Pacific Northwest National Laboratory Overview for SiD Workshop

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August 22, 2012

Presentation Outline

- Introduction to PNNL
- Overview of HEP at PNNL
- Status of Computing for SiD at PNNL
- Status of Update to e+e- → $t\bar{t}$ at 500 GeV
- Cost Saving Potential of siting ILC at Hanford

Pacific Northwest National Laboratory: Battelle-managed and mission-driven

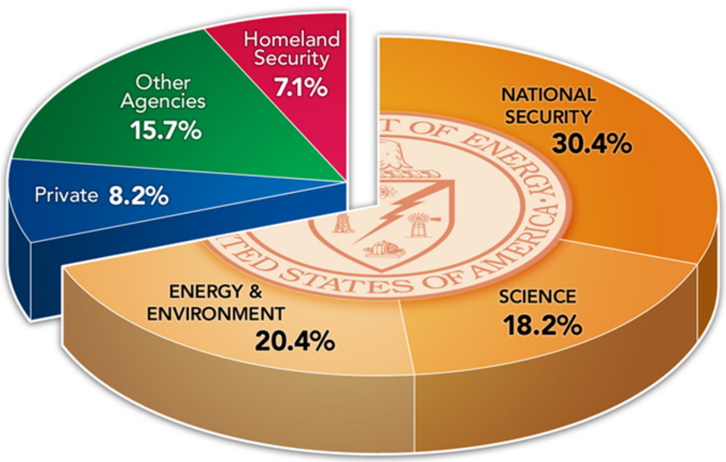
<u>Our vision</u>

PNNL science and technology inspires and enables the world to live prosperously, safely, and securely

- DOE Office of Science Laboratory
- Operated by Battelle since 1965
- Outstanding science, impactful solutions

PNNL facts & figures for FY2011

- $1.1 billion in R&D expenditures
- 69% of cost is from DOE
- More than 4,800 staff, including 3,000 technical staff
- 994 peer-reviewed publications
- 49 patents issued



- Among top 1% of research institutions in publications and citations in:
  - Chemistry
  - Geosciences
  - Physics
  - Engineering
  - Biology and Biochemistry
  - Environment/Ecology
  - Materials science
  - Clinical medicine
  - Microbiology

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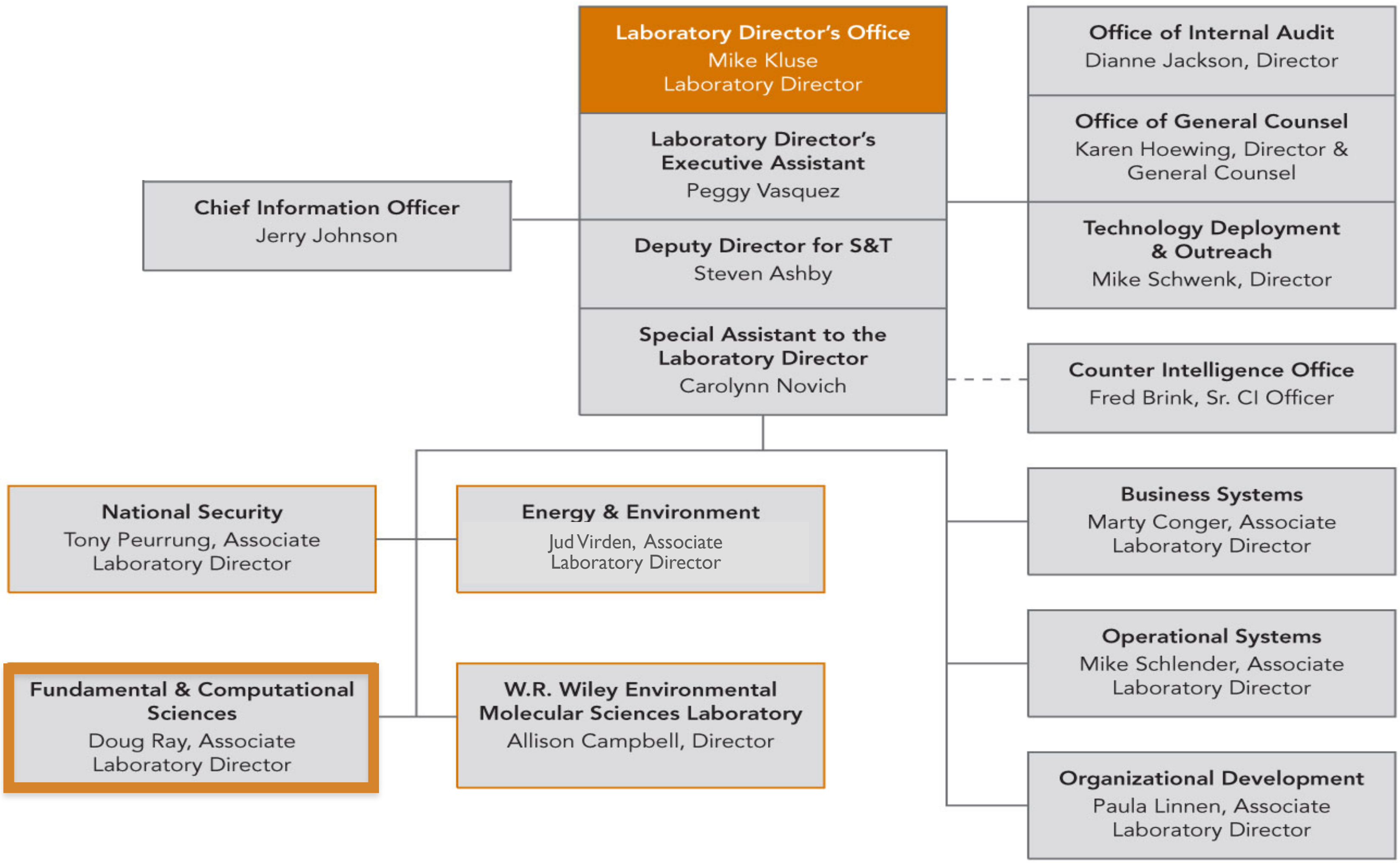
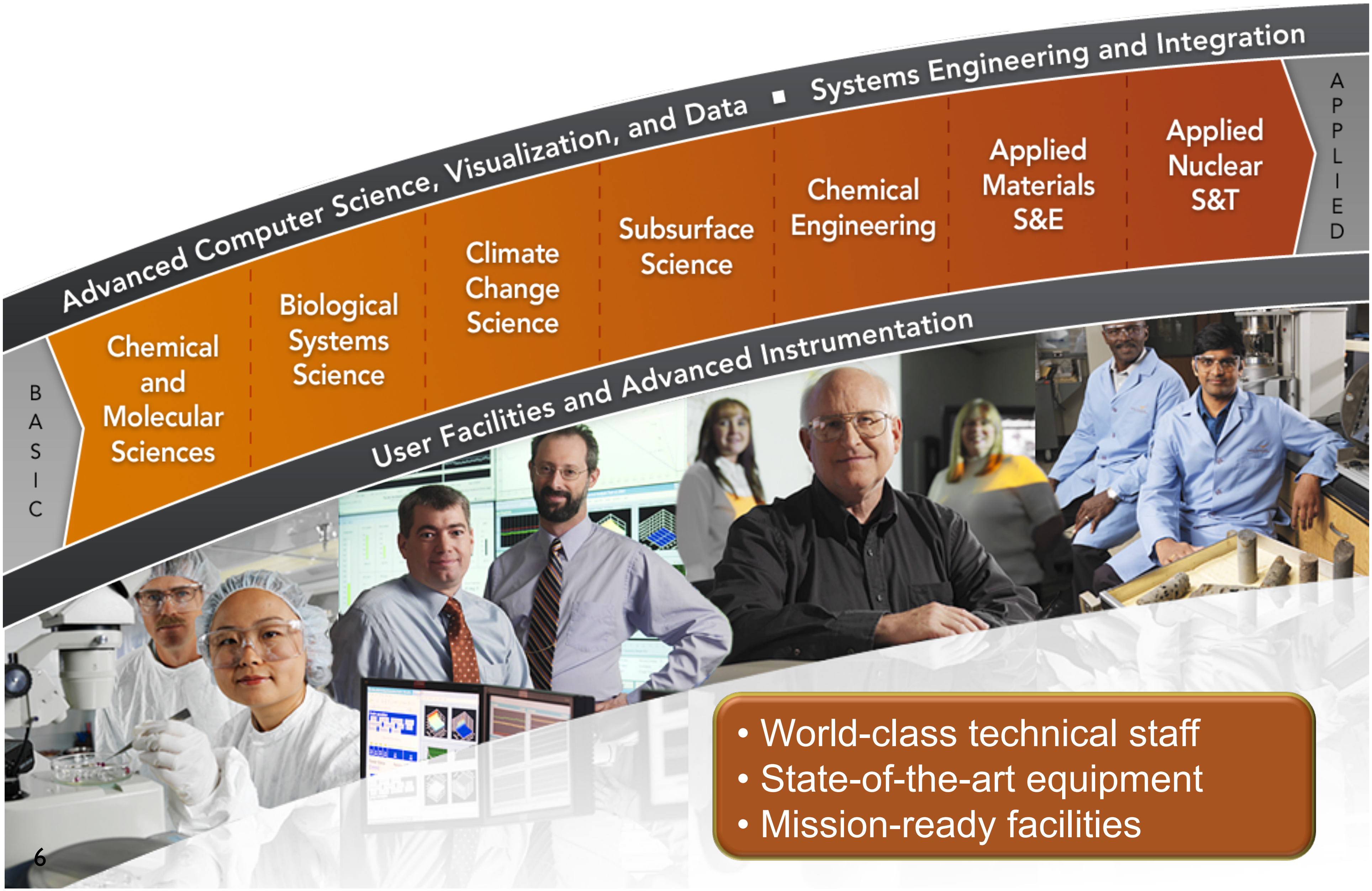


