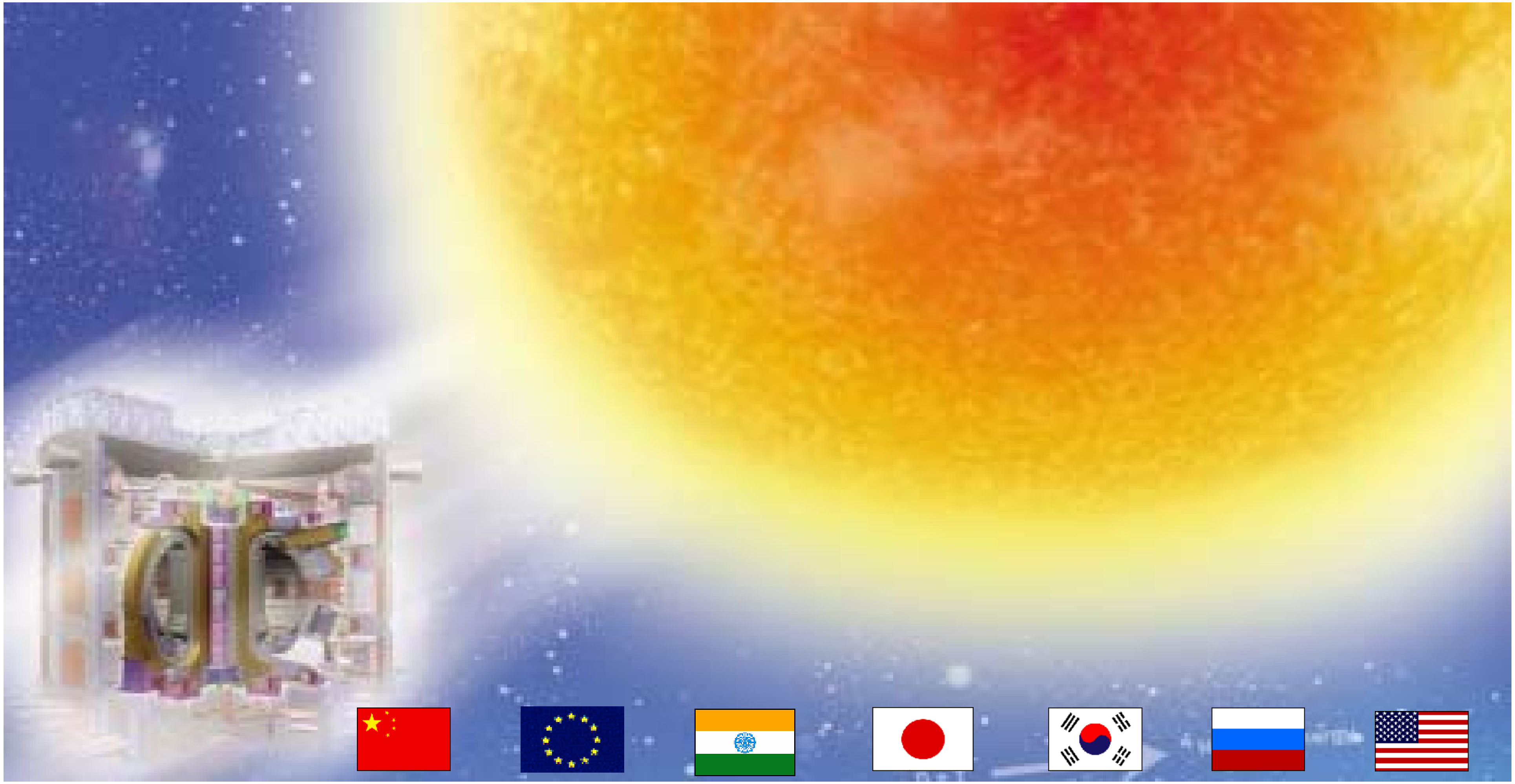

Norbert Holtkamp

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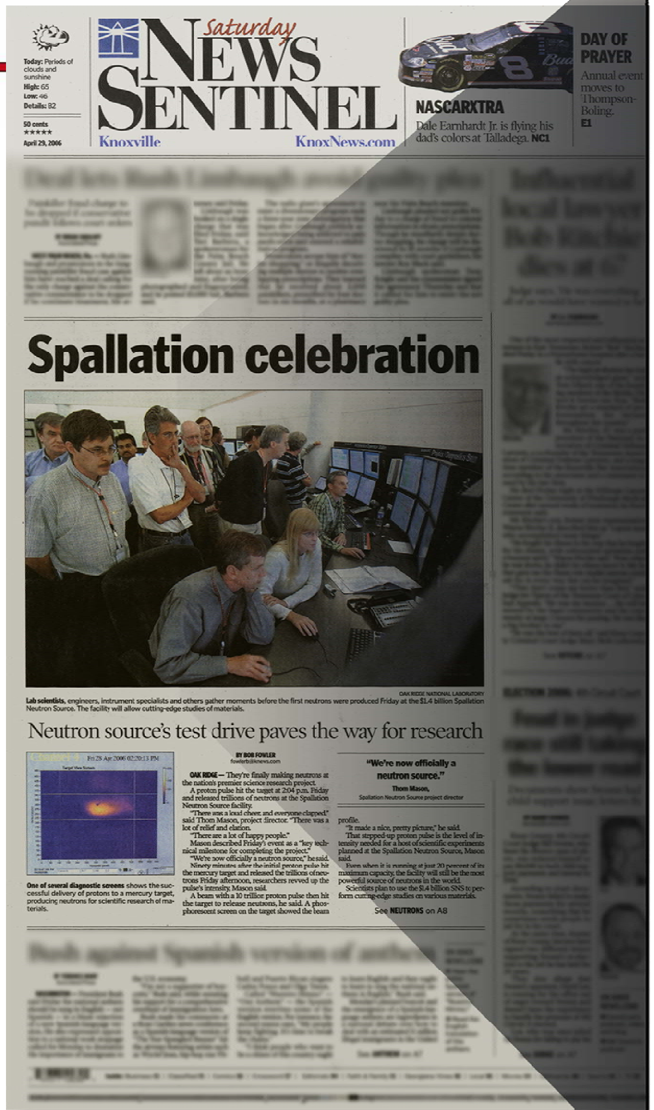
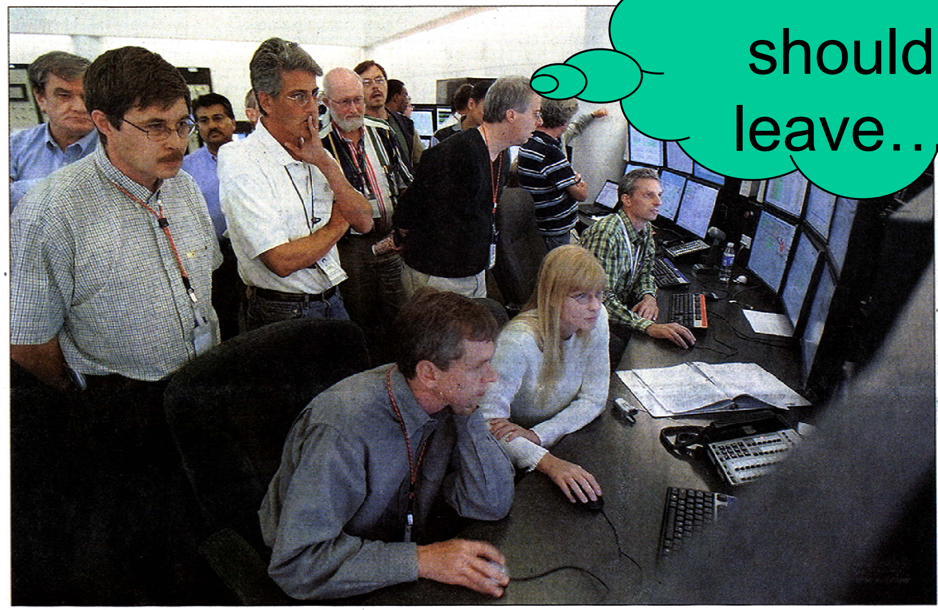
SNS Papers On This Conference

- MOPCH127 SNS Warm Linac Commissioning Results
  Presenter Alexander V. Aleksandrov (ORNL, Oak Ridge, Tennessee)
- MOPCH129 Status of the SNS Beam Power Upgrade Project
  Presenter Stuart Henderson (ORNL, Oak Ridge, Tennessee)
- MOPCH130 Simulations for SNS Ring Commissioning
  Presenter Jeffrey Alan Holmes (ORNL, Oak Ridge, Tennessee)
- MOPCH131 SNS Ring Commissioning Results
  Presenter Michael Plum (ORNL, Oak Ridge, Tennessee)
- MOPCH144 Low Temperature Properties of Piezoelectric Actuators Used in SRF Cavities Cold Tuning Systems
  Presenter Guillaume Martinet (IPN, Orsay)
- MOPCH193 SNS 2.1K Cold Box Turn-down Studies
  Presenter Fabio Casagrande (ORNL, Oak Ridge, Tennessee)
- MOPCH197 Integration and Standardization in a Multi-laboratory Project: Experiences of the SNS Survey and Alignment Group
  Presenter Joseph Error (ORNL, Oak Ridge, Tennessee)
- **TUOCFI01 Radiation Measurements vs. Predictions for SNS Linac Commissioning**
  Speaker Irina Igorevna Popova (ORNL, Oak Ridge, Tennessee)
- **TUOCFI02 First Results of SNS Laser Stripping Experiment**
  Speaker Viatcheslav V. Danilov (ORNL, Oak Ridge, Tennessee)
- TUPCH198 LINAC RF Control System of Spallation Neutron Source
  Presenter Lawrence Doolittle (LBNL, Berkeley, California)
- TUPLS060 The Spallation Neutron Source (SNS) Superconducting Linac: Installation, Commissioning and Initial Operation
  Presenter Isidoro Enrico Campisi (ORNL, Oak Ridge, Tennessee)
- TUPLS140 An Overview of the SNS Accelerator Mechanical Engineering
  Presenter Graeme R. Murdoch (ORNL, Oak Ridge, Tennessee)
- THPCH131 SNS Injection and Extraction Kicker Control System Integration, Commissioning, and Performance
  Presenter Johnny Y. Tang (ORNL, Oak Ridge, Tennessee)
- THPCH156 SNS Transverse and Longitudinal Laser Profile Monitors Design, Implementation and Results
  Presenter Saeed Assadi (ORNL, Oak Ridge, Tennessee)





Spallation celeb

OAK RIDGE NATIONAL LABORATORY

Lab scientists, engineers, instrument specialists and others gather moments before the first neutrons were produced Friday at the $1.4 billion Spallation Neutron Source. The facility will allow cutting-edge studies of materials.

Neutron source's test drive paves the way for research

Fri 28 Apr 2006 02:20:13 PM

Target View Screen

One of several diagnostic screens shows the successful delivery of protons to a mercury target, producing neutrons for scientific research of materials.

BY BOB FOWLER
fowlerb@knews.com

OAK RIDGE — They're finally making neutrons at the nation's premier science research project.

A proton pulse hit the target at 2:04 p.m. Friday and released trillions of neutrons at the Spallation Neutron Source facility.

"There was a loud cheer, and everyone clapped," said Thom Mason, project director. "There was a lot of relief and elation.

"There are a lot of happy people."

Mason described Friday's event as a "key technical milestone for completing the project."

"We're now officially a neutron source," he said.

Ninety minutes after the initial proton pulse hit the mercury target and released the trillions of neutrons Friday afternoon, researchers revved up the pulse's intensity, Mason said.

A beam with a 10 trillion proton pulse then hit the target to release neutrons, he said. A phosphorescent screen on the target showed the beam profile.

"It made a nice, pretty picture," he said.

That stepped-up proton pulse is the level of intensity needed for a host of scientific experiments planned at the Spallation Neutron Source, Mason said.

Even when it is running at just 20 percent of its maximum capacity, the facility will still be the most powerful source of neutrons in the world.

Scientists plan to use the $1.4 billion SNS to perform cutting-edge studies on various materials.

> **"We're now officially a neutron source."**
> **Thom Mason,**
> Spallation Neutron Source project director

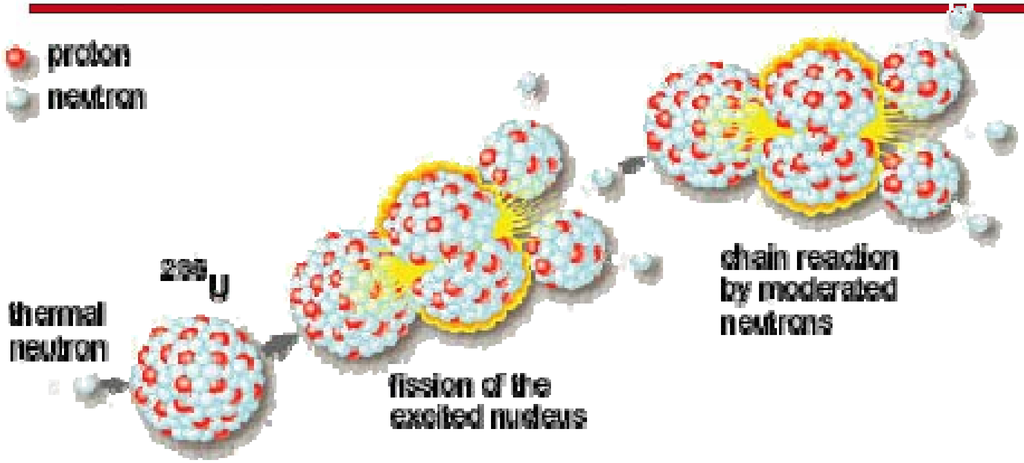
See **NEUTRONS** on A8

Now he should leave…

06-G00735/arm

Thanks for all the congratulations !!!!

Spallation-Evaporation Production of Neutrons and Why to use heavy metal target!

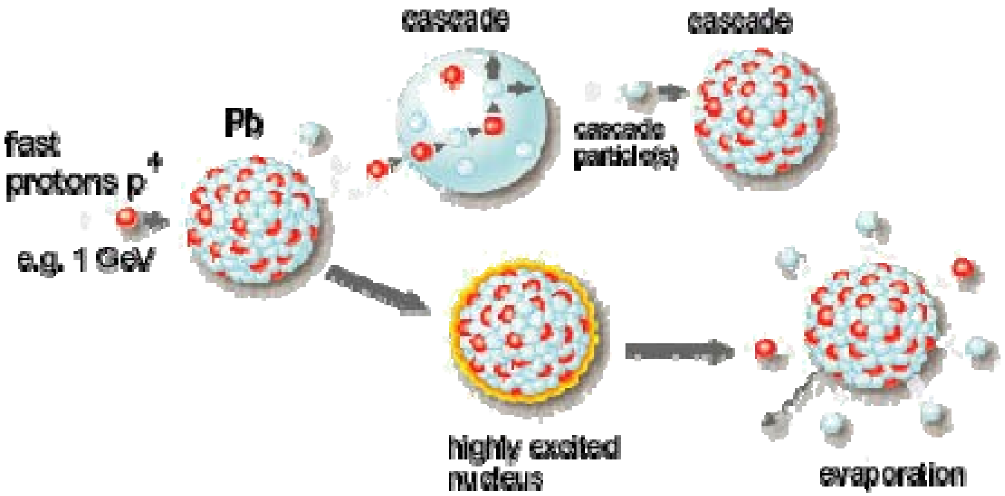


Fission

- chain reaction
- continuous flow
- 1 neutron/fission

$$\overline{P}_{beam} = E[eV]\cdot I[A]\cdot T_{pulse}[sec]\cdot f_{rep}[Hz]$$

SNS : Goal is to achieve 1.4 -> 2 ++ MW average power



Spallation

- no chain reaction
- pulsed operation
- 30 neutrons/proton
- Time resolved exp.

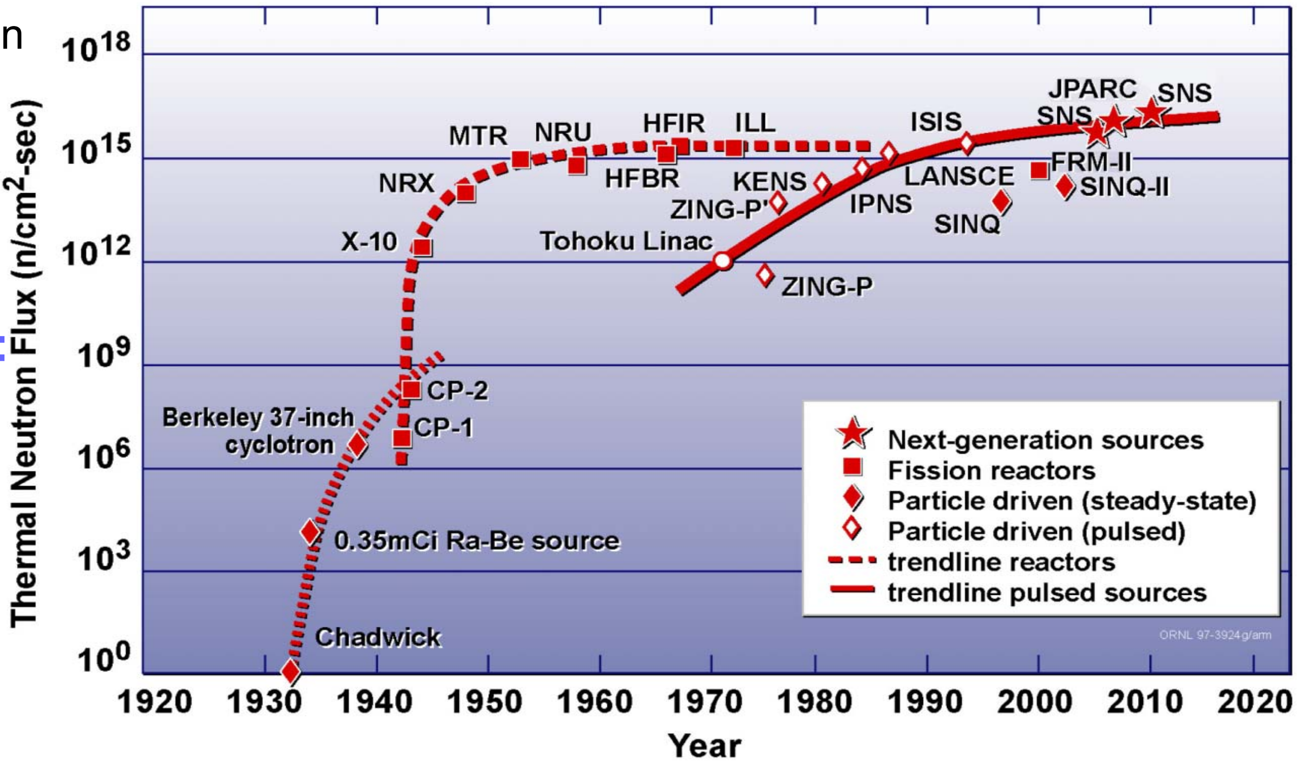
Reactors vs. Accelerator-Driven Sources

Reactor-based source:

- neutrons produced by fission reactions
- Continuous neutron beam
- 1 neutron/fission

Accelerator based source:

- Neutrons produced by spallation reaction
- 25 neutrons/proton for Hg
- Neutrons are pulsed and follow proton beam time structure
- A pulsed beam with precise t_0 allows neutron energy measurement via TOF



(Updated from *Neutron Scattering*, K. Skold and D. L. Price: eds., Academic Press, 1986)

The SNS Mega Terms– What it is and what it is supposed to be in a few years…

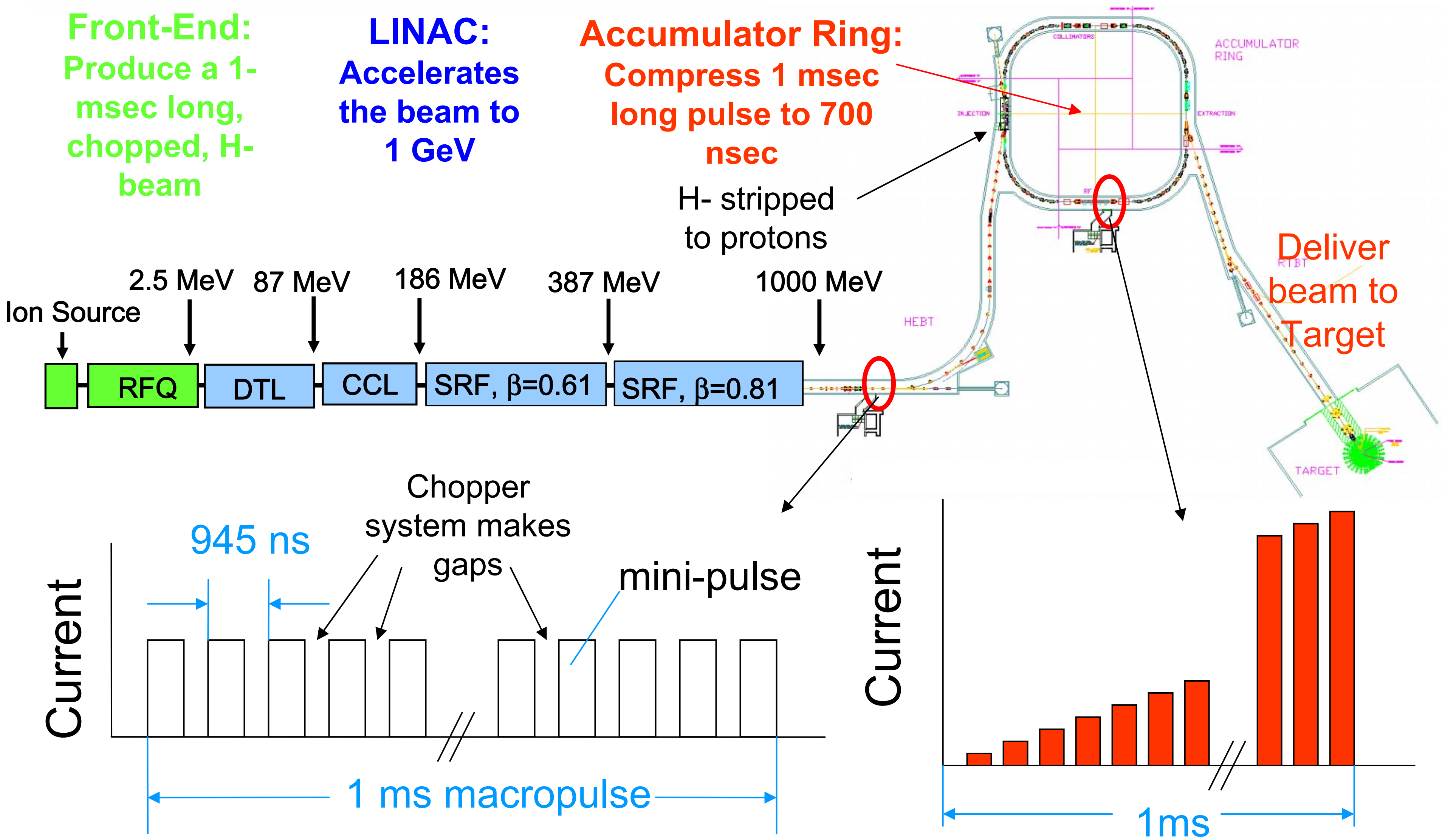
- It is:
  - The first high energy proton linac largely built with superconducting RF structures (0.812 GeV out of 1.0 GeV).
  - The worlds highest energy proton linac (operated with H^-)
  - The second largest accelerator RF installation in the US.
  - The first Multilab collaboration with fully distributed responsibility for accelerator construction.
  - A project that finished “On Time and within budget” according to a schedule/budget set in 2000.

