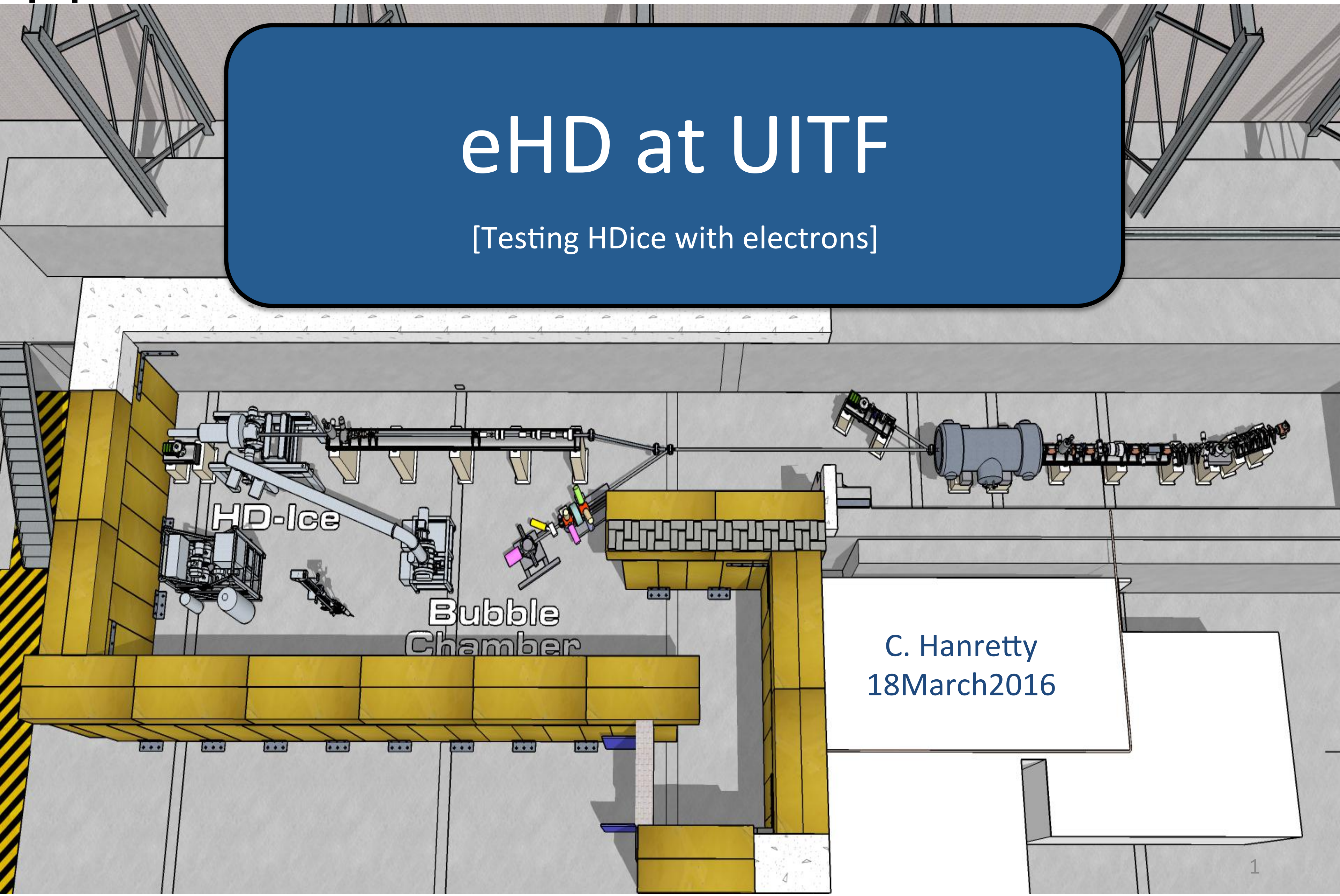
eHD at UITF

[Testing HDice with electrons]



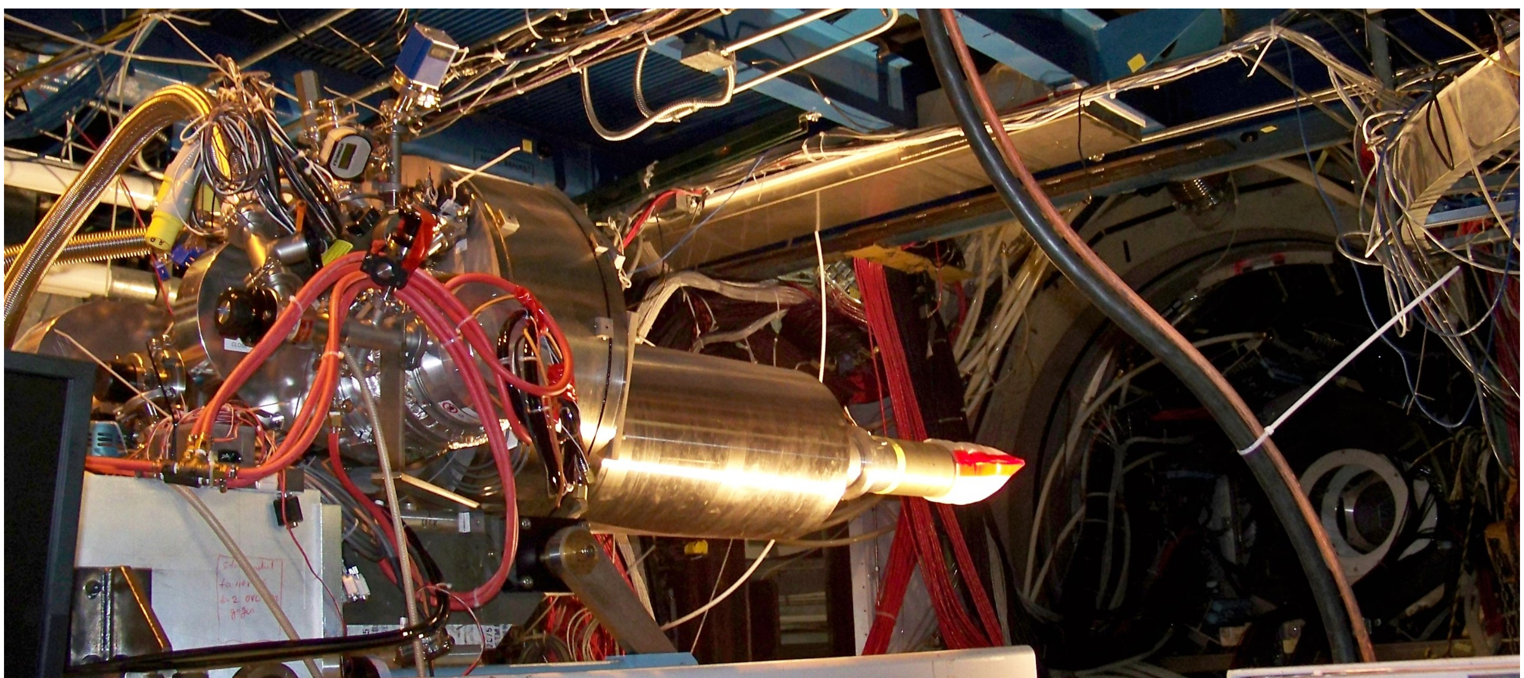
C. Hanretty
18March2016

Outline

- Brief overview of HDice
- Lessons learned from 2012 eHD tests
- Why MeV-scale electrons?
- Challenges of using MeV electrons with IBC
- Beam requirements for eHD at UITF
- Remaining tasks

What is HDice?

- A new type of frozen spin target.
- Target material consists solely of polarizable protons and neutrons → no dilution factor coming from the target material.
- Target material possesses a T1 (relaxation time) on the order of years → no repolarization needed.
- Is a very complicated target system requiring many steps in the production of a single polarized target cell.



What's it good for?

