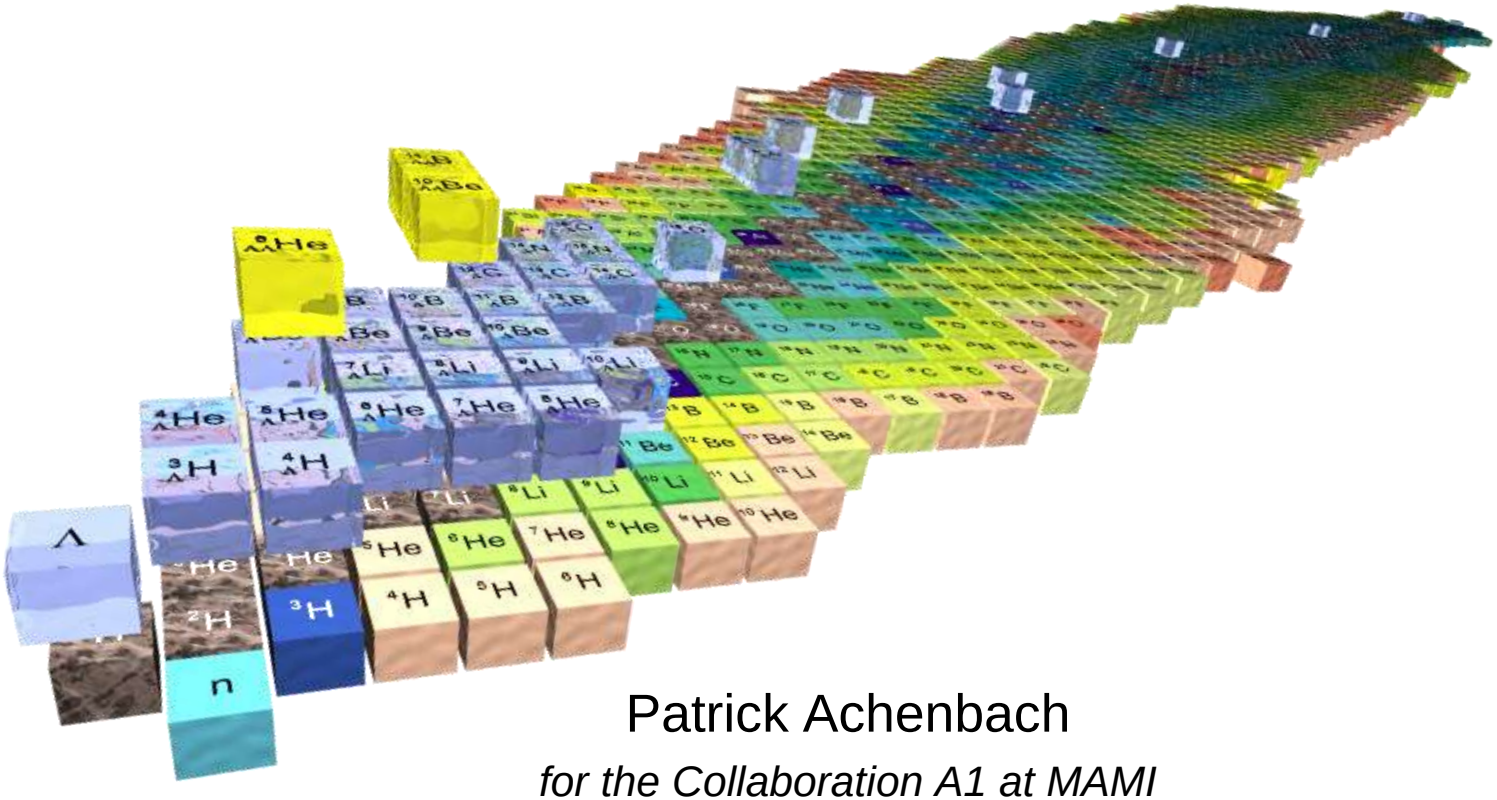
A roadmap to hypernuclear physics at MAMI and PANDA



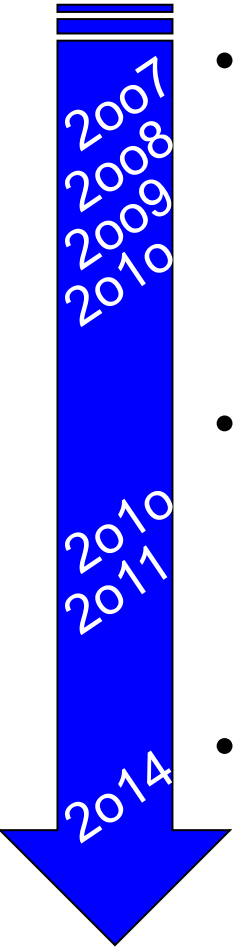
Patrick Achenbach

for the Collaboration A1 at MAMI

and the PANDA group at U Mainz

April 2oo9

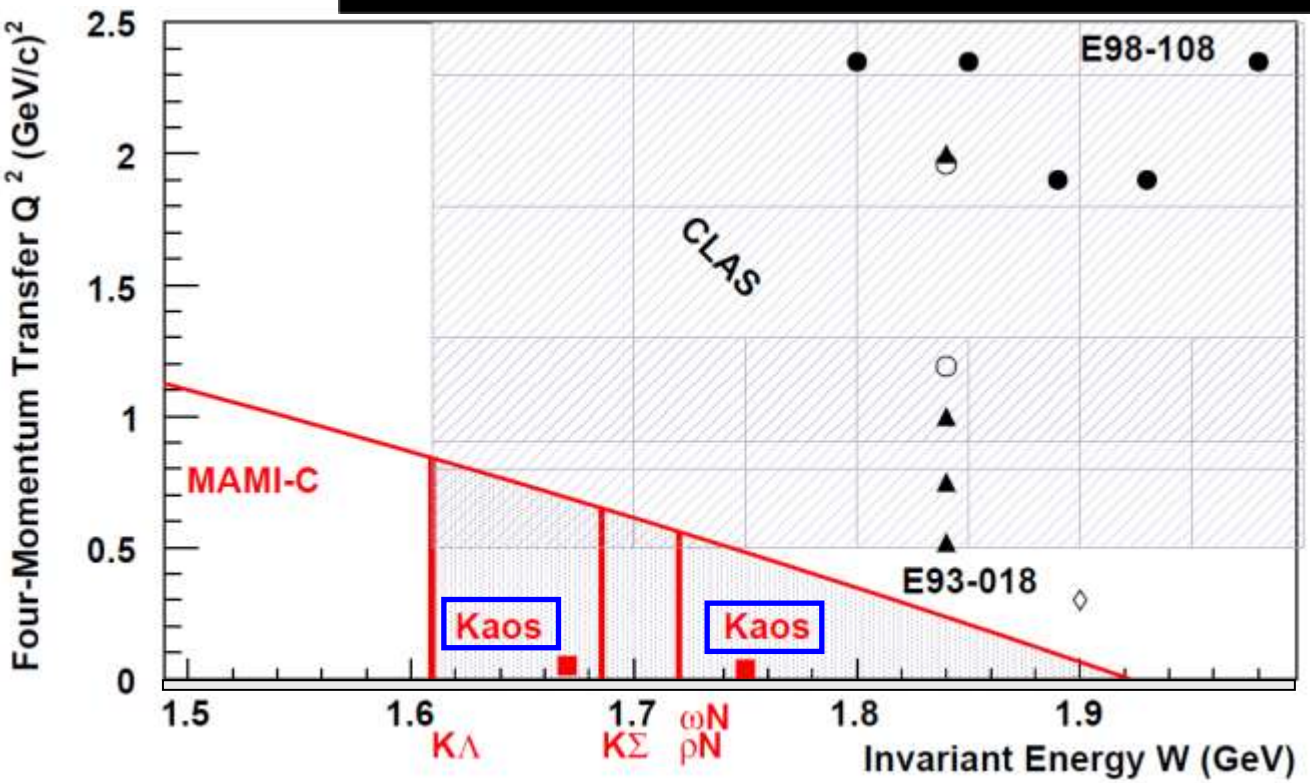
Tour d'horizon



- open strangeness electro-production at MAMI
  - installation and commissioning of the KAOS spectrometer in 2007/08
  - reaction spectroscopy at two kinematic settings with low Q^2 in 2008/09
  - forward scattering angle measurements scheduled for 2010
- roadmap to hypernuclei electro-production at MAMI
  - operation of KAOS as double spectrometer under zero degree in 2010
  - pilot hypernuclear experiment at MAMI in 2010/11
- preparations for hypernuclear experiments at PANDA
  - the Mainz group involvement in the hypernuclear programme

Kaon electro-production

Kaon electro-production measurements



[E93-018: R. M. Mohring *et al.*, *Phys. Rev. C 67*, 055205 (2003); reanalysis in G. Niculescu *et al.*, *Phys. Rev. Lett. 81*, 1805 (1998).

E98-108: M. Coman, PhD thesis, Florida International University, 2005 (unpublished).

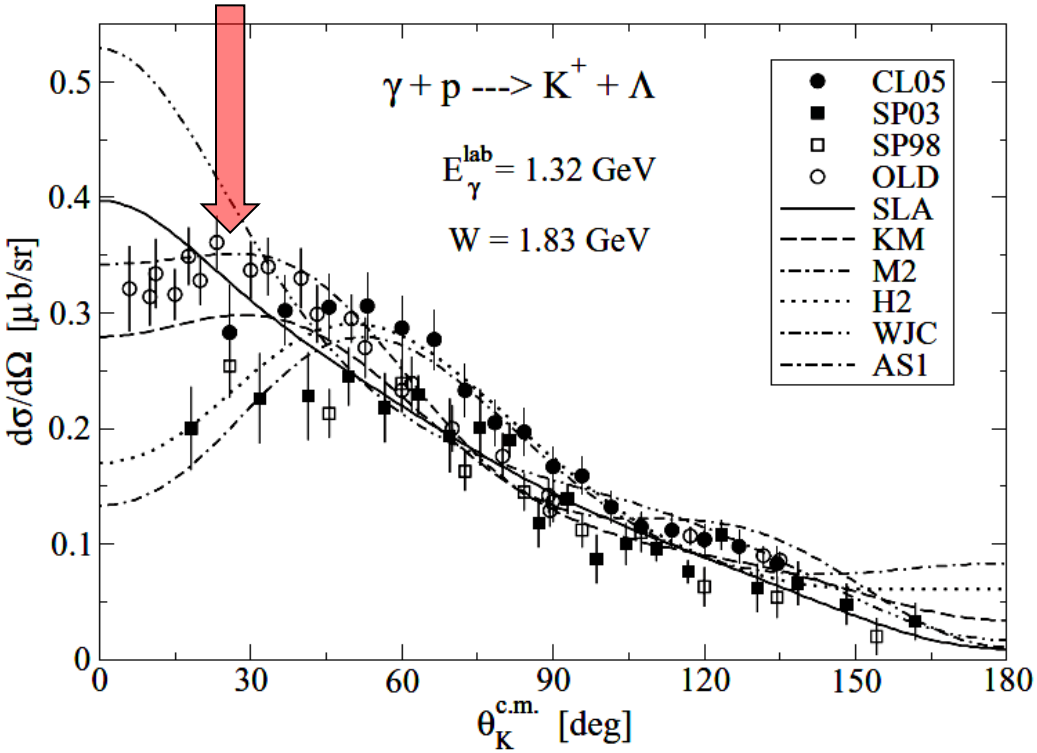
CLAS: Ambrozewicz *et al.*, *Phys. Rev. C 75*, 045203 (2007).]

