Harmonic Measurements at LCLS

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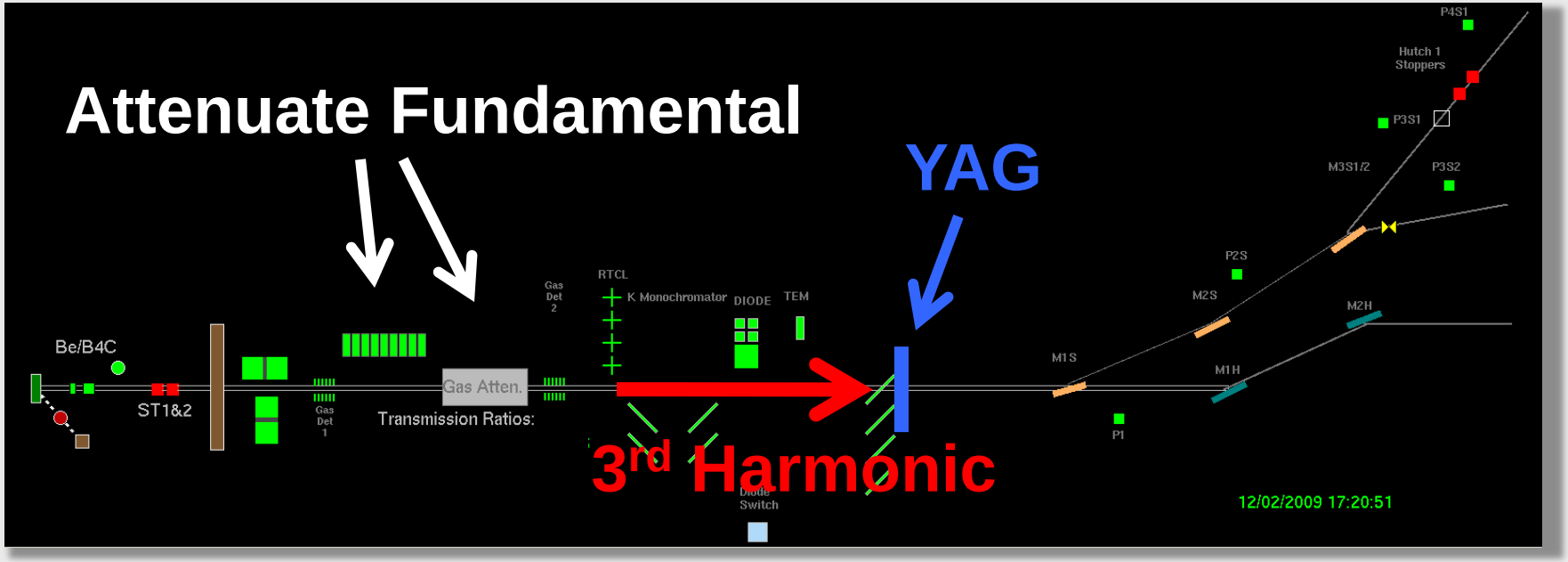
Harmonic Content at LCLS

- Measure harmonics at normal operation
  - H.D. Nuhn will discuss amplification
- Third Harmonic
  - Strongest harmonic
  - Potential source of harder X-rays
- Second Harmonic
  - Background noise for users

Third Harmonic

- Third harmonic content
- Block fundamental
  - Gas (N_2) or solid (10um-30mm Be)
  - Measure counts on 100um YAG

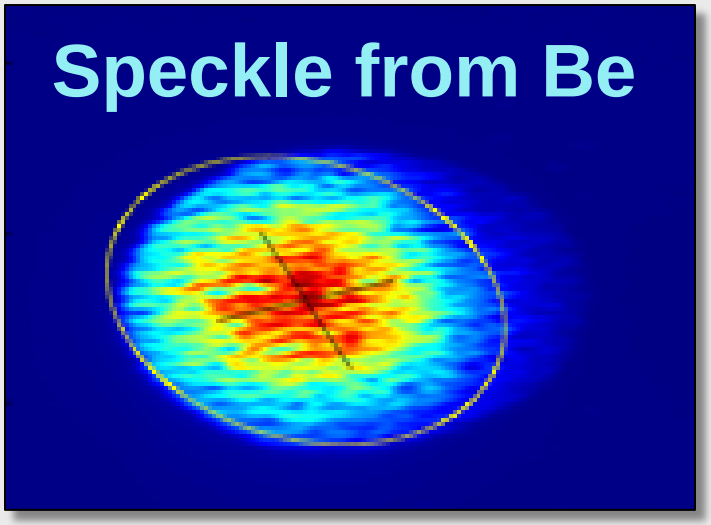
X-ray Diagnostics (J. Welch, FROA1)



