# Physics at ELSA – Status and Perspectives

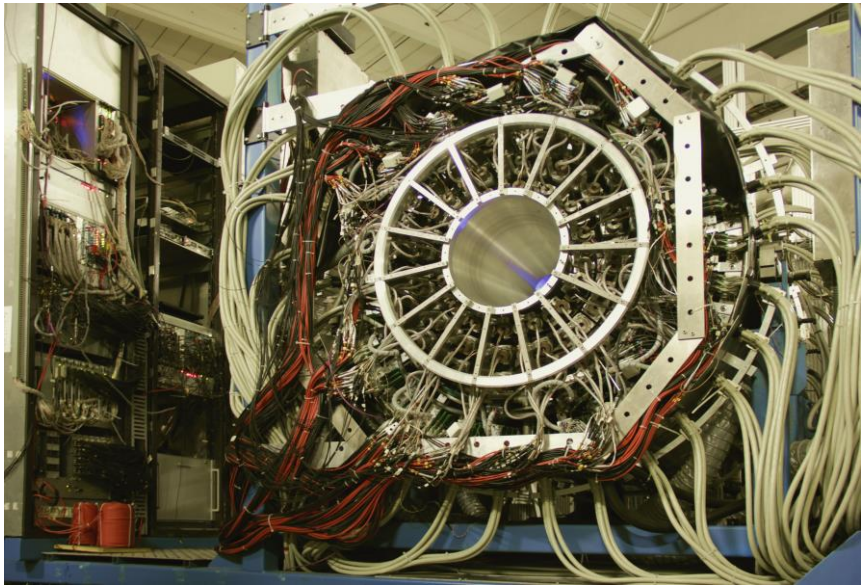
UNIVERSITÄT BONN

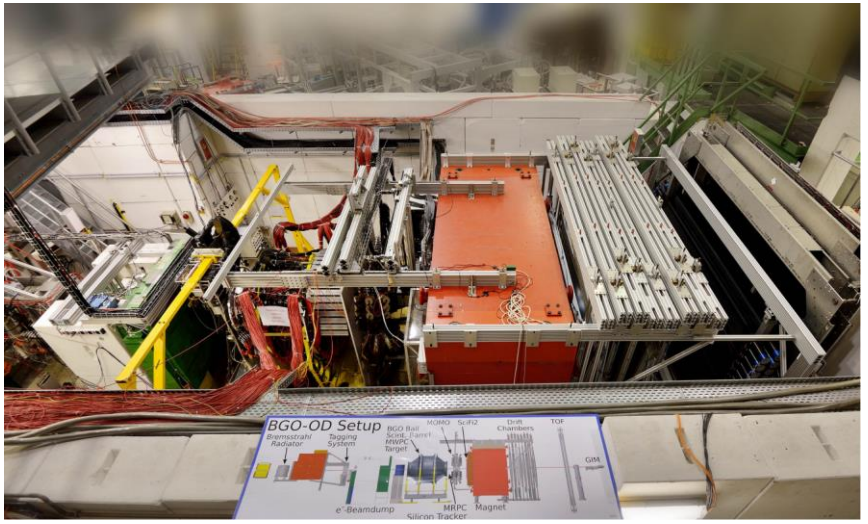
KHuK Jahrestagung

8-10 December 2022
Physikzentrum Bad Honnef

**U.Thoma, Bonn**

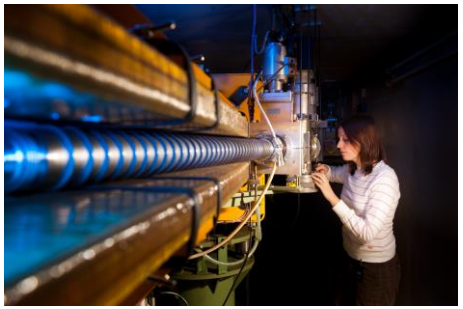
- **ELSA**
- **Selected Results**
- **Status and Perspectives**

