LQCD-ext II Project
2017 Annual Review

Answers to science questions

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For USQCD
http://www.usqcd.org

LQCD-ext II Project 2017 Annual Review
Fermilab
May 16-17, 2017

- *4. How are foreign collaborators involved in USQCD?*
- *How many foreign collaborators are there?*
- *Would a world lattice collaboration be more effective?*

- Foreign collaborators are welcome in participate in USQCD projects as members of US collaborations.
- Those of us at the review know of at least 47 foreign collaborators, and we suspect there may be many more.
- Negotiating with funding agencies of foreign countries strikes us as very challenging.

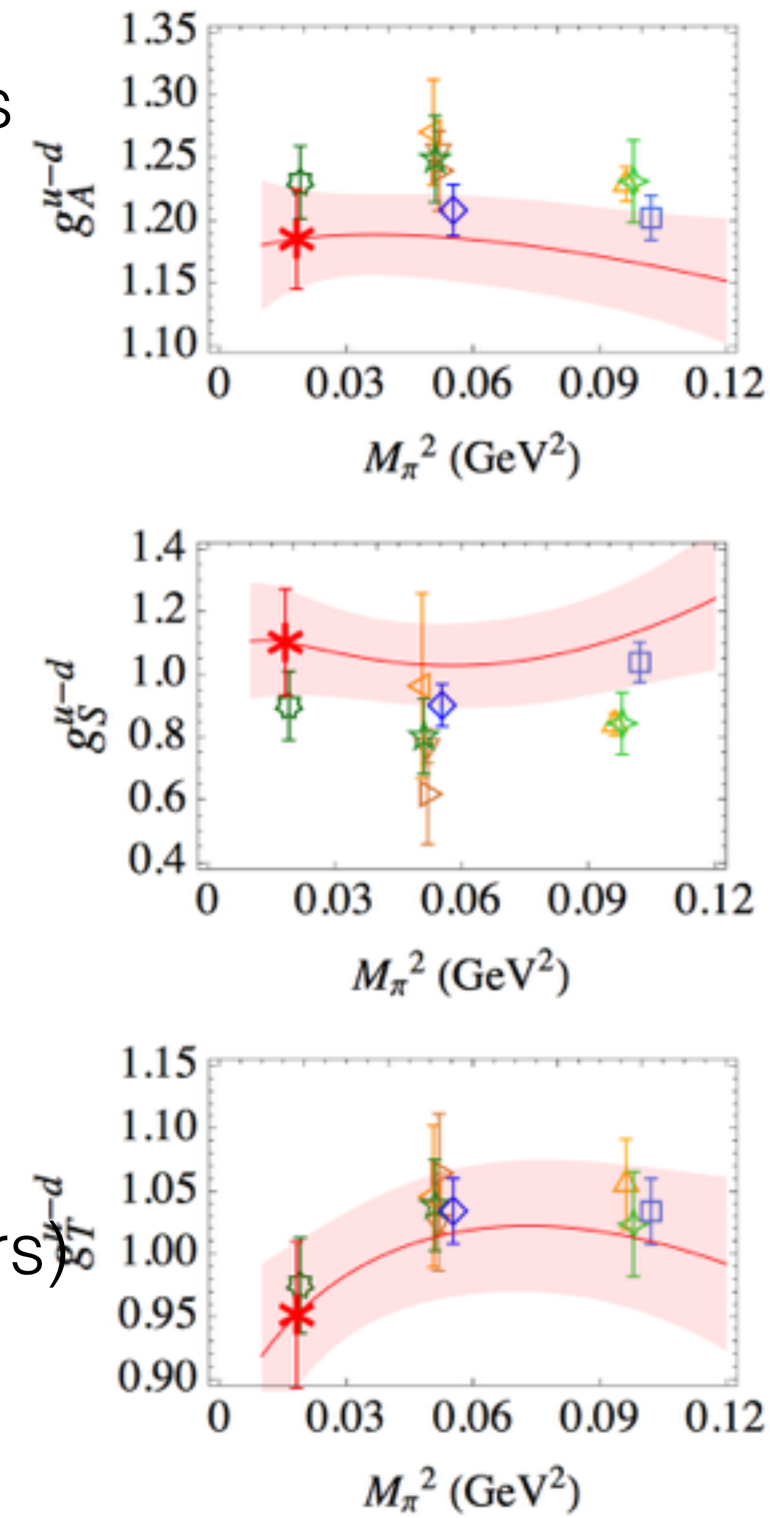
5. What is the status of physical pion mass calculations?