- It will have:
  - The highest intensity proton storage ring of its kind.
  - The highest average beam power available in the world.
  - The most advanced Neutron scattering facility with the best in class instruments


Spring 1999


Spring 2006

SNS Accelerator Complex



Original SNS CDR for CD-1 May 1997

National Spallation Neutron Source

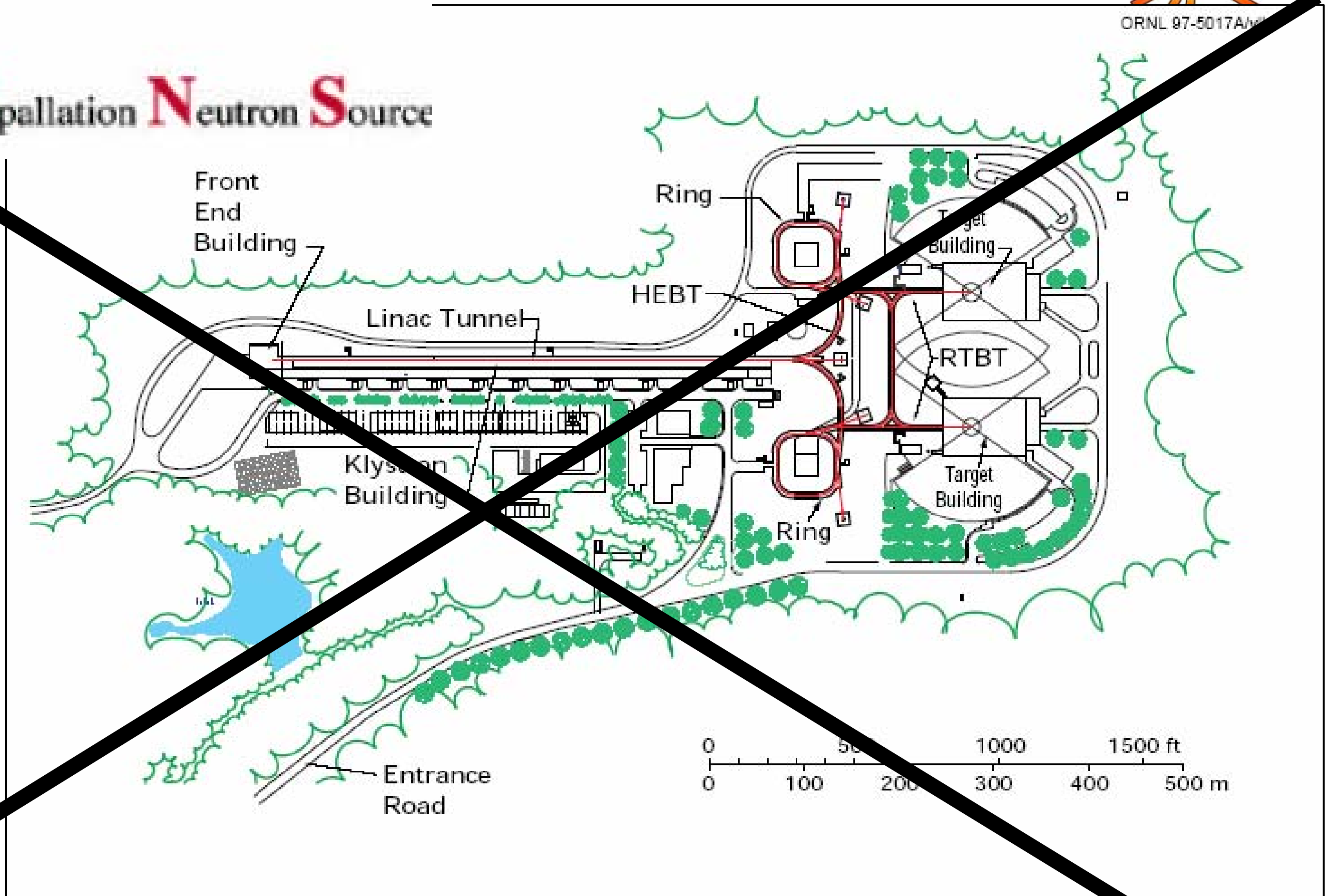


Fig. 8.0-1. Schematic of fully upgraded facility.

- 1.0 MW 1.0 GeV copper CCL linac with no room for increased energy, only current HEBT and Ring magnets sized for 1.0 GeV H-
- **Orginal Design has very little to do with what was built.**

Long History of SNS

- **May 1997**
  - Original SNS CDR for CD-1
  - 493-m-long 1.0-GeV copper DTL -DTLCCL-CCL Linac
- **November 1999**
  - Original SCL PDR
  - 9 (med-beta) x 3 + 20 (high-beta) x 4 = 107 cavities
  - 29 cryomodules
  - 29 spaces for cryomodules
- **March 2000**
  - Above SCL implemented with PCR LI 00 007
- **April 2001**
  - With PCR OPS 01 006, the SCL came to final its configuration
  - 11 (med-beta) x 3 + 12 (high-beta) x 4 = 81 cavities
  - 23 cryomodules
  - 32 spaces for cryomodule
  - 322-m-long

The Spallation Neutron Source

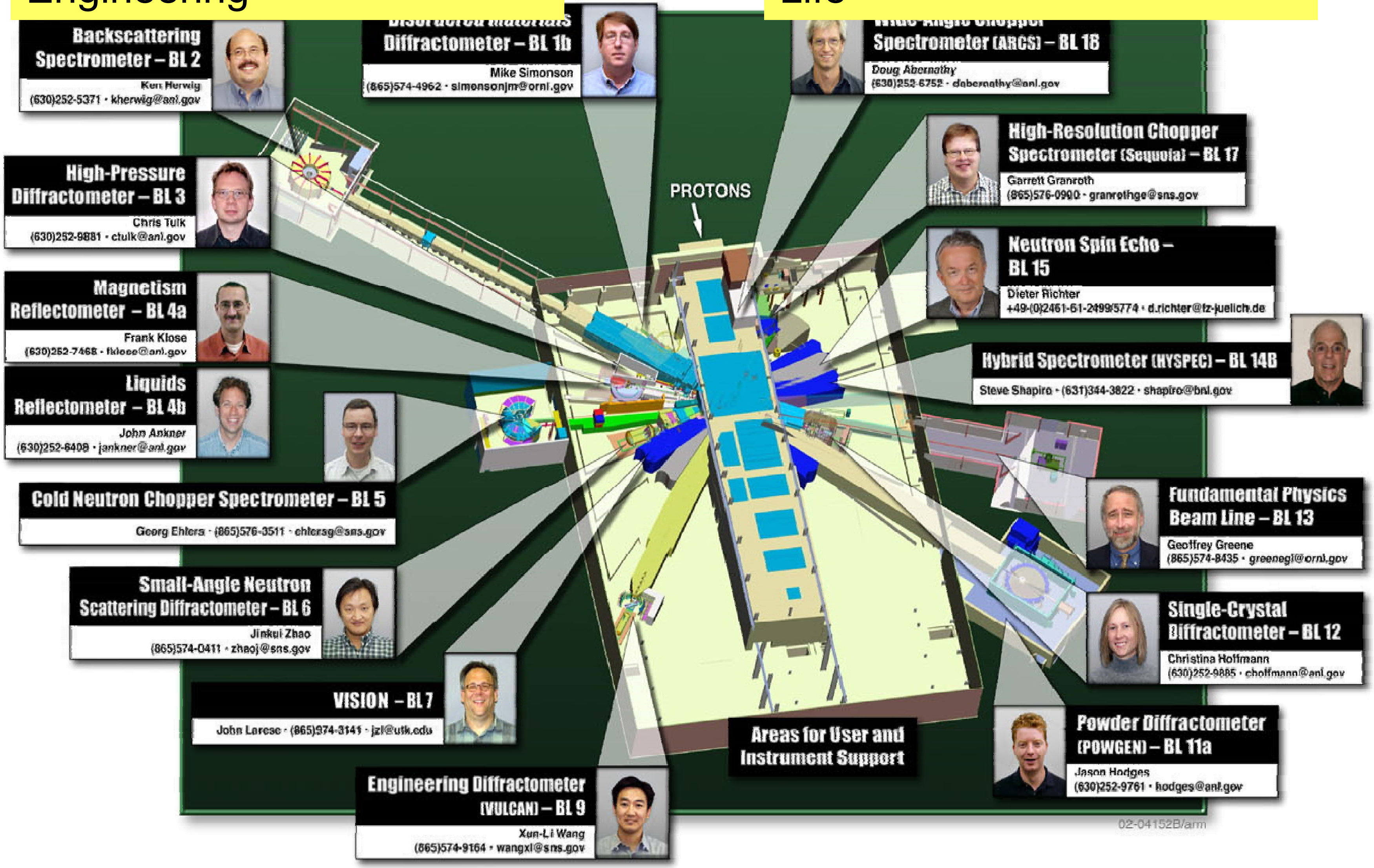
- SNS is funded through DOE-BES and has a Baseline Cost of 1.4 B$
- 1.3 GeV facility designed, build to operate at 1 GeV to begin with
- SC linac
- Single ring ready for 1.3 GeV
- One target station
- The peak neutron flux will be ~20–100x ILL
- SNS has begun operation with 3 instruments installed.

SNS High Level Baseline Parameters

Beam Energy	**1.0**	**GeV**
Average Beam Current	**1.4**	**mA**
Beam Power on Target	**1.4**	**MW**
Pulse Repetition Rate	60	Hz
Beam Macropulse Duty Factor	6.0	%
H^- Peak Linac Current	**38**	**mA**
Linac Beam Pulse Length	**1.0**	**ms**
Ring Beam Extraction Gap	250	ns
Protons Per Pulse on Target	1.5×10^{14}	
Proton Pulse Width on Target	**695**	**ns**
Uncontrolled Beamloss Criteria	**1 Watt/m**	
Linac length	335	m
Total Beamline Length	903	m
Target Material	**Liquid Hg (1 m^3; 18 tons)**	
Energy Per Beam Pulse	**24 kJ**	
Maximum Number Instruments	24	

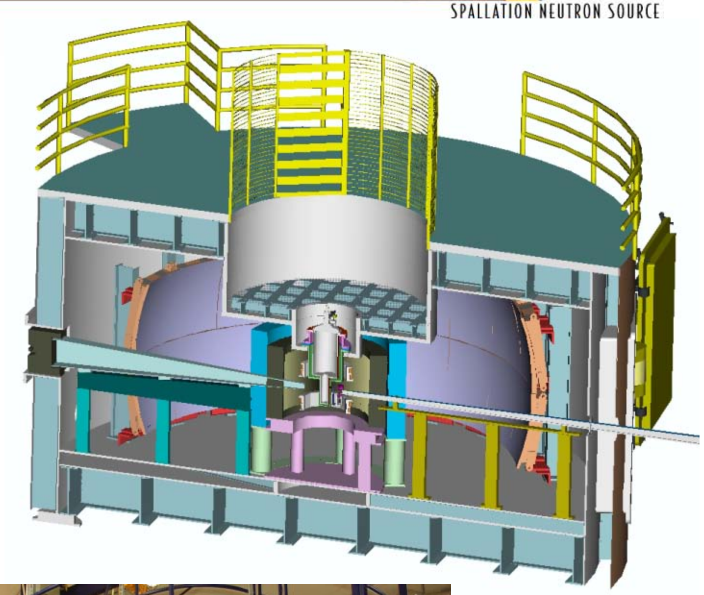
18 Instruments Now Formally Approved (20+ funded)

- •Fundamental Physics to Engineering
- •Chemistry to “Genomes to Life”

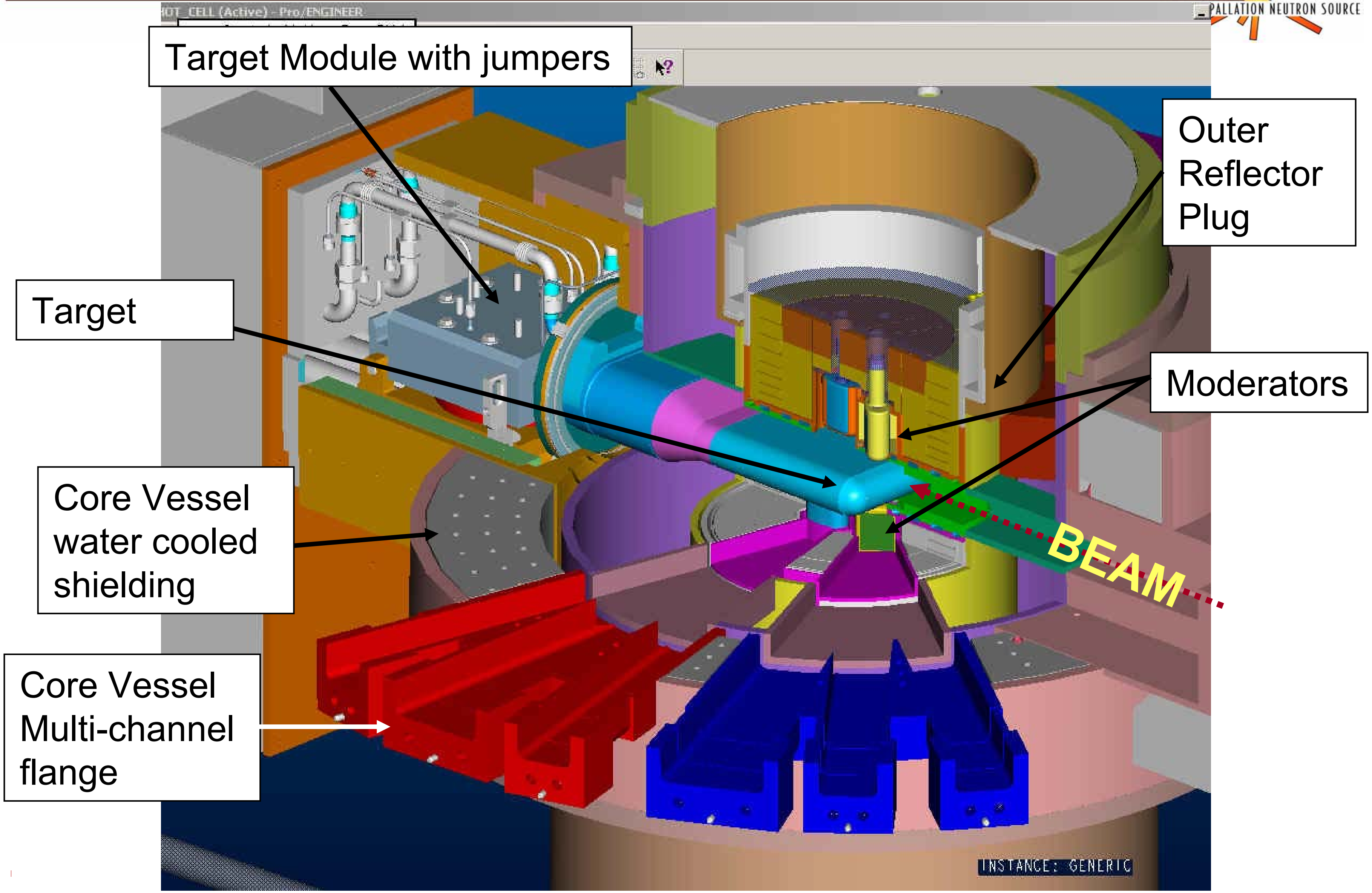


Backscattering Spectrometer

- **84 m incident flight path designed to provide high energy resolution – 2.5 μeV (fwhm) at the elastic line – slow dynamics (100's psec, 3 – 35 Å)**
- **Approximately 50 x faster then current world's best comparable instruments – better Q-resolution simplifies studies involving crystalline materials**



Target Region Within Core Vessel



SNS CD-4 Scope Criteria

Level 0 – DOE Deputy Secretary

- Accelerator-based neutron scattering facility capable of at least 1 megawatt proton beam power on target

Level 1A – Director, Office of Science

- Five specific research instruments

Level 1B – Associate Director BES

- Performance test demonstrating
  - 1.0E+13 protons per pulse
  - 5.0E-3 neutrons/steradian/incident proton, viewing moderator face

Level 2 – DOE Project Director

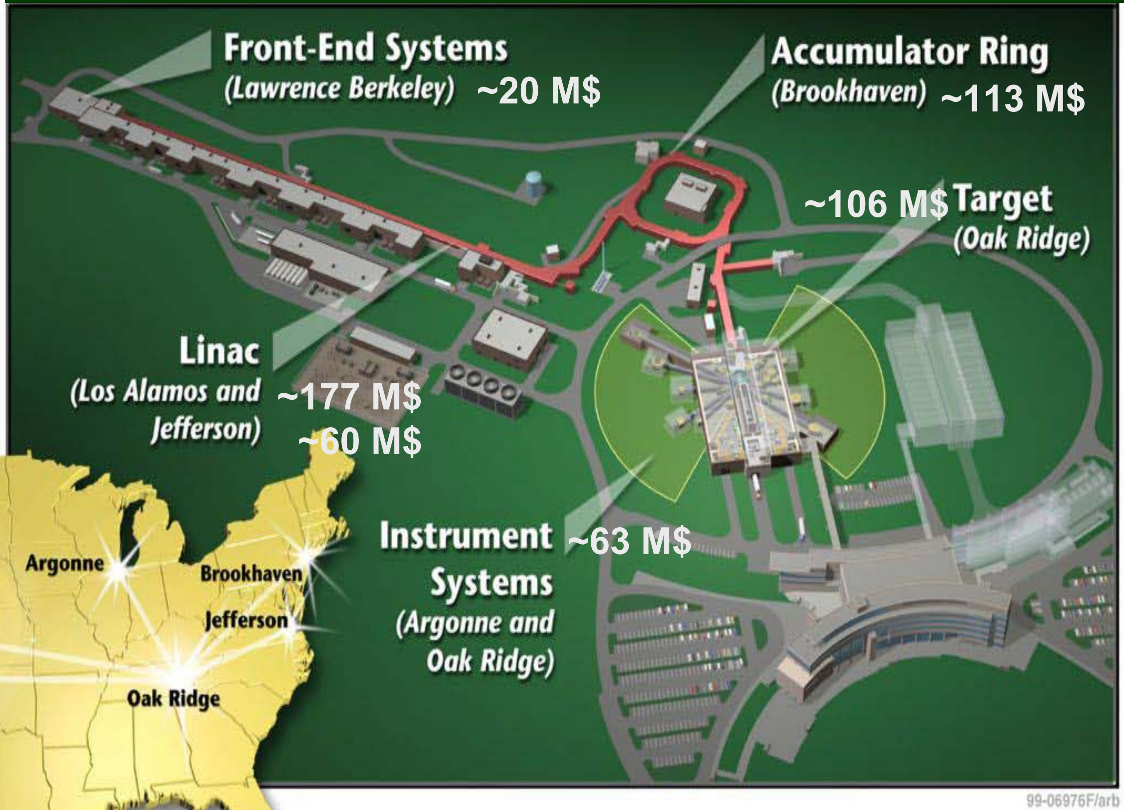
- At least 3 of the 5 instruments installed and tested; the other 2 procured and on site
- **Trained staff, operating permits, and systems documentation in place**

The Spallation Neutron Source Partnership

Description	Accelerator	
Project Support	75.6	
Front End Systems	20.8	20.8
Linac Systems	311.0	311.0
Ring & Transfer System	146.6	146.6
Target Systems	108.2	
Instrument Systems	63.3	
Conventional Facilities	378.9	
Integrated Control Syst	58.5	58.5
BAC	1,162.9	
Contingency	29.8	
TEC	1,192.7	
R&D	99.9	79.9
Pre-Operations	119.1	95.3
TPC	1,411.7	712.1

