VIII. SUMMARY SESSION

R. Palmer, Chair

VIII. SUMMARY SESSION, *R. Palmer* (BNL), Chair

Muon Collider Research and Development Plan - *J. Wurtele* (UC Berkeley/LBNL)
Technology R&D and Future High Energy Physics Facilities - *D. Sutter* (DOE)
Physics with $\mu^+\mu^-$ Colliders: A Perspective - *W. Marciano* (BNL)
Announcement: 5th International $\mu^+\mu^-$ Collider Conference (Dec. 1999)

Muon Collider Research and Development Plan

Jonathan S. Wurtele
UC Berkeley/LBNL
August 13, 1997

Ongoing R&D

- Feasibility study presented at Snowmass96
  - » Catalyst for present collaboration (formalized in June)
  - » Identified critical research topics
- FY97 series of topical workshops on these areas, International Workshop in May
- Initial experimental work:
  - » Proton driver (E932 at AGS, PSR Experiment)
  - » Capture and target (E910 at AGS)
  - » Cooling experiment planning (Geer Talk)
- Theoretical work now concentrated on low energy machine

Present Status

- Increased community interest in muon colliders
- Multilab and university collaboration has prioritized research plan
- Further progress needs
  - » more dedicated personnel for expanded theoretical studies
  - » experimental research funds

Theoretical Research

- Present level of effort: 21 FTEs (but 100 researchers!)
- Expanded level of effort: 48 FTEs
- Critical immediate need is dedicated personnel
- Goals:
  - » Theoretical studies of muon collider complex
  - » Develop simulations of muons in systems of the collider
  - » Identify and prioritize areas that require experimental research.
  - » Determine a single self-consistent set of parameters for the lower and higher energy colliders

Theoretical Research: Critical Problem Areas (I)

- Proton Driver:
  - Define parameters for the proton source,
  - Investigate beam stability and short bunch production
- Target:
  - Study target options
  - Benchmark codes --yield is (historically) difficult to predict.
- Capture and phase rotation systems:
  - develop particle transport code
- Cooling: Define and simulate a complete cooling scenario.

Theoretical Research: Critical Problem Areas (II)

- Acceleration:
  - Define a preferred acceleration scenario
  - Perform complete simulations including wakefields.
  - Design cavity for pulsed operation, high gradient, minimized HOM loads
  - Pulsed lattice studies
- Collider ring:
  - continue lattice design including lattice errors, higher order multipole correctors
  - stability and impedance budgets
  - rf system for BNS damping of transverse instabilities
  - beam-beam integration with nonlinear tracking and wake codes
  - design a halo scraping system

Theoretical Research: Critical Problem Areas (III)

- Detector and background:
  - » optimization of the shielding
  - » straw man detector with all components capable
  - » of withstanding the backgrounds,
  - » simulate some representative physics observations.
- General:
  - » Investigate the operation with polarized and/or very low energy spread bunches.
  - » Investigate muon-electron collider
  - » Begin design work towards integrated front end of complex.
  - » Study safety and radiation exposures both on and off site, including the hazards from neutrino fluxes.
  - » Site power budget

Proton Driver Experiment: Short bunch production at the AGS

The proton driver technology is an extrapolation of that needed for spallation neutron sources. Major difference: muon collider requires a short bunch (~1-2ns). This leads to stability concerns.

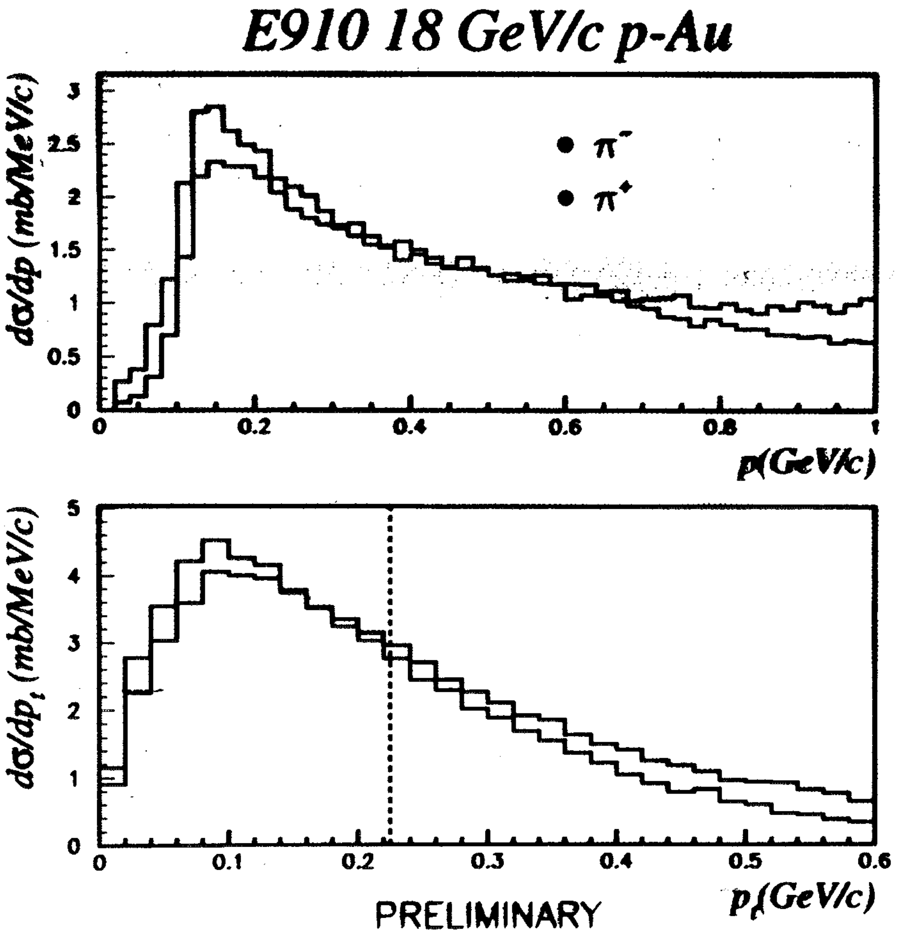
- Initial experiment at E932 at AGS has demonstrated a reduction of bunch length (10ns-->3ns) by operating near transition. Future plan calls for systematic studies at higher currents and shorter bunch length.
- Experiment operated with a longitudinal phase space volume of 1.5V-s, comparable to proton driver requirements; the total charge was lower than needed by a factor of 10.

Proton Driver Experiment: Test of inductive inserts at the PSR

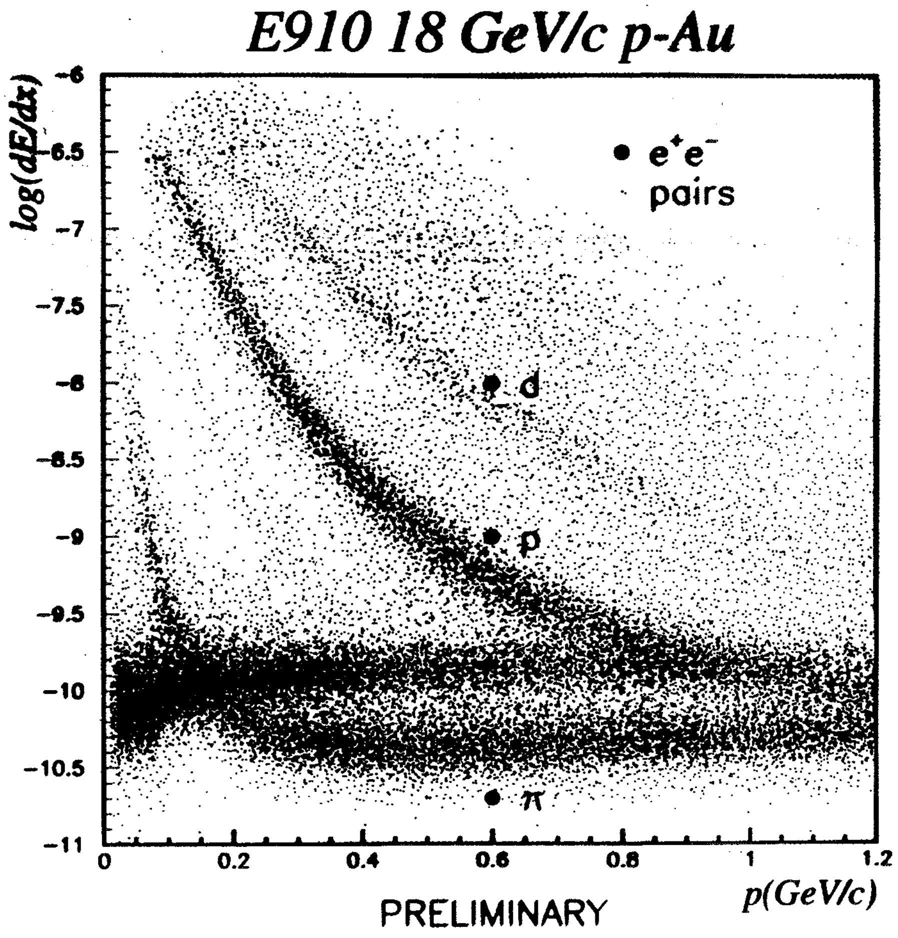
- Results from PSR at LANL show that longitudinal space charge was modified and RF thresholds were lowered.
- With $3\text{x}10^{13}$ ppp rf required to suppress instability was reduced by 40%.
- Similar results have been obtained at KEK

