THE 5 YEAR PLAN

Outlook, resources & schedule

INTRODUCTION

- The 5 year plan is:
  - A joint NFMCC-MCTF Plan with broad input from the NFMCC-MCTF community, & endorsement from the NFMCC & MCTF leadership
  - A measured program which is based on the solid muon accelerator R&D achievements of the last decade
  - Sufficiently ambitious to make substantial progress before the next round of long-term decisions by the particle physics community
  - Meets our existing commitments (NF-RDR, MICE) and in addition will deliver:
    - MC performance requirements based on physics needs
    - A first end-to-end MC simulation
    - Critical component development & proof-of-principle experiments
    - A first MC cost estimate

ACTIVITIES: YEARS 1 - 2

- **MC-ZDR Physics & Detector**
  - Establish physics reach vs E & L
  - **Define performance goals (E, L, …)**
  - Set up background & detector simulations
  - Define detector requirements & plan detector R&D to inform ZDR
- **MC-ZDR Design & Simulations**
  - **Study alternatives for the accelerator subsystems** using defensible parameters
  - Cross-check promising subsystems with 2 simulation codes
- **NF-RDR Studies**
  - Determine relevant underground conditions at FNAL
  - Detector magnetization design & procurement for test
  - Interim NF-RDR report in 2010
- **Components & Experiments**
  - MICE: Complete Steps III – V (1 RF section + 2 absorbers)
  - **RF in magnetic field studies: Determine viable options & performance**
  - HCC: 4-coil models (2009) & conceptual design + short demo HCC magnet (2010)
  - Other magnets (ring, fast-ramping): Study options, define parameters

ACTIVITIES: YEAR 3

- **MC-ZDR Physics & Detector**
  - Detector R&D, simulation & physics studies
  - **Establish likely MC detector performance**
- **MC-ZDR Design & Simulations**
  - Specify baseline accelerator design & study optimization (minimize work on alternatives)
  - Simulate representative matching sections
  - Carry out representative tolerance studies
  - **Freeze accelerator design**
- **NF-RDR Studies**
  - Underground engineering: begin cost, schedule, risk analysis
  - Build detector test magnet
- **Components & Experiments**
  - **MICE: Complete Last steps III – V (2 RF sections + 3 absorbers)**
  - Study 6D cooling experiment options
  - **HCC-Section: Engineering design & procurement (magnet+RF)**
  - **Guggenheim-Section: RF Cavity and magnet conceptual design**
  - Other magnets (ring, fast-ramping): Define technology tests to inform ZDR

ACTIVITIES: YEAR 4 (& 5 ?)

- **MC-ZDR Physics & Detector**
  - Continue detector R&D
  - **Compare simulated physics reach with other machines (e.g. CLIC)**
- **MC-ZDR Design & Simulations (& cost)**
  - Complete design of all matching sections
  - **End-to-end simulation of accelerator complex**
  - Detailed tolerance studies
  - **Cost estimate**
- **NF-RDR Studies**
  - **Complete RDR report**
- **Components & Experiments**
  - MICE: Simple 6D cooling experiment (LiH wedge ?)
  - 6D Cooling experiment design studies to inform decision about what to propose
  - **HCC Section: Magnet test & RF integration & test**
  - **Guggenheim-Section: Engineering design & procurement (magnet+RF) … build & test in year 5-6**
  - Other magnets (ring, fast-ramping): Technology tests to inform ZDR & post-ZDR R&D needs

KEY QUESTIONS FRAMED BY BOB - 1

- What machine performance is required of a muon collider (e.g. integrated luminosity in 10 yrs operation) to achieve the physic goals endorsed by the HEP community?
  - The 1995 MC study concluded we need to aim for $\sqrt{s}$ = 1-4 TeV and L =10^{34} cm^{-2} s^{-1}.
  - Our understanding will be updated by the first two years of the physics study. For example, there are scenarios in which LHC results (e.g. discovery of special Z' bosons) could motivate a much lower luminosity MC … understanding this will be part of the physics study.

