Leonid Landsberg: 1930–2005

Was interested in many areas of physics.

Structure and properties of mesons and baryons: searches for quarks; searches for new hadronic states, including exotics; searches for new decay modes; improvements in limits and precision. Quite naturally:

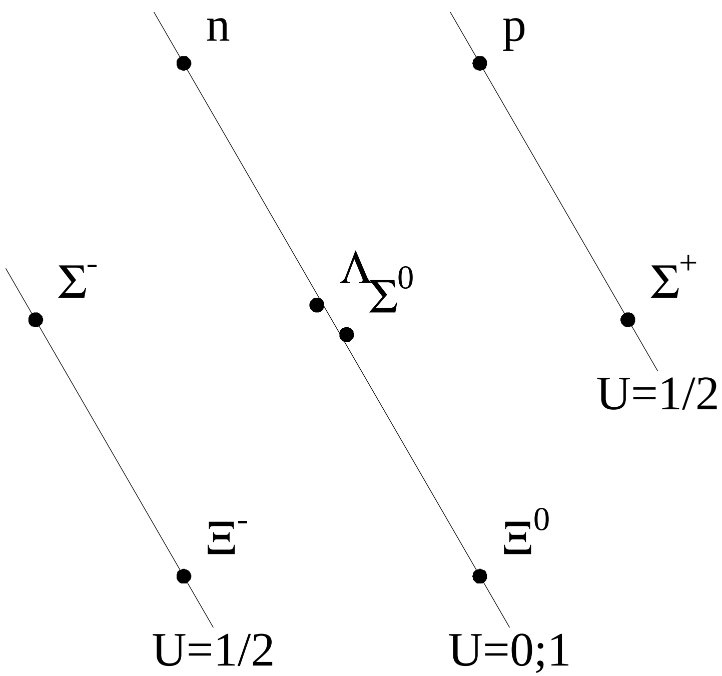
Hyperon Radiative Decays

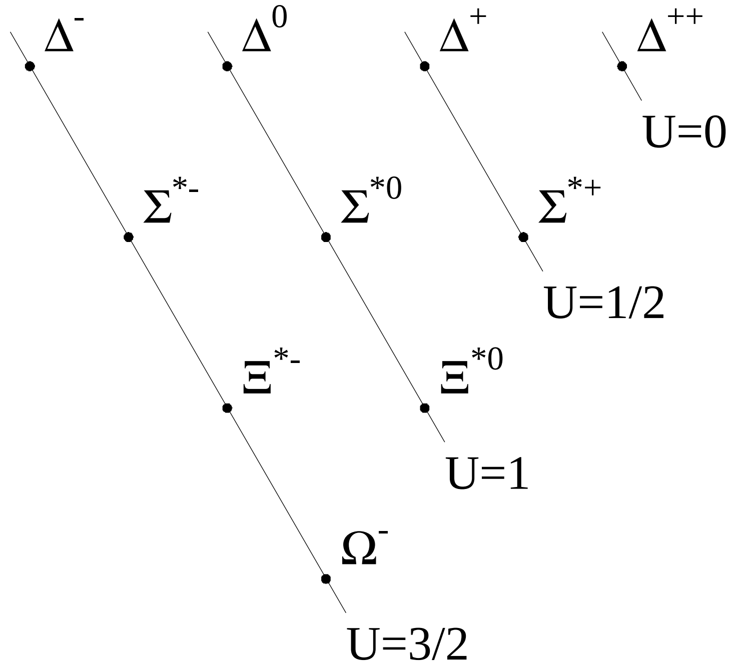
Review:
L.G.Landsberg
Yad. Fiz. 59 (1996) 2161–2186
Phys. Atom. Nucl. 59 (1996) 2080–2104
“Radiative decays of hyperon resonances”

Overview of the talk:

- Hyperons
- Old measurements
- Recent measurements
- Future

Octet and Decuplet





$$|00\rangle = \frac{\sqrt{3}}{2}\Sigma^0 - \frac{1}{2}\Lambda \qquad \Sigma^0 = \frac{\sqrt{3}}{2}\,|00\rangle + \frac{1}{2}\,|10\rangle$$

$$|10\rangle = \frac{1}{2}\Sigma^0 + \frac{\sqrt{3}}{2}\Lambda \qquad \Lambda = \frac{\sqrt{3}}{2}\,|10\rangle - \frac{1}{2}\,|00\rangle$$

Higher mass states

There are many, but two are of special interest:

