Recent Spectroscopic Investigation of P-Shell Λ-hypernuclei by the (e, e'K+) Reaction

-Analysis Status of E05115-

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Introduction

E05115:

The 3rd generation spectroscopic investigation of Lambda hypernuclei by the Reaction (e,e'K$^+$) at Jlab Hall C

Merits of (e,e'K$^+$) experiment:

- Large momentum transfer → Excitation of deeply-bound state
- p to Λ conversion → Mirror or Neutron-rich hypernuclei
- Production of both spin-flip/non-flip states;
- High resolution because of the quality of the CEBAF beam

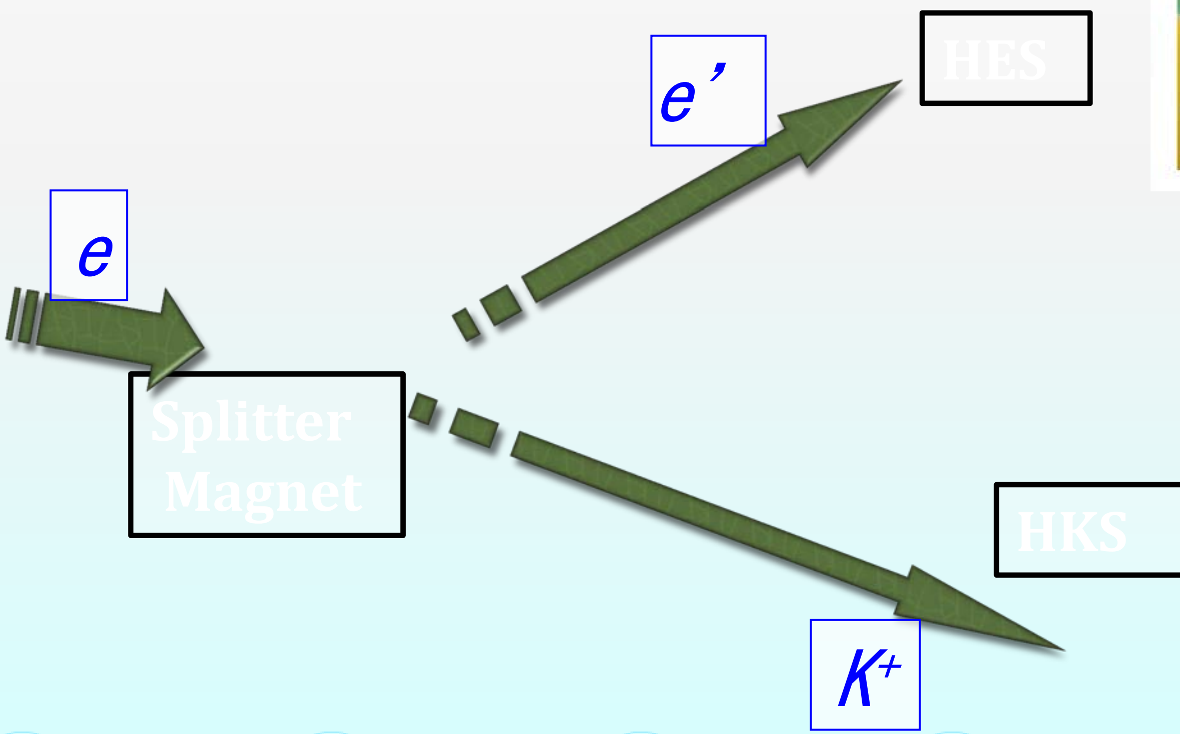
Experimental Goals:

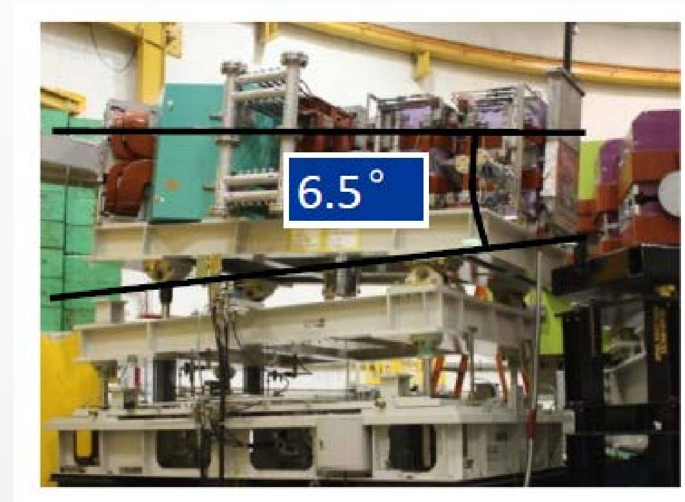
- **Spectroscopy of Medium - heavy hypernucleus**
  $^{52}Cr(e,e'K+)\ ^{52}{}_{\Lambda}V$
- **Spectroscopy of Light Λ hypernuclei-** p shell hypernuclei
  $^{12}C(e,e'K+)^{12}{}_{\Lambda}B$, $^{7}Li(e,e'K+)^{7}{}_{\Lambda}He$, $^{10}B(e,e'K+)^{10}{}_{\Lambda}Be$, and $^{9}Be(e'K+)^{9}{}_{\Lambda}Li$

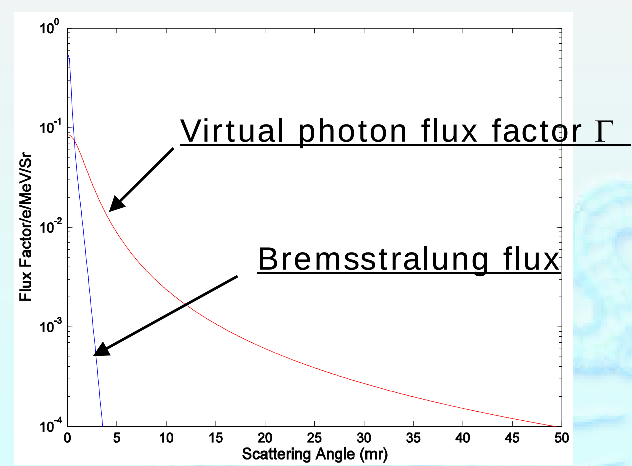
Calibration by the elementary process p(e,e'K$^+$)Λor Σ: H_2O and CH_2

Results are important in determining $\Lambda\Sigma$, S_N and V_0 terms from Λ_s states and S_Λ term from states with Λ at higher orbits **Dr. Tang's Talk**

