The Upgraded Injector Test Facility

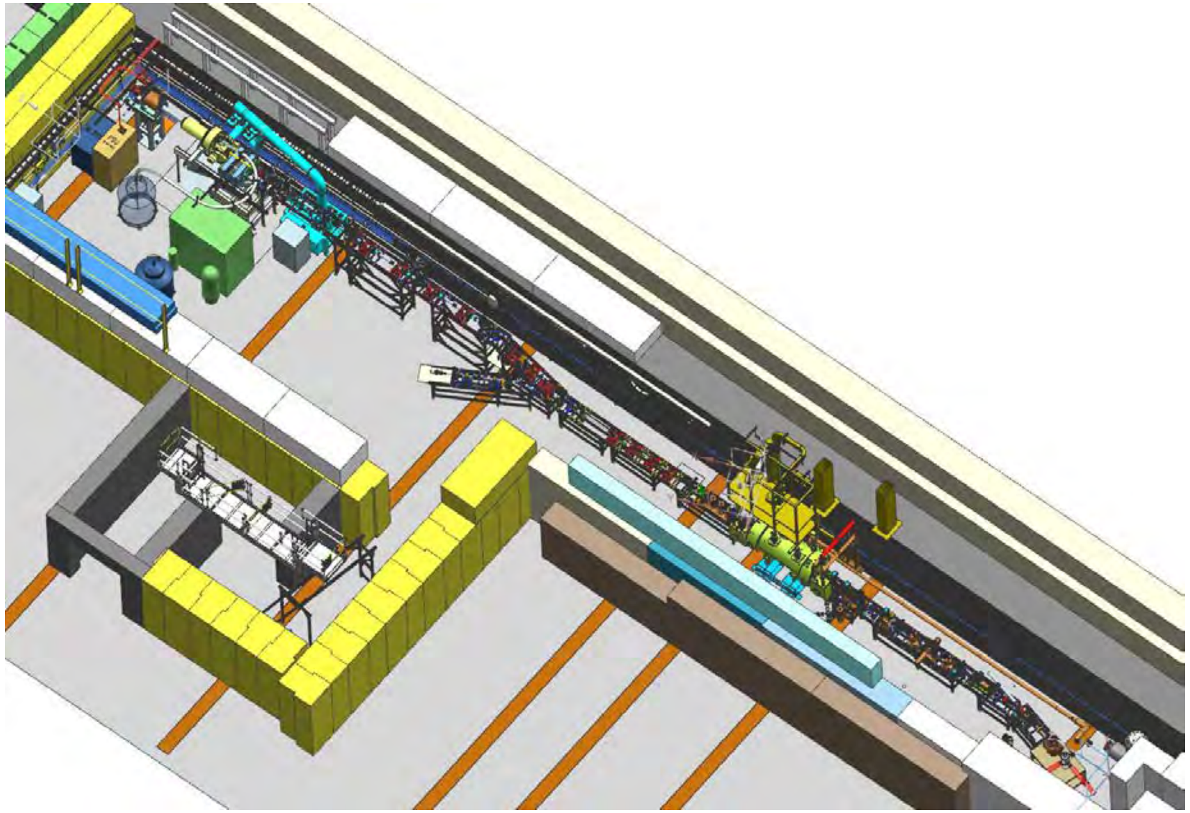
FRIB - Michigan State University

Accelerator Physics and Engineering Seminars

Matt Poelker

February 11, 2022

Yan Wang, Max Bruker, Mike McCaughan, Dennis Turner, Joe Grames, Phil Adderley, Marcy Stutzman, John Hansknecht, Carlos Hernandez-Garcia, Shaun Gregory, Team HDIce, Software Group, DC Power Group, I&C Group, Cryo, and many many others



CEBAF – a good place for parity violation experiments

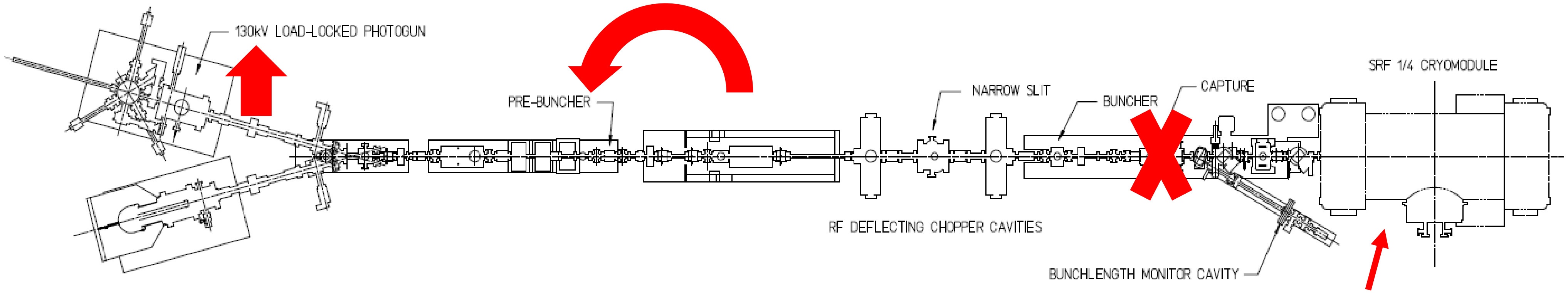
Experiment	Energy (GeV)	Pol (%)	I (μA)	Target	A_{pv} (ppb)	Charge Asym (ppb)	Position Diff (nm)	Angle Diff (nrad)	Size Asym (δσ/σ)
HAPPEx-I 1998 – 1999	3.3	38.8 68.8	100 40	^{1}H (15 cm)	15,050	200	12	3	
G0-Forward 2003 – 2004	3.0	73.7	40	^{1}H (20 cm)	3,000-40,000	300±300	7±4	3±1	
HAPPEx-II 2004 – 2005	3.0	87.1	55	^{1}H (20 cm)	1,580	400	2	0.25	
HAPPEx-III 2009	3.484	89.4	100	^{1}H (25 cm)	23,800	200±10	3	0.5±0.1	10^{-3}
PREx-I 2010	1.056	89.2	70	^{208}Pb (0.5 mm)	657±60	85±1	4	1	10^{-4}
QWeak 2010 – 2012	1.162	88.7	180	^{1}H (30 cm)	226.5±9.3	20.5±1.7	-2.3±0.1	-0.07±0.01	$<10^{-4}$
PREx-II 2019	0.953	89.7	70	^{208}Pb (0.5 mm)	550±18	20.7±0.2	1.1	0.28	$<10^{-5}$
CREx 2019-2020	2.1825	87.1	150	^{48}Ca (5 mm)	2659± 113	<100	<10	<2	$<10^{-4}$
MOLLER	11	90	65	^{1}H (125 cm)	35.6±0.74	<10	<0.6	<0.12	$<10^{-5}$

Success means providing polarized beam with very small "helicity correlated beam asymmetries"

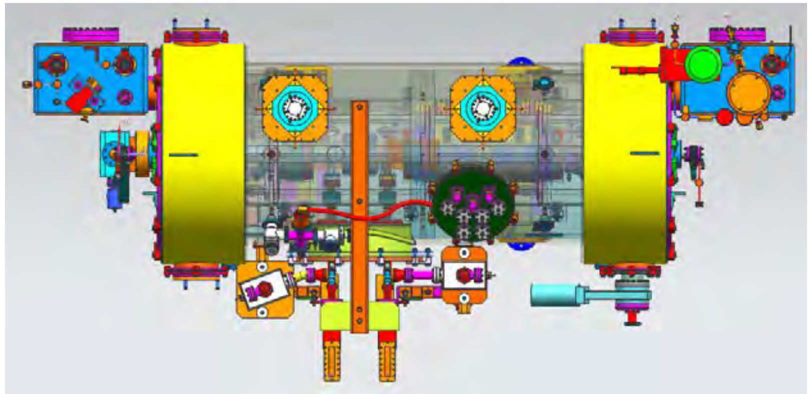
That means identical beam properties in both polarization states

challenging

CEBAF injector upgrade should help

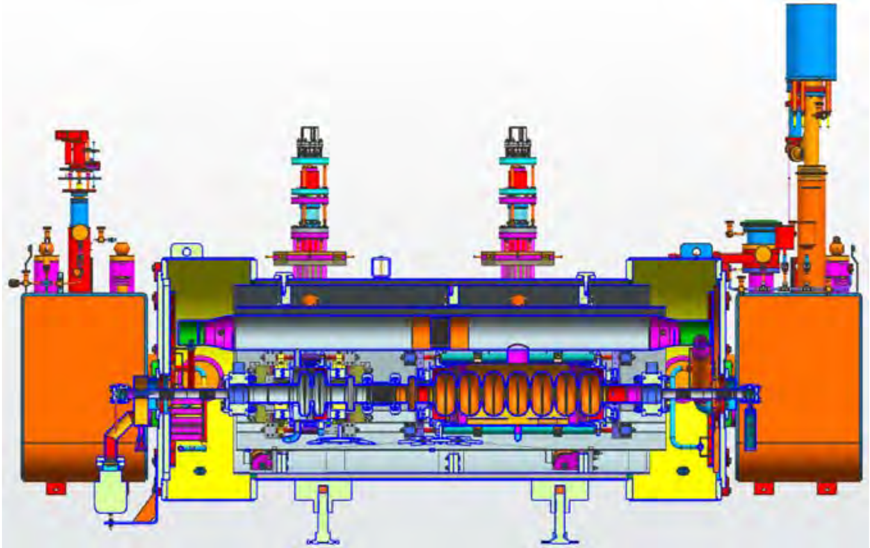


- **Increase gun voltage to 200 kV** to suppress space-charge effects and improve parity quality beam, and to be compatible with booster design (must modify Wien filters too)
- **Locate Wien filters** (energy filters) upstream of pre-buncher cavity and install quadrupoles to better compensate astigmatism
- **Increase aperture of chopper and beam line solenoids** to suppress existing astigmatism and improve parity quality beam
- **Install new SRF booster** that eliminates warm-rf capture cavity, RF deflection and x/y coupling
- **Similarities between UITF and CEBAF injector** are intentional

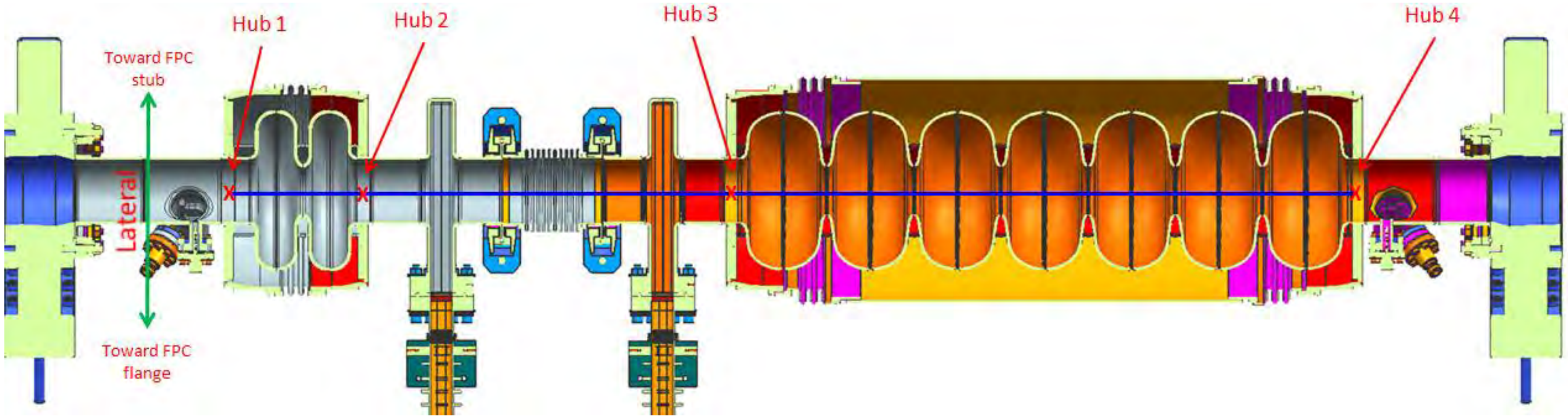


Our new “booster”:
2 cell capture section + 7 cell cavity,
Provides up to 10 MeV beam and should introduce no x/y coupling, allow better matching, more adiabatic damping –
Will help achieve Moller (parity violation experiment) beam requirements

Booster cryomodule



- New 2-cell β_g=0.6 cavity design, SRF "capture" cavity
- Refurbished low loss 7-cell (β_g=0.97) cavity from Renaissance (R-100)
- Free of skew quadruple (x-y coupling)
- Minimization of RF x-kick
- Full use of C100 cavity components and techniques



H. Wang, et al, Injector Cavities Fabrication, Vertical Test Performance and Preliminary Cryomodule Design, WEPWI030, IPAC 2015

G. Cheng, et al,. Mechanical Design of a New Injector Cryomodule 2-cell Cavity at CEBAF, WEPAC47, NA-PAC 2013

$\vec{H}\vec{D}$Ice polarized target for Hall B

electron experiments with transversely polarized HD

Hall-B Run Group-H	PAC 38-39 rating	PAC 38-39 decision	PAC 41 impact
SIDIS, C12-11-111, Contalbrigo,…	A	C1	✪
dihadron production, PR12-12-009, Avakian,…	A	C1	✪
DVCS, PR12-12-010, Elouadrhiri,…	A	C1	✪

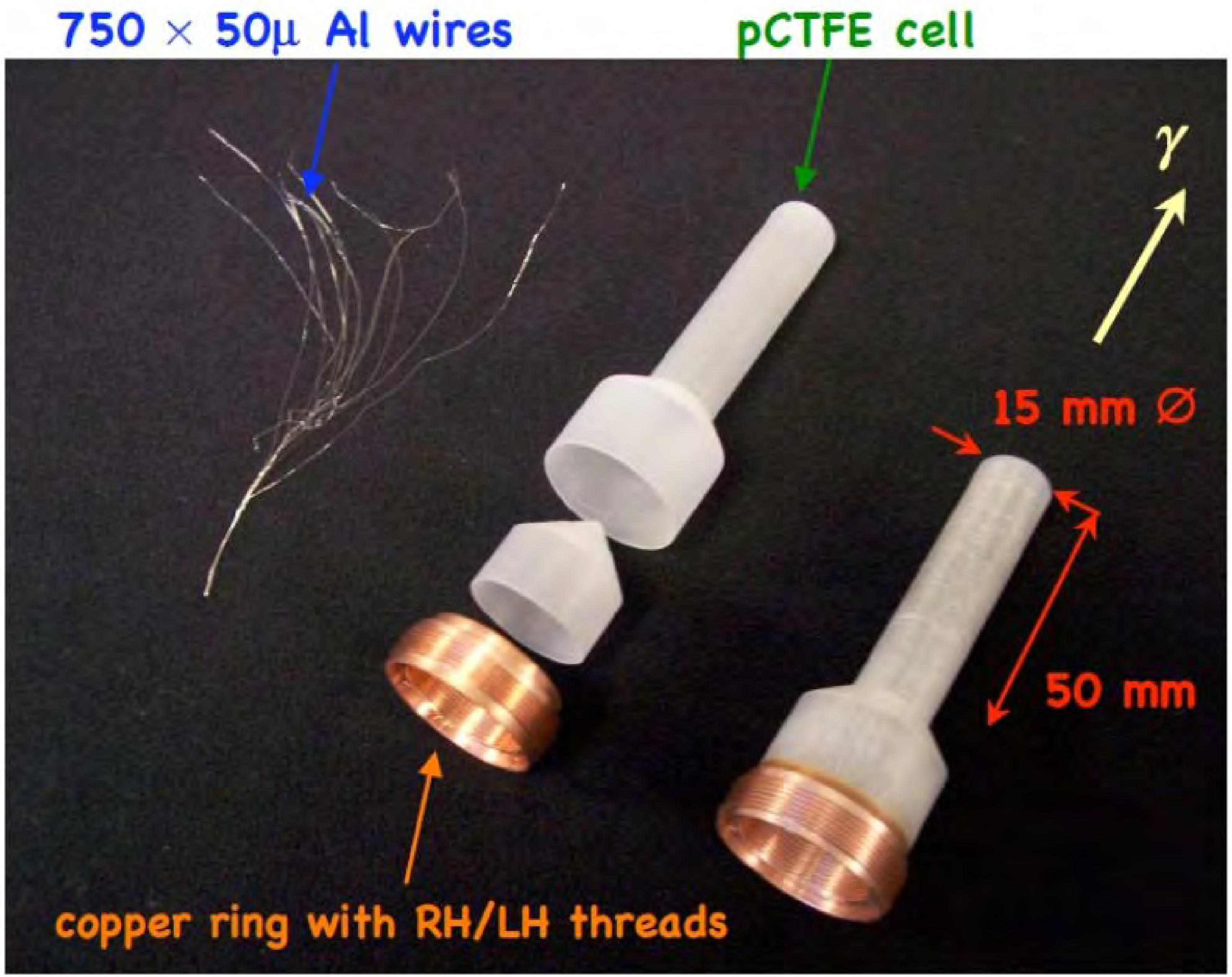
C1 ⇨ successful demonstration of viable performance in an eHD test

✪ all transverse experiments designated as ***High Impact*** for Hall B

challenge: transverse holding fields bend electrons into the detector !

mitigation: small B•dL ⇔ **frozen-spin HD** ⇔ low B, short dL

What is HDIce?



Installed at Hall B in 2010, worked great with photons, quickly depolarized with 1nA electron beam

After this test, Team HDIce made changes to the target, hoping to improve it, to better remove heat

e+HD depolarization mechanisms

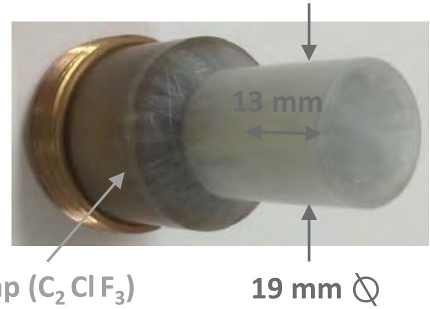
Mechanisms for beam-induced depolarization:

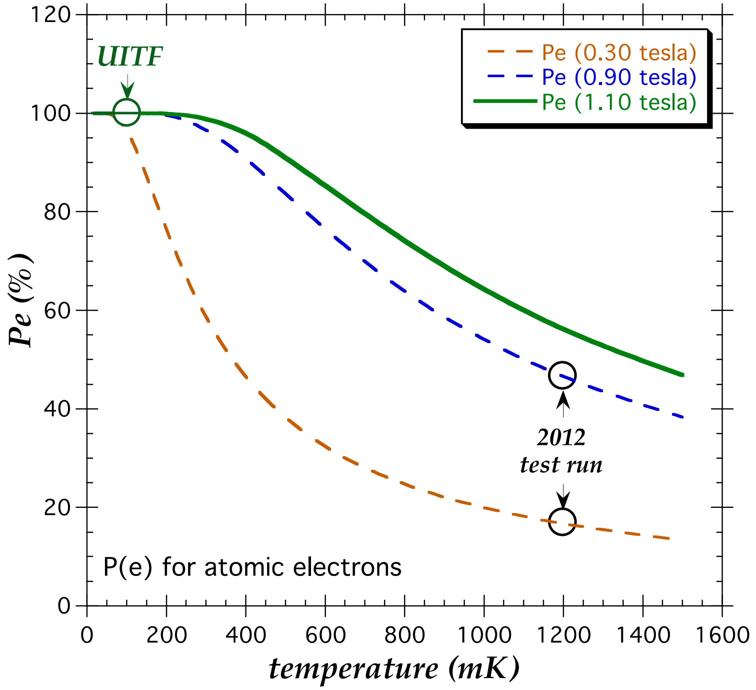
I. beam-heating

- *heat ➤ partially polarized molecular electrons ➤ interact with HD spins*
- *solution: keep HD cold so that molecular electrons are 100% polarized and frozen*

