STRONG-2020

Annual Meeting 2024

Plan of presentation

01 Progress achieved by the WP during the last year

02 Important highlights of the performed work (last year + full project duration)

03 Tasks and achievements beyond the initial Work Program and/or tasks which could not be carried out

We kindly ask you to focus your presentations on the scientific progress of your WP (financial and administrative aspects of the implementation of the tasks to be included in the written report before 31/07/2024)

Access during last year (July 23 – July 24)

Project	Title	users	AU	person-days
TA4-1	eta beam asymmetry	32	81+135(July)	~ 15
TA4-2	eta' at threshold	21	192+170(July)	~ 15
TA4-3	multiquark states	35	31 (July)	~ 10
TA4-4	K* photoprod. & DCs	15	—	
TA4-5	Aerogel Cherenkov	15	—	
TA4-6	MWPC upgrade	7	19	~9
TA4-7	pi0 off polarised p/n	3*	36	0*
TA4-8	eta' off polarised p/n	3*	37	0*
TA4-9	MRPC detector develop.	32	—	

* Dubna group took part but is not counted

Total Access overview until July 24

total Access Units until …		
Oct 23	**June 24**	**July 24**
907	CB: +73	
	BGOOD: +192	336
	Lab: +12	
total:	1,184	1,520

Estimation of deliverables - table (p183) of the Strong 2020 proposal

Deliverables (brief description and month of delivery)
One unit of access (1AU) is 1 beam-hour (1BH) for the accelerators or 1 lab-day (1LD) for the laboratories of the FTD research building. In average, 100 LD + 250 BH = 350 AU shall be provided per year to international UGs.

Deliverable n.	Unit of access	Unit cost (EUR)	Min. quantity of access to be provided	Estimated number of users	Estimated number of days spent at the infrastructure	Estimated number of projects
D-6.1	1 AU	88	525	75	375	15
D-6.2	1 AU	88	525	75	375	15
D-6.3	1 AU	88	1400	200	1000	40

Deliverable description:
D-6.1) Transnational Access provision - multi annual implementation plan over the first 18 months (month 1-18).
D-6.2) Transnational Access provision - m annual implementation plan over the next 18 months (month 19-36)
D-6.3) Transnational Access provision - multi annual implementation for the whole duration of the project (month 1-48)

min. quantity of access to be provided: **1400 AU**

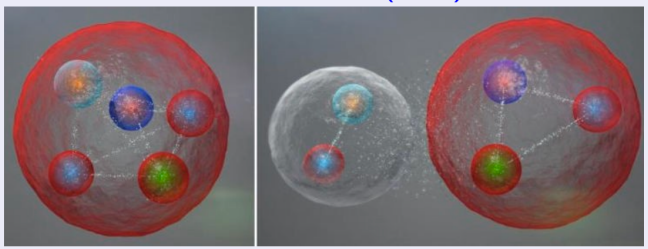
since last October: +73 (CB) + 192 (BGOOD Feb/March) + 336 (BGOOD July) + 12 (lab access)

General theme: N* spectroscopy & multi-quark configurations

Relevant degrees of freedom?

- 3 quark states only?
- Molecule-like states, meson-baryon degrees of freedom?

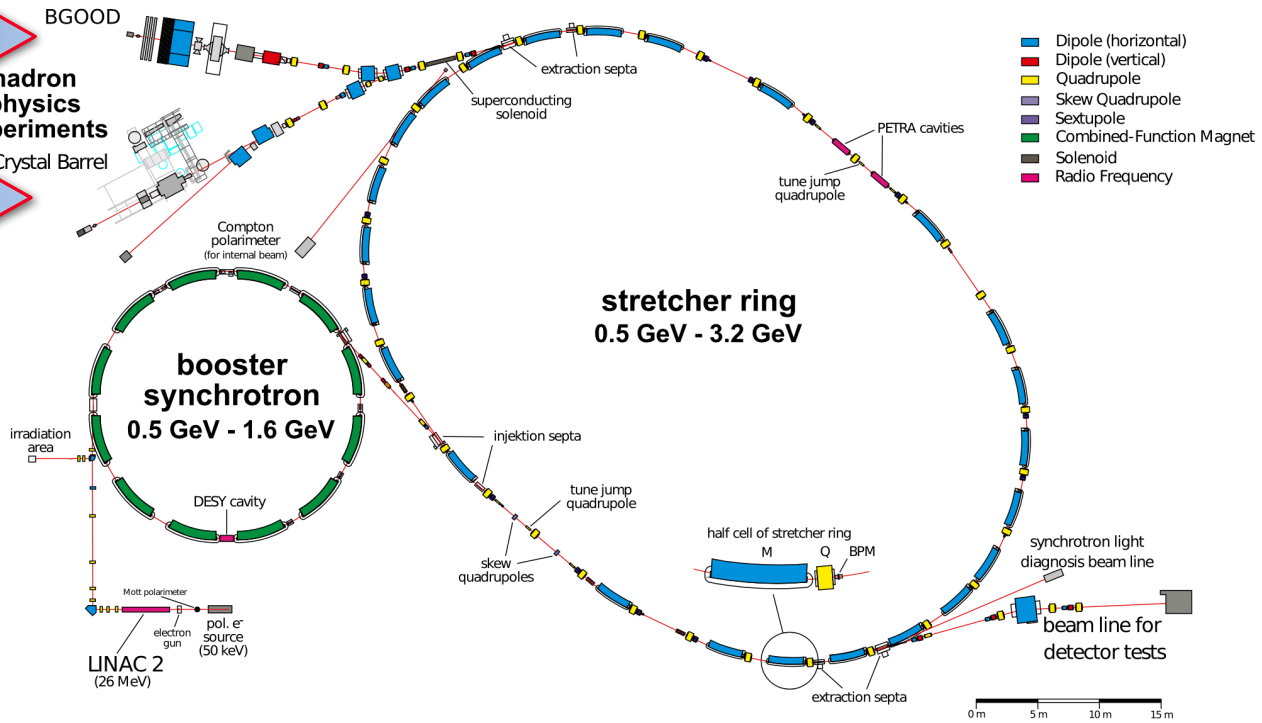
Glozman & Riska, Phys. Rep. 268 (1996) 263,
Garcia-Recio et al., PLB 582 (2004) 49,
Lutz & Kolomeitsev, PLB 585 (2004) 243



