RA1 „Bound states of light and heavy quarks“

Qbjectives / main research areas:

- Understand the spectrum, properties, and inner structure of hadrons. (Mesons, Baryons – light and heavy)
- Clarify the nature of exotic hadrons and what they tell us about QCD.
- Operate the new experiment INSIGHT @ ELSA and investigate the non-strange and strange baryon spectrum, search for multi-quark and molecular states.
- Understand occurrence of two-pole structures in meson and baryon sectors.
- Investigate final-state interactions in hadronic decays.

⇔From the light to the heavy quarks

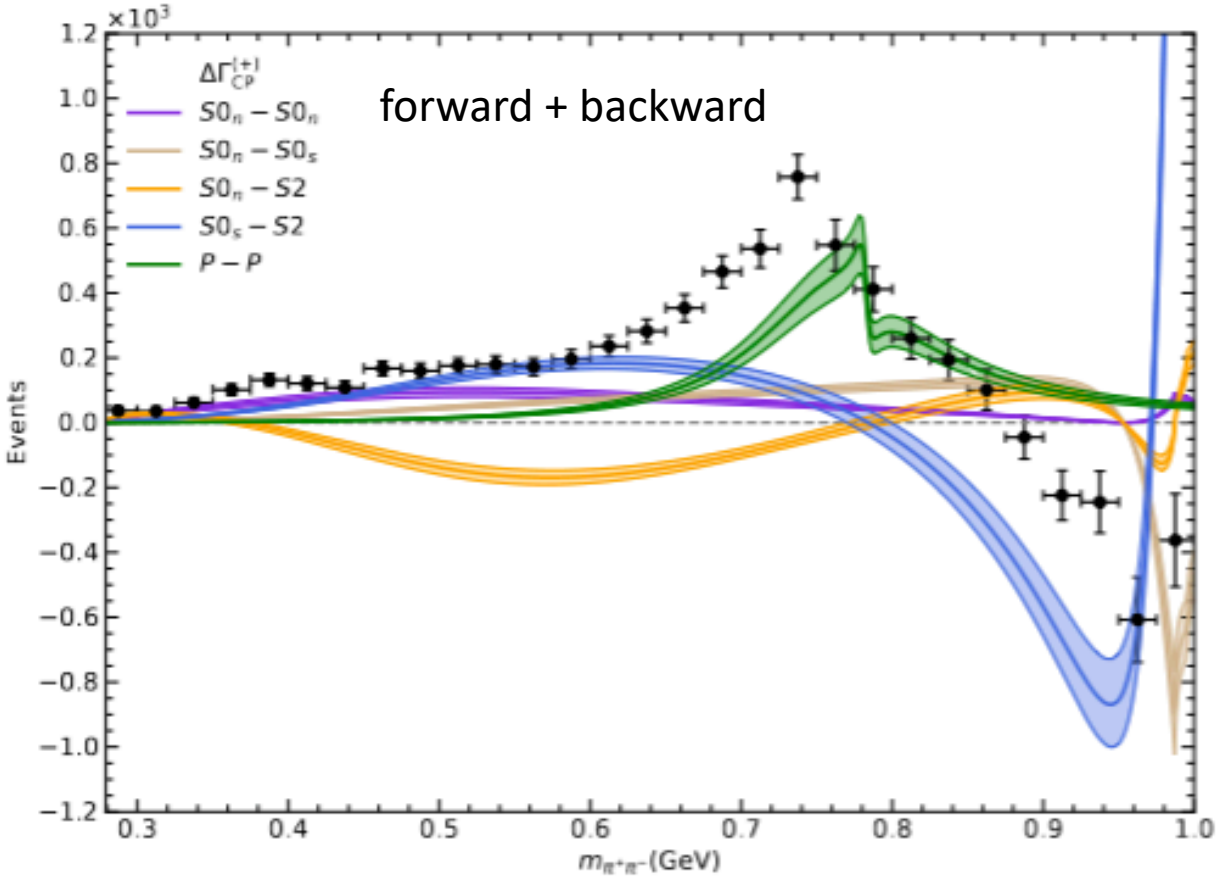
⇔Connecting to the other RA’s, especially RA2

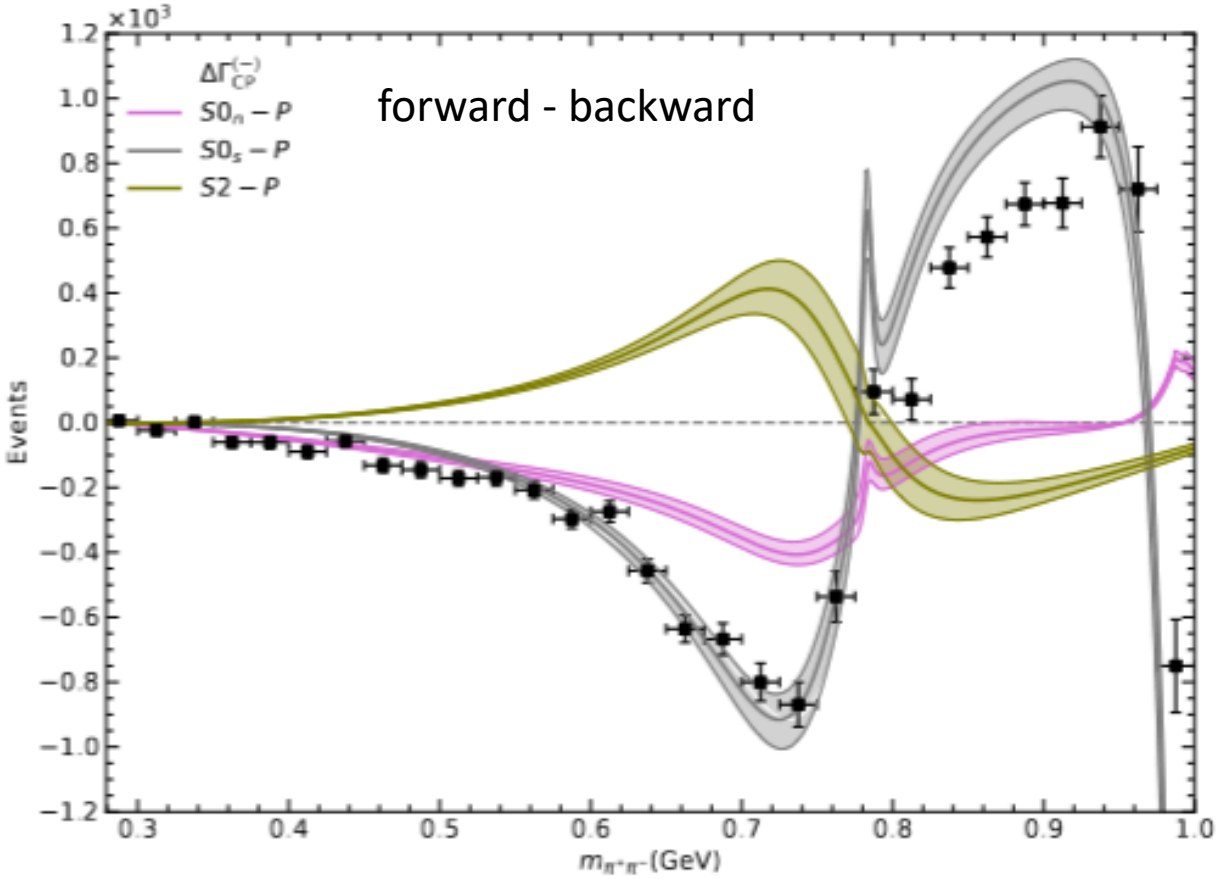
RA1 „Bound states of light and heavy quarks“

