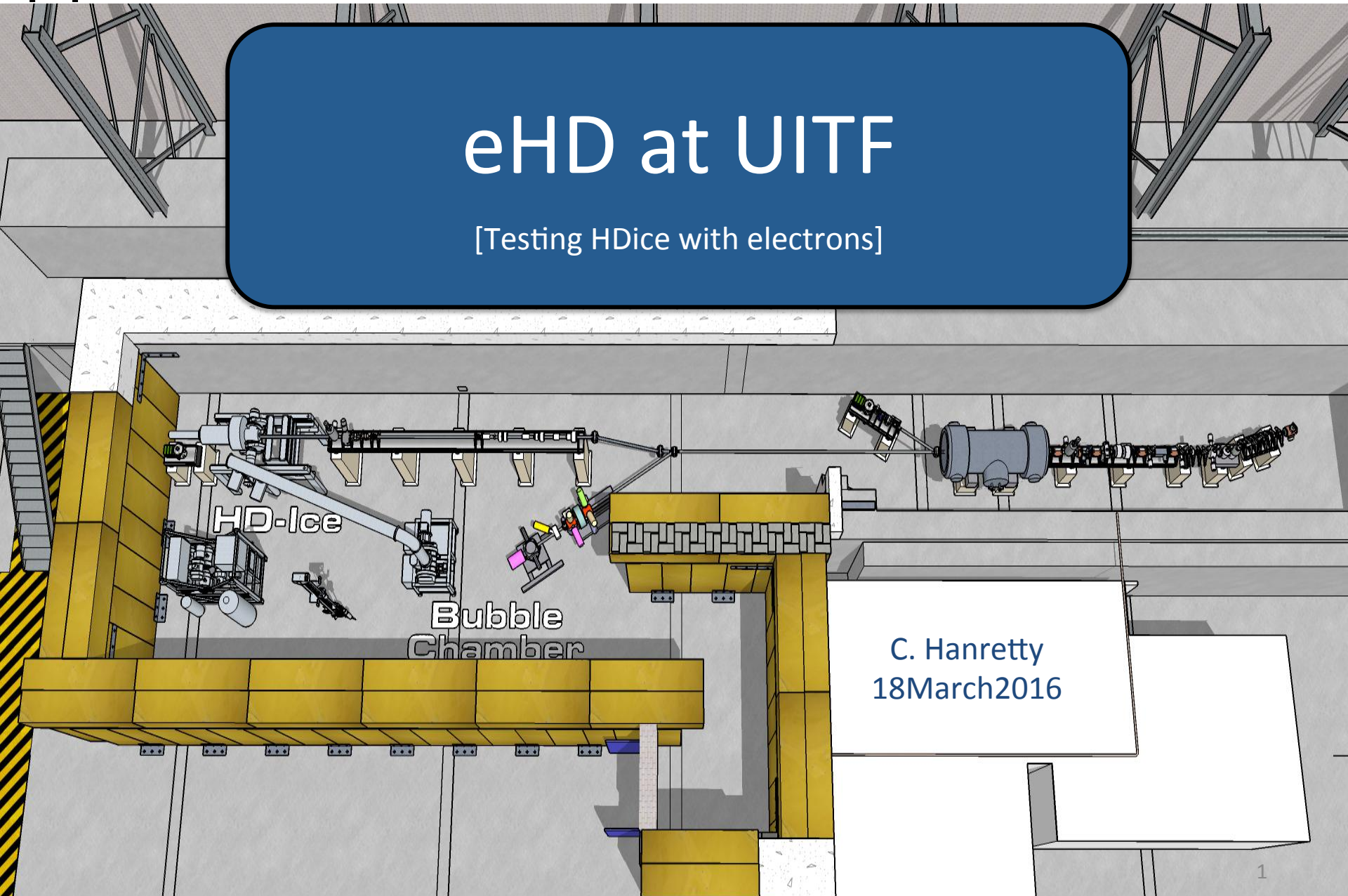
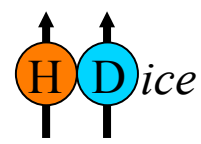


# eHD at UITF

[Testing HDice with electrons]

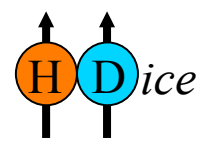


C. Hanretty  
18March2016



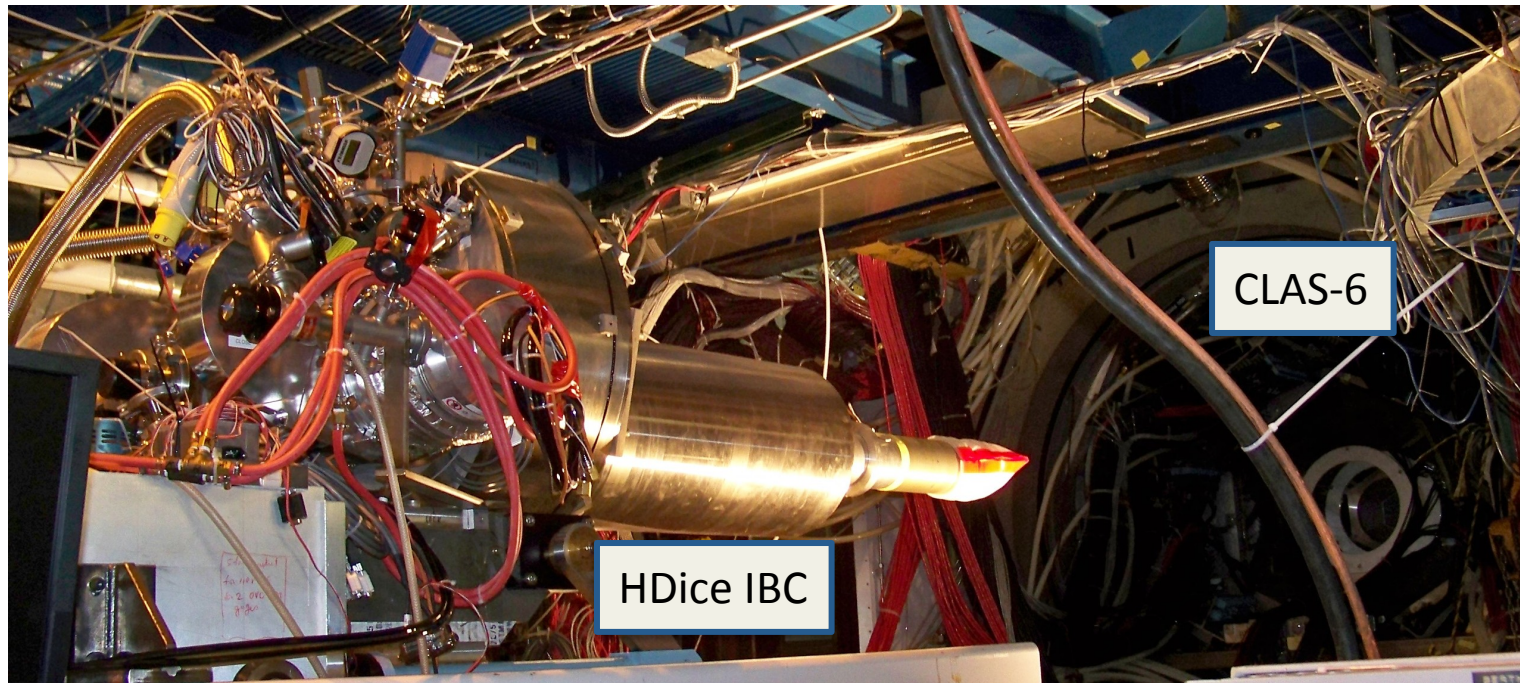
# Outline

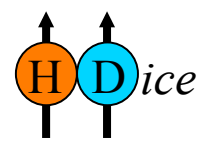
- Brief overview of HDice
- Lessons learned from 2012 eHD tests
- Why can we use MeV-scale electrons?
- Challenges of using MeV electrons with IBC
- Beam requirements for eHD at UITF
- Remaining tasks



# What is HDice?

- A new type of frozen spin target.
- Target material consists solely of polarizable protons and deuterons  
→ 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.

