XVI International Conference on Science, Arts and Culture

International Conference ON SESAME

In Honour of Paolo Budinich

29 August - 2 September 2016

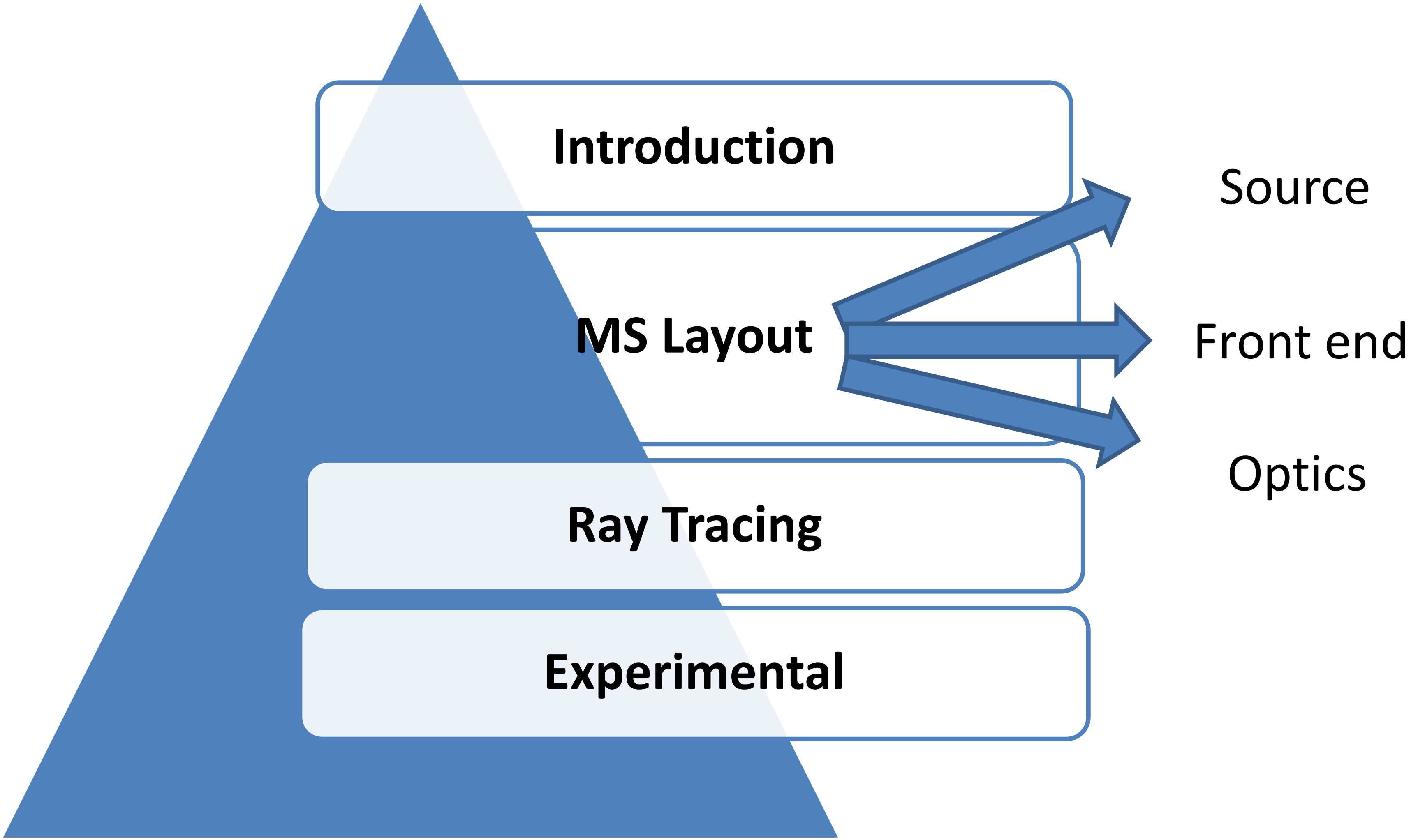
Veli Lošinj, Croatia

ECSAC
European Centre for Science Arts and Culture

SESAME Materials Science Beamline

Mahmoud Abdellatief, PhD
Materials Science BL Scientist
SESAME Synchrotron
Jordan

Outlines

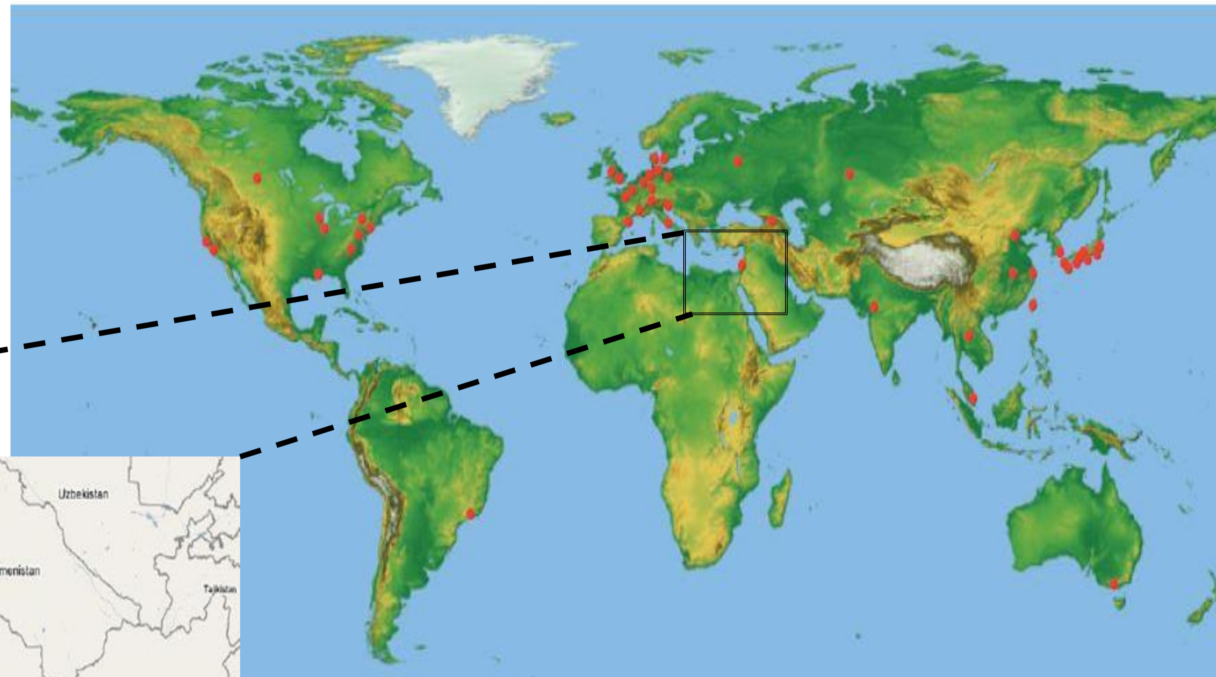

Introduction
MS Layout
Ray Tracing
Experimental
Source
Front end
Optics

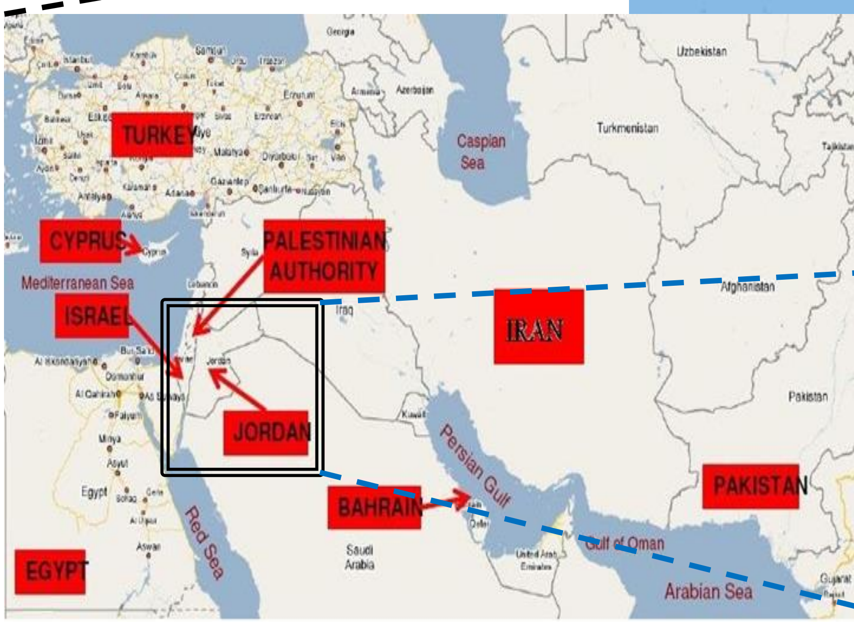
SESAME Synchrotron

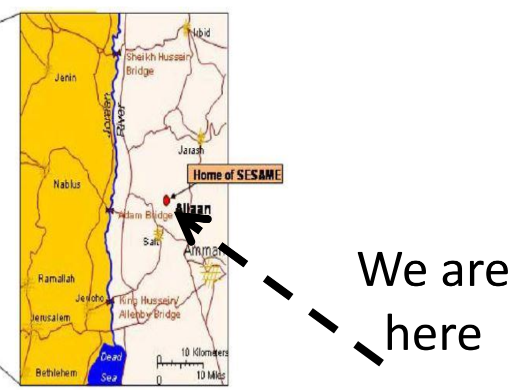
Synchrotron light for Experimental Science and Applications in the Middle East