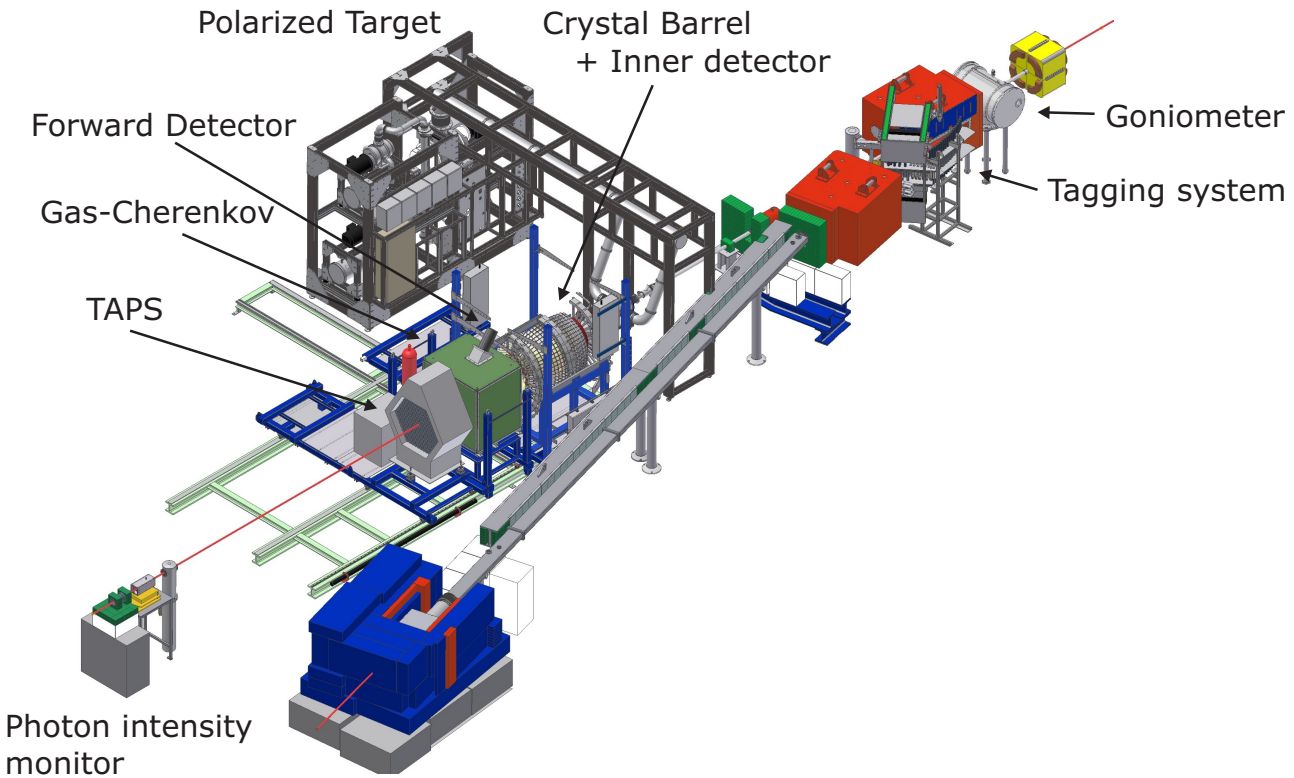
ELSA facility

TA4-1..6 projects @BGOOD

TA4-7 & 8 projects @CB



Recent Results CBELSA-TAPS / TA4-7/8 Setup

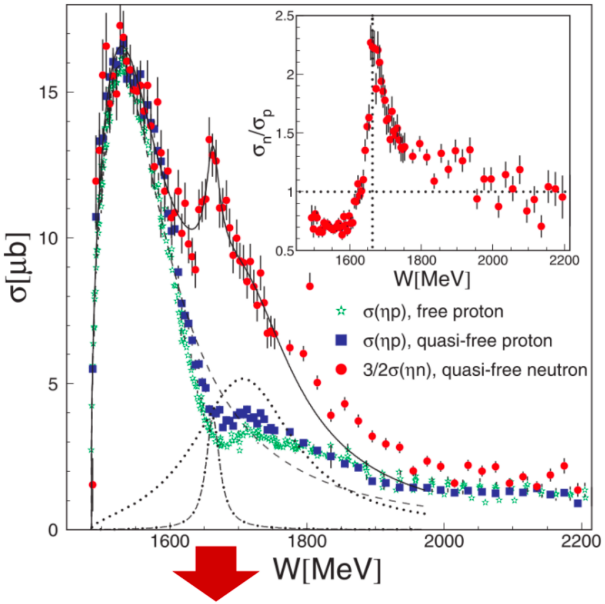


Recent Results CB / TA4-7

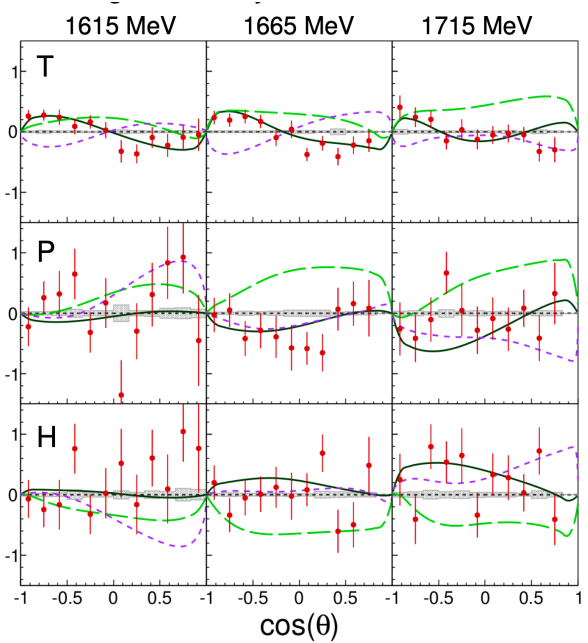
η-photoproduction off neutron

$$\vec{\gamma}\,\vec{d} \rightarrow \eta\, n\, (p)$$

I. Jaegle et al, EPJA 47 (2012) 89 (CBELSA/TAPS)



$$W = 1665 \pm 25\ \text{MeV}$$



N. Jermann (CBELSA/TAPS)
EPJA 59 (2023) 10, 232

Predictions:

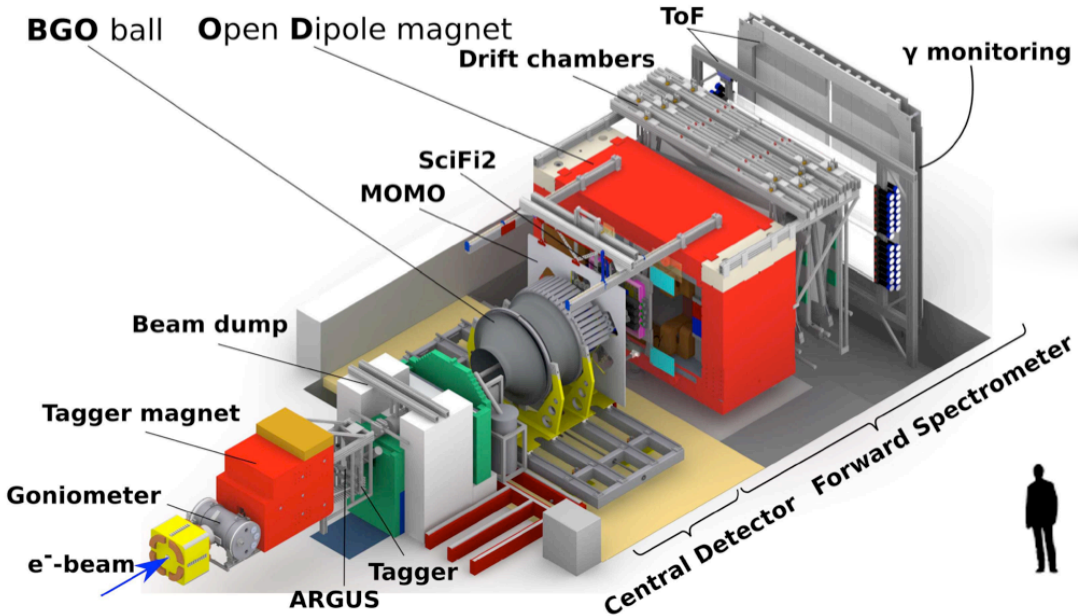
BnGa: interference in the $1/2^-$-wave

BnGa: structure explained by narrow $N(1685)1/2^+$

MAID: $N(1535)1/2^-$ $N(1710)1/2^+$

BnGa PWA fits including new double-polarisation data: narrow $1/2^+$ state ***not*** needed

