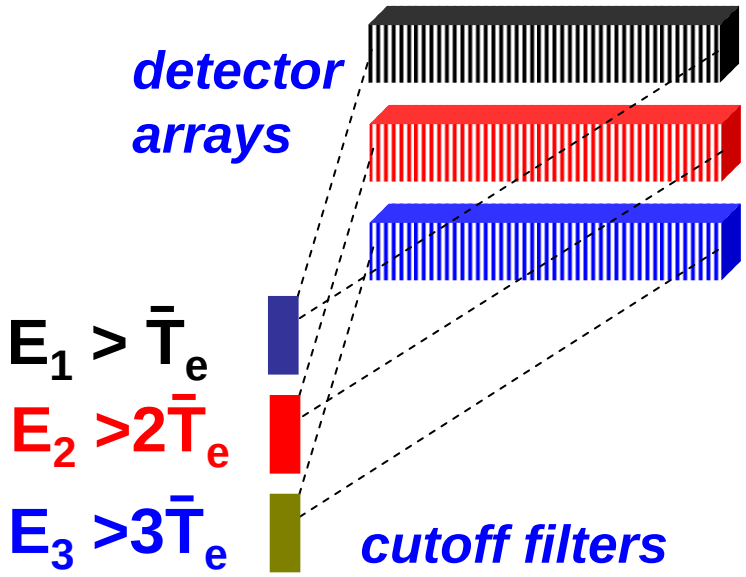
BP relevant diagnostic development at Johns Hopkins University

Presents Dan Stutman

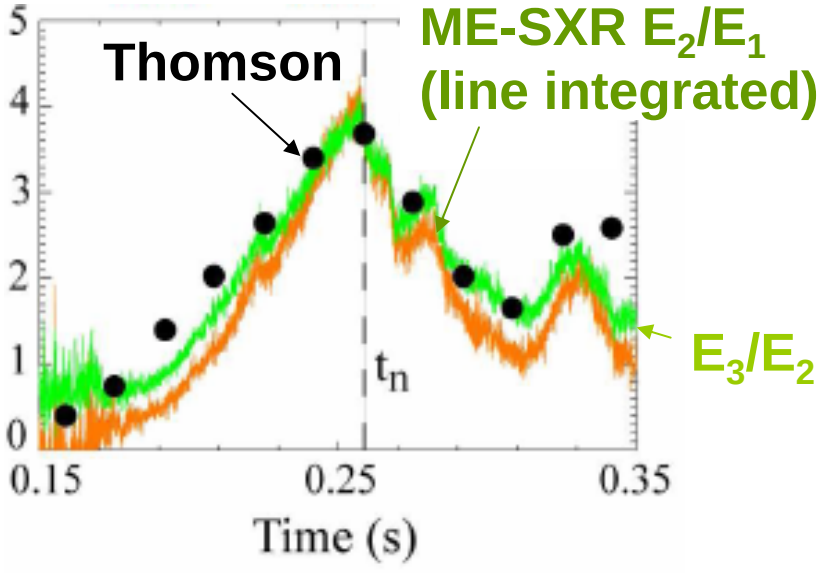
for the

Plasma Spectroscopy-Diagnostic Group

Multi-energy SXR imaging (ME-SXR)