←*photo-production*

virt. photon				beam	electron arm		kaon arm	
$\langle Q^2 \rangle$ $(\mathrm{GeV}/c)^2$	$\langle W \rangle$ GeV	$\langle \epsilon \rangle$ (trans.)	$\langle \omega \rangle$ GeV	E_e GeV	$\langle q_{e'}^{lab} \rangle$ GeV/c	$\langle \theta_{e'}^{lab} \rangle$ deg	$\langle p_K^{lab} \rangle$ GeV/c	$\langle \theta_K^{lab} \rangle$ deg
0.050	1.670	0.540	1.044	1.508	0.455	15.8	Λ : 0.466	-31.5
0.036	1.750	0.395	1.182	1.508	0.318	15.5	Λ : 0.642	-31.5
							Σ : 0.466	

Kaon production at forward angles

Planned measurements with Kaos at MAMI in 2oo9 and 2o1o



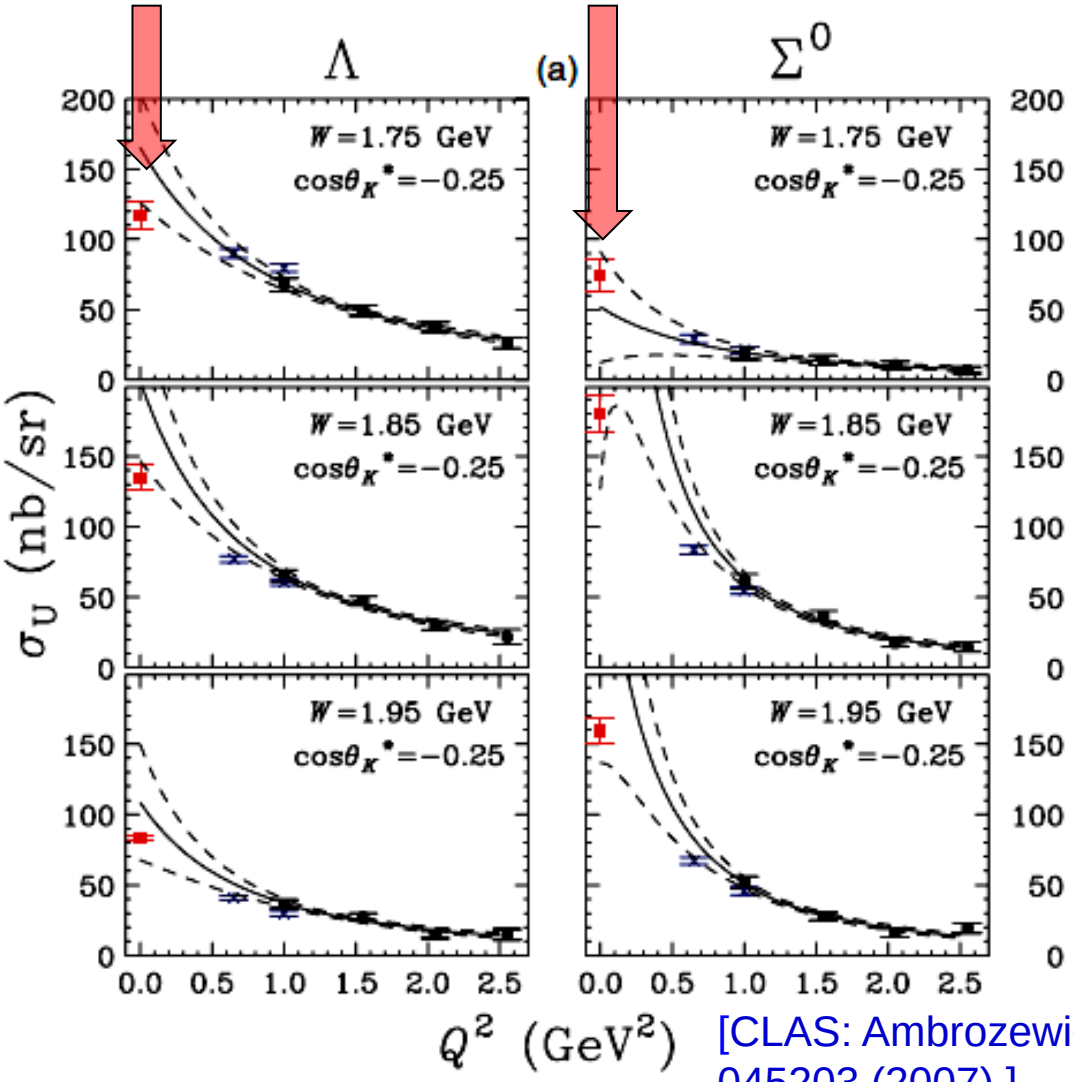
Name	Observable	Symbol
SAPHIR 2004	Differential cross section	$d\sigma/d\Omega$
	Recoil polarization	P
	Total cross section	σ_{tot}
CLAS 2006	Differential cross section	$d\sigma/d\Omega$
	Recoil polarization	P
	Total cross section	σ_{tot}
LEPS 2006	Differential cross section	$d\sigma/d\Omega$
	Photon asymmetry	Σ
OLD	Target asymmetry	T
	Total cross section	σ_{tot}
Total data		

From: [T. Mart and A. Sulaksono, *Phys. Rev. C 74,* 055203 (2006).]

Data points: [K. H. Glander *et al., Eur. Phys. J. A 19,* 251 (2004).
R. Bradford *et al. (CLAS Collaboration), Phys. Rev. C 73,* 035202 (2006).
M. Sumihama *et al. (LEPS Collaboration), Phys. Rev. C 73,* 035214 (2006).
K. H. Althoff *et al., Nucl. Phys. B 137*, 269 (1978).
M. Q. Tran *et al. (SAPHIR Collaboration), Phys. Lett. B 445,* 20 (1998).]

Kaon production at low Q^2

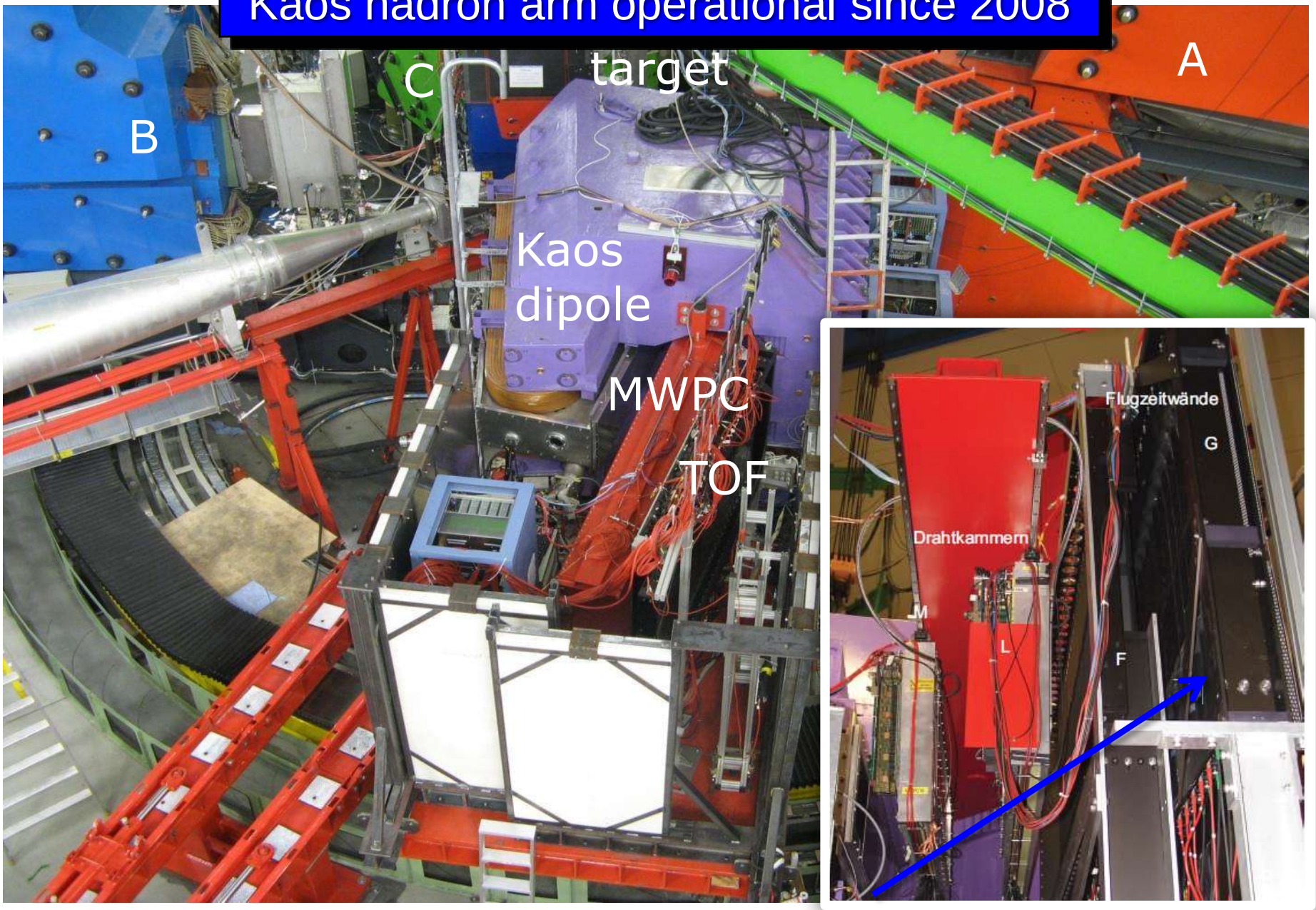
Planned measurements with Kaos at MAMI in 2oo9 and 2o1o



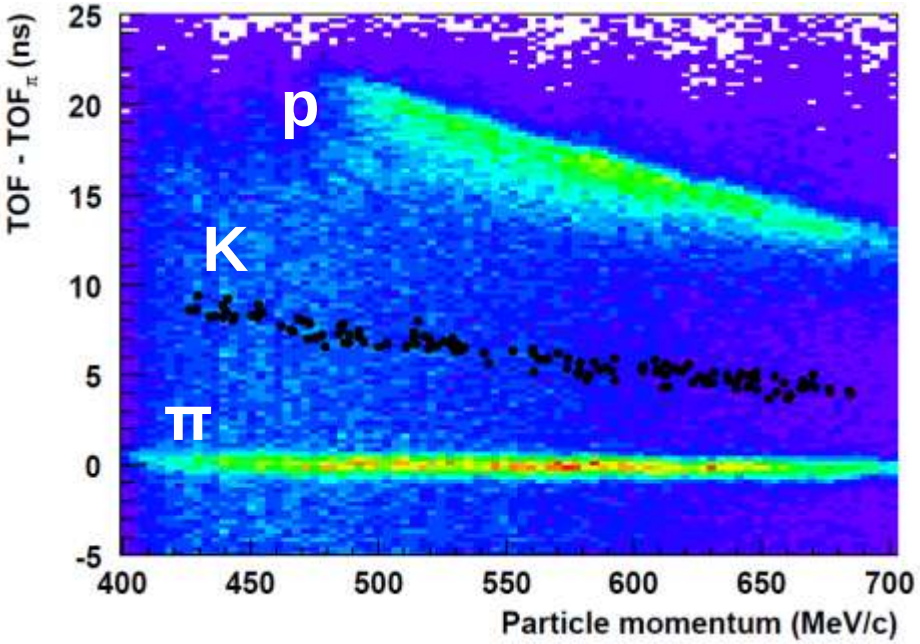
[CLAS: Ambrozewicz *et al.*, *Phys. Rev. C 75*, 045203 (2007).]