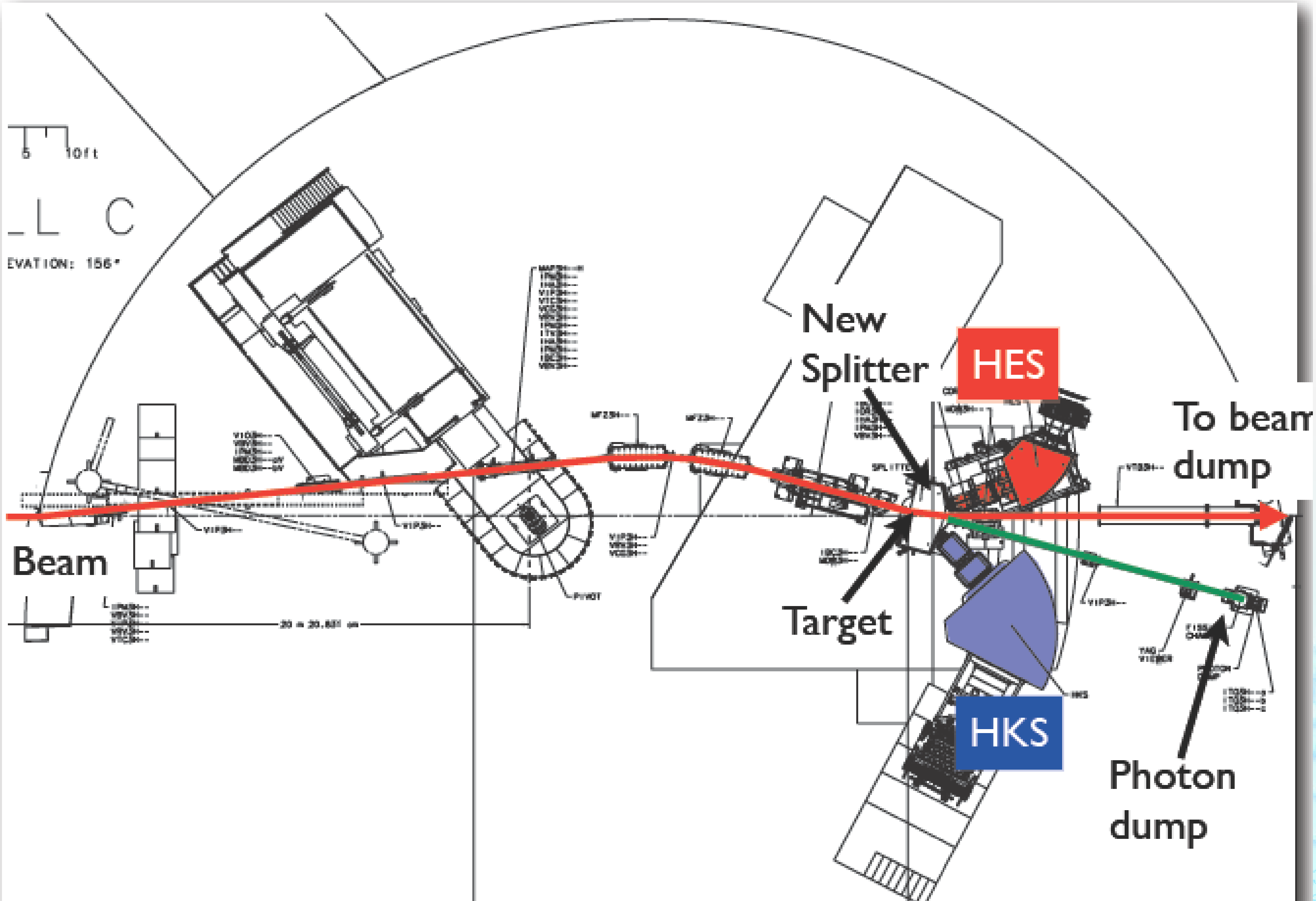
Experimental Setup







PreChicane-SPL-(HKS+HES) Configuration

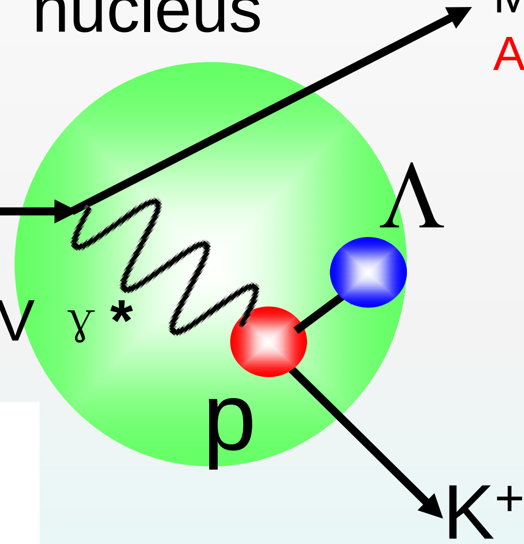


Kinematics of the E05-115 Experiment

Electron beam

Momentum: 2.344GeV/c

Target nucleus



1.5GeV γ^*

Scattered electron

Momentum: 0.844GeV/c ±17%

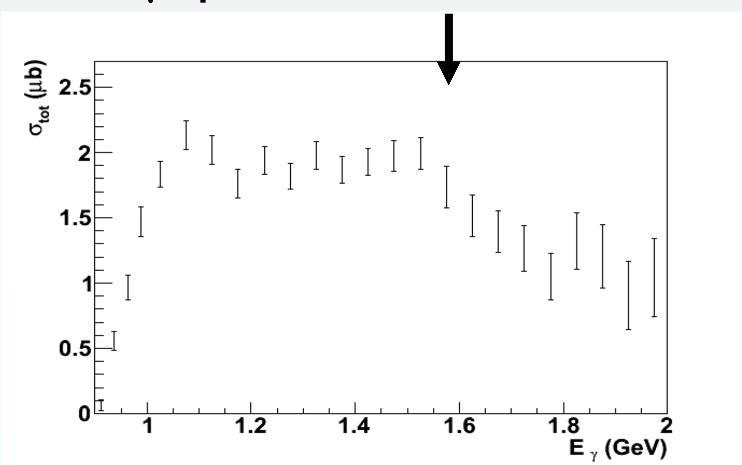
Angular acceptance: 3° ∽9°

Coincidence measurement

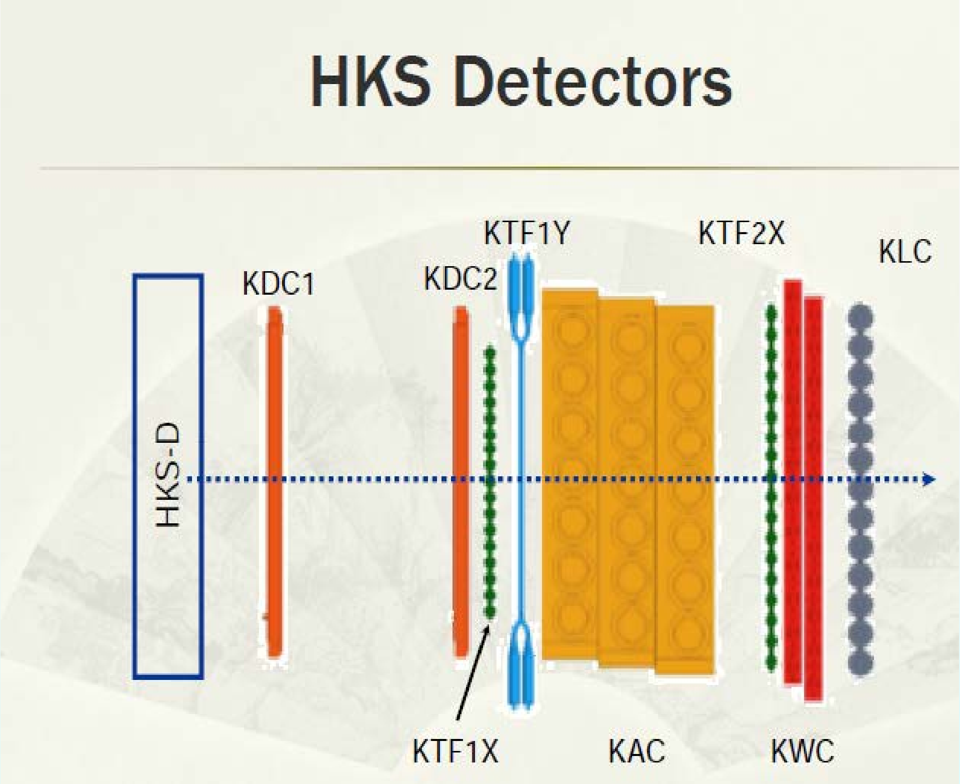
Momentum: 1.2GeV/c ±12.5%

Angular acceptance : 1° ∽13°

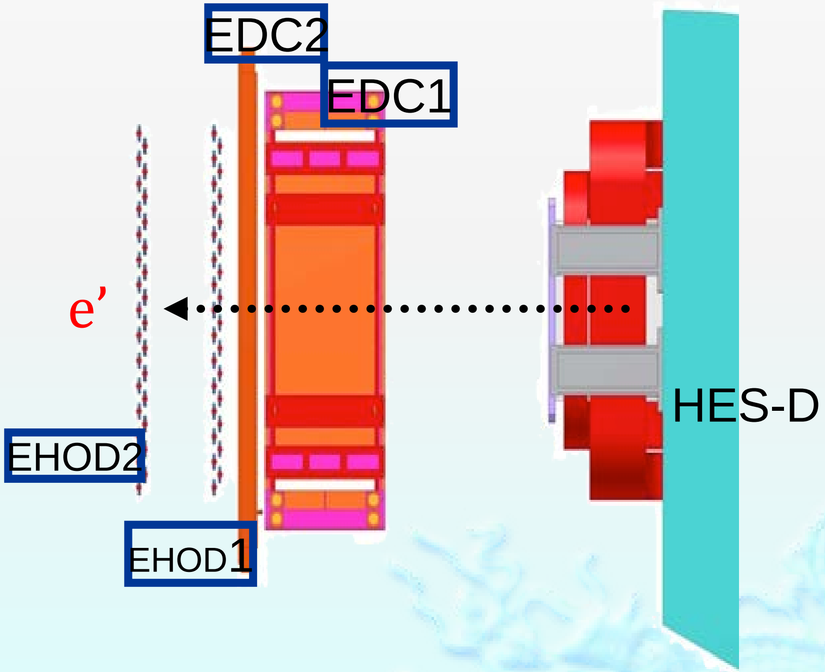
$\gamma + p \rightarrow \Lambda + K^+$



