The Future of Accelerator Physics

Presented

to

The COOL05 Workshop

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September 19, 2005

Acknowledgements

The following persons provided significant input to this talk!

W. A. Barletta, LBNL
Ilan Ben-Zvi, BNL
John Cary, U. of Colorado
Jean Delayen, TJNAF
Alex Dragt, U. of Maryland
Persis Drell, SLAC
Steve Gourlay, LBNL
Jay Hirshfield, Yale/Omega-P
Chan Joshi, UCLA
Tom Katsouleas, USC
David Larbalestier, U. of Wisconsin
Wim Leemans, LBNL
Hasan Padamsee, Cornell U.
Bob Siemann, SLAC
Sami Tantawi, SLAC
Rick Temkin, MIT
Maury Tigner, Cornell U.
Mike Zisman, LBNL

The Status of HEP Research:

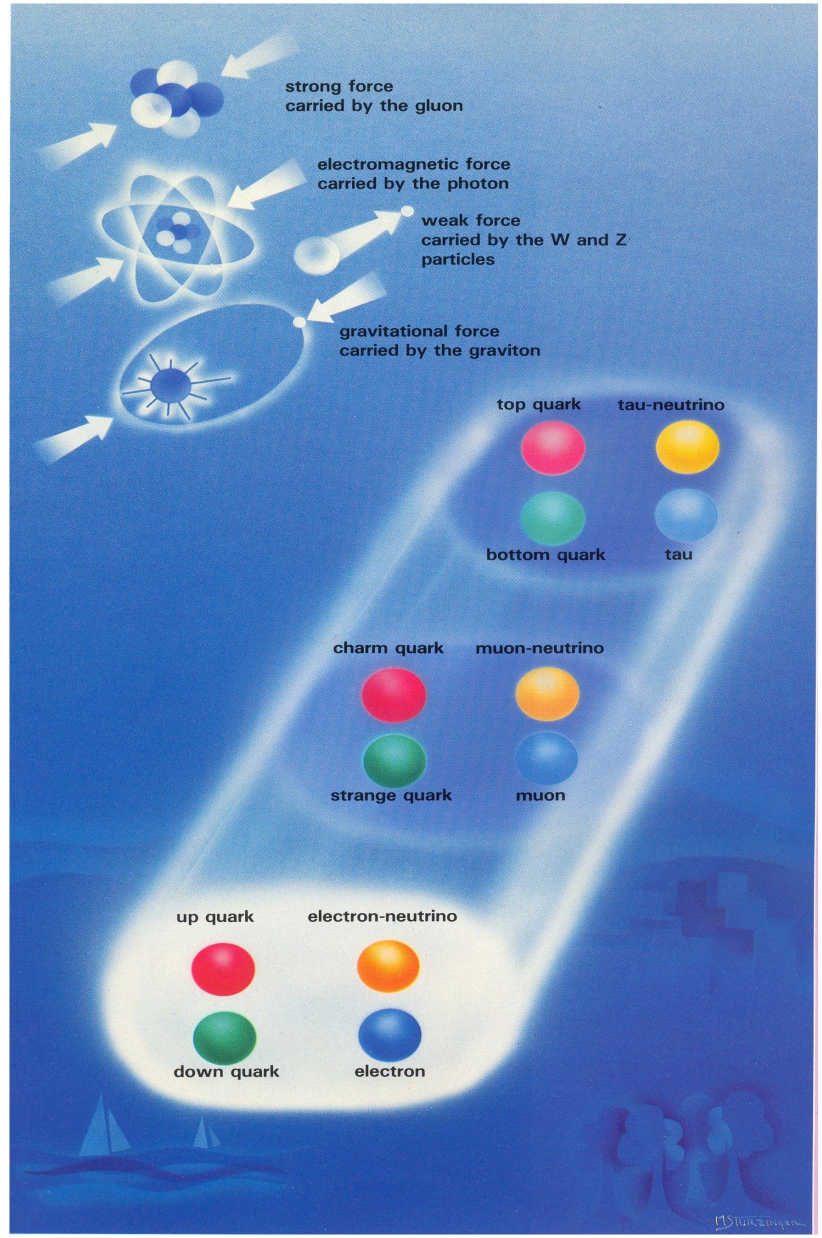
The Standard Model

This is pretty much the picture that we had in 1990!