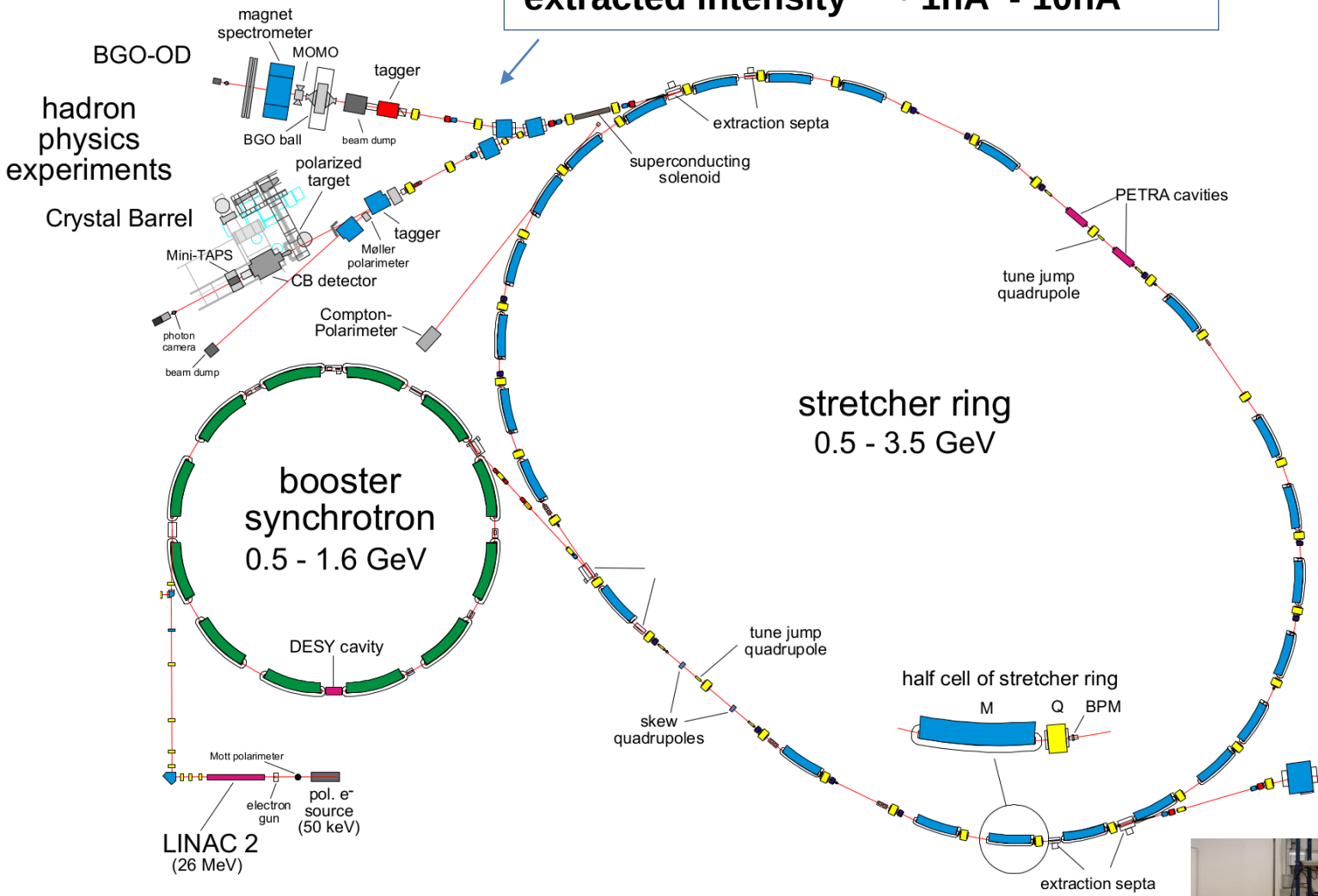




# The Electron Accelerator ELSA

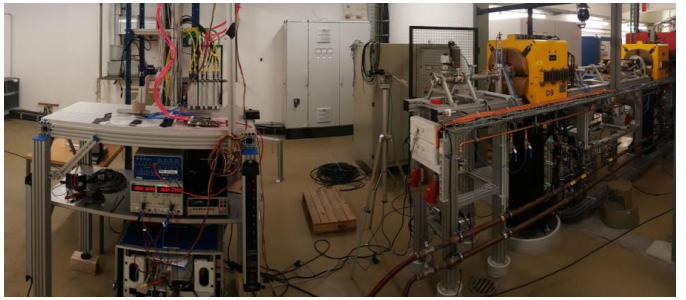
**internal beam intensity ~ 20 - 200 mA**
**extracted intensity ~ 1nA - 10nA**






**wide range of electron-rates:**
**few Hz – 625 MHz**
**Beam spot size:**
**σ = 0.5 - 7mm**

Detector test area

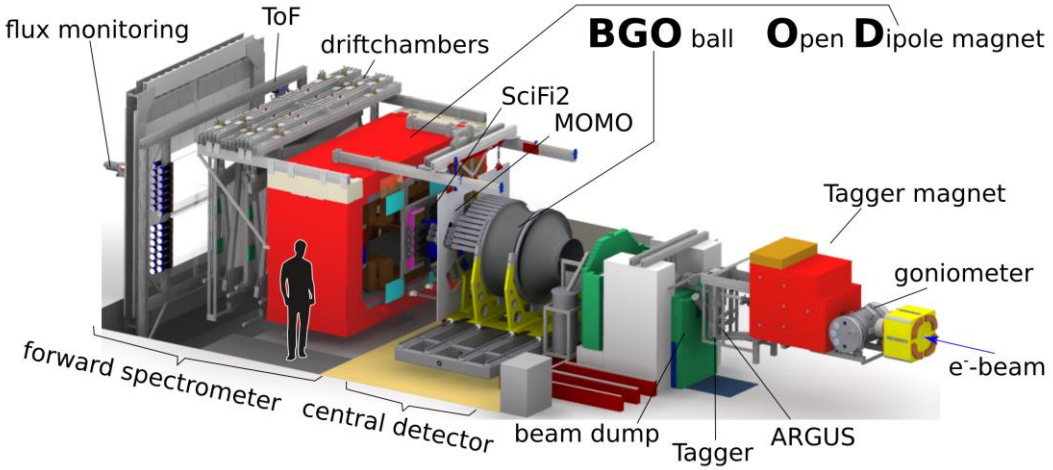


**Measurements with:**

- **polarized beam**
- **polarized target** ⇔ **collaboration: Bonn-Bochum-Mainz-Dubna**

