

# Meson Bound States in Nuclei

## *An experimental view*

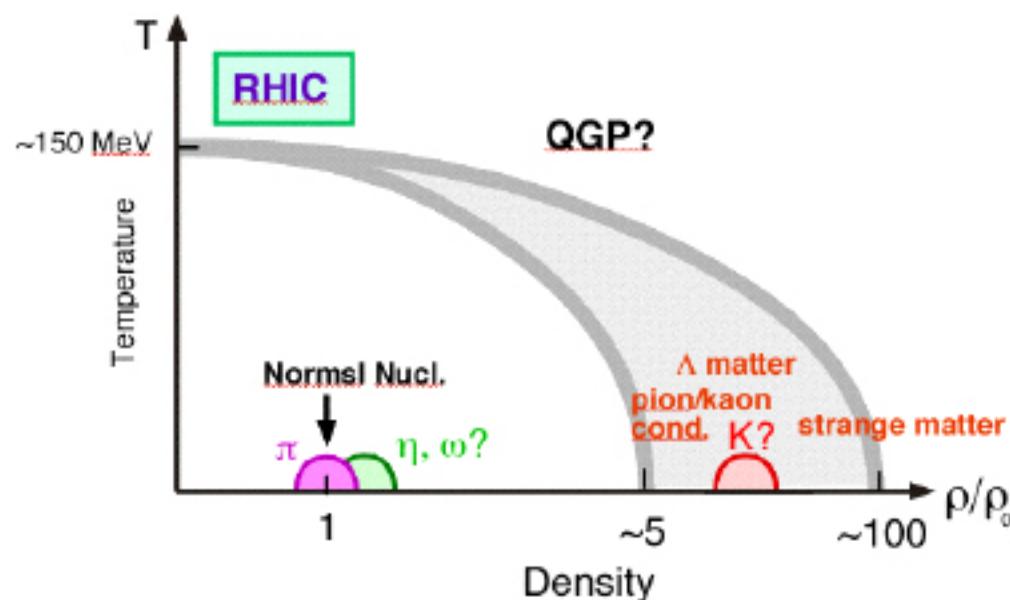
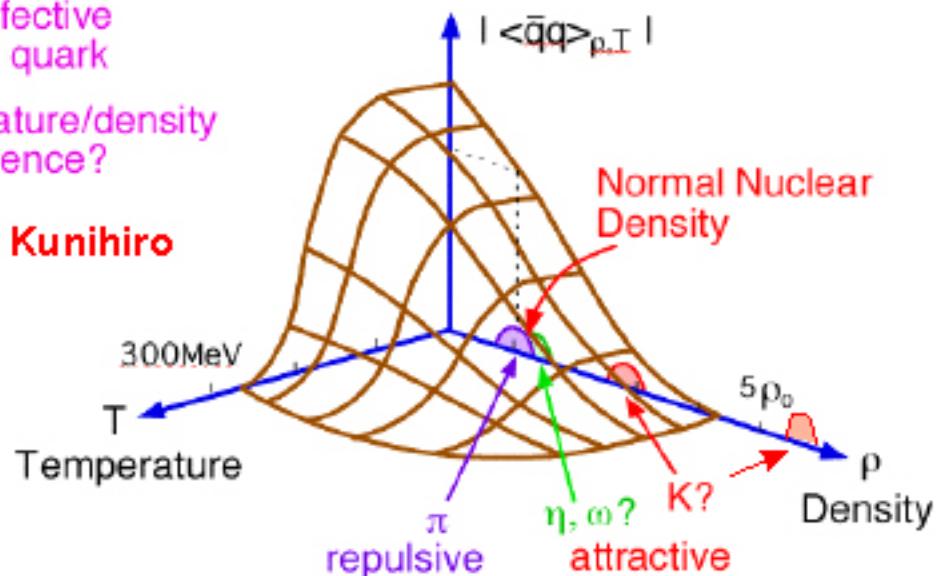


M. Iwasaki  
*Tokyo Institute of Technology*

# MESON BOUND STATES

$\langle\bar{q}q\rangle$  gives effective mass to quark  
temperature/density dependence?

Hatsuda, Kunihiro



# $\pi$ atom

T. Yamazaki, R. S. Hayano *etc*

Toki, Hirenzaki

*Can one embed  $\pi$  in Nuclei??*

**Yes!!!**

# $\eta$ , $\omega$ nuclei

R. S. Hayano, M. Iwasaki, K. Itahashi *etc*      Hirenzaki

*How about  $\eta$  and  $\omega$ ?*

We need totally new detector

$\sim 10^8$  protons / sec

TORCH development

# DeepK

M. Iwasaki, K. Itahashi, R.S. Hayano *etc*      Y. Akaishi and T. Yamazaki

*How about  $K$ ?*

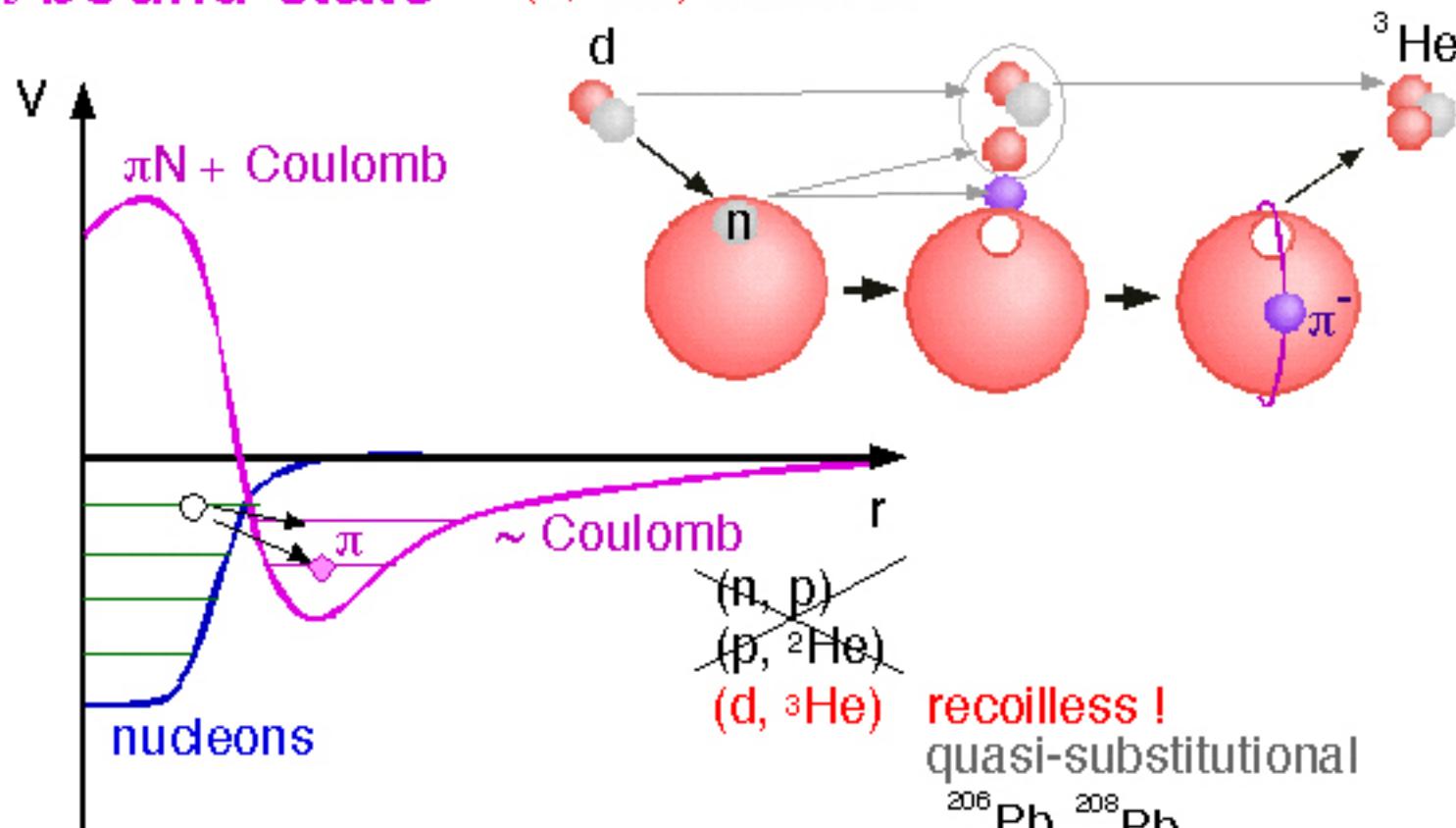
Extremely high density?