And it still is, and we know it is not complete!

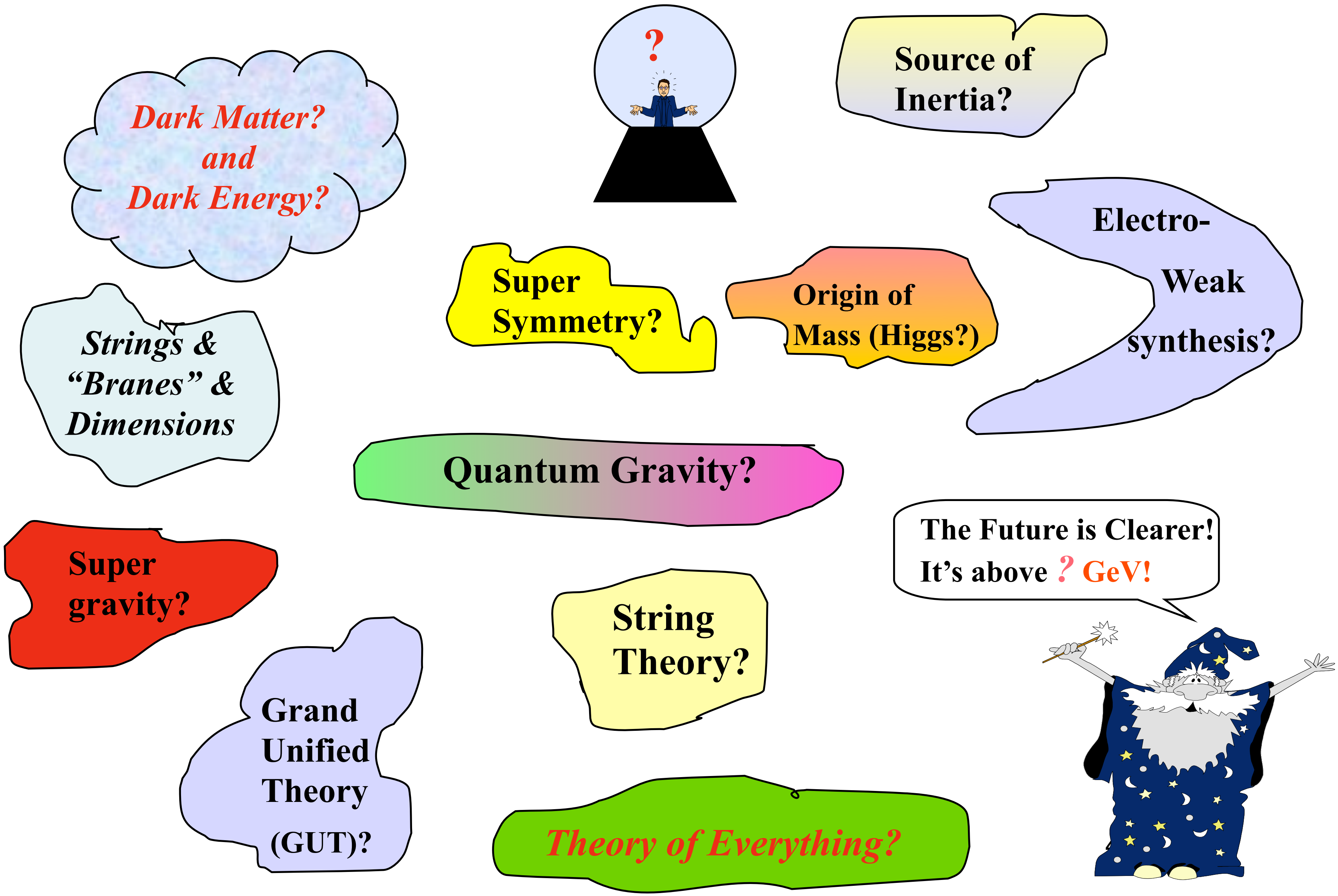
Data At Higher energy!