- Has been used with photons in Hall B as part of the N* program → g14 (Nov 2011 – May 2012).
- Next up: Transversely polarized frozen spin target for use with electrons.
- Three (A-rated) proposals from PAC41 rated as having a high impact for Hall B:
  - SIDIS, C12-11-111, Marco Contalbrigo,… [A;C1]
  - Dihadron production, PR-12-009, Harut Avakian,… [A;C1]
  - DVCS, PR12-12-101, Latifa Elouadrhiri,… [A;C1]

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C1 ⟶ requires successful demonstration to Lab management of viable performance in a subsequent eHD test runs

2012 eHD Test in Hall B

- Results attributed to three possible depolarization mechanisms:

1) Beam-induced chemical changes
   - HD molecule is ionized and becomes highly reactive
   - A chain of reactions begin:
     - ➔ Temperature spikes occur from "recombination flashes"
       - Also seen in g14 photon runs (from $e^+ e^-$ pairs) with low frequently but with no apparent effect.
     - ➔ Buildup of ortho-H_2 which can shorten T1 of material
       - Analysis of gas after 1nA-week in beam showed no large increase of ortho-H_2 (analysis may not have had required resolution)

HDice

2012 eHD Test in Hall B

- Results attributed to three possible depolarization mechanisms:

2) Hyperfine mixing of unpaired electrons with H (or D) spins
   - Electrons polarized by holding field possess spins opposite to H
   - Hyperfine mixing dilutes H polarization
   - Depolarization first occurs locally, depolarization spreads
   - Temperature independent (function of B^{-2})

Solution:

Use RF to align H (or D) spins with electron spins to prevent this mixing.

2012 eHD Test in Hall B

- Results attributed to three possible depolarization mechanisms:

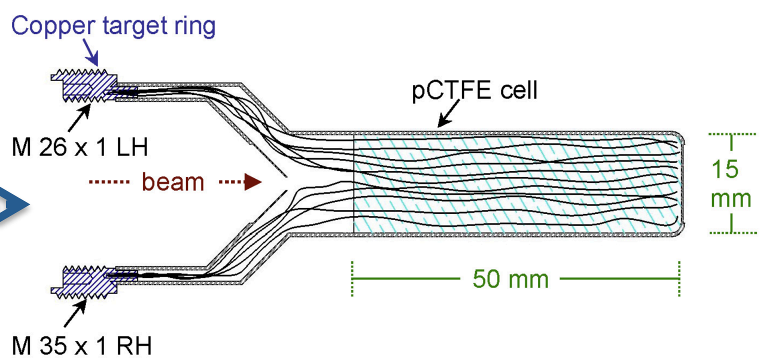
3) Beam unpairs 1s molecular electrons in target material
   - Electron(s) may be unpolarized (depends on temperature)
   - If unpolarized (or has low polarization), flips with frequency that has harmonics at nuclear Larmor frequencies of H and D
   - Depolarization of local HD begins
   - Depolarization spreads to rest of HD crystal

Solution:

Suppress this effect through mitigation of beam heating.

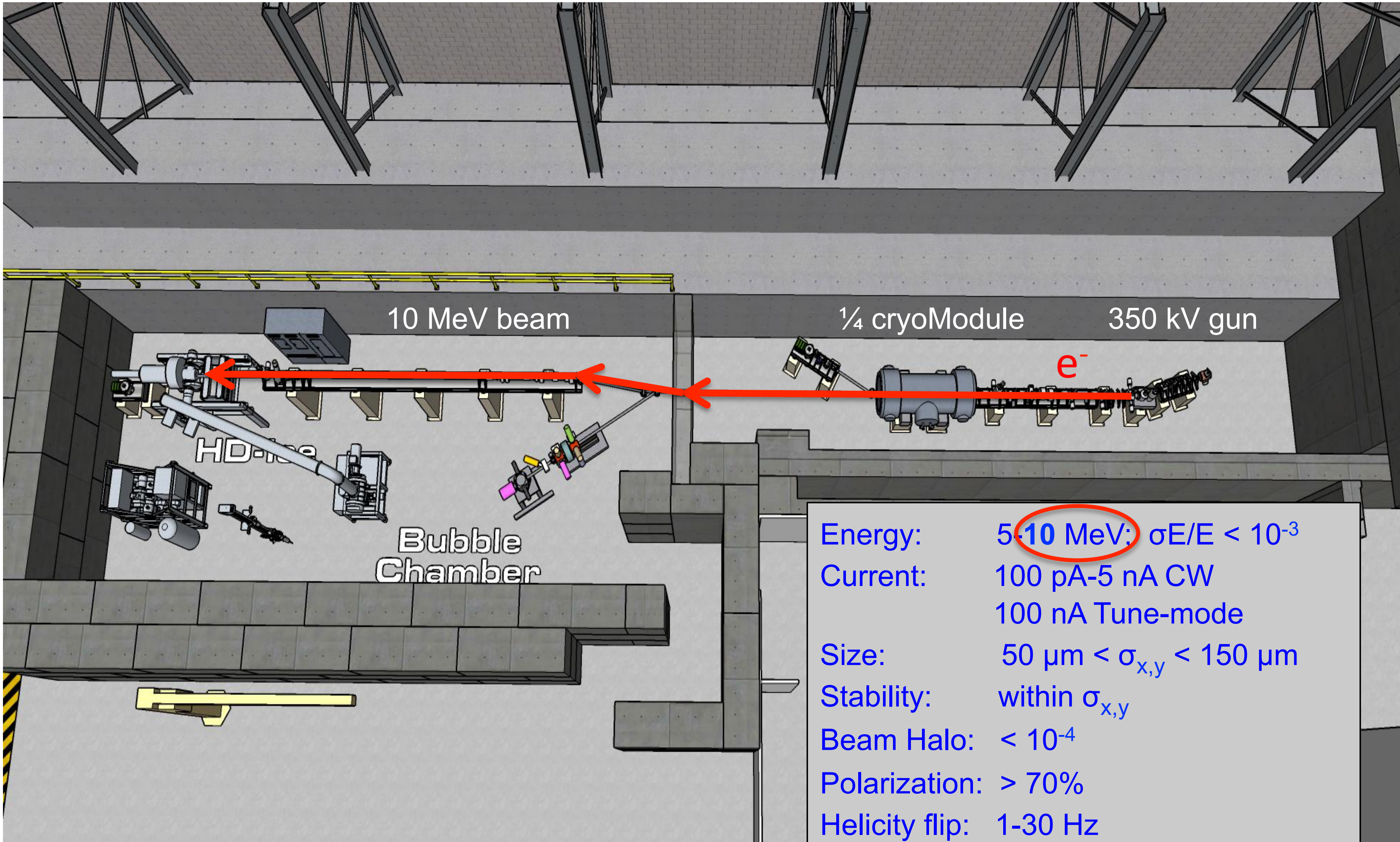
➔ Faster Raster, shorter Al wires, higher purity Al, smaller HD cell

