New opportunities of physics study by FIReTIP and Poloidal Scattering system on NSTX-Upgrade

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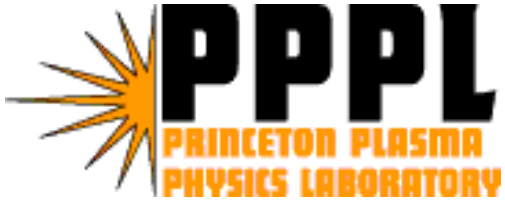

Abstract

A reconfiguration of the Far Infrared Tangential Interferometer/Polarimeter (FIReTIP) and the high-k scattering systems are planned for the National Spherical Torus Experiment (NSTX) Upgrade (FY2013-14). The FIReTIP upgrade design comprises three channels: a core channel (R_T ~ 40 cm) for the main density monitoring and real time density feedback control, a middle channel (R_T ~ 90 cm) for HHFW heating localization studies and MHD studies including Alfven Eigen modes, and an edge channel (R_T ~ 140 cm) for the boundary electron density fluctuation measurements which are important for H-mode and pedestal physics studies. The high-k scattering system will be reconfigured as a poloidal scattering system for measurement of k-spectra relevant to ETG modes. Details of the reconfiguration plan will be presented with recent physics results from these diagnostics, together with a discussion of the physics areas to be addressed with the upgraded diagnostic tools.

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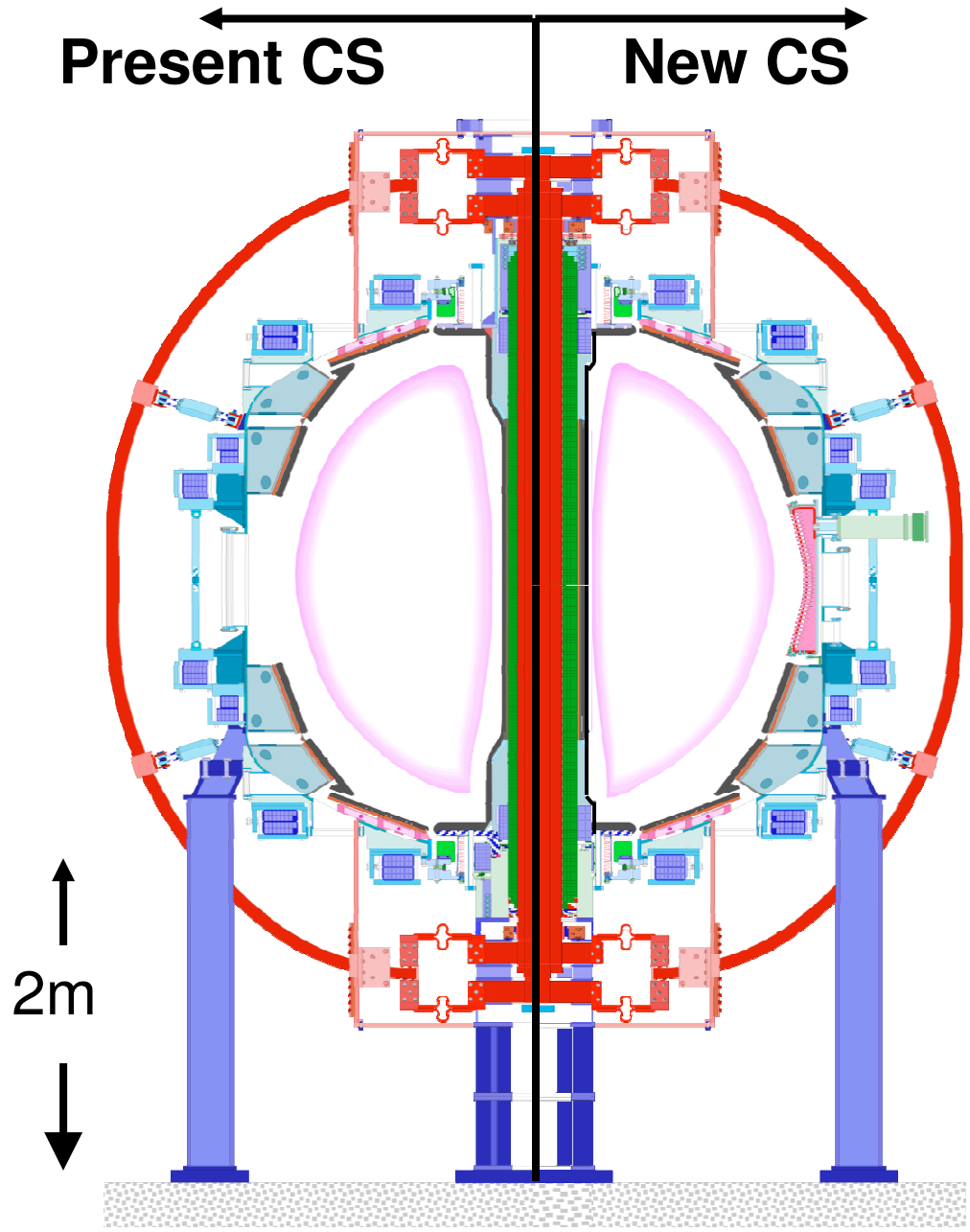
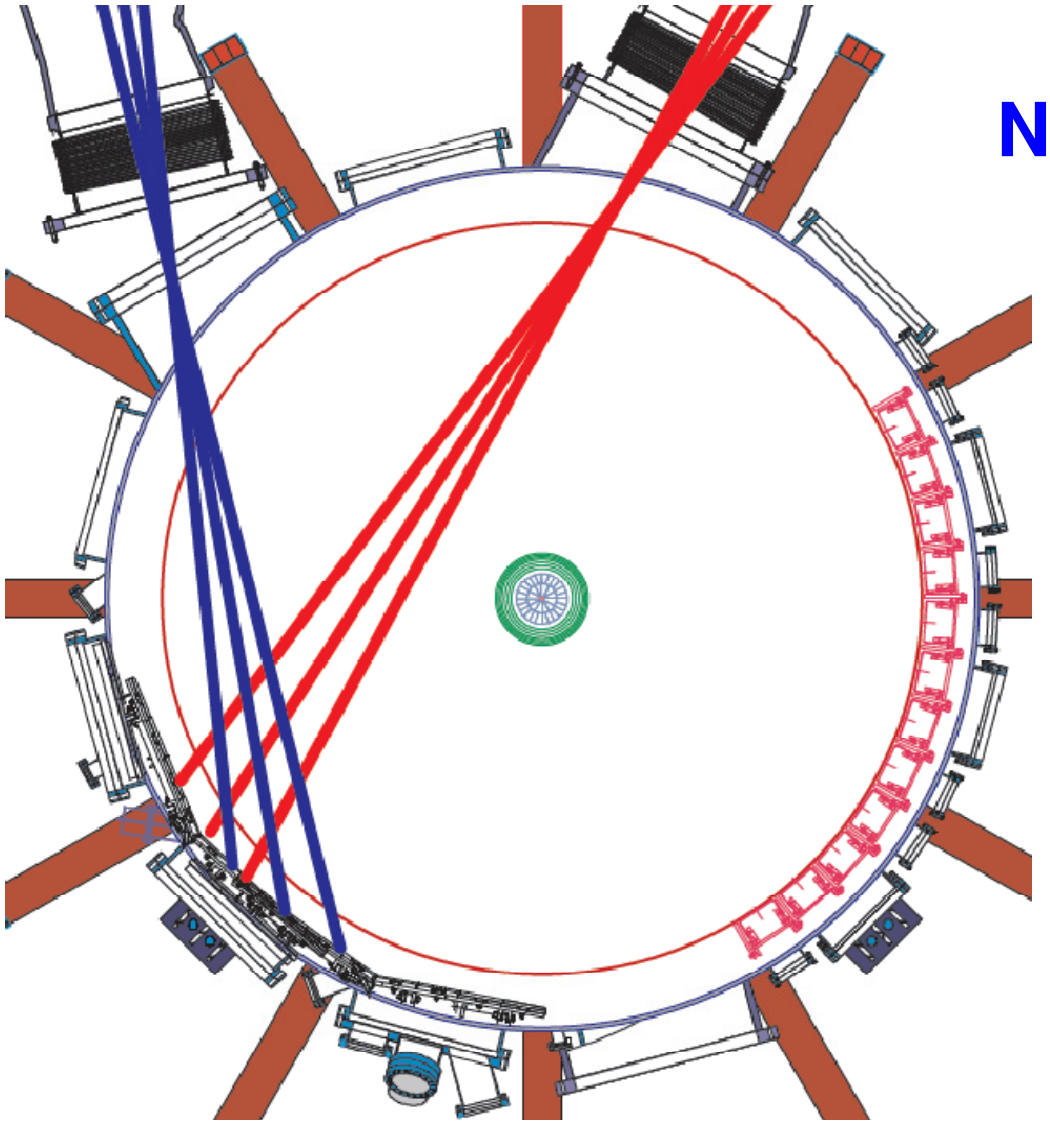