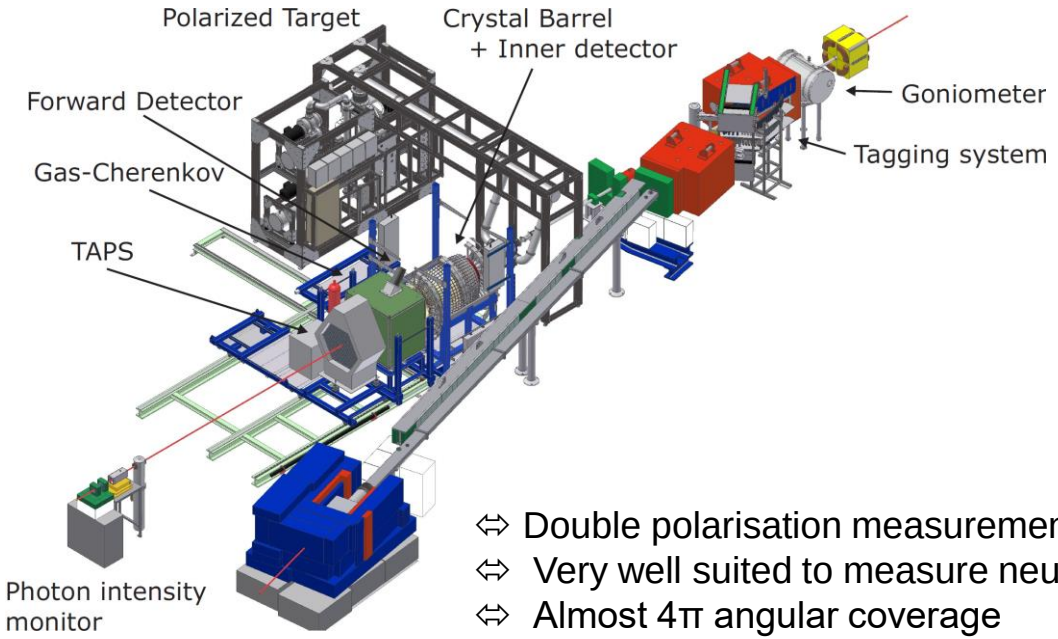
# Hadron Physics at ELSA

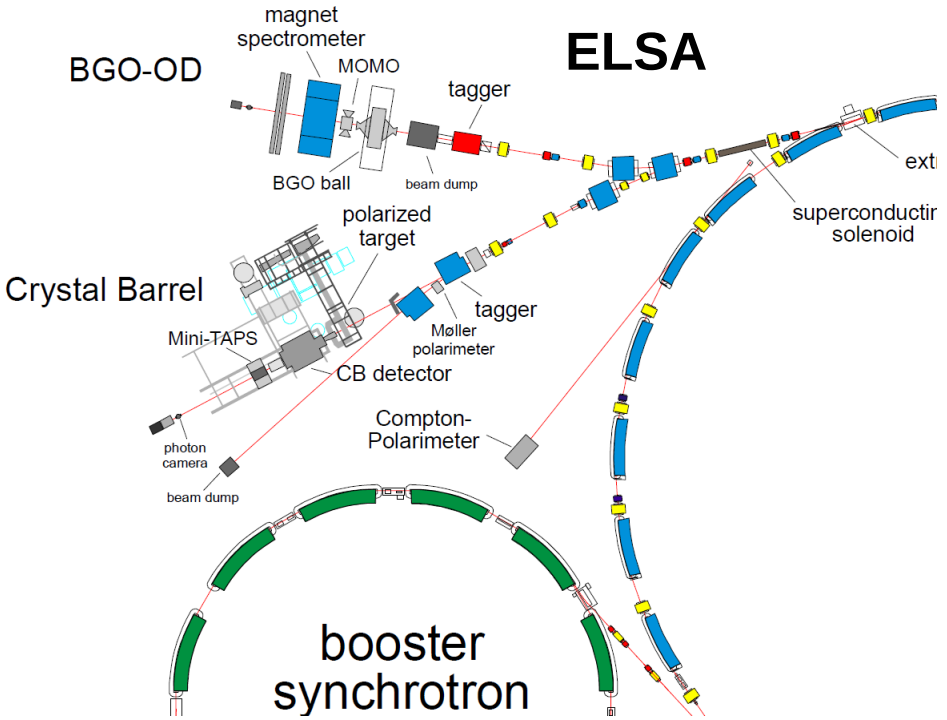
## BGOOD Experiment




⇔ Open dipole setup combined with BGO calorimeter
⇔ Very well suited to measure strange baryons produced at low t (forward $K^+$) ⇔ states of molecular nature

## CBELSA/TAPS Experiment

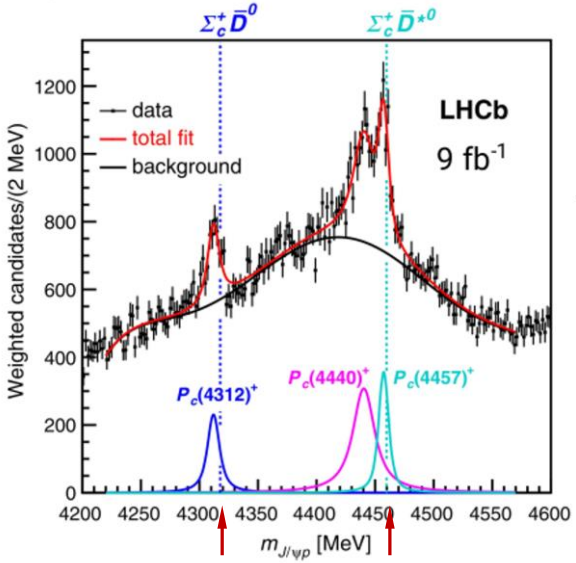



⇔ Double polarisation measurements
⇔ Very well suited to measure neutral mesons decaying into photons
⇔ Almost 4π angular coverage

⇔ Baryon spectroscopy

# BGOOD - Experiment




**At thresholds**

$\Lambda_b^0 \to J/\Psi p K^-$

⇔ **If multi-quark states exist in the charm-sector shouldn‘t they also occur in the strange-sector?**

prominent example: Λ*(1405)