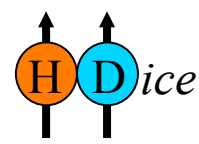




# What experiments benefit?

- 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]

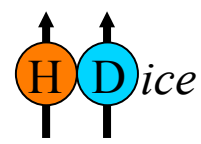




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  - DVCS, PR12-12-101, Latifa Elouadrhiri,... [A;**C1**]

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

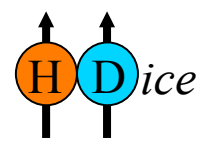


# 2012 eHD Test in Hall B

- 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 frequency but with no apparent effect.
  - ➔ Buildup of ortho- $H_2$  which can shorten  $T_1$  of material
    - Analysis of gas after 1nA-week in beam showed no large increase of ortho- $H_2$  (measurements had limited resolution)



# 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

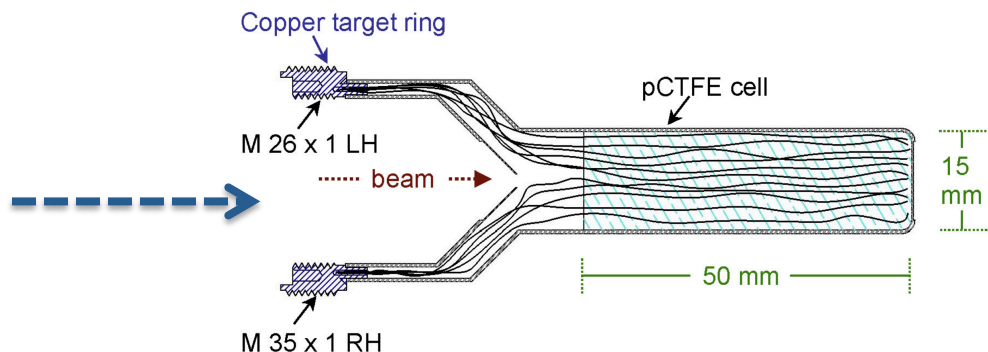
- Results attributed to three possible depolarization mechanisms:
- Beam unpairs 1s molecular electrons in target material
    - Electron(s) may be unpolarized (depends on temperature)
    - If unpolarized (or has low polarization), flips with frequency that has harmonics at nuclear Larmor frequencies 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.

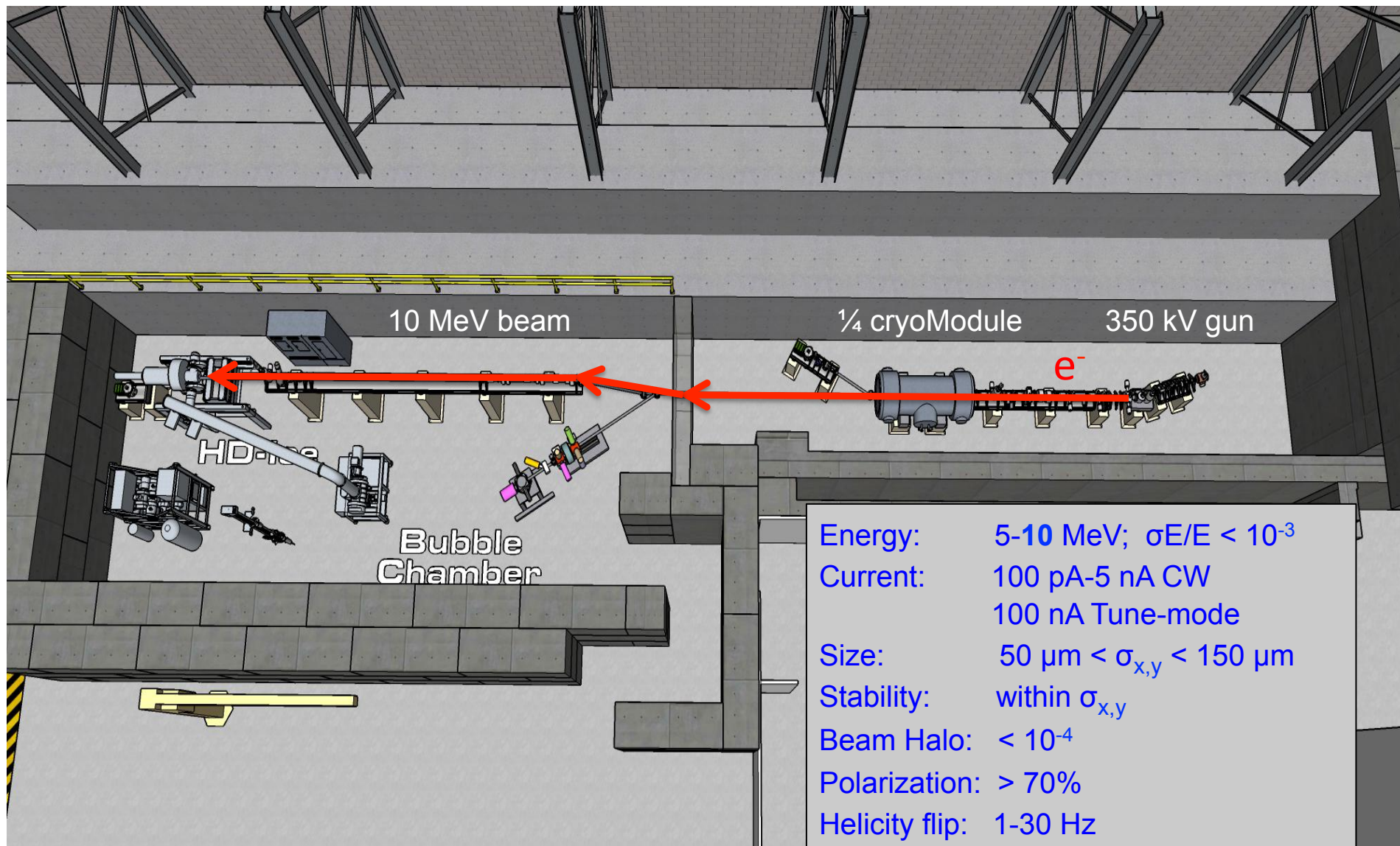
➔ Faster Raster, shorter Al wires, higher purity Al, smaller HD cell