Example: *Phys.Rev.Lett.* 136 (2026) 11, 111901

CP Violation in $B^\pm \to K^\pm \pi^+ \pi^-$

$$\mathcal{A}^{\pm}(s,z) = \sum_i f_i(s,z) P_i(s) \Omega_i(s) \mathcal{A}_i^{\pm}$$





non-resonant amplitude S2 is needed!

RA1 „Bound states of light and heavy quarks“

Coordinators: Deborah Rönchen + someone from experiment

Team-Baryon

PWA to understand the light (u,d) and (u,d,s) baryon sector

⇔ Understand QCD-bound states, including exotics

⟸ **INSIGHT data** (+ add. Data, coupled ch.)

⟹ Two pole structures
Exotics, multiquark states

⟺ **TA2**

⟺ **Methods**
CFTR III

INSIGHT

Combining light baryon spectroscopy data (from ELSA) **with LHCb-data in a PWA**

$\Lambda_b \to p\,K^-\gamma,\ \Lambda_b \to p\,K^-\psi(1S),\ \Lambda_c \to p\,K^-\pi^+$

⇔ Understand QCD-bound states, including exotics

LHCb - data

Combining light baryon spectroscopy data (from ELSA) **with LHCb-data in PWA: Pentaquark quantum numbers**

e.g. $\Lambda_b \to p\,K^-\mu^+\mu^-$

⟸ **LHCb data**
(RA2 – analysis)

⟺ **RA2**

Ab initio calculation of hadronic three-particle decays in QCD (lattice+EFT)

⇔ πN-scattering in the Roper channel, incl. $N\pi\pi$

⟺ **TA2**

RA1 „Bound states of light and heavy quarks“

Coordinators: Bastian Kubis + someone from experiment

Team ExoticMesons

Light and strange exotic mesons – Advanced fitting methods

⟺ **TA2**

- **Tool developments: unitary fit models, coupled channel analysis, inclusion of rescattering effects, extraction of branching ratios**

⟸ **From theory groups: unitary constraints, analyticity**

⟺ **Methods also for CFTR I (Baryons)**

⇔ analysis of COMPASS data / later AMBER (2031) data
- $\pi_1(1600) \to \eta\pi,\ \eta'\pi$
- development of unitary models for 3 particle states
- analysis of $3\pi,\ K\pi\pi$

⇔ **Understand QCD-bound states, incl. exotics**

⇔ **with RA2**: Excited meson spectrum for $B \to 3h$,
- final state interactions and role of D-meson loops and exotics
- understand decay spectra, Dalitzplots
- amplitudes, strong phases ⇔ **CP-violation**

⟺ **RA2**

Ab initio calculation of hadronic three-particle decays in QCD

⇔ excited kaons from the lattice

⟺ **TA2**

RA1 „Bound states of light and heavy quarks“

Coordinators: Vadim Baru + Sebastian Neubert:

Team ExoticMultiQuark

Chiral EFT + LHCb-Data + lattice ⇔ Exotics ⟷ **TA2**

From LHCb to Lattice QCD: an extended chiral EFT approach to P_c Pentaquarks and $\Lambda_c \bar{D}^{(*)}$-dynamics

- Include $\Lambda_c \bar{D}^{(*)}$ - LHCb –data into pentaquark analysis
- Extend analysis to finite volume => analysis of emerging lattice data
- Strange sector of hidden charm pentaquarks

⟵ **LHCb data**

$\Lambda_b^0 \to \Lambda_c^+ \bar{D}^{(*)} K^-$

$\Lambda_b^0 \to \Sigma_c^+ \bar{D}^{(*)} K^-$

… also in the strange sector

⟵ **JüBo** – work on $\Lambda_c \bar{D}^{(*)}$ – $\Sigma_c^{(*)} \bar{D}^{(*)}$ interact.

Stefan, Christoph: Lattice Quantum Chromodynamics study of exotic hadrons

Light-quark mass dependence of doubly heavy tetraquark

- Analysis of lattice results for $T_{cc}^{(\prime)}$ and T_{bc} states, predictions for spin partners

