Hyper nuclear physics

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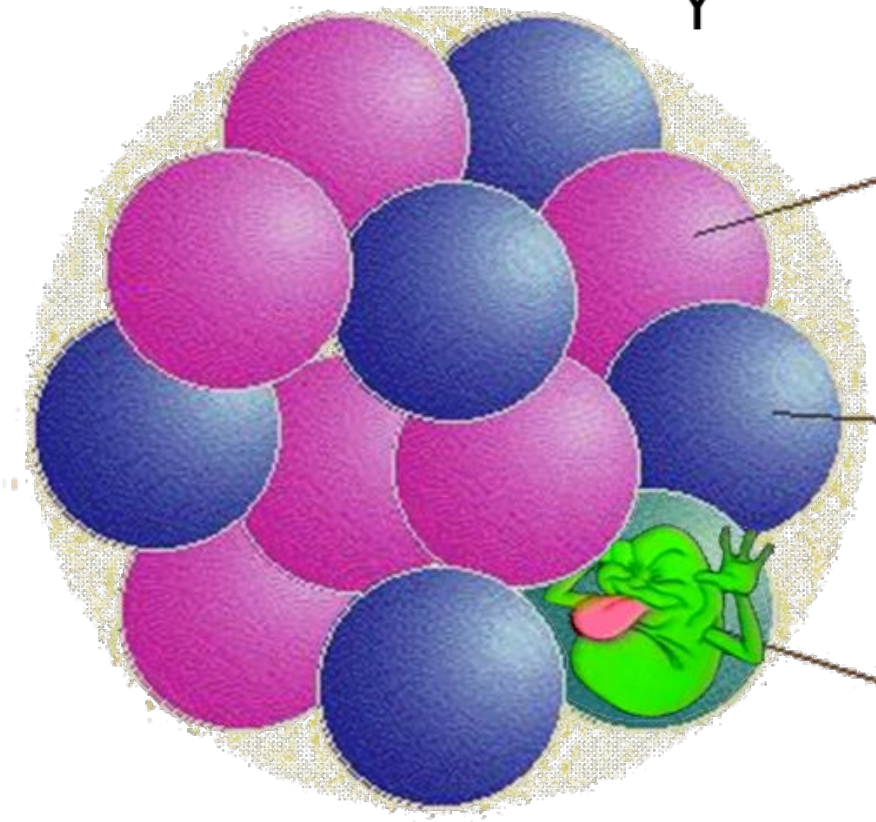
Outline

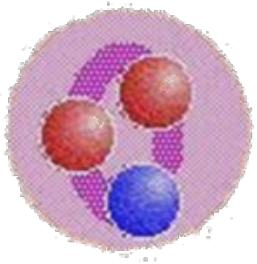
- Hyper nuclei
- Double Λ hyper nuclei
- Hyper atoms
- Experimental setup @ Panda

There's something strange ...

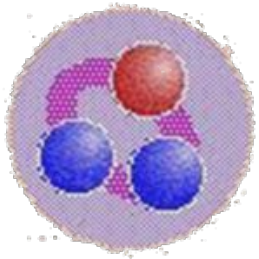
Hyper nucleus ${}^{B}_{Y}Z$



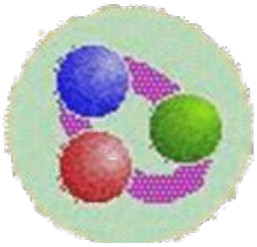
Z Protons



N Neutrons



Y Λ particles



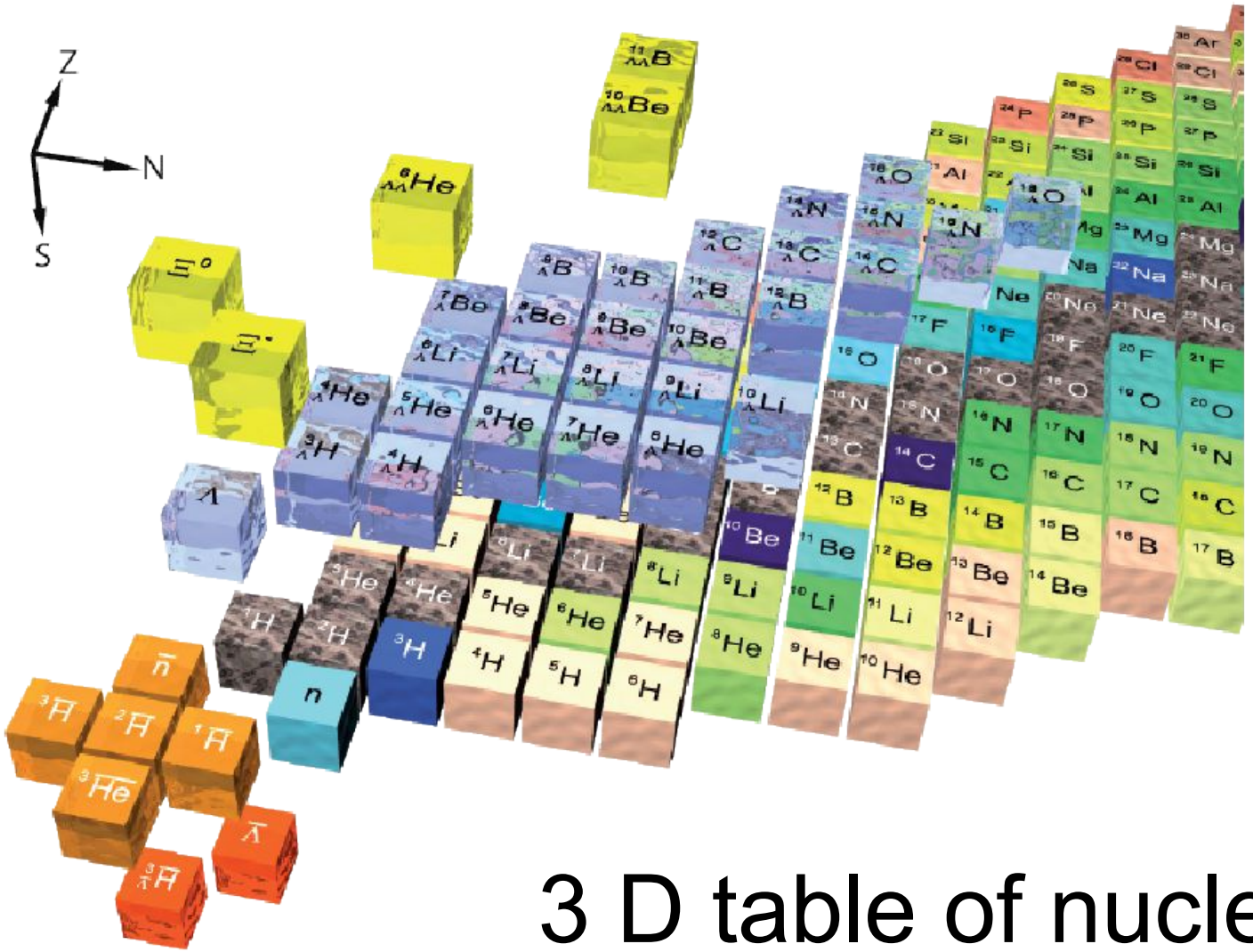
Number of baryons B = Z+N+Y

Up quark

Down quark

Strange quark

… in the neighbourhood

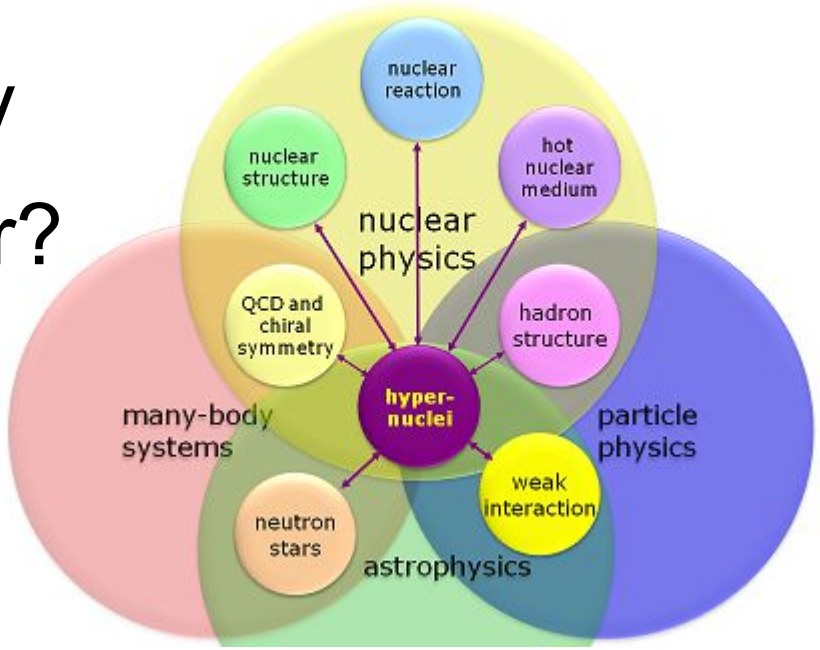


3 D table of nuclei

Hyper nuclei – why?

