The secondary target for the hypernuclear experiment

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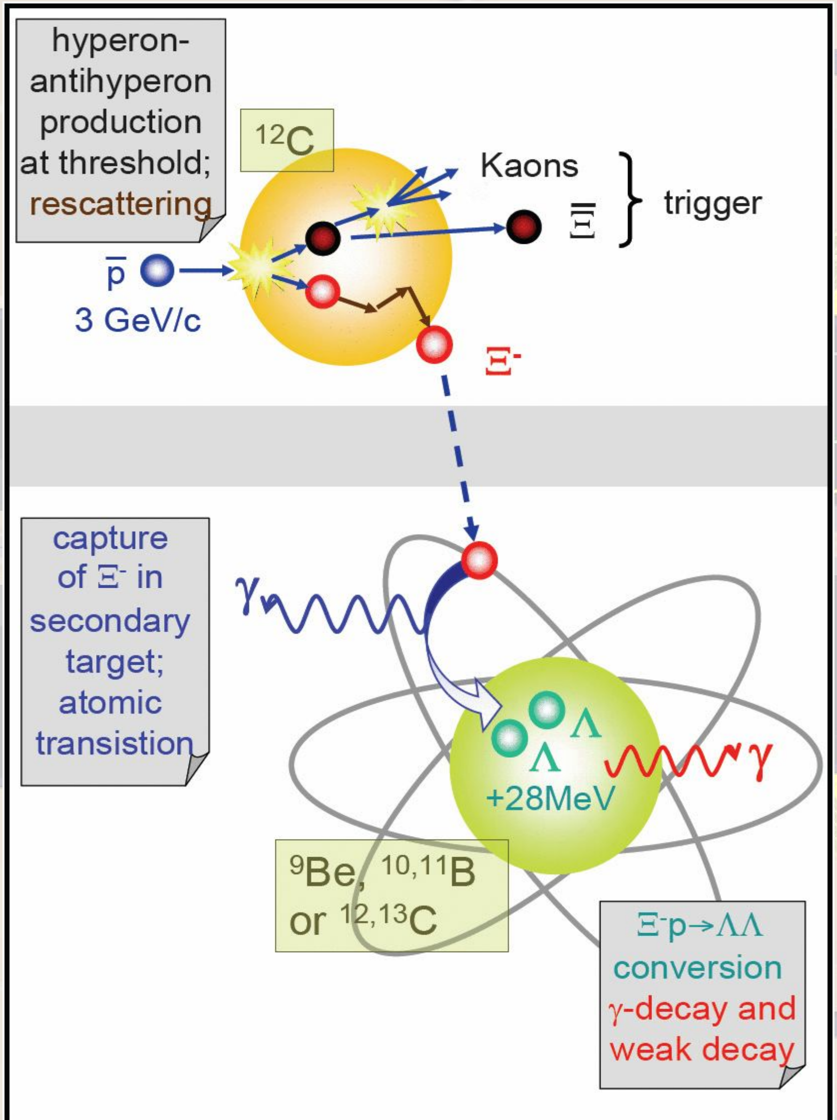
Motivation



Production and detection of Λ-Λ-hypernuclei at $\overline{\text{P}}$ANDA

Primary target (C-12):

- formation of Ξ^--particles in $\bar{p}$ + ^{12}C – reactions

Secondary target (Be, B, C):

- deceleration of Ξ^--particles
- integration in the atomic shell of absorber atoms
- capture of Ξ^- by nucleus
- formation of Λ-Λ-hypernuclei by conversion: $\Xi^- p \rightarrow \Lambda\Lambda$
- detection of weak decay products

Ge detector array:

- γ-spectroscopy of Λ-Λ-hypernuclei with Ge detectors

→ *Talk of Marcell Steinen*

Design of the secondary target

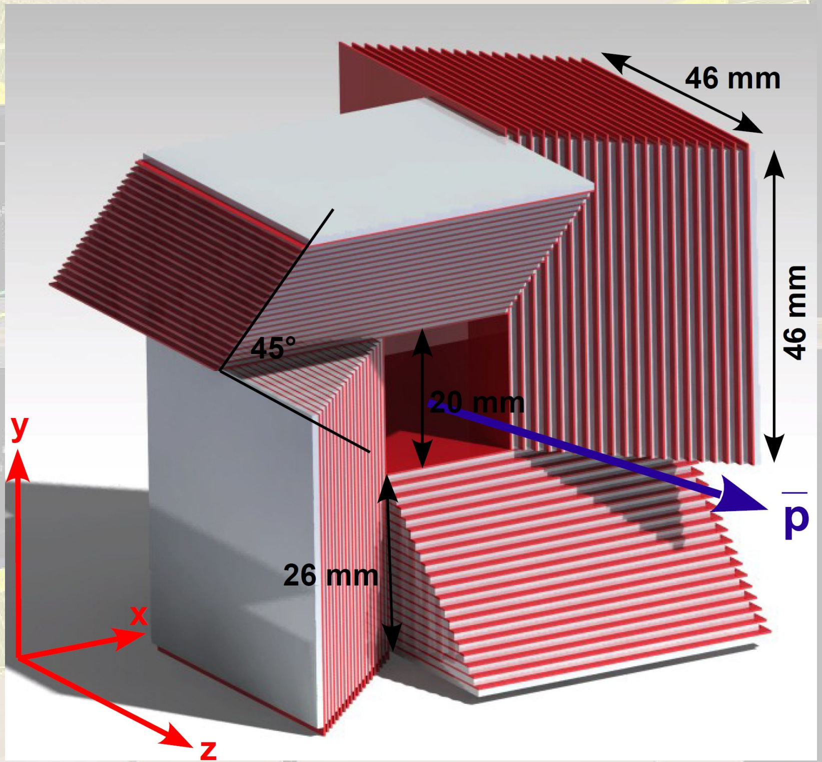
Requirements for the secondary target

- adjusted to stop time and life time of Ξ^- (τ = 0.164 ns) as well as geometry

  ⇒ compact structure without gaps (t_{stop} ≈ 0.06 ns)

- tracking of Ξ^- and the decay products of Λ-Λ-hypernuclei

  ⇒ alternating layers of Si strip detectors and absorber material



red:

