Accelerator Status

Michael Tiefenback

content contributed by many others

The Rest Of The World

- Mid-range
  - Cryogenics (CHL)
  - SRF
  - Injector
  - Operations
  - Facility Improvements
- Long-range
  - MEIC
  - LDRD tasks
- Close to home: beam in Hall B
  - Beam line updates
  - Beam spot sizes

Central Helium Liquifier

From Jonathan Creel

- Activities involved (but not limited to):
  - CHL2 4K Cold Box Modifications

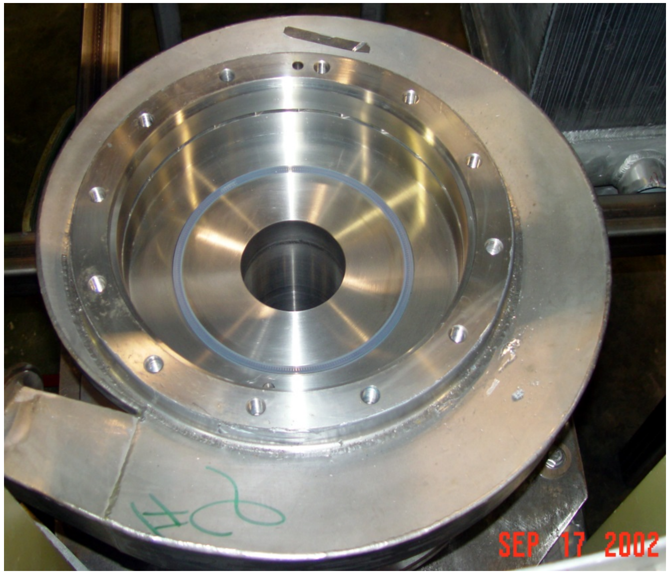
    improve efficiency
  - SC1 2K Cold Box CC4 Failure

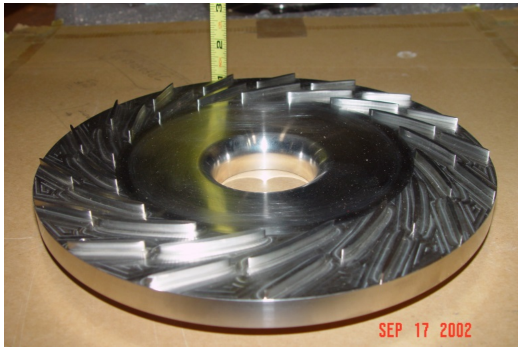
    repairs after critical UPS failure
  - Helium and LN2 Losses

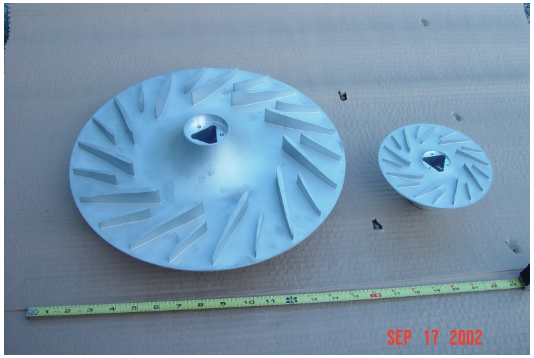
    reduce leaks, costs

Typical Cold Compressor

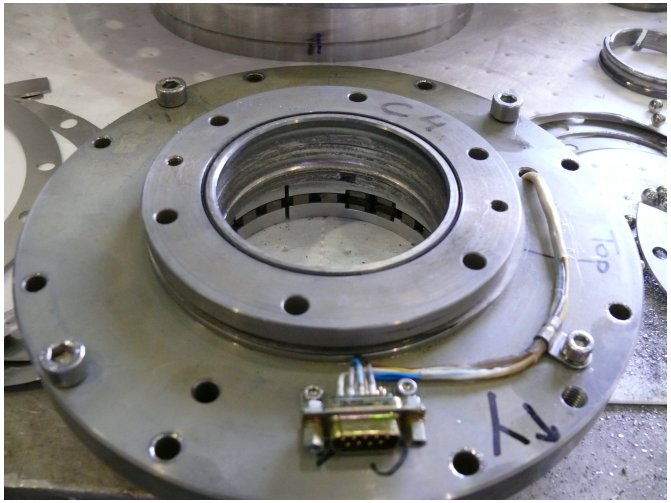
Source: Jonathan Creel







SC1 CC4 Findings



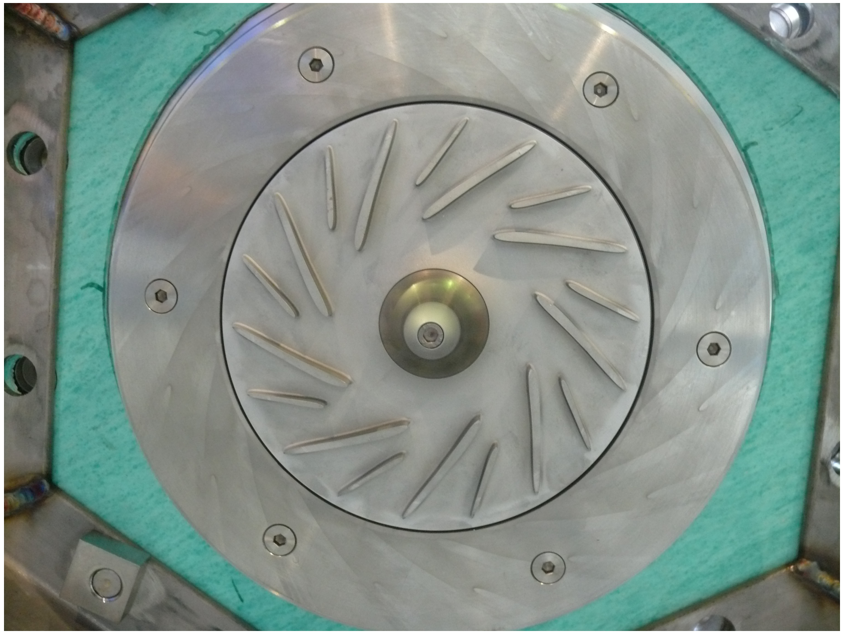
Source: Jonathan Creel

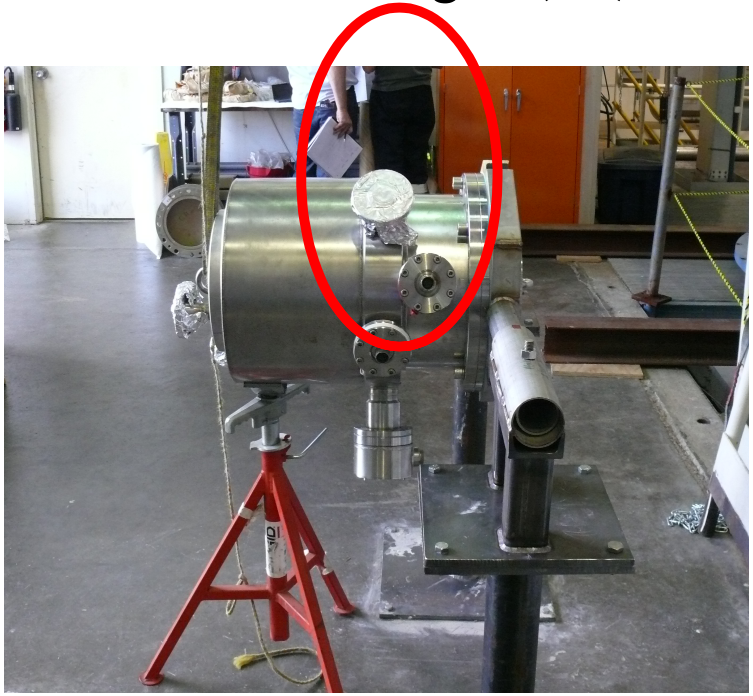
- Backup ball bearing failure
  - When rotor fell bearing 0 to 35,000 RPM instantly
  - Inner and outer races shattered
  - Balls damaged
  - Shaft scored
  - Position sensors damaged
  - Air Liquid and S2M working on estimates
    - CC4 repair
    - Balancing spare wheels
    - List of recommended future spare parts

