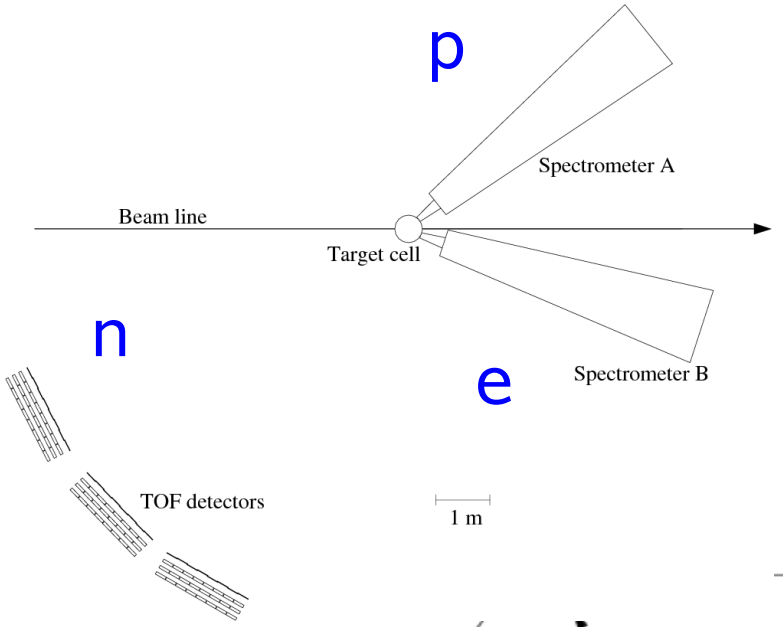
M1: Σ negative


visible yield
E_γ = 350 MeV
NN
3N/FSI
π
E_m < 50 MeV
asymmetry [%]
miss. energy [MeV]
miss. momentum [MeV]

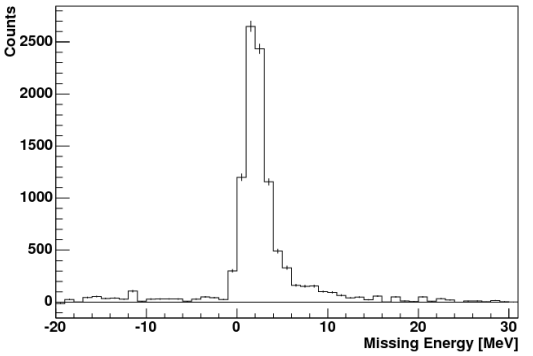
now (e,e'pN) reactions



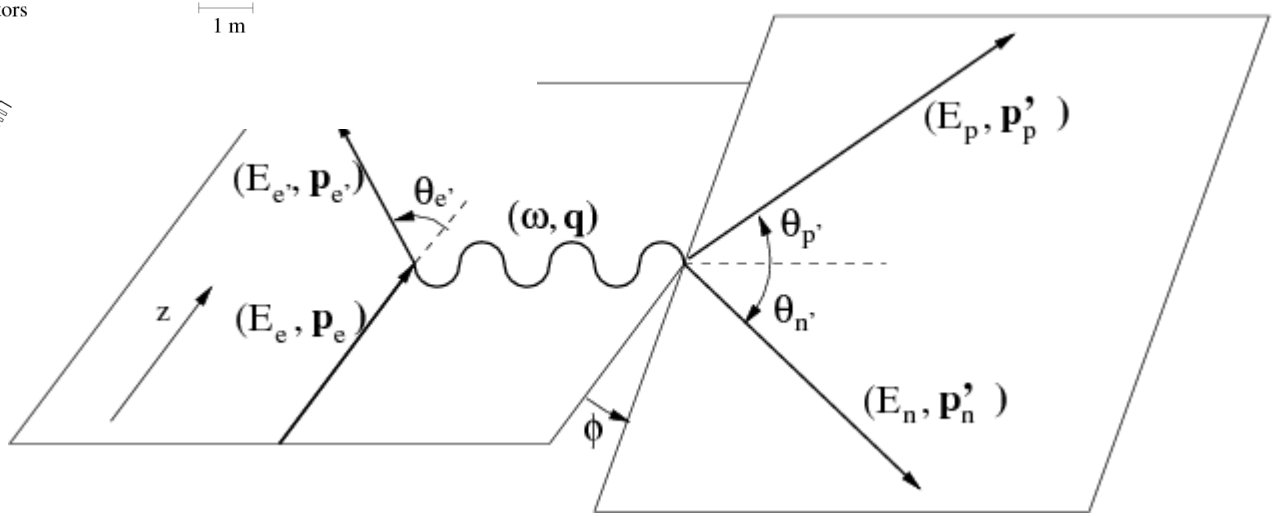
^{16}O(e,e'pn)



D(e,e'pn)



