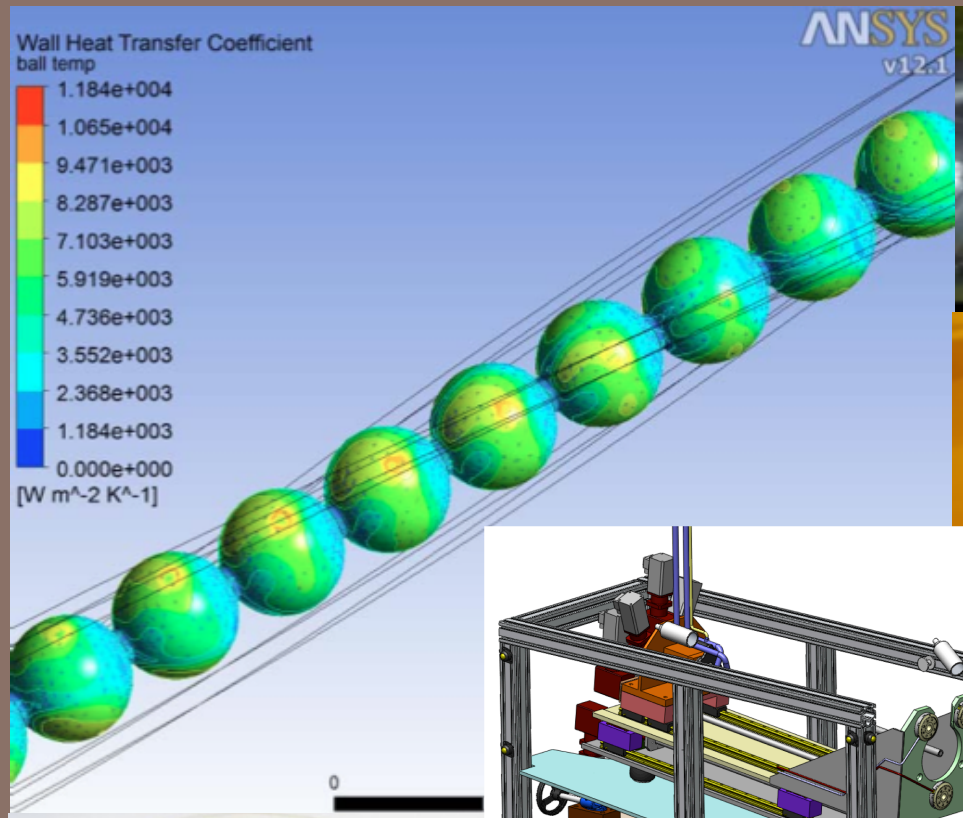


HIGH POWER TARGET DEVELOPMENT AT FERMILAB

Accelerator Sector Planning and Strategy Workshop
P. Hurh

Introduction- Where we are

- AD/MS and Pbar and Ext. Beams operates 3 target facilities:
  - P-bar Source (off) – 70 kW proton beam on inconel (nickel alloy) target with Be cover (110 kW/mm^2)
  - NuMI/MINOS – 400 kW proton beam on graphite (carbon) target (14 kW/mm^2)
  - MiniBooNE – 32 kW proton beam on beryllium target (1 kW/mm^2)

Note: Values in red refer to total beam power divided by nominal 3 sigma spot size

