Physics with the HKS
- hypernuclear spectroscopy E01-011

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For HKS collaboration

Department of Physics

Tohoku university

2005 HallC Summer Workshop

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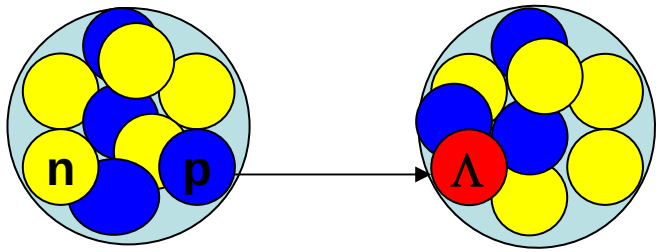
Λ hypernuclei

Core Nucleus + Λ hyperon

Nucleon replaced by Λ hyperon.



- **ΛN interaction**
  - Unified view of baryon-baryon interaction by including new degree of freedom, strangeness.
  - Central and spin-dependent **ΛN** interaction.

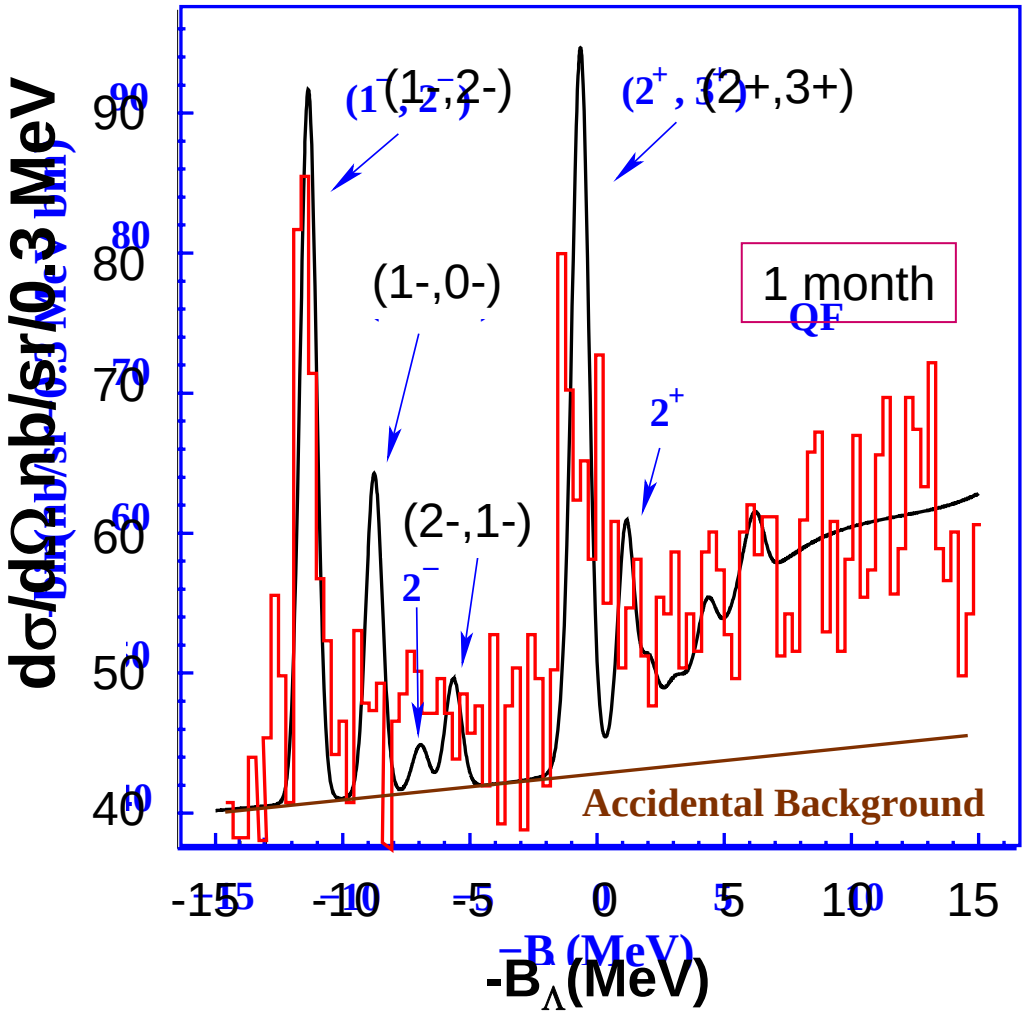
    $V_{\Lambda N}$ (~30 MeV) < V_{NN} (~50 MeV)
- **Unique structure of hadronic many-body system**
  - Deeply bound states, no **Pauli blocking**.
  - Core excited states.
  - Glue role of a Λ hyperon in nucleus.

Narrow widths of excited states ⇒ **High precision spectroscopy**

Physics issues

- $^{12}C \rightarrow {}^{12}_{\Lambda}B$
  - Precision analysis of core excited states
  - p-orbit states splitting ?
  - comparison with the mirror hypernucleus, $^{12}_{\Lambda}C$
- $^{28}Si \rightarrow {}^{28}_{\Lambda}Al$
  - The first precision spectroscopy beyond the p-shell
  - *ls* splitting in the p, d orbits ?
- Other targets ($^{6,7}Li$, ^{9}Be, $^{10,11}B$, ^{51}V, ^{89}Y)
  - Rate study for heavier targets
  - p-shell spectroscopy
  - Target mass dependence --- quasifree K^+ electroproduction

