Strangeness photoproduction at the BGO-OD experiment

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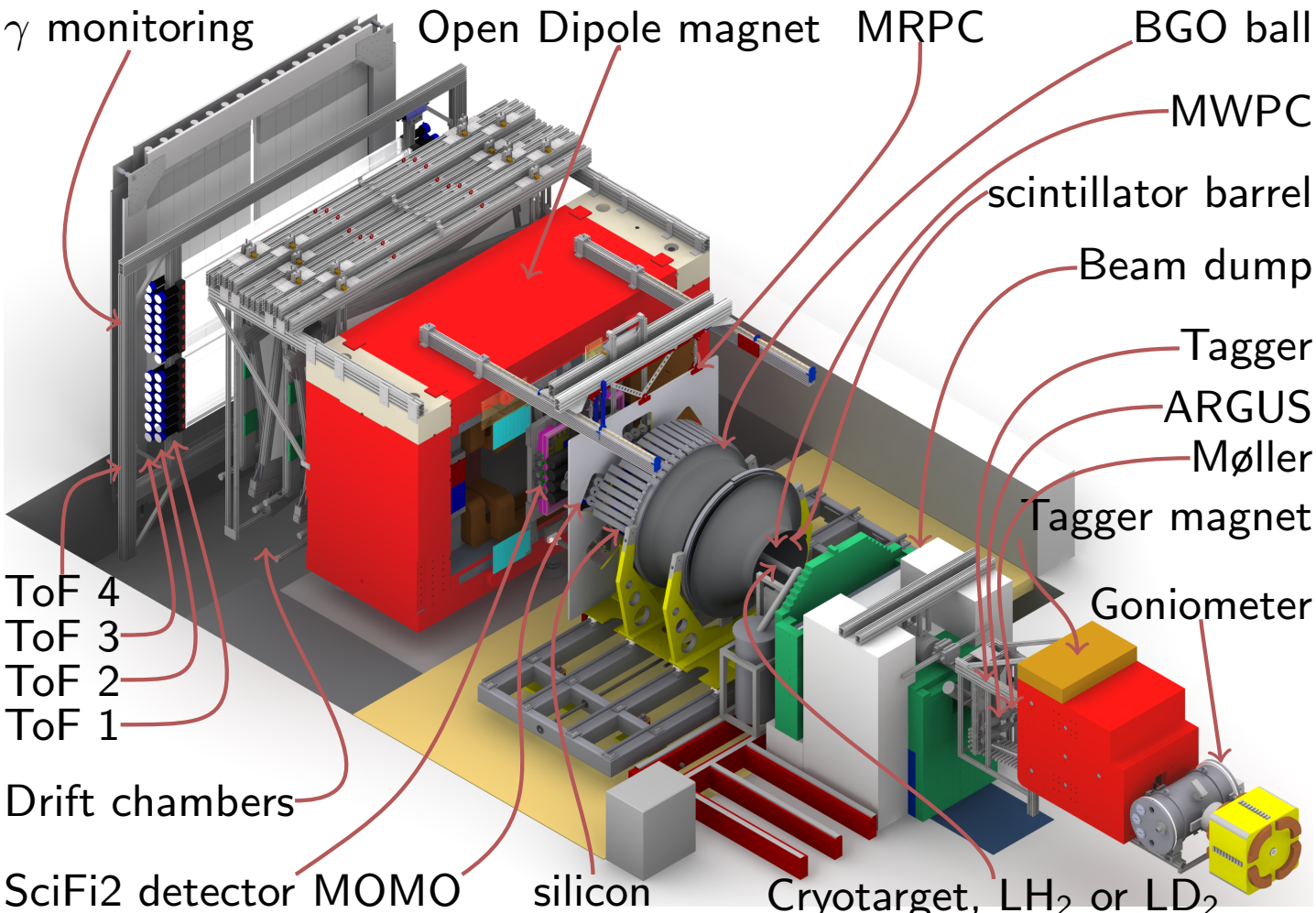
Supported by the DFG / SFB tr-16

NSTAR 2015

The BGO-OD experiment at ELSA

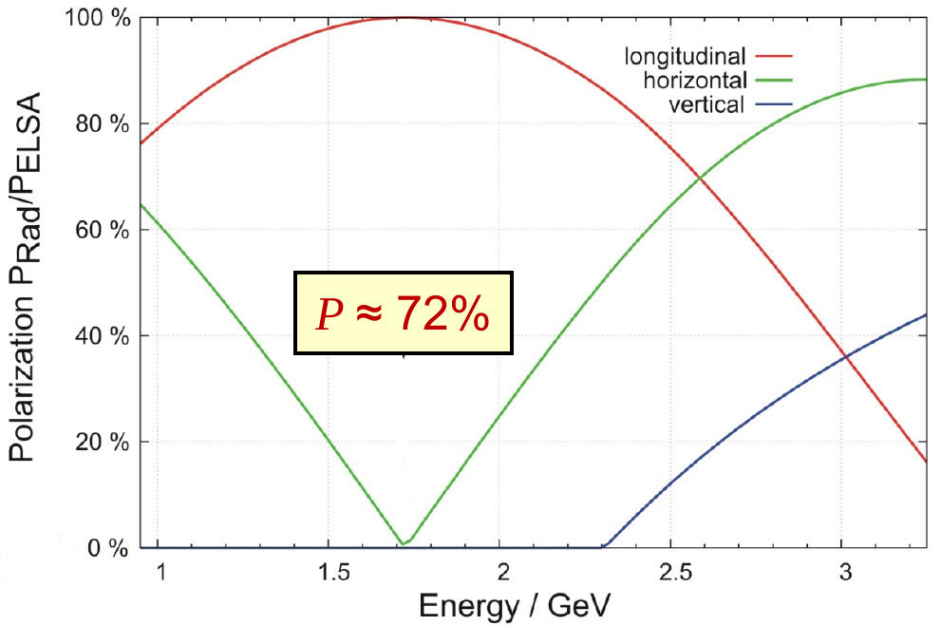
- Energy tagged bremsstrahlung photon beam up to 3 GeV
- BGO calorimeter (central region) & Forward Spectrometer combination
- High momentum resolution, excellent charged and neutral particle ID



