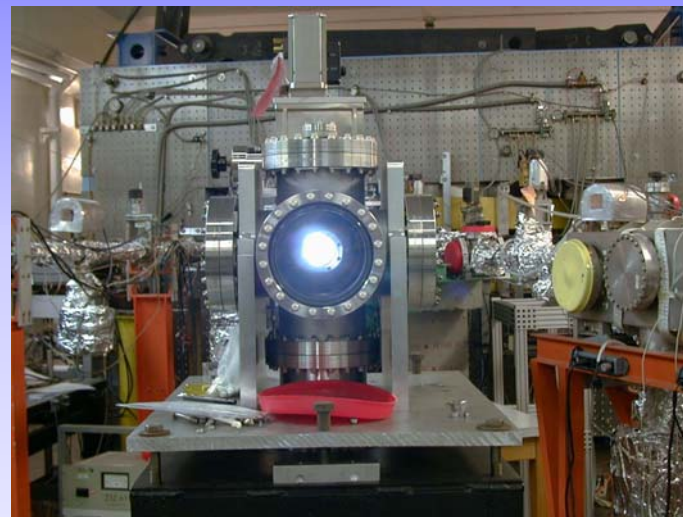


# A method of characterizing narrow-band filtered radiometers using synchrotron radiation

Ping-Shine Shaw, Uwe Arp, and Keith R. Lykke

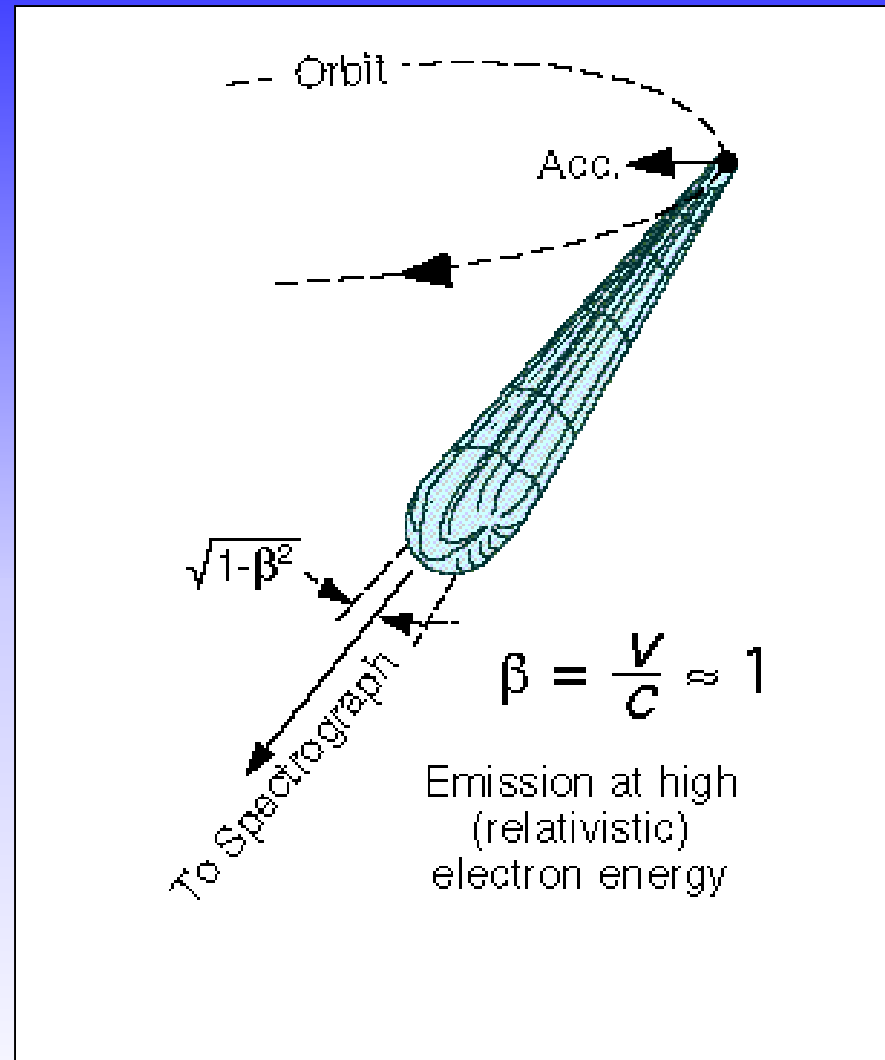
National Institute of Standards and Technology, Gaithersburg, MD, USA