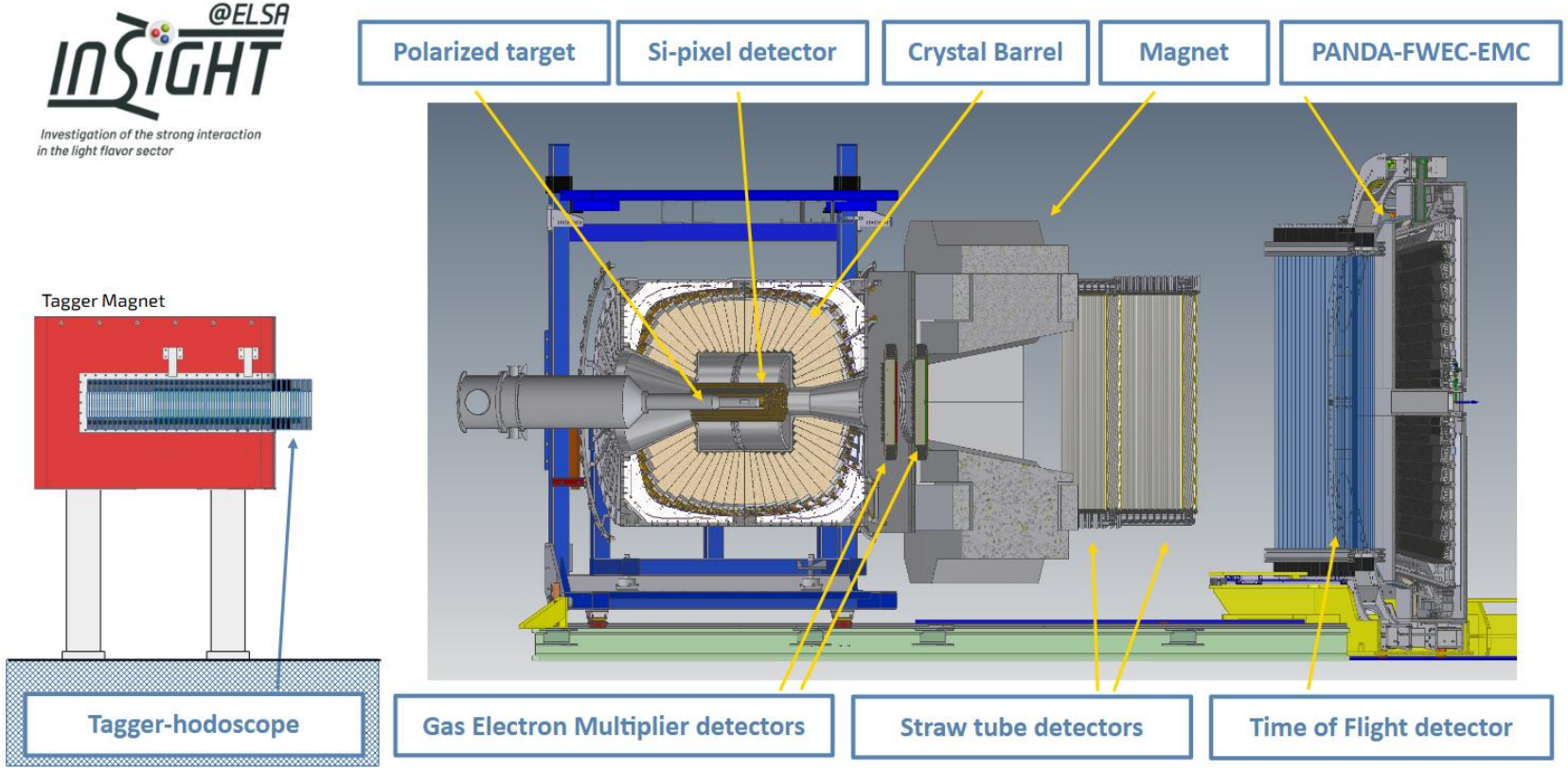
Lattice Quantum Chromodynamics study of exotic hadrons

- Investigation of the structure of exotic charmed hadrons ($T_{cs}(2900)0^+$, $T_{cs}(2900)1^+$, $T_{cc}(3875)$, and $T_{c\bar{s}}(2900)^{++}$)
- lattice QCD simulations for $\bar{c}\bar{s}ud$, $c\bar{s}u\bar{d}$, $cc\bar{u}\bar{d}$, and $c\bar{c}u\bar{d}$ with Nf = 2 + 1 dynamical quarks
- Extraction of scattering information and pole positions

RA1+TA1: INSIGHT-Experiment @ELSA

color meets flavor

@ELSA INSIGHT
Investigation of the strong interaction in the light flavor sector

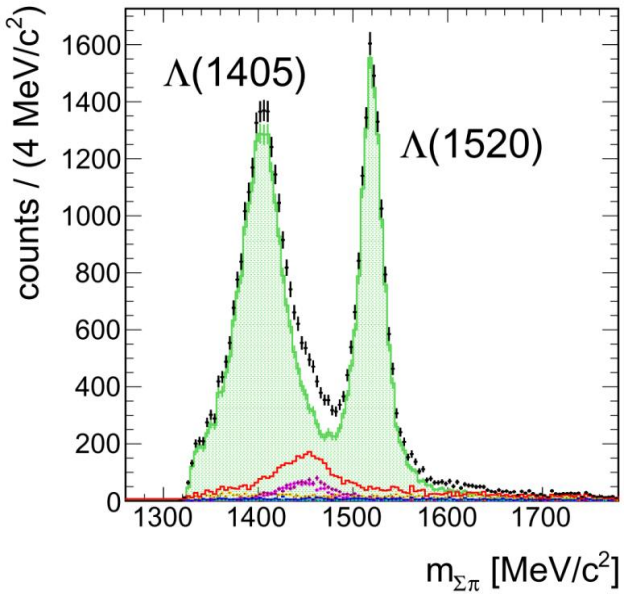


⇔ non-strange and
⇔ strange baryon spectroscopy

$\gamma p \rightarrow K^+ \Lambda^* \rightarrow K^+ \Sigma^0 \pi^0$

isospin selective

$\rightarrow K^+ \Lambda \gamma \pi^0 \rightarrow K^+ (p\pi^-) \gamma \pi^0$



➡ **Over almost the entire 4π-solid angle:**
- **High resolution photon measurements**
- **Precise charged particle detection**

