HypHI Phase 0 experiment. Hypernuclei spectroscopy at GSI

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Gesellschaft für Schwerionenforschung (GSI)
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XIX International Baldin Seminar on High Energy Physics Problem
"Relativistic Nuclear Physics Quantum Chromodynamics"

Outline

- Hypernuclei
- HypHI project
- Phase 0 of HypHI
  - setup
  - detectors
  - trigger
- Test experiments
- Summary and Outlook

Hypernuclei

Baryon-baryon interactions:

- N-N interactions are well known
- N-Y and Y-Y need to be studied

Ways to study:

- $\tau(Y) \sim 10^{-10}$s $\rightarrow$ no hyperon target
- hyperon beam $\rightarrow$ only high energy hyperon beams are available
- low energy secondary produced hyperons $\rightarrow$ poor beam profile

It is possible to bound a hyperon inside a nucleus

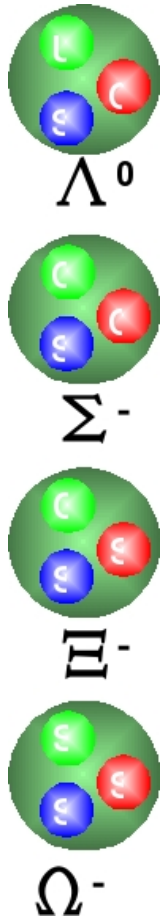
Hypernuclei

Hypernuclei: nuclei with strange quark

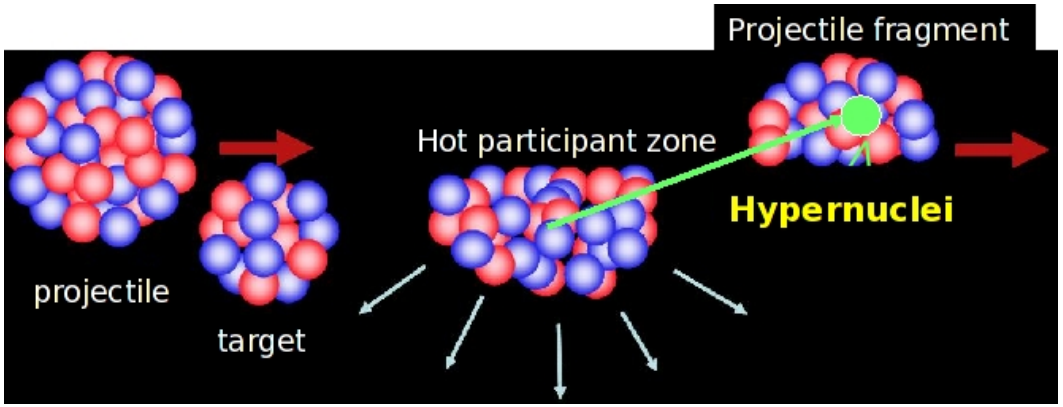
- nuclear bound system with hyperon
- a "laboratory" to study baryon-baryon interaction

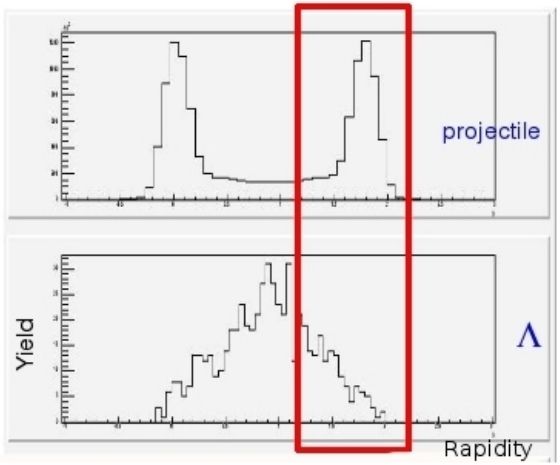
How to produce hypernuclei?

- meson interactions: (π^+, K^+), (K^-, π^-)
  - hypernuclei only near the β-stability line
  - hypernuclei cannot be separated from the target
  - missing mass spectroscopy
- heavy ion collision



Production mechanism





Large Lorentz factor $\gamma = 3$ @ 1.9 A GeV

Effective lifetime is longer by the Lorentz factor

$200\text{ps} \rightarrow 600\text{ps}$ with $\gamma = 3$

Experiment at JINR (Dubna):