Target and Pion Capture

- Monte-Carlo model of pion production to be based on data from ongoing E910 at AGS on pion production
- Experimental plan:
  - Design and construct (or obtain) high field, large bore solenoid
  - Study target integrity with high-power beam. Thermal cooling may require liquid (jet) target.
  - Optimize target for π production
  - Measure π/p capture ratio in 20T field
  - Test rf cavity in high-radiation environment.

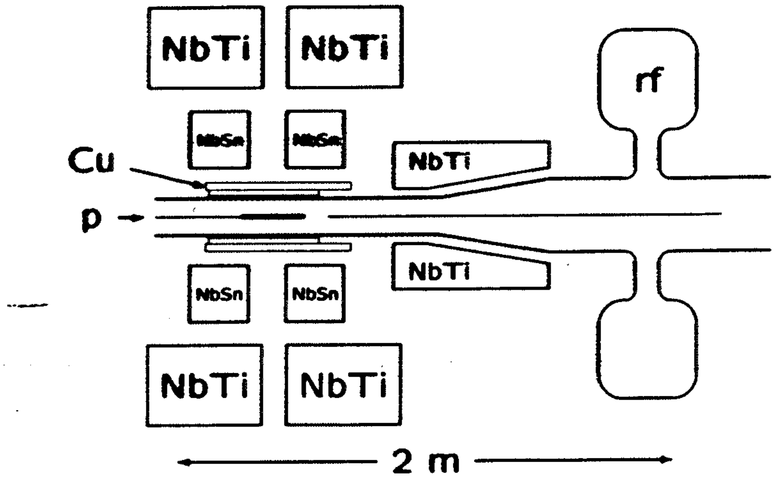

E910 18 GeV/c p-Au

PRELIMINARY


E910 18 GeV/c p-Au

PRELIMINARY

The Target and π Capture Experiment



Superconducting Mag Development

Design dominated by
- High radiation environment
- high fields
- low costs

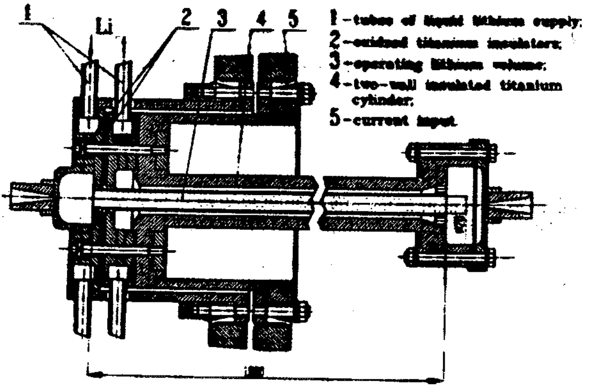
- *SC Dipole development--higher field increases lum*
- *SC IR quadrupoles are critical magnets at 4 TeV--*
  after IP & shielding increases distance to magnet

Lithium Lens R&D

- Build prototype long Li lens
- Bench test at high repetition rate
- Cooling test in beamline
- Add rf and second lens
- Develop higher gradient lens

μ - Cooling – Lithium Lens R&D

LITHIUM CURRENT CARRYING COOLING ROD



1 - tubes of liquid lithium supply;
2 - oxidized titanium insulators;
3 - operating lithium volume;
4 - two-wall insulated titanium cylinder;
5 - current input.

- build prototype long Liquid Li lens
  - bench test – test at high rep. rate
- cooling test – in beam line
  - add rf (100 MV), add second lens

- develop higher gradient lenses

μ-Cooling Li lens parameters

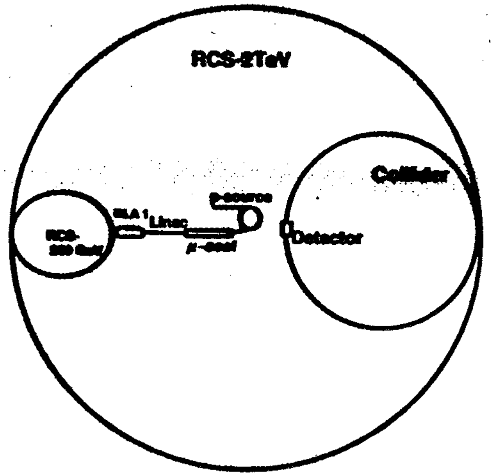
B(T)	B′ (T/m)	radius(cm)	Length(m)	I (MA)	τ(δ=0.7r)
10	1000	1	1	0.50	1ms
15	3000	0.5	1	0.375	250μs
20	8000	0.25	1	0.25	63μs
20	16000	0.125	1	0.125	15 μs
20	40000	0.05	1	0.050	2.2 μs

Acceleration R&D

- Rapid Cycling R&D
  - pulsed magnets prototypes --high field and eddy currents require innovative designs
  - pulsed lattice studies
- SRF R&D
  - Pulsed SRF operation tests (350MHz, 1300MHz)
  - HOM load--design to minimize loads and test HOM configurations and materials for pulsed SRF

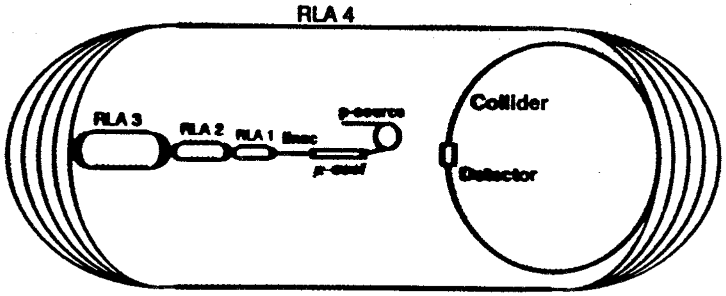
μ - Acceleration - Rapid-Cycling Synchrotrons