C.D. Bass, *et al.*, NIM A 737 (2014) 107-116



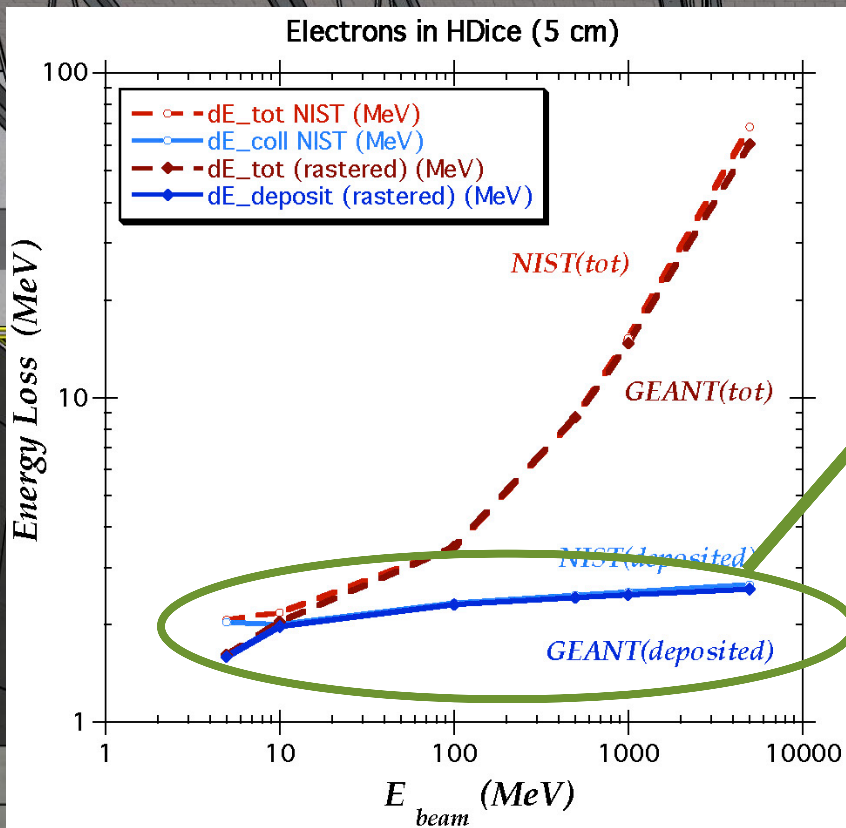
HDice

eHD Tests in UITF



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

eHD Tests in UITF



Ionization and energy deposition are approx independent of E_{beam}

UITF at 10 MeV ≃ Hall B at 10 GeV

Energy:	5-**10** MeV; σE/E < 10^{-3}
Current:	100 pA-5 nA CW 100 nA Tune-mode
Size:	50 μm < $\sigma_{x,y}$ < 150 μm
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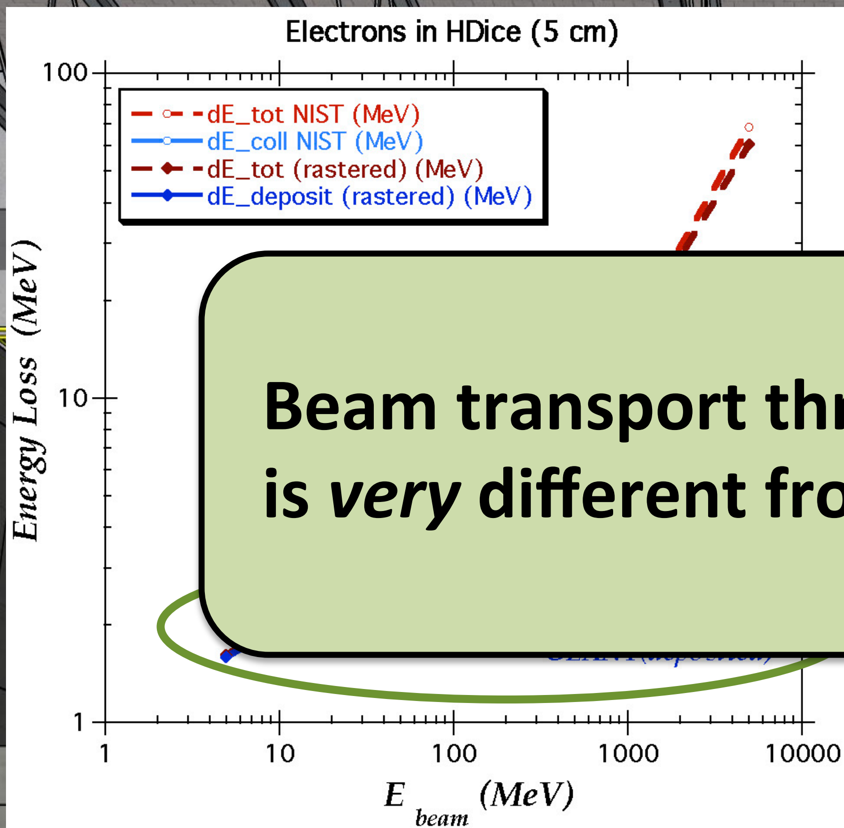
eHD Tests in UITF



Ionization and energy deposition are approx independent of E_{beam}

at 10 GeV

Beam transport through IBC at 10 MeV is *very* different from 10 GeV!!!

Energy: 5-**10** MeV; $\sigma E/E < 10^{-3}$
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100 nA Tune-mode
Size: 50 μm < $\sigma_{x,y}$ < 150 μm
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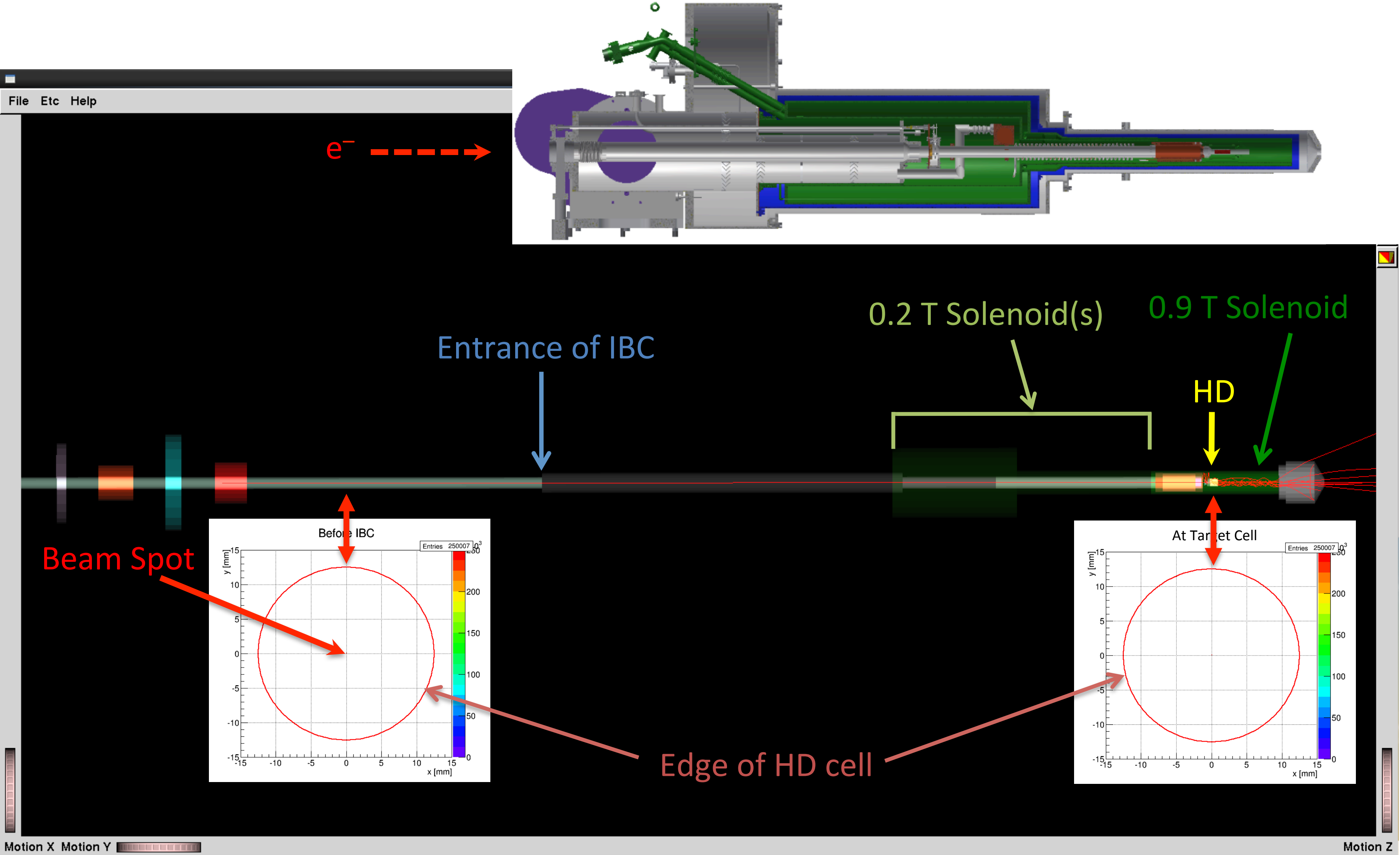
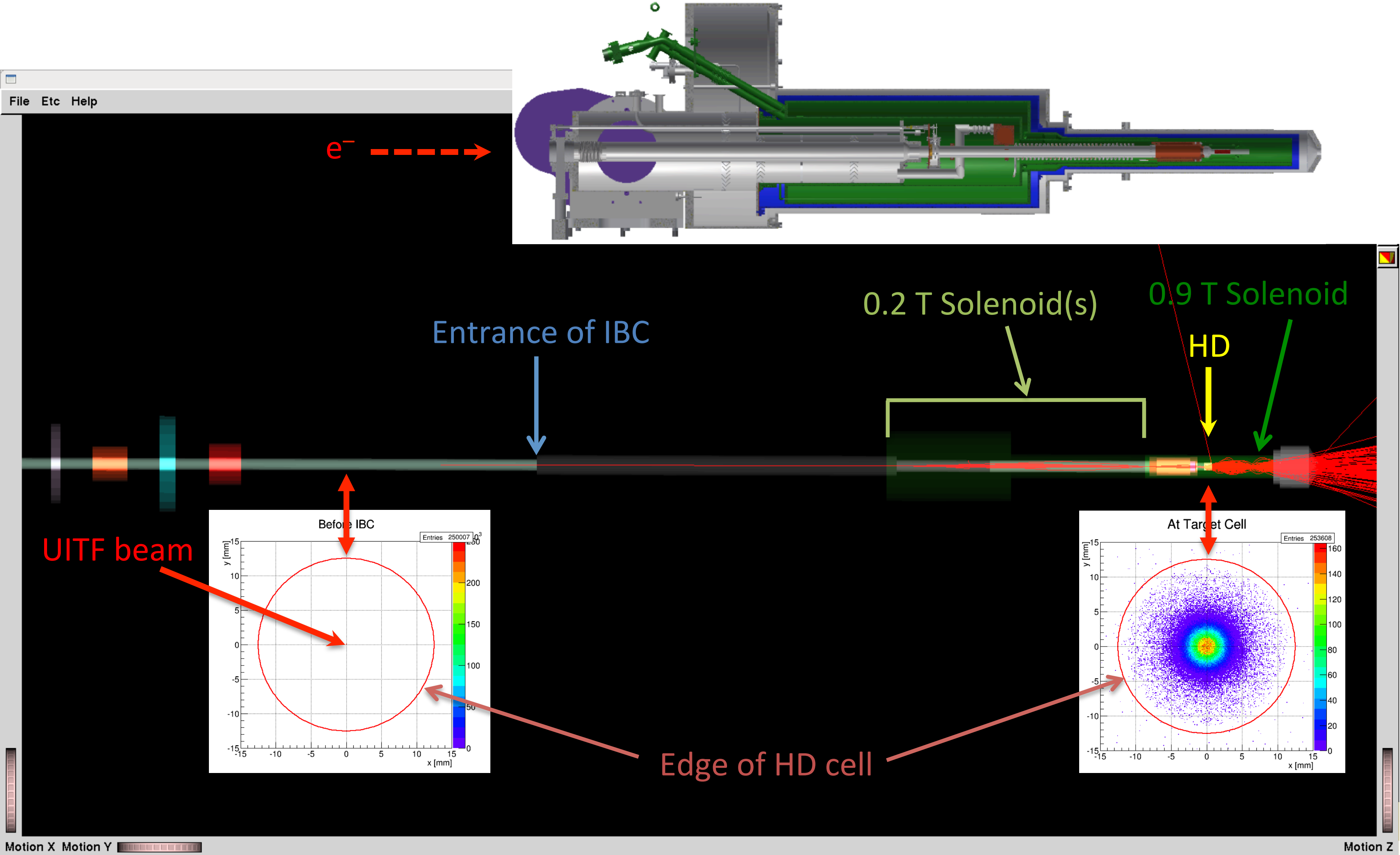
Pencil beam into IBC with normal orientation at **10 GeV**

