Spectroscopic Investigation of Hypernuclei (E05-115)

HES+HKS Project

Hall C User Meeting

(6 Jan 2006)

S N Nakamura, Tohoku Univ.

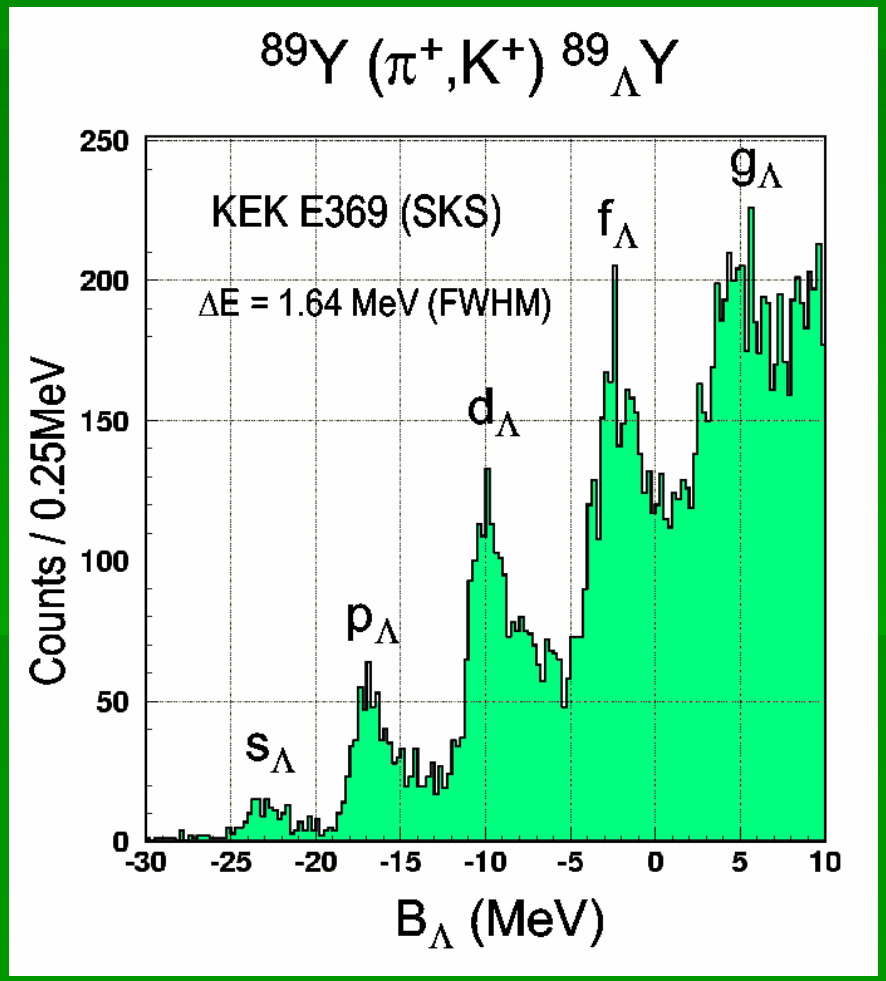
Λ, probe to deep inside of the nuclei

Single particle nature of Λ

Free from
nucleons' Pauli blocking

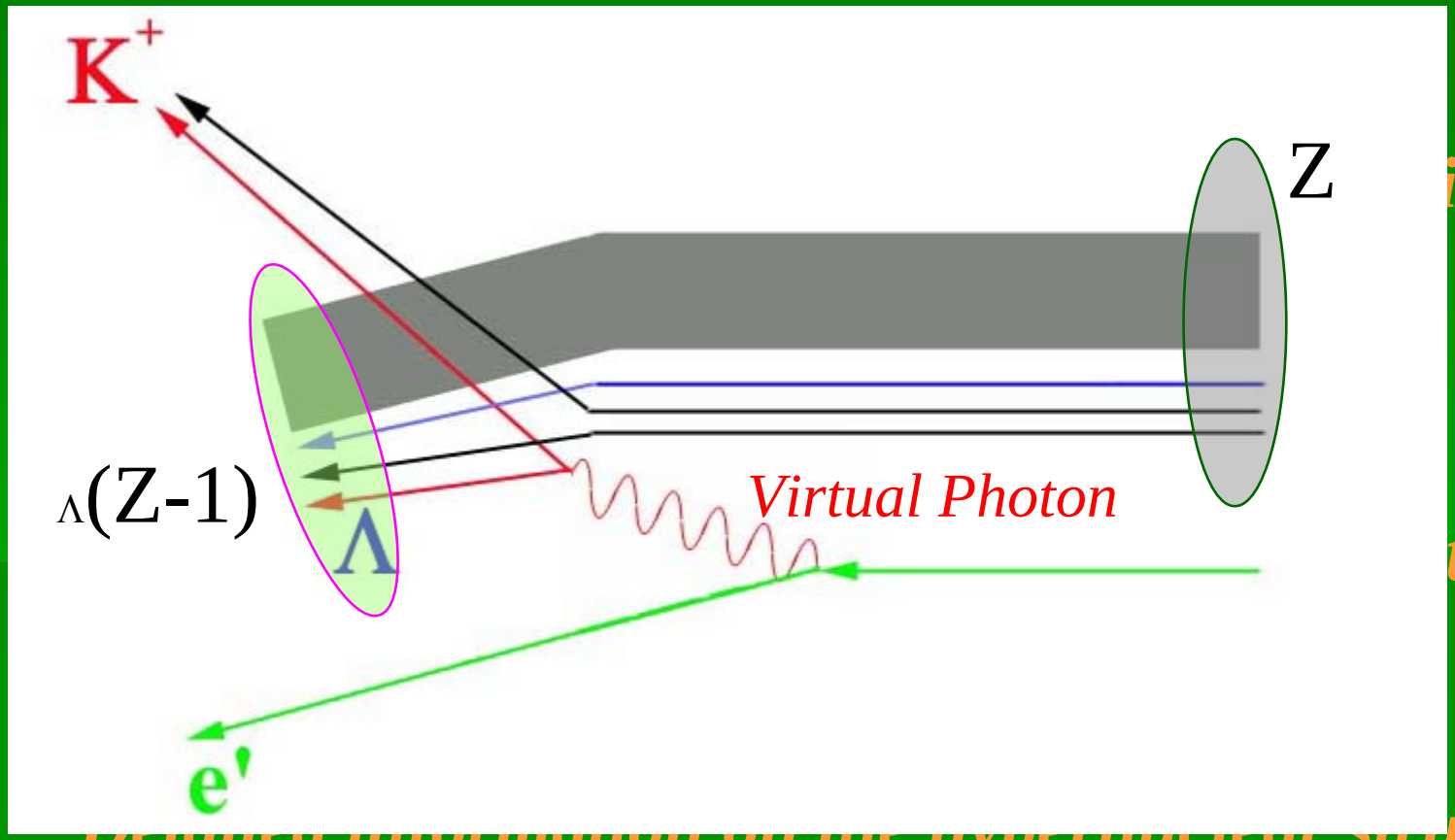
(N^{-1},Λ) narrower than
(N^{-1},N) states
Λ isospin=0,
Int(ΛN) < Int(NN)