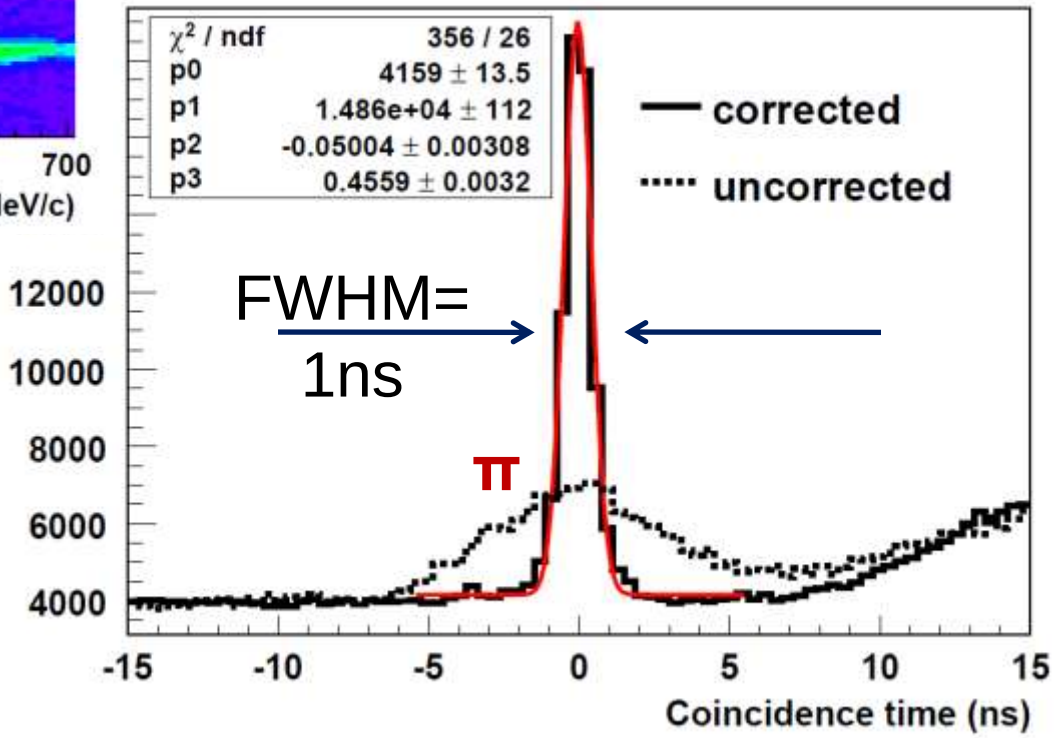
Status of the spectrometer

Kaos hadron arm operational since 2008

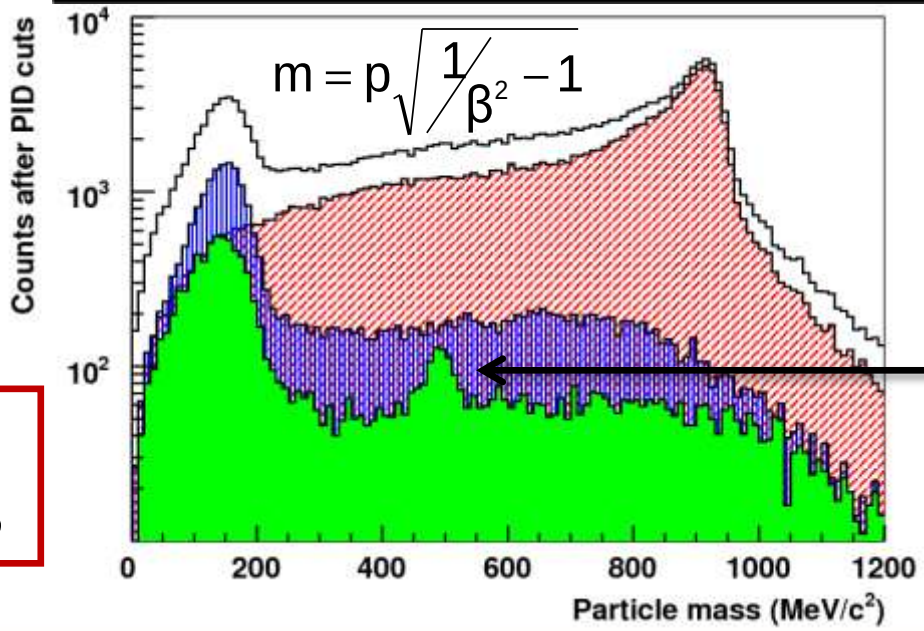


Coincidence time resolution





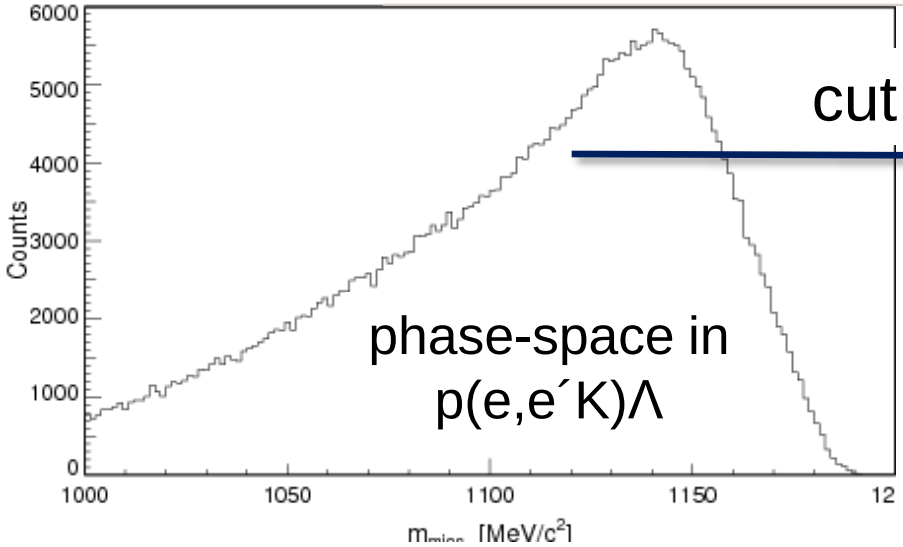
Missing Mass reconstruction



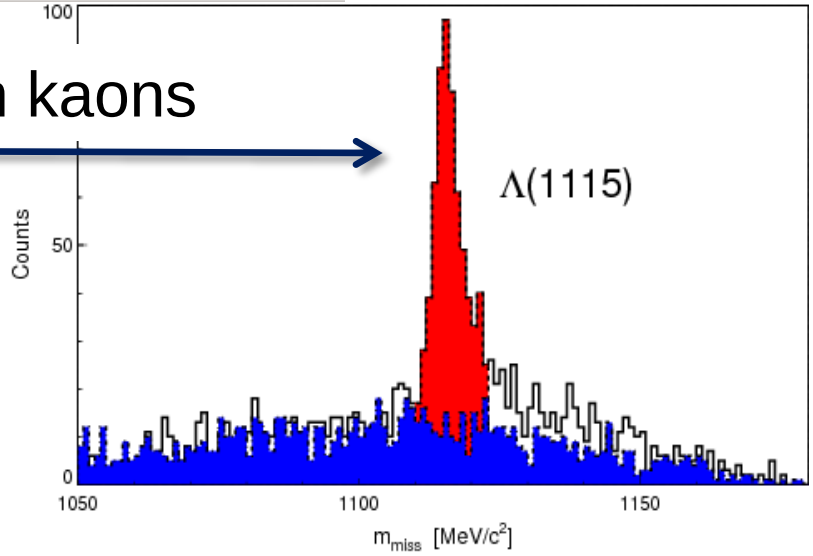
kaon peak after dE/dx cut

π : K : p =
1 : 0.03 : 1.38

[Kaos at MAMI: preliminary analysis]

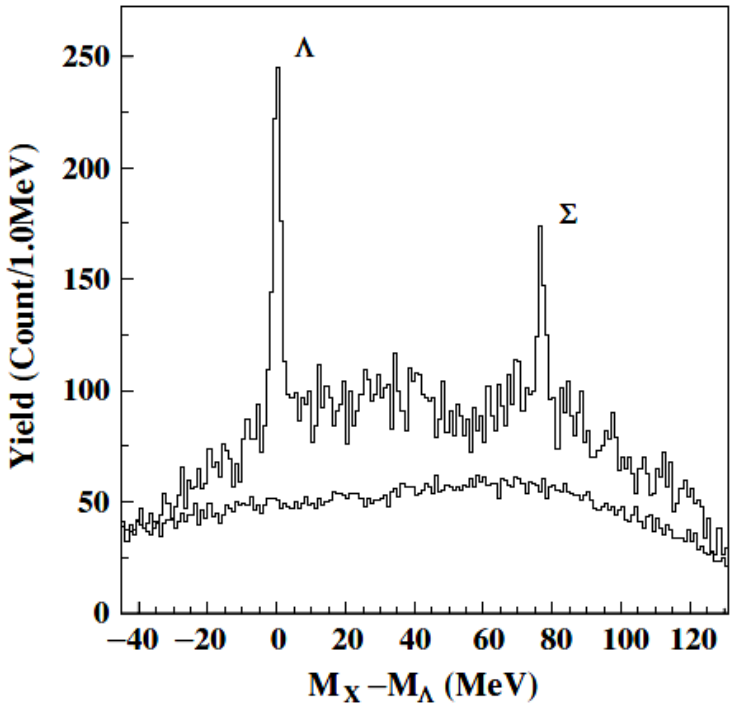


cut on kaons

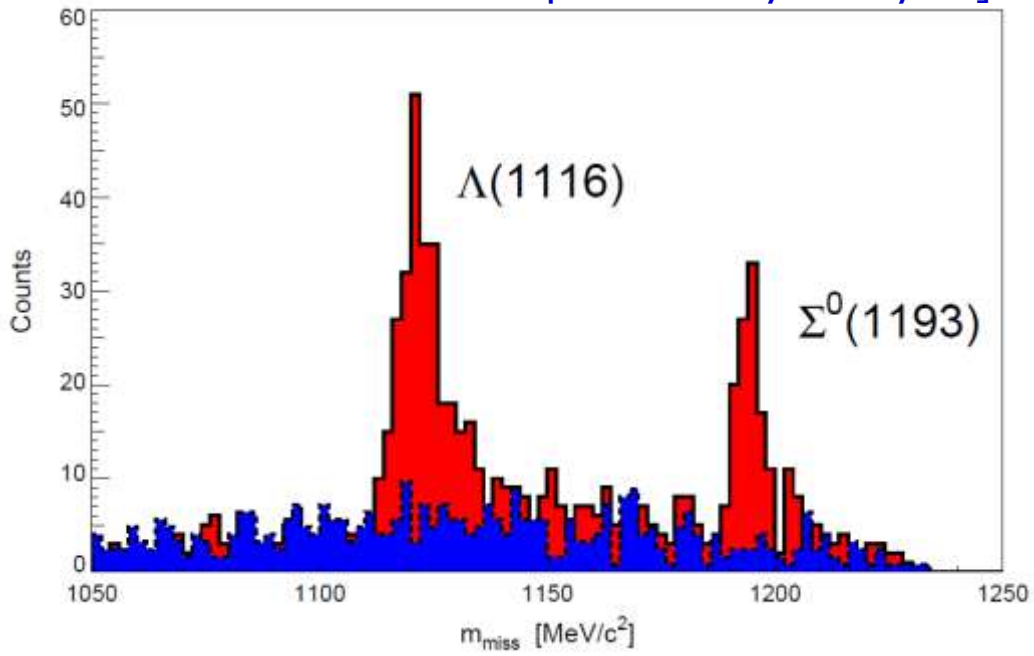


Λ- and Σ-hyperons in a single kinematic setting

[Jefferson Lab: L. Yuan et al., *Phys. Rev. C 73,* 044607 (2006).]