Recent Results BGOOD / TA4-3



Multiquark States

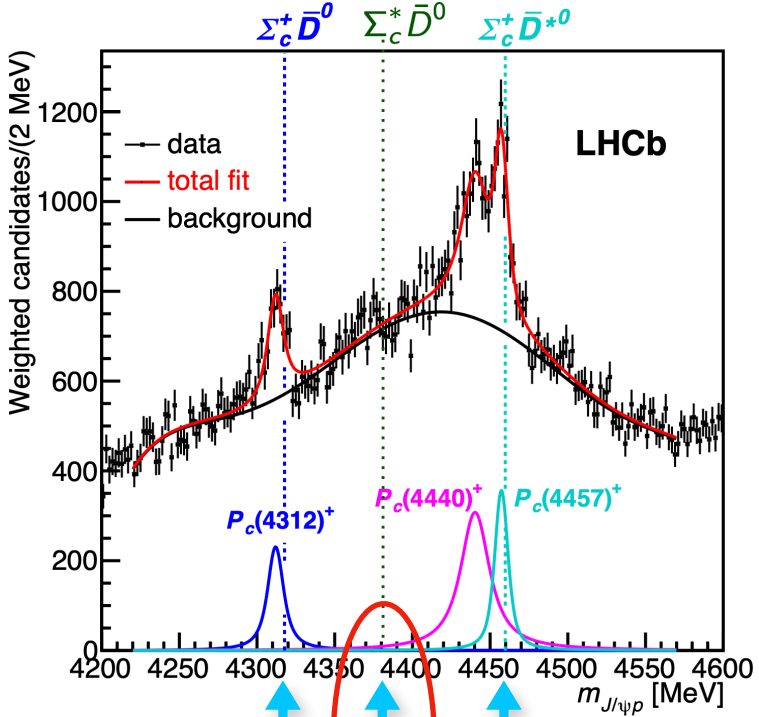
$$\gamma\ p/n \rightarrow K^{0,+}\ Y^{(*)}$$

- combination of BGO central calorimeter & forward spectrometer
- high momentum resolution, excellent neutral & charged particle id in (very) forward direction

Recent Results BGOOD / TA4-3

LHCb,
PRL 122 (2019) 222001

Meng-Lin Du et al.,
PRL 124 (2020) 072001
Hadronic molecules & HQSS



uds sector N*(1535) Σ K Σ* K Σ K* N*(2030/80)

$\gamma p \to K^+\Sigma^0$

T.C. Jude et al.,
Phys. Lett. B 820 (2021) 136559

$\gamma p \to K^+\Lambda(1405)$

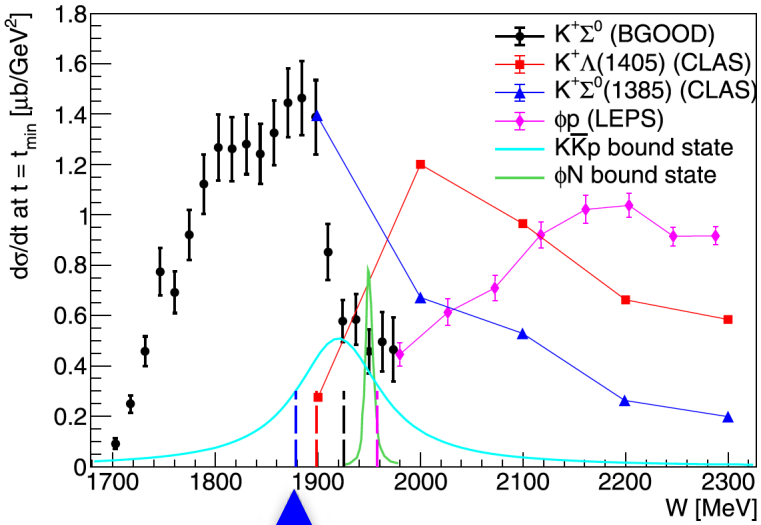
G. Scheluchin, T.C Jude et al.
Phys. Lett. B 833 (2022) 137375

