JLab Hypernuclear Collaboration Meeting 2026
https://indico.jlab.org/event/985/

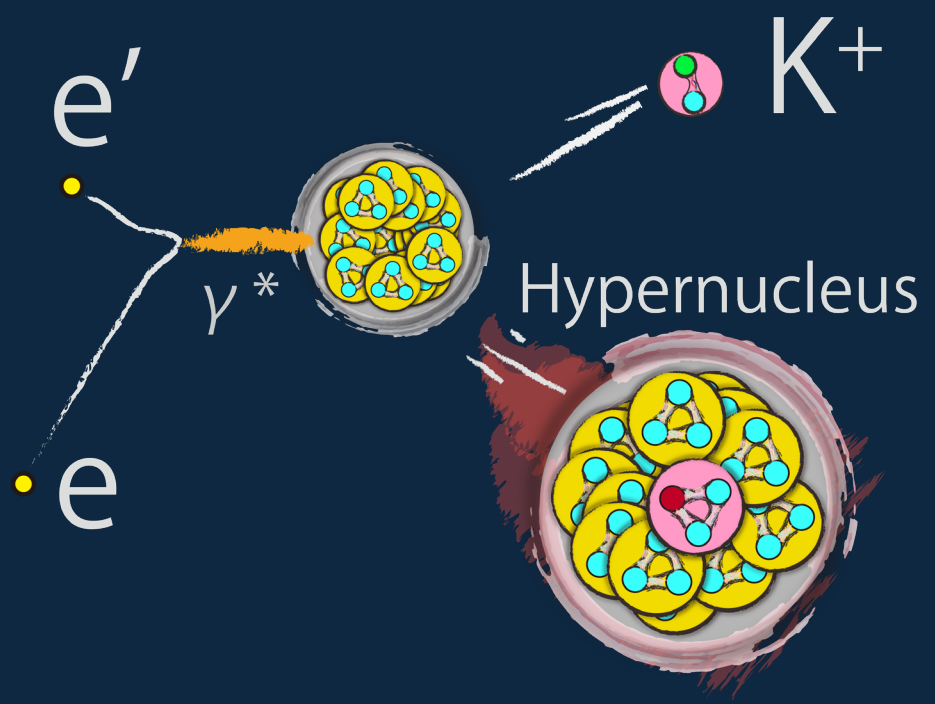
Overview of HKS-HES updates

Graduate School of Science, Kyoto University

Toshiyuki Gogami

February 12, 2026

Missing-mass spectroscopy



$$M_H = \sqrt{(E_e + M_T - E_{e'} - E_K)^2 - \left(\overrightarrow{P_e} - \overrightarrow{P_{e'}} - \overrightarrow{P_K}\right)^2}$$

To be measured

$$B_\Lambda = M_H - M_{core} - M_\Lambda$$

Electro-production

- Better understanding of reaction — GOOD
- Small cross section — Bad
- Larger noise as Z gets larger — Bad

Primary beam

- High precision / small emittance — GOOD
- High intensity → thin target — GOOD
  (→ High energy resolution)