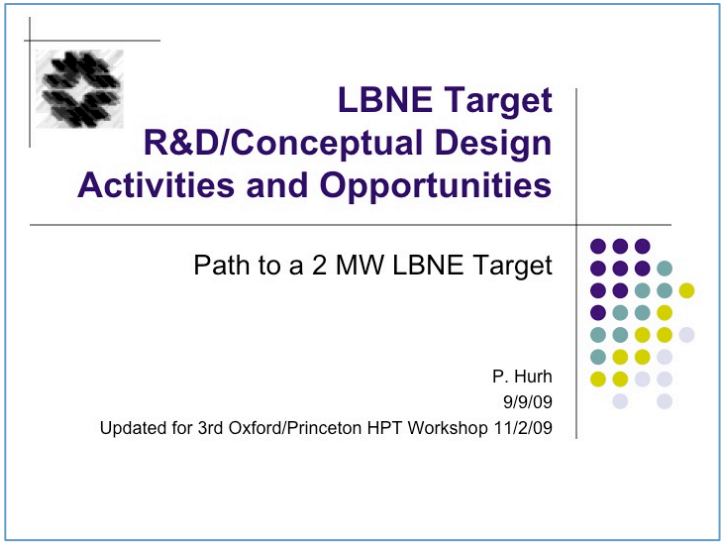
Introduction- What we are working on

- Currently have resources working on:
  - ANU/NOvA upgrade - 700 kW proton beam on graphite (carbon) target (15 kW/mm^2)
  - LBNE - 700 kW proton beam on graphite (beryllium?) target (15 kW/mm^2)
  - LBNE upgrade – 2.3 MW proton beam on graphite (beryllium?) target (36 kW/mm^2)
  - Mu2e – 25 kW-8 GeV (maybe lower now) proton beam on gold (tungsten?) target (1 kW/mm^2)
  - G-2 – 27 kW-8 GeV proton beam on inconel target (??)

Note: Values in red refer to total beam power divided by nominal 3 sigma spot size

Introduction – Current Issues

- Design Challenges
  - Heat removal
  - Thermal Shock (Stress Waves)
  - Radiation Damage
  - Radiation Accelerated Corrosion
  - Spatial Constraints
  - Residual Radiation
  - Manufacturing techniques
  - Physics Optimization
- Not just targets, but entire target systems (beam windows, collection optics, absorber, decay pipe, etc.)



Introduction – Current Issues

- Operational/Infrastructure Challenges
  - Operational crises divert scarce resources from R&D and future projects
  - Reliance on Single Source Vendors
  - Radiological Issues
    - Shielding
    - Air Activation
    - Tritium
    - Remote handling and long term storage requirements
      - Current long term storage filled after 3-4 years of NOvA
      - Not just targets, but whole facility design

Introduction – Current Issues

- Organizational Challenges
  - Resources spread among different organizations with diffuse accountability and competing responsibilities
  - Projects only fund specific R&D efforts, not fundamental, general R&D efforts that benefit all
- Success at the High Intensity Frontier requires success at High Power Target Facilities

Strategy – Ultimate Goal (10 year)

- Support all target facility needs in the Project X era
  - LBNE at 2.4 MW
  - Muon Experimental Facility at 1 MW
  - Kaon Experimental Facility at 1 MW
  - Nuclear Experimental Facility at 1 MW
- Be poised to embark on informed design of the next large machine (Nu Factory/Muon Collider)

Strategy – Near Term Goals (1-3 yrs)

- Remote Handling and Long Term Radioactive Component Storage
  - Commission C-0 Remote Handling Facility
  - Begin construction of LT RC Storage Facility
- Continue radiation damage materials testing
  - Finish current data analysis of LBNE graphite testing
  - Start irradiation of 2nd generation candidate materials
- Single pulse failure testing of target materials at a suitable facility (GSI, AP-0, CERN)

Note: Not including Project CD milestones

Strategy – Near Term Goals (1-3 yrs)

- Organizational
  - Create HPT team or department
  - Tap into global HPT community to form R&D collaboration
  - Establish network of vendors (incl labs and universities) to design/build high quality target facility components
  - Fully understand Project X era experiment target requirements

Note: Not including Project CD milestones

Project X era target requirements (?)