Spectroscopy of
the deeply bound Λ states



Hotchi et al., PRC 64 (2001) 044302

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



Hypernuclei in wide mass range

A: 1 — E89-009 (^{12}C) — 20 — 50 — 200 — 10^{57}

E01-011: ^{12}C – ^{28}Si

Elementary Process

Strangeness electro-production

Light Hypernuclei (s,p shell)

Fine structure

Baryon-baryon interaction in SU(3)

$\Lambda\Sigma$ coupling in large isospin hypernuclei

Cluster structure

Neutron/Hyperon star,

Strangeness matter

Hyperonization → Softening of EOS ?

Superfluidity

Medium - Heavy hypernuclei

Single-particle potential

Distinguishability of a Λ hyperon

$U_0(r)$, $m_\Lambda^*(r)$, $V_{\Lambda NN}$, ...

Hypernuclei in wide mass range

A

1 20 50 200 10^{57}

E05-115

^{6,7}Li ^{10,11}B ^{12}C ^{51}V ^{89}Y

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Goals of the E05-115 experiment

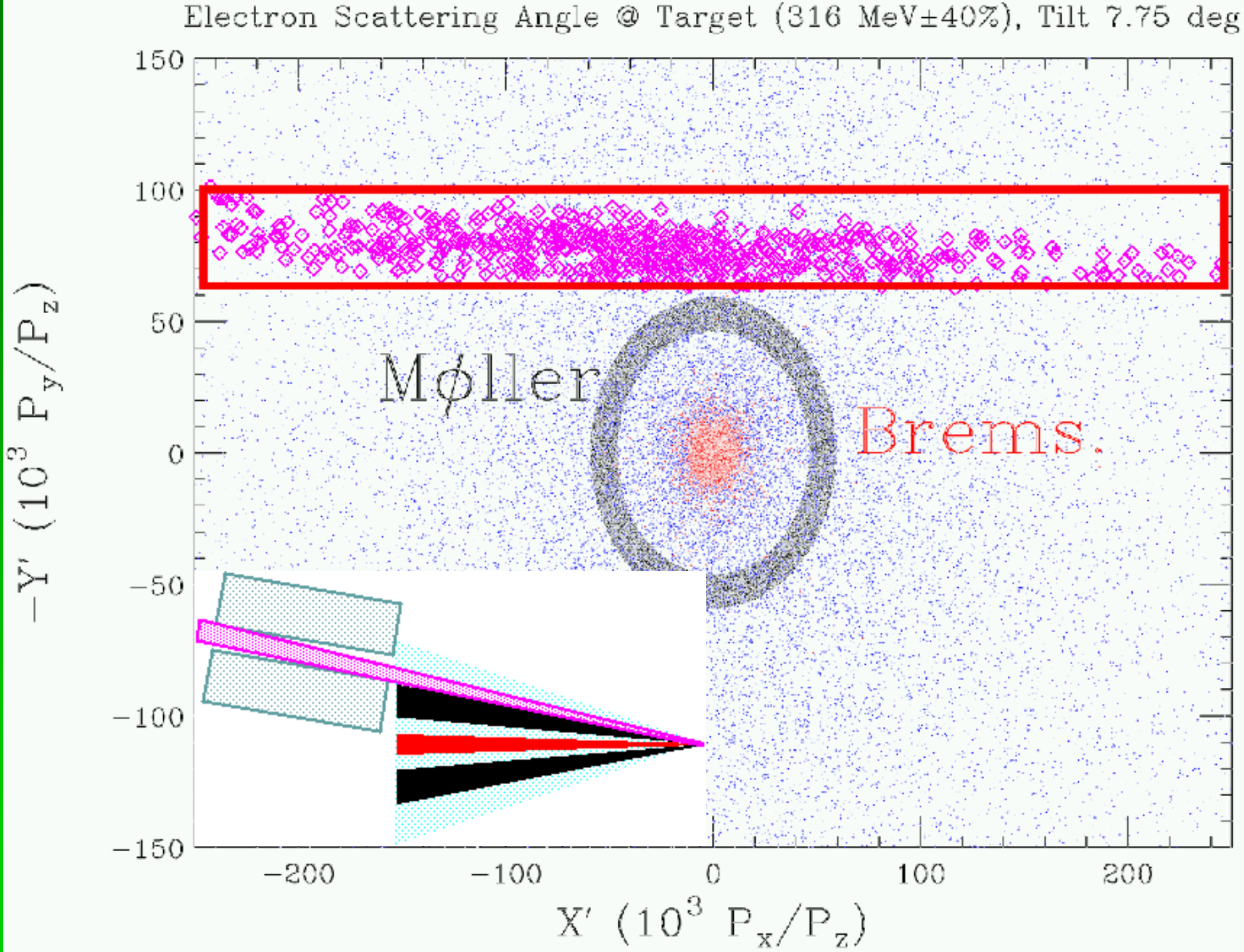
E01-011 shows that :