KEY QUESTIONS FRAMED BY BOB - 2

- What range of plausible machine parameters will deliver that machine performance (. e.g. bunch charge, emittance, life times, etc.) ?
  - Presently exploring 3 design strategies spanning a range of parameters.
  - Understanding cooling channel design & the associated component performance (e.g. rf in magnetic fields) is key to down-selecting.
  - Plan is to down-select after the first 3 years … once further rf results and cooling channel simulation results are available, and the physics study has established the luminosity goal.

KEY QUESTIONS FRAMED BY BOB - 3

- How will the R&D plan demonstrate that these parameters are feasible?
  - Plan includes paper studies of how to upgrade Project X to produce a suitable 4MW source with right bunch structure.
  - MERIT has already demonstrated feasibility of the required 4MW target technology. Jet nozzle and target lifetime studies will extend our understanding of the performance.
  - The magnet & rf R&D will establish the feasible parameters for the cooling channel components including bench tests of 6D cooling channel section(s), and MICE will provide the proof-of-principle demonstration for the early transverse cooling channel.
  - An end-to-end simulation of the front-end will take us from the established component parameters to the overall MC front-end performance.
  - Acceleration & collider ring simulations (informed by a collider ring magnet study) will establish the expected luminosity for the given MC front-end.

KEY QUESTIONS FRAMED BY BOB - 4

- Assuming the desired machine parameters can be met, what machine backgrounds does one expect?
  - The 1995 study showed background levels comparable to those at the LHC ($L=10^{34}$ $cm^{-2}s^{-1}$) once the final focus plus shielding had been carefully designed.
  - As the collider ring design evolves the final focus, shielding, & detector studies must be repeated – iterative process
  - The first step in this iterative process is to set up the background and detector simulation tools – activity for the first year of the plan
  - Lower backgrounds probably cost luminosity, so it is likely that the final focus & shielding design will correspond to the maximum background rates considered acceptable for the detectors. Guidelines for the maximum acceptable background rates will be established in the first year of the plan.

KEY QUESTIONS FRAMED BY BOB - 5

- What detector performance is needed to do the physics of interest in the presence of these backgrounds?
  - An initial set of detector requirements will be given after the first year of study, so that the iterative final-focus, shielding and detector studies can proceed.
  - Initial detector performance requirements will be refined as physics & detector studies proceed.
  - There will be regular meetings plus occasional (annual?) workshops to co-ordinate the physics, background and detector studies, and the final focus design work.
    - Workshops include participation of broader community

KEY QUESTIONS FRAMED BY BOB - 6

- What detector technologies will be employed to achieve this performance?
  - Since backgrounds are likely to be comparable with LHC backgrounds, the tracking technologies will likely be based on LHC tracking detectors & the experience gained at the LHC.
  - Calorimetry must be studied for precision measurements at high energies in the appropriate background environment. The 1995 study considered LAr em calorimeters & Fe-scintillator had calorimeters, which yielded satisfactory performance. However, expectations for detector performance have become more ambitious in recent years, so detector design & performance must be revisited. These studies will start in year 2 of the plan, along with some modest detector R&D (to be defined) to inform the design & simulation

KEY QUESTIONS FRAMED BY BOB - 7

- What can be learned from simulation vs experimental measurements?
  - Experimental measurements are essential to establish the component performance assumed in the simulations, and demonstrate that engineering & safety constraints are understood.
  - Proof-of-principle experiments (e.g. MERIT, MICE, and an eventual 6D cooling experiment) are essential to build confidence in sub-system performance, reliability of the simulations, & front-end cost estimates.
  - Ultimately end-to-end simulations must be used to assess the performance of the overall accelerator complex.

