120 GeV Targeting

Neutrino beams utilizing 120 GeV protons from Project X Main Injector

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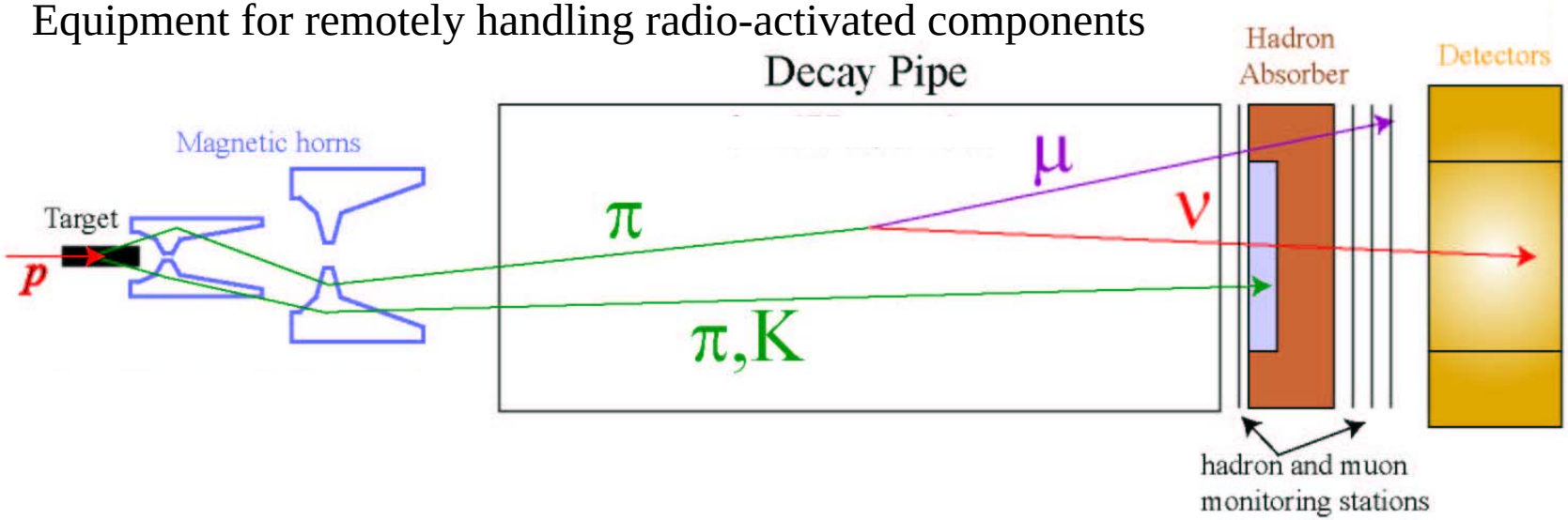
Outline