The tilt method applied to the electron spectrometer

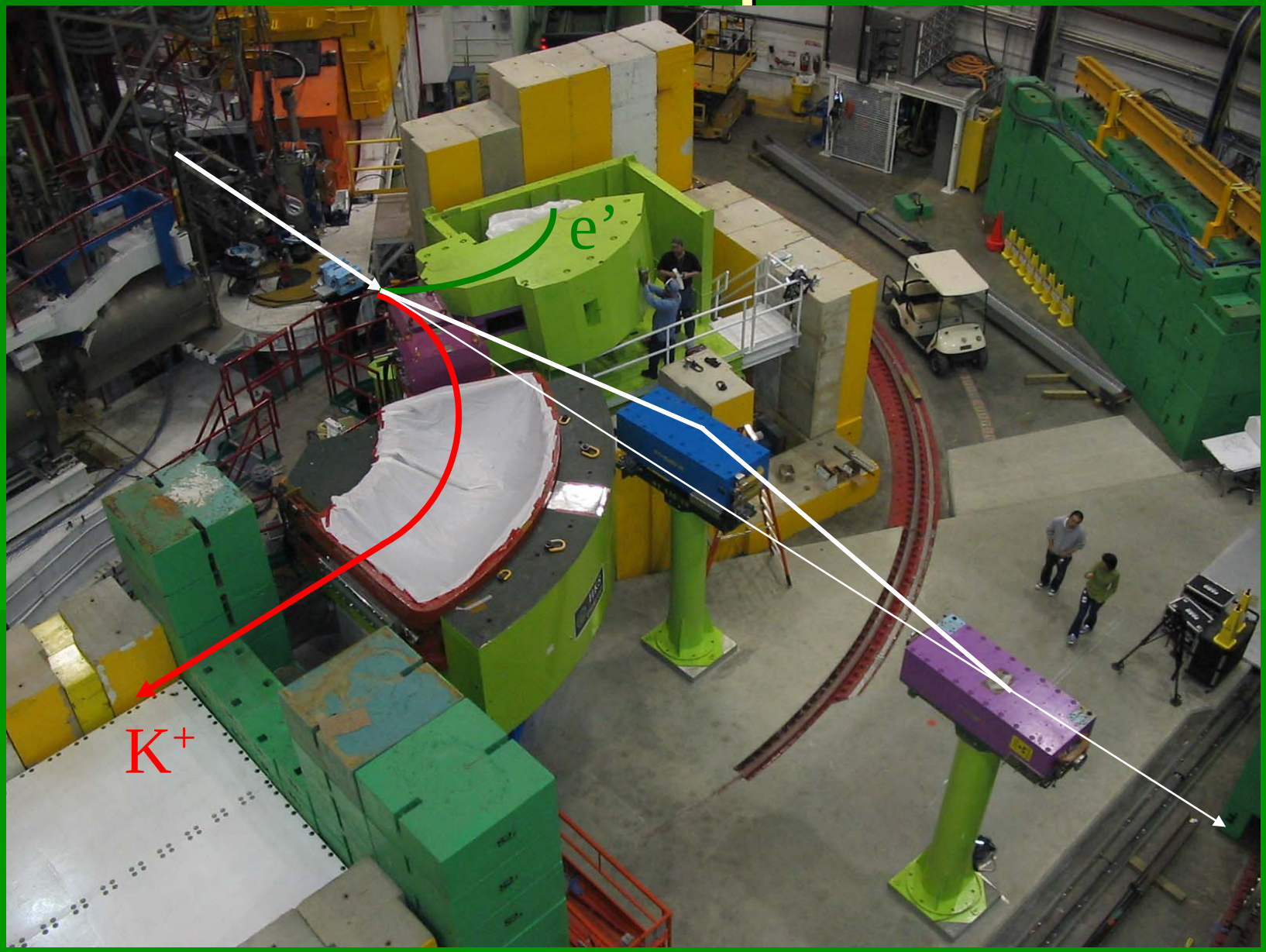
New HKS spectrometer

Open door to

the heavier hypernuclear study with (e,e'K) reaction


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

E01-011 Setup



Goals of the E05-115 experiment

E01-011 shows that :

The tilt method applied to the electron spectrometer

New HKS spectrometer

Open door to the heavier hypernuclear study with (e,e'K) reaction

- $^{51}V(e,e'K^+)^{51}{}_{\Lambda}Ti$ reaction
  - Λ binding energies for s,p,d orbits determined
  - Λ hypernuclear structure investigated
  - *ls* splitting in l=2,3 orbits to be derived if the splitting is sizable
- $^{89}Y(e,e'K^+)^{89}{}_{\Lambda}Sr$ reaction
  - Exploratory run to examine feasibility of (e,e'K+) spectroscopy in heavier hypernuclei
- $^{6,7}Li(e,e'K^+)^{6,7}{}_{\Lambda}He$ and $^{10,11}B(e,e'K^+)^{10,11}{}_{\Lambda}Be$
  - Precision hypernuclear structure in neutron-rich Λ hypernuclei
  - $\Lambda\Sigma$ coupling effect changing isospins with neutron number