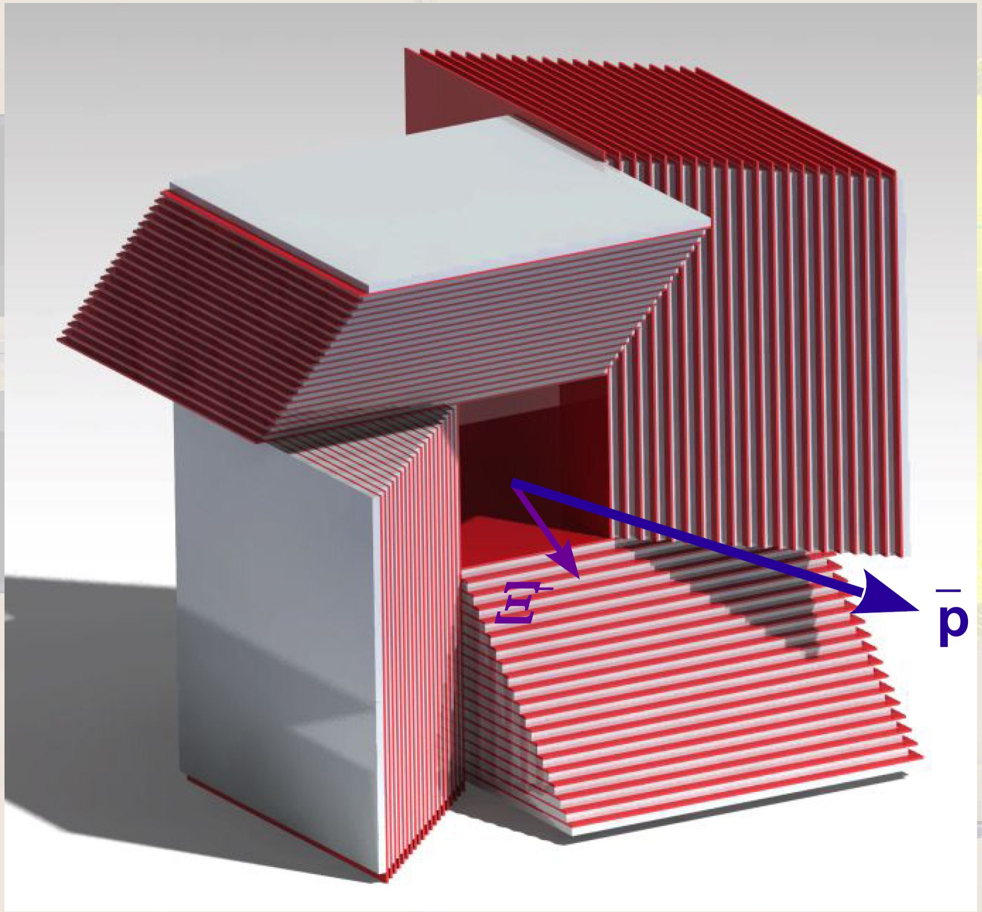
20 layers of double sided silicon strip detectors (thickness 300 µm) in each block

gray:

20 layers of absorbers (thickness 1 mm) different for each block (^{9}Be, ^{10,11}B or ^{12,13}C)

Design of the secondary target

Stopping of Ξ^- in absorber layers:



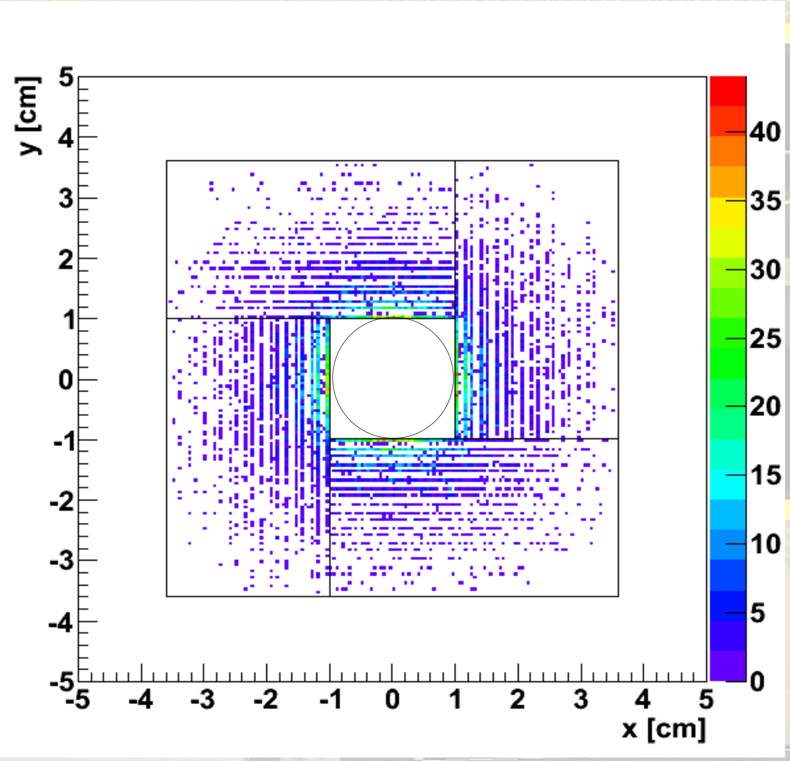
First information to detect a double Λ hypernucleus:

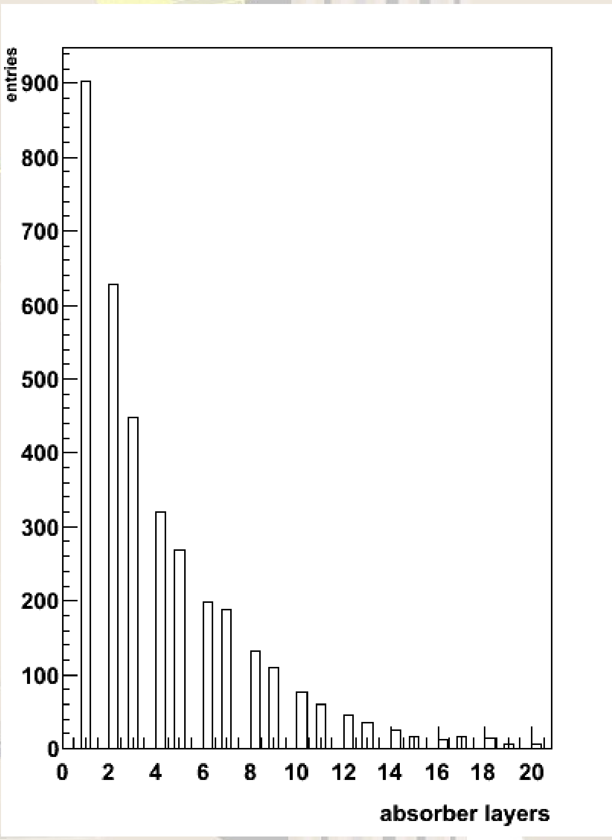
- Energy loss measurement of Ξ^- in DSSD
- First layer DSSD because of early stopping