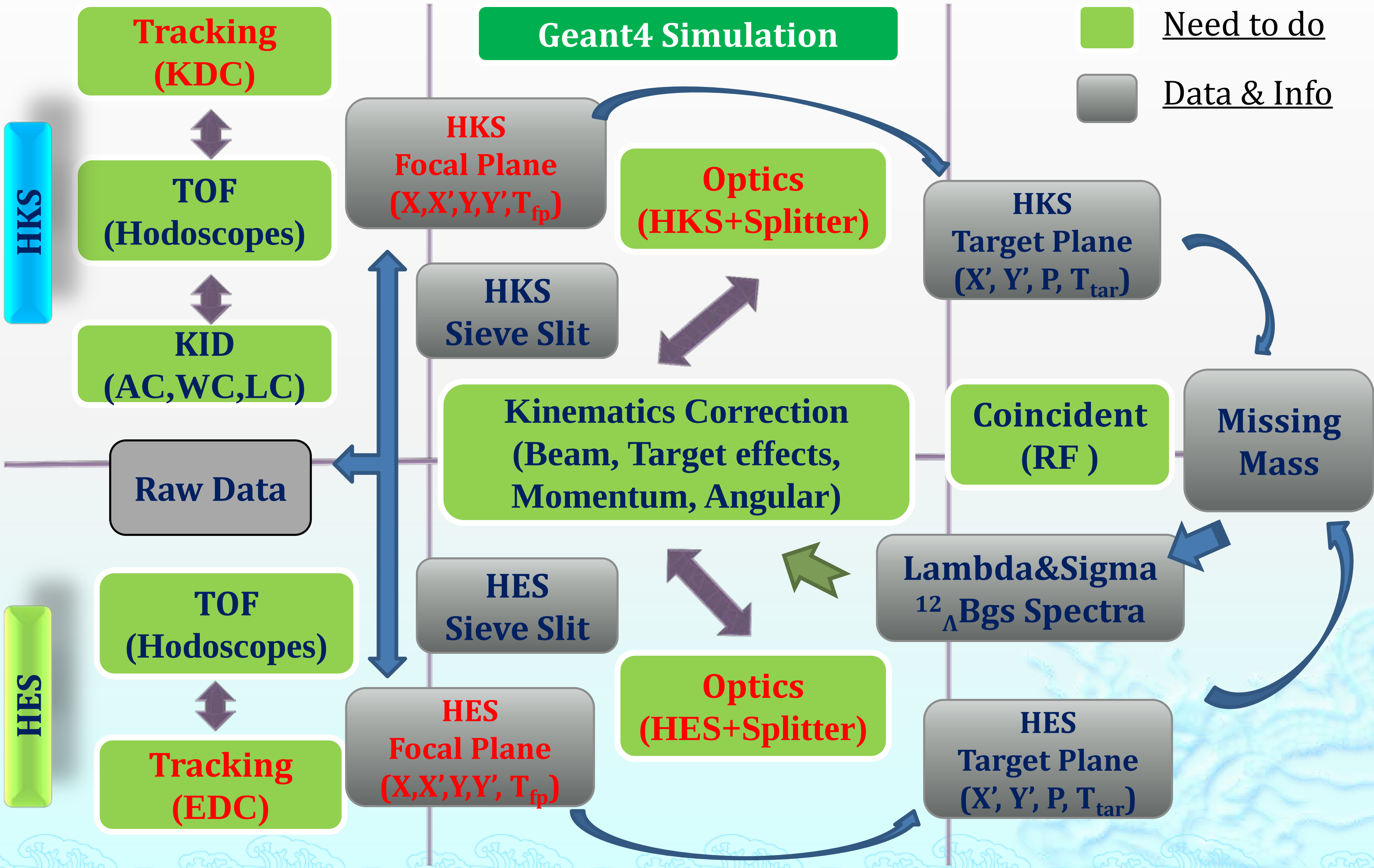
Experimental Setup
-Detector Package-



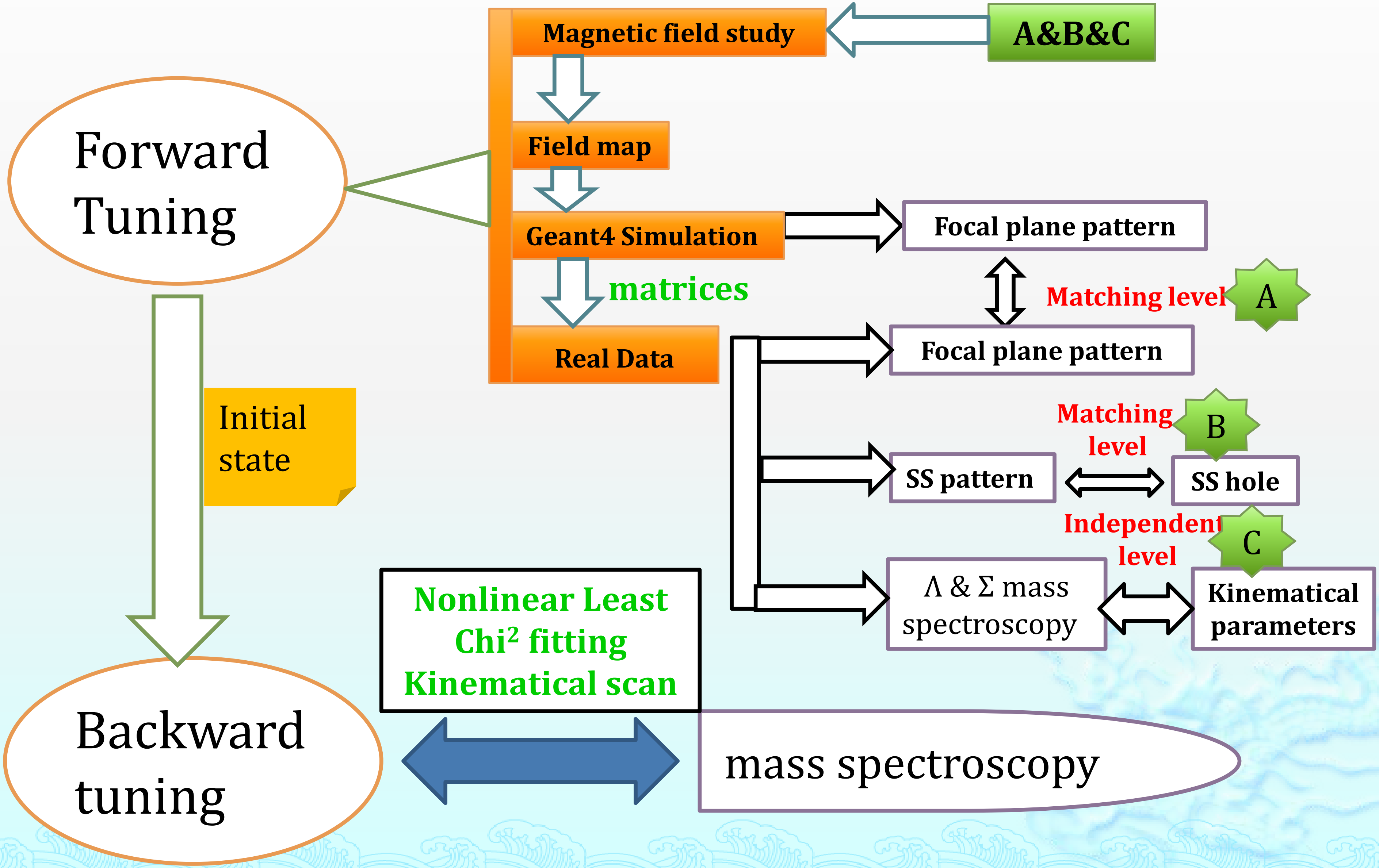
HES Detectors



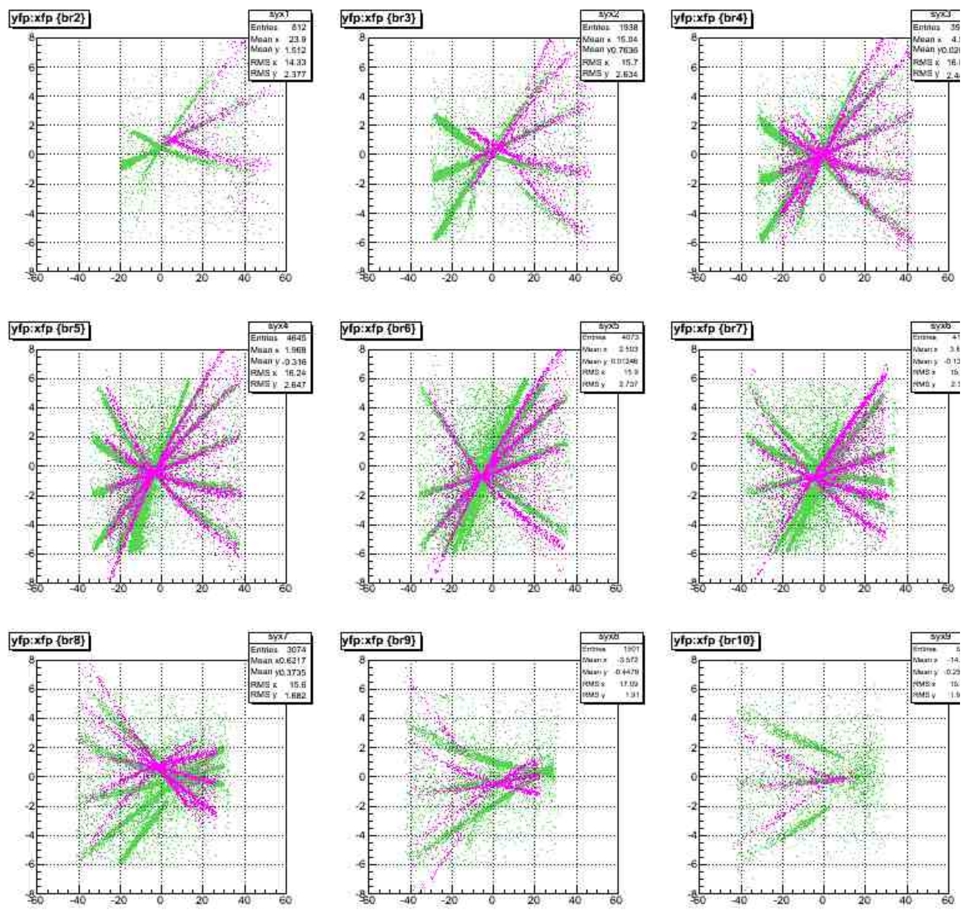
Analysis Flow Chart



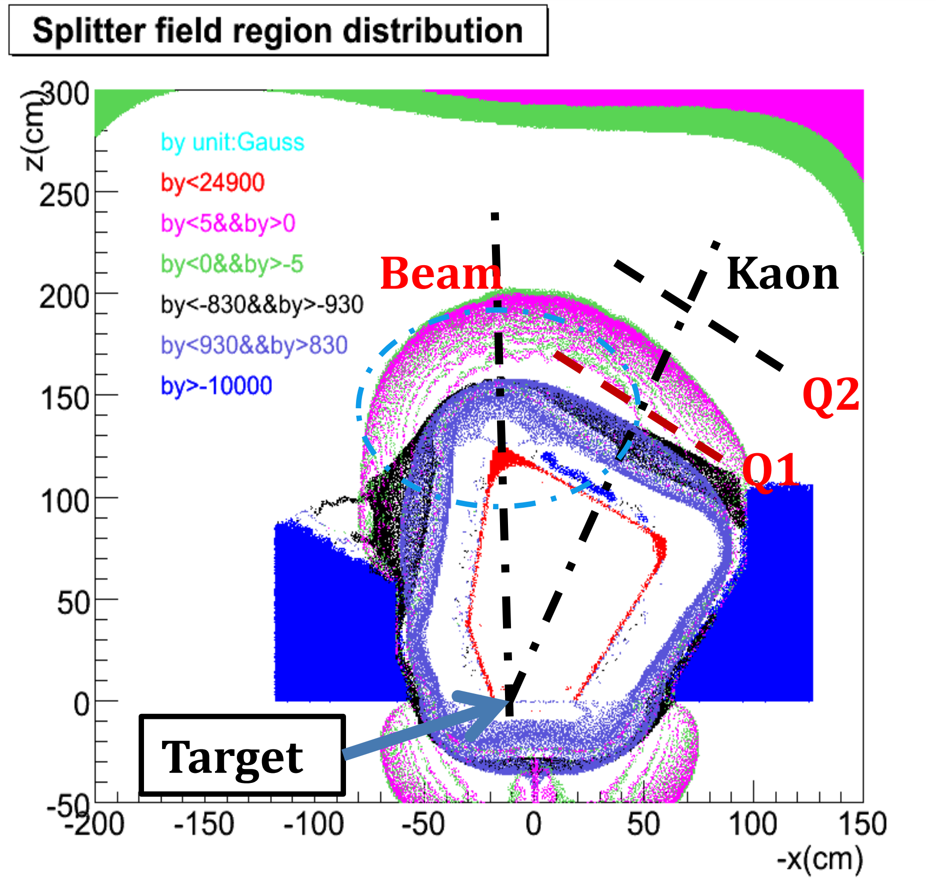
Calibration Procedure of the Spectrometer System



Forward Optics Tuning



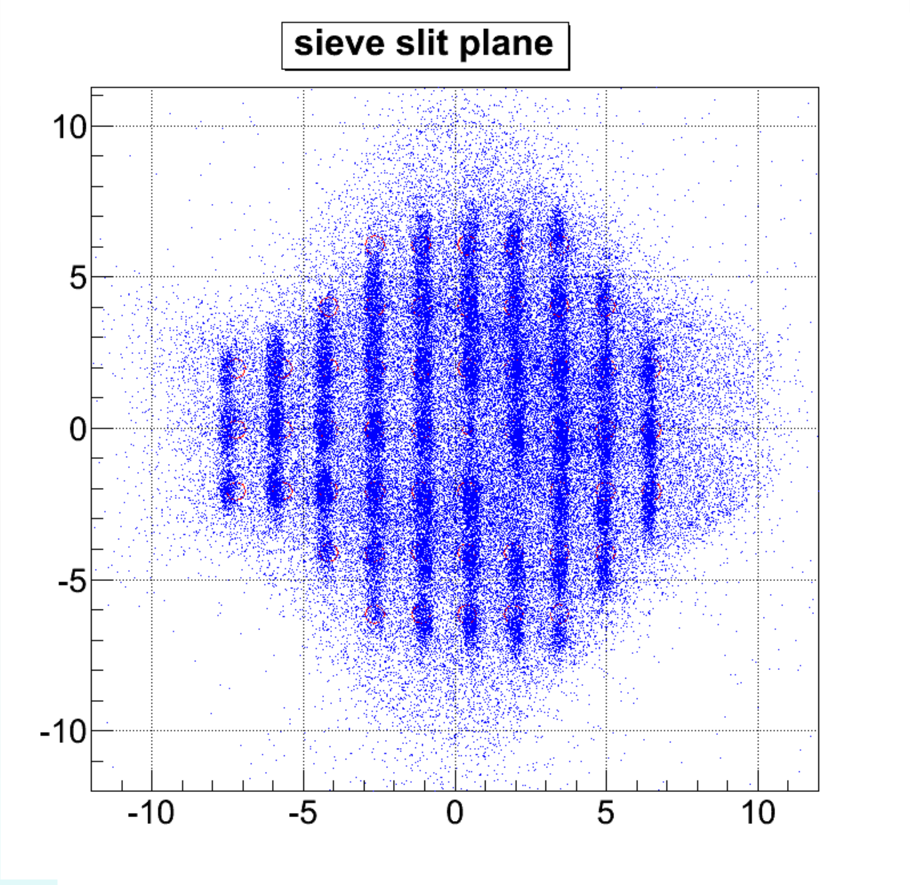
Purple: Geant4 simulation green: Real HES SS data

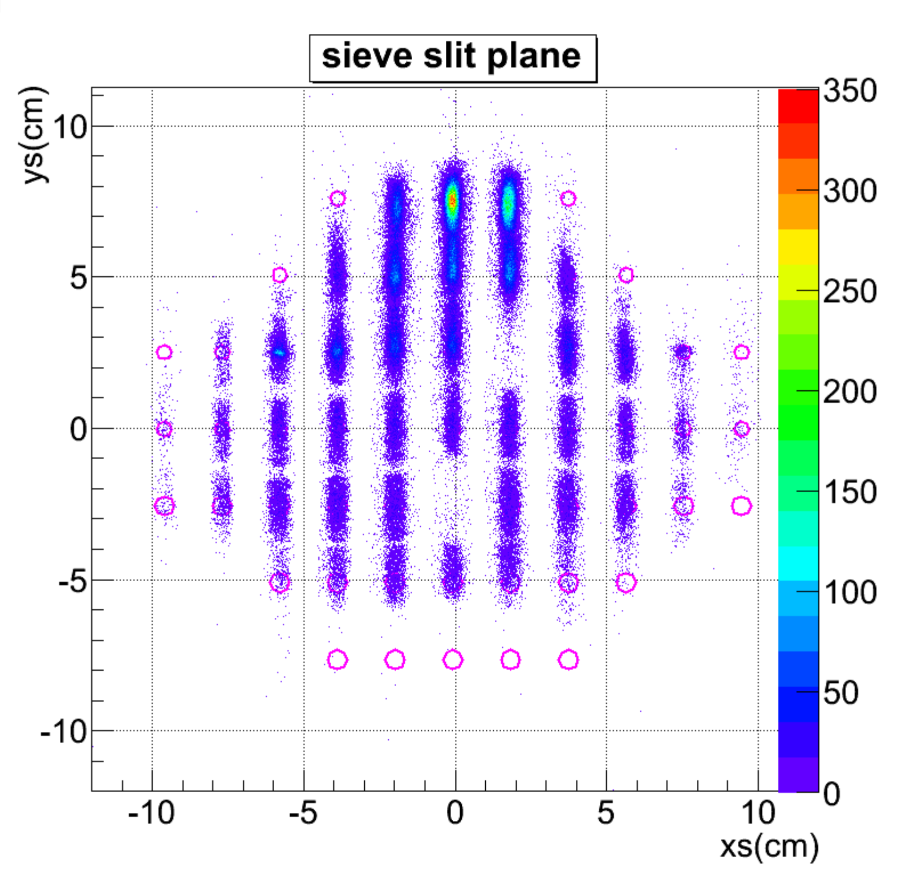


Splitter field contour on xoz plane

The leakage of splitter fringe field causes the cross talk between the splitter and quadrupoles

