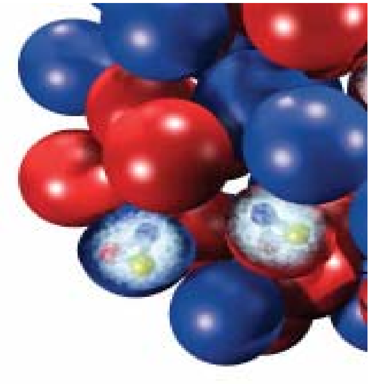
L.P. Kaptari, BLTPh, JINR, Dubna

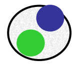


High Energy Electron Scattering from Nuclei

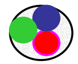
- **Motivation**
- **eN-scattering, kinematics, structure functions..**
- **A(e,e‘)X, PWIA, Spectral Function, 2NC..**
- **y-scalning, momentum distribution**
- **FSI**
- **Semi – Inclusive quasi-elastic A(e,e’p)X**
- **DIS A(e,e’X) (A-1). Hadronization**
- **Summary**

Mesons & baryons; static properties

Gel-Man, Okubo…(u,d,s..) → SU(3) →

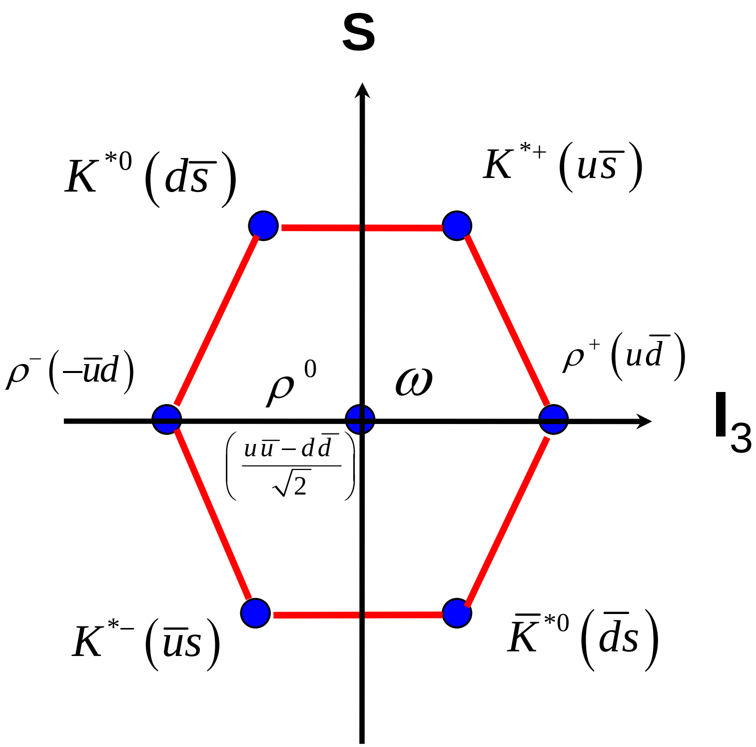


mesons



baryons

SU(3) vector mesons

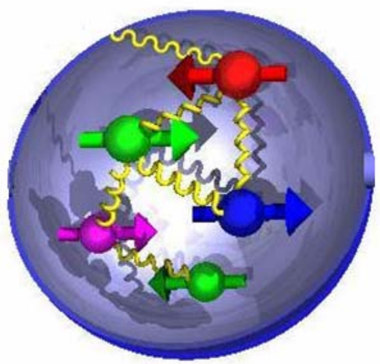


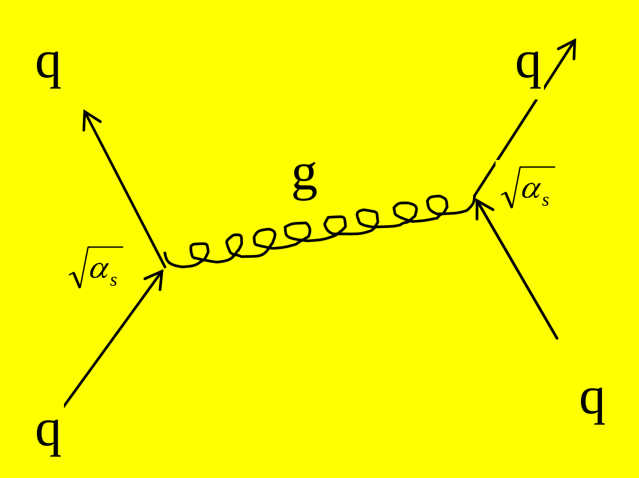
$J^P = 1^-$

$$M_8^2 = \frac{1}{3}\left(4M_{K^*}^2 - M_\rho^2\right) = (926\,MeV)^2 \neq M_\omega^2 \neq M_\phi^2$$

Mesons & baryons; QCD

- Field theory for strong interaction:
  - quarks interact by gluon exchange
  - quarks carry a 'colour' charge (R,B,G)
  - exchange bosons (gluons) carry colour





The QCD Lagrangian

$$\mathcal{L}_{QCD} = i\sum_q \overline{\psi}_q^j \gamma^\mu (D_\mu)_{jk} \psi_q^k - \sum_q m_q \overline{\psi}_q^j \psi_q^k - \tfrac{1}{4} G_{\mu\nu}^a G_a^{\mu\nu}$$

(j,k = 1,2,3 refer to colour; q = u,d,s refers to flavour; a = 1,..,8 to gluon fields)

Covariant derivative:

$$D_\mu = \partial_\mu + i\tfrac{1}{2} g_s \lambda_a G_\mu^a$$

Free quarks

$$G_{\mu\nu}^a = \underbrace{\partial_\mu G_\nu^a - \partial_\nu G_\mu^a}_{\text{Gluon kinetic energy term}} - \underbrace{g_s f_{abc} G_\mu^a G_\nu^a}_{\text{Gluon self-interaction}}$$

Gluon kinetic energy term

Gluon self-interaction

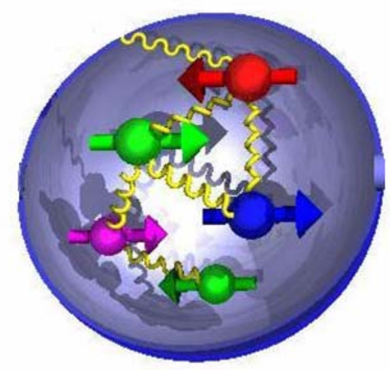
qg-interactions
SU(3) generators:

$$\lambda_1 = \begin{pmatrix} 0 & 1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \lambda_2 = \begin{pmatrix} 0 & -i & 0 \\ i & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \lambda_3 = \begin{pmatrix} 1 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & 0 \end{pmatrix} \quad \lambda_4 = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 0 \end{pmatrix}$$

$$([\lambda_a, \lambda_b] = i\tfrac{1}{2} f_{abc} \lambda_c)$$

$$\lambda_5 = \begin{pmatrix} 0 & 0 & -i \\ 0 & 0 & 0 \\ i & 0 & 0 \end{pmatrix} \quad \lambda_6 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix} \quad \lambda_7 = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 0 & -i \\ 0 & i & 0 \end{pmatrix} \quad \lambda_8 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & -2 \end{pmatrix}$$

Mesons & baryons; QCD



- Field theory for strong interaction:
  - quarks interact by gluon exchange
  - quarks carry a '**colour**' charge (**R,B,G**)
  - exchange bosons (gluons) carry **colour** $\Rightarrow$ self-interactions (cf. QED!)
- Hadrons are colour neutral:
  - RR, BB, GG or RGB
  - leads to confinement:

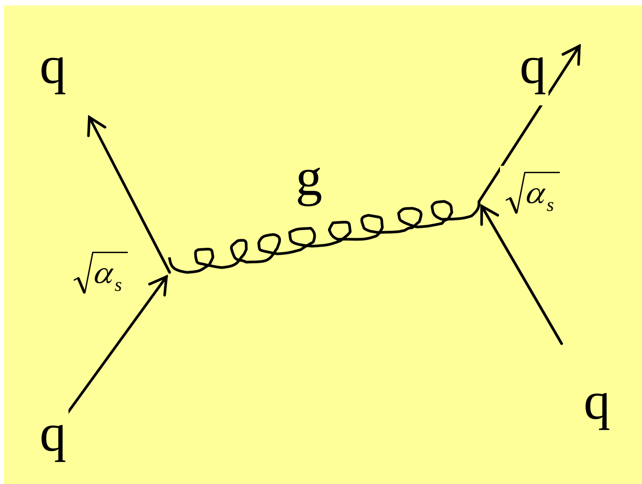
$$|q\rangle, \ |qq\rangle \ \text{ or } \ |qq\bar{q}\rangle \quad \text{forbidden}$$

- Effective strength ~ gluons exch.

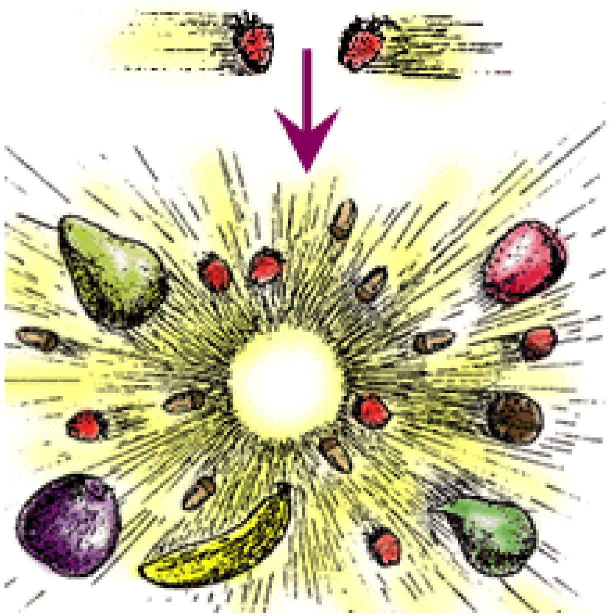
  i) low Q^2: more *g's*: **large** eff. coupling

  ii) high Q^2: few *g's*: **small** eff. coupling

  (α_S~0, asymp. freedom, pQCD)



How to probe the quarks?



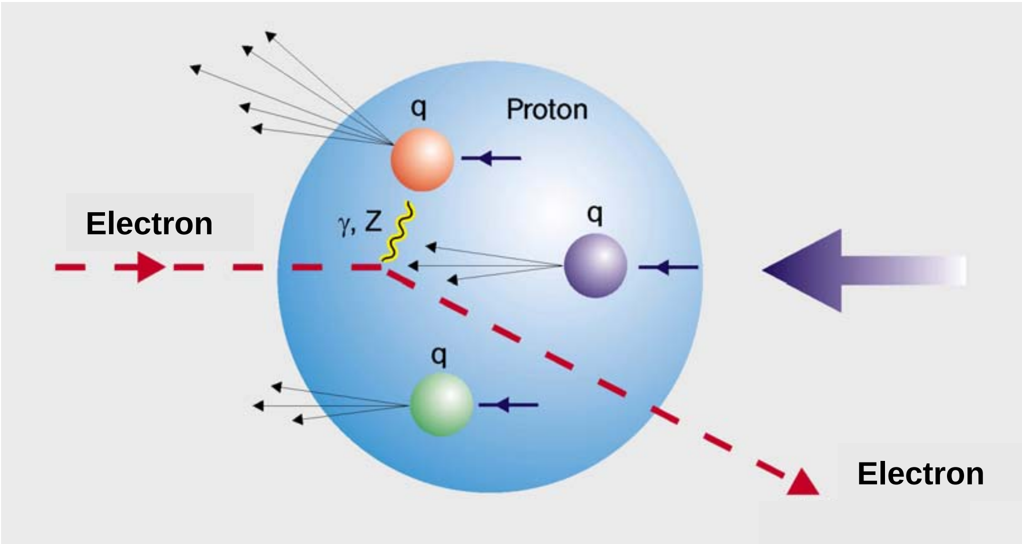
Energy → Matter
$E=mc^2$

Bang two particles together and observe the types of particles that fly out (and their directions). In this way we can deduce the existence of new types of particles, investigate the properties of the known particles, and study the fundamental forces.