Incident photon beam parameters

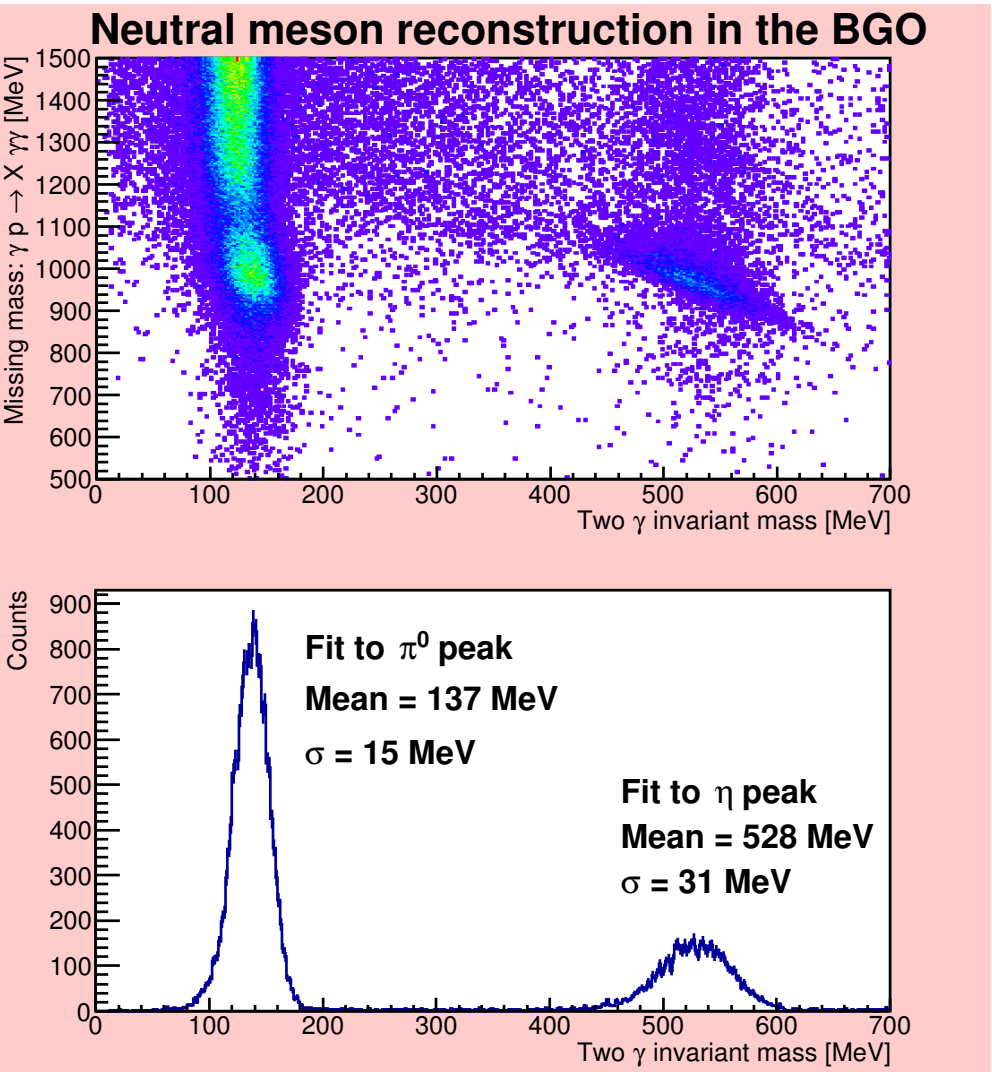
- ELSA e^- beam $\leq$ 3.5 GeV, BGO-OD experiment - Tagged γ beam $\leq$ 3 GeV
- Current $\leq$2 nA (ideal for tagged photon beam), 10 nA upgrade planned
- Linearly polarised γ beam - coherent bremsstrahlung using a diamond radiator
- Circularly polarised γ beam - ELSA achieves full spin rotation maximum polarisation at E_e ~1.7 GeV ($W \sim 2$ GeV)

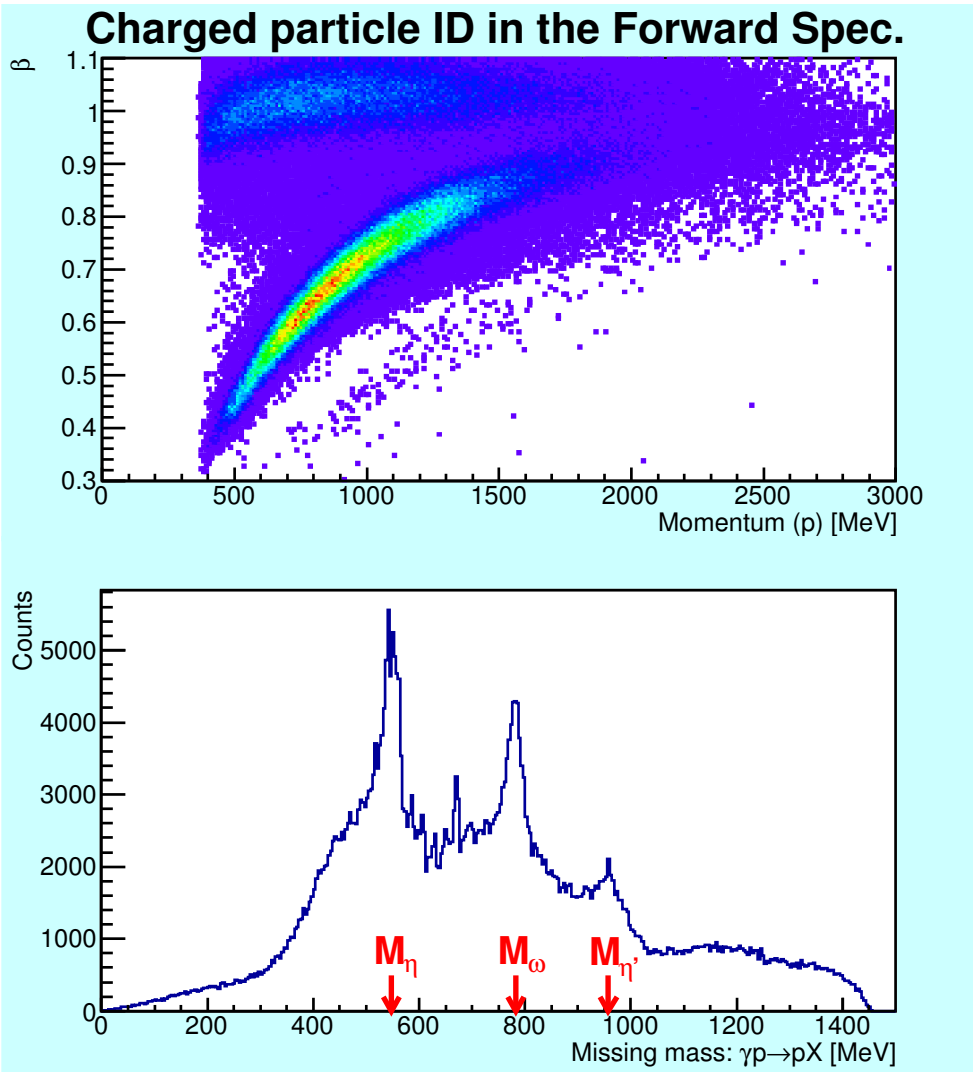
- Energy region of unresolved/missing resonances
- K^*Y thresholds
- ω and η' thresholds
- Non-understood "bump" structure in ϕ photoproduction



Analysis overview (Preliminary Data)

- Example of recent commissioning data (preliminary calibrations)
- $E_{e^-} = 2.9$ GeV, linearly polarised beam





Strangeness Photoproduction - Physics Motivation

- Acceptance at forward angles with BGO-OD - ideal for dominantly t-channel exchange mechanisms
- Identify final states of mixed charge - investigation of Y^* resonances, eg $K^+\Lambda(1405) \rightarrow K^+\pi^0\Sigma^0 \rightarrow K^+\pi^0\gamma\Lambda \rightarrow K^+\gamma\gamma\gamma p\pi^-$