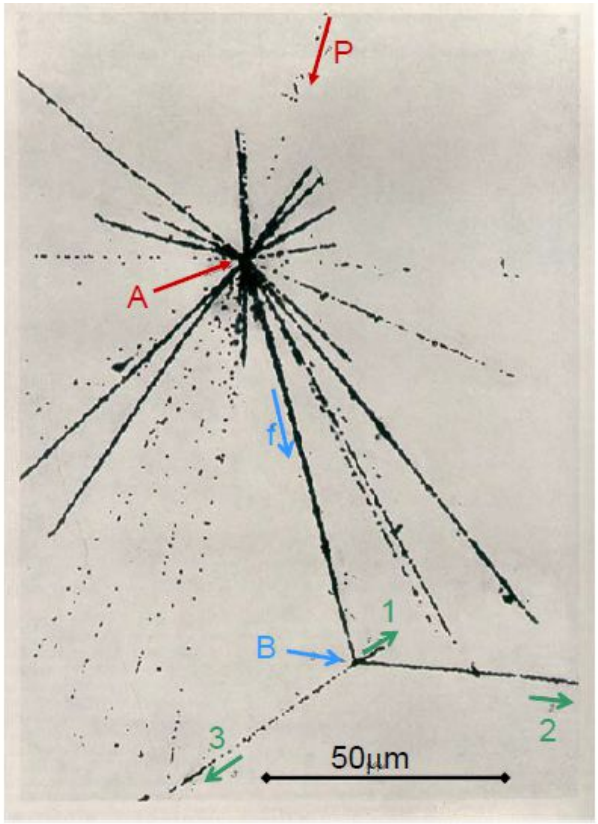
- No pauli blocking of levels

- Λ as a probe inside the nucleus
- YN – interaction, Binding Energy
- Λ modifications in nuclear matter?



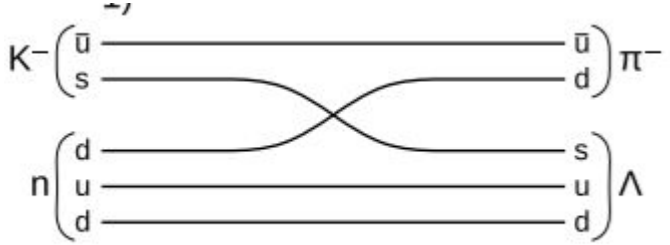
Hyper nuclei

- First observation in 1953, by M. Danysz and J. Pniewski
- Cosmic events in 26 km heigth, stack of emulsion
- High energy primary proton
- Weak decay of hyper fragment
  → longer life time
  → displaced vertex

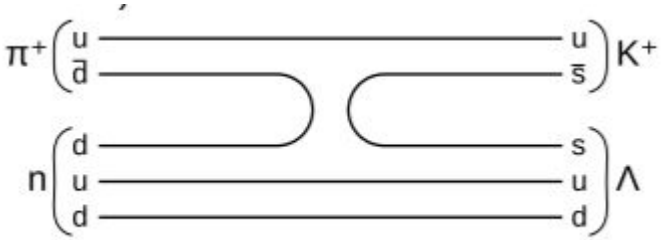


Production mechanisms

- "strangeness exchange" (K^- beams) :
  - $K^- + n \rightarrow \Lambda + \pi^-$
  - Cern, BNL (1975 -)
  - Low beam rates, high cross section

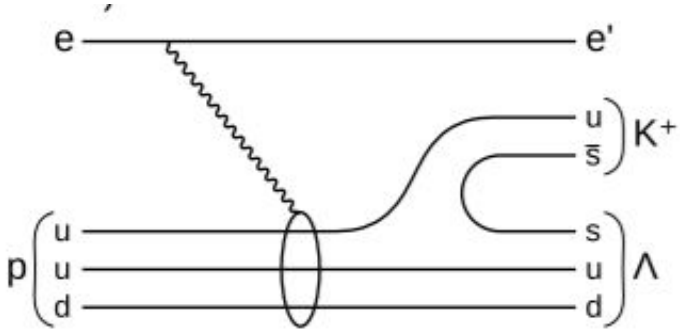


- π^+ beams:
  - $\pi^+ + n \rightarrow \Lambda + K^-$
  - BNL, KEK (JPARC) (~1980 -)
  - Lower cross section, overcompensated by much higher beam intensities

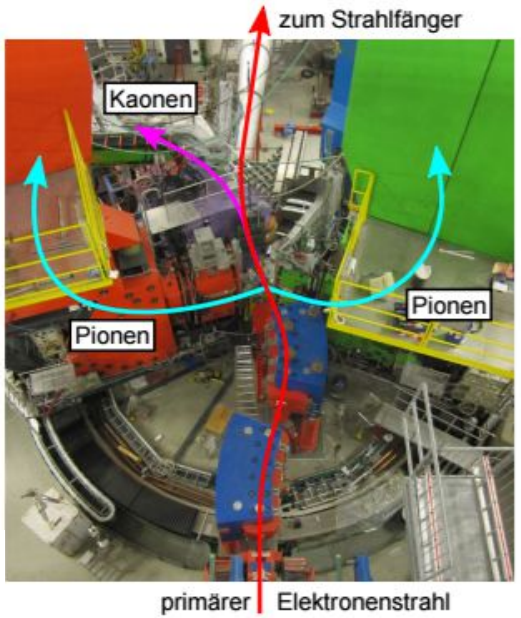


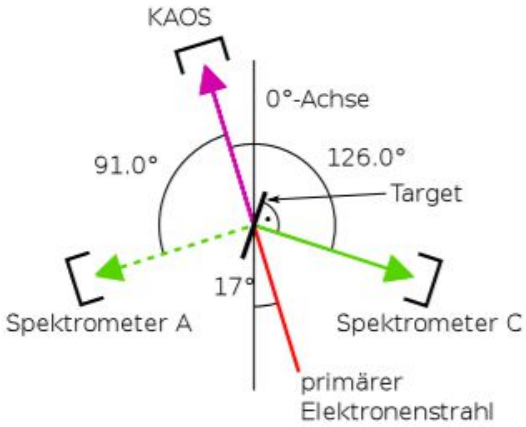
Production mechanisms (2)

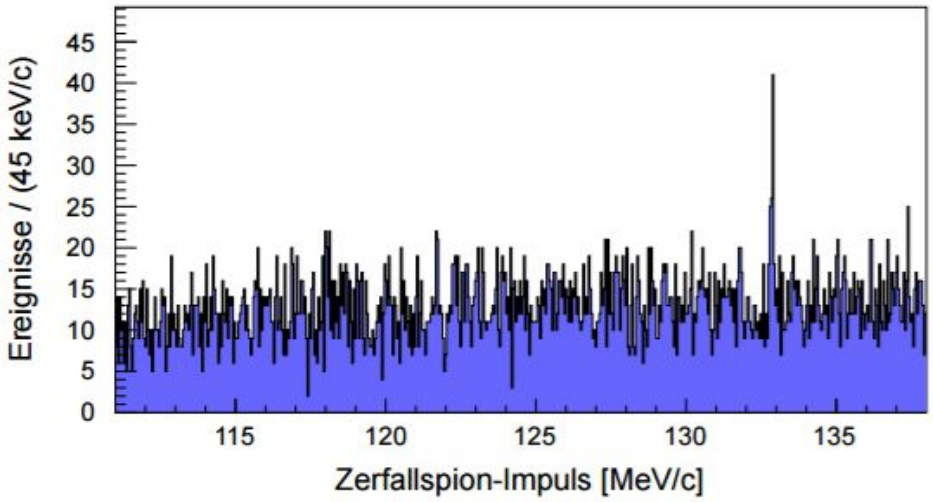
- Photoproducktion/electroproduction :
  - ${}^{A}_{Z}(\gamma,K+){}^{A}_{\Lambda}(Z-1)$
  - (e,e'K^+), via virtual photon
  - Jlab, MAMI-C (A1/KAOS)
  - Very high beam rates, low cross section
  - Missing mass spectroscopy
- Heavy ion collisions
  - ALICE, SPARK, HypHi@GSI