Polarized beam and polarized target

➡ **unique possiblilities!**

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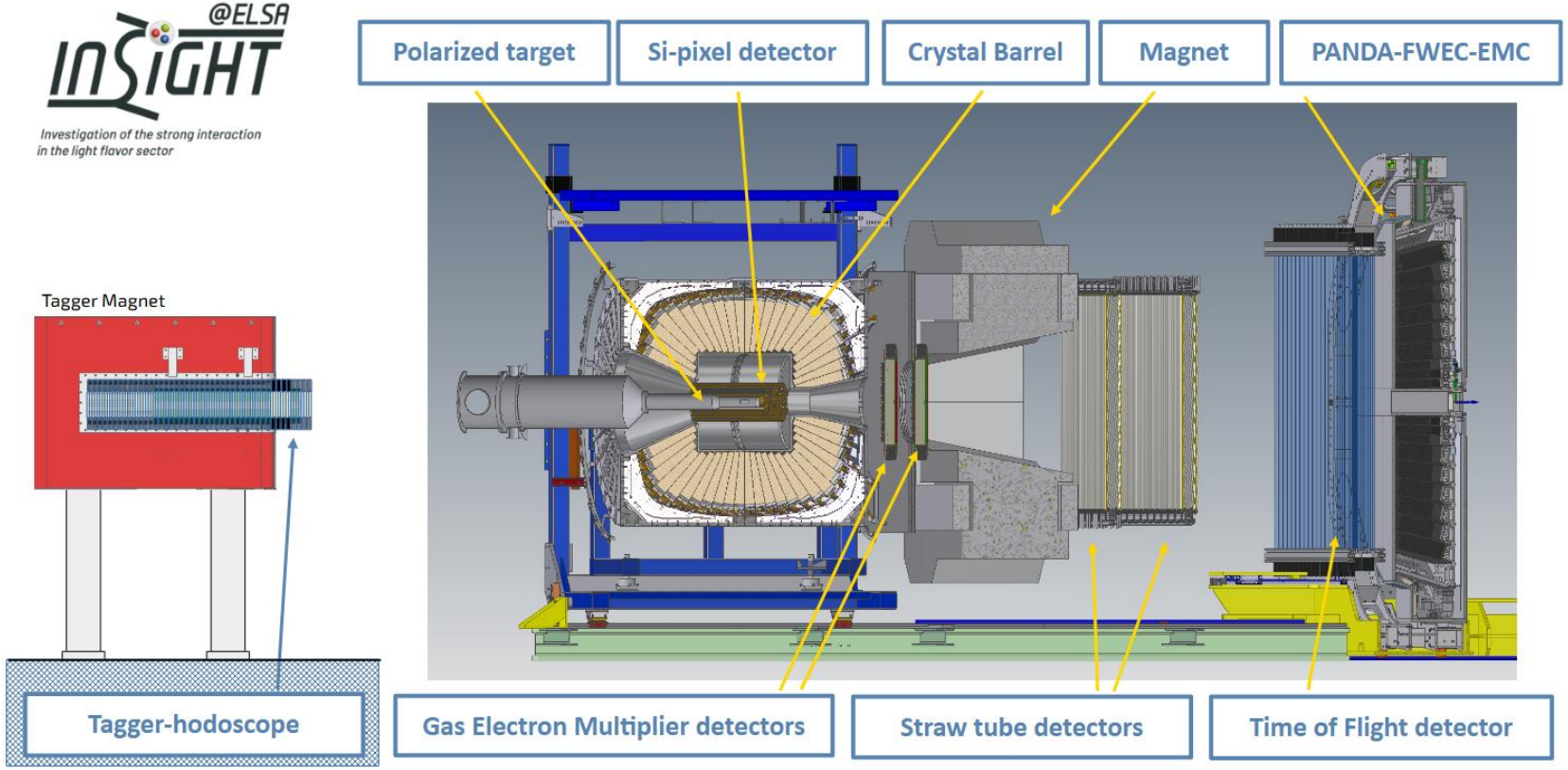

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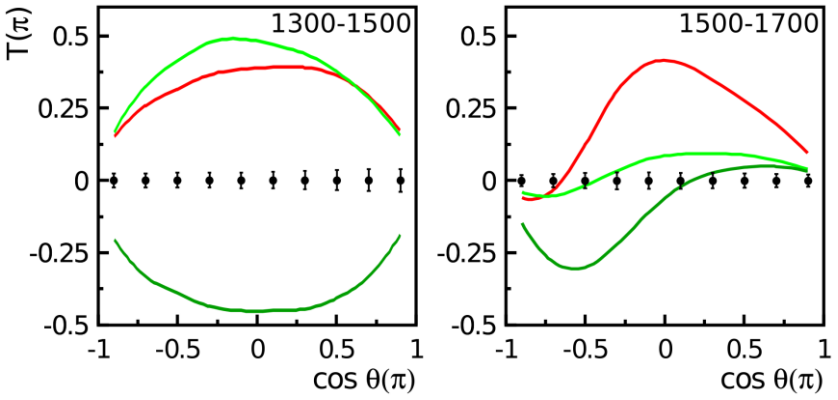

Undistinguisable based cross section data
Pole positions: — BnGa, — ANL A, — ANL B

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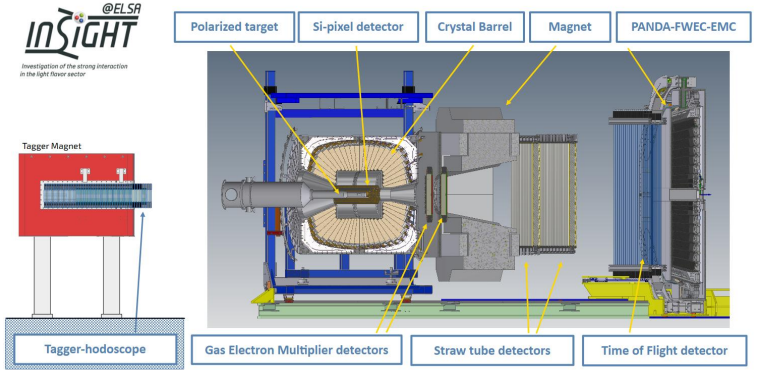
TA1: INSIGHT-Experiment @ELSA

color meets flavor

➡ **New detector components are presently developed / built**

Coordinators/Convenors:

- Tagger : Peter Hurck
- Pixel: Jens Weingarten
- Crystal Barrel: Michael Lang
- Pixel: Jens Weingarten
- GEMs: Bernhard Ketzer
- Magnet: Sebastian Neubert
- Straws: Jerzy Smyrski / Dirk Wiedner
- ToF: Christoph Schmidt
- FWEC: Christoph Schmidt
- DAQ: Martin Bieker / Jan Hartmann
- Target: Hartmut Dutz
- Experimental area: Marcus Grüner (Mechanics, Infrastructure) / Michael Lang (Electro-installations)



