Topical Group RF7, Hadron Spectroscopy

Conveners:

Richard Lebed (Arizona State U.)

Tomasz Skwarnicki (Syracuse U.)

Subgroups and their conveners:

Heavy-Quark Conventional Hadrons
Bryan Fulsom (PNNL), Alexis Pompili (U. of Bari), Elena Santopinto (INFN Geona)

Heavy-Quark Exotic Hadrons:
Liupan An (INFN Firenze), Ryan Mitchell (Indiana U.), Sasa Prelovsek (U. of Ljubjana)

Light-Quark Exotic Hadrons:
Sean Dobbs (Florida State U.), Justin Stevens (College of William&Mary),
Adam Szczepaniak (Indiana U.)

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- *2014 P5 Report:* No explicit mention of hadron spectroscopy, yet some major discoveries happened since then illustrating our lack of understanding of hadronic structures (e.g. solid observations of pentaquark and tetraquark hadrons)
- *Main physics issues:*
  - Only lightest hadrons for each flavor content are predominantly $q\bar{q}$ or qqq
    Our understanding of full bound-state spectrum of QCD is scandalously poor:
    - Are diquarks $[qq]$, strongly motivated by fundamental QCD, good building blocks for more complex hadrons: baryons $q[qq]$, tetraquarks $[qq][\overline{qq}]$, pentaquarks $[qq][qq]\bar{q}$, …?
    - Can gluons g be valence hadron constituents: hybrids $q\bar{q}g, qqqg, \ldots$, glueballs gg?
    - Can mesons bind with other mesons or baryons via nuclear-type forces to create loosely bound "molecular" states?
    - Can color fields create compact multiquark states beyond baryons (with or without diquark substructure)?
    - How does mixing between different types of bound states of the same quantum numbers affect observable hadrons? How does one distinguish different structures?
  - Development of theoretical tools (phenomenology and lattice QCD) needed to predict mass spectrum, decay, and production patterns
    The same applications are also used by researchers in EF06
  - Searches for BSM physics possible in decays of heavy quarkonia

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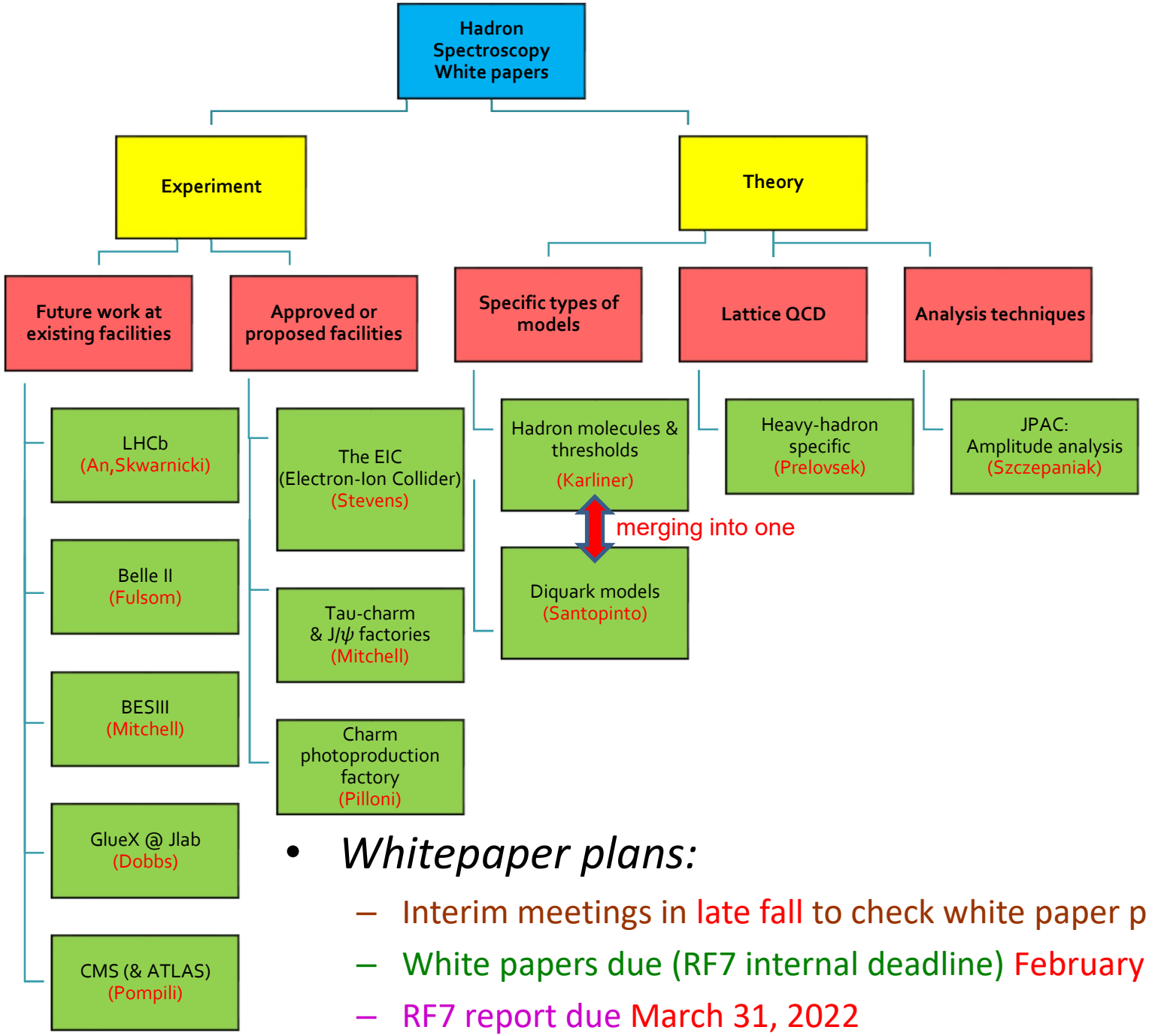
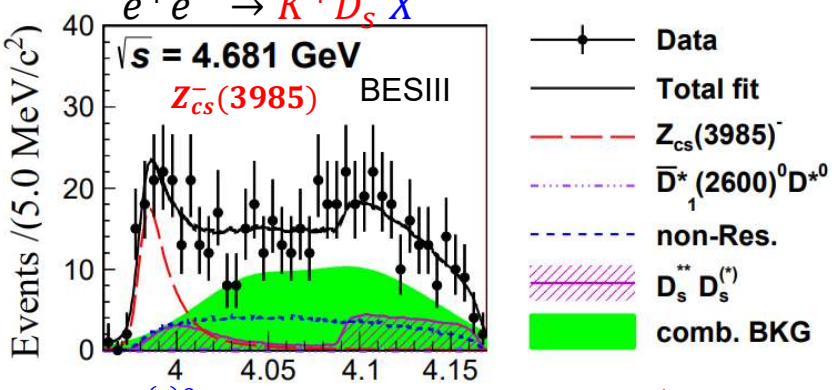
- *Request for P5:*
  - Statement in support of experiments addressing fundamental questions in hadron spectroscopy (previous slide):
    - At present, the field is driven by the experiments rather than theory
    - Lasting legacy and future opportunities at heavy-flavor experiments: LHCb, b-factories (Belle II), charm-factories (BESIII and future tau-charm factory)
    - Opportunities at high-p_T experiments (CMS, ATLAS) using special final states like, *e.g.*, $\mu^+\mu^-\mu^+\mu^-$ (tetraquarks decaying to $\Upsilon\,\Upsilon$, $J/\psi\Upsilon$, $J/\psi J/\psi$)
    - Synergistic activities in nuclear/medium-energy community (photoproduction at JLab and EIC [U.S.-based!], production in heavy-ion collisions)
    - Need for collaboration of experimentalists with theorists on difficult aspects of amplitude analyses of the data (*e.g.*, the JPAC Group)
  - Statement in support of theoretical efforts to improve phenomenological and lattice QCD modeling of hadron spectrum and their decay & production properties:
    - U.S. involvement has fallen far behind Europe and Asia



