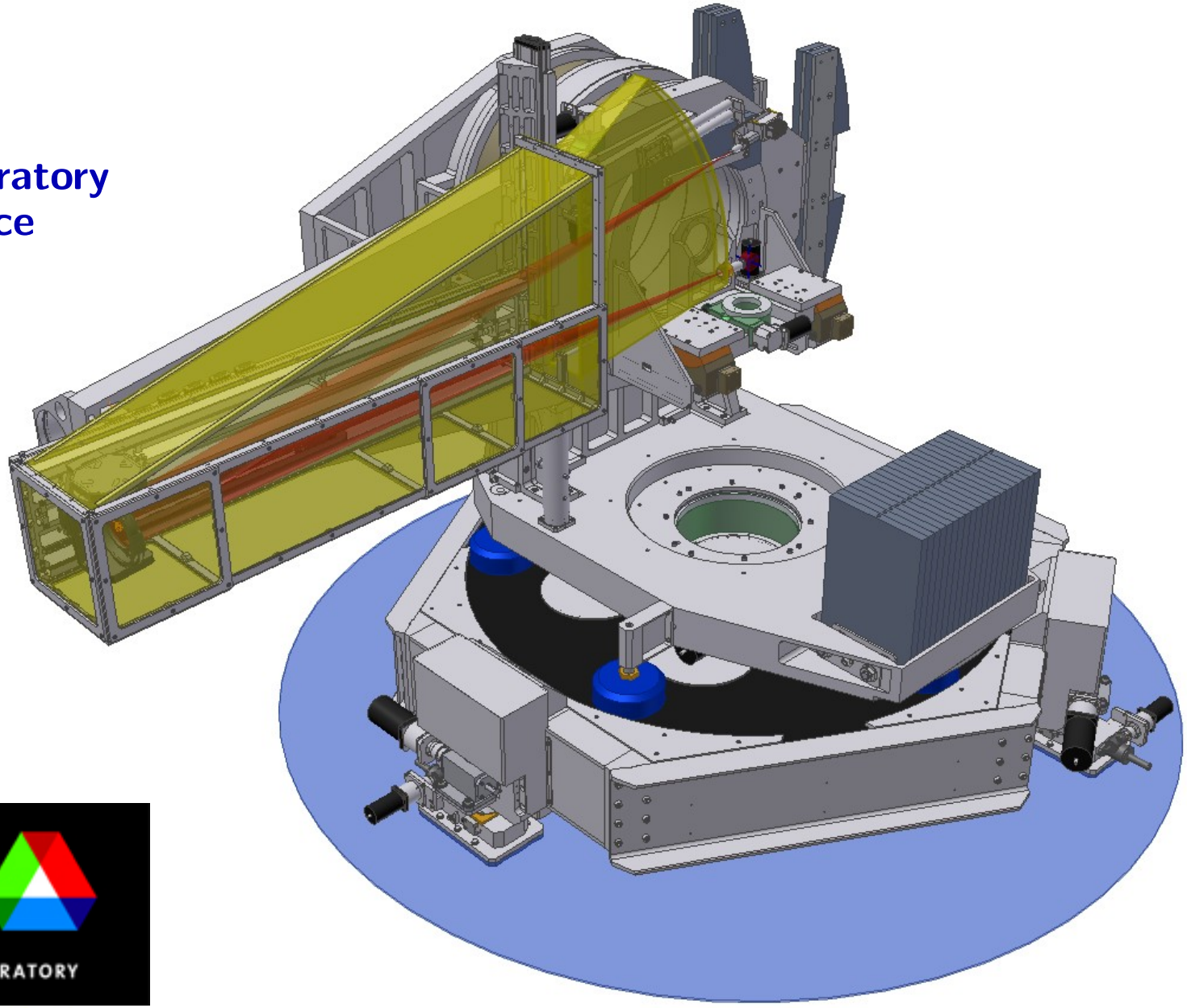
MERIX Spectrometer

Yuri Shvyd'ko

Argonne National Laboratory
Advanced Photon Source



Argonne NATIONAL LABORATORY

MERIX Design Team

- Clement Burns (WMU)
- Scott Coburn (BNL)
- John Hill (BNL)
- Ayman Said (APS)
- Yuri Shvyd'ko (APS)

Also:

- Ercan Alp, Tim Roberts, Harald Sinn, Wolfgang Sturhahn, Tom Toellner, Hasan Yavas (APS, XSD)
- Kurt Goetze, Xuesong Jiao, Joe Sullivan (APS, AES-BC)
- Bran Brajuskovic, Curt Preissner, Demin Shu (APS, AES-MED)
- Yeldez Amer, Mohan Ramanathan (APS, AES-MIS)
- Ruben Khachatryan, Michael Wieczorek (APS, XSD-OFM)

Content

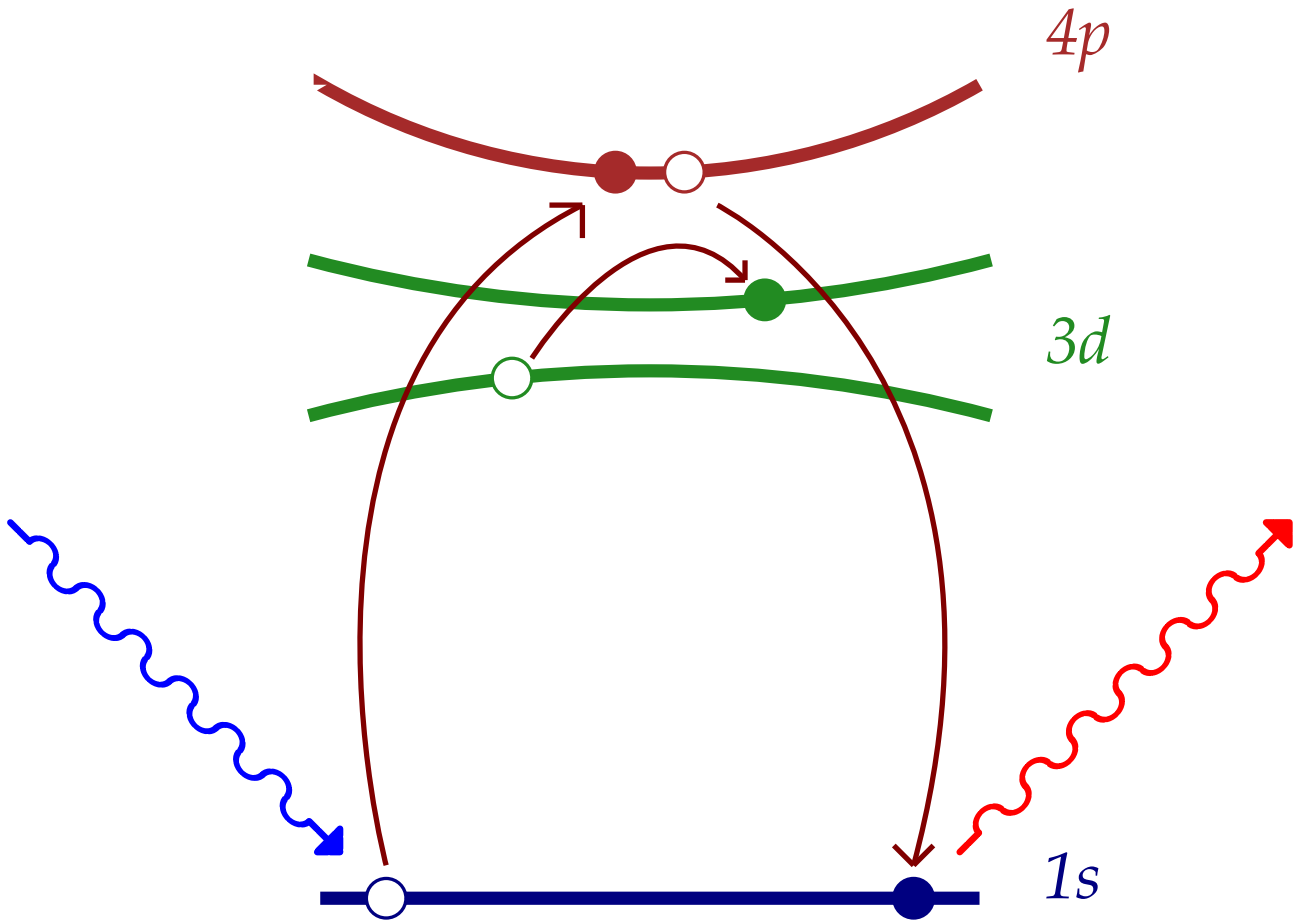
- Scientific Mission
- Overview of the instrument.
  Design parameters
- November 2006: MERIX commissioning.
  Design parameters achieved.
- March 2007: X-ray optics and detector developments.
  Better energy resolution is achieved.
  Count rates increased by a factor of > 10.
- Outlook

Scientific Mission of MERIX

- **Purpose: study of electronic excitations.**
- **Technique: resonant IXS (RIXS) and non-resonant IXS.**
- **Incident photon energies 4 - 14 keV**
  (K-edges of 3d elements, L-edges of 4f elements, M-edges of U).
- **Energy resolution about 100 meV.**
- **Polarization dependence - scattering in horizontal and vertical plane.**
- **Increased flux and improved analyzer design.**
- **Sample environments:**
  low and high temperatures, high pressure, magnetic field.

K-edge RIXS

RIXS: Photon-in Photon-out spectroscopy.
No charge particles enter or leave the sample.



Energy losses are due to a "shake-up" process of the valance $3d$ electrons, in between the creation and annihilation of the $1s - 4p$ core exciton.

RIXS vs. XAS, PES, ARPES, EELS

RIXS: captures the physics of charge dynamics by observation of momentum-dependent excitations across the gap.