- $\Lambda(1405)$

$M = 1406.5 \pm 0.4\,\text{MeV}$

$\Gamma = 50 \pm 2\,\text{MeV}$

- $\Lambda(1520)$

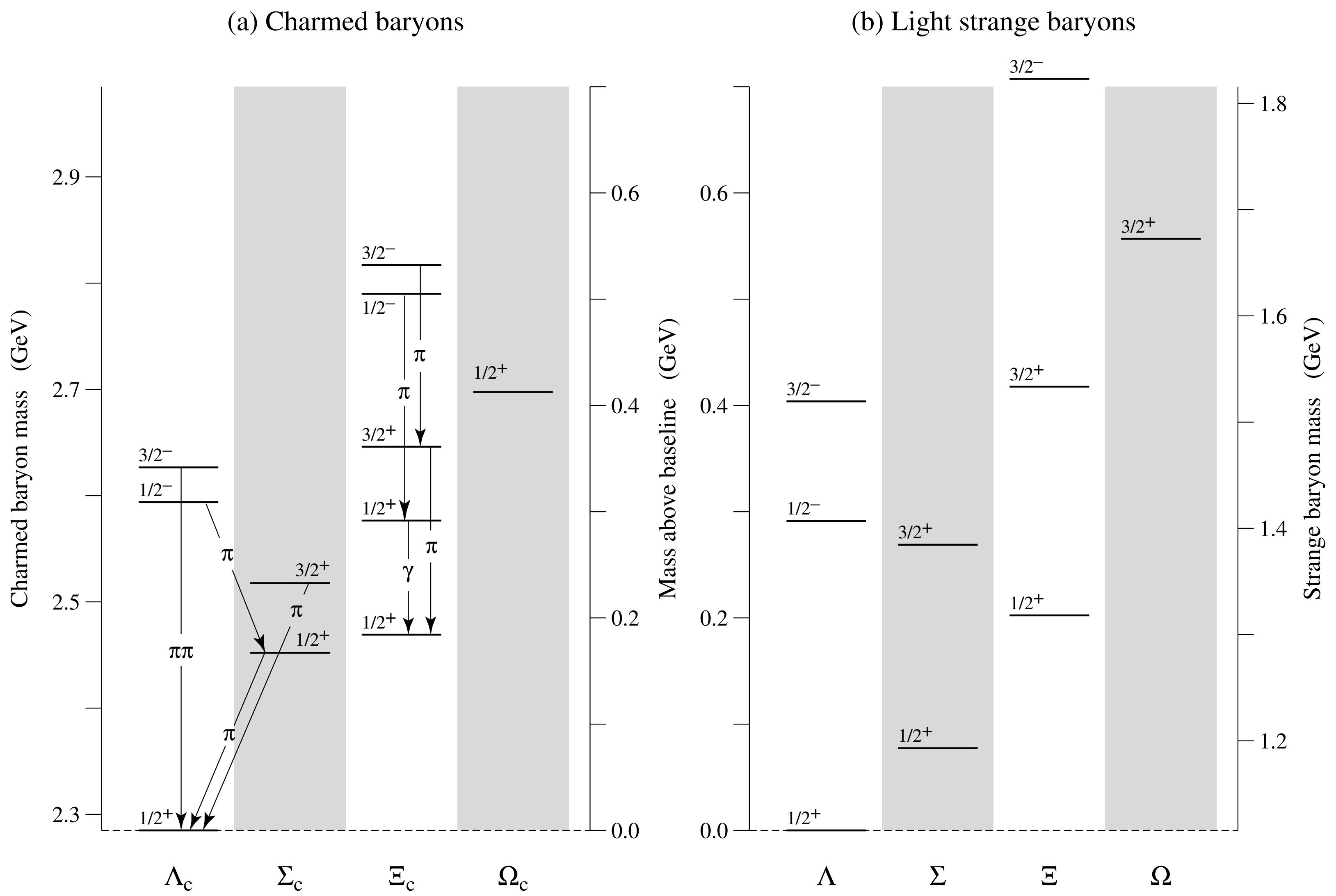
$M = 1519.5 \pm 1.0\,\text{MeV}$

$\Gamma = 15.6 \pm 1.0\,\text{MeV}$

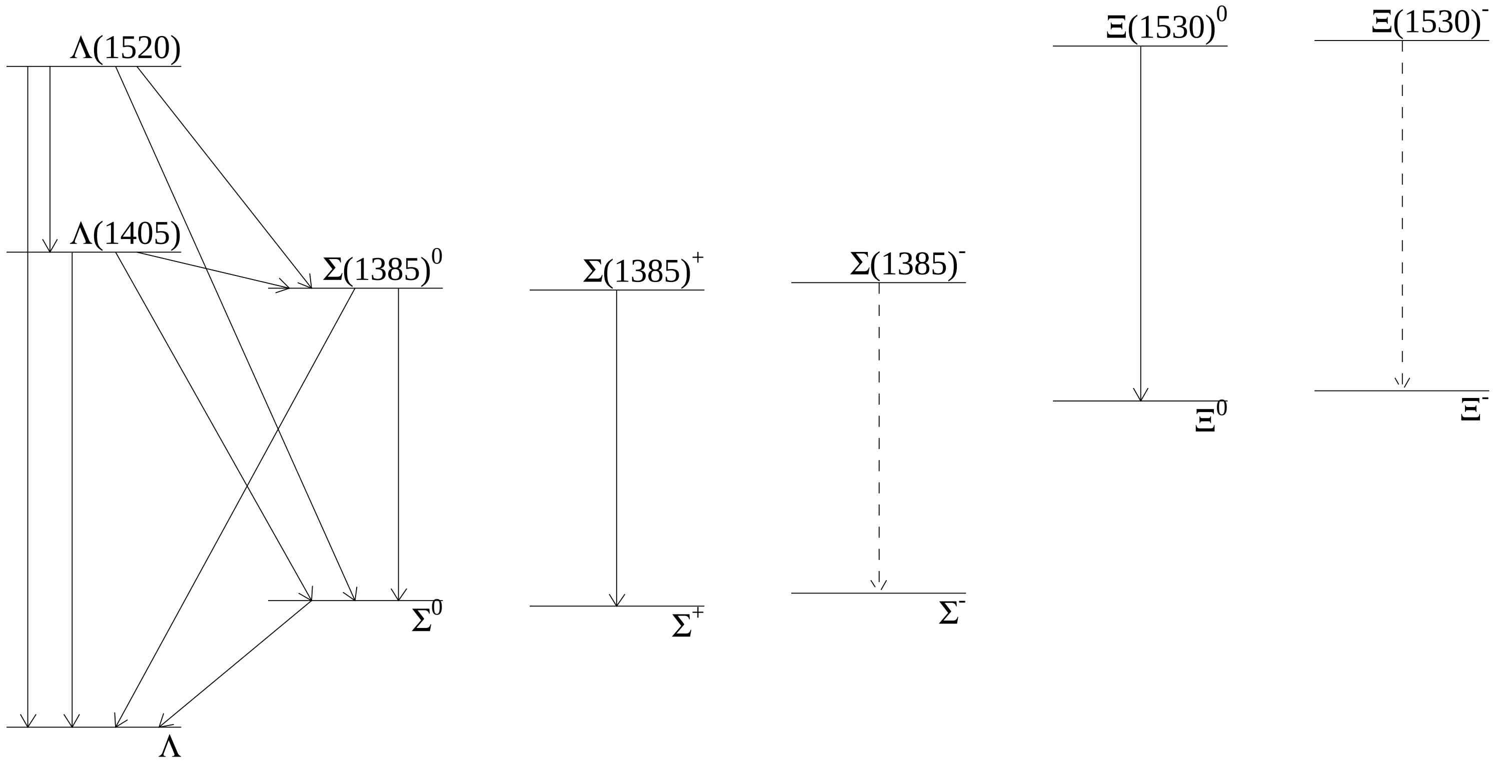
While having quite complex structure in terms of quark model description, these states are experimentally well defined:

- firmly established
- quite narrow
- no overlapping resonances (like in 1670 MeV region)

Nature of $\Lambda(1405)$



Main radiative transitions



Our Knowledge In 1996

	Decay	Γ [keV]	1996
86	$\Sigma^0 \to \Lambda\gamma$	8.9 ± 1.0	●
	$\Sigma(1385)^+ \to \Sigma^+\gamma$		
77	$\Sigma(1385)^- \to \Sigma^-\gamma$	<24	*
75	$\Sigma(1385)^0 \to \Sigma^0\gamma$	<1750	*
75	$\Sigma(1385)^0 \to \Lambda\gamma$	<2000	*
	$\Lambda(1405) \to \Sigma(1385)^0\gamma$		
91	$\Lambda(1405) \to \Sigma^0\gamma$	19 ± 4 or 23 ± 7	●
91	$\Lambda(1405) \to \Lambda\gamma$	27 ± 8	●
	$\Lambda(1520) \to \Lambda(1405)\gamma$		
	$\Lambda(1520) \to \Sigma(1385)^0\gamma$		
87	$\Lambda(1520) \to \Sigma^0\gamma$	47 ± 11	●
68,87	$\Lambda(1520) \to \Lambda\gamma$	134 ± 23 and 31 ± 11	●
	$\Xi(1530)^- \to \Xi^-\gamma$		
	$\Xi(1530)^0 \to \Xi^0\gamma$		

