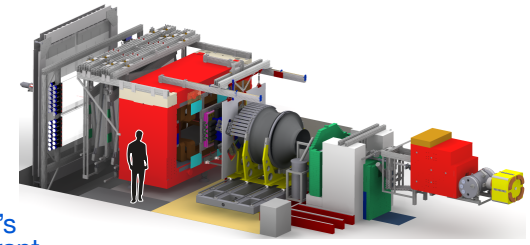
Threshold KY photoproductuion at the BGOOD experiment at ELSA

- multi-quark structures in the uds sector ?

Hartmut Schmieden
Physikalisches Institut
Universität Bonn

Outline

- motivation
- BGOOD experiment
- recent results
- conclusions



supported by DFG
PN 50165297 and
PN 405882627

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

Why look for multi-quark structures in uds secctor ?

Status N* spectroscopy

- missing resonances ?
- relevant degrees of freedom ?

state	J^P	PDG status in 2010	PDG status in 2020 (Nγ)
N(1860)	$5/2^+$	*	*
N(1875)	$3/2^-$		**
N(1880)	$1/2^+$		**
N(1895)	$1/2^-$		****
N(1900)	$3/2^+$	****	****
N(1990)	$7/2^+$	**	**
N(2000)	$5/2^+$	**	**
N(2060)	$5/2^-$		***
N(2100)	$1/2^+$	*	**
N(2120)	$3/2^-$		***
N(2190)	$7/2^-$	****	**
N(2220)	$9/2^+$	****	**
N(2250)	$9/2^-$	****	**

- 3 const. quarks unlikely
- quark – diquark ??
- meson d.o.f. ?

e.g.

L.Ya. Glozman and D.O. Riska,
Phys. Rep. 268 (1996) 263

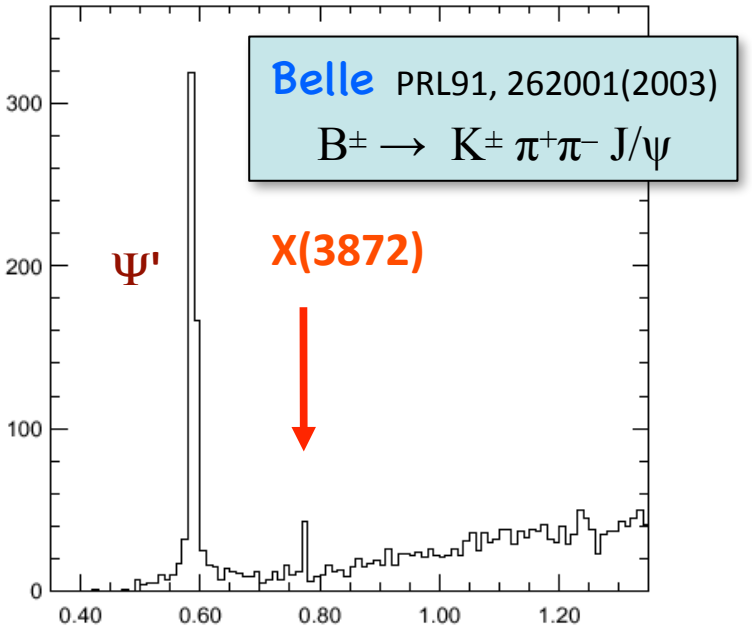
C. Garcia-Recio et al., PLB 582 (2004) 49

M. Lutz, E. Kolomeitsev, PLB 585 (2004) 243

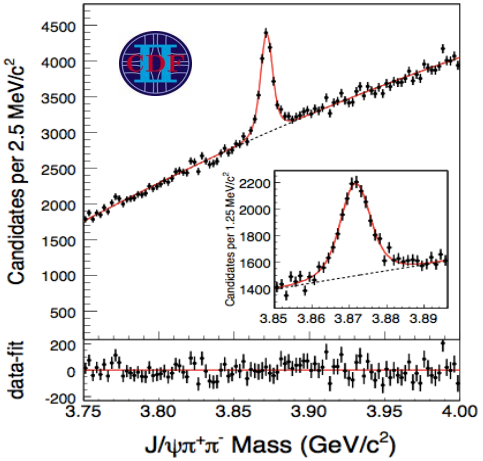
- inclusion of CLAS, GRAAL, MAMI, ELSA data
- confirmation of known resonances w/ improved parameters
- observation of few (!) new states

context c-quark sector

X(3872)

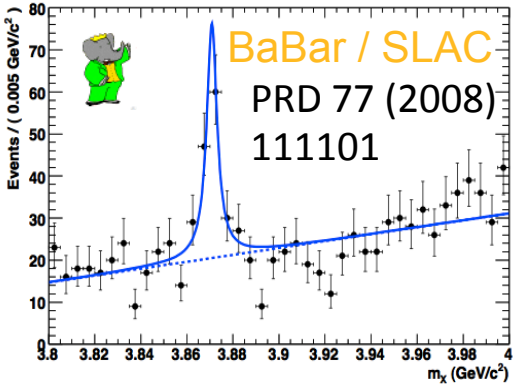


$M(\pi^{+}\pi^{-}l^{+}l^{-}) - M(l^{+}l^{-})$



CDF / Tevatron

PRL 103 (2009) 152001



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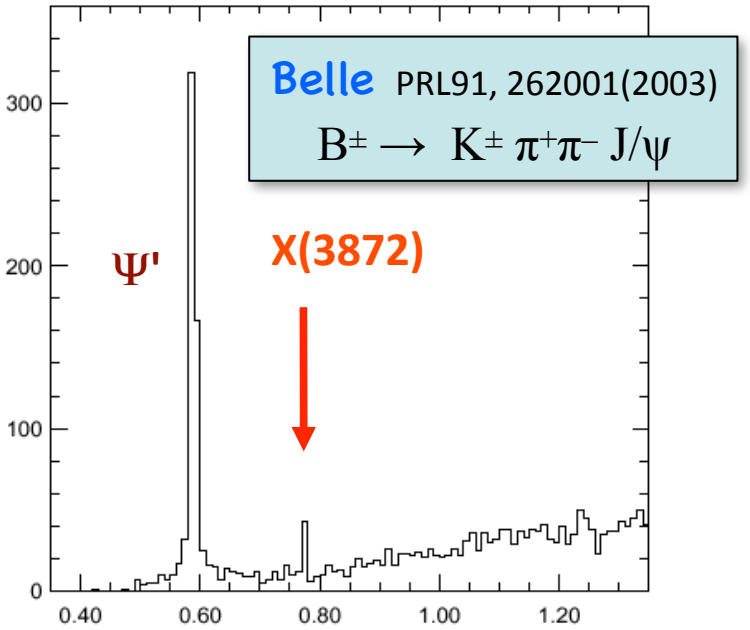
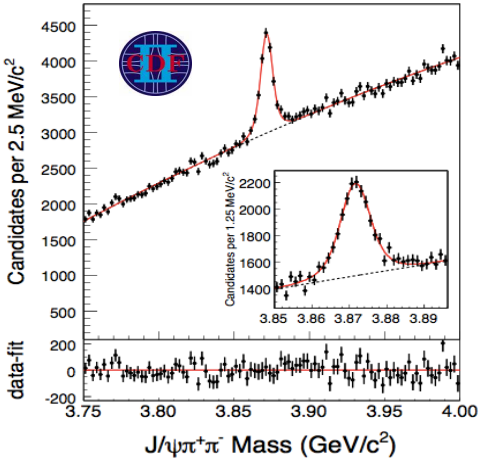


M(π+π-l+l-) - M(l+l-)



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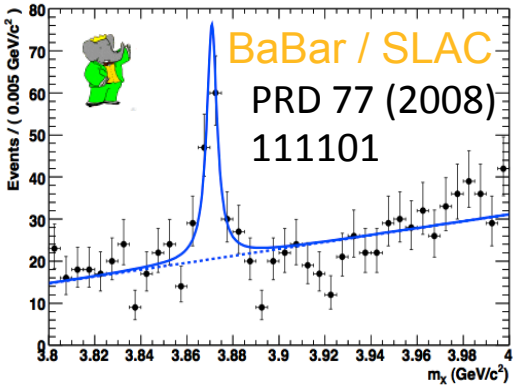
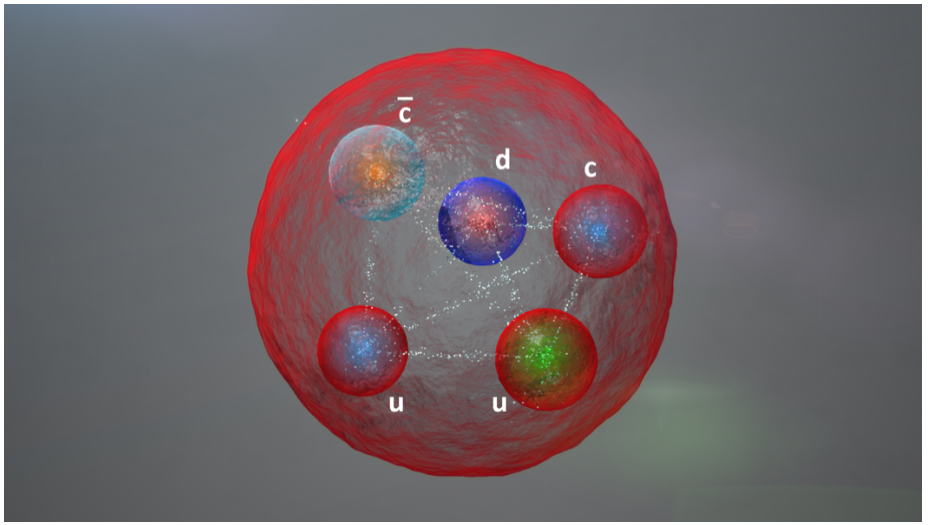
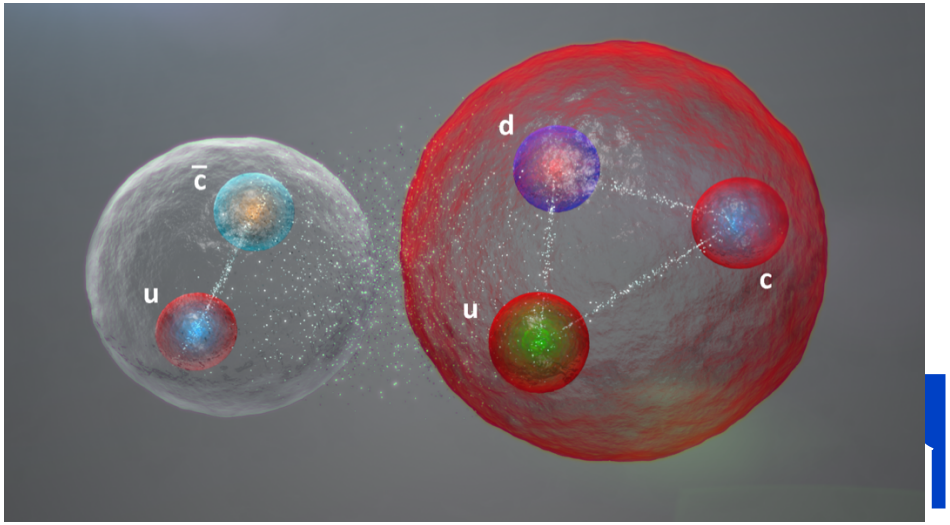


PARTICLE PHYSICS

Forsaken pentaquark particle spotted at CERN

Exotic subatomic species confirmed at Large Hadron Collider after earlier false sightings.





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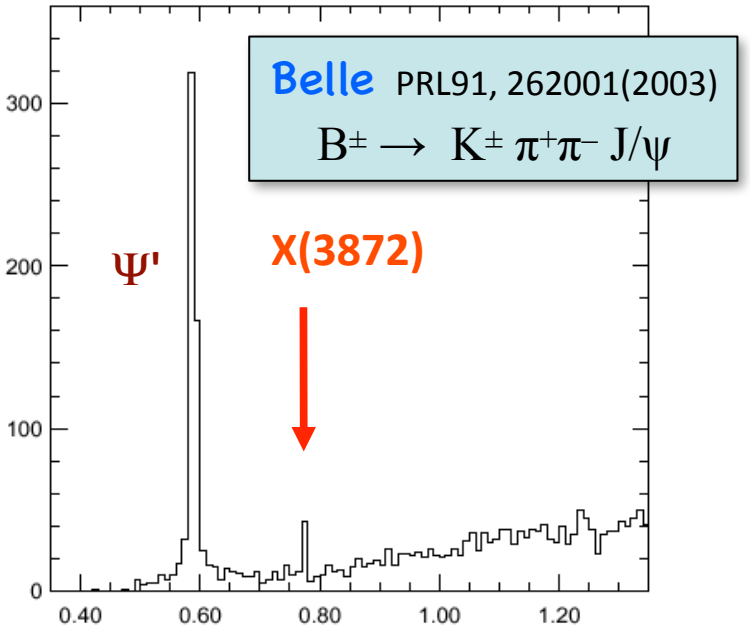

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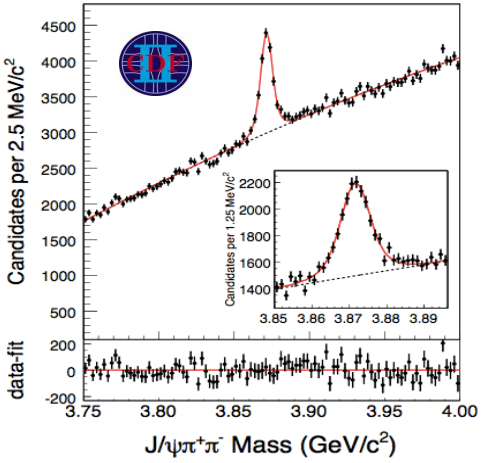

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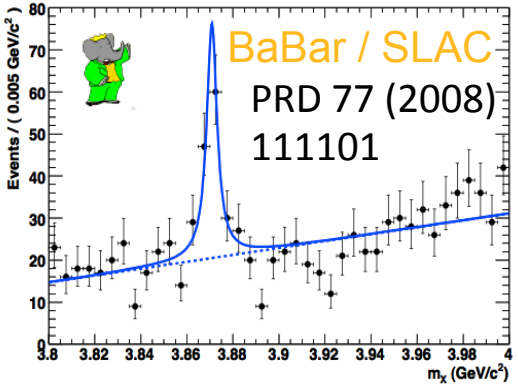
PRL 103 (2009) 152001



BaBar / SLAC
PRD 77 (2008) 111101

$P_c^+(4380, 4450)$

PARTICLE PHYSICS

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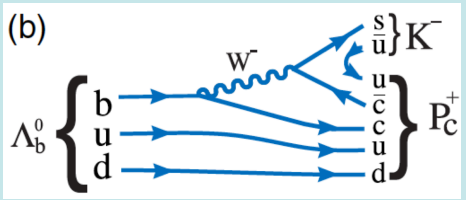
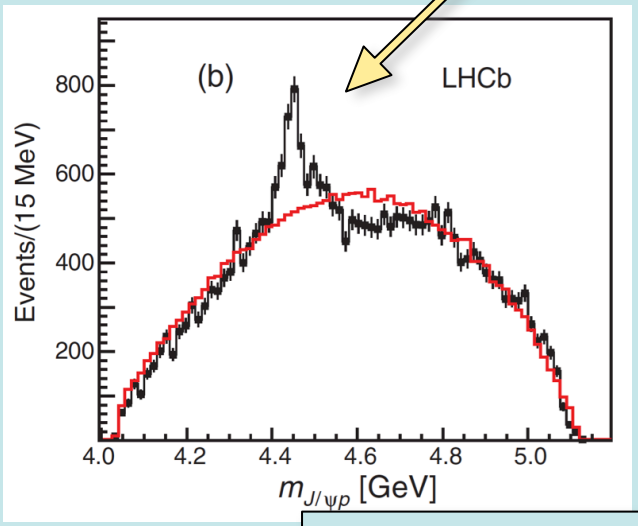
R. Aaij et al., PRL 115 (2015) 072001





PB / VB hidden c predicted from meson-baryon interactions:
Oset, Zou et al., PRL 105 (2010)

"new N^*_{cc} states are simply brothers or sisters of the well known N*(1535) and Λ*(1405) ... and many other dynamically generated states ..."

context c-quark sector

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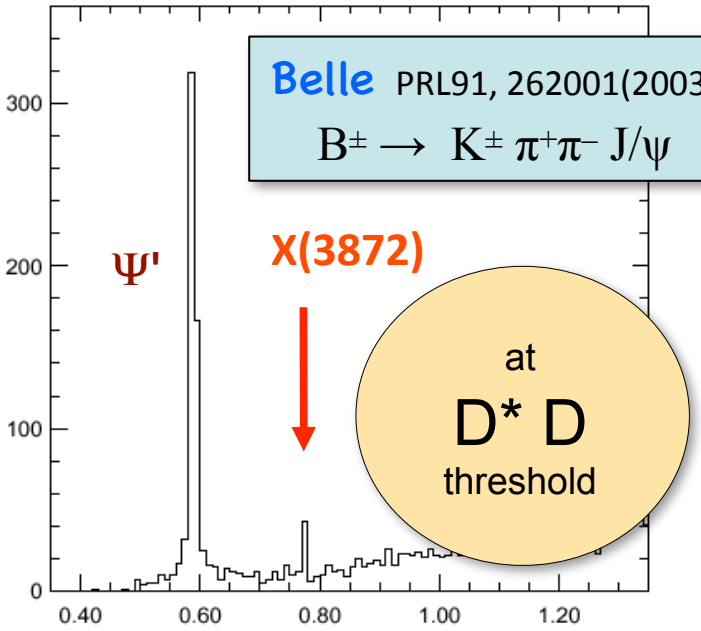