SC1 Repair Using SNS Compressor

Source: Jonathan Creel

- Moved our wheel and backplate to the SNS compressor
- JLAB modified SNS compressor
  - LN2 supply and LN2 return connections
  - Magnetic bearing power and controls feedthroughs (x4)





Cryo Status

Source: Jonathan Creel

- Both CHLs operational
- Three major losses found/repaired
  - CHL1 C6 (~110 liquid liters/day)
  - ESR utility piping (~110 liquid liters/day)
  - CHL1 bearing gas (~ 110 liquid liters/day)
- Contamination remains a concern

Gradient Loss: Identifying the Root Cause

At present the CEBAF gradient loss is a statistic quantity derived through evaluating SRF and CEBAF performance over the past 20 years on over 320 cavities.

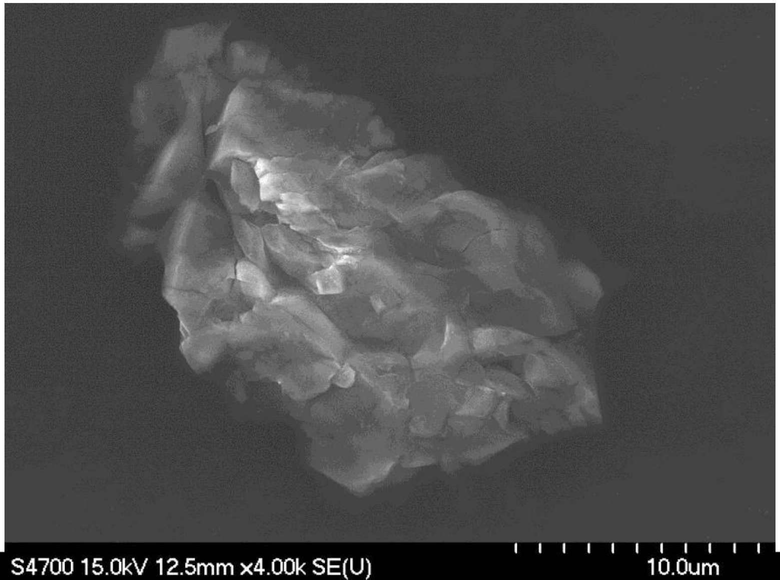
The fact that gradient is restored via Helium processing, suggests that field emitters play a significant role in the gradient loss.

Recent systematic evaluation of the SRF surface on a C20 module (from the LERF) prior to refurbishment has generated significant data, interest and discussion.

Need to continue this approach on all future C20s prior to refurbishement into C50s.

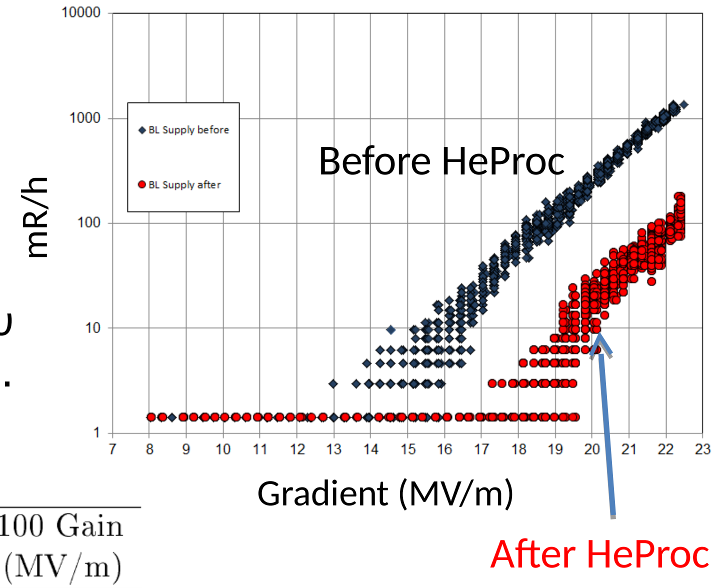
Rongli Geng collecting surface samples

https://www.jlab.org/indico/getFile.py/access?contribId=11&sessionId=2&resId=0&materialId=slides&confId=109



Helium Processing

- Utilized during 6GeV era to improve maximum operating gradient of SRF cavities (to reach 6GeV).
- Insert small amount of gaseous He into the cavity.
- Process cavity with RF power, watch for the radiation signature to drop (field emitters extinguished).
- Cryo-cycle the cavity to remove the He.
- Determine the new maximum operating gradient



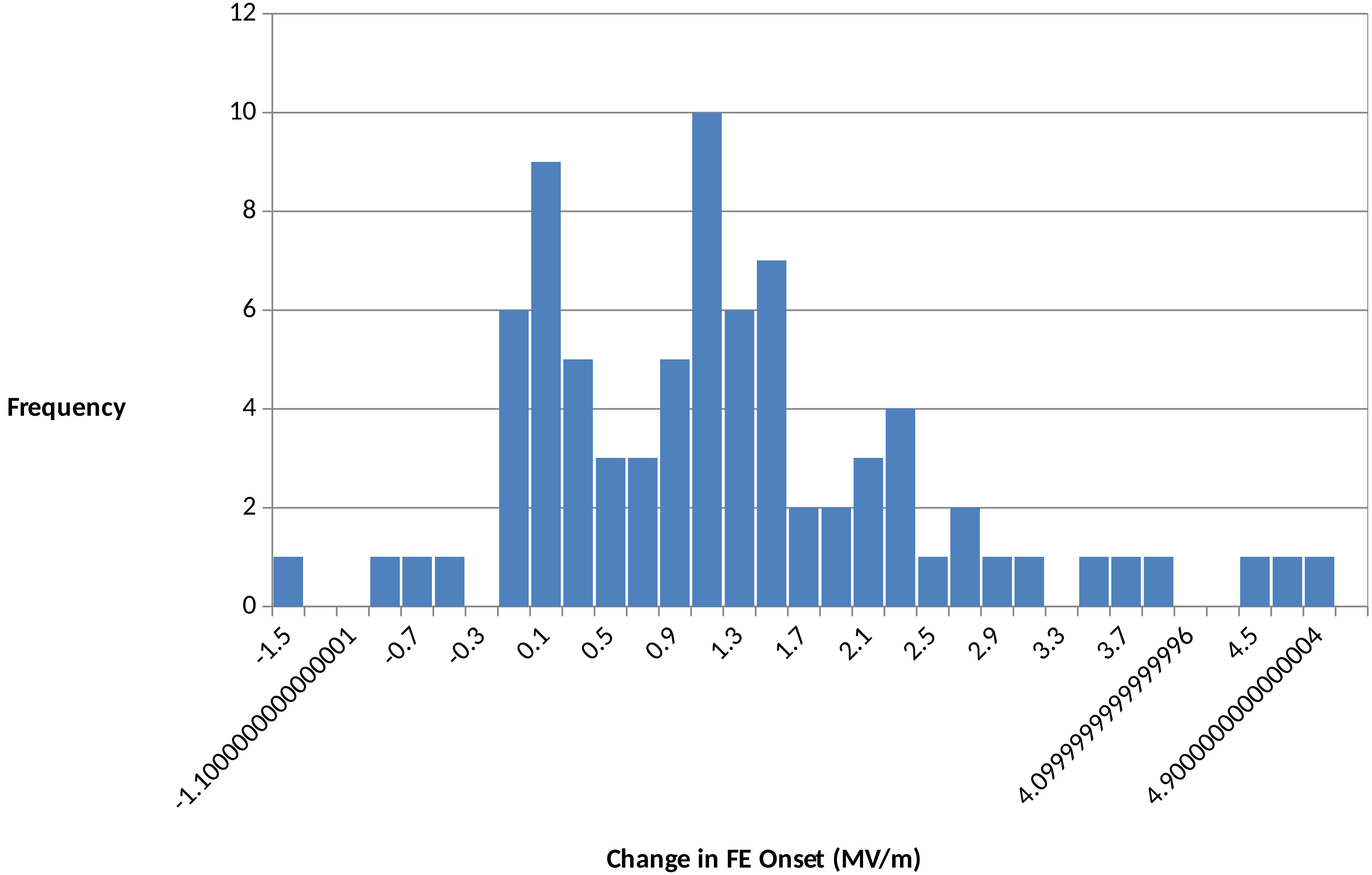
Representative gain (~4MV/m) on one C100 cavity recently Helium processed.