$^{12}_{\Lambda}$B spectrum of E89-009



Ground state doublet

Binding energy

B_Λ = 11.4±0.5 MeV

Emulsion data

B_Λ = 11.37 MeV

Cross section

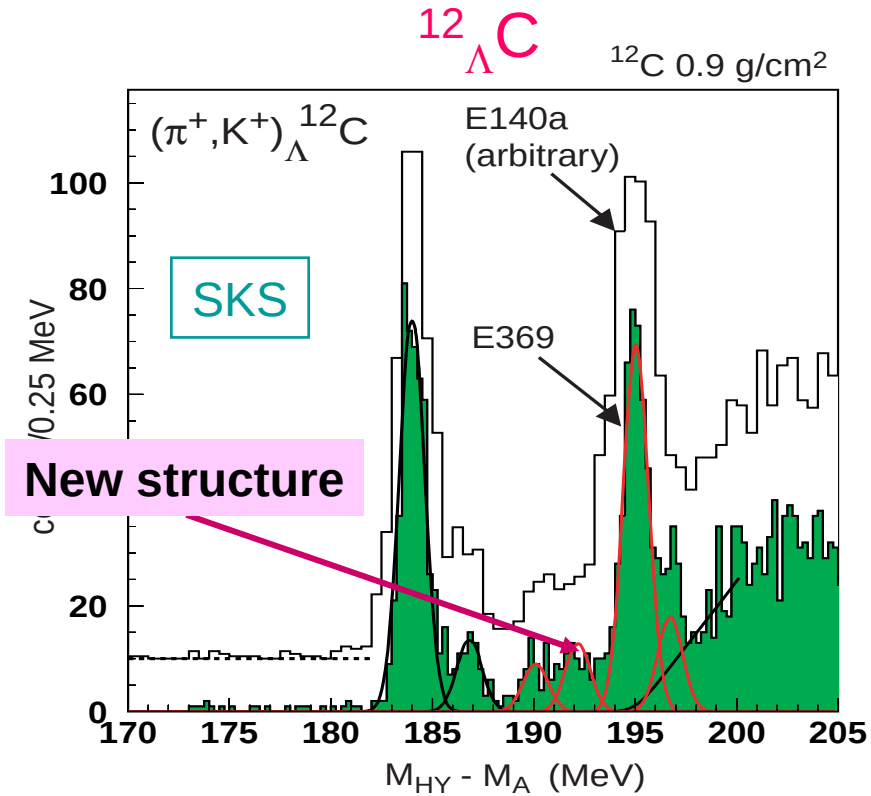
140±17(stat) ±18(sys) nb/sr

Motoba's calculation

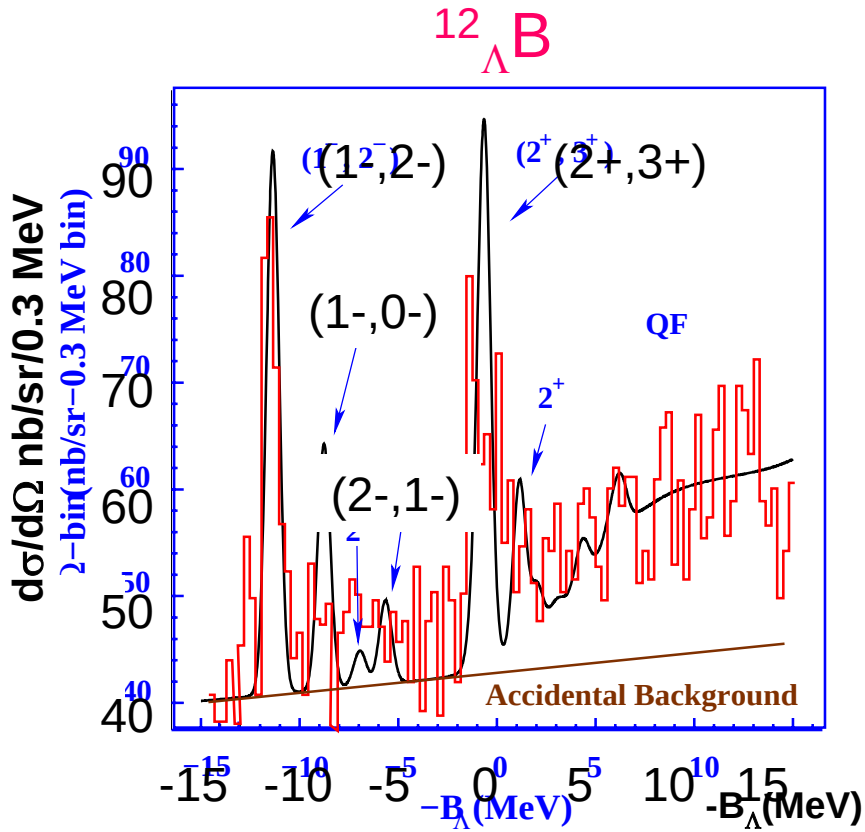
138 nb/sr

More statistics and better resolution are required to see more precise structure of core-nucleus excited states.

Energy spectra in $^{12}_{\Lambda}$C and $^{12}_{\Lambda}$B



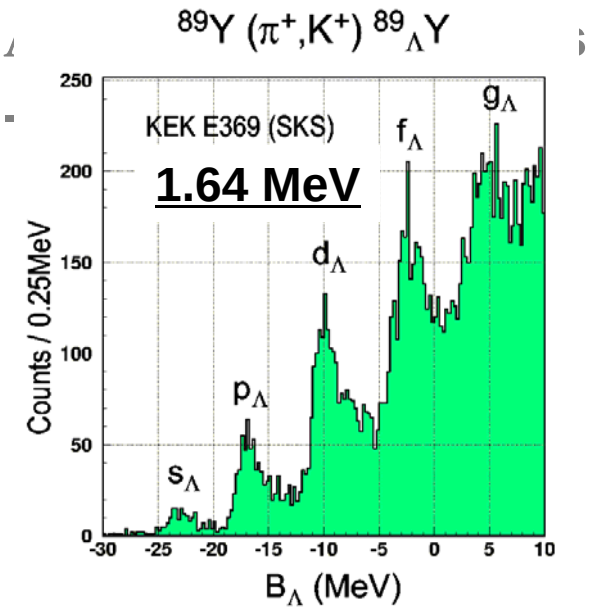
KEK E369 1.45 MeV(FWHM)



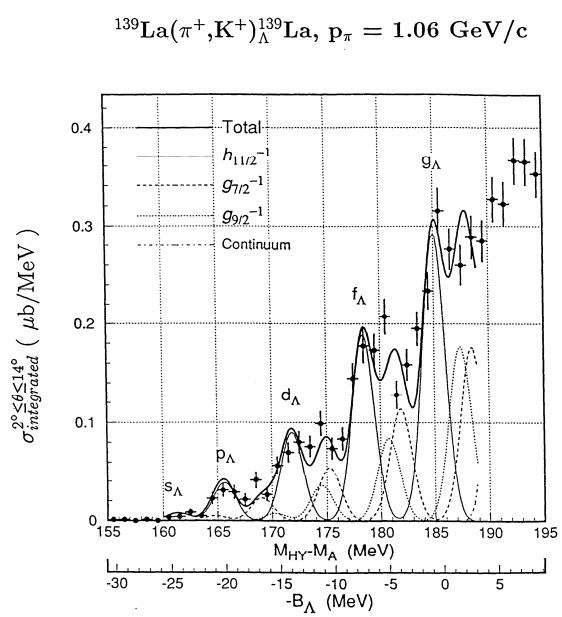
E89-009 900keV

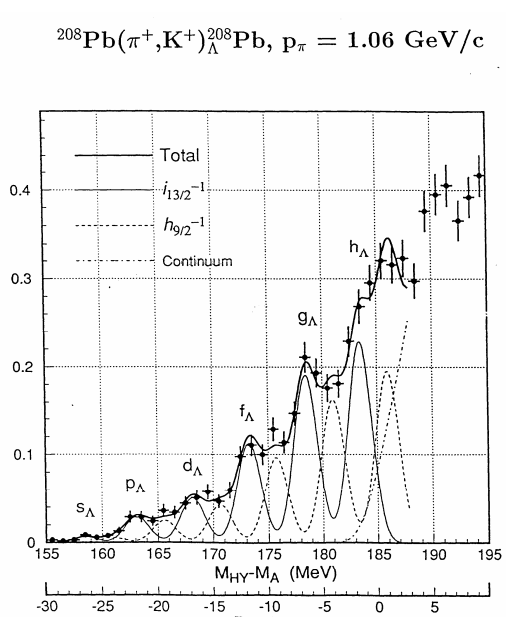
- Core-nucleus excited states
- Splitting in p shell
- Charge symmetry

Medium-Heavier hypernuclei



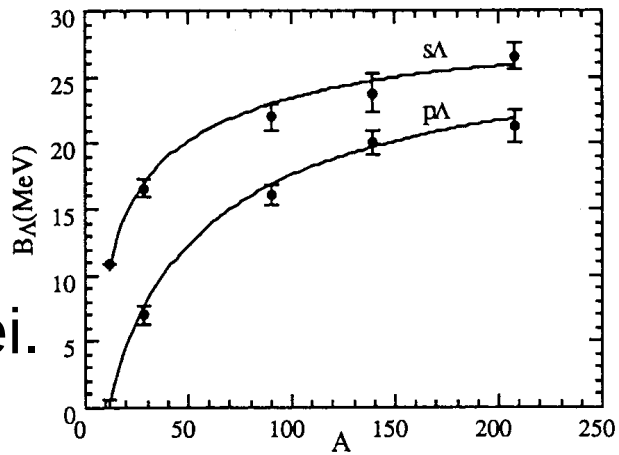
Hotchi et al., PRC 64 (2001) 044302





KEK E140a

- Taking data of ^{28}Si -> $^{28}_{\Lambda}$Al.
- A dependence.
  - Behavior of Λ in large A
- *ls* splitting in d, f orbits of heavier nuclei.
  - *ls* of YN is ~1/30 smaller than NN in small A.



Basic characteristics of (e,e'K^+) spectroscopy

Hadron (K or π) beam :

Large cross section,

the energy resolution is 1.5 MeV,

limited by ΔE of secondly beam.

Electron beam :

Small cross section, recovered by high intensity continuous e beam in JLAB.

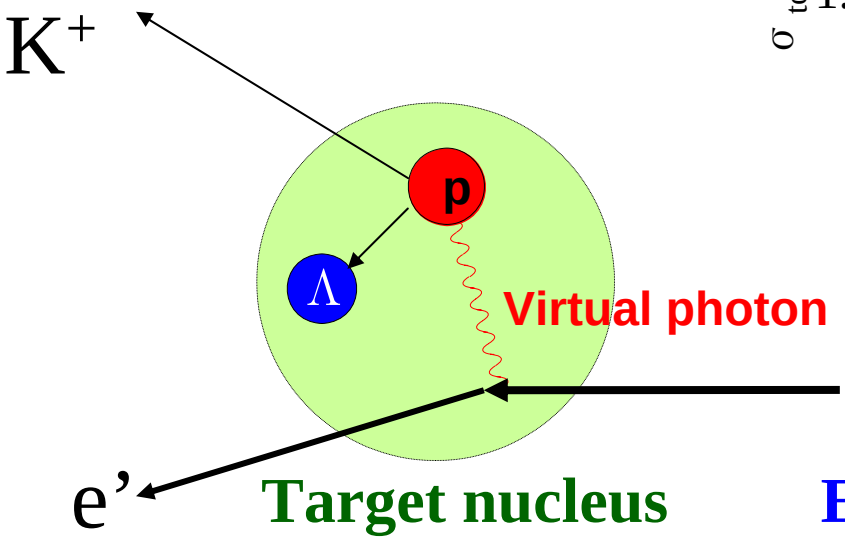
the 400 keV energy resolution is possible.