- About 10 theoretical papers
- $\Sigma^0 \to \Lambda\gamma$ is the only sufficiently precise and non-controvercial measurement

New developments

- Theory:

collective approach in 3-flavor Skyrme	Abada:1996db, Haberichter:1997cp
HBχPT	Napsuciale:1997ny
chiral CQM with EM exch. curr.	Wagner:1998bu, Wagner:2000ii
algebraic model of hadron structure	Bijker:2000gq
$1/N_c$ expansion of QCD	Lebed:2004zc
light cone QCD	Aliev:2004ju
Bonn CQM	VanCauteren:2005sm

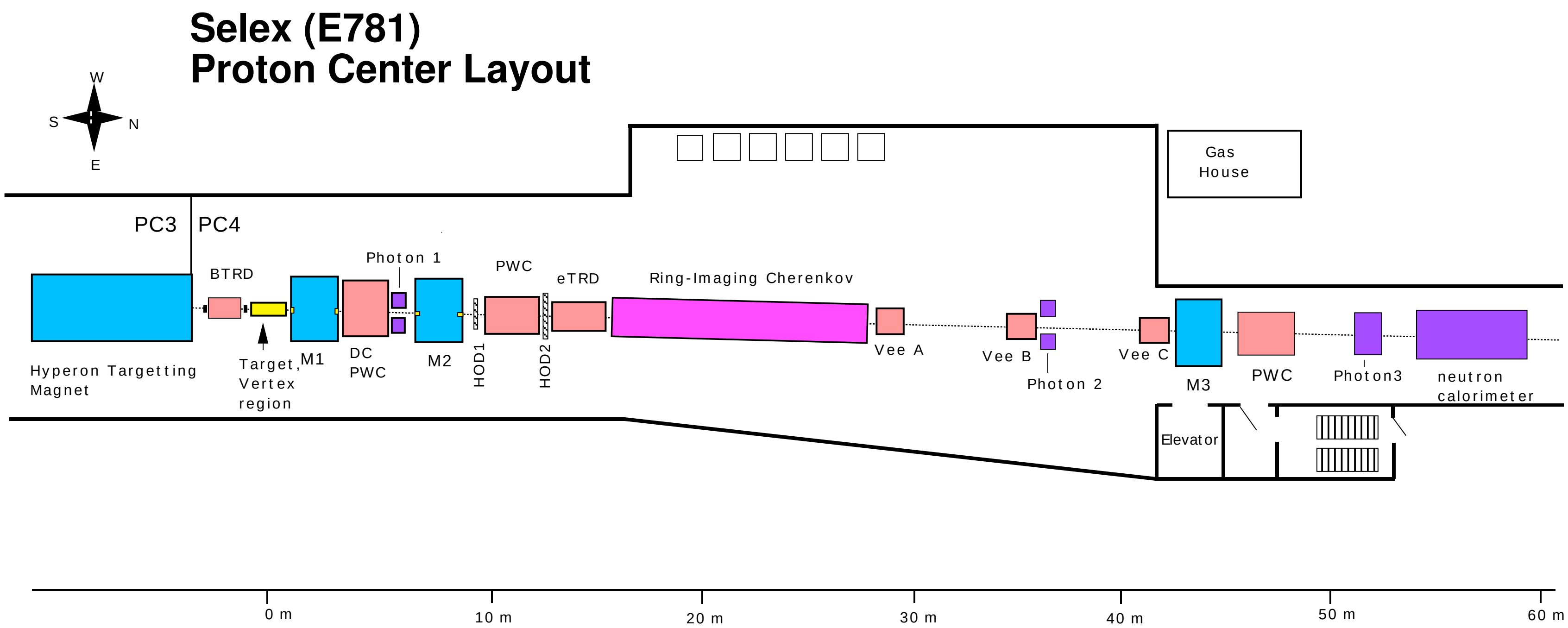
- Pentaquark $\Theta(1540)^+$ connection

Y.Oh, K.Nakayama and T.S.Lee. hep-ph/0511198.
$\Lambda(1520)$ radiative decays are of interest for understanding strangeness photoproduction mechanisms

- Experiment:

SELEX FNAL
SPHINX Protvino
CLAS JLAB

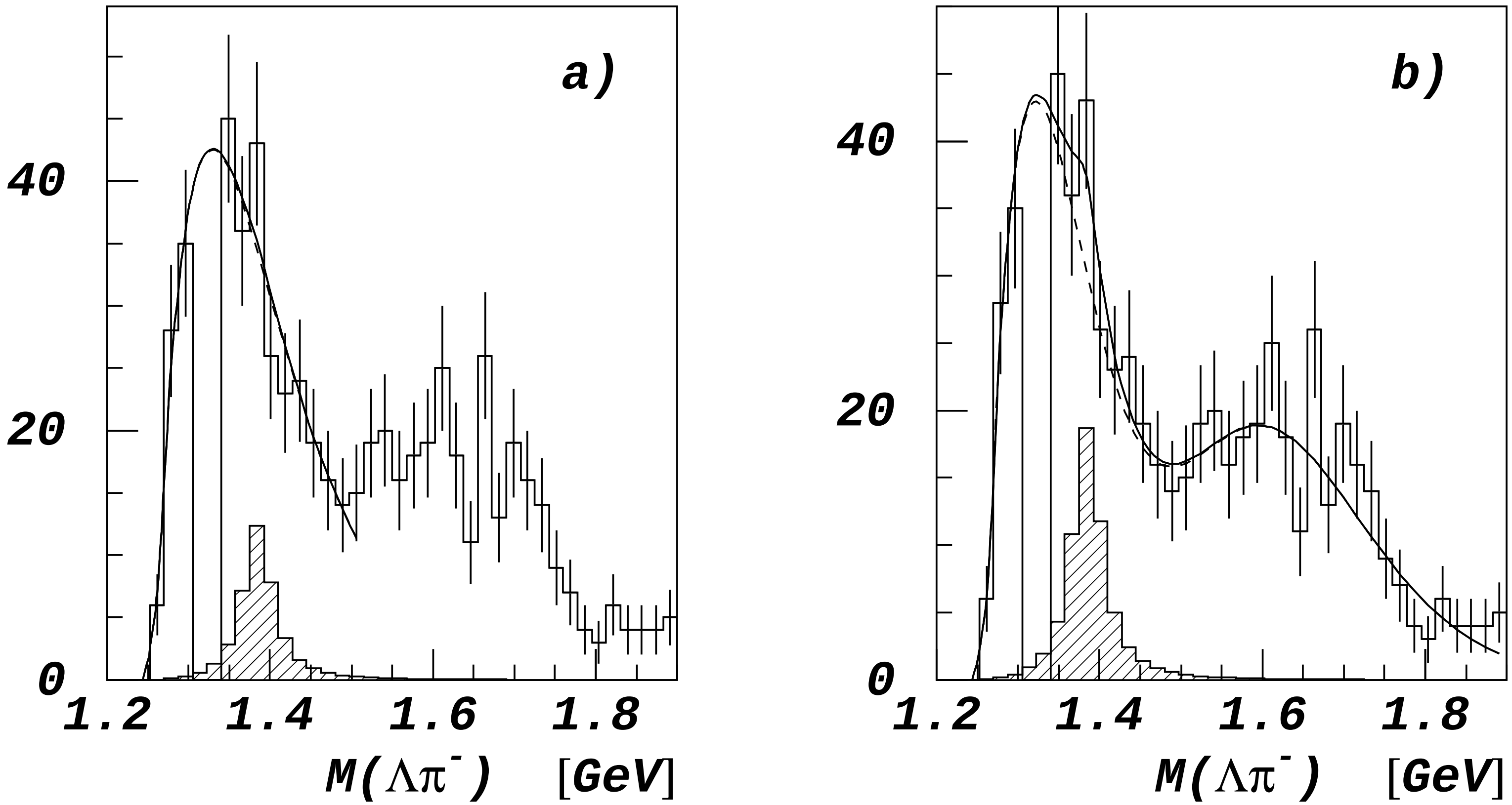
SELEX Detector



Search for Primakoff $\Sigma(1385)^-$ production

$$\Sigma^- + \mathrm{Pb} \rightarrow \Lambda\pi^- + \mathrm{Pb}$$

SELEX: $\Sigma(1385)^- \to \Sigma^-\gamma$



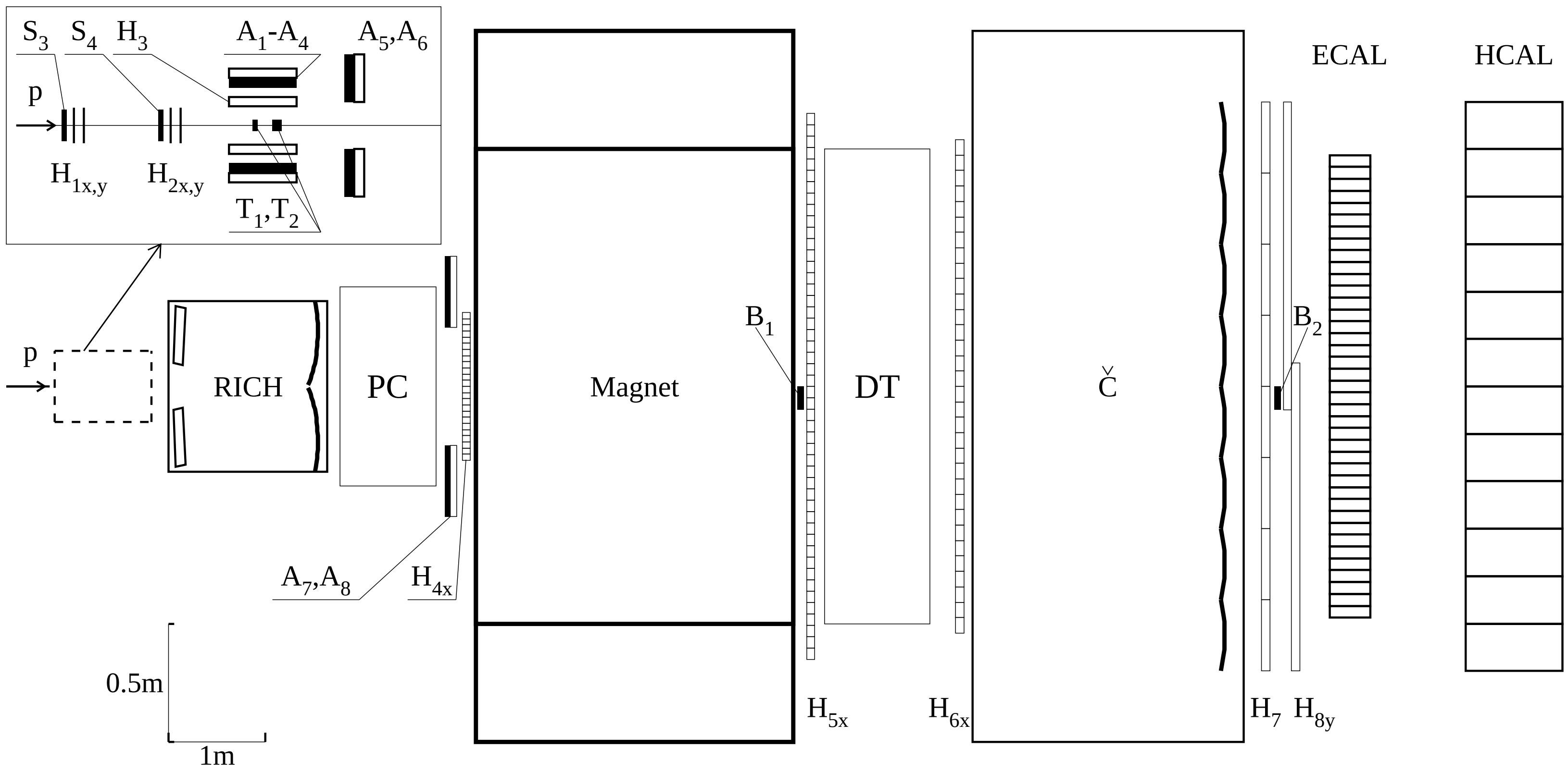
- No clear evidence for $\Sigma(1385)^-$ production $\Longrightarrow$ only an upper limit

$$\Gamma[\Sigma(1385)^- \to \Sigma^-\gamma] < 9.5\,\text{keV} \quad (90\%\,\text{CL})$$

Predictions for $\Sigma(1385)^- \to \Sigma^-\gamma$

SU(3/6) breaking			1–7
MIT bag	R.H.Hackman...	PR D18(1978)2637.	1.5
NRQM	J.W.Darewych...	PR D28(1983)1125	2.5
HBχPT	M.N.Butler...	NP B399(1993)69	1.6–2.4
HBχPT	M.Napsuciale...	NP B494(1997)260	9.5
Qunched lattice	D.B.Leinweber...	PR D48(1993)2230	3.3 ± 1.2
field-theoretic QM	R.K.Sahoo...	PR D52(1995)4099	2.5
bound-state soliton	C.L.Schat...	PL B356(1995)1.	1
3-flavor Skyrme	A.Abada...	PL B366(1996)26	1; 2
3-flavor Skyrme	T.Haberichter...	NP A615(1997)291	1.17–2.27
χCQM / exch. curr.	G.Wagner...	PR C58(1998)1745	3.61
χCQM / exch. curr.	G.Wagner...	J.Phys. G26(2000)267	3.1
$1/N_c$ expansion	R.F.Lebed...	PR D70(2004)057901	0.58 ± 0.70
light cone QCD	T.M.Aliev...	hep-ph/0406331	0.38 ± 0.06
Bonn CQM	T.VanCauteren...	nucl-th/0509047	11.7