Simulations

Simulation results after generation (box generator) of 200,000 Ξ^- -particles with momentum range 100 MeV/c to 500 MeV/c (including beampipe)

Stopped Ξ^- (≈ 7%) in beryllium absorbers of 20 x 1.0 mm thickness

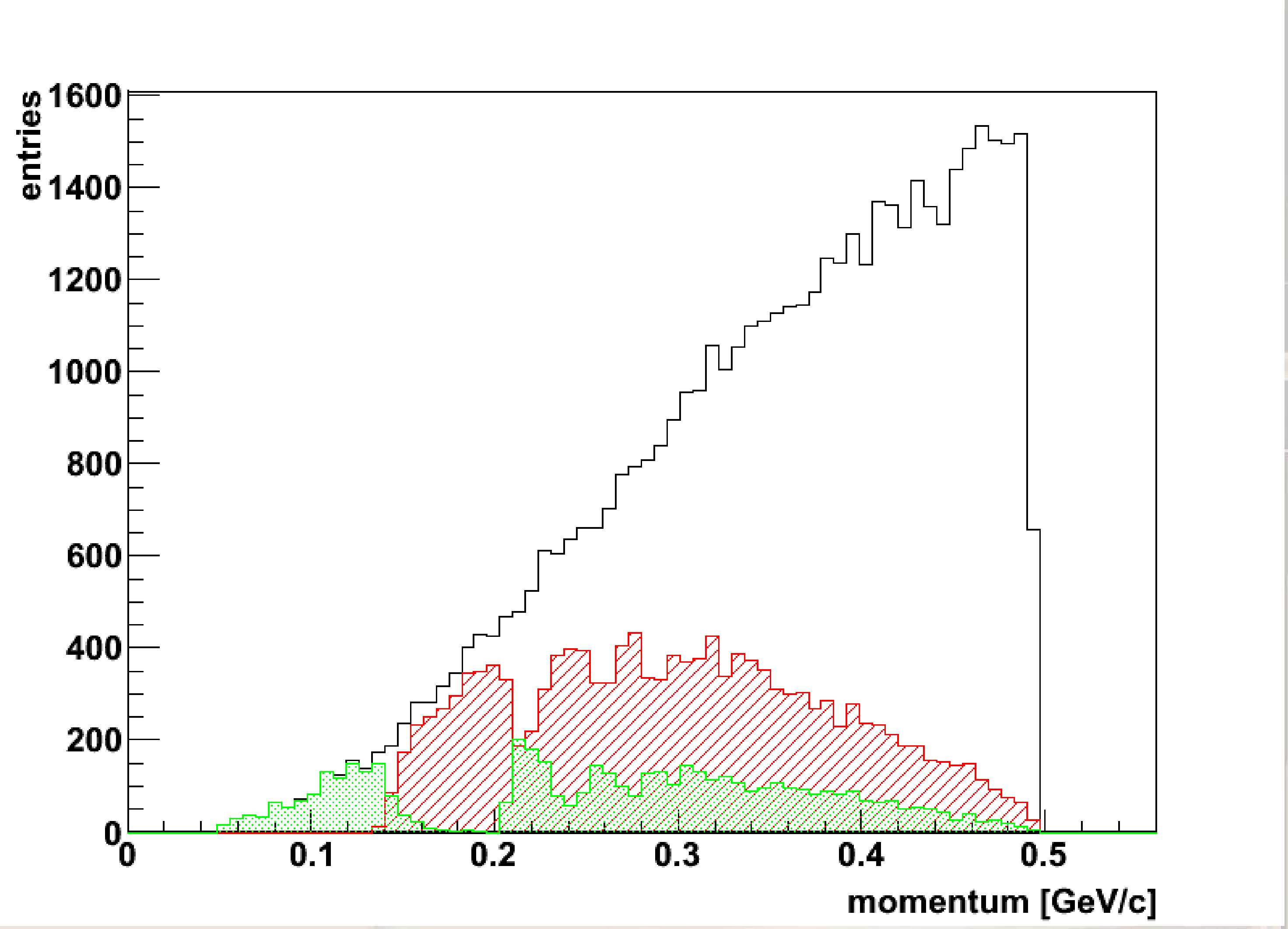




> 90% stopped Ξ^- in inner 10 layers
⇒ number of absorbers must be optimized

Simulations

Simulation results after generation of 200,000 Ξ^- -particles with momentum range 100 MeV/c to 500 MeV/c



Momenta at the entrance of the secondary target

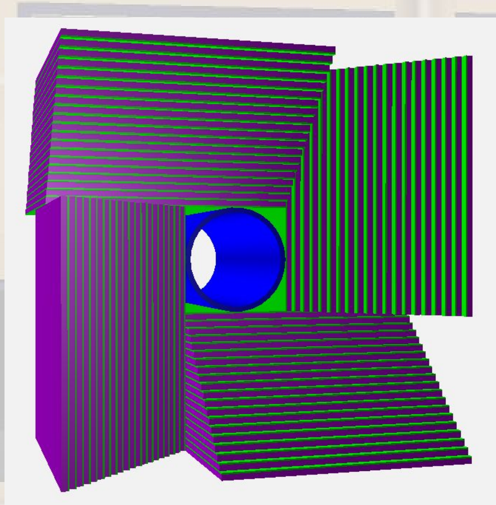
black curve:
all Ξ^- entering the secondary target

red curve:
Ξ^- stopped in absorber layers

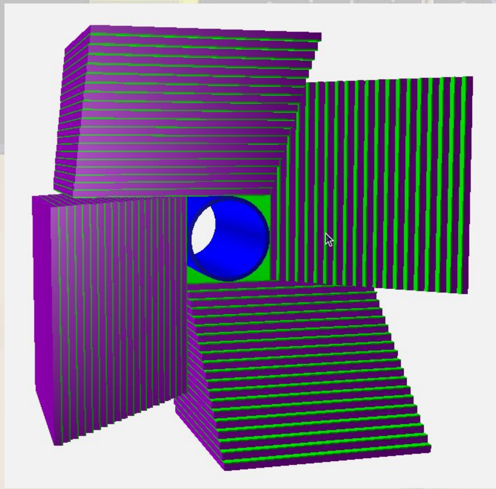
green curve:
Ξ^- stopped in silicon strip detectors