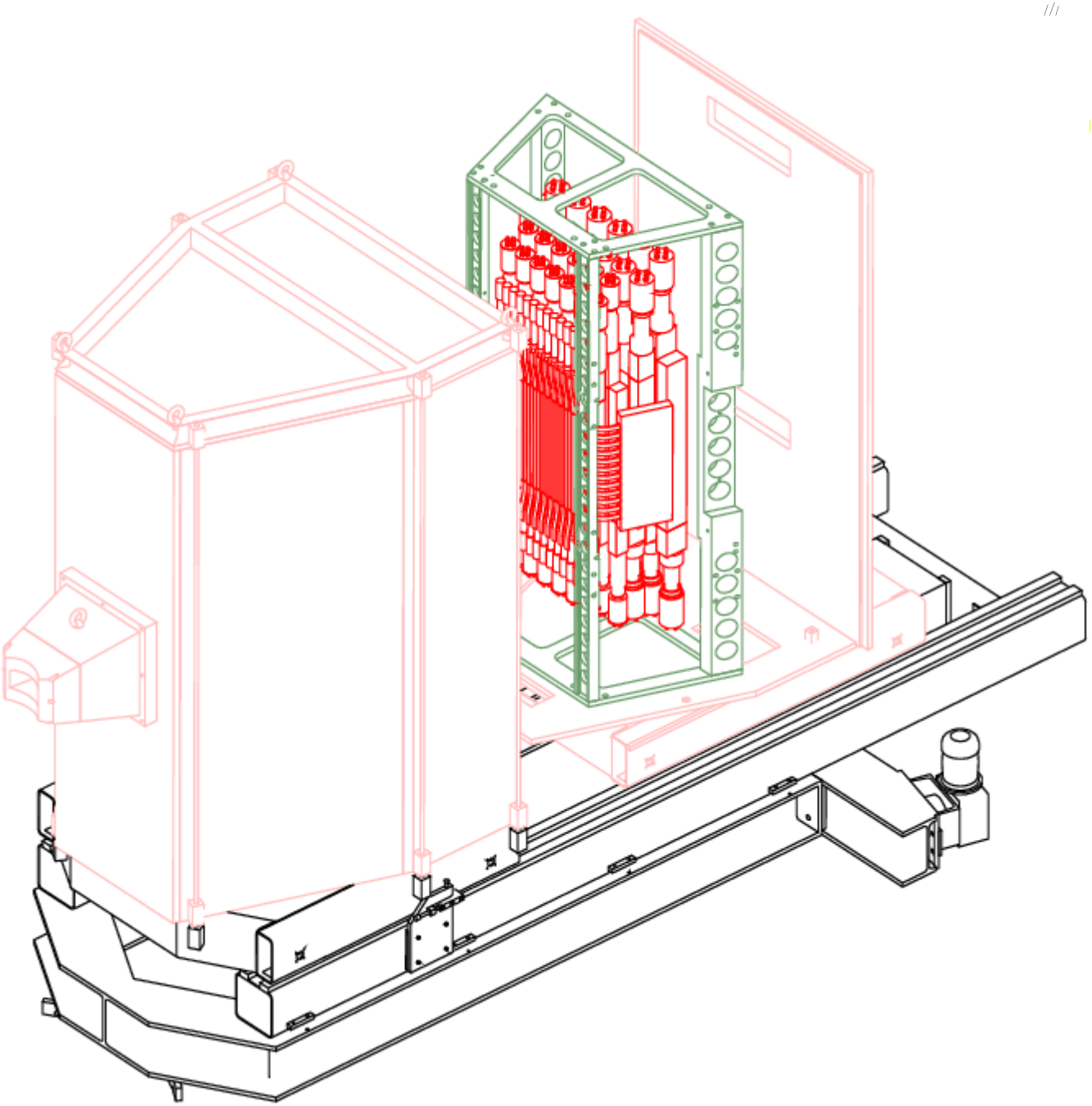
FWHM ~2.1 MeV



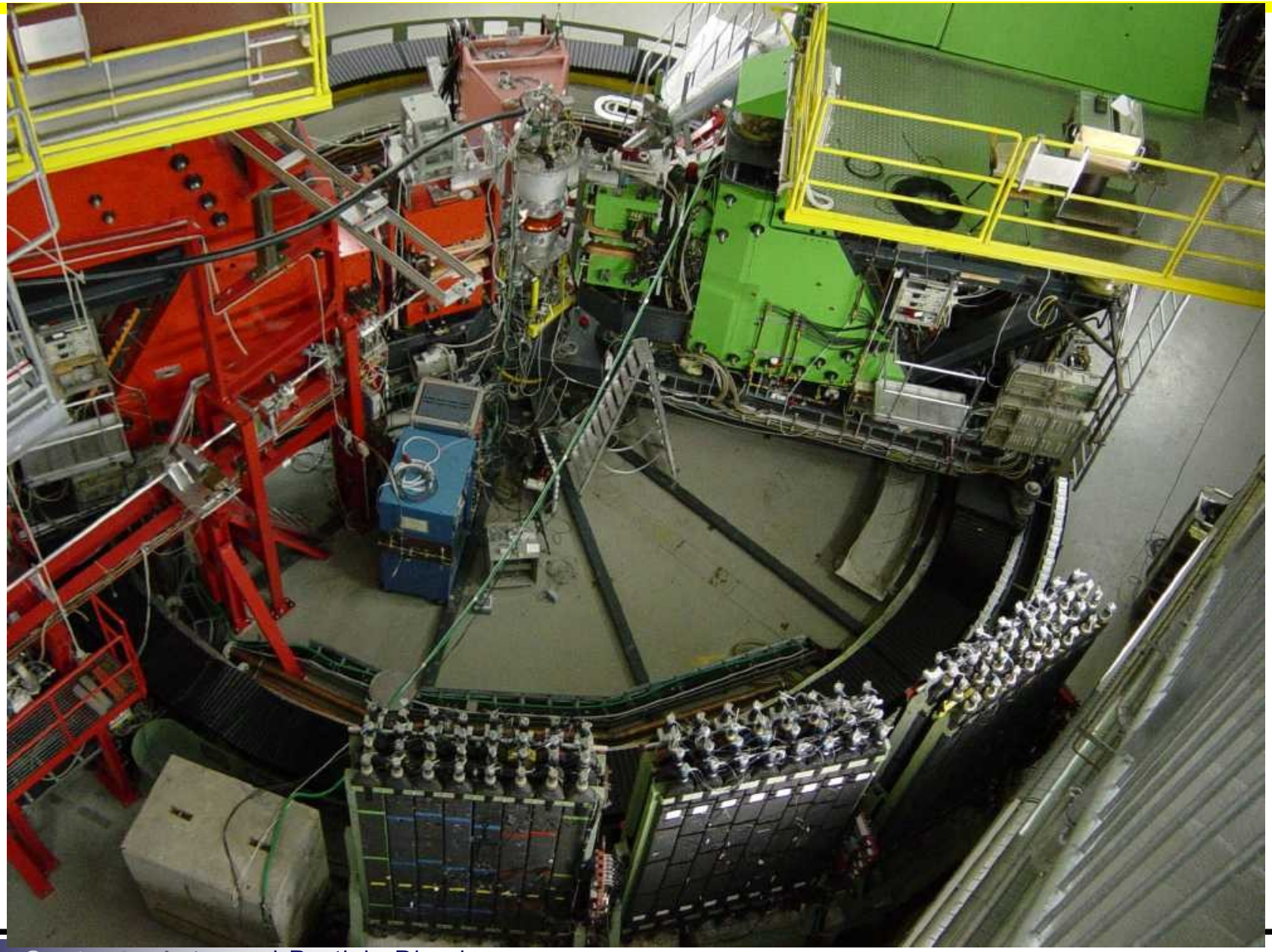
D. Middleton etal.
EPJA 29(2006) 261

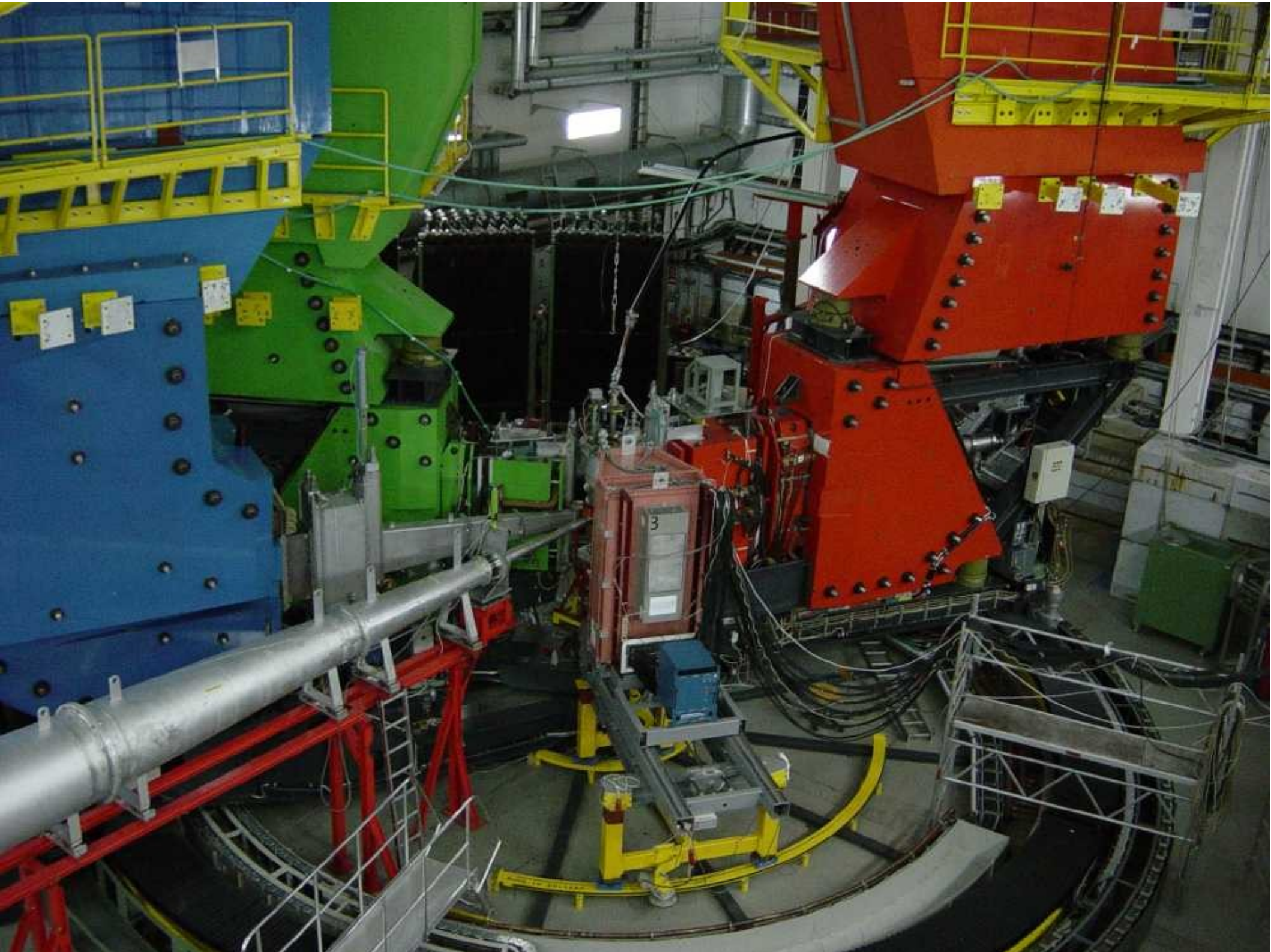
HADRON for ^{3}He

NIKHEF

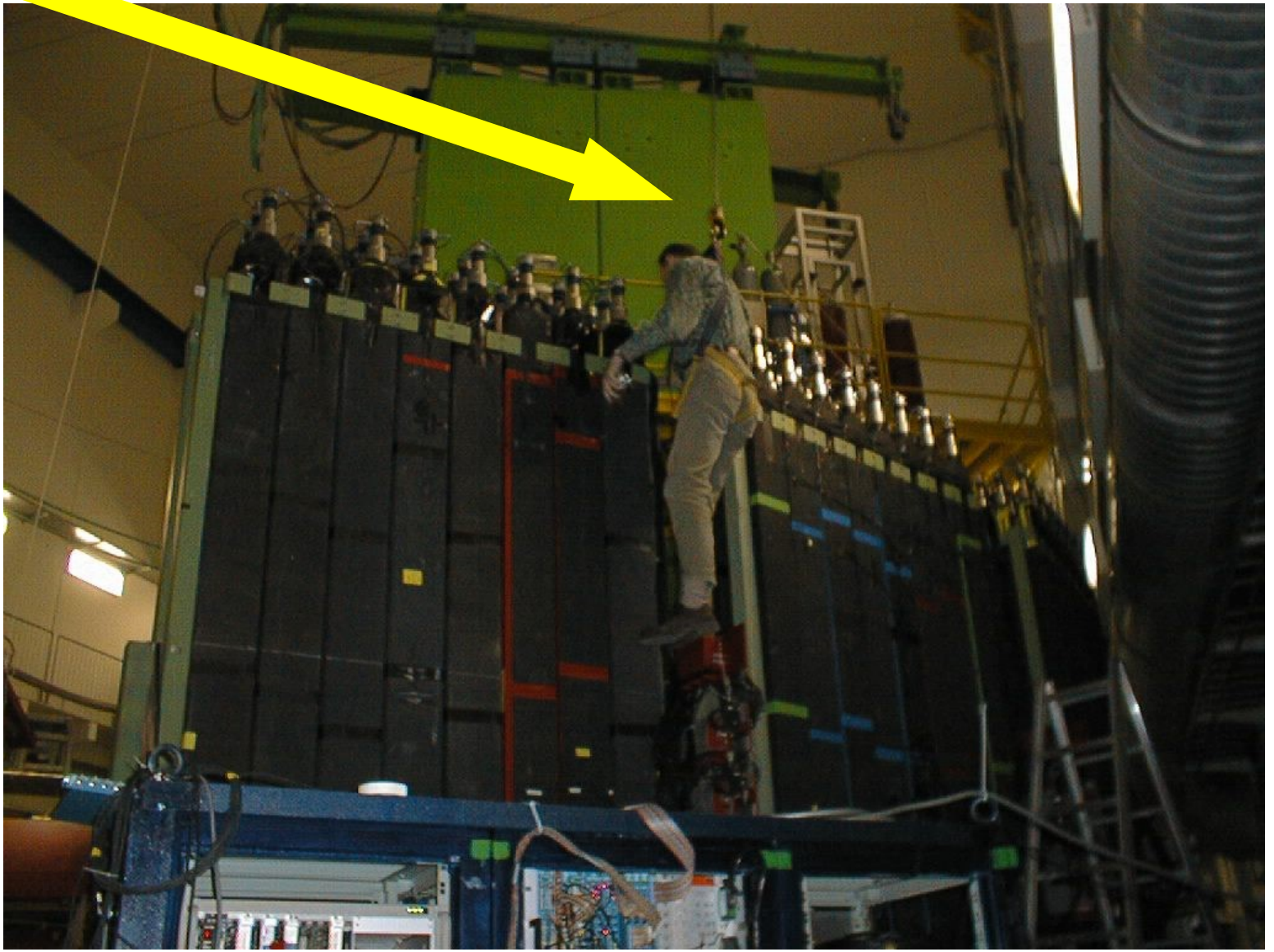


setup in 3-spectrometer hall of A1

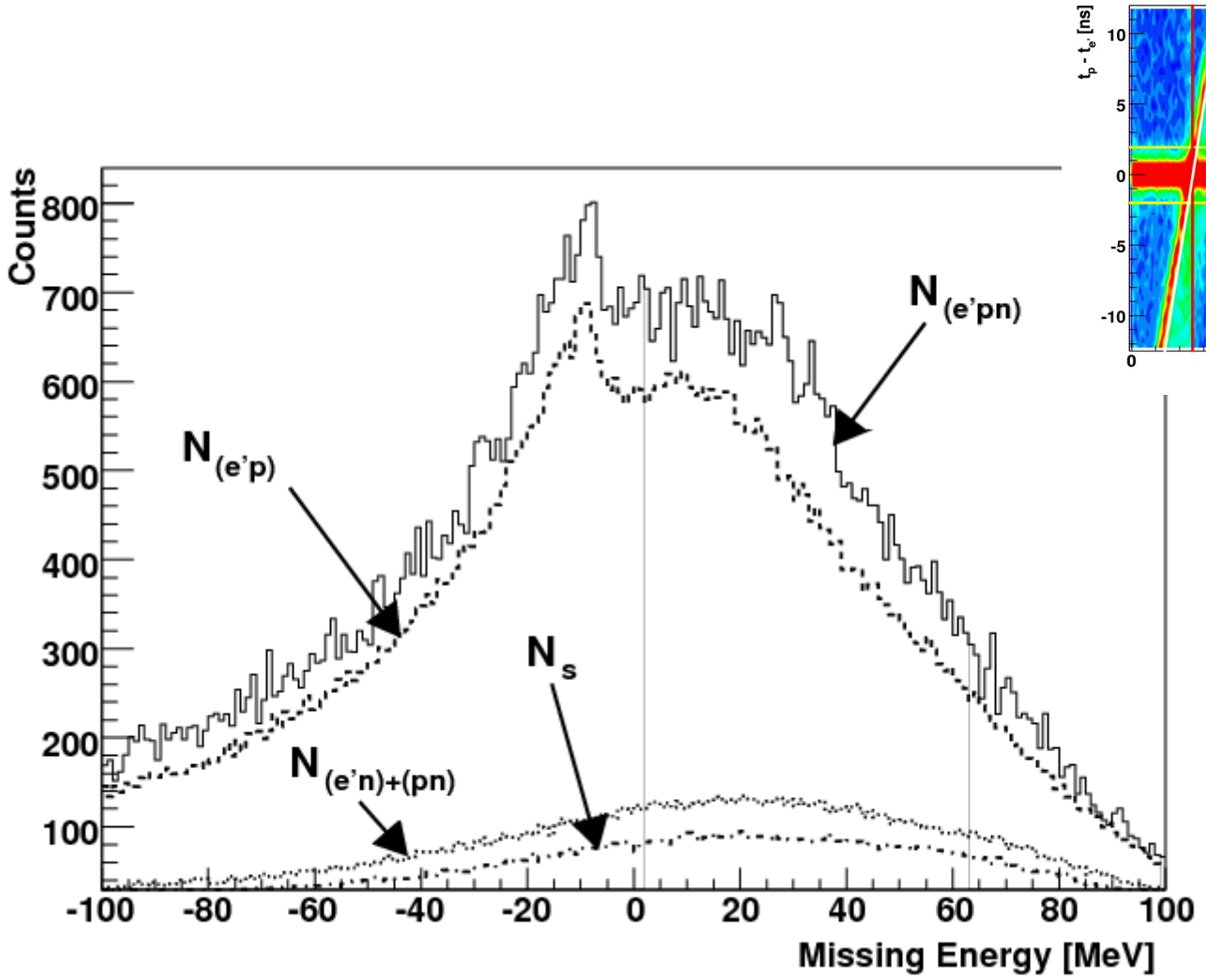


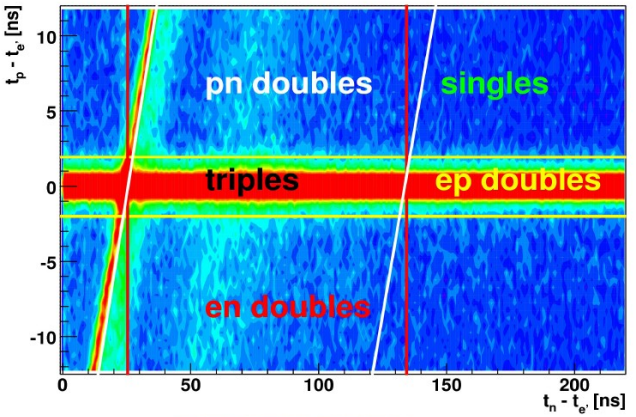


repair

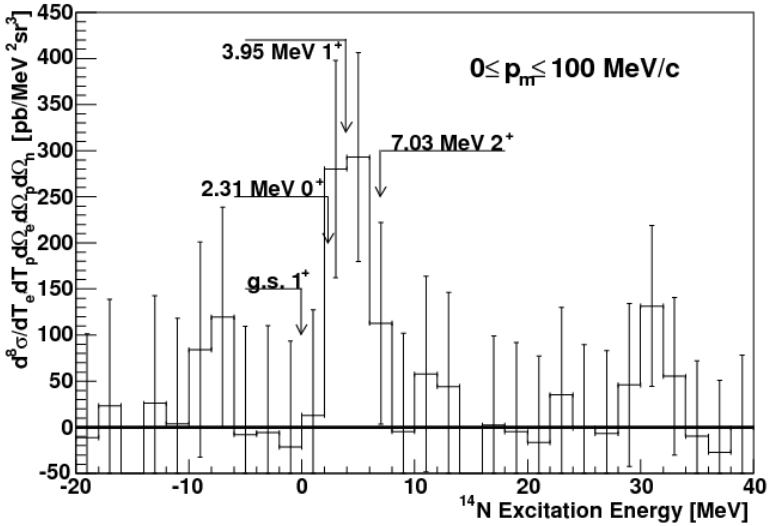


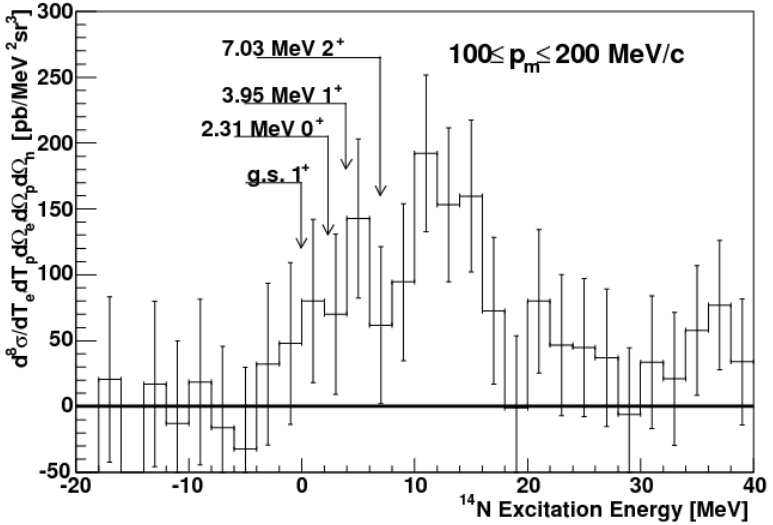
triple coincidences for ^{16}O



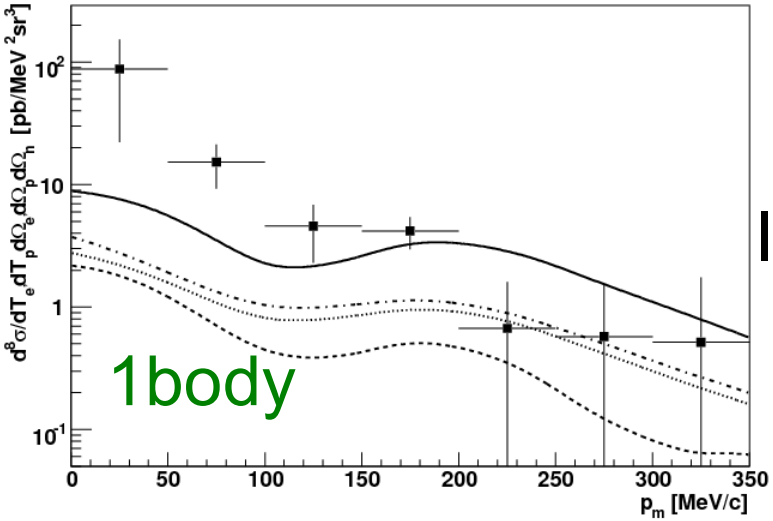


missing energy and momentum



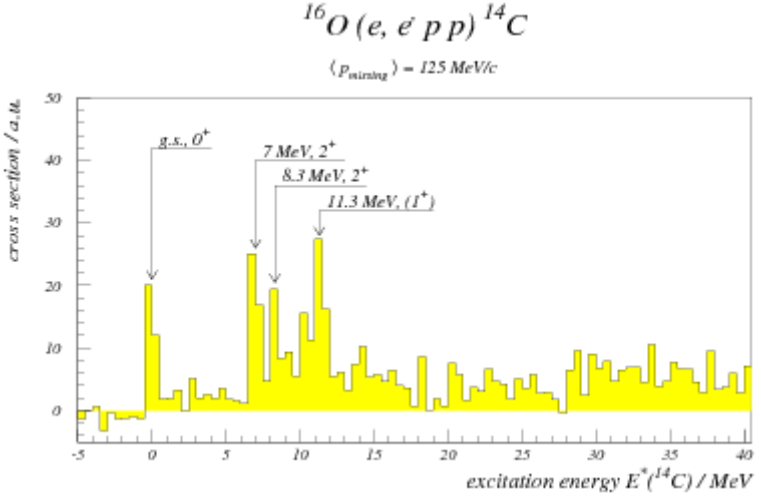


Pavia calc. C.Barbieri, PRC70

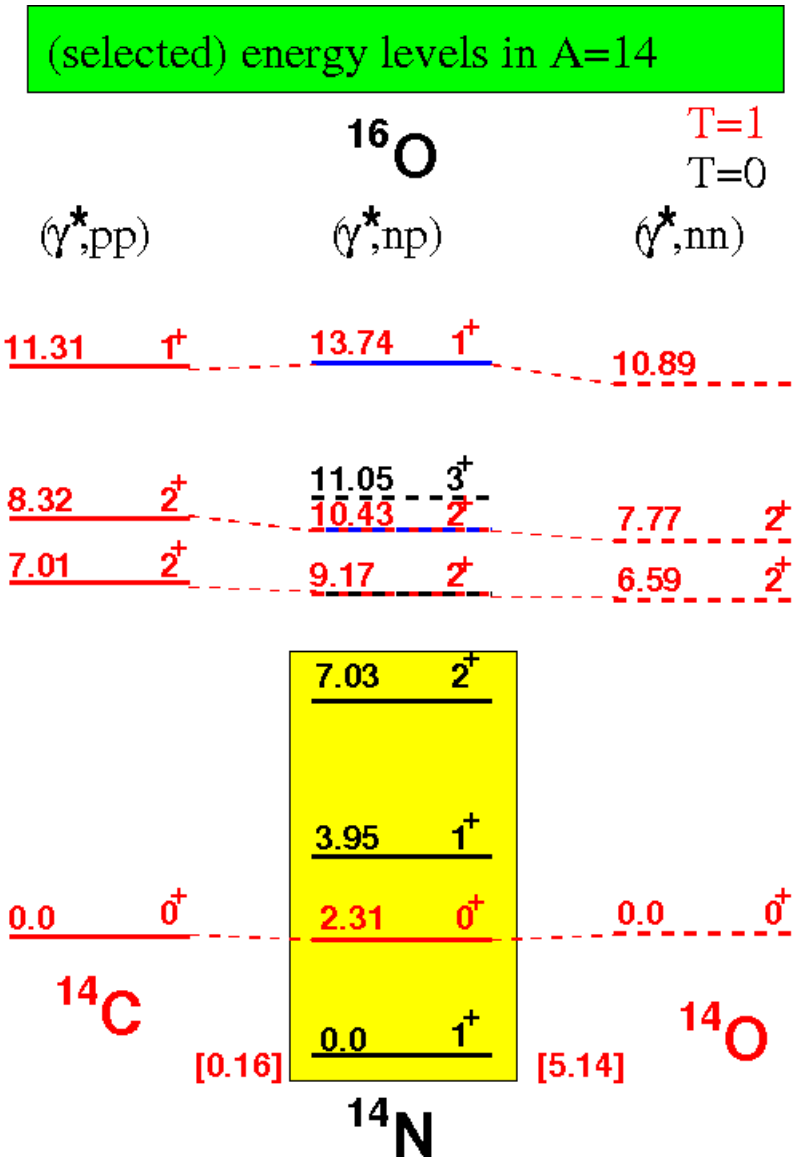


IC

π



nuclei as spin/isospin filter



$(p_{3/2})^{-2}$

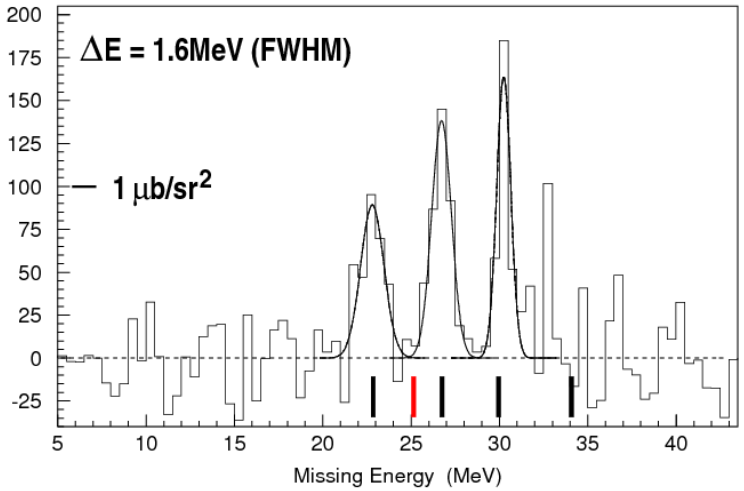
$(p_{1/2})^{-1}(p_{3/2})^{-1}$

$(p_{1/2})^{-1}(p_{3/2})^{-1}$

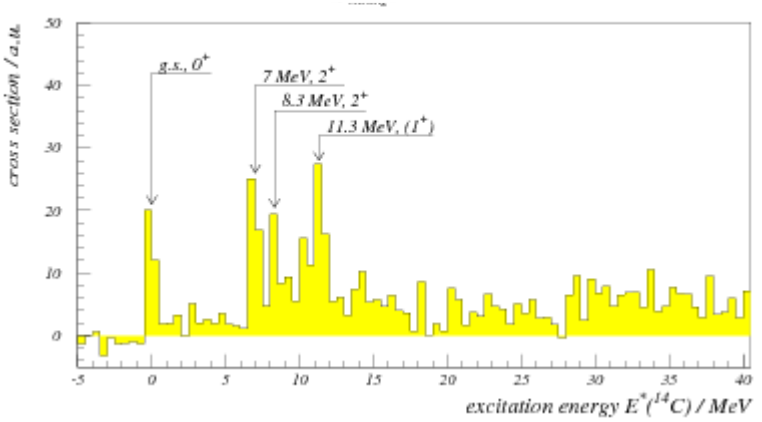
$(p_{1/2})^{-2}$

$(p_{1/2})^{-2}$

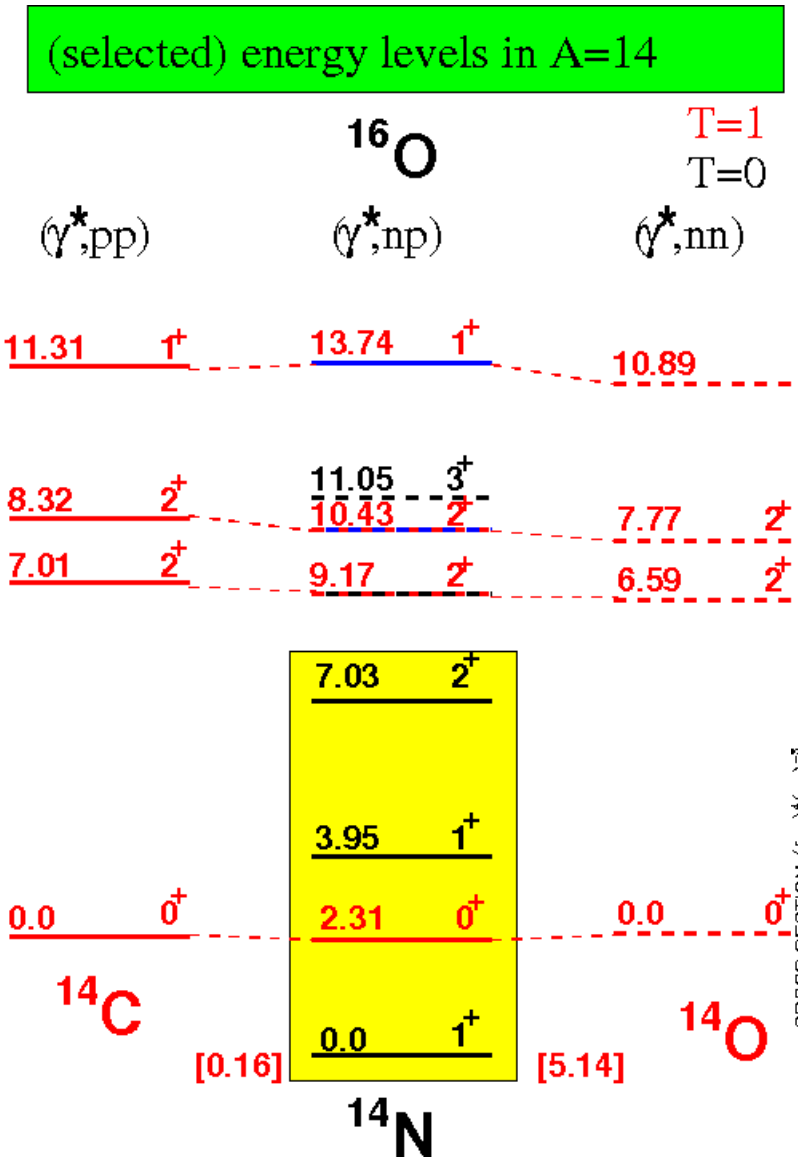
$^{16}O(\gamma,np)^{14}N$ PRL 83(99)3146



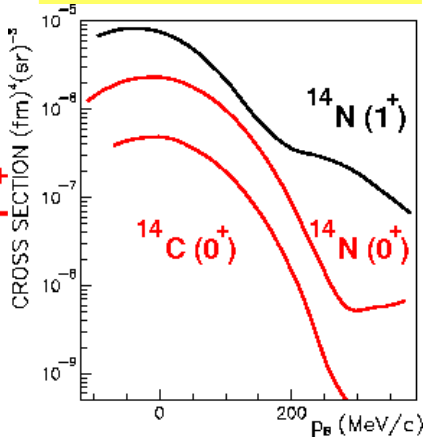
$^{16}O(e,e'np)^{14}C$



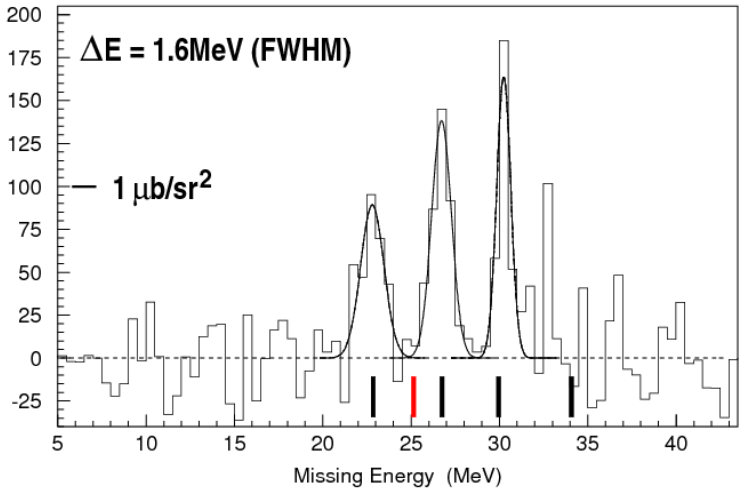
nuclei as spin/isospin filter



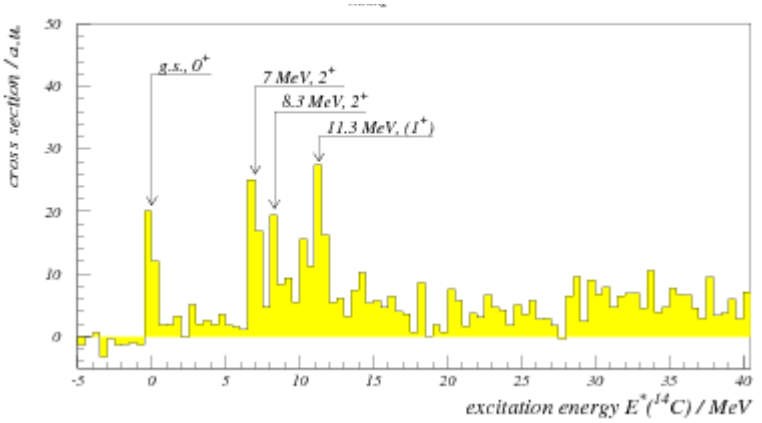
C. Giusti



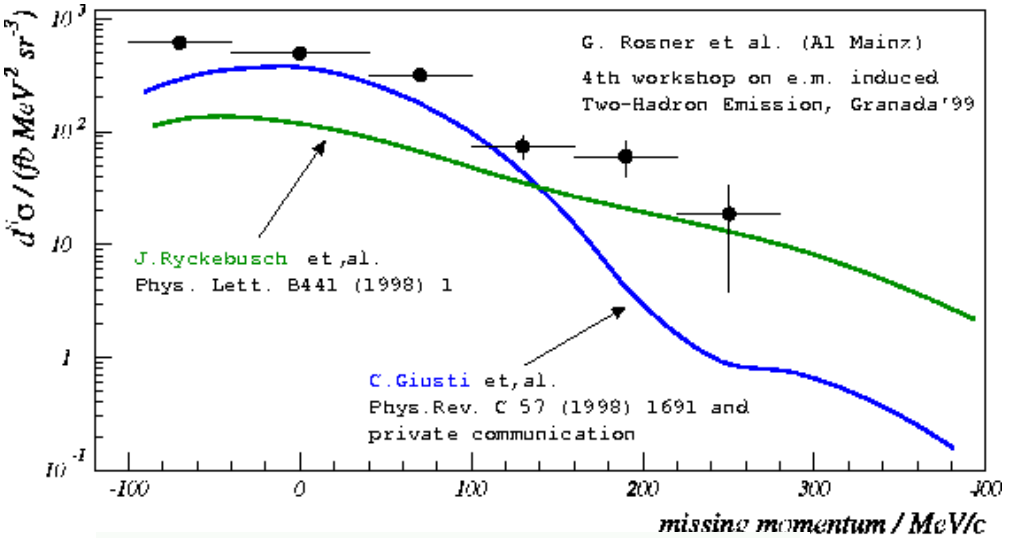
$^{16}O(\gamma,np)^{14}N$ PRL 83(99)3146



$^{16}O(e,e'np)^{14}C$

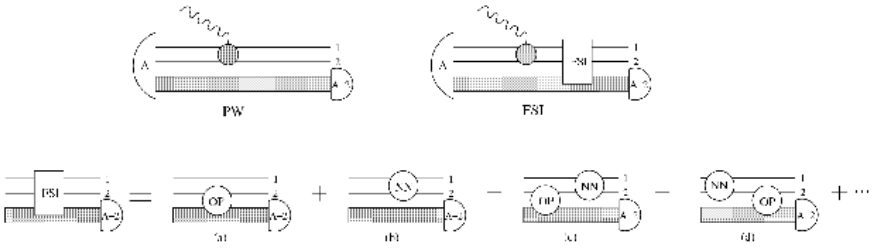


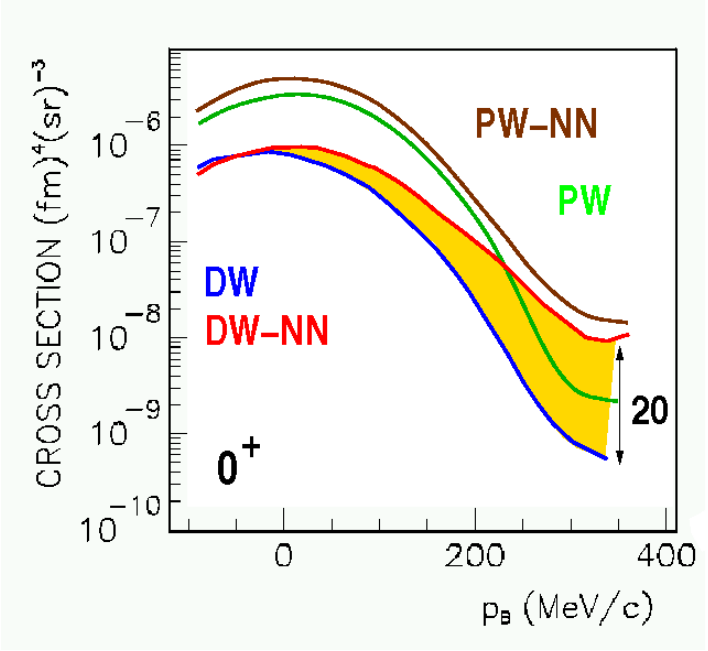
M.Schwamb and C.Giusti

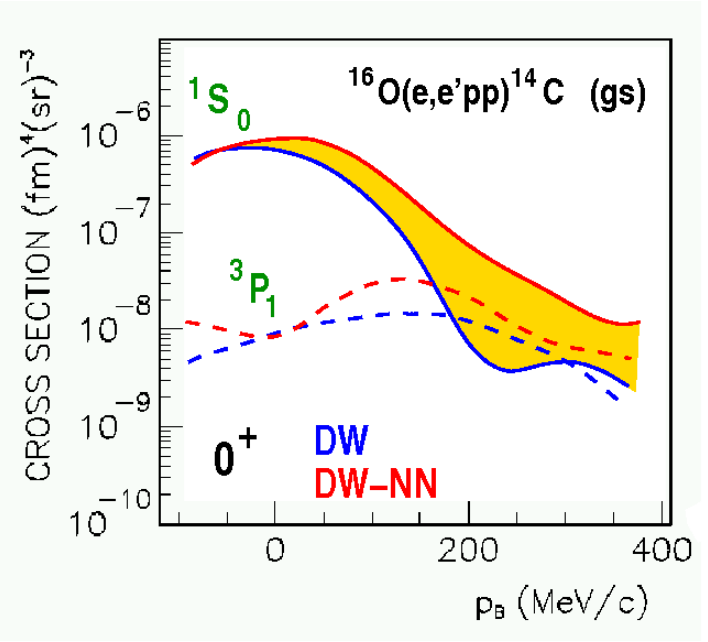


^{12}C / ^{16}O(e,e'pp)