Beamline	Energy GeV	Power kW	Target material	Power (in target) kW	Sigma mm	Power/3sigma kW/mm^2
Neutrino (LBNE)	120	2400	graphite (Be?)	15	1.5	0.24
Muon (Ring)	3	1000	tungsten??	200	2	1.77
Muon (CRFI)	3	1000	tungsten??	200	2	1.77
Kaon (Chrg/Ntrl)	3	1000	carbon??	4	3	0.02
Nuclear	1	1000	Thorium??	500	10	0.18
Irradiation	1	1000	Various	300	10	0.11
ADSR	1	1000	Lead-Bismuth Eutectic	1000	10	0.35

	Spill length usec	Bunches #	P per Bunch #	P per spill #	Bunch length nsec	Bunch spacing nsec	Spill spacing sec
Neutrino (LBNE)	9.5	504	3.20E+11	1.60E+14	2	18.9	1.3
Muon (Ring)	??	??	1.90E+08	??	0.04	12.4	1.00E-06
Muon (CRFI)	??	??	1.90E+08	??	0.04	12.4	1.00E-06
Kaon (Chrg/Ntrl)	??	??	1.90E+08	??	0.04	12.4	1.00E-06
Nuclear	??	??	1.90E+08	??	0.04	12.4	1.00E-06
Irradiation	??	??	1.90E+08	??	0.04	12.4	1.00E-06
ADSR	??	??	1.90E+08	??	0.04	12.4	1.00E-06

Strategy – Mid-term Goals (4-7 yrs)

- PoT (protons on target) goals for operating target facilities
- Complete conceptual design of Project X era target facilities
- Continue radiation damage and single pulse failure testing of candidate target/window materials
- Commission new Long Term Radioactive Component Storage Facility
- Continue to build, fill in the HPT group with needed personnel

Note: Not including Project CD milestones

Strategy – Long Term Goals (8-10 yrs)

- Complete detailed design and begin construction of Project X era target facilities
- PoT goals of operating target facilities
- Continue to contribute to the global HPT community by establishing a sustained HPT R&D program including:
  - Irradiation Testing (Nuclear facility)
  - Single Pulse Failure Testing
  - Simulation and Analysis
  - Exploring novel target technologies and their applications

Note: Not including Project CD milestones

Strategy – Overall Plan

- Recent "white paper" on Target Support at the Intensity Frontier presents, in detail, the overall plan
- Lacks implementation schedule, but instead identifies the organization that needs to be in place over the next 5-10 years
- Reviewed by Target experts from ORNL, RAL, and CERN

- Scope
  - Operational Support
    - NuMI/NOvA (700 kW)
    - LBNE (700 kW)
    - Mu2e
    - G-2
    - MiniBooNE
  - Future Target Facility R&D
    - LBNE (2.4 MW)
    - Project X era facilities (Kaon, Muon, Nuclear)
    - Muon Collider/NuFact
    - LHC Collimators

Targets at the High Intensity Frontier

The Ideal Target Support Group at Fermilab

Patrick Hurh

ABSTRACT

Current Fermilab efforts to support targets and related systems and technology have been spread across Accelerator Division Departments dictated by the specific needs of various projects. This has resulted in a rather scattered and reactionary support effort without the cohesive and forward-looking vision required for Fermilab on the cusp of the High Intensity Frontier. This document describes an ideal Target Support Group (Department)

- Capabilities Required
  - Leadership
  - Mechanical Design
  - Multi-Physics Analysis
  - Physics Simulation
  - Material Science
  - Fabrication & Assembly
  - Pulsed Power Engineering
  - Cooling Utilities
  - Remote Handling
  - Alignment and Metrology
  - Health Physics
  - Instrumentation