At peak: ~500 People worked on the construction of the SNS accelerator

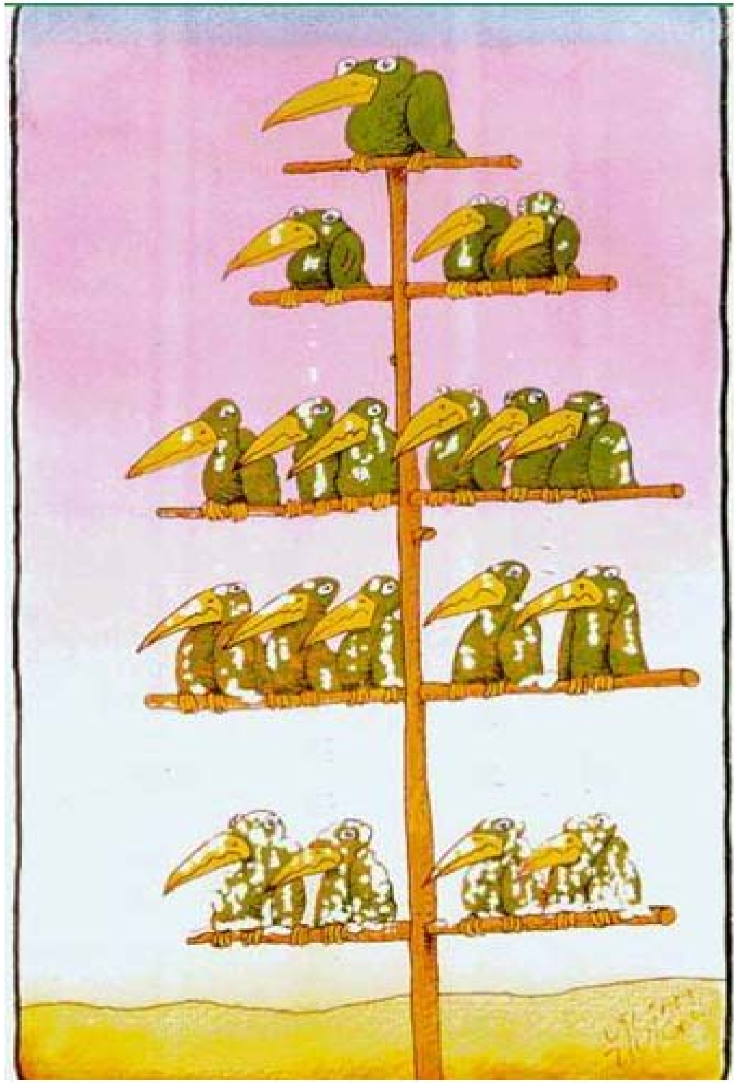
SNS-ORNL Accelerator systems: ~167 M$



The partners developed and built – SNS/ORNL integrated, installed + operated

SNS Multilab Organizational Chart

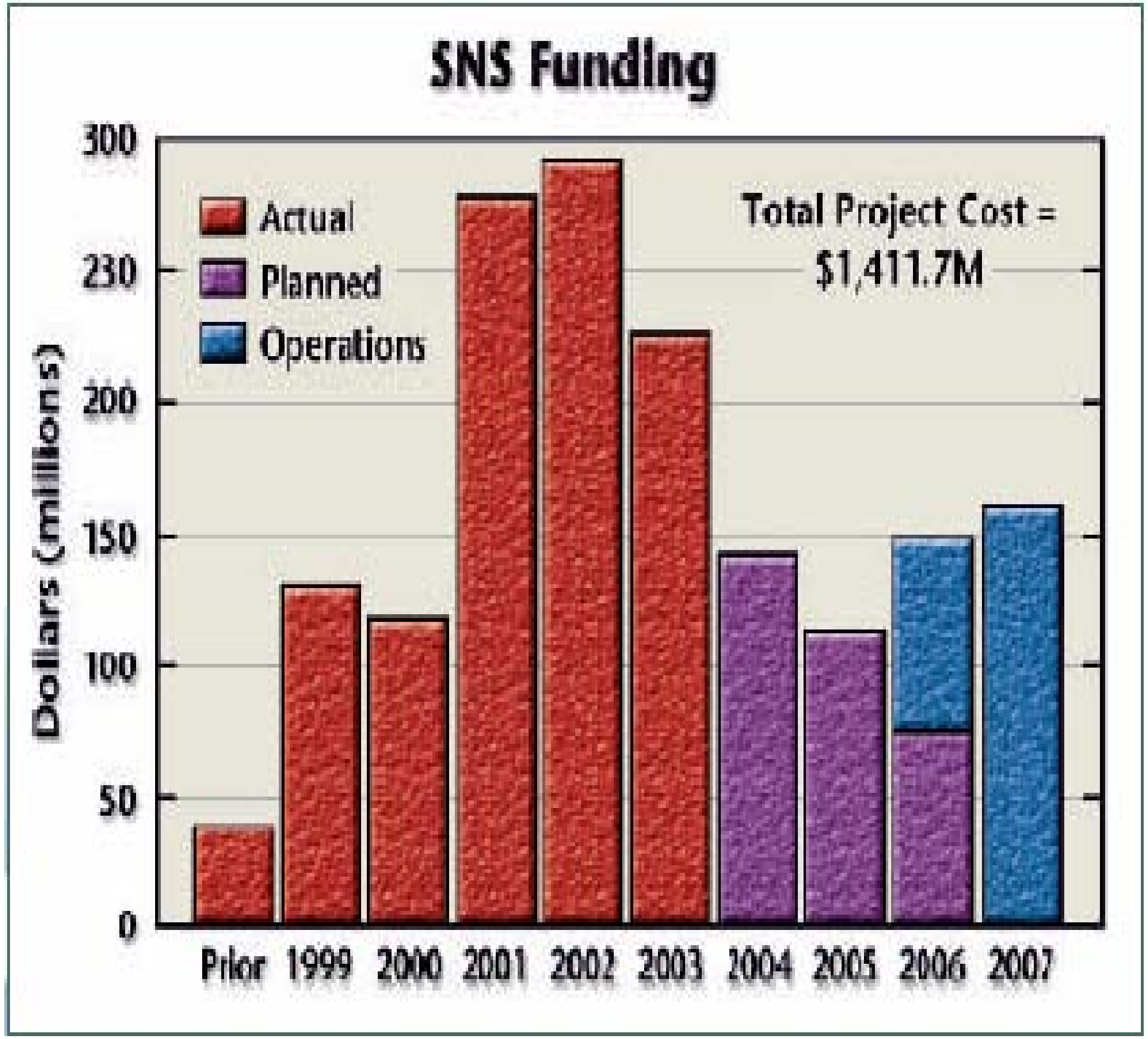
- The Multi Lab Organization of SNS has brought an enormous amount of expertise and healthy competition to the table.
- It has made it easier to transition the required workforce in and out of the project.
- SNS is just one of several models that I m sure will be used to built large science projects in the future.



Budget Driving the Schedule

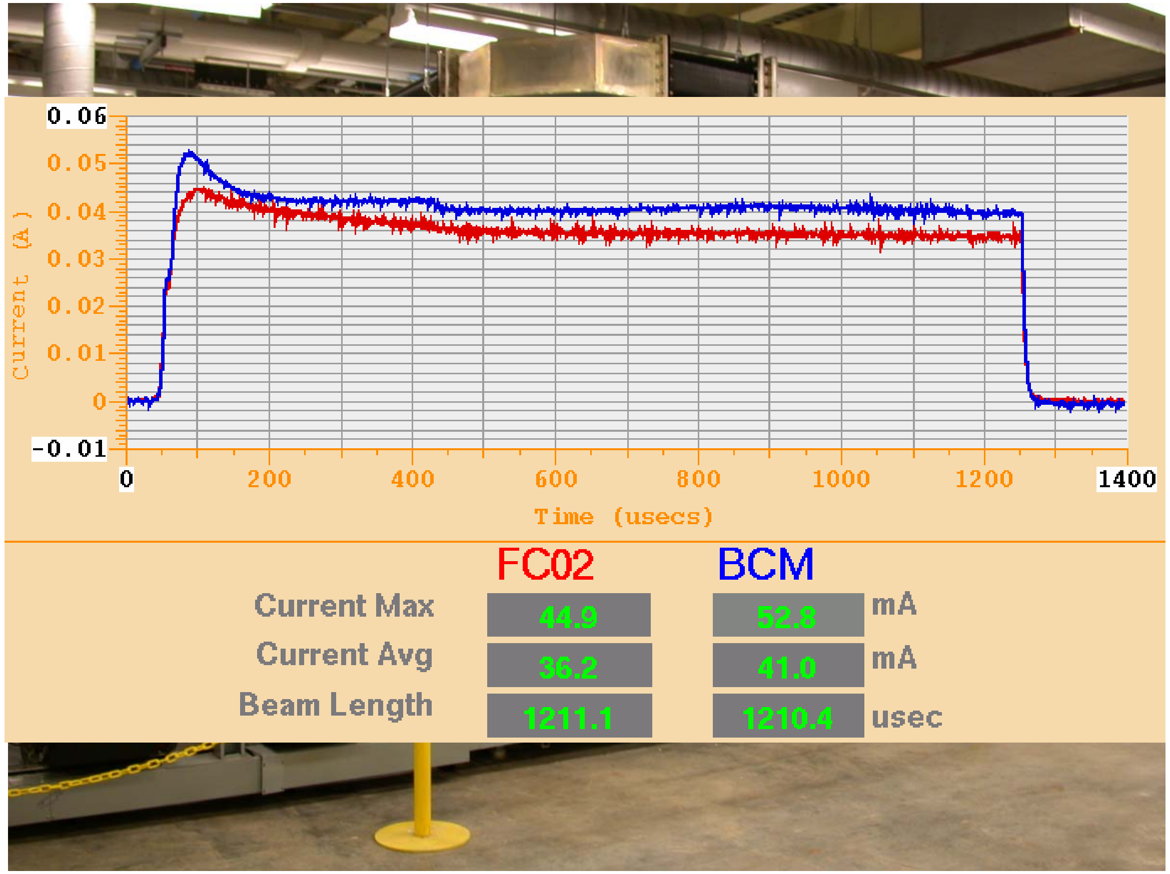
- DOE supported SNS immensely by making sure that we got the budget to execute the plan that was laid out.

- The schedule had a very aggressive procurement plan, that was based on the idea of an "accelerator in the box"

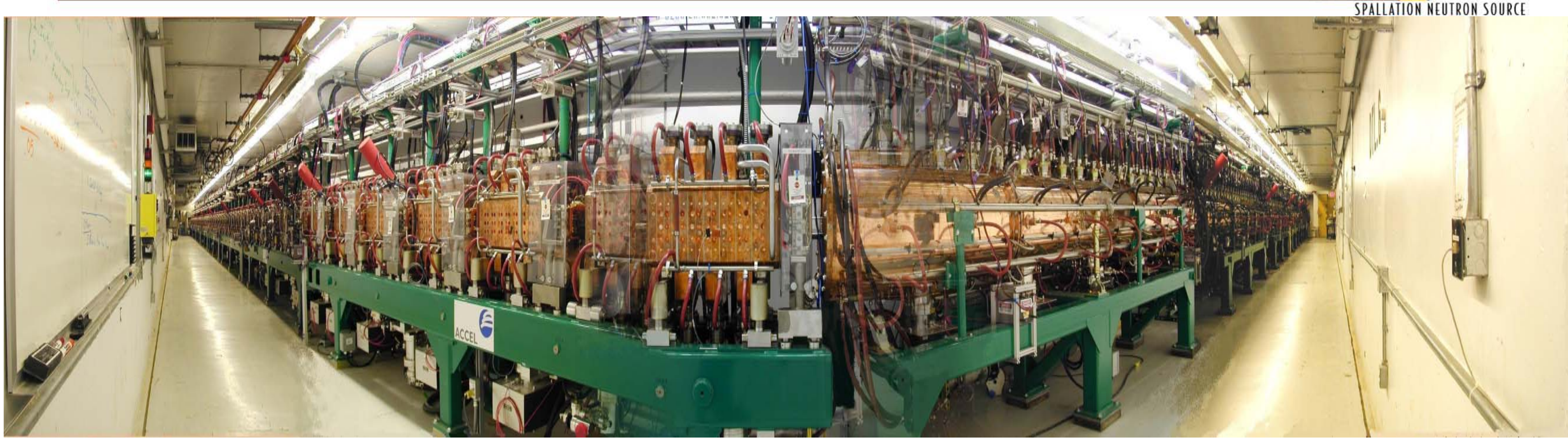


LBNL: SNS Front-End Systems

- Front-End H^- Injector was designed and built by LBNL
- 402.5 MHz Radiofrequency quadrupole accelerates beam to 2.5 MeV
- Medium Energy Beam Transport matches beam to DTL1 input parameters
- Front-end delivers 38 mA peak current, chopped 1 msec beam pulse
- H^- Ion Source has operated at baseline SNS parameters in several endurance runs since 2002.
  - >40 mA, 1.2 msec, 60 Hz



LANL: Normal Conducting Linac & RF Systems



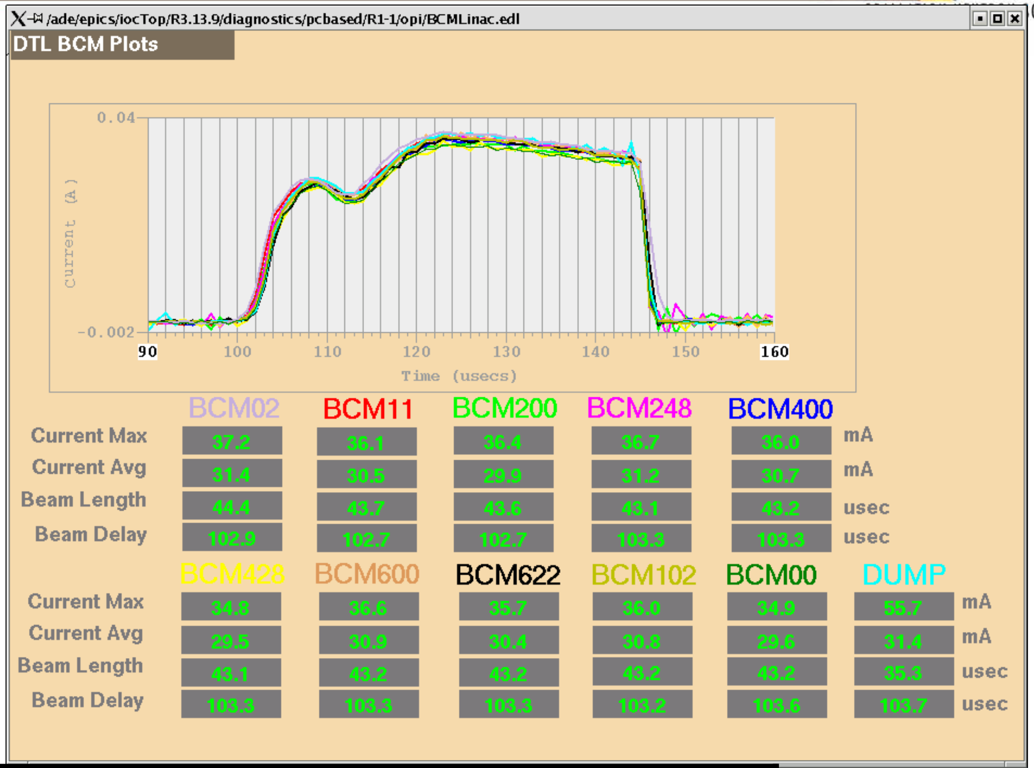
- CCL Systems designed and built by Los Alamos
- 805 MHz CCL accelerates beam to 186 MeV
- System consists of 48 accelerating segments, 48 quadrupoles, 32 steering magnets and diagnostics

- 402.5 MHz DTL was designed and built by Los Alamos
- Six tanks accelerate beam to 87 MeV
- System includes 210 drift tubes, transverse focusing via PM quads, 24 dipole correctors, and associated beam diagnostics

DTL/CCL Commissioning Results

- Full transmission of accelerated beam to the beamstop (with few % measurement uncertainty)

- Typical beam pulse: 20 mA, 40µs, 1 Hz (limited by intercepting diagnostics and beamstop)



Module	Design [MeV]	Measured [MeV]	Deviation [%]
DTL6	86.83	87.48±0.03	0.75
CCL1	107.16	107.36±0.12	0.19
CCL2	131.14	131.53±0.14	0.40
CCL3	157.21	158.08±0.40	0.55

JLAB: The Superconducting Linac

- Designed and built by Jefferson Laboratory.
- SCL accelerates beam from 186 to 1000 MeV.
- SCL consists of 81 cavities in 23 cryomodules.
- Two types of cavity geometries are used to cover broad range in particle velocities (β=.65, .85).
- Cavities are operated at 2.1 K with He supplied by Cryogenic Plant.
- Operation so far mostly at 4.2 K.

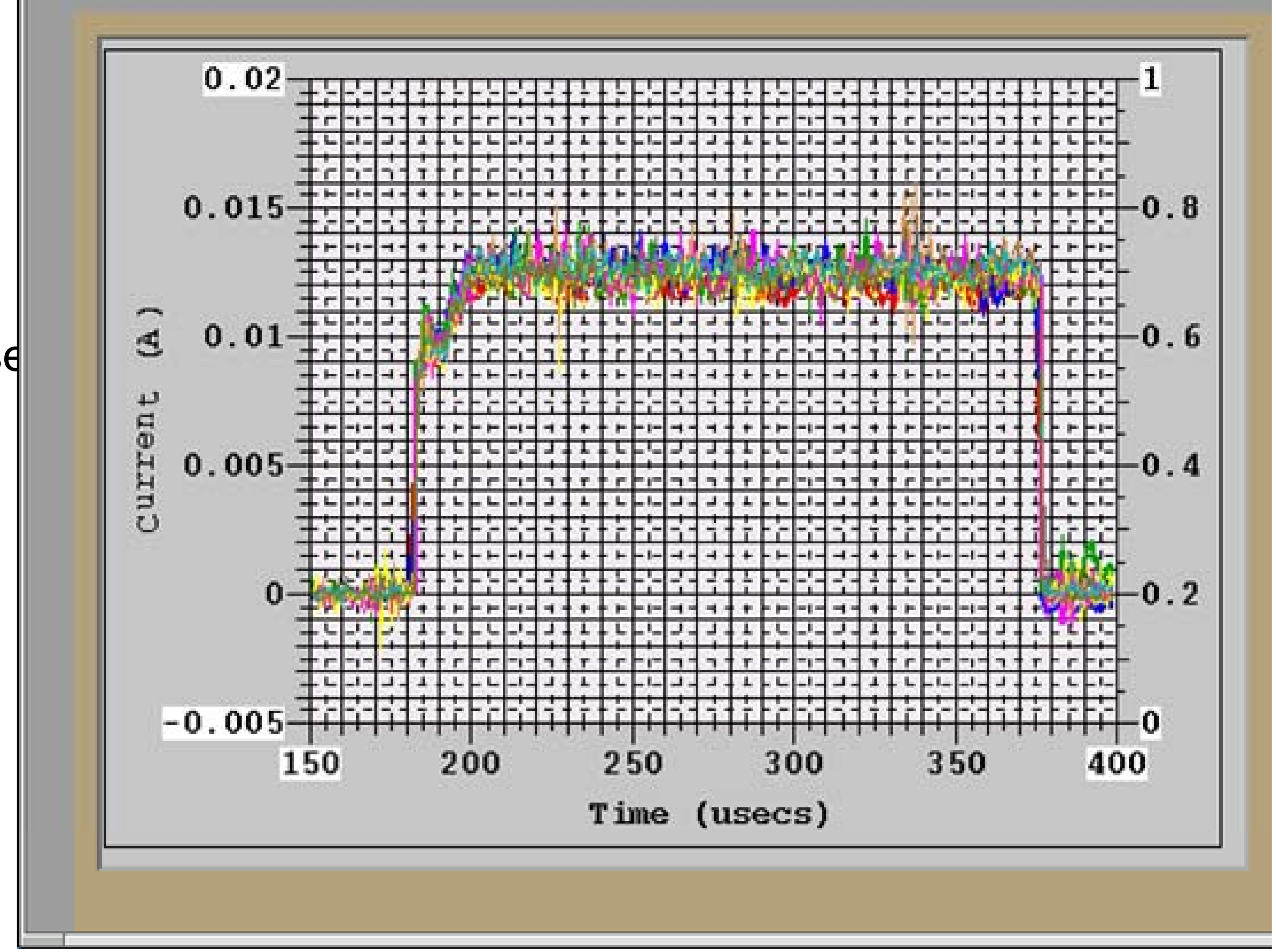
<u>Superconducting RF Advantages:</u>

1. **Flexibility ➔ gradient and energy are not fixed**
2. **More power efficient ➔ lower operational cost**
3. **High cavity fields ➔ less real estate**
4. **Better vacuum ➔less gas stripping**
5. **Large aperture ➔ less aperture restrictions ➔ reduced beam loss ➔reduced activation**

Representative Linac Beam Pulse

- 860 MeV
- 18 mA peak current
- 200 μsec
- 70% Chopping
- 12 mA average pulse current
- 1.5×10^{13} H-/pulse

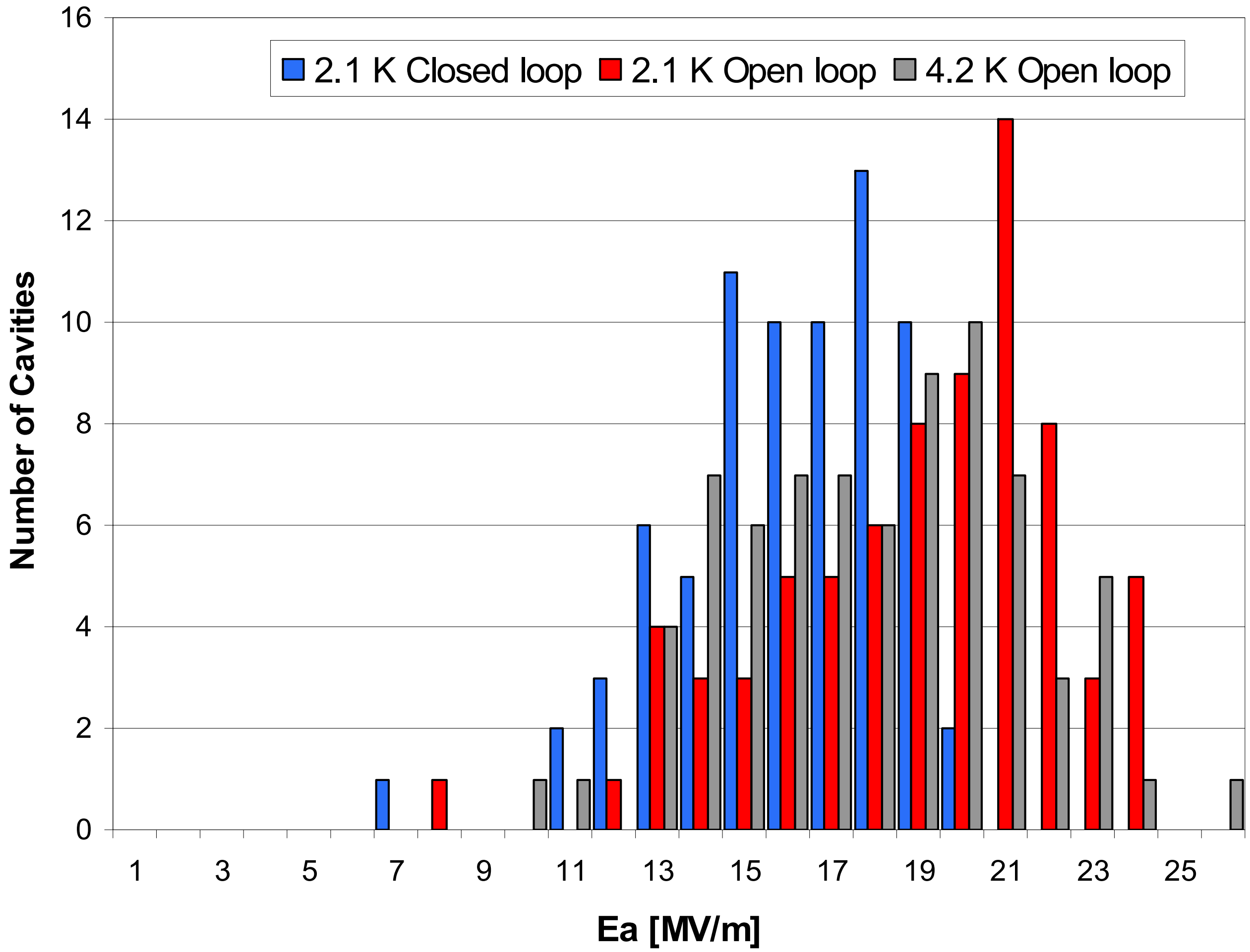
Overlay of 12 linac beam current monitors



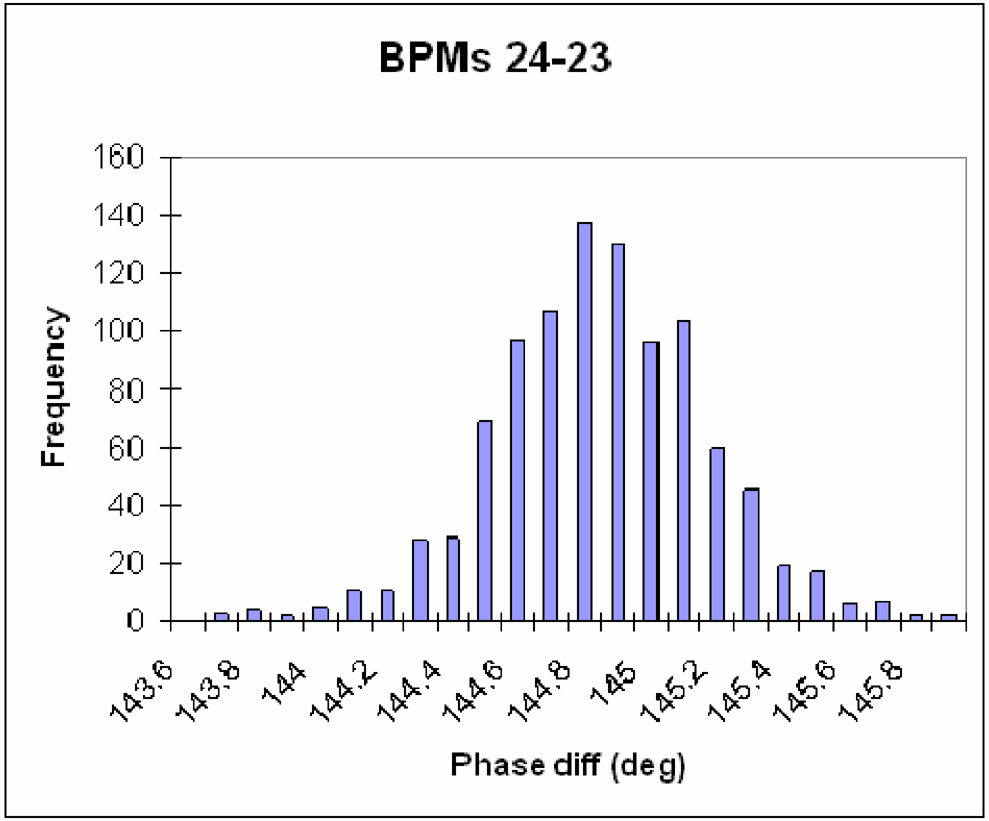
Cavity Gradient Performance

Maximum fields achieved in the installed cavities.