PNNL nurtures ten Core Capabilities



- World-class technical staff
- State-of-the-art equipment
- Mission-ready facilities

High Energy Physics at PNNL

- (Mostly) High Energy Physics Projects
  - Heavy Flavor Physics (Belle, Belle II)
  - Dark Matter Science (CoGeNt, C4, …)
  - Neutrino Physics (Majorana, Project 8) (Nuclear Physics)
  - Collaboration with FNAL (Mu2e, Project X, PXIE)
  - Fission TPC (DOE-NE)
  - HEP Computing (Belle, Belle II, Fission TPC, ILC, Project 8)
- Related R&D
  - Extending underground science capability
    - Under ground laboratory, low background materials, assay, low noise electronics, radiochemistry, gas handling
  - Improved photocathode R&D for electron LINAC
  - Ion processing of Cu, Al to mitigate electron cloud
  - Nuclear LQCD calculations
  - Generic Detector R&D

Initial HEP Computing Capability at PNNL focused on Belle/Belle II Computing

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- May 2011
  - DOE approved funding to support PNNL project team from June 2011 through end of May 2012
  - PNNL approved funding for project team during transition to DOE funding
  - Substantial PNNL resources <u>temporarily</u> allocated for Belle Computing
- January 2012
  - Proposal submitted to DOE to support Belle computing at PNNL through the transition to Belle II
- July 2012
  - Transition from temporary to permanent computing resources at PNNL
  - SiD simulation effort will utilize the same resource – see next slide
- August 2012
  - Initial funding from DOE of January 2012 proposal arrives at PNNL

Original PNNL resources for Belle Computing to be retired at the end of July 2012

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- PNNL reconfigured NW-ICE cluster for Belle Computing
  - NW-ICE renamed “belle.pnl.gov”
  - 6 racks of 27 compute nodes with 8 cores
  - 1 PB disk/1 PB tape
- PNNL allocated 3% of 163 TF Chinook Super Computer (600k hours) in FY11 and FY12 for Monte Carlo Generation
- Data skims transferred from KEK
- MC samples generated at PNNL
- 95 Belle & 5 ILC users at PNNL
- **NW-ICE cluster retired at the end of July 2012**

Partnering with PNNL Institutional Computing

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- New Belle hardware is being added to PNNL Institutional Computing (PIC) resource (Olympus Cluster) providing
  - Infrastructure for computing & storage
  - Floor space in PNNL's Computational Science Facility
  - Power and cooling
  - Network infrastructure
  - Experienced support staff for general system maintenance
  - Surge capacity
- SiD allocation on Olympus cluster
  - 1.5M cpu hours, 200 TB storage

Progress toward grid at PNNL

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- Belle VO membership granted
- ILC/calice VO membership requested, waiting on access

- Installed and configured Open Science Grid middleware
  - Successfully submitted and completed test jobs using the Belle VO to our grid services
  - This grid service is now available to all members of the Belle VO
  - Grid service will have access to Olympus cluster

- Olympus Cluster Details
  - 624 compute nodes (planned to expand to 800) – ~1% HEP contribution
  - 32 cores per node (20k nodes)
  - 2 GB of memory per core
  - 4 PB of storage on disk
  - 3 PB of storage on tape

(Near) Future Work

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- Be able to utilize PNNL's Olympus cluster via the grid
  - Olympus stats: 162 Teraflops, 2.75 Petabytes shared Lustre storage, 840 Gigabytes local disk (scratch) space
  - osg.pnl.gov will be used to submit grid jobs (globus), then will in turn launch jobs on Olympus
  - Olympus uses SLURM for job management; OSG middleware does not currently support it as a batch system backend
    - PNNL is in collaboration with the University of Nebraska-Lincoln to support SLURM in the OSG grid software stack

- Key users (direct logon) to deploy ILC software on Olympus
  - No need to wait for ILC VO at PNNL to generate SiD simulation

- Support the Belle and ILC Virtual Organizations

"Pacific Network and Computing Requirements" Workshop hosted by PNNL - Oct 17-18, 2012

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- Workshop is being organized by PNNL-KEK-ESNET-Belle II
  - Is explicit ILC participation warranted?

- The purpose of this workshop is to begin preparation for addressing the wide-area networking requirements for science in general and of the Belle II experiment in particular. Objectives include: developing a common understanding of Belle II science objectives, discovery workflows, cyber-infrastructure requirements, and data models; discussing challenges posed by Belle II data rates; and developing a concrete plan for establishing a Belle II grid site at PNNL and assuring that adequate capabilities for data transport (including monitoring and measurement infrastructure) are in place and thoroughly tested before they are needed by the experiment.