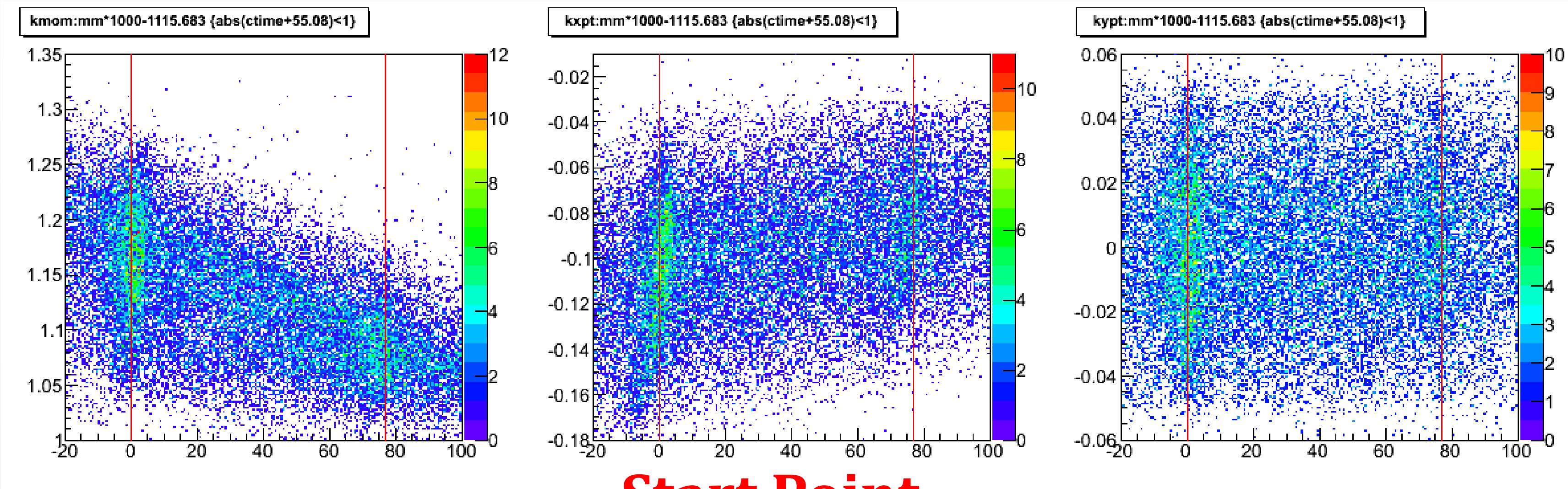
Forward Optics Tuning



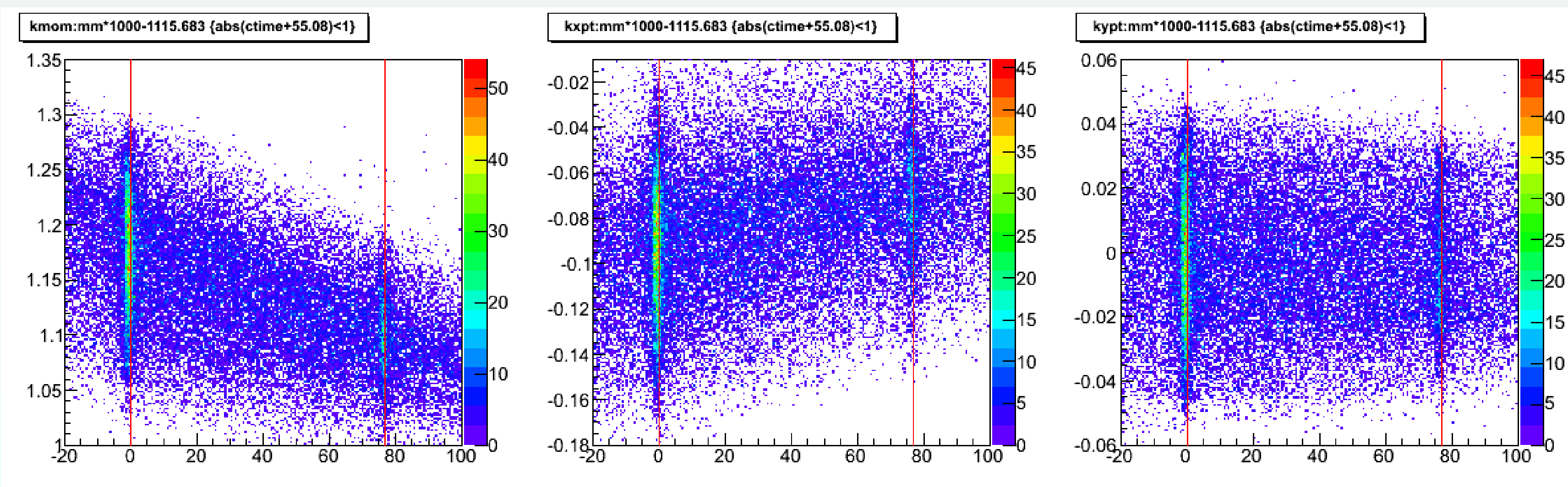


The asymmetry functions are introduced and tuned for HKS&HES quadruple field Bx and By, independently.

The Mass Status of Forward Optics Tuning



Start Point



after forward tuning

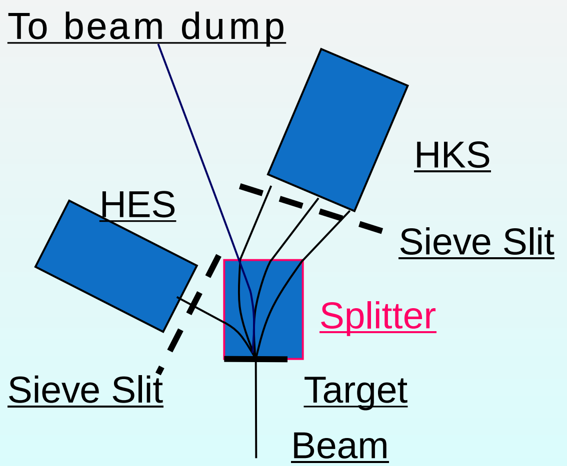
Backward Spectrometer System Calibration

Spectrometer system calibration key： to reach 400 keV energy resolution

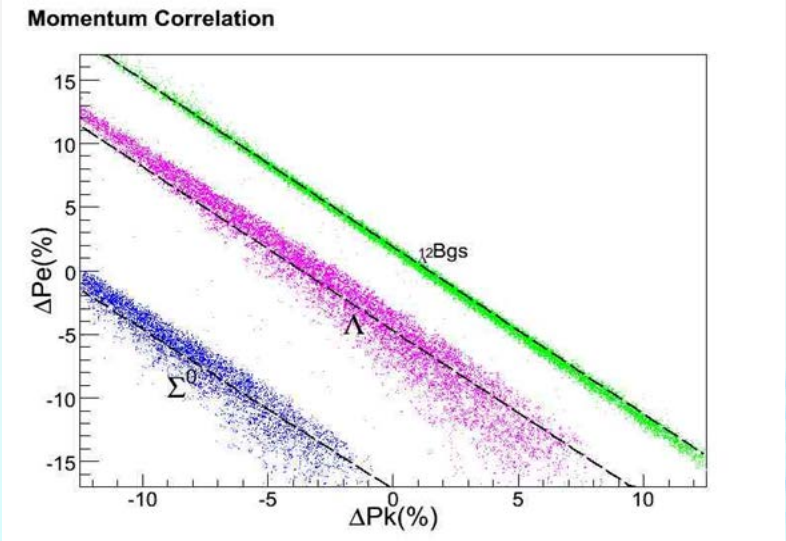
- Common splitter : Separated single arm kinematics and optics calibration is not possible
- Technique: 2-arm coupled calibration for both kinematics and optics

Using known masses of Λ, Σ^0 from CH2 target and identified known hypernuclear bound states $^{12}{}_{\Lambda}$Bgs for spectrometer calibration

HES spectrometer system



Kinematics coverage



Calibration Procedure

$$MM = f(E_{beam}, P_k, xt'_{k}, yt'_k, P_{e'}, xt'_{e'}, yt'_{e'})$$
$$= f(Ebeam_0 + \Delta E_{beam0}, P_{k0} + \Delta P_{k0}, xt'_k, yt'_k, P_{e'0} + \Delta P_{e'0}, xt'_{e'}, yt'_{e'})$$

$$P = P0(1+\delta/100)$$

$$\begin{pmatrix} xt' \\ yt' \\ \delta \end{pmatrix} = (M) \begin{pmatrix} xf \\ xf' \\ yf \\ yf' \end{pmatrix}$$
$$= \begin{pmatrix} M\_angle \\ M\_momentum \end{pmatrix} \begin{pmatrix} xf \\ xf' \\ yf \\ yf' \end{pmatrix}$$

❖ Mathematical optimization by **Nonlinear Least Chi^2 fitting**

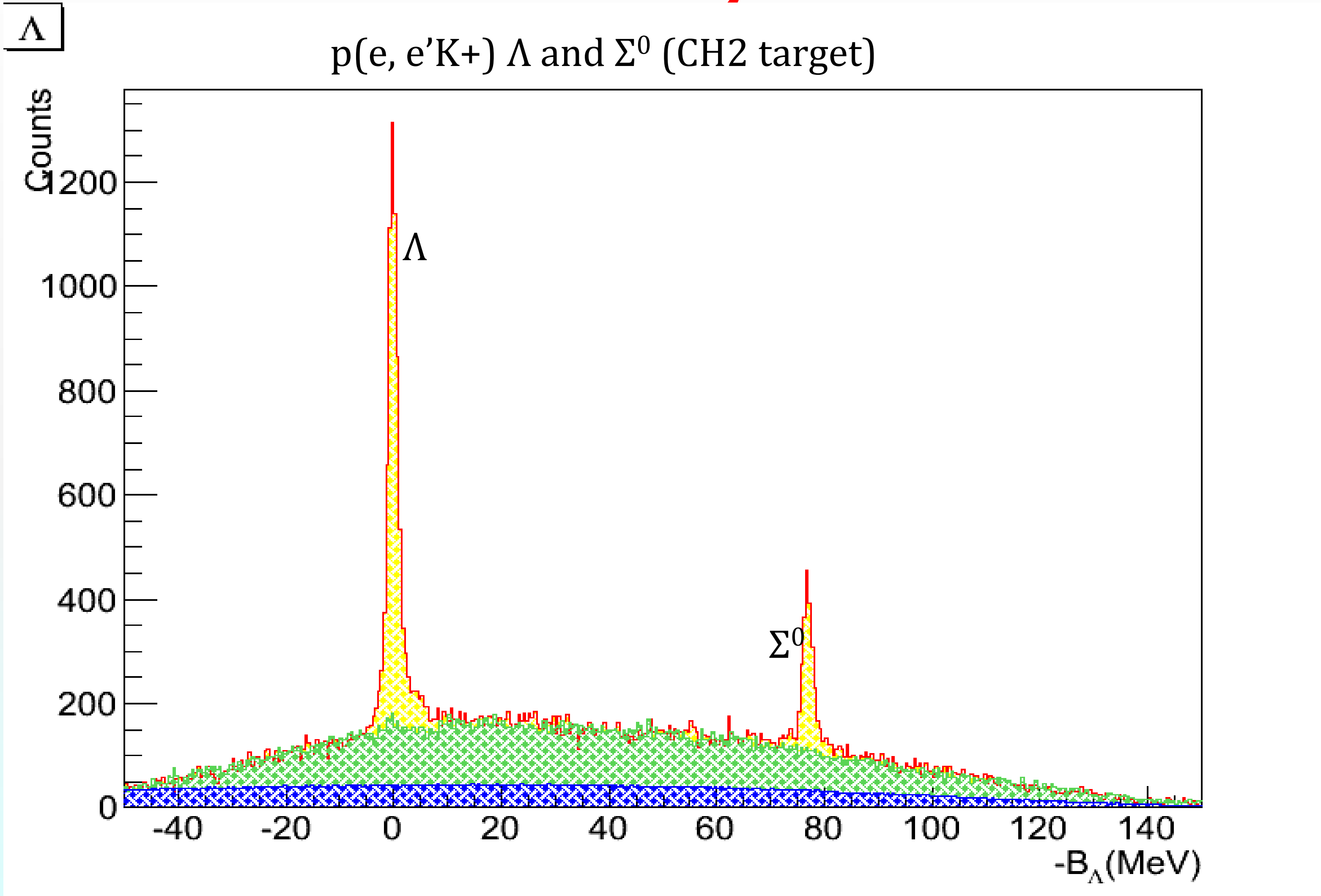
a. Central kinematics scan (m_Λ,m_Σ,$\Delta m_{\Lambda\Sigma}$)

b. Angular matrices (m_Λ,m_Σ,σ)

c. Momentum matrices ($^{12}{}_\Lambda$Bgs)