⇔ **Threshold structures in the strange sector?**

**$\Sigma_c \bar{D}^*$**

**uudcc**

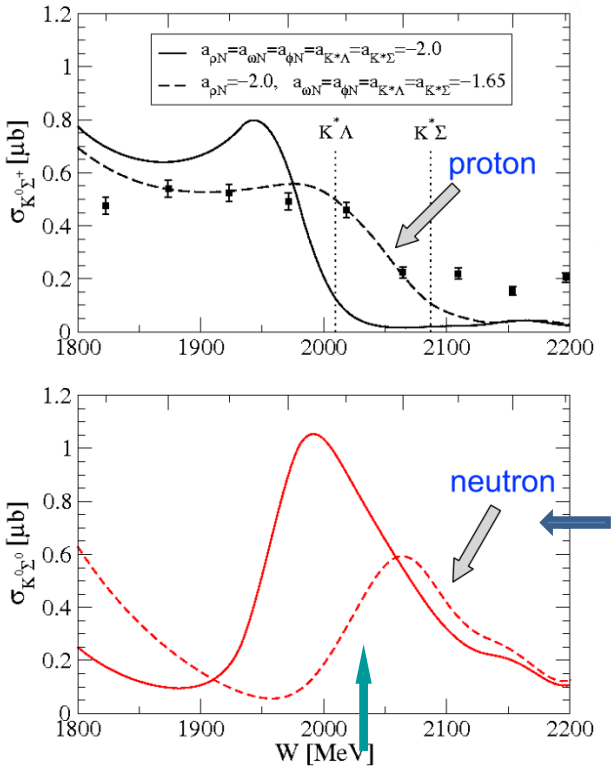
⇕

**Σ K***

**uudss̄**

@ 2081 MeV

**γp → K⁰ Σ⁺** R. Ewald et al., PLB 713 (2012) 180

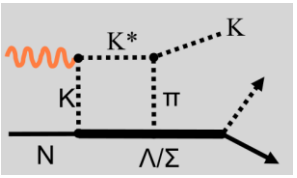



$M_R$=2035 MeV, $\Gamma_R$ =125 MeV

Predictions by Ramos+Oset vectormeson-baryon interaction

⇔ Dynamical generation of resonances ($K^*\Lambda$-$K^*\Sigma$)

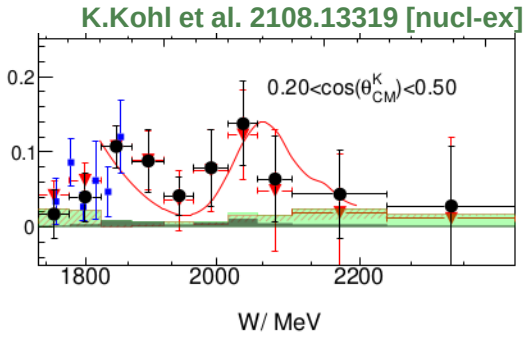
PLB 727 (2013) 287




BGO-OD

**γn → K⁰ Σ⁰**

K.Kohl et al. 2108.13319 [nucl-ex]

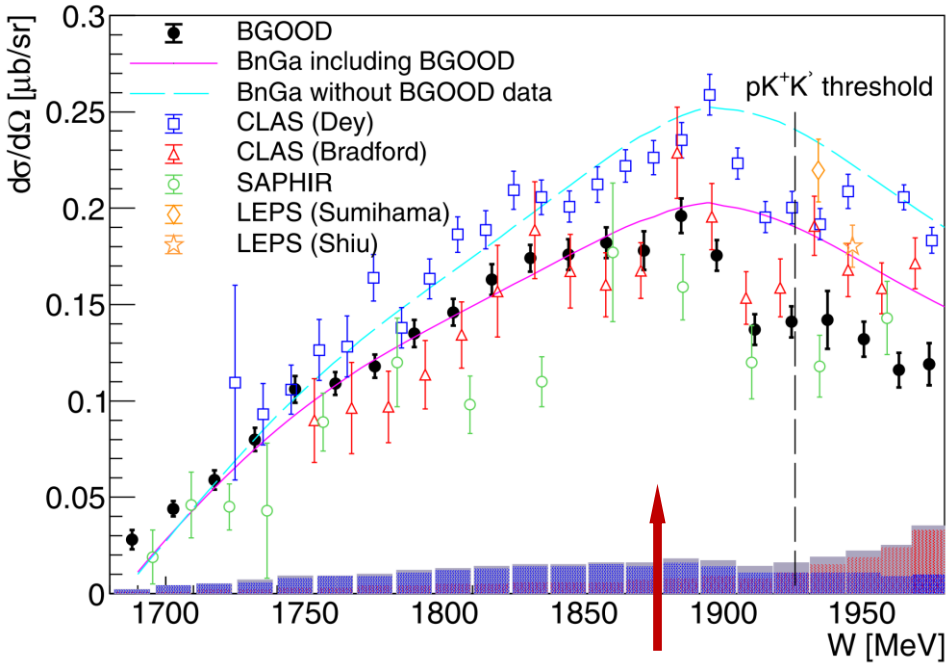



Additional statistics on disc (2x)