Extremely deep potential?

# $\pi$ Meson Bound States

$\pi$  bound state

(d,  ${}^3\text{He}$ ) reaction!



peripheral reaction

# Pion in Nuclei

First observation of  
Deeply Bound Pionic State  
1s Pionic State Observed!

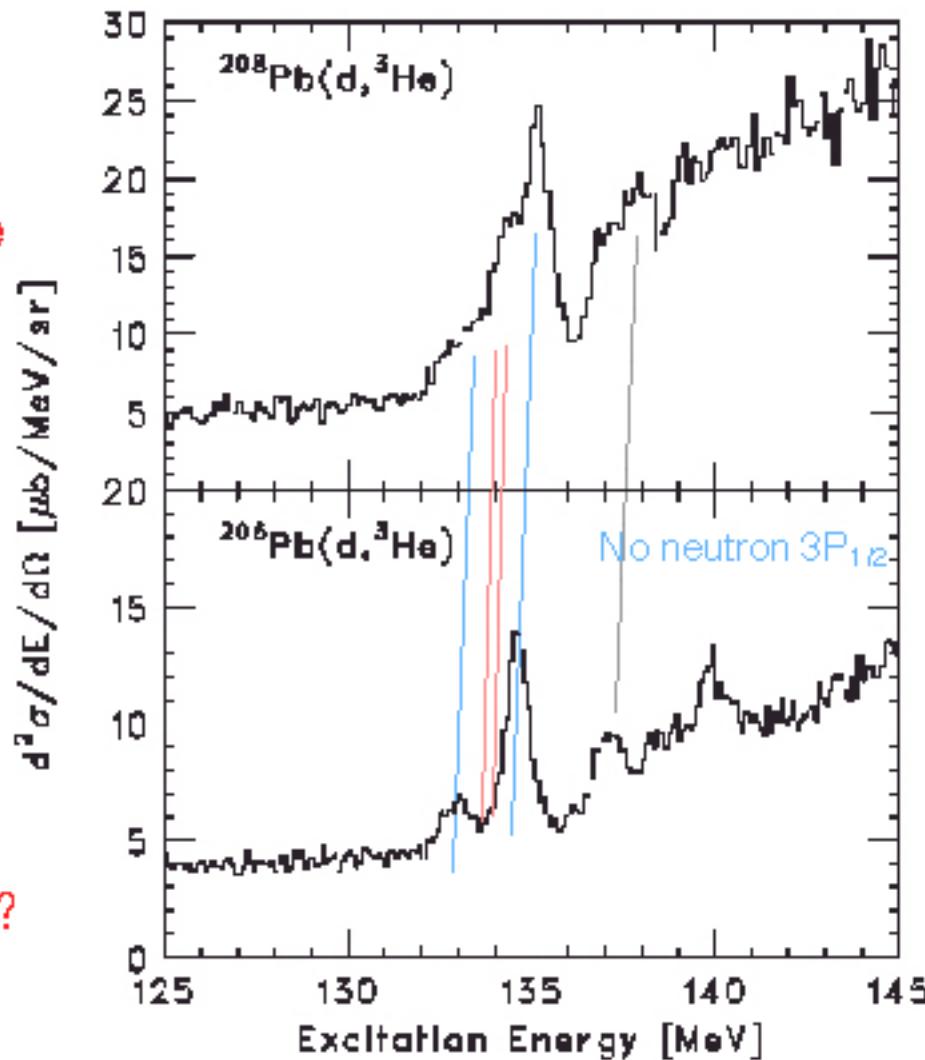
Complex of  
 $(1s)_\pi(3p_{3/2})_n$   
 $(1s)_\pi(2f_{5/2})_n$

Surface Effect



Sn Isotopes

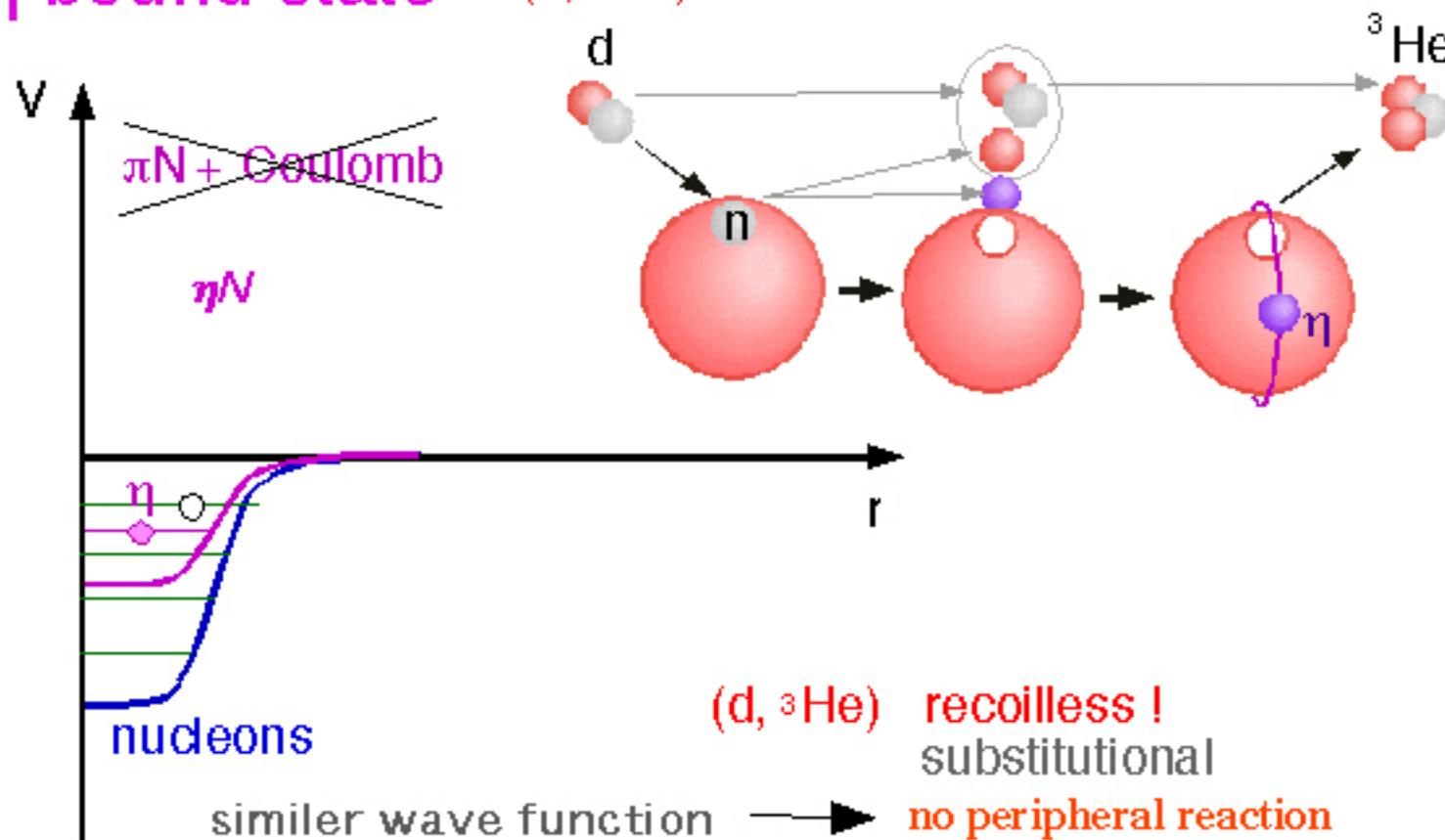
What's about other mesons?