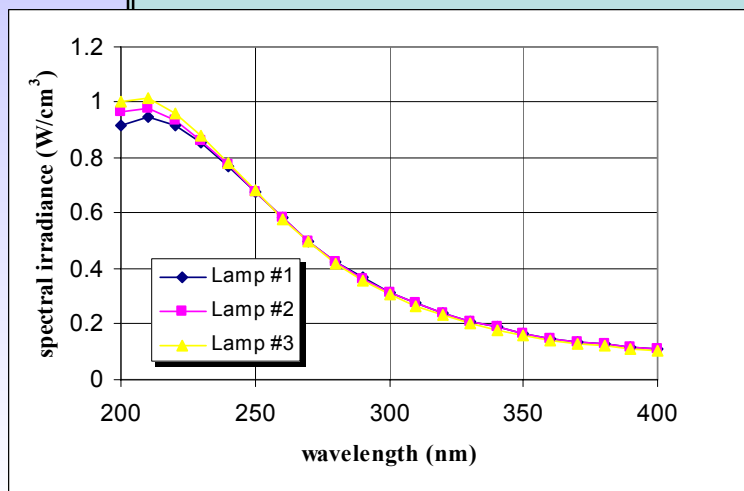
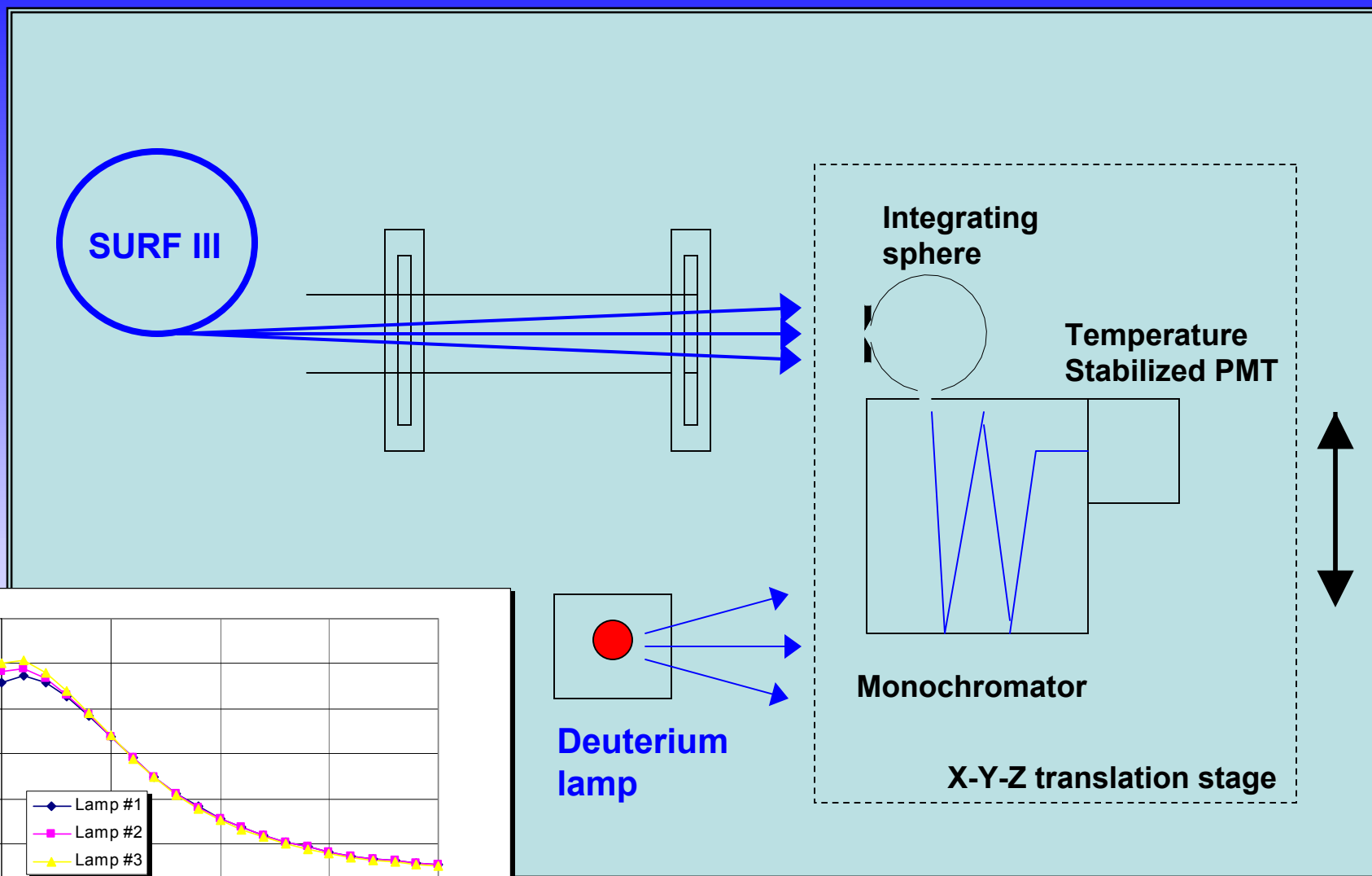
# Synchrotron radiation as an absolute radiometric source

## Synchrotron radiation

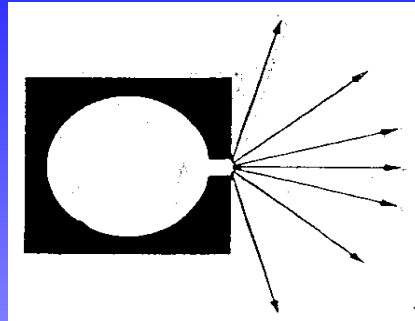
- **Calculable**
- **Primary radiation standard**
- **From IR to x-ray**



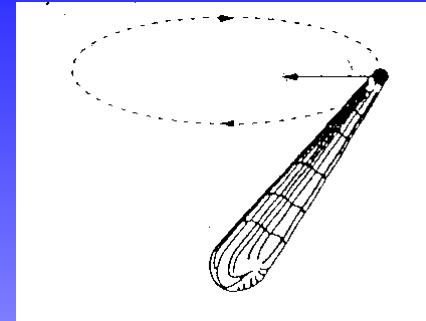
# Facility for Irradiance Calibration Using Synchrotrons at SURF III