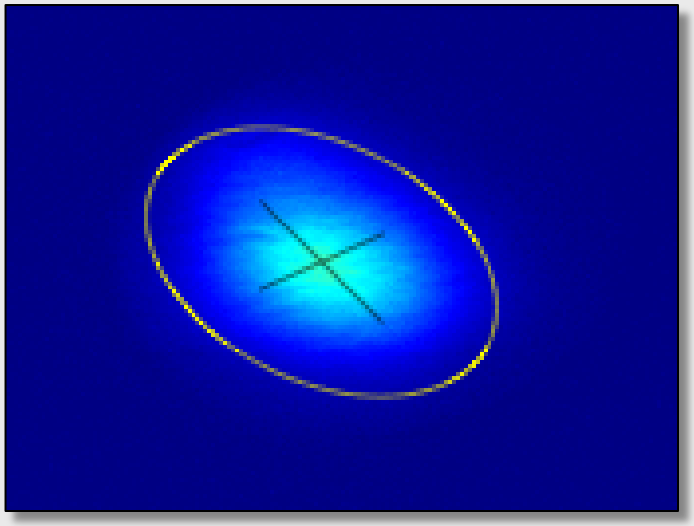
Third Harmonic

- Simplest harmonic measurement:
  - Take ratio of counts from two images
  - 900 eV fund: 1.7% 3rd Harmonic
  - 1.7 keV fund: 2.7% 3rd Harmonic

Fundamental



3rd Harmonic



Third Harmonic

- Scanning attenuation

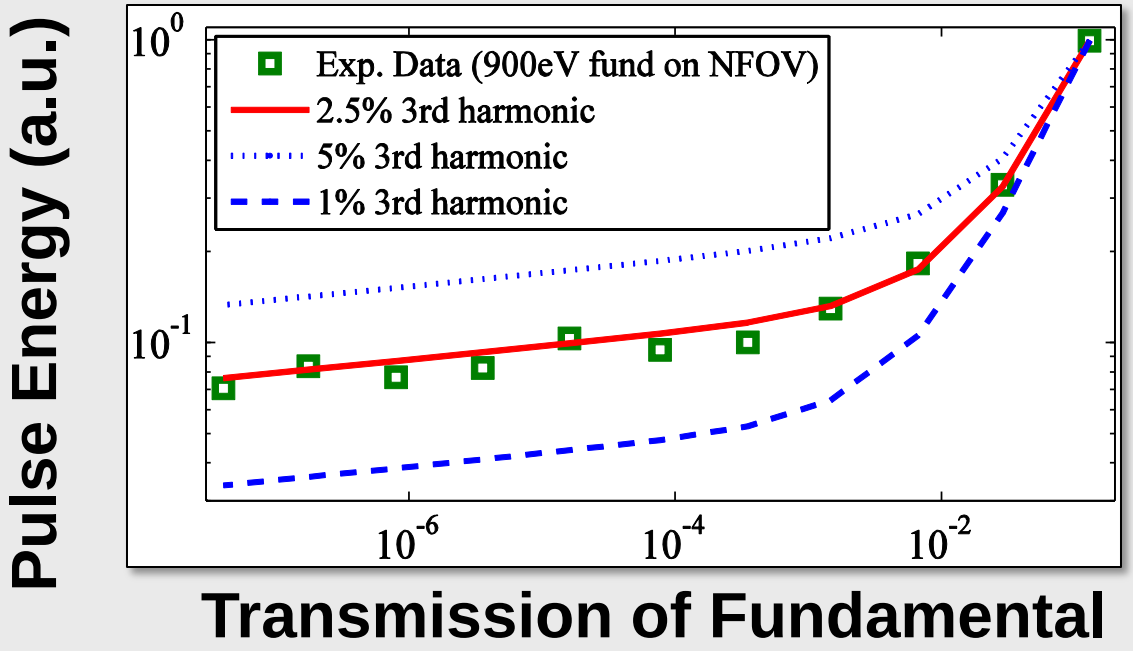
Transmission

$$\text{Counts} \propto T_{1st} \times P_{1st} + T_{3rd} \times P_{3rd}$$

$$\Rightarrow \text{Counts} \propto T_{1st} + T_{3rd} \times (P_{3rd} / P_{1st})$$

Power

- 900 eV fund: 2.5% 3rd Harmonic (~1 mJ 1st)