How to probe the quarks? (Con't)

Probes – particles with well established structure and well known interaction with quarks – e.w. quark-lepton interaction

Most experiments operate at the energy frontier

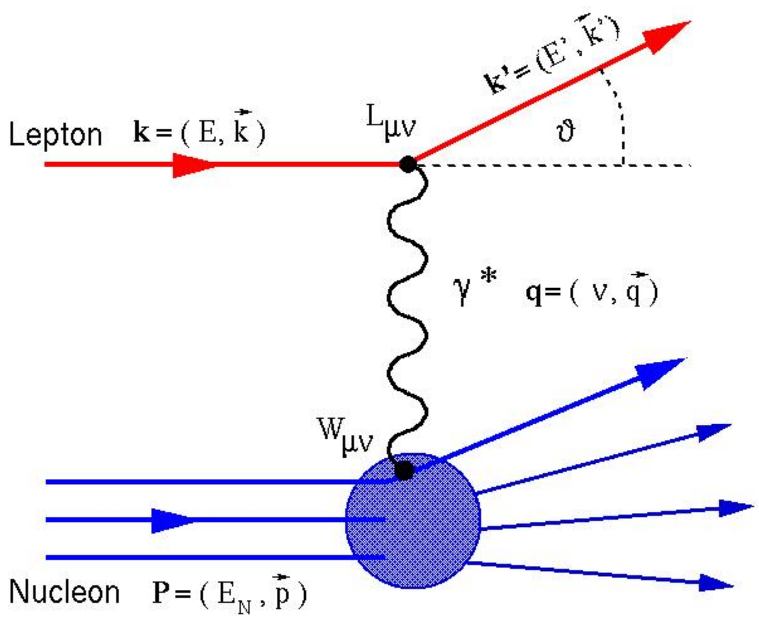


Highest energy *e-p* collider: HERA at DESY in Hamburg: ~ 300 GeV

$$d_{probed} \propto \lambda\!\!\!^{-} = \frac{\hbar}{p} \approx 10^{-18}\ \mathrm{m}$$

Electron Nucleon Scattering

- kinematics:



$L_{\mu\nu}$: lepton tensor

$W_{\mu\nu}$: hadron tensor

- Four-momentum transfer:

$$q^2 = (E-E')^2 - (\vec{k}-\vec{k}')\cdot(\vec{k}-\vec{k}') =$$

$$= m_e^2 + m_{e'}^2 - 2(EE' - |\vec{k}||\vec{k}'|\cos\theta) =$$

$$\approx \boxed{-4EE'\sin^2\tfrac{\theta}{2} \equiv -Q^2}$$

- Mott Cross Section ($\hbar c$=1):

$$\left(\frac{d\sigma}{d\Omega}\right)_{Mott} = \frac{4\alpha^2 E'^2}{Q^4}\cos^2\frac{\theta}{2}\cdot\frac{E'}{E}$$

$$= \frac{4\alpha^2 E'^2}{16E^2E'^2\sin^4\frac{\theta}{2}}\cos^2\frac{\theta}{2}\cdot\frac{1}{1+\frac{E}{M}(1-\cos\theta)}$$

$$= \frac{\alpha^2\cos^2\frac{\theta}{2}}{4E^2\sin^4\frac{\theta}{2}}\cdot\frac{1}{1+\frac{E}{M}(2\sin^2\frac{\theta}{2})}$$

Electron scattering of a spinless point particle

Cross Section for N(e,e')X in OPEA

$$d\sigma_{\text{lab}} = \frac{\delta^4(p+Q-p_f)}{2\sqrt{\lambda(\mathrm{k},\mathrm{p})}} \overline{\sum_{if}} \left|M_{fi}\right|^2 \left[\frac{d^3k'}{(2\pi)^3}\right] d\tau_f$$

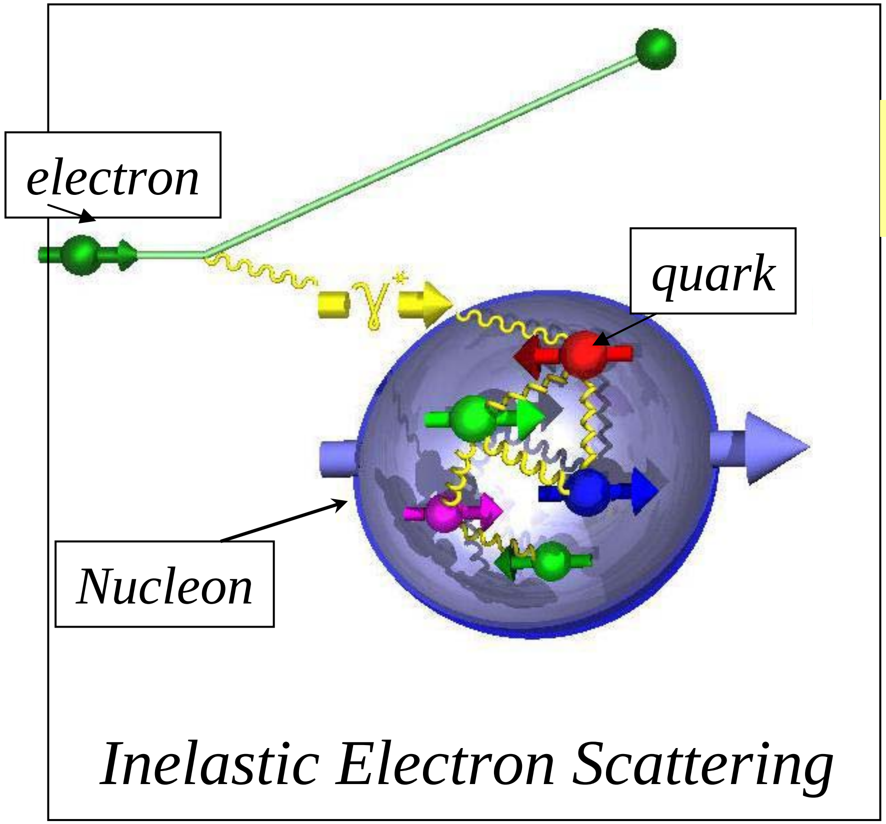
Current-Current Interaction

$$M_{fi} = \frac{4\pi\alpha}{Q^2} \left\langle k'\lambda' \middle| j_\mu \middle| k\lambda \right\rangle \left\langle p \middle| J^\mu \middle| p_f \right\rangle$$

$$\overline{\sum_{if}} \left|M_{fi}\right|^2 \propto \underbrace{\overline{\sum_{if}} \left\langle k'\lambda' \middle| j_\mu \middle| k\lambda \right\rangle^* \left\langle k'\lambda' \middle| j_\nu \middle| k\lambda \right\rangle}_{\text{Leptonic tensor } \eta_{\mu\nu}} \frac{\alpha^2}{Q^4} \underbrace{\overline{\sum_{if}} \left\langle p \middle| J^\mu \middle| p_f \right\rangle^* \left\langle p \middle| J^\nu \middle| p_f \right\rangle}_{\text{Hadronic tensor } W^{\mu\nu}}$$

Leptonic tensor $\eta_{\mu\nu}$ → $Tr\left[\hat{k}\gamma_\mu \hat{k}'\gamma_\nu\right]$

Hadronic tensor $W^{\mu\nu}$ → $\propto g_{\mu\nu}W_1\left(p,Q^2\right) + p_\mu p_\nu W_2\left(p,Q^2\right)$

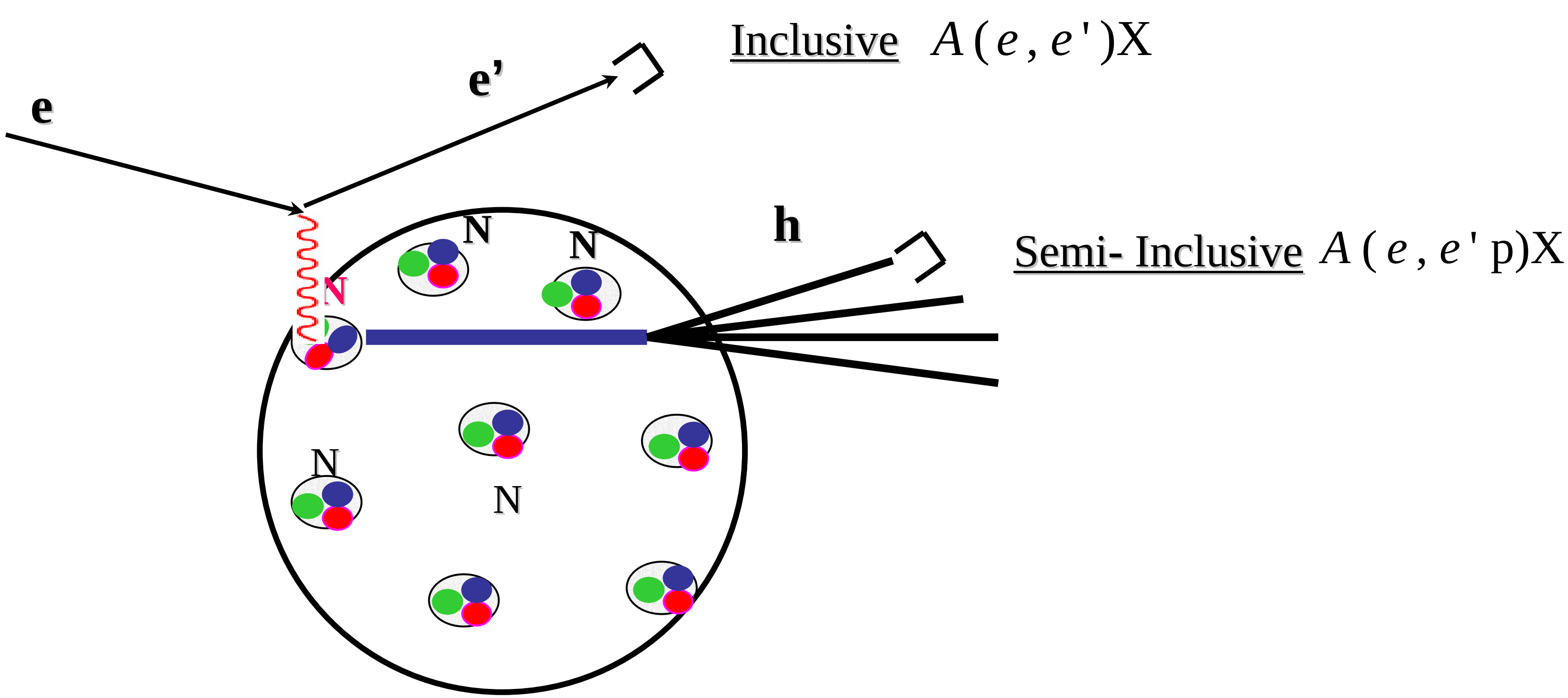


- Cross section:

$$\frac{d\sigma}{dE'd\Omega} = \sigma_{Mott}\left(W_2(\nu) + 2W_1(\nu)\tan^2(\theta/2)\right)$$

- with
  - Mott cross section σ_{Mott} : scattering off point charge
  - Structure functions W_1, W_2 with dimension [GeV]$^{-1}$
  - Key issue: *if quark is not a fermion we will find W_1=0*

