Kaon-Nucleus Potential and the In-Flight (K^-, N) Reaction Mechanism

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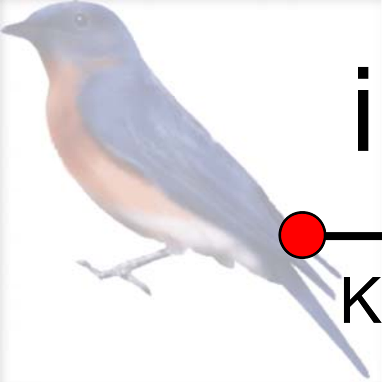
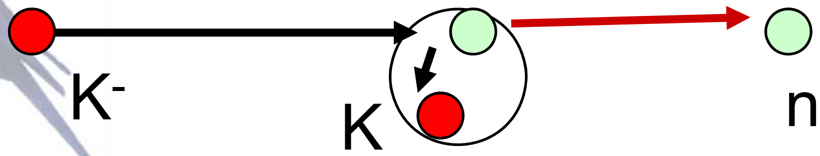
K-nucleus interaction

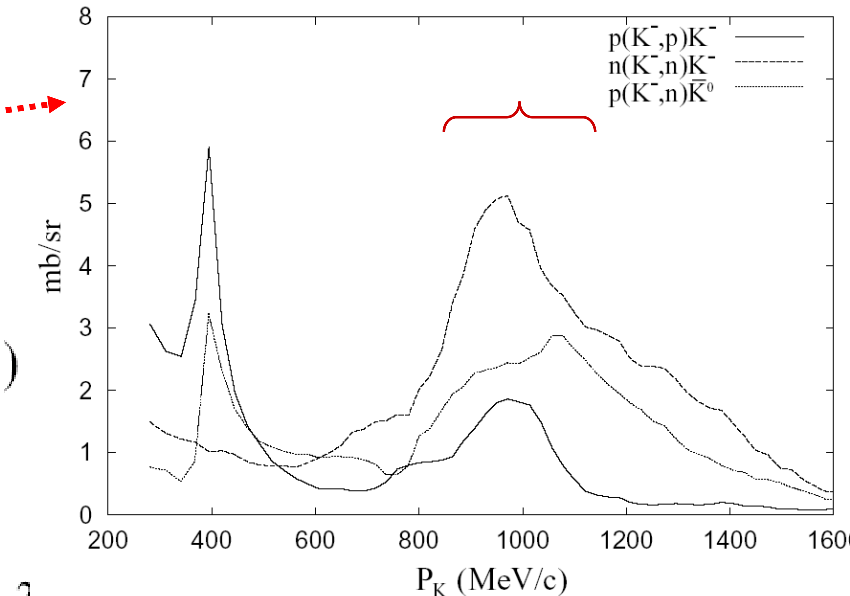
- Atomic X ray data: two solutions (Batty, Friedman, Gal)
  - deep ~180 MeV and/or shalow ~80 MeV
- Λ(1405)
  - K^- p X ray data
- K^- production in HI reaction: attractive
- Recent experiments
  - structure in deeply bound region (potential ?)
    - FINUDA, KEK, GSI
- Reaction mechanism
  - Theory: structure
  - Experiment: reaction

in-flight (K⁻,N) reactions





Elementary cross section



$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)^{K^- N \to N K^-}_{L,0^\circ} \mathrm{FF}_{\mathrm{state}}$$

$$\mathrm{FF}_{\mathrm{state}} = (2J+1)(2j_N+1)(2\ell_K+1) \times \begin{pmatrix} \ell_K & j_N & J \\ 0 & -\frac{1}{2} & \frac{1}{2} \end{pmatrix}^2 F(q)\,.$$

$$F(q) = \left(\int r^2\, dr\, R_K(r) R_N(r) j_L(qr)\right)^2$$

TK, PRL83

- $q \sim 0.3$ GeV/c $\sim p_F$

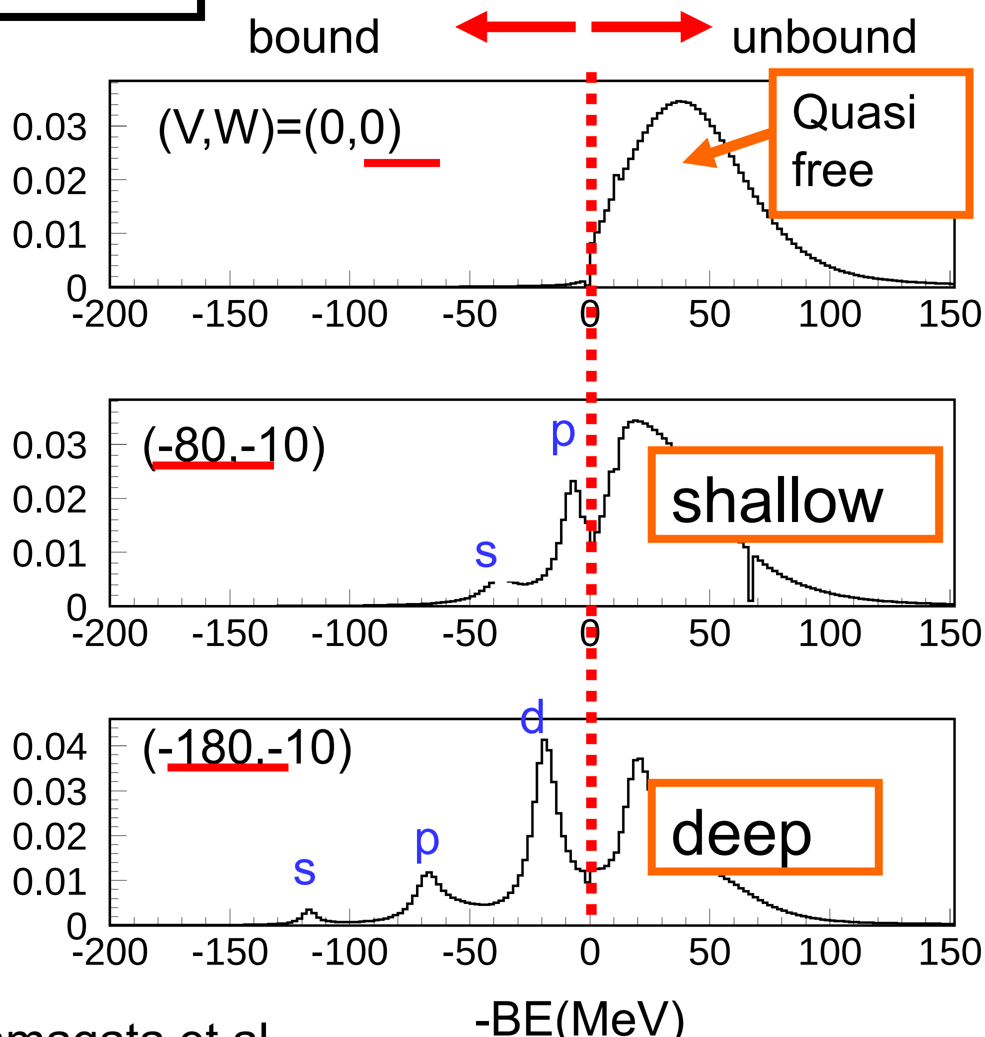
$d\sigma/d\Omega(\mathrm{lab}) = (P_l/P_{cm})^2 d\sigma/d\Omega(\mathrm{CM})$ ~10mb/sr