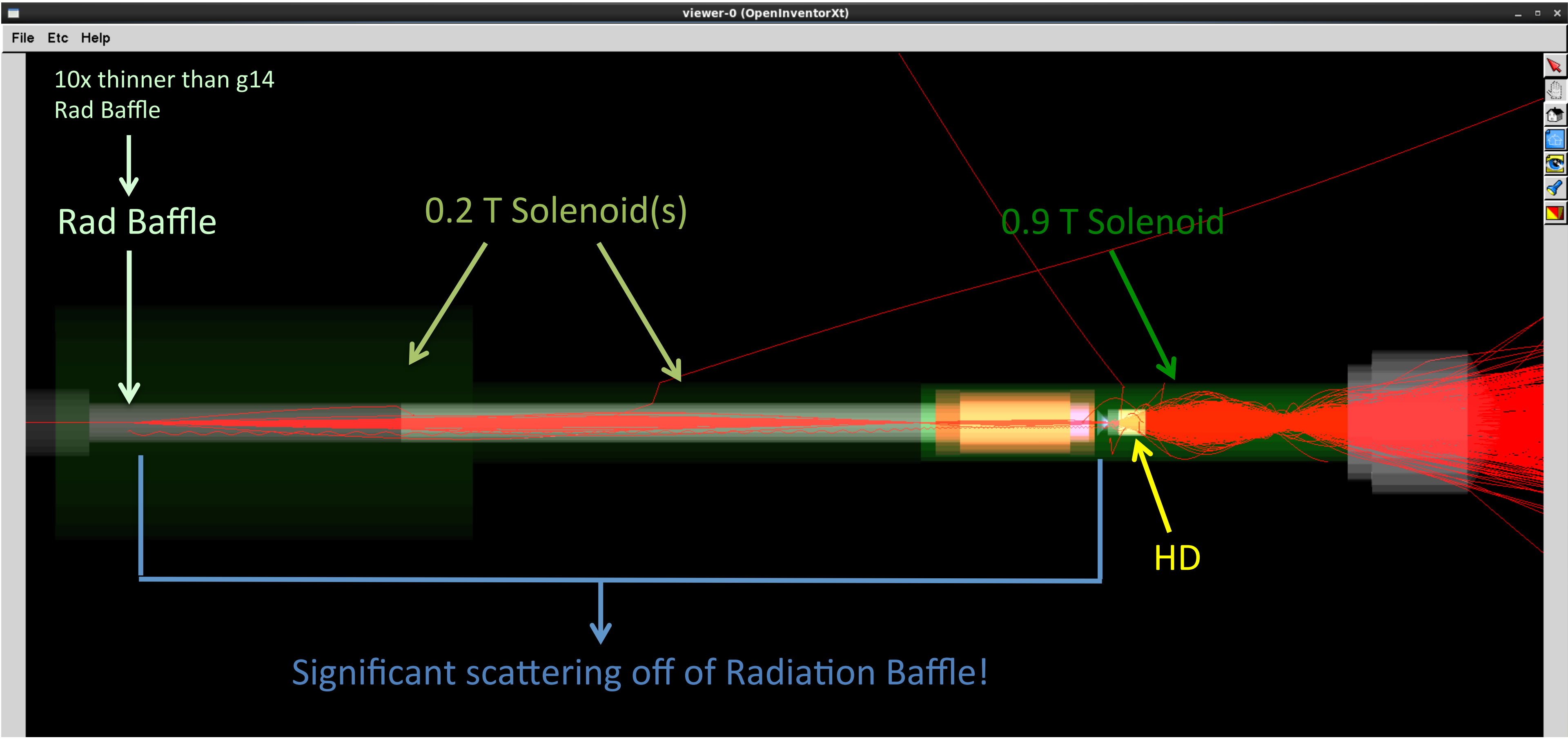


Pencil beam into IBC with normal orientation at **<10 MeV**



Pencil beam into IBC with normal orientation at <10 MeV

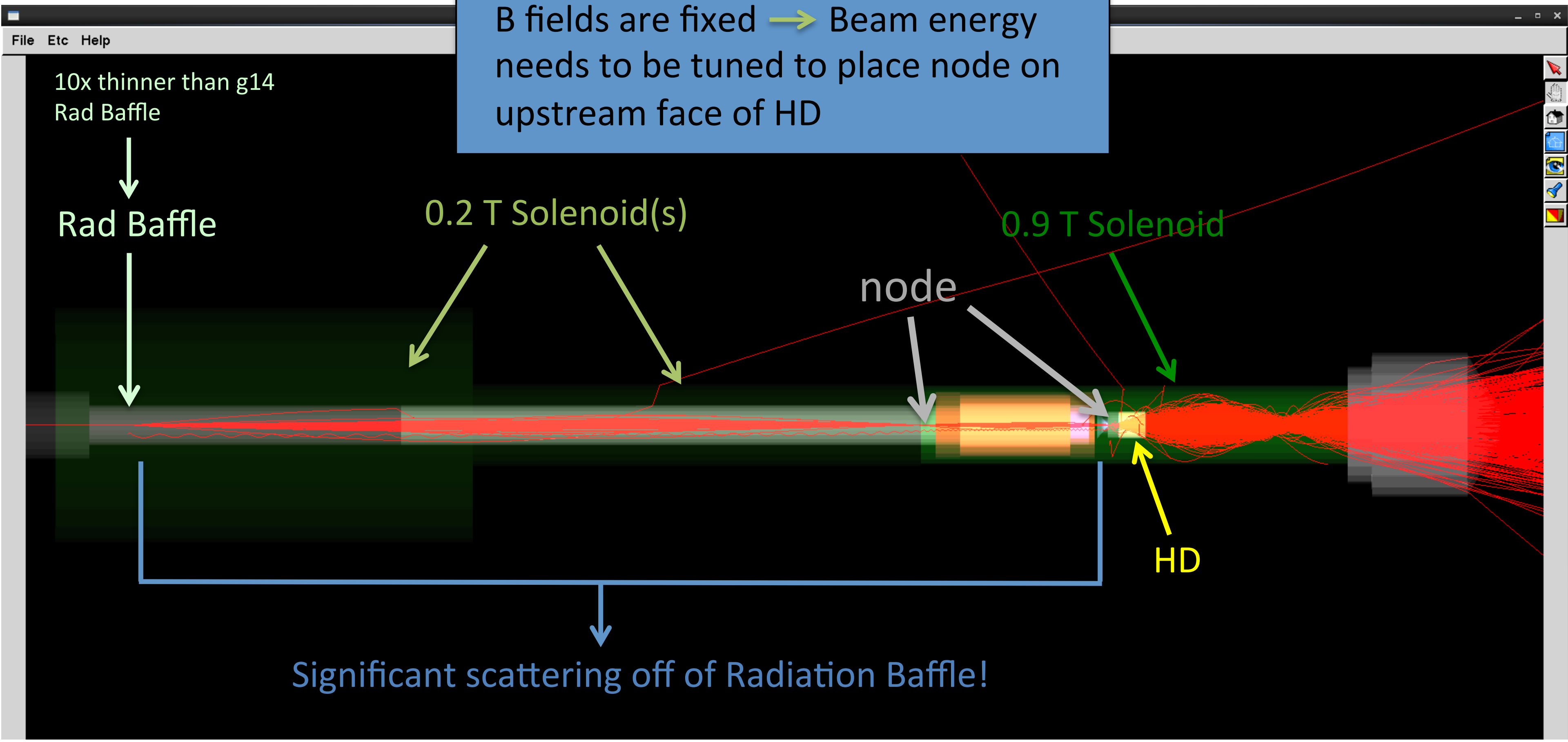
…… a closer view



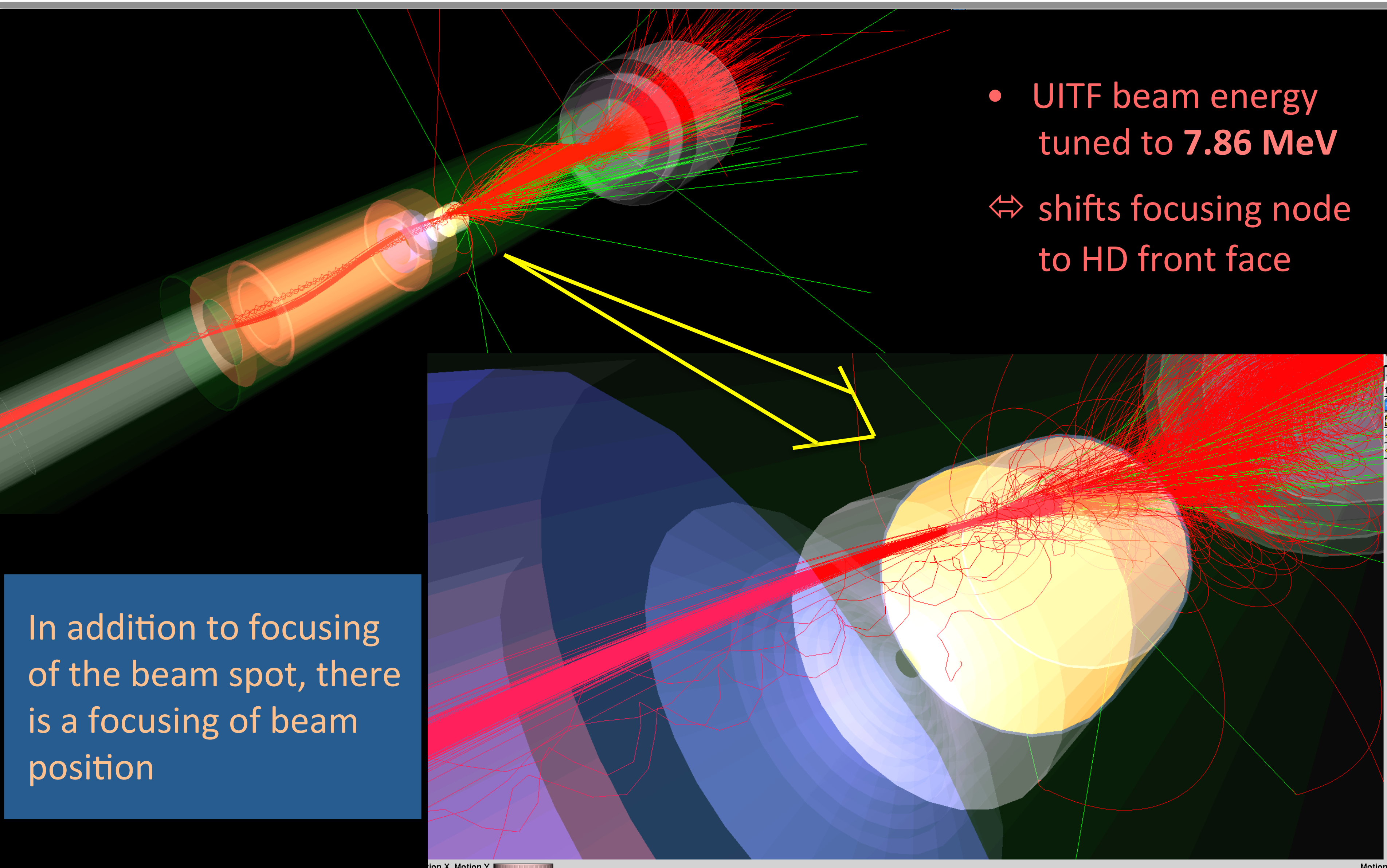
Pencil beam into IBC with normal orientation at <10 MeV

…… a closer view

B fields are fixed → Beam energy needs to be tuned to place node on upstream face of HD