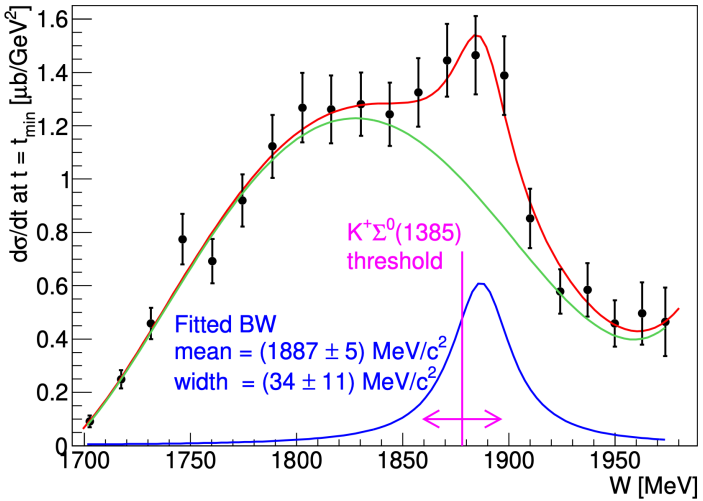
$\gamma n \to K^0\Sigma^0$

K. Kohl, T.C. Jude, et al.,
EPJA 59 (2023) 254

Recent Results BGOOD / TA4-3

$\gamma p \rightarrow K^+ \Sigma_{gs}$ at $\Sigma^*(1385)$ threshold





threshold
$K^+ \Sigma^0(1385)$

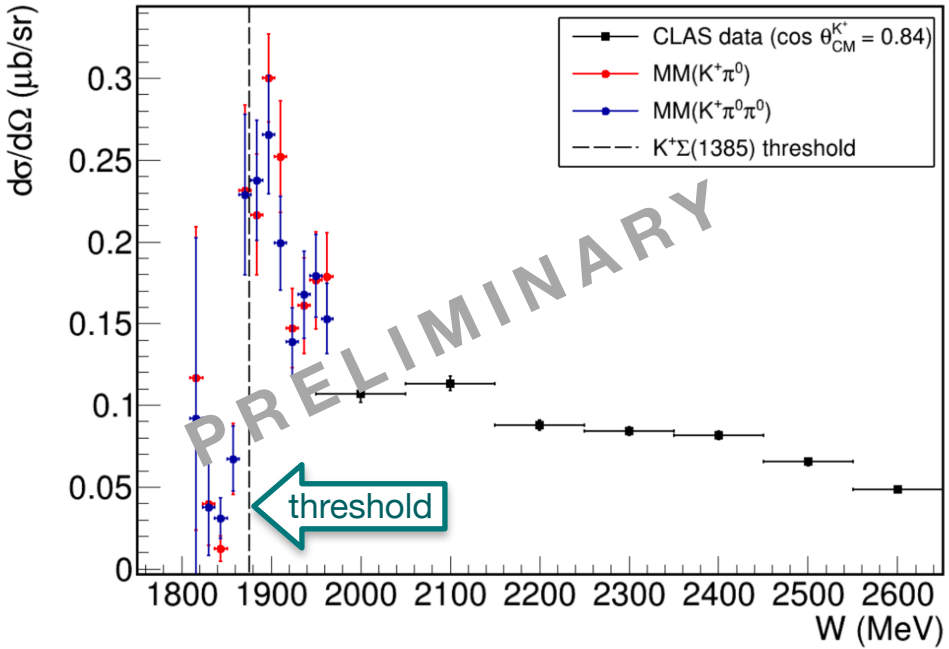
T. Jude *et al.* [BGOOD]
Phys. Lett. B 820 (2021)
& later analysis

Recent Results BGOOD / TA4-3

$\gamma p \rightarrow K^+ \Sigma^*(1385)$ at $\Sigma^*(1385)$ threshold

M. Jena Masters thesis (Bonn 2024), data preliminary

- Differential cross section for $\cos\theta^K_{\mathrm{CM}} > 0.9$
- First data from threshold
- large peak at $W \approx 1900\,\mathrm{MeV}$

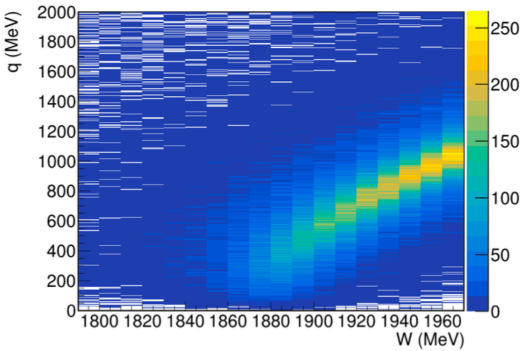


Recent Results BGOOD / TA4-3

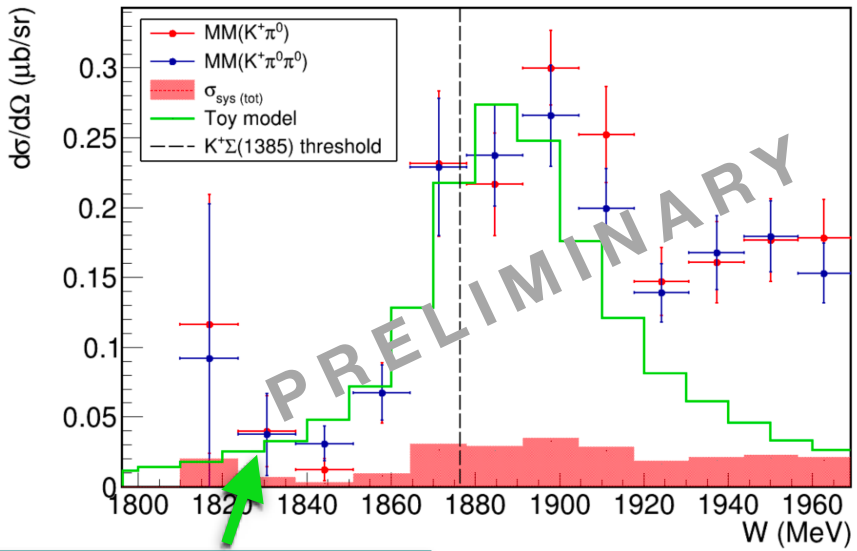
$\gamma p \rightarrow K^+ \Sigma^*(1385)$ at $\Sigma^*(1385)$ threshold

M. Jena Masters thesis (Bonn 2024), data preliminary

- Relative $K^+ - \Sigma(1385)$ momentum:



- Assume $\frac{d\sigma}{d\Omega} \propto \frac{1}{(m_\pi^2 + q^2)^2}$



π-exchange toy model

$K^+ \leftrightarrow \Sigma^0(1385)$

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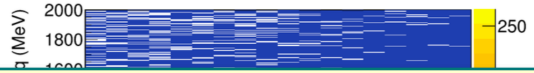
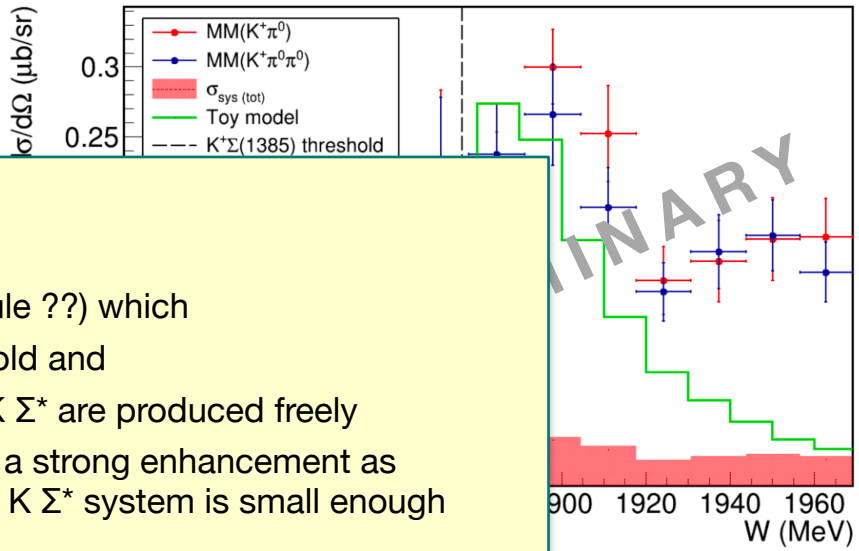




this all looks as if

- K Σ* (1385) system is formed (molecule ??) which
- drives K Σ_{gs} channel below Σ* threshold and
- generates cusp in gs channel when K Σ* are produced freely
- where then the strength reappears in a strong enhancement as long as the relative momentum in the K Σ* system is small enough

