Instrumentation for Nuclear Resonant Scattering at 3ID, APS

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Workshop on Data Evaluation using CONUSS and PHOENIX
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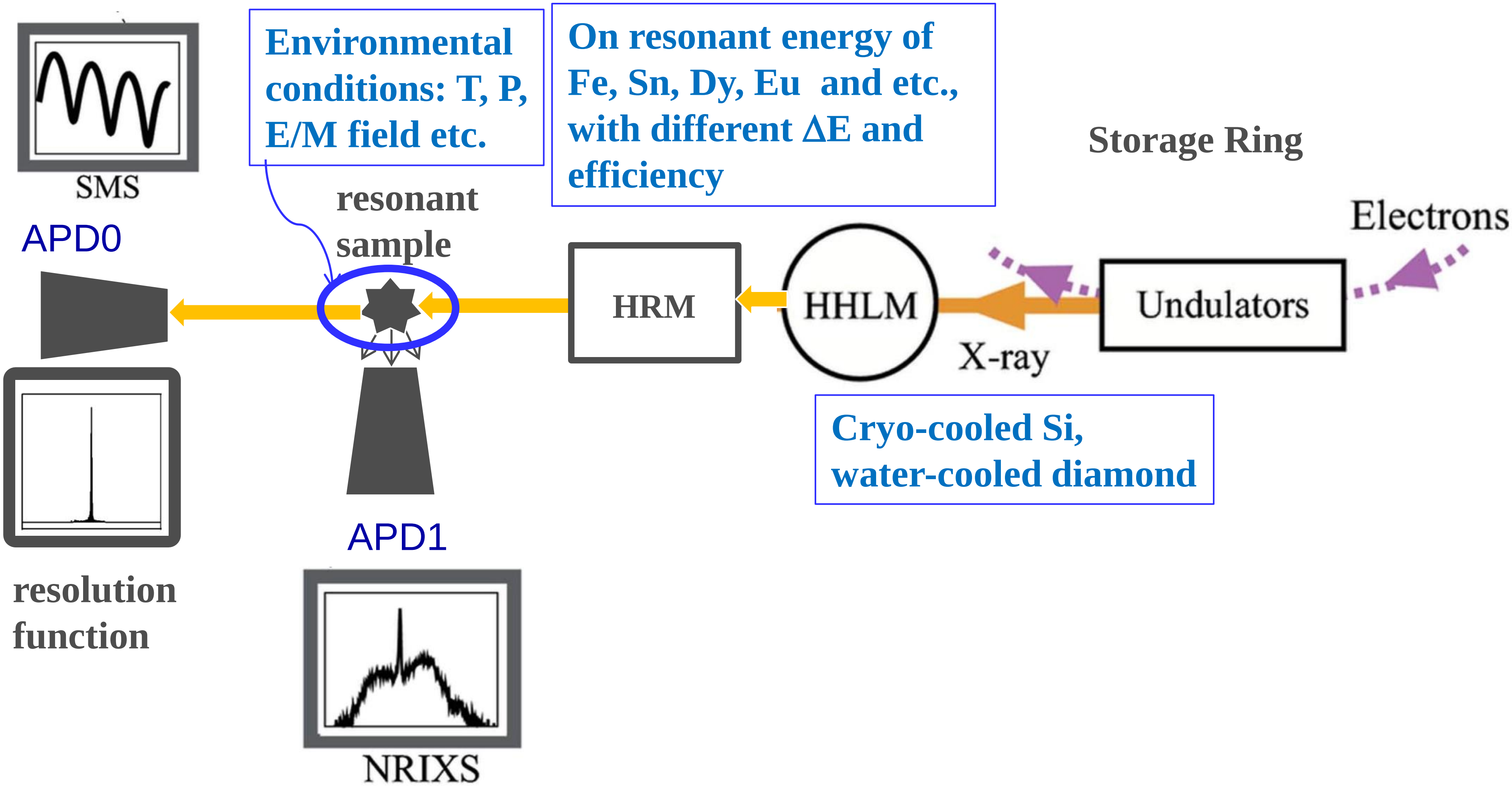
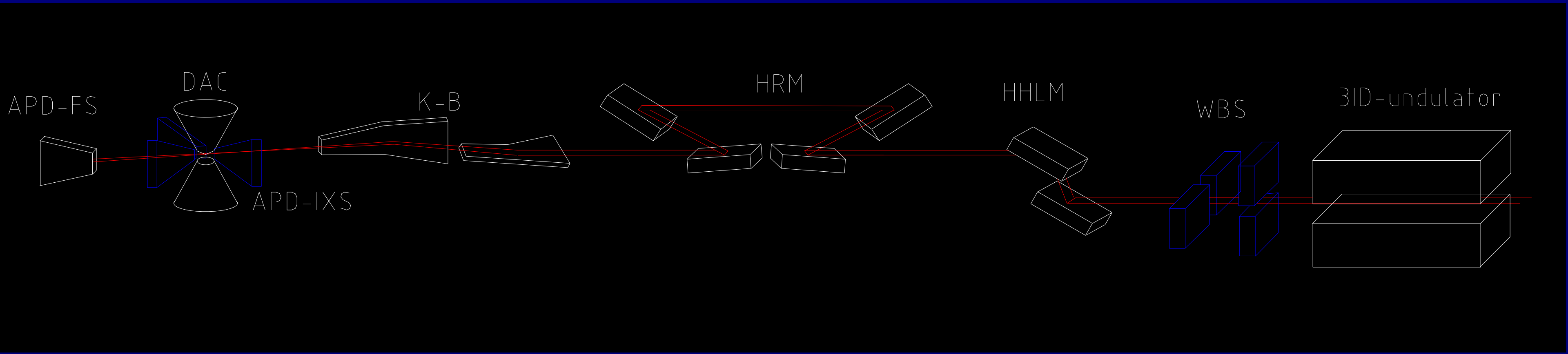
Setup for a synchrotron radiation nuclear resonant scattering experiment



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)

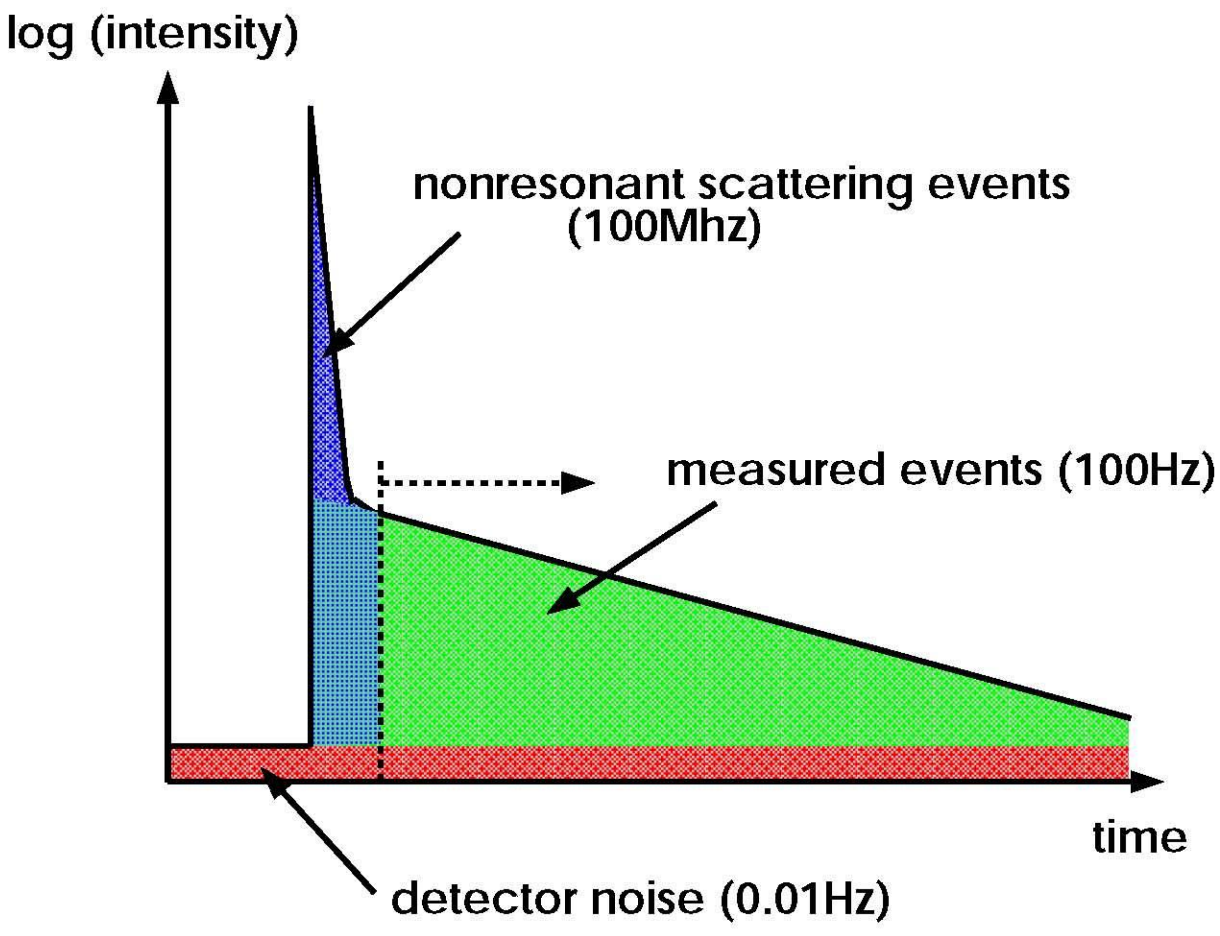
The time discrimination trick:

