A New Experiment to Study Hyperons, Charm, and the Charmonium System

Daniel M. Kaplan

ILLINOIS INSTITUTE OF TECHNOLOGY
Transforming Lives. Inventing the Future. www.iit.edu

Round Table: pbar Experiments
Quarkonium Working Group Meeting
DESY, Oct. 18, 2007

Fermilab "Climate"

- Urgent need to identify intermediate mission for on-site accelerators while awaiting ILC decision
- Target the "intensity frontier":
  - Neutrino oscillations, rare and forbidden decays:

    $K \rightarrow \pi\nu\nu$

    $\mu \rightarrow e$
- Clear & strong theoretical connection with "Quantum Universe" themes

"Project X"

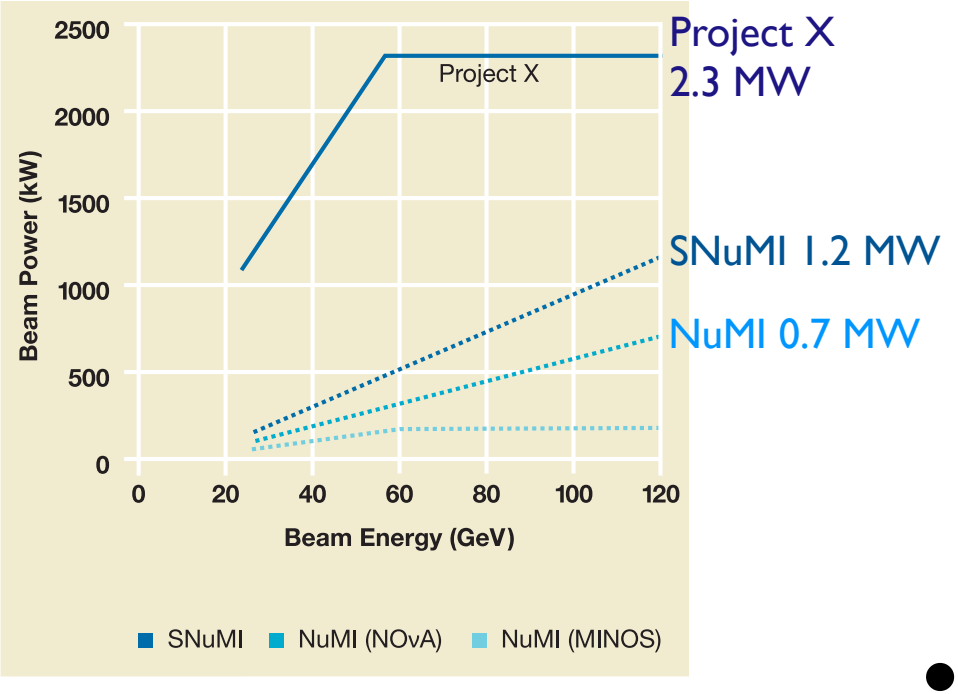
- In spring, Fermilab Steering Group formed to recommend plan for intermediate period before ILC
- Recommends construction of 8 GeV proton linac using ILC technology (~$1/2B project, ~5y constr)
  - enables neutrino "SuperBeam," rare K decay expts
  - if adopted, will extend life of pbar Source by obviating need for "Super-NuMI" intensity upgrade

➡ In this scenario, new pbar expt seems possible:

  - modest on scale of other projects
  - attractive opportunity to keep results flowing while other projects under construction

"Project X"

from Fermilab Steering Group Report
http://www.fnal.gov/pub/directorate/steering/index.shtml



Proton beam power

Beam power versus beam energy for possible proton facilities at Fermilab.

- Project X strengthens
  - ILC R&D/industrialization
  - neutrino program
  - proposed μ2e program
  - proposed K program
  - proposed pbar program
- Recommended if:
  - ILC delayed ≳ 5y or
  - built "offshore"

pbar Physics

- Hyperons – search for new physics
- Charm mixing – is it new physics?
- Charmonium – feasible, but QCD
  - but apparatus that can do hyperons and charm can do charmonium also
  - and improved understanding of (nonperturbative) QCD important for interpreting above and other physics

Hyperon CP Violation...

- SM predicts small CP asymmetries in hyperon decay
- NP can amplify them by orders of magnitude:

Table 5: Summary of predicted hyperon CP asymmetries.

