Review of strangeness and dilepton production in elementary collisions at HADES

Rafał Lalik

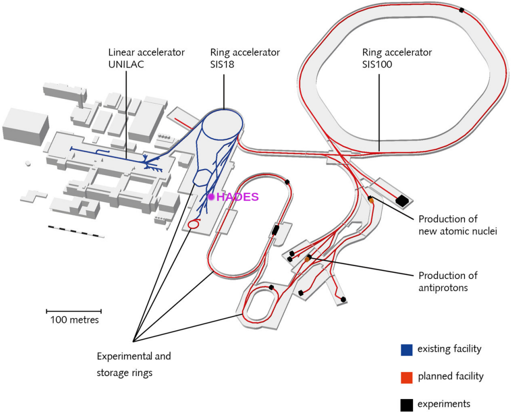
Jagiellonian University
Faculty of Physics, Astronomy and Applied Computer Science

rafal.lalik@uj.edu.pl


HADES

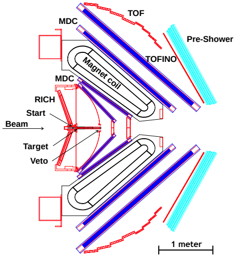
HADES – High Acceptance Dielectron Spectrometer @ GSI/FAIR

© J. Hosan, GSI/FAIR

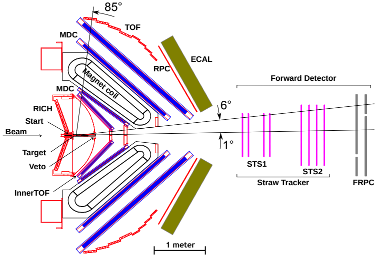


© GSI/FAIR

HADES in 2007



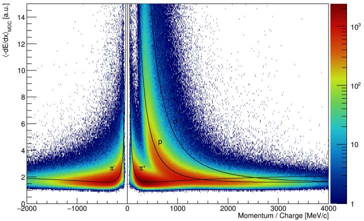
HADES in 2022

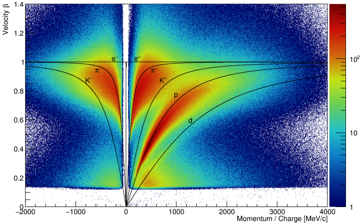


Major HADES upgrades:

- RPC (2010)
- Pion Tracker (2014)
- ECAL (2017-2021)
- RICH upgrade (2018)
- Forward Detector (2021)
- iTOF (2021)
- new START (2021)

Particle identification: dEdx, β vs momentum

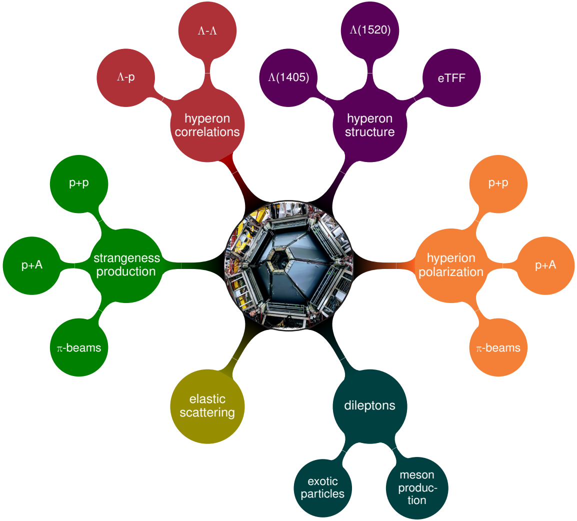




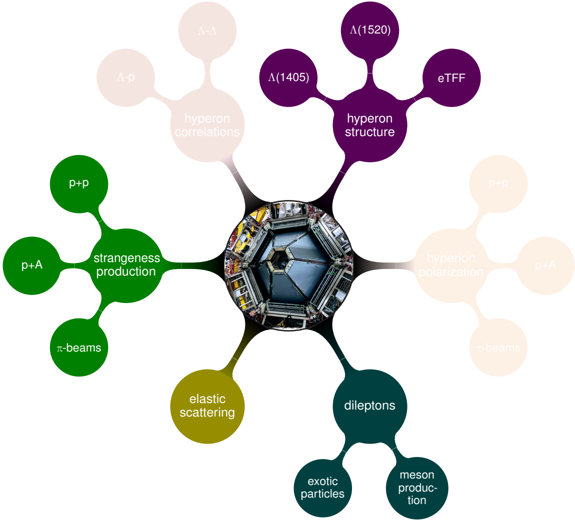
Previous experiments:

- various HI beams (Ar+KCl, Au+Au, Ag+Ag, C+C)
- light system beams:
  - p+p@3.5 GeV ('07)
  - p+Nb@3.5 GeV ('07)
  - π^-+p / π^-+A ('14)
  - p+p@4.5 GeV ('22)

