ELSA – FTD

Highlights & Future Perspectives

Hartmut Schmieden

Physikalisches Institut
Universität Bonn
Germany

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Outline

- Infrastructure
  - Center for Detector and Accelerator Research
  - Research and Technology Center Detector Physics (FTD)
  - ELSA accelerator & experiments
- Highlight results
- Future perspectives

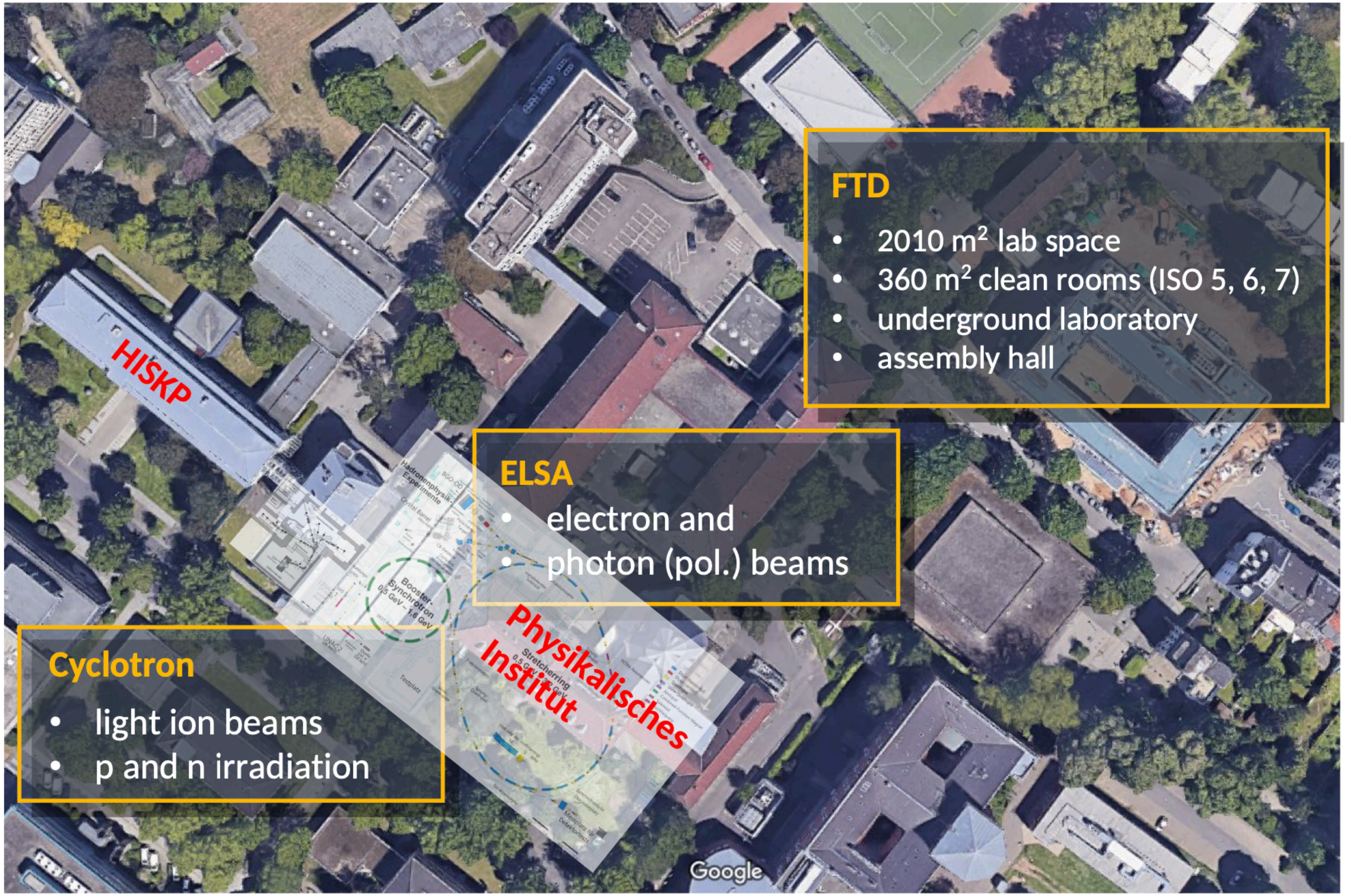
CENTER FOR DETECTOR AND ACCELERATOR RESEARCH

Comprises **3 large research infrastructures:**

- FTD
- ELSA (Phys. Institut)
- Cyclotron (HISKP)

Development of **detector and accelerator technologies** for fundamental physics

- international collaborations
- local experiments
- open for external users through EU-funded transnational access (STRONG-2020)



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FTD – Research and Technology Center Detector Physics

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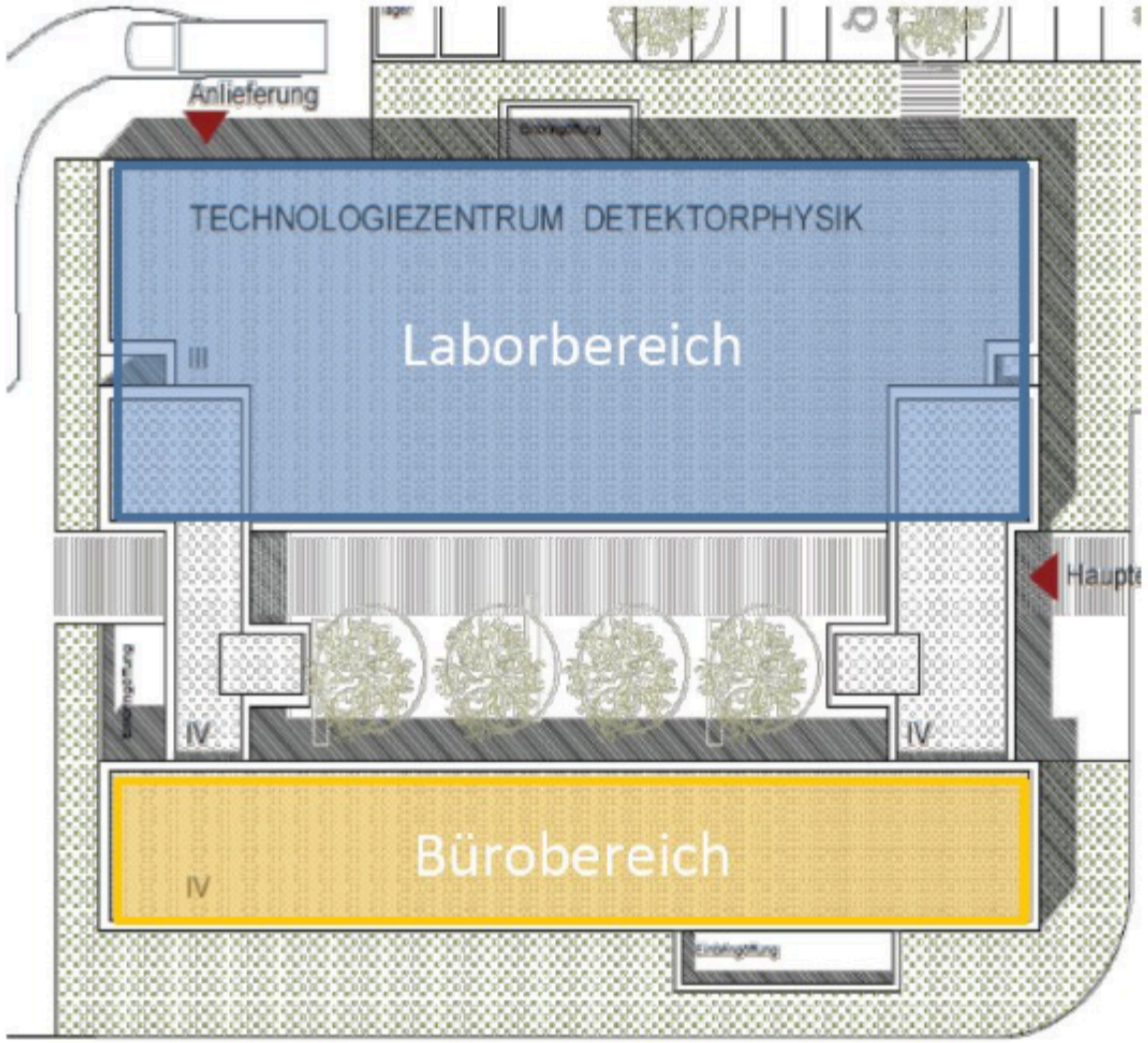
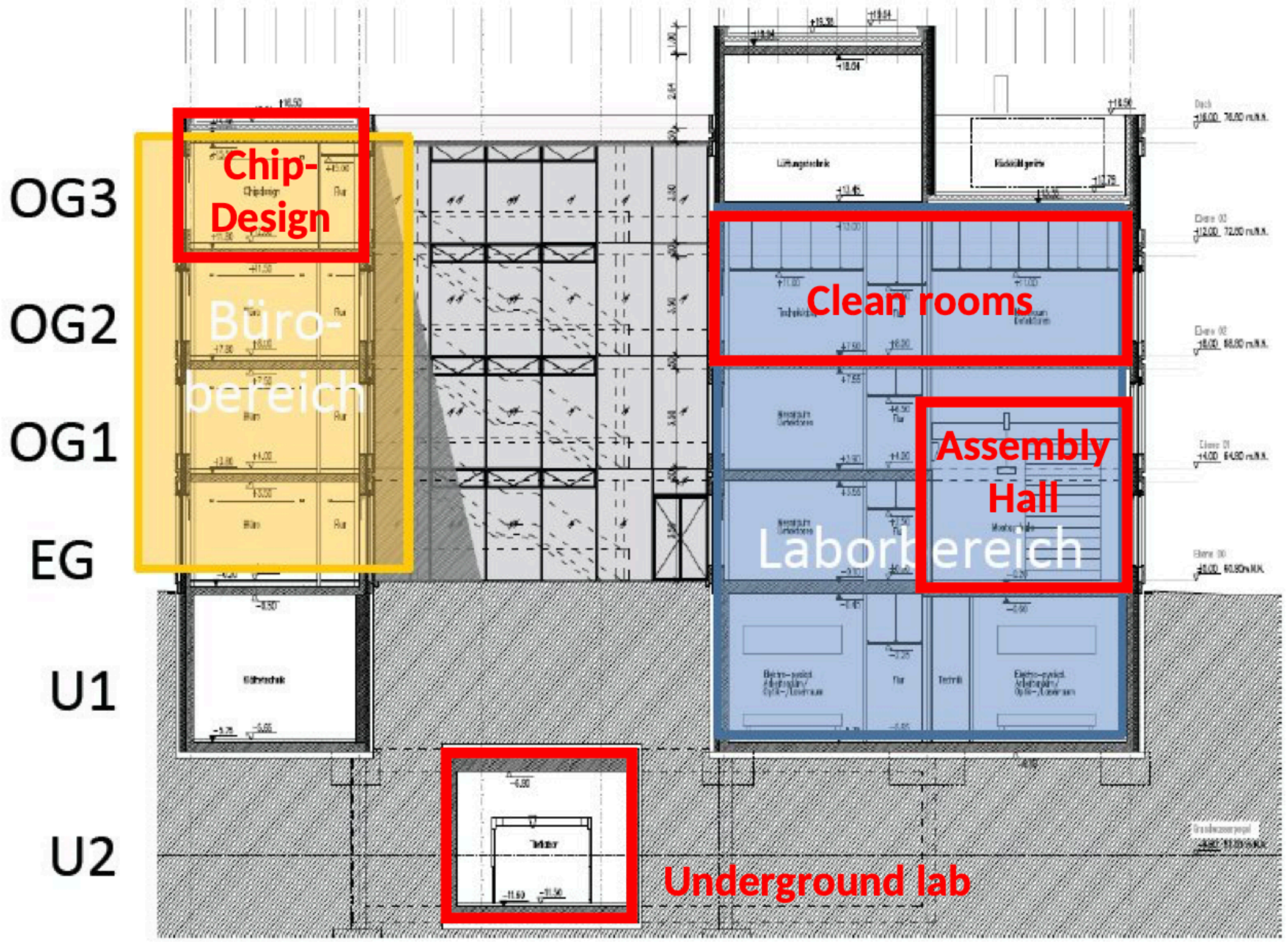
FTD – Research and Technology Center Detector Physics

Office space:
- 880 m^2
- 4 Levels



Lab space
- 2010 m^2
- 4 Levels + Underground Laboratory
- 360 m^2 clean rooms (ISO 5, 6, 7)



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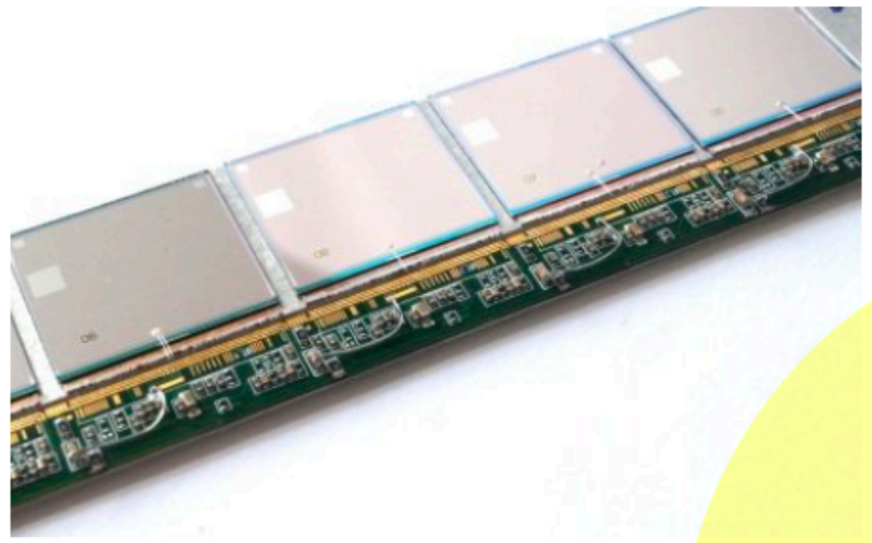
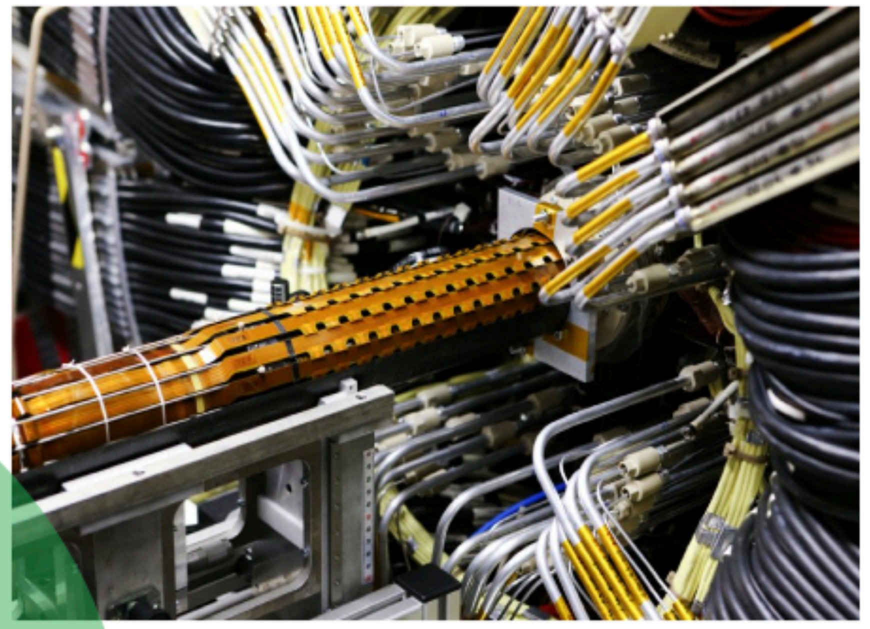
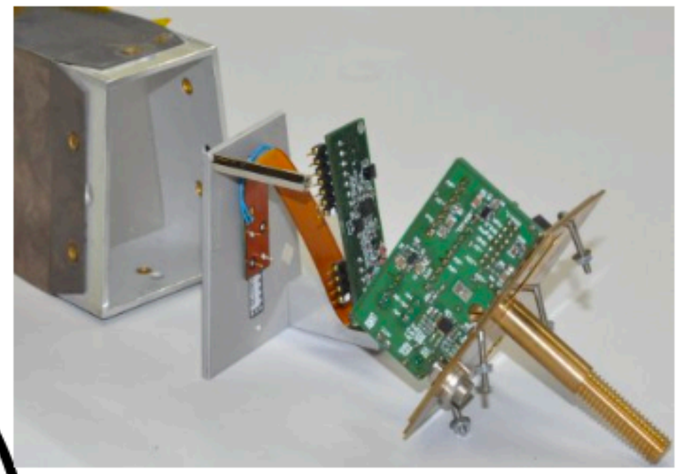
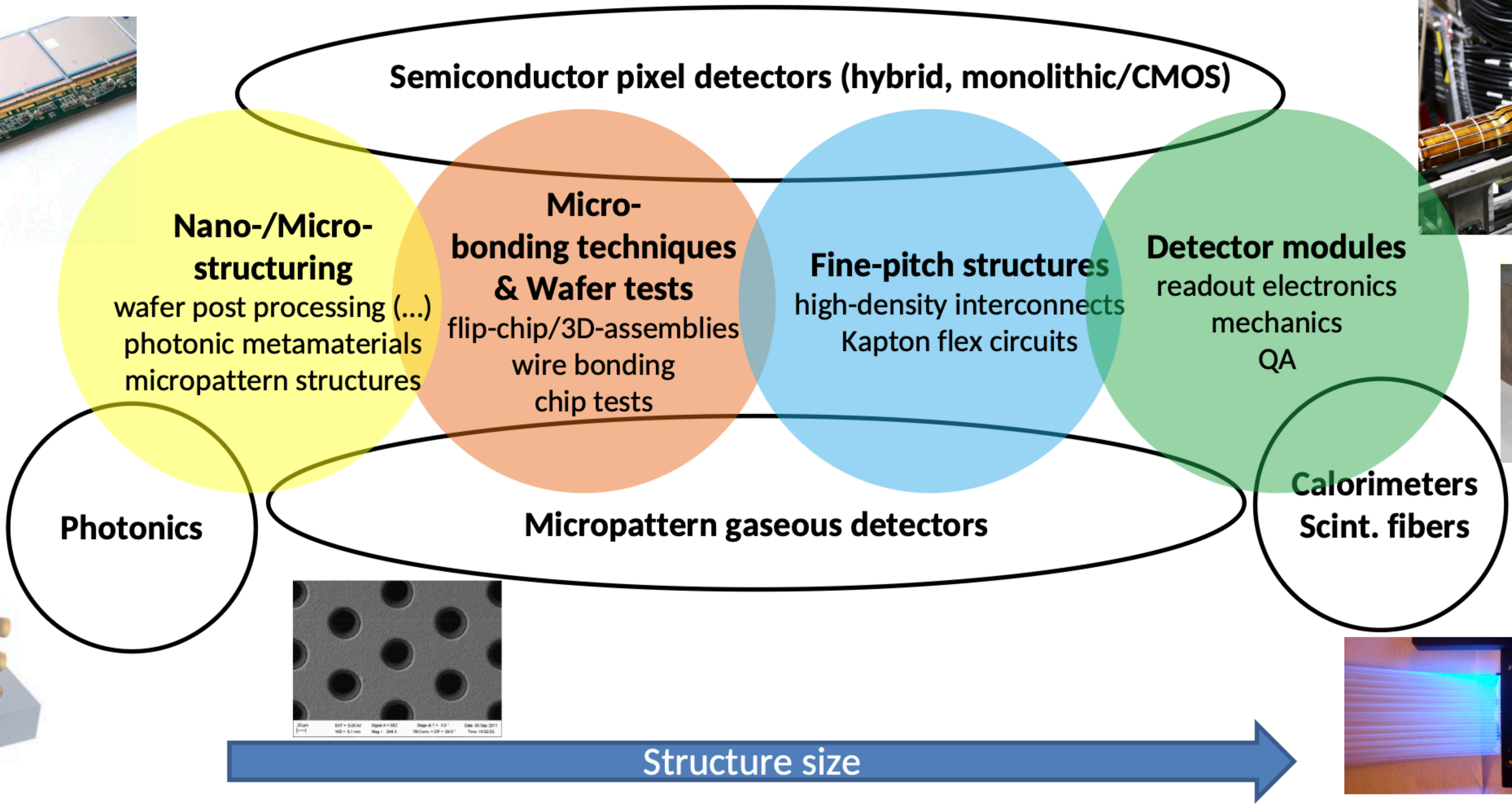
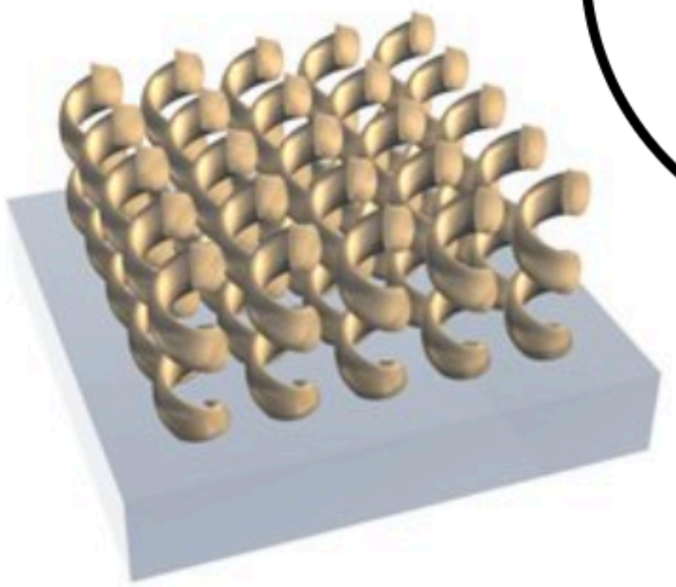
FTD – Key Technologies and Applications