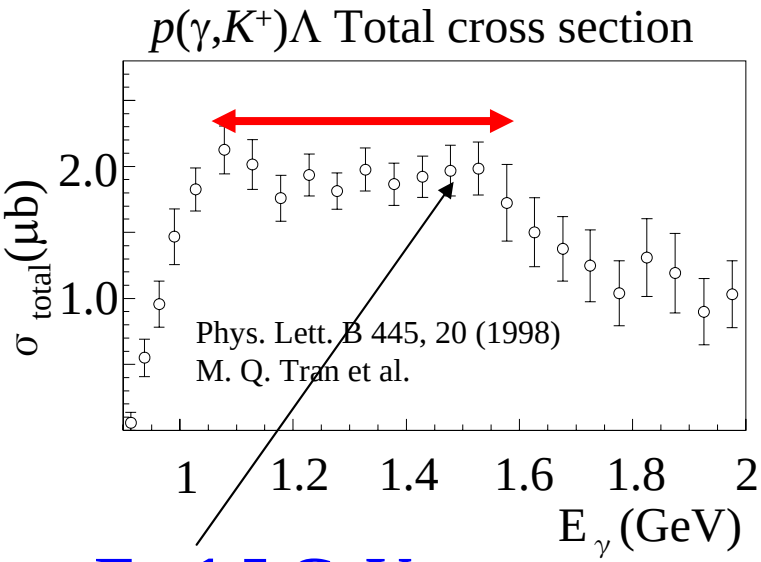
- Proton converted to Λ → Neutron rich Λ hypernuclei, charge symmetry
- Large angular momentum transfer → Similarly to (π^+,K^+) reaction
- Spin-flip amplitude → Unnatural parity hypernuclear states
- Sub MeV resolution ← High quality primary beam

Kinematics of the (e,e'K$^+$) reaction

p_K=1.2 GeV/*c*

HKS (new spectrometer)





E_γ=1.5 GeV

e^- Beam

E_e=1.853 GeV

p_e=0.3GeV/*c*

ENGE (tilted)

Previous experiment (E89-009)

- **The first (e,e'K^+) experiment**
  - In Hall C
  - Electron spectrometer --- Enge split pole
  - Kaon Spectrometer --- SOS (existing)

    the energy resolution - 500keV
  - 0 degree tagging geometry.

    large backgrounds of electrons/positrons

    from pair creation.

In the new experiment,

Need to

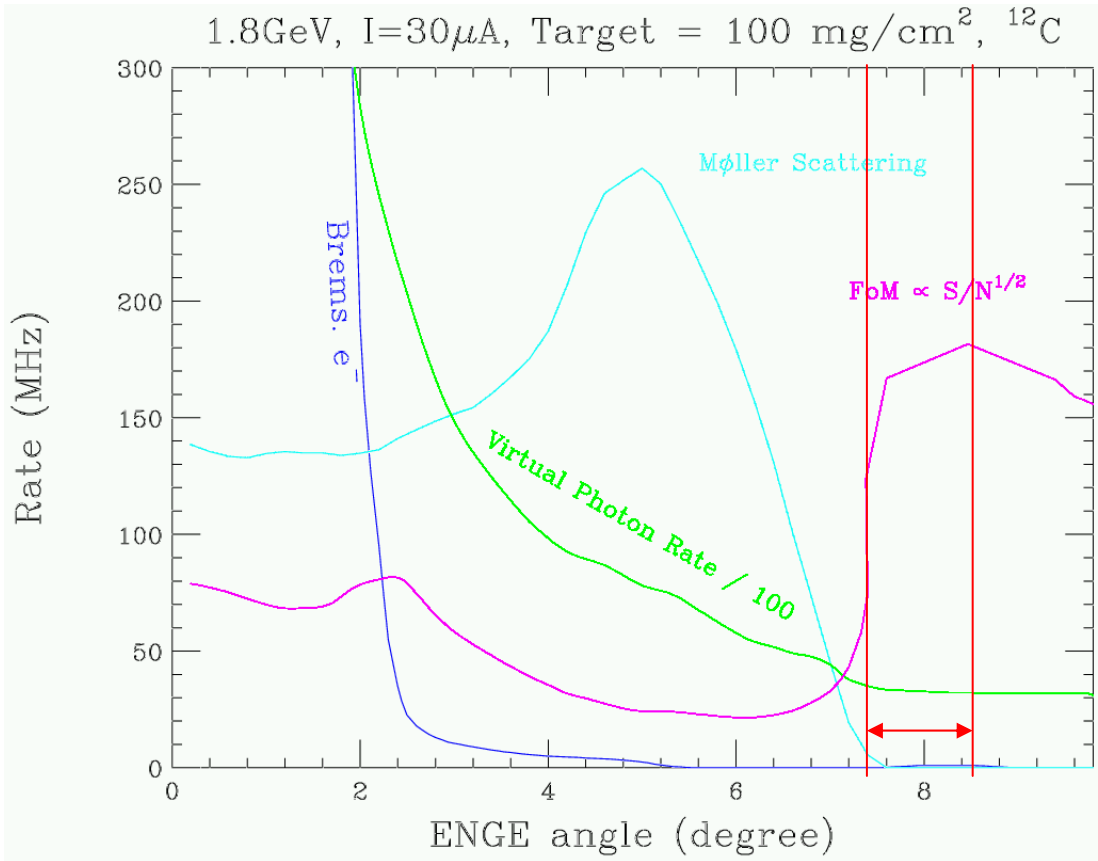
1 Reduce the accidental rate in e' arm.

2 Improve the energy resolution in Kaon arm.

Tilt method for ENGE to reduce the accidental rate

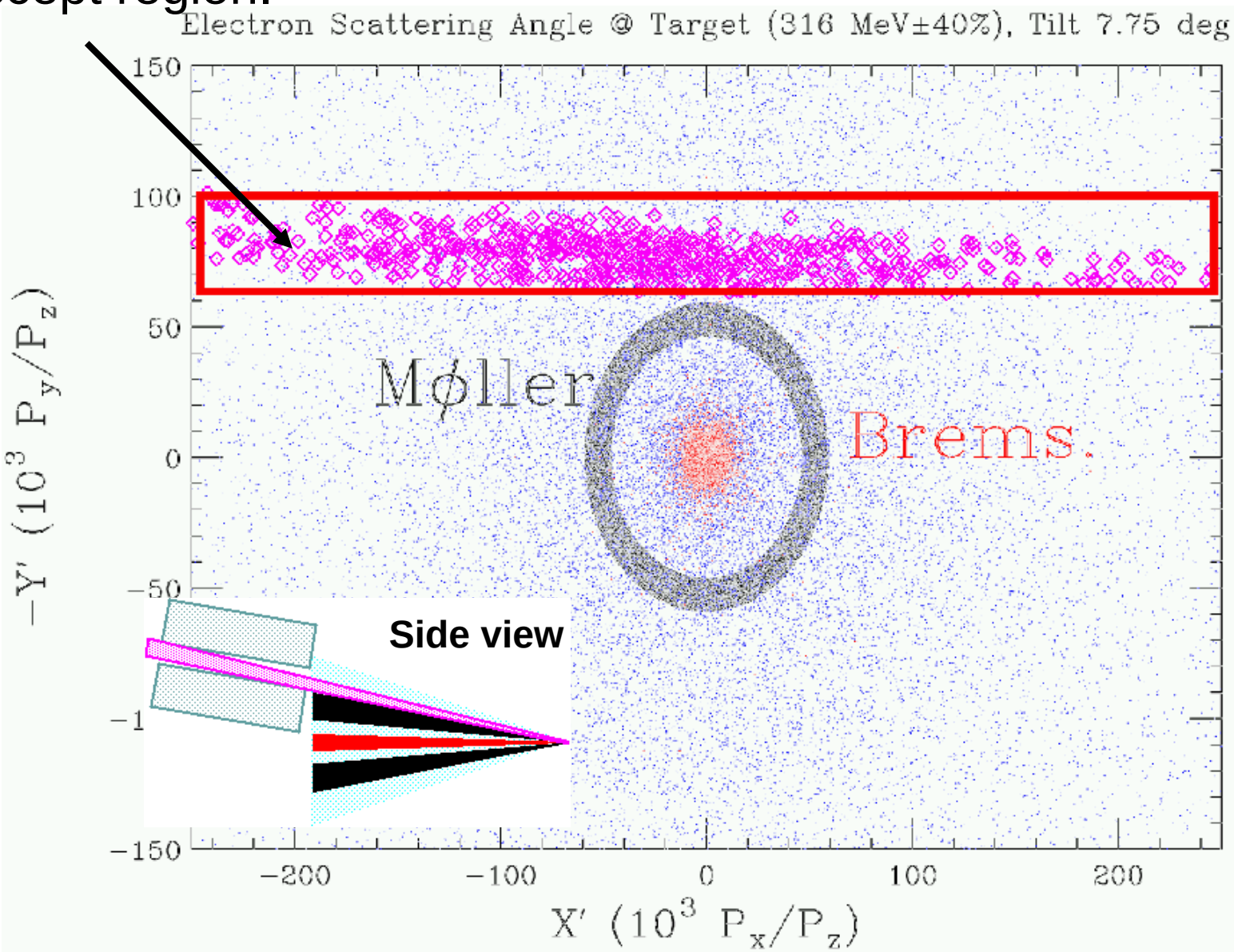
Scattered electrons
(0.2 to 0.4 GeV/c)
(1) Bremsstrahlung
(2) Møller scattering
(3) Virtual photons

Locate ENGE with 7.74 degree. to avoid (1) and (2) processes.