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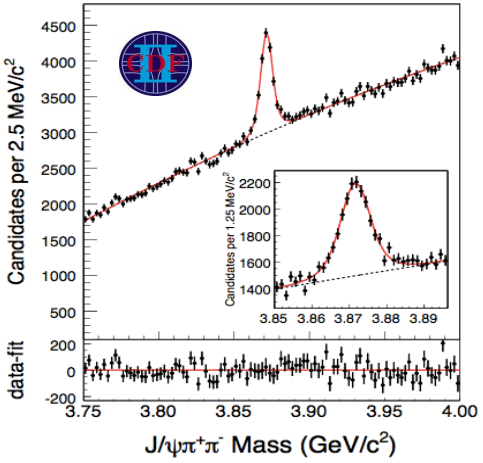

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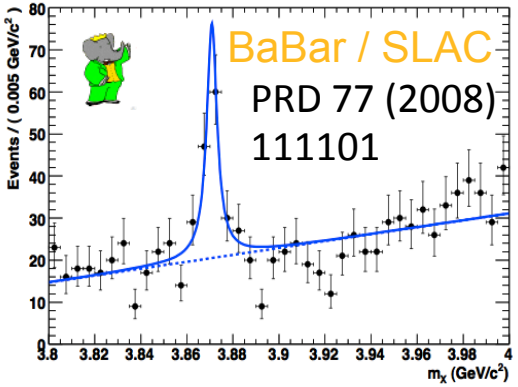

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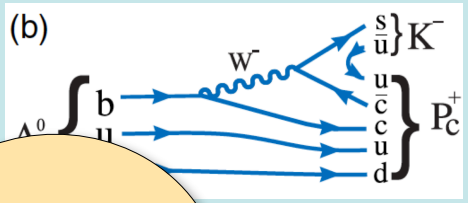
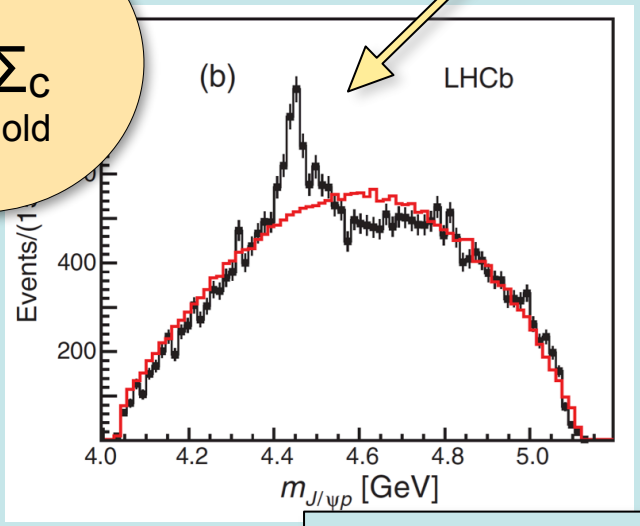


p J/ψ

at
$D^* \Sigma_c$
threshold



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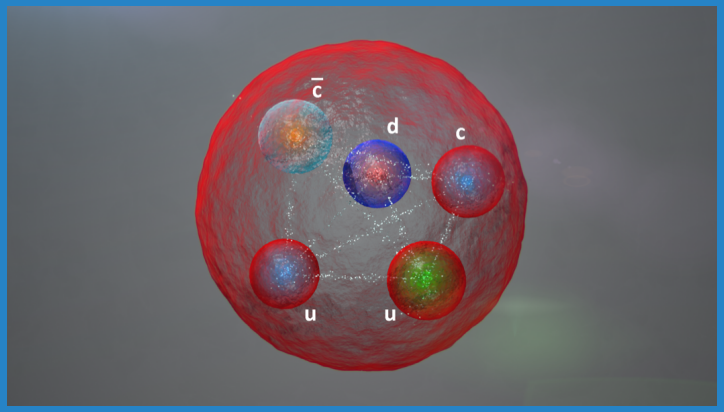
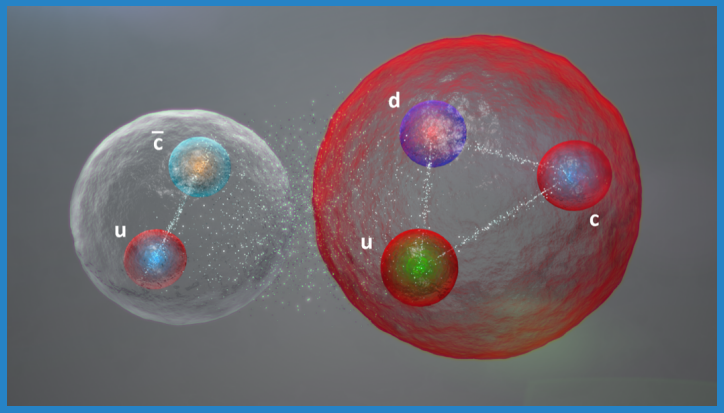




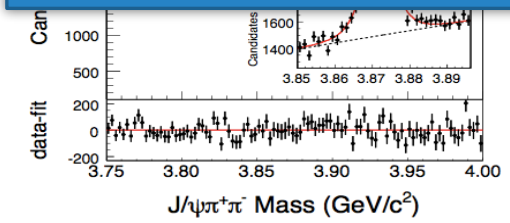
- 5-quark structures definitely observed
- (hidden) c-quark sector
- similar 4-quark states in meson sector
- structure/binding mechanism under debate

→ paradigm change in hadron physics

→ general feature of structure formation in QCD ?

→ similiar structures in (hidden) s-quark sector ??

but: – mass pattern D – D* / K – K* and
– widths D* – K* different



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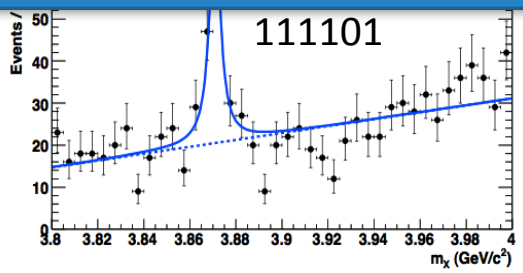

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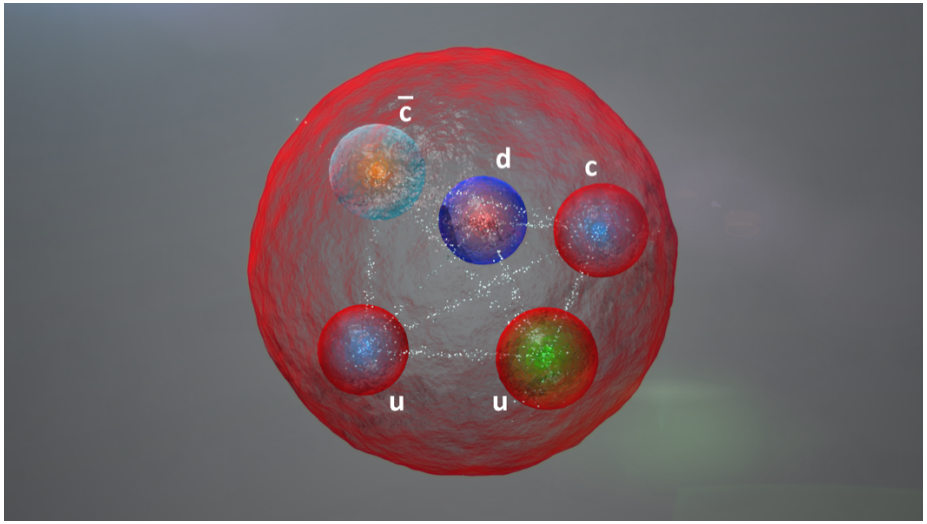
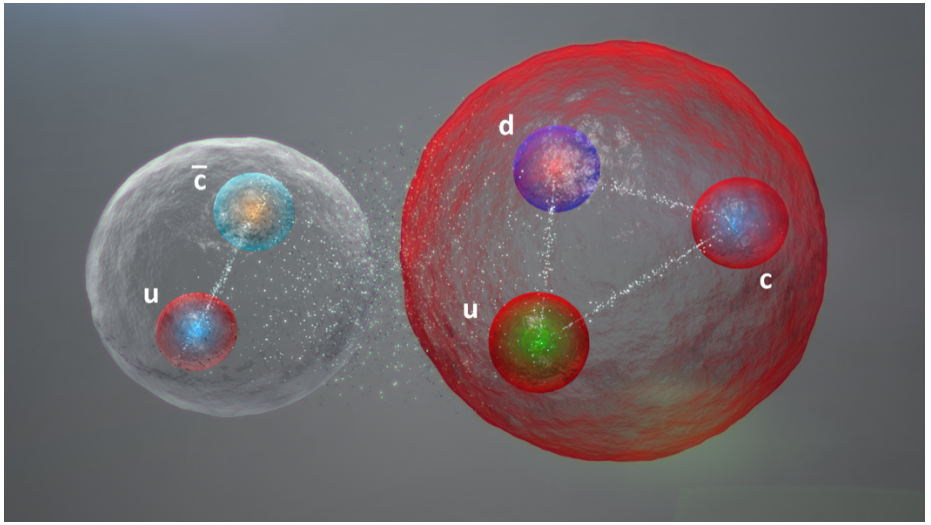
Parallels in s-quark sector ?





$D^{(*)}\ \Sigma_c^{(*)}$ thresholds

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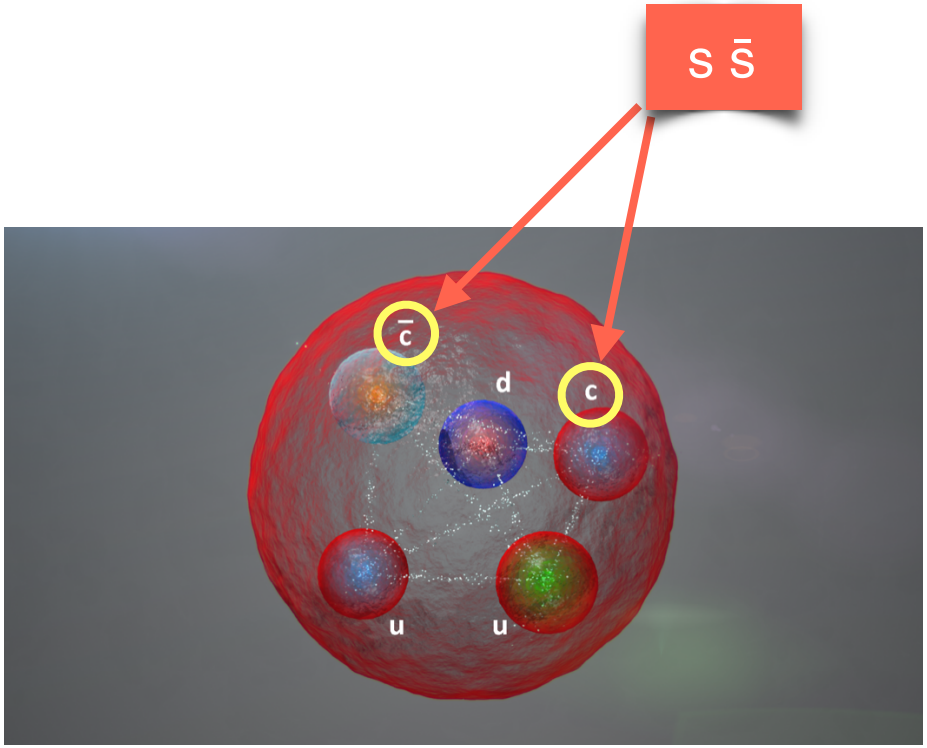
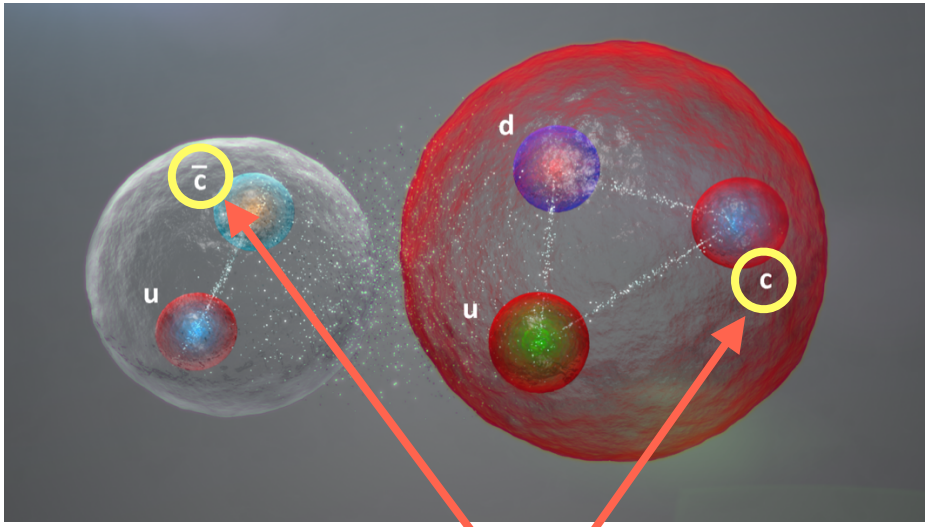
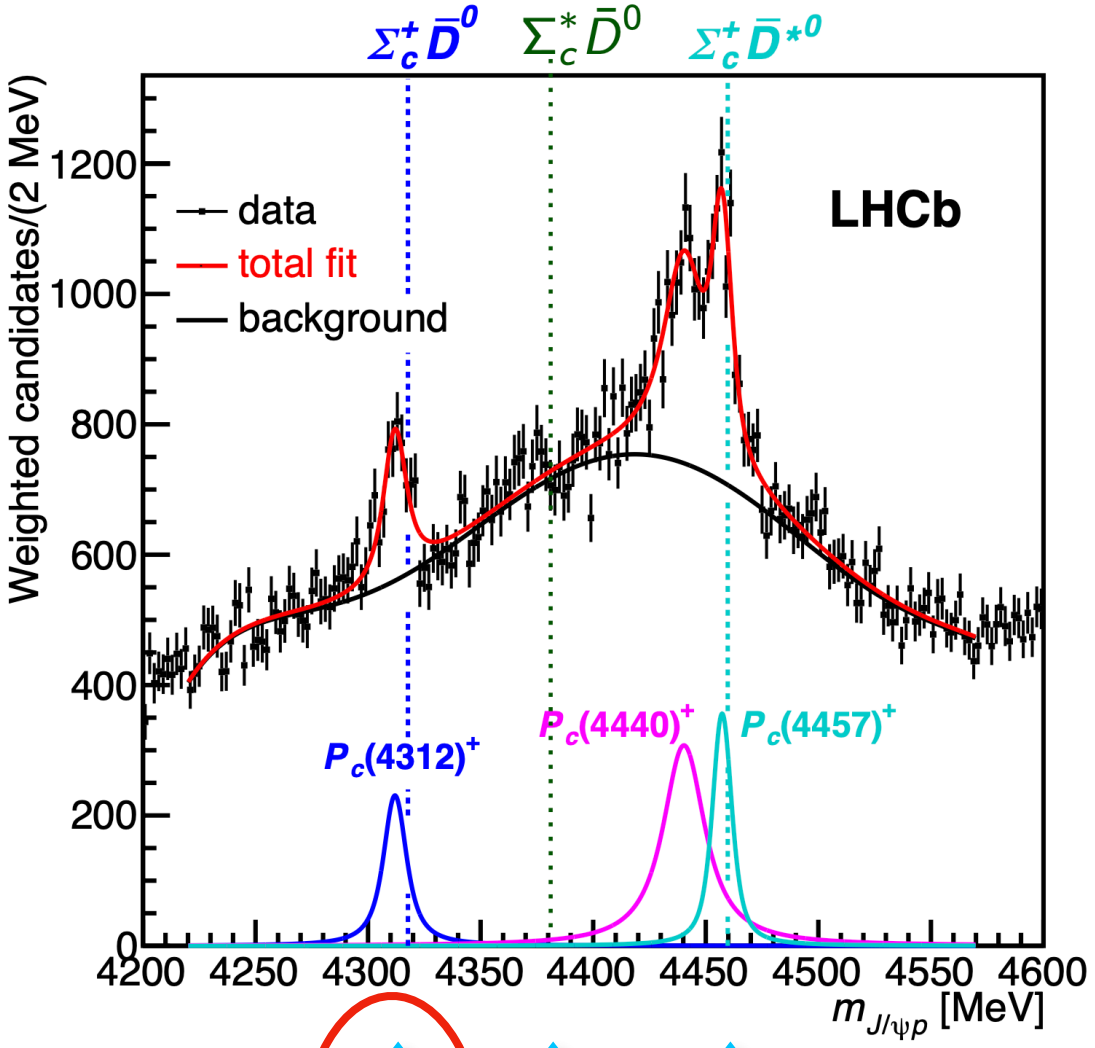