π-exchange toy model

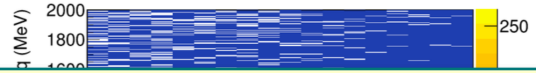
$K^+ \leftrightarrow \Sigma^0(1385)$

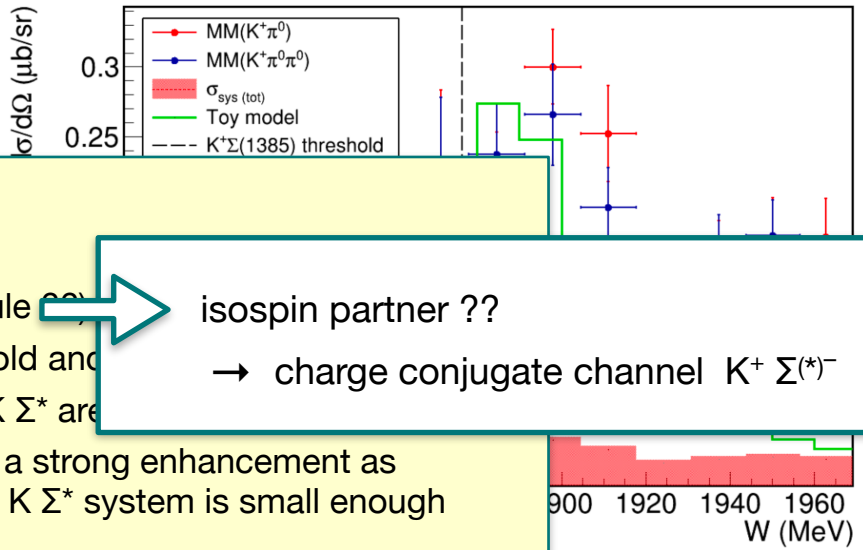
Recent Results BGOOD / TA4-3

$\gamma p \rightarrow K^+ \Sigma^*(1385)$ at $\Sigma^*(1385)$ threshold

M. Jena Masters thesis (Bonn 2024), data preliminary

- Relative $K^+ - \Sigma(1385)$ momentum:





this all looks as if

- K Σ* (1385) system is formed (molecule
- drives K Σ_{gs} channel below Σ* threshold and
- generates cusp in gs channel when K Σ* are
- where then the strength reappears in a strong enhancement as long as the relative momentum in the K Σ* system is small enough

isospin partner ??

→ charge conjugate channel $K^+ \Sigma^{(*)-}$

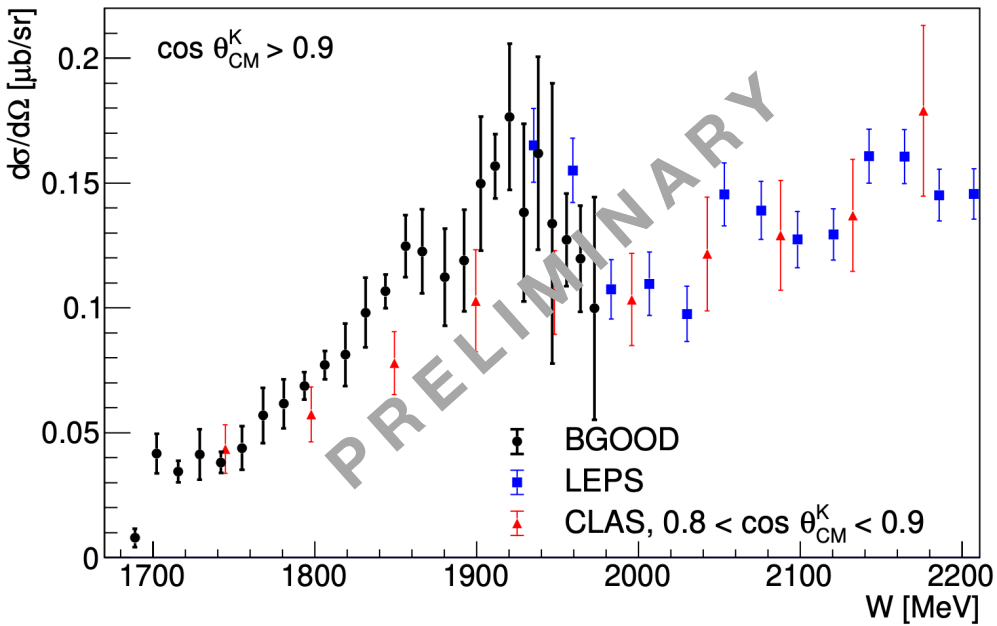
π-exchange toy model

$K^+ \leftrightarrow \Sigma^0(1385)$

Recent Results BGOOD / TA4-3

$\gamma\, n \rightarrow K^+ \Sigma^-_{gs}$ at $\Sigma^*(1385)$ threshold

J. Groß, PhD thesis in preparation



- first data from threshold for $\cos\theta^K_{cm} > 0.9$
- good agreement w/ CLAS & LEPS where overlap
- enhancement in forward directions ↔ smallest $p_\perp$!

Recent Results BGOOD / TA4-3

$\gamma\, n \rightarrow K^+ \Sigma^-_{gs}$ at $\Sigma^*(1385)$ threshold

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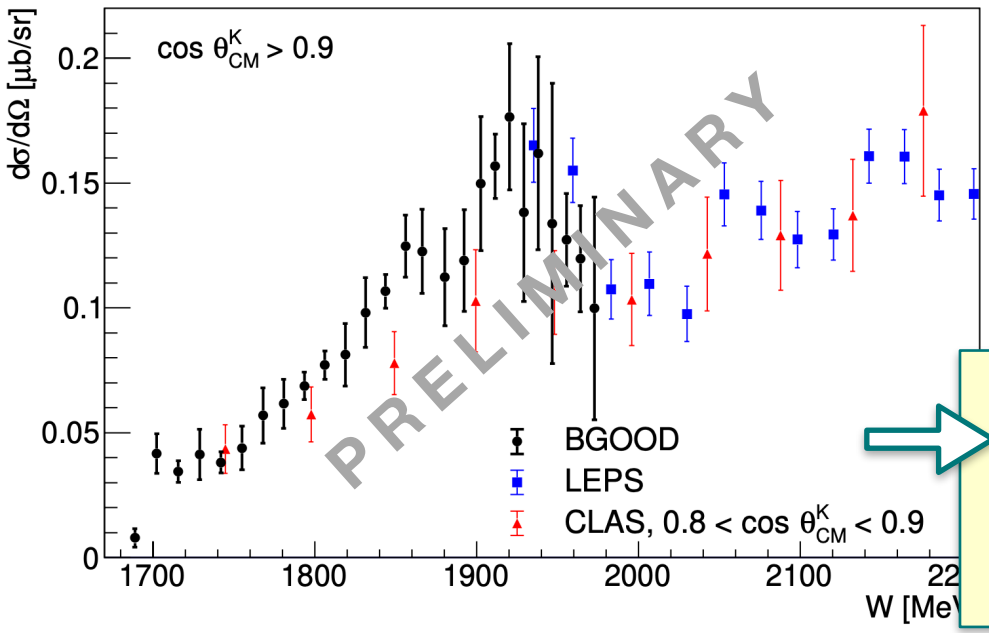