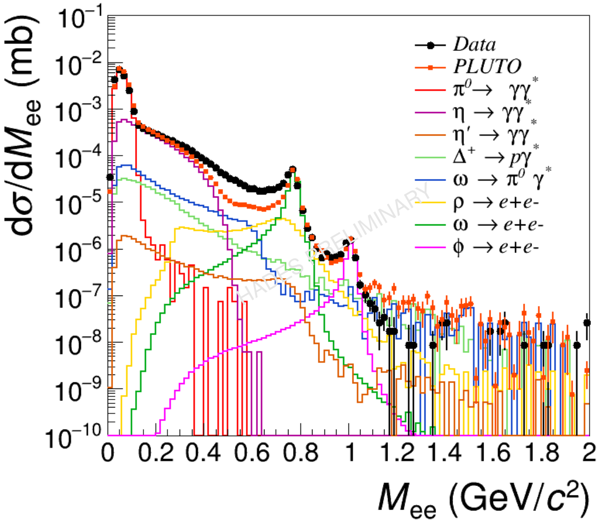
HADES elementary programme



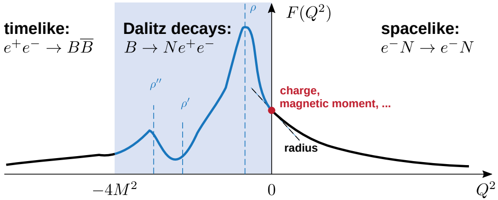
HADES elementary programme

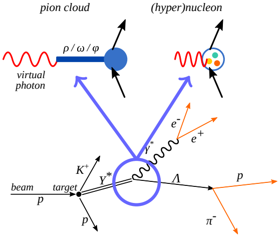


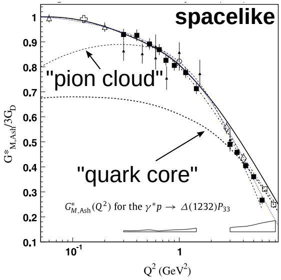
Dilepton spectra in p+p@4.5 GeV



eTFF – sensitive probes of baryon internal structure







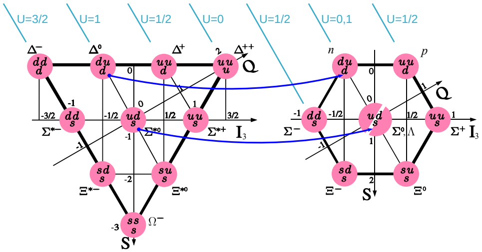
- Space-like region $|Q^2| > 0$ is inaccessible for excited hyperons (as a target or beam)
- Time-like high $|Q^2|$ is probed by electron-positron anihilation (BaBar, CLEO-C, BESIII)
- Time-like low $|Q^2|$ available via Dalitz decays in HADES, sensitivity to Vector Meson ($\rho/\omega/\varphi$) – Vector Dominance Model $\to$ pion/kaon cloud contributions

HADES is an excellent experiment for a Dalitz decay measurement

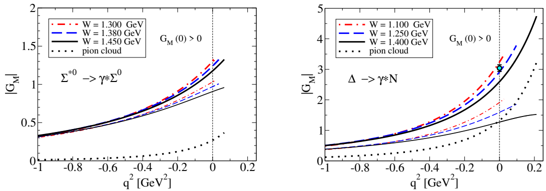
Aznauryan and Burkert, *Prog. Part. Nucl. Phys.* 67 (2012 1) pp. 1–54

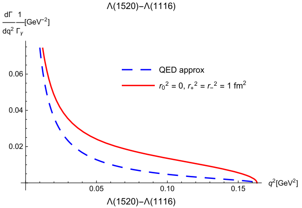
Comparison of strange and non-strange baryons

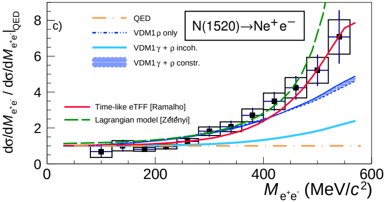
i.e. $\Delta(1232)\to Ne^+e^-$ / $\Sigma(1385)^0\to\Lambda e^+e^-$ and $N^*(1520)\to Ne^+e^-$ / $\Lambda(1520)\to\Lambda e^+e^-$ (flavor sym. partners)

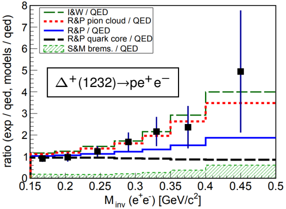


Ramalho, *Phys. Rev. D* 102 (2020 Sept.) p. 054016









Salone and Leupold, *Eur. Phys. J. A* 57 (2021 6) p. 183

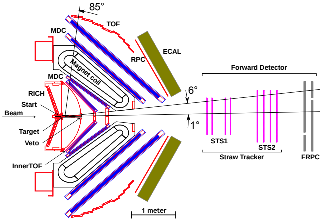
π^-+p, $\sqrt{s}=1.5\,\mathrm{GeV}$
arXiv: `2205.15914` (nucl-ex)

p+p@1.25 GeV
Phys. Rev. C 95 (2017 June) p. 065205

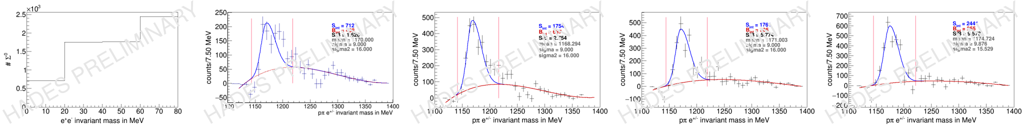
Σ^0 production in p+p@4.5 GeV

Motivation

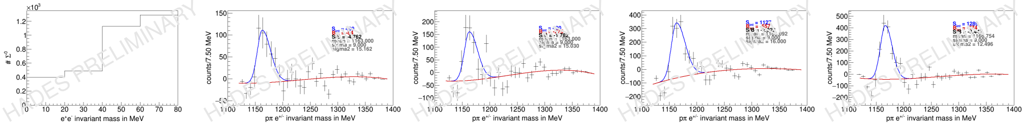
- $\Sigma^0 \to \Lambda\gamma$ (BR=100 %)
- $\Sigma^0 \to \Lambda e^+e^-$ (prediction: BR=0.5 %) – not observed yet
- $\Sigma(1385) \to \Lambda e^+e^-$ (prediction: BR=1.25×10^{-2} %) – not observed yet
- $\Lambda(1520) \to \Lambda e^+e^-$ (prediction: BR=0.85×10^{-2} %) – not observed yet