Third Harmonic

- Fit proportion from attenuation

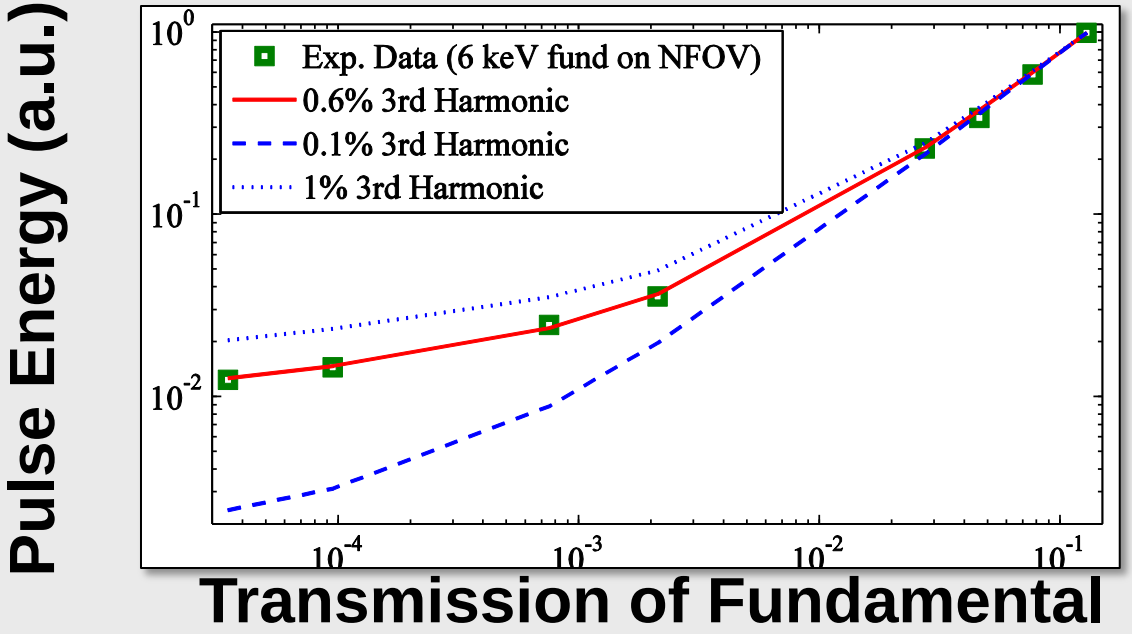
Transmission

Power

$$\text{Counts} \propto T_{1st} \times P_{1st} + T_{3rd} \times P_{3rd}$$

$$\Rightarrow \text{Counts} \propto T_{1st} + T_{3rd} \times (P_{3rd} / P_{1st})$$

- 6 keV fund: 0.6% 3rd Harmonic (0.6 mJ 1st)