- Please contact david.asner@pnnl.gov for more information

Status of Update to e+e- → $t\bar{t}$ at 500 GeV

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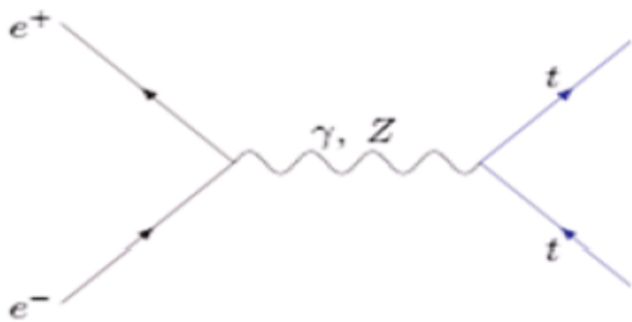
- Objective
  - Plan to continue the effort by Erik Devetak, Andrei Nomerotski, and Michael Peskin as written "Top quark anomalous coupling at the International Linear Collider" - **Phys.Rev. D84 (2011) 034029**
  - That is to develop analysis tools to measure:
    - Top-quark production cross section
    - Top-quark mass
    - Bottom-quark forward-backward asymmetry
    - Top-quark forward-backward asymmetry

Physics Motivation

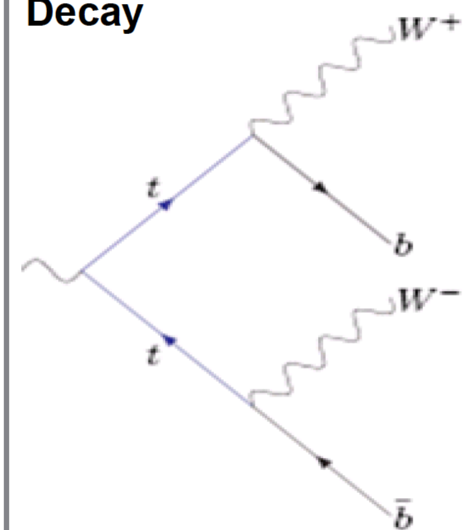
- The top quark is significantly heavier than any other known particle. Why? What is the underlying physics?
- Precision studies of top quark properties are important
- Top quark coupling to photon, Z and W bosons are among the interesting quantities to measure
- These quantities are not easily accessible at the the LHC

Signal Event Topology

ILC - main production channel



Decay



Br(t→Wb)~99.8%

Channels :

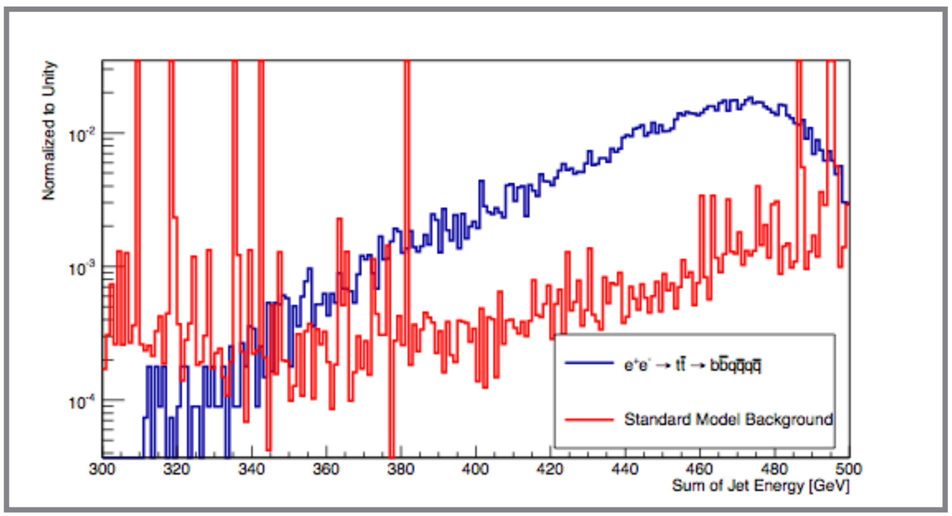
- $tt \rightarrow bbll\nu\nu$ *(11%)*
- $tt \rightarrow bbl\nu + 2\ jets$ *(44%)*
- $tt \rightarrow bb + 4\ jets$ *(45%)*

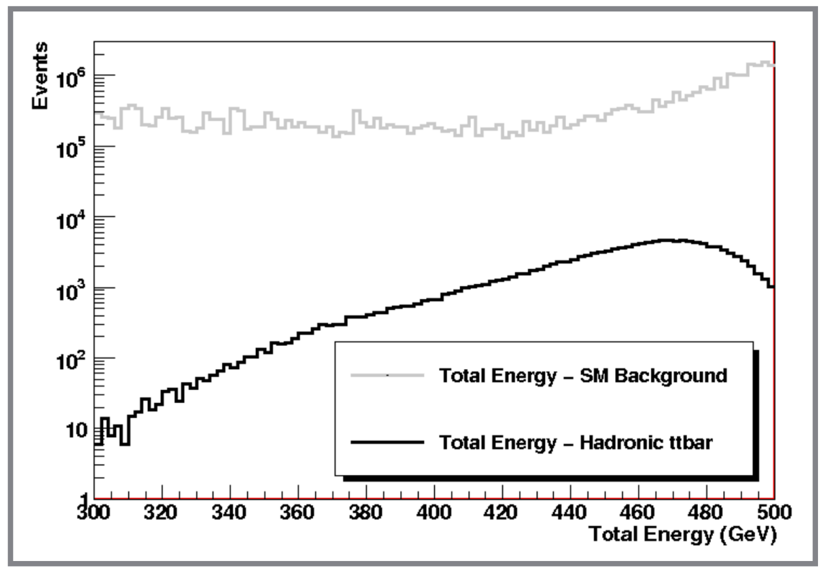
- Full event reconstruction
  - No undetected neutrinos
  - Allows kinematic constraints to
    - suppress background
    - Calibrate b-jet identification
    - Improve W, t mass reconstruction

Initial Comparisons with LOI Sample

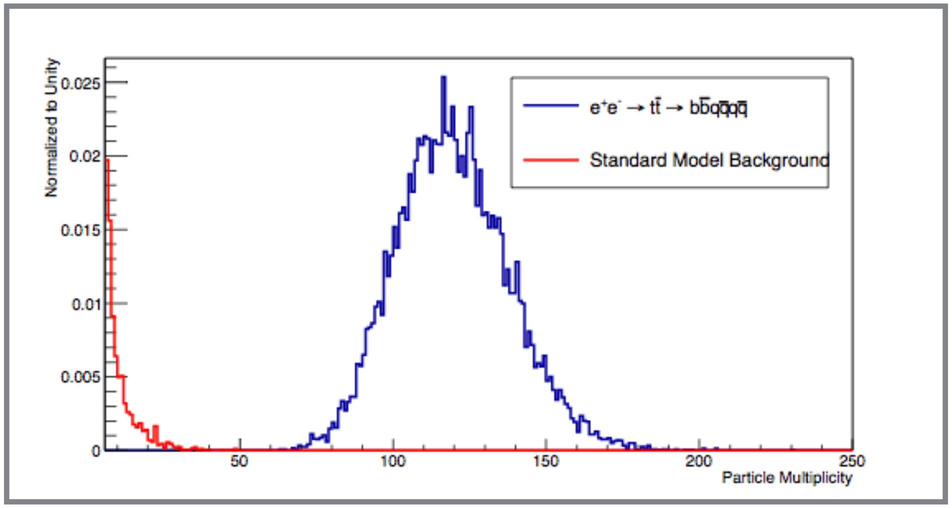
- Event Selection
  - Reject events with isolated lepton
  - Require 6 jets
  - Track multiplicity > 30
  - Sum of the jet particle constituent > 80