# $\eta$ Meson Bound States?

$\eta$  bound state

(d,  ${}^3\text{He}$ ) reaction!



(d,  ${}^3\text{He}$ ) recoilless !  
substitutional  
no peripheral reaction  
tiny cross section  
huge breakup proton

$\sim 1/100$

$\sim 10^8/\text{sec}$

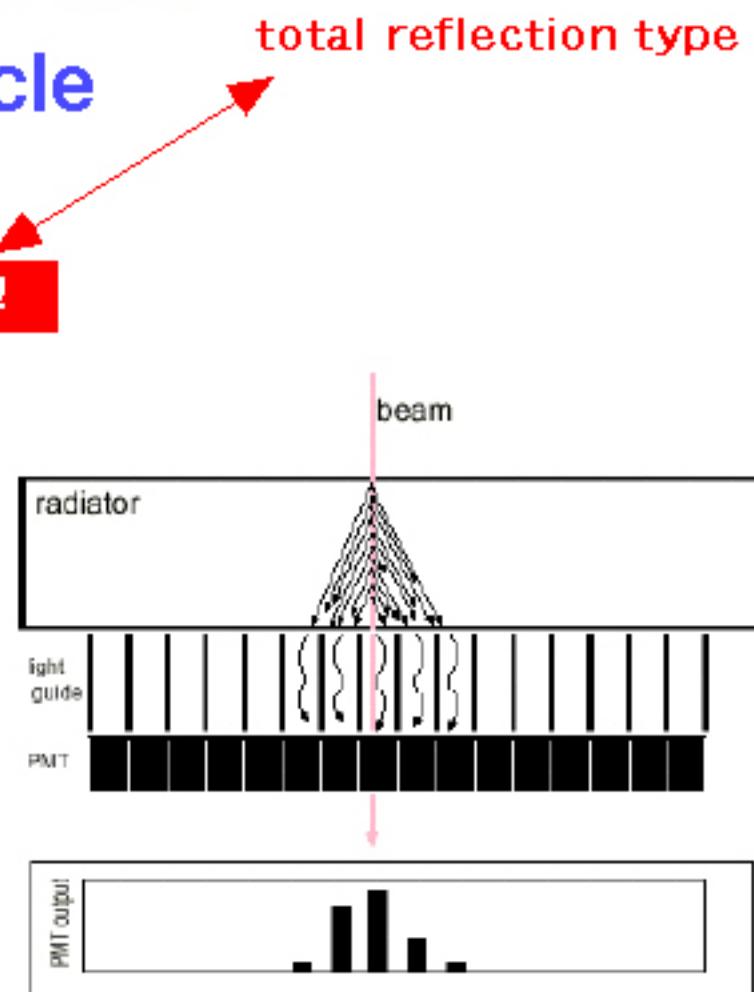
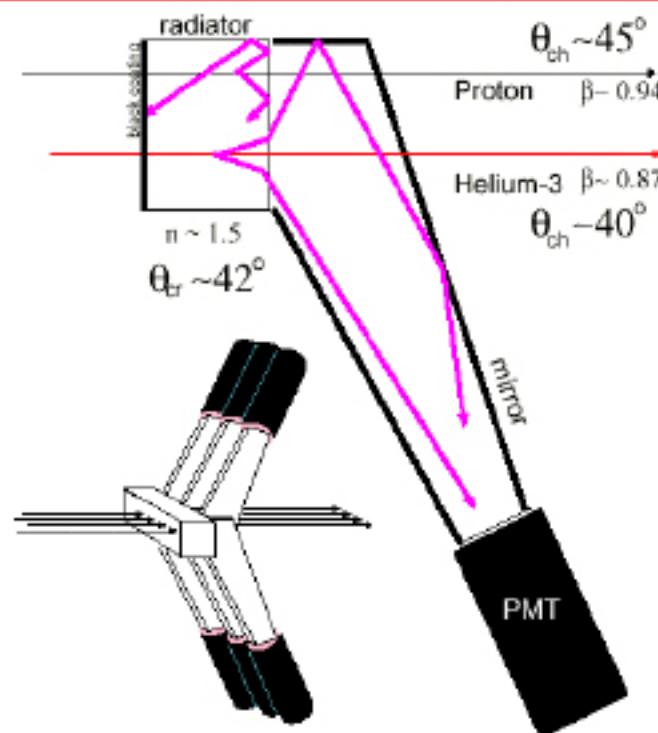
How?



# TORCH

insensitive to high  $\beta$  particle  
sensitive to low  $\beta$  particle  
position sensitive

Cherenkov light from high  $\beta$  to garbage!



# $K$ Meson Bound States?

Is  $\bar{K}N$  interaction Repulsive?