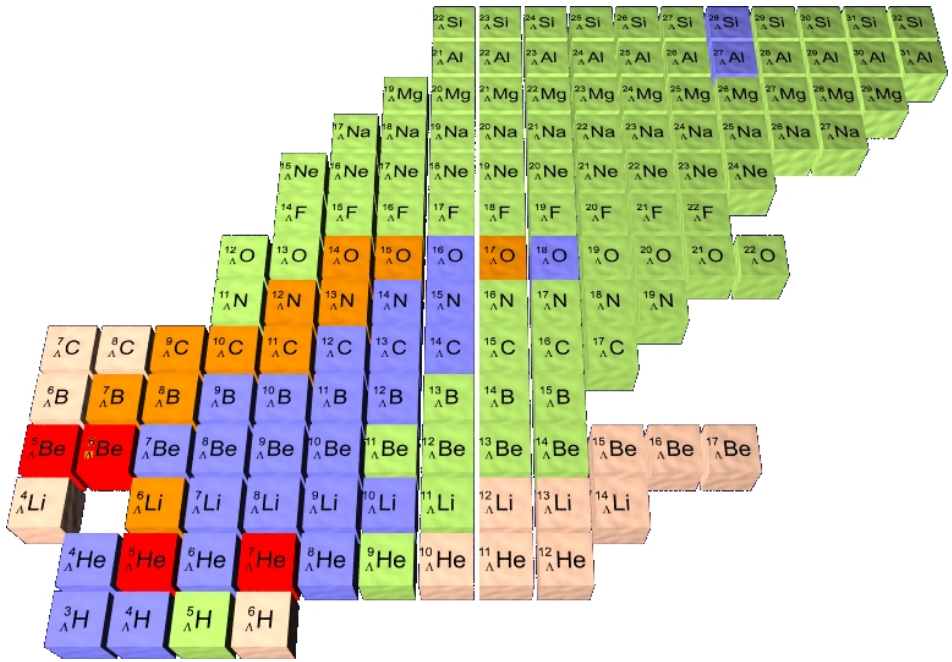
^{4}He, ^{7}Li + polyethylene

$^3_\Lambda$H, $^4_\Lambda$H $\sim 0.2\mu$b

HypHI project

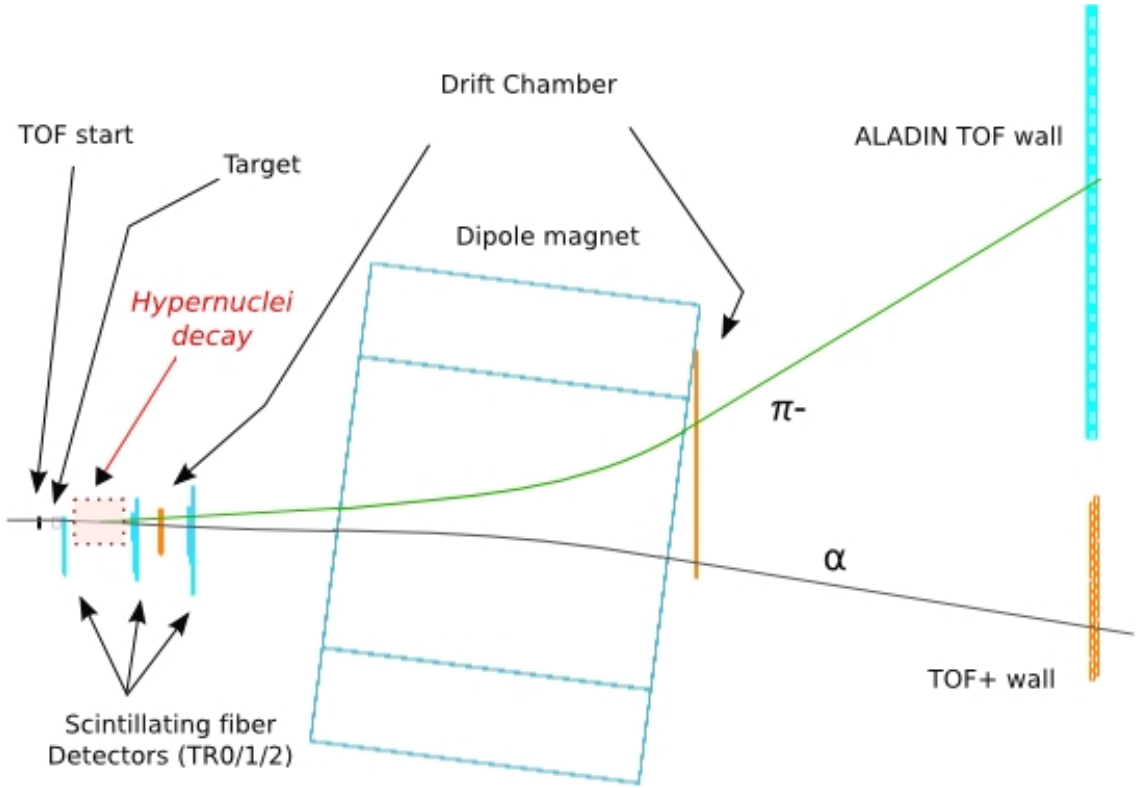
Hypernuclear spectroscopy with stable heavy ion beams and rare isotope beams:

- neutron/proton rich hypernuclei
  - stability of nuclear matter with hyperons
  - Hyperon - Nucleon interaction in neutron rich environment
  - $\Lambda - \Sigma$ coupling at different isospin
- measurement hypernuclear magnetic moment
  - the most sensitive prove of hyperon wave function in the nuclear matter