  ⬄ *target cells with high conductivity cooling wires and new fast raster*

- eHD test cell with 960 Al cooling wires ➤

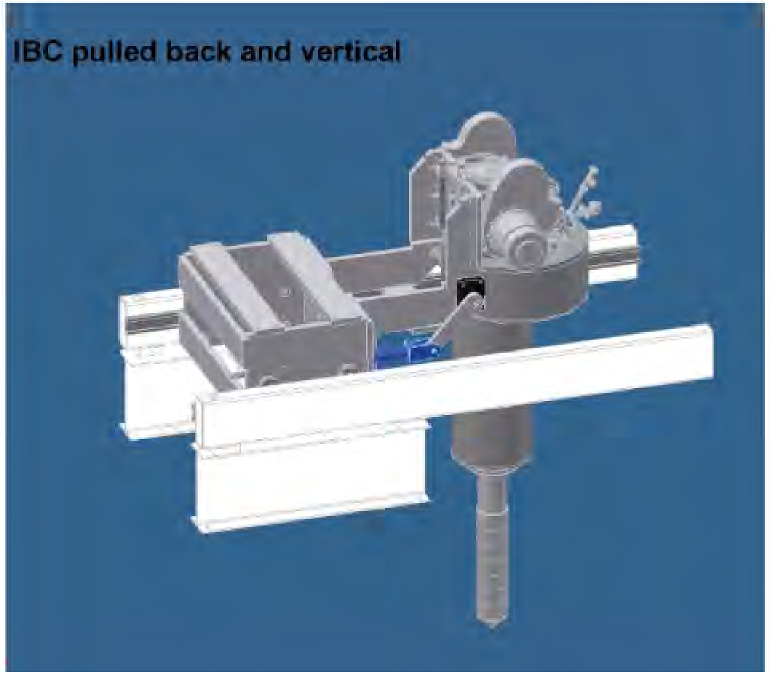


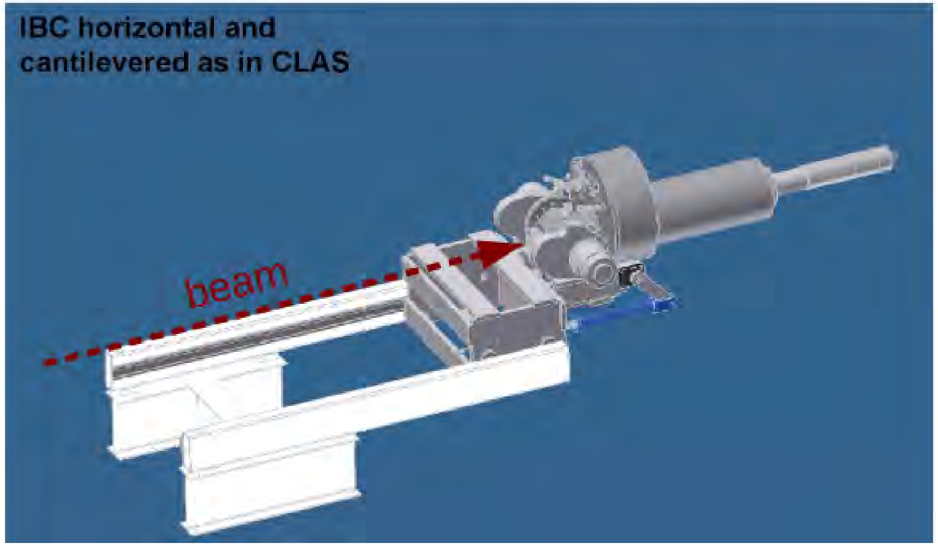


In Beam Cryostat….it's big

To load a target, IBC must be rotated vertical. Need ~ 3m vertical space

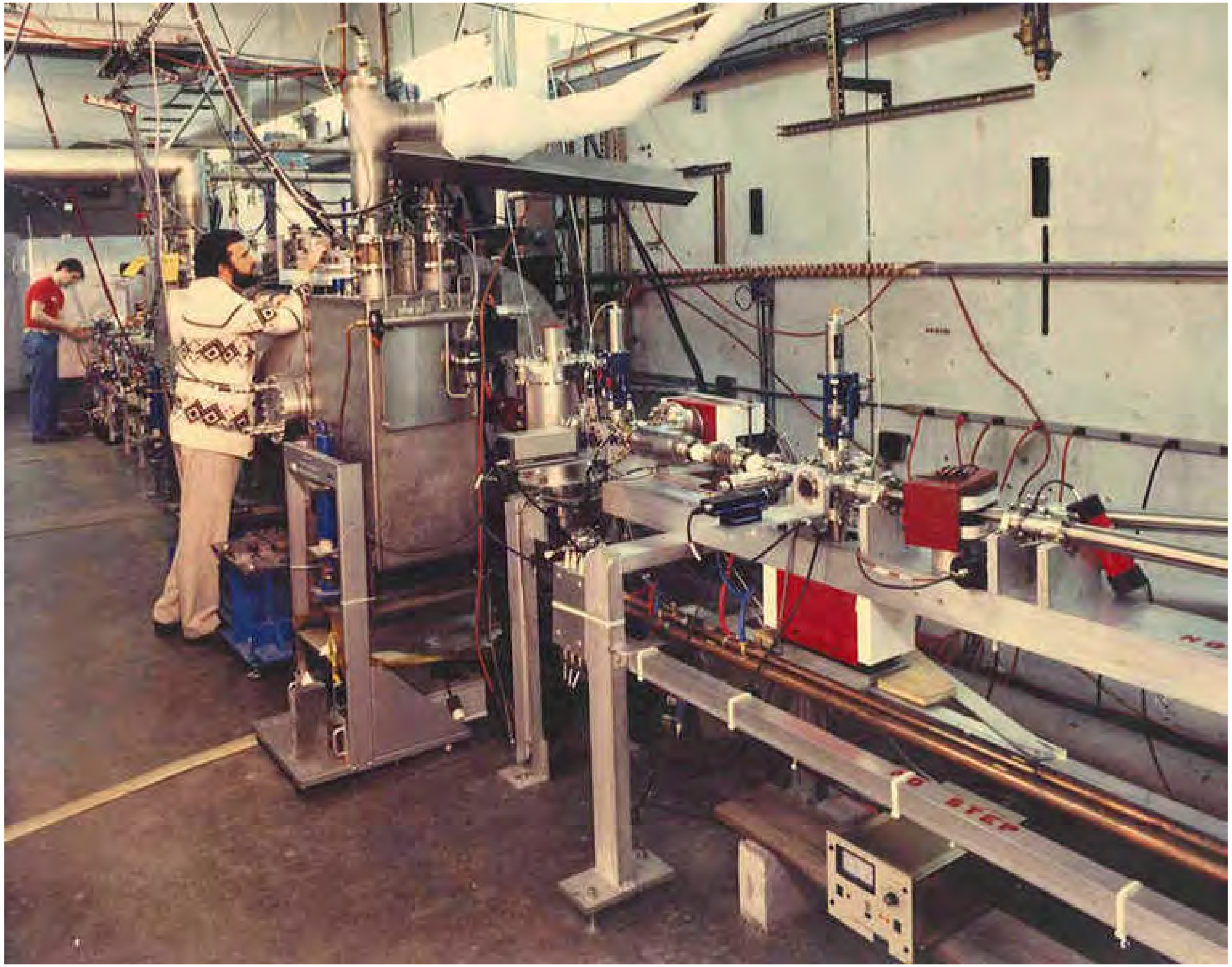
- IBC is a Dilution Refrigerator capable of operating both vertically (for docking with TC) and horizontally (for data-taking).
- T = 50 mK
- B = 1 T (solenoid); 0.075 T (saddle)





Thanks C. Hanretty and A. Sandorfi for HDIce slides

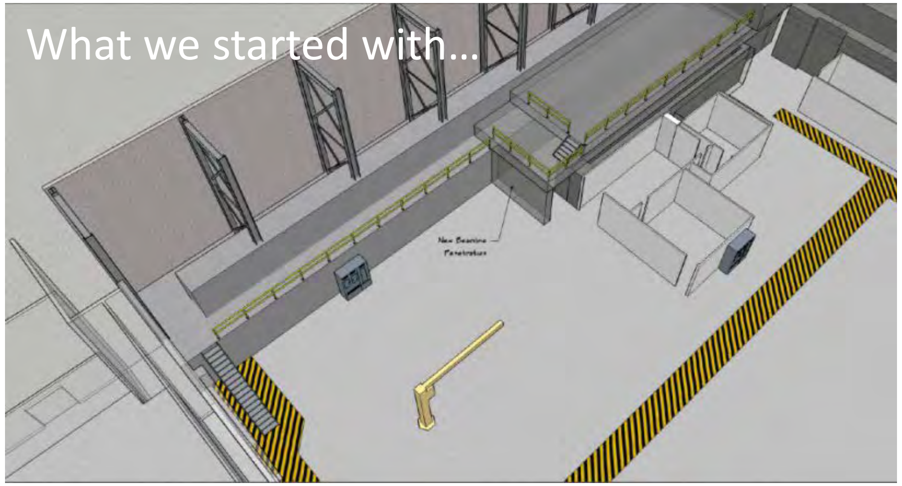
We inherited a shielded test cave from NASA



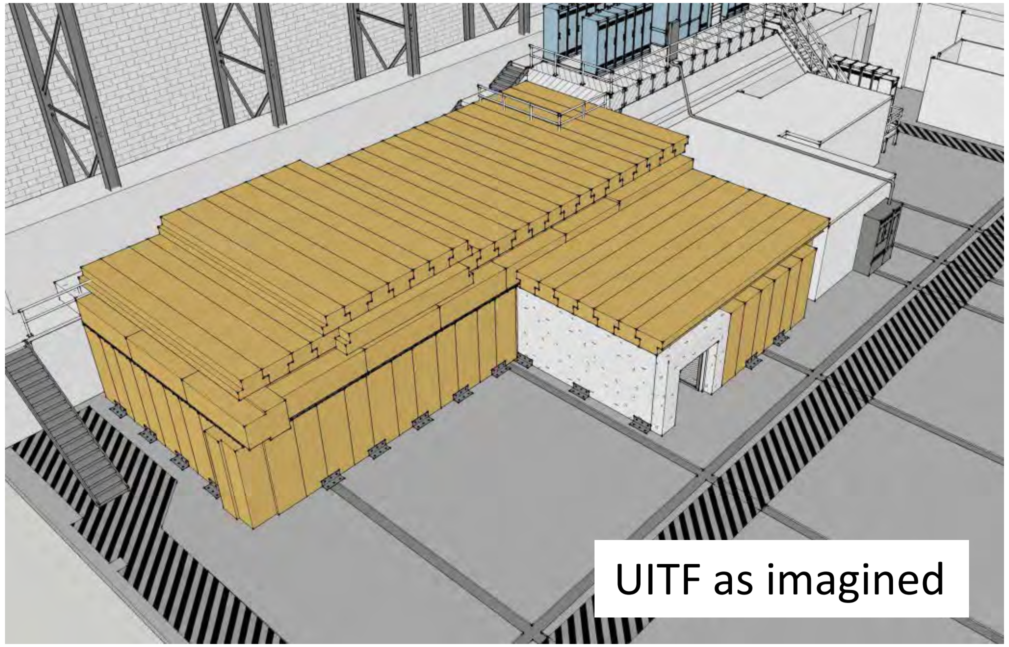
Used it to commission the CEBAF pre-injector in early 1990s:

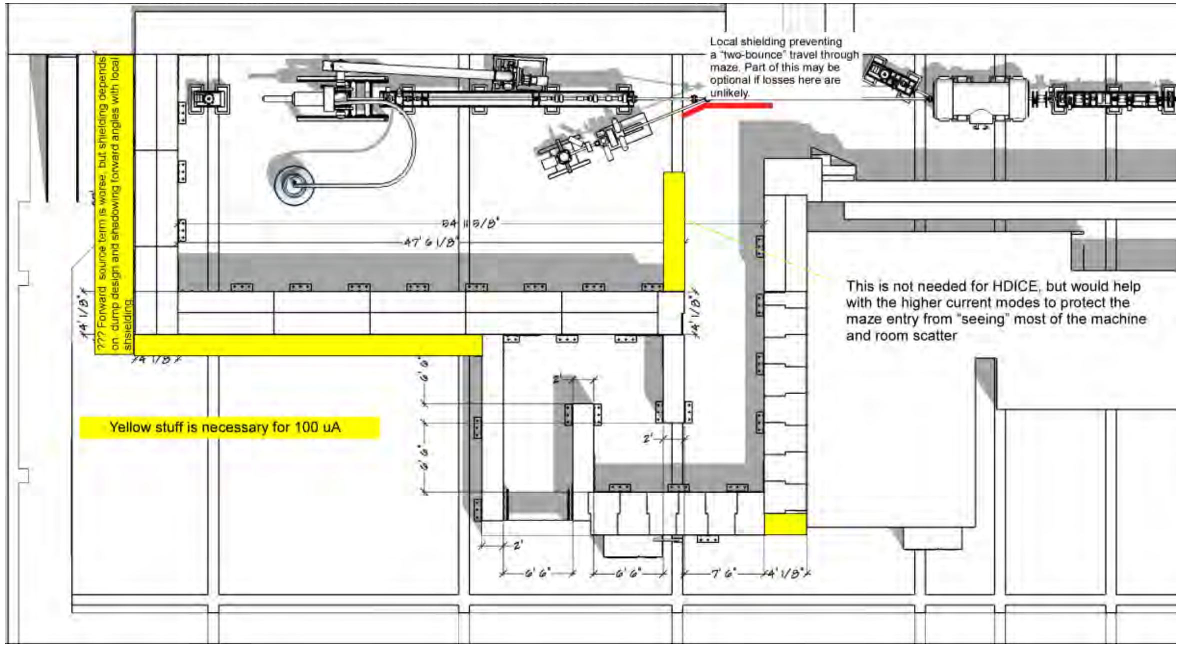
- DC high voltage thermionic gun
- Low duty factor machine safe mode
- RF deflector/chopper system to make three independent 499 MHz beams
- ¼ cryomodule

How to help Physics Division test new and improved HDIce?

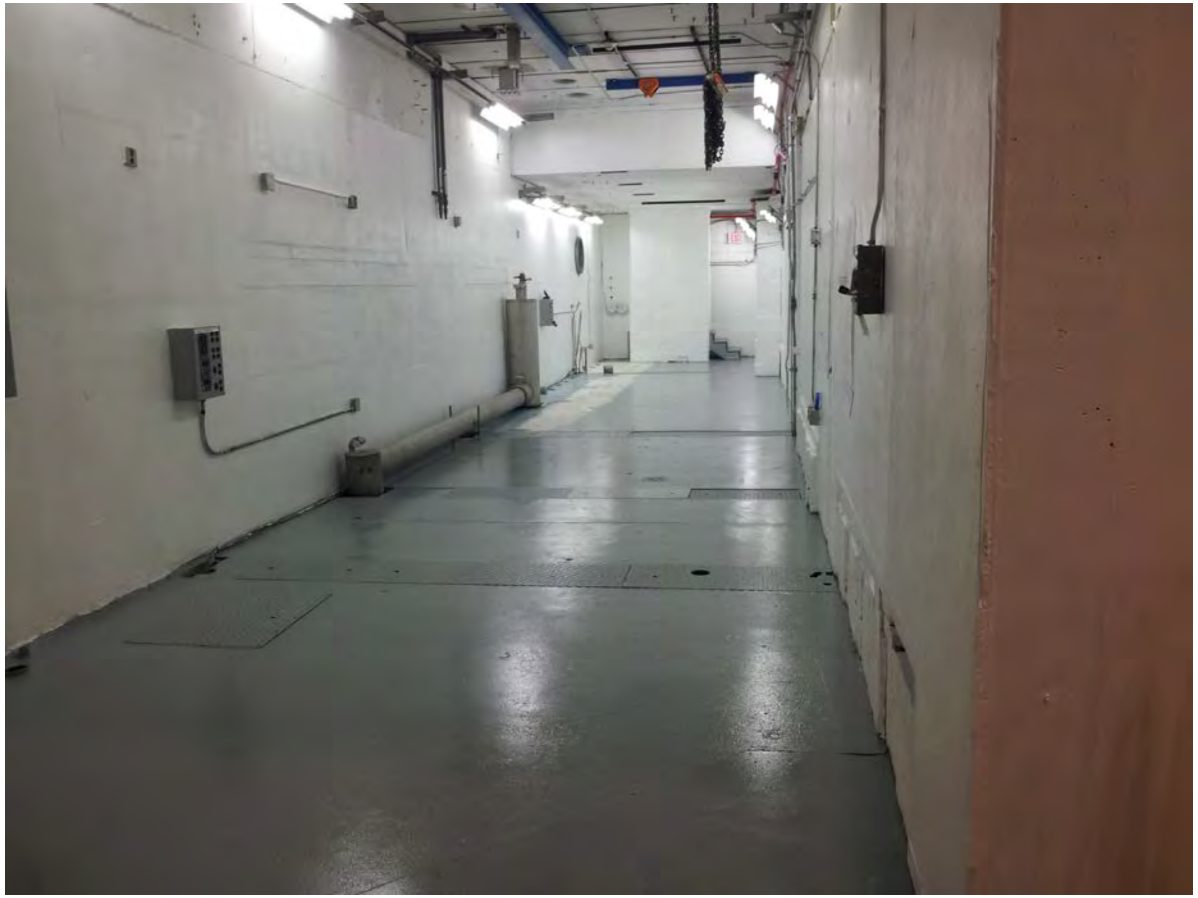


Build a 10 MeV accelerator located in building 58 high bay, using the new booster cryomodule: test two important devices, HDIce and booster





Cleaned out Cave1 and built Cave2 with on-site concrete block shielding



Circa 2016

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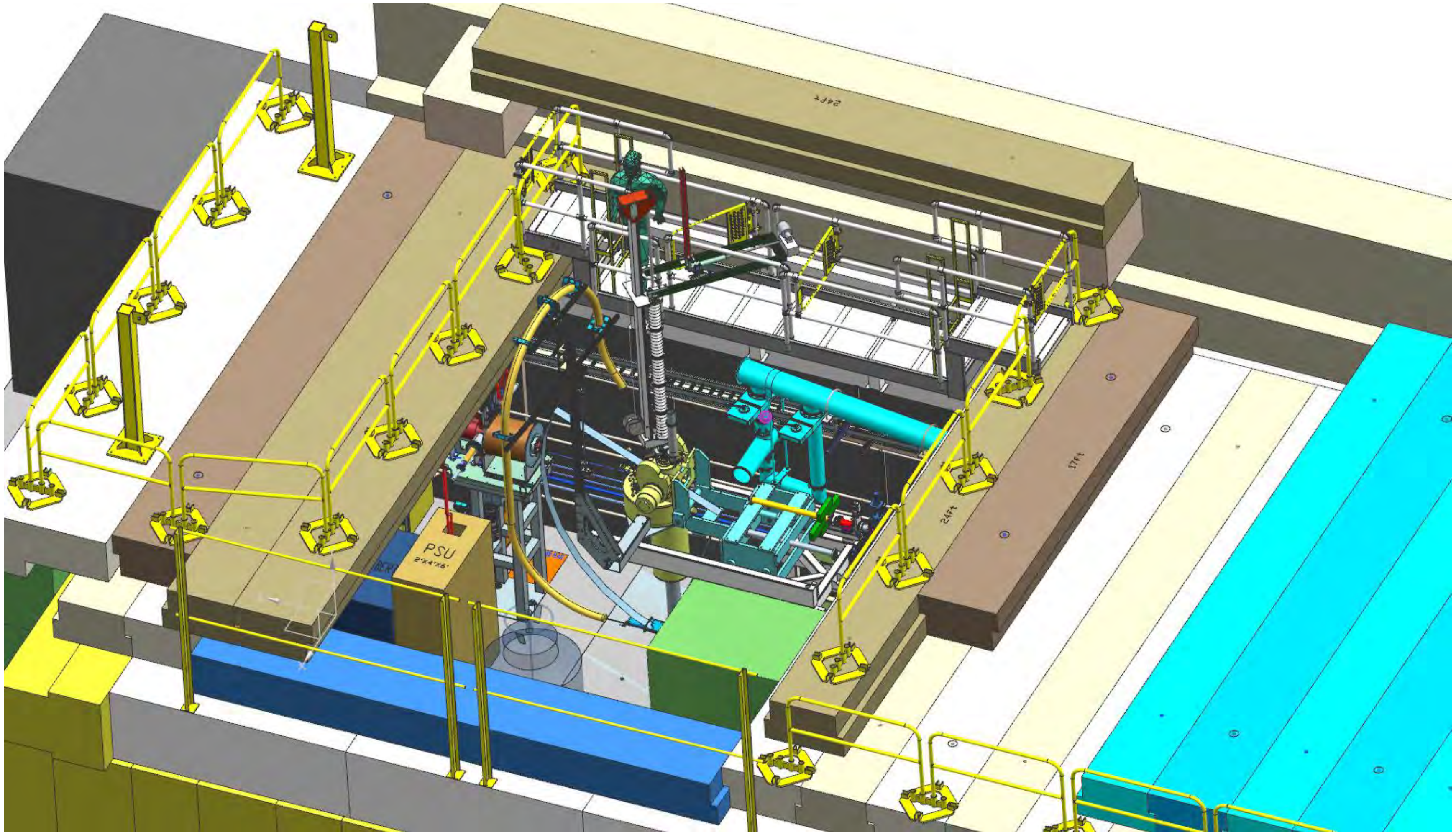
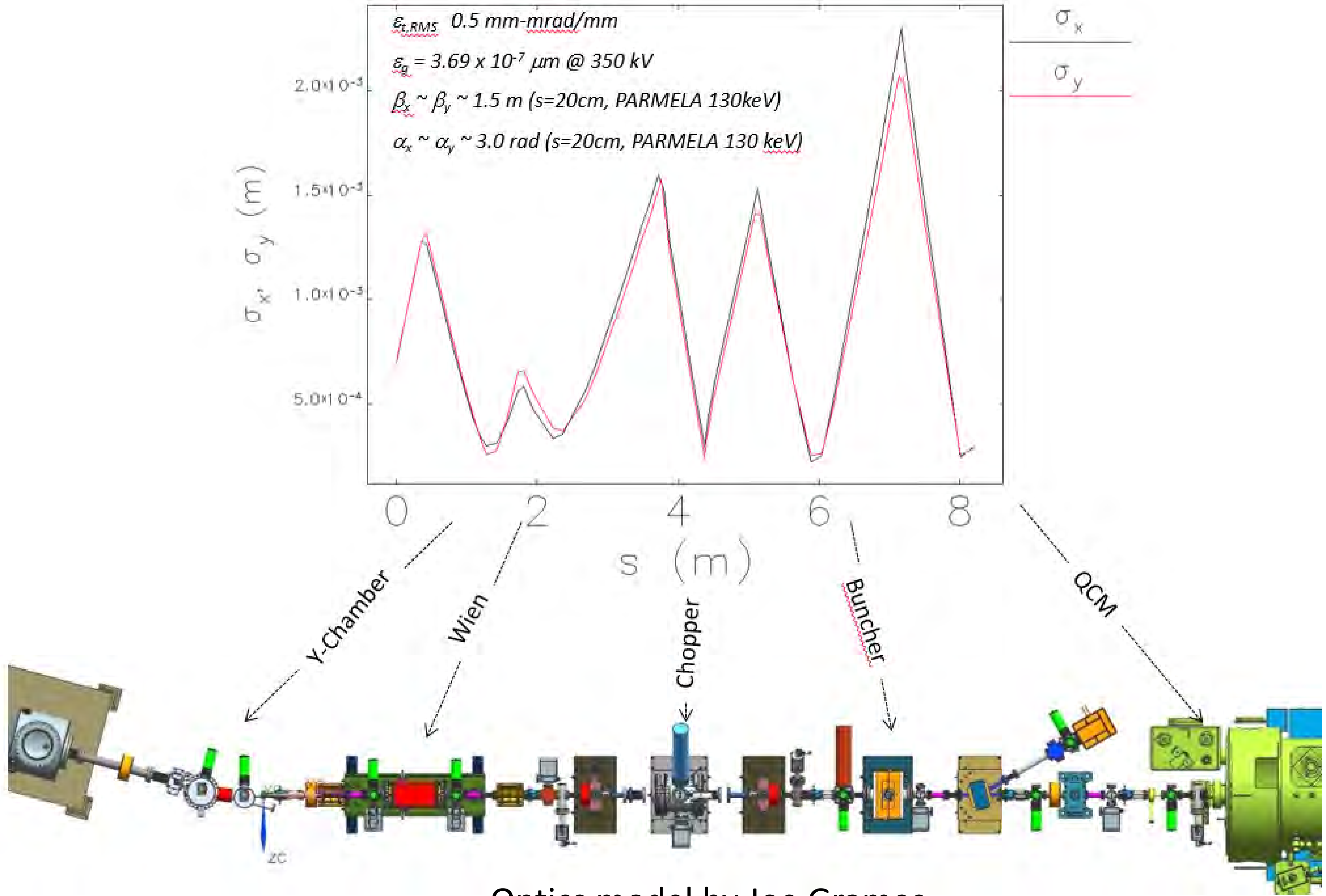
Removable roof tiles to support the HDIce target