★predictable cross section

★Little background (p_N~1.3GeV/c for p_K~1 GeV/c)

Missing mass spectroscopy (Excitation energy spectra vs DWIA)

DWIA calc.



Yamagata et al.

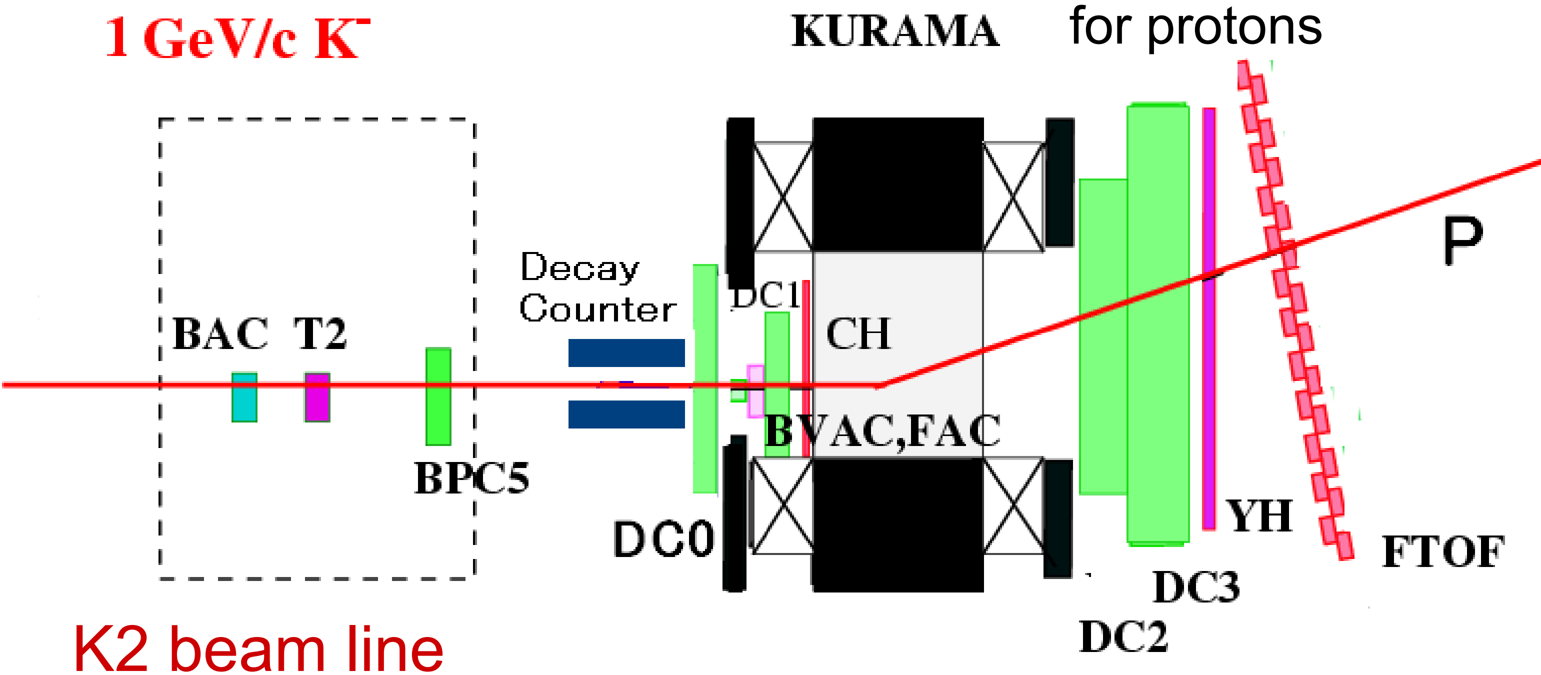
- Energy integrated cross section ~ N_{eff} x $(d\sigma/d\Omega)_{elem}$ =10~20 mb/sr

Imaginary part smears structure

KEK-PS E548

- (K^-,p) and (K^-,n) reactions on
  - ^{16}O (water target)
  - ^{12}C (graphite and CH_2 targets)
- Improvements over BNL experiment
  - Proton (KURAMA spectrometer): 12MeV(σ)@BE=150MeV
  - Neutron counter: ~20msr, 10MeV(σ)@BE=150MeV
  - Decay counter (NaI array): ~0.5 of 4π