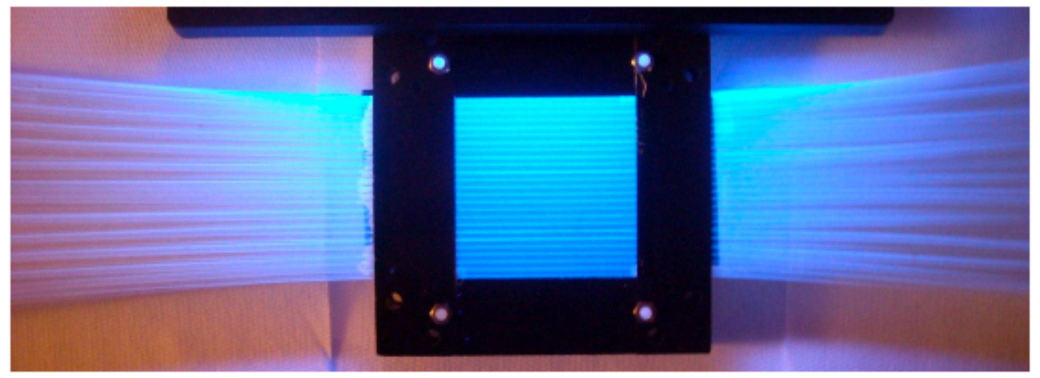












Goal: maximize synergies between development areas

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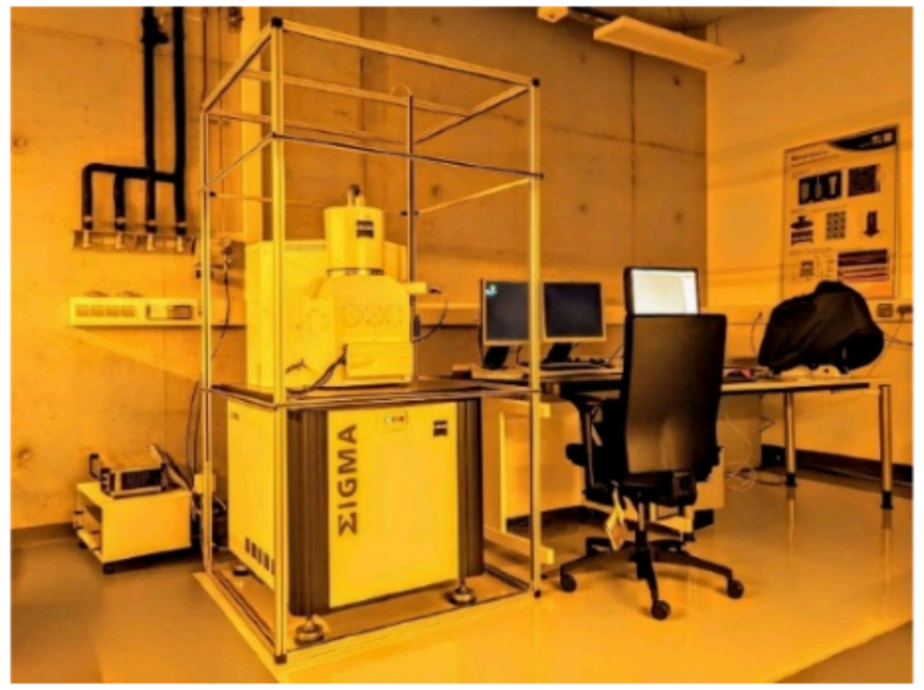
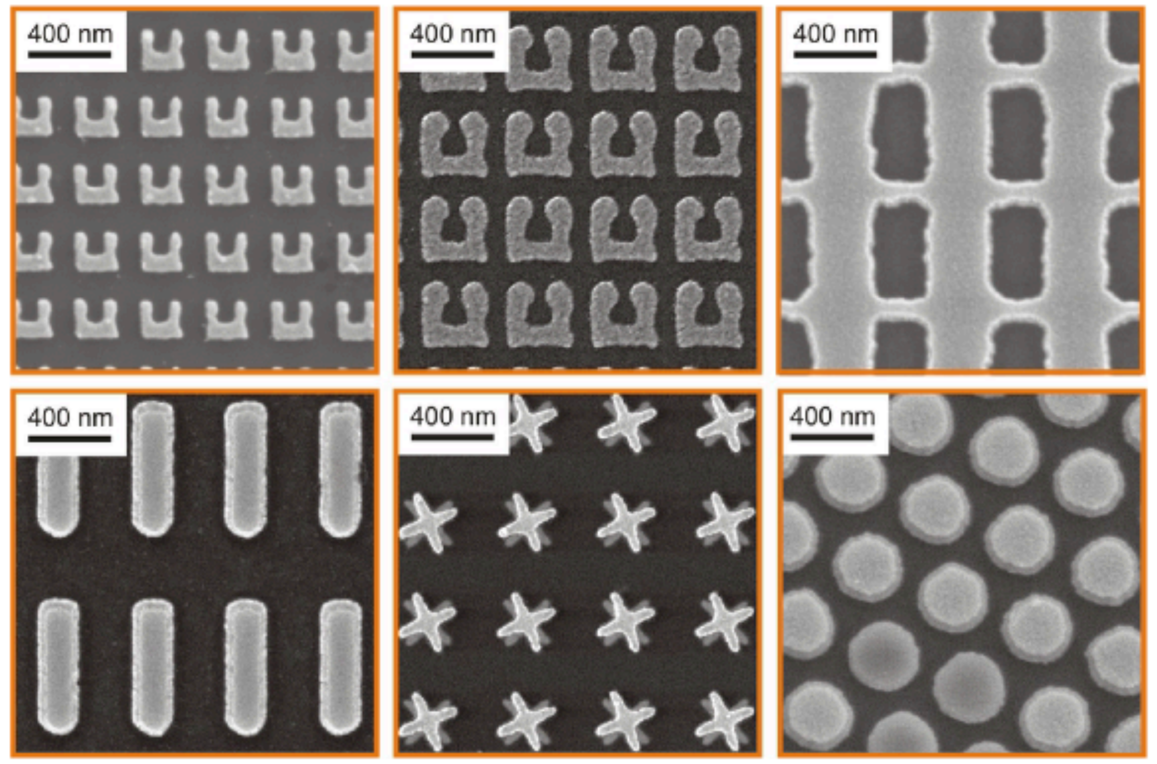
FTD – Nano and Micro Fabrication

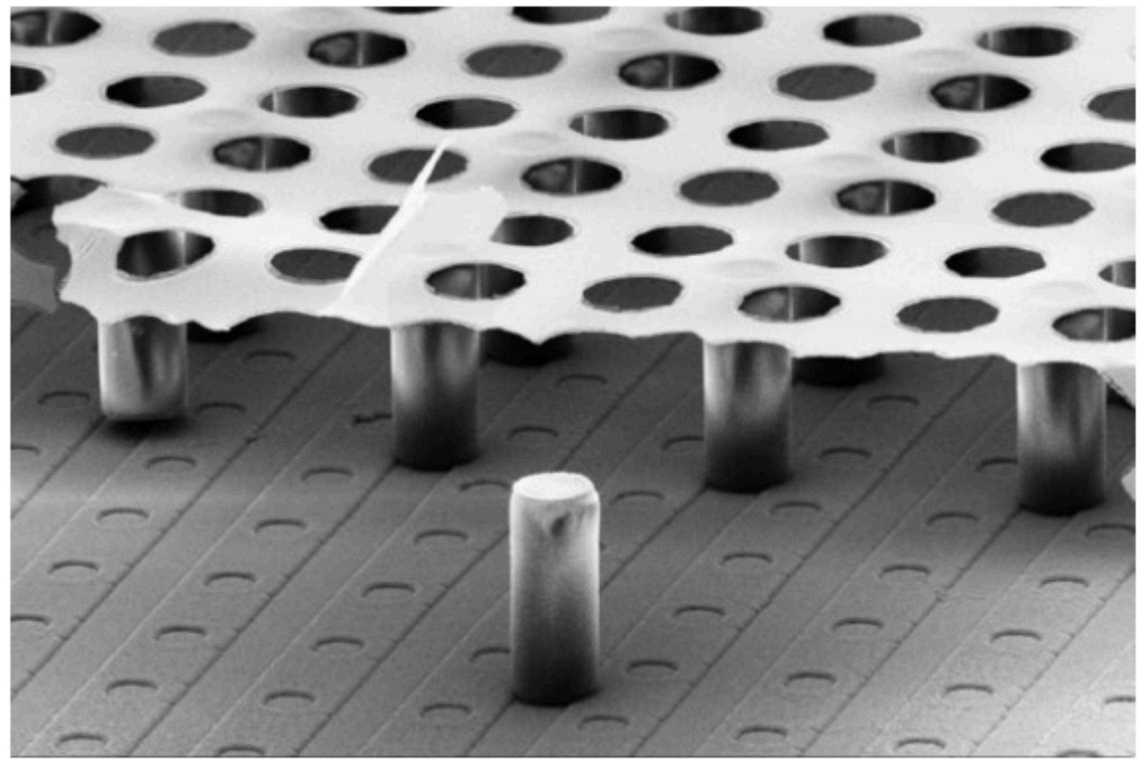
Electron beam + optical lithography





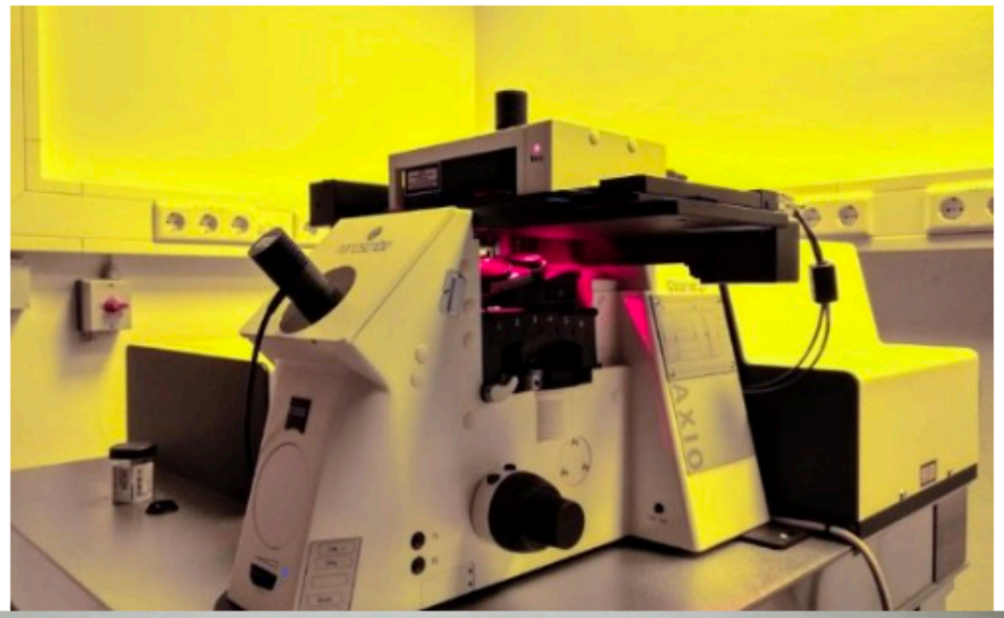
- Planar nanostructures with feature sizes down to 50 nm

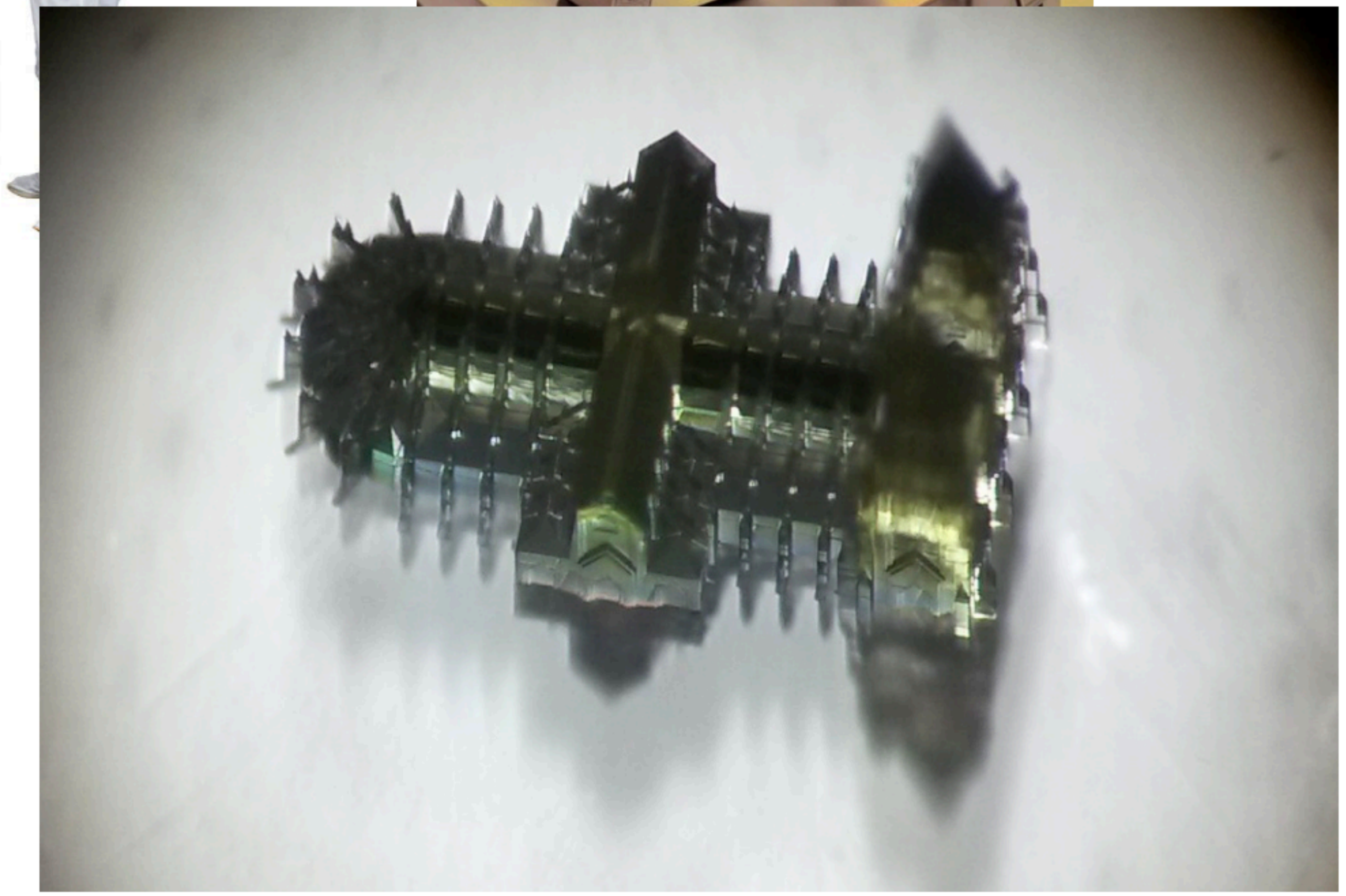
Postprocessing



- Etching (chemical, plasma)
- Deposition (metals, dielectrics)

3D Direct laser writing



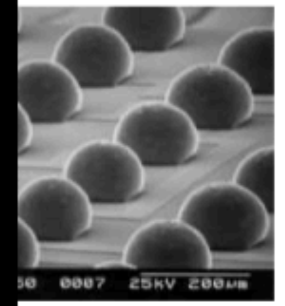


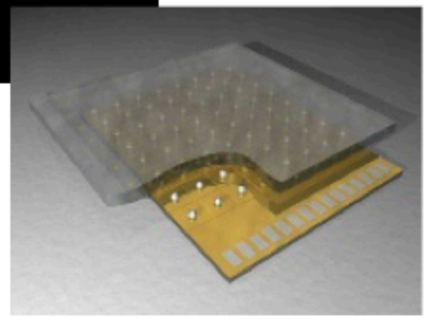
Mer han d'r Dom och en Bonn!

Translation provided by https://mingsprooch.de/

FTD – Interconnect and Characterisation

r Ball Placer





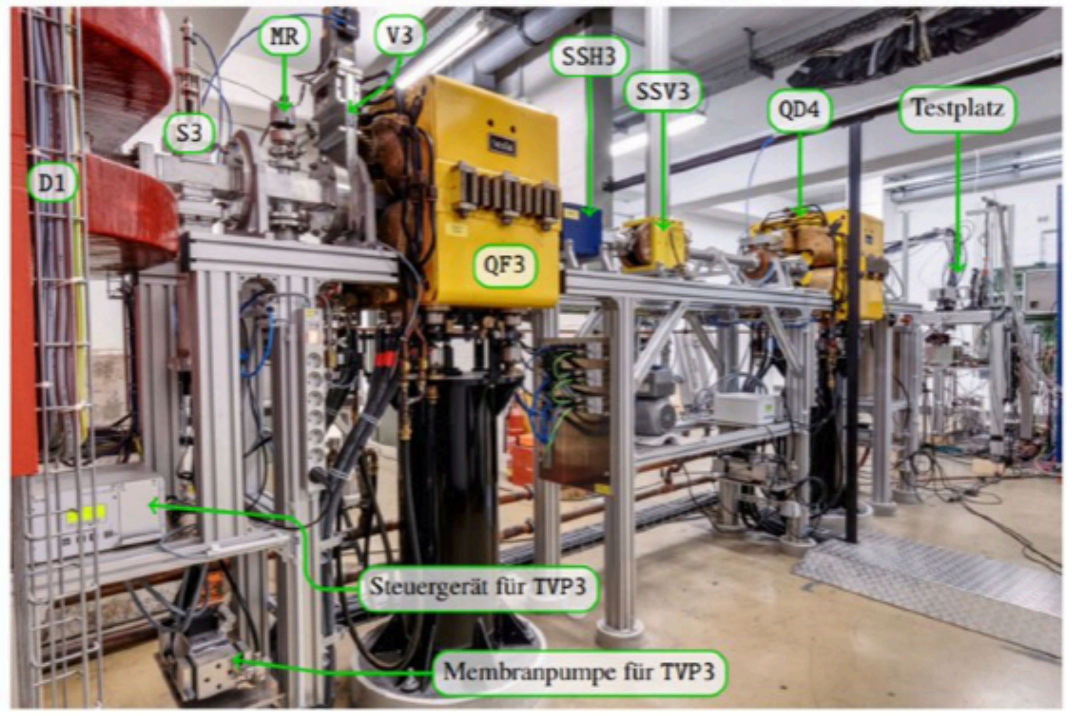
CR: Nikon

X-ray Inspection Device

X-ray Irradiation Device

Scanning Electron Microscope

3D Laser Tracker



Dissertation N. Heurich (2017)

In-beam testing and irradiation

- Cyclotron
- ELSA

Flip Chip Bonder

Wire Bonder

Wafer Probe Station

FTD – Example: GEM production

Multi-Step microstructuring of Polyimide foils:

a) Raw foil: 50 μm Polyimide with 5 μm Cu coating

b) Lamination of photoresist

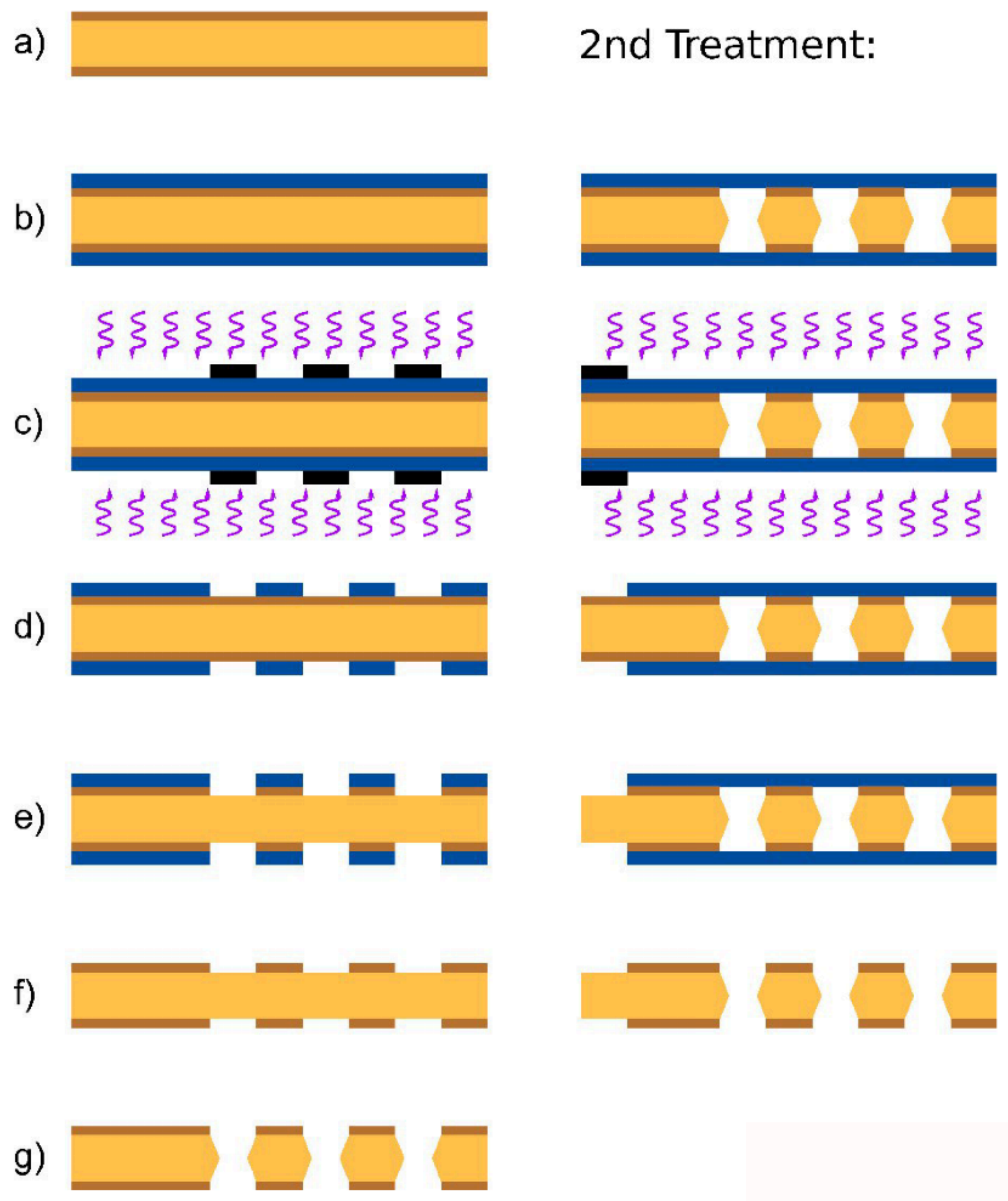
c) Exposition with UV light

d) Development

e) Cu etching

f) Stripping of photoresist and Cr etching

g) Polyimide etching (dissolution)

