

Investigation of Baryon Resonances with the BGO-OD experiment at ELSA

Hartmut Schmieden
Physikalisches Institut
Universität Bonn

BGO-OD collaboration



Investigation of Baryon Resonances with the BGO-OD experiment at ELSA

Hartmut Schmieden
Physikalisches Institut
Universität Bonn

BGO-OD collaboration

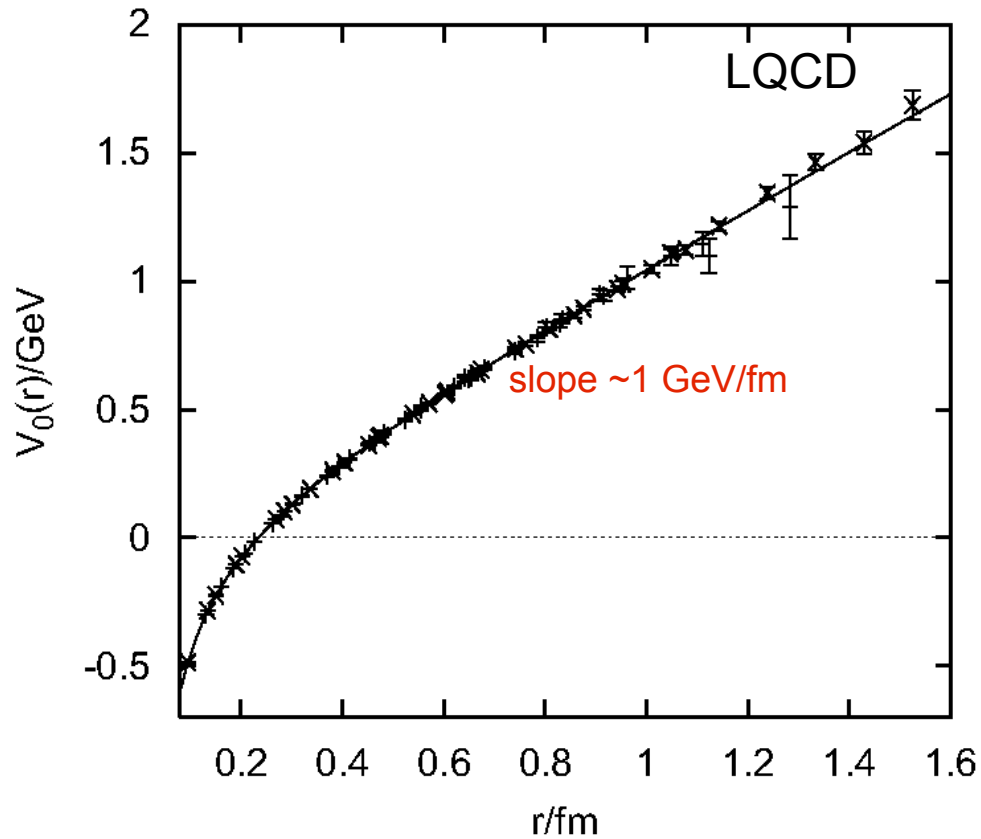
Outline

- physics motivation
- detector concept
- particle id & event reconstruction
- first preliminary results
- summary

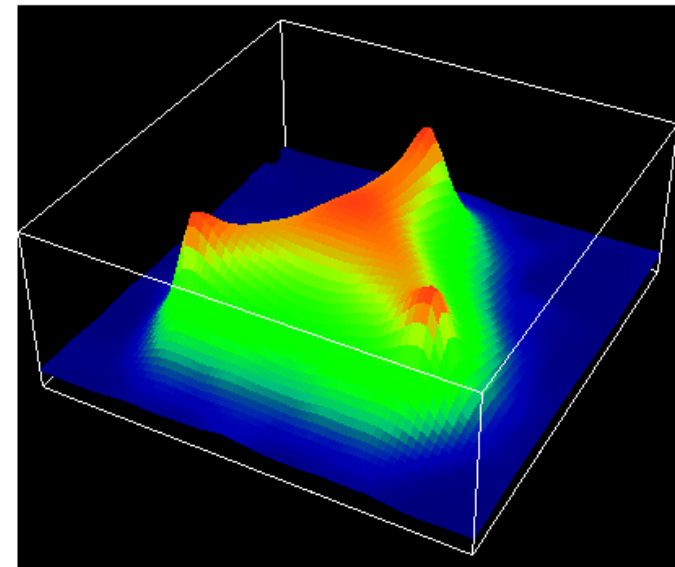


Physics Motivation

hadronic resonances



G.S. Bali,
Phys. Rep. 343 (2001) 1

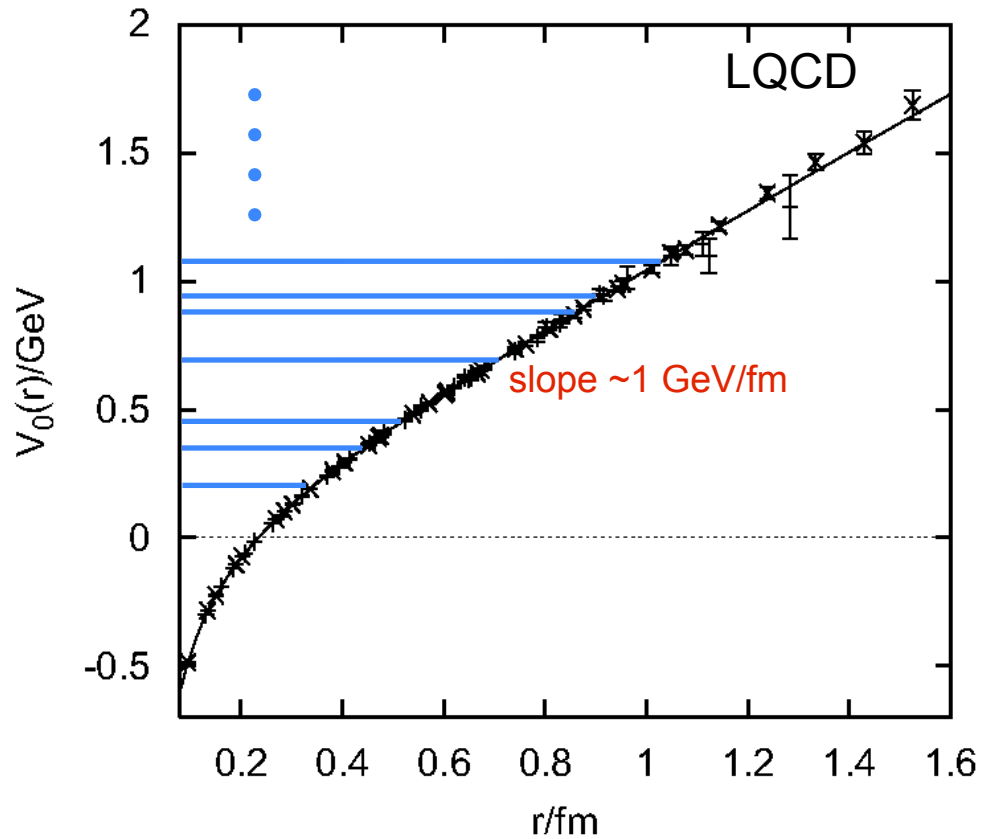


Energy density distribution
inside nucleon in LQCD simulation
(F. Wilczek, Physics today 11/99 & 1/00)

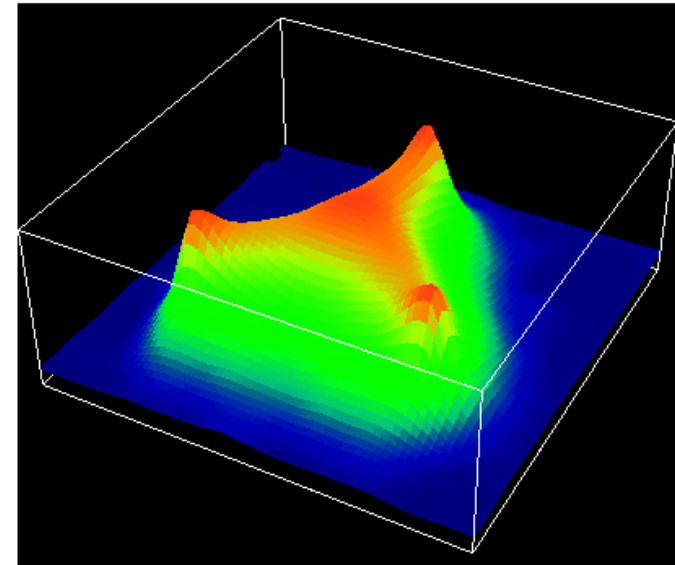
Physics Motivation

hadronic resonances

models: excitation in mutual potential



G.S. Bali,
Phys. Rep. 343 (2001) 1



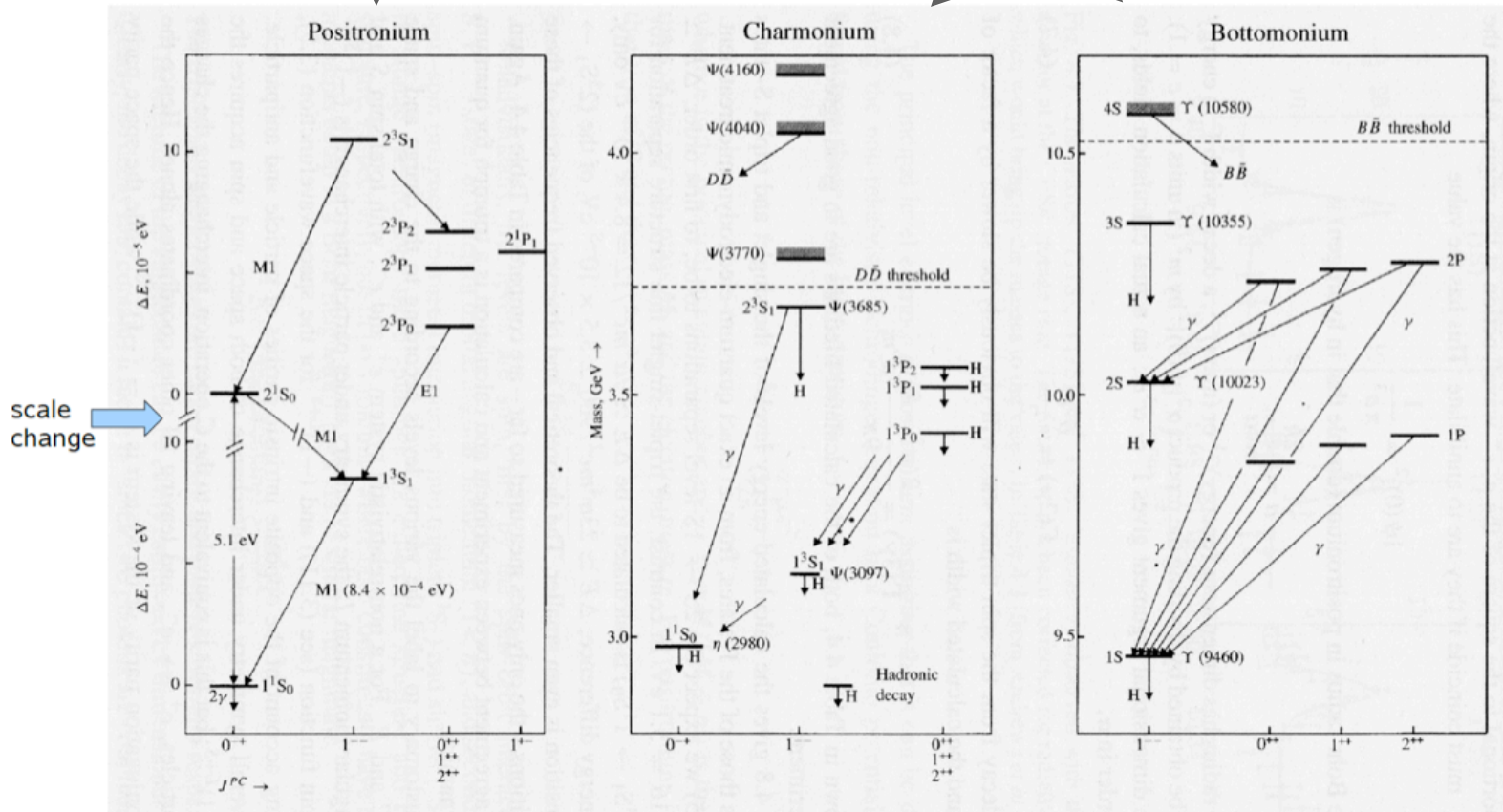
Energy density distribution
inside nucleon in LQCD simulation
(F. Wilczek, Physics today 11/99 & 1/00)

heavy quarks / mesons

positronium

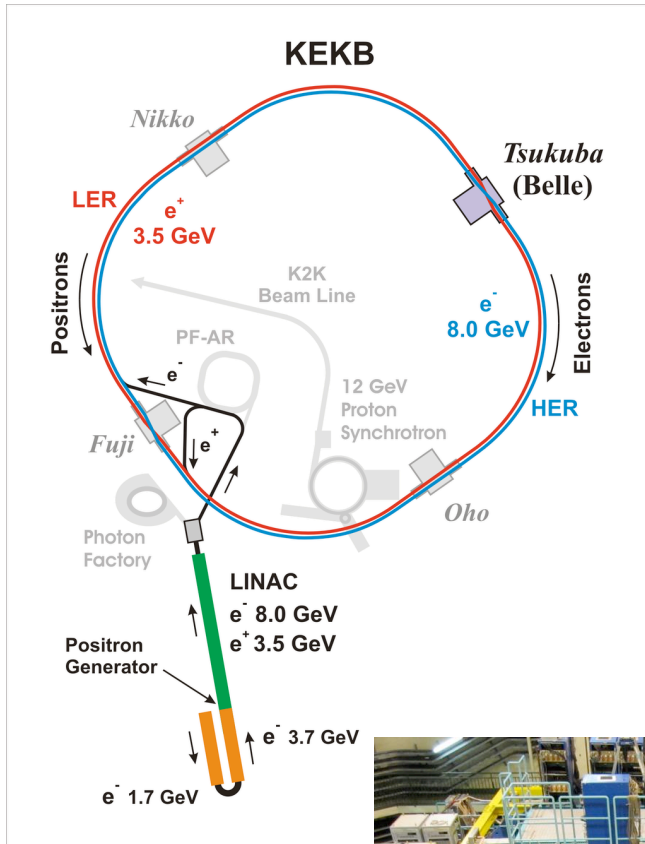
heavy quarks

textbook: Perkins

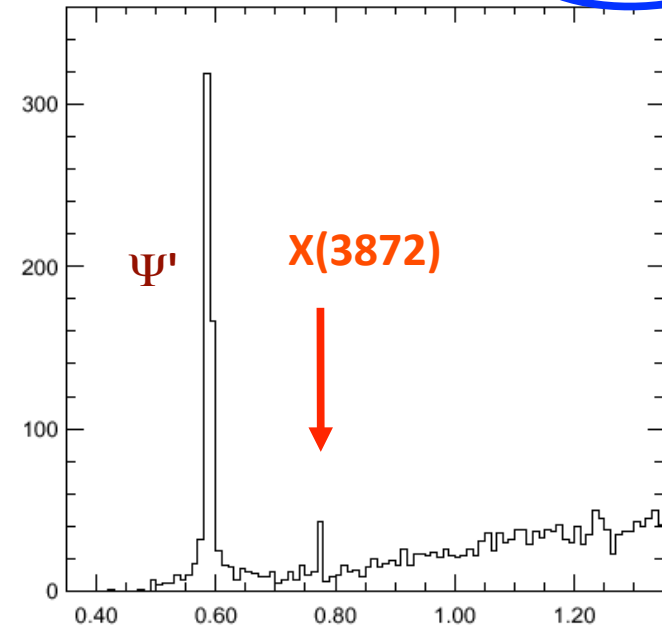


X(3872)

Observed by Belle in $B^\pm \rightarrow K^\pm \pi^+ \pi^- J/\psi$

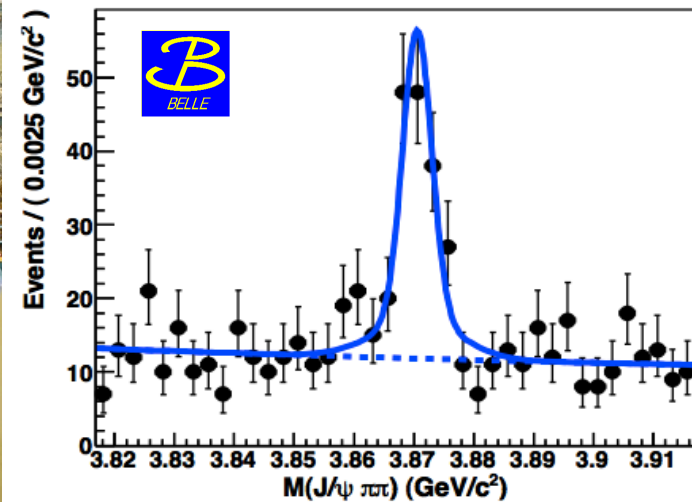
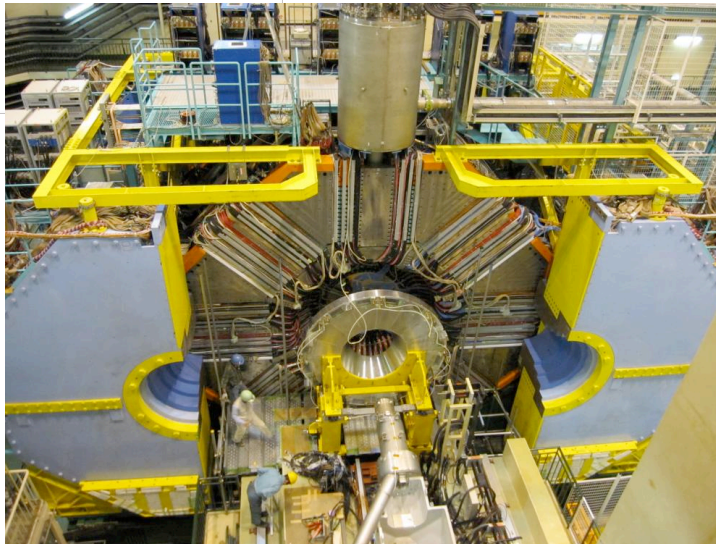


PRL91, 262001(2003)



arXiv:0809.1224 (2008)
(ICHEP 2008)