$D^{(*)}\ \Sigma_c^{(*)}$ thresholds

$K^{(*)}\ \Sigma^{(*)}$ thresholds

context c-quark sector



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

Hadronic molecules & HQSS

LHCb data: PRL 122 (2019) 222001

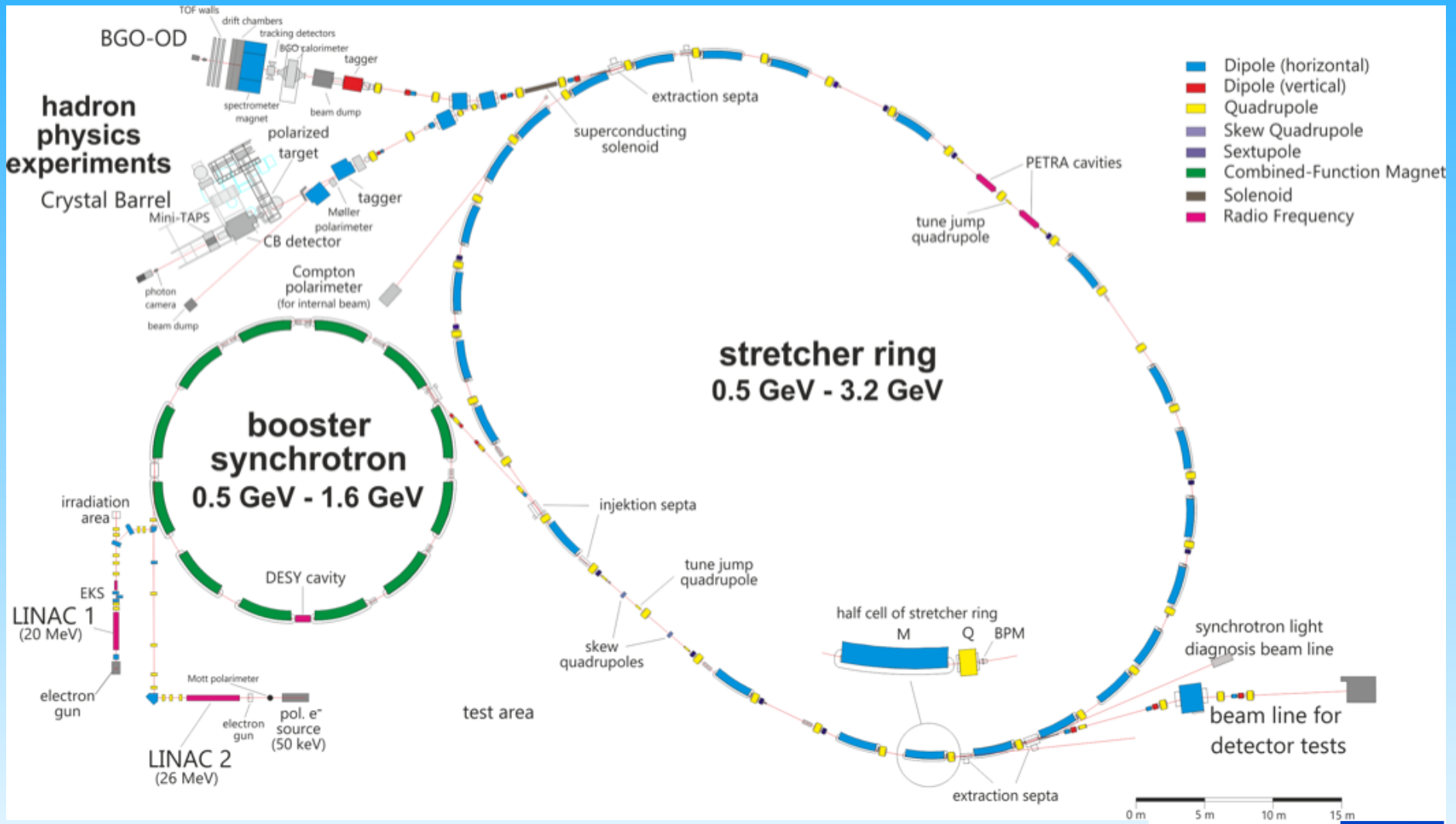
uds sector N*(1535) Σ K Σ* K Σ K*

uds sector ?

BGOOD experiment

& selected results

located at ELSA
electron accelerator
Physikalisches Institut
Universität Bonn



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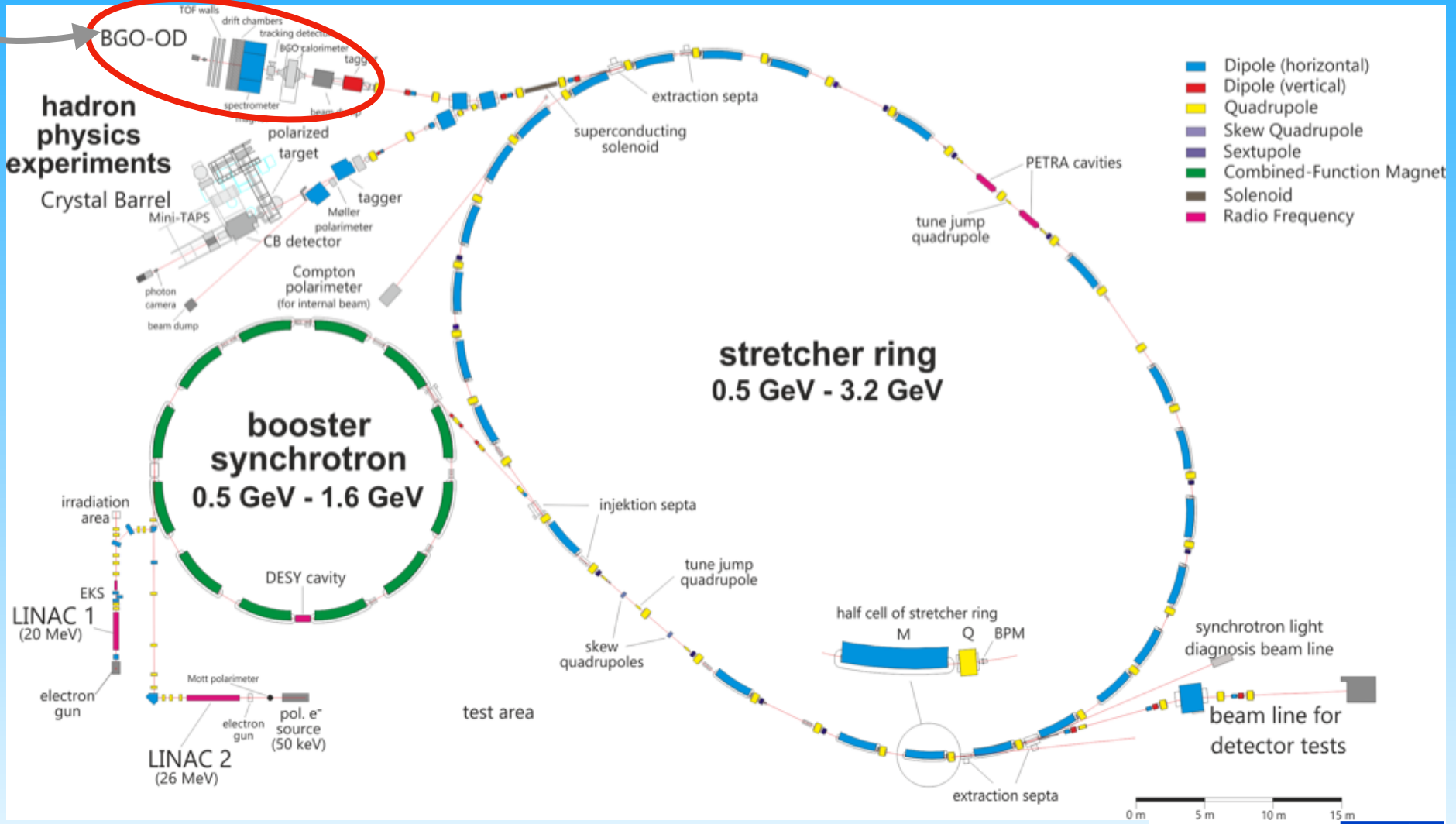

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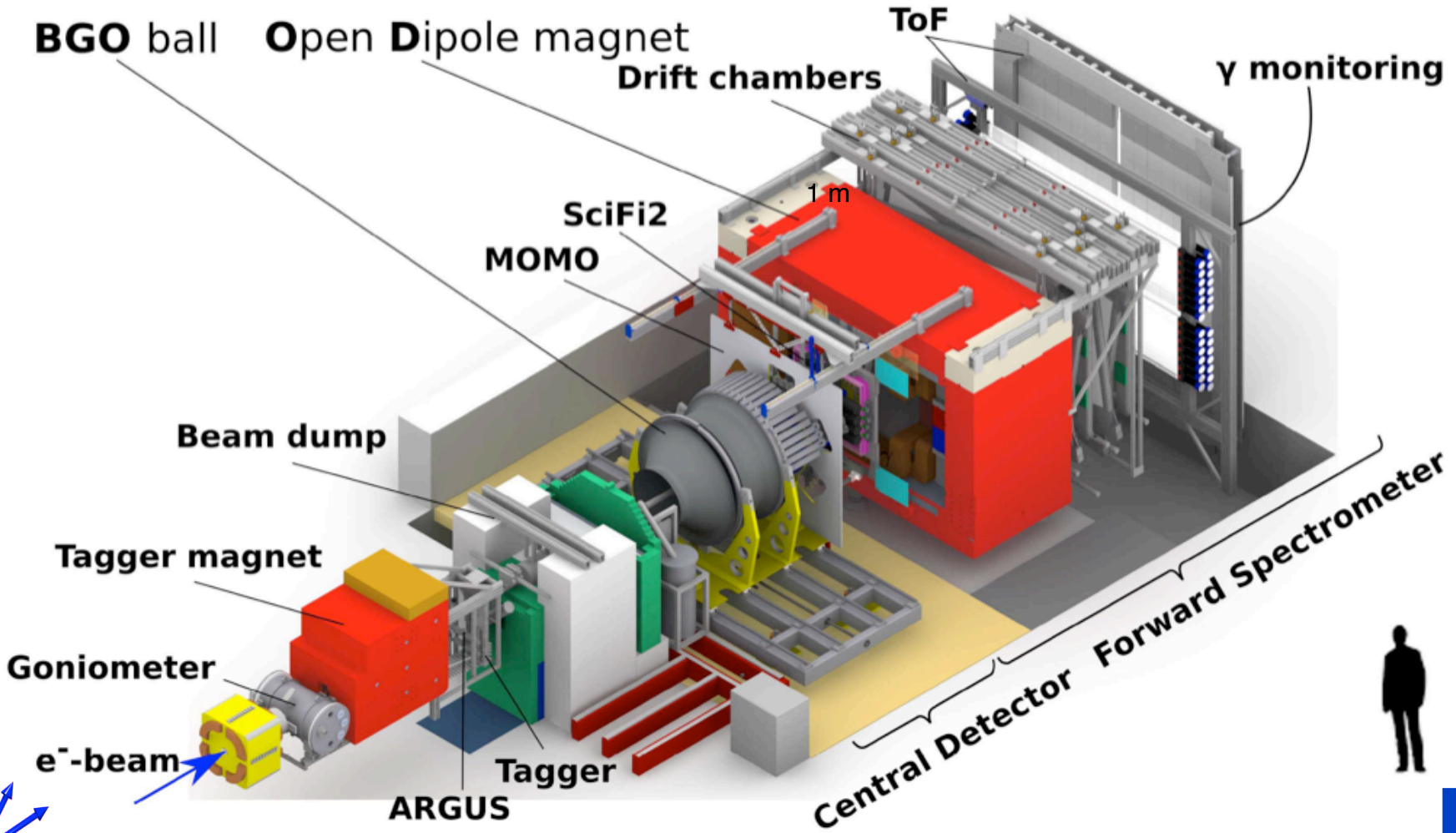
BGOOD experiment

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

spokespersons: P. Levi Sandri (Frascati) & H.Schmieden (Bonn)

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



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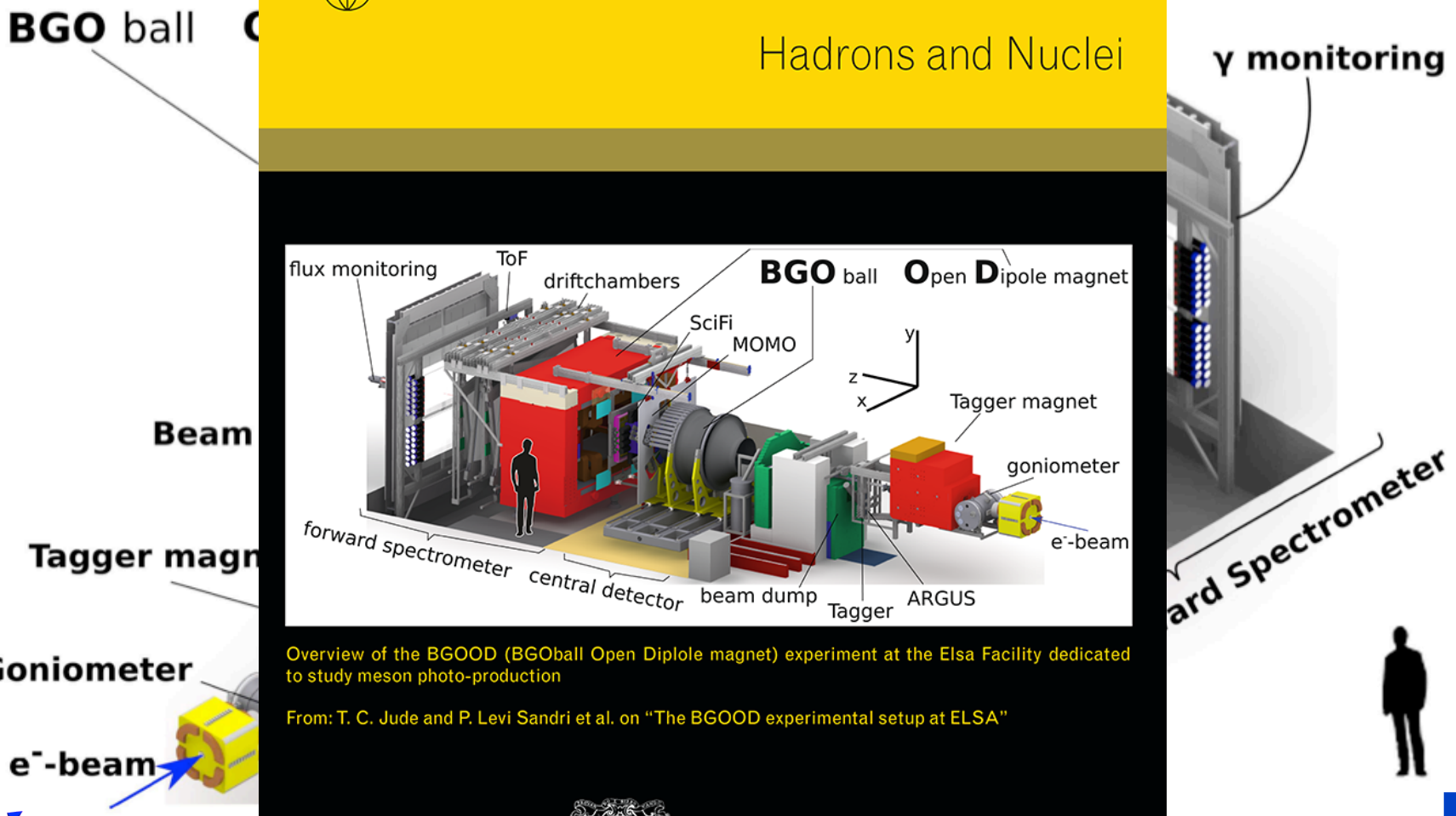
S. Alef et al. [BGOOD collab.], EPJ A 56 (2020) 104

Levi Sandri (Frascati) &
.Schmieden (Bonn)

- combination
- high moment

trometer
particle id



The European Physical Journal volume 56 · number 4 · april · 2020

EPJ A

Recognized by European Physical Society

Hadrons and Nuclei

Overview of the BGOOD (BGOball Open Diplole magnet) experiment at the Elsa Facility dedicated to study meson photo-production

From: T. C. Jude and P. Levi Sandri et al. on "The BGOOD experimental setup at ELSA"

