

$\gamma p \rightarrow K_S^0 \Sigma^+$ photoproduction

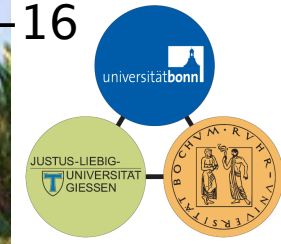
- Motivation
- Experiment
- Results
- Interpretation
- Summary & Outlook

Crystal-Barrel / TAPS
BGO-OD collaborations

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SFB/TR-16



Motivation

- ▶ relevant degrees of freedom ?
- ▶ dynamics behind baryon excitation spectrum ?
 - 3q
 - 3q-g hybrids
 - q-2q quark-diquark correlations
 - qq̄q-q̄q̄ baryon-meson

▶ $|N\rangle = |qqq\rangle + |qqq q\bar{q}\rangle + |qqq g\rangle + \dots$

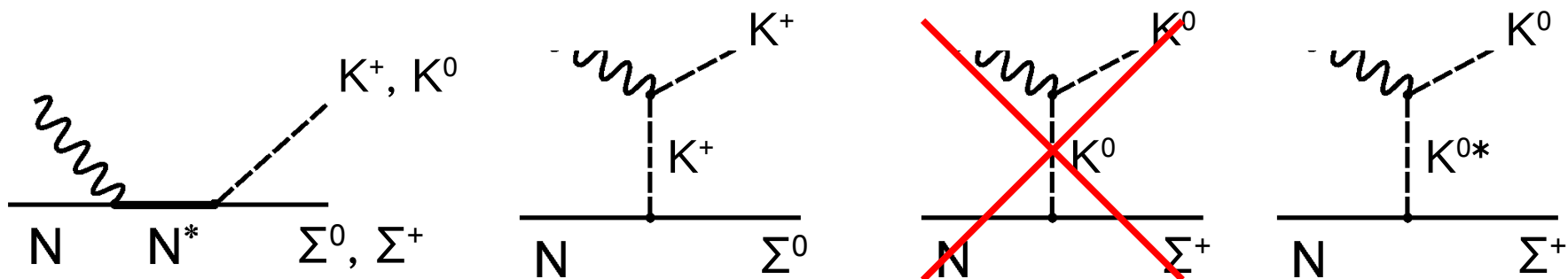
short range long range

low t

Motivation

Why $K^0\Sigma^+$ channel ??

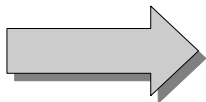
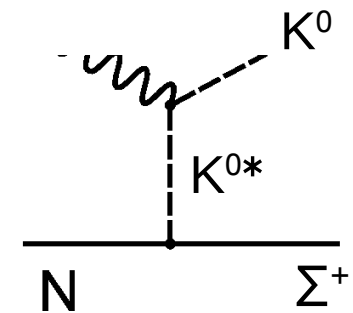
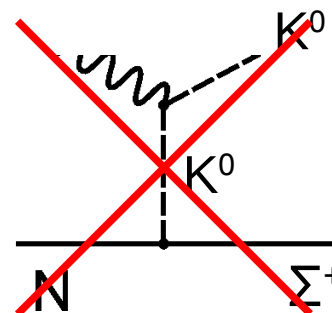
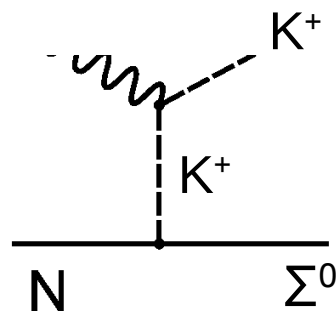
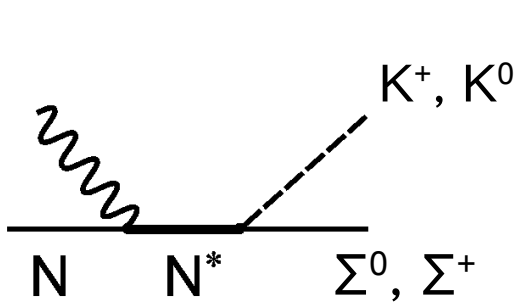
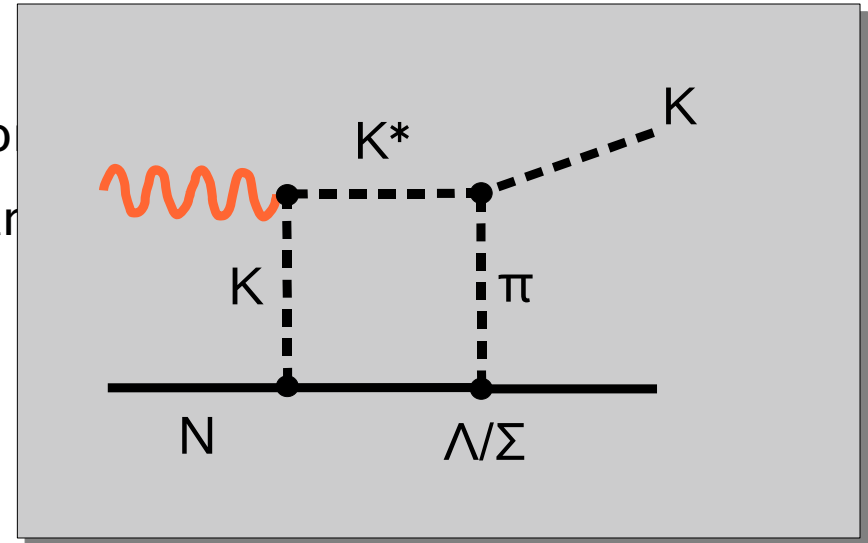
- ◆ non-pionic **photoproduction** of baryon resonances
- ◆ Born contributions suppressed compared to K^+ production
- ◆ in particular: t-channel
- ◆ but: K^{0*} exchange
- ◆ box-formation possible



Motivation

Why $K^0\Sigma^+$ channel ??

- ▶ non-pionic **photoproduction** of baryon
- ▶ Born contributions suppressed compar
- ▶ in particular: t-channel
- ▶ but: K^{0*} exchange
- ▶ box-formation possible