KAOS@MAMI







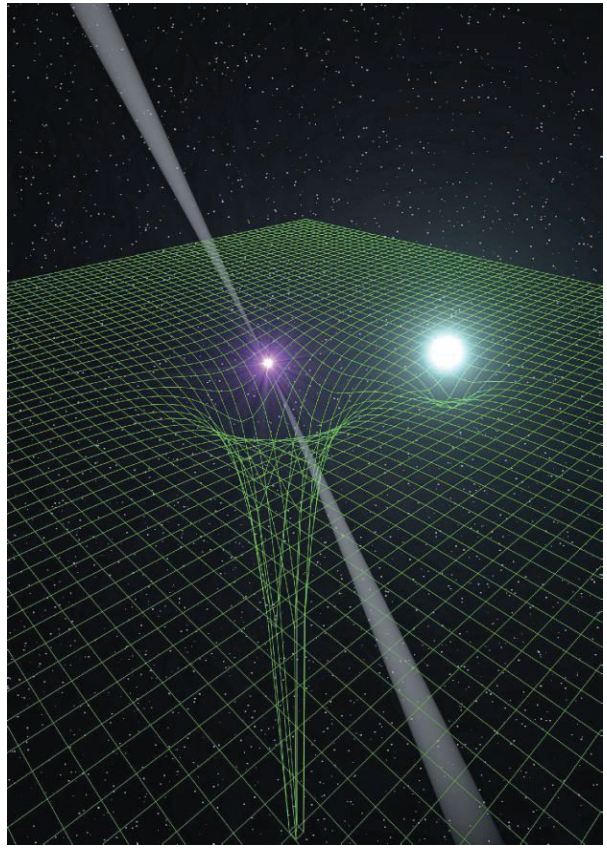
${}^{4}_{\Lambda}$H pion peak

PhD thesis F.Schulz

- Double Λ hyper nuclei

Neutron stars (in the lab?)

- Huge densities offer a unique combination of all fundametal forces
- Recent observation of high mass neutron stars [1][2] exclude many models
- Possible formation of hyperons at $2\rho_{nuc}$ (Pauli principle, Fermi energy)
- Understanding of baryon baryon interaction is very limited



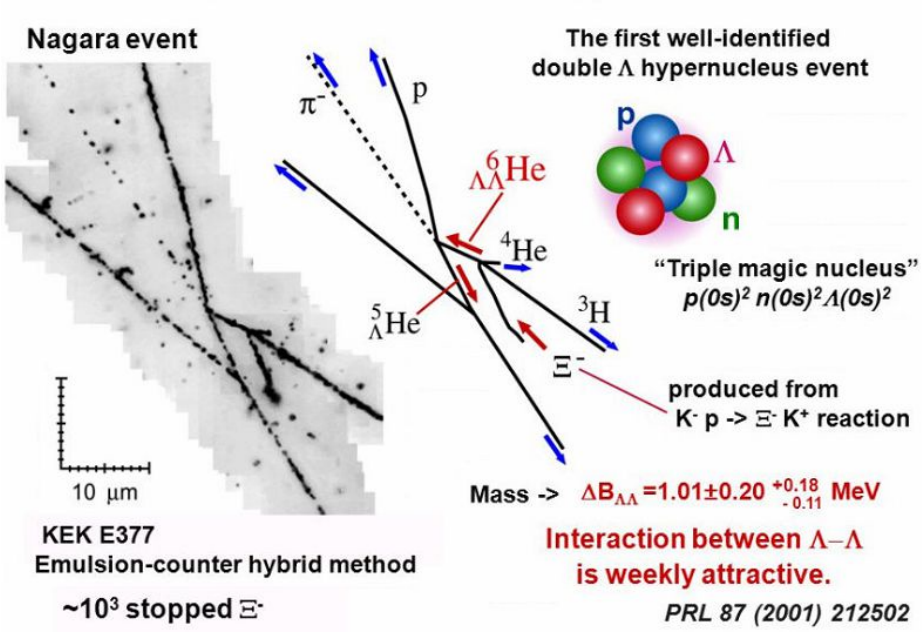
[2]

[1] P.B. Demorest, et al., Nature 467 (2010) 1081.
[2] J. Antoniadis, et al., Science 340 (2013) 1233232.

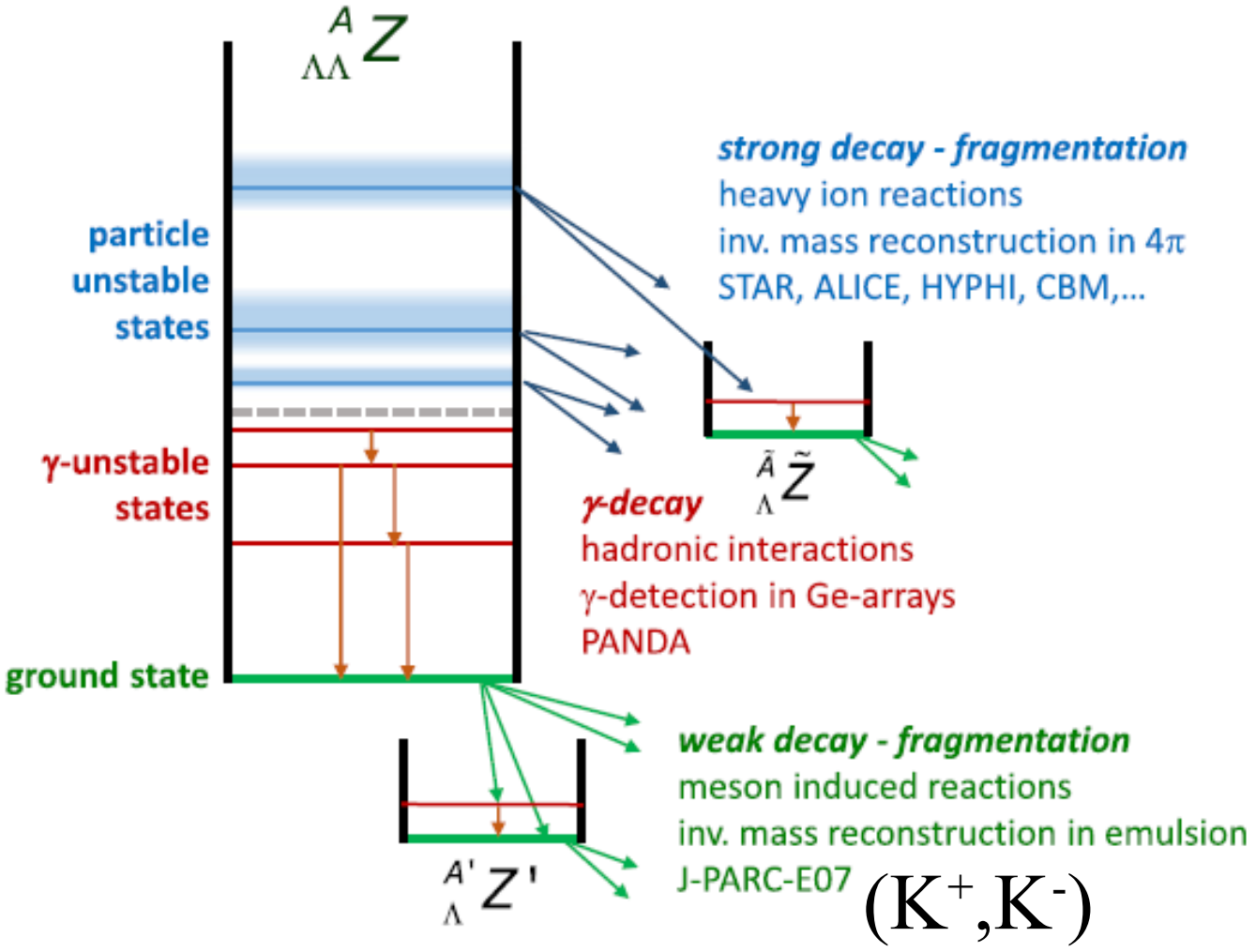
Double Λ hyper nuclei

- Until now only found in emulsion experiments
- Information based on SINGLE(!!!) events
- Experiments @ BNL and J PARC still not fully electronic