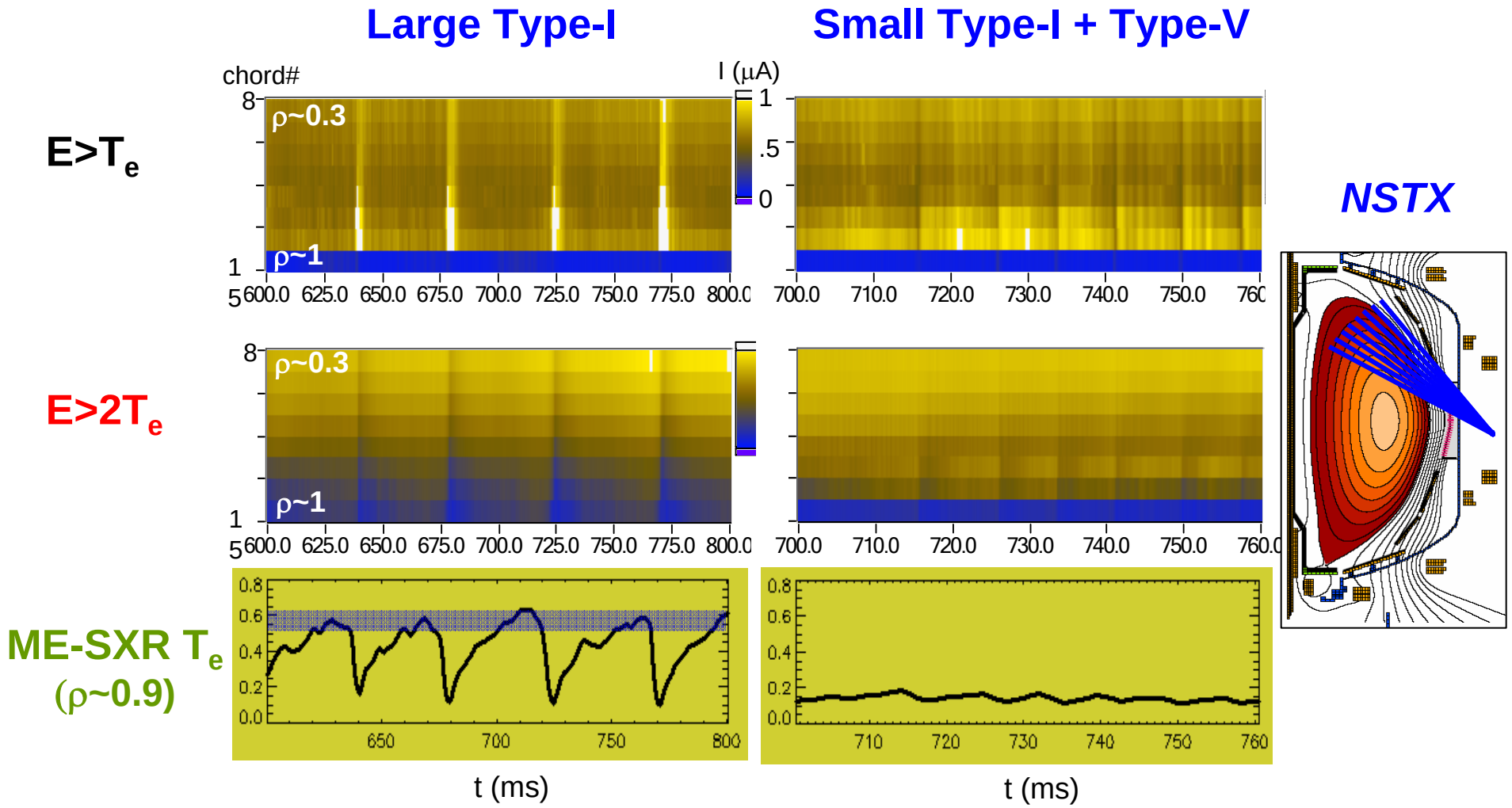
Central T_e during RF heating on NSTX



$$\varepsilon_i^{SXR} \propto n_e \times n_Z \times F(T_e, Z, E_i)$$

- **Same plasma volume simultaneously imaged in a few energy ranges**
- **Fast and simple indicator of T_e and $n_e x n_z$ profiles**
- **High potential for MHD and plasma control in the BP**

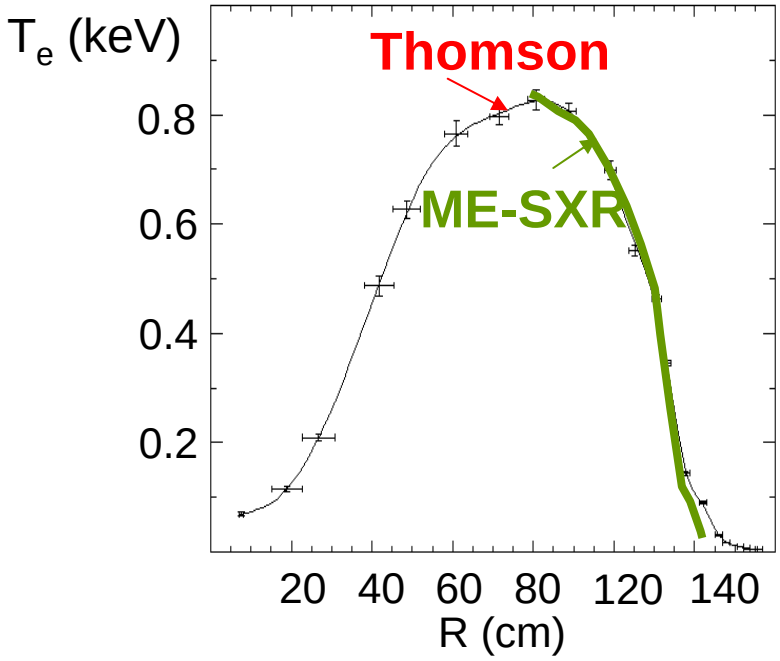
ME-SXR indicates ELM occurrence and type