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

$\tau = \hbar / \Gamma$

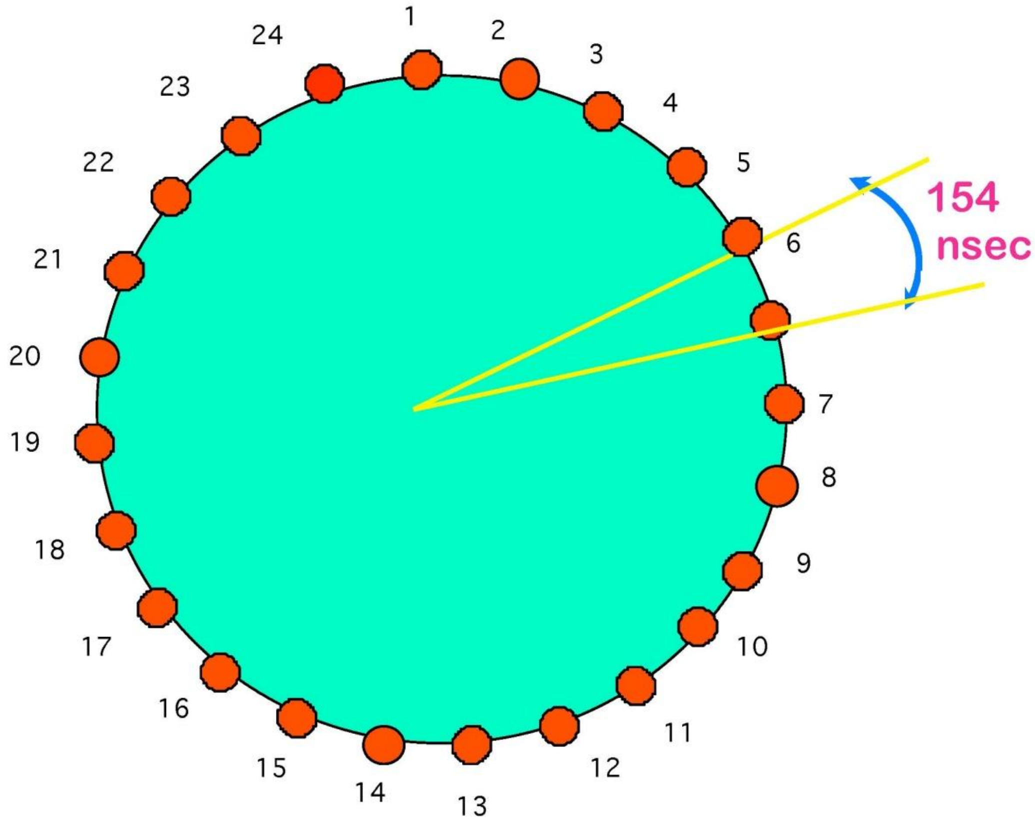
↓

141 ns for ^{57}Fe



Standard Time structure @ APS

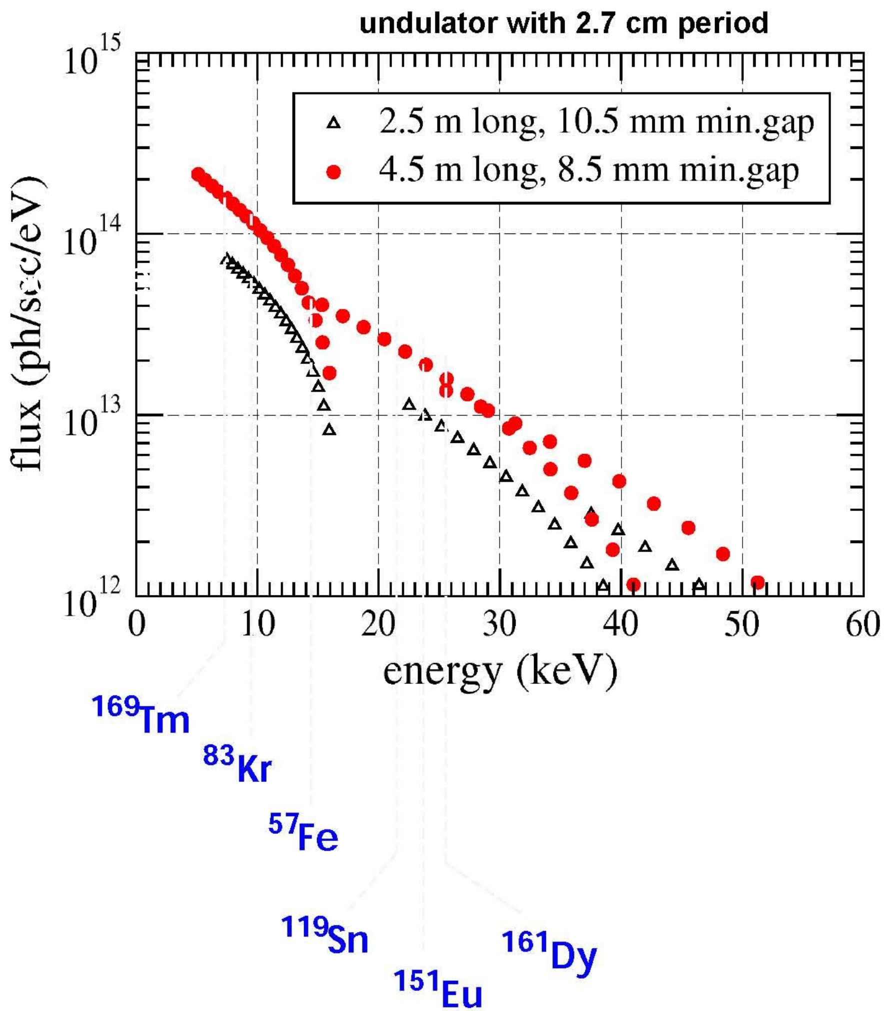
24 bunches

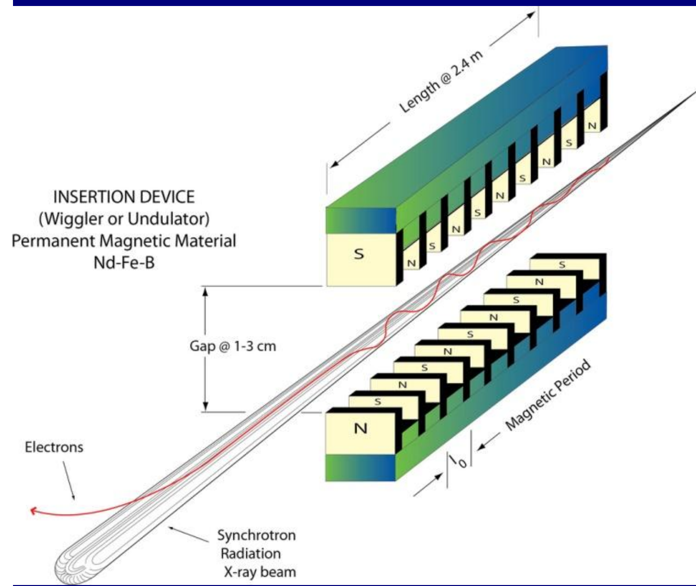


1 revolution=3.68 μsec =>1296 buckets

Nuclear resonance beamlines around the world, 2010

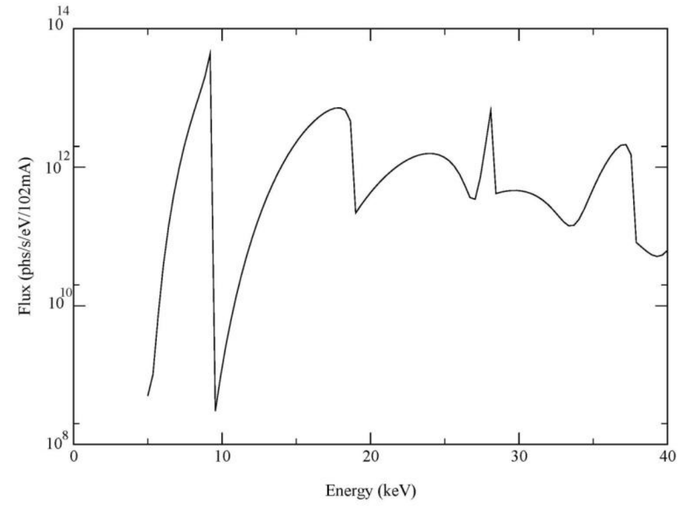
Synchrotron radiation at the Advanced Photon Source:





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

3ID undulator and HHLM



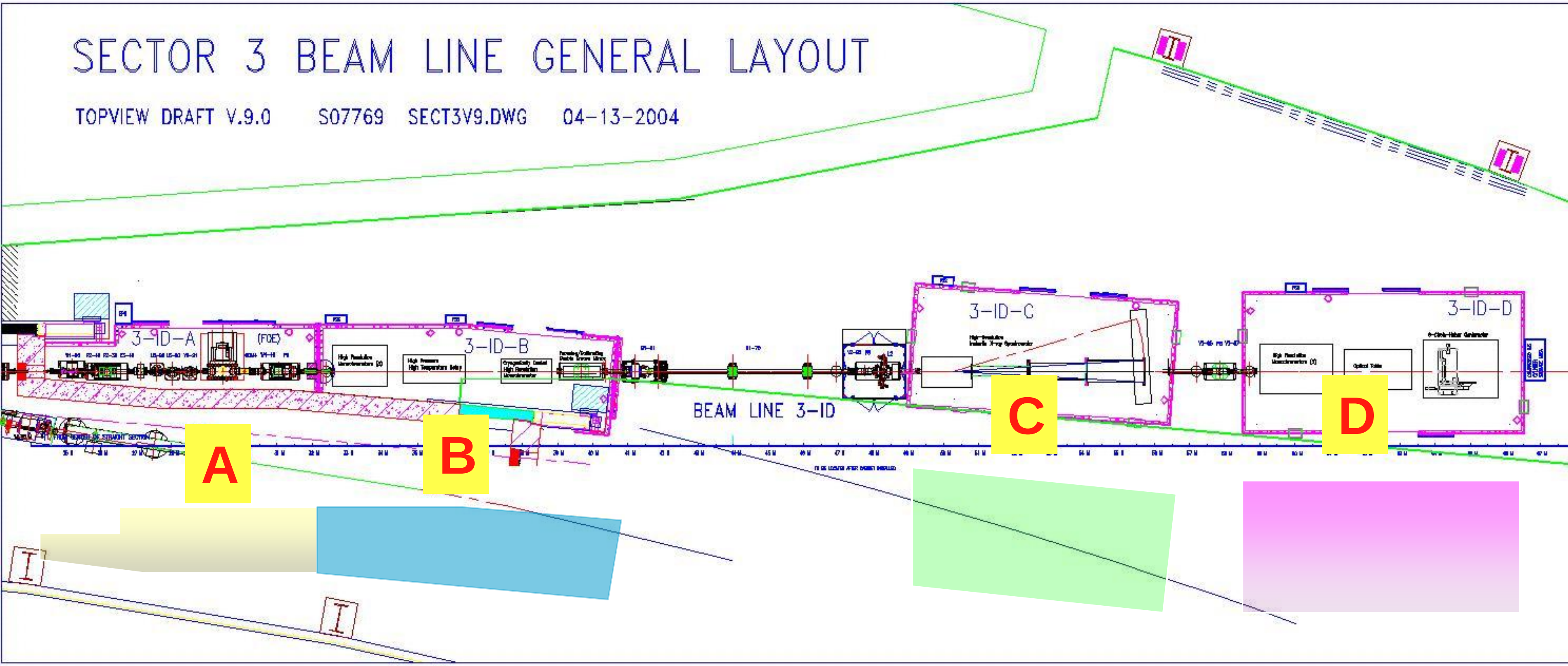
Parameters for running 3ID_undulators
Two undulators: 2.7cm, 88 periods
& Performance of Diamond (111) HHLM