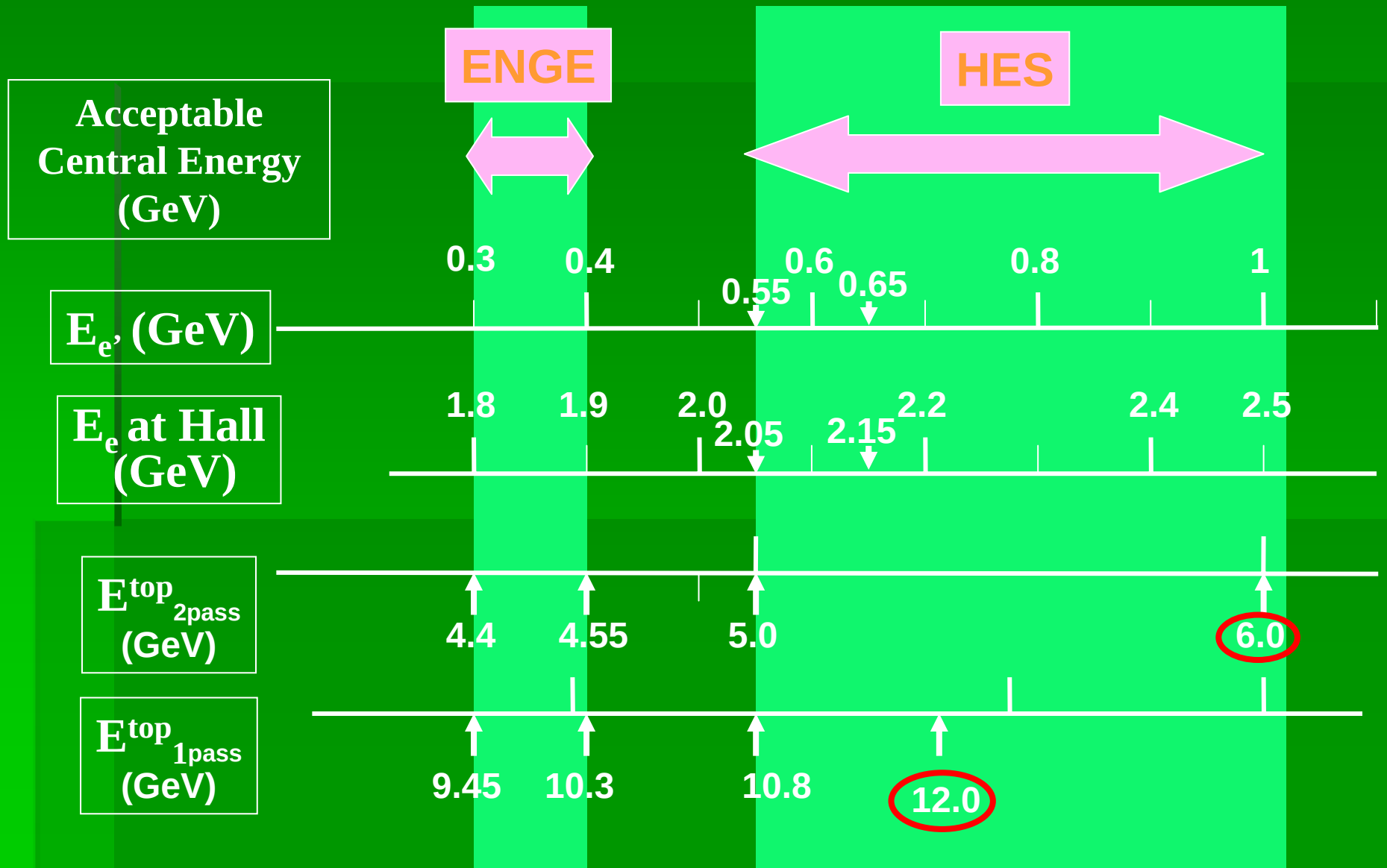
Introduction of the new electron spectrometer (HES)

Requested beam time
E05-115 proposal

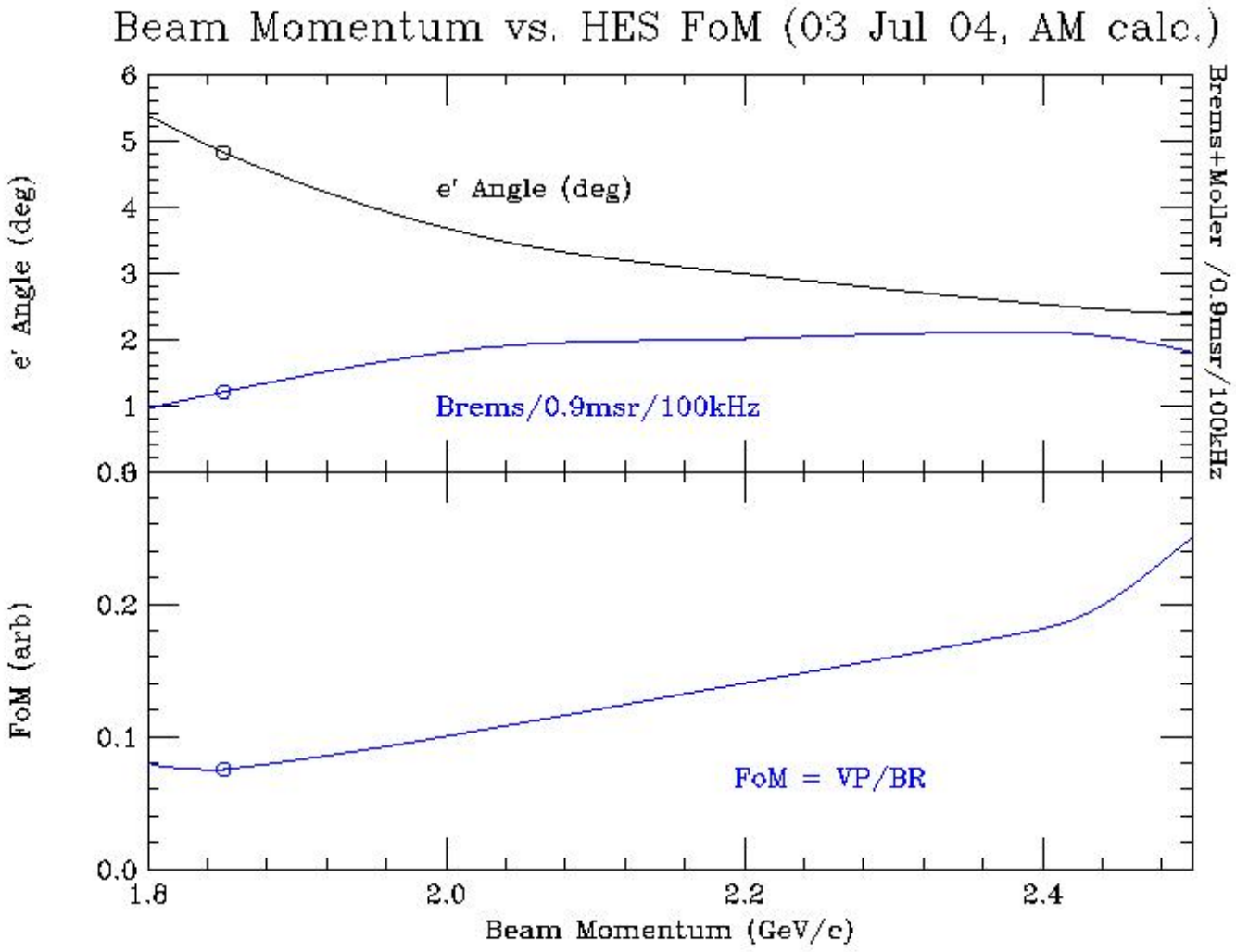
	Target	Hypernucleus	# of days	# of hours
Spectrometer commissioning & calibration			4(8)	96(192)
Data taking	^{6,7}Li, ^{10,11}B	$^{6,7}_{\Lambda}$He, $^{10,11}_{\Lambda}$Be	5	120
	^{51}V	$^{51}_{\Lambda}$Ti	14	336
	^{89}Y	$^{89}_{\Lambda}$Sr	5	120
Subtotal for data taking			24	576
Grand total			28(32)	672(768)