A quantum picture of the universe



"Back to the Cosmos," CERN Publications, July 1991

What are the Missing Pieces?



Facilities Available for HEP Research

Fermilab Tevatron	***Shut down in 2008 – 2010?***
Fermilab Neutrino Beam	***Upgrades? In - - - ?***
SLAC B-factory	***Shut down in 2008***
SLAC 50 GeV linac	***Off in 2006. LCLS { 10 GeV }, SABER @ 30 GeV > 2008?***
KEK B-factory	***Upgrade to Super B?***
RHIC	***Shut down or continue? { NSAC Study! }***
LHC	***First operation in 2007 – 2008***

Where Next? – What are the Real Physics Needs?

Proposed but Not Approved

The realm of Near Term and Some Mid Term R&D

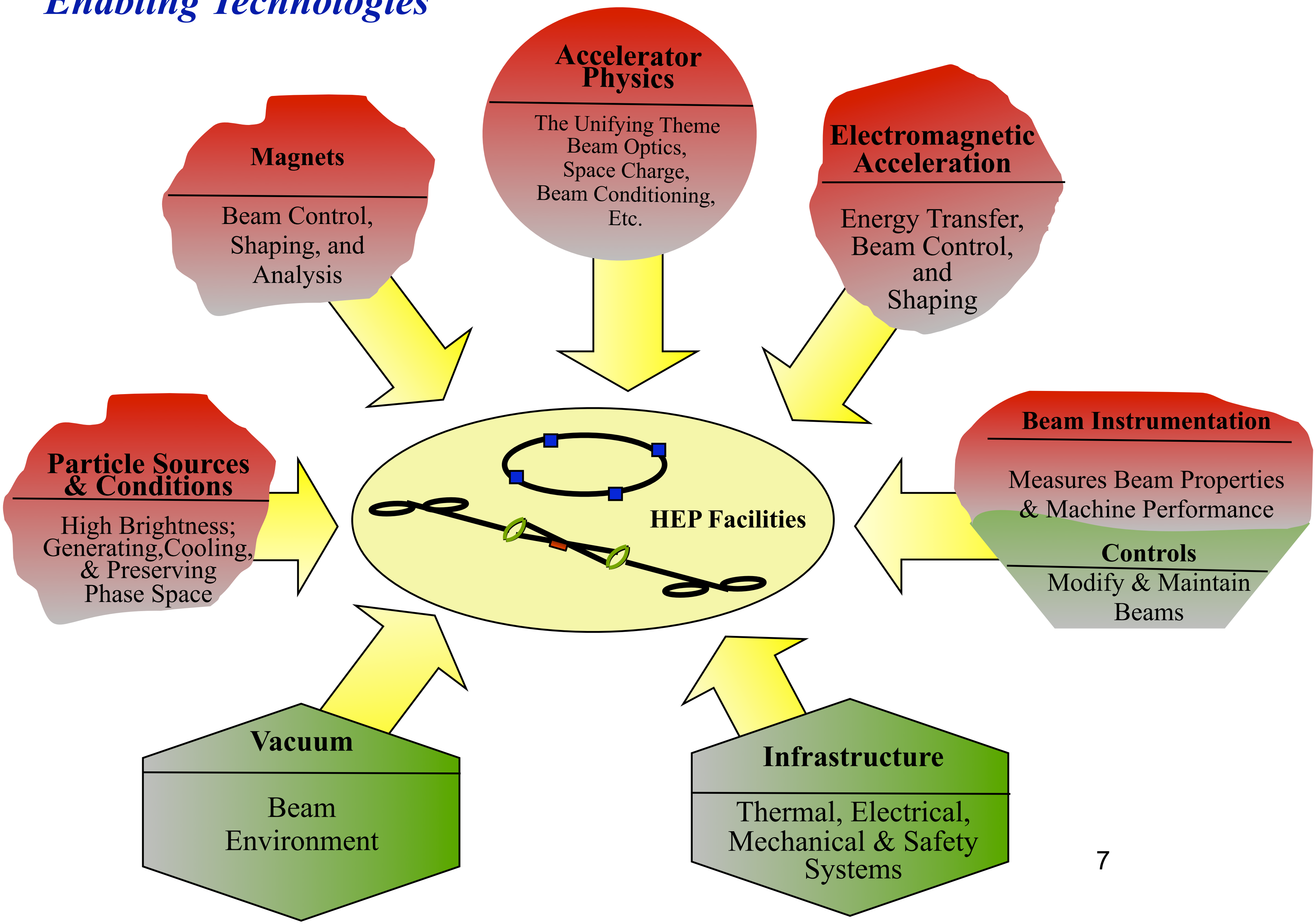
Facility	***Status***	***Issues***
ILC @ .5 to 1 TeV	*R&D – GDE In place.*	*Location! Politics!*
Super ν Beams @ Fermi	*R&D – Hope!*	*Funding, Timing & the ILC*
CLIC @ 2 t0 4 TeV	*R&D – A Prayer*	*The ILC, Energy needs of HEP*
Japanese Super ν	*Unclear*	*ILC in Japan?*