Virtual photo production

→ Large spin flip amplitude — GOOD Bad

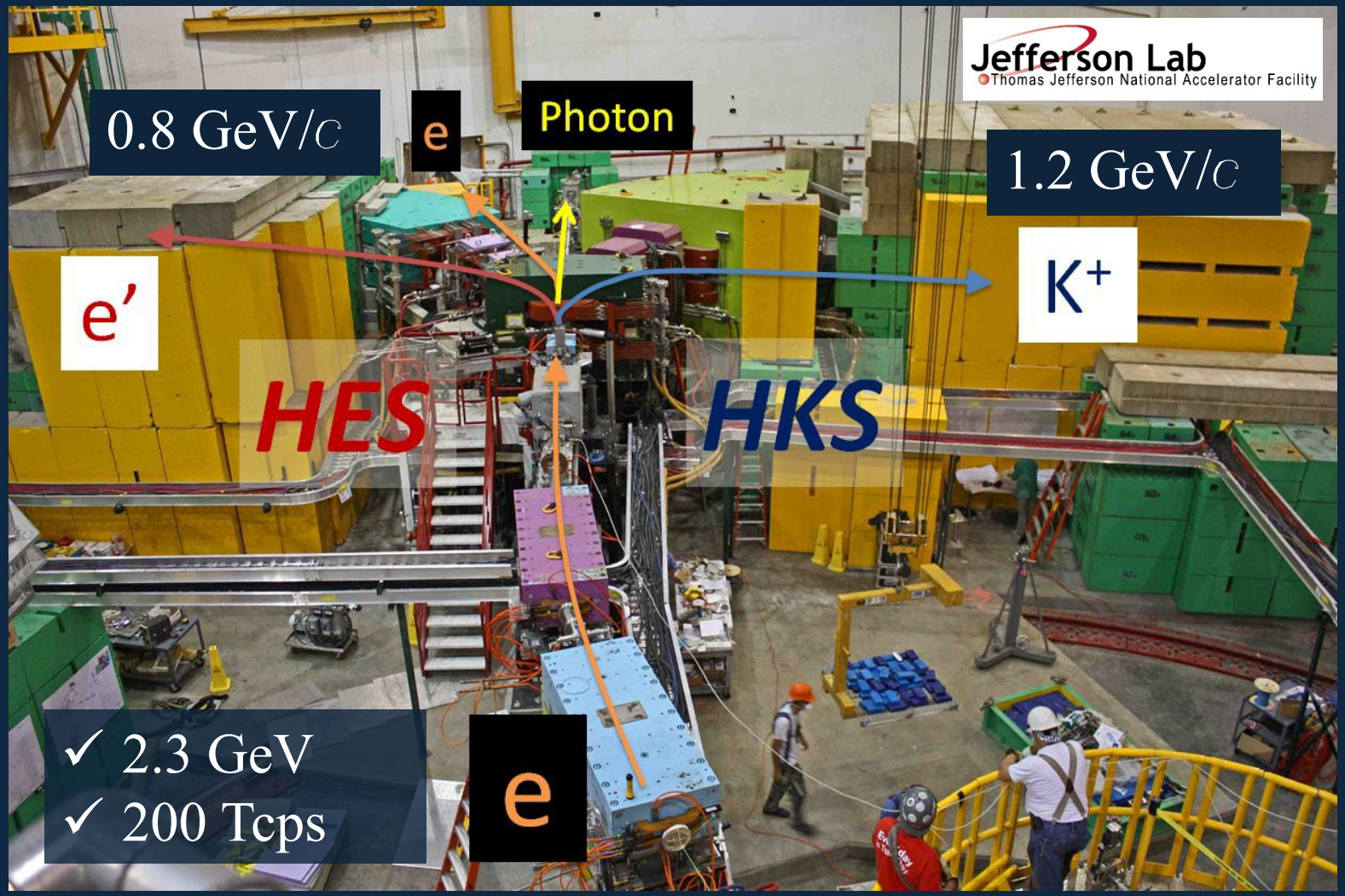
p → Λ

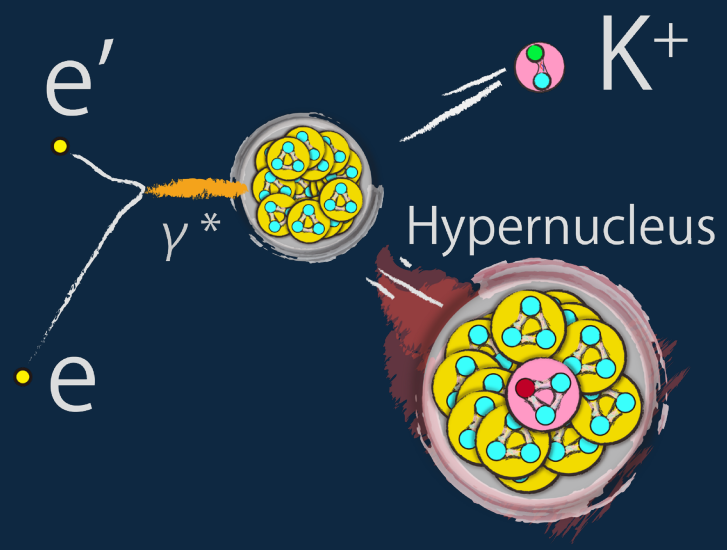
GOOD

→ Good calibration with proton target

→ Mirror Hypernuclear study — GOOD

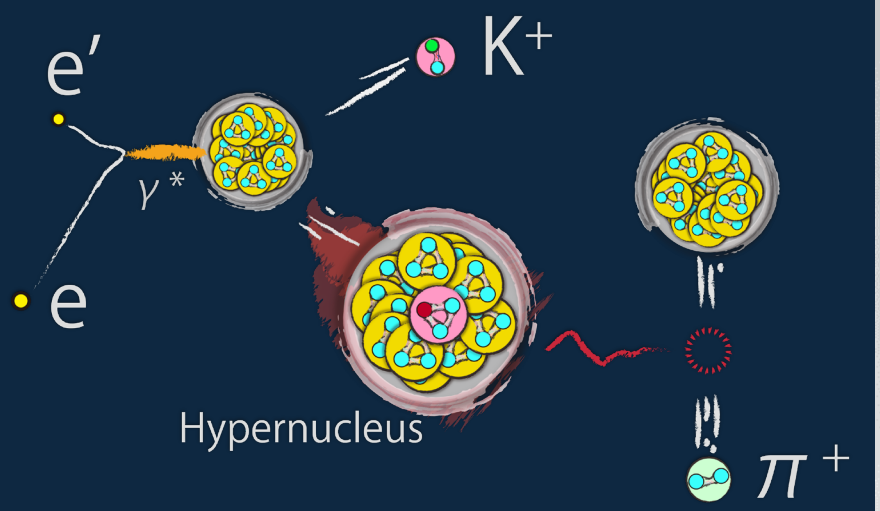
Magnetic spectrometers (JLab E05-115, 2009)





TG et al., PRC 103, L041301 (2021)
TG et al., NIMA 900, 69—83 (2018)
TG et al., PRC 94, 021302(R) (2016)
TG et al., PRC 93, 034314 (2016)
Y. Fujii et al., NIMA795, 351—363 (2015)
L. Tang et al., PRC 90, 034320 (2014)
TG et al., NIMA 729, 816—824 (2013)

New experiment at JLab Hall-C



Decay pion:
- Sho (Feb 12)
- Shunsuke (Feb 13)

Radiation:
- Pavel (Feb 12)
- Jin (Feb 13)

e': HES

0.7 GeV/c
2×10^5 /sec

K+: HKS

1.2 GeV/c
5×10^4 /sec

π^+: ENGE

2.2-GeV Electron
50 μA (3×10^{14} /sec)
→ Hypernuclei: 0.003 /sec

Jefferson Lab
Thomas Jefferson National Accelerator Facility

Comprehensive projects, unique research

Experiment	Hypernucleus	Title	PAC Days
E12-19-002	${}^{3}_{\Lambda}\mathrm{H}$, ${}^{4}_{\Lambda}\mathrm{H}$	High accuracy measurement of nuclear masses of hyperhydrogens	14.5
E12-24-004	${}^{6}_{\Lambda}\mathrm{He}$, ${}^{9}_{\Lambda}\mathrm{Li}$, ${}^{11}_{\Lambda}\mathrm{Be}$	Study of charge symmetry breaking in p-shell hypernuclei	24
E12-24-013	${}^{40}_{\Lambda}\mathrm{K}$, ${}^{48}_{\Lambda}\mathrm{K}$	An isospin dependence of the ΛN interaction through the high precision spectroscopy of Lambda hypernuclei	55
E12-24-011	${}^{27}_{\Lambda}\mathrm{Mg}$	Study of a triaxially deformed nucleus using a Lambda particle as a probe	28
E12-24-003	${}^{208}_{\Lambda}\mathrm{Tl}$	Studying Lambda interactions in nuclear matter with the ${}^{208}\mathrm{Pb}(e,e'K^{+})^{208}_{\Lambda}\mathrm{Tl}$ reaction	42
Run group (E12-15-008A)		High-resolution spectroscopy of light hypernuclei with the decay-pion spectroscopy	N/A

