High-k Scattering Development 2016

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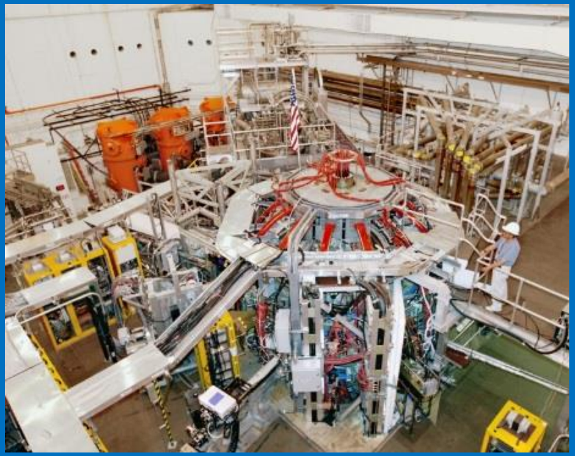
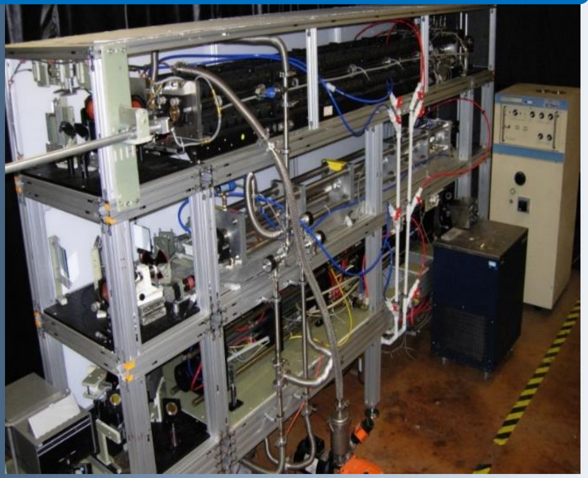




Friday, July 8th, 2016

PPPL

D.M.R.C
Davis MM-Wave Research Center

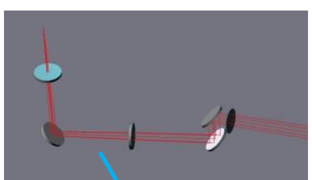
NSTX-U High-k Scattering System

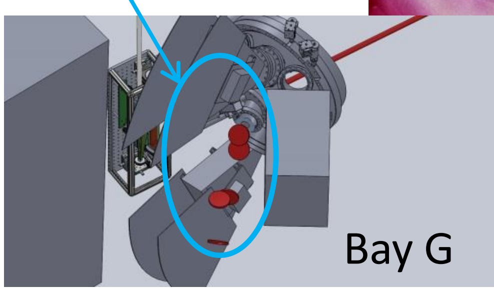
FIR Laser System

- 180 W CO_2 pump laser
- 100 mW FIR formic acid laser

20 m Corrugated Waveguide

Bay G launch optics

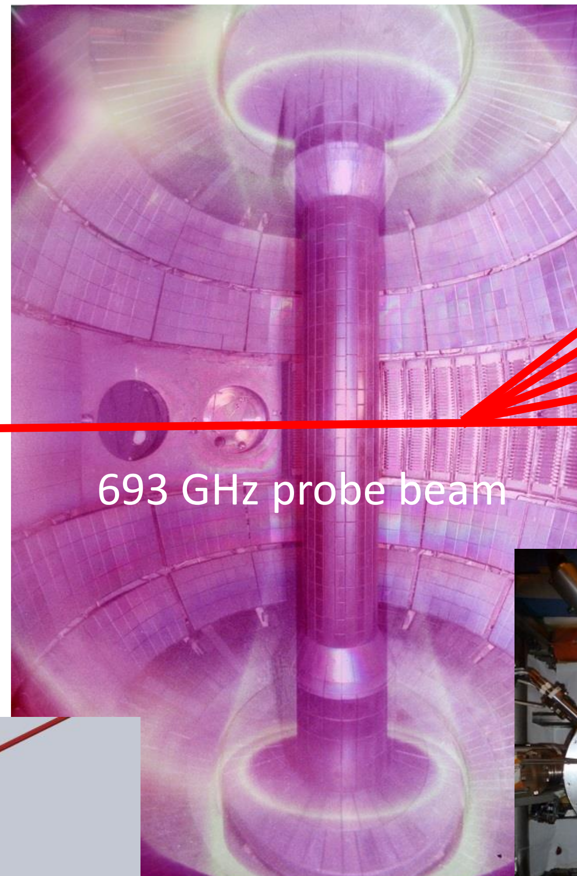




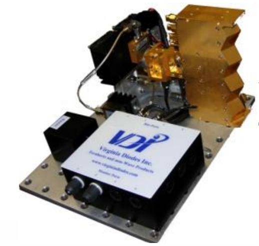
Launch Optics

- Remotely steerable beam ± 2.5˚
- HDPE lenses shape beam

NSTX



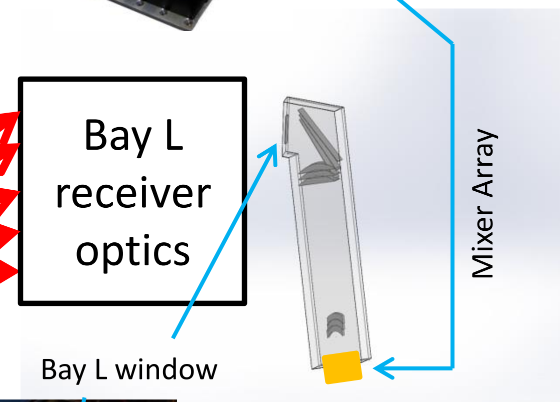
693 GHz subharmonic 4-pixel receiver array