- HEP and Thermodynamics are working at the physical pion mass now.
  - Not all calculations are born equal
    - nucleons are more challenging - need larger volumes and have worse signal to noise.

- Nucleon Structure
  - clover on MILC - physical (2+1+1, no QED)
  - clover on clover - pions ~ 170 MeV, with 135 in production
  - DW on Overlap - pions ~ physical

- Nucleon Spectroscopy
  - pions ~ 230 MeV, anisotropic clover on clover
  - isotropic clover on clover - 170 MeV
  - 135 MeV in production (first results in 1 year+)

- Nuclear Forces
  - pions ~ 230 MeV, clover on clover (first results in +2 years)



- All projects sharing clover cfgs where practical
- No dynamical QED, no isospin breaking

- *6. Belle and BaBar are discovering many new, sometimes exotic heavy quark states. Why isn't there more work from lattice? Could there be a more systematic effort?*

- Exotics, typically unstable with multi-hadron final states, are notoriously difficult to do honestly.
- Technology for lattice calculations of such states is in an embryonic form.
- It's a better topic for phenomenologists at this state of lattice technology.
- The group best positioned for this is the JLab group, based on its light quark exotics program.

7. What is the relative strength of NP lattice physics vs HEP lattice physics. Is NP growing faster?

- Yes, but only by a bit over the last 14 years: 13 junior faculty jobs vs 11 in HEP.

NP's growth is a good thing for HEP as well as NP. There is so much overlap between our HEP and NP efforts that strengthening either strengthens the other.

	Year	Research institution, HEP	Research institution, NP	Computational scientist	Teaching college	Industry	Foreign
Zohreh Davoudi	2017		Maryland/RBRC				
Luchang Jin	2017	Connecticut/RBRC					
Phiala Shanahan****	2017		William&Mary/JLab				
Raul Briceno****	2017		Old Dominion/JLab				
Heechang Na	2017			Ohio Supercomp.			
Xu Feng	2017						Peking
Mridupawan Deka	2017						Dubna
Anyi Li	2017					IBM	
Prasad Hegde	2017						Indian Inst Sci
Chris Bouchard	2016						Glasgow
Sergei Syritsyn	2016		Stony Brook/RBRC				
Martha Constantinou	2016		Temple				
Andrea Schindler	2016		MSU				
Huey-Wen Lin	2016		MSU				
Alexei Bazavov	2016		MSU				
Mattian Wagner	2015					NVIDIA	
Ethan Neil ***	2015	Colorado/RBRC					
Christoph Lehner **	2014	BNL					
Mei-Feng Lin	2014			BNL			
Stefan Meinel ***	2014	Arizona/RBRC					
Hiroshi Ohno	2014						Tsukuba
Heng-Tong Ding	2013						CCNU
Todd Evans	2013			TACC			
Andre Walker-Loud**,****	2013		Wm & Mary/JLab→LBL				
Jack Laiho	2013	Glasgow→Syracuse					
Will Detmold **	2013		Wm & Mary →MIT				
Christopher Thomas	2013						Cambridge
Ruth Van de Water	2012	BNL→Fermilab					
Brian Tiburzi ***	2011		CUNY/RBRC				
Andrei Alexandru *	2011		GWU				
Elvira Gamiz	2011						Granada
Kate Clark	2011					NVIDIA	
Ron Babich	2011					NVIDIA	
Christopher Aubin	2010				Fordham		
Swagato Mukherjee	2010		BNL				
Changhoan Kim	2010					IBM	
Enno Scholz	2009						Regensburg
Taku Izubuchi	2008	BNL					
James Osborn	2008			Argonne			
Chris Dawson	2007	Virginia/JLab					
Nilmani Mathur	2007						Tata Institute
Joel Giedt	2007	RPI					
Matthew Wingate	2006						Cambridge
Jozef Dudek **,****	2006		Old Dominion/JLab→William&Mary				
Jimmy Juge	2006				U. of the Pacific		
Peter Petreczky	2006		BNL				
Balint Joo	2006			JLab			
Kieran Holland	2006				U. of the Pacific		
Kostas Orginos **,****	2005		Wm & Mary/JLab				
George Fleming	2005			Yale			
Tom Blum ** ***	2003	Connecticut/BNL					
Silas Beane *	2003		UNH→U Wash.				
Total		11	13	4	3	3	7

* NSF Early Career Award
** DoE OJI/Early Career
*** RIKEN/BNL bridge positions
**** JLab joint positions

8. What are the demographics of your field like? Do you track the number of graduate students, post docs, etc.

- 22 current grad students.
- 83 PhDs granted since 2003.
- 45 found jobs in physics or computing.