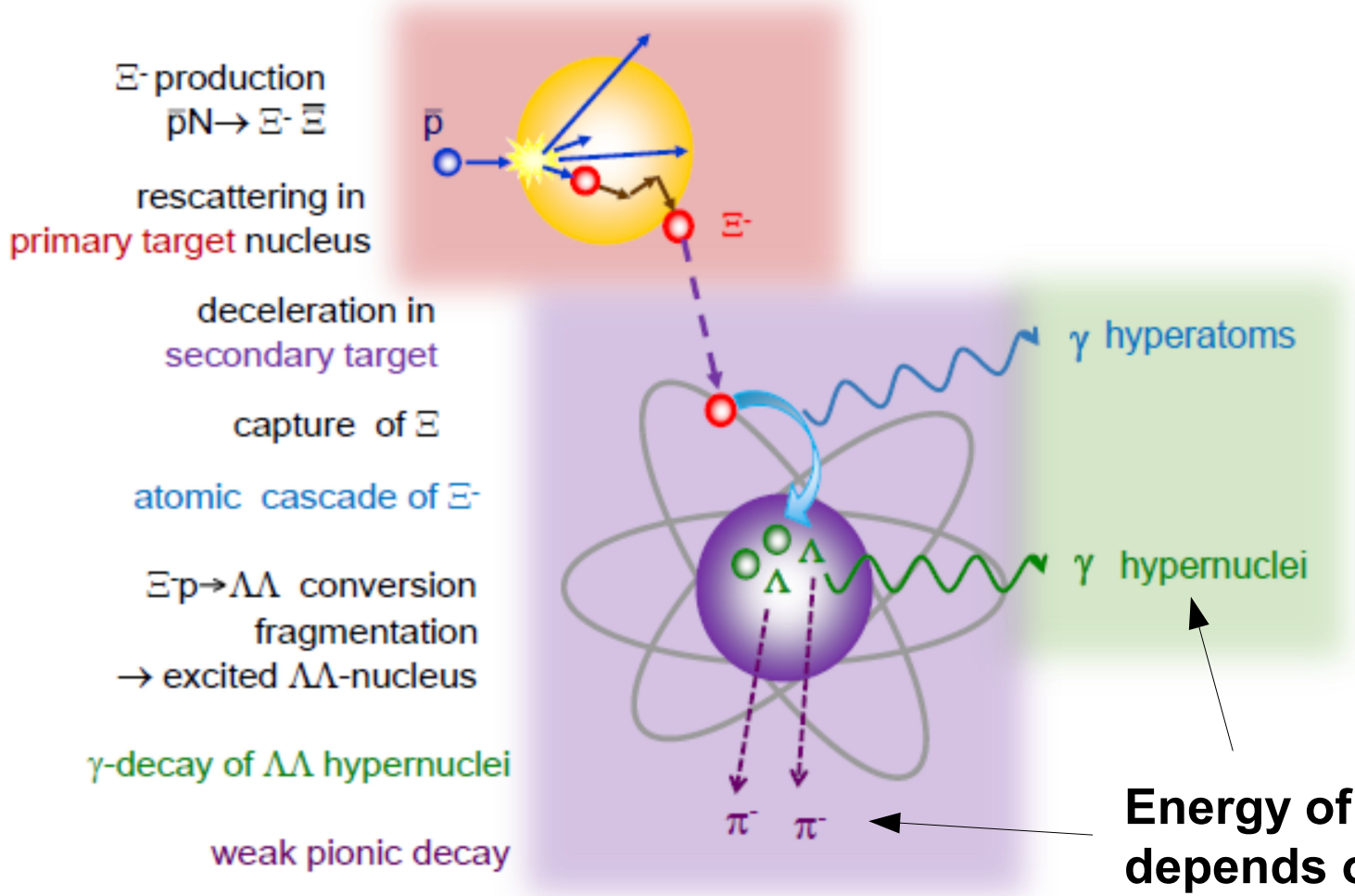
Nucleus	$\Delta B_{\Lambda\Lambda}({}^{A}_{\Lambda\Lambda}Z)$ (MeV)	Reference
${}^{6}_{\Lambda\Lambda}$He	4.7 ± 0.6	Prowse (1966) [50]
${}^{6}_{\Lambda\Lambda}$He	$1.01 \pm 0.20^{+0.18}_{-0.11}$	KEK-E373 (2001) [53, 54]
${}^{10}_{\Lambda\Lambda}$Be	4.3 ± 0.4	Danysz (1963) [49]
${}^{10}_{\Lambda\Lambda}$Be	-4.9 ± 0.7	KEK-E176 (1991) [53, 54]
${}^{13}_{\Lambda\Lambda}$B	4.8 ± 0.7	KEK-E176 (1991) [53, 54]



Experimental landscape of ΛΛ hyper nuc



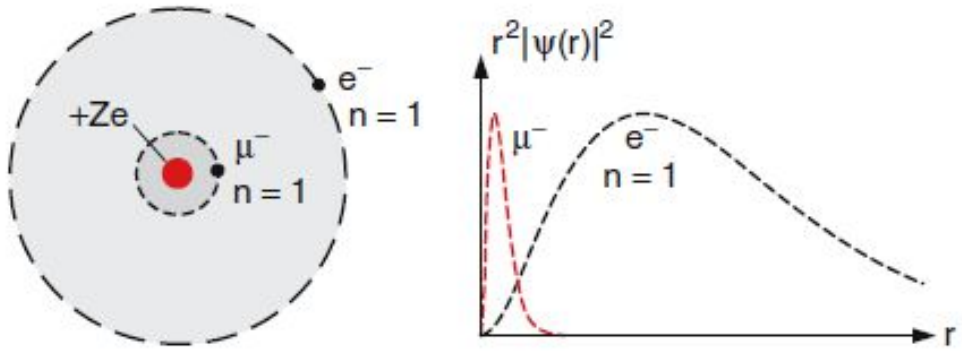
Production of hypernuclei at PANDA



Energy of γ and pions depends on the ΛΛ binding energy

Hyper atoms

- Similar to μ atoms
- Atom with Ξ^- in atomic shell
- Heavier particle closer to/inside the nucleus



Hyper atoms

- X-rays calculated via QED
- Last transition affected by strong interaction
- Shift and Width depend on Ξ^- - nucleus interaction
- Measurement needs high precision!