SESAME observers

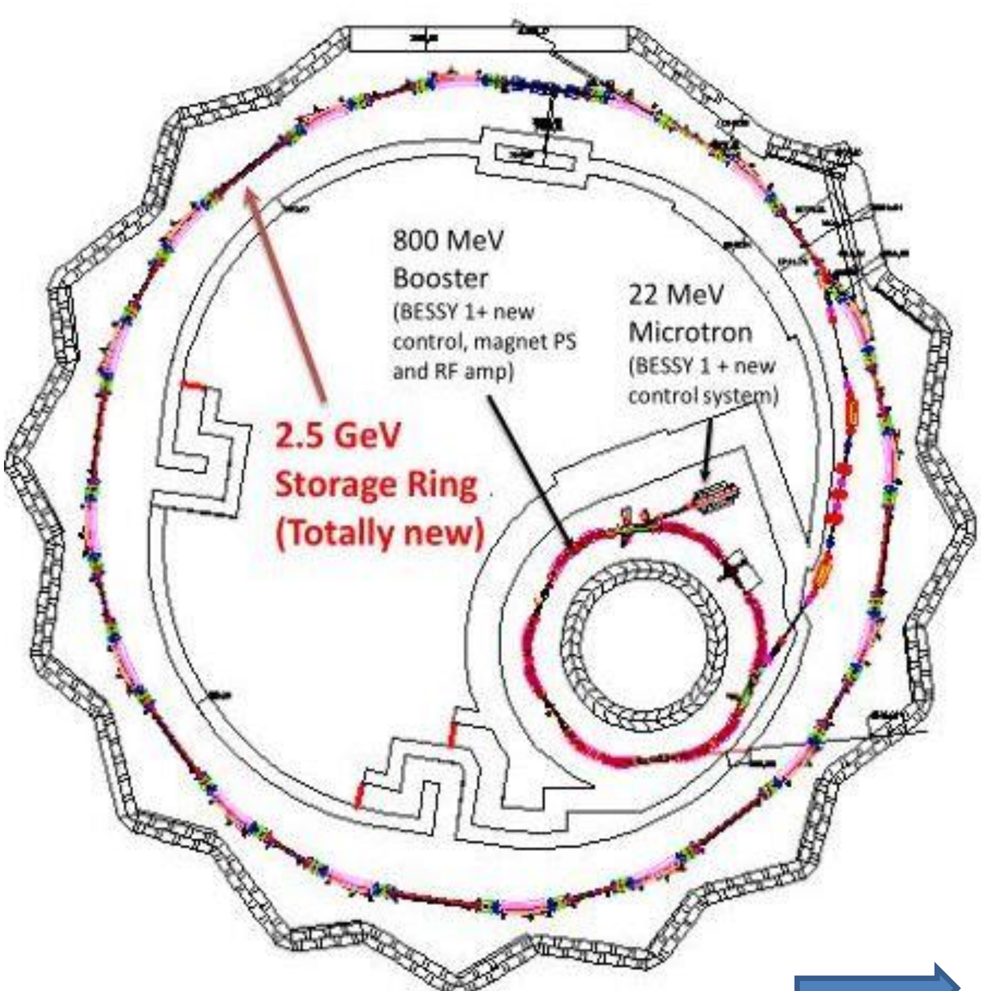
France, Germany, Greece, Italy, Japan, Kuwait, Portugal, Russian Federation, Sweden, Switzerland, UK, USA







First beamlines



Energy (GeV)	2.5
Maximum Beam Current (mA)	400
Bending Flux Density (T)	1.455
Circumference (m)	133.2
Emittance (nm.rad)	26
Maximum ID Length (m)	3.9
Beam Cross Section in the Long Straight Sections (σ_x, σ_y) (µm)	828 x 21
Available Straight Sections for Insertion Devices	12
Number of Bending Magnets	16
Number of Quadrupoles	64
Number of Sextupoles	64

Phase one beamlines

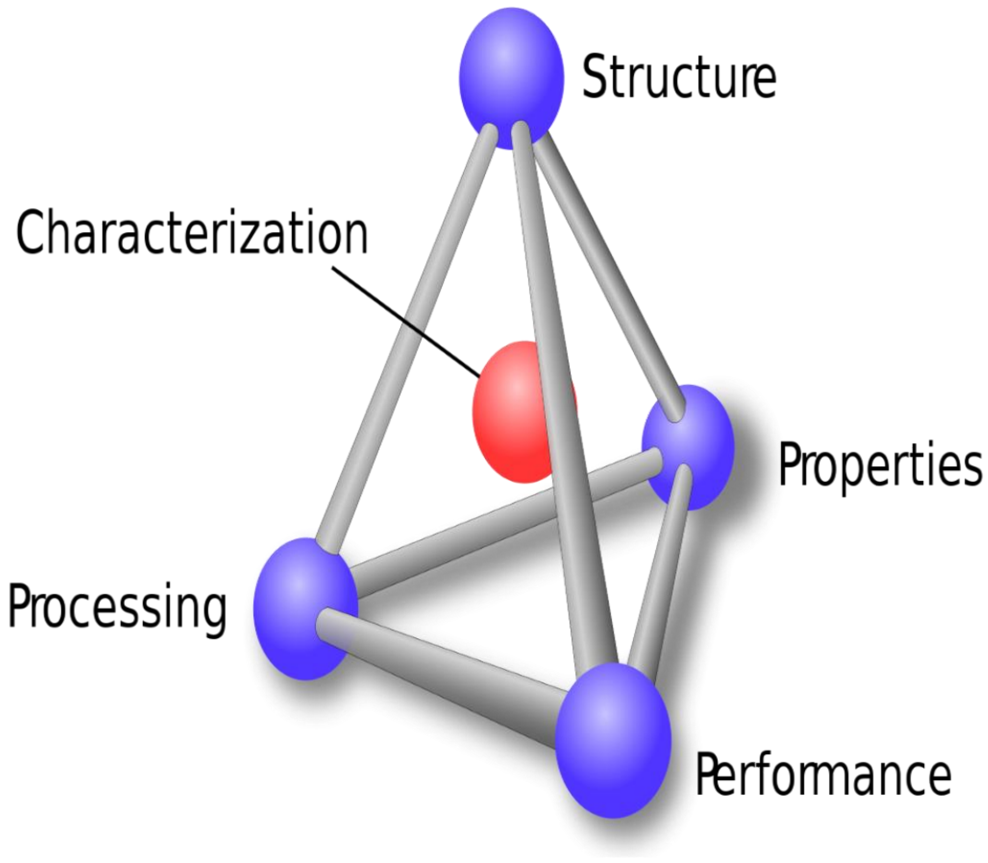
XAFS - XRF

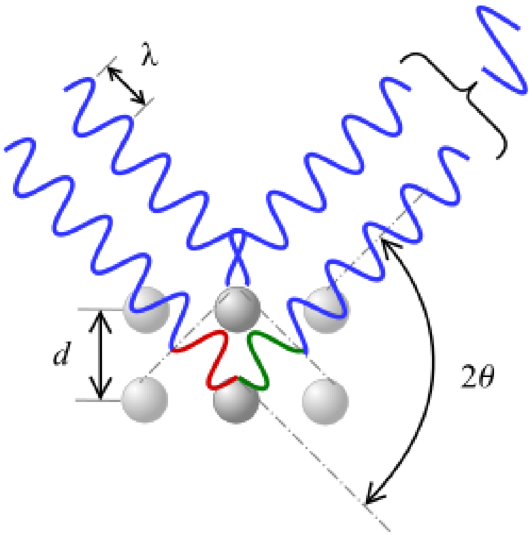
IR

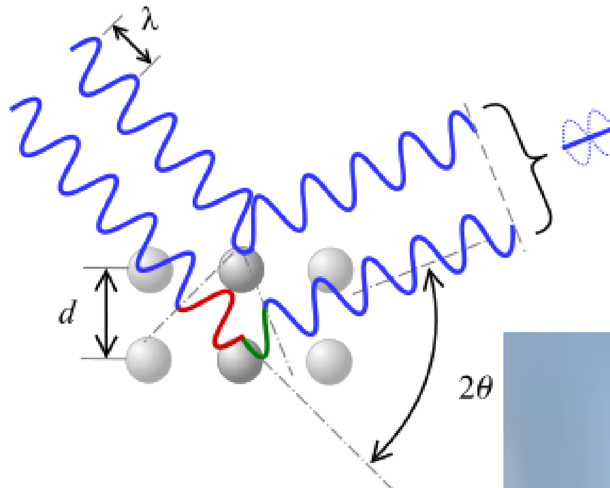
Materials Science MS (XRD)

MX (Macro Molecular XRD)

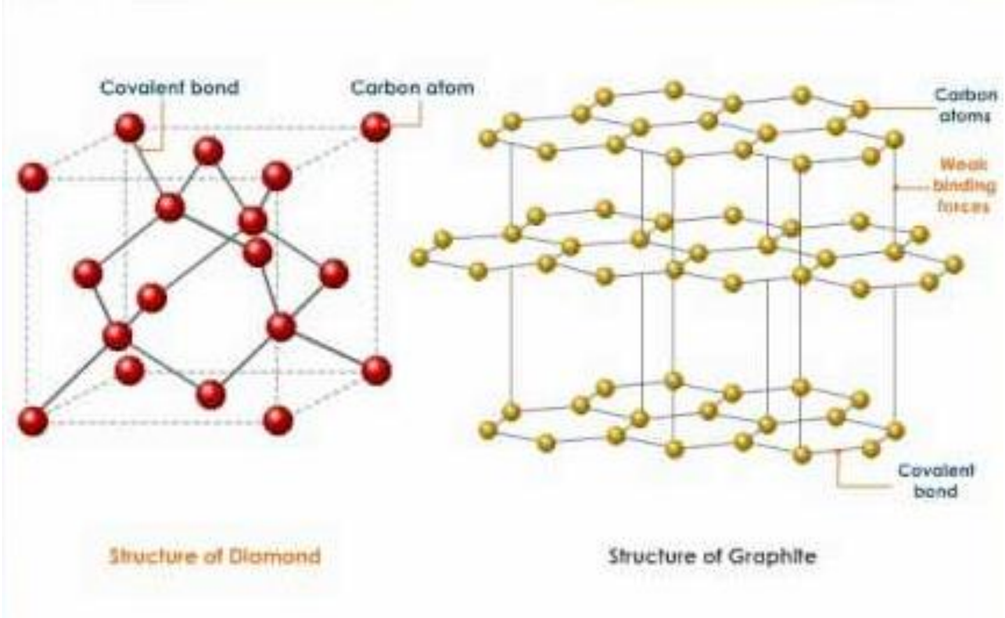
What is MS beamline ?