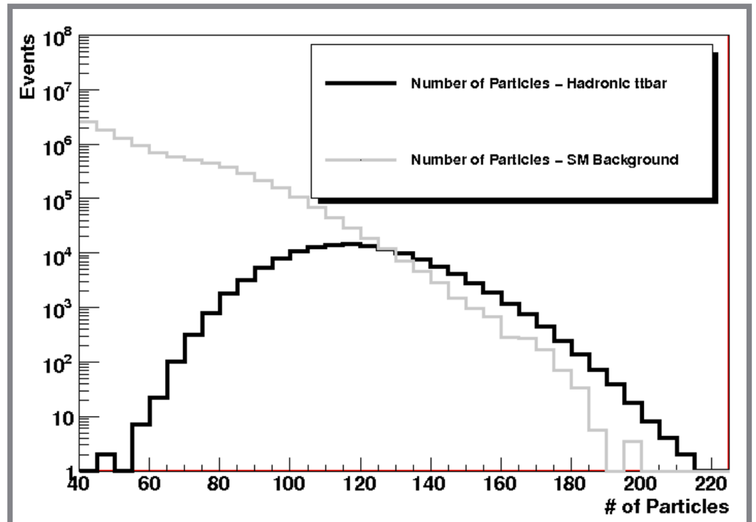
Note: Below and on the following slide(s) the B&W are from the Phys. Rev. D.
The color plots we have made for comparison to vet our analysis are low statistics using a small portion of the LOI samples.

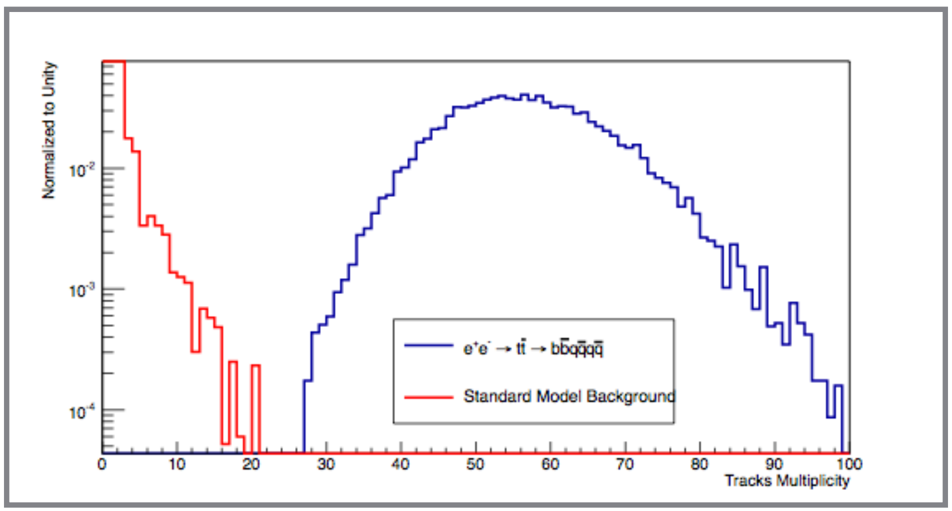


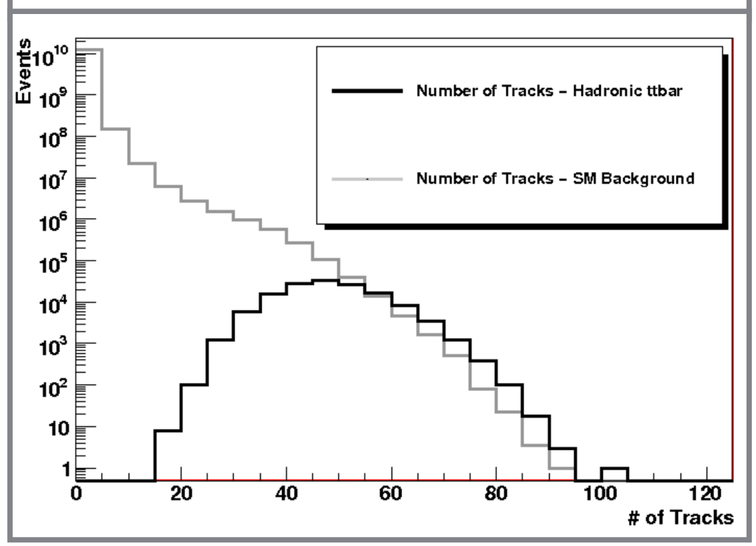


Event Selection Variables



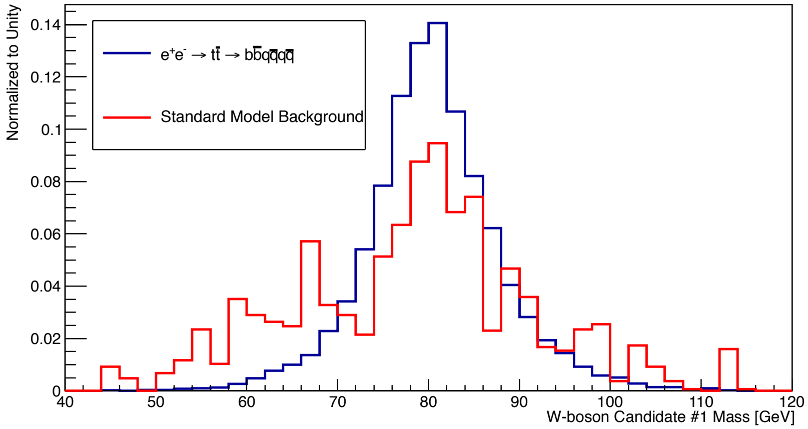


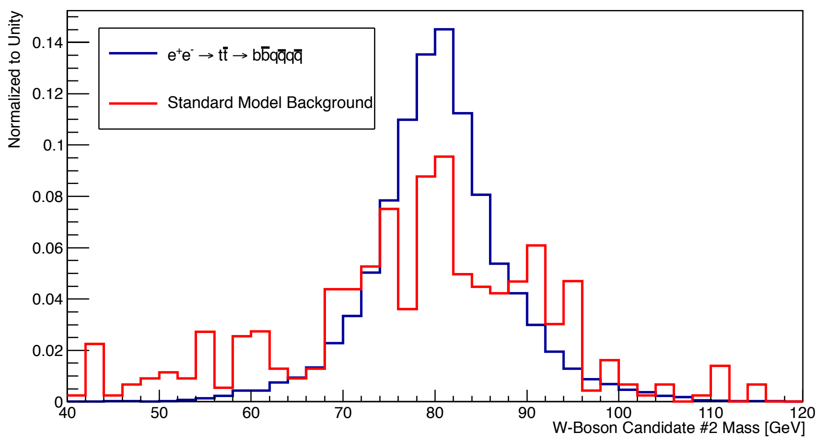




b jet Identification and W Boson Reconstruction

- b jet identification
  - LCFI flavor tagging algorithm identifies the two most likely b-jets
- W boson reconstruction
  - W's decay hadronically in signal events
  - Each W composed of 2 jets
  - Pairs of jets that compose each W are determined by minimizing the following equation

