E97-006

Correlated spectral function $S(E_m,P_m)$ via $(e,e'p)$

(Daniela Rohe)

Contens:

- Introduction
- Kinematics (perp. + parallel)
- H_2 data (only for checks)
- 2 analysis features
- Extraction of the spectral function
- Results for parallel kin.
- Results for perp. kin. } comparsion to Benhar's theory
- Summary

Spectral function S(E,k)

= probability of finding a proton with E , k in the nucleus

$S(E,k) = S_{1p}(E,k) + S_{cor}(E,k)$

shell structure of nuclei
$k < k_F$
$E < E_F$

short range and tensor correlations: strong interaction p↔p
$k > k_F$

Independent Particle Shell Model (IPSM)

calculated for nuclear matter

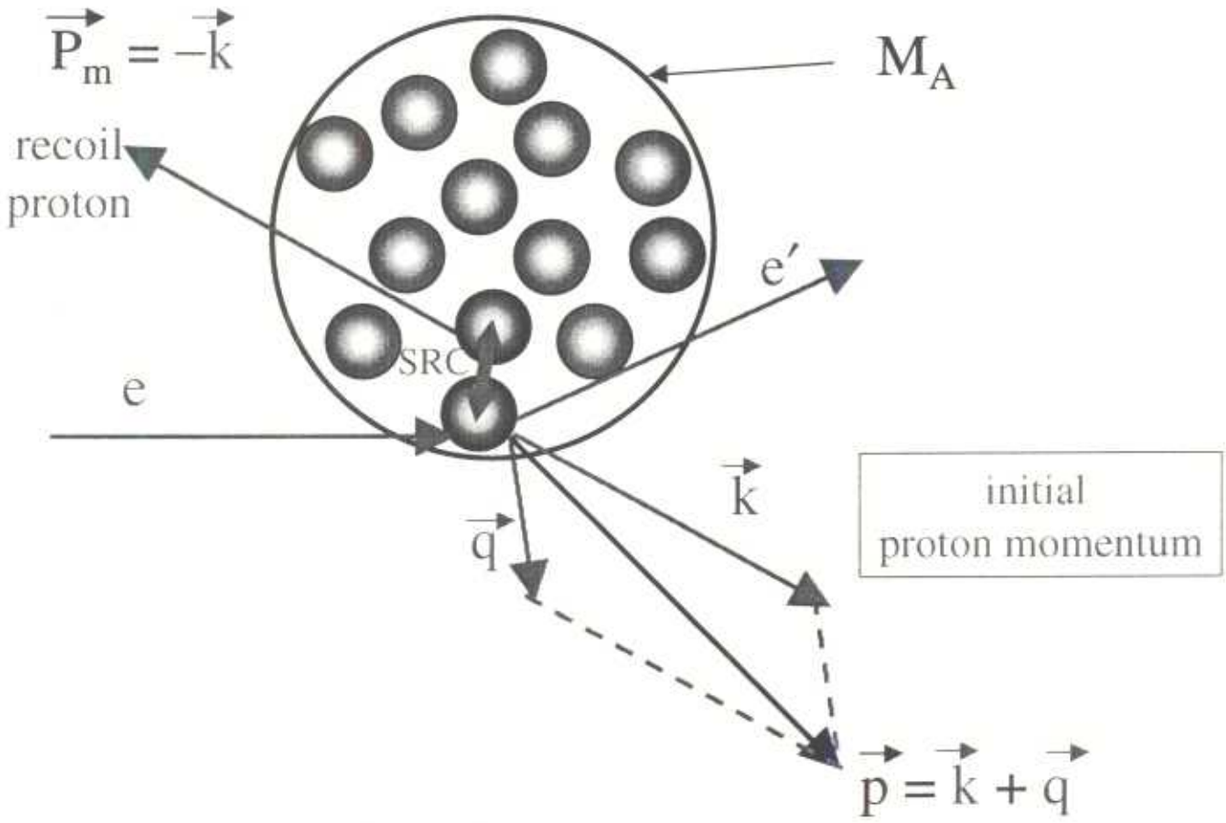
Local Density Approximation (LDA)

finite nuclei

(O.Benhar et. al, Nucl.Phys.A579,493,1994)

Kinematics:

scattering process in PWIA:



$$E_m = E_e - E'_e - T'_p - T_{rec}$$

in PWIA:

$$\boxed{\begin{aligned} E &== E_m \\ k &== P_m \end{aligned}}$$

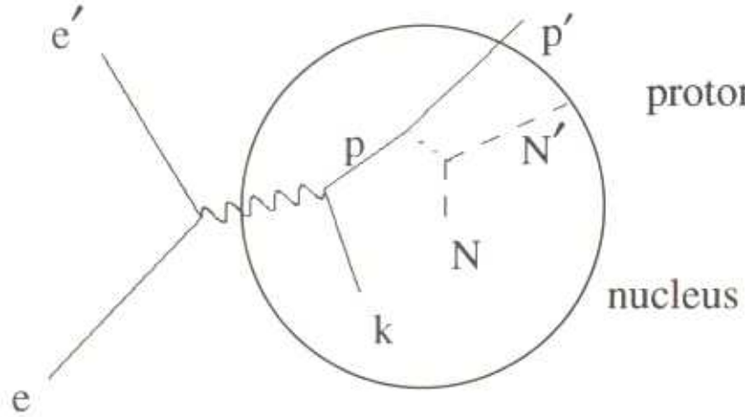
in the correlated particle region:

$$E_m \approx \frac{k^2}{2M_p} == \frac{P_m{}^2}{2M_p}$$

expected: maximum of the spectral function (ridge)

Reaction mechanismen:

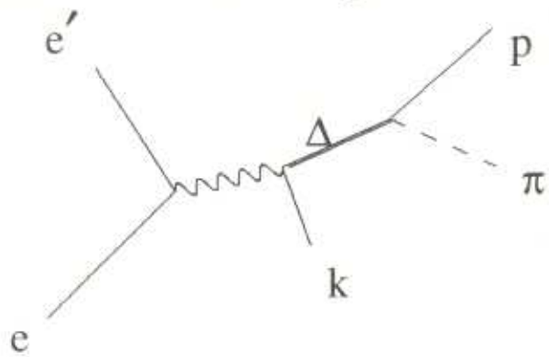
1) Multi-step process: (e,e′p) + (p,p′N)



proton „reappears“ with different (reconstructed) E_m,P_m

- depends on size of nucleus $R_A \sim A^{1/3}$
  correlated strength ≈ independent of A
  ⟶ measure at different nuclei
- moves strength to large E_m, smaller P_m (under most kinematics)
  ⟶ effect minimized above the ridge

2) Δ–excitation:



π : E/p large ⇒ influence at large E_m

parallel kinematics: $\vec{k} \parallel \vec{q}$

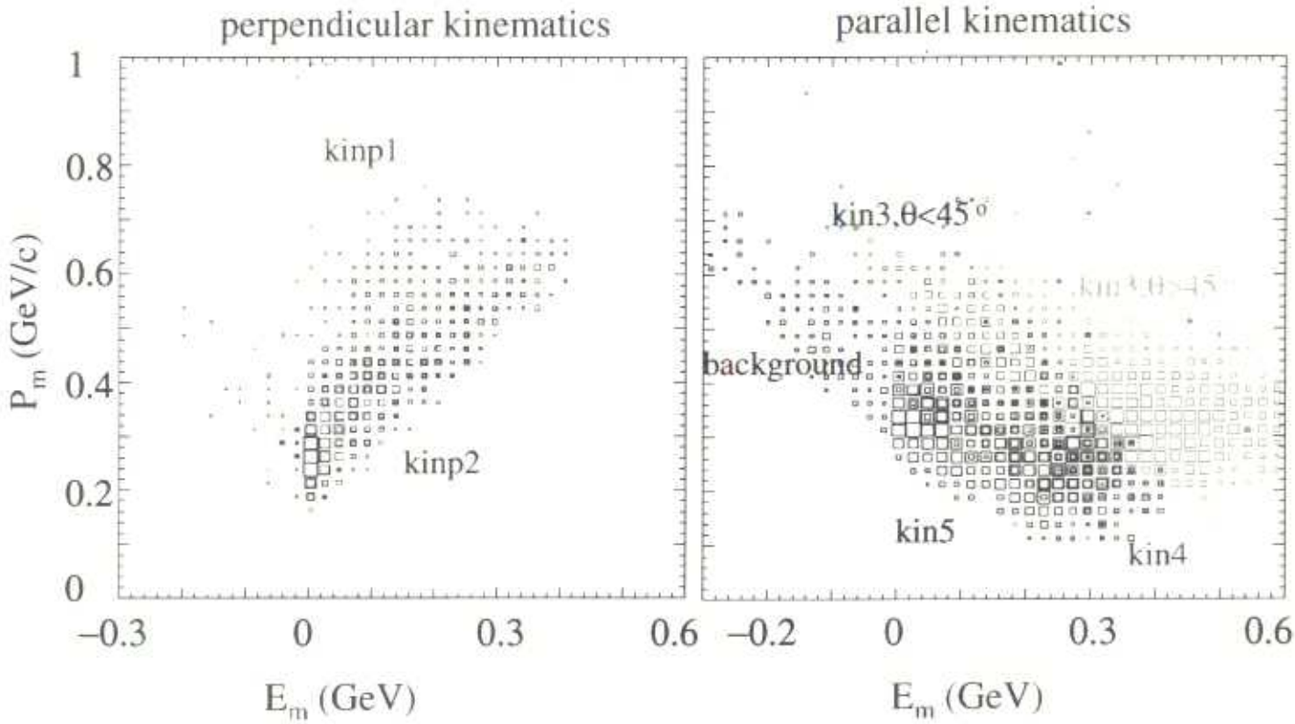
⊕ suppression of multi-step processes (FSI)