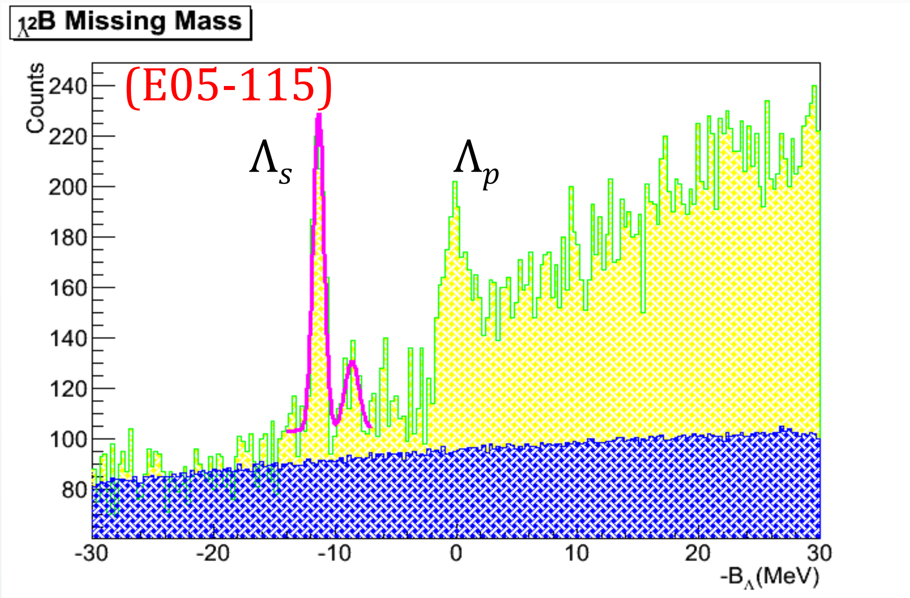
d. Iteration

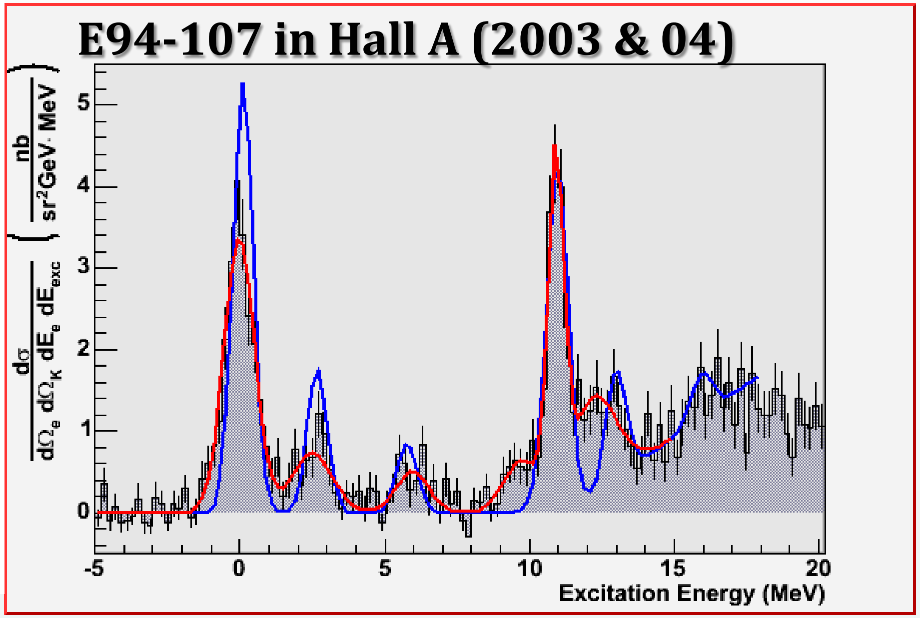
Preliminary status

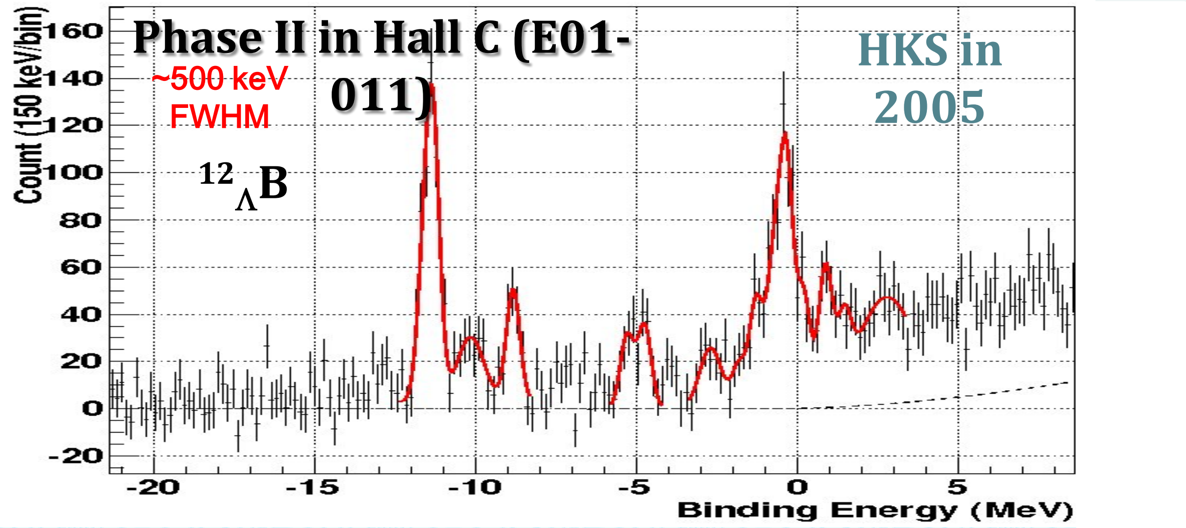


Allowing precise calibration of mass scale

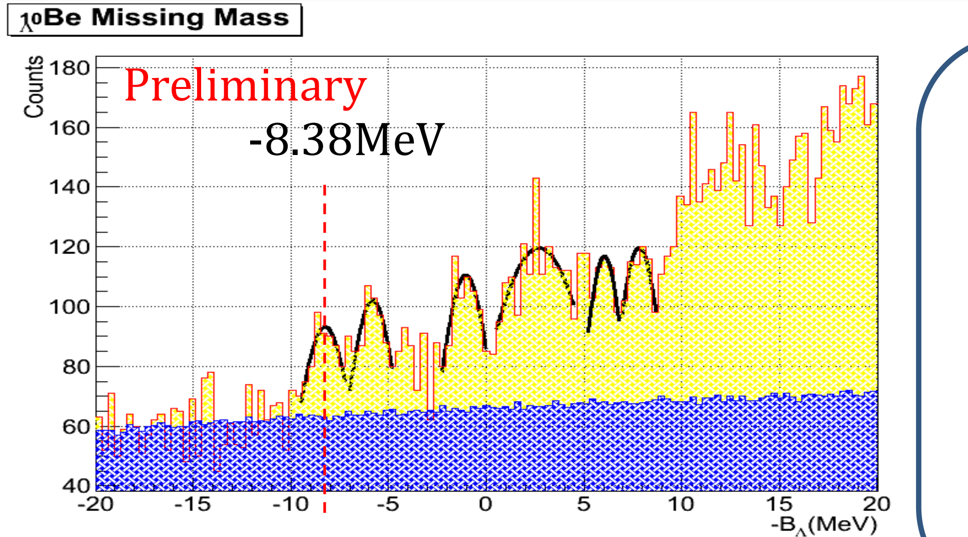
Preliminary status – $^{12}{}_{\Lambda}B$

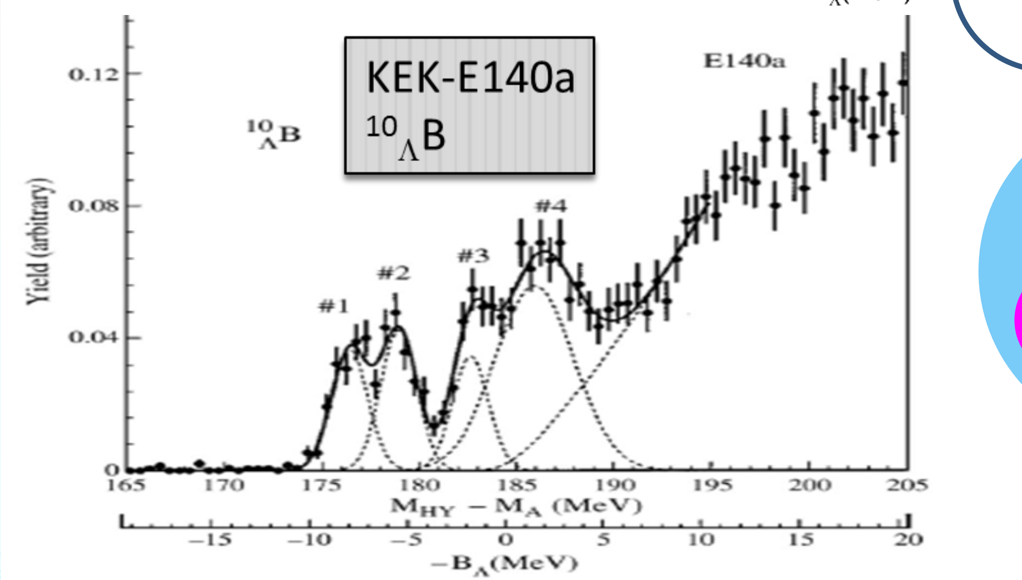






Preliminary status – $^{10}{}_{\Lambda}Be$



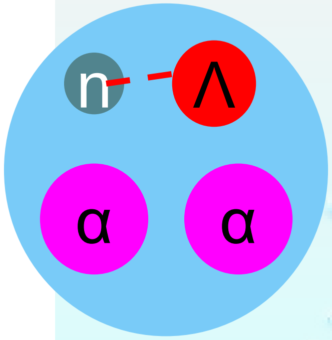


0 MeV $^{9}Be+\Lambda$

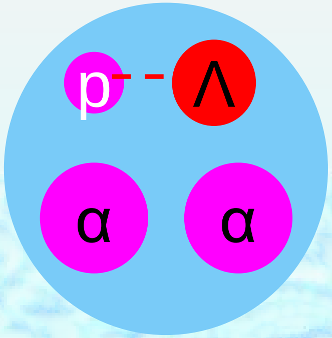
Cal: 8.84 MeV (without CSB)

Cal: 8.76 MeV (with CSB)