# BGOOD - Experiment

**Further interesting observations, e.g.:**

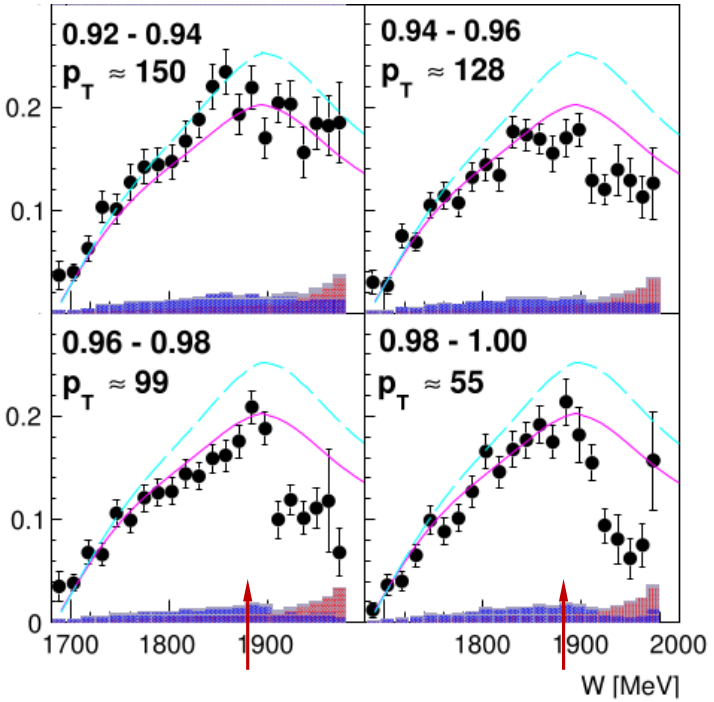
**γp → K⁺ Σ⁰ BGOOD** T. Jude et al.,PLB 820 (2021) 136559




**Σ(1385) K**

**$\cos(\Theta)_K > 0.9$**

**γp → K⁺ Σ⁰**




**Σ(1385) K**

**Good understanding of the data needed**

**⇔ Contributing amplitudes?**

**⇔ Properties? / Quantum numbers?**

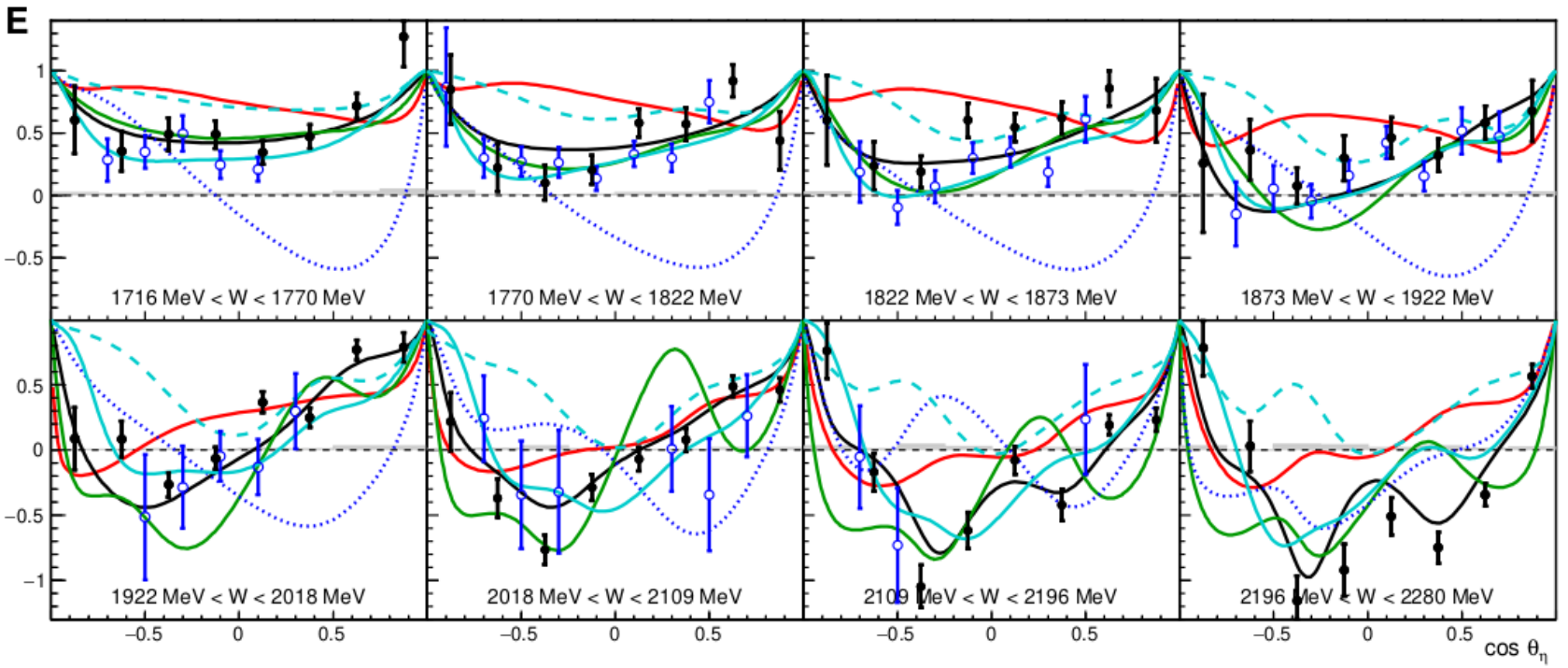
**Forward angles indicate „low momentum exchange“ production ⇔ molecular structures?**

# CBELSA/TAPS - Experiment

## Aim: Understanding of the spectrum and properties of baryon resonances – bound states of strong QCD

**(Double) polarization experiments as key to resolve the baryon spectrum**

**circ. pol. photons, long. pol. target, CBELSA/TAPS high energy bins,** **blue: CLAS**




$\vec{\gamma}\vec{p} \rightarrow p\eta$

$E = \frac{\Leftarrow\Rightarrow - \Rightarrow\Rightarrow}{\Leftarrow\Rightarrow + \Rightarrow\Rightarrow}$