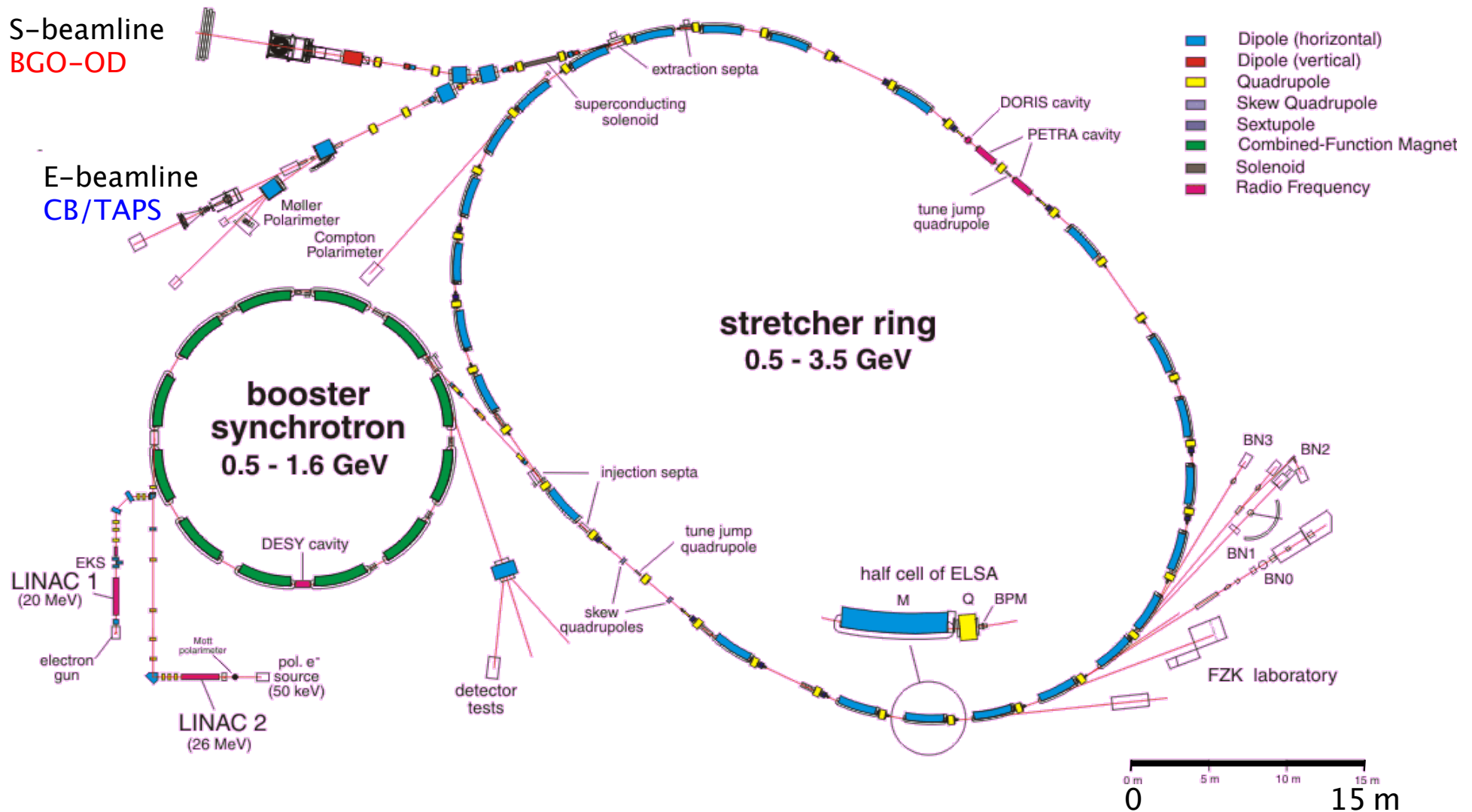


$\gamma p \rightarrow K^0\Sigma^+ @ K^*$ threshold

previous data inconclusive

S-beamline
BGO-OD

E-beamline
CB/TAPS



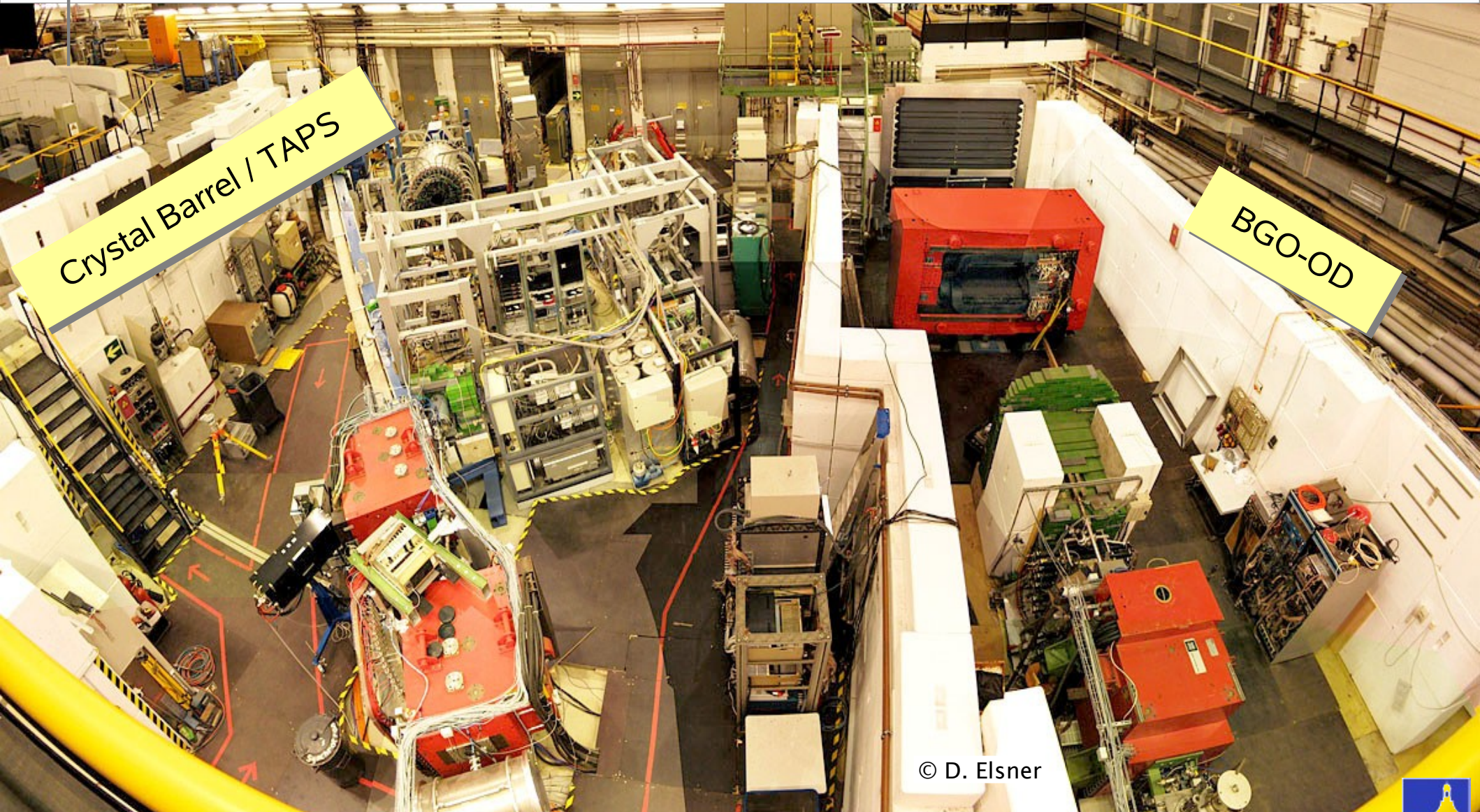
- Dipole (horizontal)
- Dipole (vertical)
- Quadrupole
- Skew Quadrupole
- Sextupole
- Combined-Function Magnet
- Solenoid
- Radio Frequency



ELSA experimental areas

Beamline E

Beamline S

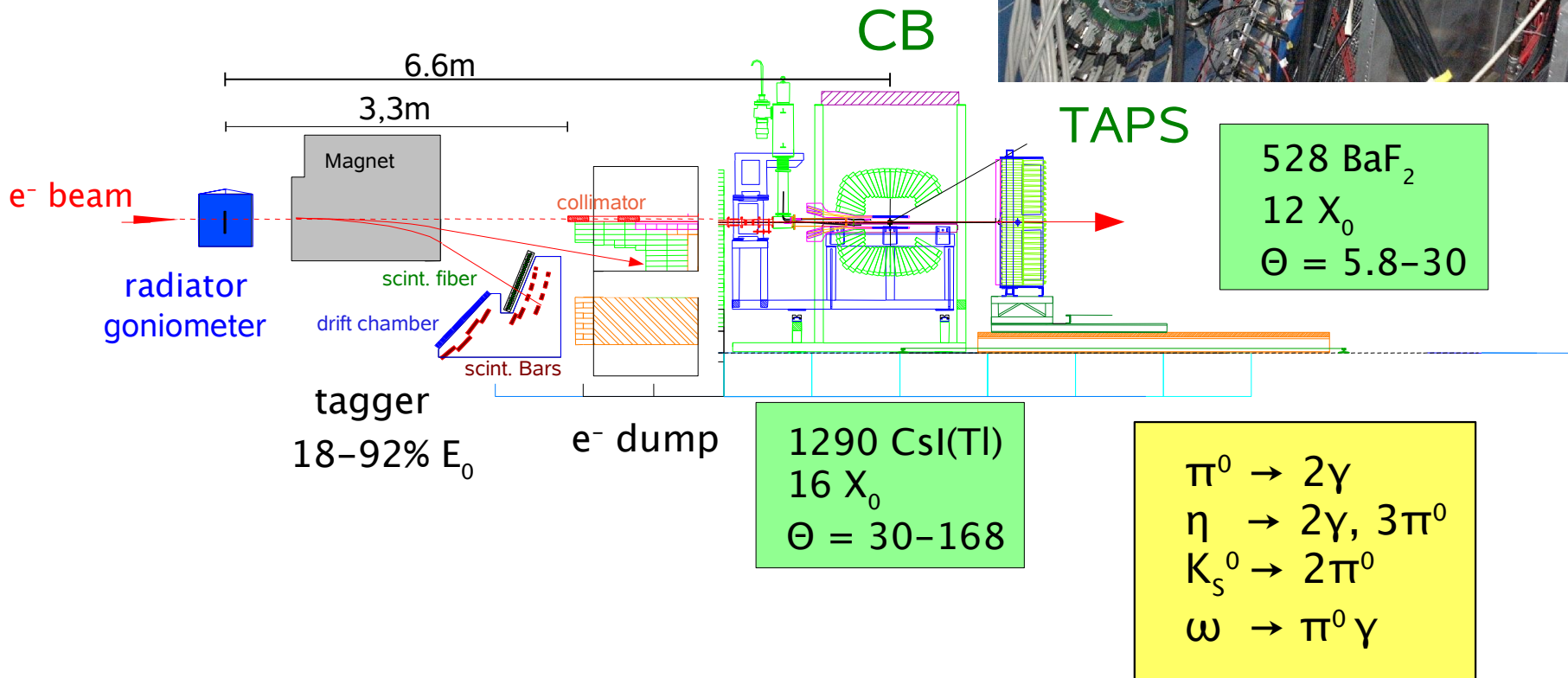
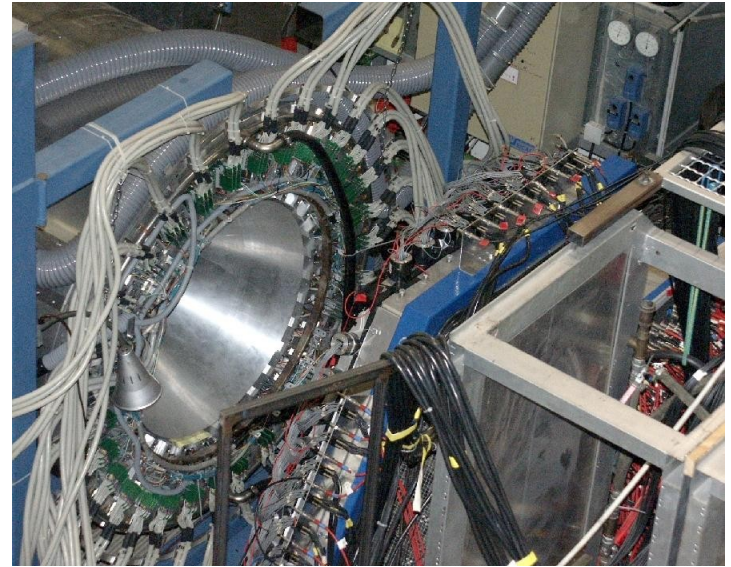