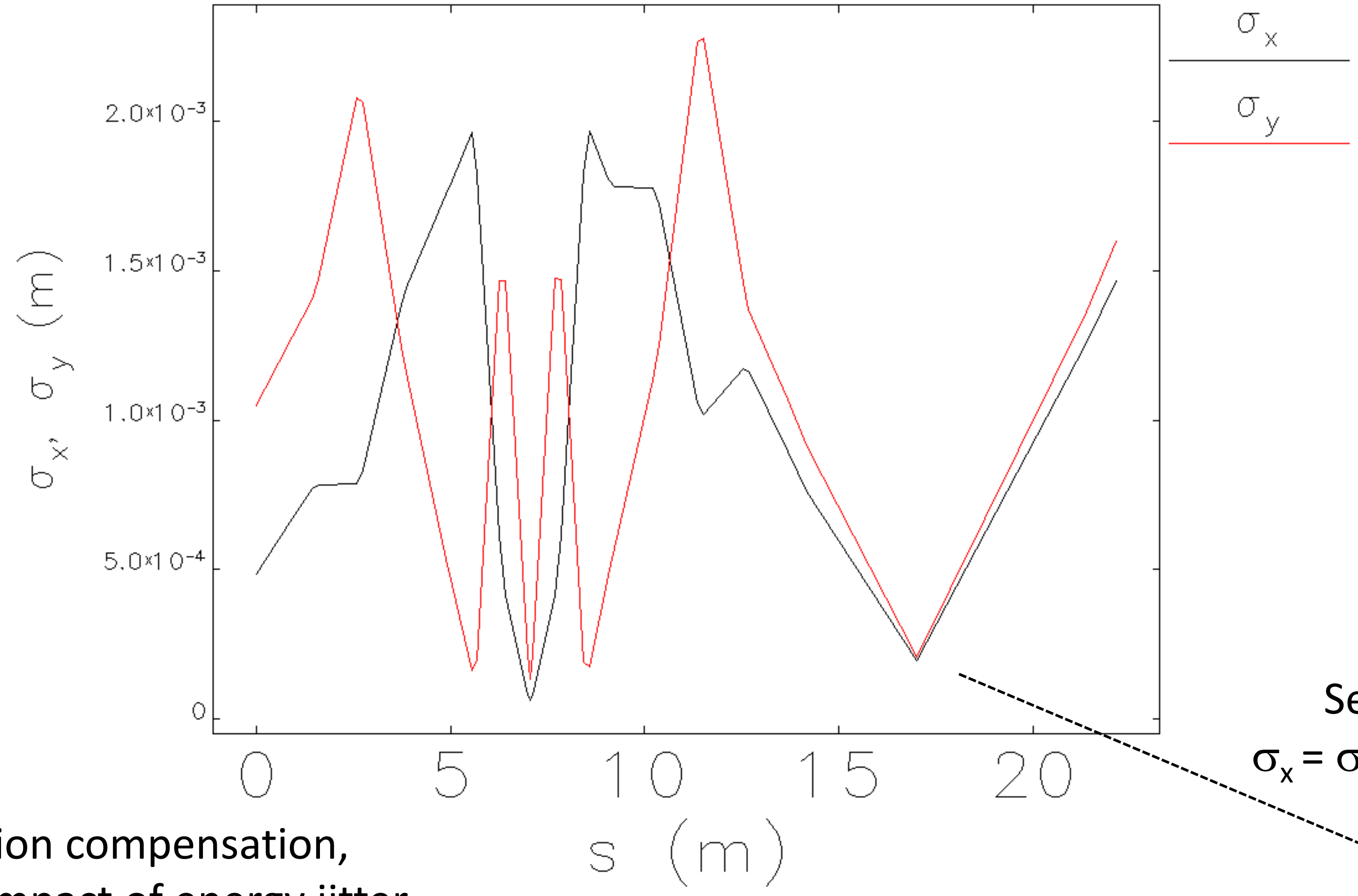
Shaun Gregory provided the mechanical design for the entire accelerator, including HDIce

keV optics (similar to CEBAF photoinjector)



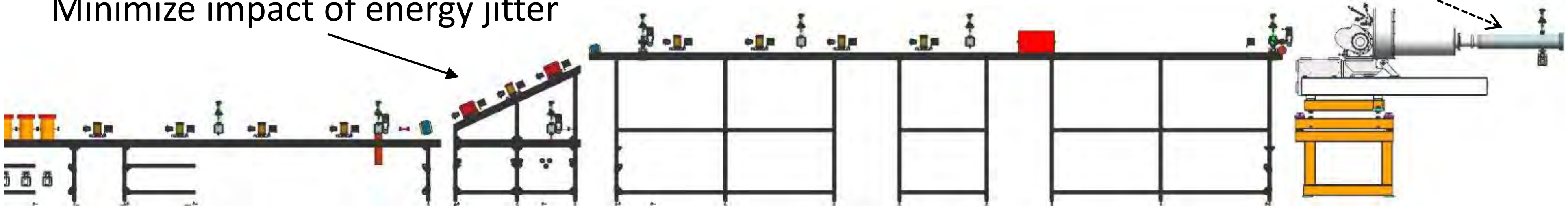
Optics model by Joe Grames

HDIce, elevated beamline optics



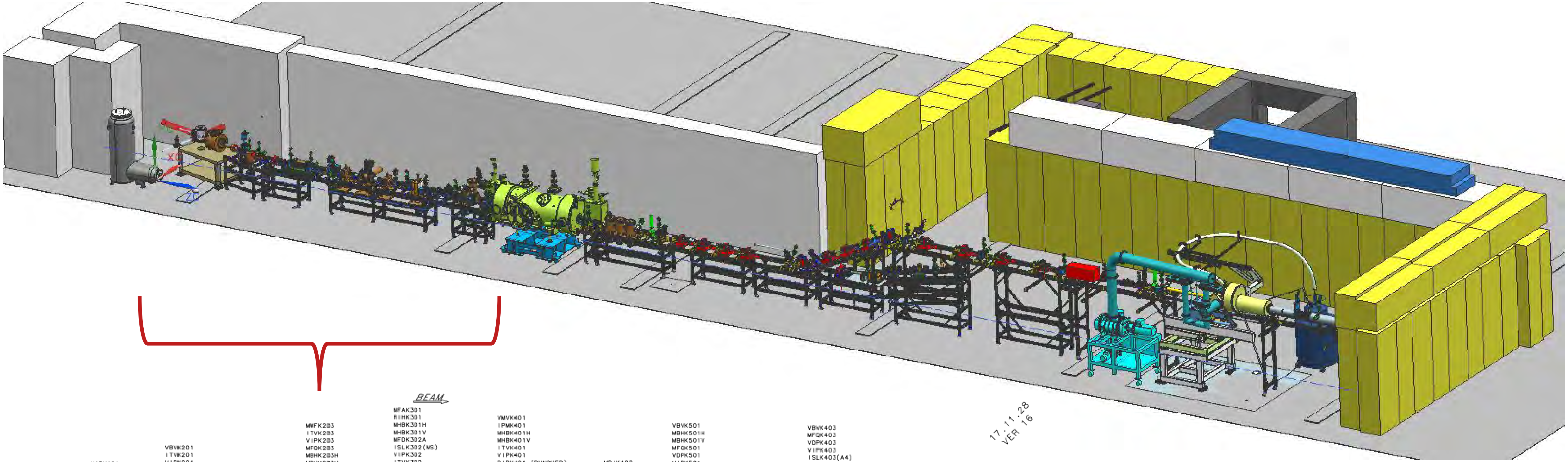
Set waist
$\sigma_x = \sigma_y \approx 200\ \mu m$

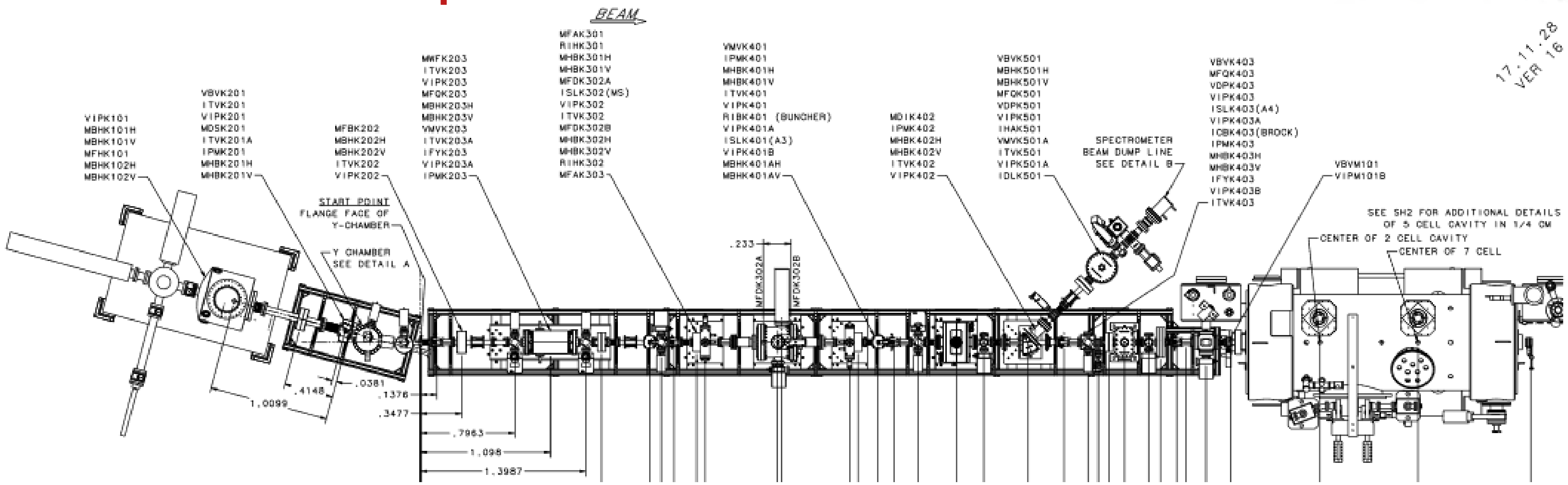
Dispersion compensation,
Minimize impact of energy jitter



Optics model by Joe Grames

keV beamline commissioned, RF applied to cold "Booster", no MeV beam yet





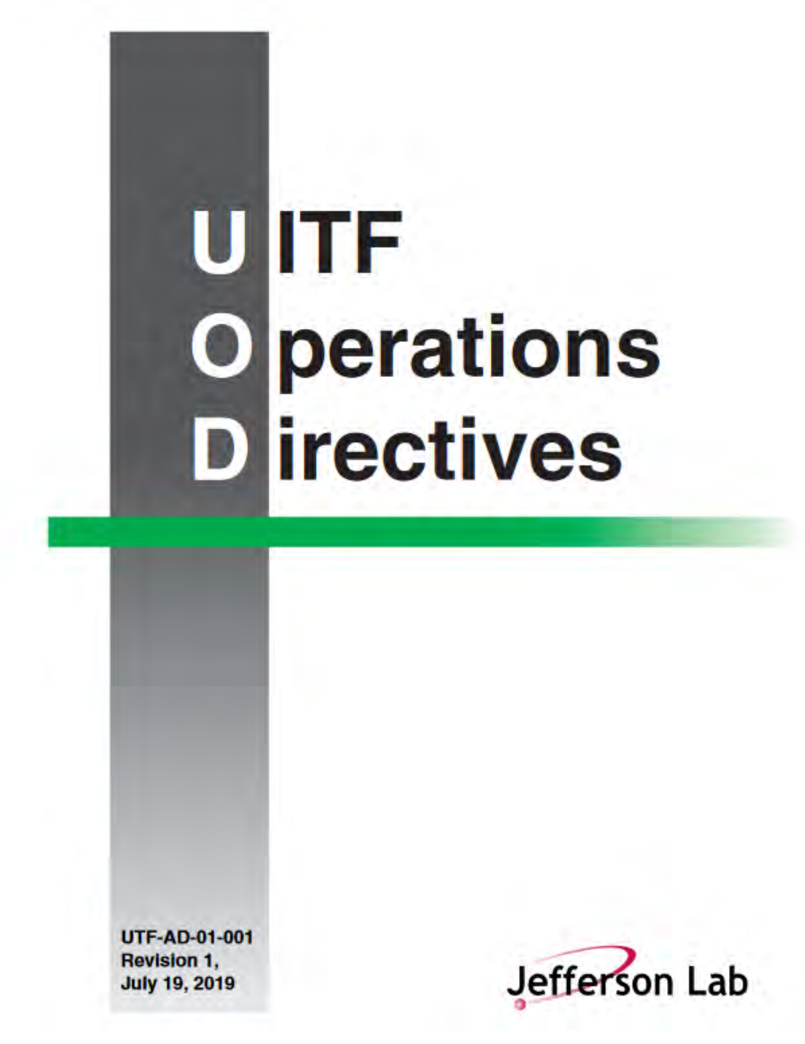
Before we built the MeV beamline, we were making keV beam and we re-commissioned the booster RF – but we were not allowed to make MeV beam

The long road to obtaining permission - Reviews of UITF

- Review #1: UITF Operations Review, aka “will it work?” March 18, 2016
  - https://wiki.jlab.org/ciswiki/index.php/UITF_Meeting_-_March_18,_2016
- Review #2: UITF Safety Review, May 10, 2016
  - https://wiki.jlab.org/ciswiki/index.php/UITF_Meeting_-_May_10,_2016
- Review #2.5: PSS BCM review *, October 21, 2016
  - https://wiki.jlab.org/ciswiki/index.php/UITF_Meeting_-_October_21,_2016
- Review #3: Conduct of Operations Review, April 24, 2019
  - https://wiki.jlab.org/ciswiki/index.php/UITF_Meeting_-_April_24,_2019
- Shielding Design Package, June 2019, JLAB-TN-18-020
- Accelerator Readiness Review: June 26-28, 2019
  - https://www.jlab.org/indico/event/322/timetable/#20190626

* the PSS BCM, once deemed necessary now deemed optional, following detailed shielding assessment

Official Documentation


UITF Operations Directives

UTF-AD-01-001
Revision 1,
July 19, 2019

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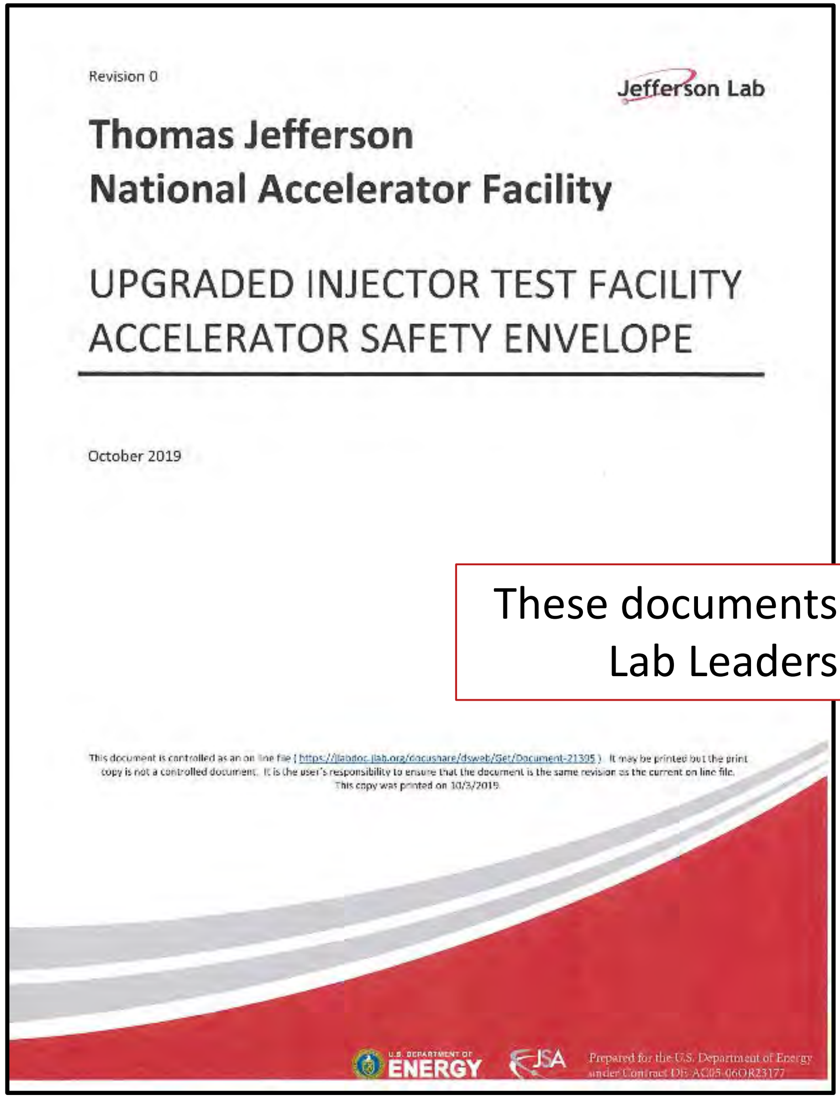
Revision 0

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Thomas Jefferson
National Accelerator Facility

UPGRADED INJECTOR TEST FACILITY
ACCELERATOR SAFETY ENVELOPE

October 2019

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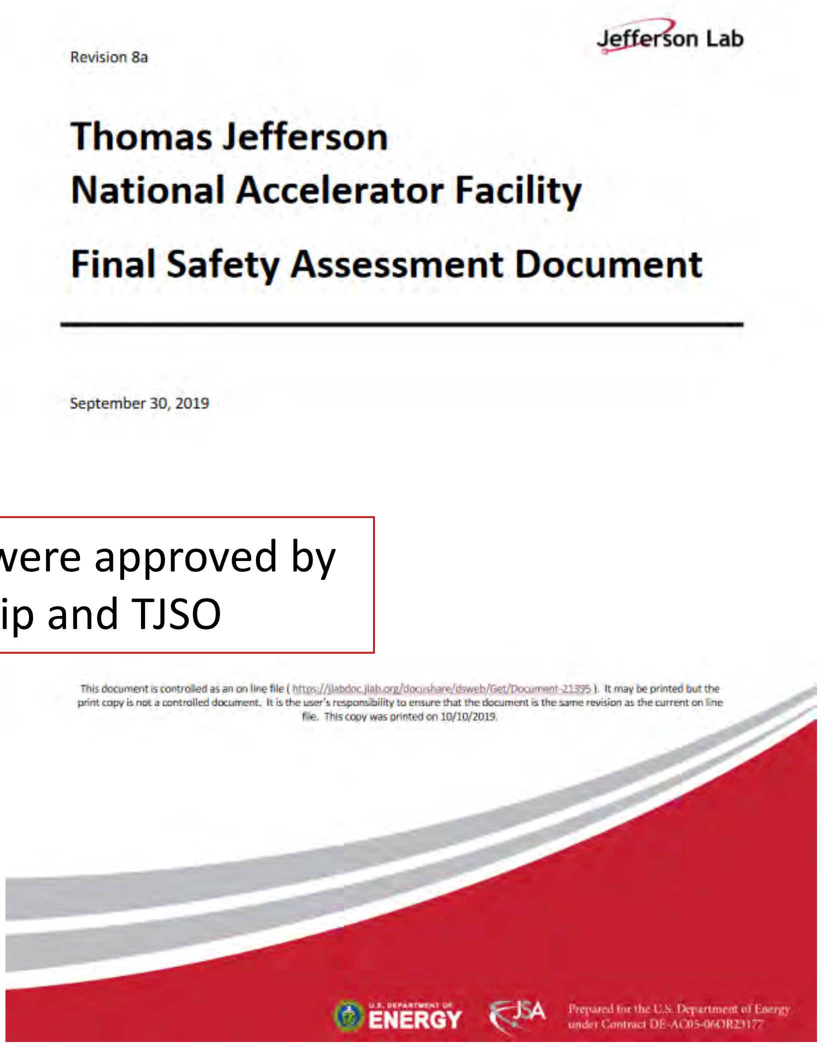
U.S. DEPARTMENT OF ENERGY JSA Prepared for the U.S. Department of Energy under Contract DE-AC05-06OR23177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Revision 8a

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National Accelerator Facility

Final Safety Assessment Document

September 30, 2019

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U.S. DEPARTMENT OF ENERGY JSA Prepared for the U.S. Department of Energy under Contract DE-AC05-06OR23177

These documents were approved by Lab Leadership and TJSO

https://wiki.jlab.org/ciswiki/index.php/UITF_Official_Documents

https://www.jlab.org/eshq/ProgramDocs

Official Documentation

UITF Safety Documents

UITF cave 2 catwalk engineering calculations media:catwalk engineering calculations from Tom Renzo.pdf

UITF Cave2 ceiling roof tile removal, OSP and THA, revision 2, in review media:UITF Cave2 ceiling roof tile removal OSP.pdf**** media:UITF Cave2 ceiling roof tile removal THA.pdf

Shielding Design Package from Vashek, approved by SCMB File:JLAB-TN-18-020 Radiation Safety Aspects of the Upgraded Injector Test Facility Vashek Vylet.docx, Photos of trench foam and lead shielding media:UITF trench shielding with photos.xls

Cool and Operate HDice IBC and its superconducting magnets in cave2 of UITF ENP-18-80380-OSP File:Cool and Operate HDice IBC and its superconducting magnets in cave2 of UITF ENP-18-80380-OSP.pdf

UITF 748.5 MHz Buncher Cavity Operation at the Upgraded Injector Test Facility: Revised OSP #82655 File:Revised OSP 82655 748.5 MHz Buncher Cavity Operation at the Upgraded Injector Test Facility.pdf and File:Revised THA for 748.5 MHz Buncher Cavity Operation at the Upgraded Injector Test Facility.pdf. These files can be accessed at https://mis.jlab.org/mis/apps/mis_forms/operational_safety_procedure_form.cfm?ENTRY_ID=82655

UITF Commissioning the QCM with RF, no beam acceleration, revision2: https://misportal.jlab.org/mis/apps/mis_forms/operational_safety_procedure_form.cfm?entry_id=82424 File:OSP 82424 QCM Operation at the Upgraded Injector Test Facility (UITF) revision 2.pdf****File:OSP 82424 QCM Operation at the Upgraded Injector Test Facility (UITF) revision 2.docx

UITF Commissioning the QCM with RF, no beam acceleration, Task Hazard Analysis, revision2: File:THA for the OSP 82424 QCM Operation at the Upgraded Injector Test Facility (UITF)revision2.pdf

UITF SF6 tank pressure vessel assessment PS-ACC-17-001 can be found in DOCUSHARE at https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-38867 (Note, the pressure vessel assessment for a similar SF6 tank used at CEBAF can be found at https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-38417)

UITF QCM Vacuum Vessel assessment: File:QCM Vacuum Vessel Assessment by Gary Cheng.docx

UITF Laser OSP: File:LOSP ACC-17-64784.pdf

UITF keV Beam Operations OSP (note this is revision3 of previously approved OSP): File:OSP UITF keV beam operations approved revision3.docx **** File:OSP UITF keV beam operations approved revision3.pdf **** File:OSP-UITF keV beam operations approved revision3 approved OSP format with signatures.pdf

UITF keV Beam Operations THA (note this is revision3 of previously approved THA): File:THA UITF keV beam operations approved revision3.pdf

UITF sweep procedure, updated 6/25/2019: available on Docushare at https://jlabdoc.jlab.org/docushare/dsweb/View/Collection-27494/ and here: File:UITF sweep procedure S6024.pdf

UITF Final Approved ODH Assessment: File:UITF ODH Assessment.pdf and available at https://misportal.jlab.org/railsForms/oxygen_deficiency_reviews/74180/edit

UITF Industrial Hygiene Assessment for SF6 exposure: File:UITF SF6 assessment.pdf

UITF TOSP_high voltage conditioning a new photogun with 225kV Spellman supply: File:UITF TOSP gun HV conditioning.pdf **** File:UITF THA gun HV conditioning.pdf

https://wiki.jlab.org/ciswiki/index.php/UITF_Safety_Documents

CATS items following ARR

Found: 52 records matching your search criteria
Click on the record number to see the full details.