- **Probes excited electronic states (charge-transfer, $d-d$, etc. excitations)**
- **Momentum-dependent information.**
- **Absence of the deep core hole effects (no lifetime broadening).**
- **Bulk sensitive.**
- **Element specific.**
- **Resonantly enhanced.**
- **Applicable to metals and insulators (photon-in, photon-out).**
- **Allows studies under extreme conditions (high pressure, magnetic fields, extreme temperatures, etc.).**

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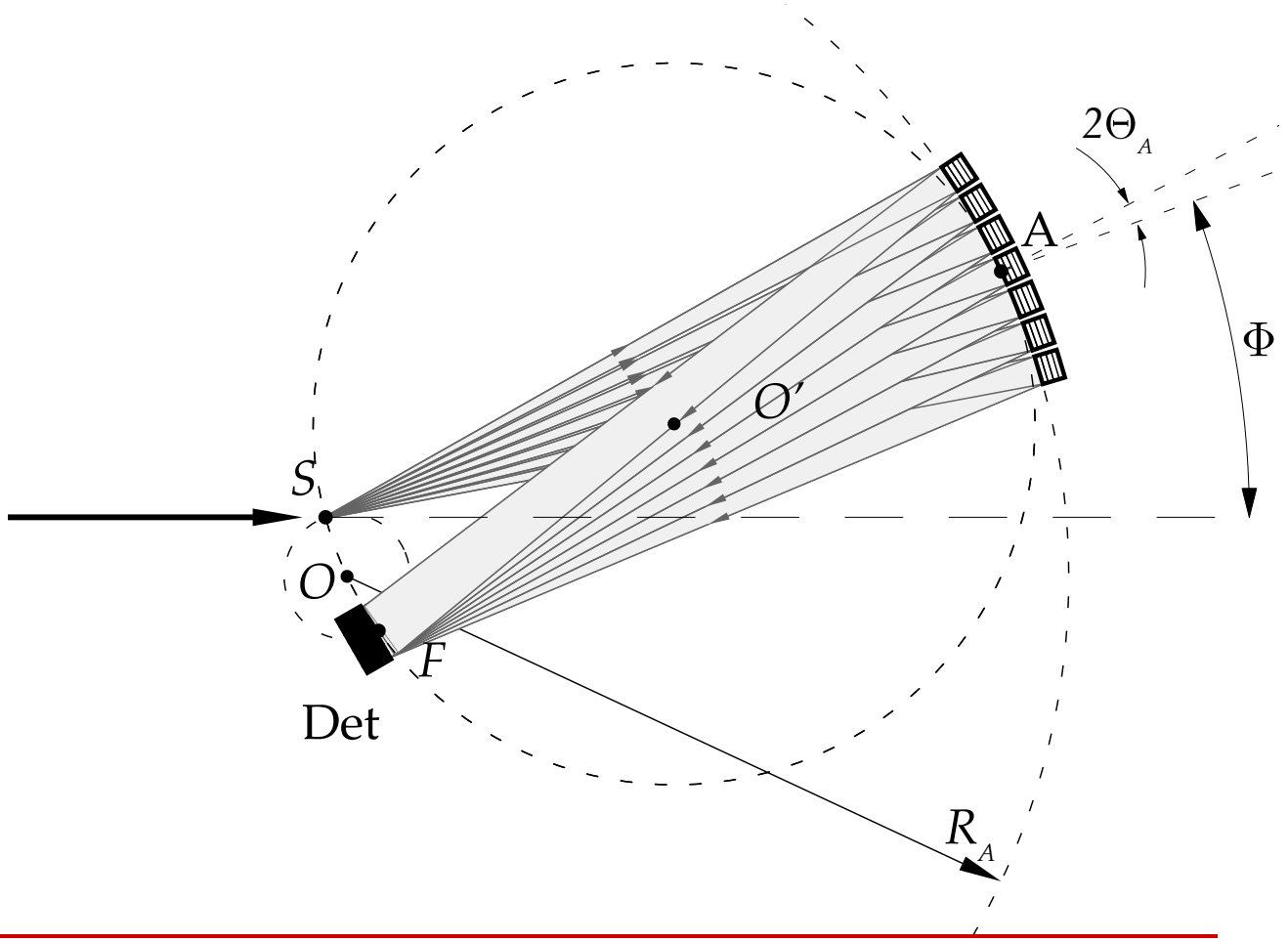
MERIX optical scheme

Scheme of gathering, focusing, and spectral analysis of x-rays by a segmented spherical crystal analyzer.



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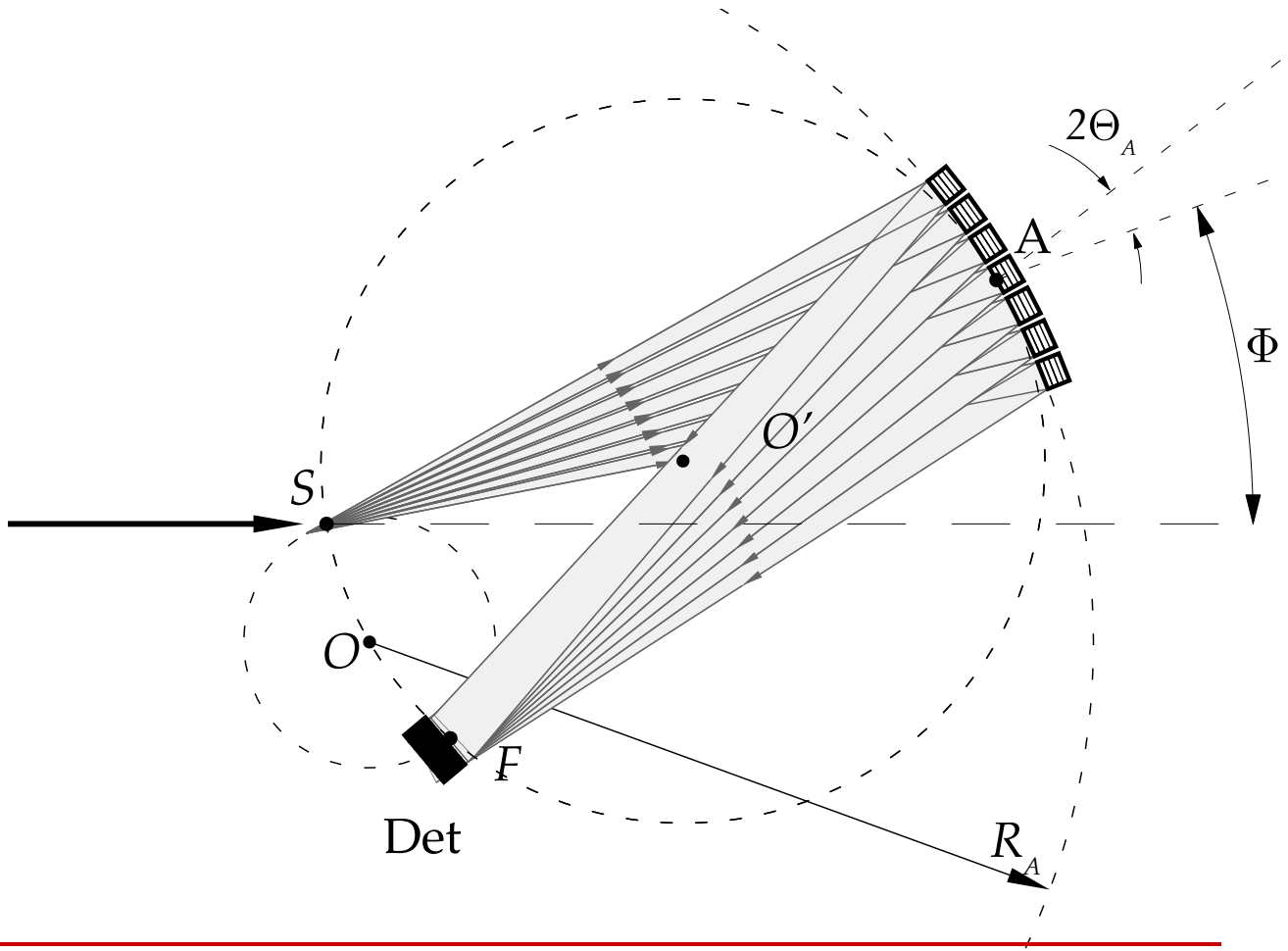
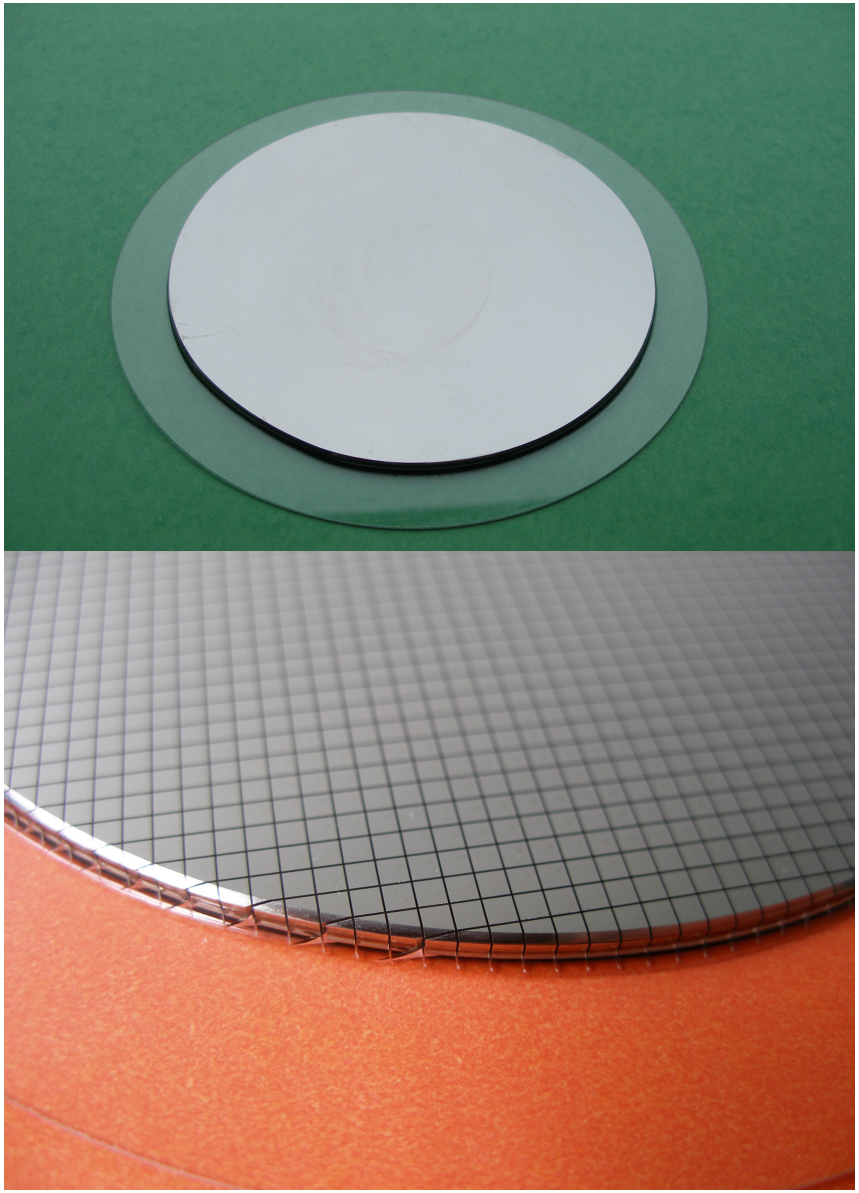
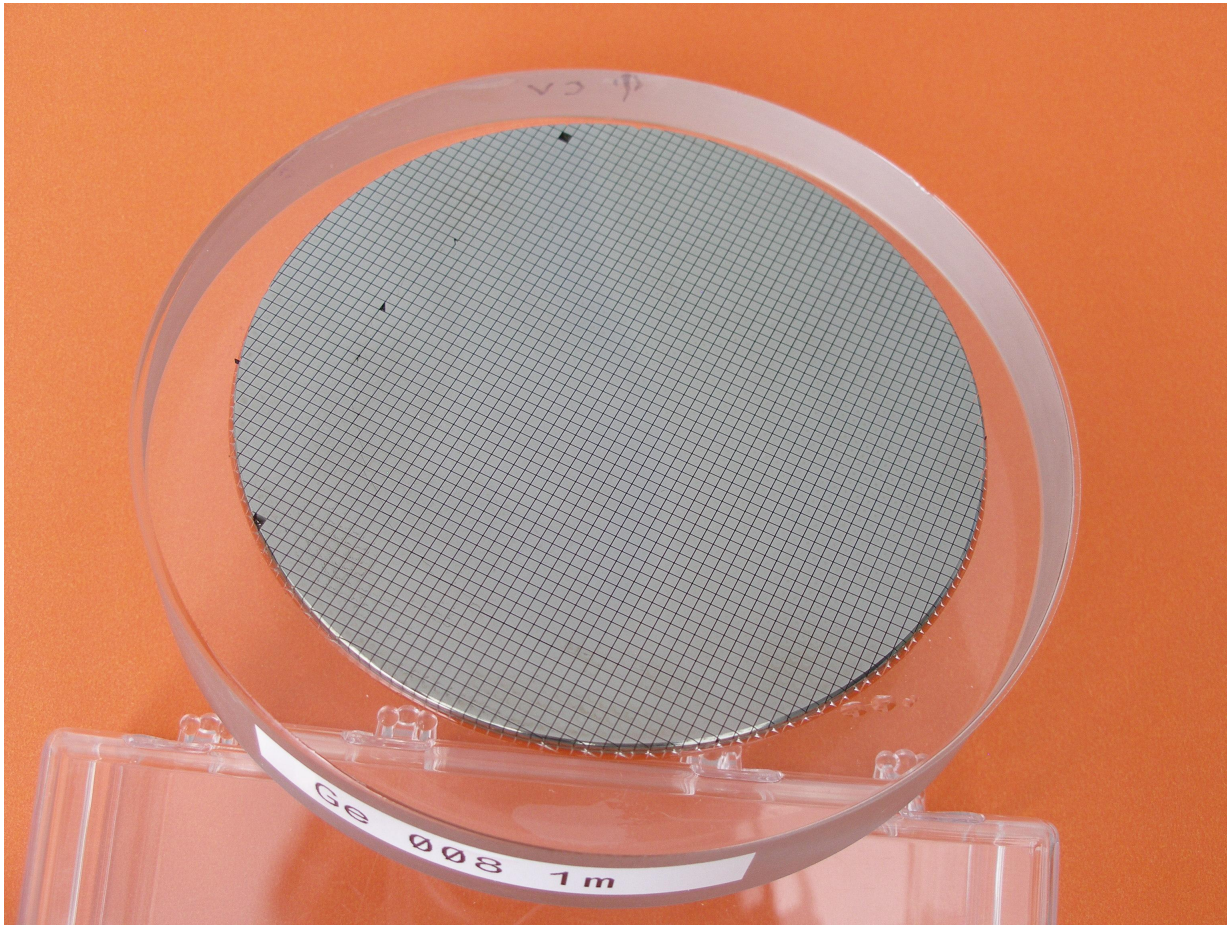