Neutron Structure; electron scattering from nuclei

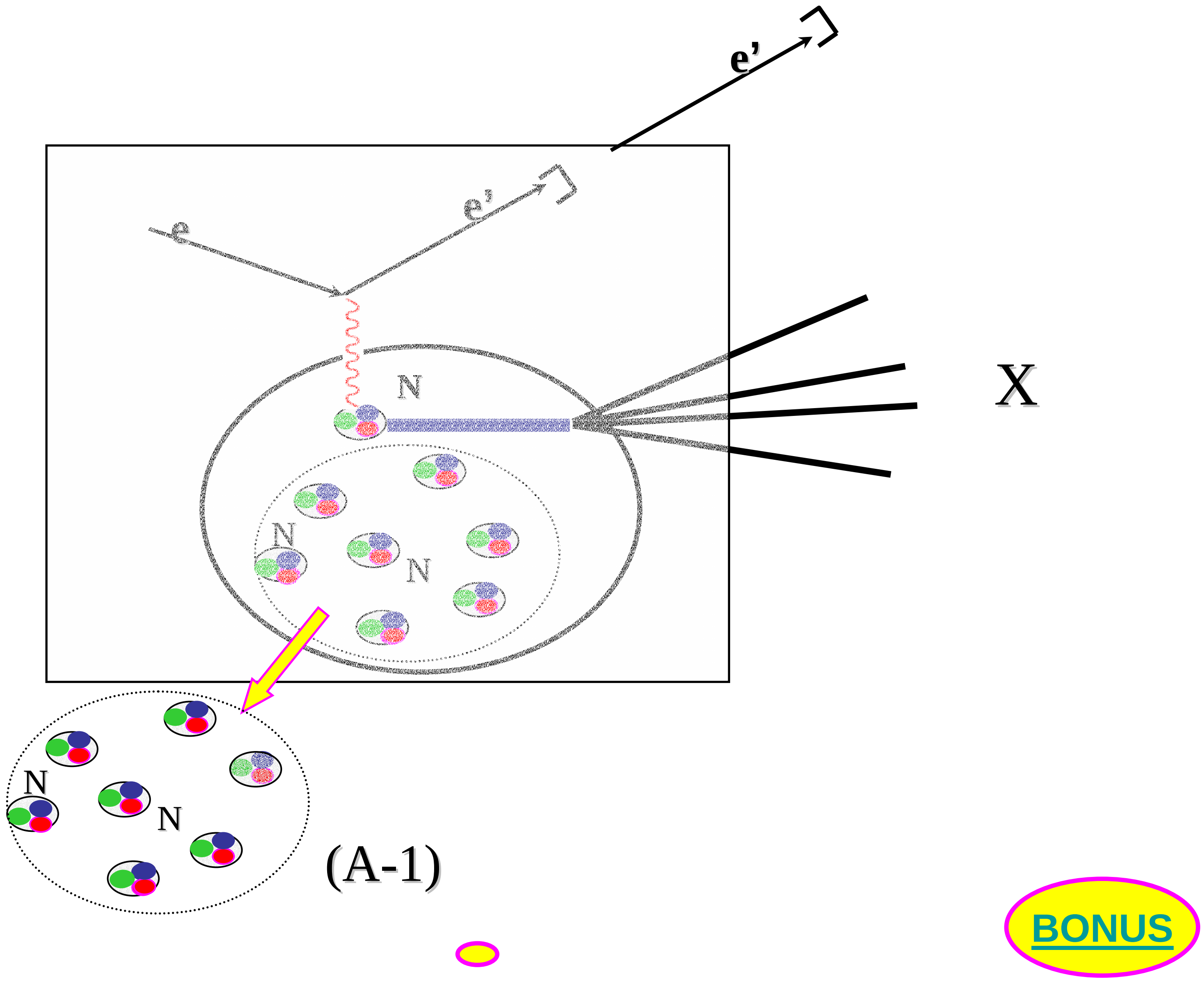


Inclusive $A(e,e')X$

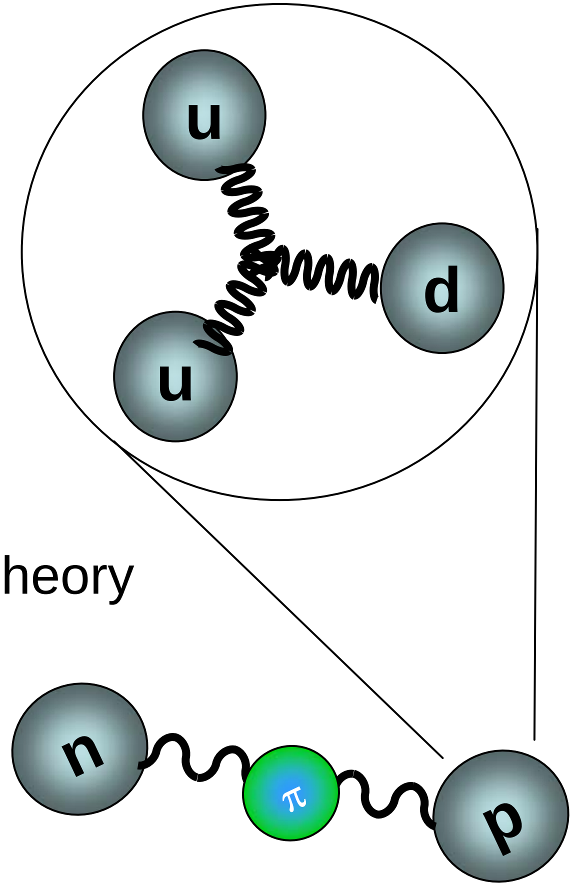
Semi- Inclusive $A(e,e'p)X$

Semi- Exclusive $A(e,e'A-1)X$ **(detection of spectators)**

Semi-Exclusive A(e, e' (A - 1))X



•Short distances (r <<r_N) - pQCD and/or experimental eN-scattering

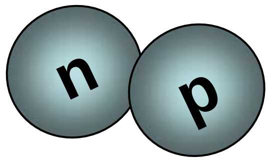


•Large distances (r >>r_N) – effecftive Meson-Nucelon Theory

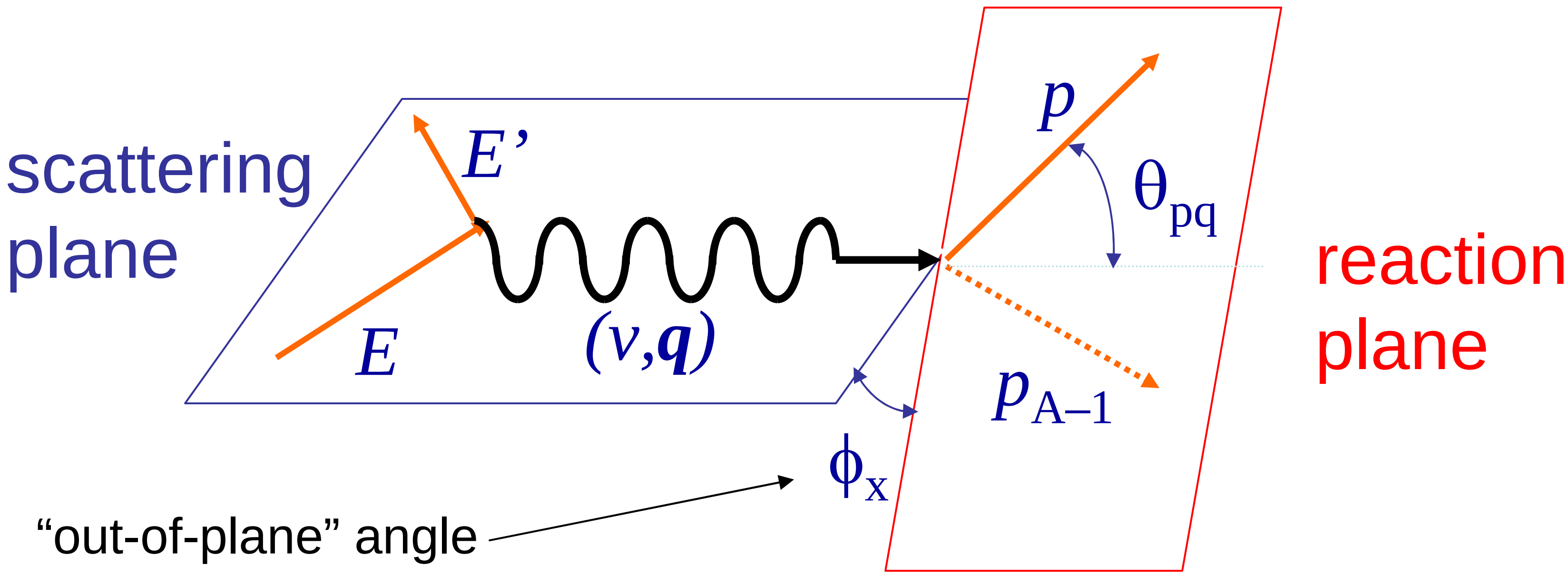
$$\hat{H}_A \psi_A = E_A \psi_A$$

$$\hat{H}_A = \hat{H}_0 + V, \quad V \text{ - realistic (OBE) potential}$$

•“Intermediate” distances (r ~r_N) - NN-correlations?



Kinematics A(e,e'p)(A-1)



$$Q^2 \equiv -q_\mu q^\mu = \boldsymbol{q}^2 - \nu^2 = 4EE' \sin^2\theta/2$$

Missing momentum: $\boldsymbol{p}_m = \boldsymbol{q} - \boldsymbol{p} = \boldsymbol{p}_{A-1}$

Missing energy: $E_m = \nu - T_p - T_{A-1}$

$$d\sigma_{lab} = \frac{\delta^4(p+Q-p_f)}{2\sqrt{\lambda(k,p)}} \eta_{\mu\nu} \frac{\alpha^2}{Q^4} W^{\mu\nu} \left[\frac{d^3k'}{(2\pi)^3}\right] d\tau_f$$

Consider Unpolarized Case

Lorentz Vectors/Scalars

3 indep. momenta: $Q\,,\,p_i\,,\,p\quad (P_{A-1} = Q + p_i - p)$

target nucleus → p_i

ejectile → p

6 indep. scalars: $\cancel{p_i^2},\ \cancel{p^2},\ Q^2,\ Q\bullet p_i\,,\ Q\bullet p\,,\ p\bullet p_i$

$p^2 = m^2$

$p_i^2 = M_A^{\,2}$

Nuclear Response Tensor

$$W^{\mu\nu} = X_1 g_{\mu\nu} + X_2 p_i^{\mu} p_i^{\nu} + X_3 p^{\mu} p^{\nu} + X_4 p^{\mu} p_i^{\nu} + X_5 p_i^{\mu} p^{\nu}$$

$$+ X_6 q^{\mu} p^{\nu} + X_7 p^{\mu} q^{\nu} + X_8 q^{\mu} q^{\nu} + X_9 q^{\mu} p_i^{\nu} + X_{10} p_i^{\mu} q^{\nu}$$

$$+ (\text{PV terms like } \varepsilon_{\mu\nu\rho\sigma} q_{\rho} p_{\sigma})$$

Gauge invariance (current conservation $q^{\mu} j_{\mu} = 0;\ \eta_{\mu\nu} \propto j_{\mu} j_{\nu}$)

X_i are the response functions

$$q^{\mu}\eta_{\mu\nu} = q^{\nu}\eta_{\mu\nu} = 0 \quad \Longrightarrow \quad X_{6..10} = 0$$

$$\eta_{\mu\nu} = \eta_{\nu\mu} \quad \Longrightarrow \quad W_{\mu\nu} = W_{\nu\mu} \quad \Longrightarrow \quad X_4 = X_5 \ ; \text{PV} = 0$$

4 independent responses $\mathbf{R}_{\mathrm{L}}, \mathbf{R}_{\mathrm{T}}, \mathbf{R}_{\mathrm{LT}}, \mathbf{R}_{\mathrm{TT}}$

Putting all together ...

$$\left(\frac{d^6\sigma}{d\Omega_e d\Omega_p dp\, d\nu}\right)_{LAB} = \frac{pE_p}{(2\pi)^3}\sigma_M\left[\rho_L R_L^A + \rho_T R_T^A + \rho_{LT} R_{LT}^A \cos\varphi_x + \rho_{TT} R_{TT}^A \cos 2\varphi_x\right]$$

with

$$\sigma_M = \frac{\alpha^2 \cos^2\theta/2}{4e^2 \sin^4\theta/2}$$

$$\rho_L = \left(\frac{Q^2}{q^2}\right)^2 \qquad \rho_T = \frac{Q^2}{2q^2} + \tan^2\theta/2$$

$$\rho_{TT} = \frac{Q^2}{2q^2} \qquad \rho_{LT} = \frac{Q^2}{q^2}\sqrt{\frac{Q^2}{q^2} + \tan^2\theta/2}$$

How to calculate the response functions?

PWIA

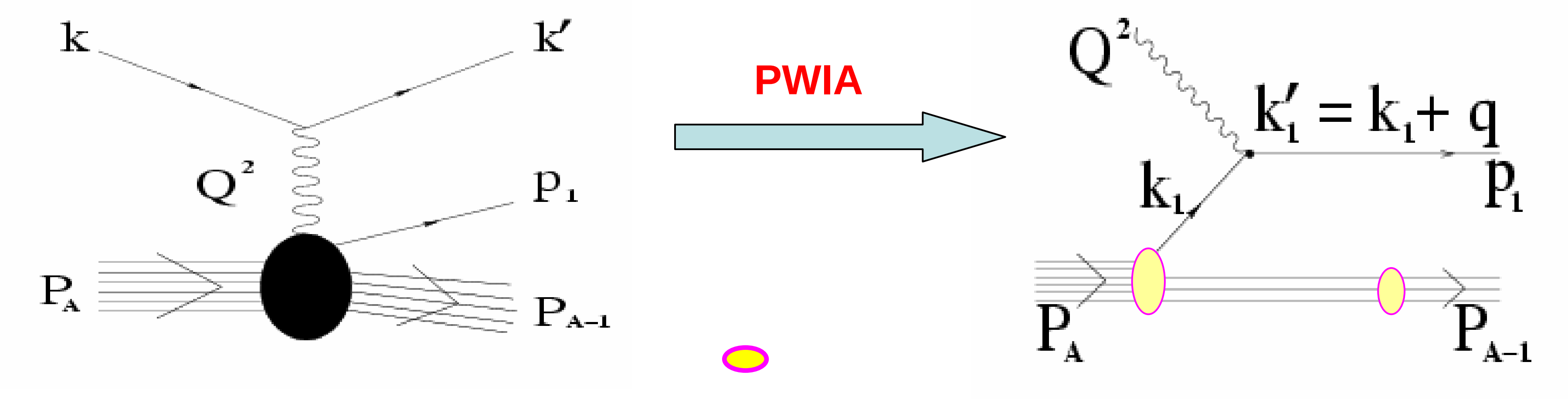
- The nuclear (A) current operator is the sum of one—body nucleon current operators, i.e the sum of currents for Dirac particles treated within an effective quantum field theory

$$\hat{J}_{\mu}^{A}\left(Q^2\right)=\sum_{N=1}^{A}\hat{J}_{\mu}^{N}\left(Q^2\right)$$

- The final hadronic state asymptotically consists of two non interacting systems

$$|\alpha_N p_1;\alpha_{A-1}P_{A-1}E_{A-1}^{f}\rangle=\hat{A}\left\{|\alpha_N p_1\rangle\,|\alpha_{A-1}P_{A-1}E_{A-1}^{f}\rangle\right\}$$

- The incoherent contributions leading to the emission of nucleon N, due to the interaction of γ with **A-1** , are disregarded (well justified at high Q^2).



In PWIA: $R_i^A = \underbrace{R_i^N \, S(p_m, E_m)}_{}$ (i = L, T, TT, LT)

exact factorization !!!

$$\frac{d^6\sigma}{d\nu d\Omega_e dp d\Omega_N} = K \, \sigma_{eN} \, S(p_m, E_m)$$

e-N cross section

nuclear spectral function

For bound state of recoil system:

nucleon momentum distribution

$$\rightarrow \frac{d^5\sigma}{d\nu d\Omega_e d\Omega_N} = K' \sigma_{eN} \left|\Phi(p_m)\right|^2$$

The Spectral Function

$$S(\vec{k}_1, \mathrm{E_m}) = \sum_f \left| \left\langle (A-1)_f \middle| a(\vec{k}_1) \middle| A \right\rangle \right|^2 \delta(\mathrm{E_m} - \sqrt{P_{A-1}^2} - M_N + M_A)$$

where $\vec{k}_1 = -\vec{p}_m = \text{ initial momentum}$

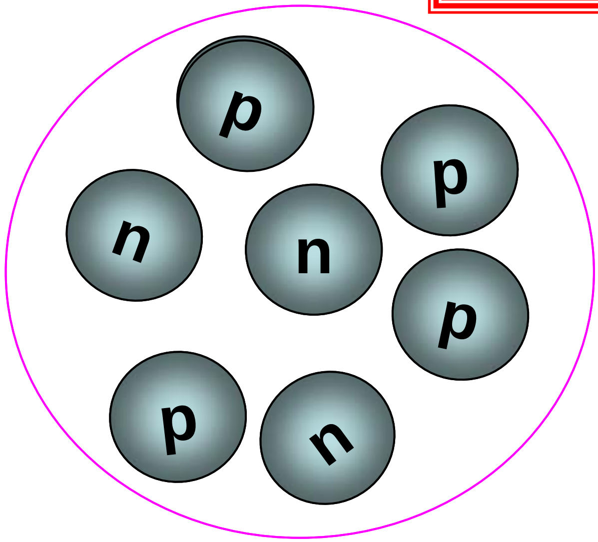
$$E_m = E_{\min} + E^*_{A-1} = \nu - \mathrm{T}_{k_1} - \mathrm{T}_{\mathrm{A\text{-}1}} = \text{missing (removal) energy}$$

Note: *S* is not an observable!