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	

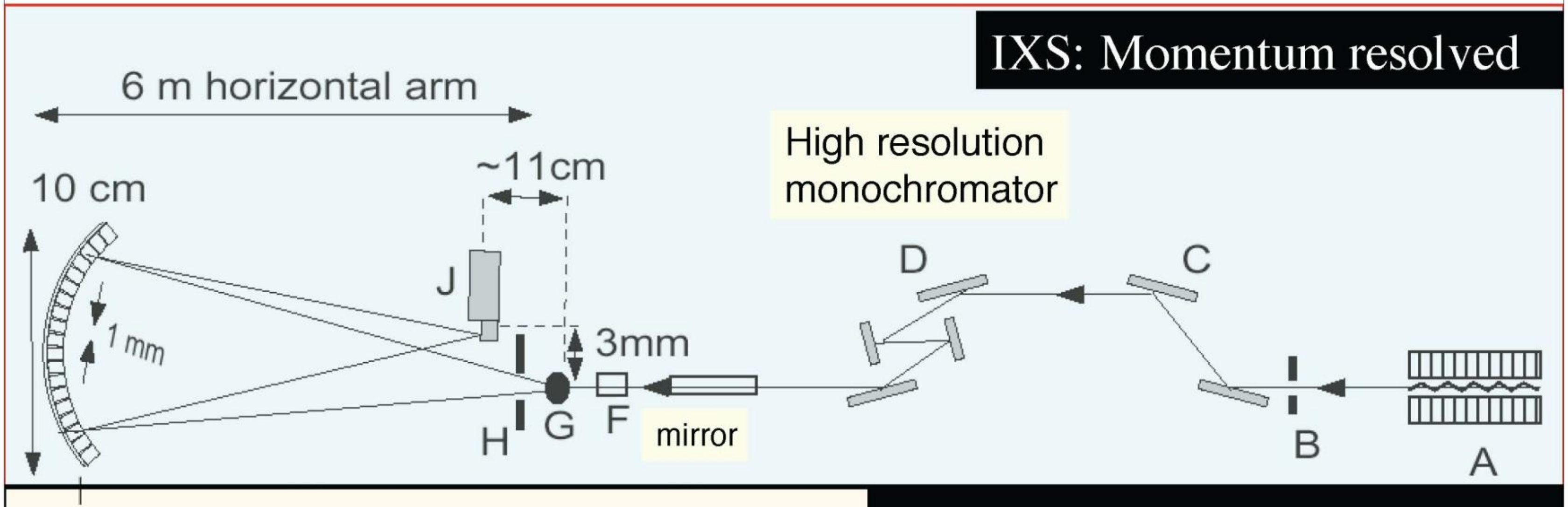
Nuclear data for Mössbauer isotopes

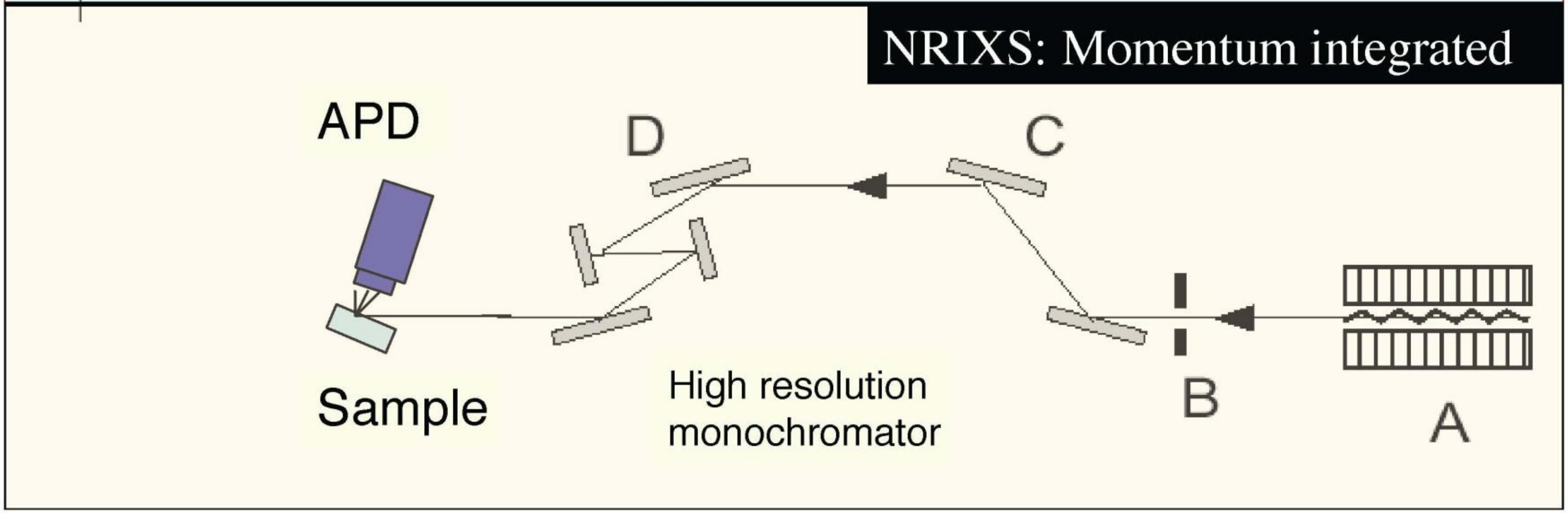
Isotope	Energy E(keV)	Life time $t_{1/2}$(ns)	Energy width Γ(neV)	Natural abundance(%)	Internal conv. coefficient α	Cross section σ_0(cm^2 10^{-18})	Recoil energy E_R (meV)	Type
^{181}Ta	6.22	6800	0.067	99.99	46	1.6	0.116	E1
^{169}Tm	8.41	3.9	1.17	100	268	0.31	0.24	M1
^{83}Kr	**9.40**	**147**	**3.1**	**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

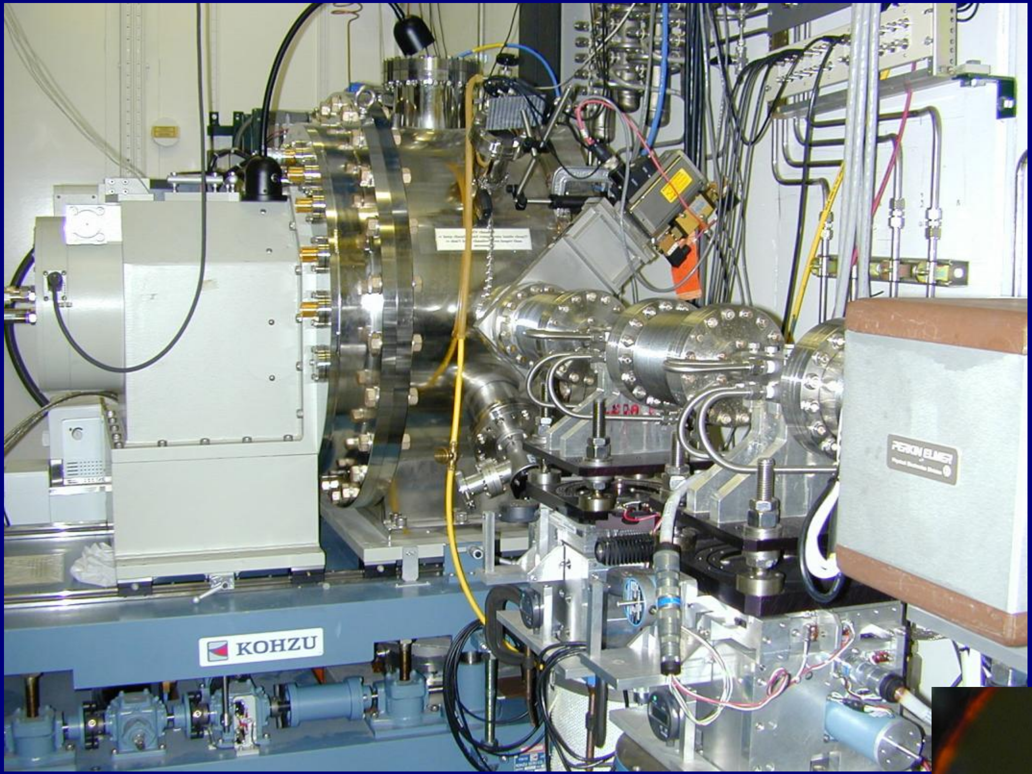
4 stations: **A-B-C-D**

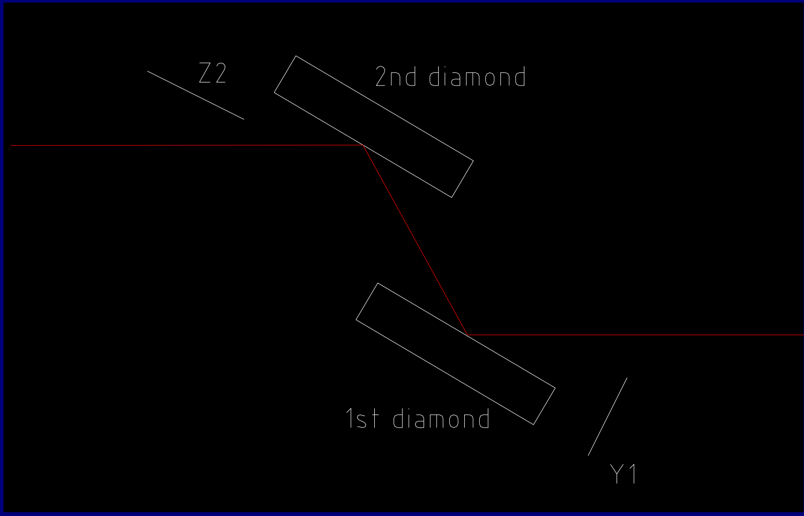


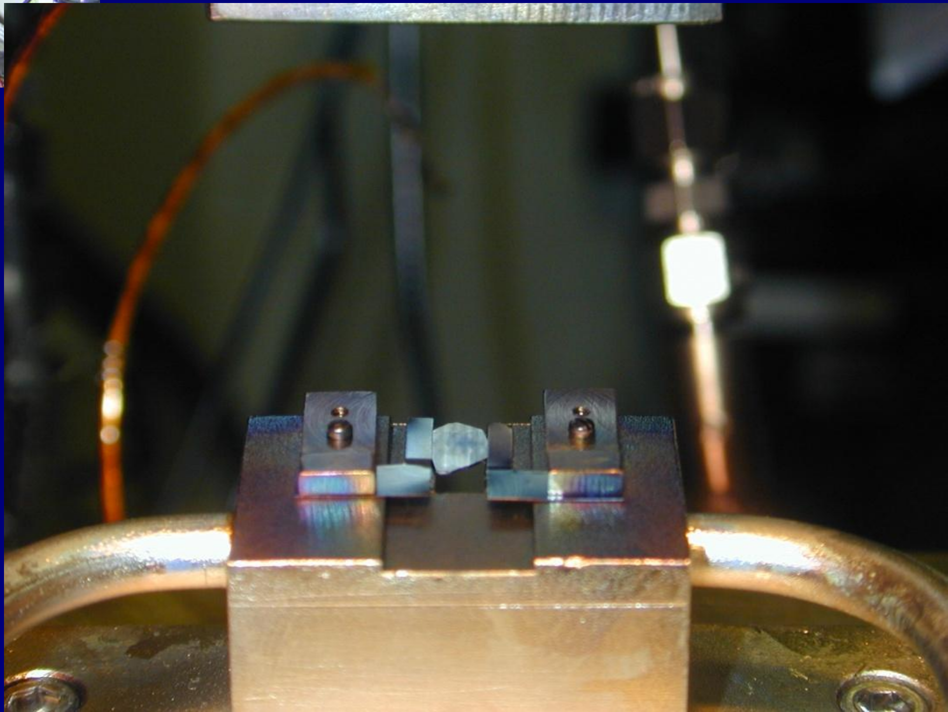
Inelastic X-Ray Scattering: two approaches











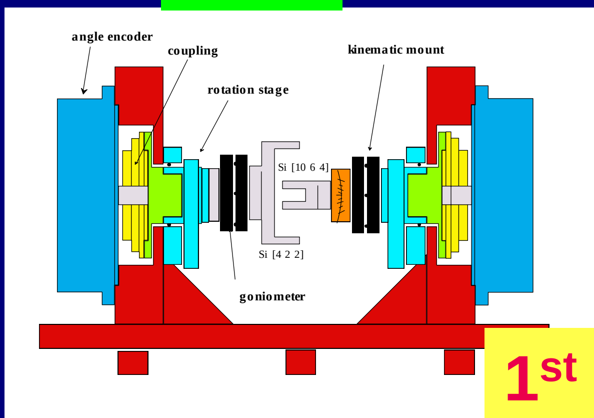
Kohzu high-heat-load monochromator consists of two water-cooled Diamonds,

3ID, Advanced Photon Source

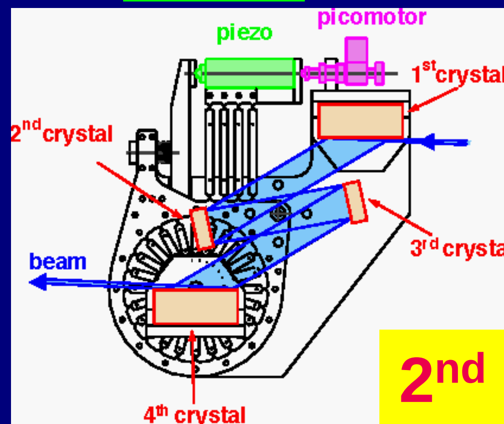
Unique capability at 3ID, APS: in-line, artificial channel-cut HRM; cryogenic cooled HRM