ACTION_#	ACTION_OWNER	ORG			COMPLETE_BY	COMPLETED
IA-2019-03-02-01	Poelker, Matthew	Ctr for Injectors&Sources	Develop UITF Specific Training approach. Please provide the		2020-06-30	open
IA-2019-03-04-02	Poelker, Matthew	Ctr for Injectors&Sources	Continue to turn Test Plans int Test Procedures and method	ted	2020-06-30	2019-11-04
IA-2019-03-05-01	Poelker, Matthew	Ctr for Injectors&Sources	Install additional "operator aid Please provide the following cl	onitor.	2020-06-30	open
IA-2019-03-04-01	Poelker, Matthew	Ctr for Injectors&Sources	Use the process/steps from th closure evidence: "Approved S	wing	2020-03-31	2019-11-04
IA-2019-03-06-01	Poelker, Matthew	Ctr for Injectors&Sources	Modify UITF Sweep procedure moved (e.g. shielding blocks m	ally	2020-03-31	open
IA-2019-03-01-01	Poelker, Matthew	Ctr for Injectors&Sources	Establish operator proficiency requirements for achievement	he	2019-11-08	2019-11-04
IA-2019-03-01-02	Poelker, Matthew	Ctr for Injectors&Sources	Post the list of qualify operato provide the following closure e	ase	2019-11-08	2019-11-04
IA-2019-03-03-01	Poelker, Matthew	Ctr for Injectors&Sources	Revise and approve the UOD "Approved UOD record"	e:	2019-11-08	2019-11-05
IA-2019-03-03-04	Poelker, Matthew	Ctr for Injectors&Sources	Implement a Shift Plan to estal provide the following closure e		2019-11-08	2019-11-05
IA-2019-03-03-05	Poelker, Matthew	Ctr for Injectors&Sources	Verify that the use of the Test the following closure evidence	ovide	2019-11-08	2019-11-05

Requesting Permission to Commission

ML

Mary Logue <logue@jlab.org>
Tue 11/12/2019 11:56 AM
Andrei Seryi; Camille Ginsburg; Matthew Poelker; Bob May; Harry Fanning

Andrei,

The Performance Assurance Office has verified that the actions to address the pre-start findings from the UITF ARR have been completed, and I have approved closure of the issues in CATS. At this point all the "boxes" have been checked and we are ready for Stuart to request permission to commission the UITF. In the past my Division has drafted such letters. We can do that for UITF, unless you prefer to do so.

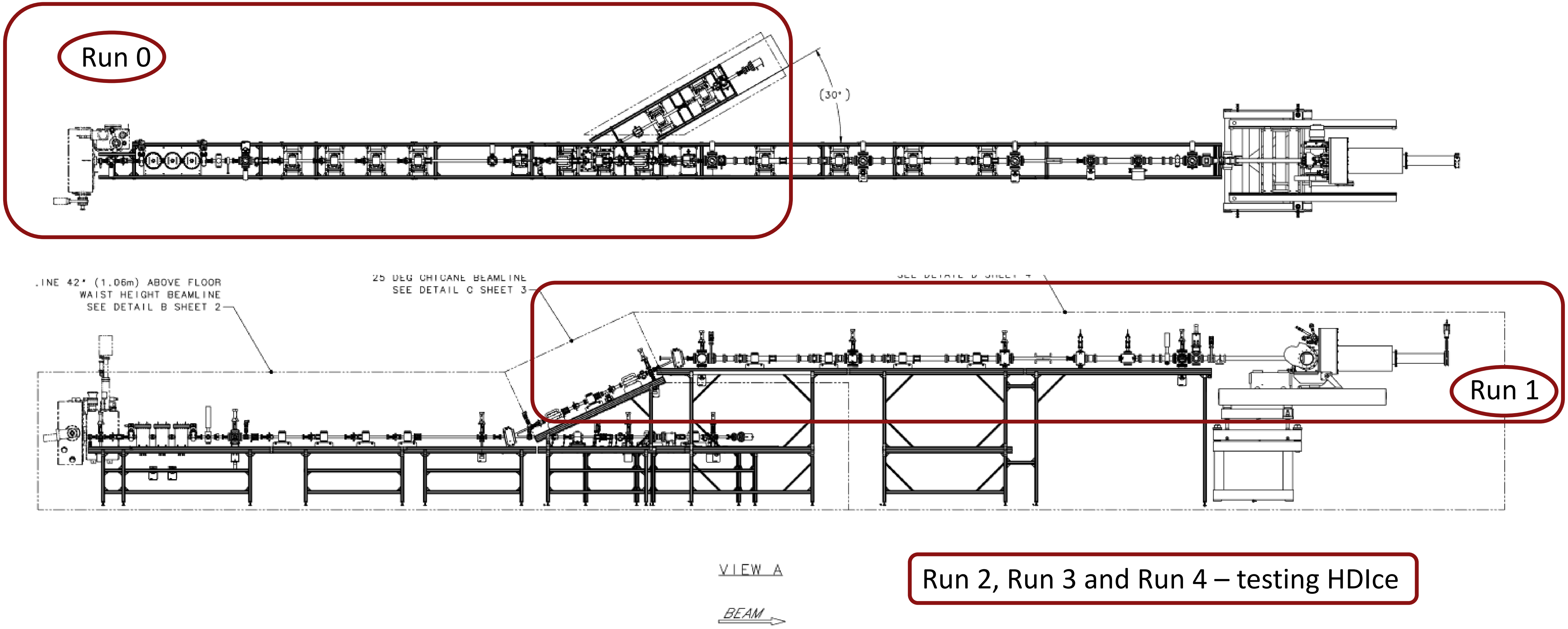
Let me know what I can do to help.

Mary

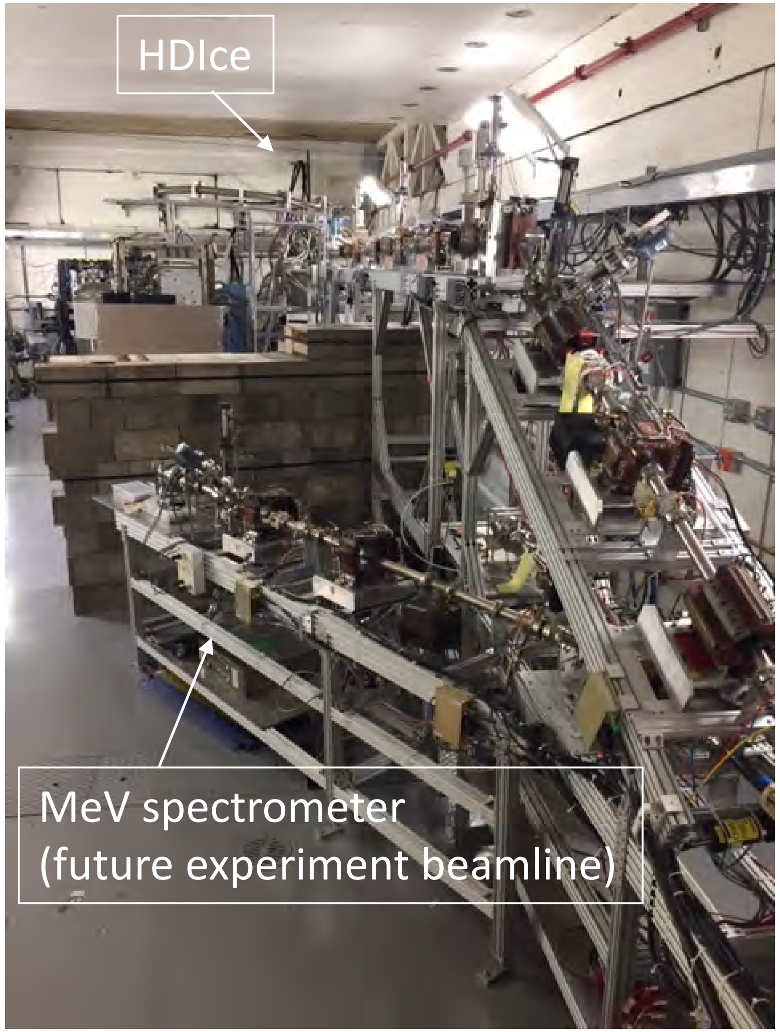
--
Mary Logue
Associate Director, ESH&Q
Thomas Jefferson National Accelerator Facility
12050 Jefferson Avenue, Suite 602
Newport News, VA 23606
757-269-7447

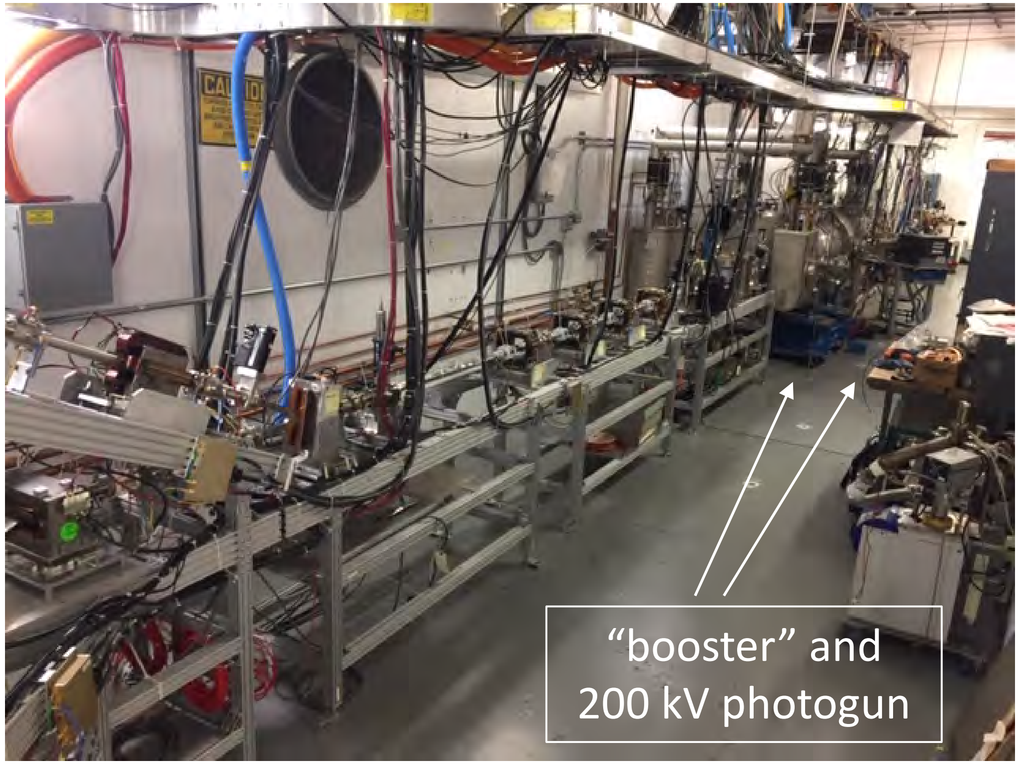
all prestart findings have been addressed

Permission granted, we proceed in steps…. (because we were sharing LHe)



The Accelerator is complete, HDIce our first "User"



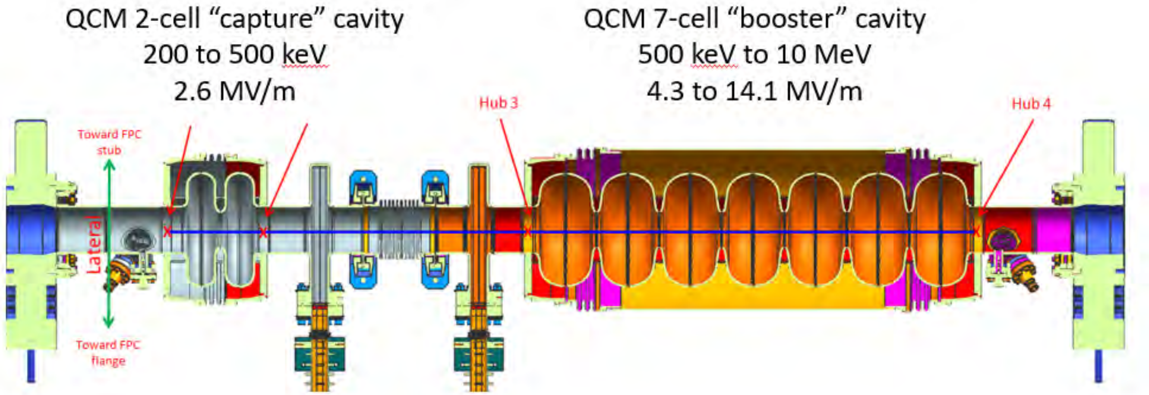


- 200 kV DC high voltage spin-polarized photogun
- SRF Booster: 2-cell capture section and 7-cell
- With spin manipulator, temporal chopper and buncher: 10 meter-long polarized photoinjector
- HDIce must rotate vertical to remove/install targets, necessitated elevated beamline and removable roof tile shielding

Booster tested with RF at UITF (no beam acceleration)

Booster commissioning results at UITF

	Cavity 7 (2-cell)	Cavity 8 (7- cell)
QextFPC	6.2E+06	9.9E+06
QextFP	2.9E+12	2.3E+12
Emax (MV/m)	16.5	18.0
Emaxop (MV/m) (1 Hour run)	16.0	18.0
Limit	Quench	Forward Pwr
FE onset (MV/m)	11.5	16.0
RF heat load at typical operating gradients	9.5E+09 (< 1W at 6 MV/m)	1.2E+10 (~12 W at 6 MV/m)
Static heat load	20 W	



Inside the QCM

Maximum beam energy at UITF?

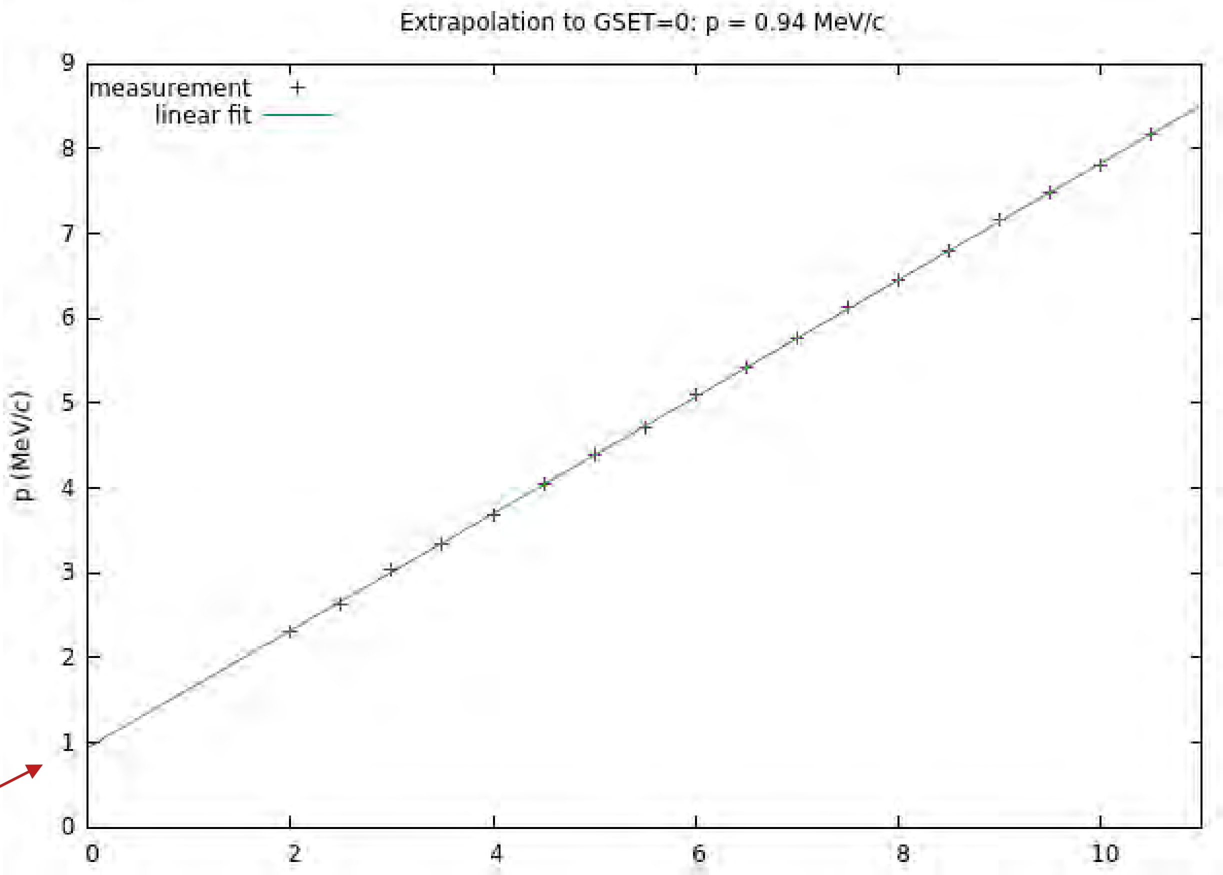
16 MV/m x 0.7m = 11.2 MeV
(7-cell cavity effective length 0.7 m)
+ gun and capture section = 0.53 MeV
So ~ 12 MeV

(only need ~ 6 MeV at CEBAF)

Similar results from first tests at CMTF

Setting the 2-cell Gradient

- Per design, the gun plus 2-cell provide 533 keV beam
- Initially, it was difficult to float keV beam to the MeV spectrometer, and thus, hard to set 2-cell gradient
- Guessed a 2-cell GSet and then calibrated the 7-cell Gset
- Did this a few times for different 2-cell GSets



7-cell GSet

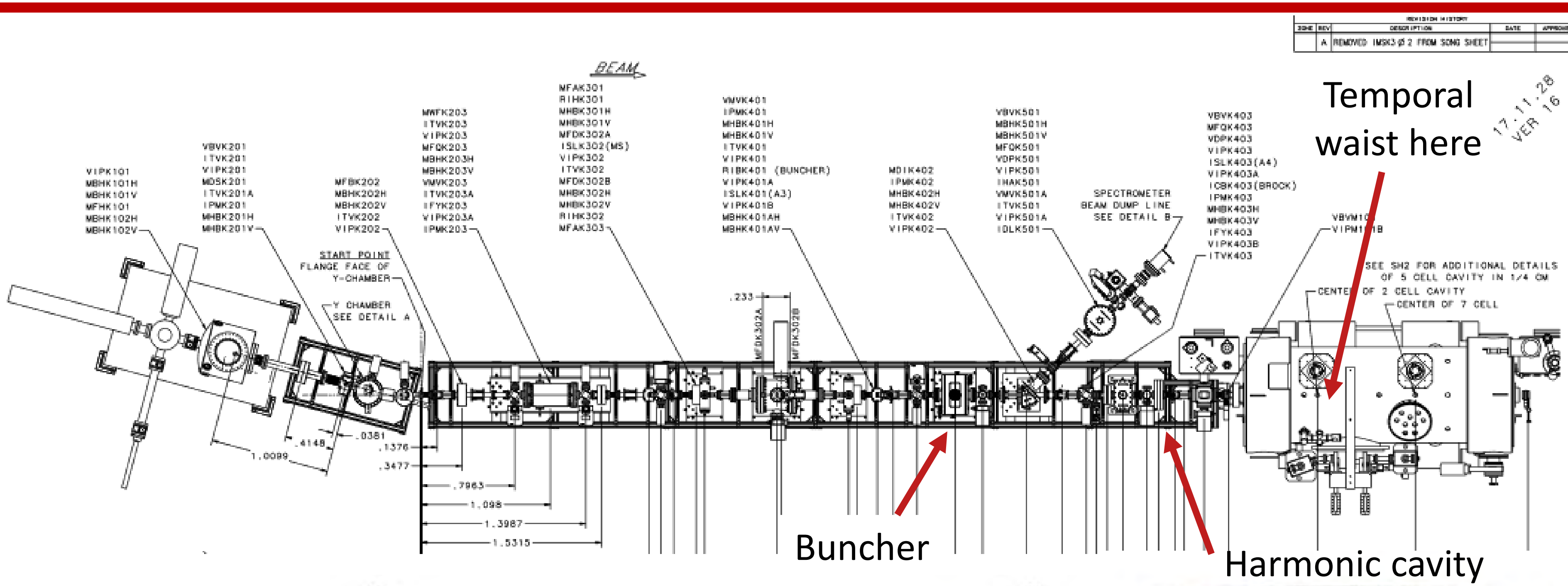
$$p = 0.91\ MeV/c$$

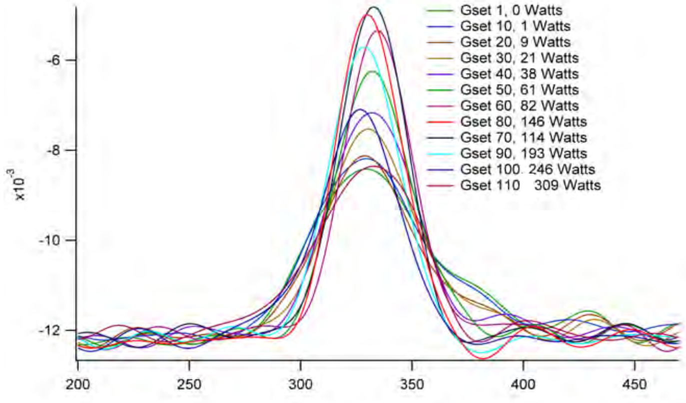
$$p = \sqrt{(0.533 + 0.511)^2 - 0.511^2}$$

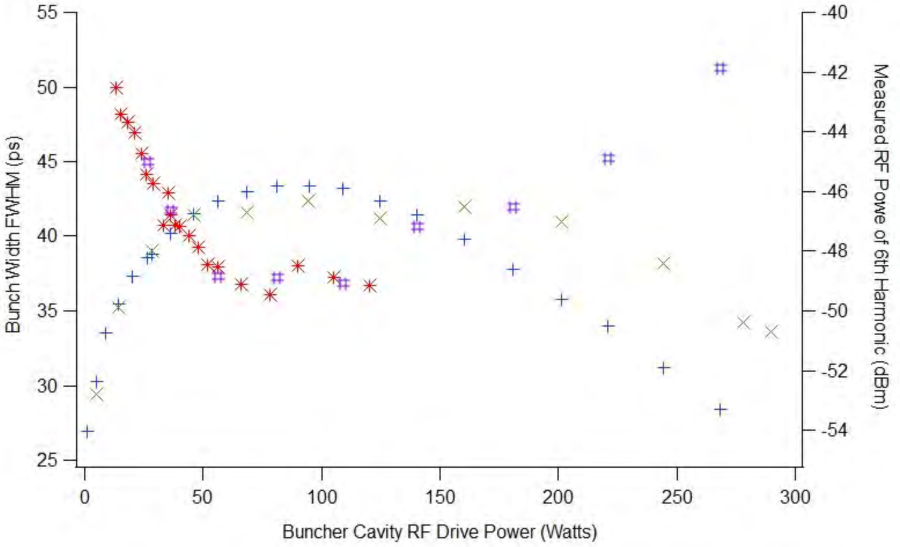
$$p = \sqrt{(K + m)^2 - m^2}$$

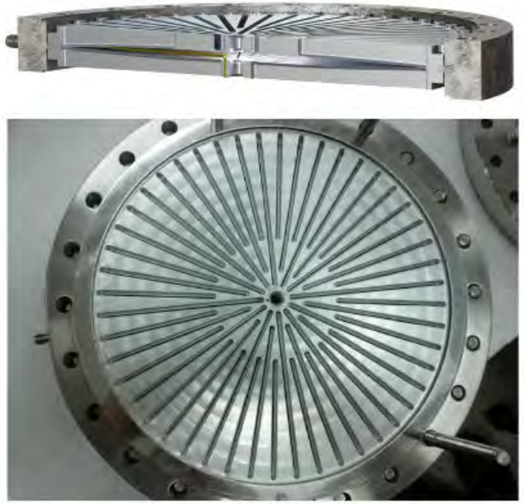
GSet = gradient setpoint
Spectrometer = calibrated dipole magnet
we measure beam momentum