20 days approved by PAC28, 2005

Acceptable energy windows of HKS system with ENGE or HES



e' spectrometer tilt angle, FoM



HES Parameters
(HES is basically smaller version of the HKS)

- Splitter (27 tons)

Magnetic field	1.8 T
Full gap	17 cm (including vacuum chamber thiclness)
Length (beam direction)	1.2 m
Splitter-Q1	0.8 m

- Q1 (2.7 tons)

Field gradient	7.8 T/m
Length	0.6 m
Bore diameter	0.2 m (Effective full width 0.4 m)
Q1-Q2	0.3 cm

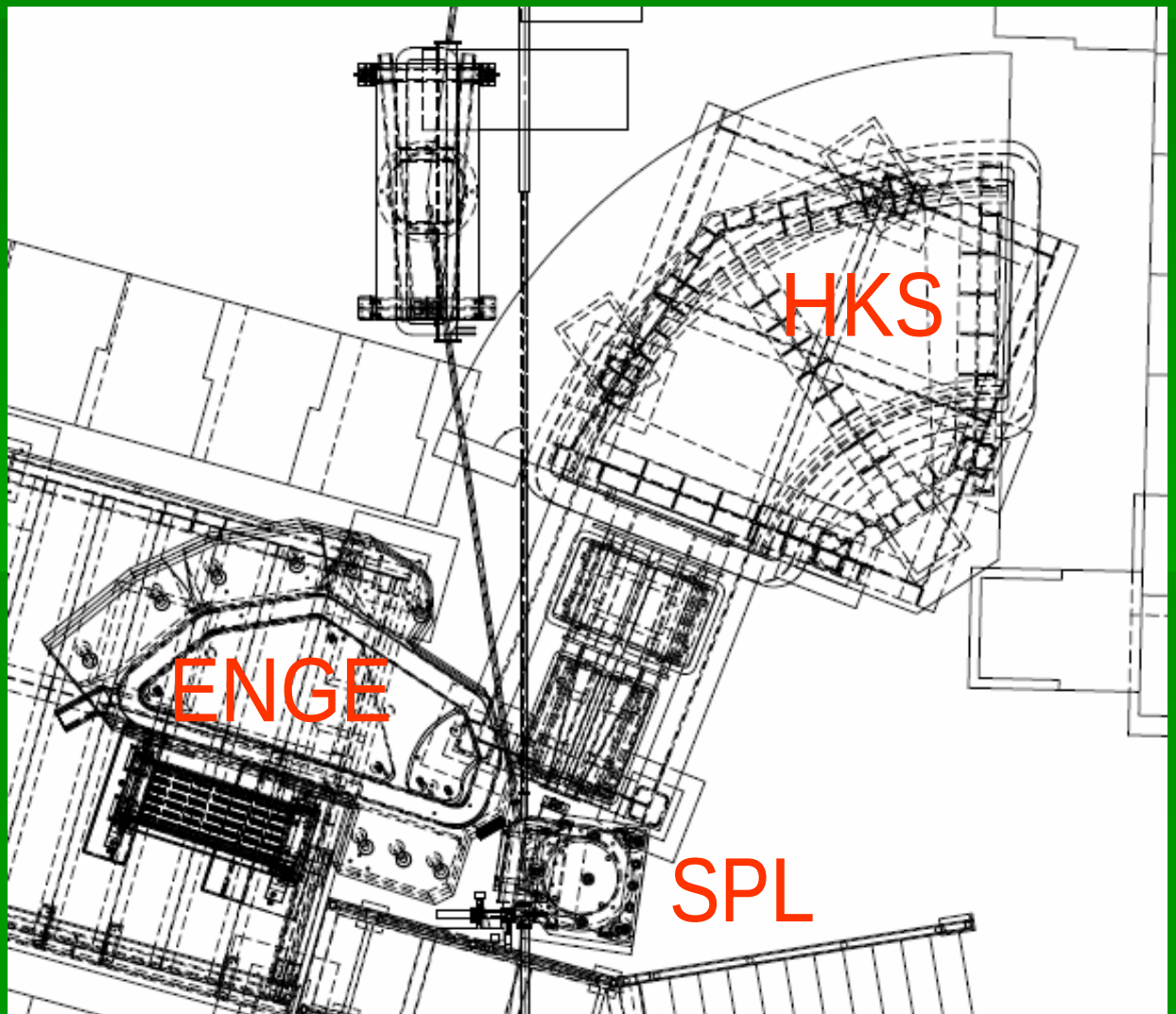
- Q2 (3.05 tons)

Field gradient	5.0 T/m
Length	0.5 m
Bore diameter	0.25 m (Effective full width 0.5 m)
Q2 – D	0.8 m