Next campaign

+ New run group:
η', ω, ρ^{0} measurements
(talk by Ralph on Feb 13)

Target:
- D. Meekins (Feb 12)
- K. Ishido (Feb 13)

TG et al., PoS (QCHSC24), 230 (2025)

Kinematic parameters

Item		Value
Beam (e)	Energy (/GeV)	2.24
	(Required) energy spread and drift	1×10^{-4} (FWHM)
PCS + HES (e')	Central momentum $p_{e'}^{\text{cent.}}$ [/(GeV/c)]	0.74
	Central angle $\theta_{ee'}^{\text{cent.}}$	8.5°
	Solid angle acceptance $\Omega_{e'}$ (/msr) (at $p_{e'}^{\text{cent.}}$)	3.4
	Momentum resolution $\Delta p_{e'}/p_{e'}$	4.4×10^{-4} (FWHM)
PCS + HKS (K^+)	Central momentum $p_{K^+}^{\text{cent.}}$ [/(GeV/c)]	1.20
	Central angle $\theta_{eK^+}^{\text{cent.}}$	11.5°
	Solid angle acceptance Ω_{K^+} (/msr) (at $p_{K^+}^{\text{cent.}}$)	7.0
	Momentum resolution $\Delta p_{K^+}/p_{K^+}$	2.9×10^{-4} (FWHM)
$p(e,e'K^+)\Lambda$	$\sqrt{s} = W$ (/GeV)	1.912
	Q^2 [/(GeV/c)^2]	0.036
	K^+ scattering angle wrt virtual photon, $\theta_{\gamma^* K^+}$	7.35°
	ϵ	0.59
	ϵ_L	0.0096