Application	C20 Gain (MV/m)	C50 Gain (MV/m)	C100 Gain (MV/m)
First	**1.2**	1.9	**3.8**
Second	**0.9**	1.4	2.9
Third	**0.7**	1.0	2.2

Table 12: Estimated gains from initial and subsequent applications of Helium processing on the three CEBAF cavity types. **Bold** values are derived from the references, plain text values are a best guess.

Jefferson Lab

Distribution of FE Onset Deltas (July 2015)



Source: Mike Drury

Energy Reach: Maintenance and Risks

Energy reach degrades ~34 MeV/pass-year

- Expected headroom after Summer 2015: ~100MeV/pass.
- Time until CEBAF can no longer support 12GeV operations: 3yrs (2018).

C50 program:

- Refurbish original CEBAF C20 module, one per year.
- ~20MeV of net energy reach per C50.
- Time until CEBAF can no longer support 12GeV operations: 7yrs (2022).
  - If no other gradient mitigation in place by 2022, another round of Helium processing will be required to restore the energy reach in 2022.

C100 Spare:

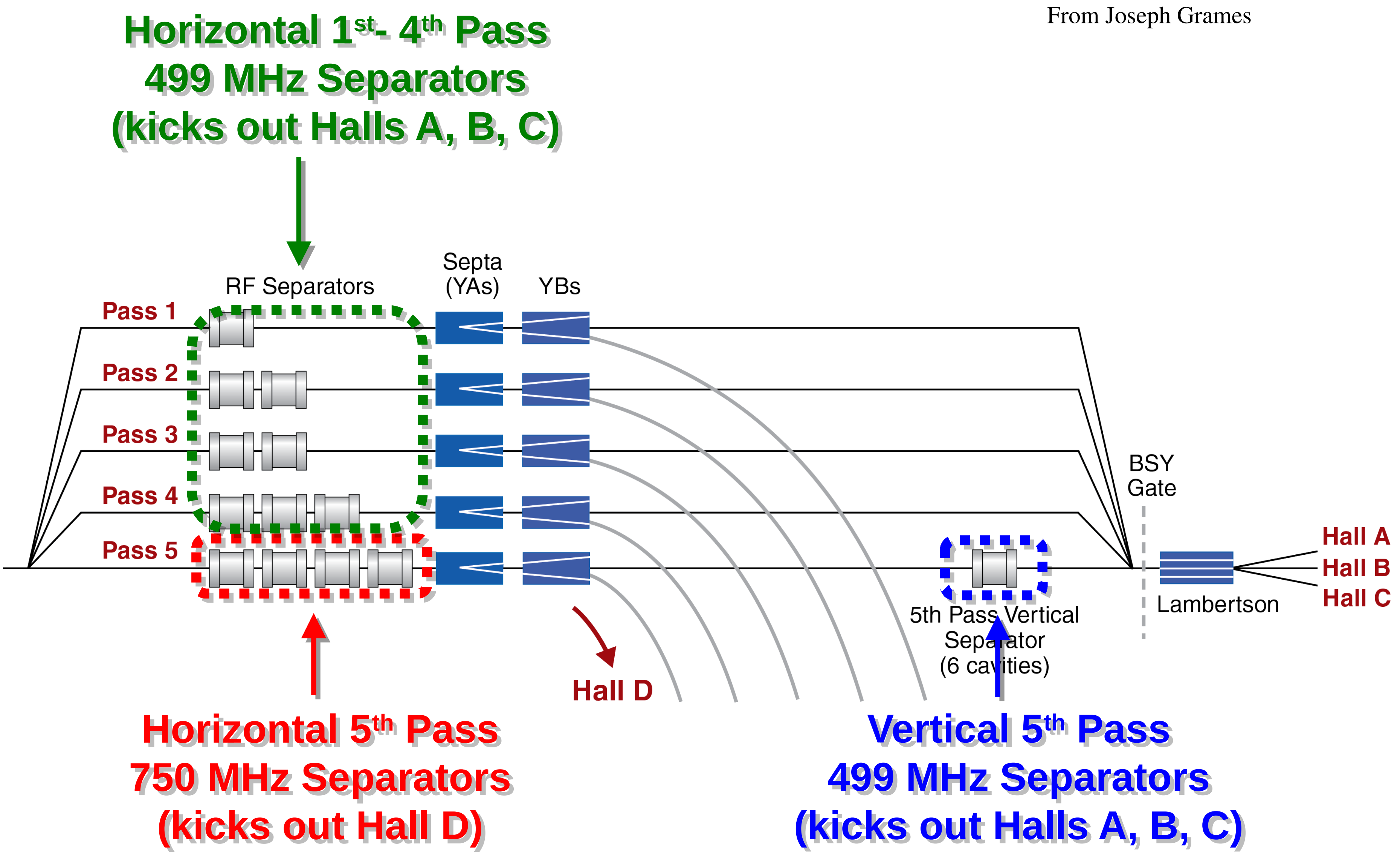
- Peak gradient headroom is expected to be about 100MeV/pass.
- Loss of one C100 cryomodule (~100MeV energy gain) results in CEBAF's inability to operate at 12GeV: Major impact to the Physics program.
  - Near miss: C100 vacuum event during Fall2014.
    - Sufficient gradient headroom (CEBAF @ 1.8GeV/pass), allowed the program to proceed without altering the energy (by-passed the leaky module, repaired during accelerator maintenance period).