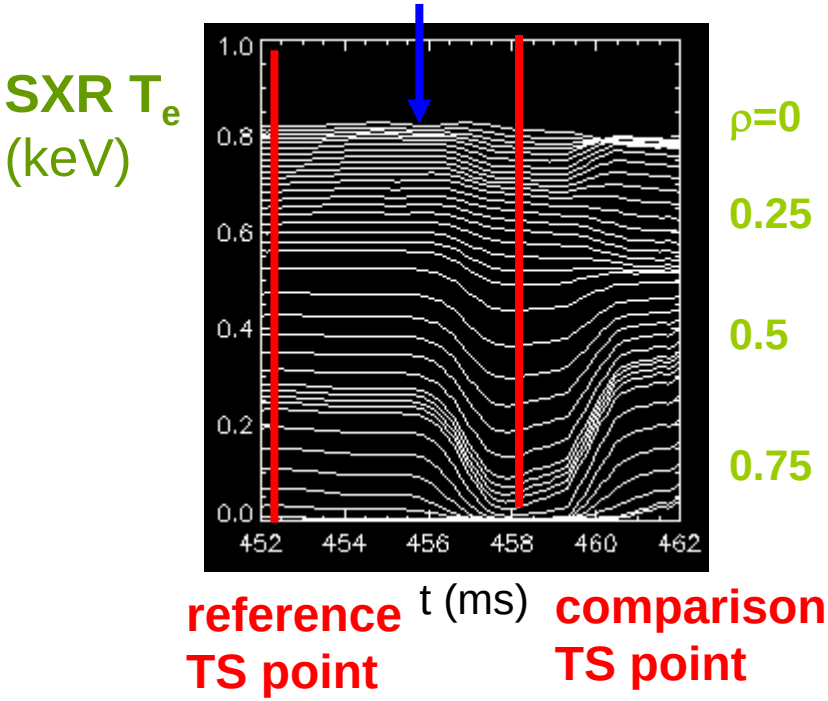
- **Robust ELM indicator using plain line-integrated intensity ratios**
- **Active ELM control with ME-SXR may save 60-70% of τ_{ELM} (~ 1s in ITER)**