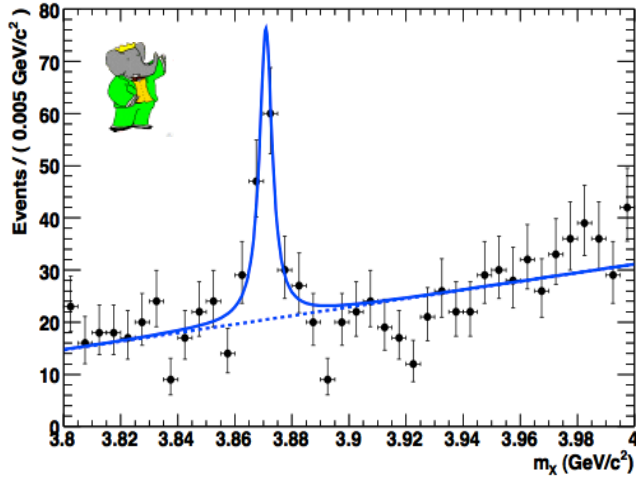
$$M(\pi^+ \pi^- l^+ l^-) - M(l^+ l^-)$$



X(3872)

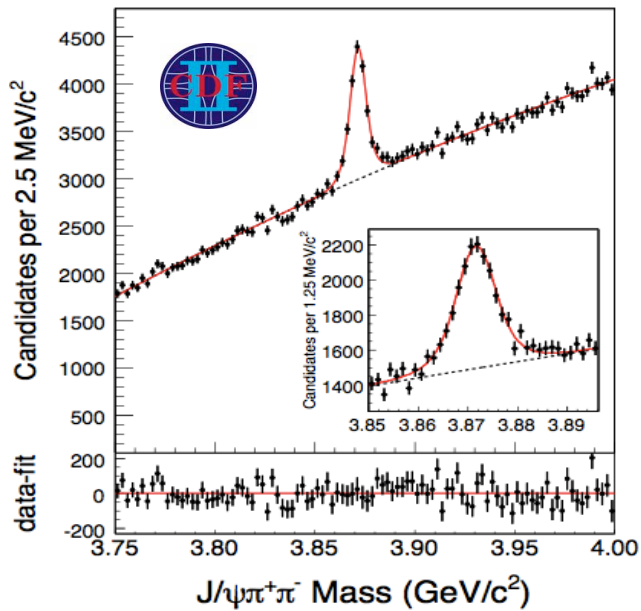
BaBar / SLAC

arXiv:0803.2838 (2008)

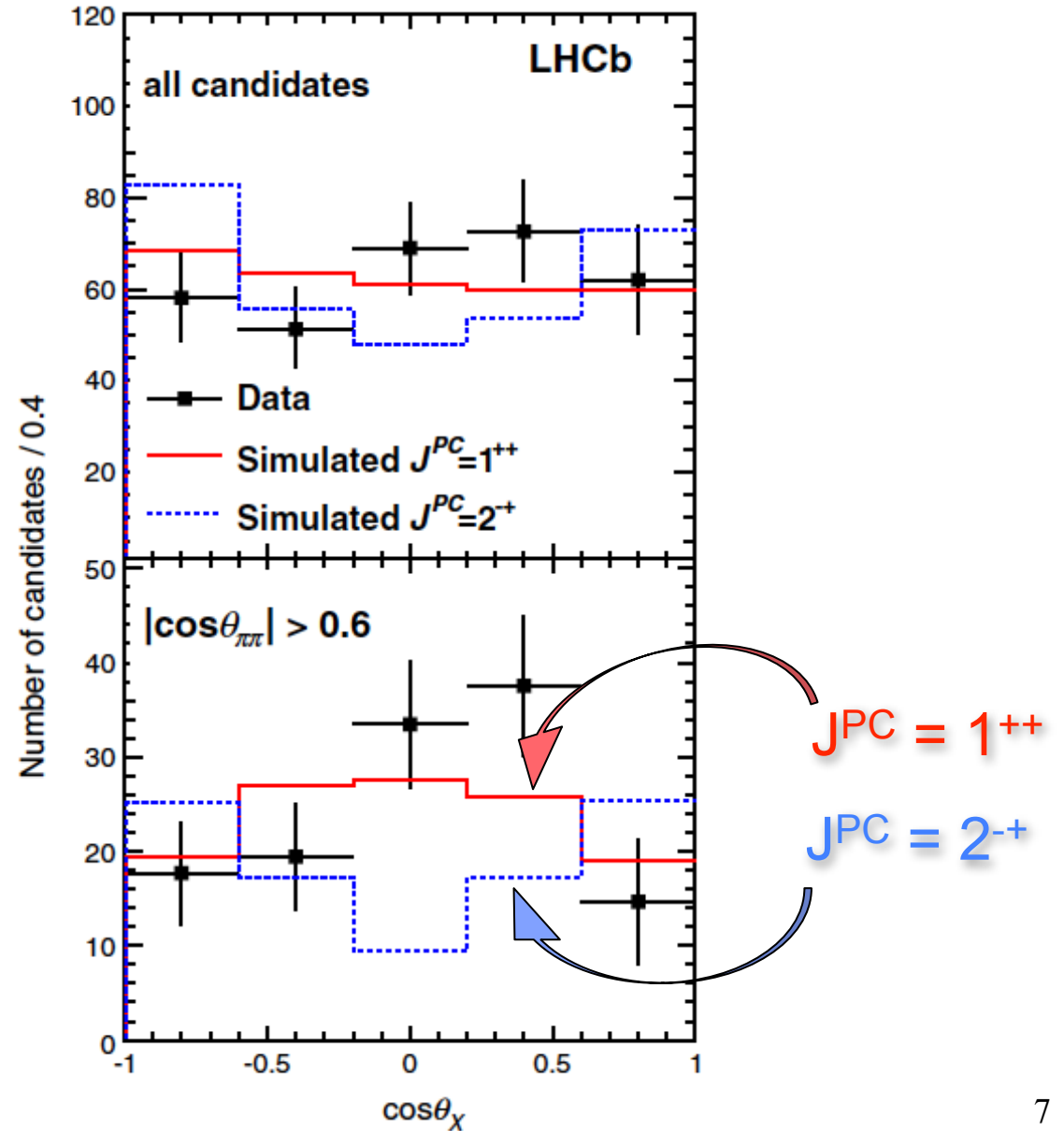


CDF / Tevatron




arXiv:0906.5218 (2009)



PRL 110 (2013) 222001



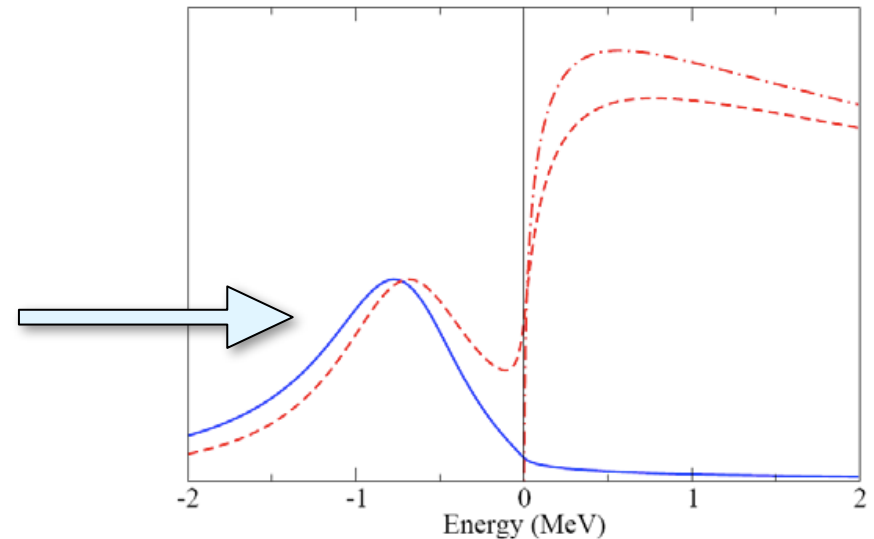
X(3872)

		$M(X(3872)), \text{MeV}/c^2$	$\Gamma(X(3872)), \text{MeV}/c^2$
	$B \rightarrow XK$	$3871.46 \pm 0.37 \pm 0.07$	< 2.3 @ 90% C.L. (2003)
	$B \rightarrow XK$	$3871.4 \pm 0.6 \pm 0.1$	< 3.3 @ 90% C.L. (2008)
	$X \rightarrow J/\psi \pi^+ \pi^-$	$3871.61 \pm 0.16 \pm 0.19$	1.34 (fixed from first two)
average		3871.50 ± 0.19	
$M(D^0) + M(D^{*0})$		3871.81 ± 0.36	

"molecule"

possible bound state of $D^0 D^{*0}$

$J^P = 0^- \quad 1^-$



X(3872)

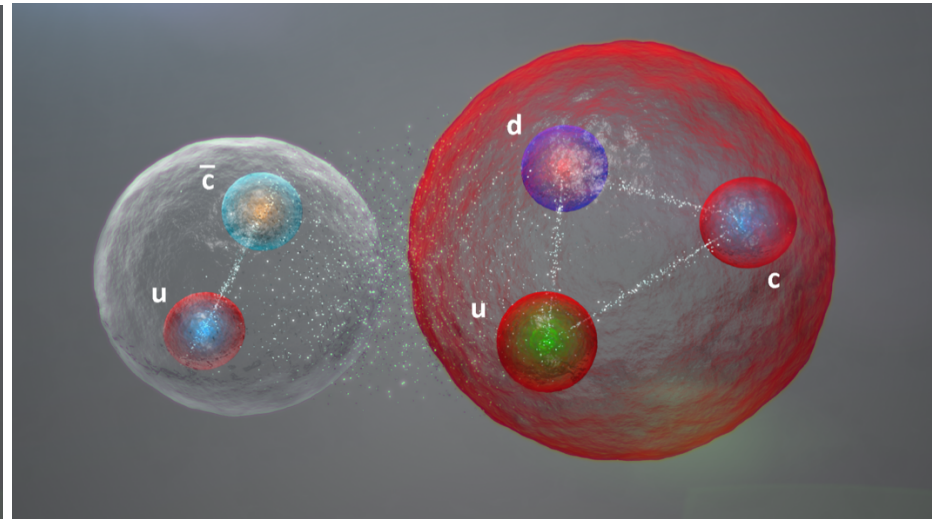
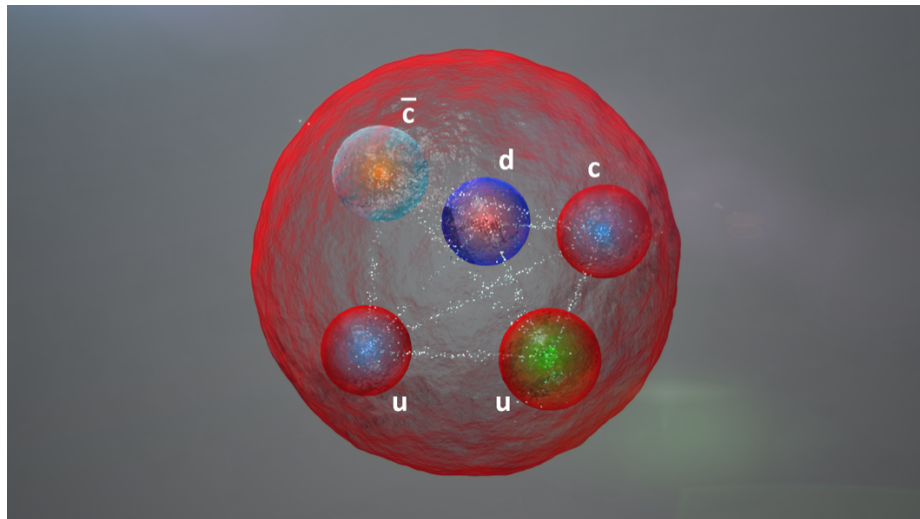
Interpretation

- CP quantum numbers determined $J^{PC} = 1^{++}$
- X(3872) likely not a charmonium state
 - radial excitation of χ_{c1} ($J^{PC} = 1^{++}$) expected at 3950 MeV/c²
 - η_{c2} ($J^{PC} = 2^{-+}$) should have $X \rightarrow J/\psi\gamma$ suppressed
 - ➔ **no satisfactory $c\bar{c}$ assignment**
- D^0D^{*0} molecule? [N.A. Törnqvist, Phys. Lett. B590, 209 \(2004\)](#)
 - explains proximity of D^0D^{*0} threshold
 - favors DD^* decay over $J/\psi\pi\pi$ over $J/\psi\gamma$ (as observed)
 - isospin $I = 0$ favoured
 - expect $X \rightarrow \psi(2S)\gamma$ to be suppressed (**contrary to observation**)
- tetraquark state? [L. Maiani et al., Phys. Rev. D71, 014028 \(2005\)](#)
 - 2 neutral and 2 charged states predicted
 - neutral states produced in B^0 and B^+ decays: $\Delta m \approx (7 \pm 2) \text{ MeV}$
 - measurement $\Delta m = (+0.18 \pm 0.89 \pm 0.26) \text{ MeV}$ in $B \rightarrow J/\psi\pi^+\pi^-$
 - expect charged partners (**contrary to observation**)
- Dynamic interplay of quark & meson d.o.f @ thresholds ?
 - ➔ components in Fock expansion [V. Baru et al., Eur. Phys. J. A 44, 93 \(2011\)](#)
- Something else?... **not yet settled**



Hidden charm **baryon** sector

LHCb 2015



PARTICLE PHYSICS

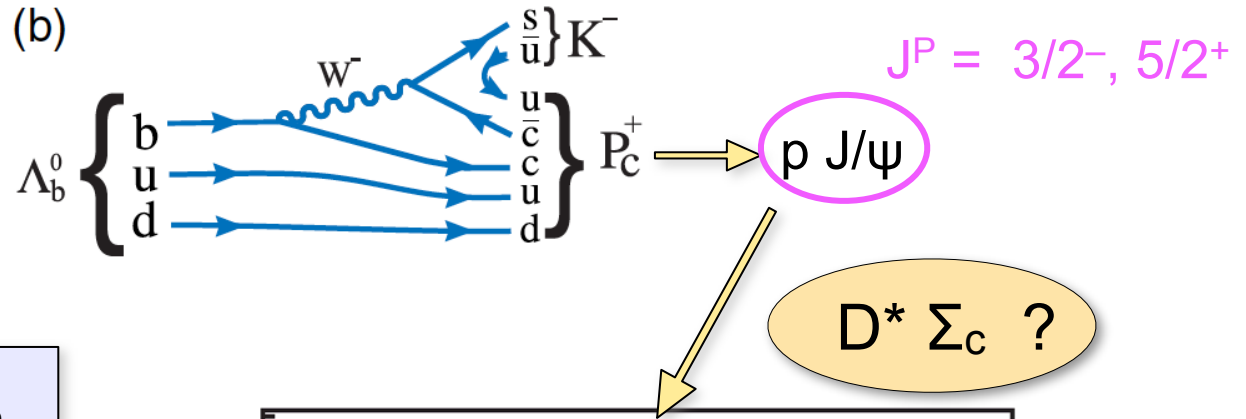
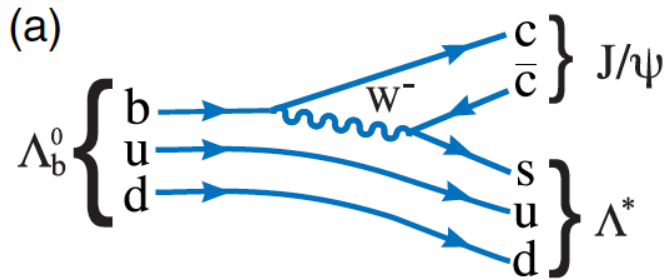
Forsaken pentaquark particle spotted at CERN

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



LHCb: $P_c^+(4380, 4450)$

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

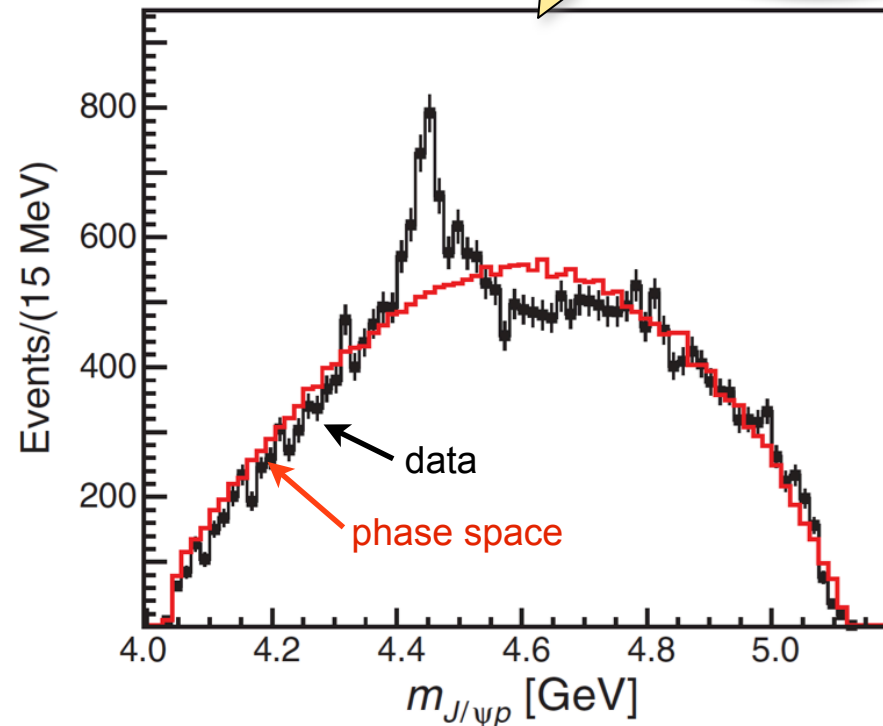


PB / VB hidden c predicted from meson-baryon interactions:
Oset, Zou et al., PRL 105 (2010)

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

$\chi_{c1}p$ threshold dynamics?