By E. Hiyama

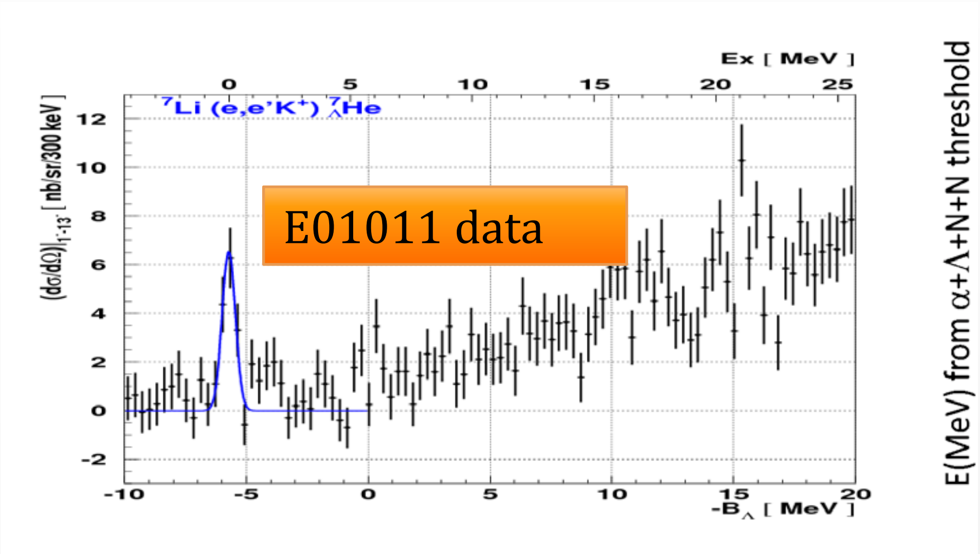


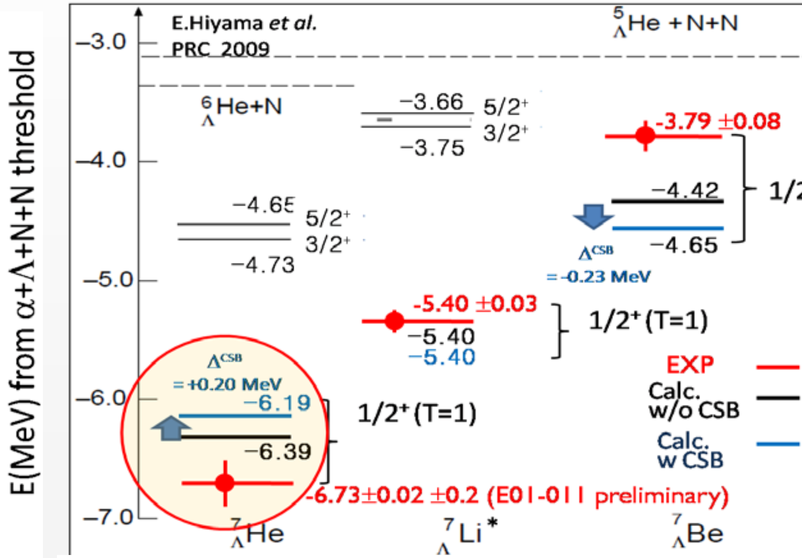
$^{10}_{\Lambda}Be$

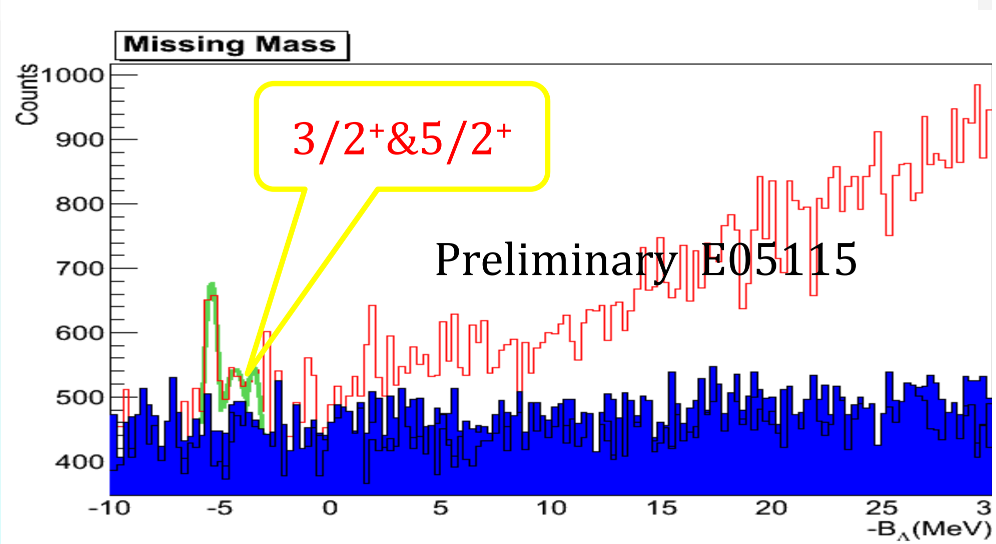


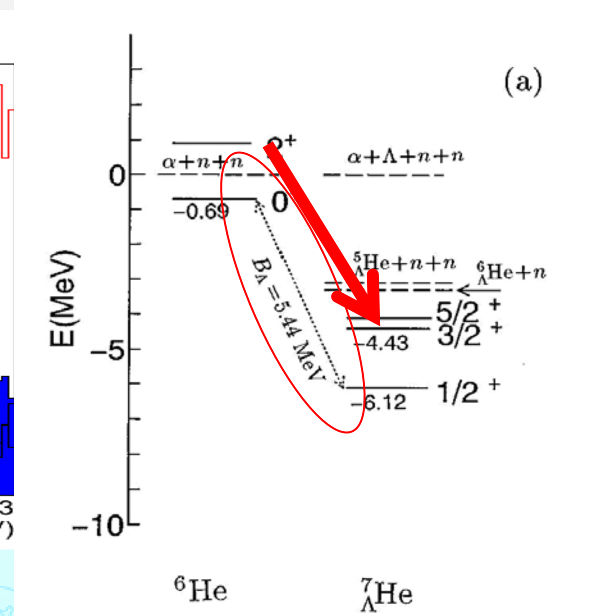
$^{10}_{\Lambda}B$

Preliminary Result - $^{7}_{\Lambda}He$



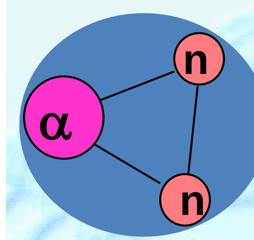




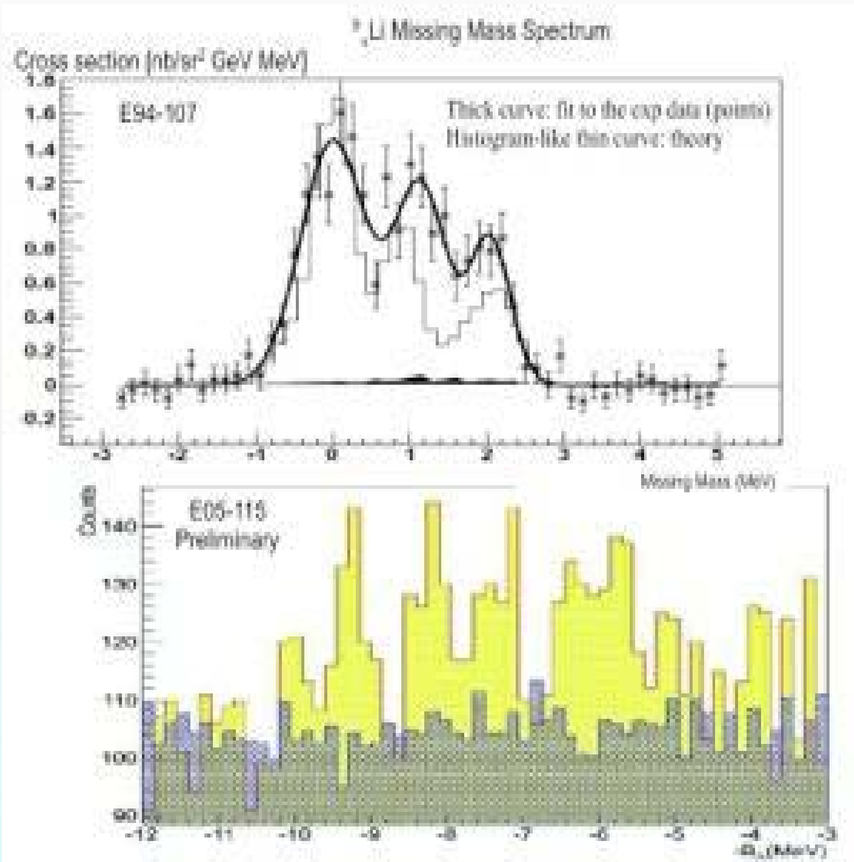


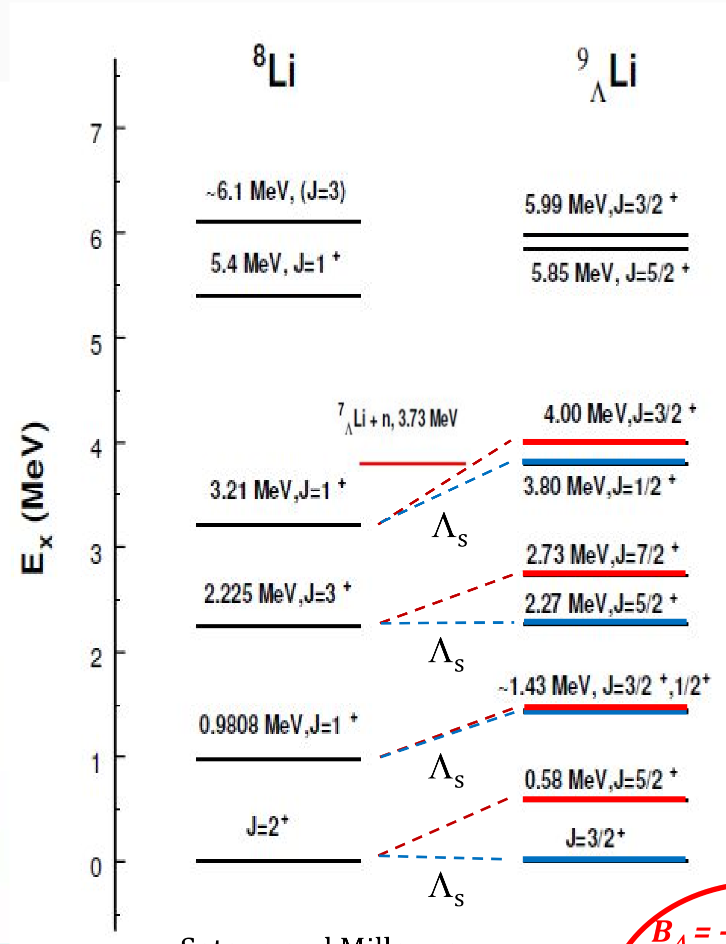
E. Hiyama, et al., PRC53 2078 (1996)