NN-FSI as 3body problem



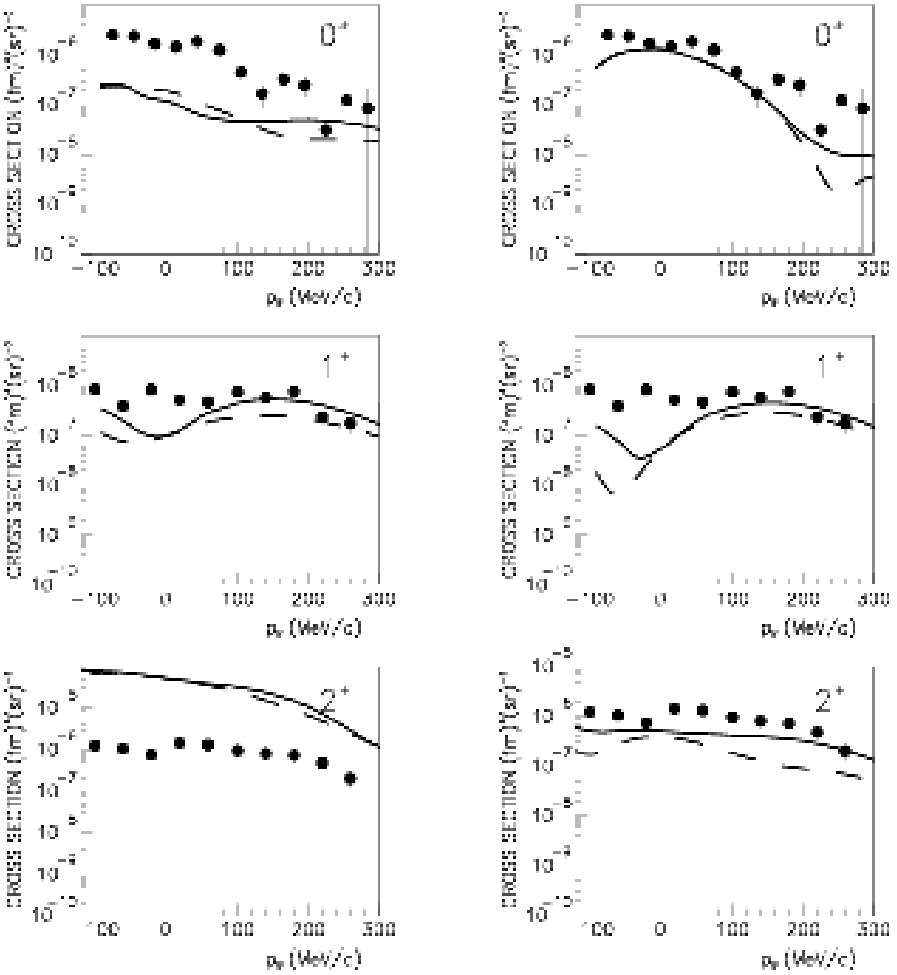


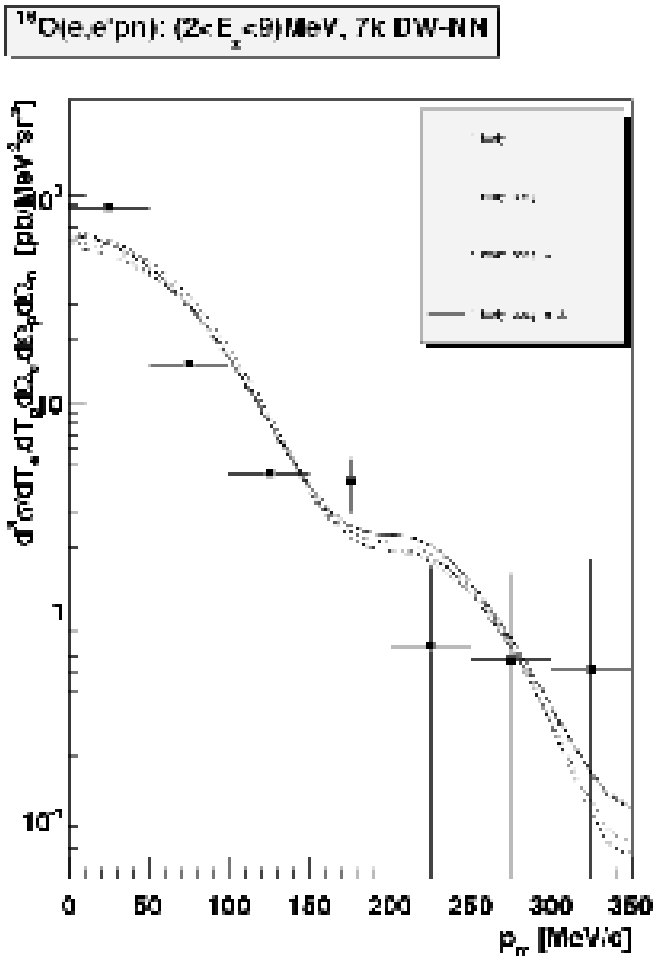


improved orthogonalisation

SM-SRC

SF-B

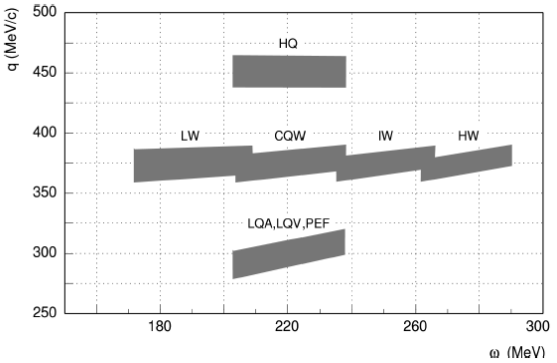


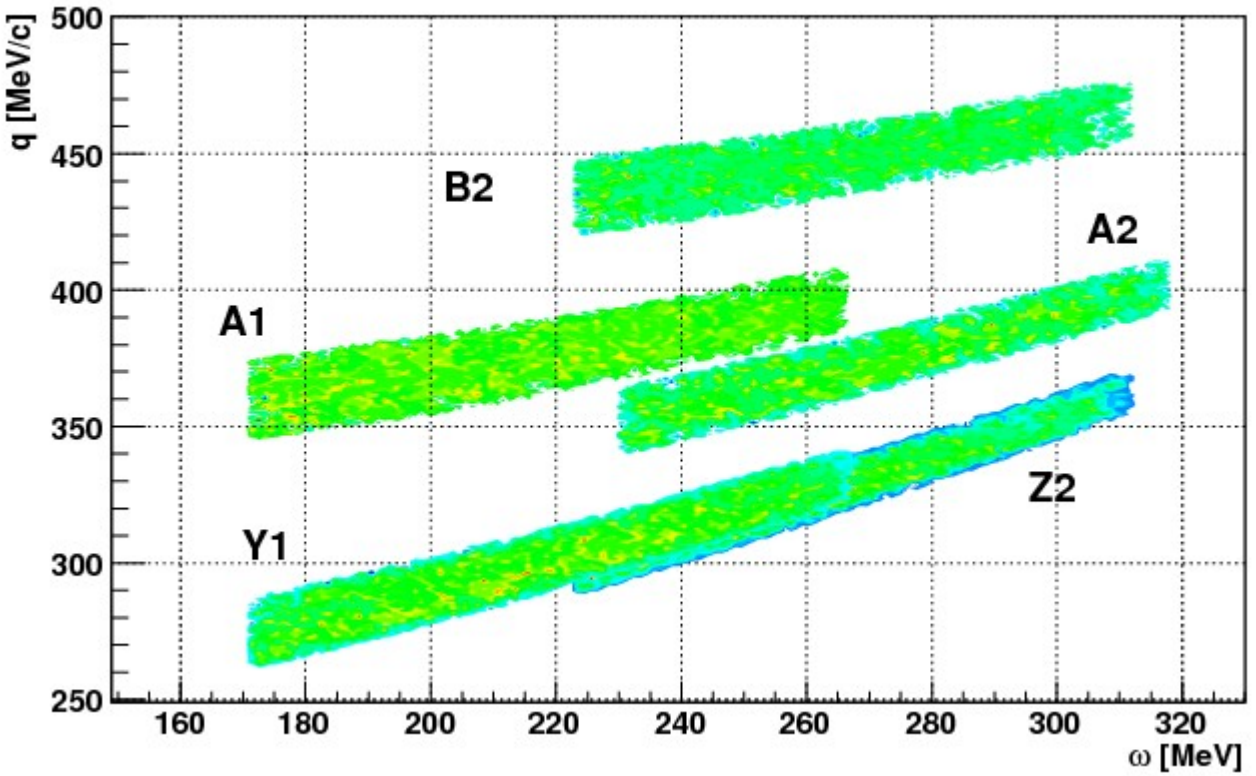


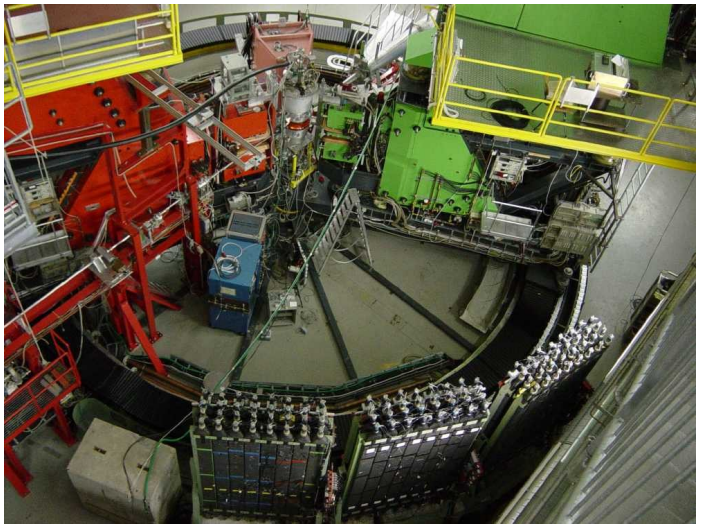
Schwamb priv. comm.

kinematics for ^{3}He(e,e'pn)

similar to the ^{3}He(e,e'pp) @NIKHEF

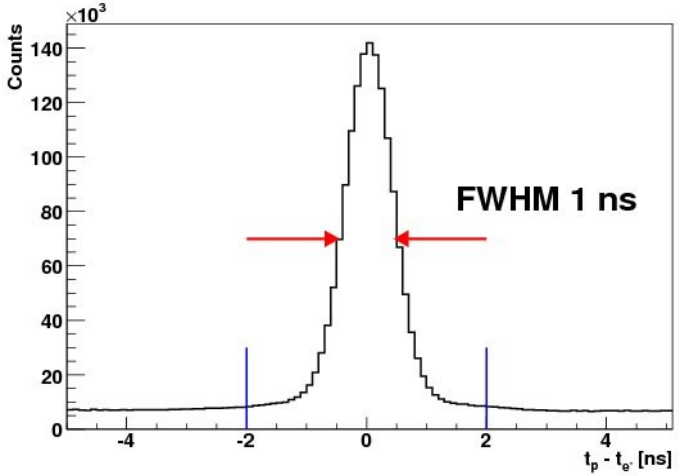




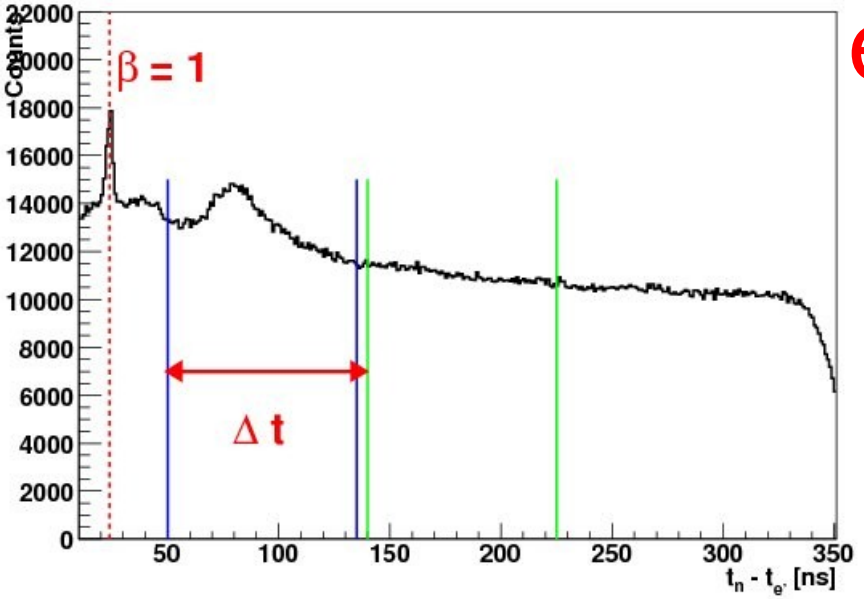


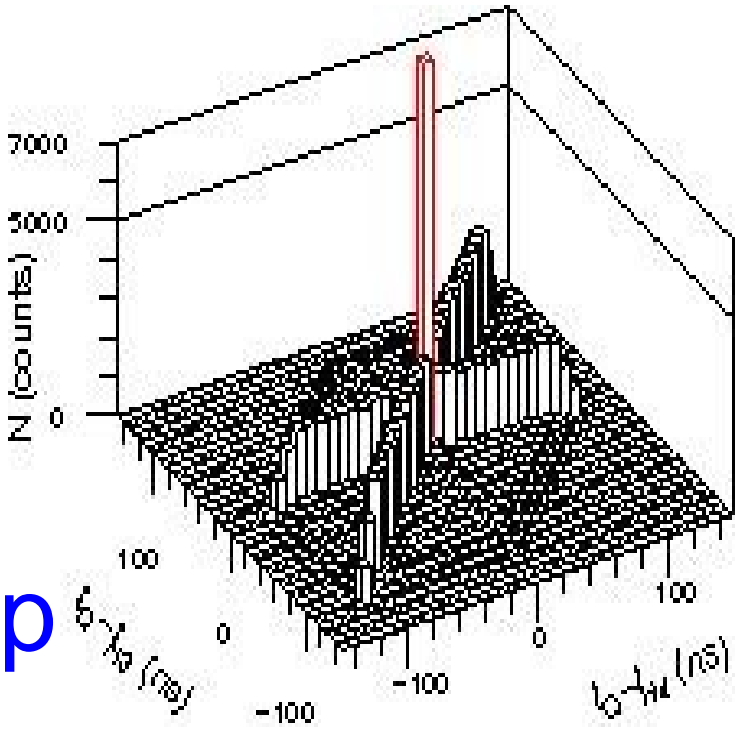
timing and randoms

e'p

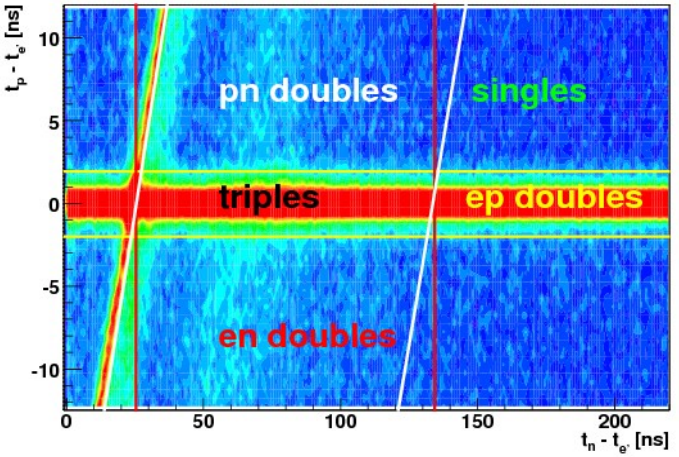


e'n



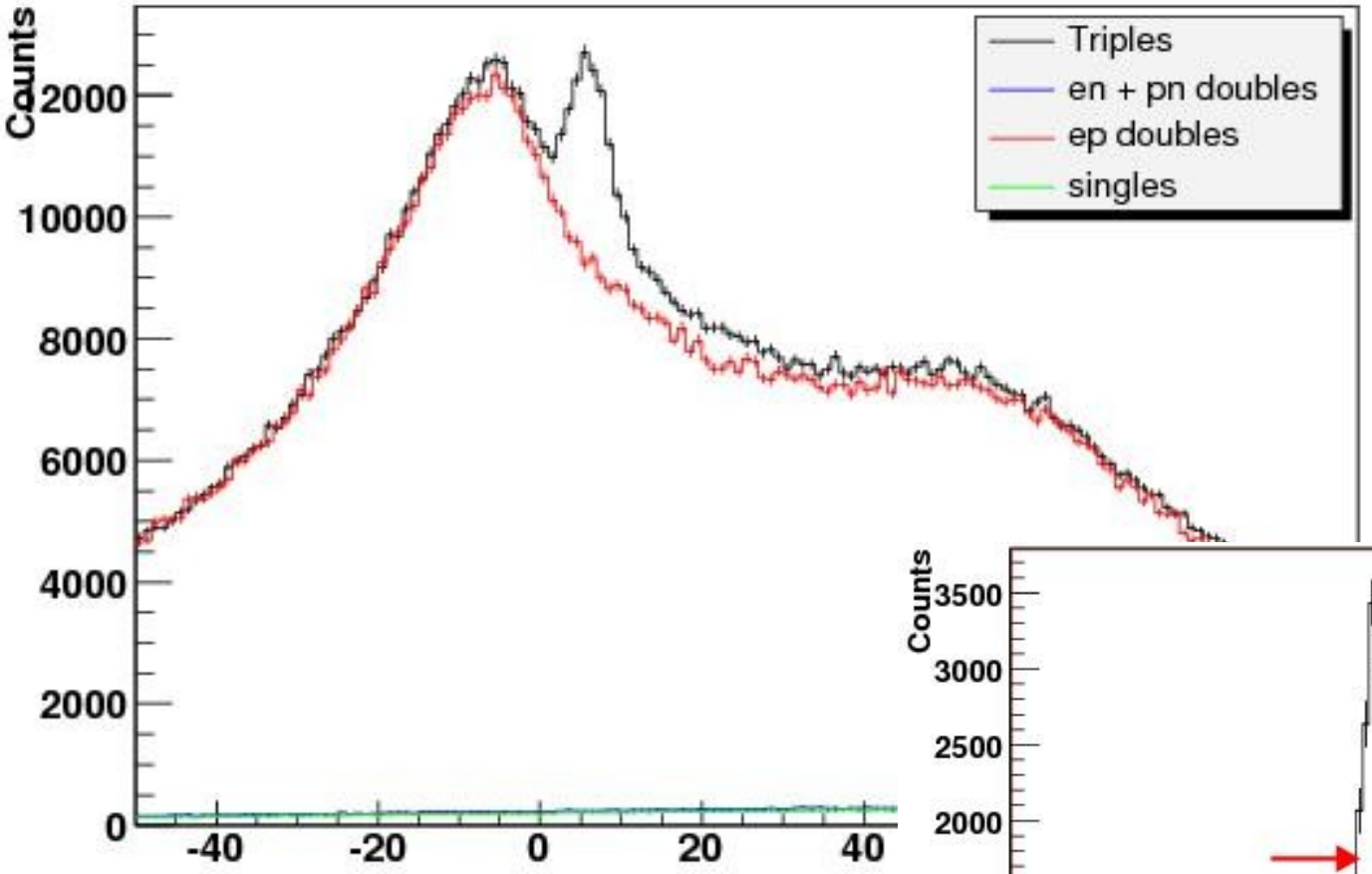


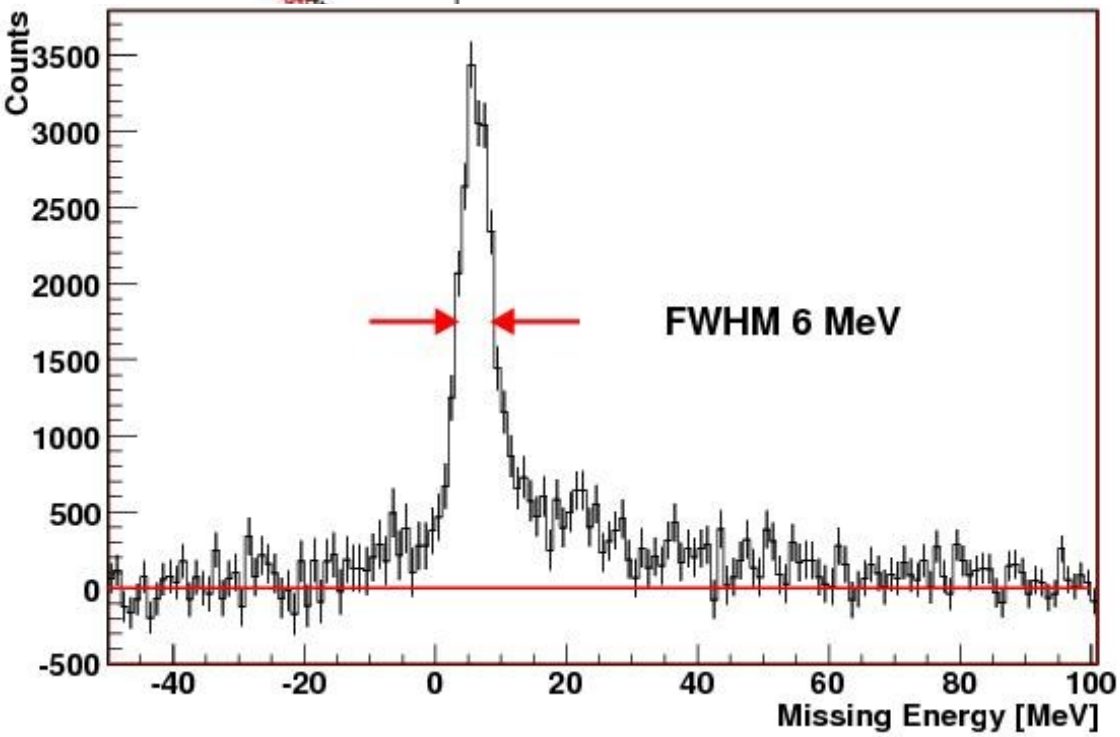
e'pp



e'pn

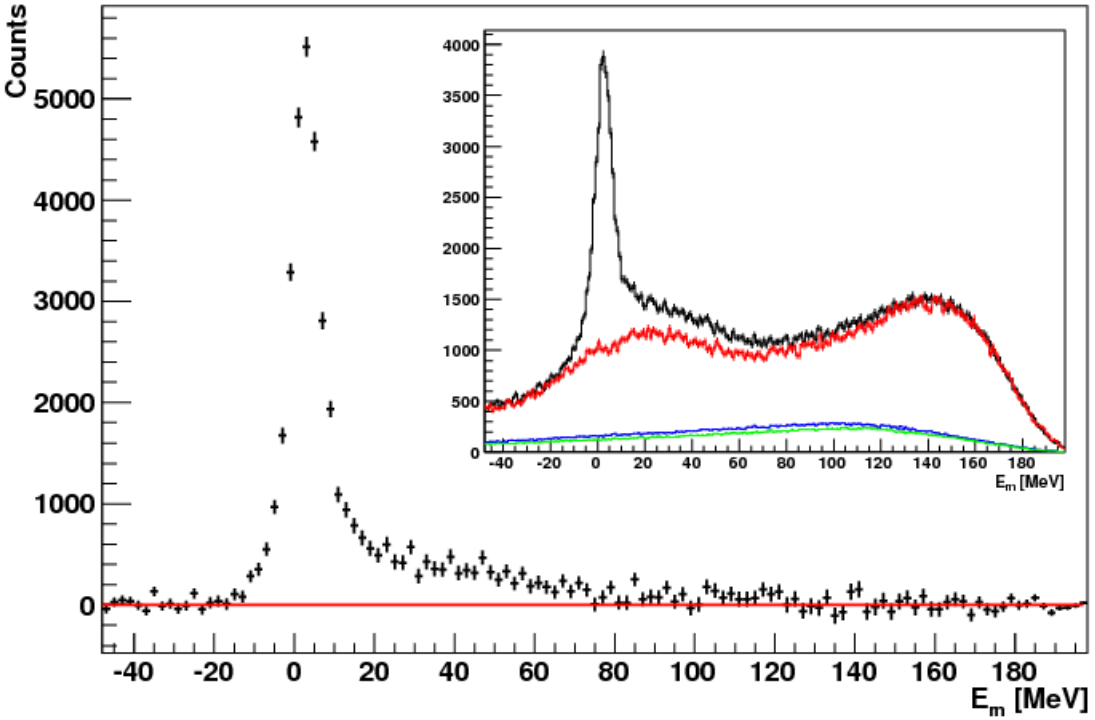
missing energy





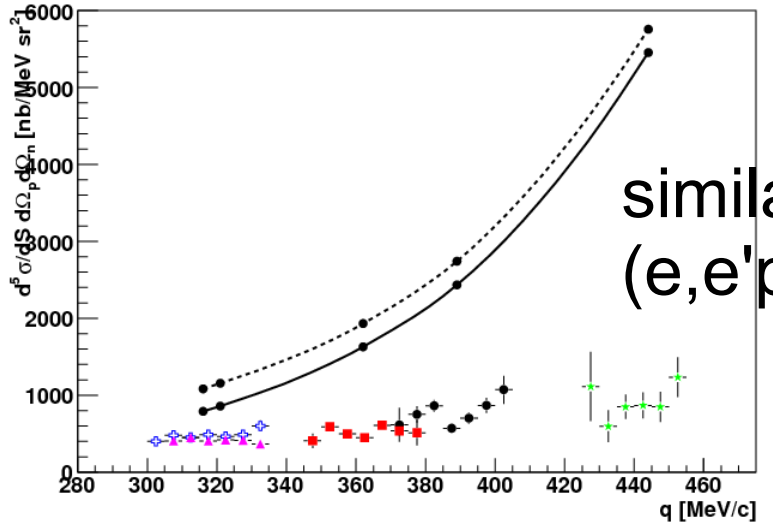
$$E_m = E\text{-}E' - T_p - T_n$$

^{3}He(e,e'pn)

