Neutrino beams from the Main Injector for Project X

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Workshop on Physics for a high intensity proton source
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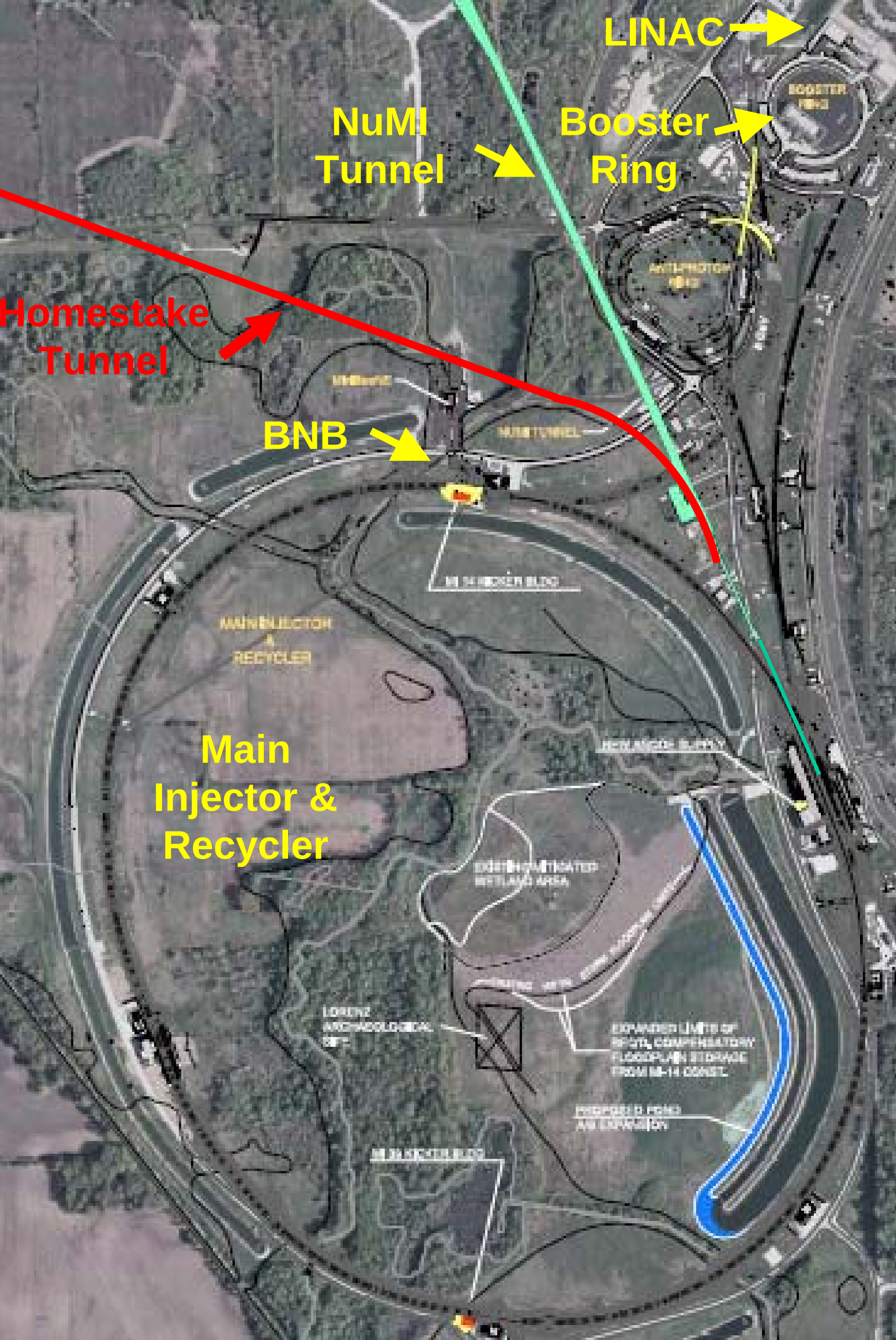
With thanks to Mike Martens, Patrick Hurh, Dixon Bogert,
and others for their work