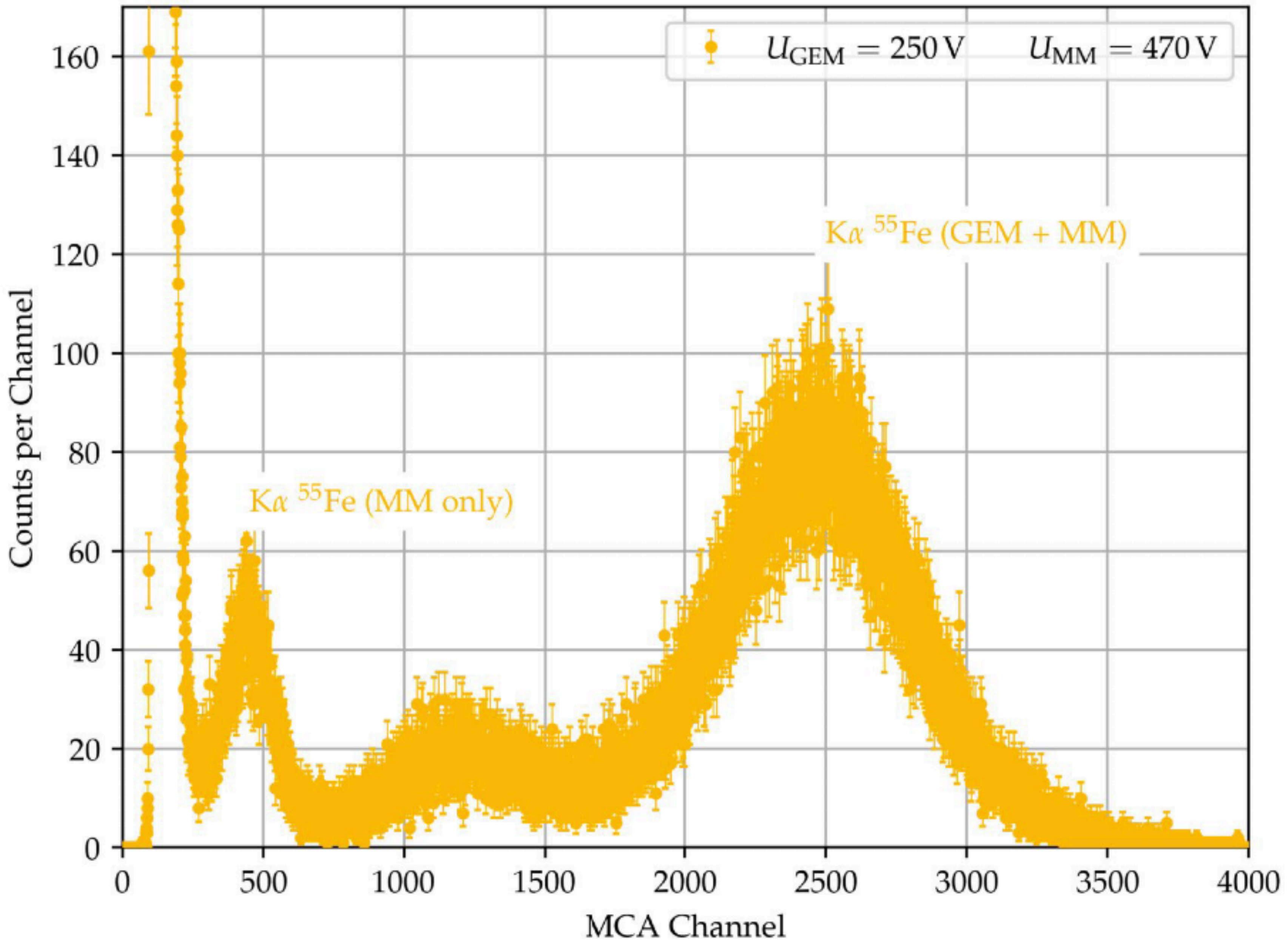


FTD – Example: GEM production

Lamination

Development/
etching

First successful GEM
production at Bonn



Test with MM+GEM hybrid detector

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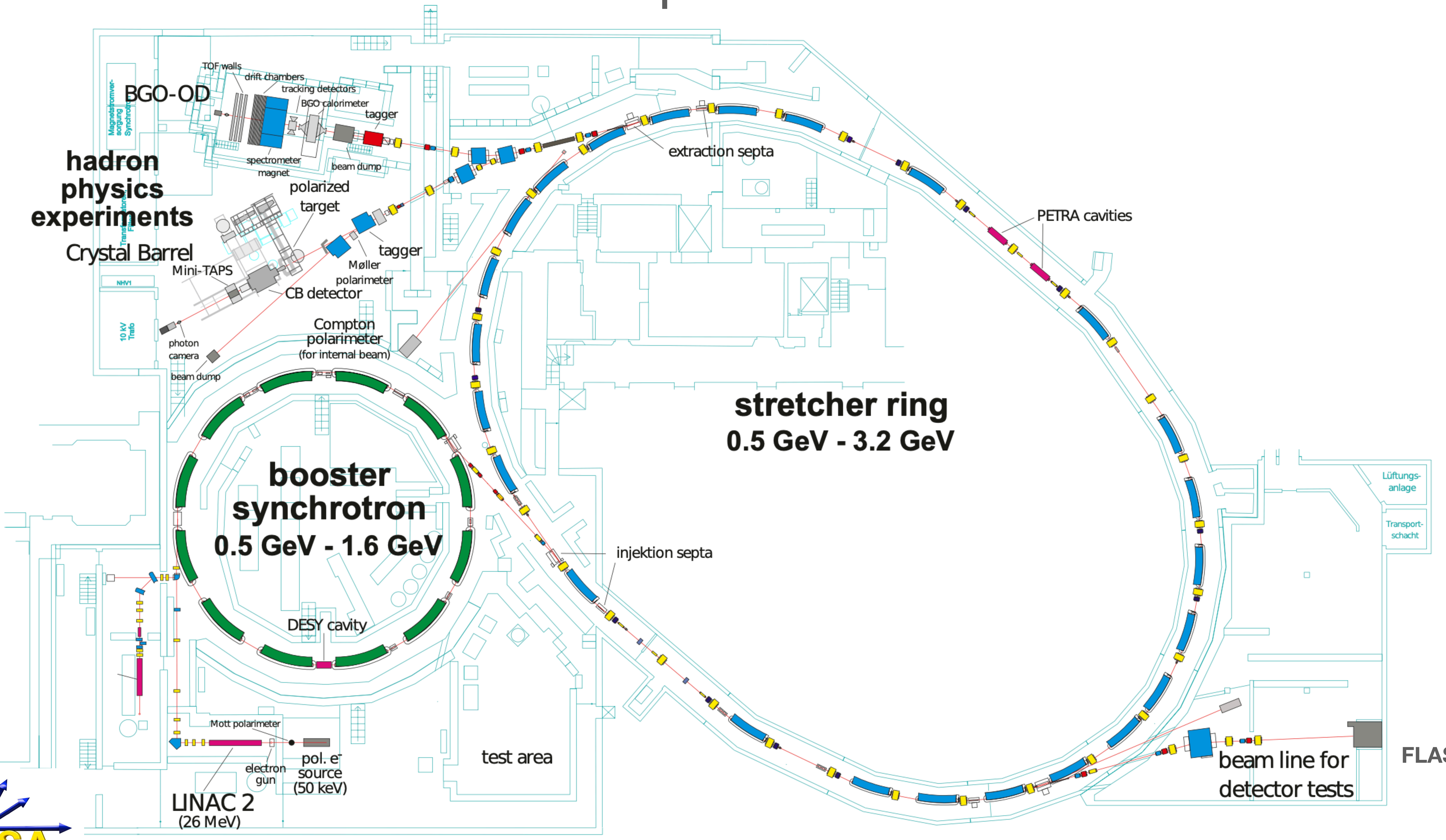
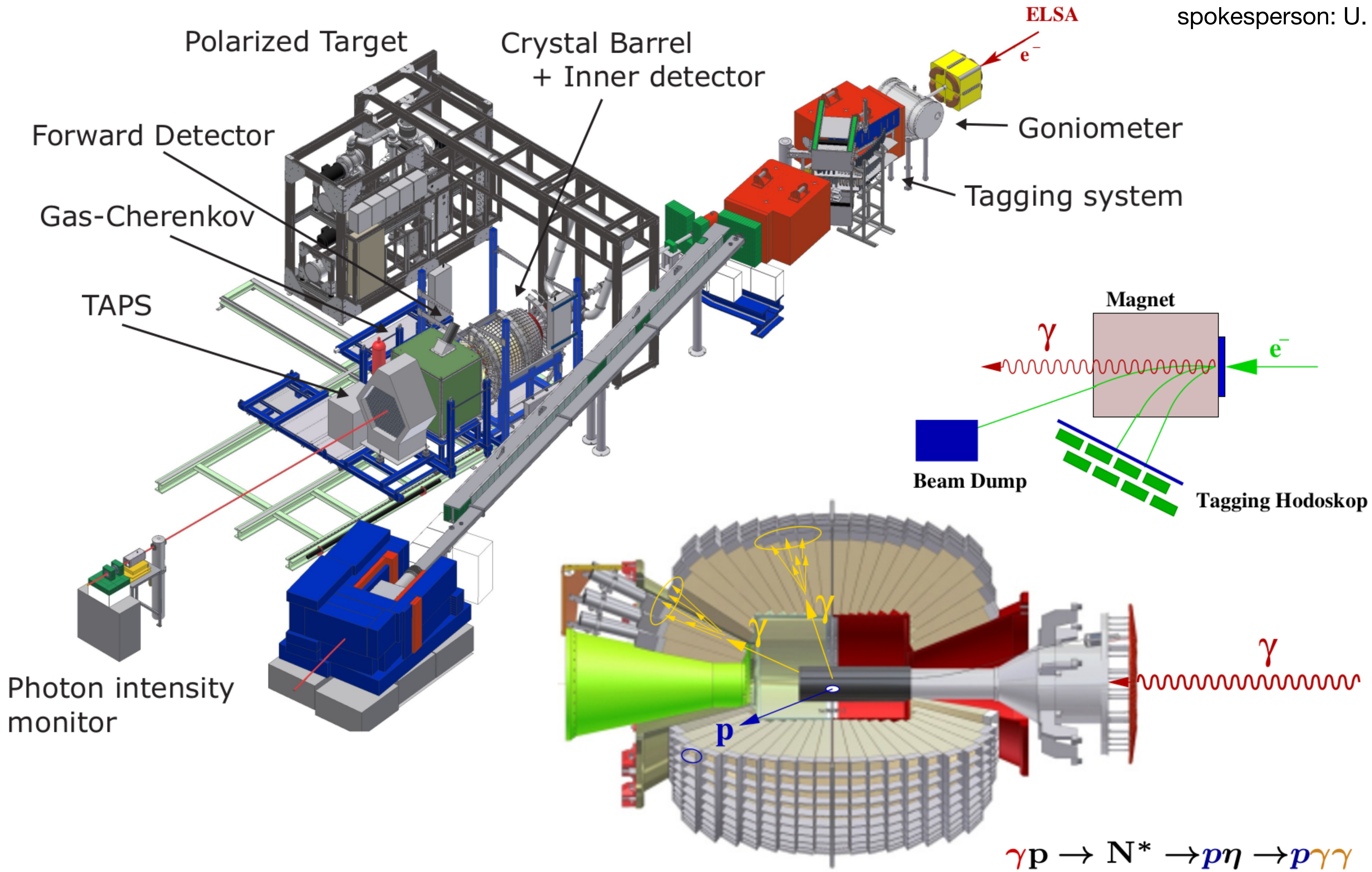
ELSA – Accelerator & Experiments



ELSA – Accelerator & Experiments

CBELSA/TAPS experiment

spokesperson: U. Thoma (Bonn)



$\gamma p \rightarrow N^* \rightarrow p\eta \rightarrow p\gamma\gamma$

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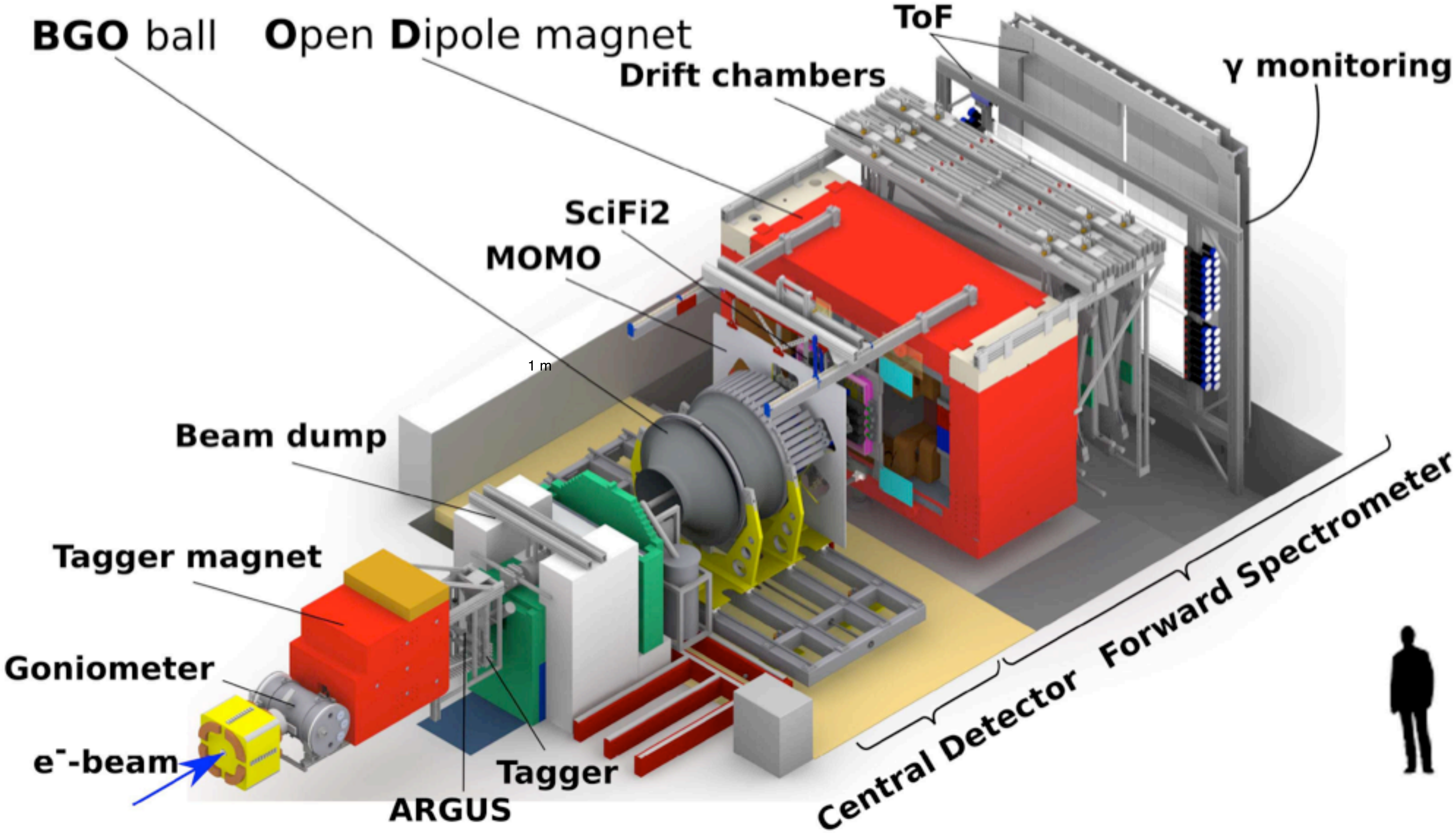
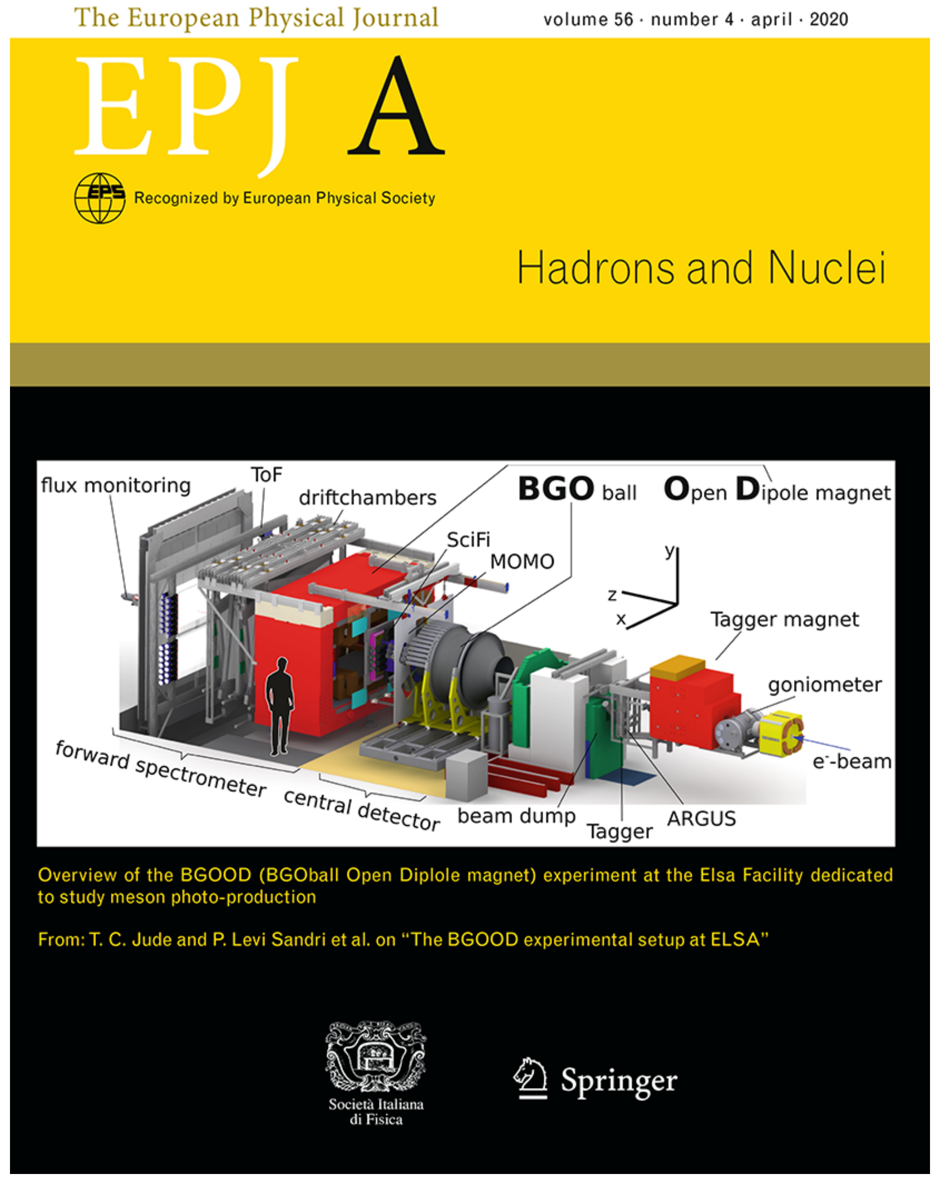
ELSA – Accelerator & Experiments

BGOOD experiment

spokespersons: P. Levi Sandri (Frascati) & T. Jude (Bonn)





S. Alef et al. [BGOOD collab.], EPJ A 56 (2020) 104

- combination of BGO central calorimeter & forward spectrometer
- high momentum resolution, excellent neutral & charged particle id

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ELSA – Accelerator & Experiments

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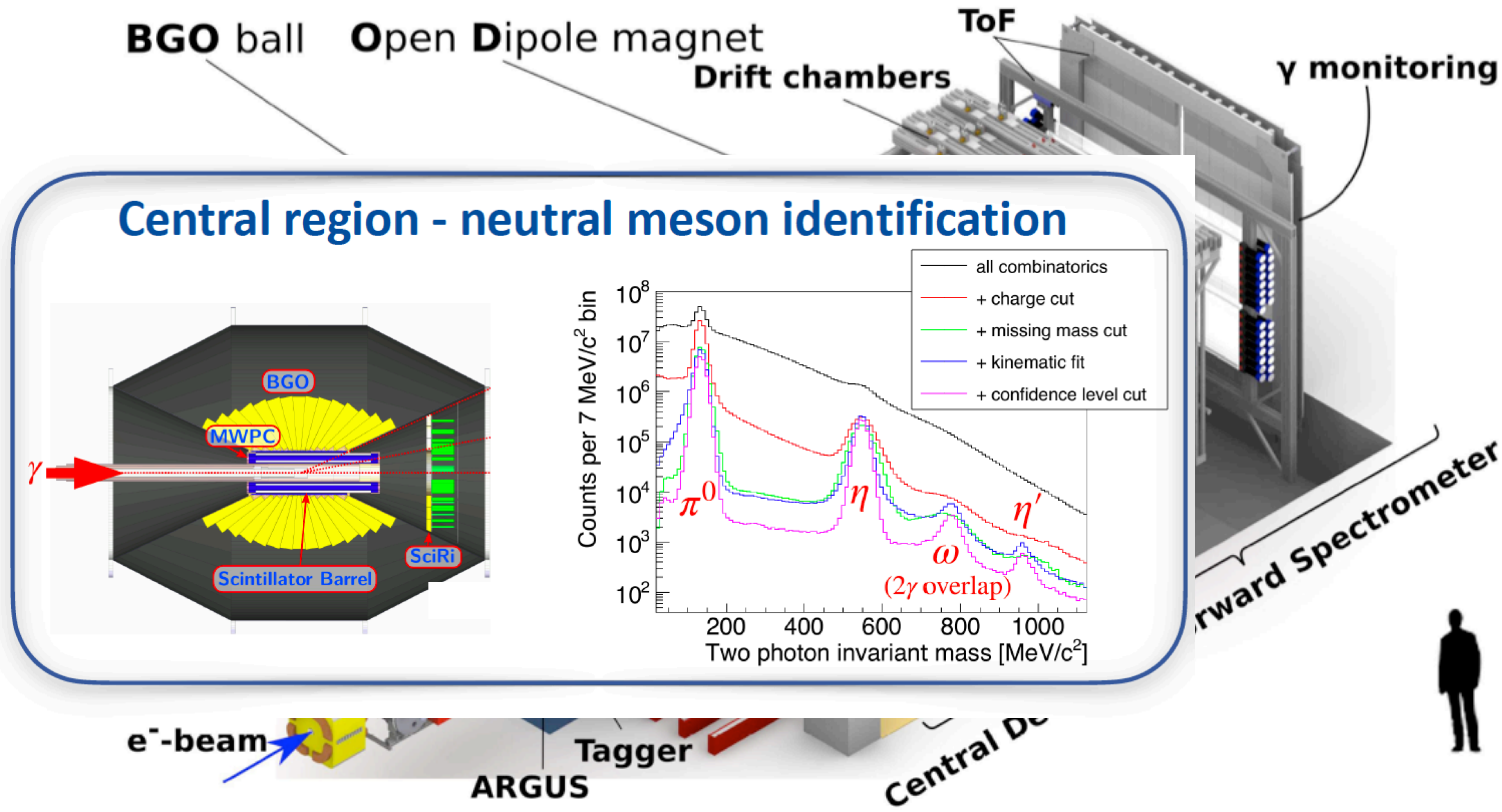

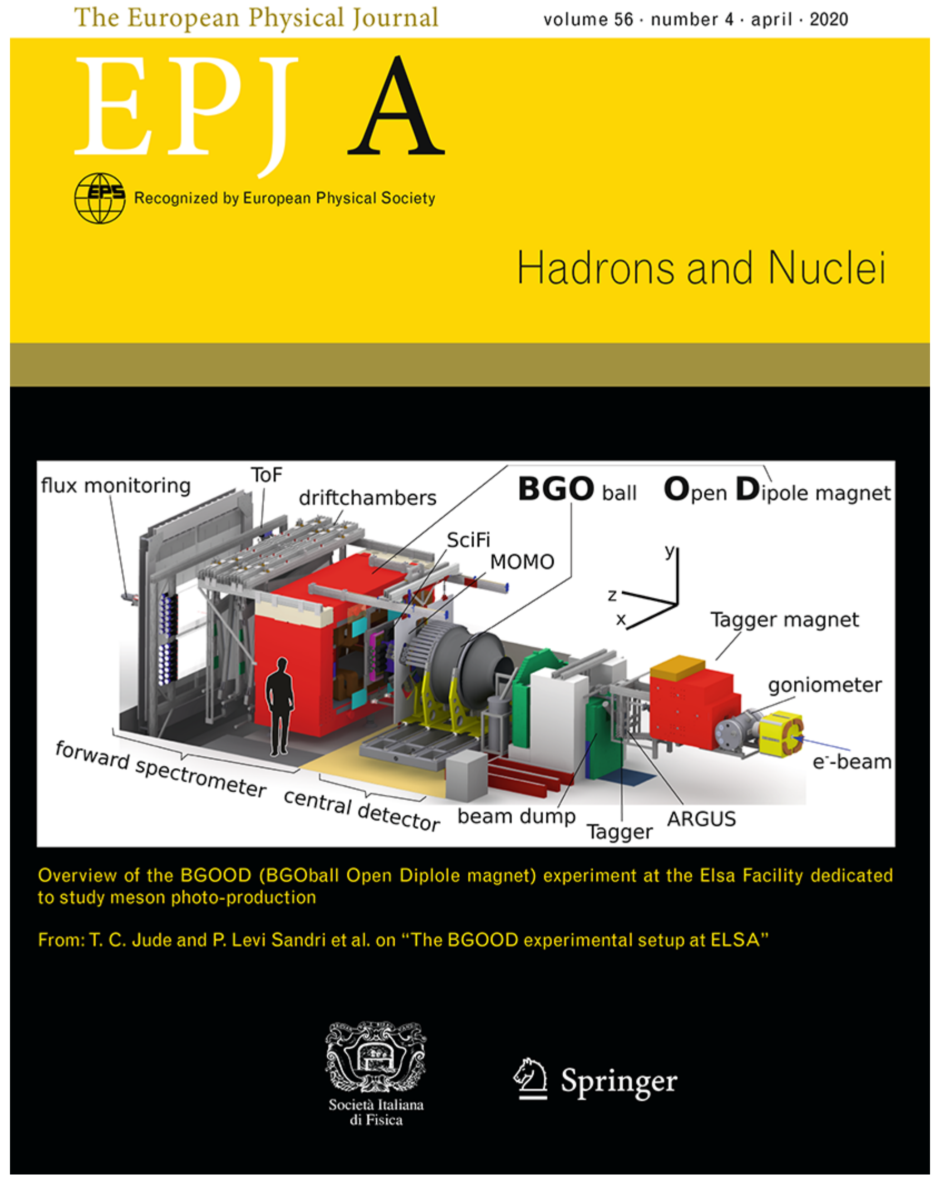

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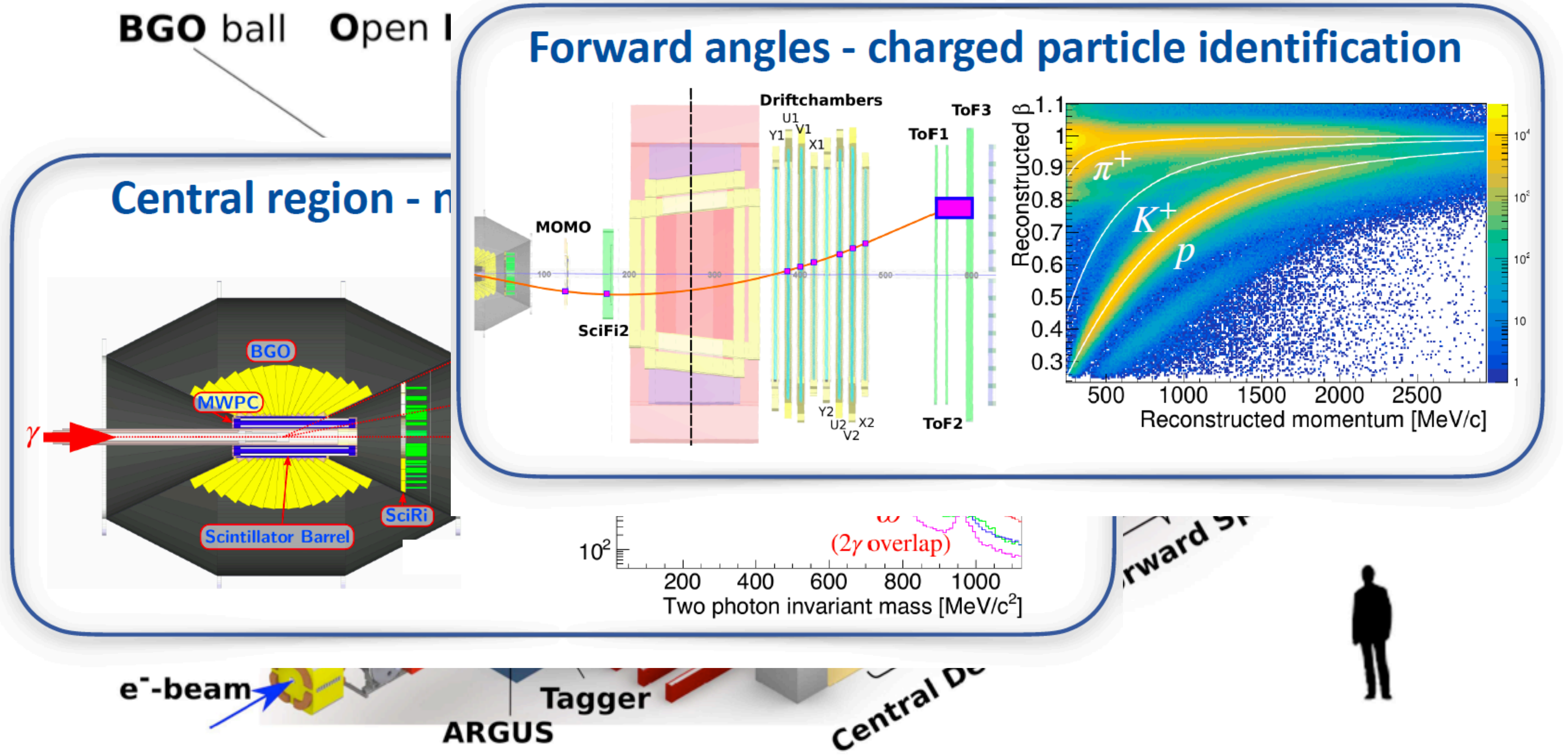