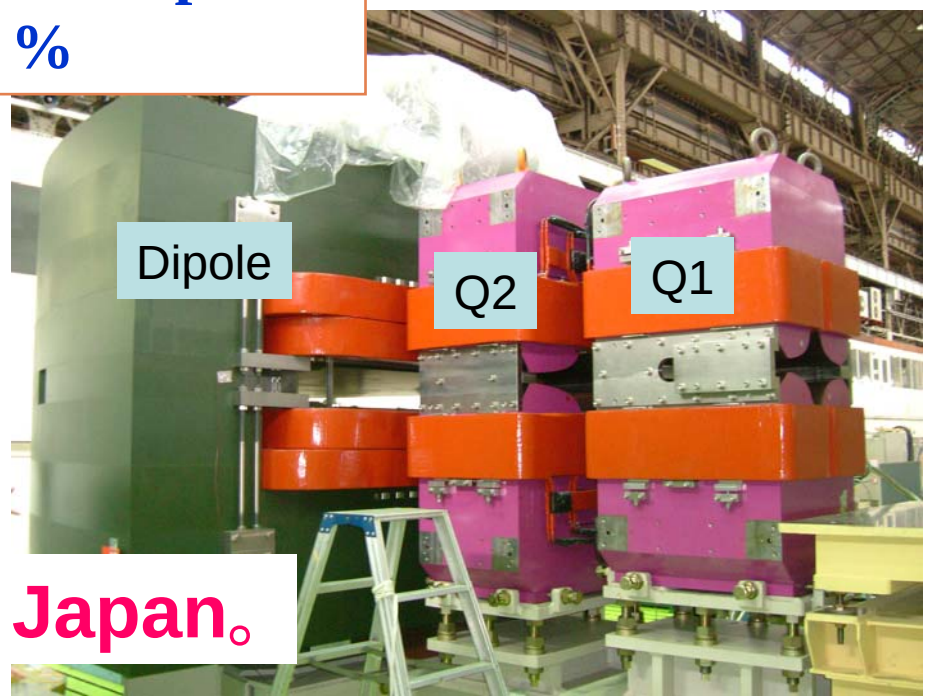
Optimization of the tilt angle

Accept region.



New spectrometer HKS

Configuration	**Q+Q+D**
Central momentum	**1.2 GeV/c**
Dispersion	**4.7 cm/%**
Momentum resolution	**2 x 10^{-4}(FWHM)**
Solid angle	**16 msr w splitter**
Momentum acceptance	**12.5 %**

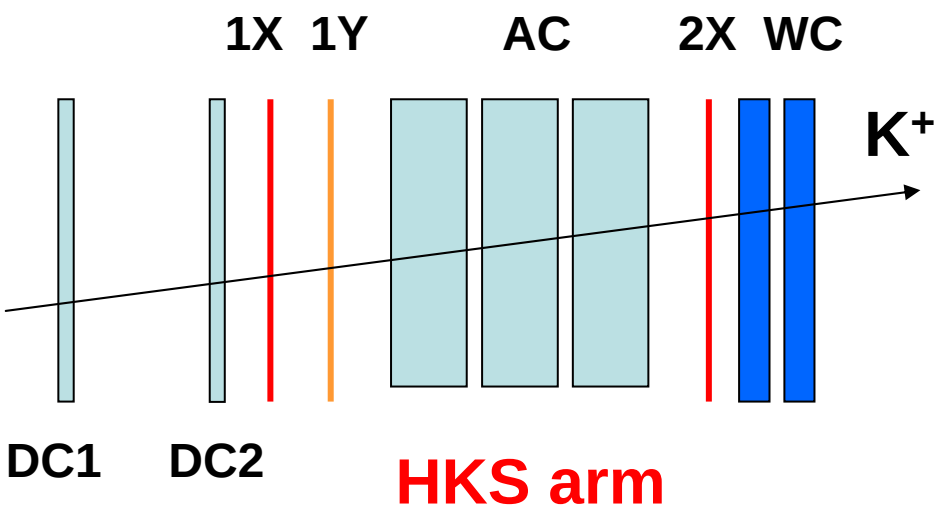


Made in Japan。

HKS detector package

Detectors:

- **Drift chamber**
- **TOF**
- **Aerogel cherenkov (veto π)**
- **Water cherenkov (veto p)**