$KpX$  Existence of  $\Lambda(1405)$   
Kaonic Atom Data  
Scattering Data

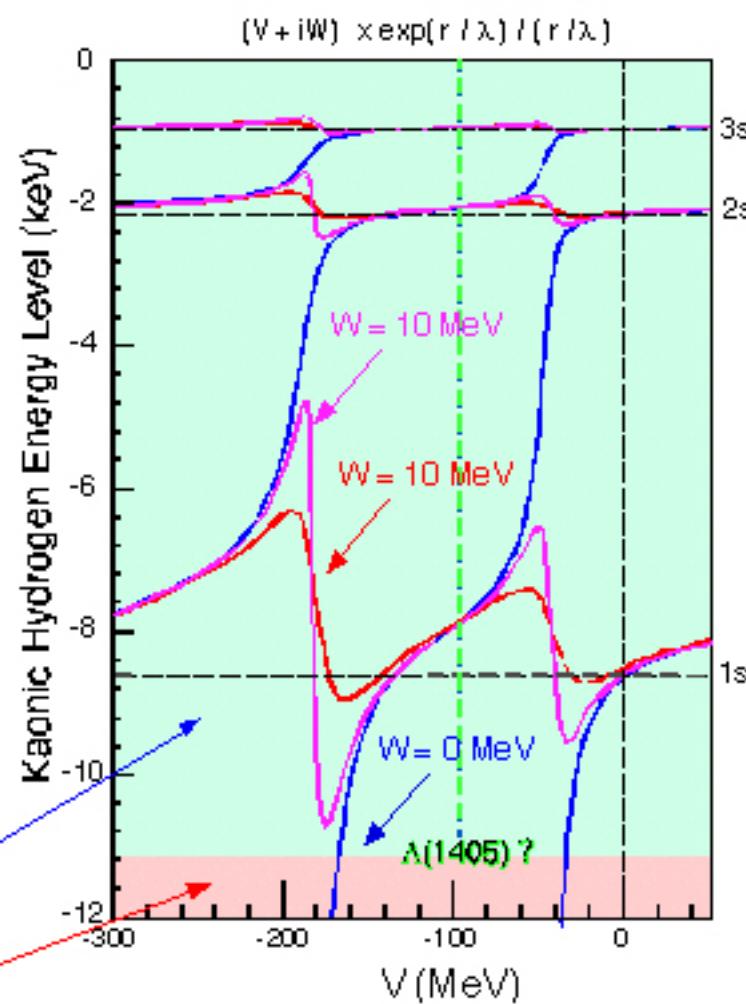
$\Lambda(1405) = K^- p$  bound state  
by the Strong Int.

No! STRONGLY Attractive!!