[Kaos at MAMI: preliminary analysis]

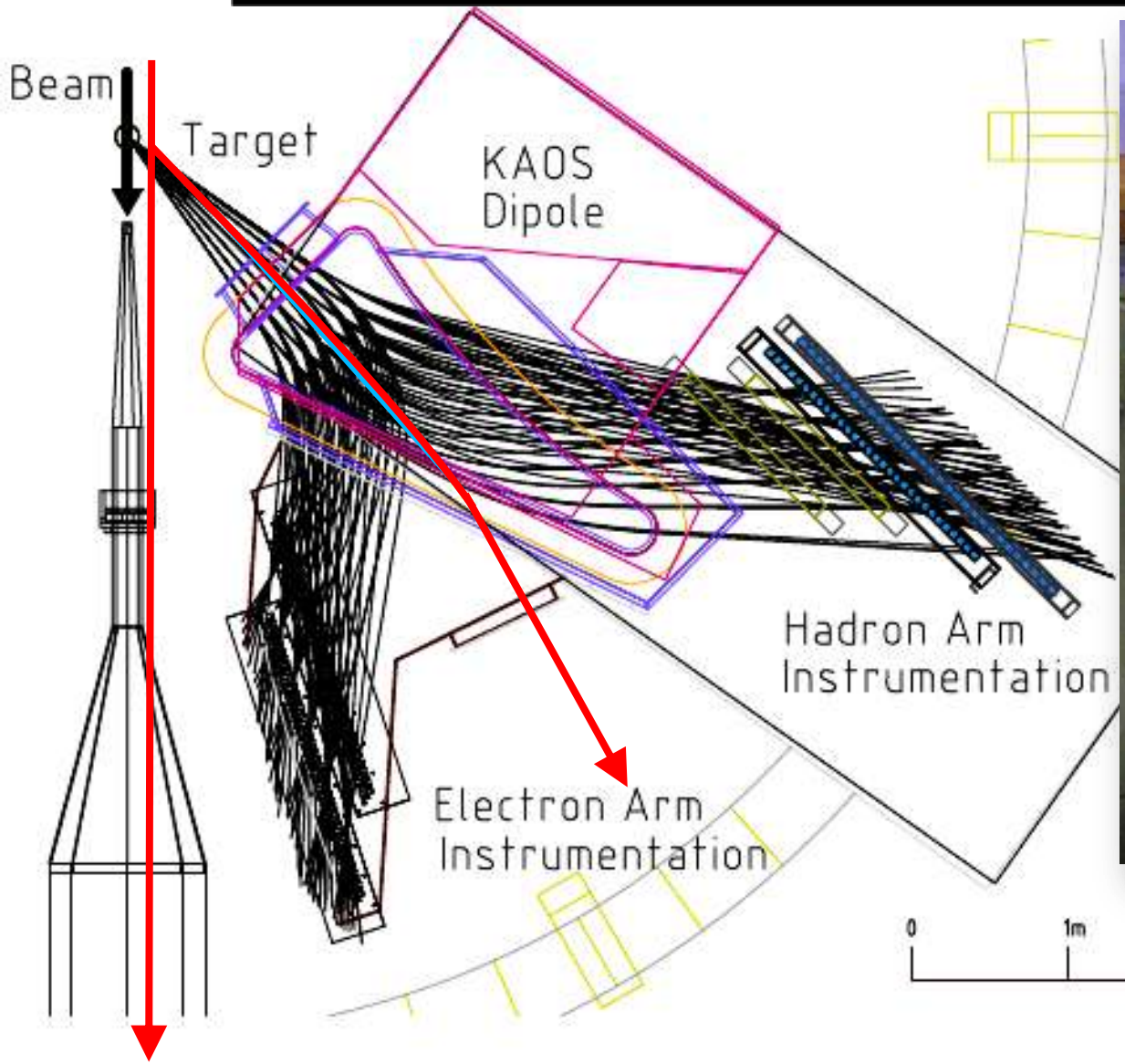


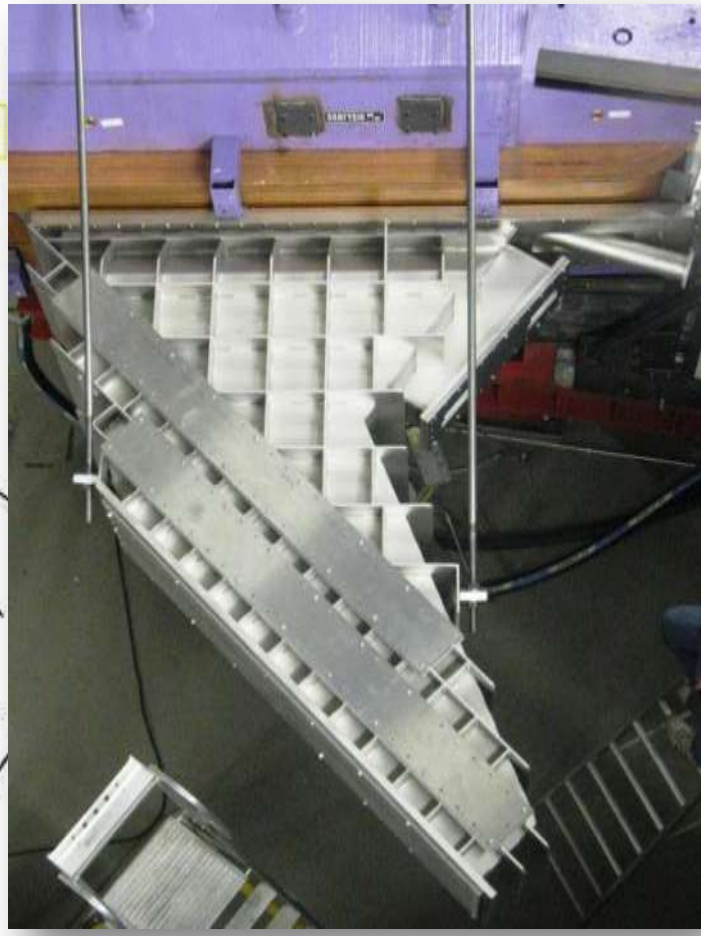
‹p_K› = 642 MeV/*c*

‹p_K› = 466 MeV/*c*

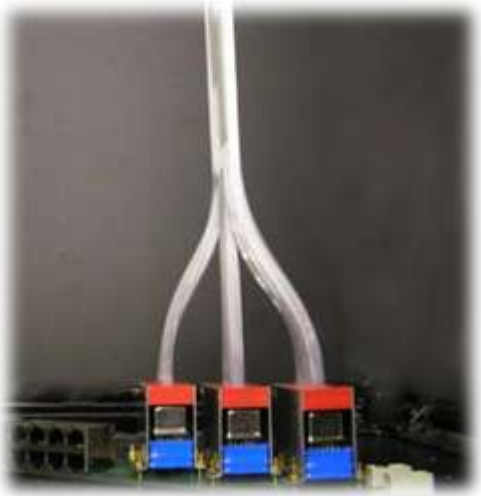
Towards a hypernuclei experiment at MAMI

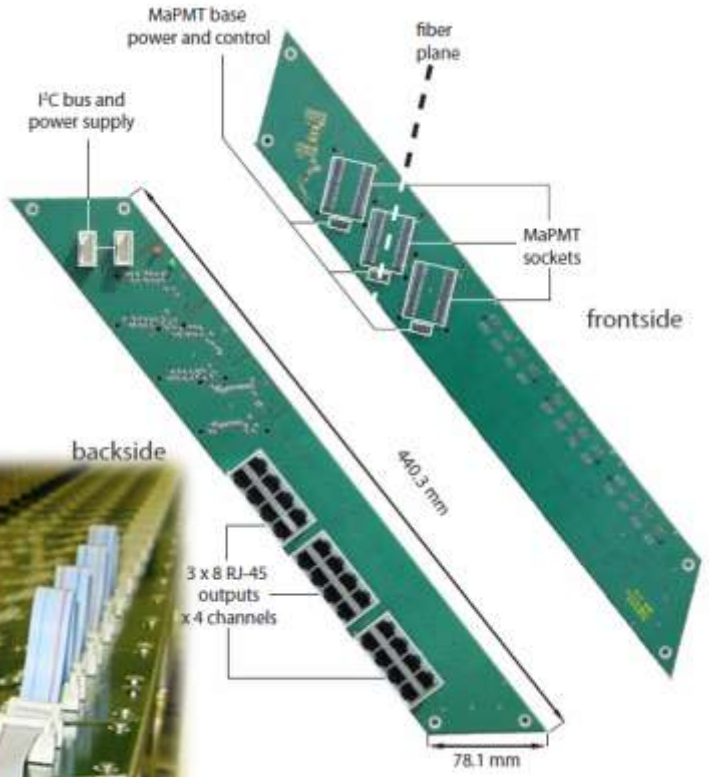
Realisation of Kaos as a double spectrometer





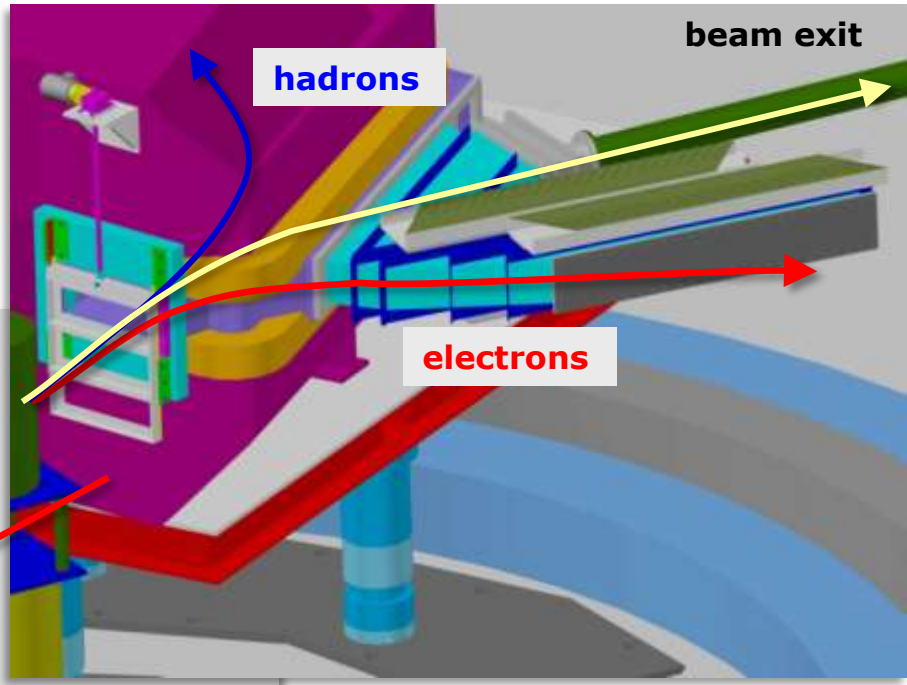
Status of the detector for the electron arm

