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# Interaction of applied 3D fields with detachment


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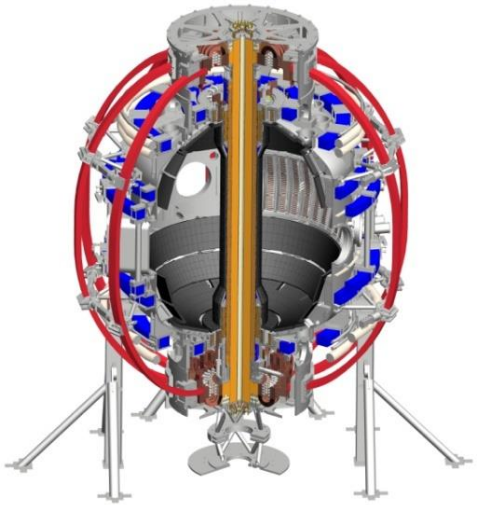


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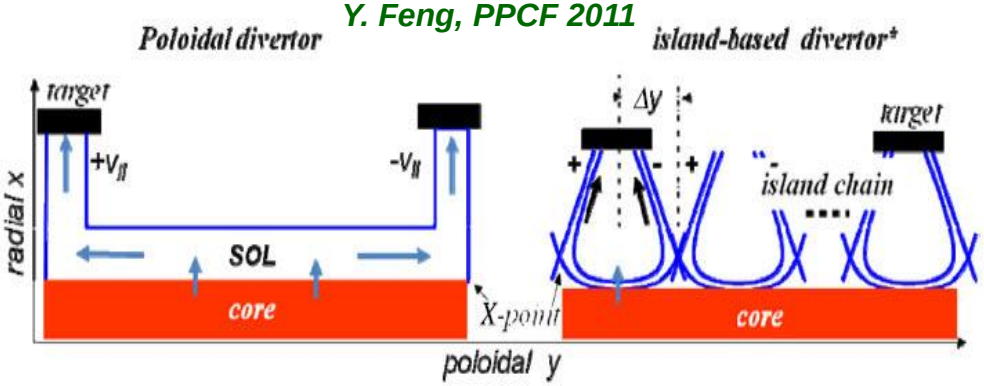
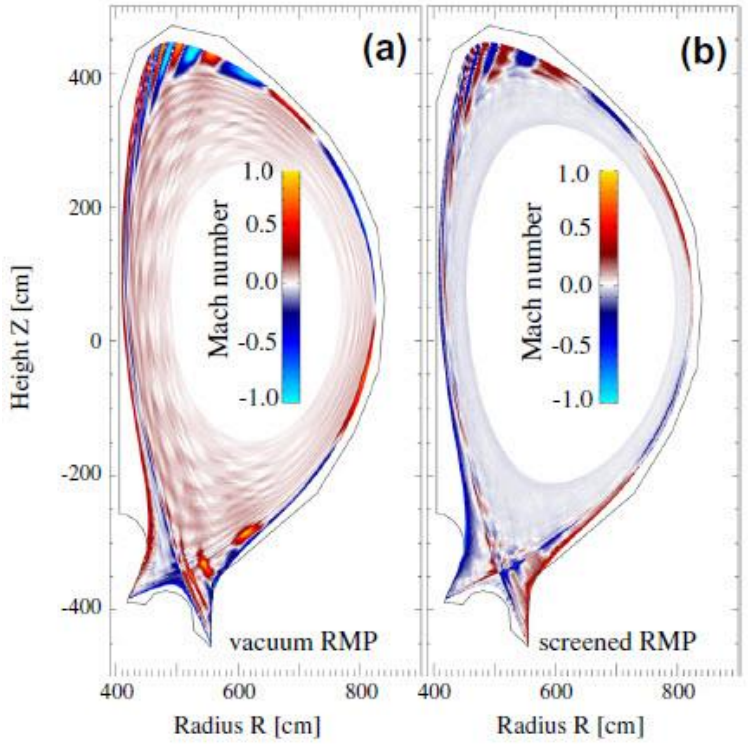
# Enhanced momentum loss from helical SOL facilitates detachment in stellerator