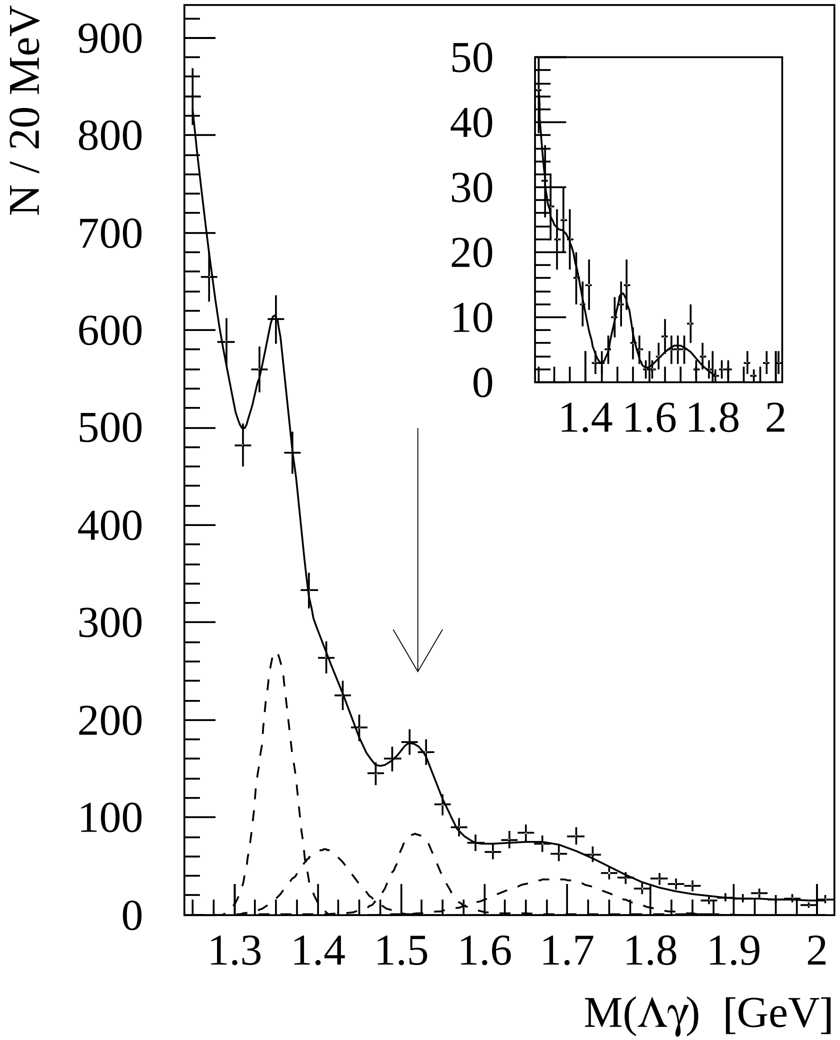
SPHINX Detector



$$p + \mathrm{C} \rightarrow \Lambda\gamma K^{+} + \mathrm{C}$$

$$p + \mathrm{C} \rightarrow \Sigma^{0}\gamma K^{+} + \mathrm{C}$$

SPHINX: $\Lambda(1520) \to \Lambda\gamma$

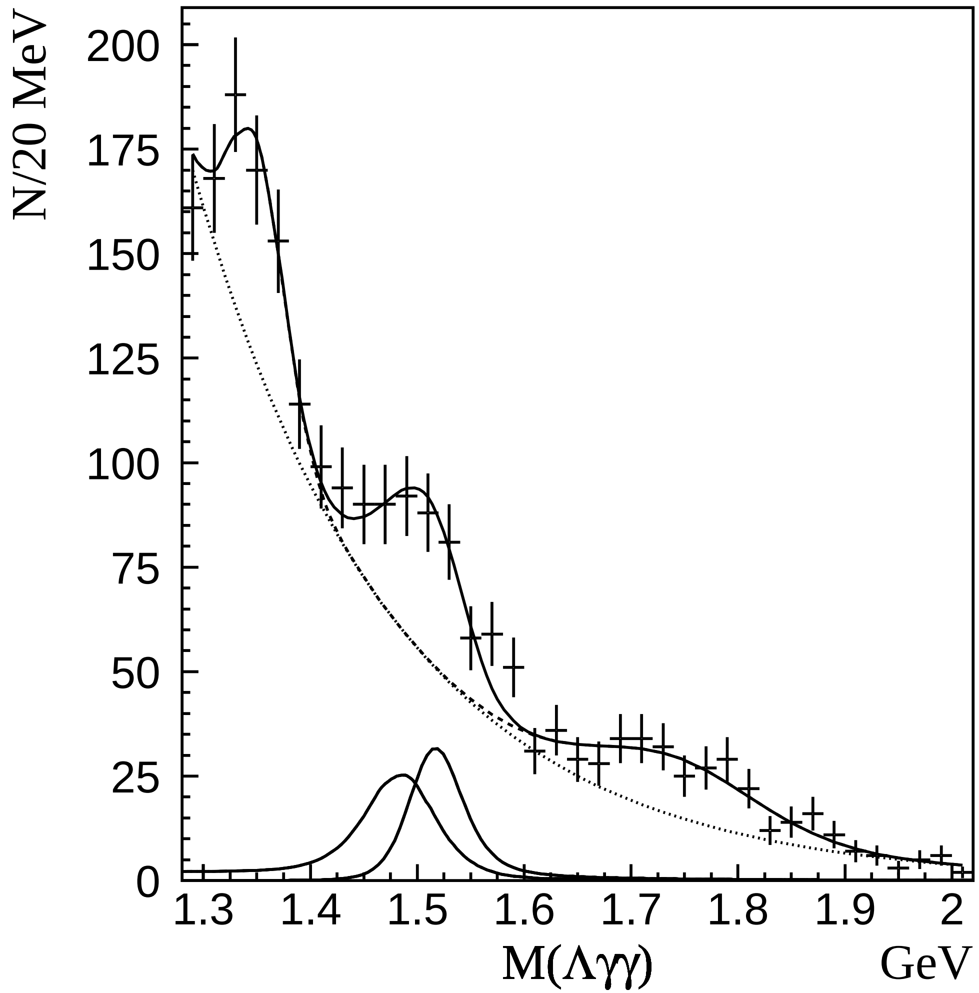


Backgrounds:

- $\Sigma(1385)^0 \to \Lambda\pi^0$ (1γ lost)
- $\Lambda(1405) \to \Sigma^0\pi^0$ (2γ lost)
- $\Lambda(16xx)$, $\Sigma(16xx)^0$
- $\Lambda(1520) \to \Sigma^0\pi^0$ (2γ lost)
- $\Lambda(1520) \to \Sigma^0\gamma$ (1γ lost)