Optimal for Λ and Σ⁰

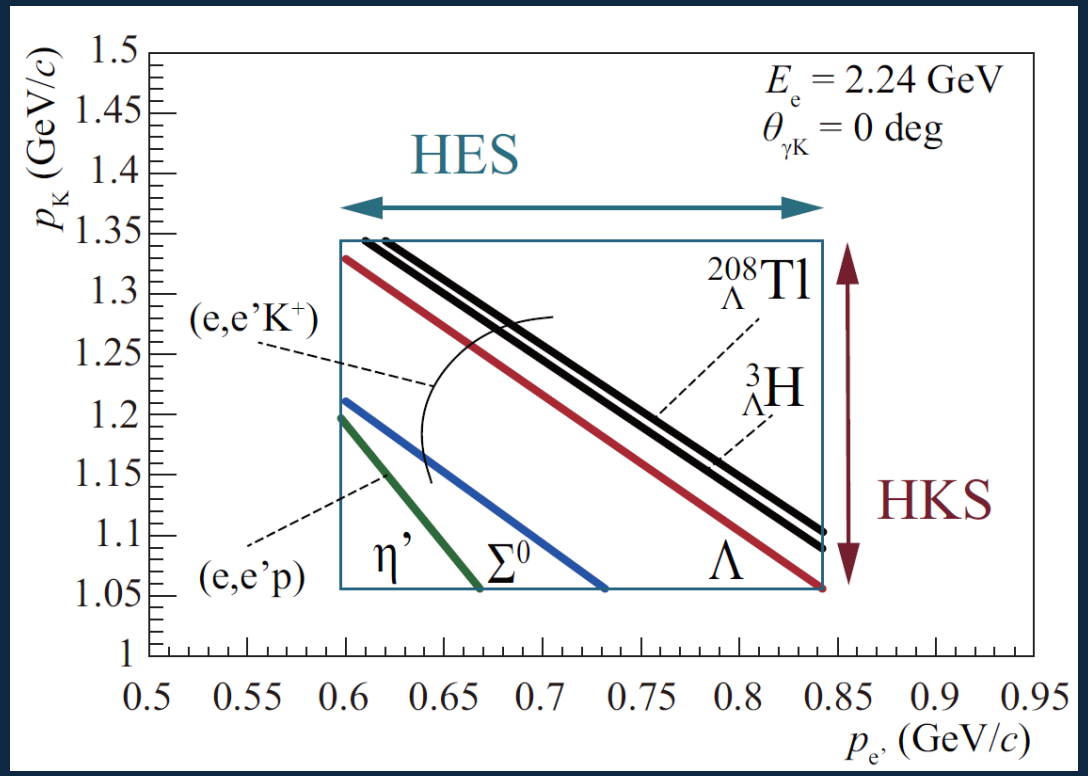
Small Q²
➔ Almost real photon

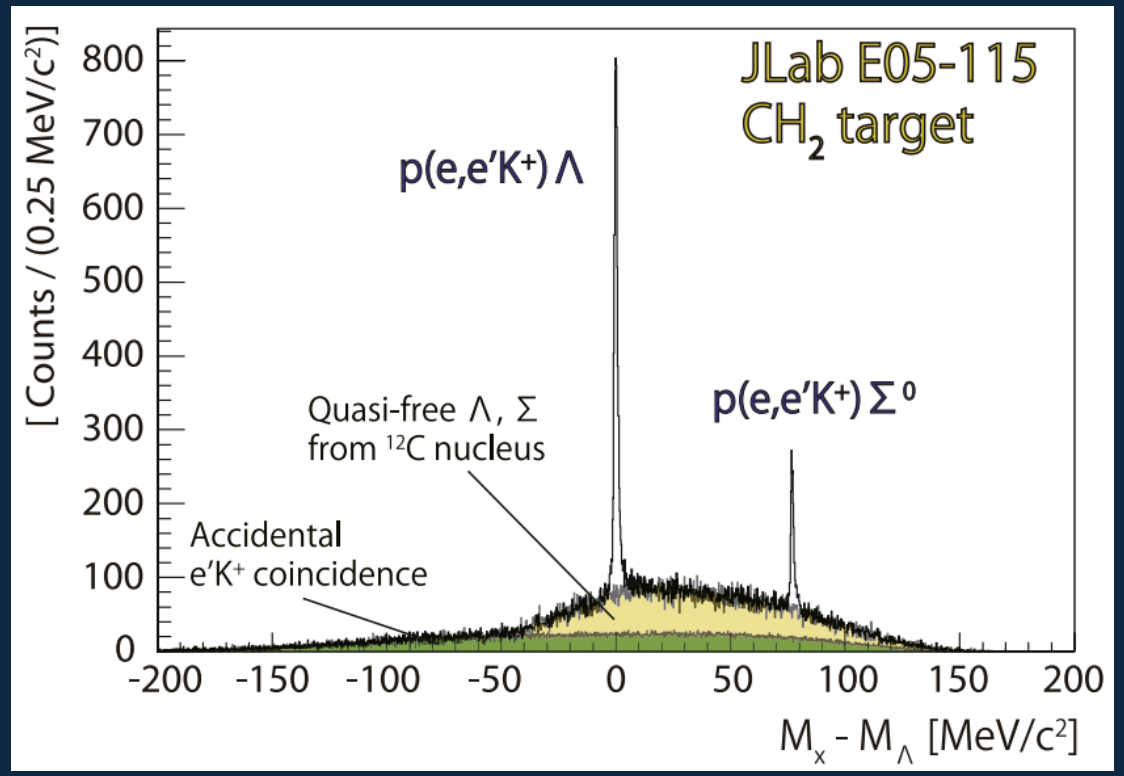
Forward angle
➔ Large cross section

TG et al., PoS (QCHSC24), 230 (2025)

Energy Calibration

TG et al., NIMA 900, 69—83 (2018)





➔ Systematic error $|\Delta B_\Lambda^{\mathrm{sys.}}| \simeq$ **60 keV**

c.f.) T. Toyoda, Master's Thesis, *Kyoto U*niversity, Kyoto, Japan, 2021 (in Japanese)