Simulations

Secondary target built by the root geometry package

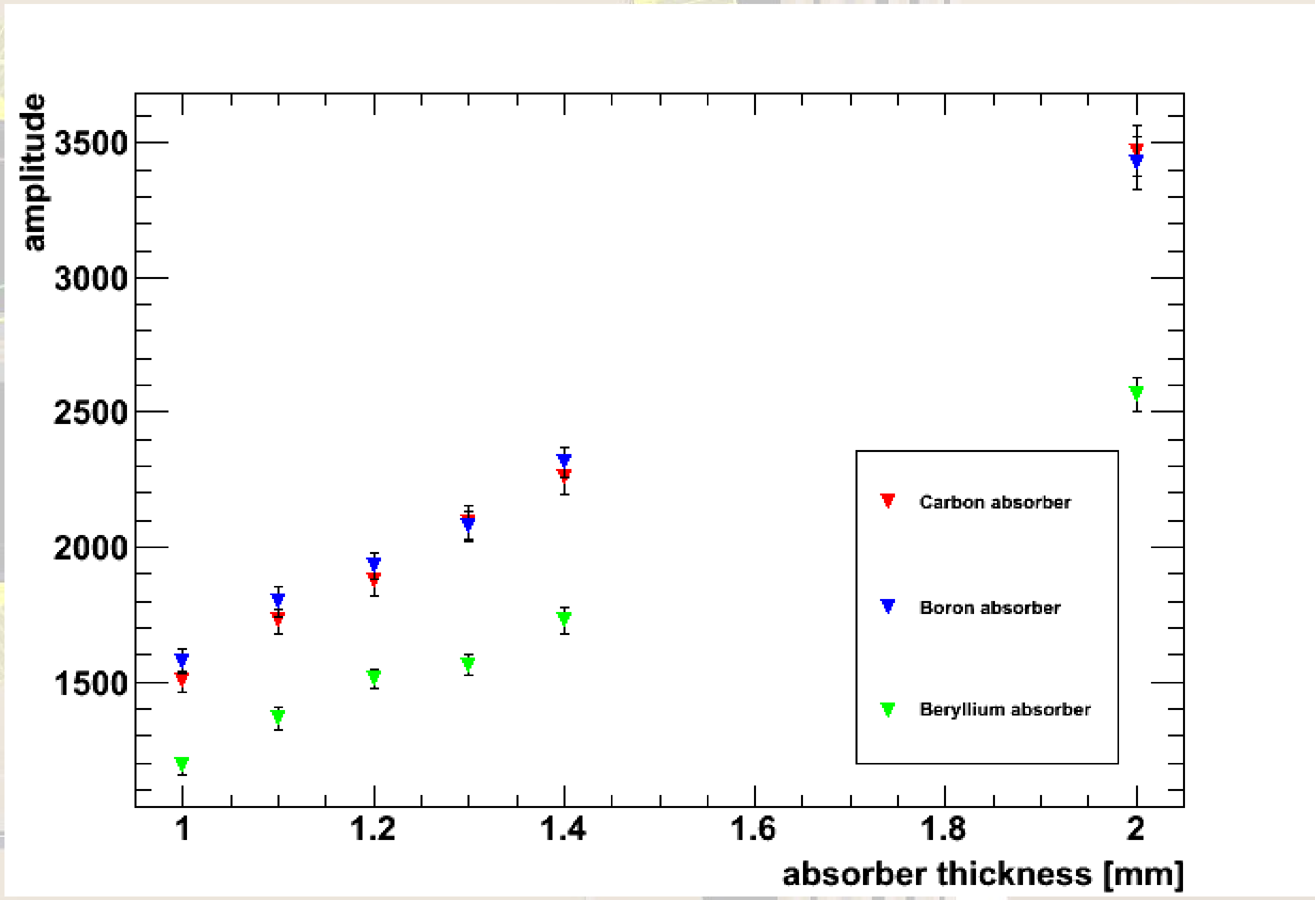


Absorber thickness 1.0 mm



Absorber thickness 1.4 mm

Variation of absorber material and thickness



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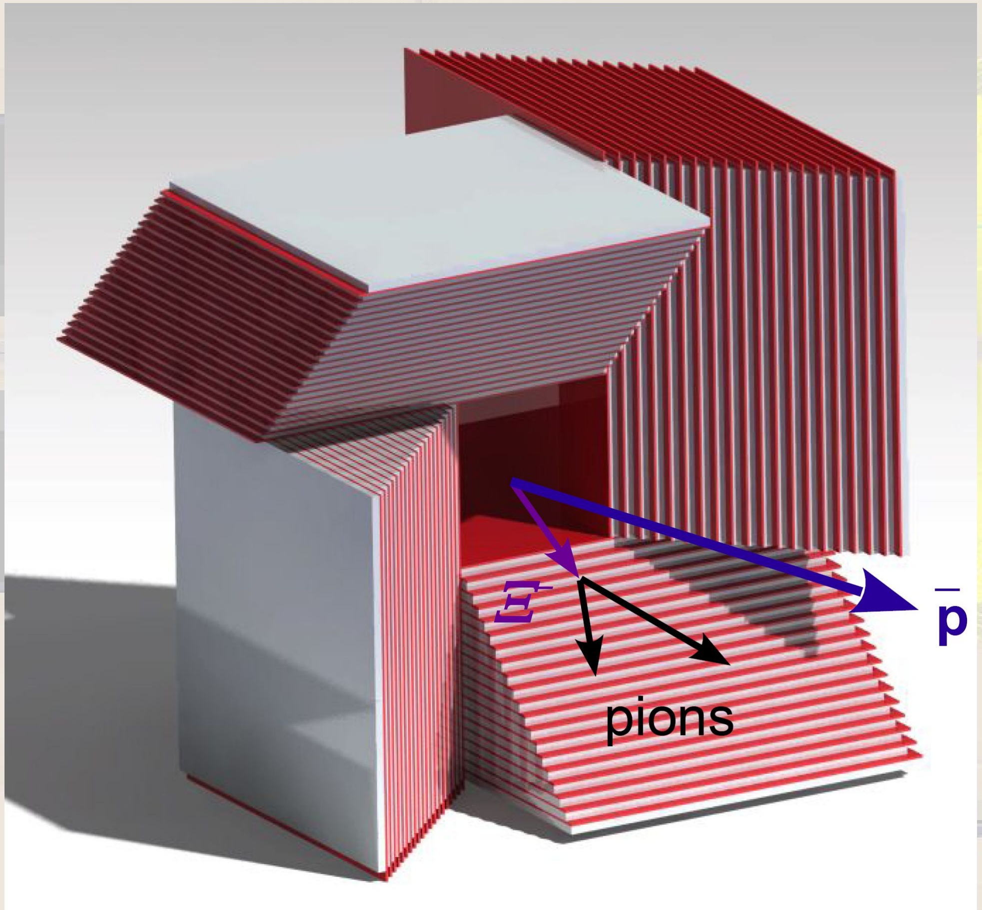
Design of the secondary target