Totals by subject area (since 2000):

HEP: 46
Cold NP: 41
BSM: 22
Thermo: 3
HEP, Cold NP: 4

USQCD PhD students (1)

	Given Name	Year	Institution	Advisor	Current institution (Leave blank if not known. For USQCD internal use.)
Sui	Chengzhong	2000	Columbia	Christ	
Chen	Ping	2000	Columbia	Christ	
Dolgov	Dmitri	2000	MIT	Negele	
Savage	Van	2001	Washington U St Louis	Bender, Bernard	UCLA (tenured prof. in Biomath)
Fleming	George	2001	Columbia	Mawhinney	Yale
Zhestkov	Yuri	2001	Columbia	Christ	
Wu	Lingling	2001	Columbia	Christ	
Tamhankar	Sonali	2002	Indiana University	Gottlieb	University of Seattle
Liao	Xiaodong	2002	Columbia	Christ	
Calin-Radu	Christian	2002	Columbia	Mawhinney	
Burch	Tom	2003	University of Arizona	Toussaint	
Liu	Guofeng	2003	Columbia	Christ	
Smigielski	Brian	2003	University of Washington	Savage	
Arndt	Daniel	2004	University of Washington	Savage	
Tiburzi	Brian	2004	University of Washington	Miller	City College, New York
Aubin	Christopher	2004	Washington U St Louis	Bernard, Ogilvie	Fordham U (tenured prof.)
Laiho	Jack	2004	Princeton	Soni	Syracuse
Levkova	Ludmilla	2004	Columbia	Mawhinney	
Kim	Changhoan	2004	Columbia	Christ	IBM, Watson Research
Renner	Dru	2004	MIT	Negele	LANL
Bulava	John	2005	Carnegie Mellon U	Morningstar	Odense U
Menscher	Damian	2005	UIUC	El-Khadra	Google
Sato	Ikuro	2005	U Maryland	Wallace	Denso IT Lab, Tokyo
Lichtl	Adam	2006	Carnegie Mellon U	Morningstar	Delta-Brain Inc.
Lin	Huey-Wen	2006	Columbia	Christ	Michigan State
Walker-Loud	Andre	2006	University of Washington	Savage	LBNL
Bailey	Jon	2007	Washington U St Louis	Bernard	Seoul National U. (research position)
Deka	Mridupawan	2007	University of Kentucky	Liu	Dubna
Endres	Michael	2007	University of Washington	Kaplan, David B	Harvard (IQSS)
Loktik	Oleg	2007	Columbia	Christ	
Cohen	Saul	2007	Columbia	Mawhinney	Google
Lin	Meifeng	2007	Columbia	Mawhinney	BNL
Evans	Todd	2008	UIUC	El-Khadra	TACC, UT Austin
Hashimoto	Koichi	2008	Kanazawa	Izubuchi	FIXSTARS (computer industry)
Na	Heechang	2008	Indiana University	Gottlieb	Ohio Supercomputer Center
Li	Shu	2008	Columbia	Christ	
Cheng	Michael	2008	Columbia	Christ	
Sigaev	Dmitry	2008	MIT	Negele	HBK Capital Management
Babich	Ronald	2009	Boston University	Rebbi	NVIDIA Corp
Chowdhury	Saumitra	2009	UConn	Blum	
Wong	Chik Him	2009	Carnegie Mellon U	Morningstar	Wuppertal U
Torok	Aaron	2009	U New Hampshire	Beane	
Li	Min	2009	Columbia	Christ	
Bratt	Jonathan	2009	MIT	Negele	Sapling Learning
Billeter	Brian	2010	U Utah	DeTar	
Du	Xining	2010	Washington U St Louis	Bernard	EXA Corp. (software)
Hegde	Prasad	2010	Stony Brook	Karsch	Indian Institute of Science, Bangalore, India
Li	Anyi	2010	University of Kentucky	Liu	IBM
Liu	Liuming	2010	William and Mary	Orginos	Bonn U, HISKP
Engelson	Eric	2010	U Maryland	Wallace	
Mankame	Devdatta	2010	University of Kentucky	Draper	
Schneible	Joe	2010	Syracuse	Catterall	
Zhou	Ran	2010	UConn	Blum	FNAL

USQCD PhD students (2)