$\mu^+\mu^-$ Accelerator and Collider System-
Rapid-Cycling Scenario

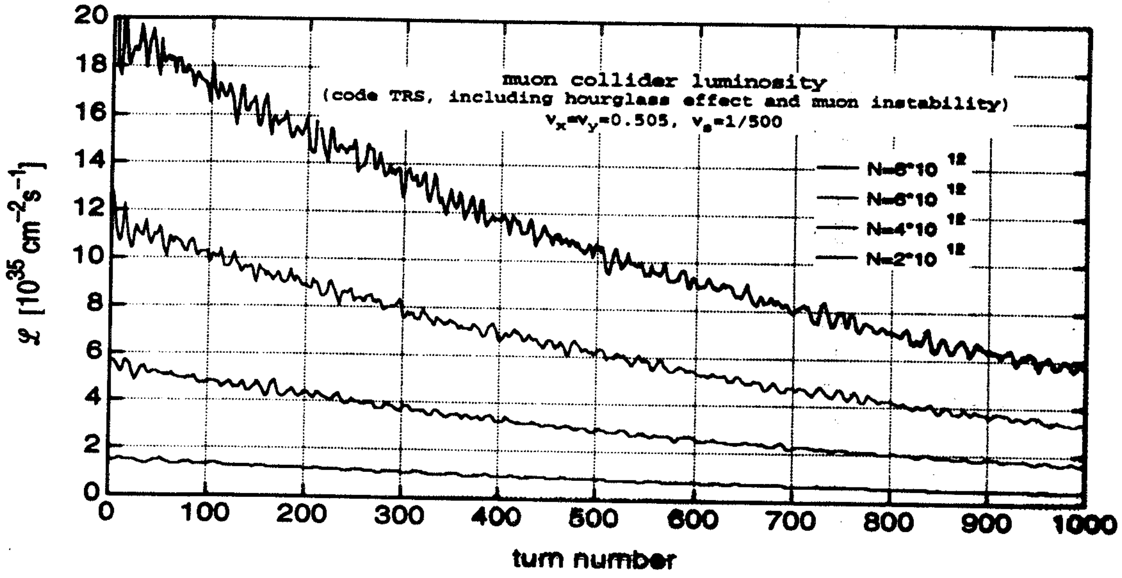


or Recirculating Linacs:

$\mu^+\mu^-$ Collider Facility



Luminosity in a high-energy muon collider



R & D Needs

- Next five years: Identify and test critical components for collider complex.
    - » Proton driver experiments
    - » Target and capture experiments
    - » Cooling experiments (Geer Talk)
    - » Pulsed and superconducting magnet development
    - » Theoretical studies

MILE STONES

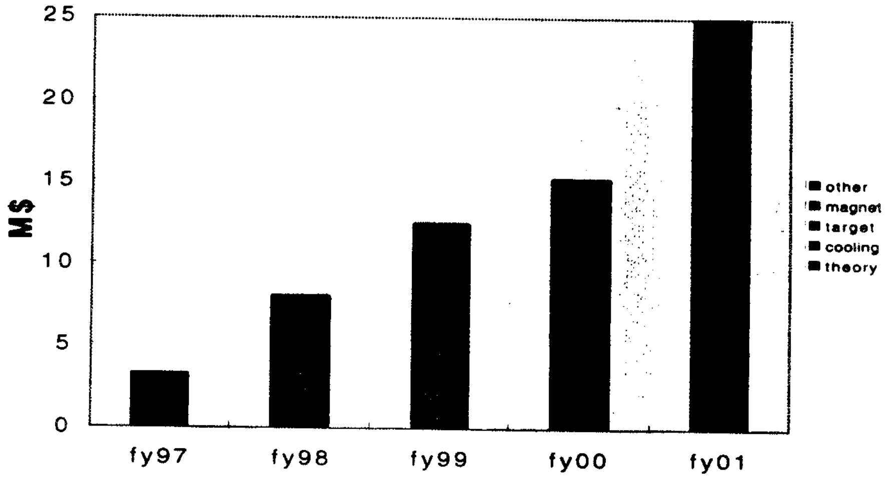
- 1998 Higgs Collider Feasibility Study
- 2002 Higgs Collider Technical Design Report
- 2007 Complete Prototypes

Status after 5 years of R & D

- Goal: Decision on feasibility of muon collider
  - » Demonstration of critical collider components:
    - – driver
    - – target
    - – capture
    - – cooling
  - » Numerical and theoretical models of the full collider complex
  - » Designs for further R & D needed prior to an actual proposal

Short term funding needs

- » These numbers are a first estimate. They do not include contingencies or EDIA.
- » Fiscal year 01 is very approximate, but indicates that increased funding will be needed.



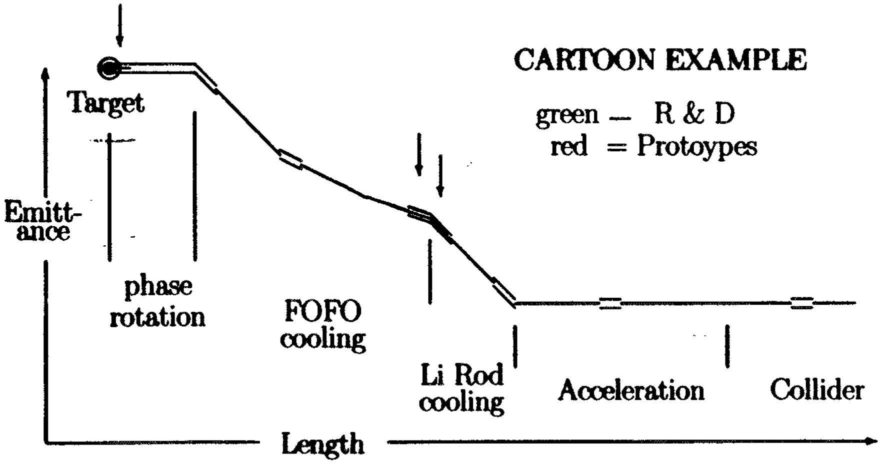
Long Term Plans

- The switch from R & D to machine building could take place between years 6-9.
- Successful R & D program could lead to first muon collider in 10-15 years.
- Complex could allow for a series of higher energy colliders (100GeV--> 4TeV).

LONG TERM PLAN

Assuming R & D successful

- Front End Construction and Systems Test
  - π Production at full proton intensity
  - full phase rotation and decay
  - first stage of cooling
- Recycler Accelerator Magnet Prototype
- SC Collider Magnet Prototype
- Detector component prototypes