Two options are being discussed:

i) upgrade the existing NuMI beamline to handle higher power

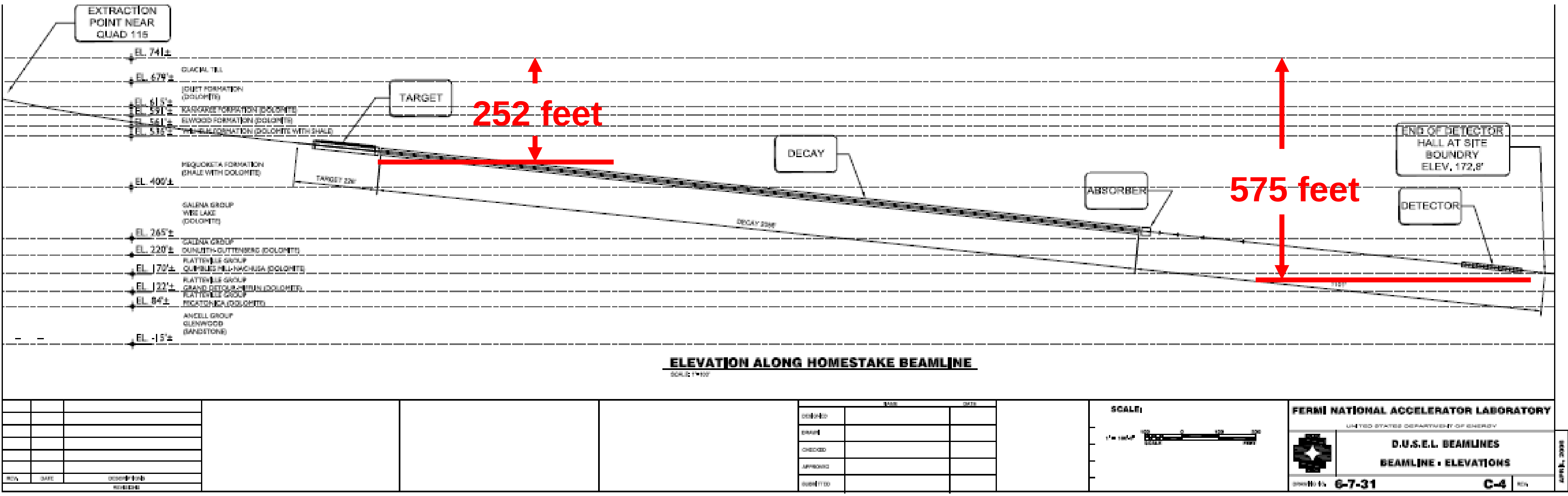
ii) Build a new beamline directed at DUSEL/Homestake

Both lines share the existing MI-60 extraction system

M.I. Proton Beam Parameters for Project X

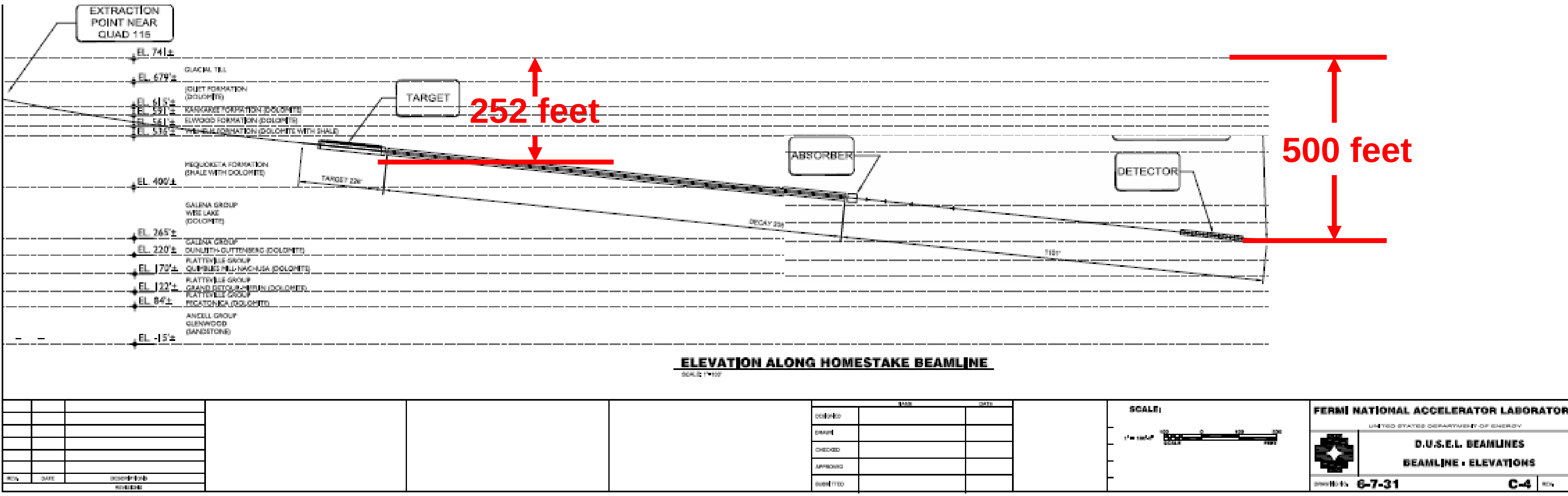
Proton Beam Parameter	**Comment**
120 GeV beam energy	yields 2.3 MW beam power *(Could also run at 60 GeV with 2.3 MW)*
1.7e14 Protons on target / spill	
1.4 second repetition rate	
10 microsecond spill length	Single turn extraction
2.4e21 Protons on target / year	Based on 2e7 seconds per year full power