*Y. Feng, PPCF 2011*



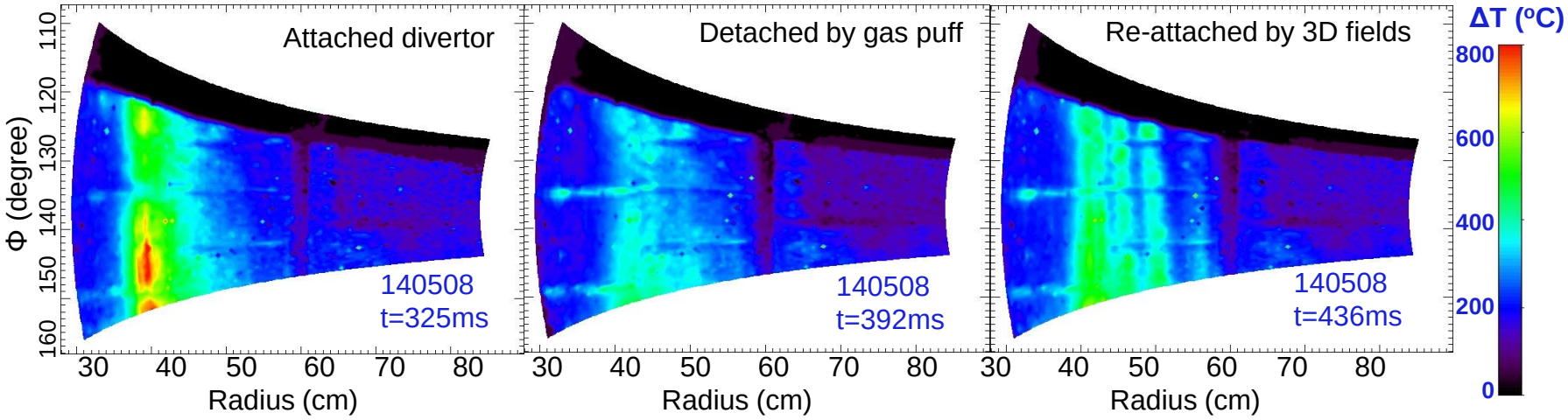

*O. Schmitz, JNM 2013*

- 2D Tokamak: opposite ion flows of inner and outer legs are isolated from each other
- Island divertor: channels of opposite flows approach to each other or overlap → momentum exchange and loss → $p_{up}/p_{down}$ ↑ → reduced particle flux at divertor → no high recycling regime → detachment occurs in lower $n_{e,div}$ and higher $T_{e,div}$
- Similar thing can occur in 3D tokamaks?

# 3D field effect on detachment needs to be identified for ITER

- 3D ELM control to be compatible with detached plasmas in ITER

- 3D tokamaks:
  - Momentum loss effect vs enhanced parallel transport
  - NSTX: parallel transport reattached plasma in some cases




*J-W. Ahn, IAEA 2014*

# Experimental plan

- Plasma configuration and parameters for maximum 3D effects should be identified prior to experiment
  - n=2 and/or n=3
  - q95, triangularity
- Optimization of gas injection to be identified prior to experiment
  - Impurity seeding? Combined with deuterium puff?
  - Detachment with high NBI power?
- Variation of coil current amplitude and gas amount
- Comparison to EMC3-Eirene simulation

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# Role of plasma response in the formation of lobe structures by 3D fields

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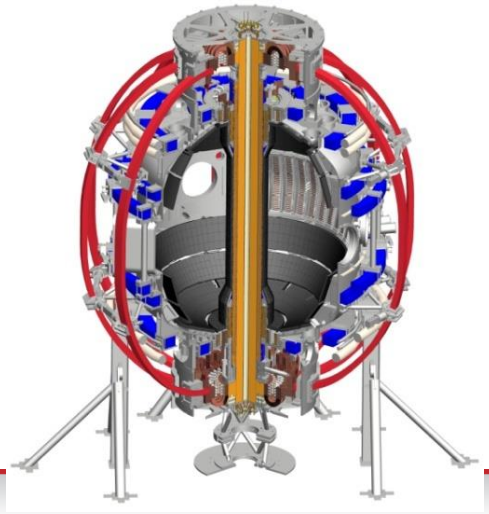