Note: Text in red denotes areas of great need

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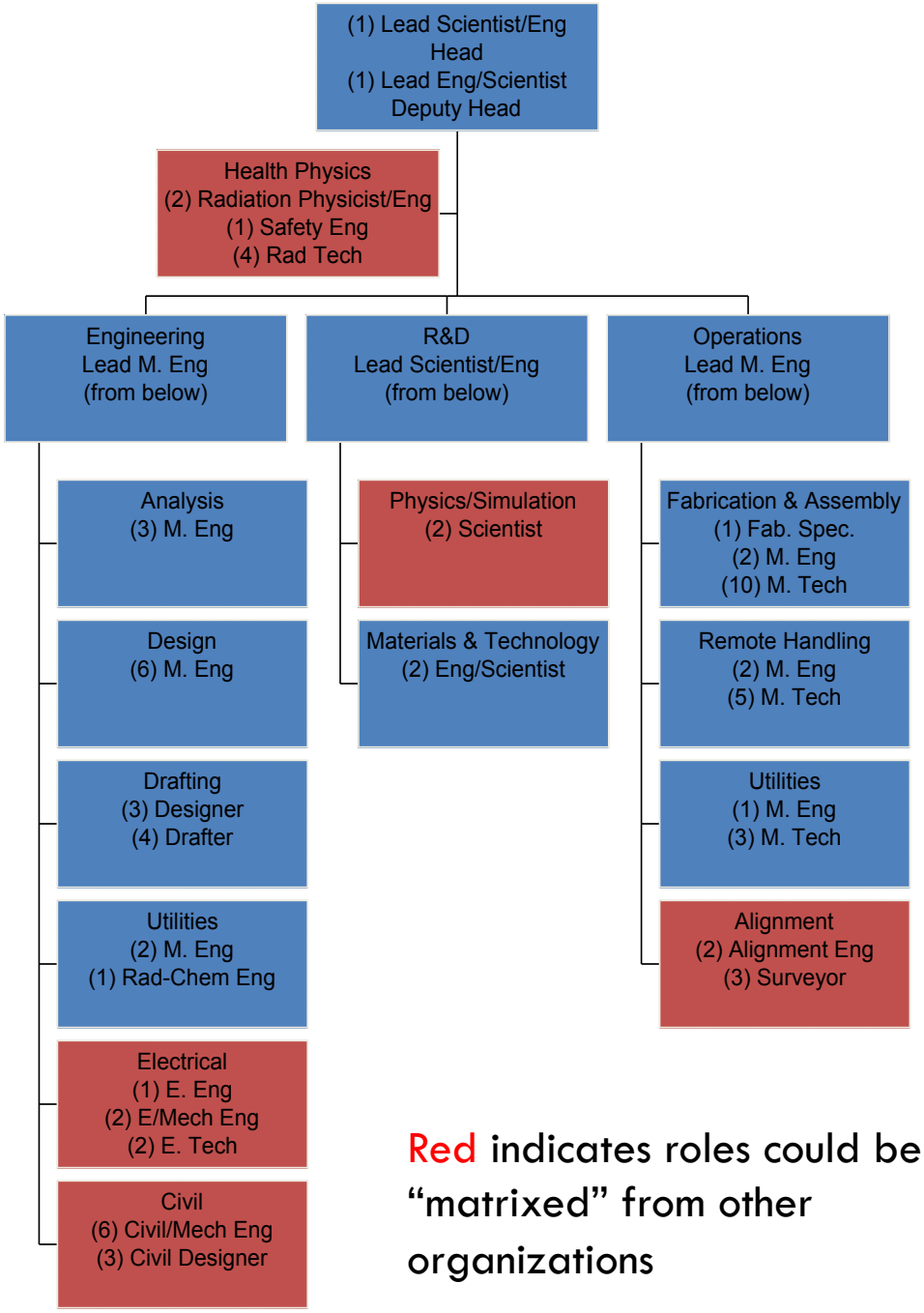