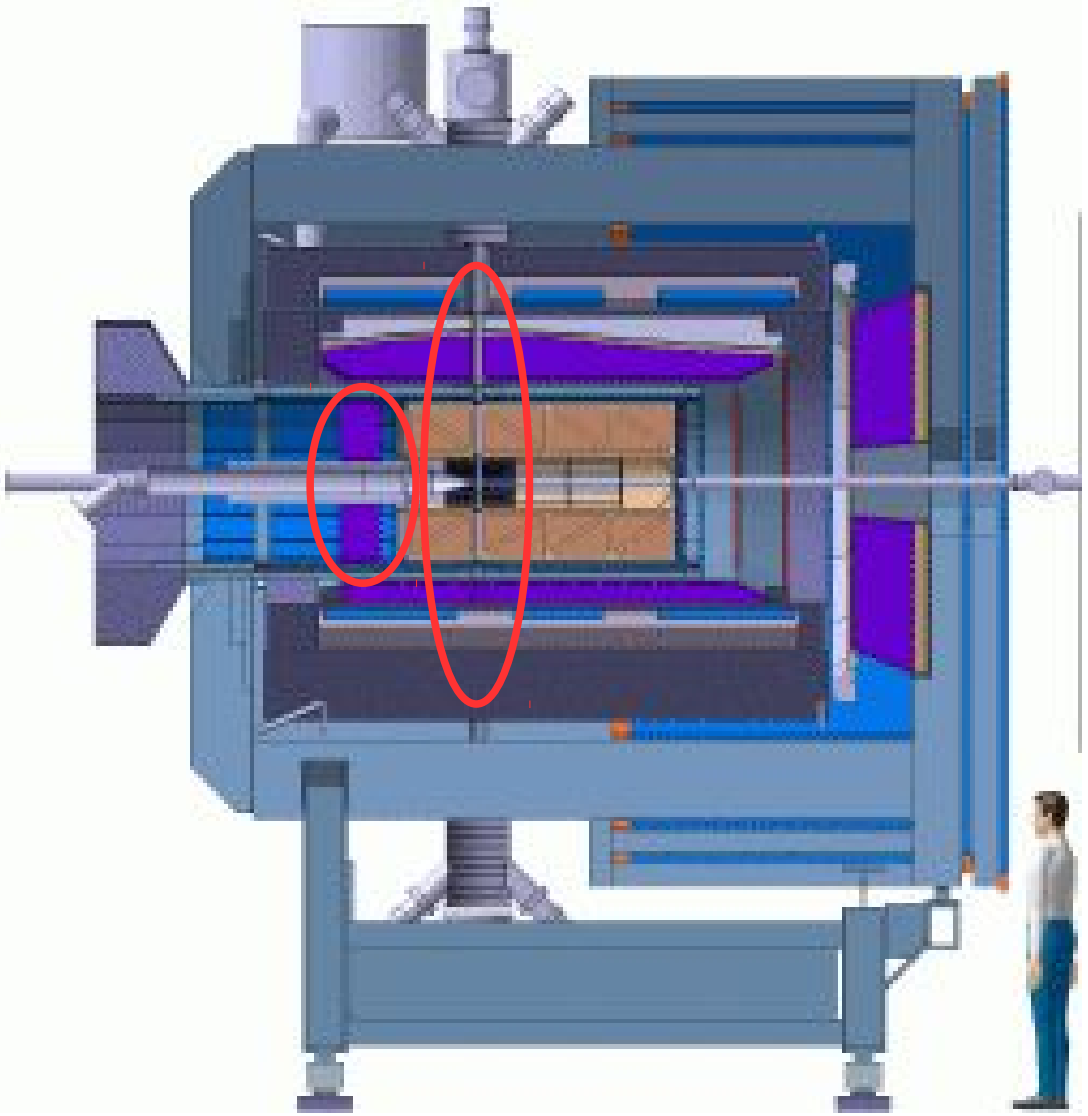
Target	F	Cl	Sn	I	Pb
Transition	$4F \rightarrow 3D$	$5G \rightarrow 4F$	$8J \rightarrow 7I$	$8J \rightarrow 7I$	$10L \rightarrow 9K$
E_x (keV)	131.29	223.55	420.25	474.71	558.47
Y	0.31	0.37	0.76	0.43	0.58
Shift (keV)	1.56	1.84	0.67	2.79	1.73
Width (keV)	0.99	1.14	0.43	2.21	1.26

