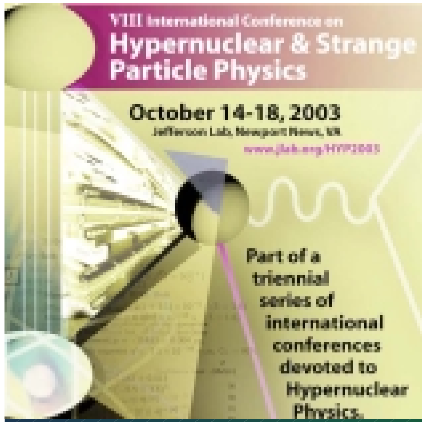
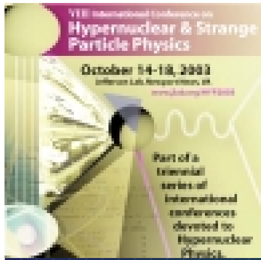


HYP03

Future Hypernuclear Program at Jlab Hall C

Satoshi N. Nakamura
Tohoku University

18th Oct 2003, HYP03 @ JLab



HYP03

The (e,e'K$^+$) reaction for hypernuclear spectroscopy

- **Proton to Λ**

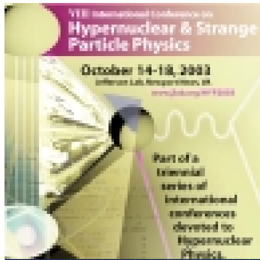
New Hypernuclei
(Mirror, Neutron Rich)

- **Large angular momentum transfer**
- **Spin-flip amplitude**

Various multiplet states

- **Higher energy resolution**

Detailed information on the hypernuclear structure



HYP03

The first (e,e’K$^+$) hypernuclear experiment (E89-009)

- Demonstrated that

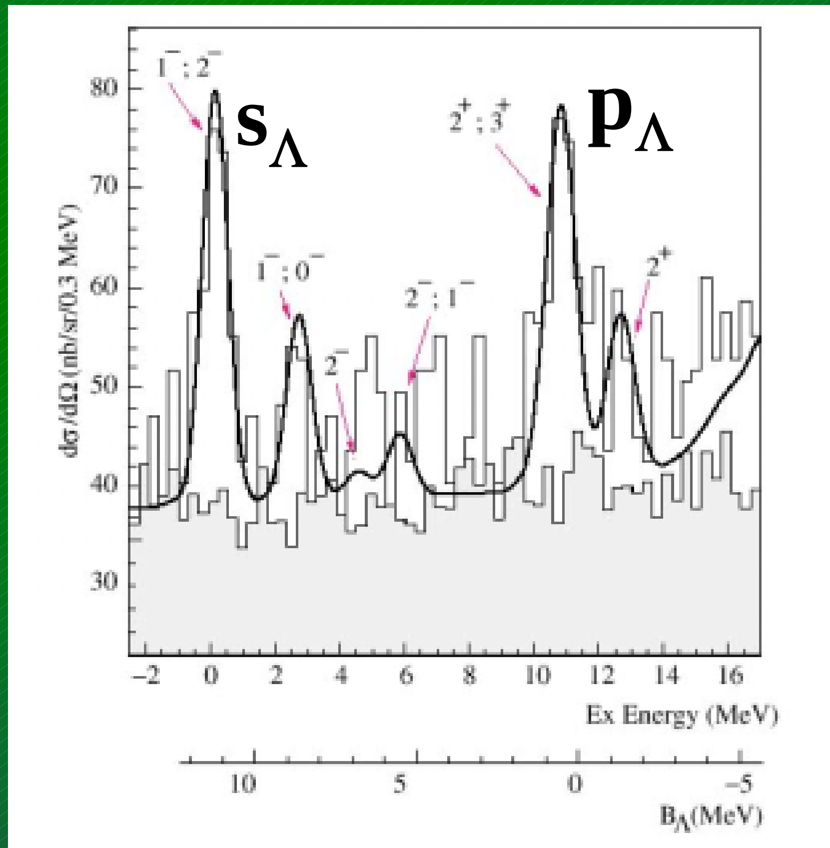
  the (e,e’K) hypernuclear spectroscopy is possible!

- Good energy resolution

  900 keV (FWHM)

  The best hypernuclear energy resolution achieved by the reaction spectroscopy

$^{12}C(e,e'K^+)\,^{12}_{\Lambda}B$



PRL 90 (2003) 232502, *E89-009 Result*

HYP03

General experimental condition

- As low as possible momenta (p_e,$p_{e'}$,p_K)
  - ➢Better energy resolution
  - ➢Avoid unnecessary reaction channels

•**Virual Photon energy E_γ ~1.5 GeV**

Phys. Lett. B 445, 20 (1998)
M. Q. Tran et al.

•**Beam en**

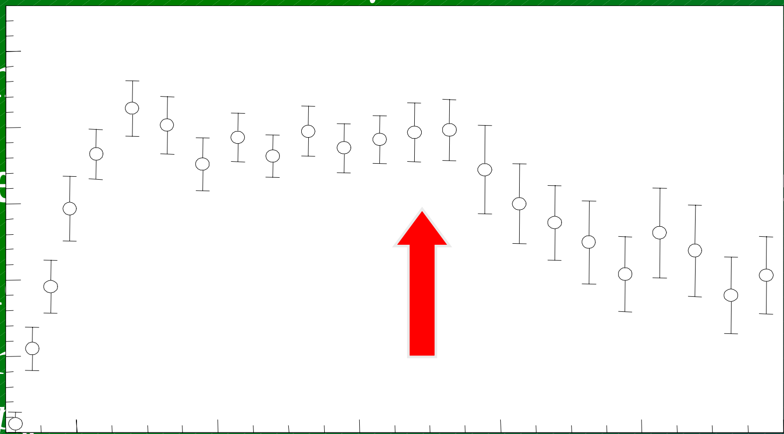
•**e' mome** **eV**

•**Kaon m**

E_γ deter

Lower p_K

Better resolution, particle ID



p(γ,*K*+)Λ Total cross section

HYP03

Improvement of the E89-009 experiment

- Energy resolution as well as acceptance are limited by the kaon spectrometer

  New Spectrometer

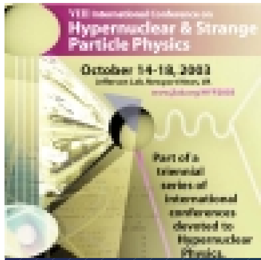
  High resolution Kaon Spectrometer (HKS)

