Conducting Nuclear Resonant Scattering Experiment at 3ID, APS

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Advanced Photon Source

To plan for an experiment of NRS at 3ID

1. What can be measured?

   NRIXS: thermal dynamics
   SMS: hyperfine interactions

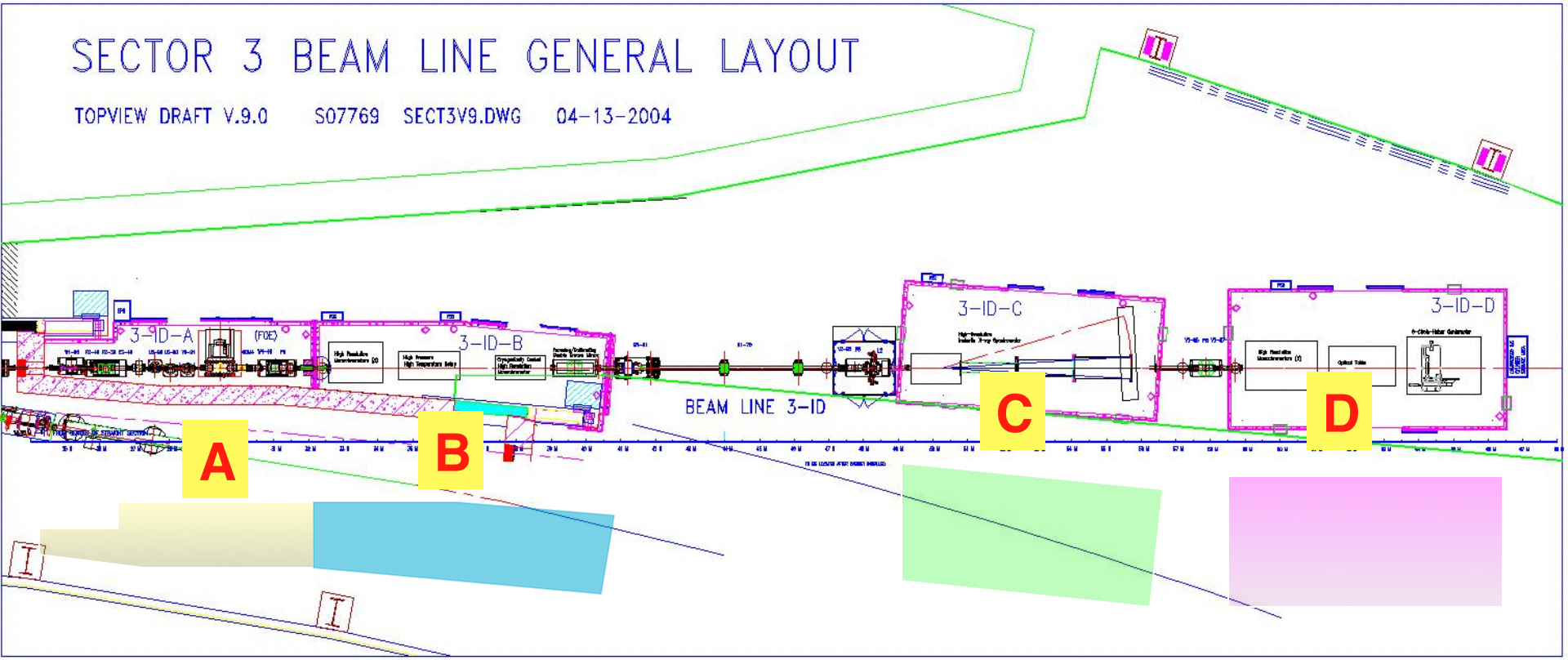
2. What's available at the beamline

   how strong the beam, how small the beam size,
   how low/high the temperature or field etc.

3. How and when to apply the beam time

Nuclear resonance beamlines around the world, 2010

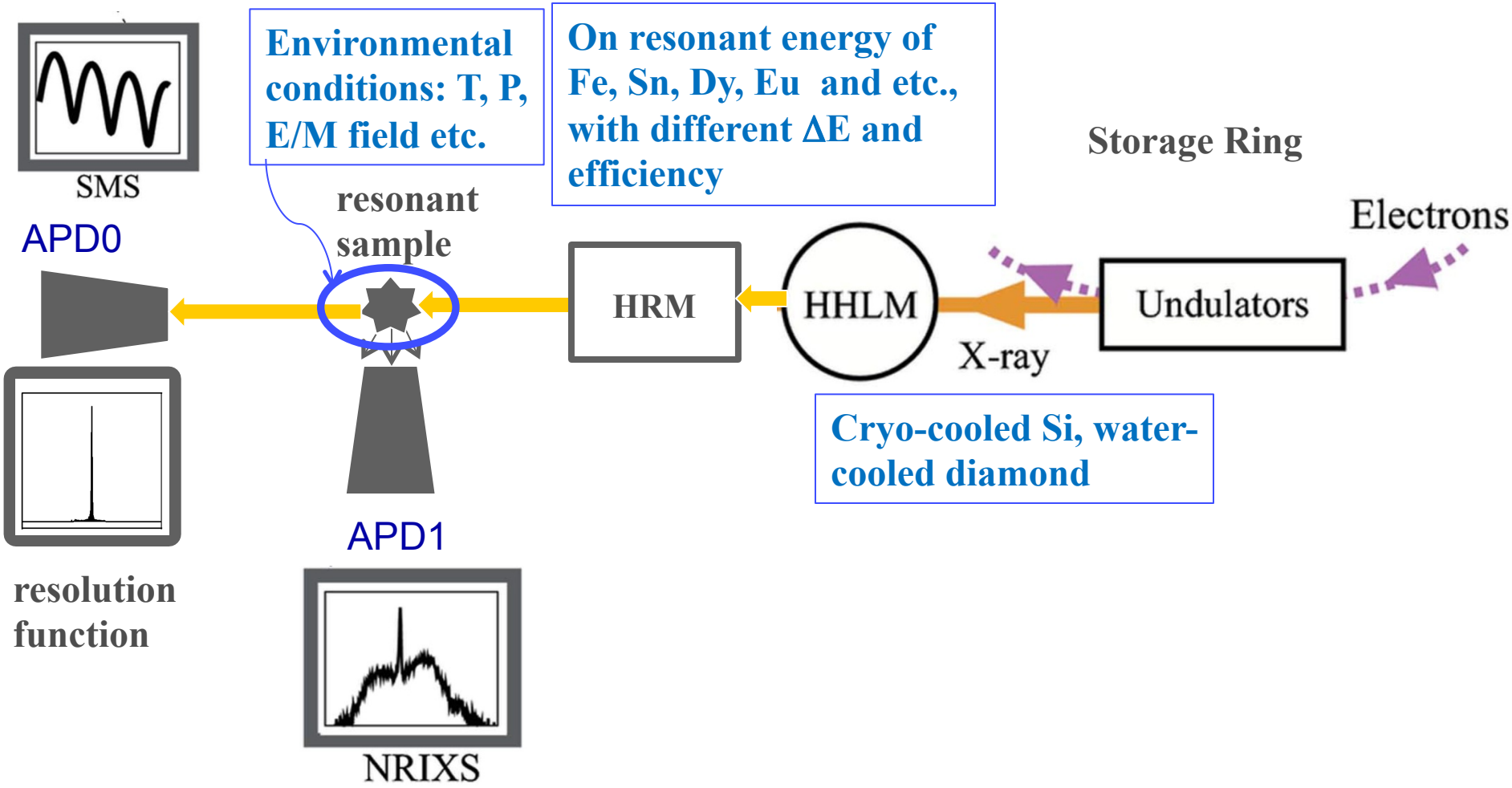
4 stations: A-B-C-D at 3ID, APS



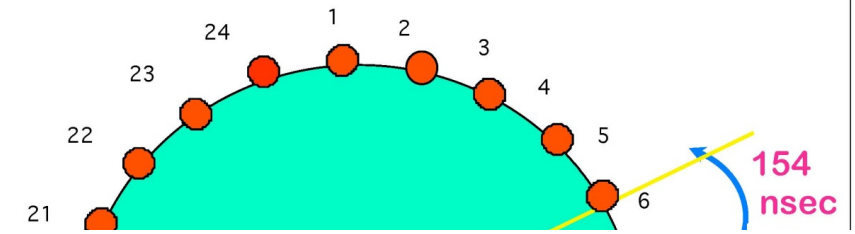
X-ray Source and Instruments for NRS

1. SR Source (undulator)
2. Monochromator (HHLM, HRM)
3. Focusing (KB, toroidal mirror, CRL)
4. Environments (HT, HP, LT,E/M-field)

Setup for a synchrotron radiation nuclear resonant scattering experiment

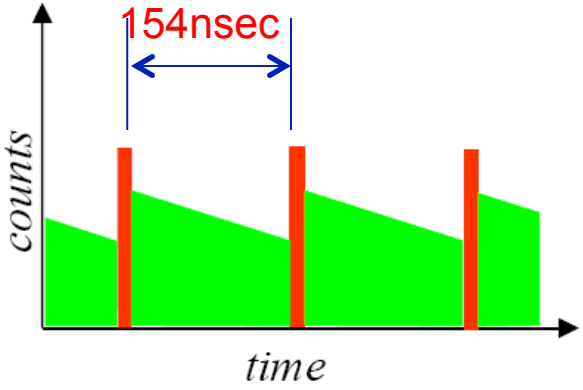


Standard Time structure @ APS



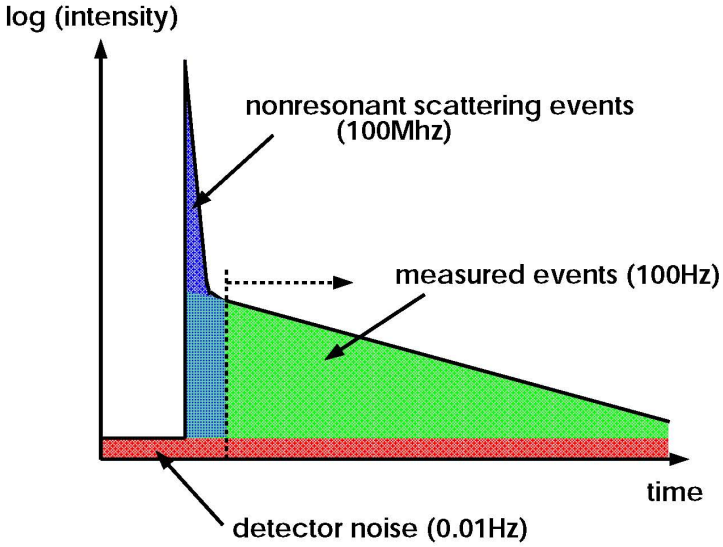
The time discrimination trick:

The excited nucleus decays incoherently with its natural life time τ.