Phase 0 of the HypHI project

Perform precise hypernuclei spectroscopy with heavy ion collision



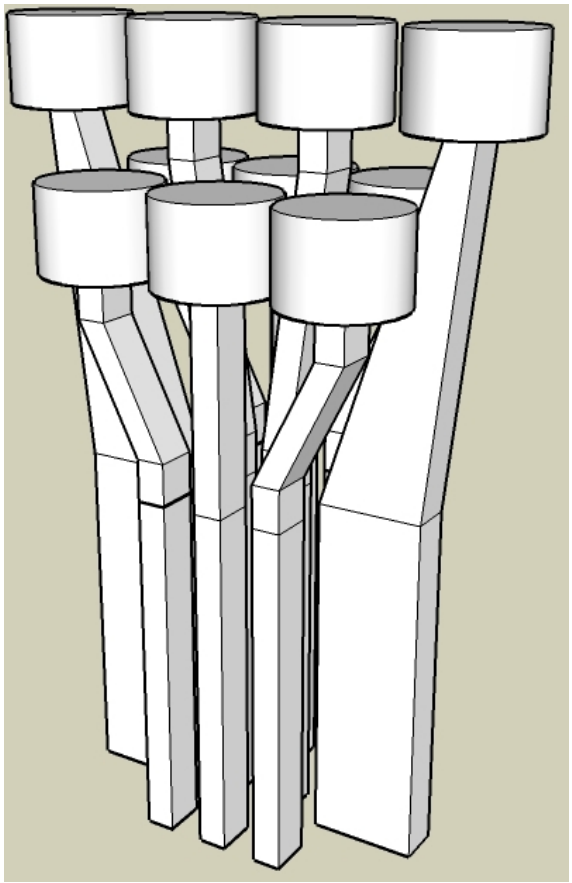
^{6}Li (2 A GeV) + ^{12}C

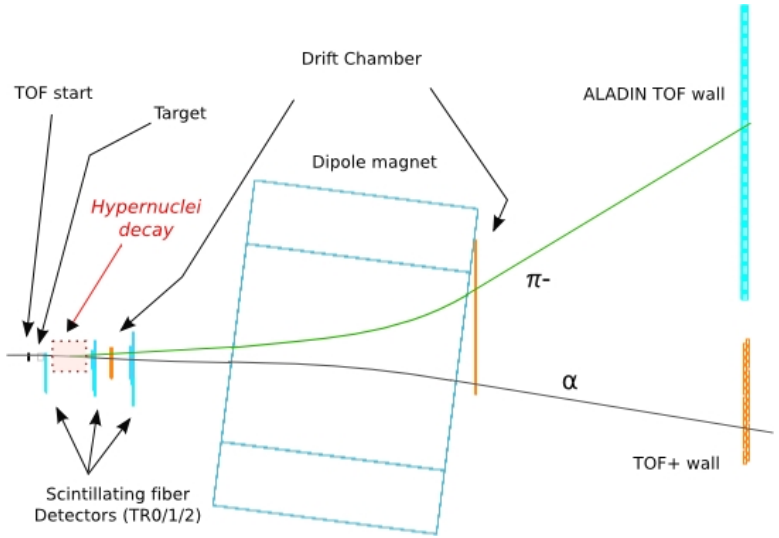
$^{3}_{\Lambda}$H $\rightarrow ^{3}$He+π^-

$^{4}_{\Lambda}$H $\rightarrow ^{4}$He+π^-

$^{5}_{\Lambda}$He $\rightarrow ^{4}$He+p+π^-

Start counter



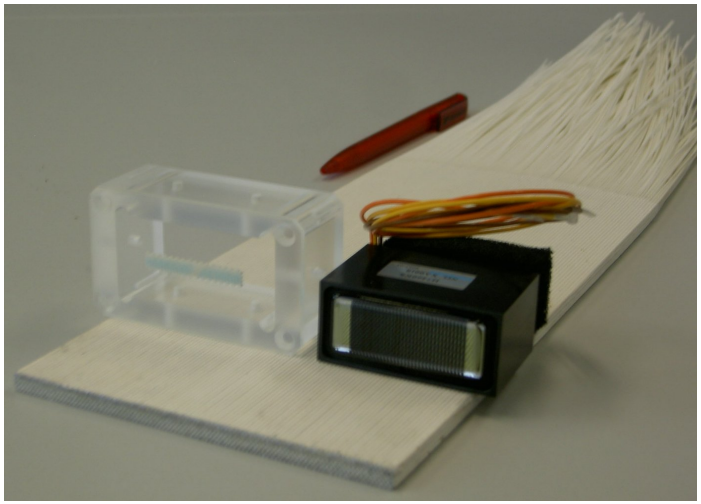


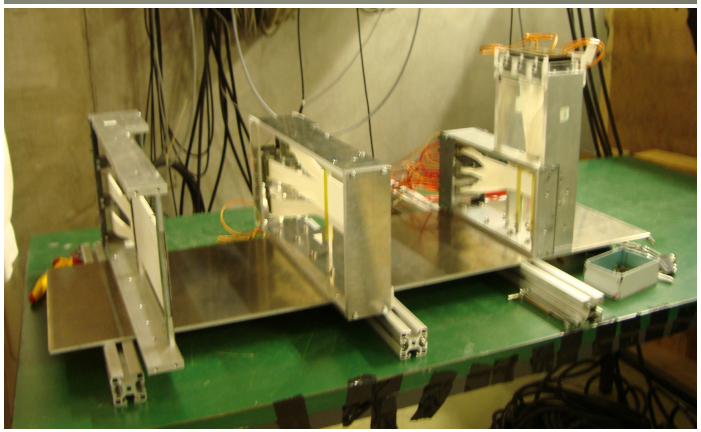
- scintillating hodoscope
- size: $53 \times 50\text{mm}^2$
- Bicron BC-420
- Hamamatsu R7400U-06 PMT's
- time resolution $\sigma \sim 200\text{ps}$
- energy resolution $\sim 30\%$ for ^{6}Li

Scintillating fibers detectors (SciFi)

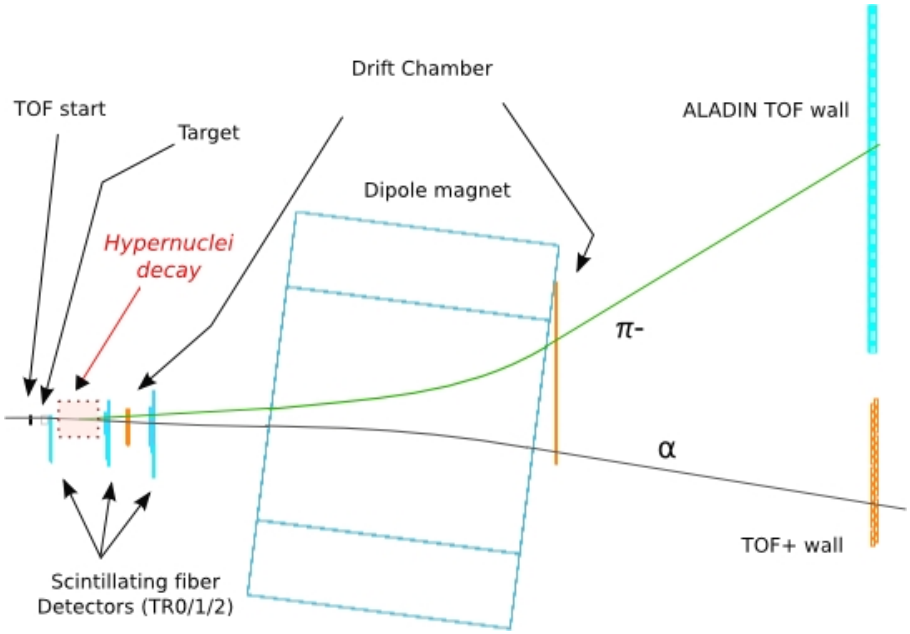
- outer diameter 0.83 mm
- active core 0.73 mm
- decay constant 2.8 ns
- time readout by VUPROM with granularity 2.5ns
- position resolution $\sigma < 0.4$mm

