Testing Frozen-Spin HD with electrons at Jefferson Lab

- status update -

Xiangdong Wei

Jefferson Lab

09/23/2019-09/27/2019

Collaborators

***JLab - HDice Group**:*

G. Dezern, C. Hanretty, T. Kageya, M.M. Lowry, A. M. Sandorfi, and **X. Wei**

***JLab - Injection Group*:**

J. Grames, S. Gregory, M. Poelker

***University of Connecticut**:*

T. O'Connell, K. Wei

Universita di Ferrara and INFN di Ferrara:

L. Barion, M. Contalbrigo

Universita di Roma "Tor Vergata" and INFN-Sezione di Roma2:

A. D'Angelo

$e+\vec{H}\vec{D}$ studies at the UITF – a prelude to $e+\vec{H}_{transverse}$

- $\vec{H}\vec{D}$ lifetimes with photon beams ~ 2 years :
  - PRL **102** (2009) 172002; PRL **118** (2017) 242002; …
  - NIM A**737** (2014) 107; NIM A**815** (2016) 31; …
- next goal – viable transverse frozen-spin target with electron beams
- electron *experiments with transverse polarization :*

	PAC 39		PAC 41
	rating	decision	impact
◊ SIDIS, C12-11-111, Contalbrigo,…	A	C1	✪
◊ dihadron production, PR12-12-009, Avakian,…	A	C1	✪
◊ DVCS, PR12-12-101, Elouadrhiri,…	A	C1	✪

C1 ⇨ successful demonstration of viable performance in an eHD test

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

- challenge: transverse holding fields bend electrons into the detector !
- mitigation: small B•dL ⇔ **frozen-spin HD**

$e+\vec{H}D$ depolarization mechanisms

Mechanisms for beam-induced depolarization:

I. beam-heating

- *heat ➤ reduce T1s of HD*
- *solution: keep HD cold to stay in frozen-spin mode*
  - ⇔ *new target cells to optimize the cooling*
  - ⇔ *new fast raster to minimize the dwell time*

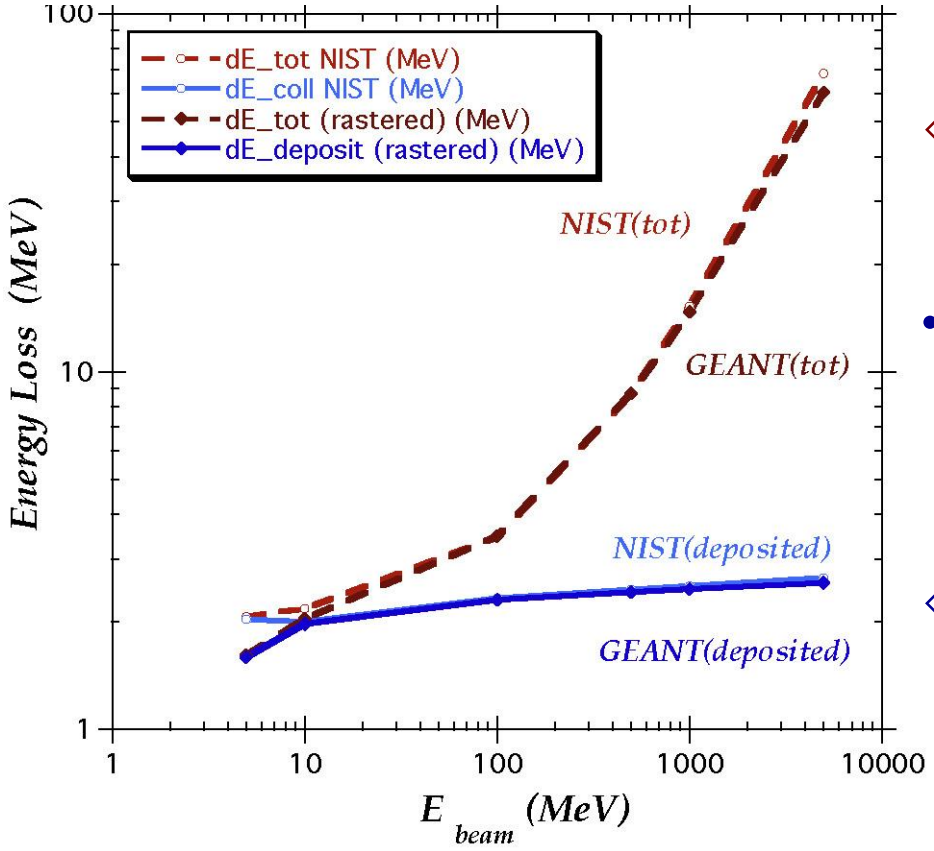
II. Hyperfine mixing

- $\vec{\mu}$(e) opposite to $\vec{\mu}$(p) ➤ *polarized electrons mix and dilute H polarization*
- *solution: flip H spin against field, so that e and H polarizations are parallel*

III. Radiation damage

- *beam ionization ➤ chemical changes that could bring HD out of frozen-spin state*
- *expected to be temperature dependent ⇔ needs detailed study*

Electron energy loss in 5 cm of HD:



⇦ loss dominated by bremsstrahlung

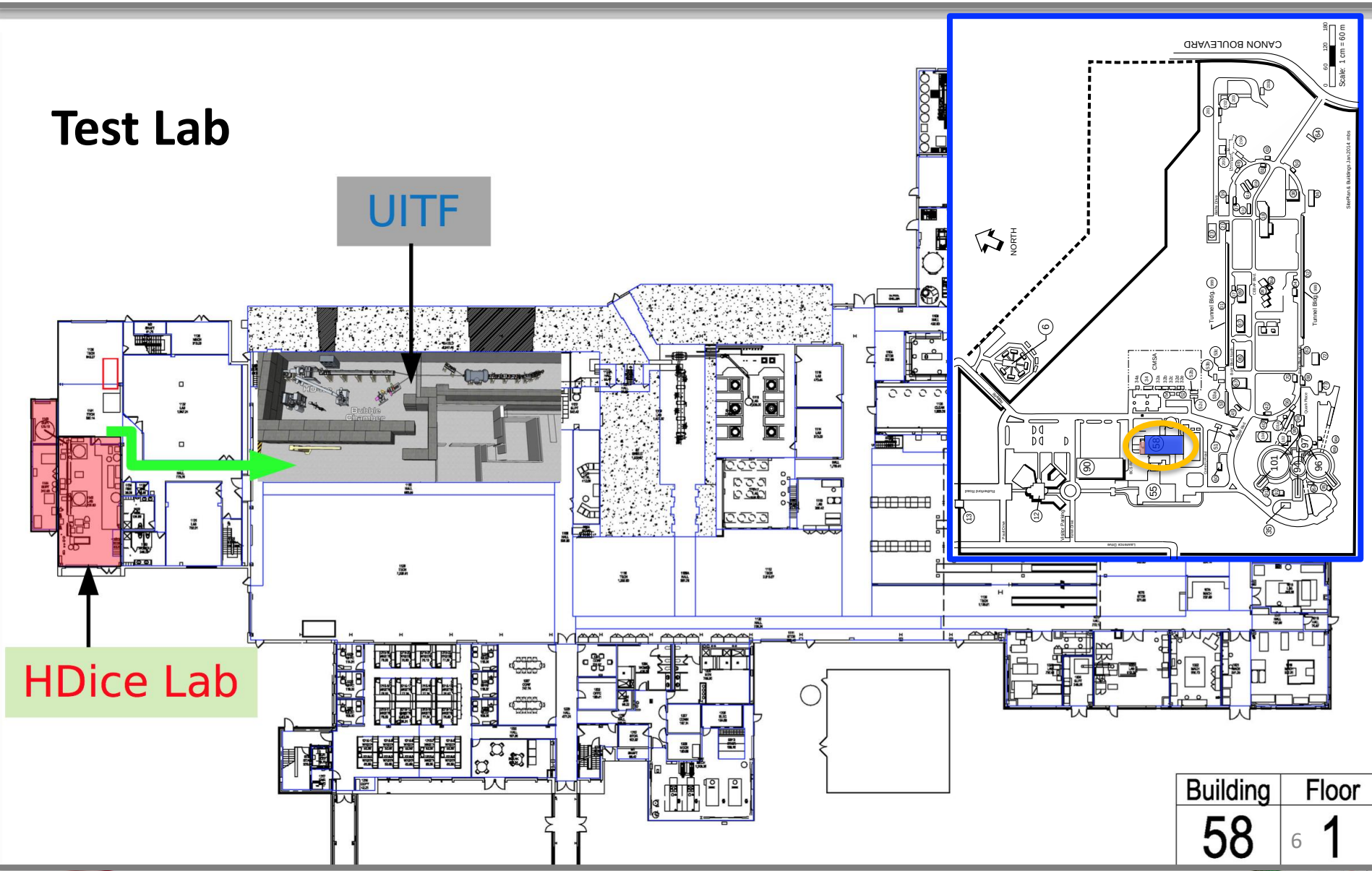
- deposition dominated by Møllers
  $\sigma_{Møller} \sim (1 + 1/\gamma)^2$
  ~ independent of beam energy