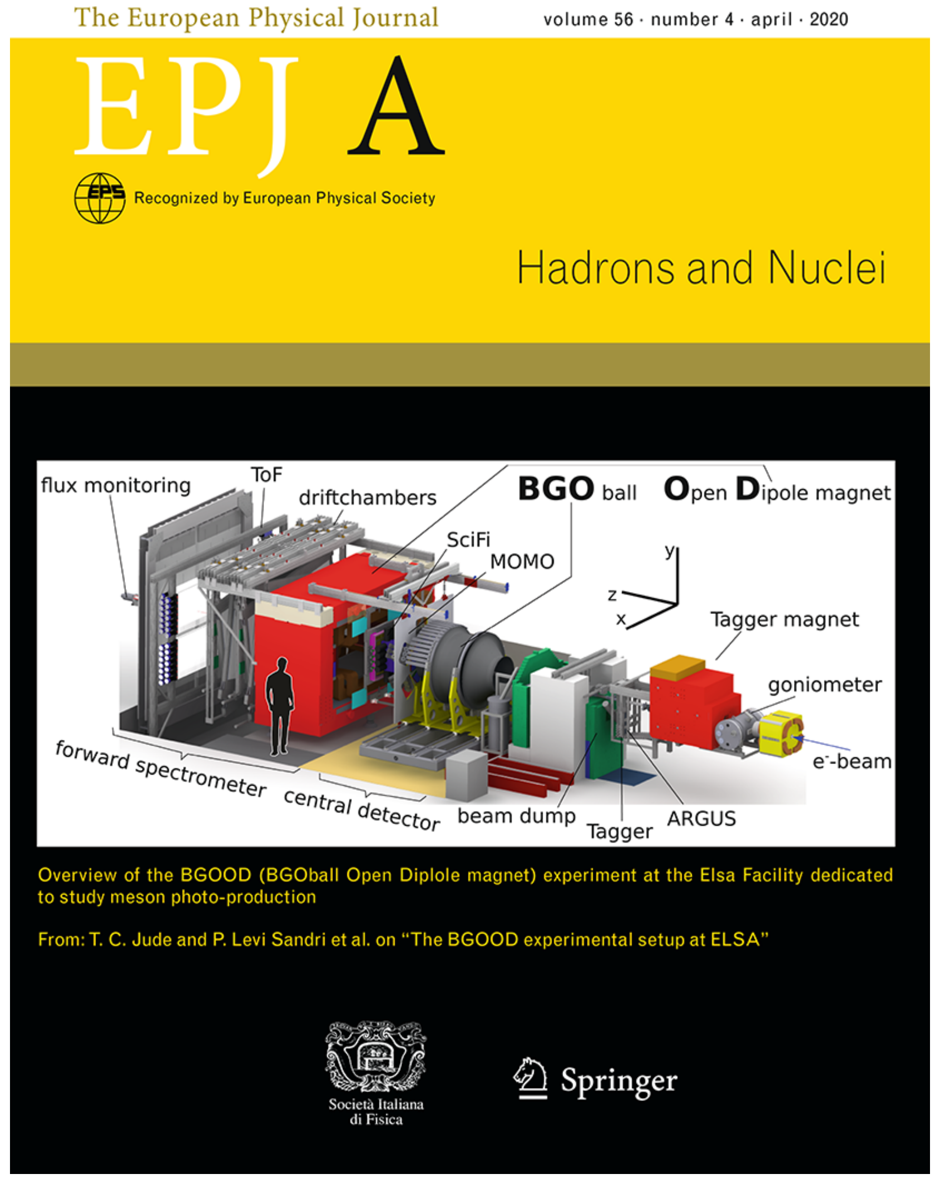

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ELSA – Accelerator & Experiments

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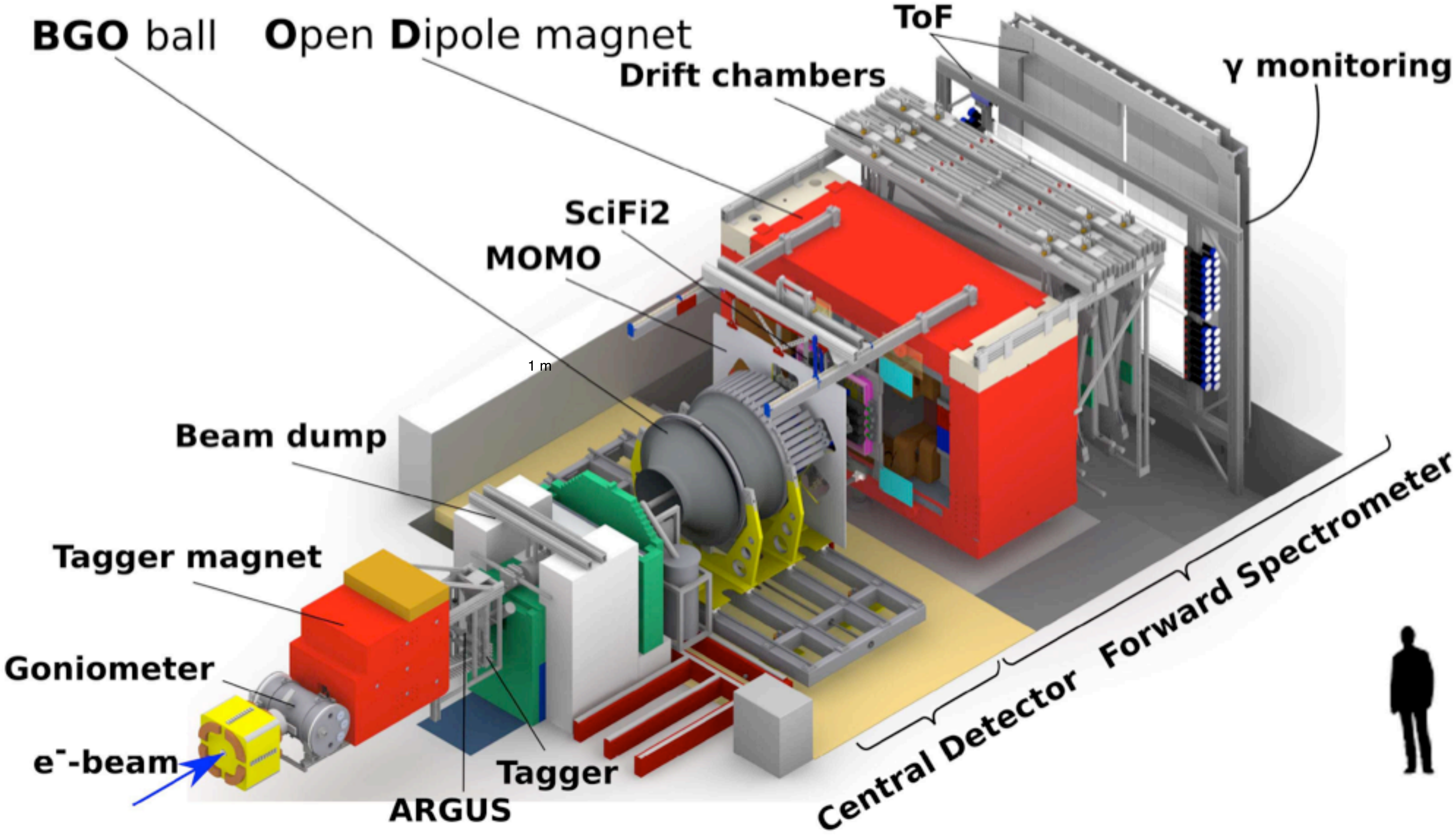
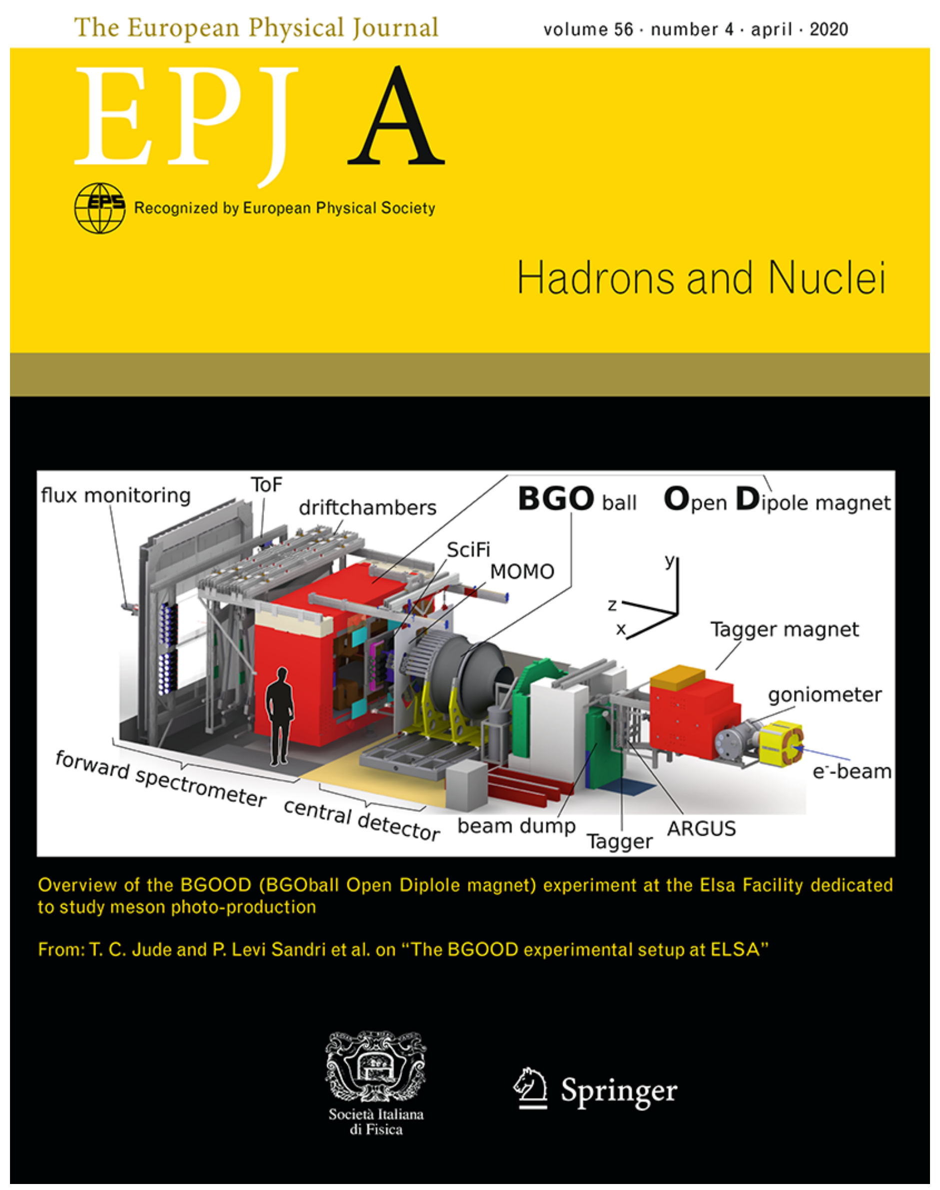




S. Alef et al. [BGOOD collab.], EPJ A 56 (2020) 104

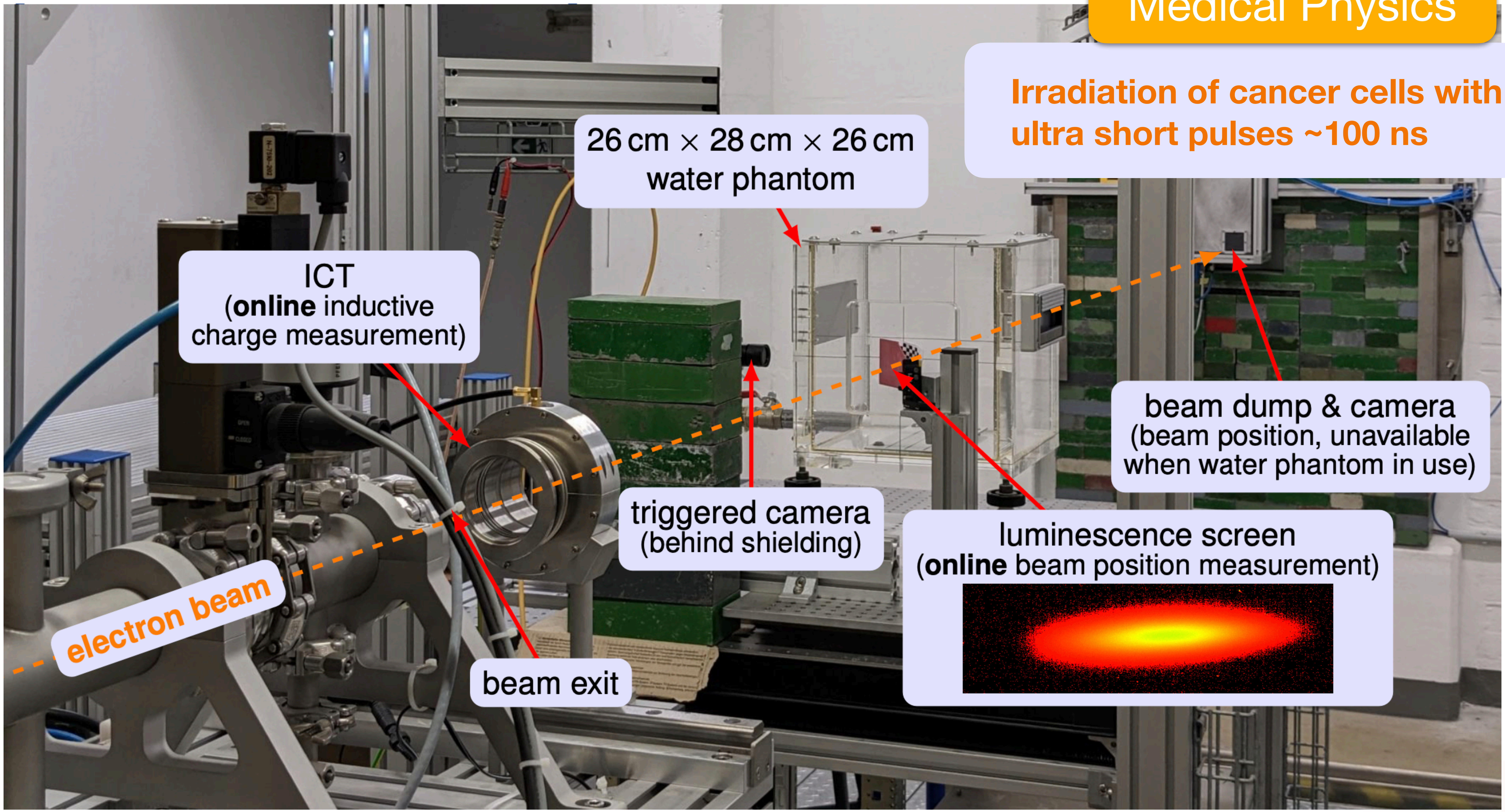
- combination of BGO central calorimeter & forward spectrometer
- high momentum resolution, excellent neutral & charged particle id

ELSA – Accelerator & Experiments

FLASH setup @ E3 beamline

Medical Physics

Irradiation of cancer cells with ultra short pulses ~100 ns



ELSA – Accelerator & Experiments

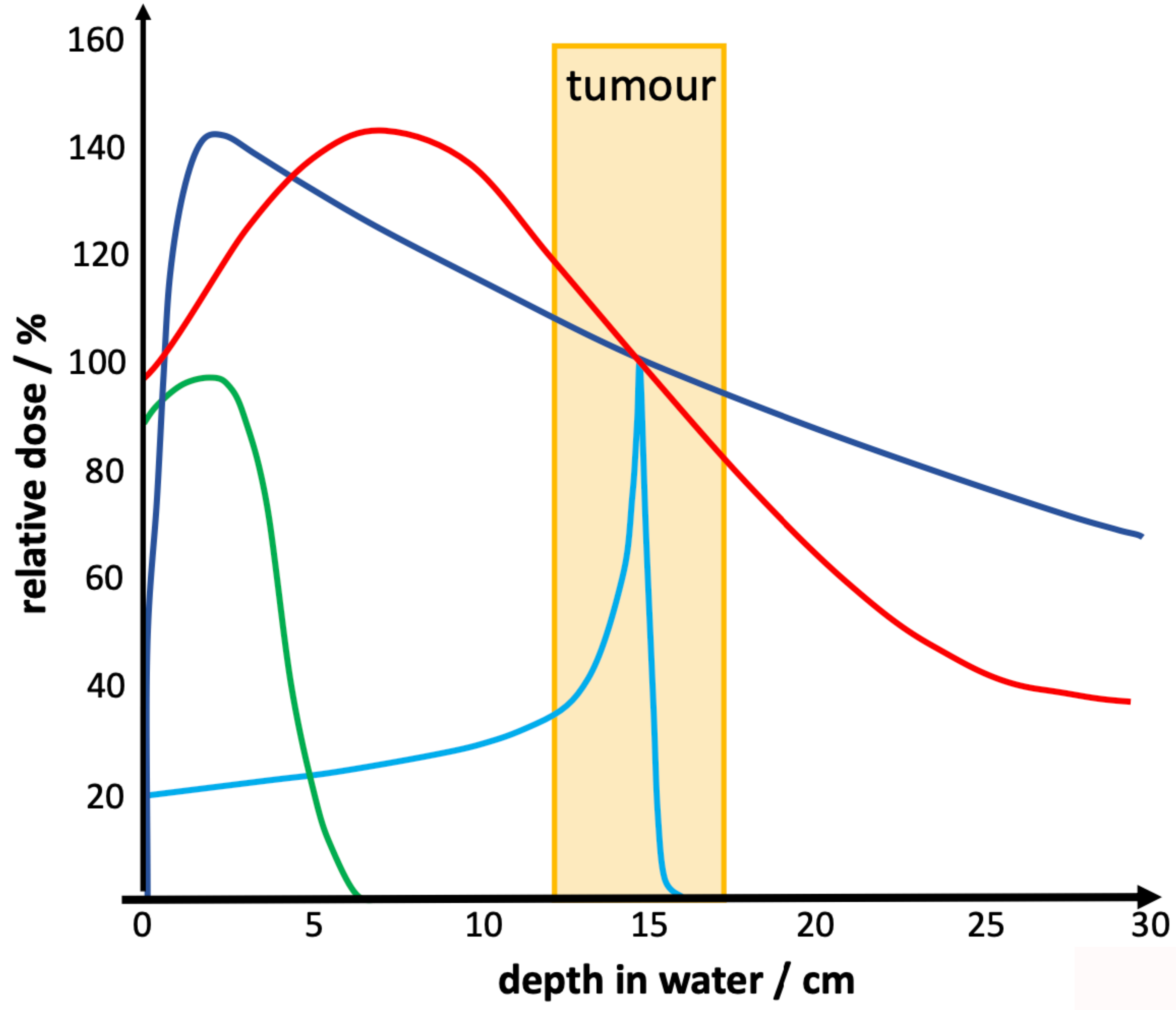
FLASH setup @ E3 beamline

Medical Physics

Radiotherapy against cancer

- Electrons (~MeV) surface tumours
  - Medical Linac
- Photons (~MeV) deep seated tumours
  - Medical Linac
- Protons (~ 100 MeV) tumour at Bragg peak
  - Small facility, multi-room facility
- Very high energy electrons (~100 MeV) → deep seated tumours

Why use Ultra-high energy electrons (~1 GeV)?