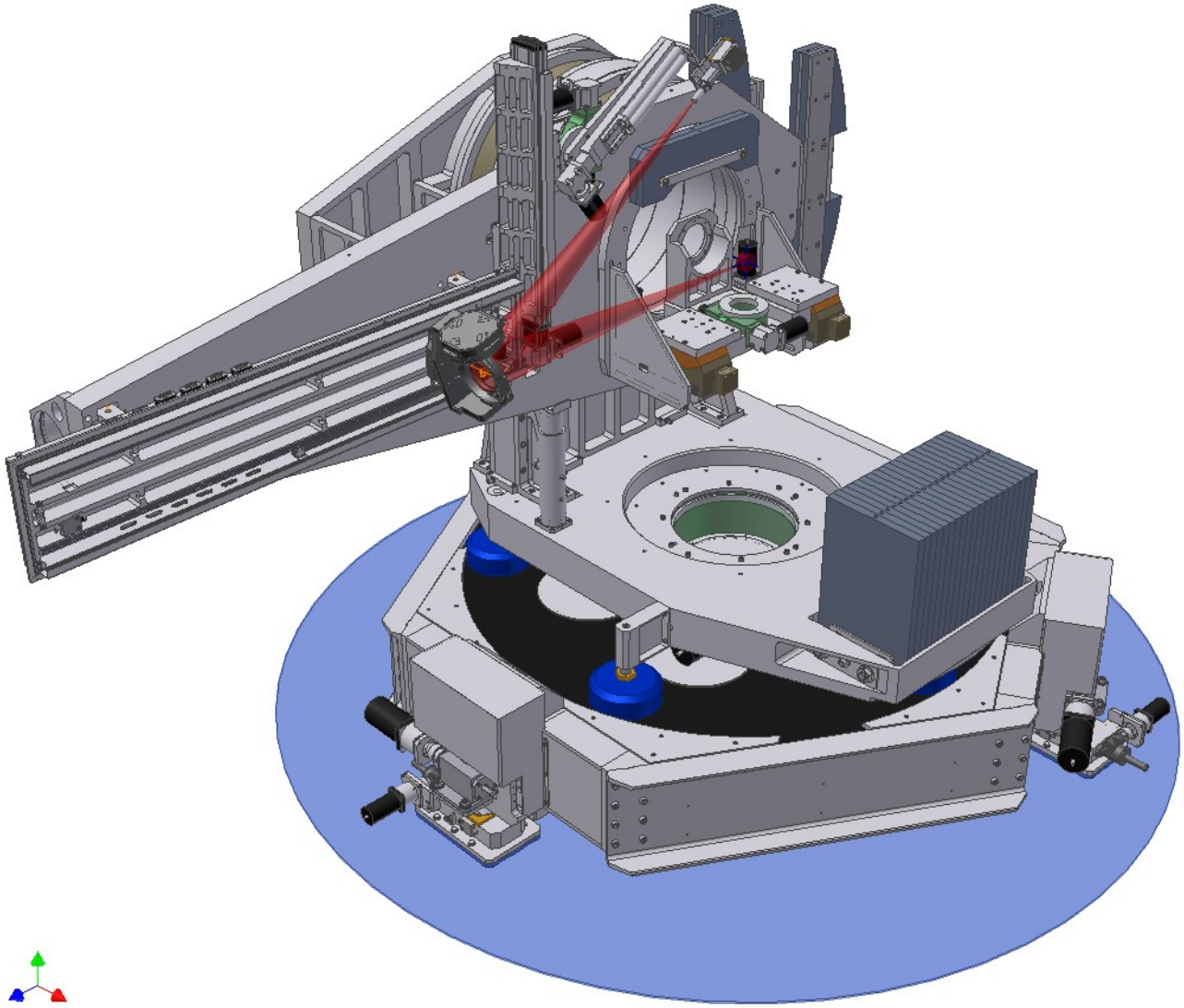
Analyzer Development and Production





Ayman Said
Michael Wieczorek
Ruben Khachatryan
Yuri Shvyd'ko

MERIX Spectrometer - Design



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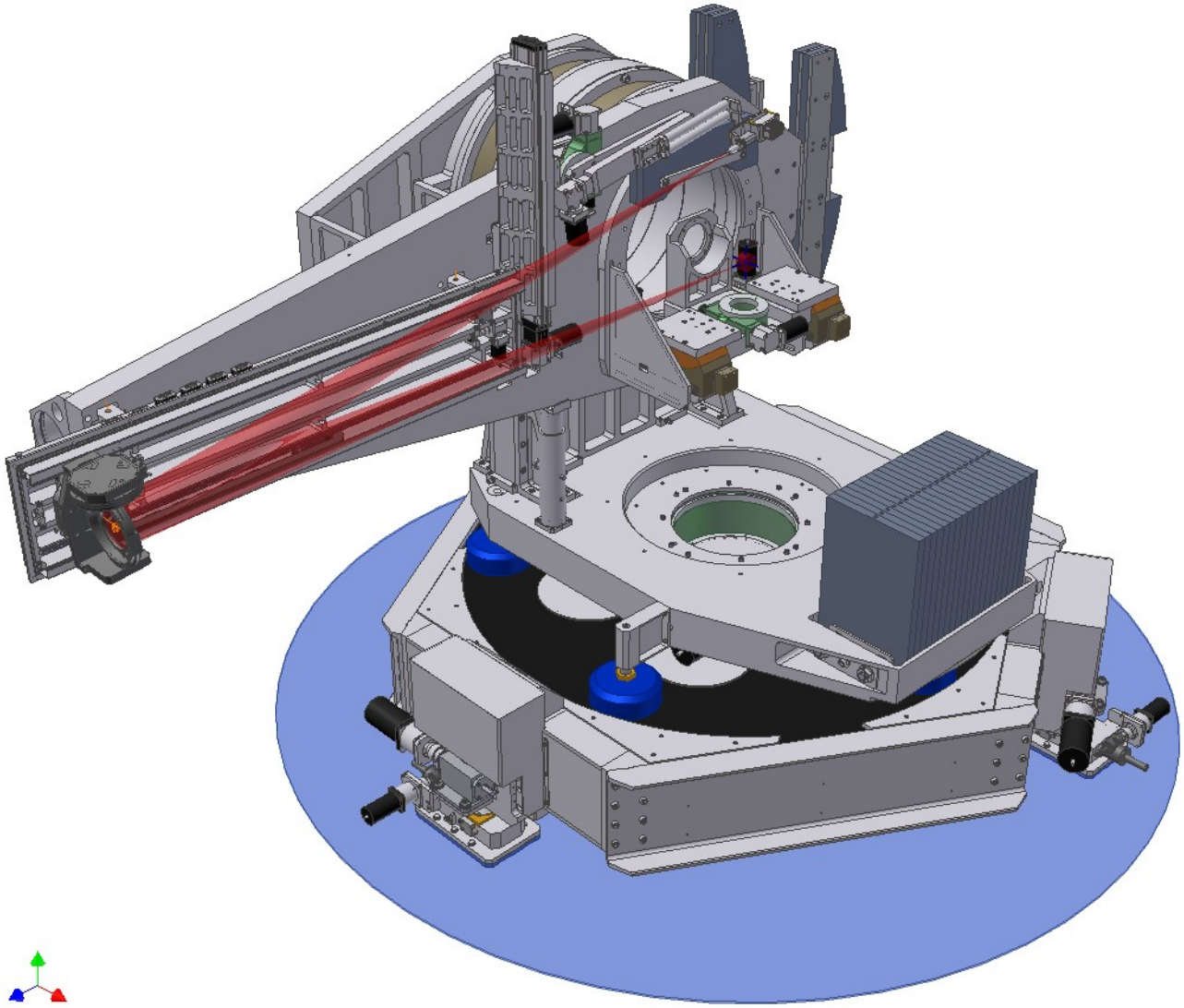