⊕ helps also with the Δ–resonance

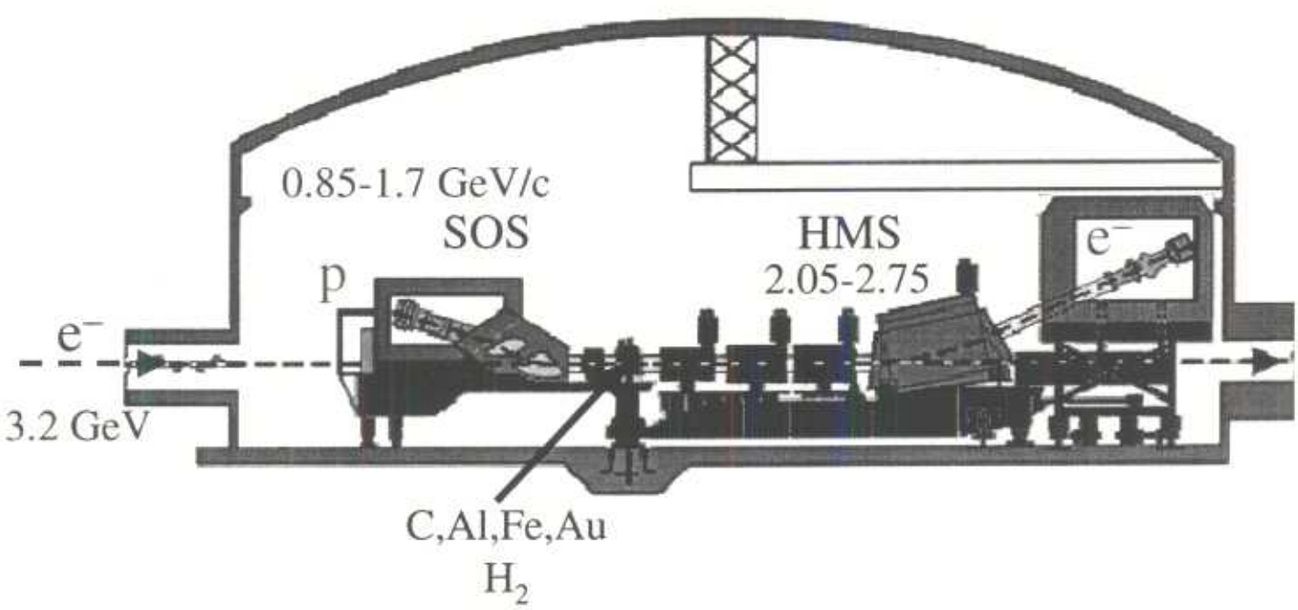
⟺ perpendicular kinematics: $\vec{k} \perp \vec{q}$

most of previous exp.:
large excess in data compared to PWIA

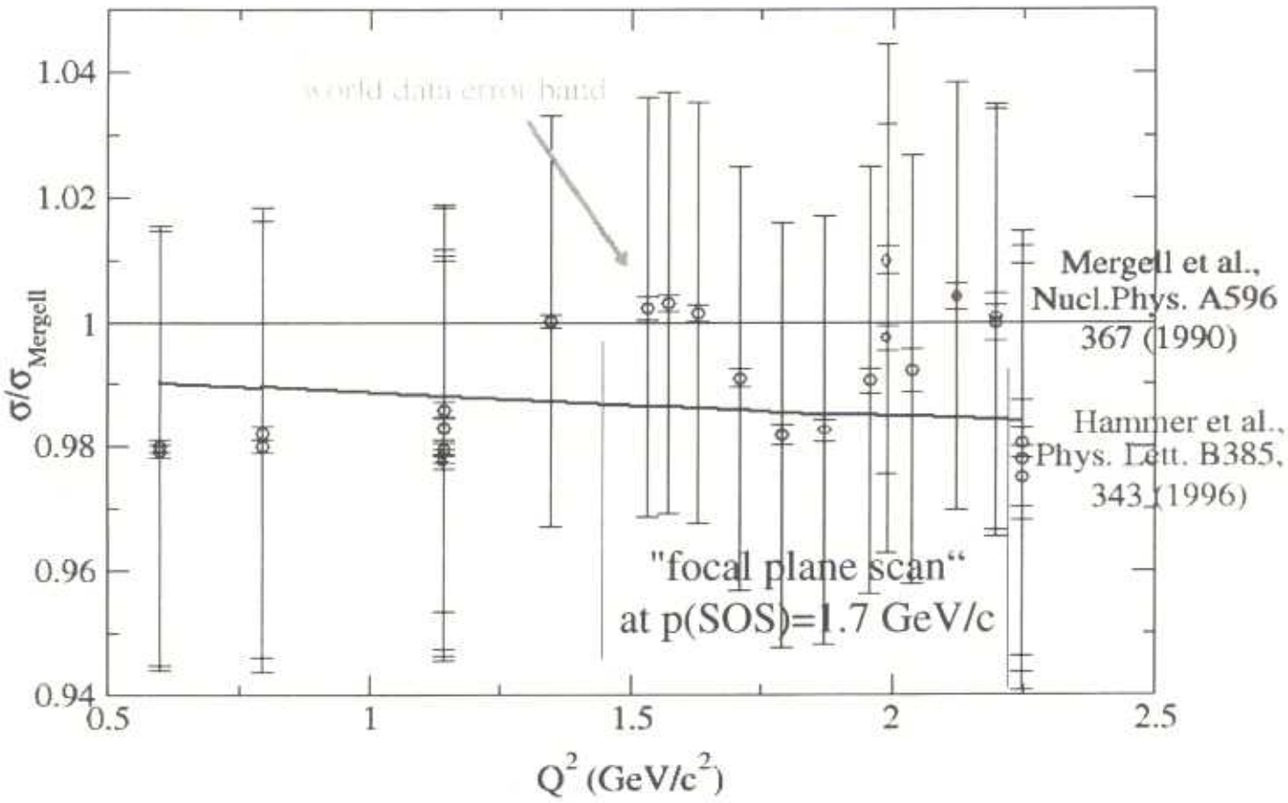
Covered E_m-P_m range:



Setup in Hall C at TJNAF:



H_2 cross section



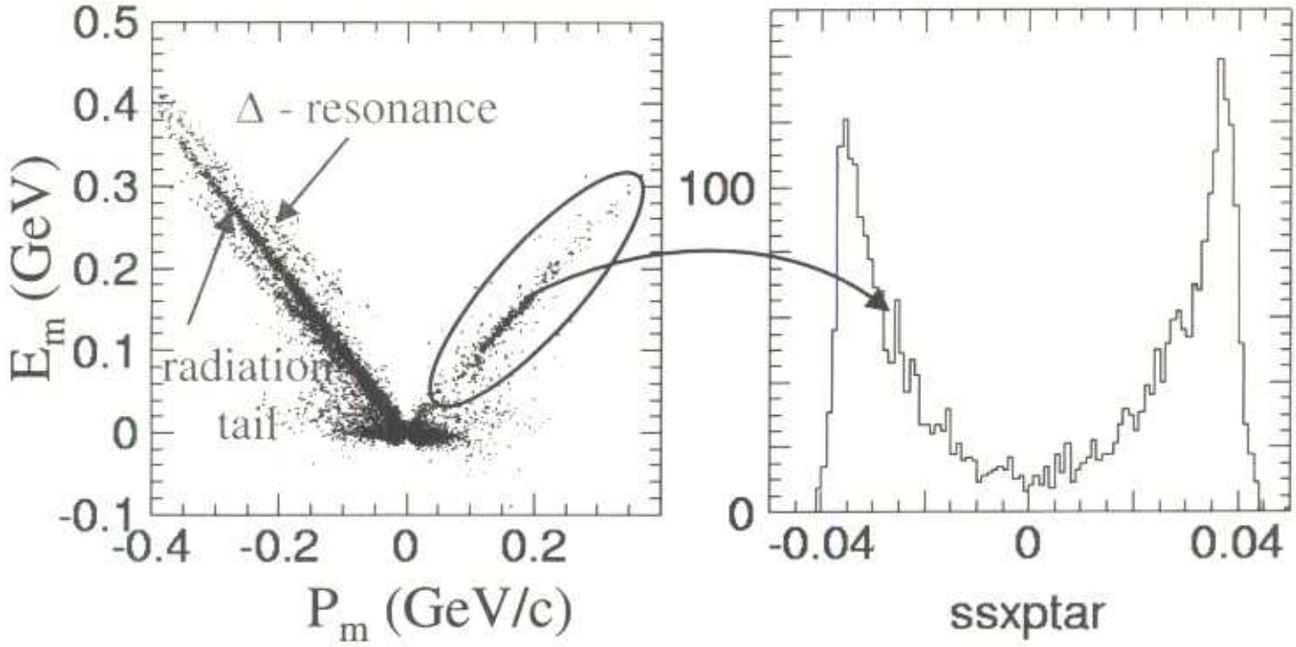
statistical error negligible
systematical error of ~ 3.5 %:

- uncertainty in beam energy: 10^{-3}
- in electron angle: 1mrad
- current, efficiencies ...

Corrections:

- dead time(10-20%), detector efficiency (Č,tracking 98%)
- proton transmission (95.2%):
  = protons in SOS/electrons in a small centered region
- blocking of coincidence events
  due to a single event (1-2%)
- " focal plane efficiency " (~3%)
  using inelastic data at different momenta and fixed angle

H_2 - data: Some strange events ...



Further examinations:

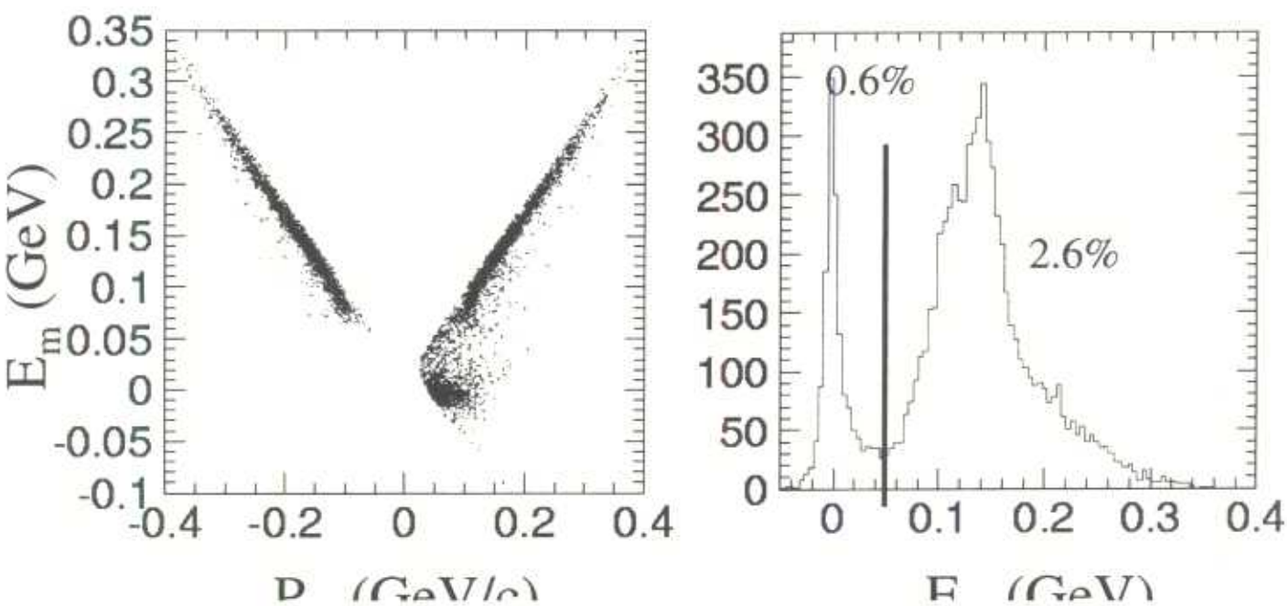
1) Select "good" electrons

   Cut on hsyptar-hsdelta relation,

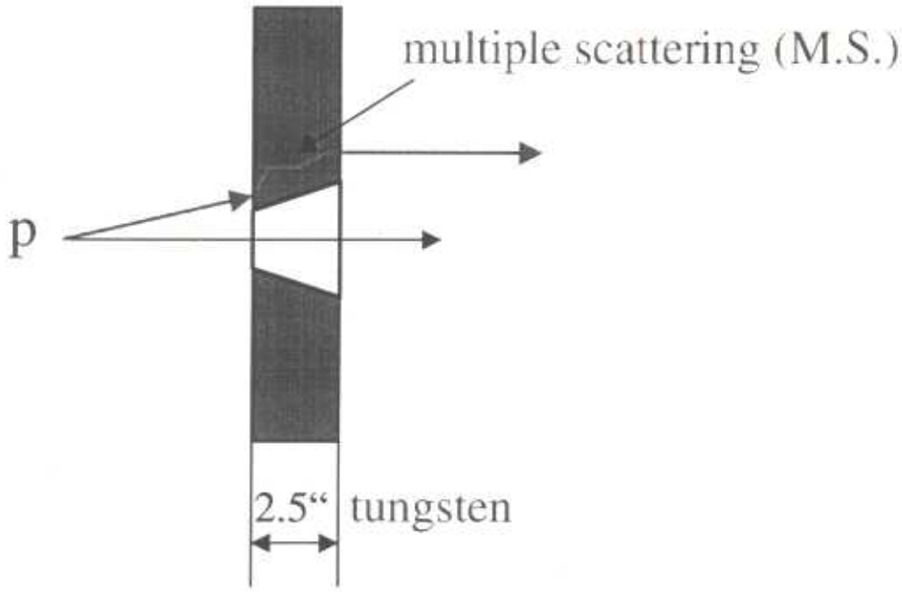
   Cut off Δ-region

2) Eliminate good protons

   Cut below ssyptar-ssdelta relation



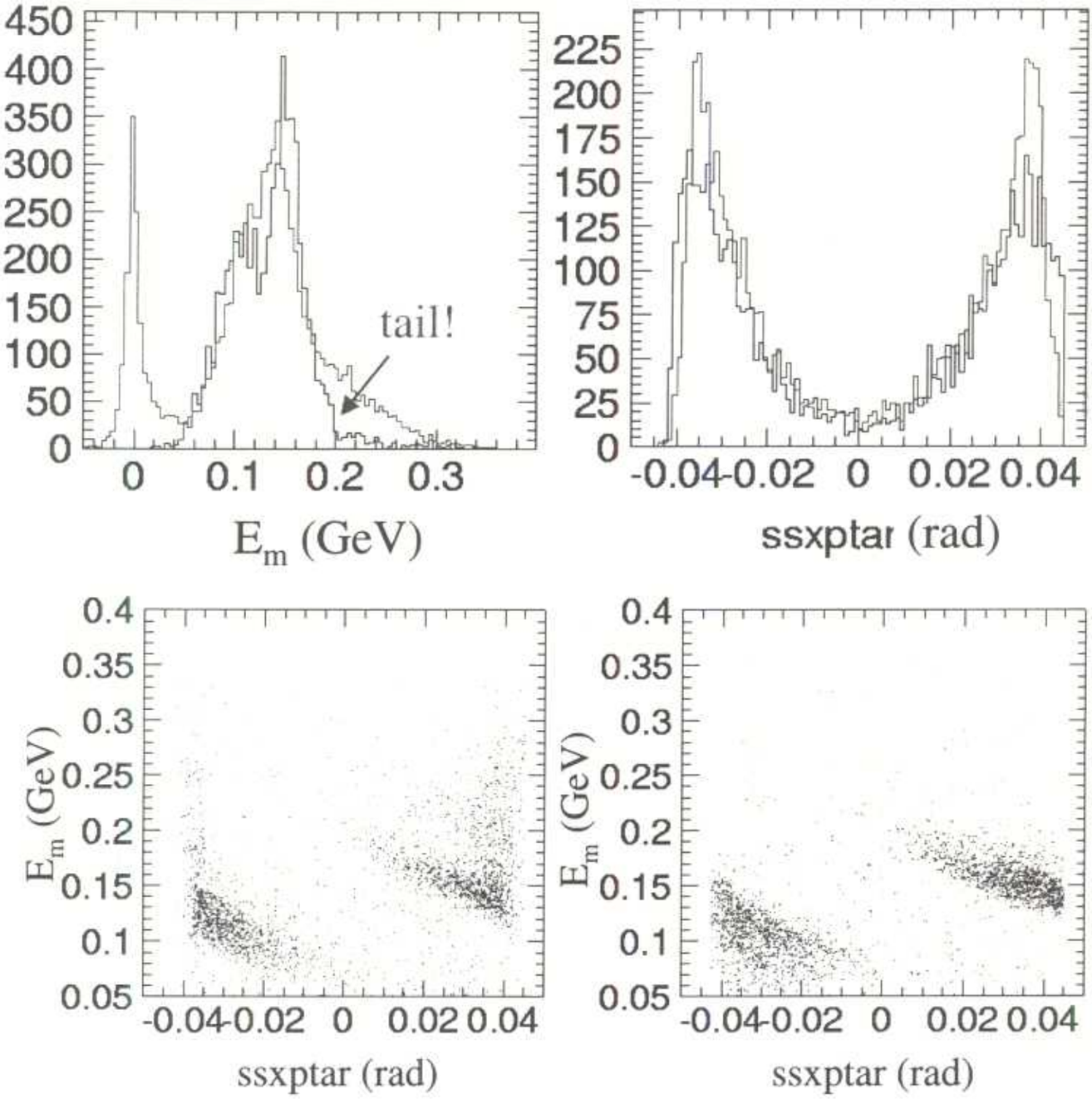
Idea:
Protons (p>1GeV/c) penetrate collimator



Monte-Carlo model:

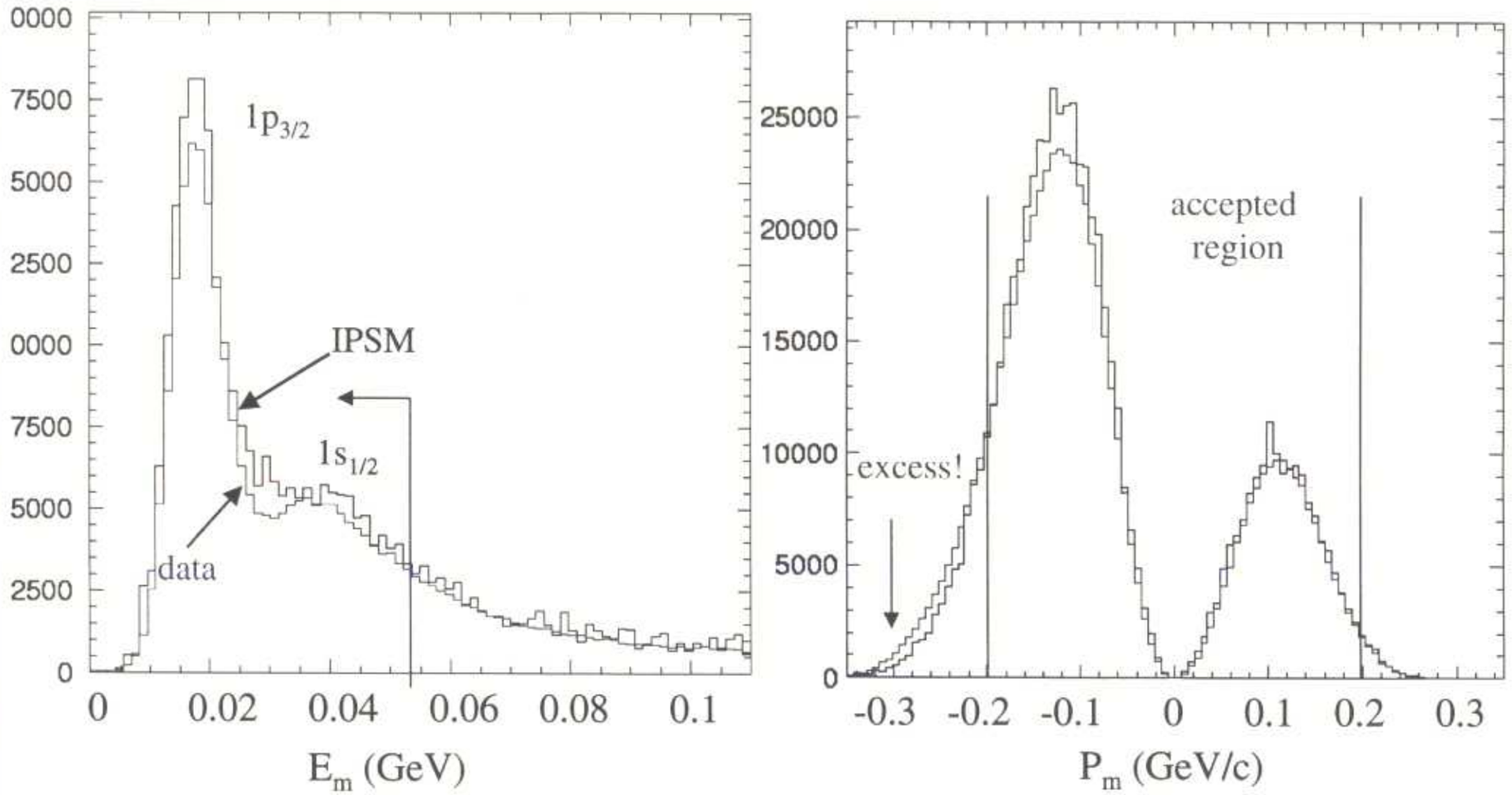
1) Gaussian distribution around most probable energy loss in tungsten:
   p=1.7 GeV/c: $\Delta E \approx 150$ MeV
   p=1.2 GeV/c: $\Delta E \approx 170$ MeV
2) Applying M.S. after passing through
3) Assume, that 50 % of the protons will be lost somewhere ...

Comparing M.C. and data:



agreement between simple M.C. model and data is quite good!