Crystal Barrel / TAPS

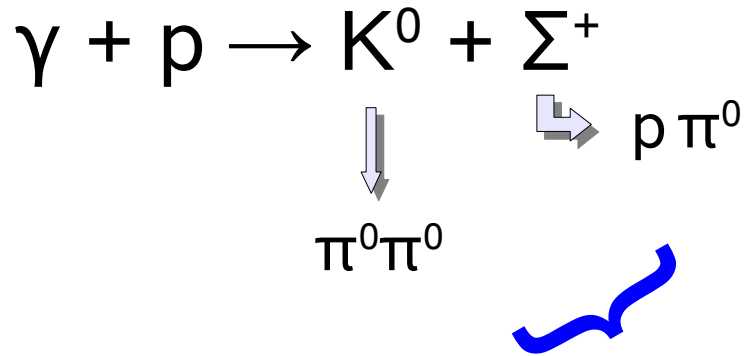
BGO-OD

© D. Elsner

Experiment: Crystal Barrel / TAPS



Event reconstruction & data analysis

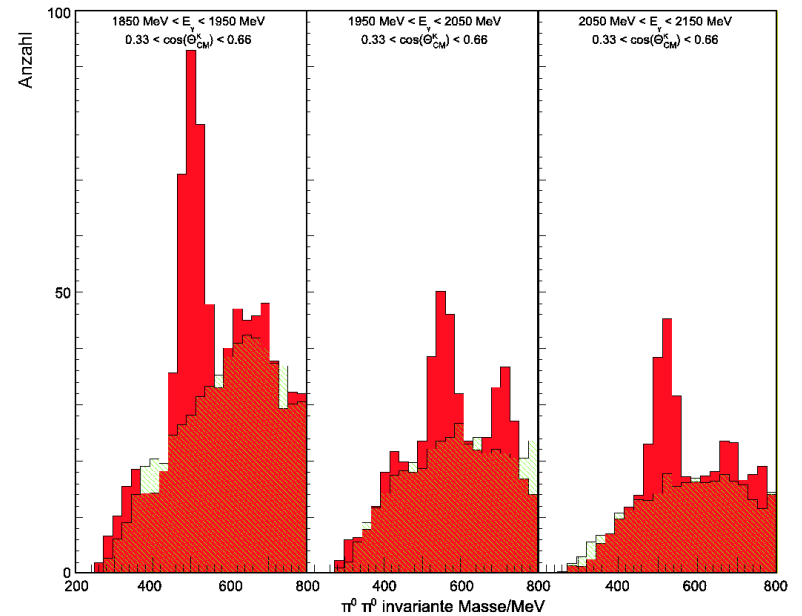
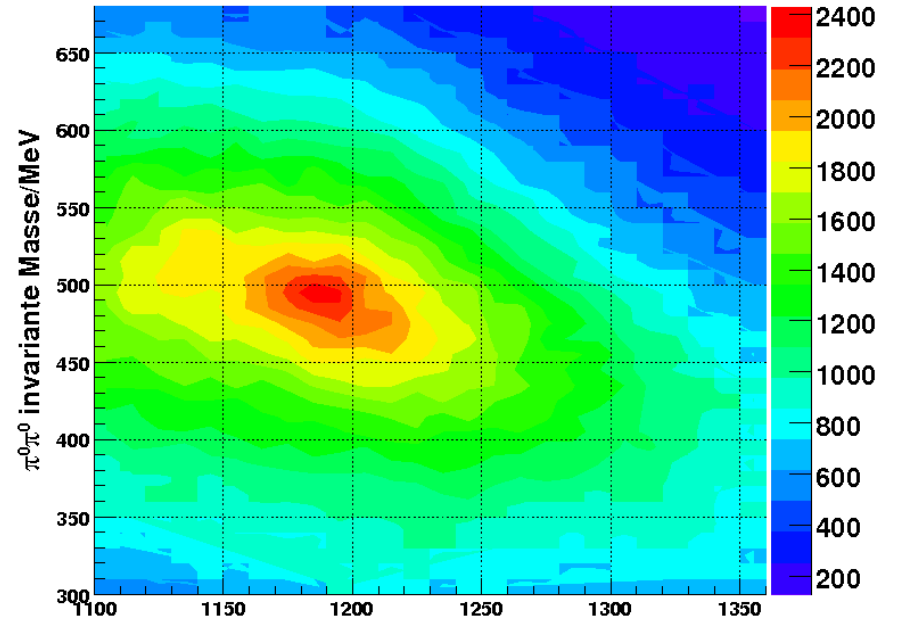


6 & 7 PED events

$p + 6\gamma$

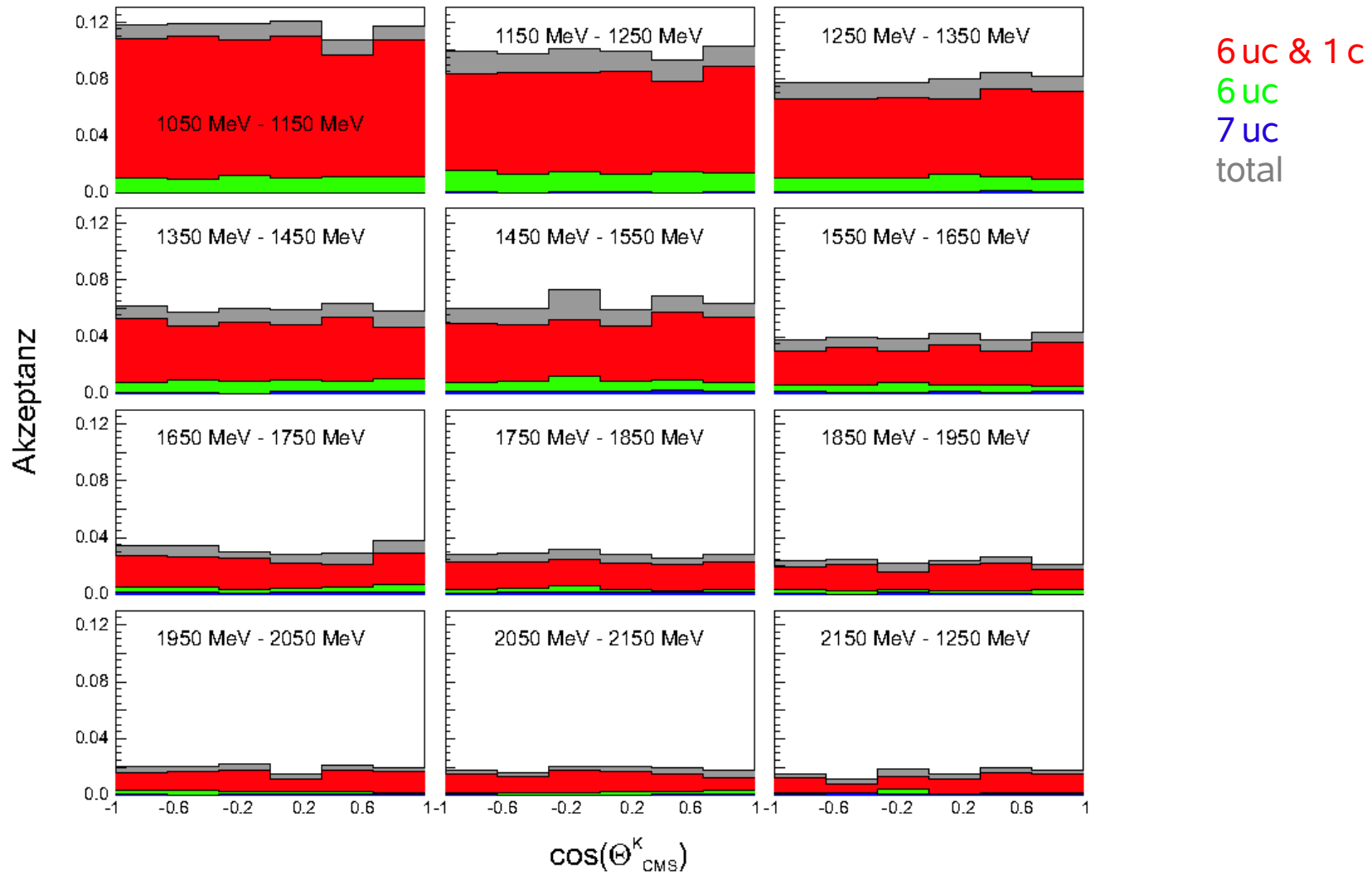
kinematic fit

- beam E_γ along axis
- target proton at rest
- detected γ 's E, θ, ϕ
- ejected p not required



Event reconstruction & data analysis

acceptance



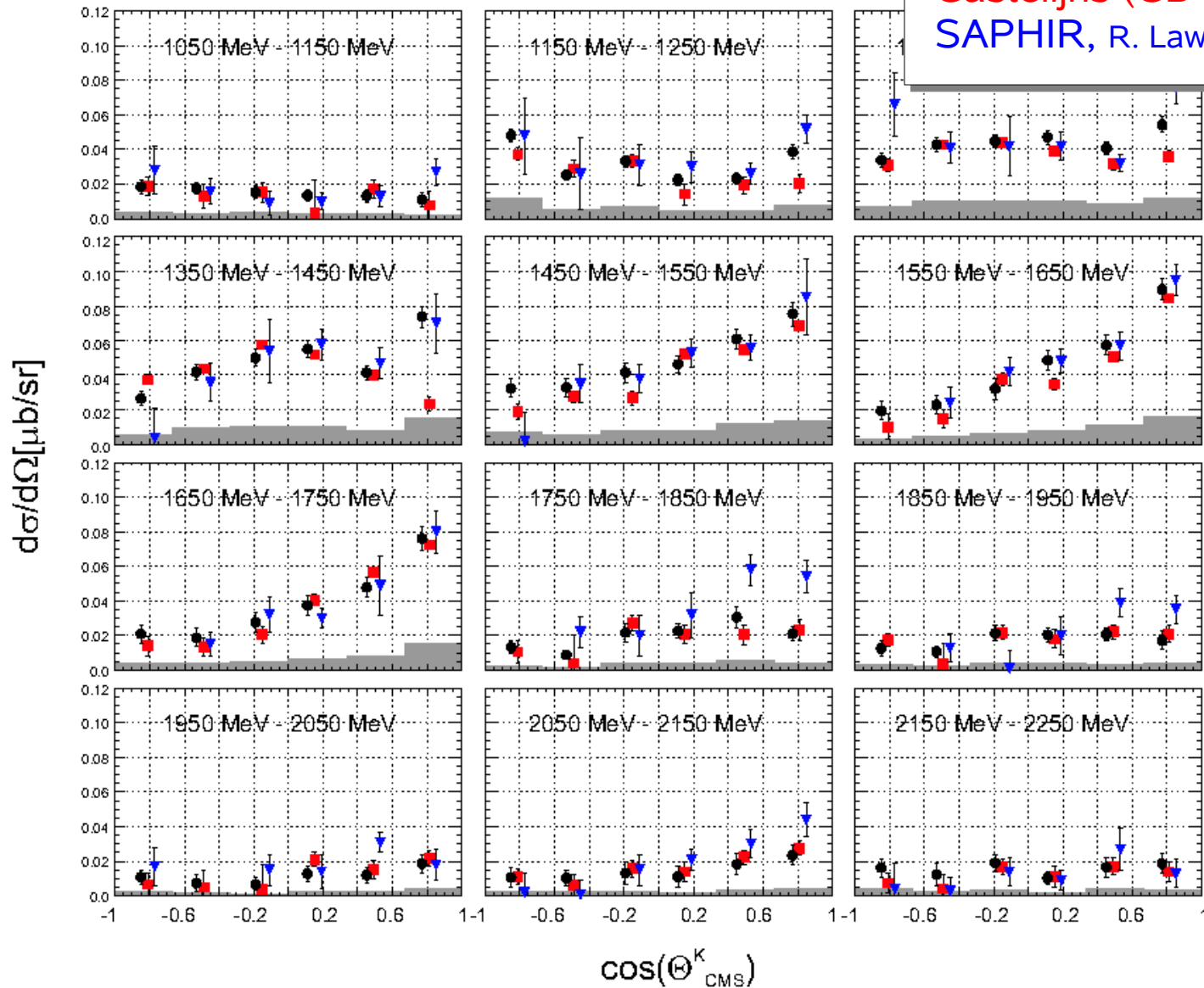
$\gamma + p \rightarrow K^0 + \Sigma^+$: cross sections