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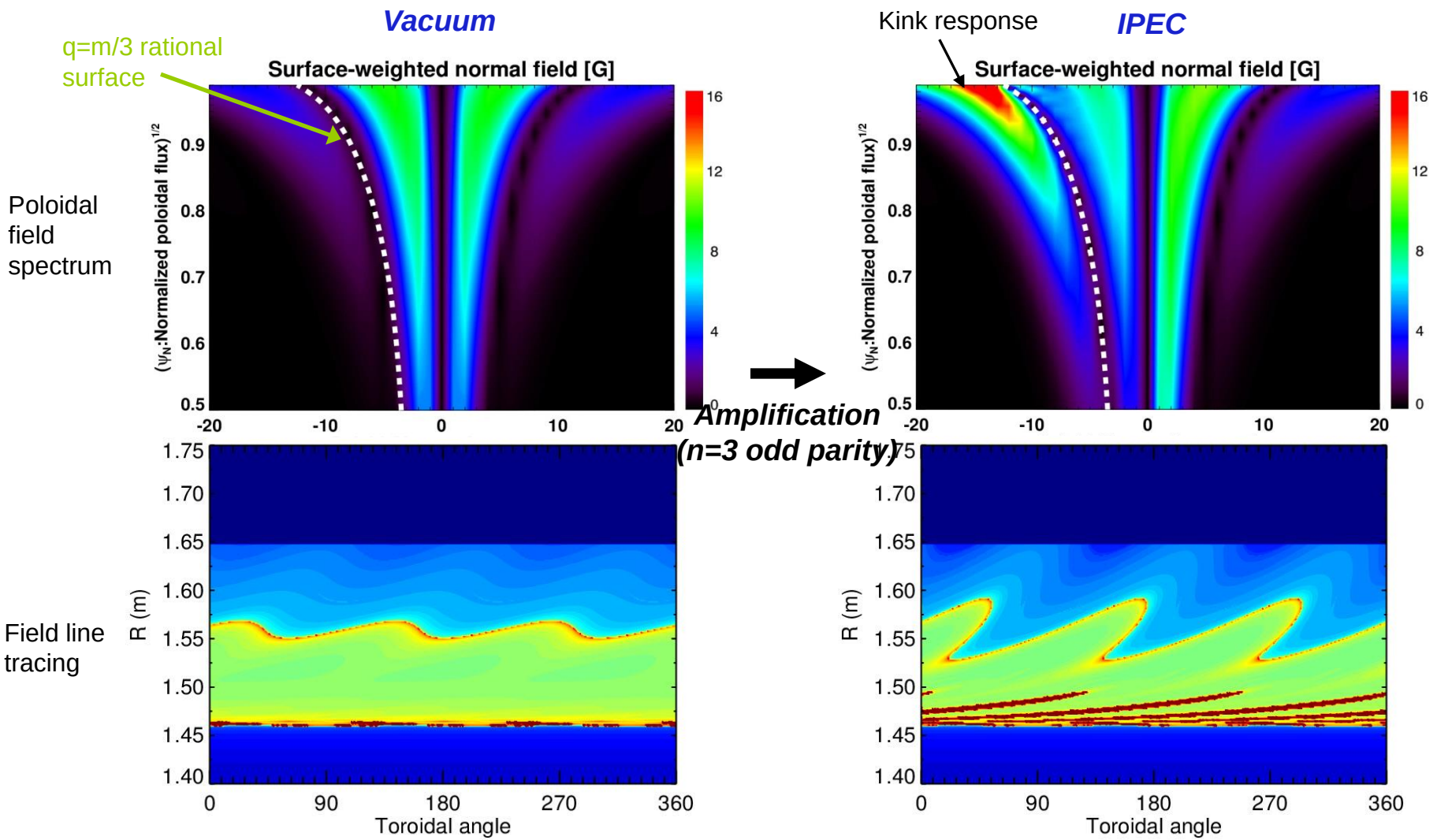
# Why care for lobe structures by 3D fields?