- Zero degree tagging method to maximize virtual photon flux

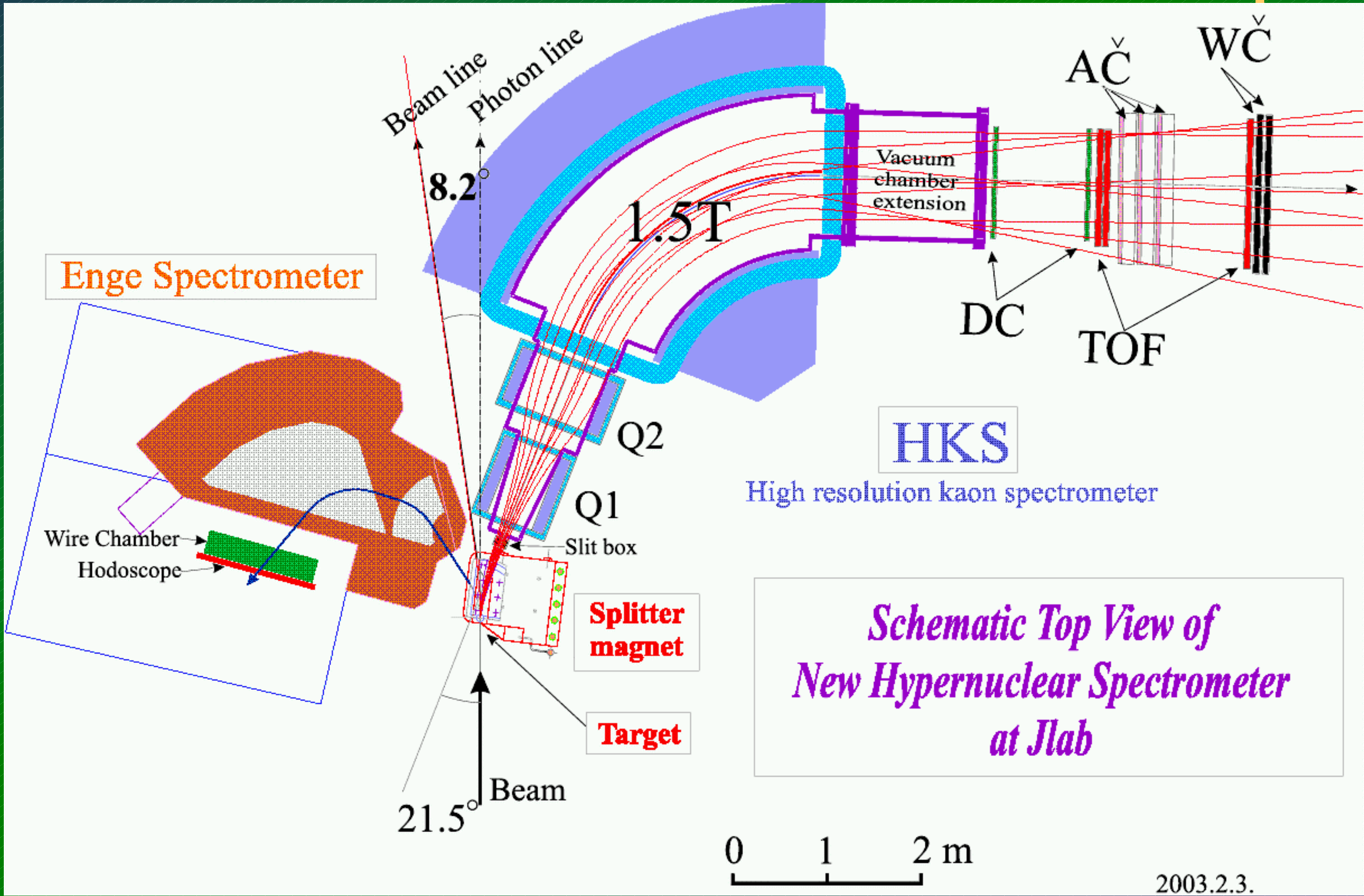
  Severe background from electrons associated with Bremsstrahlung (200 MHz for e' arm) ***Tilt Method***

New Experiment was approved by Jlab PAC19

E01-011 (Spokesmen: Hashimoto, Tang, Reinhold, Nakamura)