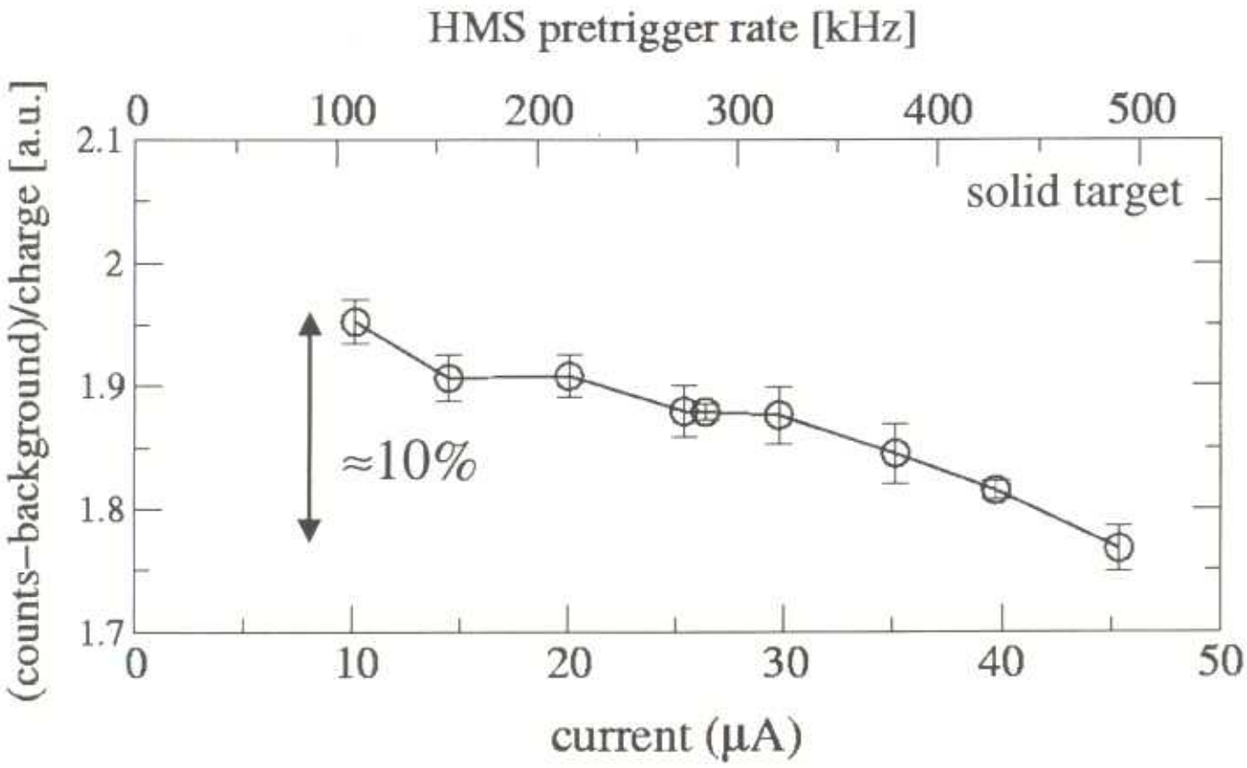
Quasielastic data for ^{12}C in IPSM-region



data / IPSM $\cong$ 81 %

$\longrightarrow$ agrees with expected correlated contribution of $\approx$ 20 %

Rate dependence on current?

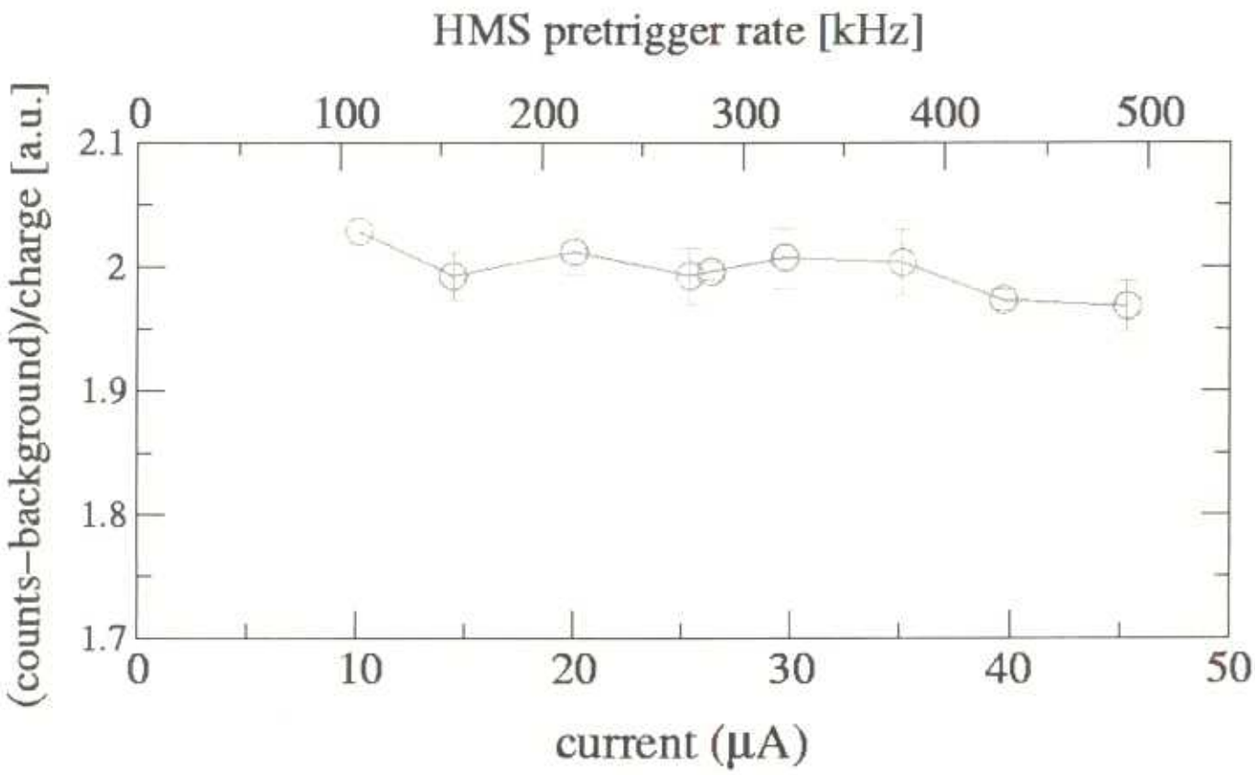


Examination using event displayer:

1) possible tracks > 3:
often wrong track chosen
→ use only events with tracks ≤ 3

2) at high rate:
good events can have > 15 hits in one chamber
(condition in calculating the tracking efficiency)
→ drop this condition

in addition:
resonable constraints for choosing the right track:
e.g.: |hsdelta|<20%, |ytar|<10 .....


HMS pretrigger rate [kHz]
0
100
200
300
400
500
2.1
2
1.9
1.8
1.7
(counts−background)/charge [a.u.]
0
10
20
30
40
50
current (μA)

Extraction of the spectral function:(in PWIA)

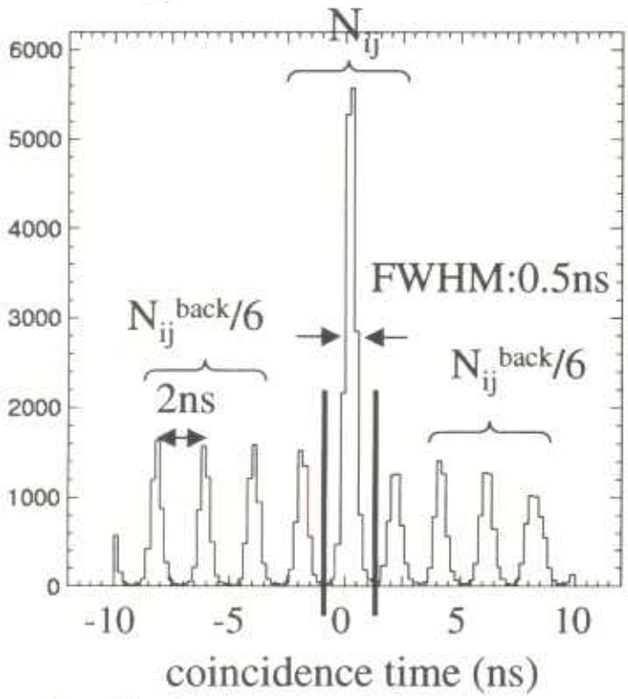
$$\frac{d\sigma}{d\Omega_e\, d\Omega_p\, dE'_e\, dE'_p} = K\ \sigma_{ep}\, S(E_m,P_m)\, T_p$$

e-p off shell c.s. (de Forest,CC1)

nuclear transparency (=0.6 for C)

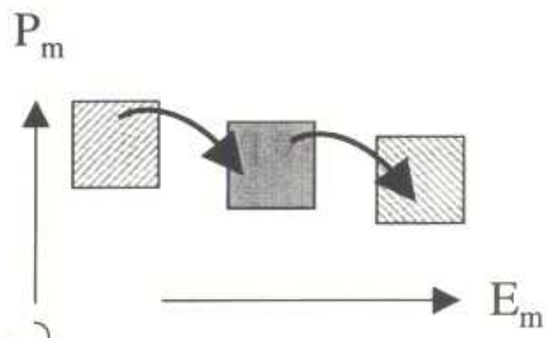
Binning of data in $(E_m,P_m)_{ij}$: ΔE_m= 10-50 MeV, ΔP_m= 40 MeV/c

- Phase space taken from M.C.
- Background substraction:



- Radiative process:

events are radiated in and out of a given (E_m,P_m) bin



$$[S(\overline{E}_m,\overline{P}_m)_{ij}]_{derad} = S(\overline{E}_m,\overline{P}_m)_{ij}\ \frac{N_{ij}^{norad}}{N_{ij}^{rad}}$$

spectral function is needed

weighted events from MC

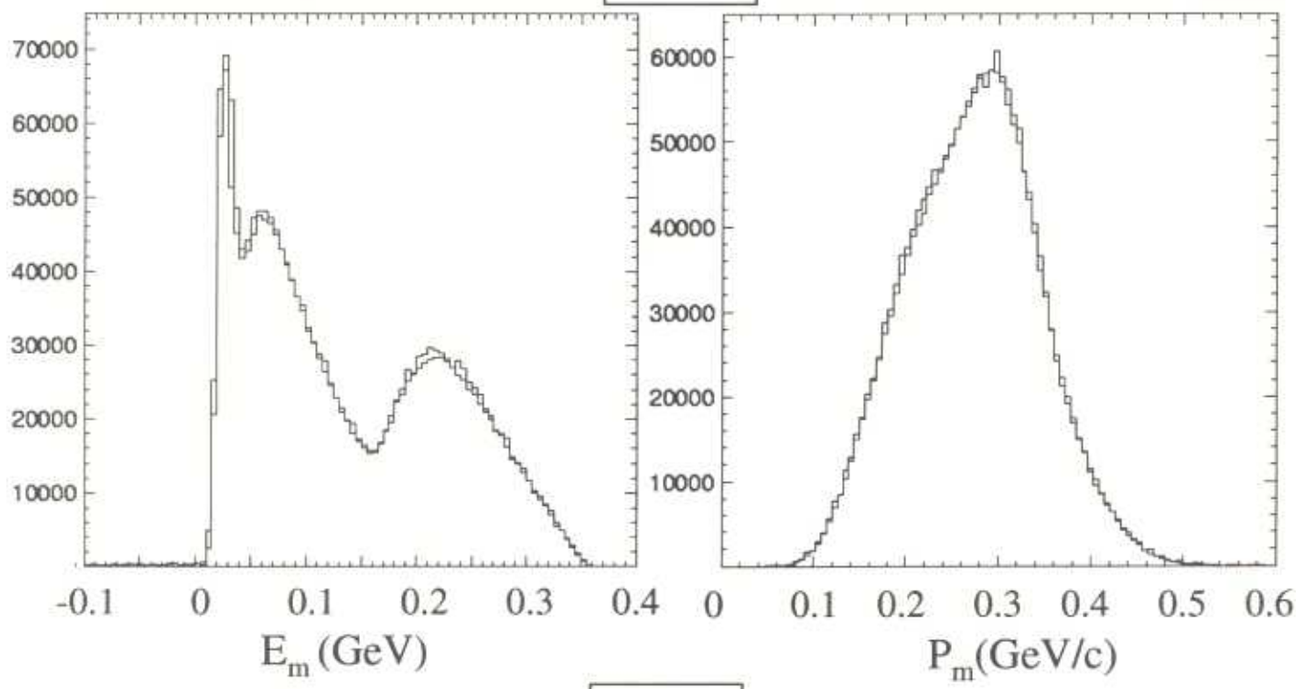
fit to exp. spectral function

after some iterations . . .