Beam line and spectrometer

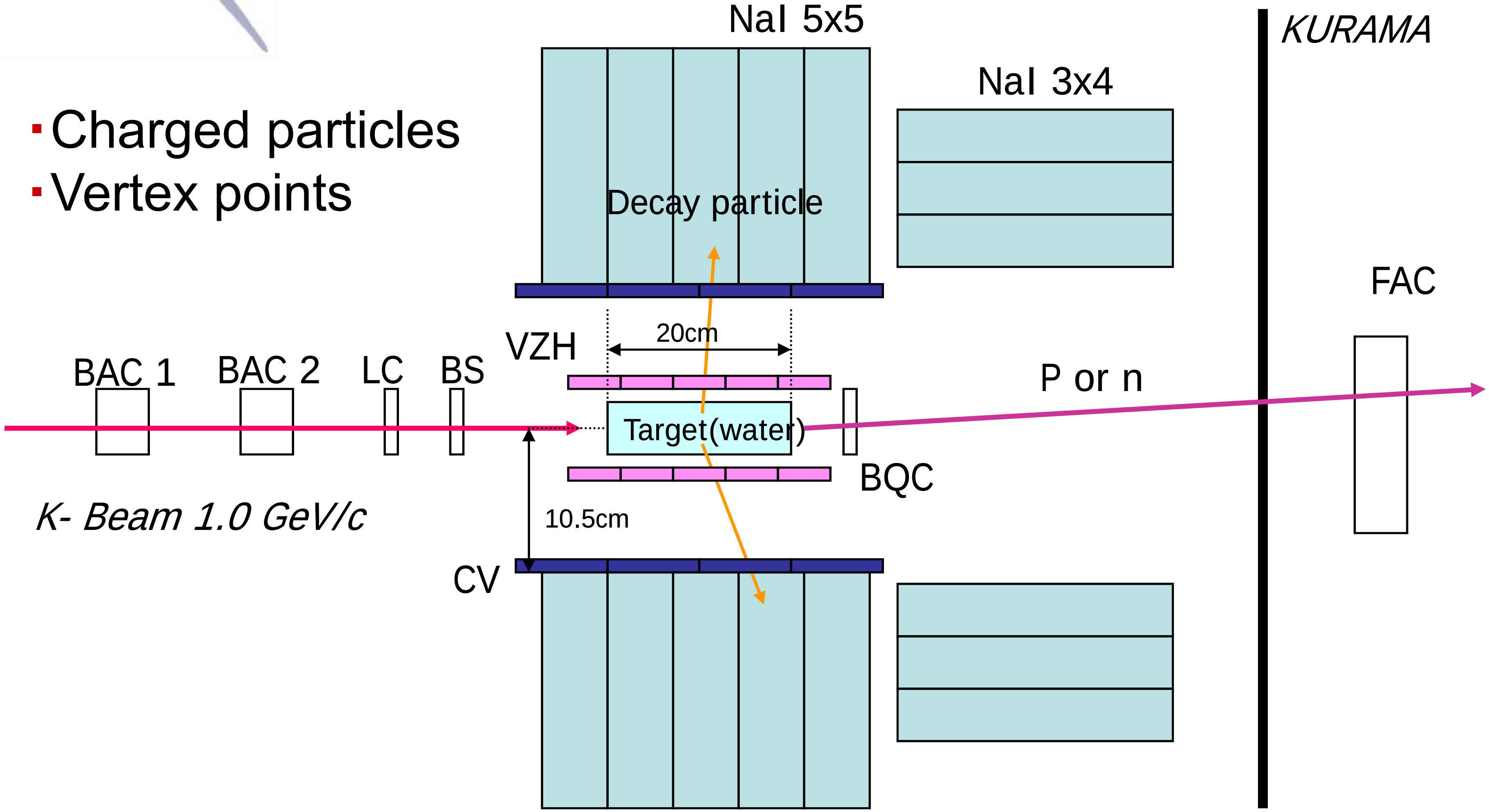


p_K=1 GeV/c (p_N=1.2~1.3 GeV/c)
10k K^- for 3Tp (~1/10 of BNL)
Trigger rate ⇨ ∼500/spill
~1G K^- on Target

Liquid scintillator + plastic scintillator for Neutrons

Decay counter

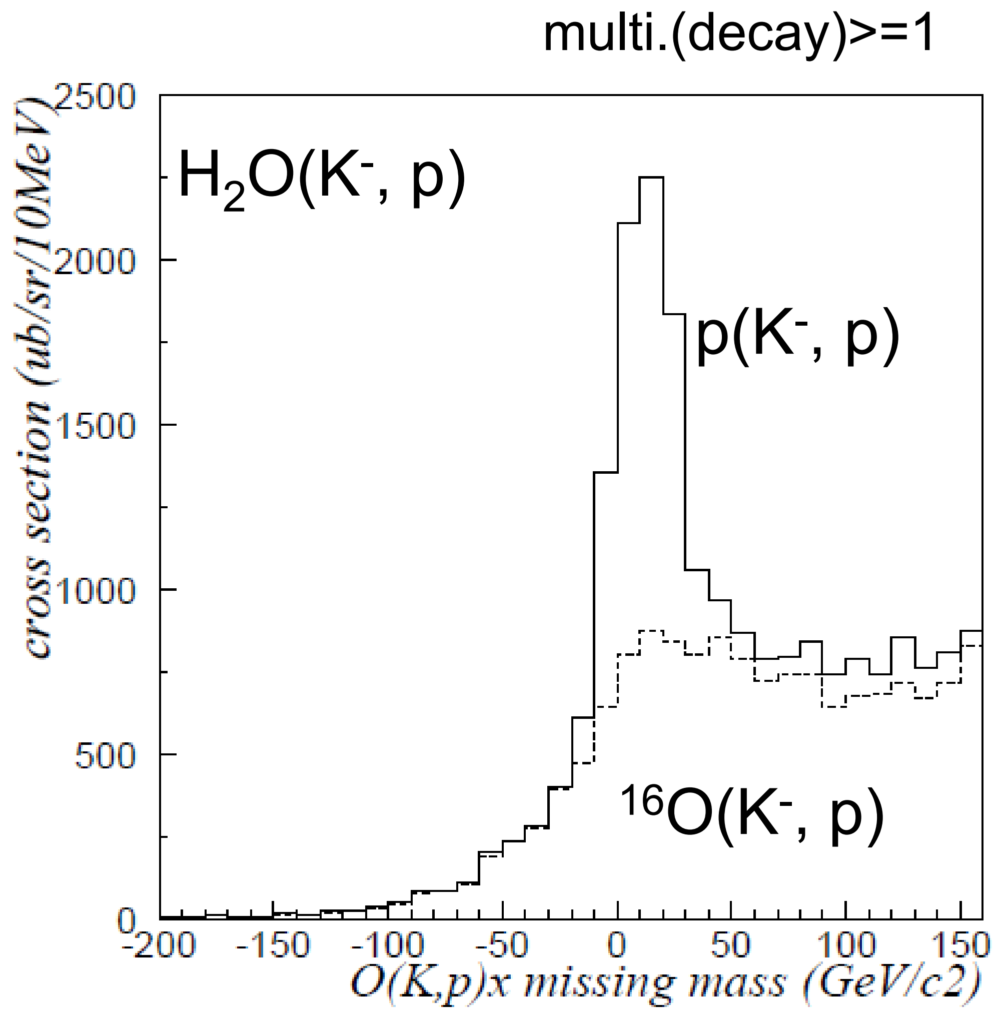
- Charged particles
- Vertex points



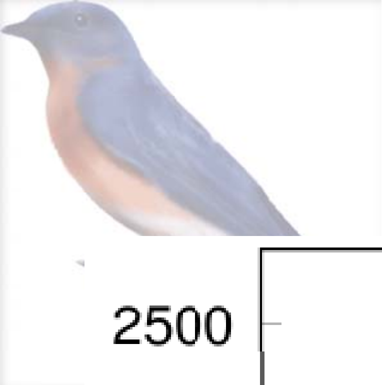
VZH is to identify vertex to give neutron flight length

