Study of the Strangest Baryons with CLAS12

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GW-HU-JLab-FSU

- Where we are now
- Ω in Photoproduction
- Ω cross section for CLAS12
- Ω measurements with CLAS12

PSHP Frascati, October 2010

Our First Goals

- **Cross section** measurement for $\gamma p \to \Omega^- K^+ K^+ K^0$ which is still unknown
- Study of a **mechanism** of the Ω^- photoproduction which should be quite specific, since it is the first baryon with constituents none of which could come from the target proton

Further Physics Goals

- Determination of the **quantum numbers** of the Ω^- with no assumptions
- Search for Ω^- **excited states**
  PDG2010 gives only the small number of weak signals for $\Omega(2250)^-$, $\Omega(2380)^-$, and $\Omega(2470)^-$

Particle	$I(J^P)$	rating	Particle	$I(J^P)$	rating
$\Xi(1318)$	$\frac{1}{2}(\frac{1}{2}^+)$	****	$\Omega(1672)$	$0(\frac{3}{2}^+)$	****
$\Xi(1530)$	$\frac{1}{2}(\frac{3}{2}^+)$	****	$\Omega(2250)$	$0(?^?)$	***
$\Xi(1620)$	$\frac{1}{2}(?^?)$	*	$\Omega(2380)$	$?(?^?)$	**
$\Xi(1690)$	$\frac{1}{2}(?^?)$	***	$\Omega(2470)$	$?(?^?)$	**
$\Xi(1820)$	$\frac{1}{2}(\frac{3}{2}^-)$	***			
$\Xi(1950)$	$\frac{1}{2}(?^?)$	***			
$\Xi(2030)$	$\frac{1}{2}(\geq \frac{5}{2}^?)$	***			
$\Xi(2120)$	$\frac{1}{2}(?^?)$	*			
$\Xi(2250)$	$\frac{1}{2}(?^?)$	**			
$\Xi(2370)$	$\frac{1}{2}(?^?)$	**			
$\Xi(2500)$	$\frac{1}{2}(?^?)$	*			

Some LHC Highlights

[Courtesy of Michel Spiro, July 2010]

- High rapidity plateau: gluon gluon collider?
- ***Rediscovery*** of all Standard Model particles: K, π, p, Λ, 1000 Ω, 1000 W,100 Z, 10 top
- Use data from less than a week!!!
- 100 papers
- Measurements of jets, di jets, soon α_s already competitive with Tevatron
- However uncertainties on luminosity and jet energy scale to be improved

May be a rival for some investigations

Where we are Now

- Critical limiting factors in any experiment of this kind are the photoproduction **cross section** (i.e. rate) and the **background**, neither of which are known

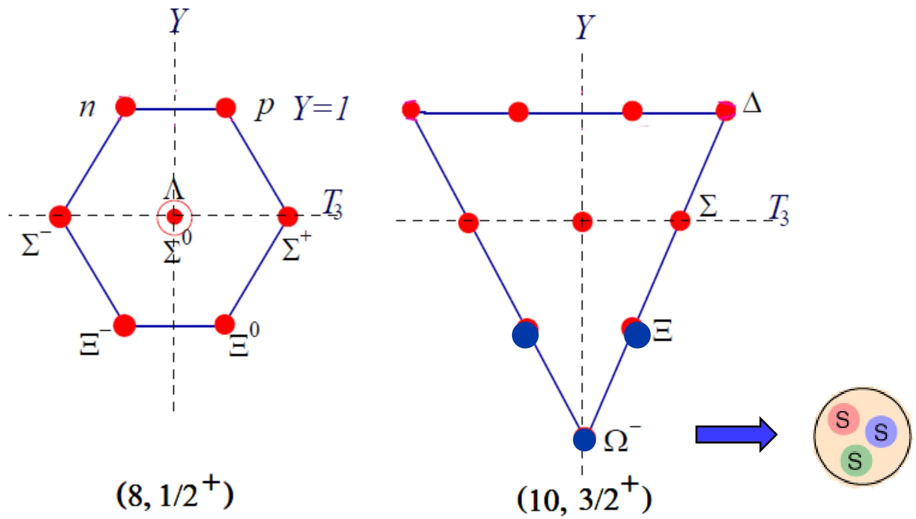
- Despite the fact that its prediction and eventual discovery was one of the brightest highlights in hadron physics, not much is known about Ω^- baryon **properties** and **mechanism** of the Ω^- production

- There are some basic facts: →

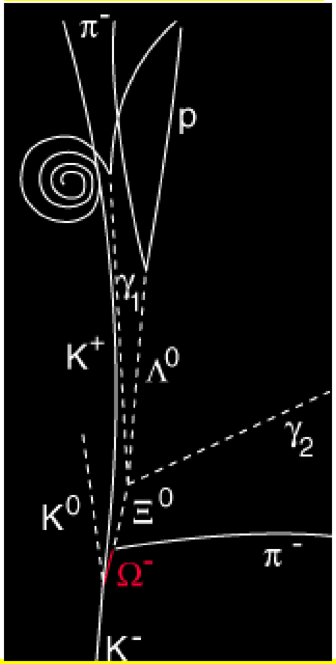
Pre-History

- In **1962**, Gell-Mann and Ne'eman predicted a new baryon, Ω^-, with S = –3, $J^P = 3/2^+$, and the mass about **1670** MeV

  [M. Gell-Mann and Y. Ne'eman, *The Eightfold Way* (W.A. Benjamin, Inc. NY, 1964)]



$K^- p \rightarrow \Omega^- K^+ K^0$



- The $\Omega(1670)^-$ observation in **1964** at **BNL** triumphantly confirmed the hypothesis of **$SU(3)_F$**
- The unambiguous discovery in both **production** and **decay** was reported [V.E. Barnes *et al* Phys Rev Lett **12**, 204 (1964)]

1 event
They scan > **100k** BC pictures with **5-10 K⁻** per picture

PDG10 for Ω^- & Statistics

[K. Nakamura *et al* [RPP] J Phys *G* **37**, 075021 (2010)]