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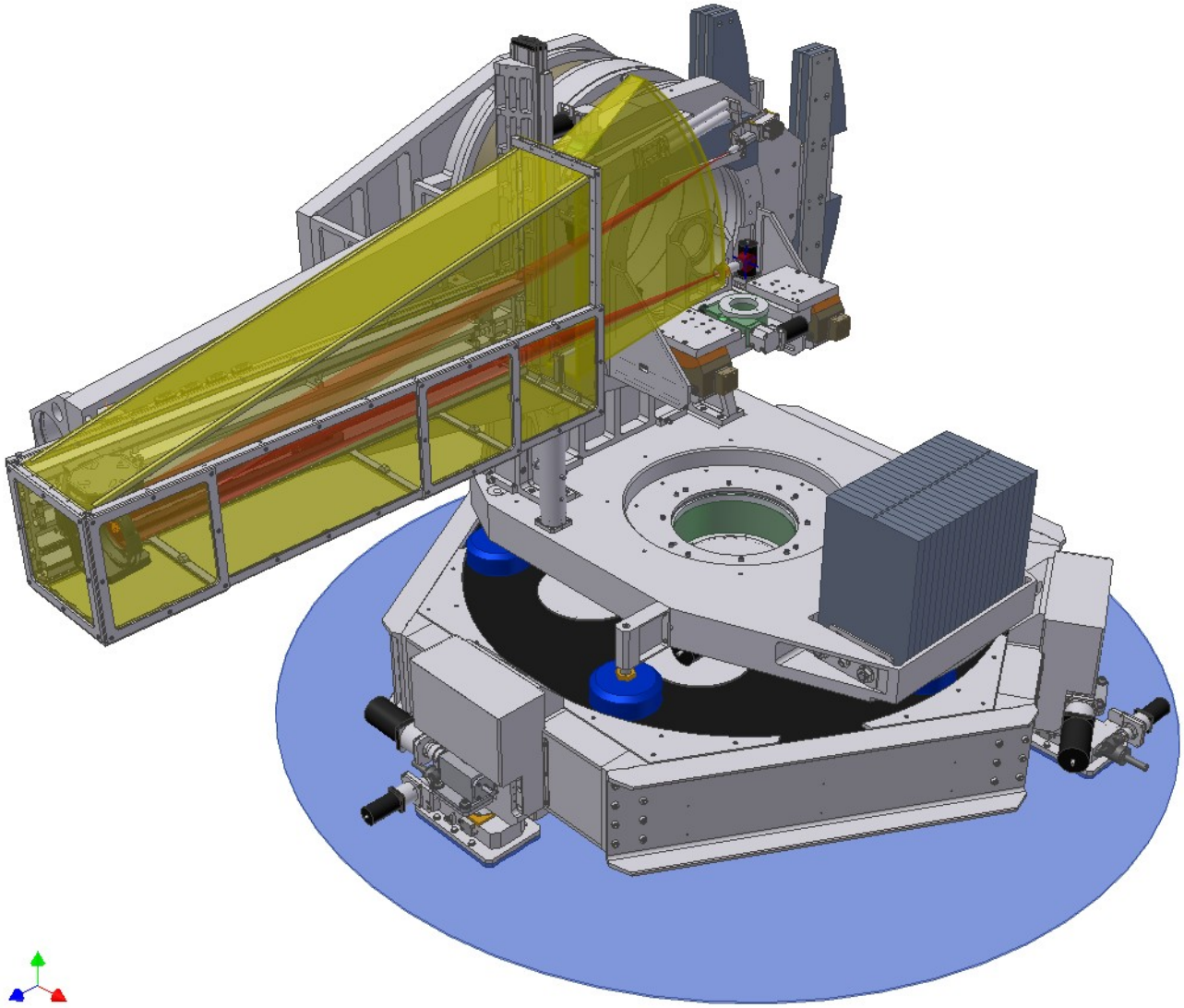

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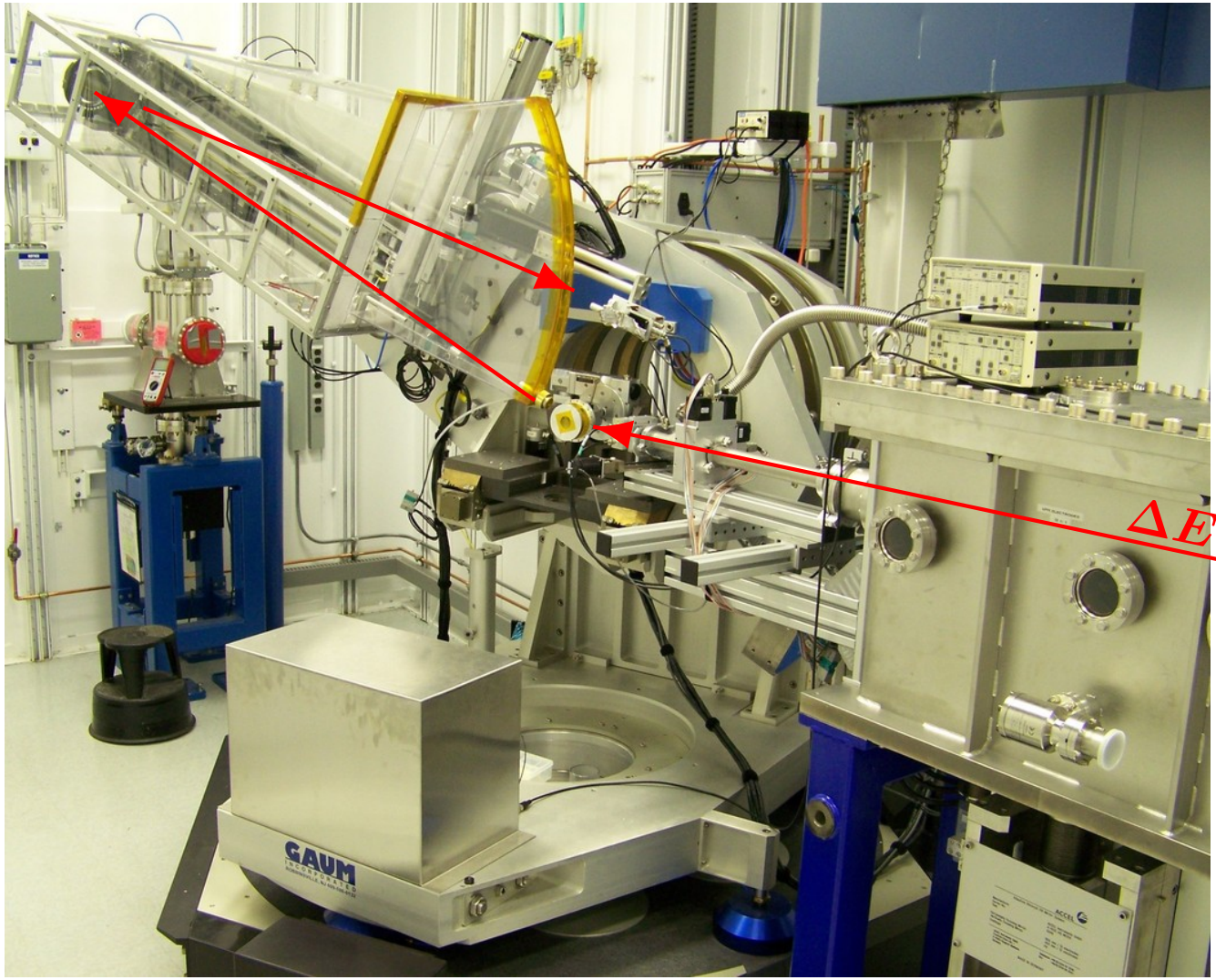
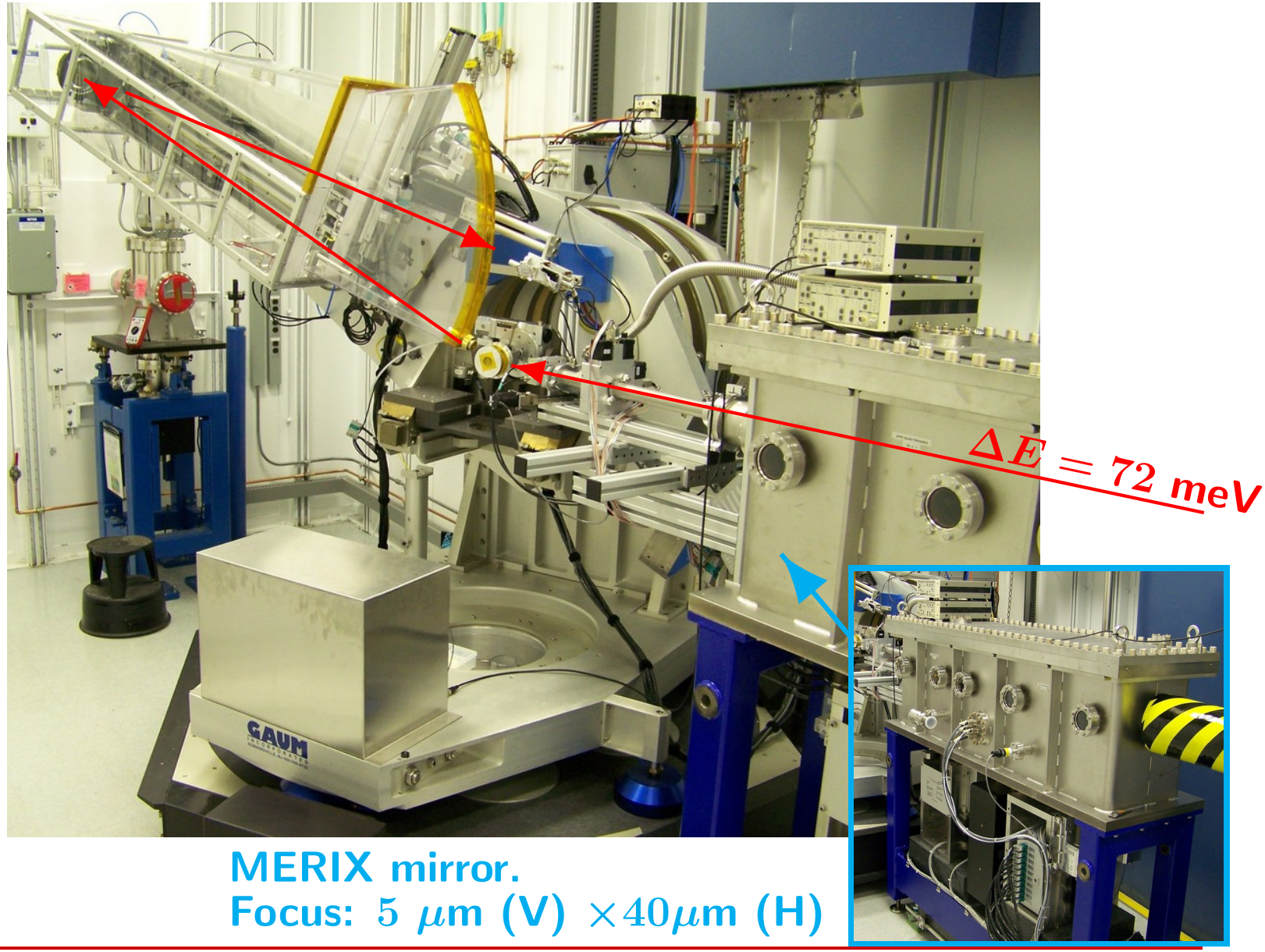
MERIX Installation History