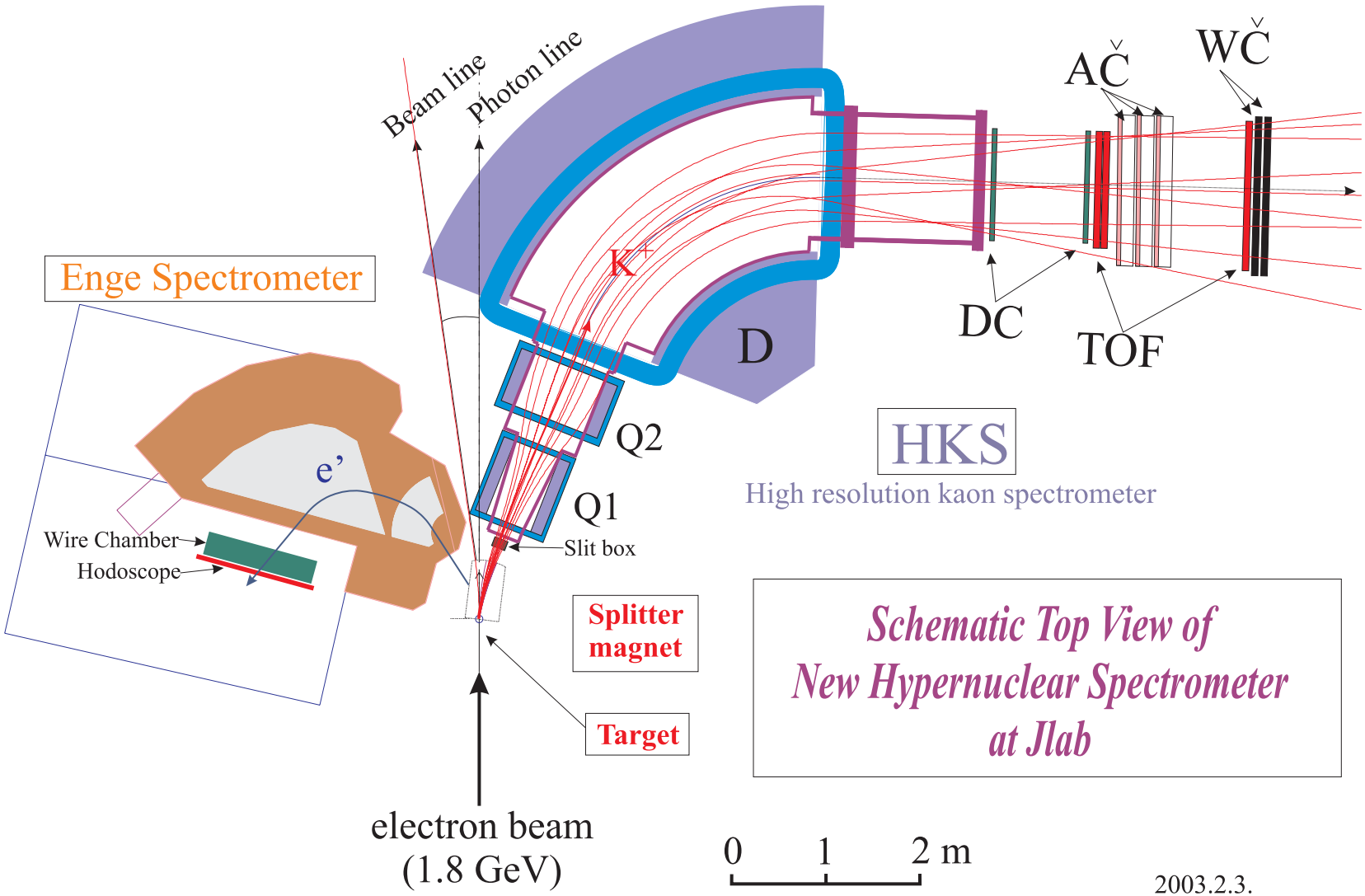


Expected Energy Resolution

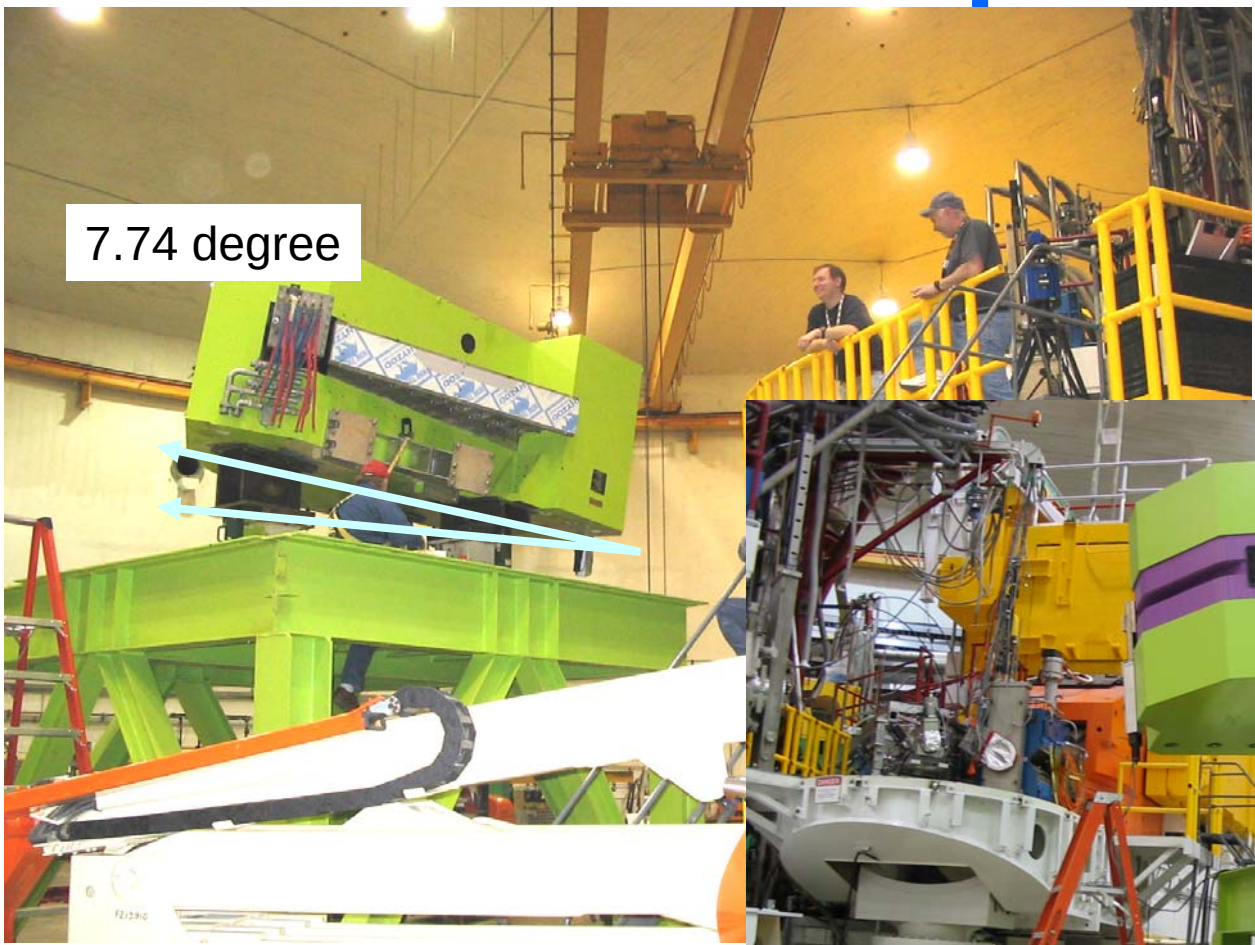
Item	Contribution to the resolution (keV, FWHM)			
Target	^{12}C	^{28}Si	^{51}V	^{89}Y
HKS momentum	230 (⟵ 500 -SOS)			
Beam momentum	< 180			
Enge momentum	120			
K^+ angle	134	56	32	18
Target thickness	< 180	< 171	< 148	< 138
Overall	**< 390**	**< 360**	**< 350**	**< 345**