- 3D fields are increasingly used for many physics purposes, eg ELM suppression, NRMF for QH-mode, NTV control, etc

- Separatrix splitting and striation poses specific erosion pattern which will need to be accurately predicted

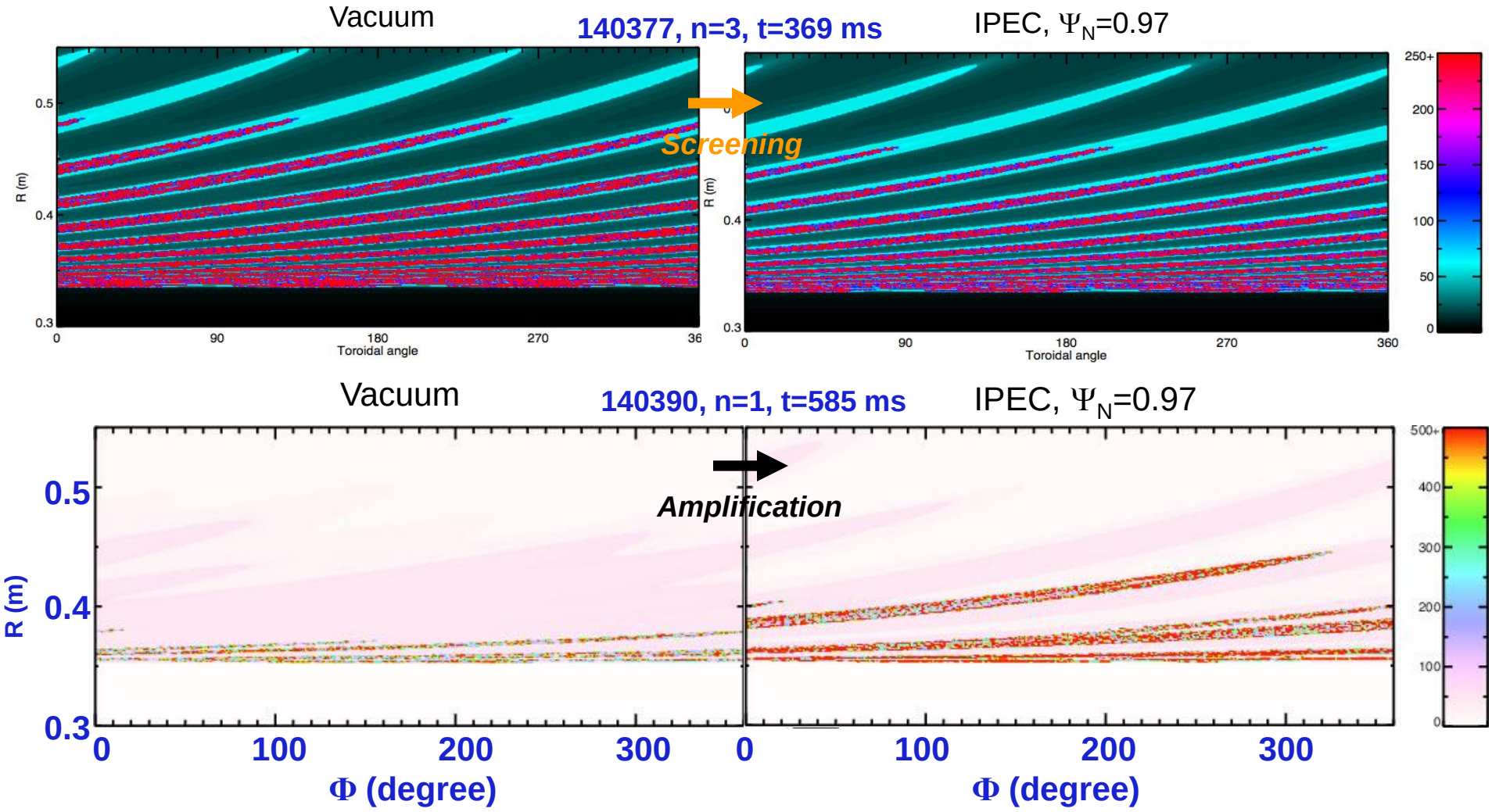
- Experiments in NSTX and DIII-D showed the magnetic lobe structure can be significantly modified by plasma response, different from vacuum field line tracing