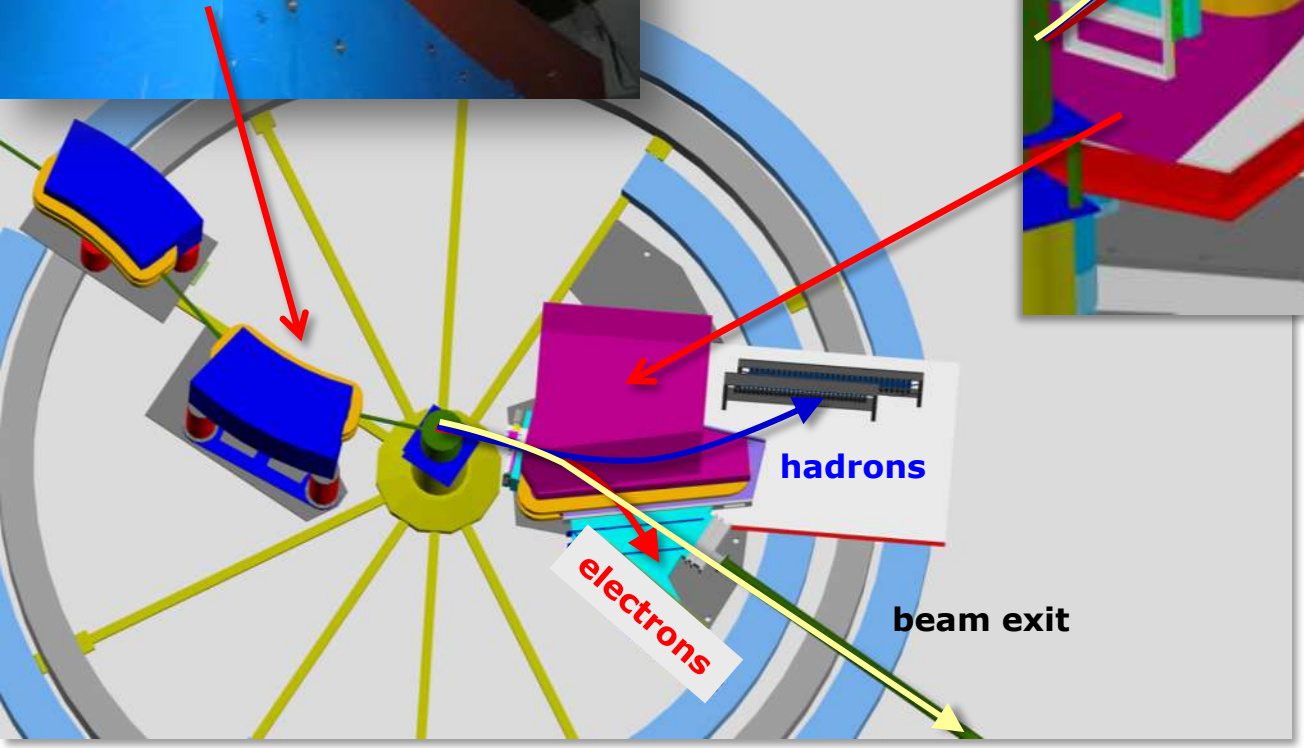




[P. Achenbach, et al., Front-end electronics for the Kaos spectrometer at MAMI, IEEE Trans. Nucl. Sci. 56 (2009)]

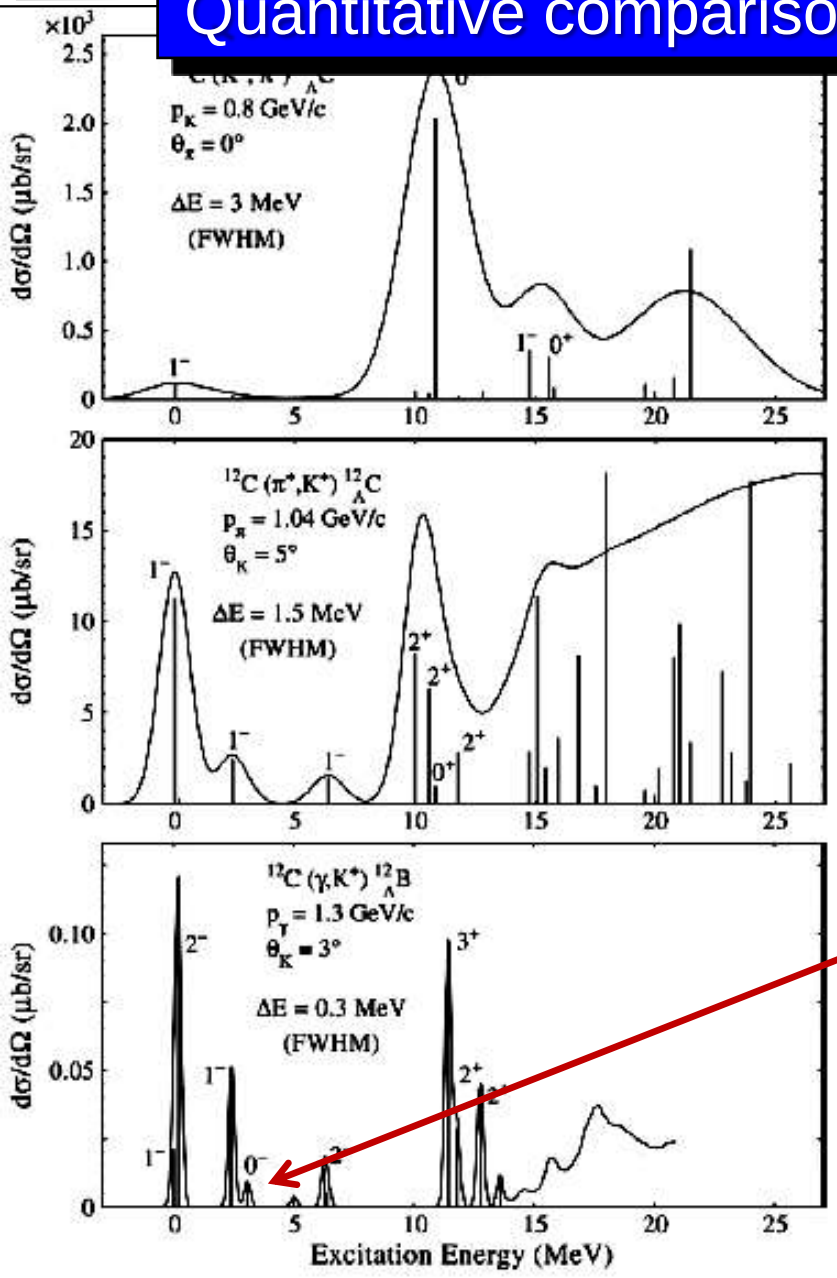
Installation of a beam chicane for zero-degree operation of KAOS





Hypernuclei electro-production

Quantitative comparison to meson production methods



The goal of the hypernuclear programme at MAMI is

- the detection of unknown (core-excited) hypernuclear states
- and the measurement of kaon angular distributions

experimental requirements:

→ missing mass resolution δmm <1 MeV/c²

→ large kaon angle acceptance

[O. Hashimoto and H. Tamura, *Prog. Part. Nucl. Phys. 57,* 564 (2006).]

Jefferson Lab hypernuclear spectra (available 2oo9)

[F. Dohrmann *et al.*, *Phys. Rev. Lett. 93*, 242501 (2004).

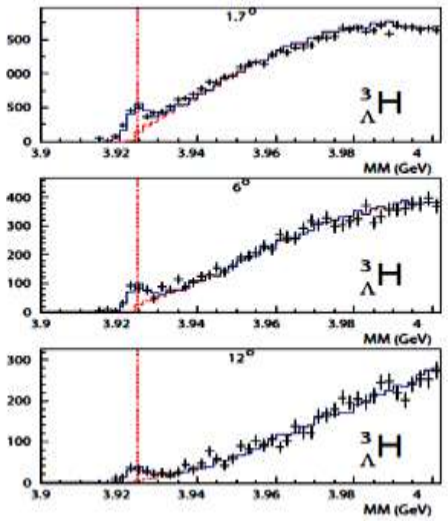
L. Yuan *et al.*, *Phys. Rev. C 73,* 044607 (2006).

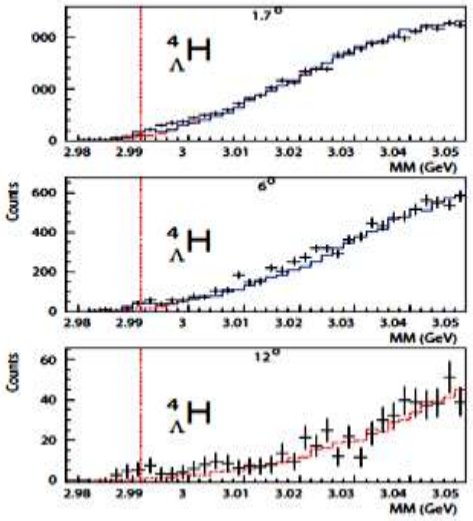
J. J. LeRose *et al.*, *Nucl. Phys. A 804*, 116 (2008).

F. Cusanno *et al.*, arXiv:0810.3853 [nucl-ex].

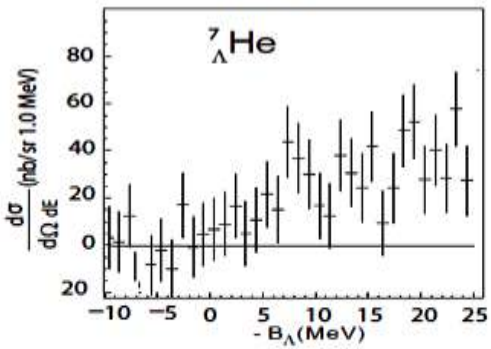
O. Hashimoto, Proc. Int. Conf. Hypernuclear and Strange Particles 2006 (HYP06), pp. 41-46, Springer 2007.]