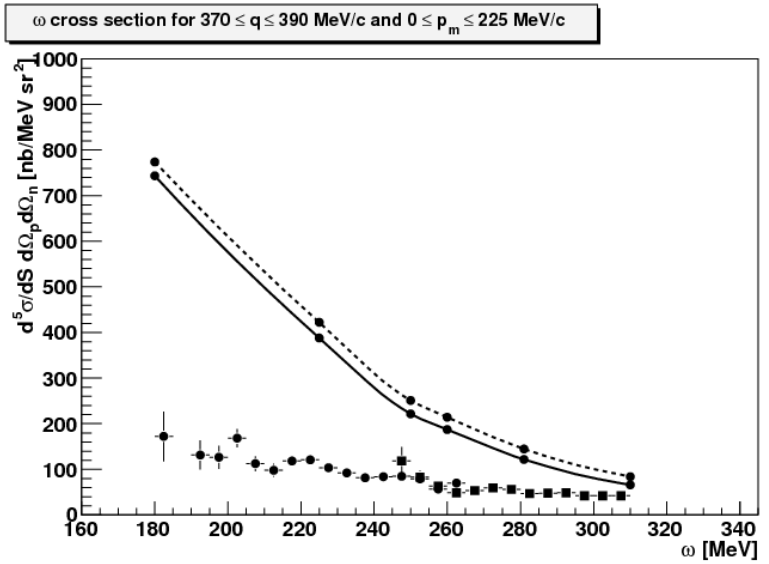


missing energy (Z2)

J. Golak etal.

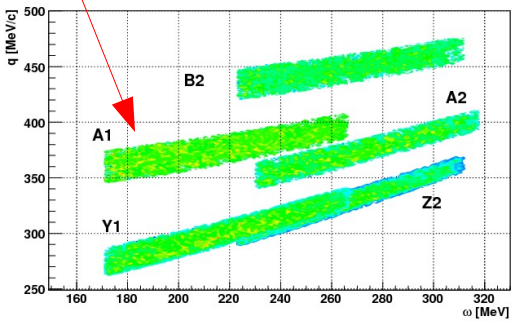


similar to (e,e'pp)

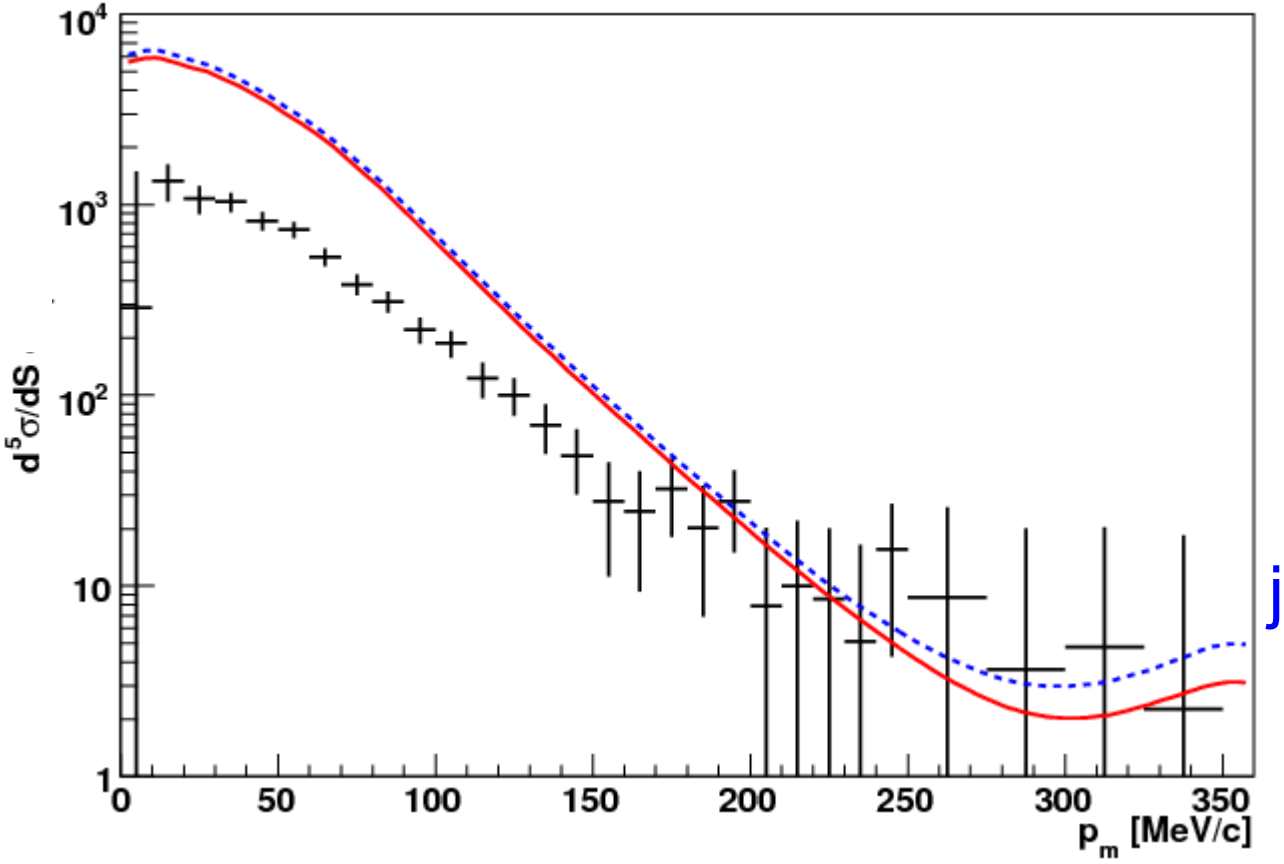


missing momentum

A1 kinematics



Golak etal.



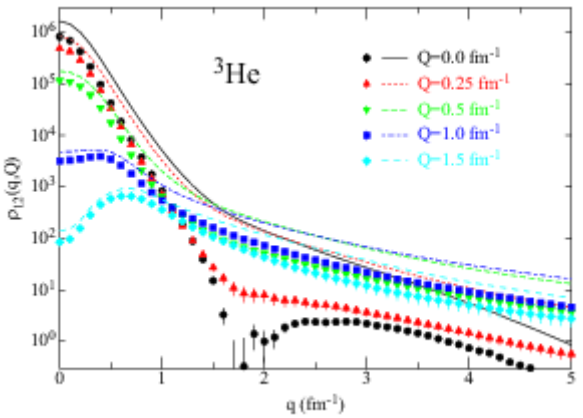
j1+MEC

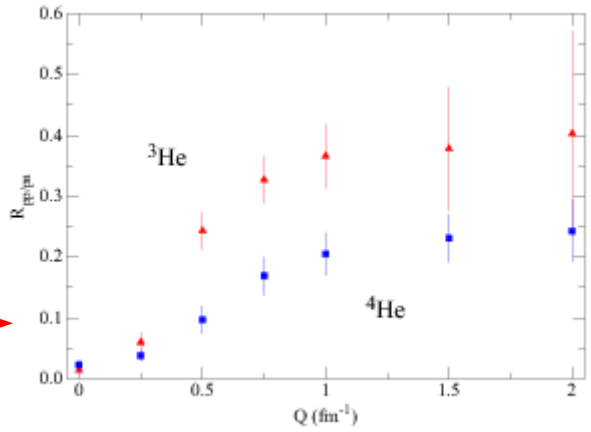
j1

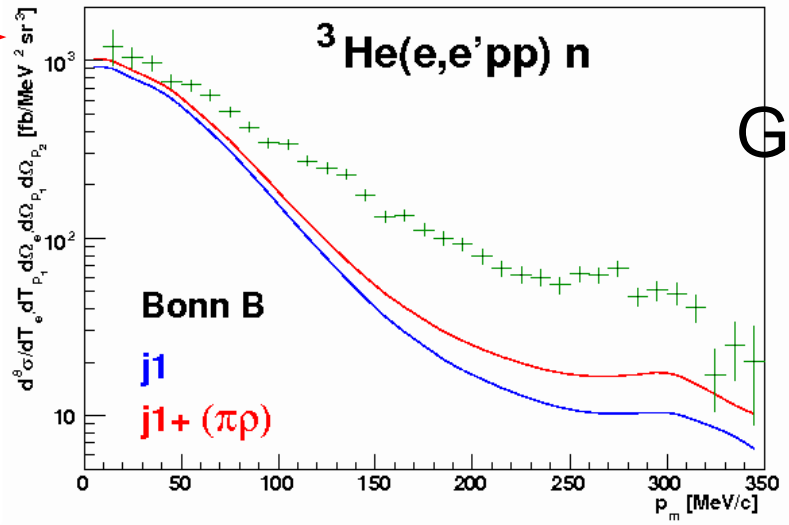
ratio pp vs pn

Dependence of two-nucleon momentum densities on total pair momentum

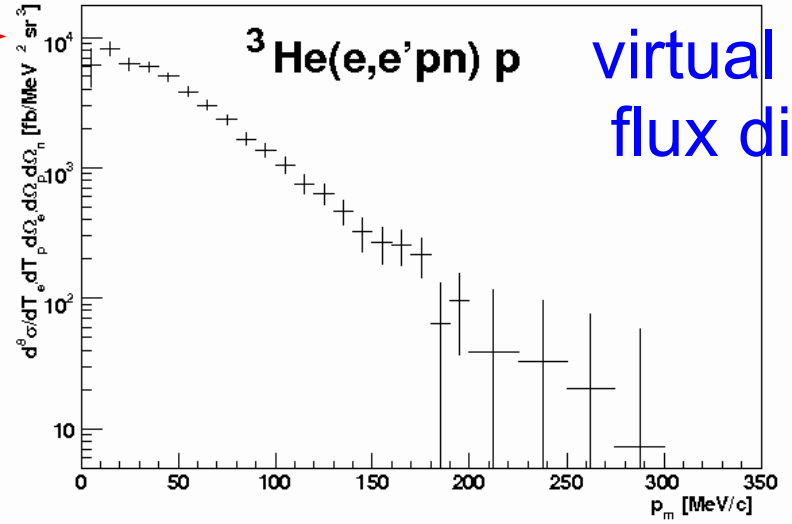
R.B. Wiringa[1], R. Schiavilla[2,3], Steven C. Pieper[1], and J. Carlson[4]
[1] *Physics Division, Argonne National Laboratory, Argonne, IL 60439*
[2] *Theory Center, Jefferson Laboratory, Newport News, VA 23606*
[3] *Department of Physics, Old Dominion University, Norfolk, VA 23529*
[4] *Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545*
(Dated: June 10, 2008)







Groep etal



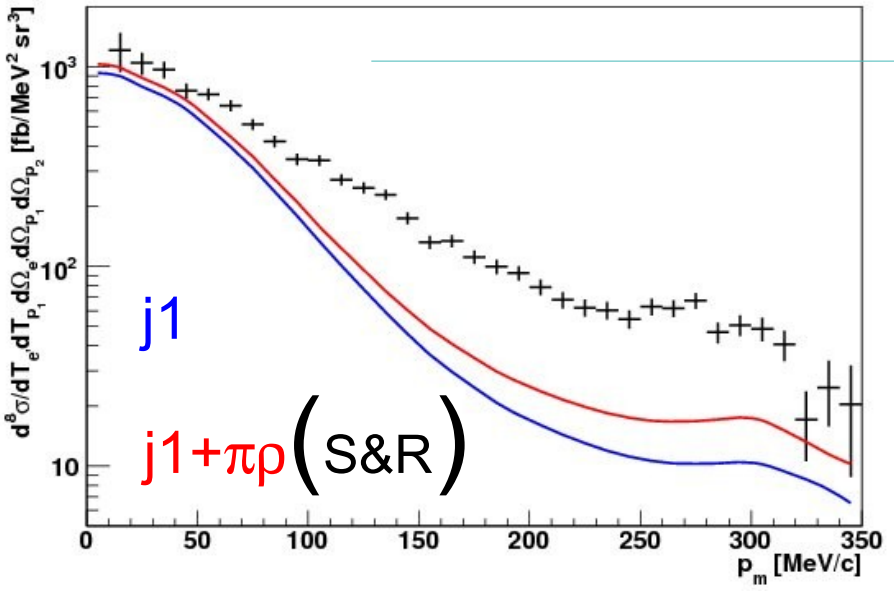
virtual photon flux differs

p_m missing momentum

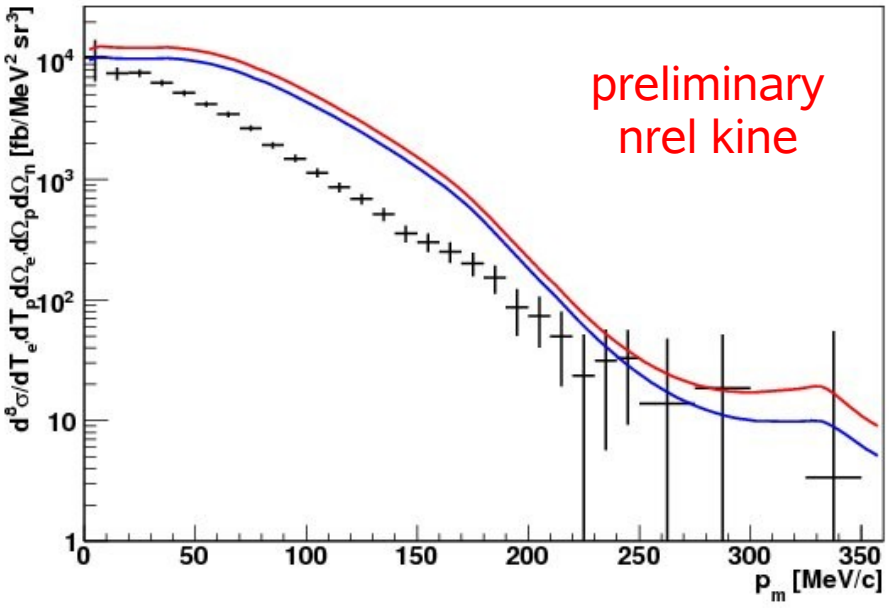
q=300, ω=220 MeV

e,e'pp

10^3 fb/(MeV^{2}sr^3)



e,e'pn

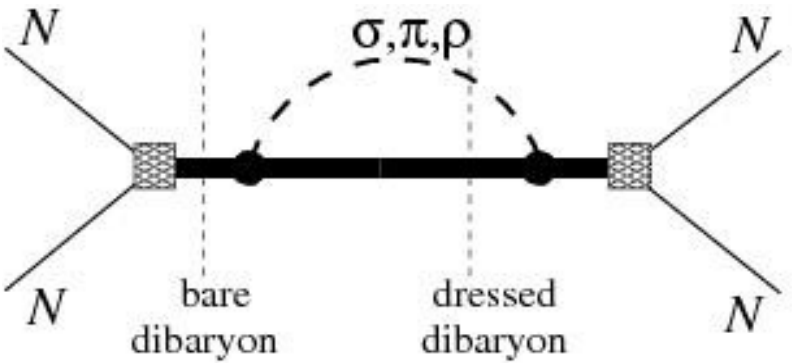


p_m

J. Golak et al., PRC51 (1995) 1638
continuum Faddeev calculations by Bochum/Cracow
NN potential : Bonn B

6q model

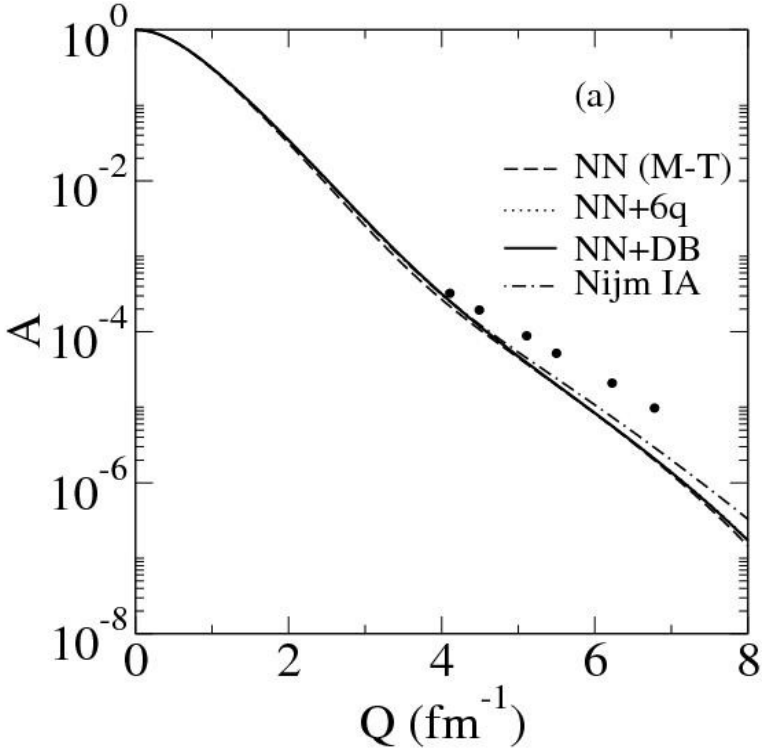
VI Kukulin; Moscow-Tübingen

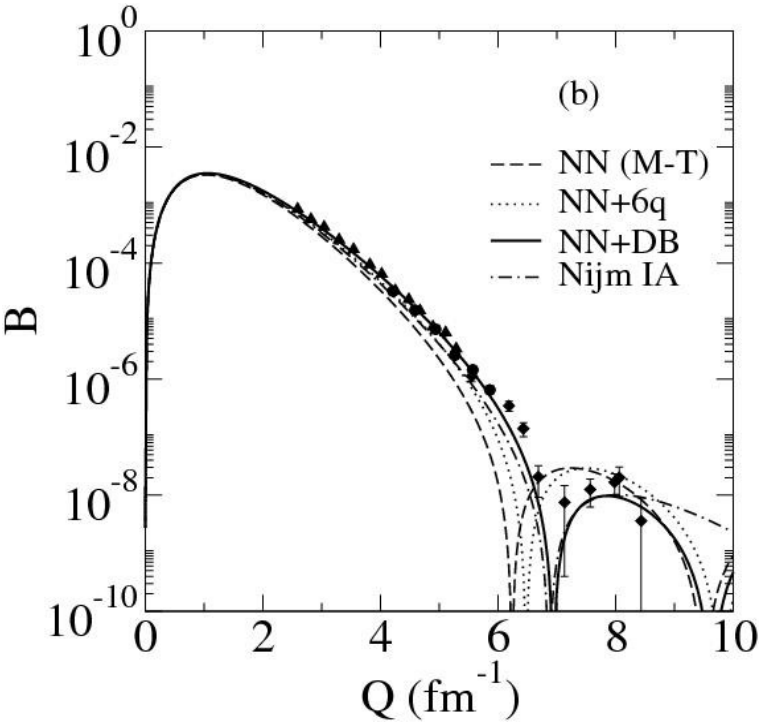


PR C74 (2006) 64005

elastic e-D

magnetic m
n capture





summary

- 2N emission experiments test
  reaction mechanisms and NN interaction

$$H\Psi = E\Psi$$

- NN correlations are a model dependent concept
- use results from ab initio calculations for
  reaction calculations, solve 3He problem
- correlations (SRC) input to NME calculations for
  neutrinoless double beta decay (GERDA starts in 2009)

the nucleon

do we understand the nucleon ?

Gerasimov Drell Hearn sum rule

neutron electric form factor

use (double) polarisation to find small amplitudes

the setting

nucleons play a key role

- bags for the quarks
- constituents of nuclei (stable or exotic)
- stable

electro magnetic form factors

- elastic scattering (relatively easy to measure)
- response to momentum transfer by em probe
- meeting point for experiment & theory
- GPD, strange FF, structure functions

Goal: understanding of strong interaction

Introduction

What is 'easy' ? The proton !?

$G_D(Q^2)=(1+Q^2/\Lambda^2)^{-2}$

$\Lambda^2_D = 0{,}71\ \mathrm{GeV}^{-2}$

Low q, π cloud

CQM + π ; BATES

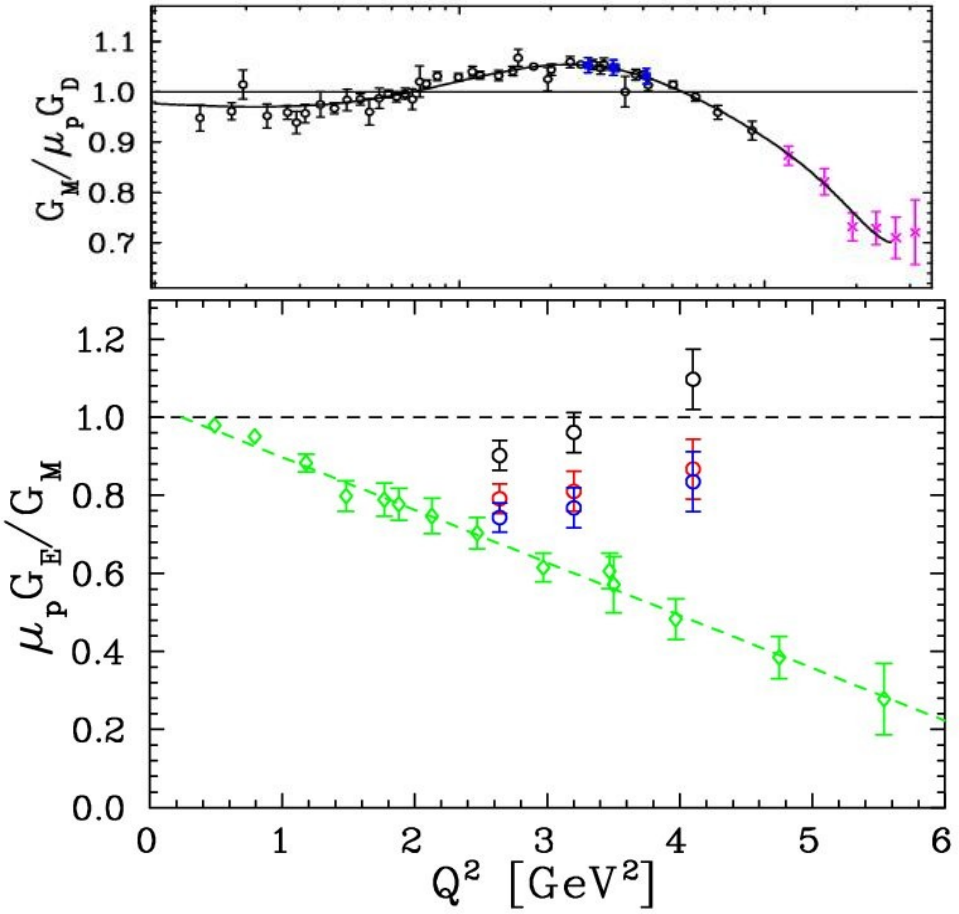
FW-fit [EPJA 17 (2003) 607]

Rosenbluth analysis

Arrington, Jones, Day

$$\sigma_R = \tau G_M^2(Q^2) + \epsilon G_E^2(Q^2)$$

$$\tau = Q^2/4M_N^2$$



models : relativistic constituent quark model

Melde,Plessas etal., accepted by PRD (2007) , nucl-th/0612013

Goldstone Boson Exchange CQM
within relativistic quantum mechanics
spectator model currents in instant/point form
compare to NRIA

in the PFSM: in all frames the photon strikes only one quark
the PFSM current is manifestly invariant
one factor N more than IFSM (charge @ $Q^2=0$)

TABLE I: Magnetic moments of the proton and neutron (in n.m.) as predicted by the GBE CQM with the the IFSM, PFSM, and the NRIA current operators. Experimental data after the PDG [51].