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

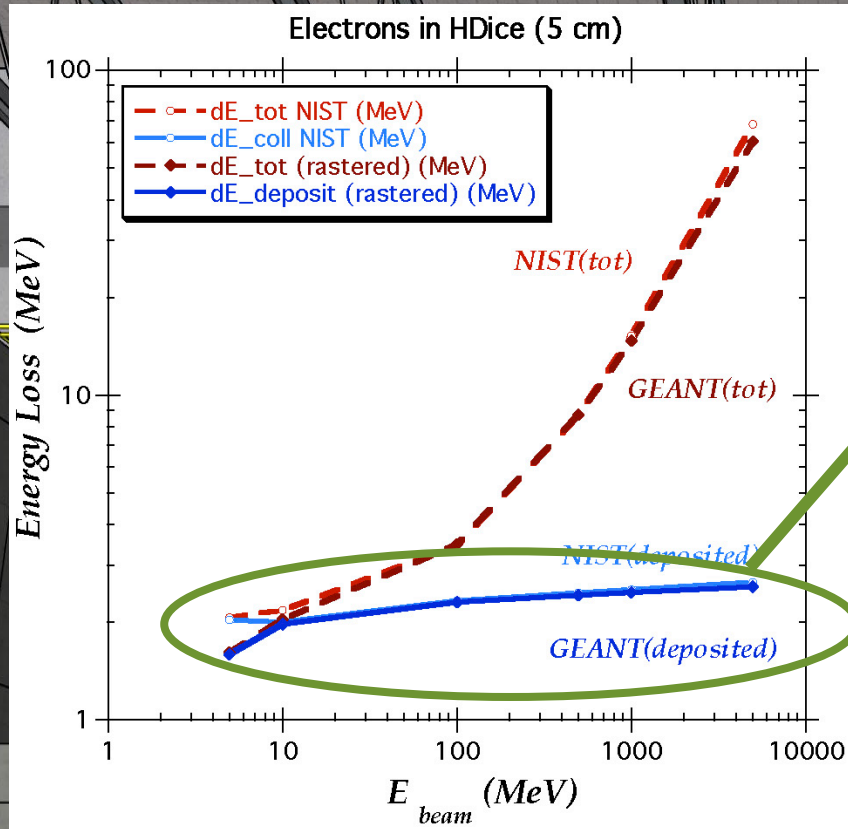




# eHD Tests in UITF



# eHD Tests in UITF

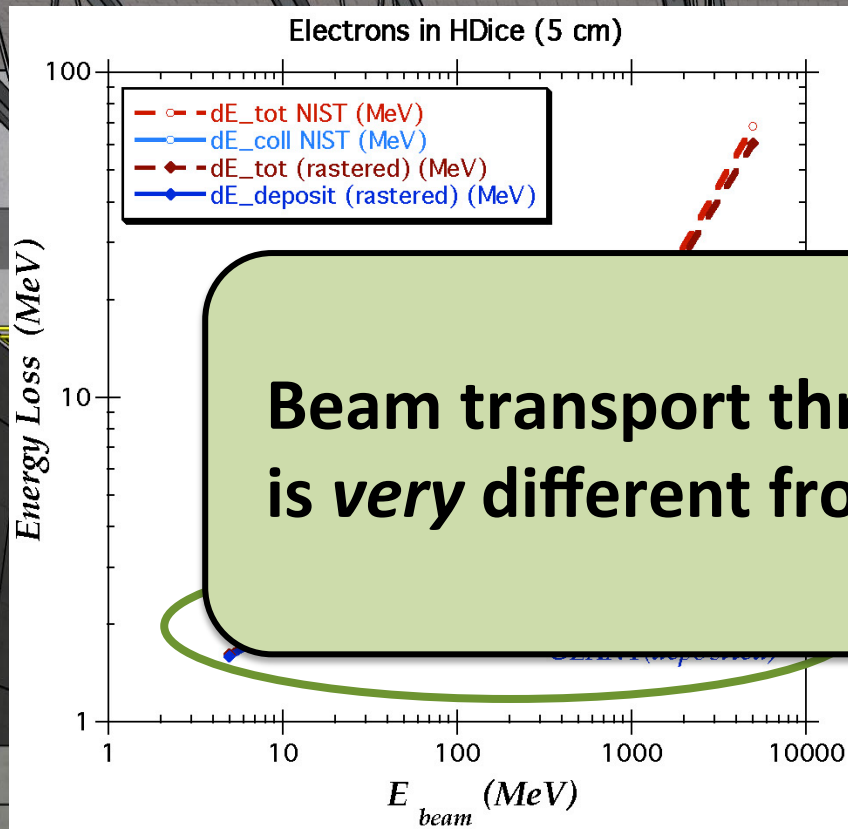


Ionization and energy **deposition**  
are approx independent of  $E_{beam}$

UITF at 10 MeV  $\approx$  Hall B at 10 GeV

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

# eHD Tests in UITF



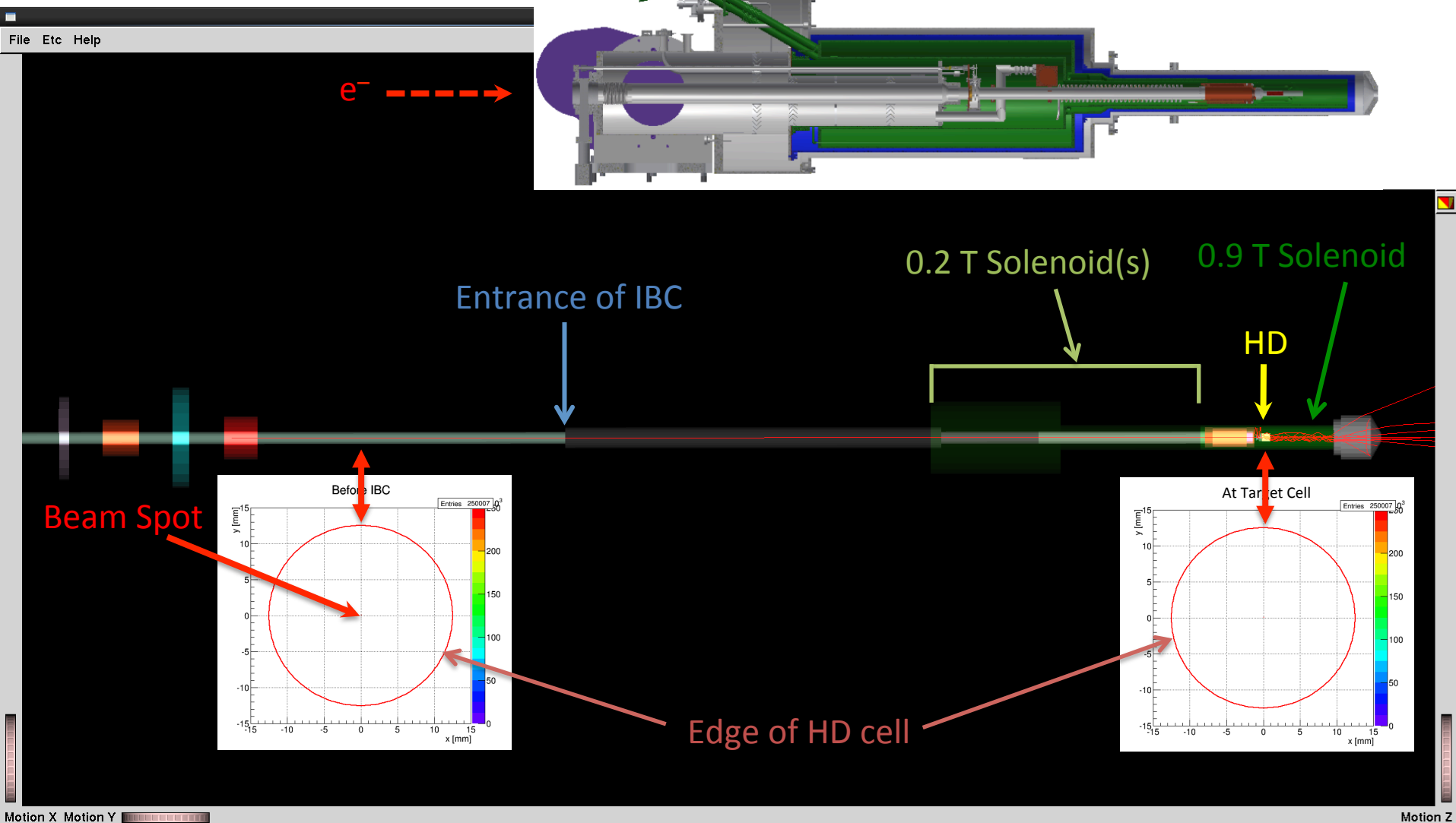
**Beam transport through IBC at 10 MeV  
is *very* different from 10 GeV!!!**