Fast, accurate T_e diagnostic with detailed modeling

ME-SXR / Thompson comparison



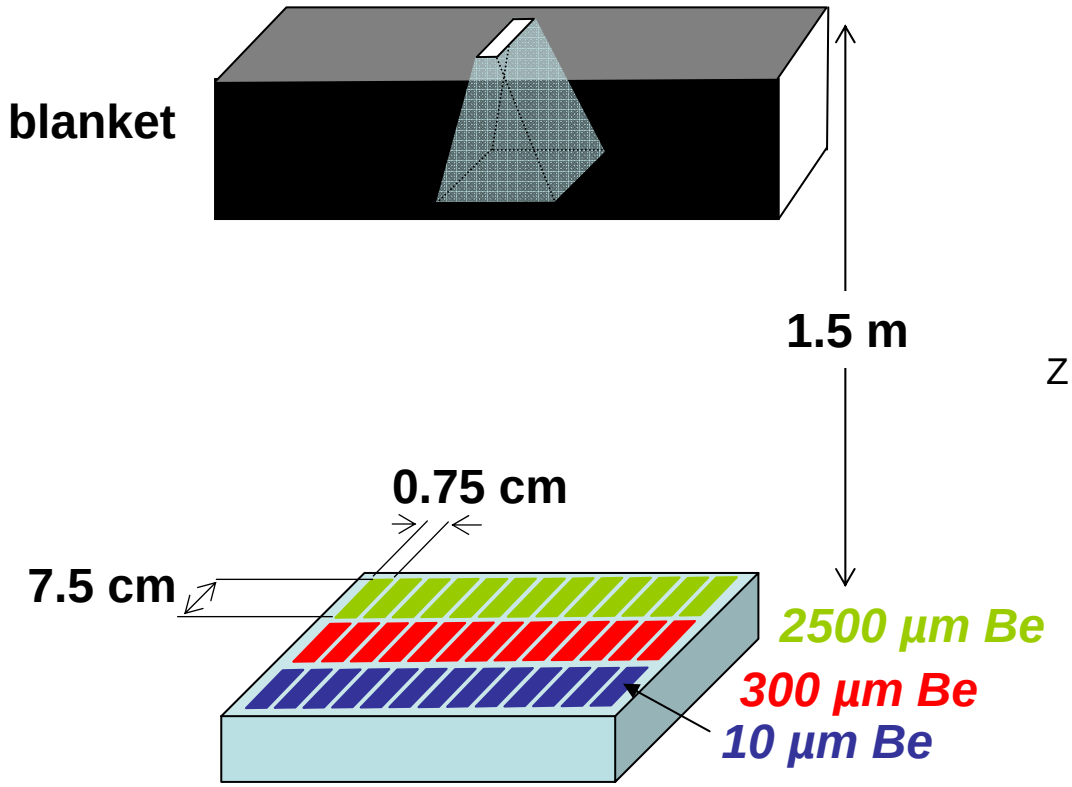
Li pellet injection

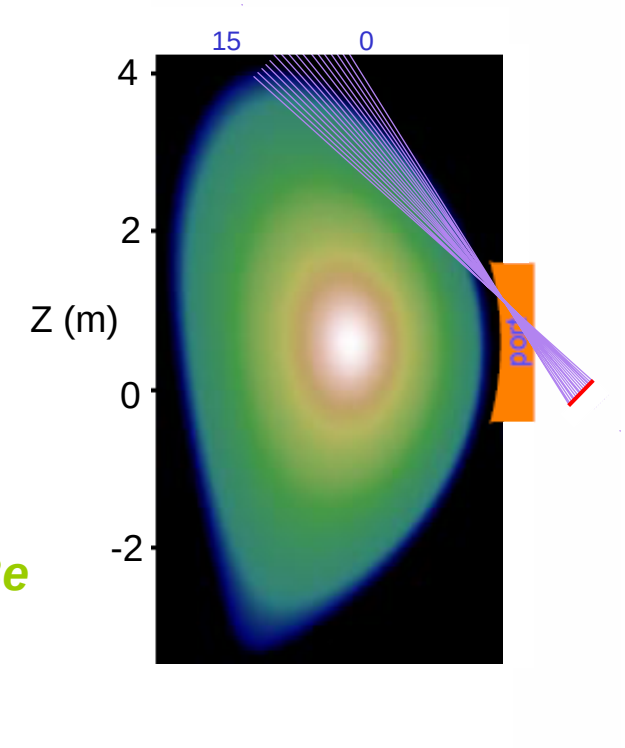


- **SXR T_e 'propagated' in time from reference TS point (n_e, n_z with $\int n_e dl$)**
- **Powerful tool for ELM, pellet, NTM, disruption studies**

  (not impacted by non-thermal bursts, density limits)

ME-SXR diagnostic proposed for ITER pedestal



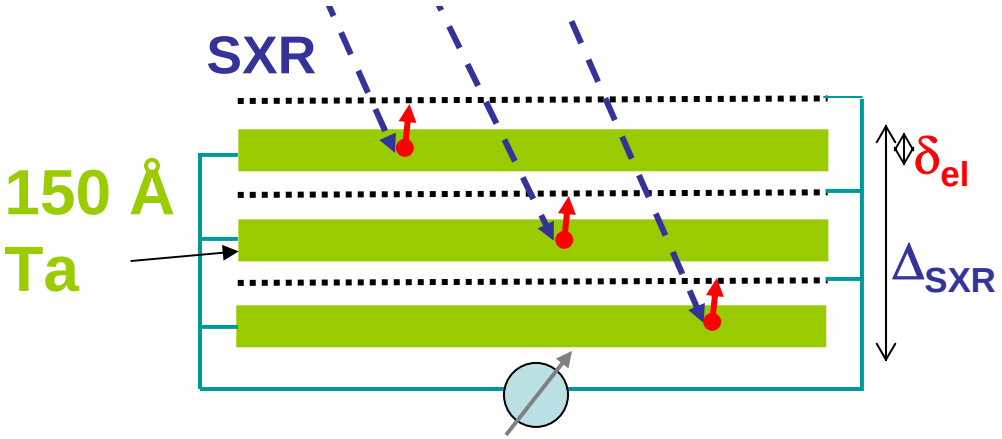


- Physics and mitigation of ELM, RWM, NTM, disruption
- Real-time ELM occurrence and type, L-H transition indicator
- Fast, high resolution T_e (n_e, n_z); reduce exposure of TS first mirrors ?
- Three-energy system for T_e accuracy, high-Z impurity capability

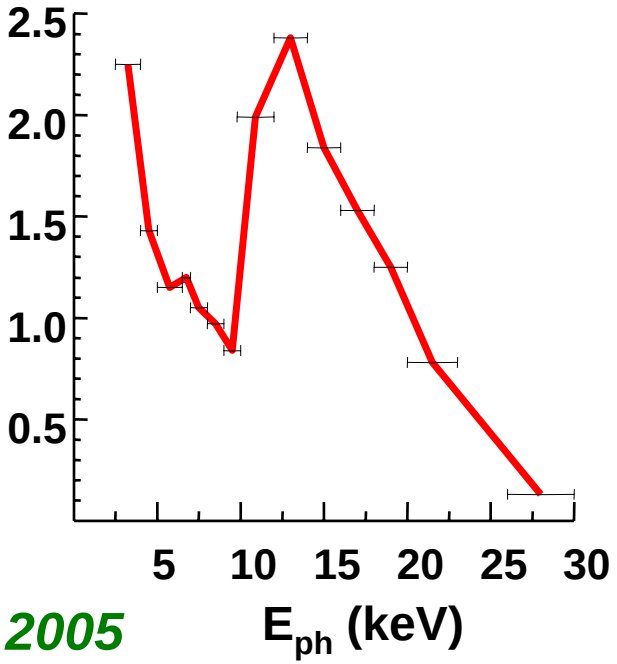
SXR detector needs work, but basic ingredients exist