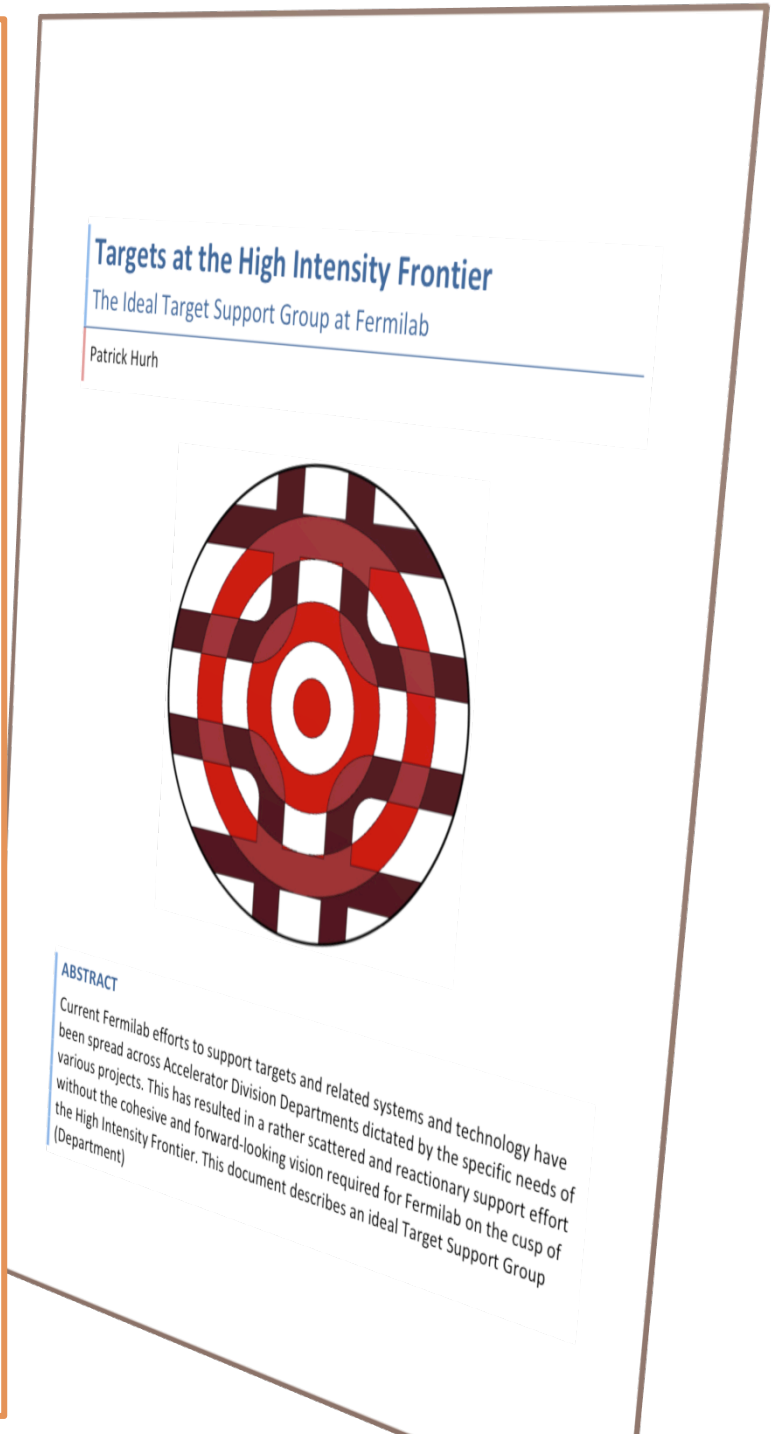

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Resource Type	Ideal Target Group	Matrix-ed Target Group	Current Target Support	Current Matrix-ed Target Support
Physicist/Scientist	4	2	2.5	0
Mechanical Engineer	17	17	11	8
Mechanical Tech	18	18	12	10
Mechanical Designer	3	3	2	2
Mechanical Drafter	4	4	2	2
Fabrication Specialist	1	1	.5	.5
Electrical and Electro-Mech Engineer	3	0	.5	0
Electrical Tech	2	0	.5	0
Health Physics Physicist/Engineer	2	0	1	0
Health Physics Radiation Tech	4	0	2	0
Safety Engineer	1	0	1	0
Rad-Chem Engineer	1	1	.25	0
Civil Engineer	6	0	4	0
Civil Designer	3	0	1.5	0
Alignment Engineer	2	0	1	0
Surveyor	3	0	2	0
Totals	**74**	**46**	**43.75**	**22.5**

- 74 FTE required for full support
- Approximately twice what we have currently
- Probably a low estimate depending upon Project X era target facilities requirements

- Current Facilities
  - MI-8
  - C-0 RHF
  - TSB
  - AP-0
  - MI-65
- Additional Req'd Facilities
  - LT Radioactive Component Storage
  - Assembly and Test Area
  - Radioactive Work Cell
  - Offices