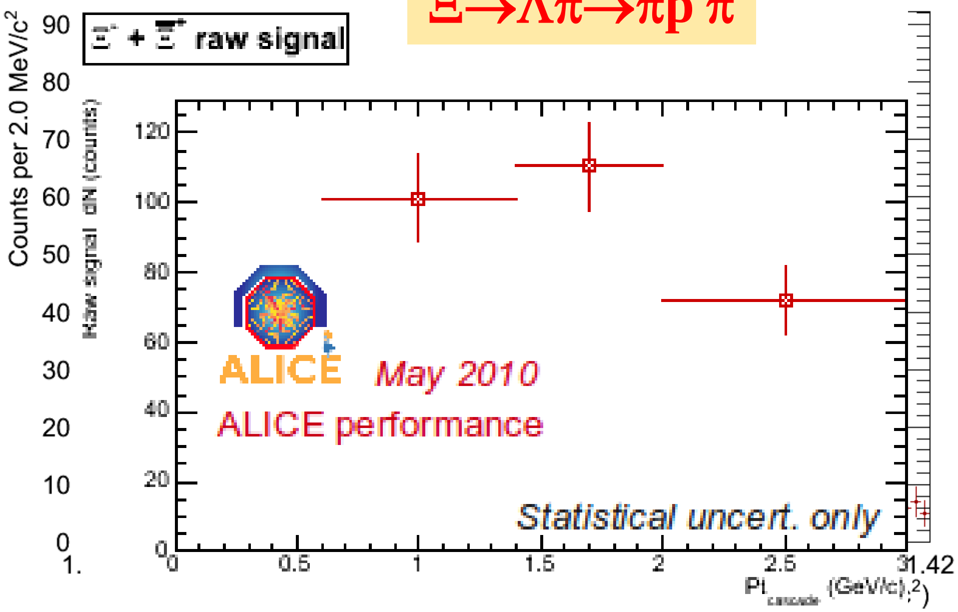
• $M = 1673 \pm 1$ MeV	100 evts	HARTOUNI-85	SPEC	80–280 GeV $K^0_L C$
• $\tau = (0.823 \pm 0.013) \times 10^{-10}$ s	12k evts	BOURQUIN-84	SPEC	SPS hyperon beam
• $\mu_N = -2.024 \pm 0.056$	235k evts	WALLACE-95	SPEC	Ω^- 300–550 GeV
• $\Gamma(\Lambda K^-)/\Gamma_{tot} = 0.678 \pm 0.007$	14k evts	BOURQUIN-84	SPEC	SPS hyperon beam
$\Gamma(\Xi^0\pi^-)/\Gamma_{tot} = 0.236 \pm 0.007$	1947evts	BOURQUIN-84	SPEC	SPS hyperon beam
$\Gamma(\Xi^-\pi^0)/\Gamma_{tot} = 0.086 \pm 0.004$	759 evts	BOURQUIN-84	SPEC	SPS hyperon beam
$\Gamma(\Xi^-\pi^+\pi^-)/\Gamma_{tot} = (4.3+3.4-1.3) \times 10^{-4}$	4 evts	BOURQUIN-84	SPEC	SPS hyperon beam
$\Gamma(\Xi(1530)^0\pi^-)/\Gamma_{tot} = (6.4+5.1-2.0) \times 10^{-4}$	4 evts	BOURQUIN-84	SPEC	SPS hyperon beam
$\Gamma(\Xi^-\gamma)/\Gamma_{tot} < 4.6 \times 10^{-4}$ (CL=90%)	0 evts	ALBUQUERQ..94	E761	Ω^- 375 GeV
$\Gamma(\Lambda\pi^-)/\Gamma_{tot} < 2.9 \times 10^{-6}$ (CL=90%)	? evts	WHITE-05	HYCP	pCu 800 GeV

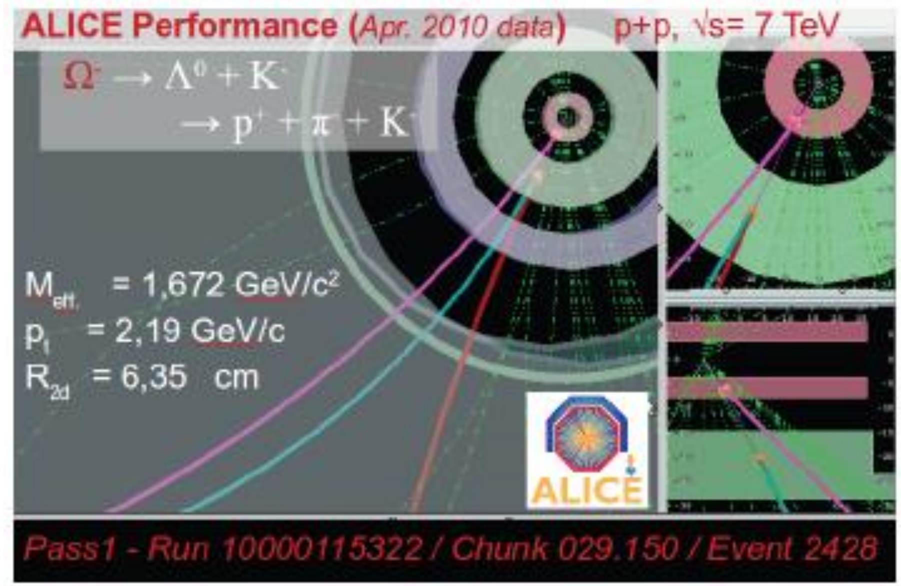
$< 7 \times 10^{-5}$ at 90% CL at FNAL [*HyperCP Collab*, arXiv:1008.4405]

Strange Particles: Cascade & Omega Reconstruction

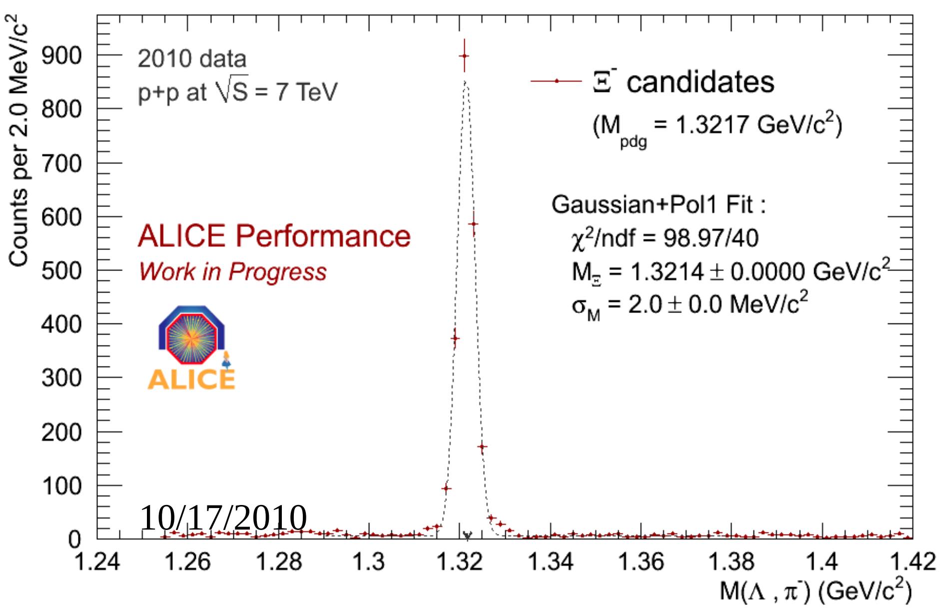
[Courtesy of Iouri Belikov, July 2010]