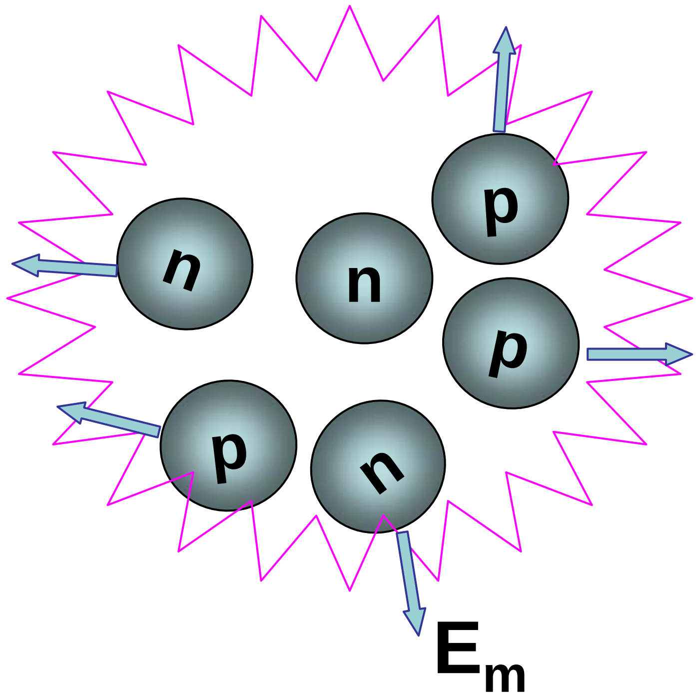
$$n(\vec{\mathrm{k}}_1) = \int_{E_{\min}}^{\infty} dE_m \, \mathrm{S}(\vec{\mathrm{k}}_1, \mathrm{E_m})$$ - nuclear momentum distribution

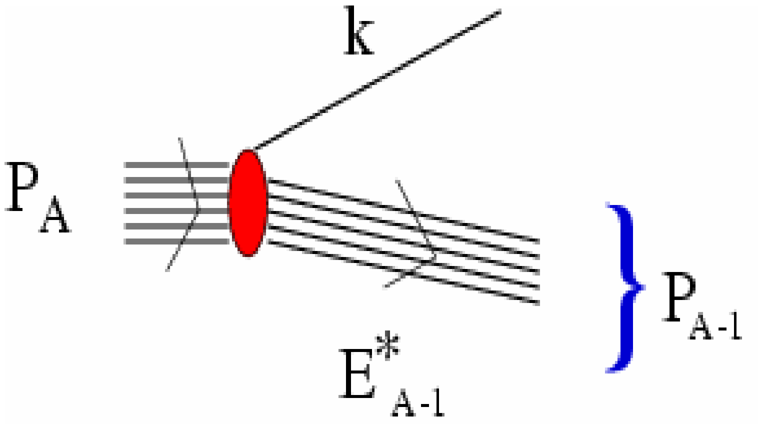
The physical meaning of S

A

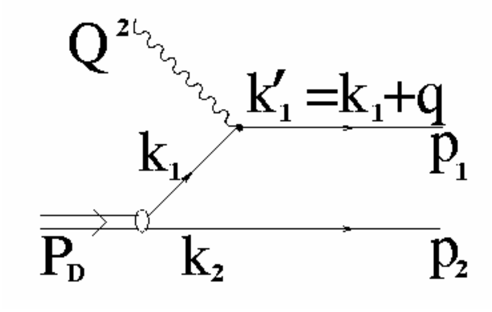


k





The simplest nucleus: the deuteron



$$S(\vec{k}_1,E_m)=\left|\langle p_2|a(\vec{k}_1)|D\rangle\right|^2\delta(E_m-\varepsilon)=\left|\langle pn|D\rangle\right|^2\delta(E_m-\varepsilon),\quad \varepsilon\approx 2.22\,\mathrm{MeV}$$

⇓

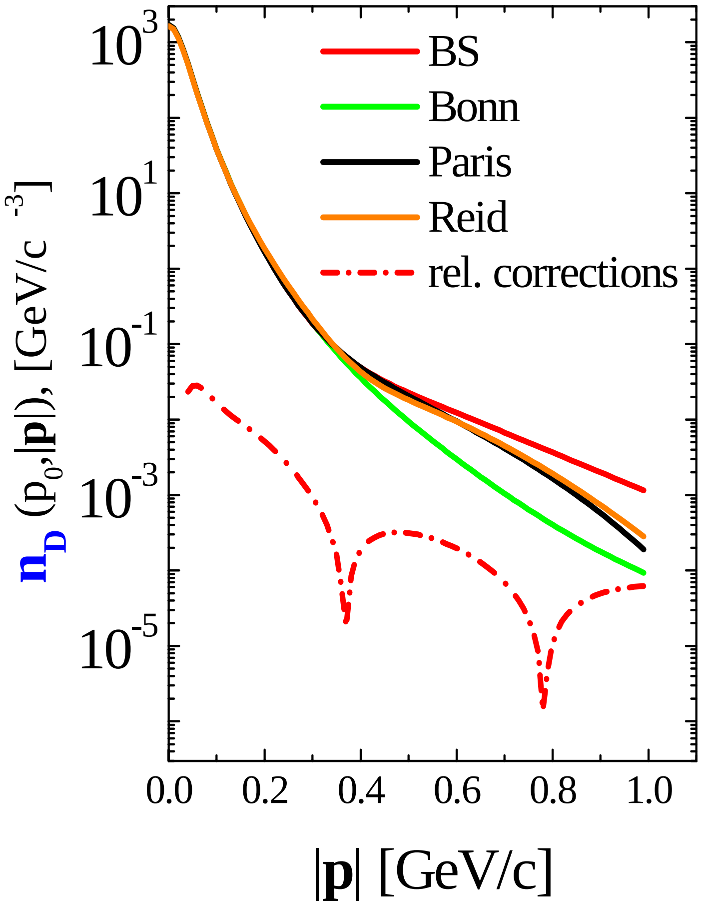
the deuteron momentum distribution

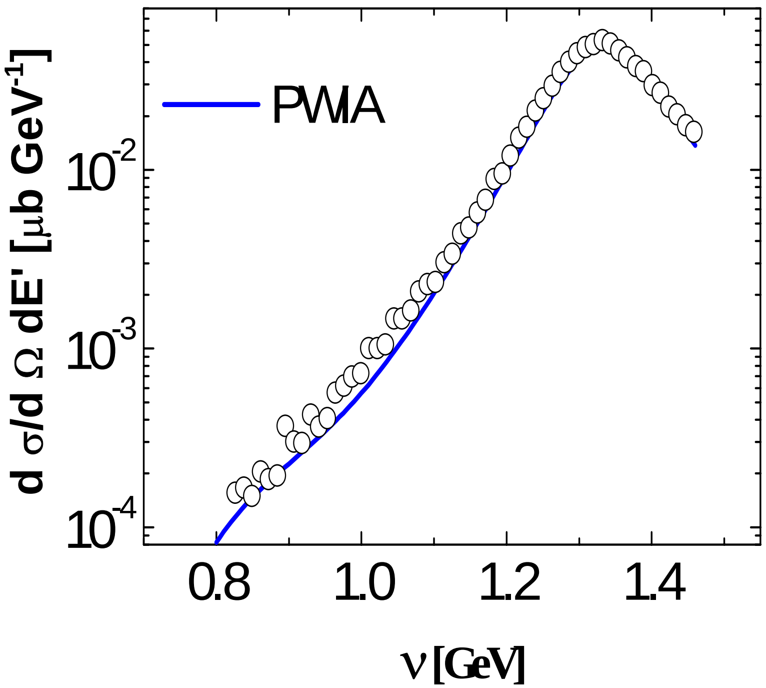
BS formalism

$$\boldsymbol{\Psi}^{S++}_{\mathcal{M}_d}(p_1',p_2')=\mathcal{N}(\hat{k}_1+m)\frac{1+\gamma_0}{2}\hat{\xi}_{\mathcal{M}_d}(\hat{k}_2-m)\boldsymbol{\phi}_{\mathbf{S}}(p_0,|\mathbf{p}|),$$

$$\boldsymbol{\Psi}^{D++}_{\mathcal{M}_d}(p_1',p_2')=-\frac{\mathcal{N}}{\sqrt{2}}(\hat{k}_1+m)\frac{1+\gamma_0}{2}\left(\hat{\xi}_{\mathcal{M}_d}+\frac{3}{2|\mathbf{p}|^2}(\hat{k}_1-\hat{k}_2)(p\xi_M)\right)$$
$$\times(\hat{k}_2-m)\boldsymbol{\phi}_D(p_0,|\mathbf{p}|),$$

$$n_D(p)\approx|\varphi_S(\bar{p}_0,p)|^2+|\varphi_D(\bar{p}_0,p)|^2,\quad \bar{p}_0=M_D/2-E_p$$

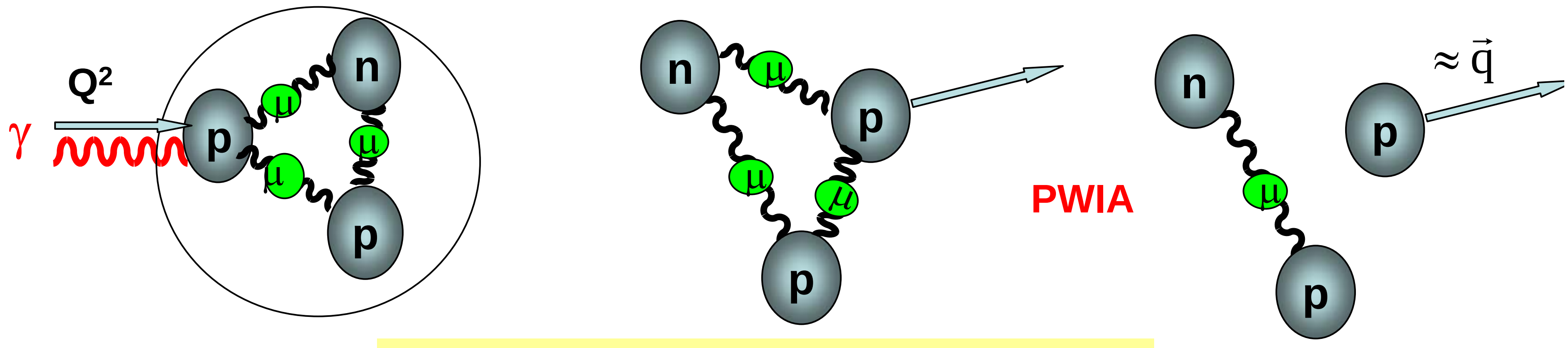




- Relativistic corrections are negligibly small
- Further calculations – nonrelativistic Schroedinger approach

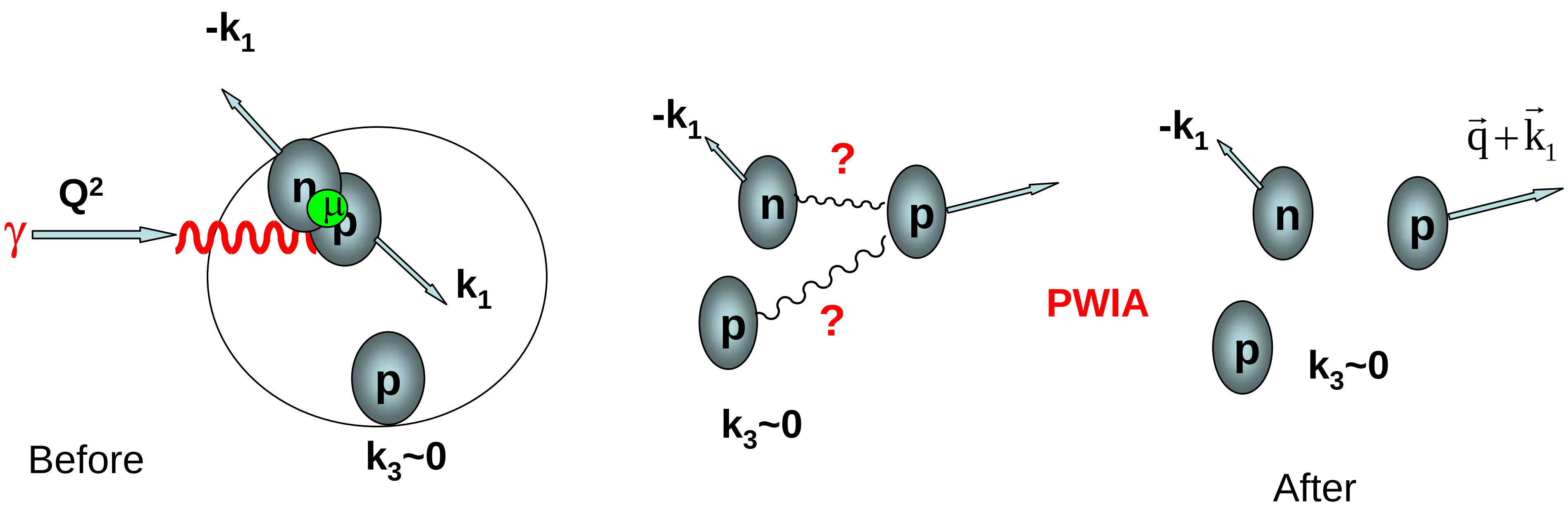
^3He

Low momenta $|k_i|$~(0-50) MeV/c (uncorrelated):