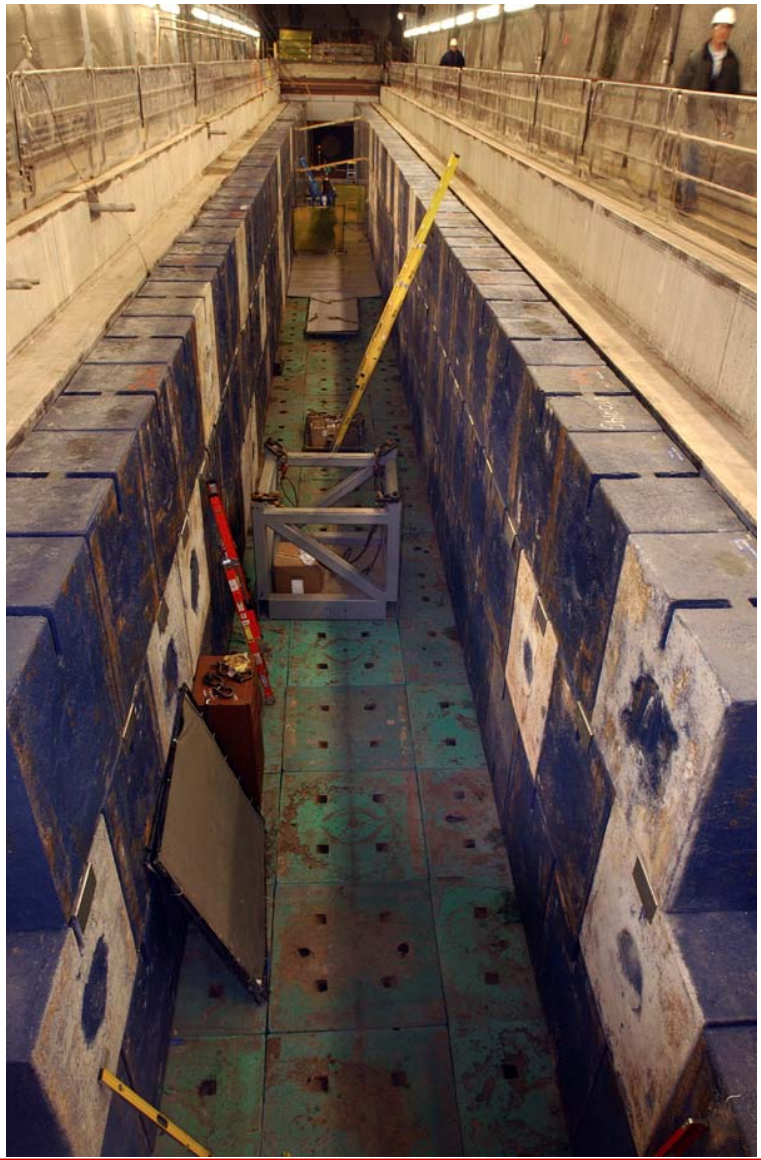
- Overview of components that make up a conventional neutrino beam-line
- Issues related to a new neutrino beam-line, utilizing the specific example of a detector at the Homestake Mine DUSEL site
- Issues related to use of Project X beam for the existing NuMI beam-line

Components of a conventional ν beam-line

Transport line carrying protons to target
Vacuum window at end of transport
Target, producing pions from proton interactions
Magnets (horns) to focus pions
Drift space to allow pions to decay to neutrinos (vacuum or helium)
Absorber to catch left-over beam
Lots of radiation shielding
Cooling (Radio-activated water systems)
Ventilation
Instrumentation
Equipment for remotely handling radio-activated components