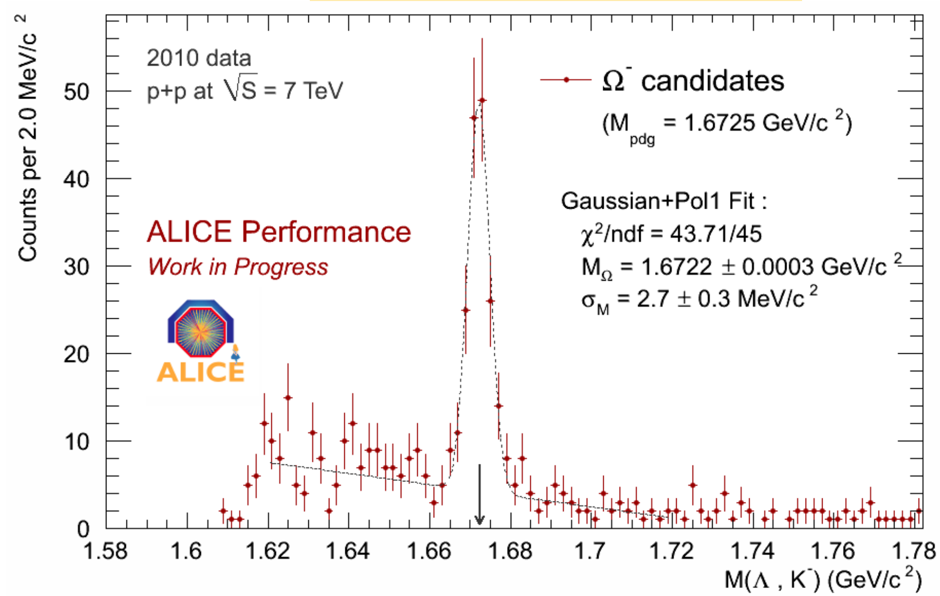
$\Xi \rightarrow \Lambda\pi \rightarrow \pi p\ \pi$





$\Omega^- \rightarrow \Lambda^0 K^- \rightarrow \pi^- p^+ K^-$





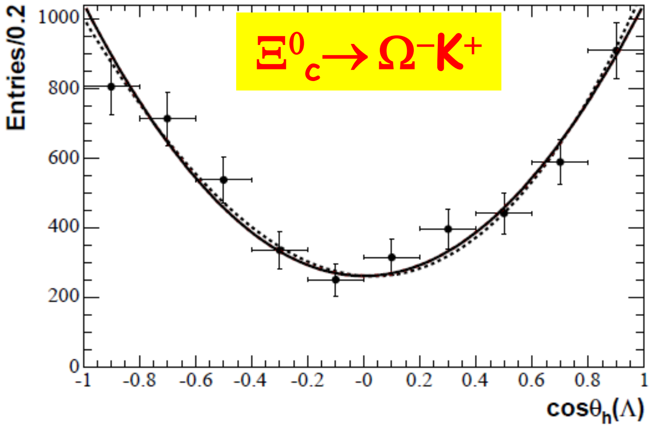
History

- The **quantum numbers** follow from the assignment of the particle to the baryon decuplet

- Study [M. Deutschmann *et al* (*Aachen-Berlin-CERN-Innsbruck-London-Vienna Collab*) Phys Lett **73B**, 96 (1978); M. Baublillier *et al* Phys Lett **78B**, 342 (1978)] ruled out spin $J = \frac{1}{2}$ and find consistency with $J = 3/2$

- The **spin** of the Ω-hyperon has been recently determined (but with some assumptions) by the BaBar at SLAC [B. Aubert *et al* (*BaBar Collab*) Phys Rev Lett **97**, 112001 (2006)]

- **The parity of the Ω stays totally unknown**

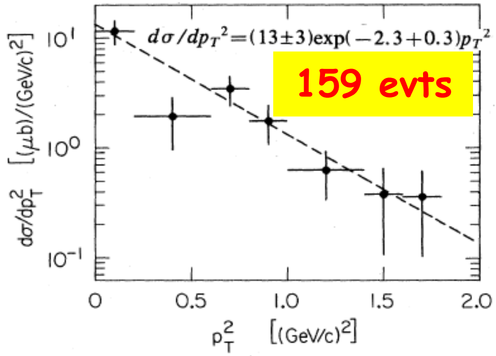


- In each of the measurements, only a small Ω^- data sample was obtained, and the Ω^- **production mechanism** was not well understood

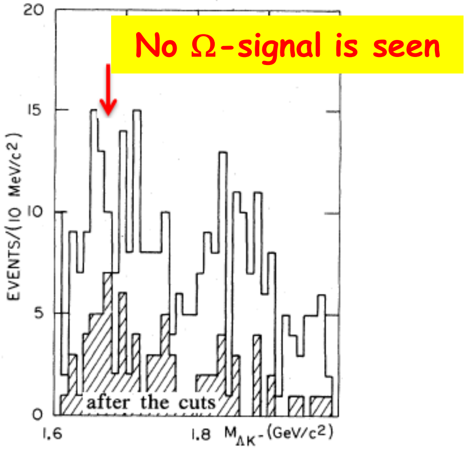
Ω in Photoproduction

- The cross sections of the Ω-production have been measured using **Kaon beams**

- The **ANL** experiment measured the $K^-p \to \Omega^- X$ cross section at 6.5 GeV/c as
  σ = 1.4±0.6 mb [J.K. Hassall *et al* Nucl Phys **B189**, 397 (1981)]



- The experiment **SLAC**-E-135 measured only forward differential cross section for $K^-p \to \Omega^- X$ at 11 GeV/c
  [D. Aston *et al* Phys Rev D **32**, 2270 (1985)]



