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Overview

- Prompt Photons.
- Factorization in Photoproduction?
- Neutrino Status.
- Neutrino Cosmophysics.
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- Prompt Photons.
- Factorization in Photoproduction?
- Neutrino Status.
- Neutrino Cosmophysics.
- Pentaquarks!
And now to...

Prompt Photons
Prompt photons at HERA

Inclusive and $\gamma + \text{jet}$ (’96–’00 $\Rightarrow \mathcal{L} > 100\text{pb}^{-1}$):

Backgrounds: $\gamma$ from electron ISR and FSR, from jet, and from decays.
Prompt photons at HERA

Inclusive and $\gamma + \text{jet}$ (’96–’00 $\Rightarrow \mathcal{L} > 100\text{pb}^{-1}$):

\[ e q \rightarrow e q \gamma \]

$Q^2$: $< 1\text{GeV}^2$ in PP

$\gamma$: isolated (prompt) photon ($E_{\perp}^\gamma$)

jet: isolated in DIS; $p_{\perp}$ bal. in PP

Backgrounds: $\gamma$ from electron ISR and FSR, from jet, and from decays.

- **DIS**: First observation by ZEUS (+ comparison to MC and NLO).
- **Photoproduction**: New results from H1 (+ comparison to NLO)
Prompt photons at HERA

DIS:
- PYTHIA and HERWIG differ on $\gamma +$ jet. Neither gives a good description. Room for work?
- NLO calculations (Kramer & Spiesberger) agree better on rates and general trends.

Photoproduction:
- Inclusive: well described by NLO (Fontannaz et al) and shapes by PYTHIA.
- $\gamma +$ jet well described by NLO (with multiple interactions a la PYTHIA).
Prompt photons at LEP ($\gamma\gamma \rightarrow \gamma X$)

**OPAL experiment**

Single-resolved process

Direct process with FSR (suppressed by isolation)

Double-resolved process

After selection: 137 events in data.  
(CERN-EP/2003-023)
Prompt photons at LEP \((\gamma\gamma \rightarrow \gamma X)\)

- **Total and diff. cross sections:**

\[
\sigma_{\text{tot}} = 0.32 \pm 0.04 \pm 0.04 \text{ pb.}
\]

PYTHIA describes the shape, but is a bit low.

NLO agrees in shape and normalization.
And now to...

Factorization in Photoproduction?
Dijets and factorization breaking

The problem: HERA pdf’s used for diffractive dijets (w/ tagged $\bar{p}$) at Tevatron $\implies$ cross section 1 order of mag. above data!

Due to presence of second hadron in initial state?
(spectator interactions break up the $\bar{p}$, $\implies$ “rapidity gap survival probability”)
The problem: HERA pdf’s used for diffractive dijets (w/ tagged $p$) at Tevatron $\rightarrow$ cross section 1 order of mag. above data!

Due to presence of second hadron in initial state? (spectator interactions break up the $p$, $\rightarrow$ “rapidity gap survival probability”)

If that is the reason $\rightarrow$ HERA pdf’s ought to fail for photoproduction. (VMD photon $\sim$ hadron)
Factorization in Photoproduction?

But:

H1 Diffractive $\gamma p$ Dijets

New (2002) fit describes data!
Factorization in Photoproduction?

Shapes (cross sections normalized):

H1 Diffractive $\gamma p$ Dijets

- H1 Preliminary
- H1 2002 fit (prel.)
- H1 Fit 2

Also well described!
Factorization in Photoproduction?

Shapes (cross sections normalized):

H1 Diffractive $\gamma p$ Dijets

- H1 Preliminary
- $H_1$ 2002 fit (prel.)
- $H_1$ Fit 2

Also well described!

$\Rightarrow$ Factorization works in (resolved) photoproduction?!
And now to...

Neutrino Physics
The Solar Neutrino Anomaly


- Remaining part of low $\Delta m^2$ parameter space excluded.

KAMLAND only

Chooz + KAMLAND + solar
The Atmospheric Neutrino Anomaly

- Status: (hep-ph/0205216)

![Graph showing the relationship between $\Delta m^2 (eV^2)$ and $\sin^2 2\theta$.]

Super-K + IMB + Soudan2 + MACRO + Chooz
CMB and large scale structure are sensitive to absolute neutrino masses.

- May ’02: 2dF Galaxy redshift survey results.
- Feb. ’03: WMAP results.
WMAP: Measuring the CMB fluctuations.

