CHARM 2010: Experiment Summary and Future Charm Facilities

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First Thing

- I want to thank our hosts at IHEP for organizing a very full and interesting meeting.

- Thanks, too, to all the speakers for informative and well prepared presentations.

Outline

- Charm 2010 context
- Emphasis of this summary
- Renewed interest in charm
- What we have seen and not seen here
- Utility of more data and an alert
- What if CPV is seen in charm mixing?
- Production physics comments
- Spectroscopy comments
- Fermilab as a Future Charm Facility?
- Final Words

Charm 2010 Context

- This is only the 4th International Workshop on Charm Physics!
- IHEP Beijing, Cornell Ithaca, NY; Leimen, Germany; IHEP Beijing
- Then and now
  - Then: “this revival interesting has been driven by experimental reports of the narrow D_{sJ} states, X(3872), X(3940), Y(3940) and the newest unexpected Y(4260) from B factories and other related experiments, the proton-antiproton threshold enhancement and X(1835) observed at BESII also attracted people's attention. In the meanwhile, MIMD Lattice Calculation (MILC) and High Precision QCD (HPQCD) collaborations predicted f_{D+}=201+-3+-17MeV, CLEO-c collaboration also reported the result f_{D+}= 223+-16+-8 MeV.”
  - Now: Charm physics has experienced a renaissance in the past several years. High statistics charm samples from the B factories and Tevatron, along with new precision measurements from CLEO-c, have led to the discovery of new states of charm and charmonium, and detailed determinations of decay properties of many particles. The current excitement is bound to grow over the next several years; as BES-III is taking data, exciting experiments at LHC are ready, and new experiments, for example PANDA and a SuperFlavor factory are on the horizon.

Why the Renewed Interest Now?

- Not since the discovery of charm and its immediate impact (belief in quarks for real!) has charm had so much interest.
  - Size of D^0 mixing and possibility of CPV (BSM NP)
  - Before, SM mixing in charm was too far away to be interesting
  - Recently, small background from SM mixing (relative to B's where SM now an annoying background to any NP signal)
- More fundamentally, only u-type quark with mixing having unique sensitivity to beyond-SM physics.
- Up-quark sector = location of NP in Minimum Flavor Violation Models since down-quark sector has such good agreement with Sthe M (K's and B's – ignoring some $< 3\,\sigma$ clues).

What I Will Emphasize

- Over 30 presentations of experimental results before the new facilities talks this morning.

- Not enough time even to summarize all that we have seen from experiments, to recognize all the memorable plots and results – tempting as it is to show the many clean signals and data vs theory, the quantum correlations plots, and the D-mixing plots before and after the latest CLEO-c data is added.

- So, my plan is to give you my personal observations, exposing my prejudices, my ignorance, no doubt,

- I will give an overview at a fairly high level of abstraction – not re-showing individual plots or results. I ask the forgiveness of those of you who will have been slighted in this way – meaning all the presenters. You won't see your slides repeated here.

What We Have Seen?

- Truly impressive numbers of events in plots. Note that we often need the pressure of data to force us to think creatively about underlying physics, to change our prejudices. I remember well how increased data forced E791 collaborators in Rio to propose S-wave resonances (sigma and kappa) to explain the otherwise unfittable Dalitz distribution – though in hindsight earlier data sets had shown evidence of the same need, just not as dramatically. Similarly, data forced FOCUS to see the interference with the S-wave under the K* in D semileptonic decays.

- At the same time, we should not forget the lesson cited by Will Johns who remembered how FOCUS "learned more about the realities of the higher-statistics environment". In my experience these realities have included how to take, manage, and analyze the added data – as well as solving problems in the physics that the new data may cry out about.

- Is the disagreement at high q^2 between the LQCD form factors and data trying to tell us something important?

What We Have Seen?

Many results which are the first such observation or first such measurement – even now in this arguably mature field!

- New hadronic, radiative, and semileptonic decay modes
- New excited states of charm mesons
- Wide resonances, visible above background with enough data
- Form factors for Cabibbo-suppressed D decays
- A_{CP}'s in new decay modes

What We Have Seen?

A surprising number of new results, even among the most interesting new results, have systematic errors which are significantly smaller than the statistical errors – even from the full CLEO-c, BaBar, or Belle data sets.

So, the case for new facilities is very strong on that basis. There is room and utility for much more data.

What We Have Seen?

- More data [and more analyses of existing data] are also needed to help reinforce or remove states from the growing list that need to be explained, to see additional decay modes of states already indicated – even those multiply confirmed.
- We have all been uncomfortable with the idea that QCD would only choose to make states of q q-bar and three quarks of different color. We seem to be forced against our will to accept other states that we have every reason to believe must exist.
- On the other hand, it is unlikely that every newly observed state will survive an onslaught of new data. Possible states near thresholds need to be tested against other explanations: e.g., possibility of fluctuations in threshold-enhancement-shaped backgrounds and/or fluctuations of backgrounds otherwise incompletely modeled as phase-space shaped.

What We Have Seen?

- With the LHC really just starting its turn-on, we are getting a whiff of what may lie ahead from ATLAS, CMS, LHCb, and ALICE.
- Nevertheless, it has been useful for charm data that the LHC turn-on has been slower than some optimists have expected.
- This may be our only chance to see the low-pt production region.
- We will have to see how charm-physics goals fit into LHC “full-luminosity” trigger menus.