Wish You Were Here!

The realm of Advanced & Some Mid Term R&D

Facility	***Status***	***Issues***
Muon Storage Ring et al	*R&D - Targets & Cooling*	*Funding & HEP priority*
LHC Upgrades – L and E	*R&D – LARP (In U.S.)*	*Priority versus LHC Start*
Linear Collider @ >100MeV/m	*U.S. High Gradient R&D*	*Funding & HEP priority*
VLHC	*No Activity*	*LHC & ILC in U.S.*
"Other" Facilities	*No Activity*	*Unidentified Physics needs!*

Enabling Technologies



Advanced R&D – To give Access to New Research Ability

The Principal Thrusts:

- ***Plasma Accelerators – Particle and laser driven***
- ***Very high gradient structures – for warm and cold radio frequency systems***
- ***Beam Cooling – beyond stochastic and radiation means***
- ***Space charge dominated Beams – There is life after $\Delta\nu < 1/4$!***
- ***Super conducting Magnets – The future is A15 & other compounds {Nb_3Sn, MgB_2}***
- ***Accelerator Theory – Advanced simulation & the merging of particle & plasma physics***

The above areas of R&D are by no means the only ones supported by the DOE And NSF. They are the principal ones addressing new approaches to facilities.

Plasma Based Acceleration - *A Rich & Active Field of R&D!*

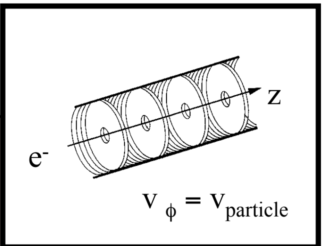
- *Particle Driven Plasma Wake field Accelerators*

- *The first demonstration, Simpson & Rosenzweig, ANL & U. of Wisc. – Mid 80's*
- *Doubling the energy of an electron beam via beam driven plasma wake fields*
  - *Experiments E - 157 thru E - 167 at SLAC FFTB*
  - *Verified Gradient variation with $1/\sigma_z$*
  - *Gradients > 40 GeV/m over 10 to 30 cm!*
  - *Energy gain greater than 4 GeV in a 10 cm plasma, E-164*
  - *Positrons accelerated*
  - *E-167 doing better!!!*
- *In 10 years – Full Demonstration of an Afterburner @ E > than 2X's drive beam's*