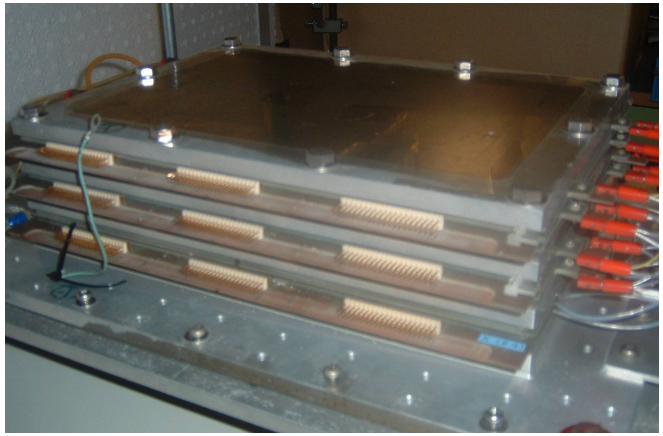
32-channels multi-anode Hamamatsu photomultiplier H7260

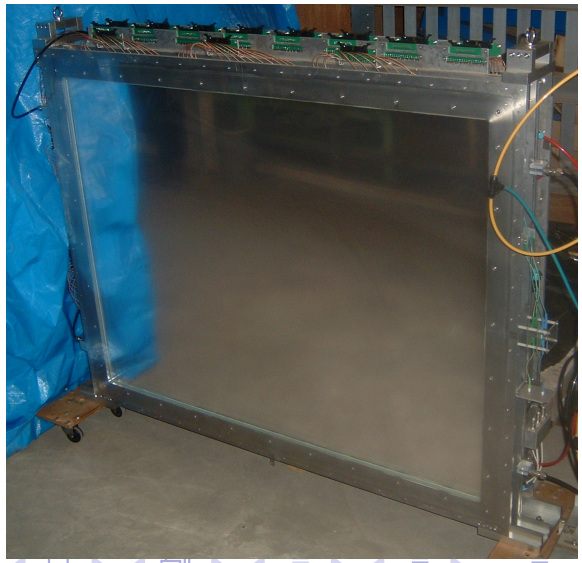




Drift chambers from KEK

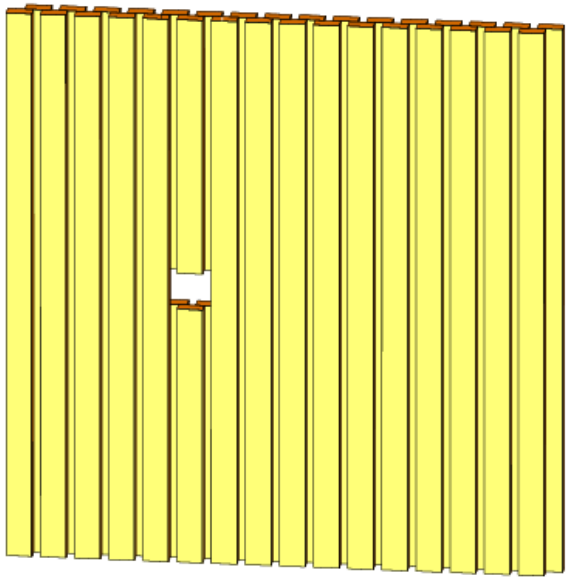


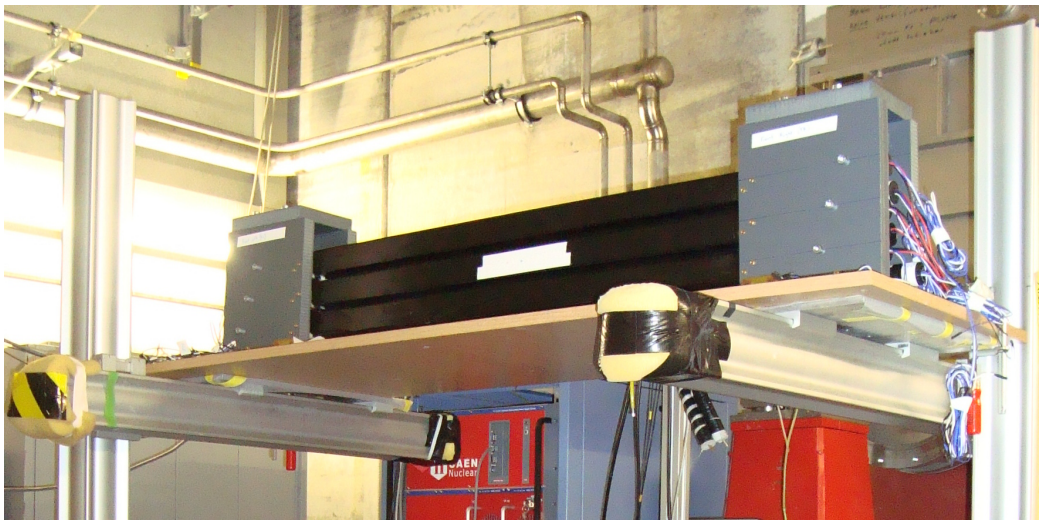




- in front of the magnet
  - size: 24×15 cm^2
  - position resolution $\sigma = 0.3$mm
- behind the magnet
  - size: 120×90 cm^2
  - position resolution $\sigma = 0.3(0.4)$mm