Wasem	Joseph	2010	University of Washington	Savage	LLNL
Syritsyn	Sergey	2010	MIT	Negele	Stony Brook (assistant professor)
Bouchard	Chris	2011	UIUC	El-Khadra	University of Glasgow (Lecturer)
Freeman	Walter	2011	University of Arizona	Toussaint	Syracuse
Joseph	Anosh	2011	Syracuse	Catterall	ICTS-TIFR, Bangalore (postdoc)
Neil	Ethan	2011	Yale	Fleming	CU Boulder (assistant prof)
Schaich	David	2011	Boston University	Rebbi	U. Bern (postdoc)
Shi	Zhifeng	2011	William and Mary	Detmold	
Lightman	Matthew	2011	Columbia	Christ	
Jin	Xiaoyong	2011	Columbia	Mawhinney	Argonne
Liu	Qi	2012	Columbia	Christ	
Chen	Chen	2013	Rensselaer Poly. Inst.	Giedt	Siemens PLC
Parikshit	Junnarkar	2013	U New Hampshire	Beane	Mainz
Qiu	Shuhei	2013	U Utah	DeTar	NIH
Briceno	Raul	2013	University of Washington	Savage	JLab (Assist. Prof. ODU/JLab starting Fall 2017)
Green	Jeremy	2013	MIT	Negele	DESY, Berlin
Davoudi	Zoreh	2014	University of Washington	Savage	MIT (Assist. Prof. at UMD starting Fall 2017)
Cheng	Anqi	2014	CU Boulder	Hasenfratz	Rule14 (data science industry)
Li	Ruizi	2014	Indiana University	Gottlieb	Indiana University (postdoc)
Lin	Zhongjie	2014	Columbia	Christ	
Yu	Jianglie	2014	Columbia	Christ	Google
Brown	Zachary	2015	William and Mary	Orginos	
Chang	Chia-Cheng (Jason)	2015	UIUC	El-Khadra	LBNL
Galvez	Richard	2015	Syracuse	Catterall	Vanderbilt
Komijani	Javad	2015	Washington U St Louis	Bernard	TUM, Munich (postdoc)
Mastropas	Ekaterina	2015	William and Mary	Richards	
Petropoulos	Gregory	2015	CU Boulder	Hasenfratz	SecurityScorecard (data science industry)
Shultz	Christian	2015	Old Dominion U	Dudek	
Veernala	Aarti	2015	Syracuse	Catterall	Fermilab
Weinberg	Evan	2015	Boston University	Brower	BU Postodoctoral Fellow
Zhang	Daiqian	2015	Columbia	Christ	Google
Howarth	Dean	2016	Rensselaer Poly. Inst.	Giedt	Temple U.
Lee	Song-Haeng	2016	U Utah	DeTar	Synopsys Inc, Mountain View, CA (industry)
Sun	Mingyang	2016	University of Kentucky	Liu	Riverbed
Winterowd	Christopher	2016	U Utah	DeTar	U Kent (postdoc)
Jin	Luchang	2016	Columbia	Christ	BNL (postdoc)
Murphy	David	2017	Columbia	Mawhinney	
Sufian	Raza	2017	University of Kentucky	Liu	JLab
Wagman	Michael	2017	University of Washington	Savage	(Papparlardo Fellow at MIT starting 2017)
Bassler	Scott	current	Syracuse	Laiho	Syracuse
Brown	Nathan	current	Washington U St Louis	Bernard	Washington U
Butt	Nouman	current	Syracuse	Catterall	Syracuse
Carosso	Andrea	current	CU Boulder	Hasenfratz	CU Boulder
Cheng	Tu	current	UConn	Blum	
Grebe	Anthony	current	MIT	Detmold	MIT
Hackett	Daniel	current	CU Boulder	DeGrand	CU Boulder
Hoying	Daniel	current	UConn	Blum	DOE Grad Student Fellowship at BNL (2017-2018
Jay	William	current	CU Boulder	Neil	CU Boulder
Jha	Raghav	current	Syracuse	Catterall	Syracuse
Kanwar	Gurtej	current	MIT	Detmold	MIT
Rendon	Gumaro	current	U Arizona	Meinel	U Arizona
Steinbrecher	Patrick	current	BNL/Bielefeld	Karsch	BNL
Wang	Gen	current	University of Kentucky	Liu	
Yamamoto	Shuhei	current	U Utah	DeTar	U Utah

USQCD PhD students (3)

Bailey	Ziyuan	current	Columbia	Christ	
Wang	Bigeng	current	Columbia	Christ	
Wang	Tianle	current	Columbia	Christ	
Saenz	Jesus	current	NM State University	Engelhardt	

9. How easy is it for Phenomenologists to become a Lattice Gauge Theorist?

- The structure of the USQCD collaboration, and our willingness to make codes, algorithms and configurations available makes it straightforward for a phenomenologist to learn the techniques, perform calculations and become a lattice gauge theorist.