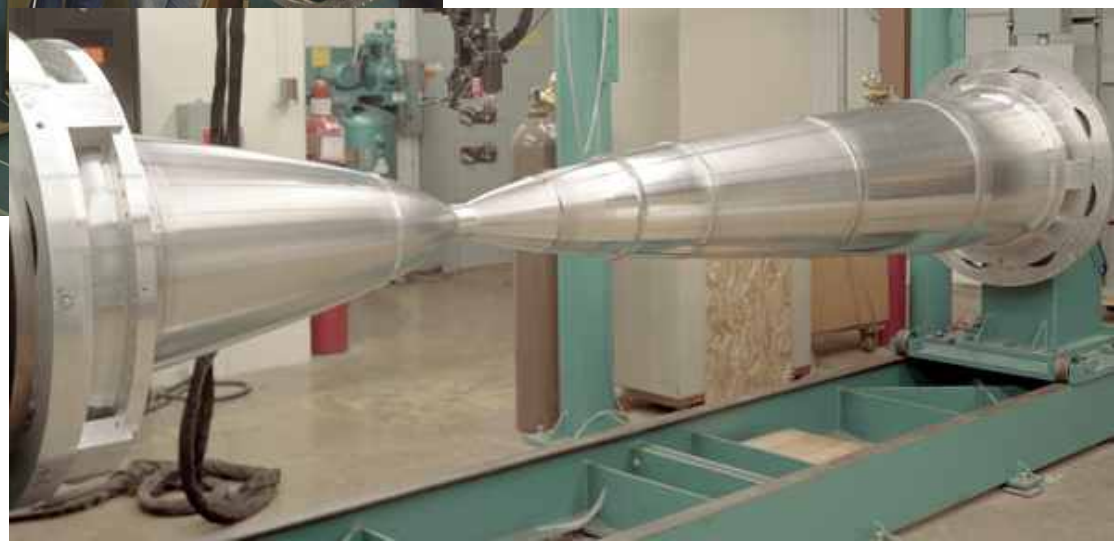
Target Hall, Decay Pipe, Beam Absorber

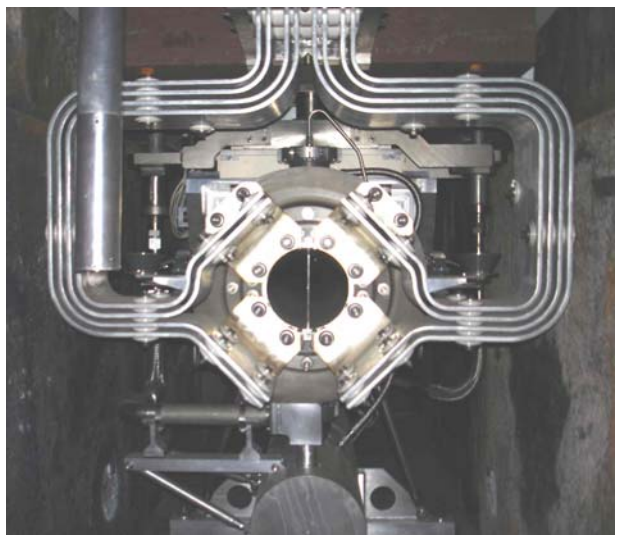


Target

Horns

Parabolic inner conductors:
- 3 Tesla max. magnetic field
- 3 m active length each horn
- 200 kA current pulse