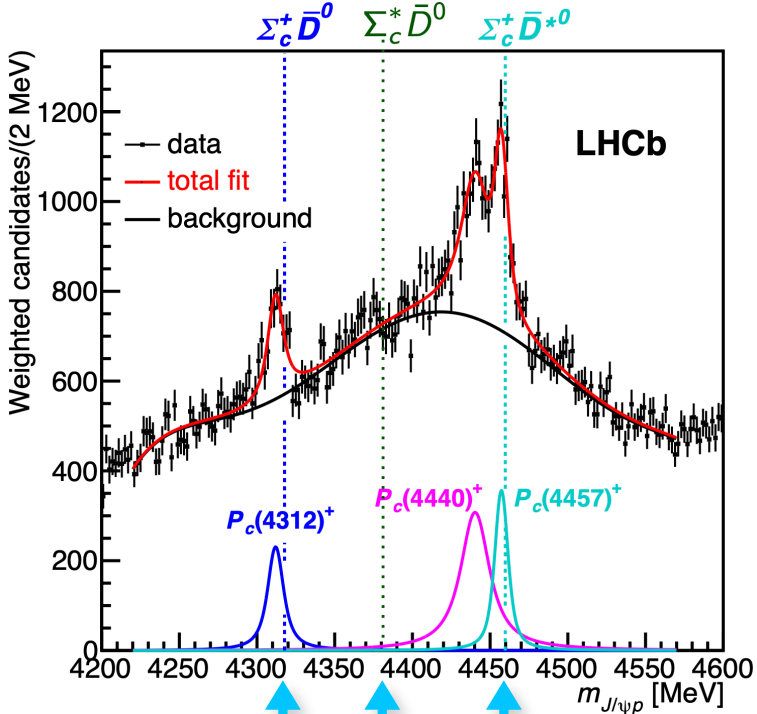
- first data from threshold for $\cos\theta^K_{cm} > 0.9$
- good agreement w/ CLAS & LEPS where overlap
- enhancement in forward directions ↔ smallest $p_\perp$!

- very similar to $K^+ \Sigma^0_{gs}$
- as expected for "molecule"
- cusp shifted ↔ isospin breaking in $\Sigma^{+,0,-}$ system !

SUMMARY "penta-quark systems"

LHCb,
PRL 122 (2019) 222001

Meng-Lin Du et al.,
PRL 124 (2020) 072001
Hadronic molecules & HQSS



$\gamma p \to K^+\Sigma^0$

T.C. Jude et al.,
Phys. Lett. B 820 (2021) 136559

$\gamma p \to K^+\Lambda(1405)$

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Phys. Lett. B 833 (2022) 137375

$\gamma n \to K^0\Sigma^0$

K. Kohl, T.C. Jude, et al.,
EPJA 59 (2023) 254

& new results shown

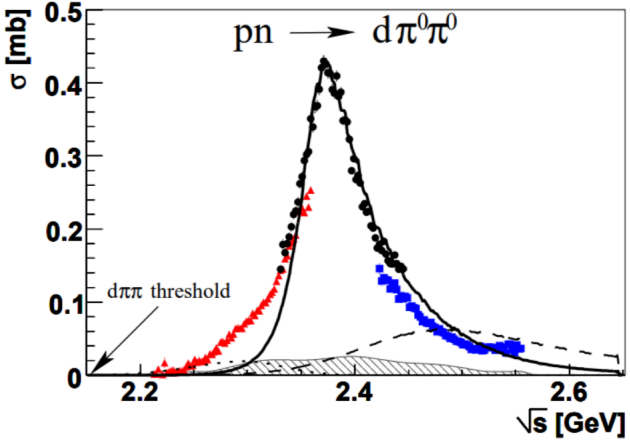
apparent similarity between P_c states in c- and structures observed in s-sector

uds sector N*(1535) Σ K Σ* K Σ K* N*(2030/80)

[K-Σ(1385)]

Recent Results BGOOD / TA4-3 – Hexa-quarks ?

- early SU(6) predictions – NN, NΔ & ΔΔ type dibaryon candidates
  Dyson & Xuong, PRL 13 (1964) 815
- 3-body calculations NΔ & ΔΔ in good agreement
  Gal & Garcilazo, NPA 928 (2014) 73

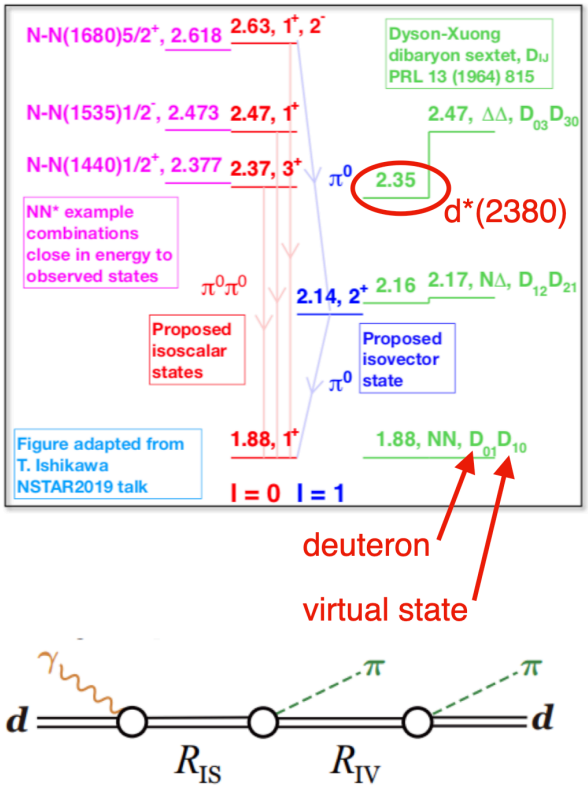


d(2380)*

observed in pn fusion reaction at WASA experiment at COSY

P. Adlarson et al. [WASA@COSY], PRL 106 (2011) 242302

- *(I)* $J^P = (0)\,3^+$
- ΔΔ type object ?
- observed in multiple final states in pn reactions

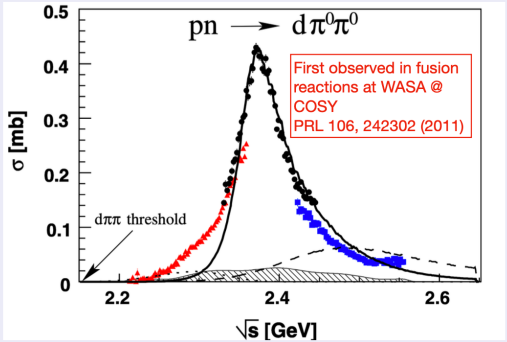


Recent Results BGOOD / TA4-3 – Hexa-quarks ?