- Joining one of the existing collaborations would allow a phenomenologist to rapidly contribute at the bleeding edge

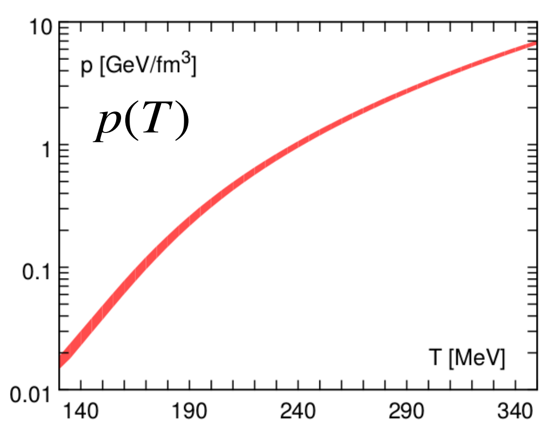
- Can contribute at different ``levels''.
  - Analysis of correlation functions - minimal new skills required - statistics, python, mathematica, …
  - Production running, writing scripts to run etc, not difficult
  - Writing science application code - a few weeks under guidance from expert (Sabbatical is ideal)

- e.g., Beane, Bedaque, Detmold, Savage, Freeland, Davoudi,Soltz, Luu, and more are people who have transition as postdocs or Assistant Prof. or Prof. or Lab Staff to LQCD researchers from phenomenologists, theorists, experimentalists. All are, or have, written science application code and have done production.

Without USQCD, these people would likely not have transitioned to Lattice QCD

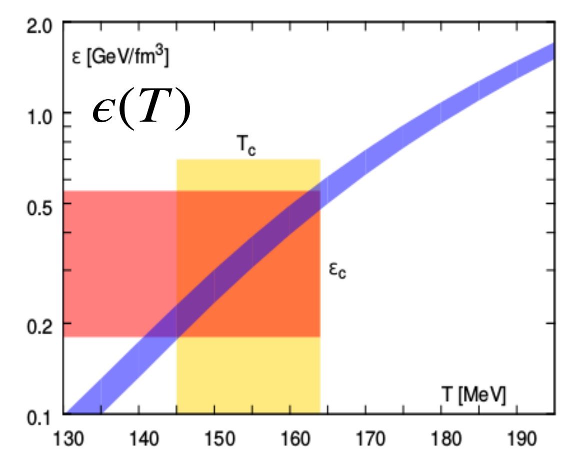
10. How strong is the link between the RHIC program and lattice thermodynamics calculations.

Hot-dense LQCD calculations primarily provide equilibrium properties of QGP. These QCD inputs are used within dynamical simulations, modeling the time evolution of QGP. Outputs of these dynamical models are compared with experimental data to infer various other properties of QGP. E.g.:



QGP properties

LQCD: equation of state

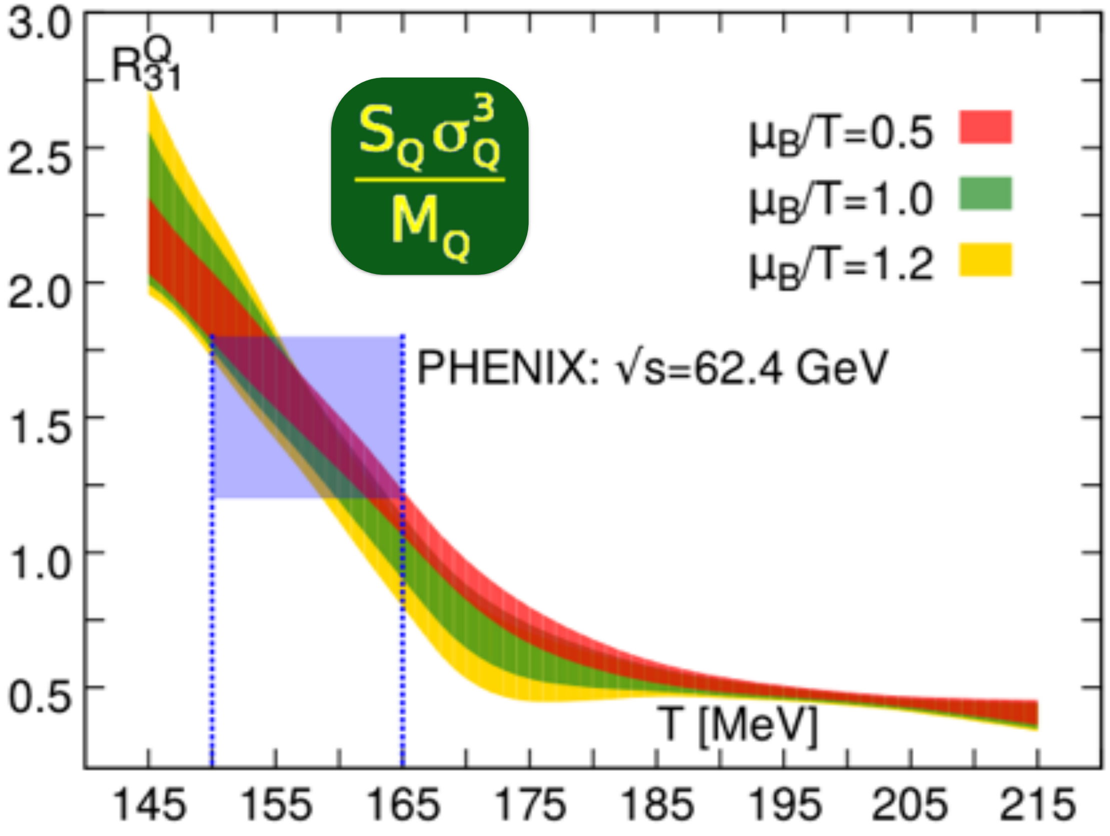


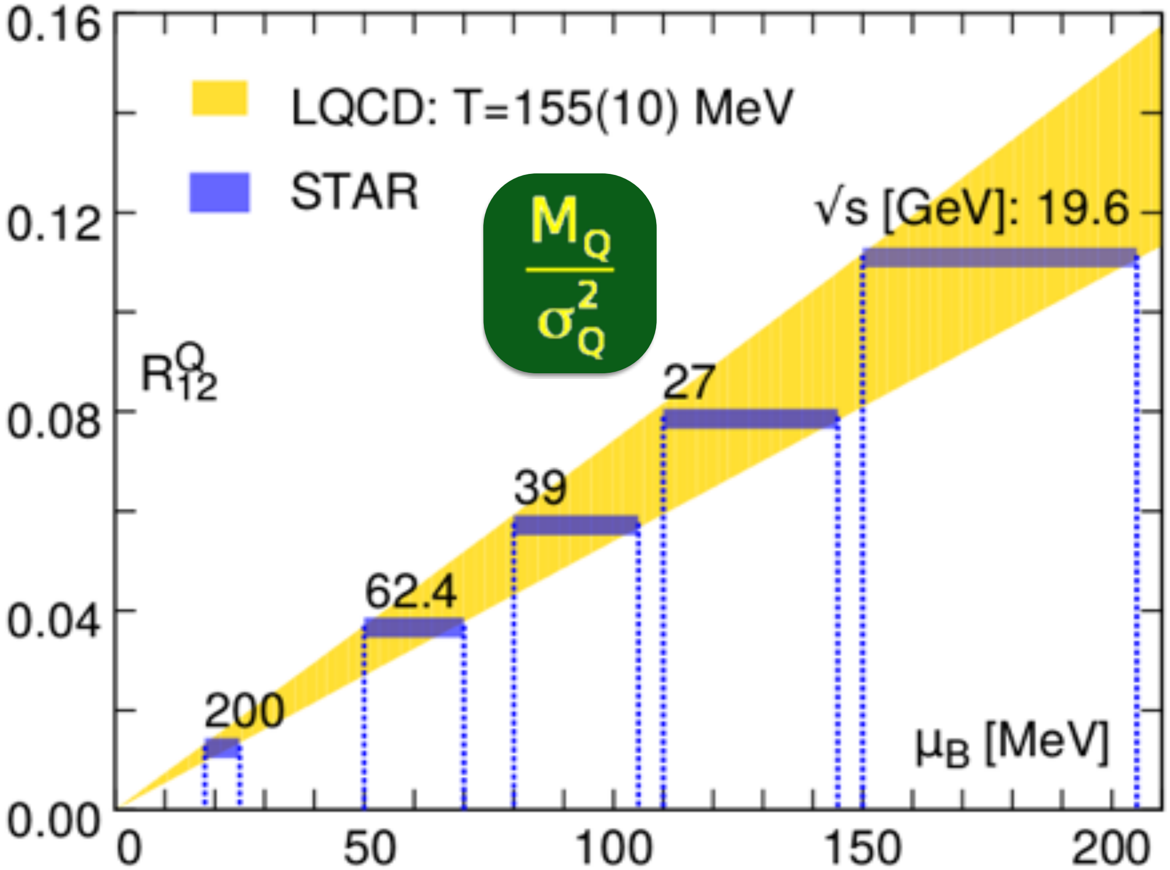
HotQCD:
Phys. Rev. D90, 094503 (2014)