NSTX –Upgrade (I) Center stack

Parameter	Present	Upgrade
Minor Radius, a	0.67 m	0.61 m
Major Radius, R_0	0.85 m	0.91 m
Aspect Radio, A	≥ 1.28	≥ 1.5
R_0 - a	18.5 cm	30.5 cm
Plasma Current, I_P	1.5 MA	2 MA
Toroidal Field, B_T	0.55 T	1 T
TF coil current	65 kA	127 kA
TF flat top time	0.8 sec	5.6 sec
OH -flux	0.75 V-S	2.59 V-S
Flap-top V S	0.29	1.59

2nd NBI



NSTX –Upgrade (II)

Neutral Beam Injection

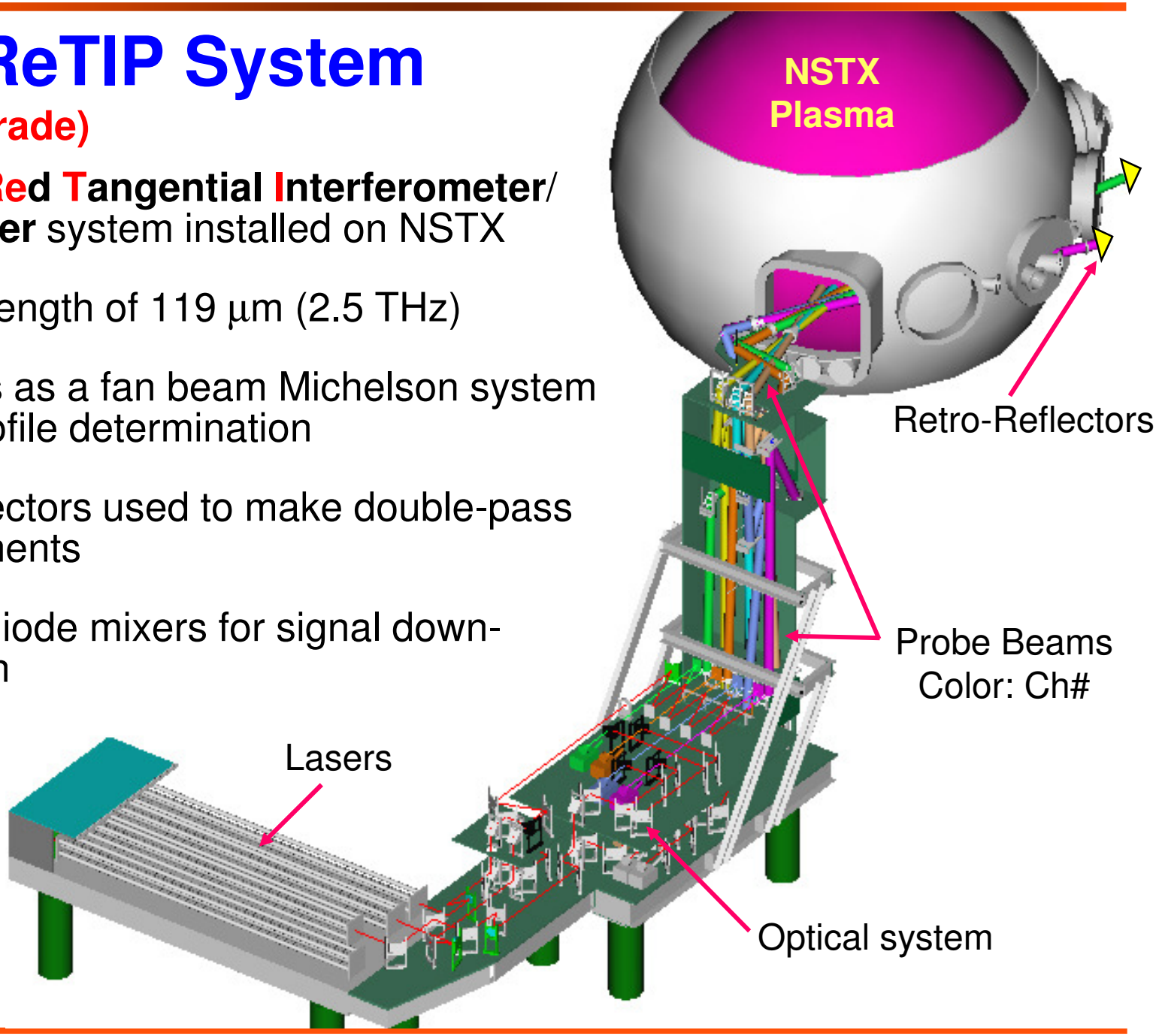
► **Second NBI to double heating and CD power with current profile control for full non-inductive operations**