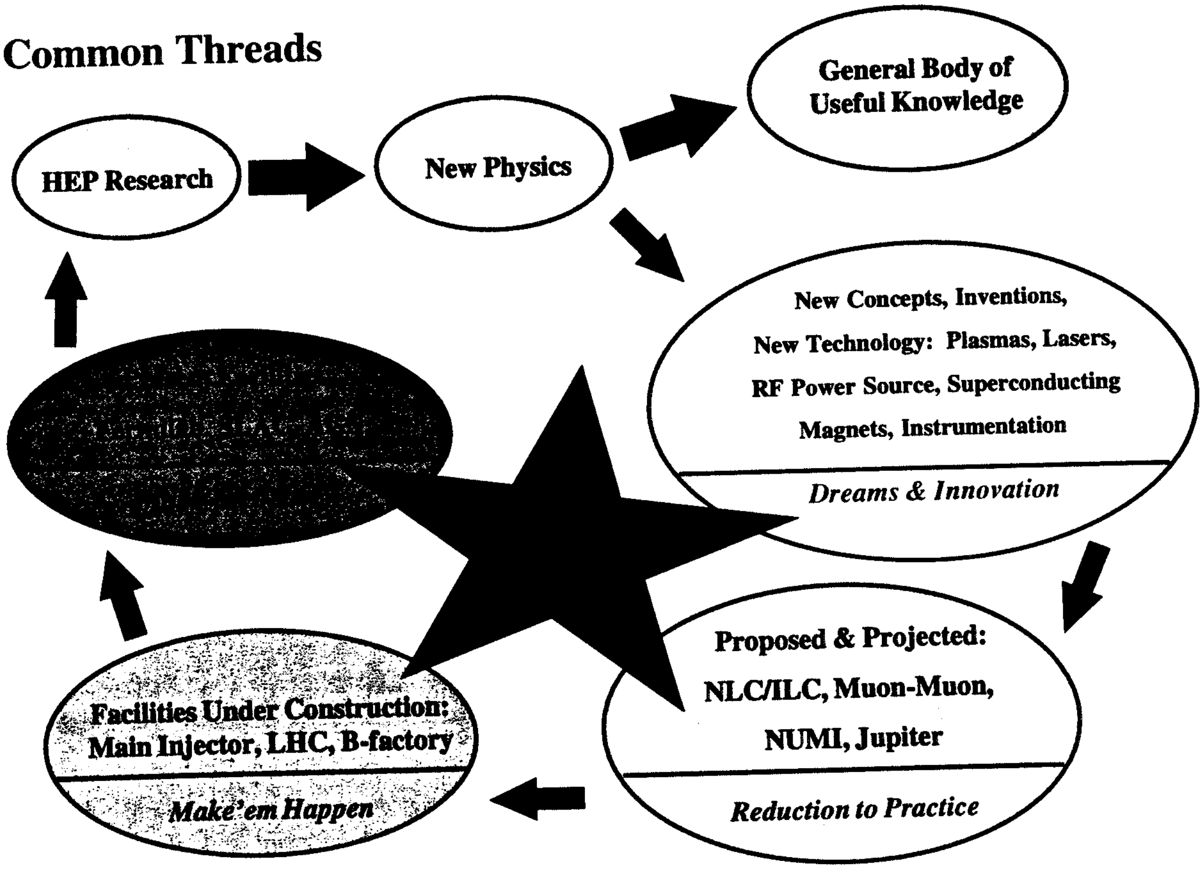


Technology R&D
and
Future High Energy Physics Facilities

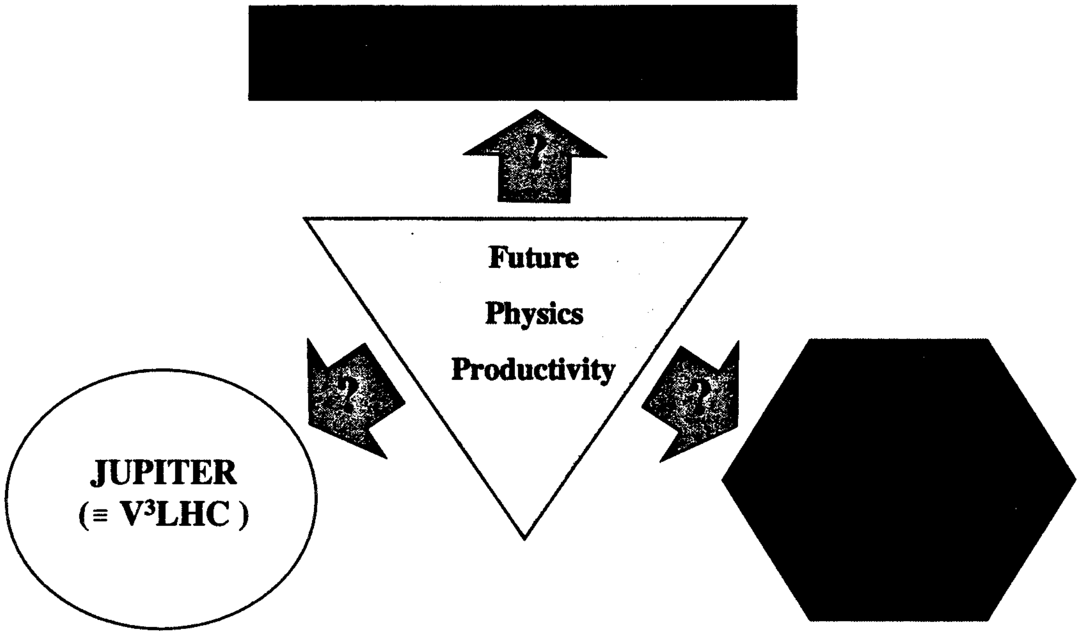
Presentation
to
The Muon-Muon Collider Workshop
San Francisco, CA

David F
Decemb

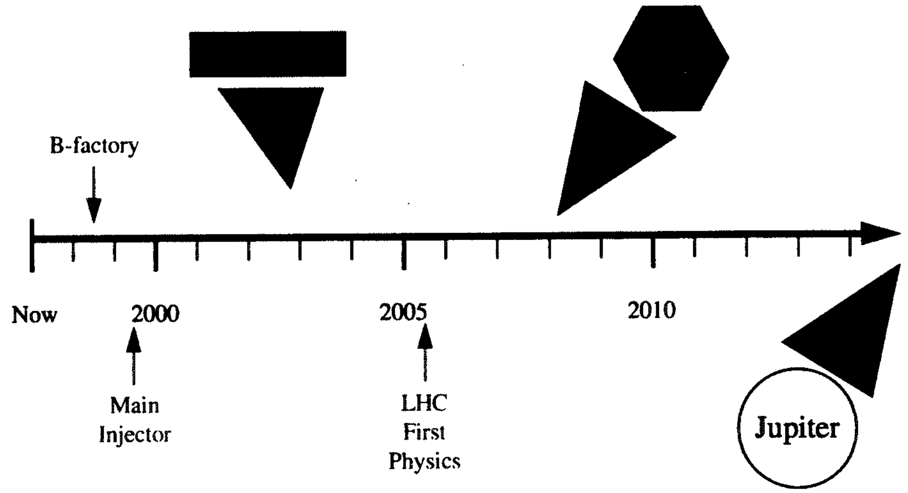
Common Threads



The Snomass `96 Legacy



The Best of All Worlds



Time from first concept To turn on of New Facility	~ 12 yrs in 1980 > 20 yrs in 2000

HEP - TECHNOLOGY R&D

Future Facilities (cont'd)

Next Linear Collider

- R&D most advanced
- Zeroth order design report
- Beginnings of international collaboration
- Systems tests; NLCTA, FFTB, and SLC complete or in progress
- Engineering and manufacturing R&D starting - "Design for Manufacture"

?

Issues: 1. Present cost of project (~$4-$7B), must come down! - whatever it is!

2. DOE support for KD-1, political commitment unknown.

3. Formation of International Collaboration & site selection -- political!!!

HEP - TECHNOLOGY R&D

Future Facilities (cont'd)

.05x.05

Muon Muon Colliders (Energy ~ .2 x.2 to 2X2 TeV)

New Concept!? (Budker suggested 30 years ago,
serious thought: 1992 workshop)

Need to do critical go-no go experiments

- Momentum cooling
- Production target and capture (source test)

Accelerator physics theory

Have a national collaboration = National focus/leadership

Issues: 1. Magnets for storage ring -- technology not in hand!

2. Funding, Funding, Funding!

3. Not known if has "fatal technical flaw" (But looking good!)

HEP - TECHNOLOGY R&D

Future Facilities (cont'd)

JUPITER (Really Large Hadron Collider) (energy significantly > 20 x 20 TeV)

Two Options: High Field, Low Field

High Field R&D issue S.C. Magnets (B > 15 Tesla), Beam Dynamics

Low Field issue - Circumference > 600 km - tunneling cost, Beam Dynamics

Theoretical studies of special problems of really large machine

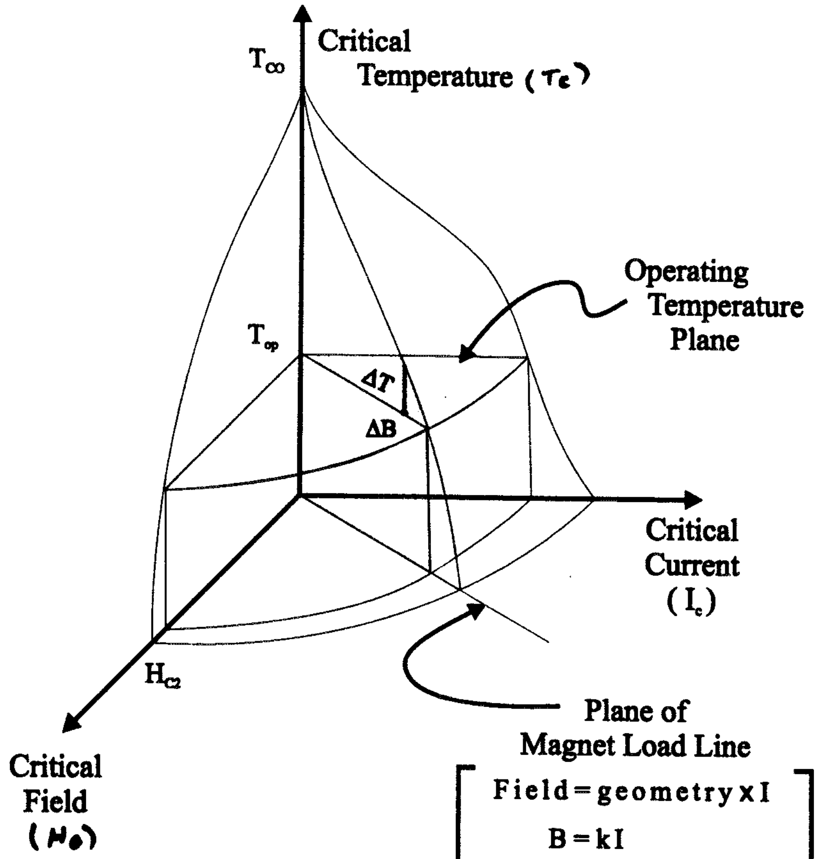
Lead time 15-20 years - to be assured of a cost effective technology