RF Separation and Hall D

- Four-hall operation upgrade
  - Laser operation with 249.5 (“250”) MHz lasers
  - Separation at 499 MHz and 748.5 (“750”) MHz
  - Constraints on hall pulse structure
- New separators installed and commissioned
  - Improved couplers and temperature control
- Laser frequency constraints:
  - Hall D OFF long-term:
    - A/B/C may use 250/499 MHz
  - Hall D ON
    - One of A/B/C shares 5th pass beam (250 MHz) with D
    - Pass 1-4 users might use 250/499 MHz

RF Separation for 4-Hall Operation

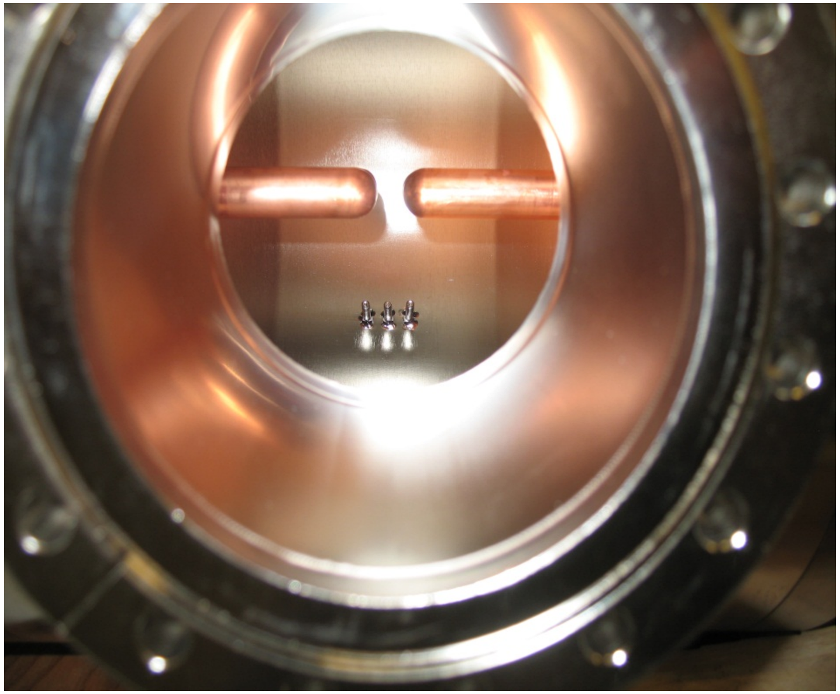
From Joseph Grames

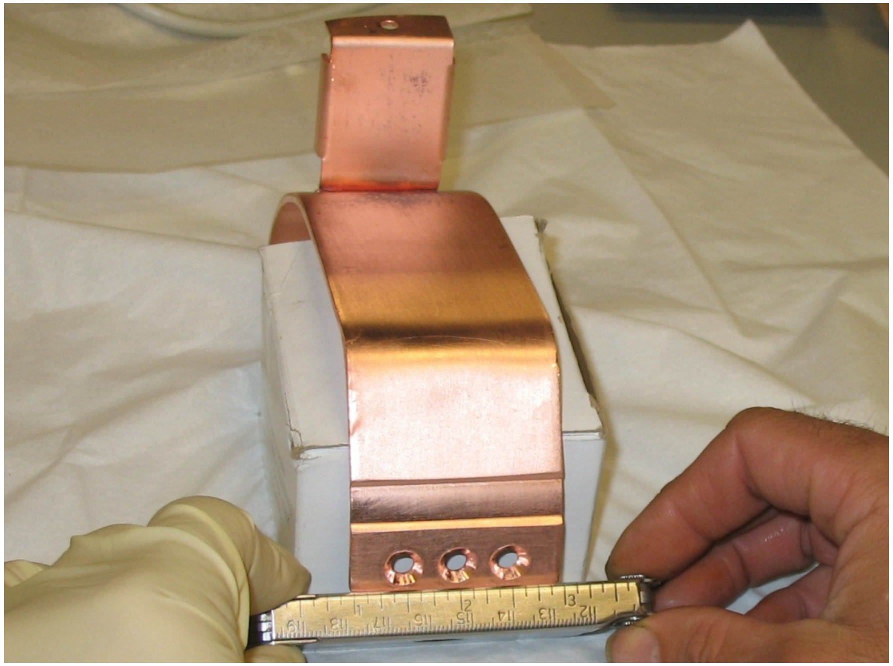


Inside A Separator Cavity

From Mark Wissman

Tuning Plate Removed





750 MHz Cavity Couplers

From Mark Wissman

Modified coupler geometries being compared

Polarized Source Gun - October 2015

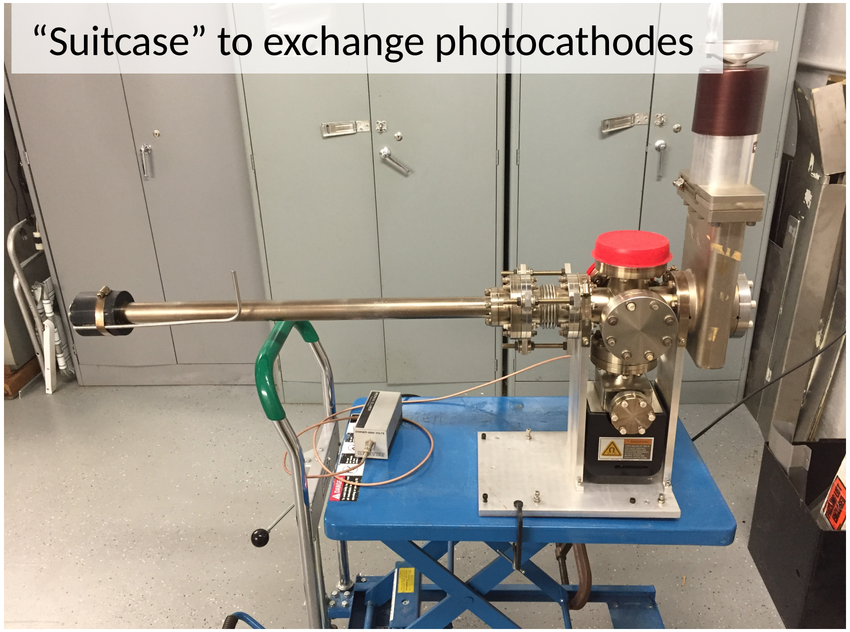
CEBAF Gun 2 is Ready…

From Joseph Grames

- Inventory includes two GaAs/GaAsP photocathodes with high-polarization (>85%)
- Good initial QE (>1%) and charge lifetime (>100 C) mean infrequent spot moves
- Used "Suitcase" to exchange two "old" photocathodes with two new R&D samples for Beam Study testing that offer improved polarization or lifetime
- In FY16 we ramp-up efforts toward the 200 kV Gun upgrade to improve beam quality for all Users, especially high current parity-violation experiments