(UITF) Pencil beam into IBC with 14 mm offset



- UITF beam energy tuned to **7.86 MeV**

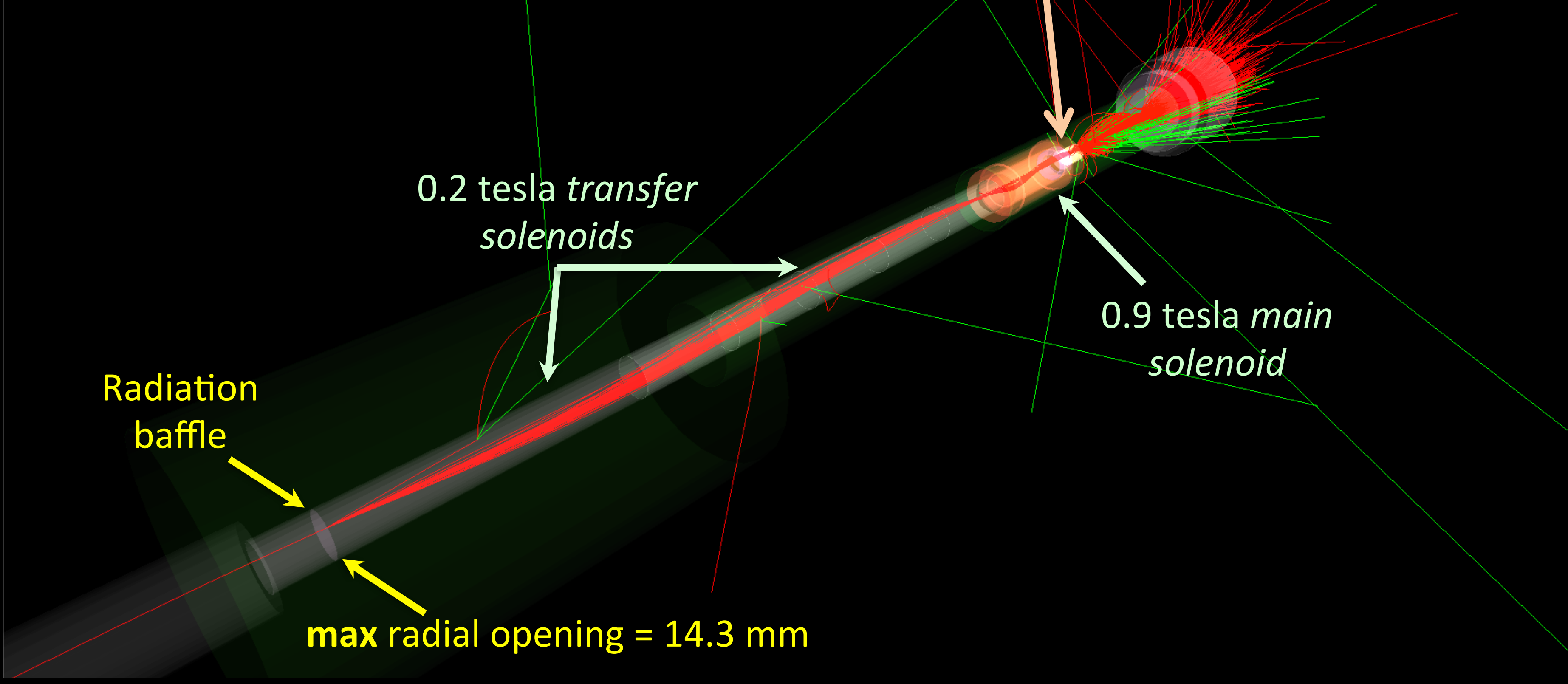
⇔ shifts focusing node to HD front face

In addition to focusing of the beam spot, there is a focusing of beam position

(UITF) Pencil beam into IBC with 14 mm offset

Pencil beam offset 14 mm at launch

⇔ 13.6 mm offset at Radiation Baffle,
from solenoid edge focusing
≈ maximum offset