$\Gamma[\Lambda(1520) \to \Lambda\gamma] =$
$159 \pm 33 \pm 26\,\text{keV}$

SPHINX: $\Lambda(1520) \to \Sigma^0\gamma$



Backgrounds:

- $\Lambda(1405) \to \Sigma^0\pi^0$
- $\Lambda(16xx) \to \Sigma^0\pi^0$
- $\Lambda(1520) \to \Sigma^0\pi^0$

Very preliminary:

$\Gamma[\Lambda(1520) \to \Sigma^0\gamma] \sim 130\,\mathrm{keV}$

CLAS Detector

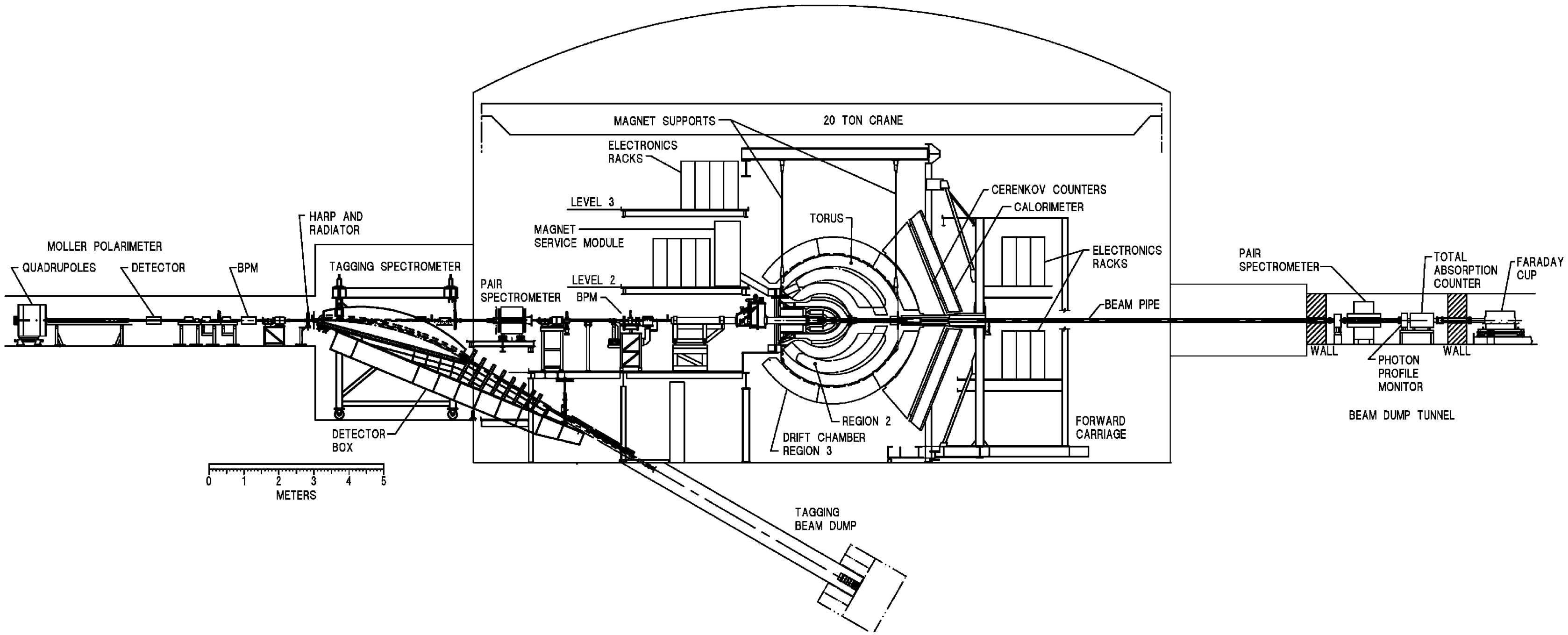
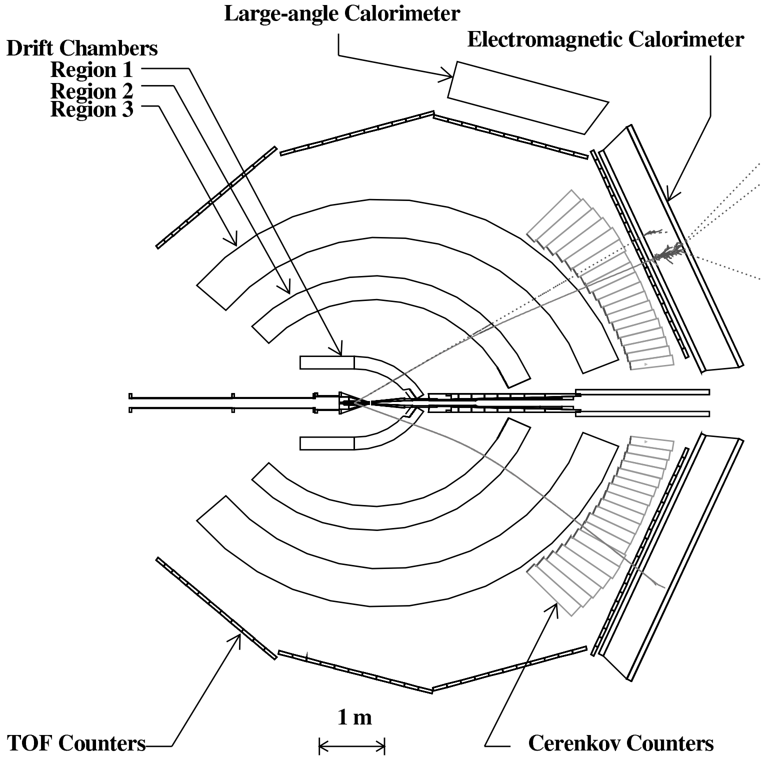
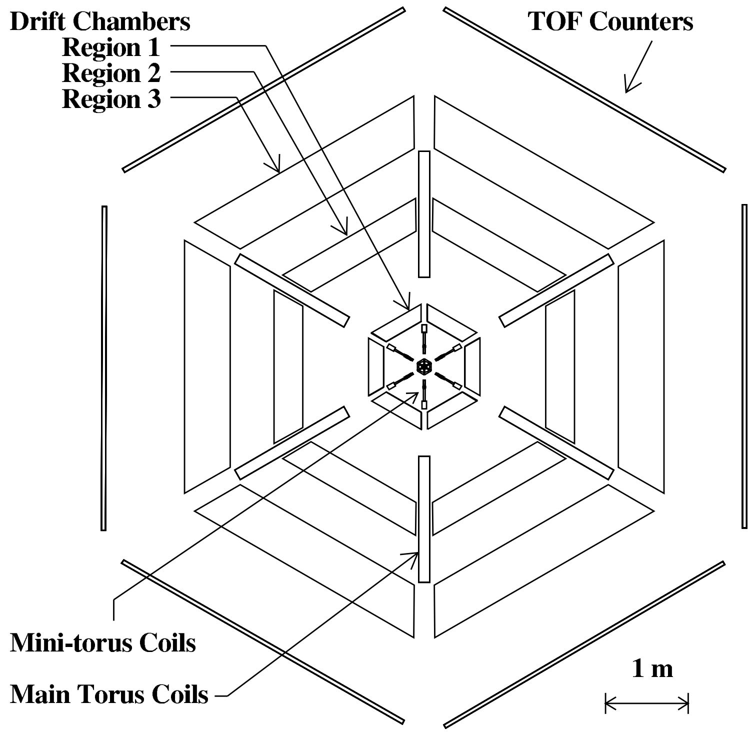


Fig. 2. Side view of the CLAS detector in Hall B with beamline and associated equipment.