Setting the Buncher Gradient









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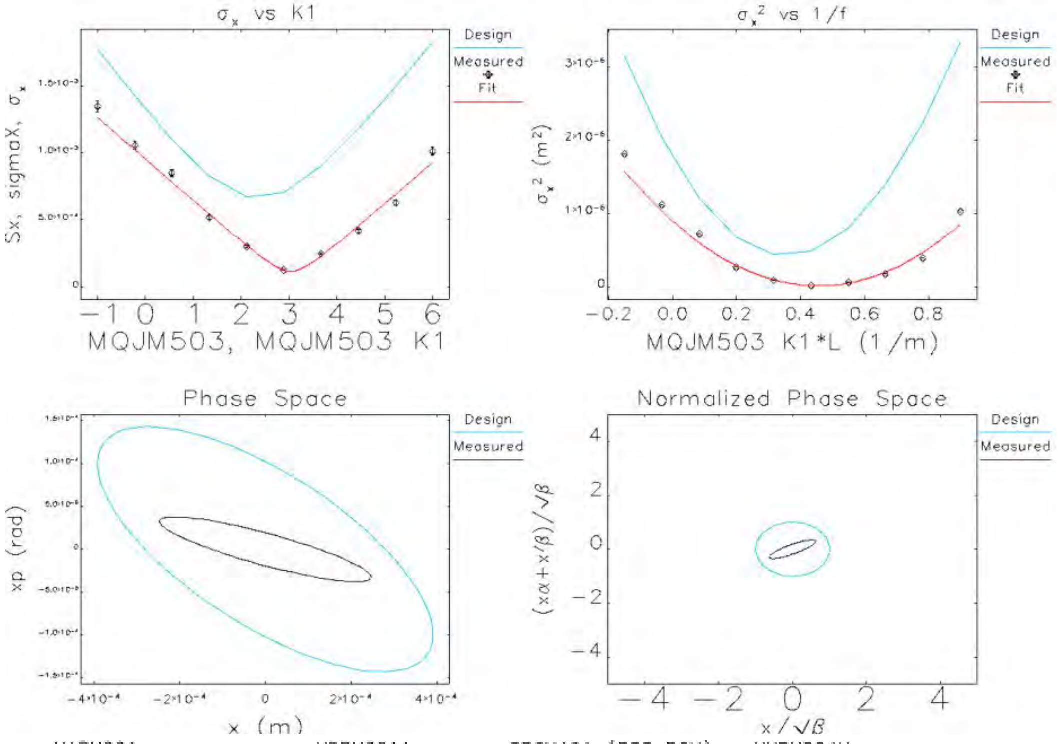
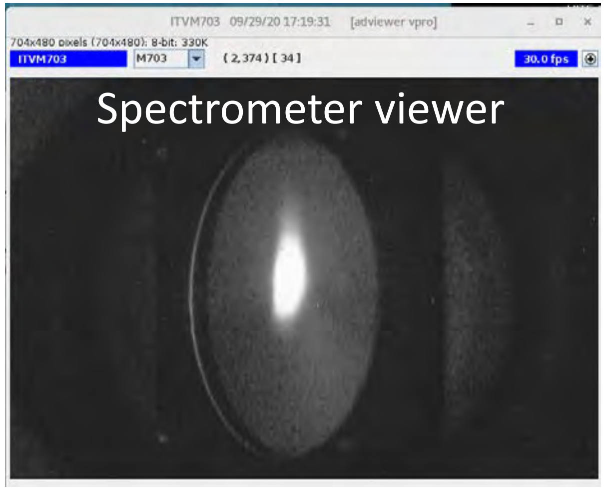
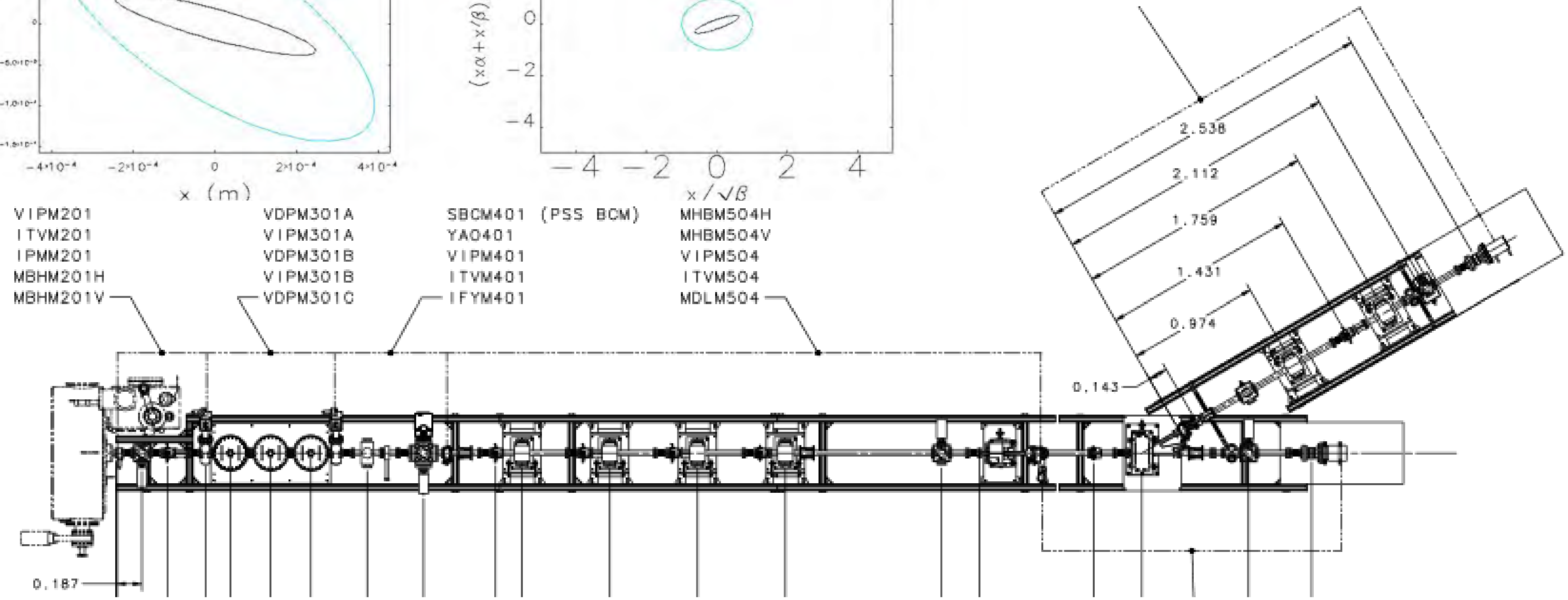
9.7 MeV/c beam to spectrometer

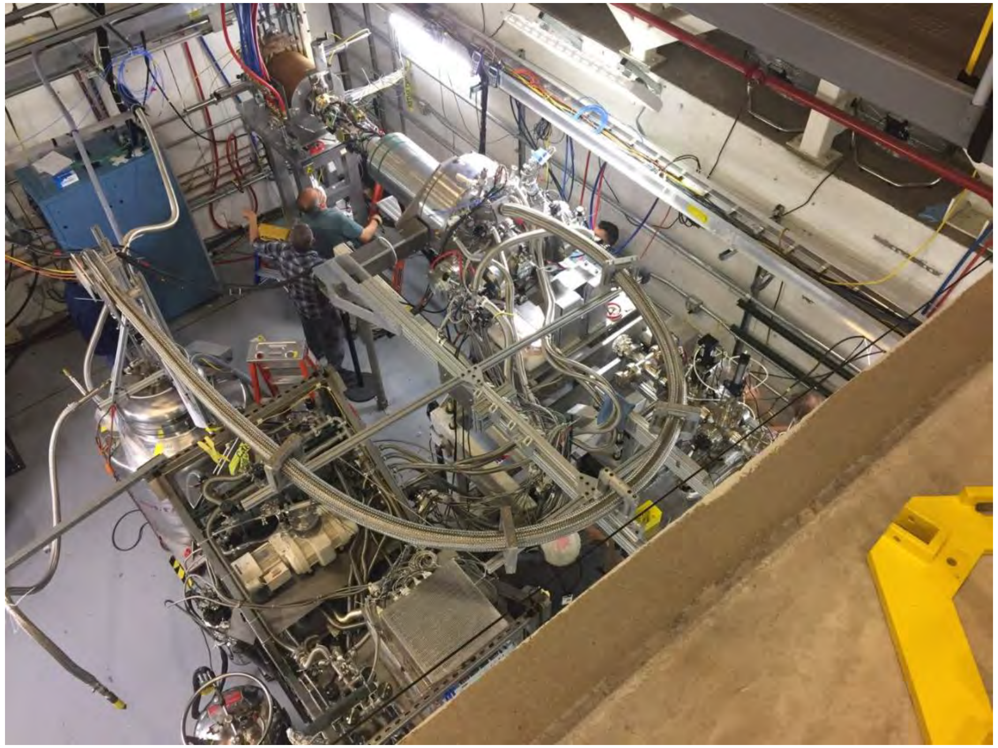


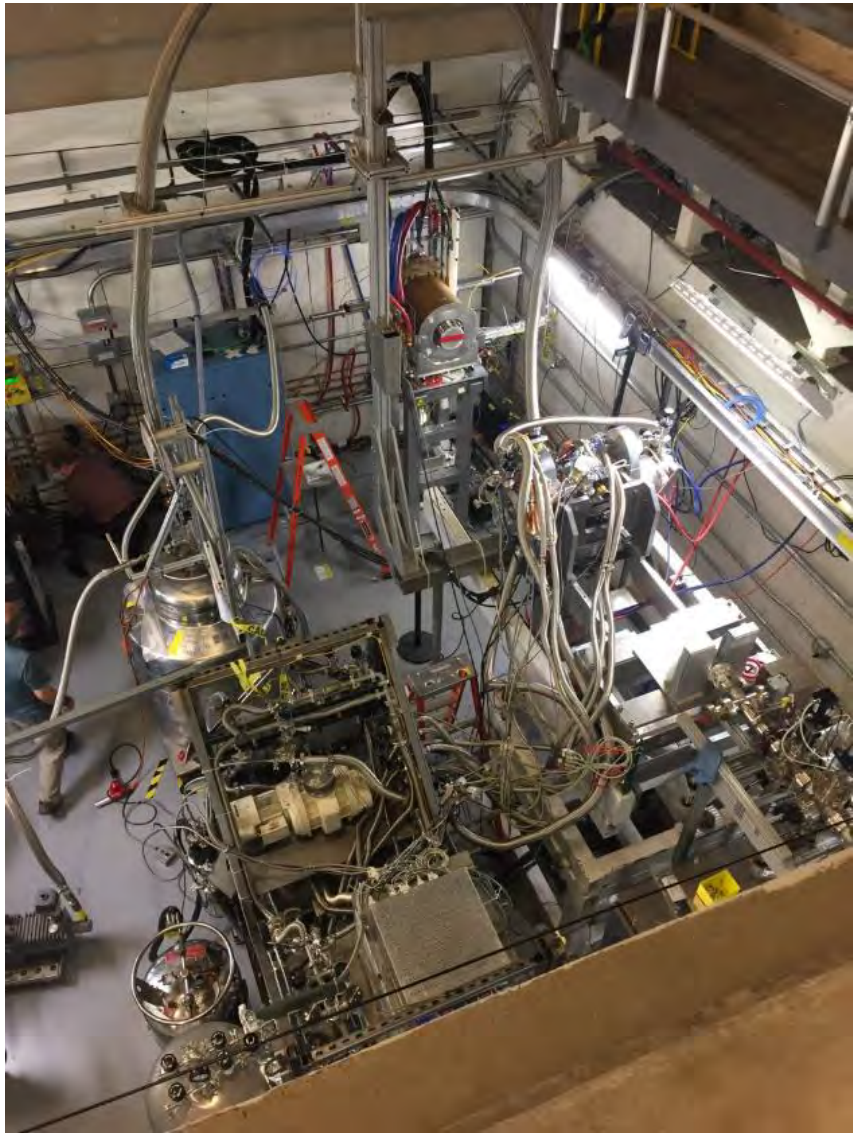




Yan Wang did most of the accelerator commissioning

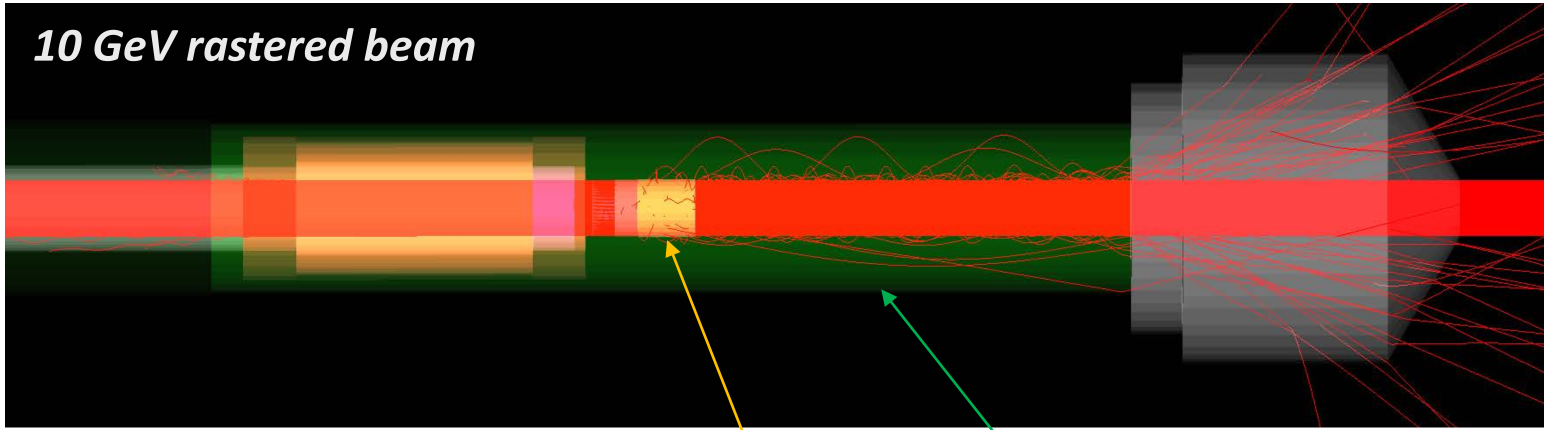
HDIce Run1



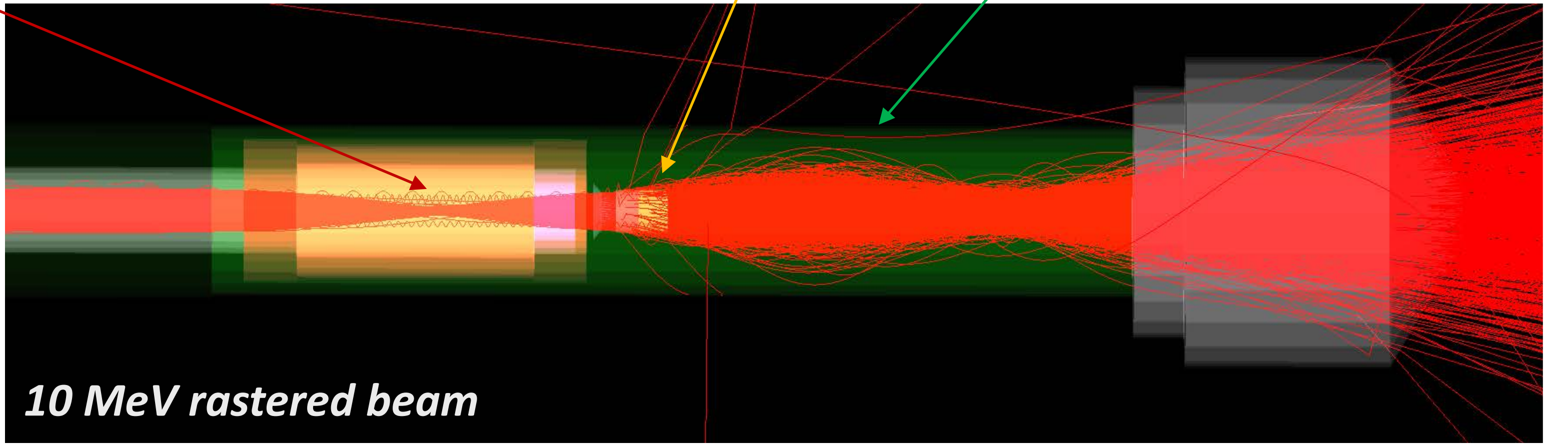


- Find “golden orbit”, beam through IBC and aligned on solenoid magnet field axis
- Set raster pattern, amplitude
- Set aperture dimensions that prevent beam hitting target walls
- Test the target removal process

UITF beam transport through the IBC



- ***10 MeV energy loss ~ same as 10 GeV, but beam optics are VERY DIFFERENT***
- ***solenoid edge focusing creates nodes through IBC***



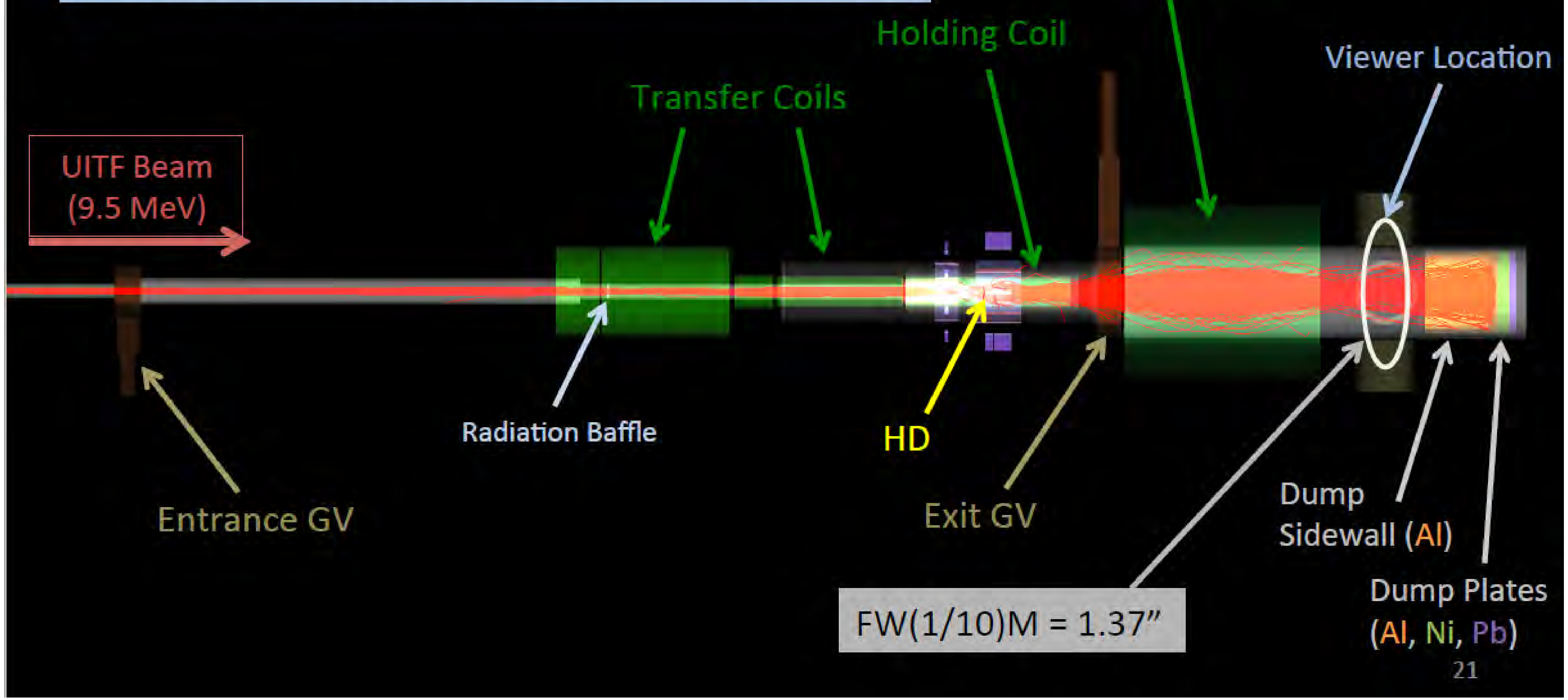
Team HDIce:
G. Dezern, C. Hanretty,
T. Kageya, M.M. Lowry,
A. M. Sandorfi, X. Wei,
T. O'Connell, K. Wei

Thanks for all the slides

HDIce Run1

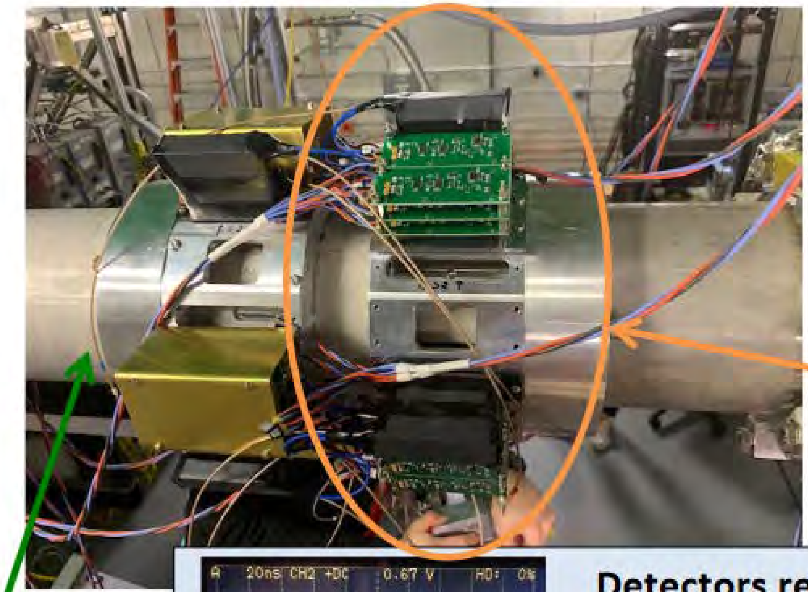
Slide courtesy Team HDIce

Solution:
- Employ a solenoid downstream of IBC with enough B · dl to "corral" and focus beam on a Viewer package.
- Beam Dump shortly after Viewer.
- Solenoid field can also shield HD from backscattering electrons.