J. Müller et al,
PLB 803, 135323 (2020)

⇓

⇔ **Large sensitivity!**

⇒ **Determination of precise pη-branching ratios**
- **BnGa-PWA / JüBo dynamical coupled channel approach**

# Results – Properties of Baryon Resonances

## Results including new data on $E$, $G$, $T$, $P$, $H$, $\Sigma$, $\sigma$

**Data allowed a new determination of $p\eta$-branching ratios for many resonances, e.g.:**

J.Müller et al. (CBELSA/TAPS), PLB 803, 135323 (2020)

| | $N(1535)1/2^-$ | $N(1650)1/2^-$ | $N(1710)1/2^+$ | $N(1895)1/2^-$ |
|---|---|---|---|---|
| BnGa | 0.41±0.04 | 0.33±0.04 | 0.18±0.10 | 0.10±0.05 |
| PDG'2012 | 0.42±0.10 | 0.05 - 0.15 | 0.10 - 0.30 | no PDG estimate |

⇔ **Additional constraints from new (polarization) data fix PWA-solutions much better than before**

⇓

**Large and heavily discussed difference in the $p\eta$-branching ratio of N(1535)1/2$^-$ and N(1650)1/2$^-$ now significantly reduced**

**New (double) polarization data was also included in JüBo:**

D. Rönchen et al., e-Print: 2208.00089 [nucl-th]

⇓

**$\eta N$ residue of N(1650)1/2$^-$ increased by almost a factor of 2!**

⇔ **Clearly shows the power of polarisation experiments**

# Results – The Spectrum of Baryon Resonances

**Multi-channel Bonn-Gatchina PWA:**

⇒ **Confirmation known resonances, better determination of their properties**

⇒ **New resonances observed**

| | RPP 2010 | our analyses | RPP'22 (2018-22) |
|---|---|---|---|
| N(1710)1/2$^+$ | *** | ****  | **** |
| **N(1860)5/2$^+$** | | * | ** |
| **N(1875)3/2$^-$** | | *** | *** |
| **N(1880)1/2$^+$** | | *** | *** |
| **N(1895)1/2$^-$** | | **** | **** |
| **N(1900)3/2$^+$** | ** | **** | **** |
| **N(2060)5/2$^-$** | | *** | *** |
| N(2100)1/2$^+$ | * | ** | ** |
| **N(2120)3/2$^-$** | | *** | *** |
| **$\Delta$(1600)3/2$^+$** | *** | *** | **** |
| **$\Delta$(1900)1/2$^-$** | * | ** | *** |
| **$\Delta$(1940)3/2$^-$** | * | ** | ** |
| **$\Delta$(2200)7/2$^-$** | * | ** | *** |

**from 2000-2010 not one new baryon resonance was considered by the PDG**

↔ **Results from photoproduction do now enter the PDG and determine the properties of baryon resonances!**

( before: almost entirely $\pi N$-scattering and some $\pi$-photoproduction )

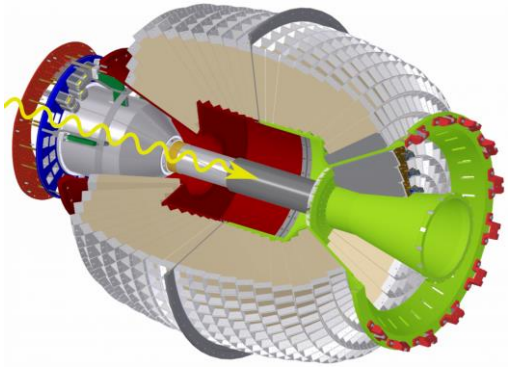
**Photoproduction provides access to the "inelastic channels"**

⇒ **better determination of resonance properties**

BnGa-PWA: A. V. Anisovich et al., EPJA 48 (2012) 15, PRL 119 (2017) 062004, PLB 772 (2017) 247, J. Müller et al.,PLB 803 (2020) 135323 ...

# Next steps: The Bound States of the Strong Interaction @ ELSA

## Recent CB-Calorimeter Upgrade



APDs and
Sampling ADC-readout

⇔ Trigger / time

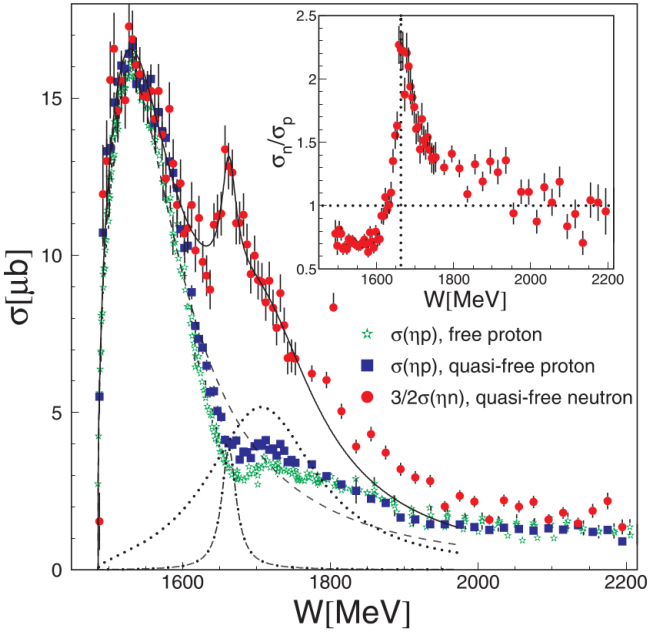
**=> Opens a new window into the spectrum of light baryons:**
**- Photoprod. off the neutron !**
(Isospin dependence)

⇔ **Higher data taking rates** (factor ~7)

