HEPAP Accelerator R&D Subpanel Progress Report

Don Hartill on behalf of the Subpanel

HEPAP Meeting 12/8/2014

Outline

- Subpanel was formed in response to a 2013 OHEP COV recommendation (follows three previous Subpanels on Accelerator R&D)
- Summary of the Charge to the Subpanel
- Members of the Subpanel
- Meetings
- Information gathering process
- GARD thrust areas
- Challenges
- Community input for resources needed – sticker shock
- Results of preliminary discussions
- Gathering further information for advanced acceleration
- Developing a priority map for the GARD program
- Paying attention to workforce needs
- Support for fundamental accelerator science
- Next steps to a final report by late March 2015

History

- First HEPAP Subpanel on Accelerator R&D was the “Tigner” Subpanel in 1980.

  Main recommendation was that support for Accelerator R&D should be 4% of the HEP operating budget.

- Second HEPAP Subpanel on Accelerator R&D was the first “Marx” Subpanel in 1996.

  Its report endorsed the 4% support level and added further justification for this level of support and pointed out that accelerators were useful in a number of areas outside of high energy physics.

History

- Third HEPAP Subpanel on Accelerator R&D was the second "Marx" Subpanel in 2006.

    Its report suggested that the level of support should be

    4% for the coming year with 5% the next year and increasing to 6% smoothly over the next ten years and remaining at that level afterword. Another recommendation was that the NSF begin a program in Accelerator Science. Introduced the concept that HEP should be the "steward of accelerator R&D" that could support accelerator needs in other branches of the Office of Science and that these branches should provide some support for these activities.

- Only four members of the second "Marx" Subpanel are members of the current Subpanel.

Summary of the Charge to the Panel

National Goals: Appropriate goals in broad terms for medium ($\leq$ 10 years) and long term ($\leq$ 20 years) U. S. Accelerator R&D for a world leading future program in accelerator based particle physics aligned with the recommendations of P5

Current Effort: Examine the scope of the current effort and evaluate how well these address the HEP mission as expressed by P5

Impediments: Describe any impediments that may exist in achieving these goals

Summary of the Charge to the Panel

Training: Accelerator R&D efforts play a major role in training future accelerator scientists and technologists. Are local partnerships between laboratories and local universities performing adequately?

Balance: How do we maintain a healthy and appropriately balanced national program? Provide further guidance for a plan based on the science and technology case for increased investment in HEP Accelerator R&D called for in P5's Scenario C

Preliminary report by end of November with final report by March 2015

Members of the Subpanel

Bill Barletta MIT
Ilan Ben-Zvi BNL & Stonybrook
Marty Breidenbach SLAC
Oliver Bruning CERN
Bruce Carlsten Los Alamos
Roger Dixon Fermilab
Steve Gourlay LBNL
Don Hartill (Chair) Cornell
Georg Hoffstaetter Cornell
Zhirong Huang (BES) SLAC

Young-Kee Kim U of Chicago
Tadashi Koseki KEK/J-PARC
Geoff Kraft (NP) JLAB
Andy Lankford (ex officio) UC Irvine
Lia Merminga Triumf
Jamie Rosenzweig UCLA
Mike Syphers MSU
Bob Tschirhart Fermilab
Rik Yoshida Argonne

Guidance from P5

- Science Drivers
  - Use the Higgs boson as a new tool for discovery
  - Pursue the physics associated with neutrino mass
  - Identify the new physics of dark matter
  - Explore the unknown: new particles, interactions, and physical principles
  - (Cosmic Acceleration)
- Projected startup dates for existing projects

LHC: Phase 1 upgrade	~ 2020
HL-LHC	~ 2025
LBNF	~ 2028
ILC	~ 2030

- Possible future projects
  - Multi-MW proton source
  - 1 TeV e+e- collider
  - 100 TeV pp collider
  - $\geq$ 3 TeV lepton collider
  - Neutrino factory
- Assuming ~ 10 years for prime era for discovery of new physics of each of the “existing” projects sets the time scale for the construction start of future projects
- Assuming ~ 10 year R&D phase to develop the needed technologies to produce a credible conceptual design sets the start date of a significant R&D program

Meetings of the Subpanel

First Meeting (Organizational) at SLAC July 7 & 8.

Road Trip to BNL, Fermilab & Argonne, and SLAC & LBNL week of August 25 to 30.

