Feasibility studies of Hyperons Dalitz decays @ HADES

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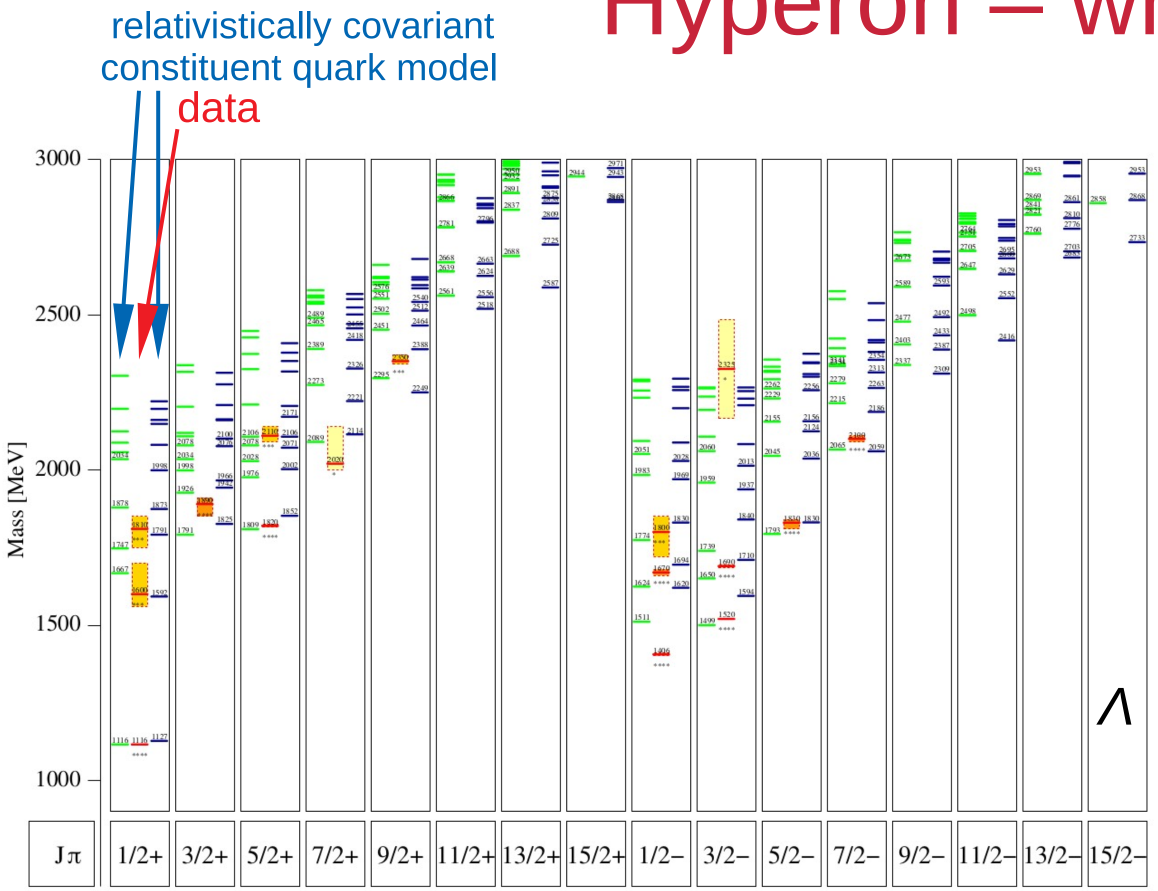
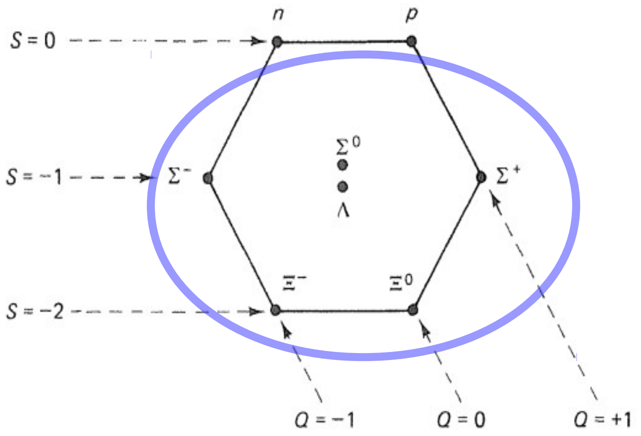
Hyperon – why?