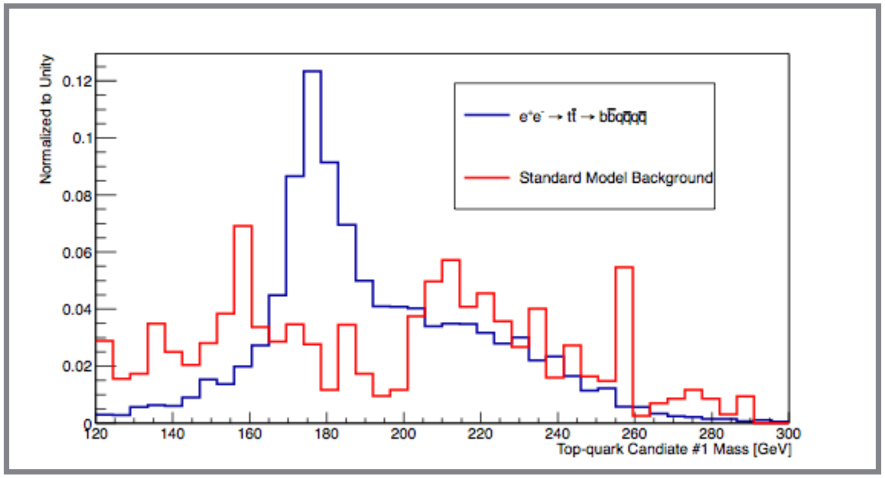


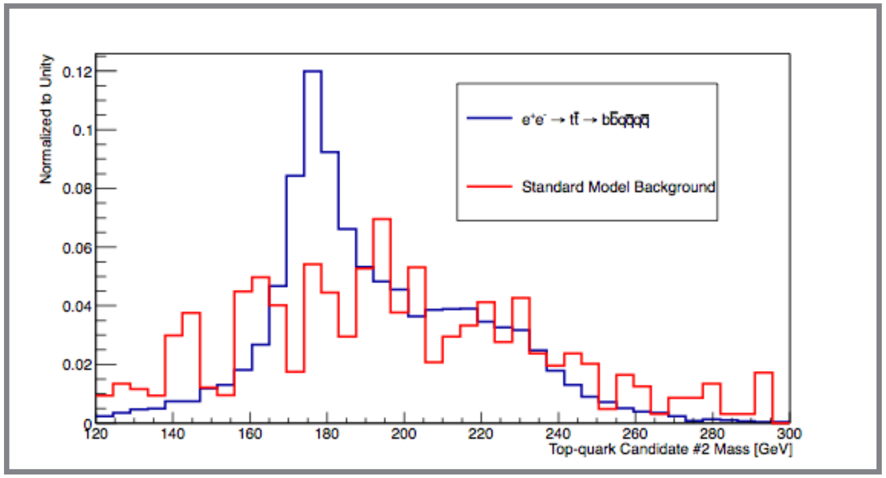


$$\Delta M = \sqrt{(M_w - M_{j1,j2})^2 + (M_w - M_{j3,j4})^2}$$

Top quark Reconstruction

- Top quark mass determined from global minimization using the W-boson mass and the 4-vector kinematic constraints
- Plots below do not (yet) include b-jet identification





Future Analysis Work

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- Investigate jet algorithms
- Study b-jet identification
- Optimize top reconstruction algorithm
- Study/develop quark charge reconstruction used for forward-backward asymmetry

There are significant near term and life cycle cost advantages of locating and operating an accelerator at Hanford

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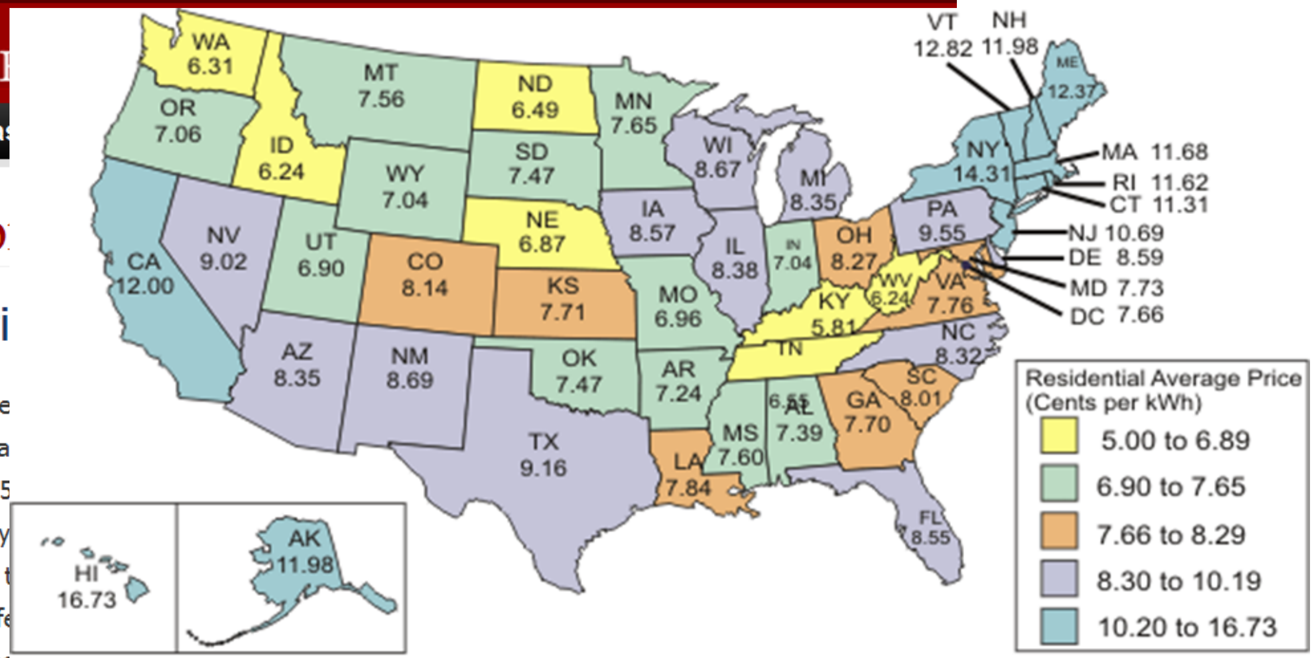
- Comparison between Richland and 5 other sites
  - Initial construction
    - Regional construction costs are 10%-15% lower at Hanford
    - Geography and geology could result in 5% additional savings
    - Estimate additional savings of cut & cover relative to tunneling on Hanford site to be (40±10)%
  - Life Cycle Operations
    - Electricity – annual bill could be up to 50% lower
    - Regional price differential is 10% - 15% on non-PNNL labor.
  - All other factors considered not materially different
    - ES&H, staffing, user support

Electricity cost is a significant advantage of the Hanford site

Midwest Informatio

Average Energy Pri

Chicago area consumers paid prices above
utility (piped) gas in October 2011, as mea
reported today. Electricity prices were 18.5
higher. In comparison, Chicago area utility
Commissioner Charlene Peiffer noted that t
(piped) gas prices narrowed while the diffe
this release are not seasonally adjusted; ac



Source: Energy Information Administration, Form EIA-861, "Annual Electric Power Industry Report."