Two Day Meeting Newport Beach, CA Nov. 6 & 7

Second Two Day Meeting Chicago, IL Dec. 3 & 4

Final Two Day Meeting on the West Coast Early Jan. 2015

Information Gathering by the Subpanel

Meetings were held at BNL, Fermilab, Argonne, SLAC and LBNL on a road trip during the last week in August

Subpanel Website:
http://www.usparticlephysics.org/p5/ards

The website has the agendas and the talks for the lab visits.

Town Hall meetings were held at most of the labs.
In addition, a virtual Town Hall meeting was held on Oct. 10

More on the Road Trip

The energy frontier was the focus at BNL.

The intensity frontier was the topic at Fermilab.

Novel particle acceleration schemes were the themes at SLAC and LBNL.

A two hour executive session was held at end of the LBNL visit and was followed by having a two page written report submitted by each subpanel member of their impressions from the road trip.

HEP General Accelerator R&D Thrust Areas

Superconducting RF Cavities

Accelerator Beam Physics

Particle Sources

Beam Instrumentation and Controls

NC RF and High Gradient Accelerating Structures

New Accelerator Concepts

Super Conducting Magnets and Materials

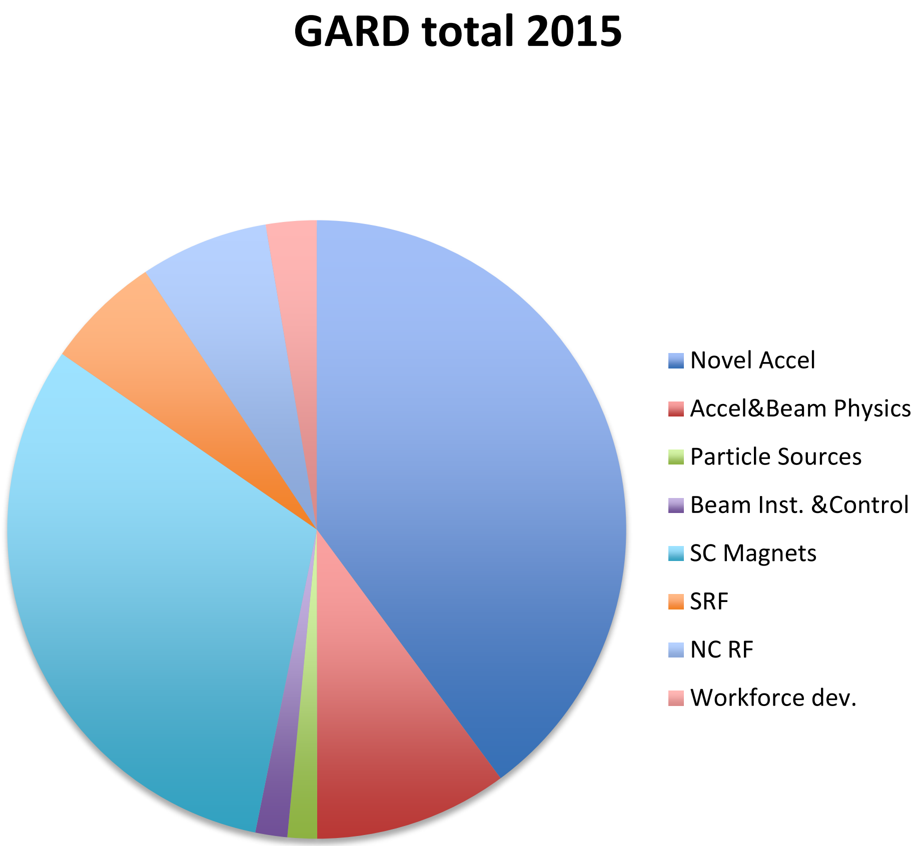
Current GARD Program (FY 2015)

For FY 15 (President's request) the current General Accelerator Research and Development budget is 71 M$.

This includes the facility operation costs at Argonne (AWA), Fermilab (SRF and SC Magnets), SLAC (FACET) and LBNL (BELLA) which total 30.4 M$.

This leaves a net of ~ 40.6 M$ for the GARD base programs and is divided among the previously listed seven GARD thrusts areas (assisting workforce development). The following pie chart illustrates the current division:

Current GARD Program



The NSF Program in Accelerator Science

In addition to the DOE GARD program, NSF has started their new program in Accelerator Science with a total funding level of 9.8 M$ for this year.

Fourteen awards have been made covering a broad range of topics in Accelerator Science.

Of the 9.8 M$ ~ 1.2 M$ is for SRF research.

And, it is a very welcome addition to the NSF portfolio.