Weak decay of double Λ hypernuclei:



Second information to detect a double Λ hypernucleus:

reconstruction of the secondary vertex

For low momentum pions (80-120 MeV/c) material budget too high

- huge energy loss
- multiscattering effects

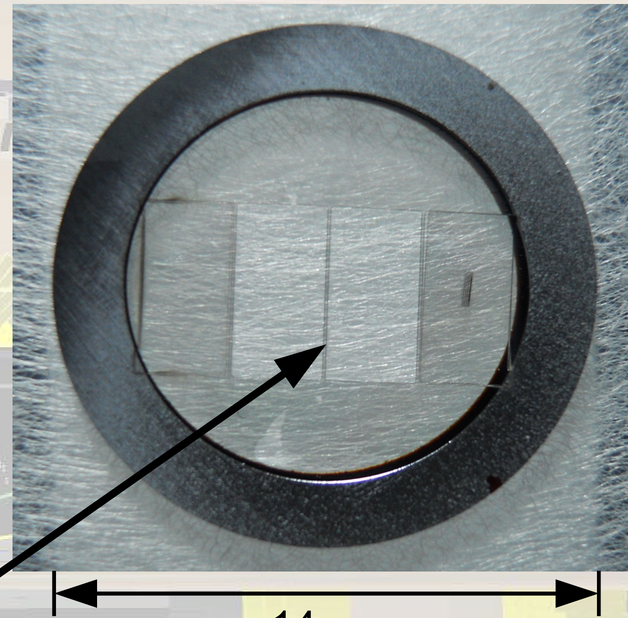
⇒ no sufficient momentum resolution

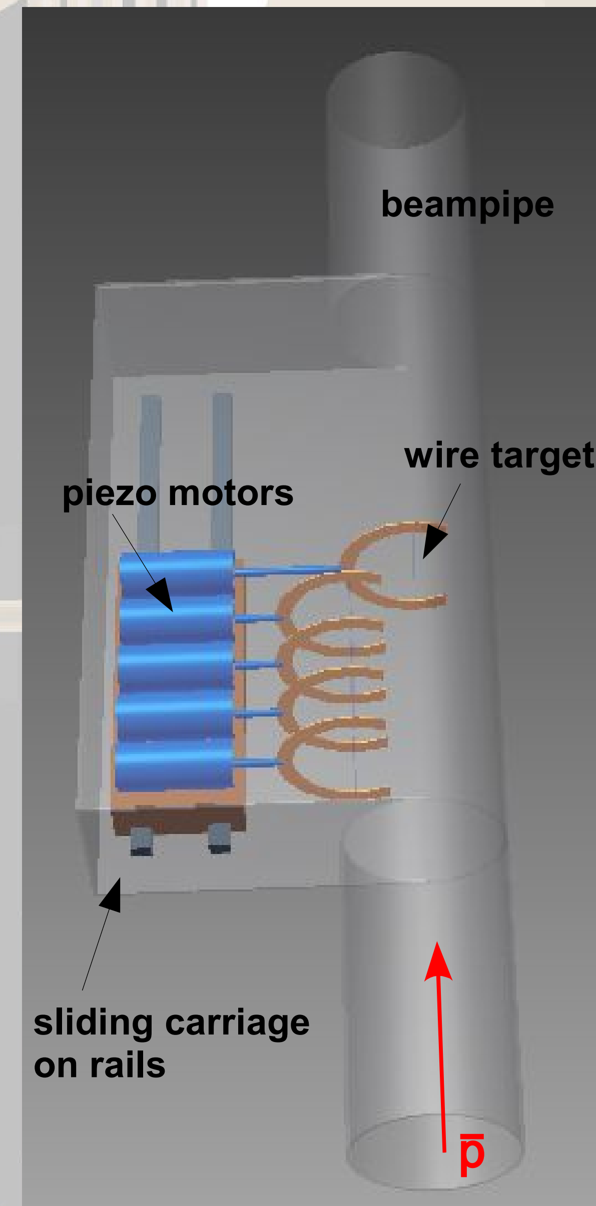
Primary target

Task of the primary target:
production of slow Ξ^-

Requirements:
- minimal hadronic background in backward direction
- constant luminosity of $\bar{p}$-beam
  $\Rightarrow$ beam losses, mainly due to coulomb scattering, must be kept low

$\Rightarrow$ ^{12}C micro-wire target with thickness 3 μm, width 100 μm





Insertion to the beam:
- controlling interaction rates by moving target into beam halo
- easy replacement