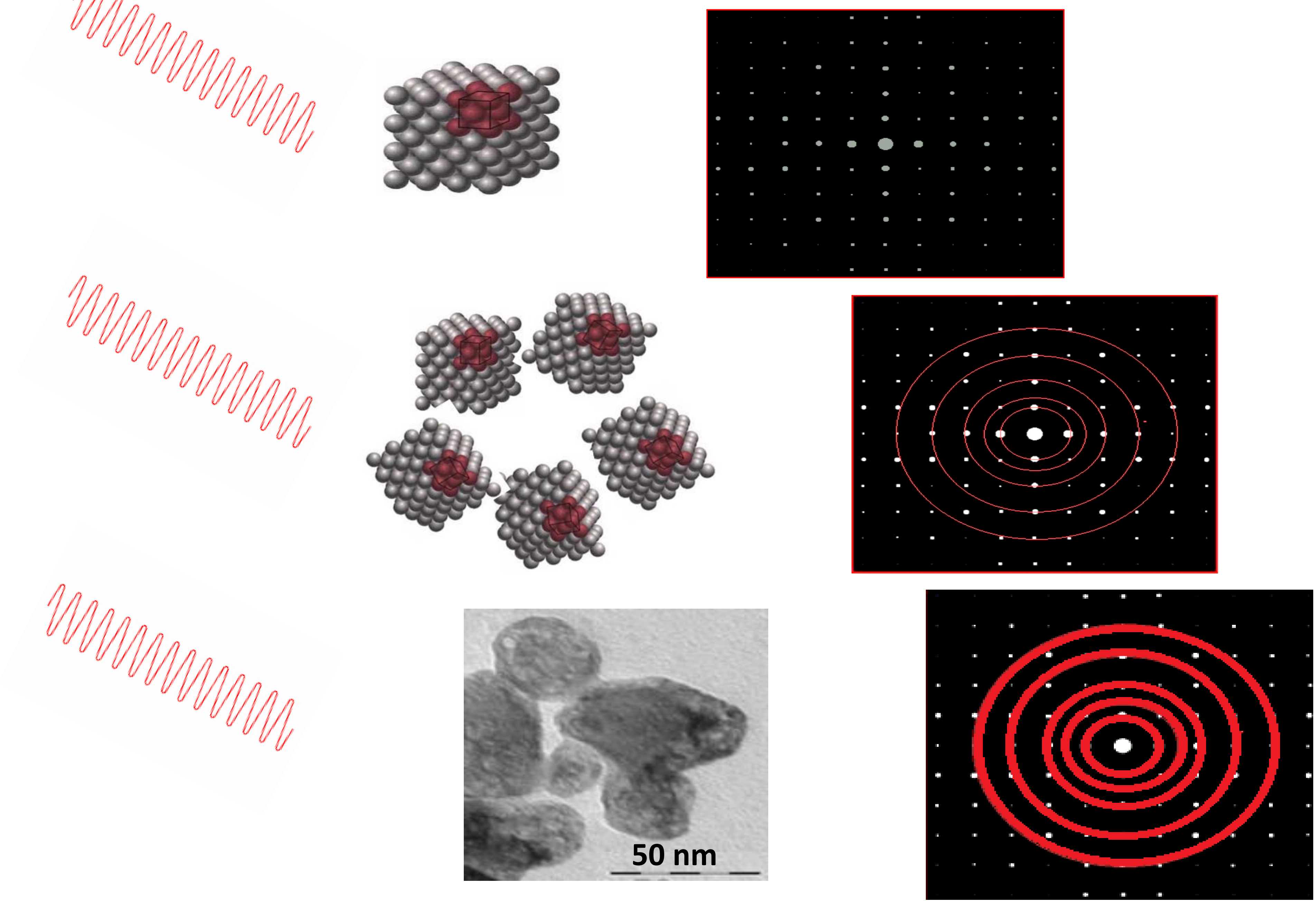




$$\lambda = 2\ d_{hkl}\ \sin\theta_B$$

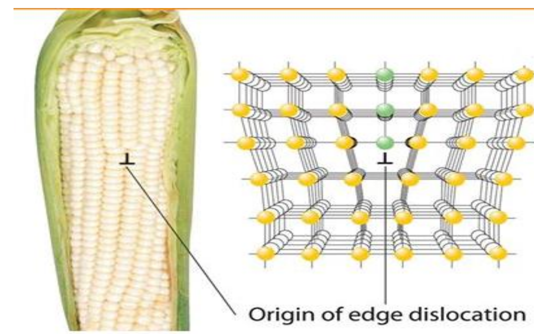


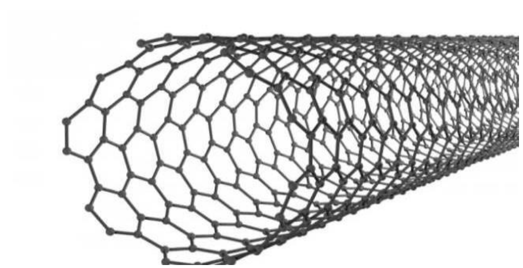
Single – Poly – Nano



XRD diffraction frequent uses

- Materials Science
- Pharmacological
- Geology
- Environmental
- Energy
- Nano Materials
- Biological materials
- ……..
  ……





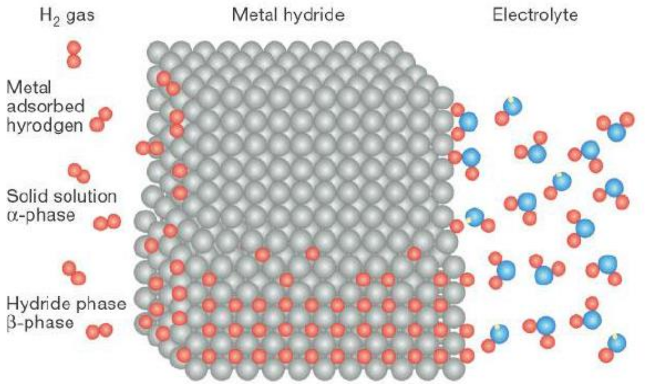
Why do we need SR-XRD?

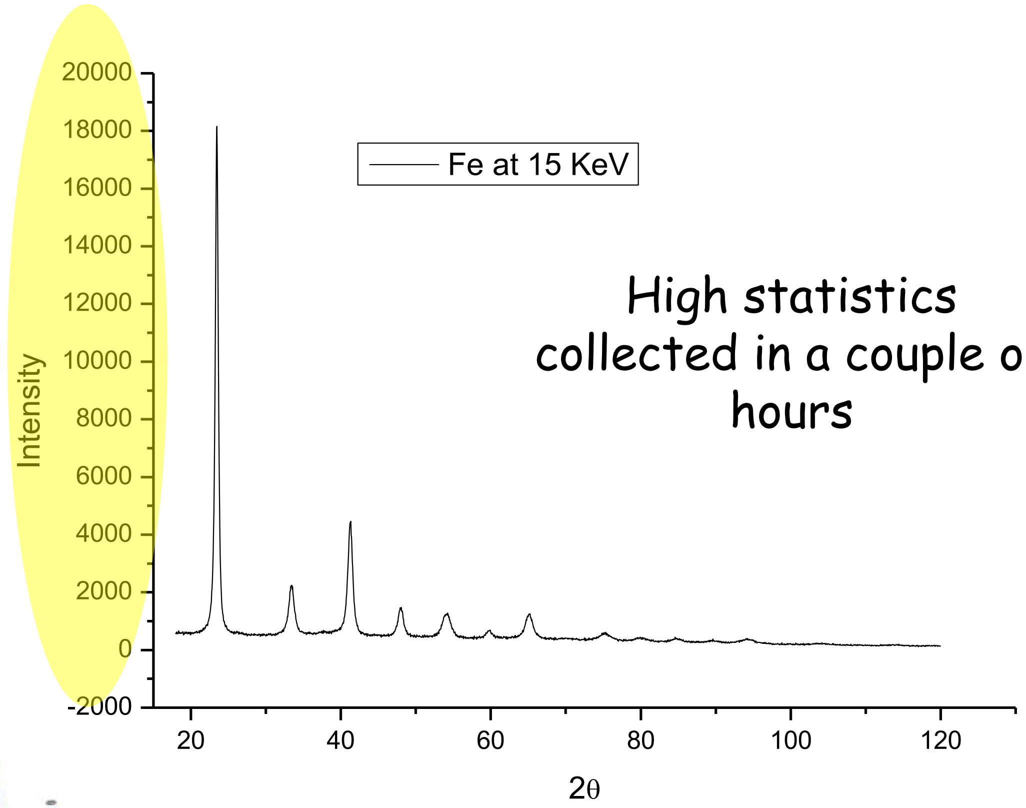
"PHYSICS IS, HOPEFULLY, SIMPLE. PHYSICISTS ARE NOT."