Issues:
1. Technology for high field S.C. Magnets <u>not in hand</u>, for low field magnets: unproven
2. Funding -- needs to be paced to timescale, but needs to start strongly & soon
3. National focus & leadership lacking

Enabling Technologies -- The Sandbox of the R&D

Technology	***Use***	***Intellectual Source/Developer***	***Principal Application*** of Advanced Tech.
• **Magnet**	Beam Transverse Control Beam Analysis (momentum)	Nat'l Labs, Universities & Industry	Protons & Muons (μμ, Jupiter)
• **Acceleration**	Energy Transfer Longitudinal Beam Control	Nat'l Labs & Universities	Electron (NLC/ILC)
• **Vacuum**	Beam Friendly Environment	Industry	All
• **Infrastructure**	Utilities (Cooling, Electrical, Mechanical, Safety)	Industry (mostly)	All
• **Particle Sources & Conditioning** Ref	Hi Brightness beams	Nat'l Labs & Universities	All
• **Controls & Instrumentation**	Measure Beam Performance & Modify It	Controls--Industry Instrumentation--Nat'l Labs & Some Universities	All
• **Accelerator Physics** (A Unifying Theme)	Beam Optics Machine Design New Concepts	National Labs & Universities	All

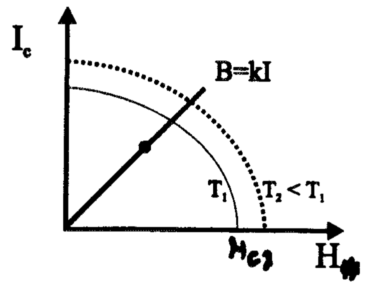
Superconductor Properties



Field = geometry x I

$B = kI$

$U = \frac{1}{2}LI^2 \sim N^2I^2$



Magnet Technology -- Central to Feasibility of Jupiter and Muon-Muon Collider

Needs	*Issues*	*Directions*	*Technologies*
Precision Fields for small spot sizes for high event rates	Variety of Geometries (Solenoids, Dipoles, Quadrupoles, Sextupoles...) $B_{design} - B_{actual} \rightarrow 0$	Better Engineering Mostly Known	Precision Instru. Design Software
High Fields for control of [redacted] High Energy Beams [Energy ~ Bxp]	Momentum/Radius ~ B Self Forces ~ B^2 B ~ geometry x I (~KxI) Heat ~ I^2R	Move to High I, Low R	Superconductors (Materials & Structure)

Superconducting Magnets -- Needed R&D on Materials

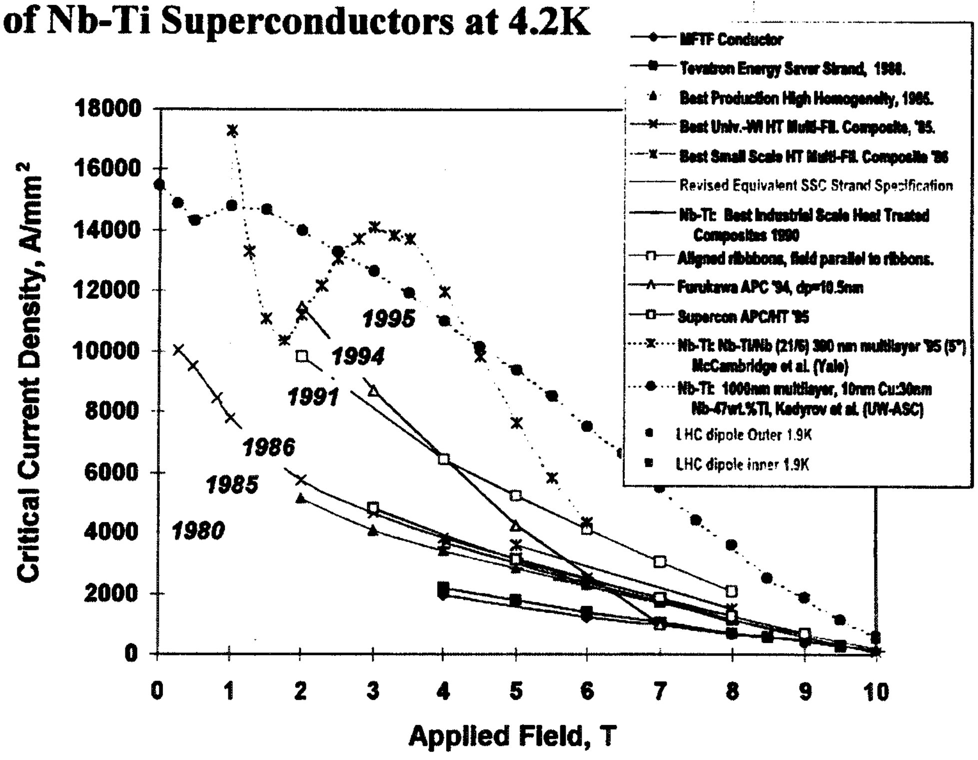
Superconductors	T_{co} (Kelvin)	T_{op} (Kelvin)	H_{c2} (*Tesla*)	*R&D*
Ductile: NbTi, NbTiTa	9.2	1.8-4.2	11-14	J_c at High B, Cost
Hard Ceramics, A15's: Nb_3Sn, Nb_3Al	18.0	1.8-4.2	19-27	J_c at High B, Production, Cost
Soft Ceramics, HTS: BSSCO 2212 & 2223, YBCO	≥72.0	1.8-72	40-80	J_c any B, Mechanical, Production, Cost

R&D Players

- Universities: U. of Wisconsin, Ohio State
- Industry: IGC, Oxford S.C., American Superconductor Corp.
- National Labs: LBNL, BNL, Fermilab

Tech. Transfer -- U.S. Wire Workshops, SBIR

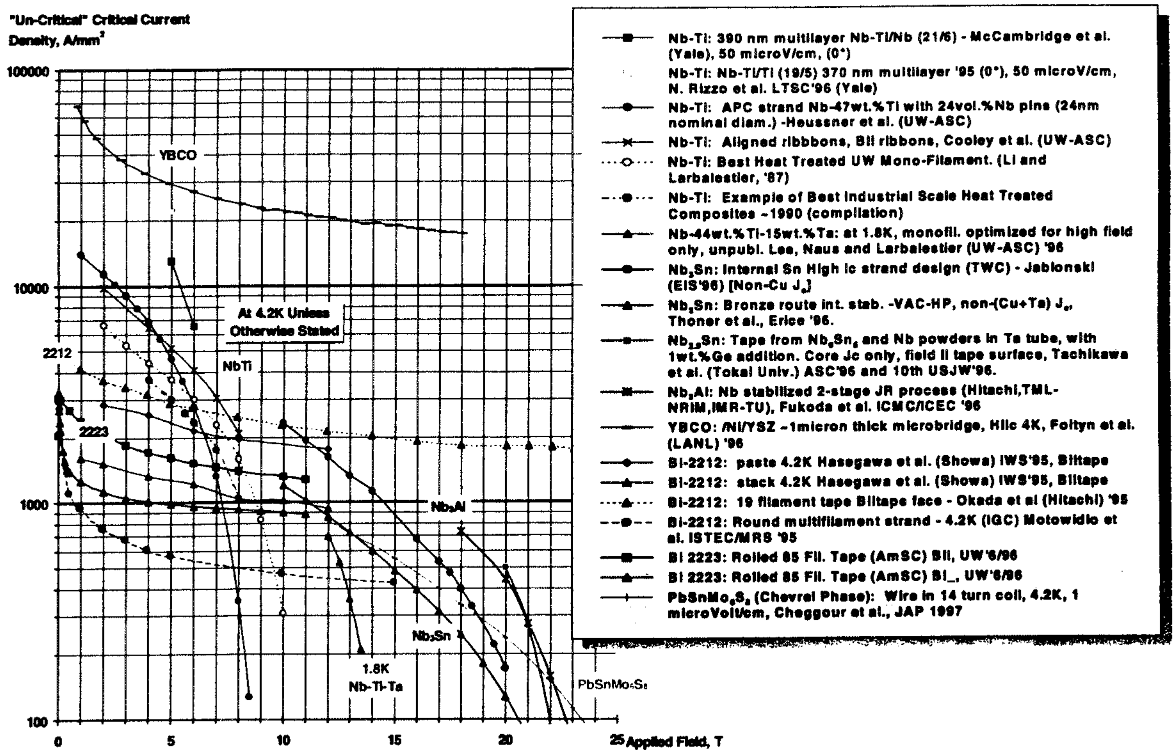
Advances in the Critical Current Density of Nb-Ti Superconductors at 4.2K