Società Italiana di Fisica

Springer

ELSA

H. Schmi

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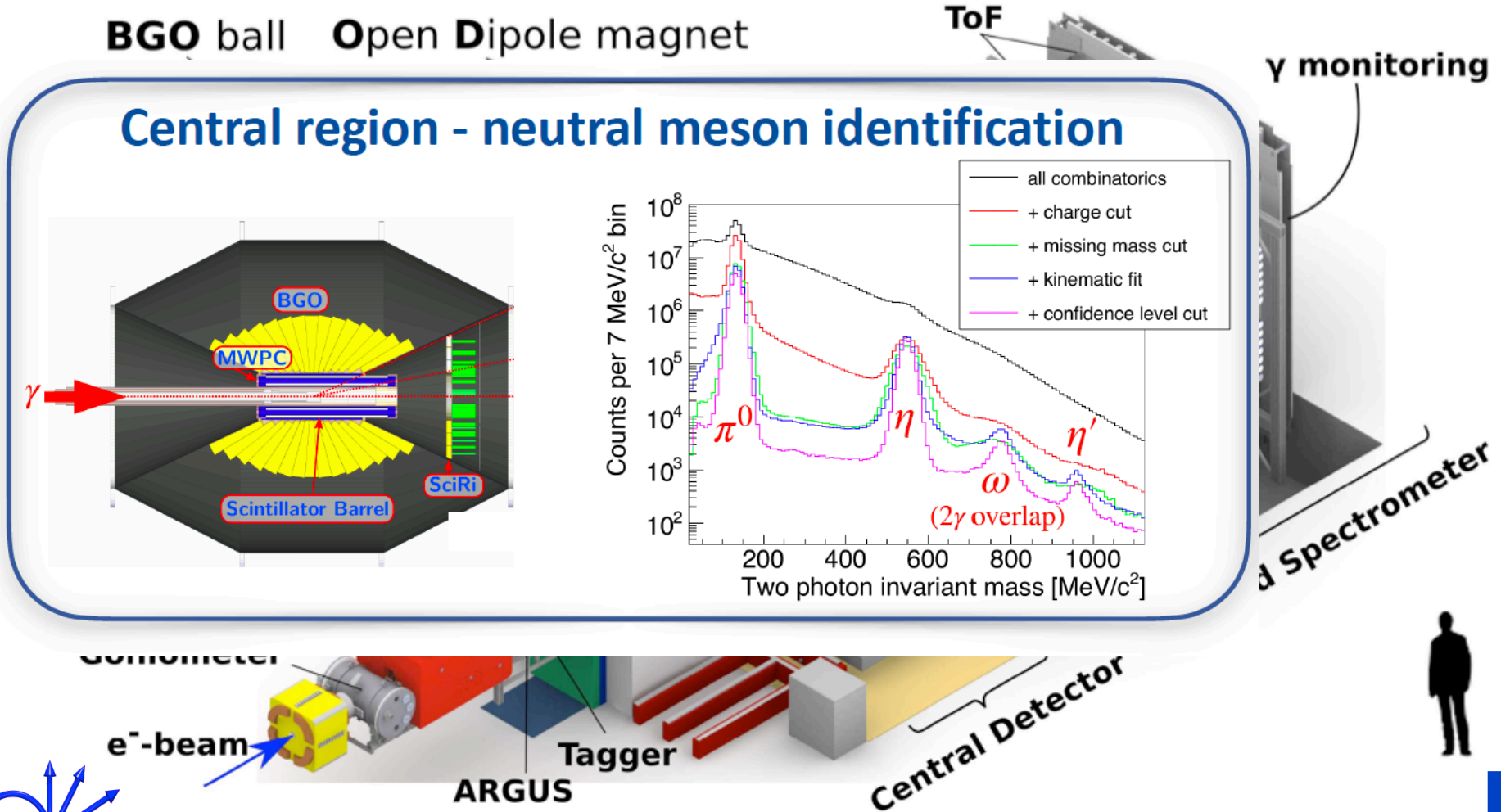

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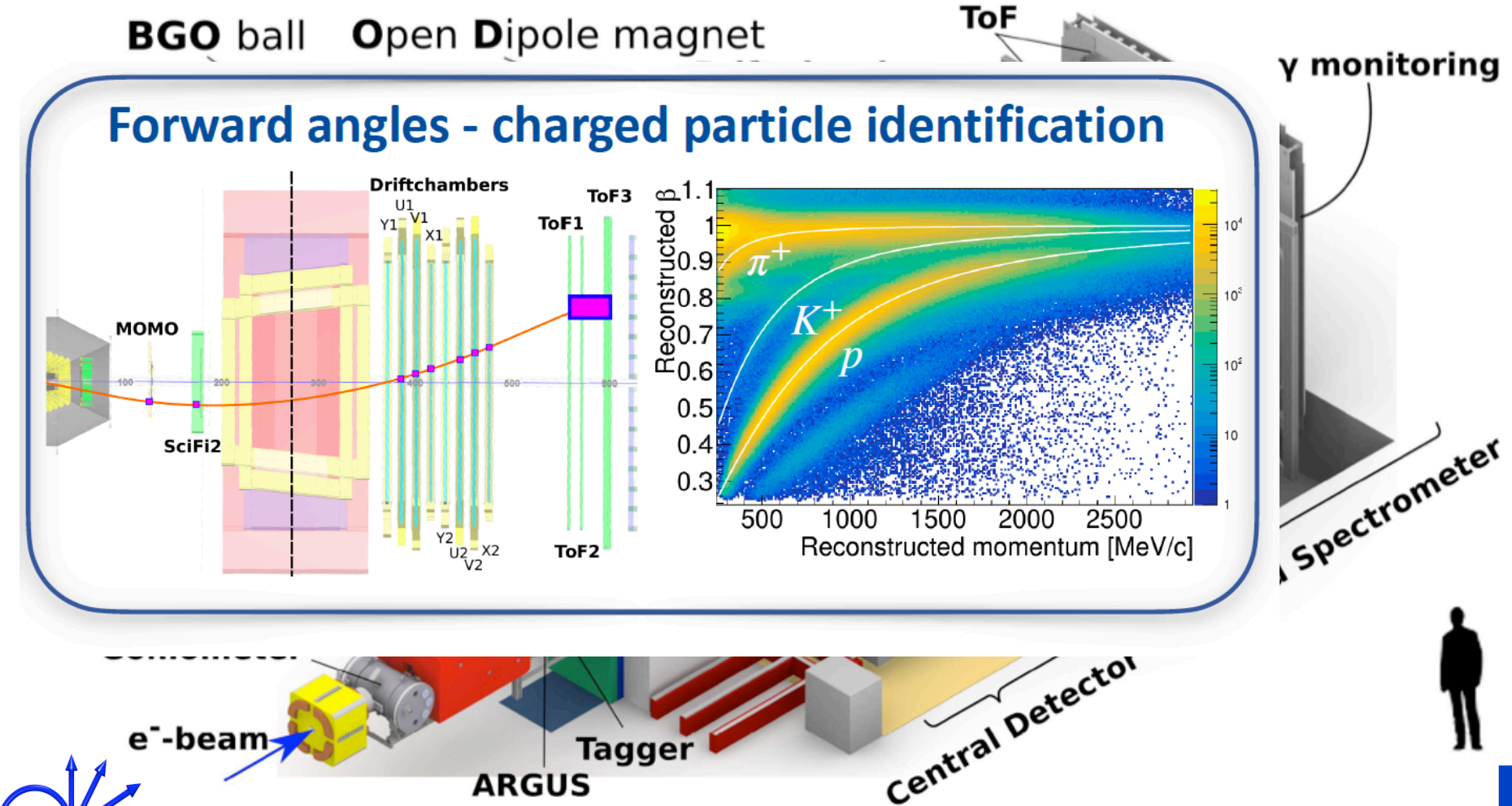
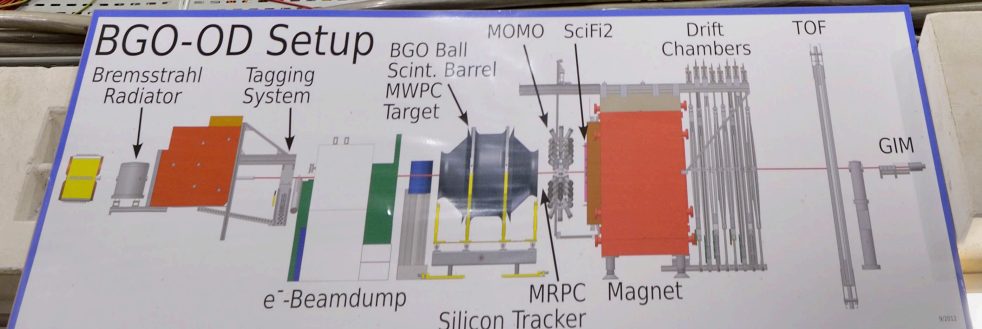


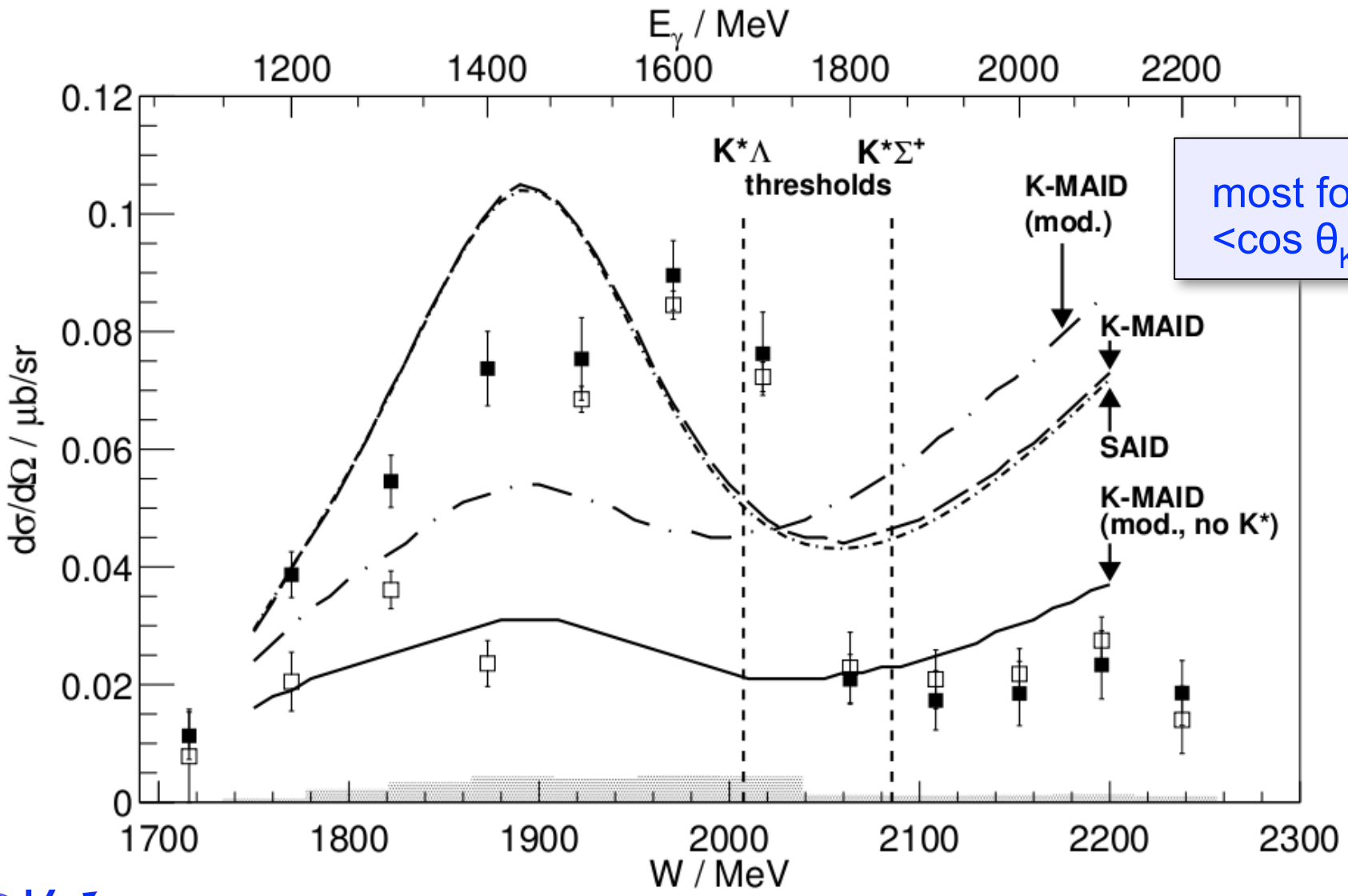
BGOOD experiment at ELSA



BGOOD

γ + p -> K⁰ + Σ⁺ anomaly @ K* threshold

R. Ewald et al. (CB/TAPS), PLB 713 (2012)



most forward bin
$\langle \cos \theta_K^{cm} \rangle = 0.83$

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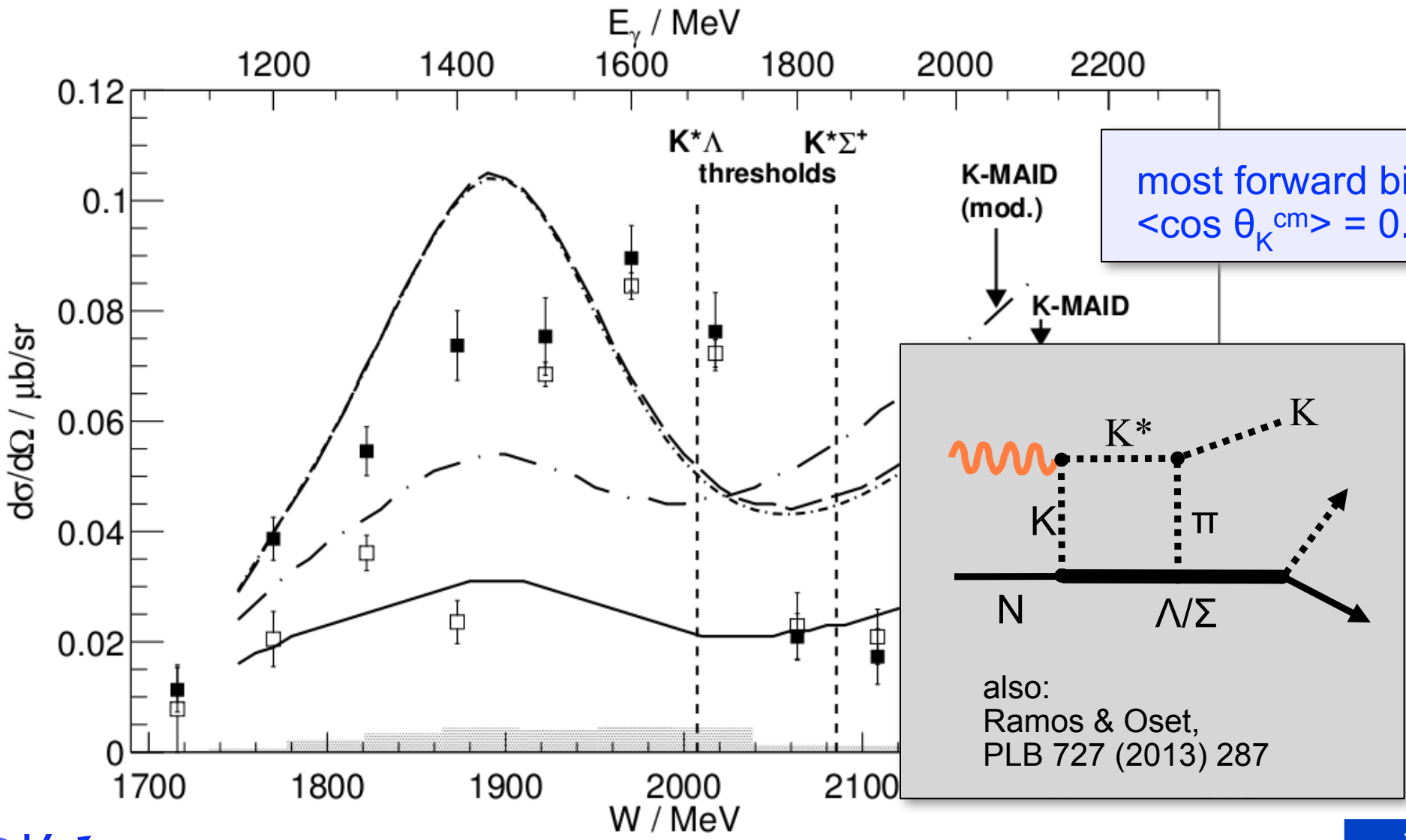

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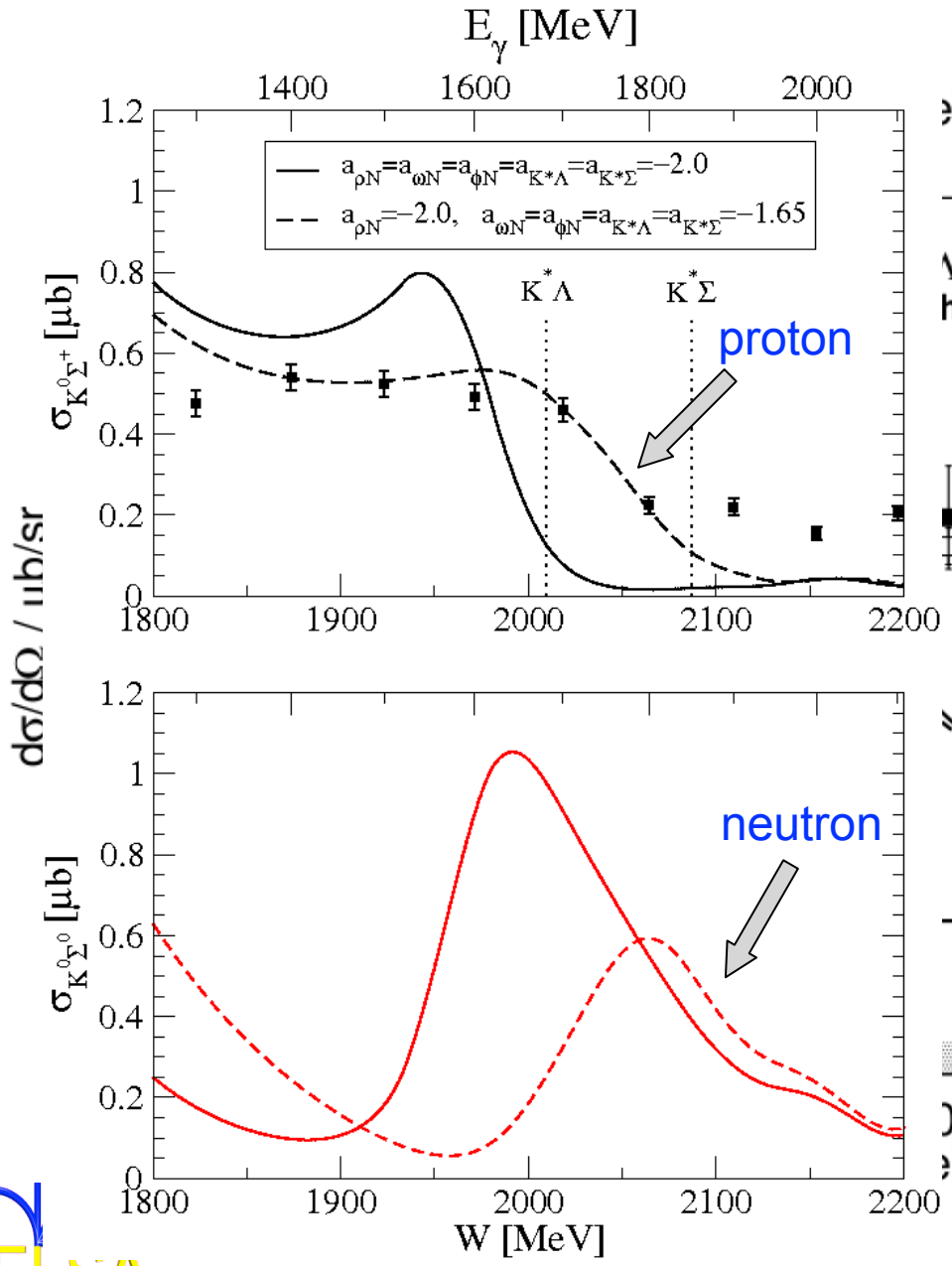