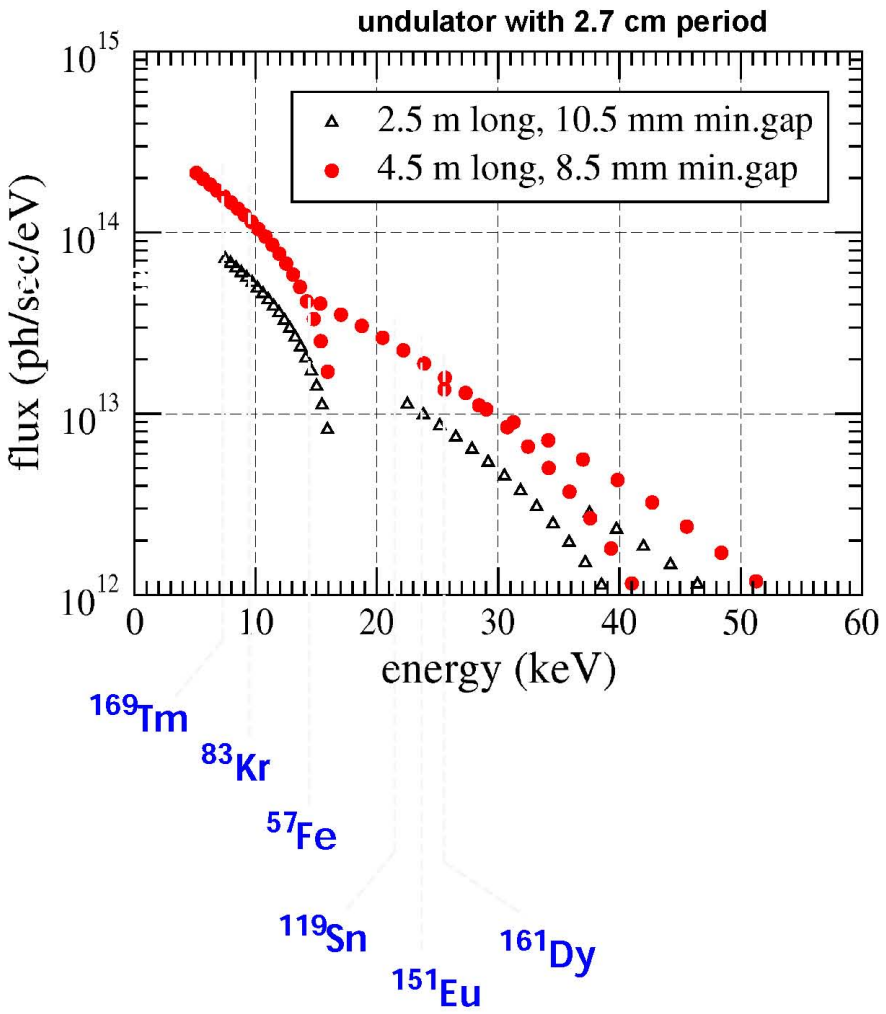
$\tau = \hbar / \Gamma$

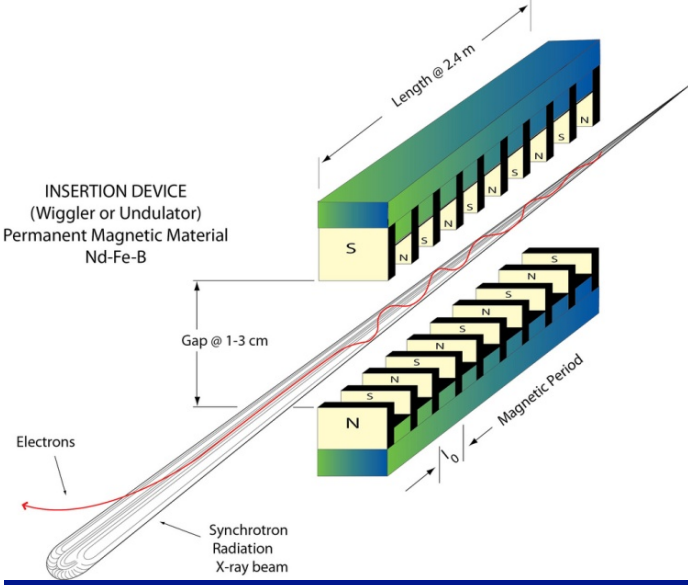
141 ns for ^{57}Fe



Time gating

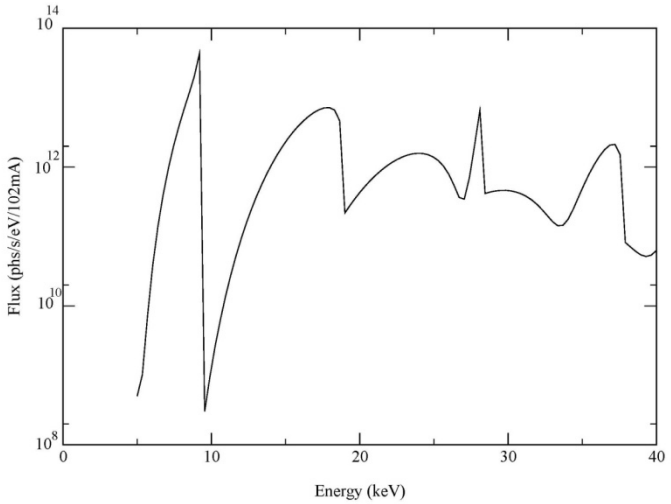
Synchrotron radiation at the Advanced Photon Source:





At 3ID, there are two 2.4 m long undulators, with 2.7 cm period

3ID undulator and HHLM



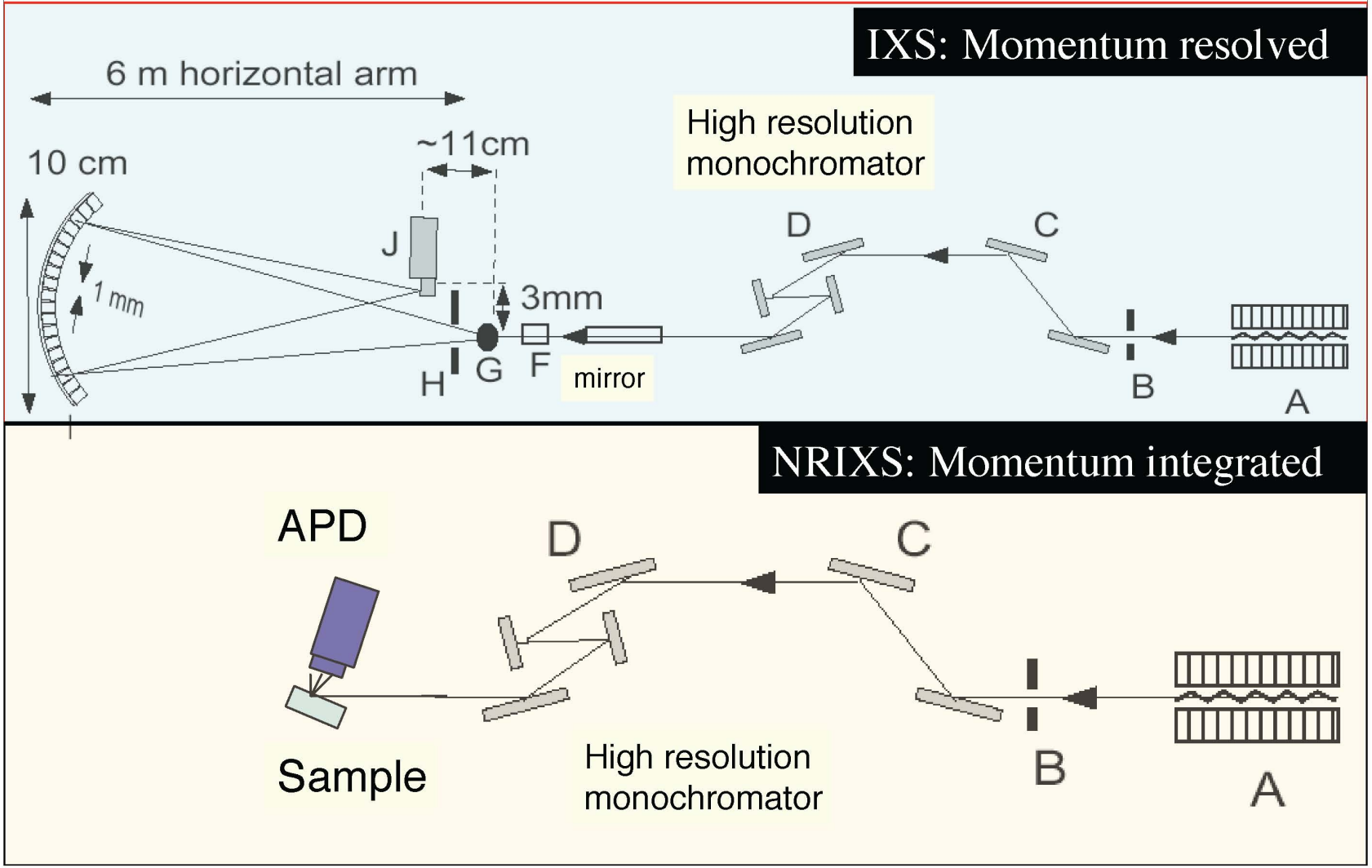
Parameters for running 3ID_undulators
Two undulators: 2.7cm, 88 periods
& Performance of Diamond (111) HHLM

Energy (KeV)	Isotopes	Ky	Gap (mm)	Vertical Divergence of 3ID_U (μrad)	HHLM acceptance (μrad)		ΔE after HHLM (eV) (measured)		Flux after HHLM while WBS 0.4mmX3mm THz (phs/sec/100mA)	
					Calculated	Measured	Caculated	Measured	Calculated	Measured
9.403	^{83}Kr	1.3	12.7	15.6	19.3		0.7		70	
14.413	^{57}Fe	0.6	19.5	13.7	12.3	14.4	0.82	0.93	29	20
21.657	^{151}Eu	1.7	10.7	12.4	8.0	9.5	1.23	1.57	27	10
23.880	^{119}Sn	1.5	11.5	12.1	7.6	8.0	1.29	2.7	23	