Table A. Average prices for electricity, gasoline, and utility (piped) gas, United States and Chicago area, October 2010 and October 2011, not seasonally adjusted

	October 2010			October 2011		
	United States	Chicago area	Percent difference	United States	Chicago area	Percent difference
Electricity (per Kwh)	$0.127	$0.145	14.2	$0.130	$0.154	18.5
Gasoline per gallon	2.843	2.966	4.3	3.521	3.561	1.1
Utility (piped) gas per therm	1.069	0.833	-22.1	1.047	0.855	-18.3

NOTE: A positive percent difference measures how much the price in the Chicago area is above the national price, while a negative difference reflects a lower price in the Chicago area.

Pacific Northwest electricity rates are the lowest in the nation*.

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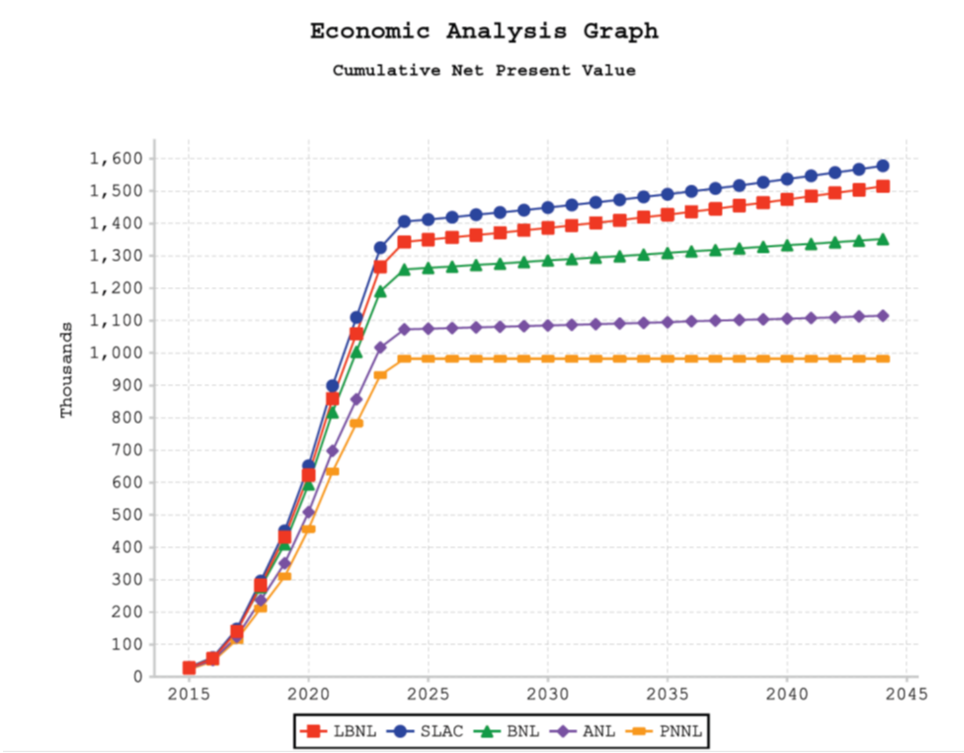
Electricity Cost - Industrial Rate		
State	**Lab**	**Cents/KWH**
California	LBNL	12
California	SLAC	12
New York	BNL	10.1
Chicago	ANL	7.5
Washington	PNNL	5.2

- Electricity rates are negotiated and the actual rate paid is usually lower than the average.
- Estimated PNNL savings could be $4.5M/yr.



Life Cycle Impact – cost advantage compounds over time

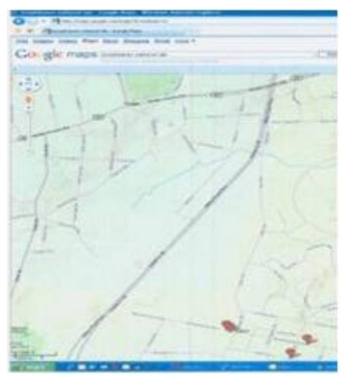
* Almost. Utah, Wyoming, Louisiana, Oklahoma, Kentucky and West Virginia are lower. Coal and oil.

Hanford site offers many *low risk* building locations

- Flat, few easements, minimal ground water issues, relatively simple seismic issues.
- Existing large-footprint facilities – LIGO