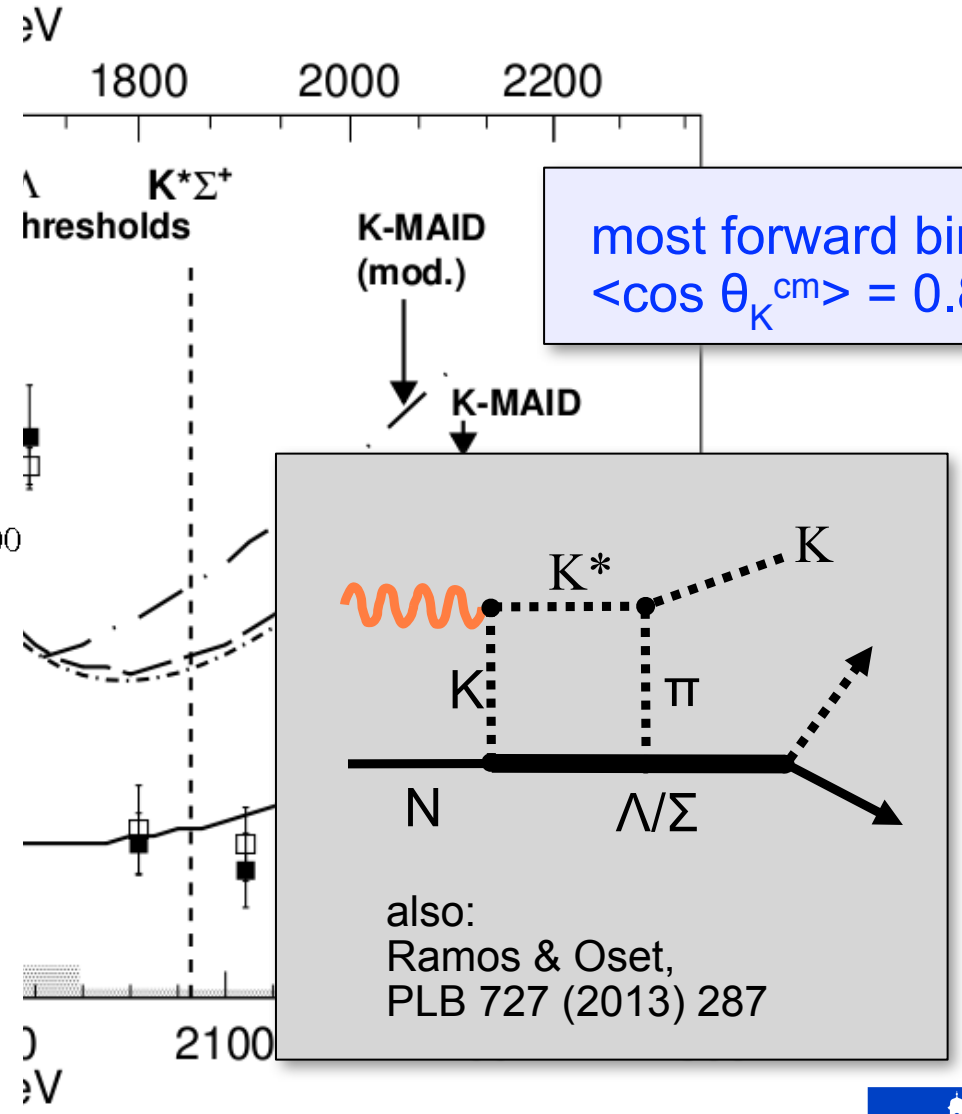

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also:
Ramos & Oset,
PLB 727 (2013) 287

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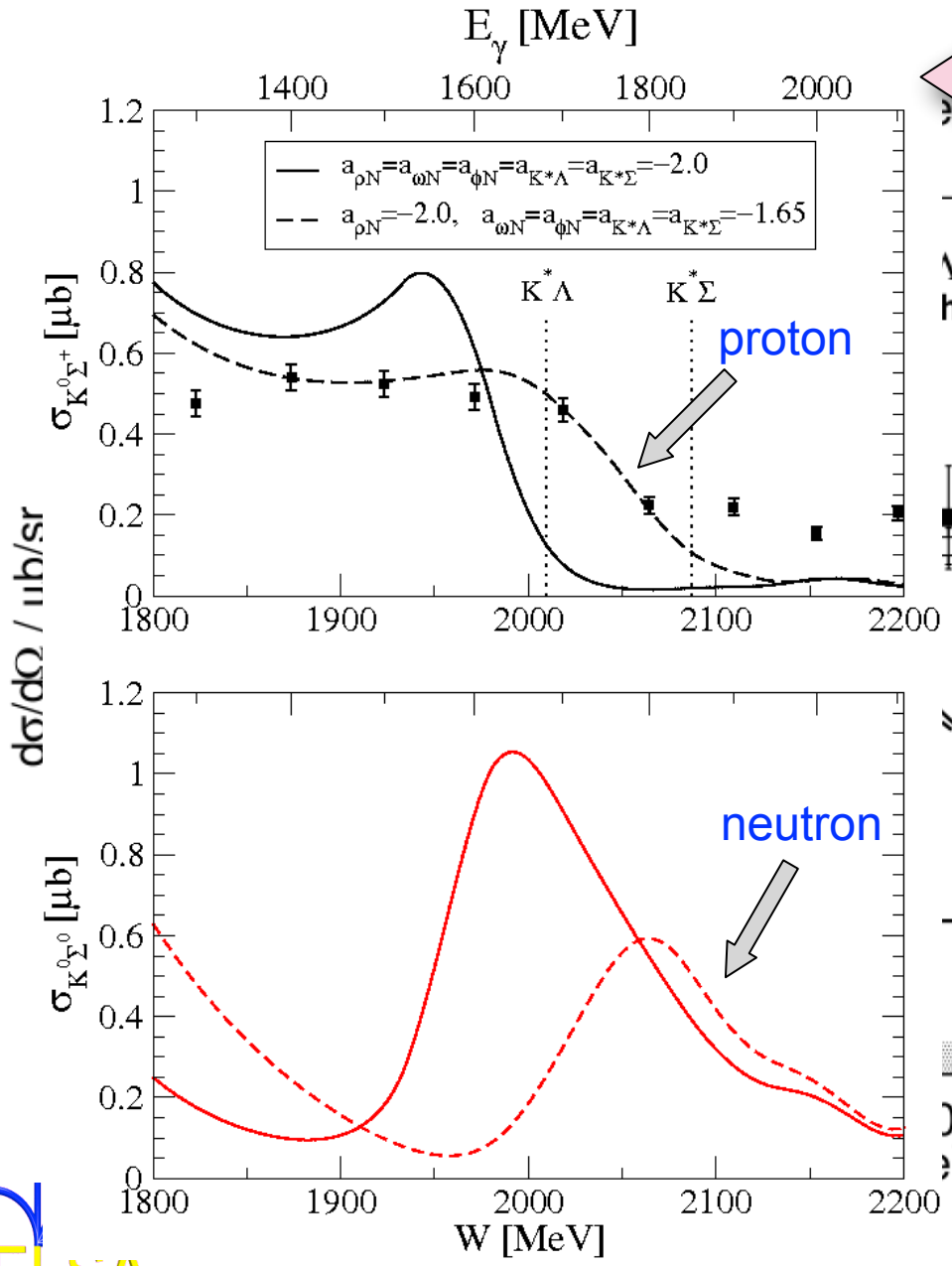

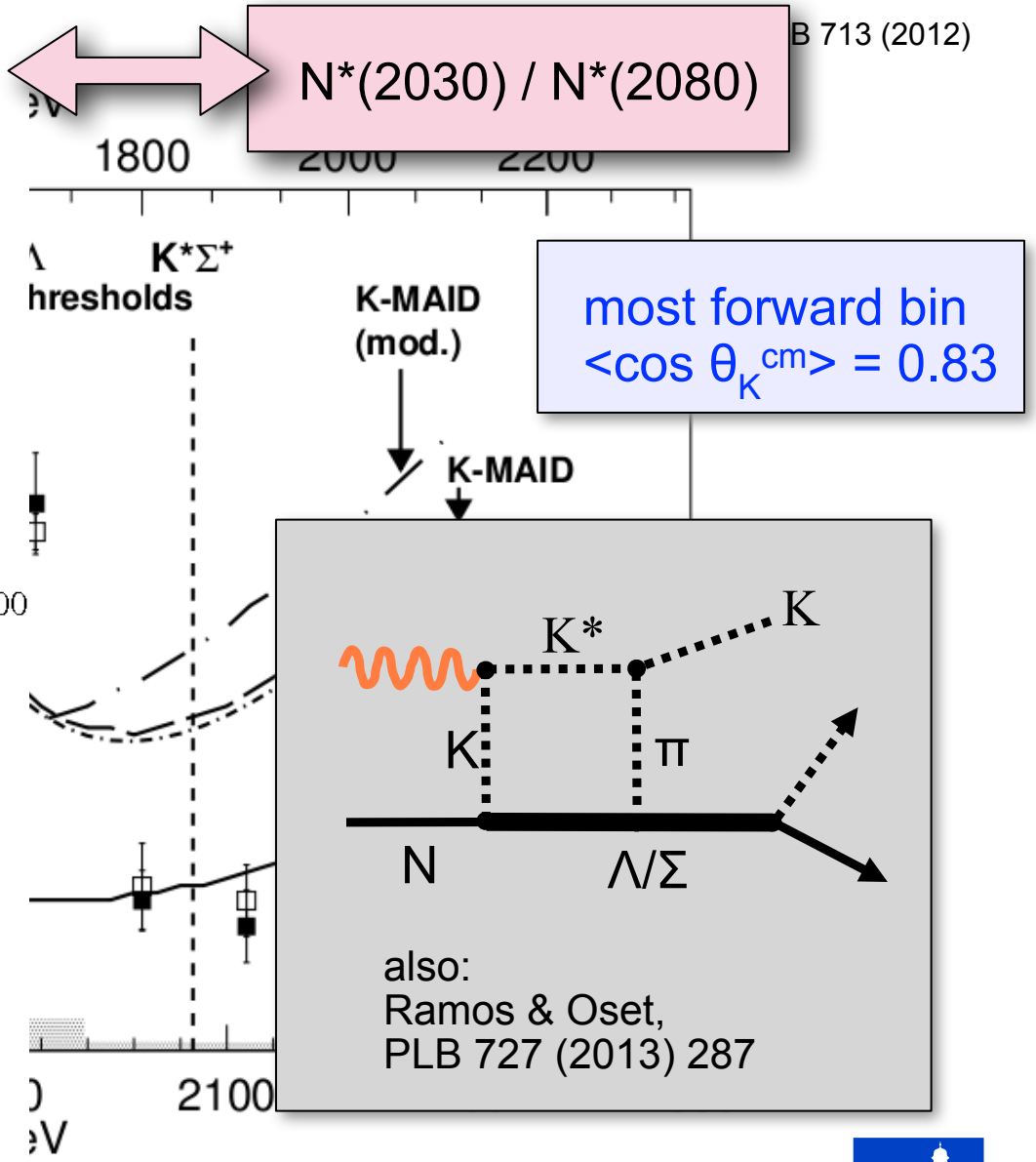

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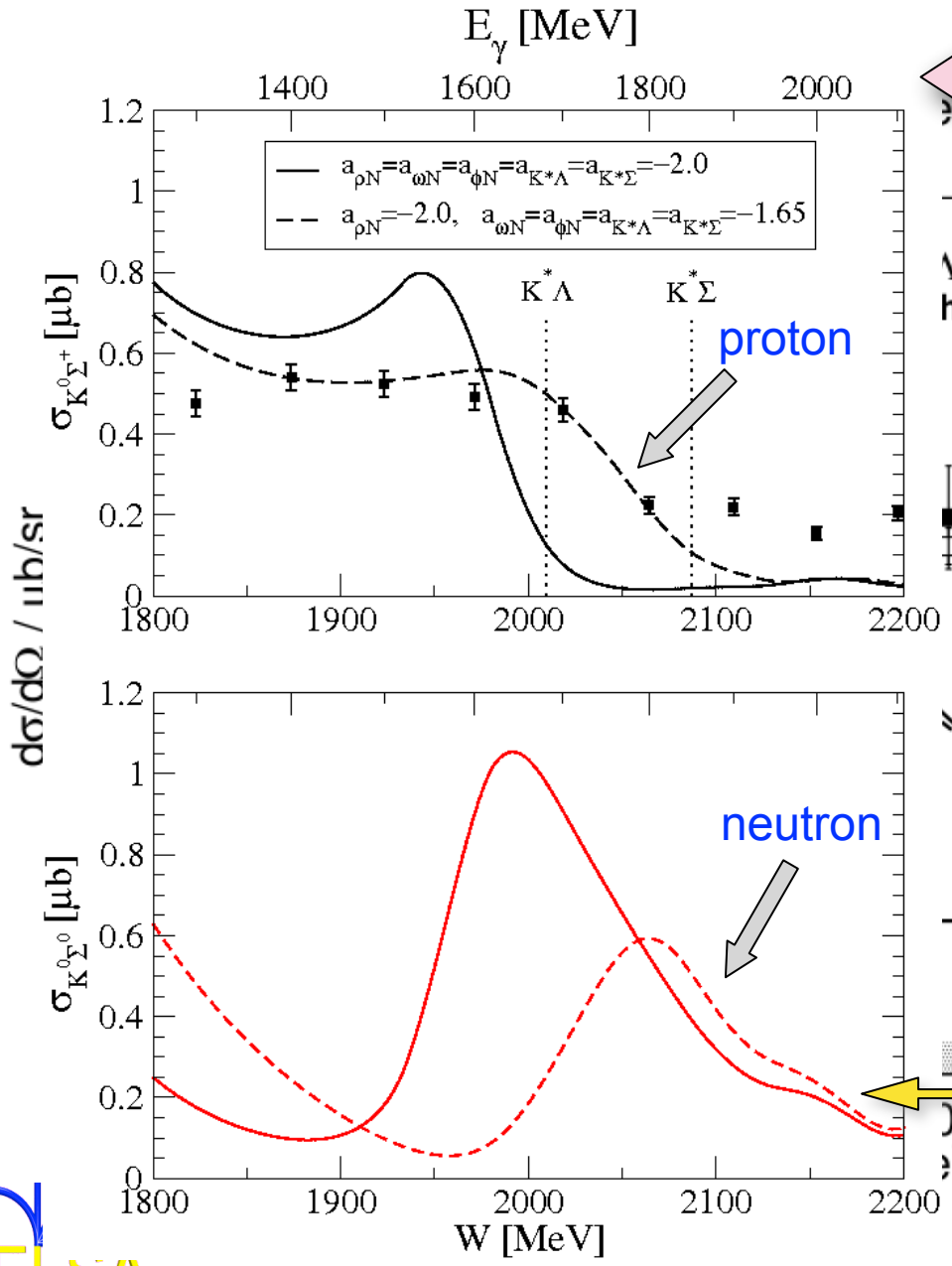
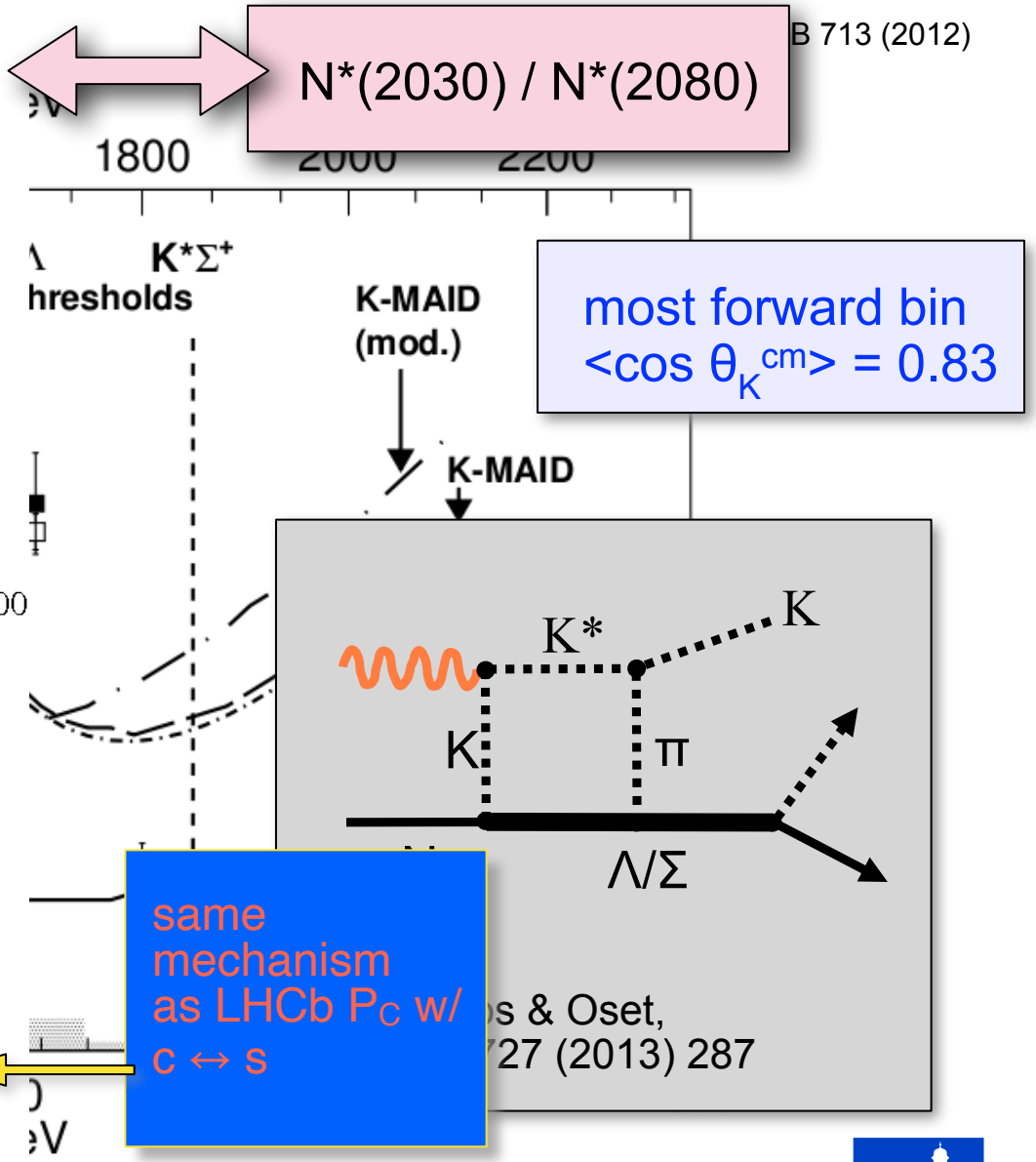