⇦ deposition: 2 Mev/e⁻ = 1 mW/½ nA
  ~ independent of beam energy

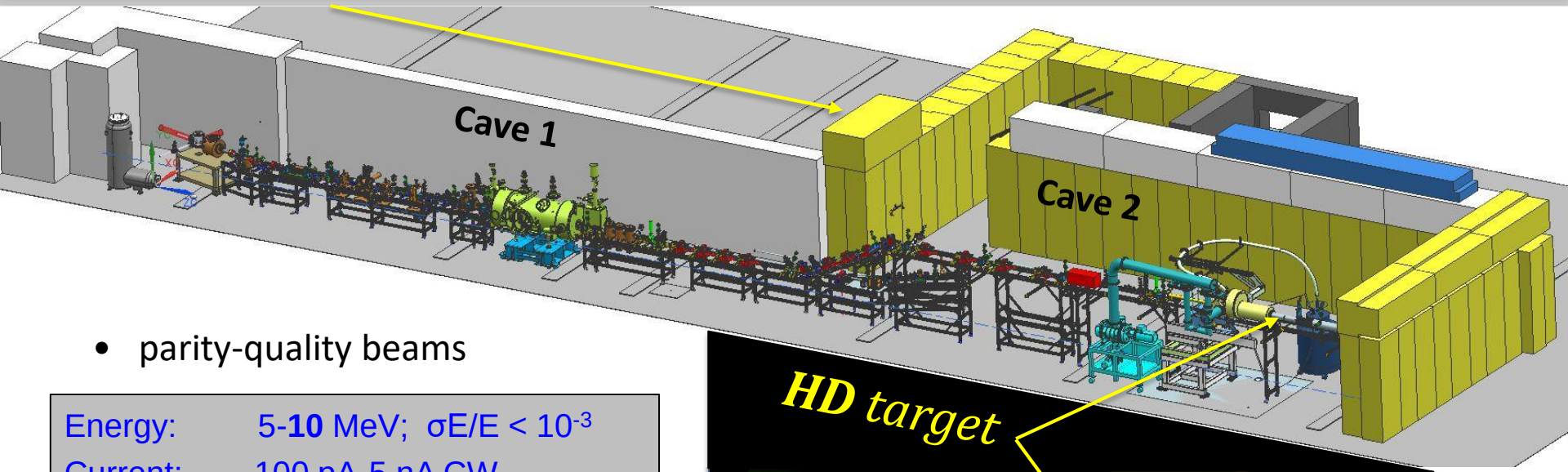
⇨ **10 MeV beams will test the HD performance at 10 GeV !**

Upgraded Injector Test Facility (UITF)

Test Lab

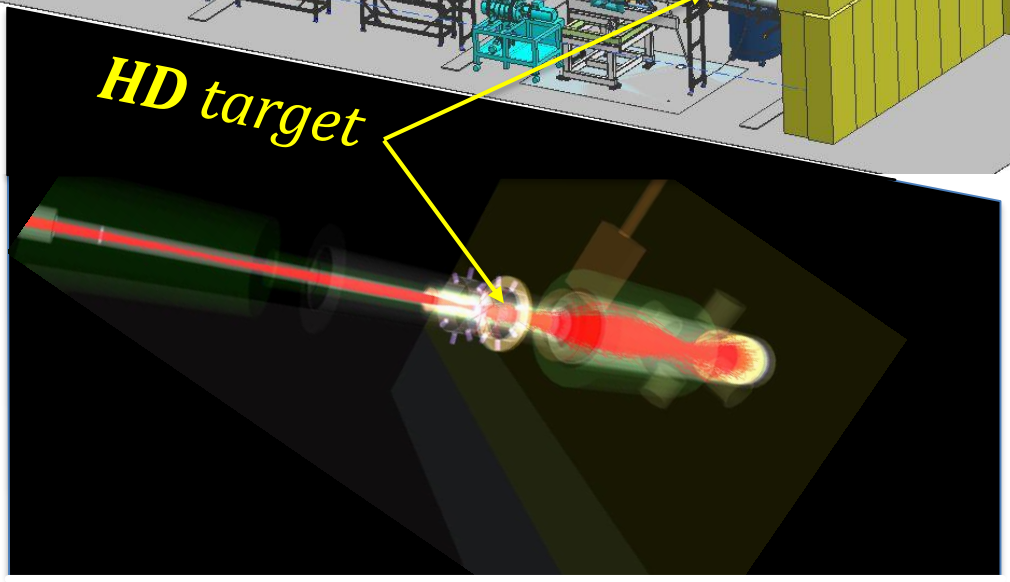


*U*pgraded *I*njector *T*est *F*acility (UITF)



- parity-quality beams

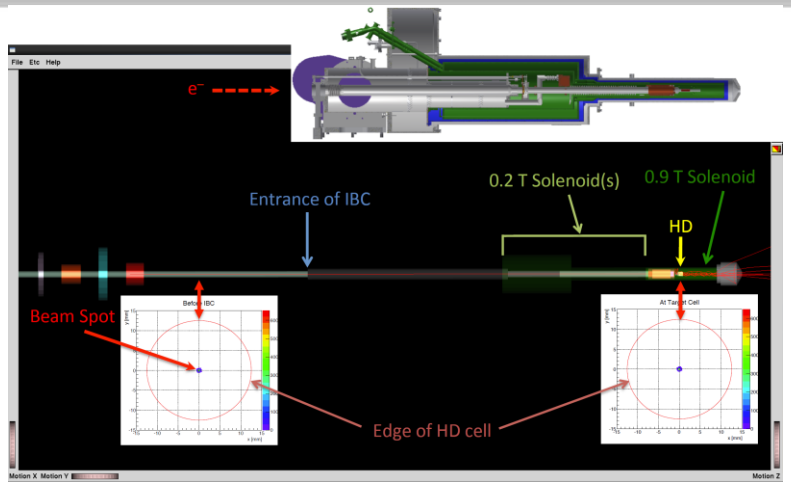
Energy:	5-**10** MeV; $\sigma E/E < 10^{-3}$
Current:	100 pA-5 nA CW
	100 nA Tune-mode
Size:	50 μm < $\sigma_{x,y}$ < 150 μm
Stability:	within $\sigma_{x,y}$
Beam Halo:	< 10^{-4}
Polarization:	> 70%
Helicity flip:	1-30 Hz