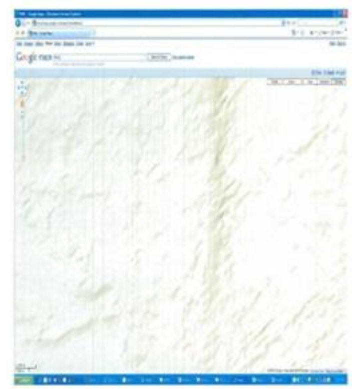
LBNL

SLAC



BNL

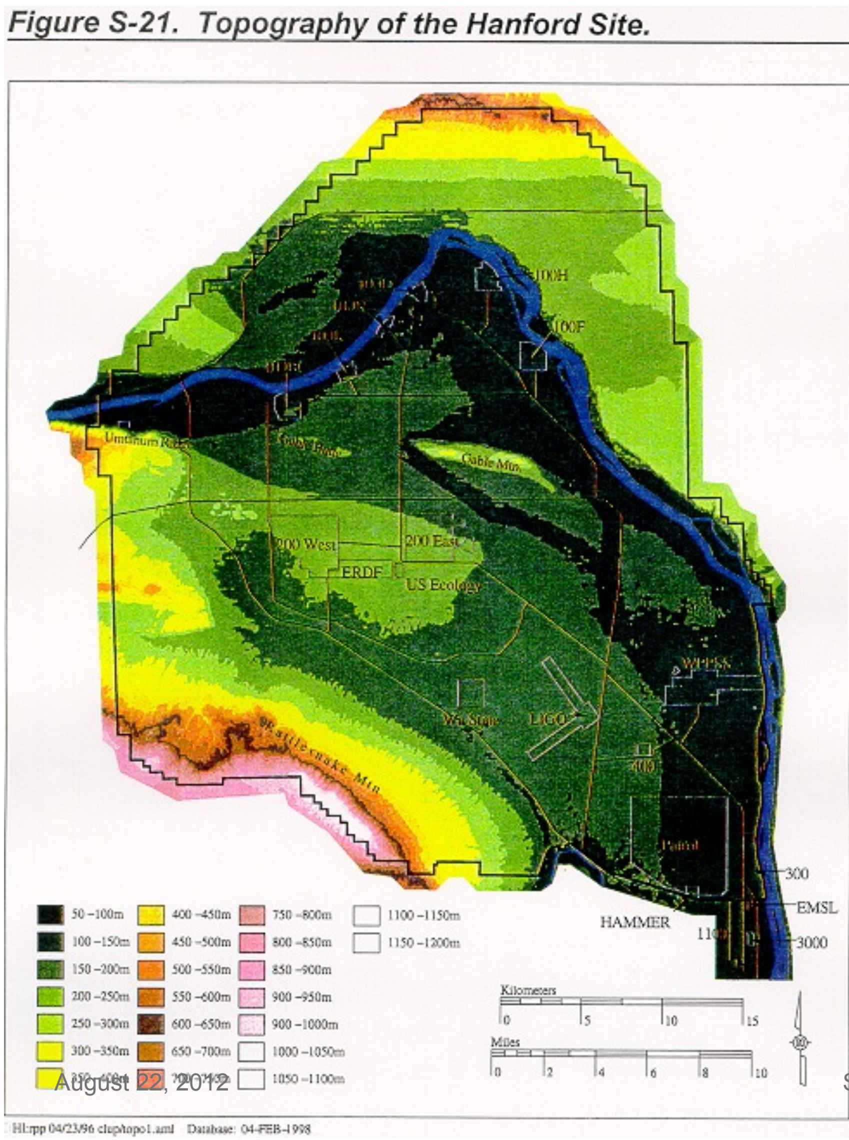
ANL

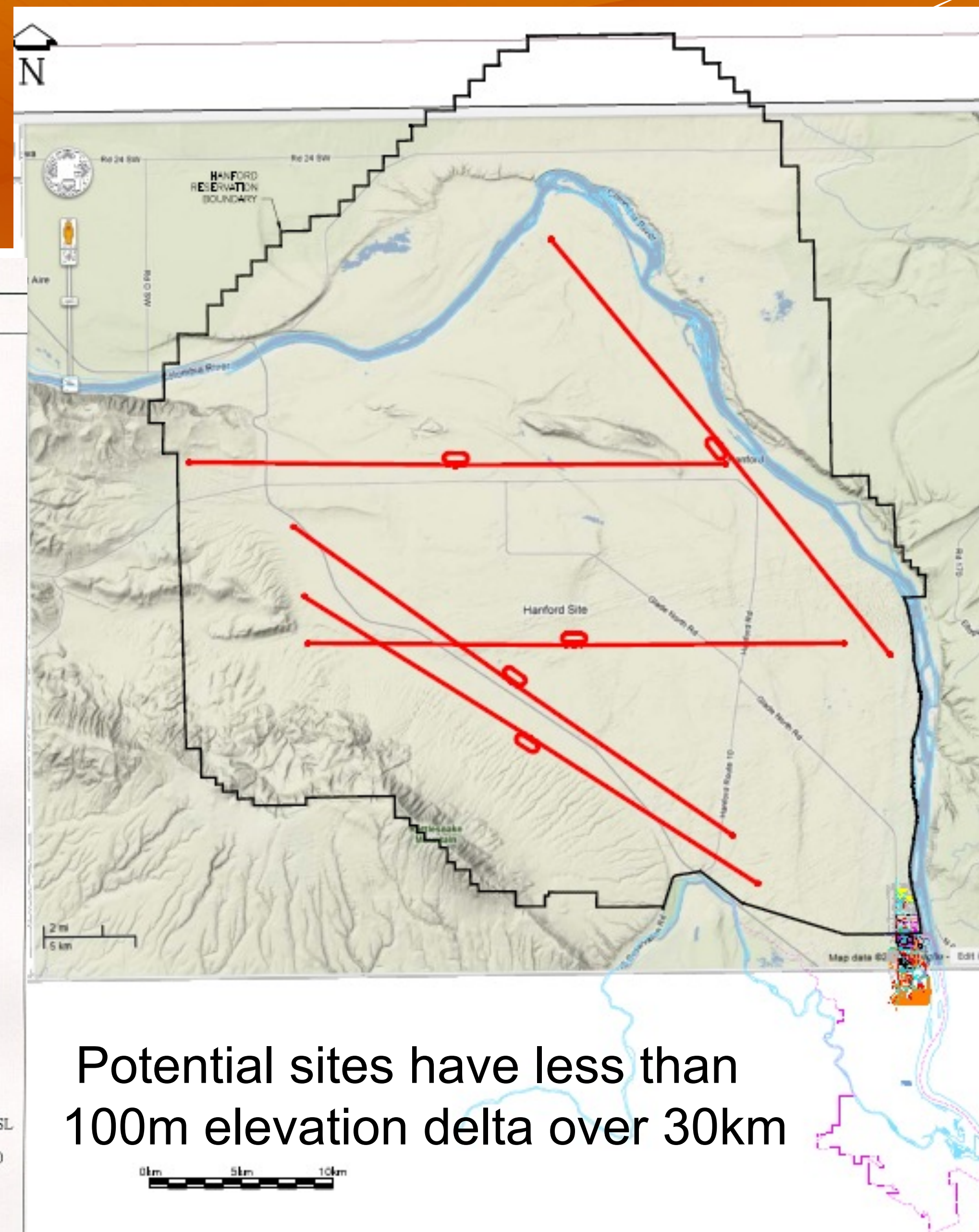


PNNL

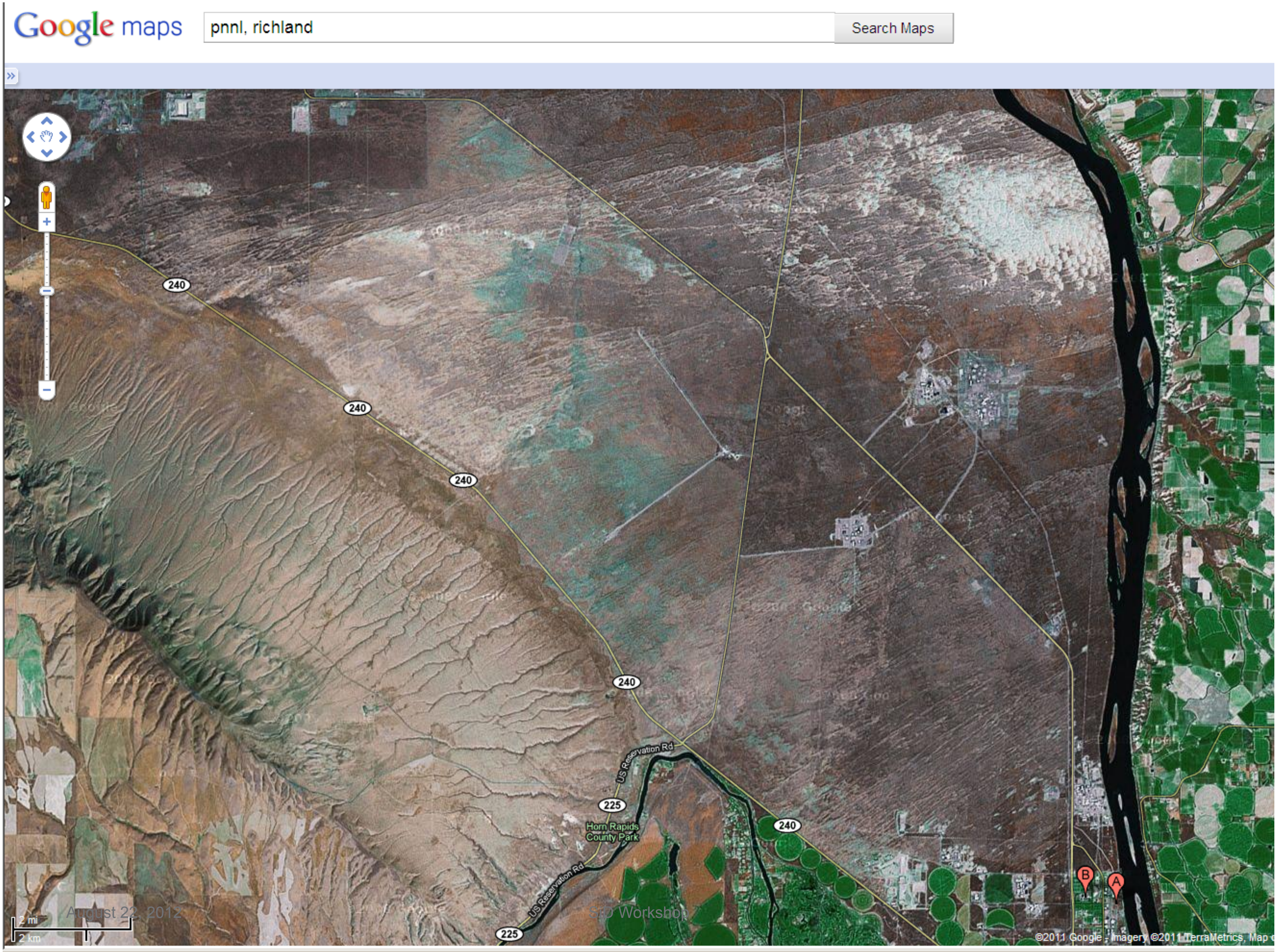
- Google maps at same general elevation and scale