Asymm.	Mode	SM	NP	Ref.
A_Λ	$\Lambda \to p\pi$	$\lesssim 10^{-5}$	$\lesssim 6 \times 10^{-4}$	[68]
$A_{\Xi\Lambda}$	$\Xi^\mp \to \Lambda\pi,\ \Lambda \to p\pi$	$\lesssim 0.5 \times 10^{-4}$	$\leq 1.9 \times 10^{-3}$	[69]
$A_{\Omega\Lambda}$	$\Omega \to \Lambda K,\ \Lambda \to p\pi$	$\leq 4 \times 10^{-5}$	$\leq 8 \times 10^{-3}$	[36]
$\Delta_{\Xi\pi}$	$\Omega \to \Xi^0\pi$	2×10^{-5}	$\leq 2 \times 10^{-4}$ *	[35]
$\Delta_{\Lambda K}$	$\Omega \to \Lambda K$	$\leq 1 \times 10^{-5}$	$\leq 1 \times 10^{-3}$	[36]

*Once they are taken into account, large final-state interactions may increase this prediction

...& Rare Decays

PRL **98,** 081802 (2007) PHYSICAL REVIEW LETTERS week ending 23 FEBRUARY 2007

Does the HyperCP Evidence for the Decay $\Sigma^+ \to p\mu^+\mu^-$ Indicate a Light Pseudoscalar Higgs Boson?

Xiao-Gang He*
Department of Physics and Center for Theoretical Sciences, National Taiwan University, Taipei, Taiwan

Jusak Tandean†
Departments of Mathematics, Physics, and Computer Science, University of La Verne, La Verne, California 91750, USA

G. Valencia‡
Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, USA
(Received 2 November 2006; published 22 February 2007)

($\mathcal{B} \approx 10^{-8}$)

The HyperCP Collaboration has observed three events for the decay $\Sigma^+ \to p\mu^+\mu^-$ which may be interpreted as a new particle of mass 214.3 MeV. However, existing data from kaon and B-meson decays provide stringent constraints on the construction of models that support this interpretation. In this Letter we show that the ''HyperCP particle'' can be identified with the light pseudoscalar Higgs boson in the next-to-minimal supersymmetric standard model, the A_1^0. In this model there are regions of parameter space where the A_1^0 can satisfy all the existing constraints from kaon and B-meson decays and mediate $\Sigma^+ \to p\mu^+\mu^-$ at a level consistent with the HyperCP observation.

Some Hyperon Goals

- Observe many more $\Sigma^+ \to p\mu^+\mu^-$ events and confirm or refute SUSY interpretation

- Discover or limit $\Omega^- \to \Xi^-\mu^+\mu^-$ and confirm or refute SUSY interpretation

Predicted $\mathcal{B}$ ~10^{-6} if P^0 real

- Discover or limit *CP* violation in $\Omega^- \to \Lambda K^-$ and $\Omega^- \to \Xi^0\pi^-$ via partial-rate asymmetries

Predicted $\Delta\mathcal{B}$ ~10^{-5} in SM, $\lesssim 10^{-3}$ if NP

Charmonium

- Thanks to superb precision of antiproton beam energy and momentum spread, E760/835 @ FNAL AA made very precise measurements of charmonium parameters, e.g.
  - best measurements of various η_c, χ_c, h_c masses, widths, branching ratios,...
  - interference of continuum & resonance signals

Covered by others

Summary

- Best experiment ever on hyperons, charmonia, and charm may run a few years from now at Fermilab
- More focused than PANDA, could happen sooner & get more beam
- Aligned with FNAL Steering Group plan

- Want to join?

...or help us make the physics case?

...or at least, help spread the word?

Proto-Collaboration

- I am drafting LoI and soliciting collaborators
- So far:

Thomas J. Phillips
Duke University, Durham, N. Carolina 27708 USA

Giorgio Apollinari, Daniel R. Broemmelsiek, Charles N. Brown,
David C. Christian, Paul Derwent, Keith Gollwitzer, Alan Hahn,
Vaia Papadimitriou, Steven Werkema, Herman B. White
Fermilab, Batavia, IL 60510, USA

Wander Baldini, Giulio Stancari, Michelle Stancari
INFN, Sezione di Ferrara, Ferrara, Italy

Gerald P. Jackson
Hbar Technologies, LLC, West Chicago, IL 60185, USA

Daniel M. Kaplan,* Howard A. Rubin, Yagmur Torun, Christopher G. White
Illinois Institute of Technology, Chicago, Illinois 60616, USA

HyangKyu Park
KyungPook National University, DaeGu, Korea

Todd K. Pedlar
Luther College, Decorah, IA 52101, USA

Jerome Rosen
Northwestern University, Evanston, IL 60208, USA

E. Craig Dukes
University of Virginia, Charlottesville, Virginia 22903, USA

...& growing...

Schedule?

Highly speculative...!

- 2010? Tevatron closes
- 2011 pbar installation & startup?
- 2012-17? Project X construction?
- 2017 pbar source closes?
- 2019 ILC construction starts???

Note:

- Letter of Intent for new Fermilab antiproton experiments available at

  http://capp.iit.edu/hep/pbar

- Klaus Peters & DMK organizing antiproton parallel session at Project X physics workshop, Fermilab, Nov. 16–17, 2007; see

  http://www.fnal.gov/directorate/Longrange/Steering_Public/workshop-physics.html