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

at 10 GeV

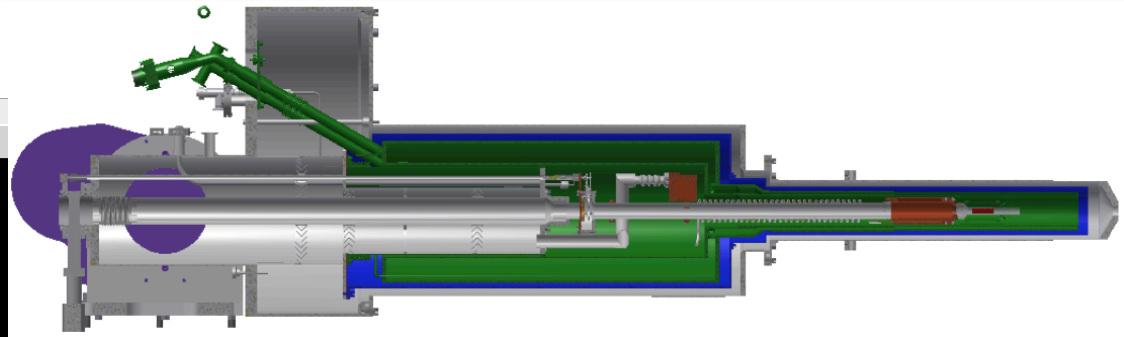
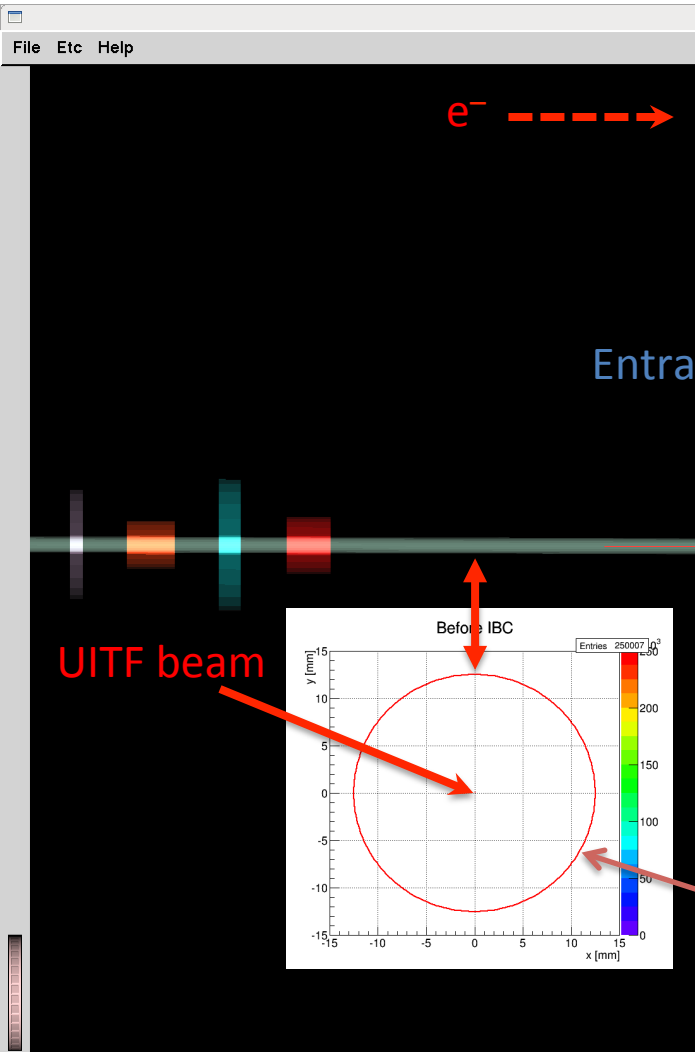
Energy: 5-10 MeV;  $\sigma E/E < 10^{-3}$   
 Current: 100 pA-5 nA CW  
 100 nA Tune-mode  
 Size:  $50 \mu\text{m} < \sigma_{x,y} < 150 \mu\text{m}$   
 Stability: within  $\sigma_{x,y}$   
 Beam Halo:  $< 10^{-4}$   
 Polarization:  $> 70\%$   
 Helicity flip: 1-30 Hz