R. Ewald et al., PLB 713 (2012)

this work (CB polarised beam)

Castelijns (CB unpol. beam, EPJ A35 (08) 39)

SAPHIR, R. Lawall et al., EPJ A24 (05) 275

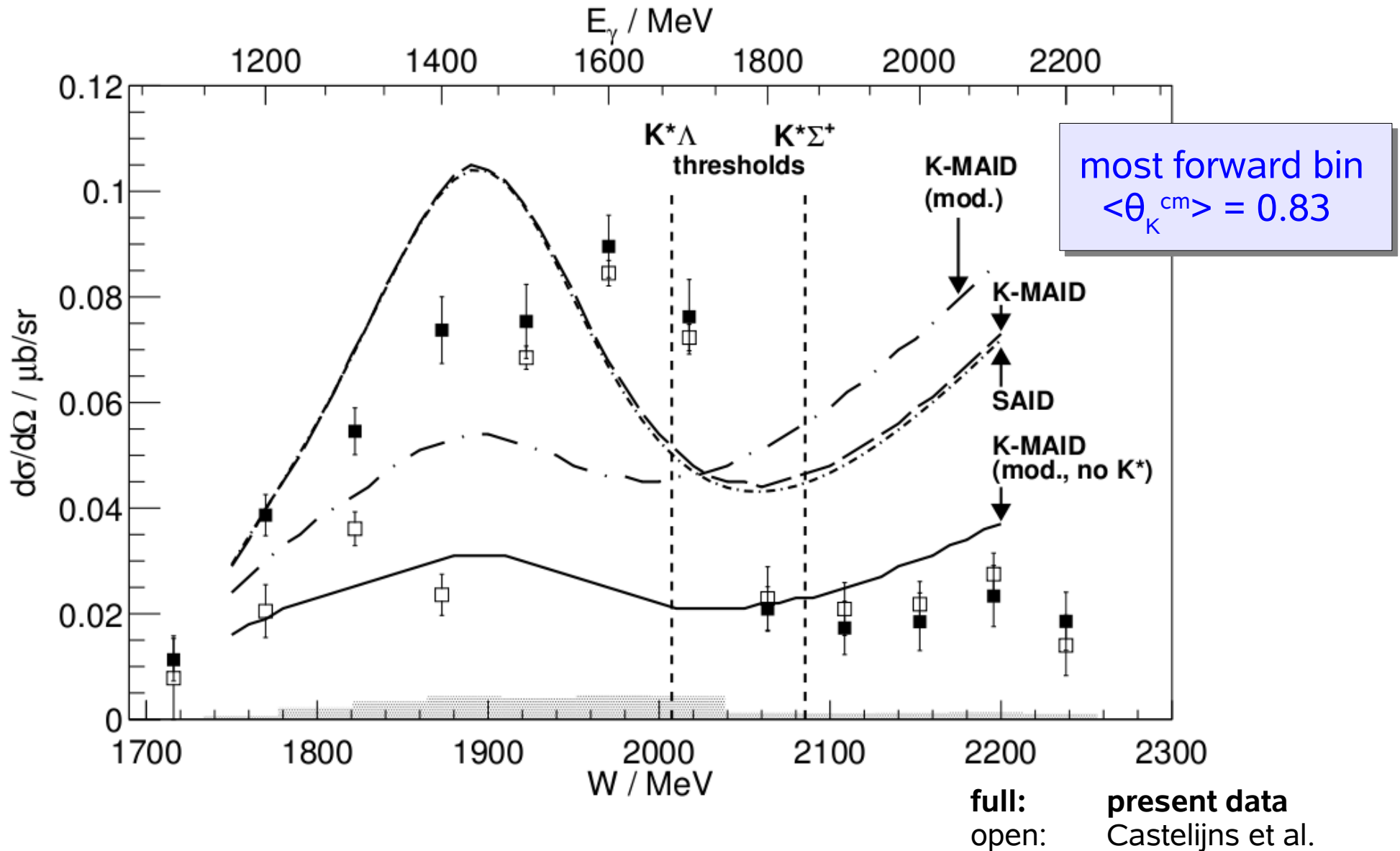


main syst. errors

- backgrd subtr.
- kin.fit (cut cf level)
- acceptance
- photon flux

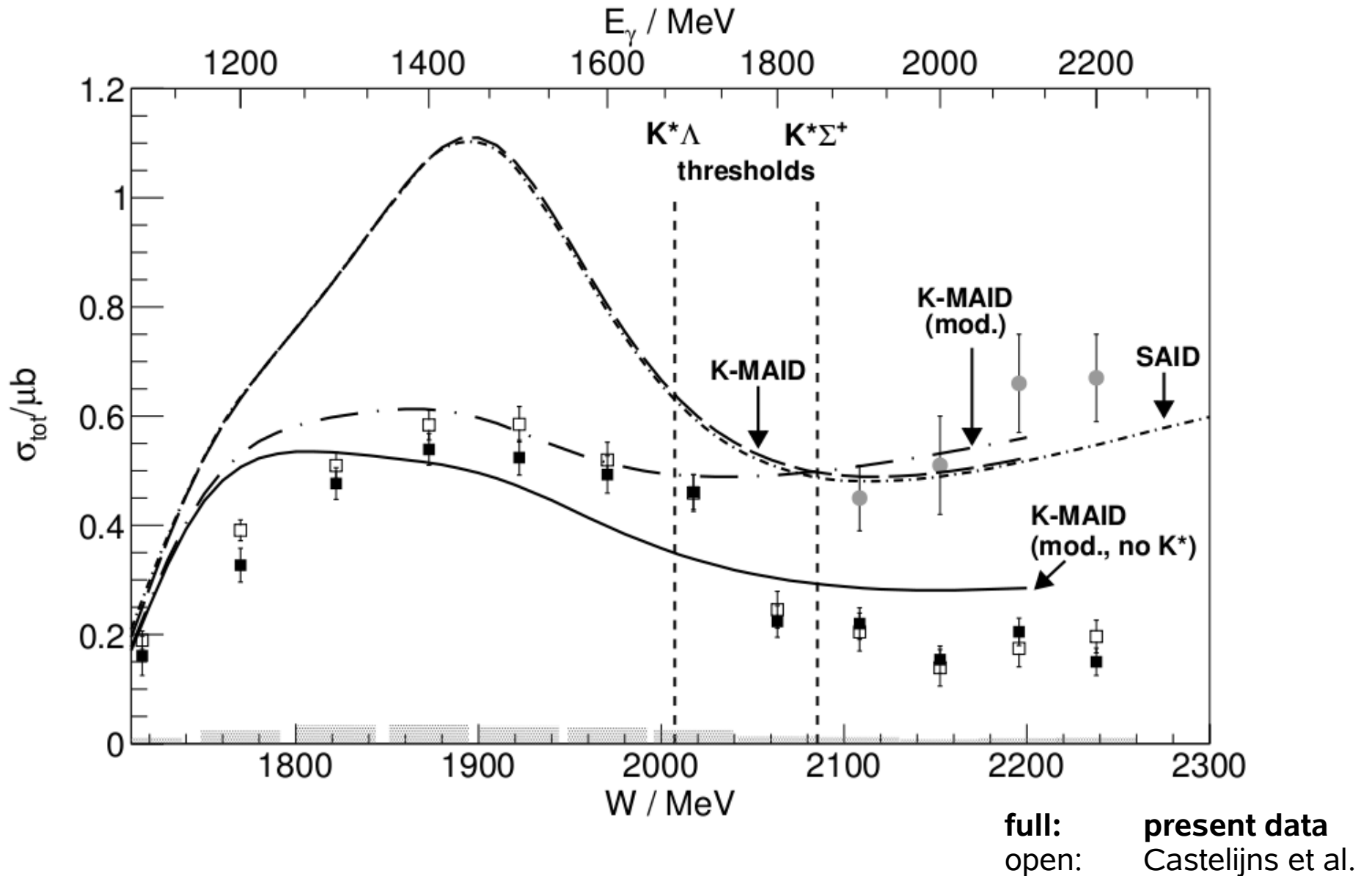
$\gamma + p \rightarrow K^0 + \Sigma^+$: cross sections

