Detector Developments
for the hypernuclear programme at PANDA

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The hypernuclear landscape

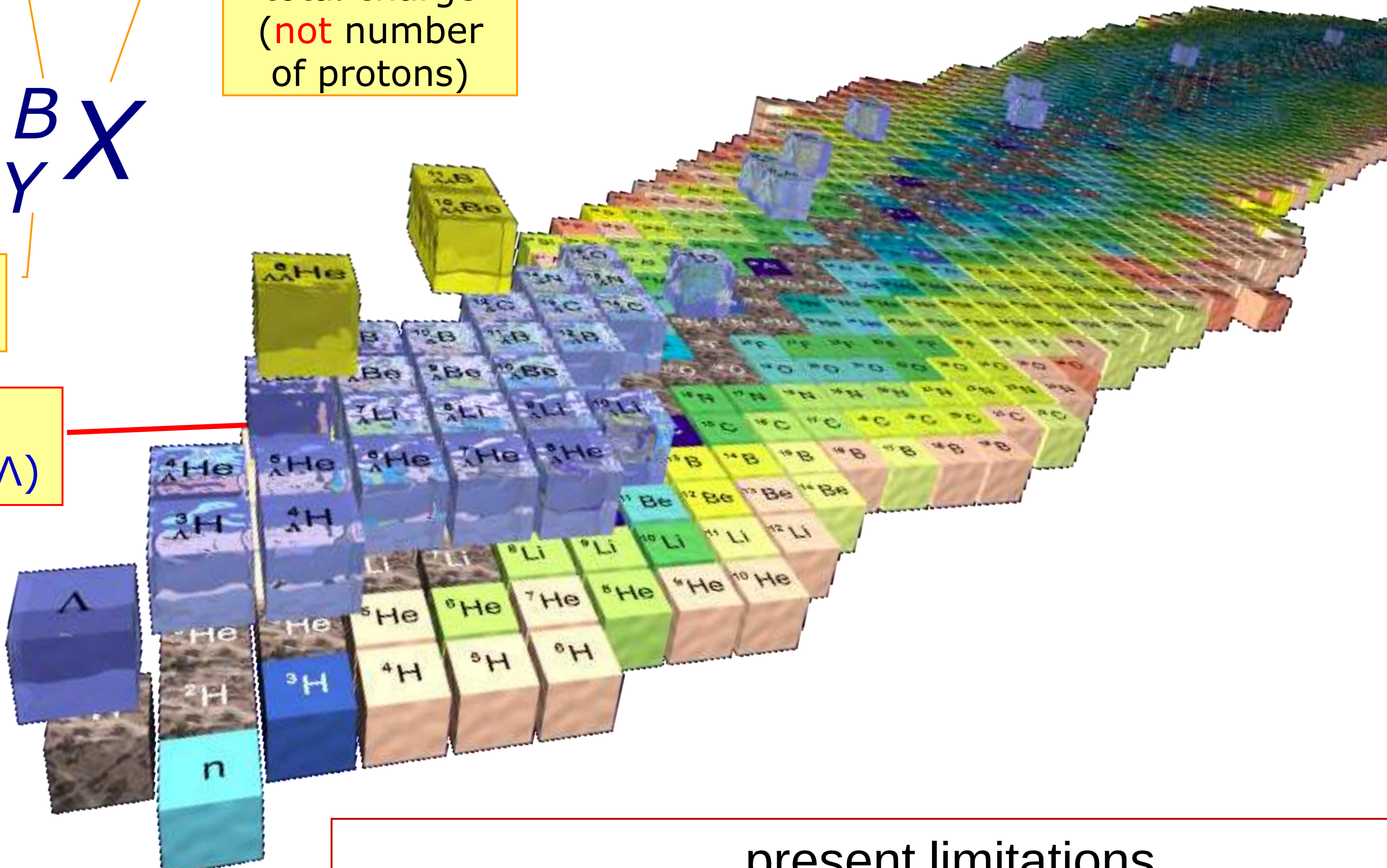
number of baryons $N+Z+Y$

element = total charge (not number of protons)

$^{B}_{Y}X$

number of hyperons Y

Example: $^{7}_{\Lambda}Li$ ($^{6}Li + \Lambda$)



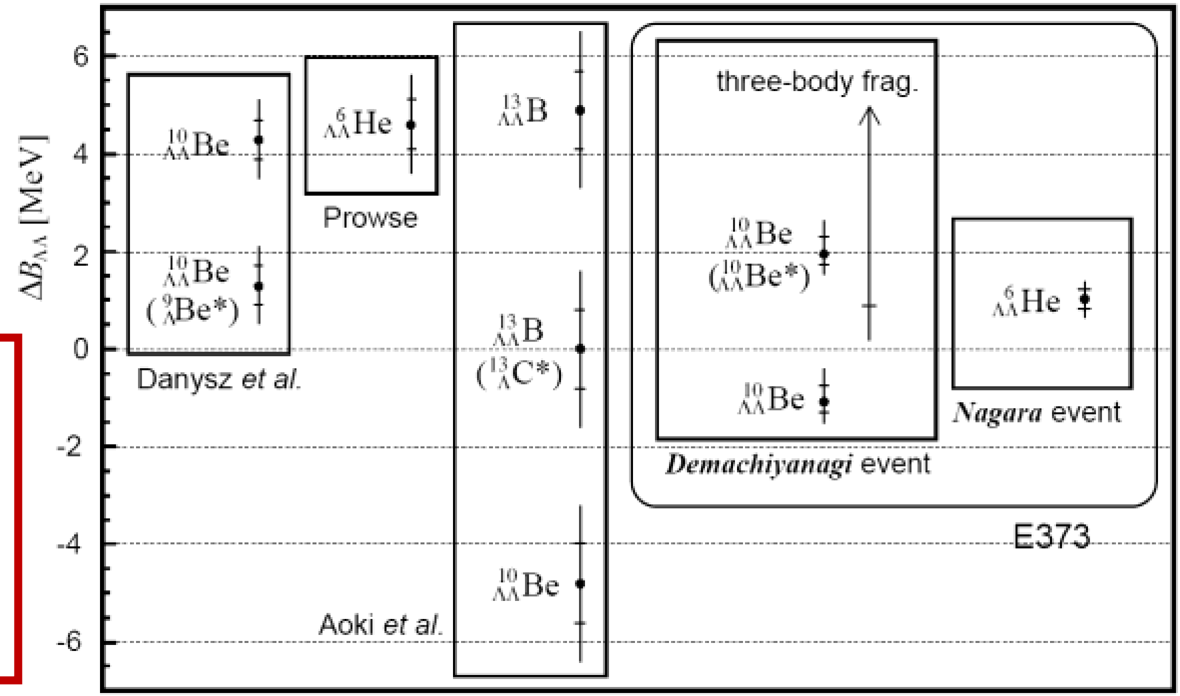
increasing strangeness

present limitations

– only single Λ-hypernuclei close to valley of stability
– only very few ΛΛ-hypernuclei events

Hyperon-hyperon interaction

1963: Danysz *et al.* $^{10}_{\Lambda\Lambda}$Be
1966: Prowse $^{6}_{\Lambda\Lambda}$He
1991: KEK-E176 $^{13}_{\Lambda\Lambda}$B
2001: KEK-E373 $^{6}_{\Lambda\Lambda}$He
2001: AGS-E906 $^{4}_{\Lambda\Lambda}$H?