Operational fields are kept in general at 75-80% of the maximum fields



Energy Stability – Pulse to Pulse



865 MeV beam

~ 1000 pulses

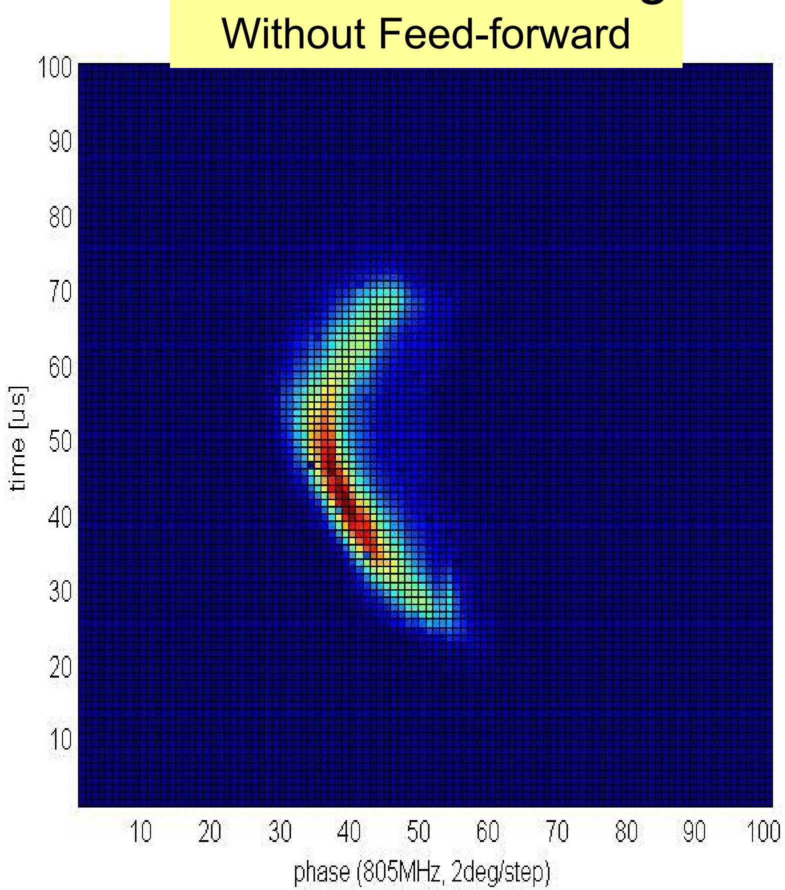
20 μsec pulse

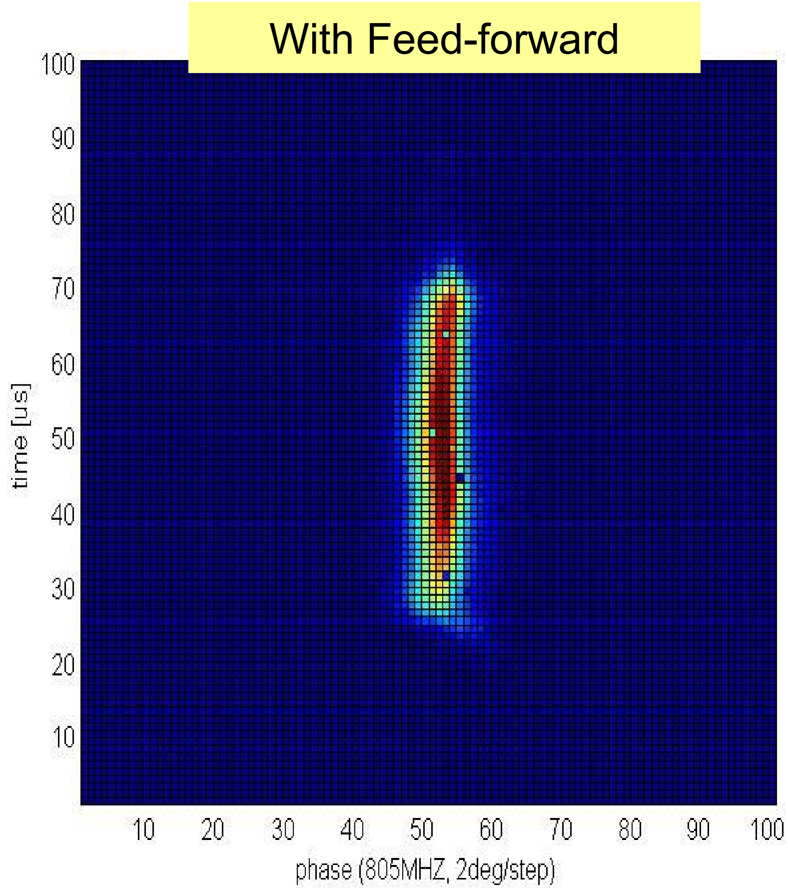
12 mA beam

- RMS energy difference jitter is 0.35 MeV, extreme = ± 1.3 MeV (without any energy feedback)
- Parameter list requirement is max jitter < ±1.5 MeV

Low-level RF Feedforward within the Beam Pulse

- Beam turn-on transient gives RF phase and amplitude variation during the pulse, beyond bandwidth of feedback.
- LLRF Feedforward algorithms have been commissioned.





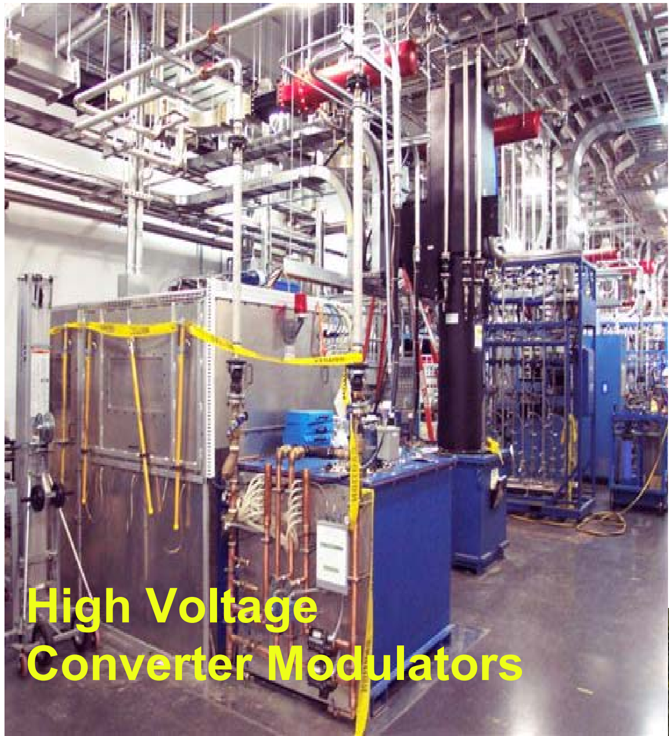
Linac RMS Transverse Emittance

	Measured ε (H, V) norm. π-mm-mrad	Parameter List ε (H, V) norm. π-mm-mrad	Notes
MEBT Entrance	0.22, 0.25	0.21	RFQ Exit Twiss study
CCL Entrance	0.22, 0.25	0.33	Matching 7 CCL profile sets
SCL Entrance	0.27, 0.35	0.41	Matching 3 SCL profile sets
Linac Dump	0.26, 0.27	0.41	1 wire, vary quads

- Measured RMS emittance is within specification but beam parameters are different for various runs.

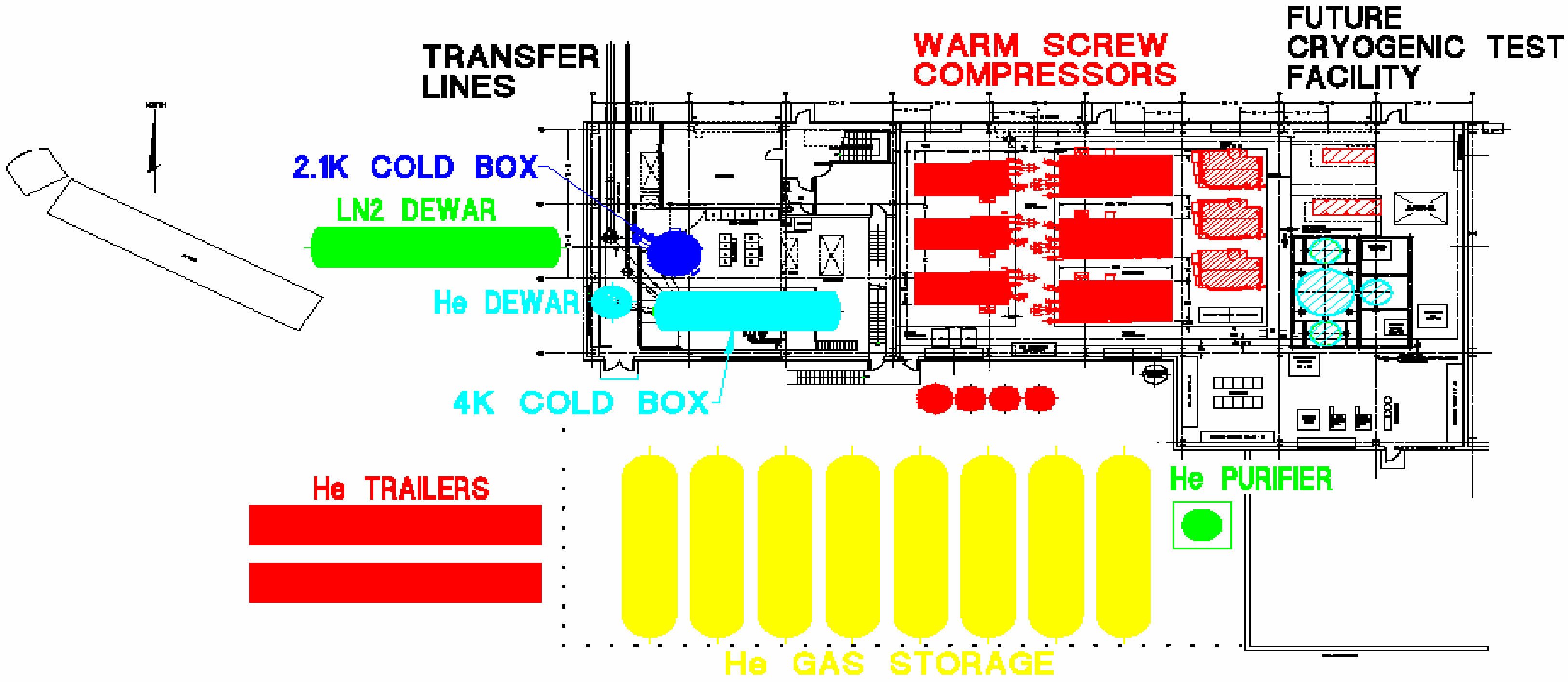
Linac RF Systems

- Designed and procured by LANL
- All systems 8% duty factor: 1.3 ms, 60 Hz
- 7 DTL Klystrons: 2.5 MW 402.5 MHz
- 4 CCL Klystrons: 5 MW 805 MHz
- 81 SCL Klystrons: 550 kW, 805 MHz
- 14 IGBT-based modulators



- 2nd largest klystron and modulator installation in the world!

JLAB: SNS CHL Facility



SNS HELIUM REFRIGERATION SYSTEM
EQUIPMENT ARRANGMENT

Warm Compressors System Status

- 3 warm compressor streets

4.5K Cold Box has been Commissioned

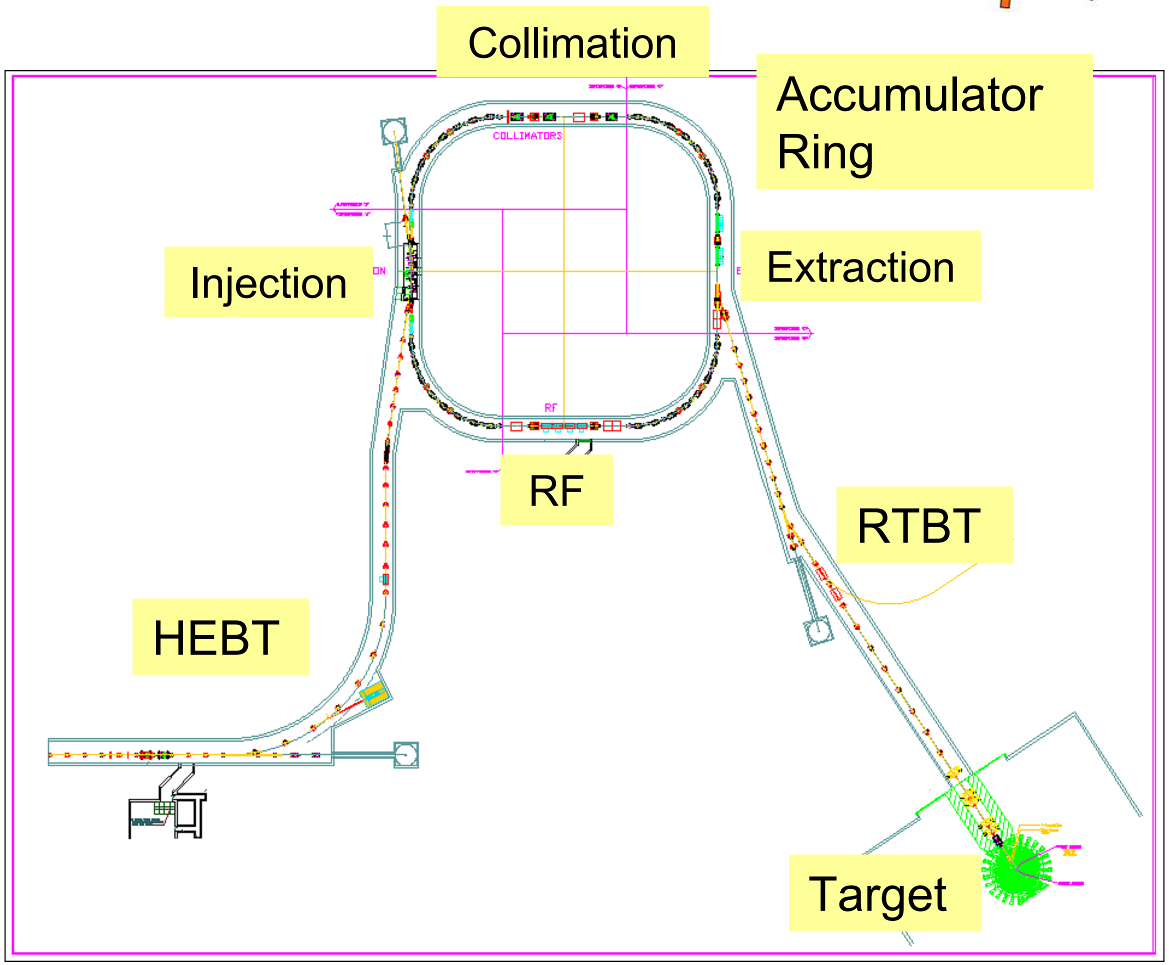
- 8 kW at 4.5 K

JLAB + ORNL: The SNS Cryogenic Support System

- ~2 kW @ 2.0 K ($\rightarrow$ 40mBar)
- Operated since Oct 2004 uninterrupted. Mainly at 4.5K
- Very reliable and build to accommodate an additional 9 (23->31) cryomodules.

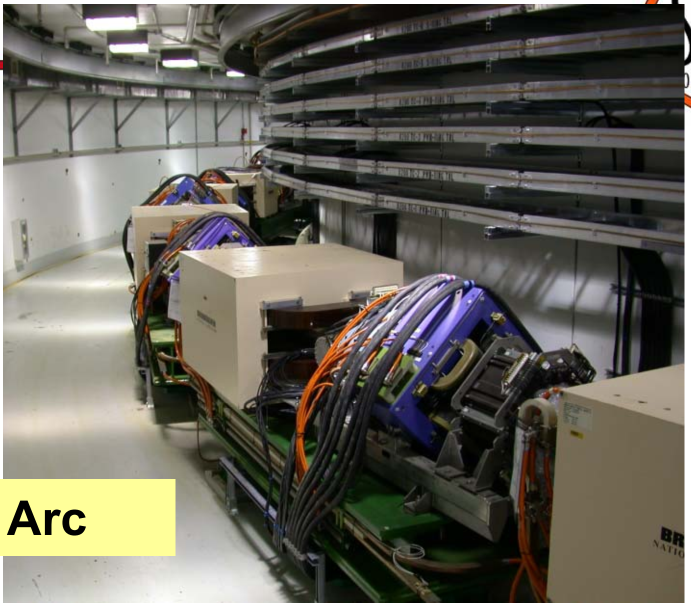
BNL: Accumulator Ring and Transport Lines

Circum	248 m
Energy	1 GeV
f_{rev}	1 MHz
Q_x, Q_y	6.23, 6.20
$\Delta Q_{x,y}$	0.15
ξ_x, ξ_y	-7.9, -6.9
Accum turns	1060
Final Intensity	1.5×10^{14}
Peak Current	52 A
RF Volts (h=1)	40 kV
(h=2)	20 kV