# DIII-D data showed amplification (n=3 odd) and screening (n=3 even) of vacuum lobe structures




- High triangularity shape more beneficial for stronger kink response

# NSTX data shows slight shielding for n=3 and significant amplification for n=1




- Field line tracing compared to wide angle visible camera image

# Experimental plan

- Varying fraction of resonant and non-resonant components of response fields for screening or amplification of applied 3D fields
  - q95 scan
  - Triangularity scan
- Only mid-plane coils available in NSTX-U
  - Significant n=1 and n=3 intrinsic error fields → Phase of n=3 fields, dynamic rotation of n=1/n=2 fields
- Field line tracing with inclusion of plasma response (IPEC and M3D-C1) and 3D edge transport simulation (EMC3-Eirene)
  - Comparison to wide angle IR and visible camera images

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# Performance optimization of divertor detachment


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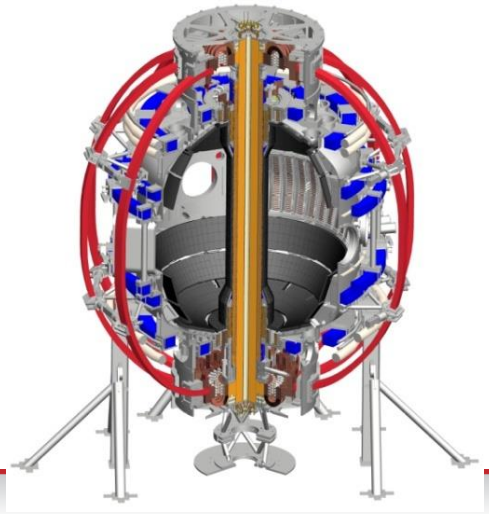

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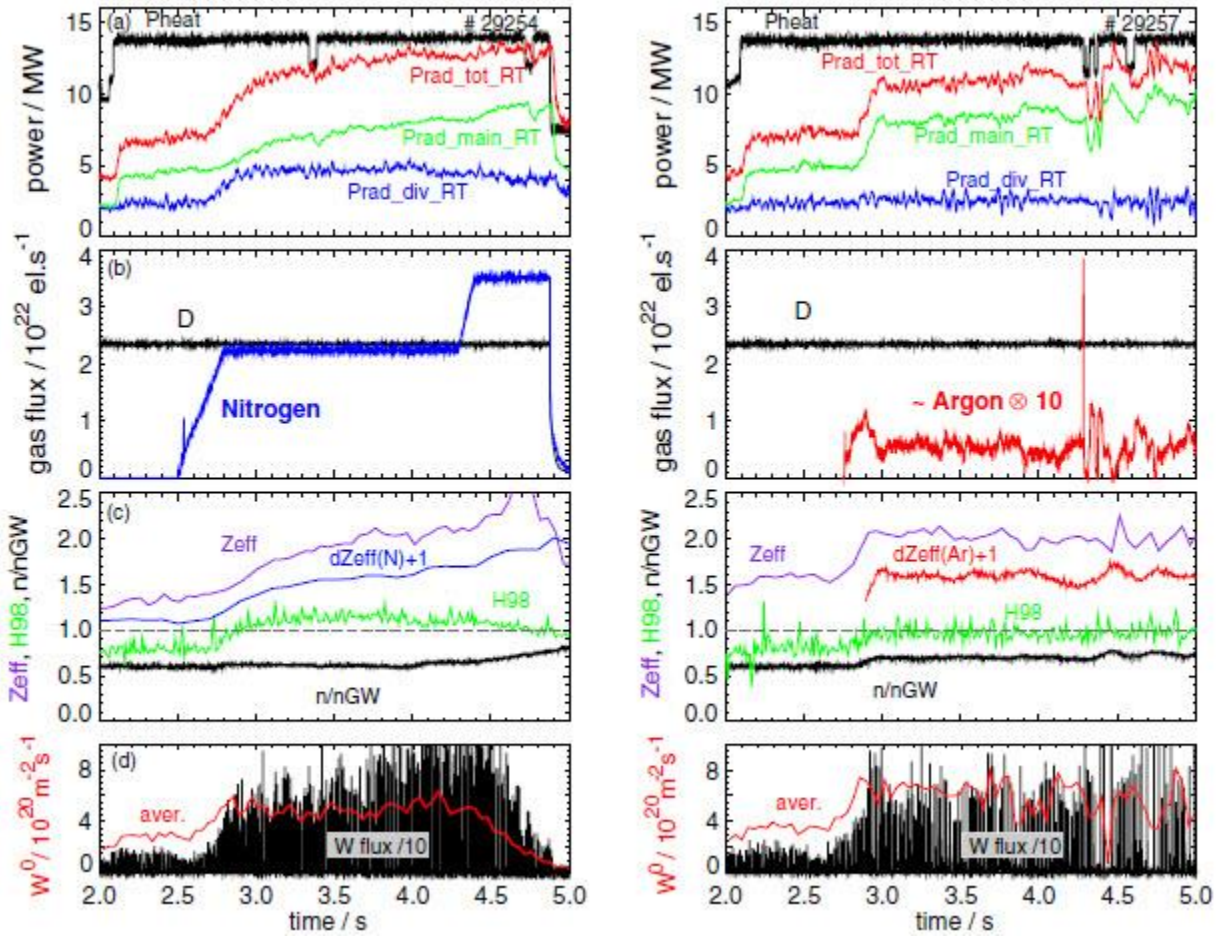
# Detachment with high P/R is necessary for ITER and FNSF