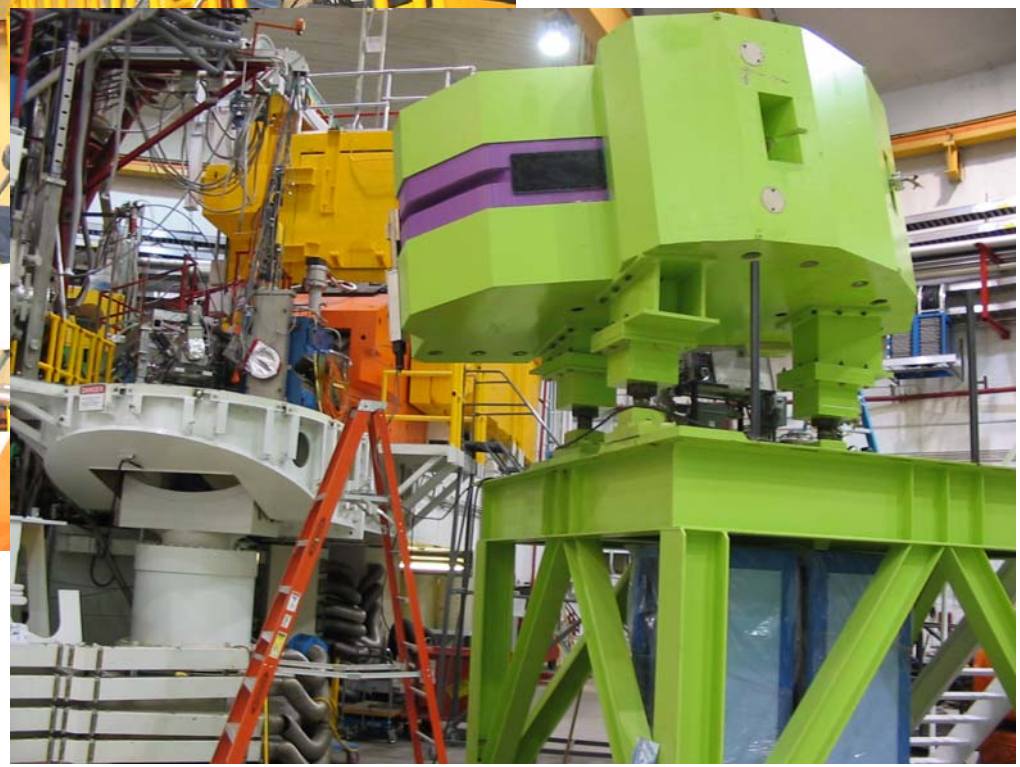
~400 keV

Experimental setup

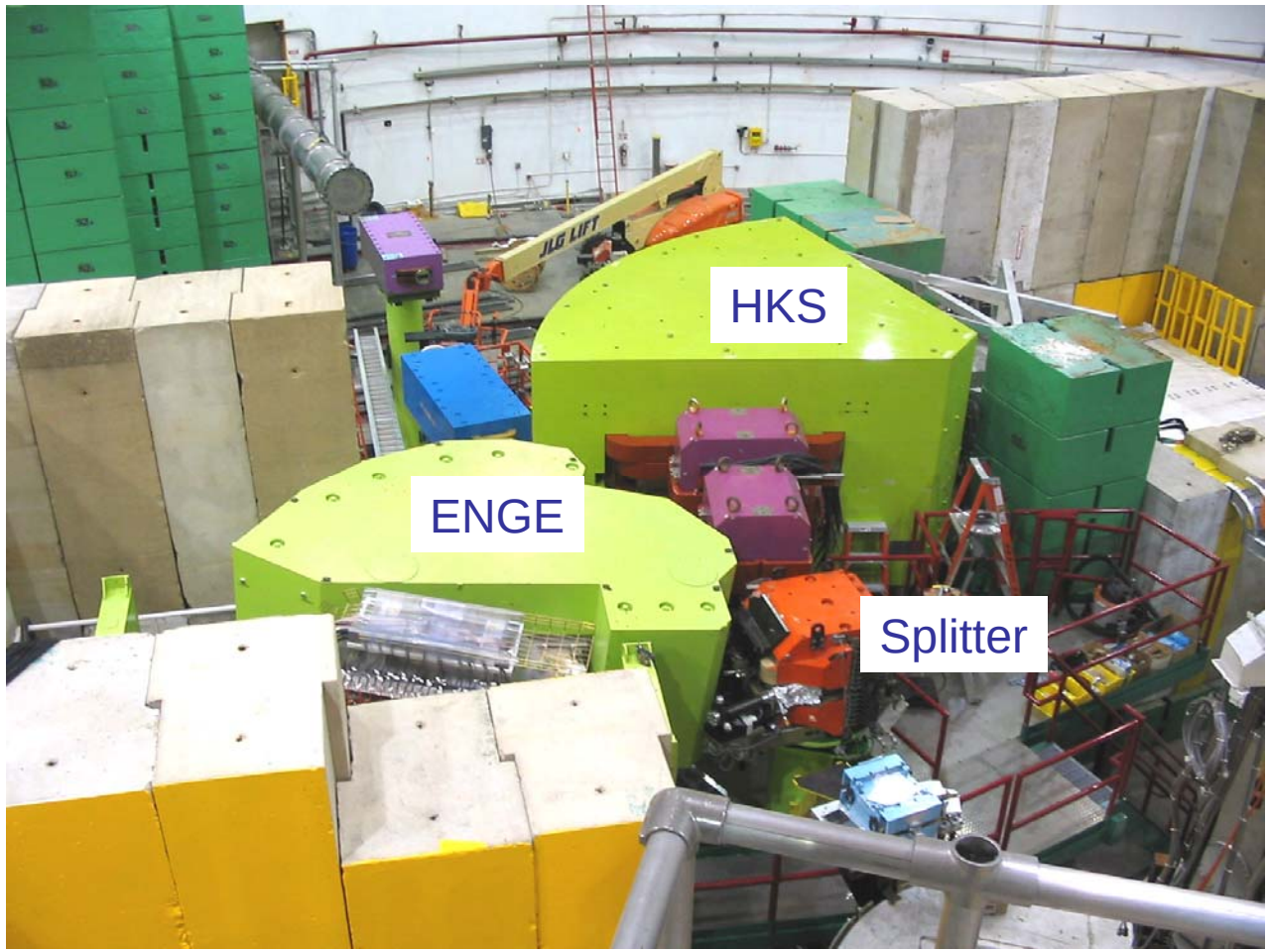


Tilted ENGE spectrometer





HKS + ENGE + Splitter



Performance of detectors

HKS (K^+ detection)

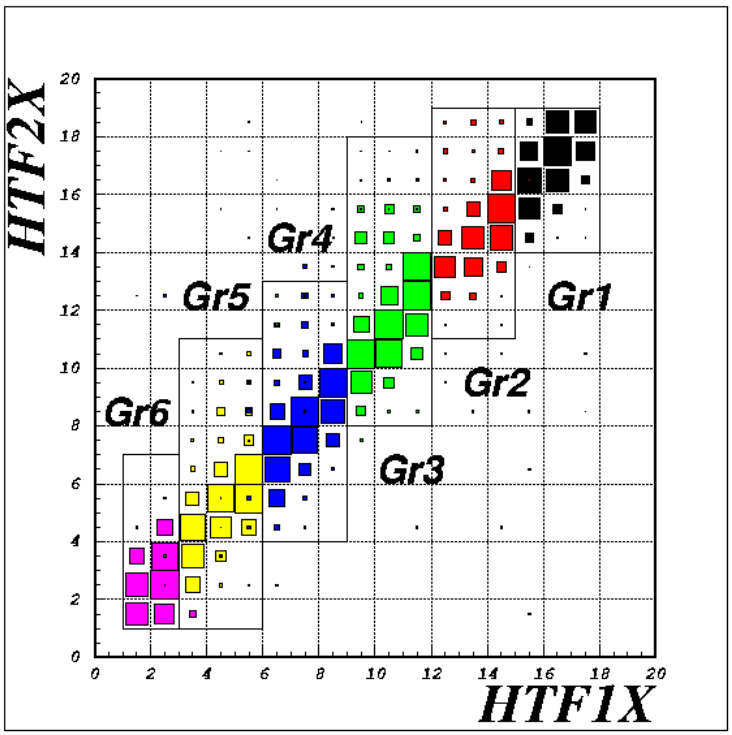
- Drift chambers
  Position resolution σ~220 μm
  Detection efficiency ~98%
- TOF counters
  σ~250 ps
- Aerogel cherenkov (veto π)
  index = 1.05, efficiency >98%
- Water cherenkov (veto p)
  index = 1.33, efficiency >98%

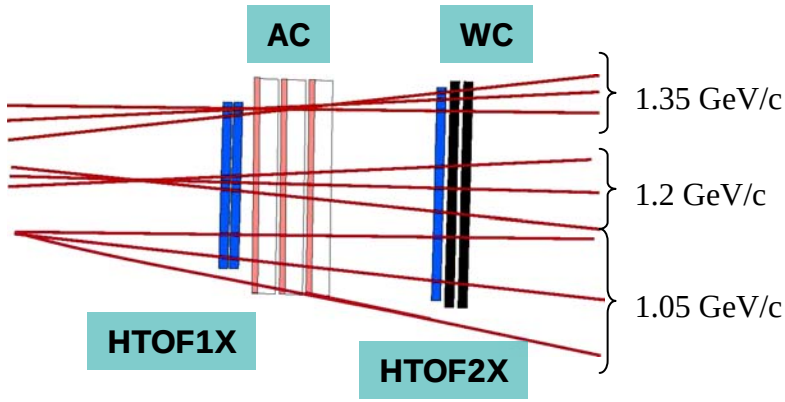
Enge (e' detection)

- Drift chamber :
  Position resolution
  σ = 300~370 μm
  Detection efficiency >99%
- Hodoscope :
  σ~150 ps

Grouping trigger in K^+ arm

Hit pattern correlation between HTOF 1X & HTOF2X.



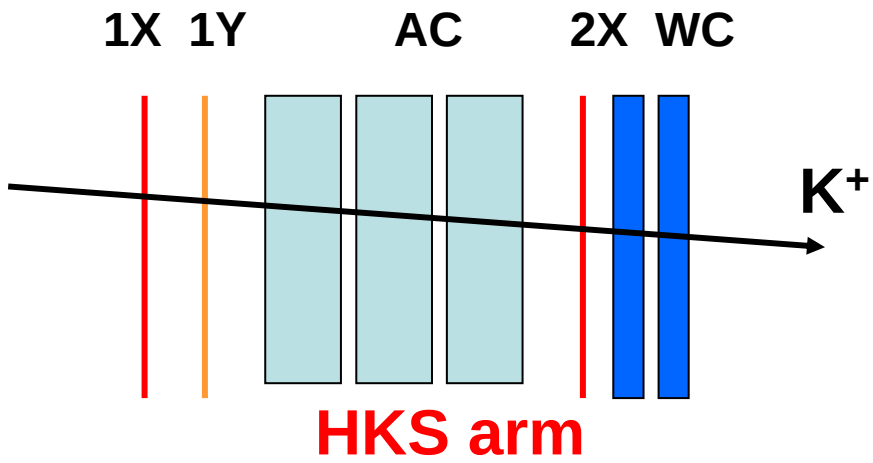


Grouping trigger

- 6 segments.
- Select Good trajectory.
- Reduce Kaon accidental kill.
- HKS rate decreases by 35%.

Trigger condition

- HKS (Kaon trigger) --- 12 kHz
  - 1X & 1Y & 2X & AC & WC
  (1X - 2X -1.1 MHz)
  Rejection rate by AC / WC
  is 1/100
- ENGE --- 1.2 MHz <- 100MHz
  Hodoscope 1layer & 2layer
- Coincidence trigger
  ~500 Hz
  DAQ dead time ~5%



*Rates are with carbon target (100 mg/cm^2) , 26 μA

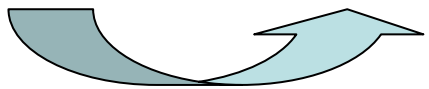
E89-009 vs. E01-011

E89-009 vs. E01-011

- Beam intensity 1 μA : 26 μA
- Target thickness 20 mg/cm^2 : 100 mg/cm^2

  Luminosity 1 : 130
- Singles rate of e' arm >100 MHz : 1.2 MHz

Tilt method is quite useful!