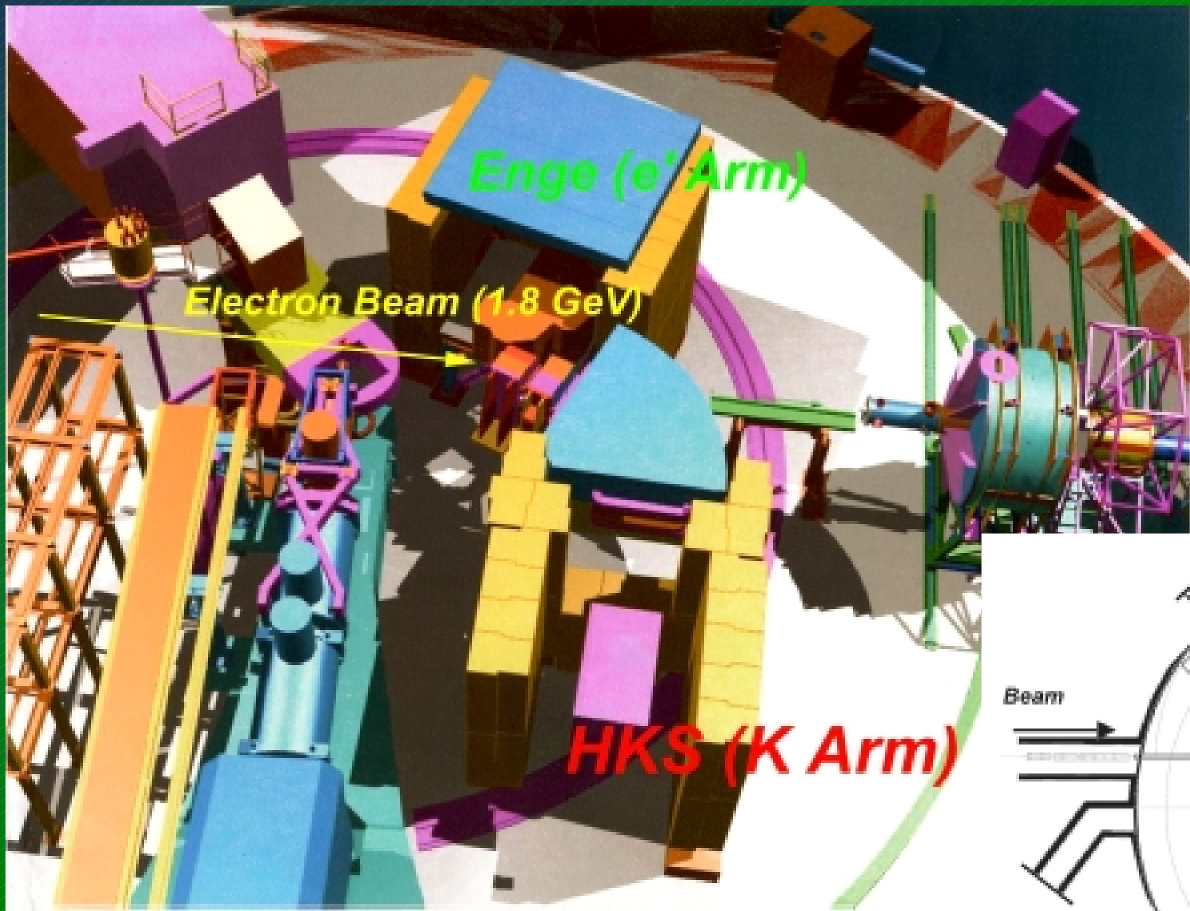


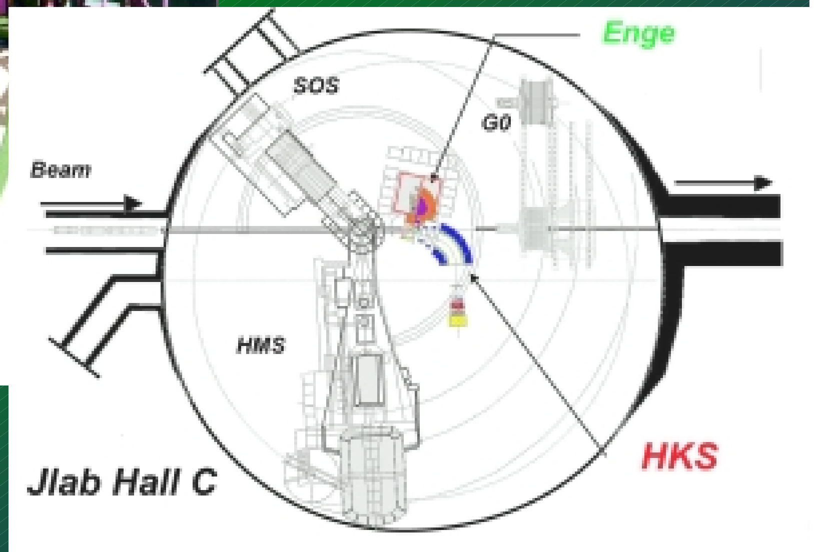
New kaon spectrometer and Jlab E01-011 setup



HYP03

Jlab E01-011 setup plan





HYP03

Tilt method

- The scattered electrons to be measured are associated with the virtual photons

Very forward

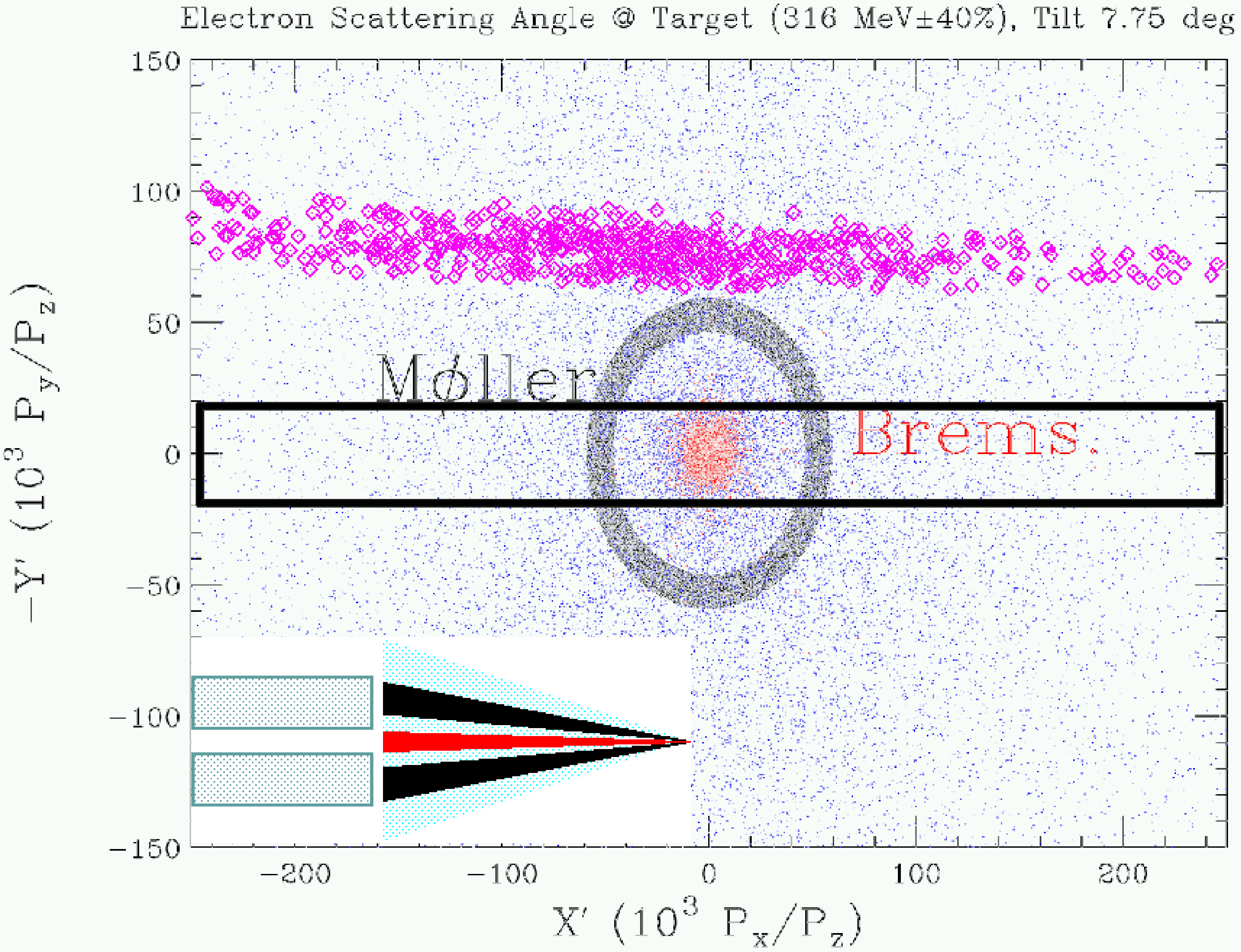
- The most serious background source is the electron associated with the bremsstrahlung

Hyper forward!