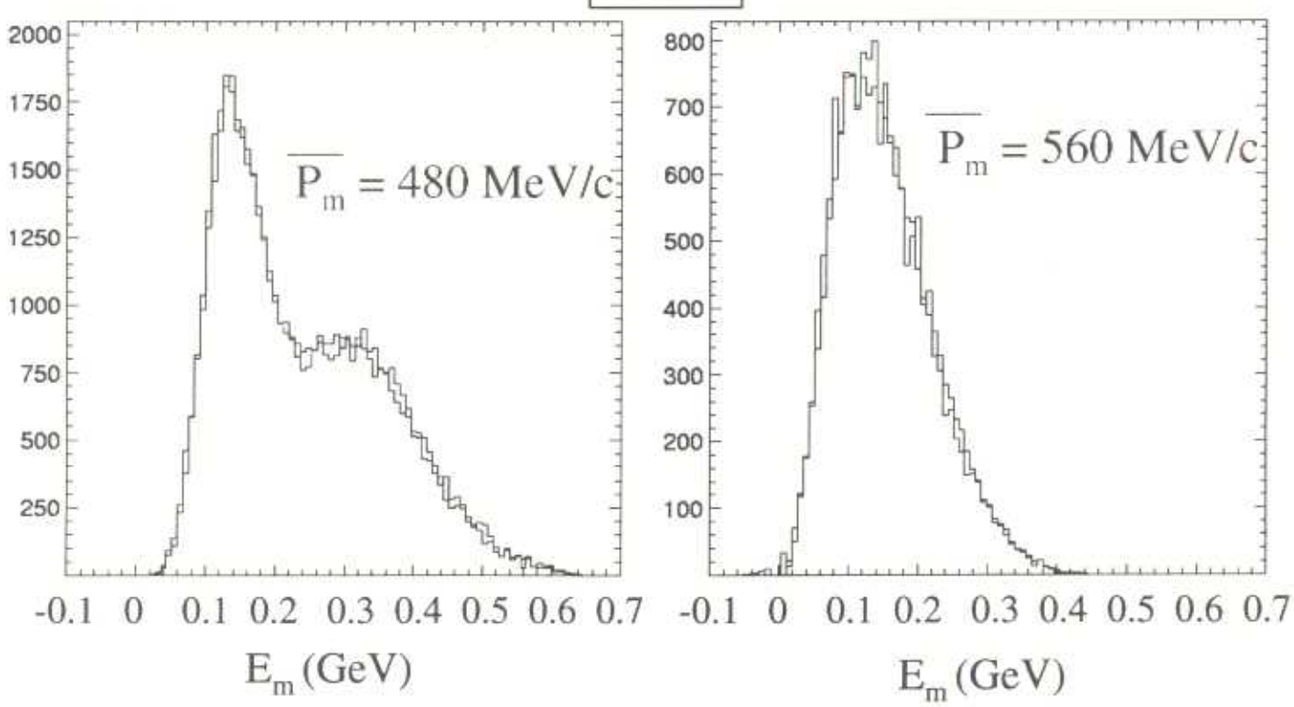
data:black

MC with fitted exp. spectral function: red

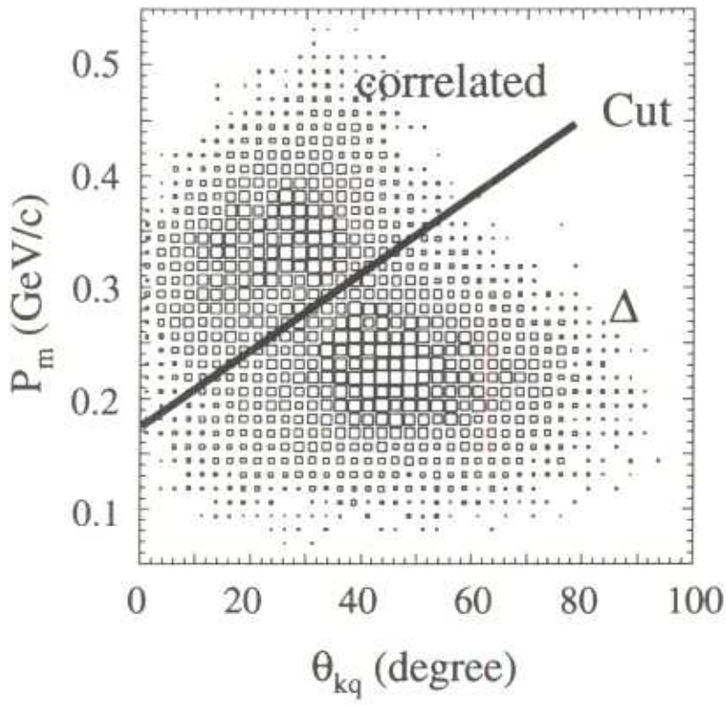
Kin5

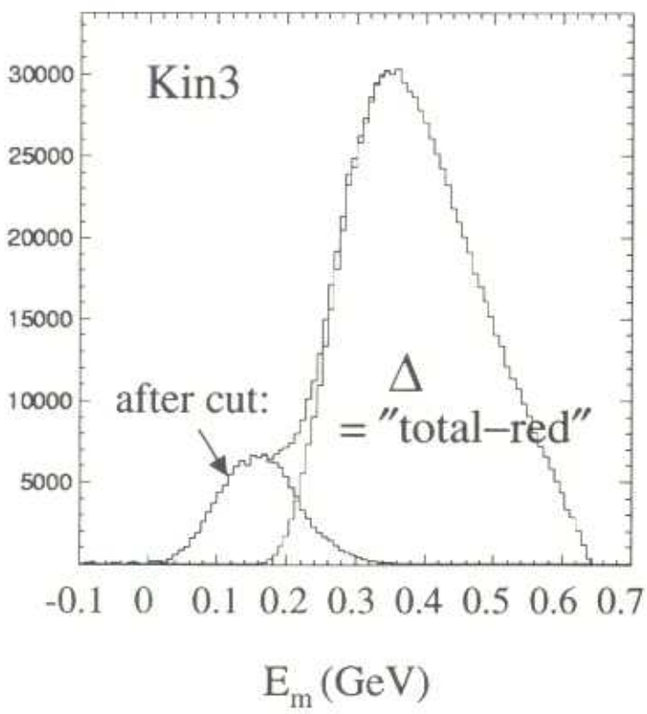


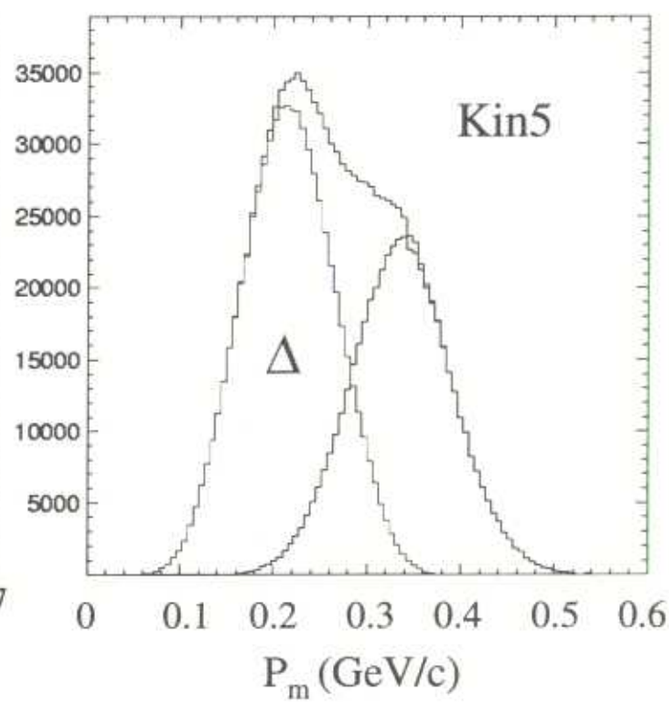
Kin3



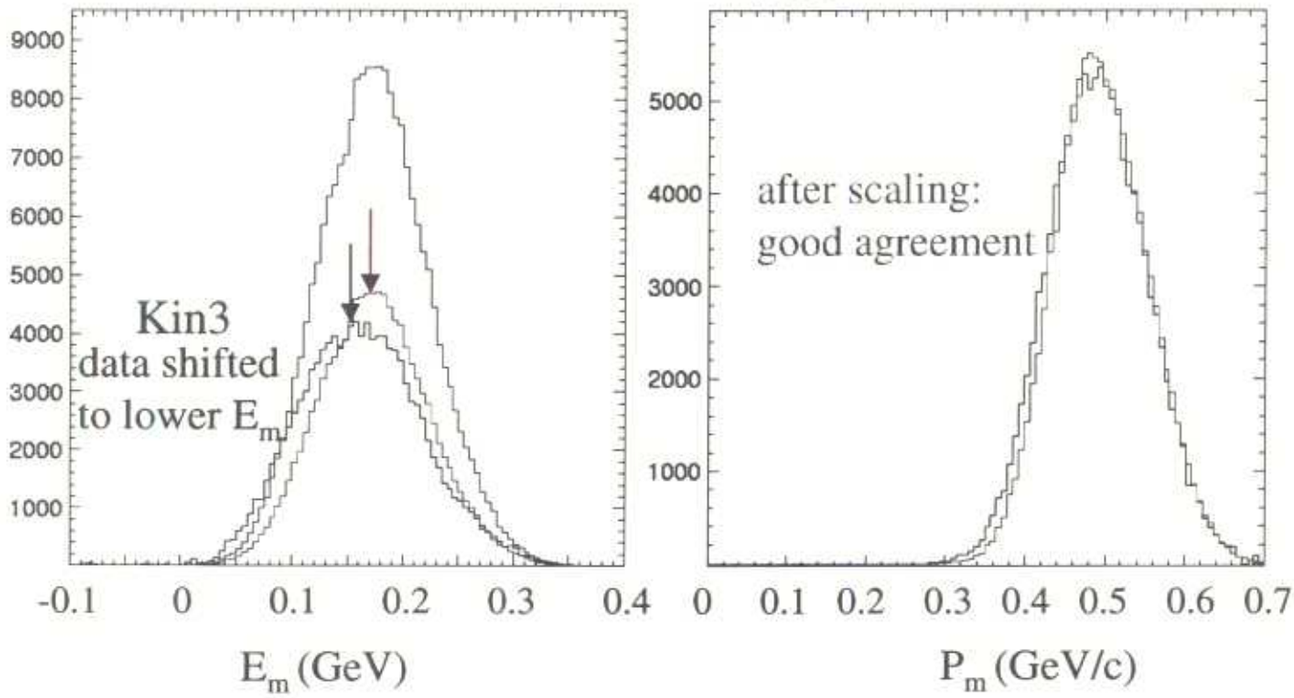
Separation of the correlated from Δ region