# Pencil beam into IBC with normal orientation at 10 GeV





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



0.2 T Solenoid(s)

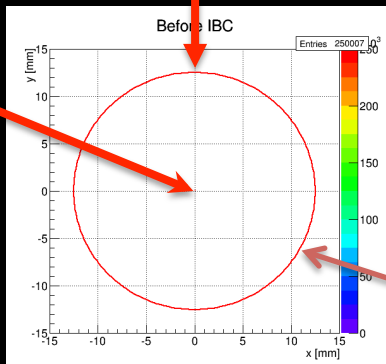
0.9 T Solenoid

HD

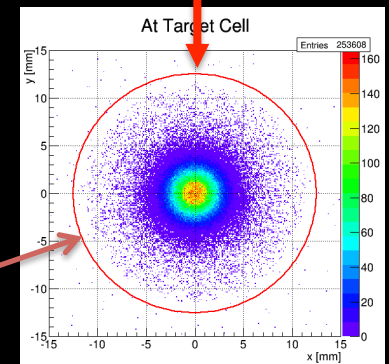
Entrance of IBC

UITF beam

Before IBC

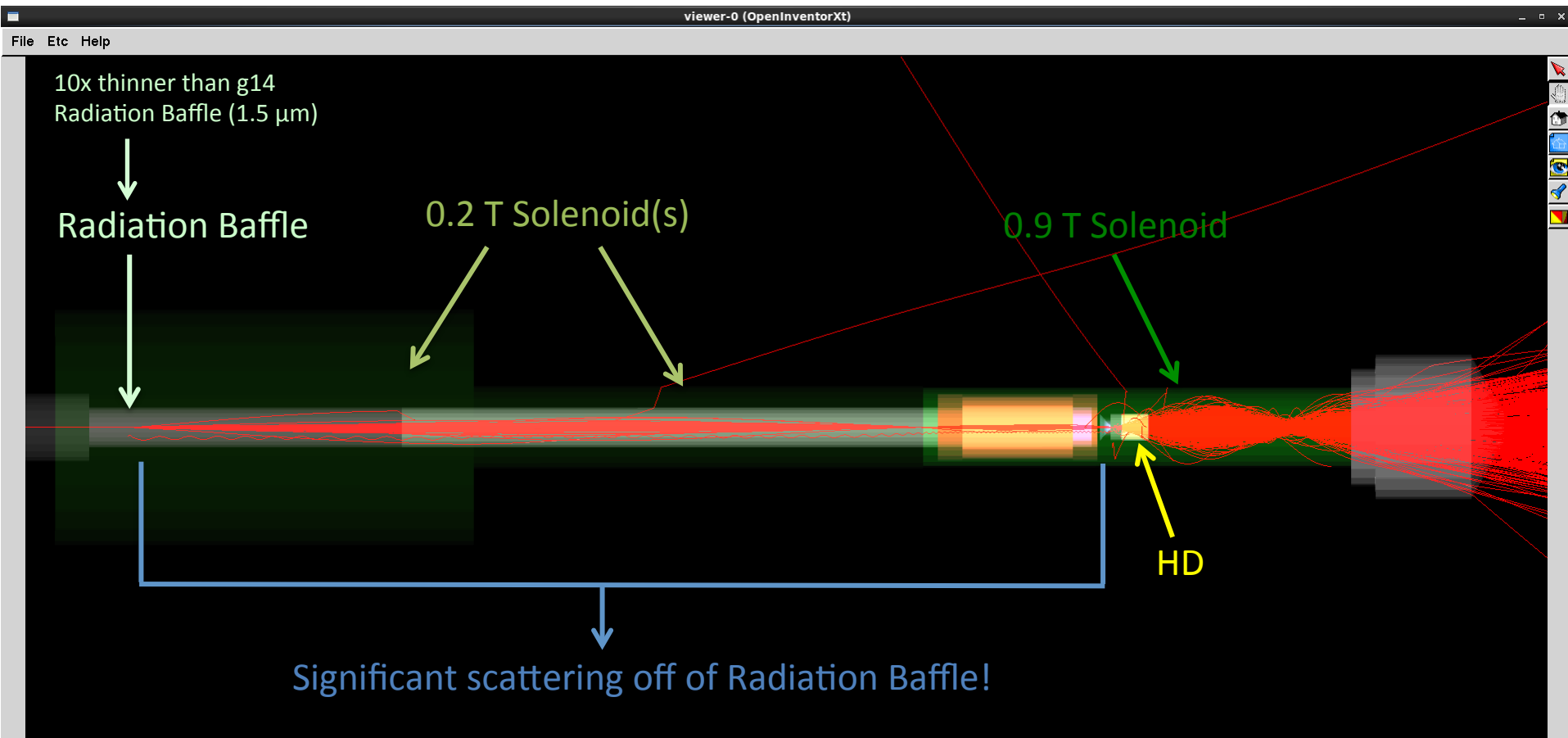


At Target Cell

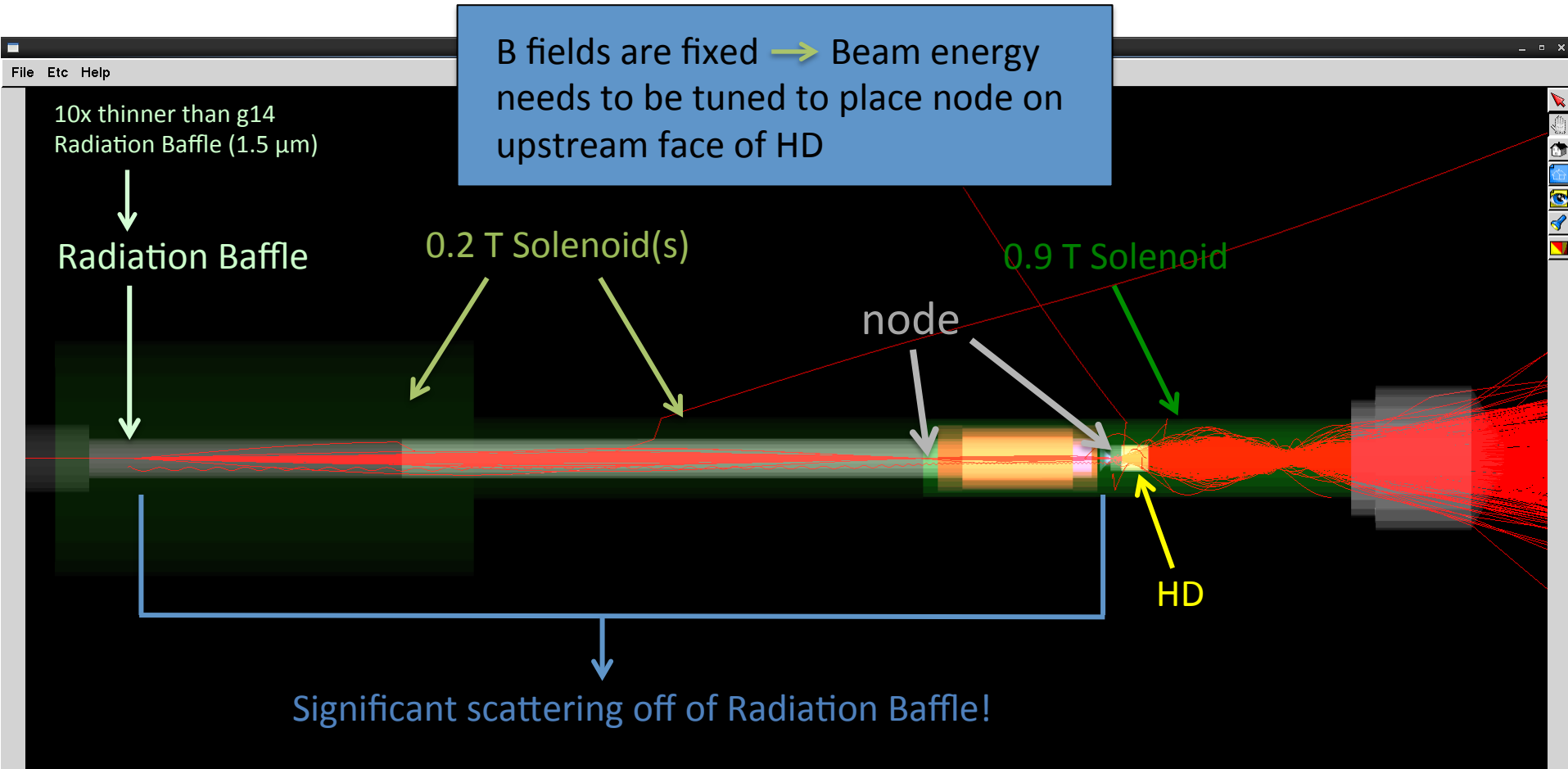


Edge of HD cell

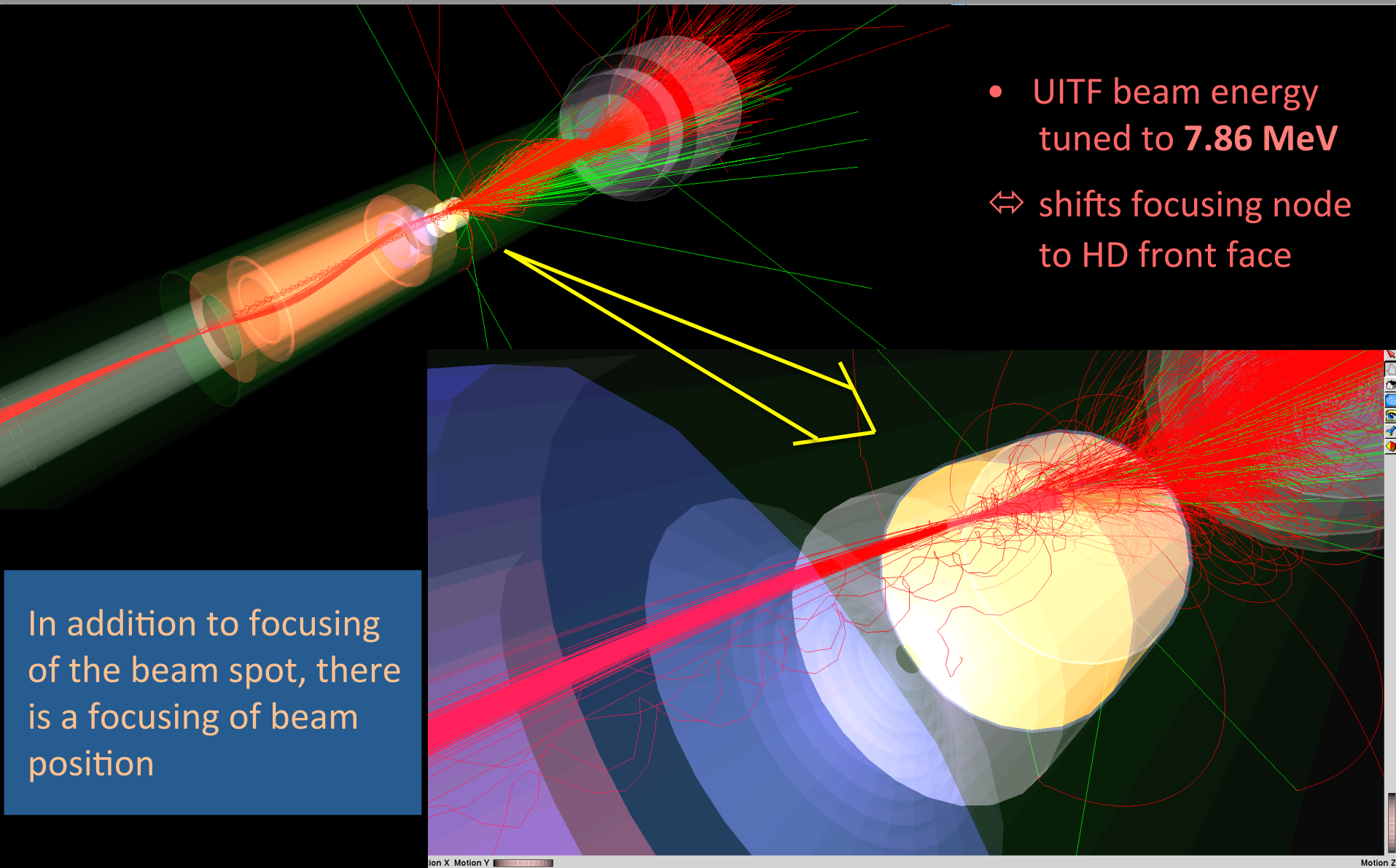
..... a closer view



## ..... a closer view



# (UITF) Pencil beam into IBC with 14 mm offset



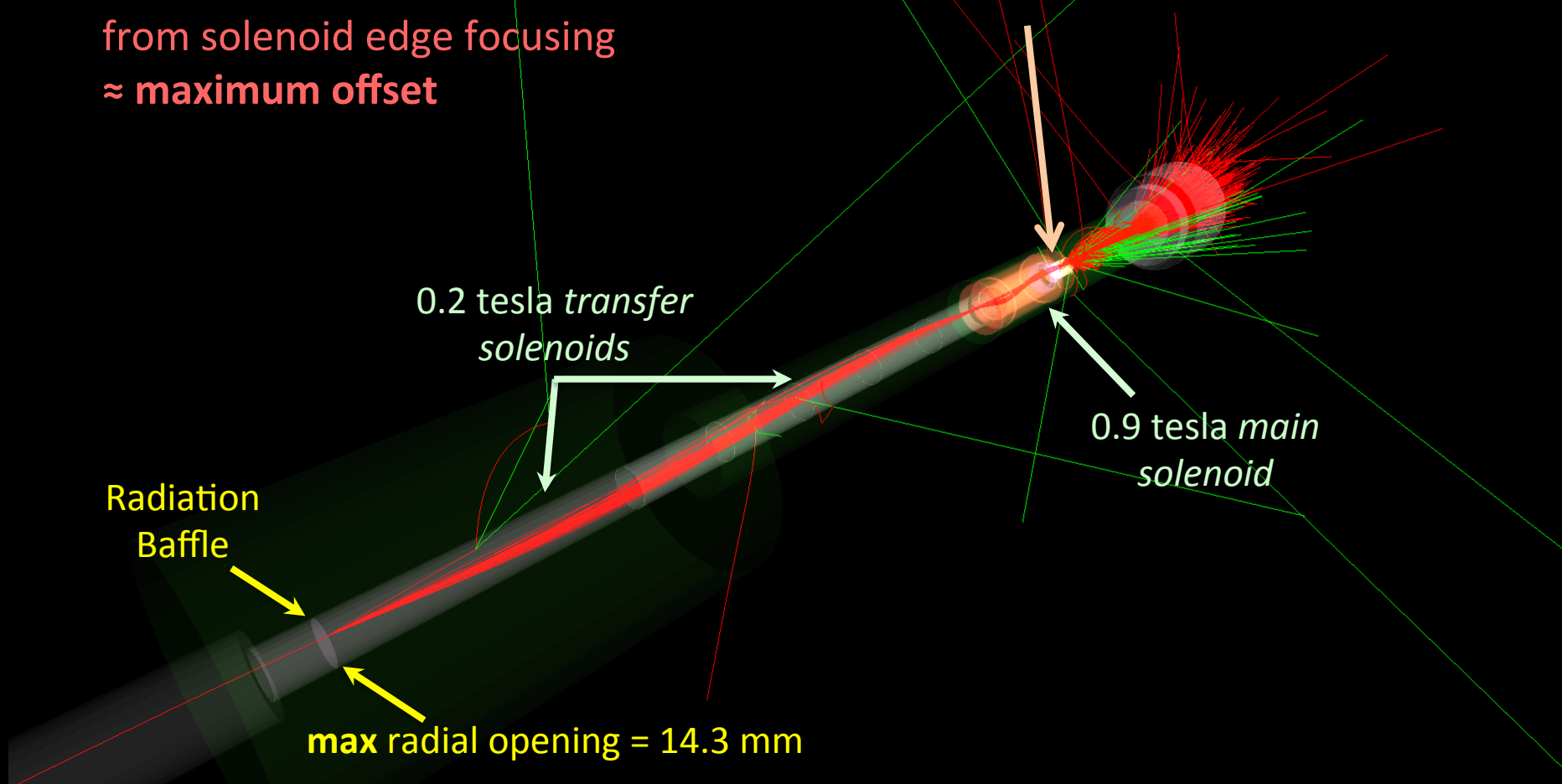


# (UITF) Pencil beam into IBC with 14 mm offset

Pencil beam offset 14 mm at launch

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

Focused to 10mm at HD



# (UITF) Pencil beam into IBC with 14 mm offset

Pencil beam offset 14 mm at launch

↔ 13.6 mm offset at Radiation Baffle,  
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Focused to 10mm at HD

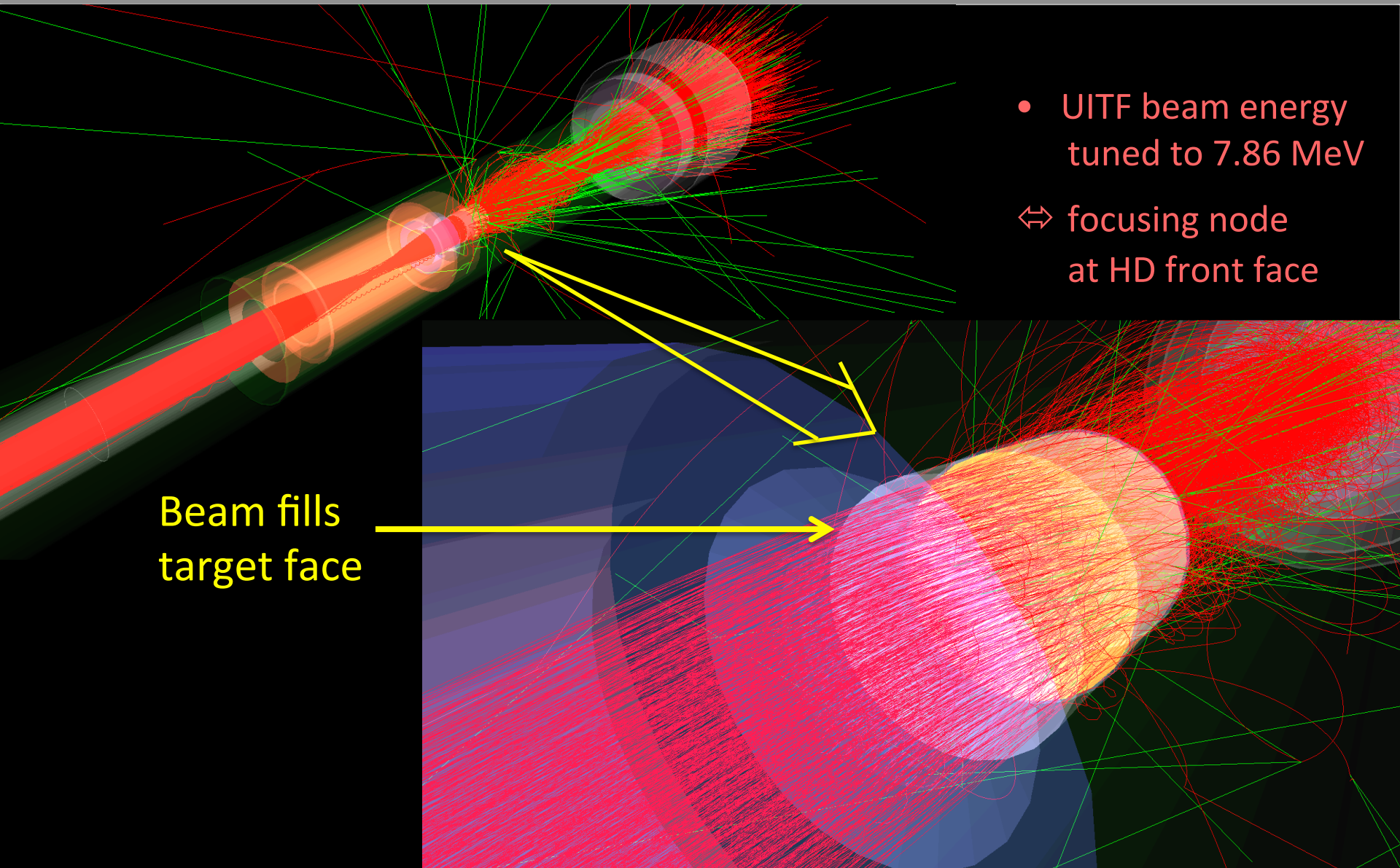
Reduce target radius:  
12.5 mm → 9.5 mm  
[CLAS-12] [UITF]

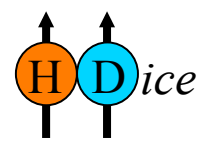
0.9 tesla *main*  
*solenoid*

Radiation  
Baffle