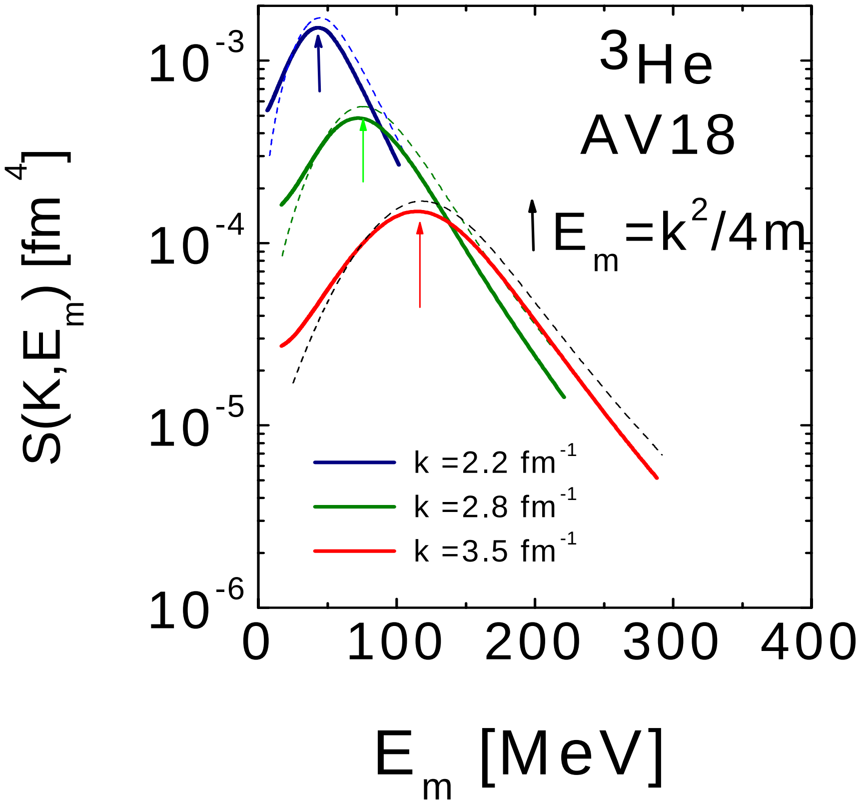
High momenta $|k_{1,2}|$~(100-500) Mev/c

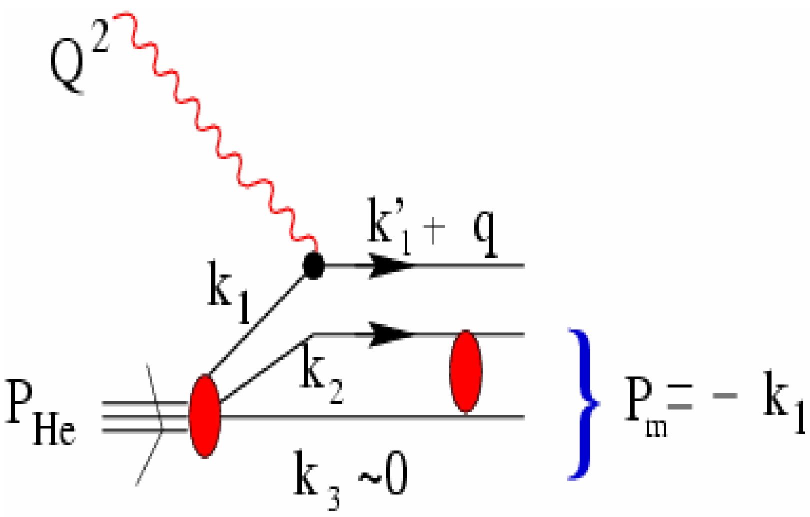
(correlated 1,2), low $|k_3|$~0



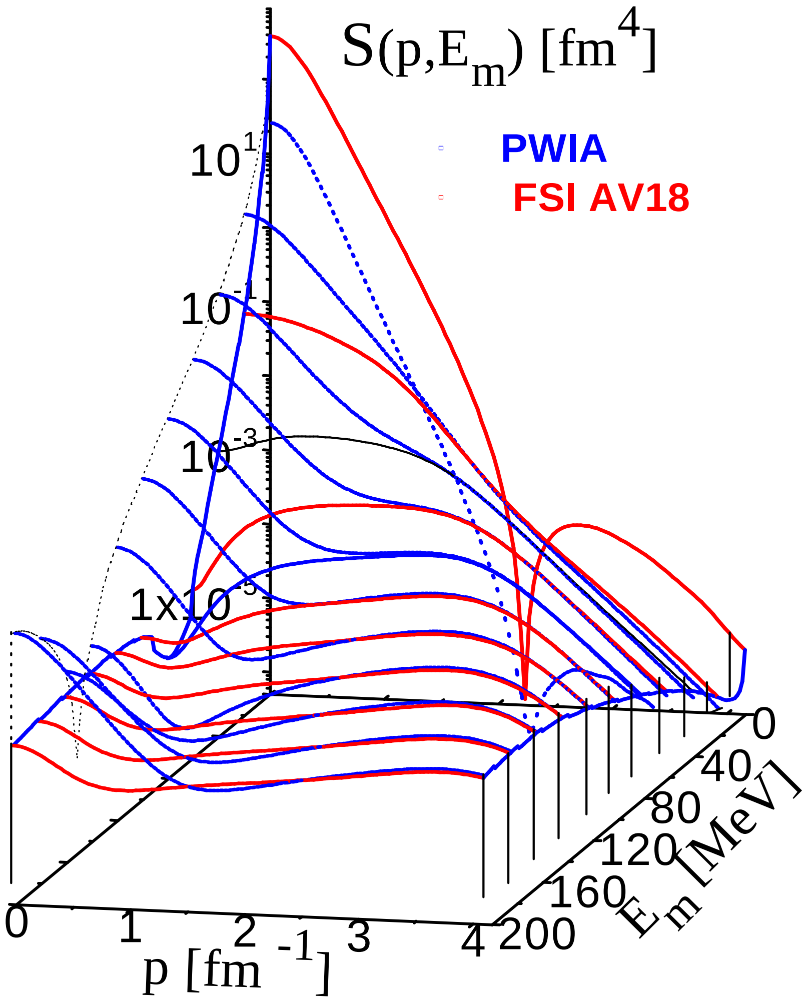
2NN-correlation condition

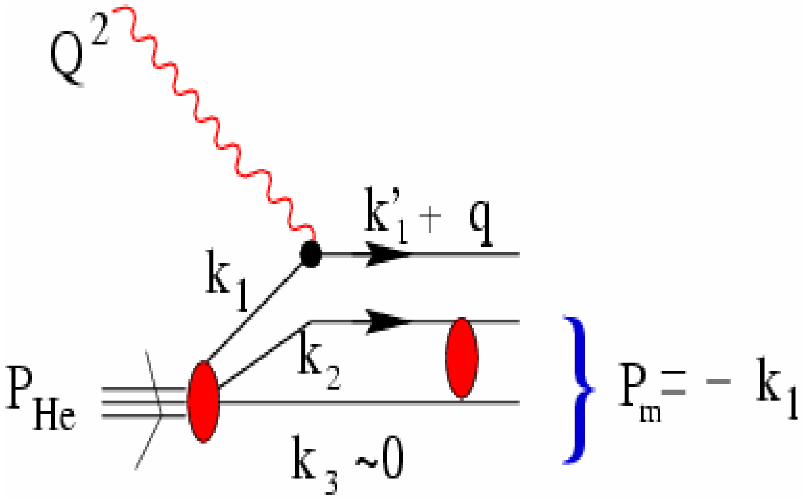
$$E_m \approx E_{rel} = \frac{\left(\vec{k}_2 - \vec{k}_3\right)^2}{4m} = \frac{\vec{k}_1^{\,2}}{4m}$$