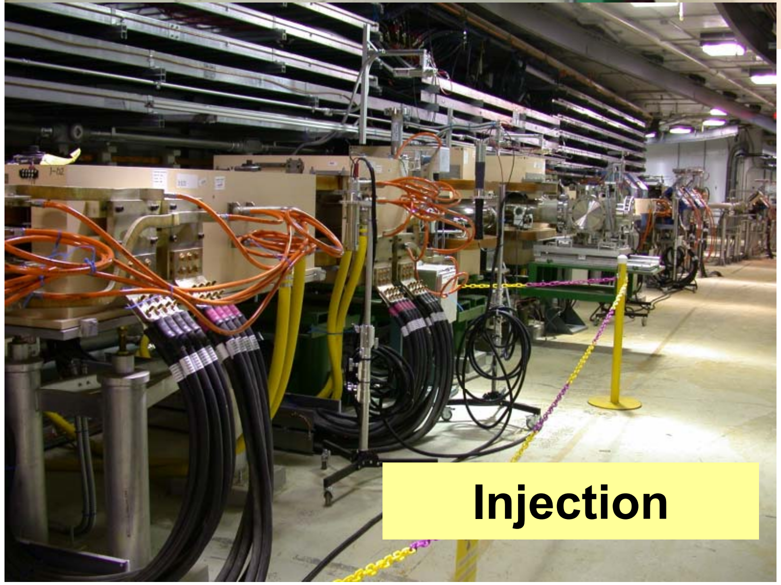


Ring and Transport Lines

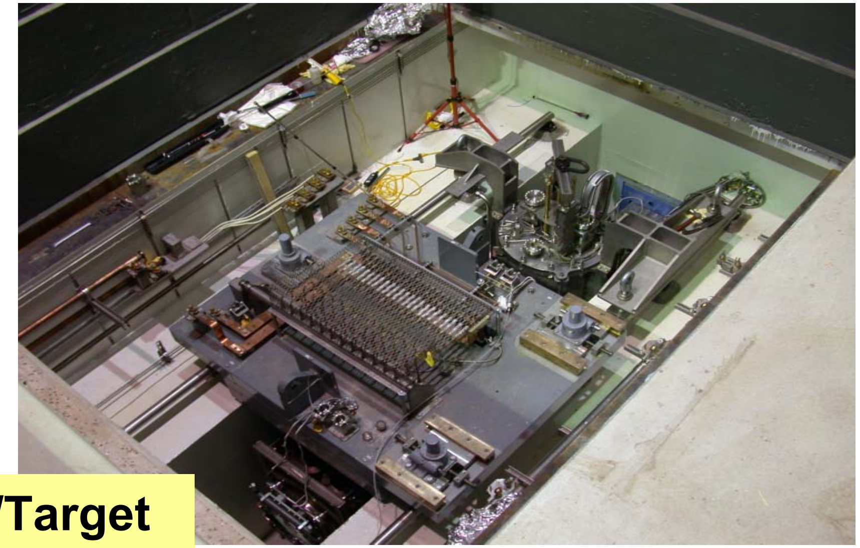
HEBT Arc



Ring Arc

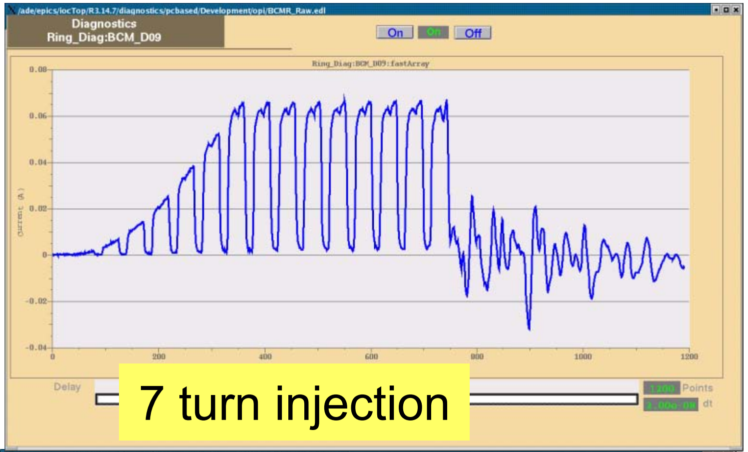


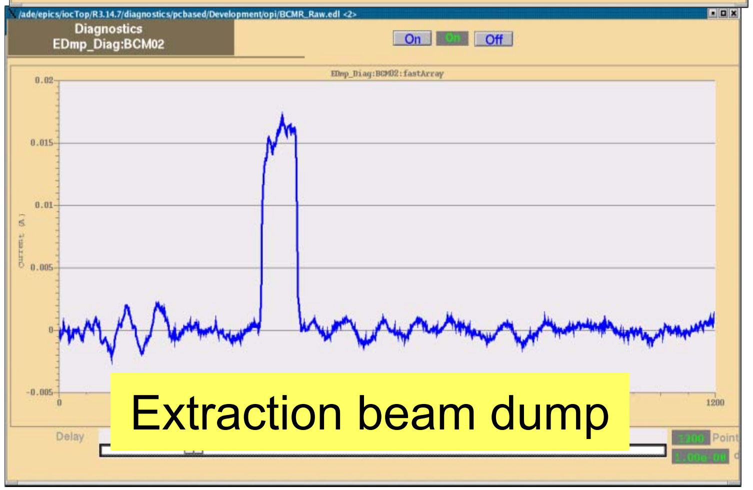
Injection



RTBT/Target

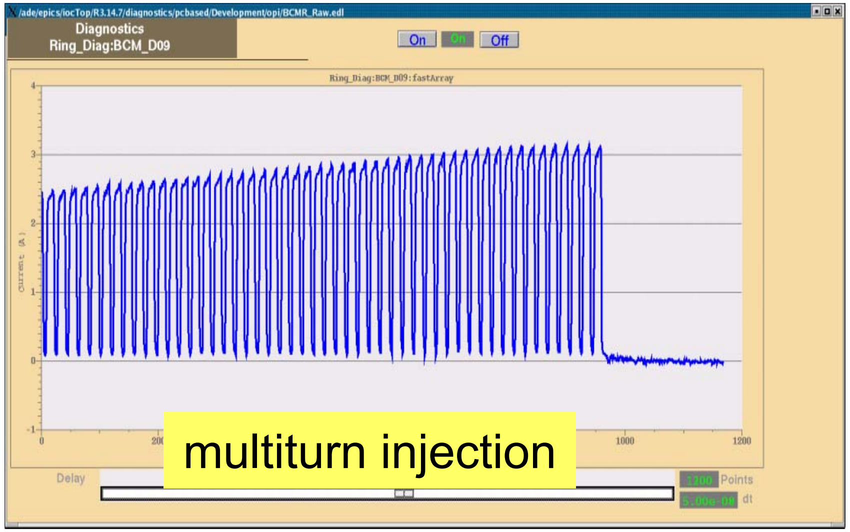
Recent Achievements

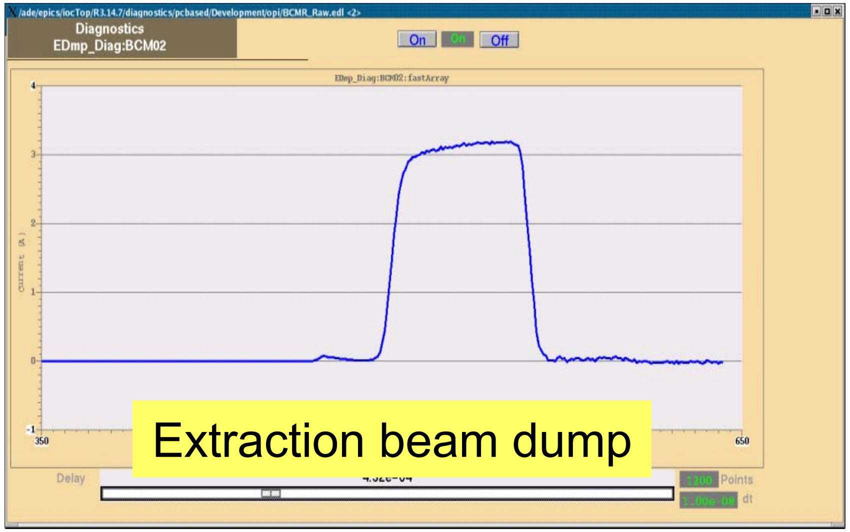




- Ring commissioning started Jan 12th, 2006.
- Status on January 14th in the picture.
- Quick start up of charge exchange injection, accumulation, and extraction since all diagnostics online at commissioning begin.

Push For High Intensity

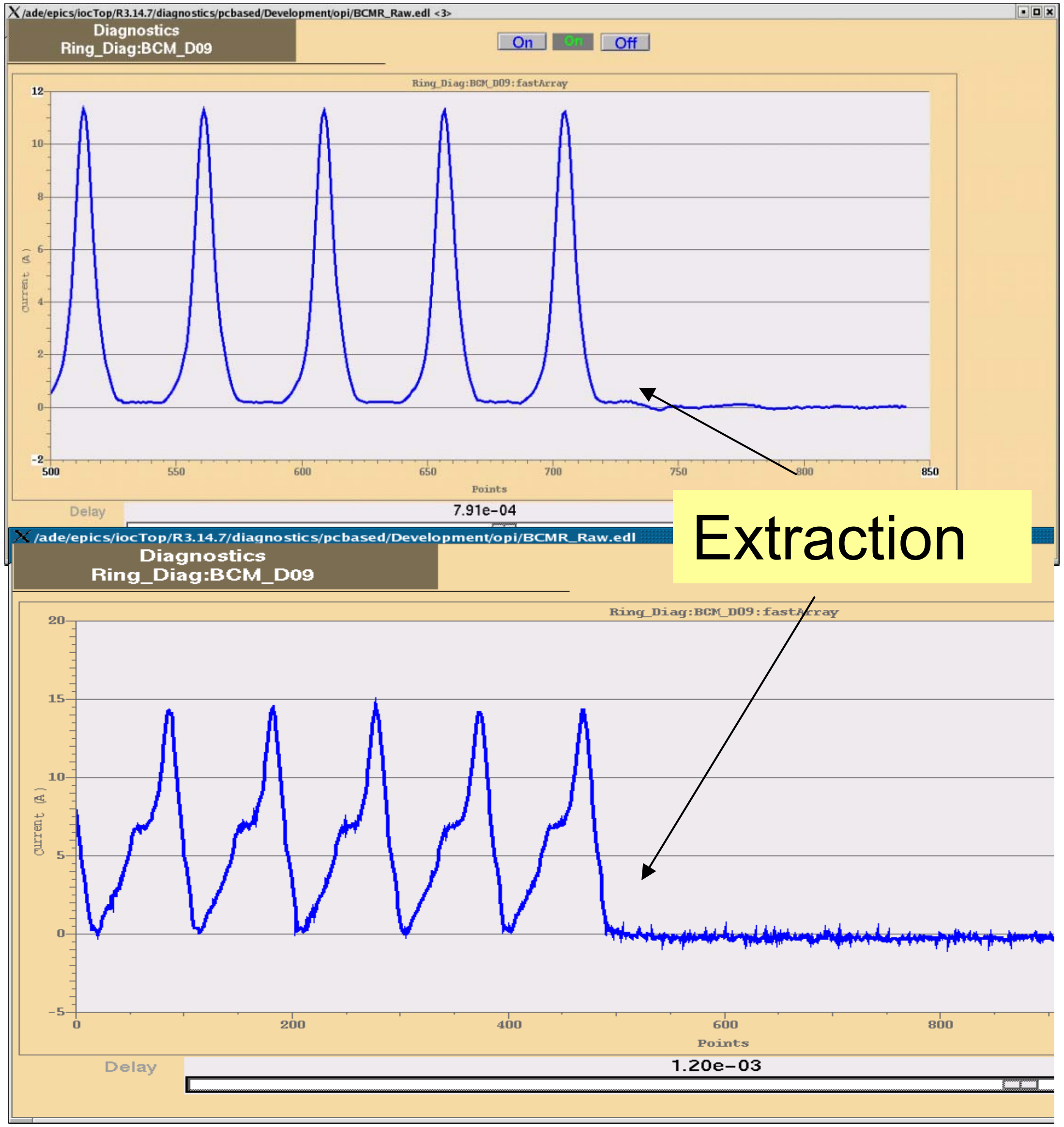




- Achieved CD4 1.3 x 10^{13} ppp intensity on Jan 26.

High Intensity Results: Beam Loading in the Ring RF System

SNS SPALLATION NEUTRON SOURCE



3×10^{13} protons per pulse

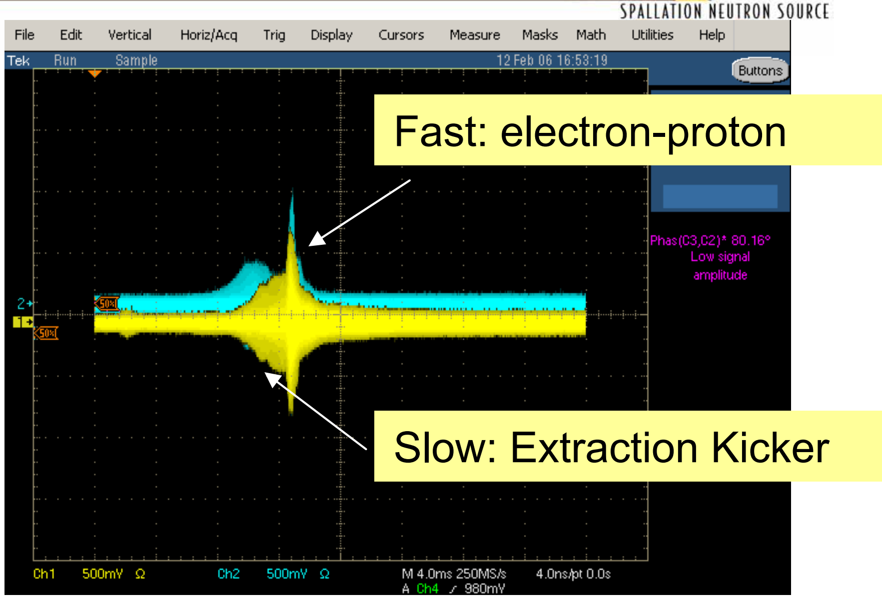
5×10^{13} protons per pulse

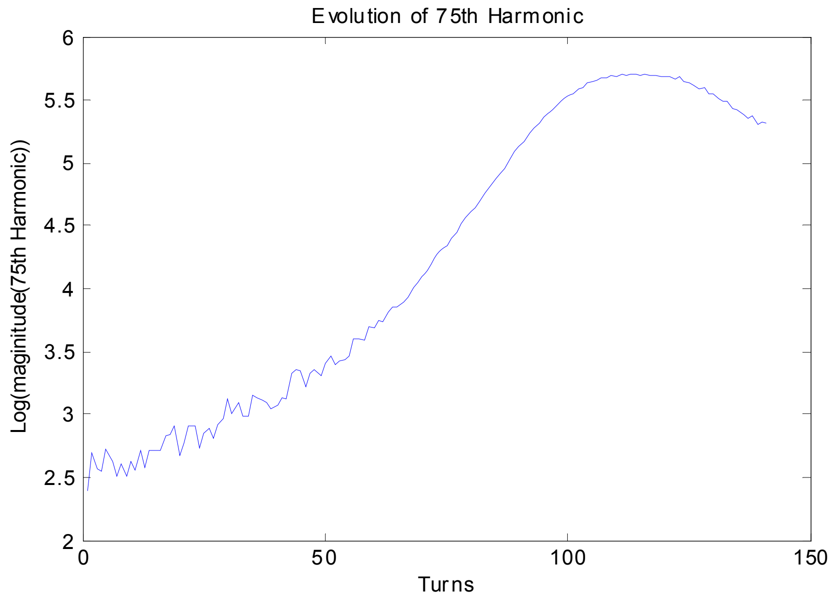
- Shows distortion of longitudinal profile and beam leaking into gap due to untuned compensation of beam loading in RF

Instability Studies at Up to 10^{14} Coasting Beam

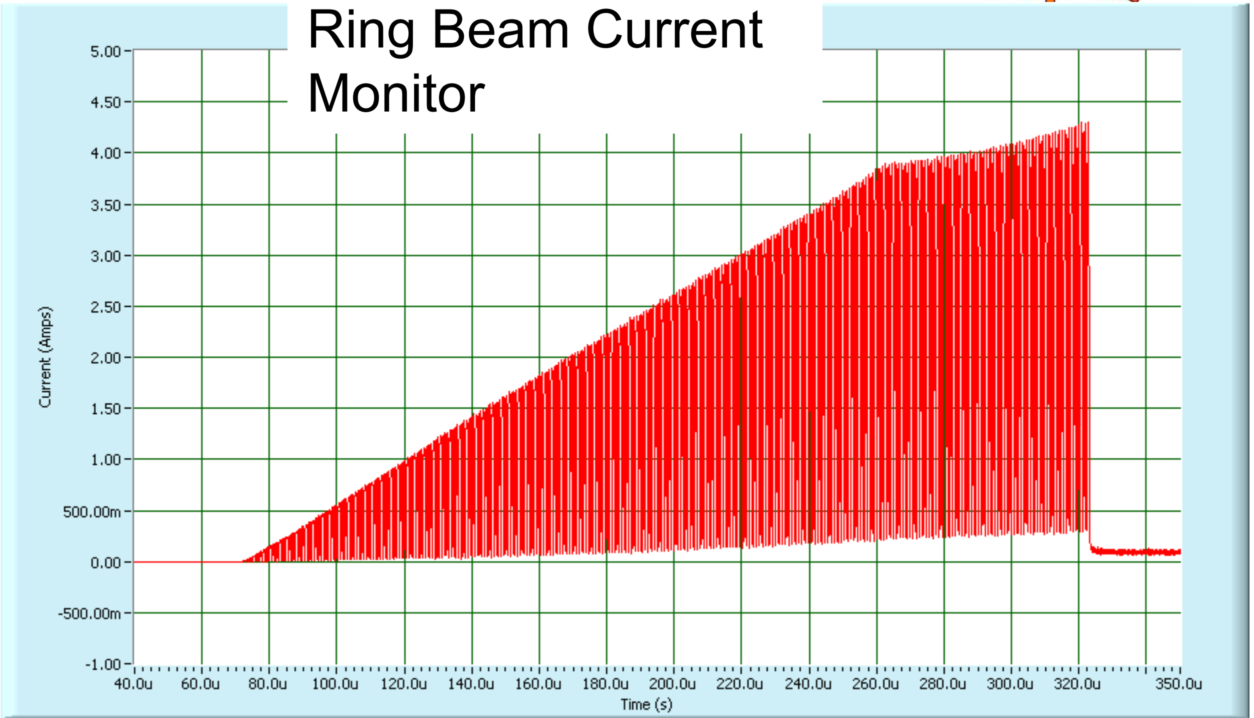
SNS
SPALLATION NEUTRON SOURCE

- During high-intensity studies we searched for instabilities by
  - delaying extraction
  - operating with zero chromaticity
  - storing a coasting beam
- No instabilities seen thus far in “normal” conditions
- First instability observed with central frequency about 6 MHz, growth rate 860 us for 10^{14} protons in the ring,
- Scaling these observations to nominal operating conditions predicts threshold > 2 MW

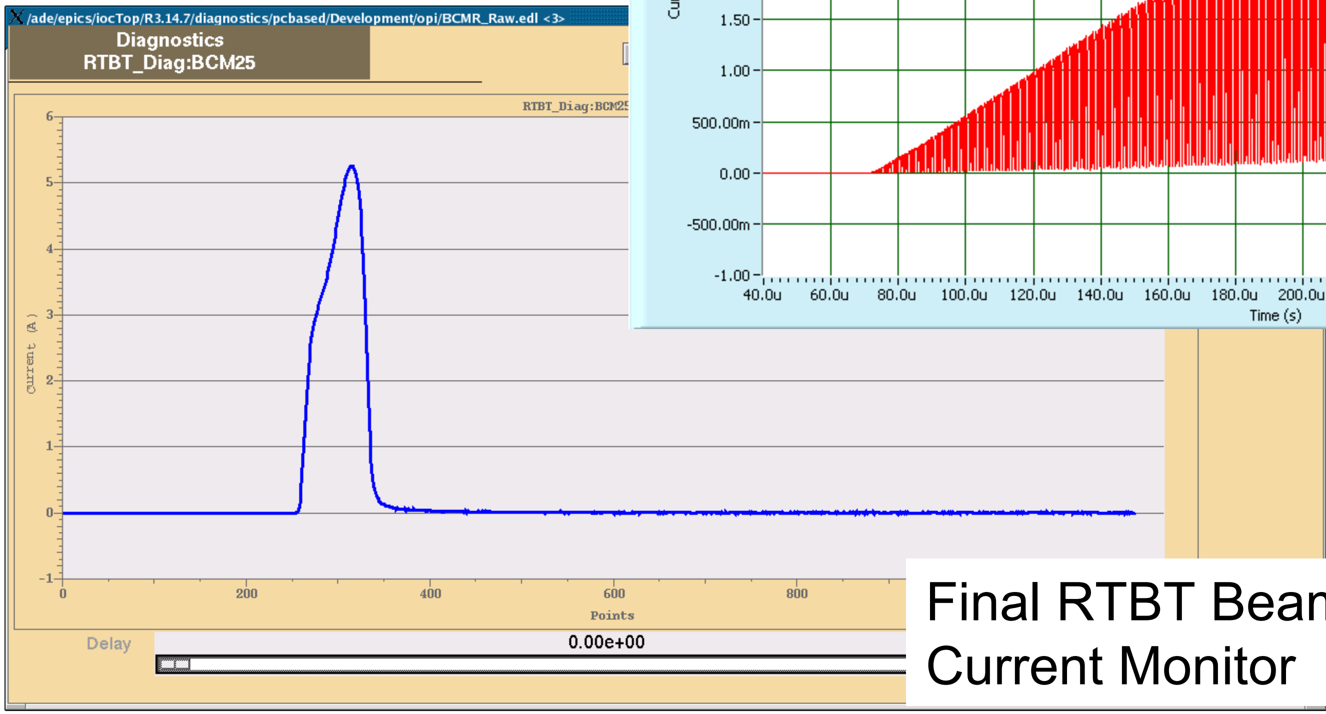




1.6×10^{13} Protons Delivered to the Target for CD4 Beam Demonstration (April 28, 2006)