- NSTX-U is a good test bed for high power detachment
  - $P_{NBI}$ up to 12MW, $P_{HHFW}$~4MW → P/R~20 (~15 for ITER), good test bed for high power detachment
  - Higher $I_p$ → higher peak heat flux → detachment harder to achieve
- Need versatile control knobs for radiative and detached divertor
  - Enhanced neutral pressure
  - Divertor radiation (N not compatible with Li)
  - Core radiation
  - Snowflake
- Combine snowflake and gas injection to maximize detachment performance with minimal confinement degradation

# Independent control of divertor and core radiation with different gas species demonstrated in other machines

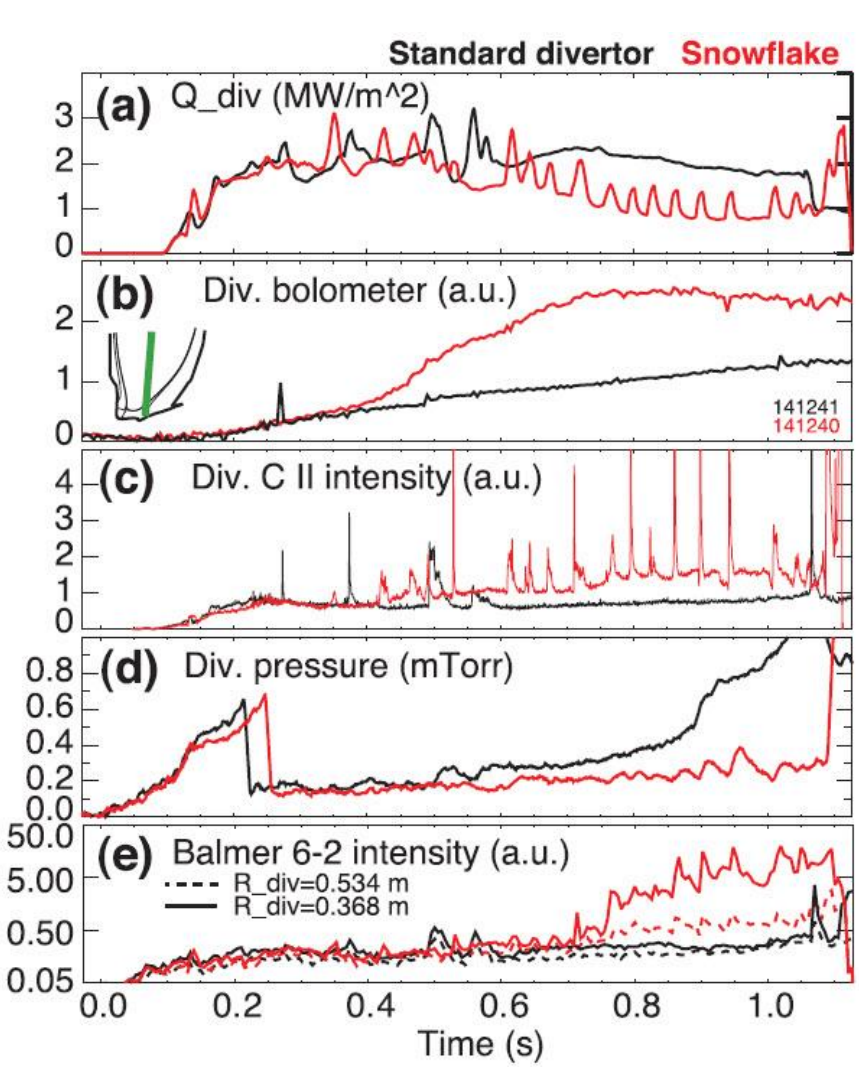