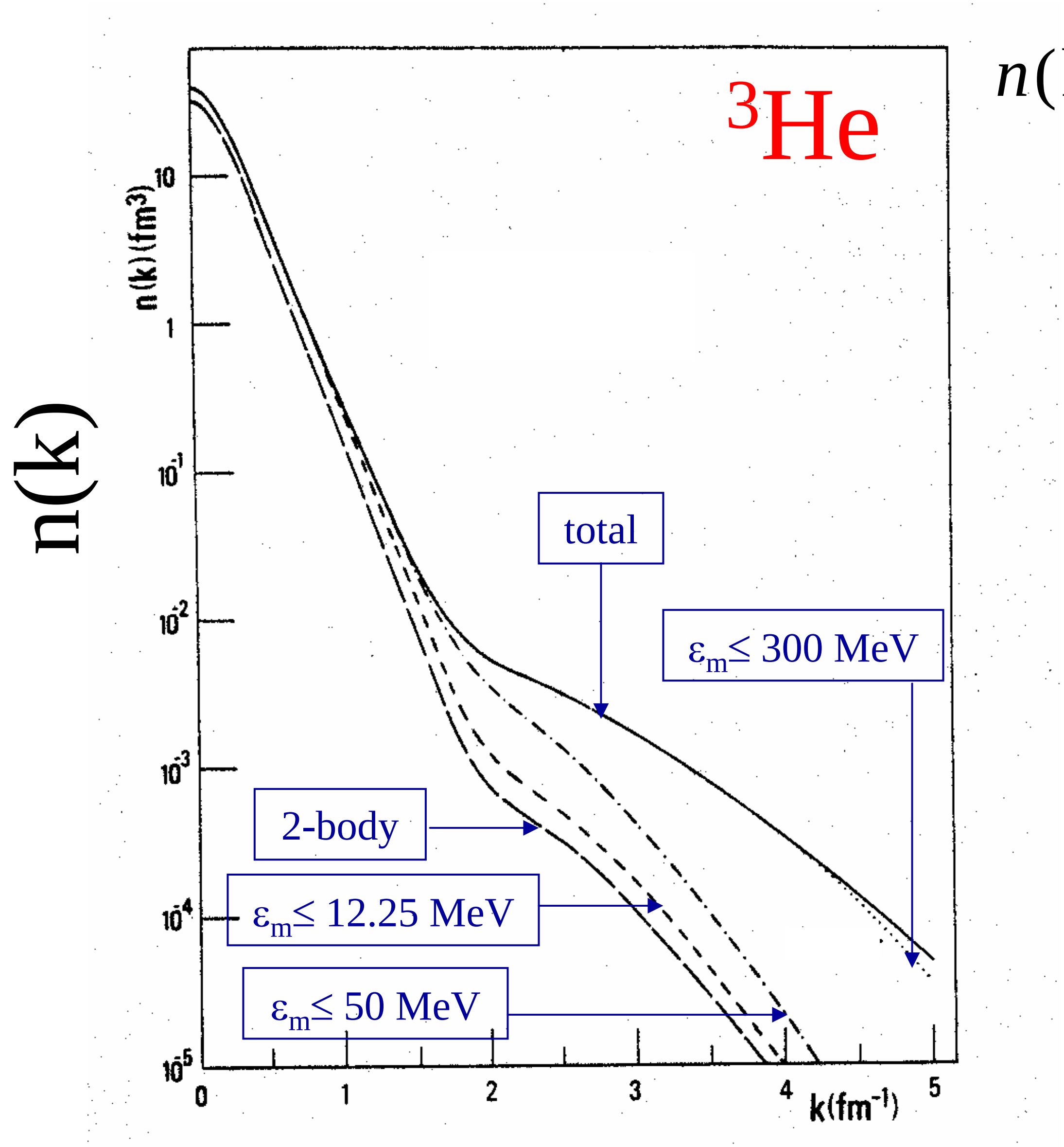




^3He Spectral Function AV18



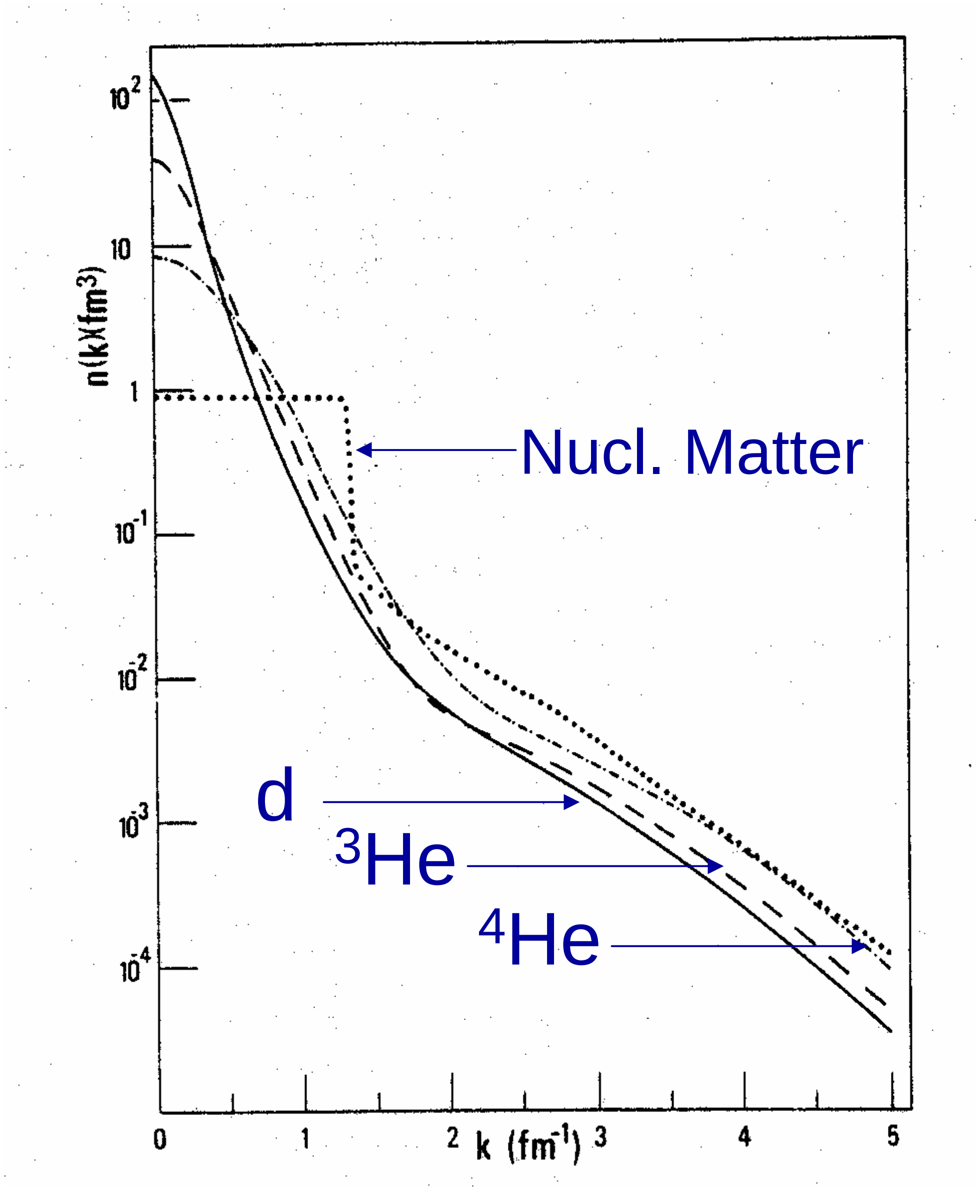




$$n(\vec{k}) = \int_{E_{\min}}^{\varepsilon_m} dE_m \; S(\vec{k}, E_m)$$

Short Range Corr. dominate at high *k* (=p_m) and are related to large values of E_m.

C. Ciofi degli Atti, E. Pace and G. Salmè, Phys. Lett. **141B**, 14 (1984).



C. Ciofi degli Atti, E. Pace and G. Salmè,
Phys. Lett. **141B**, 14 (1984).

Similar shapes for few-body nuclei and nuclear matter at high k (=p_m).

Some applications ....

Inclusive D(e,e')X process; y-scaling

$$\frac{d^3\sigma}{d\omega d\Omega_e} \cong \sigma_{eN} \frac{m}{|\vec{q}|} \int_{|p_{\min}|}^{\infty} p\,dp\; \mathbf{n_D}(p)$$

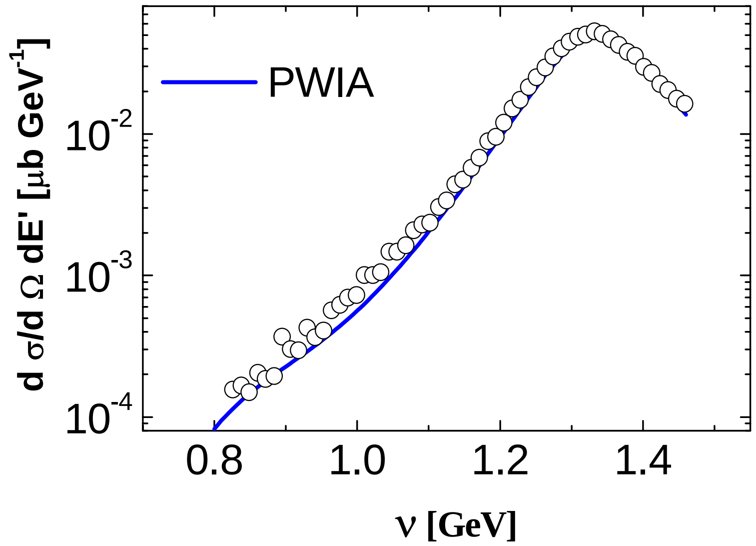
$$y \equiv p_{\min}(\vec{q}, \nu)$$

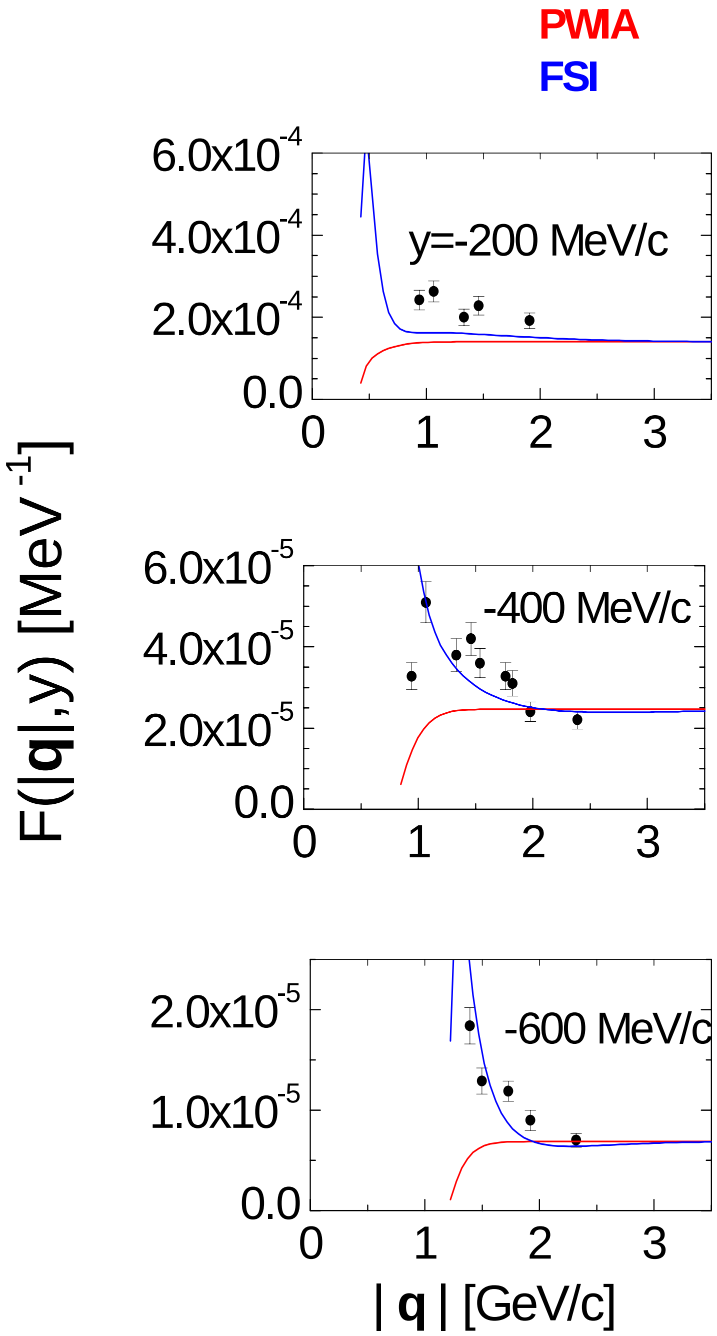
$$F(y) \equiv \frac{\dfrac{d^3\sigma}{d\omega d\Omega_e}}{\sigma_{eN} \dfrac{m}{|\vec{q}|}} = \int_{|\mathbf{y}|}^{\infty} p\,dp\; \mathbf{n_D}(p)$$

$$F'(y)/\mathrm{p} = \mathrm{n_D}(p)$$

C. Ciofi degli Atti, L.P.K. D. Treleani

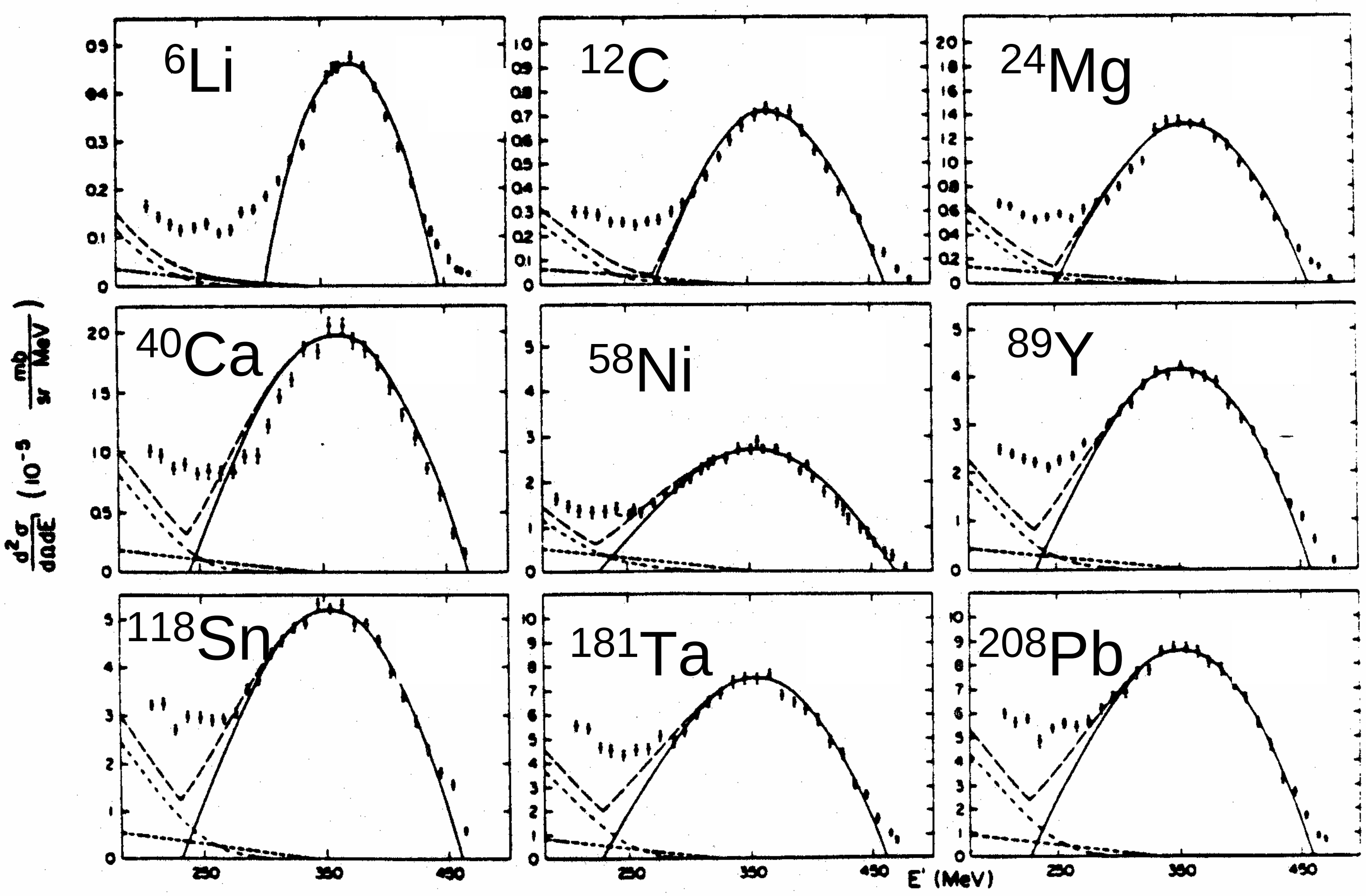
Phys. Rev. C63 044601 (2001)





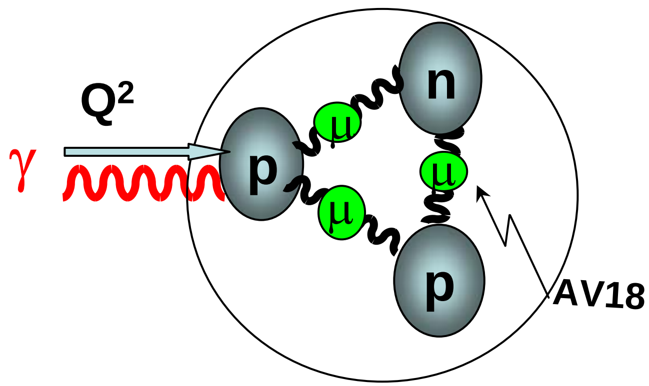
$$F'(y)/p = n_D(p)$$

Quasielastic Electron Scattering

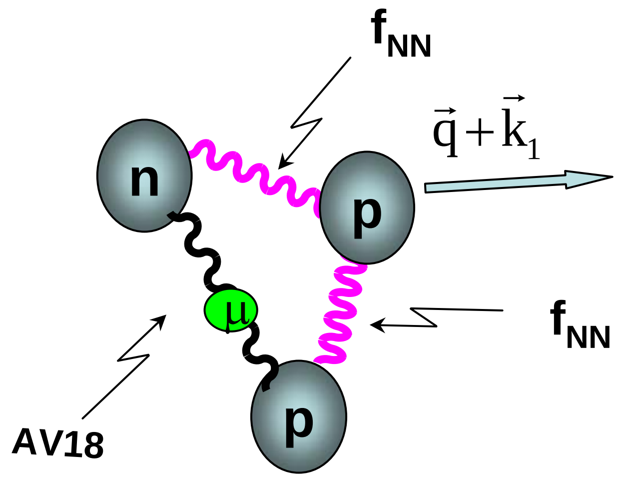


R.R. Whitney *et al*., Phys. Rev. C **9**, 2230 (1974).