hydrodynamic modeling ⟷ $\dfrac{4\pi T\eta}{\epsilon + p}$ ⟷ experimental measurements

energy-momentum conservation

In some cases, direct comparisons between LQCD results and experimental data are also possible. E.g. comparisons of cumulants of net-charge fluctuations lead to extractions of freeze-out parameters of heavy-ion collisions.





11. What is lattice doing for the Belle program.

- USQCD lattice gauge theorists heavily engaged in Belle II Theory Interface Platform (B2TIP), including:
  - Junko Shigemitsu (Ohio State) on Advisory Committee
  - Andreas Kronfeld WG convener: “Semileptonic & Leptonic B decays”
  - Steve Sharpe (U. Washington) WG convener: “Charmless Hadronic B Decays”
  - Aida El Khadra gave plenary talk at May 2016 B2TIP workshop
  - Parallel talks at several B2TIP workshops
- USQCD B- and D-physics calculations support the future Belle-II physics program, including:
  - **$B \to \pi$ form factors** (both for tree and rare decays)
  - **$B \to D, D^*$ form factors** (including the tensor form factors in both cases)
  - **Neutral B-meson and D-meson mixing matrix elements** (plans for obtaining mixing parameters to ~<1% precision)
  - **Leptonic and and semileptonic D decay constants and form factors**

11. What is lattice doing for the Belle program?

- US experiments are pushing us in different directions, but we've had spectacular success in flavor physics and are happy to keep doing it (we're already doing many things for the LHCb and Belle programs).
- Feel free to suggest in your report that we emphasize it more.

12. Is there a plan for lattice people to be involved in LHCb?

Support of LHCb

- Tree / CKM determinations
- Loop / new-physics searches

- USQCD lattice gauge theorists interact frequently with LHCb experimentalists and are engaged in numerous calculations supporting the LHCb physics program
- Recent relevant papers include:
  - **$B_{(s)}$ meson decay constants** [Fermilab/MILC, PoS LATTICE2016 (2016) 294; HPQCD, PRL110 (2013) no.22, 222003, PRD91 (2015) no.11, 114509; RBC/UKQCD, PRD91 (2015) no.5, 054502]
  - **$B \to \pi ll$ & $B \to K l^+ l^-$ form factors** [Fermilab/MILC, PRL115 (2015) no.15, 152002, PRD93 (2016) no.2, 025026]
  - **$\Lambda_b \to p\, l^- \nu$, $\Lambda_b \to \Lambda_c\, l^- \nu$ & $\Lambda_b \to \Lambda\, l^+ l^-$ form factors** [Detmold, Lehner, Meinel, 014512, PRD92 (2015) no.3, 034503, PRD93 (2016) no.7, 074501]
- Works in progress include updates of earlier calculations plus (see Lattice 2017 agenda):
  - **Neutral D-meson mixing** [Fermilab/MILC, *in preparation*]
  - **$B_s \to K l \nu$ (/ $B_s \to D_s l \nu$)** form factors [Fermilab/MILC, RBC/UKQCD]
  - **$B \to D^* l \nu$ form factor at nonzero recoil** [Fermilab/MILC; LANL/Seoul]
  - **$B \to K^* l^+ l^-$ form factors** [Meinel & Leskovec]
- van de Water gave keynote talk at 2016 workshop "Implications of LHCb measurements and future prospects"; also lattice-QCD talks by Hansen on multi-hadron decays & Moir on heavy-flavor spectroscopy

13. Most of present current thermodynamic activities are using staggered fermions. What about chiral anomalies for staggered fermions in the chiral limit? Can these be checked with other fermions? How expensive with that be?

We have quantitatively demonstrated, for physical quark masses, staggered and chiral Domain Wall Fermions (DWF) provide very similar chiral crossover temperature, and also show similar patterns of chiral and axial symmetry breaking close to Tc.