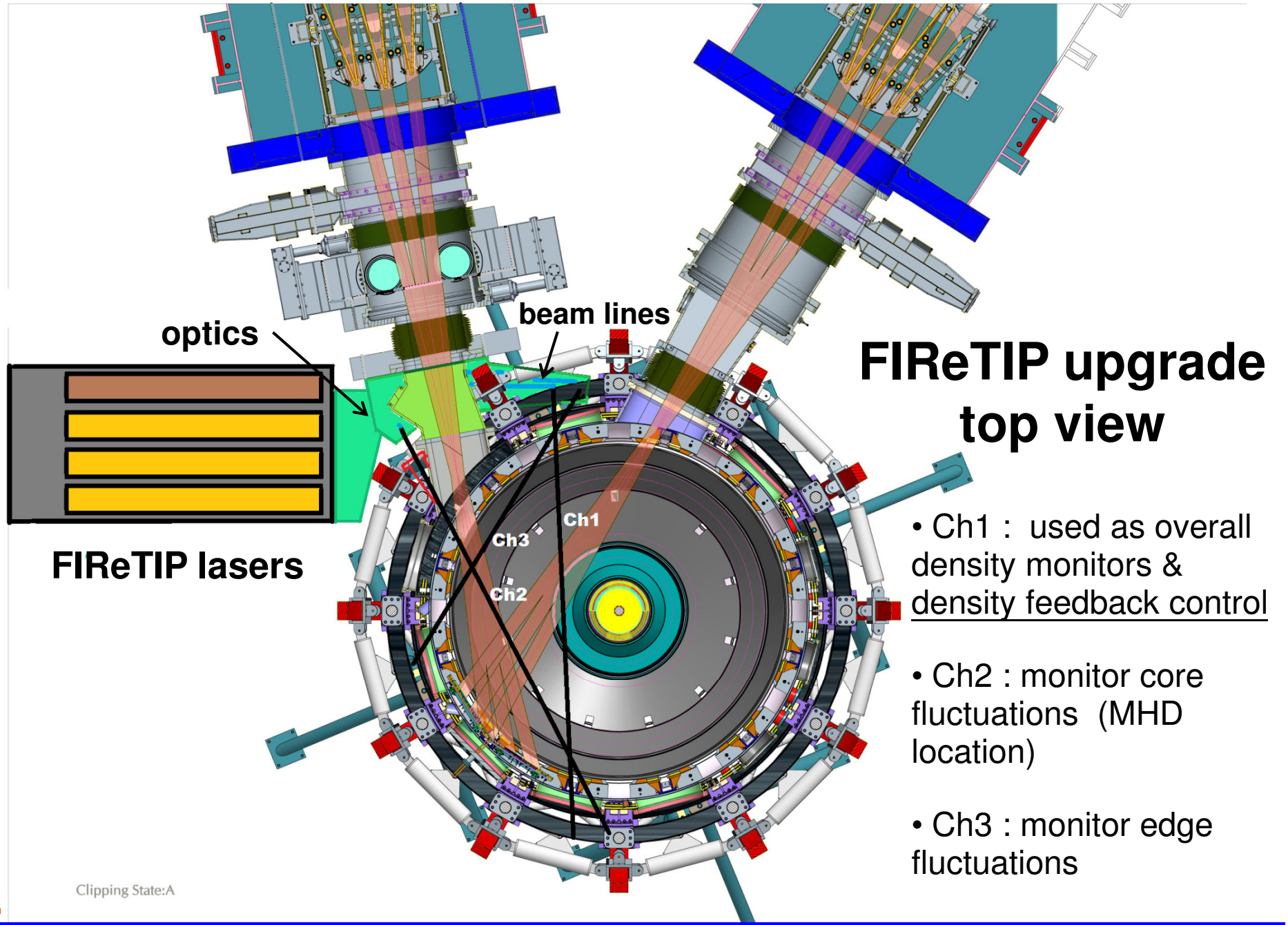
► **More tangential injection up to 2 times higher efficiency, current profile control**

The FIReTIP System

(before upgrade)

- **F**ar **I**nfra**R**e**d** **T**angential **I**nterferometer/ **P**olarimeter system installed on NSTX
- FIR wavelength of 119 μm (2.5 THz)
- Six chords as a fan beam Michelson system for 2-D profile determination
- Retro-reflectors used to make double-pass measurements
- Schottky diode mixers for signal down-conversion