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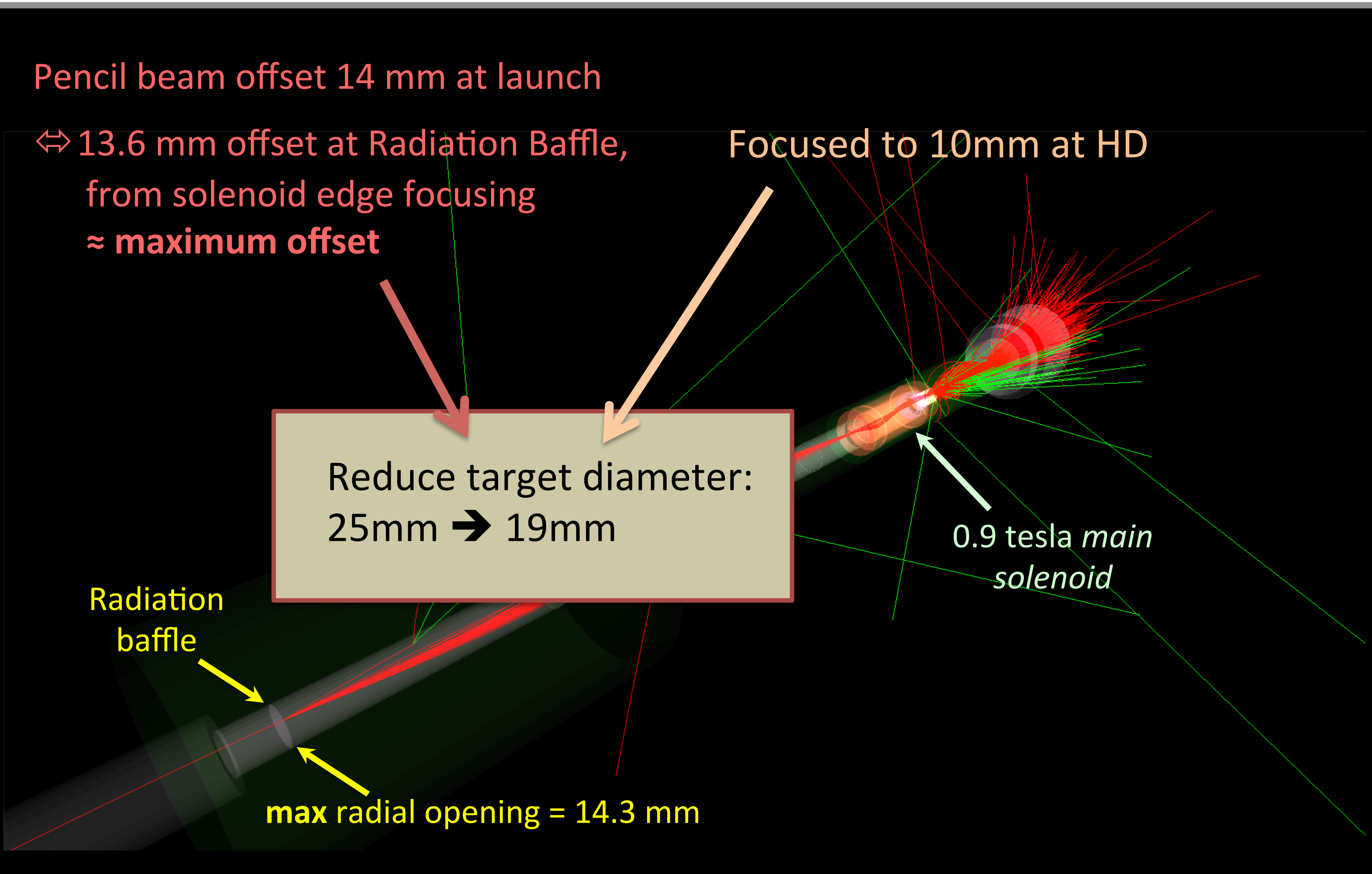
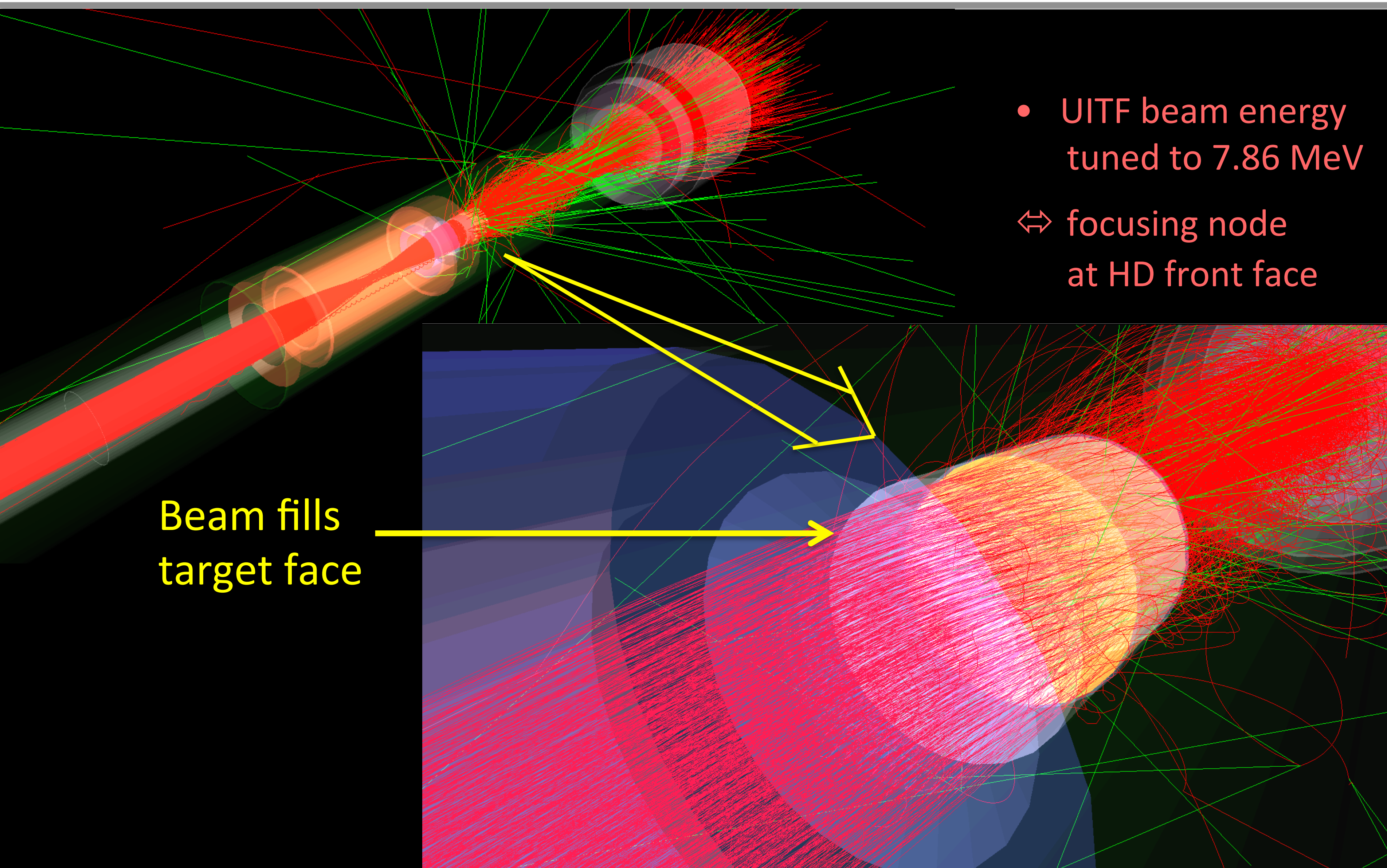
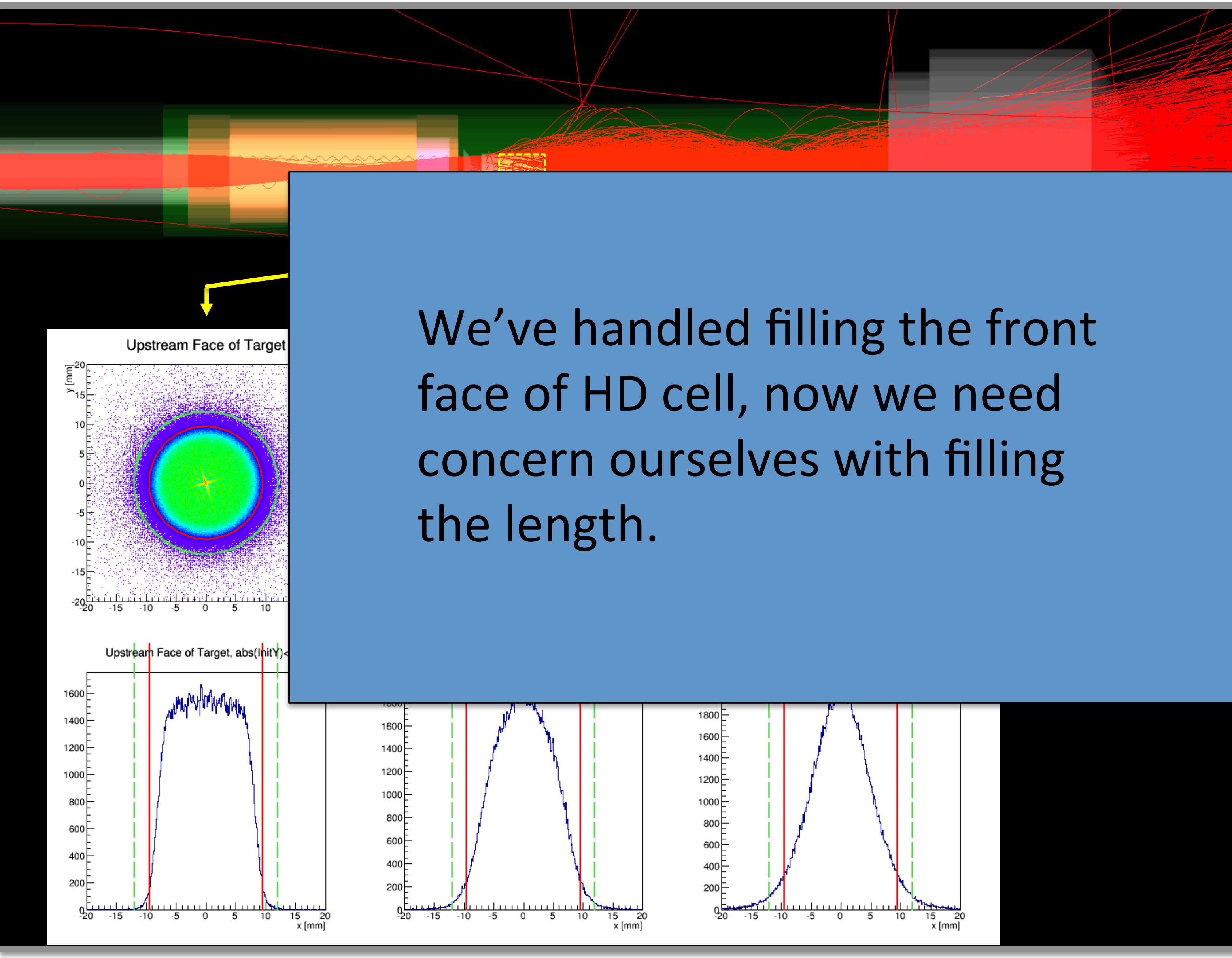