EDWARD TELLER

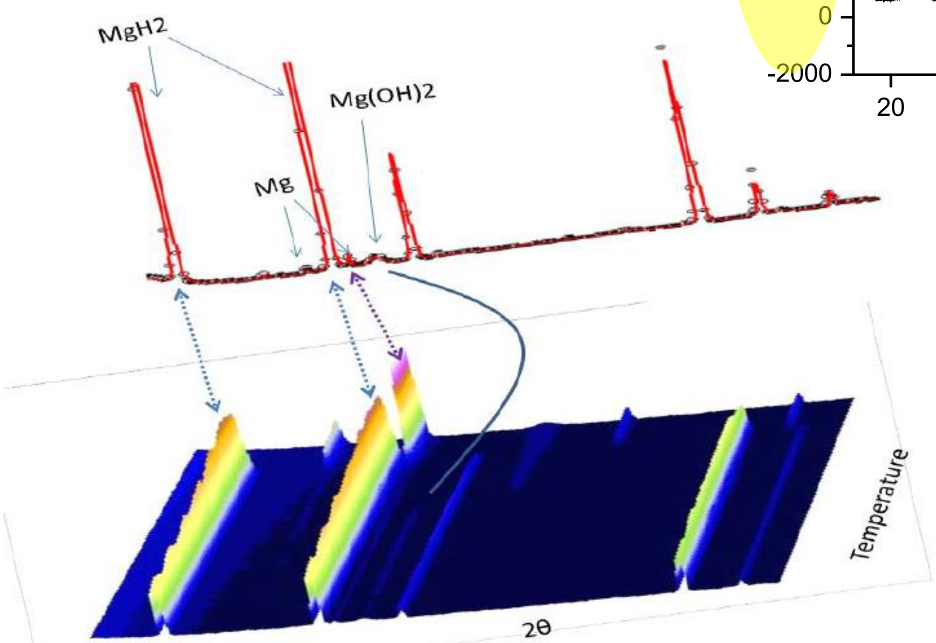
Think simple

1. Brilliance (time and statistics , e.g. in-situ XRD)





High statistics collected in a couple of hours

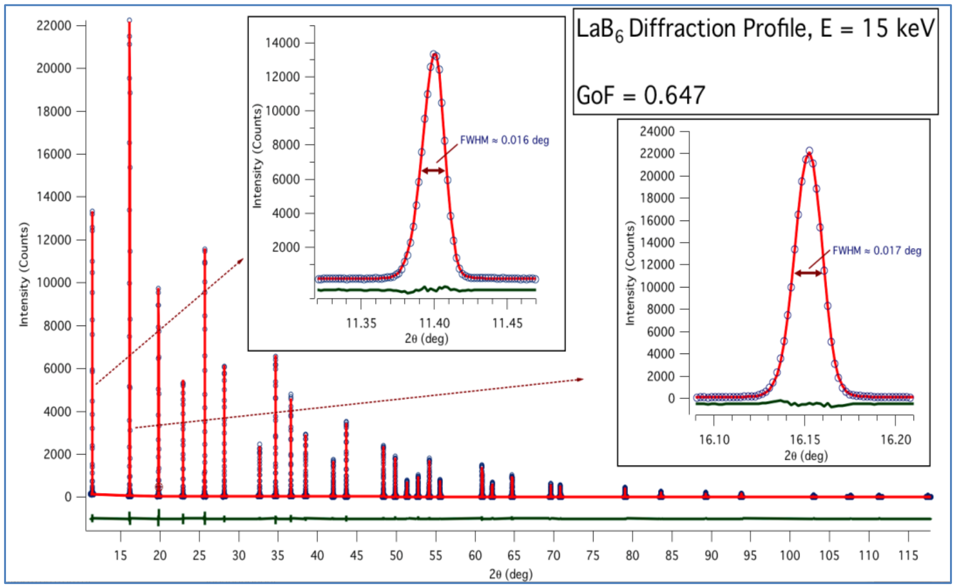


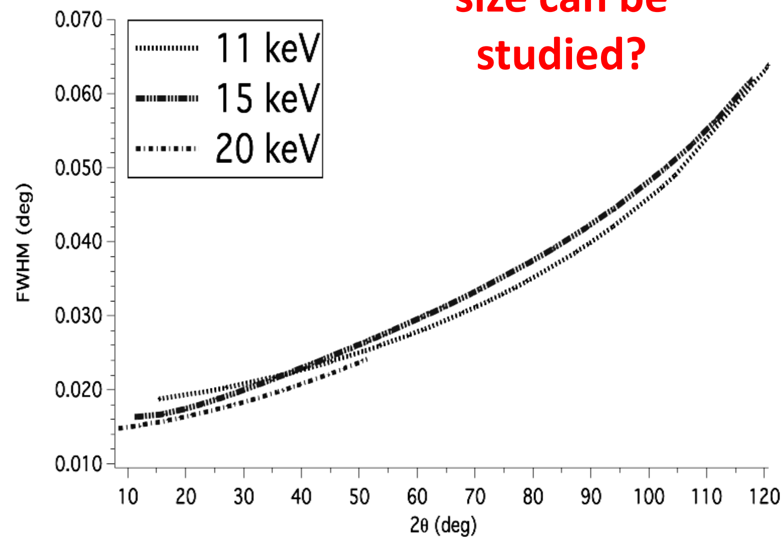
In situ XRD for hydrogen desorption kinetics

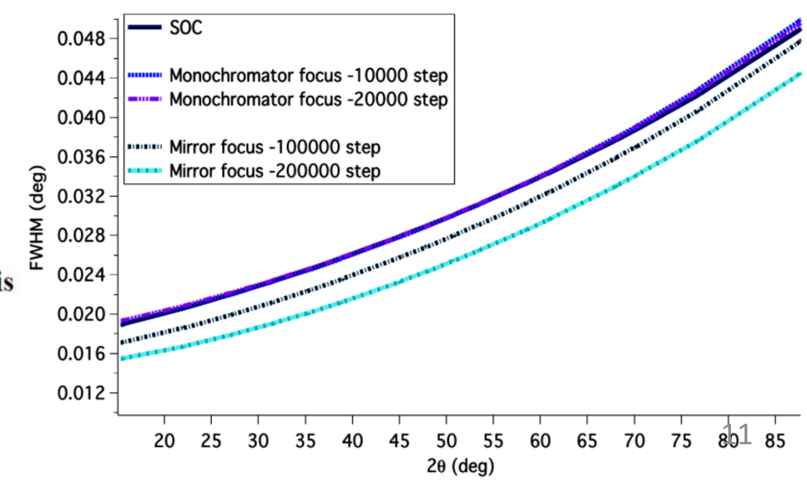
2. Instrumental resolution and instrumental profile

Diffraction pattern is a **sum** of two contributions:
Sample + Instrument

Maximum crystal size can be studied?







MCX: a synchrotron radiation beamline for X-ray diffraction Line Profile Analysis

Luca Rebuffi,*[a,b] Jasper R. Plaisier,[a] Mahmoud Abdellatief,[a] Andrea Lausi,[a] and Paolo Scardi[b]

Zeitschrift für anorganische und allgemeine Chemie ZAAC Journal of Inorganic and General Chemistry

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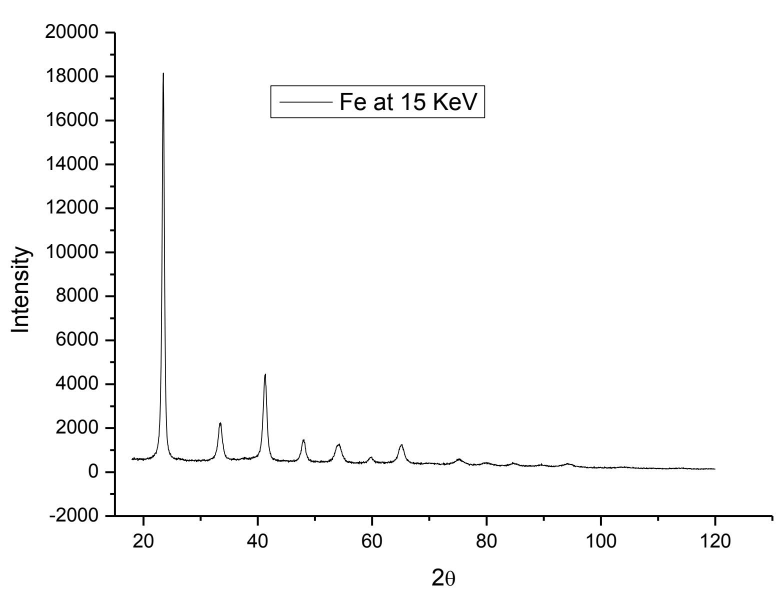
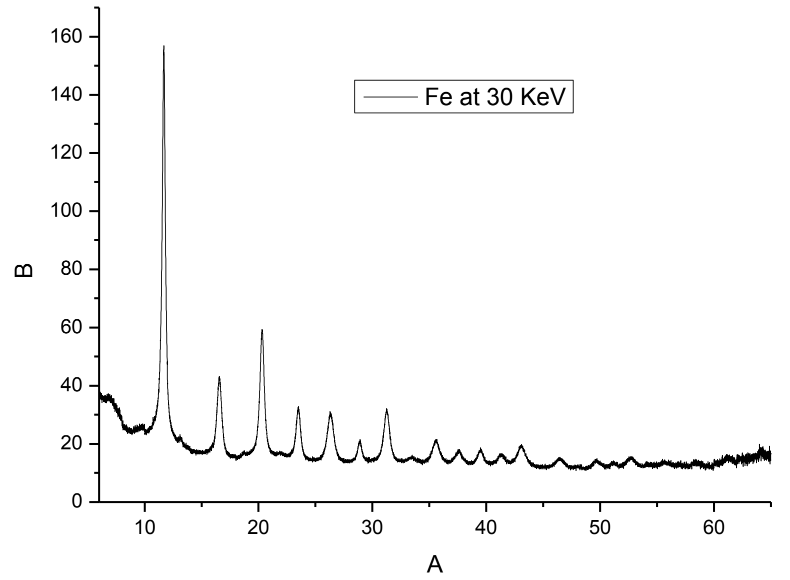
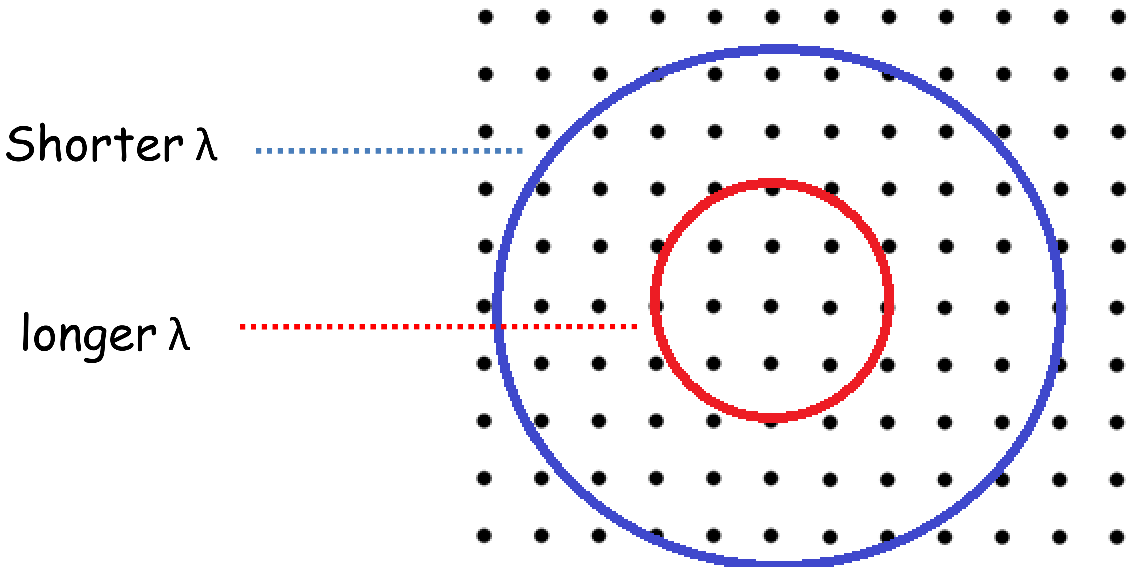
3. Larger limiting sphere (radius 1/λ)