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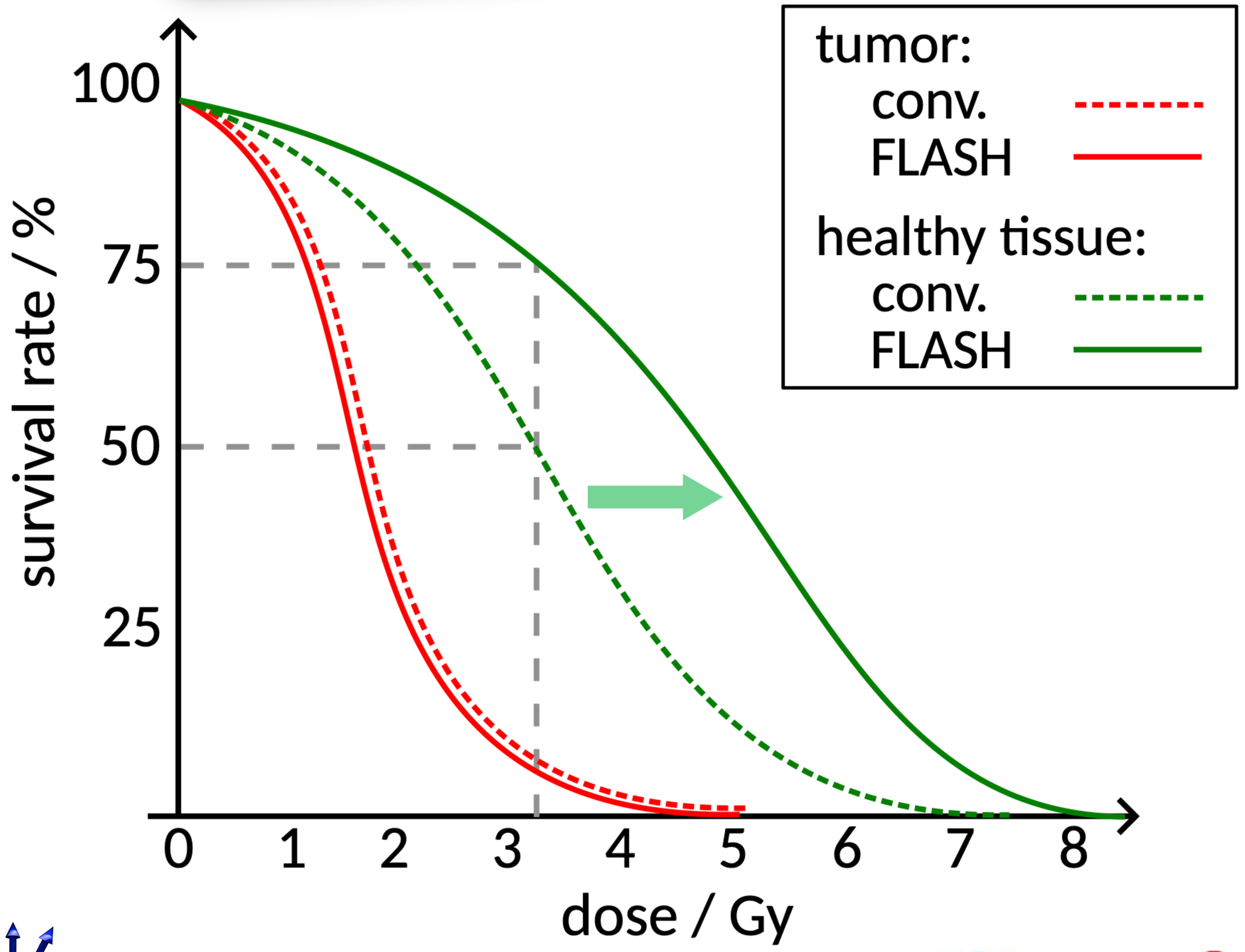
ELSA – Highlight Results

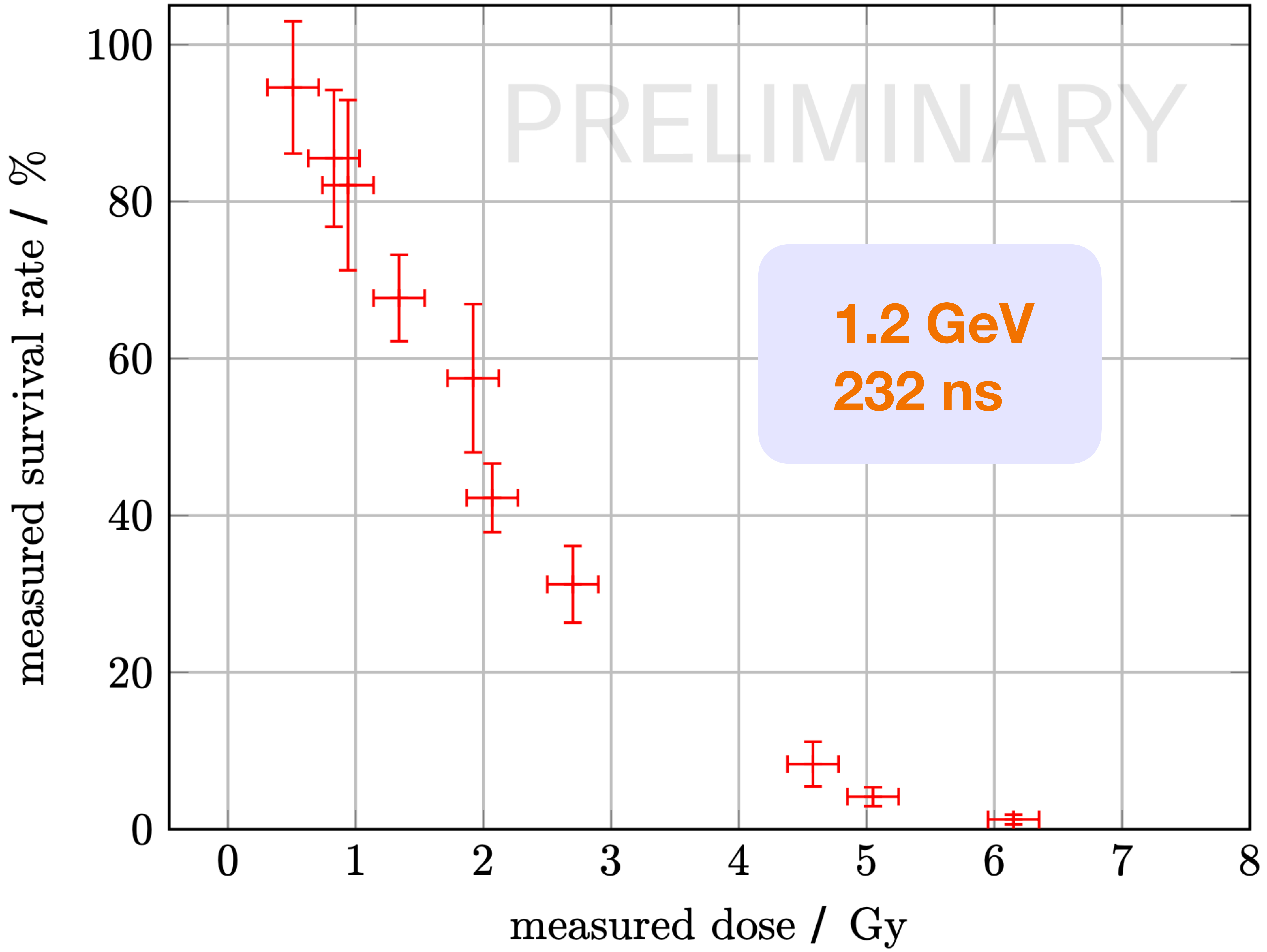
FLASH setup @ E3 beamline

Medical Physics

First successful “treatment“ of cancer cells

D. Proft, K. Desch et al.



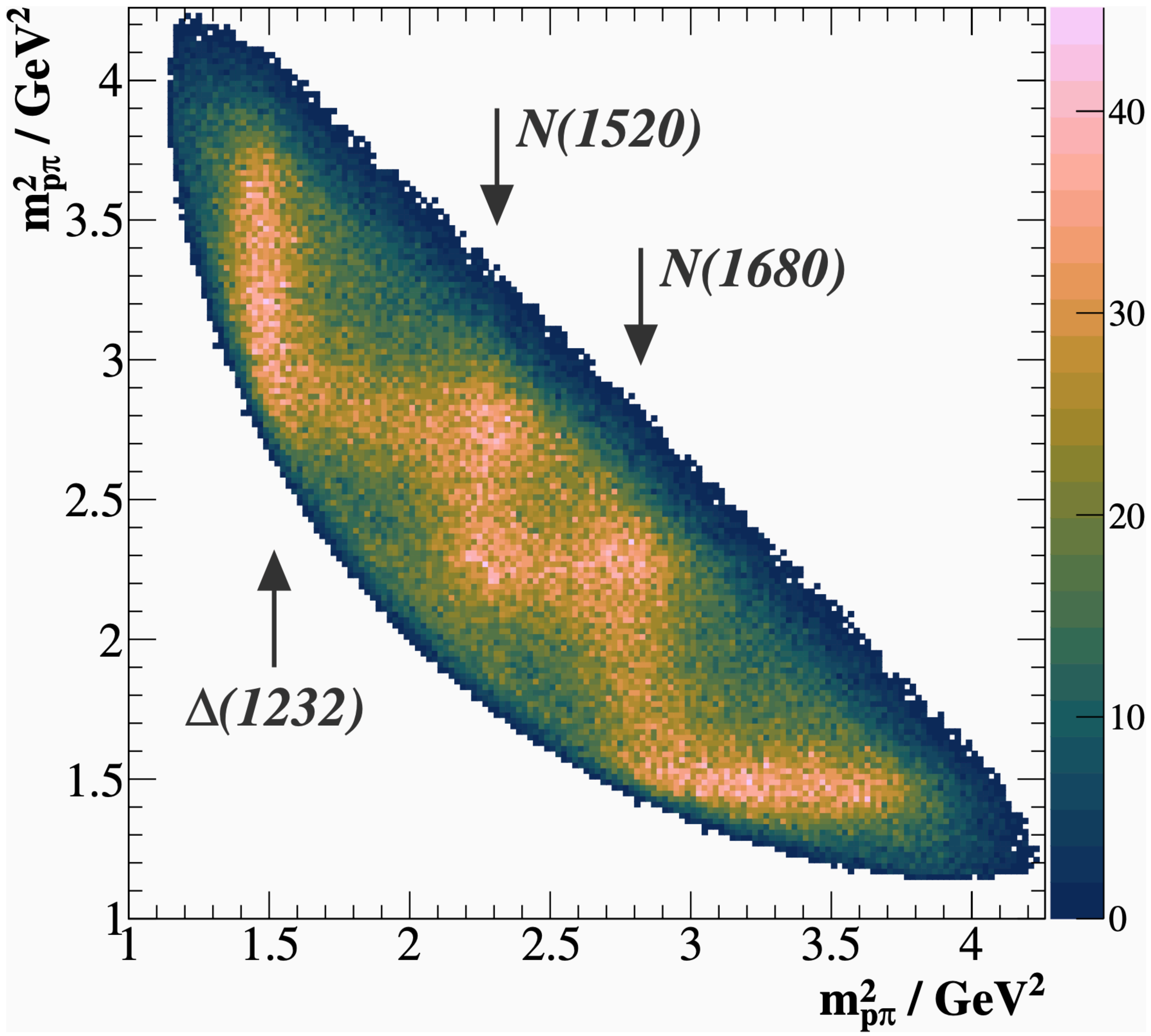


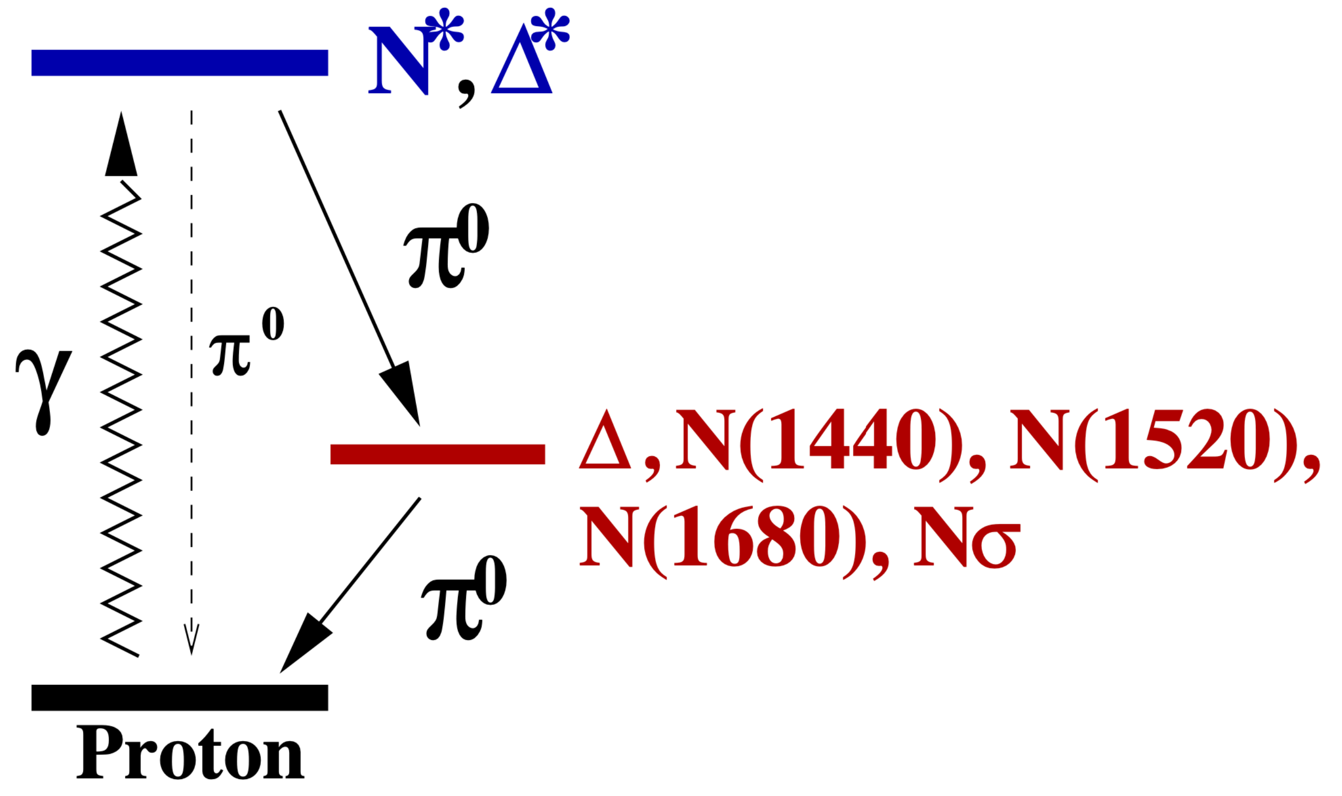
ELSA – Highlight Results

CBELSA/TAPS

baryon spectroscopy: double polarisation & one/two mesons

$\gamma p \rightarrow p\pi^0\pi^0, \gamma p \rightarrow p\pi^0\eta$





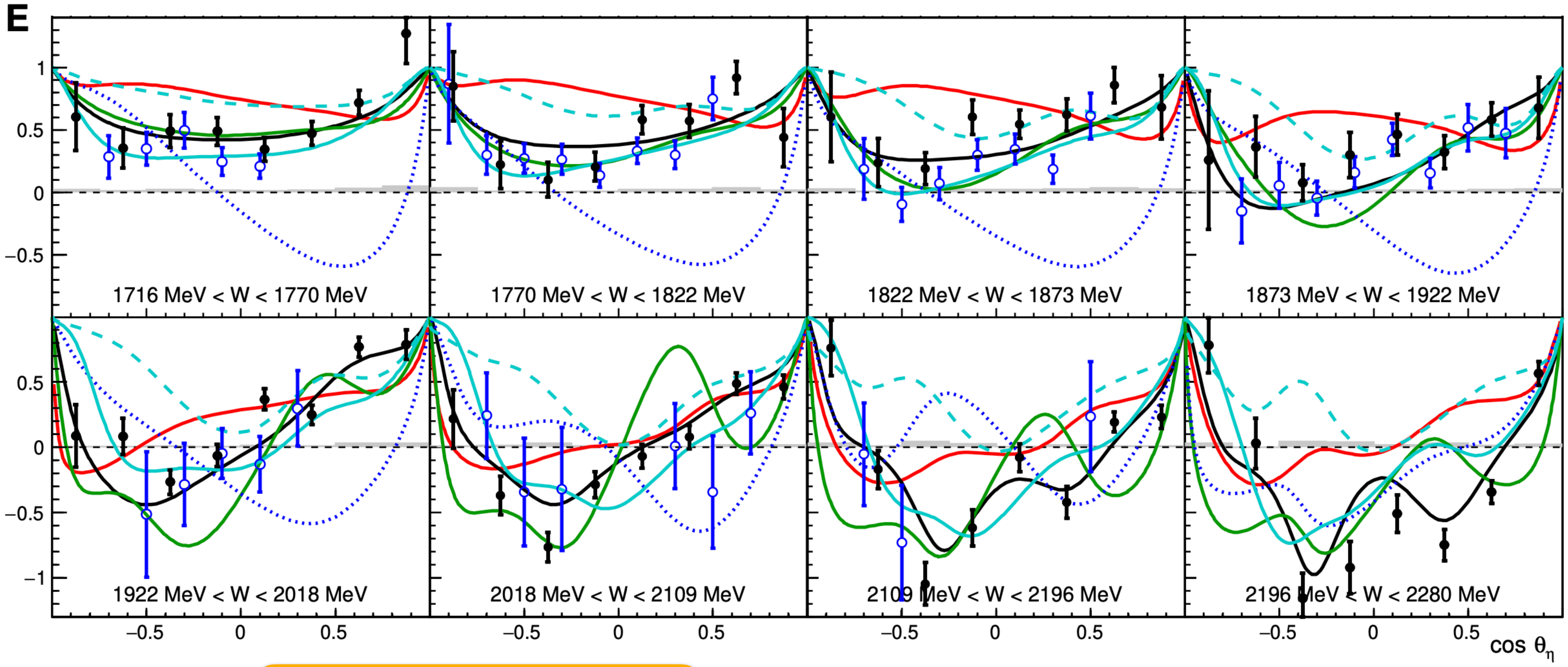
cascade decays observed !

- $\Delta(1910)1/2^+, \Delta(1920)3/2^+, \Delta(1905)5/2^+, \Delta(1950)7/2^+$
  in average: negligible decay fraction $(5 \pm 2\%)$ **into:**
  $N(1520)3/2^-\pi, N(1535)1/2^-\pi,$ ($L \neq 0$-resonances)
- $N(1880)1/2^+, N(1900)3/2^+, N(2000)5/2^+, N(1990)7/2^+$
  in average: 21% decays into:
  $N(1520)3/2^-\pi, N(1535)1/2^-\pi, N\sigma$ ($L \neq 0$-resonances)

V. Sokhoyan et al. (CBELSA/TAPS-collaboration), EPJA 51 (2015) 95
A. Thiel et al. (CBELSA/TAPS-collaboration), PRL 114 (2015) 091803, T.Seifen et al., arXiv:2207.01981 [nucl-ex]

ELSA – Highlight Results $\vec{\gamma}\vec{p} \rightarrow p\eta$ CBELSA/TAPS

polarisation: photons circular, target longitudinal **data**: CBELSA/TAPS black, CLAS blue



→ more data with transverse target polarisation

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ELSA – Highlight Results $\vec{\gamma}\vec{p} \to p\eta$ CBELSA/TAPS

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., Eur. Phys. J. A58 (2022) 229

⇓

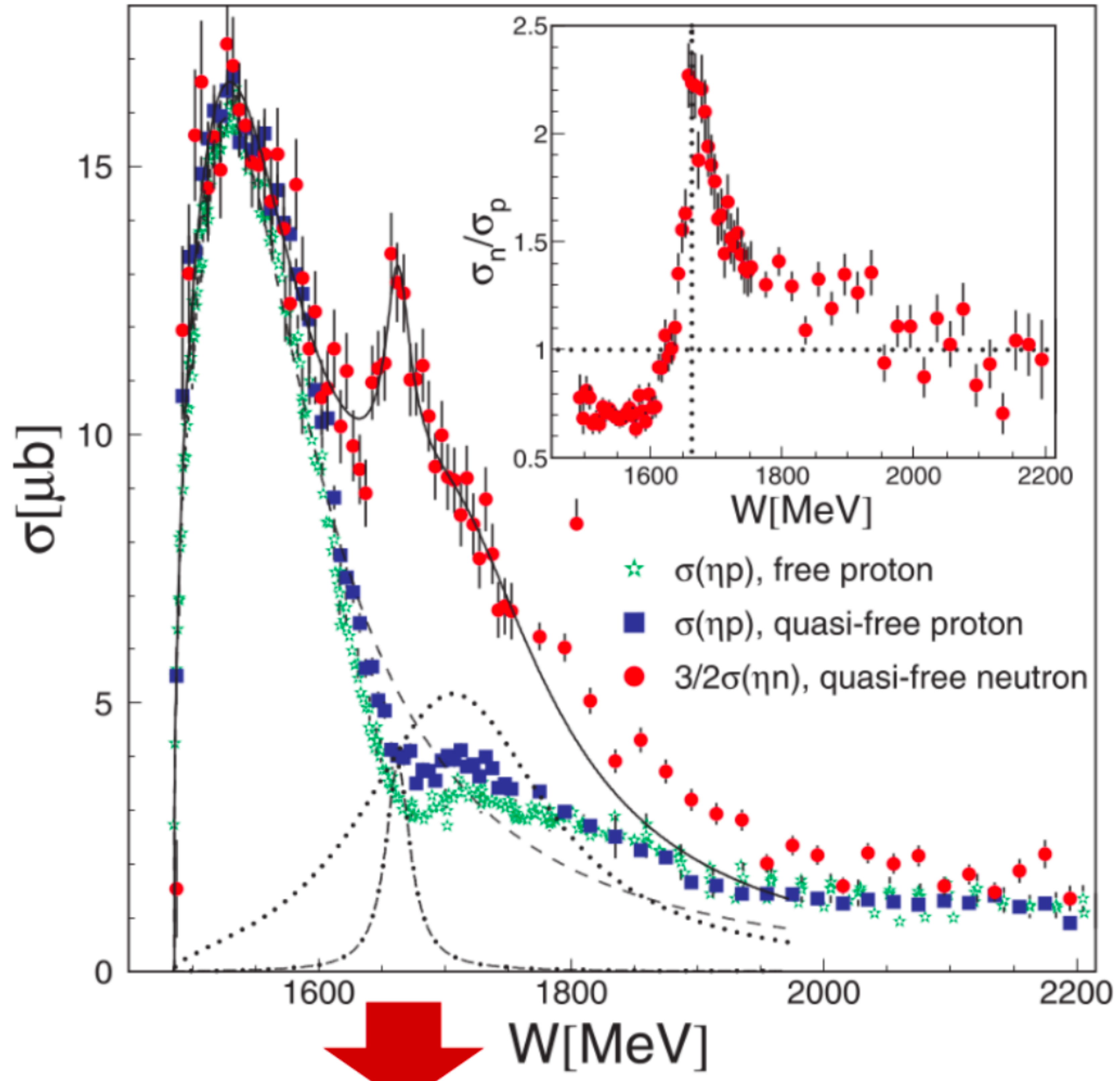
ηN residue of N(1650)1/2⁻ increased by almost a factor of 2!