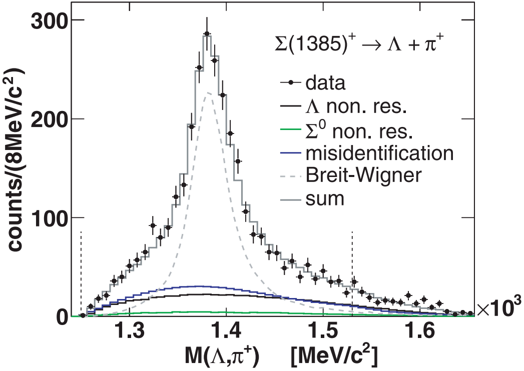
p in HADES (HH) (Λe^+e^-)



p in Forward Detector (HF) (Λe^+e^-)



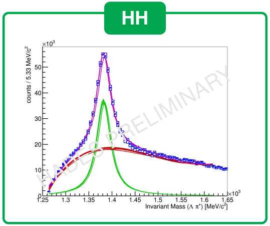
$\Sigma(1385)$ exclusive and inclusive

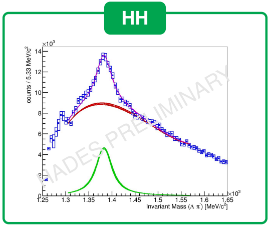


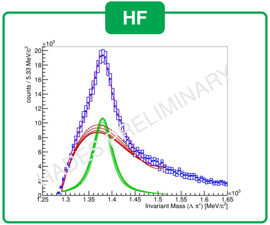
$$\sigma_{p+p\rightarrow nK^+\Sigma(1385)^+} = 22.27 \pm 0.89 \pm 1.56^{+3.07}_{-2.10}\ \mu b$$

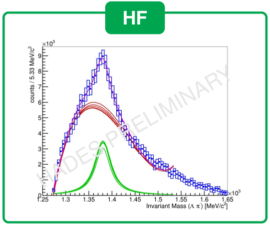
p+p@3.5 GeV: *Phys. Rev. C* 85 (2012 Mar.) p. 035203

$\Sigma(1385)^+$	$\Sigma(1385)^-$



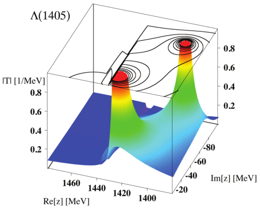




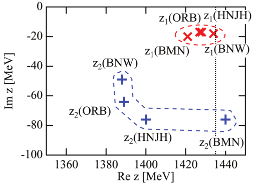


work in progress

Hyperon hadronic decays – $\Lambda(1405)$

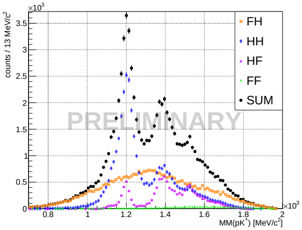


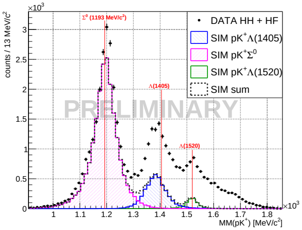
Hyodo and Jido, *Prog. Part. Nucl. Phys.* 67 (2012 1) pp. 55–98

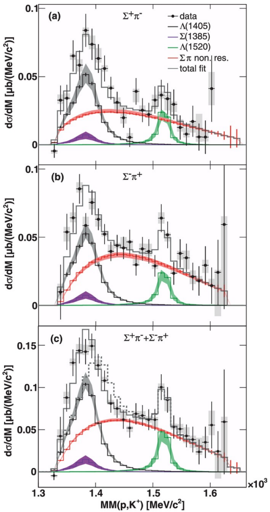


Hyodo and Wiese, *Phys. Rev. C* 77 (2008 Mar.) p. 035204

- ECAL allows to measure $\Lambda(1405)$ via $\Sigma^0\pi^0 \rightarrow p\pi^-3\gamma$ (not allowed for $\Sigma(1385)^0$)

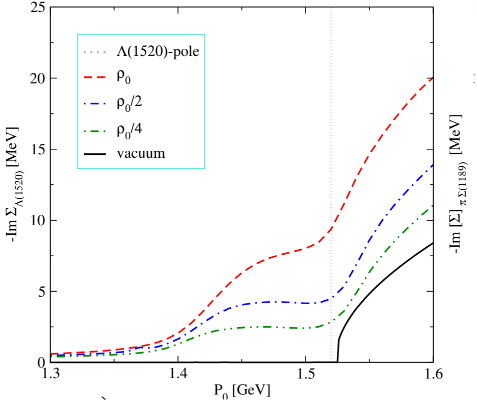




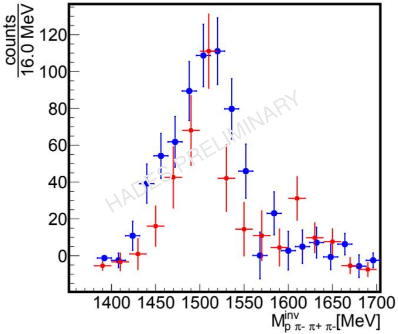


p+p@3.5 GeV
Phys. Rev. C 87 (2013 Feb.) p. 025201

- is $\Lambda(1520)$ a $\Sigma(1385)\pi$ molecule?
- studies of in-medium modifications of $\Lambda(1405)$



Kaskulov and Oset, *Phys. Rev. C* 73 (2006 Apr.) p. 045213

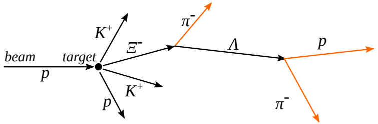


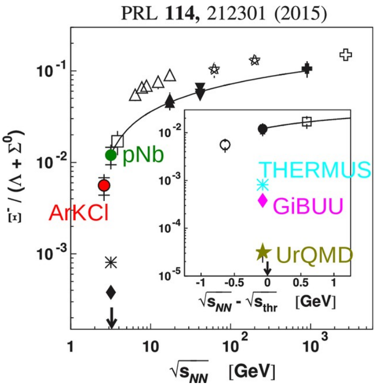
of $\Lambda(1520)$	M [MeV/c^2]	σ [MeV/c^2]	Γ [MeV/c^2]
p+p	1504.5 ± 4.7	14.7 ± 6.7	15.6 ± 1.0
p+Nb	1507.7 ± 3.3	14.7 ± 6.7	34.6 ± 5.2

paper in preparation

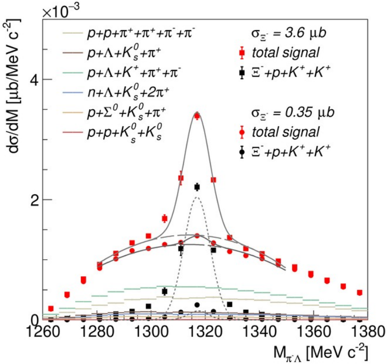
Double strangeness reactions – Ξ^- production