University of Wisconsin-Madison
Applied Superconductivity Center

January 2nd 1997 - Compiled by Peter J. Lee NbTiJcProgress.ppt, JCProg37.xls

Advancing Critical Currents in Superconductors



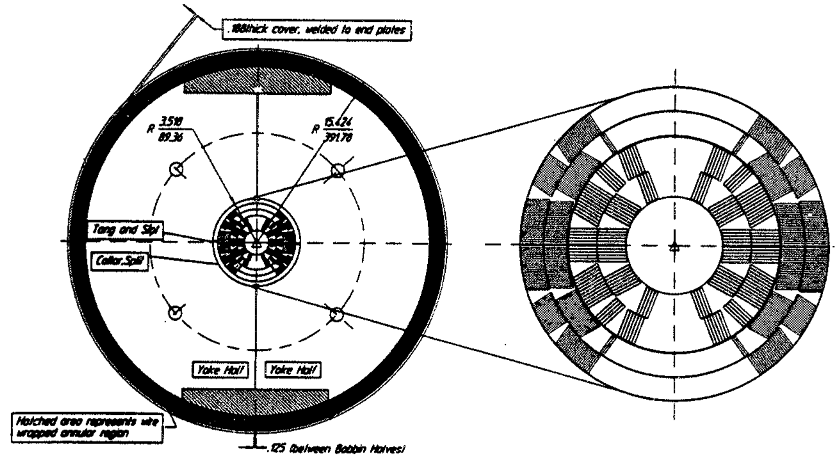
November 3rd 1997 - Compiled by Peter J. Lee - BestinClass.ppt, JCProg40.xls

Superconducting Magnets -- R&D on Structure

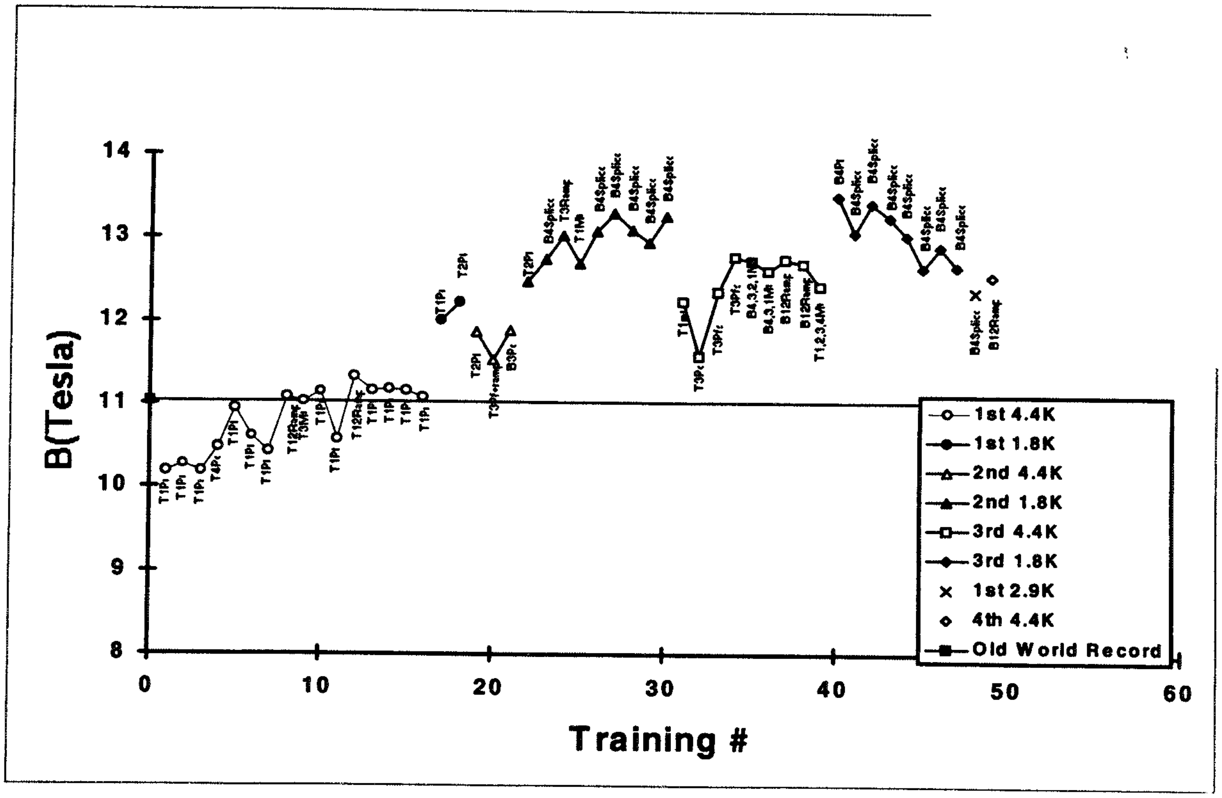
Structure	*Advantage*	*Disadvantage*	*Status*
Cos θ, Cos 2θ (dipole, quad)	Min. Conductor Field Correction Long Experience	Large Shear Forces Σ body forces Complex, High Precision	Tevatron HERA SSC LHC
Rectangular	Low Shear Forces Simple Mechanics Lower Mech. Precision	More Conductor Σ body forces Harder Field Correction	Beamline Magnets
Endoskeletol Rectangular	Low Shear Forces Manageable Body Forces Lower Mech. Precision	More Conductor Harder Field Correction	New

R&D Players }
Universities: Texas A&M
National Labs: LBNL, BNL, Fermilab

D20 Cross Section



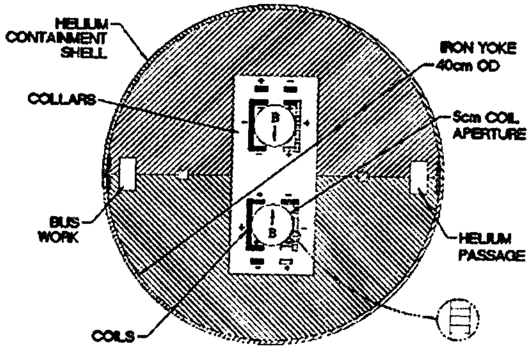
D20: Training History



Superconducting Magnet - Rectangular Geometry (LBNL)