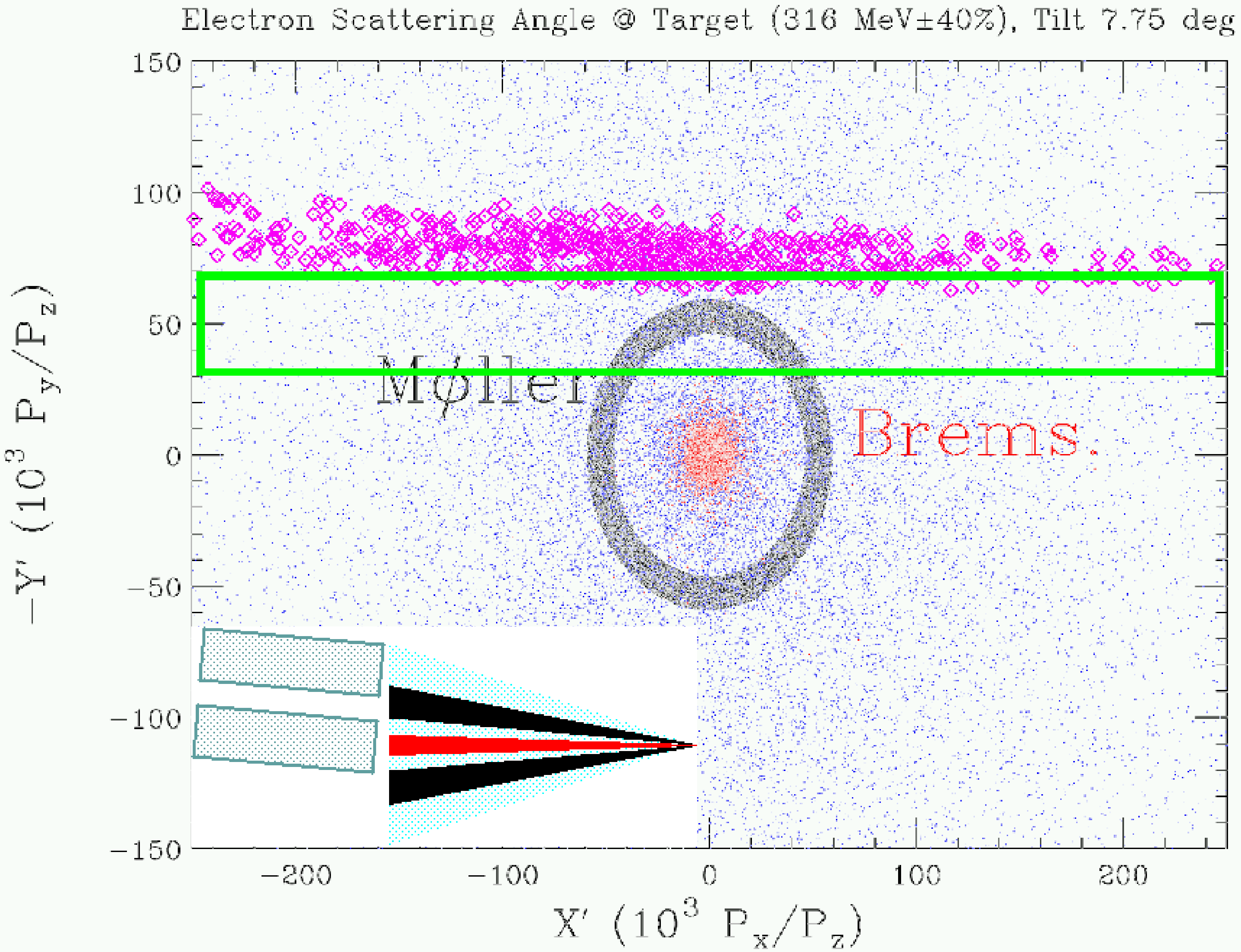
Optimize the detection angle for the scattered electrons:
Improve S/N drastically, Reduce e's rate

Spectroscopy of the *medium-heavy* hypernuclei

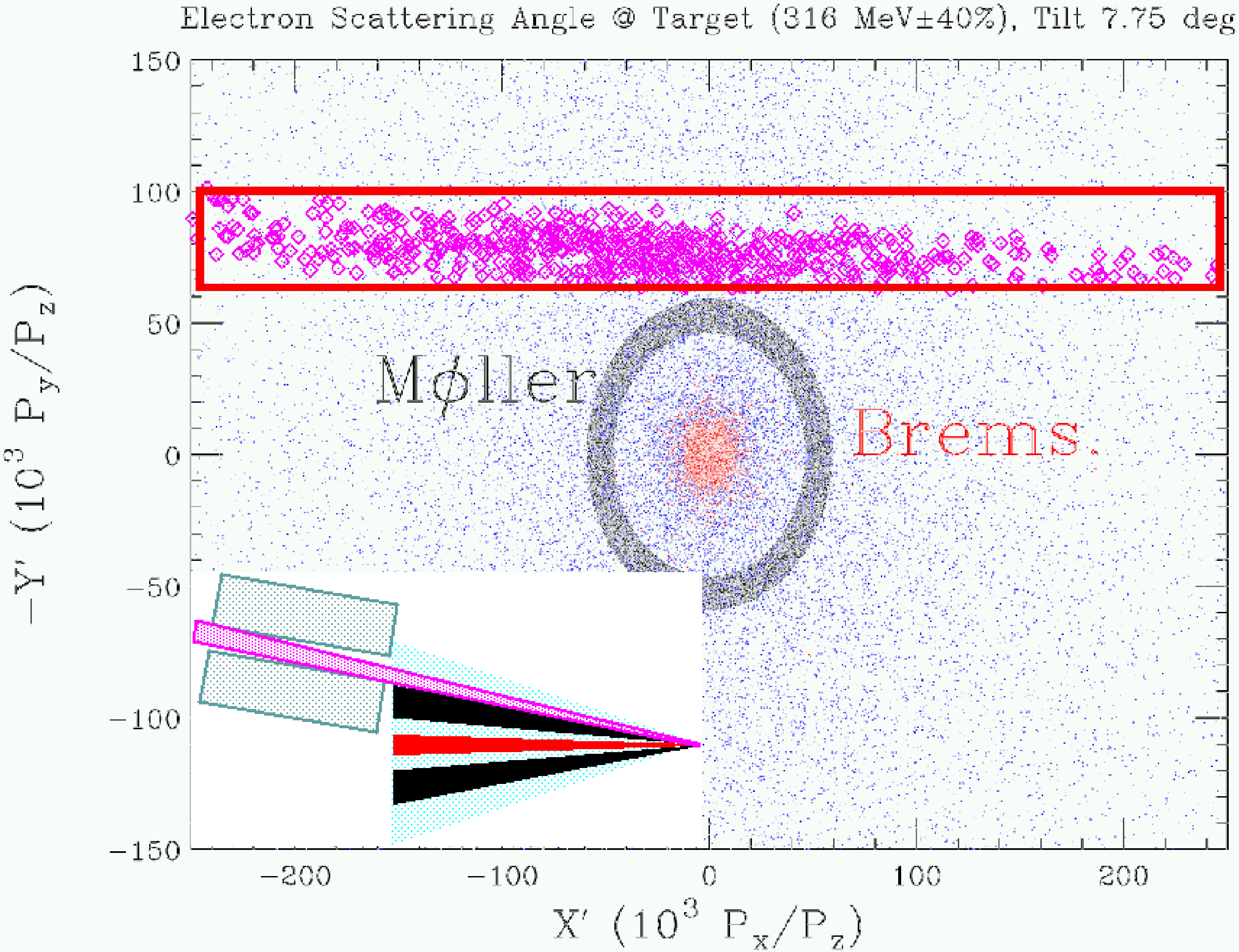
Virtual photon loss : higher beam intensity and thicker target