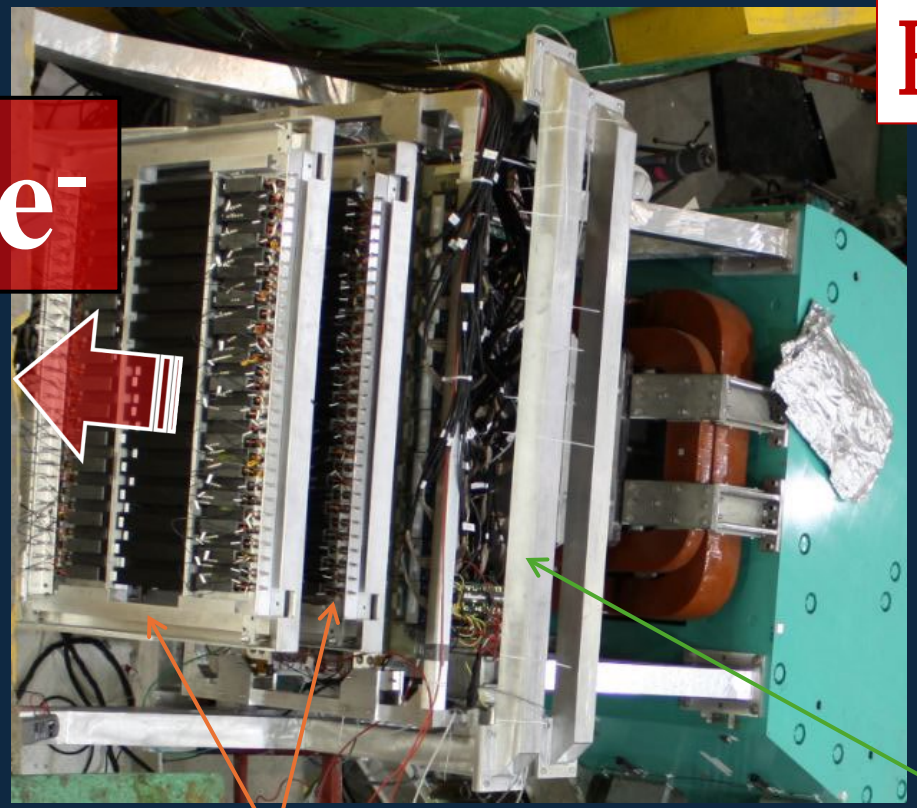
Particle Detectors

Cherenkov detectors
- **Aerogel (n=1.05)**
- **Water (n=1.33)**

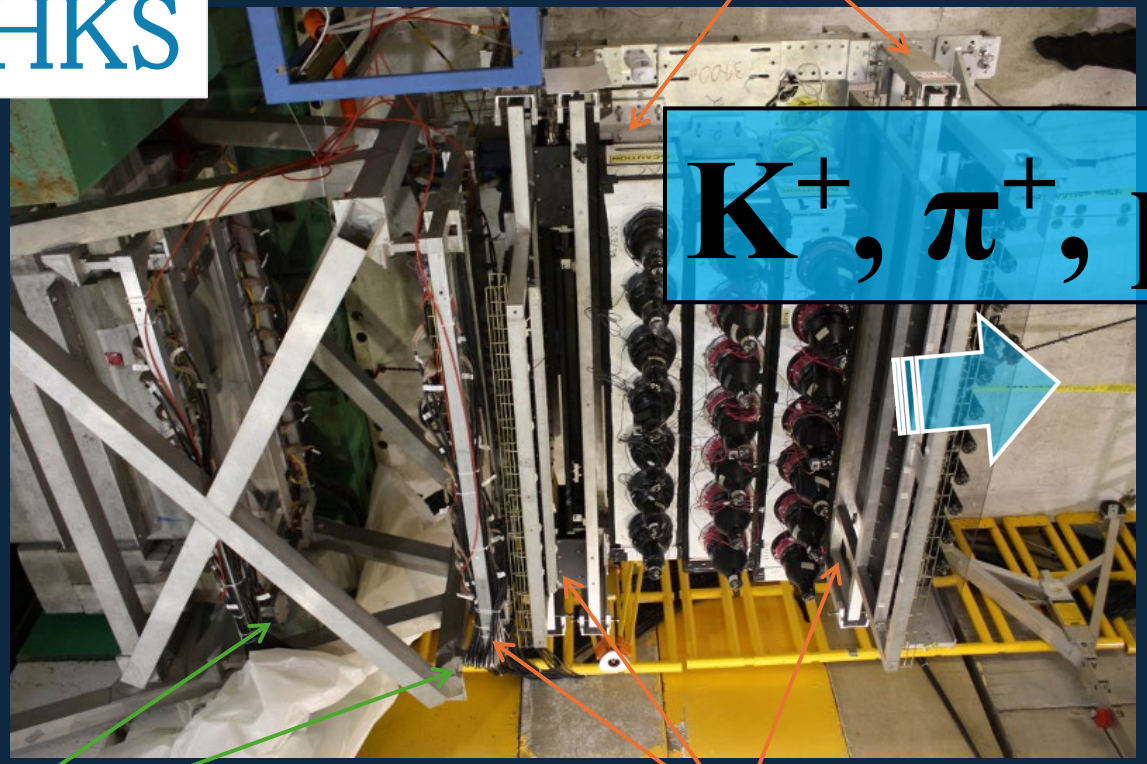
HES

HKS

e^-



K^+, π^+, p



TOF walls (Plastic scintillators)

Drift chambers

TOF walls (Plastic scintillators)

The number of channels for detectors

Spectrometer	Detector	FADC (ADC/TDC)	Low resolution TDC	High resolution TDC
HKS	KDC	-	640 + 640	
	TOF	88	-	88
	AC	42	-	-
	WC	48	-	-
HES	EDC	-	1120	-
	TOF	116	-	116
Number of total channels		294	2400	204

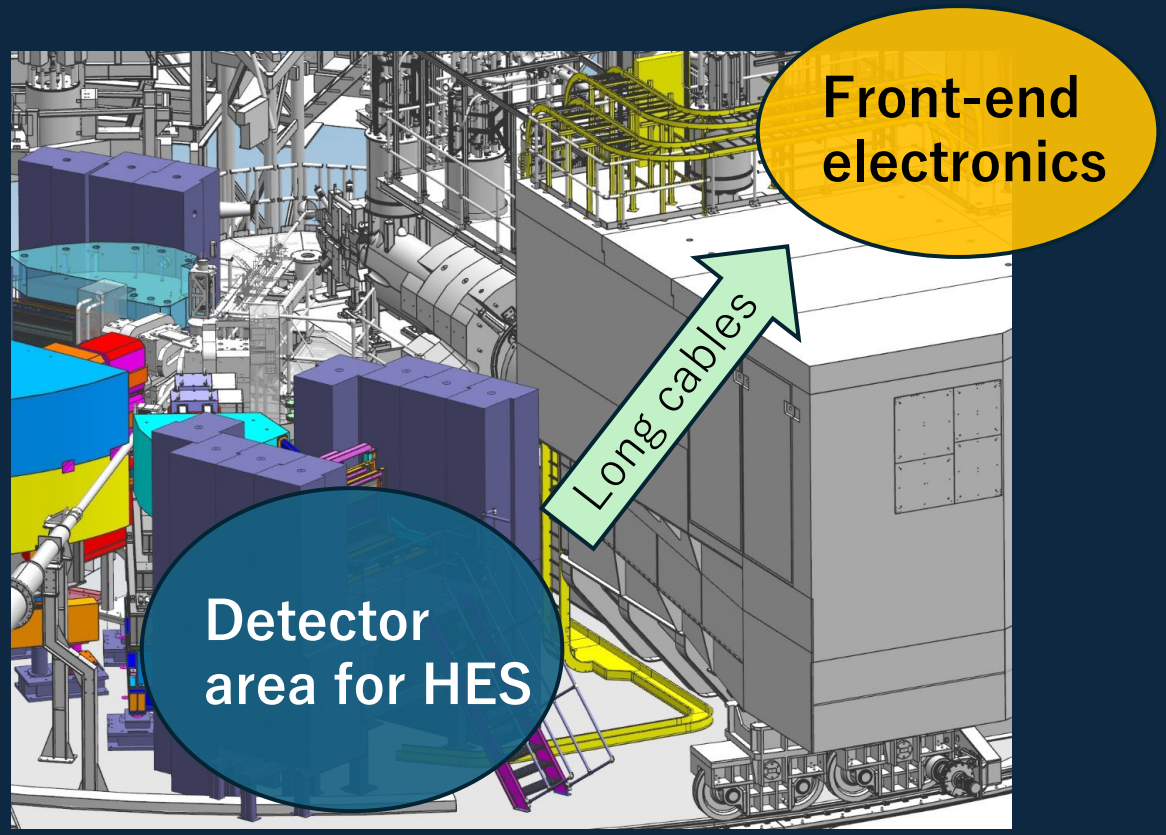
Ravindu (Feb 13)