ELSA – Highlight Results

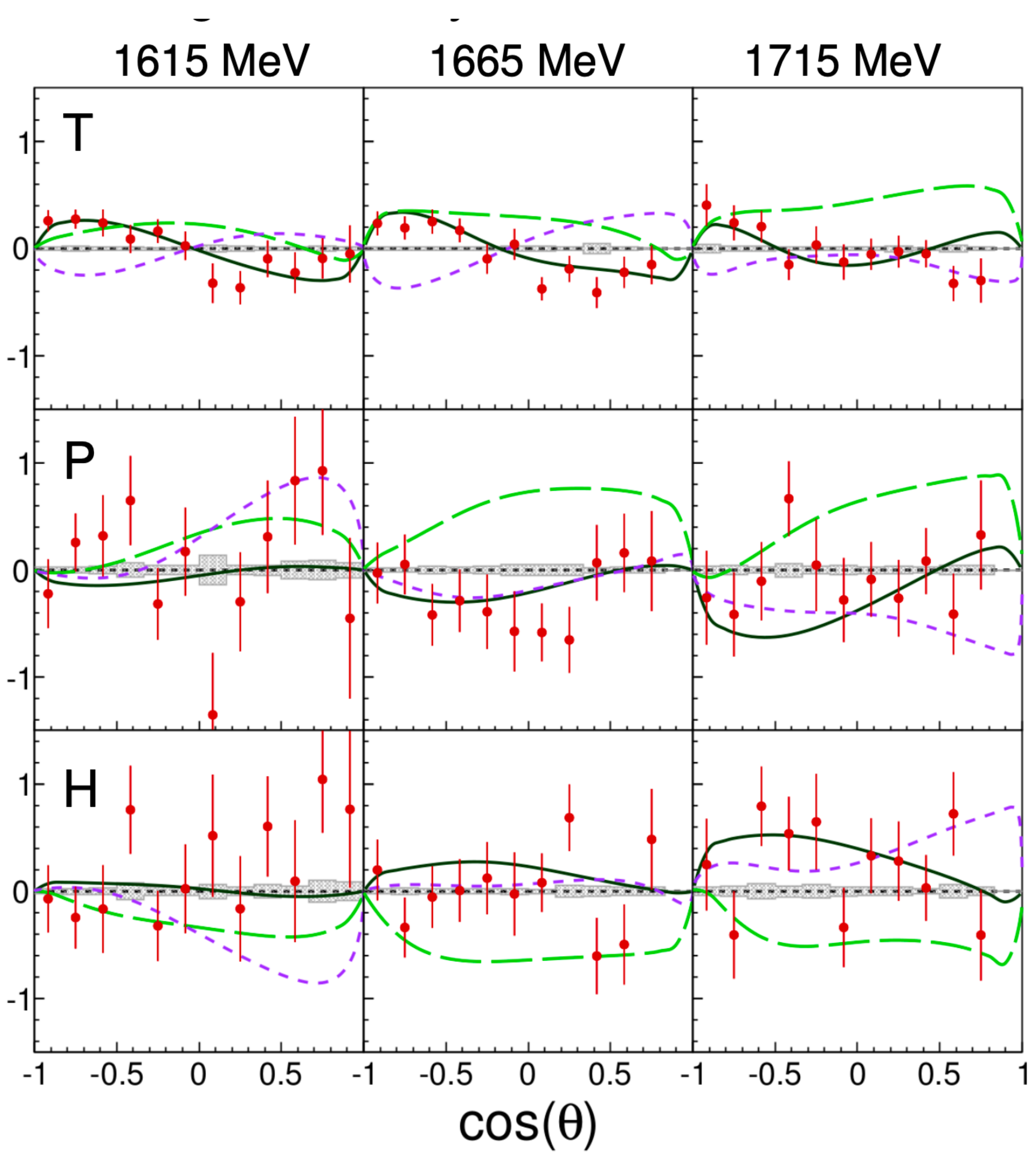
CBELSA/TAPS

$\vec{\gamma}\,\vec{d} \rightarrow \eta\; n\; (p)$ η-photoproduction off neutron

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



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



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

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ELSA – Highlight Results

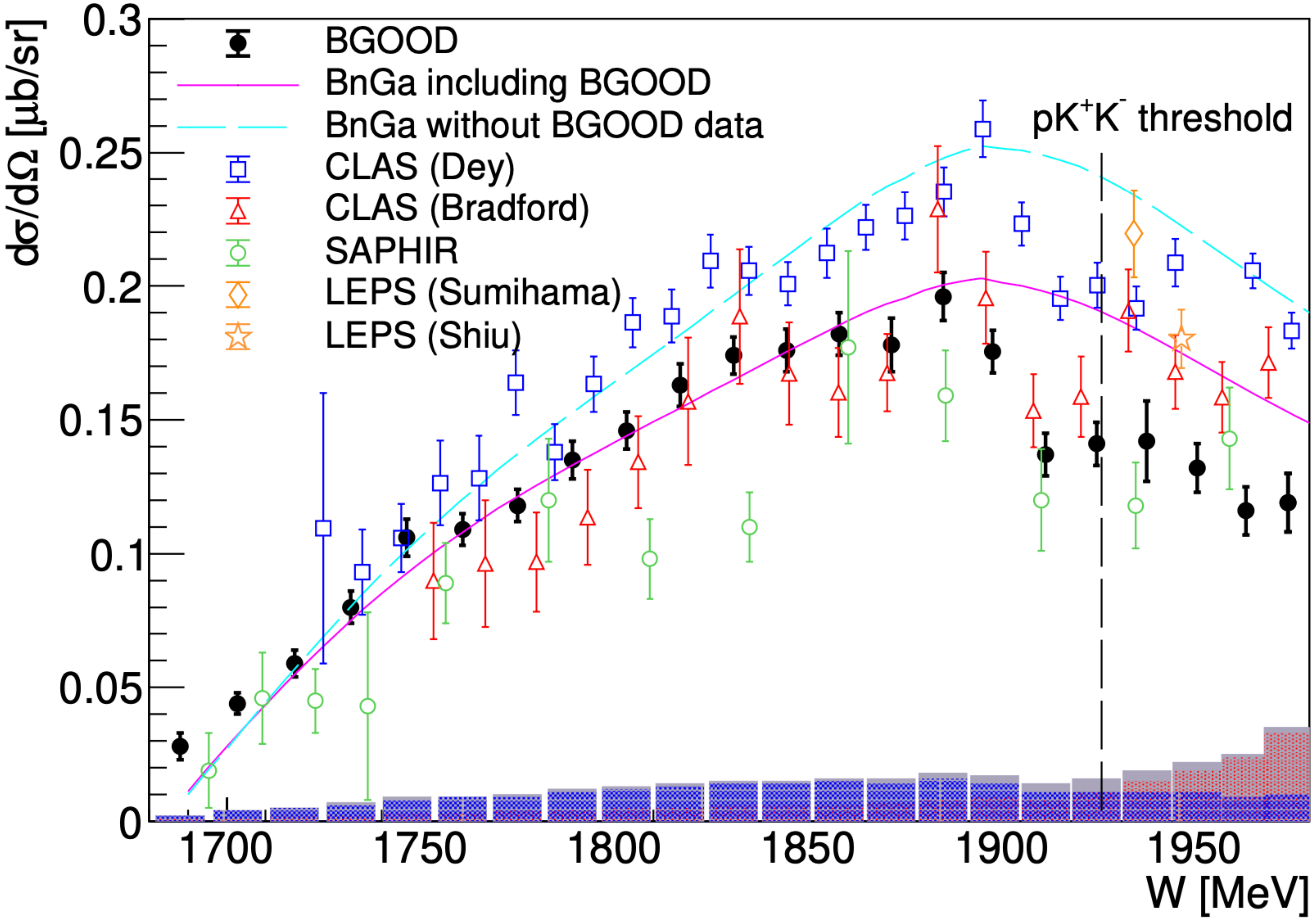
BGOOD

multi-quark states in uds sector:
penta-/hexaquarks ??

special feature:
forward K+ sensitivity

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

T.C. Jude et al. [BGOOD collab.],
Phys. Lett. B. 820 (2021) 136559



R. Bradford *et al.* (CLAS), PRC 73, 035202 (2006),
B.Dey *et al.* (CLAS), PRC 82, 025202 (2010),
CLAS data in $\cos\theta^K_{\mathrm{CM}}$ 0.85 to 0.95 interval,
K.H. Glander *et al.* (SAPHIR), EPJA 19, 251 (2004),
BnGa PWA - without BGOOD/with BGOOD

- discrepancy resolved between conflicting data sets

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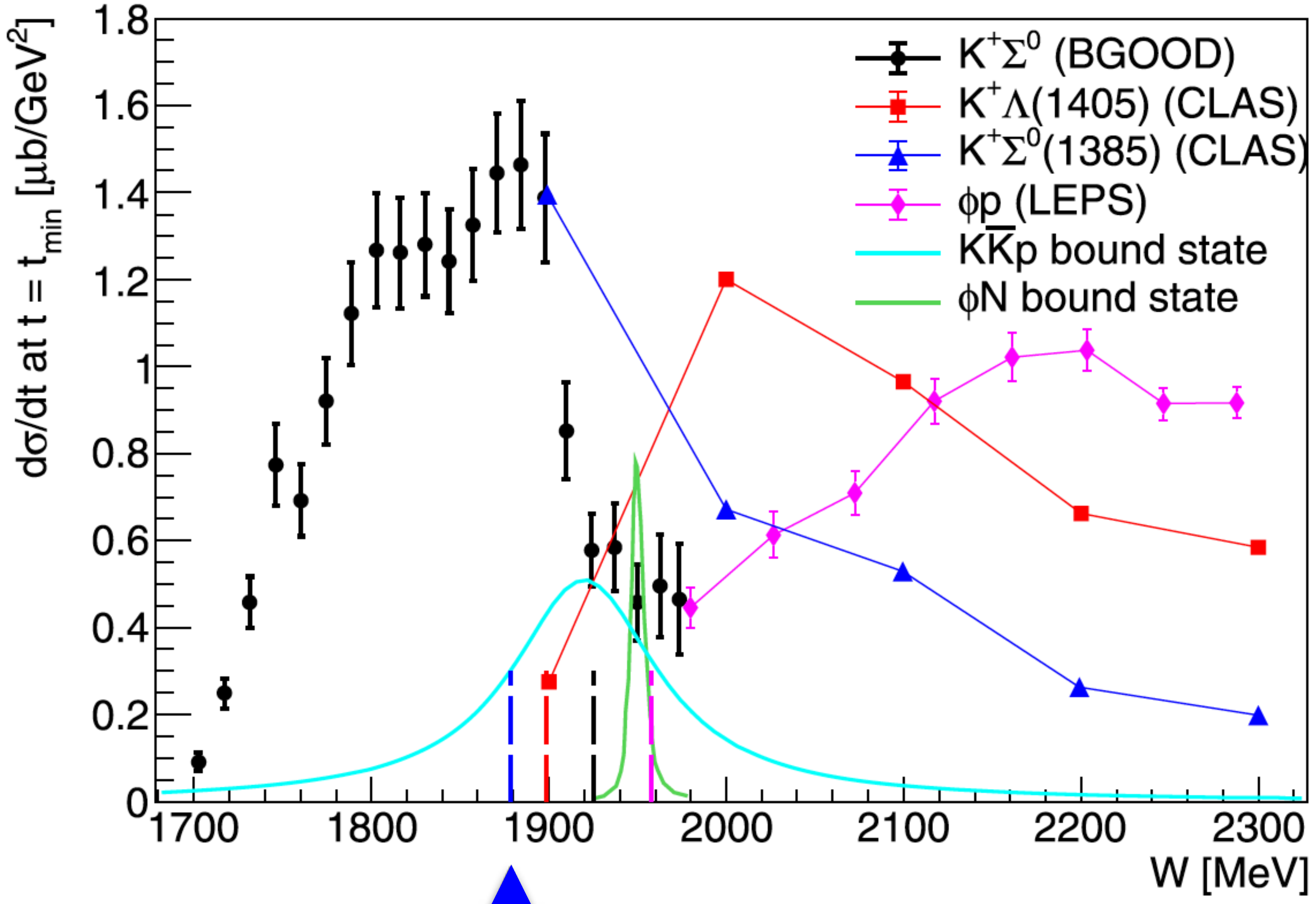
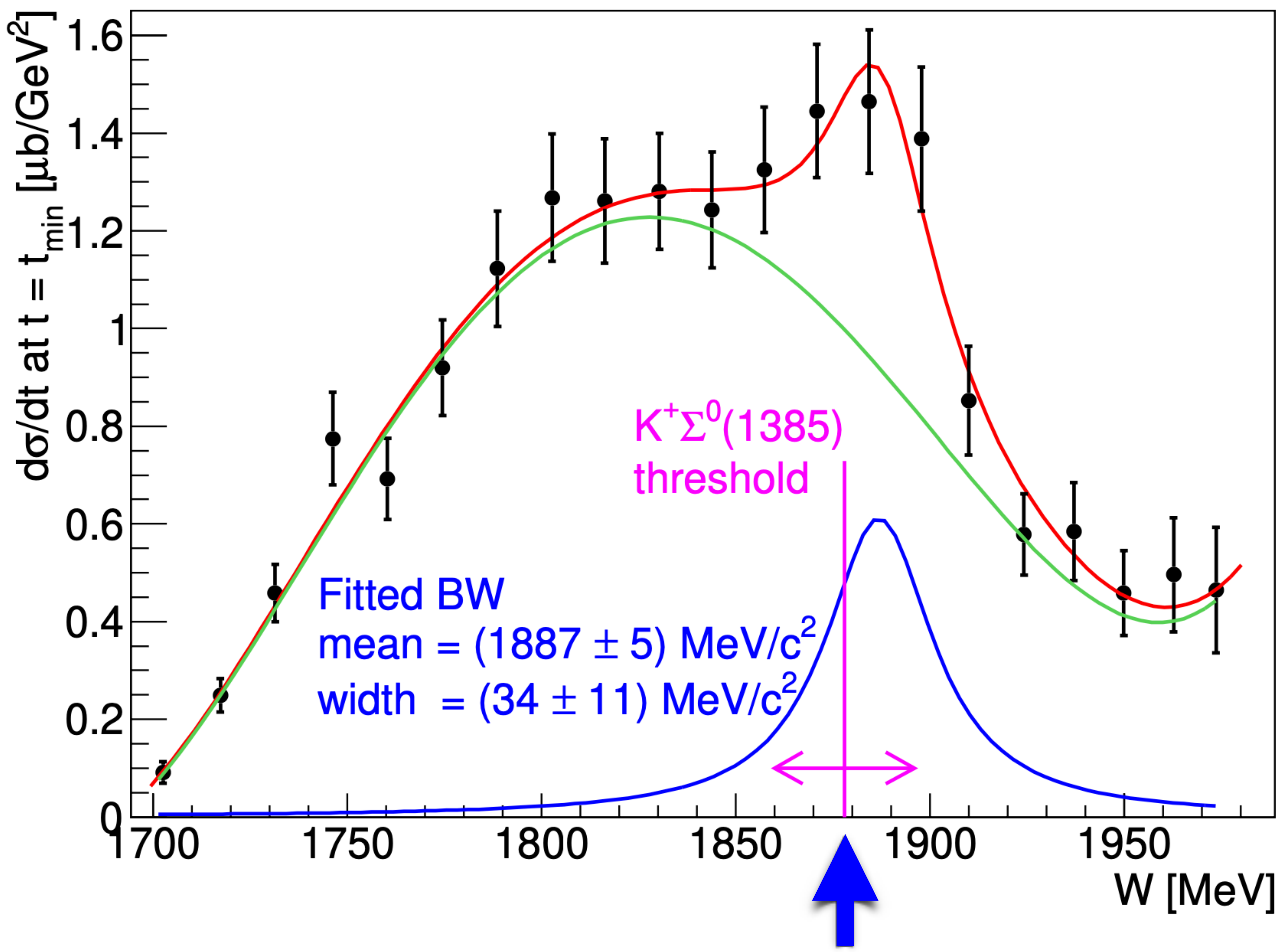
ELSA – Highlight Results

BGOOD

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



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



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

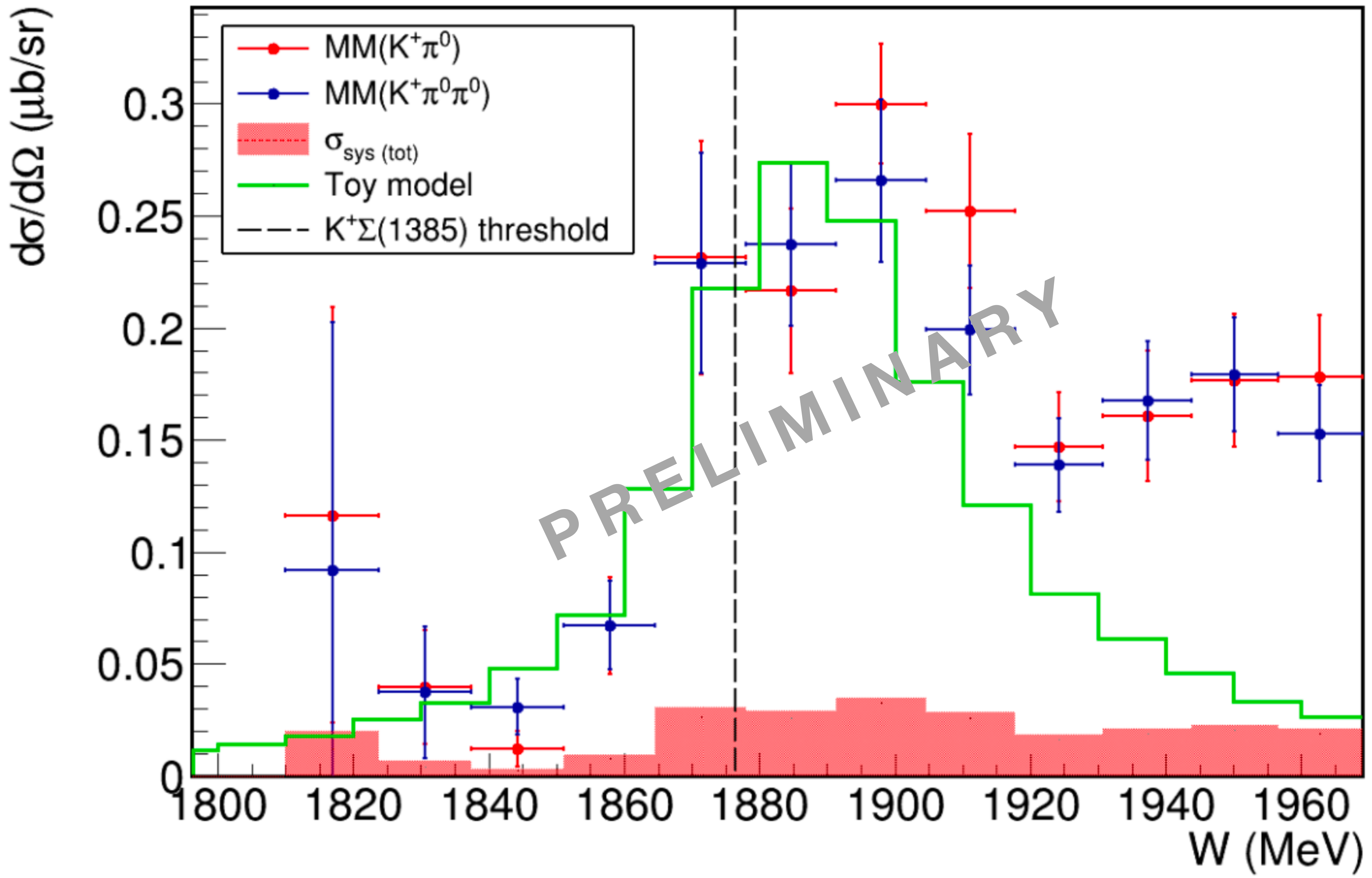
T. Jude *et al.* [BGOOD]
Phys. Lett. B 820 (2021)
& later analysis

ELSA – Highlight Results

BGOOD

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

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



ELSA – Highlight Results

BGOOD

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

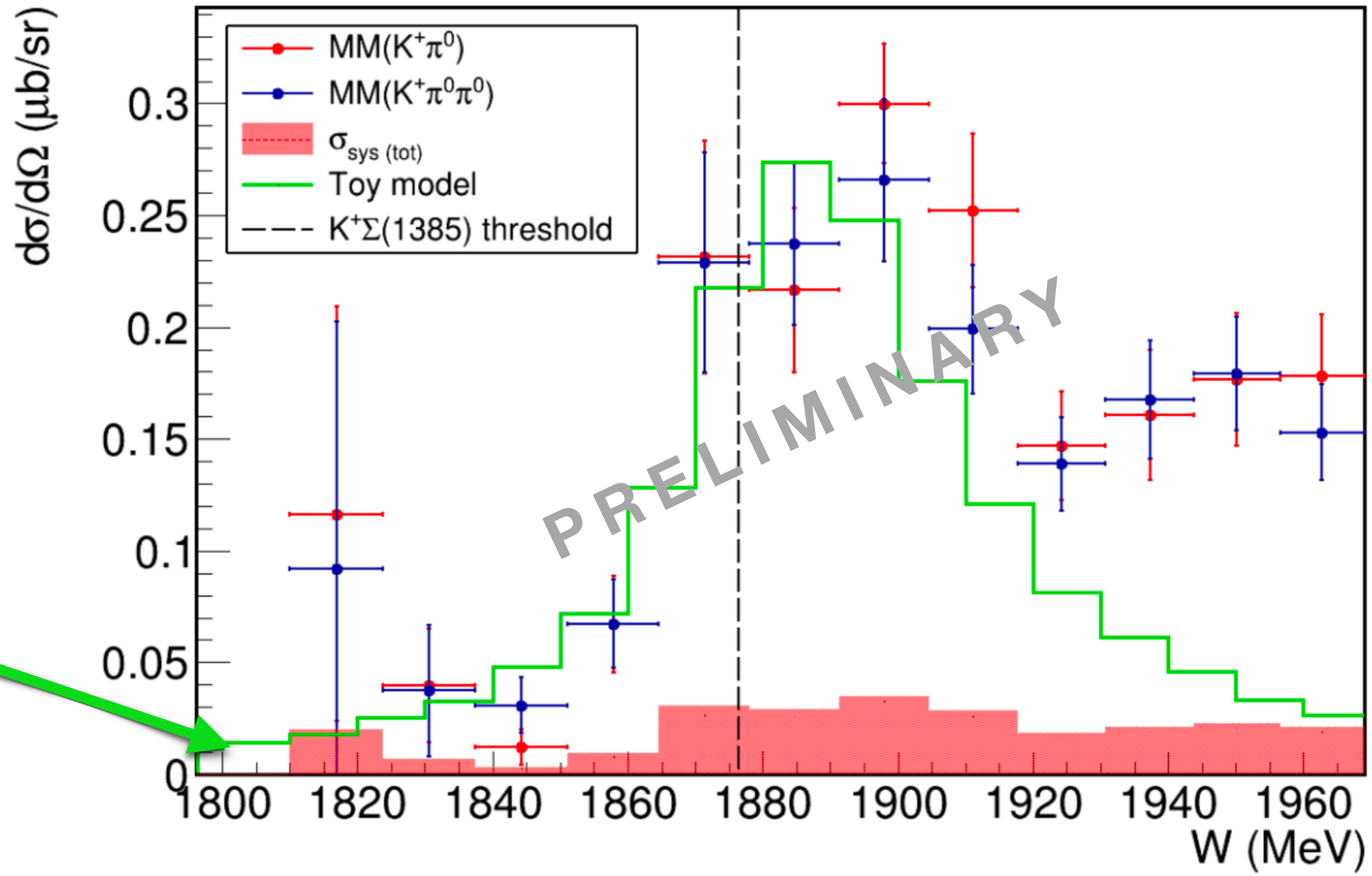
M. Jena Masters thesis (Bonn 2024), data preliminary

π-exchange toy model
$K^+ \leftrightarrow \Sigma^0(1385)$

- assume

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

- and width of Σ^*



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ELSA – Highlight Results

BGOOD

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

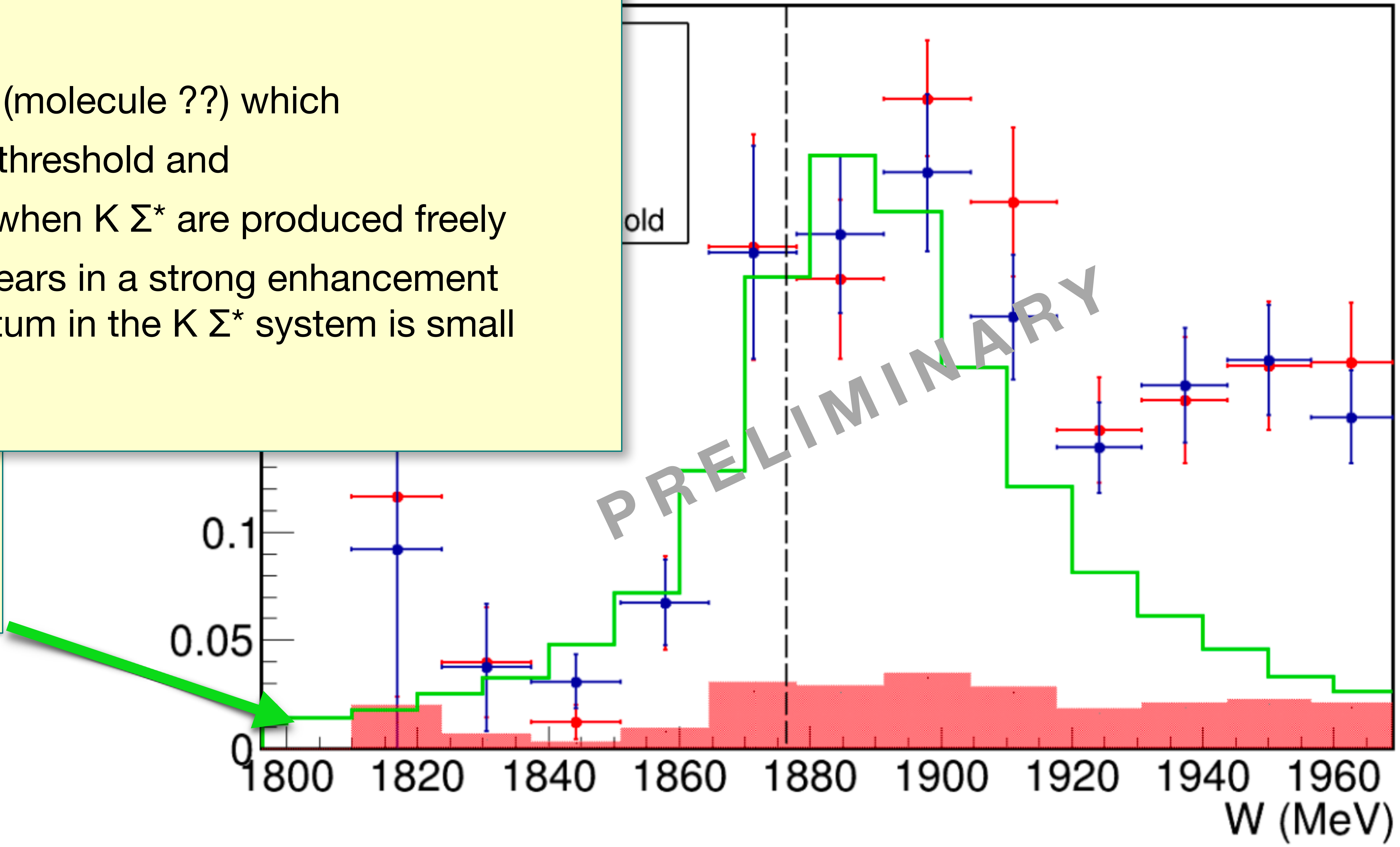
M. Jena Masters thesis (Bonn 2024), data preliminary