Deeply Bound Kaonic State  
in Nuclei

atomic state

nuclear state



# PHYSICAL REVIEW D

VOLUME 50

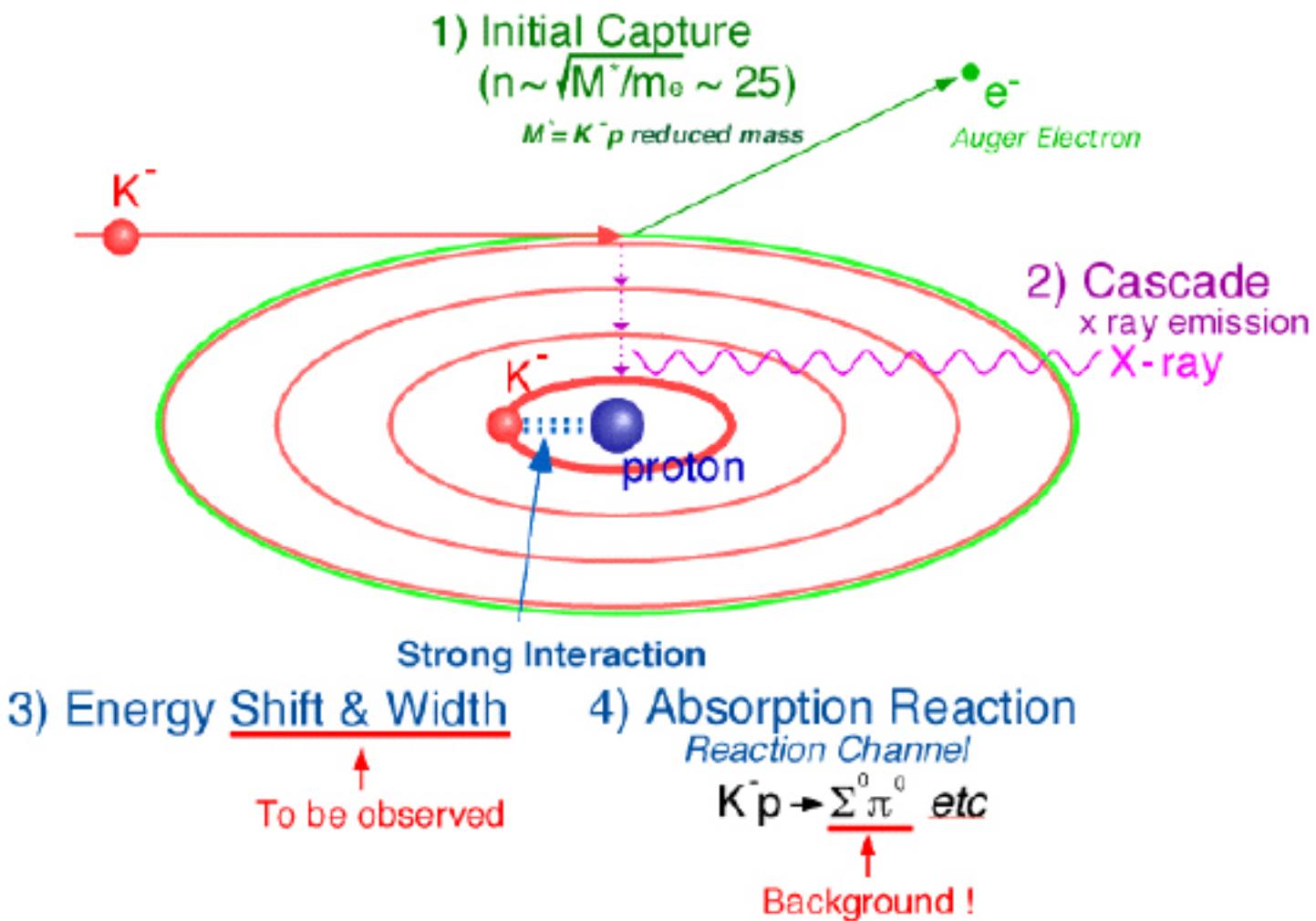
1 AUGUST 1994

## THE $\Lambda(1405)$ by R.H. Dalitz, Oxford University

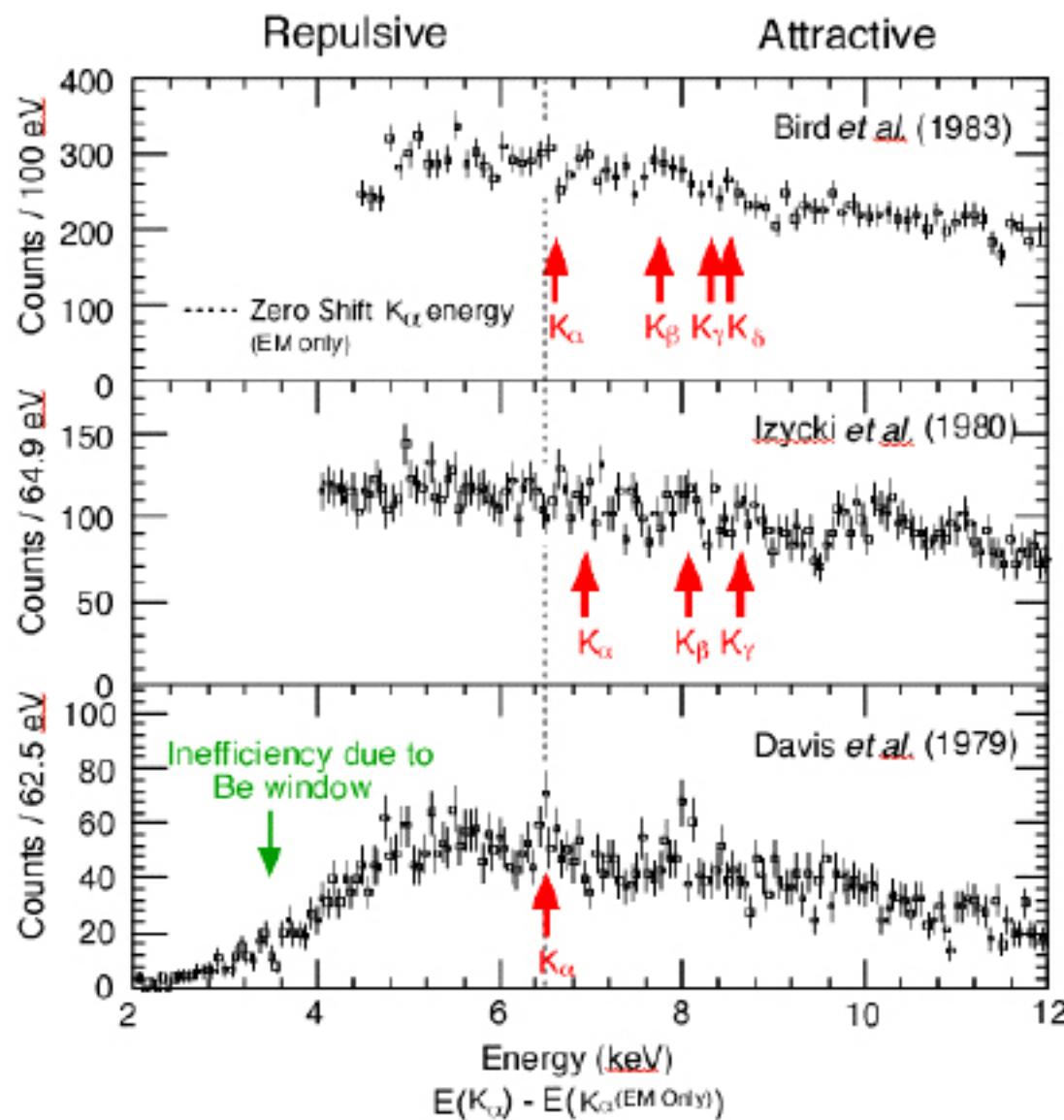
The present status of the  $\Lambda(1405)$  thus depends heavily on theoretical arguments, a somewhat unsatisfactory basis for a four-star rating. Nevertheless, there is no known reason to doubt its existence or quantum numbers. A measurement of the energy-level shifts and widths for the atomic levels of kaonic hydrogen (and deuterium) would give a valuable check on analysis of the  $(\Sigma\pi, N\bar{K})$  amplitudes, since the energy of the  $K^*p$  atom lies roughly midway between those for the two sets of data. The three measurements of  $(\Delta E - i\Gamma/2)$  for kaonic hydrogen are inconsistent with one another and require that the sign of  $\text{Re}(A_{J=0} + A_{J=1})$  be opposite that deduced from  $N\bar{K}$  reaction data (see BATTY 89). Accurate measurements of  $(\Delta E - i\Gamma/2)$  values for kaonic hydrogen are badly needed, but may not be possible until the KAON factory becomes operational.

→ Kaonic Hydrogen Puzzle!