Generations of high-resolution monochromators

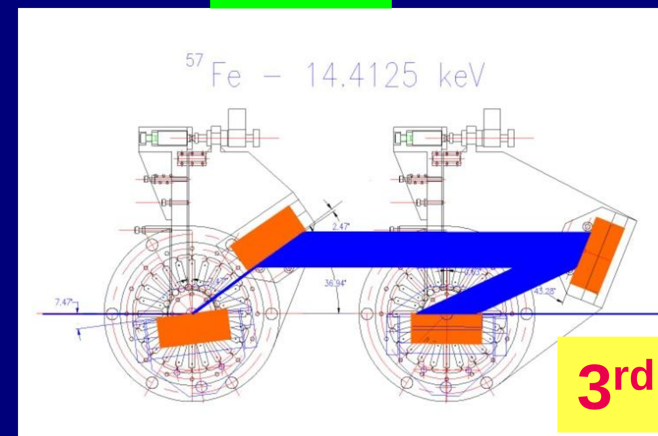
1992

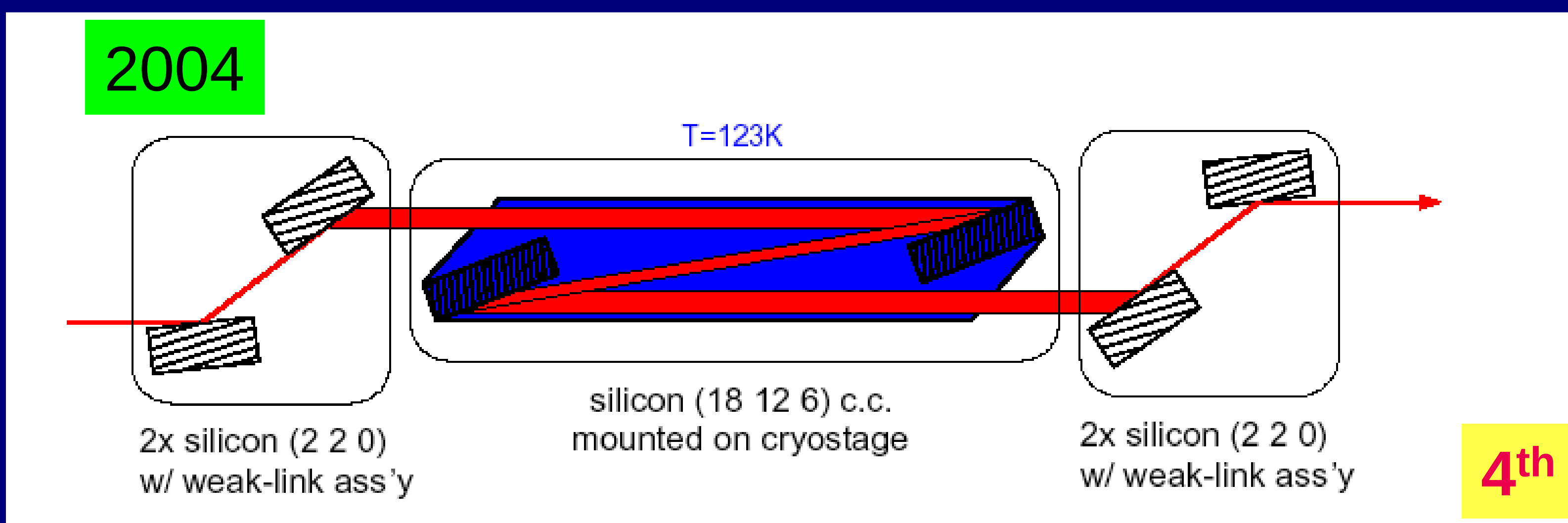


1999



2002

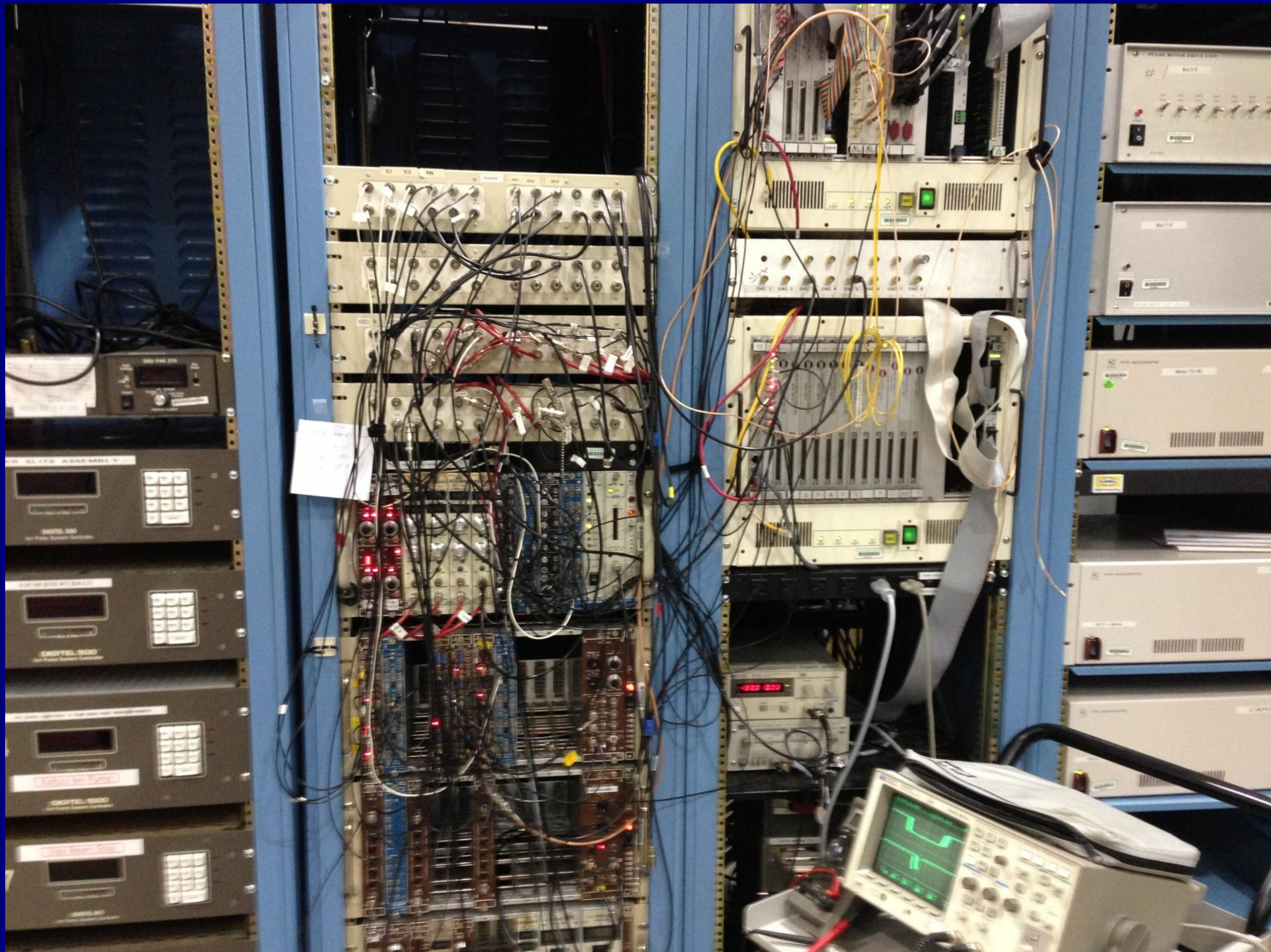




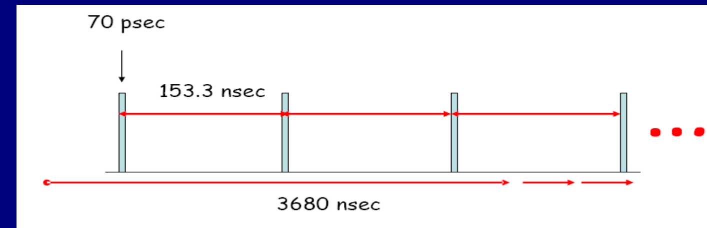
HRM at Sector 3

^{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

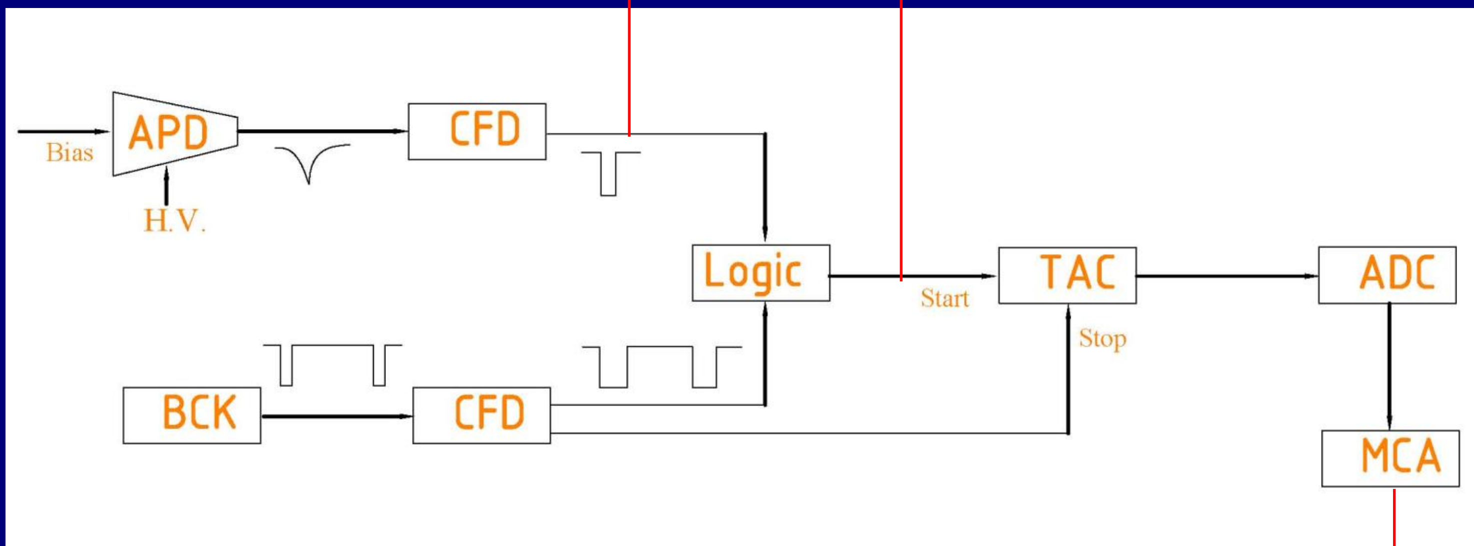


Timing technique



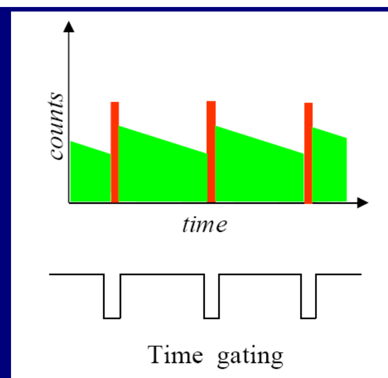
total
(prompt)

delayed



Time
spectrum

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

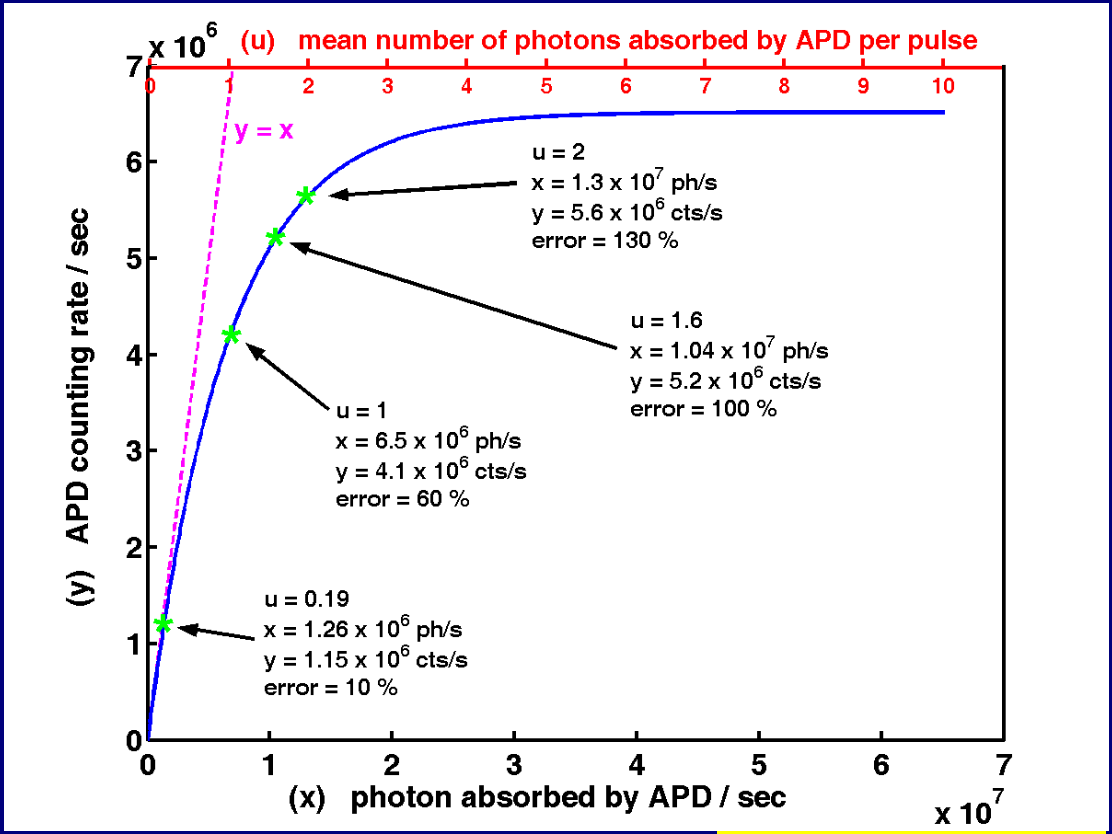


APD prompt limit and non-linearity region

APS ring:
Bunch separation: 153 ns
Corresponds to 6.5 MHz

With single photon counting per bunch, the maximum prompt count-rate is 6.5 MHz.

Mean number of absorption ~ 2 when the prompt ~ 5.6 MHz.