Gun and Preparation Load-Lock Chambers

"Suitcase" to exchange photocathodes



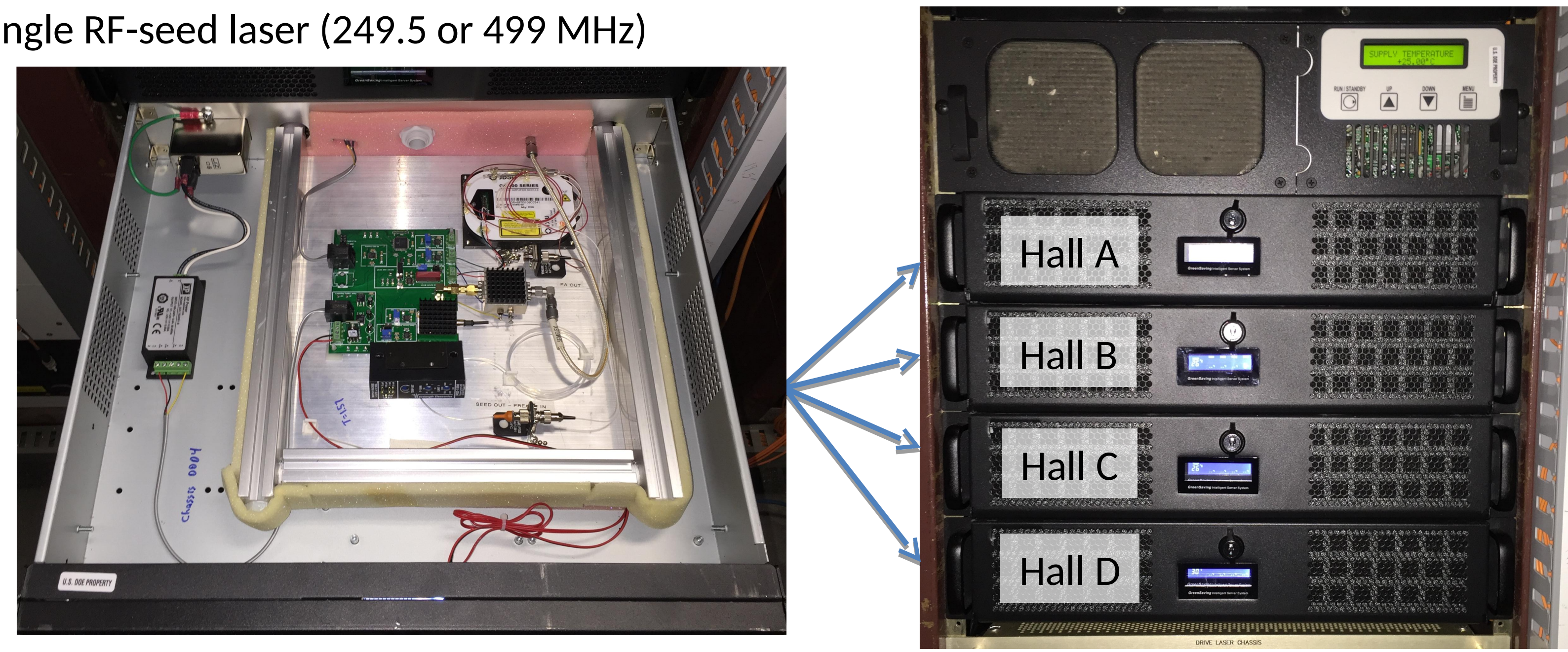
Polarized Source Laser System - October 2015

From Joseph Grames

Laser Upgrade for Hall D and 4-Hall Operations

- Each laser can be quickly configured for 249.5 or 499 MHz operation
- Laser upgrade adds 4th RF-seed laser in climate controlled rack mount configuration
- In Summer 2016 laser table modified to combine all 4-lasers to the Gun
- Upcoming: test simultaneous sharing of single chopping aperture by two beams

Single RF-seed laser (249.5 or 499 MHz)



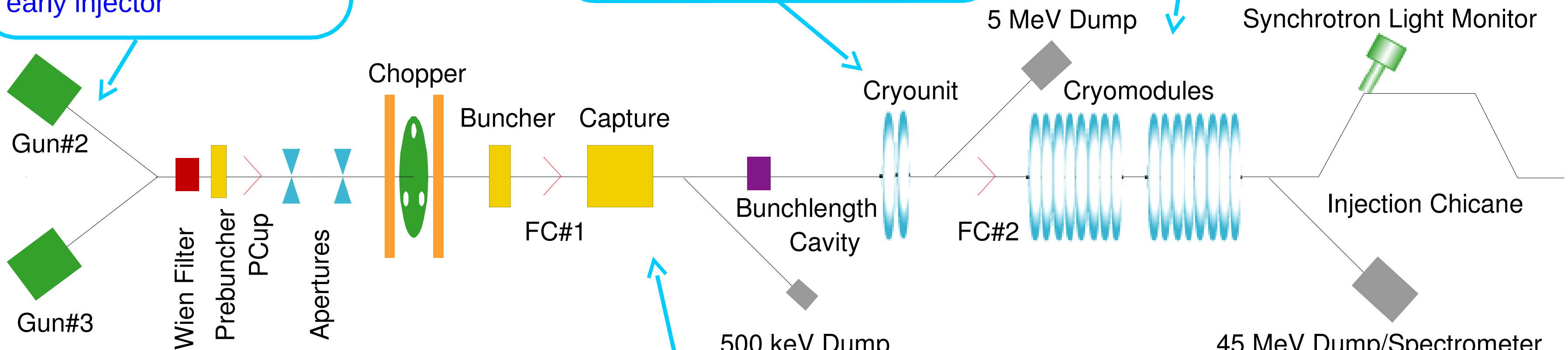
The goals of the CEBAF Injector upgrade

From A. Freyberger

Increase Gun Voltage from 100 keV to 200 keV
Lowers the space charge effect to achieve higher beam current in the early injector

New Cryounit with new SRF design
Eliminates the x/y coupling and improves and simplifies the Parity Quality beam setup.

Increase the injector final energy from 45 MeV to 123 MeV by upgrading the Cryomodules
To achieve the 12 GeV injector energy requirement



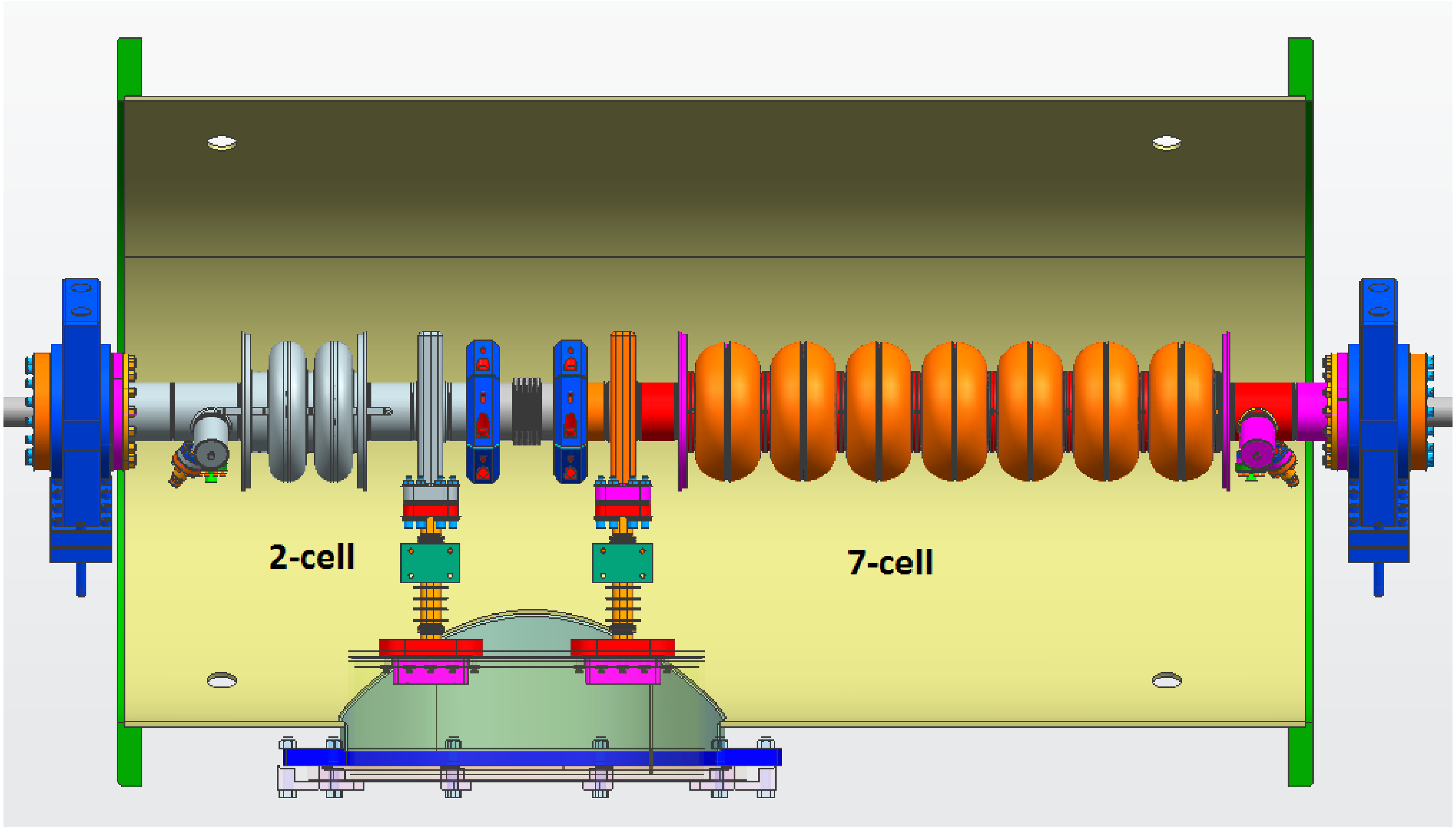
Add a second 90 deg Wien Filter
Enables 180 deg electron spin flip as required by Parity Quality experiments

Integrate Capture into the Cryounit
Simplifies the acceleration process and lowers the RF power.