- Experiment **SLAC**-BC-073 sought Ω-photoproduction in the $\gamma p \to \Omega^- X$ reaction at **20** GeV, and provided only an upper limit of σ < 17 nb
  [K. Abe *et al* (*SLAC Hybrid Facility Photon Collab*) Phys Rev D **32**, 2869 (1985)]

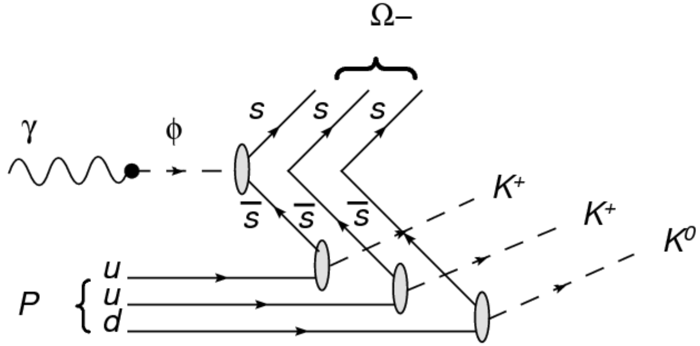
Cross Section Estimations for JLab12

- **Andrey Afanasev:**
  Translation hadronic into EM Xsection:
  - SLAC $K^-p \to \Xi^- X$ Xsection,
  - ϕ-VMD, and
  - CLAS $\gamma p \to \Xi^- KK$ Xsection

  ➡ $\sigma \sim 0.4$ nb

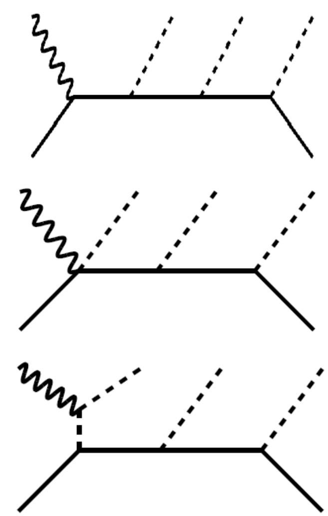
  - SLAC $K^-p \to \Xi^- X$ and
  - $K^-p \to \Omega^- X$ Xsections, and
  - CLAS $\gamma p \to \Xi^- KK$ Xsection

  ➡ $\sigma \sim 0.5$ nb



- **Winston Roberts:**
  Phenomenological Lagrangian:
  - Not all couplings known
  - Born terms are in

  ➡ $\sigma \sim 0.2$–1 nb



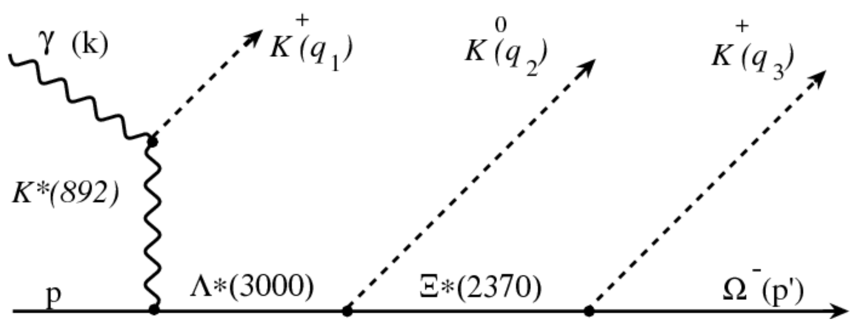
(24)

(18)

(1)

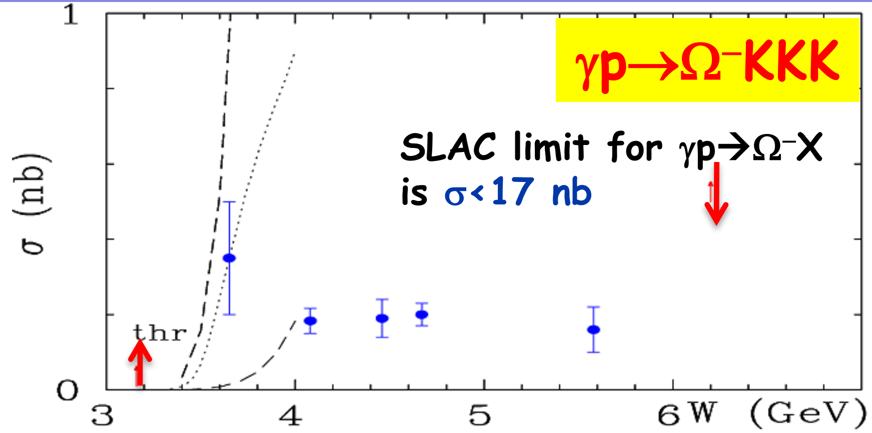
- **Vitaly Shklyar:**
  Effective Lagrangian:
  There are three additional diagrams obtained by permutations of final Kaon momenta

  ➡ $\sigma \sim 2$ nb

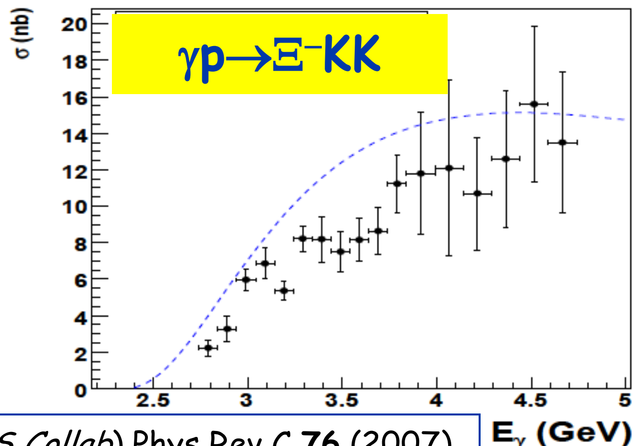


Cross Section Estimations for JLab12

- Near 4-particle **threshold**, the Xsection is small, as expected, but quickly grows into the nb range (or tens of nb)
- Xsection of a few nb level in the energy range of CLAS12 seems to be a **safe** bet
- **Overall**, all **4** estimations are reasonably consistent with each other
- **Clearly**, we **shouldn't believe** an effective Lagrangian approach very far from threshold, as the Xsections continue to rise but we have only vague idea when and where this rise should finish