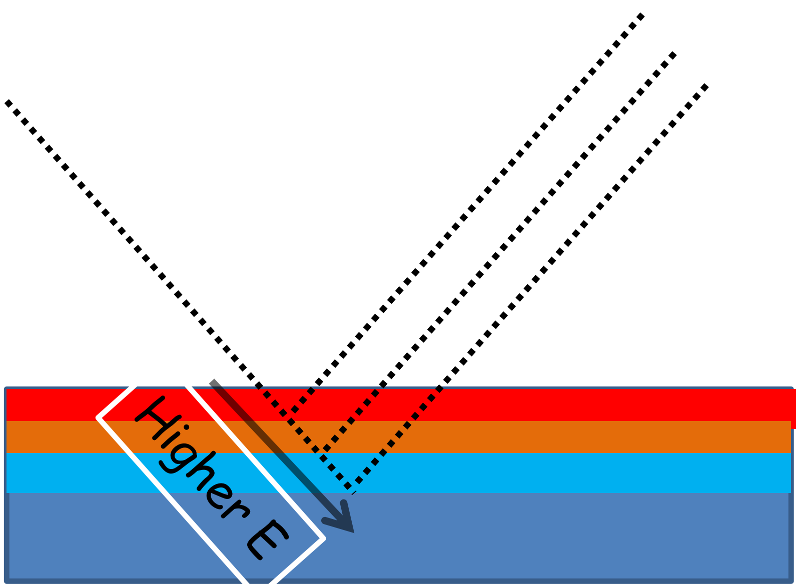


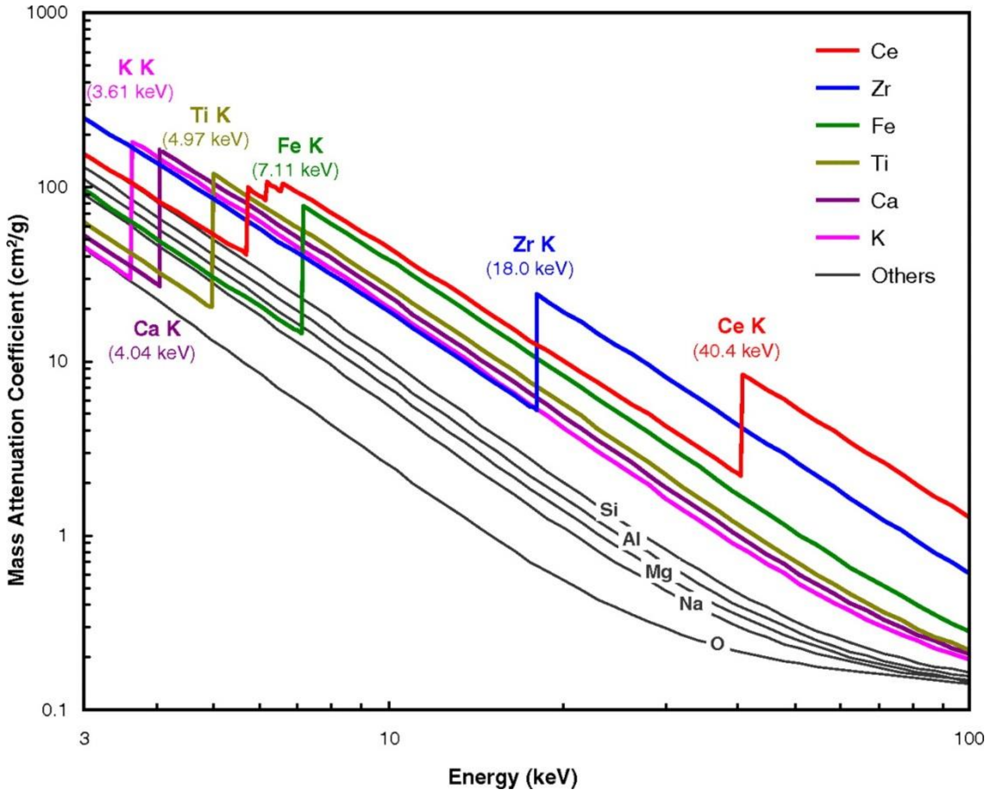
Short λ for Pair distribution function PDF for amorphous



4. Energy selectivity

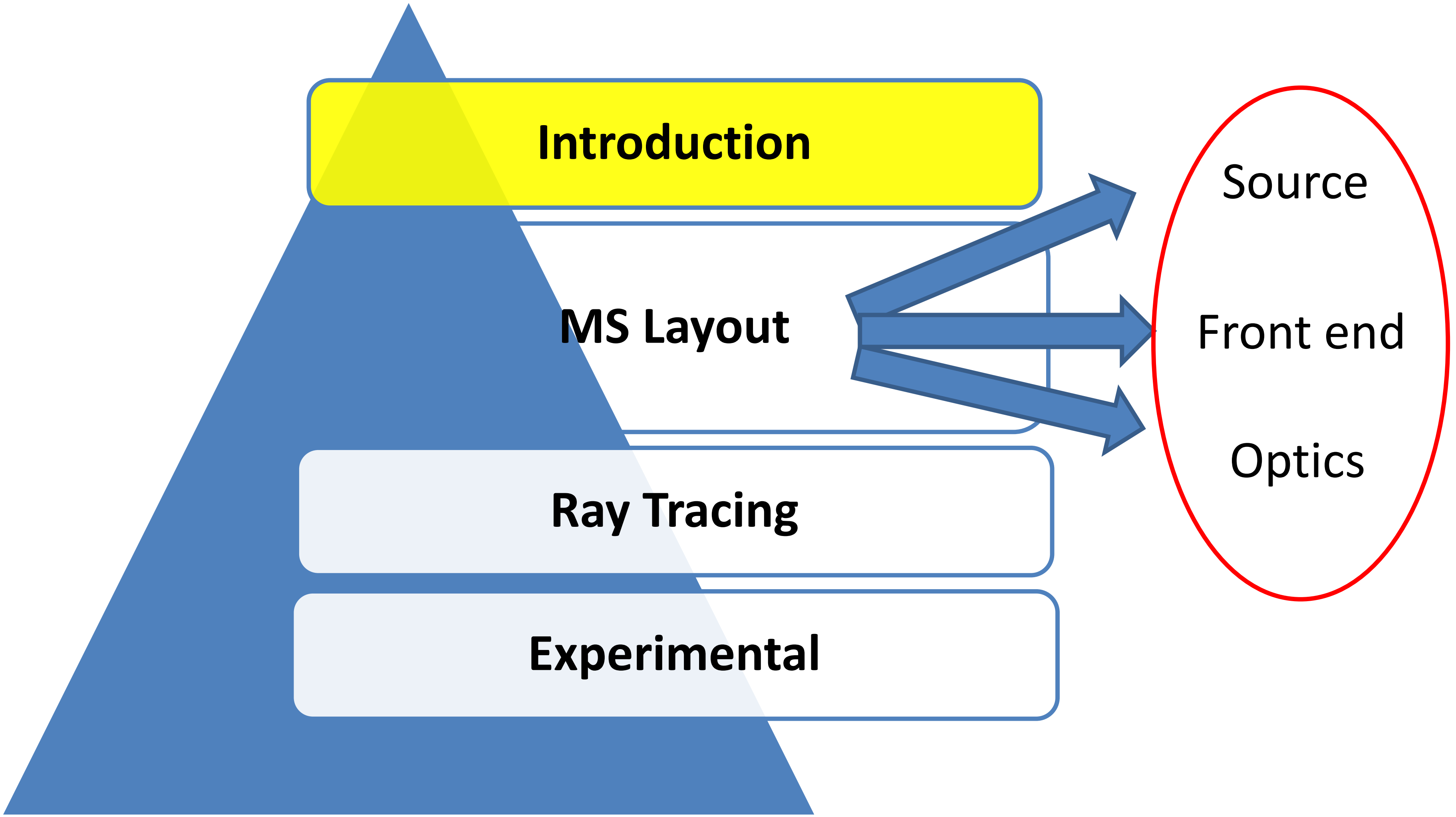
- Absorption edges
- resonant diffraction
- beam penetration depth