# Synchrotron radiation compared with blackbody



**Blackbody**



**Synchrotron radiation**

Governing equation

Planck equation

Schwinger equation

Fundamental parameters

Temperature,  
Emissivity

electron energy, orbital radius,  
beam current

Spectral range

IR to near UV

IR to x-ray

Spatial distribution

uniform

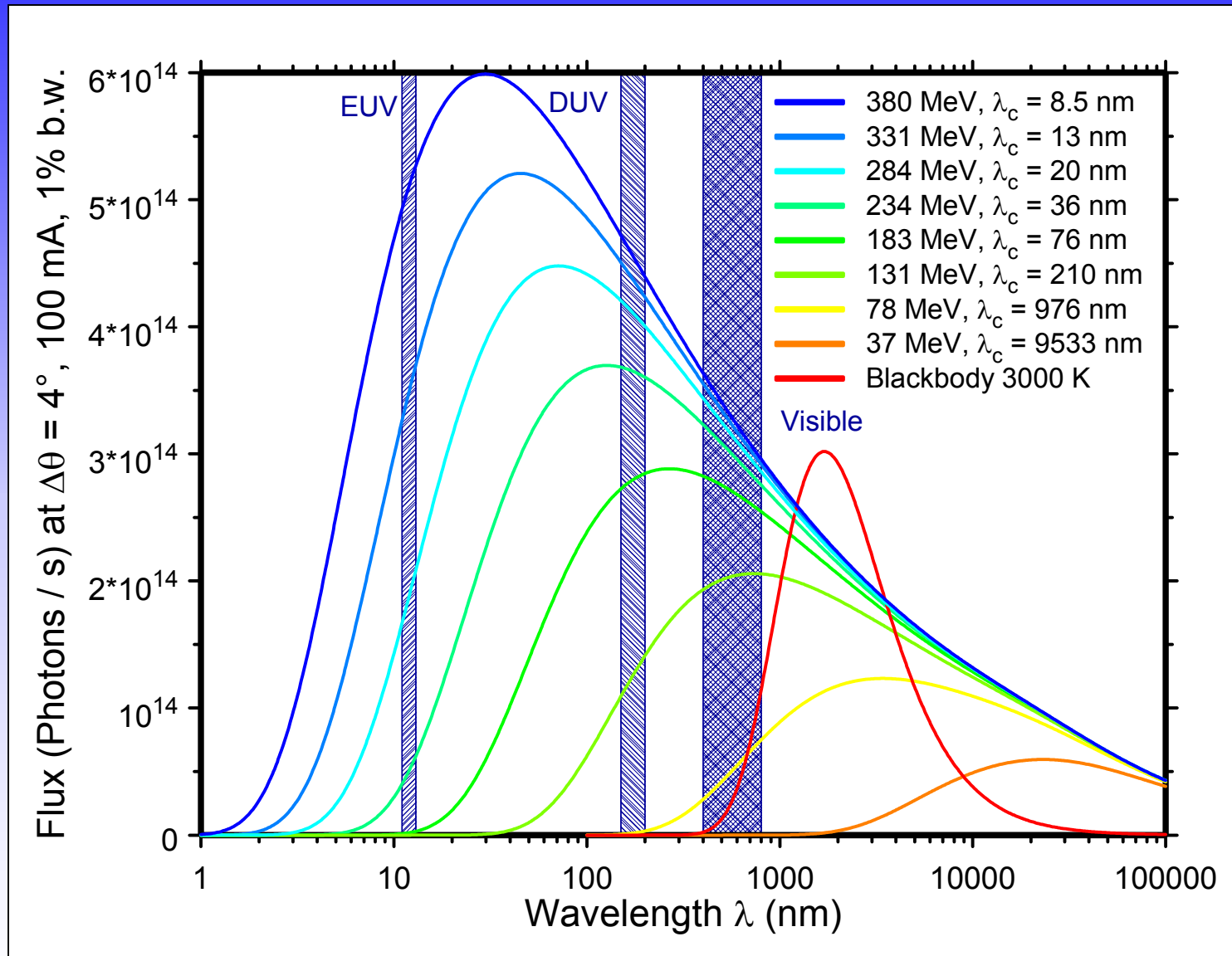
highly collimated in one  
direction

Polarization

unpolarized

