HEP Plans from the North American and HEPAP Perspectives

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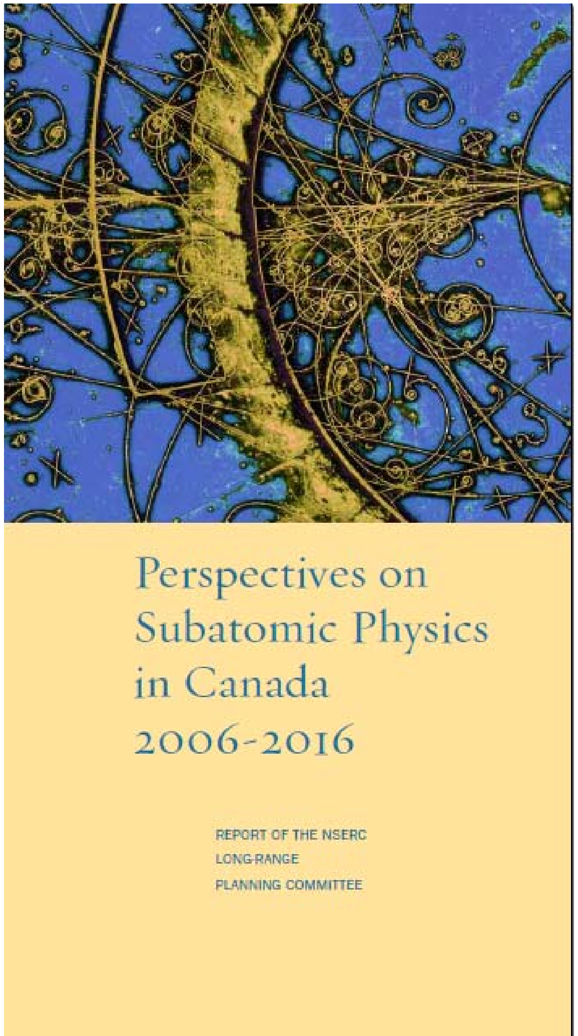
Canadian Subatomic Long Range Plan (2006-2016)



Long range plan set-out five, unranked, scientific priorities

A Explore the energy frontier with ATLAS

I Exploitation of radioactive beams at ISAC/TRIUMF

S Complete SNOLAB and equip with first expts.

T Participate in T2K program and ND280 detector

F R&D for ILC with construction with capital contribution foreseen in second half of decade

Current Status of Long Range Plan

A Detector contributions complete, recent contribution to high level trigger computing;
40 faculty and 100 students/postdocs ready to analyse ATLAS data.

I TRIUMF five year plan (2010-2015) proposes SRF eLINAC to augment RIB production.

S SNOLAB complete, working to secure stable operating funding;
Picasso, SNO+ and DEAP moving into construction phase for first measurements.

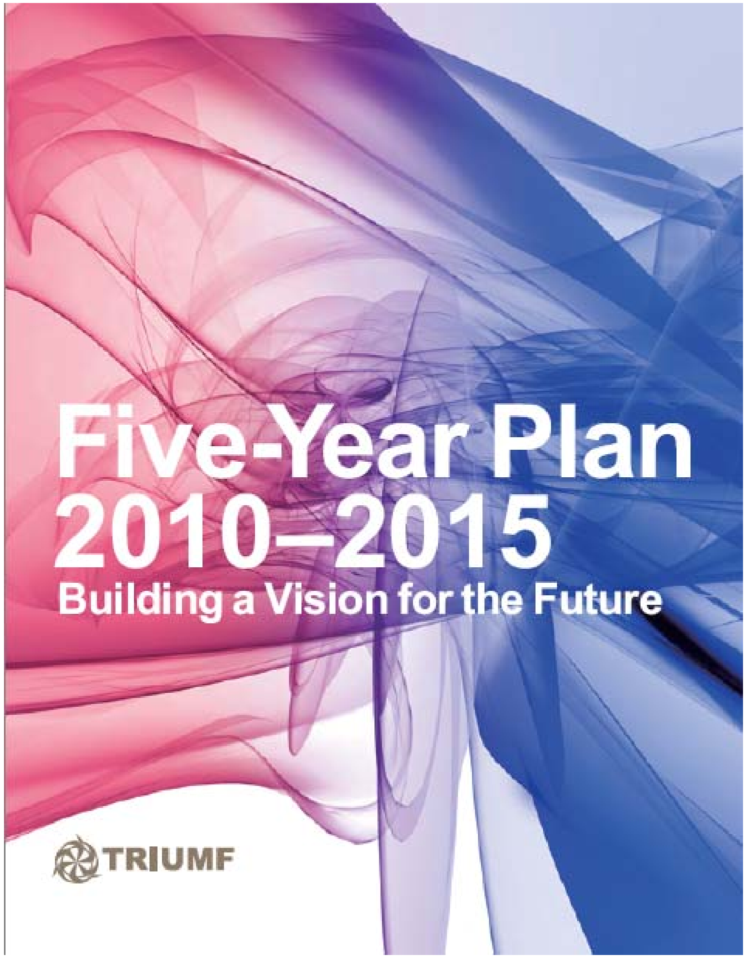
T Canadian contributions to ND280 detector being shipped to Japan this winter;
30 faculty, students and post-docs gearing up for first data.