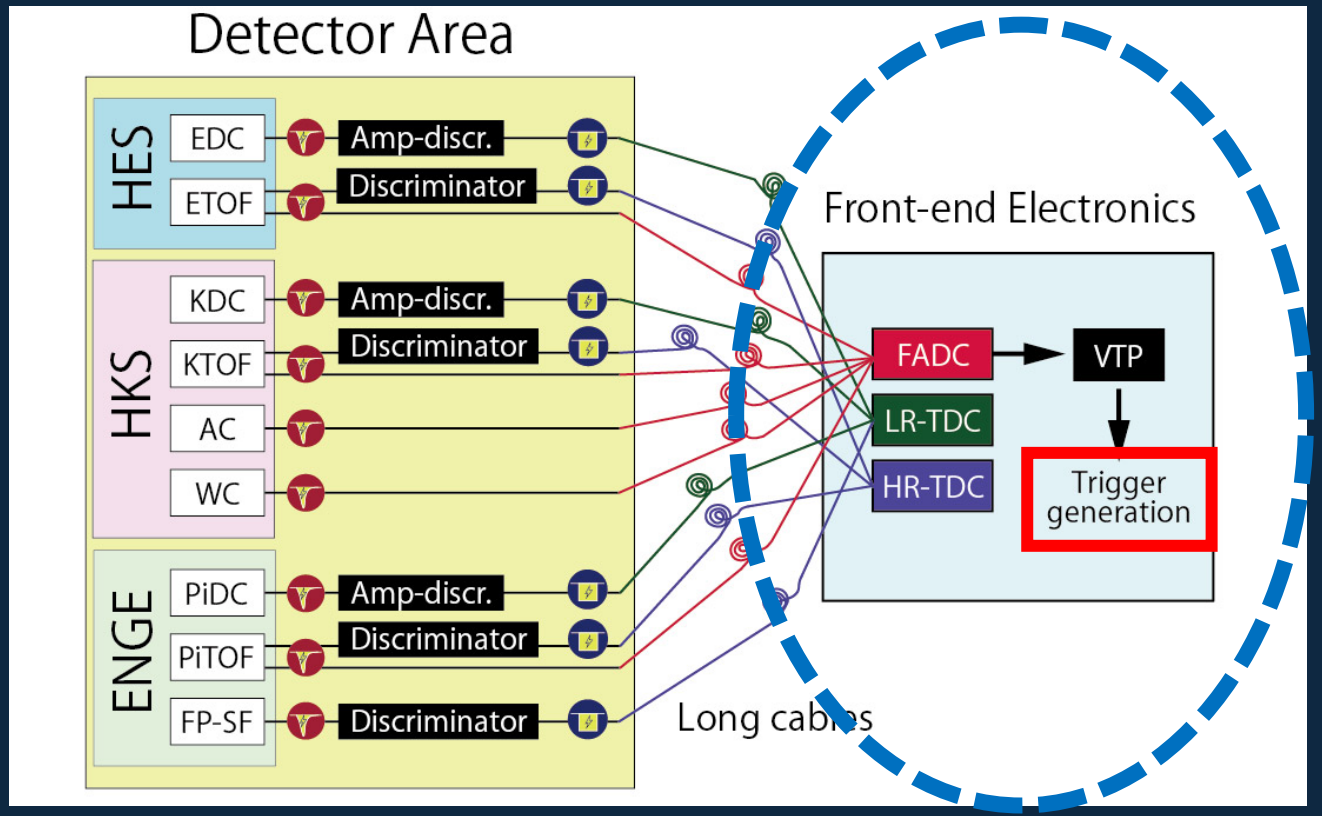
Kotaro (Feb 13)

Kaito (Feb 13)