$\phi_{SXR} \sim \phi_{\gamma,n} \sim 10^{12}\ cm^{-2}s$

Nano-layered Vacuum Photodiode (VPD)



Ta VPD efficiency (electrons/photon)

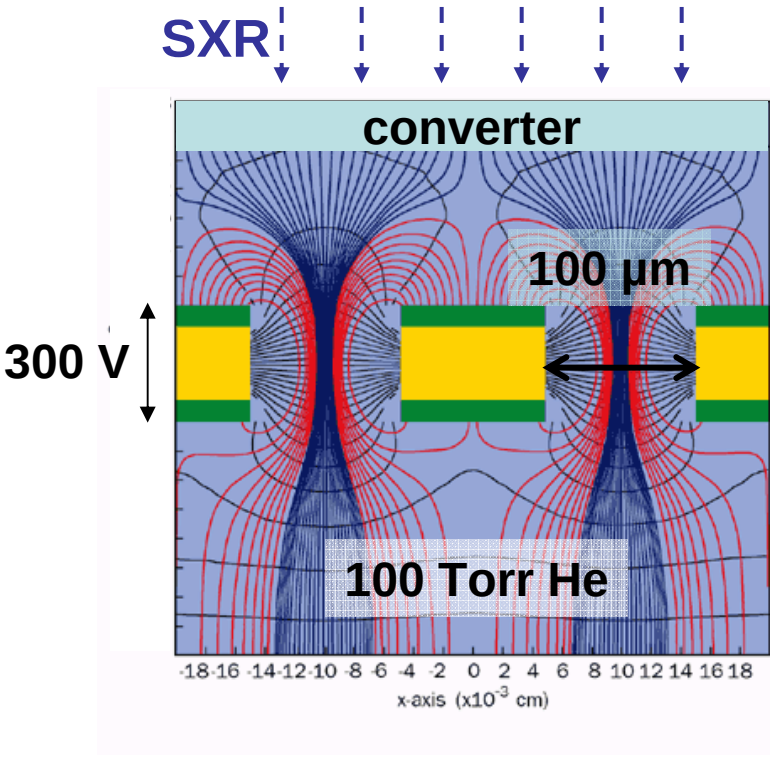


Gott and Stepanenko RSI 2005

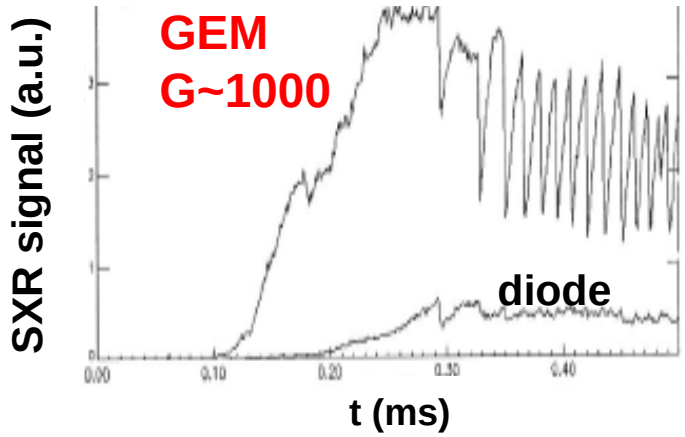
- **Use of external photoelectric effect in high-Z nano-layers solves radiation damage and background problems *(Seguin '97, Gott '05)***
- ***Internal* photocurrent amplification (μA -> mA) needed for signal extraction with good SNR and bandwidth in the BP**

Internal photocurrent amplification demonstrated

Gas Electron multiplier (GEM)



GEM on NSTX (10^9 n/cm^{2}s)