F ILC detector R&D continues;
eLINAC project will develop Canadian supplier of SRF cavities.

- After an injection of federal infrastructure funding (SNOLAB + new faculty startup), traditional operating support has been stretched thin
- Continue to work to sell the importance of basic research and secure the operating funding necessary to sustain our projects

TRIUMF Five Year Plan

- TRIUMF receives funding for five year intervals
- Recently completed request for funding for the next five years
  - Add 1.3 GHz electron machine to augment RIB production capacity
  - Support for Tier1 centre including renewal of computing and storage
  - Possible accelerator contribution to either LHC injectors **or** ILC
- International peer review (chair: Heuer) carried out in September
- Next 18 months with government (next cycle begins April 1, 2010)



Context

- **HEPAP advises the US Department of Energy and National Science Foundation on the current and future program in elementary particle physics.**
- **9 months ago: HEPAP charged with producing a 10-year strategic plan through its P5 subpanel (chair: Charlie Baltay).**
- **Why a new study? (<2 years since previous P5; NAS EPP2010)**
  - **Washington fiscal outlook had changed (now 4 explicit scenarios).**
  - **ILC cost, when translated by Washington into US accounting system, was significantly higher than they had expected.**
- **The subpanel explicitly noted that the scientific priorities had not changed since the previous reports were written, rather the context for pursuing the scientific opportunities had changed.**
  - **Fiscal situation**
  - **2 of the 3 US HEP colliders (PEP-II, CESR) had ceased operation; the 3rd (Tevatron) would in a few years.**