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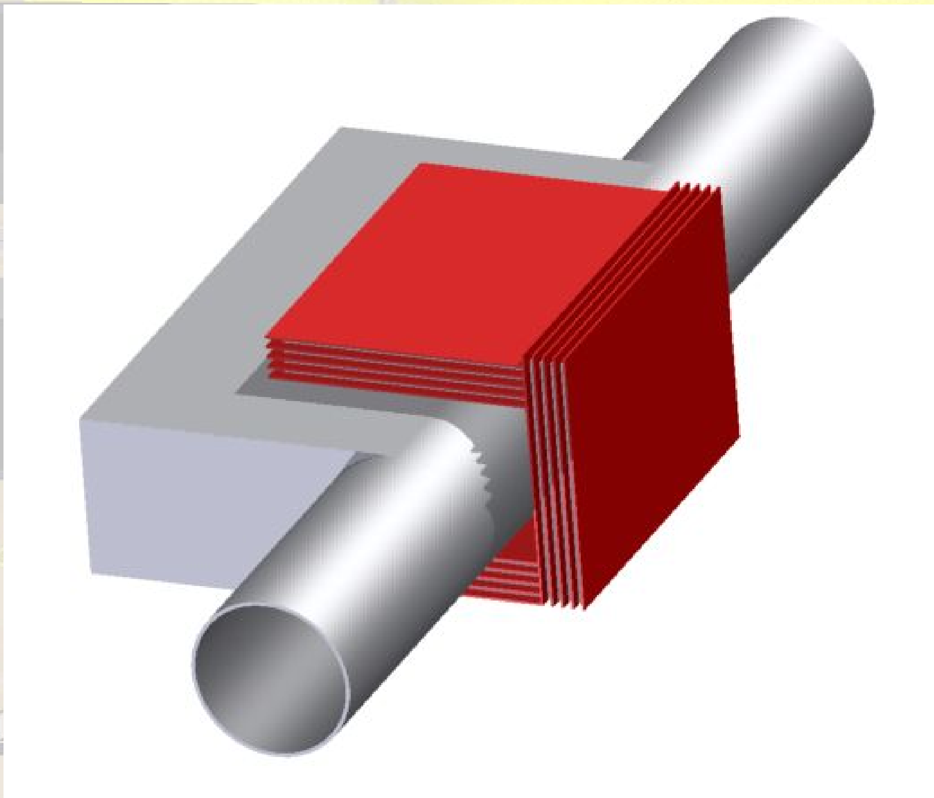
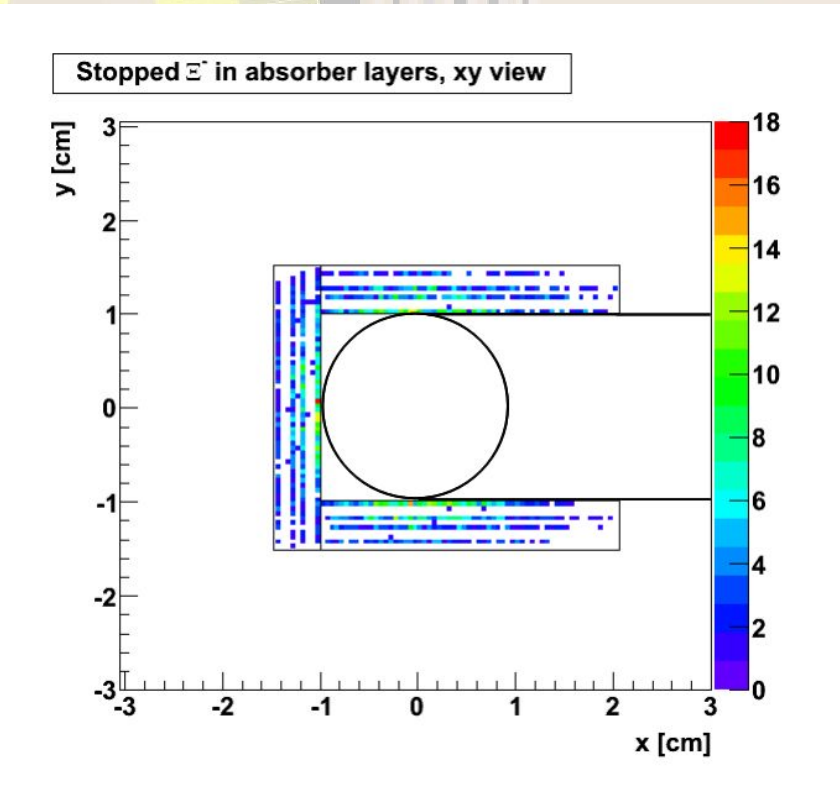
Design of the secondary target

Compromise between

- stopping rate (thickness absorber + number of layers)
- good momentum resolution
- design of the beampipe