Third Harmonic

- Fit proportion from attenuation

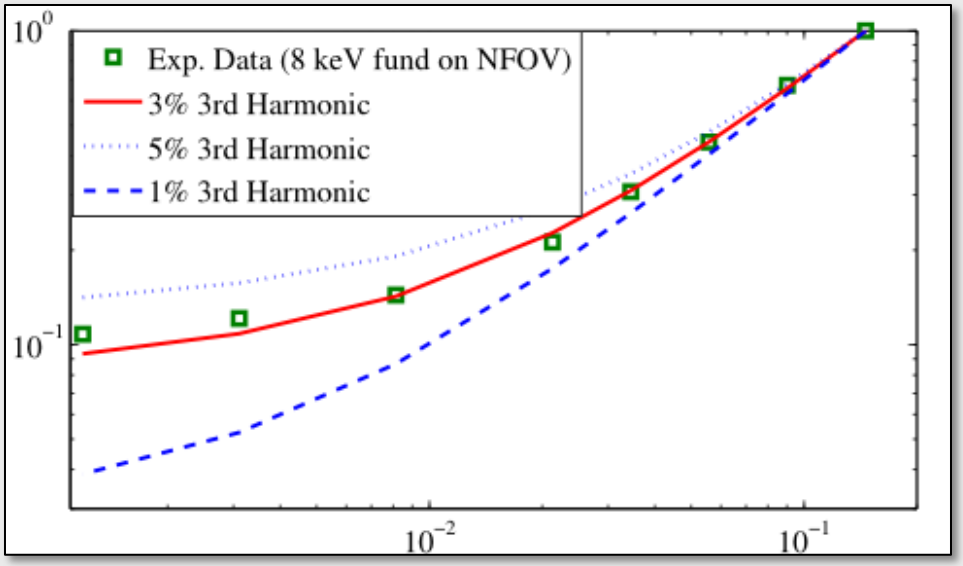
Transmission

Power

$$\text{Counts} \propto T_{1st} \times P_{1st} + T_{3rd} \times P_{3rd}$$

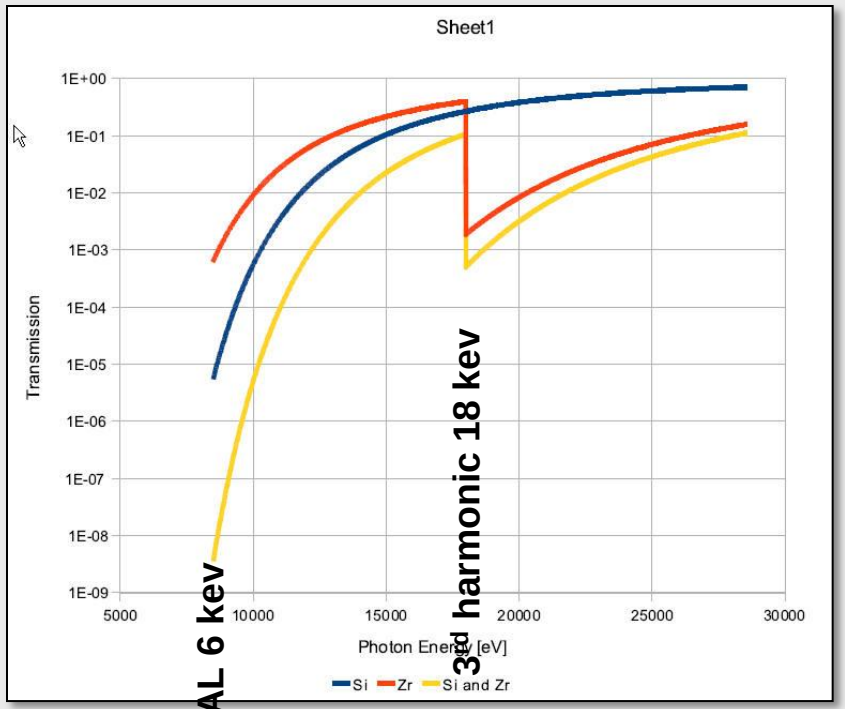
$$\Rightarrow \text{Counts} \propto T_{1st} + T_{3rd} \times (P_{3rd} / P_{1st})$$

- 8 keV fund: 3% 3rd Harmonic (1.5 mJ 1st)



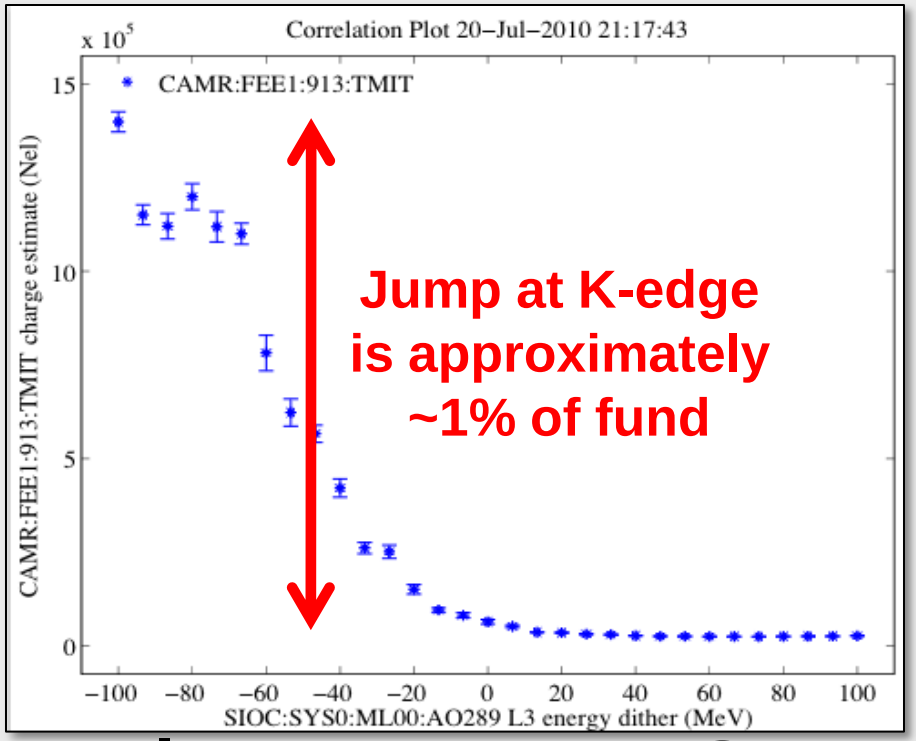
Third Harmonic

- Confirm 3rd Harmonic measurement at 6 keV
  - Zirconium K-edge
  - Confirms wavelength and intensity



Thanks to Alan Fisher!