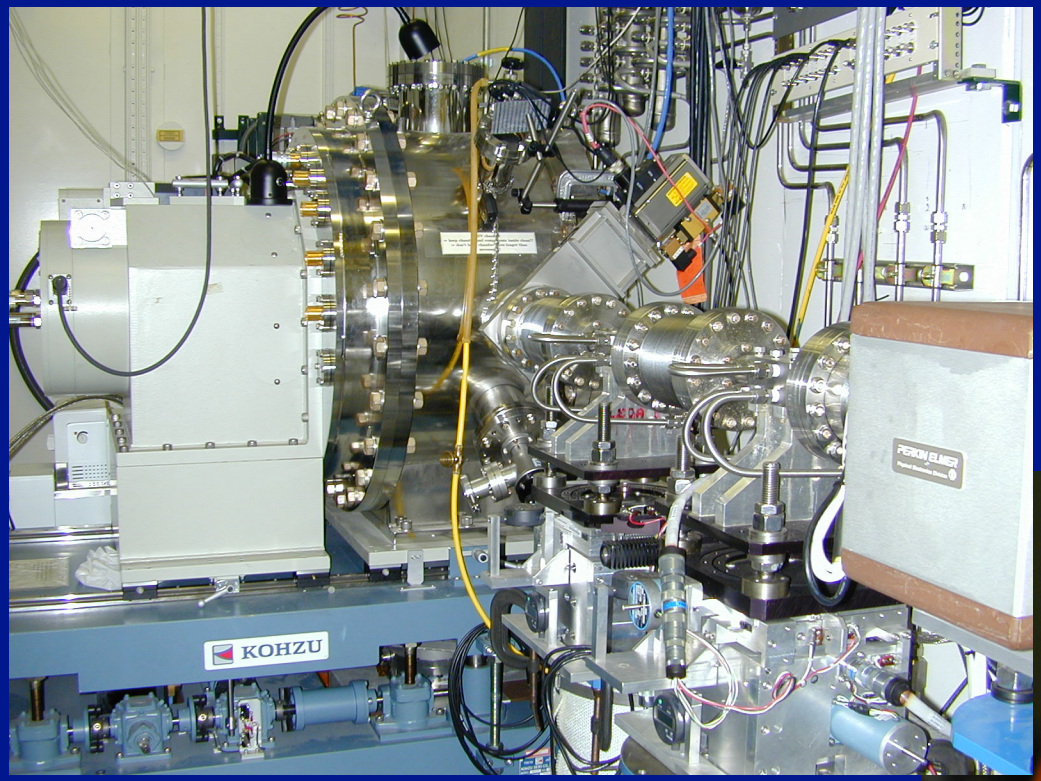
Nuclear data for Mössbauer isotopes

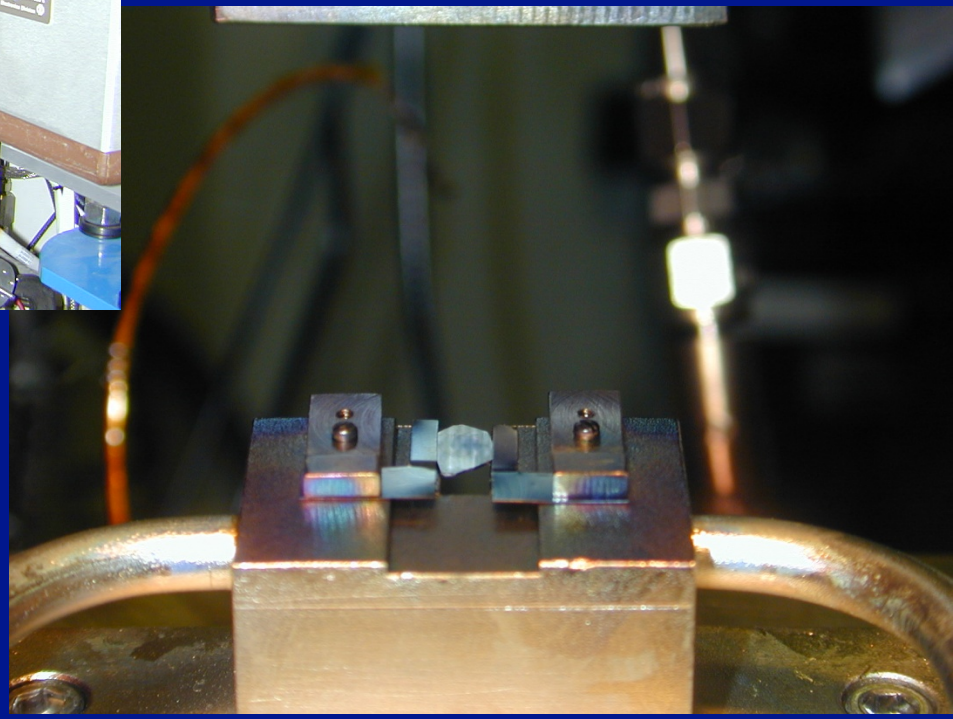
Isotope	Energy E(keV)	Life time $t_{1/2}$(ns)	Energy width Γ(neV)	Natural abundance(%)	Internal conv. coefficient α	Cross section σ_0(cm^2 10^{-18})	Recoil energy E_R (meV)	Type
^{181}Ta	6.22	6800	0.067	99.99	46	1.6	0.116	E1
^{169}Tm	8.41	3.9	1.17	100	268	0.31	0.24	M1
^{83}Kr	9.40	147	3.1	11.5	19.9	1.1	0.56	M1
^{73}Ge	13.26	4 10^3	0.11	7.8	1000	0.0076	1.29	E2
^{57}Fe	14.41	97.8	4.7	2.15	8.21	2.57	1.95	M1
^{151}Eu	21.53	9.7	0.47	47.9	28.6	0.23	1.66	M1
^{149}Sm	22.49	7.1	0.641	13.9	50	0.0711	1.82	M1
^{119}Sn	23.88	17.7	0.257	8.6	5.12	1.40	2.58	M1
^{161}Dy	25.65	28.1	0.162	19.0	2.9	0.95	2.2	E1
^{40}K	29.56	4.26	1.07	0.012	6.6	1.6	11.6	M1

Inelastic X-Ray Scattering: two approaches



3ID-A: High heat-load monochromator



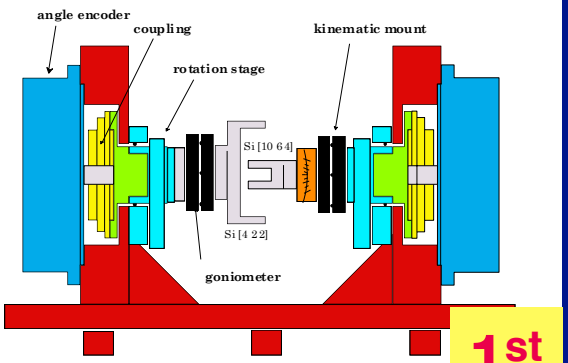


Kohzu high-heat-load monochromator consists of two water-cooled Diamonds

3ID-B: High energy-resolution monochromator and focusing optics

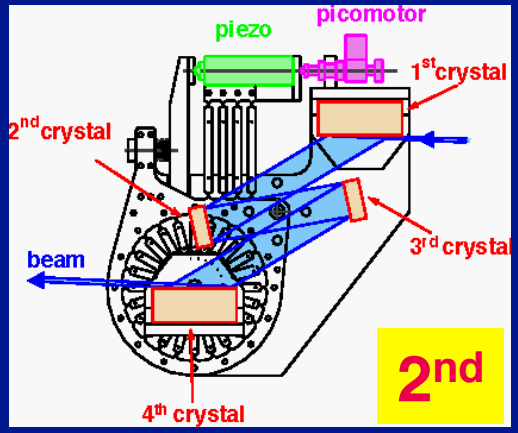
Generations of high-resolution monochromators

1992



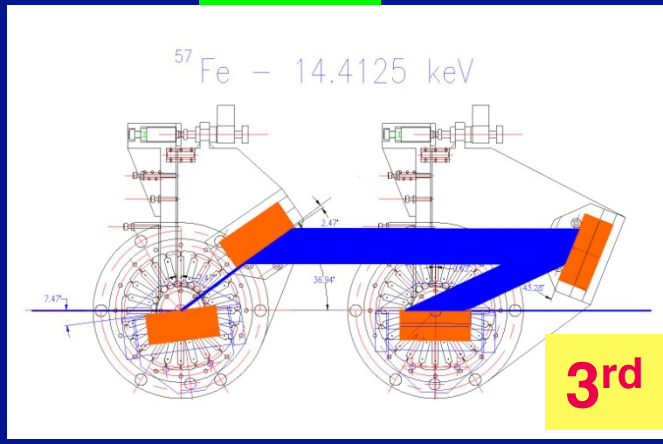
1st

1999



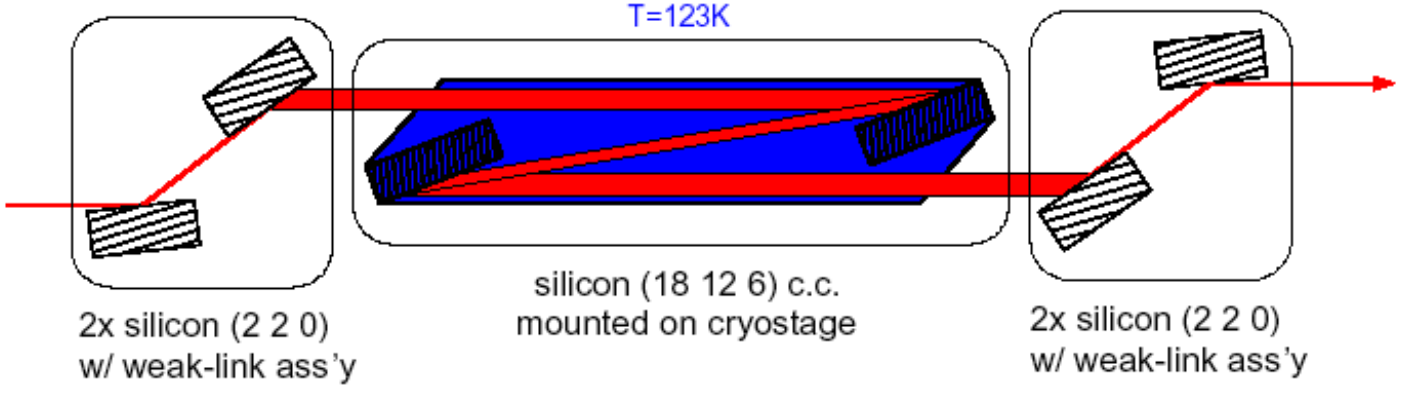
2nd

2002

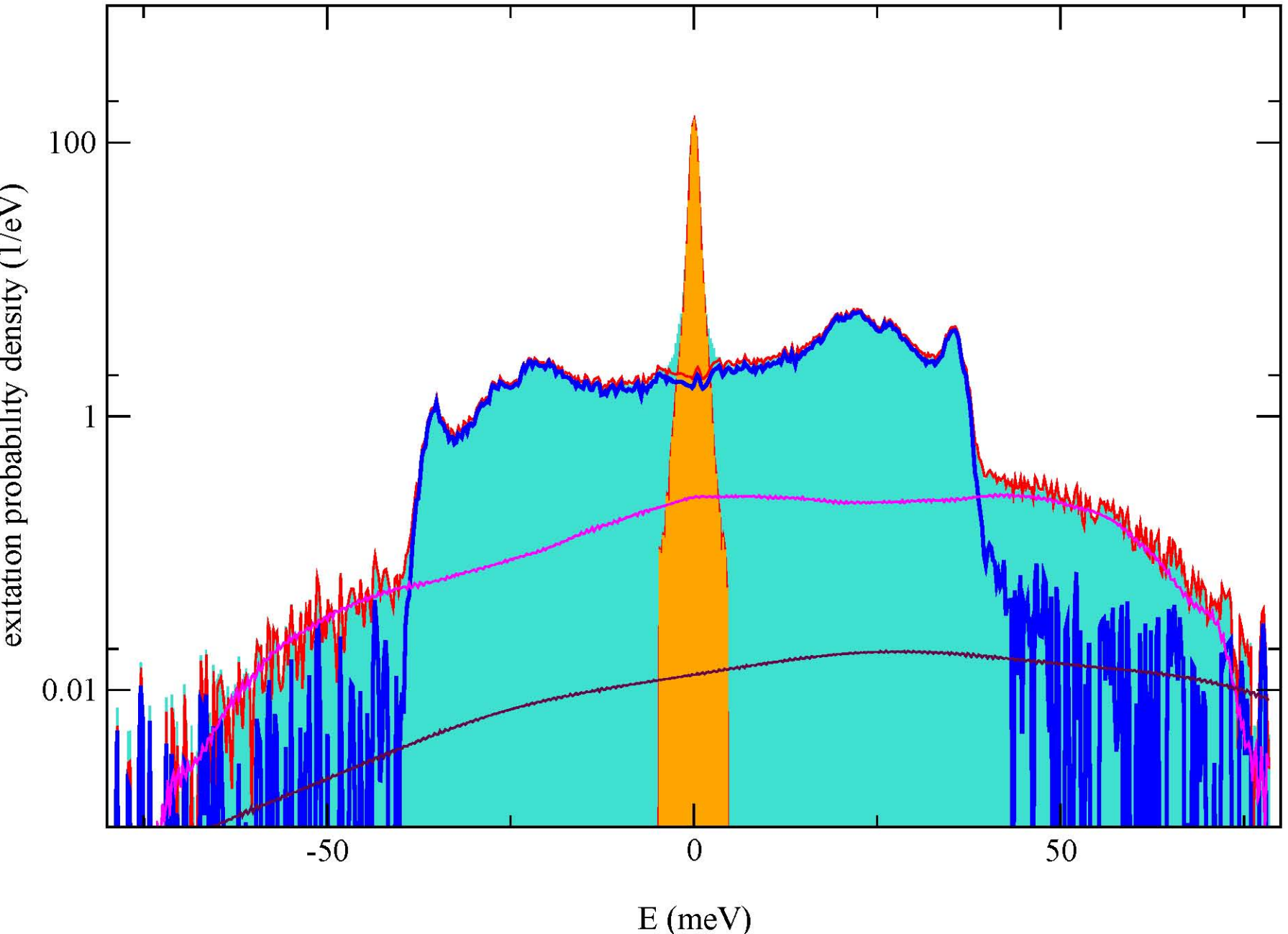


3rd

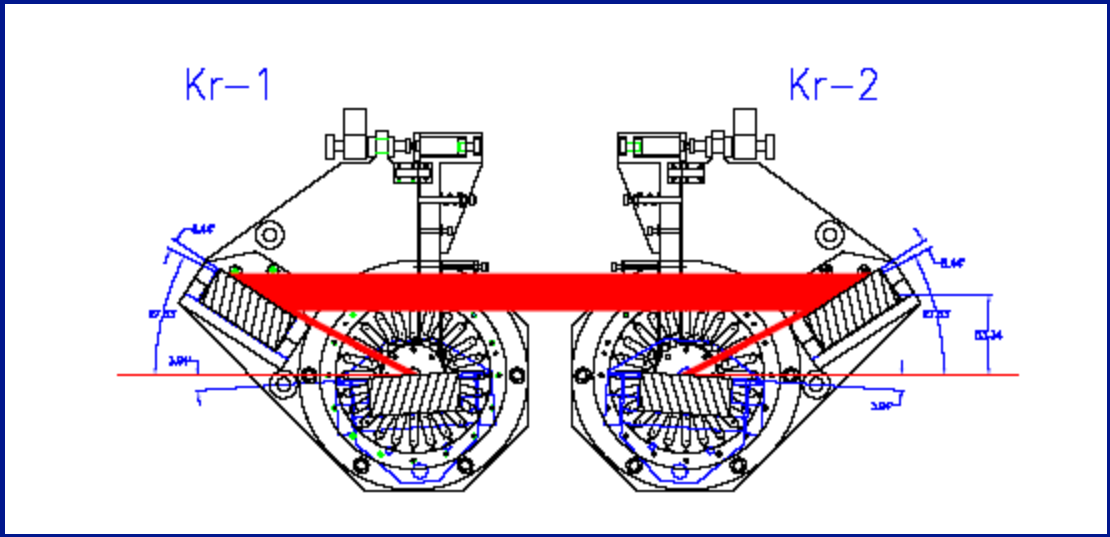
2004



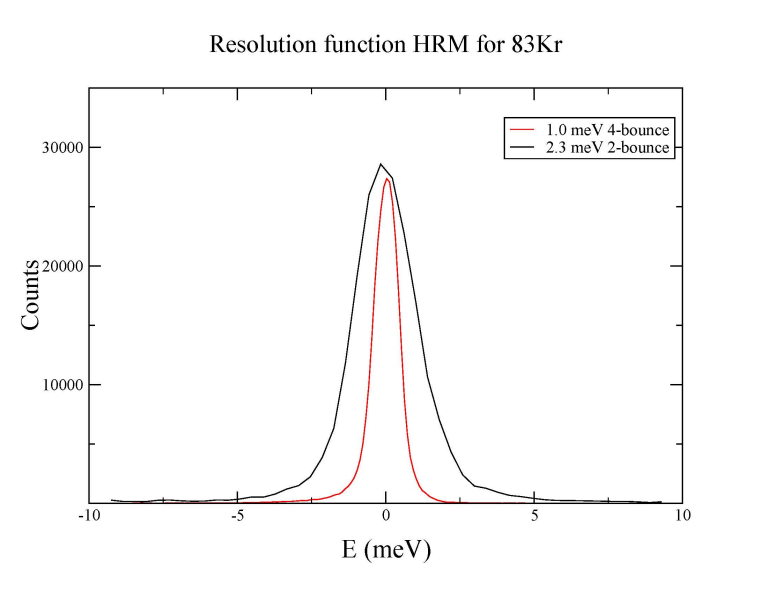
4th


100
1
0.01
exitation probability density (1/eV)
-50
0
50
E (meV)

How do we measure such a narrow energy-resolution in meV or narrower?