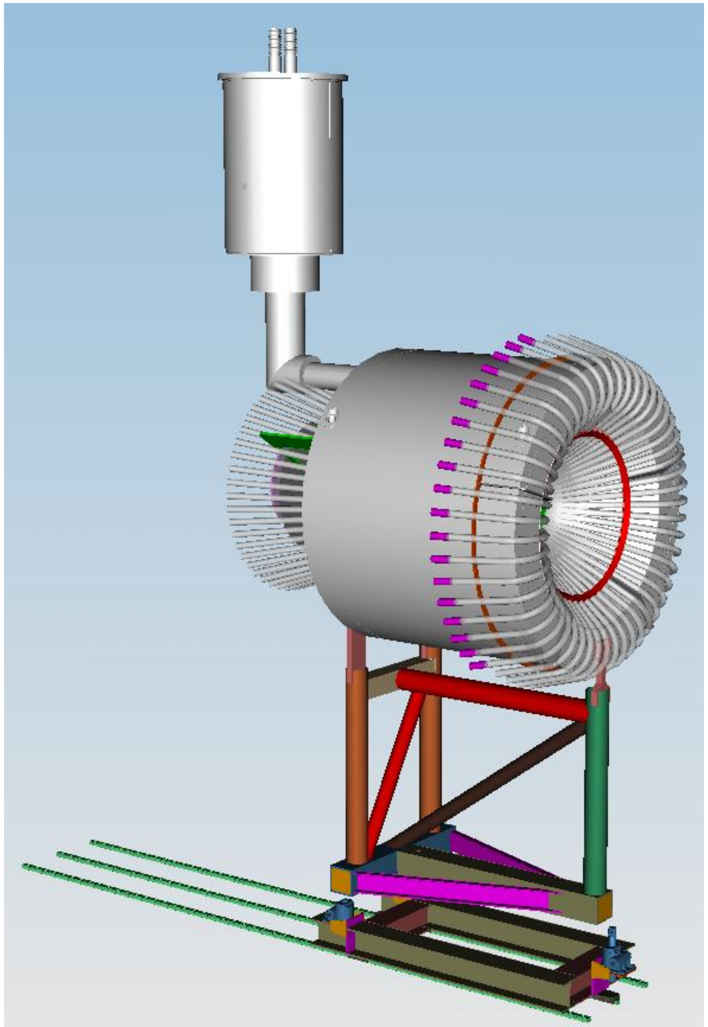


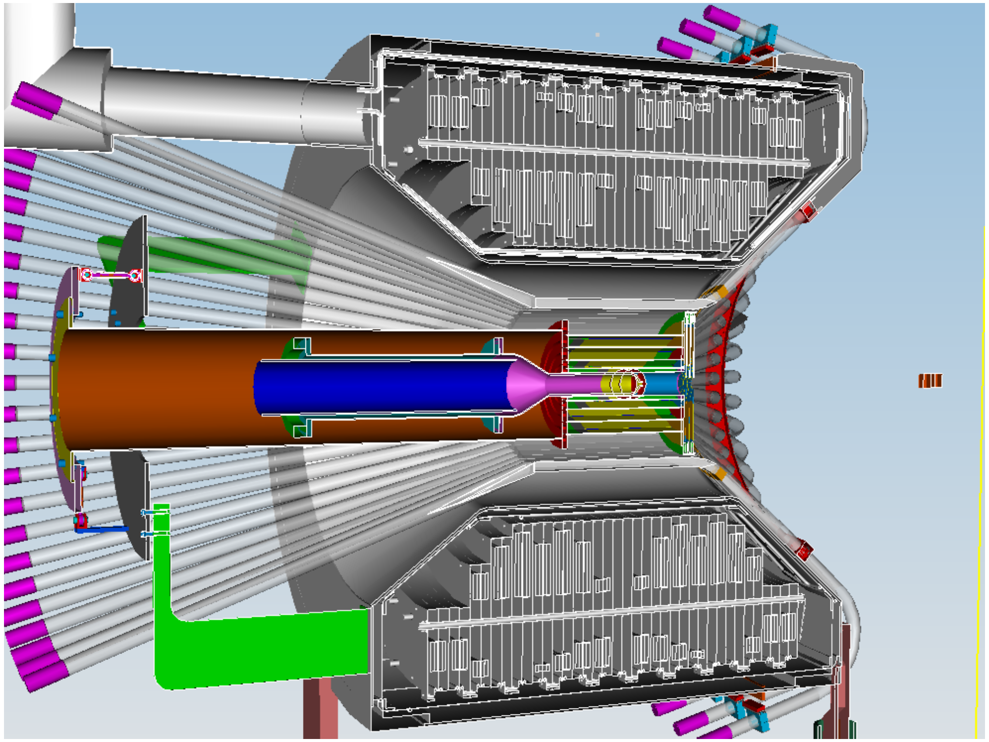
● Hadronic Data→EM: **Afanasev**
---- Phenomenological Lagrangian: **Roberts**
.... Effective Lagrangian: **Shklyar**



● L. Guo *et al* (*CLAS Collab*) Phys Rev C **76** (2007)
...... K. Nakayama *et al* Phys Rev C **74** (2006)

CLAS12 - Central Detector



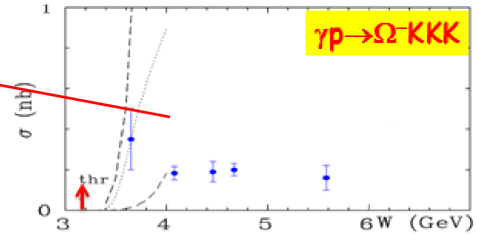


- Superconducting 5 T Solenoid 78 cm ø warm bore
- CTOF Barrel, σ_{TOF} < 60 ps
- Central Vertex Tracker
- Neutron Counter

Untagged Real Photon Experiment with the Basic CLAS12

- The **CLAS12** electron beam luminosity is expected to be **10^{35}** $cm^{-2}s^{-1}$
  Incident on hydrogen target **11** GeV electron beam generates real photons
  The photon luminosity in the range of **E** = **5–11** GeV will be **4×10^{32}** $cm^{-2}s^{-1}$

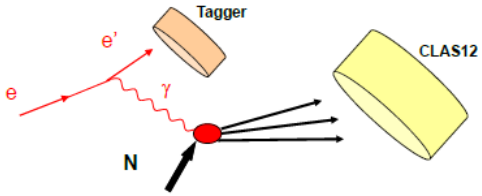
  If we take the Ω-production cross section of **0.5 nb**,
  the production rate will be about **500 Ω/hr**