[Takahashi et al.]

$$B_{\Lambda\Lambda}({}^{A}_{\Lambda\Lambda}Z) = B_\Lambda({}^{A}_{\Lambda\Lambda}Z) + B_\Lambda({}^{A-1}_{\Lambda}Z)$$

$$\Delta B_{\Lambda\Lambda}({}^{A}_{\Lambda\Lambda}Z) = B_\Lambda({}^{A}_{\Lambda\Lambda}Z) - B_\Lambda({}^{A-1}_{\Lambda}Z)$$

The Danysz event: a classical example

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OBSERVATION OF A DOUBLE HYPERFRAGMENT

M. Danysz, K. Garbowska, J. Pniewski, T. Pniewski, and J. Zakrzewski

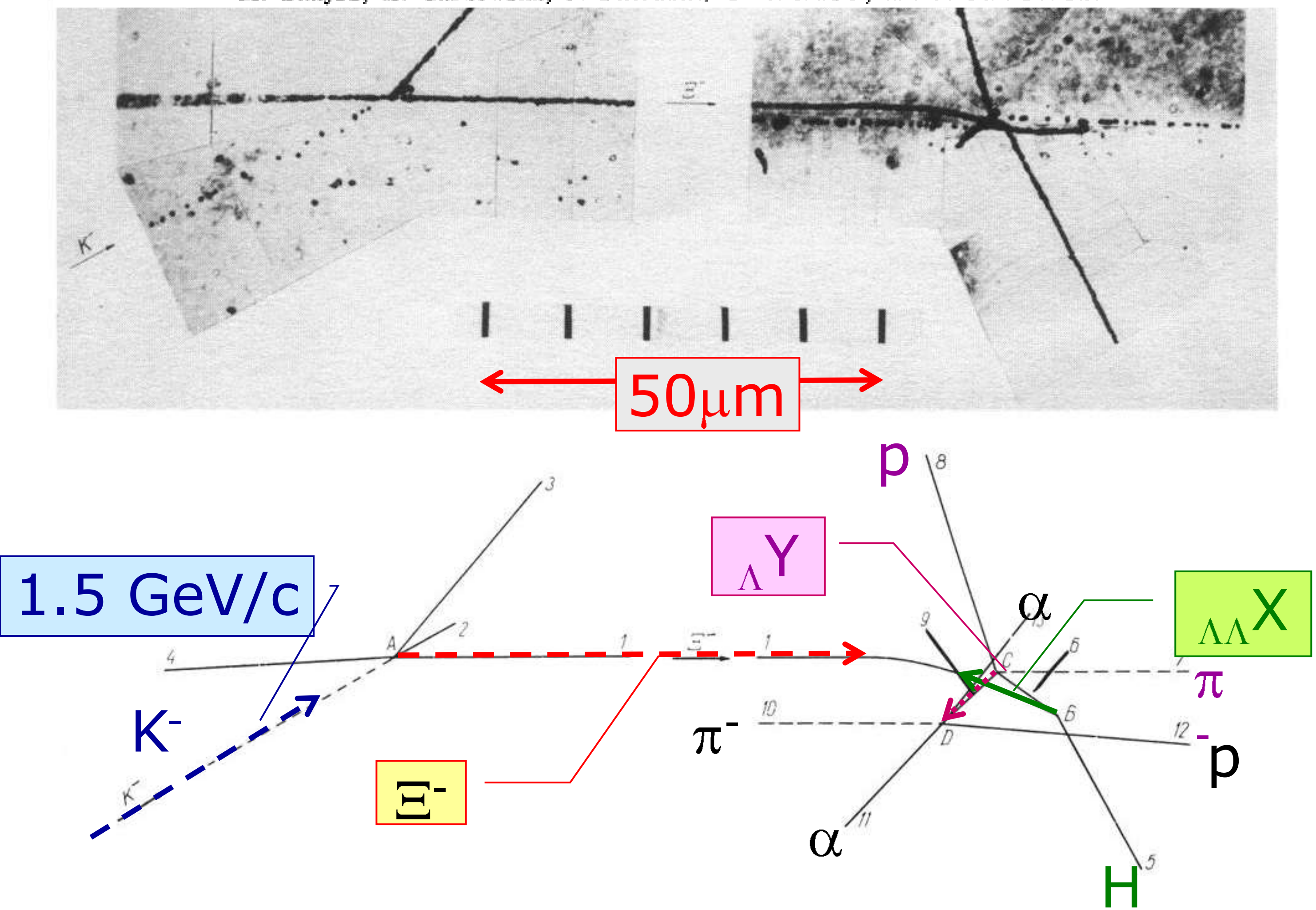
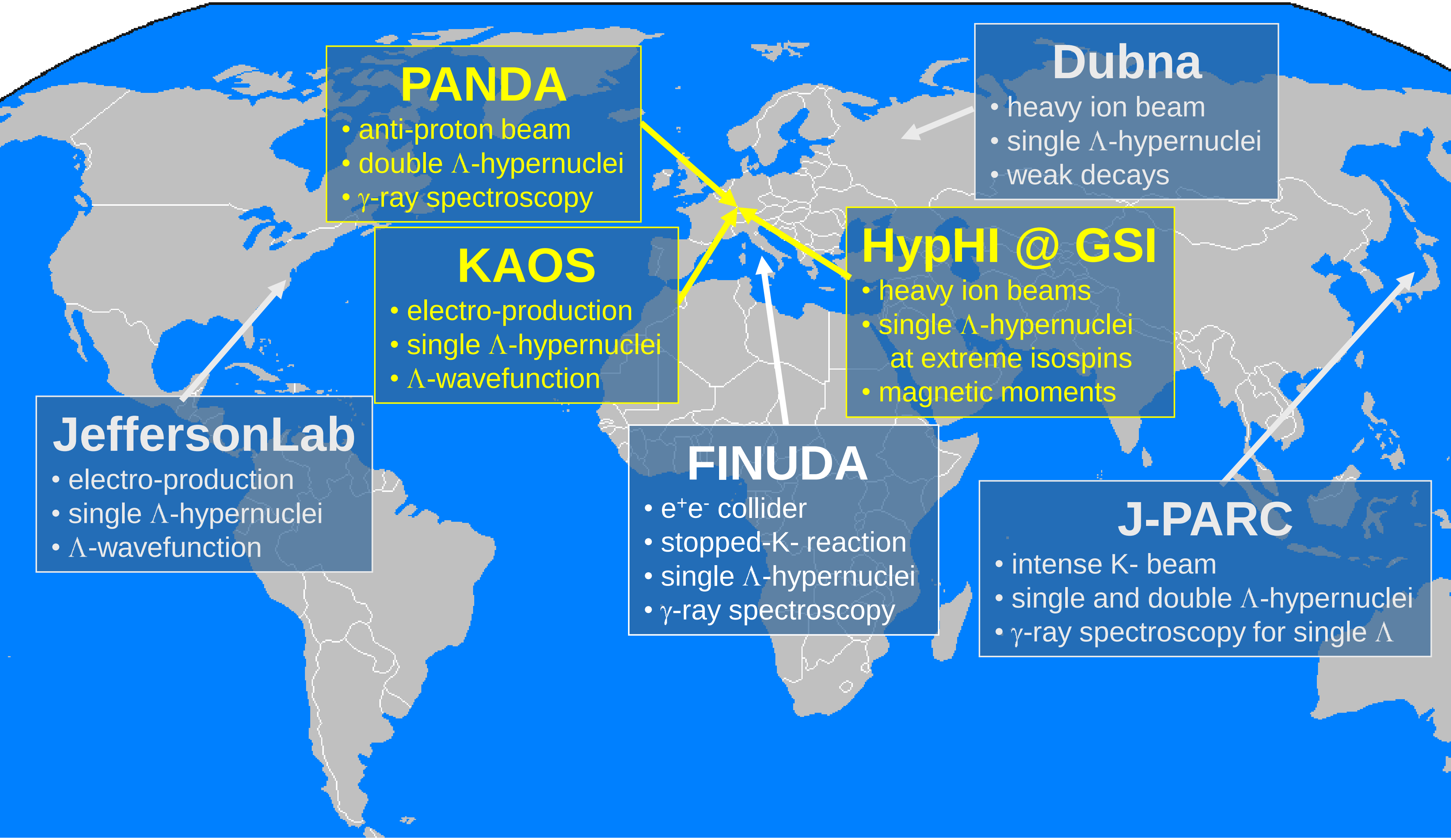
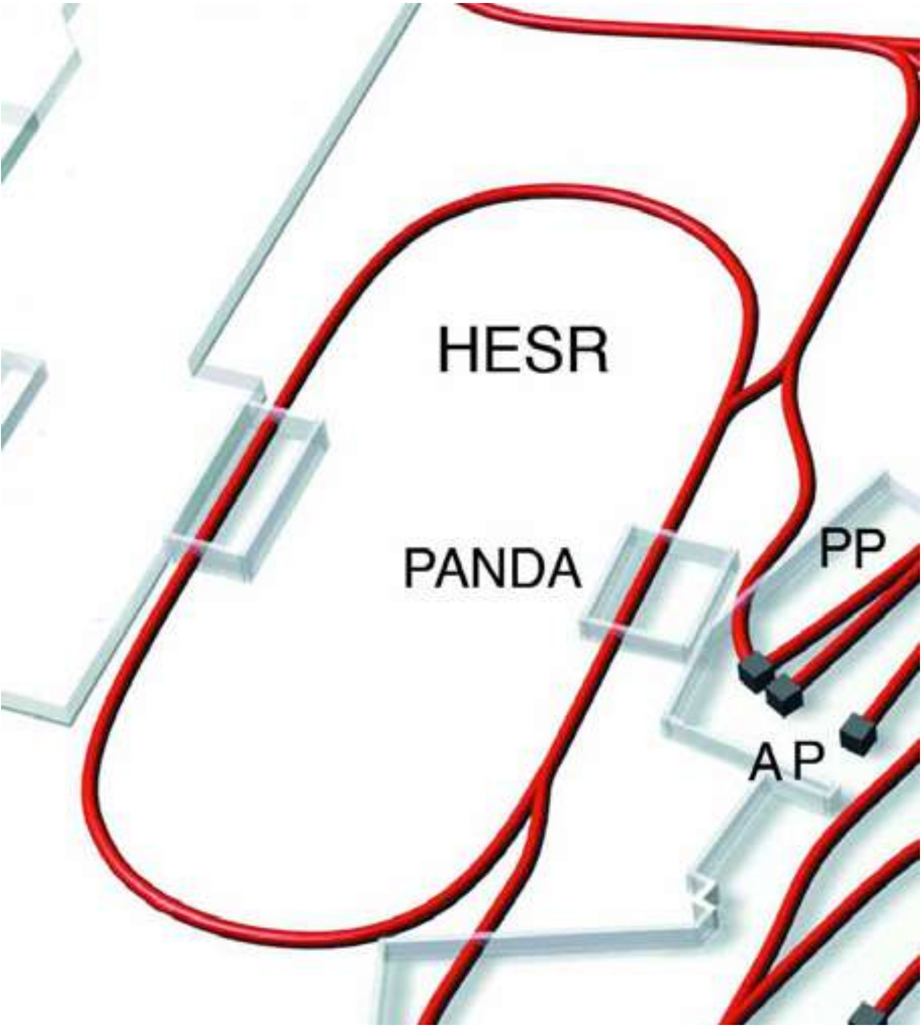