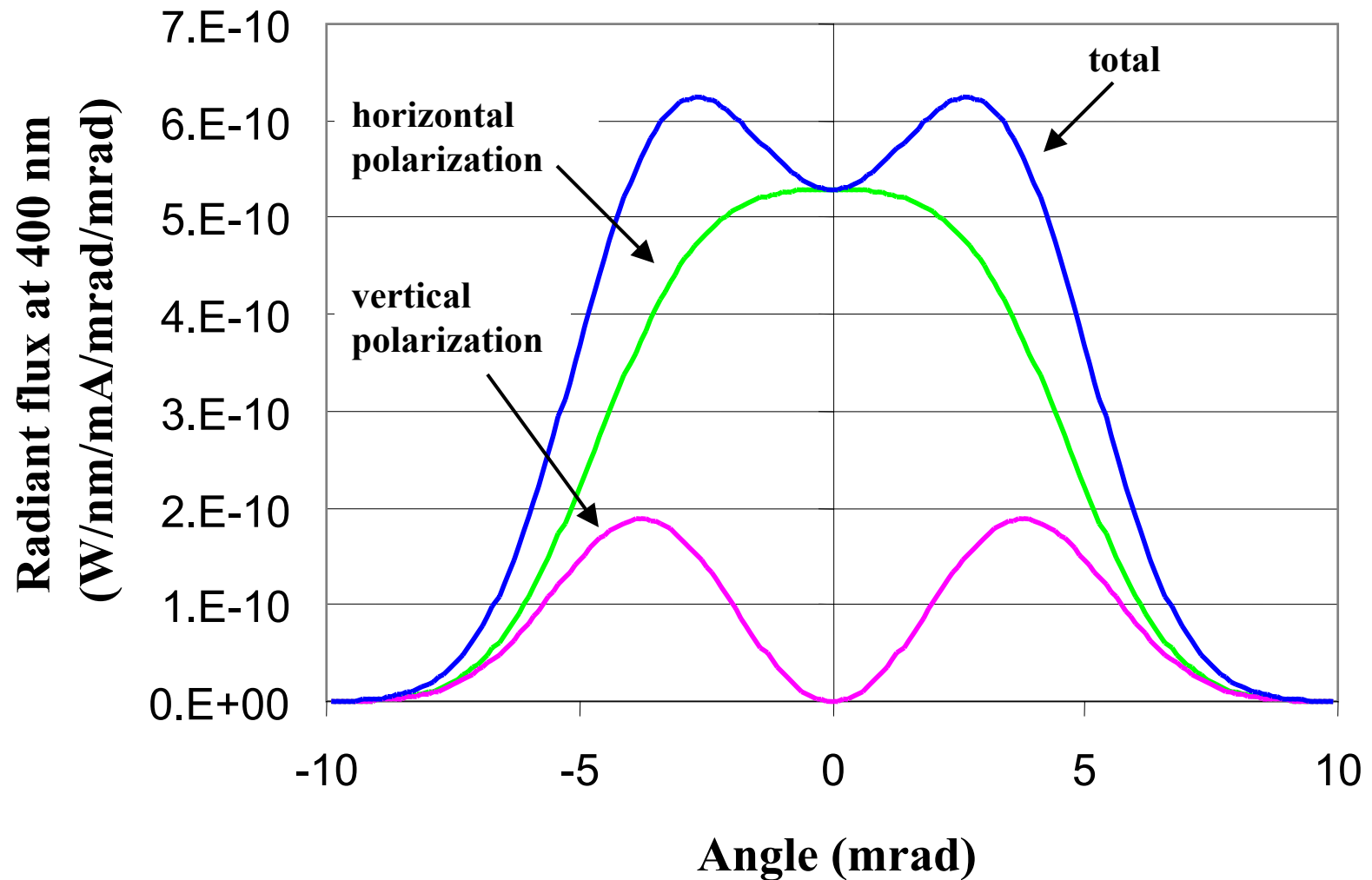
highly polarized

# SURF III spectral output with electron energy from 37MeV to 380MeV

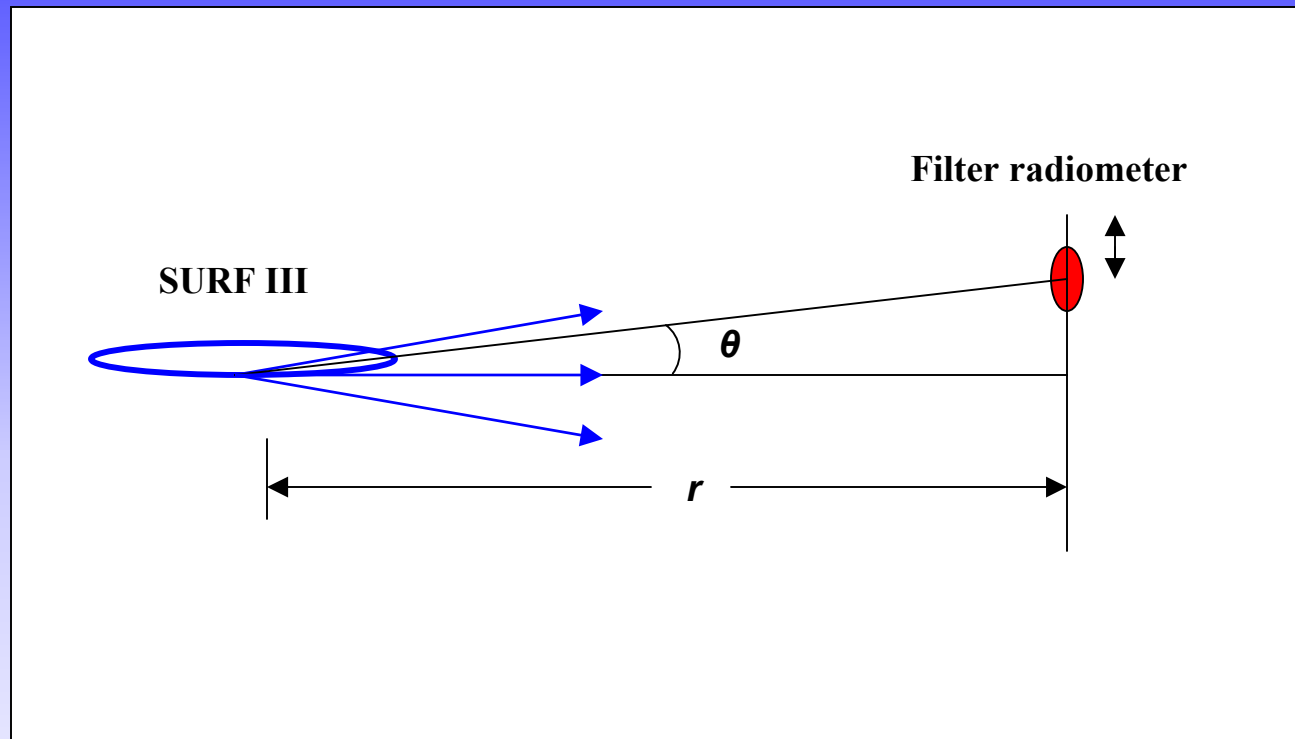


# Calculated angular distribution of SURF

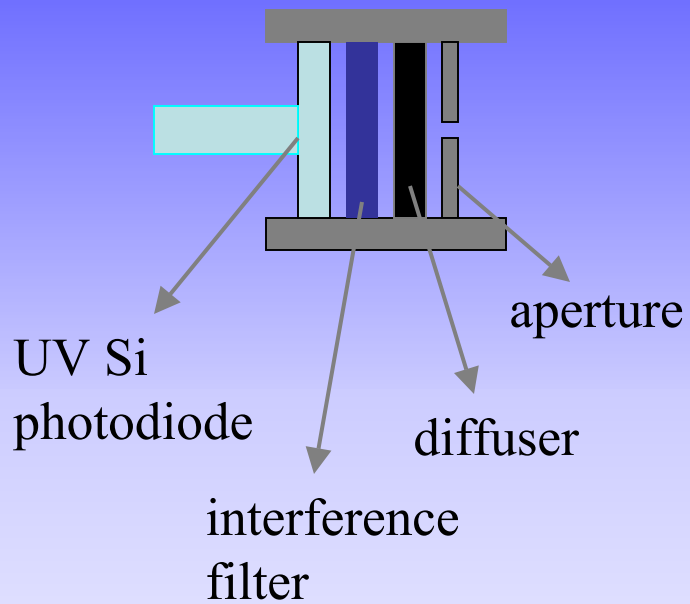
400 nm wavelength with 380 MeV electron energy



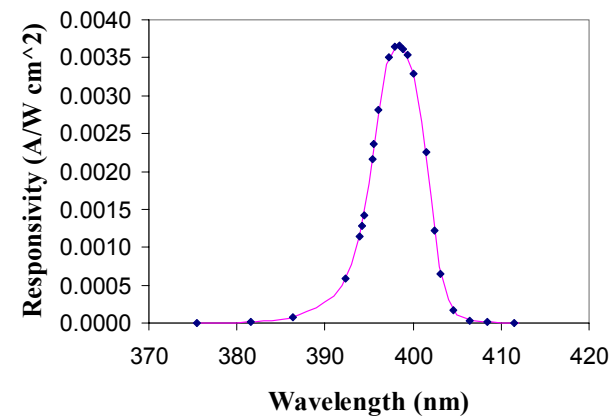
# Measuring angular distribution of synchrotron radiation using a filter radiometer