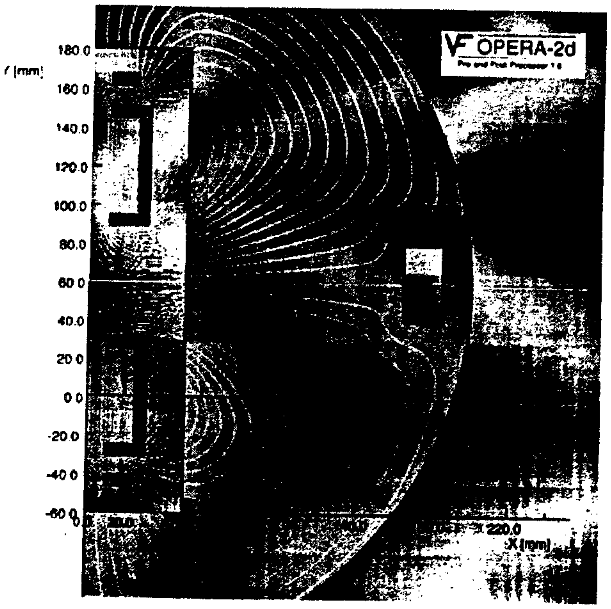
HIGH FIELD (10T-15T) TWIN APERTURE SUPERCONDUCTING DIPOLE

COMMON COIL DESIGN



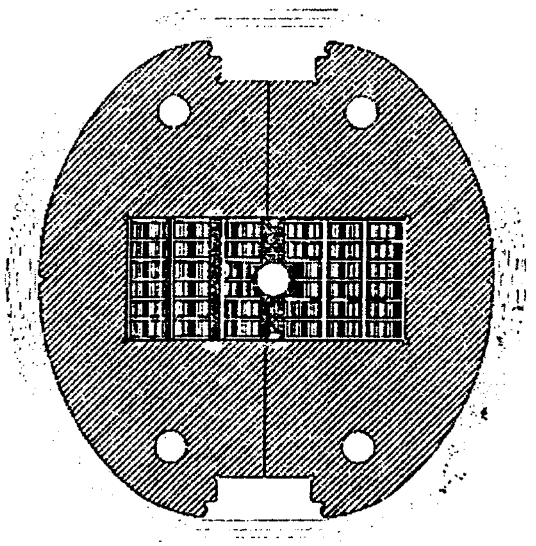
COLD MASS CROSS-SECTION
SCALE 1/4

Field Map



A Magnet with Rectangular Endoskeletal Structure

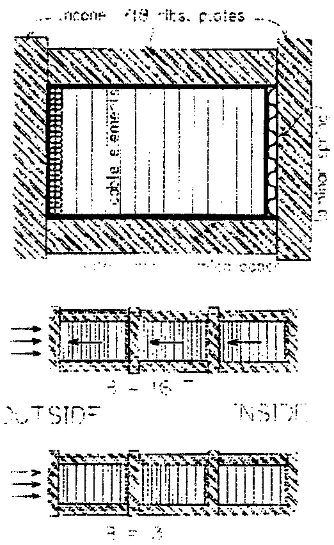
Texas A&M (McIntyre)

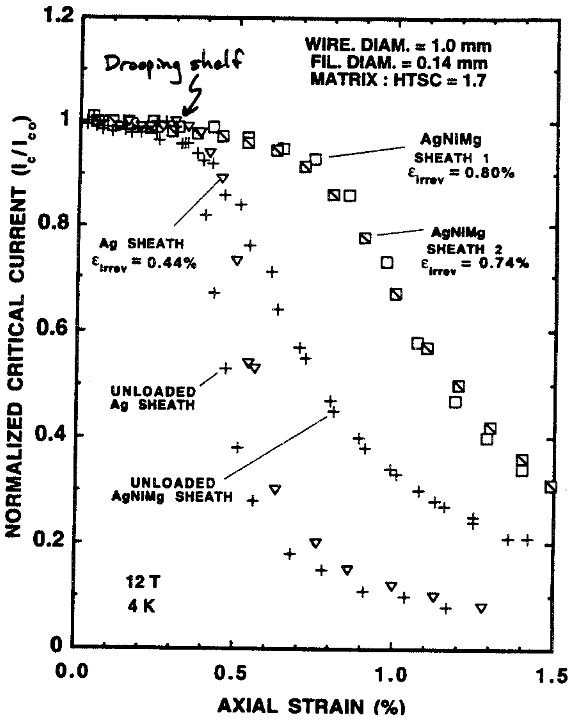


Block-coil NbTi single dipole, using same elements as Nb_3Sn dual dipole.

Stress management involves 3 ingredients:

the coil	(stiff, fragile)
support matrix	(very stiff, very tough)
spring	(very soft, elastic)





All are irreversible; ⇒ no loading without some degradation

HEP - TECHNOLOGY R&D

Future Facilities - Major HEP Issue

- Beyond current projects (FMI, B-factory, LHC)
- Time scale 2005 and beyond -- really 10-15 years down line[redacted] ?

Snowmass `96 looked at Physics and at NLC, Muon-Muon collider, and JUPITER and suppo

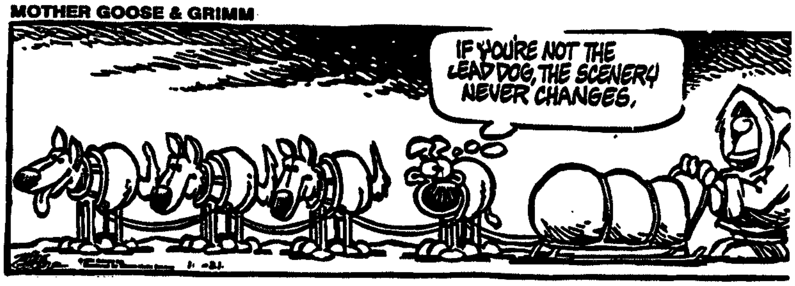
DOE response to Snowmass - \$4.0M in FY 1998, \$3.0M to NLC &?

Issue: 1. Need determination of priorities and game plan

Resolution: HEPAP Subpanel addressing future facilities (and lots of other things!)

Issue: 2. DOE/HEP flat flat budgets and commitments do not allow adequate expansion of R&D even on 15-20 yr time scale.

Resolution:
- DOE/HEP labs to commit internal resources to future facilities
- HEPAP Subpanel to recommend restructuring of program priorities on operating U.S. R&D



"R&D is about being
in the Lead
And staying There!"

Physics With $\mu^+\mu^-$ Colliders - A Perspective

Outline

1. General Theoretical Perspective

2. Muon Collider Options + Attractions (Summary)
   (Some Comment on Polarization)
   - i) Higgs Resonance $\sqrt{s} \approx 100\,GeV$ (Z factory) T. Han
   - ii) 160 ~ 500 GeV $W^+W^-, t\bar{t}, ZH, \ldots$
   - iii) 3 ~ 4 TeV } "New Frontiers"
   - iv) ~ 10 TeV }

3. Concluding Remarks

1. General Theoretical Perspective

Standard Model $SU(3)_c \times SU(2)_L \times U(1)_Y$

Tremendous Intellectual Achievement! (100 yrs)

Based on local Gauge Symmetries

Symmetry Dictates Dynamics!

Tested at ~ ±0.1% Level!

Outstanding Problem - Source of EW Symmetry Br.?
Mass Generation?
$v \simeq 250\,GeV$

Fundamentalists	vs	Dynamicists
$V(\phi) = \lambda(\phi^\dagger\phi - v^2)^2$		$SU(N)_{TC}$
$\Phi = \begin{pmatrix}\omega_1 + i\omega_2 \\ v + H + i\eta\end{pmatrix}$		$\langle 0 \vert Q\bar{Q} \vert 0\rangle \neq 0$ $\Lambda_{TC} \sim 250\,GeV$
Elementary Higgs		New Strong Dynamics 1000 × QCD

Enlightened Fundamentalists	Enlightened Dynamicists
"Supersymmetry"	?
Enlarges Space-Time Sym. sparticles boson ↔ fermion ⋮	(Problems) Technicolor? $\langle 0 \vert t\bar{t} \vert 0\rangle \neq 0$? Needs Exp. Guidance

Superstrings (M-theory) <
- Gravity
- Gauge Theories
- Supersymmetry

} Symphony

High Energy Physics Goals (We Must Do)

1) Find + Study Source of EW Symmetry Br.
   (Find Higgs + Beyond)

2) Find Supersymmetry (Sparticles) - Study

3) Find Source of SUSY Breaking

4) Uncover "New Dynamics"

5) Discover Unexpected (Explore)
   ⋮

Explore Using: *High Energy
High Precision
High Sensitivity

} Muon Collider
Potentially very important tool

2. Muon Collider Options + Attractions (Summary)

Overview - V. Barger

Options: $\mu^+\mu^-$, $\underbrace{\mu^-\mu^-, \mu^-p, \nu, \text{low energy}}$ ...