C. J. Batty, E. Friedman, and A. Gal, Phys. Rev. C 59, 295

Recipe for hyper atoms/nuc. at PANDA

1) **Remove:**

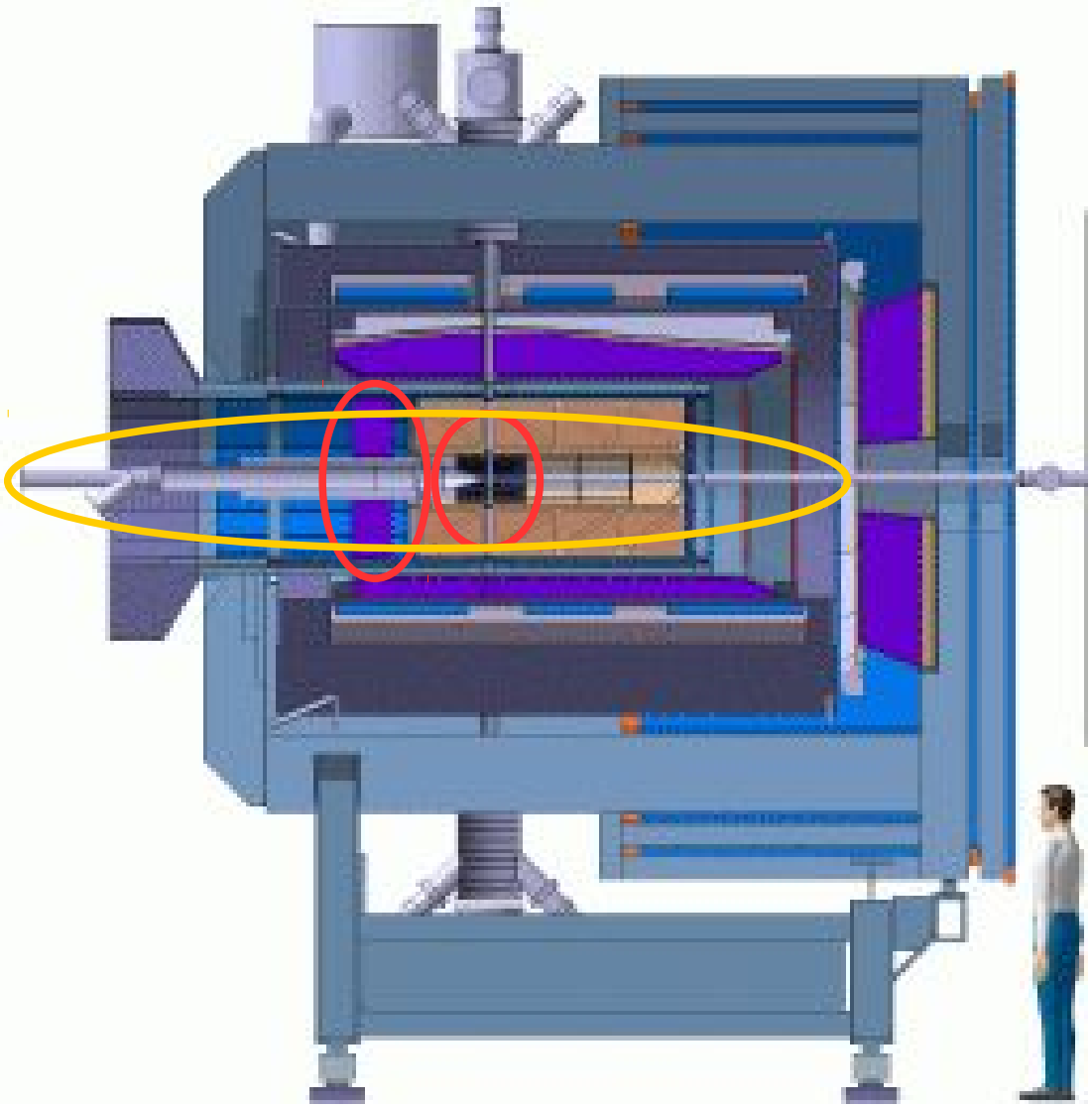
- MVD
- Backward EMC
- Target



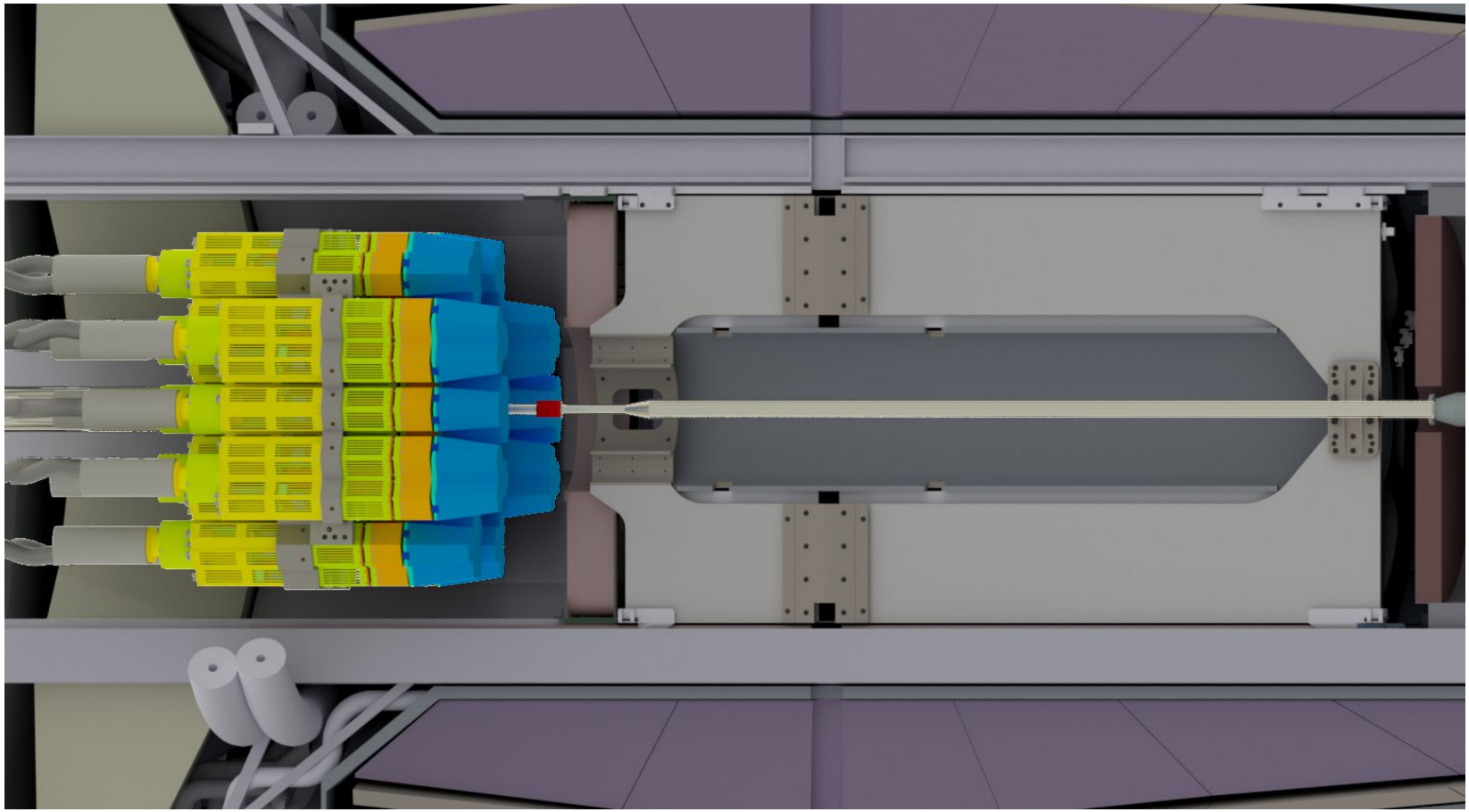
Recipe for hyper atoms/nuc. at PANDA

2) **Modify:**

- Beam pipe



Recipe for hyper atoms/nuc. at PANDA

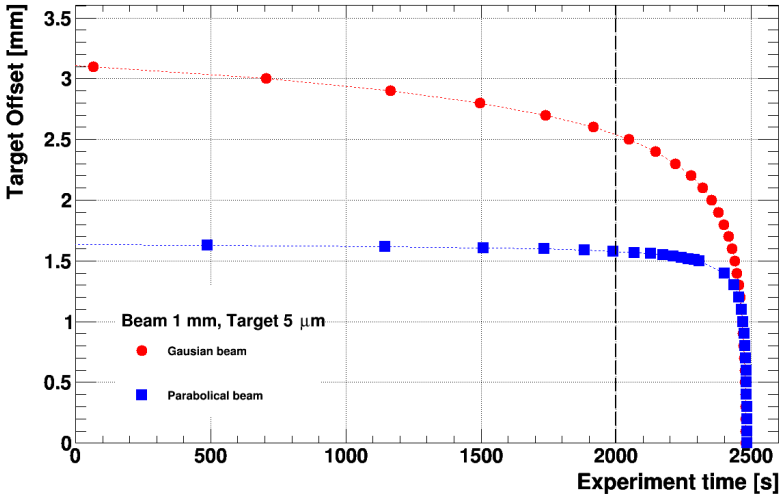


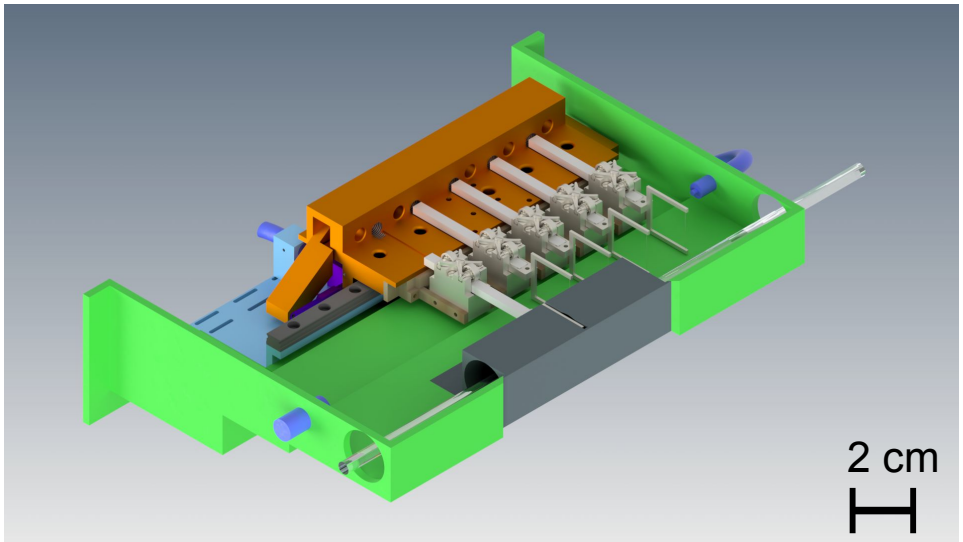
3) **Add:**

- Two-staged, active Target system
- PANGEA (Germanium detectors)

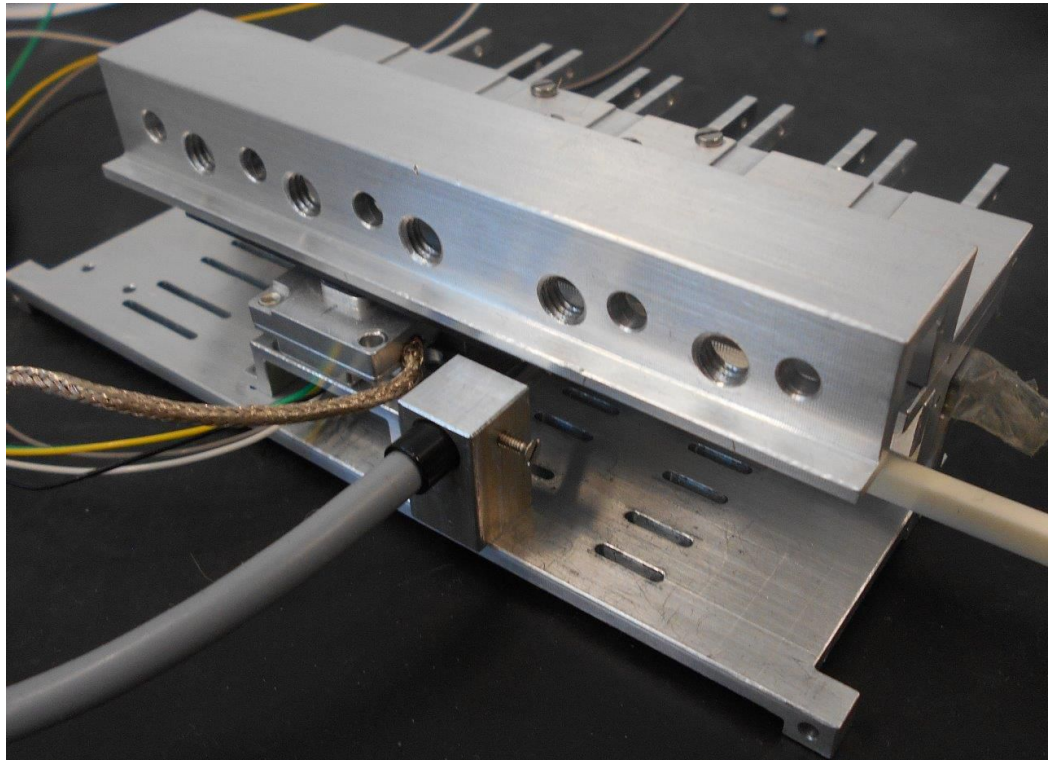
Primary target

- Primary carbon filament target
- Movable perpendicular to the beam
  - Constant luminosity
  - Save / replace targets
- 5 spare targets movable in beam direction
- Light based positioning