FIG. 1. A photomicrograph and a schematic drawing of the production of a Ξ^- hyperon in a 1.5-GeV/*c* K^--meson interaction at *A* followed by capture at rest of the Ξ^- hyperon at *B* with the emission of a double hyperfragment decaying in cascade at *C* and *D*.

International hypernuclear network



High Energy Storage Ring at FAIR



H E S R   Performance

Racetrack shaped ring: 574 m length

Luminosity/Intensity:

- Pbar production rate: 2×10^7 /s
- High luminosity mode:
  $L = 2 \times 10^{32}\ cm^{-2}s^{-1}$
- High resolution mode:
  $L = 2 \times 10^{31}\ cm^{-2}s^{-1}$
  (for target thickness 4×10^{15} atoms/cm^2)

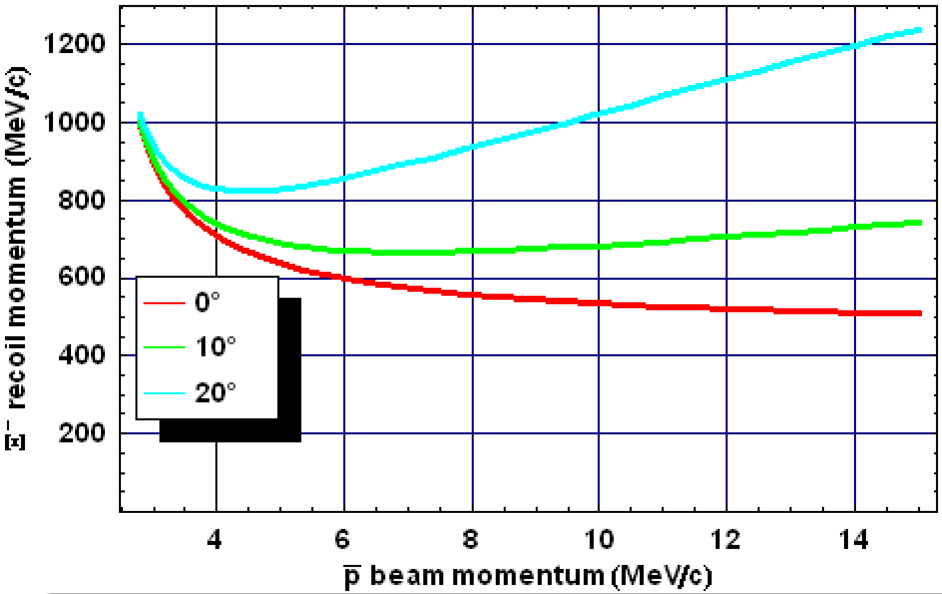
Momentum range:

- 1.5 – 15 GeV/c (0.831- 14.1 GeV)
- Revolution frequency: 5×10^5 Hz

Momentum resolution:

- High luminosity mode: $\Delta p/p = 10^{-4}$
  (stochastic cooling above 3.8 GeV/c)
- High resolution mode: $\Delta p/p = 10^{-5}$
  (electron cooling)

Formation of double hyper-nuclei from Xi hyperons



Use p-anti-p interaction to produce hyperons which are tagged by the anti-hyperons or its decay products

1. dE(Ξ^-)/dx → stop + capture
2. hyper-atom + atomic decay
3. capture in nucleus ($^{A'}{}_{\Xi}Z'$)
4. conversion: $\Xi^- + p \rightarrow \Lambda\Lambda$
5. double hyper-nucleus ($^{A'}{}_{\Lambda\Lambda}Z'$)