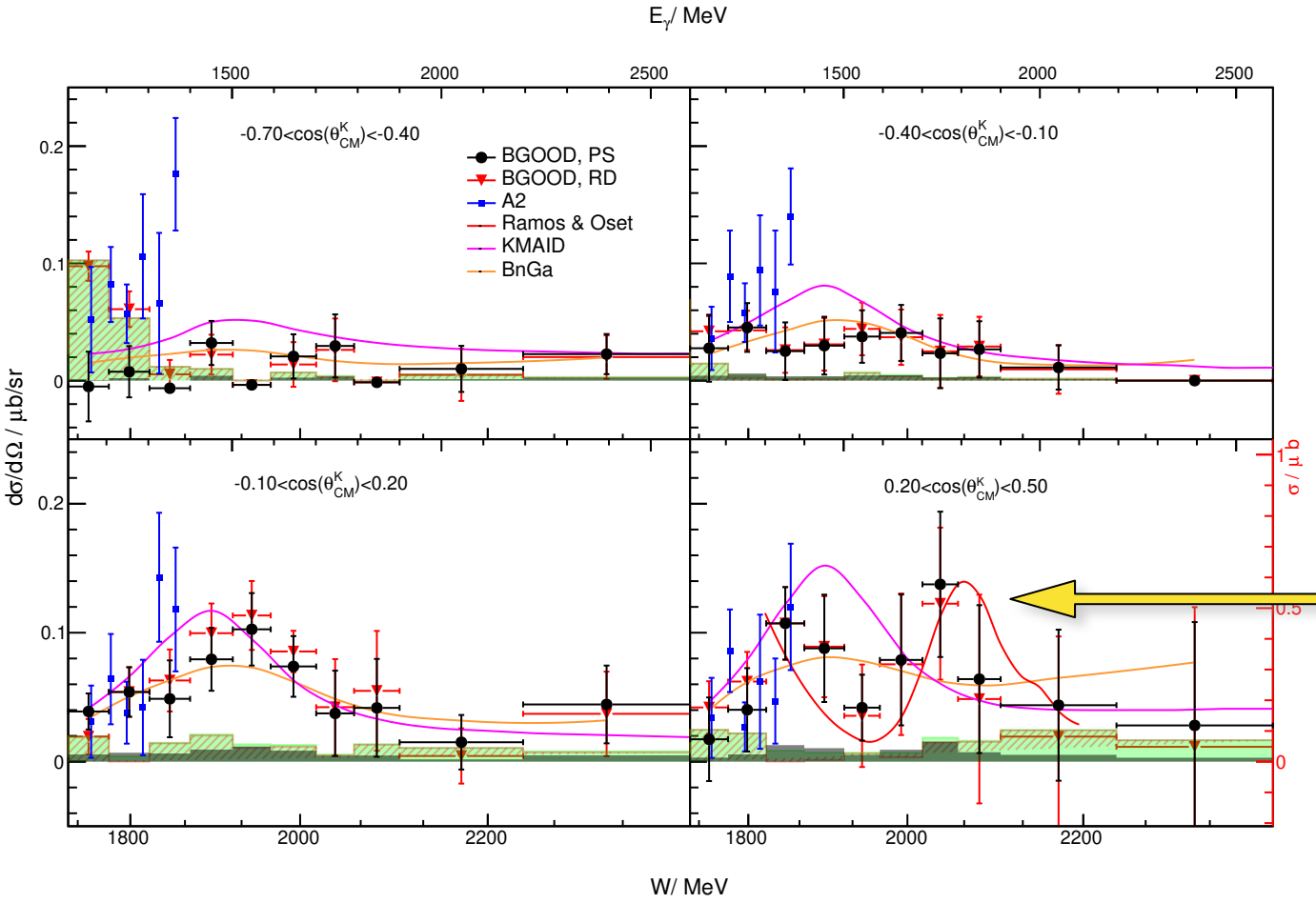
$\gamma\, n \rightarrow K^0\, \Sigma^0$

PhD thesis K. Kohl (Bonn 2021)
accepted by EPJA

C. Akondi et al. [MAMI-A2]
EPJ A 55 (2019) 202

BGOOD simulated bg fit

BGOOD real bg fit



see also:
"The molecular nature of some exotic hadrons"
Ramos, Feijoo, Llorens, Montaña
Few Body Sys. 61 (2020) 4, 34
arXiv:2009.04367 (2020)

same mechanism as LHCb P_C w/ c ↔ s

smoking gun "pentaquark", if …

$\gamma\, n \rightarrow K^0\, \Sigma^0$

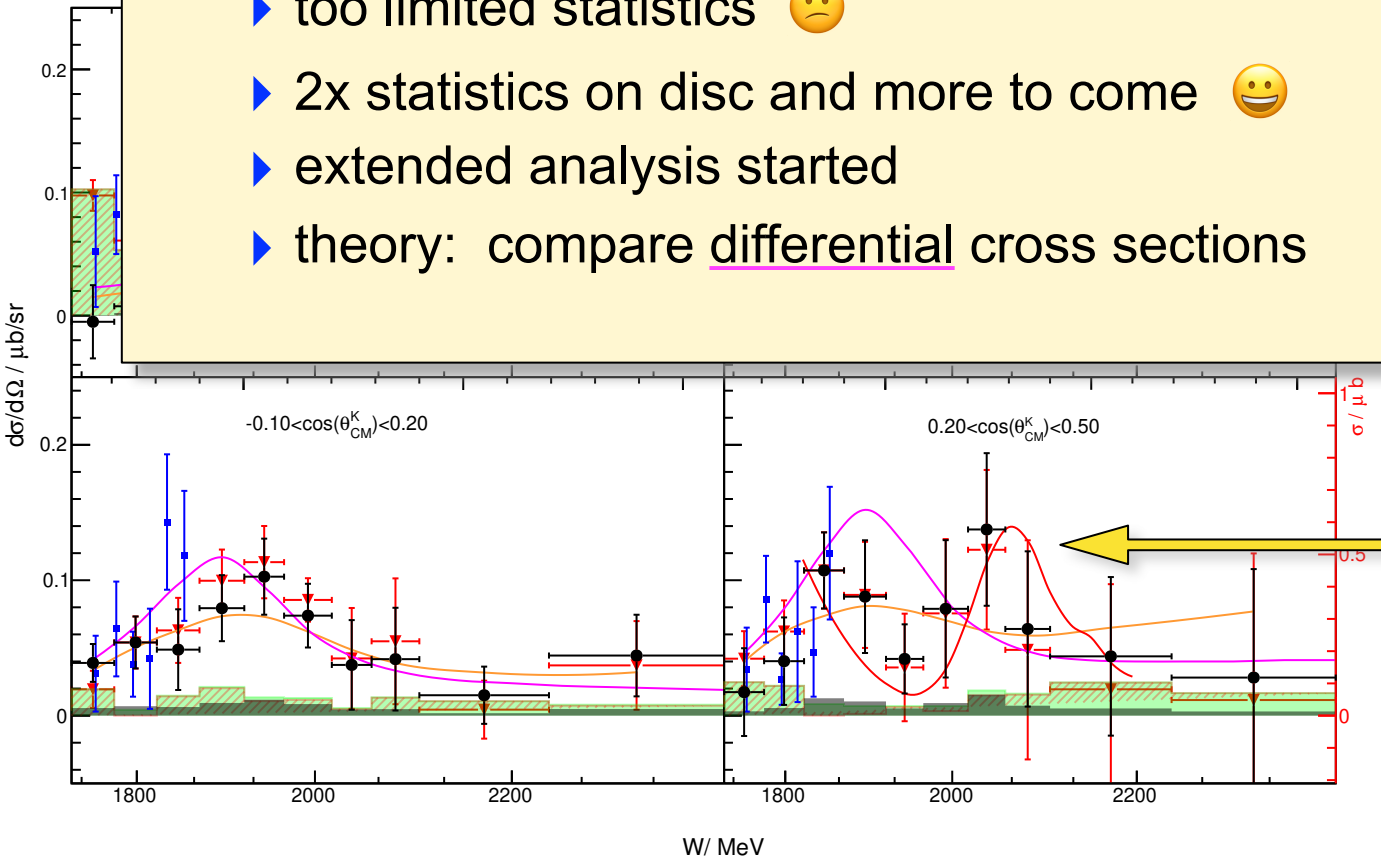
PhD thesis K. Kohl (Bonn 2021)
accepted by EPJA

C. Akondi et al. [MAMI-A2]
EPJ A 55 (2019) 202

BGOOD simulated bg fit

BGOOD real bg fit

- too limited statistics 😕
- 2x statistics on disc and more to come 😀
- extended analysis started
- theory: compare differential cross sections



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Λ(1405)

Historic remark

→ Λ(1405) predicted by Dalitz & Tuan as composed of Kaon-Nucleon
R.H. Dalitz & S.F. Tuan, PRL 2 (1959) 425

→ discovered 1961 in Kp → Σππ
M.H. Alston et al., PRL 4 (1961) 698

→ probably first "exotic" hadron

ttle the decades-long
-quark state or mere
e first interpretation.

yon scattering amplitude with the strangeness $S = -1$ and isospin $I = 0$. It is the *archetype* of what is called a dynamically generated resonance, as pioneered by Dalitz and Tuan.

Λ(1405)

PDG 2010

The clean Λ_c spectrum has in fact been taken to settle the decades-long discussion about the nature of the $\Lambda(1405)$ – true 3-quark state or mere $\bar{K}N$ threshold effect? – unambiguously in favor of the first interpretation.

PDG 2016

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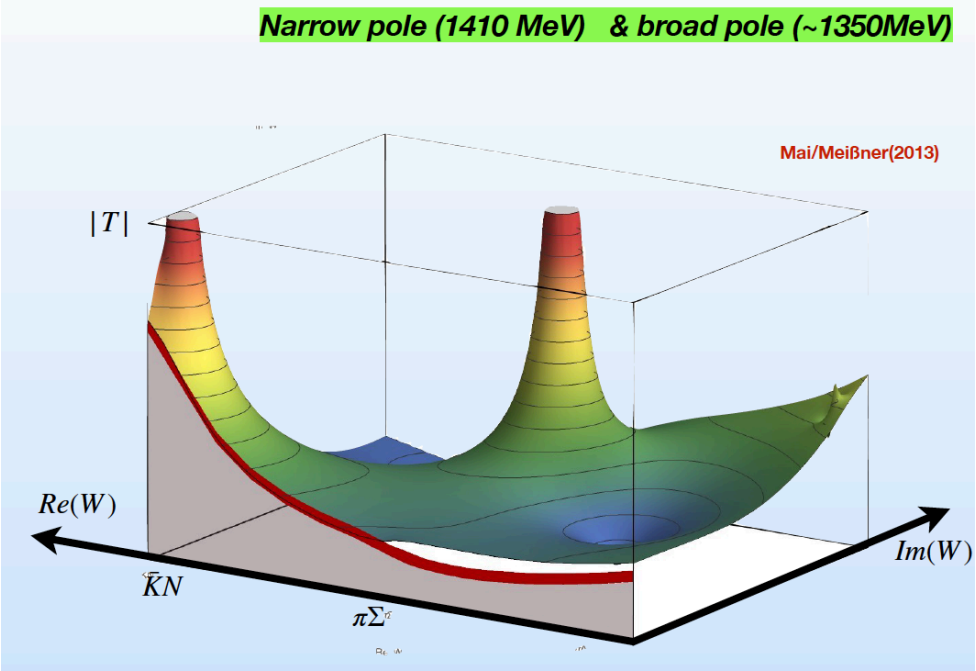
Λ(1405) 2-pole structure in χPT



taken from Maxim Mai's talk at NSTAR 2019 (Baryon ChPT)

Oller/Meißner (2001)

- *Relativistic re-summation of chiral potential*
- *Two-poles on II Riemann Sheet* → **Now part of PDG**

Kaiser/Siegel/Weise (1995) Oset/Ramos (1998)

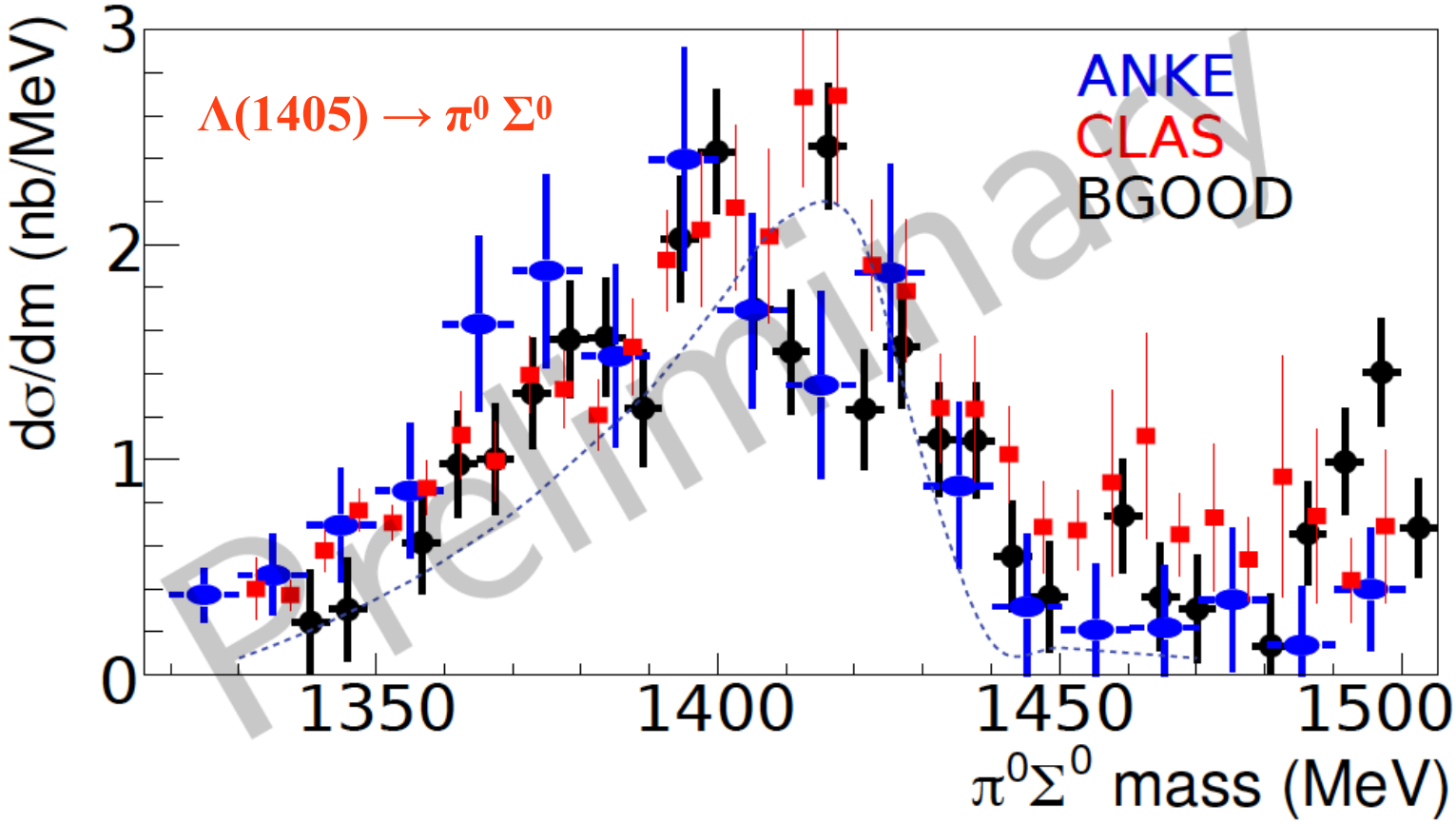
- *Lippmann-Schwinger equation for K^-p,Σπ,Λπ*
- *Potential from Chiral Lagrangian*