- Motivated by HADES-puzzle of Ξ^- enhancement in p+Nb and Ar+KCl
- VIQ: Is production through intermediate high mass (>2 GeV c^{-2}) baryonic or hyperon resonance? → pp data needed



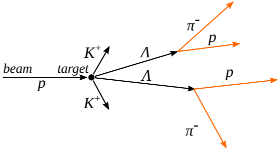


Phys. Rev. Lett. 114 (2015 May) p. 212301;
Reference HADES results with p+Nb @3.5 GeV and Ar+KCl @1.76 GeV

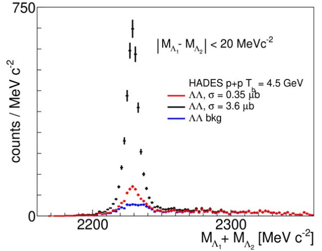


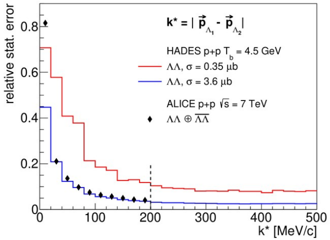
Projections for HADES with p+p@4.5 GeV
Eur. Phys. J. A 57 (2021 4) p. 138

Double strangeness reactions – ΛΛ production



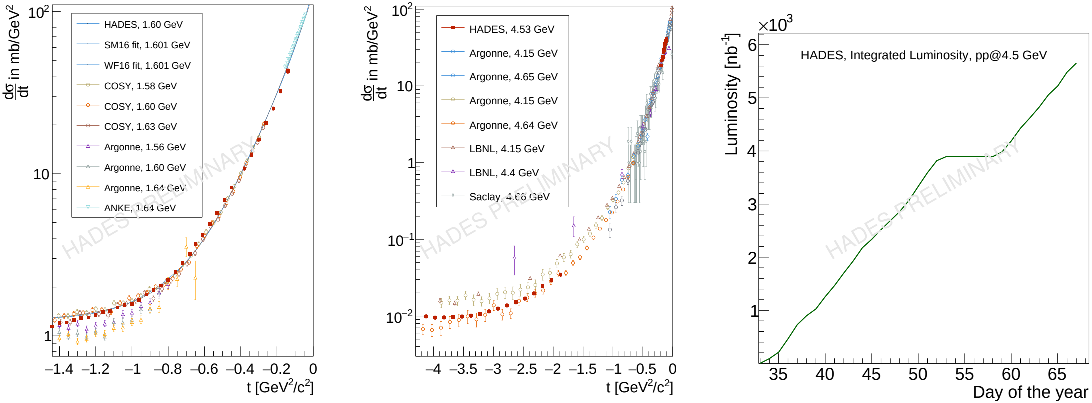
- Sensitive to Y-N and Y-Y interaction
- Complementary to PANDA program of $\Lambda\bar{\Lambda}$ at p+p̄
- HADES measured pΛ correlations *Phys. Rev. C* 94 (2016 Aug.) p. 025201, consistent with ALICE for pΛ and $\Lambda\Lambda$ *Phys. Rev. C* 99 (2019 Feb.) p. 024001.
- ALICE identified 6M Λ and $\bar{\Lambda}$, but only a small fraction in the interesting region of $k^* < 200\,\mathrm{MeV}\,c^{-1}$
- In HADES smaller contribution from feed-down of higher excited states, and smaller source-size corrections





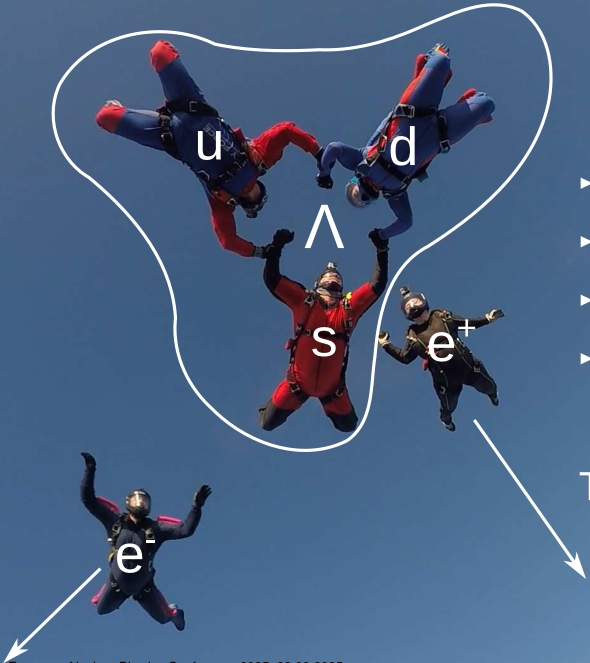
Projections for HADES with p+p@4.5 GeV
Eur. Phys. J. A 57 (2021 4) p. 138

Elastic scattering with p+p@1.58 GeV and p+p@4.5 GeV



- crucial as elastic scattering data are used for cross-section normalization
- total integrated luminosity $\mathcal{L} = 5660.6 \pm 0.1$ (stat) ± 226.4 (norm) ± 179.8 (sys) nb^{-1} at $T = 4.53$ GeV
- total integrated luminosity $\mathcal{L} = 367.4 \pm 0.2$ (stat) ± 0.4 (norm) ± 1.5 (sys) nb^{-1} at $T = 1.60$ GeV

paper in preparation



SUMMARY

- HADES has a diverse research program on dileptons and hyperons.
- Excellent detector for Dalitz decays of mesons, nucleons and hyperons.
- Allows to study internal structure of particles via eTFF.
- Very good performance for identifying hadrons allows for study of hadronic decay channels.