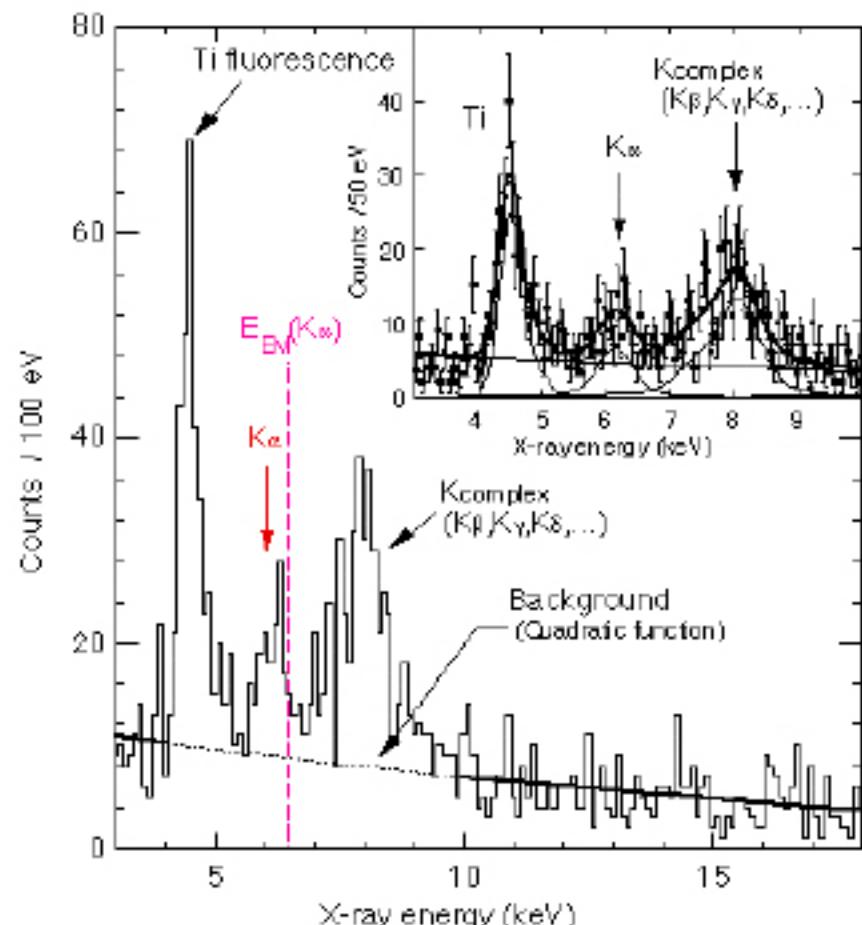
# Kaonic Atom Formation



## Previous Kaonic X-ray Measurements

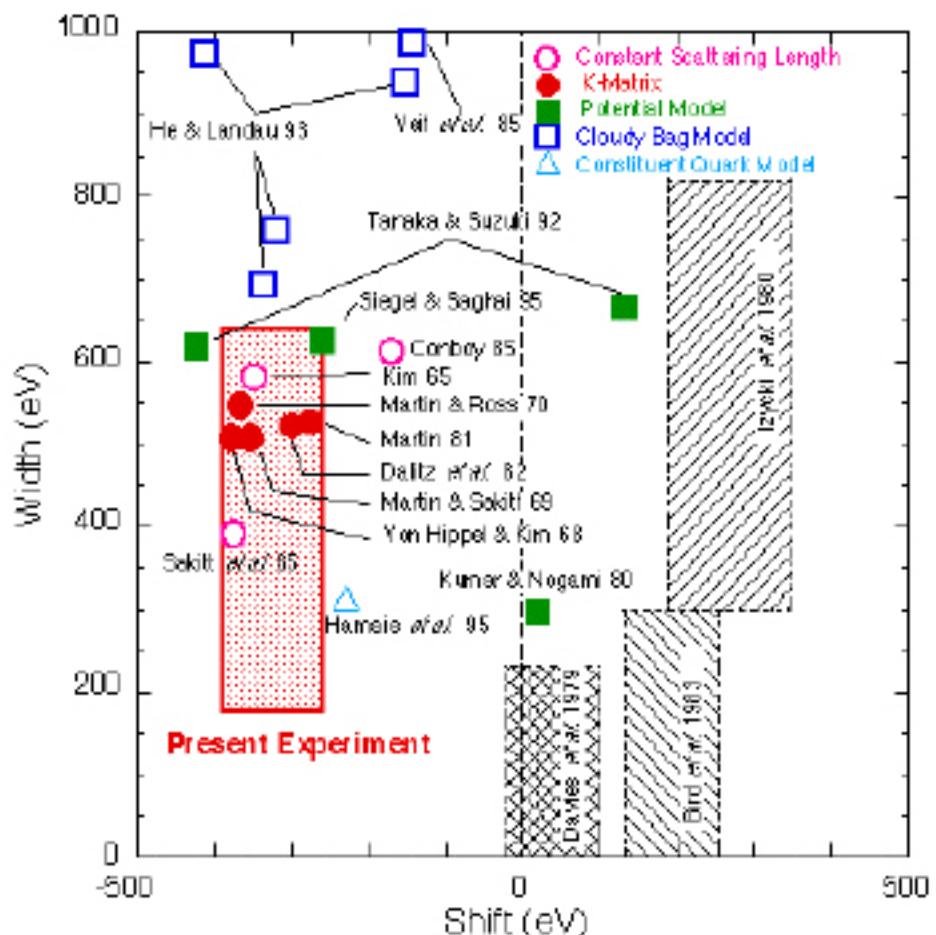


# KEK E228 (KpX) Experiment



$$\Delta E(1s) = -323 \pm 63(\text{stat.}) \pm 11(\text{syst.})$$

$$\Gamma(1s) = 407 \pm 208(\text{stat.}) \pm 100(\text{syst.})$$



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## THE $\Delta(1405)$

Revised March 1998 by R.H. Dalitz, Oxford University

From the measurement of  $2p - 1s$  x rays from kaonic-hydrogen, the energy-level shift  $\Delta E$  and width  $\Gamma$  of its  $1s$  state can give us two further constraints on the  $(\bar{\Sigma}\pi, NK)$  system, at an energy roughly midway between those from the low-energy hydrogen bubble chamber studies and those from qR( $\Sigma\pi$ ) observations below  $pK^+$  threshold. IWASAKI 97 have reported the first convincing observation of this x ray, with a good initial estimate:

$$\Delta E - i\Gamma/2 = (-323 \pm 63 \pm 11) - i(204 \pm 104 \pm 50) \text{ eV.} \quad (2)$$

the errors here encompass about half of the predictions made following various analyses and/or models for the in-flight  $K^- p$  and sub-threshold qR( $\Sigma\pi$ ) data. Better measurements will be needed to discriminate between the analyses and predictions. ...., perhaps from the DAΦNE storage ring at Frascati, information vital for our quantitative understanding of the  $(\Sigma\pi, NK)$  system in this region. ....

# K Meson Bound States?

Is  $\bar{K}N$  interaction Repulsive?

$KpX$  Existence of  $\Lambda(1405)$   
Kaonic Atom Data  
Scattering Data

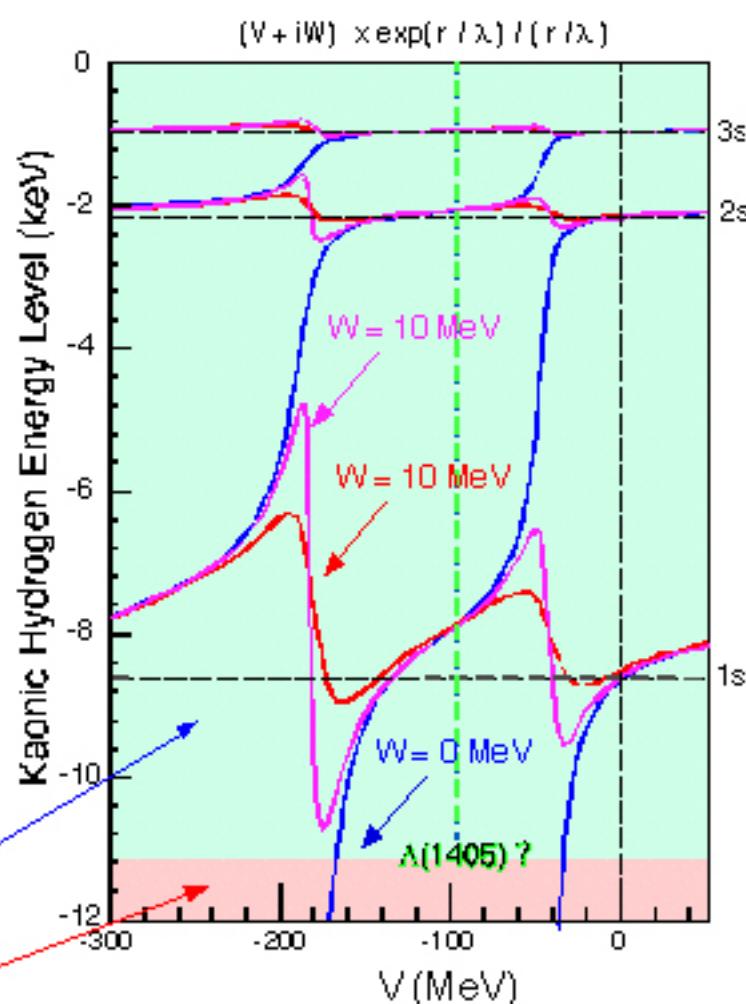
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Deeply Bound Kaonic State  
in Nuclei