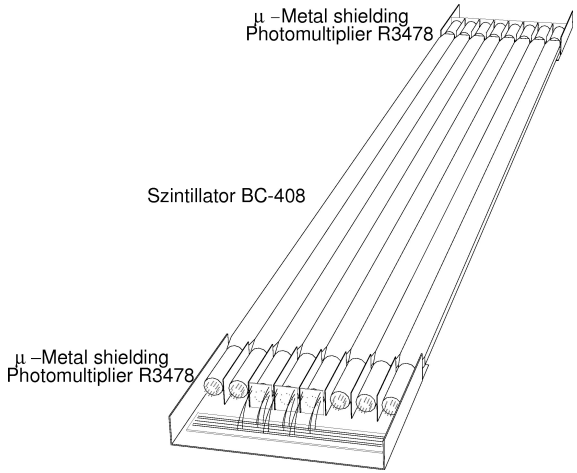
TOF+ wall

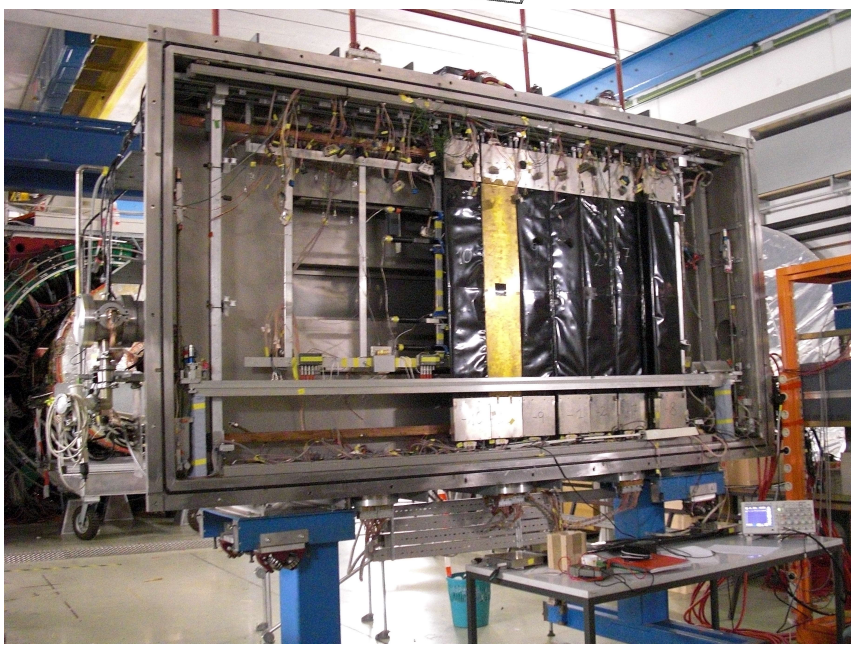




- Bicron BC-408 plastic scintillator: $4.5 \times 2.5 \times 100\text{cm}^3$
- overlap is 1.5 cm
- Hamamatsu H7415 PMT
- size is $97.5 \times 100\text{cm}^2$
- centered hole $7.5 \times 6.5\text{cm}^2$
- time resolution: ~ 350ps (FWHM)
- energy resolution $\sim 18\%$ (FWHM) for MIP

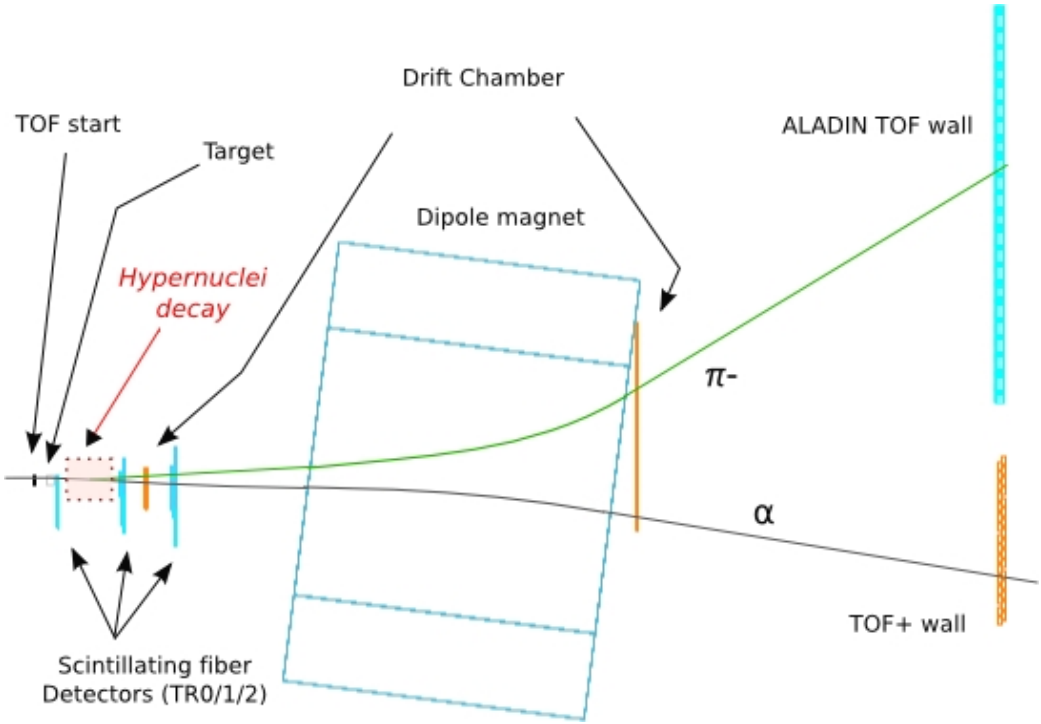
ALADiN Time-Of-Flight wall





- Bicron BC-408 plastic scintillator: $2.5 \times 1 \times 110\text{cm}^3$
- Hamamatsu R3478 PMT
- size $240 \times 110\text{cm}^2$
- for π^- detection
- time resolution $\sigma \sim 200\text{ps}$