	GBE CQM			Experiment
Nucleon	IFSM	PFSM	NRIA	
p	1.24	2.70	2.74	2.79
n	-0.79	-1.70	-1.82	-1.91

TABLE II: Charge radii of the proton and neutron (in fm^2) as predicted by the GBE CQM with the the IFSM, PFSM, and the NRIA current operators. Experimental data after the PDG [51].

	GBE CQM			Experiment
Nucleon	IFSM	PFSM	NRIA	
p	0.156	0.824	0.102	0.766
n	-0.020	-0.135	-0.009	-0.116

models : point/instant form

Melde,Plessas etal., accepted by PRD (2007) , nucl-th/0612013

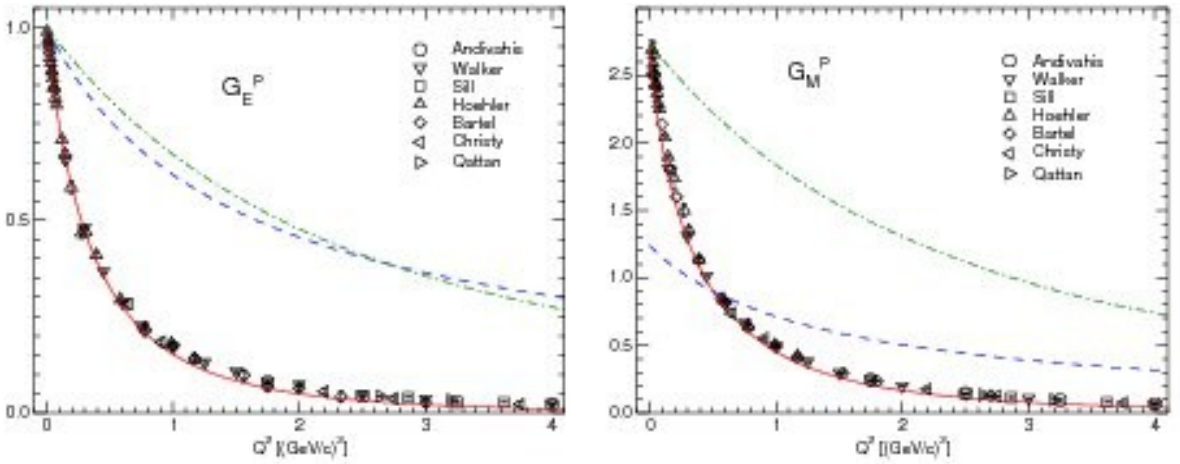


FIG. 1: Electric and magnetic form factors of the proton as predicted by the GBE CQM with the the IFSM (dashed line), PFSM (full line), and the NRIA (dash-dotted line) current operators. Experimental data are from Refs. [22–31] and [32–38].

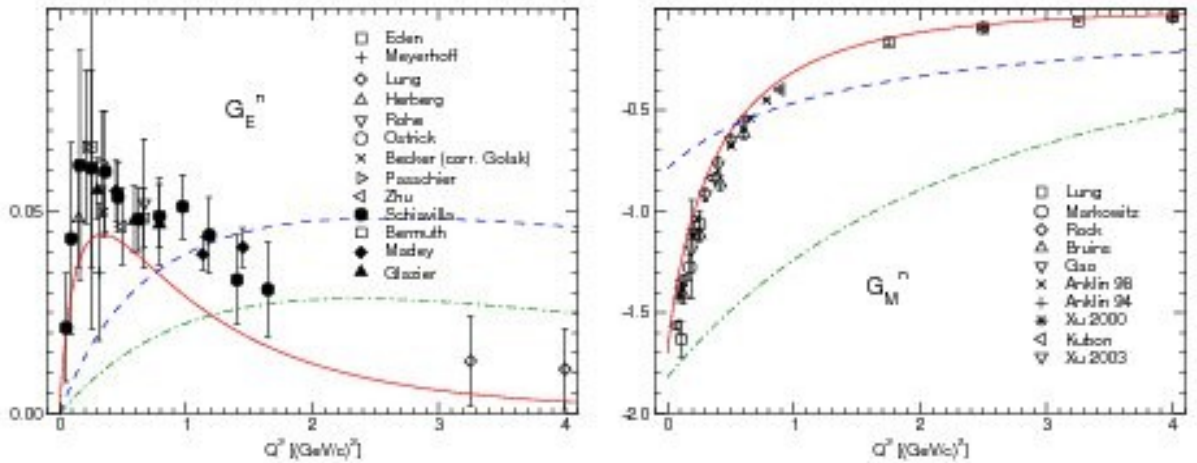


FIG. 2: Same as in Fig. 1 but for the neutron. Experimental data are from Refs. [22–31, 39–50].

instant form point form

models : point/instant form

Melde,Plessas etal., accepted by PRD (2007) , nucl-th/0612013

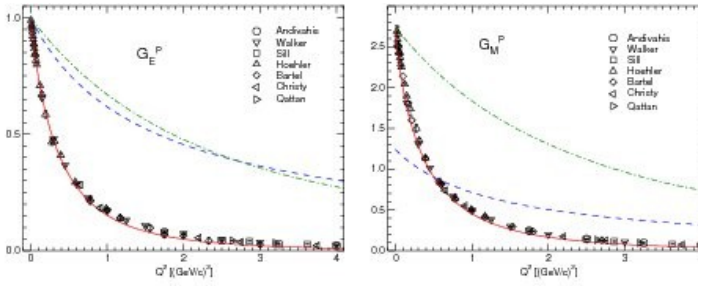


FIG. 1: Electric and magnetic form factors of the proton as predicted by the GBE CQM with the the IFSM (d
PFSM (full line), and the NRIA (dash-dotted line) current operators. Experimental data are from Refs. [22–31] ar

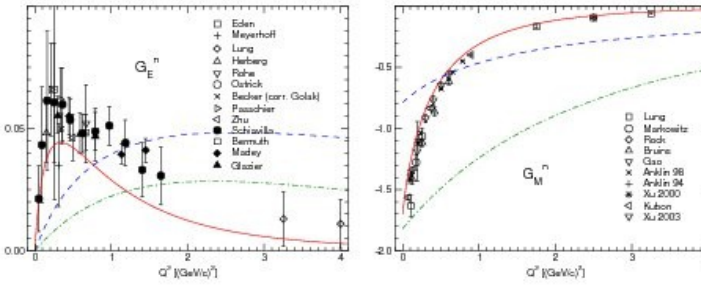
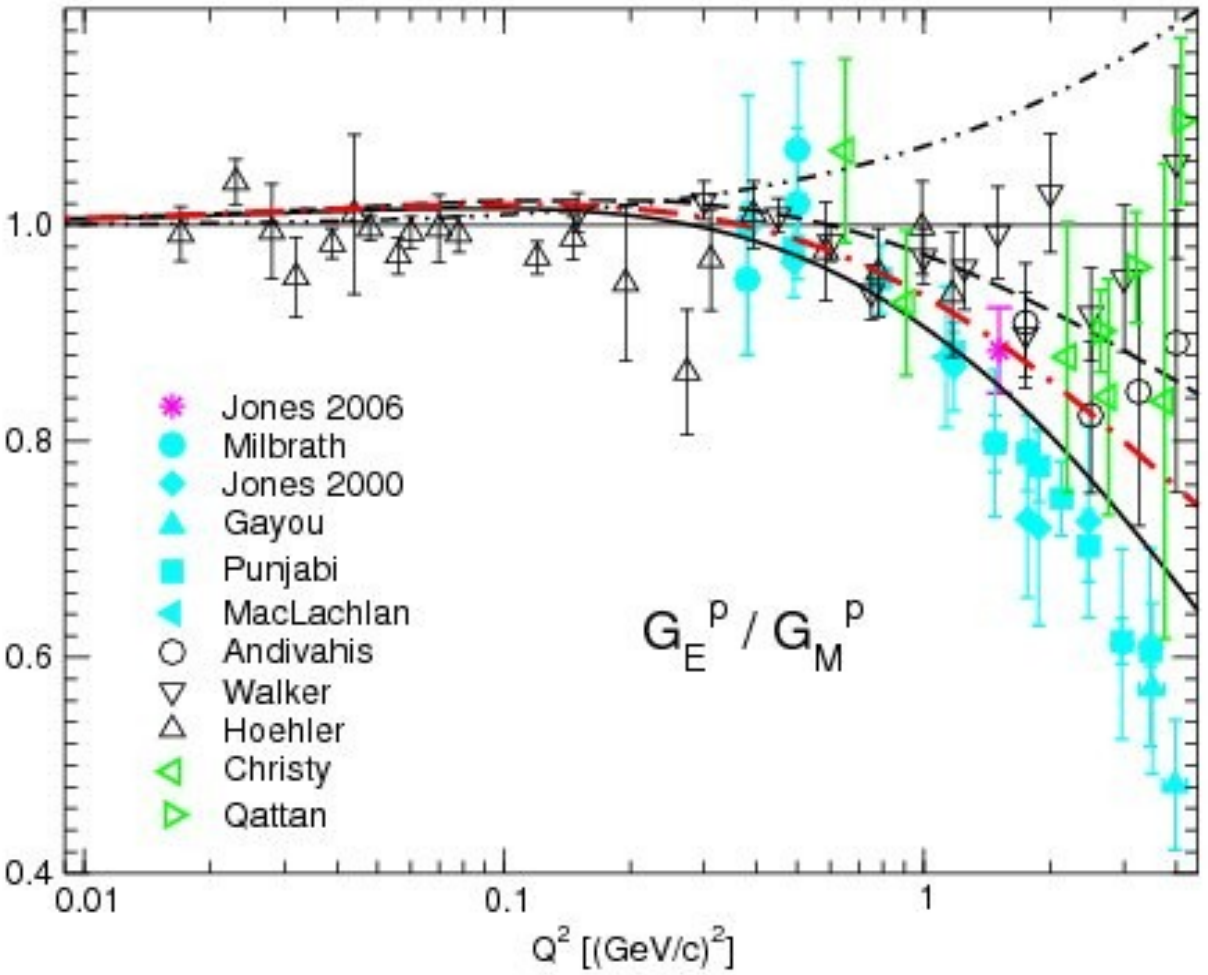


FIG. 2: Same as in Fig. 1 but for the neutron. Experimental data are from Refs. [22–31, 39–50].

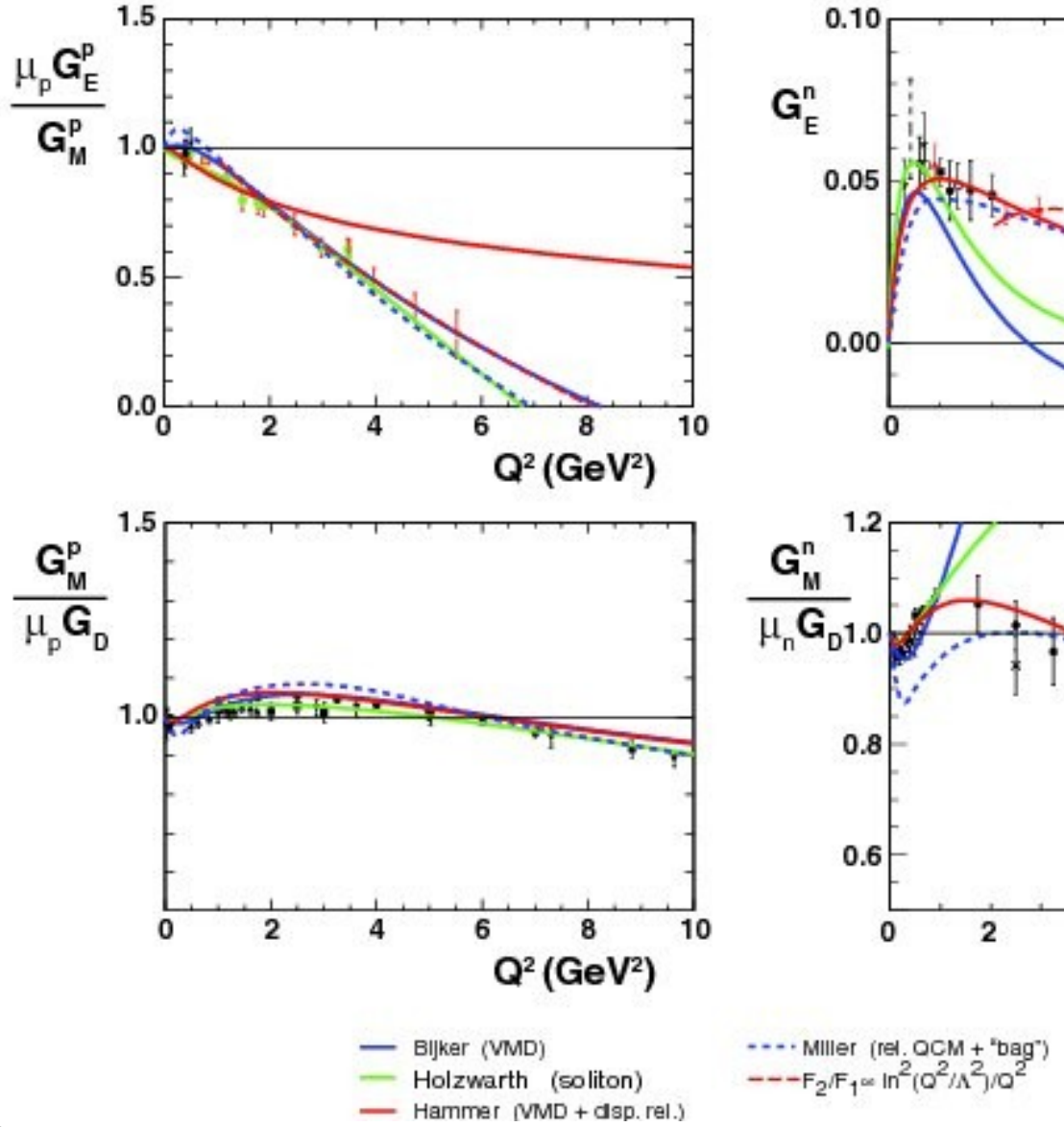


different current

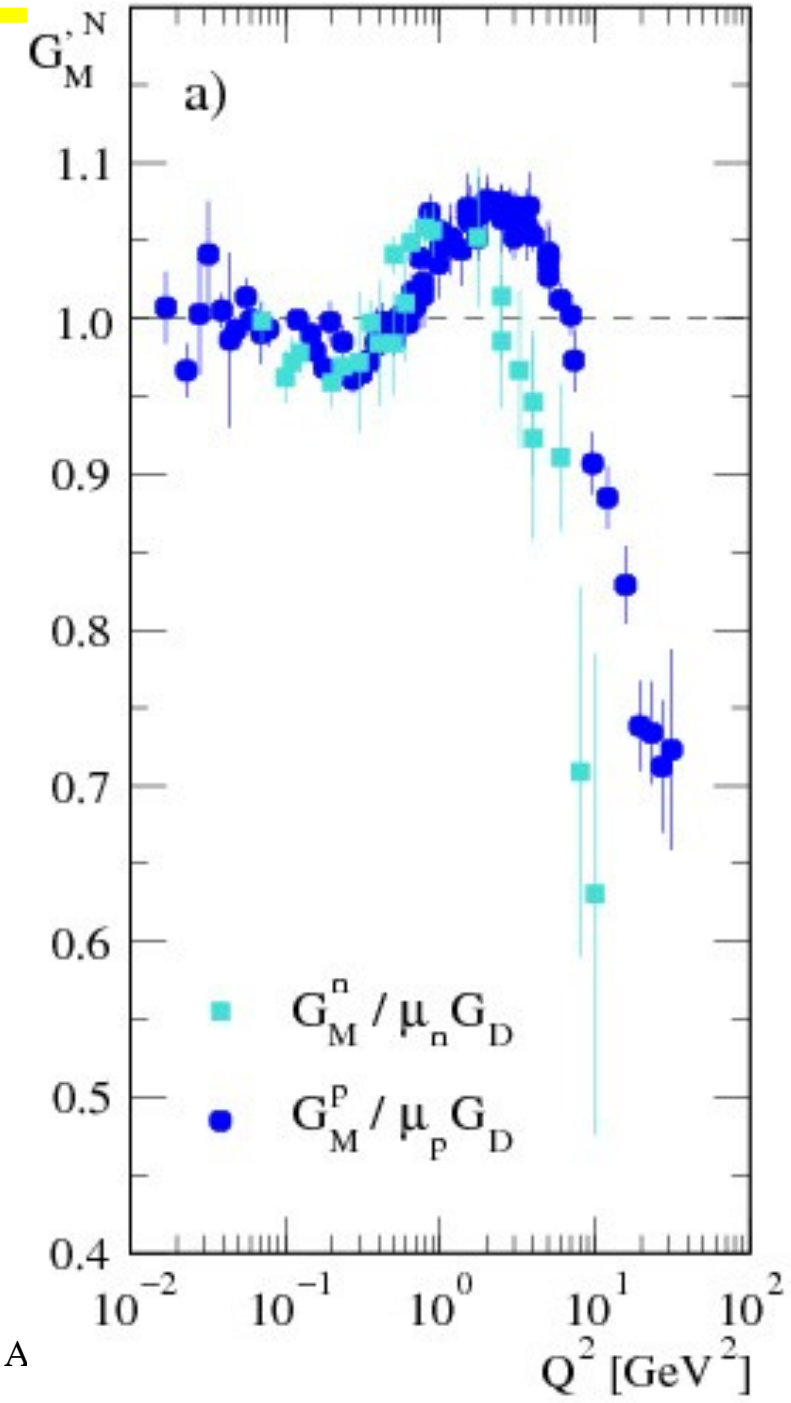
point form

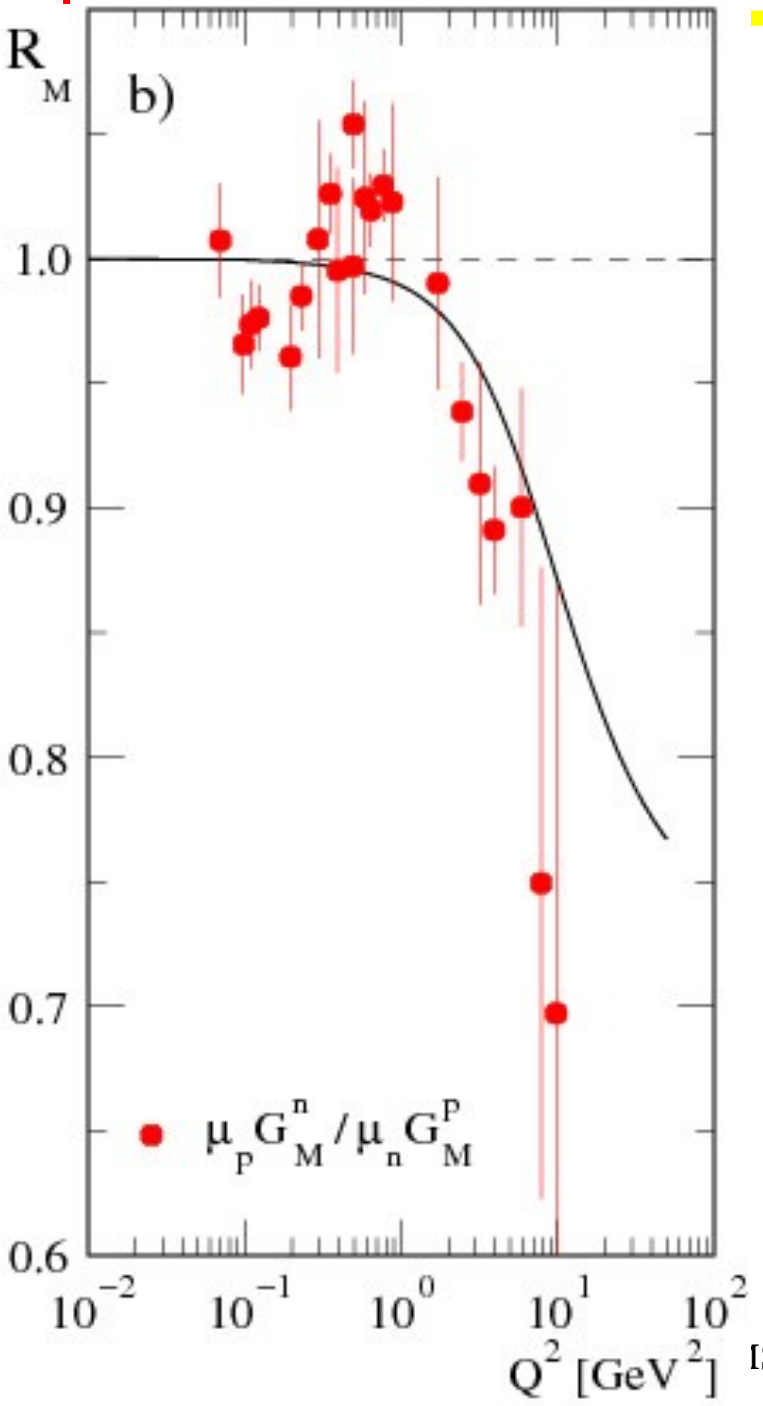
models : VDM, Soliton, QCM

shown by L. Cardmann

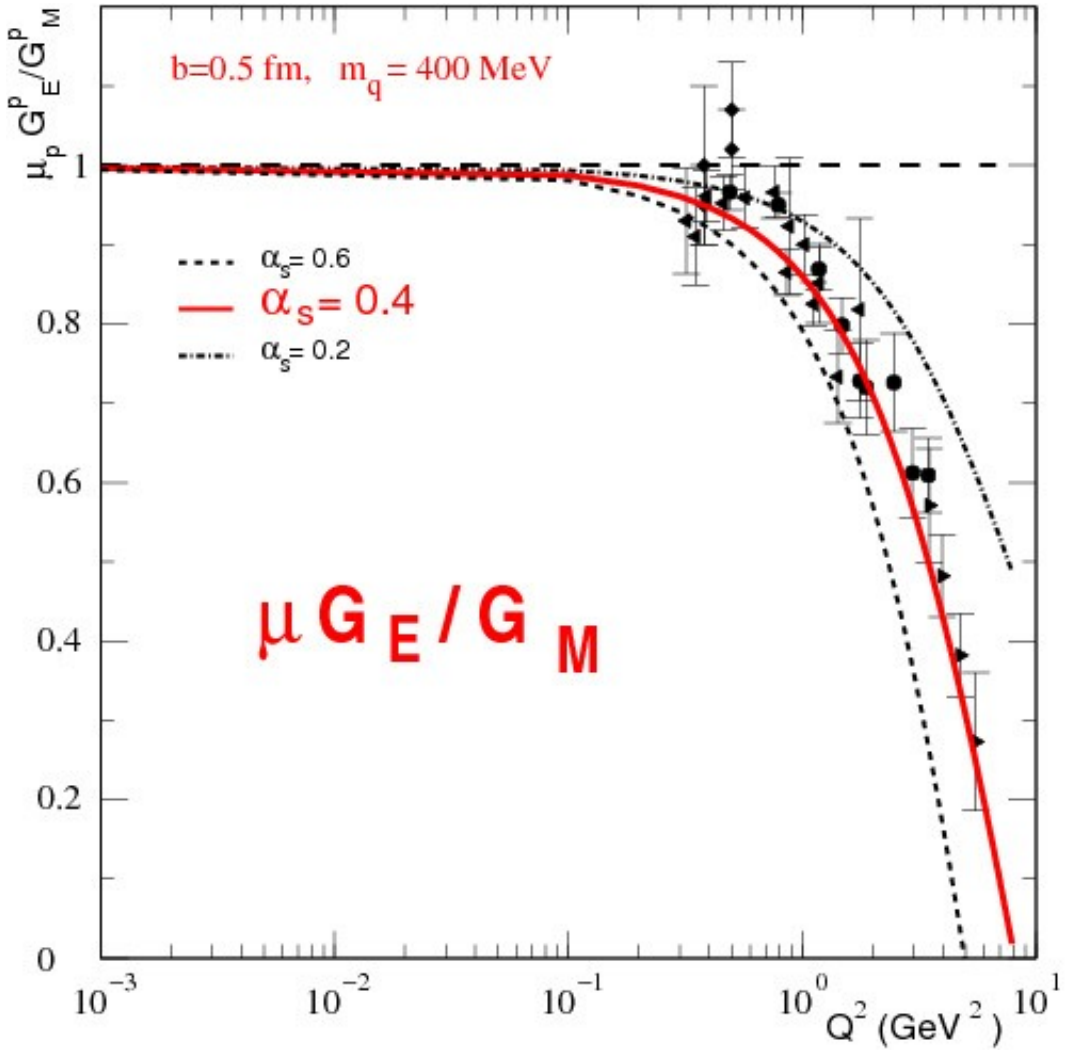


form factor ratio $R_M = \mu_p G^n_E / \mu_n G^p_M$

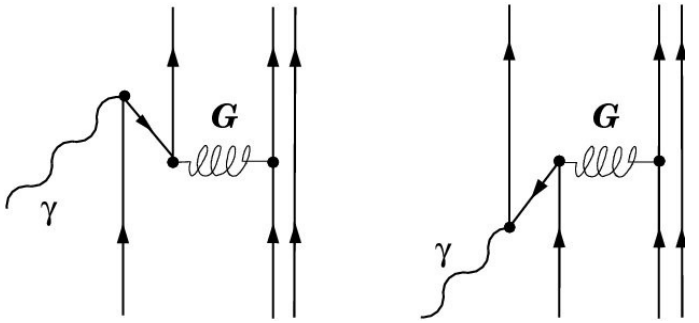




form factor ratio $R_E = \mu\, G_E/G_M$



CQM + OGE



$$\mathcal{L}^{QCD}(x) = -\frac{\alpha_s}{2}\bar{\psi}(x)\,\lambda_a\gamma_\mu G_a^\mu(x)\,\psi(x)$$