Electron Scattering Angle @ Target (316 MeV±40%), Tilt 7.75 deg
Møller
Brems.
−Y′ (10³ Py/Pz)
X′ (10³ Px/Pz)
150
100
50
0
−50
−100
−150
−200
−100
0
100
200



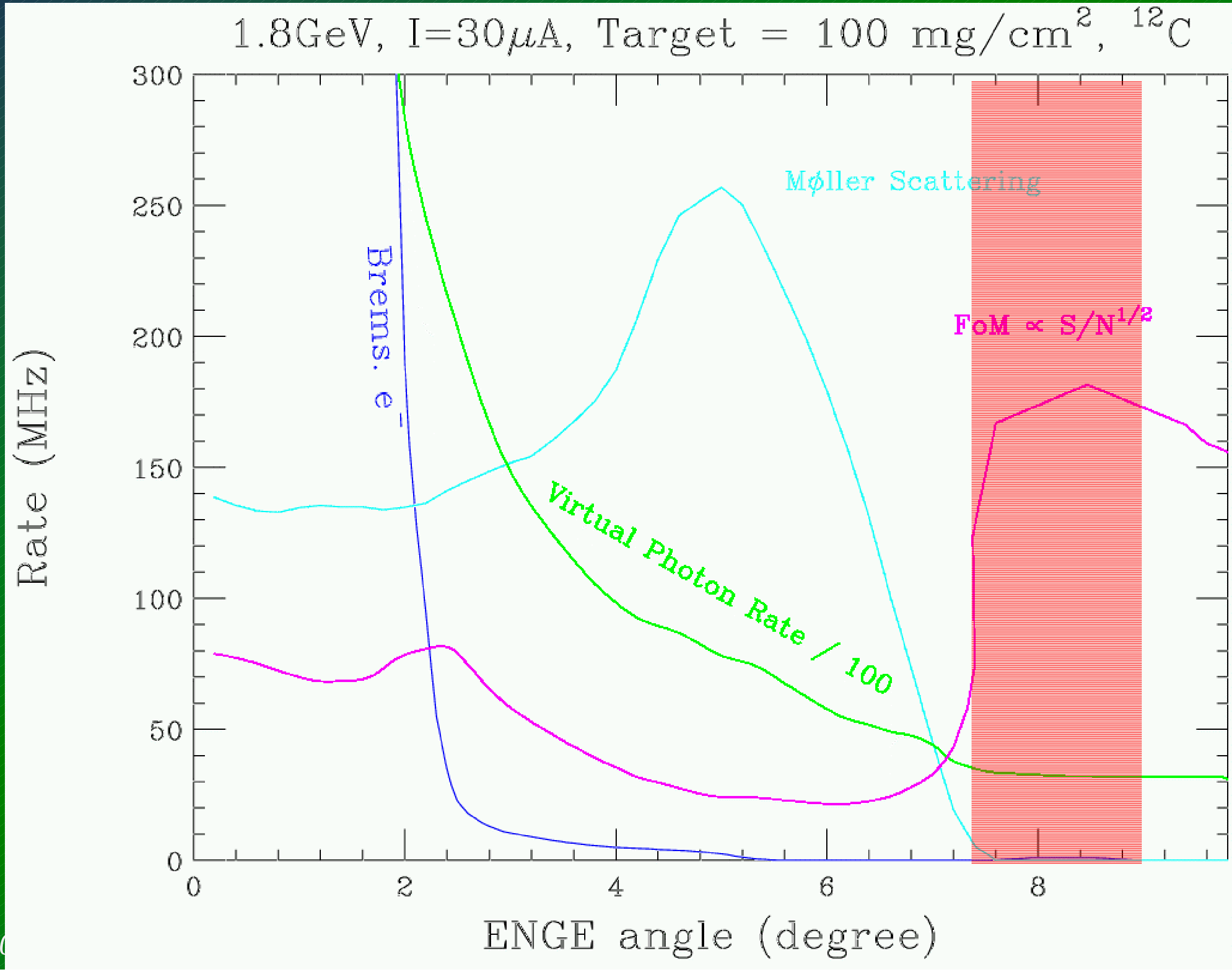
Electron Scattering Angle @ Target (316 MeV±40%), Tilt 7.75 deg
150
100
50
0
−50
−100
−150
−200
−100
0
100
200
−Y′ (10³ P_y/P_z)
X′ (10³ P_x/P_z)
Møller
Brems.



Electron Scattering Angle @ Target (316 MeV±40%), Tilt 7.75 deg
150
100
50
0
−50
−100
−150
−200
−100
0
100
200
−Y′ (10^3 P_y/P_z)
X′ (10^3 P_x/P_z)
Møller
Brems.

Tilt the electron detector by 8 degrees (θ ~4 deg).
~5 times thicker target, ~50 times stronger *e* beam

HYP03



HYP03

High resolution Kaon Spectrometer

Configuration	Q + Q + D
Central Momentum	1.2 GeV/c
Dispersion	4.7 cm/%
Momentum Resolution	2×10^{-4} (FWHM)
Solid Angle	30 msr (w/o Splitter) 16 msr (w/ Splitter)
K^{+} detection angle	1 ~ 13 degrees
Angular Acceptance	170mrad (V),180 mrad(H)
Momentum Acceptance	±12.5%
Max. Magnetic Field	1.6 T (Normal)

HKS magnets are on the way to JLab.