US GARD Opportunities

For the Intensity Frontier, the performance measure is MW•Ktons•beamtime/yr so producing higher beam power has significant leverage. Beam stability at synchrotron injection energies combined with higher power targets could have large benefits.

Future high energy colliders are expensive and complex. Optimization studies will be key to lowering the construction cost and maximizing the operating efficiency. Optimized superconducting magnet design both in field and manufacturability will require R&D. For e+e- colliders, more efficient RF sources could lower operating costs.

Advanced acceleration technologies potentially have the promise of dramatically increasing the accelerating gradient and thereby significantly reducing the cost of a very high energy e+e- collider.

LHC Hi Lumi Upgrade Program

US accelerator component includes the part of the LARP program to construct the high field quadrupoles and dipoles based on $NbSn_3$ has been moved from GARD to LHC Hi-Lumi directed R&D project. Crab SRF cavities are also part of this project.

The schedule for this upgrade is to begin installation in ~2023 with a 2.5 year duration. The LHC will then run until 2035 integrating ~ 3000 fb^{-1}. 1.2 km of the LHC will be replaced in the upgrade. The total cost of the LHC Upgrade is ~ 800 MCHF.

Event pileup will be the principal challenge for the detectors with the potential of up to several hundred interactions per bunch crossing.

Future Collider Possibilities

The construction of the ILC in Japan is under study.

Moderate energy muon colliders were not endorsed by P5.

Andy and I were at the Future Circular Collider collaboration meeting at CERN in early September. The URL for all the talks is https://indico.cern.ch/event/333236/other-view?view=standard

FCC R&D is now part of the CERN medium term plan and they have applied for EU Horizon 2020 funding to support some of the R&D. More than 25 institutions have signed MOU's to carry out different parts of the needed R&D. The FCC could be initially an ~ 300 GeV e+e- collider or an ~ 100 TeV pp collider with a circumference between 80 and 100 km and would use the present accelerators at CERN as part of the injector complex.

Further Future Collider Possibilities

The high energy physics community in China is pressing forward with a proposal for a 50 to 80 km ring. It would first be a ~ 200 GeV e+e- collider with a proposed construction start in early 2020's followed by a pp collider in the mid 2030's.

In addition, there is a 150 MEuro EU initiative spread over ten years in laser plasma acceleration with a focus on developing compact synchrotron radiation sources based on FELs.

Challenges

- Limited funding for the GARD program
- Time scales for the possible construction starts for the next generation of accelerator facilities are long
- Next generation of either multi-MW proton sources, 100 TeV pp colliders, 1 TeV e+e- colliders, and $\geq$ 3 TeV lepton colliders are complex machines
- The current sketch designs for these accelerators have a broad spectrum of maturity
- The very high stored energy of both the beams and the magnet systems of a 100 TeV pp collider provide interesting design challenges
- Intense synchrotron radiation from the beams in a 100 TeV pp collider presents very significant challenges for both the vacuum system design and the needed cryogenic cooling capacity
- The applicability of the advanced acceleration technologies to HEP colliders is at an early stage of understanding
- The cost of using known technologies for these machines is very high
- A key driver for the GARD program is to understand and develop strategies to significantly reduce the costs of construction and operation for future facilities

Further Challenges

The Accelerator R&D Subpanel is not a project review panel. Our task is to recommend a balanced program in accelerator R&D to OHEP to provide the US with a world leading program in accelerator based particle physics. And, parenthetically developing a science and technology case for increased investment in accelerator R&D.

In the information gathering process the Subpanel was briefed on several initiatives totaling ~ 25 - 30 M$ per year including capital investment, operations, and experiments. One on-going program will stop at the end of FY16 unless a significant investment is made to reconfigure a portion of the SLAC linac due to the LCLS II construction project.

The current funding level (FY2015) for the entire GARD program is 71 M$.

During our information gathering process opportunities for support by the GARD program were presented that sum to ~ 100 M$ so there is a 30% or so problem. There may be additional ones. P5 had roughly a factor of 3 to 4 problem as they began their deliberations. The P5 report has been a great help in managing expectations.

A Few Observations

To make a contribution to future high energy pp colliders, the superconducting magnet program will need increased investment both in going to higher magnetic fields and in developing manufacturing techniques that significantly reduce the magnet assembly labor costs.

For the LCLS II cryomodules, the cost of Nb for the cavities is only 10% of the cost so improved manufacturing techniques have the largest potential for significantly reducing the cost of the completed cryomodules for a high energy SRF based collider.