Thank you for your attention

Bibliography I

- Cover image: © Clara Schuster/Urban Sketchers Rhein-Main
- HADES photo: © J. Hosan, GSI/FAIR

S. Acharya et al., *Phys. Rev. C* **99** (2 2019-02), p. 024001. DOI: 10.1103/PhysRevC.99.024001.

J. Adamczewski-Musch et al., *Phys. Rev. C* **95** (6 2017-06), p. 065205. DOI: 10.1103/PhysRevC.95.065205.

J. Adamczewski-Musch et al., *Phys. Rev. C* **94** (2 2016-08), p. 025201. DOI: 10.1103/PhysRevC.94.025201.

J. Adamczewski-Musch et al., *Phys. Rev. C* **95** (1 2017-01), p. 015207. DOI: 10.1103/PhysRevC.95.015207.

Adamczewski-Musch, J. et al., *Eur. Phys. J. A* **57.4** (2021), p. 138. DOI: 10.1140/epja/s10050-021-00388-w.

G. Agakishiev et al., *Phys. Rev. C* **85** (3 2012-03), p. 035203. DOI: 10.1103/PhysRevC.85.035203.

G. Agakishiev et al., *Phys. Rev. C* **87** (2 2013-02), p. 025201. DOI: 10.1103/PhysRevC.87.025201.

G. Agakishiev et al., *Phys. Rev. Lett.* **114** (21 2015-05), p. 212301. DOI: 10.1103/PhysRevLett.114.212301.

I. Aznauryan and V. Burkert, *Prog. Part. Nucl. Phys.* **67.1** (2012), pp. 1–54. DOI: 10.1016/j.ppnp.2011.08.001.

Bibliography II

- HADES Collaboration et al., *Eur. Phys. J. A* **50.5** (2014-05), p. 81. DOI: `10.1140/epja/i2014-14081-2`.
- T. Hyodo and D. Jido, *Prog. Part. Nucl. Phys.* **67.1** (2012), pp. 55–98. DOI: `10.1016/j.ppnp.2011.07.002`.
- T. Hyodo and W. Weise, *Phys. Rev. C* **77** (3 2008-03), p. 035204. DOI: `10.1103/PhysRevC.77.035204`.
- M. M. Kaskulov and E. Oset, *Phys. Rev. C* **73** (4 2006-04), p. 045213. DOI: `10.1103/PhysRevC.73.045213`.
- R. Münzer et al., *Phys. Lett. B* **785** (2018), pp. 574–580. DOI: `10.1016/j.physletb.2018.08.068`.
- G. Ramalho, *Phys. Rev. D* **102** (5 2020-09), p. 054016. DOI: `10.1103/PhysRevD.102.054016`.
- Salone, Nora and Leupold, Stefan, *Eur. Phys. J. A* **57.6** (2021), p. 183. DOI: `10.1140/epja/s10050-021-00493-w`.
- R. A. Yassine et al. *First measurement of massive virtual photon emission from N* baryon resonances*. 2024. arXiv: `2205.15914 [nucl-ex]`.
- R. A. Yassine et al. *Investigation of the ˚^{0} Production Mechanism in p(3.5 GeV)+p Collisions*. 2023. arXiv: `2301.11766 [nucl-ex]`.

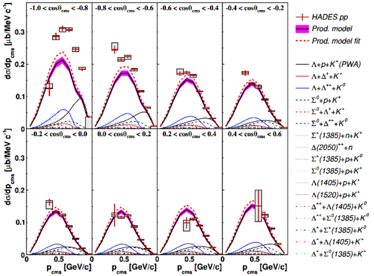
Hyperons and strange baryonic resonances in p+p@3.5 GeV