CLAS Detector





Toroidal magnetic field

CLAS Detector Parameters

- Datataking: September-October 1999
- Target: liquid H_2
- Primary beam

Electron energy	2.445, 2.897 and 3.115 GeV
Photon energy	20–95% of the electron
Photon resolution	$\Delta E/E = 1{\cdot}10^{-3}$

- Particle ID

π/K separation	$p \leqslant 2\,\mathrm{GeV}$
π/p separation	$p \leqslant 3.5\,\mathrm{GeV}$

- Resolutions

Momentum	$\sigma(p)/p \approx 0.5\%$ for $\theta \lesssim 30^\circ$
	$\sigma(p)/p \approx (1{-}2)\%$ for $\theta \gtrsim 30^\circ$
Polar angle	$\sigma(\theta) \approx 1\,\mathrm{mrad}$
Azimuthal angle	$\sigma(\phi) \approx 4\,\mathrm{mrad}$
Photon energy	$\sigma(E)/E \approx 10\%/\sqrt{E/\mathrm{GeV}}$

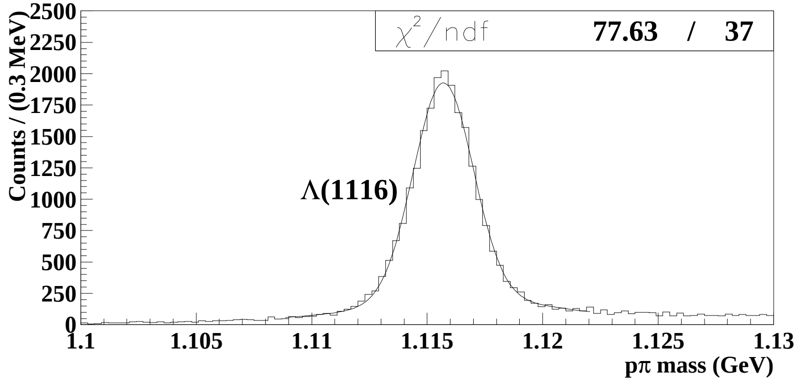
CLAS Analysis

$\gamma p \to K^+ \Lambda \pi^0$ 1C-fit

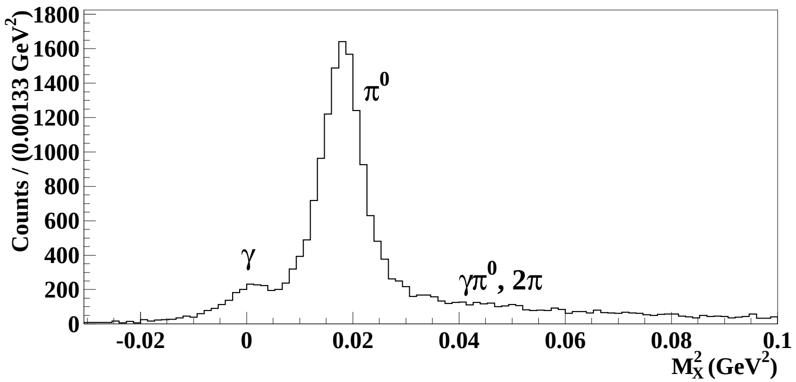
$\gamma p \to K^+ \Lambda \gamma$ 1C-fit

Only basic ideas are highlighted.