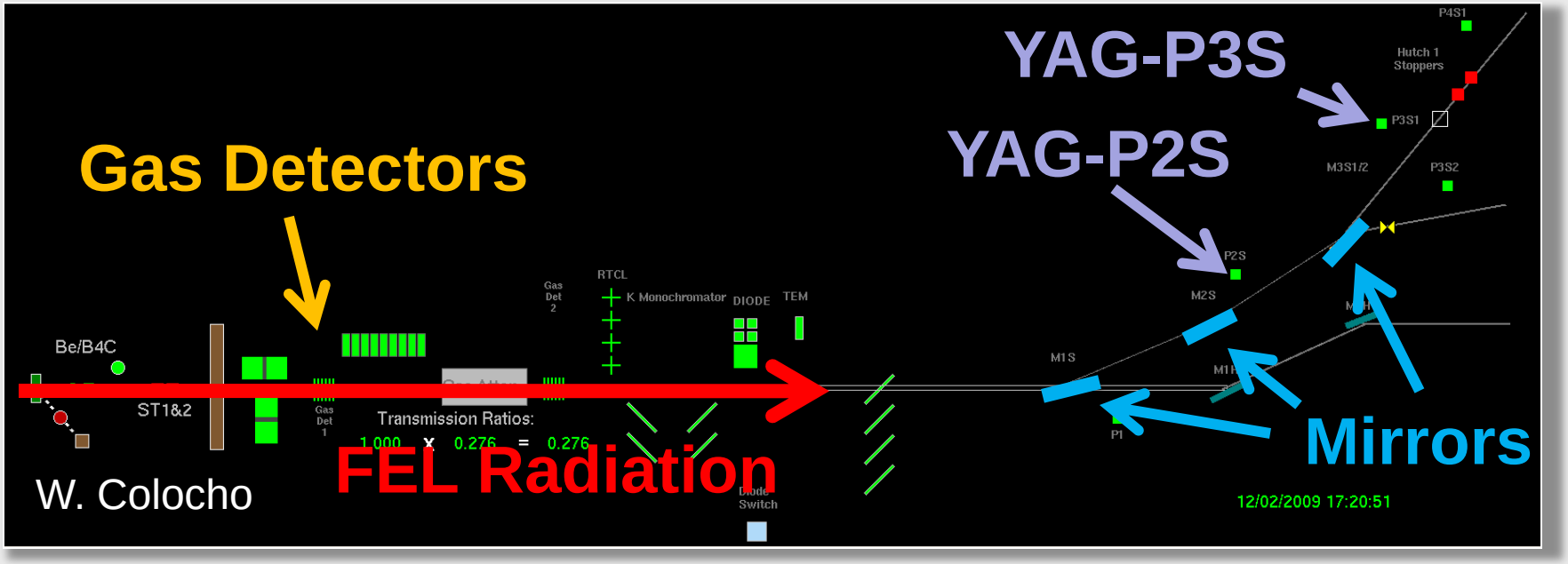
Pulse Energy (a.u.)