Status from other experiments

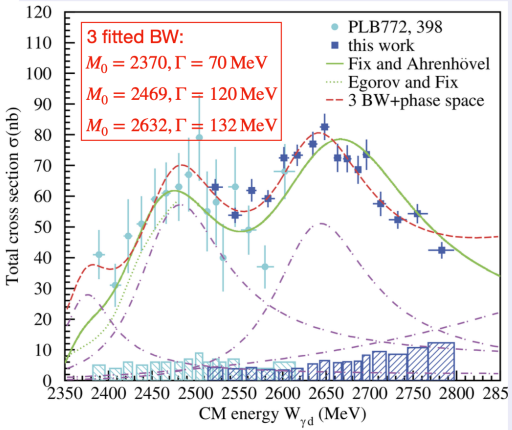
Evidence of the $d^*(2380)$

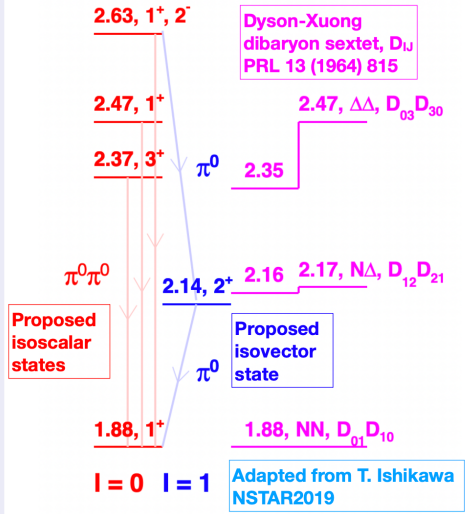
Adlarson et al PRL 106:242302, 2011
Bashkanov et al PRL 102:052301, 2009



- $(I)J^P = (0)3^+$
- Observed in multiple final states

$\gamma d \to \pi^0\pi^0 d$ at ELPH PLB 789 (2019) 413 & PLB 772 (2017) 398

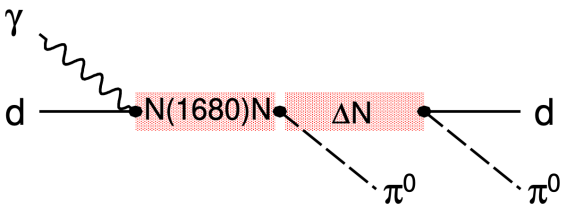


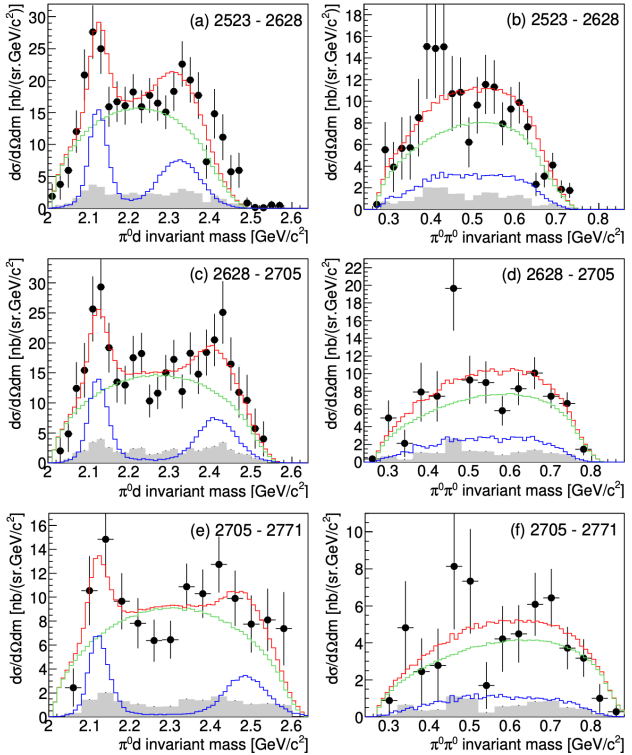


See also, preliminary data: M. Guenther et al (A2), PoS (Hadron 2017)051

Recent Results BGOOD / TA4-3 – Hexa-quarks ?

- $\pi^0 d$ & $\pi^0\pi^0$ invariant mass distributions for higher W intervals
- Simulated sequential decay - different masses & widths of the first dibaryon
- Sequential decay + Phase space = sum
- Mass of 2114 MeV/c^2 and width $\sim$ 20 MeV/c^2 (exp. resolution!) proved optimal

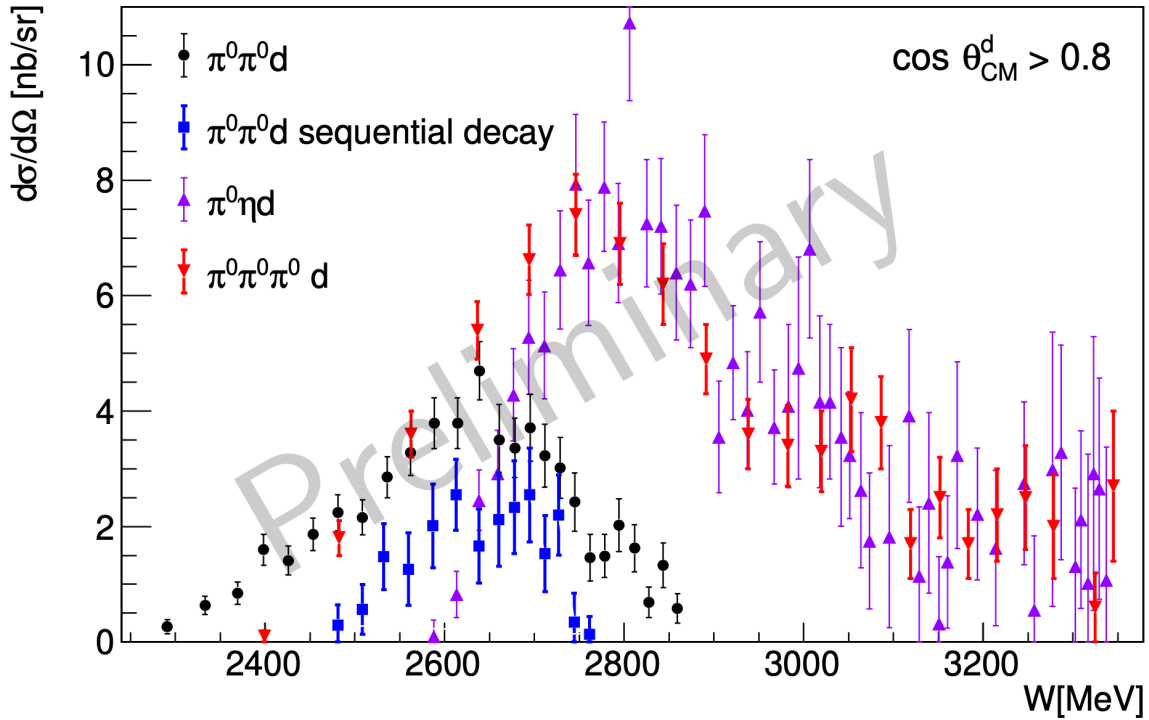




T.C. Jude et al [BGOOD], PLB 832 (2022) 137277 ⇨ mostly consistent w/ ELPH

Recent Results BGOOD / TA4-3 – Hexa-quarks ?

further channels coherent photoproduction

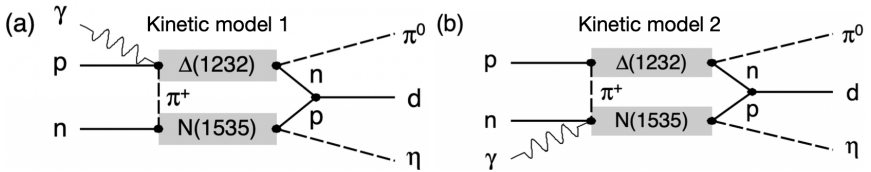


Recent Results BGOOD / TA4-3 – Hexa-quarks ?