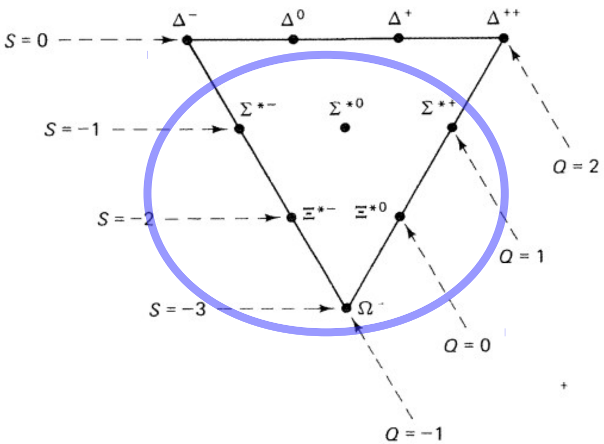


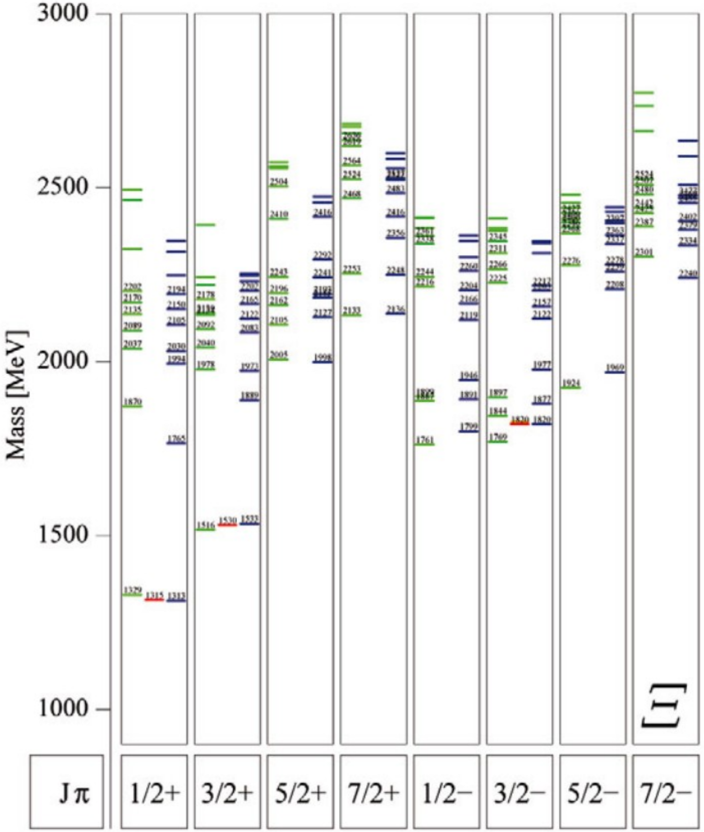
Ronniger, M. & Metsch, B.C. Eur. Phys. J. A (2011)

Spin 1/2



Spin 3/2



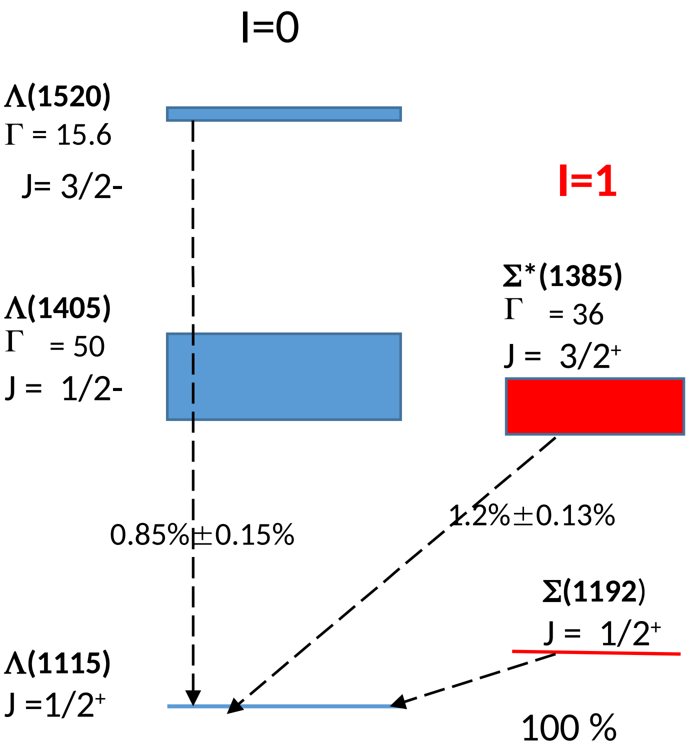


Hyperon – why?

- Hyperons spectroscopy - PANDA
- Di-leptons and radiative transitions- HADES
- Part of FAIR Phase-0 program (test of straw tube tracker for PANDA)

Ronniger, M. & Metsch, B.C. Eur. Phys. J. A (2011)

Hyperons – electromagnetic decays



Model	Decay width Γ [KeV]			
	Δ(1234)->pγ	$\Sigma^0(1385) \to \Lambda(1116)\gamma$	$\Lambda^0(1405) \to \Lambda(1116)\gamma$	$\Lambda^0(1520) \to \Lambda(1116)\gamma$
Quarks models	350-360	265-273	118-200	156-215
MIT bag	-	152	17, 60	46
Soliton	-	170, 243	44, 40	-
Skyrme	309-348	157-209	-	-
Experiment		479 ± 120		167 ± 43

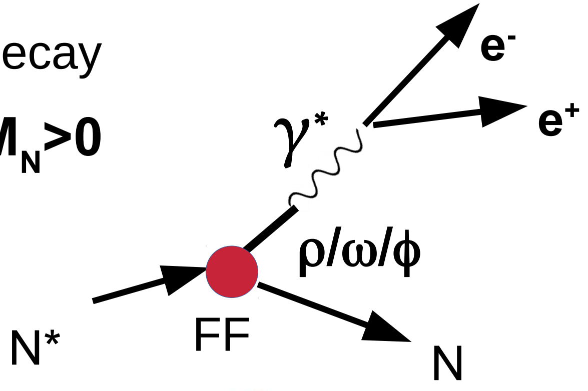
Taylor et al. (CLAS Collab.), Phys. Rev. C71 (2005) 054609

HADES: $\Gamma(\Delta(1232) \to p\, e^+e^-) = 0.66$ MeV, BR=$4.19\cdot10^{-5}$

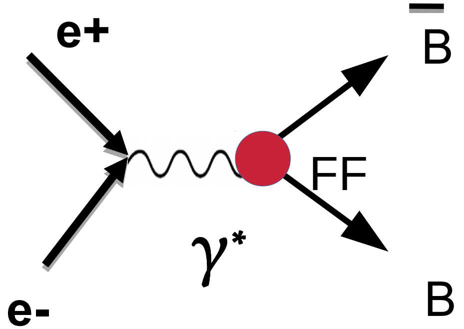
Dalitz decay – the key to electromagnetic structure