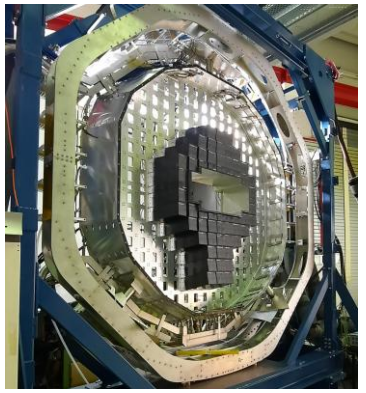
➡ **INSIGHT Collaboration founded May 28 during our Kick-Off Meeting**

- Spokesperson / Deputy Spokesperson: UT / Jens Weingarten
- Technical Coordinator: Christoph Schmidt
- Software Coordinator: Jan Hartmann

Work in progress:

- **MOU with PANDA**

  ⇔ FWEC:



  ⇔ Straws

- **Bylaws**

TA1: INSIGHT-Experiment @ELSA

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color meets flavor

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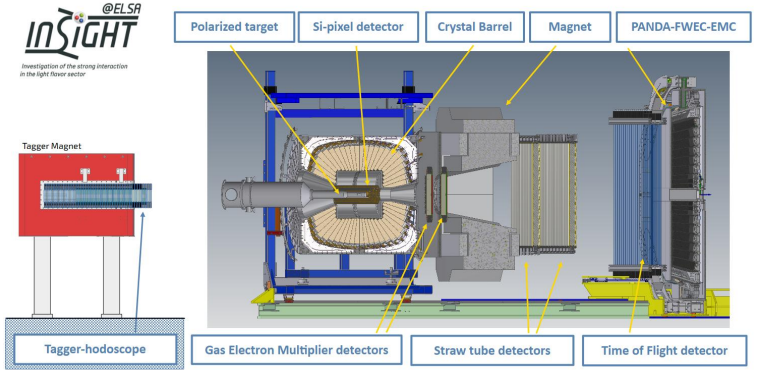

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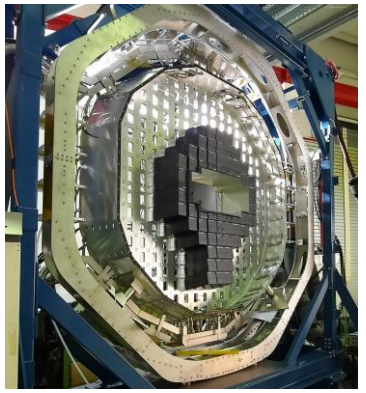
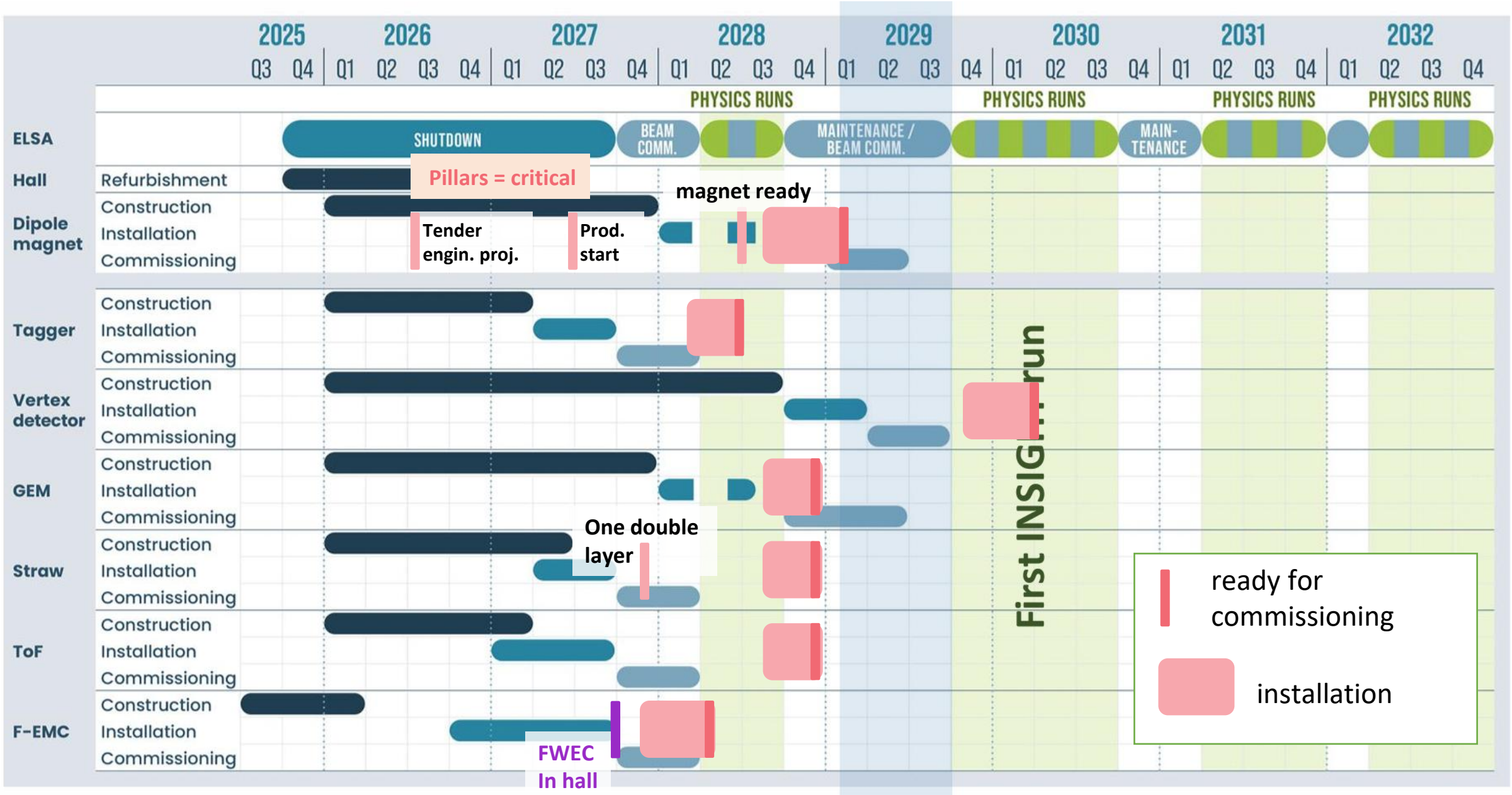