**max** radial opening = 14.3 mm

## (UITF) Uniform rastered beam into IBC

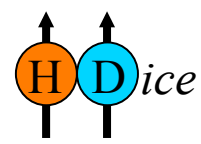




## Based on results from simulation of UITF beam:

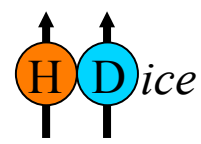
- Scattering off of Rad Baffle and focusing from solenoids give rise to nodes  
→ tune beam energy to 7.86 MeV → shifts node to front face of HD
- Focusing from solenoids also affects beam position  
→ 12.0 mm radius at launch focused to 8.5 mm radius on target front face  
→ to fill target face as much 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





# Beam Requirements for eHD at UITF

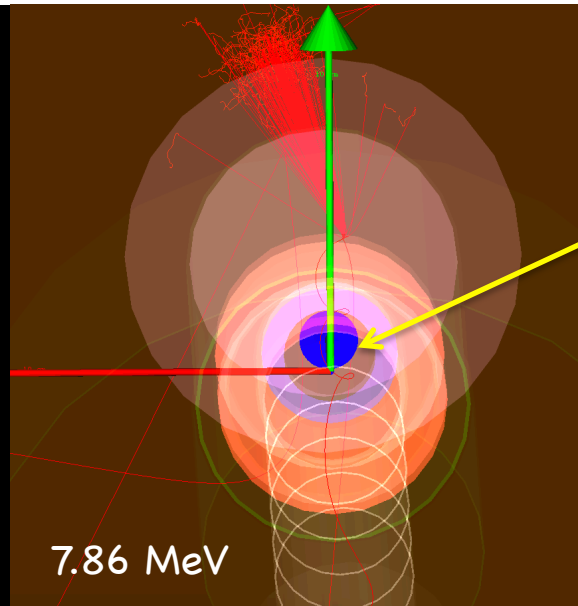
Parameter	Range	Remarks
Energy	$E_{\text{beam}} \geq 5 \text{ MeV}$	
Current	$I_{\text{beam}} < \text{few nA}$	
Beam Size	$\sigma_{x,y} \approx 150 \mu\text{m}$	<b>As small <math>\sigma_{x,y}</math> as possible is preferred</b>
Energy Spread	$\sigma_E/E < 10^{-3}$	
Polarization	$\geq 70\%$	Longitudinal only, after two $45^\circ$ bends up to the HDice IBC (which should approx. cancel the 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	<b>Contained within one <math>\sigma_{x,y}</math></b>	