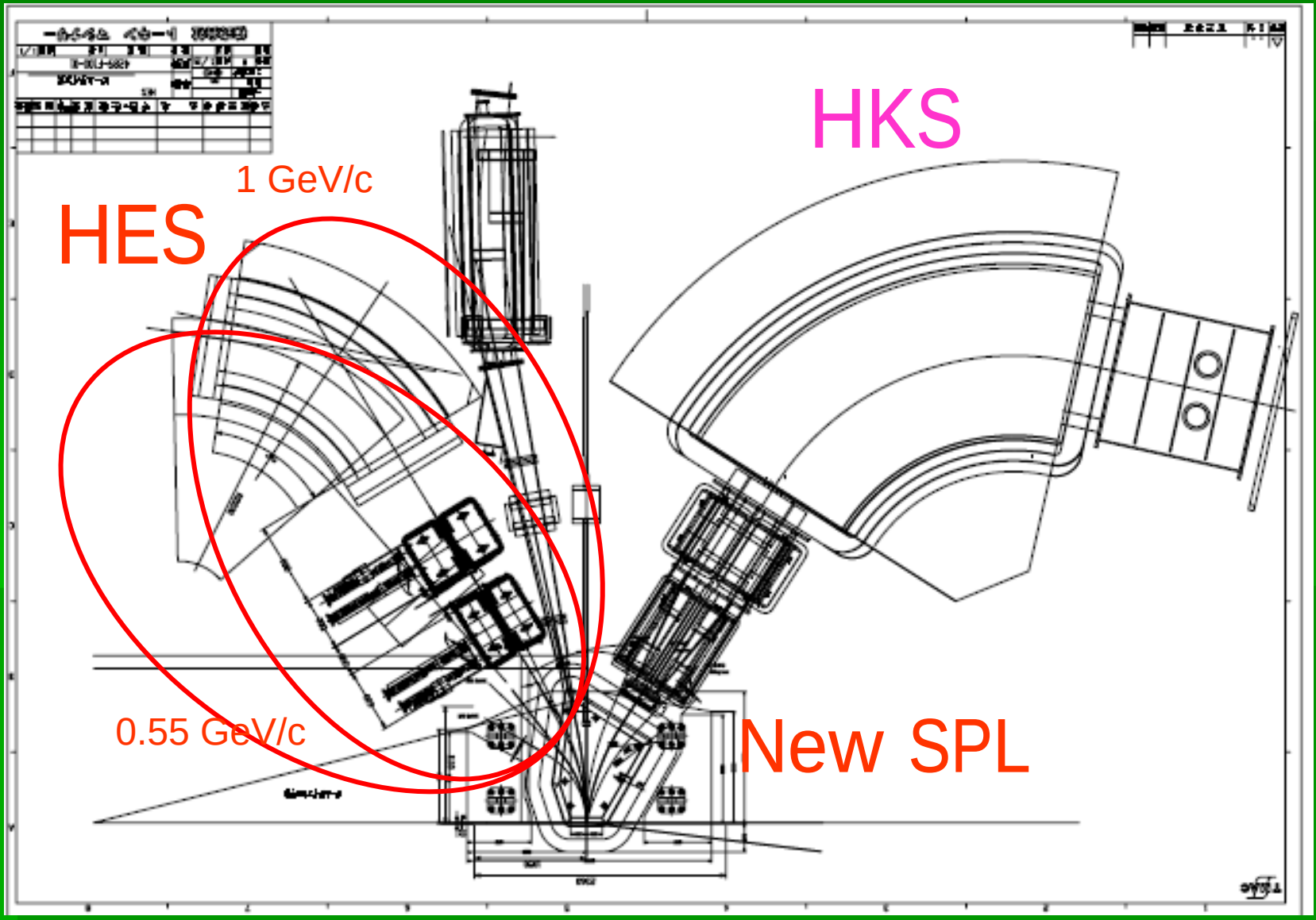
- Dipole (36 tons)

Bend	50 degrees
ρ	2.2 m
Full gap	15 cm : (Effective > 12cm)
Inner full width	0.8 m

HKS + ENGE system (E01-011)