"Thus, a potential derived from chiral dynamics with interaction ranges commensurate with the meson-baryon system necessarily produces a quasi-bound state or resonance below or near the K^-p threshold"

K^+ Λ(1405)

Λ(1405) photoproduction – line shape

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



$K^+ \Lambda(1405)$

Λ(1405) photoproduction – line shape

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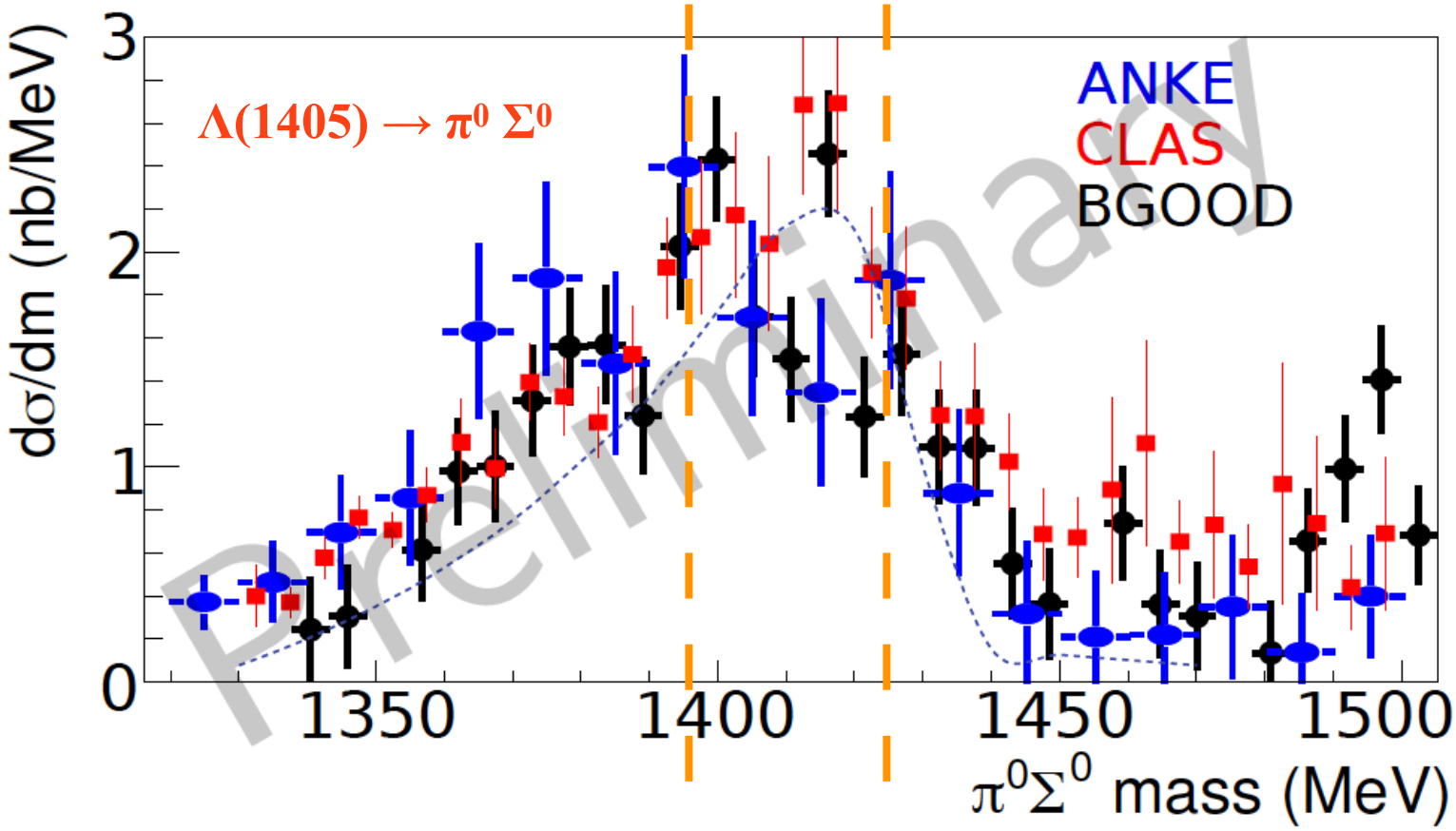
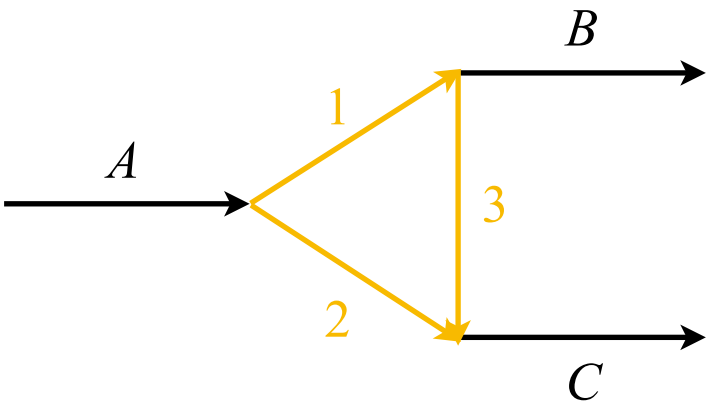
double peak strukture
@ 1395 / 1425 MeV ??



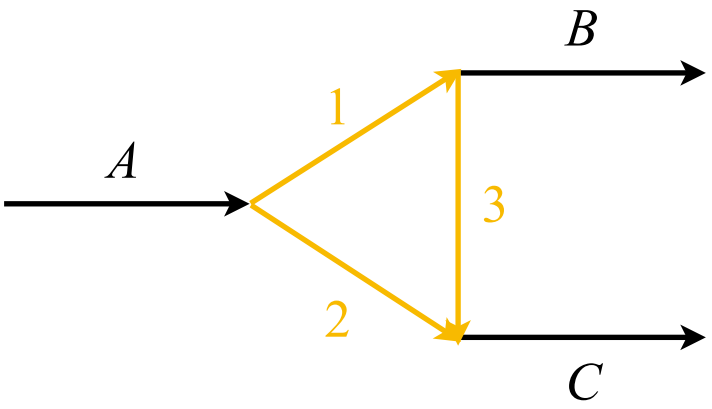
photoproduction mechanism – triangle singularity



Coleman-Norton theorem,
Il Nuovo Cimento 38 (1965) 438:
1, 2, 3 must be nearly on mass shell

can mimic resonance

photoproduction mechanism – triangle singularity



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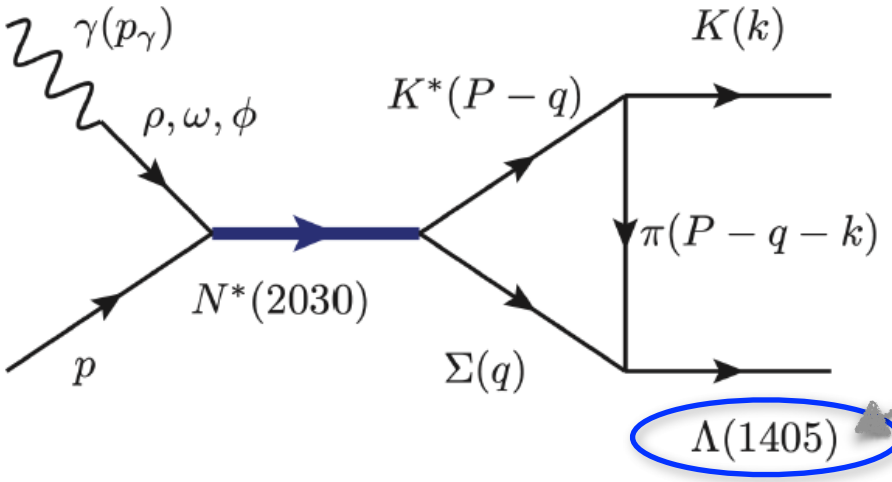
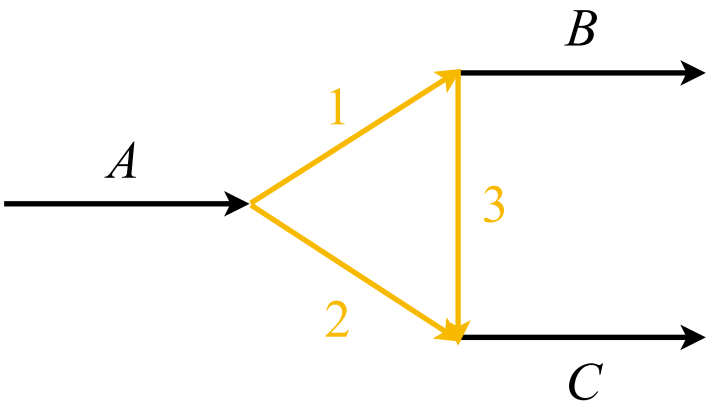


or drive (dynamically generated) resonance

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

photoproduction mechanism – triangle singularity



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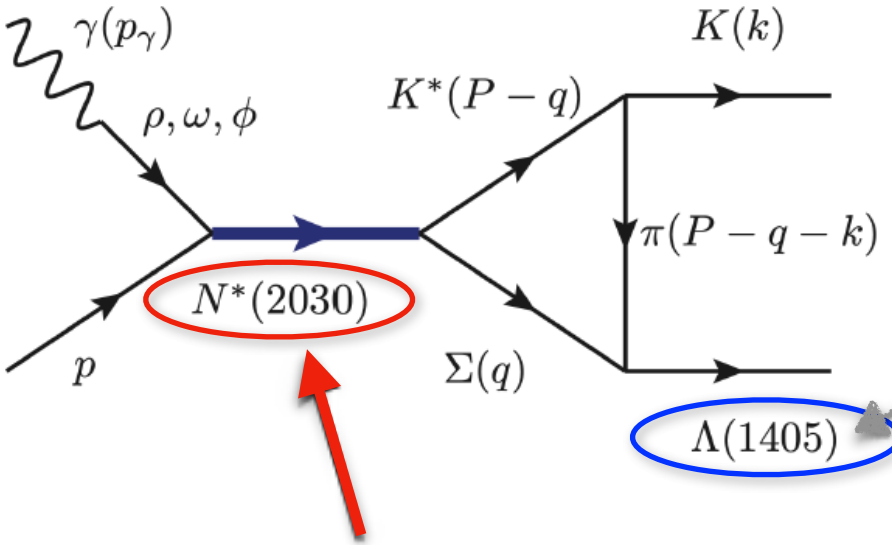

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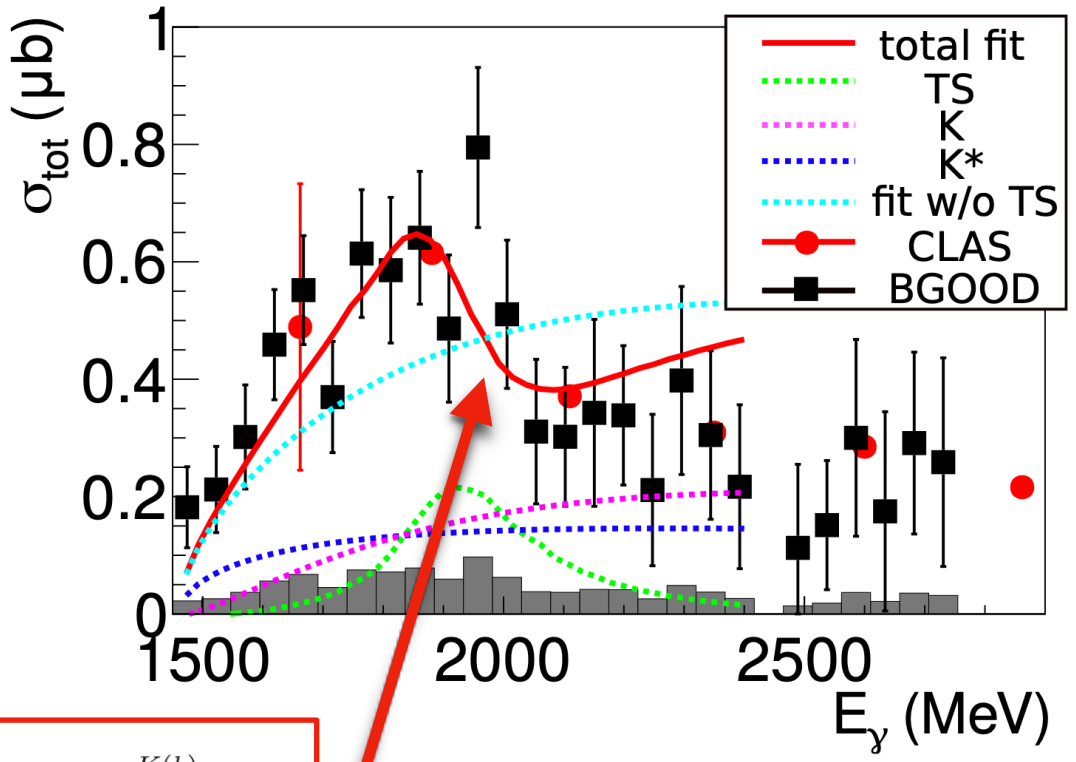
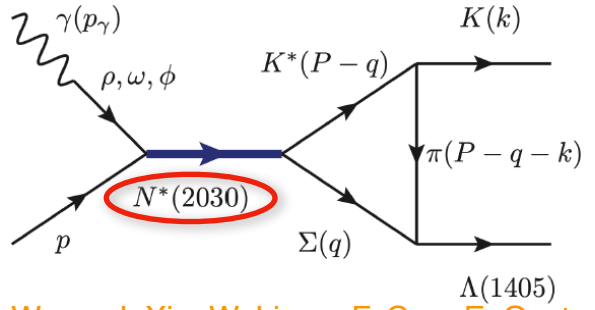
$K^*\Sigma$ suspect in $K^0\Sigma^0$ channel