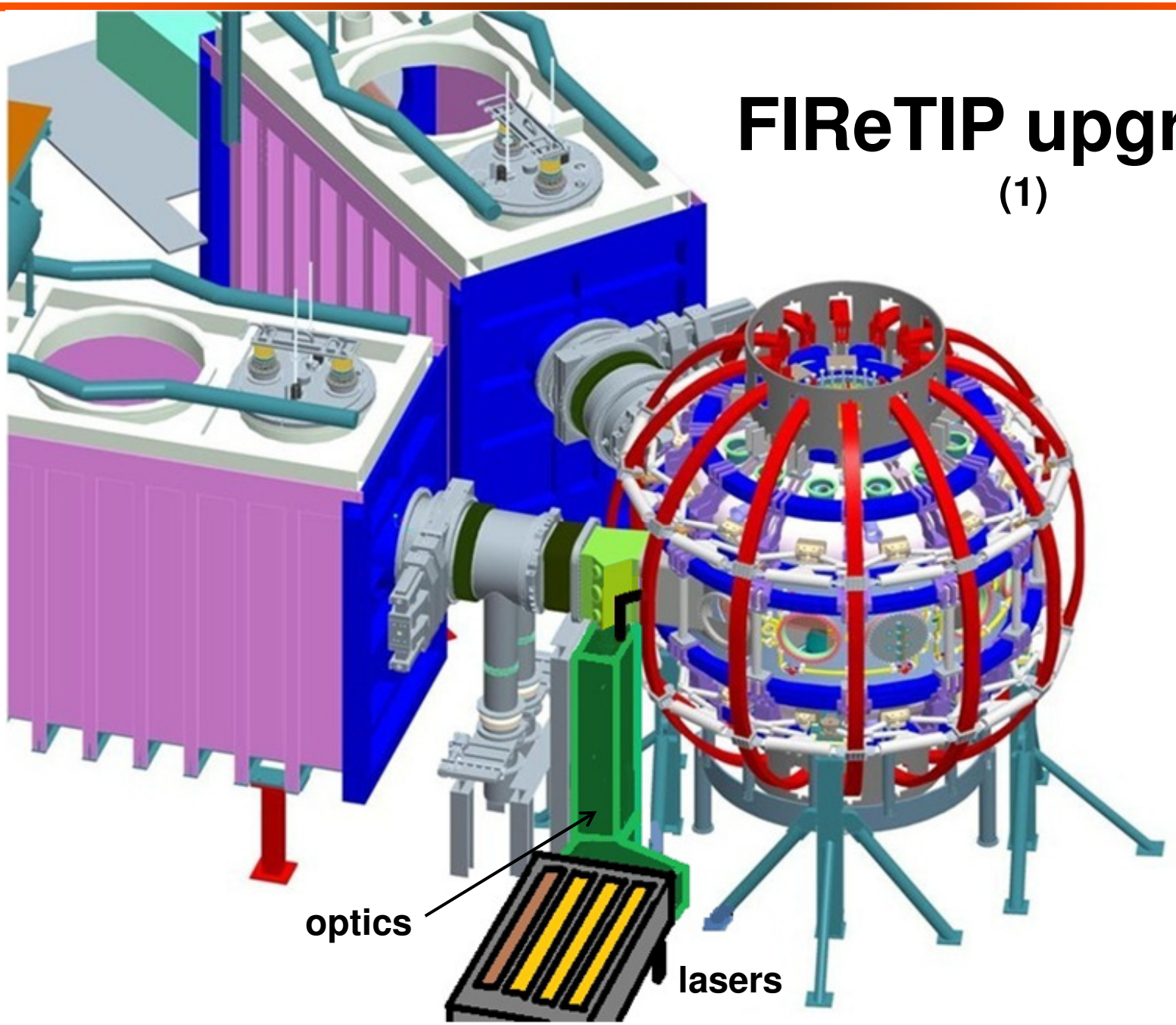




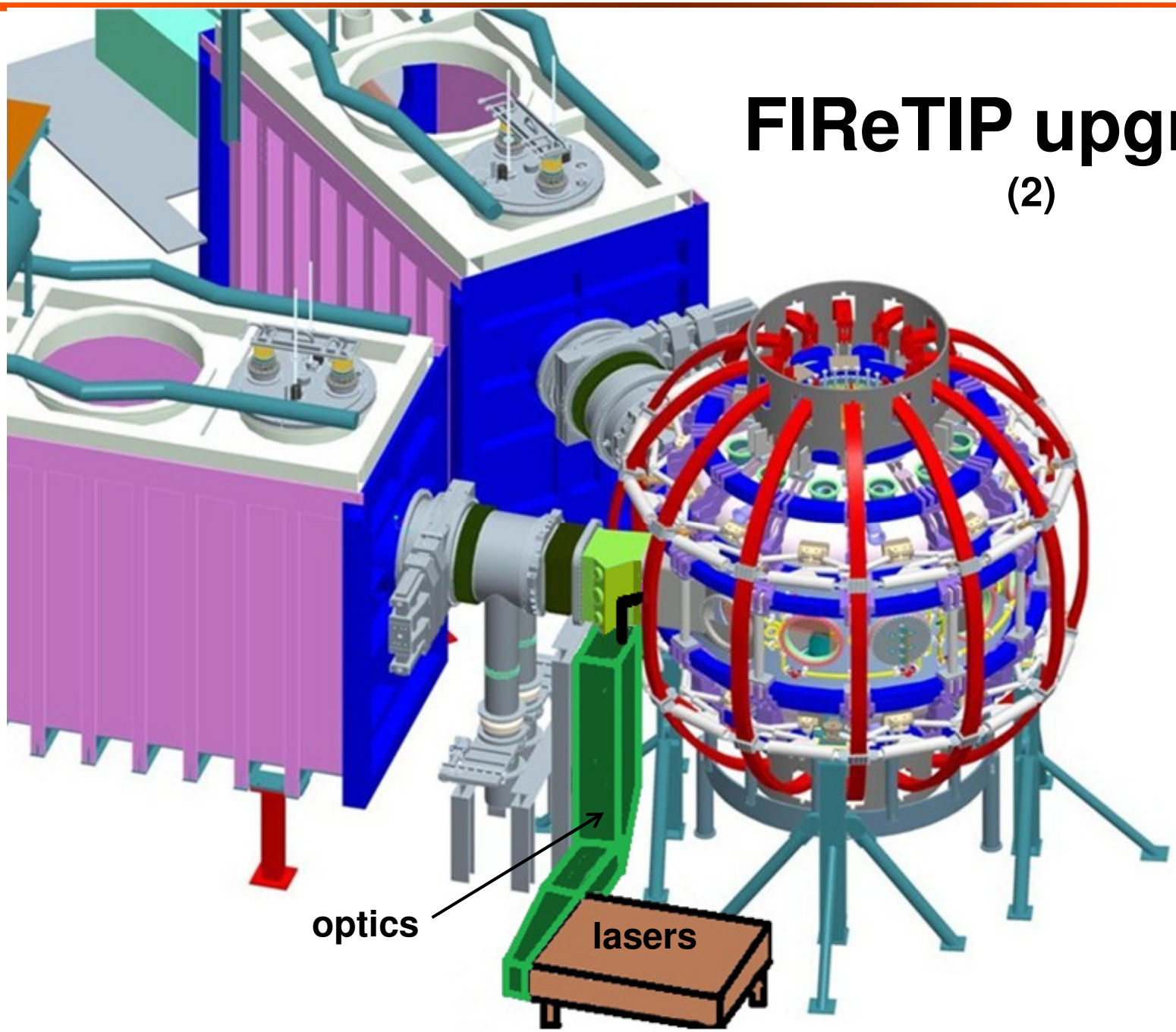
FIReTIP upgrade top view

- Ch1 : used as overall density monitors & density feedback control
- Ch2 : monitor core fluctuations (MHD location)
- Ch3 : monitor edge fluctuations

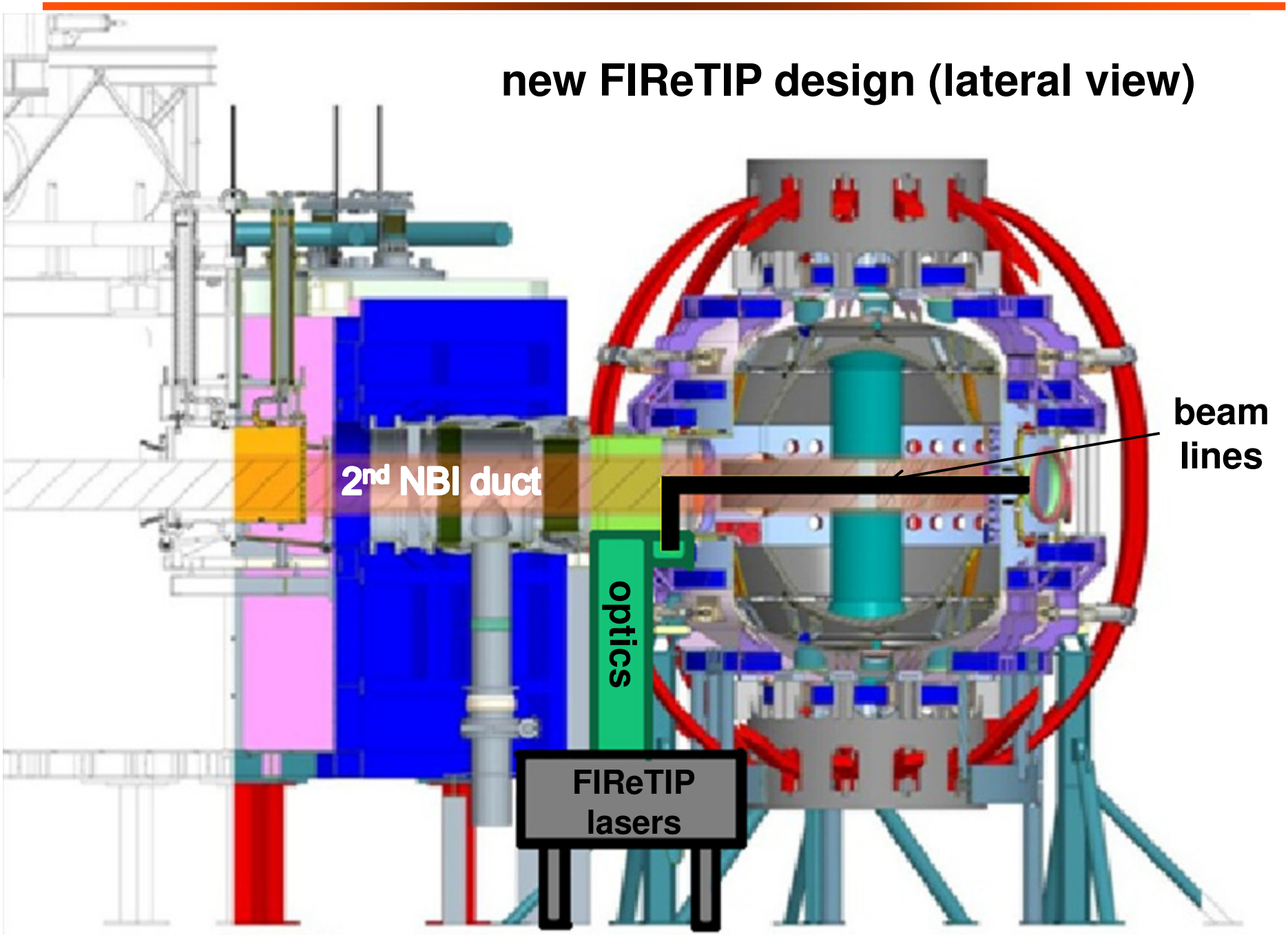
FIReTIP upgrade
(1)