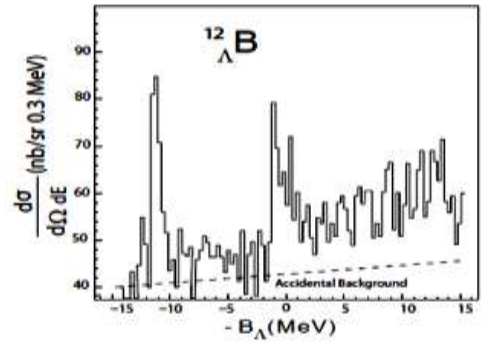
Hall C

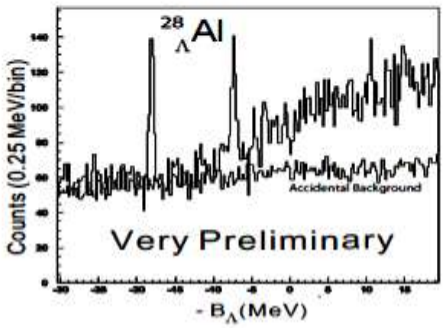




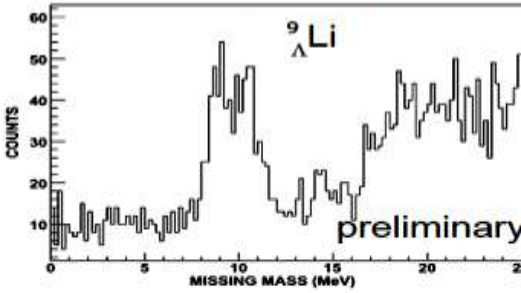
Hall C

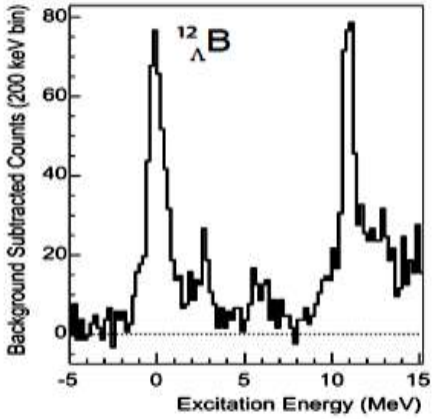


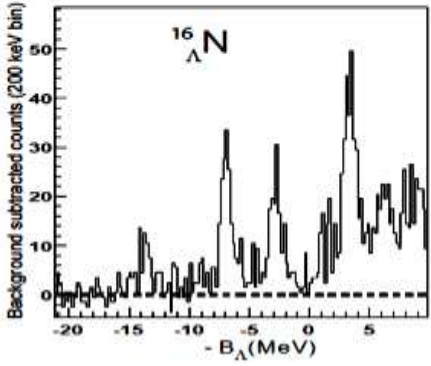




Hall A

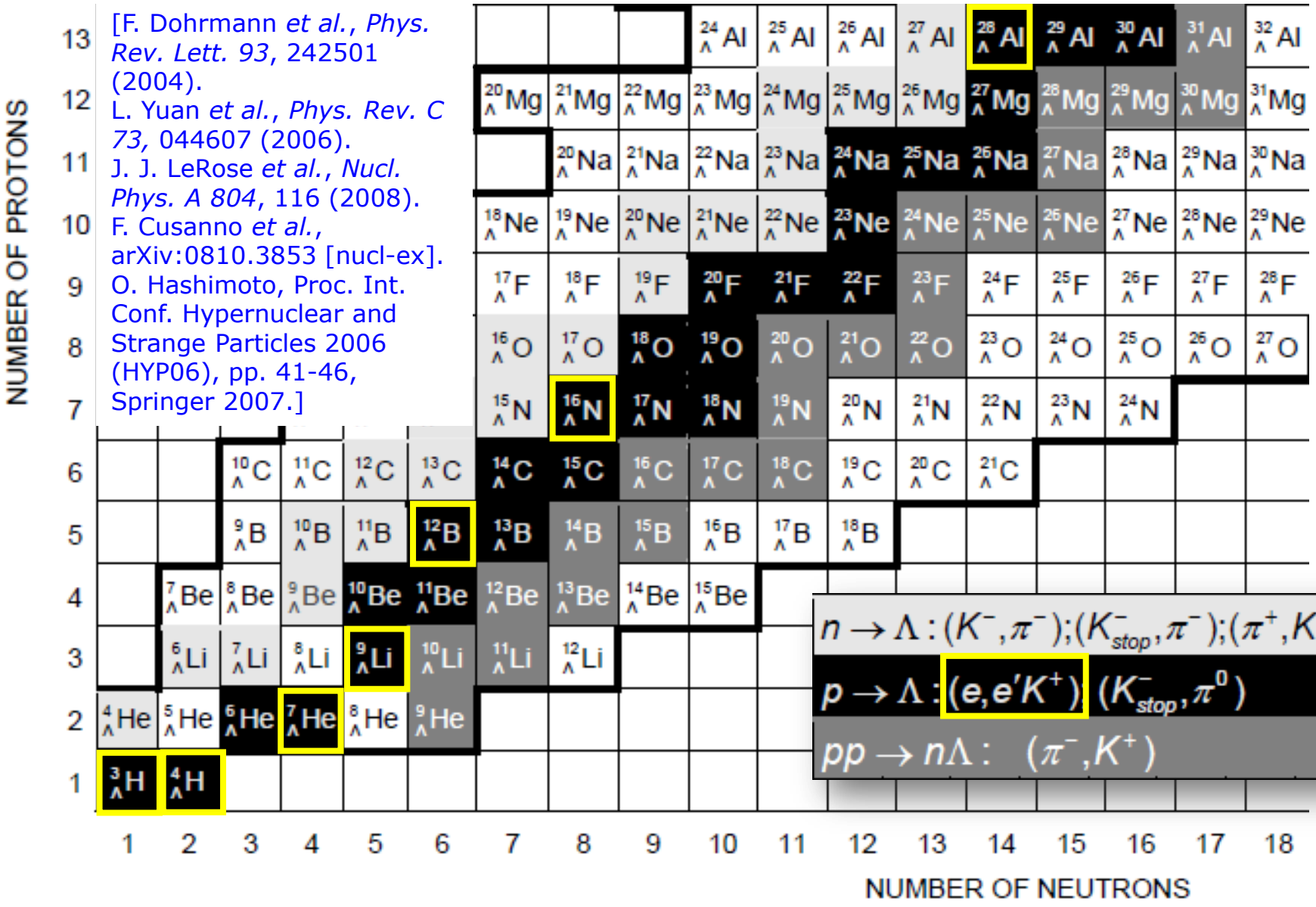






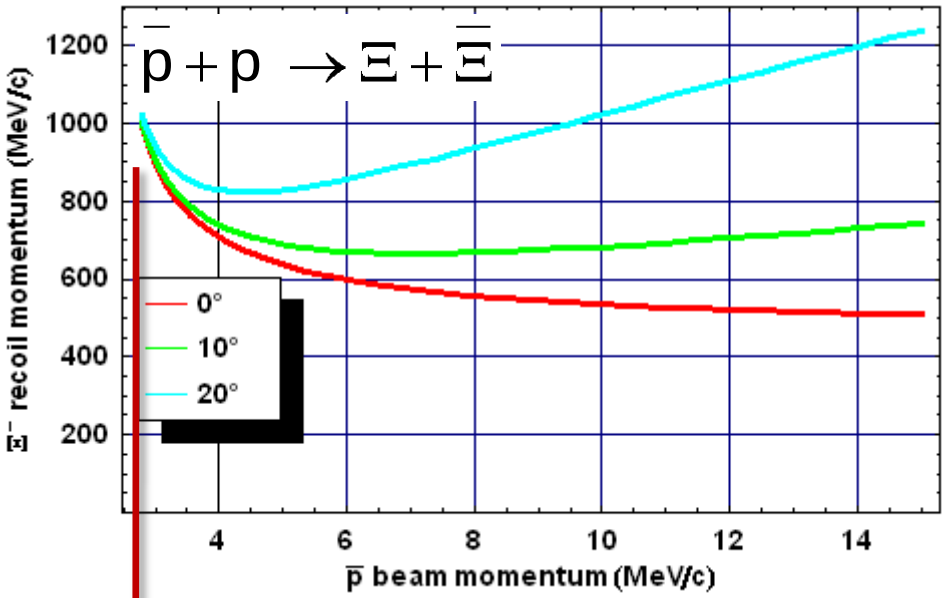
Perspectives: access to new isotopes of hypernuclei

[F. Dohrmann *et al.*, *Phys. Rev. Lett. 93*, 242501 (2004).
L. Yuan *et al.*, *Phys. Rev. C 73*, 044607 (2006).
J. J. LeRose *et al.*, *Nucl. Phys. A 804*, 116 (2008).
F. Cusanno *et al.*, arXiv:0810.3853 [nucl-ex].
O. Hashimoto, Proc. Int. Conf. Hypernuclear and Strange Particles 2006 (HYP06), pp. 41-46, Springer 2007.]



Double hypernuclei

Formation of double hypernuclei from cascade particles



the hyperons may produce:

- single hypernuclei: ${}_{\Lambda}Z$ (${}_{\Sigma}Z$)
- twin hypernuclei: ${}_{\Lambda}Z$ + ${}_{\Lambda}Z'$
- doubly strange hypernuclei: ${}_{\Xi^-}Z$
- double hypernuclei: ${}_{\Lambda\Lambda}Z$
- H particle in a nucleus(?): ΛΛ

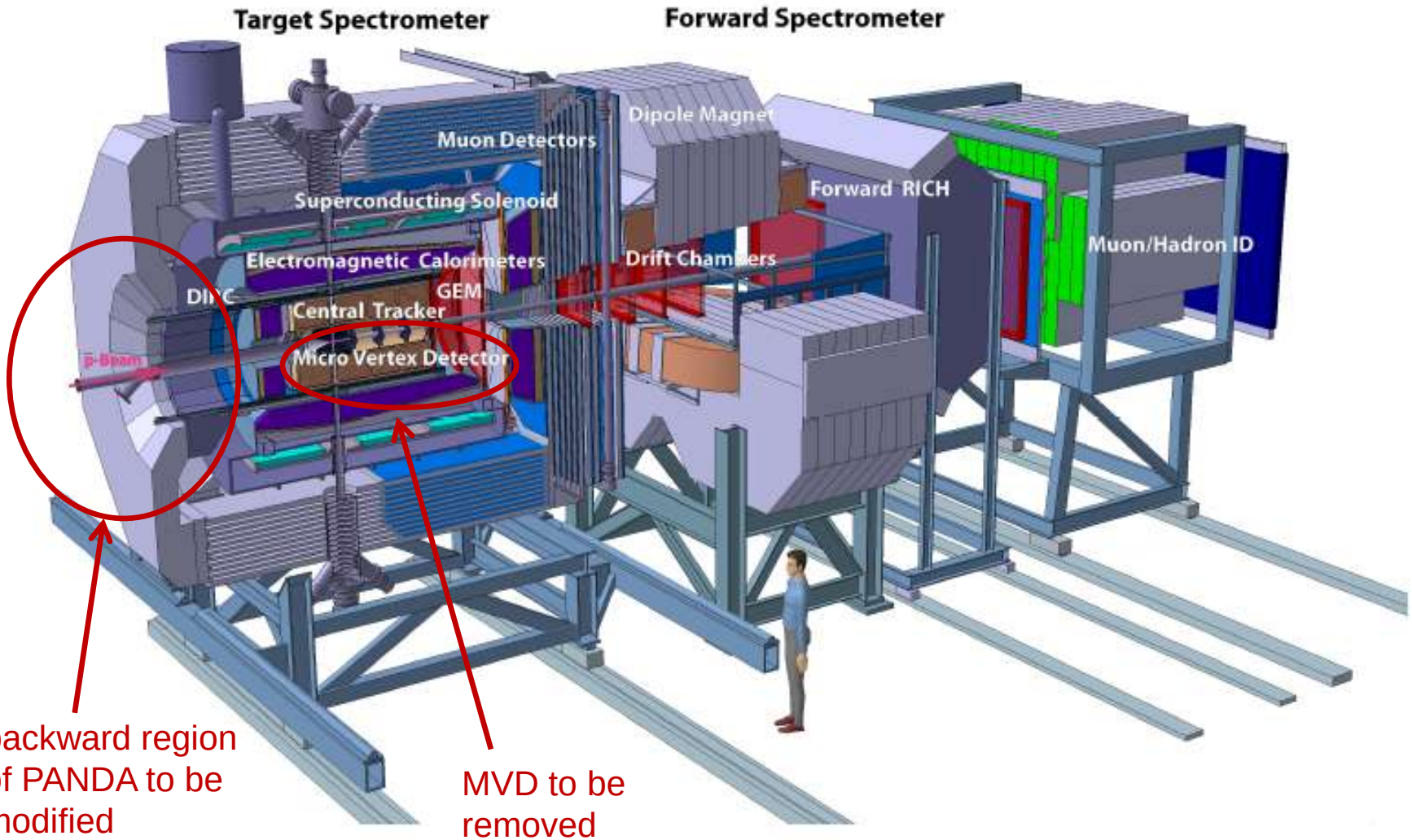
1. $dE(\Xi^-)/dx$ → stop + capture
2. hyperatom + atomic decay
3. capture in nucleus (${}_{\Xi^-}Z$)
4. conversion: $\Xi^- + p \rightarrow \Lambda\Lambda$
5. hypernuclei (${}_{\Lambda\Lambda}Z^*$ or ${}_{\Lambda}Z^* + {}_{\Lambda}Z'^*$)

strangeness production can only be tagged by the anti-hyperon or its decay products