Dalitz decay

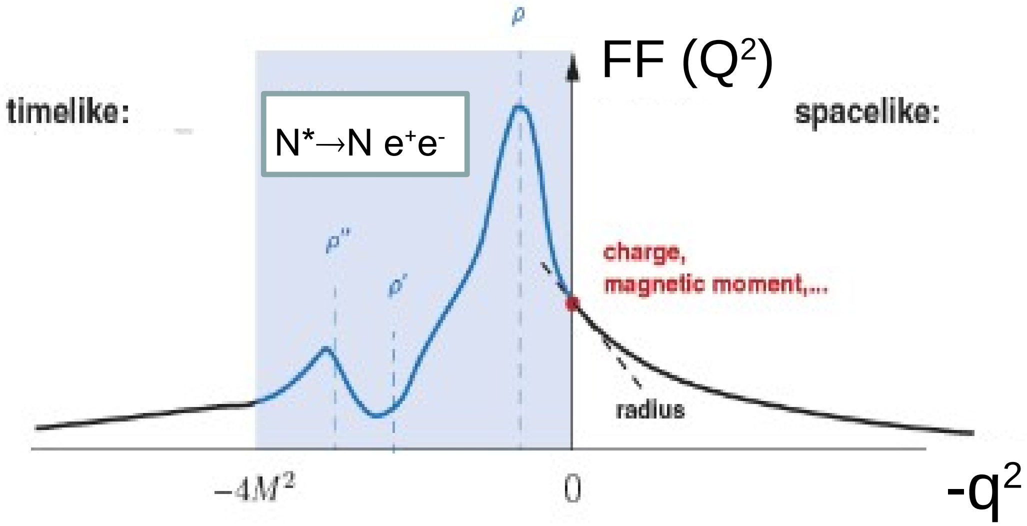
$q^2 = M_{N^*} - M_N > 0$



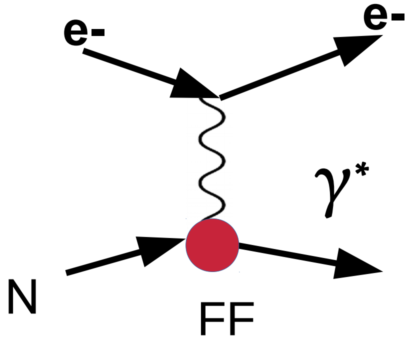
annihilation



$q^2 > 4 M_B^2$



scattering

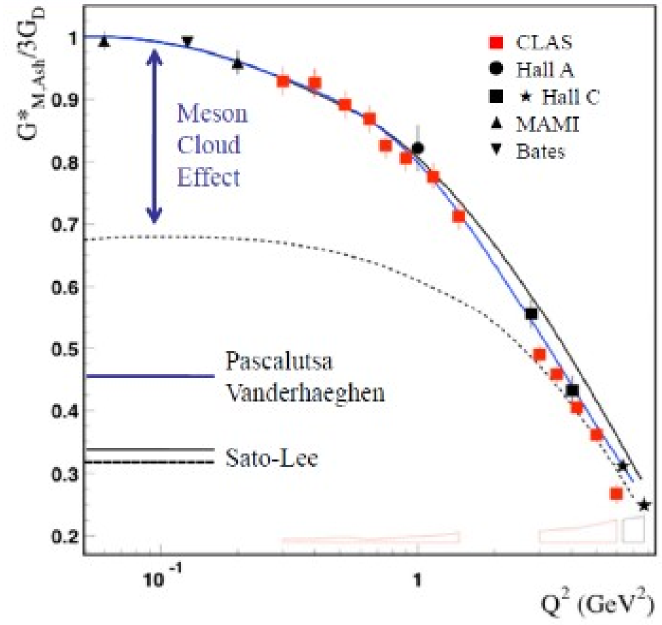


$q^2 < 0$

Dalitz decay – the key to electromagnetic structure

Dalitz decays, appearance of intermediate vector mesons! $\rho/\omega/\phi$ $J^{PC} = 1^{--}$ $(= \gamma\ !)$

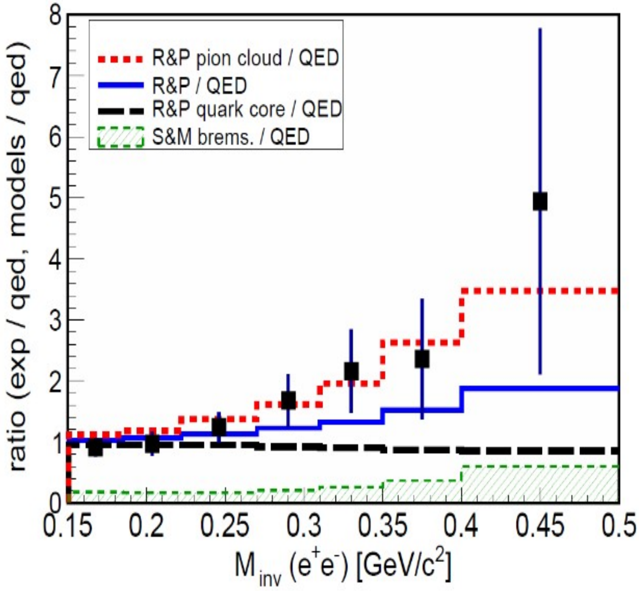
Data: CLAS, MAMI, Bates: $e\text{-}p \rightarrow \Delta\ e^-$