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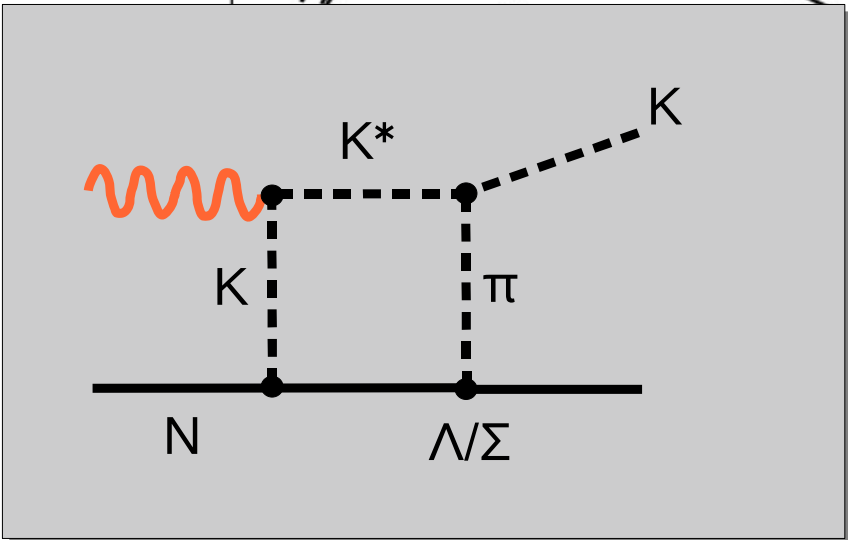
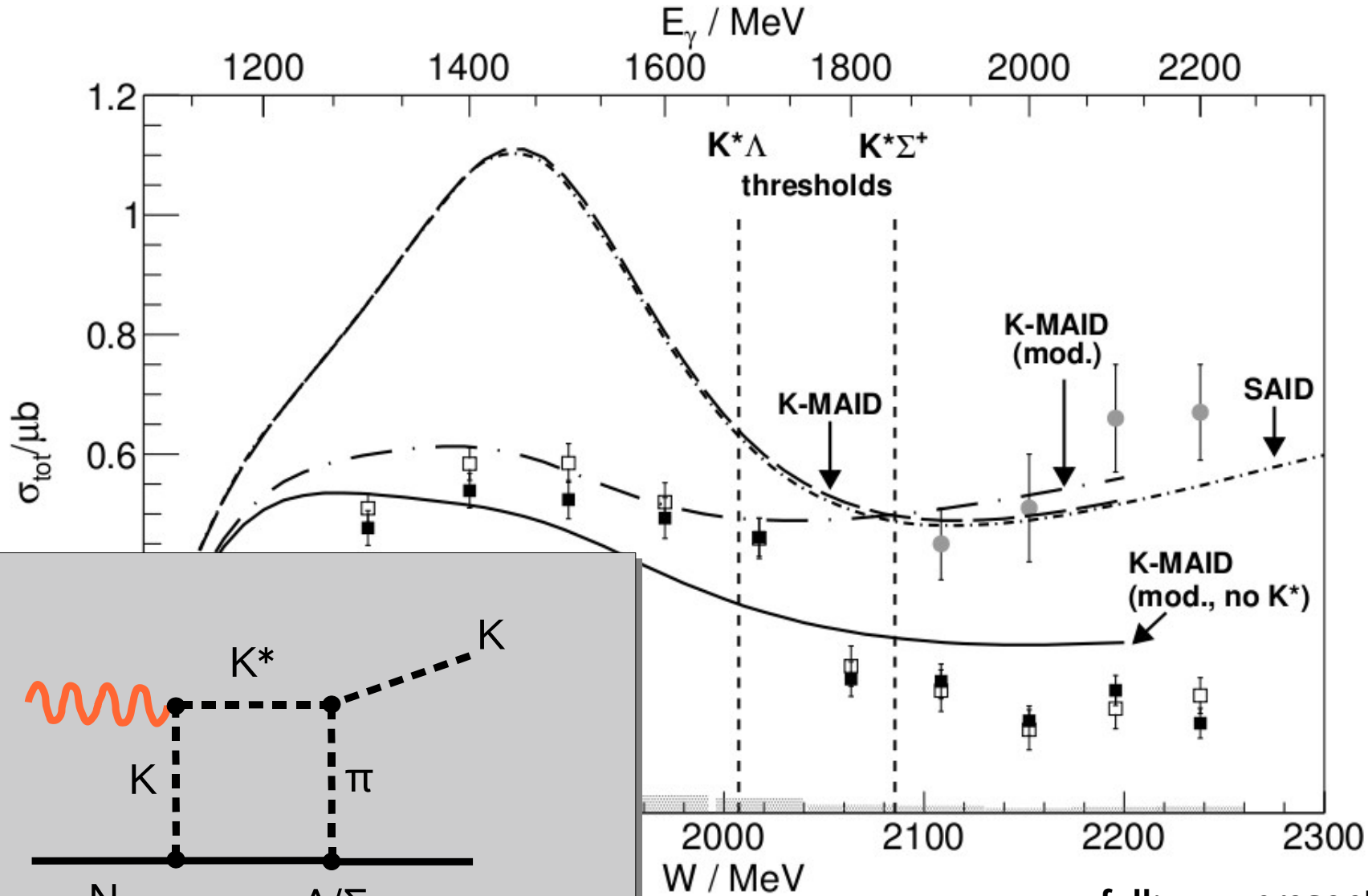
total cross section

R. Ewald et al., PLB 713 (2012)



total cross section

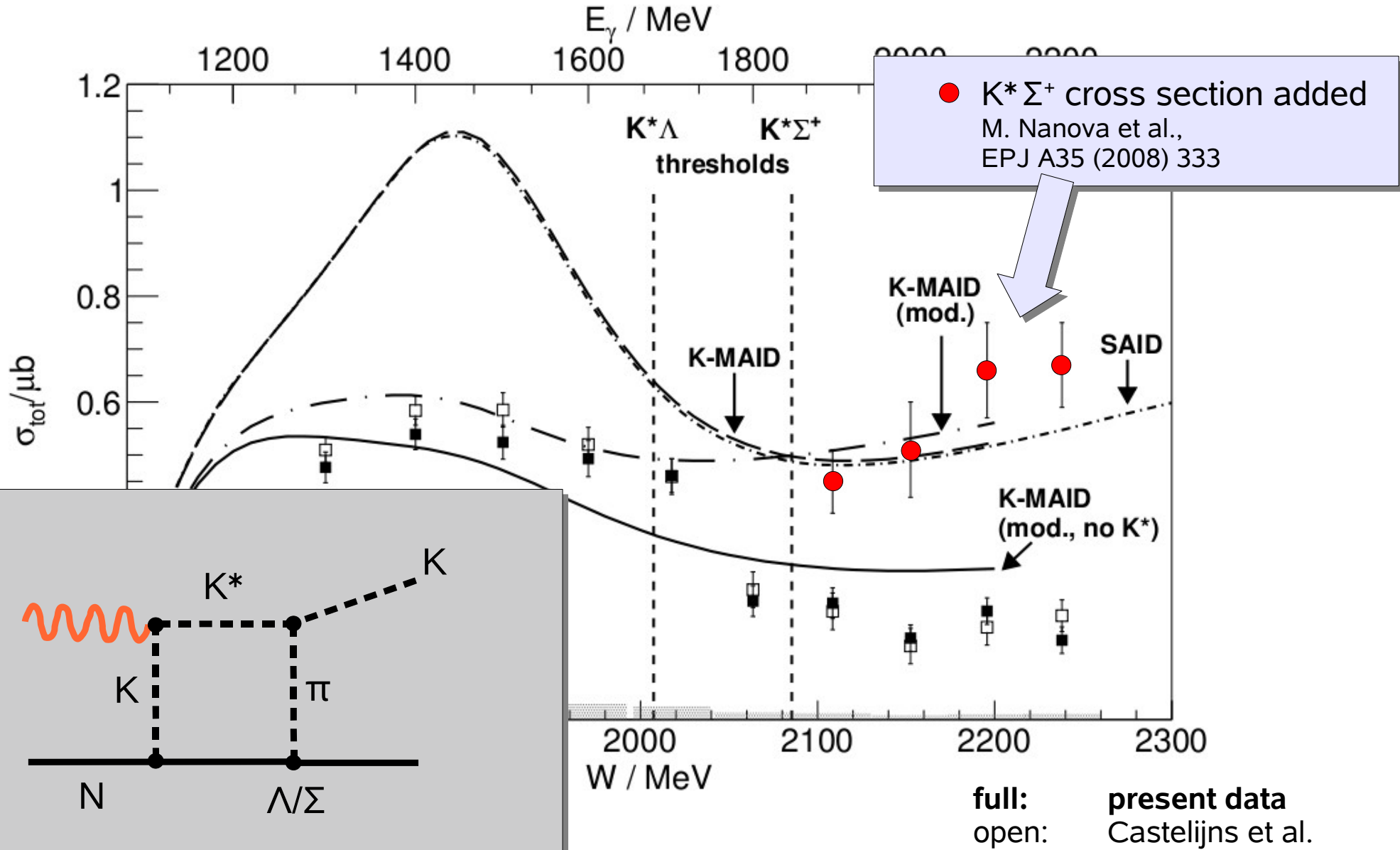
R. Ewald et al., PLB 713 (2012)



full: present data
open: Castelijns et al.

total cross section

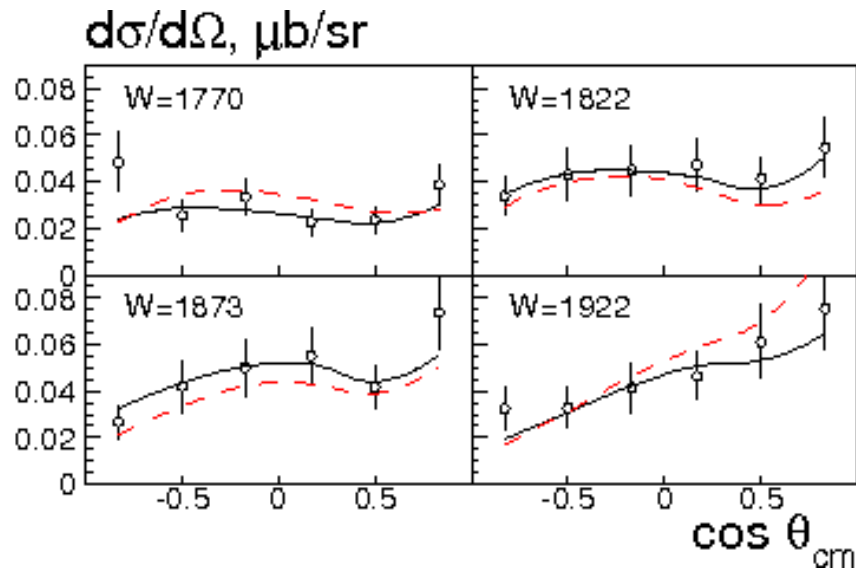
R. Ewald et al., PLB 713 (2012)