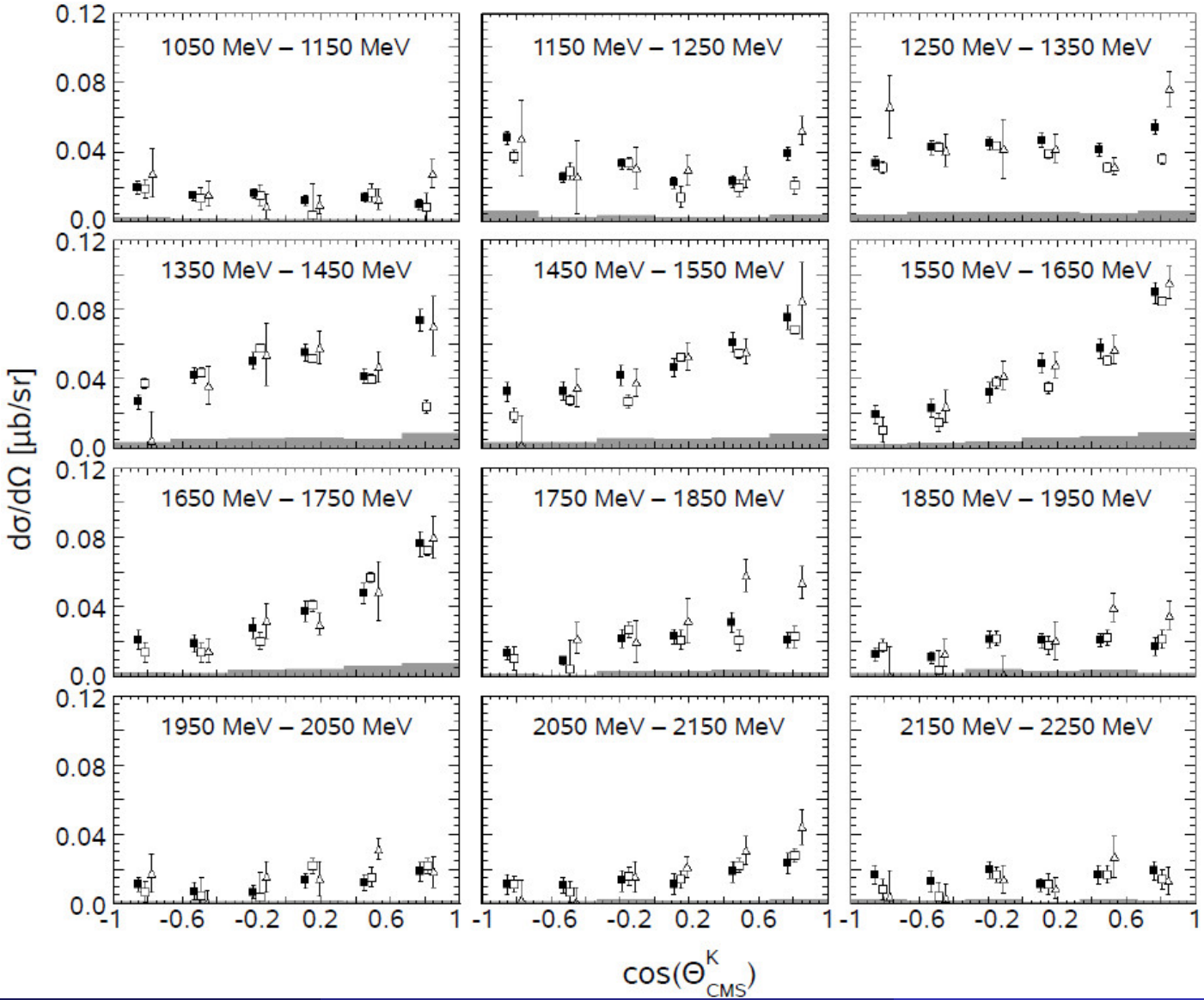
Differential cross sections & polarisation observables

- $K^+\Lambda$, $K^+\Sigma^0$
- $K^+\Sigma^*$ states
- $K^0\Sigma^+$
- $K^0\Lambda$ (deuteron target)

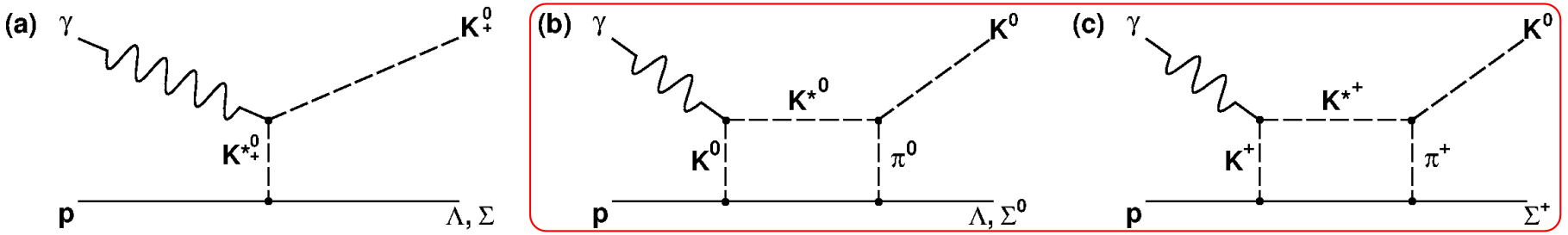
- Intense production beam times starting now

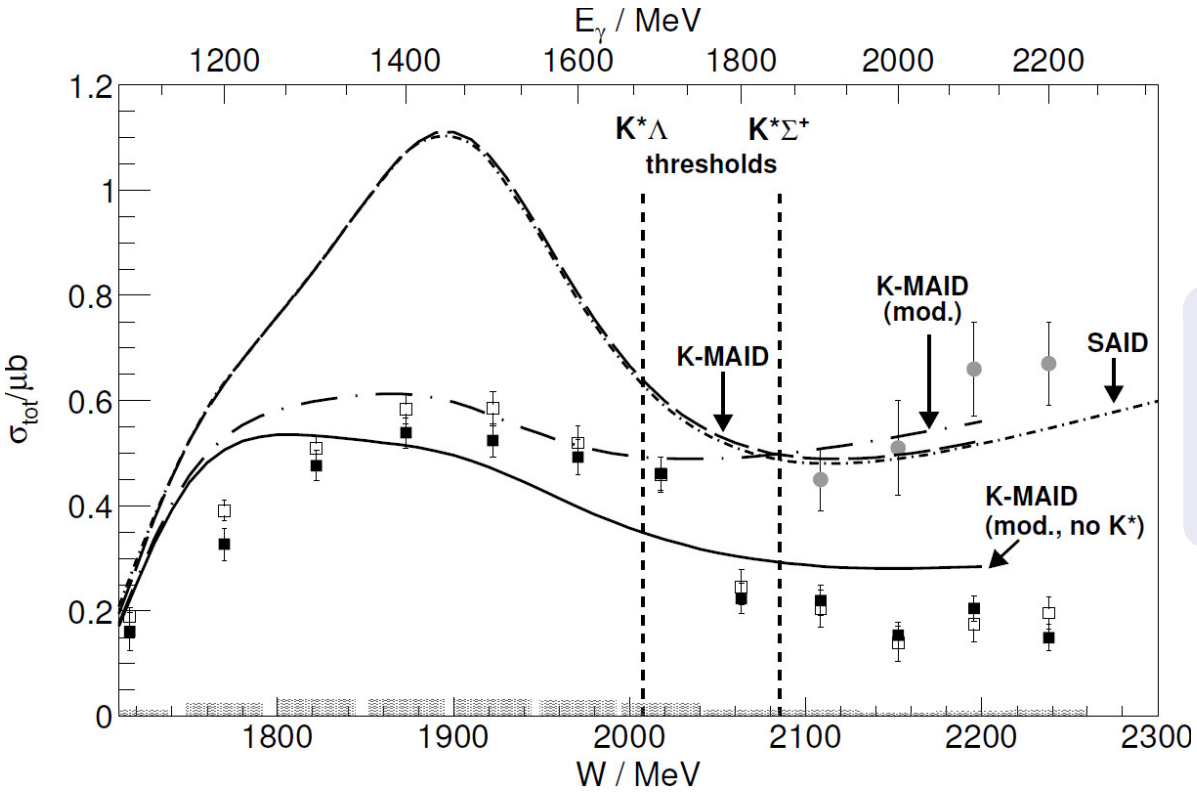
Previous $\gamma p \to K^0\Sigma^+$ measurements

R. Ewald *et al.*,Phys. Lett. B 713 (2012) 180 (CBELSA/TAPS Collaboration)



Previous $\gamma p \to K^0\Sigma^+$ measurements





Cusp structure due to K^{*0} subthreshold production rescattering to π^0 & K^0?