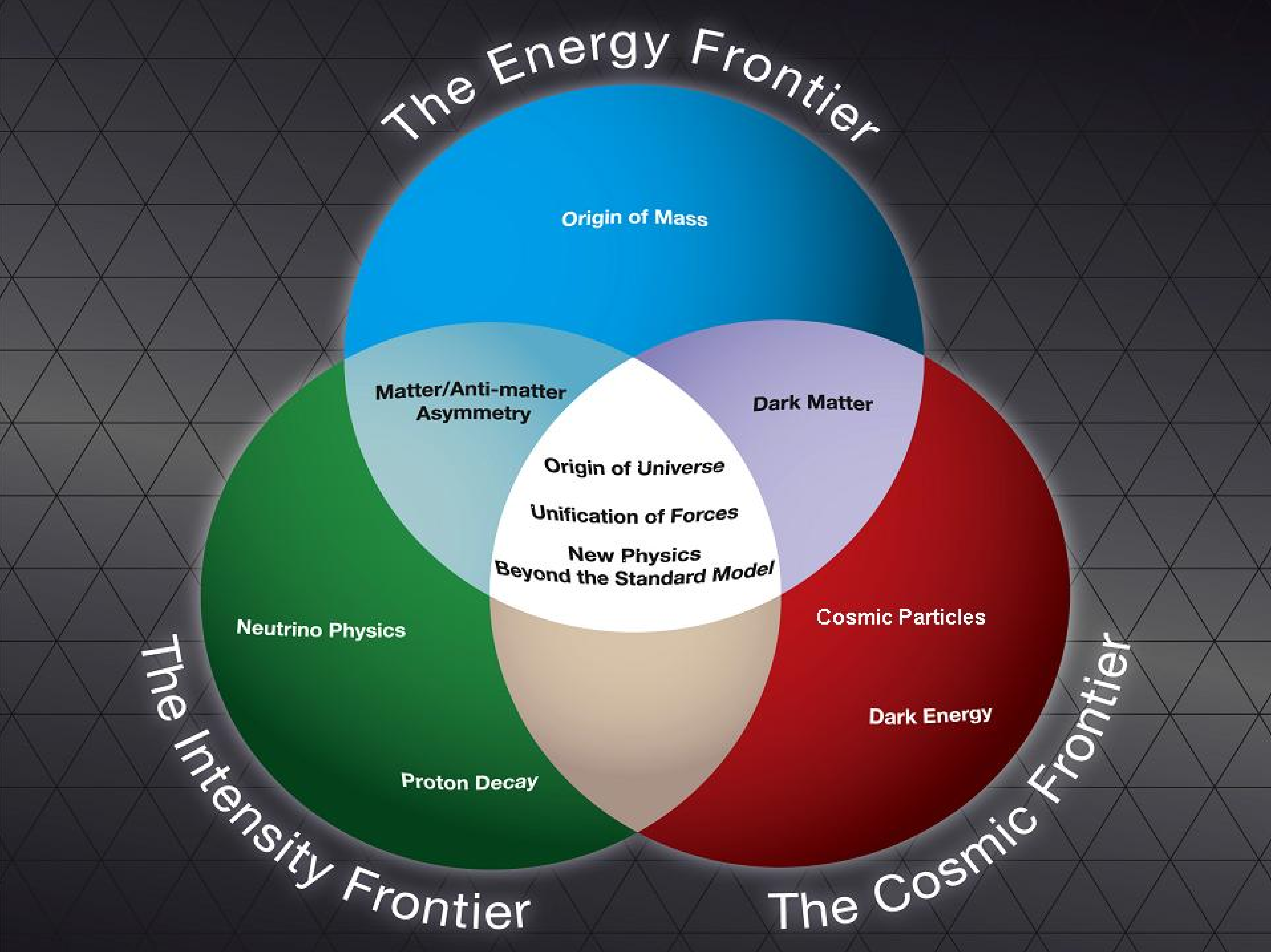
- **The analysis was to be carried out in the context of the international program being planned and carried out in Asia, Europe, and North America.**
  - **P5 had members from Europe (Fabiola Gianotti), Asia (Hiroaki Aihara)**
  - **Presentations were given by**
    - **Atsuto Suzuki on Asian plans**
    - **Rolf Heuer on European plans**

- **P5 noted that we are at an extraordinary time in the history of elementary particle physics:**
  - **Discovery of neutrino mass & mixing $\Rightarrow$ CP violation?**
  - **Discovery of the accelerating expansion of the universe $\Rightarrow$ dark energy?**
  - **Quantitative measure of the non-luminous, non-baryonic matter $\Rightarrow$ dark matter**
  - **Tevatron, LEP, SLD results $\Rightarrow$ new phenomena at the Terascale**
- **We expect fundamental new discoveries and insights in the coming decade addressing the central questions in the field.**

P5 Recommendations

To organize the recommendations for the field, the subpanel divided the field into 3 highly interrelated frontiers based on the experimental tools we utilize:

- **The Energy Frontier,** **using high-energy colliders to discover new particles and directly probe the architecture of the fundamental forces.**
- **The Intensity Frontier,** **using intense particle beams to uncover properties of neutrinos and observe rare processes that will tell us about new physics beyond the Standard Model.**
- **The Cosmic Frontier,** **using underground experiments and telescopes, both ground and space based, to reveal the natures of dark matter and dark energy and using high-energy particles from space to probe new phenomena.**


The Energy Frontier
Origin of Mass
Matter/Anti-matter Asymmetry
Dark Matter
Origin of Universe
Unification of Forces
New Physics Beyond the Standard Model
Neutrino Physics
Cosmic Particles
Dark Energy
Proton Decay
The Intensity Frontier
The Cosmic Frontier

Current Program (incomplete)