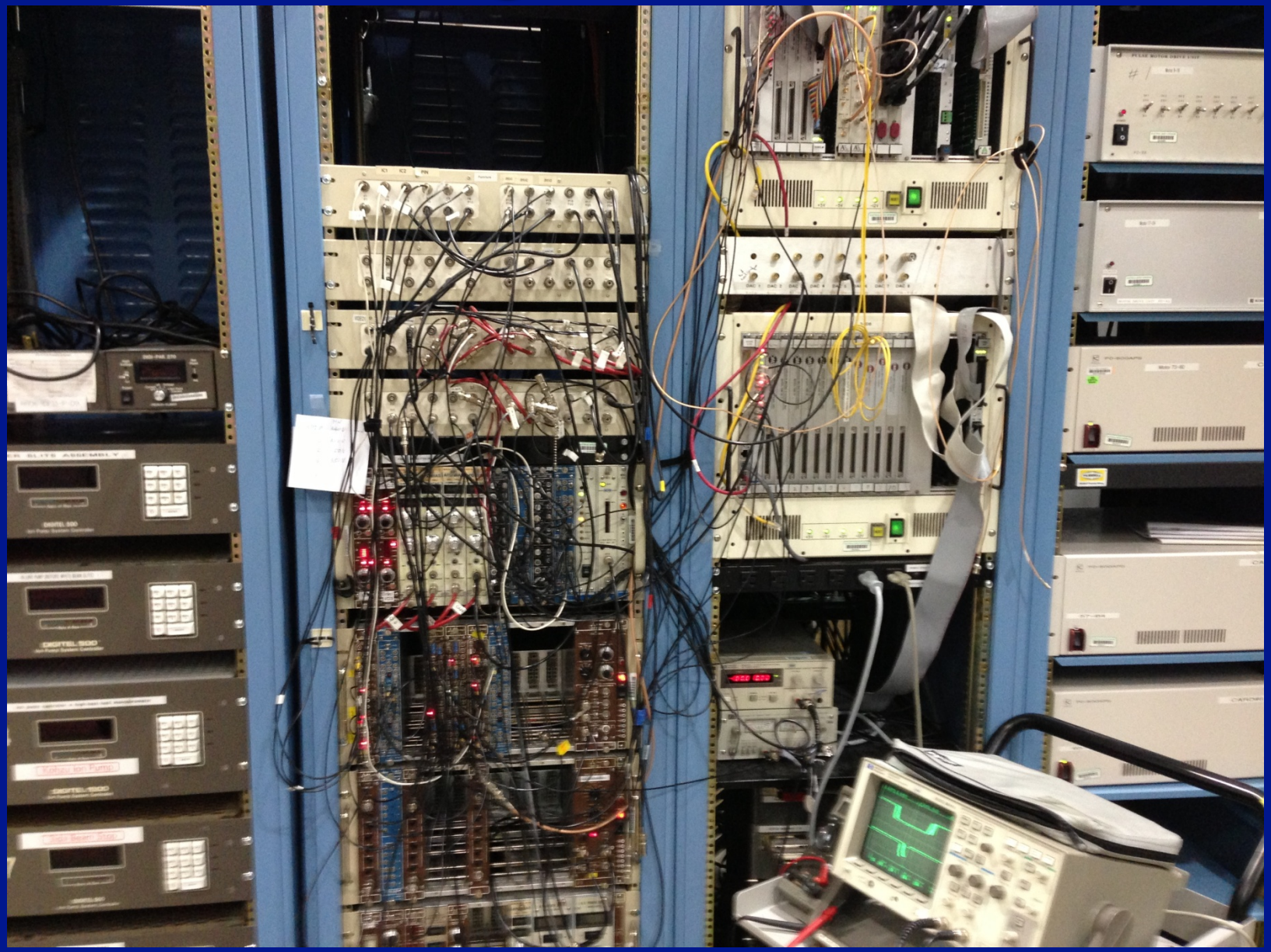
Designed by Toellner



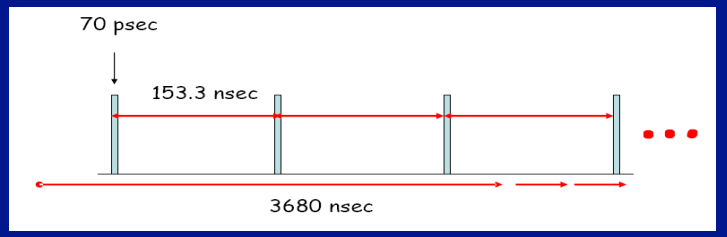
HRM at Sector 3

^{57}Fe,	14.4 keV,	HRM: 1/0.8/2.3/5 meV
^{151}Eu,	21.541 keV,	HRM: 0.8 meV
^{119}Sn,	23.880 keV,	HRM: 0.85/0.14 meV
^{161}Dy,	25.651 keV,	HRM: 0.5 meV
^{83}Kr,	9.404 keV,	HRM: 2.3/1.0 meV

Timing technique

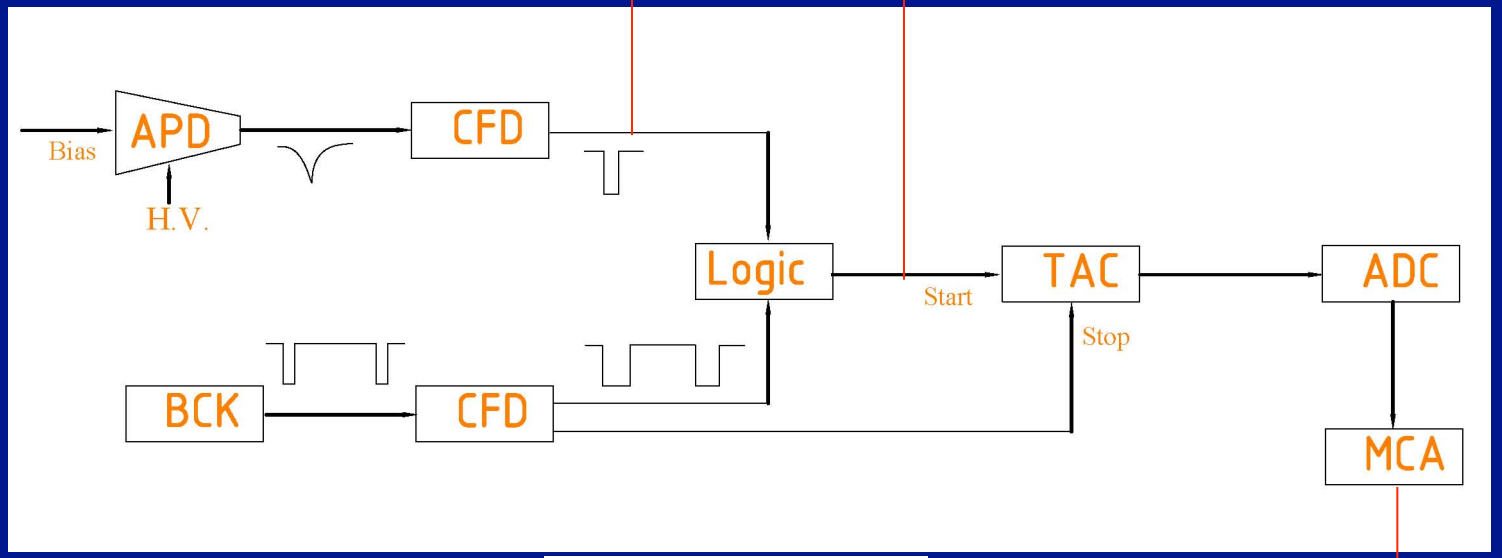


Timing technique

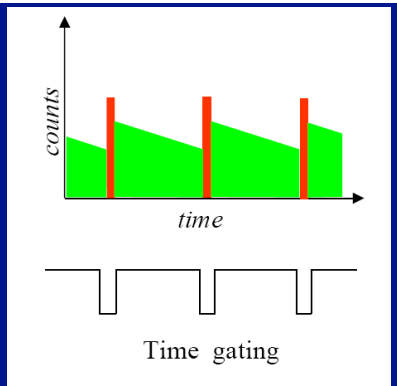


total (prompt)

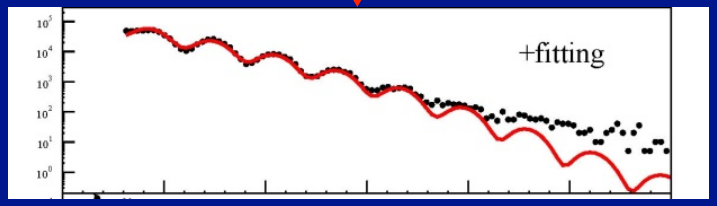
delayed



Avalanche photodiode (APD):
100μm Si diode with HV
Efficiency@14keV: 14%
Time resolution: 1ns
Dynamic range: 10^9
Noise: 10^{-2}