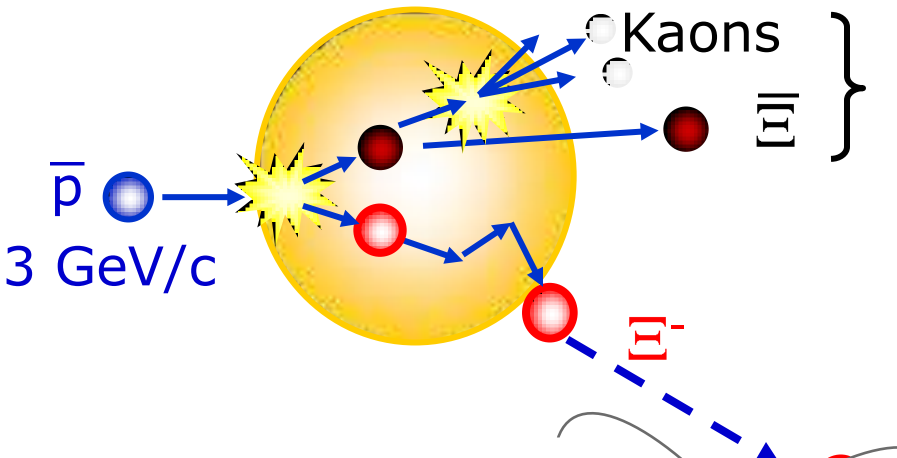
$\Xi^- + p \rightarrow \Lambda\Lambda$

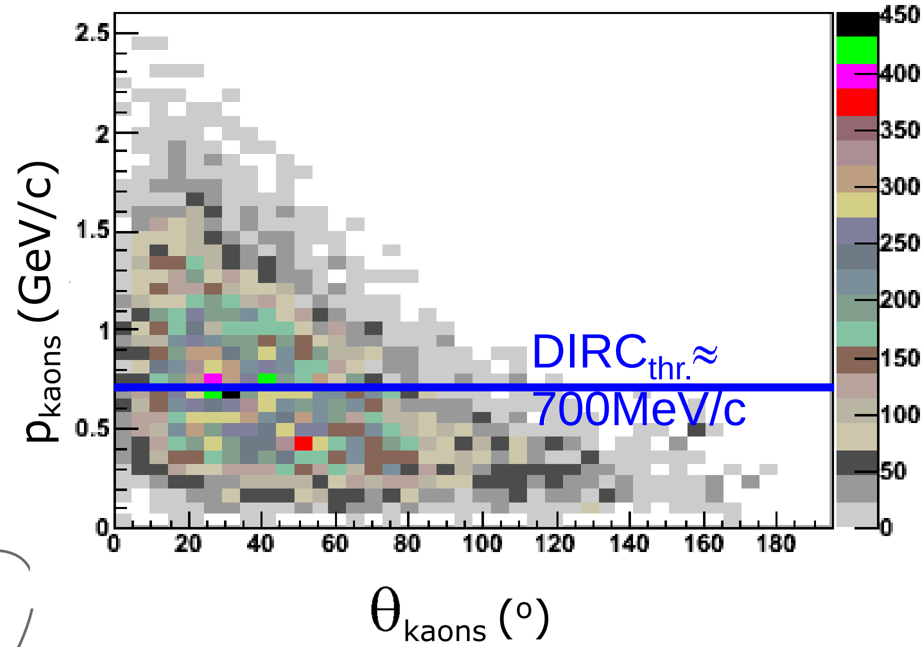
$\Delta Q = 28$ MeV

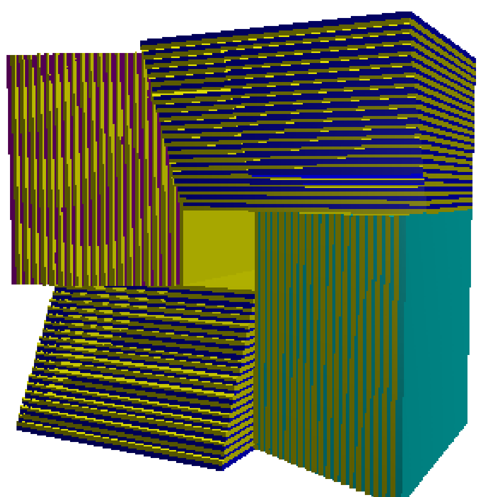
conversion probability: ~5-10%

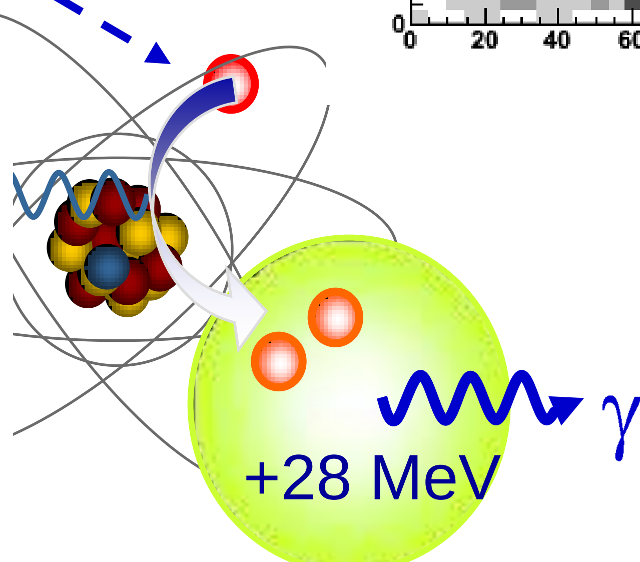
[Y. Hirate et al., Nucl. Phys. **A639**,(1998); Prog. Theor. Phys. **102** (1999)]

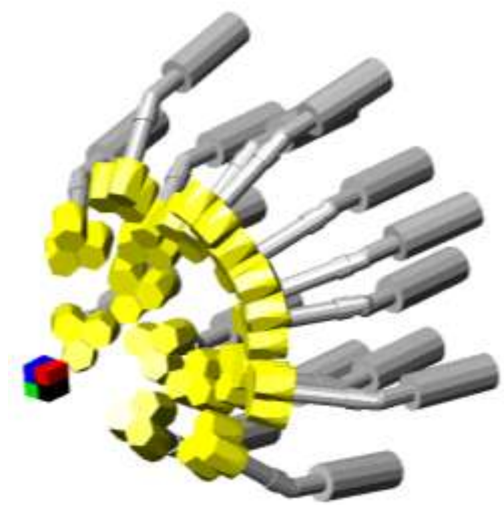
Detection and triggering of hypernuclear events