Space-like region

Data: HADES PRC2017

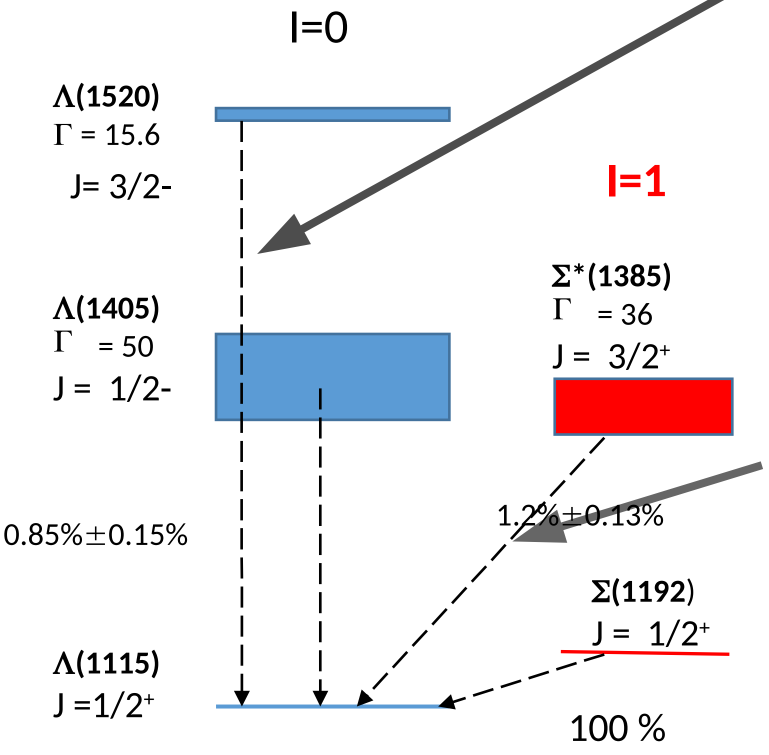
$\Delta(1232) \rightarrow p e^+ e^-$



Time-like region

Sensitivity to meson cloud effects?

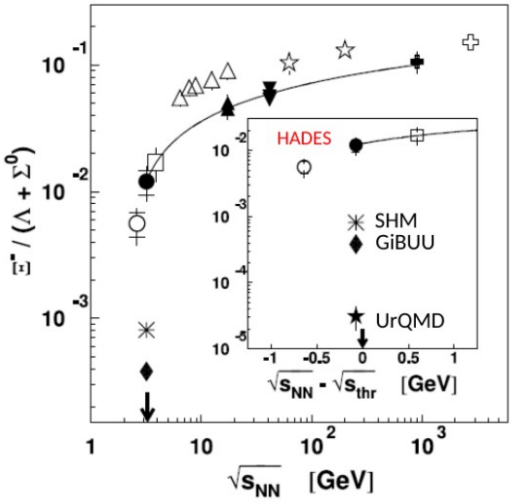
Our goals



$\Lambda(1520) \rightarrow \Lambda(1116)\ e^+ e^-$
Never measured for time-like region, relatively high BR for space-like transition

$\Sigma^*(1385) \rightarrow \Lambda(1116)\ e^+ e^-$
The SU3 symmetry partner for transition
$\Delta(1232) \rightarrow p\ e^+ e^-$ - *measured by HADES*

Double strange sector
$\Xi^- \rightarrow \pi^- \Lambda(1116)$



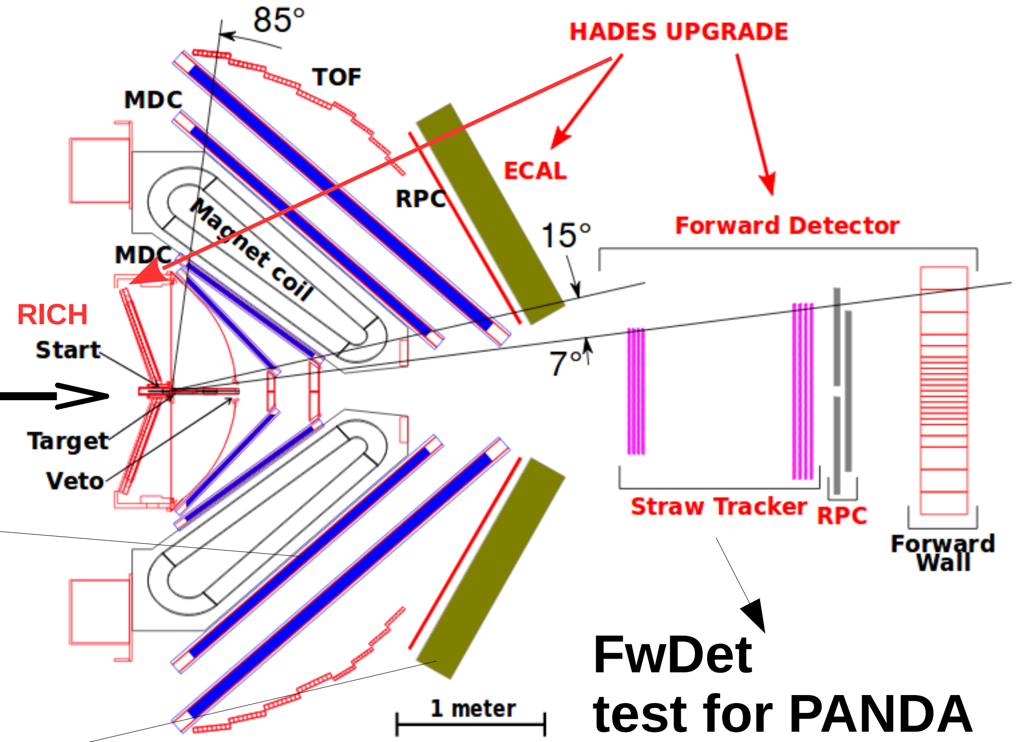
PRL114(2015)212301

HADES - now and in close future (FAIR-phase0)