**=> Multi-particle final states**
⇔ Larger statistics – larger sensitivity

η-photoproduction

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




**Photoproduction off the neutron ≠ off the proton**

Resonances may decouple from the proton and couple to the neutron

⇔ **Polarized photoproduction of neutral mesons off the polarized nucleon (n)**
⇔ **Neutral multi-meson photoproduction**

# Next steps: The Bound States of the Strong Interaction @ ELSA

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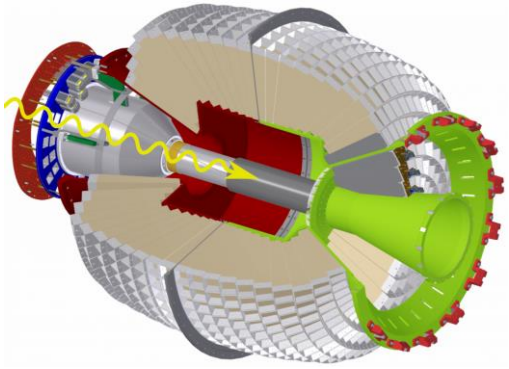

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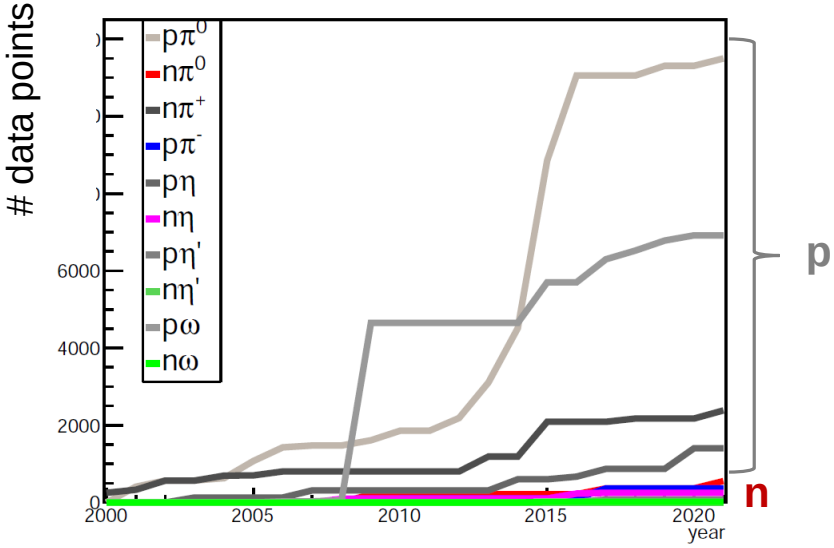
A. Thiel, F. Afzal, Y. Wunderlich, PPNP 125 (2022) 103949

**Existing polarization data**




**Measurement of polarization observables important**

**but: Very scarce !**

**First double polarisation data off the n taken - T, P, H - presently analyzed**

⇔ **Polarized photoproduction of neutral mesons off the polarized nucleon (n)**
⇔ **Neutral multi-meson photoproduction**

# Future: Hadron Spectroscopy Perspectives @ ELSA

## ELSA – mid-term perspectives (2023 – 2025): ~ 2000 beam hours/year

- **BGOOD: Photoproduction of $K^+\Lambda^*(1405)$, $\gamma n \rightarrow K^0 \Sigma^0$, … → multi-quark structures**
- **CBELSA/TAPS: Photoproduction off the neutron + Multi-meson photoproduction**
  **⇔ polarization measurements**

## ELSA – long-term perspectives after shutdown (Brandschutz) (2026 - ….)

- **Extending the physics reach from non-strange (N*, Δ*) to strange baryon spectroscopy (Λ*, Σ*) with polarized target**

> **PDG'2018:**
> Since our last edition, there have been a few measurements of properties of the lowest Λ and Σ resonances - mostly of masses and widths. **But the field remains at a standstill.**
>
> **PDG'2020/2022:**
> For several decades, there has been very little new experimental data bearing on the properties of Λ and Σ resonances. An exception was the study at JLab of the reactions $\gamma p \rightarrow K^+\Sigma^{\pm}\pi^{\mp}$ and $\gamma p \rightarrow K^+\Sigma^0\pi^0$ [1], which established the spin and parity of the Λ(1405) [2]. There was also from BNL new data on the very low energy region of $K^-p$ scattering [3–7]. **Otherwise, the field is starved for data**