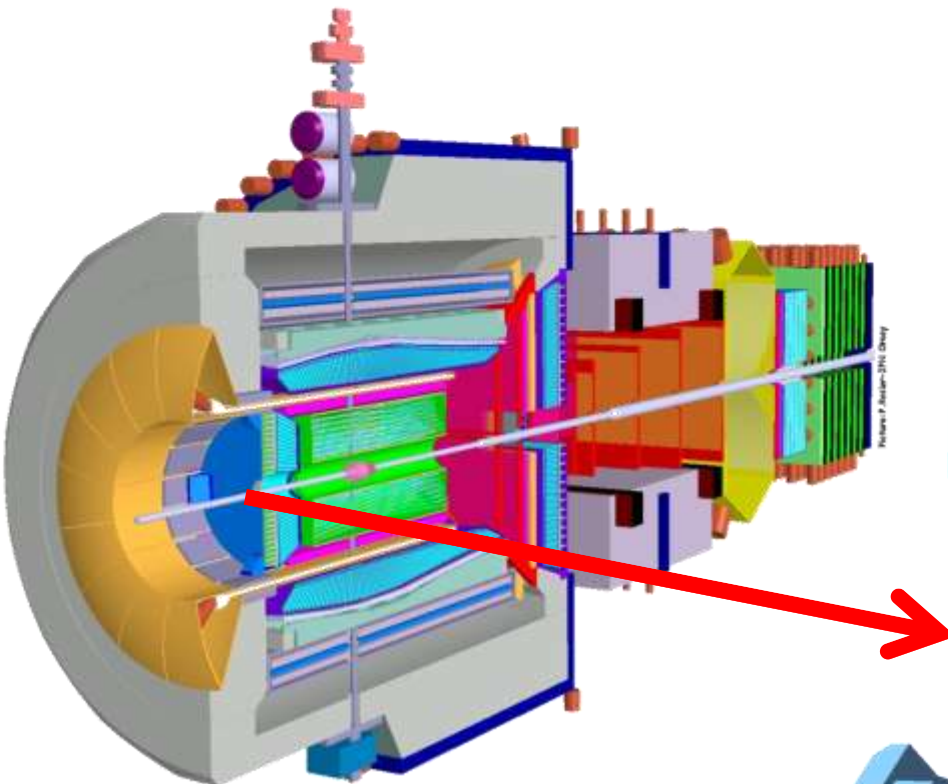


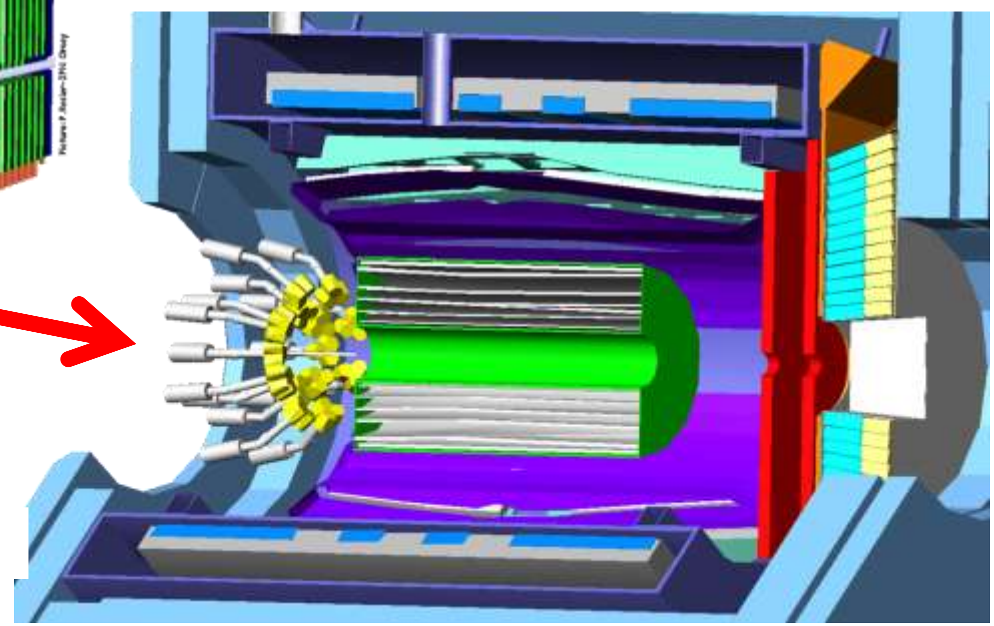


active secondary target ➔ radiation hard material

Hypernuclear set-up at PANDA

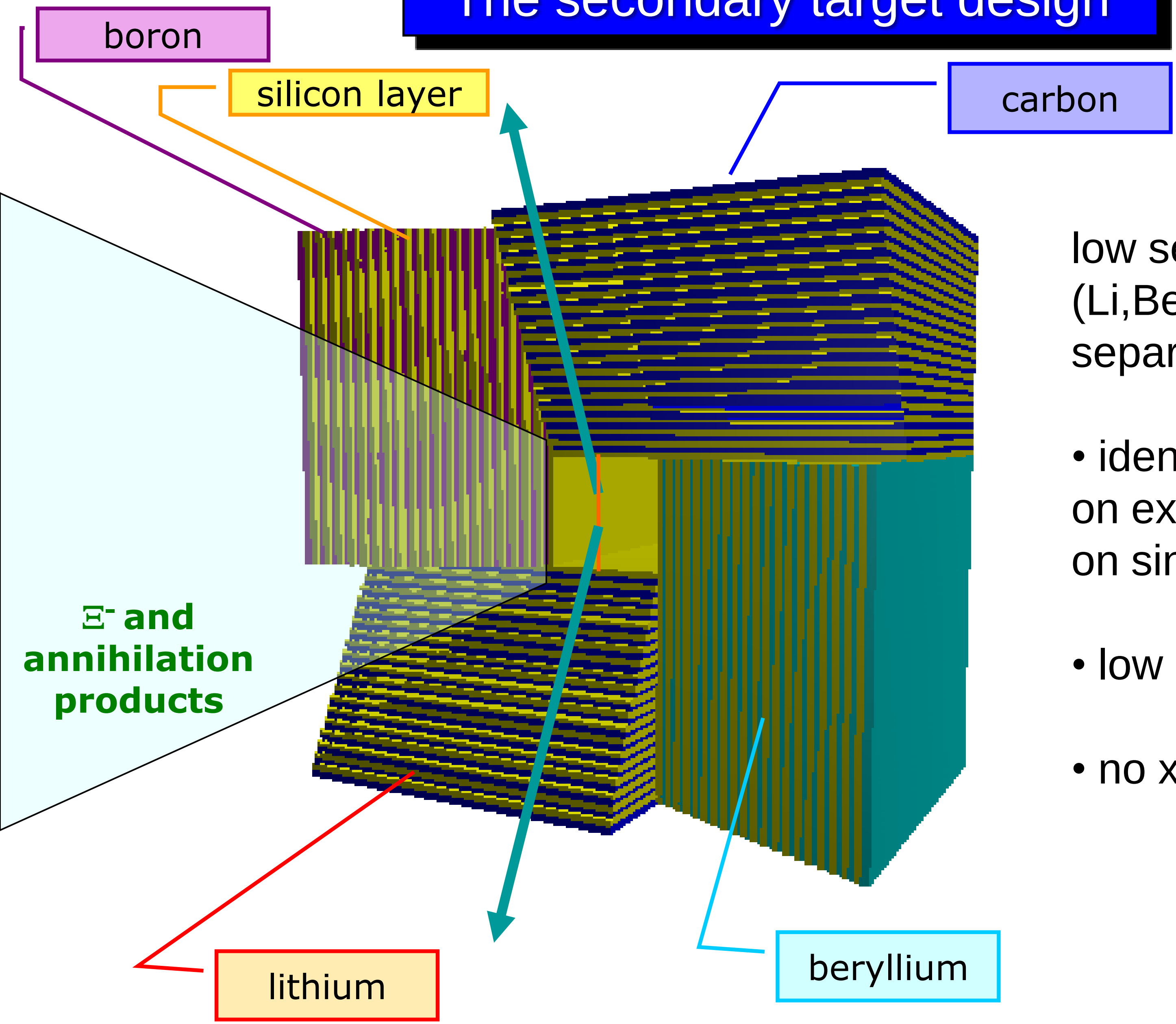
- θ_{lab}< 45°: Ξ-bar, K trigger and PID in PANDA spectrometer
- θ_{lab}= 45°-90°: Ξ-capture and hypernuclei formation
- θ_{lab}>90°: γ-detection with HPGe at backward angles





[PANDA Technical Progress Report, 2005.]