Guo, Meißner et al., PRD92 (2015) 071502

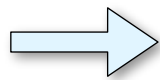
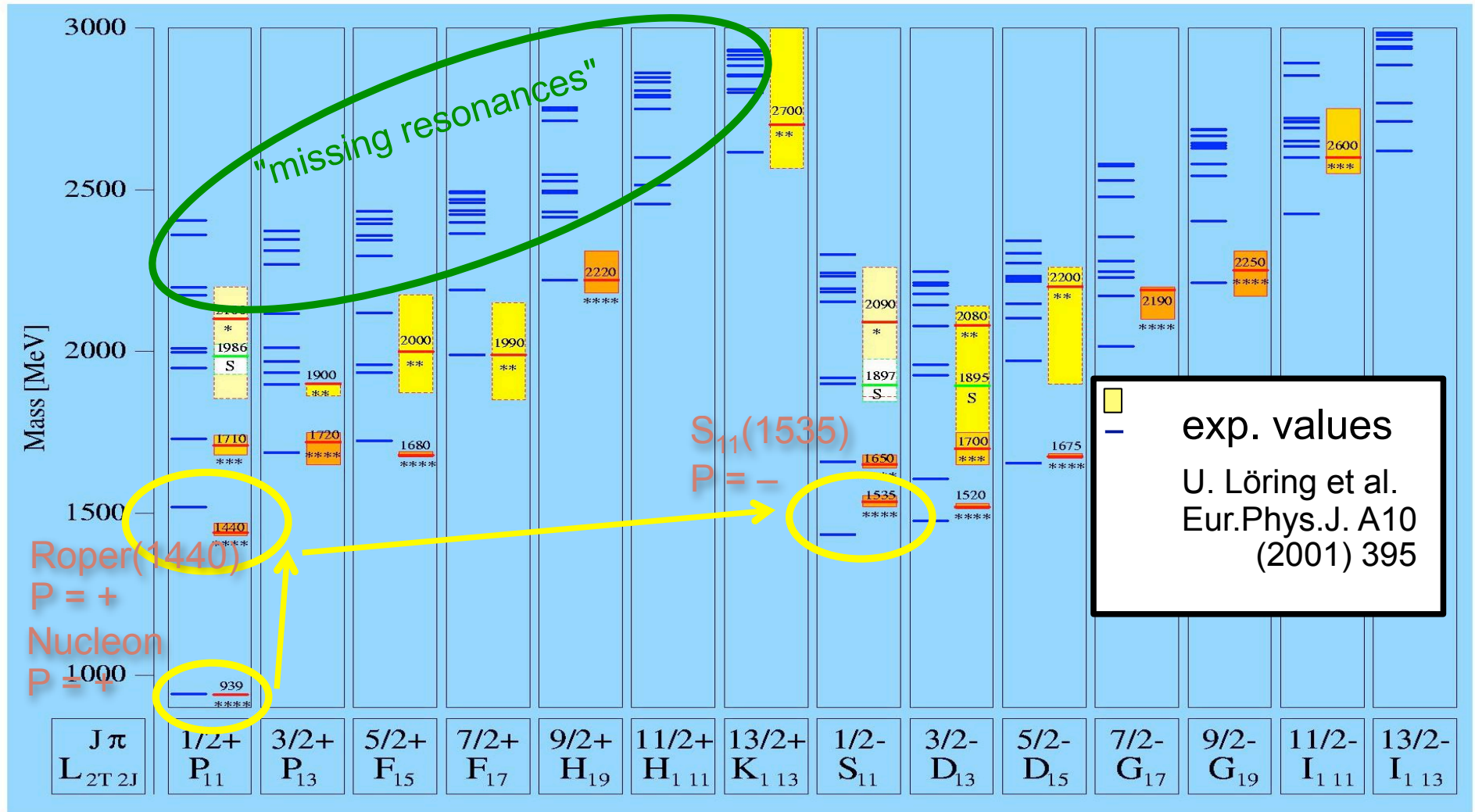


uds sector ?



uds sector ?

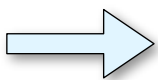
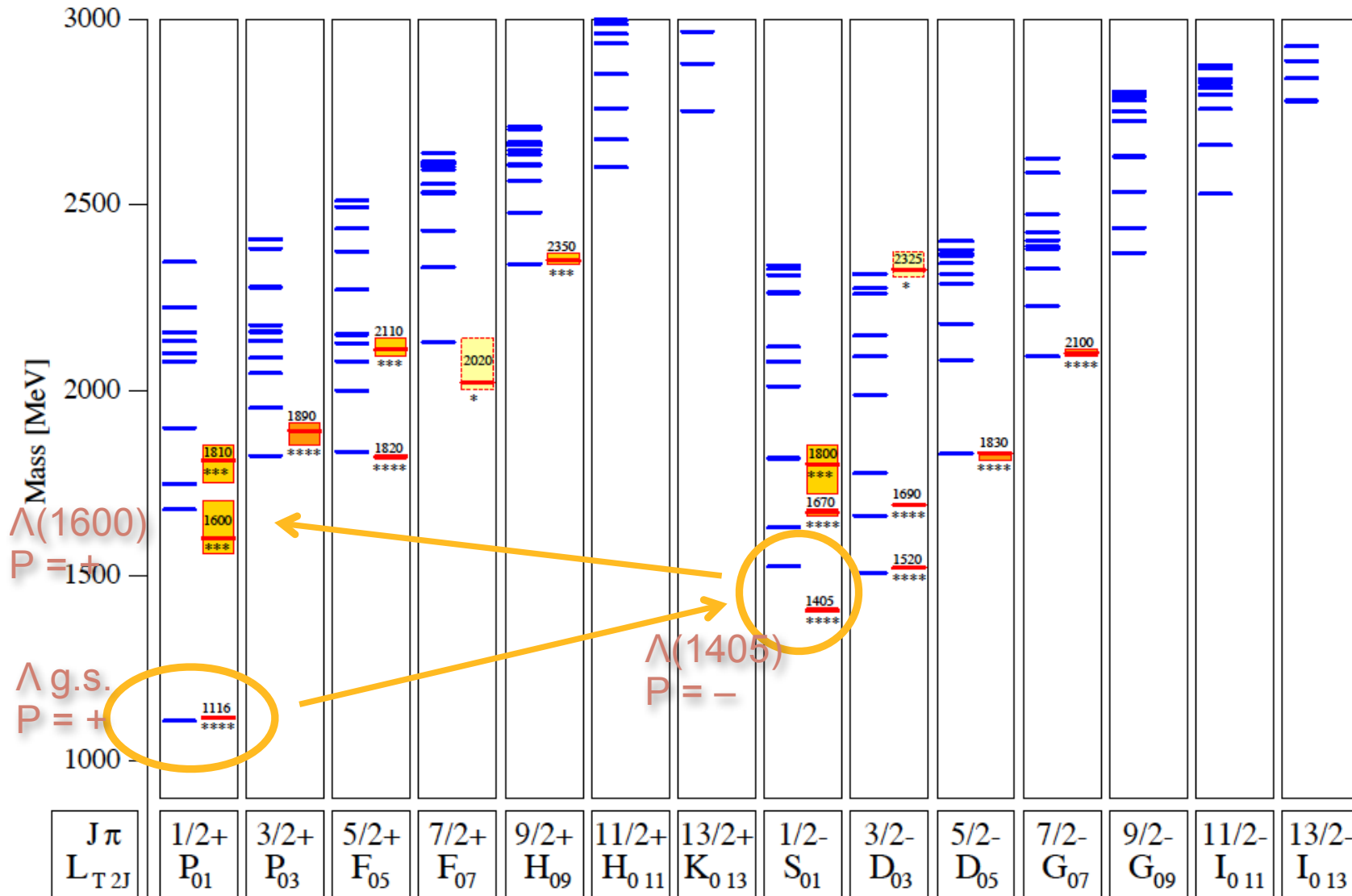
N* resonances



- parity pattern + → + → - !?!
- effective degrees of freedom ??

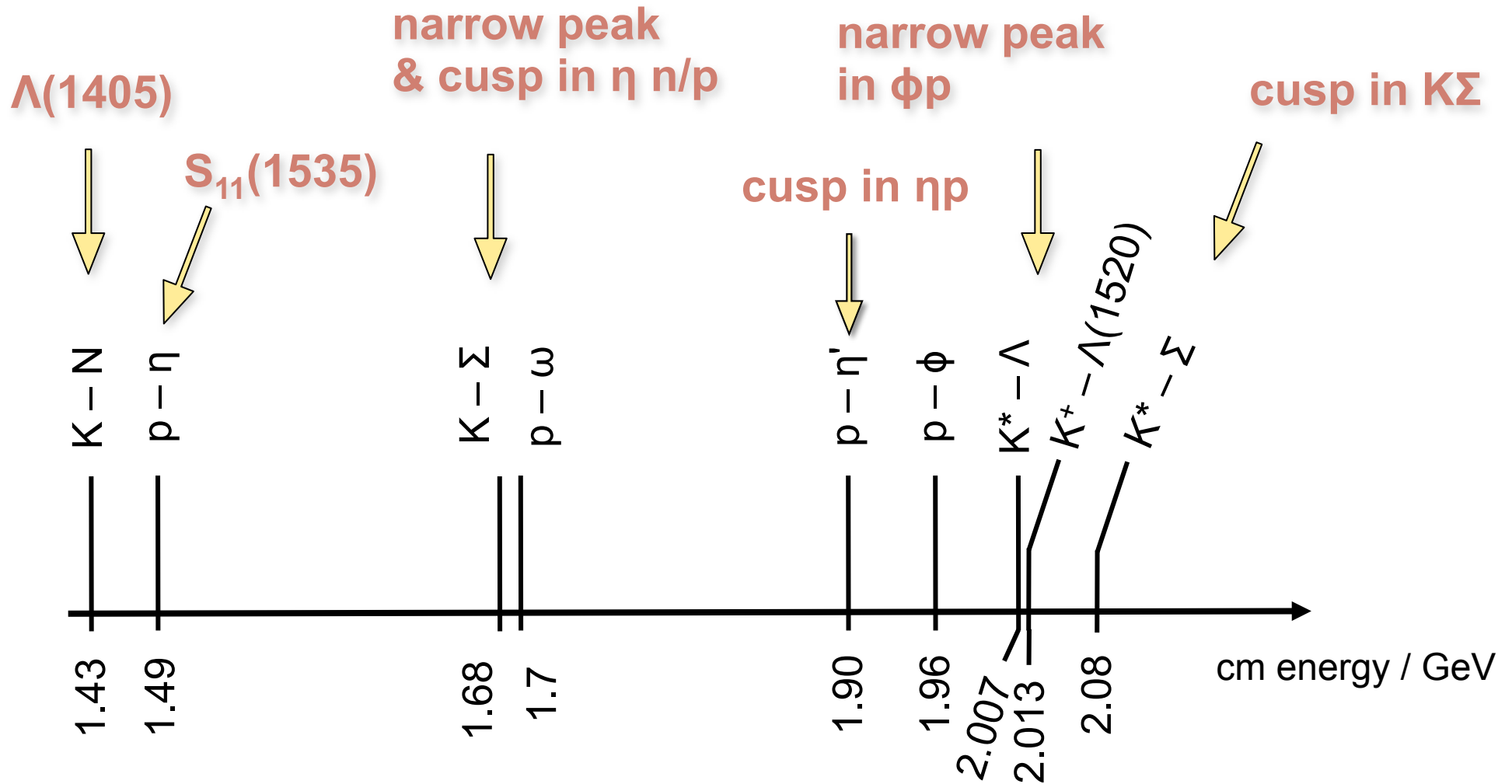
uds sector ?

Λ^* resonances

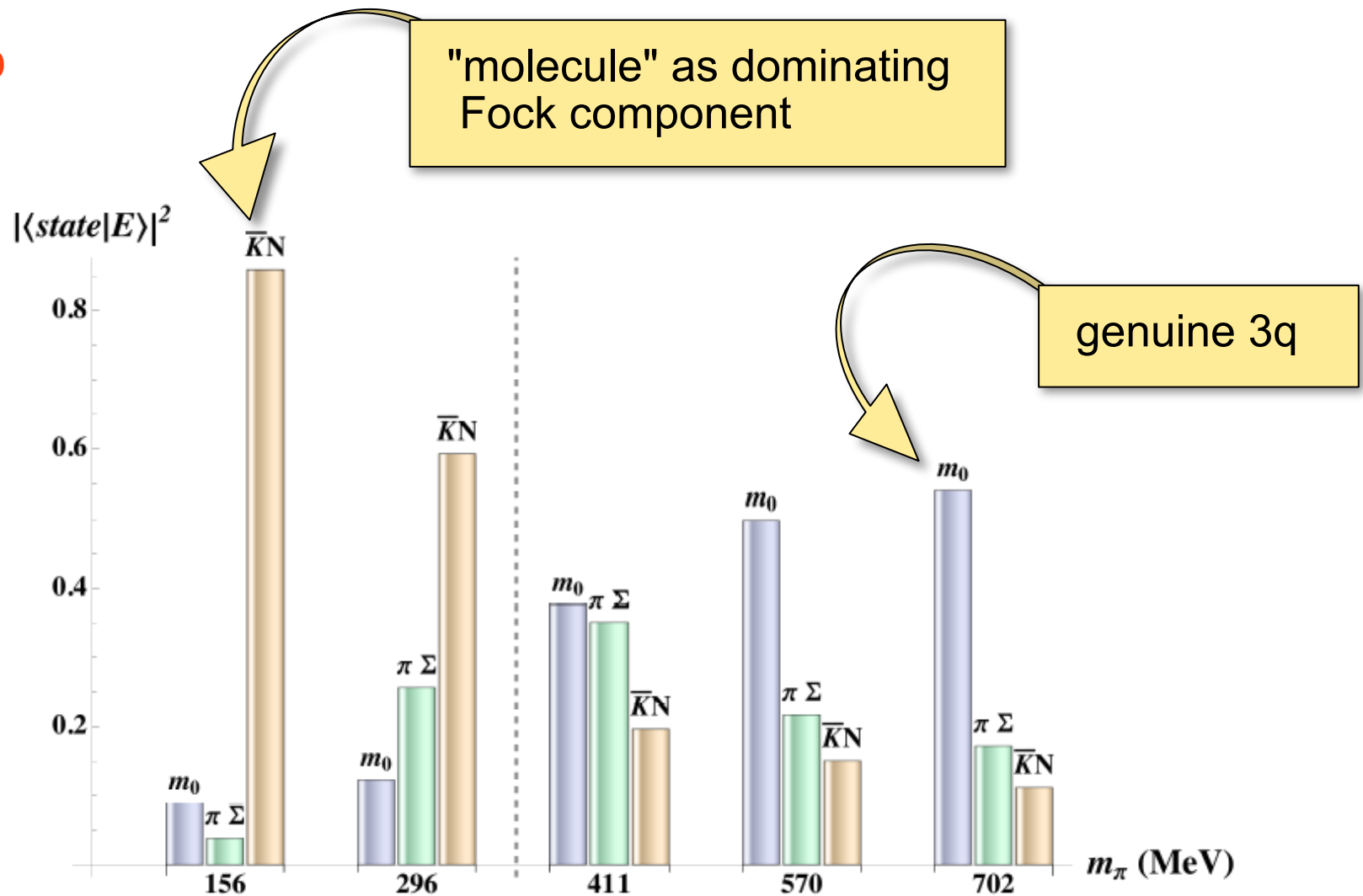


- parity pattern OK
- masses reversed ??

uds sector – threshold dynamics



L-QCD

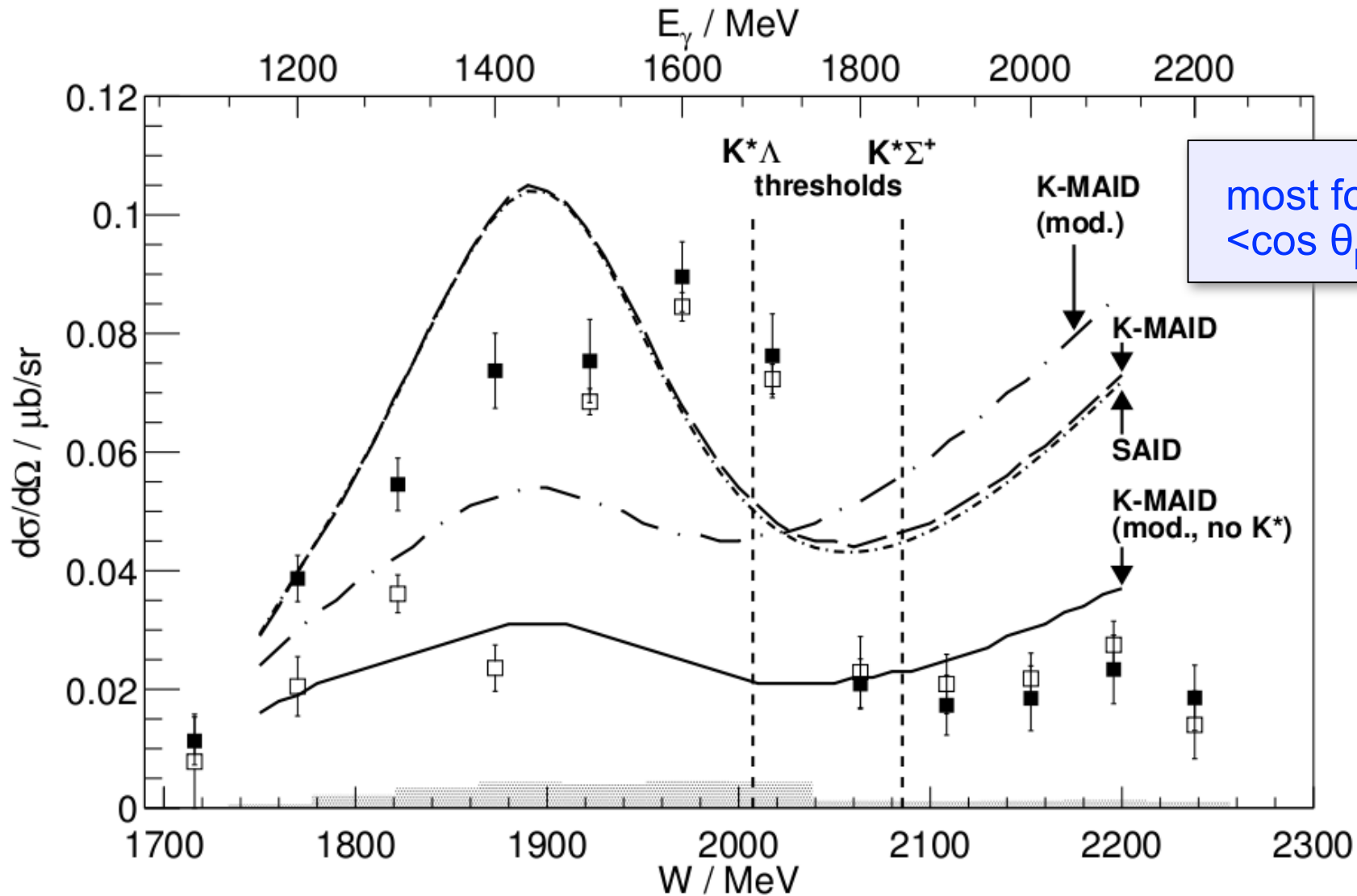


J.M.M. Hall et al. [Adelaide group], Phys. Rev. Lett. 114 (2015) 132002
arXiv::1411.3402v2 (2015)