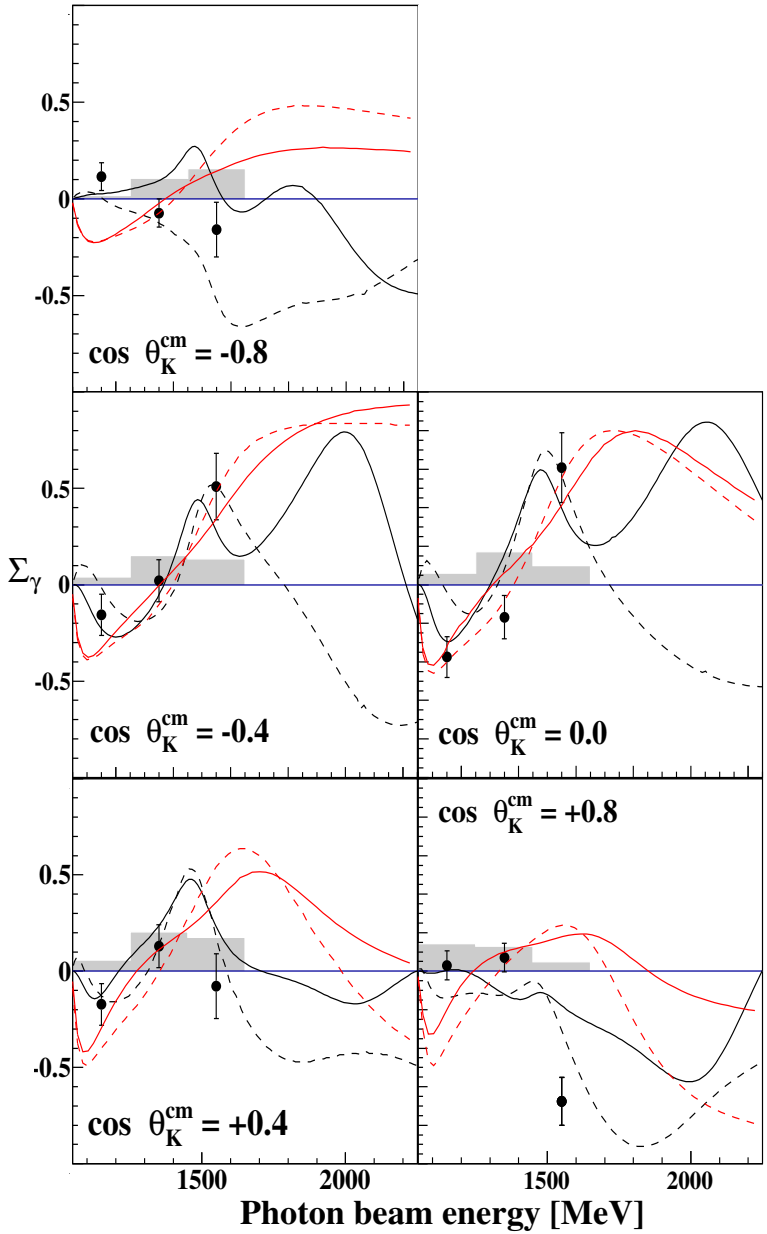
Previous $\gamma p \to K^0\Sigma^+$ measurements

- The 1st beam asymmetry measurement
  R. Ewald *et.al*, PLB 738 (2014) 268
  (CBELSA/TAPS Collaboration)

Black line - Bonn-Gatchina solution (BG2011-02)
Black dashed - BG2011-02m (includes this Σ data & CLAS P data)
Red line - Kaon-MAID
Red dashed- Kaon-MAID modified (K^* t-channel switched off)

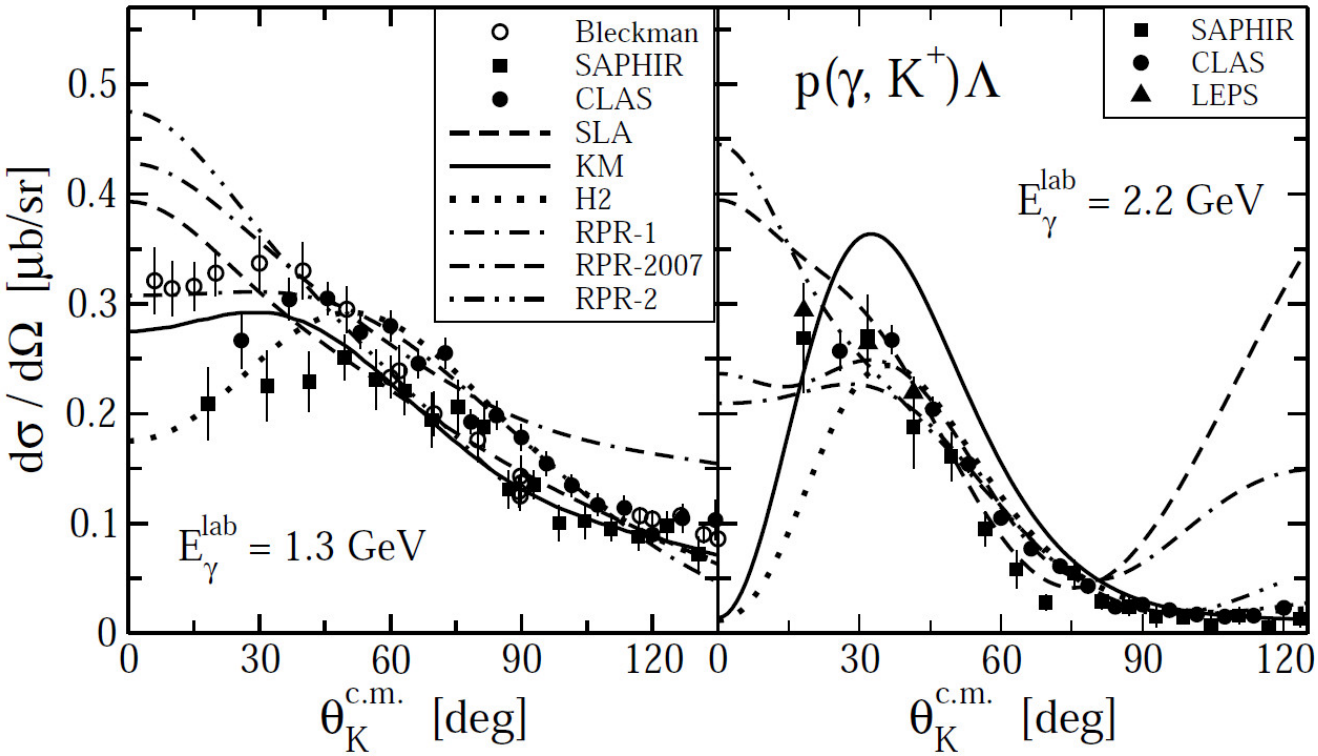
BGO-OD Proposal

- Extend the range of Σ over the cusp structure (1700-1800 MeV)
- Identify charged & neutral decay modes (higher stats.)
  - $K^0 \to \pi^0\pi^0$, $\Gamma = 31\%$
  - $K^0 \to \pi^+\pi^-$, $\Gamma = 69\%$
  - $\Sigma^+ \to p\pi^0$, $\Gamma = 52\%$
  - $\Sigma^+ \to n\pi^+$, $\Gamma = 48\%$



Strangeness photoproduction with BGO-OD

- $\gamma p \rightarrow K^+\Lambda$ - cover important range at forward angles & disputed peak structure at $W = 1900$ MeV