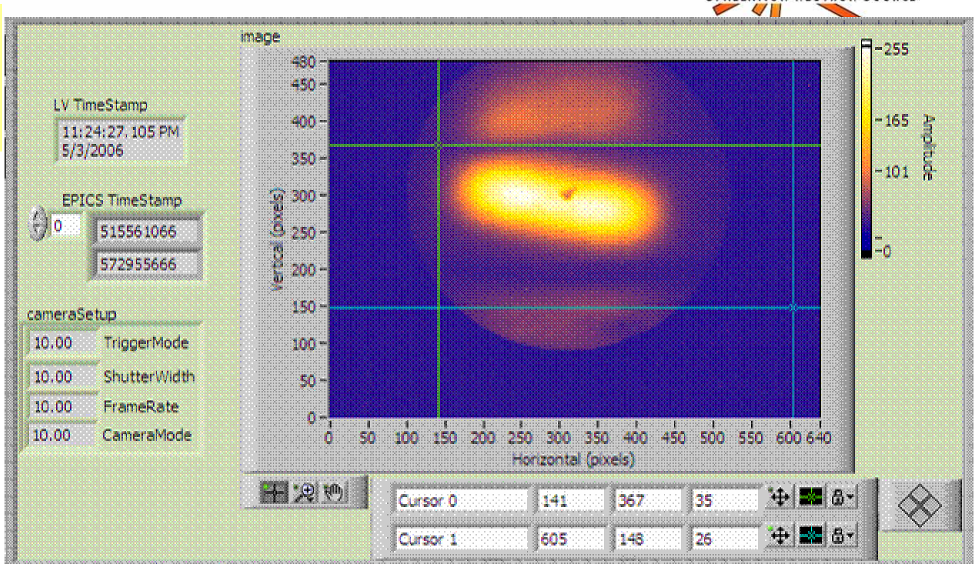
Ring Beam Current Monitor



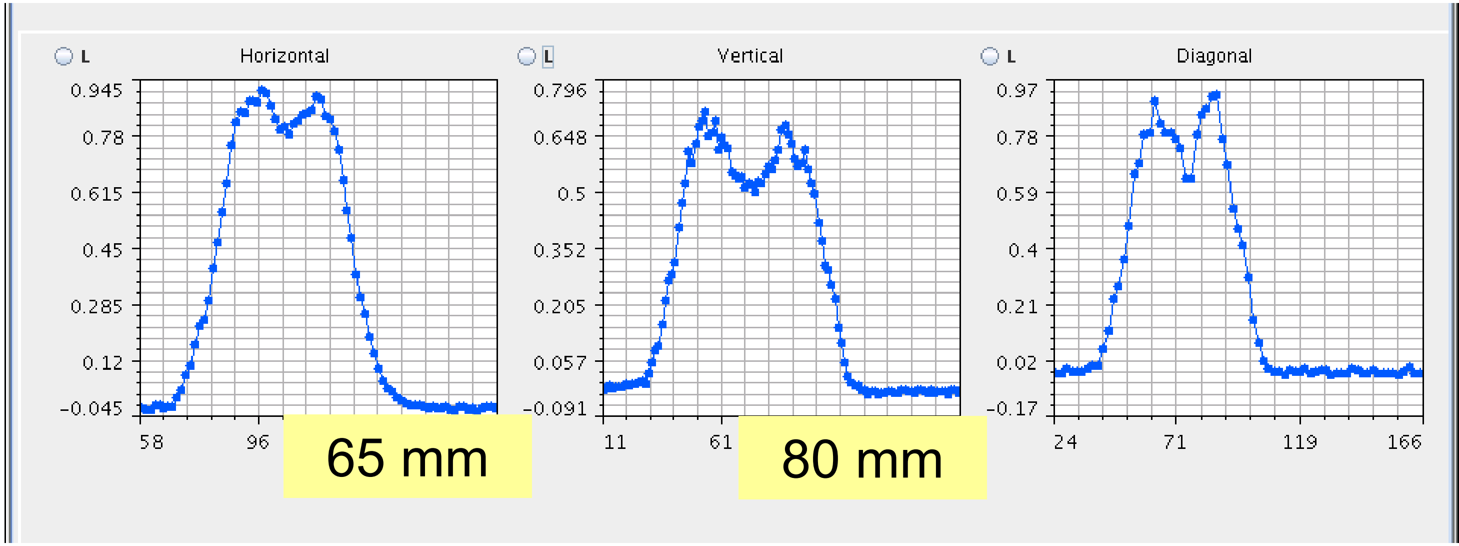
Final RTBT Beam Current Monitor

Beam on Target: Injection Painting

Beam on Target View Screen



Beam profiles in RTBT



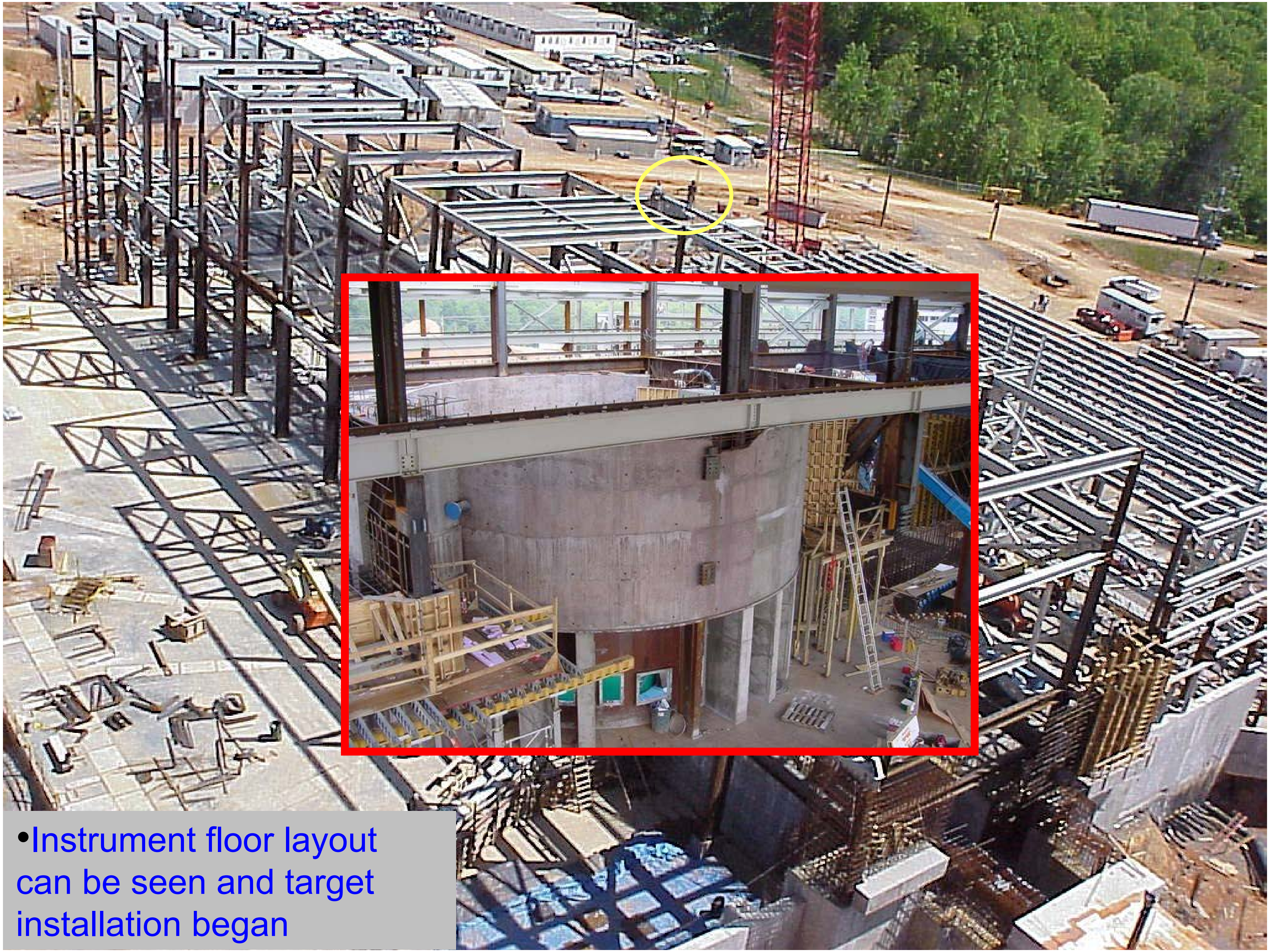
65 mm

80 mm

Ring/RTBT/Target Commissioning Timeline January-May 2006

Jan. 12: Received approval for beam to Extraction Dump.
Jan. 13: First beam to Injection Dump.
Jan. 14: First beam around ring.
Jan. 15: >1000 turns circulating in ring
Jan. 16: First beam to Extraction Dump.
Jan. 26: Reached 1.26E13 ppp to Extraction Dump.
Feb. 11: ~8 uC bunched beam (5×10^{13} ppp)
Feb. 12: ~16 uC coasting beam (1×10^{14} ppp)
Feb. 13: End of Ring commissioning run

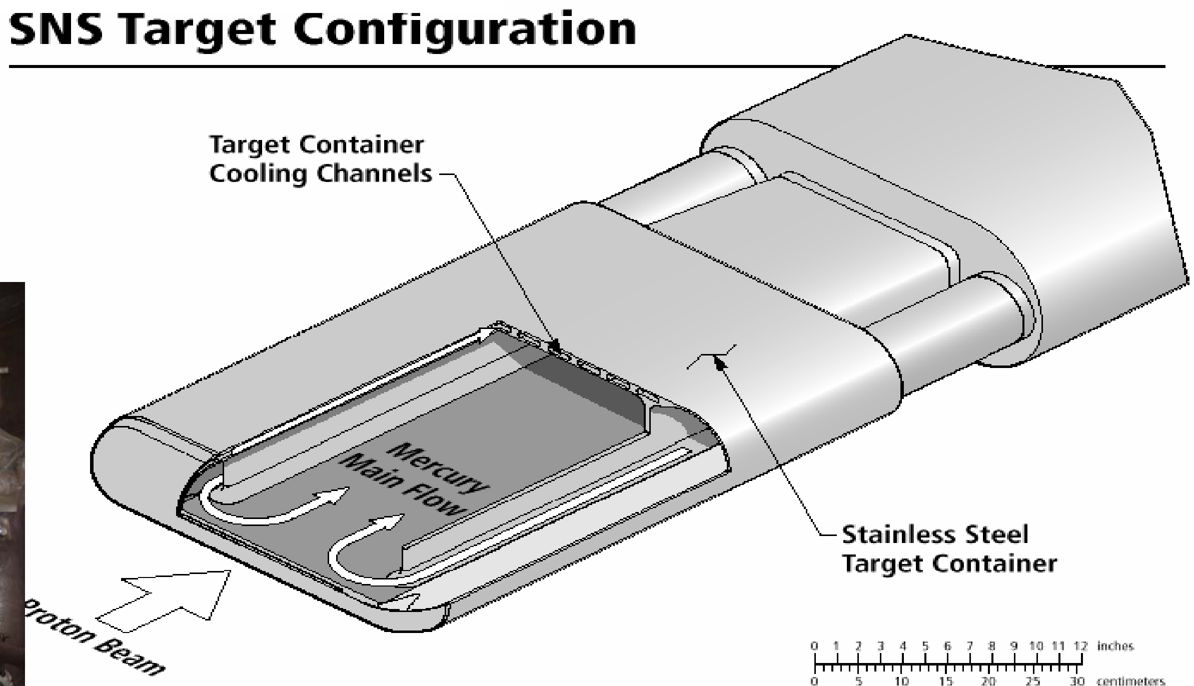
April 3-7: Readiness Review for RTBT/Target
April 27: Received approval for Beam on Target
April 28: First beam on target and 2 hours later CD4 ($>10^{13}$) beam demonstration



•Instrument floor layout can be seen and target installation began

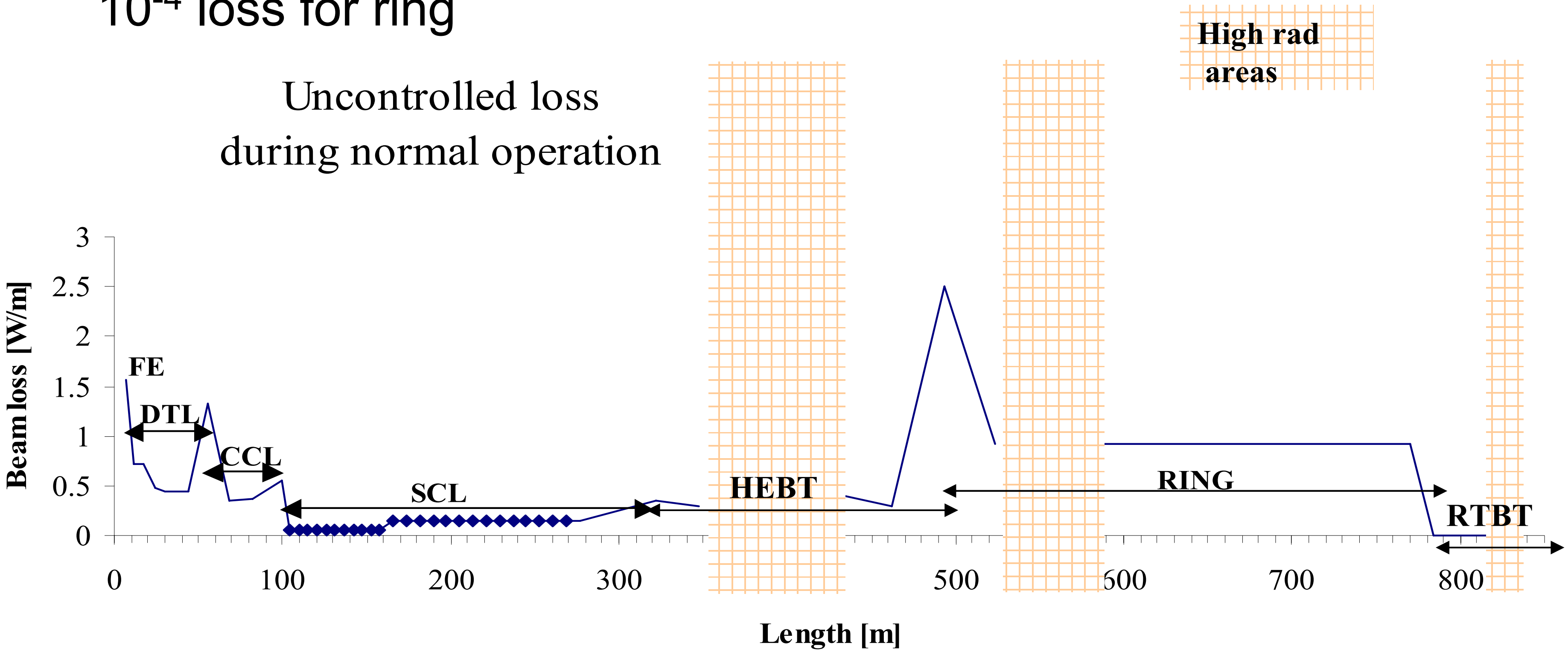
The SNS Target: 2-MW Design

- 25 kJ/pulse at 7x15cm beam size sets of transverse and longitudinal shock wave.
- Needs to be exchanged remotely every 3 month at full power operation.



Primary Concern for SNS on its Way to Full Power Operation: *Uncontrolled Beam Loss*

- Hands-on maintenance: no more than 100 mrem/hour residual activation (4 h cool down, 30 cm from surface)
- 1 Watt/m uncontrolled beam loss for linac & ring
- Less than 10^{-6} fractional beam loss per tunnel meter at 1 GeV; 10^{-4} loss for ring



SNS Diagnostics Deployment

Operational

Not Operating

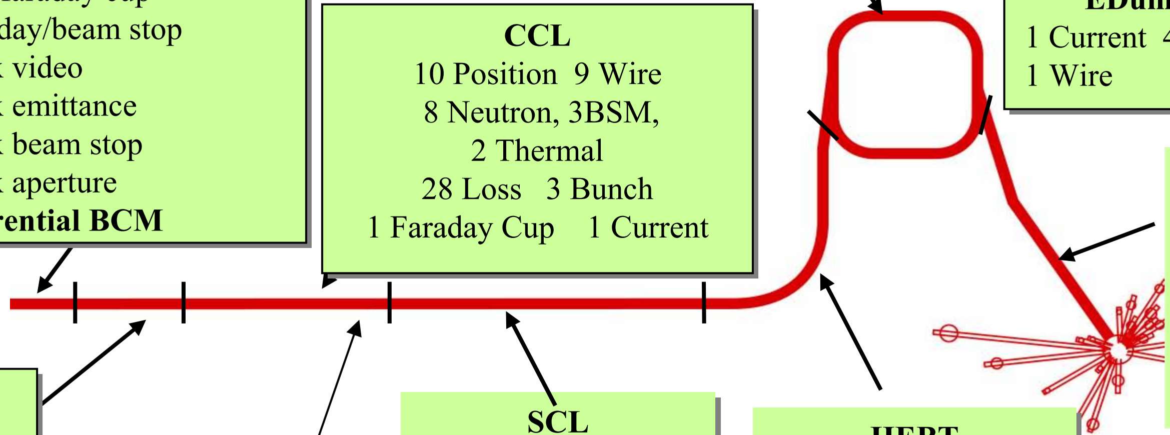
MEBT
6 Position
2 Current
5 Wires
2 Thermal Neutron
3 PMT Neutron
1 fast faraday cup
1 faraday/beam stop
D-box video
D-box emittance
D-box beam stop
D-box aperture
Differential BCM

IDump
1 Position
1 Wire
1 Current
6 BLM

RING
44 Position *2 Ionization Profile*
70 Loss 1 Current
5 Electron Det. 12 FBLM
2 Wire *1 Beam in Gap*
2 Video *1 Tune*

CCL
10 Position 9 Wire
8 Neutron, 3BSM,
2 Thermal
28 Loss 3 Bunch
1 Faraday Cup 1 Current

EDump
1 Current 4 Loss
1 Wire



RTBT
17 Position
36 Loss
4 Current
5 Wire
1 Harp
3 FBLM

DTL
10 Position 5 Wire 12 Loss
5 Faraday Cup 6 Current
6 Thermal and 12 PMT Neutron

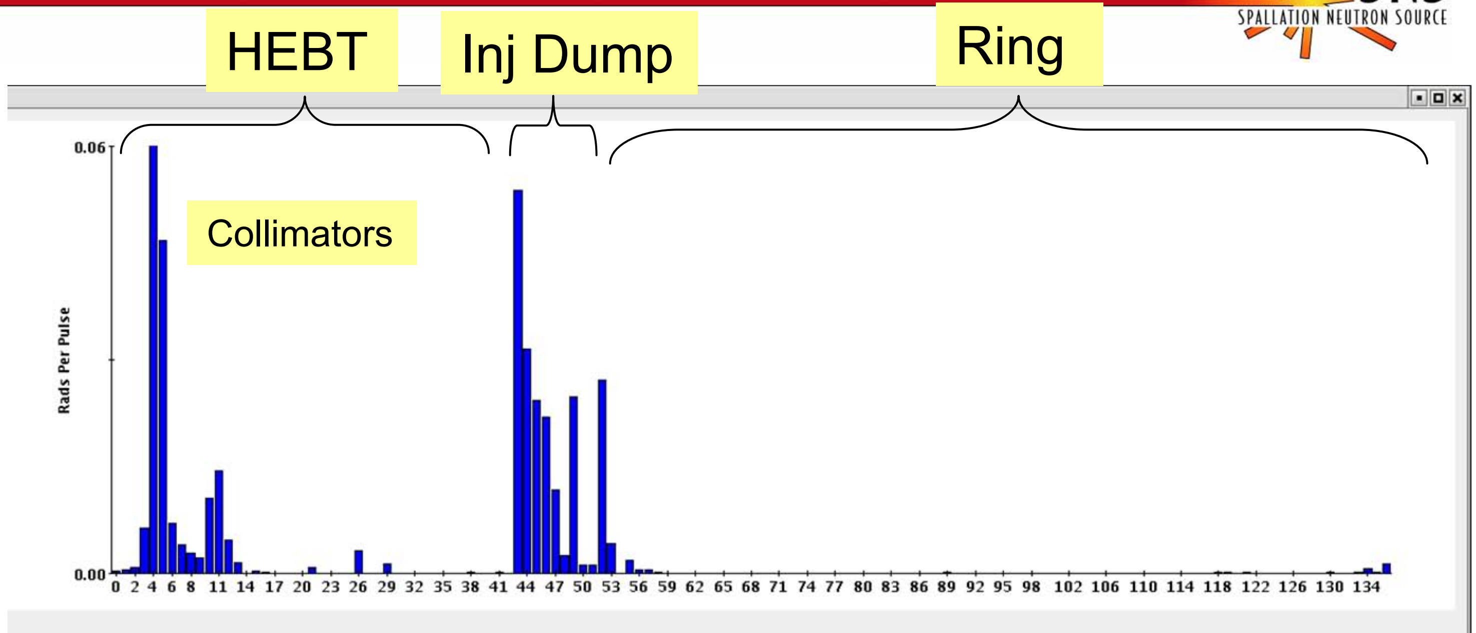
SCL
32 Position 86 Loss
9 Laser Wire
24 PMT Neutron

HEBT
29 Position
1 Prototype Wire-S
46 BLM, 3 FBLM
4 Current

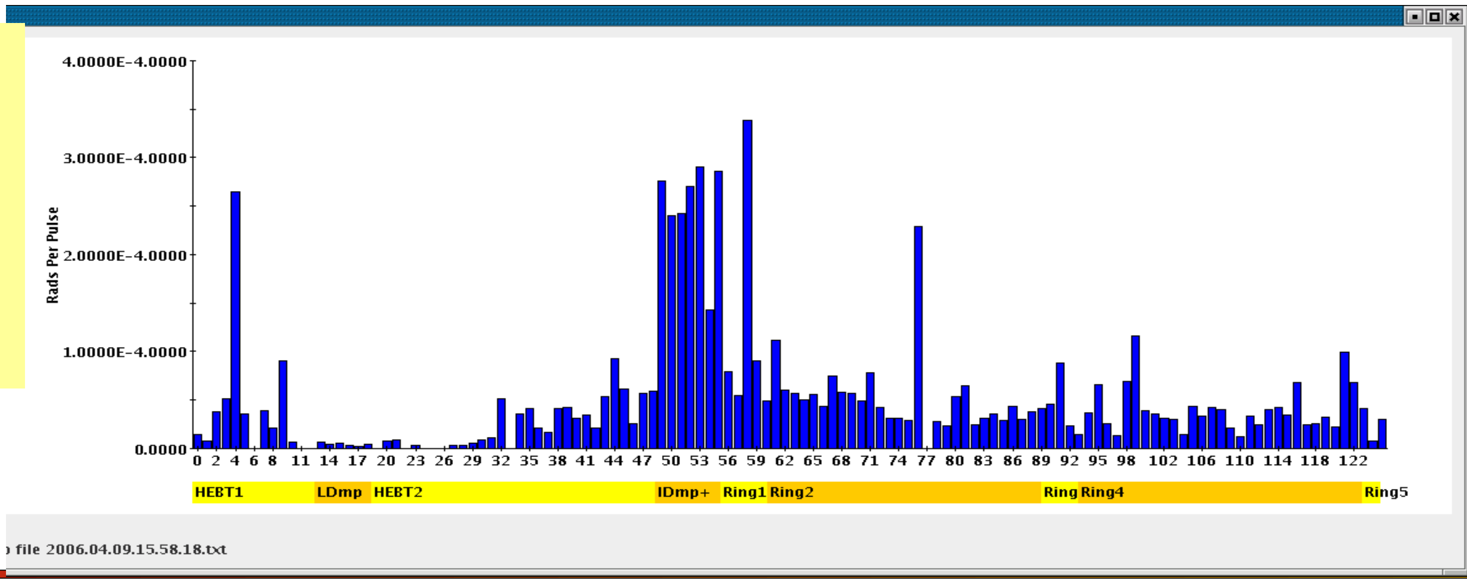
CCL/SCL Transition
2 Position 1 Wire
1 Loss 1 Current

LDump
6 Loss
6 Position
1 Wire ,1 BCM

Losses in HEBT and Ring



480 turn accumulation



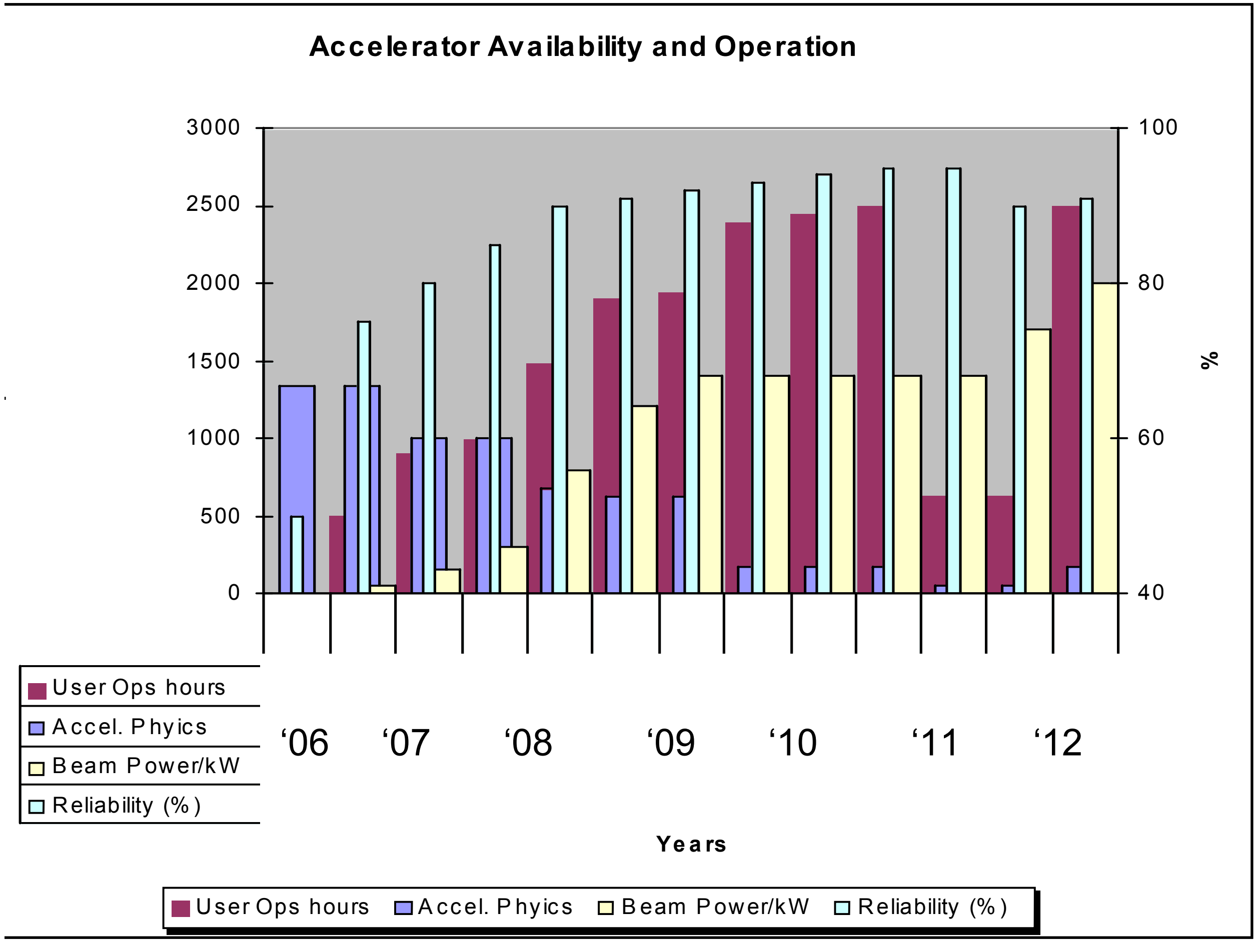
Relative Idump/Ring losses reduced with smaller spot on foil