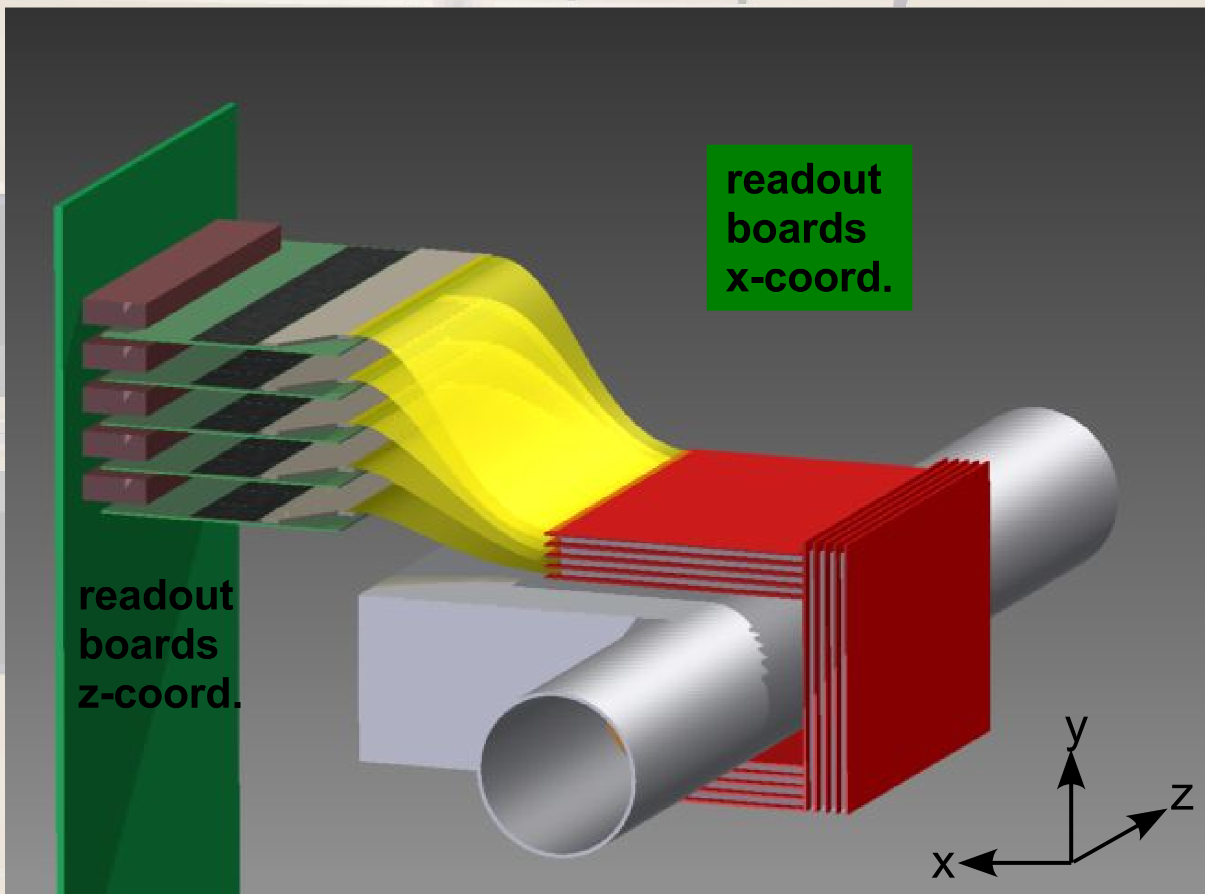


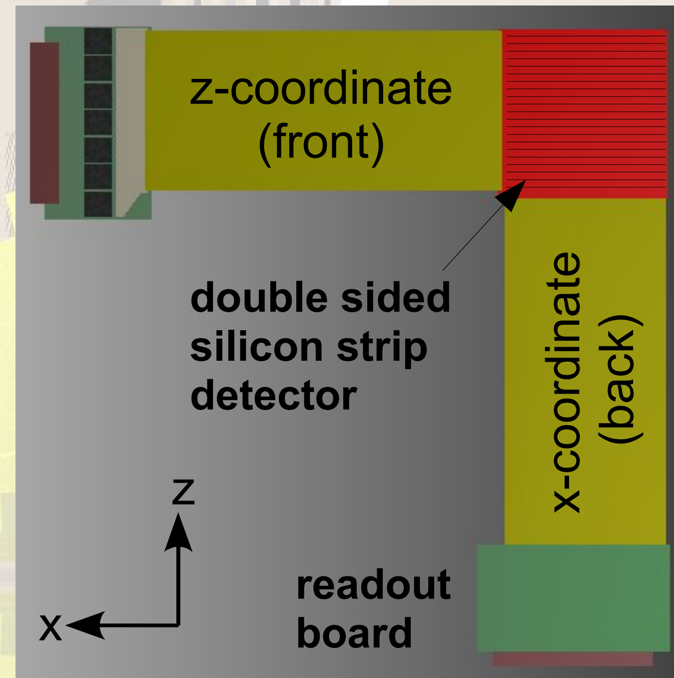


5 layers of DSSD, 4 layers of absorbers

Readout of the secondary target

tiny compact structure and high irradiation
⇒ fan out the readout electronics



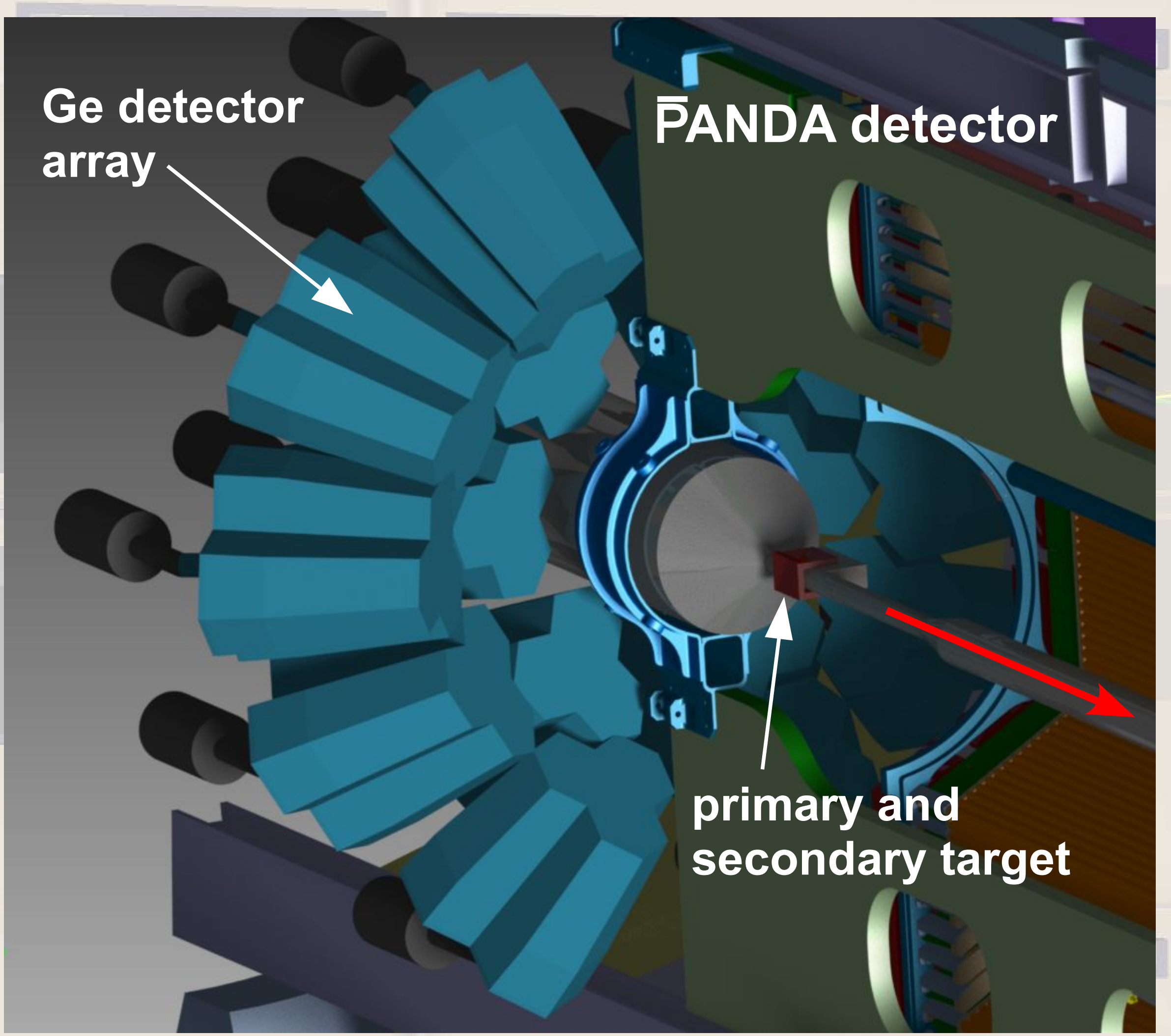


Readout of double sided silicon strip detectors:

Sensor and readout boards connected by ultra thin microcables via TAB bonding (Tape Automated Bonding)

Readout boards hosting pitch adapter, frontend chips and connector

Hypernuclear setup

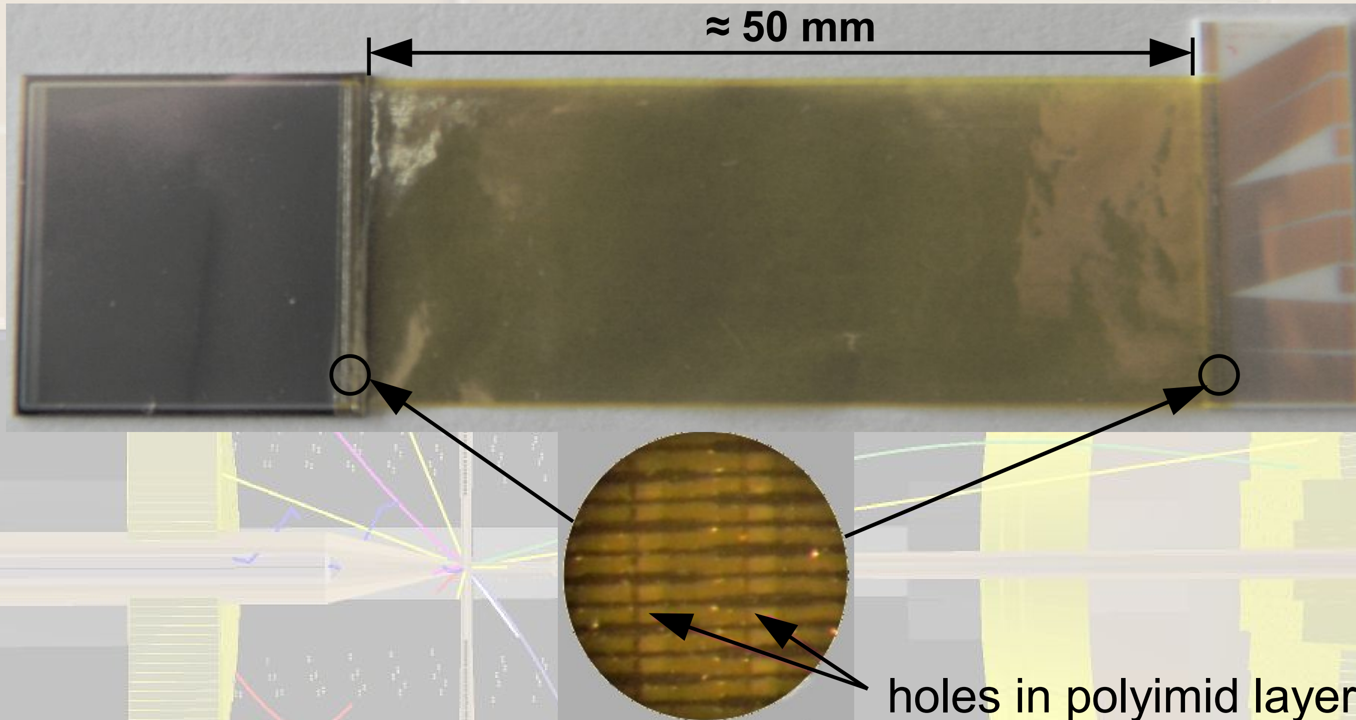


photons from excited double hypernuclei emitted isotropically

high particle flux in forward direction

⇒ arrangement of Germanium detector array in backward direction

Ultra-thin flexible cables



holes in polyimid layer for ultra-sonic TAB bonding

Manufacturer of cables:

State Enterprise Scientific Research Technological Institute of Instrument Engineering (Ukraine)

material: “foiled dielectric“ FDI-A-20

- 10μm aluminium layer
- 10μm polyimide layer

⇒ very low material budget: ≈ 99.75% of 1 MeV photons pass 10 cables

Outlook

- Determination of the momentum resolution with the present setup
- Simulation of electronic reponse of silicon strips: our digitization/clusterization tasks inherit from SDS detector classes (main class) as the microvertex, lumi detectors
- Evaluation of the radiation damage by neutrons/protons from primary raction
- Designing and adding readout electronics and holding structures to the simulations using the CadConverter

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Rates

$\bar{p}$ interaction rate	$3 \cdot 10^6\ s^{-1}$
$\bar{p}$ momentum	$3\,\mathrm{GeV/c}$
internal target	$Z \approx 6$
reactions of interest	$\bar{\mathrm{p}}\mathrm{p} \rightarrow \overline{\Xi}^{+}\Xi^{-}$
	$\bar{\mathrm{p}}\mathrm{n} \rightarrow \overline{\Xi}^{0}\Xi^{-}$
cross section ($\bar{p}N$)	$2\,\mu\mathrm{b}$
rate	$100\ s^{-1}$
Ξ^- PF	$7.5 \cdot 10^{-3}$
total stopped Ξ^-	64 800 per day
$\Xi^-\mathrm{p} \rightarrow \Lambda\Lambda$ conversion probability	5%
produced $\Lambda\Lambda$ hypernuclei	3 240 per day
probability of individual transition	10%
target escape probability ($E_\gamma = 1.332\,\mathrm{MeV}$)	70%
full energy peak efficiency	3.45%
trigger efficiency	20–30%
detected individual transitions	70 per month

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