Cross section and N_{eff}

- Energy integrated cross section (0deg) = $N_{eff}\ \sigma_{KN}\ (P_{cm}/P_{lab})^2$
- Neff = N(nucleon) $\exp(-\sigma_{NN}\rho x)$
- Eikonal distortion
- CH_2, C(graphite), H_2O
- θ_{scatt}<4 deg
  - acceptance: OK

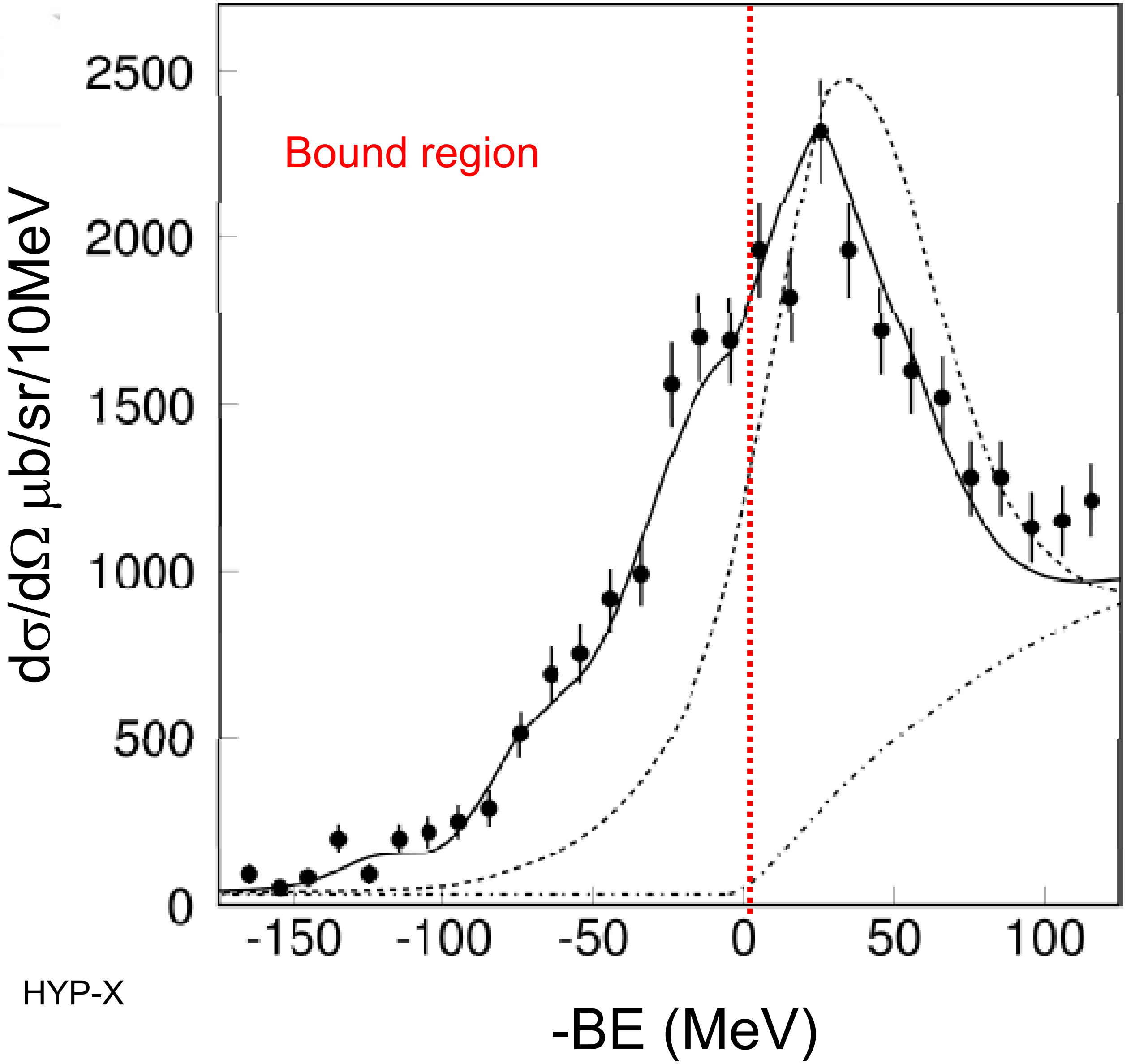


No 2N absorption



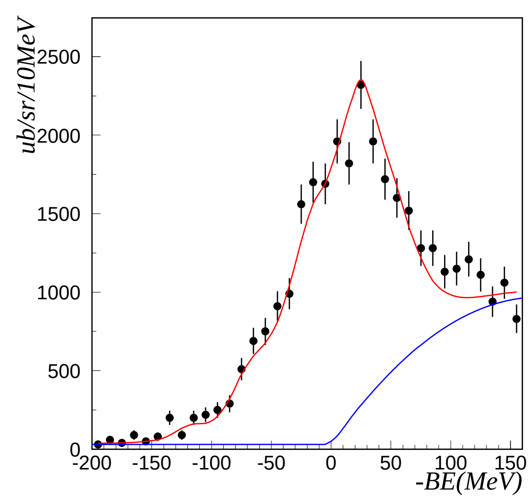
MM $^{12}C(K^-, n)$