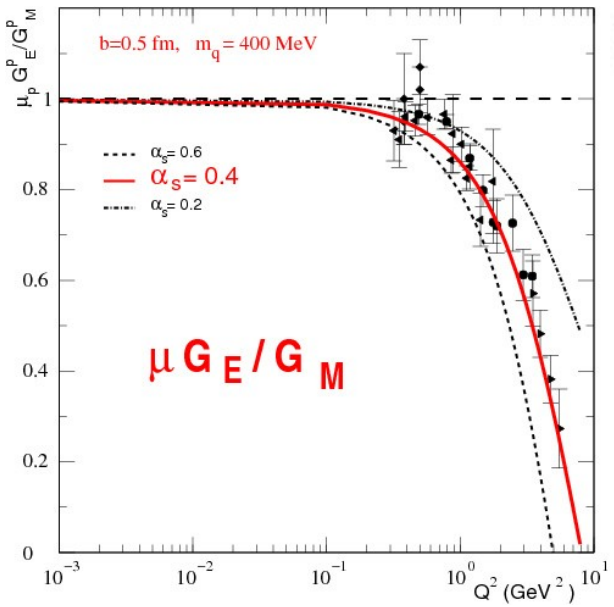
$$\left.\begin{matrix} G_{M_p}^{OGE}(\boldsymbol{q}^2) \\ G_{M_n}^{OGE}(\boldsymbol{q}^2) \end{matrix}\right\} = \frac{\alpha_s}{m_q^2}\frac{M_N}{q}\, e^{-\boldsymbol{q}^2 b^2/24} \left\{\begin{matrix} 2/3 \\ -2/9 \end{matrix}\right\} \mathcal{K}(q)$$

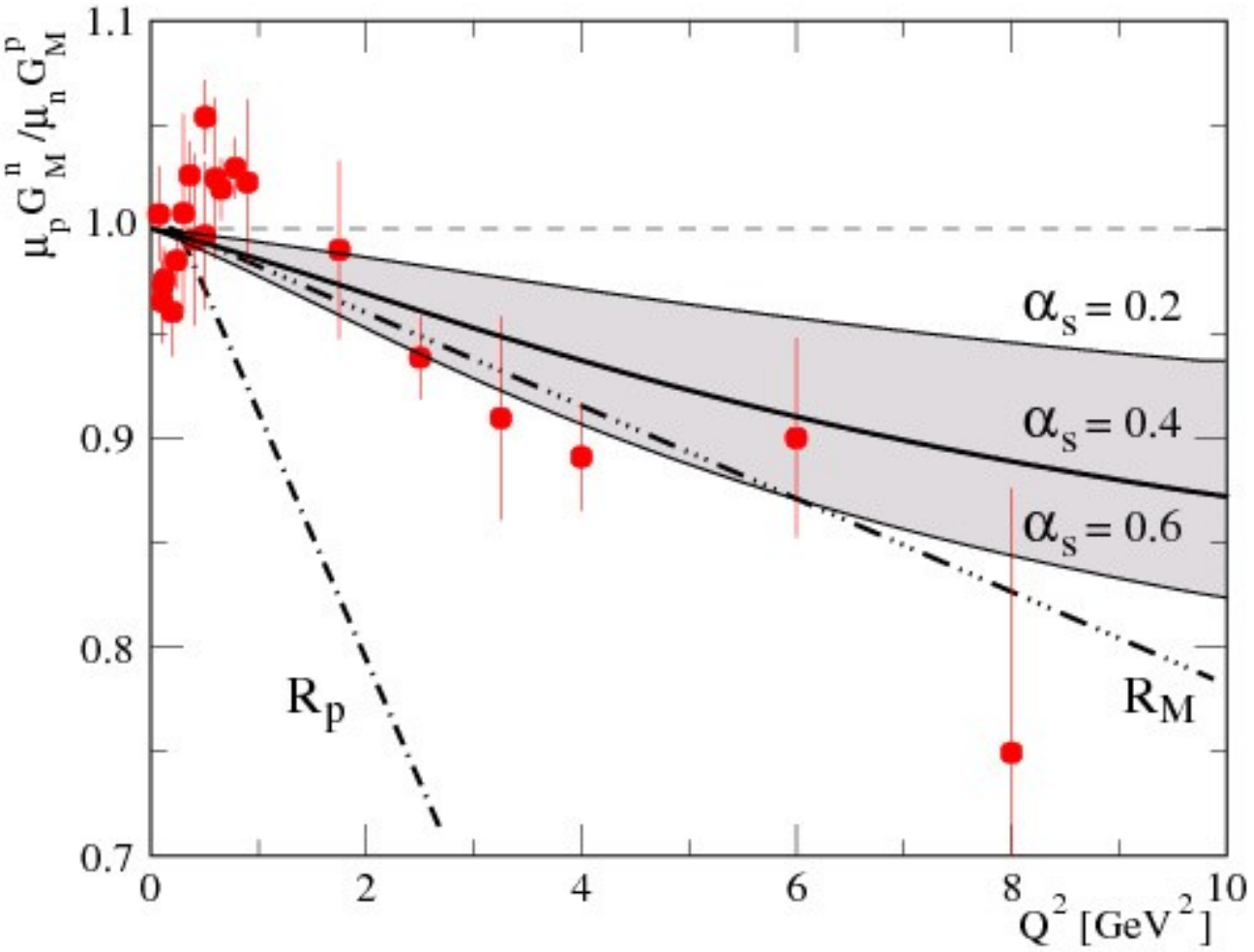
$$\mathcal{K}(q) = \frac{q}{12b}\sqrt{\frac{2}{\pi}}[3\ {}_2F_2(1,1;\frac{3}{2},2;z) - {}_2F_2(1,1;2,\frac{5}{2};z)]$$

with $z = -b^2\boldsymbol{q}^2/8$ and $q = |\boldsymbol{q}|$.

MM Kaskulov,pg, PRC 67 (2003) 042201
PRC 69 (2004) 028201

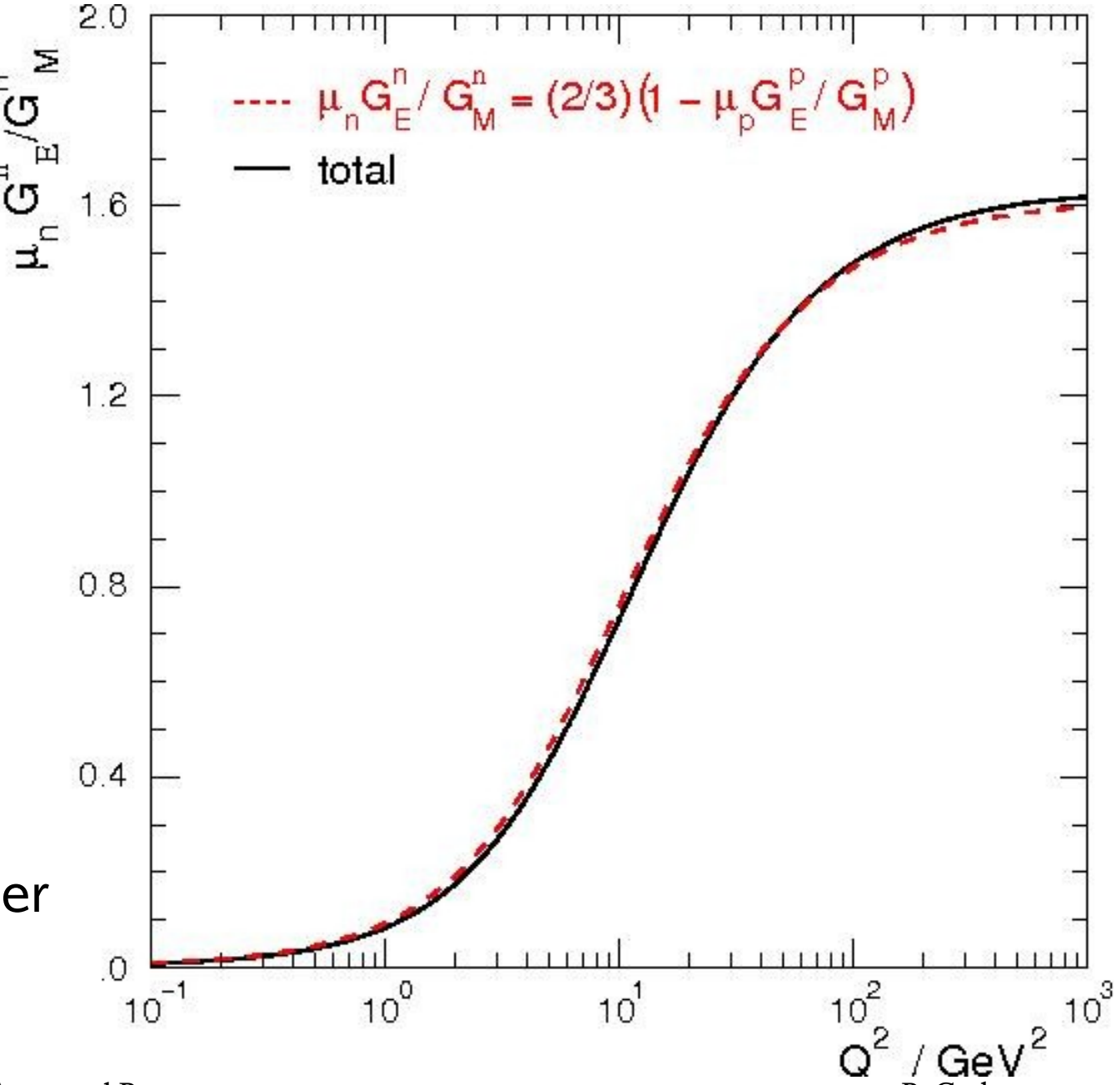
form factor ratios R_E ; R_M





MM Kaskulov,pg, PRC 67 (2003) 042201
PRC 69 (2004) 028201

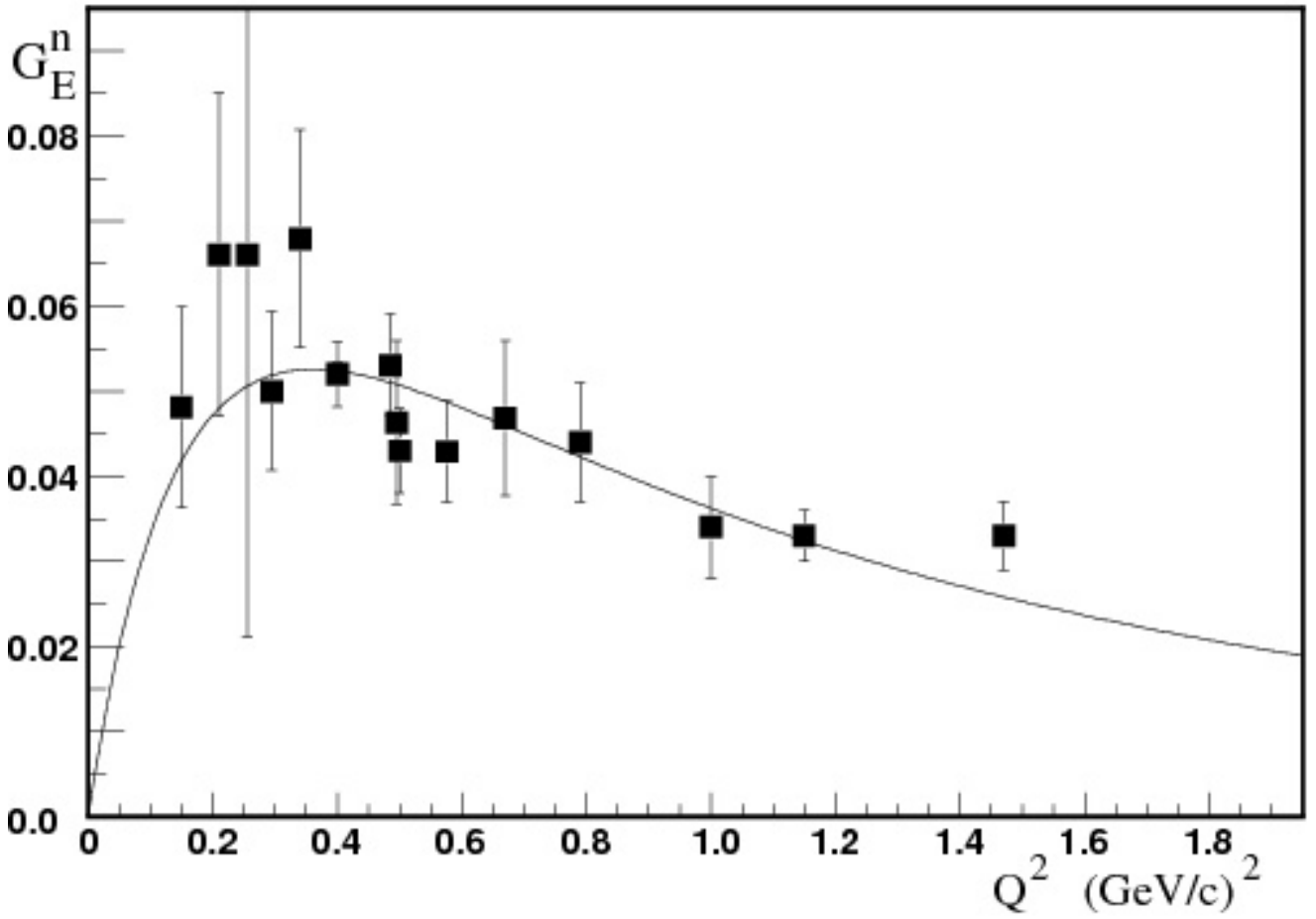
form factor ratio $R^n = \mu_n G_E / G_M$



K. de Jager
Jlab

neutron electric form factor

polarisation data



chiral interpretation

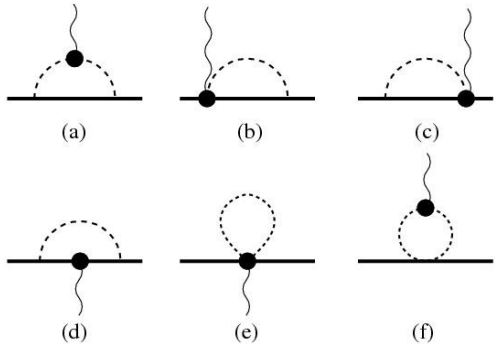
Thomas / Weise:
chiral Quark Model

photon-quark
photon-pion

Λ_π=0,53

use dipole

Galster type



$SU(2)_R \times SU(2)_L \qquad \Psi_N = (\Psi_{3q}, \Psi_{3q+\pi}) \qquad \mathcal{L} = \mathcal{L}_\pi^{(2)} + \mathcal{L}_{\pi qq}^{(1)}$

renormalisation : $\quad Z_2 \equiv 1 - \sum_\alpha \partial\Sigma_\alpha(E)/\partial E|_{E=M_N}$

spectrosc.factor : $\quad S_\pi = \sum_\alpha S_\pi^\alpha = (Z_2 - 1)/Z_2$

$$\left\{ \begin{array}{c} G_{E_n}^{\gamma qq}(\boldsymbol{q}^2) \\ \\ G_{E_n}^{\gamma\pi\pi}(\boldsymbol{q}^2) \end{array} \right\} = \left[\sum_\alpha \xi_\alpha S_\pi^\alpha \right] \left\{ \begin{array}{c} \tilde{G}(\boldsymbol{q}^2) \\ -F_\pi(\boldsymbol{q}^2) F(\boldsymbol{q}^2) \end{array} \right\}$$

where $\xi_N = 2/3$ and $\xi_\Delta = -1/3$

pion e.m. form factor $F_\pi(\boldsymbol{q}) = (1+Q^2/\Lambda_\pi^2)^{-1}$ (monopole)
nucleon axial form factor $F(\boldsymbol{q})$,
core electric form factor $\tilde{G}(\boldsymbol{q}^2)$; assume $F(\boldsymbol{q}^2) = \tilde{G}(\boldsymbol{q}^2)$

$$\begin{aligned} G_E^n(\boldsymbol{q}^2) &= \tilde{G}(\boldsymbol{q}^2)\left[1 - F_\pi(\boldsymbol{q}^2)\right] \sum_\alpha \xi_\alpha S_\pi^\alpha \\ &= \sum_\alpha \xi_\alpha S_\pi^\alpha \cdot \left[\frac{Q^2/\Lambda_\pi^2}{1 + Q^2/\Lambda_\pi^2} \right] \tilde{G}(Q^2) \\ G_E^n(Q^2) &= a' \frac{b\tau}{1 + b\tau} \, G_D(Q^2) \end{aligned}$$

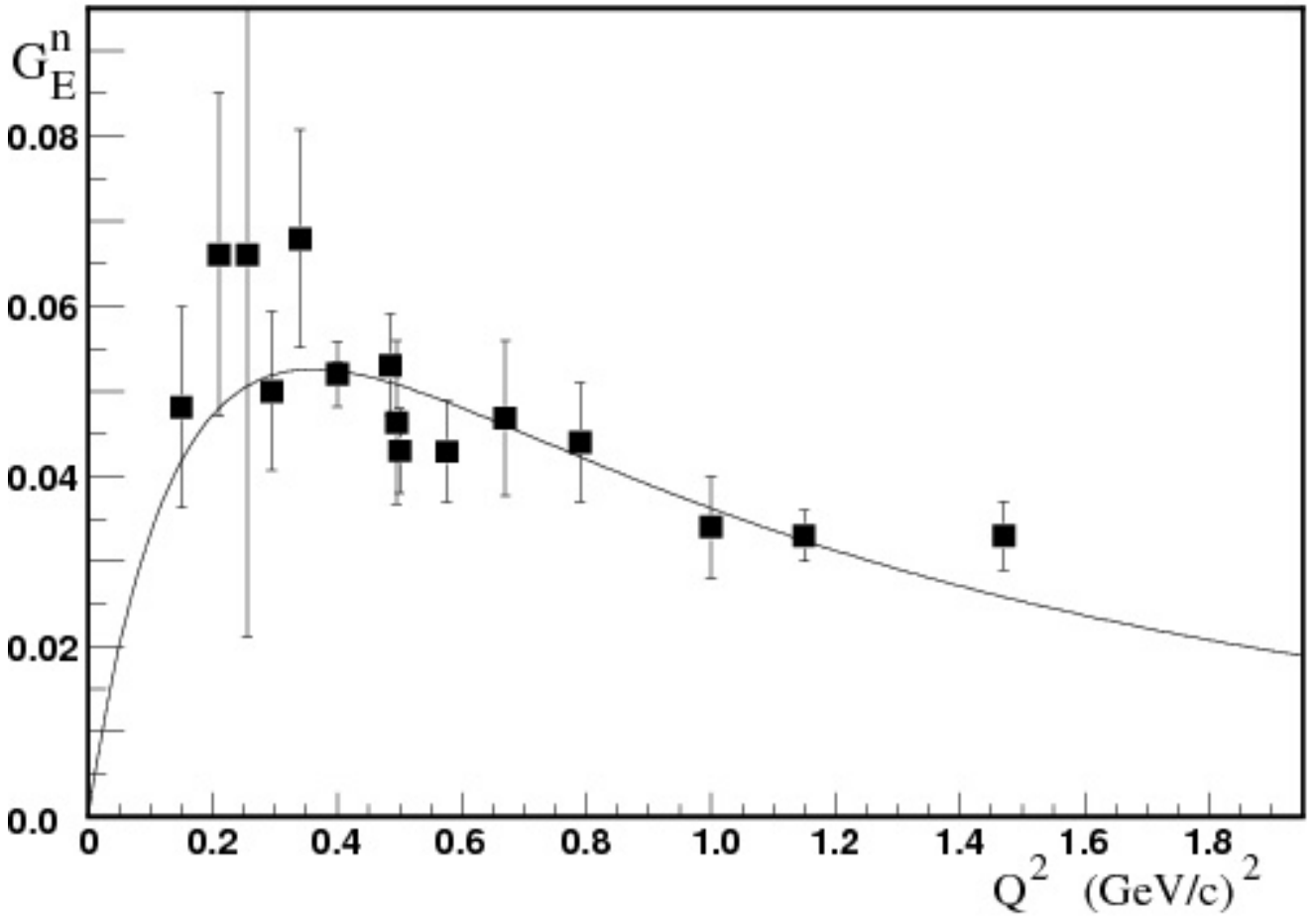
$$b = 4M_n^2/\Lambda_\pi^2 \quad \text{and} \quad a' = \sum_\alpha \xi_\alpha S_\pi^\alpha = -\langle r^2 \rangle_n (\Lambda_\pi^2/6)$$