- *Laser Driven Plasma Wakefield Accelerators*

- *International R&D competition – gradients > 150 GeV/m over mm distances!*
- *In U.S. - LBNL Center for Beam physics !*
  - *1 GeV this year*
  - *Optical injection of electrons – control of bunch length & ΔE/E*
  - *Hi beam charge*
- *In 10 years – E_{beam} >10 GEV, Commercialization for MeV energies, short pulse*

Very High Gradient Acceleration – warm rf



The Box

- *WHY???*
  - *The machine beyond the ILC*
  - *What if no ILC? Be prepared!*
  - *What if the LHC early physics shows that the energy regime of interest is > 2 TeV?*
- *Very high gradient warm structures*
  - *A major issue is material properties under high voltage breakdown*
    - *Breakdown does not scale with 1/frequency as supposed – pulse length*
    - *Surface heating due to short, high peak power pulses*
    - *What is the surface physics of very high voltage breakdown*
  - *Geometry is a factor*
    - *Iris loaded structures (NLC) –the box!*
    - *Look at other structures – photonic band gap, dielectric loaded, ???*
    - *Think out of the box!!!!*
- *The DOE Office of Science has directed that a U.S. High Gradient R&D collaboration be formed to address these issues as they apply to CLIC and beyond. This collaboration is in the process of forming.*

Very High Gradient Acceleration – Cold rf

- ***The technology of choice for the ILC and many other applications***

- ***Materials issues***
  - ***Surface physics of breakdown – some similarities to warm rf***
  - ***rf superconductivity occurs in a surface layer < a classic skin depth***
  - ***All of the physics is not understood***
  - ***The best present rf superconductor is pure Nb – a low $H_{c\,2}$ superconductor***
  - ***The maximum achievable electric field gradient appears < ~ 54 MeV/m***
    - o ***The associated magnetic field (Mr. Maxwell!) quenches the Nb!***
    - o ***There is a geometry dependence – for limited reduction of the B field***
  - ***Is there a superconductor that operates at gradients 100Mev/m?***
    - o ***Other type two superconductor materials – A-15's, MB_2, other?***
    - o ***How does the physics of $H_{c\,1}$ & $H_{c\,2}$ effect the superconducting properties?***

- ***Other R&D issues***
  - ***Are there other geometries than the current roman arch? – along range box***
  - **Cost reduction!!!!!!**
  - **If the best rf superconductor is NB, how does one beat the cost problem of going to > 2 TeV?**

Cool Beams - The Cooling There of

- *Not a new field*

  - *Radiation cooling - in electron storage rings*
  - *Stochastic cooling – in anti proton sources*
  - *Low energy electron cooling*
  - *Laser cooling – in "crystal" beam R&D*