Process

After the Road Trip the Subpanel merged the seven GARD thrust areas into the following five accelerator R&D areas for study to provide a better grouping of topics:

Accelerator physics and instrumentation:

Beam dynamics, simulation, computation, beam loss monitoring, etc

Advanced acceleration:

Normal conducting RF structures and sources
Dielectric wakefield accelerators
Beam driven plasma wakefield acceleration
Laser driven plasma wakefield acceleration
Direct laser acceleration
Fundamental aspects of muon acceleration
Issues with 100 TeV pp collider

Process

Particle Sources and Targets:

- High power beams, horns, targets, and collimators
- Beam dumps

Superconducting Magnets and Materials:

Superconducting RF:

Process

Each of the R&D areas has at least two Subpanel members assessing the information provided to the Subpanel and developing appropriate guidance and draft recommendations.

Good progress is being made by each of these subgroups who meet independently and preliminary draft reports have been written by each subgroup.

Discussion between the subgroups takes place during our weekly telecoms (twice weekly lately). These were key in preparation for our meeting on Nov. 6 and 7. At that meeting it was clear that we needed more information in the advanced acceleration trust area.

Prioritization

The original Subpanel goal of the meeting on December 3 and 4 this past week was to develop the final set of recommendations and comments that will form the draft report. It was to be presented Monday at the December HEPAP meeting. We failed to meet our goal but did make a serious start at setting up a process to prioritize the accelerator R&D programs as guidance to OHEP to manage the GARD program.

A matrix approach was proposed as a mechanism to prioritize the needed accelerator R&D and the following slides are the first pass at this.

This will then guide the level of support to be recommended for each GARD area while satisfying the budget boundary conditions. This will be the biggest challenge (and will cause the most pain).

Physics Drivers vs. Needed Accelerators

Needed Accelerators	ILC	e+e- 1 TeV collider	3 TeV lepton collider	Multi-MW Proton Source/Neutrino Factory	100 TeV pp collider
Higgs as a new tool					
Neutrino mass					
Unknown particles and interactions					
Dark matter					

Needed Accelerators vs. Accelerator R&D Area

Accelerator R&D areas	Advanced Acceleraton	Accelerator Physics & Instrumentation	Particle Sources & Targets	Superconducting Magnets & Materials	Superconducting RF
ILC					
e+e- 1 TeV collider					
3 TeV lepton collider					
Multi-MW Proton Source/Neutrino Factory					
100 TeV pp collider					

Accelerator Technical Drivers vs. Accelerator R&D Area

Accelerator R&D Areas	Advanced Acceleraton	Accelerator Physics & Instrumentation	Particle Sources & Targets	Superconducting Magnets & Materials	Superconducting RF
Next Steps					
Beam intensity for neutrino program					
Targetry for neutrino program					
Energy Efficiency					
Improved accelerating gradient and Qo for high average power					
Optimized design for 1 TeV linear collider					
Affordable construction costs for a 100 TeV pp collider					
High reliability in complex accelerators					
Long Term					
Low cost construction per constituent TeV					
Energy efficiency					

Accelerator R&D vs. Other Responsibilities

Accelerator R&D Areas	Advanced Acceleraton	Accelerator Physics & Instrumentation	Particle Sources & Targets	Superconducting Magnets & Materials	Superconducting RF
Fundamental Accelerator Science					
Training of Accelerator Scientists and Engineers					
Accelerator R&D stewardship					

Results of the discussions last week

Five possible new accelerator facilities were the focus of our discussions:

- 100 TeV pp collider
- 1 TeV e+e- collider
- Multi-MW proton source

and at a later stage:

- Neutrino factory
- $\geq$ 3 TeV lepton collider

Results of the discussions last week

- More specific information was requested prior to the meeting from both of the plasma wakefield acceleration groups along with the DLA developers and the muon collider proponents with a deadline of Dec. 1.
- One item of note from this query was the lowering of the proposed accelerating gradient for the plasma wakefield approach to ~ 1 GeV/m.
- After analyzing the answers provided by the groups, the subcommittee focusing on advanced acceleration techniques found that more information will be needed, especially with respect to the likely evolution of beam quality with further R&D.

Steps to the Final Report

- Continue to assess the information provided by the next round of requests to the advanced acceleration community.
- Continue revising the draft report sections for each of the GARD thrust areas.
- Meet again in January which may include a session where advanced accelerator proponents are invited to answer appropriate questions.
- At that meeting agree on the final set of recommendations
- Transform the final draft sections into a final report via our protected website and teleconferences during late January and February.
- Finish the final draft report by mid to late March.
- Present the final draft report to HEPAP at its early April meeting.