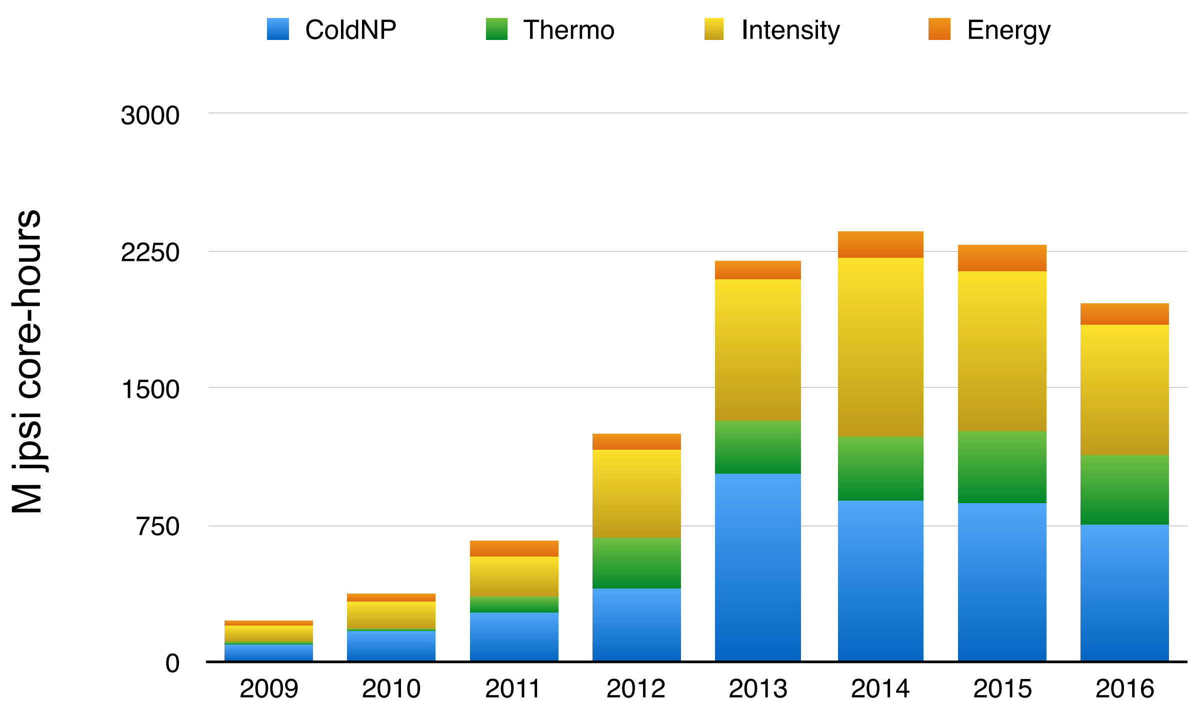
Even in the chiral limit staggered fermions are expected to reproduce the correct chiral anomaly, provided continuum limit is taken first before the chiral limit.

For QCD thermodynamics, at present, DWF is ~x30 more expensive that staggered fermions for QCD thermodynamics. Of course, in future, it will be important to check this issue with other fermions, such as the DWF.

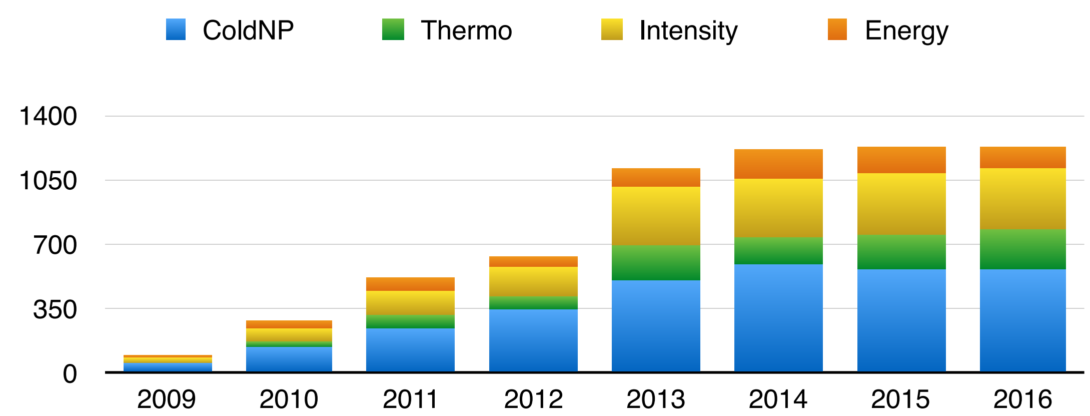
14. In your four main sub-fields, how does the SPC decide between them? How is the ratio decided?

Total by Field

All



LQCD hardware



NP and HEP are approximately equal by agreement.