10^{-4}

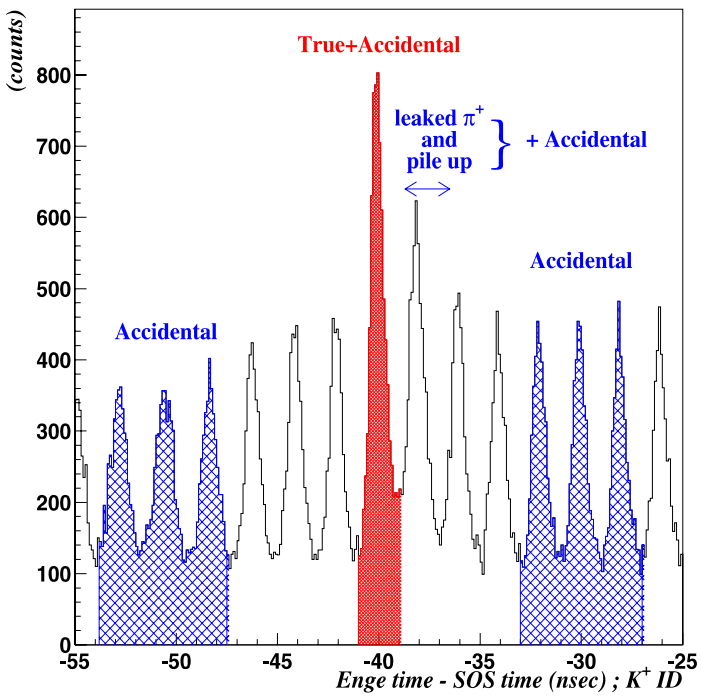
(Coincidence trigger 500 Hz with 5% dead time)

- Kaon acceptance 6 msr : 16 msr
- Energy Resolution 750keV : 400 keV

  Kaon arm ($\Delta p/p$) 5×10^{-4} : 2×10^{-4}

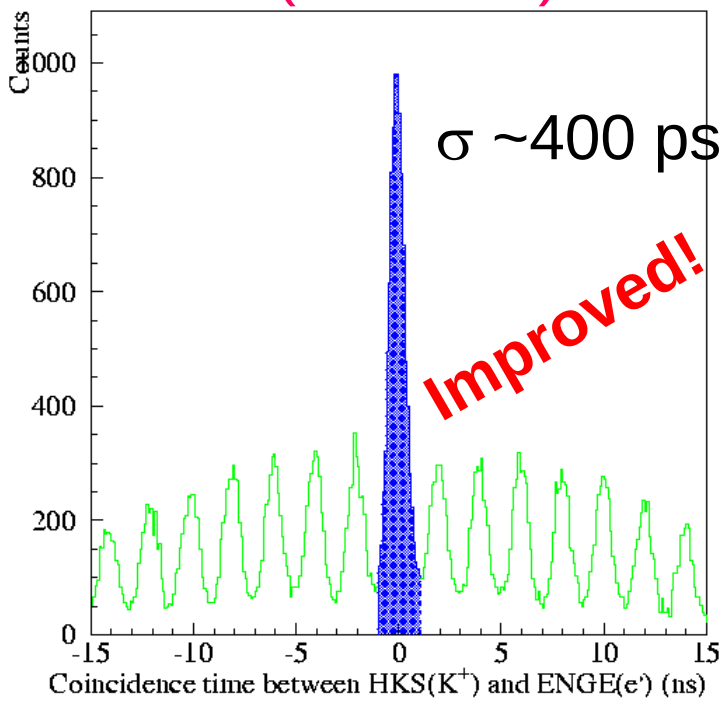
Ratio of true / accidental in coincidence time

Previous experiment (E89-009)



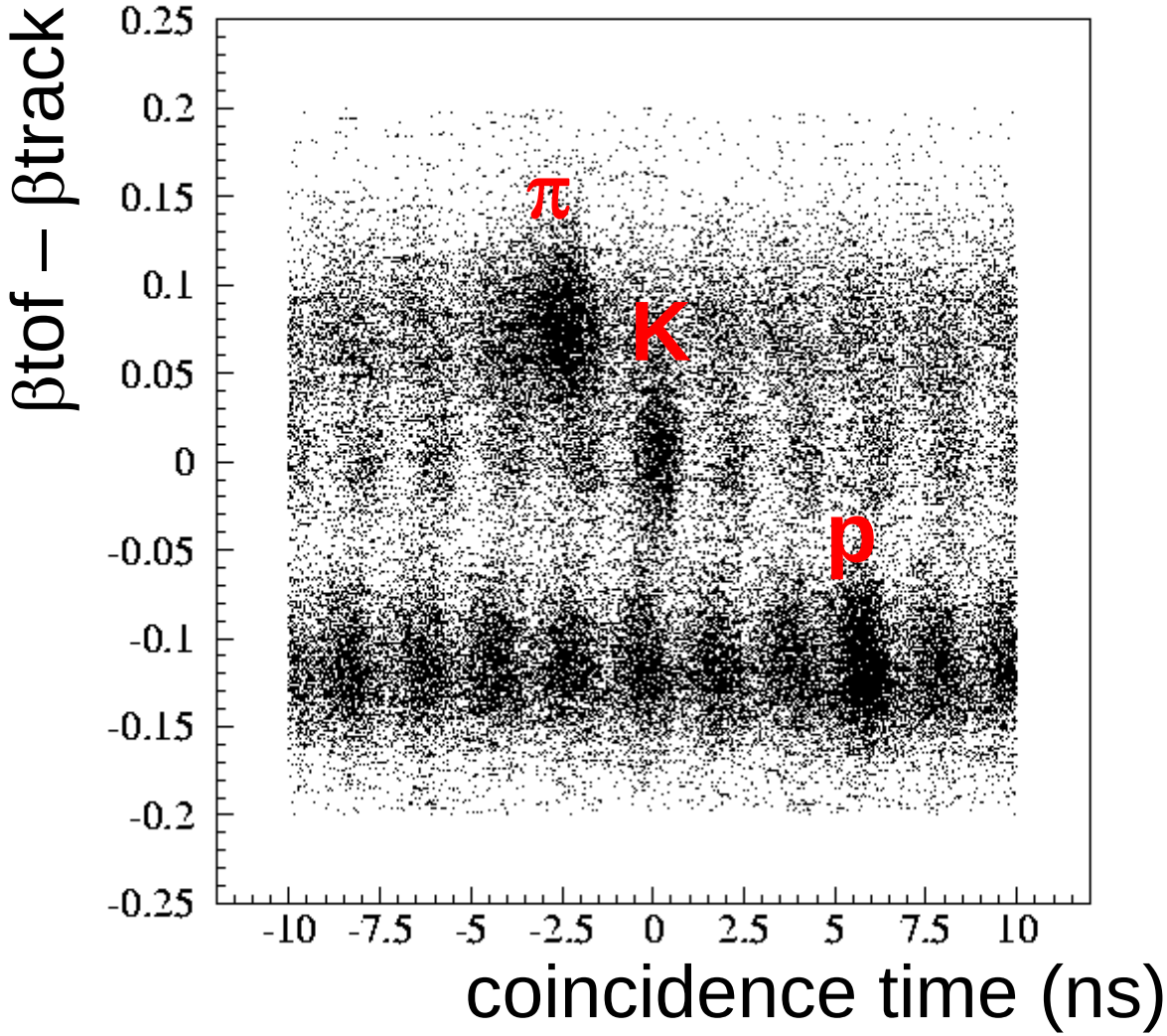
With 1 μA, CH_2 target

Present experiment (E01-011)



With 1.5 μA, CH_2 target

Kaon PID


βtof – βtrack
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
π
K
p
-10
-7.5
-5
-2.5
0
2.5
5
7.5
10
coincidence time (ns)

Calibration data

- Need new optics parameters for both arms.

  Enge is tilted. HKS is new.
- Angle calibration.

  Data with sieve slits were taken.
- Momentum calibration.

  ☺ $p(e,e'K^+)\Lambda/\Sigma^0$ reactions wirh CH_2 target

  Λ, Σ^0 masses are well known.