Bydzovsky and D. Skoupil, arXiv:1211.2684v1 (2012) Proceedings of SNP12

- Many Y^* states poorly established & CQM do not explain hyperon spectrum
- Hadronic molecules - predict new Y^* states, eg Σ^* close to $\Sigma(1385)$

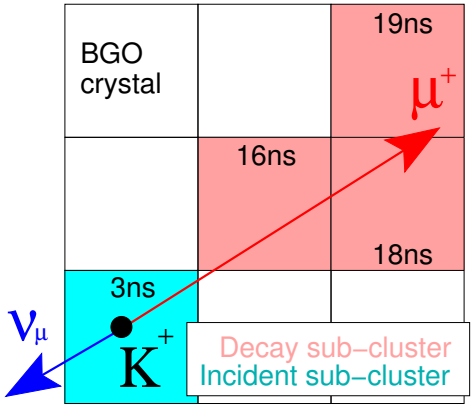
B. S. Zou, Eur. Phys. J. A 35 (2008) 325 & Jia-Jun Wu, S. Dulat & B. S. Zou, Phys. Rev. D 80 (2009) 017503

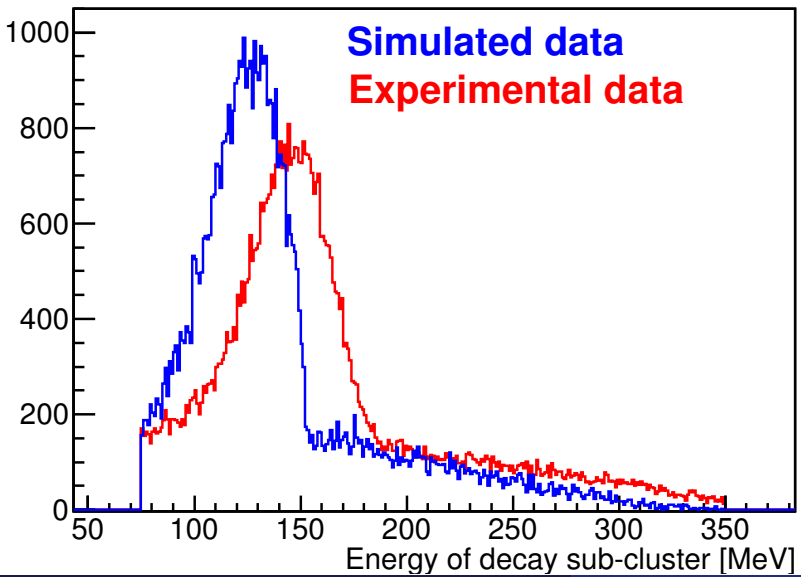
K^+ identification in the BGO

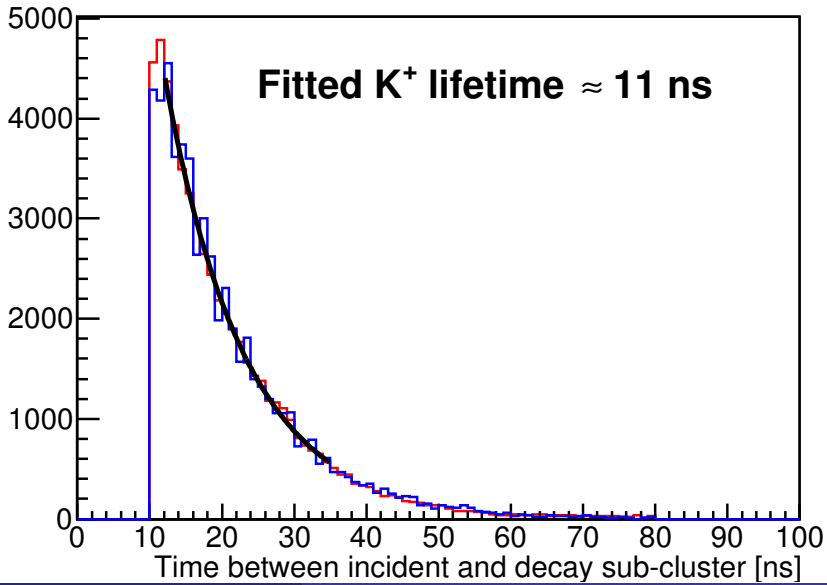
- Time delayed, K^+ weak decay within the crystals of the BGO ball
- T.C Jude, D.I. Glazier, D.P. Watts, PLB, 735 (2014) 112

Lifetime 12 ns,
2 main decay modes:

$$K^+ \rightarrow \mu^+ \nu_\mu$$
$$K^+ \rightarrow \pi^+ \pi^0$$

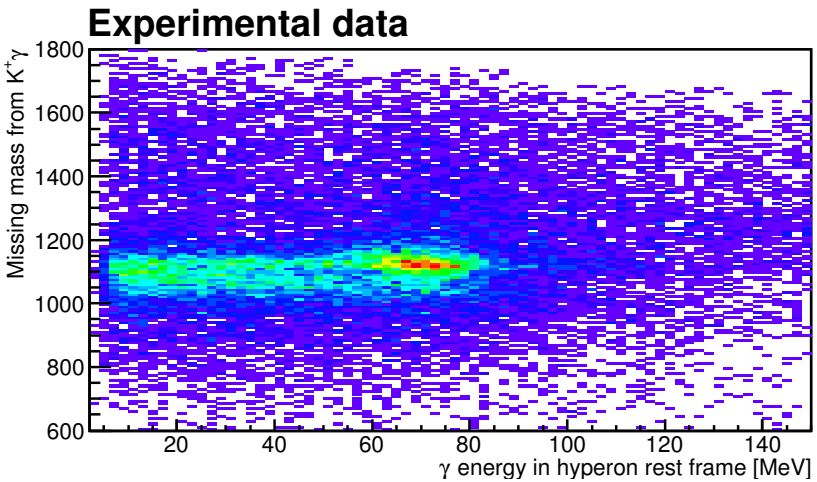


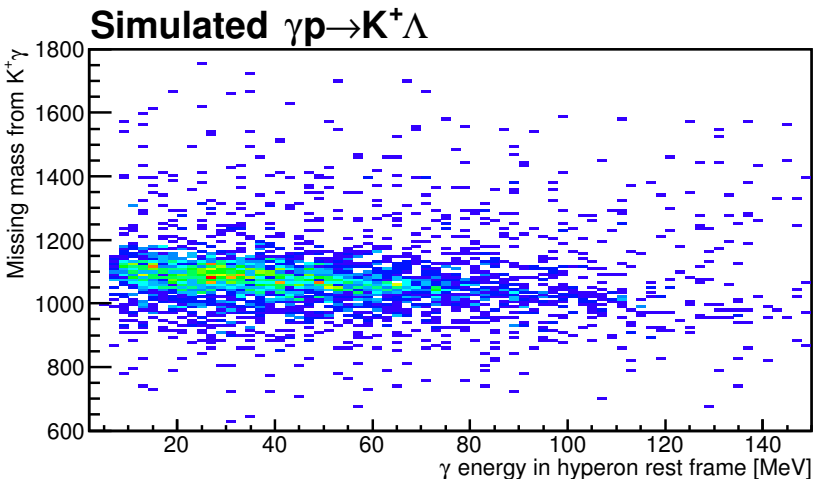


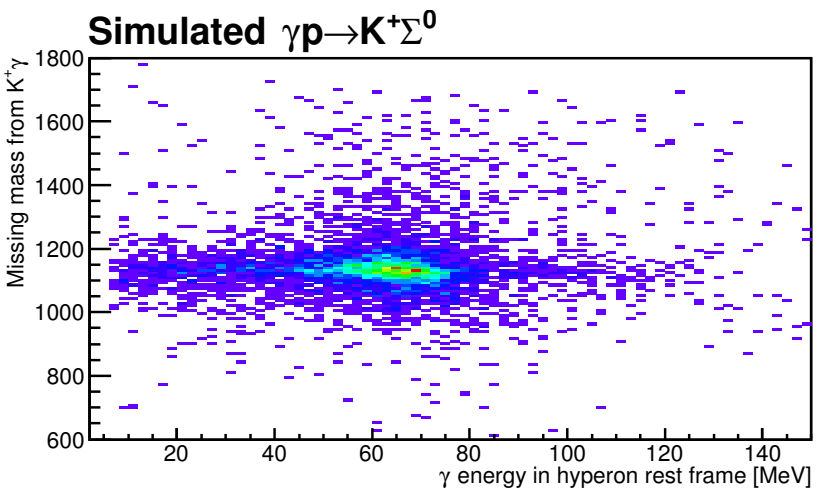


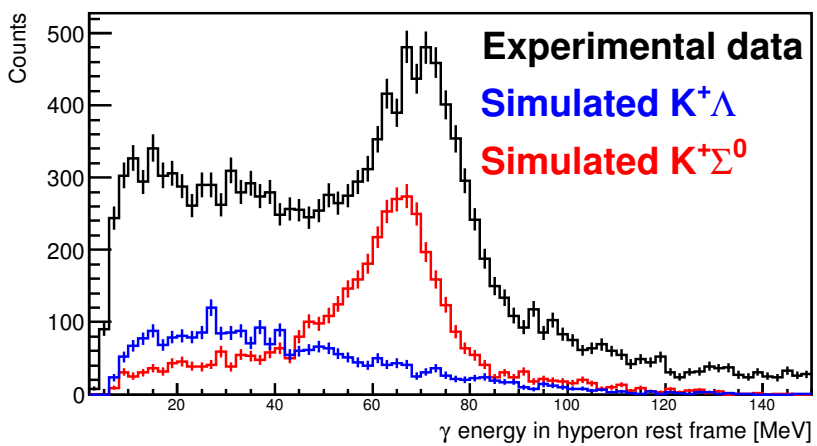
Identifying the $\Sigma^0 \to \Lambda\gamma$ decay

- Boost all neutral particles in the BGO into missing hyperon rest frame
- If $K^+\Sigma^0$:
  - Missing mass from $K^+\gamma$(lab frame) $= M_\Lambda = 1116$ MeV (Y axis)
  - γ energy (hyperon rest frame) $= M_{\Sigma^0} - M_\Lambda = 77$ MeV (X axis)



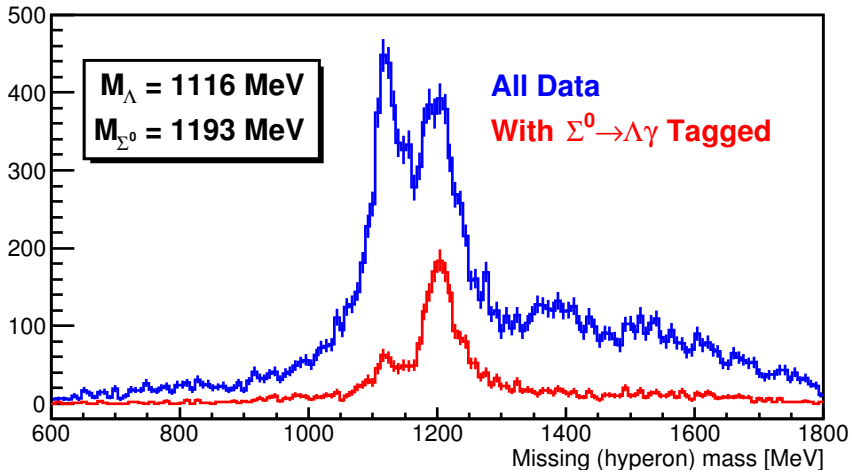


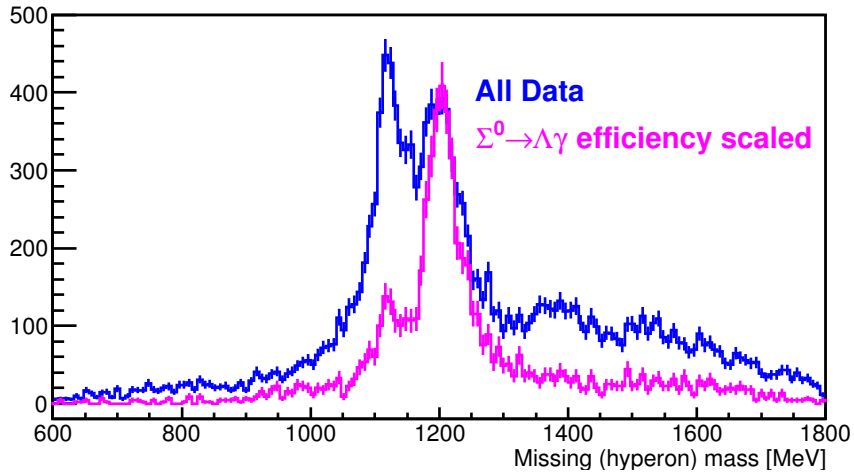


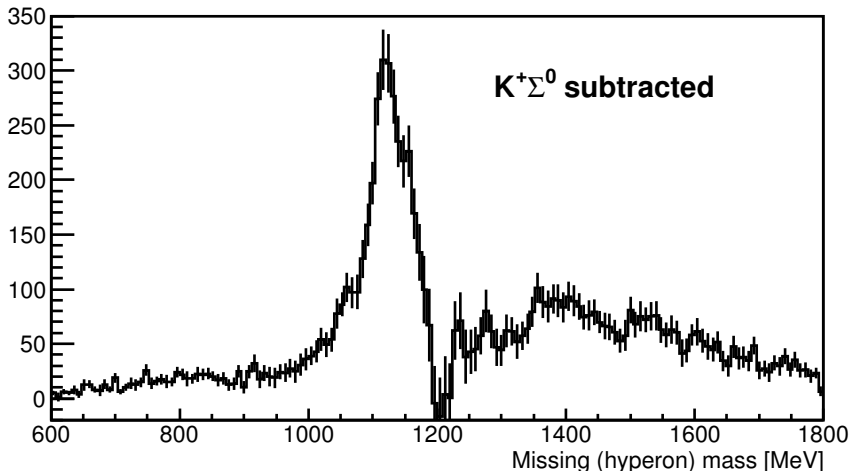


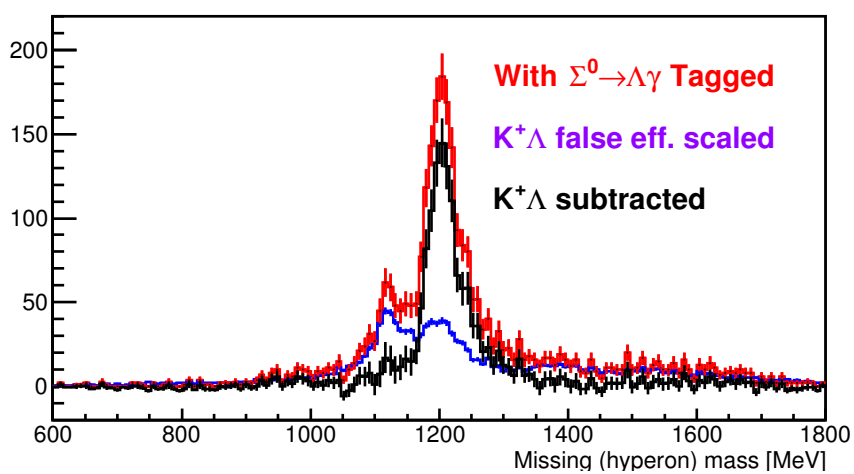
Missing hyperon masses from K^+ detection in the BGO