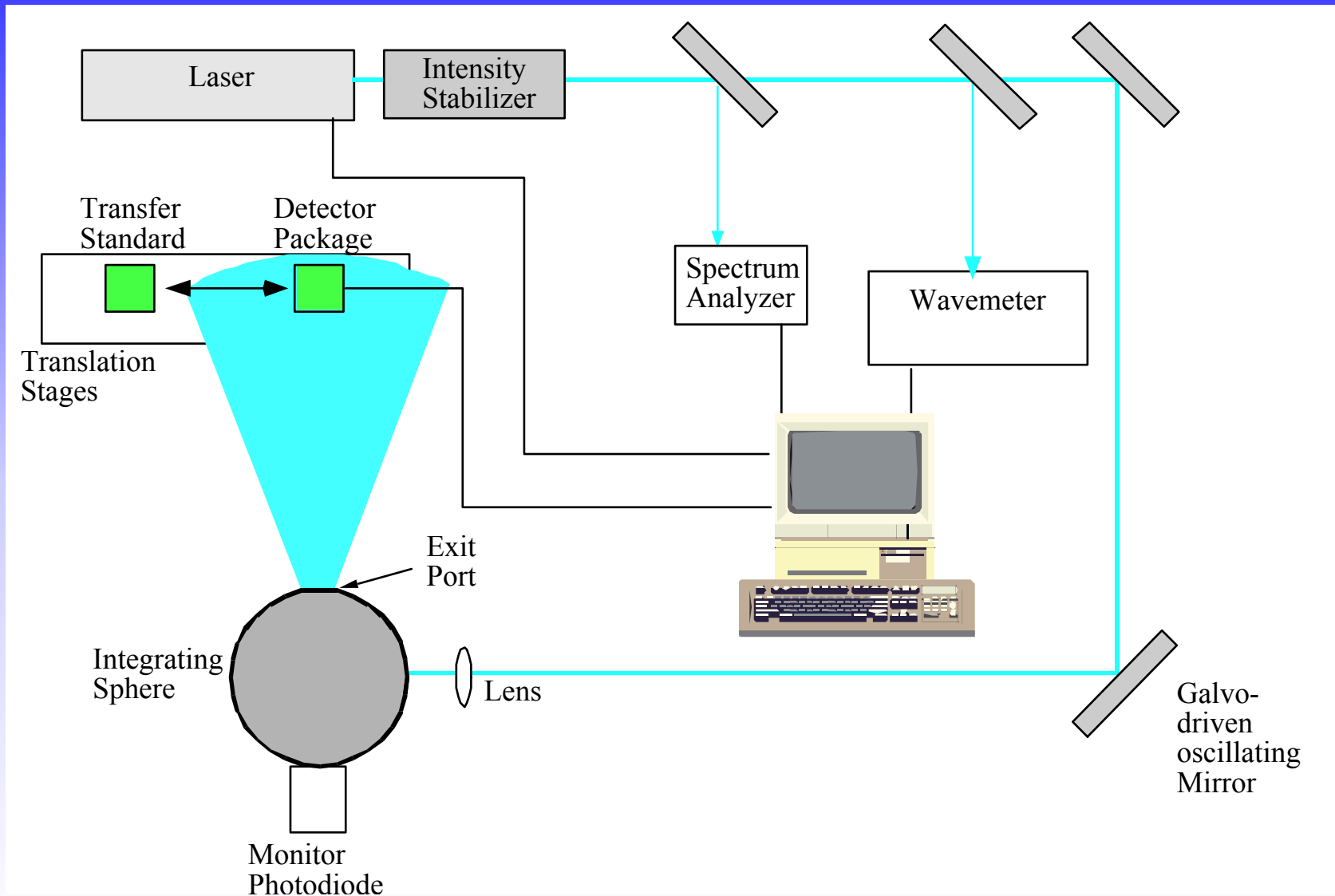
# Typical narrow-band filtered radiometer with interference filter



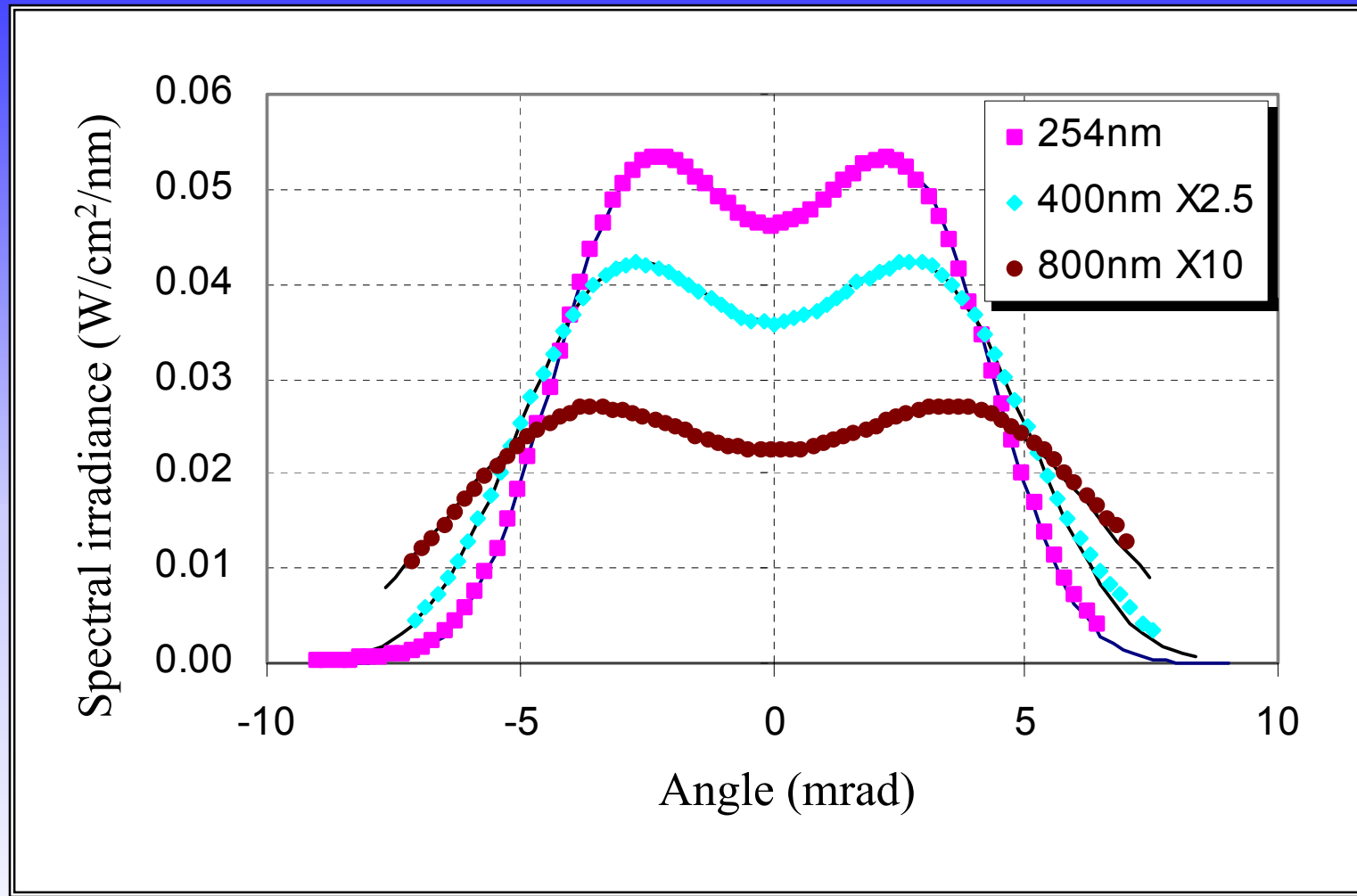
Irradiance responsivity of a 400nm filter radiometer