- The MC simulation [**Derek Glazier**] for
  $\gamma p \to K^+K^0K^+\Omega^-$, $\Omega^- \to \Lambda K^-$, $\Lambda \to p\pi^-$, $K^0(K^0_s) \to \pi^+\pi^-$
  with all **7** charged particles detected [**an unique signature**] shows that acceptance is **4×10^{-4}**
- With the production rate of **500 Ω/hr** and acceptance of **4×10^{-4}**,
  we can expect to detect in CLAS12 about **5** completely **exclusive** Ω-production events a day
- For these **exclusive** events, the **background** should be very small

Quasi-Real Photon Experiment with the Basic CLAS12 and Tagging Facility

- We can use **CLAS12** with quasi-real photon **tagging facility** as well

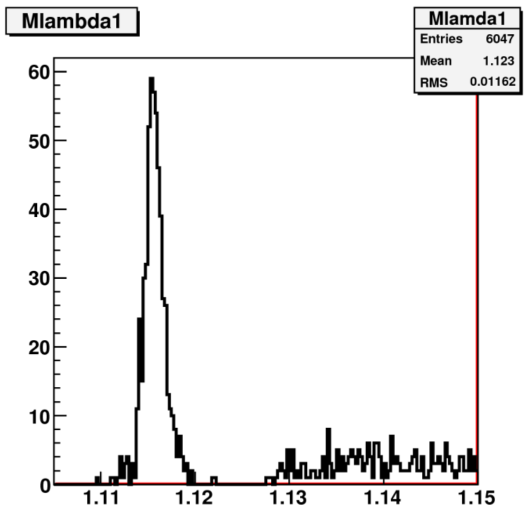


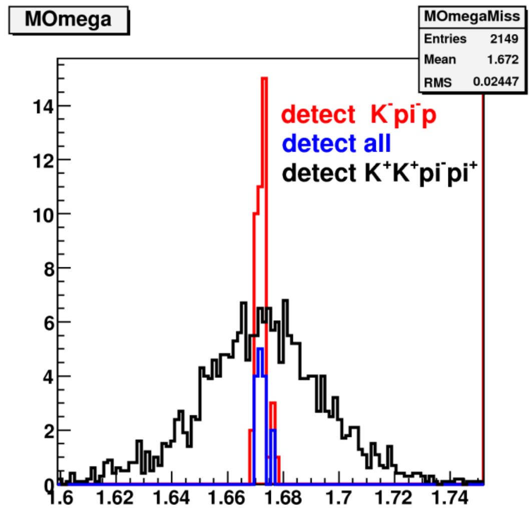
- This forward tagger will detect electron at very small angle and provide information about virtual photon
- The **luminosity** of ***quasi-real photons*** will be about an order or two of magnitude lower than the luminosity of ***real photons***
- However, we can use MM technique and therefore get significant gain in the acceptance
- If we know photon energy and momentum and detect associated $K^+K^0K^+$ to reconstruct ***Ω***-baryon using MM in this case, the acceptance is **0.08**
- **This yields comparable number of events detected**

MC for CLAS12

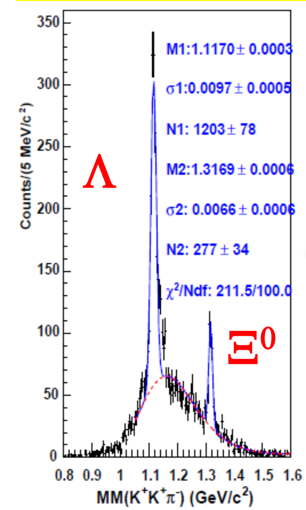
[Courtesy of Derek Glazier, Dec 2009]

- Set final state as $K^+K^+K^0\Omega^-$, track and analyze



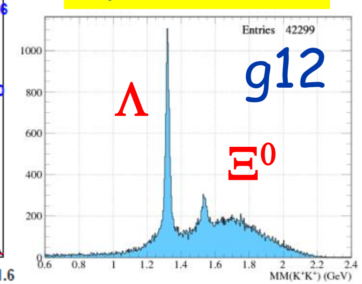


$\gamma p \to K^+K^+\pi^-X$



[L. Guo *et al* (*CLAS Collab*) Phys Rev C **76** (2007)]

$\gamma p \to K^+K^+X$



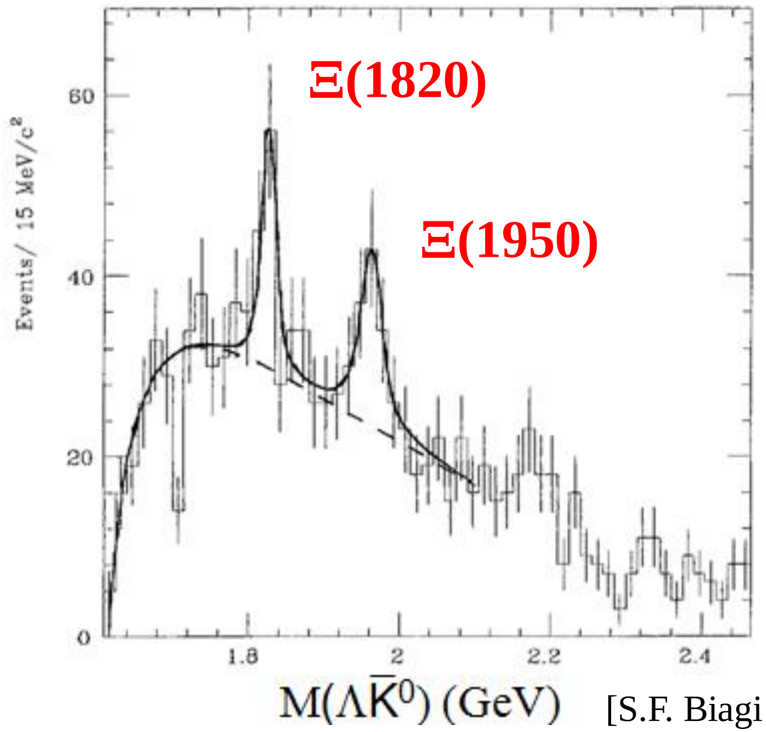
[Courtesy of Johann Goetz, Sept 2010]

- **Both scenarios for Ω** (***untagged real photon*** & ***quasi-real tagging photon***) **look feasible**
- The **common feature** of both scenarios is the possibility to collect **Ω**-baryon events concurrently with virtually ***any CLAS12 experiment***
  if we use additional trigger for **4+** charged particles without electron in CLAS12