id	pp→ reaction	$\sigma_0^{(\mathrm{id})}$ cross section [μb]	∡ var.	∡(a_2, a_4)		H	notes	fit result	
			3-body channels						
1	ΛpK^+	$35.26 \pm 0.43\ ^{+3.55}_{-2.83}$	θ^{cms}_{Λ}	0.798	0.134	✓	[16]	38.835 ± 0.026	⊤
2	$\Sigma^0 pK^+$	$16.5 \pm 20\,\%$	$\theta^{cms}_{\Sigma^0}$	0.034 ± 0.241	—		[21]+calc.	19.800 ± 0.094	⊤
3	$\Lambda\Delta^{++}K^0$	$29.45 \pm 0.08\ ^{+1.67}_{-1.46} \pm 2.06$	$\theta^{cms}_{\Delta^{++}}$	1.49 ± 0.3	—	✓	[13]	32.10 ± 0.11	⊤
4	$\Sigma^0\Delta^{++}K^0$	$9.26 \pm 0.05\ ^{+1.41}_{-0.31} \pm 0.65$	$\theta^{cms}_{\Delta^{++}}$	0.08 ± 0.02	—	✓	[13]	8.5 ± 2.1	⊥
5	$\Lambda\Delta^{+}K^+$	$9.82 \pm 20\,\%$	$\theta^{cms}_{\Delta^{+}}$	from $\Lambda\Delta^{++}K^0$			res. mod.	11.78 ± 0.15	⊤
6	$\Sigma^0\Delta^{+}K^+$	$3.27 \pm 20\,\%$	$\theta^{cms}_{\Delta^{+}}$	from $\Sigma^0\Delta^{++}K^0$			res. mod.	2.6 ± 1.3	⊥
7	$\Sigma(1385)^+nK^+$	$22.42 \pm 0.99 \pm 1.57\ ^{+3.04}_{-2.23}$	$\theta^{cms}_{\Sigma^{+*}}$	1.427 ± 0.3	0.407 ± 0.108	✓	[17]	17.905 ± 0.075	⊥
8	$\Delta(2050)^{++}n$	33 % feeding for $\Sigma^* nK^+$	θ^{cms}_{n}	1.27	0.35	✓	[17]	8.82 ± 0.13	⊤
9	$\Sigma(1385)^+pK^0$	$14.05 \pm 0.05\ ^{+1.79}_{-2.14} \pm 1.00$	$\theta^{cms}_{\Sigma^{+*}}$	1.42 ± 0.3	—	✓	[13]	16.101 ± 0.072	⊤
10	$\Sigma(1385)^0pK^+$	$6.0 \pm 0.48\ ^{+1.94}_{-1.06}$	$\theta^{cms}_{\Sigma^{0*}}$	from $\Sigma(1385)^+nK^+$		✓	[17]	7.998 ± 0.069	⊤
11	$\Lambda(1405)pK^+$	$9.2 \pm 0.9 \pm 0.7\ ^{+3.3}_{-1.0}$	—	—	—	✓	[18]	7.7 ± 3.0	⊥
12	$\Lambda(1520)pK^+$	$5.6 \pm 1.1 \pm 0.4\ ^{+1.1}_{-1.6}$	—	—	—	✓	[18]	7.2 ± 3.6	⊤
13	$\Delta^{++}\Lambda(1405)K^0$	$5.0 \pm 20\,\%$	—	—	—		[23]	6.0 ± 1.6	⊤
14	$\Delta^{++}\Sigma(1385)^0K^0$	$3.5 \pm 20\,\%$	—	—	—		[23]	4.90 ± 0.46	⊤
15	$\Delta^{+}\Sigma(1385)^+K^0$	$2.3 \pm 20\,\%$	—	—	—		[23]	3.2 ± 1.1	⊤
16	$\Delta^{+}\Lambda(1405)K^+$	$3.0 \pm 20\,\%$	—	—	—		compl. to above	4.2 ± 1.9	⊤
17	$\Delta^{+}\Sigma(1385)^0K^+$	$2.3 \pm 20\,\%$	—	—	—		compl. to above	3.2 ± 1.1	⊤
			4-body channels						
18	$\Lambda p\pi^+K^0$	$2.57 \pm 0.02\ ^{+0.21}_{-1.98} \pm 0.18$		—		✓	[13]	2.8 ± 1.5	⊤
19	$\Lambda n\pi^+K^+$	from $\Lambda p\pi^+K^0$		—				2.8 ± 1.5	⊤
20	$\Lambda p\pi^0K^+$	from $\Lambda p\pi^+K^0$		—				2.8 ± 1.4	⊤
21	$\Sigma^0 p\pi^+K^0$	$1.35 \pm 0.02\ ^{+0.10}_{-1.35} \pm 0.09$		—		✓	[13]	1.48 ± 0.76	⊤
22	$\Sigma^0 n\pi^+K^+$	from $\Sigma^0 p\pi^+K^0$		—				1.48 ± 0.84	⊤
23	$\Sigma^0 p\pi^0K^+$	from $\Sigma^0 p\pi^+K^0$		—				1.48 ± 0.75	⊤