Note: Does not include actual experimental target facilities

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Expense Description	Year-One Costs (K$)	Out-Year Costs (K$)
Thermal Shock Testing	50	30
Irradiation Testing	100	50
Remote Handling Concepts	30	30
Material Studies	50	30
Analysis (software & computing)	310	75
Travel	75	75
Professional Development	50	50
Test Stand Development	50	20
Specialized Tools (LDV, etc)	50	30
Totals	**765**	**390**

Note: Only includes General Target R&D M&S costs (not labor, experiment/project and/or facility M&S costs)

Strategy - Barriers

- Budget
  - Not enough to fund from projects alone
- People
  - Need more in specific areas
  - Can't do this alone: Need to extend/expand current collaborative activities
- R&D/Remote Handling gets pushed "off-project"
  - Fine, in theory, but rarely gets addressed appropriately once off the radar

Near Term Plan – FY 12 Activities, Deliverables (D), Metrics (M)

- Project/Operations related
  - Mu2e CD-1 (D: CDR, M: Approval)
  - G-2 CD-1 (D: CDR, M: Approval)
  - LBNE CD-1 (D: CDR, M: Approval)
  - NOvA upgrade construction/installation
  - Complete NuMI/MINOS/MINERvA runs (D/M: PoT goals)
  - Continue MiniBooNE running (D/M: PoT goals)
- R&D related (LBNE currently funding)
  - Complete BLIP graphite irradiation test data analysis (D: Final Report)
  - Begin Be 2.4 MW target conceptual design study (D: Accord in place)
  - Be single pulse testing plan (NOvA, GSI?)

Near Term Plan – FY 12 Activities, Deliverables, Metrics

- Infrastructure/Organization related
  - Project X era target facilities requirements report (D: Report, M: Review)
  - LT Radioactive Storage Task Force Recommendation (D: Report)
  - MOU with STFC in place (with work packages for collaboration identified) (Proton Accelerators for Science and Innovation Workshop, January, 2012) (D: MOU)
  - Identify collaborators with material science experience for material characterization (ANL?, LANL?, GSI?)

Near Term Plan – FY 13/14 Activities

- Project/Operational related
  - Mu2e CD-2/3?
  - G-2 CD-2/3?
  - LBNE CD-2
  - NOvA CD-4
  - Project X era experiments CD-0/1??
  - NOvA (and MiniBooNE) operations

Near Term Plan – FY 13/14 Activities

- R&D related
  - Finish LBNE 2.4 MW Be target conceptual design study
  - Finish Be single pulse failure testing(?)
  - Any required Project X era HPT R&D (may be quite a lot)
- Infrastructure/Organizational related
  - Construction of LT Rad Storage Facility
  - HPT Support organization established

Resources

- Near Term
  - Project and operational activities utilize almost all available resources
  - Leaves few resources to accomplish R&D and Infrastructure/Organization activities
  - Some minor progress in R&D and Infrastructure/ Organizational activities by myself and collaborators (RAL, BNL, ORNL), but need at least 4-5 FTE more to achieve FY12-14 goals listed
- Long Term
  - White Paper indicates 30-40 FTE needed to achieve 10 year goals (plus additional facilities and infrastructure)

Risks

- Technical Risks
  - Could be many of these depending upon Project X era target facilities requirements
  - See list of engineering challenges PLUS:
    - ADSR – spent fuel on site?
    - Increased radiological release?
    - Approaching "Nuclear Facility"
- Scope, and Schedule Risks
  - Largely related to lack of available, knowledgeable resources and lack of "generic" HPT R&D funding
  - Visibility of HPT challenges appears to be lower than appropriate at FNAL (talk to SNS, CERN, and PSI)
  - HPT facility requirements need to be determined and "vetted" ASAP to determine HPT R&D work in near future.

Motivation!


Ta-rod after irradiation
with 6E18 protons in
2.4 μs pulses of 3E13
at ISOLDE