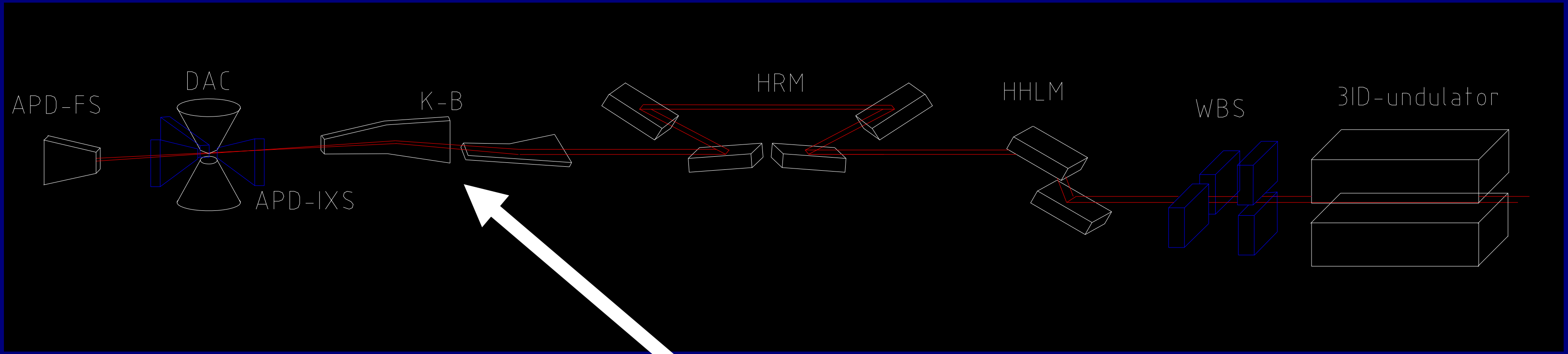
By L.F. Yan and T. Toellner

Avoid damaging the APD, have the prompt < 6.5 MHz.

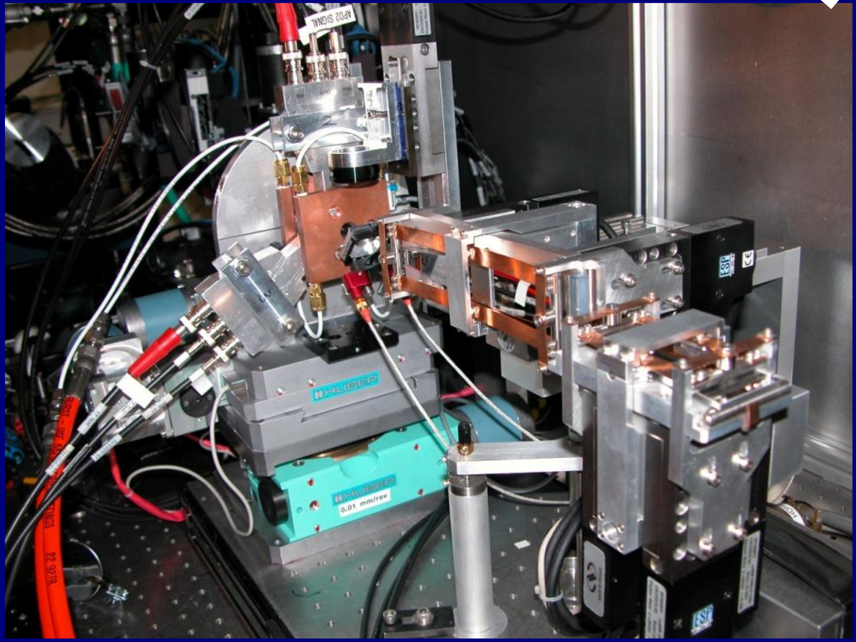
Use the ion chamber reading as the normalization detector, instead of prompt reading.

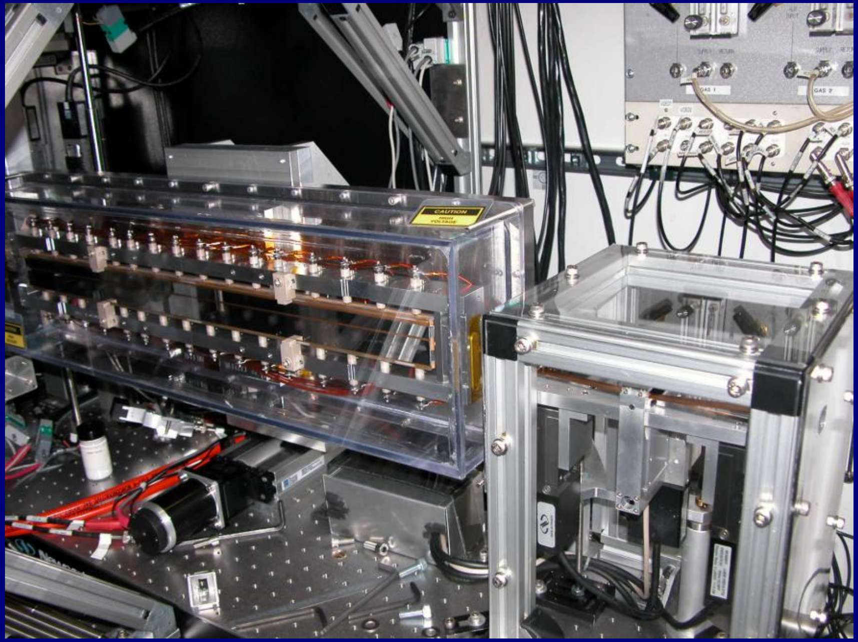
Unique capability at 3ID for NRS

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

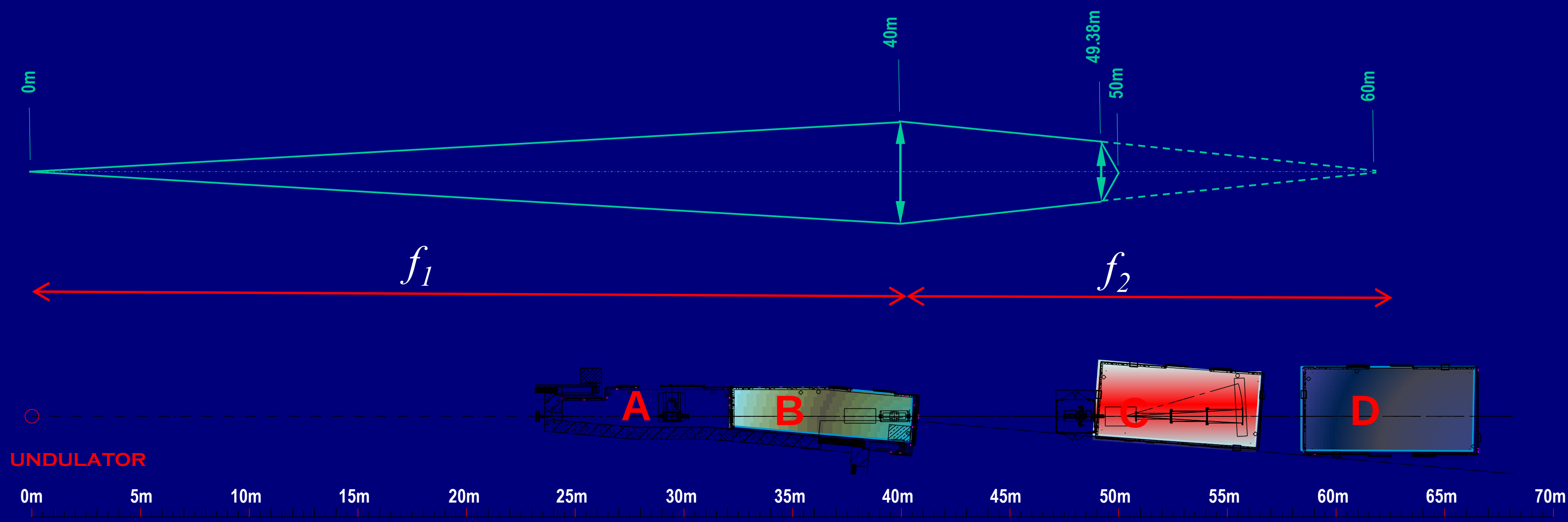
Toroidal + K-B tandem focusing at 3-ID-C (IXS), and 3ID-D (NRS)

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

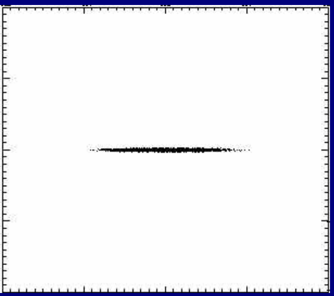
$$R_2 = \frac{R_1}{\sin^2 \theta}$$

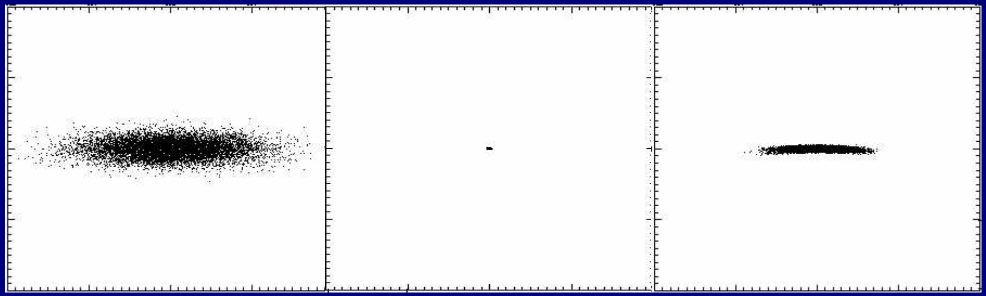
Sagittal focusing, horizontal, 46 mm

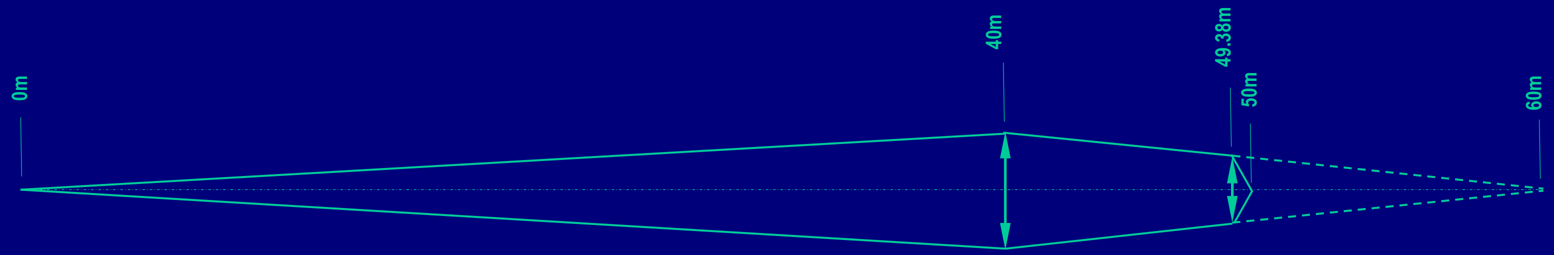
Vertical focusing, 11-33 km, θ = 1.6 mrad