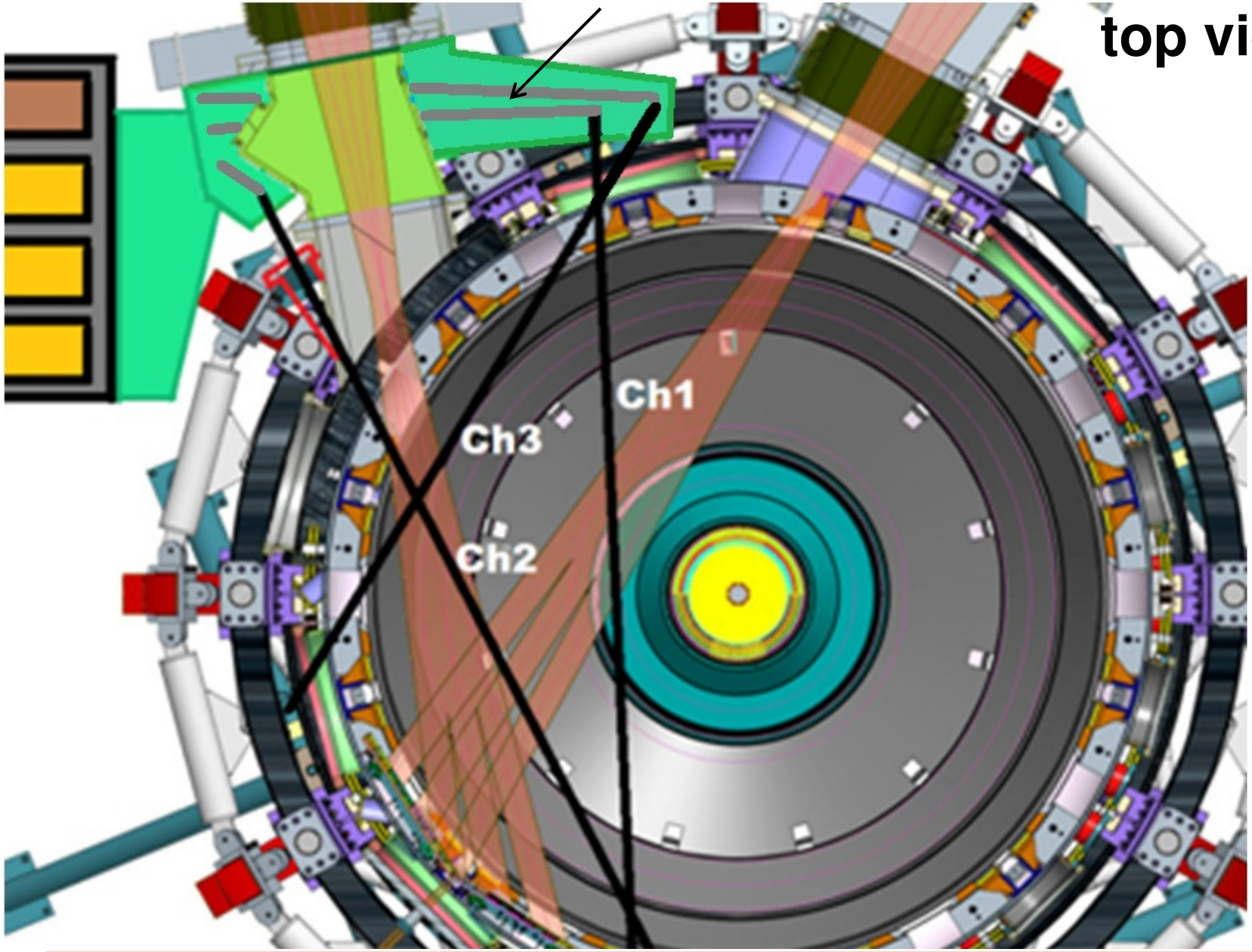
FIReTIP upgrade
(2)



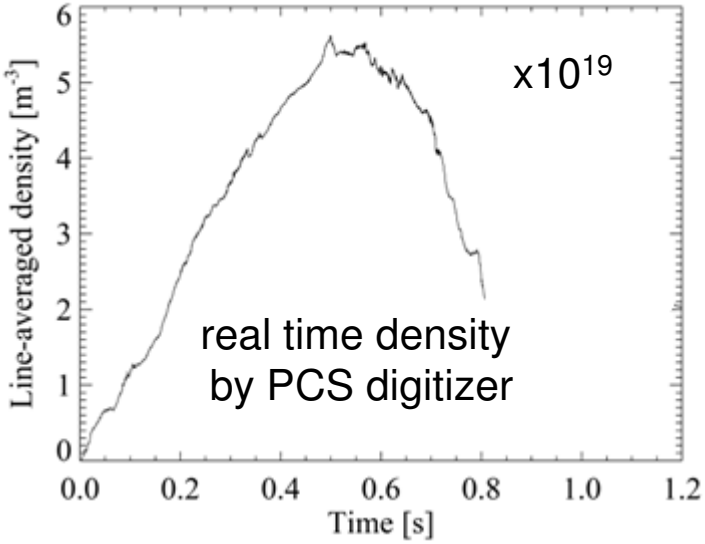
new FIReTIP design (lateral view)