+ Balloons (Boomerang, TopHat), Interferometers (CBI, DASI), and Planck (2007).
Redshifts of 250,000 galaxies in $2^\circ$ “wedge”.
The 2dF survey and beyond

- Redshifts of 250,000 galaxies in 2° “wedge”.

- + SSDS (1M galaxies!) (ongoing).
Free-streaming (massive) neutrinos affect survival of small-scale fluctuations, below $d_{FS} \sim 1200 \text{ Mpc}/m_{\nu}$

(see also astro-ph/9904001)
Neutrino mass bounds

- Latest update: $m_\nu \leq 2.2 \text{eV}$

- WMAP + 2dF + Ly$\alpha$ data
- astro-ph/0302209: $m_\nu \leq 0.23 \text{eV}$
And now to...

PENTAQUARKS!
Sudden explosion of evidence for

- Narrow $K^+n$ resonance.
- Mass 1540 MeV. Width: $< 25$ MeV SPRING8
  $< 15$ MeV DIANA

Reported by 5 experiments:

- DIANA (ITEP) hep-ex/0304040
- CLAS (JLAB) hep-ex/0307018
- SAPHIR (Bonn) hep-ex/0307083
- HERMES (DESY) ?
Pentaquarks: how to find them

Spring-8 (LEPS)  
\( nK^+ \) in \( \gamma^{12}\text{C} \rightarrow K^+K^-X \).
with cuts to select quasi-free neutrons and with correction for Fermi motion.

DIANA (ITEP)  
\( pK^0_S \) in low-energy \( K^+\text{Xe} \rightarrow K^0_p\text{Xe} \).
Since no known \( \Sigma^* \) at 1540 MeV, signal interpreted as \( \Theta^+ \).

CLAS (JLAB)  
\( nK^+ \) in \( \gamma d \rightarrow nK^+K^- (p) \).
Poor acceptance. Relying on rescattering of the \( K^- \) off the spectator proton.

SAPHIR (ELSA)  
\( nK^+ \) in \( \gamma p \rightarrow nK^+K^0_S \).
+ absence of \( pK^+ \) peak in \( \gamma p \rightarrow pK^+K^- \)!
$\sigma \sim 300 \text{nb}$
So what *are* these things?

- Minimal $\Theta^+$ content: $uudd\bar{s}$
- $Y = 2$
  - $I_3 = 0$
- Total $I$?
  - No $K^+p$ partner, so $I = 0$ (?)
Pentaquarks from quark models?

- Minimal $\Theta^+$ content: $uuudd\bar{s}$
- Negative parity! (for $S$ wave)

- Many states, some even lighter than $\Theta^+$!
Pentaquarks from (di)quark models?

- More dynamics included in picture with quark pairs in $(\bar{3}_F, \bar{3}_C)$ bosonic states with short-range repulsion?

- If so, imagine bound states of 2 diquarks and one antiquark.

- Overall singlet $\implies$ diquarks antisymmetric in colour $\implies$ repulsion $\implies$ spatial antisymmetry preferred $\implies$ p-wave $\implies$ positive parity.

- Same mass pattern as in ordinary quark model, but different parity predicted. (+ good candidates for many of the required states — the annoying Roper!?!?)
Formally integrate out gluons from QCD.

Approximate resulting (chirally symmetric) non-local quark theory by simple, quartic quark interactions.

Skyrme Model ($N_c \rightarrow \infty$) and Chiral Quark Model, both devised to describe low-energy meson physics.

However, baryons arise as soliton solutions, a nontrivial (hedgehog) classical configuration of the pion field.

Allowed baryon representations (triality zero):

$$8, 10, \overline{10}, 27, 35, \overline{35}, ...$$
Skyrme phenomenology

- So Baryon number = topological quantum number of pion field.

- But Skyrme phenomenology has a mixed record:

  - Some took it seriously...

    - Praszalowicz 1987: \( M(\Theta^+) = 1530 \text{ MeV} \)
    - Diakonov, Petrov, Polyakov 1997: \( M(\Theta^+) = 1580 \text{ MeV} \), influenced experimenters.

    - NB: \( \bar{10} \) mass quite sensitive to parameters, mass \textit{splitting}s much better “predicted”, since same (to LO) as in non–exotic multiplets.
Conclusions:

- Evidence for positive-strangeness exotic “baryon” at $M_{\Theta^+} = 1540 \text{ MeV}$.

- The battle is raging: constituent quark vs. soliton vs. quasi-molecular interpretations of light baryons.

- Important to check parity.

- Important to check for other states. Quark models always have an extra exotic octet, soliton models don’t.