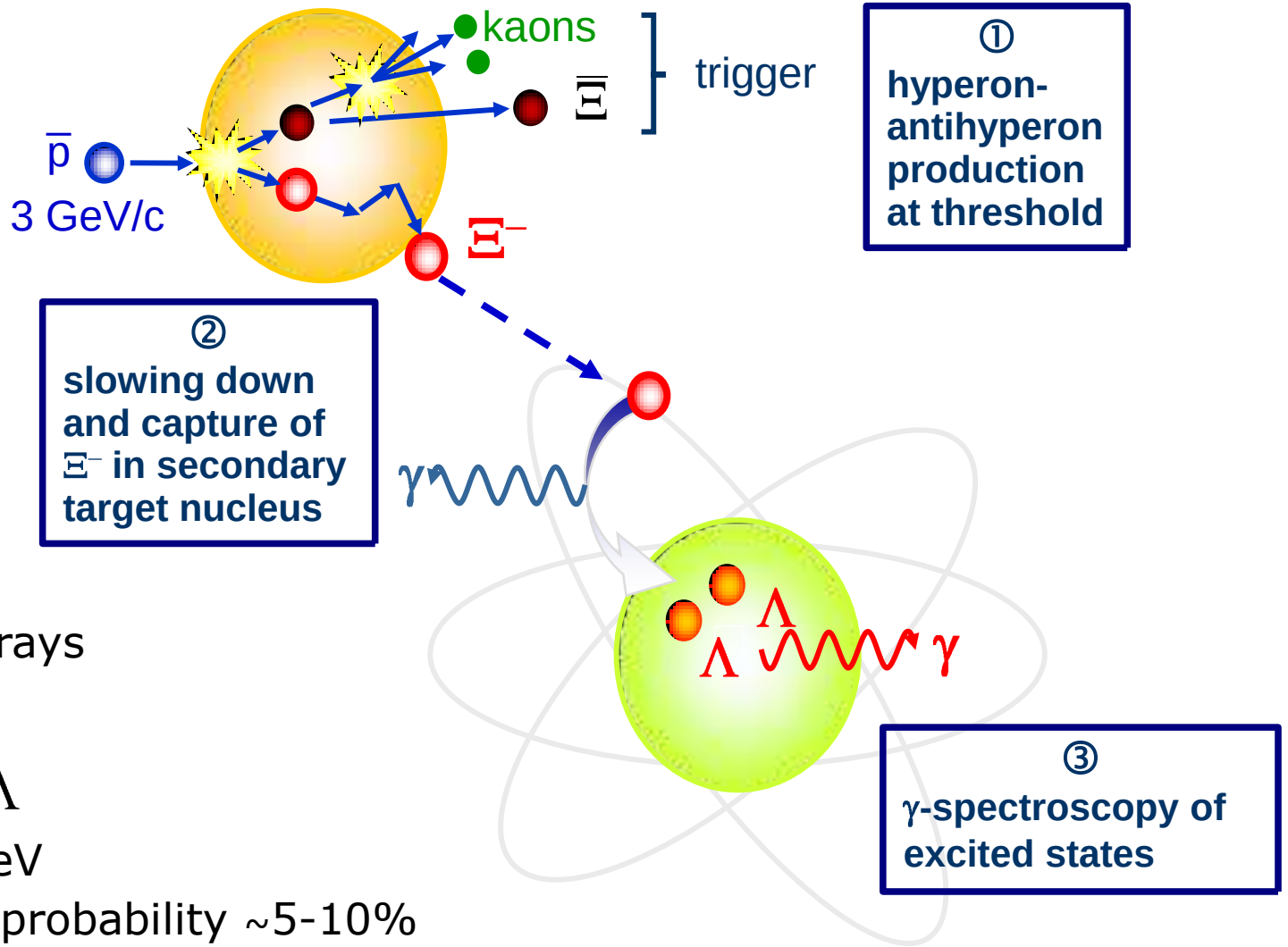
→ forward detector for trigger and particle ID

→ PANDA at FAIR

PANDA at the High Energy Storage Ring at FAIR



Production mechanism at PANDA



- Ξ^- atoms: x-rays
- conversion:

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

  $\Delta Q = 28$ MeV

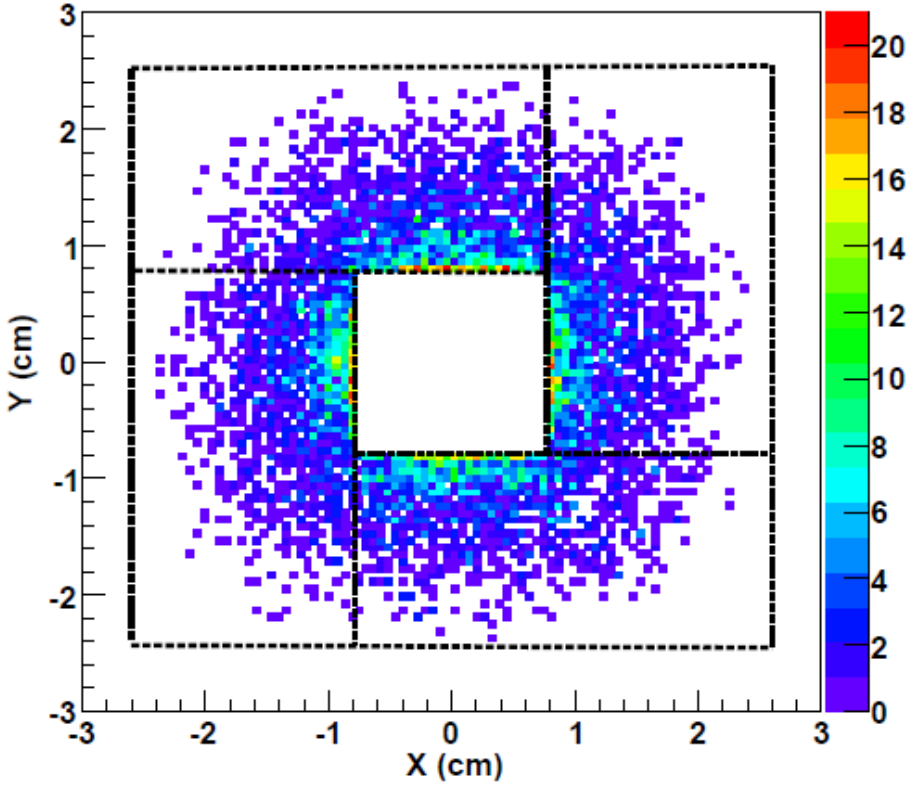
  conversion probability ~5-10%

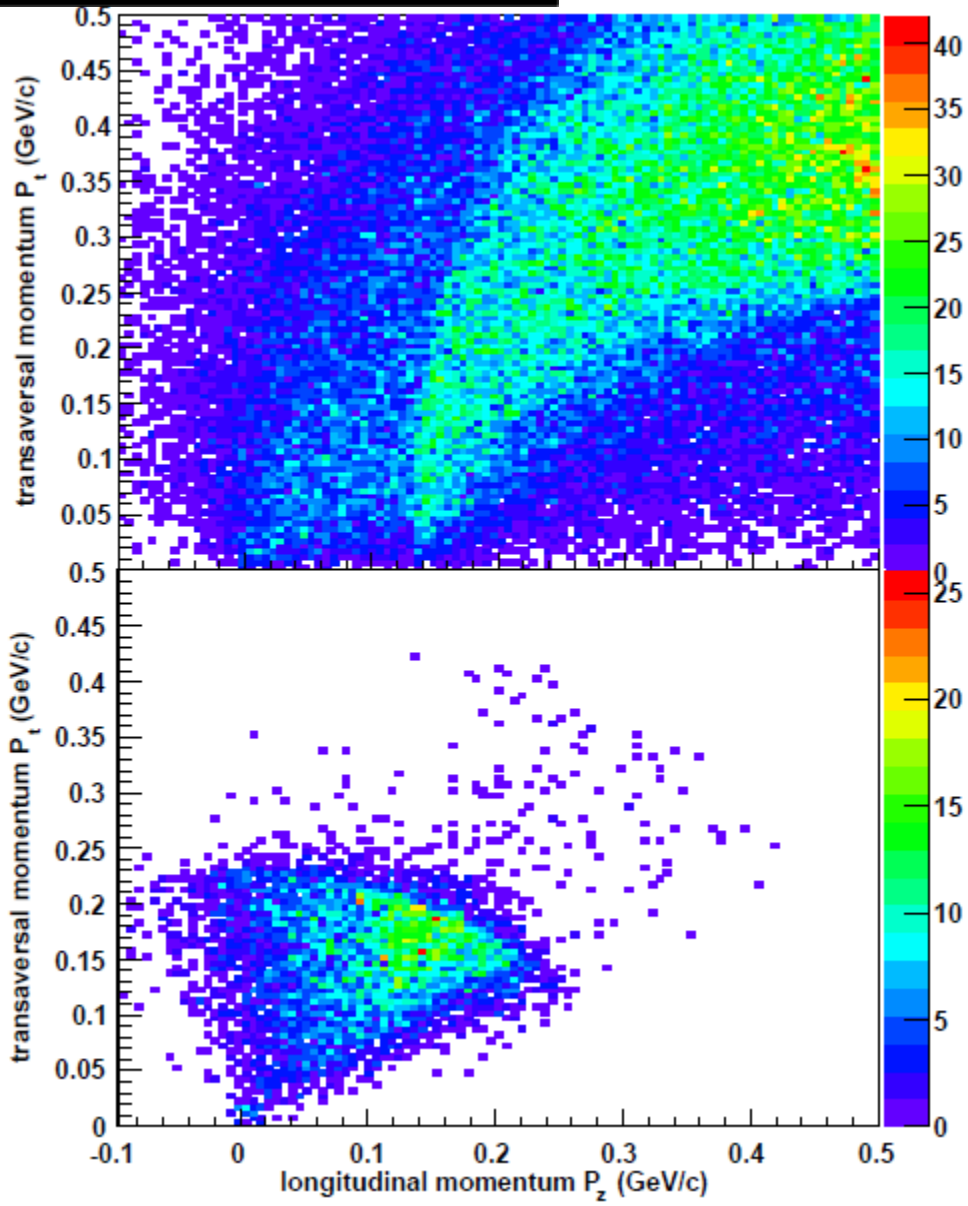
[Y. Hirate et al., *Nucl. Phys. A 639*, 389c (1998),
Y. Hirate et al., *Prog. Theor. Phys. 102*, 89 (1999)]

Open issues being studied at Mainz U

1. design of secondary target
2. design of γ-array
3. operation and electromechanical cooling of HPGe crystals
4. integration into PANDA target spectrometer
5. simulation of the expected performance