Trigger system



^{6}Li (2 A GeV) + ^{12}C

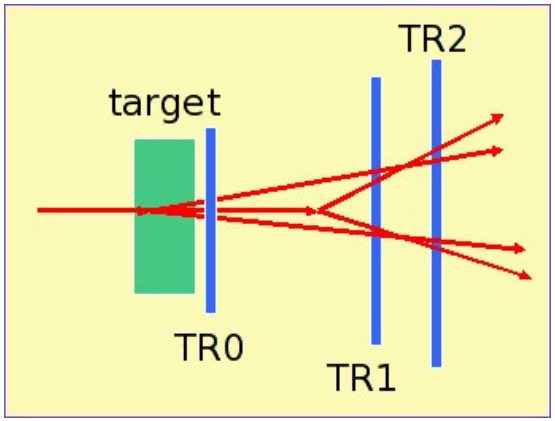
$^{3}_{\Lambda}$H $\rightarrow ^{3}$He$+\pi^{-}$
$^{4}_{\Lambda}$H $\rightarrow ^{4}$He$+\pi^{-}$

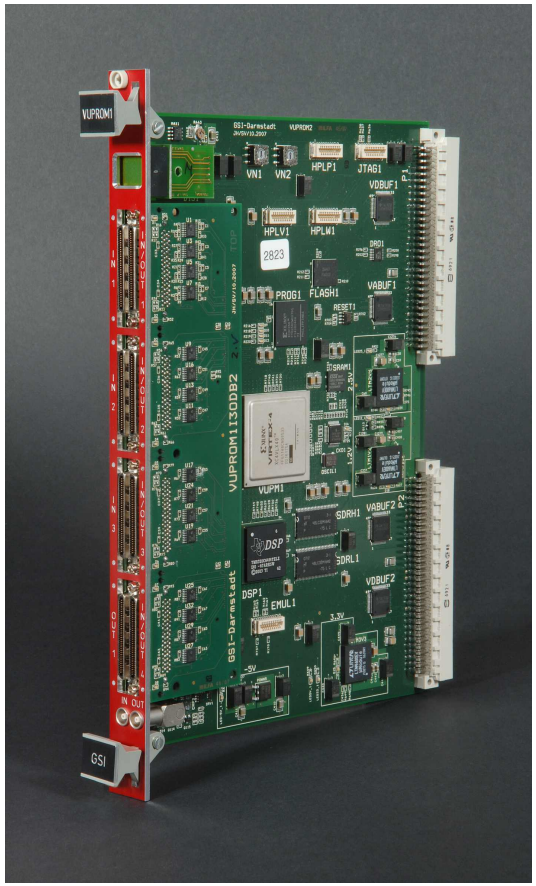
$^{5}_{\Lambda}$He $\rightarrow ^{4}$He$+$p$+\pi^{-}$

$\sigma_{hyp} \sim 0.1\mu$b
$\sigma_{tot} \sim 1$b

- tracking trigger: fibers + new logic modules VUPROM
- TOF+ trigger: $(Z = 1, 2)$
- π^{-} trigger (ALADiN TOF wall)