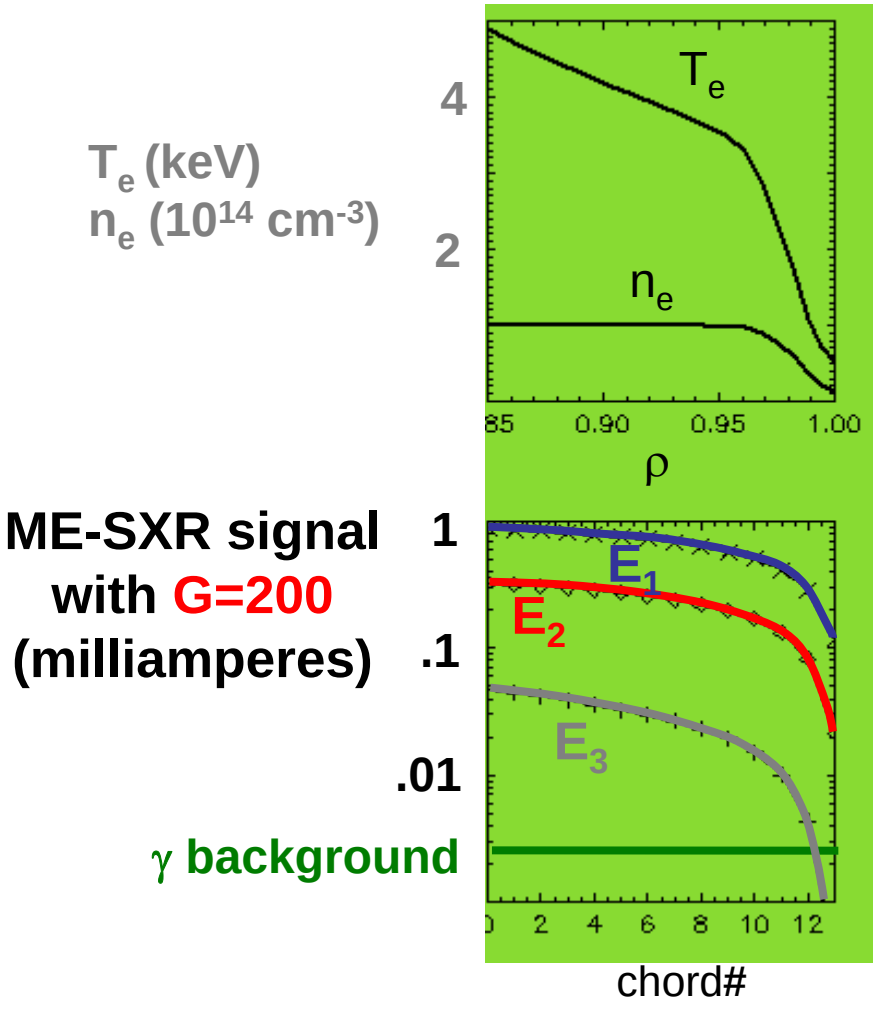


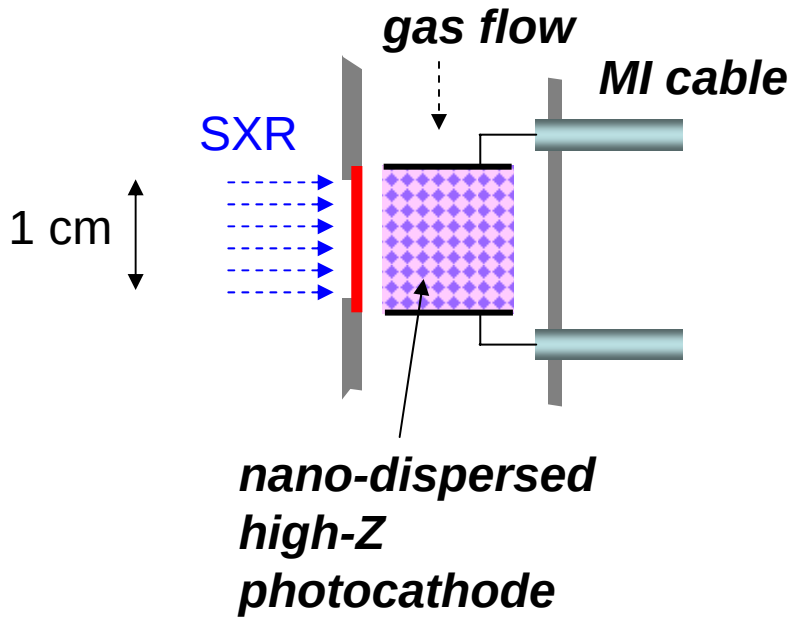
JHU-FTU collaboration

- No observable γ,n background with GEM amplification on NSTX
- Current amplification in low pressure gas observed also with the VPD