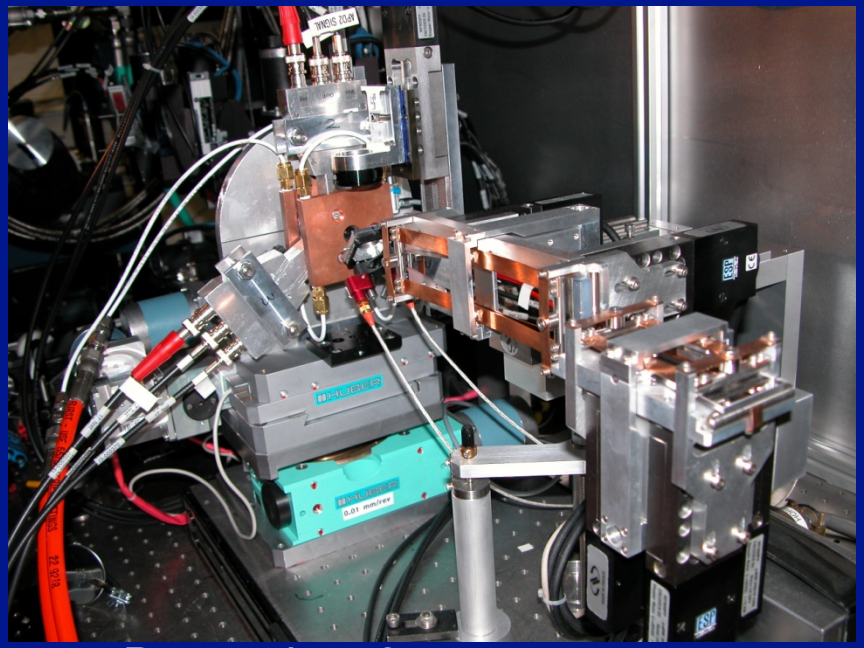
Time spectrum



Unique capability at 3ID for NRS

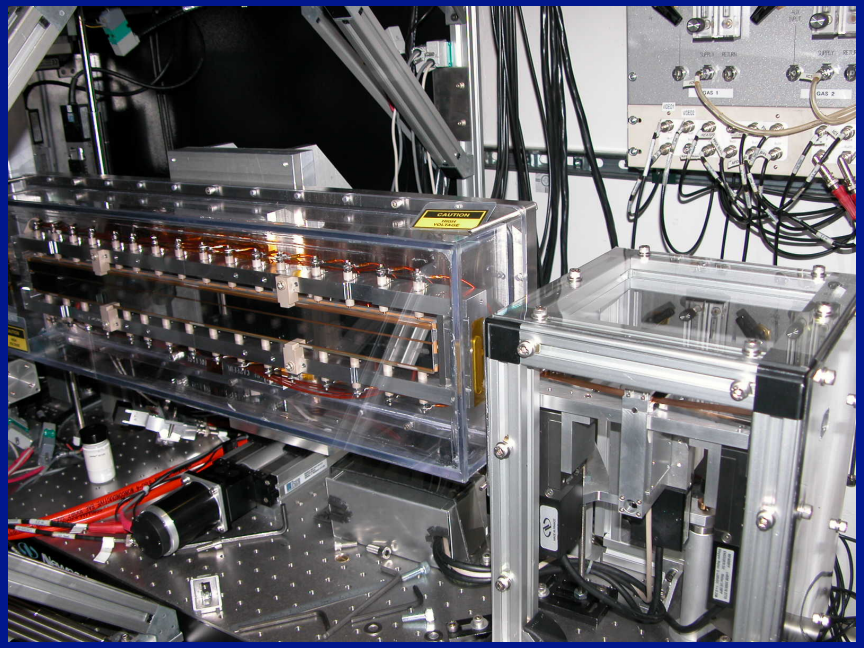
Beam focusing at 3ID-B

K-B focusing mirror



Beam size: 6 μm x 7 μm

Acceptance: 0.4mm x 0.6 mm



Beam size: 18 μm x 12 μm

Acceptance: 0.4mm x 1.8 mm

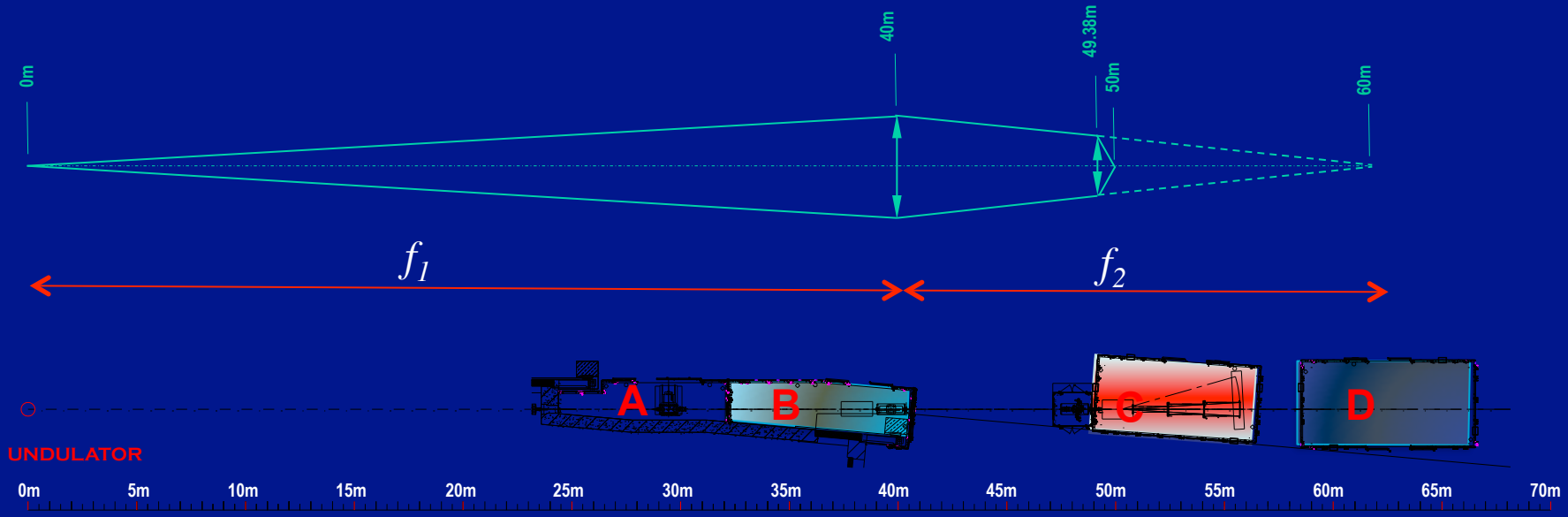
Toroidal + K-B tandem focusing at 3-ID-C (IXS), and 3ID-D (NRS)

$$R_1 = \frac{2 f_1 f_2}{f_1 + f_2} \sin\theta$$

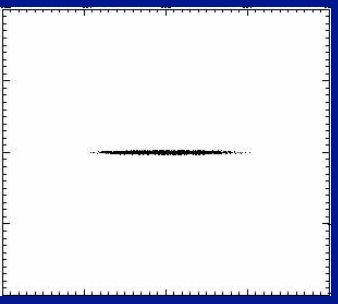
$$R_2 = \frac{R_1}{\sin^2 \theta}$$

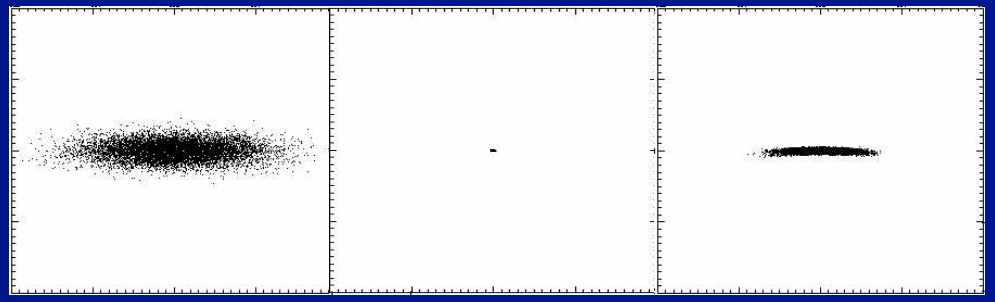
Sagittal focusing, horizontal, 46 mm

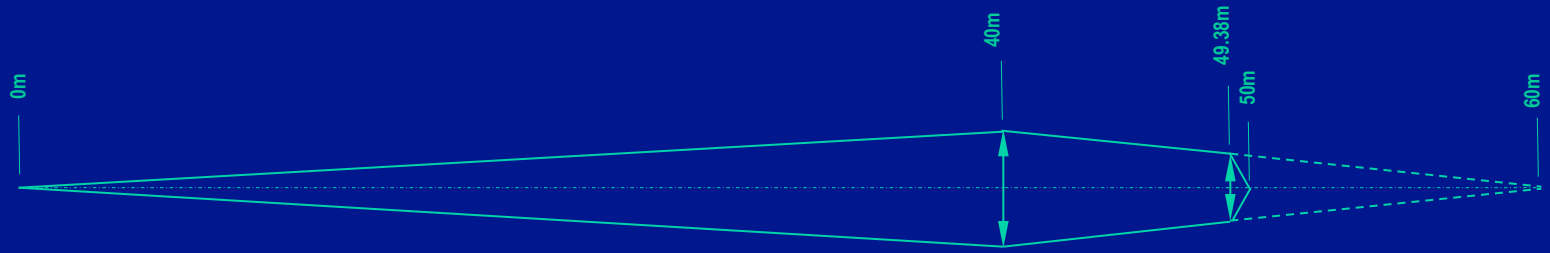
Vertical focusing, 11-33 km, θ = *1*.6 mrad

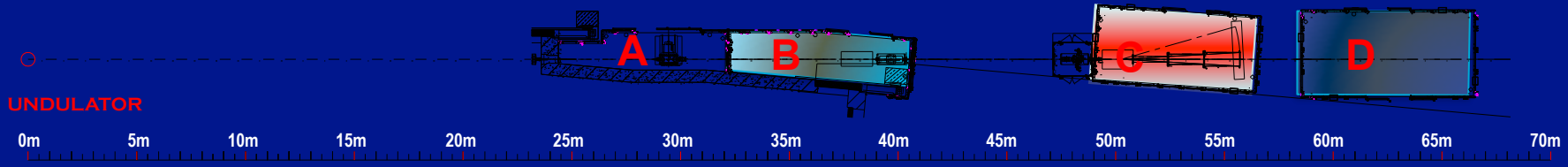


Toroidal + K-B tandem focusing at 3-ID-APS







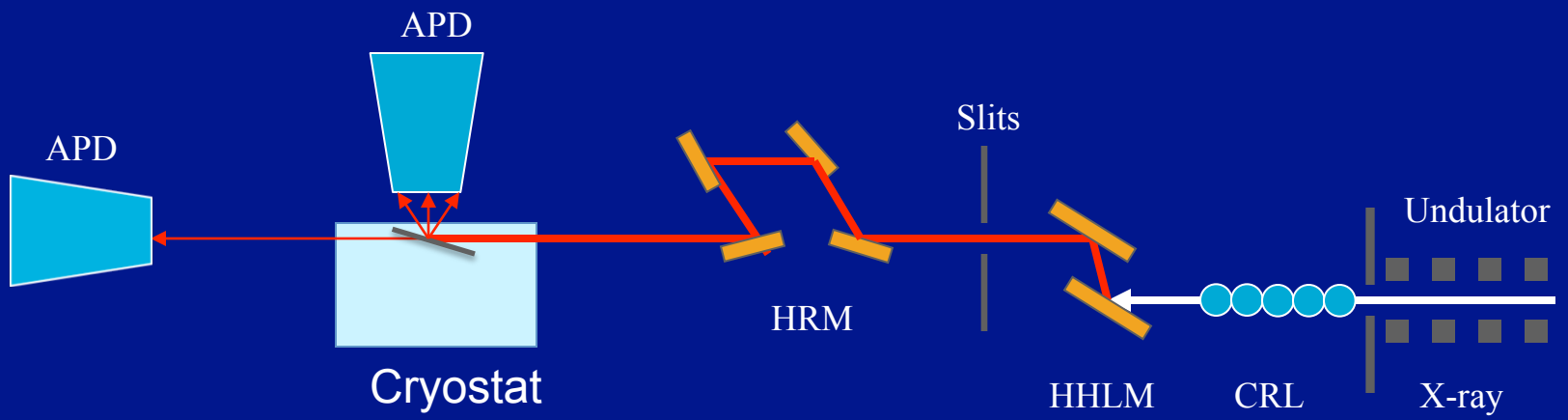


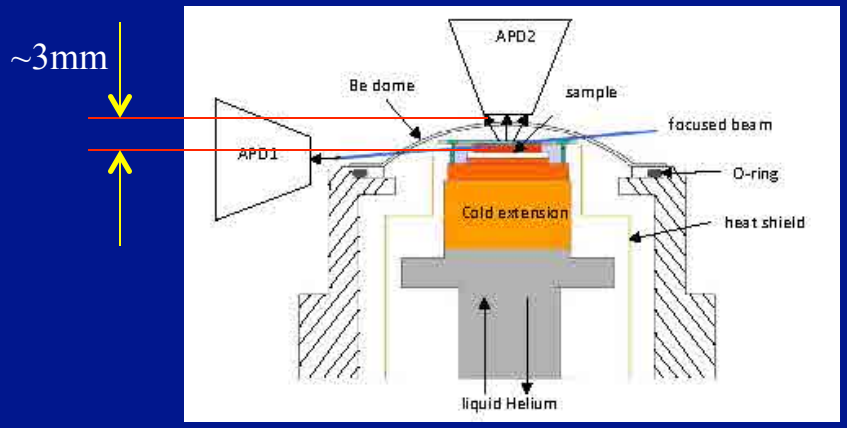
Shadow simulations, A. Alatas

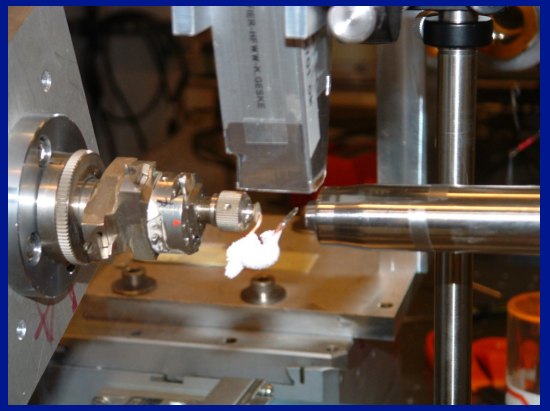
Sample environment for NRS at 3ID

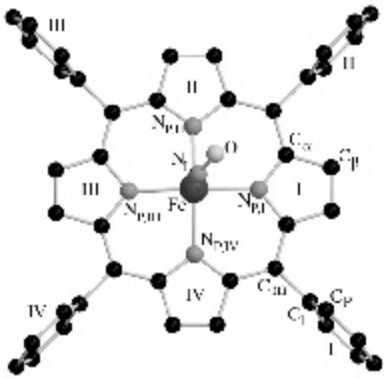
- Low temperature, flow cryostat
- High pressure and high temperature
- High pressure and low temperature