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

anomaly @ K^* threshold

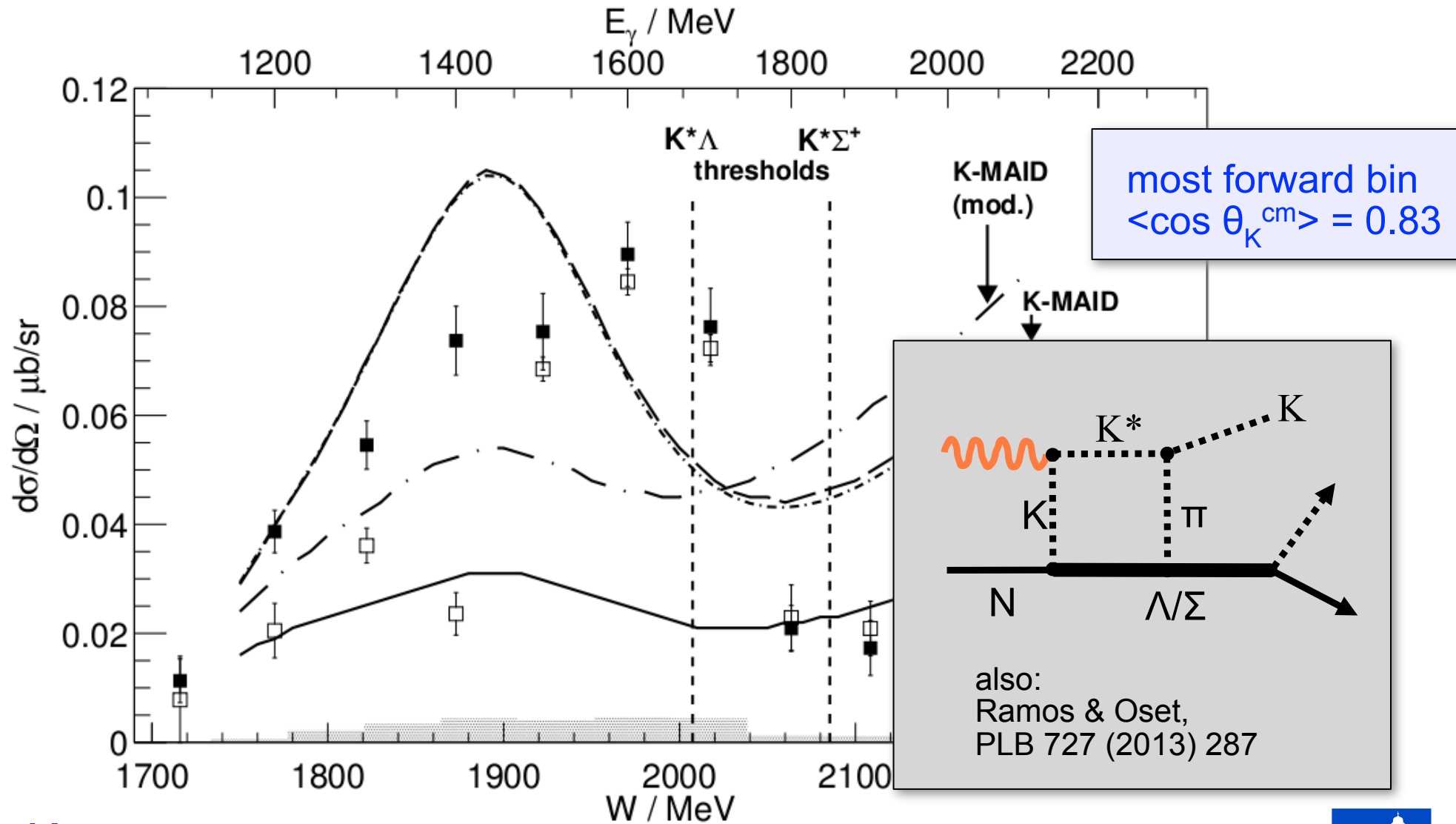
R. Ewald et al. (CB/TAPS), PLB 713 (2012)



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

anomaly @ K^* threshold

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

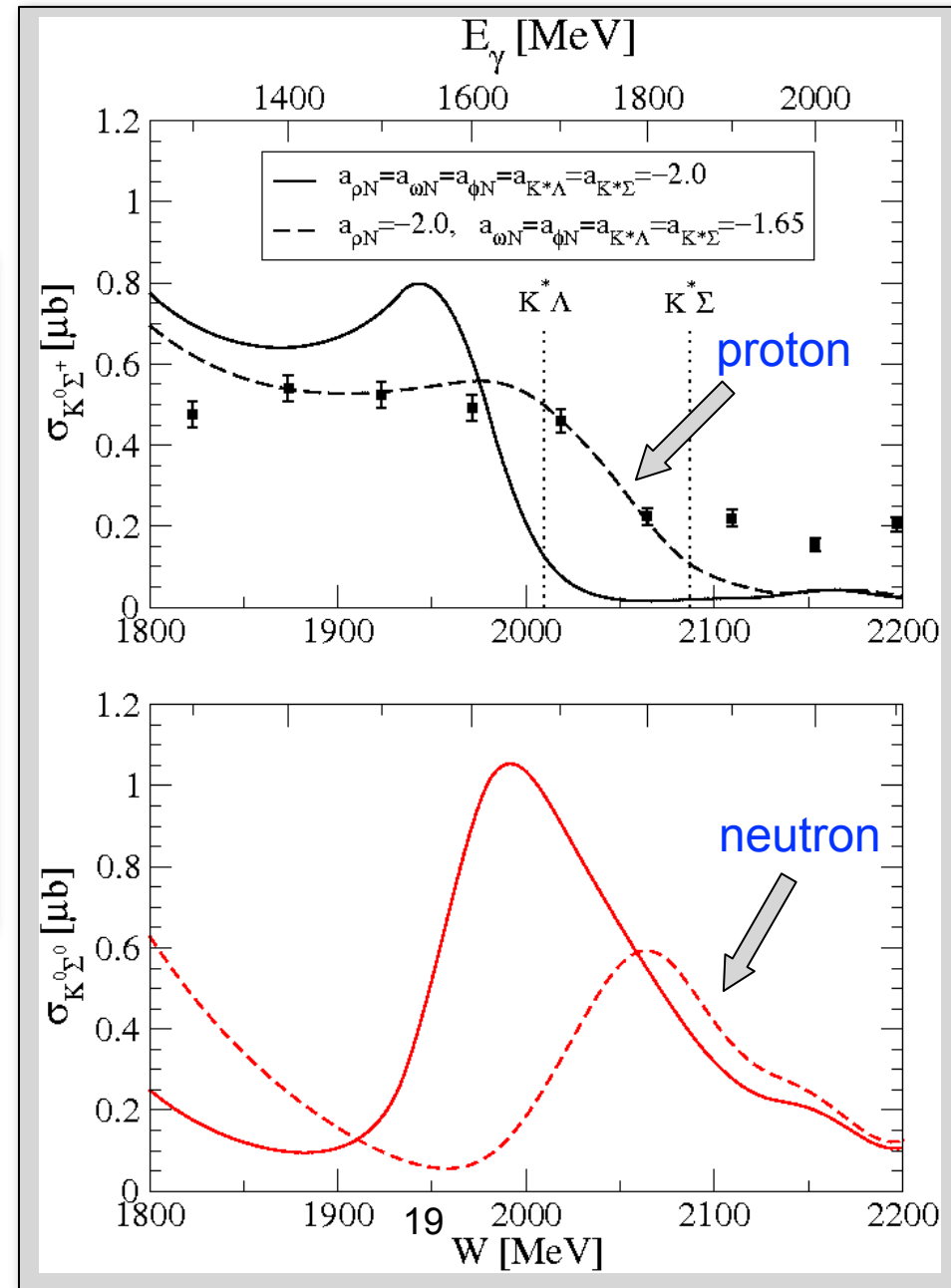




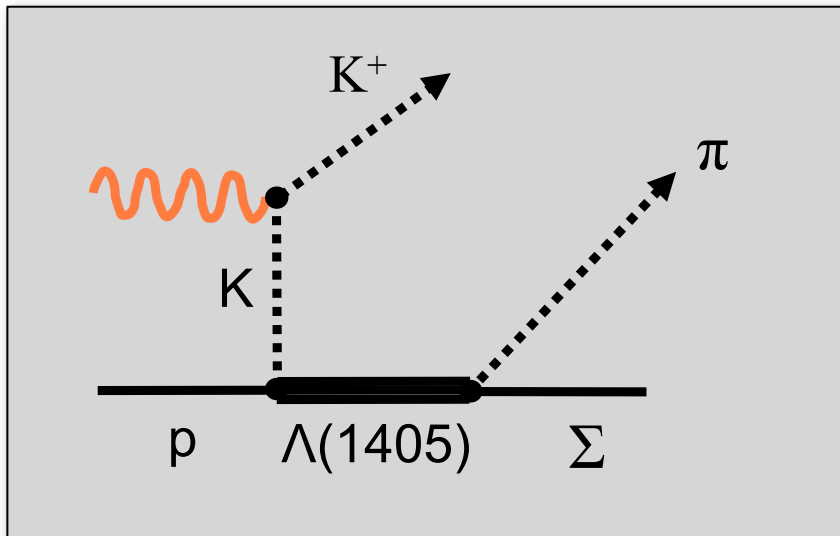
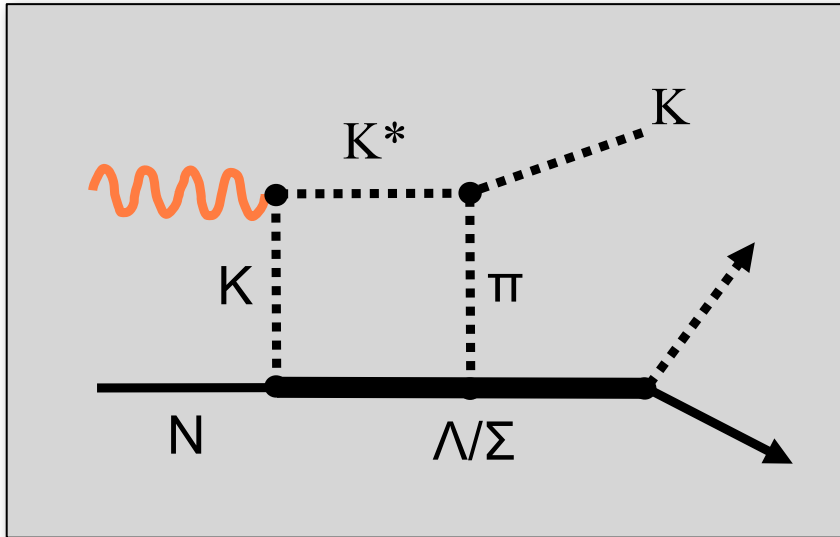
anomaly @ K^* threshold

A. Ramos & E. Oset,
Phys. Lett. B727 (2013) 287

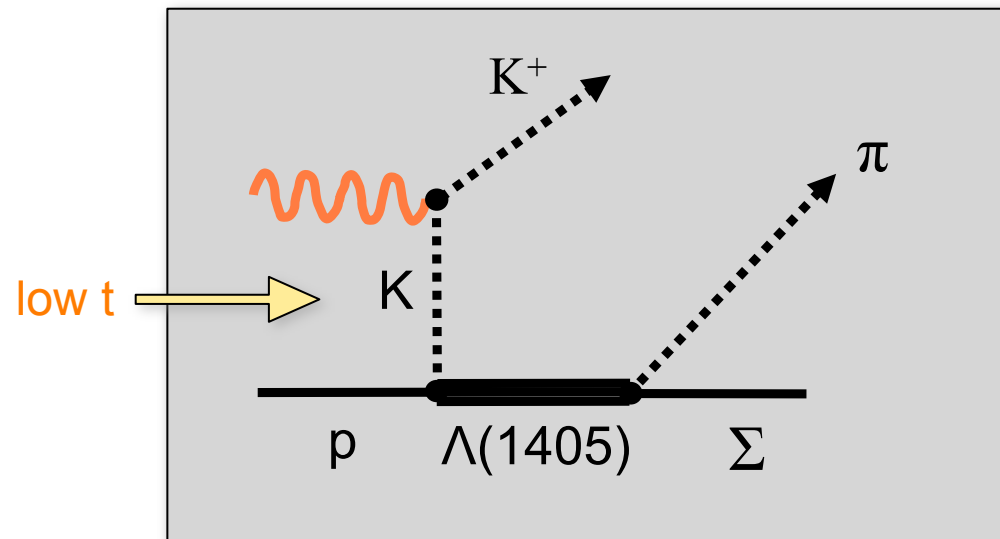
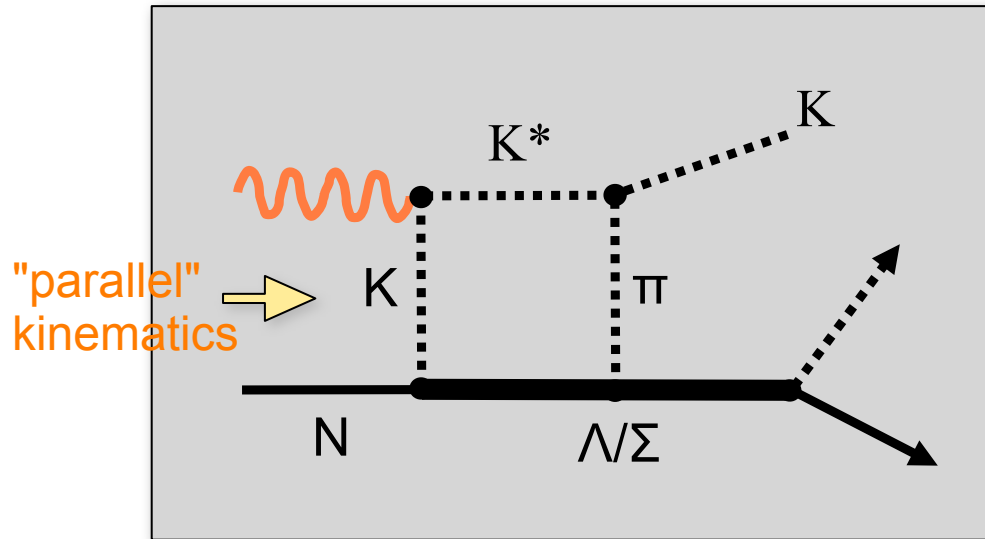
- vectormeson-baryon dynamics
- structure $\leftrightarrow N^*(2080)(3/2^-) / N^*(2090)(1/2^-)$
[removed from PDG]
- delicate interference $K^*\Lambda / K^*\Sigma$ channels
→ $K^0 \Sigma^0$ off **neutron** target to test