Phys. Rev. C 95 (2017 Jan.) p. 015207

Hyperons and strange baryonic resonances in p+p@3.5 GeV

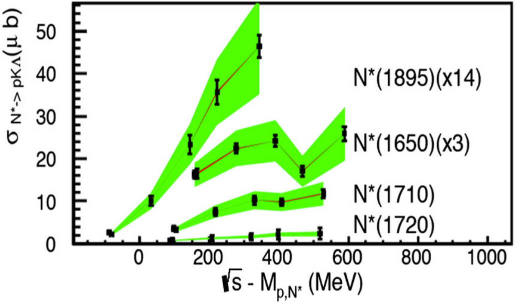
id	pp→ reaction	$\sigma_0^{(id)}$ cross section [μb]	∡ var.	∡(a_2, a_4)		H	notes	fit result	
			3-body channels						
1	$\Lambda p K^+$	$35.26 \pm 0.43\ ^{+3.55}_{-2.83}$	θ^{cms}_{Λ}	0.798	0.134	✓	[16]	38.835 ± 0.026	⊤
2	$\Sigma^0 p K^+$	$16.5 \pm 20\,\%$	$\theta^{cms}_{\Sigma^0}$	0.034 ± 0.241	—		[21]+calc.	19.800 ± 0.094	⊤
3	$\Lambda \Delta^{++} K^0$	$29.45 \pm 0.08\ ^{+1.67}_{-1.46} \pm 2.06$	$\theta^{cms}_{\Delta^{++}}$	1.49 ± 0.3	—	✓	[13]	32.10 ± 0.11	⊤
4	$\Sigma^0 \Delta^{++} K^0$	$9.26 \pm 0.05\ ^{+1.41}_{-0.31} \pm 0.65$	$\theta^{cms}_{\Delta^{++}}$	0.08 ± 0.02	—	✓	[13]	8.5 ± 2.1	⊥
5	$\Lambda \Delta^{+} K^+$	$9.82 \pm 20\,\%$	$\theta^{cms}_{\Delta^{+}}$	from $\Lambda \Delta^{++} K^0$			res. mod.	11.78 ± 0.15	⊤
6	$\Sigma^0 \Delta^{+} K^+$	$3.27 \pm 20\,\%$	$\theta^{cms}_{\Delta^{+}}$	from $\Sigma^0 \Delta^{++} K^0$			res. mod.	2.6 ± 1.3	⊥
7	$\Sigma(1385)^+ n K^+$	$22.42 \pm 0.99 \pm 1.57\ ^{+3.04}_{-2.23}$	$\theta^{cms}_{\Sigma^{+*}}$	1.427 ± 0.3	0.407 ± 0.108	✓	[17]	17.905 ± 0.075	⊥
8	$\Delta(2050)^{++} n$	33 % feeding for $\Sigma^* n K^+$	θ^{cms}_{n}	1.27	0.35	✓	[17]	8.82 ± 0.13	⊤
9	$\Sigma(1385)^+ p K^0$	$14.05 \pm 0.05\ ^{+1.79}_{-2.14} \pm 1.00$	$\theta^{cms}_{\Sigma^{+*}}$	1.42 ± 0.3	—	✓	[13]	16.101 ± 0.072	⊤
10	$\Sigma(1385)^0 p K^+$	$6.0 \pm 0.48\ ^{+1.94}_{-1.06}$	$\theta^{cms}_{\Sigma^{0*}}$	from $\Sigma(1385)^+ n K^+$		✓	[17]	7.998 ± 0.069	⊤
11	$\Lambda(1405) p K^+$	$9.2 \pm 0.9 \pm 0.7\ ^{+3.3}_{-1.0}$					[18]	7.7 ± 3.0	⊥
12	$\Lambda(1520) p K^+$	$5.6 \pm 1.1 \pm 0.4\ ^{+1.1}_{-1.6}$					[18]	7.2 ± 3.6	⊤
13	$\Delta^{++} \Lambda(1405) K^0$	$5.0 \pm 20\,\%$					[23]	6.0 ± 1.6	⊤
14	$\Delta^{++} \Sigma(1385)^0 K^0$	$3.5 \pm 20\,\%$					[23]	4.90 ± 0.46	⊤
15	$\Delta^{+} \Sigma(1385)^+ K^0$	$2.3 \pm 20\,\%$					[23]	3.2 ± 1.1	⊤
16	$\Delta^{+} \Lambda(1405) K^+$	$3.0 \pm 20\,\%$					pl. to above	4.2 ± 1.9	⊤
17	$\Delta^{+} \Sigma(1385)^0 K^+$	$2.3 \pm 20\,\%$					pl. to above	3.2 ± 1.1	⊤
18	$\Lambda p \pi^+ K^0$	$2.57 \pm 0.02\ ^{+0.21}_{-1.98} \pm 0.18$					[13]	2.8 ± 1.5	⊤
19	$\Lambda n \pi^+ K^+$	from $\Lambda p \pi^+ K^0$						2.8 ± 1.5	⊤
20	$\Lambda p \pi^0 K^+$	from $\Lambda p \pi^+ K^0$						2.8 ± 1.4	⊤
21	$\Sigma^0 p \pi^+ K^0$	$1.35 \pm 0.02\ ^{+0.10}_{-1.35} \pm 0.09$					[13]	1.48 ± 0.76	⊤
22	$\Sigma^0 n \pi^+ K^+$	from $\Sigma^0 p \pi^+ K^0$						1.48 ± 0.84	⊤
23	$\Sigma^0 p \pi^0 K^+$	from $\Sigma^0 p \pi^+ K^0$						1.48 ± 0.75	⊤

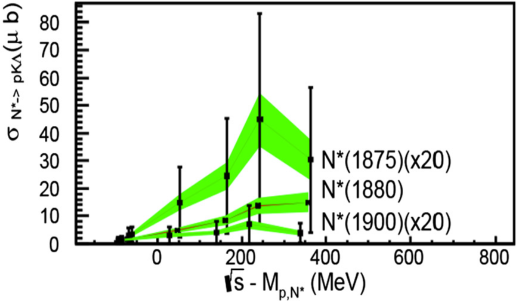


Phys. Rev. C 95 (2017 Jan.) p. 015207

$pK^+\Lambda$ combined PWA analysis

- combined PWA analysis of COSY-TOF, DISTO, FOPI and HADES
- contriution of seven N^* resonances to $pK^+\Lambda$
- 90 % of $pK^+\Lambda$ production gies via resonances

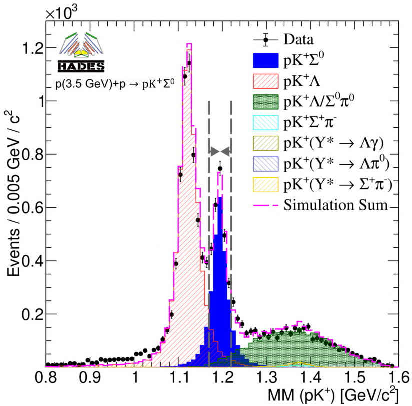


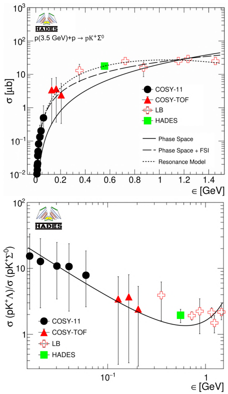


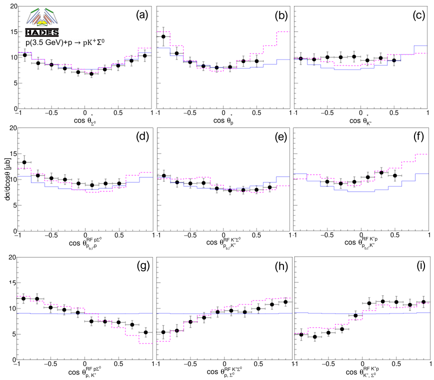
Phys. Lett. B 785 (2018) pp. 574–580

New results from 3.5 GeV – Σ^0 exclusive

- No calorimeter in data from 2007 – p+p@3.5 GeV
- New anaylsis tools (HADES + PANDA cooperation): □ Neural networks; □ Kinematic refit