ME-SXR possible in ITER with modest amplification

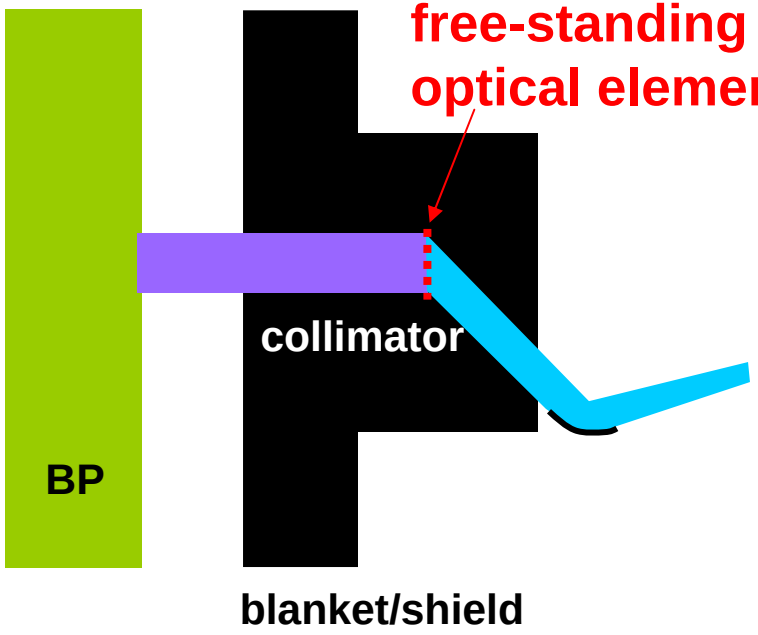
Ta VPD model + CHIANTI





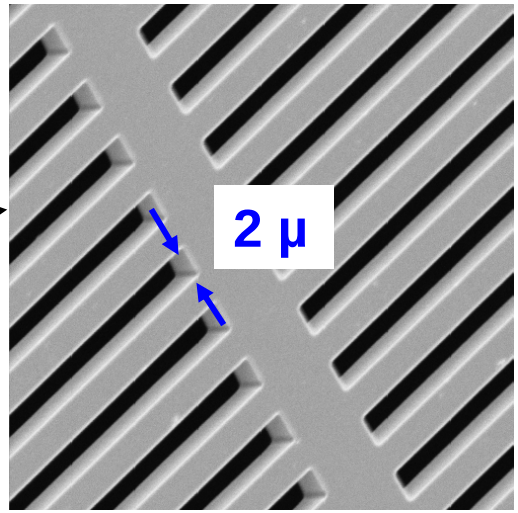
- **Novel nano-dispersed photocathodes, internal amplification mechanisms to be explored at JHU**