- Data subset where $\Sigma^0 \to \Lambda\gamma$ is tagged
- $\Sigma^0 \to \Lambda\gamma$ detection efficiency from sim. ($\sim 60\%$, $K^+\Lambda$ "false" eff. $< 10\%$)
- Scale data by efficiency - separate $K^+\Lambda$ and $K^+\Sigma^0$



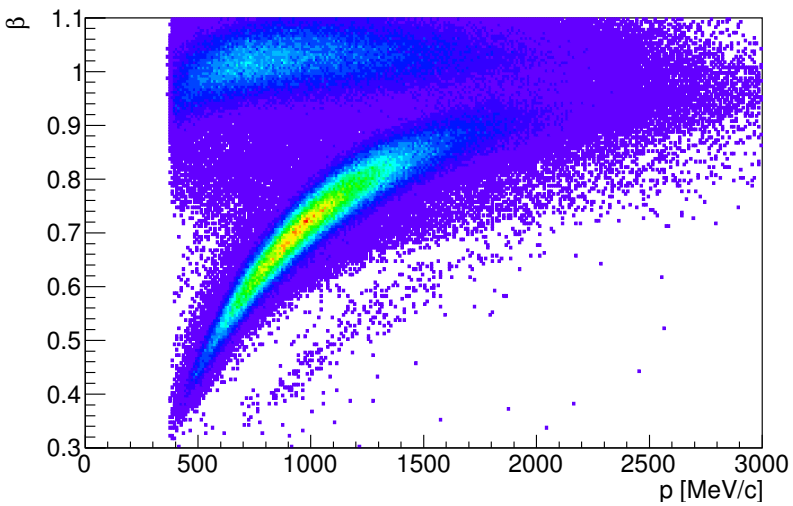






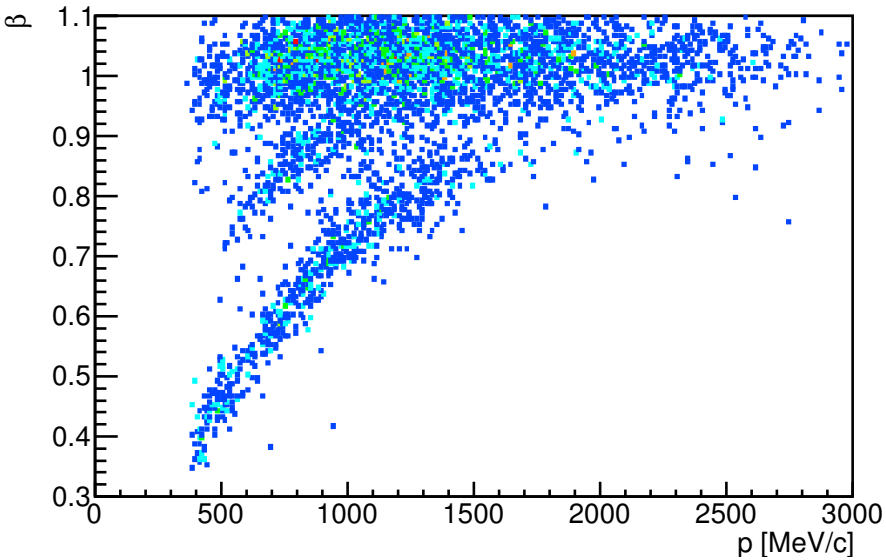
K^+ identification in the forward spectrometer

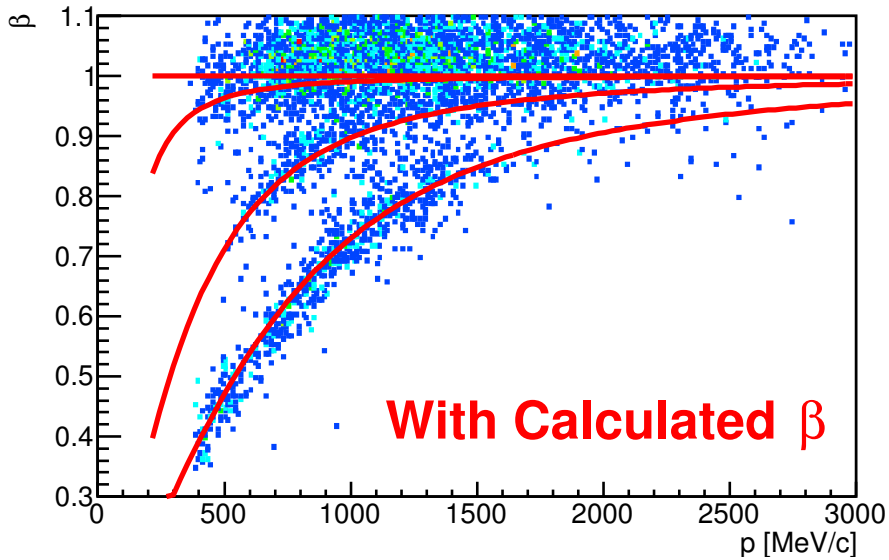
β determined from momenta measured in the forward spectrometer
Characteristic loci of protons & $\pi^{\pm} \rightarrow$



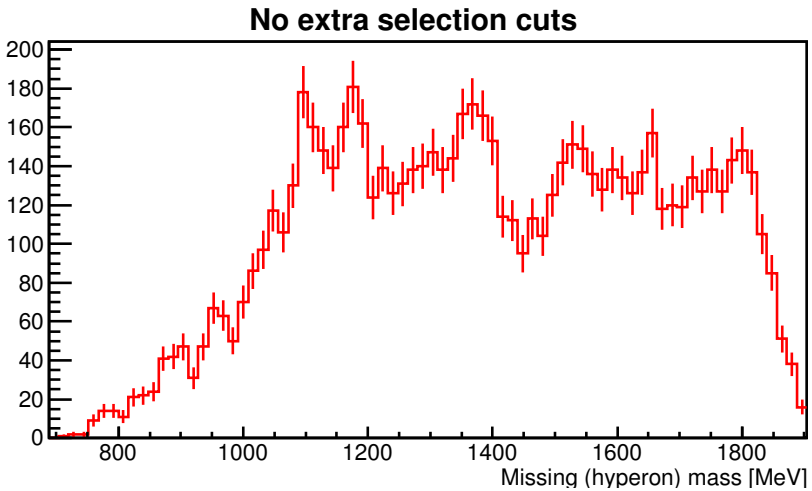
To enhance K^+ signal

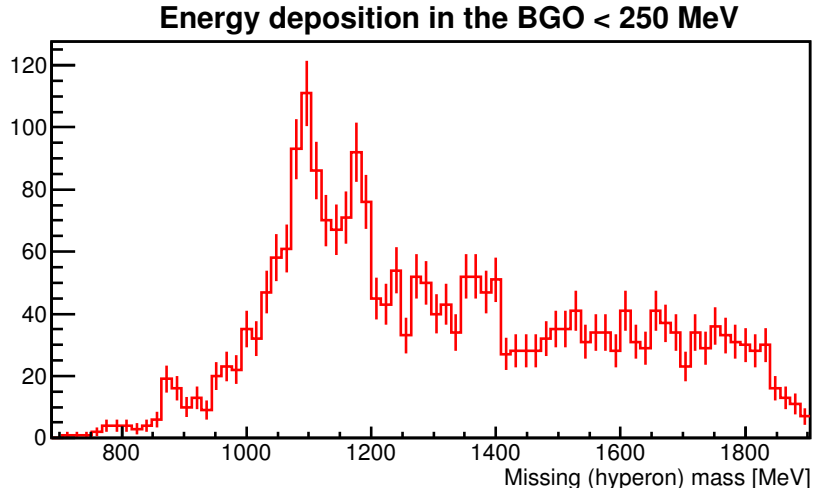
π^0 mass reconstructed in the BGO
BGO total energy deposition < 250 MeV