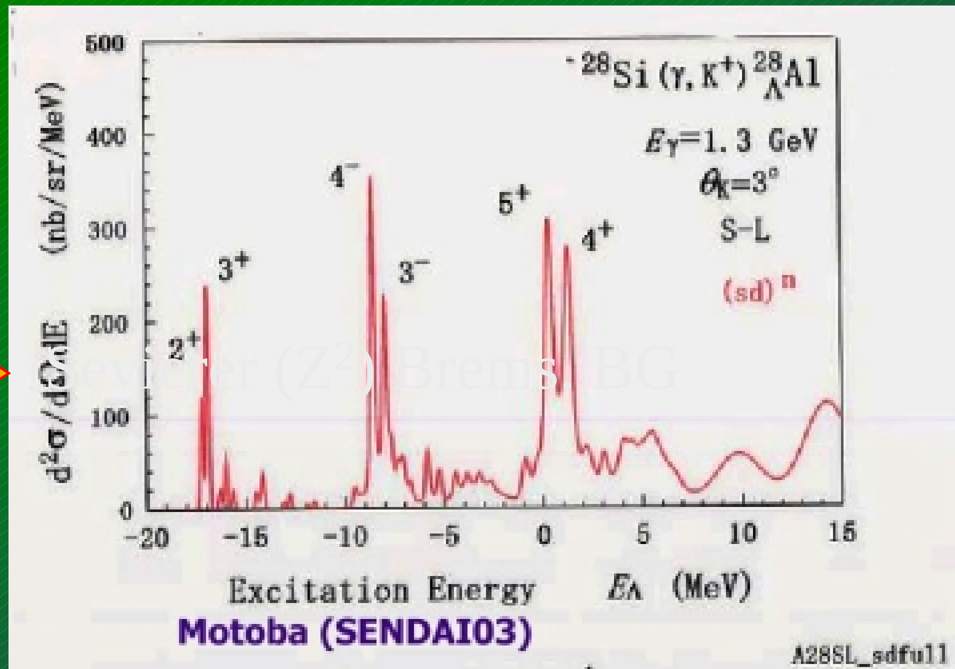
HYP03

Characteristics of E01-011

- From light to medium-heavy hypernuclei
  - Single particle nature of Λ in heavier hypernuclei
  - Core excited states
  - Spin-Orbit splitting

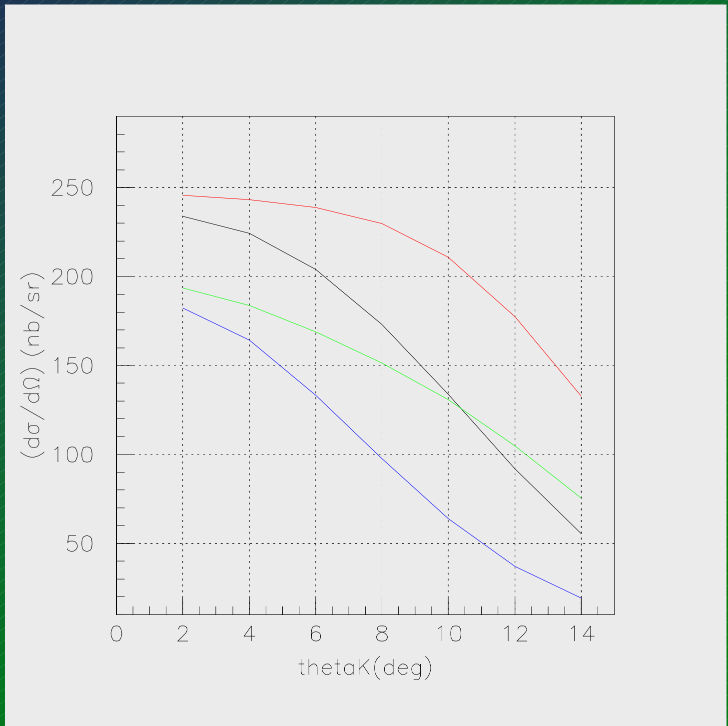
Tilt Method

Heavier target →



HYP03

Characteristics of E01-011



Angular distribution of $^{12}{}_{\Lambda}B$ states

DWIA calculation by the code of M.Sotona

$(p3/2)^{-1}(p3/2)^{\Lambda}\ 3^{+}$

$(s1/2)^{-1}(p1/2)^{\Lambda}\ 2^{-}$

$(p3/2)^{-1}(s1/2)^{\Lambda}\ 2^{-}$

$(s1/2)^{-1}(s1/2)^{\Lambda}\ 1^{+}$

- Large angular acceptance (1~13deg) of HKS
  - Angular dependence of the hypernuclear states

HYP03

Singles rates for E01-011

$I_e = 30\ \mu A, \quad 100\ mg/cm^2$

Target	HKS				ENGE	
	e^+ (Hz)	π^+ (kHz)	K^+ (kHz)	p (kHz)	e^- (kHz)	π^- (kHz)
^{12}C	-	**420**	0.34	**150**	**1000**	2.8
^{28}Si	-	420	0.29	130	1900	2.8
^{51}V	-	410	0.26	120	2650	3.0

- Scattered electron rate is **200 times** lower than E89-009
- Pion and proton rates of the kaon arm are high