multi.(decay)>=1



Solid line: best fit
Re(V)=-190MeV
Im(V)=-40 MeV

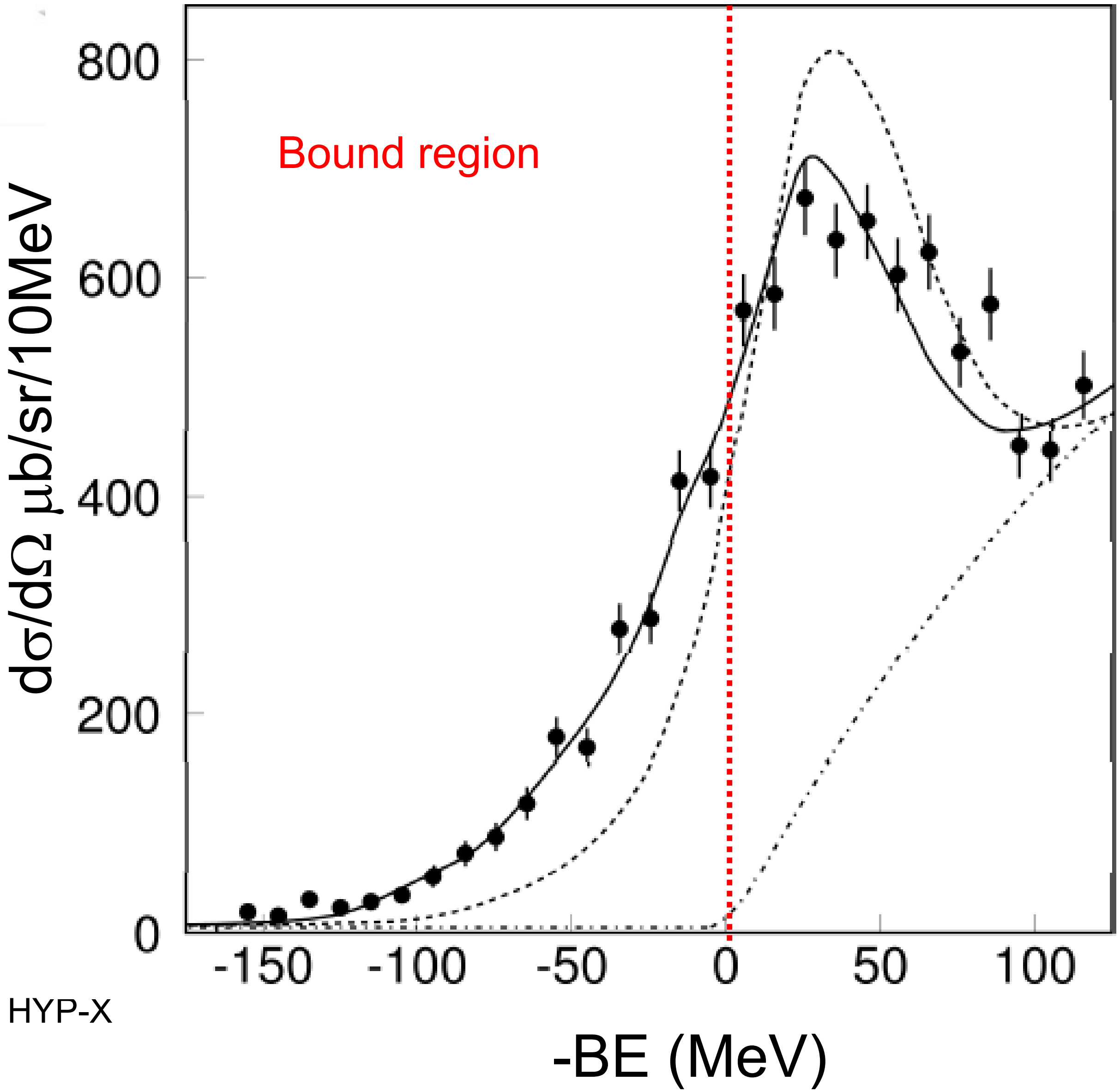
Dotted line:
Re(V)=-60 MeV
Im(V)=-60 MeV



HYP-X

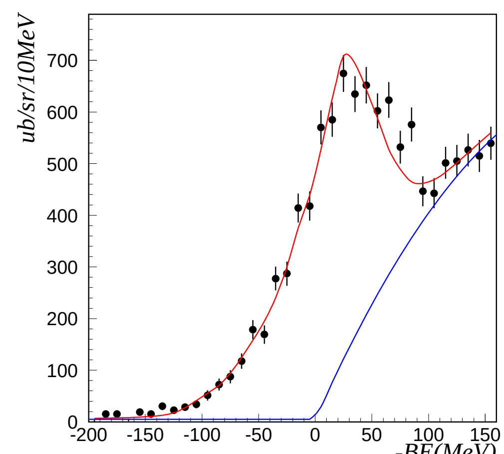
MM $^{12}C(K-, p)$

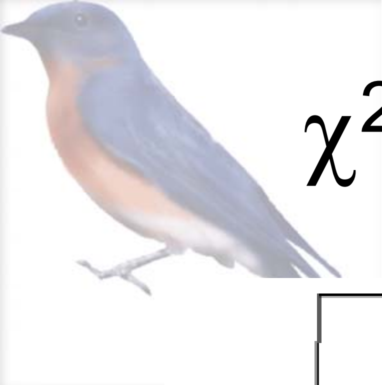
multi.(decay)>=1



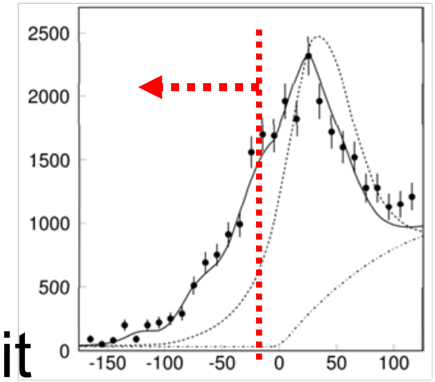
Solid line: best fit
Re(V)=-160MeV
Im(V)=-50 MeV