- *Whitepaper plans:*
  - Interim meetings in late fall to check white paper progress
  - White papers due (RF7 internal deadline) February 1, 2022
  - RF7 report due March 31, 2022

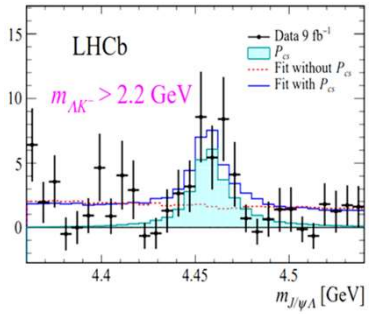
- *Previous meetings:* https://snowmass21.org/rare/hadron_spectroscopy
- *Upcoming plans:*
  - One final workshop, on Monday, October 25, 9:30am US/Central, summarizing experimental discoveries and theoretical advances made just during the 2021 Snowmass pause

$e^+e^- \to K^+ D_s^- X$

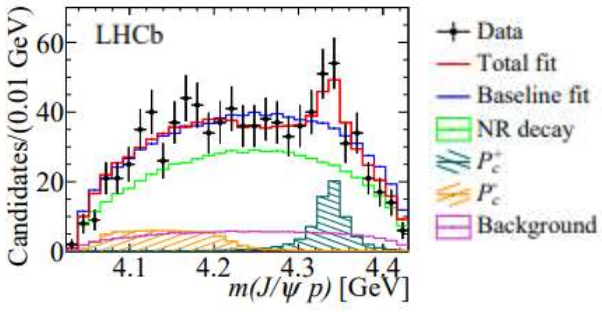


$M(D_s^- D^{(*)0})$ via Recoil Mass against K^+

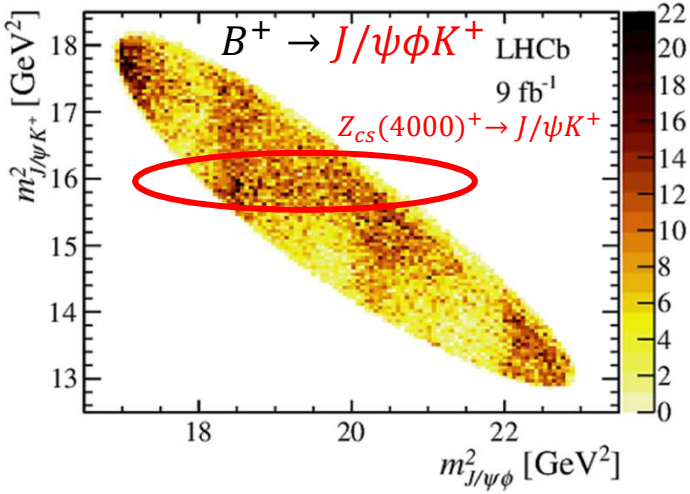
$\Xi_b^- \to J/\psi \Lambda K^-$ $P_{cs}(4459)^0$



$B^0 \to J/\psi p\bar{p}$ $P_c(4337)^\pm$



$B^+ \to J/\psi\phi K^+$



many $X \to J/\psi\phi$ states (additional ones in 2021)

$T_{cc}(3875)^+$ $\Gamma \sim 0.4\ MeV$ $pp \to D^0 D^0 \pi^+ + \cdots$