A review on magnetic monopoles

What is a RPP review good for ?

Why are monopoles important ?

What is already in the RPP ?

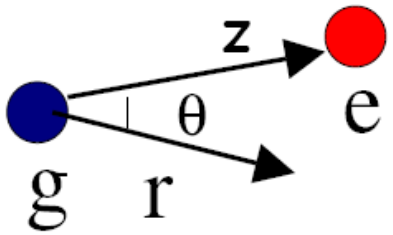
Why is a monopole review desirable and what could it look like ?

What is a RPP review good for ?

- Short review should on an important topic should be a physicist's executive summary and a good starting point for a detailed survey.
  - Overview of theory and experiment
  - Competitive current limits (and associated uncertainties)
  - Up-to-date and well chosen reference list.
- Personal perspective
  - Recent student project on muon g-2.
  - Wide literature survey and much confusion.
  - Eased by RPP article.

The importance of monopoles

(1) Dirac's argument (1931):
Angular momentum of field of monopole-electron system:



$$L = \int r \times E \times B dr d\theta d\phi$$

$$= \frac{\mu_0 eg}{4\pi} \hat{z} \Rightarrow e = \frac{nh}{g\mu_0} \qquad g_D = \frac{h}{e\mu_0}$$

One monopole needed to "explain" electric charge quantisation.
Dirac monopole of charge g_D

(2) Monopoles are also features of BSM theories, eg grand unified theories (GUT monopoles): mass=10^{15} though some models predicts lighter monopoles

(3) Symmetrise Maxwell equations

(4) Catalyse proton decay

What is in the pdg ?

- 8 page listing of searches (D. Groom)
  - Accelerator searches
  - Cosmic ray searches
  - Astrophysics
  - Matter searches
  - >120 limits
- Short summary (D. Groom)
- To be expanded
  - LHC experiments (inc. MOEDAL)
  - Cosmic ray, eg IceCube.

MAGNETIC MONOPOLE SEARCHES

Revised December 1997 by D.E. Groom (LBNL).

"At the present time (1975) there is no experimental evidence for the existence of magnetic charges or monopoles, but chiefly because of an early, brilliant theoretical argument by Dirac, the search for monopoles is renewed whenever a new energy region is opened up in high energy physics or a new source of matter, such as rocks from the moon, becomes available [1]. " Dirac argued that a monopole anywhere in the universe results in electric charge quantization everywhere, and leads to the prediction of a least magnetic charge $g = e/2\alpha$, the Dirac charge [2]. Recently monopoles have become indispensable in many gauge theories, which endow them with a variety of extraordinarily large masses. The discovery by a candidate event in a single superconducting loop in 1982 [6] stimulated an enormous experimental effort to search for supermassive magnetic monopoles [3,4,5].

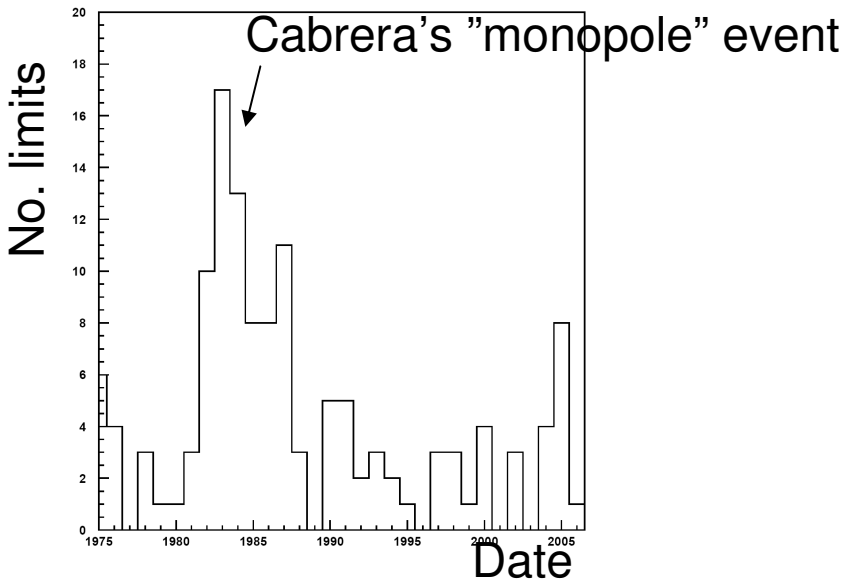
Monopole detectors have predominantly used either induction or ionization. Induction experiments measure the monopole magnetic charge and are independent of monopole electric charge, mass, and velocity. Monopole candidate events in single semiconductor loops [6,7] have been detected by this method, but no two-loop coincidence has been observed. Ionization experiments rely on a magnetic charge producing more ionization than an electrical charge with the same velocity. In the case of supermassive monopoles, time-of-flight measurements indicating $v \ll c$ has also been a frequently sought signature.

Cosmic rays are the most likely source of massive monopoles, since accelerator energies are insufficient to produce them. Evidence for such monopoles may also be obtained from astrophysical observations.

Jackson's 1975 assessment remains true. The search is somewhat abated by the lack of success in the 1980's and the decrease of interest in grand unified gauge theories.

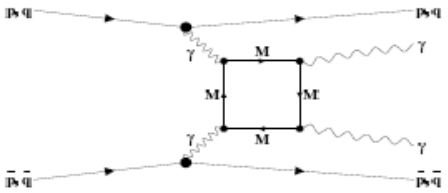
References

1. J. D. Jackson, *Classical Electrodynamics*, 2nd edition (John Wiley & Sons, New York, 1975).



Why the reader needs guidance (1)

- Many experimental techniques, some more model dependent than others
  - Ionisation (g_D equivalent to 70e)
  - Induction (SQUID : cosmic ray/matter)
  - Trajectory (non-parabolic)
  - TOF
  - Indirect search through multi-photon final states



D0: Phys.Rev.Lett.81:524-529,1998

Why the reader needs guidance (2)

- Limits dependent on theoretical ansatzes
  - Difficulty in calculating monopole processes due to inapplicability of perturbatve field theory. Eg, assumptions on:
    - Binding in matter
    - Multi-photon
    - Direct production mechanisms
- Important assumptions and uncertainties should be stated.

Possible format of a review

- A possible monopole review could look like:
  - Intro
  - Theoretical overview : Dirac's argument, monopoles in GUTs, calculations for monopoles at collders etc.
  - Detection Techniques
    - Ionisation
    - Trajectory
    - Induction
    - …
  - Limits from experiments
    - Accelerator
    - Cosmic ray
    - Matter
    - Astrophysics limits
- Length anywhere between 10-25 pages.
- Current RPP reviews between 1 and 50 pages.

Reviews

- Already detailed reviews ”on the market”
  - Most reflect the authors’ interest in specific aspects of monopoles
  - Eg Milton, Rept.Prog.Phys.69:1637-1712,2006
  - Fairbairn et al., Phys. Rept. 438: 1-2007
  - Giacomelli and Patrizii, hep-ex/0302011
- Nothing like the standard, concise RPP-style review.

Summary

- Monopole searches have been a feature of experimental particle physics for half a century
- For every new energy, new collision type, or form of matter a search is made.
- Searches to be performed at LHC and cosmic ray experiments.
- RPP maintains an excellent listing of searches
- A short review would help the reader understand easily the listing and provide the definitive ”starting point” for those interested in the field.
- I would have benefited from such a review when I made (with others) a search at HERA.