(UITF) Uniform rastered beam into IBC

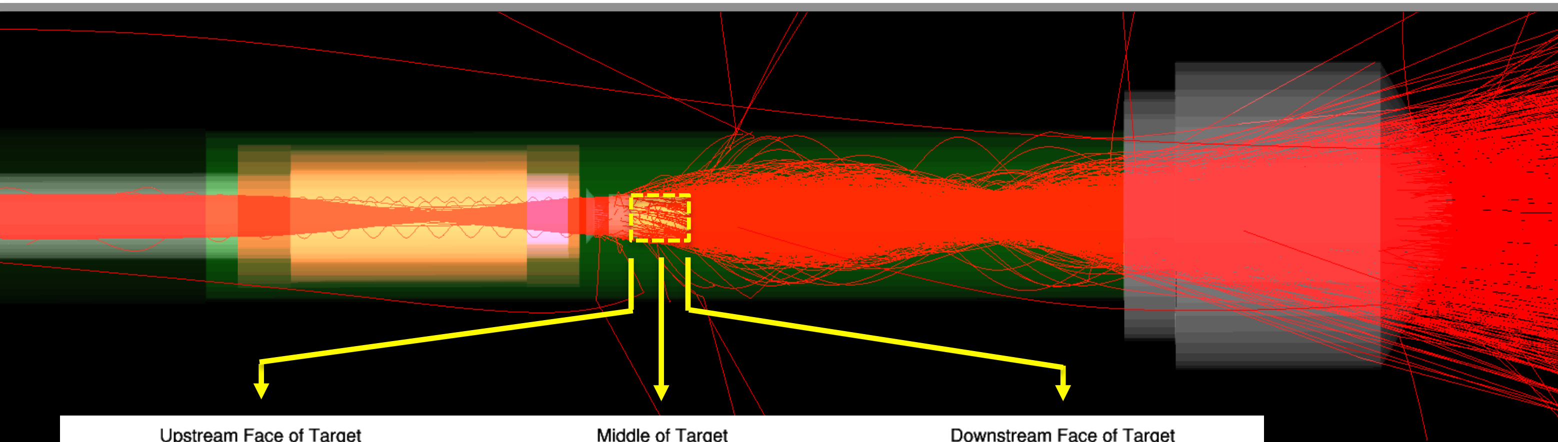


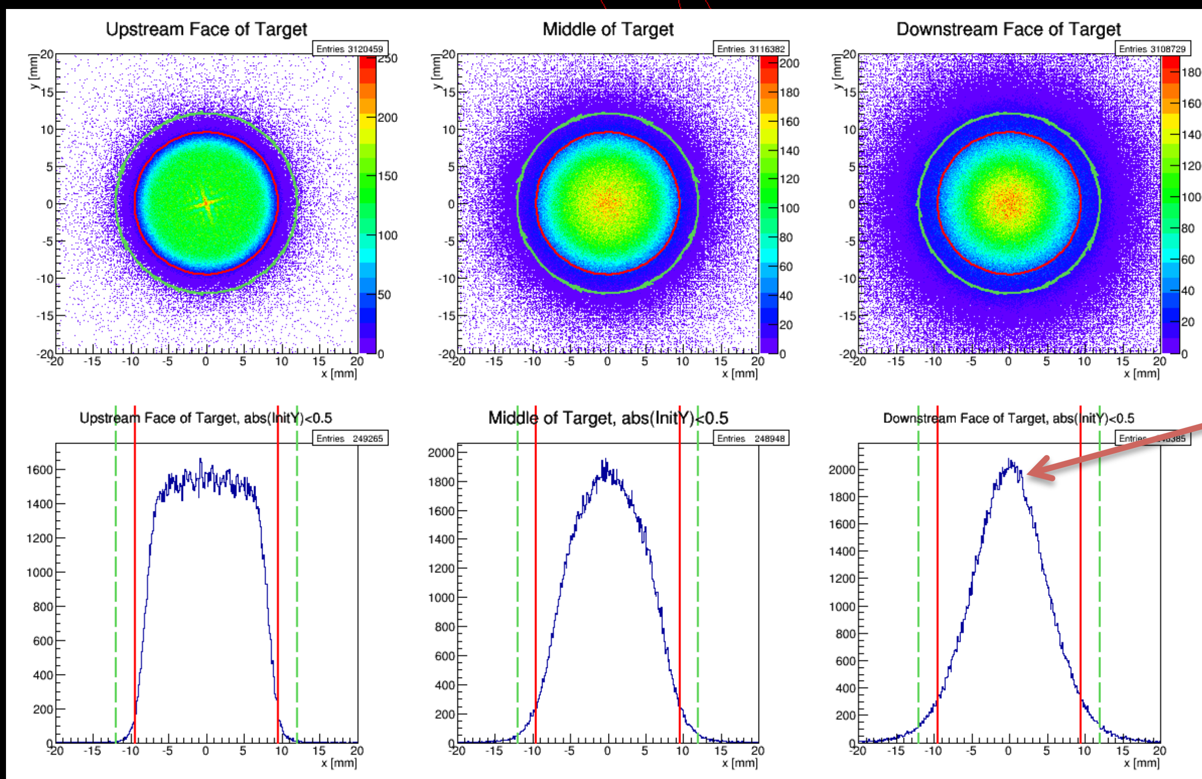
Rastered beam profiles on 25 mm long target



We've handled filling the front face of HD cell, now we need concern ourselves with filling the length.