Higher energy get diffracts by deeper layers

Outlines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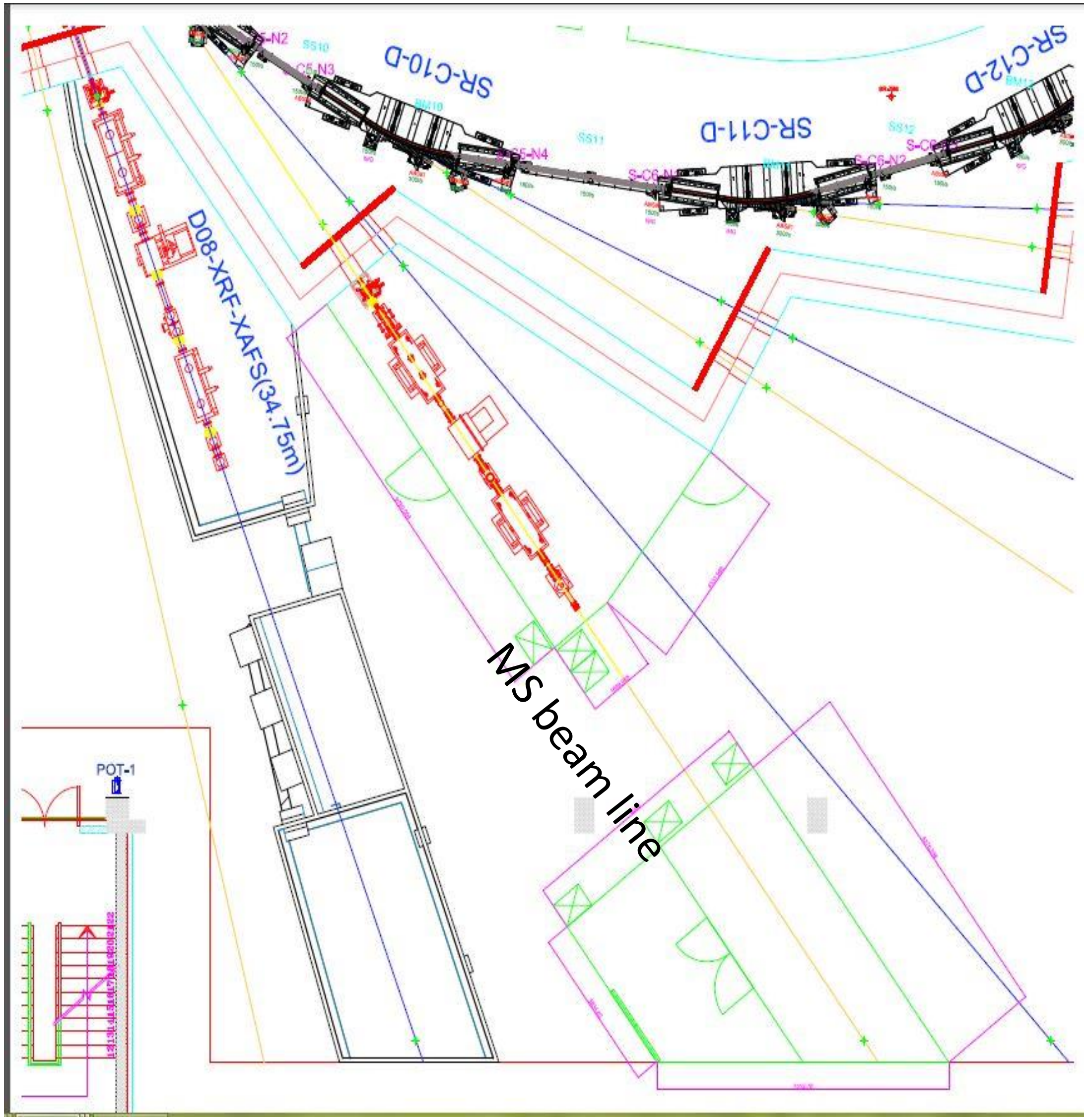
SESAME MS BL layout

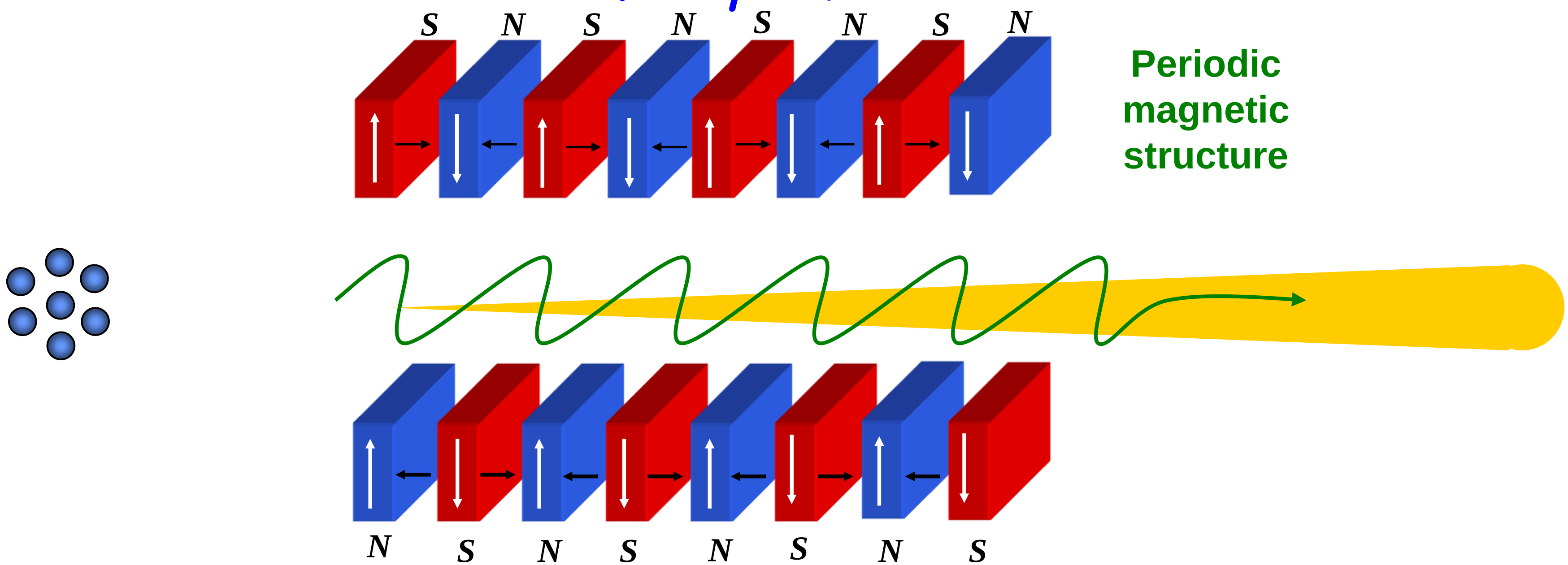
Overall W61 length (m)	2
Wiggler gap (mm)	12
Period length (mm)	60.5
Number of periods	33
Magnetic material	NdFe:B
Pole material	CoFe
Maximum field (T)	1.4
Deviation parameter K	7.8
Critical energy (keV)	5.8
Total power @ 400mA (KW)	6.01

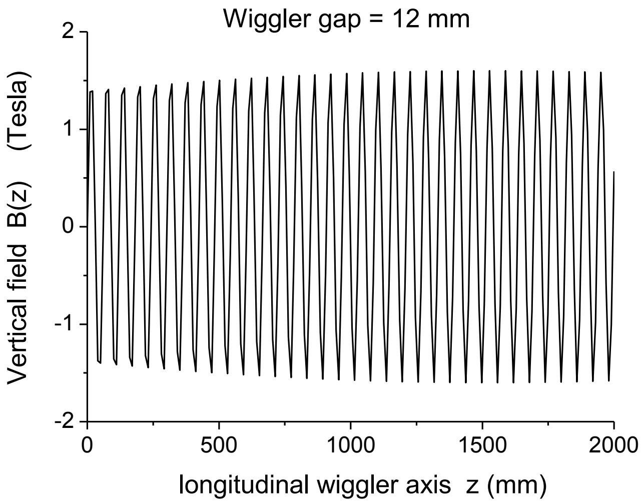


SESAME MS radiation source W61

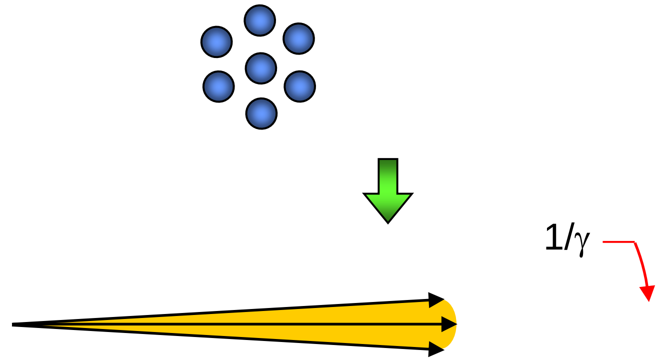
The particle follow zigzag path according to Lorentz magnetic force