RK, 2010

The New Booster

From A. Freyberger



Injector Upgrade

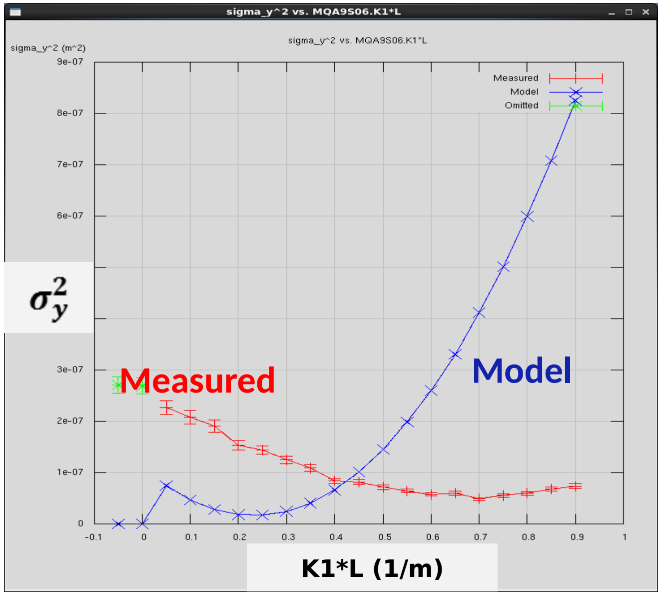
- New ¼ cryomodule will be ready for initial testing in FY16
  - Commission at the UITF
  - Cavities complete
  - Cryomodule design nearly complete, procurements started.
- Need a upgrade team and project leader/manager to manage the many aspects of this upgrade:
  - Gun 200kV operation
  - Upgrade warm RF section for 200keV transport
  - Commissioning new ¼ cryomodule in UITF (FY16/FY17)
  - CEBAF installation and commissioning FY18 and FY 19

Run IV Highlights

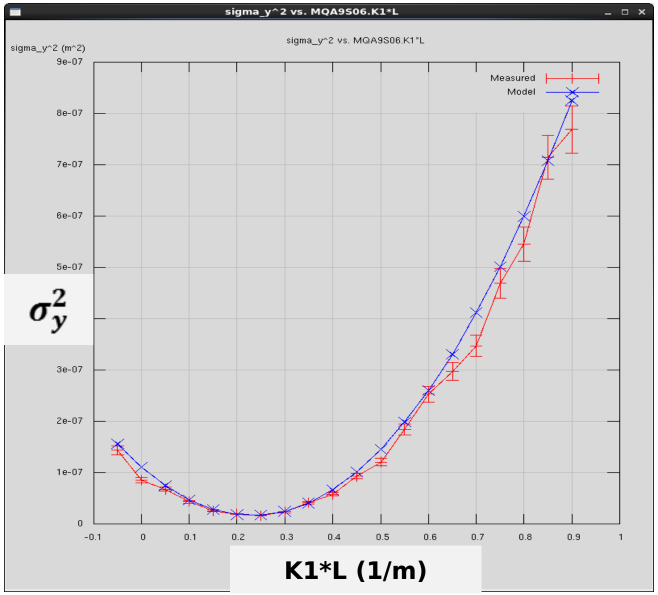
2015-Feb-13 to 2015-May-18

- E=1.9GeV/pass
- Commission new 249.5 MHz laser/injector configuration
- Commission new 750 MHz 5-pass separators
- Exercise new setup process and associated tools: New beam matching process
- Establish baseline emittance and bunch length evolution
- Support ~5wk "early Physics" Operation

Quad Scan: Before match



Quad Scan: **After** match



Spring 2015 11 GeV Measurements

Location	Design □$_X$	Meas □$_X$	Design □$_Y$	Meas □$_Y$
	All geometric rms values, [nm-rad]			
123 MeV	4.0	2.5±0.9	4.0	1.9±0.6
Arc 1	0.41	0.43±0.04	0.41	0.32±0.05
Arc 2	0.26	0.50±0.10	0.23	0.31±0.10
Arc 3	0.22	0.63±0.05	0.21	0.72±0.07
Arc 4	0.21	0.81±0.07	0.24	0.65±0.10
Arc 5	0.33	--	0.25	--
Arc 6	0.58	0.48±0.05	0.31	0.66±0.04
Arc 8	1.21	1.1±0.1	0.57	1.0±0.1
Arc 9	2.09	3.1±0.2	0.64	1.9±0.3
Arc 10	2.97	2.4±0.3	0.95	1.7±0.4

Wire scanner not installed in Arc 7 in spring 2015; reinstall for fall 2015
Wire scanner in Arc 5 in disrepair, to be repaired summer 2015
Error bars are **only** measurement statistics, often over months

From T. Satogata

Optics Summary

- 12 GeV CEBAF transverse emittance dominated by synchrotron radiation in higher-pass arcs
  - Was (somewhat) mitigated with FODO ㅍ DBA optics
  - Will explore full impact with M_{56}=0 optics in Fall 2015
- Optics matching and emittance program combined
  - Becoming efficient and mature
  - Excellent tool development
- Measurements, theory, simulations are consistent
  - Within factor of 2(ish)
  - 10.5 GeV data shows we are meeting program goals
  - Full 12 GeV commissioning in Fall 2015

From T. Satogata

Beam Commissioning Accomplishments

- 2.2GeV/pass one-pass beam transport with greater than 50% availability.
  - Accelerator 12GeV Project KPP demonstrated
  - Identified gap in SRF energy reach and developed plan to close the gap.
- Multi-pass capability established.
  - First use of small (kHz) change of the Master Oscillator to deal with large (2cm'ish) changes in CEBAF circumference.
- 5.5pass beam transported to the Hall-D dump.
  - CW beam successfully transported to Hall-D dump.
  - First **polarized** and unpolarized photons generated and sent into Hall-D.
  - Hall-D detector 12GeV Project KPP demonstrated.

Beam Commissioning Accomplishments (cont.)

- Multi-user capability established.
- CW beam, up to 50μA delivered to Hall-A (2-pass).
- Extraction system 499MHz and 750MHz commissioned.
- Physics quality beams delivered to Hall-A and Hall-B.
  - Hall-A DVCS exp. one Q^2 point measured.
  - Hall-B HPS exp. ~1/3 of the 1GeV data collected (additional runs at 2.2,4.4 and 6.6 GeV).

Every 12GeV CEBAF beamline element, except Hall-C beamline , has successfully transported beam.

Summary

ARR process successfully completed for the 12GeV upgrade.

- Roles and responsibilities well defined and appropriate for the commissioning effort.
- Processes and commissioning plan well defined.