Dotted line: Chiral
Re(V)=-60 MeV
Im(V)=-60 MeV

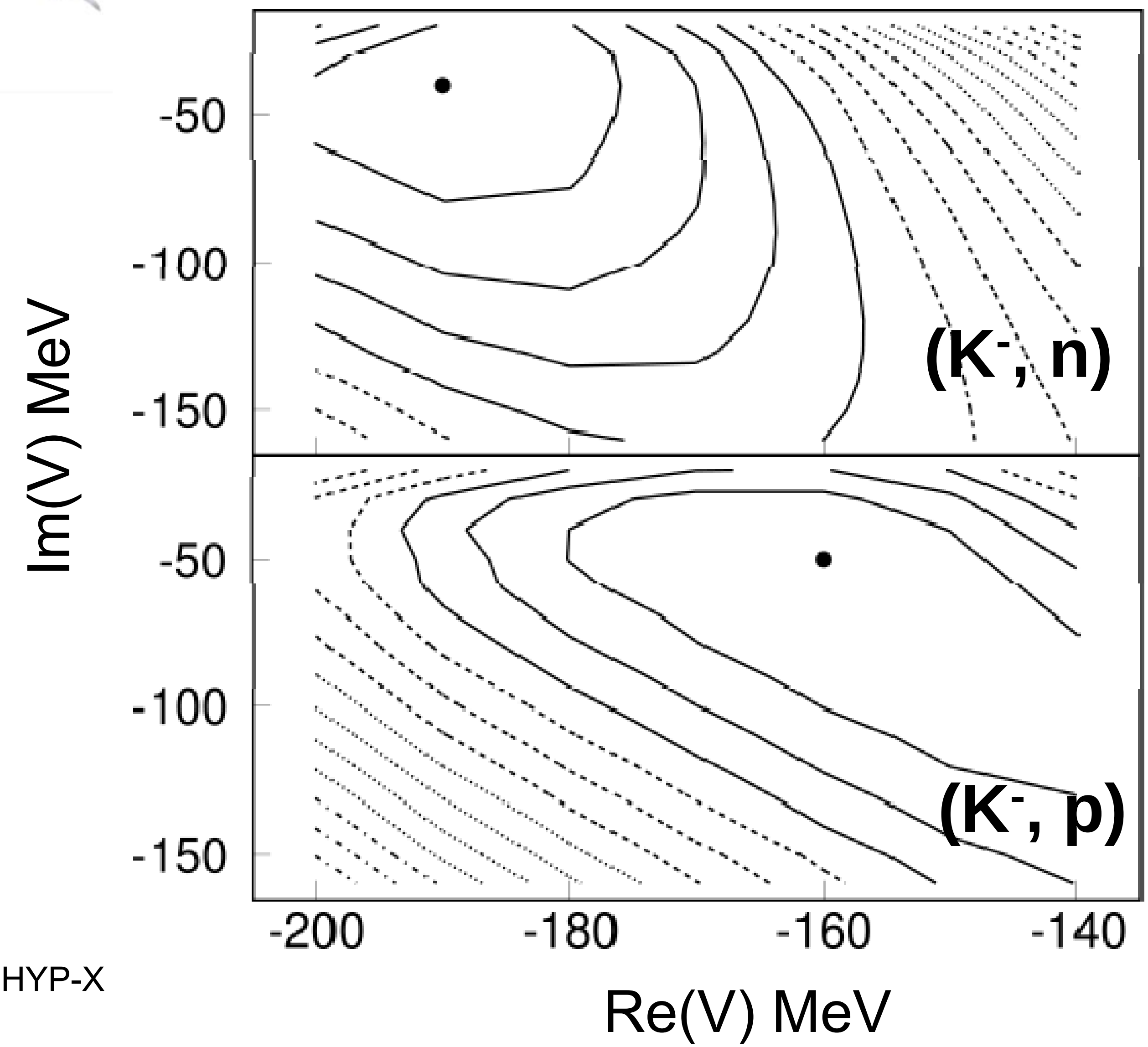




χ^2 contour plot $^{12}C(K^-,N)$



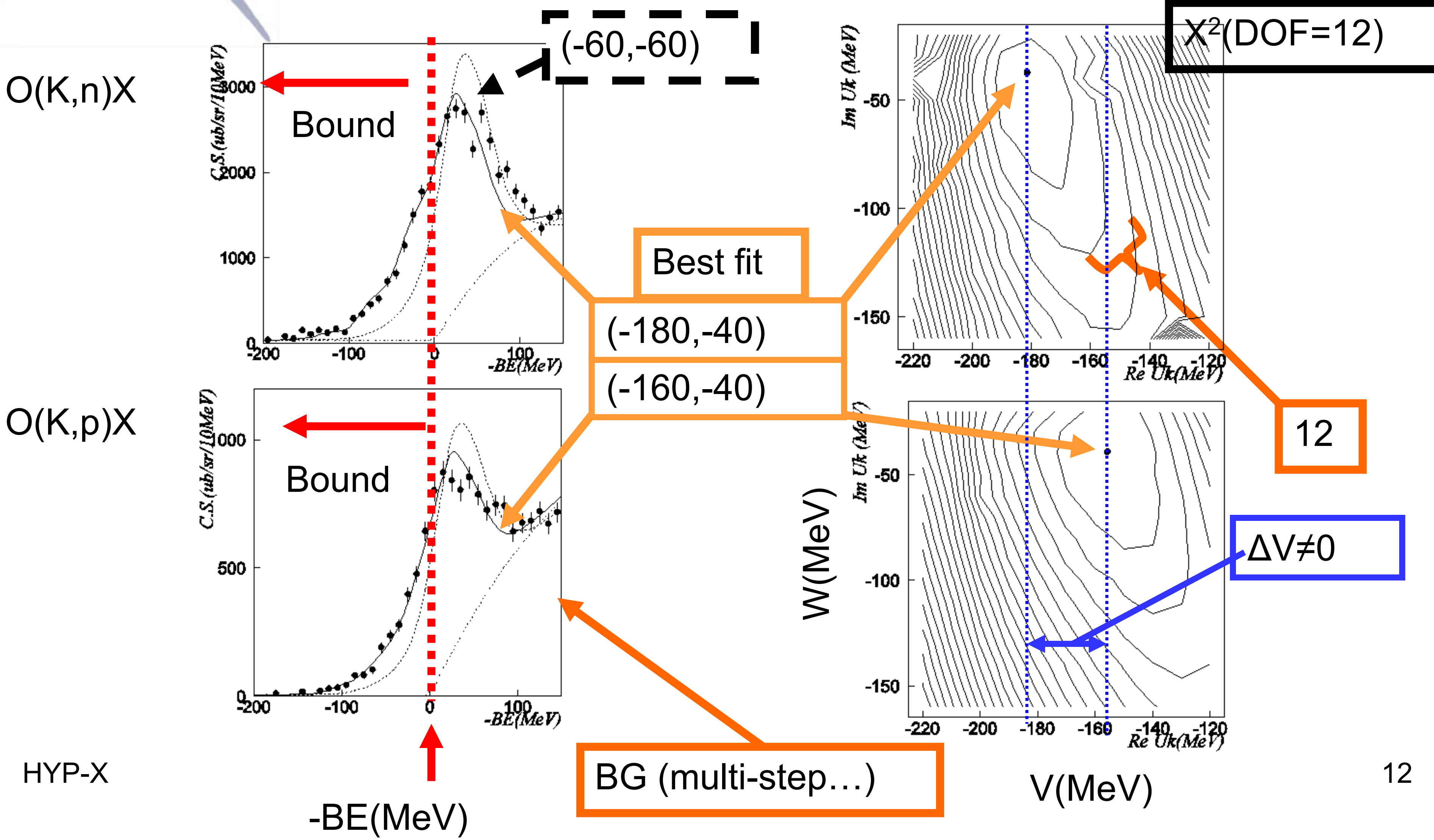
Fit
1. whole region
2. bound region



Re(V)=-190 MeV
Im(V)=-40 MeV

Re(V)=-160 MeV
Im(V)=-50 MeV

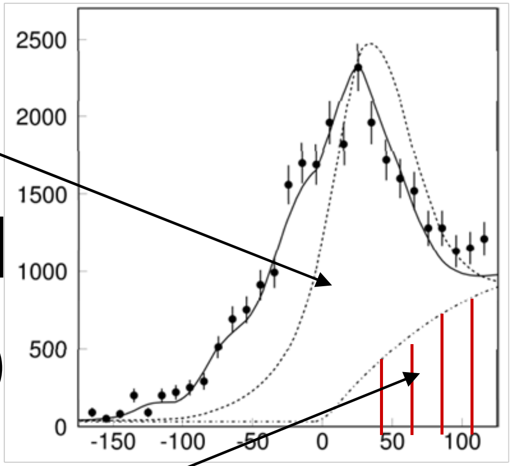
$^{16}O(K-,p)$ and $^{16}O(K-,n)$



Effective nucleon number N_{eff}