MERIX Spectrometer@30-ID.APS, October 2006



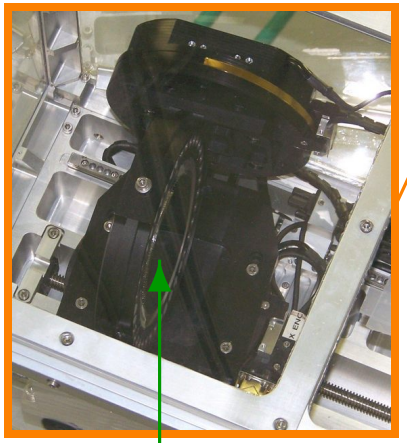
MERIX Spectrometer@30-ID.APS, October 2006

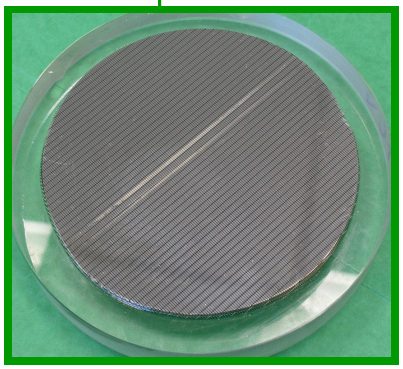


MERIX mirror.
Focus: $5\ \mu$m (V) $\times 40\mu$m (H)