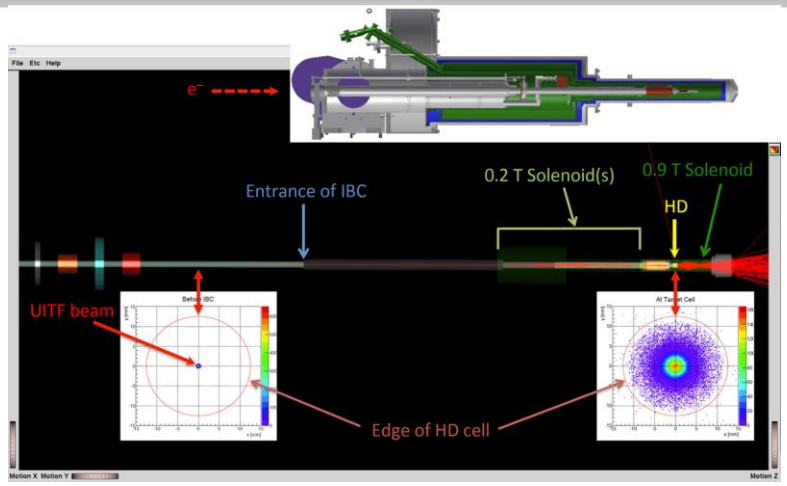


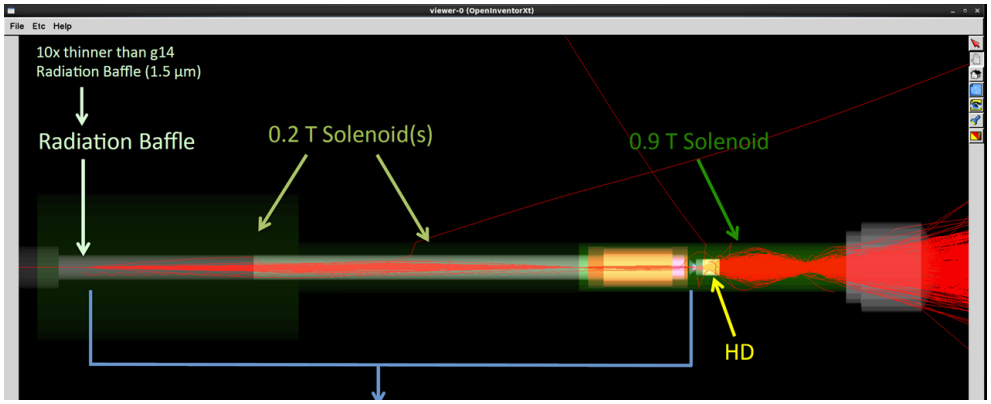
⇔ qualify CEBAF injector components

⇔ study HD characteristics with 10 MeV electrons

Tuning Beam Spot inside IBC



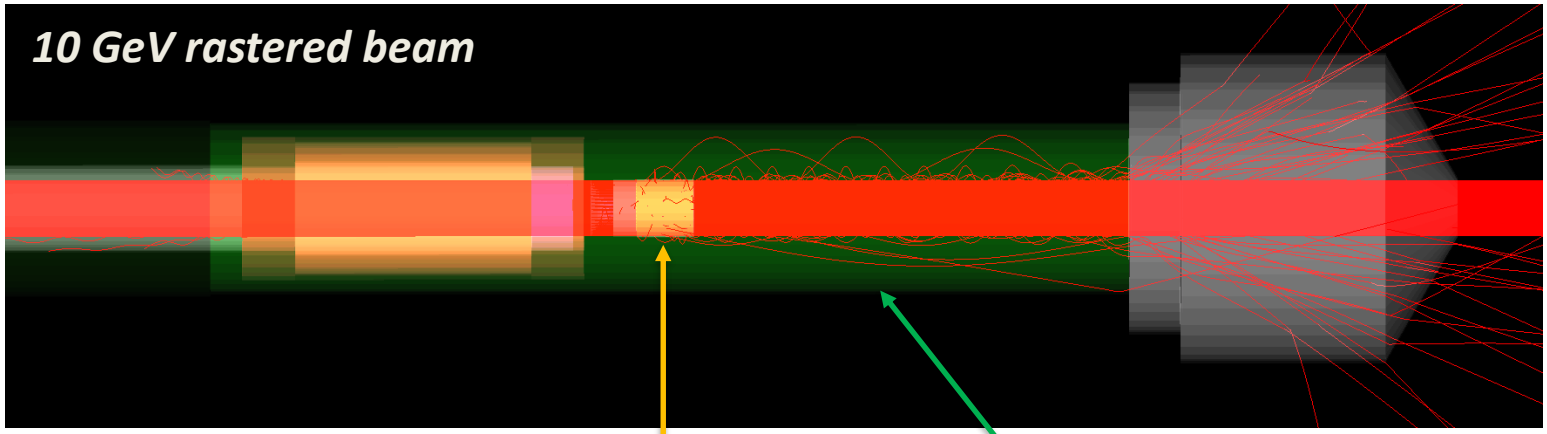




- solenoid fields focus at 10 MeV <=> energy tuned to place node at the HD surface.
  => possible to tune the beam energy and/or solenoid field to expose HD target uniformly.