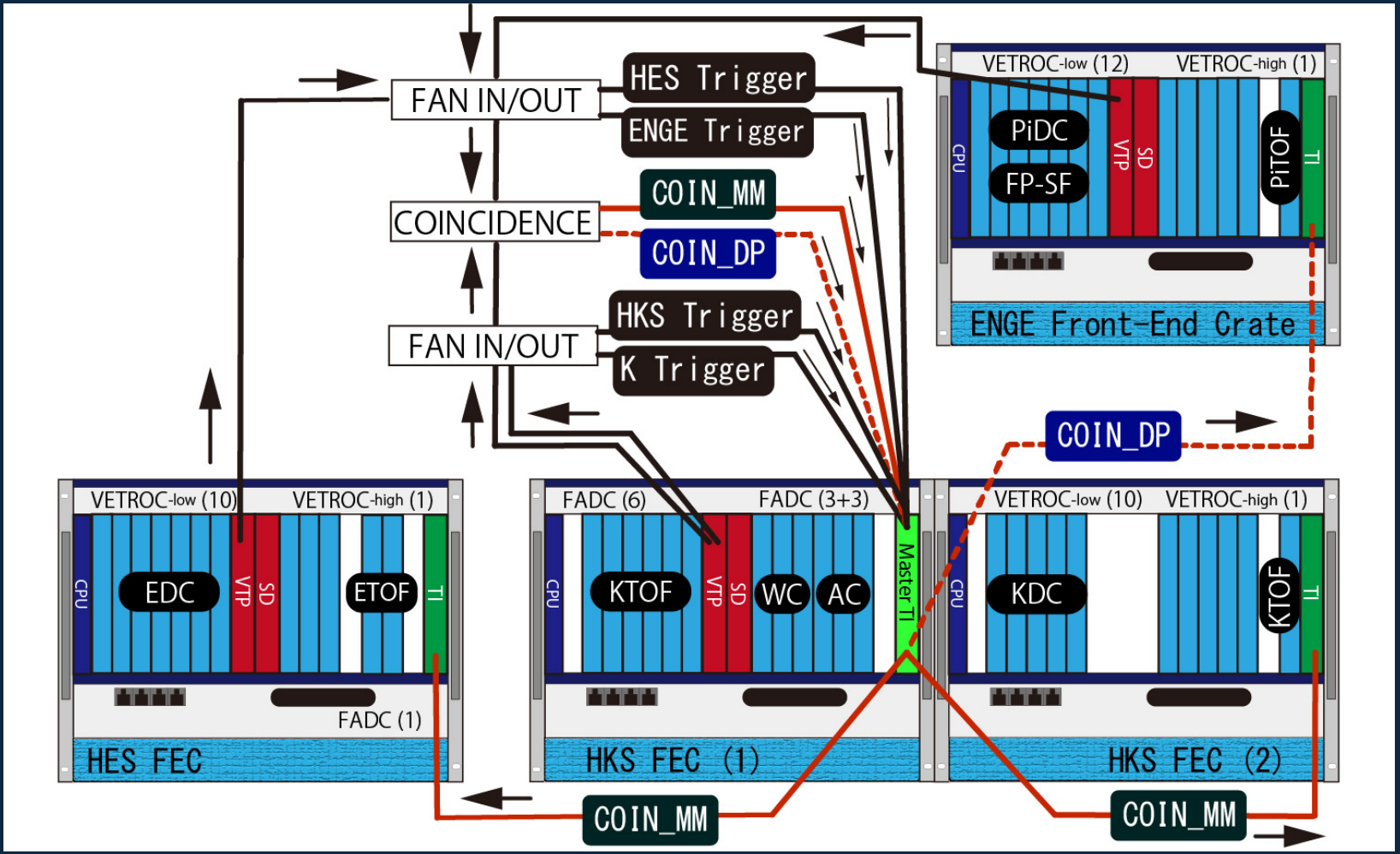
Ken (Feb 13)

Signals go up to SHMS electronics racks





Front-ends for DAQ



- Signals in FADCs are used for each trigger logic
- FPGA logics are implemented in VTP for each trigger
- Master TI distributes the triggers to labor TIs

DAQ: Alexandre (Feb 12)
Analysis software: Sanghwa (Feb 12)

Trigger conditions

Trigger Request:

$$\mathbf{COIN_{MM}} + \mathbf{COIN_{DP}} + (\mathrm{A} \times \mathrm{HKS}) + (\mathrm{B} \times \mathrm{K}) + (\mathrm{C} \times \mathrm{HES}) + (\mathrm{D} \times \mathrm{ENGE})$$

where,

$\mathbf{COIN_{MM}} = \mathrm{HES} \otimes \mathrm{HKS}$

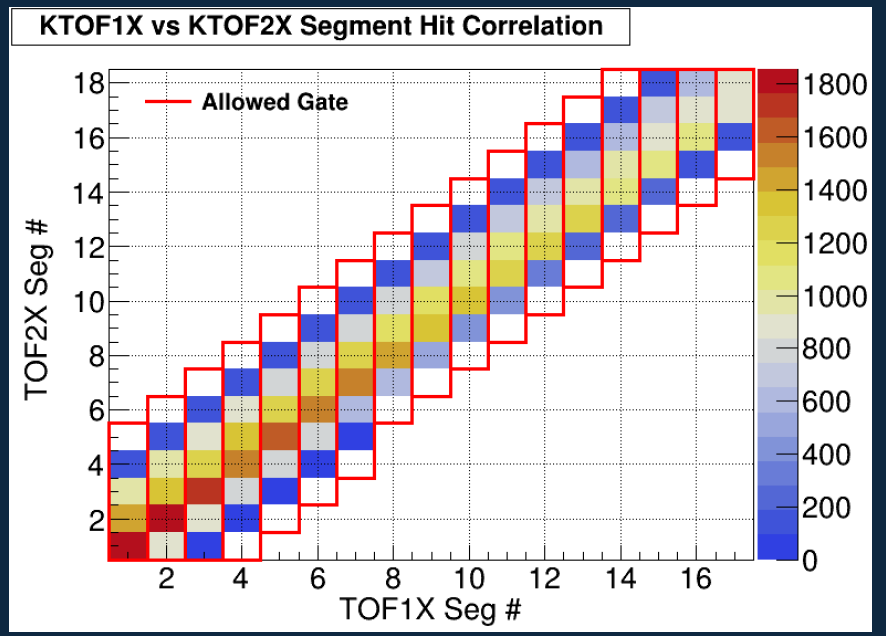
$\mathbf{COIN_{DP}} = \mathrm{ENGE} \otimes \mathrm{K}$ (or only K)

$\mathrm{HES} = \mathrm{HES_{CP}} = \sum_{i=i}^{15} (\mathrm{ETOF1} \otimes \mathrm{ETOF2})_i$