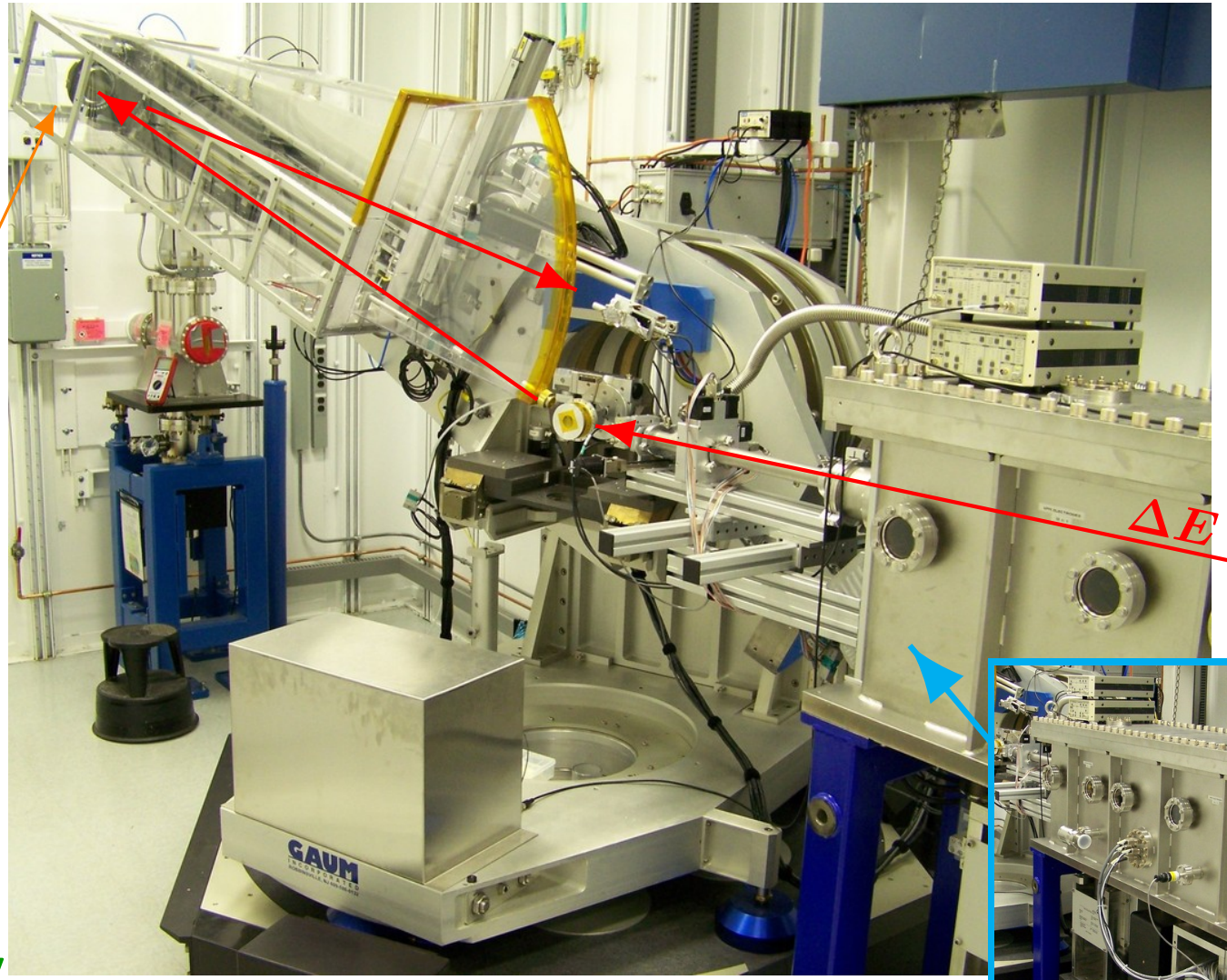
MERIX Spectrometer@30-ID.APS

Analyzer gimbal

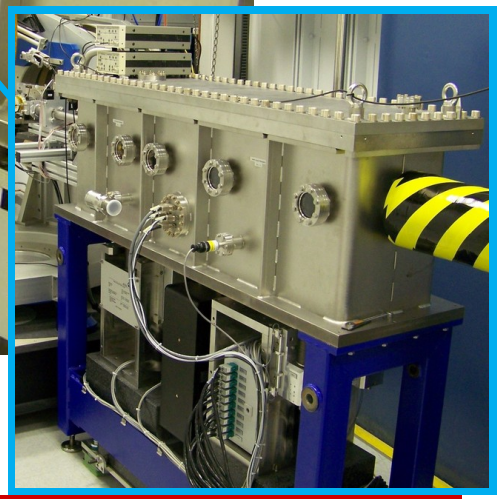




Ge(337) diced analyzer:
$\Delta E = 115$ meV



$\Delta E = 72$ meV

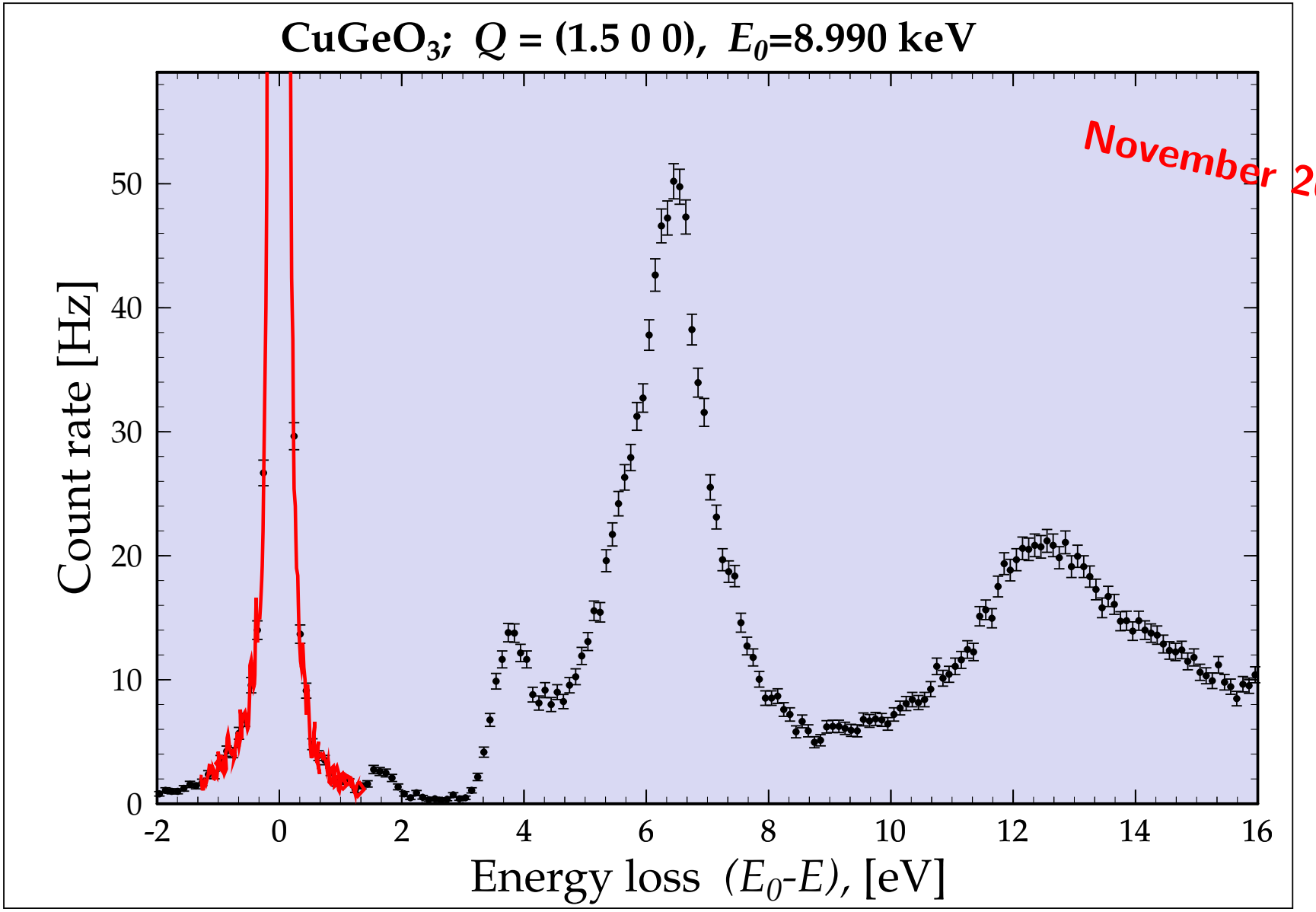


MERIX mirror.
Focus: $5\ \mu$m (V) $\times 40\mu$m (H)

Design parameters achieved

Category	design value	de facto
Spectral Flux, main monochromator [photons/s/eV]	2×10^{13}	4×10^{13}
Spectral Flux, MERIX monochromator [photons/s/100meV]	1×10^{12}	2×10^{12}
Tunability [keV]	5-12	4.5 - 14
Beam size on MERIX sample [μm$\times\mu$m]	20×40	6×45
Ge(337) Cu K-edge analyzer	1	1
Overall energy resolution [meV]	120	100-130

First RIXS Spectrum Measured with MERIX



February 2007: User Operations Started

Happy first users:

Daniele Antonangeli
Daniel Farber
(LLNL)

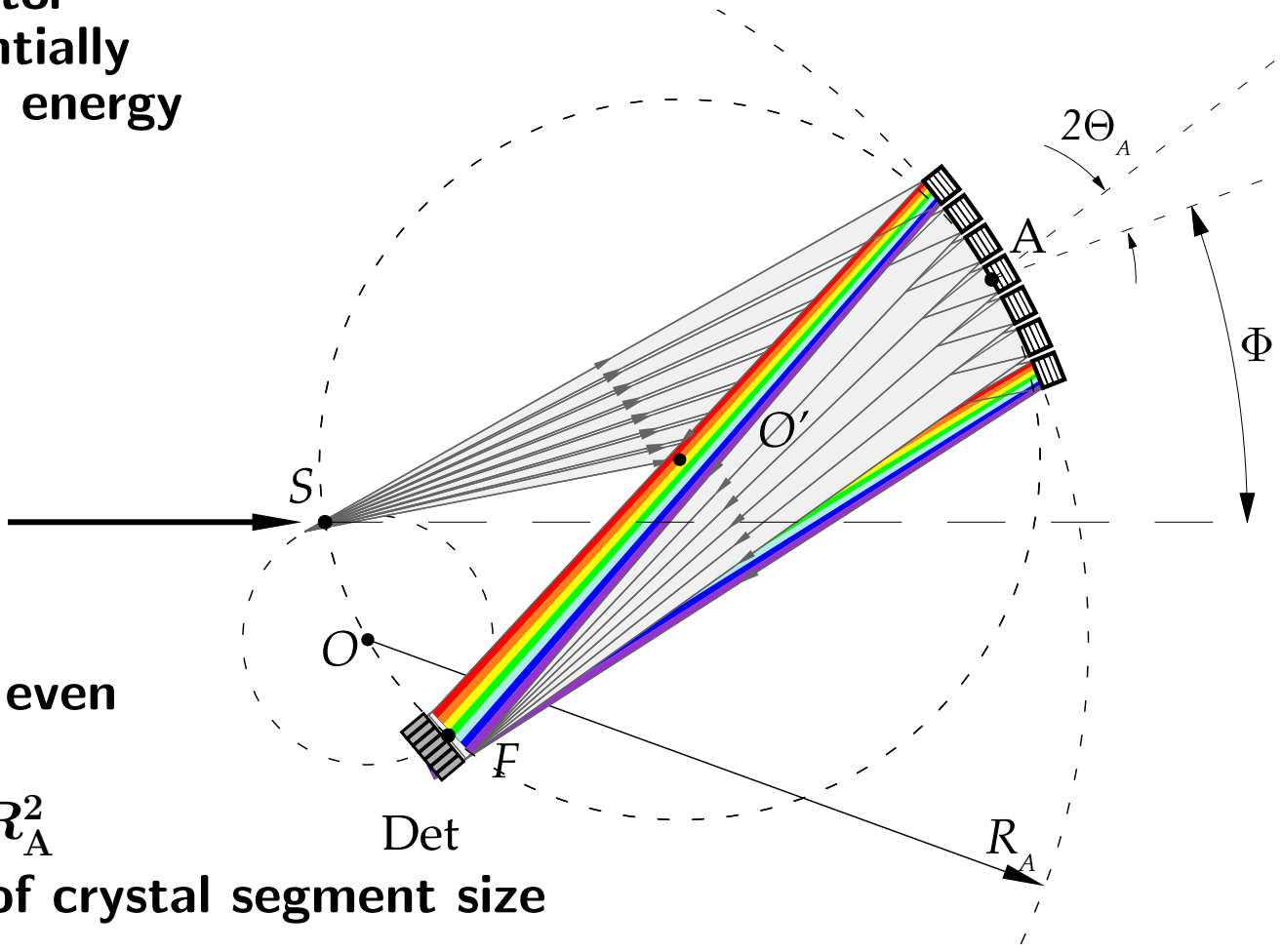
with

Ayman Said

Next generation x-ray optics and detectors for IXS

S. Houtari et al. (2005) :

Use position sensitive detector to detect IXS signal differentially in space and thus in photon energy

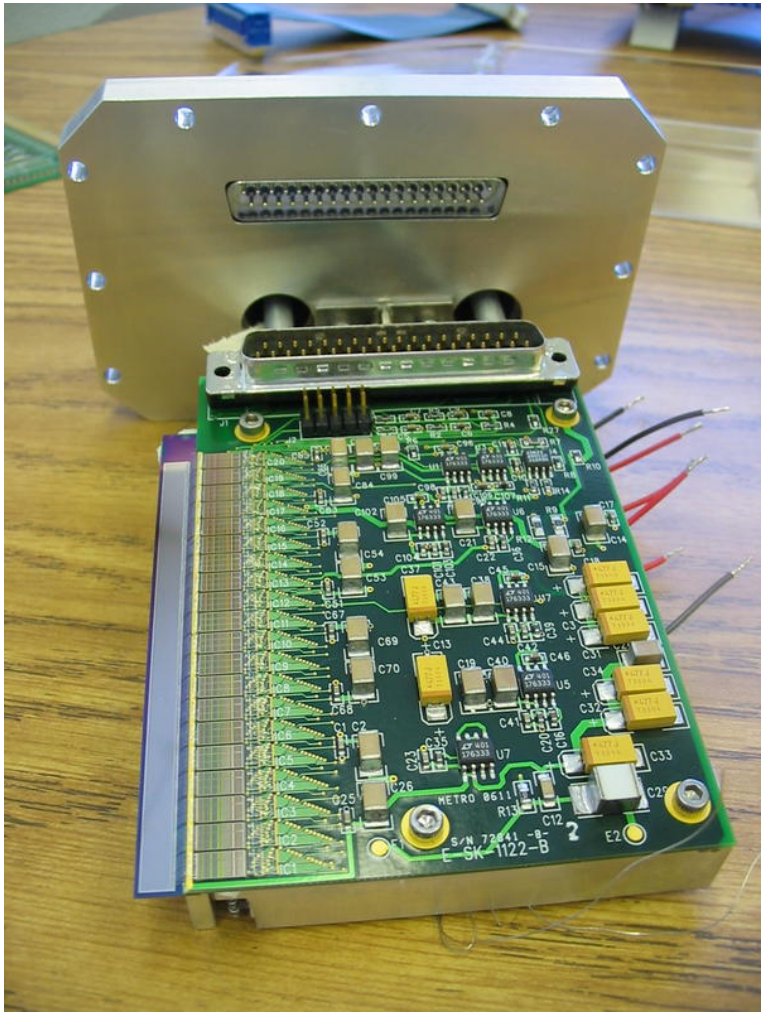


Implications for MERIX:

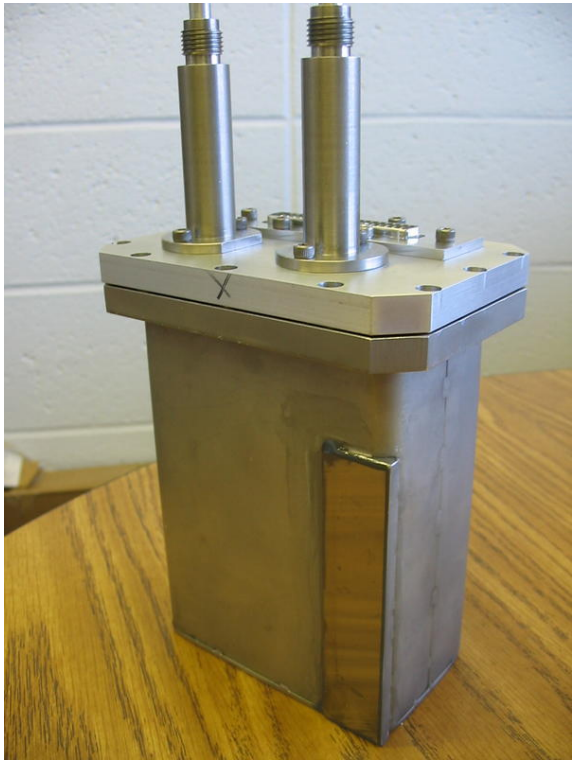
1. **Better energy resolution even with smaller $R_{\rm A}$**
2. **Higher countrates $\propto 1/R_{\rm A}^2$**
3. **Resolution independent of crystal segment size**

Photon-Counting Si Microstrip Detector

D. Peter Siddons, Brookhaven

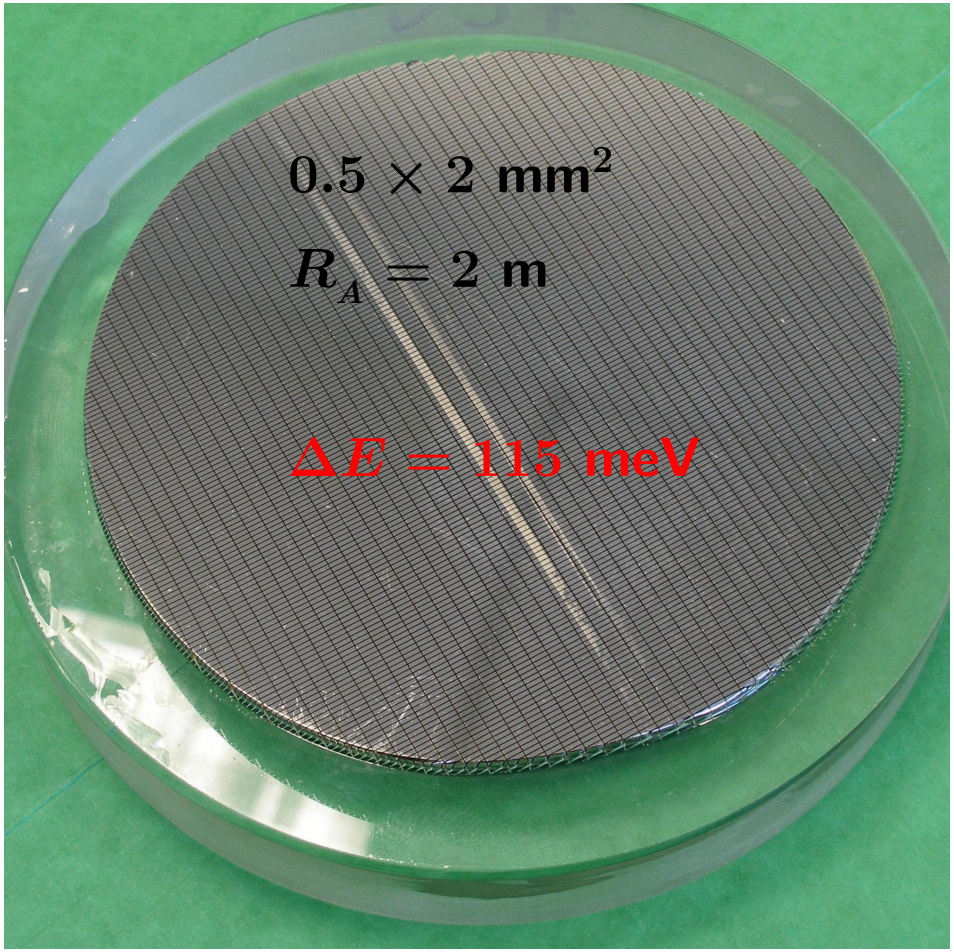


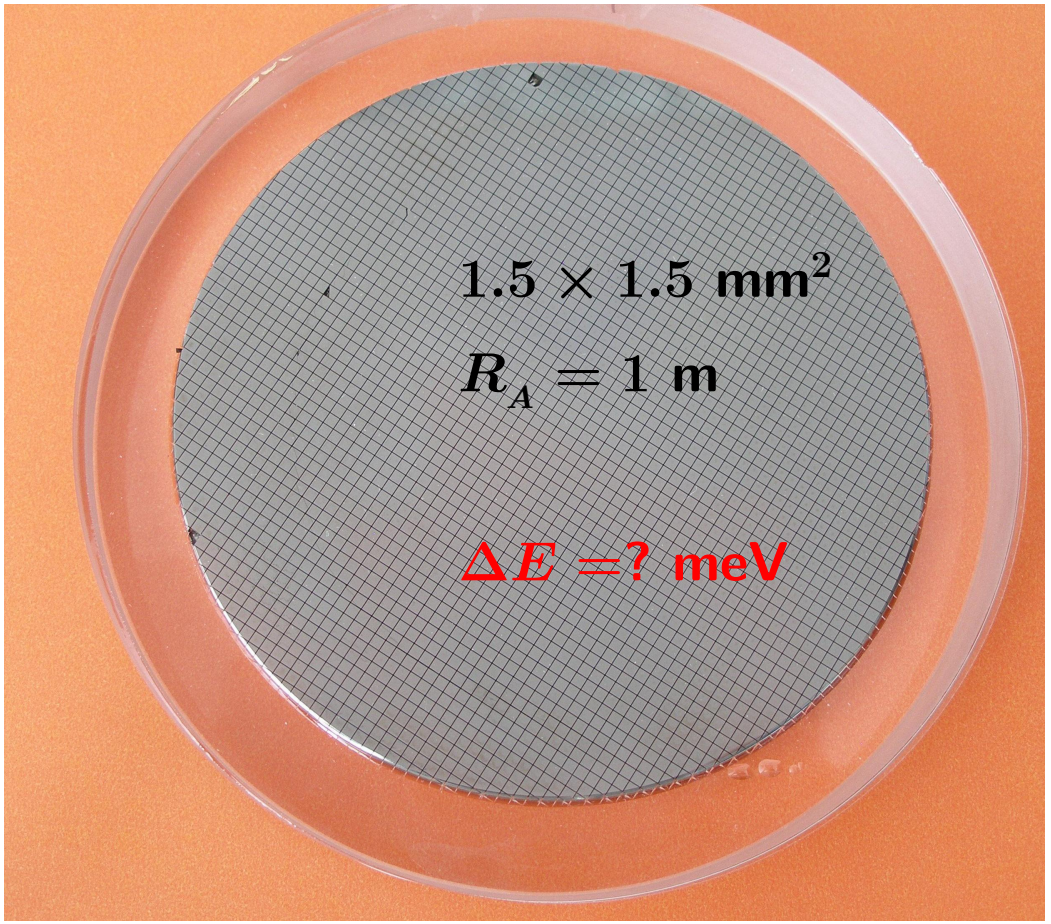
640 strips
1 strip = 125 μm
1 strip = 40 meV
640 strip = 25 eV



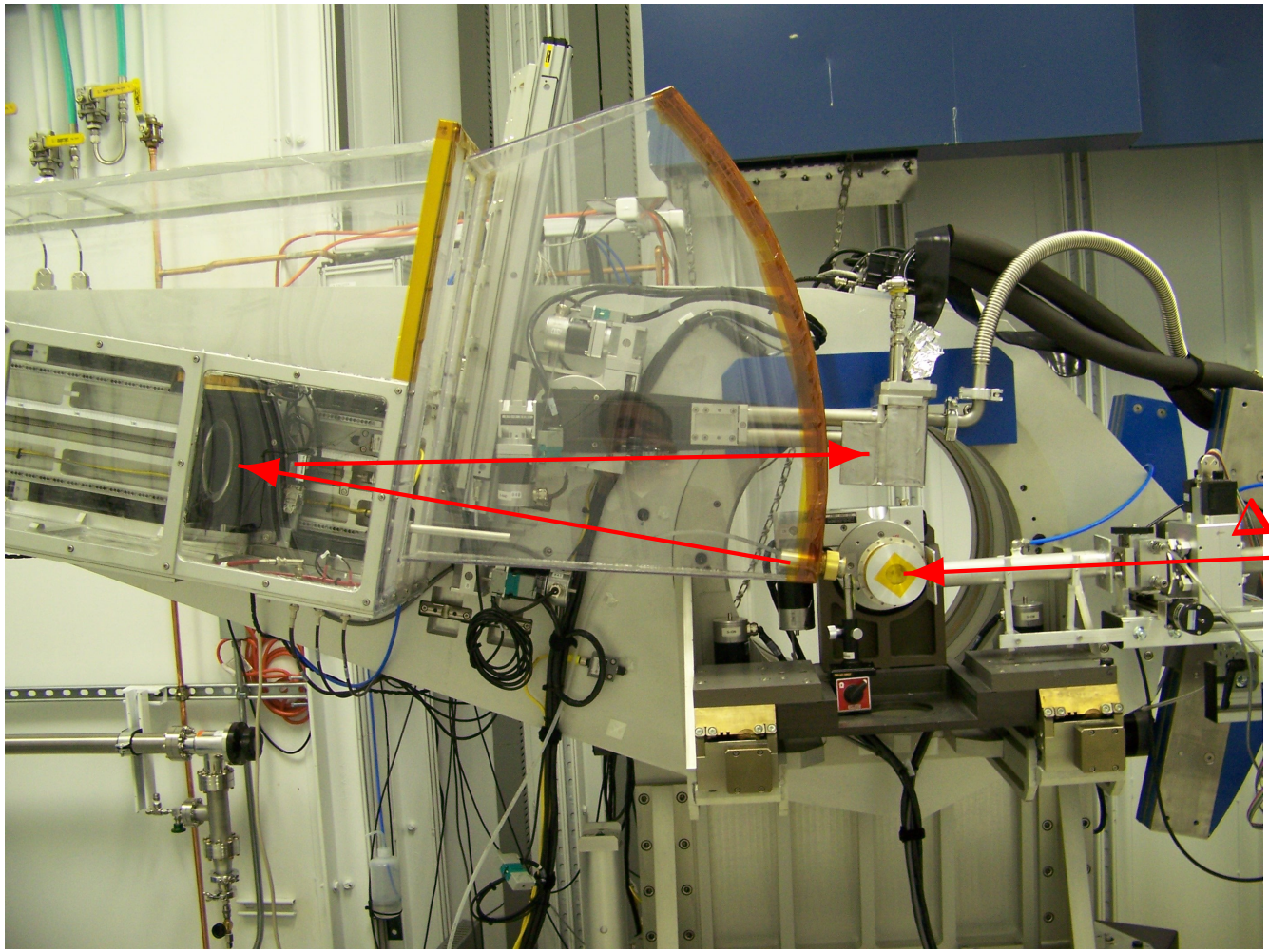
Donated to IXS-CDT by Steve Cramer, UC Davis