12GeV Project accelerator deliverable (CD-4A) achieved on 2014-July-30, five months ahead of schedule.

- 12 GeV CEBAF complete!

Accelerator effort continues to build towards robust operations and physics quality beam at the 12 GeV design energy.

- Continue the model driven, database centric approach to beam operations.
- Helium processing scheduled for Summer 2015, in support of achieving robust 12 GeV operations in Fall 2015.
- Tunnel AC, Dogleg upgrade, 750MHz cavity, vacuum system hardening, etc. in support of 12GeV operations.

CEBAF energy reach, post Helium processing, supports 12 GeV operations through 2022.

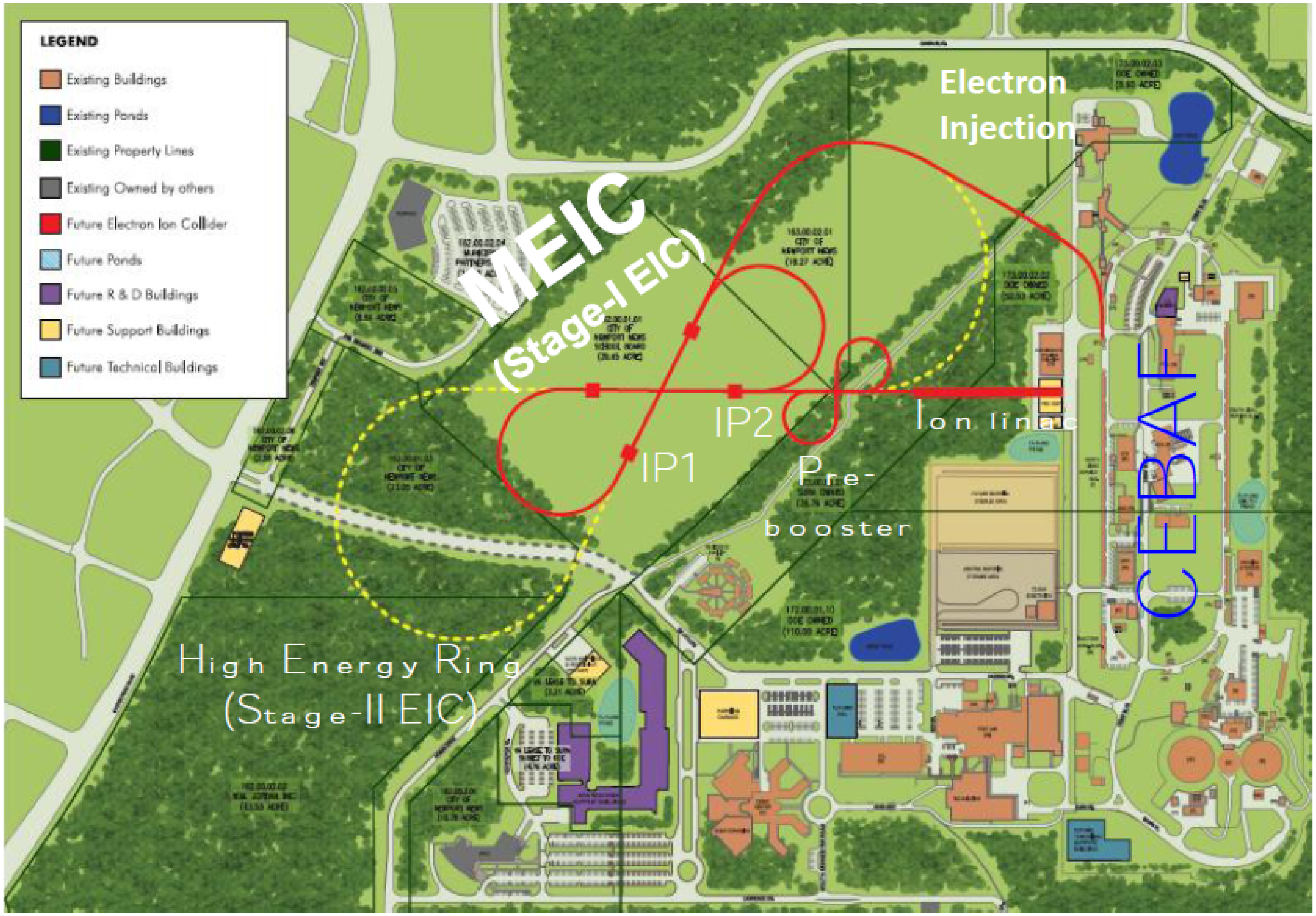
Summer 2015 Shutdown Tasks

Preparing for 12GeV Operations:

- Utilities Infrastructure Modernization upgrade
  - Power grid, cooling towers, communications
- Helium Processing
  - Energy Reach
- 750MHz Separator Cavities
  - Modifications to achieve design, enable RF separation at 11GeV.
- Cryogenic plant repair and maintenance
  - SC1 repair possible in this short time frame made possible by the generous loan of the SNS spare cold compressor. Thank you SNS!
- Pathlength chicane upgrade
  - Restoring the range of the pathlength chicane to the 6GeV equivalent.
- Tunnel Air Conditioning
  - Control temperature rise in tunnel, maintain T< 35 C. Worker safety during tunnel access.
- Vacuum system hardening
  - Preparing for synchrotron radiation induced vacuum loads
- Operations StayTreat

Looking Ahead: MEIC (on the JLab Site?)

NSAC: "We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB"



Some LDRD tasks supporting MEIC

- Enhancing Simulation Capability for Electron Cooling in MEIC
  - He Zhang
- Fast Kicker for the MEIC electron cooler
  - Andrew Kimber
- Experimental Studies of Optics schemes at CEBAF for Suppression of Coherent Synchrotron Radiation (CSR)
  - Yves Roblin
- A Pilot Study of Experimental Demonstration of Cooling of Ions by a Bunched Electron Beam
  - Yuhong Zhang

Ongoing MEIC-oriented Activities

- MEIC Collaboration meetings
- Beam-cooling workshops
- JLab MEIC sub-system and system design
- Detector Integration
  - "… physicists are working with the accelerator team for detector integration. We are looking forward for more physicists to work with us."

- "The more, the merrier," as they say

Changes to Hall B Beam Line

- Several Hall B elements are to move upstream
  - Moeller Q1
  - 2H00 girder
  - CLAS12 target
- Scale of displacement: ~1.3 m
- No significant consequence on beam envelopes
- Margin in final focus might be added easily
  - Rearrange quads/correctors on 2H00 girder

12 GeV Initial Beam Requirements

Hall	Emittance (nm-rad)	Energy Spread σ (%)	Spot Size σ (μm)	Halo
A	$\varepsilon_x < 10$ $\varepsilon_y < 5$	<0.05 (12 GeV) <0.003 (2-4 GeV)	$\sigma_x < 400$ $\sigma_y < 200$ $(\sigma_y < 100)$ (2-4 GeV)	$< 1 \times 10^{-4\dagger}$
B	$\varepsilon_x < 10$ $\varepsilon_y < 10$	<0.1	$\sigma_x < 400$ $\sigma_y < 400$	$< 2 \times 10^{-4\dagger}$
C	$\varepsilon_x < 10$ $\varepsilon_y < 10$	<0.05	$\sigma_x < 500$ $\sigma_y < 500$	$< 2 \times 10^{-4\dagger}$
D	$\varepsilon_x < 50$ $\varepsilon_y < 10$	<0.5	At Radiator: $\sigma_x < 1550$, $\sigma_y < 550$ At Collimator $\sigma_x < 540$, $\sigma_y < 520$	$< 1\%^{\ddagger}$

† Ratio of the integrated non-Gaussian tail to Gaussian core.