Jefferson Lab

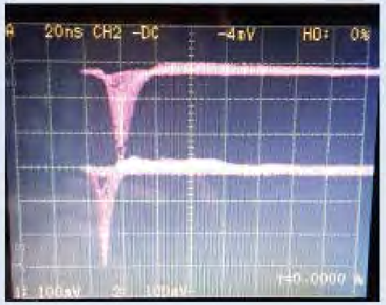
Halo Counter Detectors



IBC Nose

Detectors response to Sr^{90}

E detector
10 ns rise time

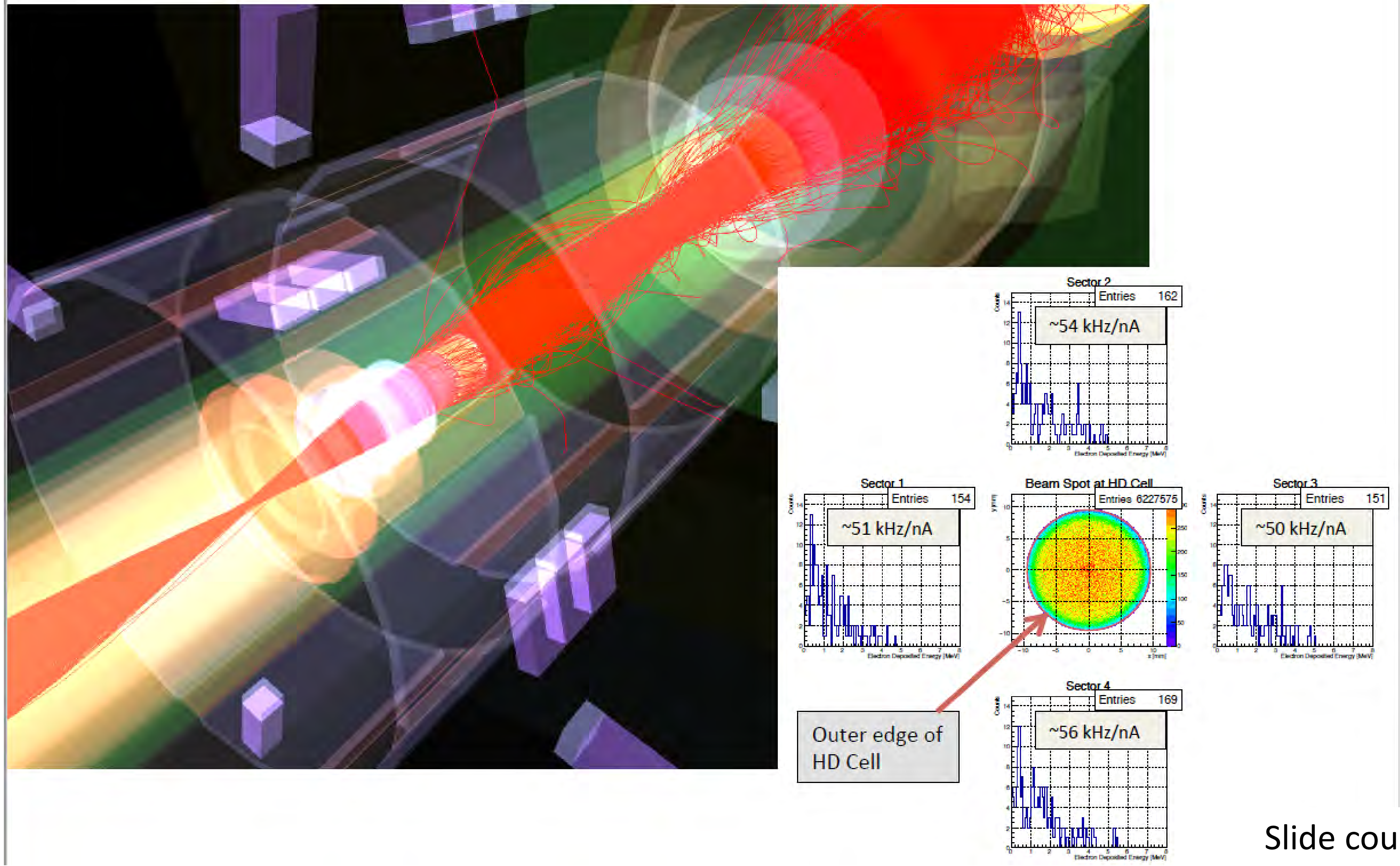


E – dE
coincidence signals

dE detector
8 ns rise time

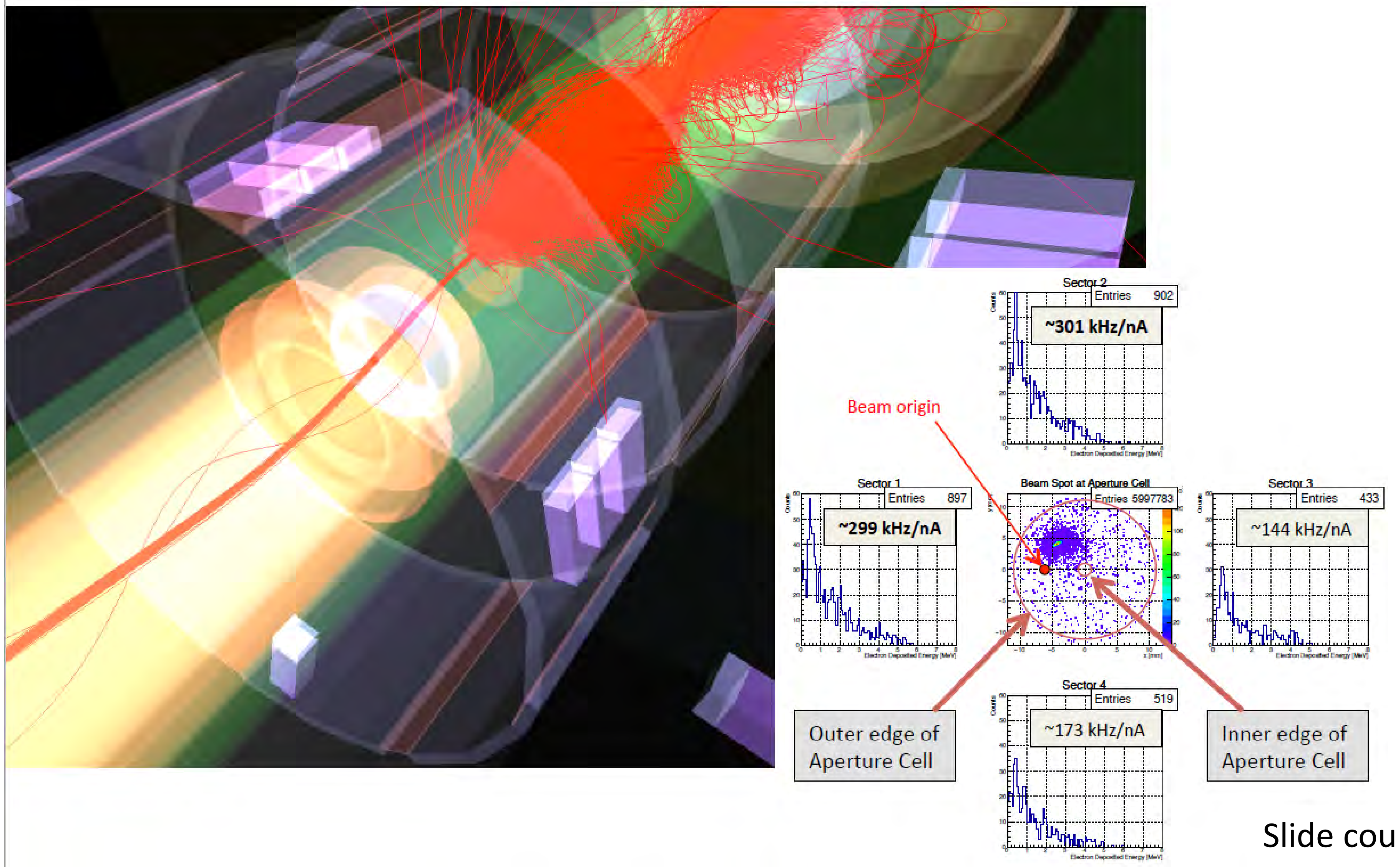
Slide courtesy Team HDIce

HDIce Run1



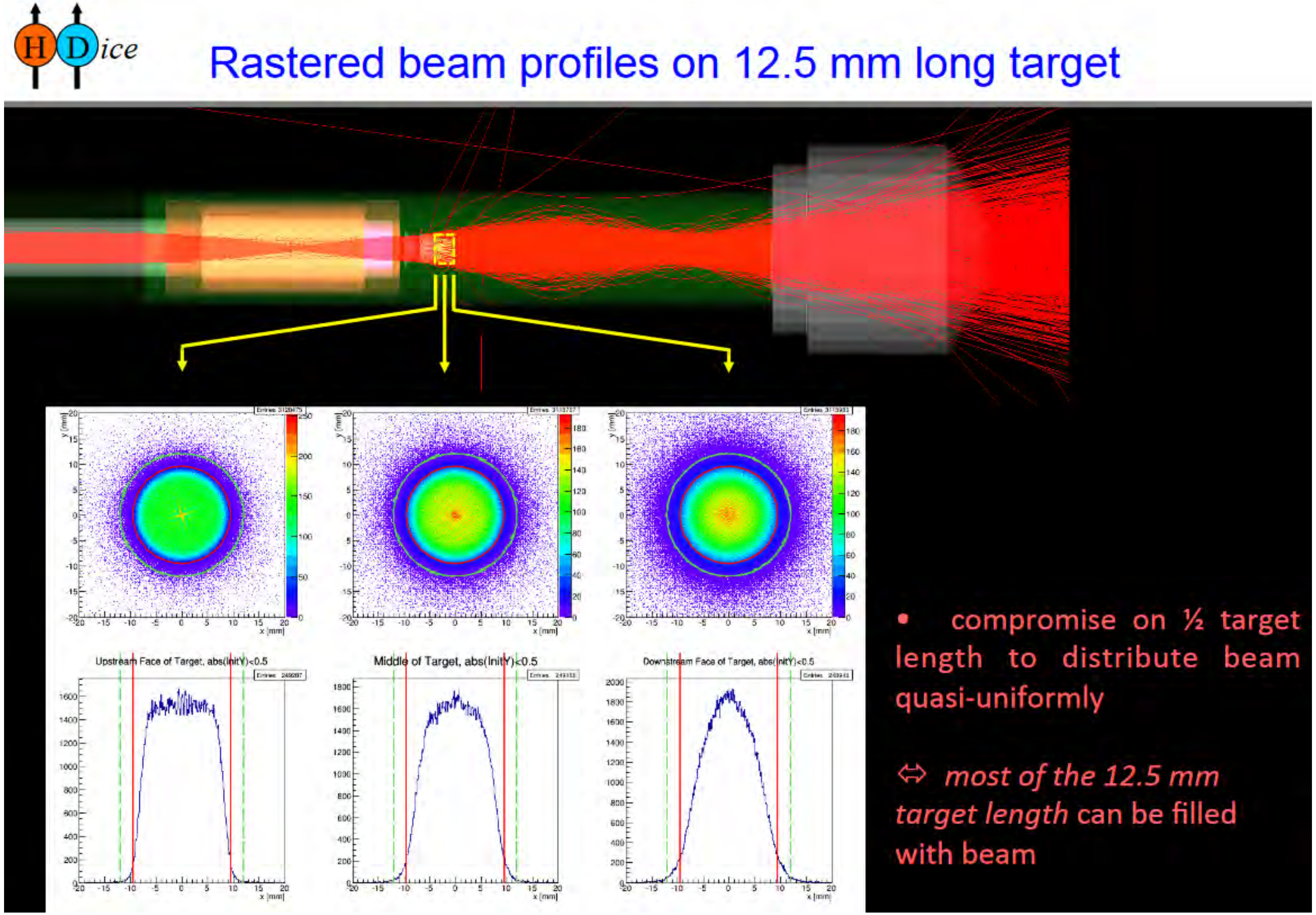
Slide courtesy Team HDIce

HDIce Run1



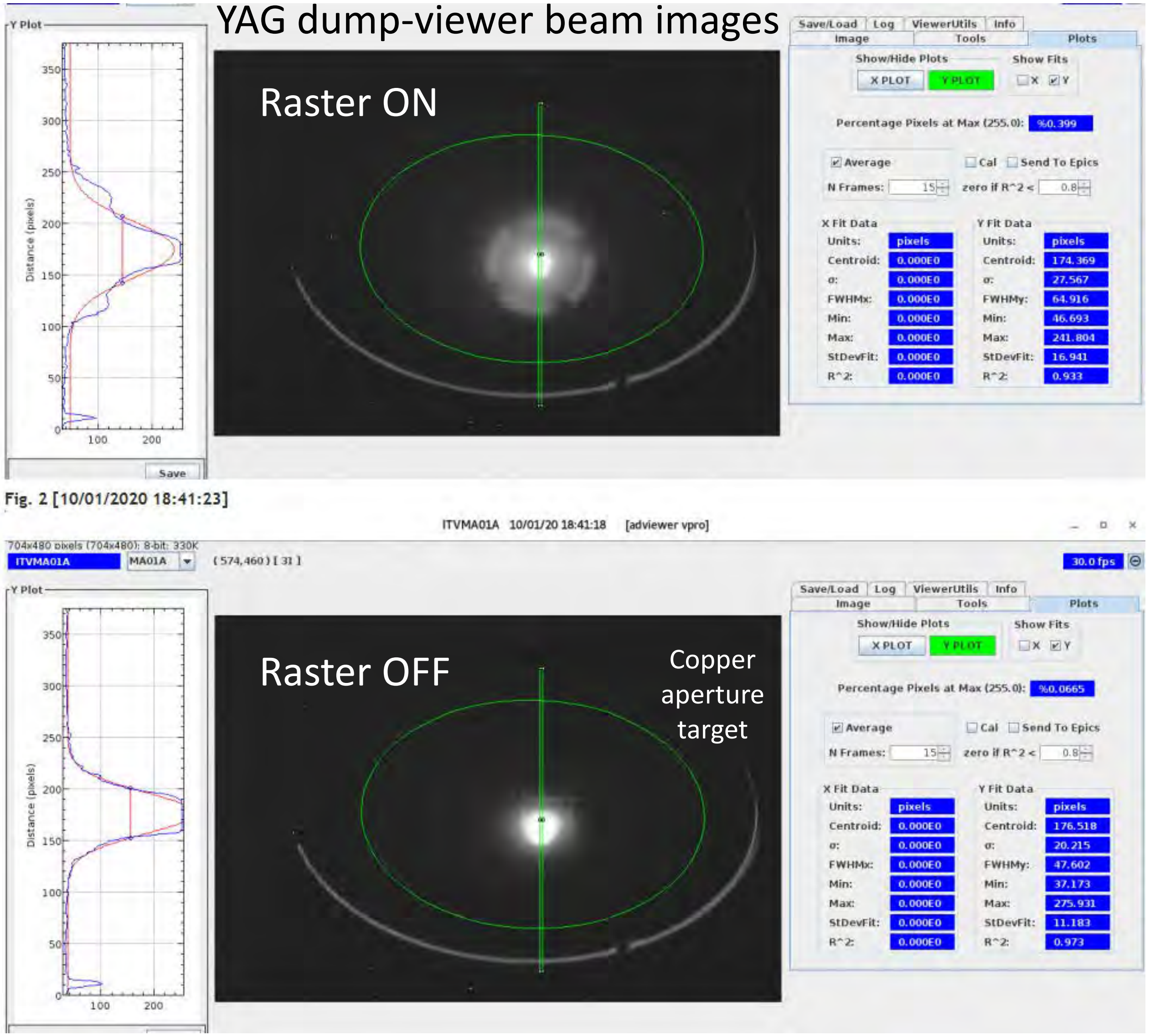
Slide courtesy Team HDIce

The Raster is Important



Slide courtesy Team HDIce

Status of the HDIce program at UITF



- Goal: target remains polarized for 7 straight days with 1.5 nA beam current ✓
- Run0: UITF accelerator commissioning, Aug 2020 ✓
- Run1: HDIce commissioning, Sept 2020 ✓
- Run2: un-polarized target, run starts Oct – Nov 2020 ✓
- Run3: polarized target, run starts Nov-Dec 2020 ✓
- Run4: opportunistic run, it helped to flesh out 2 theses, Mar 2021 ✓

All of this during Covid Lockdown!

Results of HDIce tests

HDice@UITF *Preliminary Summary of Runs 2 & 3 – Jan 06/21*

Slide courtesy Team HDIce

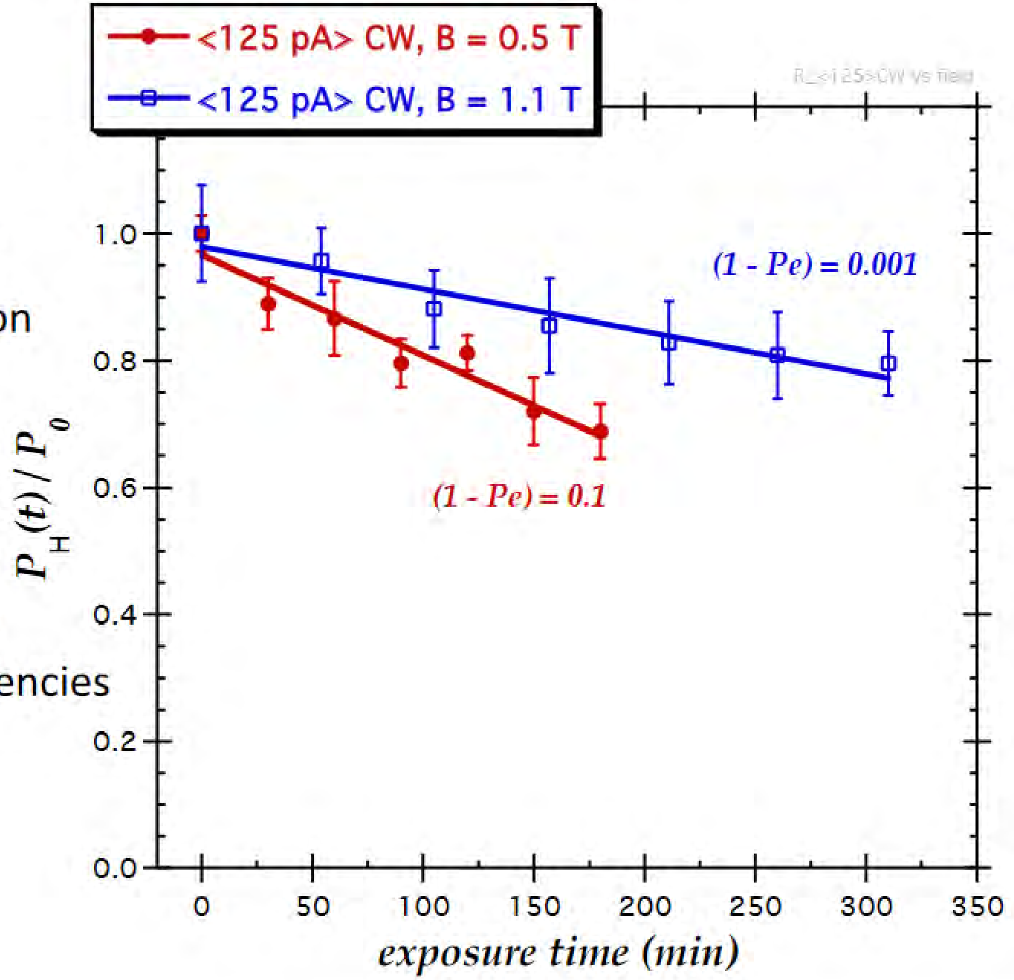
⇔ *the consequence of higher temperatures:*

Run 3, target eHD66:

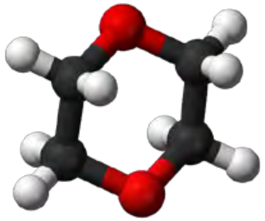
- dP/dt under different holding fields:
  - same current ⇔ same temperature
  - ⇔ different atomic electron polarization
- **High HD temperatures (> 200 mK) result in only partial atomic electron polarization**
  - ⇔ flipping electron spins have Fourier components at the H-Larmor frequencies
  - ⇔ significant dP/dt

ref – intended goal:

at 100 mK & 1.1 T, (1 - Pe) = 5 e-7



Contaminant 1,4-dioxane in wastewater…and in our drinking water



Soluble in water, colorless

HRSD, James River treatment plant
high 1,4 dioxane in landfill leachate

Good idea to remove or degrade 1,4-dioxane

- Widespread use in common products
- A likely human carcinogen
- Does not readily biodegrade in the environment
- Unable to degrade it by the conventional wastewater treatment methods
- Potential USEPA regulation with lower concentration

Sustainable Water Initiative for Tomorrow (SWIFT) at Hampton Roads Sanitation District (HRSD), Virginia.

- Treat wastewater secondary effluent to safe drinking water level
- Supply ground water to address land subsidence, sinking of Chesapeake Bay

Work of Xi Li, Hannes Vennekate, Gigi Ciovati

Electron beam irradiation

- *OH can degrade 1,4-dioxane
- Electron beam irradiation has been shown to be able to degrade many similar compounds

Oxidant Reducers

$$e^- + H_2O \rightarrow \cdot \boldsymbol{OH}(2.7) + e^-_{aq}(2.5) + \cdot H(0.6) + H_2(0.45) + H_2O_2(0.71) + H_3O^+(2.6)$$

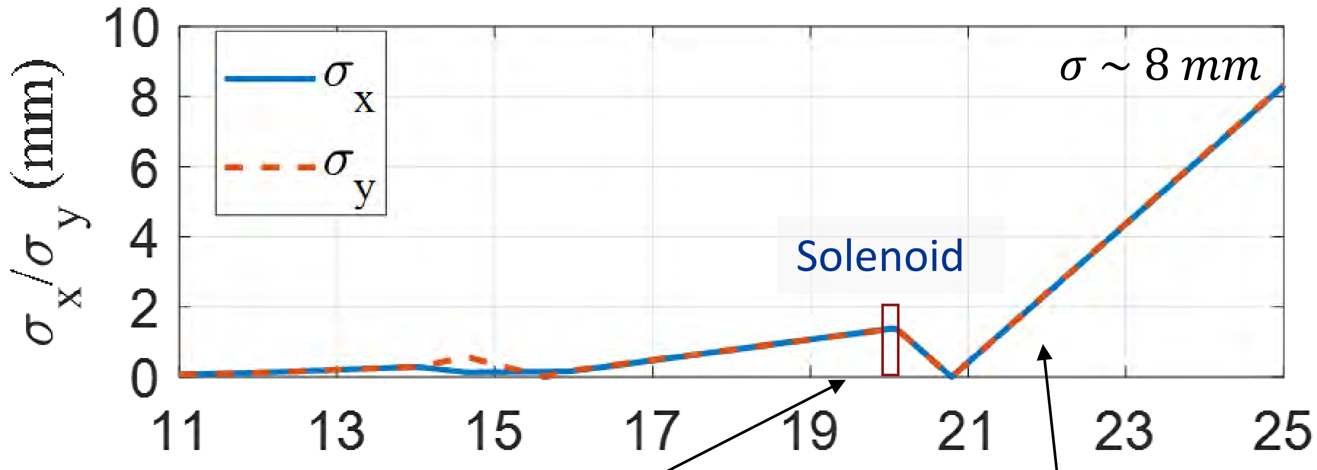
- Remove variety of contaminant compounds
- Safe
- Effective
- Efficient

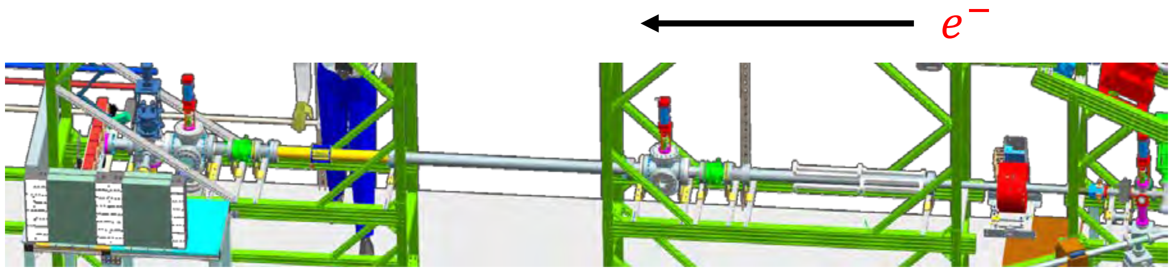
number in brackets is G value : the number of radicals per 100 eV of absorbed energy. It varies with initial concentration of samples and electron beam energy.