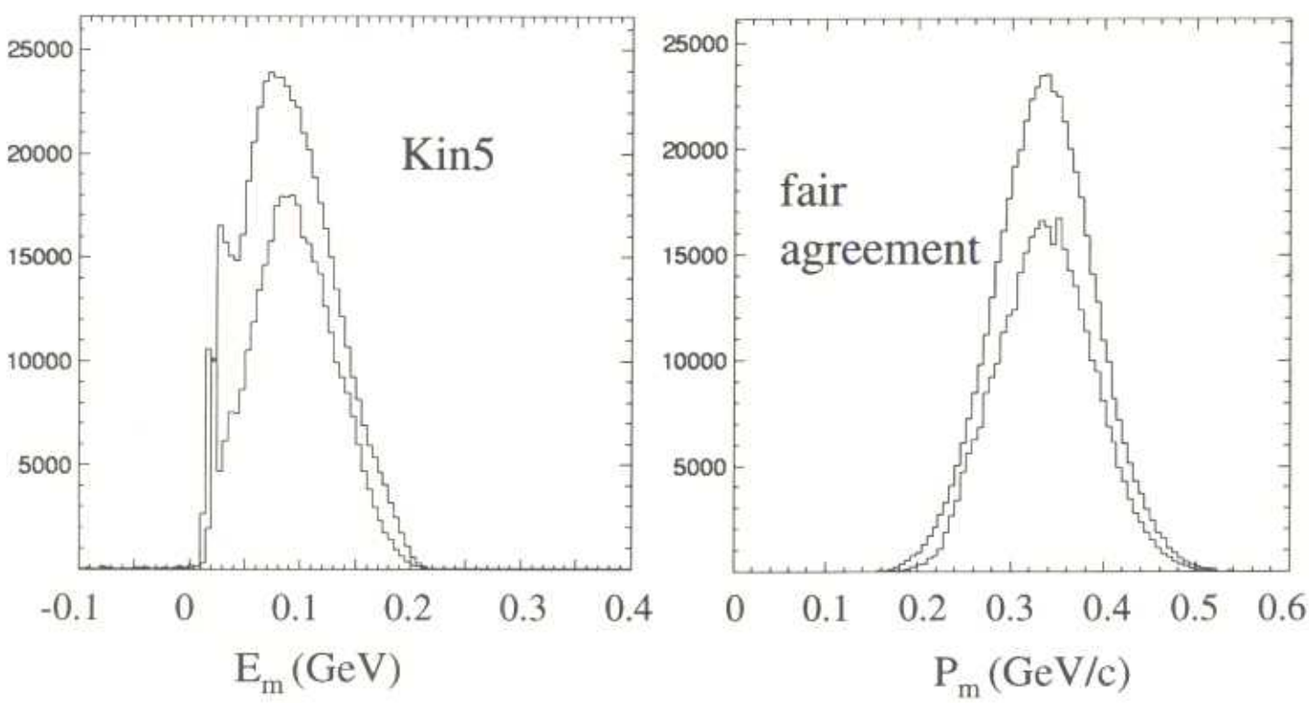




comparsion to theory, only absorption (O. Benhar):black
theory scaled by factor 0.55 : blue
data : red



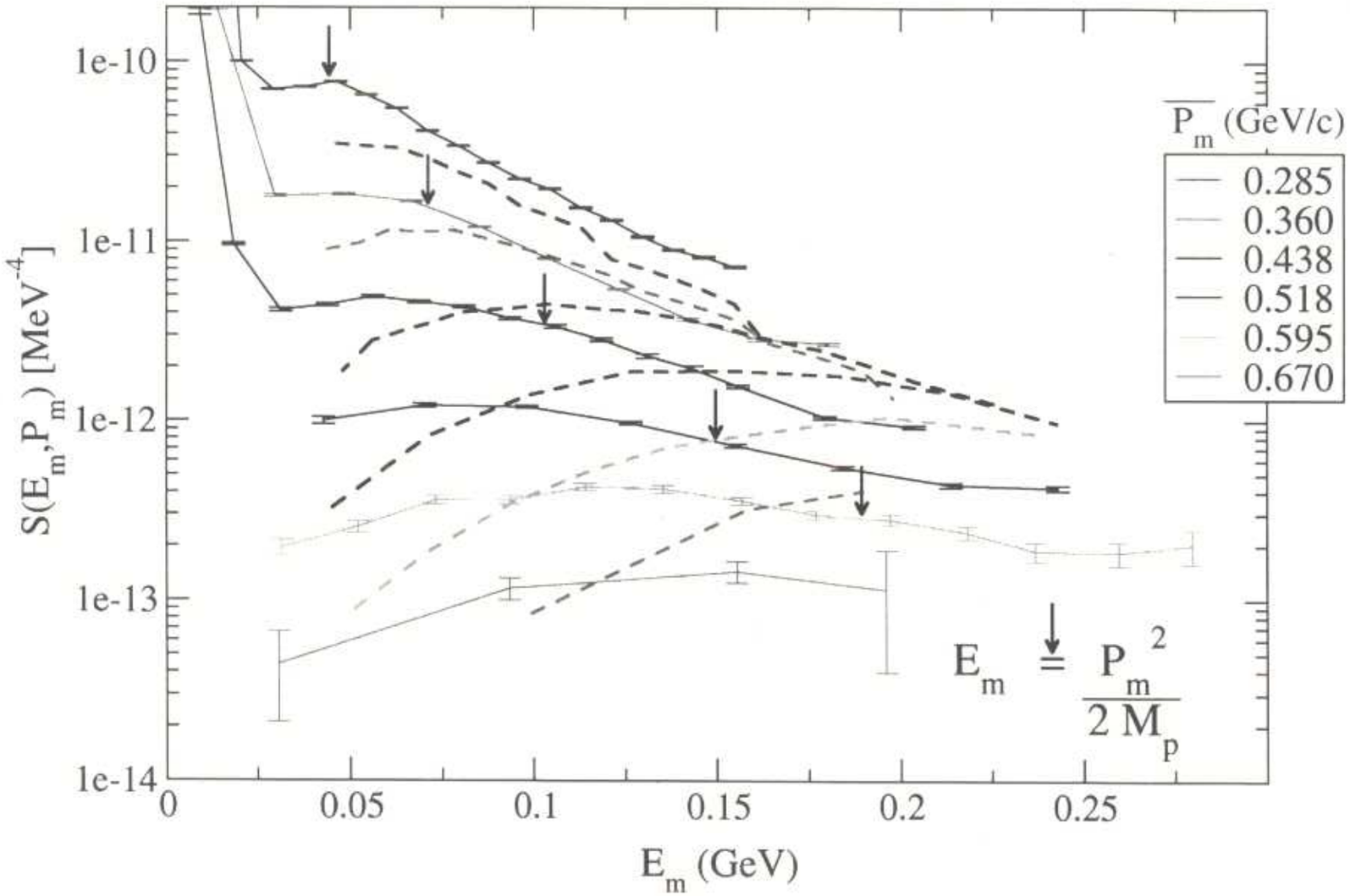
→ at high P_m: theory is a factor ≈ 2 too high!



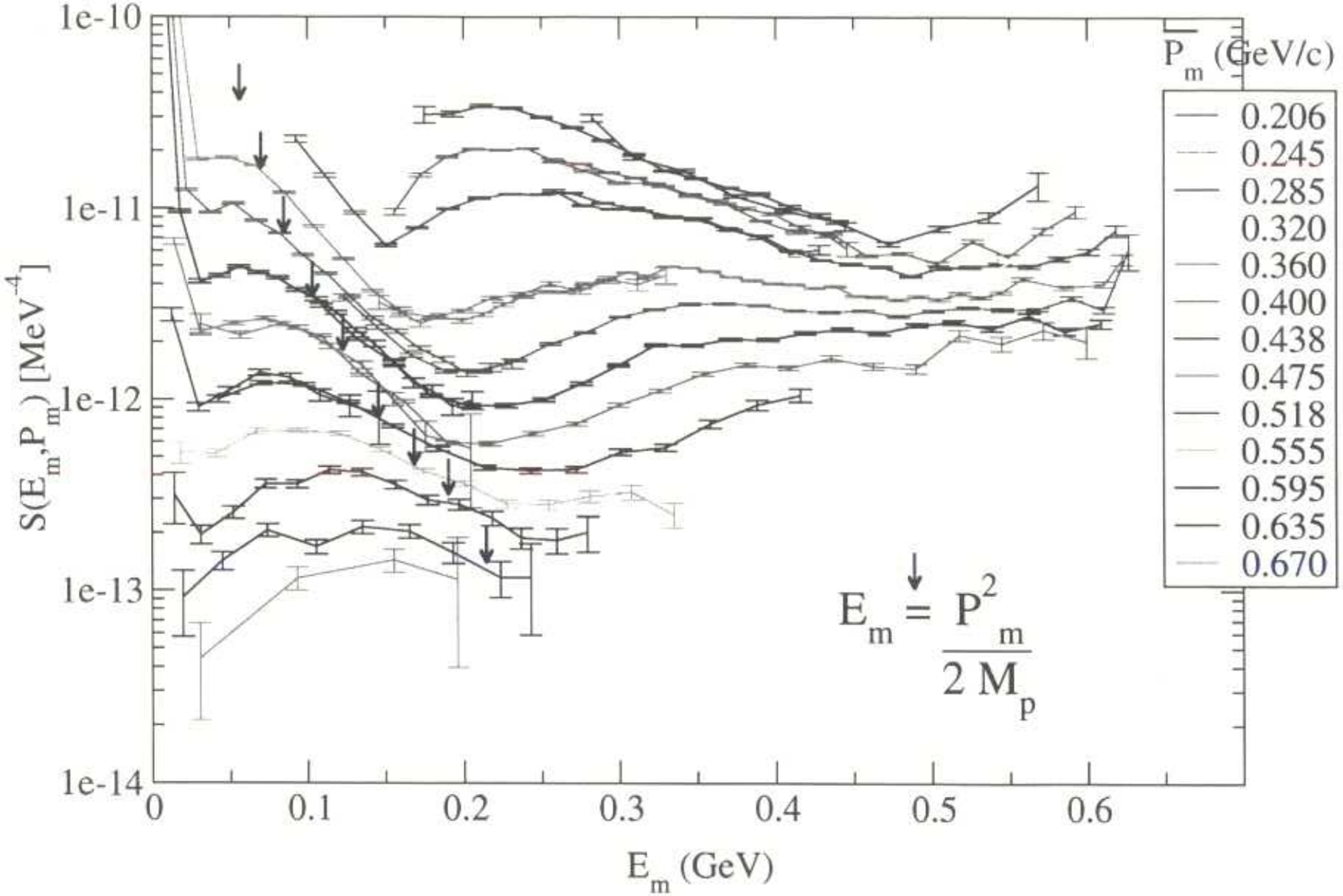
→ at low P_m: theory is a factor ≈ 1.5 too low!