FIReTIP upgrade top view

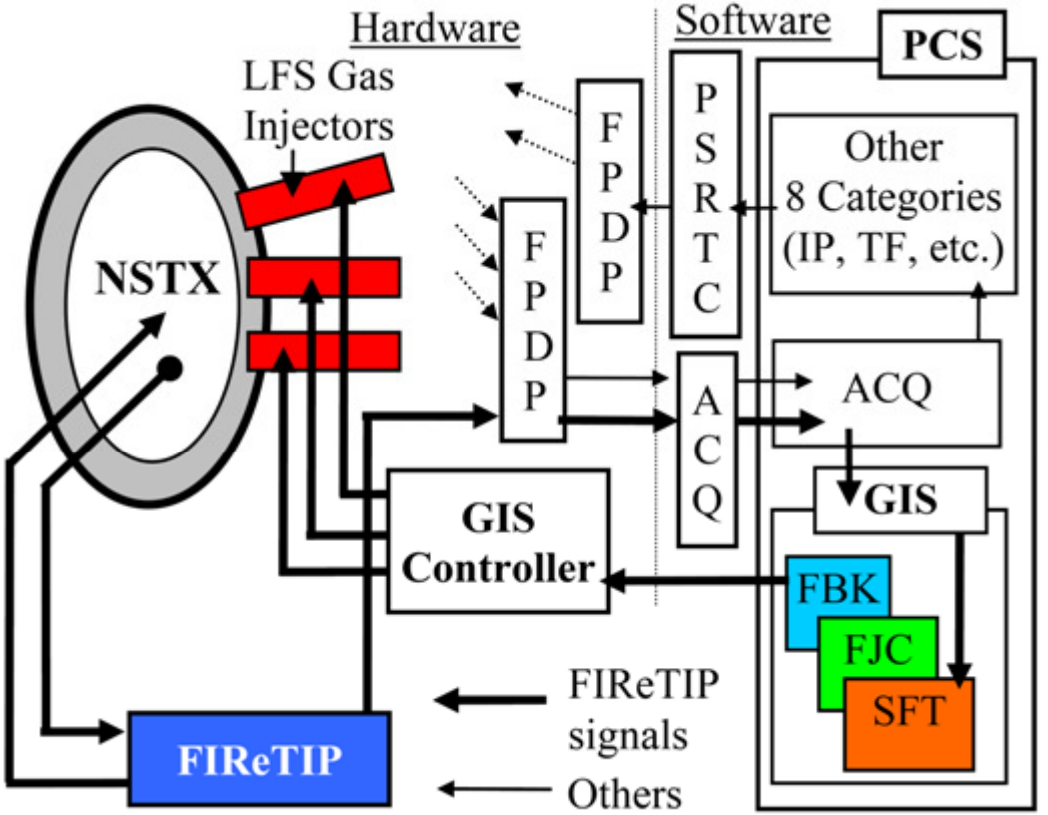


Real time density feedback control is proposed on NSTX for early density control and scaling experiment



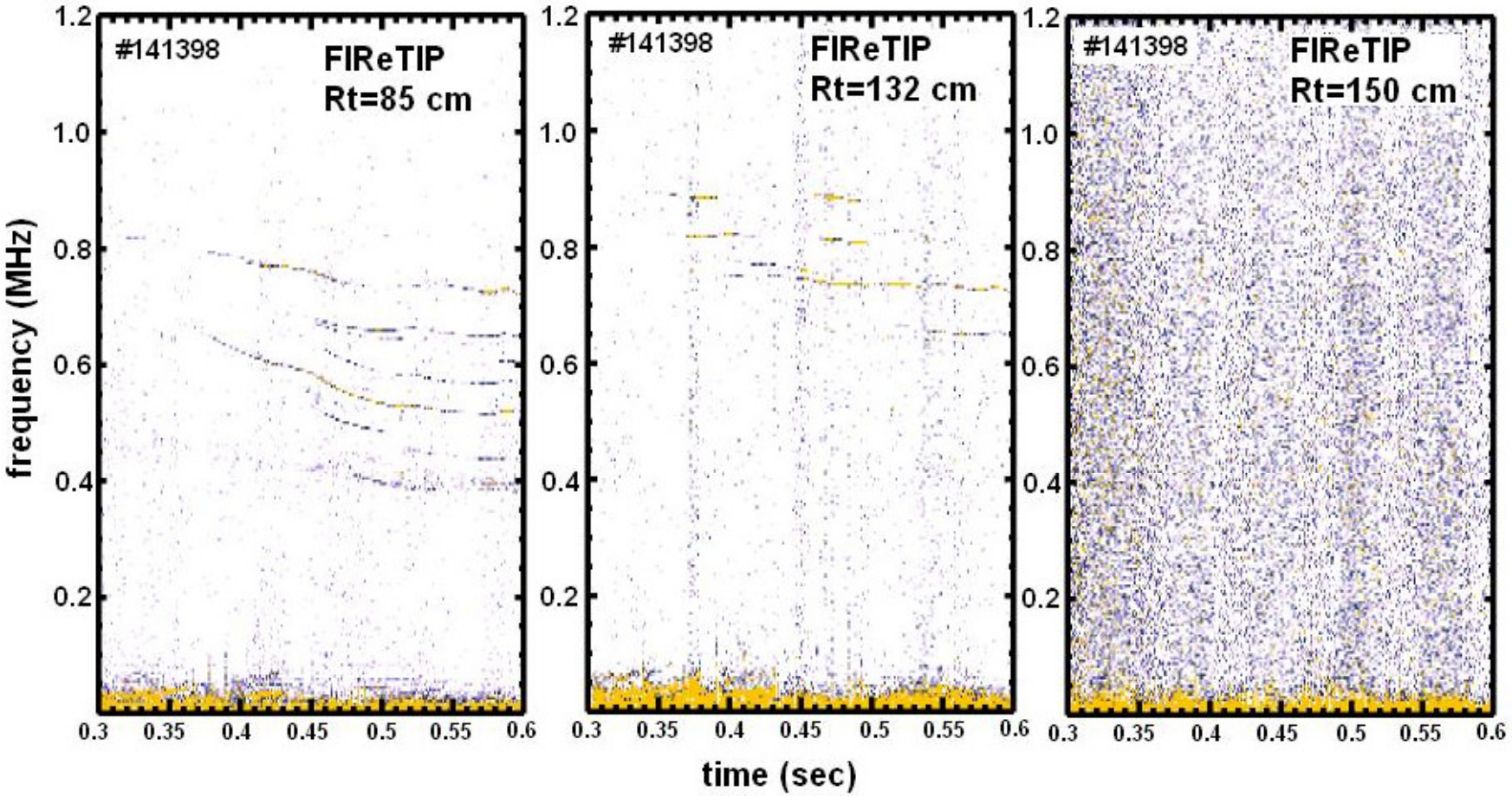
► FIReTIP data are tested and ready for feedback control. Real time density is sent through PCS digitizer.