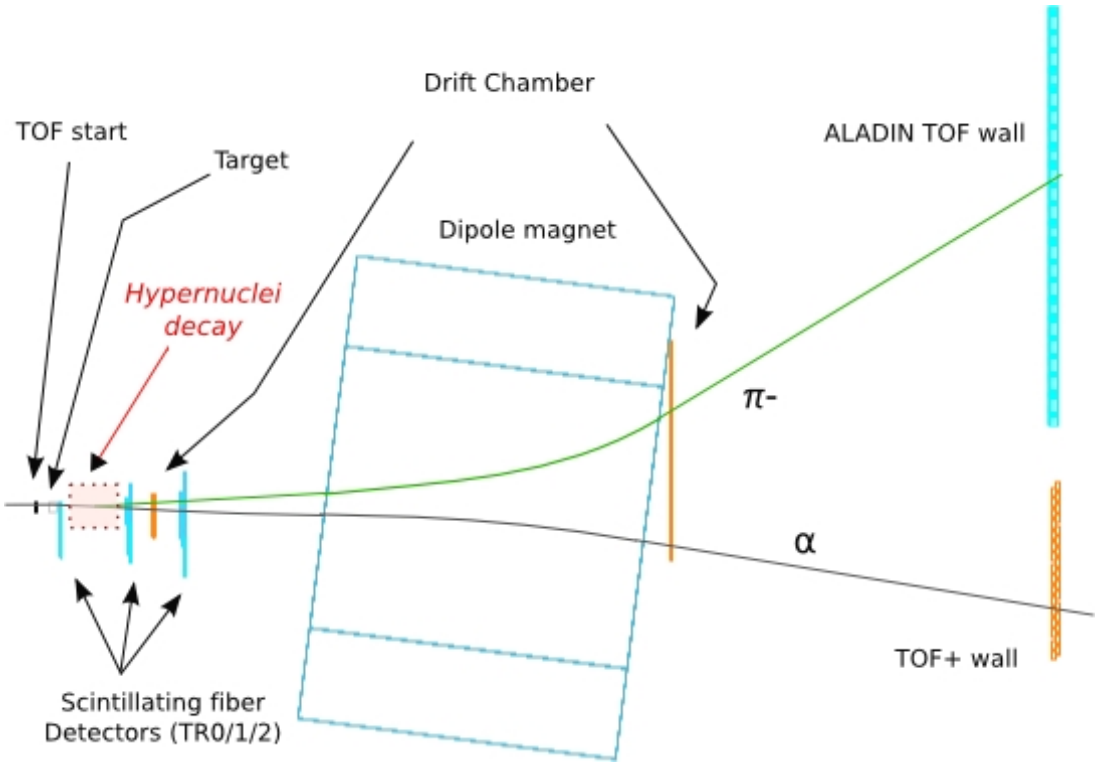
Tracking trigger with secondary vertex





- 256 channels I/O
- Fast logic calculations with a large FPGA at 400 MHz
- Slow complicated calculations by DSP at 1 GHz
- 80 modules are already produced

Trigger efficiency for ${}^{4}_{\Lambda}\mathrm{H} \rightarrow {}^{4}\mathrm{He}+\pi^{-}$



Detection efficiency:

- tracking trigger: 14%
- π^{-} trigger: 28%
- TOF+ trigger: 94%

Total trigger efficiency: 7% with background reduction down to 0.017%

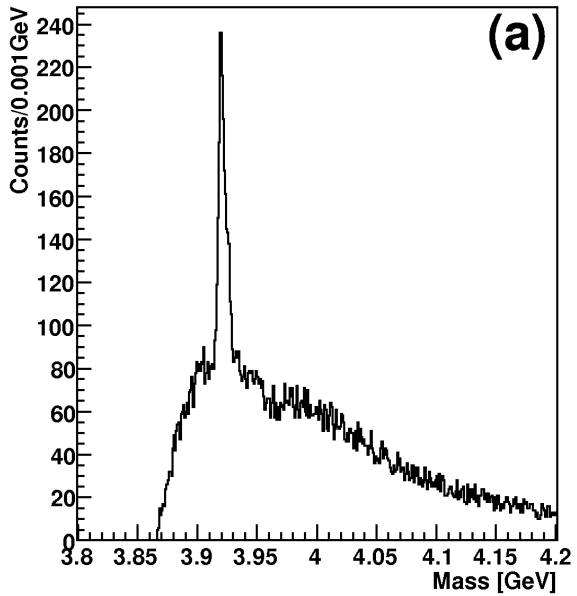
Estimates for Phase 0

- Beam: ^{6}Li, 10^{7}/s, 2 A GeV
- Target: ^{12}C, 8 g/cm^{2}
- Trigger rate: 340 Hz
- Experiment: mid of 2009

What can be measured:

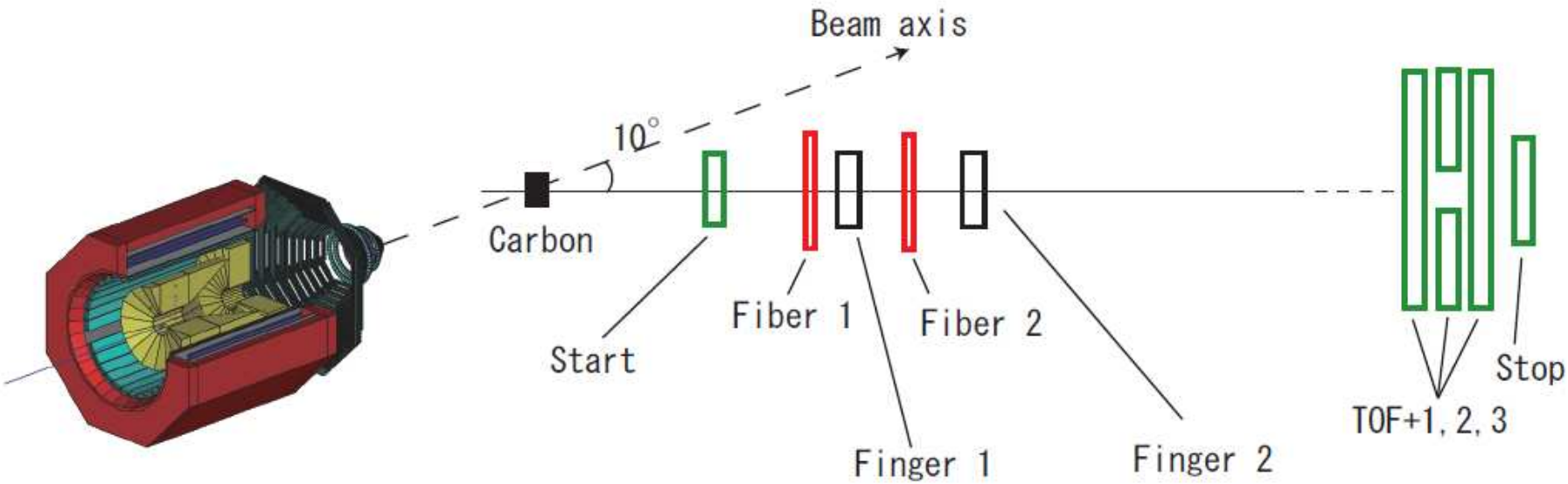
- Cross section
- Lifetime

$^{4}_{\Lambda}$He



	Expected cross section, μb	Reconstructed events/week
$^{3}_{\Lambda}$H	0.1	2.8×10^{3}
$^{4}_{\Lambda}$H	0.1	2.6×10^{3}
$^{3}_{\Lambda}$He	0.5	6.3×10^{3}