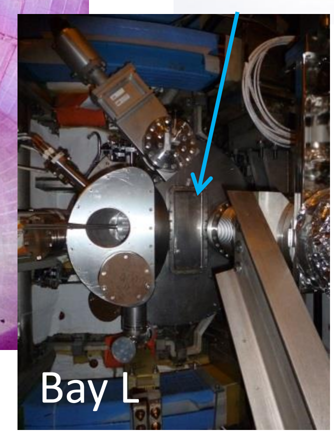


x48

14 GHz LO

Bay L receiver optics

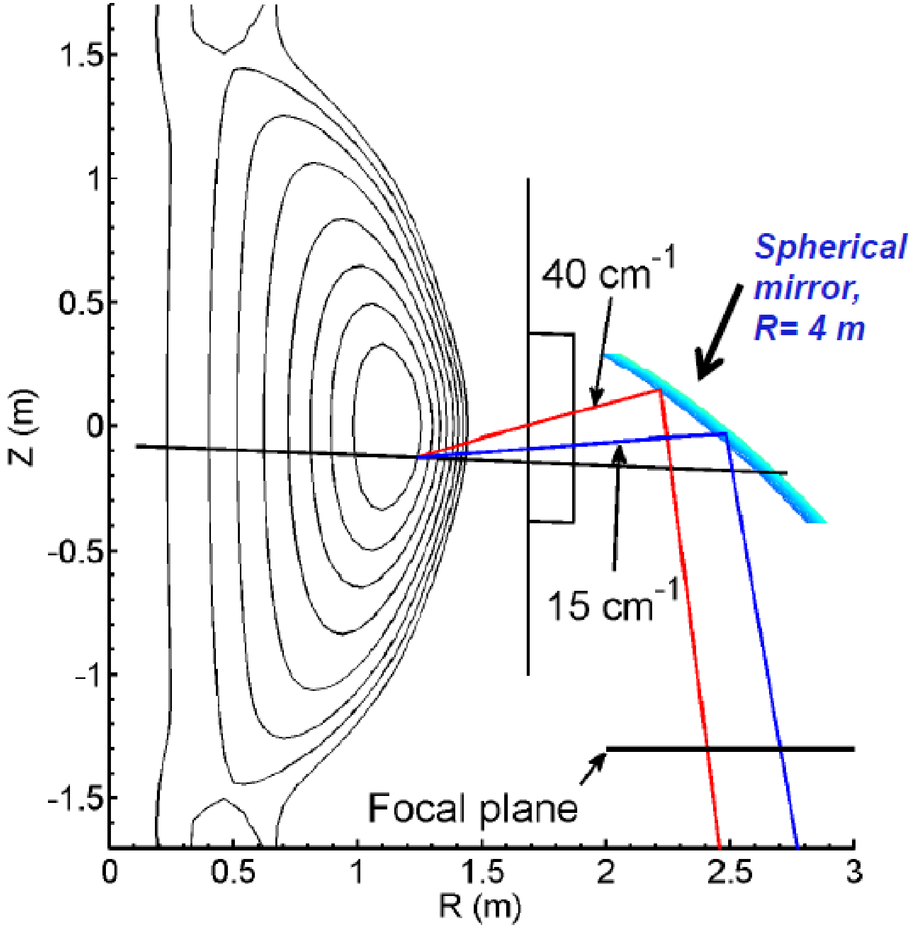


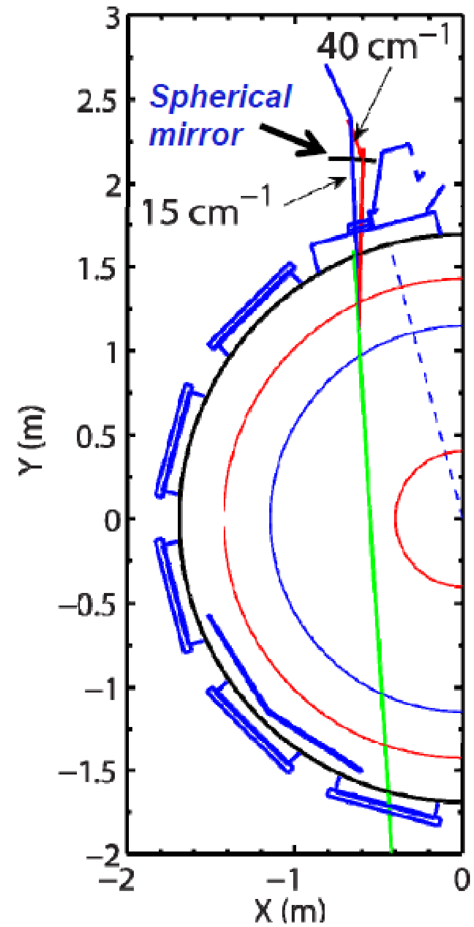


Receiver optics

- Remotely steerable elements
- Scattering angles 2˚ to 15˚
- Bay L 33 cm tall window permits k_θ detection