^{6}He core



Preliminary status – ${}^{9}_{\Lambda}$Li





Sotona and Millener
Saclay-Lyon model for elementary process

Hall C HKS E05-115

~4.38

~3.77

~ 2.75

~1.90

~0.84

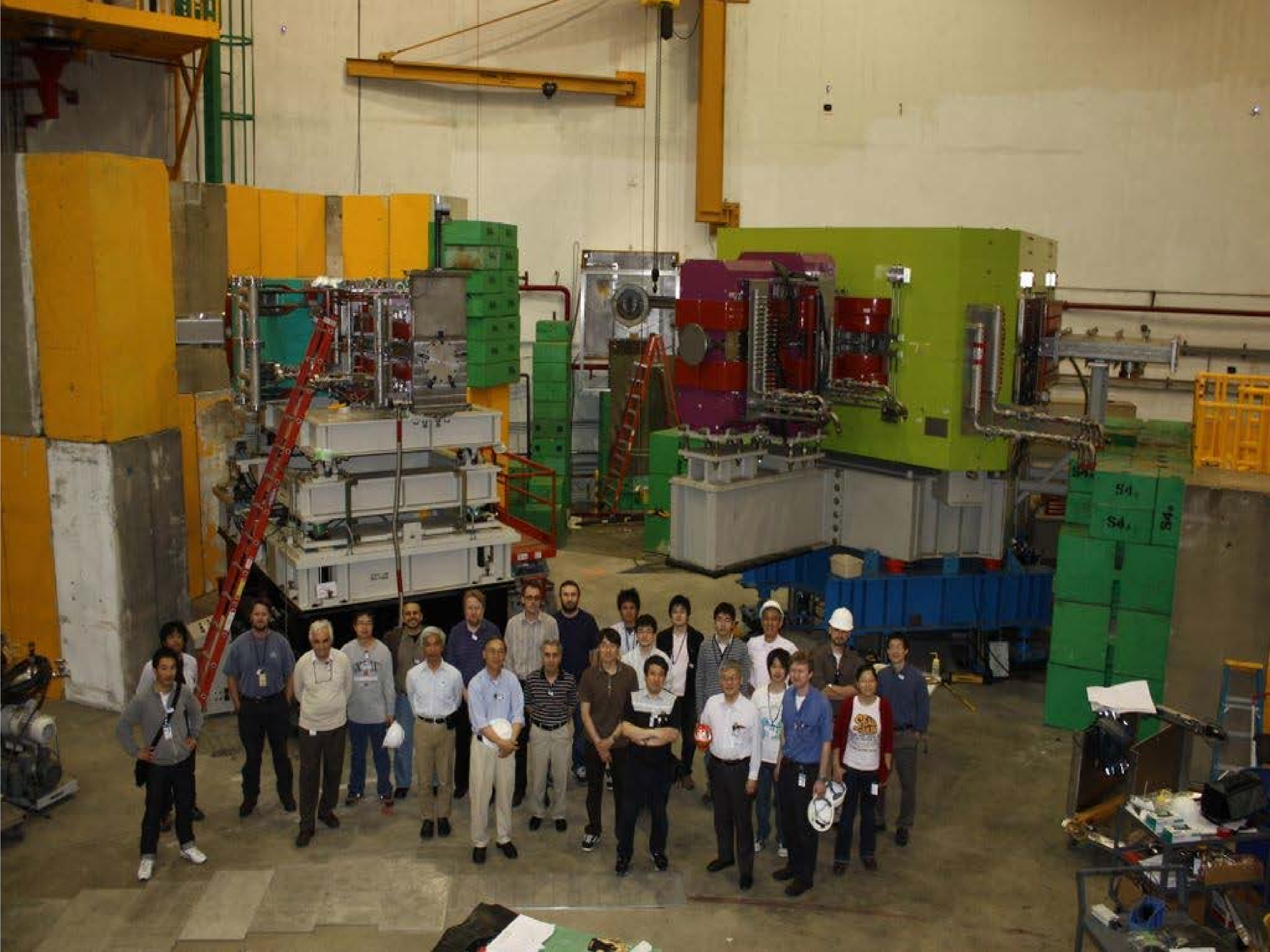
Ex: 0.0

B_Λ = -10.1 ±0.3

B_Λ = -8.53±0.18 (emulsion, average over only 8 events)

Summary and to do

- By current calibration method, we are able to get clear mass spectroscopy , which is not included in the calibration data set;
- Current resolution is still factor of 2 away from expected resolution, the iteration will continue to improve the optical matrices as well as the kinematics;
- Other issue: High multiplicity tracking problem for heavy target data, Japanese people are still working for it.



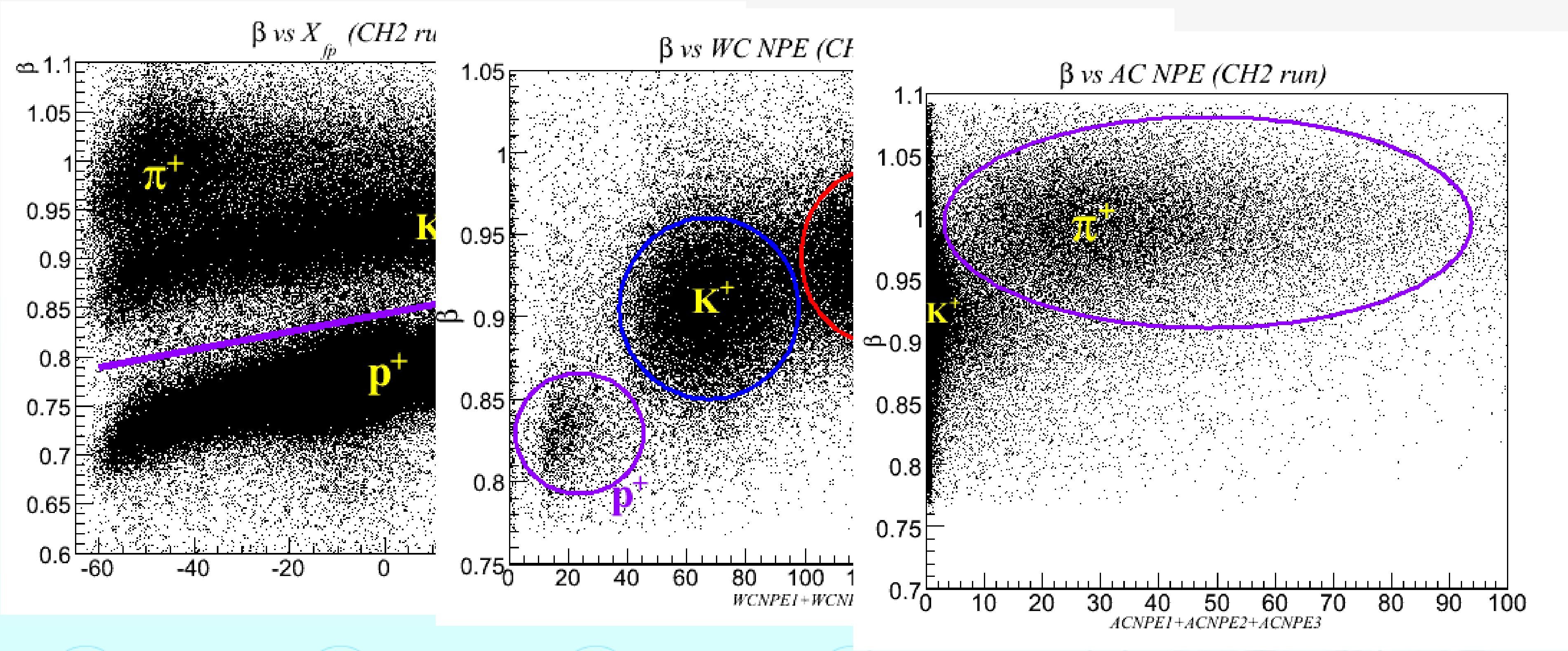
Back Up

Thank you for your attention!

Particle ID

Online Trigger: $(2/3\ (\overline{AC1 \times AC2 \times AC3})) \times (WC1 \times WC2)$
AC (rejecte $\pi^+ >$ 99%), WC (rejecte $p^+ >$99%),

Offline KID: Cuts on number of photon electrons



Experimental Setup

-Tilt Method-

$$\frac{d^5\sigma}{dE'_e d\Omega'_e d\Omega_K} = \Gamma \frac{d\sigma}{d\Omega_K}$$ Electroproduction differential cross section(Miloslav Sontan

Γ : virtual photon flux $\frac{d\sigma}{d\Omega_K}$:Photoproduction cross section by virtual photor

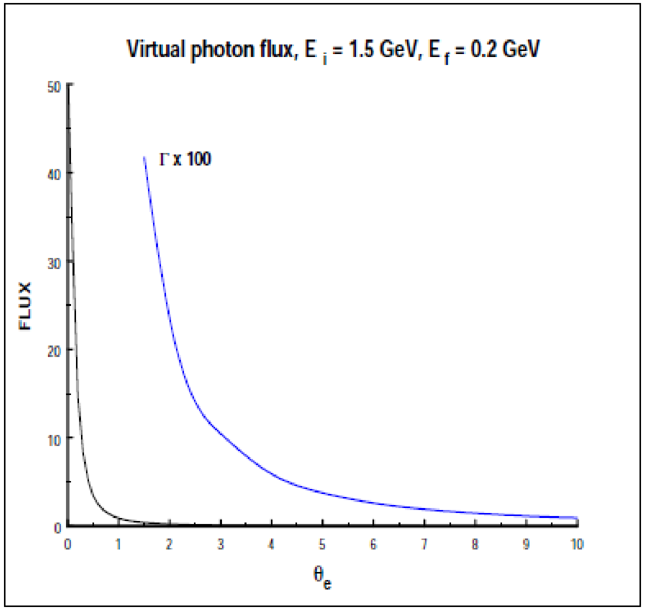
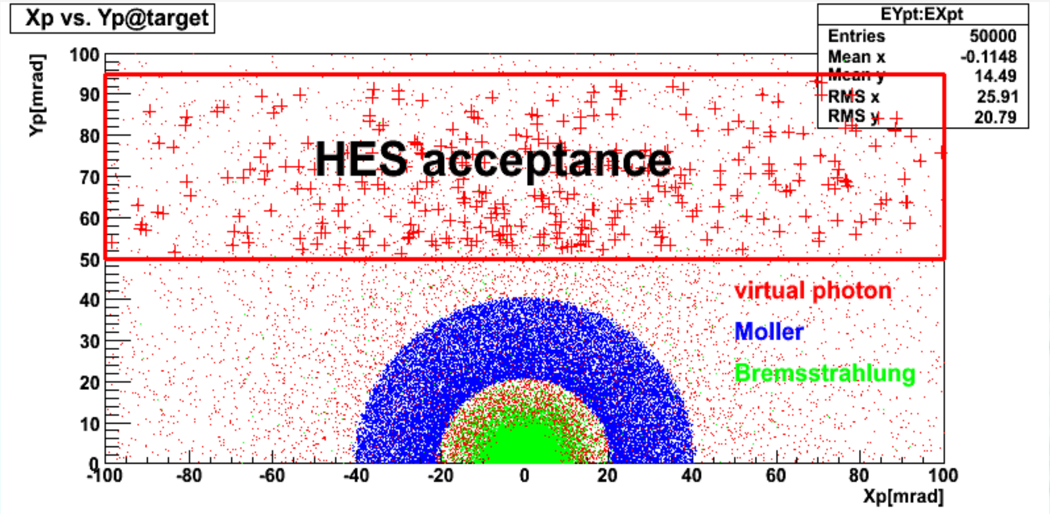


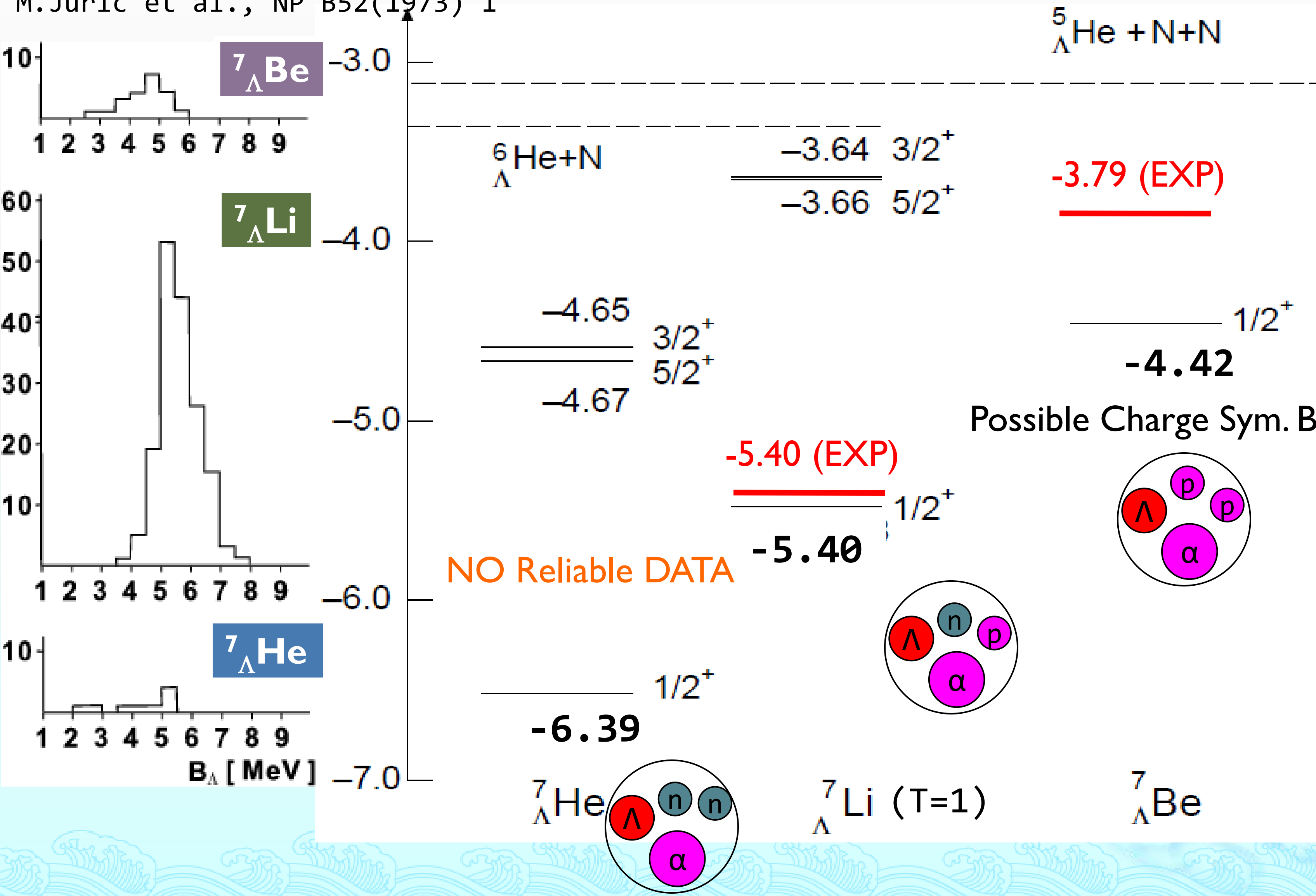
Figure 6: Virtual photon flux vs electron scattering angle