Maximum DUSEL beamline that would fit on-site



This elevation view of the Homestake Beamline (-5.84°) is drawn to take the detector to the site boundary at Kirk Road. The maximum decay pipe length available in this configuration is about 627m (compare to NuMI at 675m). The detector hall (and shaft) is about 575 feet deep (compare to MINOS at about 336 feet). This is still in the Galena-Platteville but deep.

Second Option Elevation View of the Homestake Beamline



This elevation view of the Homestake Beamline (-5.84º) is drawn with the decay pipe limited to 400m. This shortens the beamline by 741 feet, and lifts The detector hall (and shaft) by about 75 feet (500 feet deep). Overall, this configuration will be cheaper to build and is probably adequate.

Cost / Schedule courtesy of Dixon Bogert

“A DUSEL neutrino facility based upon the Main Injector, hopefully with Proton Driver-like intensities, is certainly technically possible at this site.

The design shown is similar in many respects to the NuMI/MINOS-NOVA facility already in existence, so most issues have been demonstrated to be manageable (rock tunneling, etc. etc.)

I expect costs (inflation adjusted) to be similar to NuMI/MINOS costs:
The decay tunnel is larger diameter but shorter. The shafts are deeper, but the extraction system and carrier tunnel exists. The west bend is necessary for several reasons, but is not a large tunnel cross section. The new target hall could be shorter if there is no requirement for a high energy 2-horn configuration. Outfitting costs would be similar.

The construction schedule would be similar.”

(NuMI was ~$120M, 6.3yr from baseline review to CD4/operations)

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. (This study was done assuming vacuum in the decay pipe.)

The engineering code requires a large safety factor because the decay pipe is (was) 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 possibly thus at higher power (2.3 MW). This solution requires further study. *(The NuMI decay pipe is filled with helium as of Nov. 12, and we expect to operate that way from now on).*

Monte Carlo predicts the addition of helium reduces 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 reduced 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
Target	(i) Calculations indicate that a solid graphite target (not radically different from what NuMI currently uses) can handle normal operating stress with 2.3 MW beam (ii) Estimate of radiation damage give ~1 year lifetime, but proton radiation damage not well known. (iii) Exiting water cooling style leads to high values of hydraulic shock. R&D needs to be done on target cooling schemes.
Residual Dose in work areas	Dose rate can be mitigated with additional shielding (*see Beams-doc-2844, Kamran Vaziri*)

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*).
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 was beyond last summer's study.
An R&D program has now been written down to address these issues.

NuMI upgrade cost/schedule

A WBS has been developed to do R&D necessary to have TDR by 2012 for upgrade of NuMI. For example, a high priority item is to develop a capability to remotely put in place a decay pipe window.
The cost estimate is $15M fully burdened.

Some of this R&D (e.g. horn and target design for higher beam power) is also needed for a possible DUSEL TDR, some is NUMI specific.

A Physicist WAG of project cost (2012 to completion)
was done by Mike Martens, ~$22M.

The neutrino beamline upgrades would probably not be the critical path for Project X beam schedule – would be set by completion of the accelerator.