  ⇔ Straws

- **Bylaws**

TA1: INSIGHT – updated time planning



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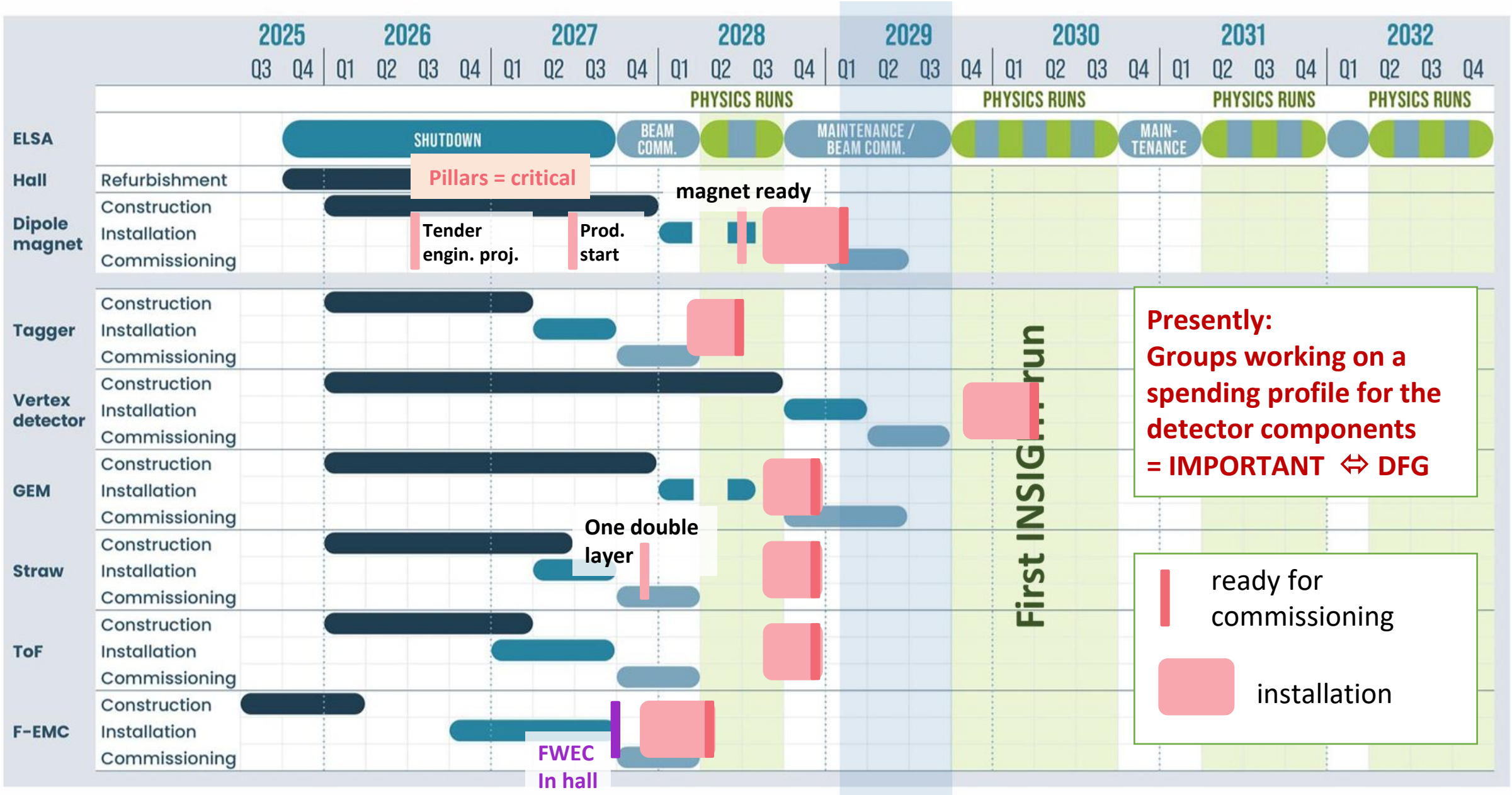
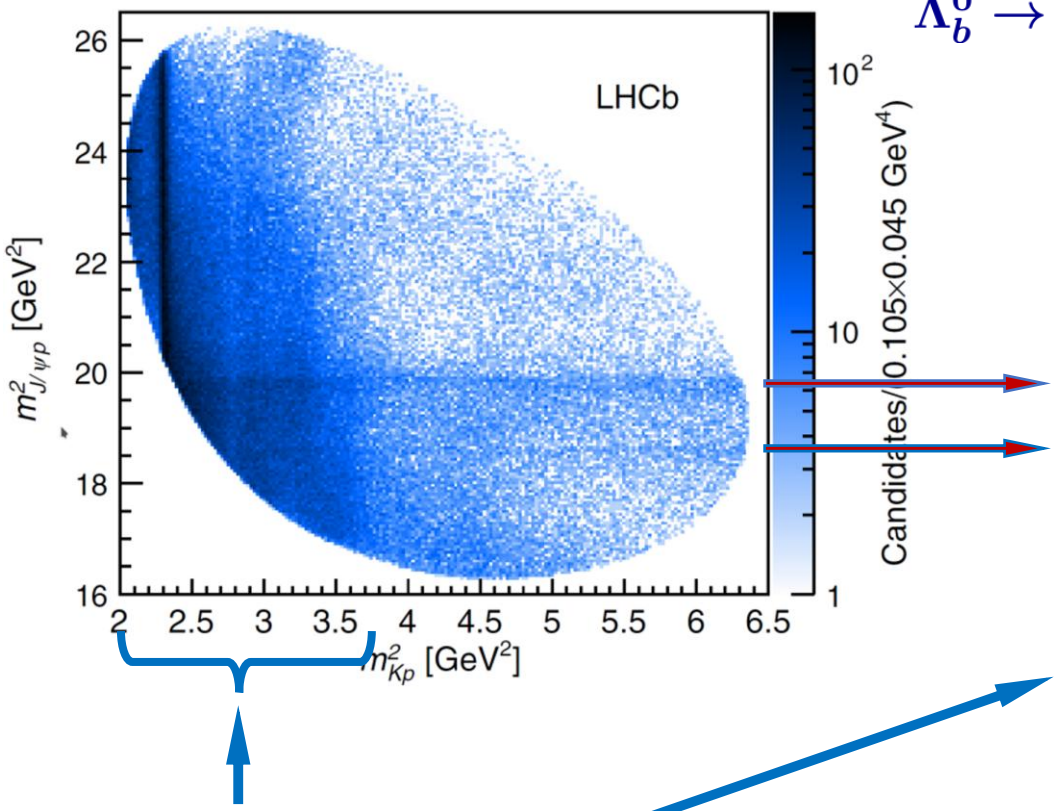
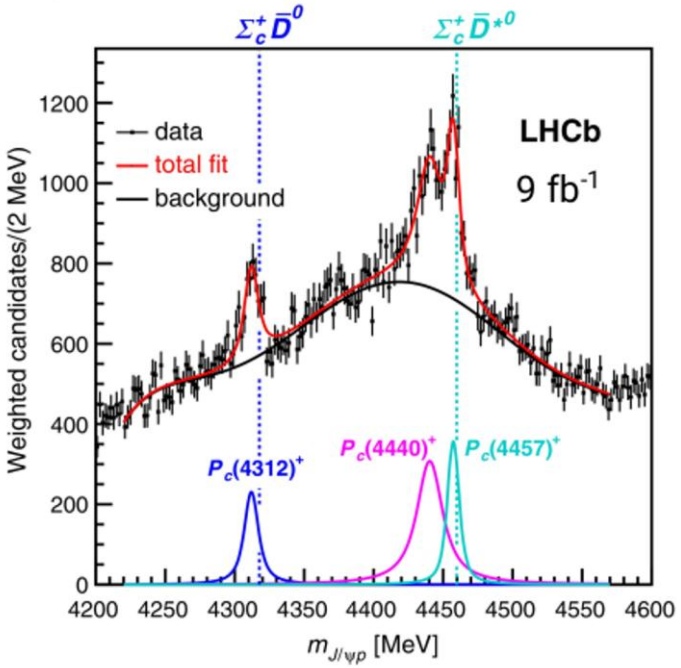