^{7}Li target :Physics of (A = 7,T=1)

E. Hiyama et al.
PRC80,054321(2009)

M.Jurič et al., NP B52(1973) 1



Another Physics of $^{7}_{\Lambda}He$ HKS-HES (E05-115)

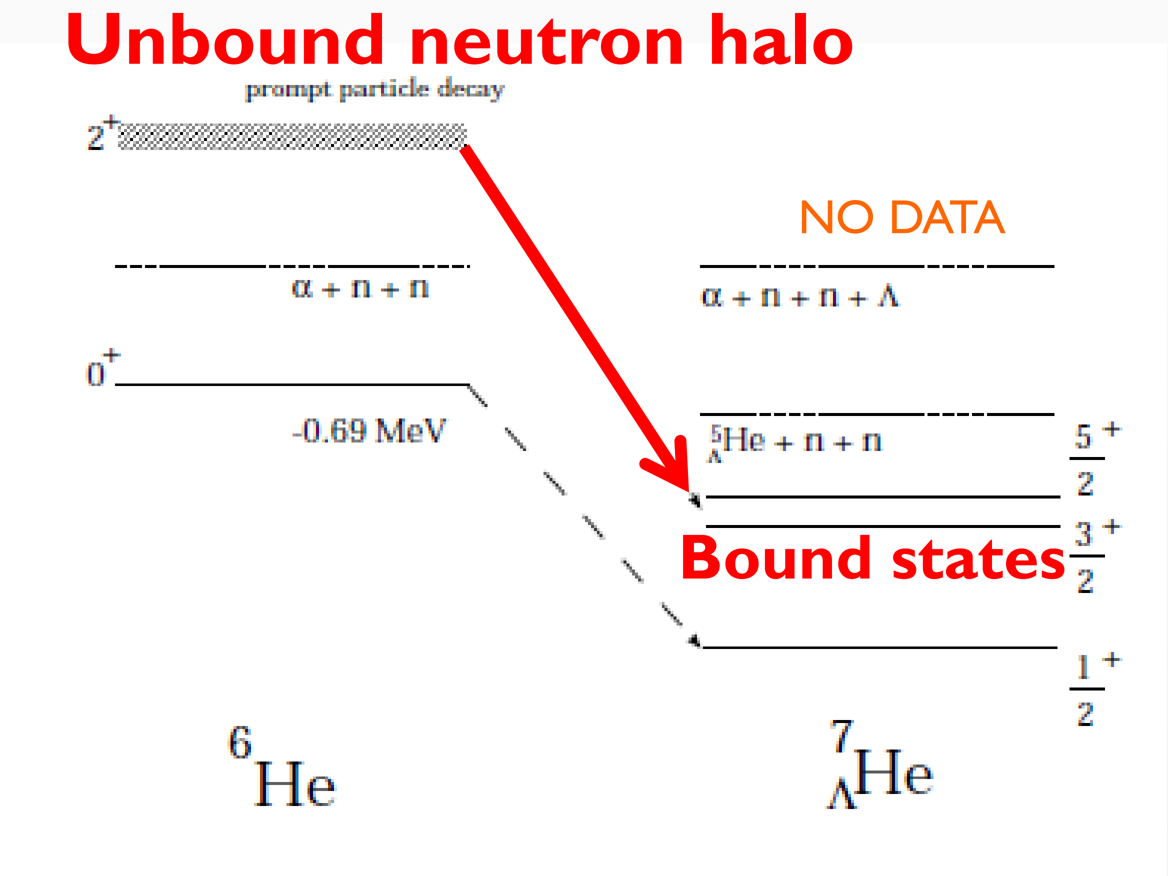
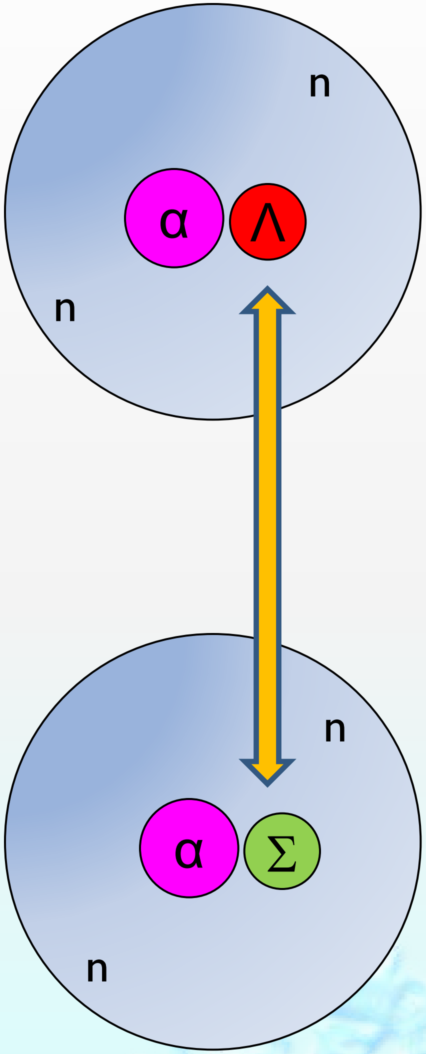
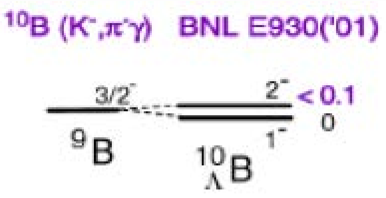


Figure 1: Energy levels for ^{6}He and $^{7}_{\Lambda}$He [7]



Direct Observation of Λ's glue-like role

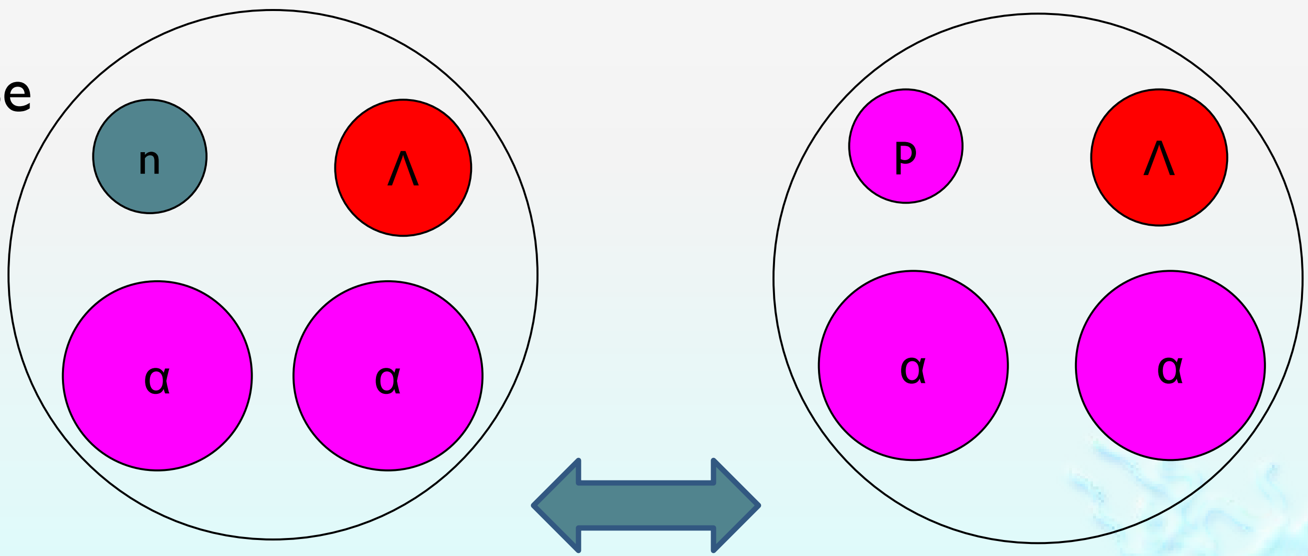
^{10}B target



Millener's parameterization(V,D,S_N,S_Λ,T)
Hyperball's γ data

predicts >200keV 1^-2^- separation

^{10}B(e,e'K) $^{10}_{\Lambda}$Be



$^{10}_{\Lambda}$B

Cluster Calc. based on the same framework

Imperfect treatment of Tensor force?

Bad wavefunction of the core nucleus?

Coincident Trigger Set

HKS :

$HKS_{trigger}$=(CP)×(K)

CP=(KTOF1X)×(KTOF1Y)×(KTOF2X)

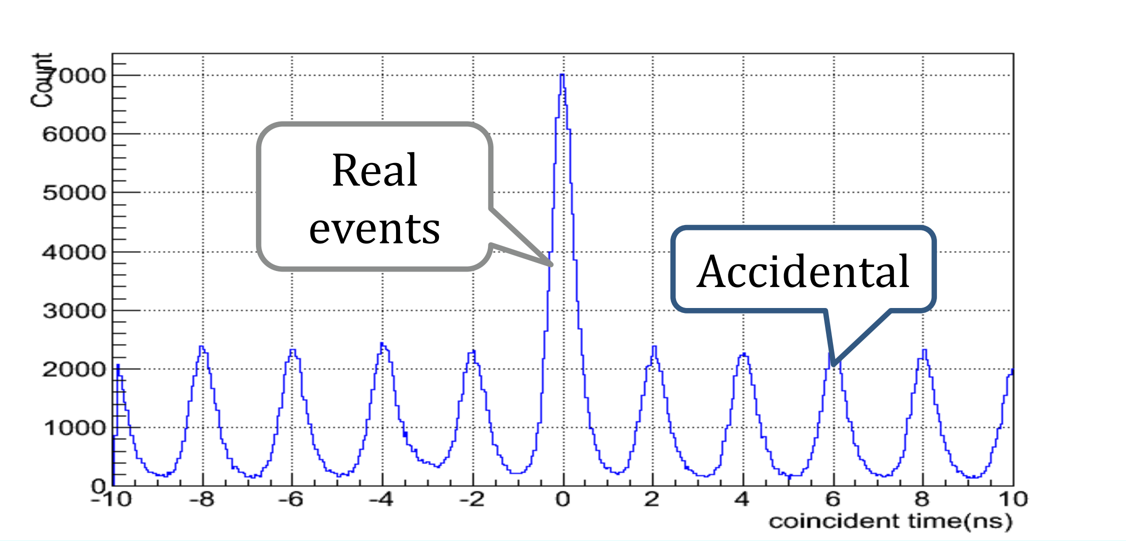
K=WC×$\overline{AC}$

HES:

$HES_{trigger}$=(EHODO1)×(EHODO2)

×:AND

$COIN_{trigger}$=($HKS_{trigger}$)×($HES_{trigger}$)



- **Coincident Time:**

The correlation of HKS target time and HES target time, give us the coincident spectrum:

$$T_{coin} = T_{tar}^{e'} - T_{tar}^{K^+}$$

PID cut is applied and path length correction has been done