# Calibration of filter radiometer using tunable laser system at Spectral Irradiance and Radiance Responsivity Calibrations using Uniform Sources (SIRCUS)



# Measured and calculated absolute irradiance at SURF III at 380 MeV



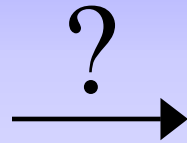
With the measured angular signal from filter radiometer (FR) exposed to synchrotron radiation (SR), given

Irradiance response of FR



Irradiance of SR

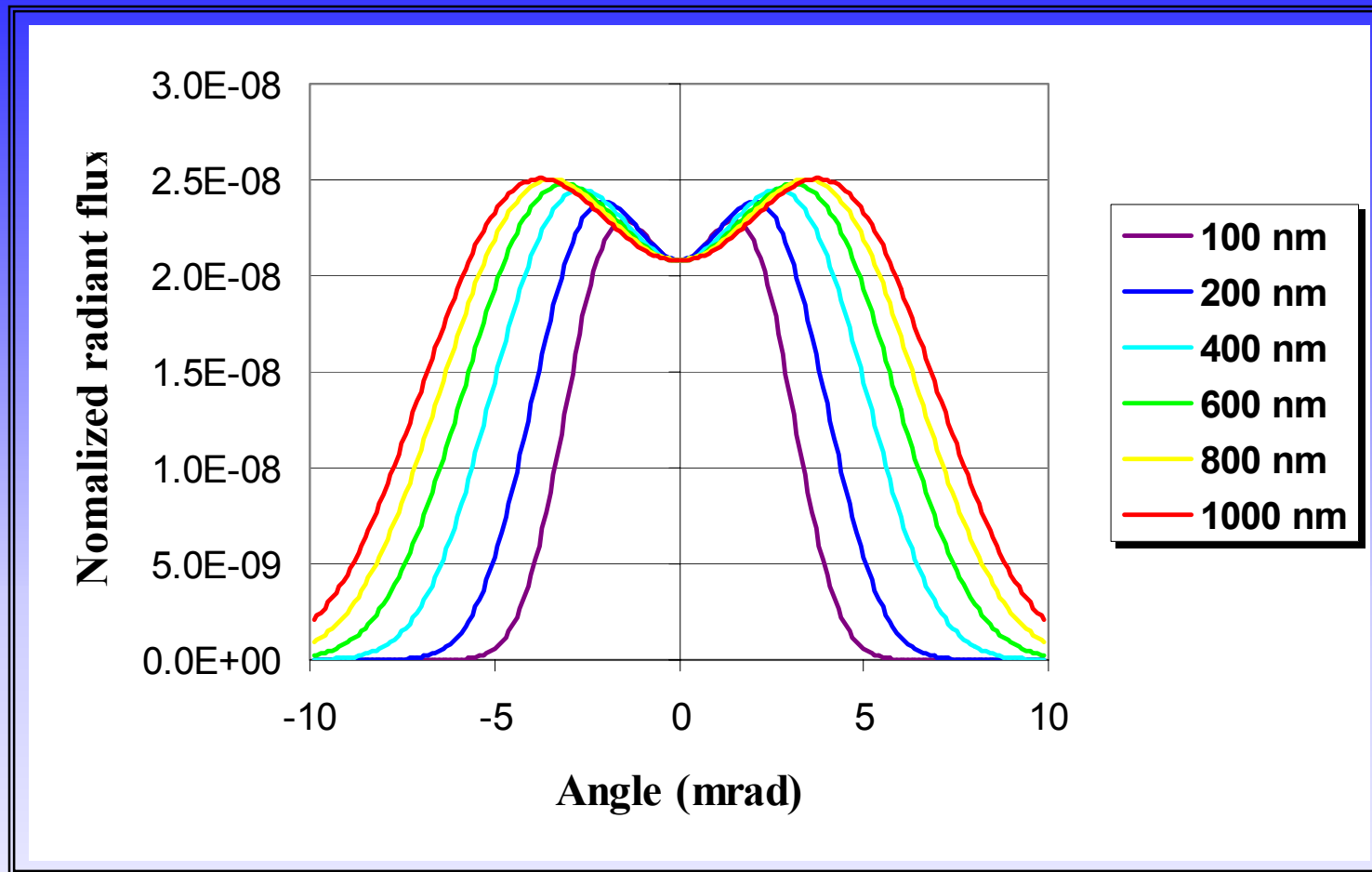
Calculated SR irradiance



Irradiance response of FR

What information about filter radiometer can be derived through angular scan?

# Normalized angular distribution for SURF III at 380 MeV



Can we fit measured angular distribution with calculated single wavelength distribution? If yes, what's the physical meaning of that wavelength?

## Measurement equation for filter radiometers

When exposed to light, the signal from the filter radiometer is given by

$$S = \int E(\lambda)R(\lambda)d\lambda$$

$E(\lambda)$  : spectral irradiance of the incident light

$R(\lambda)$  : irradiance responsivity of the filter

If  $E(\lambda)$  is a well behaved and smooth function and  $R(\lambda)$  is a narrow function then

$$E(\lambda) = E(\lambda_0) + E'(\lambda_0)(\lambda - \lambda_0) + \dots$$

$$S = E(\lambda_0) \int R(\lambda)d\lambda + E'(\lambda_0) \int R(\lambda)(\lambda - \lambda_0)d\lambda$$

If we choose  $\lambda_0 = \frac{\int \lambda R(\lambda)d\lambda}{\int R(\lambda)d\lambda}$

then

$$S = E(\lambda_0) \int R(\lambda)d\lambda$$

# Measurement equation for filter radiometers measuring synchrotron radiation

Integrated irradiance response:

$$R_i = \int R(\lambda) d\lambda$$

Response-weighted mean wavelength:

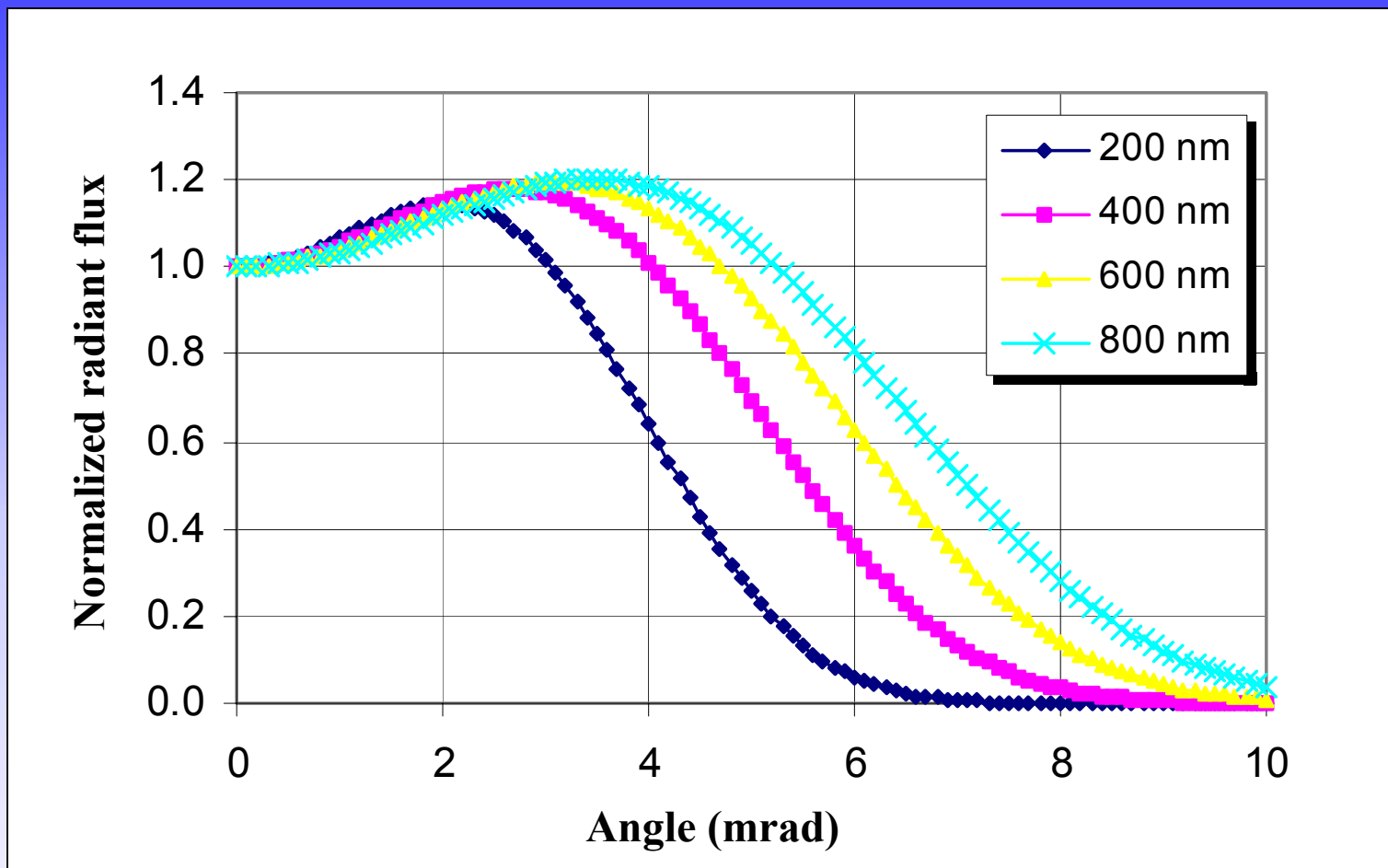
$$\lambda_0 = \frac{\int \lambda R(\lambda) d\lambda}{\int R(\lambda) d\lambda}$$

$R(\lambda)$  is the irradiance responsivity of the filter radiometer at wavelength  $\lambda$

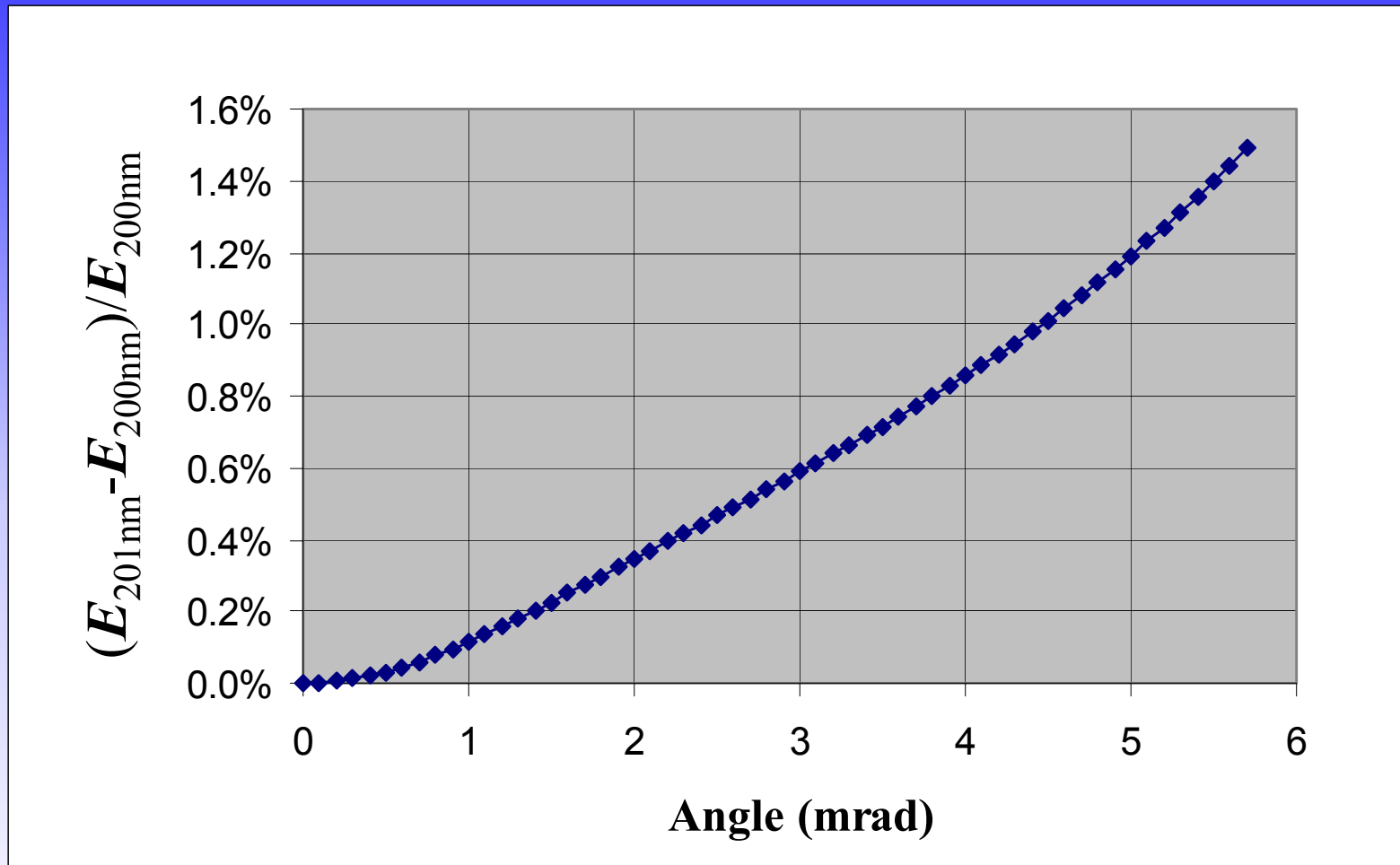
$$S(\psi) = R_i E(\psi, \lambda_0) \quad \psi \text{ is the angle}$$