RA1: INSIGHT-Experiment @ELSA ⇔ CFRT I

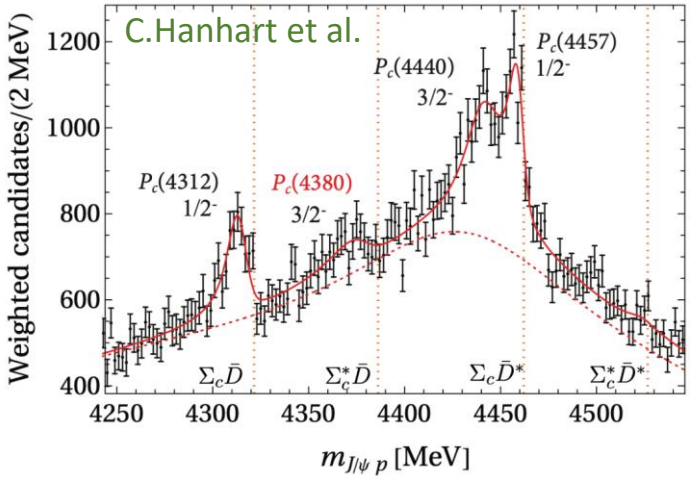
color meets flavor

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

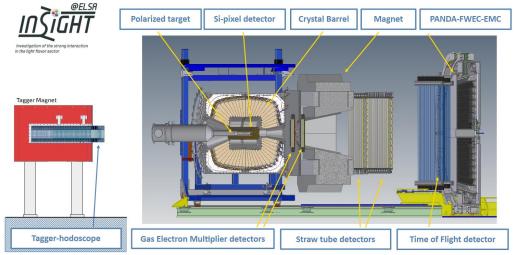




Molecular interpretation
7 states with specific J^P expected



Contribution of strange baryon resonances



For determination of pentaquark properties (J^P) ⇔ nature:

⇔ Strange baryon resonances and their properties important!

Polarisation experiments to avoid ambiguities

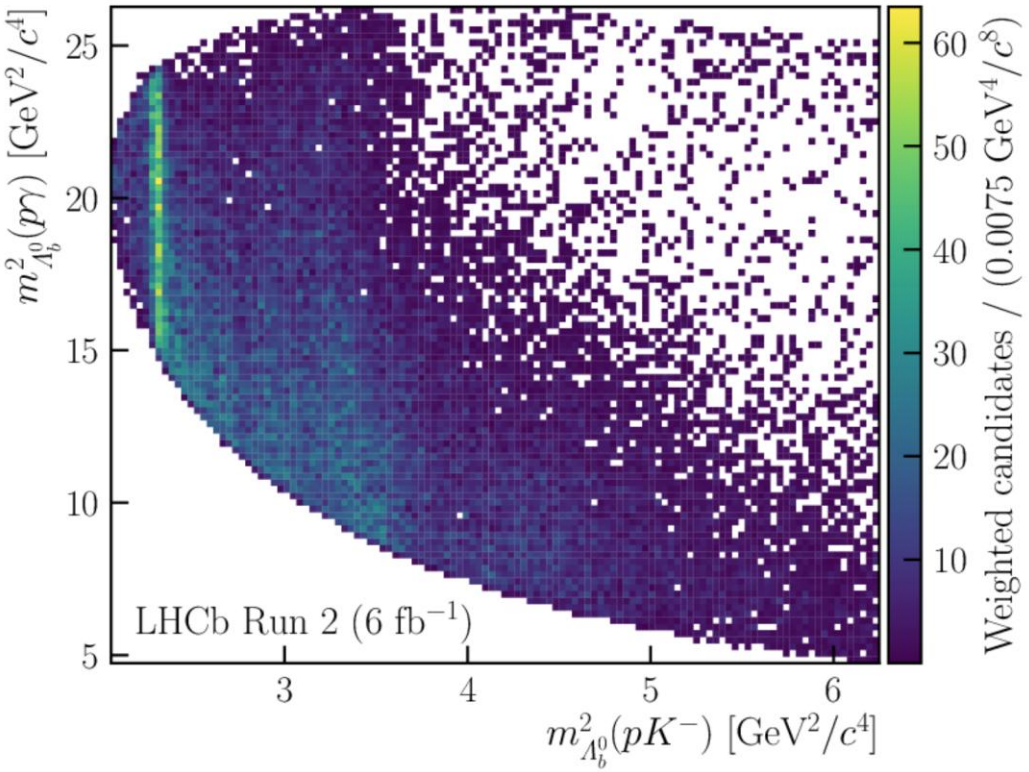
⇔ Common analysis of ELSA- and LHCb-data