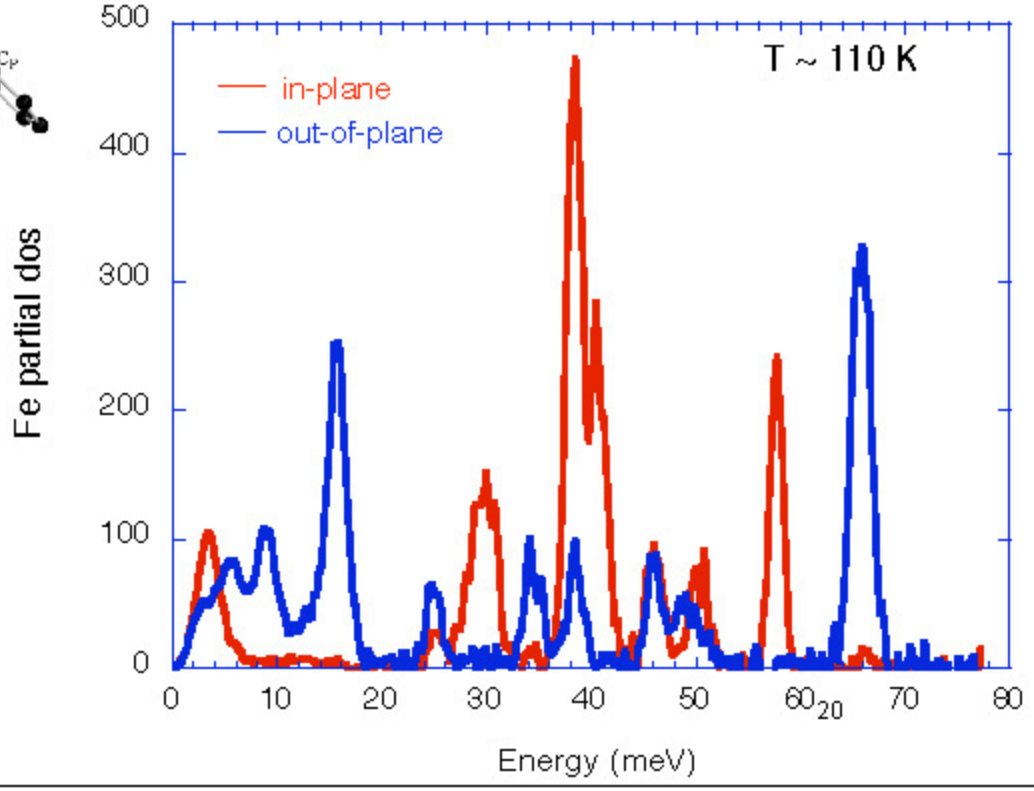
Experimental Setup for Nuclear Resonant Inelastic X-ray Scattering under low temperature







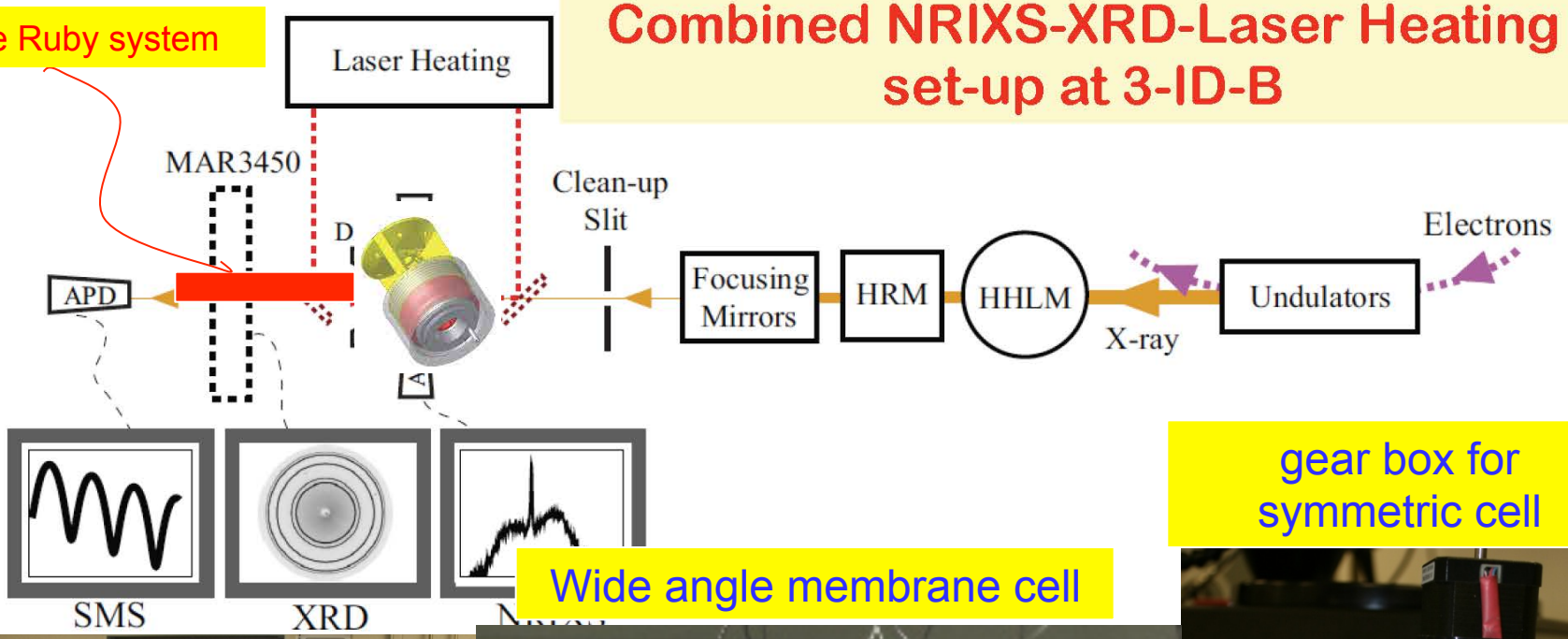



T ~ 110 K
in-plane
out-of-plane
Fe partial dos
Energy (meV)
0
100
200
300
400
500
0
10
20
30
40
50
60
70
80