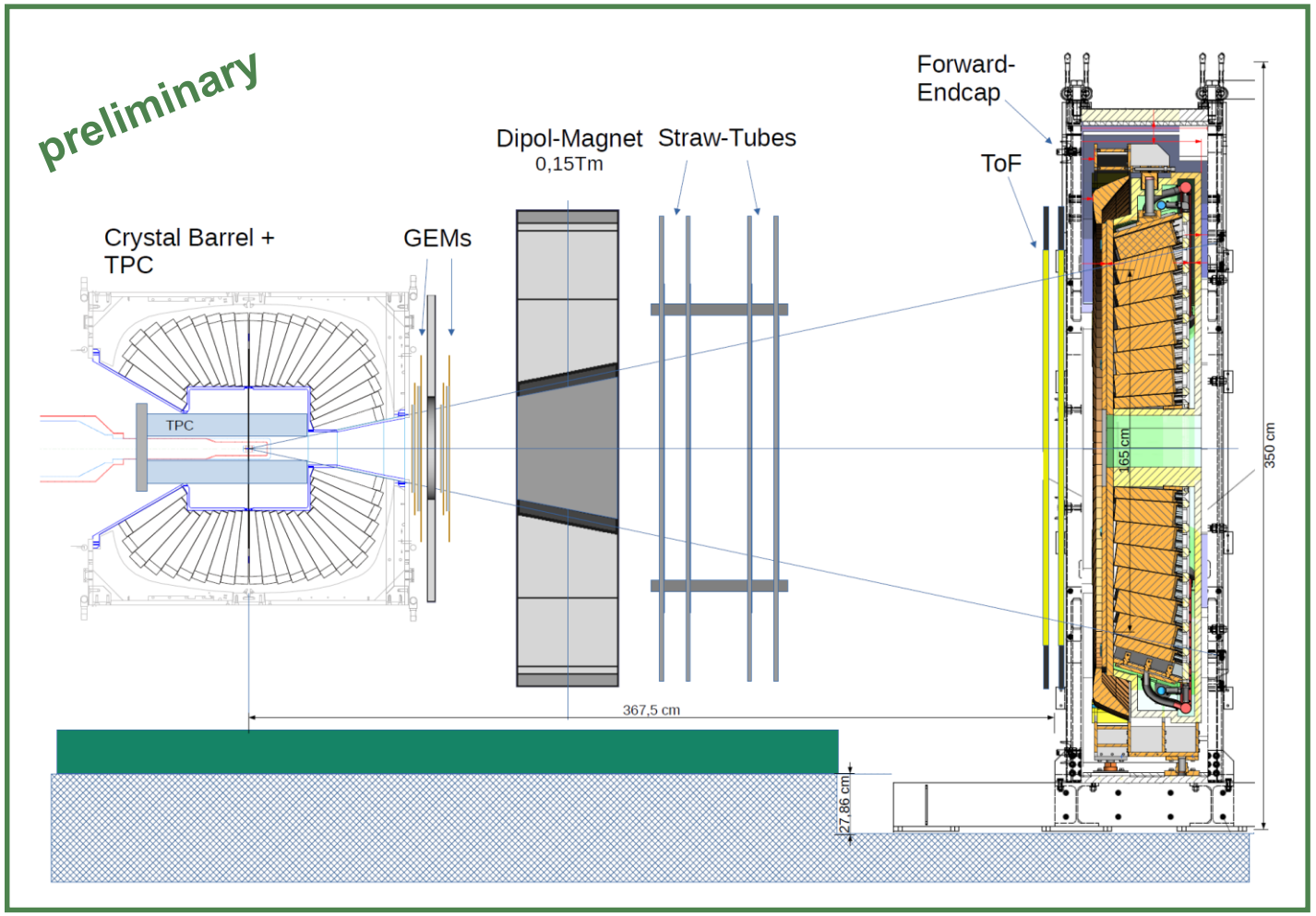
**⇔ not even all states of the first excitation band known**
**- spectrum and properties Λ*, Σ***

**⇔ Upgrade of the detector system**

# Future: Hadron Spectroscopy Perspectives @ ELSA

⇔ **Upgrade of the detector system**

**~ 4π not only for photons but also for charged particles + polarised target**




**…. where PANDA might meet Crystal Barrel …..**

**in a win-win „early science“ -situation**

( one of the discussed options for PANDA early science )

⇔ **Polarized photoproduction off proton and neutron in the non-strange and strange baryon sector**

**- spectrum / properties of baryons, search for multi-quark states**

# Future: Additional Perspectives @ ELSA


- **ELSA = a key facility related to the new „Research and Technology Center for Detector Physics (FTD)“**

- **ELSA: accelerator consolidation and accelerator research** (e.g. study of a PWA injector ….)

- **LOHENGRIN proposal** (inspired by LDMX/SLAC)
  **⇔ search for light dark matter via dark bremsstrahlung**

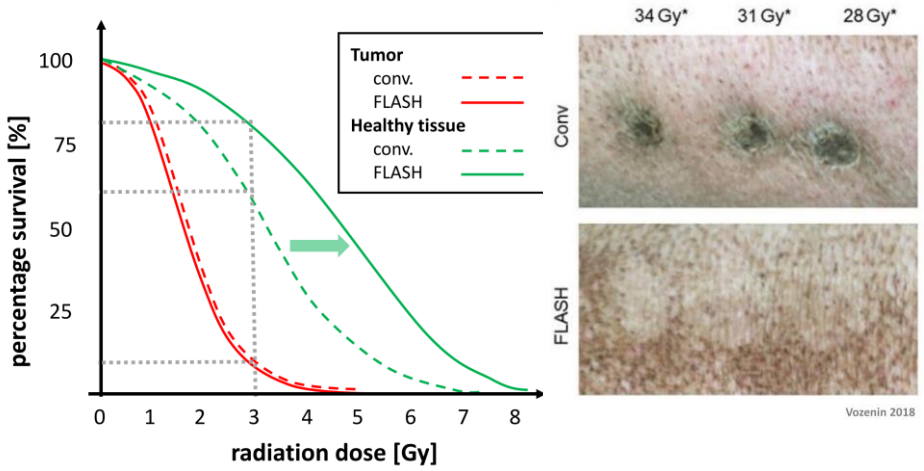
open for external users through EU-funded transnational access (STRONG-2020)

- **Interdiscipliary research: FLASH@ELSA**

  ELSA ⇔ Cancer
  - therapeutic FLASH irradiation using ultra-high energy electrons

  ⇔ search for better methods to spare healthy tissus and better tumor control
  - high E electrons => deep seated tumors
  - aim: up to 60 Gy per pulse, dose rates >> 60 Gy/s

  ⇔ faster regeneration of healthy tissue




Development of new ELSA operation modes!

- Simulations (beam model, beam focussing) / prepare beamline
- Measurement of relative biological effectivity