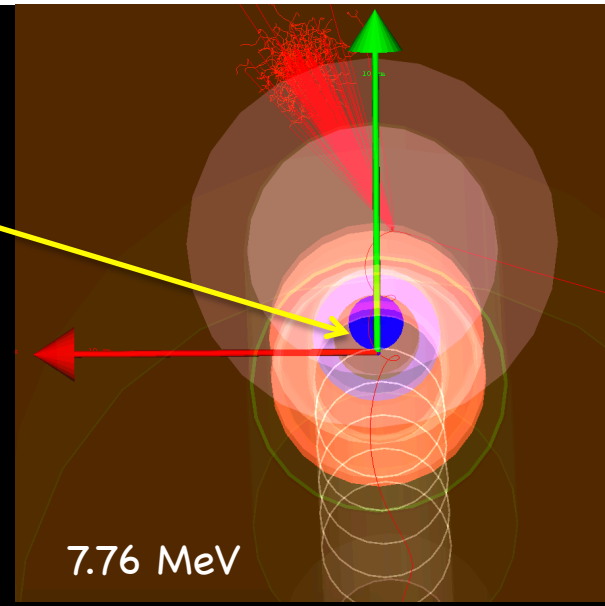
# To be sorted out - I

- Monitoring the UITF beam:
  - 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.
  - Low duty factor, high(er) current pulses ( $<10\text{nA}$ )?
  - Empty target tuning?

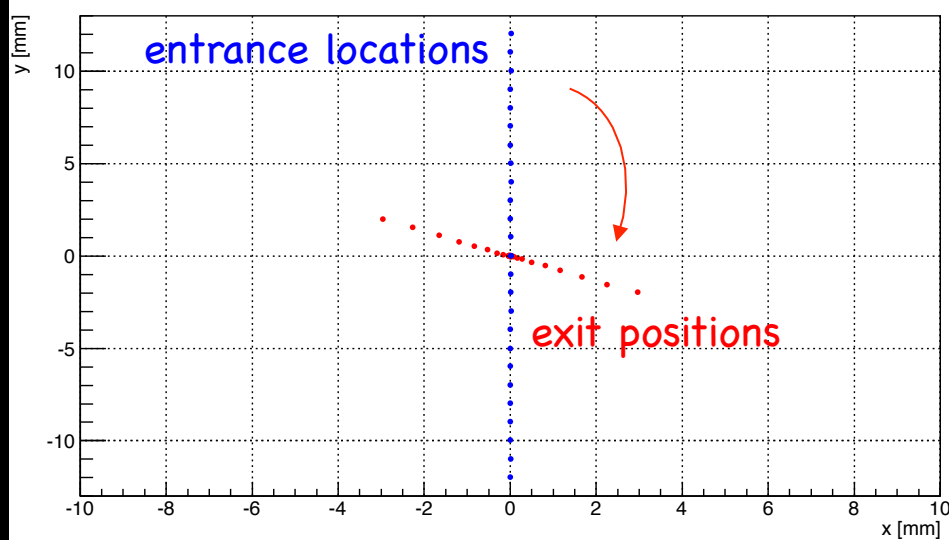
# Optics studies $\Leftrightarrow$ spot rotation sensitive to $E_e$



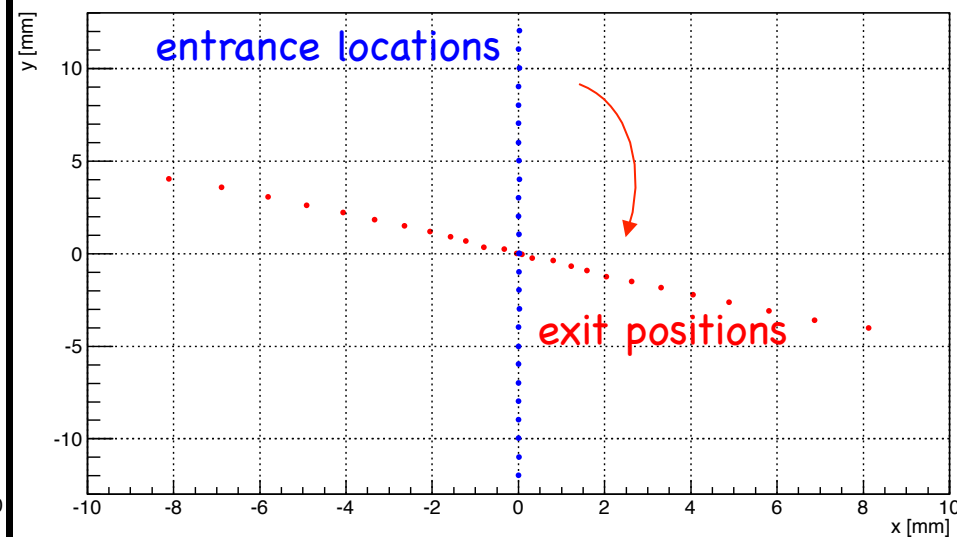
No HD cell

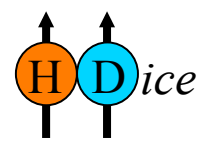


x,y At IBC Entrance (blue) and 250mm Downstream of IBC (red), 7.86 MeV



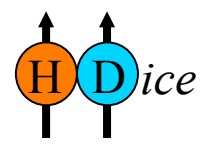
x,y At IBC Entrance (blue) and 250mm Downstream of IBC (red), 7.76 MeV