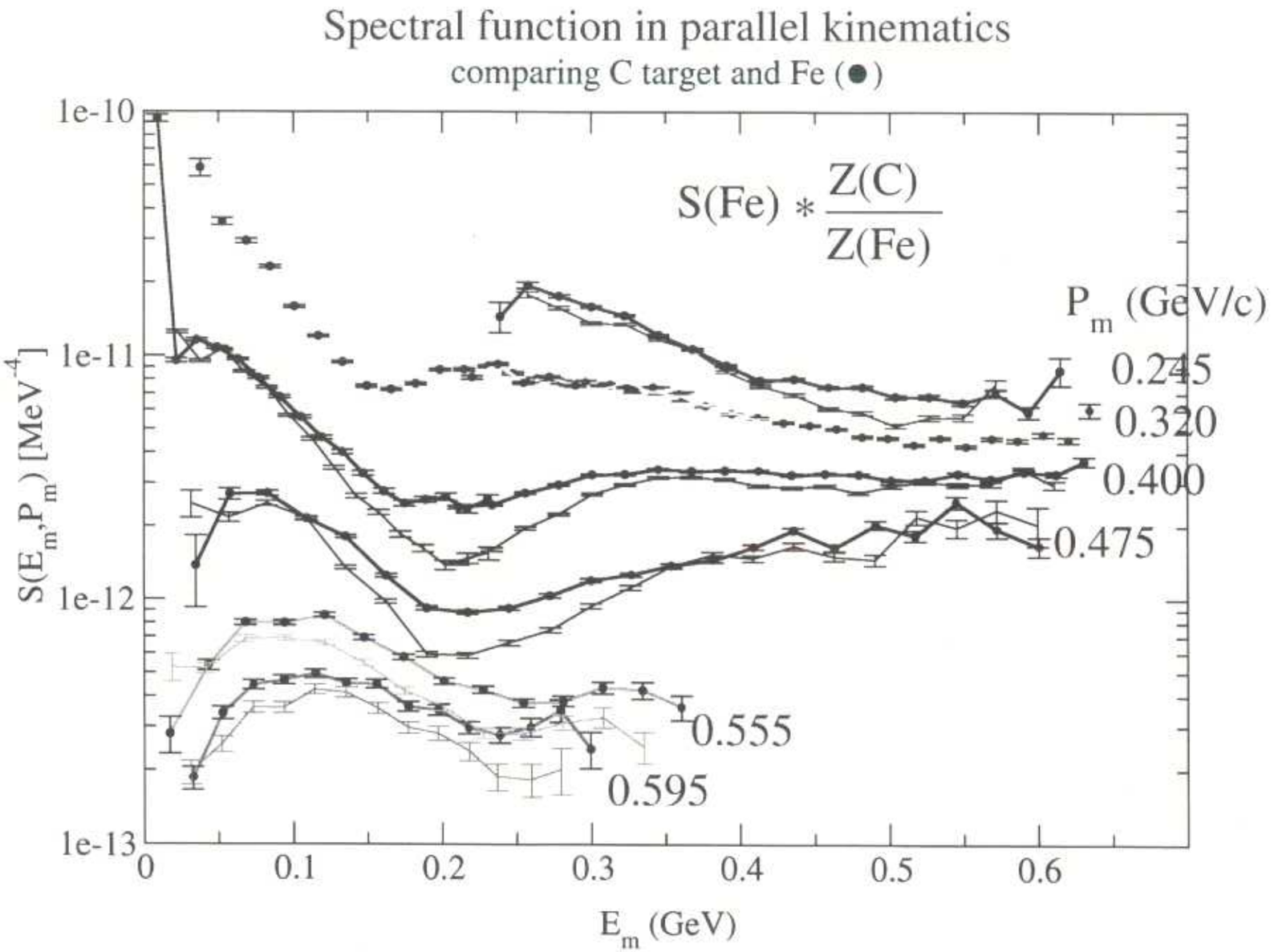
Spectral function for ^{12}C in parallel kinematics

dashed: theory (Benhar)

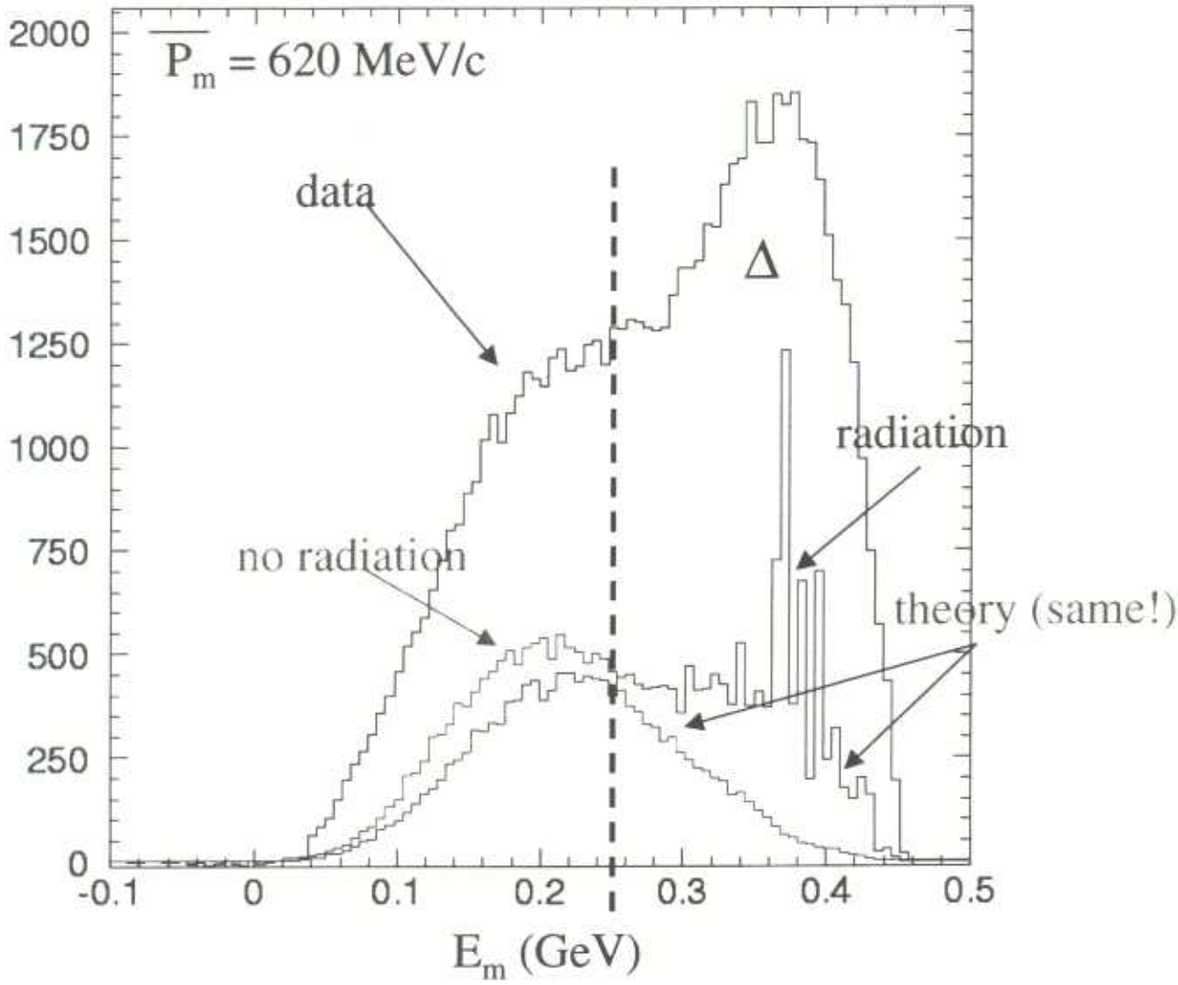


Spectral function for ^{12}C in parallel kinematics




Spectral function in parallel kinematics
comparing C target and Fe (●)
S(Fe) * Z(C)/Z(Fe)
P_m (GeV/c)
0.245
0.320
0.400
0.475
0.555
0.595
1e-10
1e-11
1e-12
1e-13
0
0.1
0.2
0.3
0.4
0.5
0.6
S(E_m,P_m) [MeV^-4]
E_m (GeV)