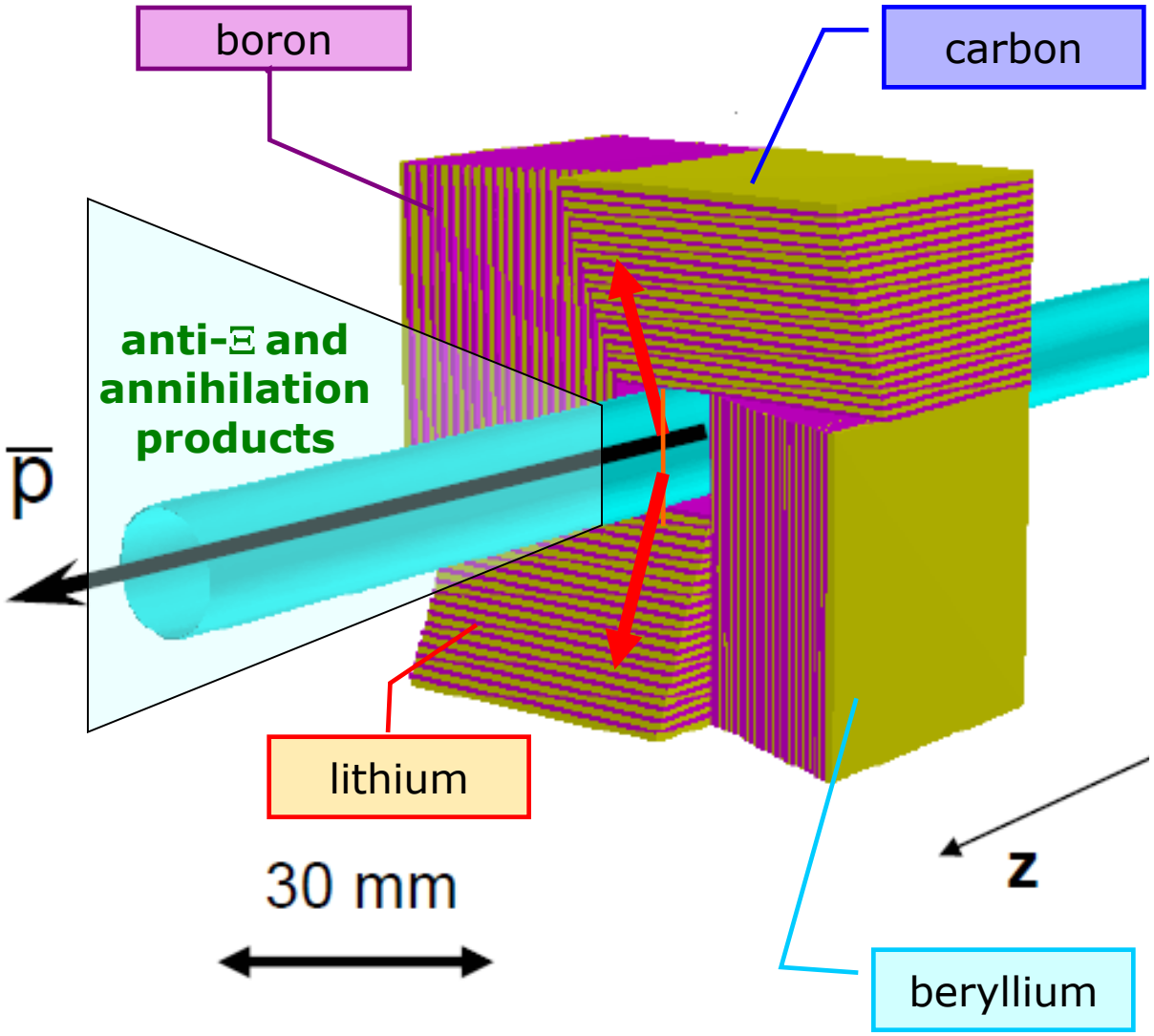
Stopping of the Xi-hyperons





[A. Sanchez Lorente, P. Achenbach, J. Pochodzalla, and S. Sánchez Majos: Detector developments for the hypernuclear programme at PANDA, Conference Record of IEEE NSS 2008.]

The secondary target design



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

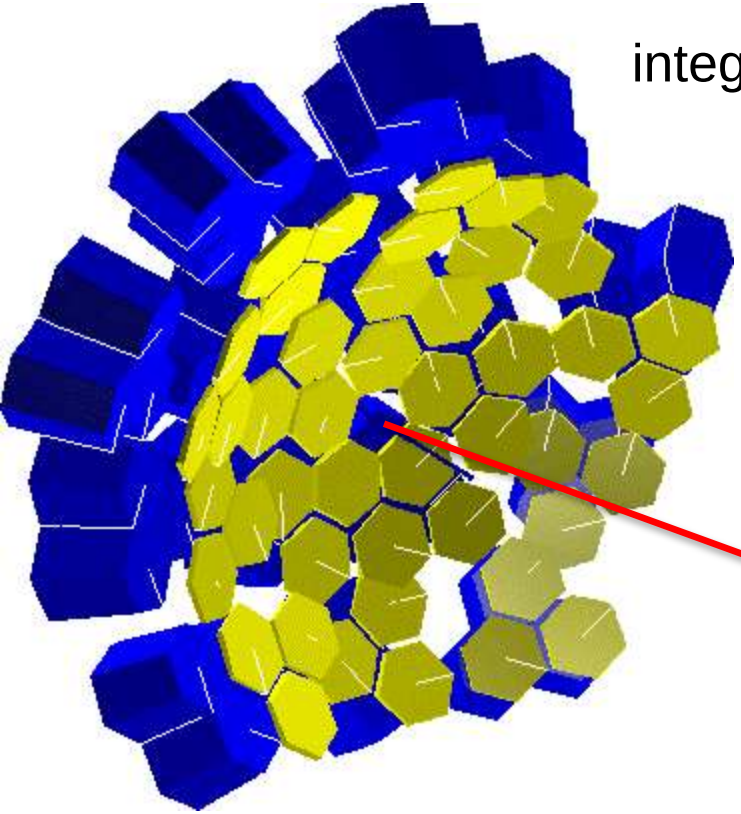
- identification can rely on existing information on single hypernuclei
- low γ-ray absorption
- no x-ray background

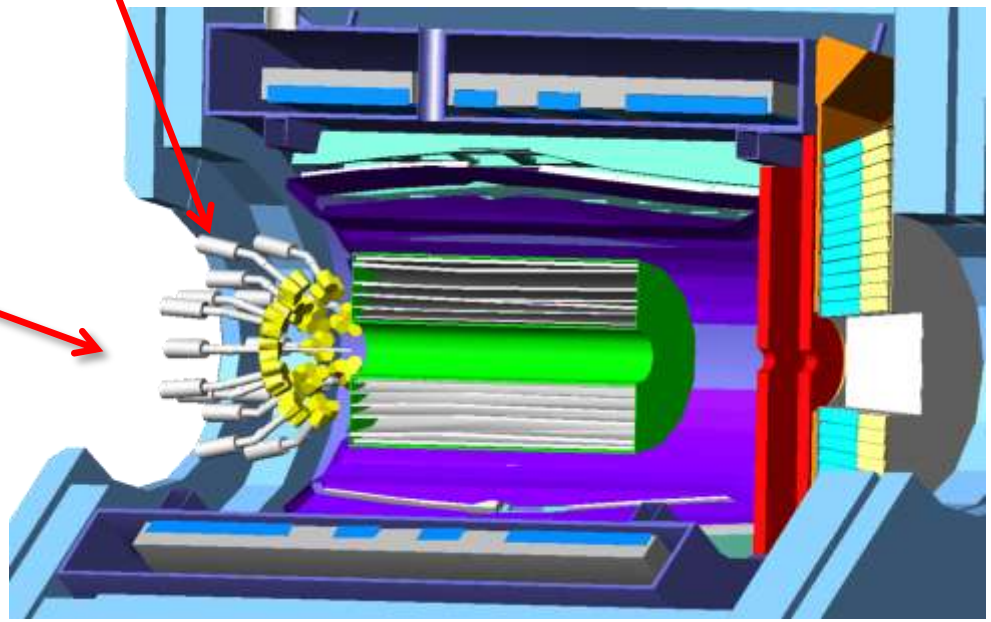
[PANDA Physics Performance Report, 2009.]

HPGe array at backward angles

- 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

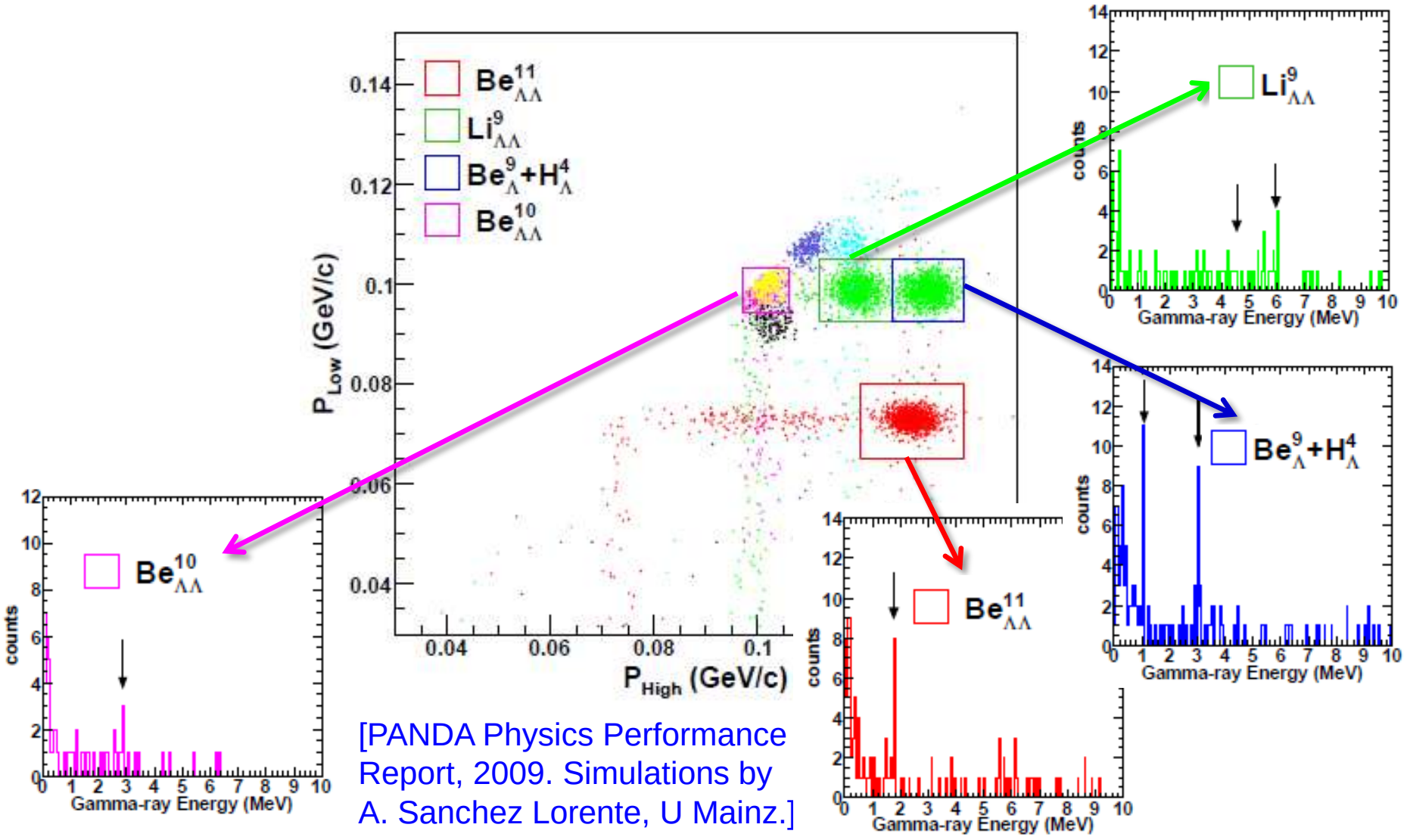
integration of electromechanical coolers for HPGe





[PANDA Technical Progress Report, 2005.]

Background suppression by decay pion correlation



[PANDA Physics Performance Report, 2009. Simulations by A. Sanchez Lorente, U Mainz.]

Conclusion

1) The strangeness physics programme at MAMI is progressing with KAOS operational since Oct 2oo8

   a first physics campaign dedicated to low Q^2 kaon electro-production is scheduled for June 2oo9

2) the extension of the KAOS spectrometer towards a two-arm operation under zero degree is progressing

   first physics campaigns dedicated to hypernuclear physics at MAMI are expected to come in 2o1o

3) the technical developments for the PANDA hypernuclei programme are progressing

   PANDA is expected to run at FAIR in 2o14