► Fringe jump correction will be included in PCS program



PCS : Plasma Control System
GIS : Gas Injection System
SFT : Safety, FJC : Fringe Jump Correction
FBK : Feedback

Energetic Particle Modes study by FIReTIP on NSTX-U



► **FIReTIP measurement of GAE data showed difference in channels**

► **Alfven mode frequency will be doubled on NSTX-U and FIReTIP bandwidth (4 MHz) will cover GAE, CAE, TAE, Angel Fish etc.**

H-mode & pedestal physics study by FIReTIP

► Ch3 of FIReTIP-upgrade is suitable for density fluctuation measurement that is important in H-mode & pedestal physics

► Density fluctuation is important parameter for both turbulence transport and H-mode transition physics according to the Gyro-Center Shift (GCS) theory [Lee, PPCF, 51 165023 (2009)]:

$$D = \frac{2}{\pi}\eta^2 \frac{kT_e}{eB} \quad , \quad \mathrm{Re} = \frac{2}{\pi}\eta^2 \frac{B}{m_i n_i (\sigma_{i-n} n_n)^2 \upsilon_\perp} \nabla\rho$$

Here $\eta \equiv \frac{\tilde{n}}{n}$ and D = diffusion coefficient, Re: Reynolds Number

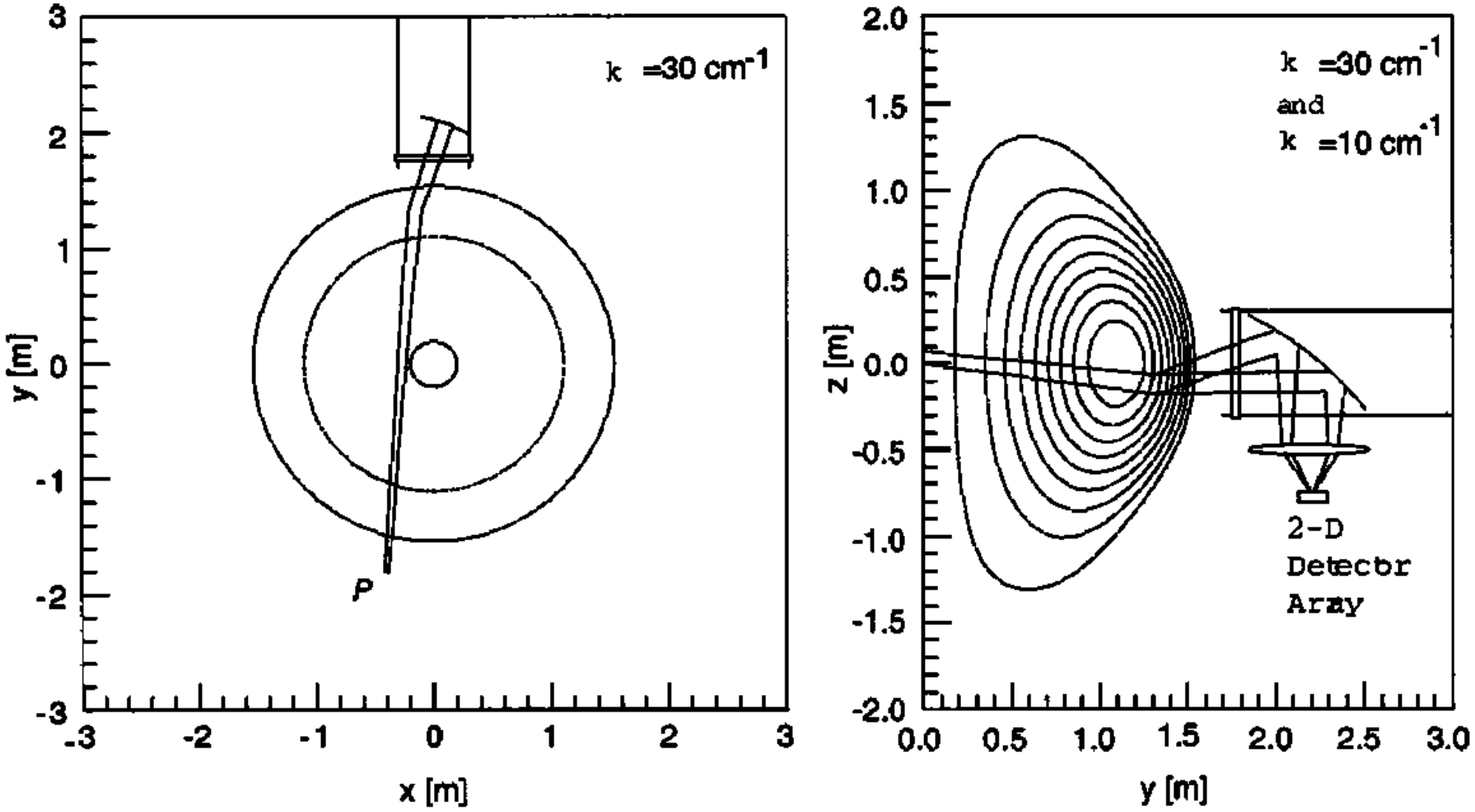
► I-mode study on NXTS is proposed where fluctuation spectrum is important

► Multi-channel of FIReTIP reveals asymmetric Density loss at Type III ELMs between high field side and low field side.