The secondary target design



low secondary masses (Li,Be,B,C) in four separated sections:

- identification can rely on existing information on single hypernuclei
- low g-ray absorption
- no x-ray background

Stopping of Xi-hyperons

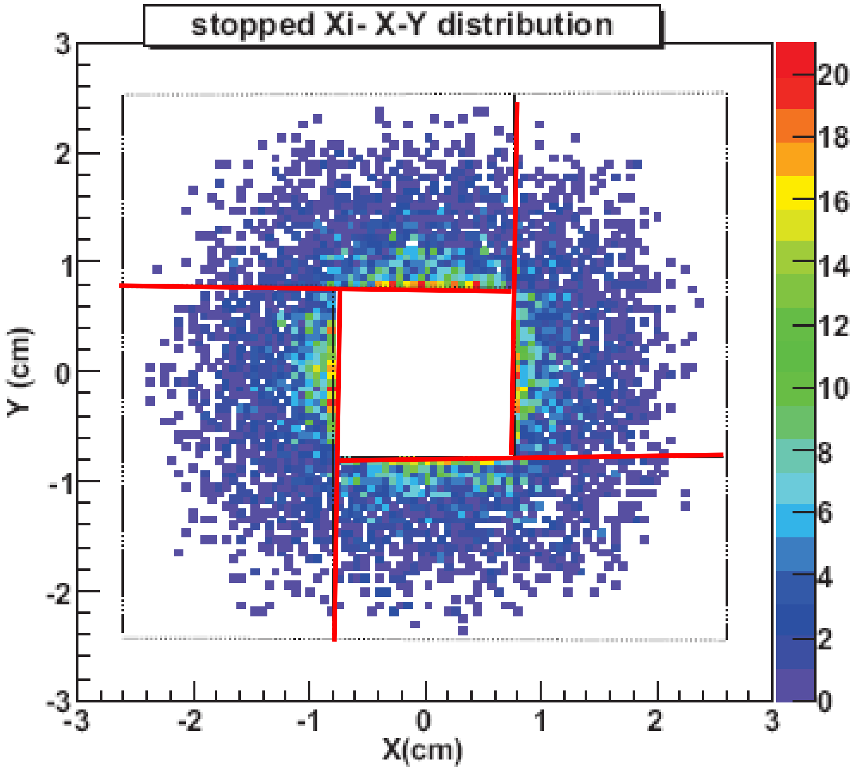


Figure 4.75: Layout out the secondary sandwich target used in the present simulations. The lower part marks the stopping points of the Ξ^- hyperons within the target in the x-y plane transverse to the beam di-

[J. Pochodzalla et al., PANDA Physics Book, to be published. Simulations by A. Sanchez, U Mainz.]

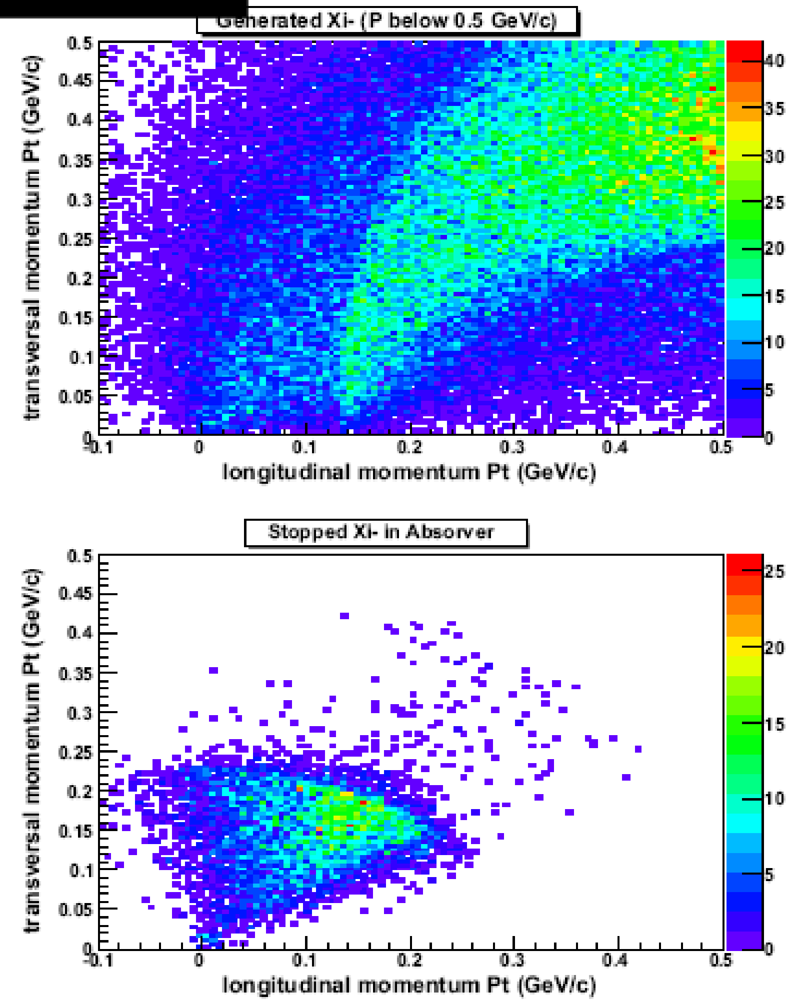
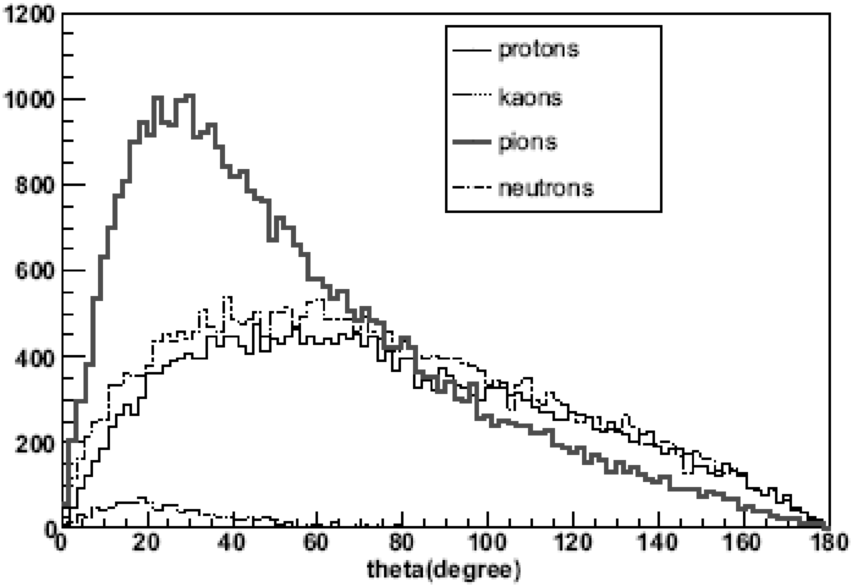


Figure 4.76: Transverse vs. longitudinal momentum distribution of Ξ^- with transverse and longitudinal momenta less than 500 MeV/c (upper part) and those stopped within the secondary target (lower part).

HPGe detectors in a mixed radiation background



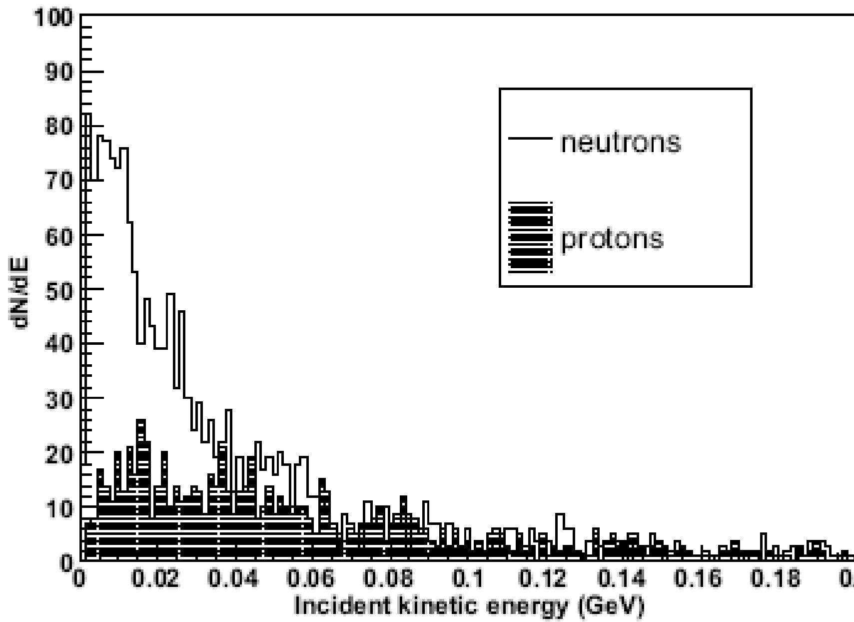


Figure 4.81: Distribution of produced particles from background reactions. The Germanium detectors will be affected mainly by particles emitted at backward axial angle.