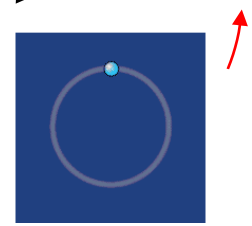
$F = q\,v \times B$

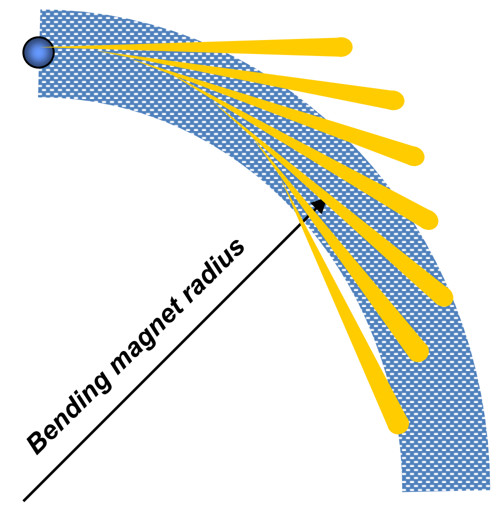




Wiggler Vs Bending magnet

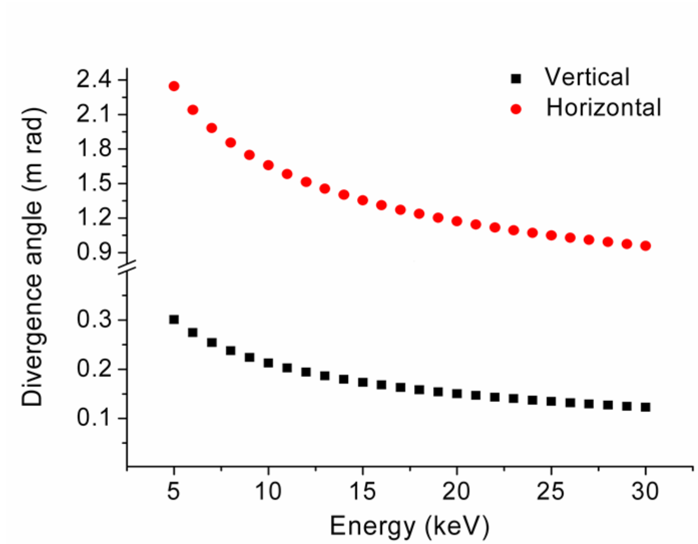


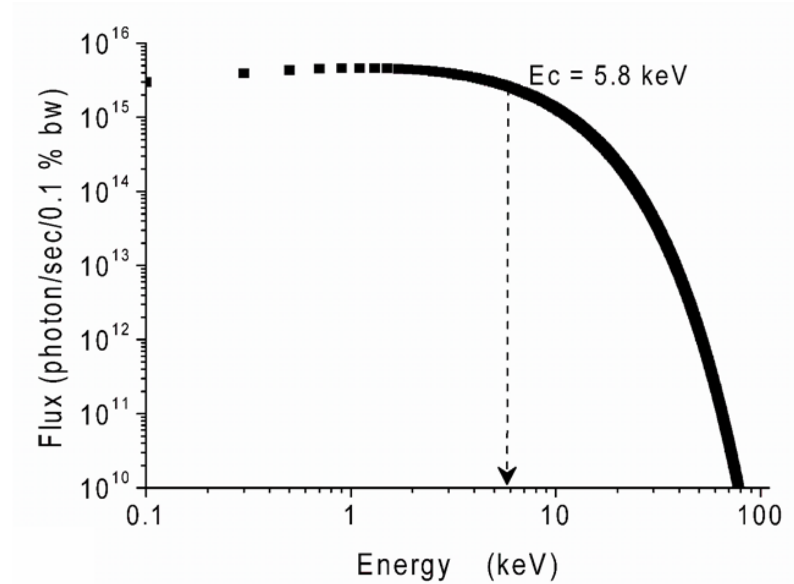




Wiggler is a series of bending magnet

- Energy shifter
- Brilliance increases by N





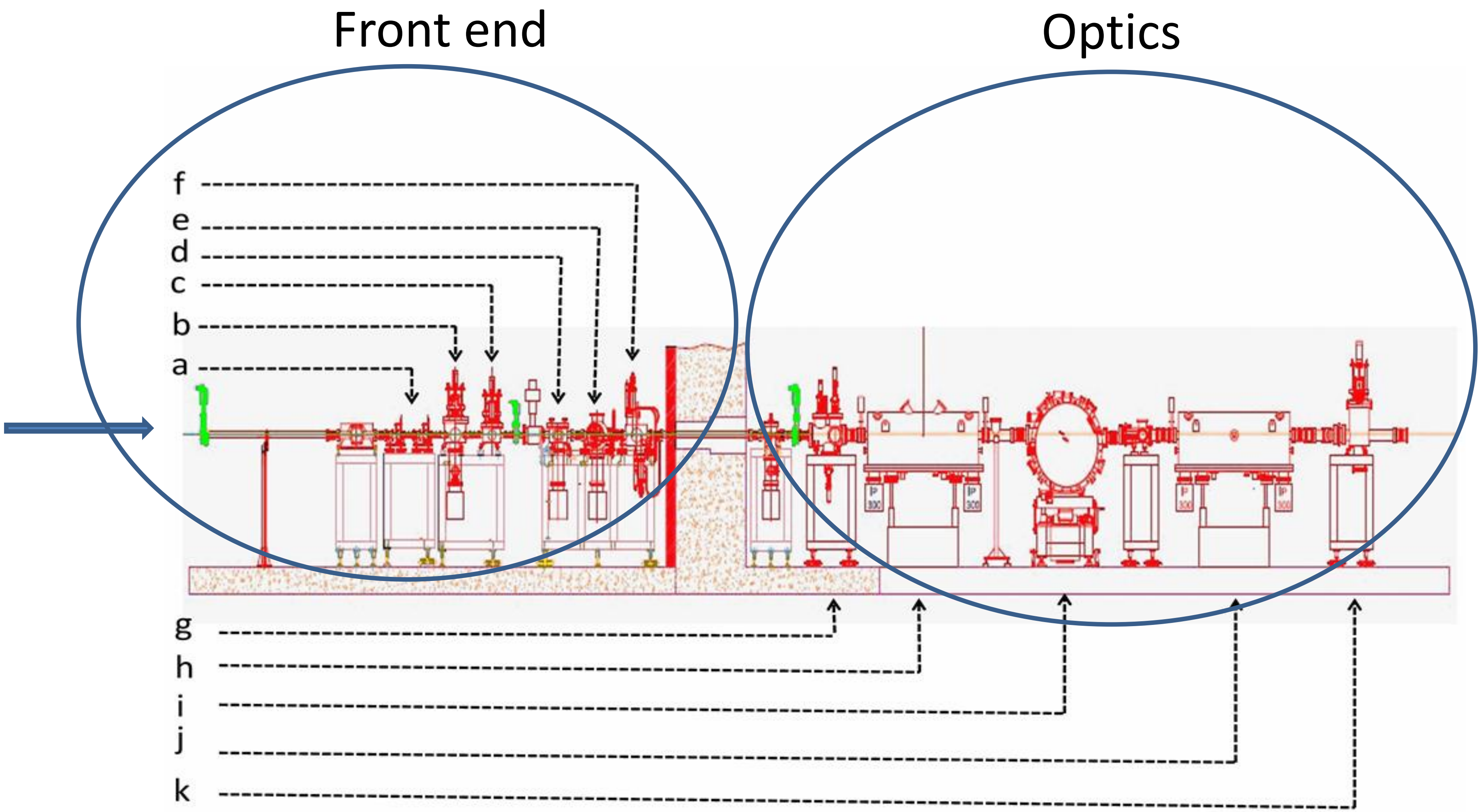
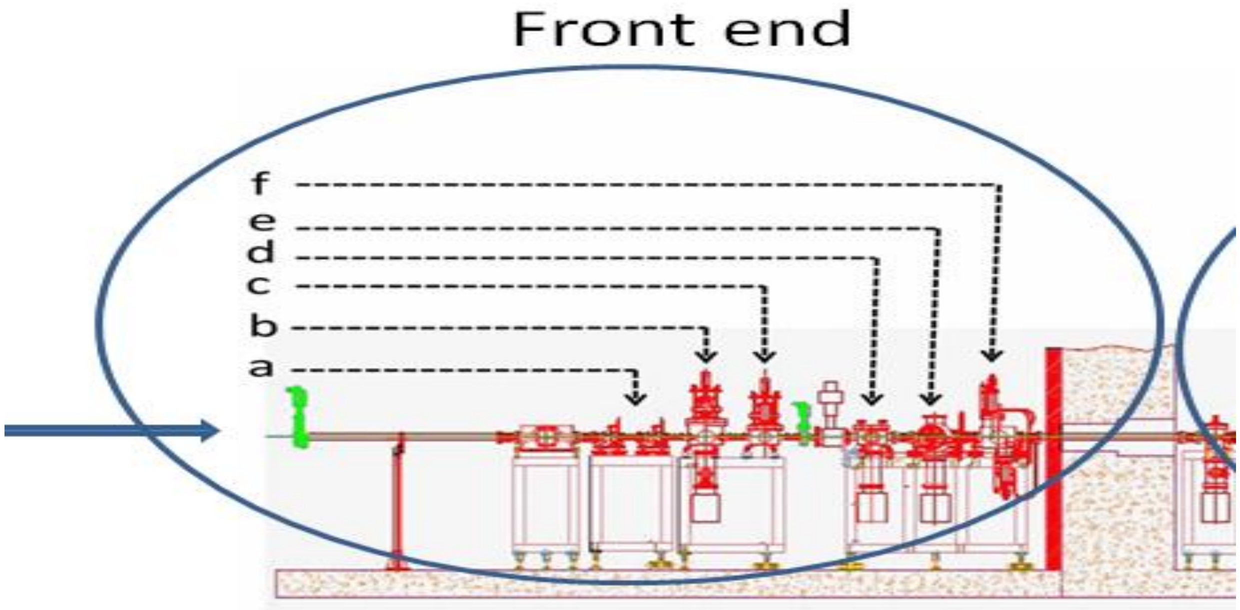


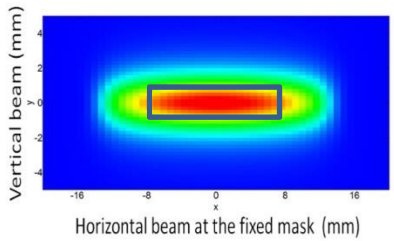
Figure front-end and optics layout starting from left hand side, fixed masks (a), shutter (b), stopper (c), filter (d), vertical slits (e), horizontal slits (f), fast absorber (g), collimating mirror (h), monochromator (i), focusing mirror (j), photon shutter (k).