Light extraction with diffractive optics



Free-standing Transmission Grating for visible light

10 μm thick, 6x6 mm, Silicon-on-oxide (SOI) wafer

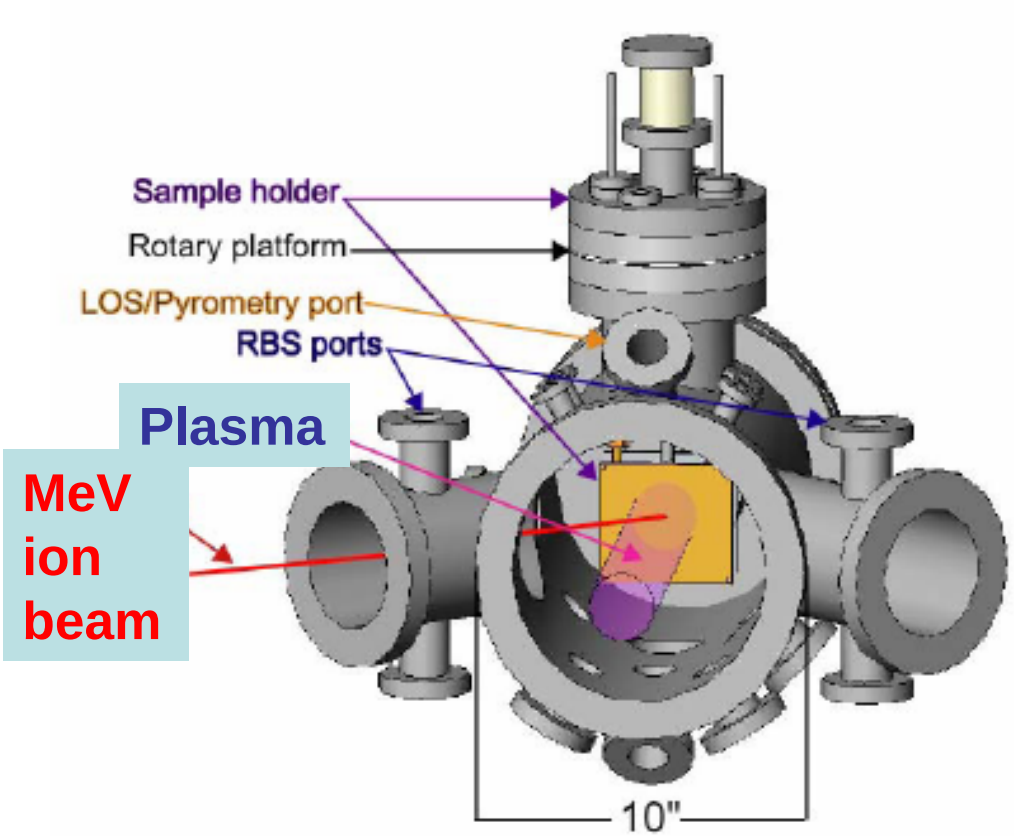


JHU-NWU collaboration

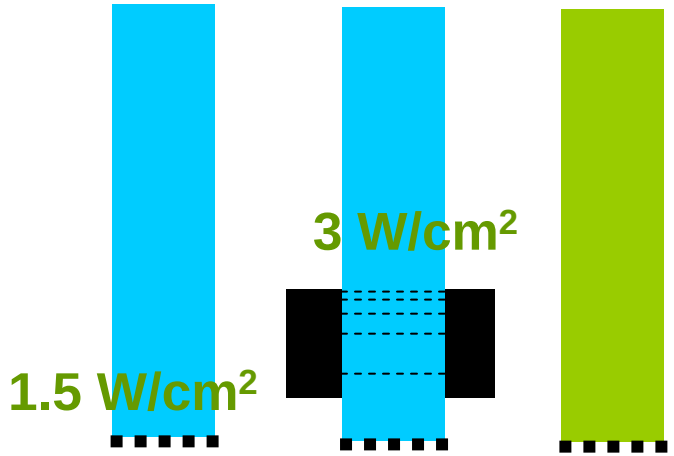
- **Light deflected by multiple slits (Transmission Gratings, Zone Plates)**
- **Less optical degradation, more stable calibration, alignment, replaceable**
- **Scalable over wide spectral range (SXR to infrared)**
- **Diffractive elements can be made in damage resistant metals (W, Ta)**

First plasma, radiation damage tests at DIONISOS (collab. D. Whyte, MIT)

DONISOS facility



plasma on bare grating	plasma on collimated grating	'neutron' damage
$2 \cdot 10^{20}$ cm^{-2}	$5 \cdot 10^{20}$ cm^{-2}	1-2 dpa
100 eV	200 eV	0.5 MeV
Ar ions	D ions	He ions

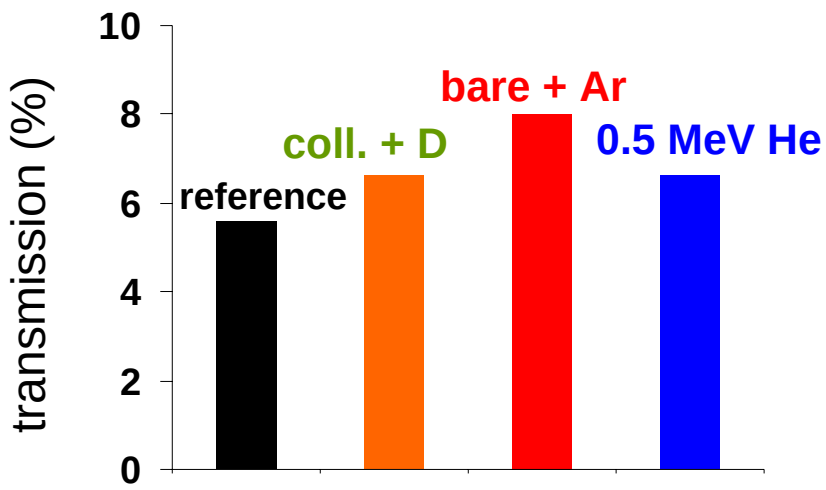


free-standing Si gratings

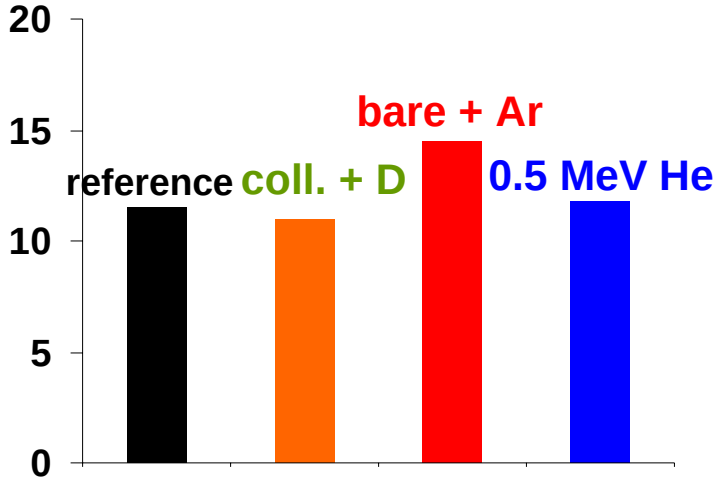
- **Exposures equivalent to a few years of 'first mirror' operation in ITER**

First results are encouraging

1st order at normal incidence
λ=630 nm
(polarization ⊥ slits)



1st order at 5° incidence



- **Gratings withstood very well high heat flux (3-10 x ITER first mirrors)**
- **Plasma, beam exposure slightly *increase* grating efficiency (3-D effect)**
- **Doubled efficiency at a few degrees off-normal incidence**

Summary

- **ME-SXR diagnostic for ITER pedestal proposed through USBPO**
- **Interesting possibilities if control and diagnostic functions are separated**
- **JHU 'Innovative Diagnostics' proposal for novel SXR detectors, development of ME-SXR for W wall conditions**
- **Results on diffractive light extractors encourage further research:**
  - **effect of plasma coatings**
  - **focusing diffractive optics**
  - **VUV extractors**
- **Visible-NIR diffractive extractors for ITER divertor may be possible**