C. Heusch
J. Gunion
S. Rajpoot
I. Ginzburg
K. Cheung
S. Geer
B. King
W. Molzon
H.C. Walter
W.Y. Keung

$\mu^+\mu^-$ Colliders $\sqrt{s} \sim 100\,\text{GeV}$, $160 \sim 500\,\text{GeV}$, $3 \sim 4\,\text{TeV}$, $10\,\text{TeV}$

Strive For Good Energy Resolution
*High Luminosity
Polarization

Comment on Polarization (Aim for little luminosity loss)
(Signal + Background Effects) *A. Skrinsky

P_+	P_-	$P_{eff} = \frac{P_+ - P_-}{1 - P_+ P_-}$
0.2	-0.2	0.385
0.34	-0.34	0.610
0.50	-0.50	0.80
0.70	-0.70	0.94
0.89	-0.89	0.993
[illegible]	[illegible]	[illegible]

} A. Skrinsky
very exciting!
Radical!

(D. Cline)

i) Higgs Resonance (+ Z Factory) - First Muon Collider

LEP → $m_H \gtrsim 78\ (88)$ GeV! { P. Bambade, Y. Pan
(low tan β being tested)

Precision EW $\sin^2\theta_W + m_W \rightarrow$ Light Higgs (G. Kane) P. Renton
(see table) $m_H \lesssim 160$ GeV! (Narrow)

LEP II → 100 GeV
FNAL → 120 GeV (C. Quigg)
SUSY → $m_H \lesssim 130\ (150)$ GeV

Looks Good For Higgs Resonance Studies

Perhaps $h, H, A, H^{--}, \tilde{\nu}$

J. Gunion
S. Rajpoot
C. Heusch
J. Feng

Standard Model Higgs   Example $m_H = 110$ GeV

$\Gamma_H \simeq 3$ MeV, $\Delta E/E = 3\times10^{-5}$, $L = 0.05\ fb^{-1}$ (?)

$N_H \simeq 3000$

$H \rightarrow$	$b\bar{b}$	$c\bar{c}$	$\tau\bar{\tau}$
N_S (events)	2400	210	270
N_B (events)	2520	2416	945
$\pm \frac{\sqrt{N_S+N_B}}{N_S}$	±0.03	±0.24	±0

Scan time ~ 3 yrs! to

Precision EW Data + Higgs Mass

$$m_W^2 = \frac{1}{2} m_Z^2 \left[1 + \sqrt{1 - \frac{A}{1-\Delta r(m_t, m_H)}} \right]$$

$$\sin^2 2\theta_W (m_Z)_{\overline{MS}} = \frac{A}{1 - \Delta\hat{r}(m_t, m_H)}$$

} $\Delta r + \Delta\hat{r}$ EW loop corr.

$$A = \frac{4\pi\alpha}{\sqrt{2} G_\mu m_Z^2} = 0.66859(3)$$

$m_t = 175 \pm 5$ GeV   (P. Renton $m_H = 115^{+116}_{-66}$ Global Fit)

m_H (GeV)	m_W (GeV)	$\sin^2\theta_W (m_Z)_{\overline{MS}}$
	∓0.034 ±0.010	±0.0002 ±0.0002
65	80.406	0.23100
100	80.383	0.23121
300	80.309	0.23179
600	80.256	0.23217
1000	80.216	0.23245

Current Ave $m_W = 80.43 \pm 0.08$ GeV   (Y. Pan), (P. Renton)
$\sin^2\theta_W (m_Z)_{\overline{MS}} = 0.23122\ (22)$ LEP + SLD

SLD Alone $\sin^2\theta_W (m_Z)_{\overline{MS}} = 0.23030 \pm 0.00048$

(LEP value update?)   (SLD update 300k Z!)

Higgs Very Light or "New Physics" (SUSY?)

If High Polarization + High Luminosity

Signal $\mu_L^- \mu_L^+ \to H$
$\mu_R^- \mu_R^+ \to H$

Background $\mu_L^- \mu_R^+ \xrightarrow{\gamma, Z} f\bar{f} \ldots$
$\mu_R^- \mu_L^+$

High Pol. → Turn Off Backgrounds!

$\frac{N_S}{\sqrt{N_B}}$ enhanced by $\frac{1+P_+P_-}{\sqrt{1-P_+P_- + (P_+-P_-)A_{LR}}}$ B. Kamal
Z. Parsa
W. M.

A. Skrinsky [redacted]
2) $P_+ = P_- = 0.7$ $\mathcal{L} \simeq 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$

[redacted]

2) Reduces Scan Time 1/400, $\underbrace{\text{3yrs} \to \text{40hrs.}}_{\text{Fantastic}}$!

Measure Higgs → $\left.\begin{array}{l} b\bar{b} \\ c\bar{c} \\ \tau\bar{\tau} \\ \gamma\gamma \\ WW^* \\ ZZ^* \end{array}\right\}$ Very Precisely
(High Luminosity)

Higgs Resonance Study Becomes Mu !

T. Han $10^7 \sim 10^8 Z$
with Pol.

Z Factory If $\mathcal{L} \simeq 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, $P_+ = P_- = 0.7 \to P_{eff} = 0.94$!

Lep $10^7 Z \to 10^9 \sim 10^{10}$ Z's with Pol.!

Forward-Backward $b + \bar{b}$ tags → CP Violation!!
$(>10^8 Z)$ $B_s \to \bar{B}_s$ osc
Rare B decays
Rare τ decays
Precision Measurements, $\sin^2\theta_W \ldots$
Rare Z Decays (eg $Z \to WX$)

Incredible Facility!

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ii) $\sqrt{s} \simeq 160 \sim 500\,\mathrm{GeV}$ (M. Berger, S. Parke)

$\mu^+\mu^- \to W^+W^-$ $(\Delta m_W \simeq \pm 6\,\mathrm{MeV}, \Gamma_W \ldots)$
$t\bar{t}$ $(\Delta m_t, \alpha_s, V_{tb} \ldots)$
ZH $(m_H, g_{HZZ} \ldots)$
} Precision Studies Pol. Useful (Important)

$\left.\begin{array}{l} \tilde{\chi}^+\tilde{\chi}^- \\ \tilde{\ell}^+\tilde{\ell}^- \end{array}\right\}$ Gunion, Berger, Lykken

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iii) $\sqrt{s} \simeq 3\text{-}4\,\mathrm{TeV}$ (Very Unique Facility)

SUSY Spectroscopy (Heavier States) Pol. Very Useful
(Gunion Lykken, Baer)

Precision Measurements (120 Parameters!)

(If) Strong WW (T. Han) → $\pi_T, \eta_T, \rho_T, \omega_T \ldots$
(Lots of Spectroscopy) Technibaryons . . .

Z′ bosons, Leptoquarks, Compositeness.... (S.Godfrey)

Pol. Very Important → $\Lambda_c \simeq 100$ TeV!

iv) $\sqrt{s} \sim 10$ TeV (A. Skrinsky, + W.M.)

Overcome Neutrino Problem! (B.King)

New Physics? Who knows? Probably!

Our Job is to explore!

3. Concluding Remarks

Can one really have high Luminosity + high Pol. ?

If A. Skrinsky is right

→ $\sqrt{s} \simeq 100$ GeV H + Z Factory Extremely Compelling
Must Do (also ZH)

First Muon Collider → Reality → Future High $\sqrt{s}$
Ideas should be thoroughly investigated

If at this meeting we have seen further than others, it is because Dave Cline provided such a stimulating environment (particularly the luncheons)

Thanks Dave
and
Organizers

THE 5^{th} $\mu^+\mu^-$ COLLIDER

CONFERENCE

$\mu\mu(99)$

Will be held at the

FAIRMONT HOTEL

DEC 1999 (→ getting ready for the Next millen—)

(if $\mu\mu$ collider still making progress)

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