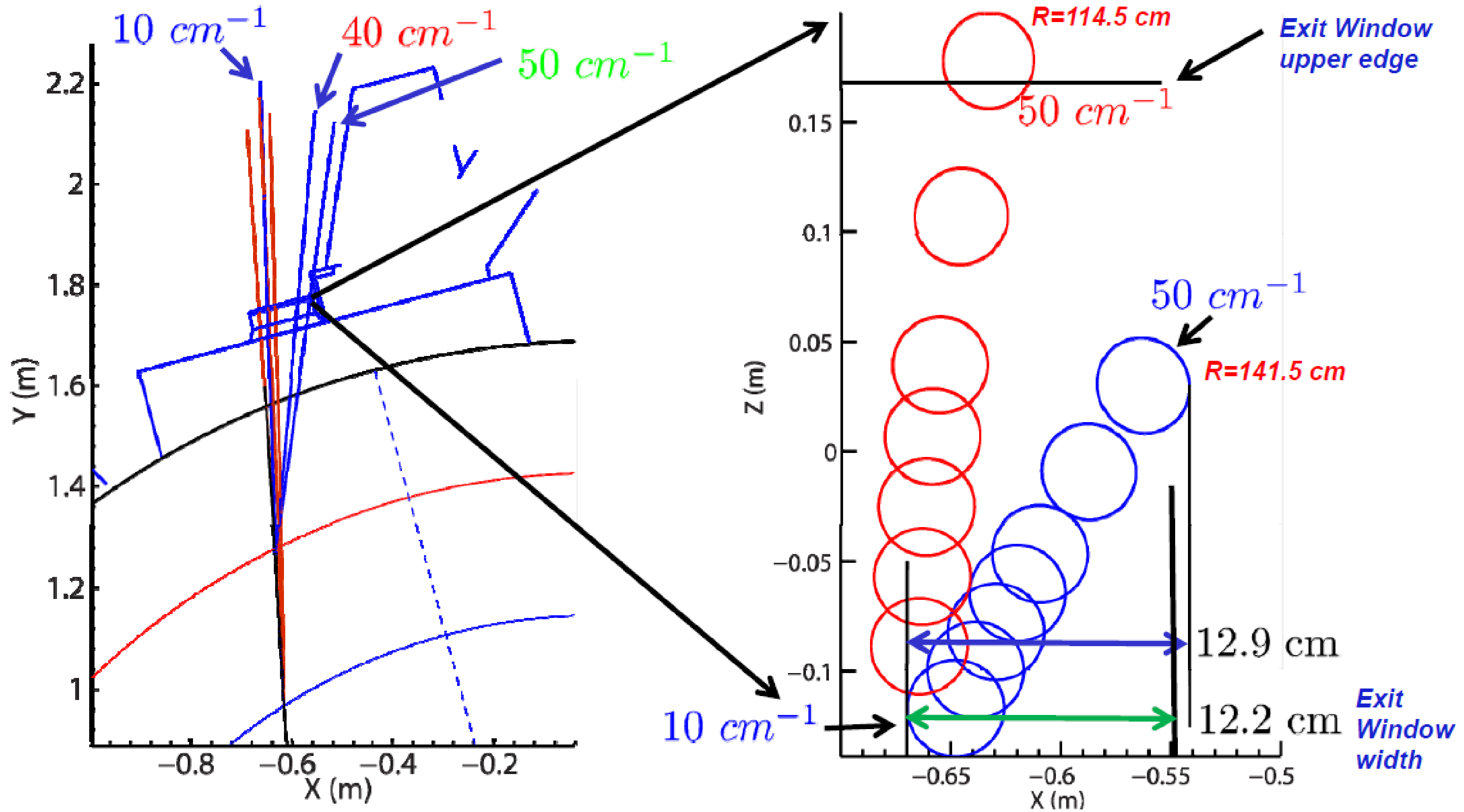
High-k Poloidal Scattering Overview





- Original design by Yang Ren employed large spherical turning mirror to deflect and focus scattered beams on to multi-channel receiver array
- Individual channels correspond to different scattering angles (both poloidal and toroidal), all aimed at the same physical location in the plasma

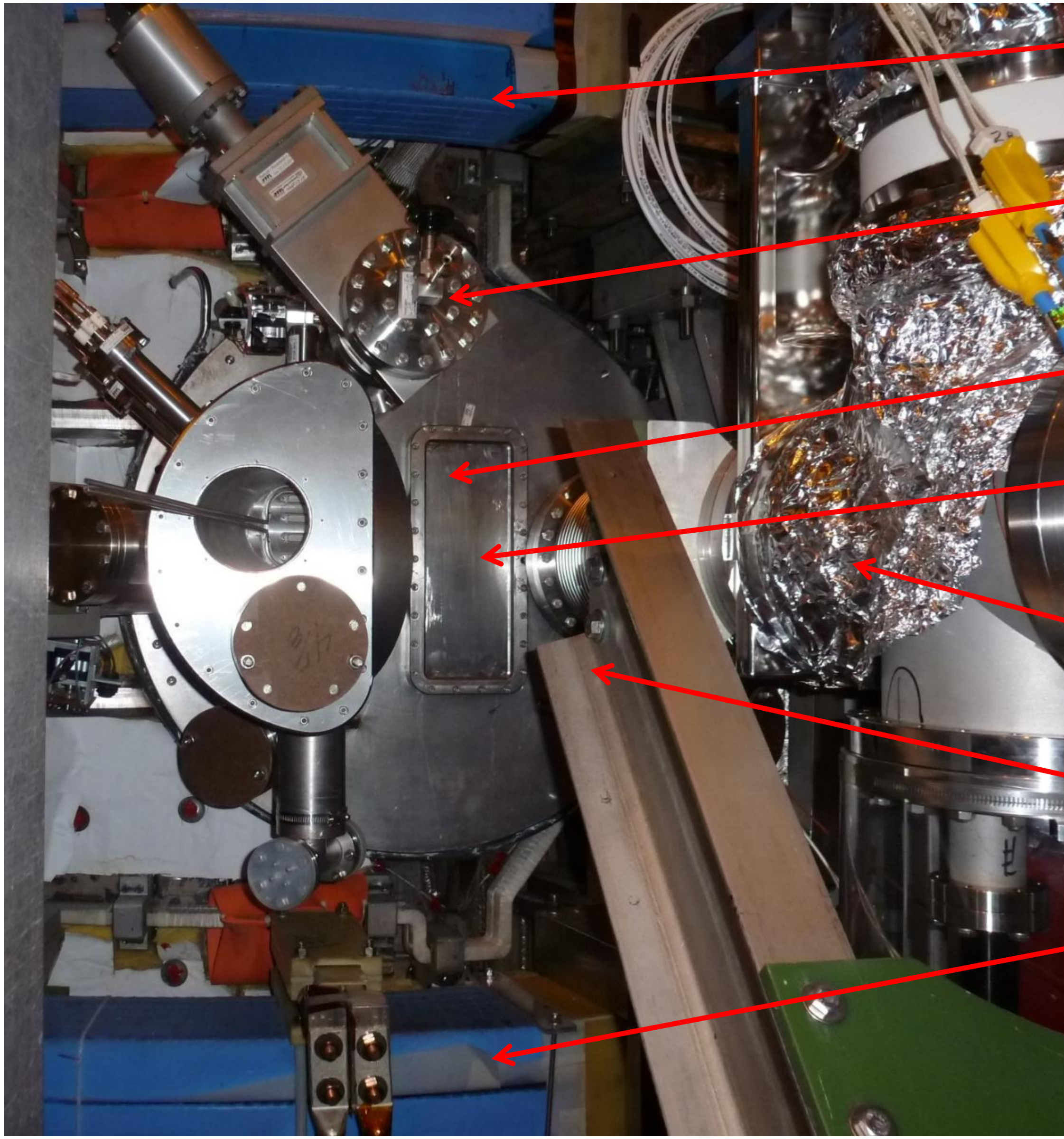
High-k Scattering Physics Goals



Scattering region to be translatable:

- ±15 cm vertically, i.e. above/below plasma midplane
- ±15 cm toroidally, so as to access a limited range of radial wavenumbers
- translatable radially from r/a = 0.1 to pedestal region (r/a ~ 0.99): Δr ~ 50 cm

High-k Optics Constraints on Bay L



Upper PF4 Coil

Fusion Product Detector (system not shown – attaches to gate valve)

Aperture: 12.25" x 4.5625" (311 mm x 116 mm)

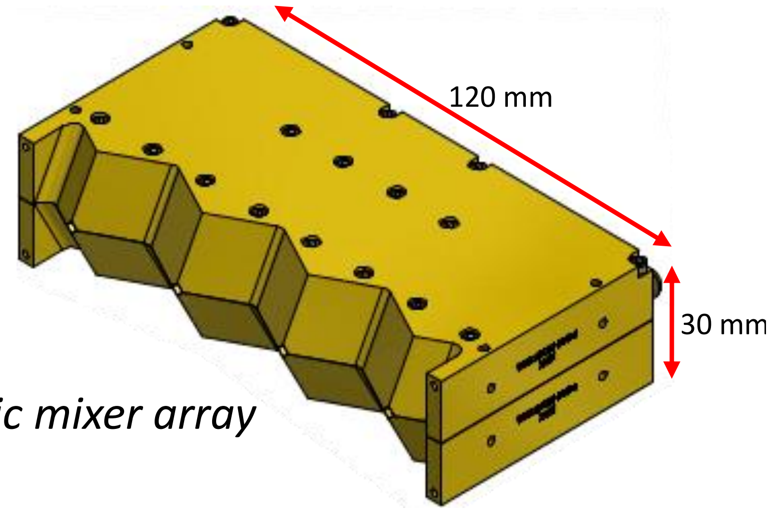
Window: 14.25" x 6.563"x 0.50" (362 mm x 167 mm x 12.7 mm)

Thomson Scattering (TS) Beam Dump

TS Support Flange

Lower PF4 Coil

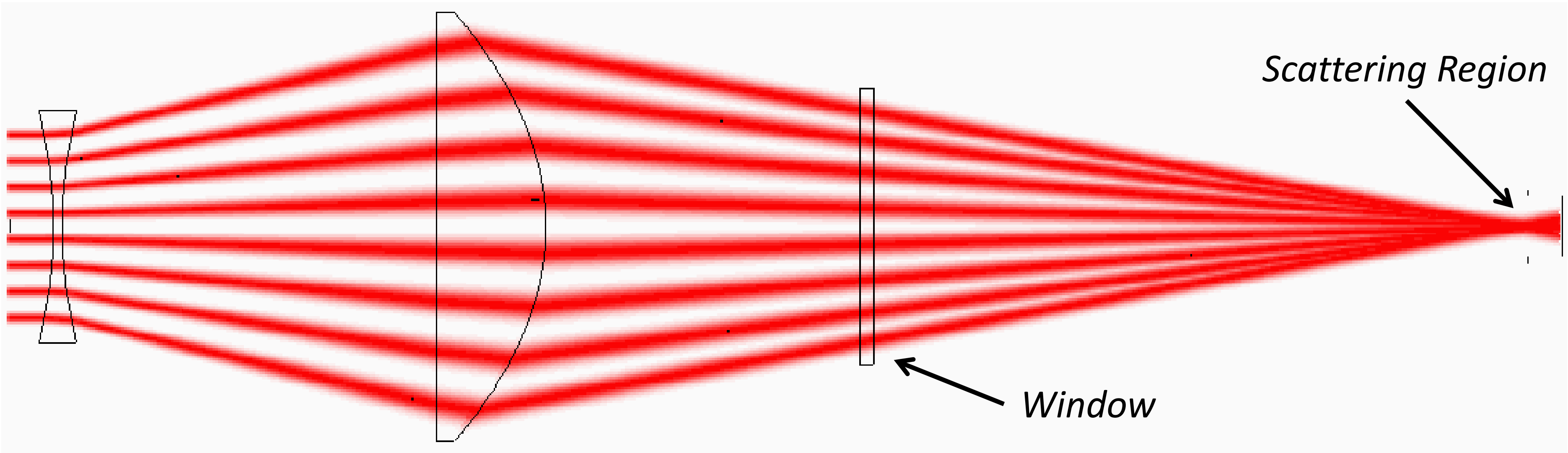
High-k Receiver



4x1 subharmonic mixer array

- The high-k launch beam is passed through the vacuum vessel from Bay G towards Bay L
- The scattered waves pass through a large exit window on Bay L, are collected and then focused down to a multi-channel receiver
- Receiver design based on employing four 4x1 subharmonic mixer arrays, arranged as 8 poloidal/vertical channels by 2 toroidal/horizontal channels
- Initial implementation will employ one 4x1 SHM array, with a second array to be purchased in 2017 to upgrade system to an 8x1 configuration
- Two optical designs (A and B) have been drawn up

High-k Optics Design A (MIR Compatible)



Advantage:

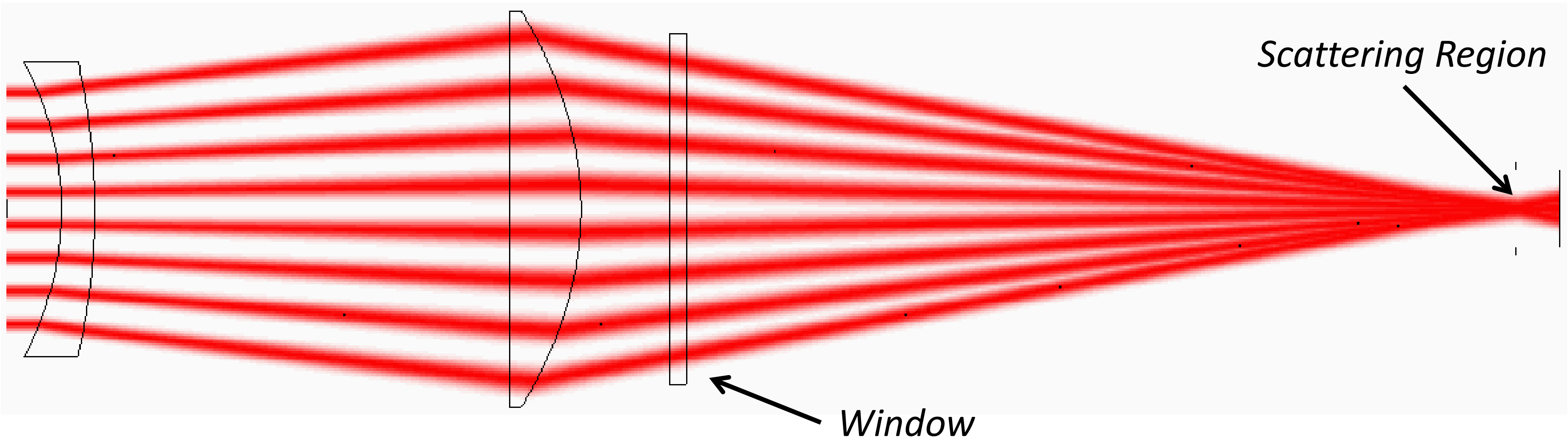
– Microwave Imaging Reflectometer (MIR) polarizing beam splitter to sit between large lens and window, reflecting the MIR beam downwards

Disadvantages:

– Interference with the Fusion Product Detector (FPD) at many scattering angles and radial positions

– Thick lens (12 cm at center) results in higher attenuation (~0.5 dB/cm loss)

High-k Receiver Design B (No MIR)



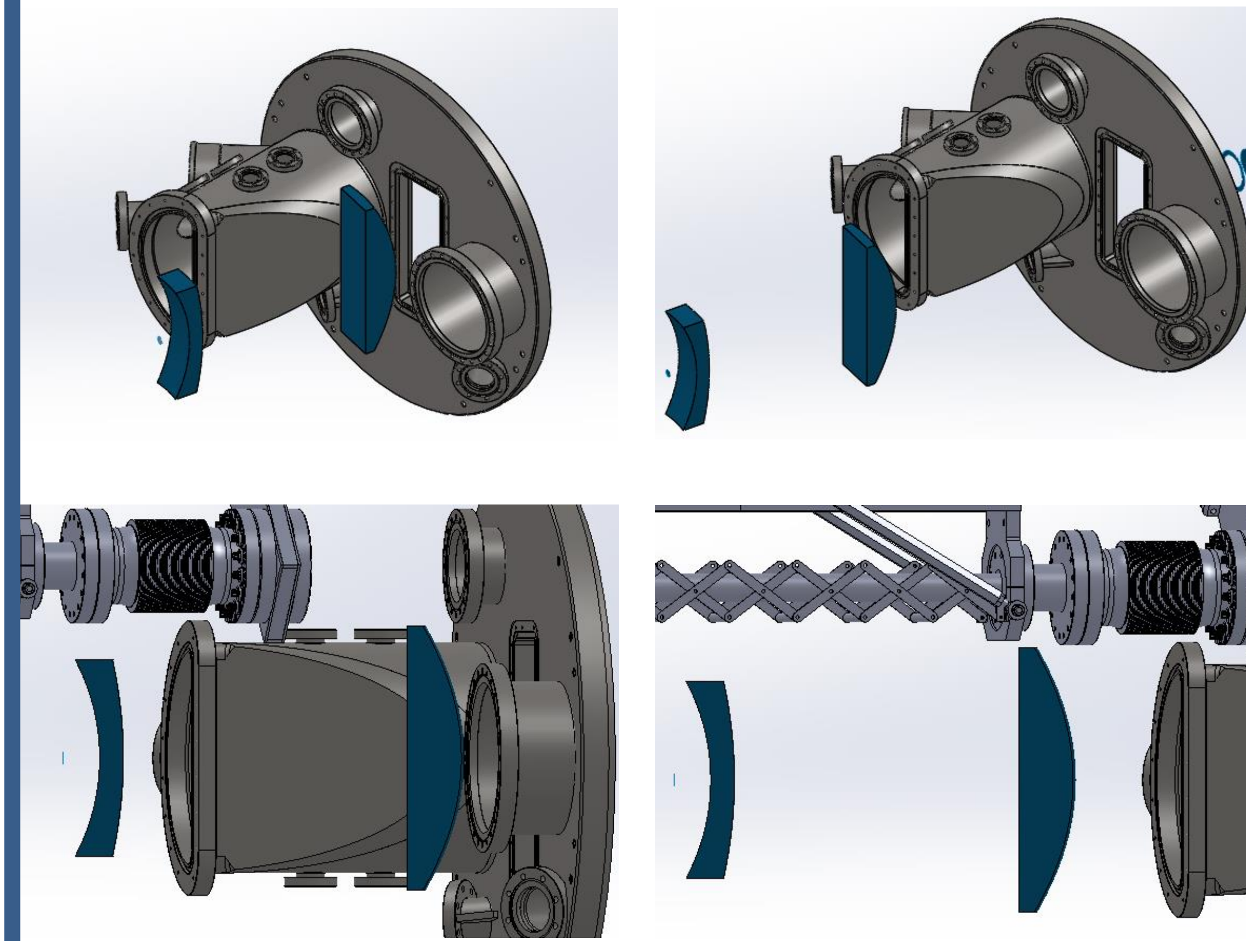
Advantages:

- Largest range of imaging
- Thinner lens (6.5 cm at center) results in reduced absorption (almost 3 dB improvement in signal levels)

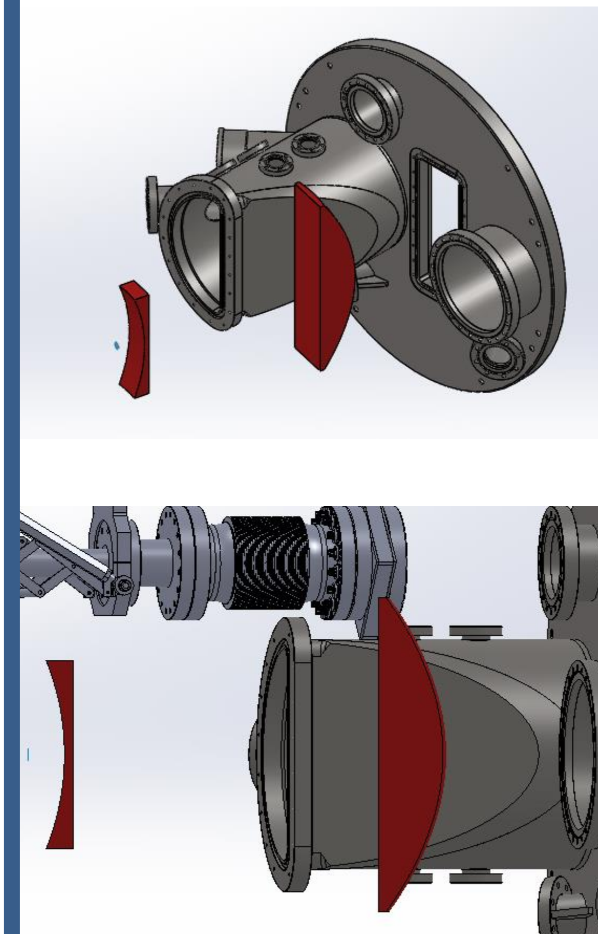
Disadvantage:

- Elimination of gap between window and high-k optics means that MIR could not share the same Bay L window

Development Concerns



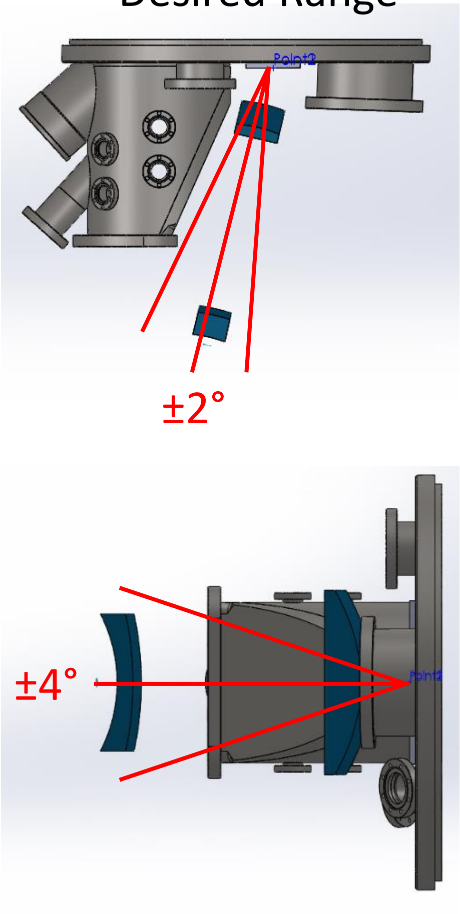
High-k With Max Range of Movement
(no MIR)

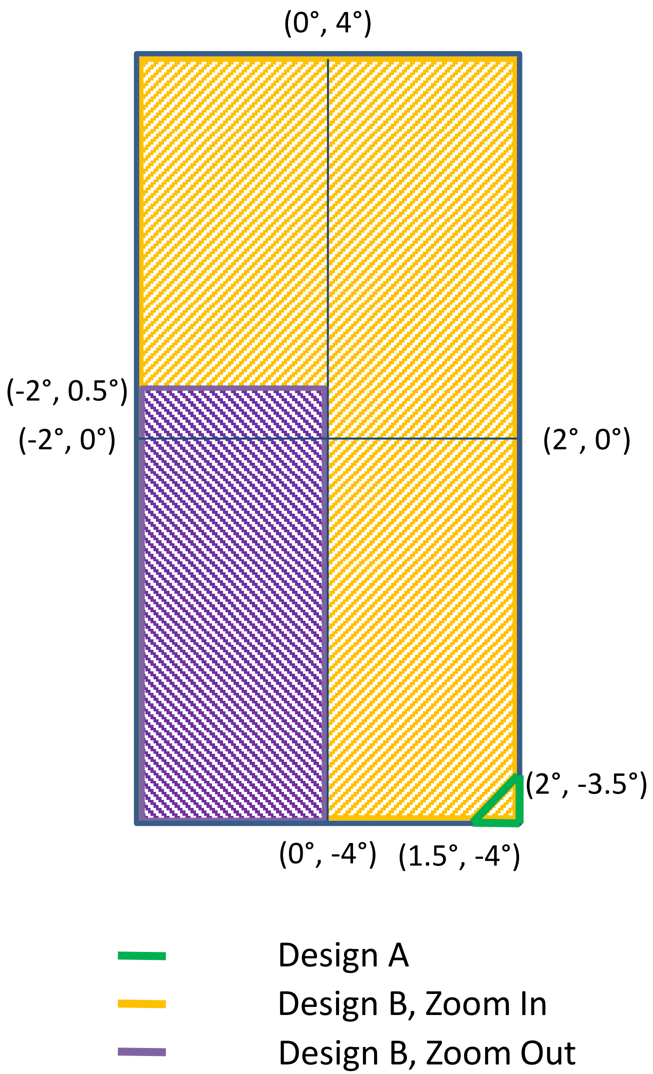


High-k With Highly
Restricted Range
(MIR Compatible)

High-k Receiver Mechanical Fit Concerns

Desired Range





Current Fit:
Design B allows for full range when zoomed in, decreases as zoomed out, mostly because of structural channel. Design A is severely impacted by FPD.