Ring **I**maging **Ch**erenkov

p+p @ 4.5 GeV

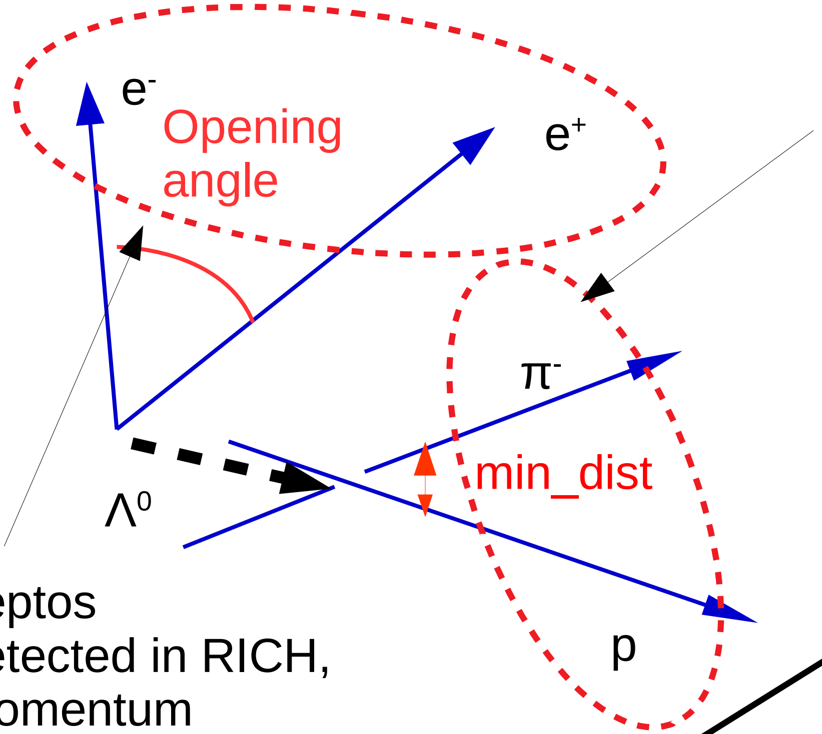
Mulit-wire **d**rift **c**hamber



New **calorimeter**

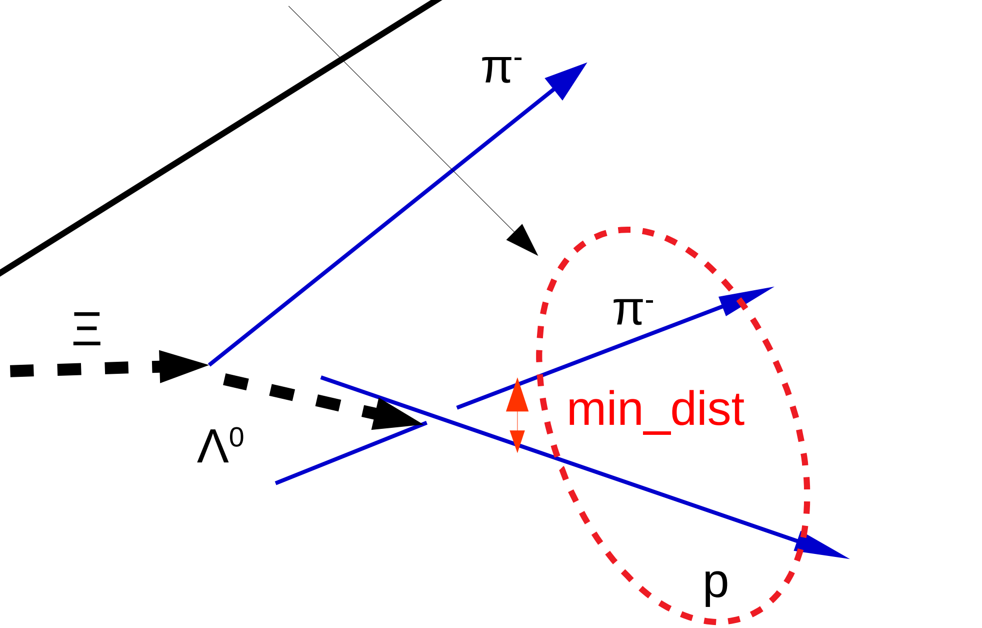
FwDet test for PANDA

Strategy of analysis

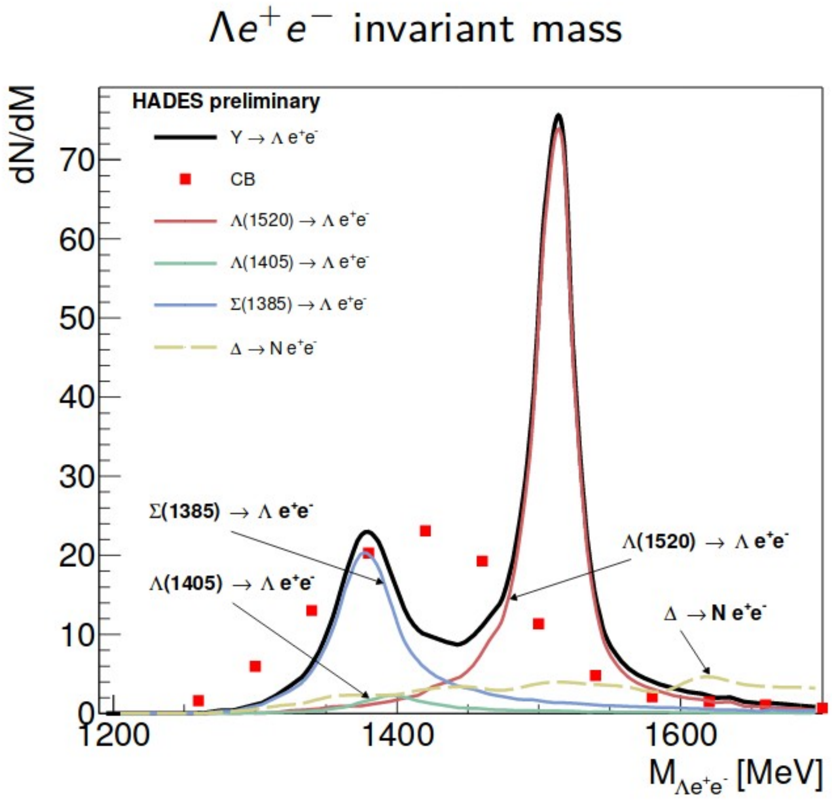


Di-leptos
- detected in RICH,
- momentum measured in MDC
- OA cut helps cut off conversion