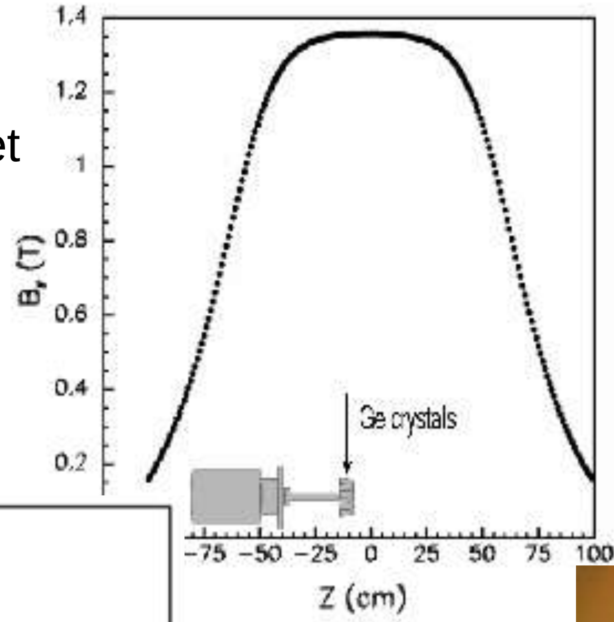
Figure 4.82: Incident kinetic energy of protons and neutrons entering the Germanium detector surface. The main contribution to a possible radiation damage of the detector is provided by neutrons.

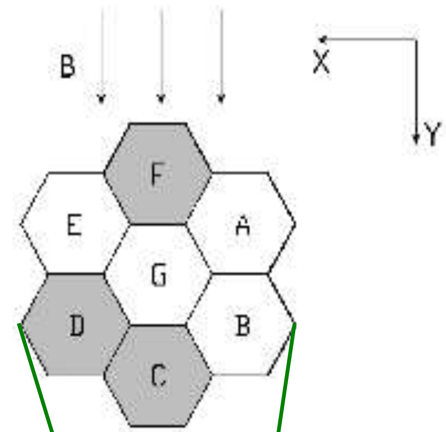
[J. Pochodzalla et al., PANDA Physics Book, to be published. Simulations by A. Sanchez, U Mainz.]

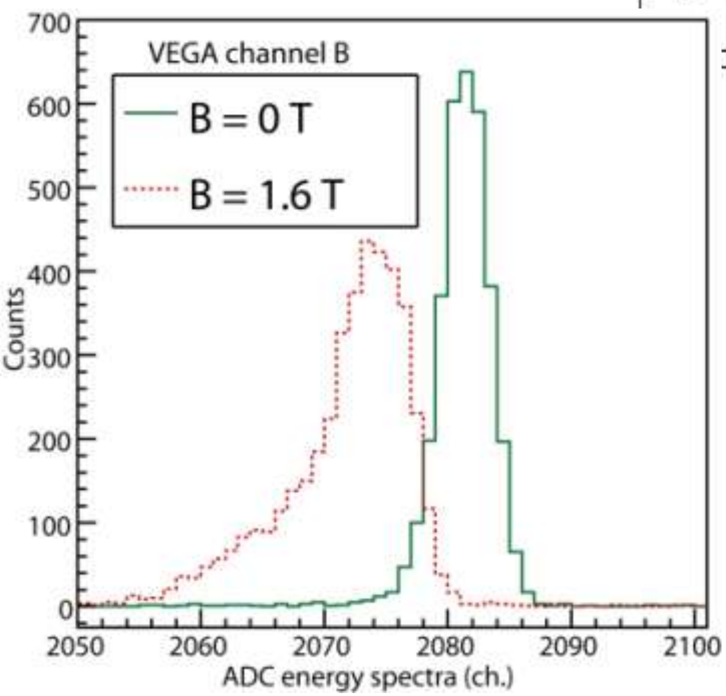
HPGe detectors in magnetic fields

experimental set-up:

- ALADiN dipole magnet
- Co source of 370 kBq
- VEGA clover and
- Euroball cluster







[6th European Framework HadronPhysics Joint Research Activity]