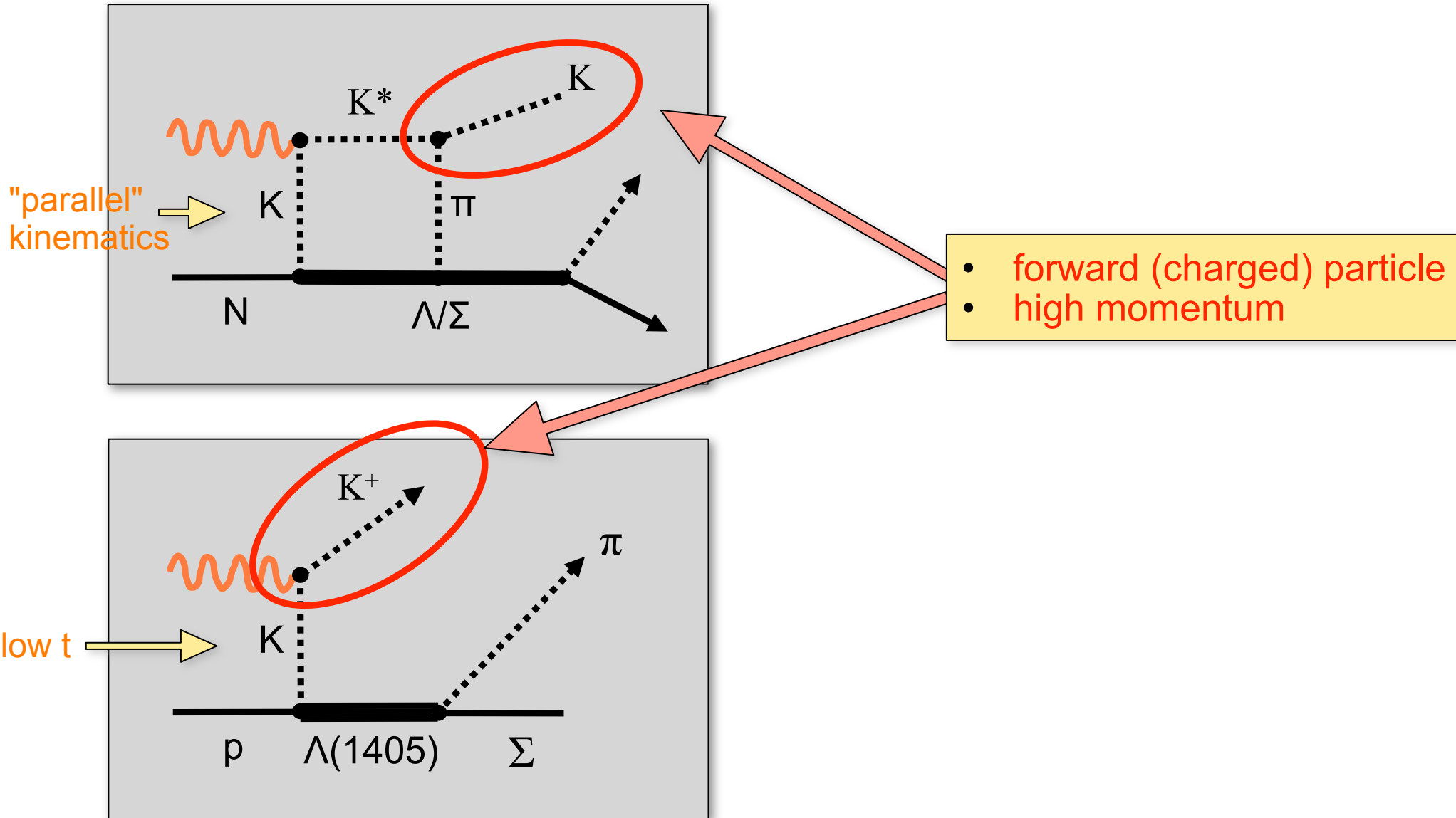
t-channel Kinematics



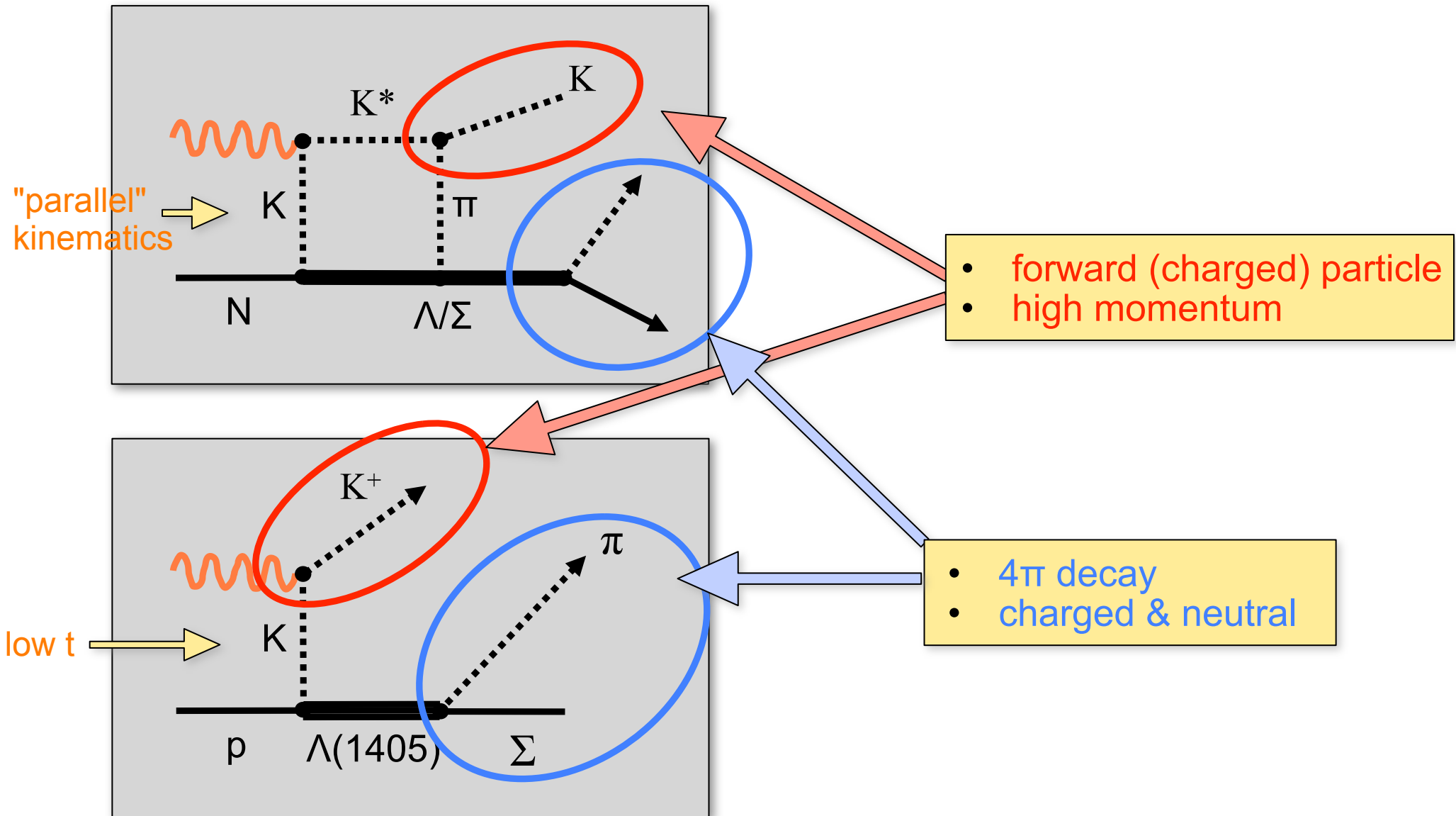
t-channel Kinematics



t-channel Kinematics



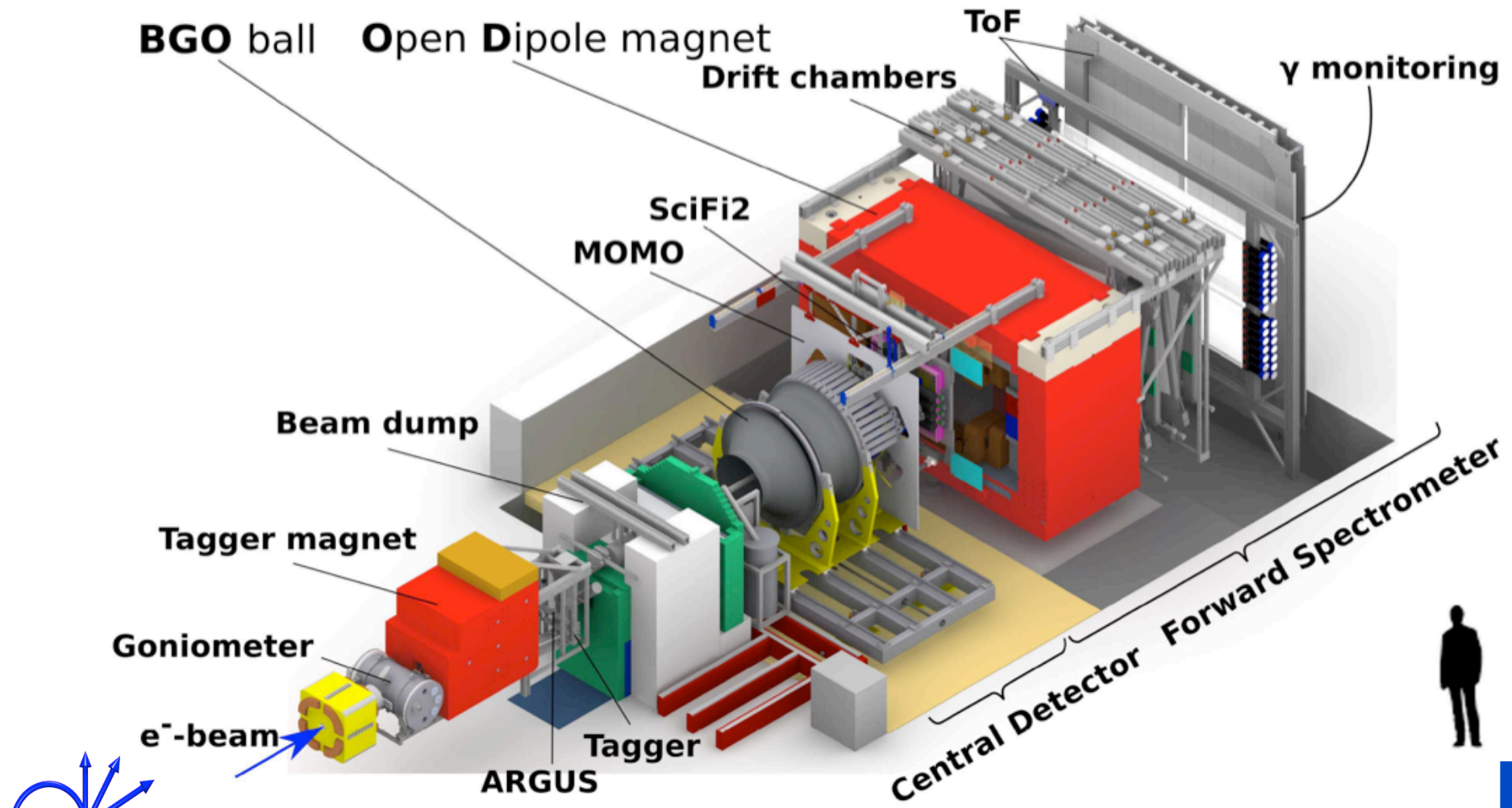
t-channel Kinematics



BGO-OD experiment

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

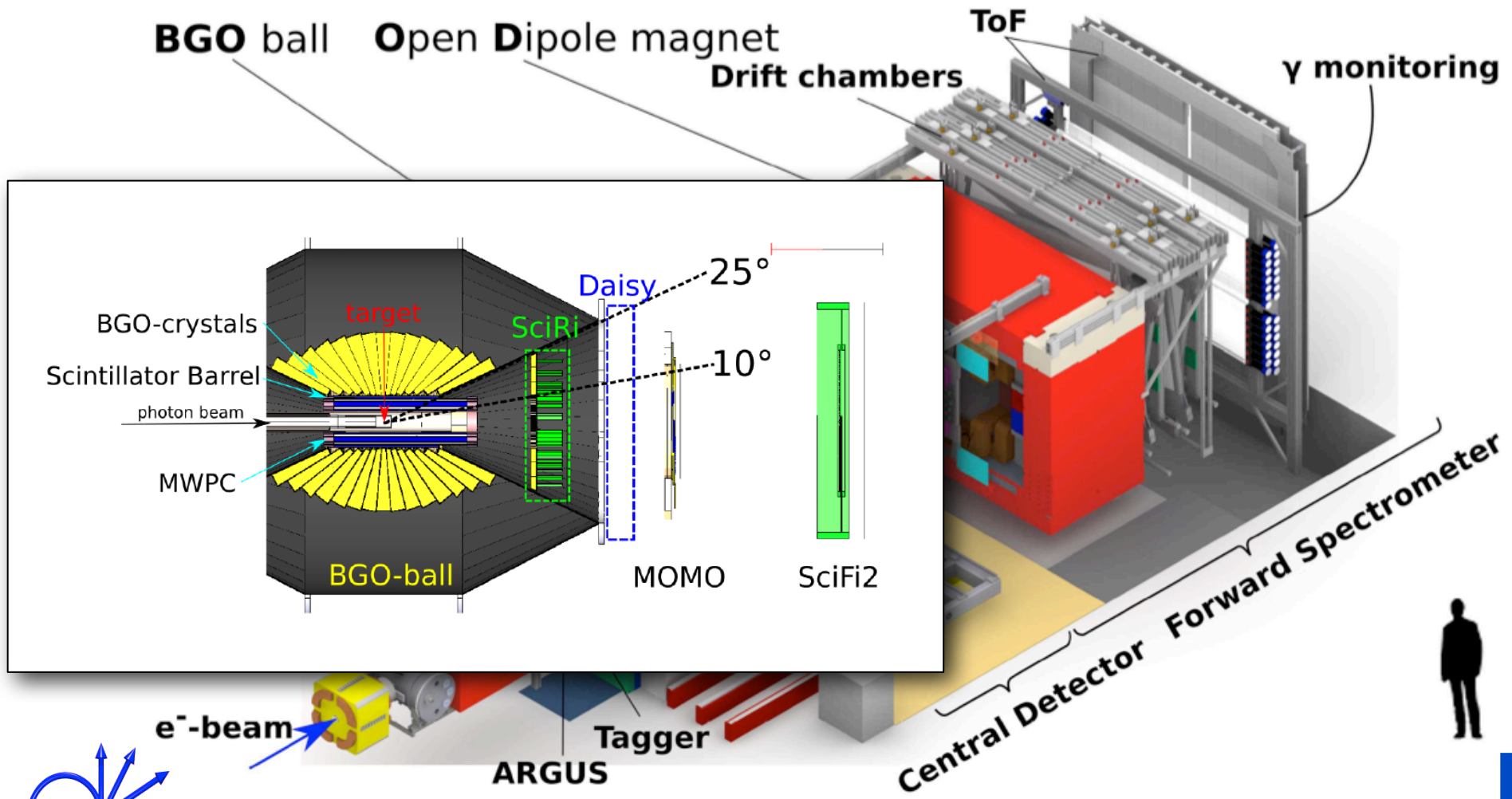
- combination of BGO central calorimeter & forward spectrometer
- high momentum resolution, excellent neutral & charged particle id



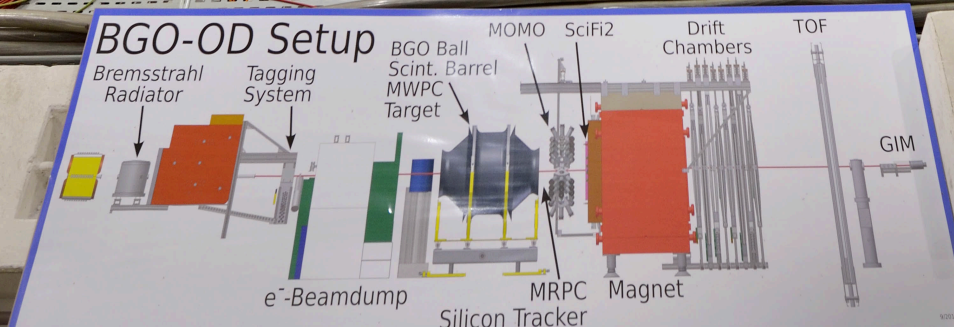
BGO-OD experiment

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

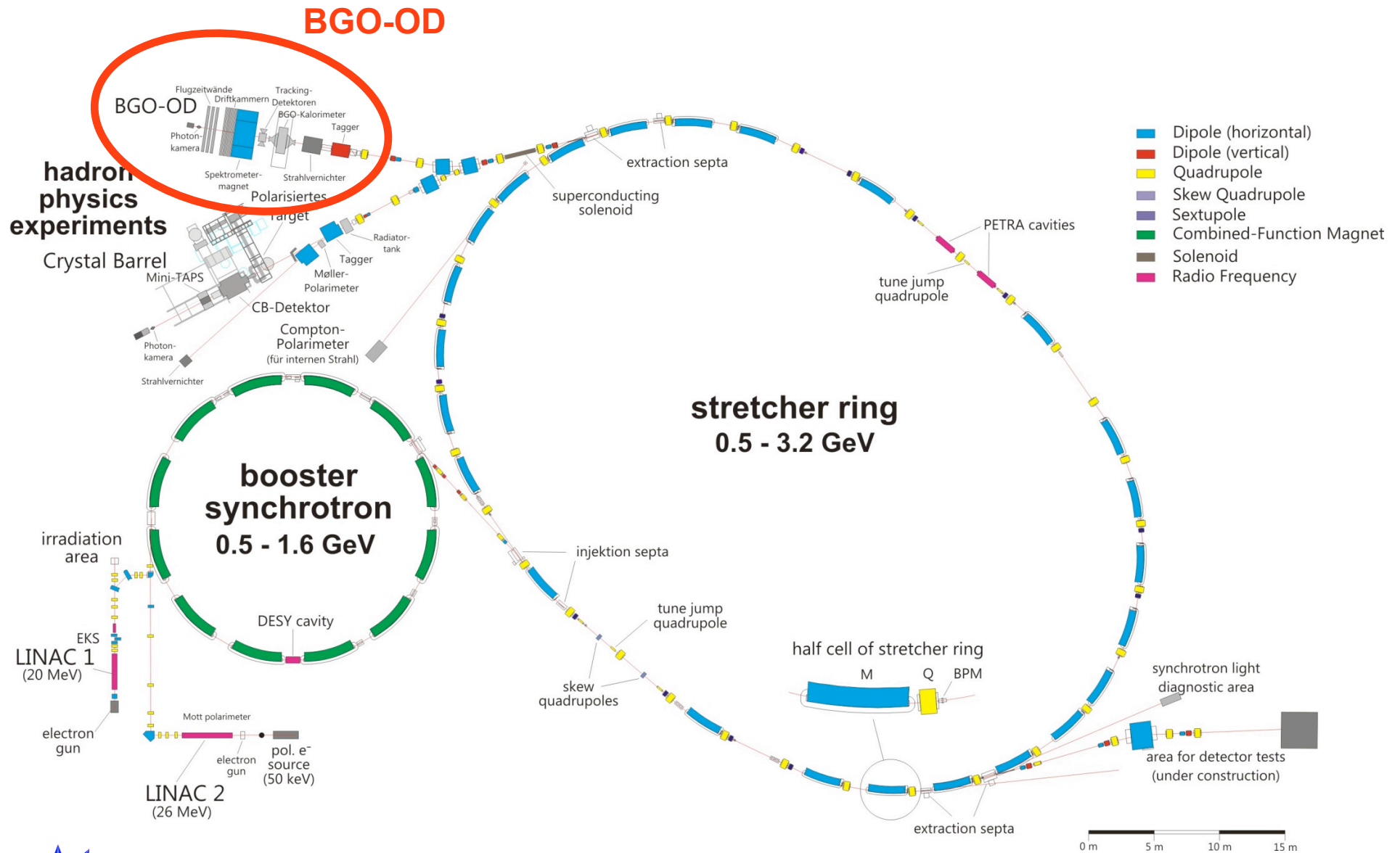
- combination of BGO central calorimeter & forward spectrometer
- high momentum resolution, excellent neutral & charged particle id