Conclusions

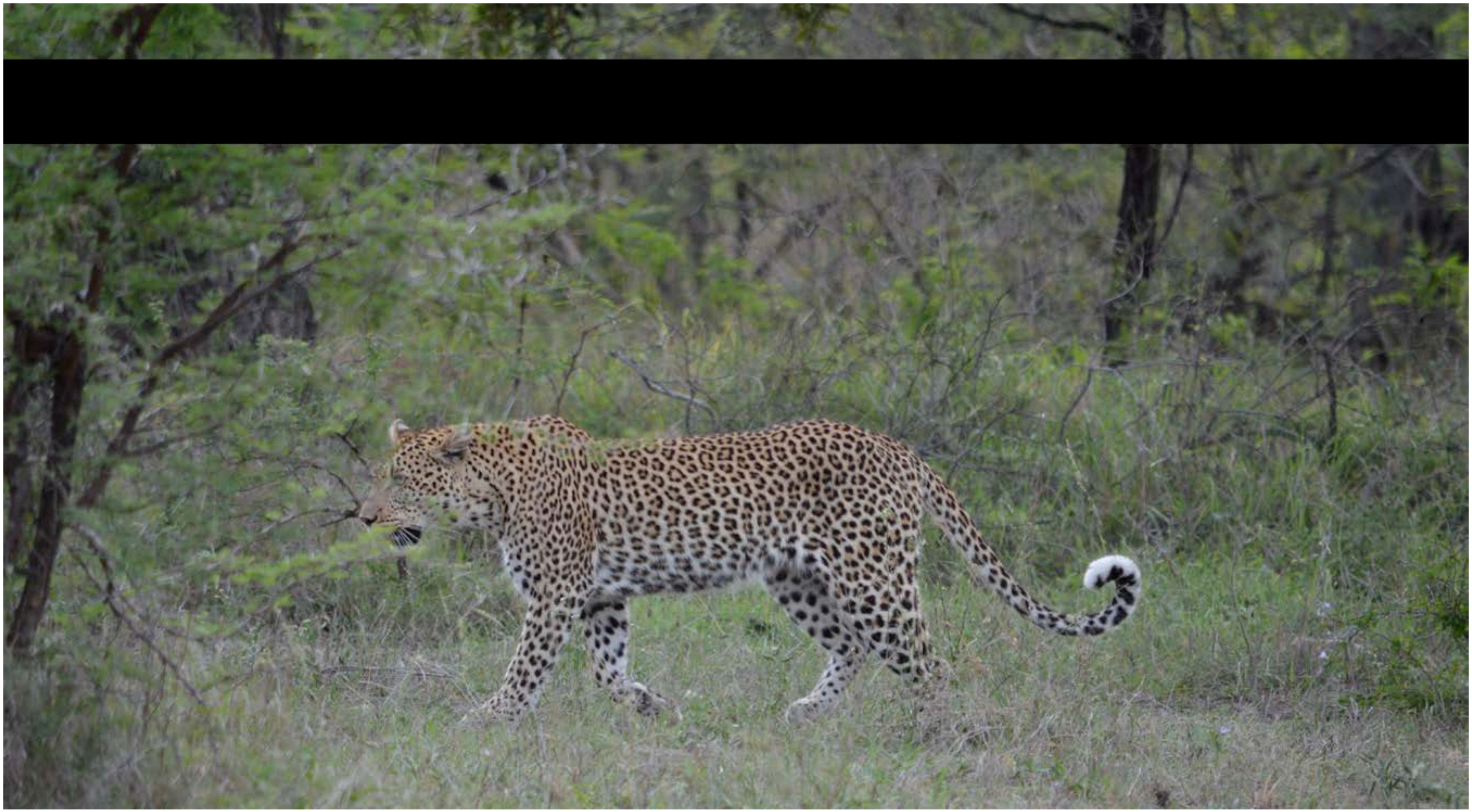
A healthy program in accelerator R&D is key to ensuring that the US accelerator based high energy particle physics program is world leading.

Training of the next generation of accelerator scientists and technologists is a very important element of the GARD R&D program. See the HEPAP Subcommittee on Workforce Development report published this past spring.

Need to provide continued support for fundamental accelerator R&D that is not directed towards the possible projects presently under discussion. This has provided us with our current suite of accelerator capabilities.

Our hope is that our report will provide useful guidance to DOE OHEP in charting the future of accelerator R&D in the US.

Help After the Report Submission



Further Help After the Report Submission

Thank you