- *About to demonstrate hi energy electron cooling at Fermilab!!!*

- *Ionization cooling*

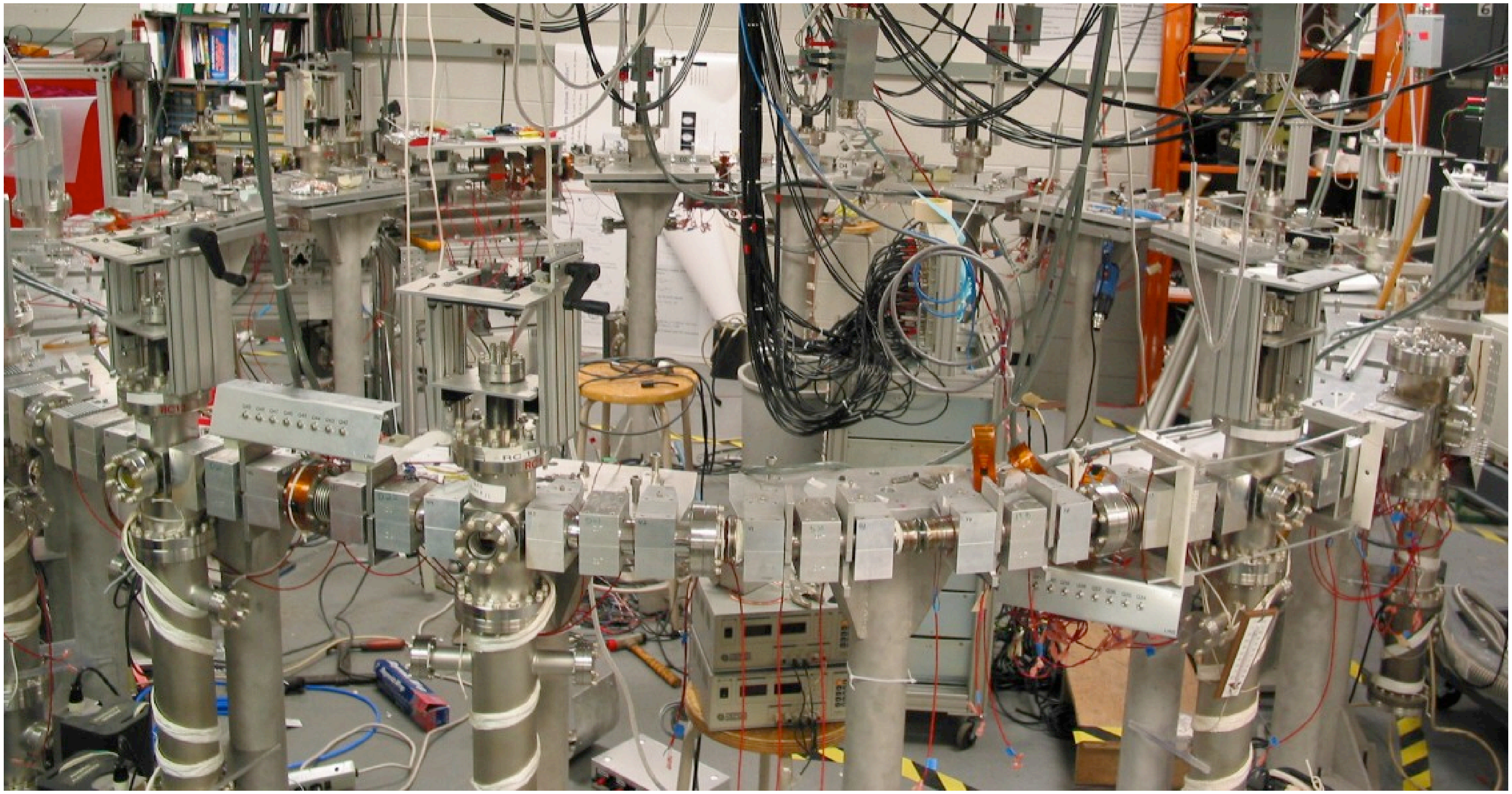
  - *Essential for future muon storage rings and colliders – and other?*
  - *Theoretically looks feasible*
  - *M ICE must be funded!!!!*

- *Have a great Workshop!*

Space Charge Dominated Beams

- *Why of interest to High Energy Physics?*
  - *Impacts ILC damping rings and muon collider front ends*
  - *Could be applied to proton & antiproton storage rings*
- *Current HEP storage ring design practice*
  - *Limit the tune shift, $\Delta\nu$, due to space charge to < ¼*
  - *Maschke demonstrated in the late 70's in the AGS at BNL that $\Delta\nu > 1$ as an experiment in support of accumulator ring design for HIF (Not published)*
- *Current research*
  - *Heavy ion fusion research*
  - *UMER 10 keV storage ring at U. of Maryland – a low energy analog for much higher energy rings*
- *R&D Issues*
  - *Beam instability control*
  - *Better simulation codes*
  - *More experiments*