- $N_{eff} = \sigma(^{12}C(K^-, N)) / \sigma(p(K^-, N))$
  - ~1.41

σ~20 mb/sr

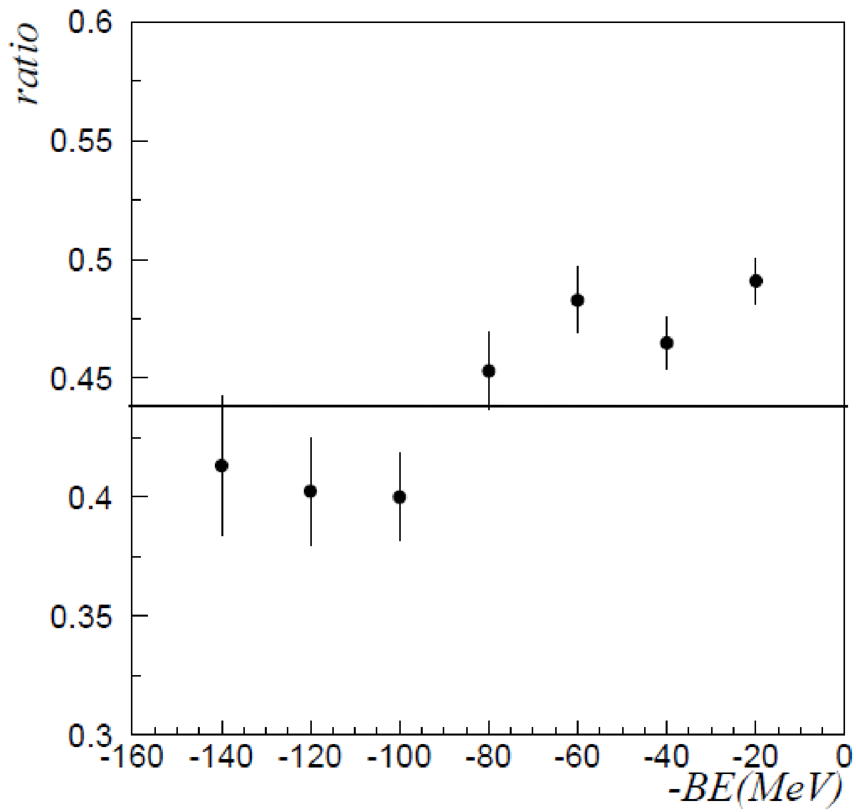


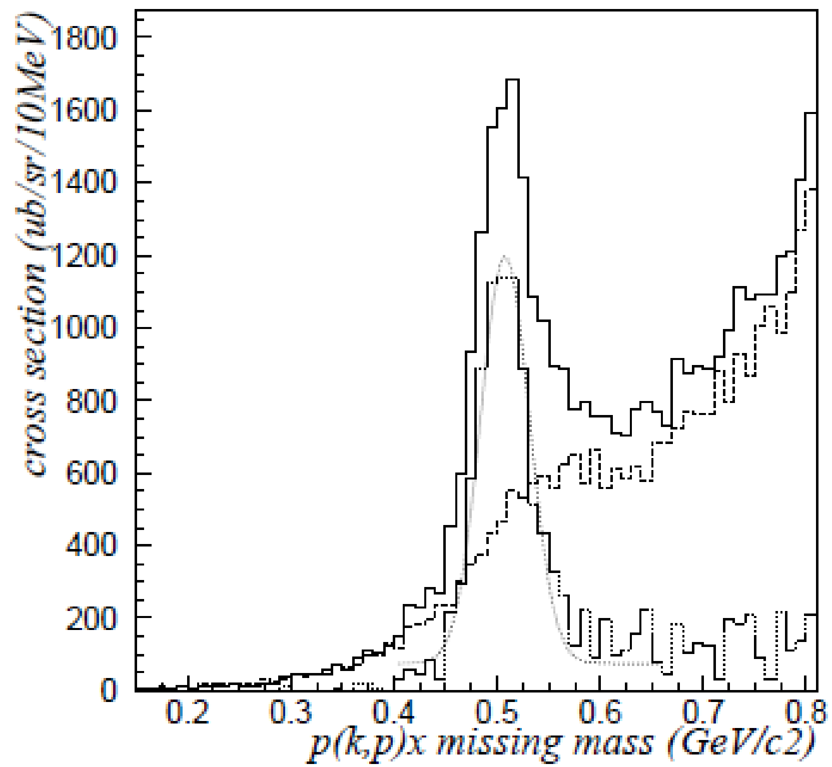
- calculation (40 mb for σ(KN) and
  - N_{eff}(Eik)~1.49 (with A-1 correction)
- $N_{eff}(^{16}O)$~1.94 (exp), ~1.72(cal)
- Background process
  - Fitting of -BE=100~200 MeV region
    - quadratic function
  - multi-step?