KEY QUESTIONS FRAMED BY BOB - 8

- What are the technical components (machine and detector) are currently beyond the state of the art such that they must be built and demonstrated to work? What is the fall back plan if they do not work?
  - Known now
    - RF performance in a magnetic lattice
    - High field cooling channel solenoid prospects
  - To be determined by the 5 year study
    - Significant detector R&D (if any)
    - HTS R&D Plan
    - 6D Proof-of-principle experiment plan
    - Needed muon-beam R&D facility

KEY QUESTIONS FRAMED BY BOB - 10

- Assuming success in the R&D program, roughly what will a MC or a NF cost ?
  - Study 2a cost estimates, presented to P5 (see next slide) give our expectation for NF cost corresponding to present design, & hence for the front-end (pre-cooling channel) part of the MC complex.
  - The 5-year study will give us a first defensible estimate of the cost of the rest of the accelerator subsystems.
  - Beyond the 5 year study we would expect that further MC R&D would be aimed, in part, at improving cost-effectiveness.

NF COST ESTIMATES

As presented to P5 in February 2008:

4 GeV NF Cost Estimate (excluding 2 MW proton source)

Start from Study 2 cost estimate scaled to account for post-study 2 improvements (ranges reflect uncertainties in scaling) →

ILC analysis suggest loading coeff = 2.07 for accelerator systems and 1.32 for CFS. Labor assumed 1.2 × M&S →

Loaded estimate = 2120 - 2670 (FY08 M$)

Unloaded estimate (M$)

Target Systems	110
Decay Channel	6
Drift, Ph. Rot, Bunch	112-186
Cooling Channel	234
Pre-Acceleration	114-180
Acceleration	108-150
Storage Ring	132
Site Utilities	66-156
TOTAL (FY08 M$)	**881-1151**

Front-end systems (including transverse cooling channel) which might be common to a MC accounts for ~50% of this cost.

KEY QUESTIONS FRAMED BY BOB - 9

- Roughly what will the R&D program cost (labor and M&S) and how long will it take?
  - 5 Year plan cost (next slides)
  - Post-5-year-plan R&D to be established by the 5-year plan. Based on our R&D to date:
    - Expect there to be substantial R&D beyond the 5 year plan.
    - If the 5 year study yields encouraging results we would expect the subsequent R&D to have a high likelihood of succeeding.
    - Our hope is that the post-plan R&D that must be done before a MC can be proposed can be accomplished within an additional decade.

RESOURCES - 1

- FY08: NFMCC + FNAL-MCTF DOE funding
- FY09-12: First pass
  - We constrained ourselves to deliver ZDR in FY12 (i.e. 4 years not 5 years)
  - Goal driven (not adjusted to fit predetermined budget)
  - With this constraint resource profile challenging, particularly SWF jump in year 1

YEAR	M&S (K$)	SWF (K$)	ENGS (FTE)	TECHS (FTE)	PDOCS (FTE)	SCIENTS (FTE)	TOTAL (K$)
FY08	1748	5808	7.3	9.5	3.3	11.9	7556
FY09	2856	14320	19.5	13	15.1	32	17176
FY10	7033	20040	30.2	19.3	22	35.5	27072
FY11	7501	21093	24	31.8	20.9	46.1	28593
FY12	5579	21431	28.5	21.8	22.6	47.5	27010

RESOURCES - 2

Same plan as previous slide, broken down by sub-activity

	FY08	FY09	FY10	FY11	FY12	TOTALS FY09-12
Design & Sims	**1885**	**6432**	**9927**	**11477**	**12289**	**40125**
M&S	0	315	1470	1345	710	3840
SWF	1885	6117	8457	10132	11579	36285
Components/Tests	**5293**	**8748**	**13903**	**13496**	**11487**	**47633**
M&S	1495	1550	3685	4160	3260	12655
SWF	3798	7198	10218	9336	8227	34978
Program Management	**378**	**1425**	**1836**	**2121**	**2118**	**7500**
M&S	253	420	471	496	493	1880
SWF	125	1005	1365	1625	1625	5620
Contingency (25% M&S)	**0**	**571**	**1407**	**1500**	**1116**	**4594**
TOTALS	**7556**	**17176**	**27072**	**28594**	**27010**	**99852**