BGO-OD experiment at ELSA



ELSA accelerator



First Results from $\gamma + p \rightarrow K + \Lambda^{(*)} / \Sigma^{(*)}$

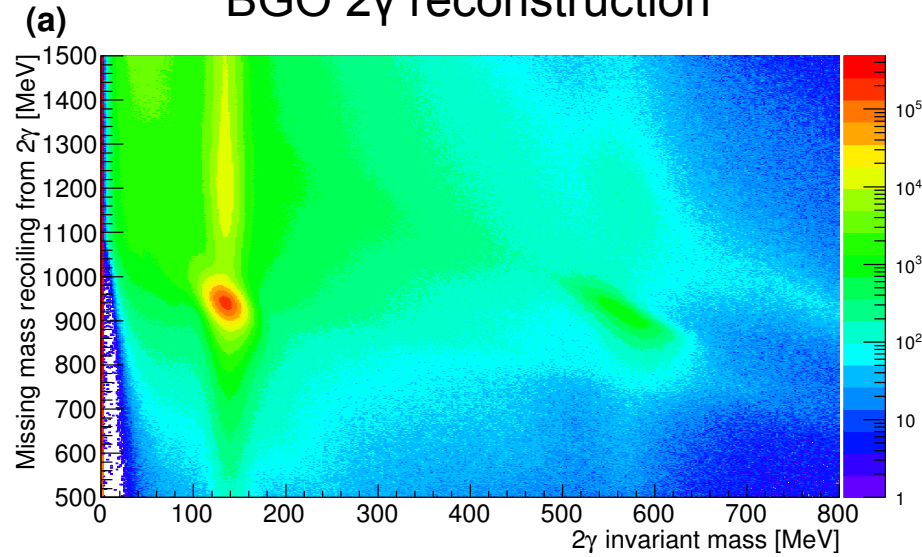


Particle ID & event reconstruction

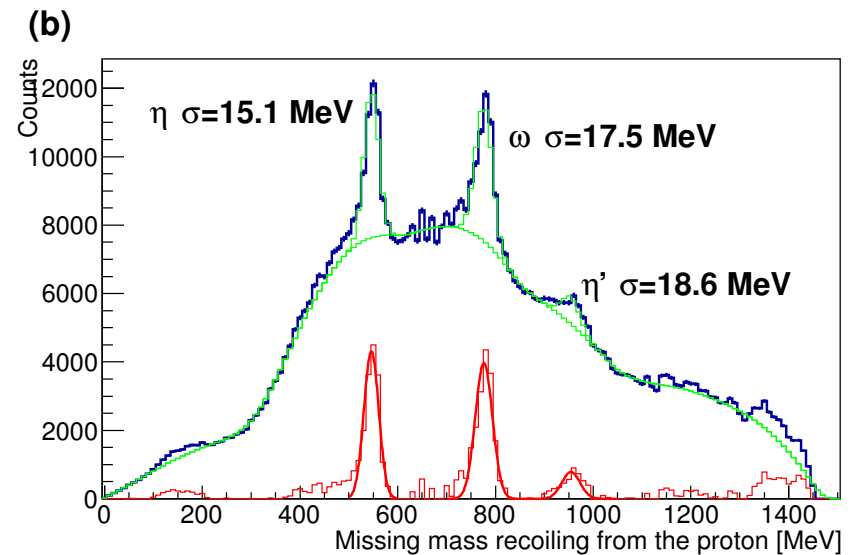
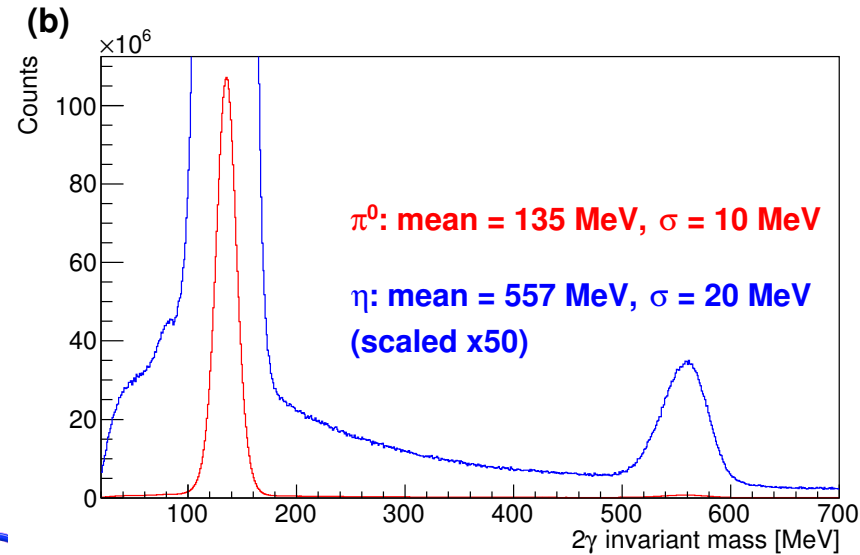
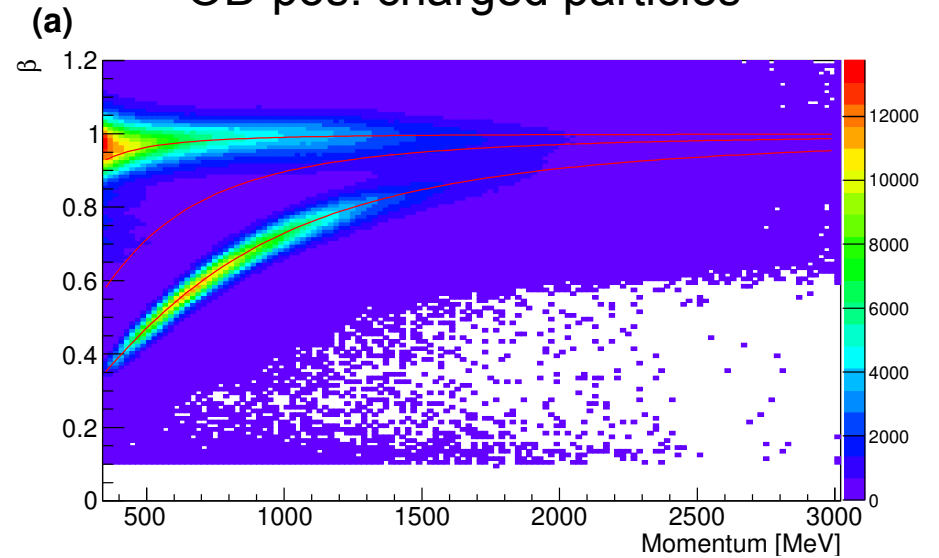
central

forward

BGO 2 γ reconstruction



OD pos. charged particles



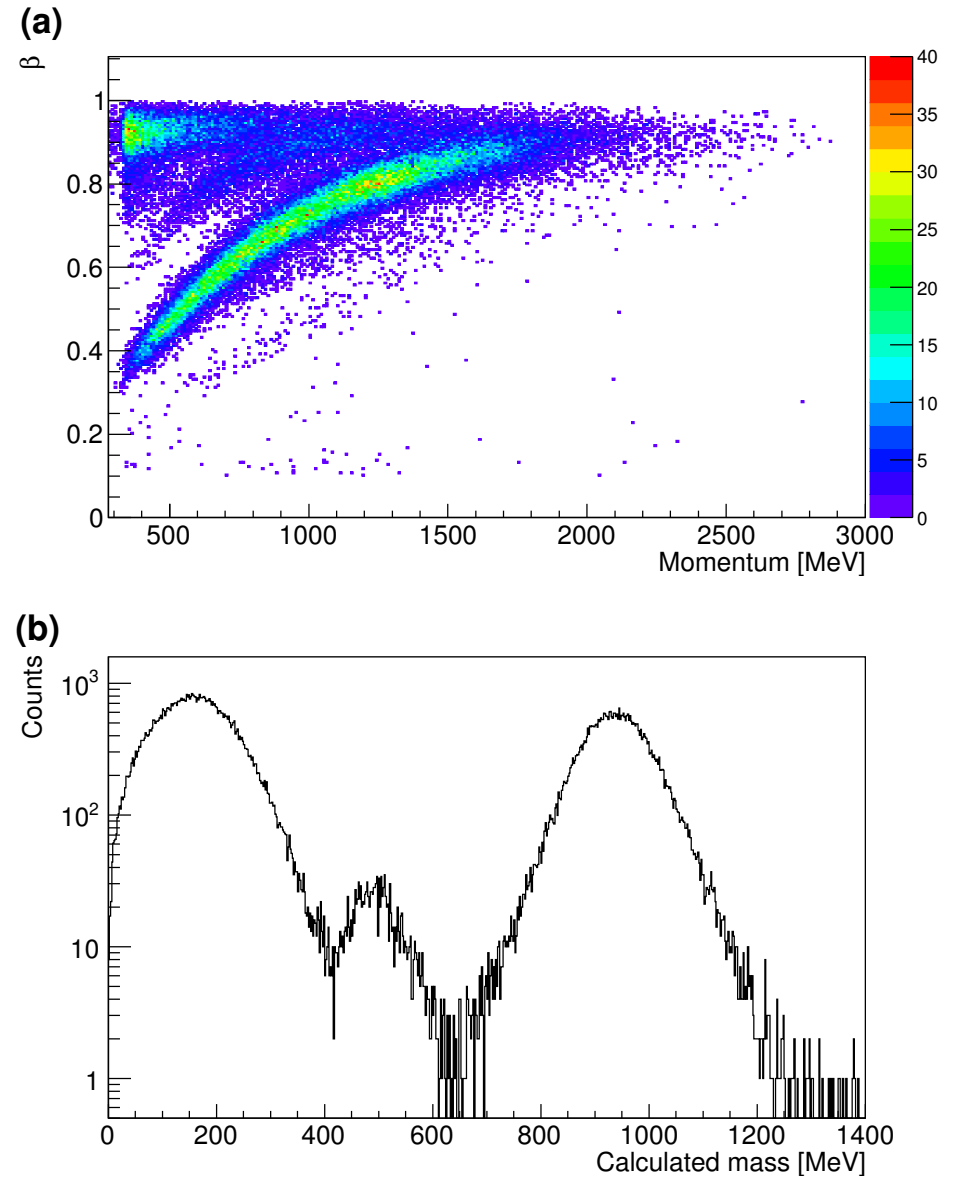
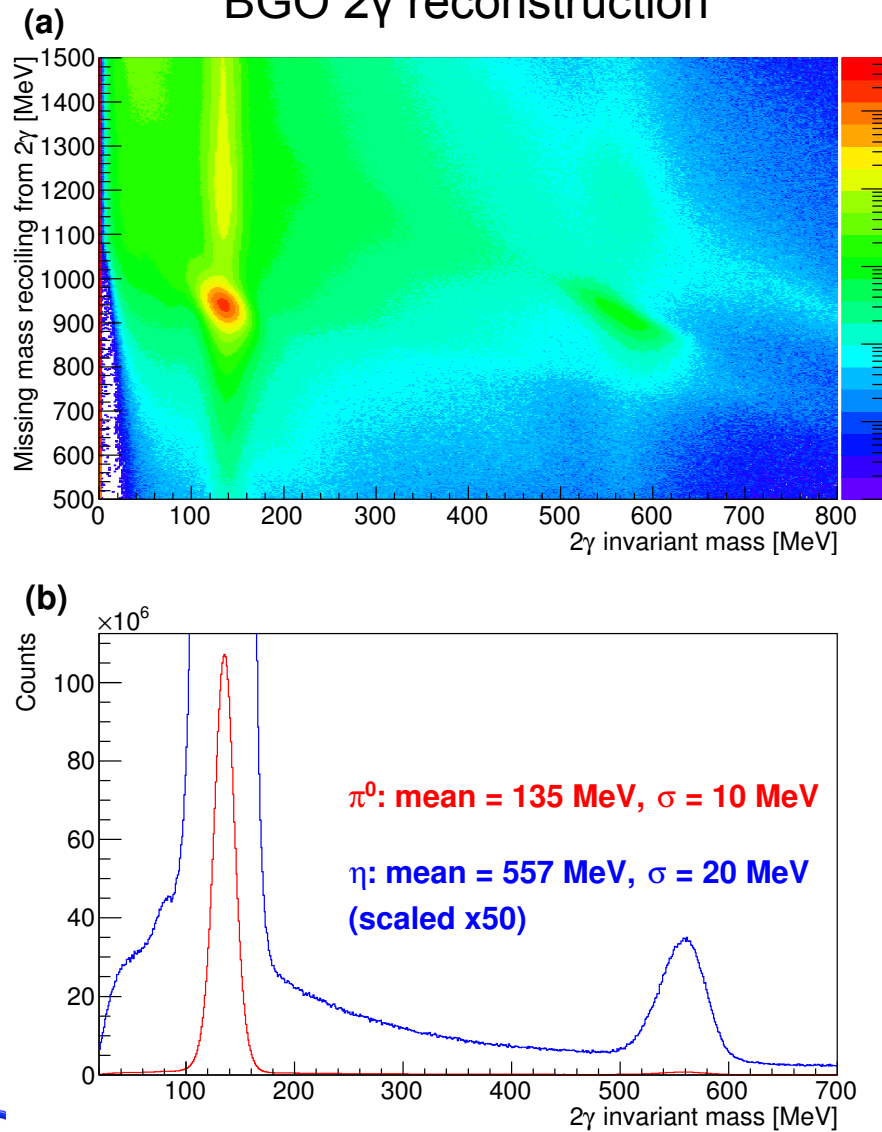
Particle ID & event reconstruction