$K^+ \Lambda(1405)$ – photoproduction mechanism

$K^+ \Lambda(1405)$ photoproduction – total x-sec

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

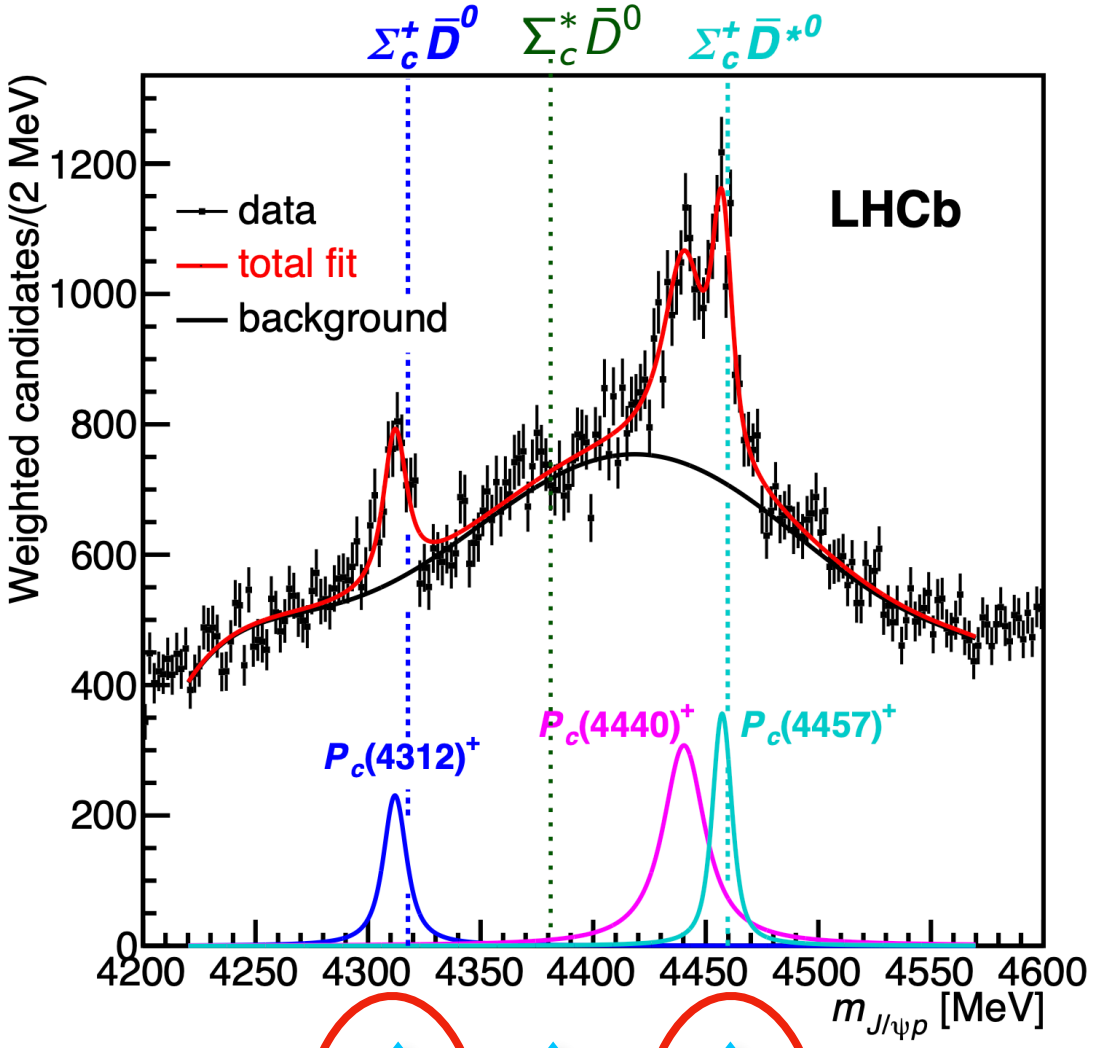




E. Wang, J. Xie, W. Liang, F. Guo, E. Oset,
PR C 95 (2017) 015205

cusp: triangle meachanism significant

reminder: LHCb



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

Hadronic molecules & HQSS

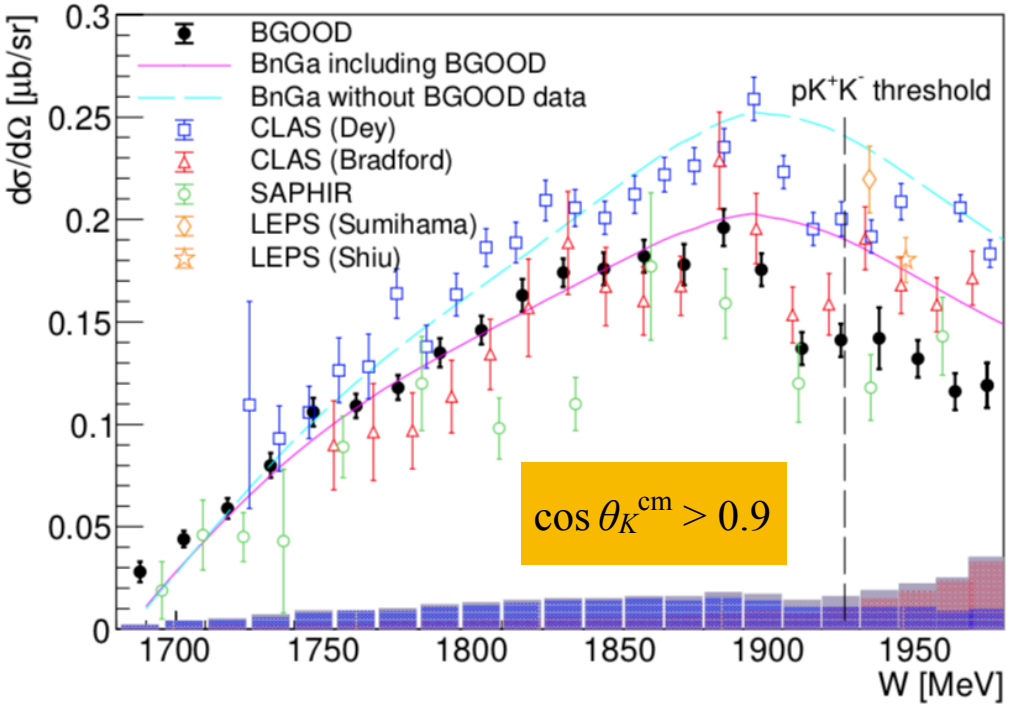
LHCb data: PRL 122 (2019) 222001

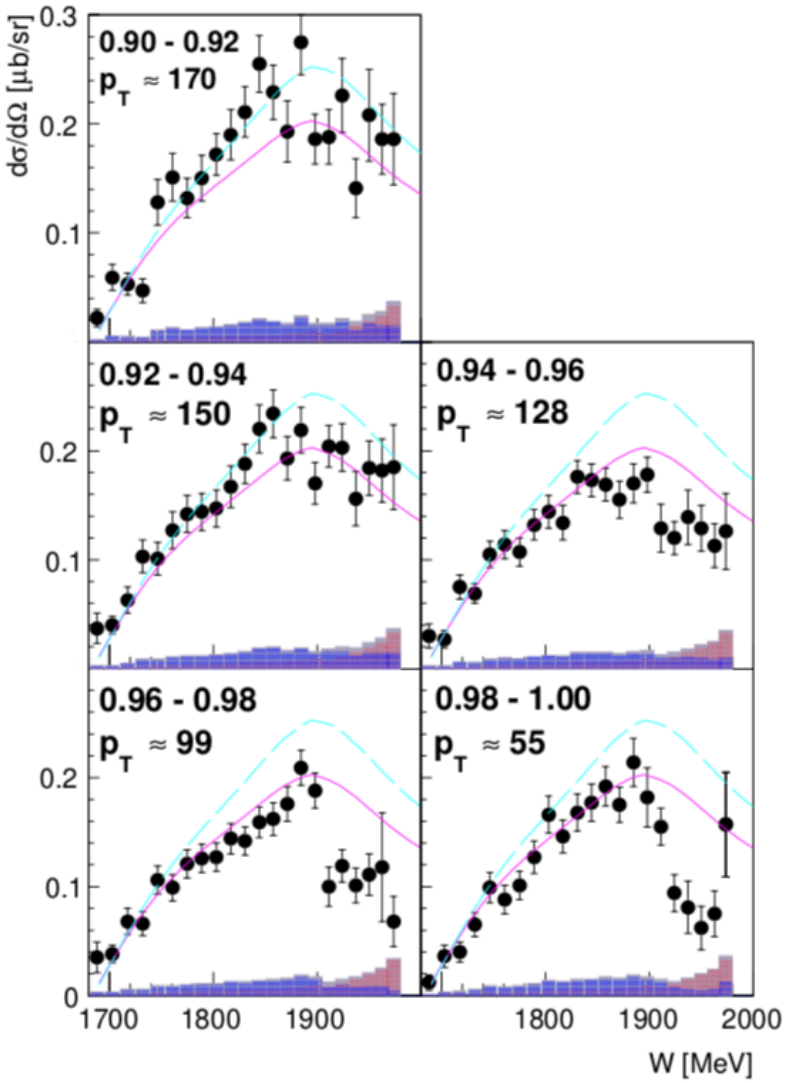
uds sector N*(1535) Σ K Σ* K Σ K* N*(2030/80)

universitätbonn

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

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





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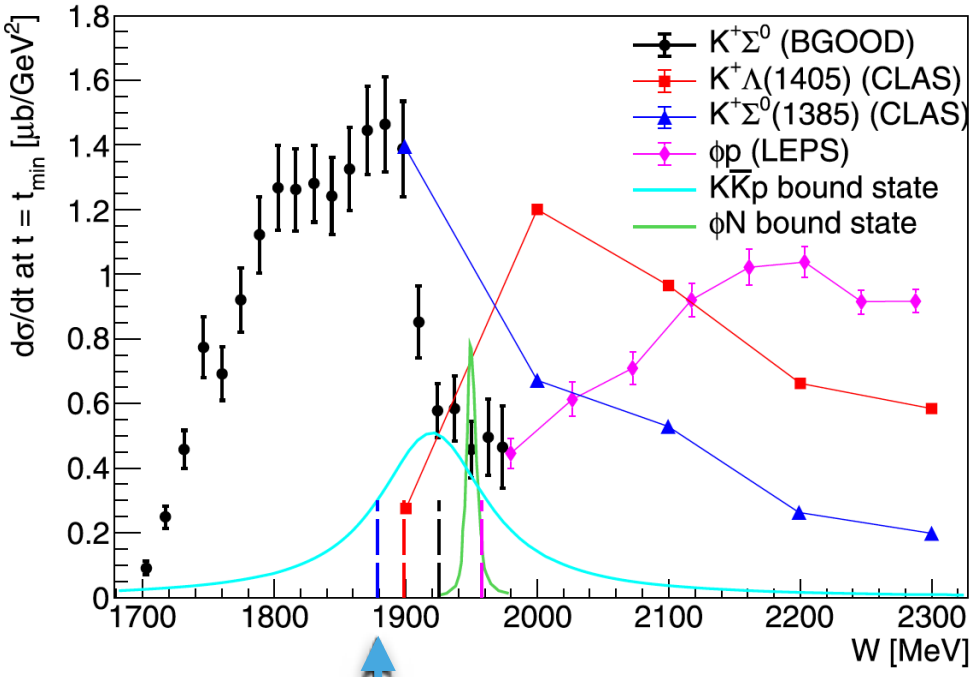

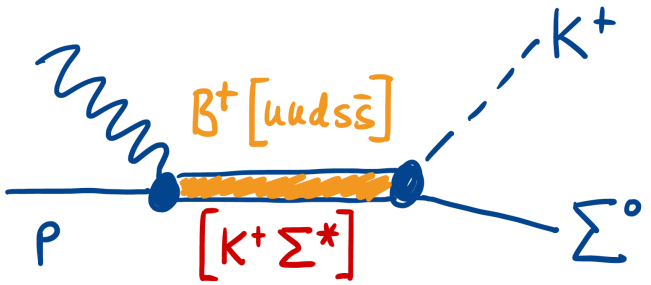

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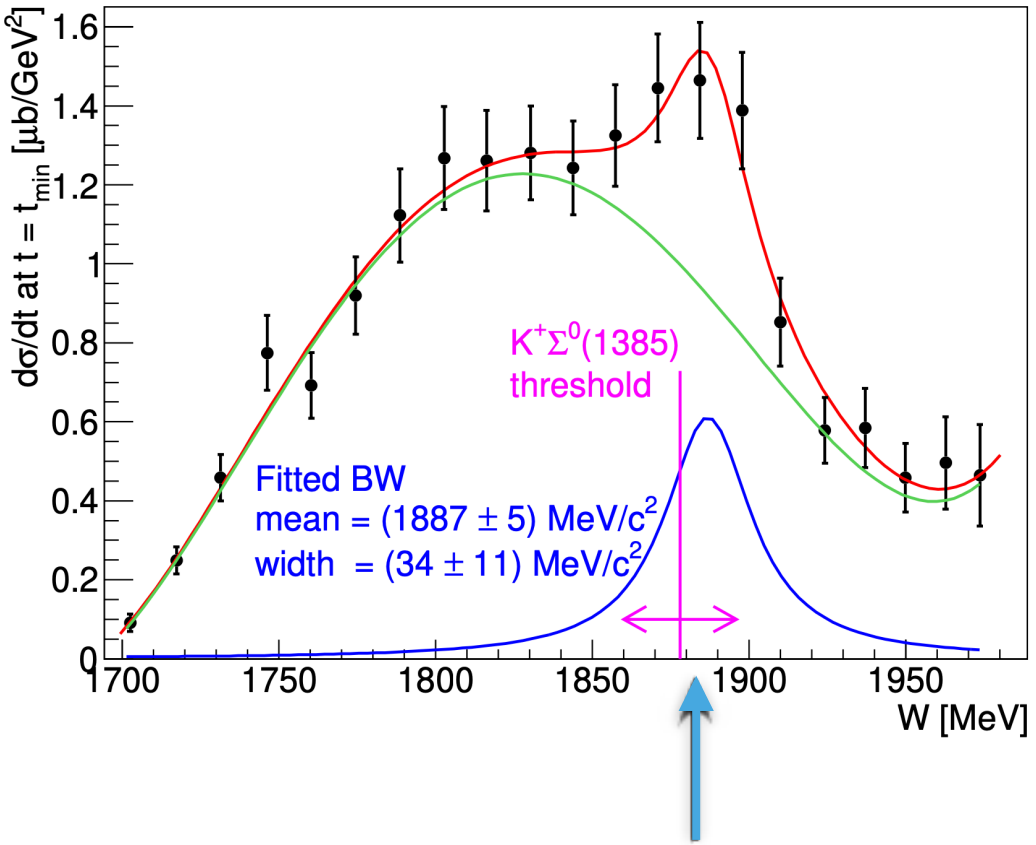
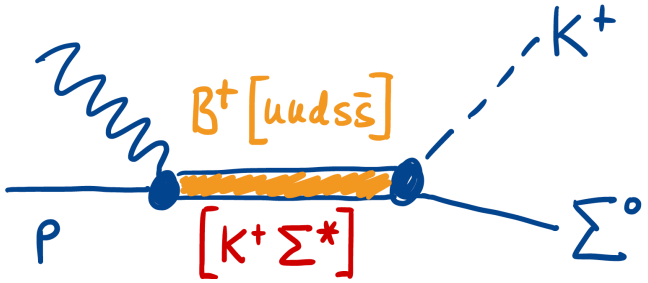
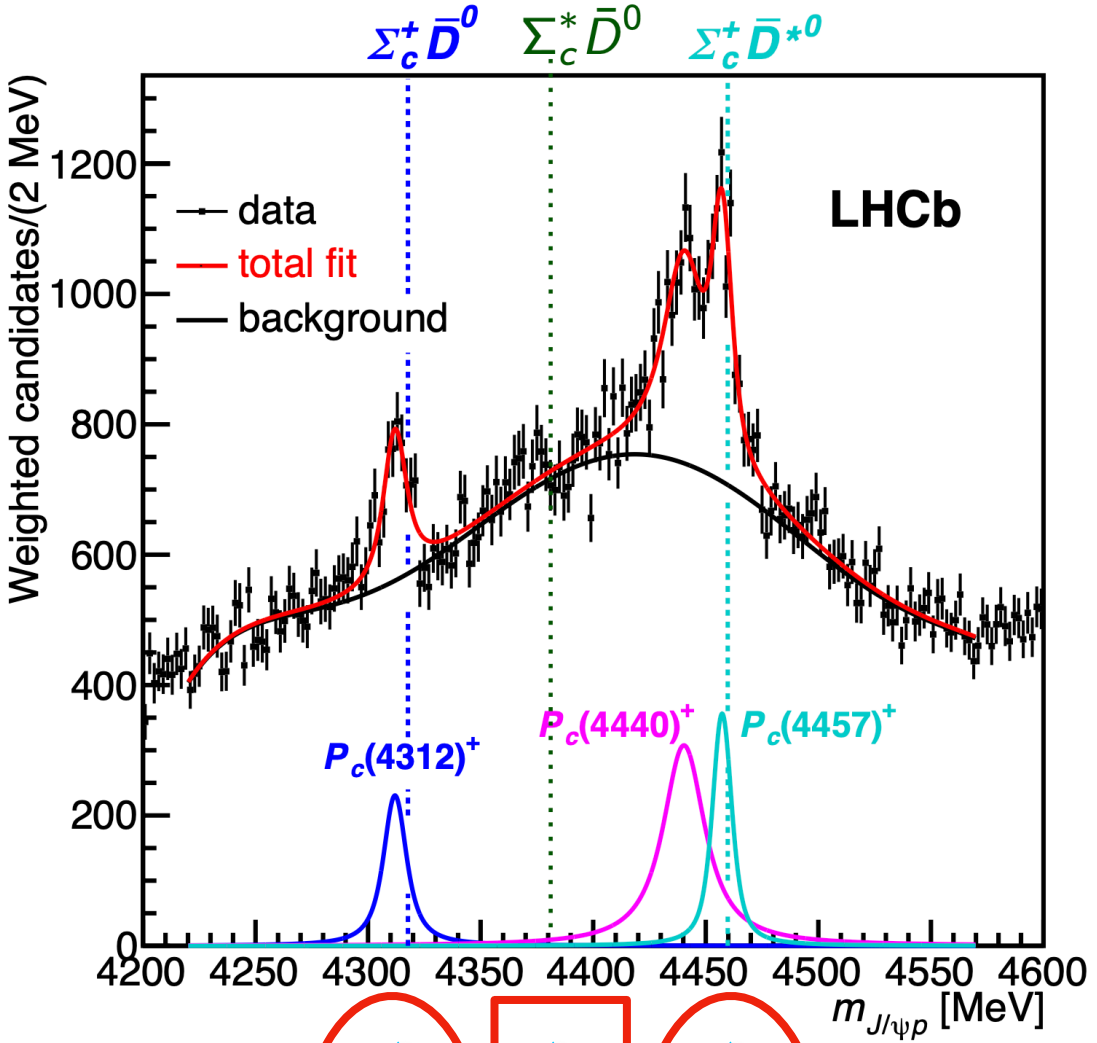




reminder: LHCb



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

universitätbonn

Conclusions

- multi-quark effects in uds sector observed w/ BGOOD experiment
- forward acceptance ⬌ meson-baryon dynamics
  @ thresholds & low t / p_T
- Λ(1405) line shape in agreement w/ molecular $\bar{K}N$ structure
- possible [K*-Σ] configuration N*(2030) in $K^0\Sigma^0$ and $K^+\Lambda(1405)$ photoproduction (triangle singularity)
- possible [K-Σ*(1385)] configuration in $K^+\Sigma^0$
- apparent similarity to (hidden) c-sector

⇨ a lot remains to be done, but:
meson-baryon interactions at thresholds do play a significant role in uds similar to c sector