Drawing of the HES + HKS



Tilt Method will be applied to HES

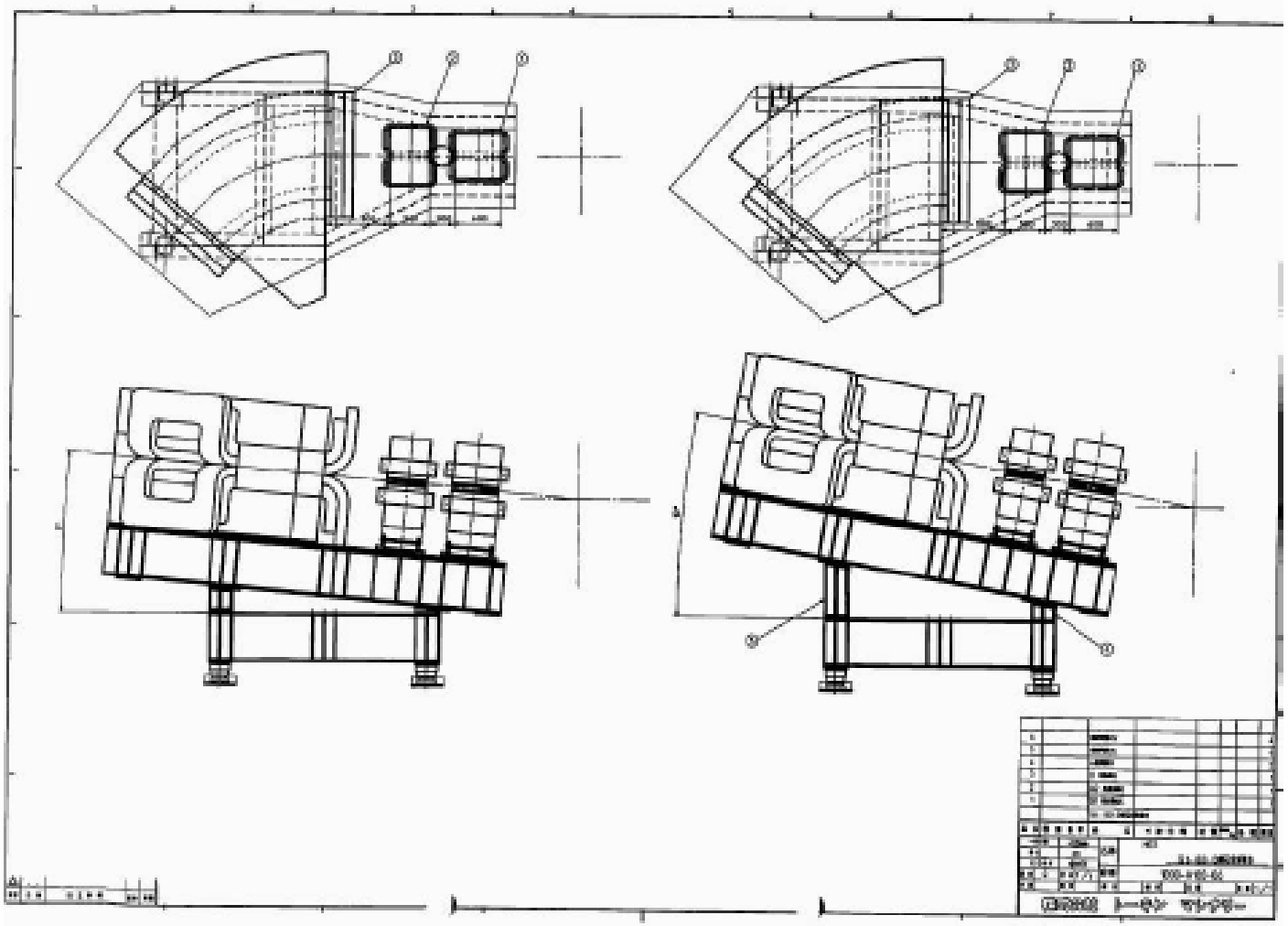
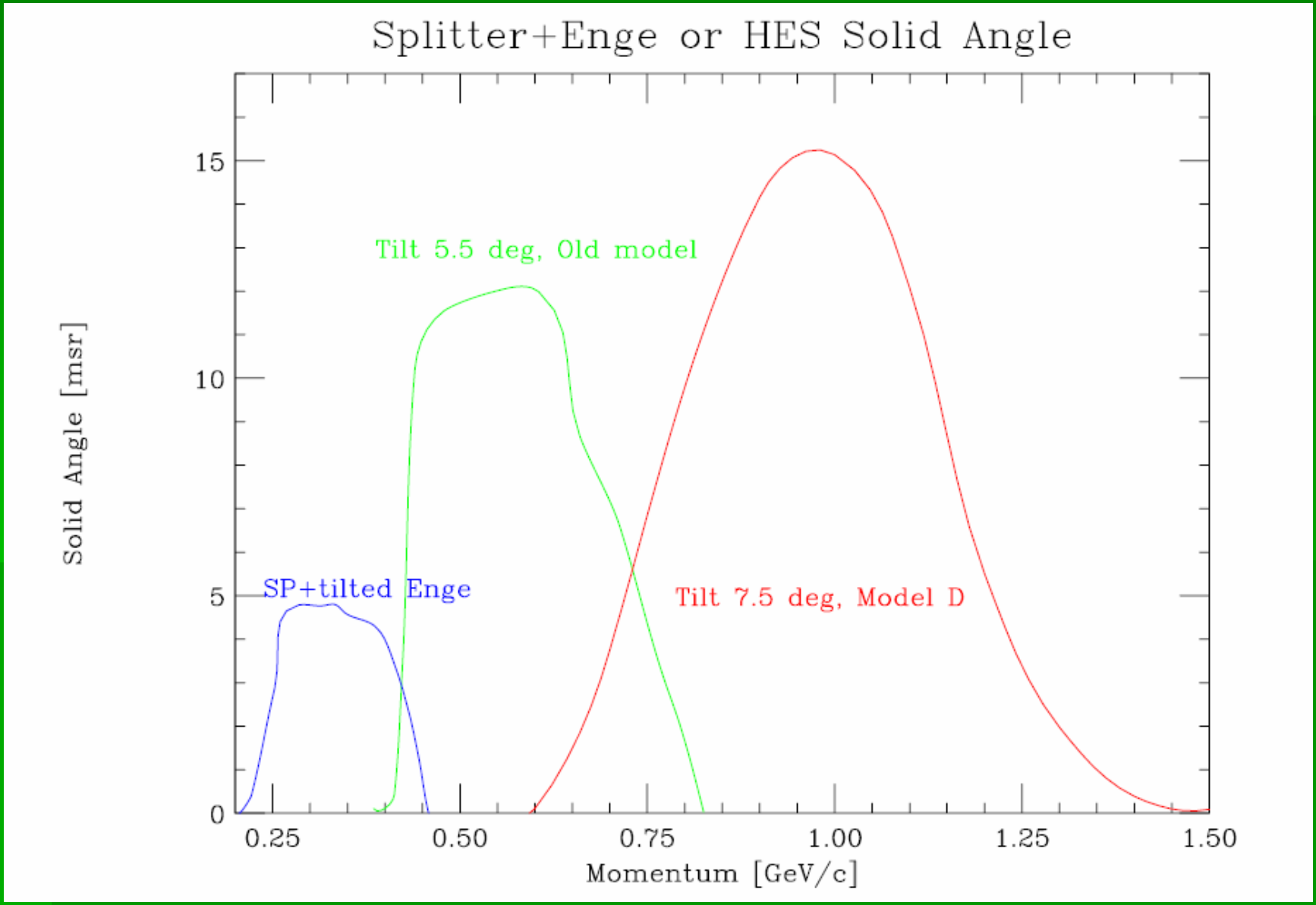
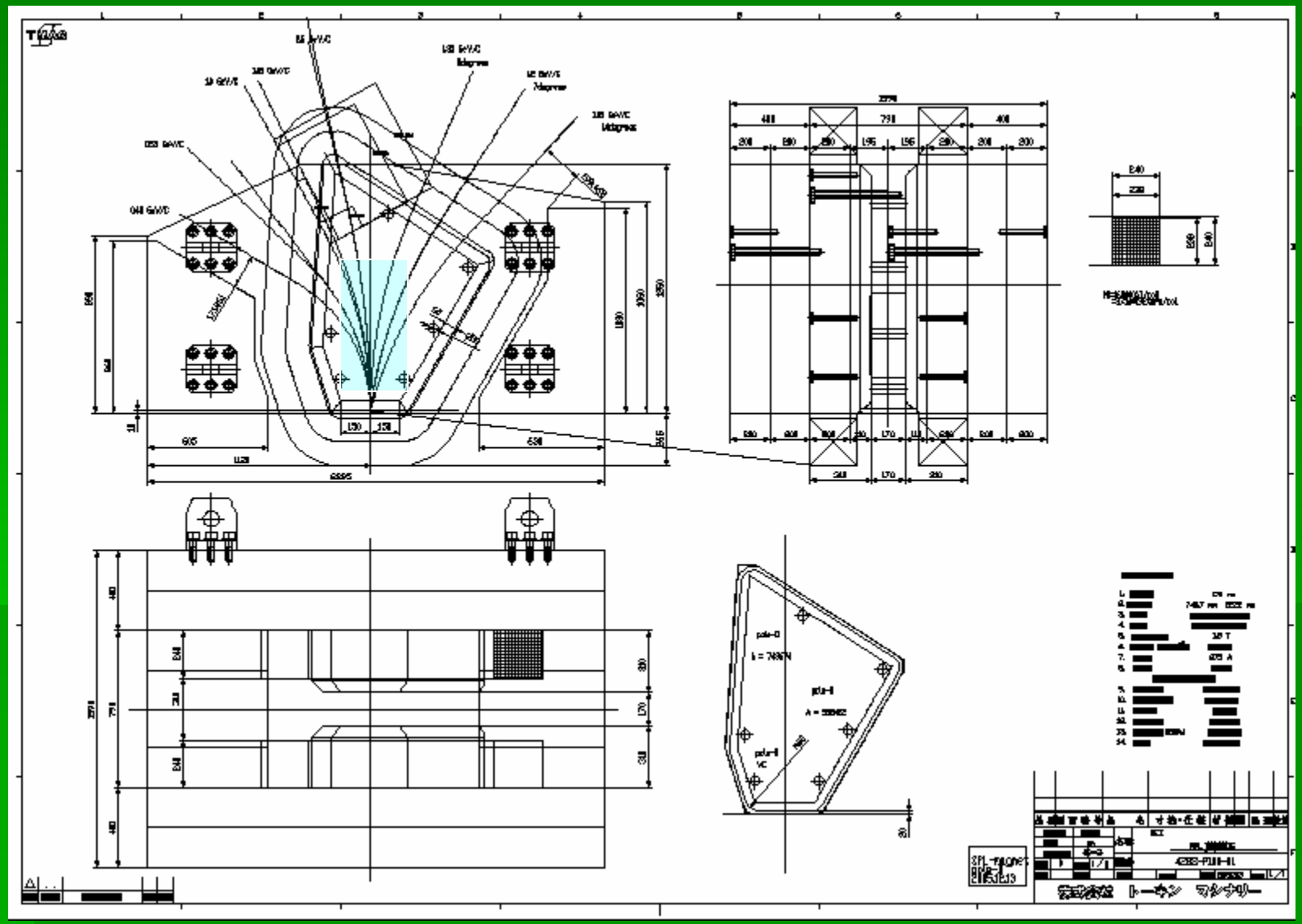