SNS Early Operations: Ramping up Scientific Productivity

- Beam lines at SNS will be fully committed in ~2-3 years

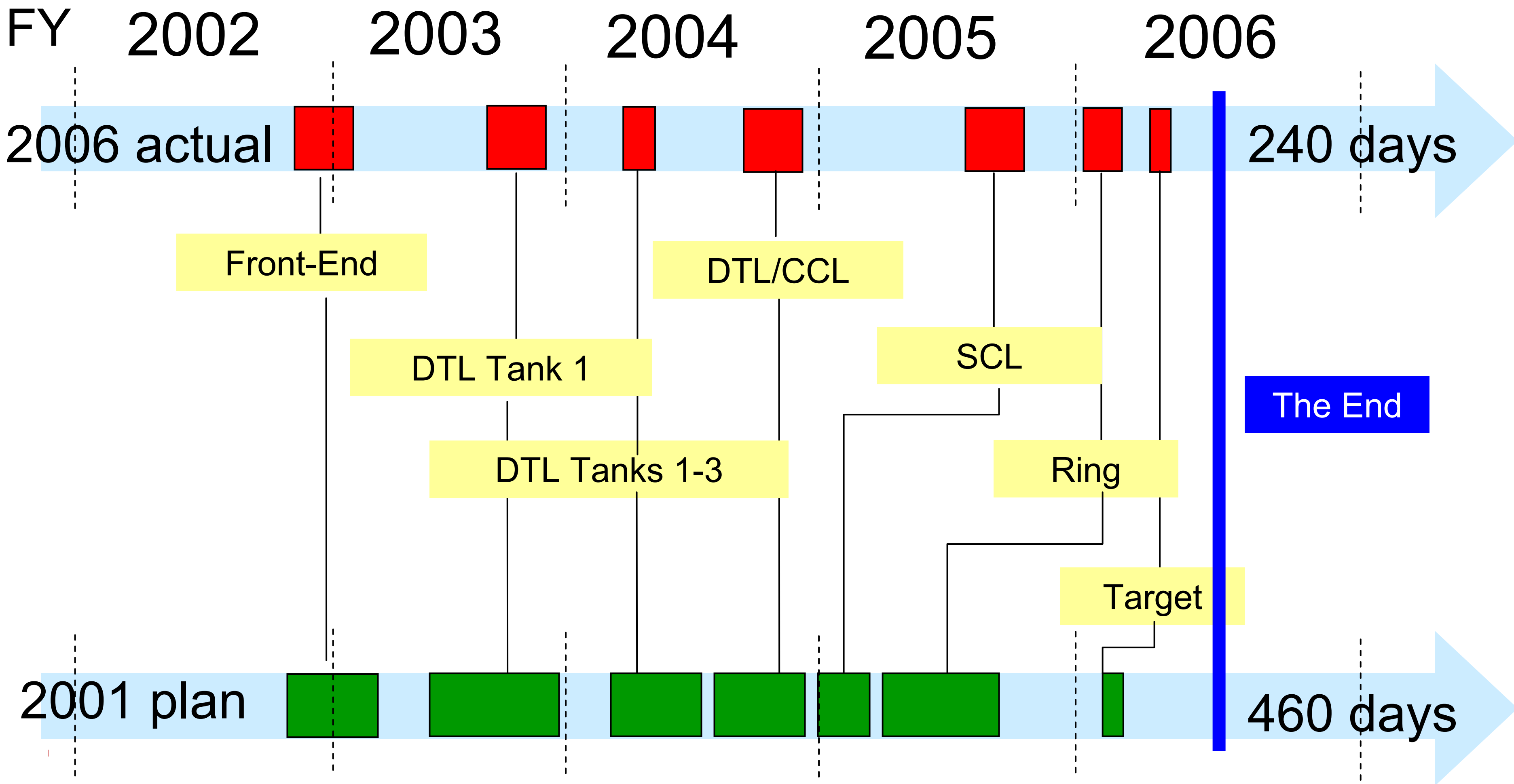
- Shared the plan with the community to get them involved early on: "Manage Expectations"

- Work has begun on the Power Upgrade (x2!) with a 9 month interruption in 2011

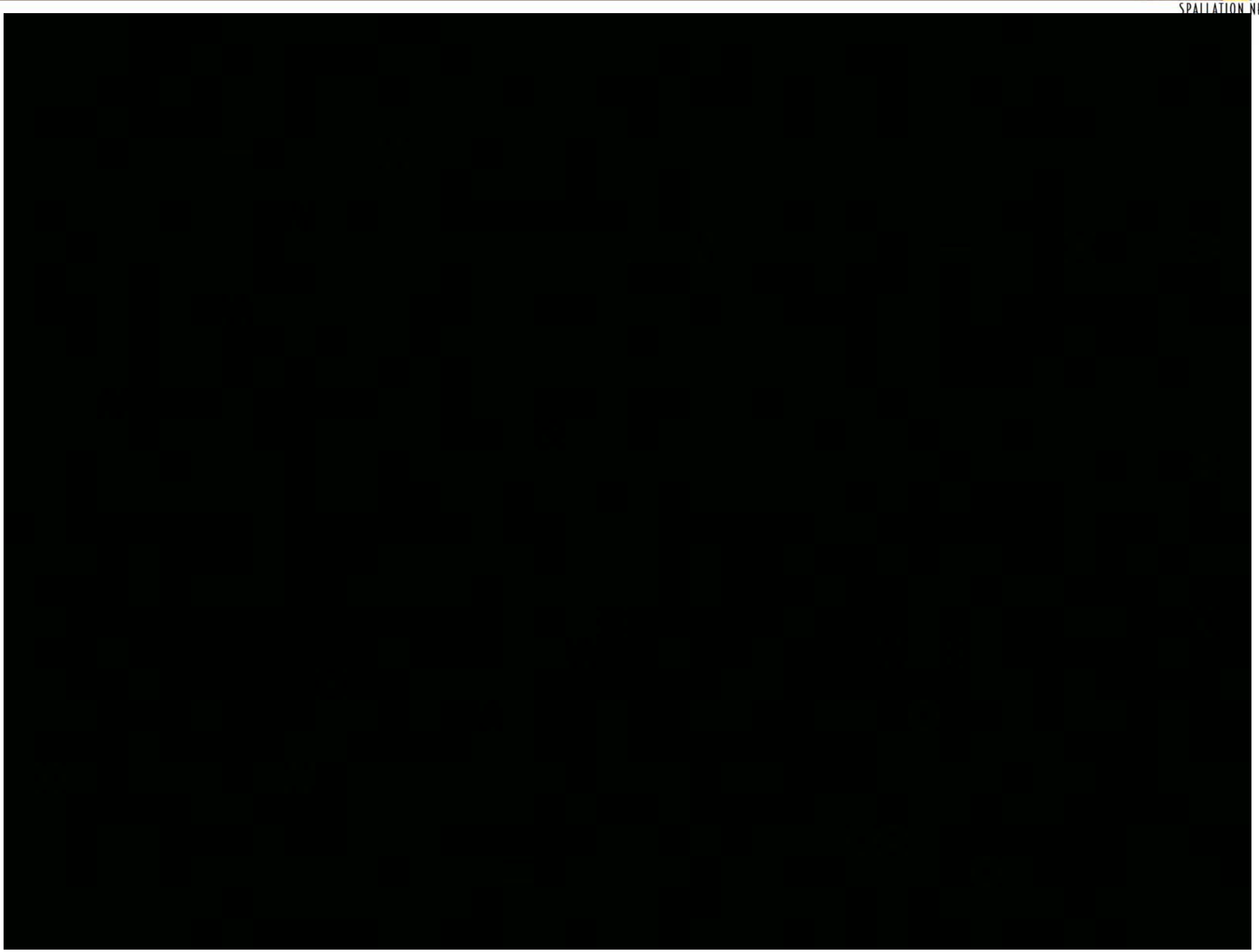


Schedule Changes…. And How Did We Make It?

- Its always the first schedule that counts to measure how well a project is doing, not the last one…..



You Have To Be Faster…. And Sometimes You Better Be Lucky



Cost Development between 2001 and 2006

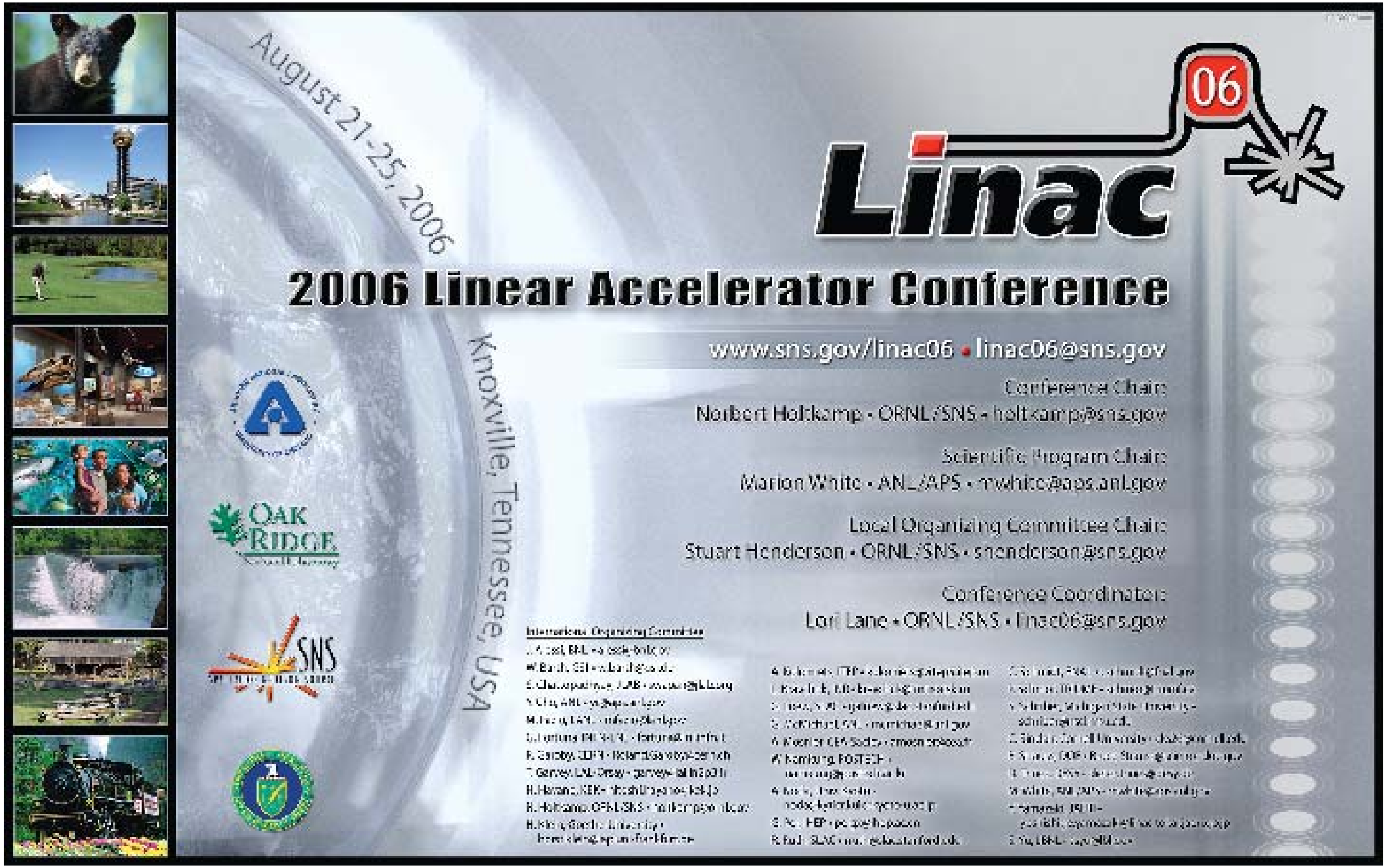
- Spend $1.41 Billion dollars in 7 years with a peak of ~ 1 M$/day during peak construction.
- ~ $6.5 M contingency left at the end for scope additions

	Nov 2001 [$M]	May 2006 [$M]	Contingency
1.01 Research & Development	103.8	99.9	-3.8%
1.10 Operations	115.2	119.1	3.4%
Total OPC (Burdened, Escalated Dollars)	**219.0**	**219.0**	0.0%
1.02 Project Support	72.3	72.1	-0.3%
1.03 Front End Systems	19.3	20.8	7.9%
1.04 Linac Systems	272.4	311.0	14.2%
1.05 Ring & Transfer System	146.2	146.6	0.3%
1.06 Target Systems	95.3	114.9	20.5%
1.07 Instrument Systems	62.3	63.9	2.6%
1.08 Conventional Facilities	310.7	398.5	28.3%
1.09 Integrated Control Systems	58.6	58.5	-0.1%
Total Line Item (Burdened, Escalated Dollars)	**1037.0**	**1186.3**	14.4%

How Much R&D Can One Do/Effort in a Construction Project?

- Quite a bit…and a construction schedule is driving the R&D to be very fast and efficient.
  - LASER profile monitor to replace standard carbon wires in the SC part of the linac which can be used while operating a full intensity beam
  - Nano-crystaline foil development for high intensity beams, tested at the PSR.
  - A fast feedback system to reduce/eliminate the PSR instability
  - A H- stripping experiment based on Laser/Magnetic stripping.

LINAC 2006 –Aug 21-25… The Last Chance to See the Complex!!!! – We Invite You to Take the Opportunity

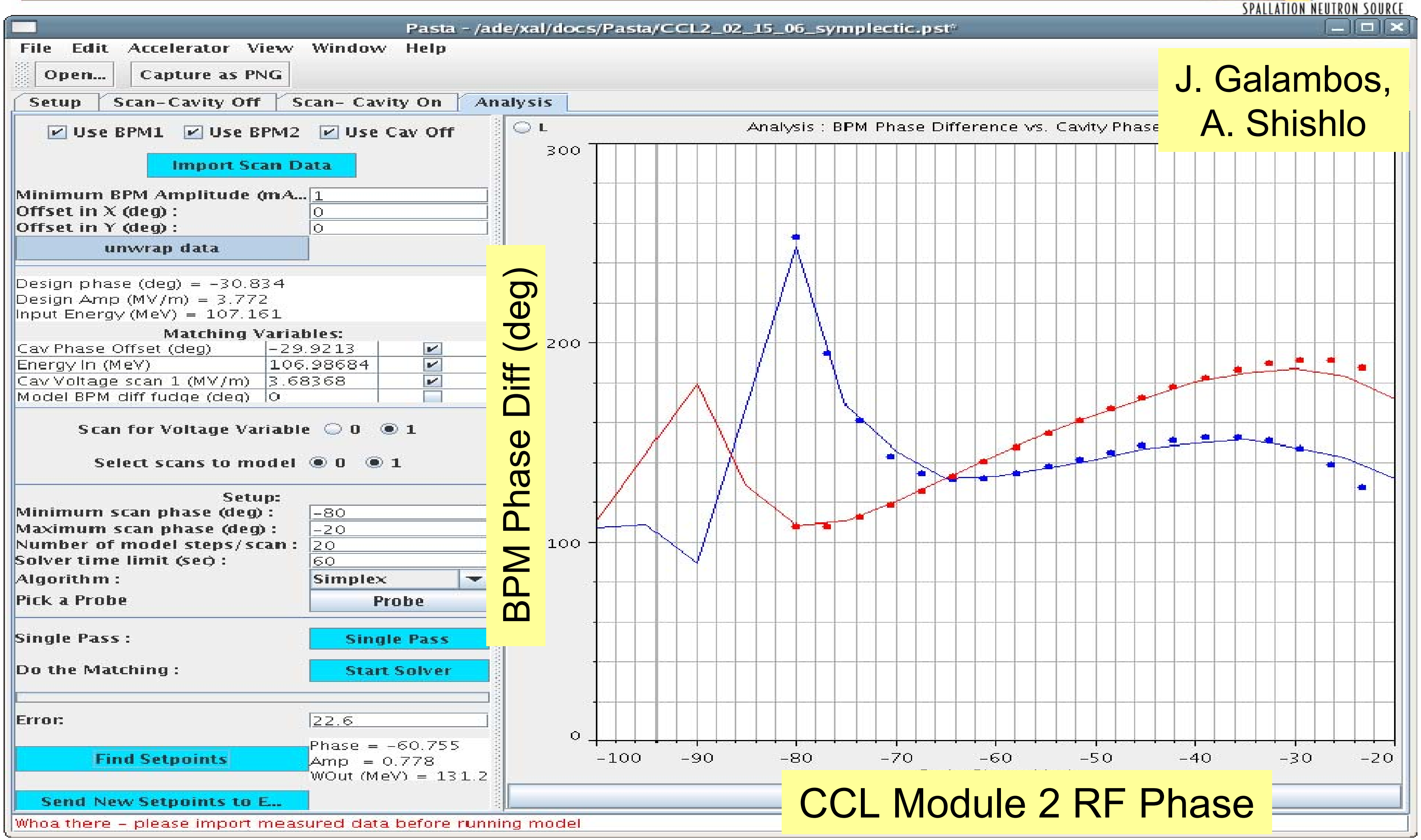


Summary

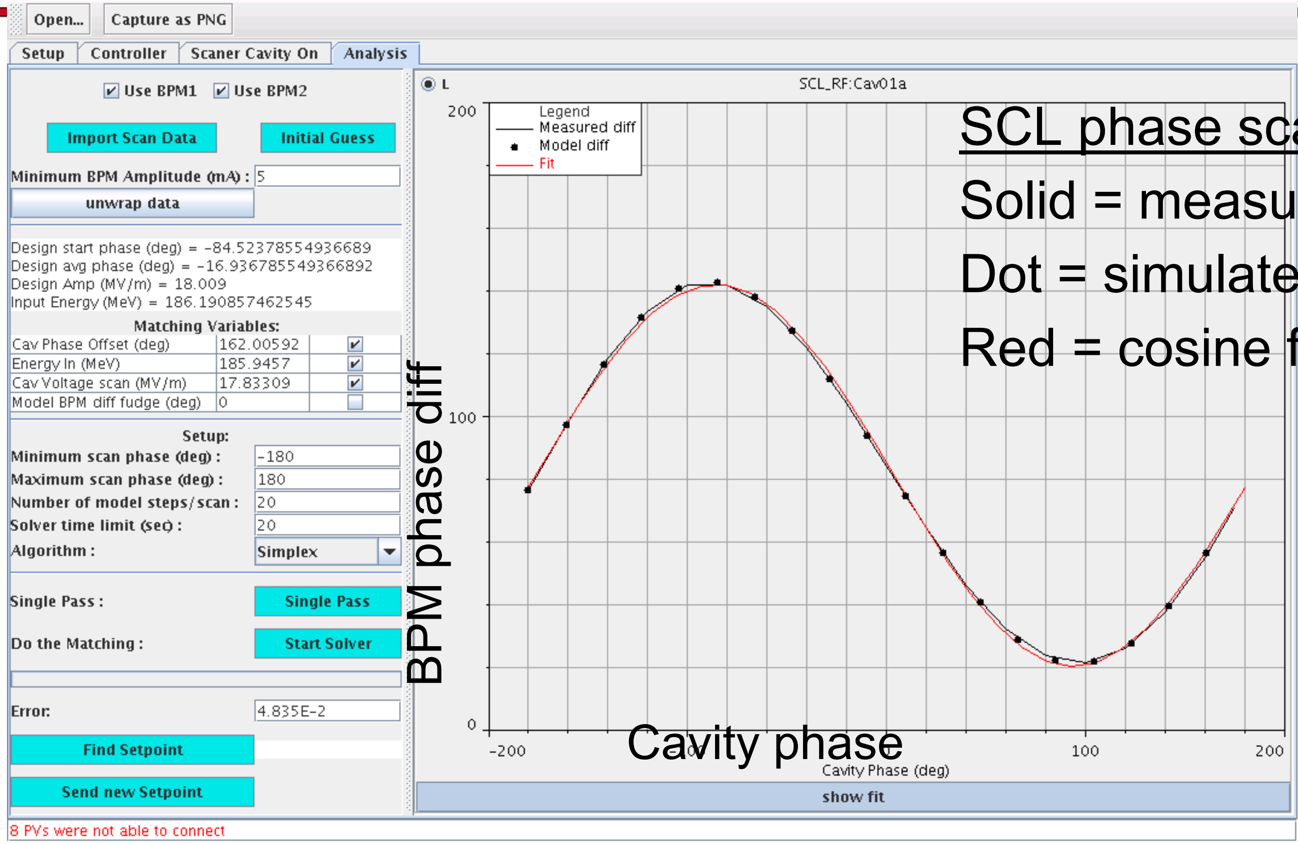
- The SNS project is officially finished end of May, 2006 (end of June 2006) with the signature of the Critical Decision 4 documents at a total project cost of $1,405,2M ($1,411.7M) .
- SNS construction was accompanied by several severe technical setbacks and subsequent MIRACLES on recovery. “Fortes Fortuna Adjuvat” -> luck is with the brave !
- I want to thank the DOE, the partnerlabs and their leadership, the people that worked on SNS, the community that helped significantly in solving many of the issues, all the vendors that delivered components (many are here) but especially every member of the Accelerator Systems Division at SNS in make this such a great success and therefore such a pleasant experience.
- I certainly hope that Stuart will be standing here in 3 years and reporting that SNS has achieved its operational goals.

- I personally look forward to giving a talk at APAC, EPAC or PAC again… but probably not on accelerators in the near future!