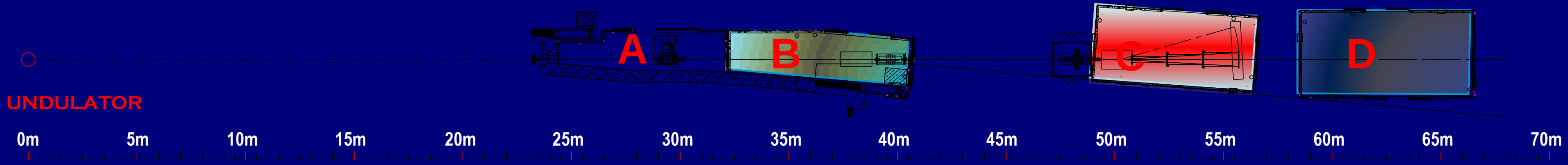


Toroidal + K-B tandem focusing at 3-ID-APS



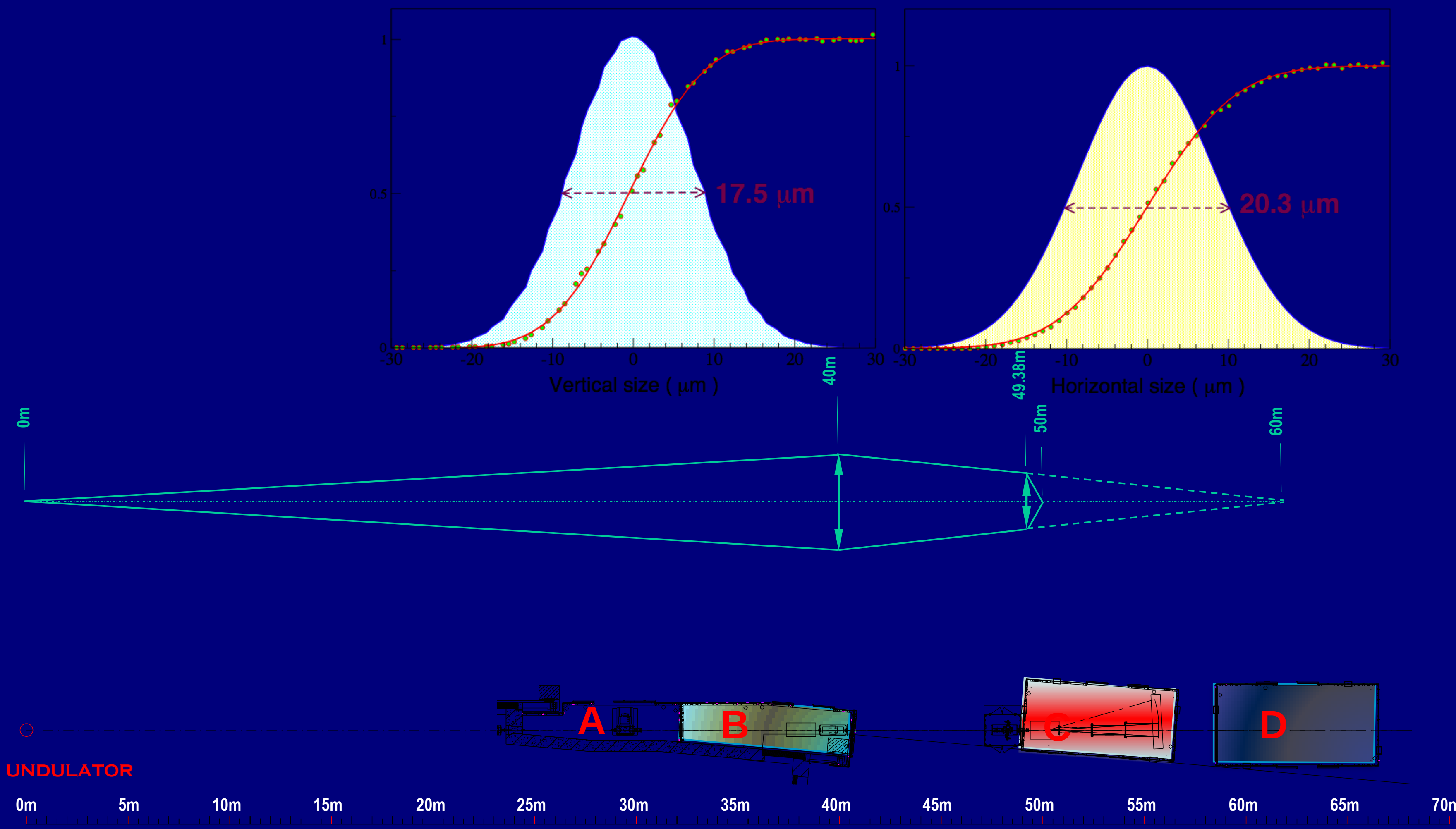






Shadow simulations, A. Alatas

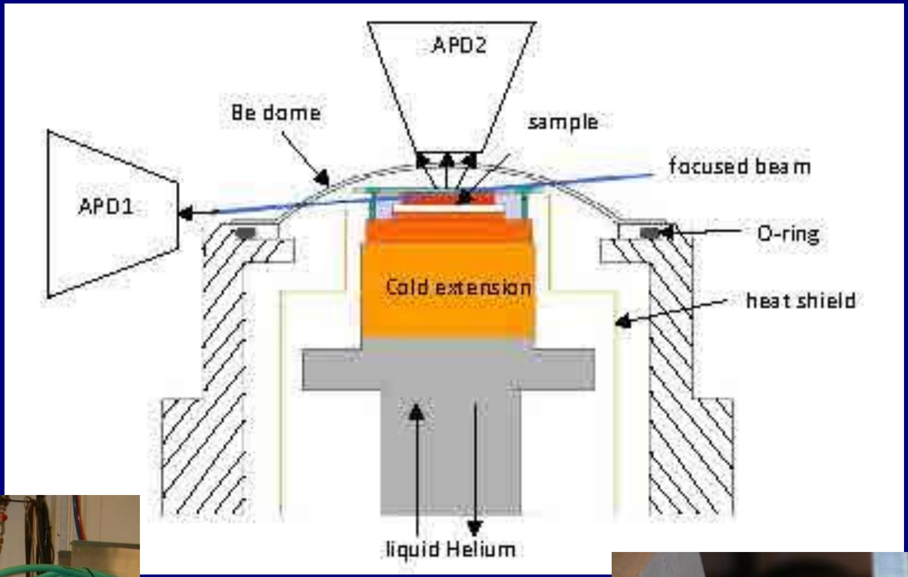
Toroidal + K-B tandem focusing at 3-ID-APS

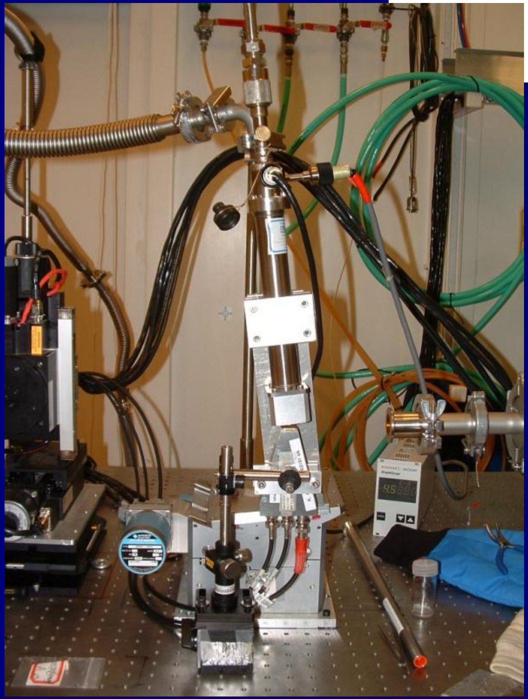


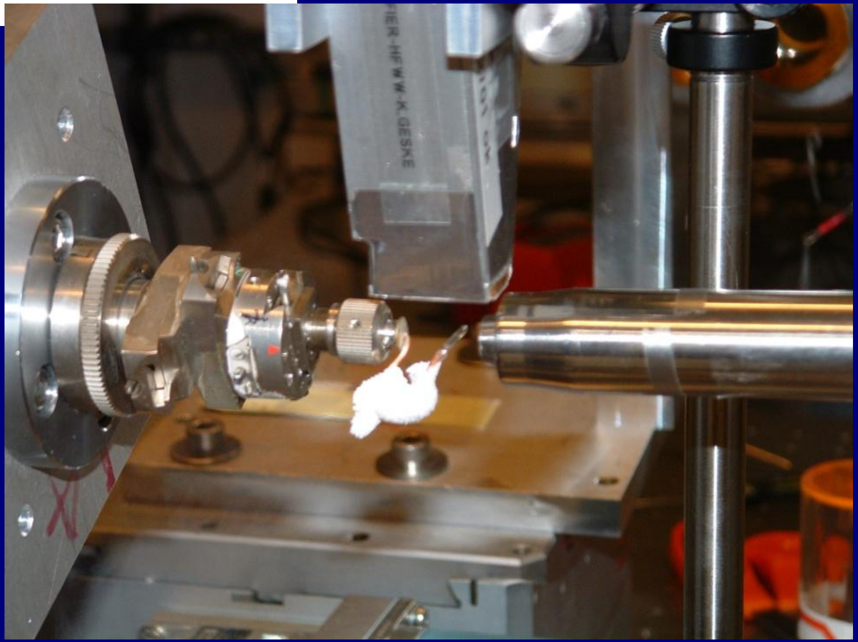
Sample environment for NRS at 3ID

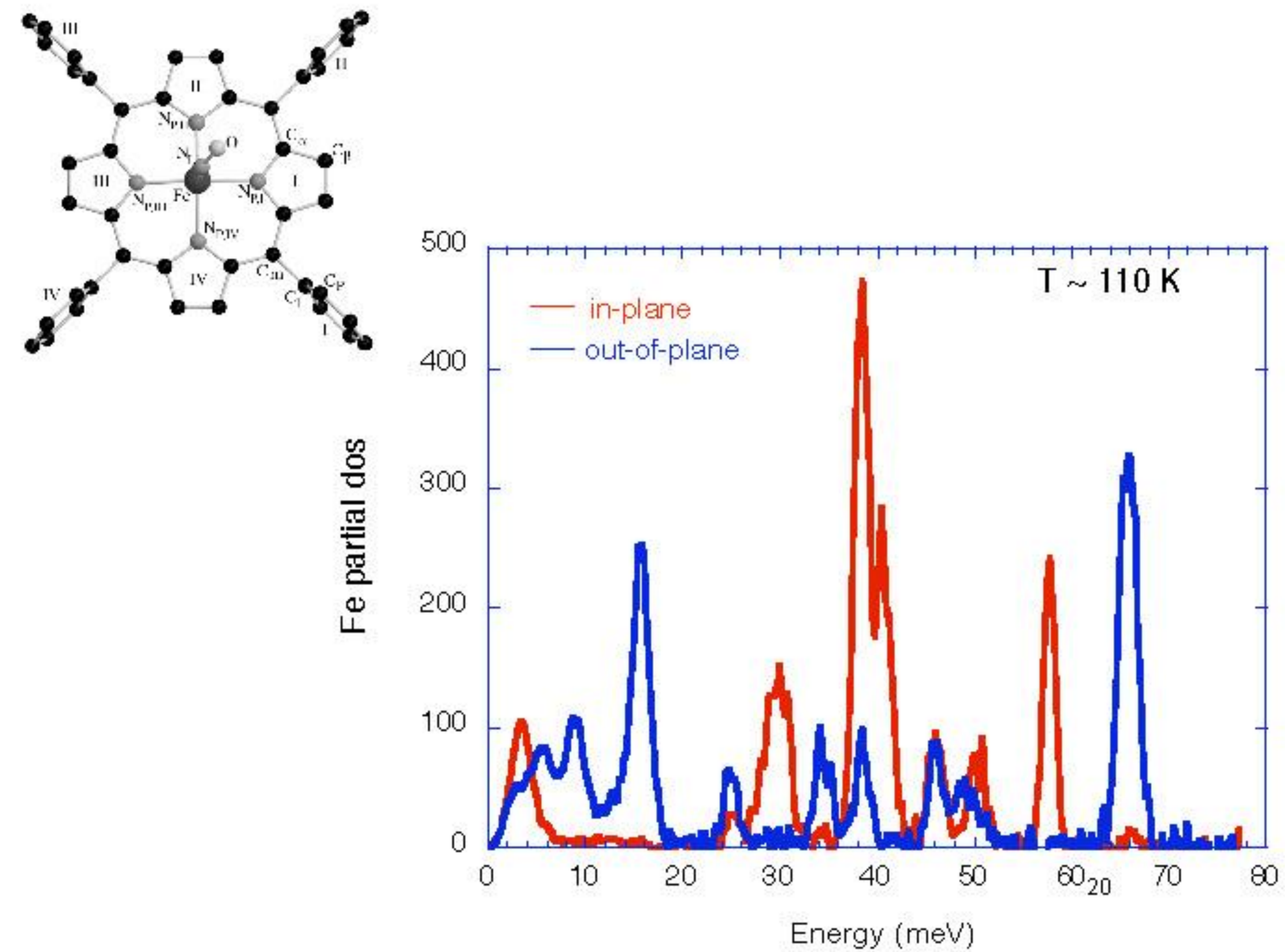
- Low temperature, flow cryostat
- High pressure and high temperature
- High pressure and low temperature

Low temperature for both SMS and NRIXS using helium flow cryostat (6K) and nitrogen jet flow (80K)