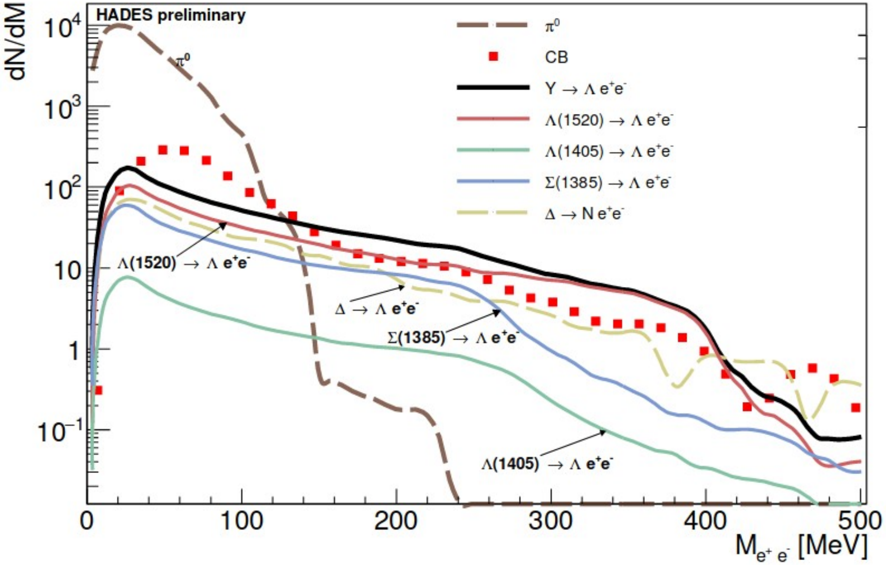
Hadrons
- Tracks reconstructed in MDC
- Geometrical cuts discriminates from prompt strong decays
- Thanks to narrow Λ^0 mass peak, good identification



Simulation results: Λ Dalitz



M_{e+e-} >140 MeV

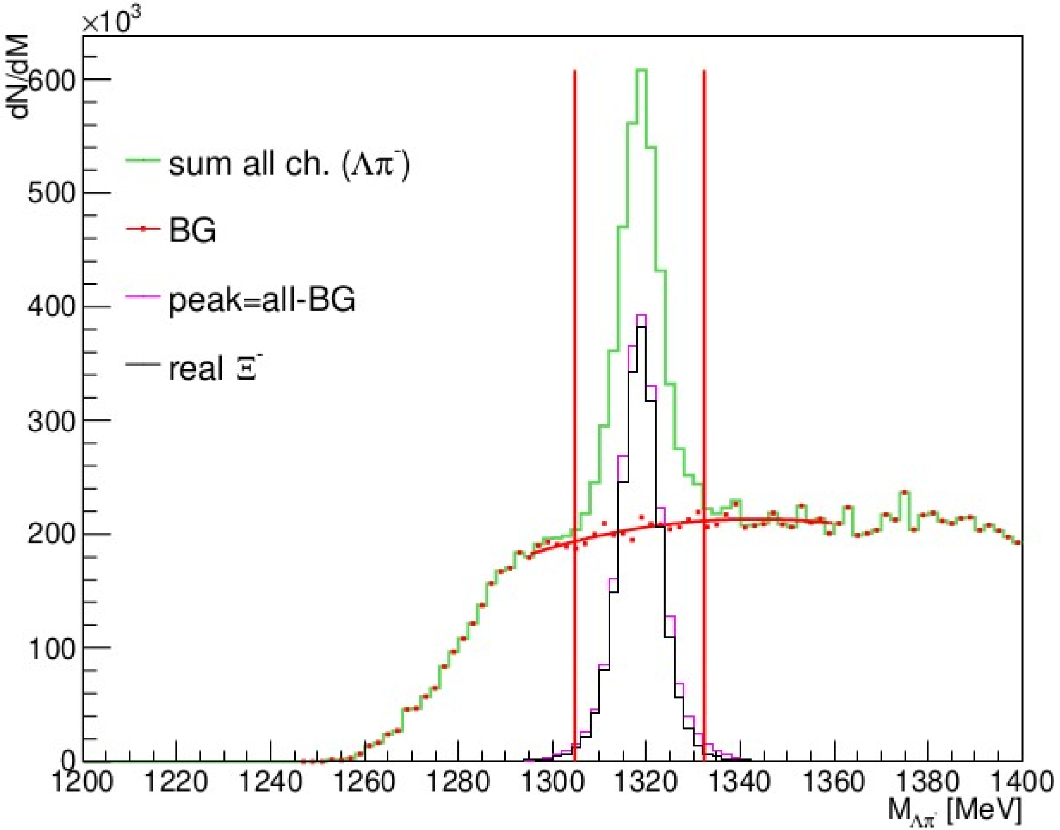


1110 MeV< M_Λ < 1120 MeV + geometrical cuts

H^* production	$pp \to pK^+\Lambda^*$	$pp \to pK^+\Sigma^*$
σ_{tot}:	130 μb	80 μb