Unique capability at 3ID: HP/HT for NRS

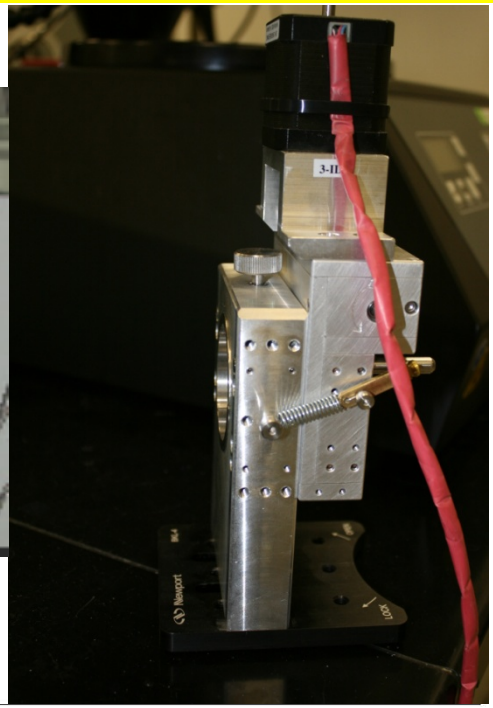
On-line Ruby system

Combined NRIXS-XRD-Laser Heating set-up at 3-ID-B



gear box for symmetric cell

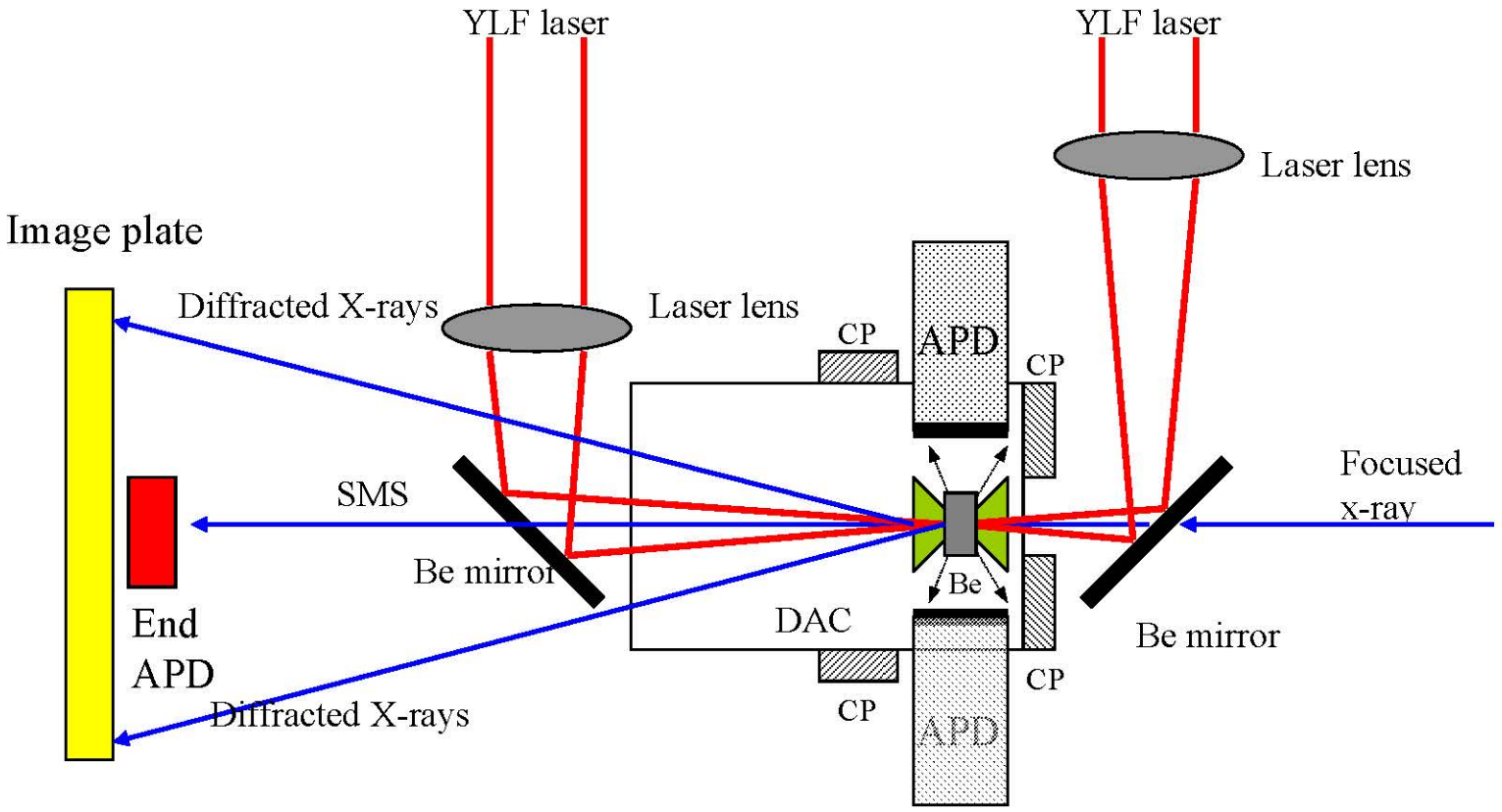
Wide angle membrane cell



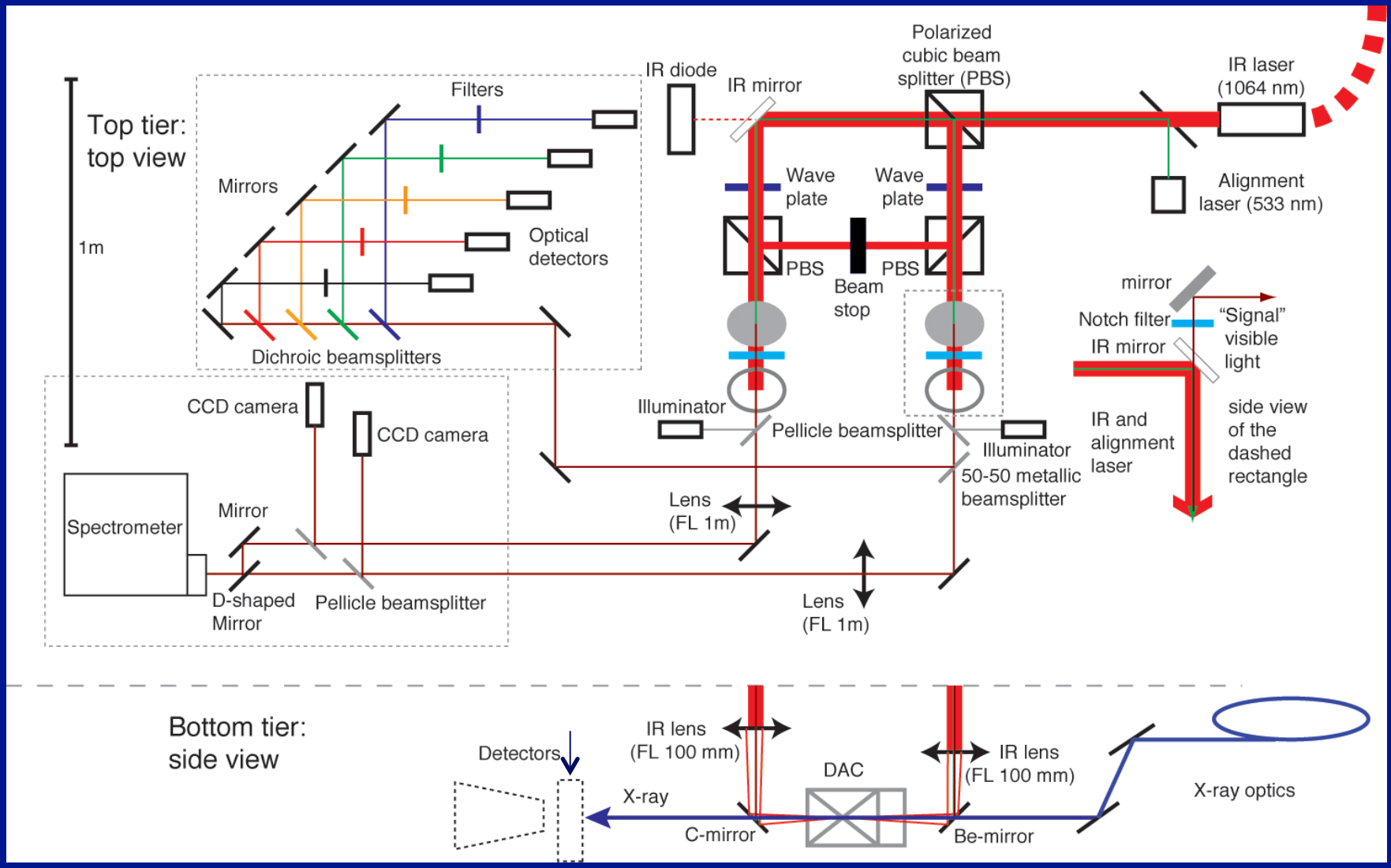
Glove box for DAC loading, H_2O: 1 ppm, O_2: 20 ppm

NRIXS-SMS and diffraction

***In situ* X-ray diffraction, NRIXS, and SMS studies in a LHDAC provide structural (density), magnetic, elastic, vibrational, and thermodynamic information of the sample. This is also a powerful tool to detect melting.**



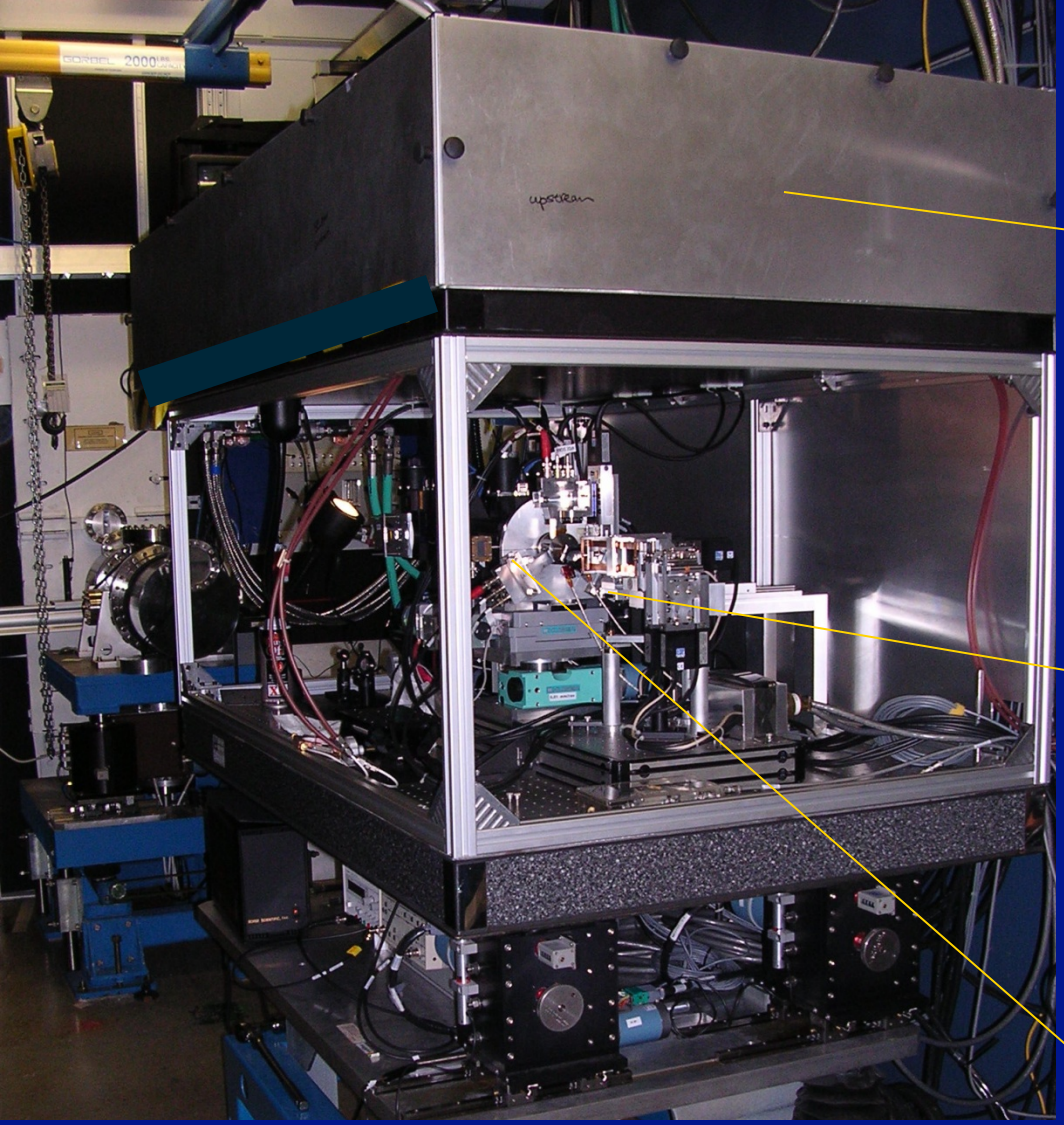
HP-HT Nuclear resonant scattering

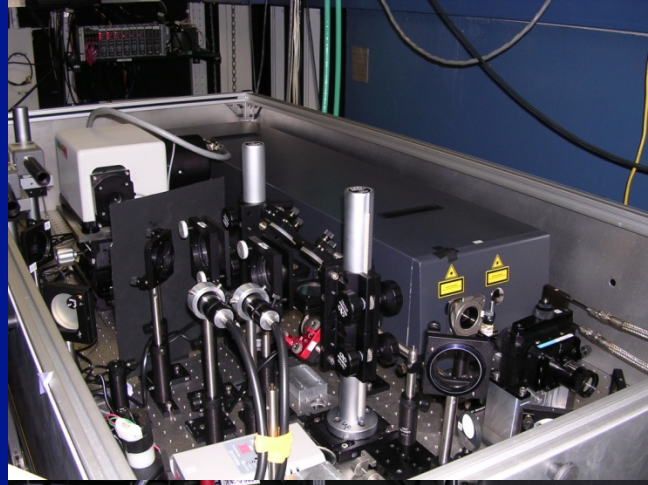


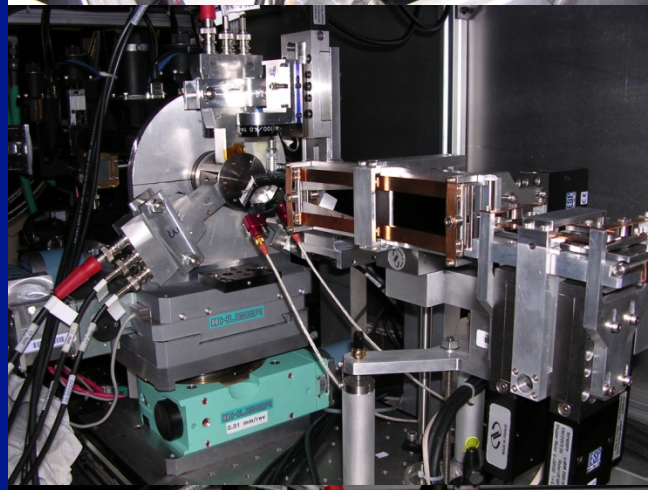
Fast Temperature Readout system(FasTeR)

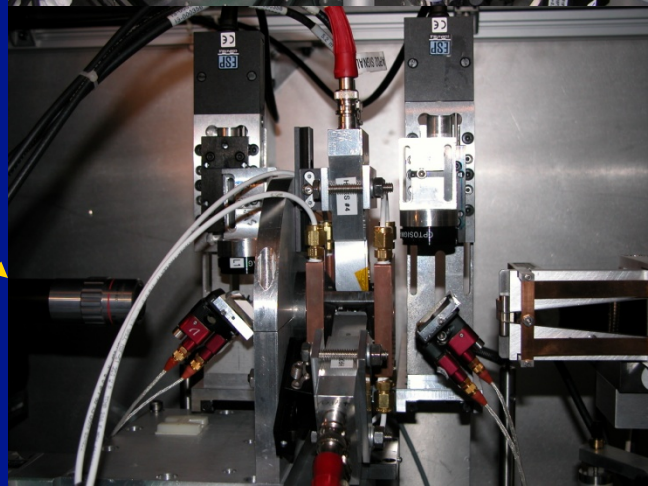
NRS+ Laser heating+ Spectroradiometer+ FasTeR spectrometer