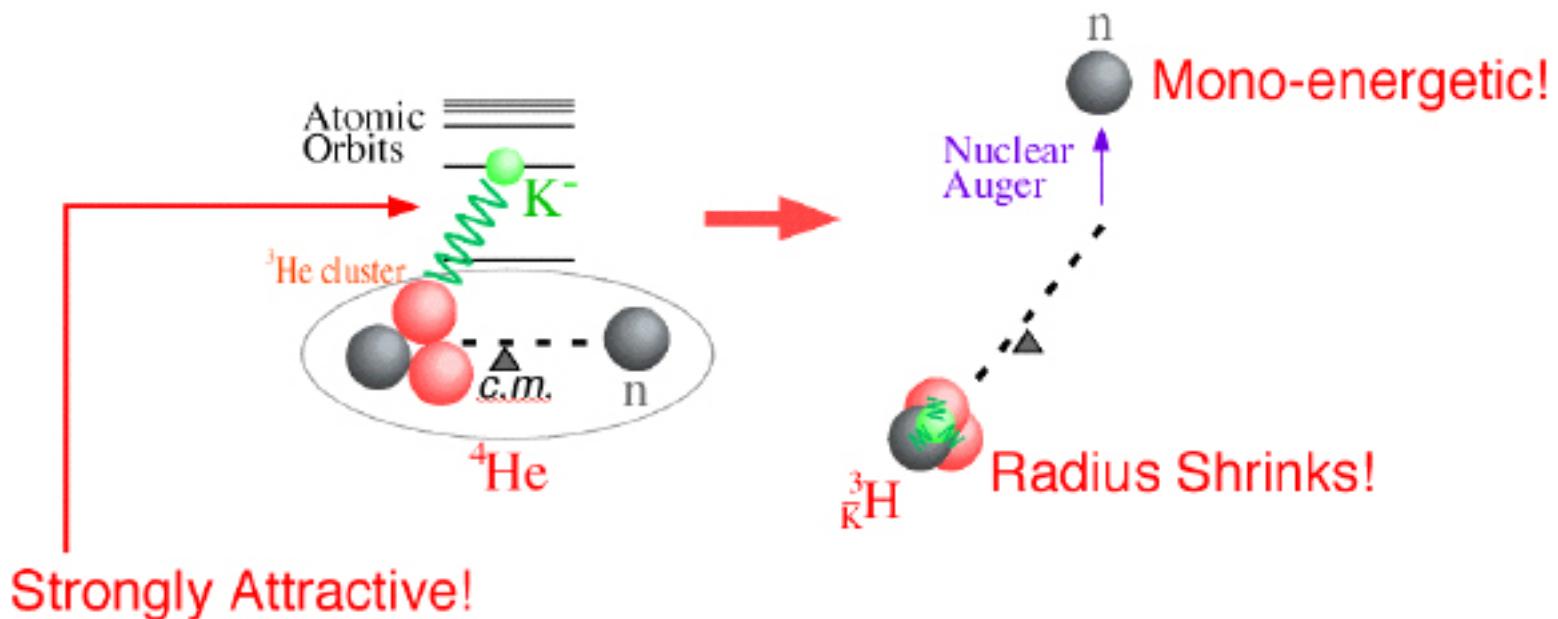
atomic state

nuclear state



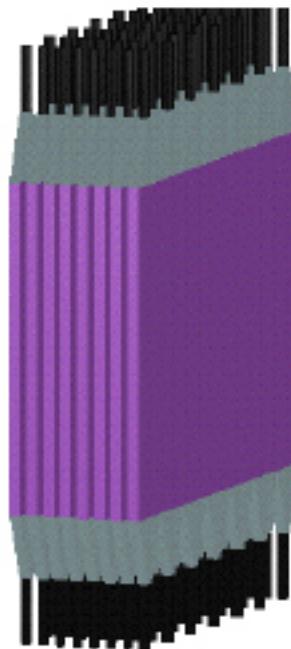
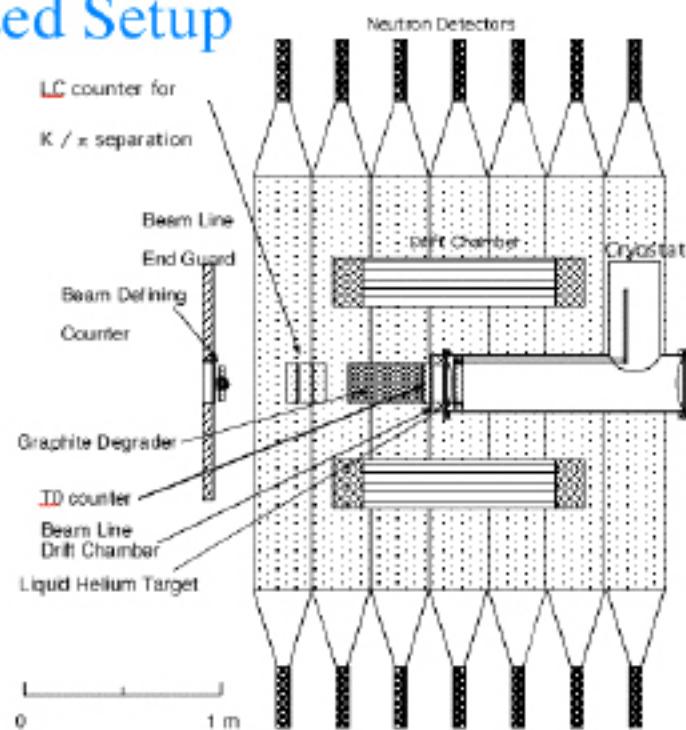
# How to Produce?

## Nuclear Auger from Atomic State of Kaon



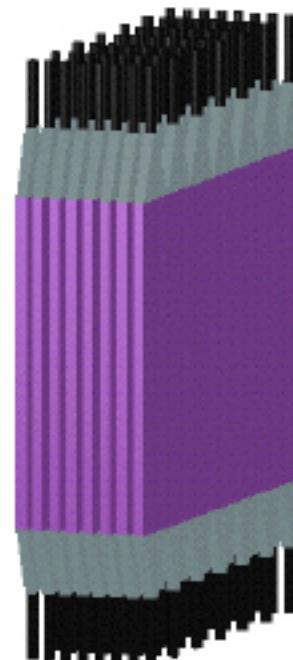
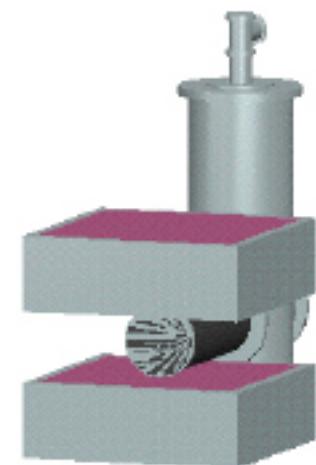
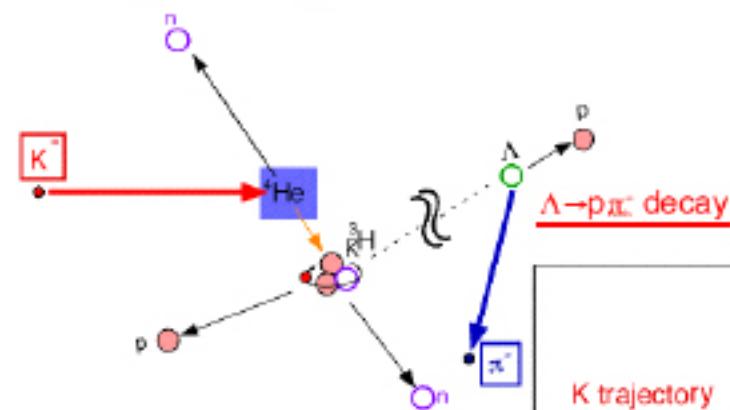
# Proposed Setup