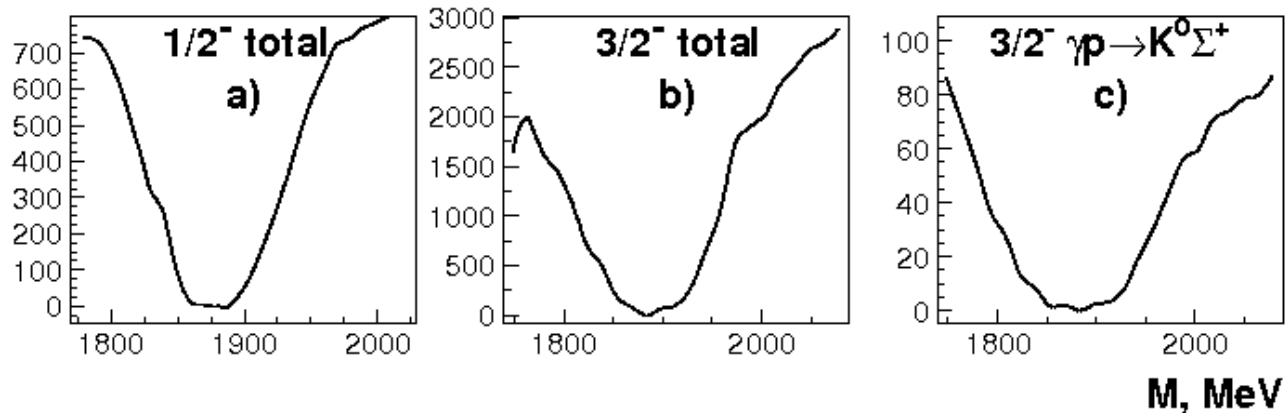
Interpretation

BoGa PWA

A.V. Anisovich et al., Phys. Lett. B 711 (2012) 162



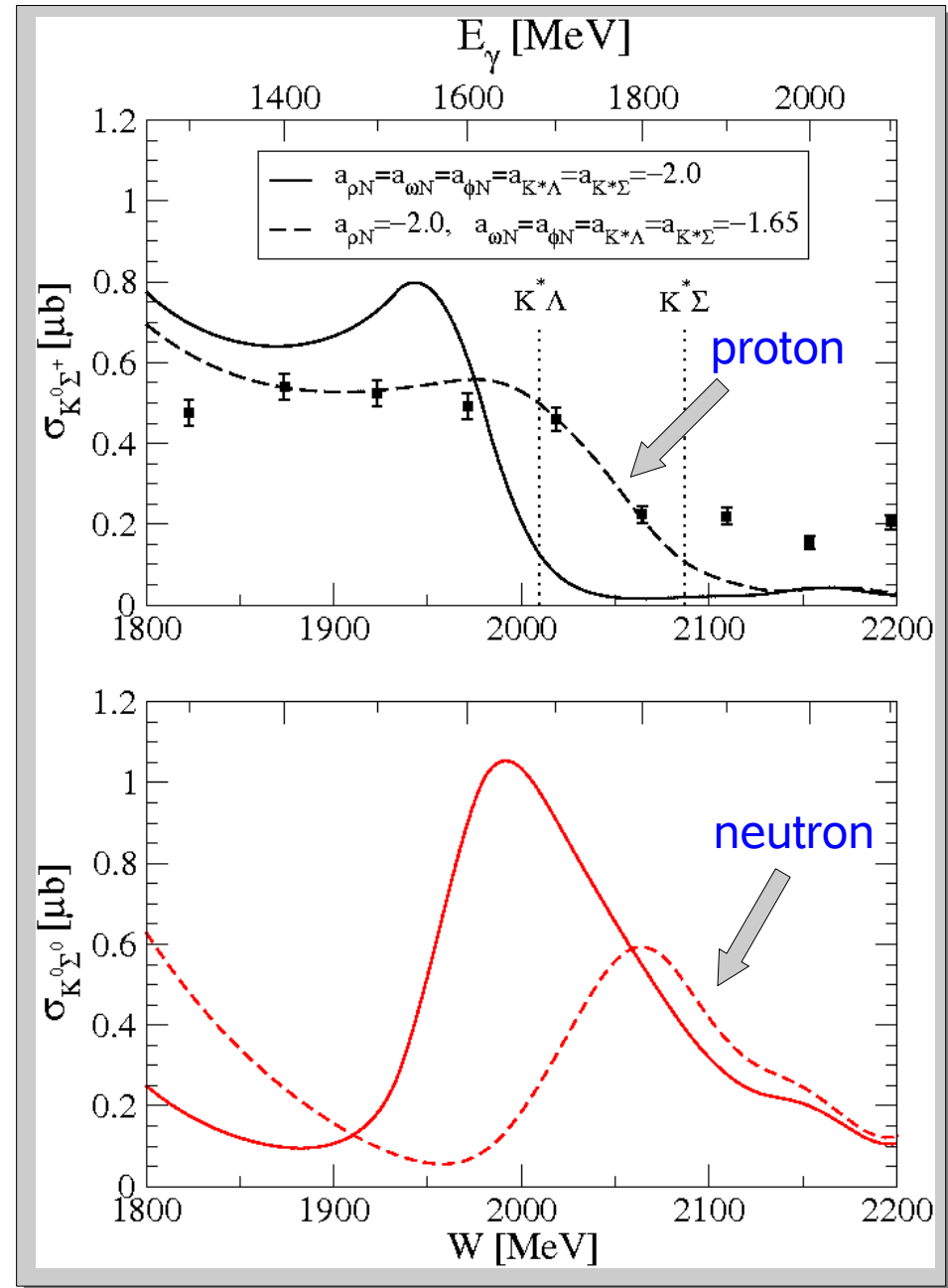
- resonances indicated below 2000 MeV
 $N_{1/2^-}$ (1895) & $N_{3/2^-}$ (1875)
- → parity doublets with
 $N_{1/2^+}$ (1875) & $N_{3/2^+}$ (1900)
- E. Klempt's idea:
 “missing” res's
 ↔ complete SU(6) multiplets ??



Interpretation

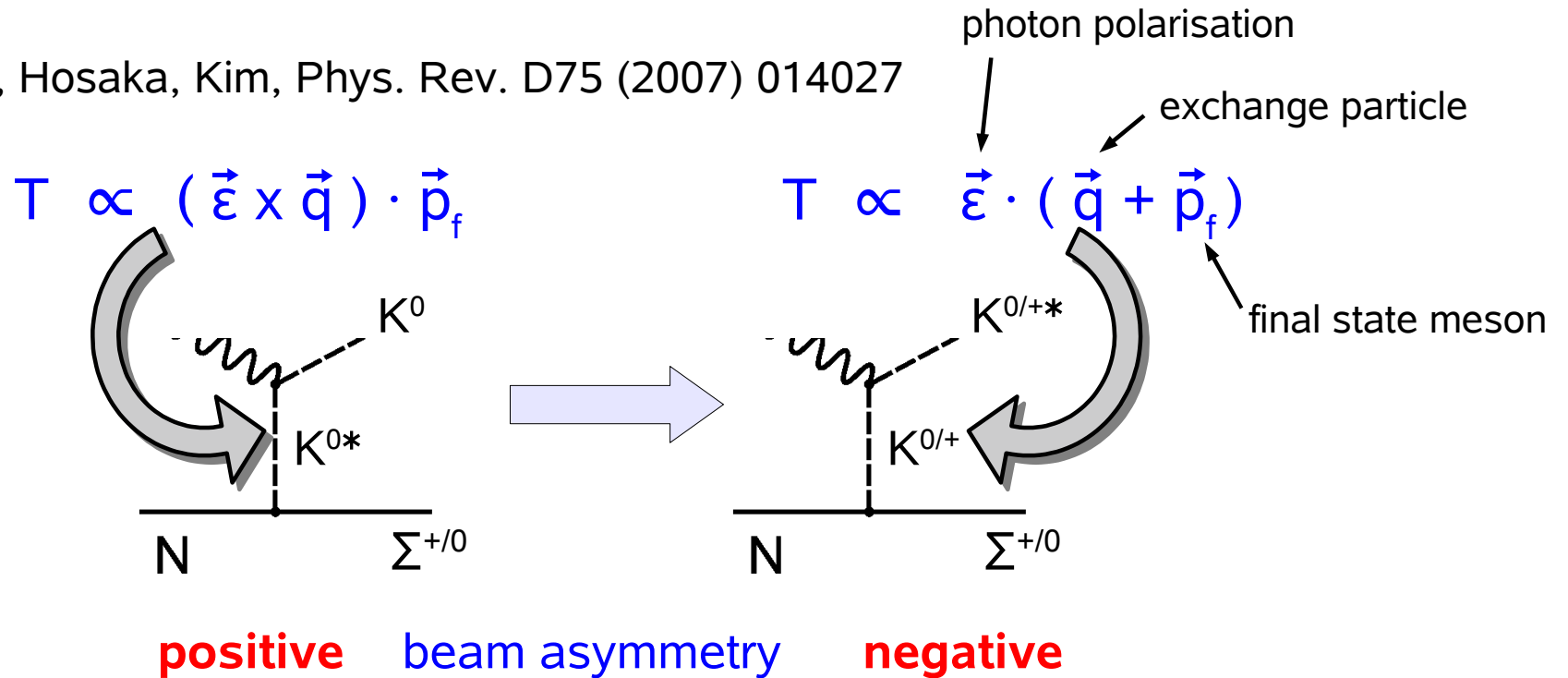
A. Ramos & E. Oset, arXiv: 1304.7975

- vectormeson-baryon dynamics
- structure \leftrightarrow $N^*(2080)(3/2^-)$ / $N^*(2090)(1/2^-)$
[removed from PDG]
- delicate interference $K^*\Lambda$ / $K^*\Sigma$ channels
- $\rightarrow K^0 \Sigma^0$ off neutron target
- ω photoproduction ??
- K^0 beam asymmetry ??