The U. of Md. UMER Ring – 10 keV e^- @ 100 mA



Superconducting Magnets – ***Still an Essential Technology!***

- ***Requirements in the LHC and other small scale future applications in HEP facilities require that the A-15 and other very high $H_{c\,2}$ compounds be mastered***

- ***The core issue remains –*** **Materials, Materials, Materials**
  - ***Industrial R&D –*** **the manufacturers must do the R&D!!!**
  - ***Development of inexpensive Powder in Tube (PIT) processes***
  - ***The goal –*** **By the Ton!!!**

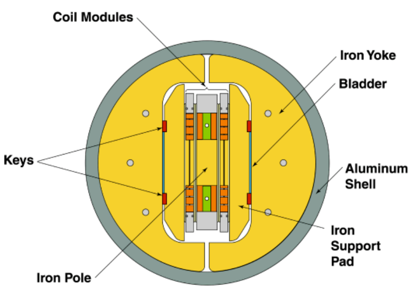
- ***Structures***
  - ***The new materials are Ceramics -*** **brittle! -** ***No Shear, no Tension!!***
  - ***For these materials, the cosine nΘ geometry sucks!***
  - ***Issues: shear, force confinement, end control, and preloading of coils***

Status
  - ***LBNL has built and tested a 16 Tesla dipole to the short sample limit***
  - ***The next step – an 18 Tesla dipole with a 35 mm free bore***
  - ***Current Nb_3Sn performance: 3000 A/mm² @ 12 Tesla and 4.2 K***

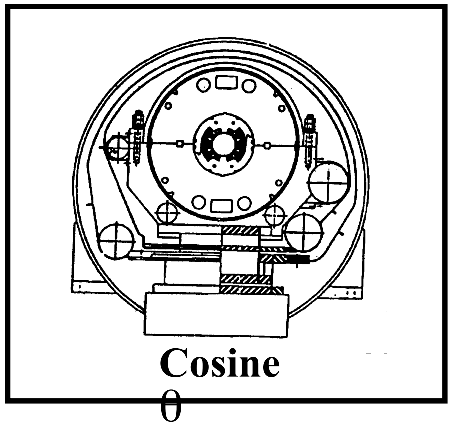
- ***Issues***
  - ***If the U.S. is to play a key role in LHC upgrades, our mastery of the new materials is critical***
  - ***Creativity –*** **Think out of the box!!!!!**

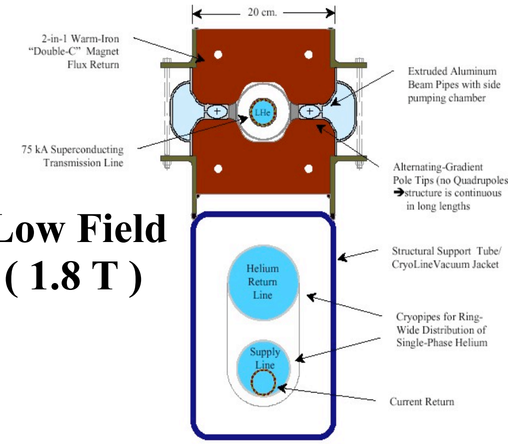
Advanced S. C. Magnets – Thinking Outside the Box

LBNL Magnet



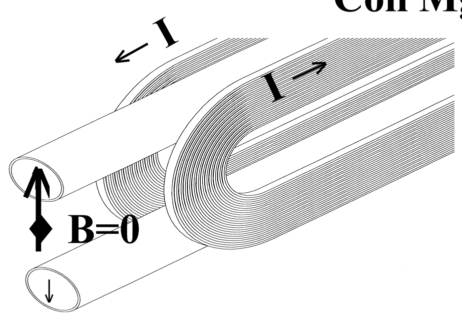
The Box



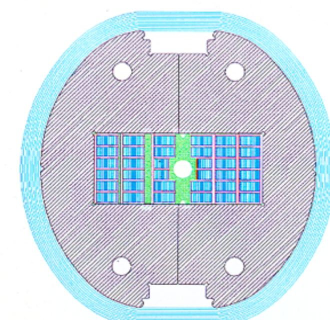


VLHC Low Field option (1.8 T)