- **Energy Frontier** (data taking/analysis, (pre)construction, R&D)
  - **Tevatron: CDF, D0**
  - **LHC: ATLAS, CMS** (largest # of scientists from any 1 nation)
  - **R&D: ILC, muon collider, CLIC, advanced techniques**
- **Intensity Frontier**
  - **ν's: MINOS, MiniBooNE, SciBooNE, NOvA, MINERvA, T2K, very large detector, Double Chooz, Daya Bay, EXO, …**
  - ***b*, *c*: BaBar, BELLE, CLEO, LHCb**
- **Cosmic Frontier**
  - **Dark matter: CDMS, Xenon, COUPP, …**
  - **Dark energy: DES, JDEM, LSST**
  - **Particle astrophysics: GLAST, IceCube, Pierre Auger, …**

Program recommended by P5

(ignoring important subtleties of varying budget scenarios)

Overall Recommendation

- the U.S. maintain a leadership role in world-wide particle physics
- a strong, integrated research program at the three frontiers

The Energy Frontier

- **Tevatron Collider: CDF, D0**
  - **It has discovery potential until the LHC is running and ATLAS/CMS are producing physics.**
    - **Higgs**
    - **Beyond the Standard Model**
    - **Precision top quark and *W* properties**
    - ***b* hadrons: CP violation in B_s decay, new states, …**
  - **The subpanel recommended running for an additional 1-2 years.**

- **LHC**
  - **As the energy frontier machine for many years to come, the LHC has enormous discovery potential.**
    - **Electroweak symmetry breaking**
    - **SUSY**
    - **Dark matter**
    - **Extra dimensions**
    - **??**
  - **Achieving its full potential will require upgrading the accelerator and detectors.**
  - *** Significant U.S. participation in the full exploitation of the LHC has the highest priority in the U.S. particle physics program.**
  - **The subpanel recommended support for the U.S. LHC program, including U.S. involvement in the planned detector and accelerator upgrades.**

- **Lepton Colliders**
  - **The consensus remains that a high-energy lepton collider will be necessary to fully understand the new phenomena that in all likelihood will be discovered at the LHC.**
  - **In previous reports, it was argued that most likely a lepton collider center-of-mass energy of 500 GeV, upgradable to 1 TeV, would be sufficient to study the new phenomena. That argument still holds.**
  - **However, we are now within a few years of knowing what the required energy will be. The approval of a construction project will almost surely occur after that. Consequently it is prudent to have an R&D program with sufficient breadth to cover a range of collider energies.**
  - **The subpanel recommended that wherever the next lepton collider is located, with whatever technology is chosen, THE U.S. SHOULD PLAN TO PLAY A MAJOR ROLE.**

- **If the optimum initial energy proves to be at or below ~500 GeV, then the ILC is the most mature option with a construction start possible in the next decade.**
- **A requirement for initial energy much higher than 500 GeV will mean considering other collider technologies.**
- **For the next few years, until the required energy is known, the U.S. should continue to participate in the international ILC R&D program so that the U.S. could take an important role if the ILC is the choice of the international community.**
- **The subpanel recommended for the near future a broad lepton collider R&D program:**
  - **Continued R&D on the ILC at approximately the proposed FY09 level**
  - **R&D for alternative accelerator technologies**
  - **R&D for lepton collider detector technologies**

The Intensity Frontier

- **Accelerator-based neutrino program**
  - **Measurements of the mass & other properties of ν's are fundamental to understanding physics beyond the Standard Model and have profound consequences for understanding the evolution of the universe.**
    - **Fermilab has unique capabilities and infrastructure.**
    - **DUSEL, proposed for Homestake mine, could house a very large ν detector**
    - **A multi-megawatt beam & 1300 km baseline would provide excellent sensitivity to the ν-mass hierarchy and CP violation.**
    - **The long baseline provides complementarity to the ν programs elsewhere. This may be essential for resolving the ambiguities in determining the important ν-sector parameters.**
  - **The subpanel recommended a world-class neutrino program as a core component of the U.S. program, with a long-term vision of a large detector in DUSEL and a high-intensity neutrino source at Fermilab.**
  - **Note: The high-intensity proton source could be a stepping stone toward a neutrino factory based on a muon storage ring & a muon collider.**