X. Wei

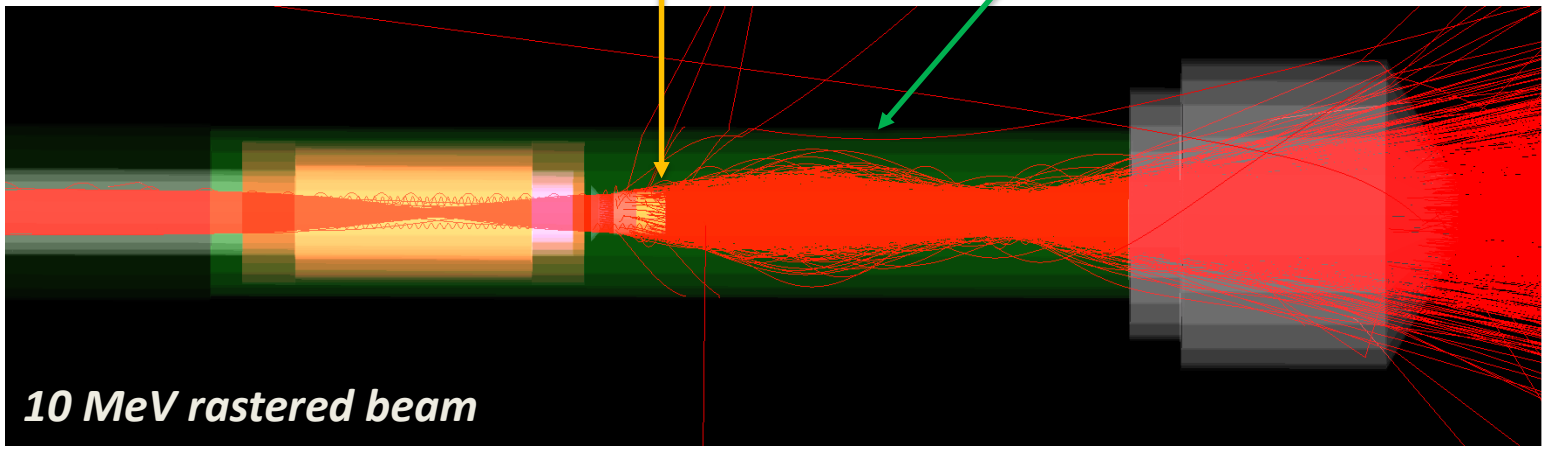
UITF beam transport through the IBC



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

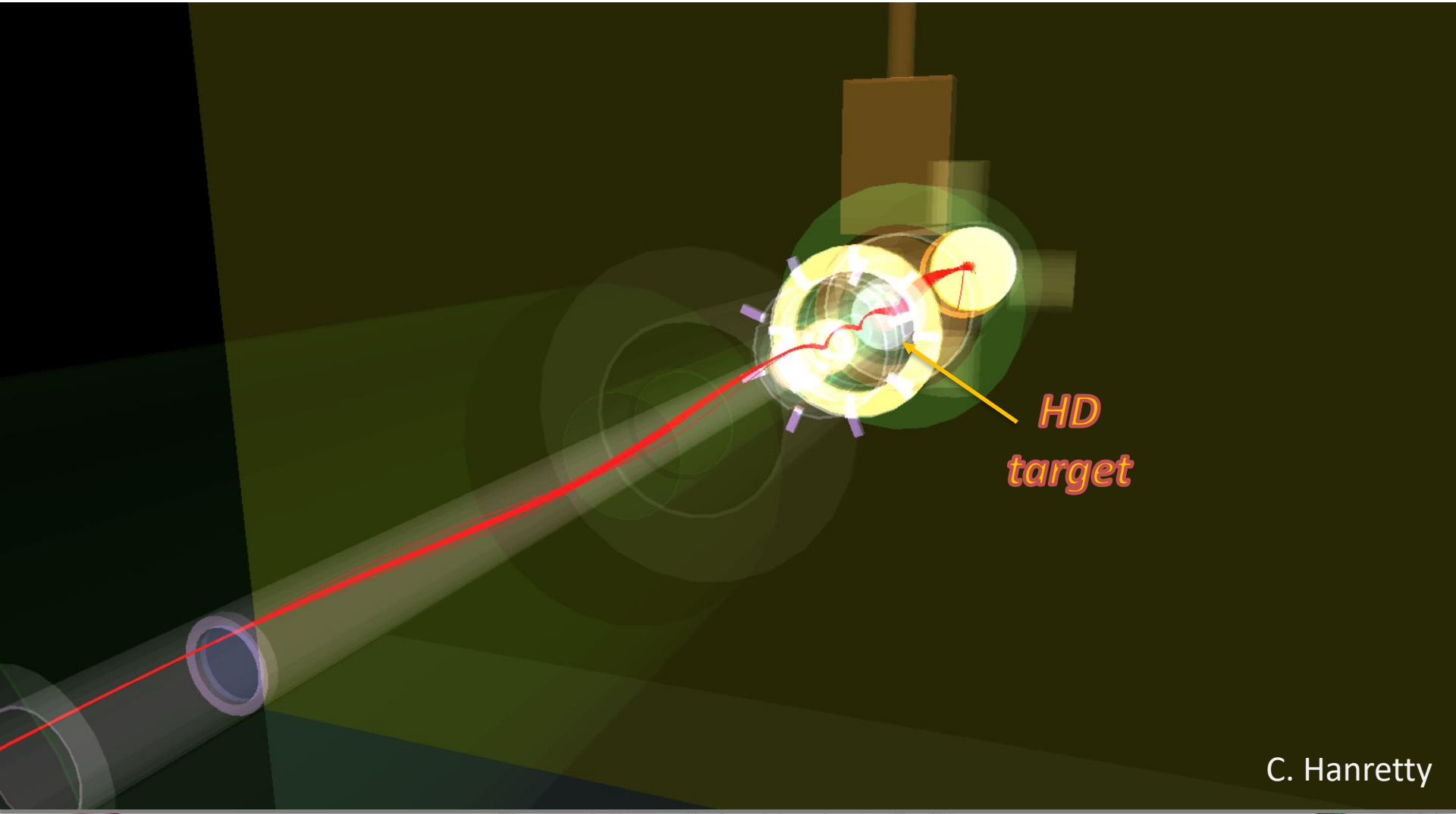
HD target

target solenoid



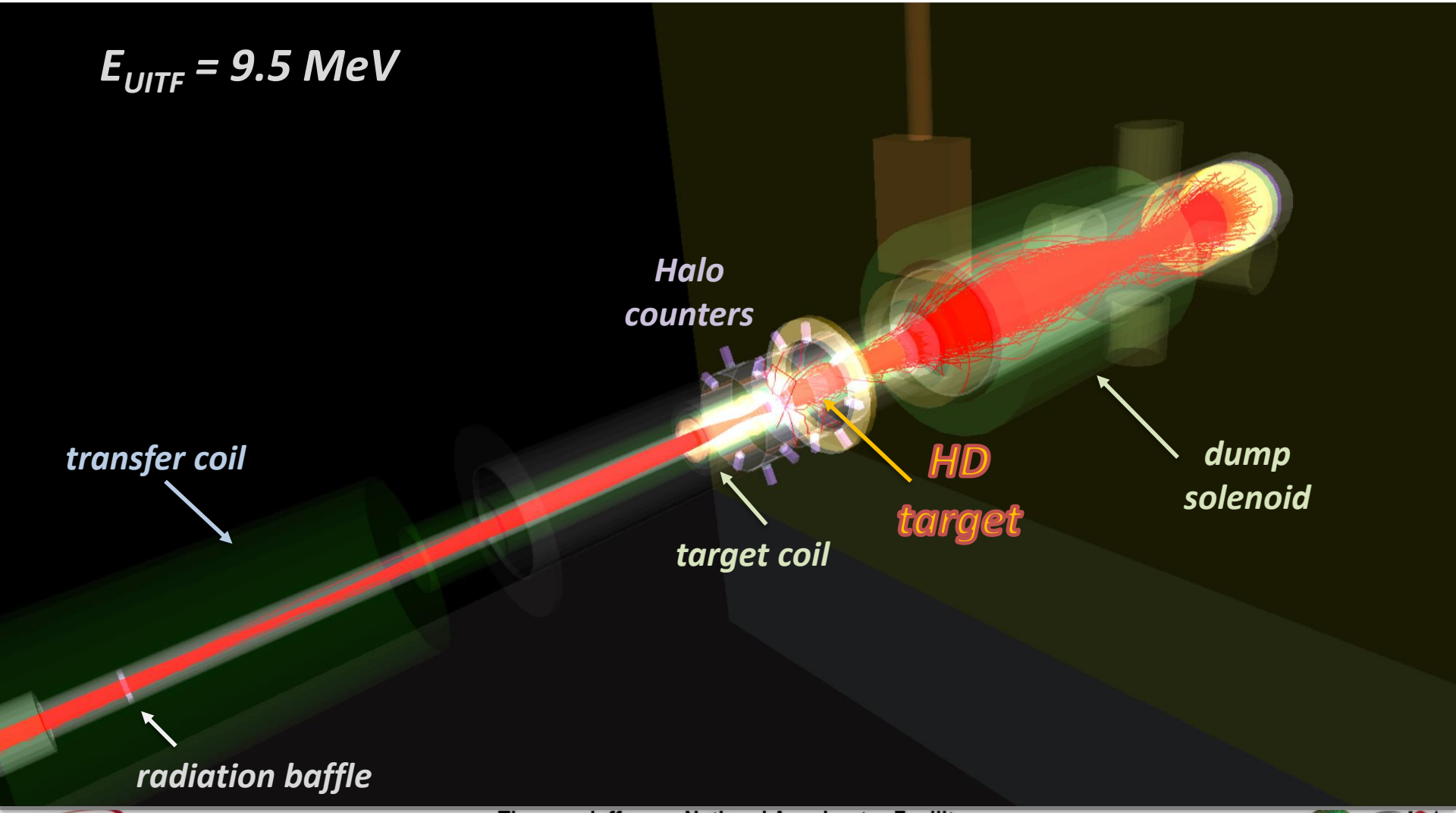
UITF beam transport through the IBC

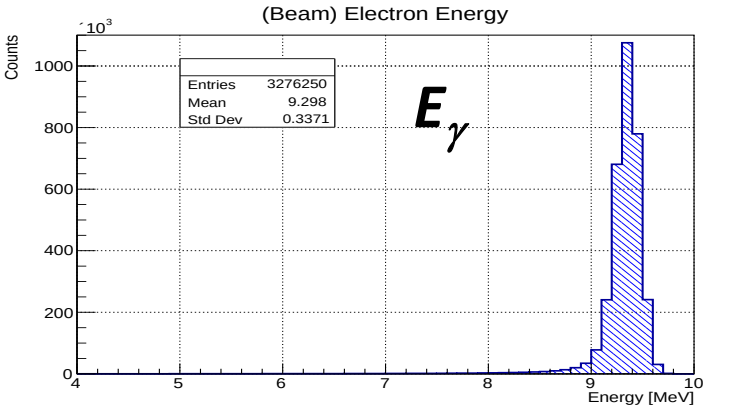
- *pencil beam offset by 12mm makes 3 revolutions through the IBC*

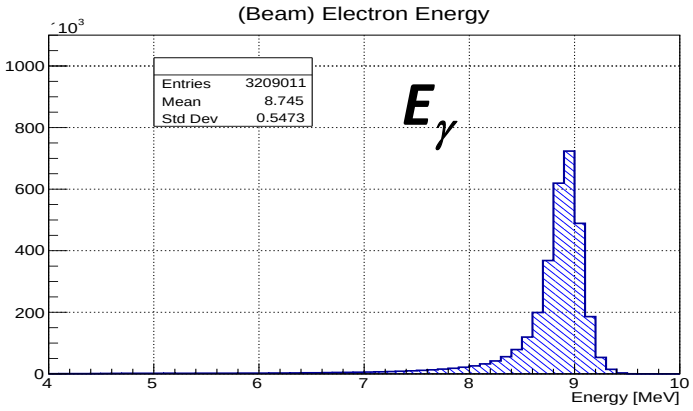


UITF beam transport through the IBC

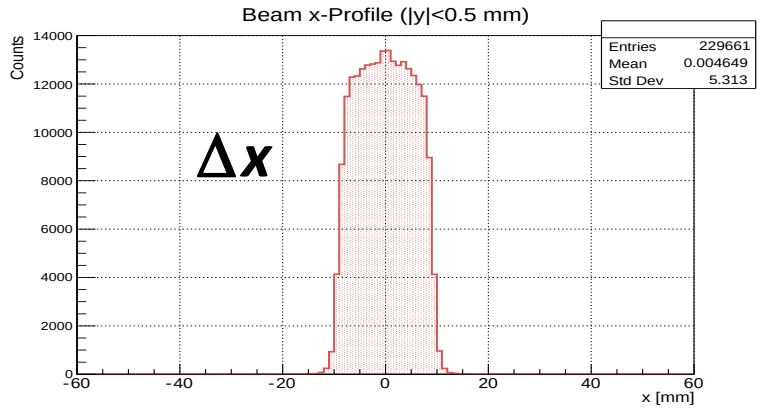
- *adjust solenoid fields and UITF energy to create ~ parallel beams through the HD target*