Figure 25: The "tilt method" will be also applied to the HES. The tilt angle will be optimized to the central momentum. It can be realized by changing the shim under the HES.

HES Solid Angle



The New Splitter



Evolution of (e,e'K$^+$) hypernucl. spectroscopy

	2000	2004-2005	2005	200X
	E89-009	E94-107 (HallA)	E01-011	E05-115
Configuration	**SOS+ENGE +Splitter**	**HRS+HRS +Septum**	**HKS**+ENGE +Splitter	HKS**+HES** +**New splitter**
Beam intensity (μA) on ^{12}C	0.66	100	24	30
thickness (mg/cm^2)	22	100	100	100
Hypernuclear yield ($^{12}_{\Lambda}B_{gr}$: /hr)	0.9	2-3	8 ~ (40)	(> 40)
Resolution (keV)	**750-900**	**~ 800**	**(3-400)**	**(3-400)**
Beam energy (GeV)	1.7-1.8	4	1.8	**2.0 - 2.4**
p_K (central : GeV)	1.2	1.9	1.2	1.2
p_e (central: GeV)	0.3	2.2	0.3	0.6 – 1.0
θ_K (degree)	0-7	6	1-13	1-13
θ_e (degree)	0	6	4.5	3-10 *

( ) expected * select one angle

Time-line of Hall C Hyp.Nucl. program

2000 E89-009 beamtime
2001 PAC19 E01-011 Proposal approved ^{12}C, ^{28}Si
2002 HKS&Detectors R&D started
2003 KEK test beamtime/HKS field mapping
HKS shipped to JLab
2004 HKS Preassembly@JLab test lab.
HES basic design started (HES approved by JP. Gov.)
2005 Jan Installation @ Hall C started
June Beam tune started
PAC25 E05-115 Proposal accepted
$^{6,7}Li$, $^{10,11}B$, ^{51}V, ^{89}Y
July Physics run started
Oct Beamtime finished

2006 HES Design & Fabrication
2007 HES shipping to JLab
200X E05-115 Beamtime

We are here!

ENGE vs HES Chicane parameters

	ENGE	HES
Beam p	1.85GeV/c	2.15-2.50GeV/c
SPL BL (for beam)	900 kG cm	~1800 kG cm
DZ	1680 kG cm	3300 kG cm ?
EZ	-820 kG cm	-1600 kG cm ?
Ver.Corr.	-24kGcm x 2	?
Hor.Corr.	3.8kGcm – 2.1kGcm	?

To be done

- Splitter Design
  - Feasibility Check, Geometry … CAD
    Mag. Field ... TOSCA
- HES system
  - Optics Study for D-QQD system
  - Optimize magnets' parameters
    - Gap, width of HES-D
- Post Beamline (Chicane design)

Schedule

- 2005 Feb.
  - Bidding for the HES concept design, Q1, Q2 fabrication -> TOKIN
- 2005 Nov.
  - Contract HES-D PS
  - Finalize Design of the new SPL + HES
- 2006
  - Fabrication of the SPL-D magnets
  - Fabricate New Drift Chamber, Hodoscopes
- End of 2006 ~ early 2007
  - Shipping SPL+HES(QQD) to JLab

Beam Profile at the Focal Plane