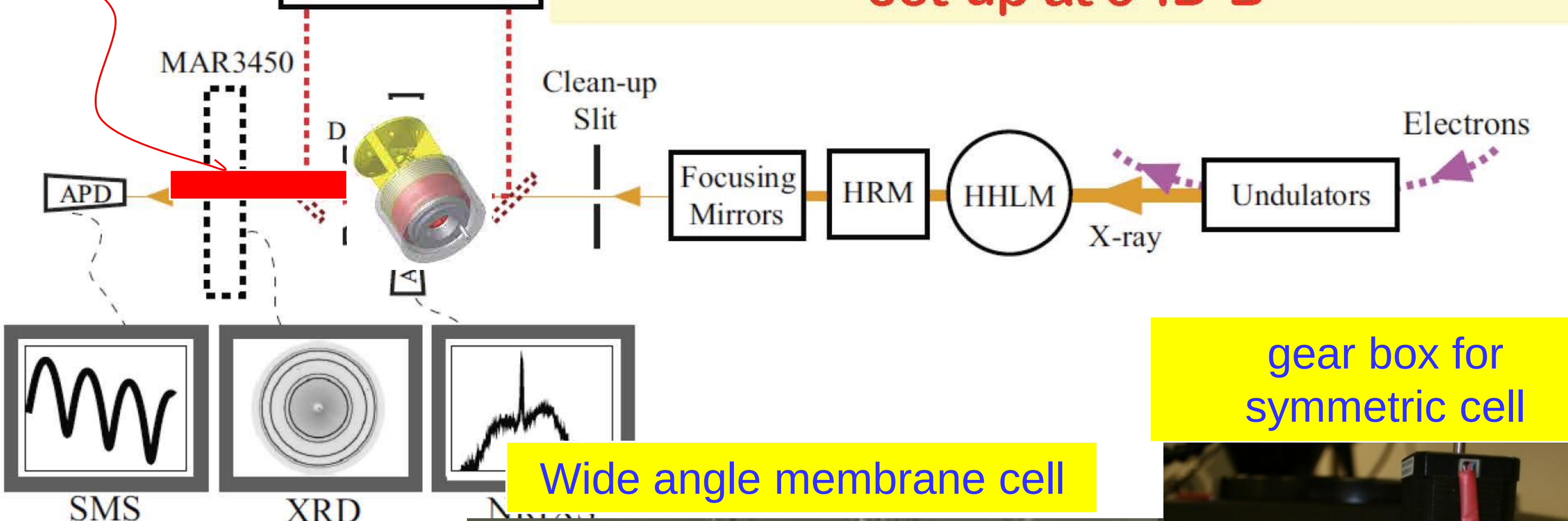


T ~ 110 K
in-plane
out-of-plane
Fe partial dos
Energy (meV)
0
100
200
300
400
500
0
10
20
30
40
50
60
70
80

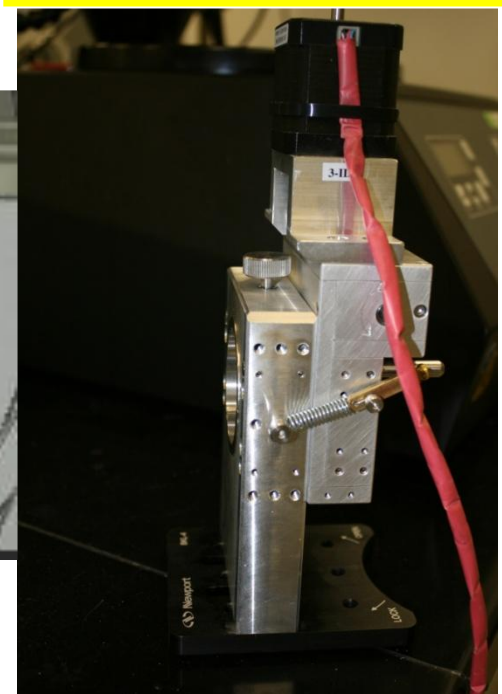
Unique capability at 3ID: HP/HT for NRS

On-line Ruby system

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



gear box for symmetric cell

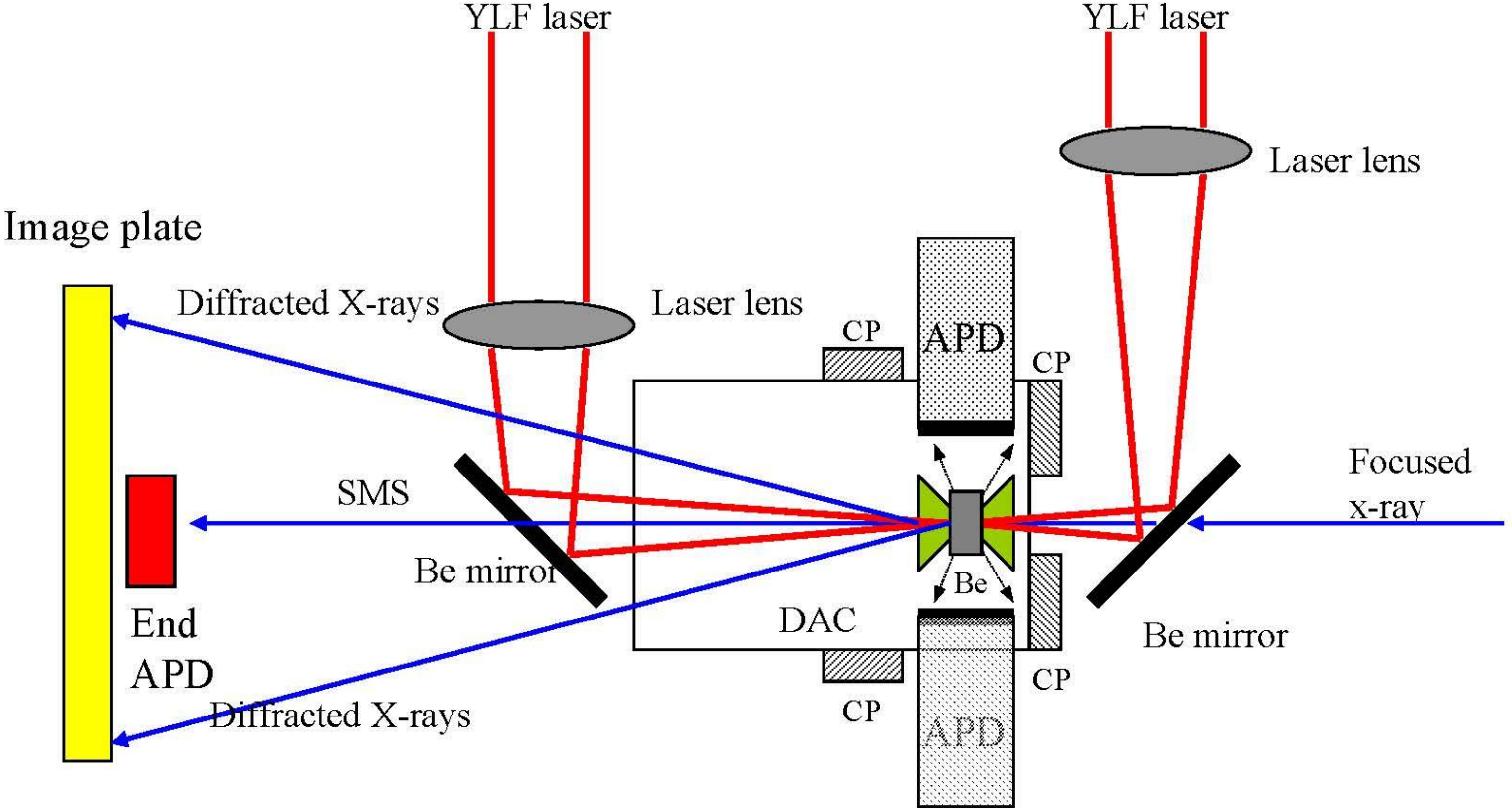


Wide angle membrane cell

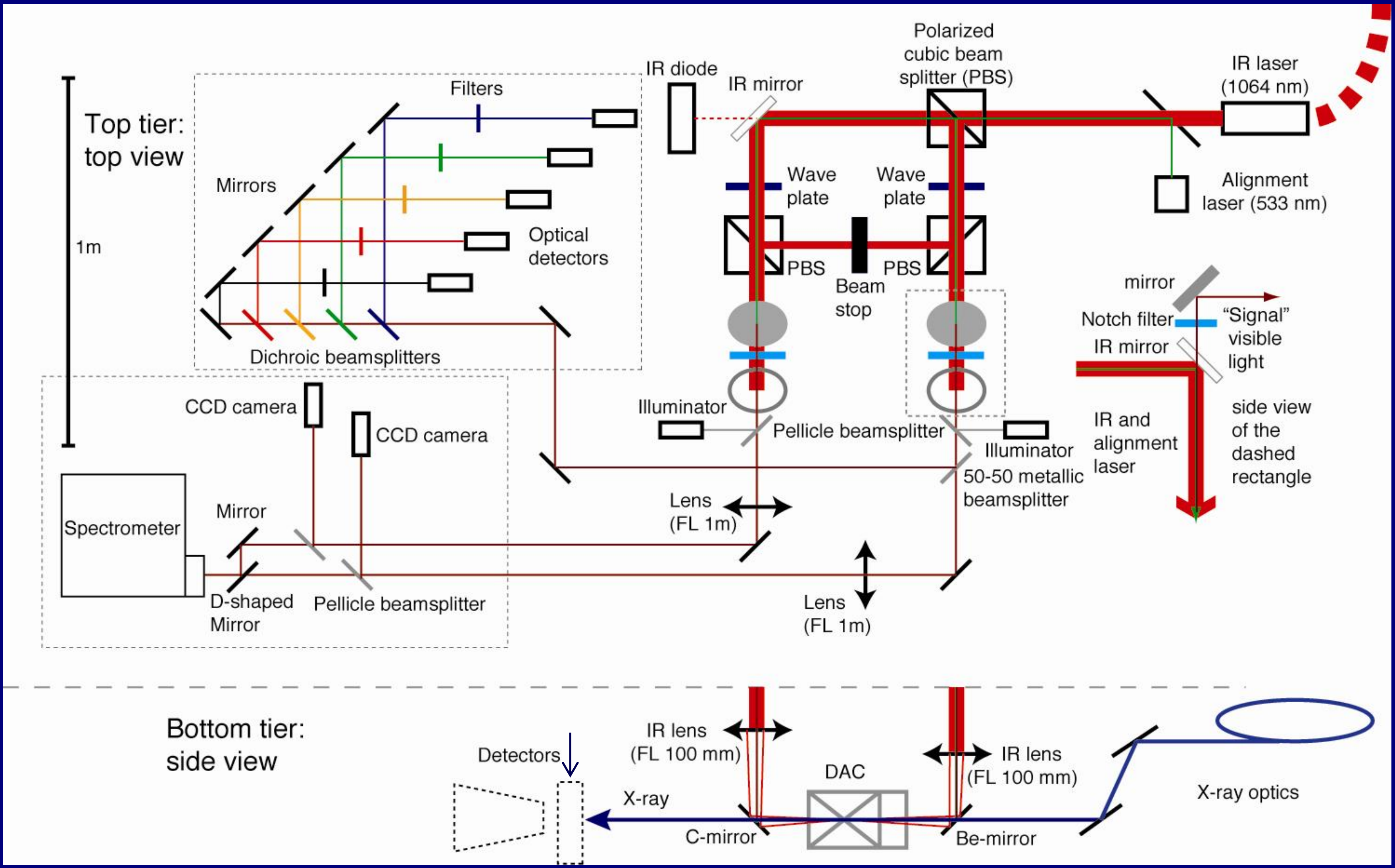
Glove box for DAC loading, H_2O: 1 ppm, O_2: 20 ppm