Potential Modifications:
With a minimal modification to the structural member the zoom out of B would double its range. With that mod and without the FPD all 3 would have full range.

High-k Scattering Goals 2016

- Fabricate/test launch optics
- Complete design for receiver optics
- Fabricate/test receiver optics
- Fabricate/test optic remote control
- Test receiver reference mixer
- Test receiver mixer array and receiver electronics
- Compile, test, and calibrate entire scattering system
- Ship completed system to PPPL
- Install components on NSTX-U (laser system, waveguide, launch optics, receiver optics, receiver electronics)
- Test and characterize completed system at PPPL

It has been suggested to move some of the development to PPPL and the Pros and Cons should be discussed

Development estimate: 3 to 4 months, Installation estimate: 2 months

High-k Development Location Options

- Continue development at UC Davis
  - Pros
    - New laser laboratory ready
    - Well stocked with test equipment and microwave components
    - Direct contact with UCD engineering team (especially for current work with electronics and microwave components)
  - Cons
    - No direct access to PPPL engineers
    - Delays in communication with PPPL
- Relocate development to PPPL
  - Pros
    - Greater insight to PPPL procedures and design constraints
  - Cons
    - Need to establish laboratory suitable for lasers and microwaves
    - Shipping and safety training will delay progress
    - Remote contact with UC Davis will likely lead to additional delays

High-k Laboratory Requirements

- Room certified for class IV lasers, microwave, and electronics (approx. 300+ sq. ft.)
  - Safety signs, lights, curtains, etc… as required
- Minimum 10’ x 4’ optical table for laser operations
- Additional 4’ x 4’ (or larger) optical table for FIR testing, 8’ x 4’ table for laser maintenance/repairs
- Electrical power needs:
  - One 208 VAC 30 A (power supply), two 208 VAC 20 A (power supply and water chiller)
  - Two 120 VAC 20 A (dry scroll and oil vacuum pumps)
  - Sixteen standard 120 VAC 15 A outlets (for low amperage equipment, expansion with power strips is OK)
- Access to water for laser cooling and dirty water disposal
- Gas cylinder rack (200 cu.ft. bottle)
- Toxic gas exhaust system for CO_2 laser, formic acid laser, and possibly methanol laser (if FIReTIP laser maintenance can be done in laboratory at PPPL)
- Storage cabinets for test equipment and optics, space for laser optic parts chest of drawers
- Desk and internet connection
- Laboratory must be on-site, otherwise no advantages can be realized
- Additional requirements:
  - Flexible access to all PPPL facilities to work around any interfering schedules
  - Machine shop access
  - Access to PPPL engineers for quicker resolution of minor problems
  - Ability to borrow test equipment/ tools as needed (or at least short term usage while waiting for shipments from UC Davis)

The laboratory must be ready in a timely manner, otherwise all benefits are lost

High-k Development Concerns

- Slow response time for feedback
  - We appreciate how busy everyone is; however, often times we wait several weeks on feedback to designs, slowing the design process
- NSTX-U run schedule
  - The proposed NSTX-U run schedule for Fall and Winter (running ~3 weeks/ month) will severely impact High-k and FIReTIP installation with limited test cell access.
- Sources of delays
  - The time estimates provided assume uninterrupted work. Purchasing, training, shipping, and other procedures necessarily slow progress.
- High-k windows
  - Purchasing, fabrication, and installation of the port windows is likely to take several months. If they are not installed in time, it will prevent finalizing the High-k installation.
- Interference from fusion products detector
  - Spatial constraints around Bay L are severely limiting the High-k receiver and MIR designs. The fusion products detector is the primary problem.

Discussion

- High-k receiver design
  - Fusion products interference?
  - Inclusion of MIR compatible design?
  - Design A is compatible with MIR but interferes strongly with FPD
  - Design B has slight interference with FPD, but excludes MIR
- High-k development
  - Continue at UC Davis?
  - Move to PPPL?

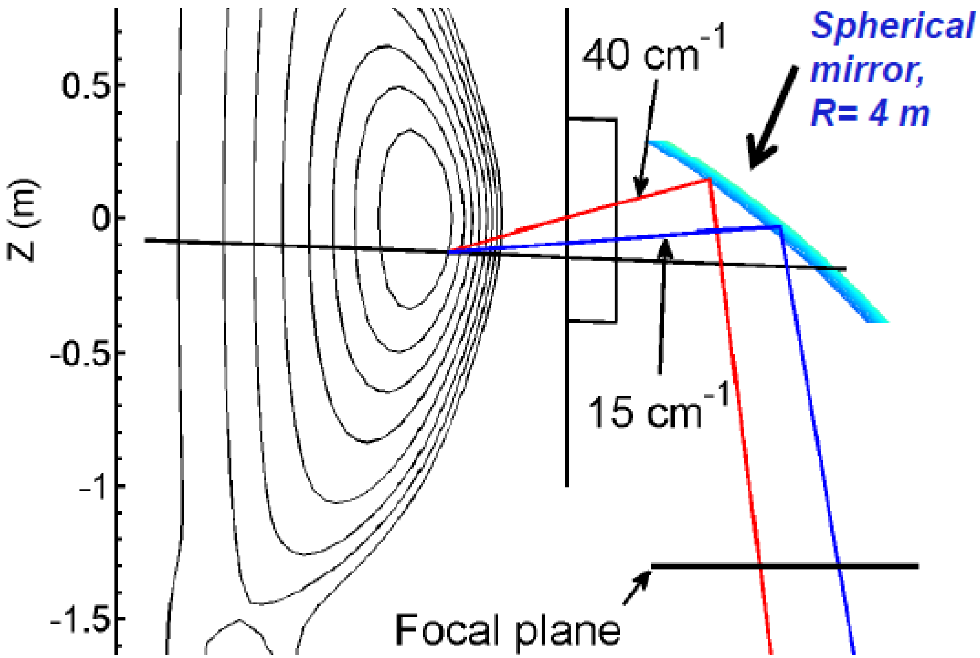
End of Presentation, Thank you!