RESOURCES – 3: STRECH BY 1 YEAR

	FY08	FY09	FY10	FY11	FY12	FY13	TOTALS FY09-13
Design & Sims	**1885**	**3216**	**8640**	**9554**	**9554**	**9161**	**40125**
M&S	0	158	1029	942	942	771	3840
SWF	1885	3059	7611	8612	8612	8391	36285
Components/Tests	**5293**	**5869**	**9079**	**11730**	**11730**	**9226**	**47633**
M&S	1495	1550	2948	3328	3328	1501	12655
SWF	3798	4319	6131	8401	8401	7725	34978
Program Management	**378**	**839**	**1469**	**1697**	**1697**	**1799**	**7500**
M&S	253	336	377	397	397	374	1880
SWF	125	503	1092	1300	1300	1426	5620
Contingency (25% M&S)	**0**	**571**	**985**	**1275**	**1275**	**488**	**4594**
TOTALS	**7556**	**10495**	**20172**	**24256**	**24256**	**20673**	**99852**

MCTF

SUMMARY: Vladimir's characterization of 5 year plan impact on MC build-ability

On the scale 1…10
0 – have no idea
6 – technology proved
10 – ready to build

Muon Collider Feasibility/Cost/Timescale
3 → 7

Proton Driver
3 → 8

Targetry
8 → 9

Mu-Collection
2 → 6

Main Cooling
2 → 6

Detector
2 → 7

Collider
3 → 6

Acceleration
2 → 5

Final Cooling
1 → 5

BACKUP SLIDES

- ADDITIONAL SLIDES ON PARTICIPATION IN 5 YEAR PLAN

LABORATORY PARTICIPATION

- Assume groups from the sponsoringing Labs for muon accelerator R&D in the U.S. (BNL, FNAL, LBNL) will be supported at an enhanced level
- This year NFMCC funding also went to: ANL, ORNL, Jlab
- Exploring collaborating with SLAC on rf in magnetic field studies

UNIVERSITY PARTICIPATION

- NFMCC & MCTF activities involve many university groups
- This year NFMCC funds went to Princeton, UCLA, U-Mississippi, IIT, UC-Riverside
- Cornell has been pursuing relevent SCRF R&D for the acceleration systems, supported by NSF funds
- NSF funds are, or in the recent past have, also supported contributions from IIT, U-Mississippi & UC-Riverside, U-NH

SBIR PARTICIPATION

- SBIR Companies presently participating
  - Muons Inc.
  - Tech-X Corporation
  - Particle Beam Lasers Inc.
- Opportunities to align SBIR activities with 5 year plan
  - HTS magnets
  - HPRF
  - Exploring 6D cooling experiment design options
  - Cooling channel simulations

INTERNATIONAL PARTICIPATION

- NF-RDR is fully international
  - Steering Group: Blondel, Kuno, Zisman, Long
  - Accelerator Group Leaders: Berg, Mori, Prior
  - Detector Group Leaders: Bross, Soler, Mondal, Cervera
  - Physics Group Leaders: Donini, Huber, Pascoli, Winter, Yasuda
- Aspire to international participation in MC-ZDR
  - Likely to be limited, but should build towards a more international post-ZDR phase
  - UK scientists have an interest in using the MICE facility beyond presently defined program → 6D cooling test ?
- We have one international post-doc fellowship
  - Joint Imperial College – FNAL fellowship which has potential to be expanded to 2 positions.
- U.S. contributions (people) to EMMA in the U.K.
- Possible collaboration with Japan
  - Cooling channel Absorber
  - Possible Cooling ring studies with protons

NF-RDR U.S. PARTICIPATION

- U.S. Activities & Institutions
  - Proton Driver: FNAL, Muons Inc.
  - Front-end: BNL, FNAL, LBNL, ORNL, TJNAF, IIT, Mississippi, UCR, UCLA, Muons Inc.
  - Acceleration: BNL, FNAL, LBNL, TJNAF, Mississippi, Muons Inc.
  - Underground Engineering: FNAL
  - Magnetization concepts: BNL, FNAL