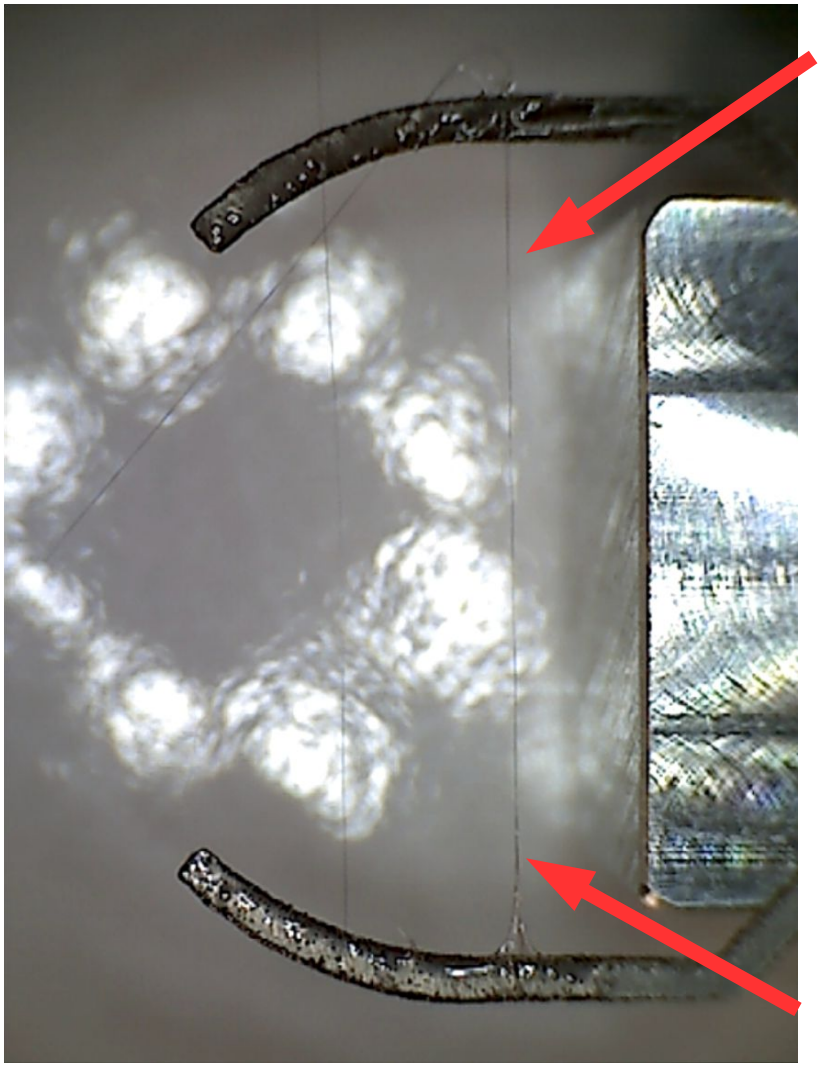




Primary target – Recent impressions



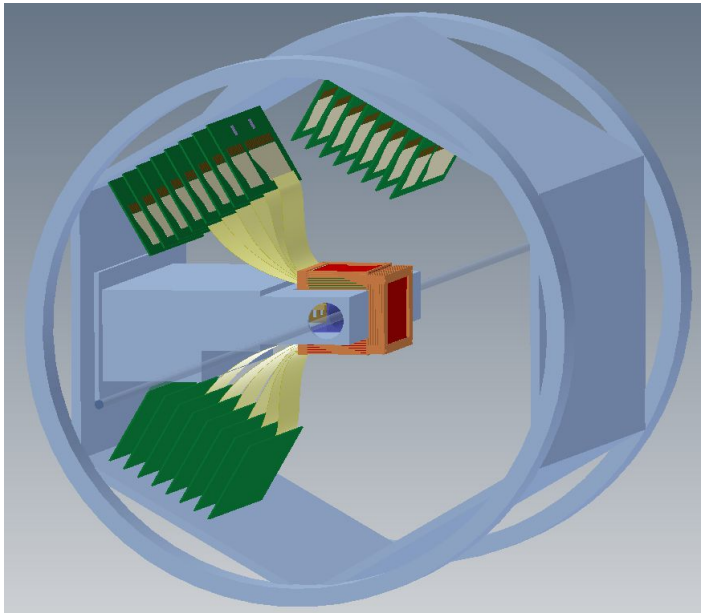
Mechanical prototype

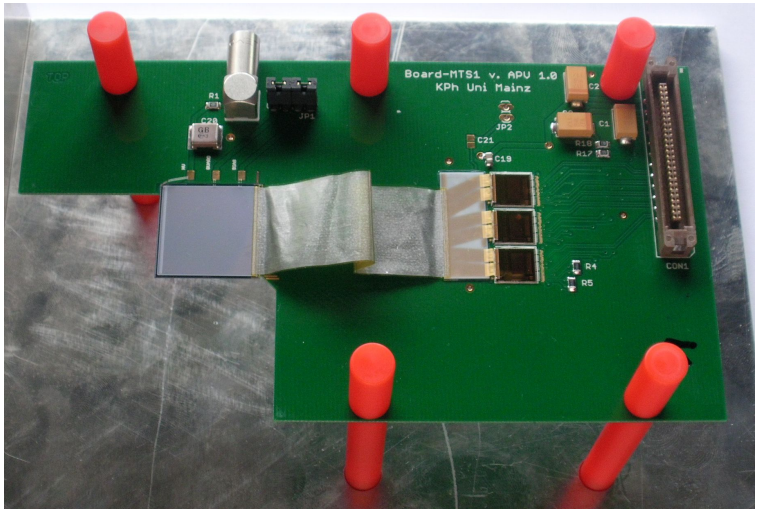


First filament glueing tests

Secondary target – hyper nuclei

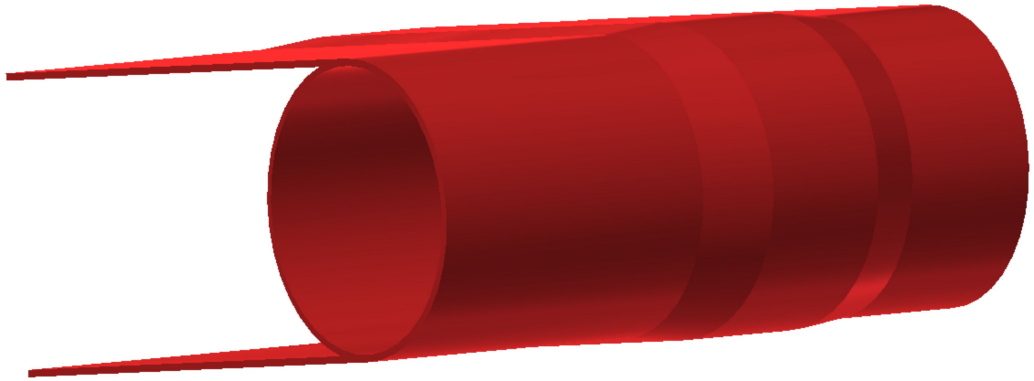
- First absorbers are part of beam pipe
- Sandwich of absorber and Si-strip-detectors
- 3 blocks (7 Si + 4 absorber each)
- Fanned out electronics