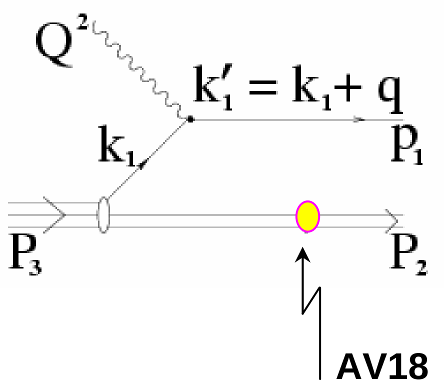
FSI



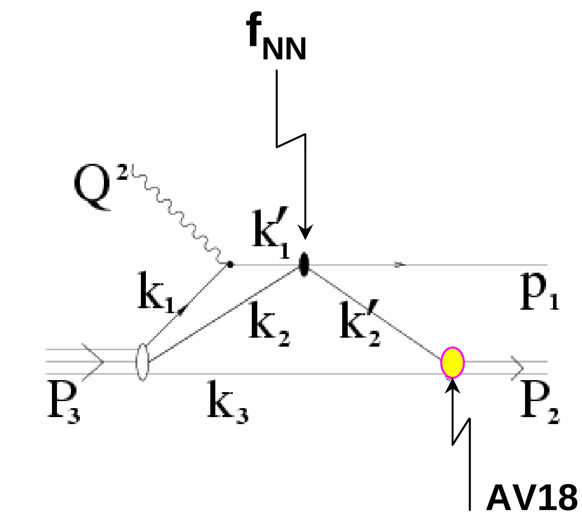
Before



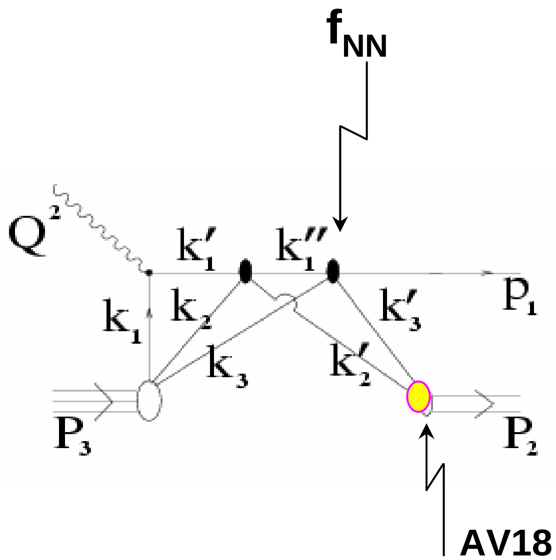
After



PWIA



Single resc.



Double resc.

FSI

$$S_A^{FSI}(\underline{p}_m, E_m) = \frac{1}{2J_A+1}\sum_f \left|\sum_{n=0}^{A-1} \mathcal{T}_A^{(n)}(\mathcal{M}_f, s_1)\right|^2 \delta\left(E_m - (E_{A-1}^f + E_{min})\right)$$

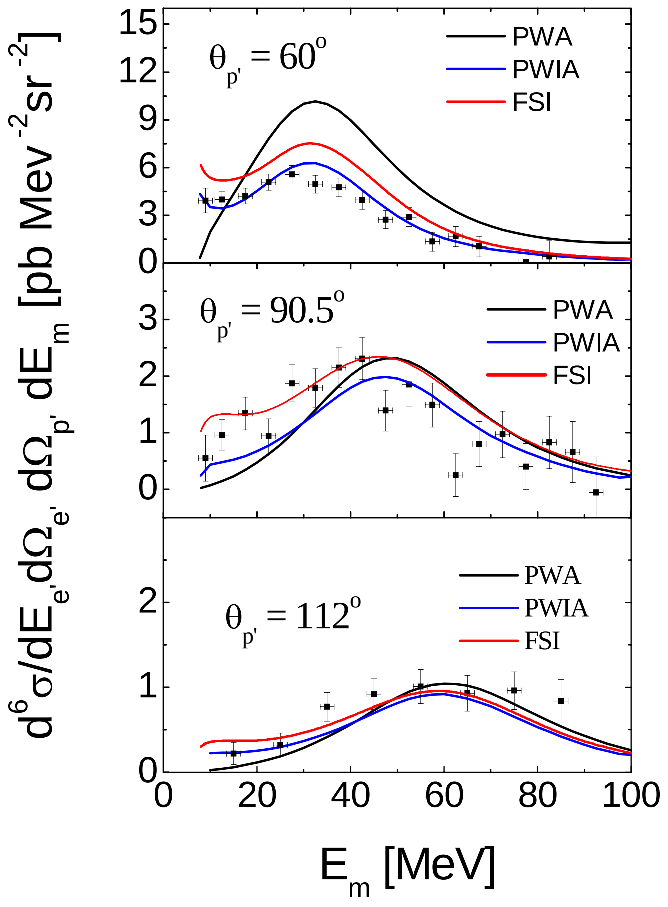
$$\mathcal{T}_3^{(1)} = \int d\tau_{23} \underbrace{\frac{G_{He\to 1(23)}(k_1,k_2,k_3,s_1,s_2,s_3)}{(k_1^2 - M_N^2)}}_{\langle s_1,s_2,s_3|\Psi_{He}^{\mathcal{M}_3}(\mathbf{k}_1,\mathbf{k}_2\mathbf{k}_3)\rangle} \frac{f_{NN}(p_1 - k_1')}{k_1'^2 - M_N^2} \underbrace{\frac{G^{+}_{(23)\to f}(k_2',k_3,s_2,s_3)}{(k_2'^2 - M_N^2)}}_{\langle s_2,s_3|\Psi_{23}^{\mathcal{M}_{23}}(\mathbf{k}_2\mathbf{k}_3)\rangle}$$

$$\mathcal{T}_3^{(1)} \approx \int \frac{d^3\kappa}{(2\pi)^3}\Psi^f_{(23)}(\mathbf{k}_3,\mathbf{k}_2';S_{23})\frac{f_{NN}(\kappa_\perp)/4M_N|\mathbf{p}_1|}{(\kappa_z + \Delta_z + i\epsilon)}\langle s_1|\Psi_{He}^{\mathcal{M}_3}(\underline{k}_1,\underline{k}_2,\underline{k}_3)\rangle \qquad \Delta_z = \frac{E_{\mathbf{k}_1+\mathbf{q}} + E_{\mathbf{p}_1}}{2|\mathbf{p}_1|}(E_m - E_3)$$

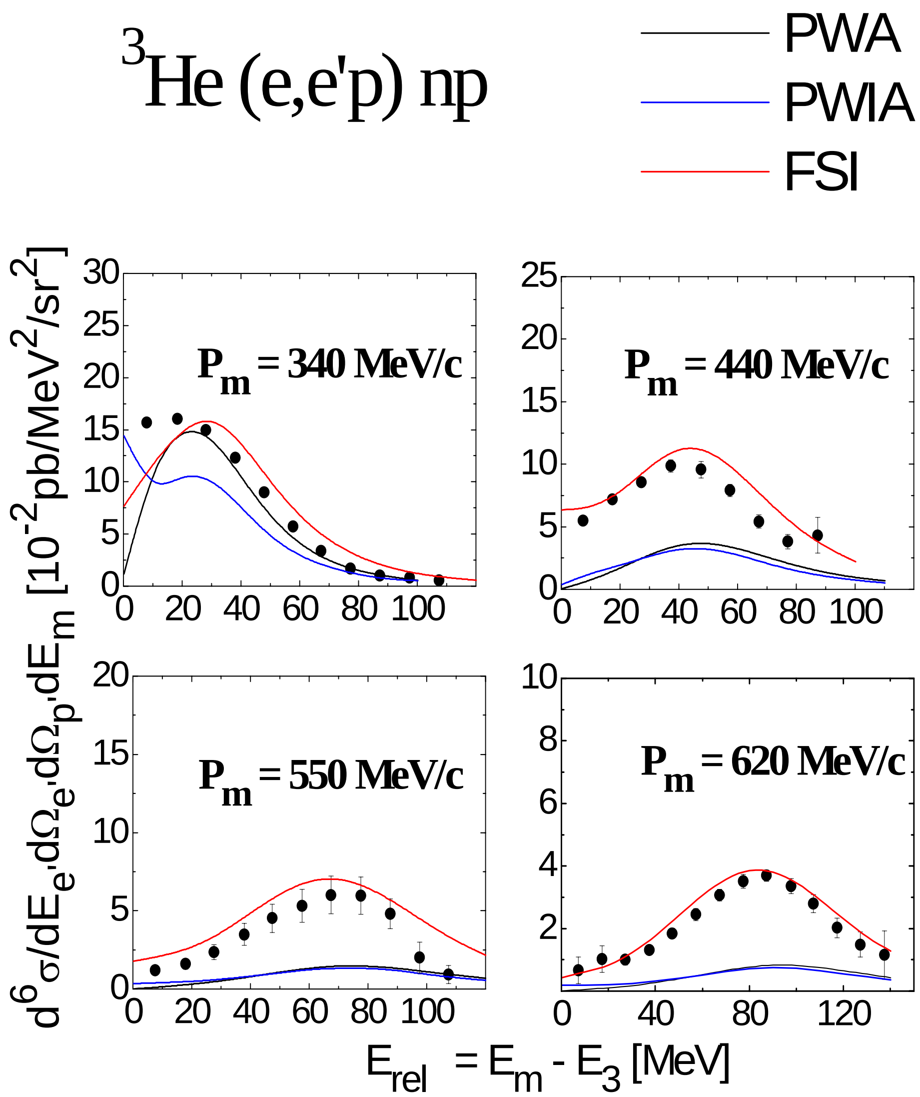
$$S_A^{FSI}(\underline{p}_m, E_m) = \sum_f \int \frac{d^3\underline{t}}{(2\pi)^3}\left|\int e^{i\rho\underline{p}_m}\chi^{\dagger}_{\frac{1}{2}s_1}\Psi^{\underline{t}\dagger}_{np}(\underline{r})\mathcal{S}_{\Delta}^{FSI}(\rho,\mathbf{r})\Psi_{He}^{\mathcal{M}_3}(\underline{r}\rho)d\rho d\mathbf{r}\right|^2 \delta\left(E - \frac{\underline{t}^2}{M_N} - E_3\right)$$

$$\mathcal{S}_{(1)}^{FSI}(\rho,\mathbf{r}) = 1 - \sum_{i=2}^{3}\theta(z_i - z_1)e^{i\Delta_z(z_i - z_1)}\Gamma(\underline{b}_1 - \underline{b}_i)$$

^{3}He(e,e'p)pn (SACLAY kinem.)