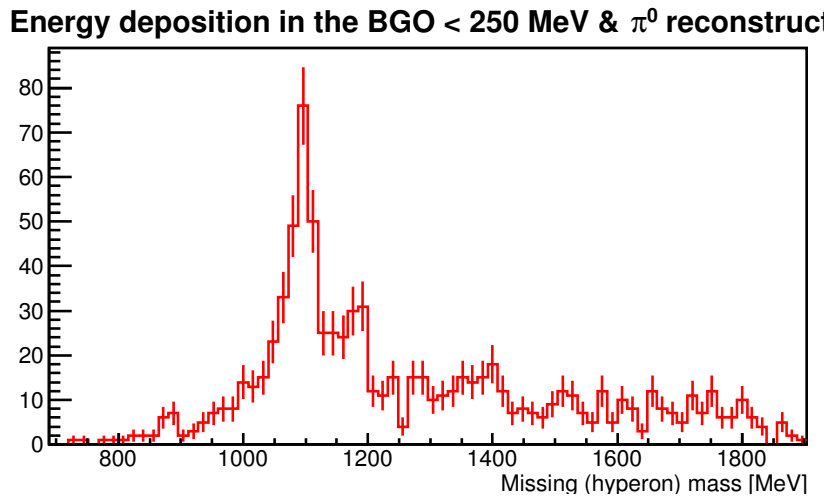


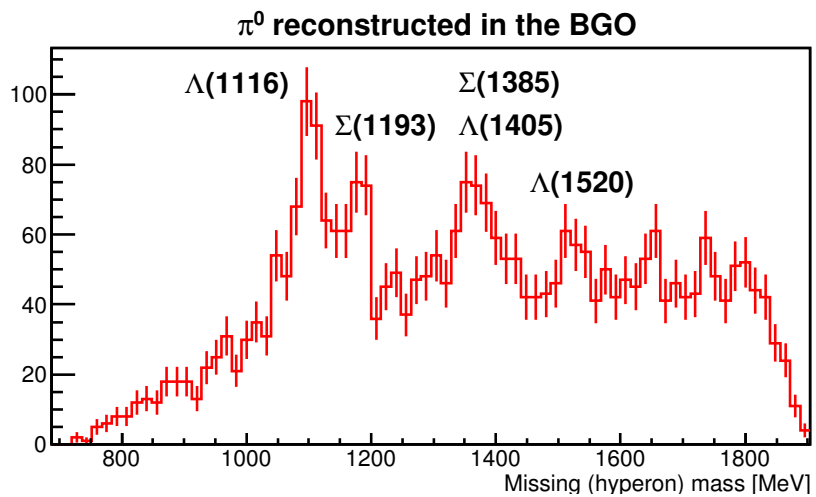


Missing (Y) mass from K^+ in the forward spectrometer









- Photon tagger hodoscope with x4 energy resolution installed

Summary & Collaborating Institutions

K^0 identification

- Analysis in preparation
- High statistics for $K^0\Sigma^+$ polarisation observables
- Basis for "neutral channels", eg $\gamma n \to K^0\Lambda$

K^+ identification

- ID reaction channels with BGO & forward spectrometer
- K^+Y cross sections at forward angles
- Σ^* states

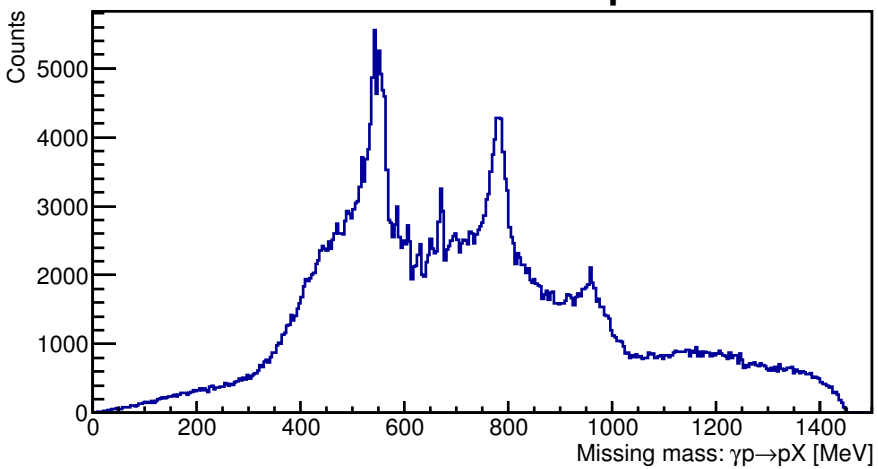
Ready for high statistics data taking

- Physikalisches Institut, Bonn, Germany
- Helmholtz-Institut für Strahlen und Kernphysik, Bonn, Germany
- Justus-Liebig-Universität Giessen, Germany
- Institut für Physik, Basel, Switzerland
- INFN sezione di Pavia, Pavia, Italy
- The University of Messina,Messina, Italy
- INFN sezione di Catania, Catania, Italy
- INFN Roma Tor Vergata, Rome, Italy
- The University of Rome "Tor Vergata", Rome, Italy
- INFN sezione di Torino, Torino, Italy
- The University of Torino, Torino, Italy
- INFN sezione di Roma, Rome, Italy
- INFN - ISS, Rome, Italy
- INFN - LNF, Frascati (Rome), Italy
- National Science Center Kharkov Institute of Physics and Technology, Kharkov, Ukraine
- Russian Academy of Sciences Institute for Nuclear Research, Moscow, Russia
- Petersburg Nuclear Physics Institute, Gatchina, Russia
- The University of Edinburgh, Edinburgh, UK

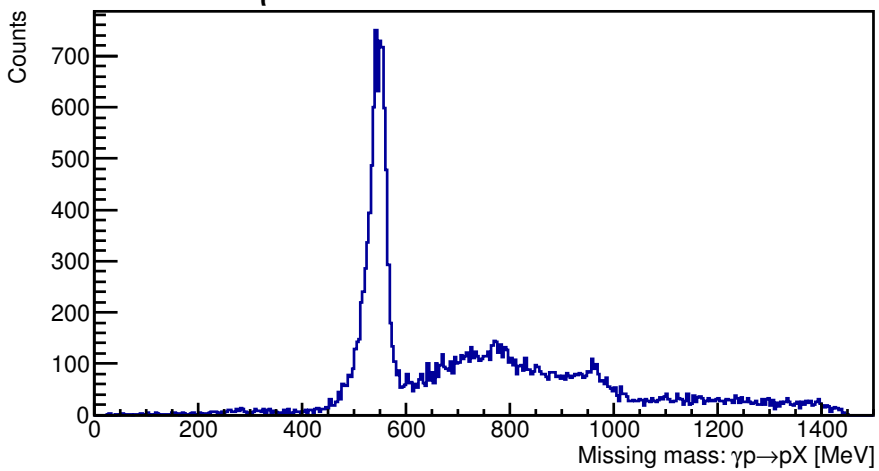
Extra slide

- Missing mass from forward protons & selecting π^0/η in the BGO ball

All Protons in the forward spectrometer



With an η reconstructed in the BGO



With a π^0 reconstructed in the BGO