RA1: INSIGHT-Experiment @ELSA ⇔ CFRT I

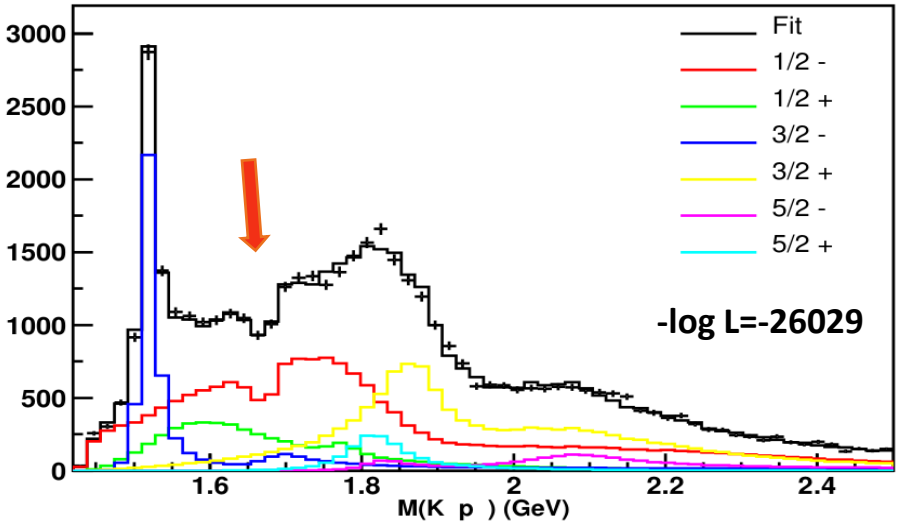
Step 0: **Use BnGa-solution based on existing KN –scattering data**
and
LHCb-data:

$\Lambda_b^0 \to \gamma\, p\, K^-$

LHCb, PRL 122 (2019) 22, 222001



Combined fit of the data (KN-scatt. + LHCb):



Quite interesting interference pattern in ½⁻ -wave: $\Lambda(1670)$, $\Lambda(1800)$ needed

But: Also the different resonance pole positions of the Kent-PWA group lead to a good description of the data

⇔ Polarisation data needed ⇔ INSIGHT

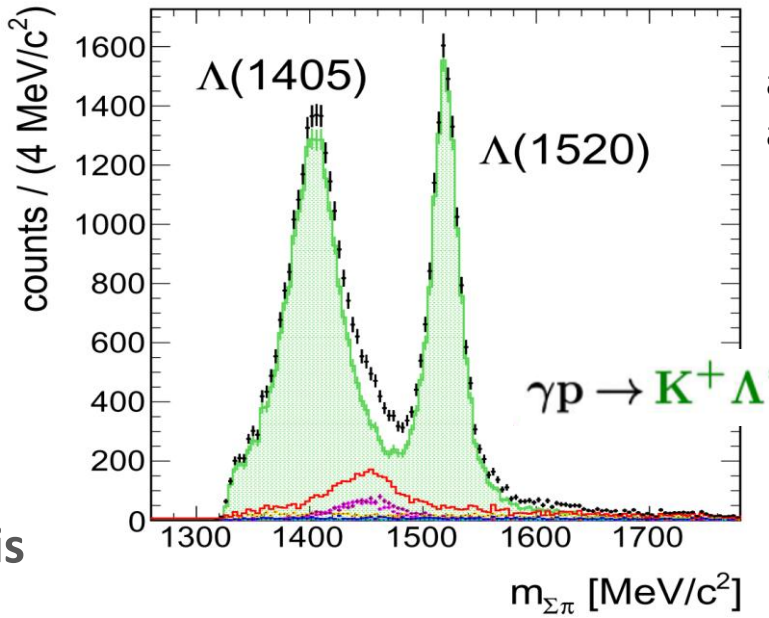
RA1: INSIGHT-Experiment @ELSA ⇔ CFRT I

Example: **Rare baryon decay → search for new phenomena**

LHCb $\Lambda_b^0 \to \Lambda(1520)\mu^+\mu^-$

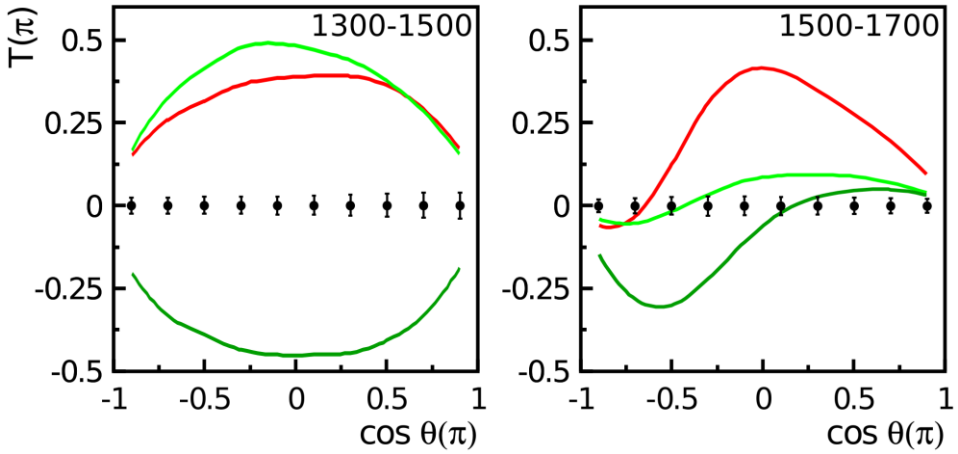
K^-p

INSIGHT



after γ-energy and Λ cut

Polarization measurements → **unambigious partial wave analysis**



@ELSA INSIGHT
Investigation of the strong interaction in the light flavor sector

⇔ **RA2**

=> High sensitivity

Pole positions: — BnGa, — ANL A, — ANL B (solutions indistinguishable based on differential cross sections)