$$G_E^n(Q^2) = -\frac{\langle r^2 \rangle_n}{6} \, Q^2 F_\pi(Q^2) \, G_D(Q^2)$$

Kaskulov, EPJA19 (2004) 157

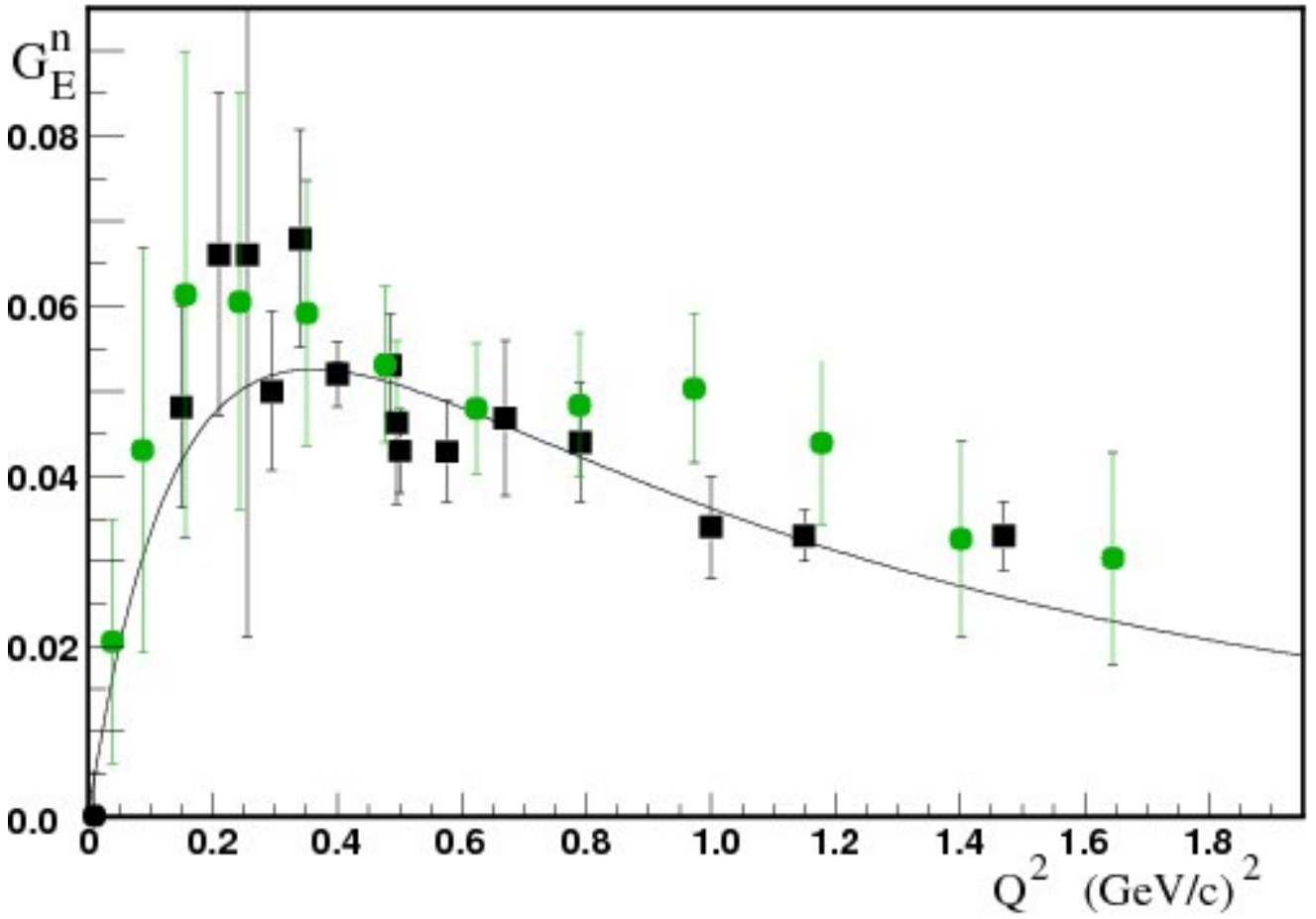
chiral interpretation

polarisation data



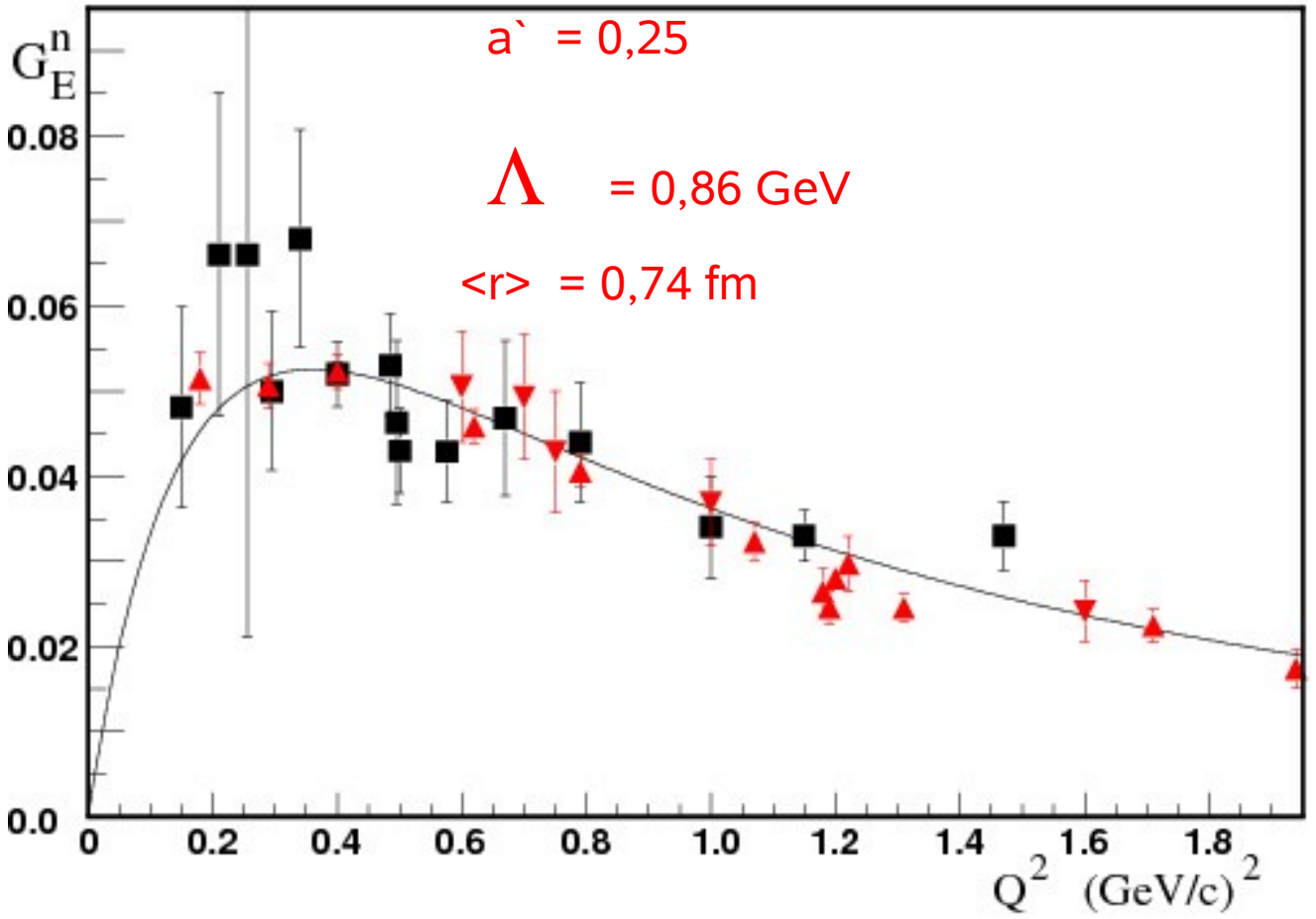
chiral interpretation

Schiavilla, Sick, PRC 64 (2001) 041002



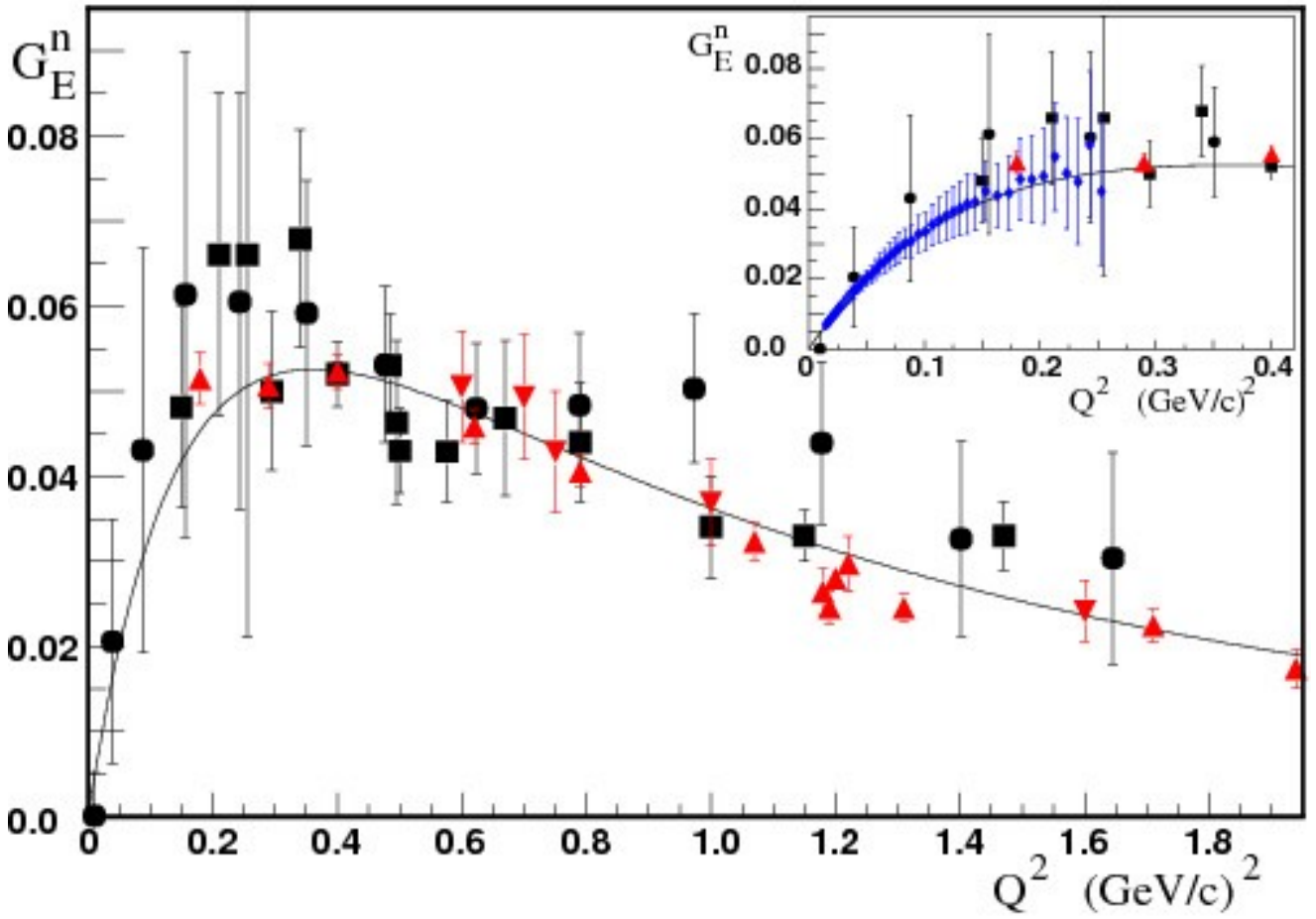
chiral interpretation

Pion data : Bebek PR 17 (1978) 1693 ; Volmer PRL 86 (2001)1713



chiral interpretation

Pion data : Amendolia NPB 277 (1986) 168

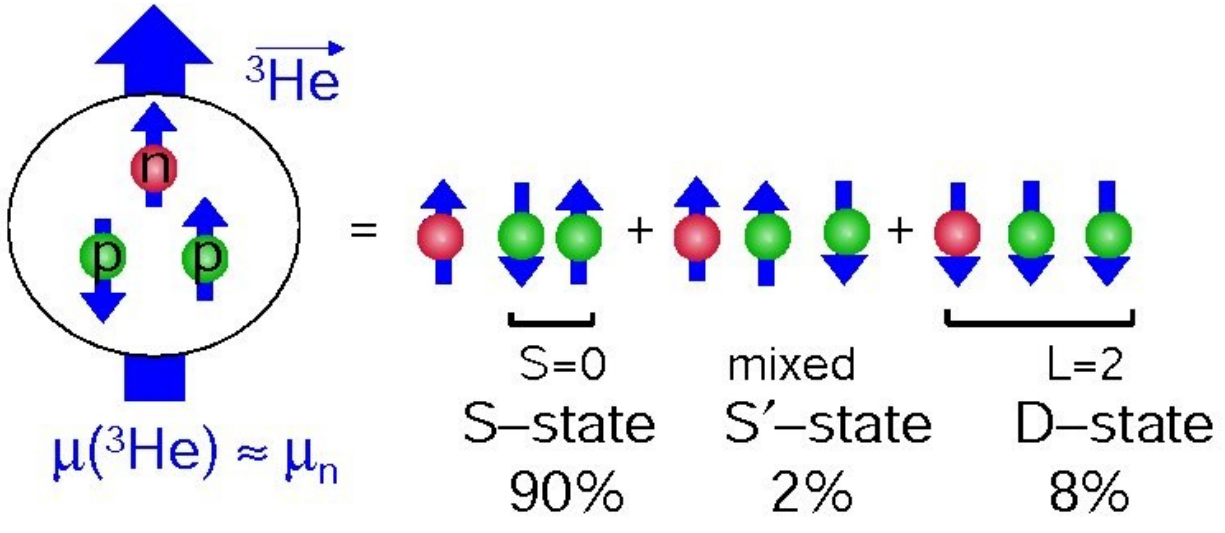


the neutron

no free neutron target: "quasi-free n" in D or ^{3}He

D: 'only' 2N, less FSI, no internal Coulomb
H. Arenhövel

^{3}He: 2 protons (S=0); $\mu(^3He) \sim \mu(n)$
P.Sauer, H.Glöckle,

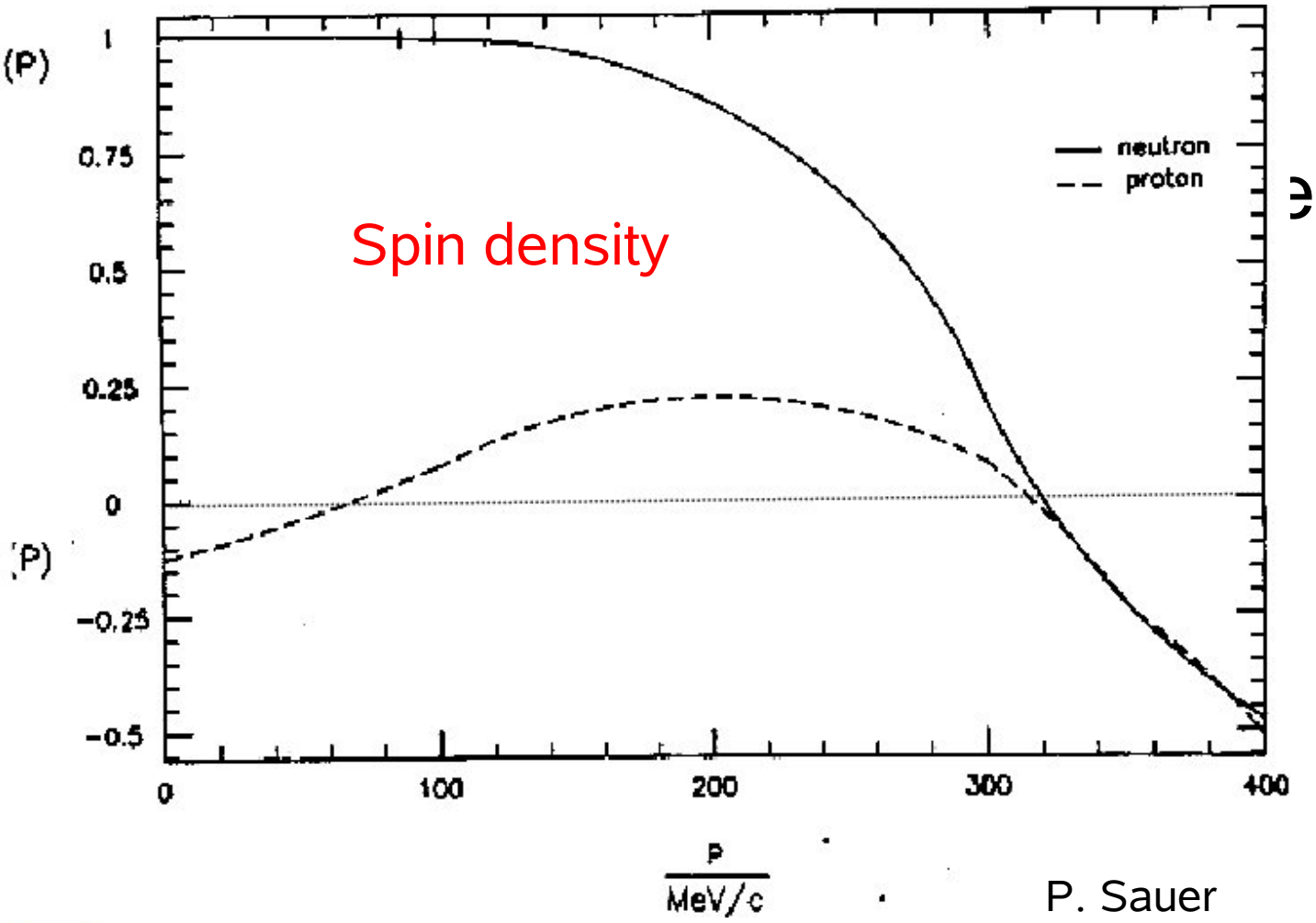


the neutron

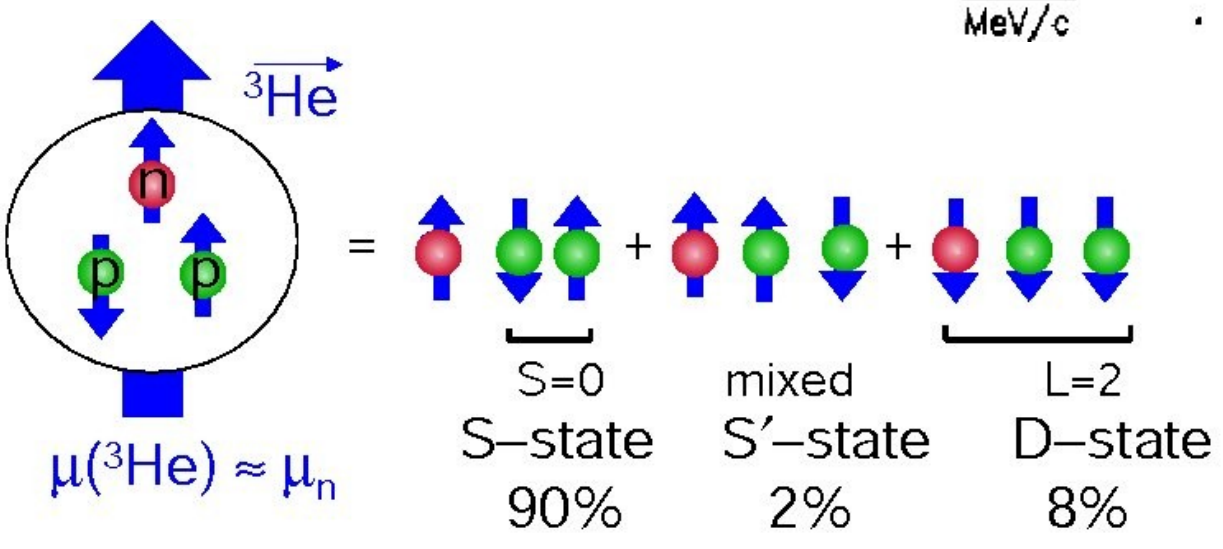
no free neutrc

D: 'only'