$R_i$  and  $\lambda_0$  can be determined by curve fitting  $S(\psi)$  with calculated angular distribution.

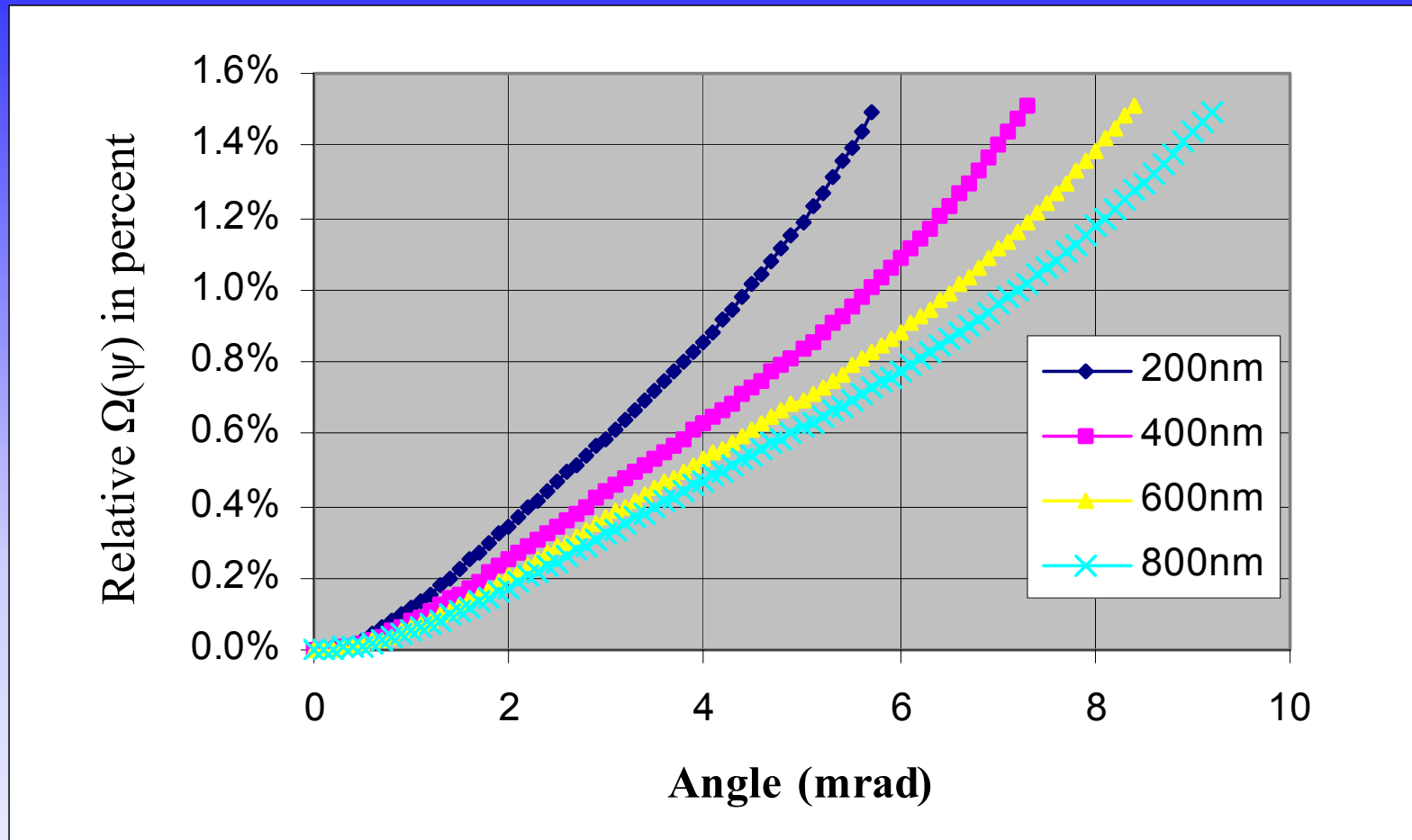
# Normalized angular distribution for SURF III at 380 MeV



# Wavelength sensitivity of 200nm angular distribution for SURF III at 380 MeV



# Wavelength sensitivity analysis on angular distribution for SURF III at 380 MeV



$$\Omega(\psi) = \frac{1}{E(\psi, \lambda)} \frac{\partial E(\psi, \lambda)}{\partial \lambda} * 0.5\% \lambda$$

## Conclusion

- Synchrotron radiation can be used to characterize the integrated response and the mean wavelength of a narrow band filter radiometer
- Simple and fast measurement, no need for transfer standards.
- Applies to a broad spectral range from x-ray to IR.
- Measurement requires good control of scattered light at off-orbital plane angles.
- Possible application to medium-broad-band filter radiometers.