Rastered beam profiles on 25 mm long target

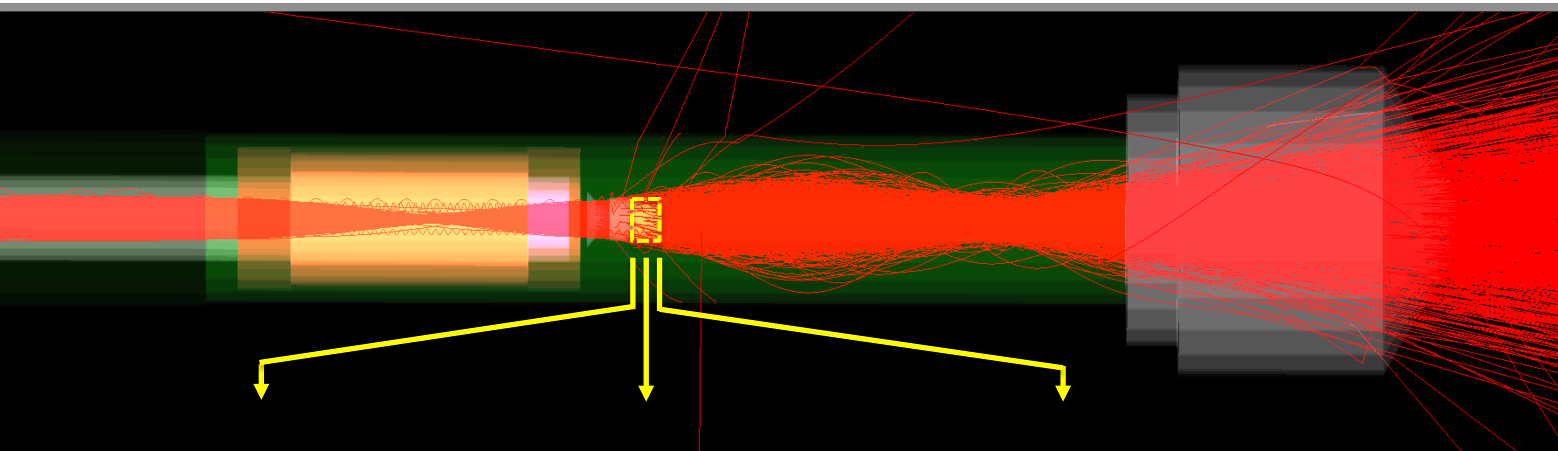


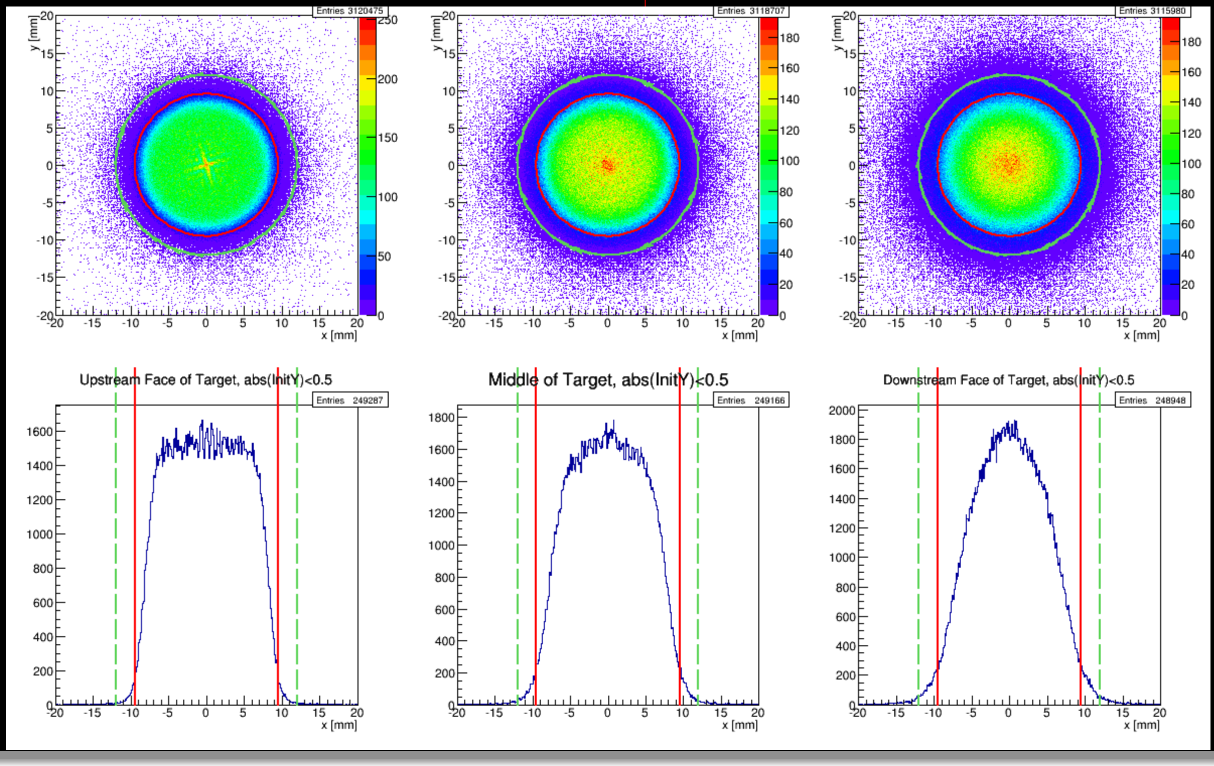


- back half of a 25 mm long target cannot be uniformly illuminated with beam, due to multiple scattering

⇔ concentrates heat and radiation damage

Rastered beam profiles on 12.5 mm long target





- compromise on ½ target length to distribute beam quasi-uniformly

⇔ *most of the 12.5 mm target length* can be filled with beam

HDice

Based on results from simulation of UITF beam:

- Scattering off of Rad Baffle and focusing from fringe fields give rise to nodes
  → tune beam energy to 7.86 MeV → shifts node to front face of HD

- Focusing from fringe fields also affects beam position
  → 12.0 mm radius at launch focused to 8.5 mm radius on target front face
  → to fill target face as much as possible, but allow for misalignments,
  max HD radius = 9.5 mm

- Multiple scattering creates an enhancement in the center of the target that grows with z
  → for a quasi-uniform illumination of the target with electrons,
  max HD length = 12.5 mm

HDice

Electron Beam Requirements for HDice target tests in the Injector Test Facility Upgrade

Parameter	Range	Remarks
Energy	$E_{Beam} \geq 5$ MeV	
Current	100 pA $\leq I_{Beam} \leq$ 2 nA	
Beam size	50 µm < $\sigma_{x,y}$ <150 µm	as small $\sigma_{x,y}$ as possible is preferred
Energy Spread	$\sigma_E/E<10^{-3}$	
Polarization	≥ 70%	Longitudinal only, after two 45^0 bends up to the HDice IBC (which should ~ cancel precession); transverse polarization is not required
Helicity Flip Rate	1 – 30 Hz	
Frequency of Polarization Measurement		Every 4 hrs. in the beginning. As confidence builds up that polarization is stable, once every 2 days.
Beam Halo	$< 10^{-4}$	At 1 mm from beam center at the target
Beam position stability	contained within one $\sigma_{x,y}$	

To be sorted out:

- Monitoring beam position:
  - Control over and verification of the beam is essential. “Flying blind” is too risky
  - Existing BPMs cannot accurately see the beam at these currents and energies.
  - “High” current pulses (<10nA)?
- Downstream beam dump:
  - Electrons will exit IBC in a cone. Size of beam dump depends on z location, exit beam pipe.
  - Electrons are low energy (won’t take much material to stop). Ex: 1 inch of Al can stop 98.8% of incident electrons
- Dealing with Earth’s B field:
  - Not an issue if beam can be steered to be normal to Radiation Baffle
  - If not, a small rotation of the IBC can be used to compensate for the bending caused by Earth’s B field.

HDice

END