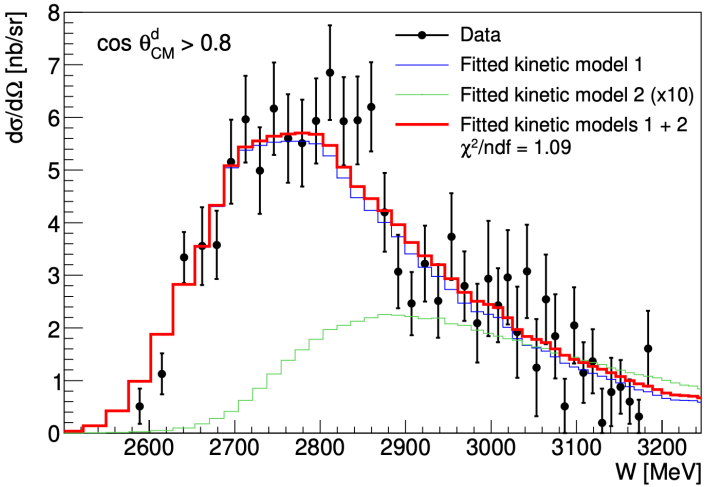
coherent $\pi^0 \eta d$ photoproduction

A. Figueiredo, T. C. Jude , et al. arXiv:2405.09392, submitted to PLB

- Distribution agrees well with models of pion re-scattering



- Similar strength of coherent channels could be explained by similar decay branching ratios::
  - $N(1535) \to \pi N,\ \Gamma_i/\Gamma = 32 - 53\,\%$
  - $N(1535) \to \pi\pi N,\ \Gamma_i/\Gamma = 4 - 31\,\%$
  - $N(1535) \to \pi\eta N,\ \Gamma_i/\Gamma = 30 - 55\,\%$



SUMMARY

- Molecular-like structure in the *uds* sector?
- BGOOD - photoproduction at forward angles & low momentum transfer

  Eur. Phys. J. A 56:104 (2020)
- $\gamma n \to K^0\Sigma^0$ - dynamically generated meson-baryon resonance contributions? (parallels to P_C states) K. Kohl, T.C. Jude, et al., EPJA 59 (2023) 254
- $\gamma p \to K^+(\Lambda(1405) \to \Sigma^0\pi^0)$ - triangle diagram mechanism?

  G. Scheluchin, T.C Jude et al. Phys. Lett. B 833 (2022) 137375)
- Cusp in $\gamma p \to K^+\Sigma^0$ - at thresholds & bound state predictions

  T.C. Jude et al., Phys. Lett. B 820 (2021) 136559, Eur. Phys. J. A (2021) 57:80
- Unaccounted reaction mechanisms in coherent $\pi^0\pi^0 d$ and $\pi^0\eta d$ - dibaryons or pion rescattering terms?

  T.C. Jude, et al., Phys. Lett. B 832 (2022) 137277, A.J. Clara Figueiredo, T.C. Jude, arXiv:2405.09392

SUMMARY

- Molecular-like structure in the *uds* sector?

Exotic multi-quark states and baryon spectroscopy workshop

25–27 Jun 2024
Universitätsclub Bonn, the University of Bonn
Europe/Berlin timezone

Enter your search term

G. Scheluchin, T.C Jude et al. Phys. Lett. B 833 (2022) 137375)

- Cusp in $\gamma p \to K^+\Sigma^0$ - at thresholds & bound state predictions

  T.C. Jude et al., Phys. Lett. B 820 (2021) 136559, Eur. Phys. J. A (2021) 57:80

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  T.C. Jude, et al., Phys. Lett. B 832 (2022) 137277, A.J. Clara Figueiredo, T.C. Jude, arXiv:2405.09392

BACKUP

Recent Results CB / TA4-7

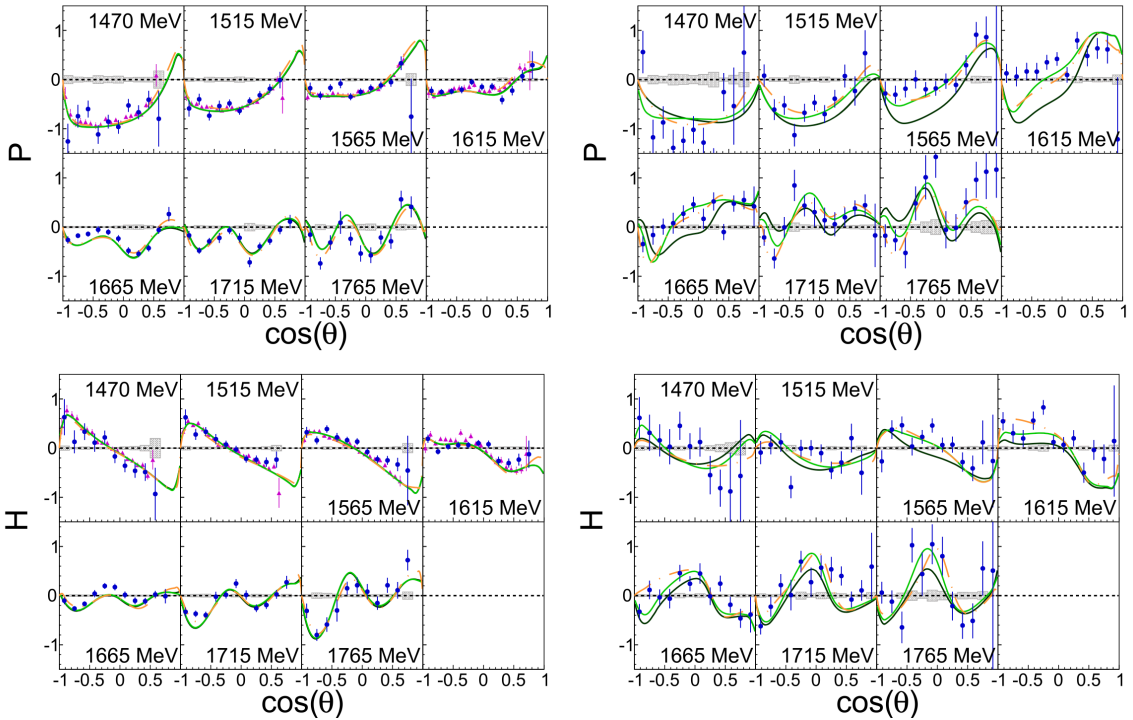

Fig. 4 Target asymmetry T, recoil asymmetry P, and polarization observable H as a function of the polar center-of-mass (c.m.) angle θ of the π^0 meson for bins at the given centroid c.m. energies W. Left (**a**): $\gamma p \to \pi^0 p$. Right (**b**): $\gamma n \to \pi^0 n$. Blue circles: this work. Magenta triangles: CBELSA/TAPS data [52]. Gray shaded areas: systematic uncertainties. Curves: model predictions from BnGa 2022-02 (solid black) [10], BnGa 2022-03 (solid green), SAID MA19 (dashed-dotted orange) [13]. BnGa 2022-03 is identical to BnGa 2022-02 but includes the results presented here in the fits

N. Jermann et al. [CBELSA/TAPS]
Eur. Phys. J. 59 (2023)

$$\vec{\gamma}\,\vec{d} \to \pi\, p\ (n)$$

⊥ polarisation

linear polarisation