central

forward

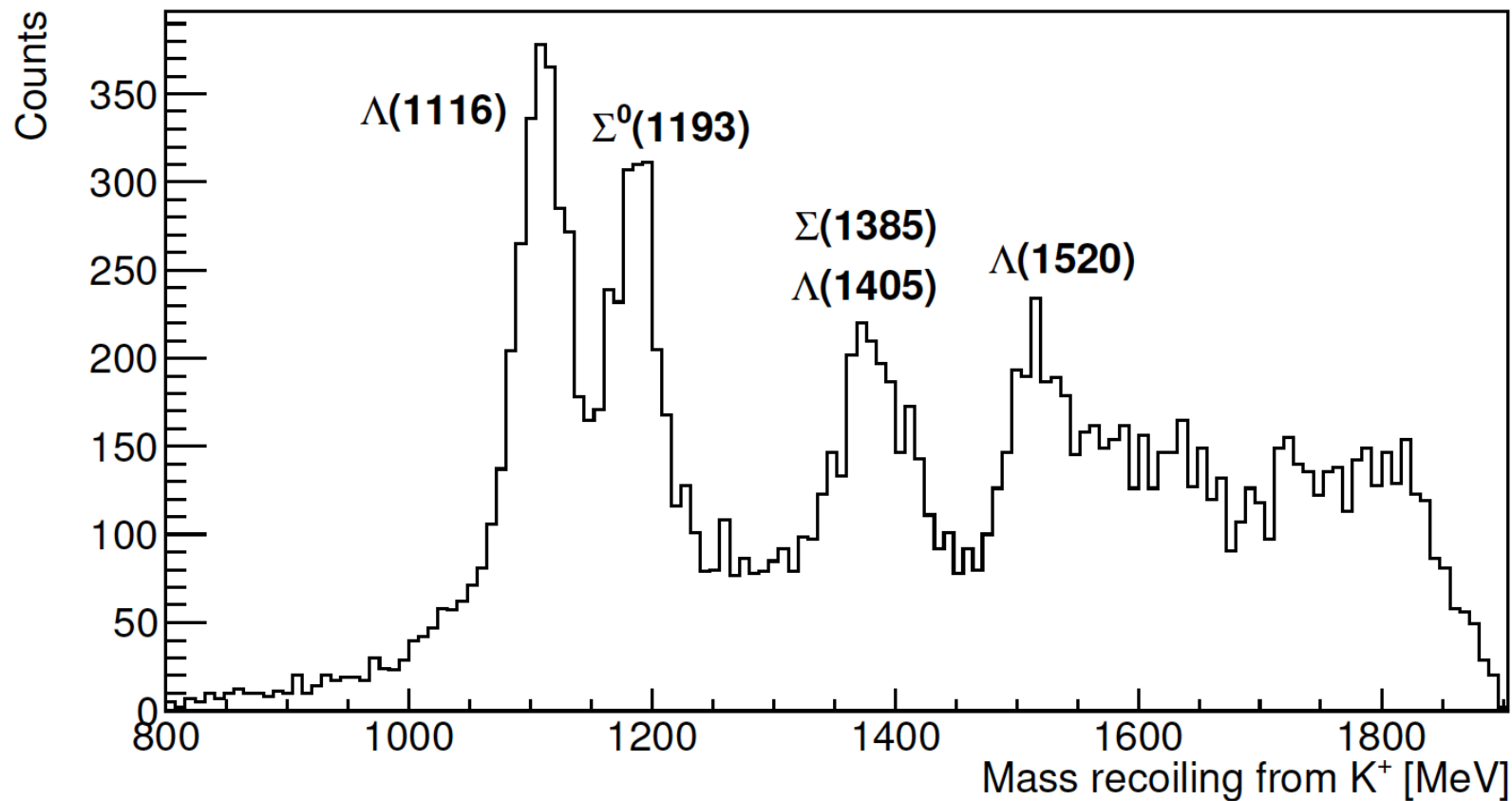
BGO 2 γ reconstruction

OD pos. charged particles



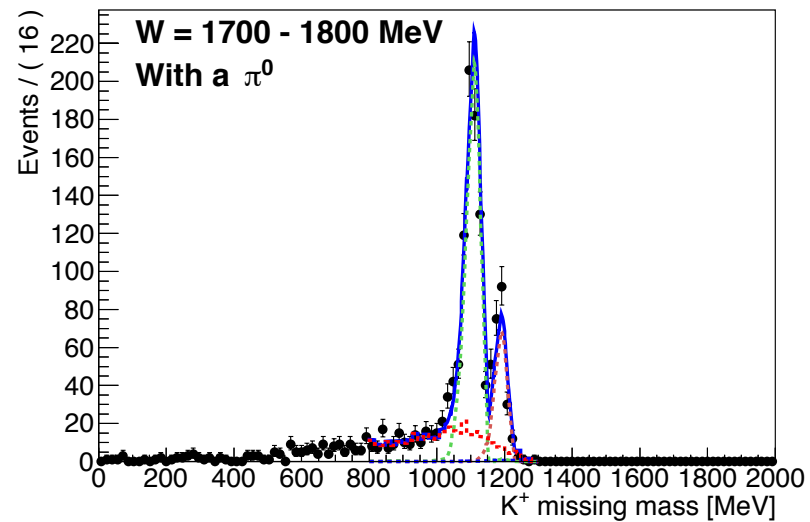
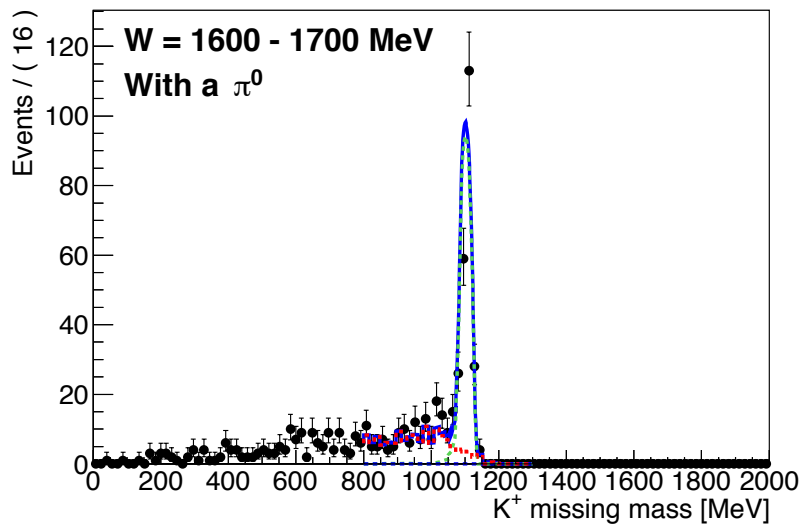
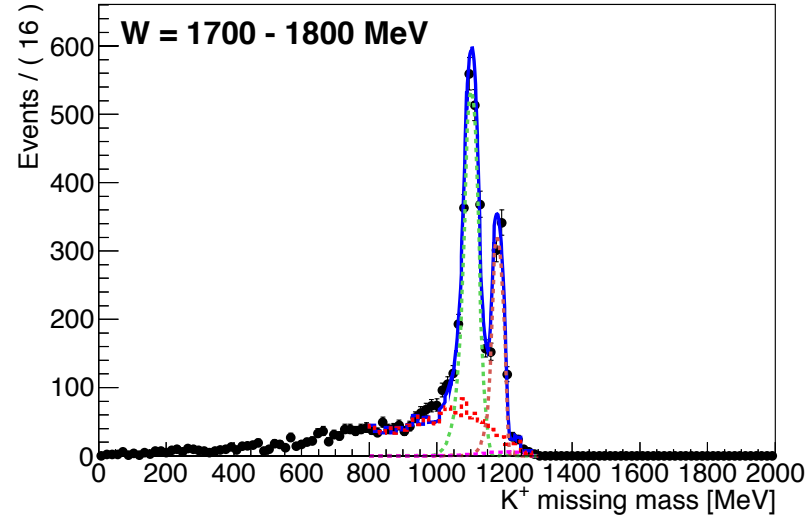
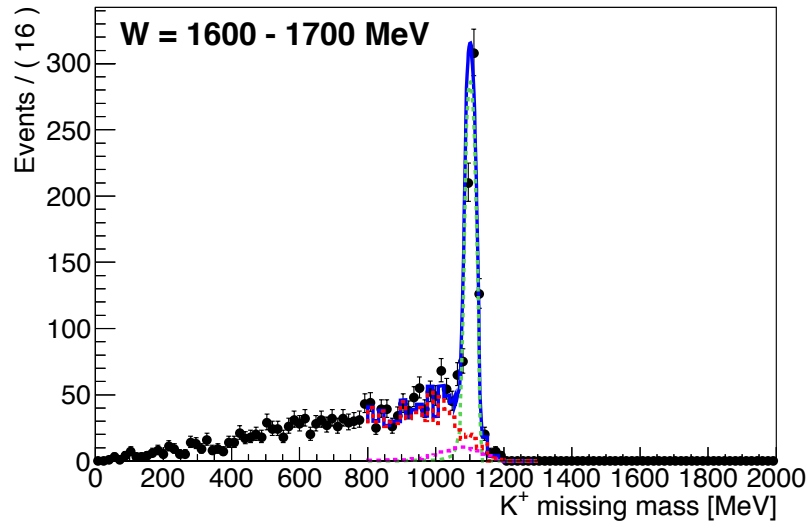
First Results from $\gamma + p \rightarrow K^+ + \Lambda^{(*)} / \Sigma^{(*)}$

forward K^+ in spectrometer



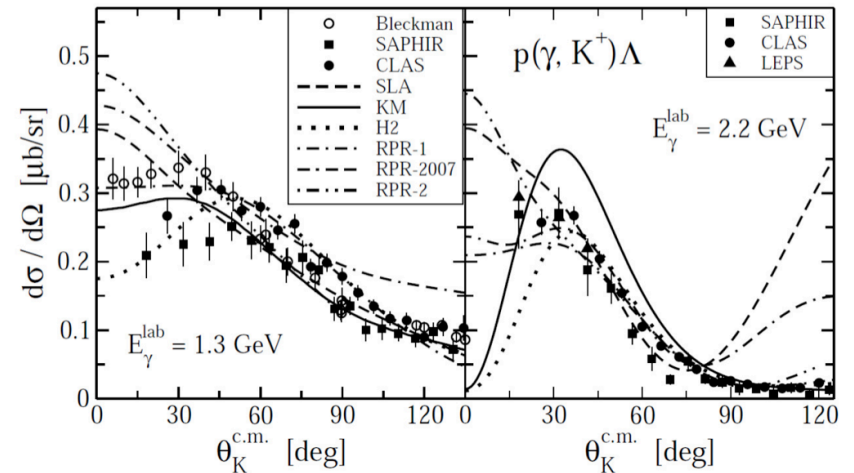
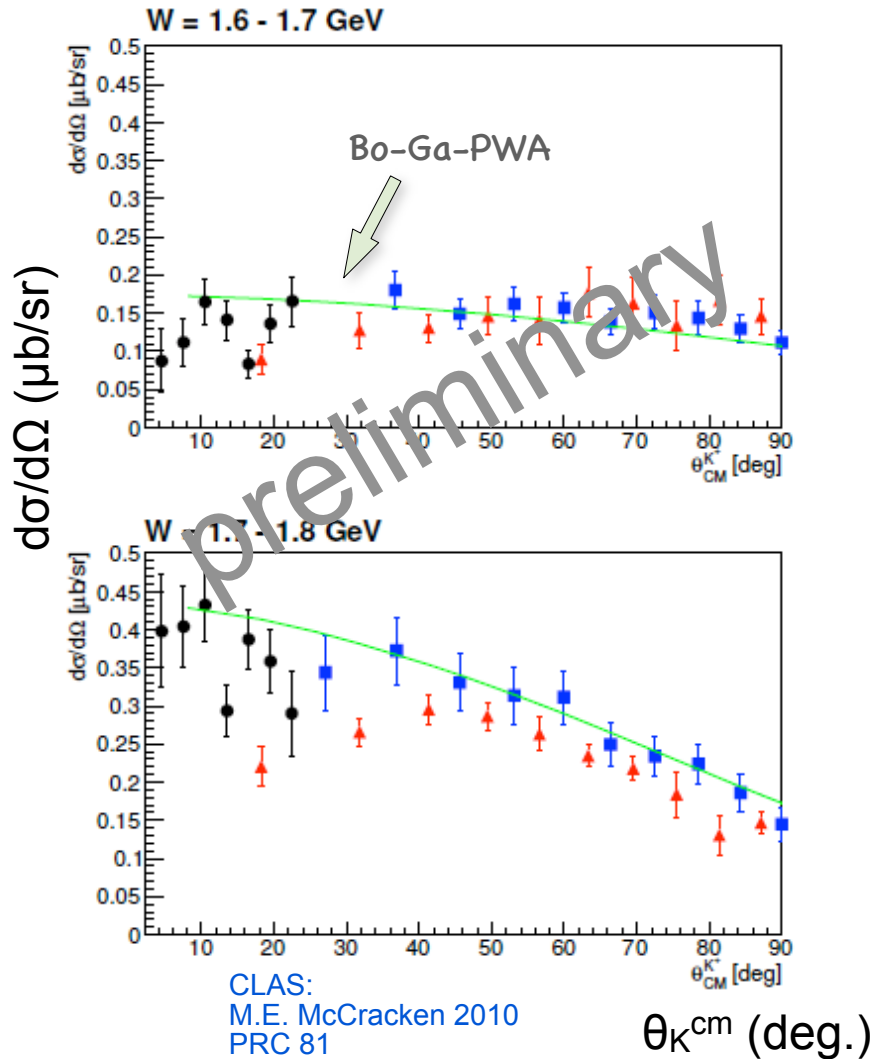
$\gamma + p \rightarrow K^+ + \Lambda(1116)$ @ forward angles

work of T. Jude



$\gamma + p \rightarrow K^+ + \Lambda(1116)$ @ forward angles

work of Th. Zimmermann & T. Jude



Bydzovsky and Skoupil, arXiv:1211.2684
 Proceedings SNP12

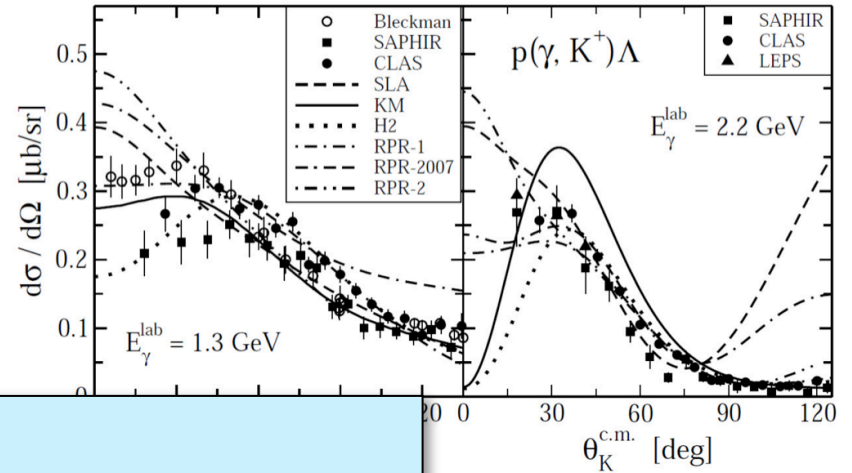
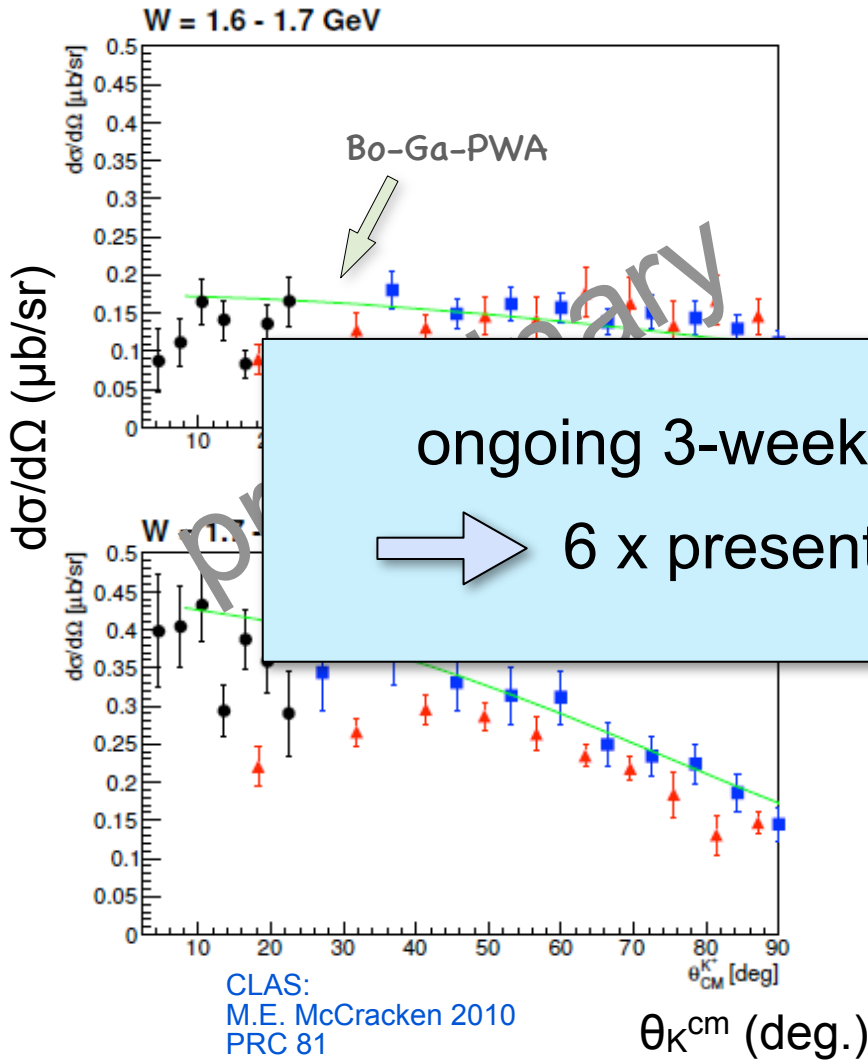
→ important constraint for
 hypernuclei production

- 11 days of data
- K^+ in forward spectrometer
- π^0 from Λ decay in BGO
- x4 statistics w/o π^0 requirement
- absolute flux



$\gamma + p \rightarrow K^+ + \Lambda(1116)$ @ forward angles

work of Th. Zimmermann & T. Jude



ongoing 3-week data taking
 → 6 x present statistics !

and Skoupil, arXiv:1211.2684
 SNP12

important constraint for
 hypernuclei production

- 11 days of data
- K^+ in forward spectrometer
- π^0 from Λ decay in BGO
- x4 statistics w/o π^0 requirement
- absolute flux