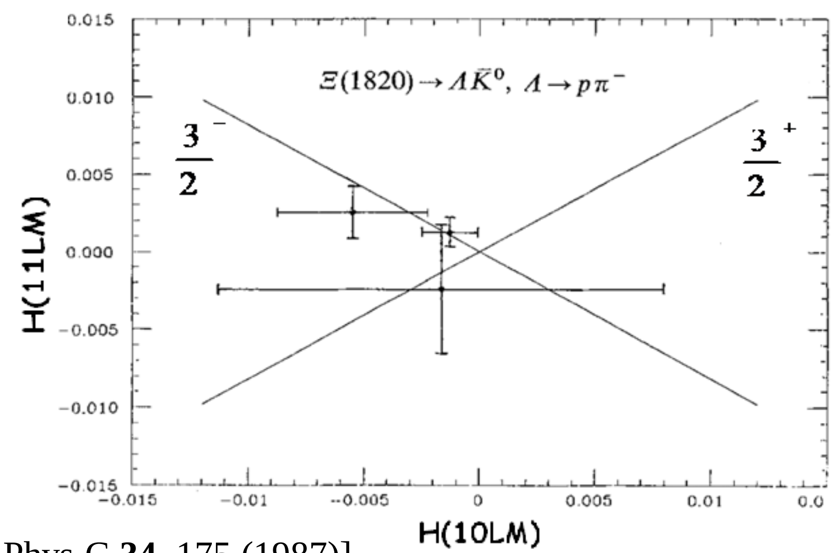
Parity measurement of Ξ(1820) using Double Moment Analysis

[Courtesy of Lei Guo, March 2008]

CERN-SPS: Ξ-Be reaction



Needs corroboration



[S.F. Biagi *et al*, Z Phys C **34**, 175 (1987)]

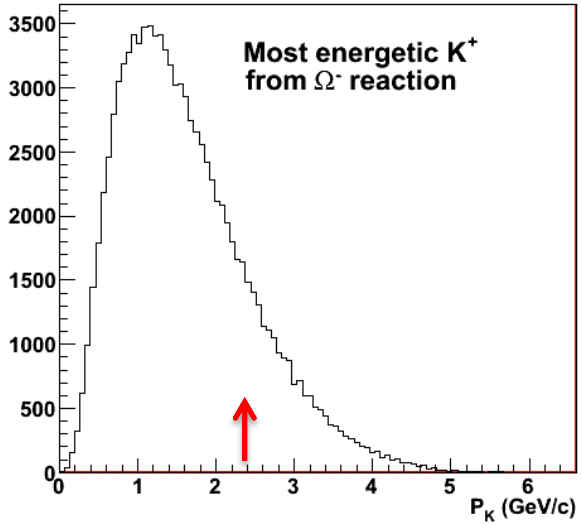
- Ξ(1820) counts: ~50
  need to detect whole decay chain

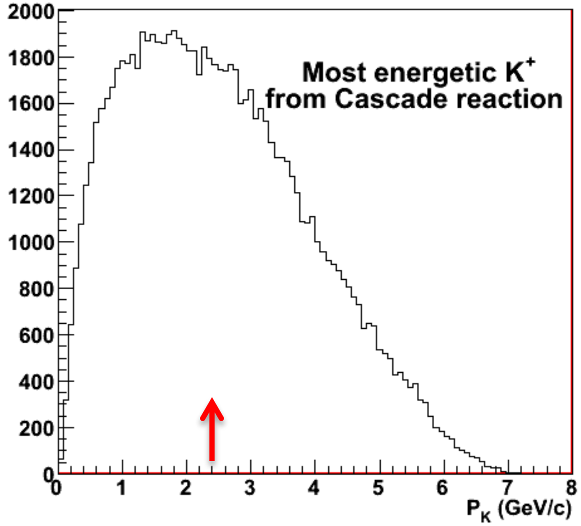
- CLAS12 estimate: 500 Ξ(1820)
  with complete decay chain
  with 3 months running at **6.6** GeV

MC for RICH and for Ξ & Ω Search

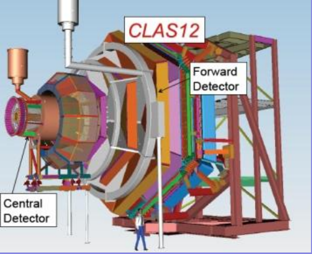
[Courtesy of Derek Glazier, Aug 2010]

- The Ω search is OK without the RICH while
- RICH may help the Ξ search





- **Below 2.5 GeV/c**, ToF is sufficient to separate **K^+** and π^+
- **Above 2.5 GeV/c**, LTCC is inefficient at **~10%**
  RICH is inefficient at **~1%**