***AUG***




- Nitrogen good for divertor radiation
- Ar/Kr good for core radiation

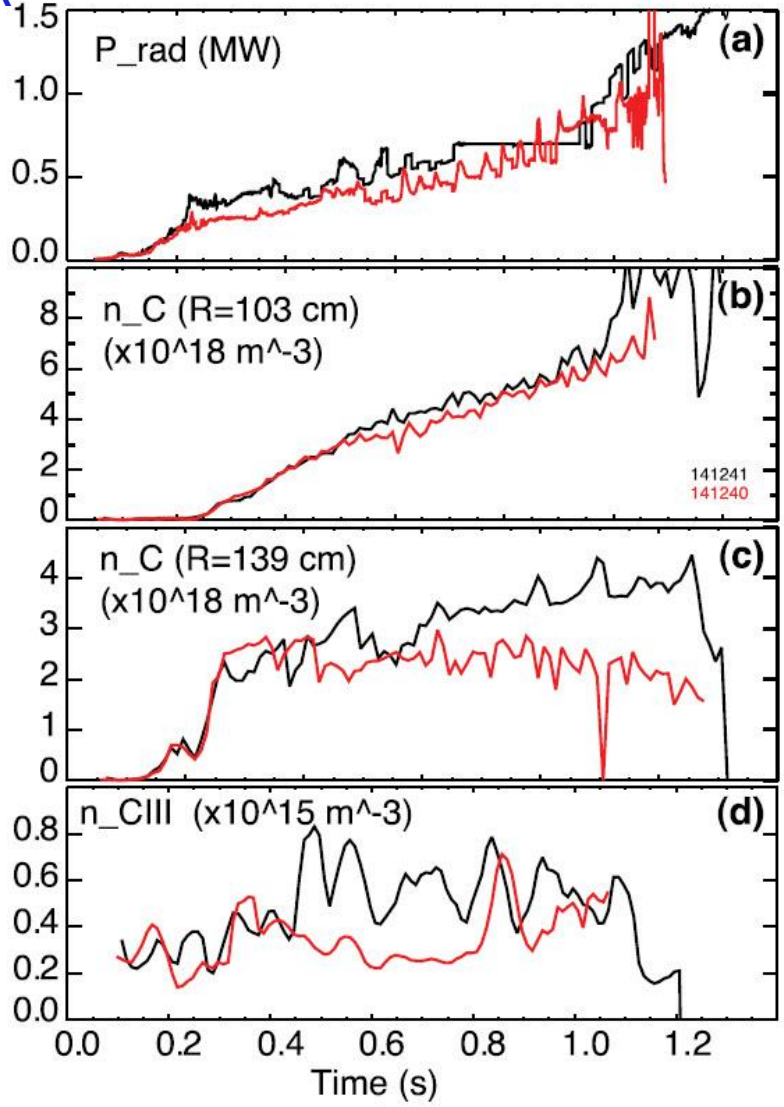
***Kallenbach, PPCF 2013***

# Snowflake could replace N to increase divertor radiation power with core radiation unchanged




*Soukhanovskii, PoP 2012*

*NSTX*



# Experimental plan

- High power detachment via combined snowflake and gas injection
  - Snowflake to enhance divertor radiation
  - D puff to raise neutral pressure
  - Ar seeding to enhance core radiation
- How to combine them all to minimize confinement degradation?
- Scoping studies needed for effect of different gas species, snowflake configuration optimization → Better suited later in FY15 or FY16?