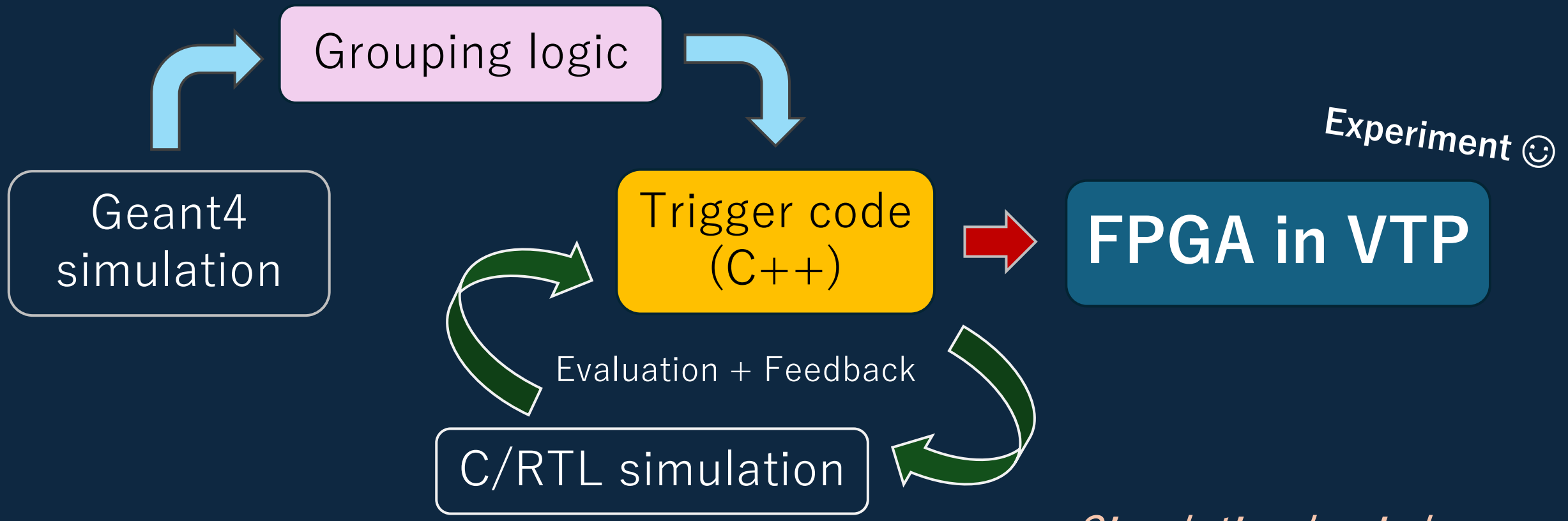
$\mathrm{HKS} = \mathrm{HKS_{CP}} = \sum_{i=1}^{17} (\mathrm{KTOF1X} \otimes \mathrm{KTOF2X})_i$

$\mathrm{K} = \mathrm{HKS_K} = \sum_{i=1}^{17} (\mathrm{KTOF1X} \otimes \mathrm{KTOF2X} \otimes \mathrm{WC} \otimes \overline{\mathrm{AC}})_i$

$\mathrm{ENGE} = \mathrm{ENGE_{CP}} = \mathrm{PiTOF}$



Toward trigger development



Simulation basis has been established

Summary

- **Detector commissioning at ESB (Rav, Ken, Kotaro, Kaito)**
  +Bill, Hanjie, Brad, Ben, Ralph, etc.
  - AC, KDC: done
  - EDC, TOF: being checked
  - WC: new water containers will be delivered to JLab (summer 2026)
- **Radiation in the experimental area (Pavel, Jin)**
  - Geant4 simulation + FULKA → Safety + detector responses
  - Realistic drawings around target is necessary for further study
- **DAQ (Alexsandre, TG)**
  - Trigger: Basis of C/RTL simulation has been established
- **Analysis software (Sanghwa), Target (Meekins, Kei), SLI/Beam (Gaskel), Erea design/Engineering (Jamie), Liaison (Henry (Bill)), + many**

Backup

Publications for hypernuclear experiments at JLab

Hall C

- TG et al., PRC 103, L041301 (2021)
- TG et al., NIMA 900, 69—83 (2018)
- TG et al., PRC 94, 021302(R) (2016)
- TG et al., PRC 93, 034314 (2016)
- Y. Fujii et al., NIMA795, 351—363 (2015)
- L. Tang et al., PRC 90, 034320 (2014)
- S.N. Nakamura et al., PRL 110, 012502 (2013)
- TG et al., NIMA 729, 816—824 (2013)
- L. Yuan et al., PRC 73, 044607 (2006)
- T. Miyoshi et al., PRL 90, 232502 (2003)

Hall A

- K. Okuyama et al, PRC 110, 025205 (2024)
- B. Pandey et al., PRC **105**, L051001 (2022)
- K.N. Suzuki et al., PTEP 2022, 1, 013D01 (2022)
- F. Garibaldi et al., PRC 99, 054309 (2019)
- G. M. Urciuoli et al., PRC 91, 034308 (2015)
- F. Cusanno et al., PRL 103, 202501 (2009)
- G. M. Urciuoli et al., NIMA612, 56—68 (2009)
- M. Iodice et al., PRL 99, 052501 (2007)

Experimental target ➔ D. Meekins

Material	Thickness / (mg/cm^2)	Length in radiation Length	Beam time /hours	Beam current / μA	Remark
CH_2	450	10.1×10^{-3}	144	2	Energy calibration, Raster 2×2 mm^2
^{6}Li	100	1.40×10^{-3}	120	50	E12-24-004, Raster 2×2 mm^2
^{9}Be	100	1.53×10^{-3}	384	50	E12-24-004
^{11}B	100	1.87×10^{-3}	72	50	E12-24-004, B_4C
^{12}C	150	2.34×10^{-3}	168	50	Energy calibration
^{12}C hole	150	2.34×10^{-3}	-	10	Beam position check Raster 2×2 mm^2
^{27}Al	150	6.24×10^{-3}	672	50	E12-24-011
^{40}Ca	150	9.31×10^{-3}	456	50	E12-15-008/E12-24-013
^{48}Ca	150	7.76×10^{-3}	552	50	E12-15-008/E12-24-013
^{208}Pb	150	23.5×10^{-3}	1000	25	E12-20-013/E12-24-003, Raster 2×2 mm^2