Manpower for LOI12-10-004

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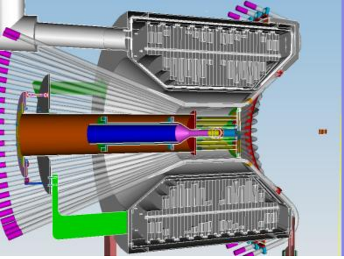
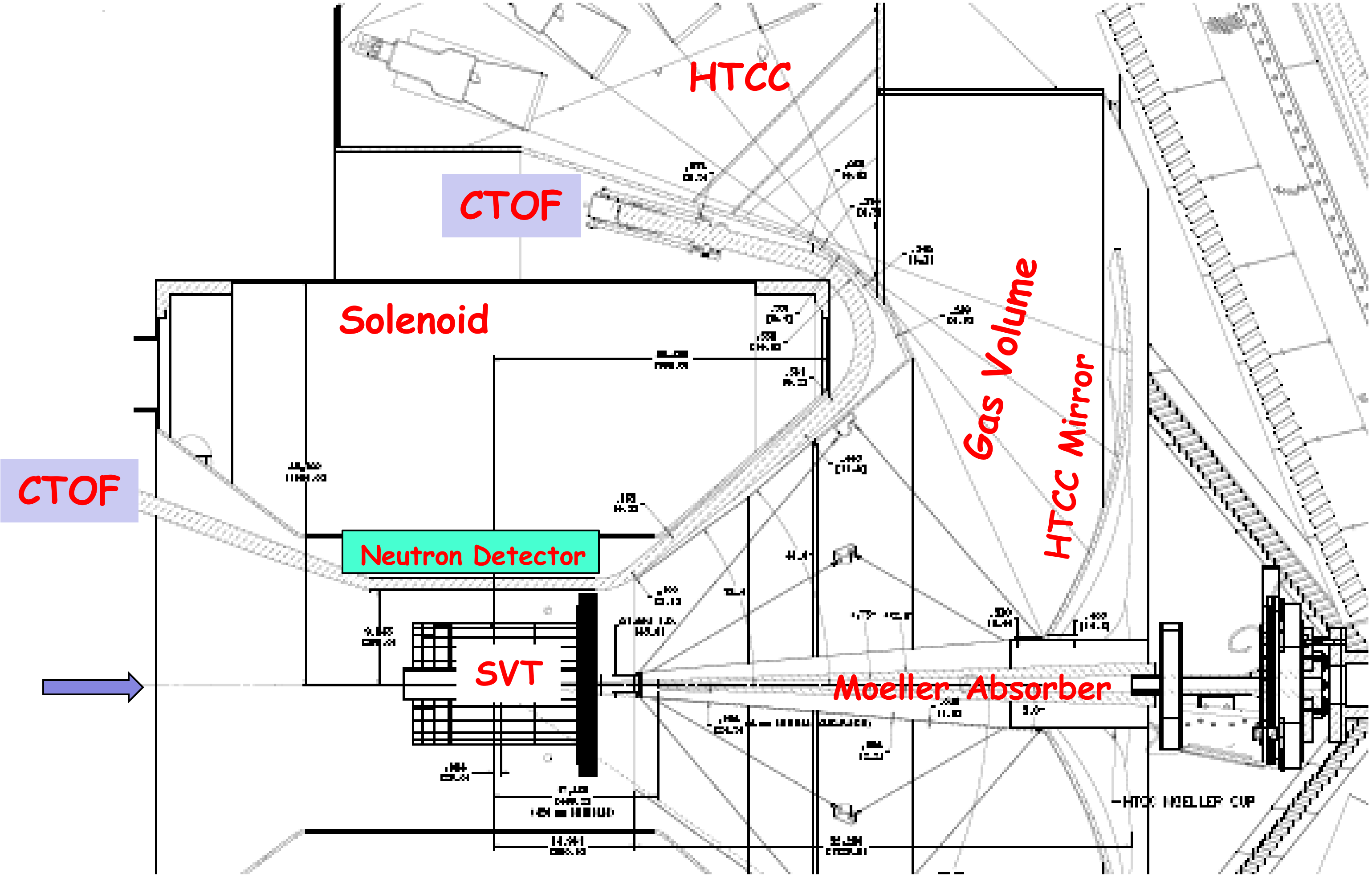
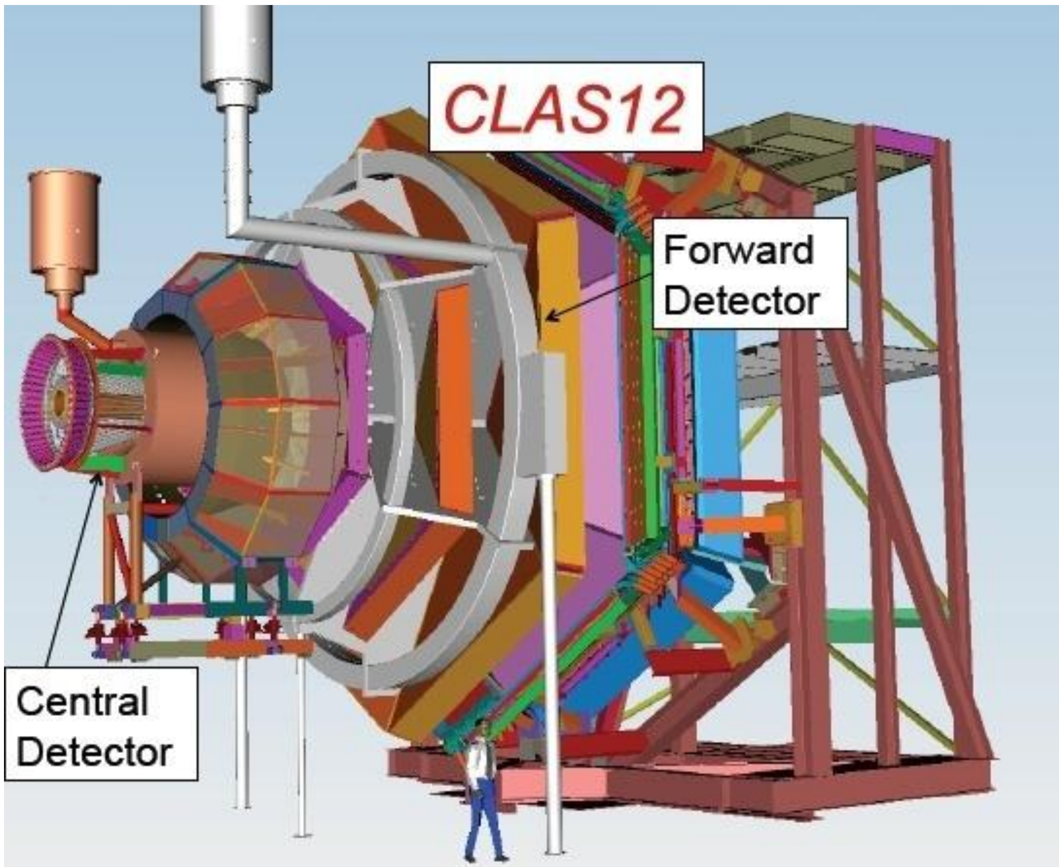


CLAS12 - Central Detector Layout



CLAS12 – Design Parameters (Base Equipment)

$L = 10^{35} cm^{-2} s^{-1}$



	Forward	Central
Angular Range		
Charged Particles	5^0–40^0	35^0–125^0
Photons	2.5^0–40^0	N/A
Resolution		
$\delta p/p$ (%) @ GeV/c	< 1 @ 5	< 5 @ 1.5
$\delta\Theta$ (mr)	< 1	< 10-20
$\delta\phi$ (mr)	< 3	< 5
Photon Detection		
E_{min} (MeV)	> 150	N/A
$\delta\Theta$ (mr)	4 (@1 GeV)	N/A
Neutron Detection		
Efficiency	< 0.7 (EC+PCAL)	under development
Particle ID		
e/π	Full range	N/A
π/p @ GeV/c	< 5	< 1.25
π/K @ GeV/c	< 2.5	< 0.65
K/p @ GeV/c	< 4	< 1
$\pi^0 \rightarrow \gamma\gamma$	Full range	N/A
$\eta \rightarrow \gamma\gamma$	Full range	N/A