Electron Energy Scan

Second Harmonic

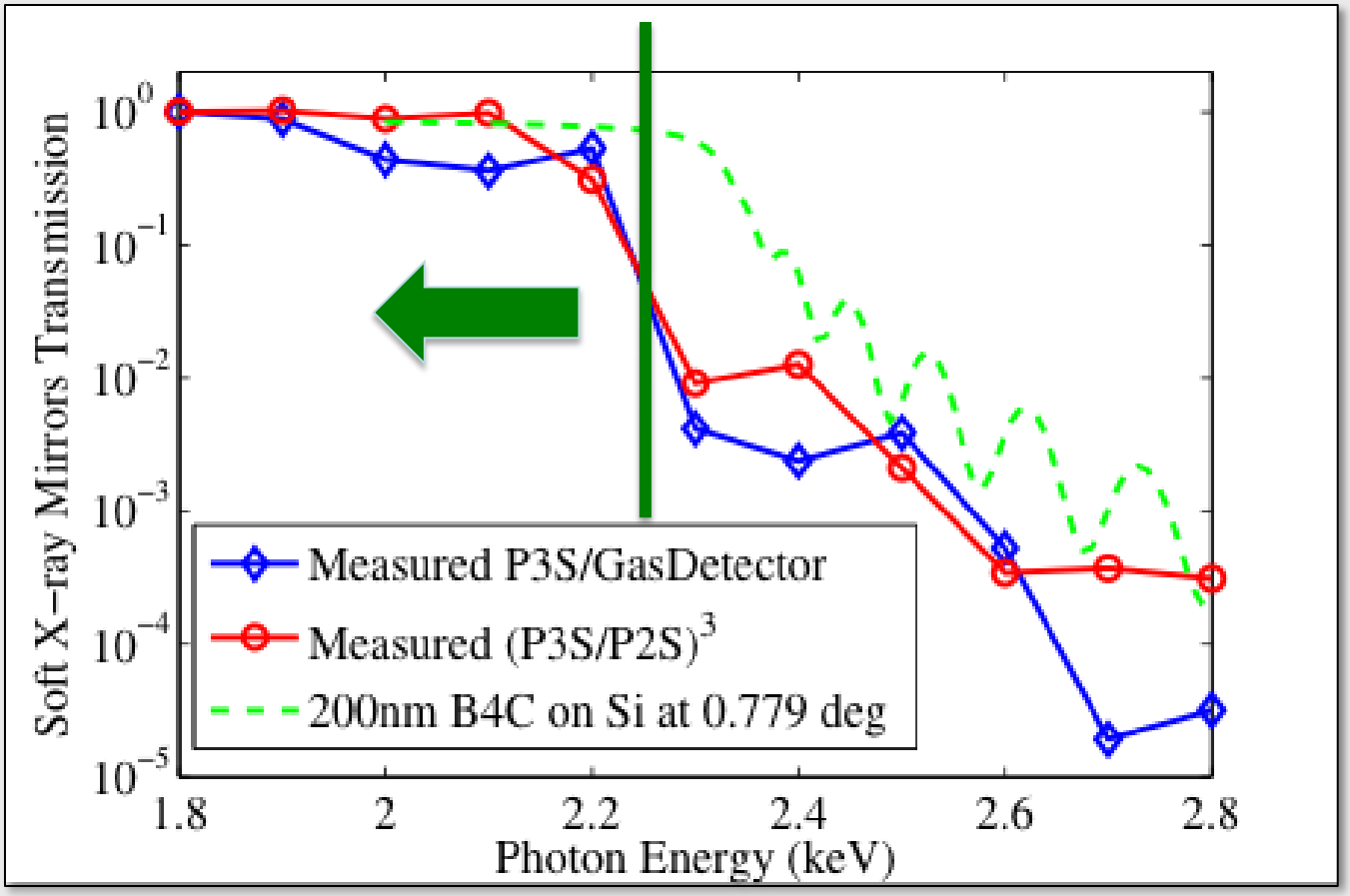
- What is 2nd harmonic content in FEL?
- What is 2nd harmonic content in beamline?
  - Measure transmission cutoff