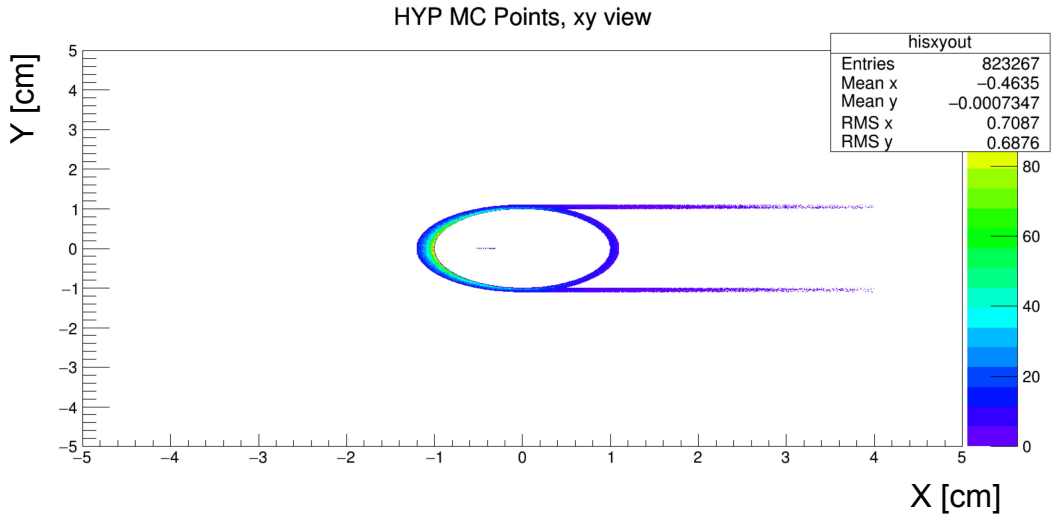




Secondary target – hyper atoms

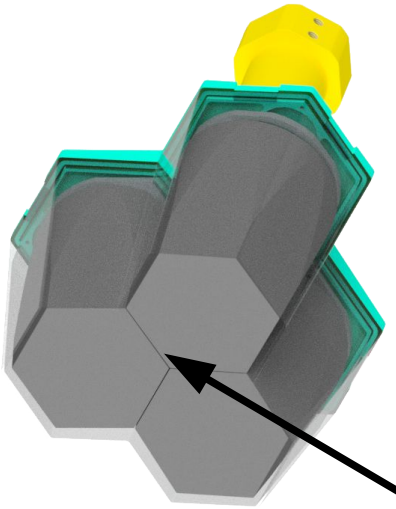
- Single iron absorber
- Part of the beam pipe
- Si-trackers around
- Geometry optimized on:
  - High Ξ^- absorption
  - Low X-ray absoption

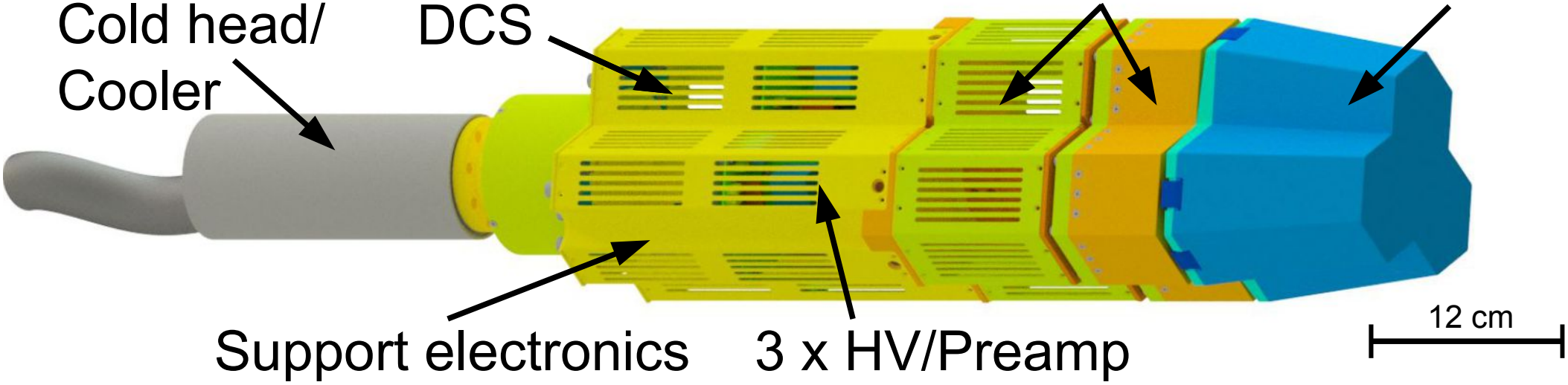




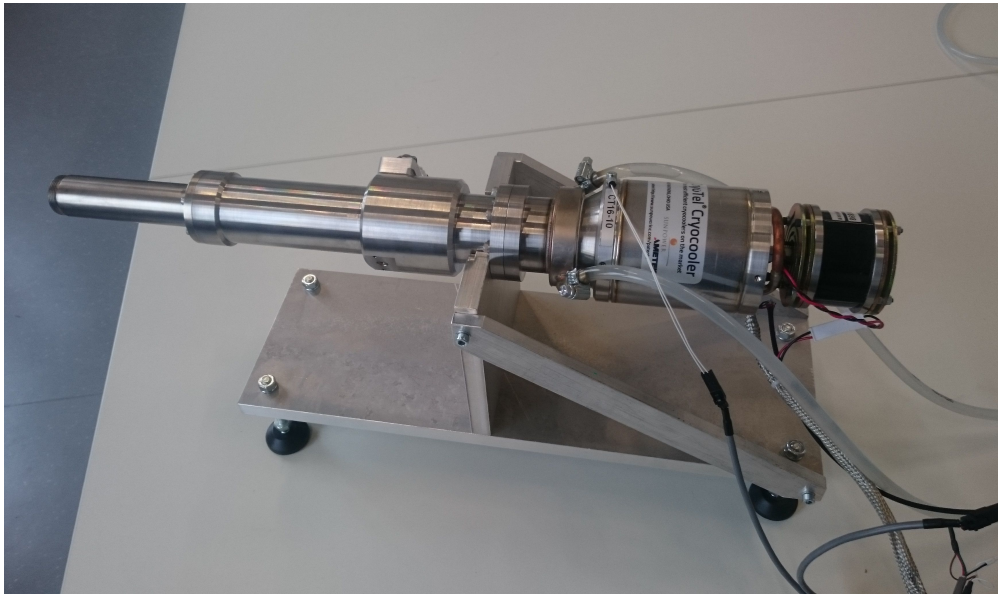
PANGEA – PAnda GErmanium Array

- 20 individual detectors,
  3 crystals each
- Electro-mech. Cooling (~LN2 temperatures)
- Fully integrated design
- Very rough conditions for Ge detectors

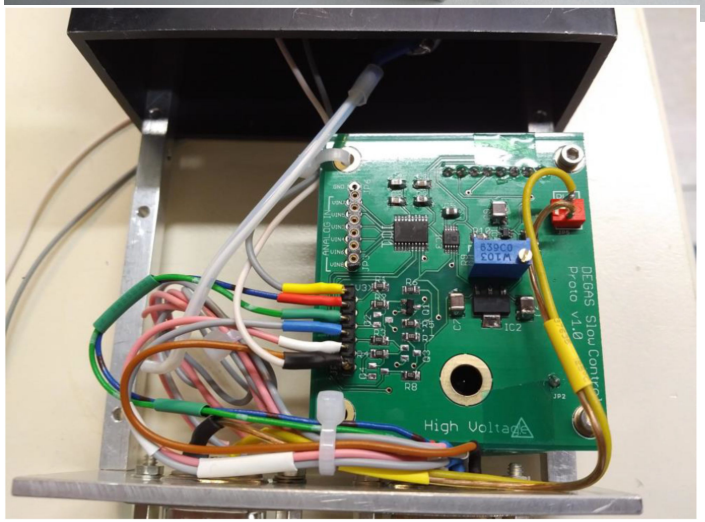




Detector head components



Cooler test (Sunpower CT)



HV module

Summary

- Strange systems offer unique ways to study the baryon baryon interaction
- Multiple ways to produce and study hyper nuclei /atoms
- PANDA is the first fully electronic experiment for double hyper nuclei

Thanks for your attention

Backup slides