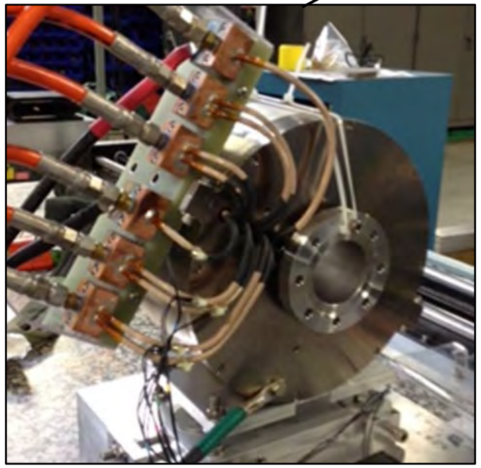
Charles N. Kurucz, et al. Full-scale electron beam treatment of hazardous wastes – effectiveness and costs. 45th Purdue University Industrial Waste Conference Proceedings. Publisher: Lewis Publishers Inc, USA, 1991. DOI: 10.1007/978-1-4615-3392-4_1.

Work of Xi Li, Hannes Vennekate, Gigi Ciovati

Beamline design







Solenoid

Raster

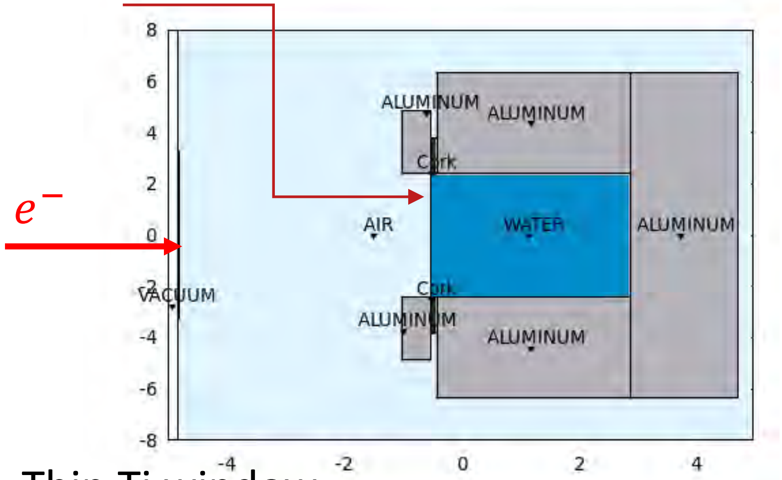
- Solenoid to over-focus the beam and blow it up to $\sigma \sim 8\ to\ 9\ mm$.
- Raster magnets, make a bigger sigma by scanning the beam along horizontal and vertical directions with a circle patternType equation here.

Work of Xi Li

Jefferson Lab

Wastewater sample holder

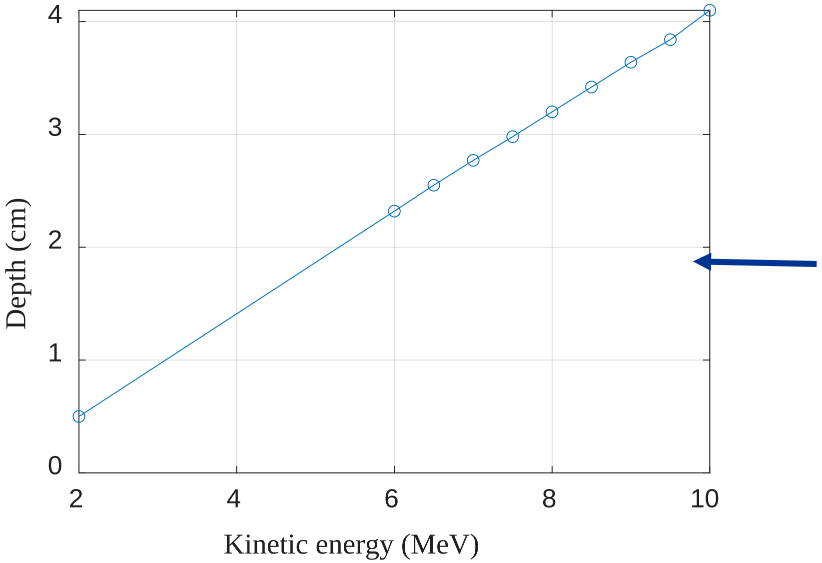
Stainless steel



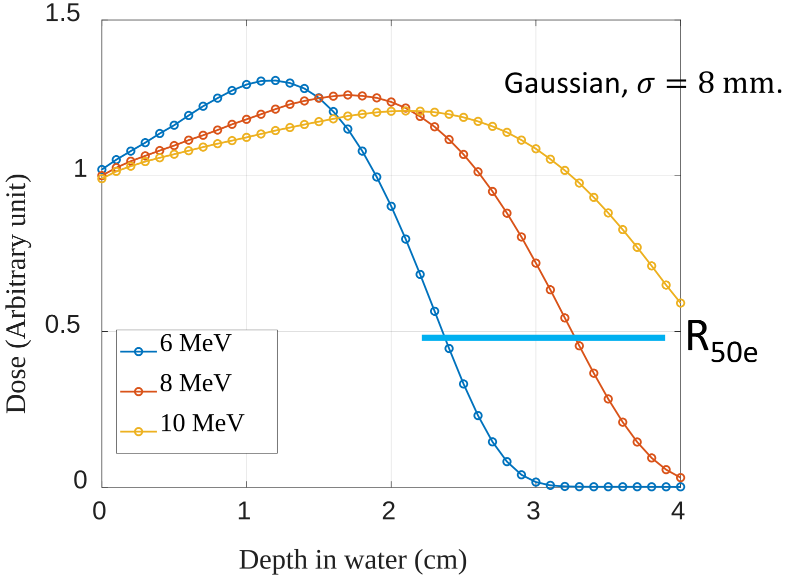
Thin Ti window 0.005”

Ref: fluka.org, fluka.cern.

Depth vs electron energy



Dose distribution



- Designed depth: **3.3** cm.
- Volume: 60 mL.

R_{50e}, The range where the dose is half of the entrance dose.

- Radial diameter: **~ 5** cm. → Beam transverse size

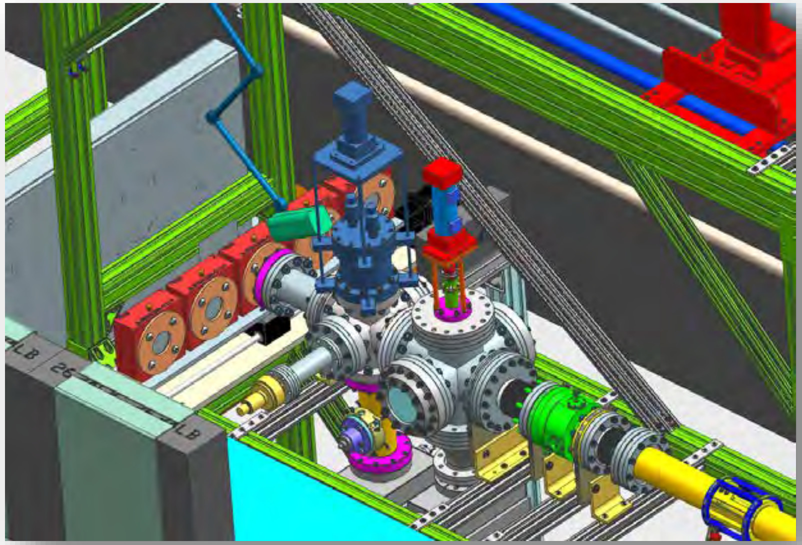
Work of Xi Li, Hannes Vennekate, Gigi Ciovati

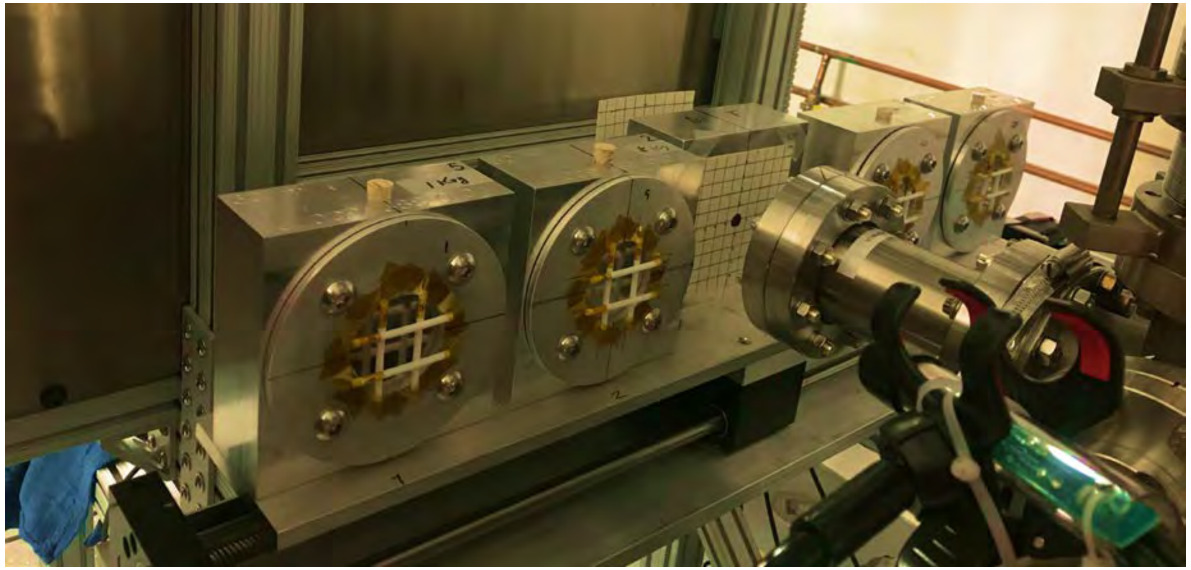
Jefferson Lab

Irradiation at the UITF (summer and fall of 2021)

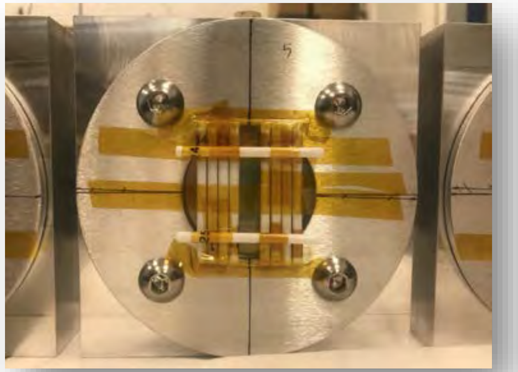
Work of Xi Li, Hannes Vennekate, Gigi Ciovati

- target rail





- target container with ~ 60 mL water
  ↪ opti-chromic rods to verify dose



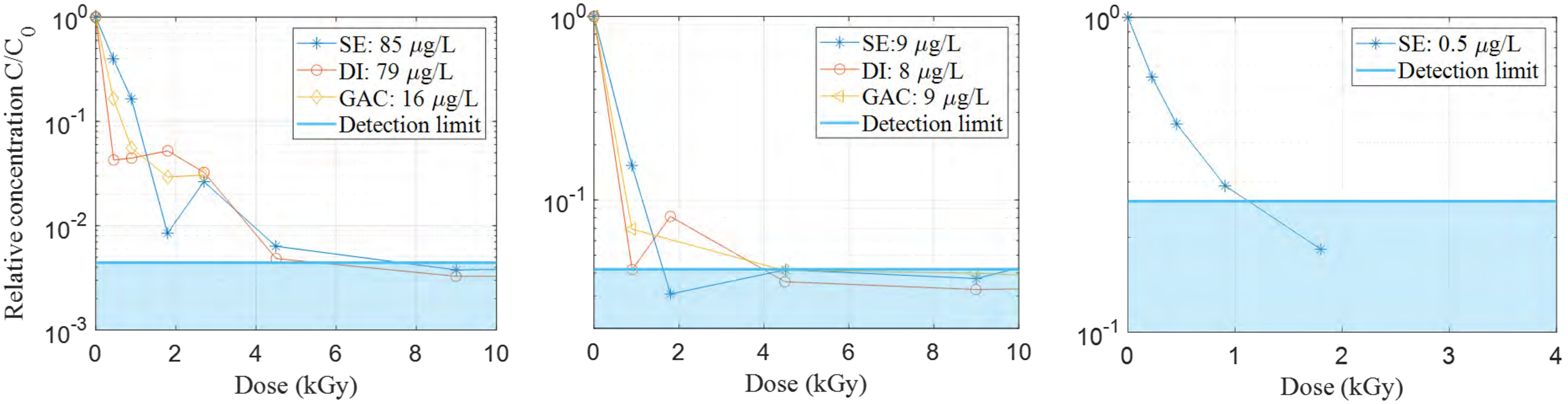
Beam on x-ray screen

Beam on water sample

1,4-dioxane concentration after irradiation

High Initial concentration

Low initial concentration



- Within less than 2 kGy, the 1,4 dioxane concentration decreases by more than 96% (or below the detection limit).

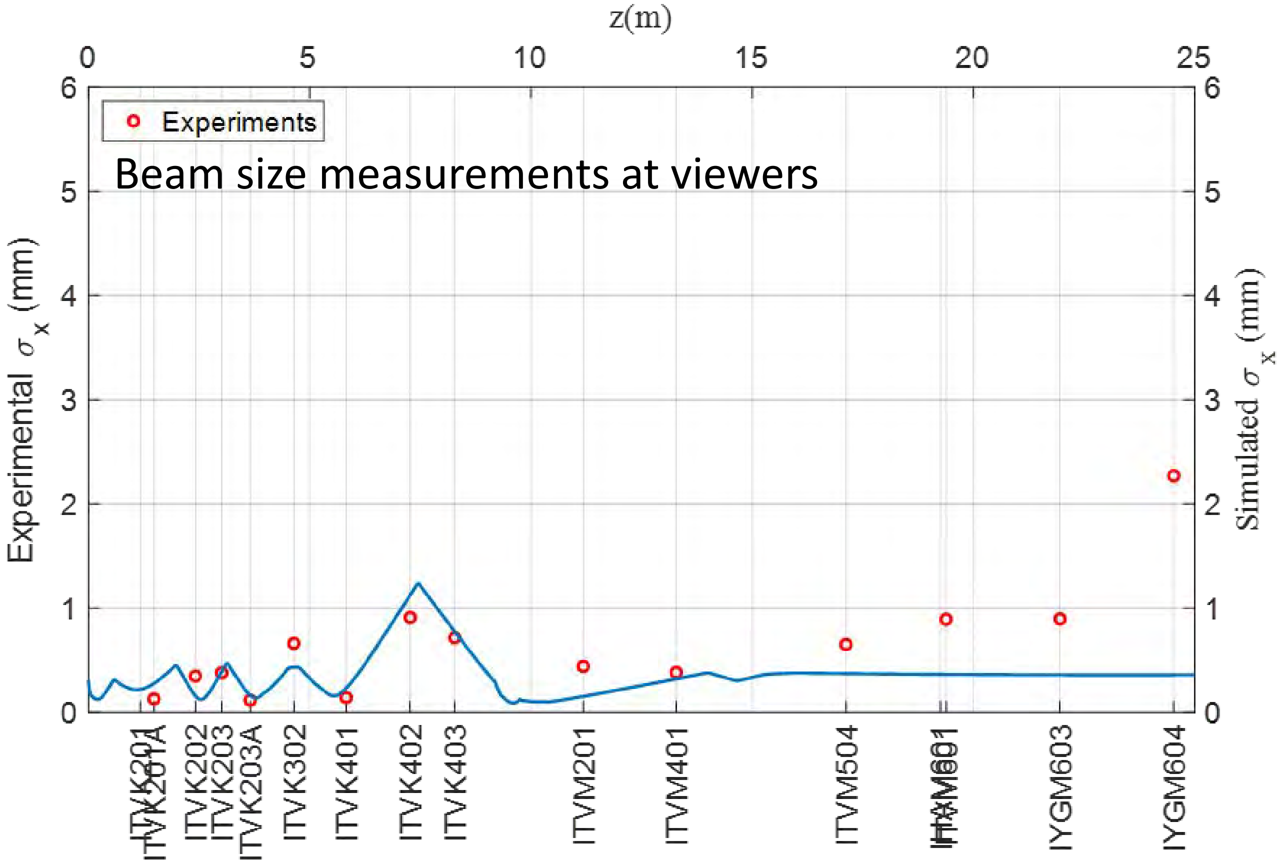
Work of Xi Li, Hannes Vennekate, Gigi Ciovati

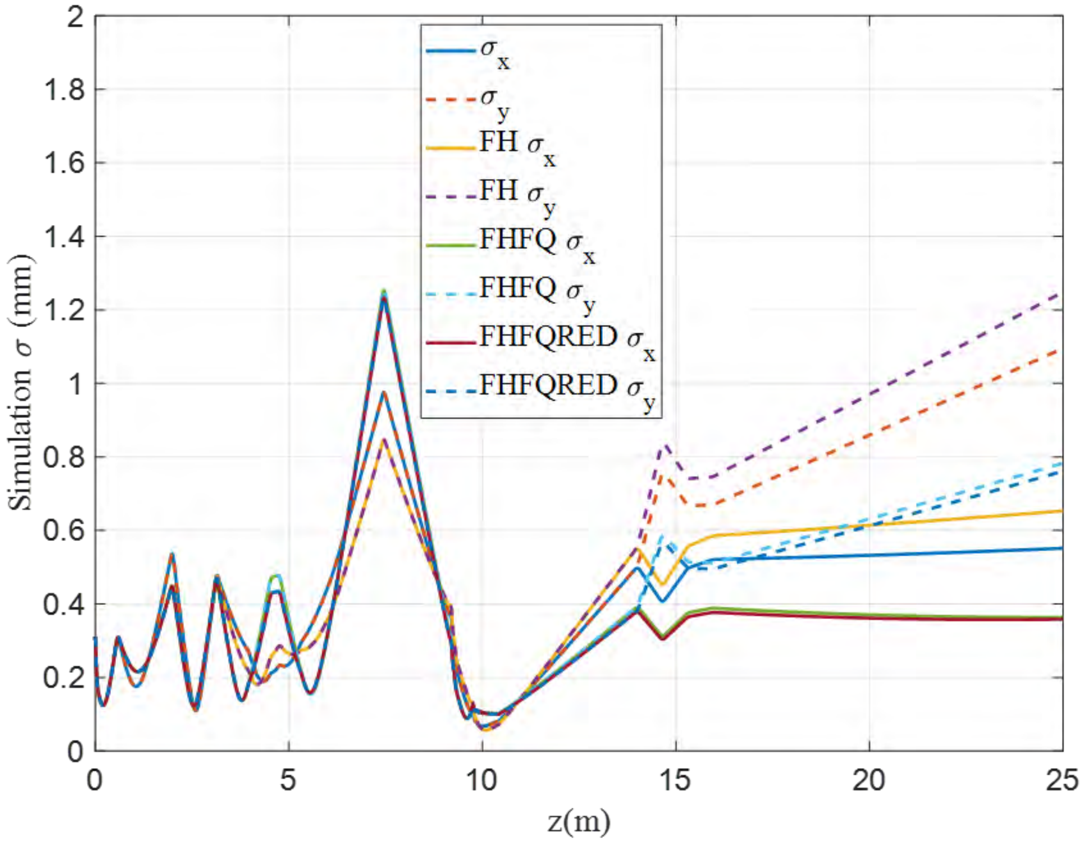
Where are we today?   Beam Studies

Characterizing the booster and the accelerator

- Beam energy capability
- beam deflection
- x/y coupling
- Minimum gun voltage required
- Emittance on either side of booster
- Optics model of machine
- Energy spread
- Jitter (short term, long term drift)

GPT Optics Model

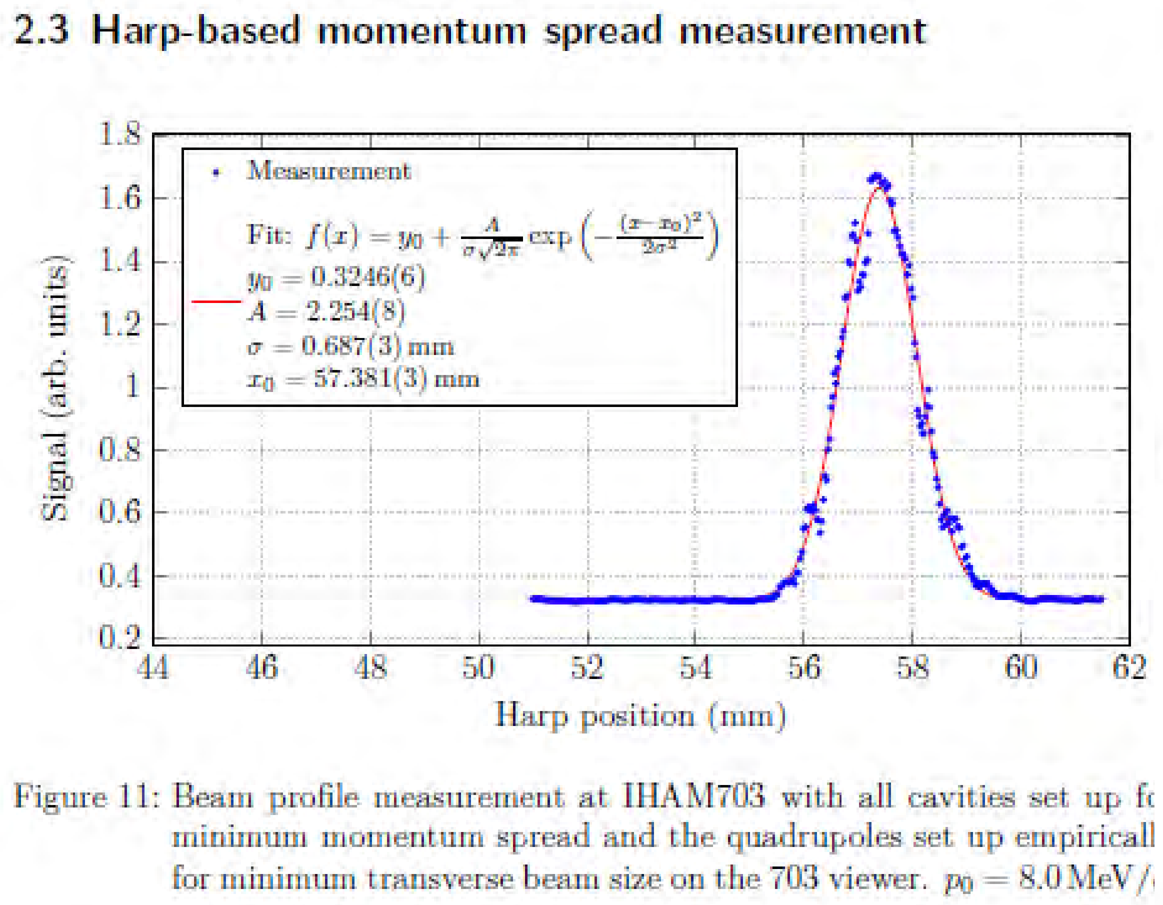




- Discrepancies likely a result of two solenoids at chopper, gun optics uncertainty, booster optics uncertainty
- some subtle effects related to unknown and unintended fields (magnetic materials on beamline?)
- UITF is a great place to “leisurely” validate optics model, which can be a challenging task for soft beams