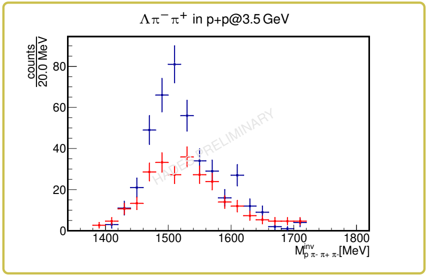


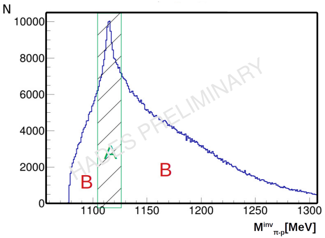
σ(p+p → pK$^+\Sigma^0$) = 17.7 ± 1.7 (stat) ± 1.6 (syst) μb

arXiv: 2301.11766 (nucl-ex) arXiv:2301.11766v1

p+p@3.5 GeV and p+Nb@3.5 GeV beams (2007)

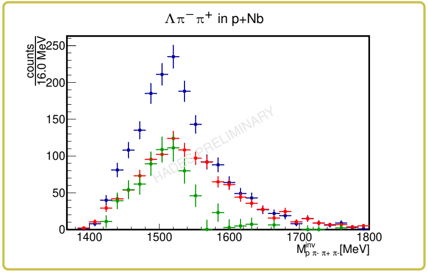
- production via $p+p \to pK^+\Lambda(1520)[\Lambda\pi^+\pi^-]$
- $\Lambda\pi^+\pi^-$ threshold is 220 MeV below total energy for p+p
- inclusive analysis of $p\pi^-\pi^+\pi^-$ final state
- dominating backgroud from $\Delta^{++}\pi^-\Delta^{++}\pi^-$ channel
- also from $p+p \to \Lambda[p\pi^-]K^0[\pi^+\pi^-]p\pi^+$





Λ selection

- TMVA based selection
- A set - $M \in (1015, 1025)$
- B set - outside above
- no simulations required



p+p

- data driven model

Phys. Rev. C 95 (2017 Jan.) p. 015207

no.	Channel	σ [μb]
	3-body reactions	
1	$\Lambda(1520)pK^+$	$5.6 \pm 1.1 \pm 0.4^{+1.1}_{1.6}$
2	$\Lambda\Delta^{++}K^0$	$29.45 \pm 0.08^{+1.67}_{-1.46} \pm 2.06$
3	$\Sigma^0\Delta^{++}K^0$	$9.26 \pm 0.05^{+1.41}_{0.31} \pm 0.65$
4	$\Sigma(1385)^+pK^0$	$14.05 \pm 0.05^{+1.79}_{-2.14} \pm 1.00$
5	$\Delta^{++}\Lambda(1405)K^0$	$5.0 \pm 20\%$
6	$\Delta^{++}\Sigma(1385)^0K^0$	$3.5 \pm 20\%$
7	$\Delta^+\Sigma(1385)^0K^0$	$2.3 \pm 20\%$
	4-body reactions	
8	$\Lambda p\pi^+K^0$	$2.57 \pm 0.02^{+0.21}_{-1.98} \pm 0.18$
9	$\Sigma^0p\pi^+K^0$	$1.35 \pm 0.02^{+0.10}_{-1.35} \pm 0.09$

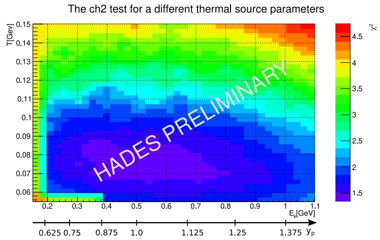
p+Nb

- with use of UrQMD model

Eur. Phys. J. A 50 (2014 May) p. 81

- no $\Lambda(1520)$ production included
- but non-resonant $\Lambda\pi^-\pi^+$ can be simulated
- $\Lambda(1520)$ simulated with thermal source from Pluto:

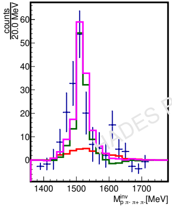
→ a static (not expanding) thermal source characterized by temperature T_s = 75 MeV and rapidity y_s = 1.04

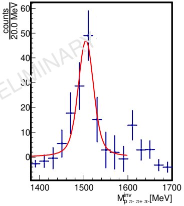


$\Lambda(1520)$ candidates

p+p

- red – non-resonant $\Lambda\pi^+\pi^-$ background
- green – $\Lambda(1520)$ signal





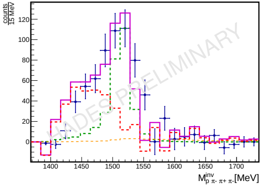
	$M_{\Lambda(1520)}$ [MeV/c^2]	$\sigma_{\Lambda(1520)}$ [MeV/c^2]
PDG	1519.5 ± 1.0	not appl.
p+p	1504.5 ± 4.7	14.7 ± 6.7
sim	1515.6 ± 2.1	11.3 ± 3.6

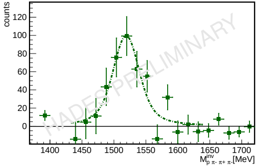
$$\sigma_{p+p\rightarrow\Lambda(1520)X} = 7.1 \pm 1.1 \pm {}^{0.0}_{2.14}\ \mu b$$

p+Nb

- red – URQMD non-resonant $\Lambda\pi^+\pi^-$ background
- green – $\Lambda(1520)$ signal
- orange – $\Sigma(1385)$ signal

of $\Lambda(1520)$	M [MeV/c^2]	σ [MeV/c^2]	Γ [MeV/c^2]
p+p	1504.5 ± 4.7	14.7 ± 6.7	15.6 ± 1.0
p+Nb	1507.7 ± 3.3	14.7 ± 6.7	34.6 ± 5.2





$$\sigma_{p+Nb\rightarrow\Lambda(1520)X} = 4.97 \pm 0.45 \pm {}^{3.58}_{2.53}\ mb$$