- **The ν plan:**
  - **MINOS (now)**
  - **NOvA (start operation ~2013); upgrade proton source to 700 kW (x2)**
  - **Large detector R&D – liquid argon and water Cherenkov**
  - **Build large detector & new proton source (design decision ~2012)**

- **Non-accelerator ν experiments**
  - **The subpanel recommended support of reactor experiments to measure θ_{13}, important for designing a high sensitivity accelerator ν experiment to probe CP violation.**
    - **Daya Bay**
    - **Double Chooz**
  - **The subpanel recommended support of neutrinoless double-beta decay experiments. They have the capability of discovering a Majorana nature of ν's – a fermion that is its own antiparticle.**
    - **Measure absolute ν mass**
    - **CP violation (leptogenesis)**
    - **Physics at extremely large energy**

- **High sensitivity non-ν experiments**
  - **Energies at and significantly beyond the Terascale can be indirectly probed by high sensitivity studies of charged leptons and mesons containing heavy quarks.**
  - **Accelerator advances in producing very intense beams make such experiments especially timely.**
  - **The subpanel recommended**
    - **a muon-to-electron conversion experiment at Fermilab**

    and depending on the size of the U.S. HEP budget
    - **significant participation in one overseas next-generation *B* factory**
    - **a program of rare *K* decay experiments at Fermilab.**
  - **The subpanel also noted that, if the U.S. participates in an overseas *g*-2 experiment, the Brookhaven muon storage ring could be a considerable in-kind contribution.**

The Cosmic Frontier

- **~95% of the universe appears to consist of dark matter & dark energy, yet we know little about them.**
- **The quest to illuminate their nature is at the heart of particle physics – the study of the basic constituents of nature, their properties and interactions.**
- **The U.S. is currently a leader in the exploration of the Cosmic Frontier.**
- **There are compelling opportunities for dark matter search experiments, and for both ground-based and space-based dark energy investigations.**
- **The subpanel recommended support for the study of dark matter & dark energy as an integral part of the U.S. particle physics program.**

- **Searching for Dark Matter**
  - **The ideal outcome if dark matter is a WIMP:**
    - **Direct observation of cosmic dark matter particles in a detector**
    - **Production of dark matter particles at the LHC & a lepton collider; determine its properties**
    - **Observe dark matter annihilation in the cosmos**
  - **The first is a technological challenge given the range of predicted interaction cross sections. R&D on cryogenic solid, liquid, and gaseous detectors is needed to understand which will be scalable to very large detectors in a cost-effective way.**
  - **The subpanel recommended that NSF & DOE jointly support direct dark matter experiments. The choice of which experiments to support in the longer term should be made after completion of the ongoing experiments and the R&D on the next generation of detectors.**

- **The nature of Dark Energy**
  - **The discovery a decade ago that the expansion of the universe is accelerating has two explanations:**
    - **75% of the universe is a mysterious “dark energy”**
    - **The theory of gravity is incomplete & must be revised**
  - **More experimental data is needed.**
  - **The subpanel recommended:**
    - **Mid-size experiments**
      - **Dark Energy Survey**
      - **Consideration of other selected ground-based experiments**
    - **Large-scale experiments**
      - **Space: Joint Dark Energy Mission (JDEM)**
      - **Ground: Large Synoptic Survey Telescope (LSST)**

- **High energy particles from space**

  (ultra-high energy cosmic rays, gamma rays, & neutrinos)

  - **at the boundary between particle physics & astrophysics**
  - **a vibrant, rapidly developing area of science**
  - **The subpanel recommended**
    - **limited R&D funding for new projects**
    - **Large construction projects would be possible under the higher budget scenarios.**

- **Advanced accelerator & detector R&D**
  - **A broad program of accelerator R&D and detector R&D was recommended.**
  - **These are critical for the U.S. to**
    - **Maintain a leadership position in particle physics**
    - **Allow the possibility of hosting a future energy-frontier accelerator**
    - **Develop applications that broadly benefit society**

Summary

- **HEPAP stressed to the U.S. funding agencies the extraordinary scientific opportunities in elementary particle physics.**
- **The U.S. should continue to be one of the leaders in the field.**
- **Toward that end, HEPAP proposed a program that, in collaboration with its international partners, would lead to major advances at all of the major frontiers of the field.**
- **(The extent of the program will of course depend on the funding level!)**