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

$d\Omega \quad (m_\pi^2 + q^2)^2$

- and width of Σ*



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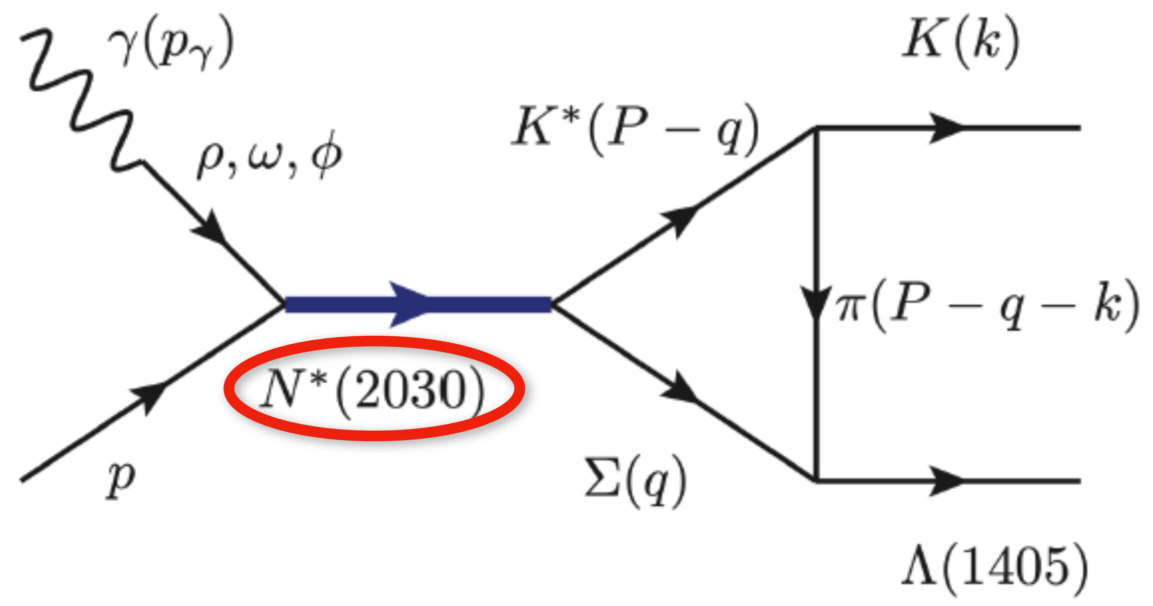
ELSA – Highlight Results

BGOOD

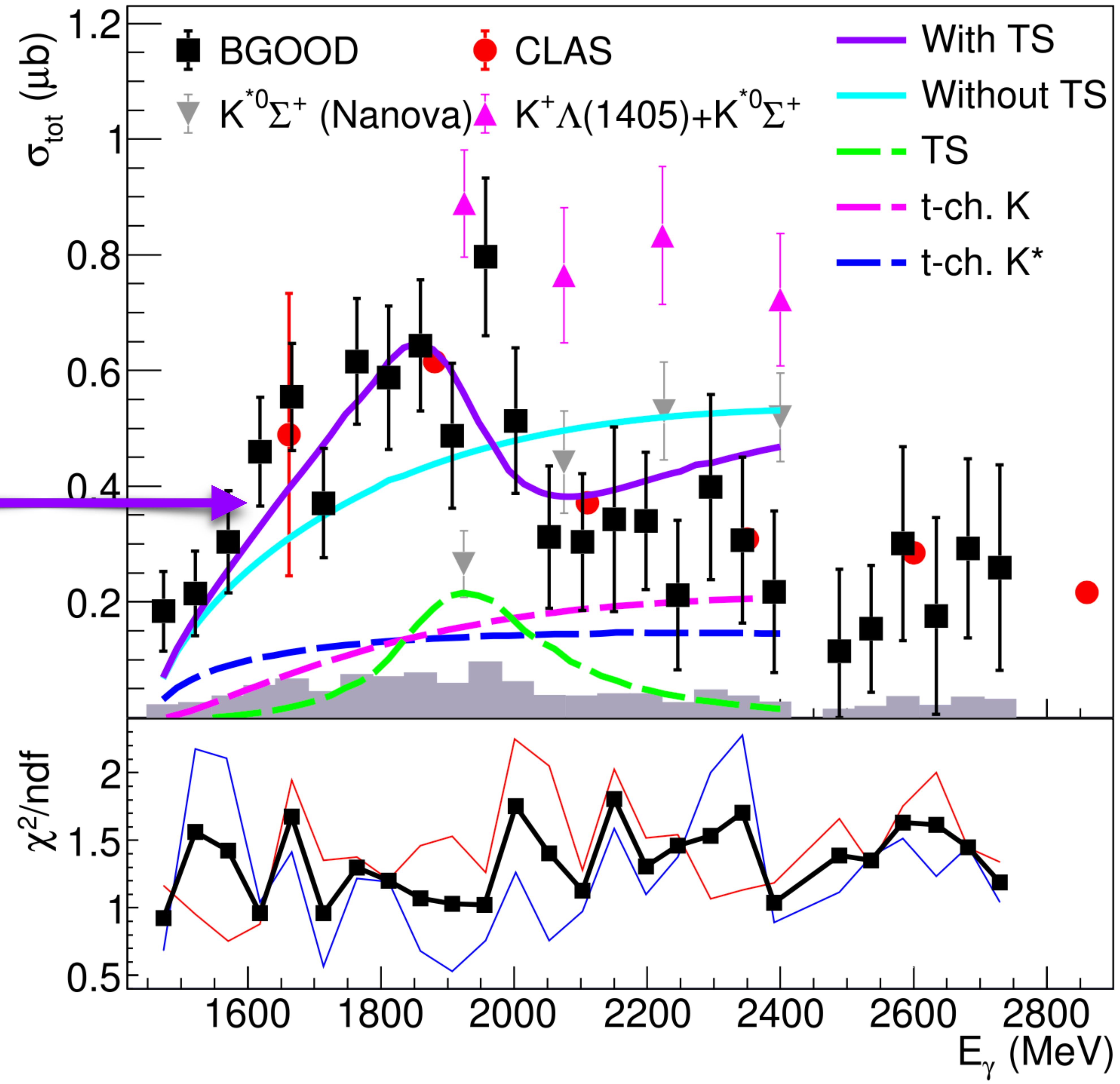
$\gamma\, p \;\rightarrow\; K^{+}\; (\, \Lambda(1405) \;\rightarrow\; \pi^{0}\, \Sigma^{0}\,)$



E. Wang, J. Xie, W. Liang, F. Guo, E. Oset, PR C 95 (2017) 015205

cusp: triangle meachanism significant !

N*(2030) as a [K* Σ] configuration



G. Scheluchin *et al.* [BGOOD collab.] Phys. Lett B 833 (2022) 137375

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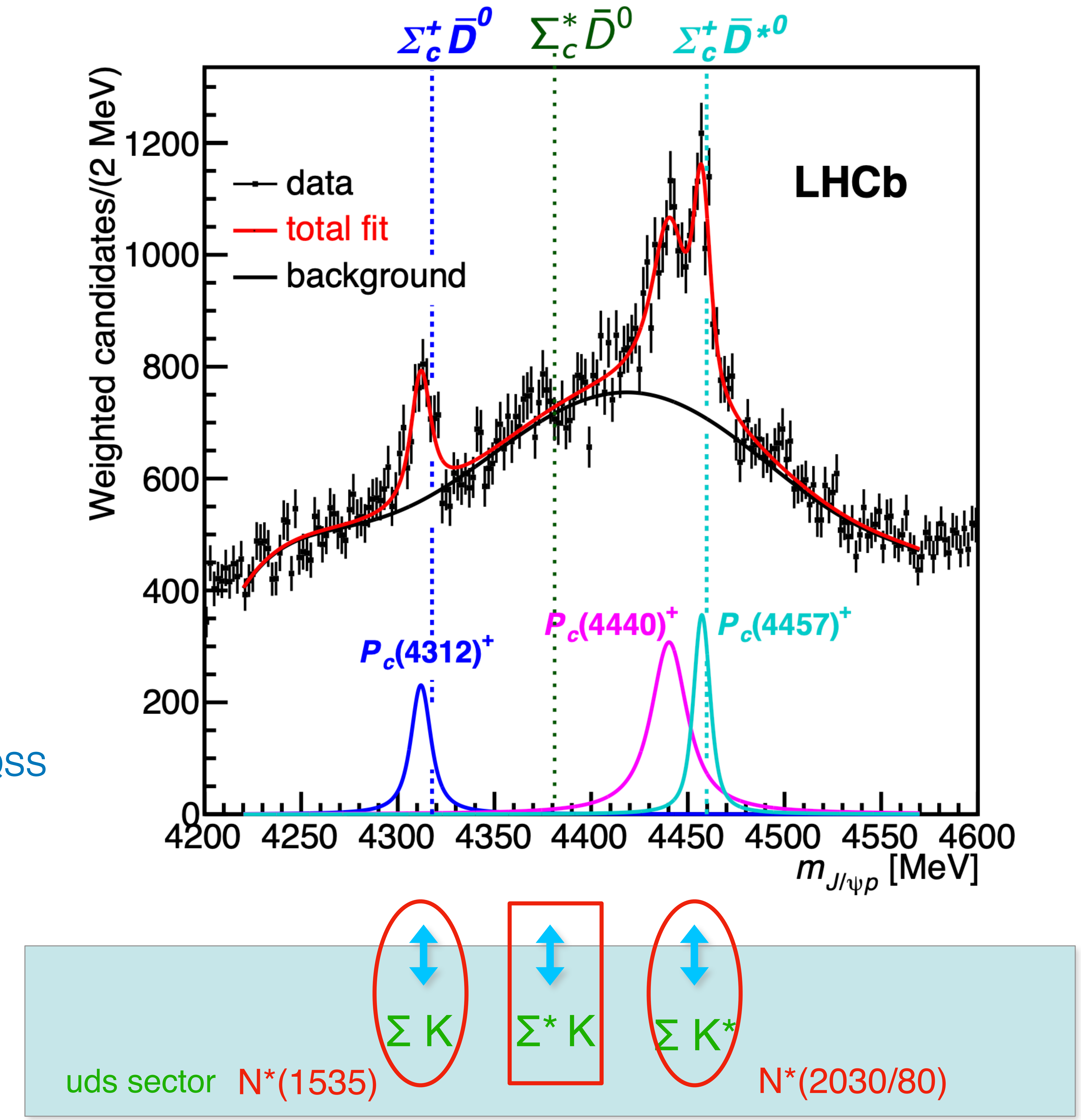
ELSA – Highlight Results

BGOOD

multi-quark states in uds sector:
pentaquark strucures
– parallels w/ c-sector ?



Meng-Lin Du et al.,
PRL 124 (2020) 072001

Hadronic molecules & HQSS

LHCb data: PRL 122 (2019) 222001

ELSA – Highlight Results

BGOOD

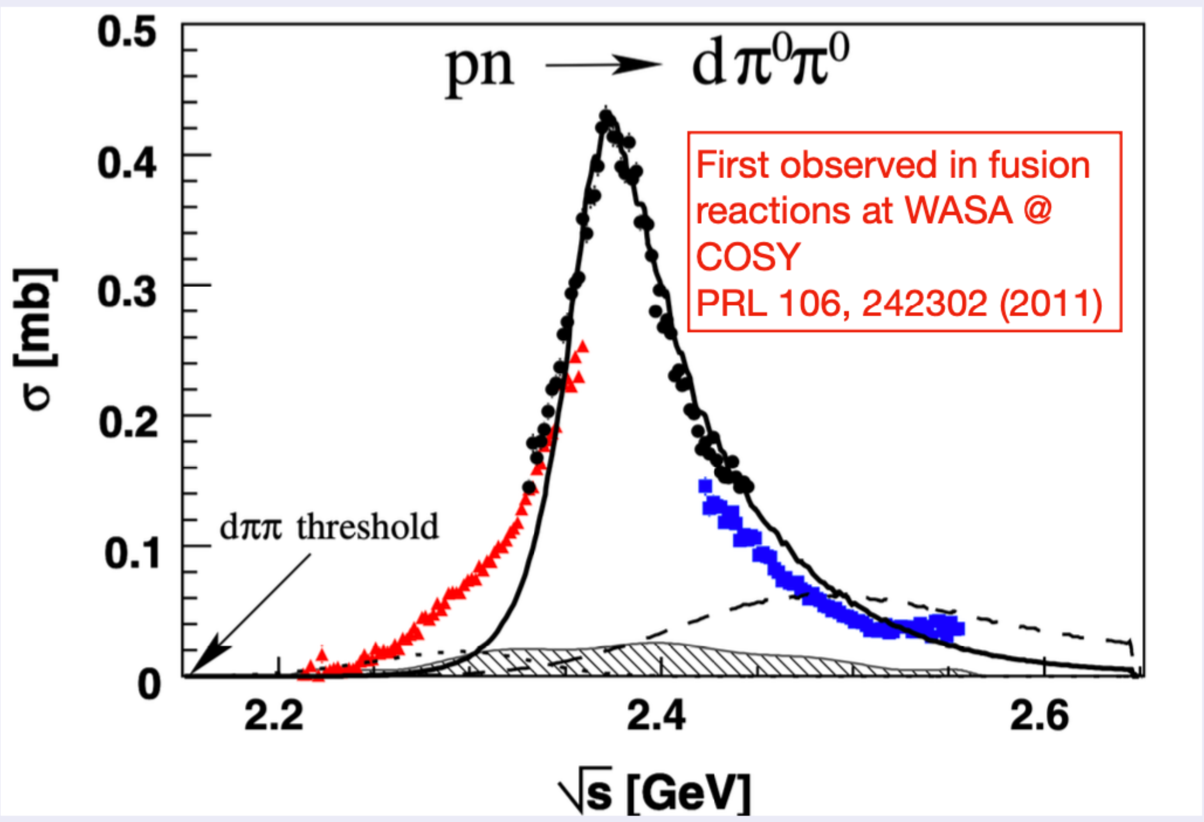
multi-quark states in uds sector:
hexaquark / di-baryon strucures

experimental context

coherent 2π photoproduction off deuteron

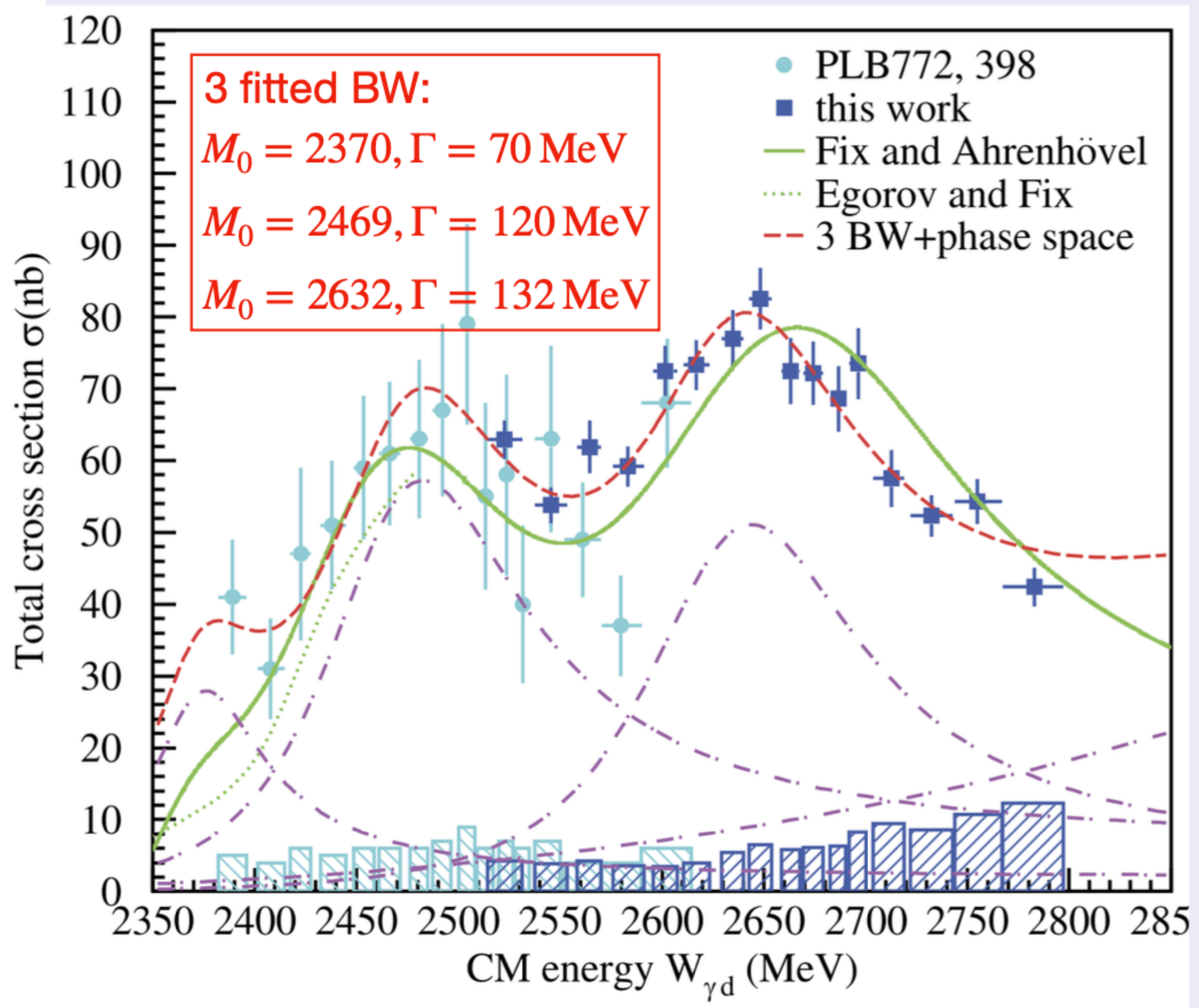
Evidence of the $d^*(2380)$

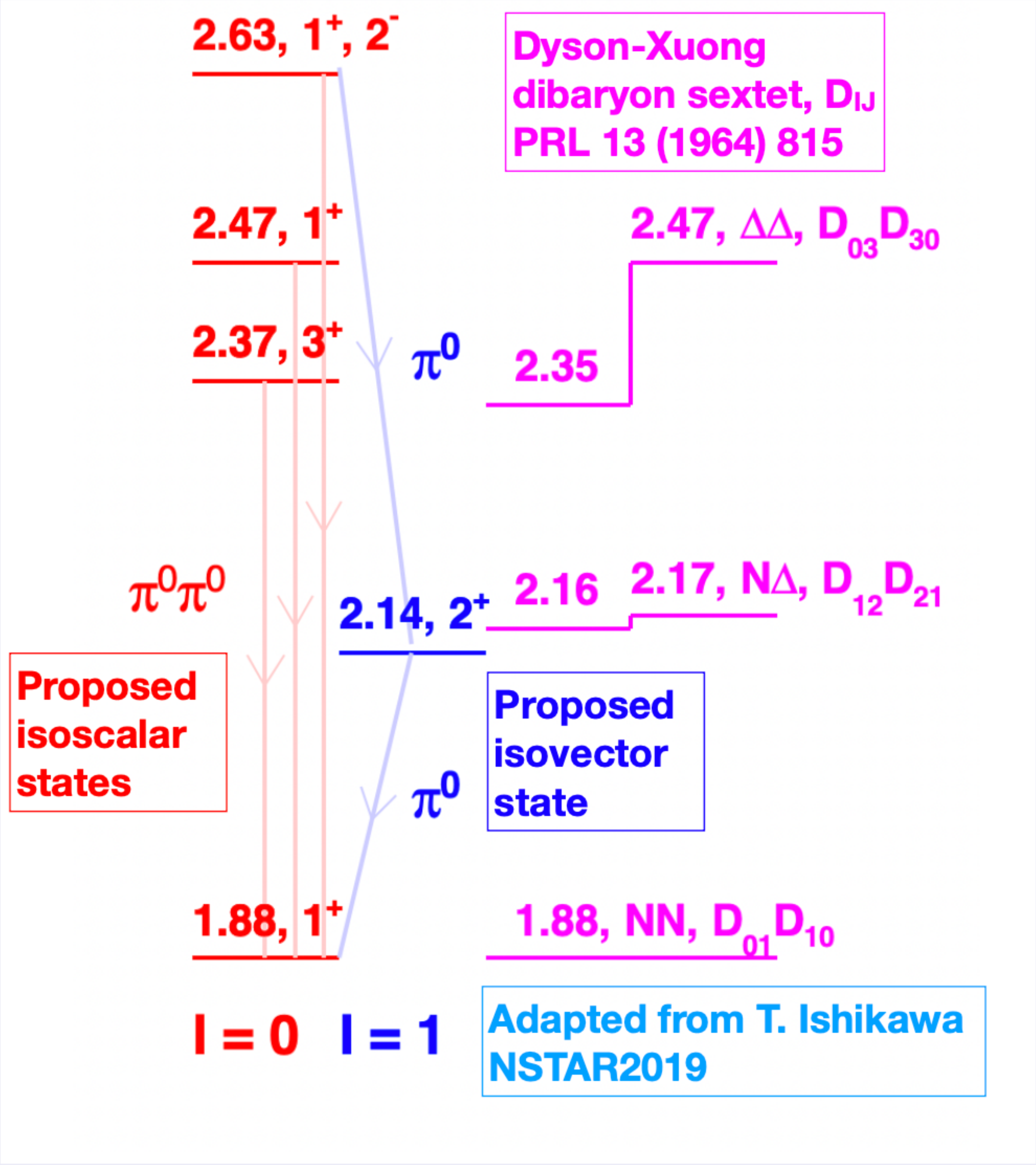
Adlarson et al PRL 106:242302, 2011
Bashkanov et al PRL 102:052301, 2009