CLAS:
 M.E. McCracken 2010
 PRC 81

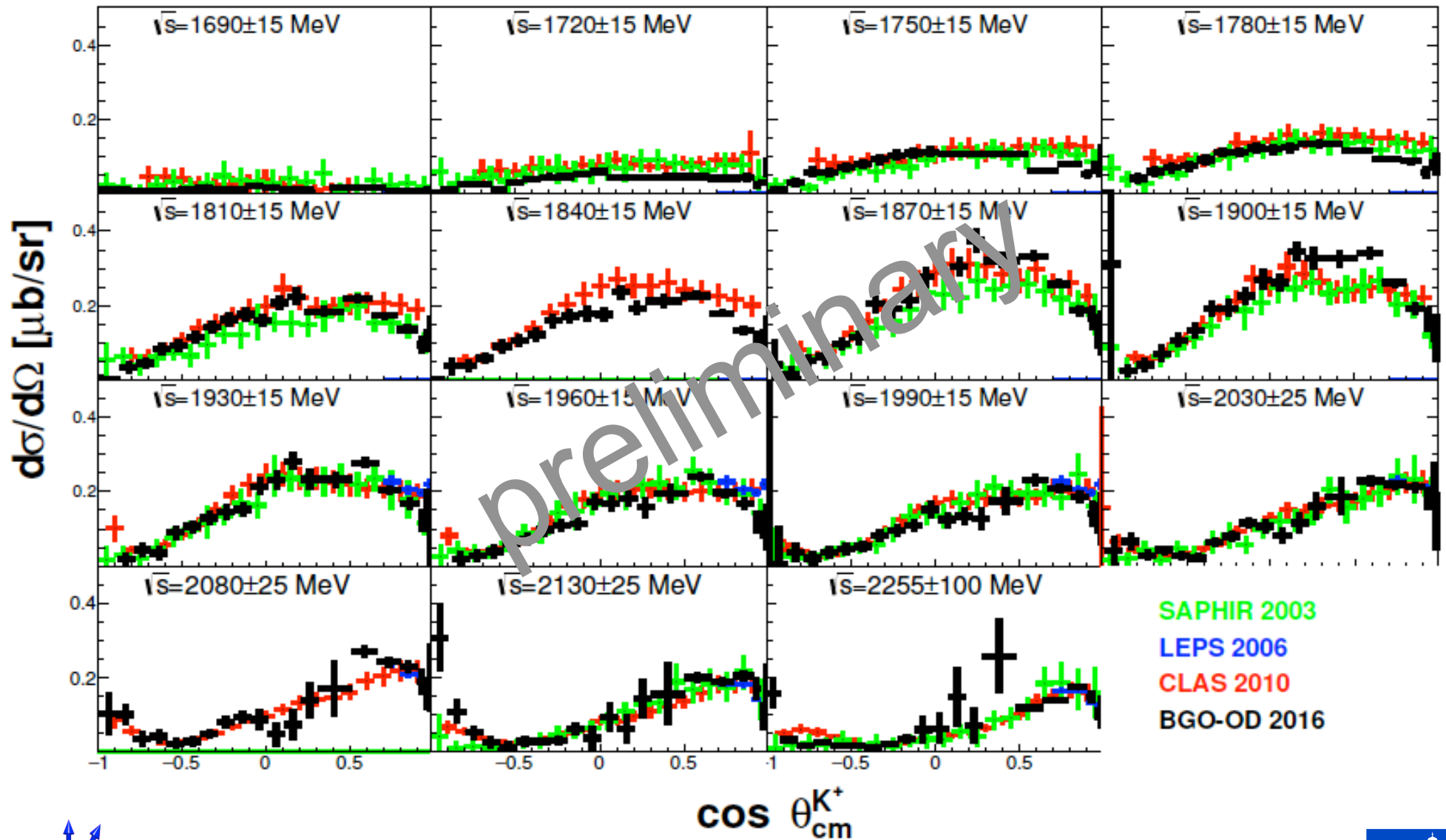
SAPHIR:
 K.H. Glander 2004
 EPJA 19



$\gamma + p \rightarrow K^+ + \Sigma(1193)$

K^+ nearly 4π acceptance & kinematic fit / neural network analysis

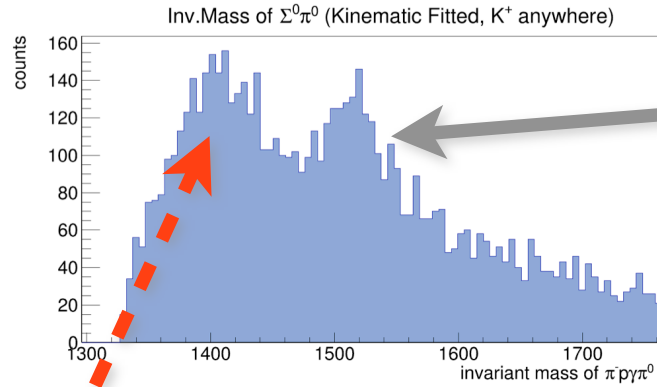
work of G. Scheluchin



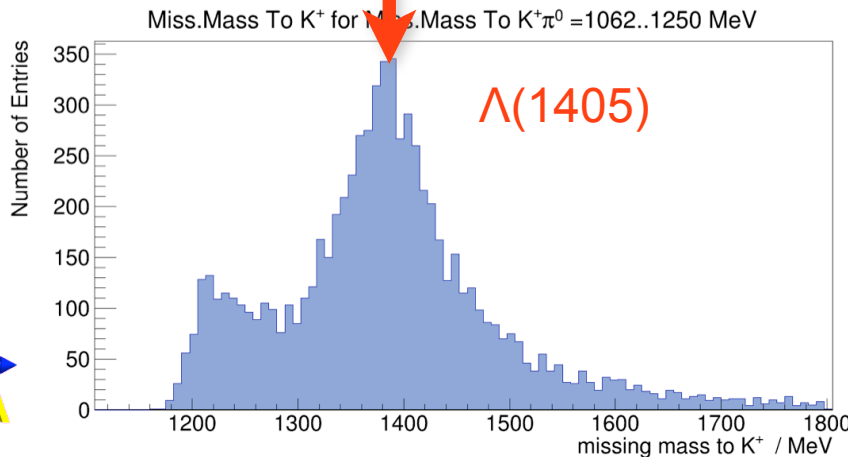
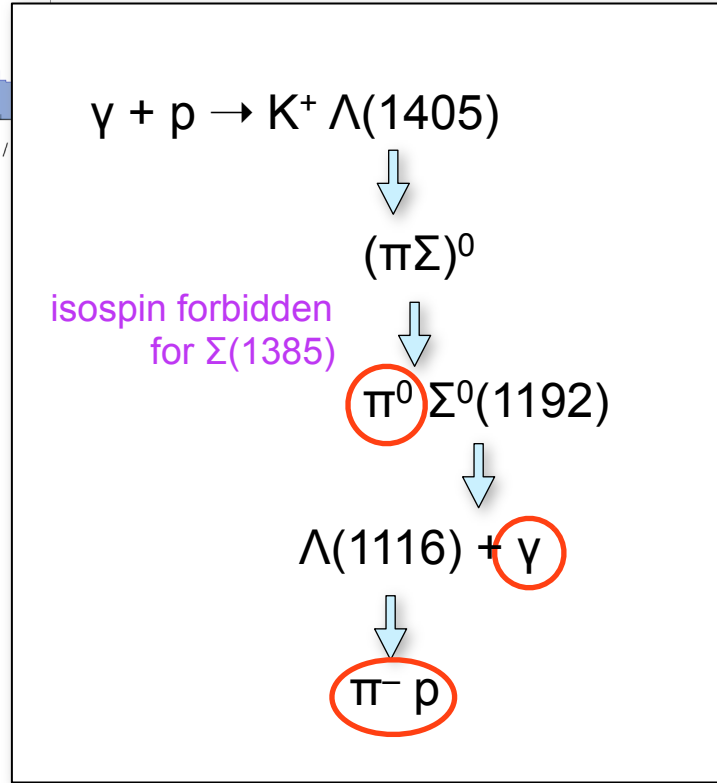
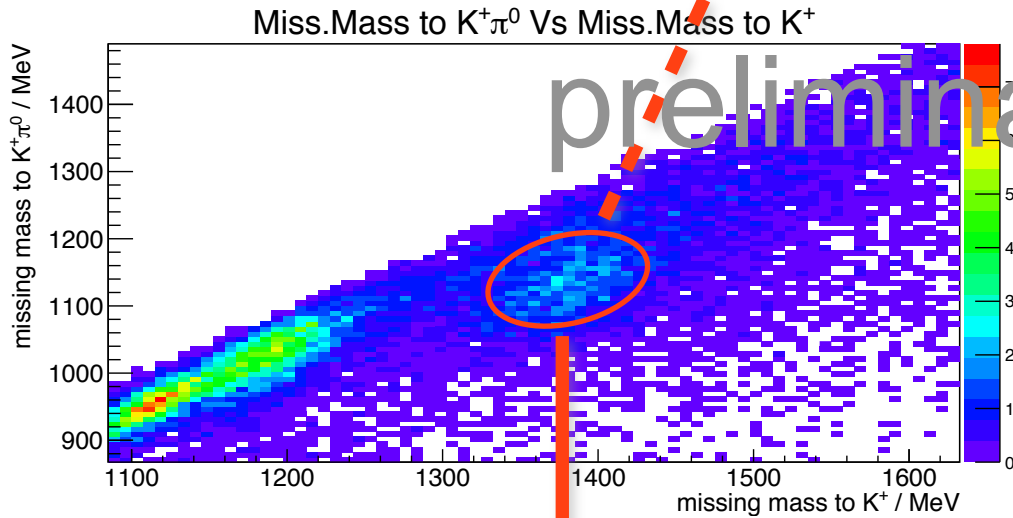
$\Lambda(1405)$: initial tests – *very preliminary*

first results: $K^+\Lambda(1405)$

work of G. Scheluchin



$\Lambda(1520) \rightarrow \Sigma\pi$ [42%]
 $\Lambda(1520) \rightarrow \Lambda\pi\pi$ [10%]



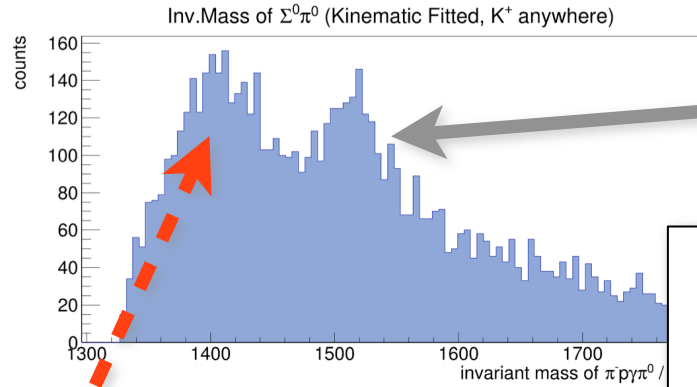
- production at small t
- inaccessible to previous expts



$\Lambda(1405)$: initial tests – *very preliminary*

first results: $K^+\Lambda(1405)$

work of G. Scheluchin



$\Lambda(1520) \rightarrow \Sigma\pi$ [42%]
 $\Lambda(1520) \rightarrow \Lambda\pi\pi$ [10%]

$\gamma + p \rightarrow K^+ \Lambda(1405)$



$(\pi\Sigma)^0$



forbidden
 $\Sigma(1385)$

$\pi^0 \Sigma^0(1192)$

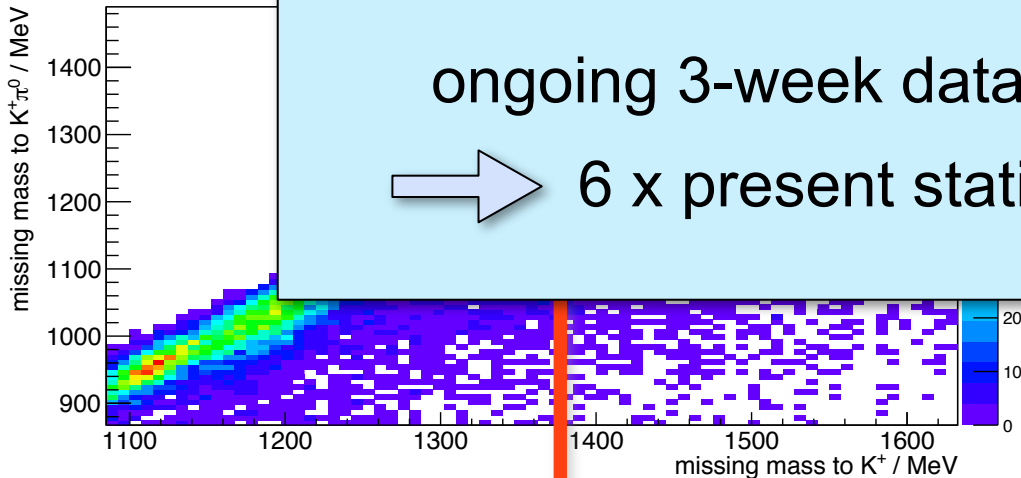


$\Lambda(1116) + \gamma$

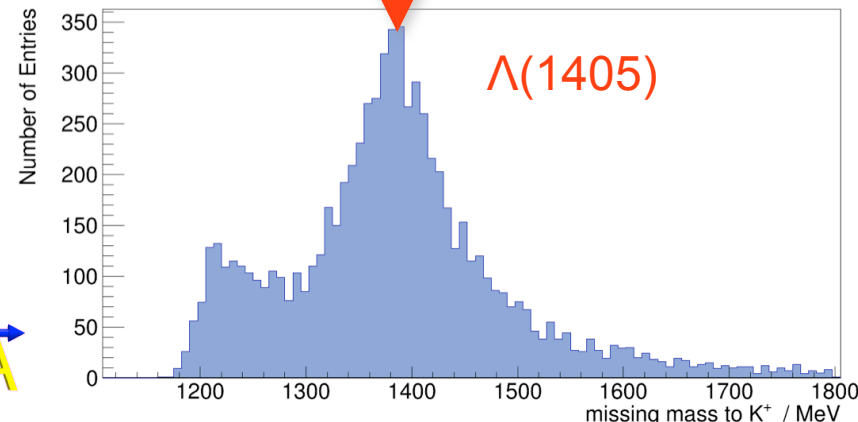


$\pi^- p$

ongoing 3-week data taking
 → 6 x present statistics !



Miss. Mass To K^+ for Miss. Mass To $K^+\pi^0 = 1062..1250$ MeV

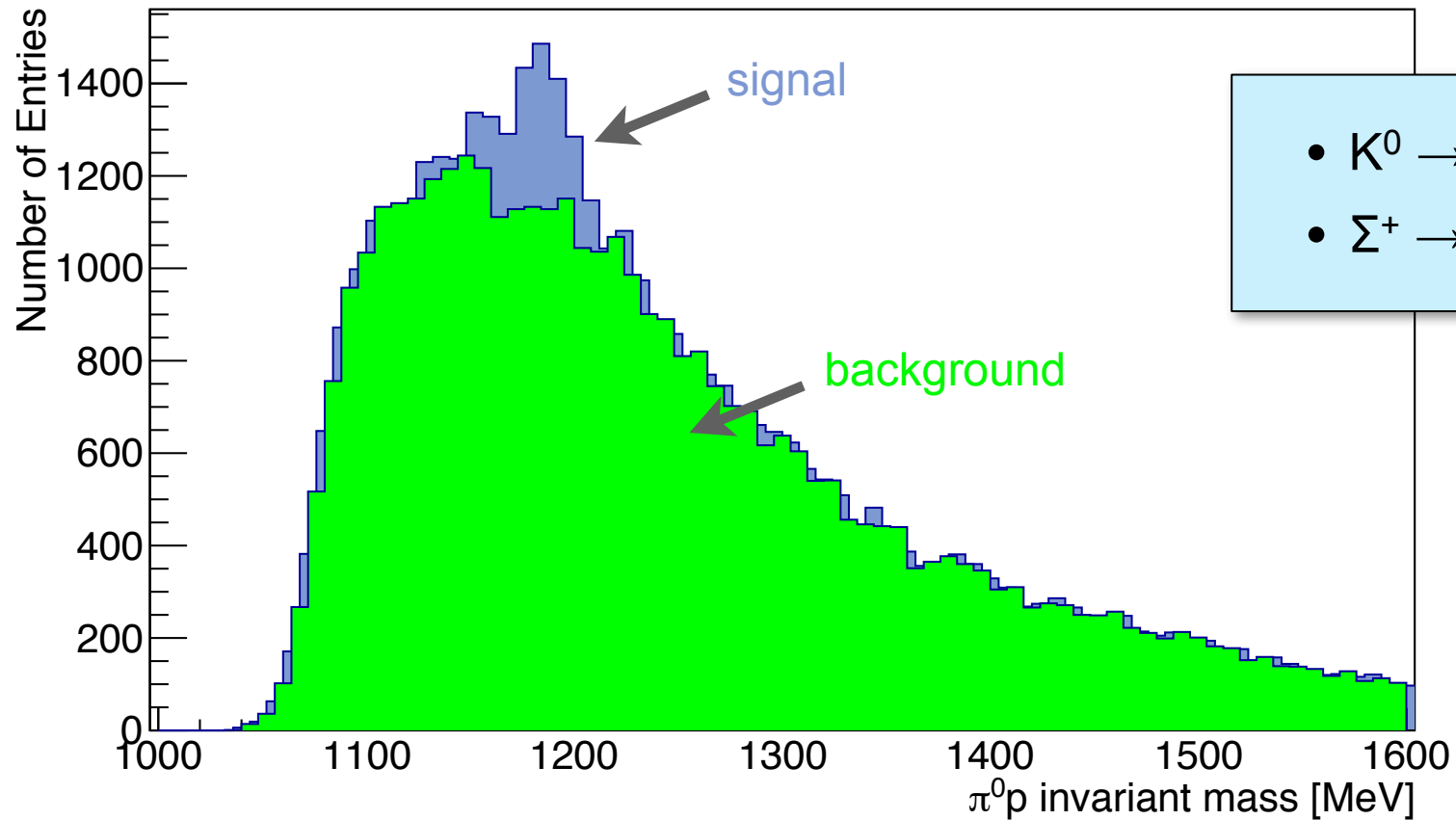


- production at small t
- inaccessible to previous expts



K^0 from *proton* target

work of B.-E. Reitz



K^0 from *neutron* target

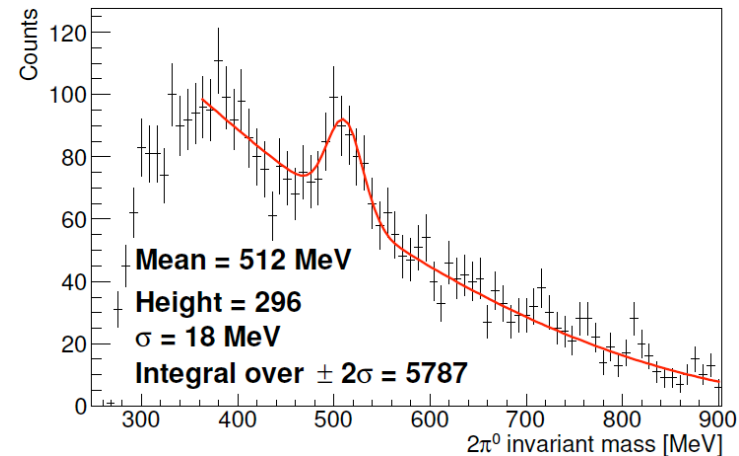
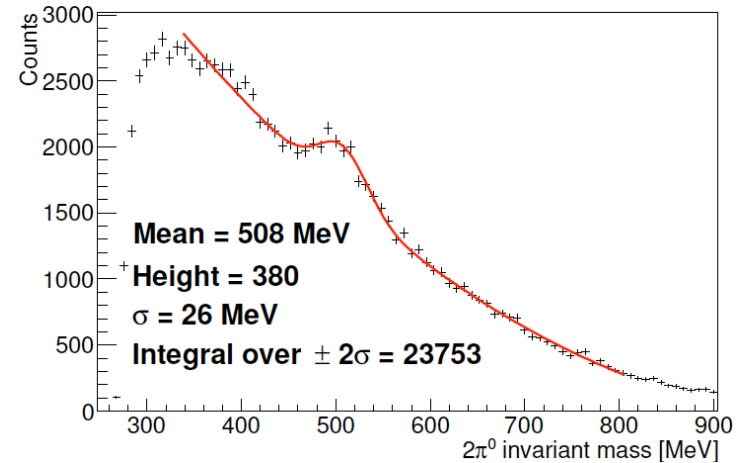
2 day test beam

work of T. Jude

- $K^0 \rightarrow 2\pi^0$ in BGO
- $n(\text{neutral}) < 6$
- $n(\text{charged}) < 3$

in addition:

- p from $\Sigma^0 \rightarrow p \pi^-$ in forward spectrometer



K^0 from *neutron* target

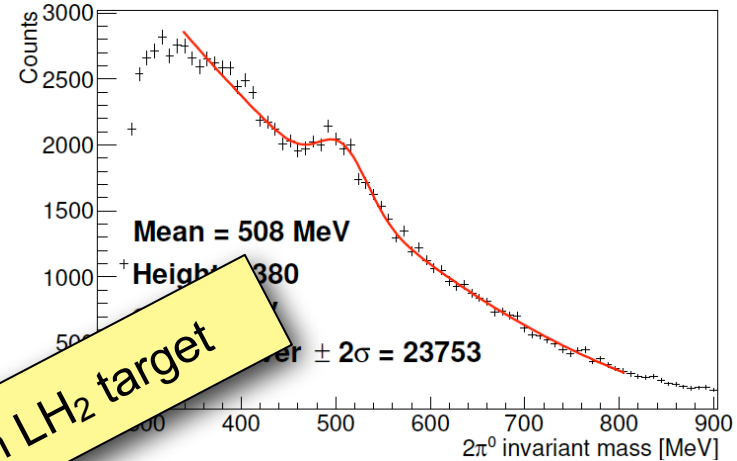
2 day test beam

work of T. Jude

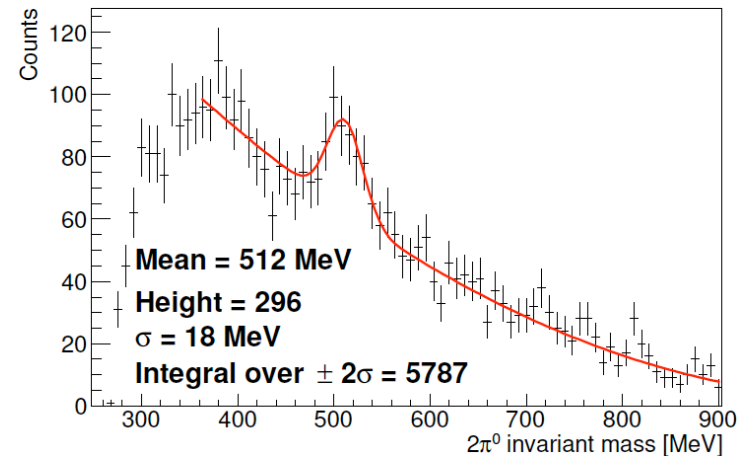
- $K^0 \rightarrow 2\pi^0$ in BGO
- $n(\text{neutral}) < 6$
- $n(\text{charged}) < 3$

in addition:

- p from $\Sigma^0 \rightarrow p \pi^-$ in forward spectrometer



NO signal from LH₂ target



Summary

- BGO-OD is a unique experiment for meson photoproduction,
- optimised for "forward kinematics" \Leftrightarrow low- t processes
- first (preliminary) results from initial tests and commissioning
 - $K^+ \Lambda_{gs}$ photoproduction at extreme (forward) angles
 - $K^+ \Sigma^0_{gs}$ as check for Y^* production
 - $K^+ \Lambda(1405)$
 - $K^0 \Sigma^+_{gs}$ from proton target over K^* threshold
 - K^0 from neutron target
- open trigger: $KY^{(*)}$ data simultaneously, also eta' etc.
- data taking ongoing



Summary

ongoing projects

- BGO-OD is a unique experiment for meson photoproduction,
- optimised for "forward kinematics" \Leftrightarrow low- t processes
- first (preliminary) results from initial tests and commissioning
 - $K^+ \Lambda_{gs}$ photoproduction at extreme (forward) angles
 - $K^+ \Sigma^0_{gs}$ as check for Y^* production
 - $K^+ \Lambda(1405)$
 - $K^0 \Sigma^+_{gs}$ from proton target over K^* threshold
 - K^0 from neutron target
- open trigger: $KY^{(*)}$ data simultaneously, also eta' etc.
- data taking ongoing