High rejection efficiencies of Cherenkov counters for pions and protons

Aerogel and Water Cerenkov counters

HYP03

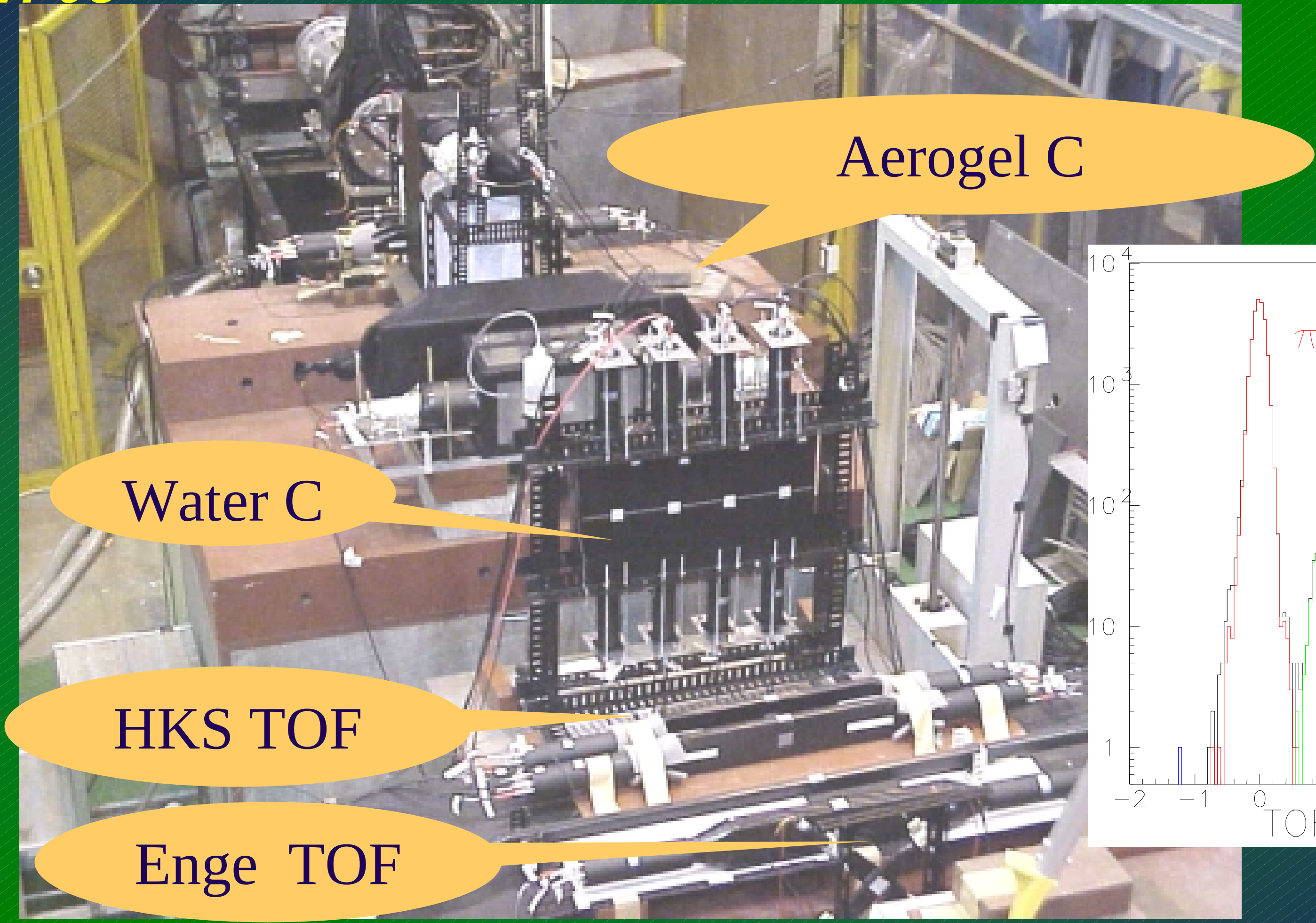
Detector R&D

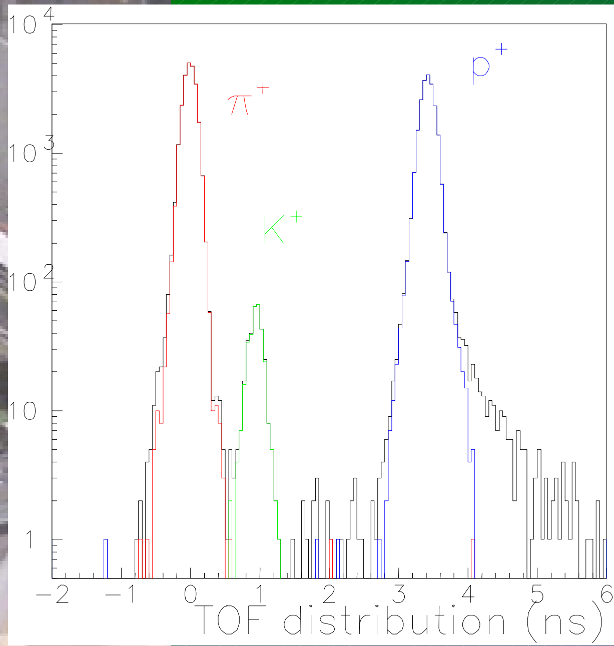
- TOF counters (resolution: 60 ps FWHM)
- Aerogel Cherenkov (n=1.05, 10^{-4} for π w/3 layers)
- Water Cherenkov (n=1.33, 4×10^{-4} for p w/ 2 layers)
- Drift Chamber for Kaon arm (SOS type)
- Drift Chamber (honeycomb cell) for e'
- Scintillator Hodoscopes (50 segments x 2 layers)

HYP03

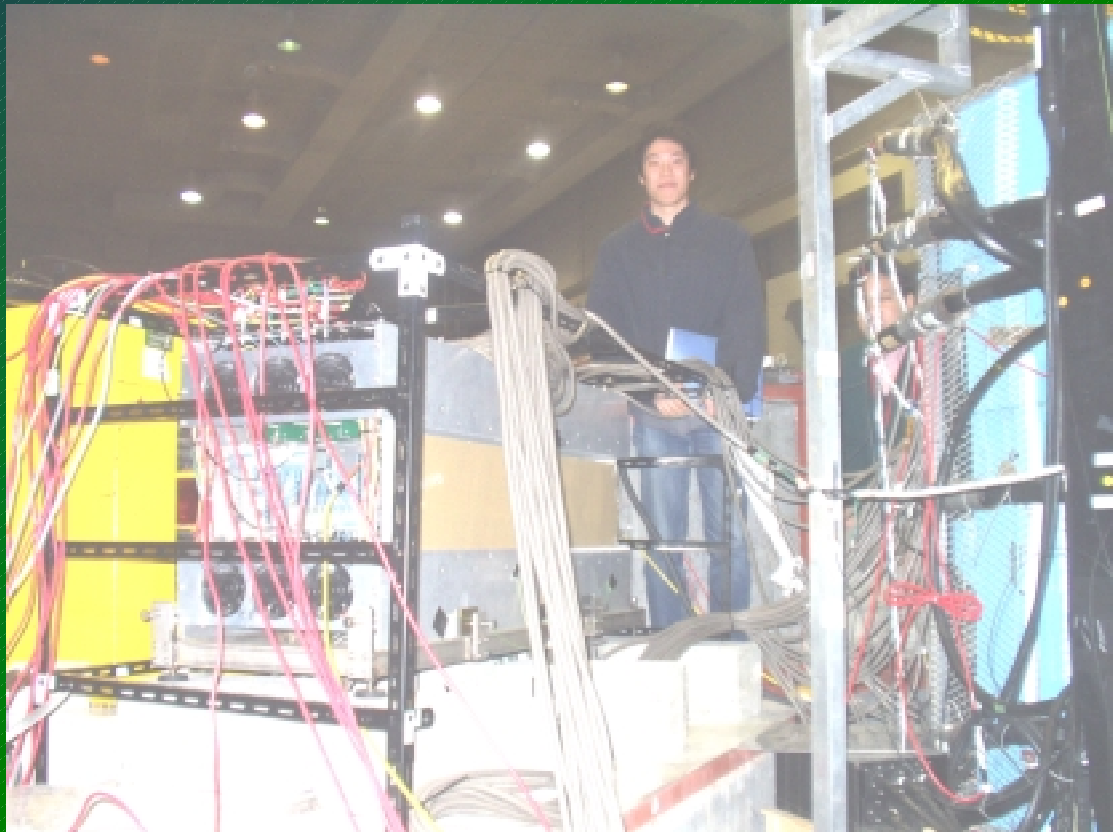
Counters' performance test

KEK PS T1:1.05~1.35 GeV/c p,K,π





EDC Test Beam at LNS-Tohoku



- Tagged photon from 1.2GeV Stretcher Booster Ring (5 - 10 Nov. ‘02)
- Converted e^{+} e^{-} pair was used for EDC test