Results: Photon Beam Asymmetry

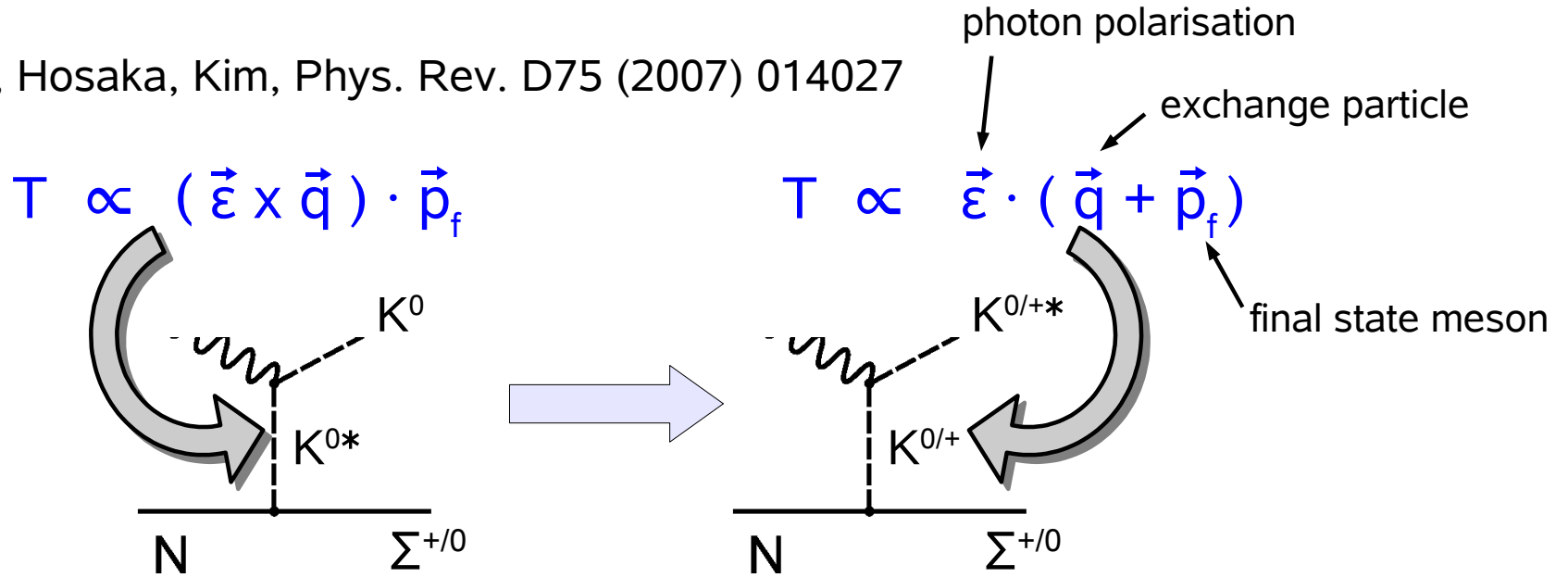
Nam, Choi, Hosaka, Kim, Phys. Rev. D75 (2007) 014027



$$\Sigma = \frac{\sigma_{\perp} - \sigma_{\parallel}}{\sigma_{\perp} + \sigma_{\parallel}}$$

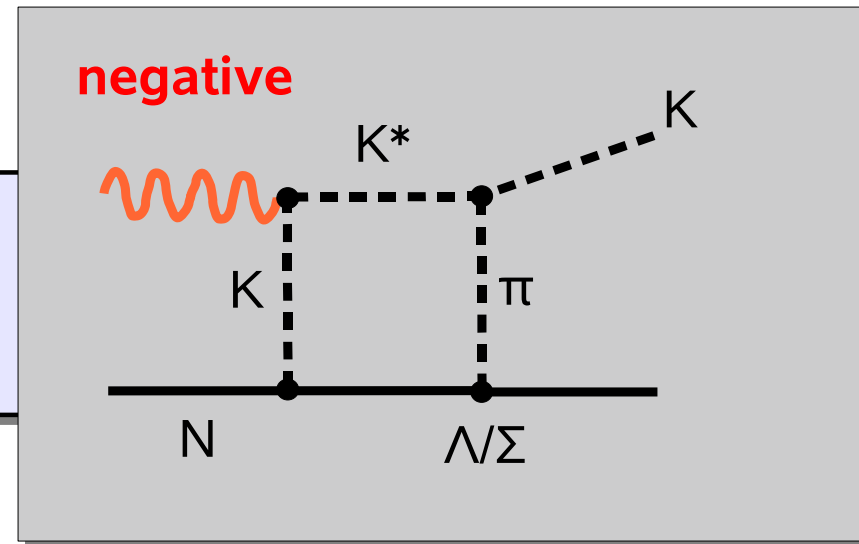
Results: Photon Beam Asymmetry

Nam, Choi, Hosaka, Kim, Phys. Rev. D75 (2007) 014027

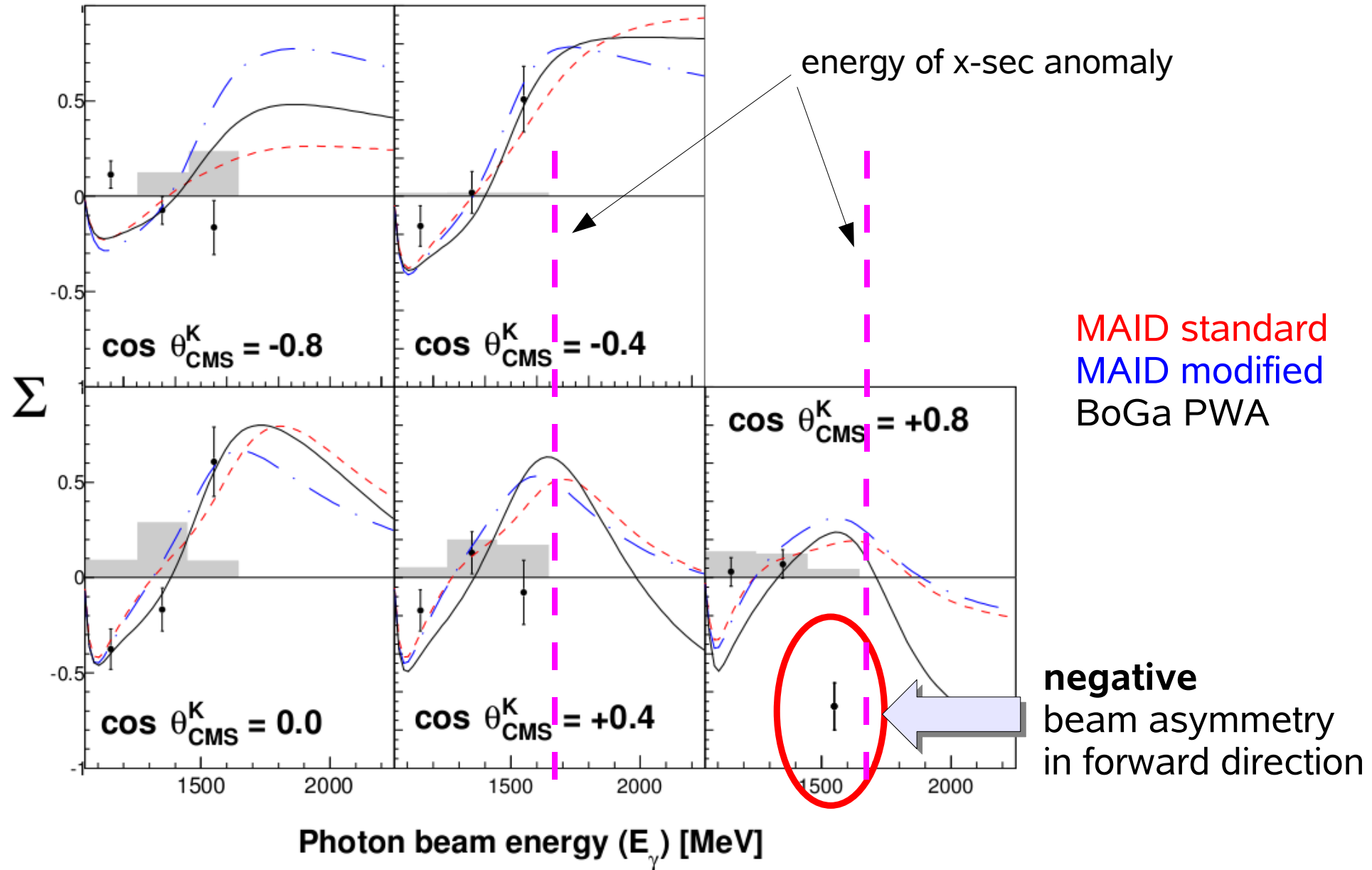


positive beam asymmetry

$$\Sigma = \frac{\sigma_{\perp} - \sigma_{\parallel}}{\sigma_{\perp} + \sigma_{\parallel}}$$