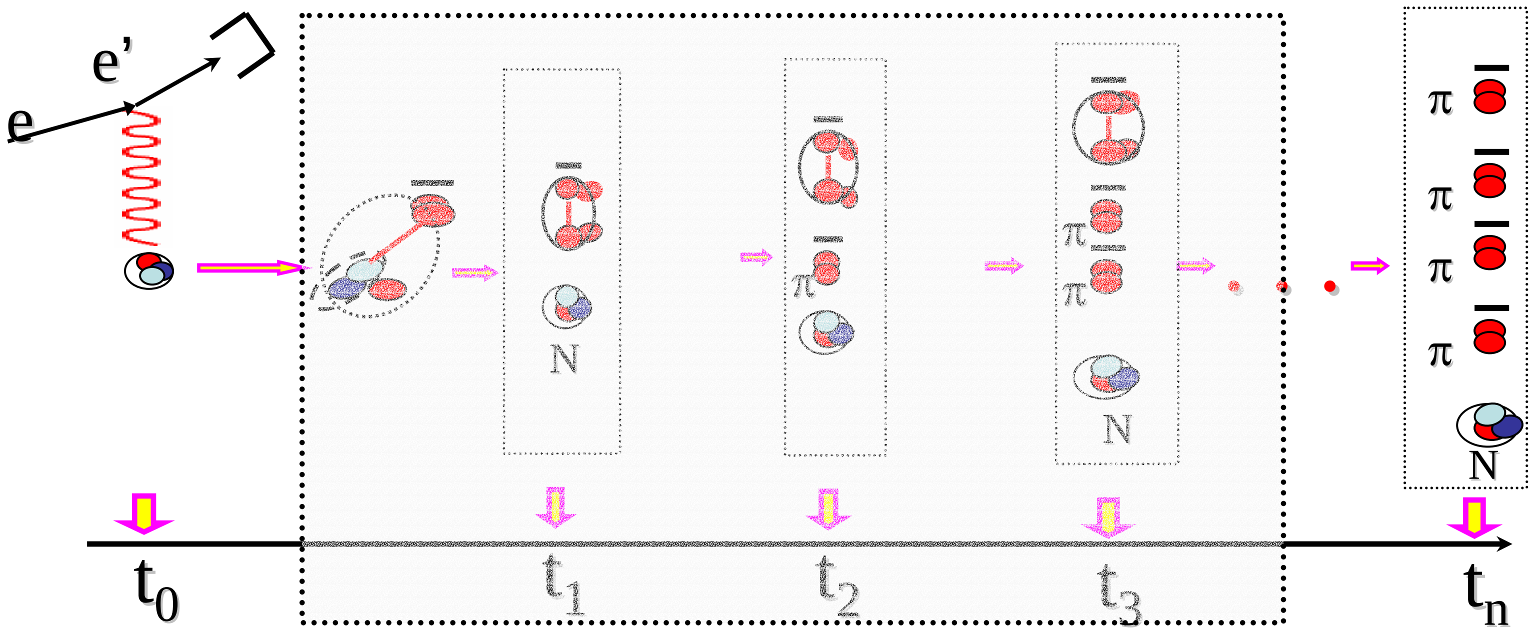


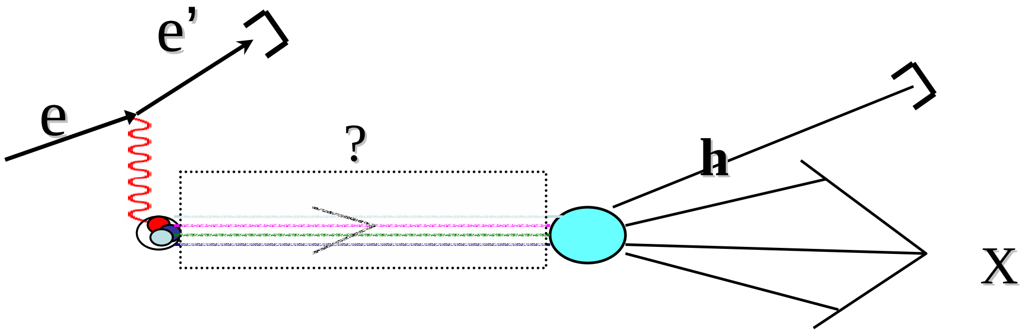
^{3}He (e,e'p) np



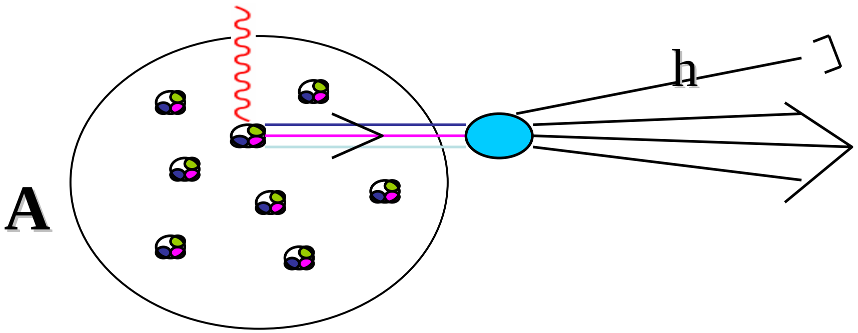
C. Ciofi degli Atti, L.P.K.

Hadronization in Deep Inelastic N(e,e')X processes

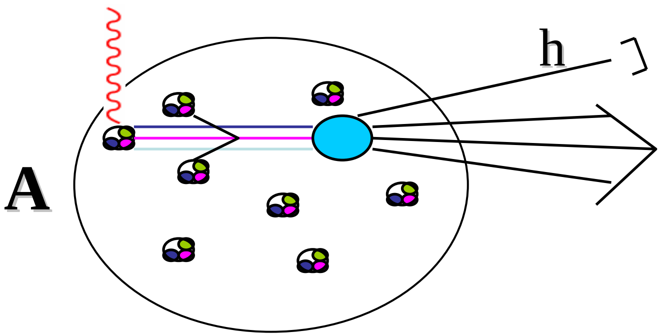




Nuclear size as "time filter" for hadronization



$$R = \frac{d\sigma_A}{d\sigma_N} \approx 1$$



$$R = \frac{d\sigma_A}{d\sigma_N} < 1$$

Color string model

Energy loss → $\frac{dE}{dz} = -\kappa$ *(string strength)*

Time evolution

After $\Delta t \approx k \approx 1 fm$ the string breaks into a qq-pair (meson) and another, less strengthened and (approx.) twice shorter string.

$$\gamma^* + N \rightarrow str \rightarrow N + str \rightarrow N + M + str \rightarrow N + 2M + str \rightarrow \ldots$$

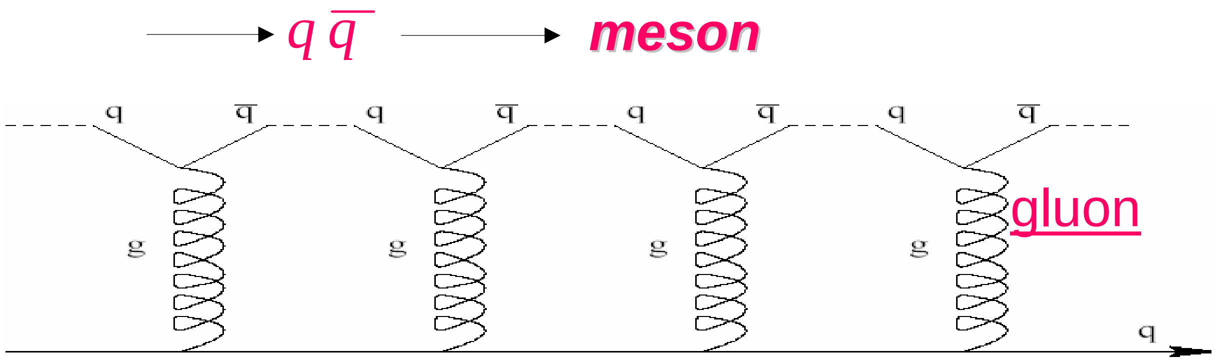
The break time ⇒ $t = \Delta t, 3\Delta t, 7\Delta t \ldots$

$$t = \Delta t \sum_{j=0}^{n} 2^j = \Delta t (2^{n+1} - 1)$$

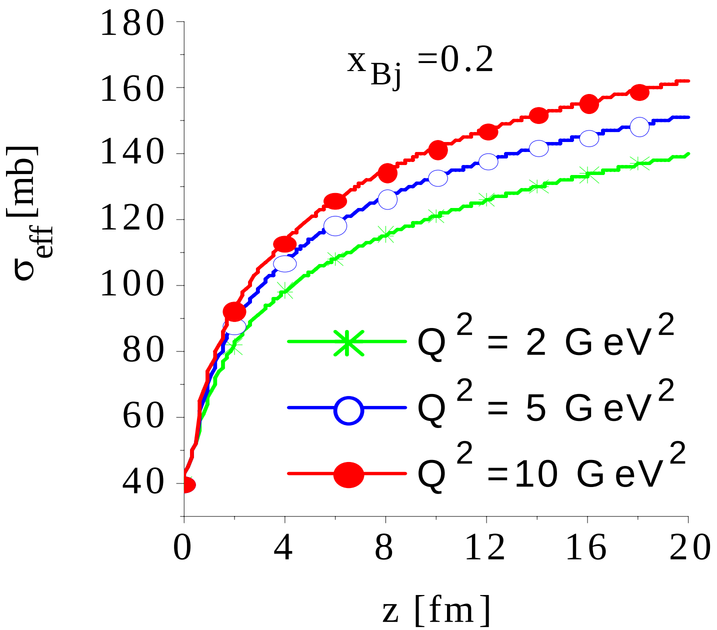
n+1 = the total number of produced mesond $= n_M(t) = \frac{\ln(1 + t/\Delta t)}{\ln 2}$

The efctive nucleon-debris cross section

$$\sigma_{eff} = \sigma_{tot}^{NN} + \sigma_{tot}^{MN} n_M(t)$$

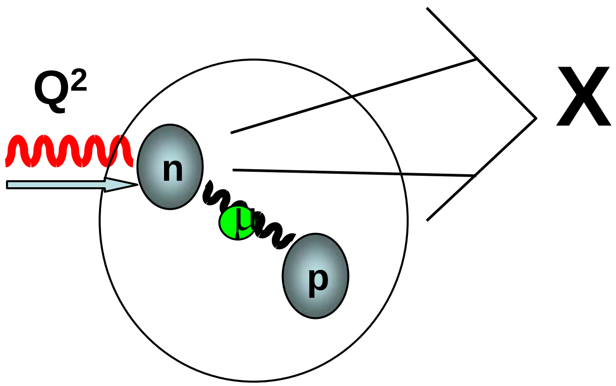


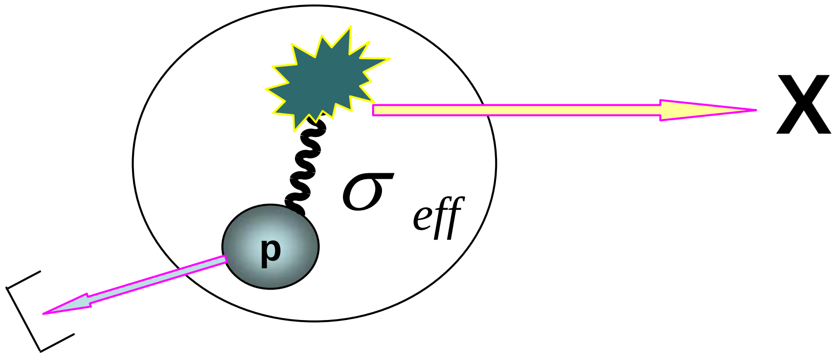
$$\sigma_{eff} = \sigma^{NN}_{tot} + \sigma^{\pi N}_{tot}\left[n_M(t) + n_G(t)\right]$$



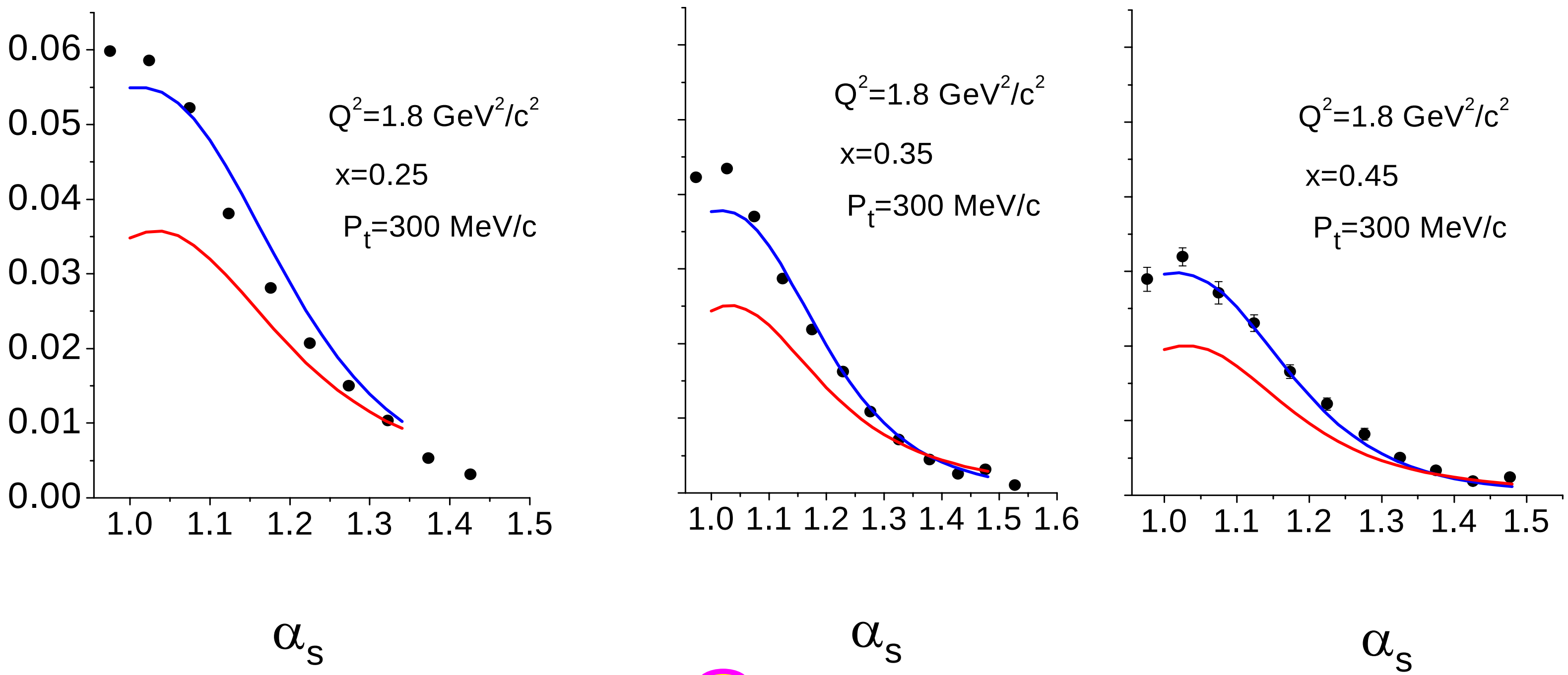
C.Ciofi degli Atti, L.P.K. B.Z. Kopeliovich
Eur. Phys. J. A17 (2003) 133

Semi Exclusive DIS BONUS: D(e,e'p)X





Cross section ~ $F_{2n}(x)\,S_D^{FSI}(p,\sigma_{eff},X)$



A-1

SUMMARY

- PWIA
  - Inclusive y-scaling: direct experimental investigation of nuclear momentum distributions
  - *NN* short range correlations via investigation of nuclear spectral function
  - reaction mechanism and the neutron structure
- FSI in quasi-elastic A(e,e'p) reactions
  - Feynman diagramatic approach and Generalized Glauber approximation
- Semi-Exclusive DIS A(e,e'X)(A-1)
  - Neutron Structure Function, binding effects
  - Mechanism of Hadronization
  - Color transparency etc…..

Thanks to:

C. Ciofi degli Atti,

M.A. Braun,

B. Kopeliovich,

G. Salme,

A. Kievsky,

P. Ulmer,

G. Steenhoven,

P. Steinberg