Beam test experiment 2007



beams

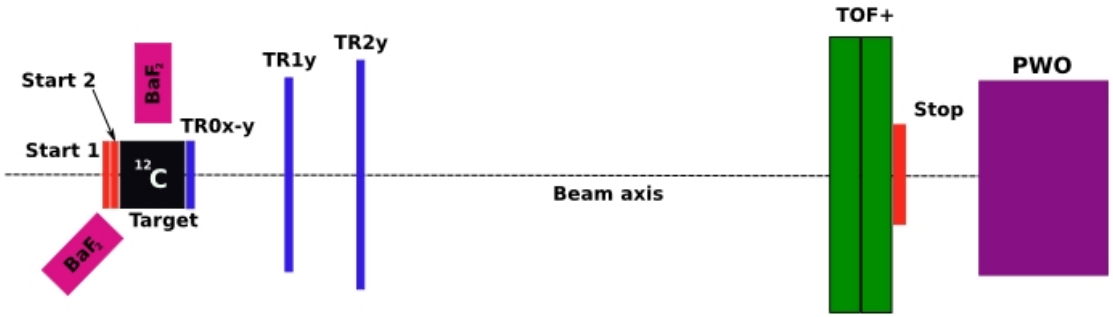
- ^{12}C at 0.850 A GeV
- ^{58}Ni at 1.9 A GeV

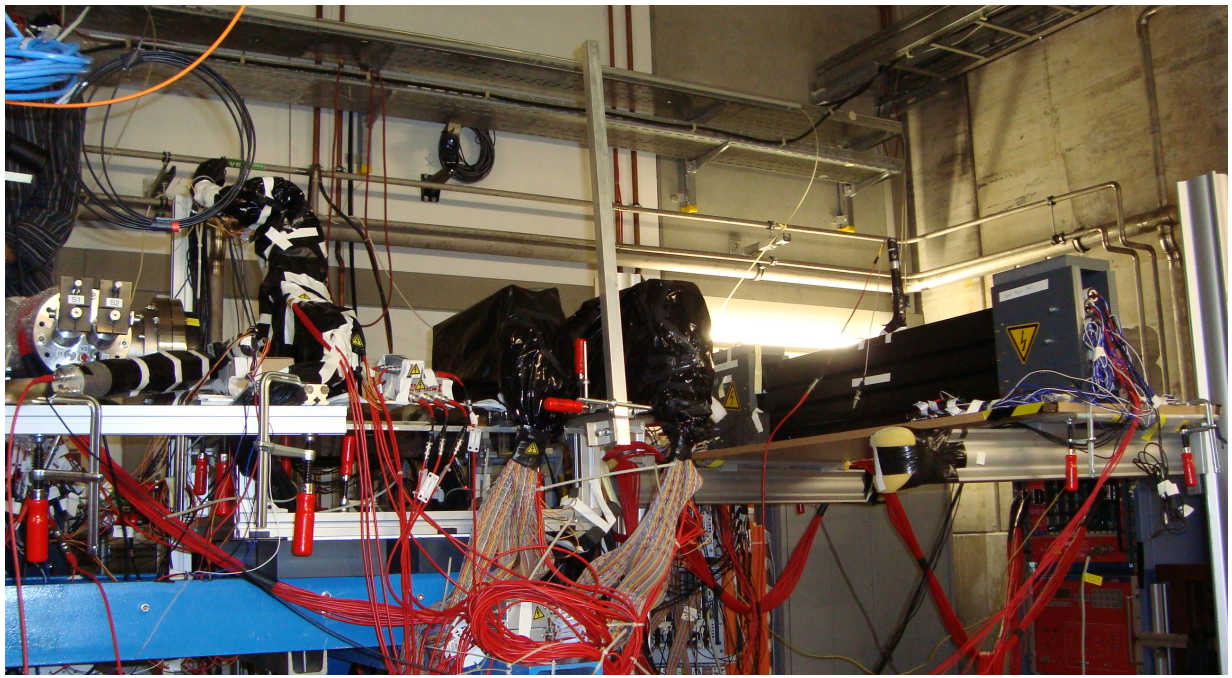
products

- $Z = 1$: p, d, π
- $Z = 2$: ^{3}He, ^{4}He
- $Z = 3$: ^{6}Li, ^{7}Li

Beam test experiment 2008: ^{6}Li (2 A GeV) + ^{12}C

Main goal: commissioning of the trigger





Data analysis is in progress

Summary and Outlook

- Hypernuclear physics
  - information of baryon-baryon interaction
- The Phase 0 experinent
  - middle 2009
  - precise spectroscopy of light hypernuclei
- The future of HypHI project
  - Phase 1 at GSI: proton rich hypernuclei
  - Phase 2 in R3B/NUSTAR at FAIR: neutron rich hypernuclei
  - Phase 3 at FAIR: hypernuclear magnetic moment

The HypHI Collaboration

- GSI Helmholz-University Young Investigators Group

  VH-NG-239

  - Group leader, HypHI Spokesperson
    - *Take R. Saito (Mainz University, GSI)*
  - Staff physicist
    - *Shizu Minami (GSI)*
  - Postdocs
    - *Sébastien Bianchin (GSI)*
    - *Banu Özel (GSI)*
  - PhD Students
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  - *M. Kavatsyuk*
- GSI HP2 and Mainz University
  - *F. Mass*
- GSI
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- Osaka University
  - *S. Ajimura, A. Sakaguchi*
- Osaka Elektro-Communication University
  - *T. Fukuda, Y. Mizoi*
- Tohoku University
  - *T. Koike, H. Tamura*
- Theoretical support
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