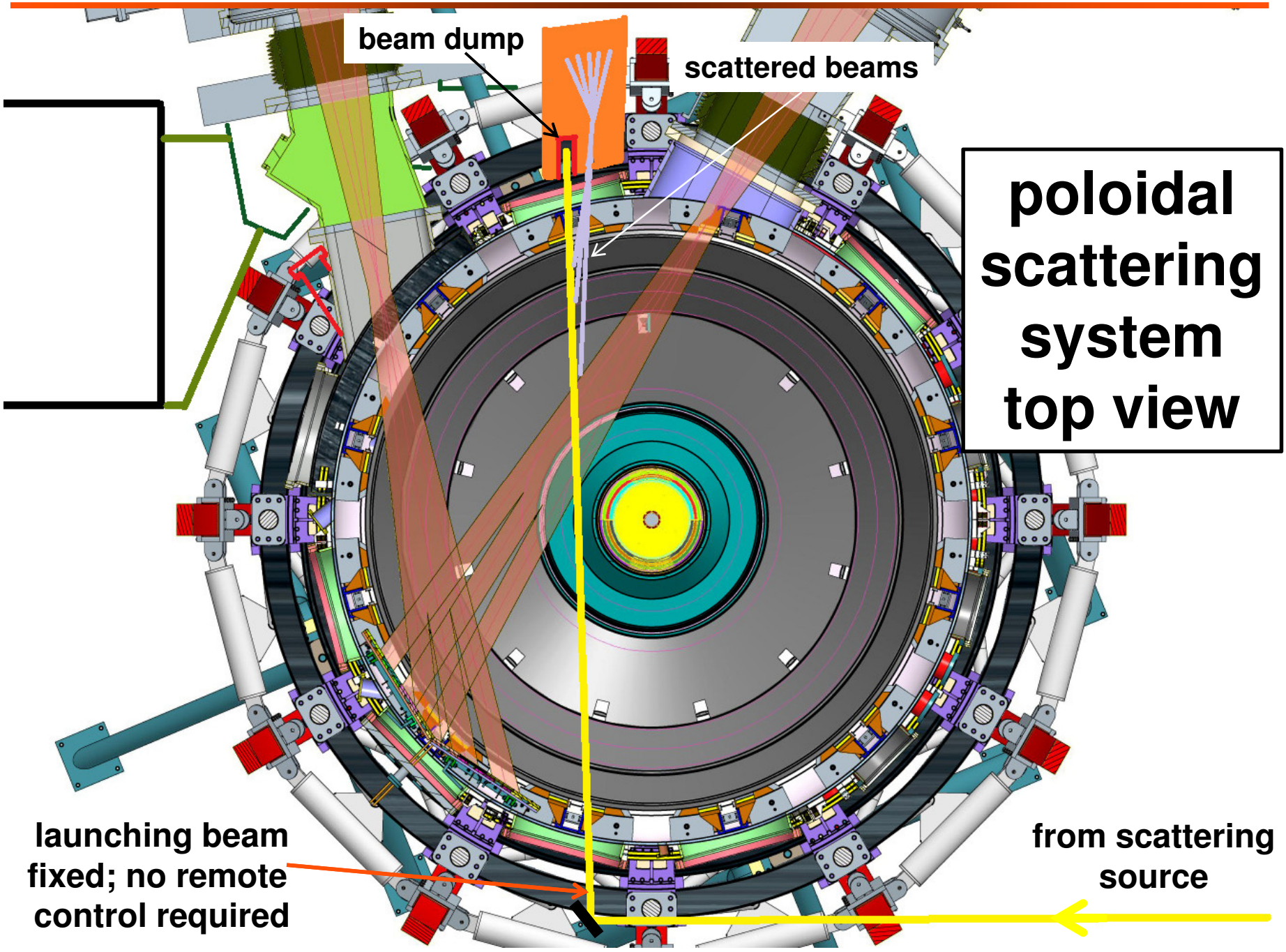
Poloidal Scattering Plan

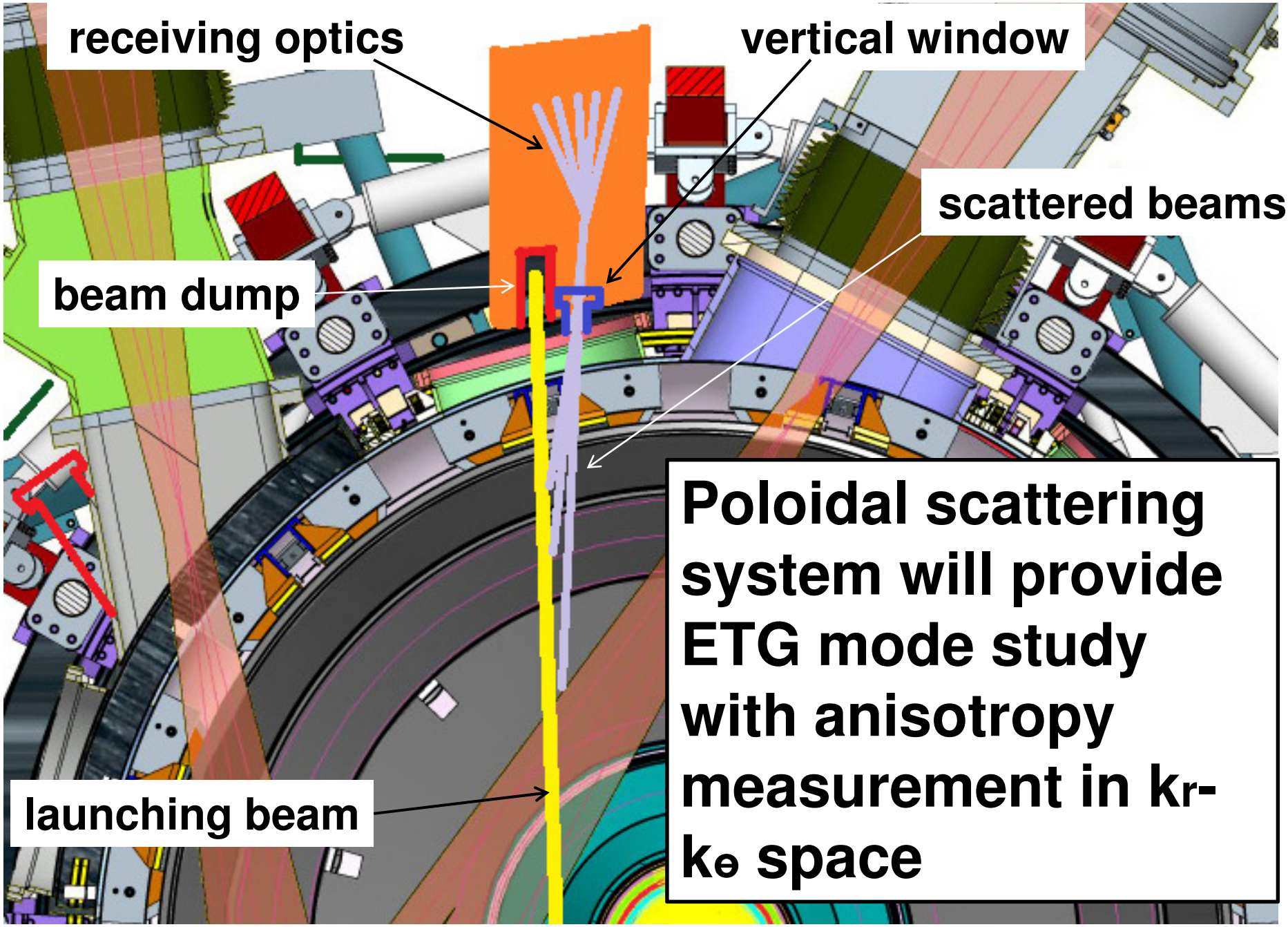
- UC Davis proposes to experimentally investigate a proof-of-principle poloidal scattering system to replace the high-k tangential scattering system.
- Figure on next page illustrates a scattering geometry for the measurement of the $k_{\perp}$-spectrum, where a 1 mm Gaussian beam with a 2 cm waist is launched along a trajectory that is nearly tangent to the machine center post. Since the beam propagates at a small angle to the density gradient, its trajectory is only slightly affected by plasma refraction.
- While the scattering cross-section is largest at the longest wavelengths, this must be traded off with respect to other concerns such as beam refraction, wavenumber coverage and resolution, spatial resolution, port access and signal-to-noise ratio. Most importantly, the spread of the scattered signals in space is minimized while having a reasonable spatial resolution at high wavenumbers relevant to the ETG range.
- Studies to date suggest that the optimum wavelength for for the poloidal scattering system on NSTX is 432 μm.

Poloidal Scattering System (schematic)



Equatorial (left) and poloidal (right) projections of a poloidal scattering geometry for NSTX with $k_{\perp}$=30 cm^{-1}. The beam trajectories are those of points with e^{-2} intensity.


beam dump
scattered beams
poloidal scattering system top view
launching beam fixed; no remote control required
from scattering source


receiving optics
vertical window
scattered beams
beam dump
launching beam
Poloidal scattering system will provide ETG mode study with anisotropy measurement in k_r-k_θ space

Conclusions

► FIReTIP and poloidal scattering systems will be upgraded for the NSTX-Upgrade

► Main density monitoring including window calibration of Thomson Scattering and real time density feedback control will be implemented by core channel (R_T ~ 40 cm) / middle channel (R_T ~90 cm) of FIReTIP

► EPM (energetic particle mode) study is available by FIReTIP with doubled Alfven frequency on NSTX-U

► Edge channel (R_T ~ 140 cm) will provide new opportunities of physics study such as investigation of gyrocenter shift theory, I-mode on NSTX, density loss of ELM etc.

► Poloidal scattering system is designed to measure ETG mode on NSTX-U