H^* Dalitz decay	$\Lambda^* \to \Lambda e^+e^-$	$\Sigma^* \to \Lambda e^+e^-$
σ_{Dalitz}	$8.3{\cdot}10^{-3}\mu$b	$7.0{\cdot}10^{-3}\mu$b
$\varepsilon_{H^* rec}$:	0.5%	0.5%
Expected count rate:		
proton target:	34 part/day	
PE target:	240 part/day	

Simulation results - Ξ



H^* production	$pp \rightarrow \Xi^- K^+ K^+ p$
σ_{tot}:	4.8 μb
H^* Dalitz decay	—
σ_{Dalitz}	—
$\varepsilon_{H^* rec}$:	0.98%
Expected count rate:	
proton target:	$2 \cdot 10^4$ part/day
PE target:	$14 \cdot 10^4$ part/day

σ_Ξ estimated based on **Λ/Σ** (PRL 114, 212301 (2015)) ratio and **Ξ/(Λ+Σ)** ratio (Phys. Ref. B 781,735-740) – quite uncertain

Summary

- Radiative decays of hyperon are an ideal tool to discriminate between different theoretical model.
- Dalitz decays were never measured – can be done by HADES and compared with results obtained for non-strange sector (N*(1520), Δ(1232)).
- Performed simulation shows good perspectives for identification of hyperions at HADES.

Backup

Results given by HADES in hyperons sector

- pp@ 3.5 GeV
  - ***"Inclusive Lambda production in proton-proton collisions at 3.5 GeV", Phys. Rev. C 95, 015207***
  - *"Partial Wave Analysis of the Reaction p(3.5GeV)+p → pK+Λ to Search for the "ppK" Bound State"*, Phys.Lett. B742 (2015) 242-248
  - ***"Lambda hyperon production and polarization in collisions of p(3.5 GeV)+Nb"*, Eur.Phys.J. A50 (2014) 81**
  - *"Baryonic resonances close to the K¯N threshold: the case of Λ(1405) in pp collisions",* Phys.Rev. C87 (2013) 025201
  - *"Production of Sigma+- pi-+ pK+ in p+p reactions at 3.5 GeV beam energy"*, Nucl.Phys. A881 (2012) 178-186
  - *"Baryonic resonances close to the Kbar-N threshold: the case of Sigma(1385)^+ in pp collisions"*, Phys.Rev. C85 (2012) 035203
- pNb@ 3.5 Gev
  - ***"Σ0 production in proton nucleus collisions near threshold"*, Phys.Lett. B781 (2018) 735-740**
  - *"The Lambda-p interaction studied via femtoscopy in p + Nb reactions at sqrt(sNN)=3.18 GeV"* Phys.Rev. C94 (2016) no.2, 025201
  - *"Two-particle correlation measurements in p+Nb reactions √s(NN) = 3.18 GeV"*, J.Phys.Conf.Ser. 668 (2016) no.1, 012037
  - ***"Subthreshold Ξ- Production in Collisions of p(3.5..GeV)+Nb"*, Phys.Rev.Lett. 114 (2015) 212301**

TABLE I. Theoretical predictions and experimental values for the radiative widths (in keV) for the transitions $Y \to \Lambda(1116)\gamma$ and $Y \to \Sigma(1193)\gamma$. Some models have multiple predictions that depend on different assumptions. For comparison the predictions and experimental value are quoted for the $\Delta(1232) \to p\gamma$ transition.

Model	$\Delta(1232)$	$\Sigma^0(1385)$		$\Lambda(1405)$		$\Lambda(1520)$	
	$p\gamma$	$\Lambda(1116)\gamma$	$\Sigma^0(1193)\gamma$	$\Lambda(1116)\gamma$	$\Sigma^0(1193)\gamma$	$\Lambda(1116)\gamma$	$\Sigma^0(1193)\gamma$
NRQM [3,4]	360 [14]	273	22	200	72	156	55
RCQM [5]		267	23	118	46	215	293
χCQM [6]	350	265	17.4				
MIT bag [3]		152	15	60, 17	18, 2.7	46	17
Chiral bag [7]				75	1.9	32	51
Soliton [8]		243, 170	19, 11	44, 40	13, 17		
Skyrme [9,10]	309–348	157–209	7.7–16				
Algebraic model [11]	343.7	221.3	33.9	116.9	155.7	85.1	180.4
HBχPT [12][a]	(670–790)	290–470	1.4–36				
$1/N_c$ expansion [13]		298 ± 25	24.9 ± 4.1				
Previous experiments	640–720 [30]	<2000 [22]	<1750 [22]	27 ± 8 [19]	10 ± 4 [19]	33 ± 11 [17]	47 ± 17 [17]
					23 ± 7 [19]	134 ± 23 [16]	
						$159 \pm 33 \pm 26$ [18]	
This experiment		$479 \pm 120^{+81}_{-100}$				$167 \pm 43^{+26}_{-12}$	

[a]The results for HBχPT [12] are normalized to the quoted empirical range (in parentheses) for the $\Delta \to p\gamma$ transition.