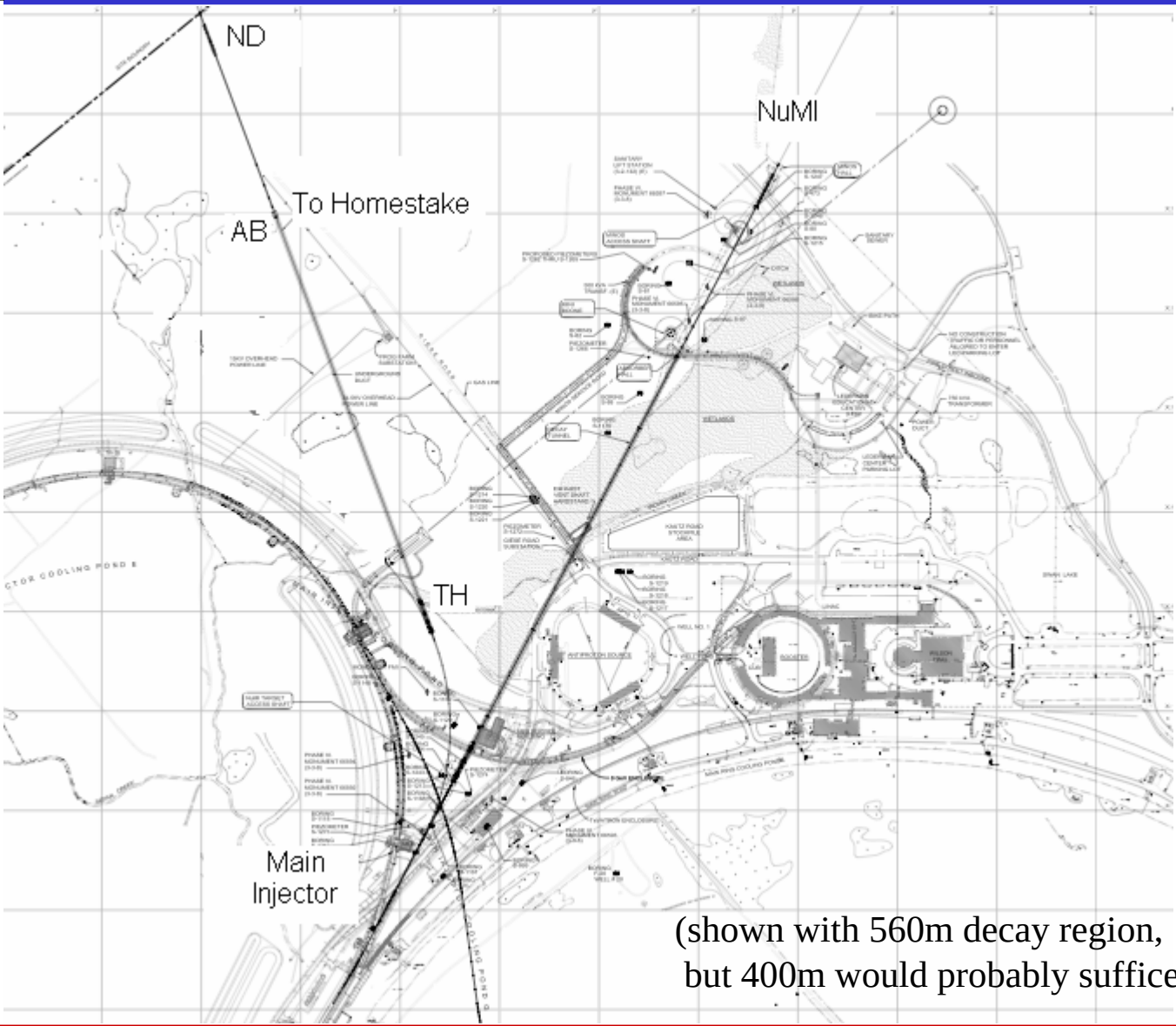




Proton Beam Parameters for Project X

Proton Beam Parameter	Comment
120 GeV beam energy	yields 2.3 MW beam power
1.7e14 Protons on target / spill	
1.4 second repetition rate	
10 microsecond spill length	Single turn extraction
2.4e21 Protons on target / year	Based on 2e7 seconds per year full power
25 pi-mm-mrad 95% transverse emittance from Main Injector (M.I.)	Estimate of what will be delivered by M.I.
momentum spread from Main Injector: 95% half spread at extraction to be smaller than 8E-4	Estimate of what will be delivered by M.I.
1.5 mm RMS beam spot size on target	Required by target design
~0.1 mm rms proton beam jitter on target	Driven by experimental systematics

New Beam-line to DUSEL (Homestake Mine)



(shown with 560m decay region,
but 400m would probably suffice)

Issues for new beam-line to DUSEL

Issues considered	Conclusion / Comment
Would a new beam-line directed toward DUSEL fit on the FNAL site?	Yes, including transfer line, target hall, decay pipe, absorber, rock for muon range-out and near detector.
Is there a target design that can survive these beam parameters?	Yes (*NuMI Note 1100, IHEP Protvino*). Target stresses are OK for a graphite target (graphite is currently used for the NuMI target); some development is needed for design of cooling.
Can a beam window survive? (Transition from accelerator transfer line vacuum to target hall)	Yes, based on scaling energy deposition density per spill by spot size from existing AP0 Beryllium window. May have to add active cooling to the window.
Would existing section of transfer line have acceptable radiation loss?	Yes, estimated emittance and momentum spread are consistent with existing transport line design.
Are there any other target hall / decay pipe / absorber issues that are technology limited?	None of the other components push the limits of current technology.

Issues for upgrading the NuMI beam-line

There is limited ability to upgrade the decay pipe and absorber of the existing NuMI facility because these systems are already radio-activated and are not designed for remote handling.

Preliminary studies indicate the issue limiting potential beam power is stress between the steel decay pipe and the concrete shielding cast around it, with the resulting limit being about 2.0 MW.

The engineering code requires a large safety factor because the decay pipe is a vacuum vessel. If we fill the decay pipe with 1 atmosphere of helium, the decay pipe would no longer be a vacuum vessel, and we could operate closer to the actual calculated failure stress point, and thus at higher power (2.3 MW). This solution requires further study.

Based on previous studies for the MINOS experiment (*NuMI-note 777*), the additional helium would reduce neutrino flux by a few percent.