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.**



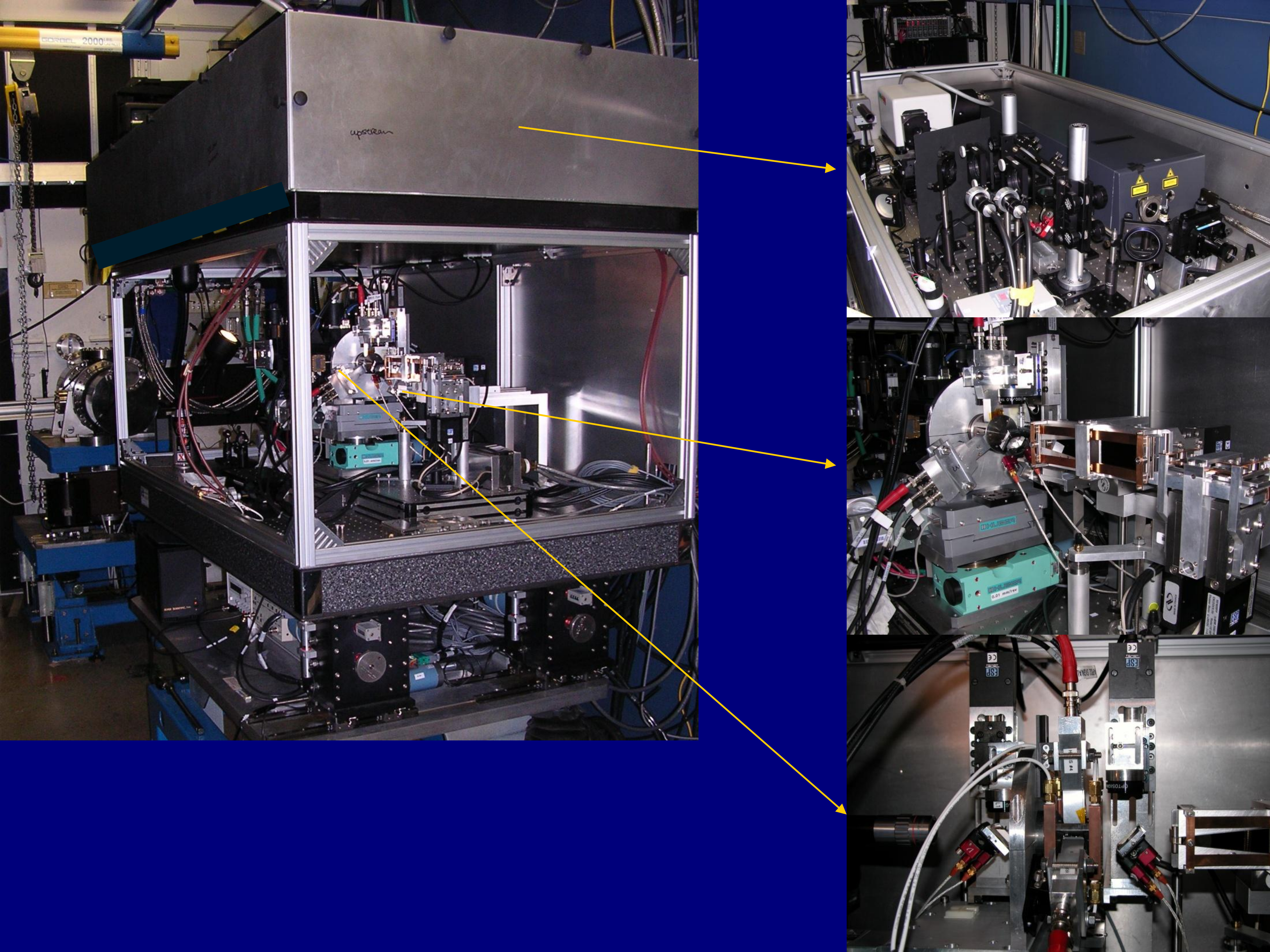
HP-HT Nuclear resonant scattering



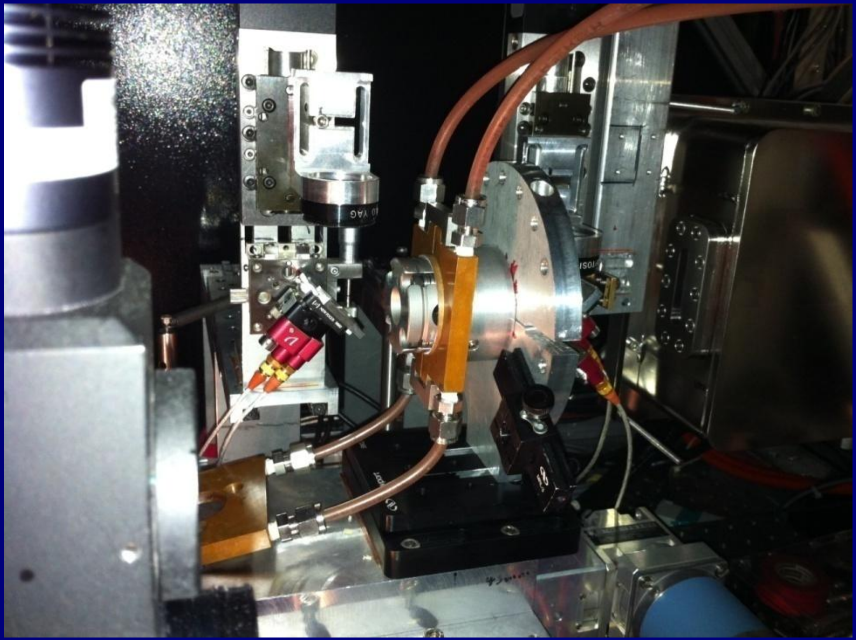
Fast Temperature Readout system(FasTeR)

NRS+ Laser heating+ Spectroradiometer+ FasTeR spectrometer

High pressure melting

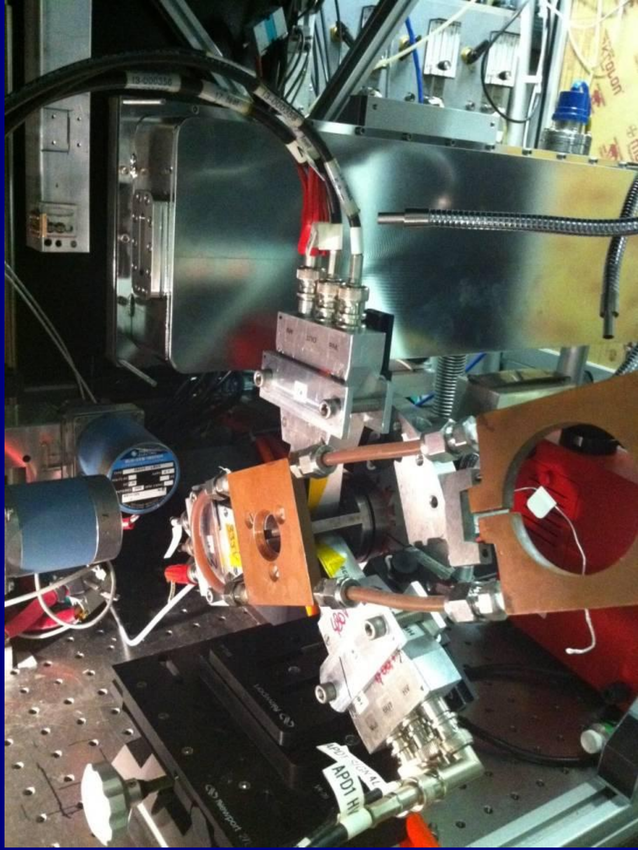

upstream

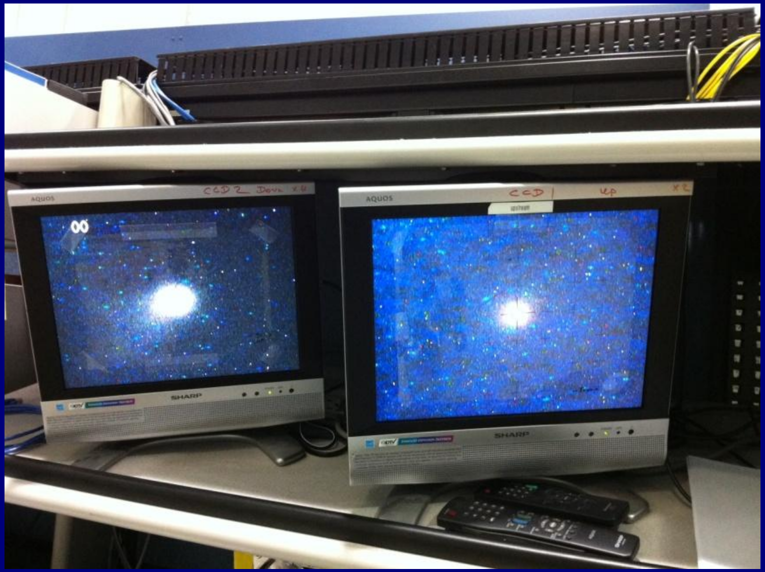
NRS at HPHT setup



NRIXS ->

<- SMS

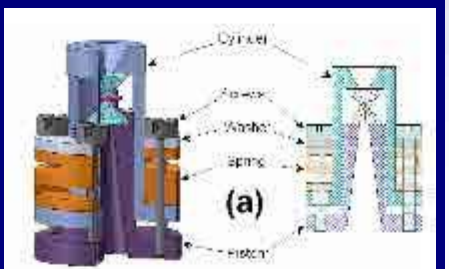


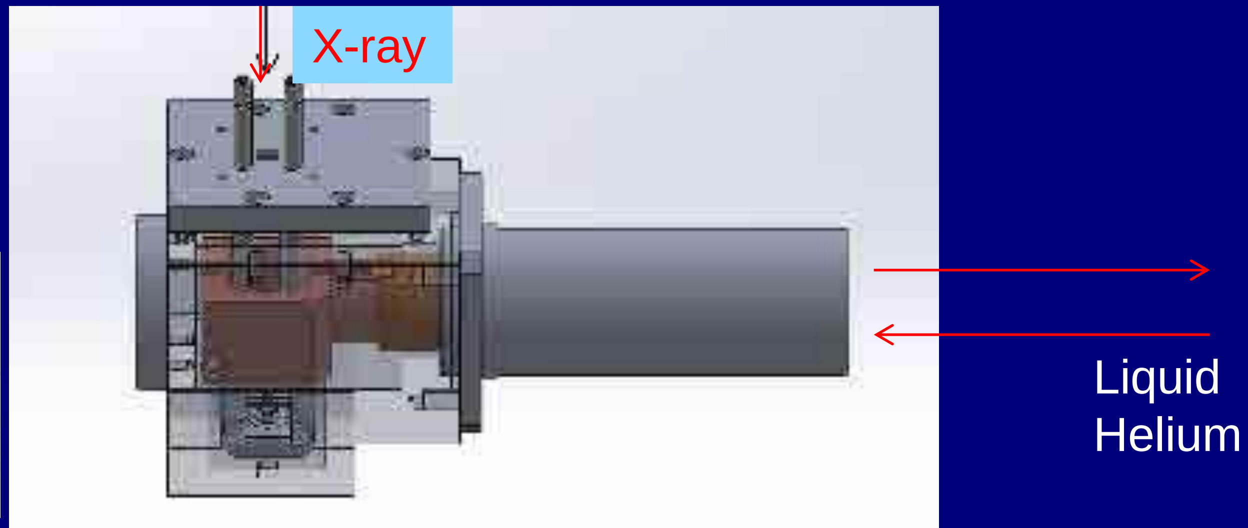


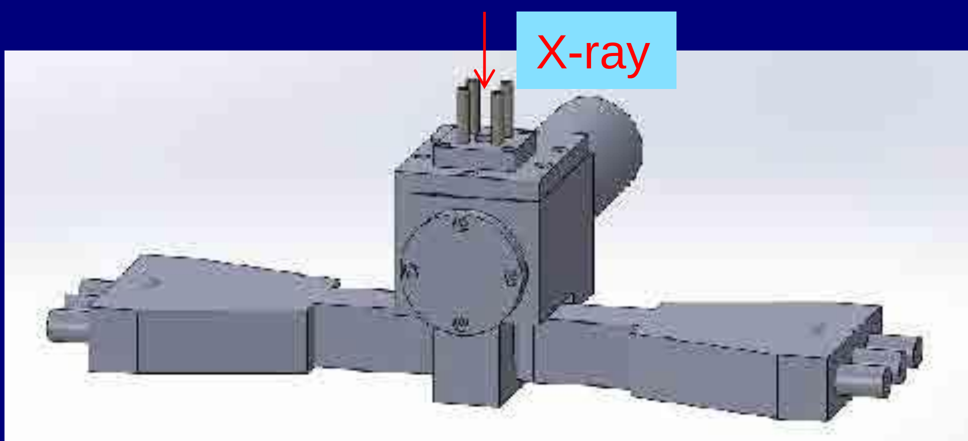
<- Hotspot

Example sample loading->

3ID unique capability: An on-going development of High pressure and low temperature for NRIXS using flow cryostat (~ 10K, 50 GPa)







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:

1. A fast temperature readout system.
2. Low temperature (4K) and high pressure (Mbar) system for NRIXS.

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: 2013-1, Oct-26-12

  2013-2, Mar-8-13

  2013-3, Jul-12-13

Thank you

and

hope to see you at the beamline!