What We Have Not Seen?

- Detailed analyses of the systematic errors and their extrapolation into the next generation of experiments.
- Just how far we will be able to push mixing and CP violation measurements before we hit a wall of systematic uncertainty?
- Of course, we will need to experience of the additional data to be certain about this.
- But knowing the likely-most-productive modes and avenues to pursue first is always useful.
- Do techniques have to change to stay competitive?
- Will we be able to use 10 times more data? 100 times more?

Alert

- Many of the results have been the result of a tour de force – “an army of researchers working for a couple of years” (David Asner).
- There is concern about the future of doing charm physics, even with new facilities replacing or upgrading old ones.
- Let me emphasize, however, that the additional data should allow new analyses to be done, new questions to be asked.
- Ulf Meissner’s “golden times ahead” for BEPCII and FAIR – and I would add others – will not be automatic.
- Bring the new data on! Force us to think harder.

If CPV is Observed in Charm Mixing

- If observed, CPV in charm mixing will be a "game-changer" (forcing paradygm change).

- Motivation for charm physics will increase beyond the often cited justification of helping to understand or certify B physics applications ["to the rescue" per Jernej Kamenik].

Comments on Charm Production

- Is color octet on its way out as major source of theory underestimate of observed production of charmonium and open charm? Polarization of charmonium?
- I have always been uncomfortable with the appearance of an easy acceptance of any suggested correction to theory that increased cross section predictions, with the lack of universality in matrix elements, and with the inconvenient lack of enough onium polarization at high pt.
- Are NLO and relativistic corrections enough to explain earlier cross section discrepancies? To flip the size and sign of charmonium polarization?
- “Important discrepancies with experiment have been resolved” – Joan Soto
- Example: factor of two in NLO prediction wrt LO. Will NNLO really be negligible on this scale?
- Theory errors even before estimating NNLO, etc. remain too large to have confidence yet.
- Have to resolve experimental situation with polarization measurements at CDF (current and earlier) and with DZero.

Hidden Charm Spectroscopy

- Yes, there is apparent progress since last Charm symposium.

- Hoever, is there any real progress in understanding?

Additional Comments on Spectroscopy

- Questions in spectroscopy are multiplying still, though some patterns may be appearing. At the same time, charm is providing input to help understand light-meson spectroscopy.
- A personal favorite is charm decay as source of information on low mass (e.g., scalar) mesons.
- Also, charm decay provides clean laboratories for the spectroscopy of excited kaon states. Many of these states still require confirmation or more precise mass and width measurements.
- As more data become available at future Super-B factories, analyses similar to the ones presented here can further elucidate light meson spectroscopy.

Fermilab as a Future Charm Facility?

- We have just heard this morning about plans for facilities for future charm physics experiments. I will not repeat or summarize these reports now.
- However, I should probably comment on the situation at Fermilab since it is not otherwise reported.
- For now, the only new Fermilab data on charm physics continues to come from CDF and DZero at the Tevatron Collider.
- The current data taking, Run II, is scheduled to end in September, 2011.

Extension of Run II?

- There is a proposal to extend Run II for three more years, through September of 2014.
- The US Particle Physics Program Prioritization Panel, P5, just considered this proposal and is to give its recommendation to the High Energy Physics Advisory Panel on October 26.
- This is just one more of the hurdles which will have to be surmounted along a possible path to approval.
- HEPAP will make its comments in transmitting the report to the Department of Energy and funding may appear in the President's budget for the next year, which will be public in February, 2011.
- Fermilab has asked for approval of a plan which requires additional funding for an extension to happen – so as not to jepordize or unduly delay the approved program at the High Intensity Frontier. Stay tuned.

Fermilab as a Future Charm Facility?

- Two other options for future charm physics experiments at Fermilab:
  - Proposal # 986 - "Medium-Energy Antiproton Physics with The Antiproton Annihilation Spectrometer (TApAS)."
  - A new fixed target experiment using the high energy Tevatron beam
- The first is a serious proposal, submitted to Fermilab and scheduled for review by the Fermilab Physics Advisory Committee (PAC) at its meeting, November 4-6.
- The second is only an attempt to keep alive the possibility of a future Tevatron experiment.
- Dan Kaplan is spokesperson for the former, serious proposal; Alan Schwartz and I have led the discussion of the latter.
- Both options require use of facilities scheduled for decommissioning and/or reuse for other programs at Fermilab. Again, stay tuned.

References

- Proposal # 986 - "Medium-Energy Antiproton Physics with The Antiproton Annihilation Spectrometer (TApAS)."
  - Reachable soon from the Fermilab PAC meeting web page:

    http://www.fnal.gov/directorate/program_planning/phys_adv_com/PACdates.html

- A new fixed target experiment using the high energy Tevatron beam
  - "Renaissance of the ~1-TeV Fixed-Target Program."
    T. Adams *et al.*, Int. J. Mod. Phys. A **25**, 777-813 (2010).
    e-Print: arXiv:0905.3004 [hep-ex]

Final Words

- Finally, thanks again to our hosts for an exceptionally well-organized and enjoyable meeting.
- Thanks again, too, to all the presenters and their collaborators for their efforts.
- Charm remains a fascinating and vibrant area of research, one with the potential to teach us new things and be hotly pursued in many places.