HYP03

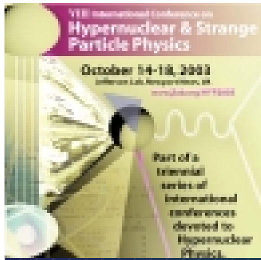
Detectors were assembled and checked at JLab EEL building

HYP03

Yield comparison between E01-011 and E89-009

Item	E01-011	E89-009	Gain factor
Virtual photon flux per electron($x10^{-4}$)	0.2	4	0.05
Target thickness(mg/cm^2)	100	22	4.5
e'momentum acceptance and e'- K^+ momenta matching	200	120	1.7
Kaon survival rate	0.35	0.4	0.9
Solid angle of K arm (msr)	16	5	3.2
Beam current(μA)	30	0.66	45
Estimated yield ($^{12}{}_{\Lambda}B_{gr}$:counts/h)	45	0.9 (measured)	50

For $d\sigma/d\Omega$(gr) = 140 nb/sr



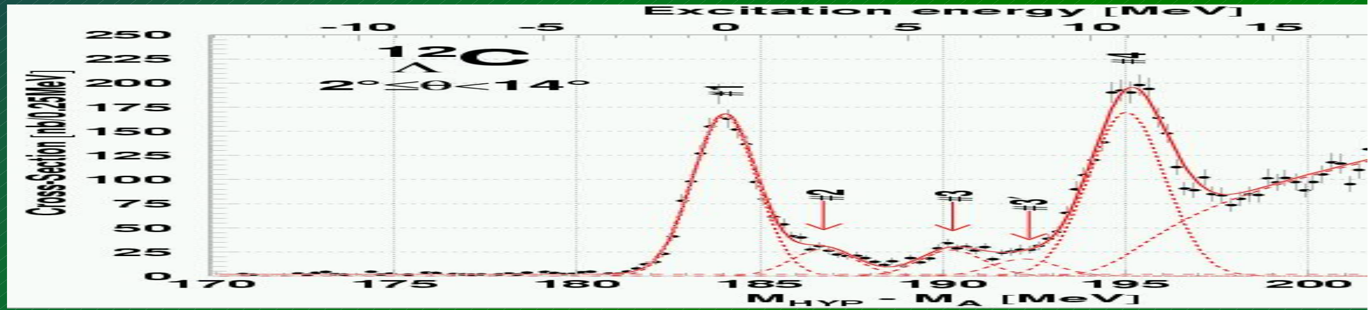
HYP03

Expected Energy Resolution

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

HYP03

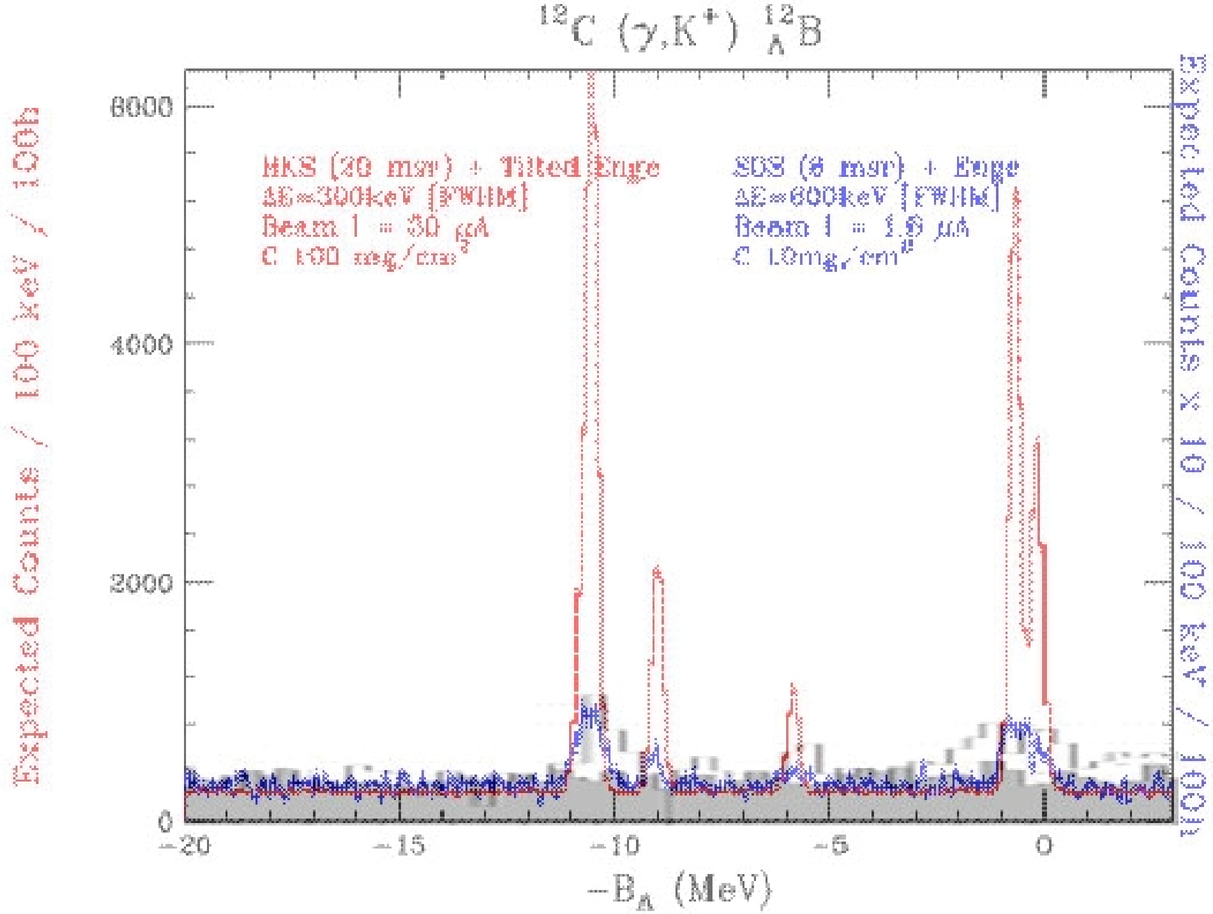
Expected Spectra



KEK-PS E336 :
w/ SKS (π,K) reaction

Jlab E01-011 (e,e'K)
[Expected]

Jlab E89-009 (e,e'K)



Summary

HYP03

- The (e,e'K) reaction = new and interesting
- E89-009 = Best energy resolution (900keV) for reaction hypernuclear spectroscopy
- With the *tilt method* and *HKS*, the E01-011 aims :

  Energy resolution by a factor of 2~3,

  S/N by a factor of ~10,

  hypernuclei yield by a factor of 50.

  From light to mid-heavy hypernuclei(^{7}*Li,*^{12}*C,*^{28}*Si,*^{10}*B,*^{11}*B,*^{51}*V,*^{89}*Y,..*
- HKS magnets and detectors are completed.

First beamtime is expected in 2004.