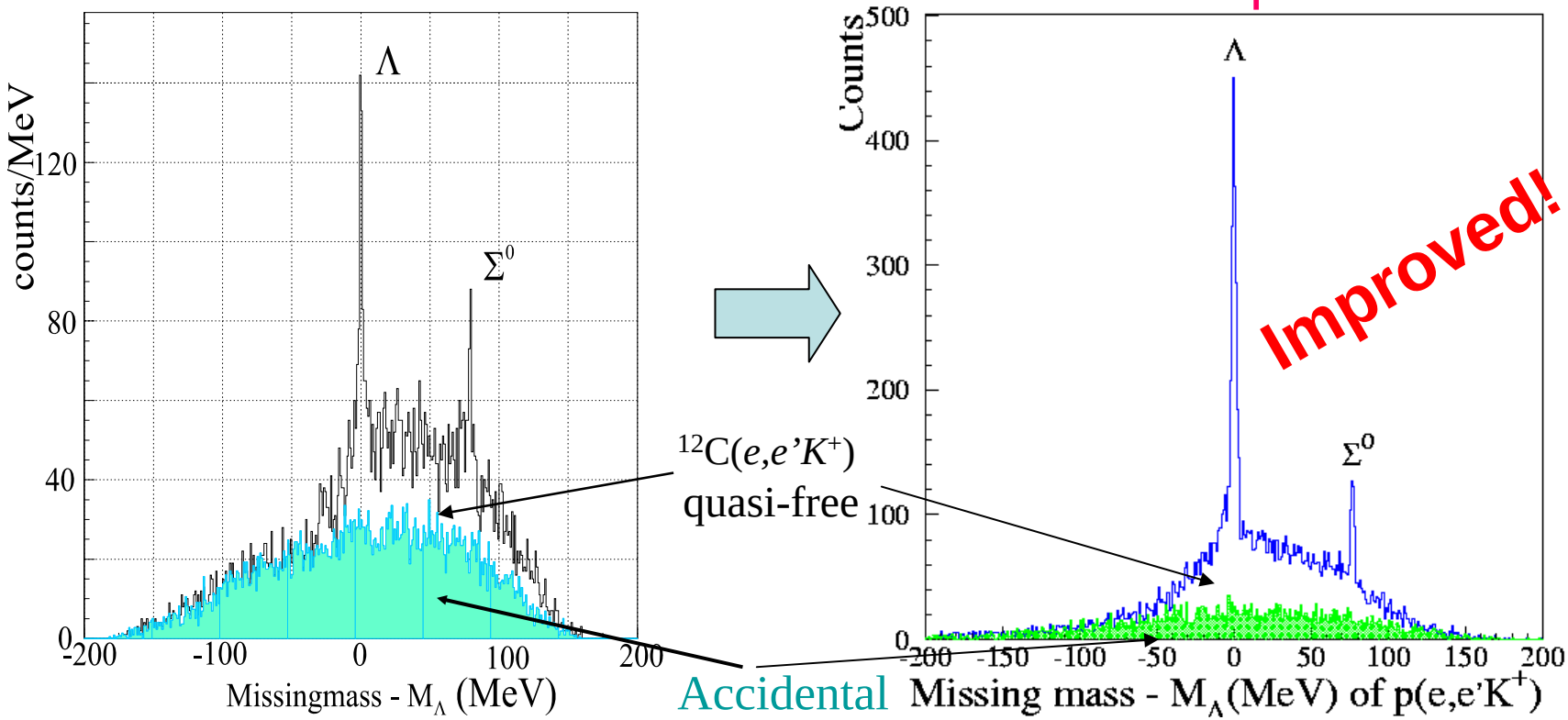
  ☺ $^{12}_{\Lambda}B$ ground state

  binding energy was measured in the previous experiment (E89-009 and emulsion exp.)

Calibration data from the p(e,e'K$^+$)Λ/Σ^0 reactions

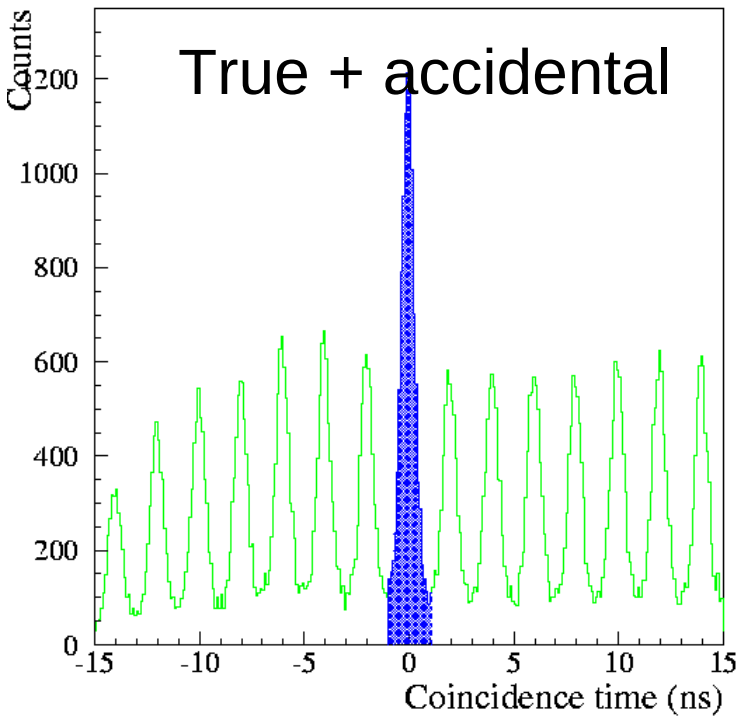
Previous experiment

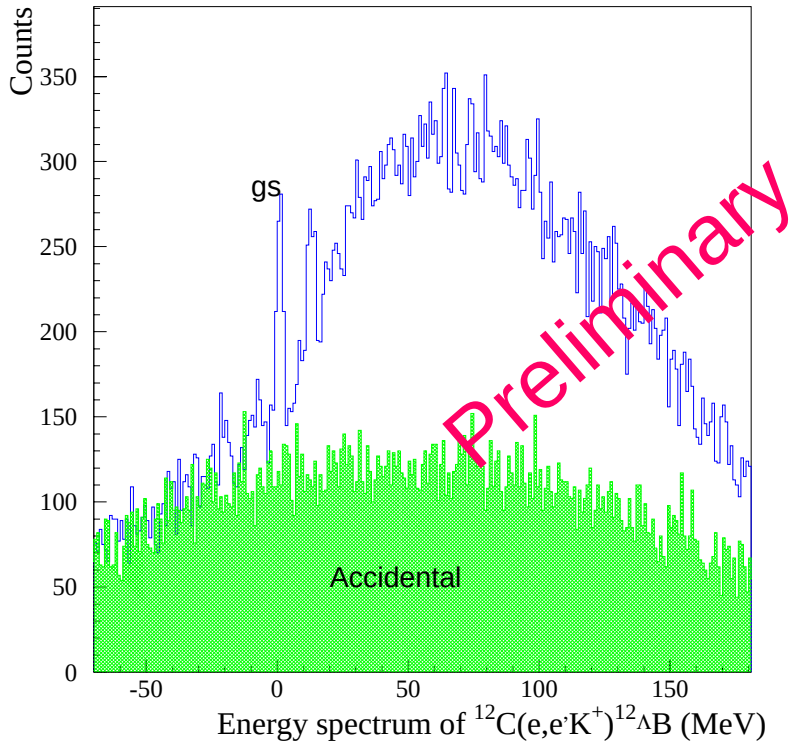
Present experiment



210 Lambdas → **1390 Lambdas**

Carbon ($^{12}_{\Lambda}$B) data





$^{12}_{\Lambda}$B g.s

~ 600 counts (~20/hr) ~1 MeV -> 400 keV

(Previous exp. (E89-009) 165 counts with 900 keV.
HallA 300 counts with 700 keV.)

Status of experiment

- Calibration runs with CH_2 and carbon targets finished.

  Optics tuning is in progress.
- Production run with Si target ($^{28}_{\Lambda}$Al) is now on going. ~ 5days
- Rate studies for heavier target

  V, Y, …

Summary

- Experiment with the tilted ENGE and the new spectrometer HKS started in this July.
- Comparing with the previous experiment, the accidental rate decreases dramatically and the kaon grouping trigger works well to take data with ~5% dead time of DAQ for 26 μA beam.
- Calibration run finished. Λ/Σ^0 peaks and $^{12}_{\Lambda}$B ground state are clearly observed. Optics study is in underway with those and sieve slit data.
- Now, production run with Si target.
- The data will provide medium-heavier hypernuclear spectra with good statistics and good resolution.