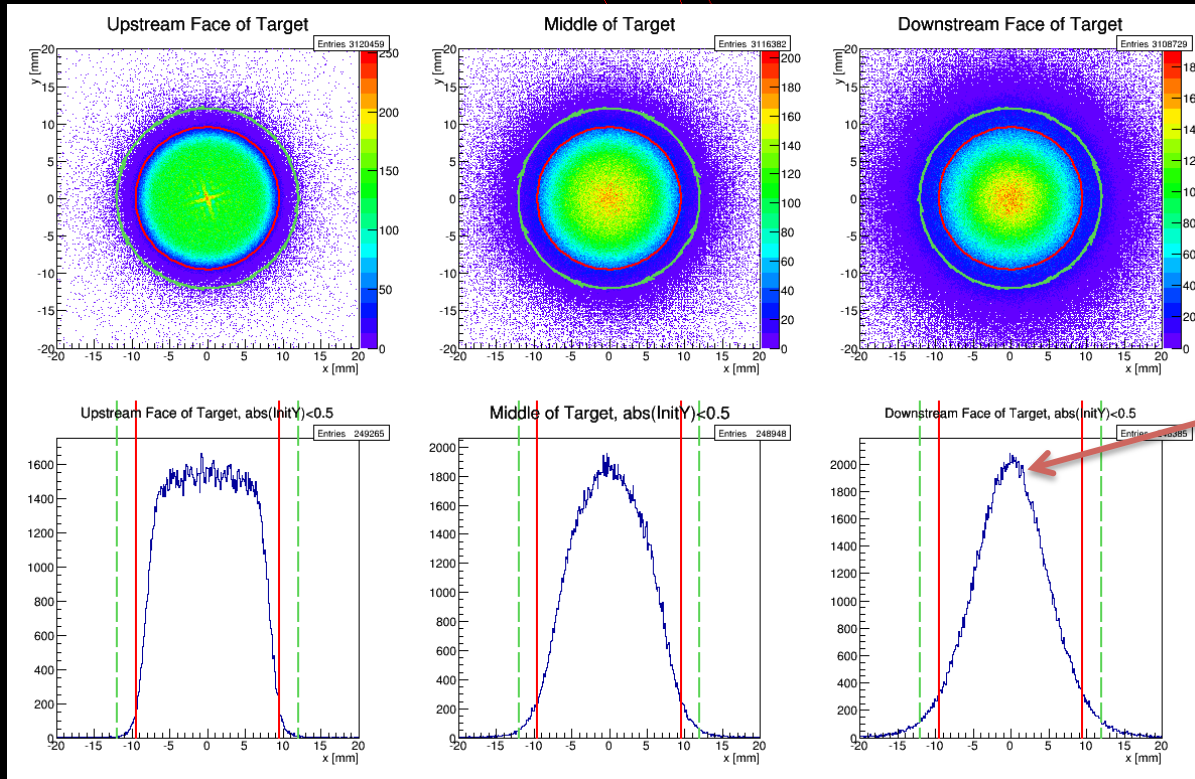
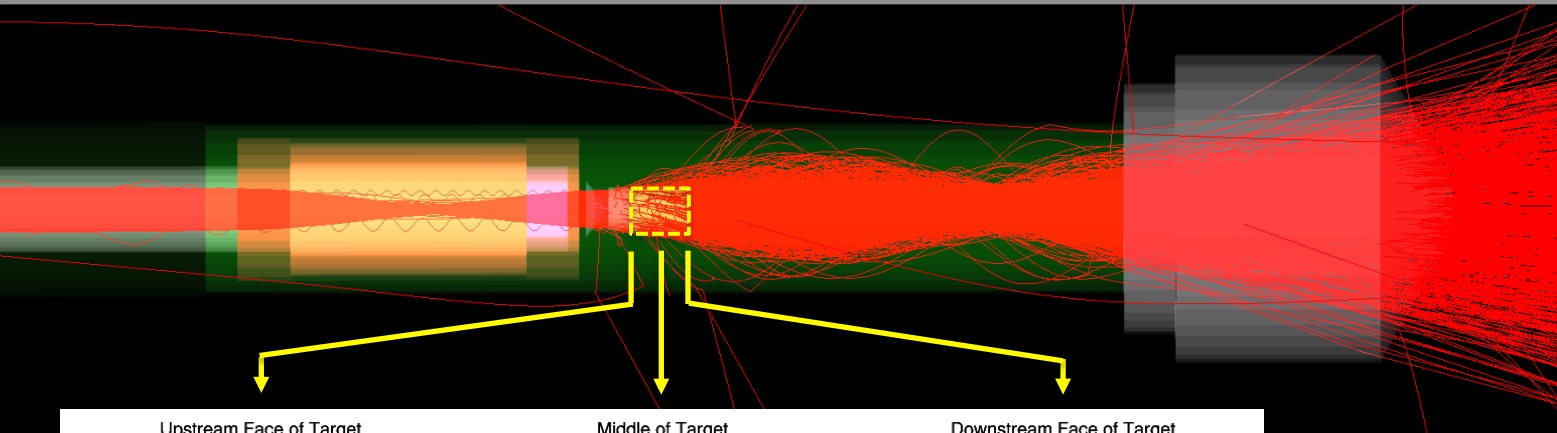
# To be sorted out - II

- Downstream Beam Dump:
  - Electrons will exit IBC in a cone. Size of beam dump depends on z location, diameter of 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.
  - Electrostatic potential on Beam Dump?
- Dealing with Earth's B field:
  - Not an issue if beam can be steered to be normal to Radiation Baffle



END

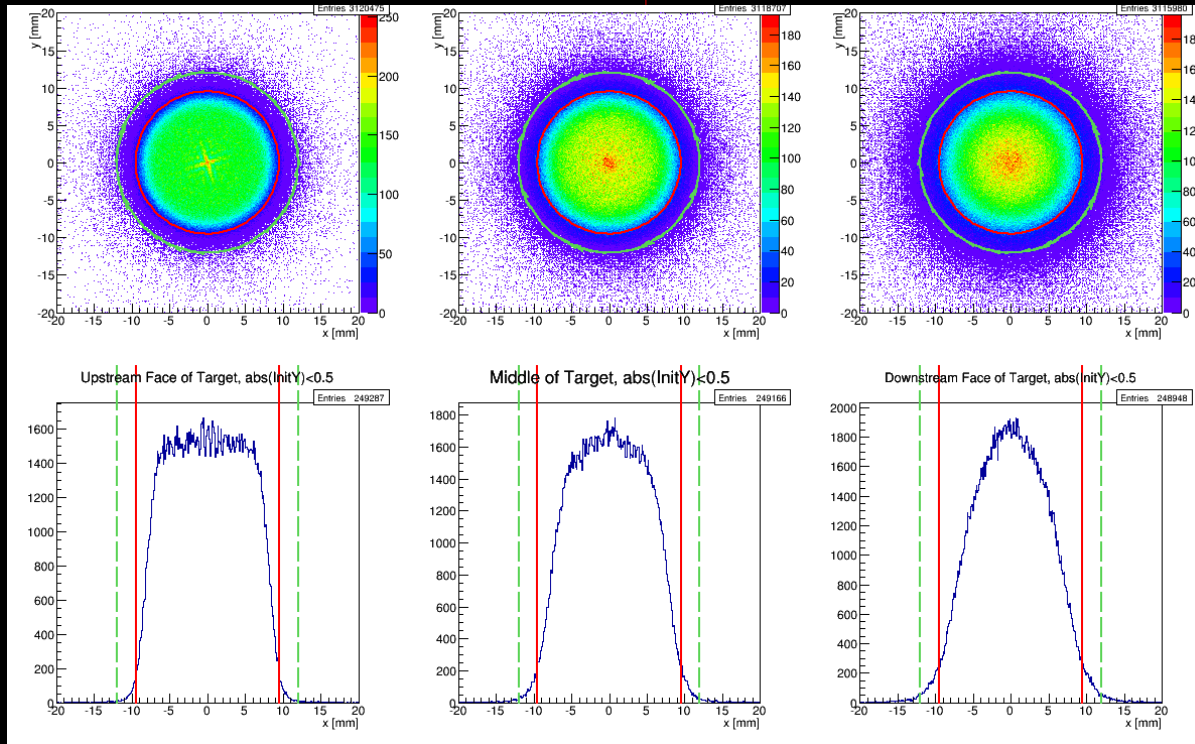
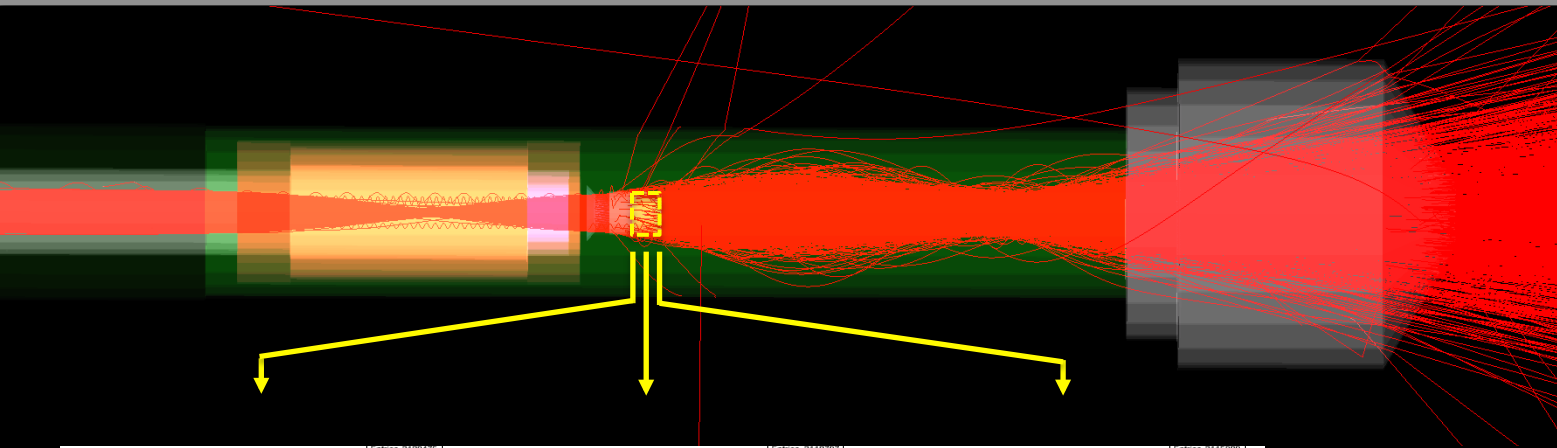
# Rastered beam profiles on 25 mm long target



- 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  $\frac{1}{2}$  target length to distribute beam quasi-uniformly

$\Leftrightarrow$  most of the 12.5 mm target length can be filled with beam