Analyzers with bigger crystal segments

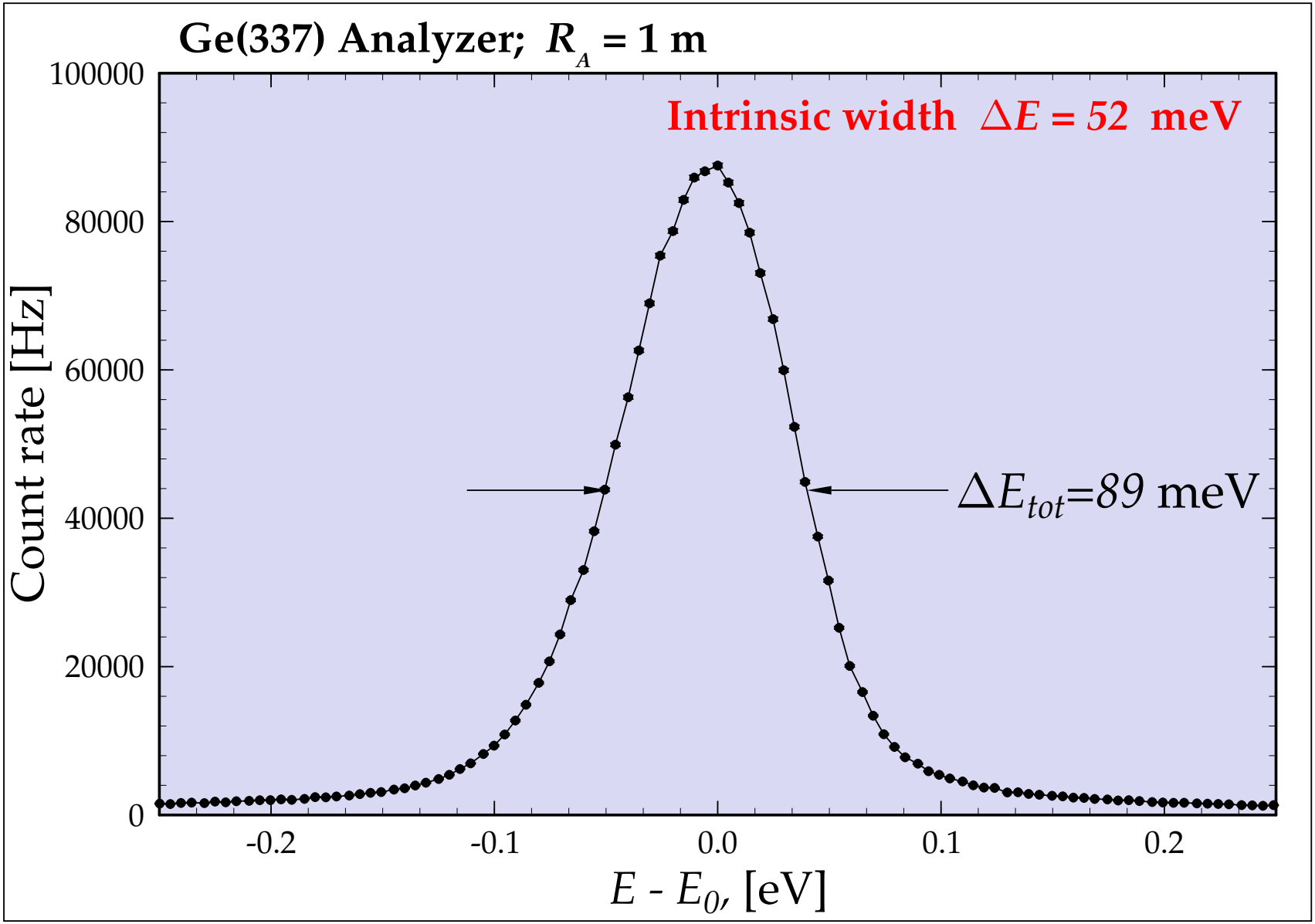




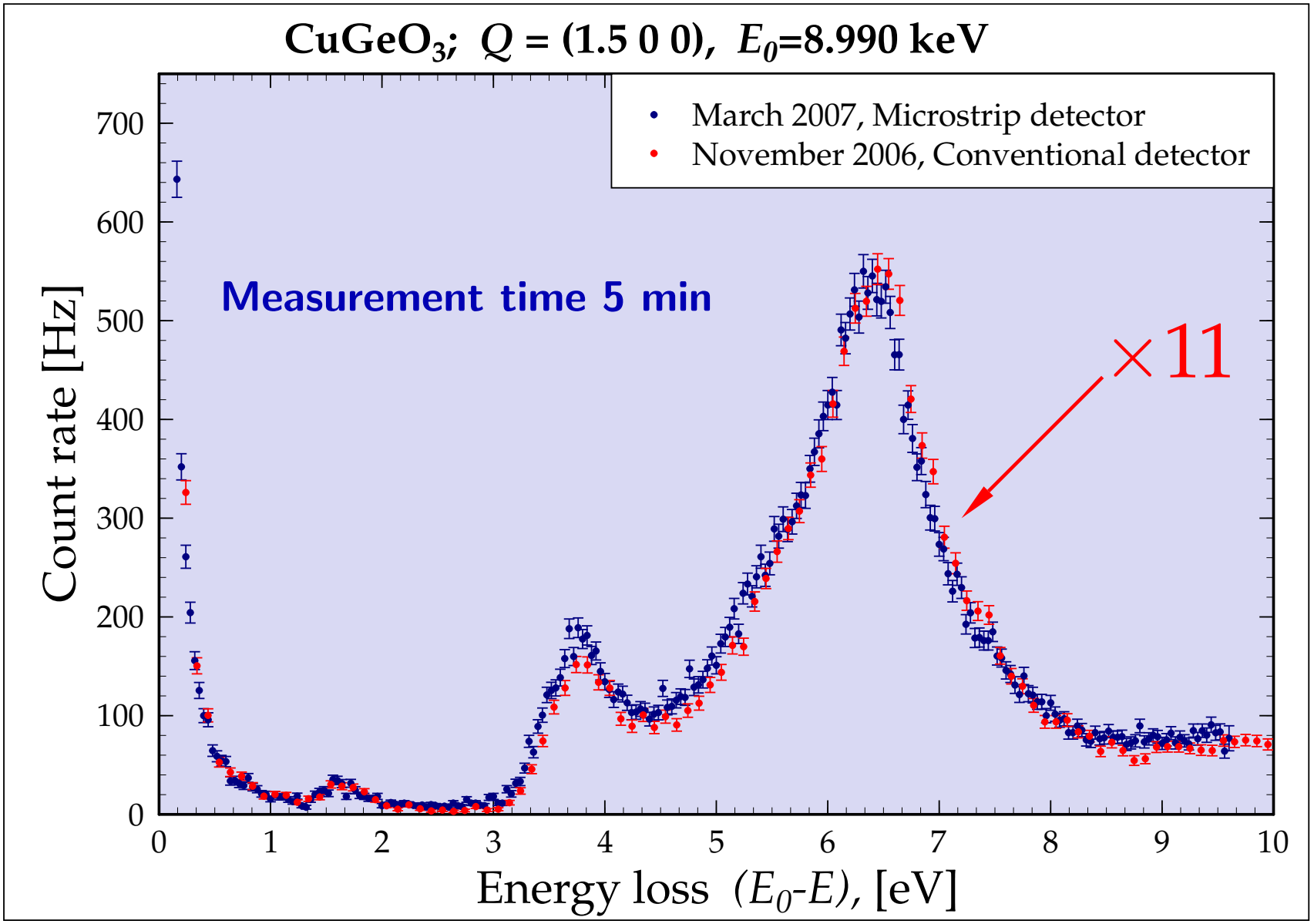
MERIX Spectrometer@30-ID.APS, March 2007



Energy resolution



Dramatic Increase in Count Rate



Conclusions

- November 2006: MERIX design parameters are achieved.
- February 2007: User operations started.
- Next generation x-ray optics and detector is tested:
  1. Narrower spectral function (90 meV)
  2. Count rates increased by a factor of > 10.
  3. Cu and Co K-edge analyzers are tested.
- Analyzer tests and development in progress for
  V, Mn, Cr, Fe, Ni (K-edge)
  Eu, Yb (L-edge)

RIXS Analyzers @ Sector 30

tested **exist** **in production**

Element	E [keV]	Crystal	Reflection	$\Delta E_{\rm i}$ intr. [meV]	$\Delta E_{\rm g}$ geom. [meV]	$\Delta E_{\rm tot}$ total [meV]
V(O)	5.480	$LiNbO_3$	$(0\ 0\ \bar{0}\ 12)$	109	71	130
Cr(O)	6.009	Si	$(5\ 1\ 1)$	52.2	61	81
Mn(O)	6.555	Si	$(0\ 4\ 4)$	62	72	95
Fe(O)	7.130	Ge	$(6\ 2\ 0)$	115	108	158
Co(O)	7.720	$LiNbO_3$	$(3\ 3\ \bar{6}\ 6)$	49	36	60
Ni(O)	8.345	$LiNbO_3$	$(0\ 6\ \bar{6}\ 0)$	50	19	54
		Ge	$(2\ 4\ 6)$	76	99	123
Cu(O)	8.990	Ge	$(3\ 3\ 7)$	42	41	59
Eu	6.977	Ge	$(6\ 2\ 0)$	112	51	123
Yb	8.944	Ge	$(0\ 0\ 8)$	64	131	145