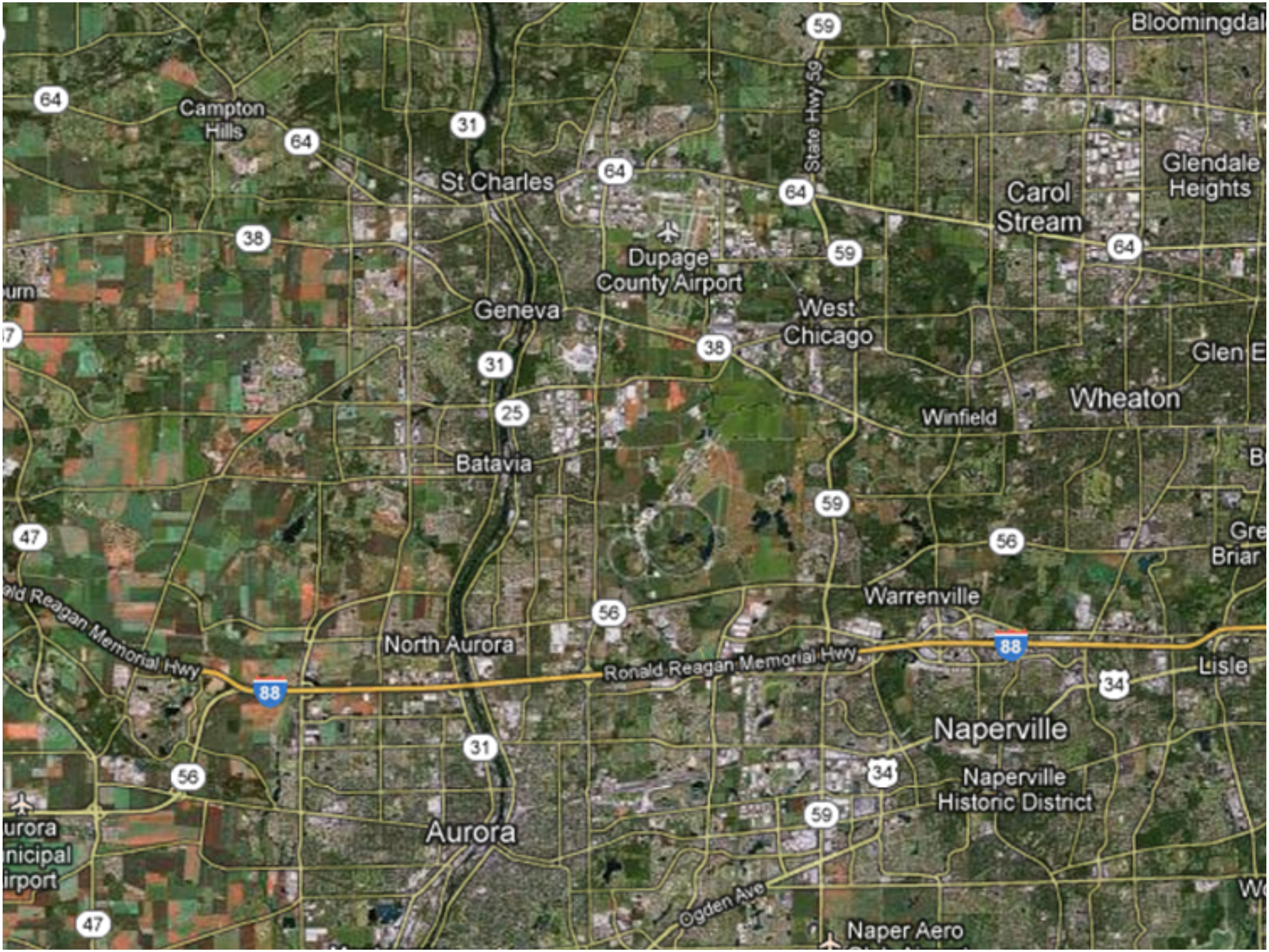
Multiple options for 30 km ILC
50 km ILC fits on Hanford site





Potential sites have less than 100m elevation delta over 30km


Google maps
pnnl, richland
Search Maps
240
225
US Reservation Rd
Horn Rapids County Park
2 mi
2 km
©2011 Google - Imagery ©2011 TerraMetrics


Bloomingdal
Campton Hills
St Charles
Carol Stream
Glendale Heights
State Hwy 59
Dupage County Airport
West Chicago
Geneva
Glen E
Wheaton
Winfield
Batavia
Warrenville
North Aurora
Ronald Reagan Memorial Hwy
Lisle
Naperville
Naperville Historic District
Aurora
Ogden Ave
Naper Aero
Gre
Briar

PNNL – Physical Sciences Facility Shallow Underground Laboratory

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- Foundation: 45' below grade.
- Structure: 32'W x 21'H x 204'L
- Concrete thicknes
  - walls 3'; floor 4.5'; ceiling 4'.
- Cost reflects high density concrete for shielding up to 5x that for "normal".
- Pictured scope cost ~$1.7M; excavation, design, steel, concrete.
- Provides – in part – basis for cut & cover cost estimate
  - Estimate cut & cover (40±10)% cost reduction relative to tunneling at Hanford

Summary

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- PNNL is the largest DOE Office of Science laboratory
  - Substantial and varied capability applicable to HEP
  - Program supported by OHEP, US-Japan, FNAL-IWO, PNNL investment
- PNNL substantial computing capability and recent experience with Belle being brought to bear (hopefully in time) for the DBD
  - Primary focus of HEP computing effort is Belle/Belle II
  - ILC VO, Direct Login to PNNL (1.5 Million cpu-hours, 200 TB approved)
- Initiated an update to the e+e- → ttbar (500 GeV) analysis
  - Real work only began 10 days ago.
  - Malachi Schram (new hire – formerly ATLAS, Babar – McGill)
- Studying the advantages associated with Hanford siting
  - Cost savings of PNW – low construction costs, low power costs
  - Cost savings of Hanford – isolated, water-free, flat, 50 km ILC fits
  - Need increased engagement with ILC leadership to refine cost estimate and cast Hanford cost/site analysis for easy comparison with other sites.