Identification strategy using decay pion correlations

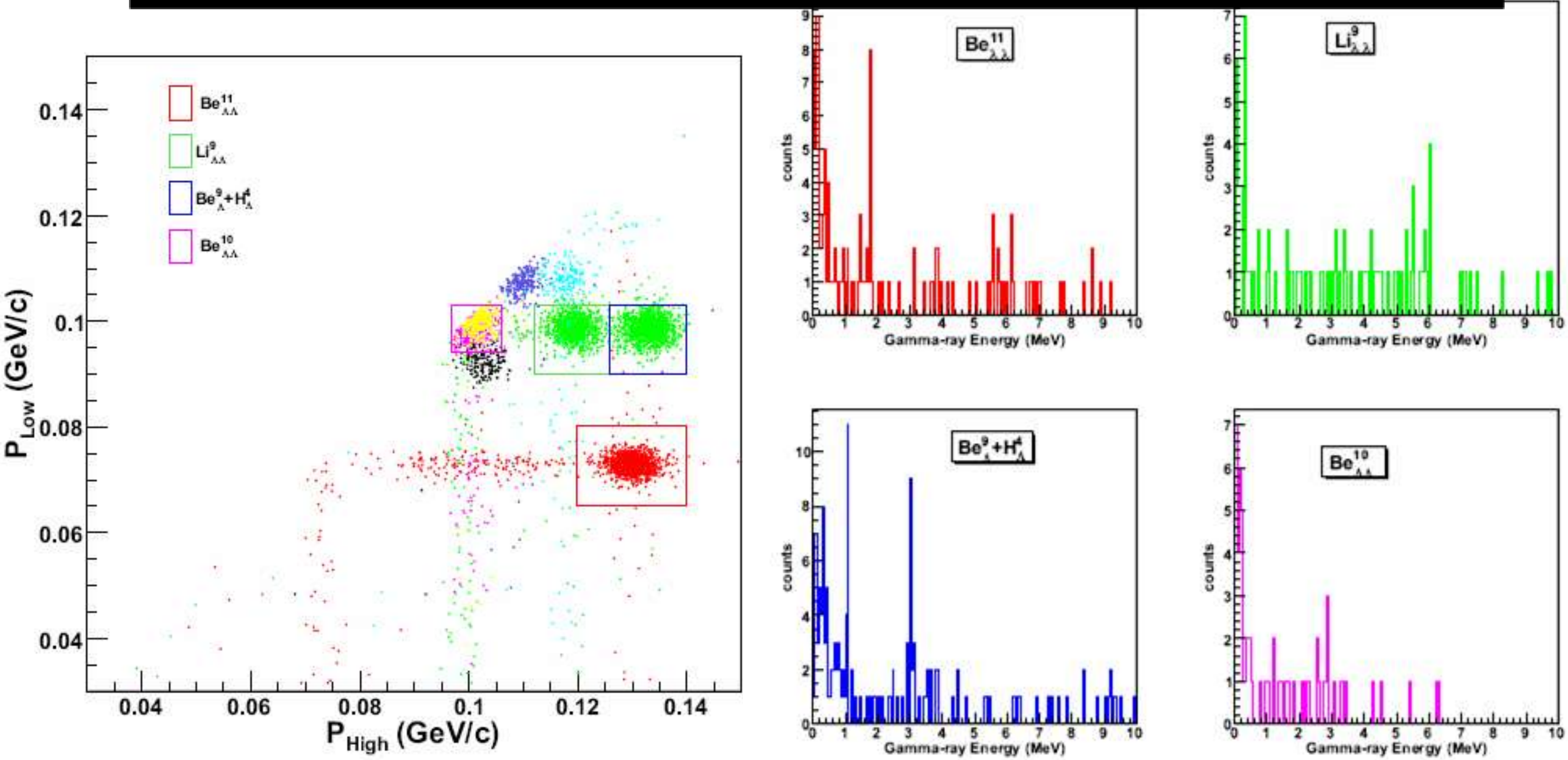
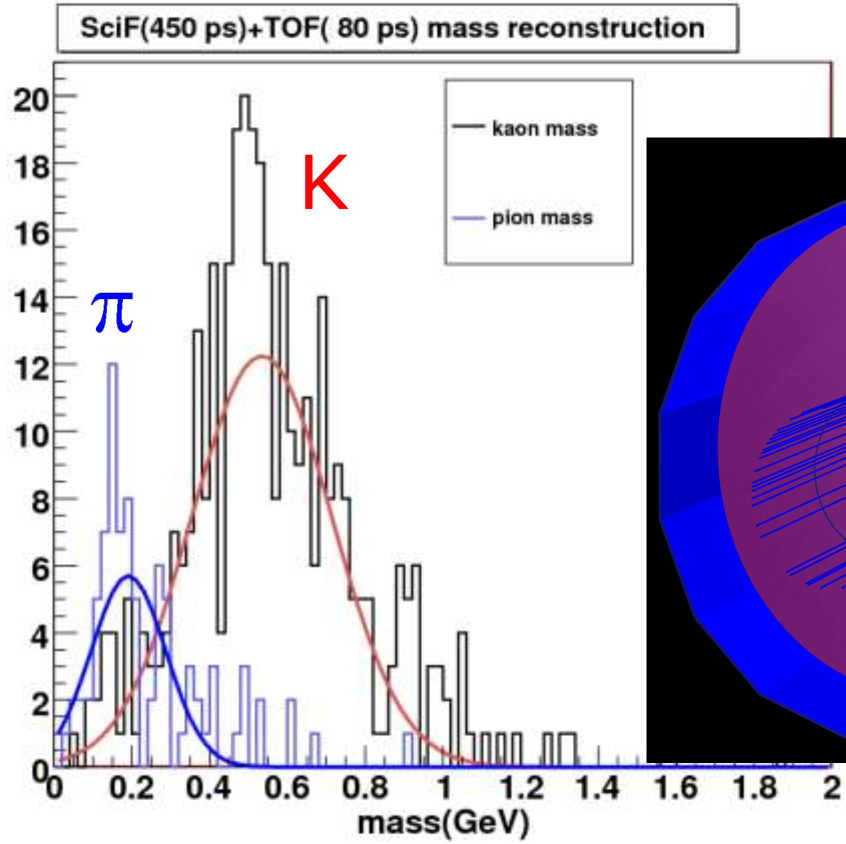
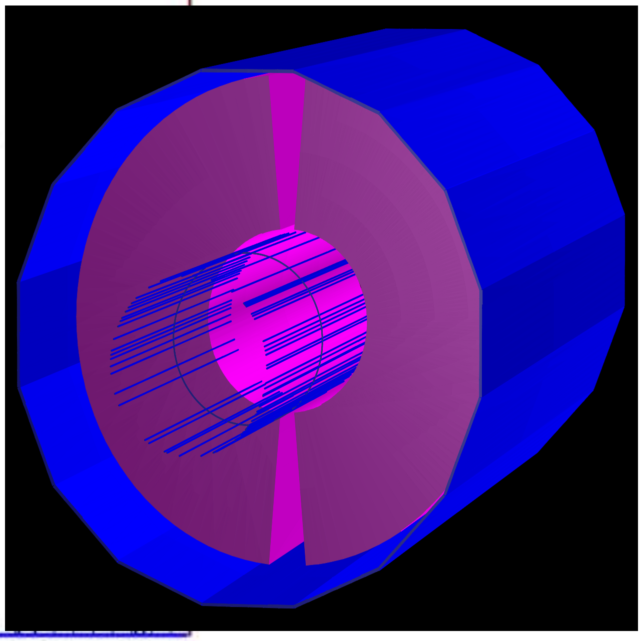


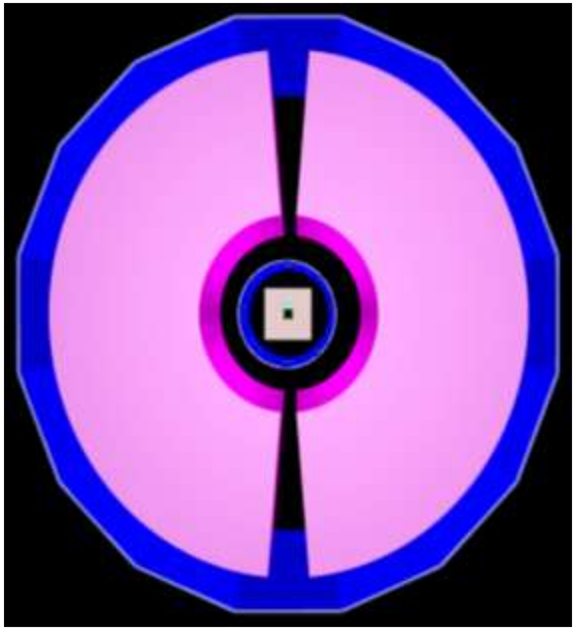
Figure 4.80: Upper part: Momentum correlation of all negative pion candidates resulting from the decay of double hypernuclei in a secondary ^{12}C target. Lower part: γ-spectrum detected in the Ge-array by cutting on the two π-meson momenta.

[J. Pochodzalla et al., PANDA Physics Book, to be published. Simulations by A. Sanchez, U Mainz.]

Strangeness tagging using low momentum kaons







- Scintillating (possibly crystalline) fibers (START)

~2000 fibers placed in two rings ⊕ readout with SiPM

- TOF barrel (STOP)

time resolution ~ 80 ps with 16 slabs

[simulations by A. Sanchez, U Mainz]

Estimated count rates

"Golden events":

luminosity $2{\cdot}10^{32}$ cm^{-2}s^{-1}

$\Xi^+\Xi^-$ cross section 2mb for pp	$\Rightarrow$	700 Hz
p(100-500 MeV/c)		$p_{500} \approx 0.0005$
Ξ^+ reconstruction probability		0.5
stopping and capture probability		$p_{CAP} \approx 0.20$
total captured Ξ^-	$\Rightarrow$	3000 / day
Ξ^- to $\Lambda\Lambda$–nucleus conversion probability		$p_{\Lambda\Lambda} \approx 0.05$
total $\Lambda\Lambda$ hypernucleus production	$\Rightarrow$	4500 / month
gamma emission/event,		$p_\gamma \approx 0.5$
γ-ray peak efficiency		$p_{GE} \approx 0.1$

~ 7/day „golden“ γ-ray events with Ξ^+ trigger

~ 700/day with *KK* trigger