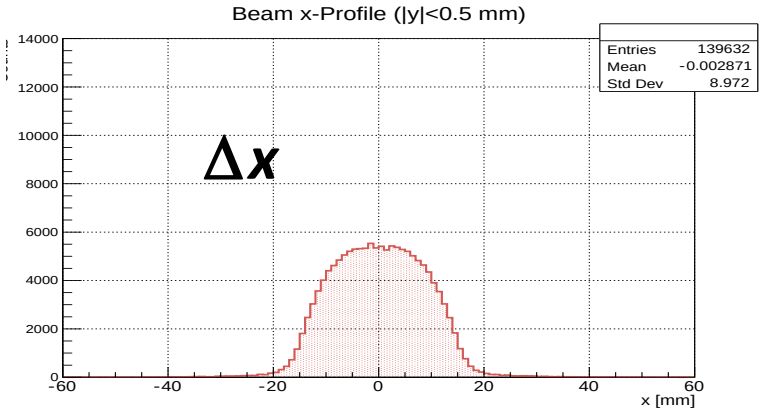


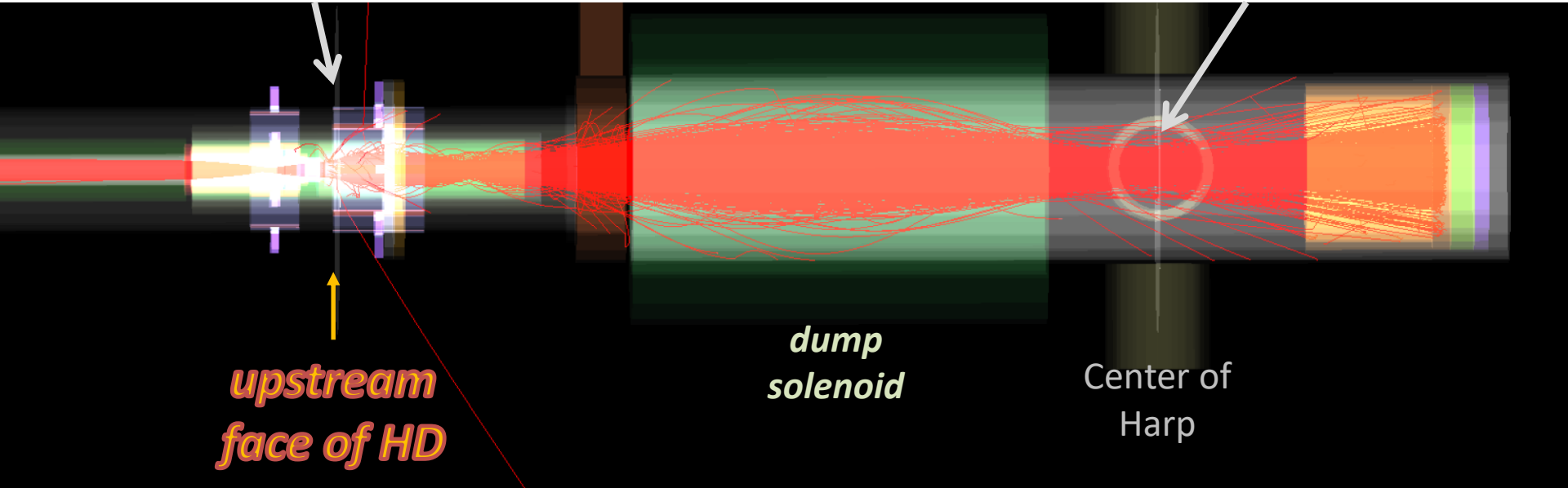




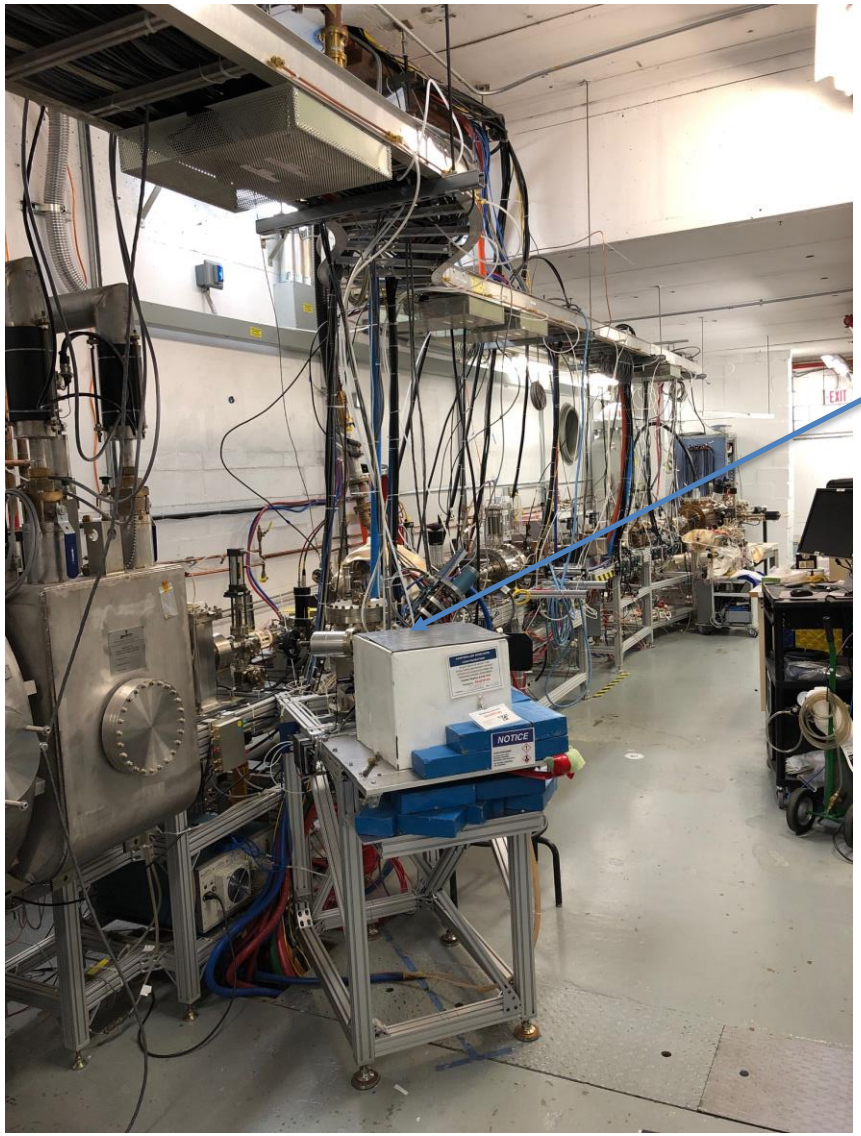
Rastered Beam
(E = 9.5 MeV)

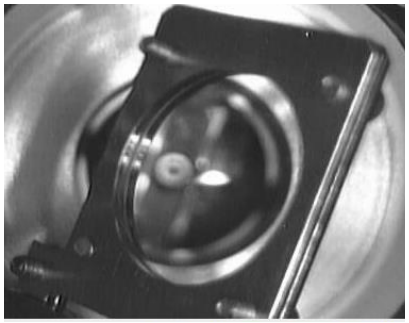






UITF status – Cave 1

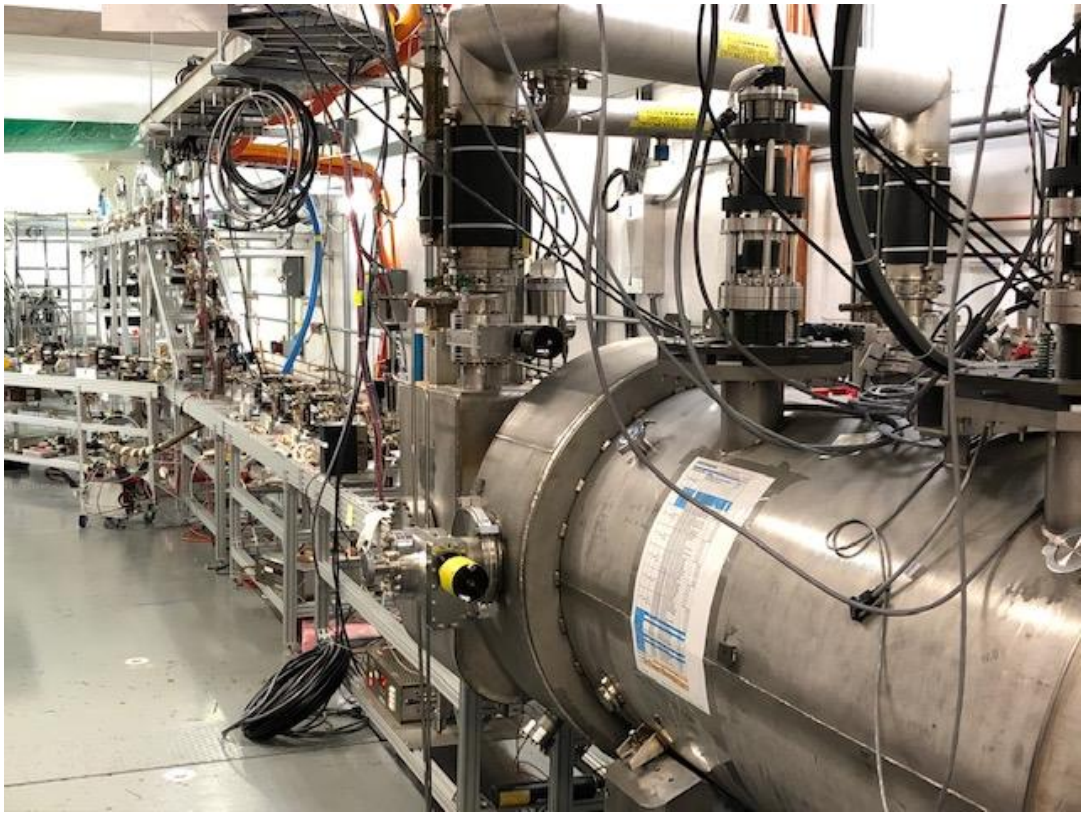




Injector:

- 200 keV beam up to dump before ¼ CryoModule ✓

UITF status – Cave 1



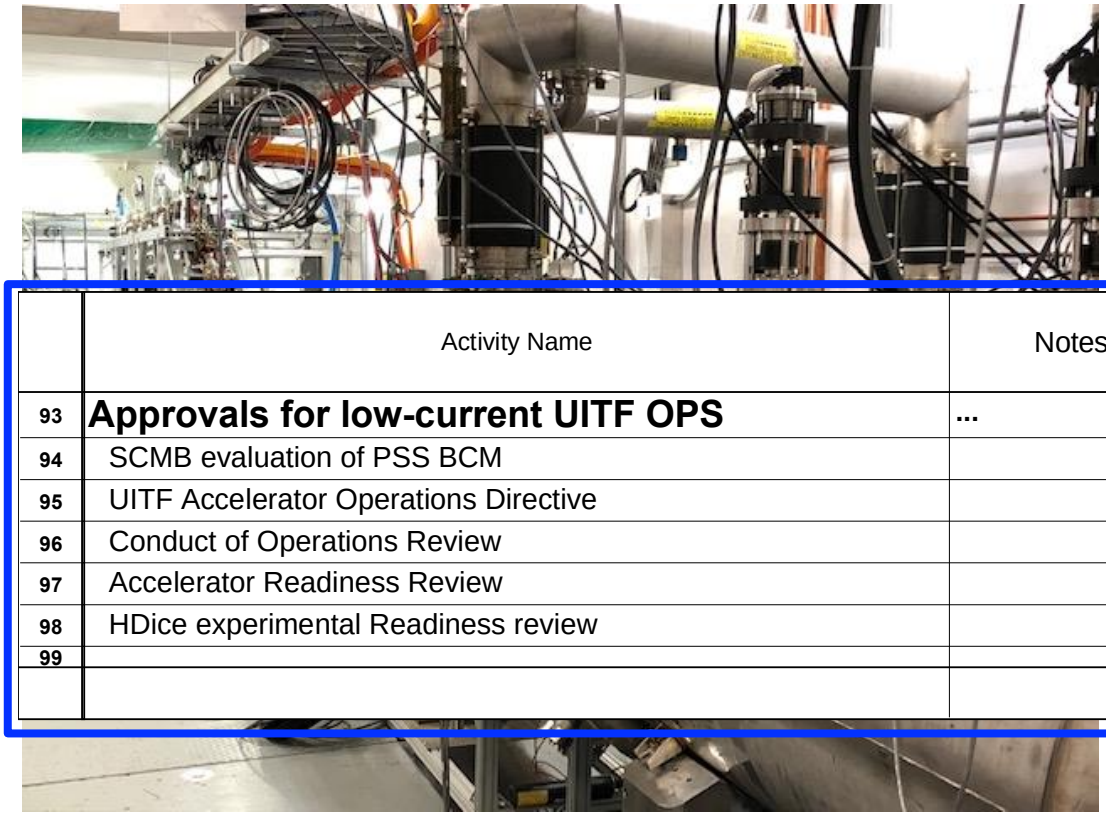
¼ Cryo-module (2 + 7 cavities):

- cooled to 4K with LHe from CTF ✓
- *PSS systems certified* ✓
- *Klystrons commissioned* ✓
- *high power RF tests complete* ✓

  ⇔ *max gradients w/o field emission*

  sufficient for 10 MeV ✓
- *parked until reviews complete*

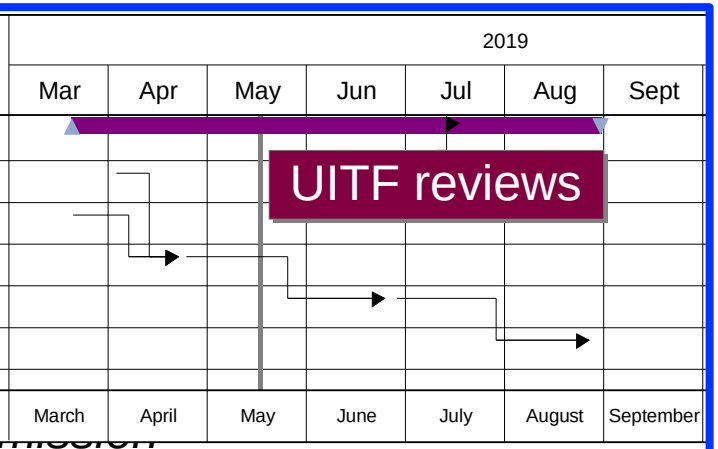
UITF status – Cave 1



¼ Cryo-module (2 + 7 cavities):

- cooled to 4K with LHe from CTF ✓
- *PSS systems certified ✓*

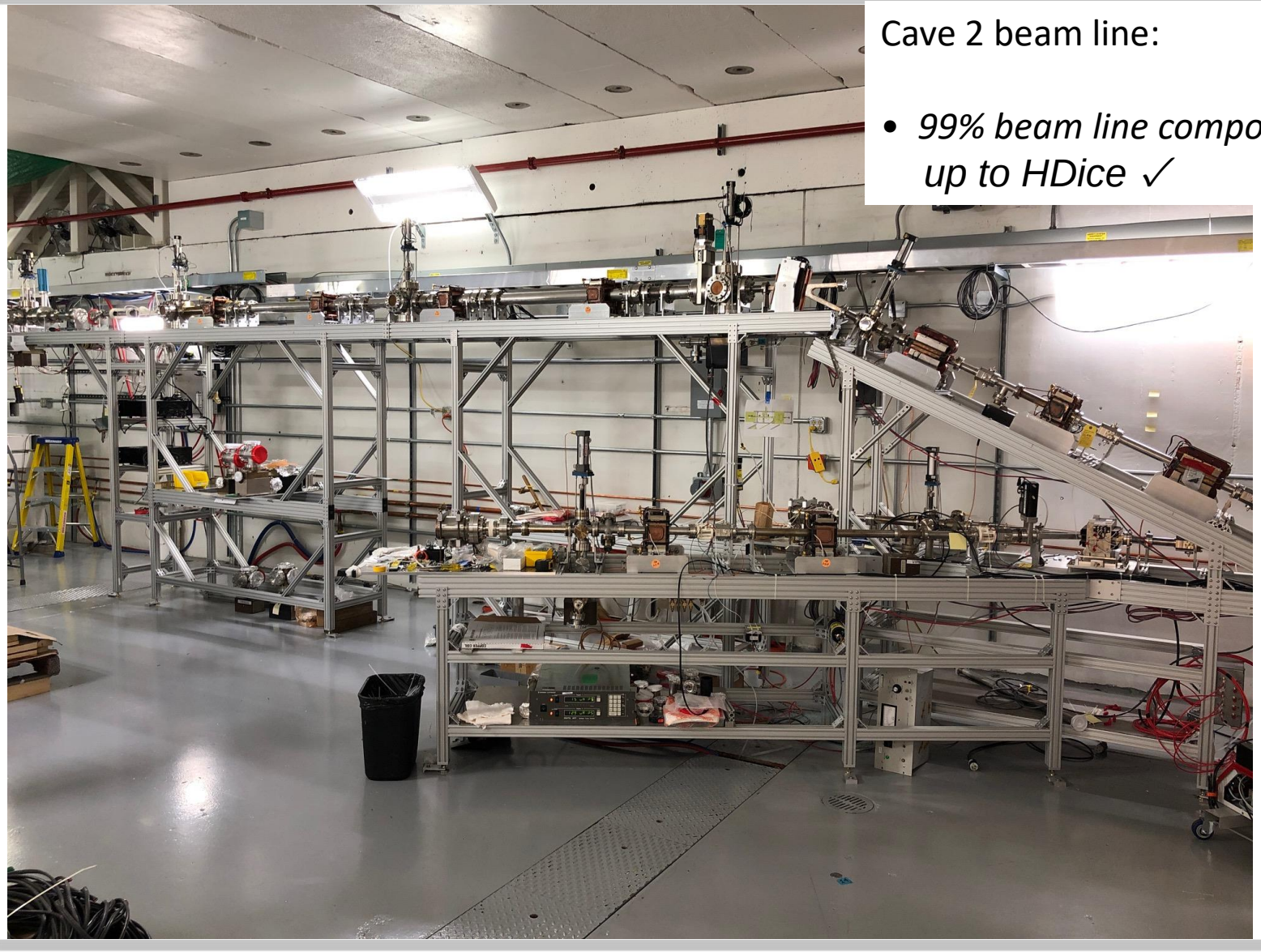
	Activity Name	Notes
93	**Approvals for low-current UITF OPS**	…
94	SCMB evaluation of PSS BCM	
95	UITF Accelerator Operations Directive	
96	Conduct of Operations Review	
97	Accelerator Readiness Review	
98	HDice experimental Readiness review	
99		



sufficient for 10 MeV ✓

- *parked until reviews complete*

UITF status – Cave 2



Cave 2 beam line:

- *99% beam line components in place up to HDice ✓*

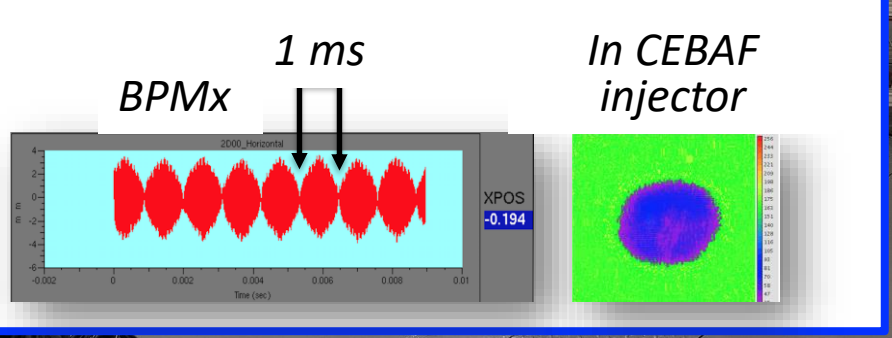
UITF status – Cave 2

Cave 2 beam line:

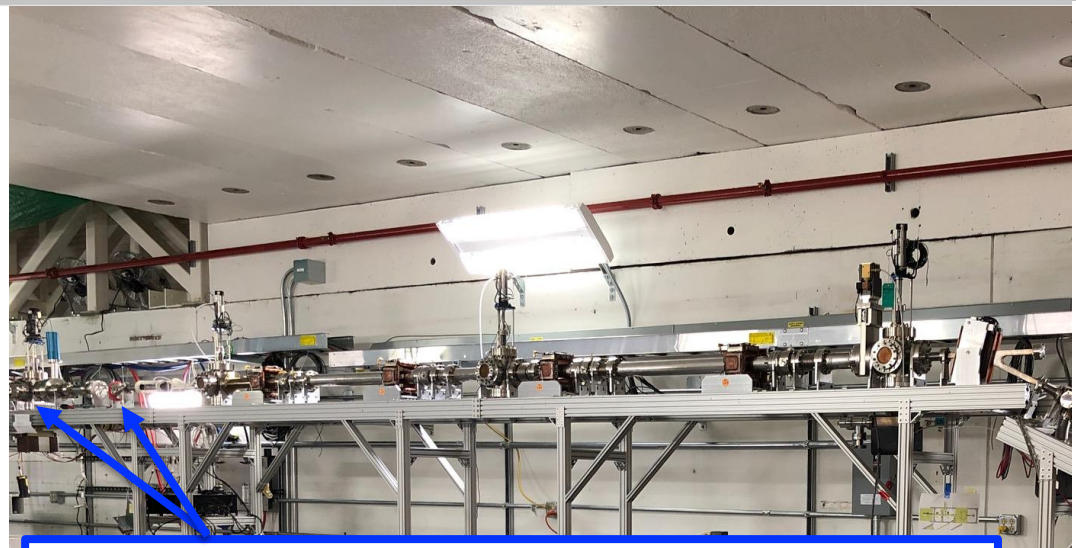
- *99% beam line components in place up to HDice ✓*
- *new fast spiral raster installed ✓*

- circular pattern: 20 KHz FM; 1 KHz AM
- tested I CEBAF injector

New Fast Raster (C. Cuevas, W. Gunning, …)



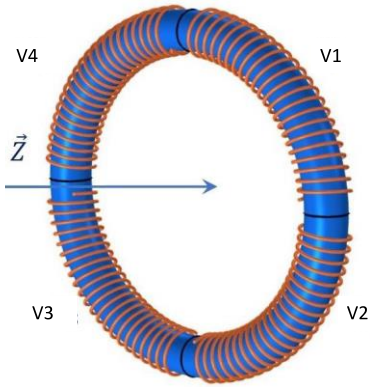
UITF status – Cave 2



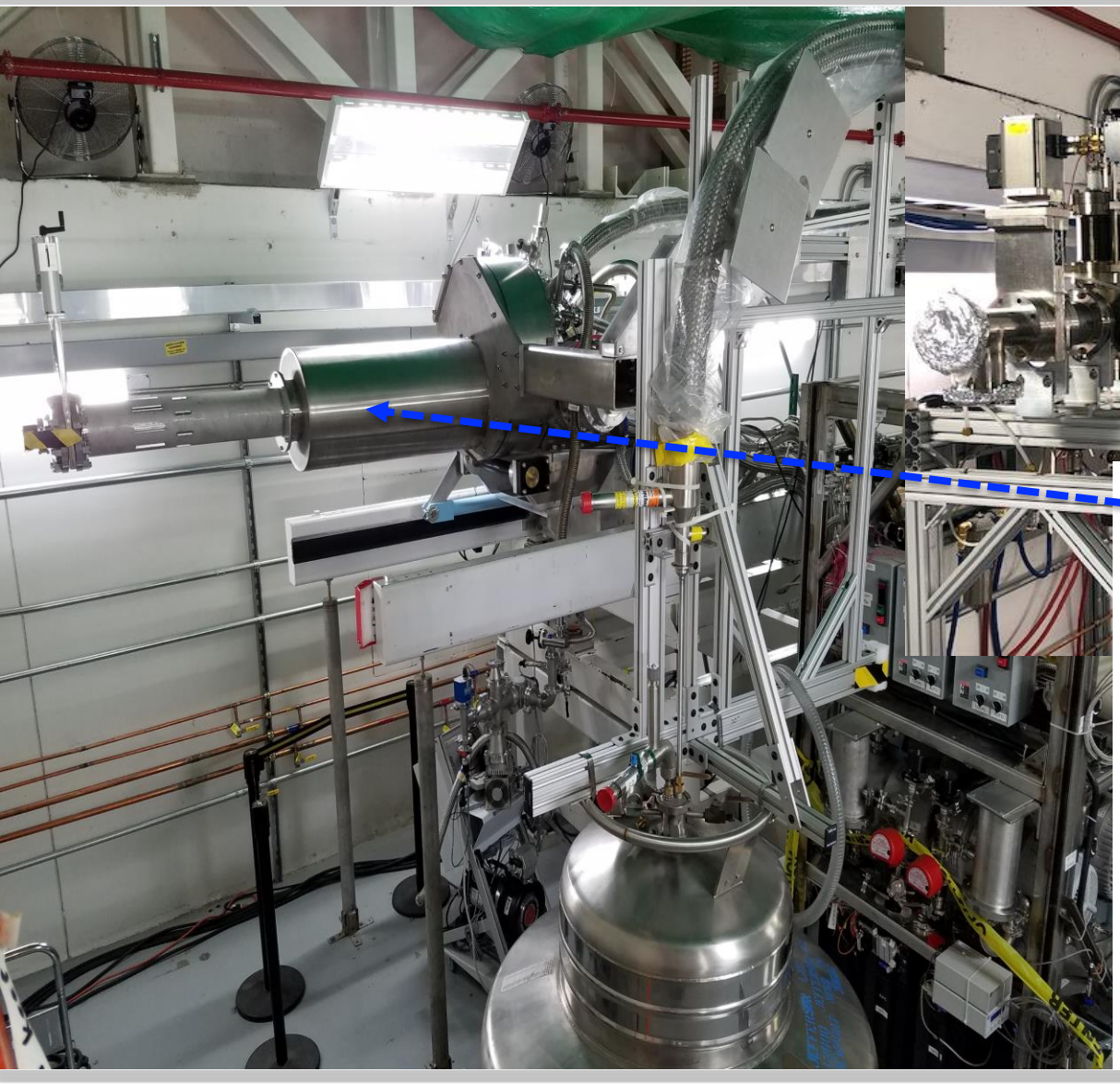
Cave 2 beam line:

- *99% beam line components in place up to HDice ✓*
- *new fast spiral raster installed ✓*
  - *circular pattern 20 KHz FM; 1 KHz AM*
  - *tested I CEBAF injector*
- *new sub-nAmp BPMs in development*
  - *"Rogowski coils" (after COSY / Jülich)*
  - *sensitivity ~ 600 pA and dropping…*

Sub-nA BPMs - Rogowski coils (K. Wei with Jülich)



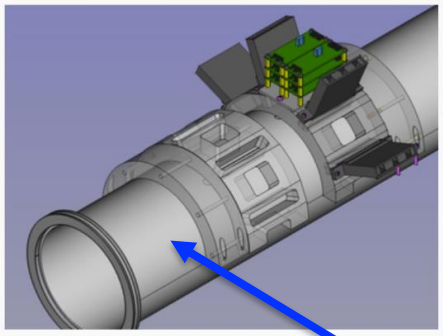
UITF status – Cave 2



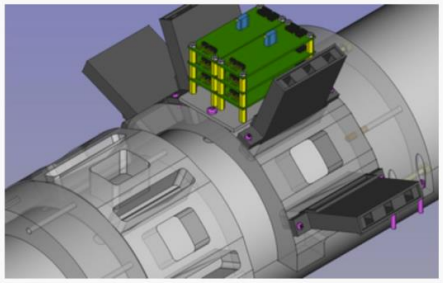
In-Beam Cryostat (IBC):

- *1.25 Tesla and 50 mK*
- *serviced, installed and ready to be cooled*
- *NMR is used for polarization monitoring*