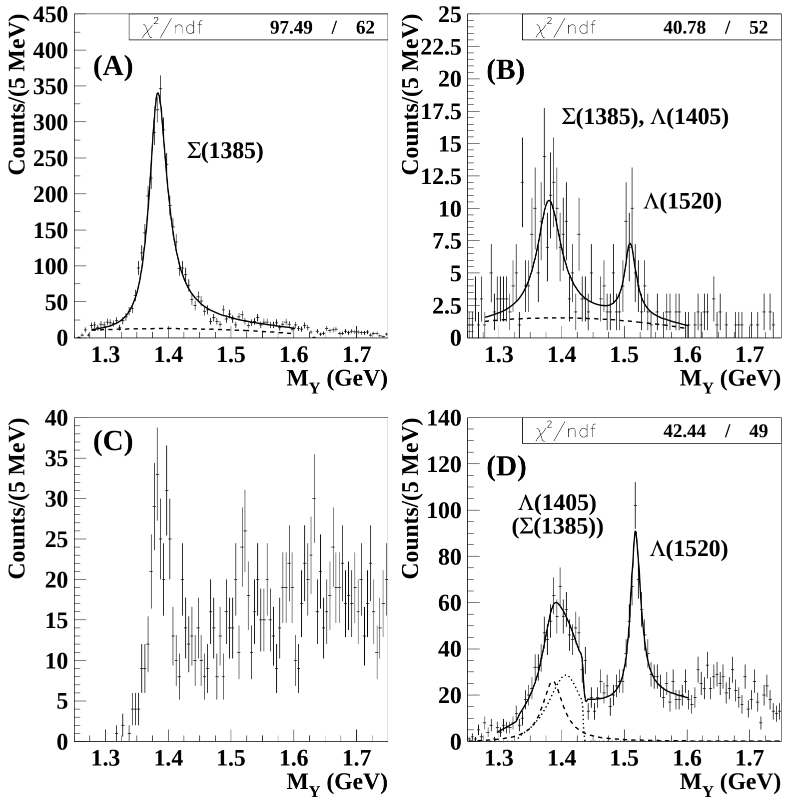
$\gamma p \to K^+ p \pi^- X$



$\gamma p \to K^+ \Lambda (X)$



A: π^0 B: γ C: both D: neither



CLAS: $\Lambda(1520) \to \Lambda\gamma$

- Favourable background conditions

Reaction	A_π	A_γ	$A_{\gamma\pi}$
$\Lambda(1405) \to \Sigma^0\pi^0$	0.083±0.004	0.0007±0.0004	0.658±0.012
$\Lambda(1405) \to \Sigma^+\pi^-$	0.088±0.005	0.0038±0.0009	0.013±0.002
$\Lambda(1405) \to \Lambda\gamma$	0.008 ±0.003	0.946±0.028	0.098±0.009
$\Lambda(1405) \to \Sigma^0\gamma$	0.585±0.019	0.380±0.015	0.837±0.023
$\Sigma(1385) \to \Lambda\pi$	0.905±0.010	0.011±0.001	0.086±0.003
$\Sigma(1385) \to \Sigma^+\pi^-$	0.050±0.002	0.0018±0.0005	0.00564±0.0008
$\Sigma(1385) \to \Lambda\gamma$	0.012±0.002	1.309±0.022	0.105±0.006
$\Sigma(1385) \to \Sigma^0\gamma$	0.548±0.016	0.24±0.01	0.99±0.02
$\Lambda(1520) \to \Lambda\gamma$		1.388±0.027	0.0010±0.0007
$\Lambda(1520) \to \Sigma^0\gamma$		0.087±0.006	0.586±0.016
$\Lambda(1520) \to \Lambda\pi^0\pi^0$		0	0.0099±0.0016
$\Lambda(1520) \to \Sigma^0\pi^0$		0.0006±0.0004	0.681±0.014

Acceptaces in units of 10^{-3}

$$\mathbf{\Gamma[\Lambda(1520) \to \Lambda\gamma] = 167 \pm 43^{+26}_{-12}\,keV}$$

CLAS: $\Sigma(1385)^0 \to \Lambda\gamma$

Much more complex than the $\Lambda(1520)$ case.

There is a background due to $\Lambda(1405) \to \Lambda\gamma$.

Fortunately, this width is measured to be $27 \pm 8\,\text{keV}$.

Ignoring contribution due to $\Sigma(1385)^0 \to \Sigma^0\gamma$ decay:

$$\boldsymbol{\Gamma[\Sigma(1385)^0 \to \Lambda\gamma] = 479 \pm 120\,^{+\ 81}_{-100}\,\mathbf{keV}}$$

This is 2–3 times larger than most model predictions

Predictions for $\Lambda(1520)$ and $\Sigma(1385)^0 \to \Lambda\gamma$

			$\Sigma(1385)^0$	$\Lambda(1520)$
MIT bag	R.H.Hackman...	PR D18(1978)2637.	211; 191	
MIT bag	E.Kaxiras...	PR D32(1985)695	152	46; 27
NRQM	J.W.Darewych...	PR D28(1983)1125	232	96
RQM	M.Warns...	PL B258(1991)431	267	215
chiral bag	Y.Umino...	NP A554(1993)593		31.46
HBχPT	M.N.Butler...	NP B399(1993)69	290–470	
bound-state soliton	C.L.Schat...	PL B356(1995)1.	243; 170	
3-flavor Skyrme	A.Abada...	PL B366(1996)26	180–209	
3-flavor Skyrme	T.Haberichter...	NP A615(1997)291	157–209	
χCQM / exch. curr.	G.Wagner...	PR C58(1998)1745	265	
χCQM / exch. curr.	G.Wagner...	J.Phys. G26(2000)267	249	
algebraic model	R.Bijker	Annals Phys. 284(2000)89	221.3	85.1
$1/N_c$ expansion	R.F.Lebed...	PR D70(2004)057901	298 ± 25	
light cone QCD	T.M.Aliev...	hep-ph/0406331	140 ± 20	
Bonn CQM	T.VanCauteren...	nucl-th/0509047	1527	258

From 1996 To 2005

Decay	1996	2005
$\Sigma^0 \to \Lambda\gamma$	●	
$\Sigma(1385)^+ \to \Sigma^+\gamma$		
$\Sigma(1385)^- \to \Sigma^-\gamma$	∗	∗
$\Sigma(1385)^0 \to \Sigma^0\gamma$	∗	
$\Sigma(1385)^0 \to \Lambda\gamma$	∗	●
$\Lambda(1405) \to \Sigma(1385)^0\gamma$		
$\Lambda(1405) \to \Sigma^0\gamma$	●	
$\Lambda(1405) \to \Lambda\gamma$	●	
$\Lambda(1520) \to \Lambda(1405)\gamma$		
$\Lambda(1520) \to \Sigma(1385)^0\gamma$		
$\Lambda(1520) \to \Sigma^0\gamma$	●	??
$\Lambda(1520) \to \Lambda\gamma$	●	●
$\Xi(1530)^- \to \Xi^-\gamma$		
$\Xi(1530)^0 \to \Xi^0\gamma$		

Experimental Perspectives in 1996

Summarized by LGL in 1996 review:

- Primakoff production (SELEX)

$\Sigma^{\pm} \to \Sigma(1385)^{\pm}$

$\overline{\Sigma}^{-} \to \overline{\Sigma(1385)}^{-}$

$\Xi^{-} \to \Xi(1530)^{-}$

$\Xi^{-} \to \Xi(1820)^{-}$

- Direct observation in exclusive production (SELEX, SPHINX)

$\Sigma^{-} + N \to \Lambda^{*}(\Sigma^{*})\pi + N$

$p + N \to \Lambda^{*}(\Sigma^{*})K + N$

- Virtual photon beam (CLAS)

$e^{-} + p \to e^{-} + \Lambda K^{+}$ study $\Lambda\gamma^{*}$ near $\Lambda(1405)$

These perspectives are now realized: SELEX performed worse than expected, SPHINX more or less as expected, CLAS better than expected.

Perspectives

SELEX, SPHINX, CLAS exhausted their possibilities (completely?)

Wait for lattice

No hyperon beam is planned anywhere

Production reactions in other beams

• JLAB Hall D γ beam
There is a proposal to search for exotic mesons.
There could be a place for hyperon EM decays as well.

• U-70 OKA K^- beam
Can produce lots of hyperons.
How to detect EM decays? Exclusive reactions.
Liquid H_2 target combined with good guard system.

• Any p beam
Like SPHINX, only x10 better.

The question LGL would ask is:
how can we take part in that game?

Speculations

How to make x10 better proton experiment in Protvino?

SPHINX was built about 20 years ago. There has been significant progress in detector technology. In particular, it is connected with developement of kaon experiments. Great deal of that expertise is concentrated in IHEP.

Increase signals and lower backgrounds:

• increase statistics	running time
	beam rate ($\approx 230\,\mathrm{MHz}$ in Kplus)
	DAQ (OKA, CKM)
• improve resolutions	microstrips (SVD)
	straw tubes ($\sigma \approx 150\,\mu\mathrm{m}$ in Kplus)
	ECAL (KOPIO: $\sigma(E)/E \approx 3\%/\sqrt{E/\mathrm{GeV}}$)
• improve veto system	Pb/scintillator sandvich (KOPIO: $\approx 1\,\mathrm{MeV}$)
• improve analysis	polarization measurement in $\Lambda \to p\pi^-$, $\Sigma^+ \to p\pi^0$
	polarized beam (planned at IHEP) allows PWA
• improve veto MC	measure veto time and amplitude (CKM)

Technically feasible.