Perpendicular kinematics: $0.1 < P_m < 0.8$ GeV/c

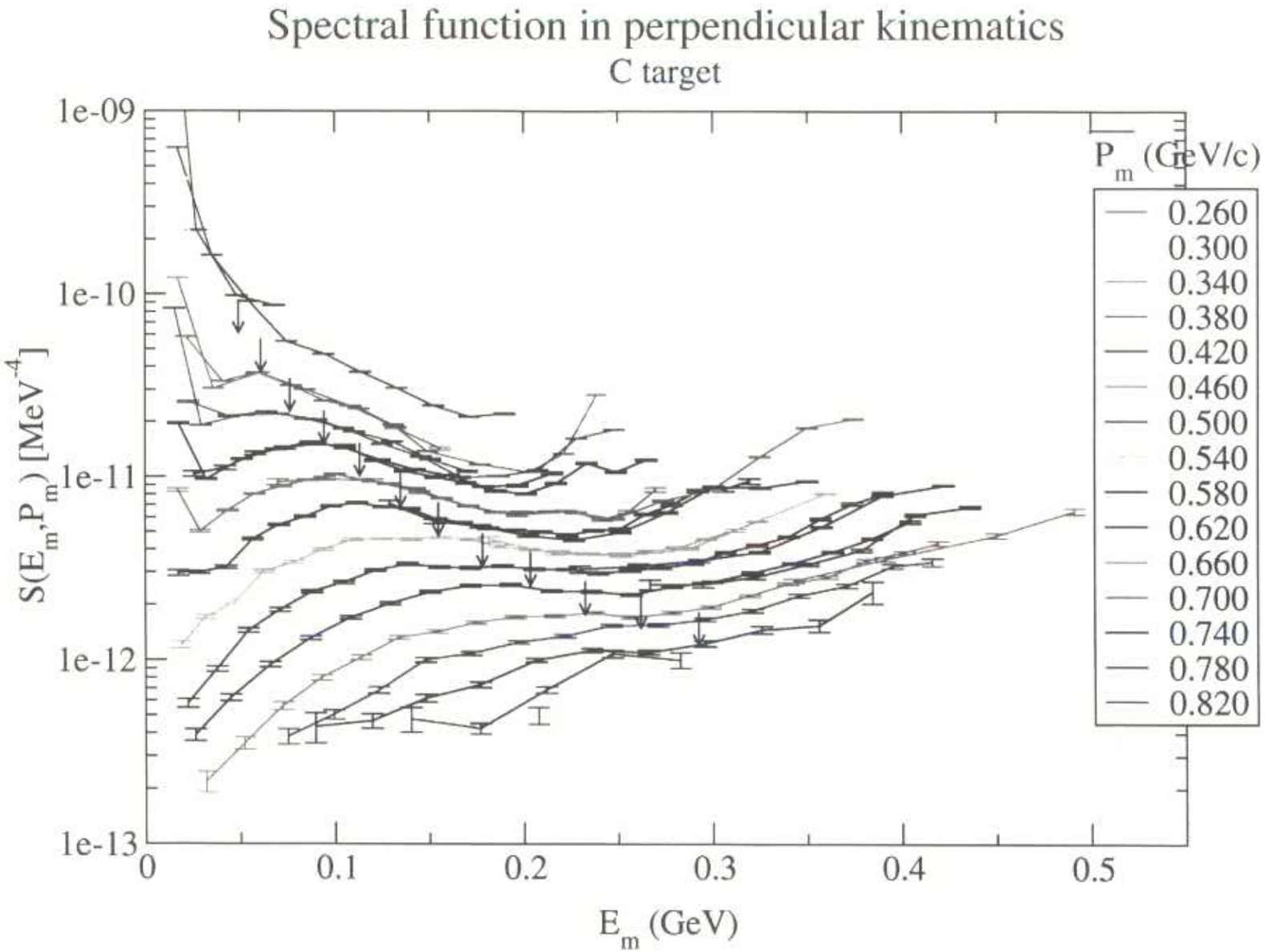


- large radiative correction at large E_m
- can not separate Δ

Comparing data and theory :

$E_m < 0.25$ GeV: $\frac{\text{data}}{\text{theory}} \approx 3$ due to multi-step reaction

C. Barbieri (Dickhoff, Müther):
calculation of 2-step processes


Spectral function in perpendicular kinematics
C target
1e-09
1e-10
1e-11
1e-12
1e-13
0
0.1
0.2
0.3
0.4
0.5
$S(E_m,P_m)$ [MeV^{-4}]
E_m (GeV)
P_m (GeV/c)
0.260
0.300
0.340
0.380
0.420
0.460
0.500
0.540
0.580
0.620
0.660
0.700
0.740
0.780
0.820

Momentum distribution:

general definition:

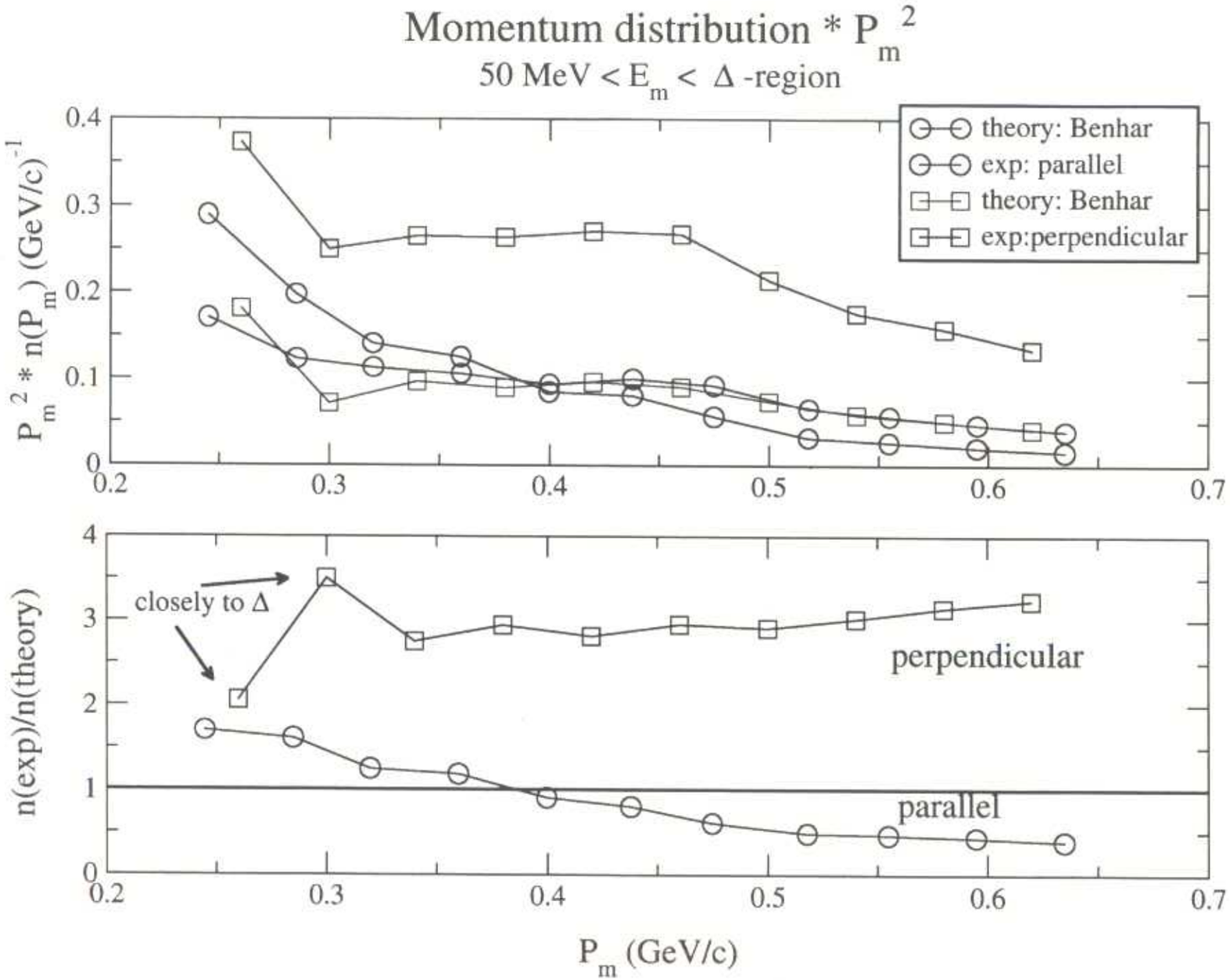
$$n(P_m) = \int_{„0“}^{\infty} dE_m \; S(E_m, P_m)$$

interested in: correlated region

excluding: single particle states and Δ region

$$n_{ex}(P_m) = \int_{50\mathrm{MeV}}^{<\Delta\,(P_m)} dE_m \; S(E_m, P_m)$$

$< \Delta$: difficult in perpendicular kinematics
„broad minimum“ between correlated and Δ-region


Momentum distribution * P_m^2
50 MeV < E_m < Δ -region
theory: Benhar
exp: parallel
theory: Benhar
exp:perpendicular
P_m^2 * n(P_m) (GeV/c)^-1
0.4
0.3
0.2
0.1
0
0.2
0.3
0.4
0.5
0.6
0.7
closely to Δ
perpendicular
parallel
n(exp)/n(theory)
4
3
2
1
0
P_m (GeV/c)

Protons in correlated region = „correlated factor Z_C“:

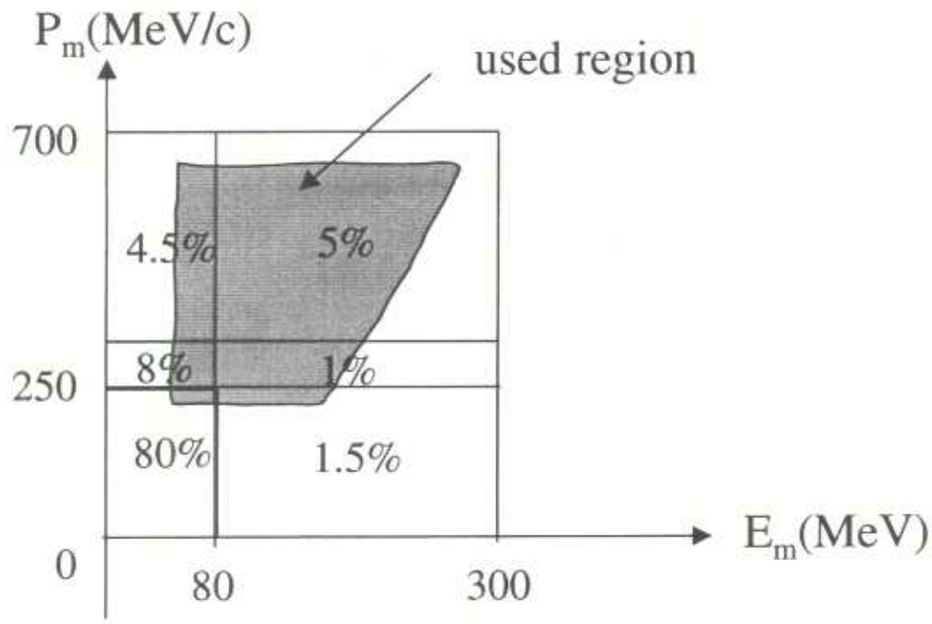
$$Z_C = 4\pi \int_{240\,\mathrm{MeV/c}}^{640} dP_m P_m^2 \, n_{ex}(P_m)$$

	exp.	theo.(Benhar)
∥	0.52	0.49
⊥	1.22	0.44

only 1/2 proton!

⟷ 20 % in „correlated region“ ?
(=1.2 proton in C)

Distribution of theoretical spectral function



⟹ only half of the total correlated region is covered

Summary:

- H_2 data (after applying corrections) are in agreement with world data fit
- Special analysis features:
  - Fast protons penetrating colli (simulated with M.C.)
  - Track selection (→ rate/current ≈ const.)
- Quasielastic scattering on ^{12}C: (IPSM-region) ratio exp. yield to IPSM model of ~ 0.8 as expected
- Extraction of the spectral function, treatment and effect of radiative corrections
- Parallel kinematics on ^{12}C: (in correlated region)
  $P_m < 400$ MeV/c: S_{theory} too small
  $P_m > 400$ MeV/c: S_{theory} too large
  shifted to larger E_m
- Perpendicular kinematics on ^{12}C:
  exp./theory: factor 3 !! (indep. of P_m)
  calculation of the rescattering (multi-step) process are underway
- Comparing spectral function for Fe and C quite similar especially at low P_m and low E_m