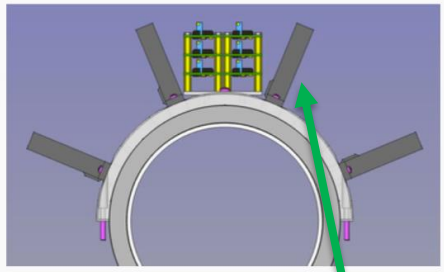
Halo Counter



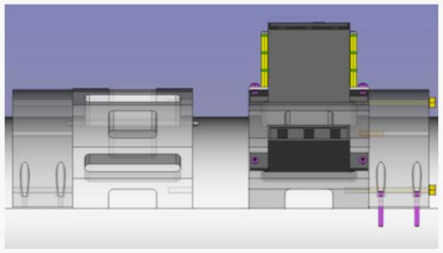
Halo counter holder 3D render



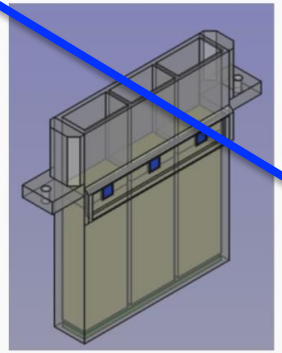
Halo counter holder 3D render



Halo counter holder 3D render



Halo counter holder 3D render



Halo counter scintillators box

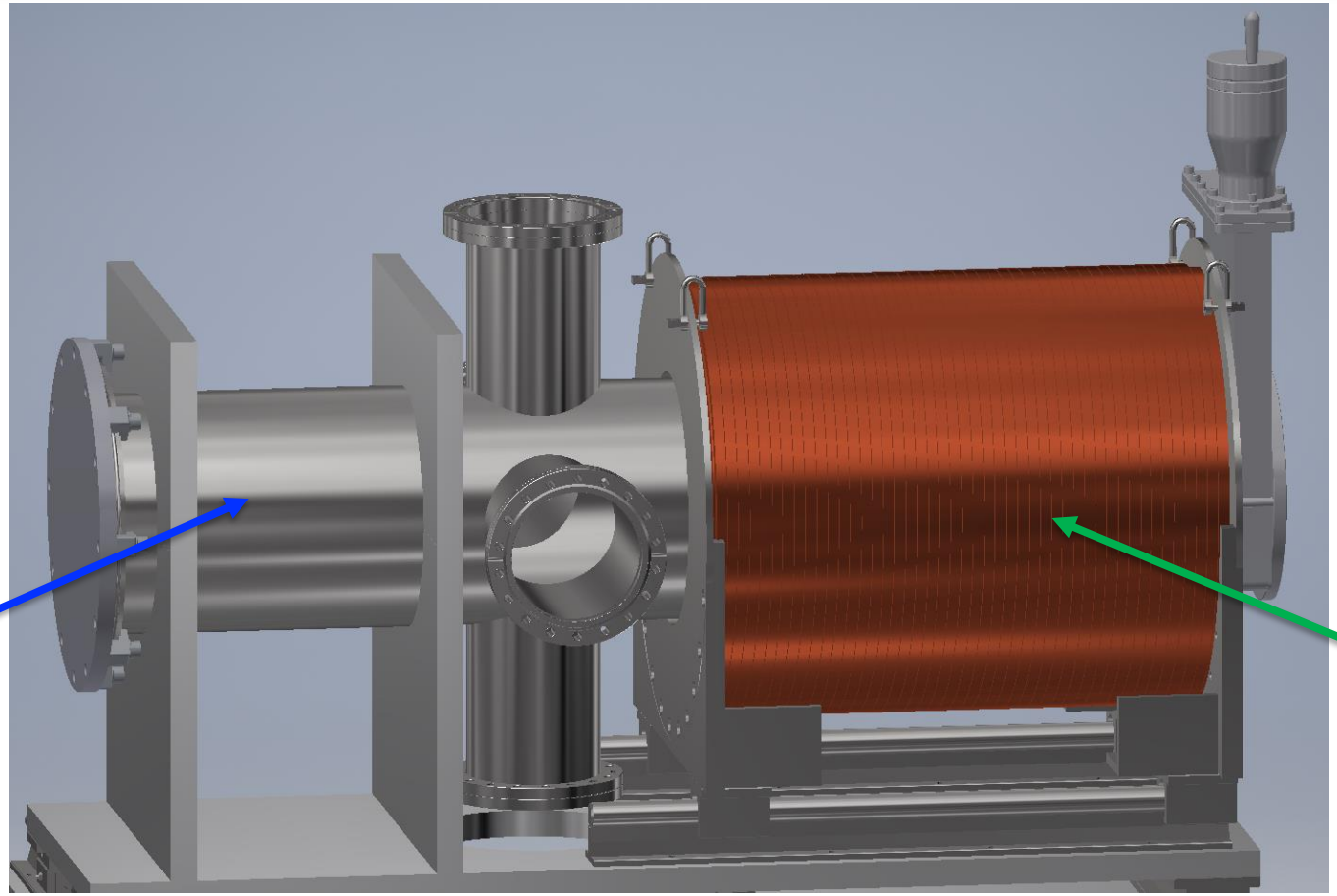
IBC Halo Counter

IBC Snout

Delivery: Oct. 2019

X. Wei

Down Stream Solenoid and Beam Dump

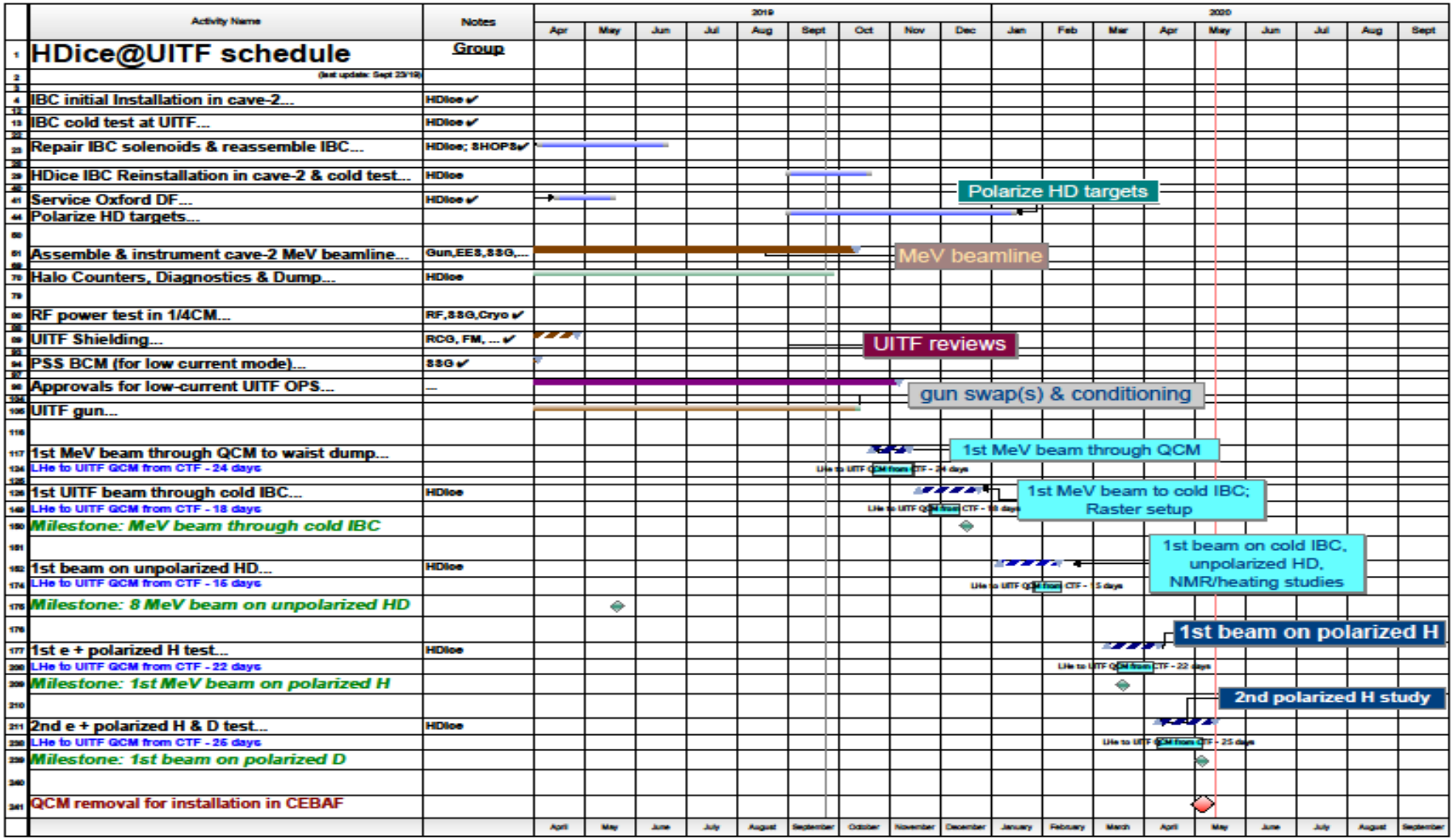


Dump Solenoid delivery: End of Sep. 2019

Vacuum Can with Beam Dump delivery: December 2019

X. Wei

eHD test schedule at the UITF



Issues to track

- *gun performance at CEBAF – replacements come from UITF*
- *UITF ¼ CM is cooled by LHe from the Cryogenic Test Facility (CTF) liquifier*

  - TestLab demand exceeds CTF capacity

  ⇔ beam-line commissioning and HD studies require ~ 80 days of LHe to ¼ CM
- *NCLS-II cryomodules are routinely stored on the roof of cave-2*

  - cave-2 roof must be removed for target transfers (~ 10 times)
- *¼ CM will be moved to CEBAF on May 6, 2020*

  ⇔ HD testing must be completed by then !