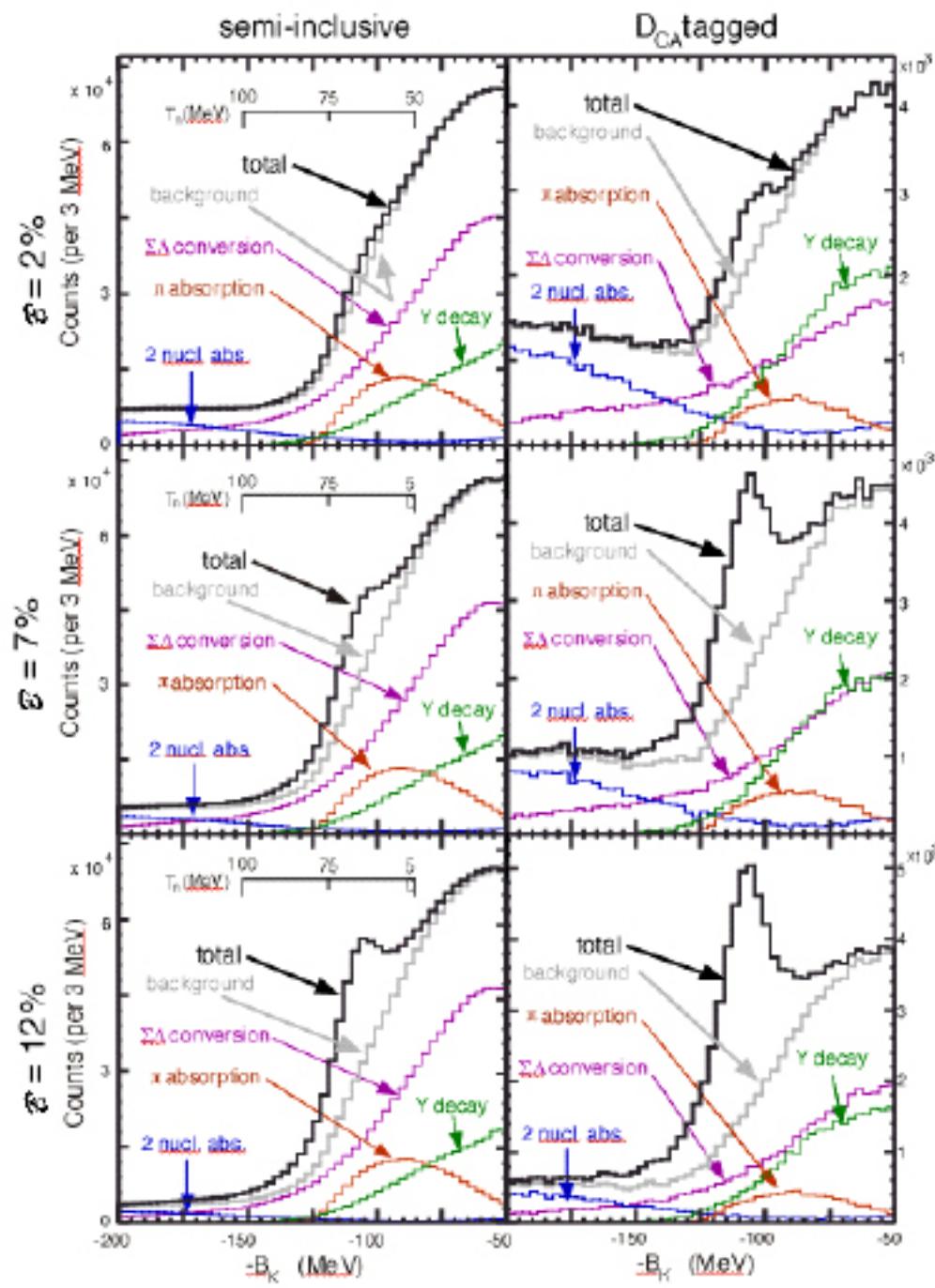
Side View



# Tagging How to improve S/N ratio?

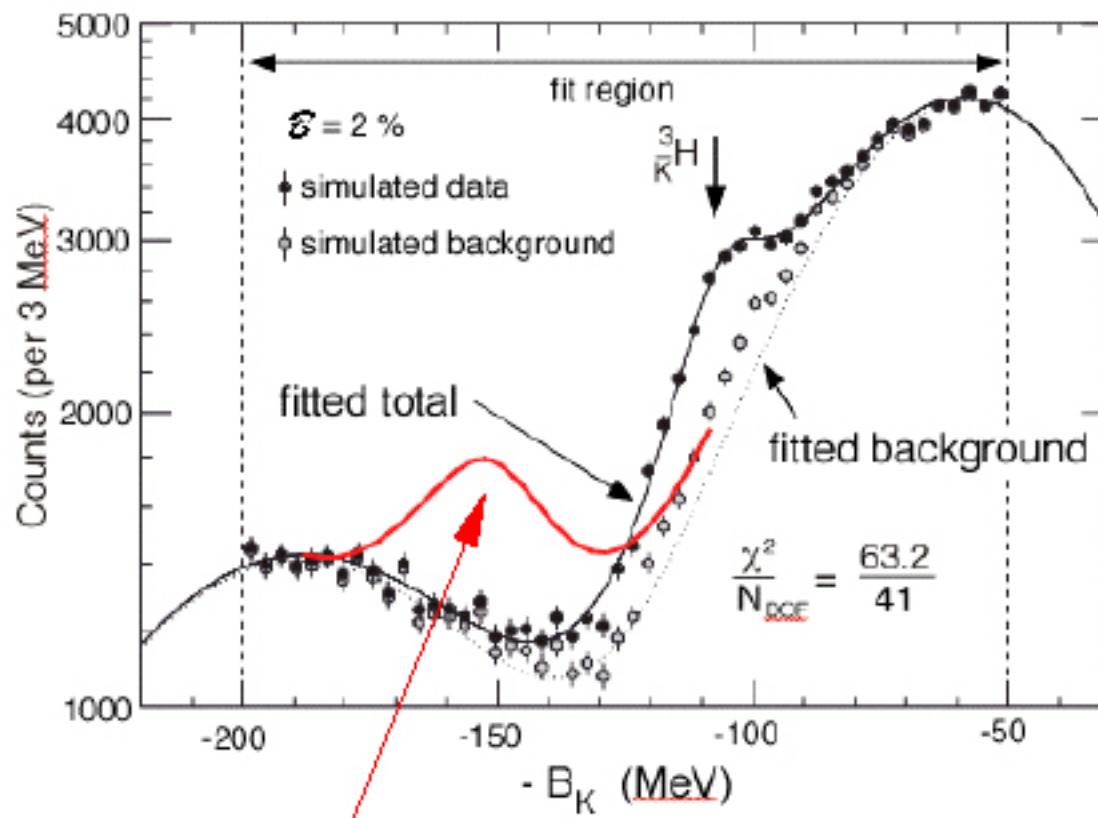
## $\Lambda$ charged decay





# Simple Fitting

## Gaussian Shape Background is Assumed



If binding energy is at 150 MeV

# DeepK must be answered!!!

hyper density material - More than neutron star!  
does kaon keep identity?  
partial restoration of chiral symmetry?  
strangeness condensation?  
strange Matter?

•  
•

**Thank You!!**