Mirror Cutoff

- Soft X-ray beamline transmission

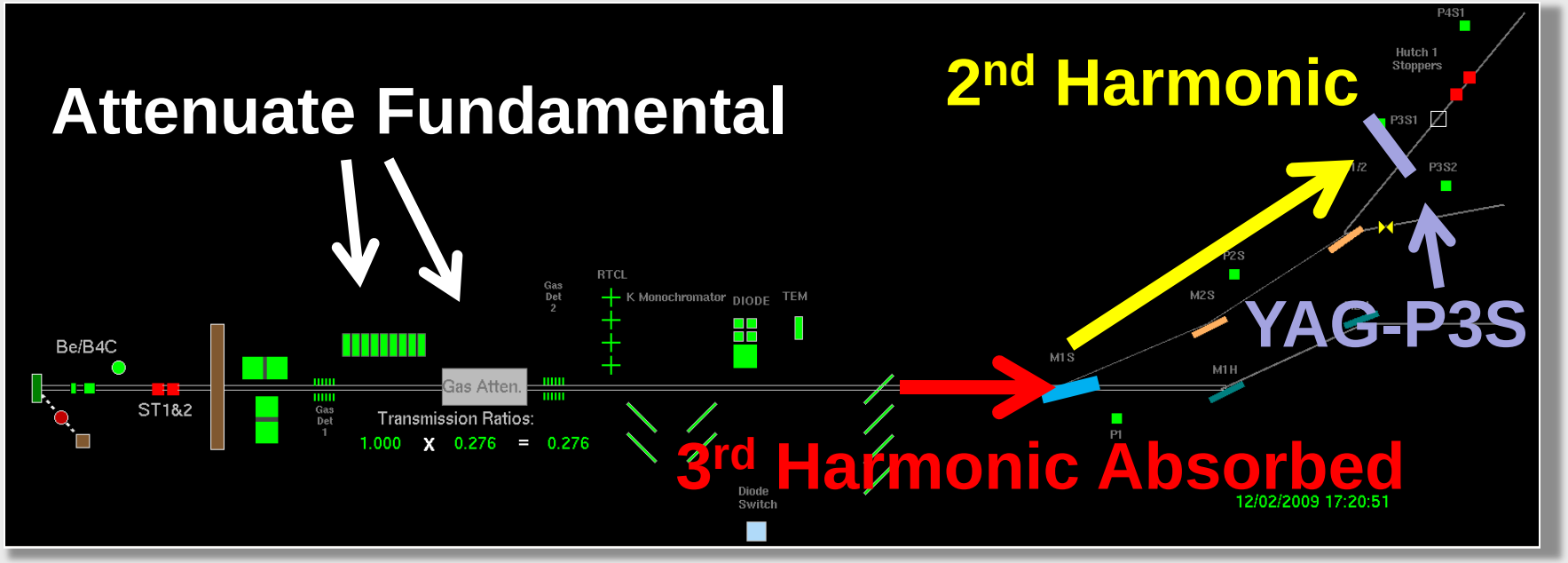
Cutoff near 2.2 keV



http://henke.lbl.gov/optical_constants/

Second Harmonic

- FEL is mostly 1st and 3rd harmonics
- Need to isolate 2nd harmonic:
  - Block fundamental with solid and gas attenuators
  - 3rd harmonic and higher absorbed in mirrors
  - Measure 2nd harmonic on P3S

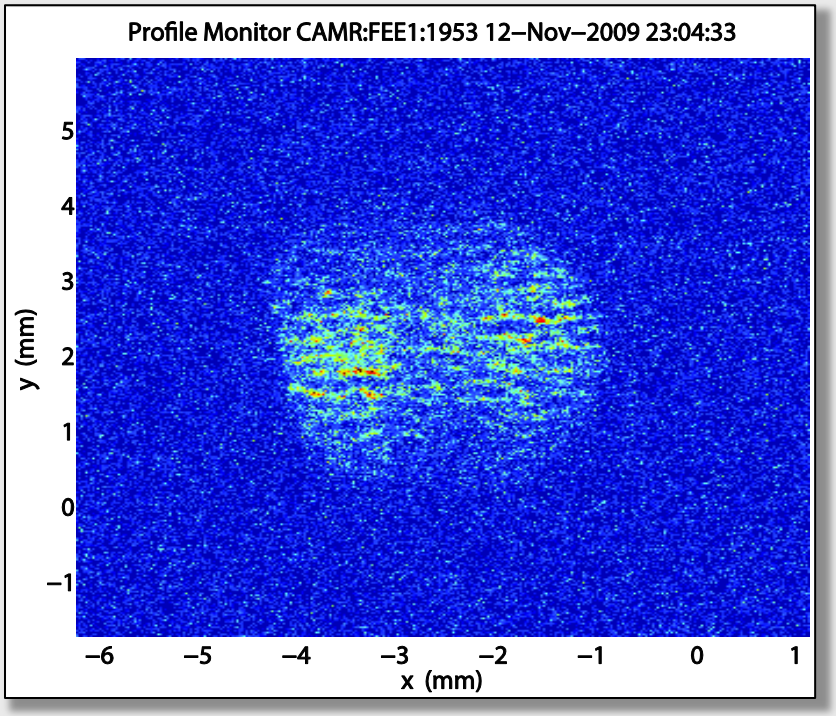


Second Harmonic Distribution

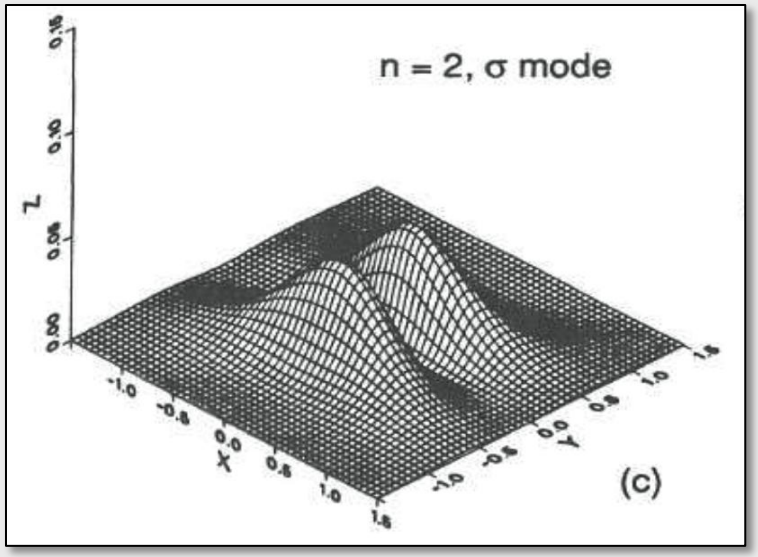
- Second harmonic image:

2.7 kev 3rd harmonic above cutoff

Image on P3S, 900eV fund
0.4 mil Be + 5.5 torr atten



Single Particle Second Harmonic Distribution



K.J. Kim, USPAS

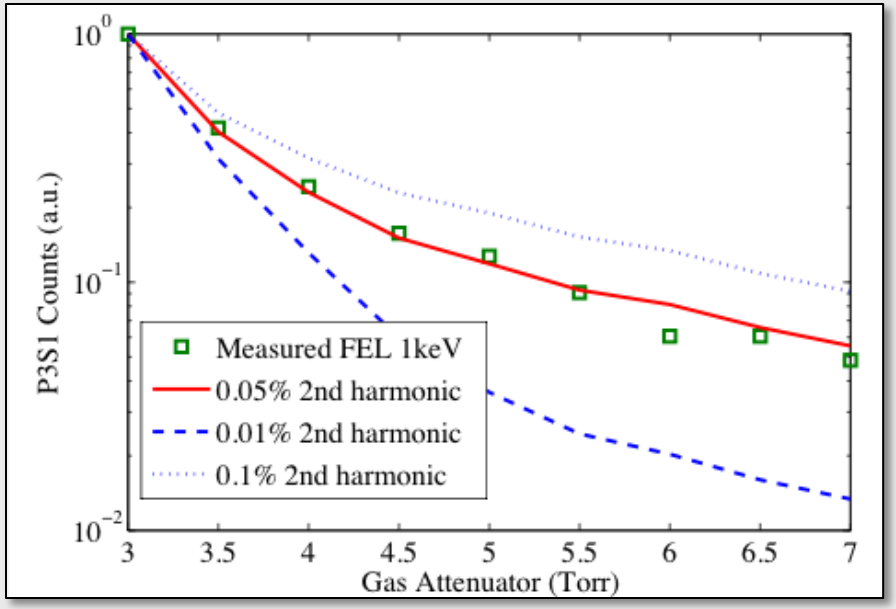
Scan Gas Attenuator N_2 Pressure

- Harmonics scale differently with attenuation

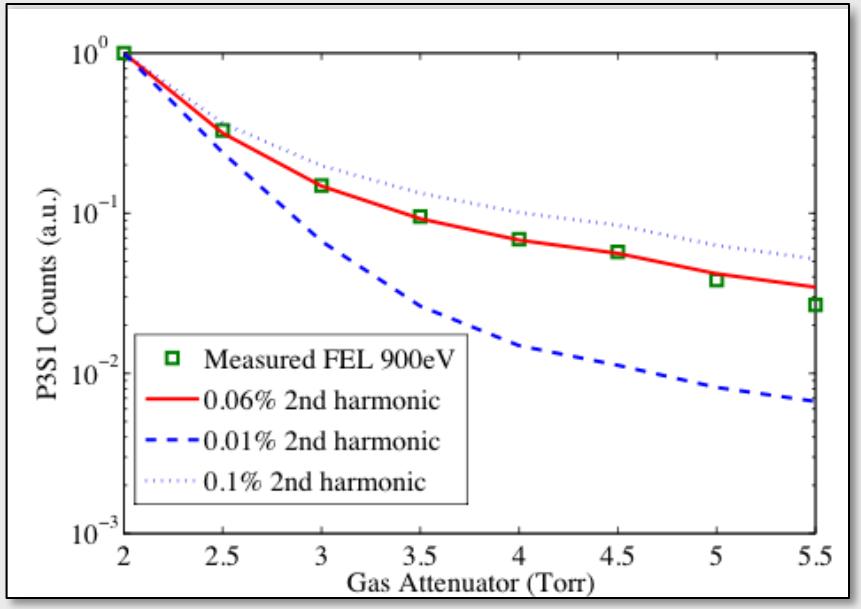
$$\text{Counts} \propto T_{1st} \times M_{1st}^3 + T_{2nd} \times M_{2nd}^3 \times (P_{2nd}/P_{1st})$$

T=Transmission from attenuators, M = Mirror transmission

1 keV fund (0.05%)



900 eV fund (0.06%)



Scan Gas Attenuator

- Second harmonic weaker than third harmonic
  - Bunching stronger at second harmonic, but…
  - Planar undulators only couple odd harmonics on axis
- Second Harmonic After Burners (SHABs)
  - Final undulators are tuned to second harmonic
  - H.D. Nuhn will discuss Thursday, 16:00, THOCI2

Third Harmonic

- Summary of results:
  - Approximately 0.5-3% 3rd Harmonic
  - Proportion depends on FEL fundamental performance

	2nd Harmonic	3rd Harmonic
900 eV	0.06%	2%
1 keV	0.05%	NA
1.7 keV	NA	3%
6 keV	NA	0.6%
8 keV	NA	2%

Second Harmonic

- Summary of results:
  - Approximately 0.05% 2nd Harmonic
  - High energy will be measured soon

	2nd Harmonic	3rd Harmonic
900 eV	0.06%	2%
1 keV	0.05%	NA
1.7 keV	NA	3%
6 keV	NA	0.6%
8 keV	NA	2%

Thanks to:

LCLS project director J. Galayda,
Commissioning Team and

many collaborators and visitors from
LBNL, LLNL, DESY