Data from previous experiments

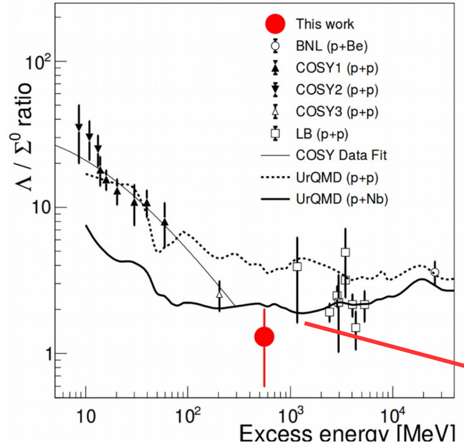
- pNb @3.5GeV
  - Sep 18 - Oct 20, 2008
  - $7.7 \cdot 10^9$ events
  - Multiplicity ≥ 3 trigger

- pp @3.5GeV
  - Apr 13 - Apr 30, 2007
  - $3 \cdot 10^9$ events
  - Multiplicity ≥ 3 trigger

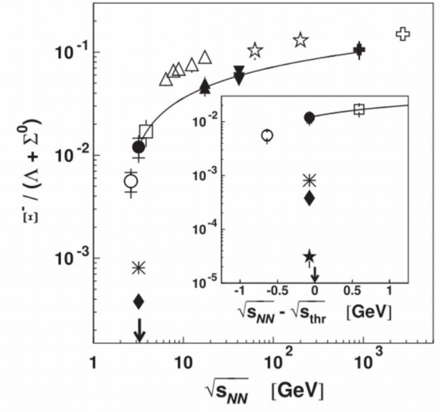
Interesting final states:

- $p\ \pi^-$ - Λ (1116) candidates
- $\Lambda\ \pi^+\ \pi^-$ - Λ (1520) candidates
- $\Lambda\ \pi^+$ - Σ^+(1385) candidates
- $\Lambda\ e^+\ e^-$ - Λ (1520) candidates
- $\Lambda\ \pi^-$- Ξ (1322) candidates

Cascade cross-section



“Σ0 production in proton nucleus collisions near threshold” Physics Letters B,2018



PRL 114, 212301 (2015)

p p → Λ Anything (Cross section units: 10^{-27} cm²)

6.000	0.32000	0.02000	Eisner,NPB123,361-77
12.000	1.15400	0.02000	Fesefeldt,NPB147,317-79
12.400	1.07000	0.11000	Jaeger,PRD11,1756-75

Landolt-Börnstein - Group I Elementary Particles, Nuclei and Atoms

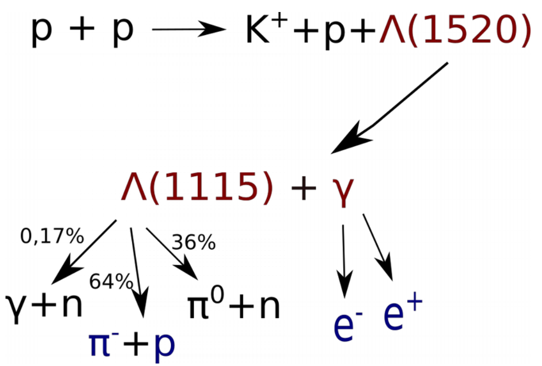
$$\frac{\sigma\Lambda^0}{\sigma\Sigma^0} \overset{E_k=4,5GeV}{=} 3.5,$$

$$\frac{\Xi}{\Lambda+\Sigma^0} = 0.44\left(1-\left(\frac{2.2GeV}{\sqrt{S_{NN}}}\right)^{0.027}\right)^{0.780}.$$

$$\frac{\Xi}{\Lambda+\Sigma^0} \overset{E_k=4,5GeV}{=} 0.0141.$$

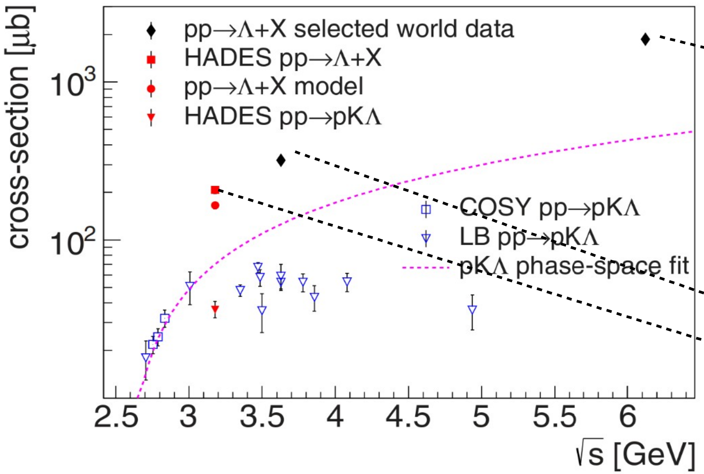
$$\sigma_\Xi \approx 4.8\,\mu b$$

Cross-section estimation

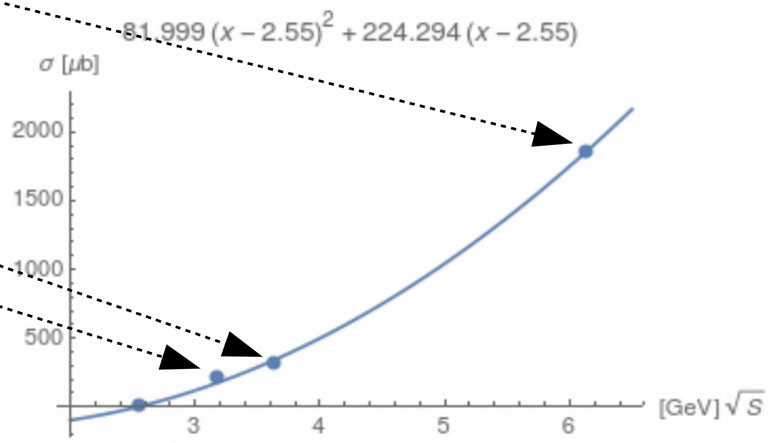


$$\sqrt{S_{\Lambda(1115)}} = m_p + m_K + m_\Lambda = 2.55GeV.$$

$$\sqrt{S_{\Lambda(1520)}} = m_p + m_K + m_\Lambda = 2.95GeV.$$



PHYSICAL REVIEW C 95, 015207 (2017)



E_k=4.5 GeV (√S=3.46 GeV) is 0.51 GeV over production threshold for Λ(1520), what corresponds to Λ(1115) production at √S=3.06 GeV. The cross section for this energy is equal 130 μb