High pressure melting

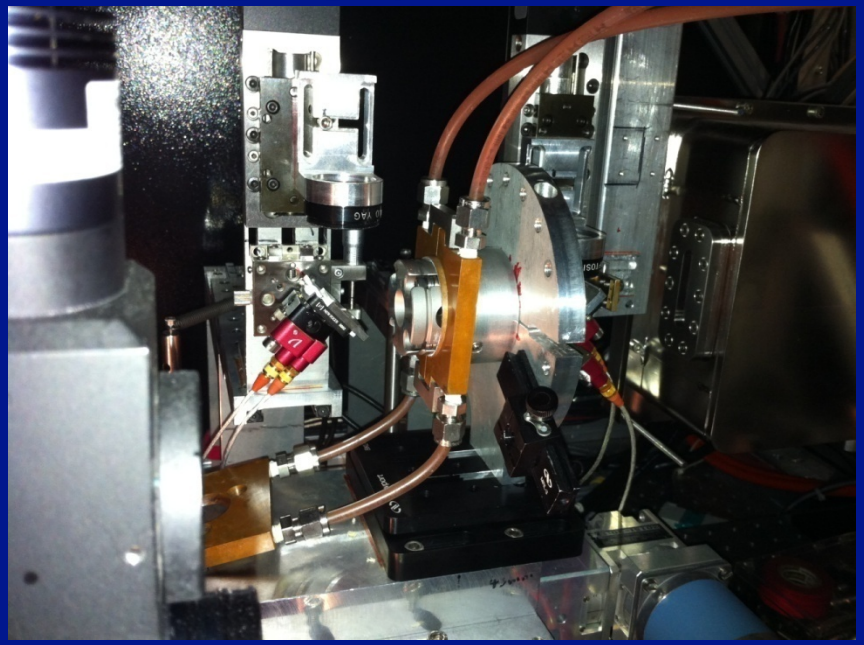

upstream





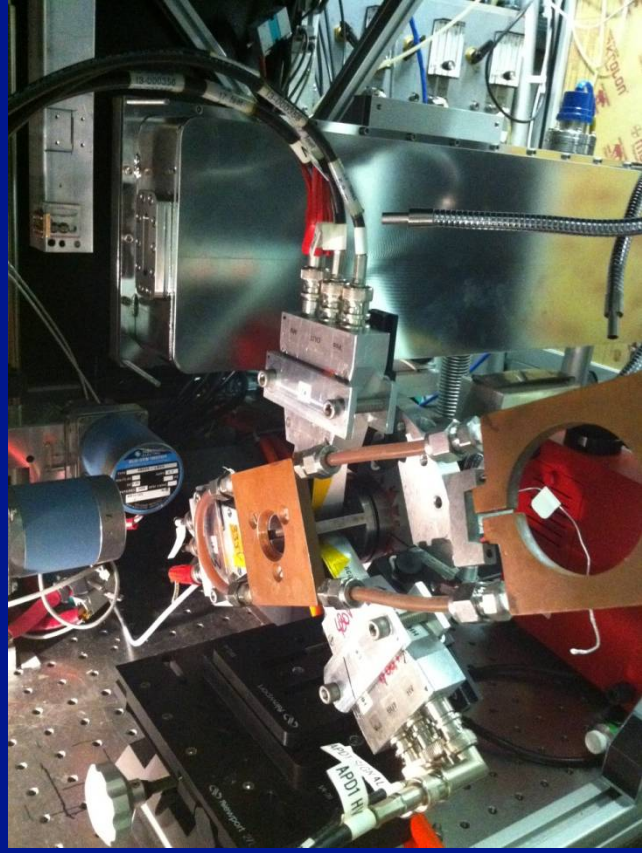


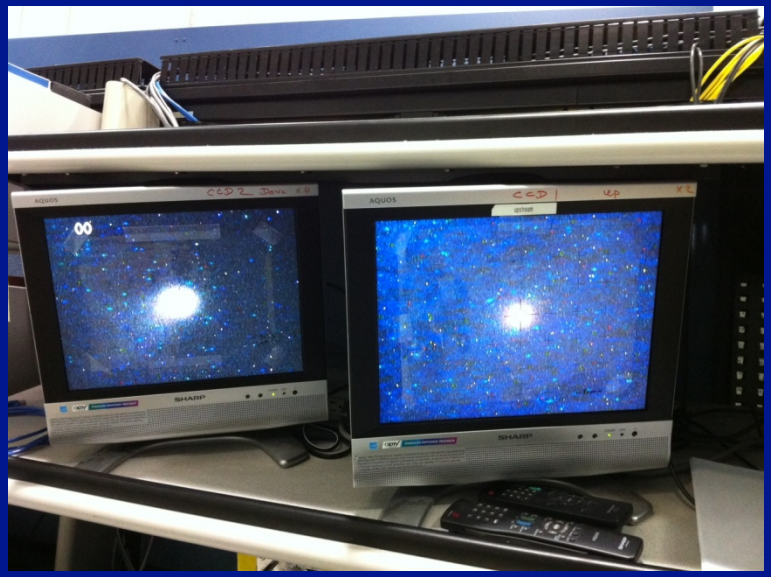
NRS at HPHT setup



NRIXS ->

<- SMS



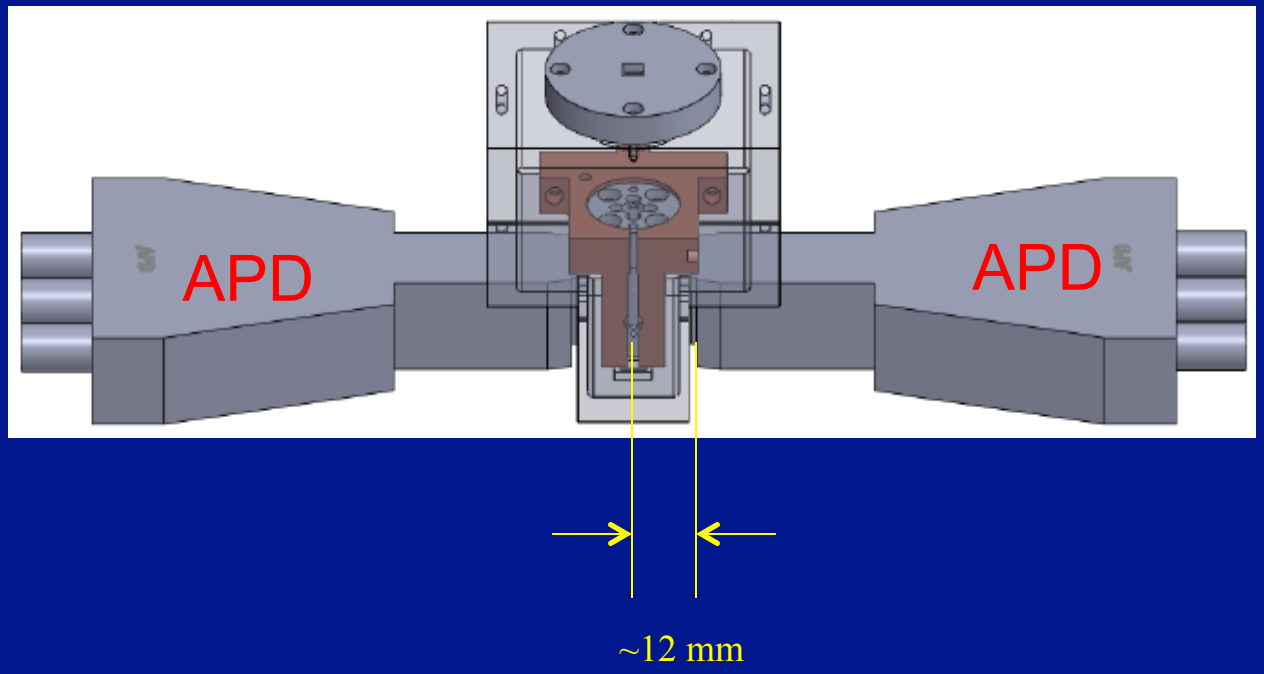


<- Hotspot

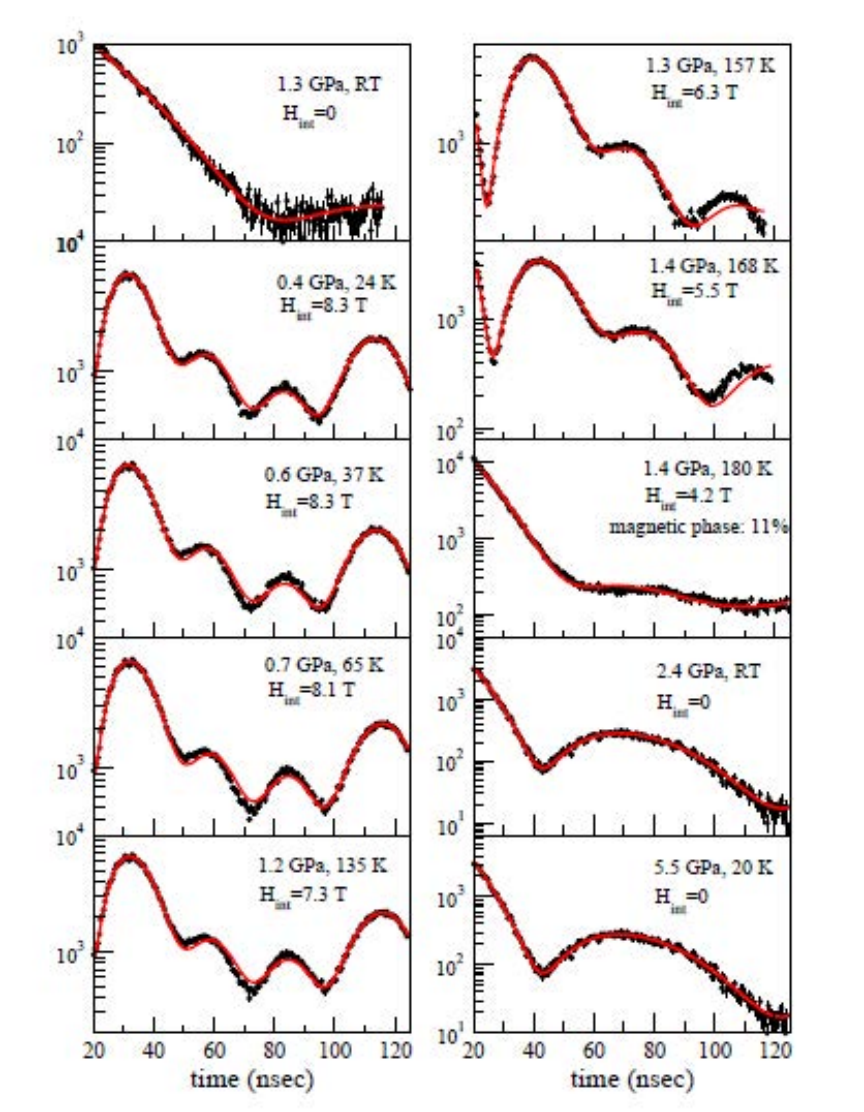
Example sample loading->

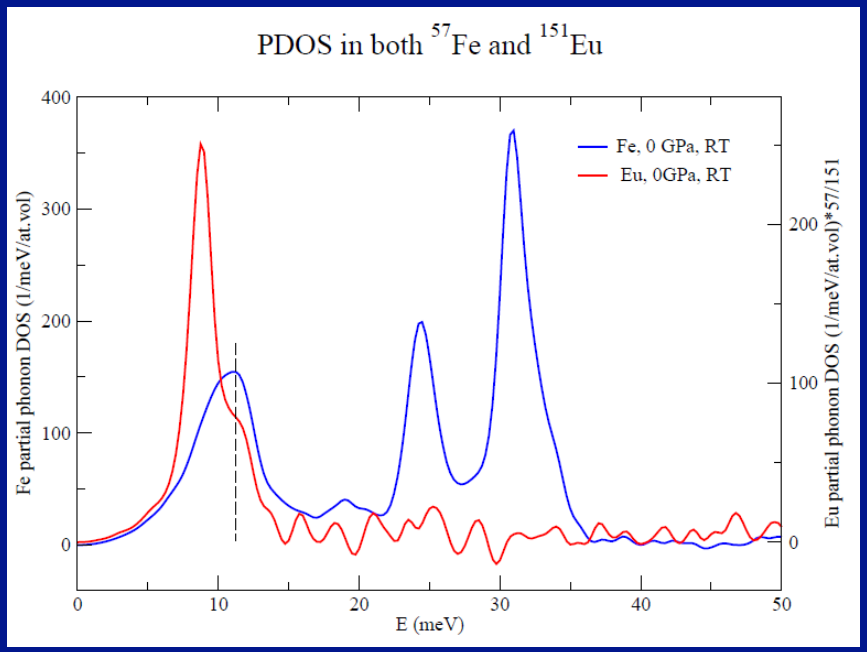
Recent Development of NRIXS at High-P Low-T

Design of a miniature panoramic diamond anvil cell (DAC) .



NRIXS and SMS of EuFe2As2 under LT and HP





Active user programs at 3ID, APS with the following unique capabilities

Currently available:

1. A low temperature (4K) and high magnetic field (9T) and high pressure system for NFS. (since 2007)
2. A laser heated diamond anvil cell system (since 2002)
3. An In-situ diffraction system (since 2008)
4. An on-line Ruby system (since 2011)
5. Dynamic pressure adjusting system
   (gear box and gas-driven membrane cell). (since 2011)

Under development:

Low temperature (4K) and high pressure (Mbar) system for NRIXS.

To use the facility at 3ID, APS

- Nine months of running, in three periods
  - T1-period, Feb~Apr;
  - T2-period, Jun~Aug;
  - T3-period, Oct-Dec.

- Two type of proposals
  - GUP (General User Proposal)
    - effective for two years
  - PUP (Partner User Proposal):
    - Jointly developing new capability for the beamline, with guaranteed beam time each run

To become a user at 3ID

- Plan ahead
- Talk to the beamline scientists
- Apply through either GUP (General User Proposal) or PUP (Partner User Proposal)

  Deadline: 2015-1, Oct-31-14

  2015-2, Mar-8-15

  2015-3, Jul-12-15

Thank you for your attention

and

See you at the beamline!