We are seeing (K-, N) reaction not backgrounds

Distortion due to tagging

- $N_{tag}(BE)/N_{inc}(BE)$
  - Assumed: constant
  - ~10% distortion due to detection efficiency





Inclusive p(K-, p)X missing mass spectra on CH_2 and C targets. Kaon peak is seen.

Potential depth

	obs(MeV)	cal(MeV)
$^{12}C(K^-, n)$	~190	190
$^{12}C(K^-, p)$	~160	158
$^{16}O(K^-, n)$	~180	190
$^{16}O(K^-, p)$	~160	166

If potential depth $\propto N_{I=0}/A$

Attraction is from $I=0$ ($K^- p$, $K^0 n$)

Isospin of kaonic nuclei	$N_{I=0}$	
	$^{16}O(K^-,N)$	$^{12}C(K^-, N)$
I=0	4.5	3.5
(K-,p) I=1	3.5	2.5
(K^-,n) I=0,1	4	3

$$N_{I=0} = \sum_{i=1}^{A} \left(\frac{1}{4} - \tau_K \bullet \tau_N\right)$$

$$= \frac{A}{4} - \tau_K \bullet T_A$$

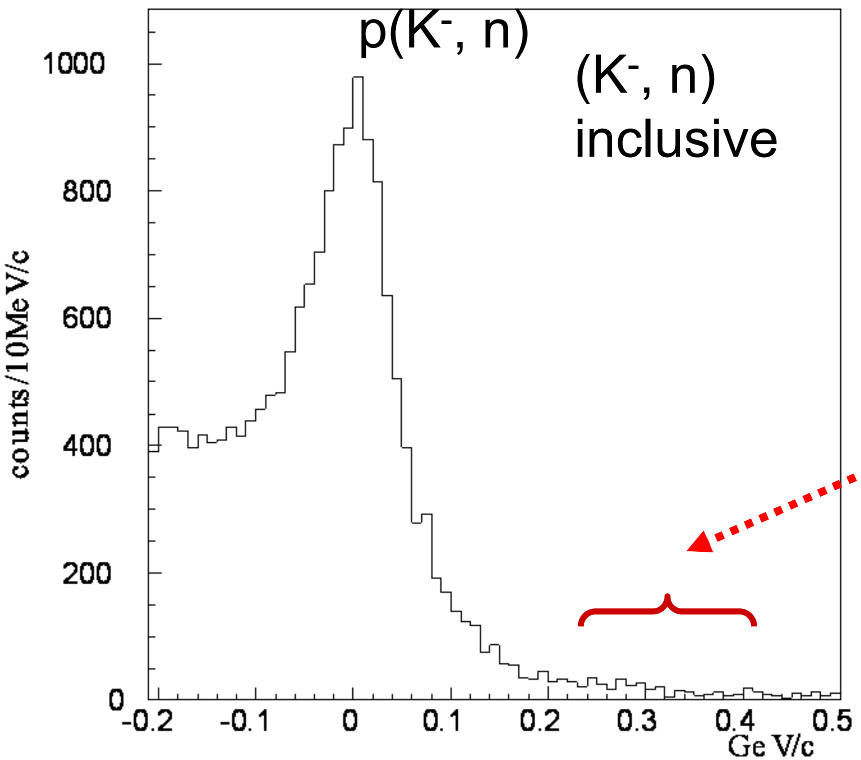
Summary

- Missing mass spectra of $^{12}C(K^{-}, N)$ indicate
  - $^{12}C\ (K^{-}, n)$: $V_r \sim 190 MeV$ $V_i \sim -40\ MeV$,
  - $^{12}C\ (K^{-}, p)$: $V_r \sim 160 MeV$ $V_i \sim -50\ MeV$,
- Effective nucleon number
  - $N_{eff}(^{12}C) \sim 1.41$, $N_{eff}(^{16}O) \sim 1.94$: Eikonal distortion
  - BG process: unlikely (~20 mb/sr)
- Isospin dependence: attraction is I=0 pair
- ^{12}C results in PTP 118, 181 (2007)
- $^{16}O(K^{-}, N)$ and $^{12}C(K^{-}, N)$ are consistent

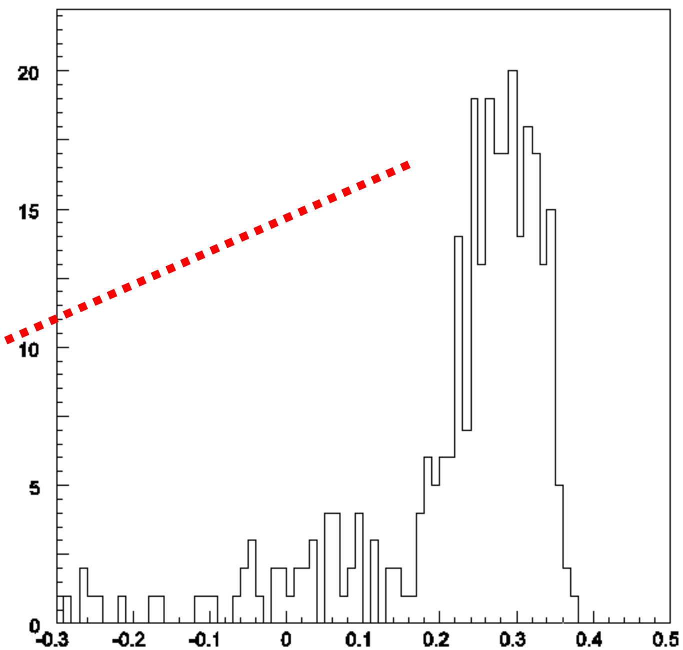
Thanks

2 nucleon absorption: negligible

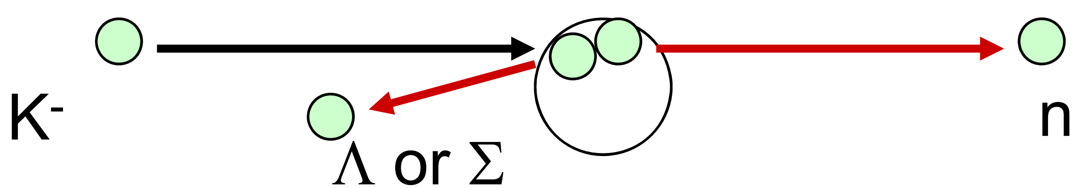
Data



Simulation for the KNN⇨YN



p_n(mes)-p(K^-,n)



Seeing two nucleon is unlikel