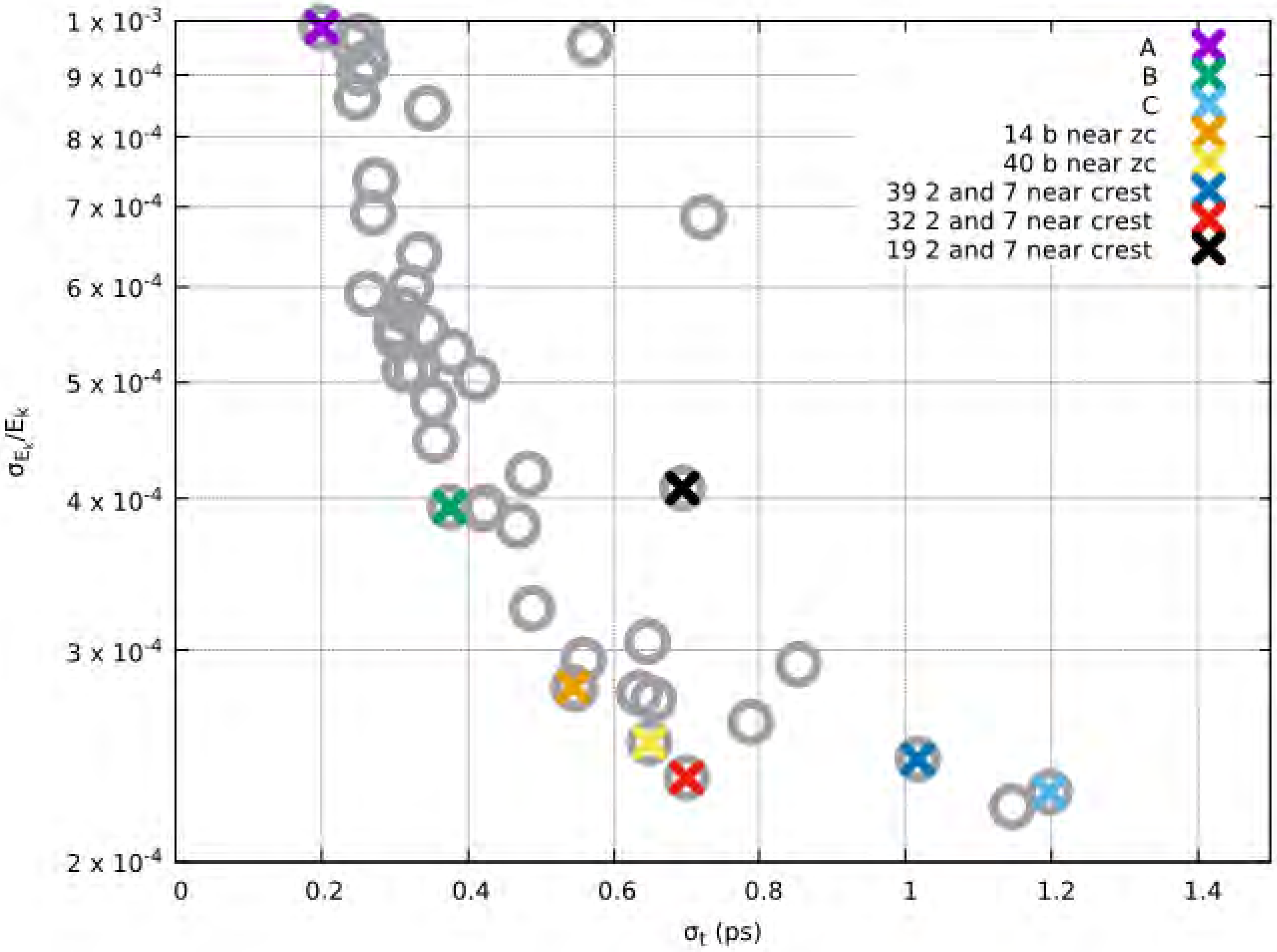
Work of Xi Li

Optics Model



Work of Max Bruker

Work of Alicia Hofler



Various solutions, Optimization via genetic algorithm

Jefferson Lab

Building 58 environment

keV

MeV straight ahead

MeV spectrometer

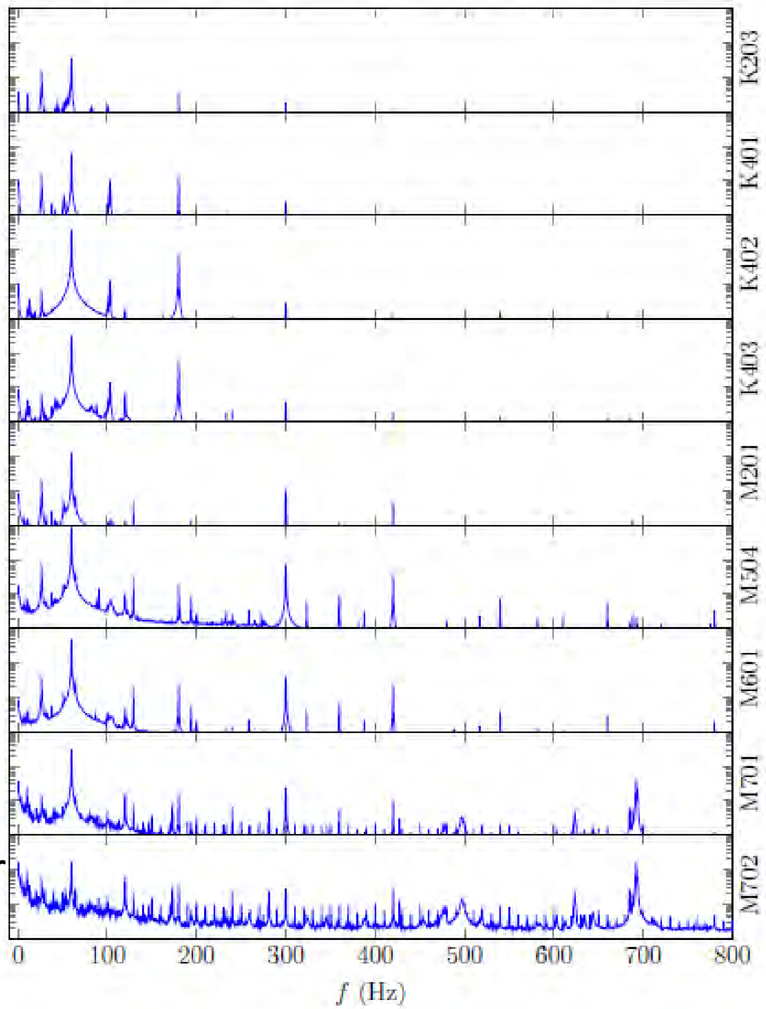


Figure 17: Average spectra of all BPMs going to the M703 dump, all in the same (arbitrary, logarithmic) units. The non-dispersive spectra mostly contain mains harmonics, 27 Hz, and 103 Hz. If the latter are mechanical, it may be interesting to try to damp them away.

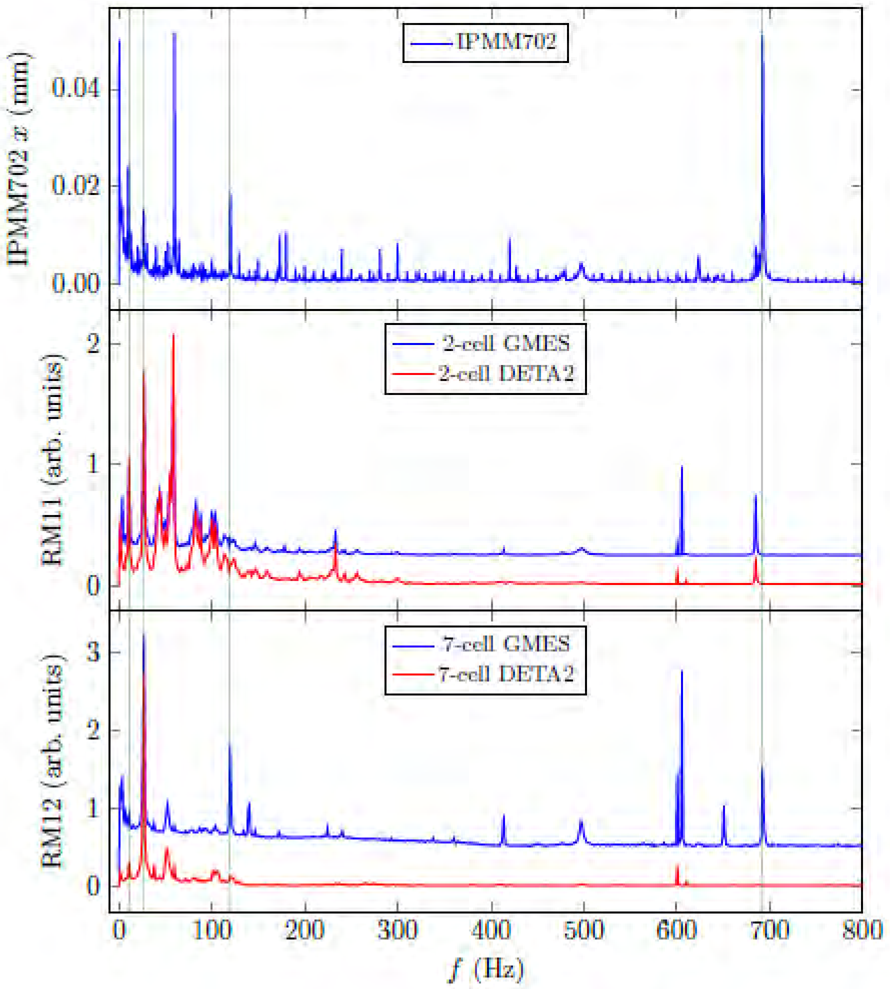


Figure 18: Spectrograms of dispersive BPM, field probes, and detune angles averaged over time; lines are shifted vertically for visibility. The green lines indicating correlation between a dominant peak in the momentum spectrum and one in the cavity spectra are located at 11, 27, 120, and 692 Hz, respectively.

What are the sources of beam modulation?

Inherent design flaws of the cryomodule?

Accelerator above ground in a busy building and noisy environment

Work of Max Bruker

Building 58 environment

jitter

drift

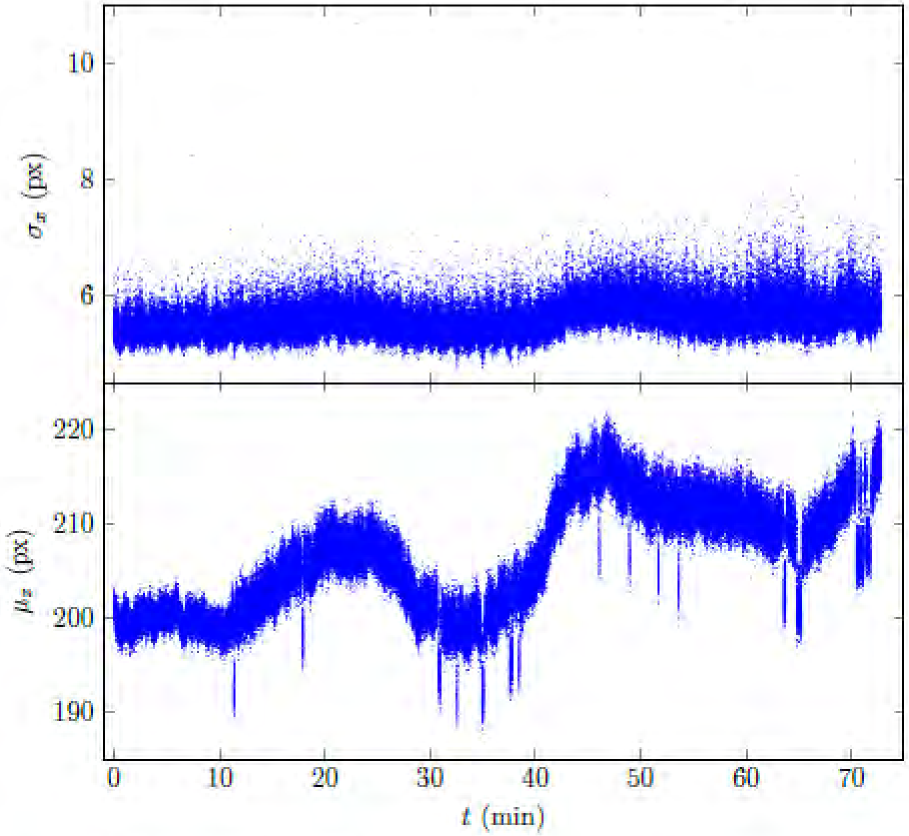
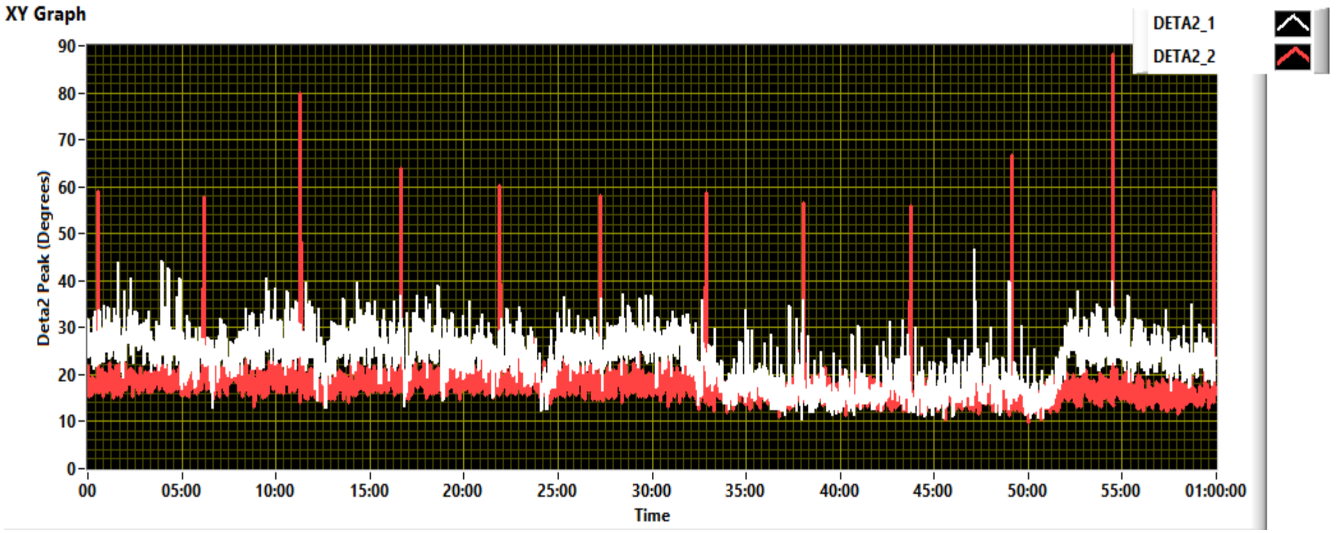


Figure 15: Evaluation of the one-hour-long movie of the M703 viewer (131 149 images in total at 30 Hz frame rate). The central position (bottom plot) shows three features: long-term drift, short-term excursions (about 10 s each), and rapid fluctuations that look like noise but are actually concentrated at sharply peaked frequencies, see Fig. 16. These data were recorded on 11/10/2021 starting at 8 p.m.

Work of Max Bruker



Typical peak-to-peak DETA2 data for one second intervals for 2-cell (white) and 7-cell (red), over a 1 hour period

Periodic “disturbance” every ~ 5 minutes

Work of Tom Powers and Peter Owen

Limitations of UITF

- Building 58 is busy and “noisy”, the accelerator is above ground
- No temperature stabilization means energy drifts
- Radiation shielding presently limits average beam current to just 100nA at 10 MeV. We can augment the shielding, and we can implement a beam loss accounting system similar to systems employed at other accelerators – but this would require rigorous design and review because it would be considered Personnel Safety equipment
- The Cryogenic Test Facility LHe refrigerator has limited capacity. LHe is shared between UITF and the Cryomodule Test Facility which is a busy place, testing cryomodules for CEBAF, SNS and LCLS2. 6 months of UITF accelerator operations would be a good year

- One more MeV beam run in 2022, then the booster gets moved to CEBAF
- Another CM installed at UITF?

What else can we do at UITF?

	Application	Beam Energy	Beam Current	Experiment Duration	Notes	Presenter
✓	Commission QCM for CEBAF	6 MeV, but prefer up to 10 MeV	up to 100 uA	three or four 1-week long tests	tests complete before long shutdown of 2020, when QCM to be installed at CEBAF	R. Kazimi
✓	Commission HDIce for CEBAF	~ 8 MeV	up to 100 nA for tuning, 0.25 to 5 nA for production	four or five run periods, one-month long each	target provides transverse polarization required for 3 A-rated Hall B experiments	A. Sandorfi
	Manufacturing polarized targets for CEBAF via DNP	10 to 18 MeV	1 to 10 uA	hours, days	likely some R&D to determine optimum polarizing conditions	C. Keith
	Bubble Chamber astrophysics	4 - 10 MeV	0.01 to 100 uA	3 weeks, ~ 3 runs/year	UITF better location than CEBAF injector, when CEBAF shutdowns are short	R. Suleiman
	MeV parity violation experiment	10 MeV	milliamps preferred, will reduce experiment duration	months to years	requires polarized electron beam, transmission geometry offers advantages	R. Carlini
	Testing Nb_3Sn-coated cavities	determining the beam energy of test cavity is point of test	up to 100 uA	as many tests as possible	Nb3Sn cavities require only 4K Helium	G. Eremeev
✓	Wastewater treatment	2- 10 MeV	100 uA	imagine week-long test durations over three years	together with local partners	G. Ciovati
	Polarized positron source	5 - 10 MeV	up to 100 uA	staged tests, likely many required, 1-week long duration	requires polarized electron beam	J. Grames
	EIC: fast kicker tests	5 - 10 MeV	up to 100 uA	two 1-week long tests	together with sbir-partner	H. Wang
	EIC: testing high bunch charge	5 - 10 MeV	up to 100 uA	two 1-week long tests	requires polarized electron beam	J. Grames and J. Guo

Thanks to

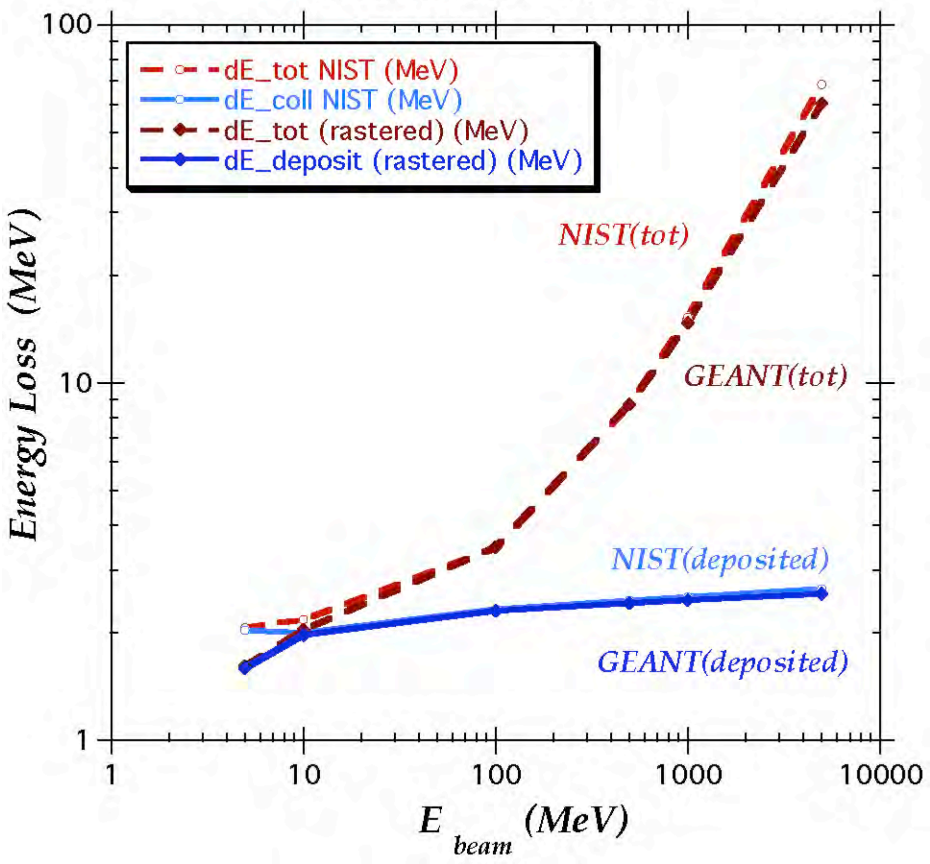
- Yan Wang, Max Bruker and Mike McCaughan who commissioned the accelerator and staffed the control room during the experiments
- John Hansknecht, Joe Grames, Carlos Hernandez-Garcia, Don Bullard, Phil Adderley and Marcy Stutzman (Phil and Marcy put nearly the entire beamline together)
- Shaun Gregory who designed everything
- Tom Renzo who shepherded construction
- Scott Higgins who coordinated all software
- DC Power and the I&C groups
- Neil Wilson, Ricky Taylor and Bern Johnson for rigging support
- Tomasz Plawski and Rama Bachimanchi for LLRF support
- Bob May and Harry Fanning for guidance related to administrative approvals
- Radiation Control Group
- Team HDIce, especially Andy Sandorfi, Xiangdong Wei and Charles Hanretty
- Team Water, Gigi Ciovati, Hannes Vennekate, Xi Li
- Many others…..

UITF is a 10 MeV spin-polarized electron accelerator

the UITF accelerator is built, ready to use….

testing polarized $\vec{H}D$ at low energies

Electron energy loss in 5 cm of HD:



⇦ loss dominated by bremsstrahlung

- deposition dominated by Møllers
  $\sigma_{Møller} \sim (1 + 1/\gamma)^2$
  ~ independent of beam energy

⇦ deposition: 2 Mev/e$^-$ = 2 mW/ nA
  ~ independent of beam energy

⇨ **10 MeV beams will test the HD performance at 10 GeV !**