Backup Slides

Backup Slides

High-k Receiver Design #1 (Old)

Design #1: Spherical mirror placed close to the Bay L window, with multi-channel receiver and additional optics located below



Advantage:

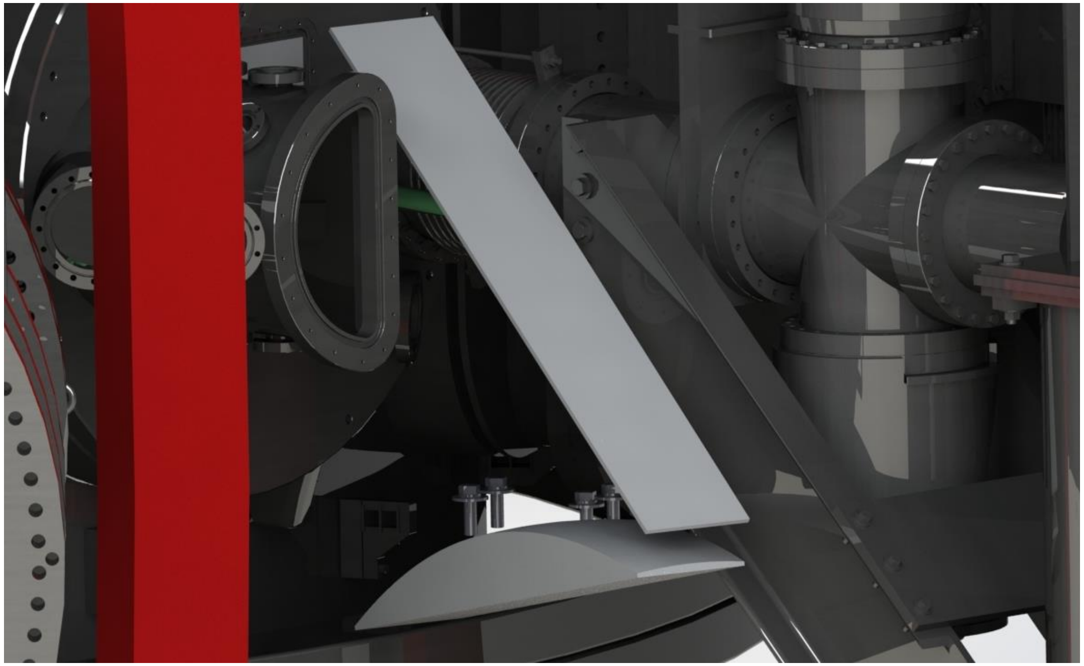
- Extremely compact geometry

Disadvantages:

- Entire system must be translated/rotated as a single unit in order to keep all channels focused at the same point in the plasma
- Insufficient space below mirror to accommodate full radial translation range

High-k Receiver Design #2 (Old)

Design #2: Large turning mirror placed far from the Bay L window, with multi-channel receiver and additional optics located below the mirror



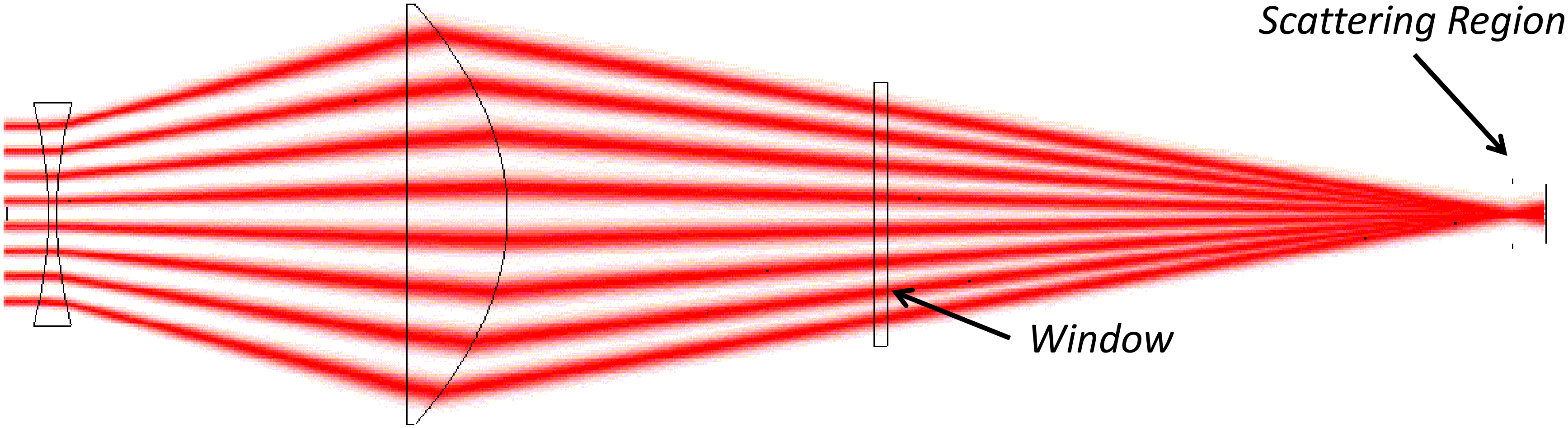
Advantage:

- Turning mirror fixed in place and rotates in 2-D, while the receiver+optics placed below the turning mirror needs only be translated axially in 1-D

Disadvantages:

- Mirror has interference with TS support at some scattering/positions
- Optics extend far below the turning mirror; interference with midplane flooring not shown in drawings available to UC Davis

High-k Receiver Design #3 (Old)



Design #3: Lens-based system, extending straight out from window

Advantage:

- Much smaller footprint than Design #2
- Entire system is translated/rotated as a single unit

Disadvantages:

- Focusing using HDPE lenses translates to signal loss (HDPE loss is ~0.5 dB/cm)
- Large focusing lens has interference with TS support at some scattering angles and radial positions (particularly as one approaches the pedestal region)
- Large focusing lens has significant interference with the Fusion Product Detector (FPD) at most scattering angles and radial positions