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

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





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

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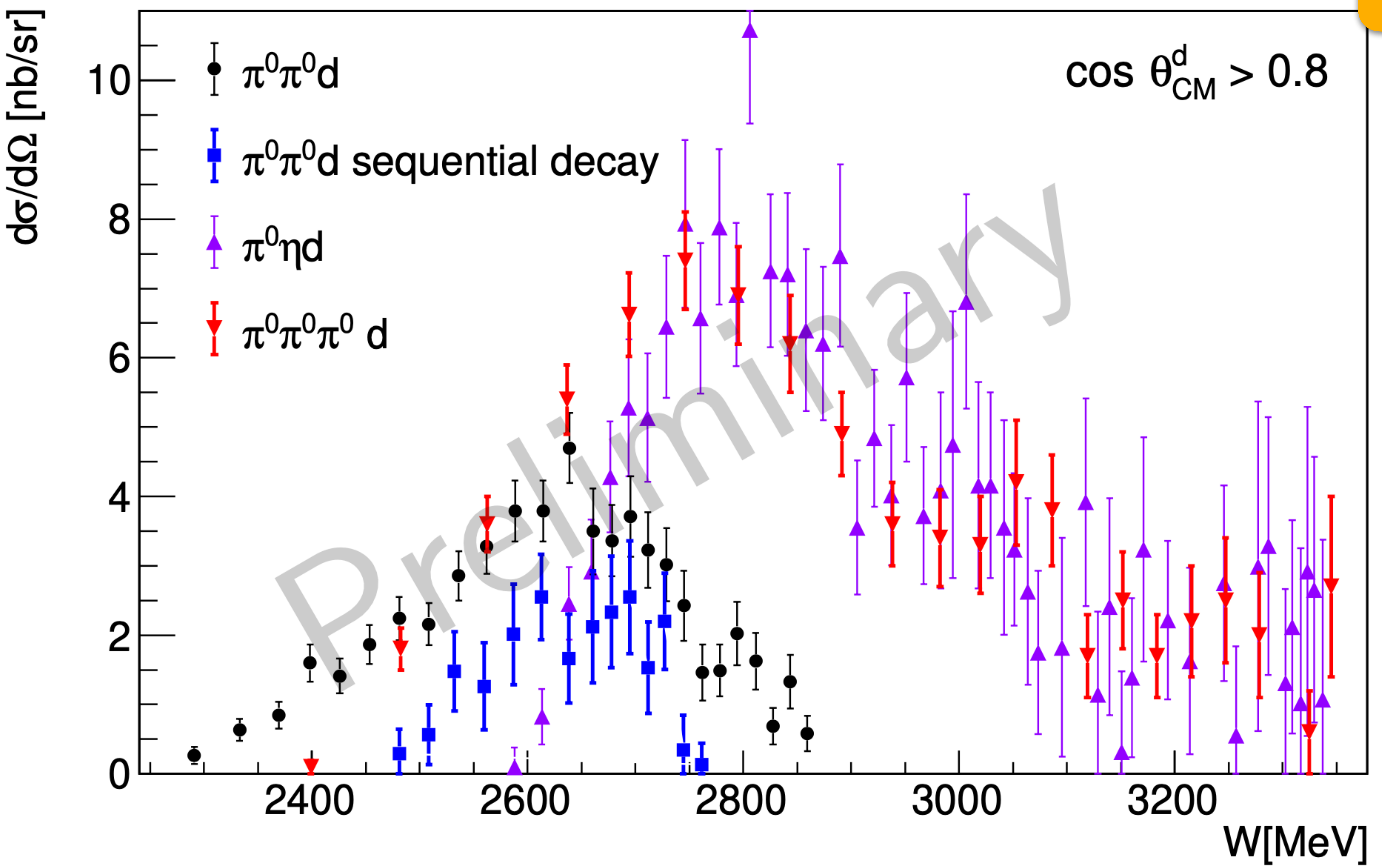

further channels coherent
meson photoproduction

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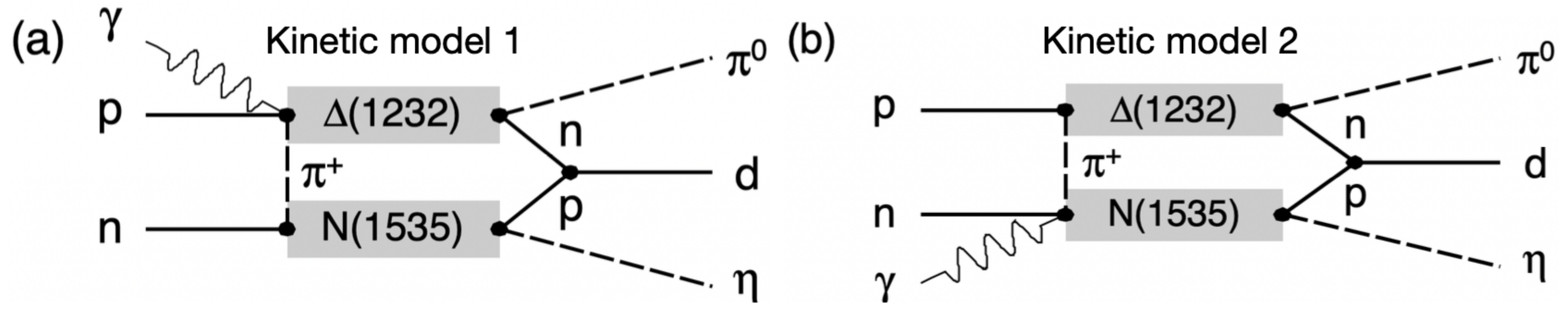
ELSA – Highlight Results

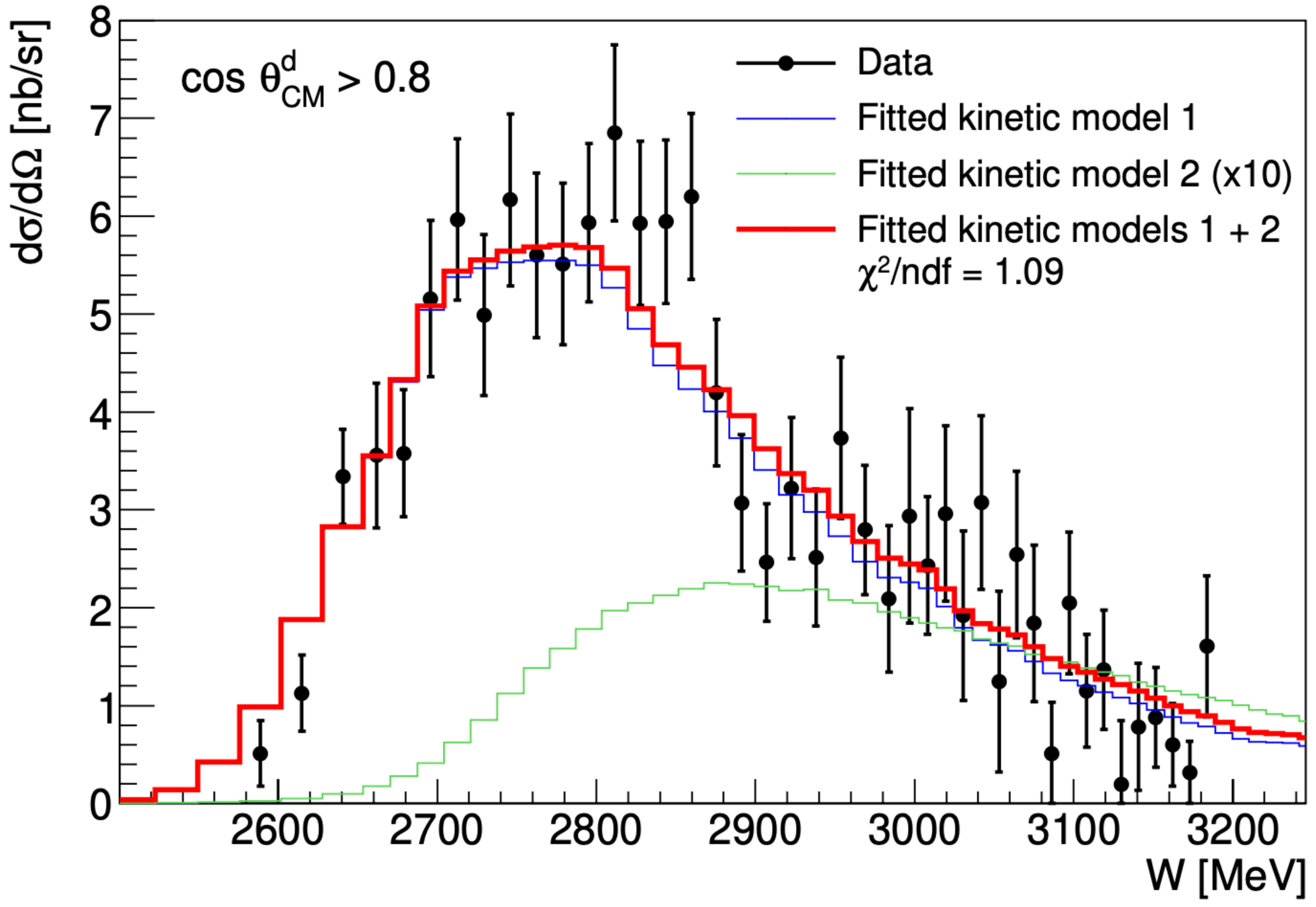
BGOOD

multi-quark states in uds sector:
hexaquark / di-baryon strucures

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::
  - $N(1535) \to \pi N,\ \Gamma_i/\Gamma = 32 - 53\,\%$
  - $N(1535) \to \pi\pi N,\ \Gamma_i/\Gamma = 4 - 31\,\%$
  - $N(1535) \to \pi\eta N,\ \Gamma_i/\Gamma = 30 - 55\,\%$

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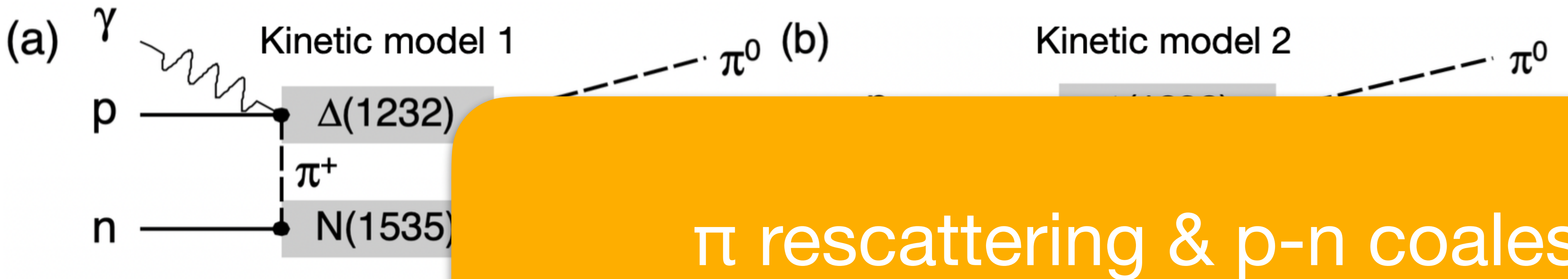

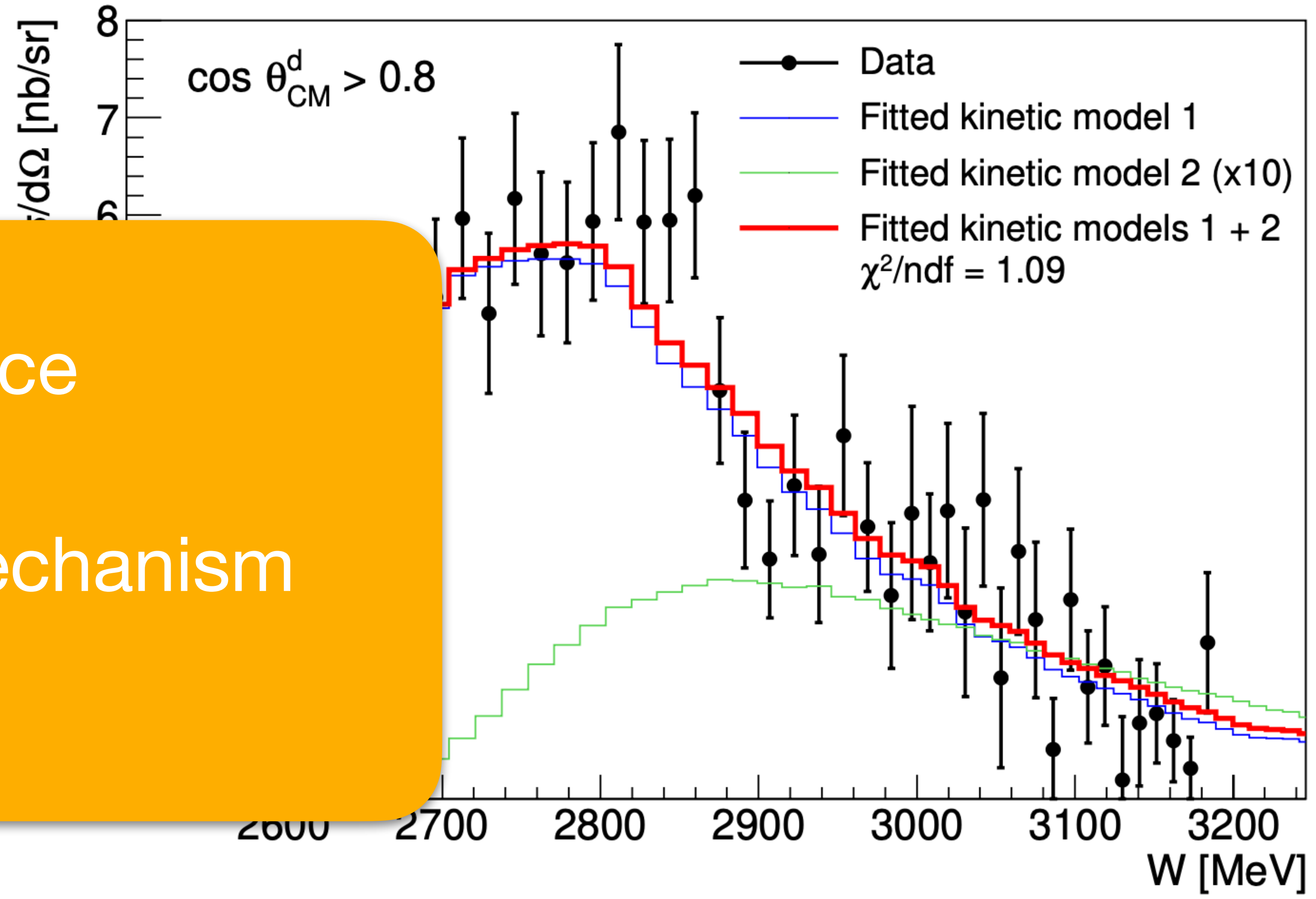

π rescattering & p-n coalescence
rather than
genuine 6-quark / 2-baryon mechanism

???

- S…
be explai…
ratios::
  - $N(1535) \rightarrow \pi N,\ \Gamma_i/\Gamma = 32 - 53\,\%$
  - $N(1535) \rightarrow \pi\pi N,\ \Gamma_i/\Gamma = 4 - 31\,\%$
  - $N(1535) \rightarrow \pi\eta N,\ \Gamma_i/\Gamma = 30 - 55\,\%$

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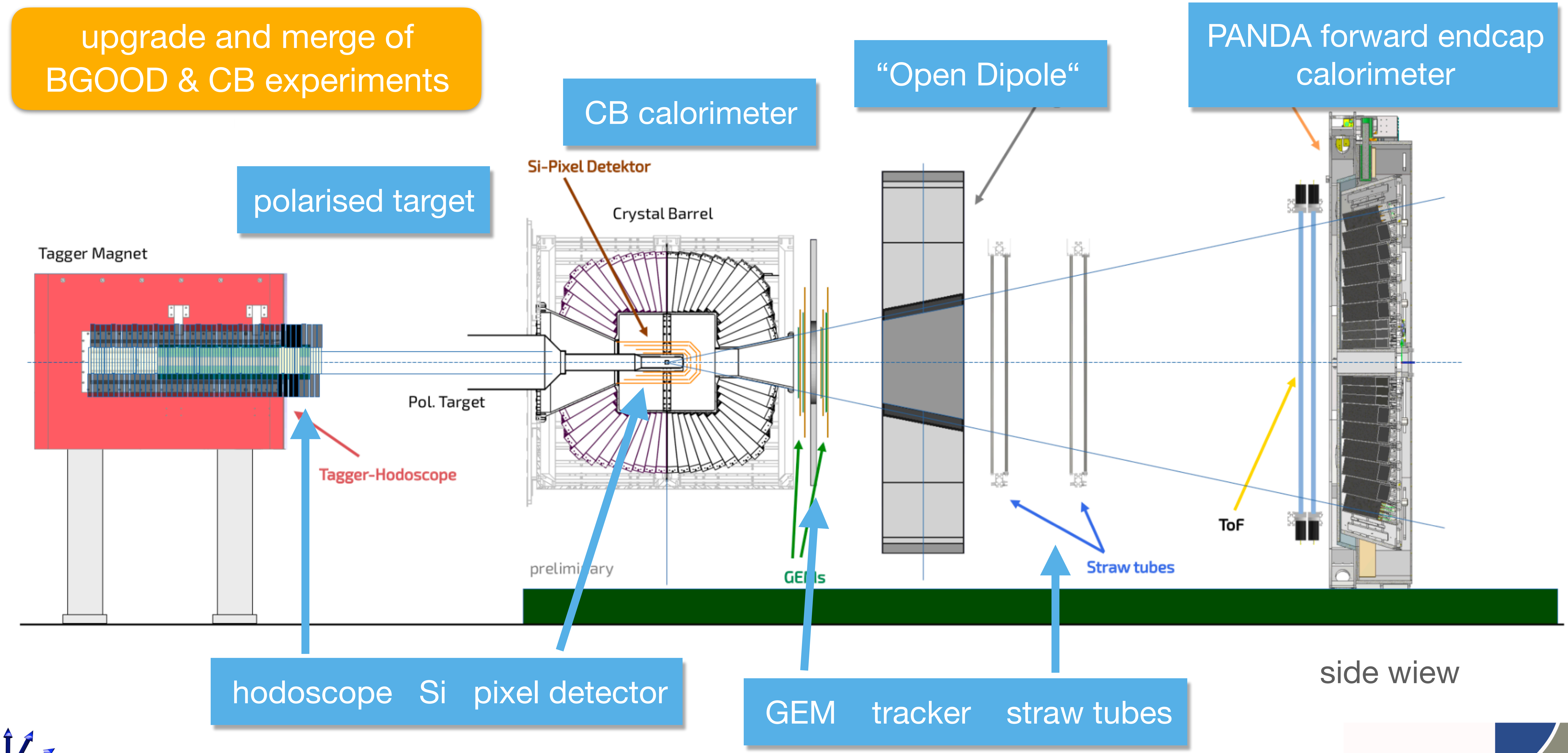
Future Perspectives – one highlight for Strong2020 community



Future Perspectives – one highlight for Strong2020 community

upgrade and merge of
BGOOD & CB experiments

physics case

- map out Y(*) spectrum & threshold effects
- understand structures in analogy to c & b sectors
- and: Y* important background for c sector analyses (LHCb)
- study emergence of complex bound (e.g. multi-quark, hybrid) states
- two pole structures extracted from ChPT, e.g. Λ(1405)

low / high Λ(1405) pole ChPT

G. Scheluchin et al. [BGOOD] *Physics Letters B 833 (2022) 137375*

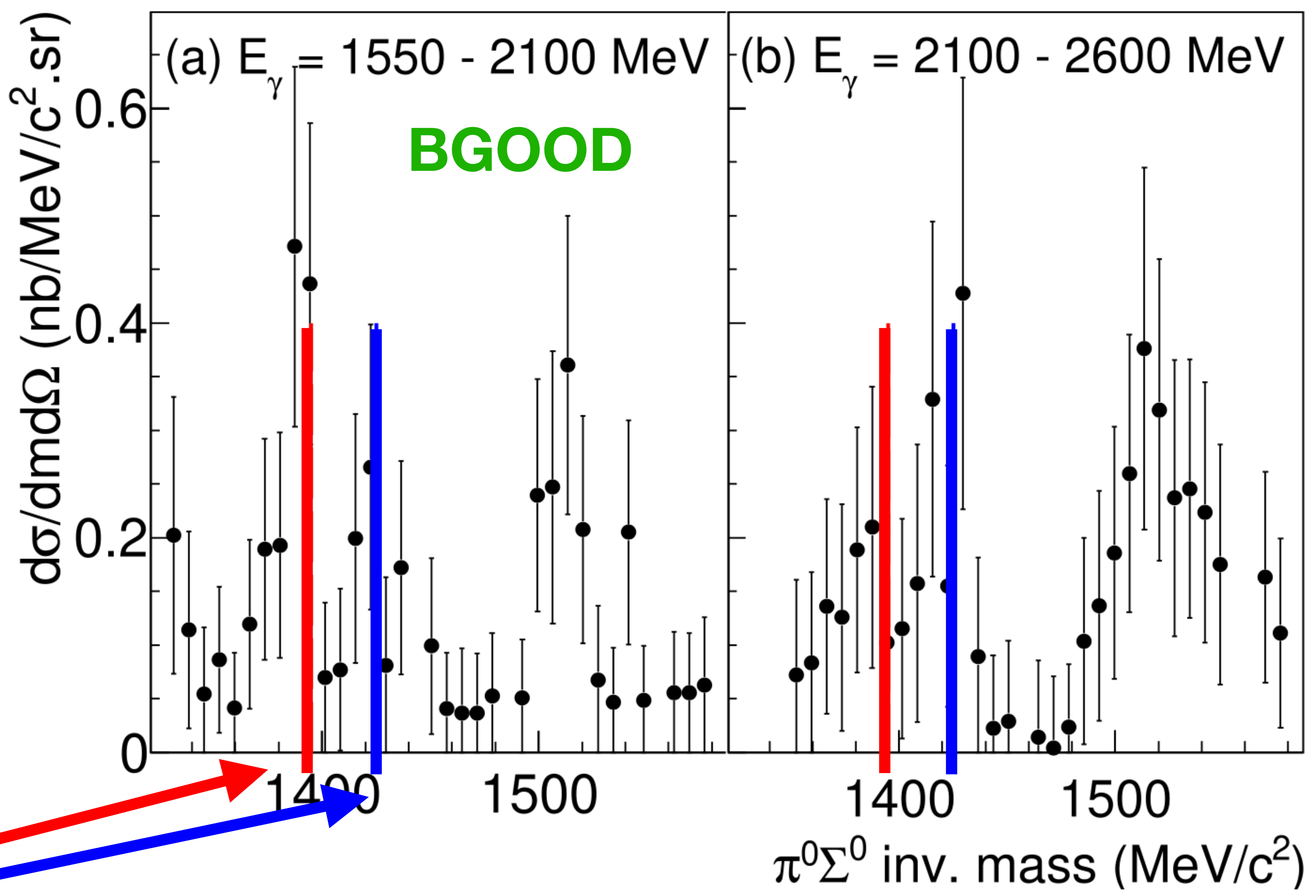


Fig. 9. The $\pi^0\Sigma^0$ line shape for $\cos(\theta) = 0.86$ to 1.00. The dashed red and blue lines indicate the proposed poles at 1395 and 1425 MeV respectively [13].

ELSA

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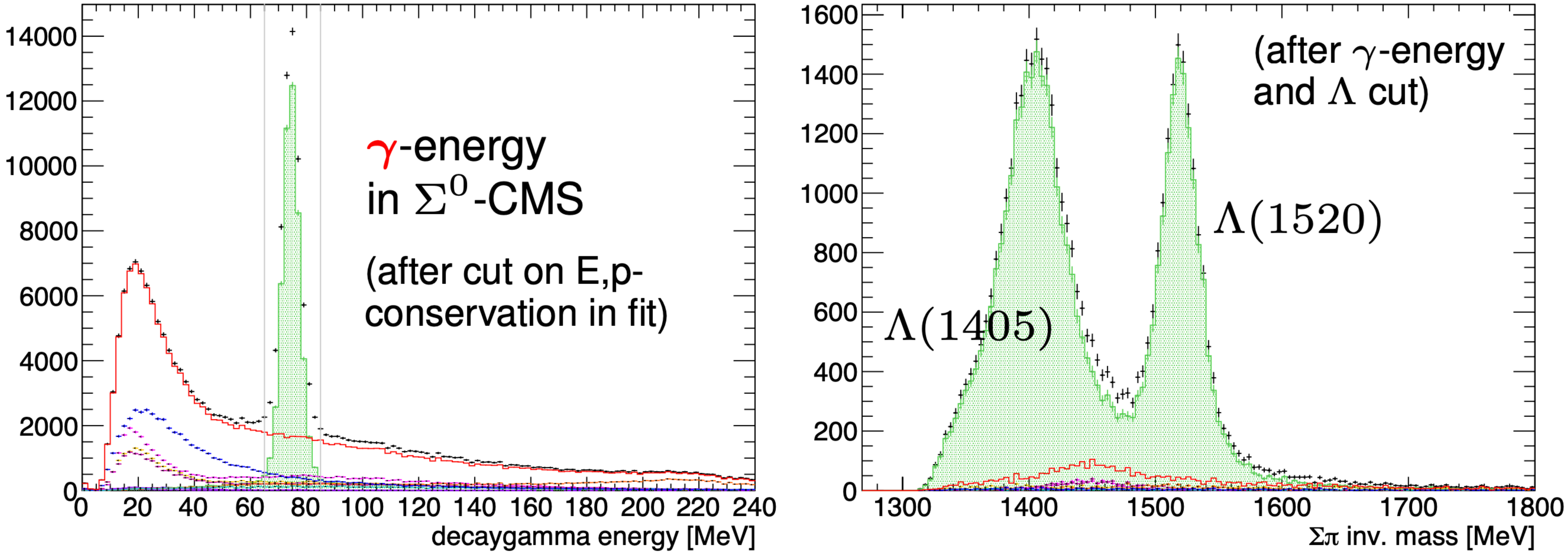
Future Perspectives – one highlight for Strong2020 community

simulation for upgraded experiment

$$\gamma p \to K^+\Lambda^* \to K^+\Sigma^0\pi^0 \to K^+\Lambda\gamma\pi^0 \to K^+(p\pi^-)\gamma\pi^0$$



SUMMARY

- significant University Bonn infrastructure CEDAR: Center for Detector and Accelerator Research
- Cyclotron – ELSA – FTD
- wide span of activities:
  medicine – detector development HEP + HP – hadron physics experiments – alp+gw searches
- highlight results
  - medical physics: FLASH
  - baryon spectroscopy w/ beam-target double polarisation: CBELSA/TAPS experiment
  - multi-quark (“penta“+“hexa“) effects uds-sector & analogy to c-sector: BGOOD experiment
- future project: upgraded & combined BGOOD+CB experiment:
  - central + forward calorimeter
  - forward magnetic spectrometer
  - polarised target

↔ high interest in future TA-style international co-operation