Issues possibly limiting beam power to NuMI

NuMI Issue	Conclusion / Comment
Ground water activation	Groundwater activation limits will not be exceeded by the projected number of protons per year (*Beams-doc-2844*)
Radioactive Air Emissions	Calculations indicate that radioactive air emissions would be just below regulatory limits (*Beams-doc-2844*). Alterations such as slowing down the ventilation fans would provide a safety factor.
Decay Pipe Window	(i) Calculations indicate that an accident pulse which missed the target and reached the window would be problematic. This can be mitigated by having the baffle upstream of the target completely occlude the area where beam would miss the target. (ii) Although direct radiation damage to the window is not expected to be problematic, accelerated corrosion due to the high radiation environment is a concern. This concern could be ameliorated by filling the decay pipe with 1 atmosphere of helium, thus reducing the stress on the window.
Decay Pipe	Stress due to thermal expansion may limit operation to 2.0 MW beam power (*Beams-doc-2845*), mitigate with helium ?

Issues possibly limiting beam power to NuMI - continued

NuMI Issue – cont.	Conclusion / Comment
Hadron Absorber	(i) Calculations indicate the absorber can handle normal operating conditions with 2.3 MW beam (ii) An accident condition where beam mis-steered off the target would hit the absorber can be prevented by changing the upstream target / baffle geometry. (iii) In an accident condition where cooling water flow fails, water could turn to steam where pipes pass through holes in the downstream steel slabs of the absorber. (At 2.3 MW, the innermost steel slab will reach 800 C). Requires further study, and may necessitate mitigation. (*Beams-doc-2845, Bob Wands*).
Residual Dose in work areas	Dose rate can be mitigated with additional shielding (*see Beams-doc-2844, Kamran Vaziri*)
General degradation by radiation damage, accelerated corrosion	Direct radiation damage will not be limiting (*although extra shielding for electronics in the target hall is needed*). Accelerated corrosion is hard to quantify, and further study/experience is needed.

Issues for upgrading the NuMI beam-line

One reason that it is possible to think of using a decay pipe and absorber meant for 0.4 MW of beam for the case of 2 MW beam is that the original systems were built with redundancy (extra cooling lines) and safety factors.

A concern operationally is that for Project X beam we would be using that redundancy / safety factor for base operations.

For instance, if a water line fails during 2 MW operation, one will need to figure out a way to repair the water line, whereas at NuMI base design power we can just turn it off and keep running.

A risk analysis should be done, but is beyond the current study.

NuMI components that may need upgrading

NuMI upgrades	Comment
Target	Preliminary design is described in *NuMI Note 1100*, IHEP Protvino, July 30, 2005
Horns	The outer conductor of each horn will require increased water cooling.
Hadron Monitor	Existing monitor would saturate; need smaller ionization gap
Beam profile monitor ?	Could certainly use the existing monitors if we drive them out of the beam for high intensity running, so did not examine this issue further
Cooling of beam pipe window	Forced air on face or water at edge
Target pile cooling	Have explored the concept of water-cooled panels lining inner walls of steel shielding
Decay pipe cooling	Increase water flow rate
Absorber cooling	Handle case of water steaming at steel penetrations if pumps fail

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NuMI components that may need upgrading -continued

NuMI components to be upgraded	Comment
RAW skids	Increase heat exchanger capacities
Cooling pond	May exceed capacity of existing cooling ponds, or evaporate tritium as ALARA
Equipment to handle and transport radioactivated horns and target	May want to dig a new side-tunnel for storage of broken horns. Will need increased shielding when working on horns and target.
Refurbishment or replacement of crane rails, target hall drip ceiling, etc.	Depends on corrosion rate and deterioration seen.
Horn and target support modules	Depending on corrosion seen, may build replacement modules.
Equipment for further air containment	Allow more time for decay of short-lived radionuclides in the air
Further shielding for electronics located inside the target hall	Increase thickness of exiting poly shielding

Conclusions

I. No showstoppers for Project X beam to a new neutrino beam-line (DUSEL)

- the specified beam parameters for 2.3 MW can be handled by a conventional neutrino beam-line

II. The technical limit to beam power that could be accepted by an upgraded NuMI beamline is ~ 2 MW

- however risk analysis is needed because of reduced redundancy and safety factor for very difficult-to-repair decay pipe and absorber