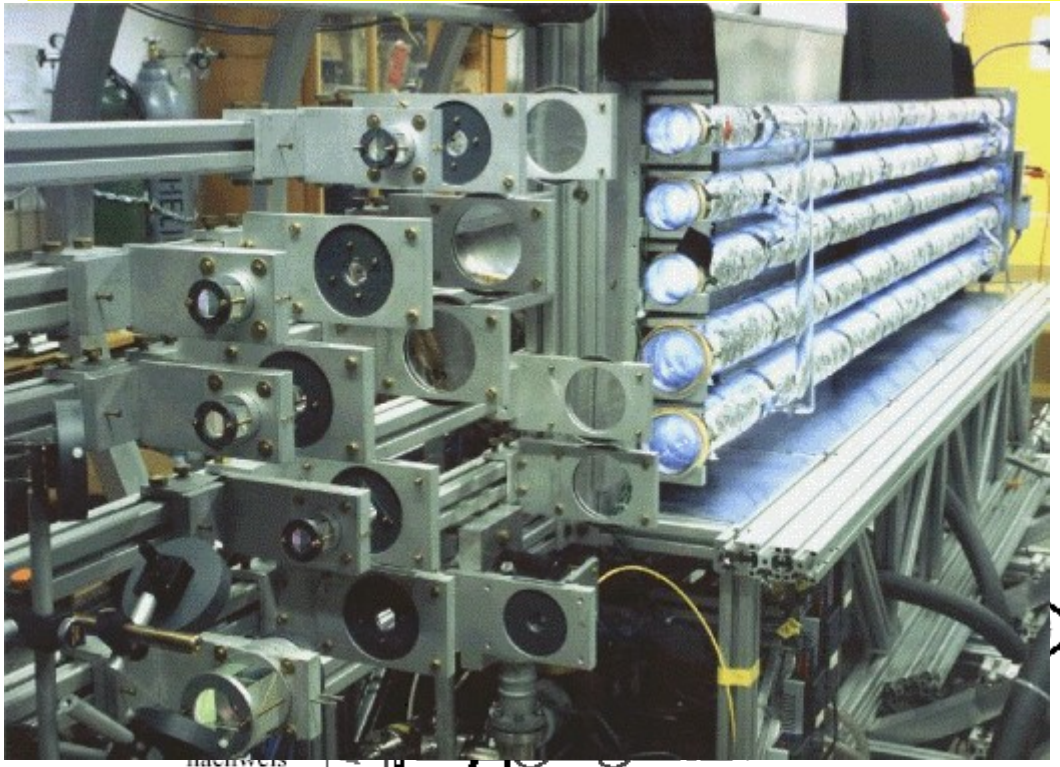
^{3}He: 2 prot

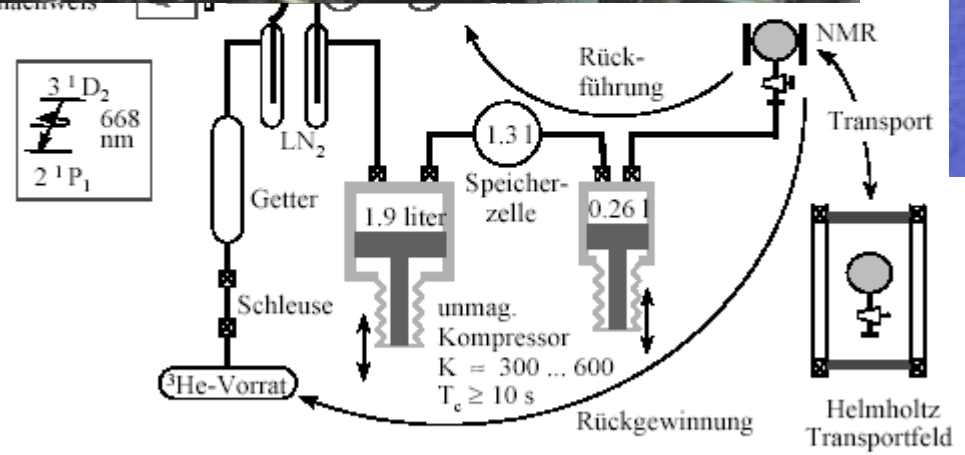


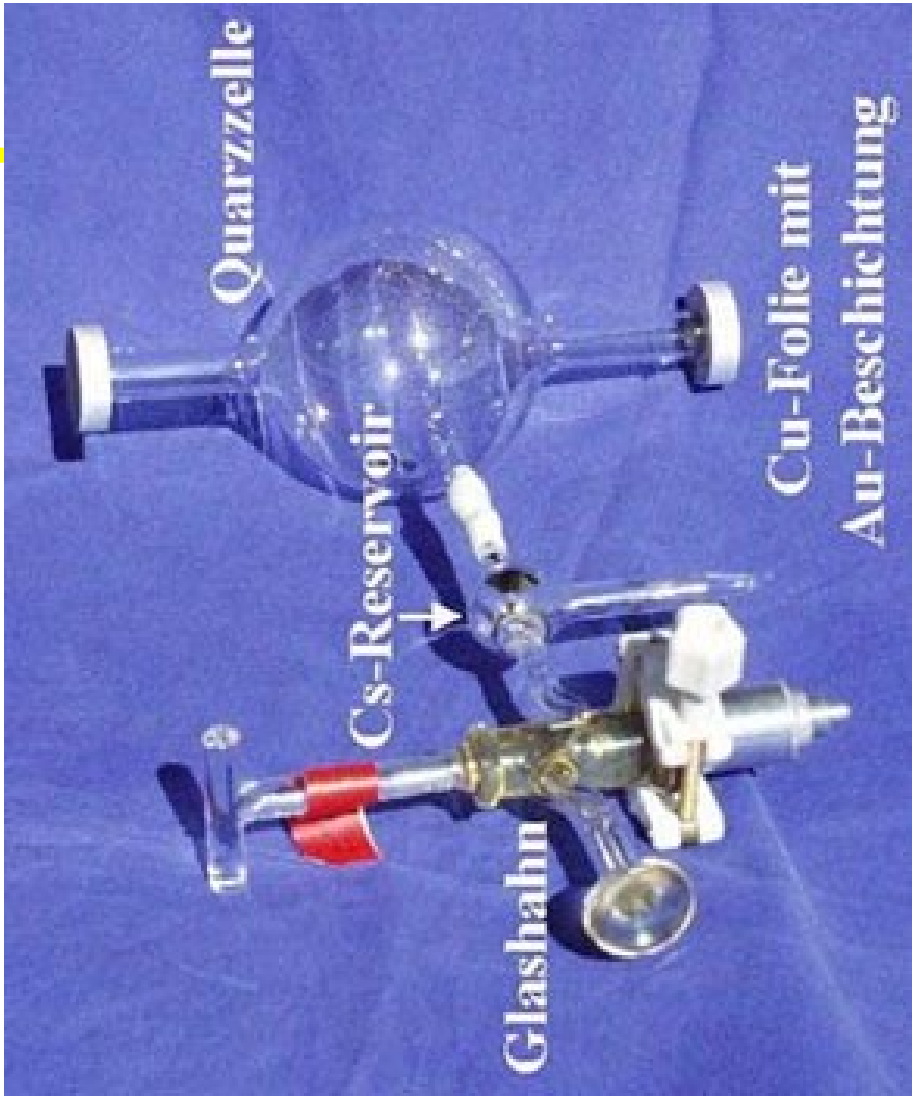
P. Sauer



polarised ^{3}He





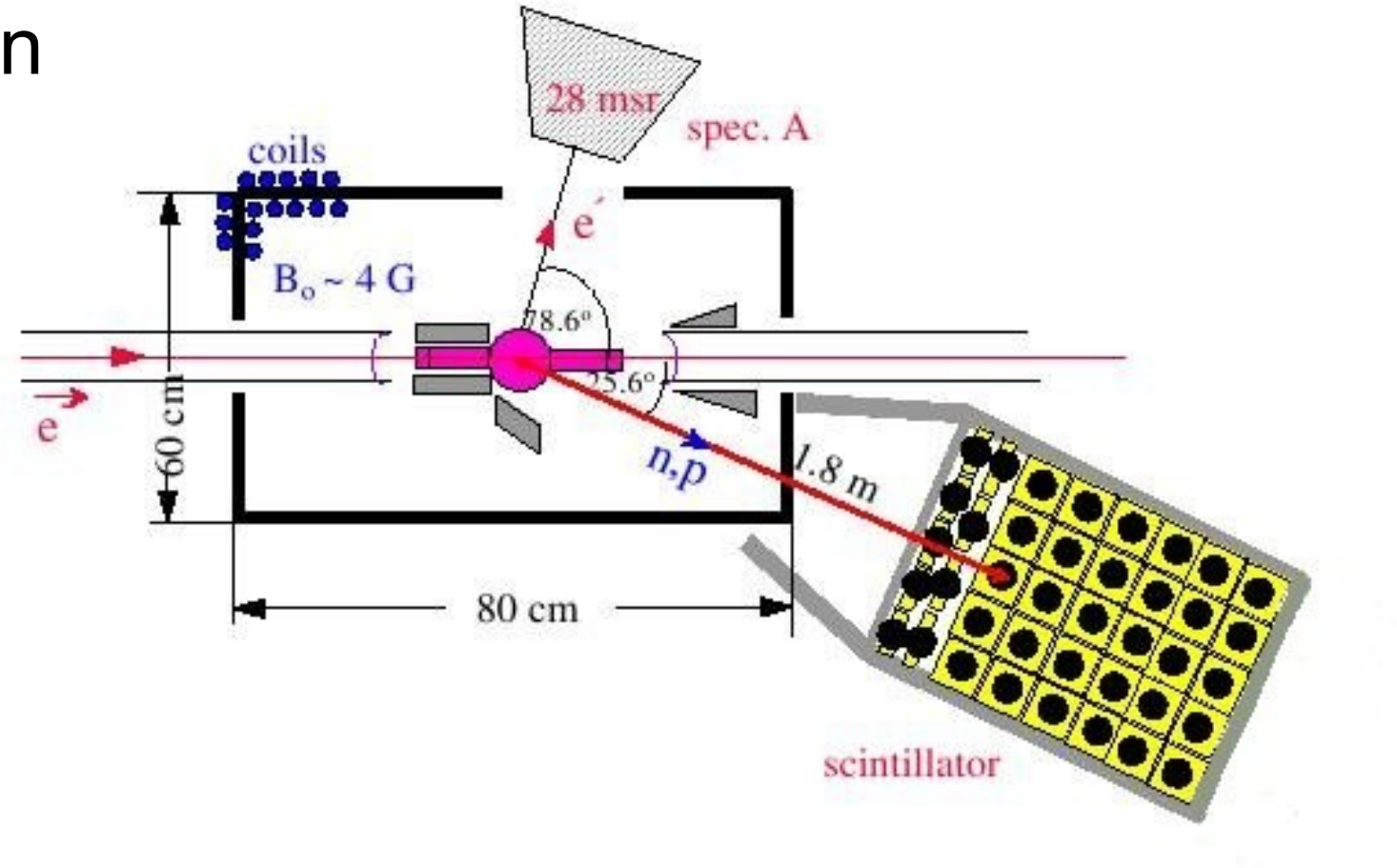


5 bar, P~50% @ 10µA; 12h

W. Heil, J.Krimmer
H5@MAMI

Setup for G_{en} @ Q^2=1,5 GeV^2

Test run



Test with 5cm Pb in front of hadron detector

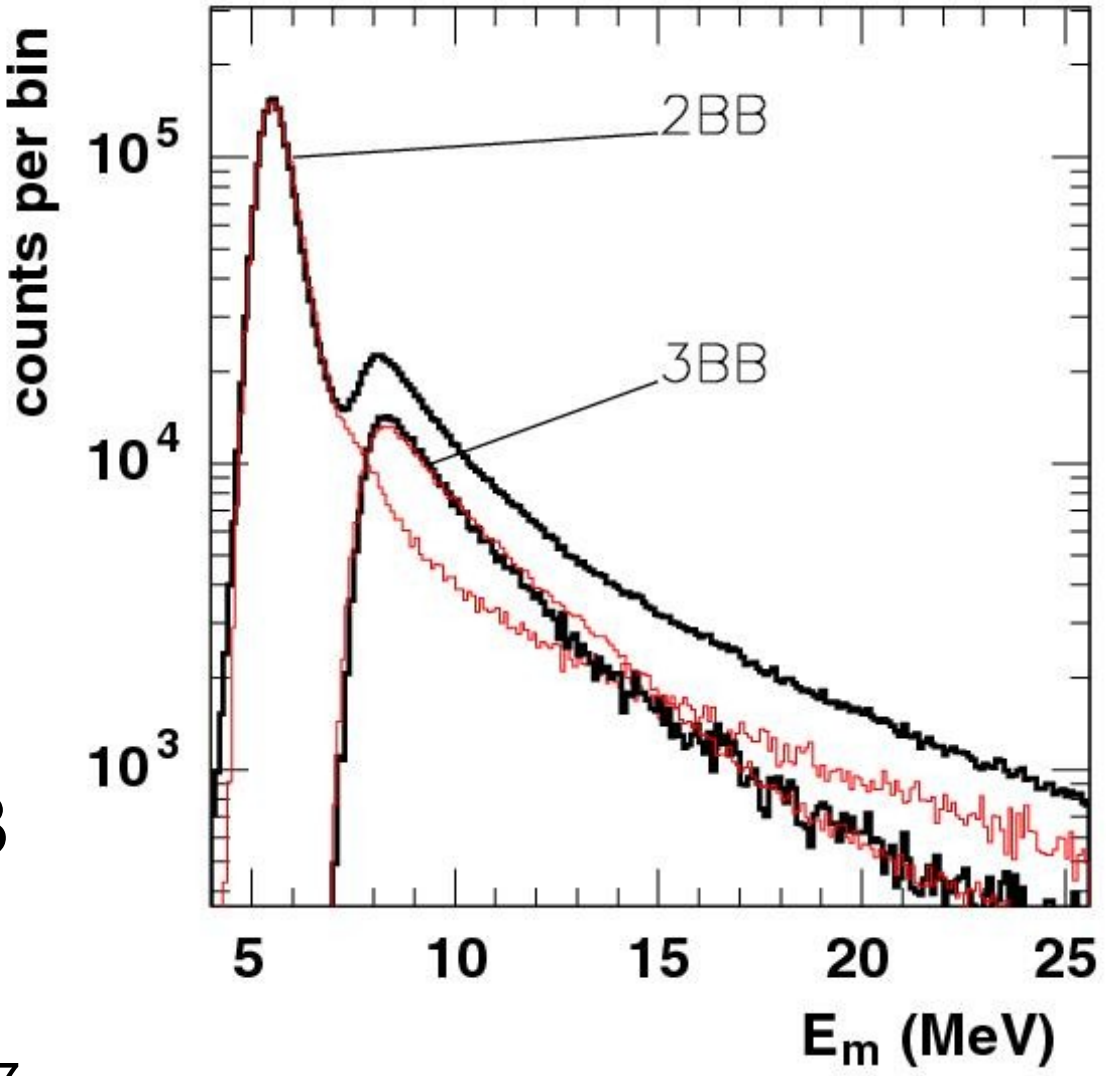
Asymmetries in $^3\vec{He}(\vec{e},e'p)$ X

X = d or pn
2B- or 3B-breakup

— data
— MC with WF of
Dieperink et al.,

Q^2 = (0,25-0,4) GeV^2

A1 spectrometers A & B
$E_m = E - E' - E_p$



P.Achenbach &A1, EPJA 25 (05) 177

Asymmetries in $^3\vec{He}(\vec{e},e'p)$ X

Gloeckle / Golak

$A_{perp} = -A_{para}$

nrel - Faddeev

PWIA

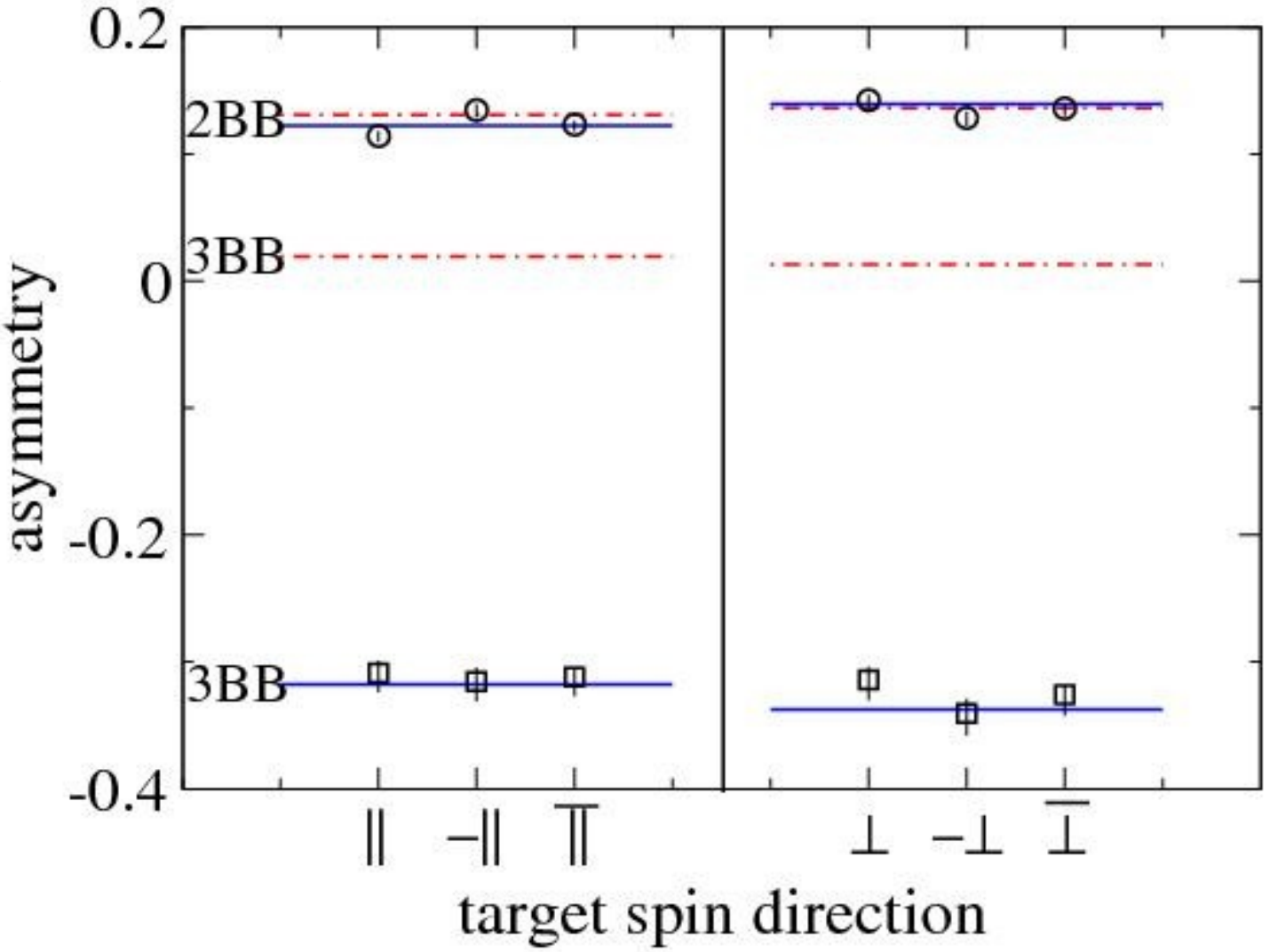
+MEC+FSI

2 body breakup

PWIA = Full

3 body breakup

FSI



Asymmetries in $^3\vec{He}(\vec{e},e'p)$ pn

Gloeckle / Golak

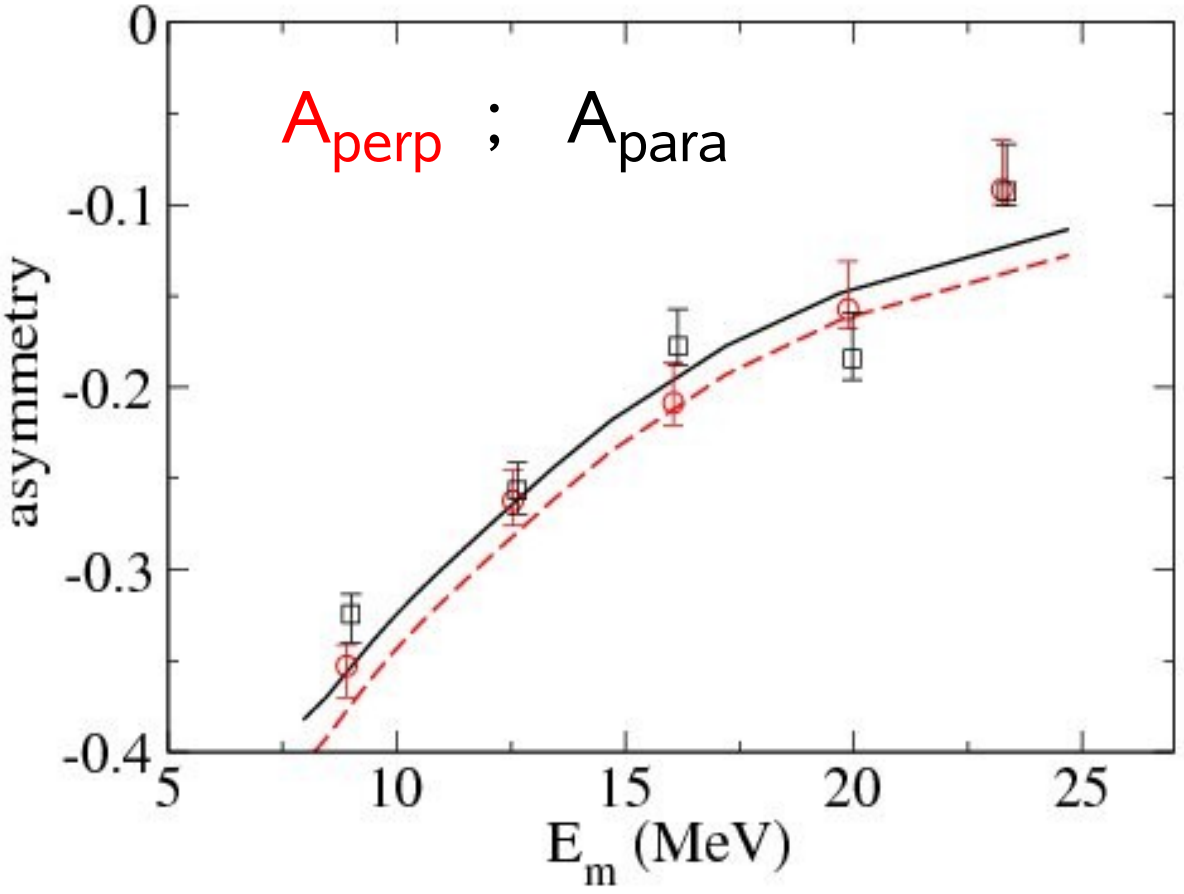
nrel - Faddeev
PWIA+FSI

AV18 - CDBonn
no MEC

3 body breakup

FSI: rescattering of
singlet/triplet ***np***

P.Achenbach &A1, EPJA 25 (05) 177



angular distr. @ 0,67GeV^2 by C.Carasco PLB 564 (2003)199

neutron electric form factor

2 (new) measurements @ MAMI

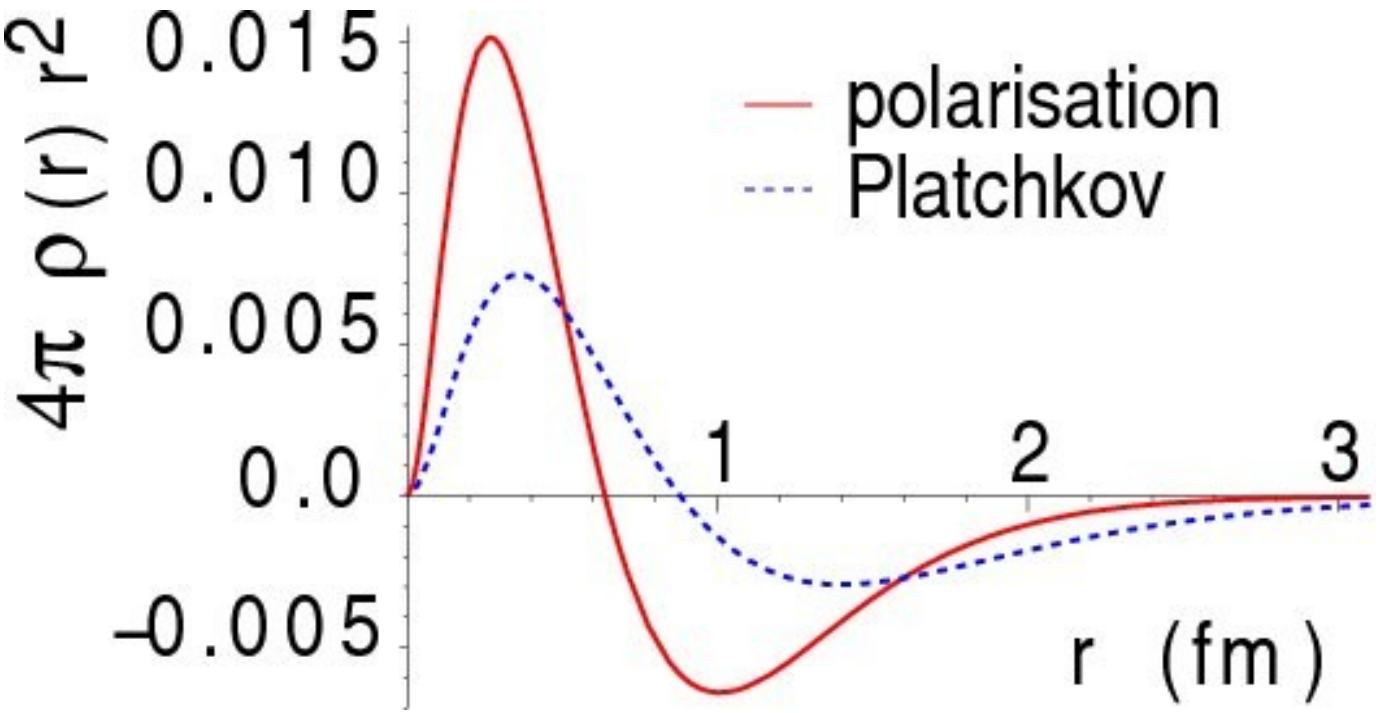
- Q^2 = 0,25 GeV^2 (0,15)
- Q^2 = 1,5 GeV^2

equipment:

- MAMI e-beam: I=10-20μA, P~80%
- polarised ^{3}He gas (opt. pumped) P~50%
- spectrometer A
- Hadron detector + heavy lead shield

old vs new neutron data:

charge distribution



summary and outlook

- 2N emission experiments test
  reaction mechanisms and NN interaction

$$H\Psi = E\Psi$$

- NN interaction including quark degrees of freedom for high momentum contributions and exotic phenomena ^3He
- nucleon form factors, resonances and nuclear structure
- correlations (SRC) input to NME calculations for
  neutrinoless double beta decay (GERDA starts in 2009)