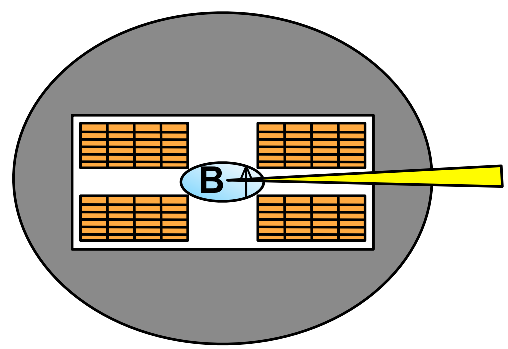
Gupta Common Coil Mgt



The Texas A&M Magnet

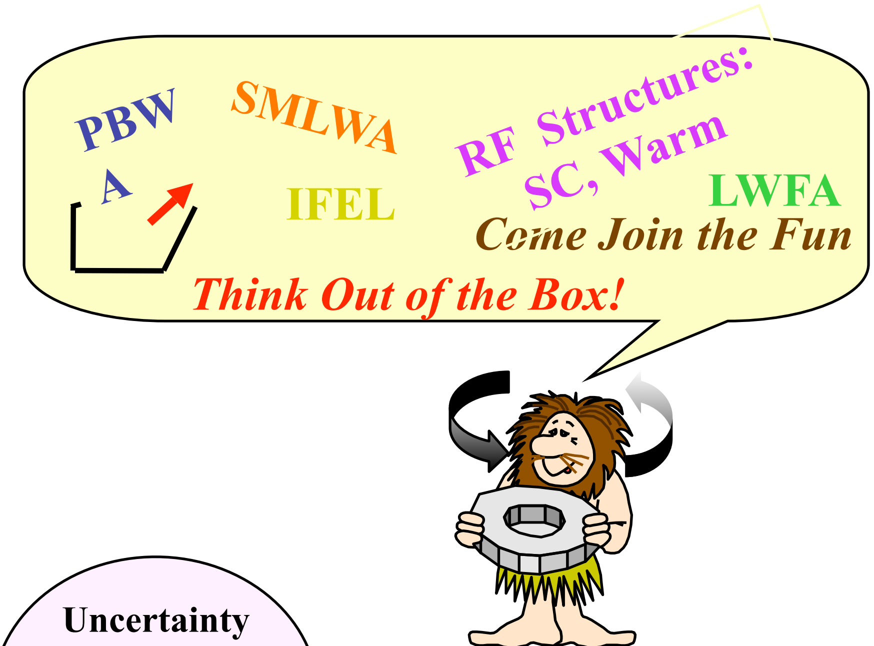


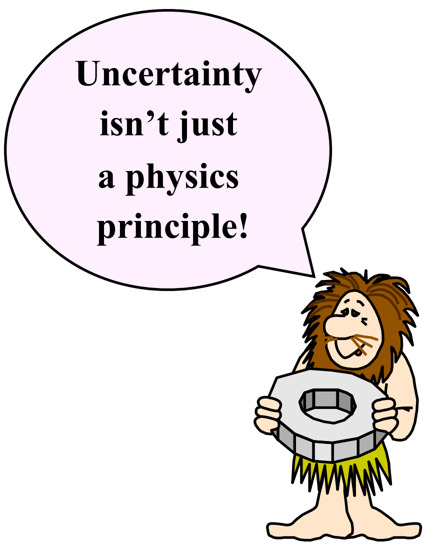
Block-coil NbTi single dipole, using same elements as Nb_3Sn dual dipole.



BNL split coil magnet

There is a lot of R&D in our Future!





We start the ILC when?