DTL and CCL RF Setpoints by Phase Scan Signature Matching



SCL Phase Scan using BPMs



SCL phase scan for first cavity

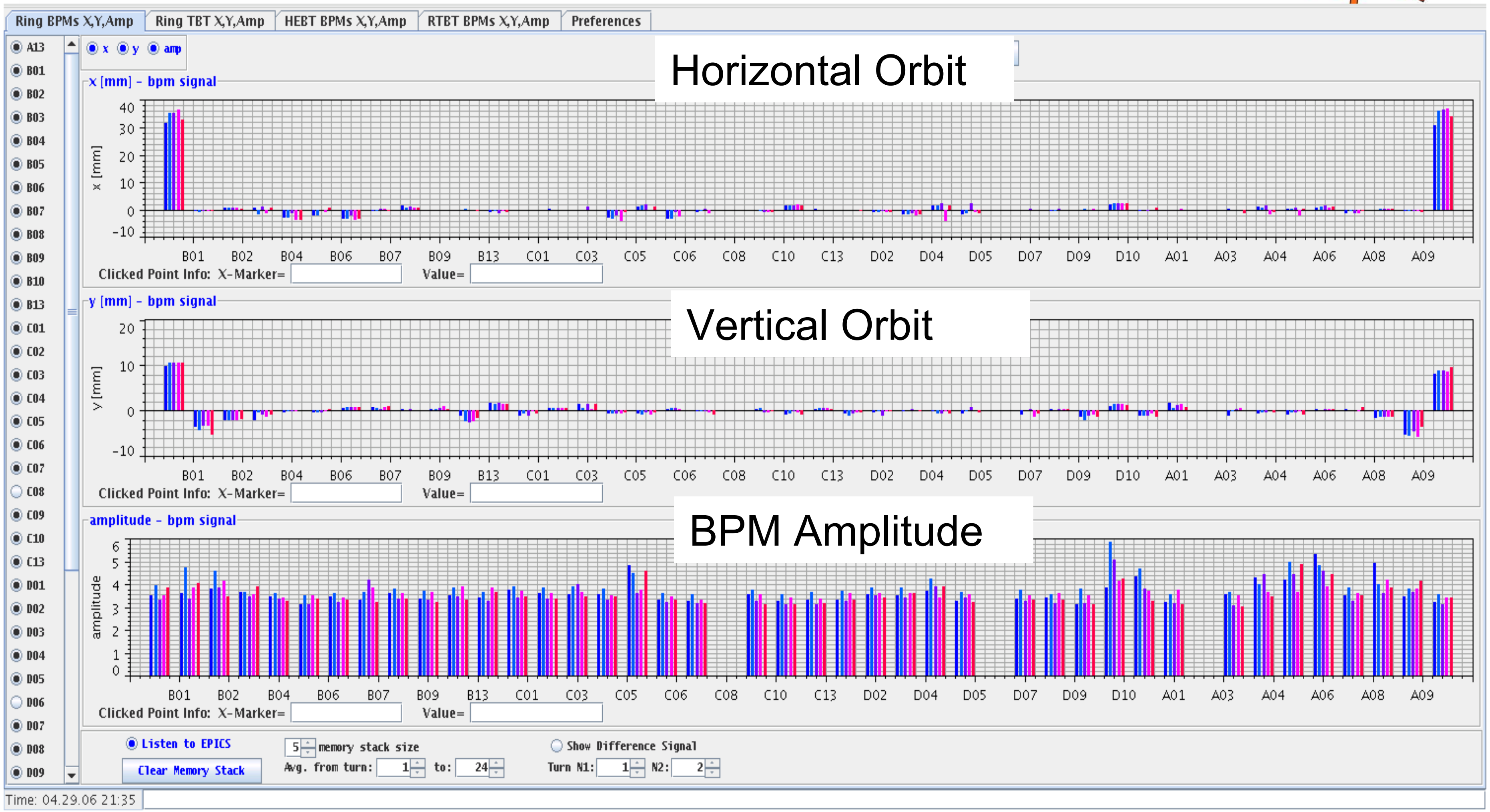
Solid = measured BPM phase diff

Dot = simulated BPM phase diff

Red = cosine fit

- Matching involves varying input energy, cavity voltage and phase offset in the simulation to match measured BPM phase differences
- Relies on absolute BPM calibration
- With a short, low intensity beam, results are insensitive to detuning cavities intermediate to measurement BPMs

Ring Closed Orbit: H,V Bumps are Due to Injection Kickers

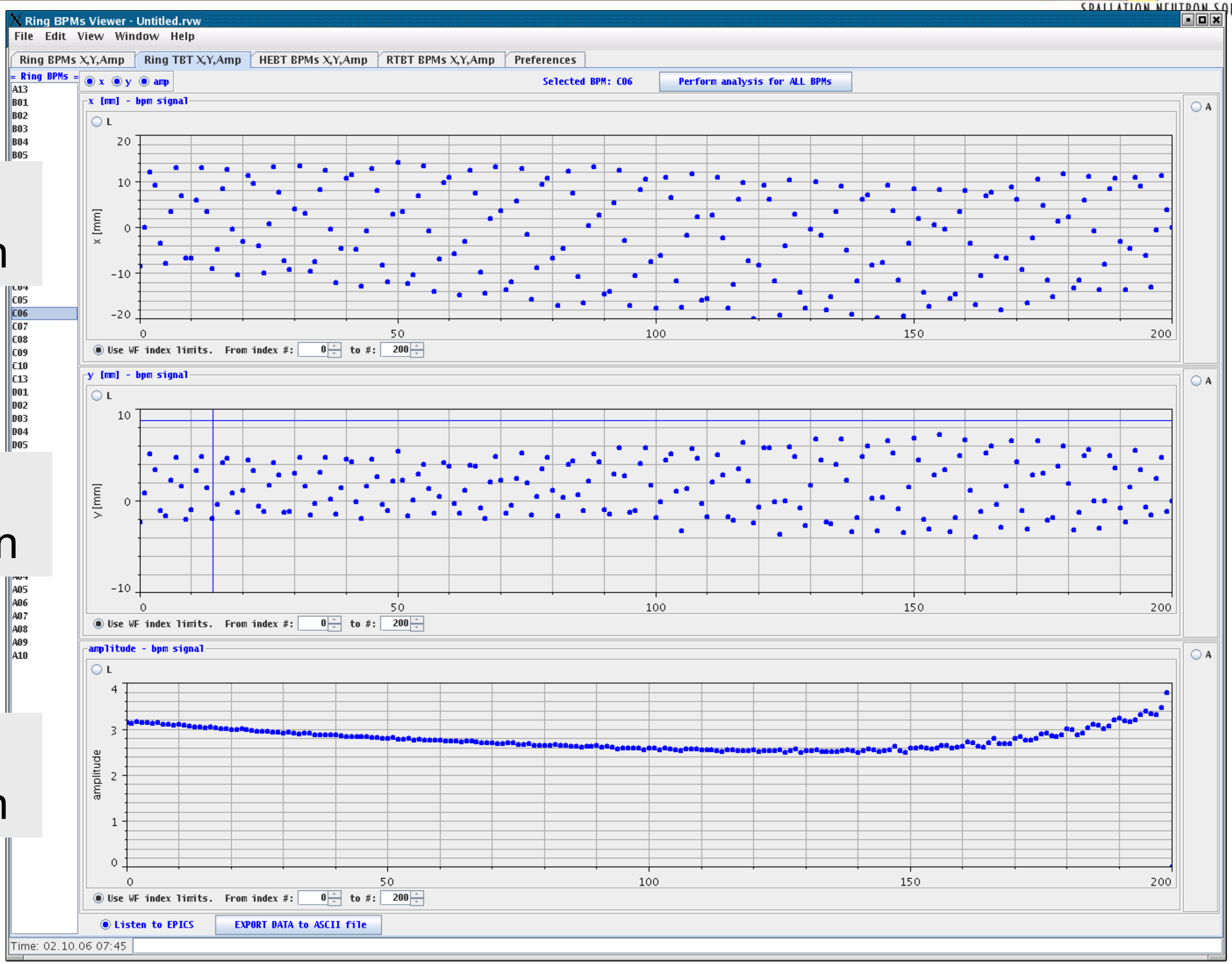


Turn by Turn Data for Zero Chromaticity

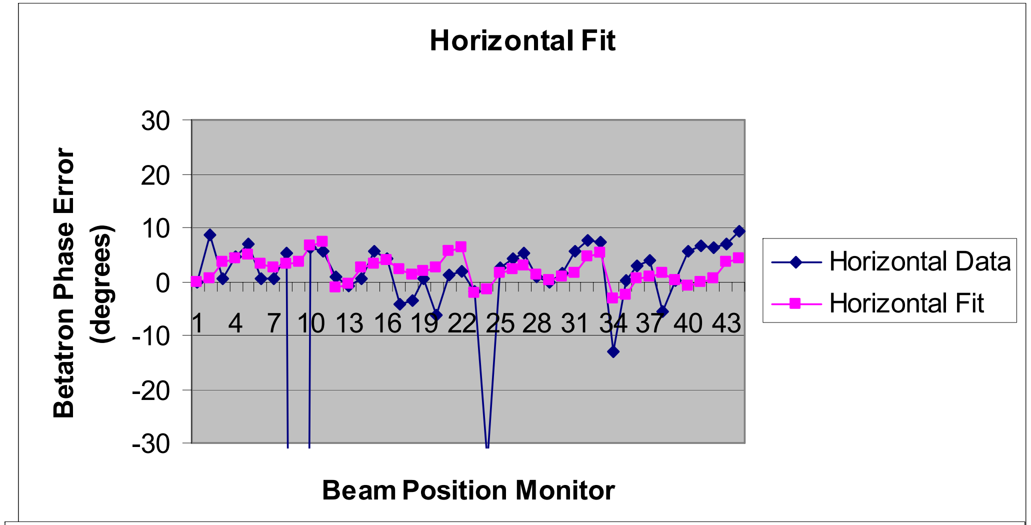
Horizontal
Turn-by-turn

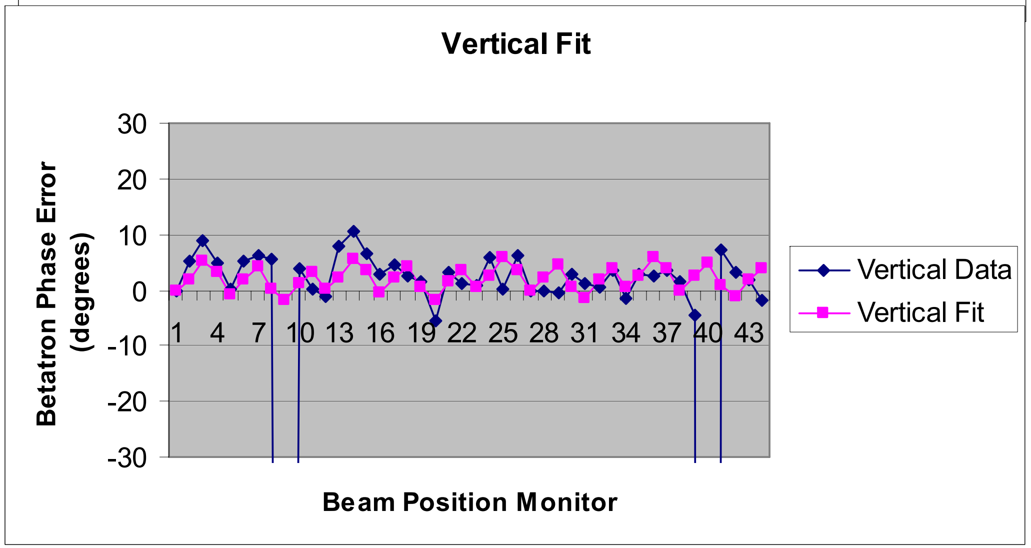
Vertical
Turn-by-turn

Amplitude
Turn-by-turn



Ring Optics Measurements: Betatron Phase Advance and Chromaticity



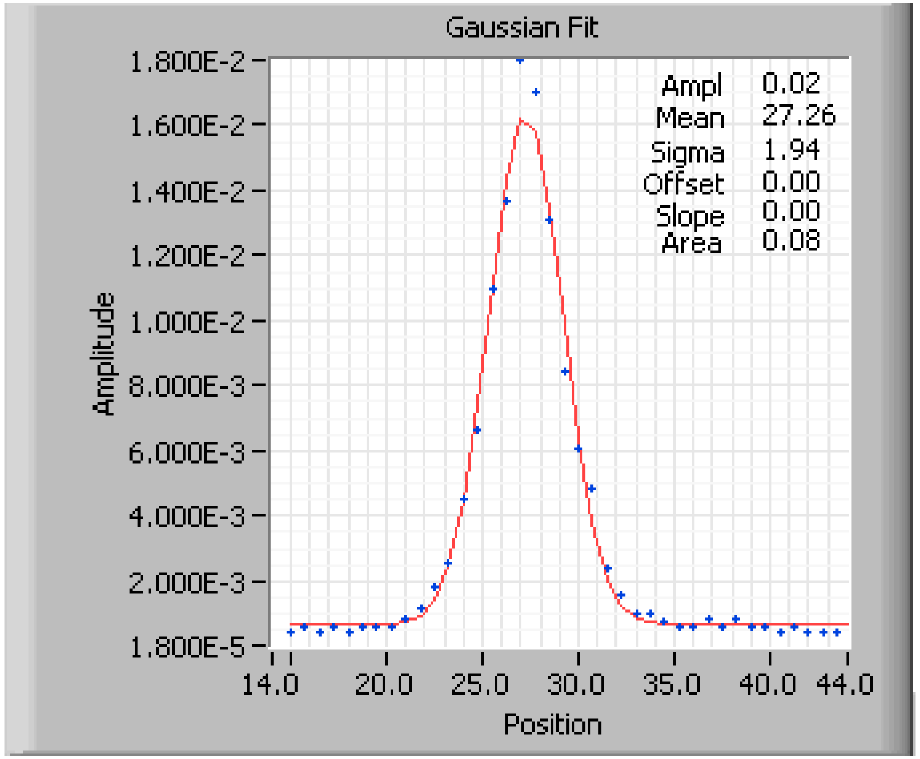


Plots show measured betatron phase error vs. model-based fit

Data indicates that the linear lattice is already very close to design

	Vert	Horiz
Natural Chromaticity (Design)	-6.9	-7.9
Natural Chromaticity (Measured)	-7.2	-8.2
Corrected Chromaticity (Meas)	0.0	0.1

SCL Laser Profile Measurements

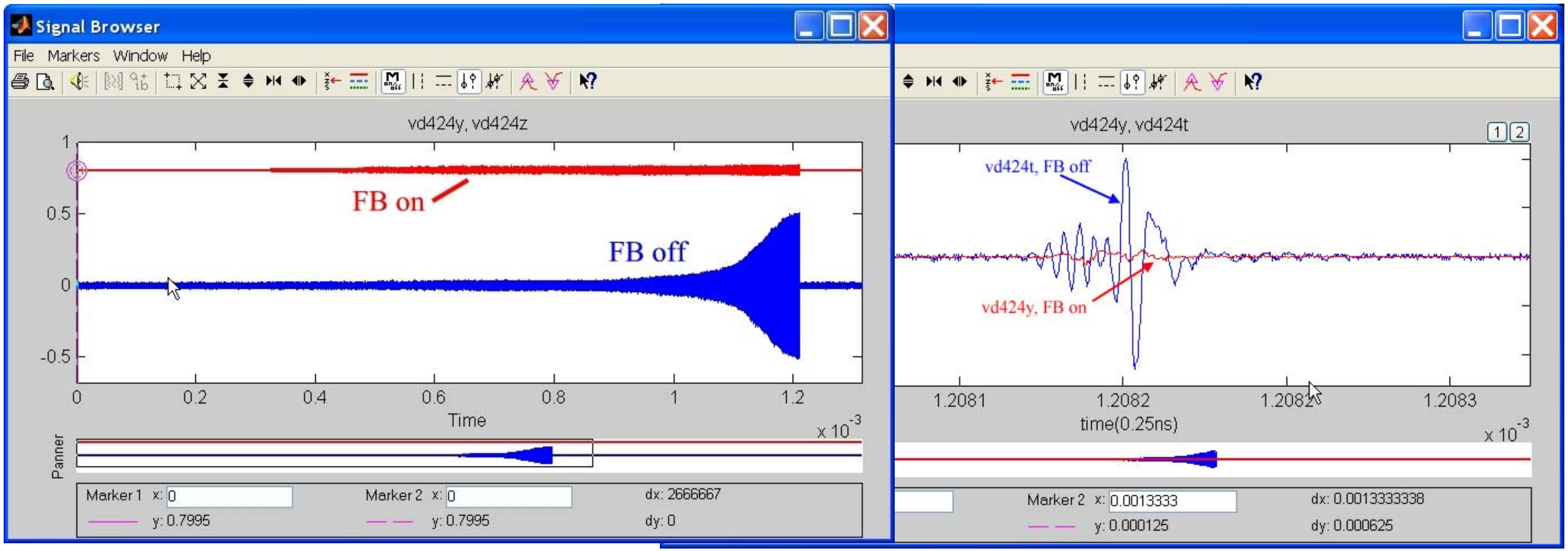


Measured horizontal profile after SCL cryomodule 4

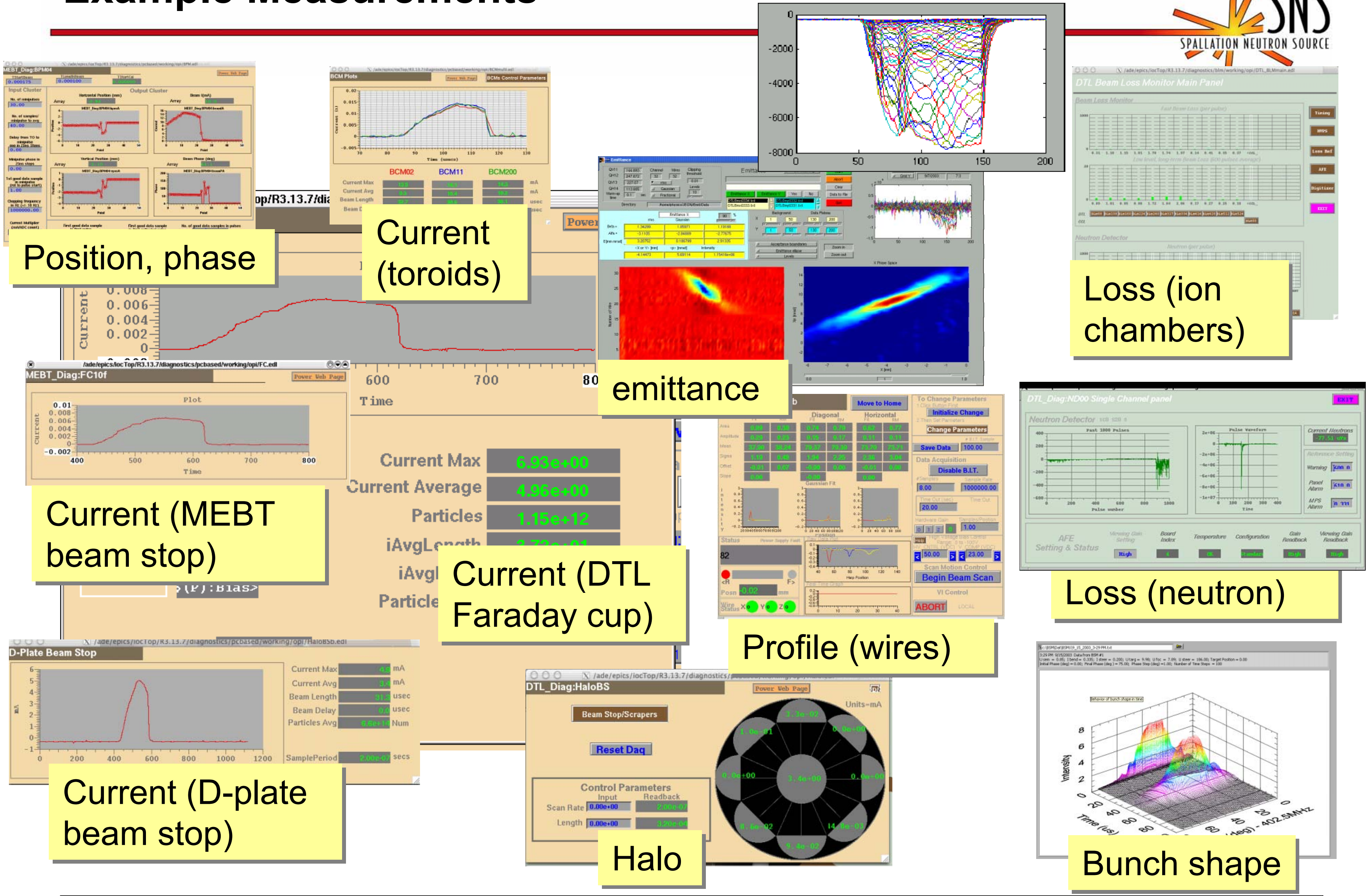
- SCL laser profiles (H + V) were available at 7 locations
  - 3 at medium beta entrance, 3 at high beta entrance and 1 at the high beta end
  - Expect reliable data beyond 3 sigma during operation.

E-P Feedback Experiment at the PSR

- We formed a collaboration to carry out an experimental test of active damping of the e-p instability at the LANL PSR:
- We deployed a transverse feedback system designed and built by ORNL/SNS and in two shifts demonstrated for the first time damping of an e-p instability in a long-bunch machine
- In subsequent studies we observed a 15-30% increase in e-p instability threshold with feedback on.
- Continued investigation of e-p feedback will be pursued, as well as simulations to benchmark experimental results.



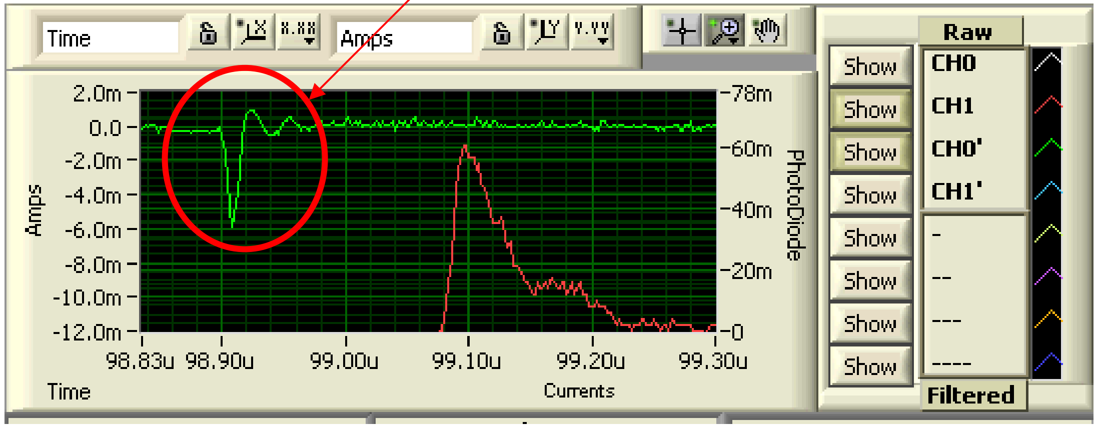
Example Measurements

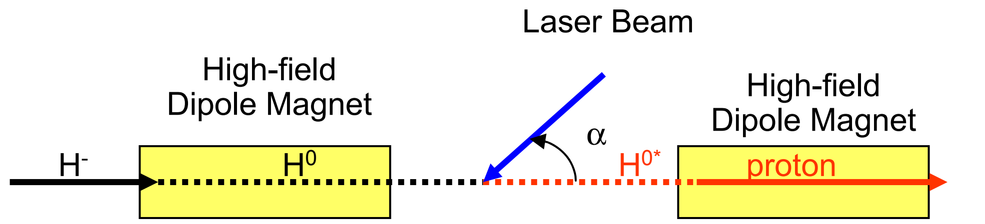


Laser-Stripping Injection Proof-of-Principle Experiment

- We are receiving funds from the Lab Directors R&D (LDRD) program to perform a proof-of-principle experiment to test a scheme for laser-stripping injection
- First experimental tests were carried out in early December
- We observed >50% double-stripping efficiency in first attempt in a one-hour run
- Further R&D will continue, with the goal of developing a realistic laser-based scheme

Flipped-sign notch on BCM indicates protons





Step 1: Lorentz Stripping
$H^- \rightarrow H^0 + e^-$

Step 2: Laser Excitation
$H^0\ (n=1) + \gamma \rightarrow H^{0*}\ (n=3)$

Step 3: Lorentz Stripping
$H^{0*} \rightarrow p + e^-$