‡ Ratio of Halo background event rate to physics event rate.

12 GeV Out-year Beam Requirements

Hall	Emittance (nm-rad)	Energy Spread σ (%)	Spot Size σ (μm)	Halo
A	$\varepsilon_x < 10$ $\varepsilon_y < 5$	<0.05 (12 GeV) <0.003 (2-4 GeV)	$\sigma_x < 400$ $\sigma_y < 200$ $(\sigma_y < 100)$ (2-4 GeV)	$< 1 \times 10^{-4\dagger}$
B	$\varepsilon_x < 10$ $\varepsilon_y < 10$	<0.1	$\sigma_x < 400$ $\sigma_y < 400$	$< 1 \times 10^{-4\dagger}$
C	$\varepsilon_x < 10$ $\varepsilon_y < 5$	<0.05 <0.03 (6 GeV)	$\sigma_x < 400$ $\sigma_y < 200$	$< 1 \times 10^{-4\dagger}$
D	$\varepsilon_x < 10$ $\varepsilon_y < 5$	<0.5	At Radiator: $\sigma_x < 1550$, $\sigma_y < 550$ At Collimator $\sigma_x < 540$, $\sigma_y < 520$	$< 1\%^{\ddagger}$

† Ratio of the integrated non-Gaussian tail to Gaussian core.

‡ Ratio of Halo background event rate to physics event rate.

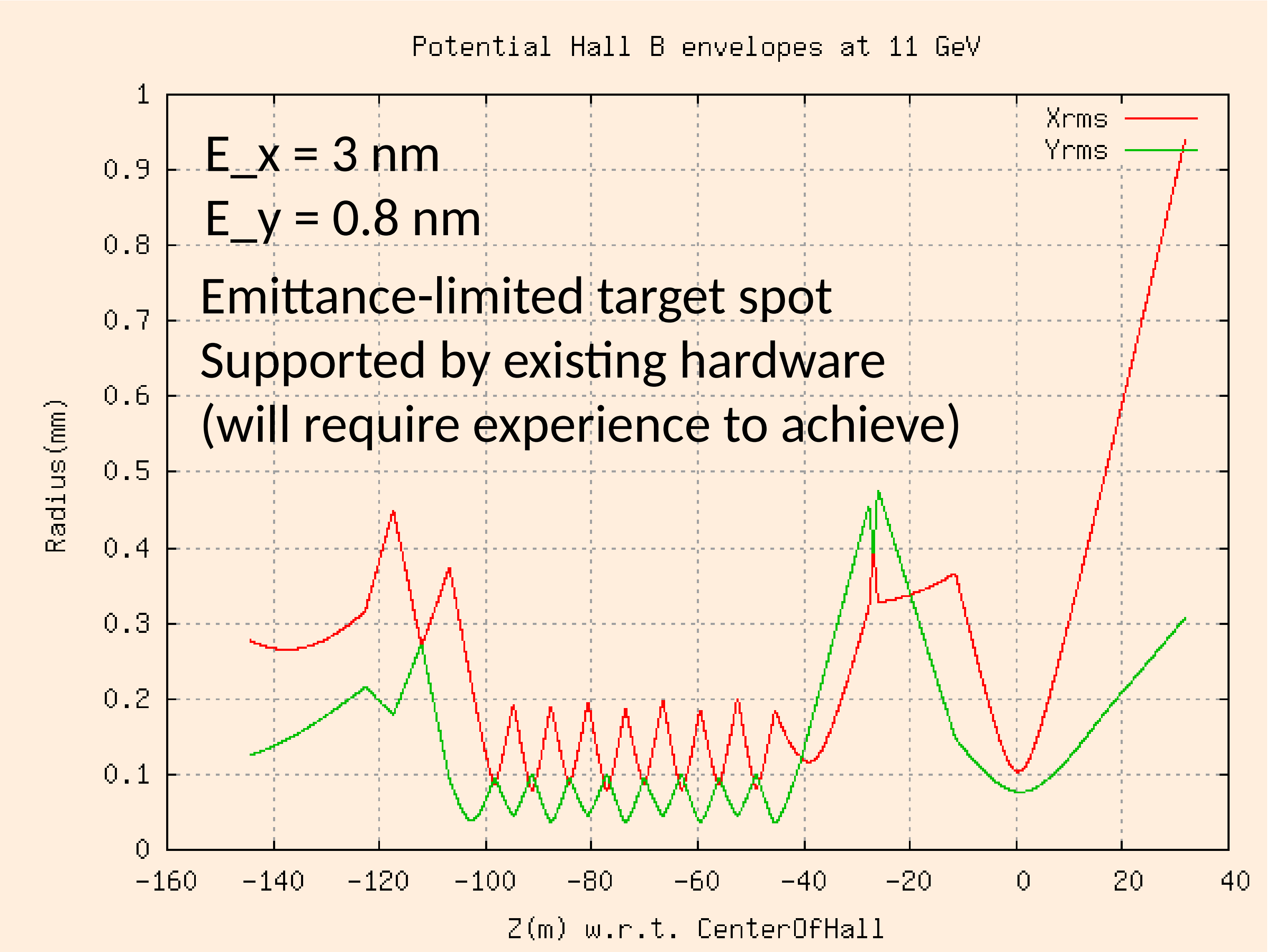
Transverse Emittance* and Energy Spread†

Area	δp/p [x10⁻³] DBA	δp/p [x10⁻³] Zero M56	ε_x [nm] DBA	ε_y [nm] DBA	ε_x [nm] Zero M56	ε_y [nm] Zero M56
Chicane	1/0.05	1/0.05	60/3.1	60/3.1	60/3.1	60/3.1
Arc 1	0.016/0.017	0.014/0.015	0.31/0.33	0.31/0.33	0.31/0.33	0.31/0.33
Arc 2	0.016/0.021	0.014/0.019	0.17/0.21	0.17/0.21	0.17/0.21	0.17/0.21
Arc 3	0.018/0.033	0.017/0.032	0.14/0.19	0.14/0.19	0.14/0.19	0.14/0.19
Arc 4	0.028/0.040	0.027/0.041	0.14/0.19	0.14/0.22	0.14/0.19	0.14/0.22
Arc 5	0.034/0.058	0.035/0.060	0.15/0.33	0.18/0.27	0.15/0.33	0.18/0.27
Arc 6	0.051/0.086	0.053/0.087	0.27/0.54	0.23/0.39	0.28/0.74	0.23/0.35
Arc 7	0.080/0.100	0.076/0.102	0.46/0.75	0.35/0.47	0.64/1.15	0.32/0.47
Arc 8	1.07/1.45	0.094/1.37	0.65/1.15	0.42/0.57	1.00/1.83	0.42/0.62
Arc 9	1.57/1.99	1.27/1.69	1.02/1.85	0.52/0.64	1.63/3.38	0.57/0.71
Bsy A	2.25/2.34	1.56/1.67	1.80/2.75	0.58/1.00	3.16/3.17	0.63/0.75
Hall A	2.34/2.44	1.68/1.79	1.80/2.80	0.60/1.00	3.05/3.38	0.81/0.83

* Emittances are geometric, † Quantities are rms. Zero M56 version, updated Hall A line

From Y. Roblin

Potential Hall B 11 GeV Beam Envelope



Overall Summary

- A lot is in progress
  - Repairs
  - Recovery
  - Upgrades
  - Improvements in hardware and procedure
- Preliminary integration is never perfect
- You may see (or be) part of the problem
- You will be part of the solution

The Beginning
(again)