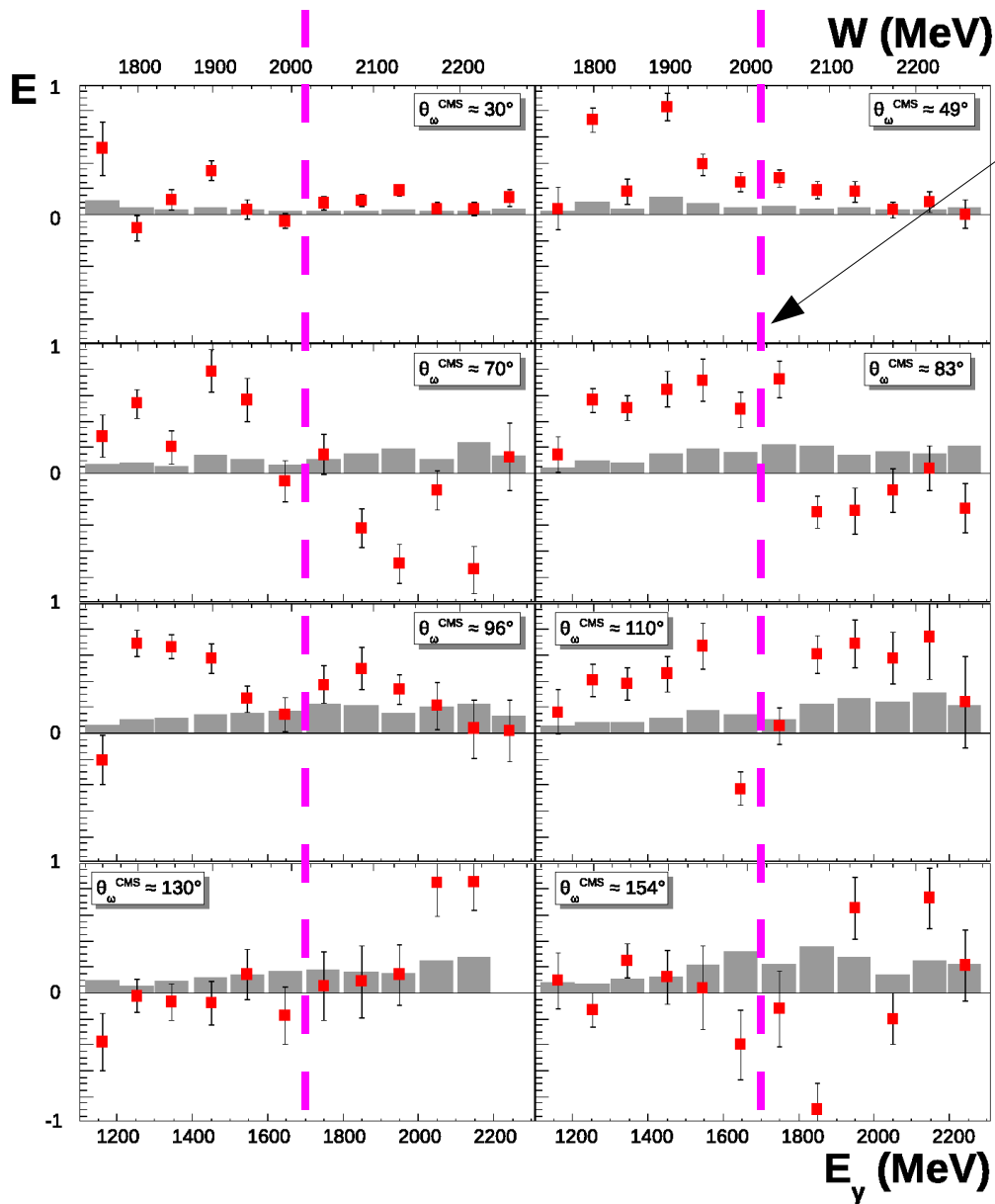


Results: Photon Beam Asymmetry

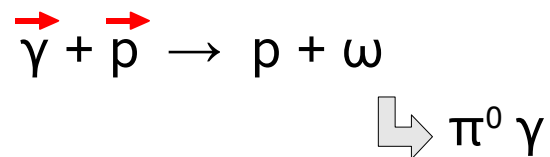


ω photoproduction: beam-target asymmetry

H. Eberhardt, Dr. thesis (2012)



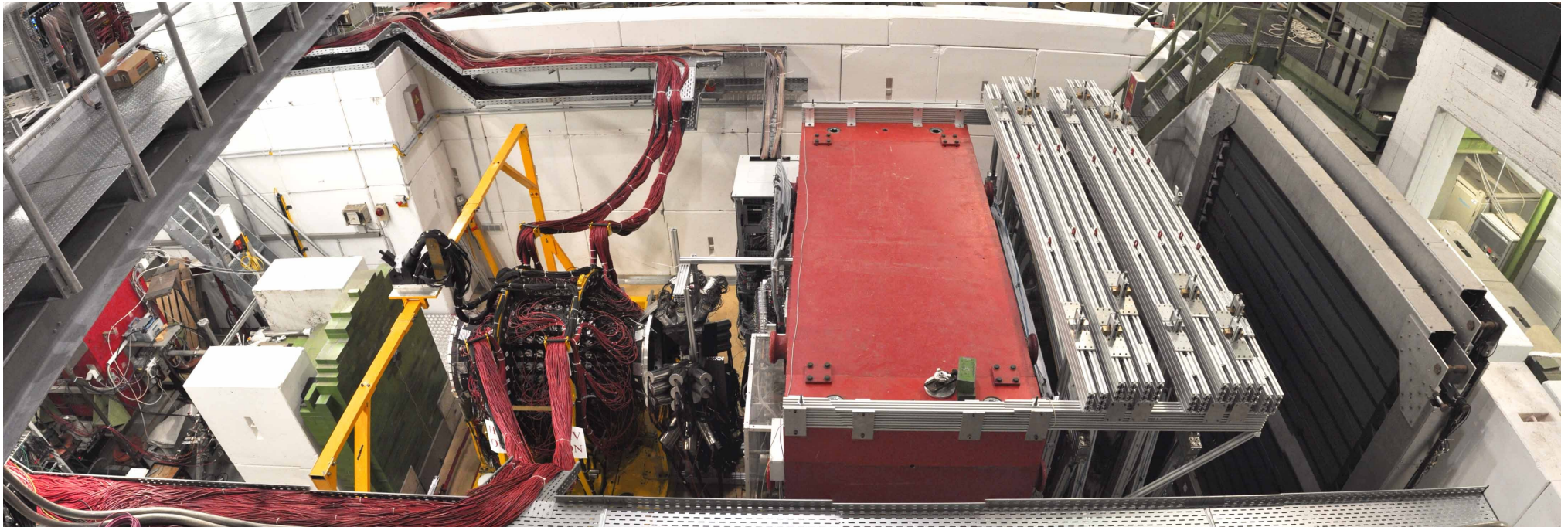
energy of x-sec anomaly
in $K^0\Sigma^+$ channel



BGO-OD experiment @ ELSA

- low-t to investigate meson-baryon components
- → forward angles / acceptance
- BGO-OD setup
 - high-res. forward detector
 - hermetic crystal calorimeter
- complementary to CB, CLAS, LEPS

$$\begin{array}{l} K_S^0 \rightarrow \left\{ \begin{array}{ll} \pi^0 \pi^0 & 31 \% \\ \pi^+ \pi^- & 67 \% \end{array} \right. \\ \omega \rightarrow \left\{ \begin{array}{ll} \pi^0 \gamma & 8.5 \% \\ \pi^+ \pi^- \pi^0 & 89 \% \end{array} \right. \end{array}$$



BGO-OD experiment

TOF walls
Horizontal & vertical bars 20cm wide, 3m long
Time res < 1ns

Drift Chambers
8 chambers, 2 layers each
x, y, u (+9 deg), v (-9 deg)
8.5 mm drift cell radius

SciFi
2 layers of 288 (x) and 352 (y) fibres,
3mm diameter, 90 deg rotation
66 x 51 cm, $\Delta t \sim 2$ ns

MOMO
3 layers of 244 fibres,
60 deg rotation.
Spatial resolution ~ 1.5 mm

BGO Ball
480 $\text{Bi}_4\text{Ge}_3\text{O}_{16}$ crystals
25 – 155 degrees
Internal plastic scintillator
& MWPC
for particle tracking

Cu/crystal radiator

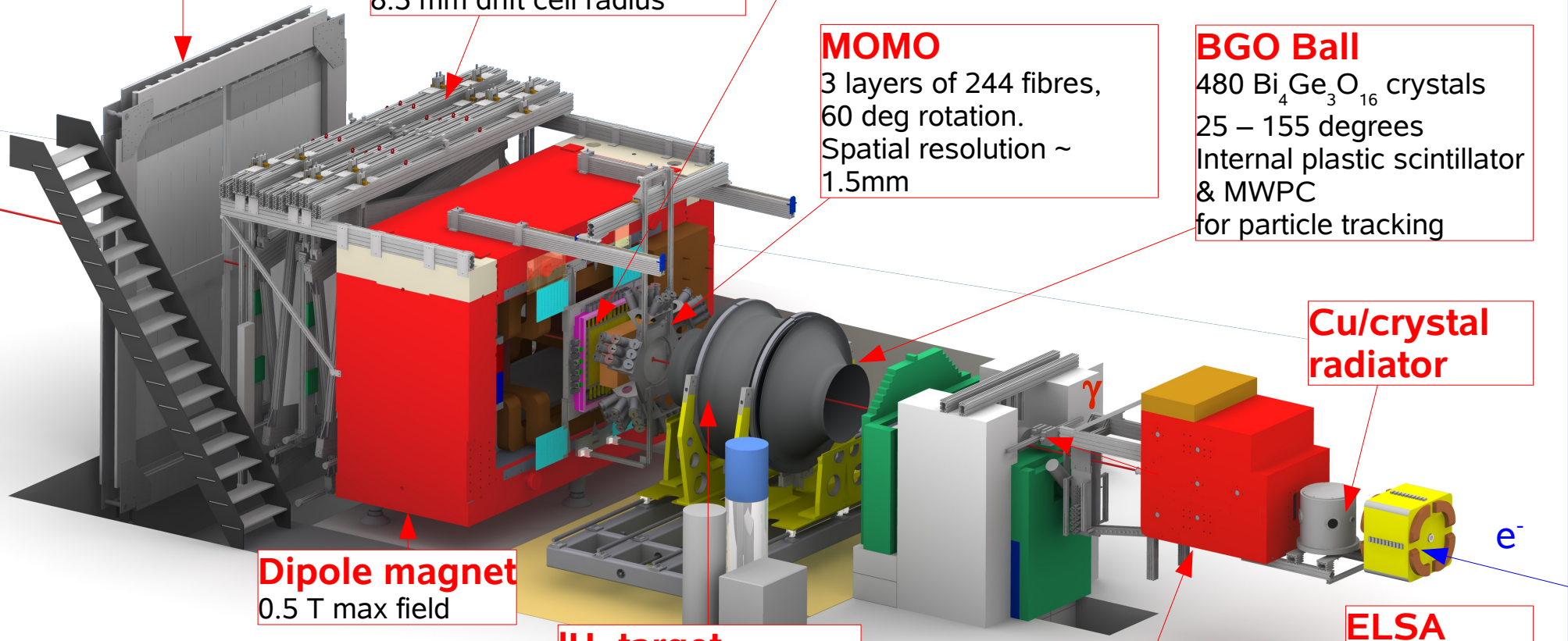
Dipole magnet
0.5 T max field

IH₂ target
Centre of BGO Ball

Photon Tagger
120 channels, 10-90% of e⁻
energy spectrum - linear and
circularly polarised photons

ELSA
e⁻ beam
< 3.5 GeV

Forward spectrometer
+/- 8 deg (vertical), +/- 10 deg
(horizontal) acceptance



Conclusions

- ◆ photoproduction of $K^0_s \Sigma^+$ off protons
- ◆ differential and total cross sections with full angular coverage & flat acceptance [R. Ewald et al., PLB 713 (2012)]
- ◆ beam asymmetry Σ (and recoil polarisation)
- ◆ indication for “cusp-like” structure in cross section in forward directions between $K^* \Lambda / \Sigma$ thresholds
- ◆ visible also in total cross section
- ◆ smooth transition t- / s-channel
- ◆ dominant $1/2^-$ & $3/2^-$ waves in PWA
- ◆ **$K^* - Y$ quasibound state** ? \leftrightarrow **hint also from beam asymmetry**
- ◆ dynamically generated states: vectormeson nonet x baryon octet
 - Oset & Ramos, EPJ A 44 (2010) 445
 - Ramos & Oset, arXiv:1304.7975
 - ↳ K^0 off neutron target !
 - ↳ photon beam asymmetry
 - ↳ ω channel

THANKS

DFG SFB/TR-16

Federal State of Northrhine-Westphalia

data analysis: doctoral thesis [Ralf Ewald](#)

Oliver Jahn & Tom Jude