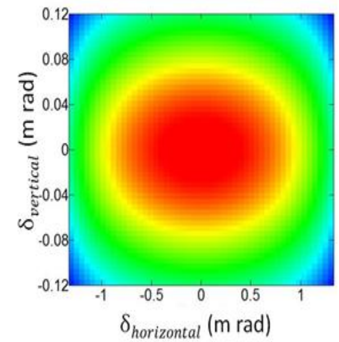
- Defining the angular acceptance
- Blocking X-ray and Bremsstrahlung radiation
- Soft X ray filtration
- Isolation the vacuum of beamline from and storage ring vacuum (Be windows)

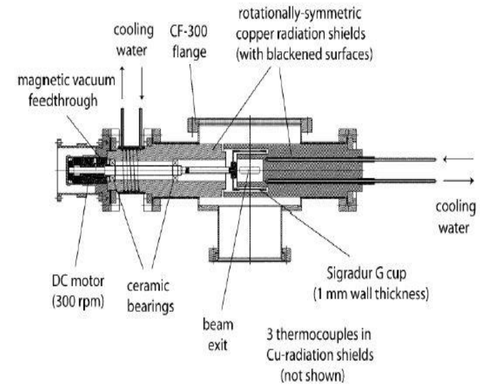
Power and heat load analysis

$$P[\mathrm{kW}] = 1.27\, E_e^2\,[\mathrm{GeV}^2]\,\frac{B_{eff}^2\,[\mathrm{T}^2]}{2}\,L_w[\mathrm{m}]\,I_e$$

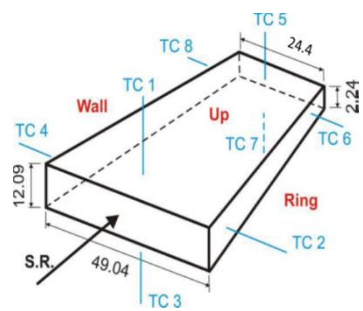


P(abs) =
2.46 K Watt





6.01 K Watt

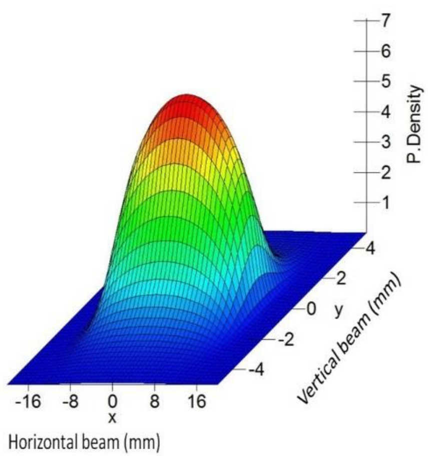


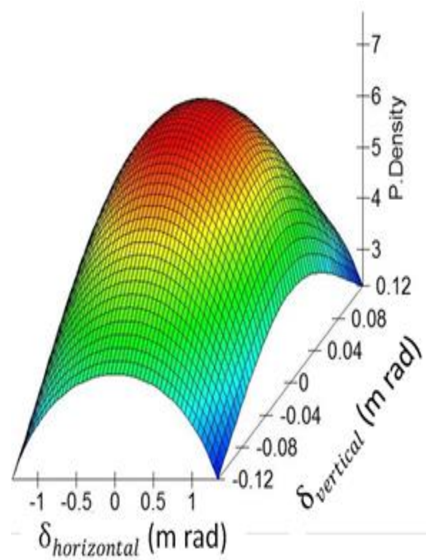
3.55 K Watt

2 mm in total
Glassy
graphite
$1.42\ g/cm^3$

Source

Diaphragm





Current (m A)	Total Absorbed power (k Watt)
200	1.3
300	1.9
400	2.6

Temperature load on the filter

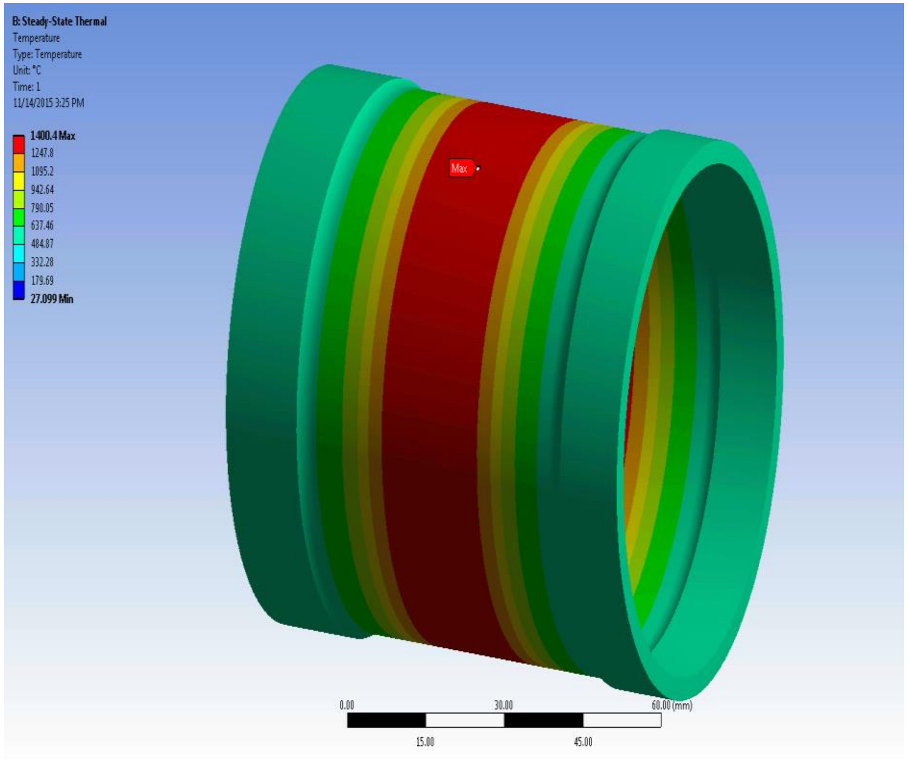
Case I

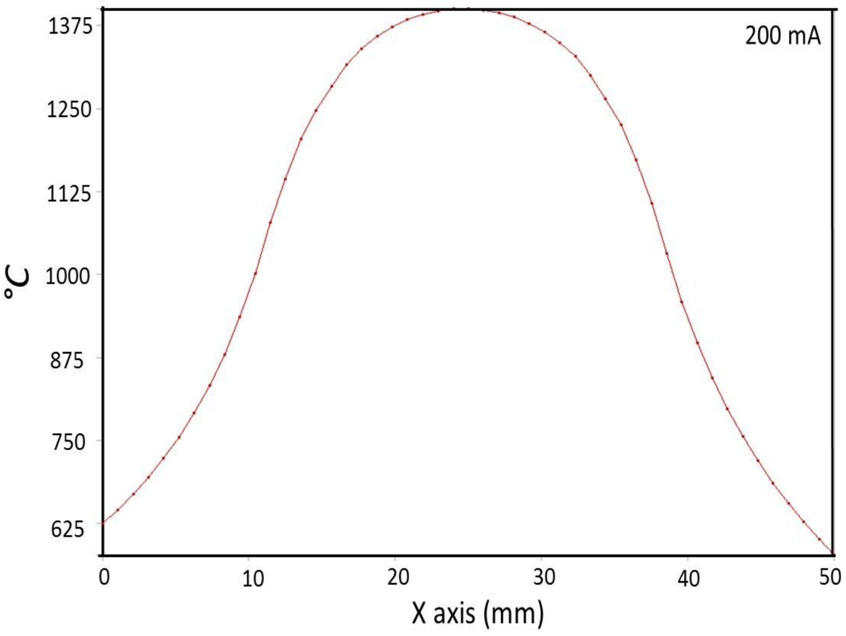
I (electrons) = 200 mA

Total absorbed power 1288W

Temperature (1400 – 625 °C)

Max Copper temp. = 100 °C





Temperature load on the filter

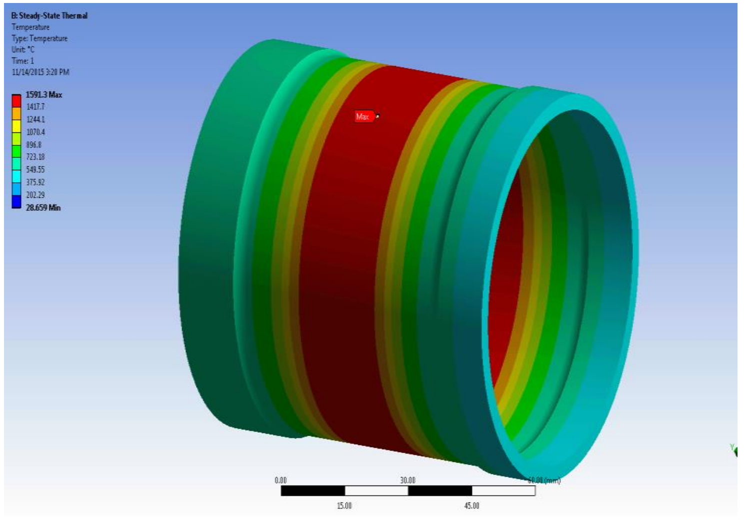
Case II

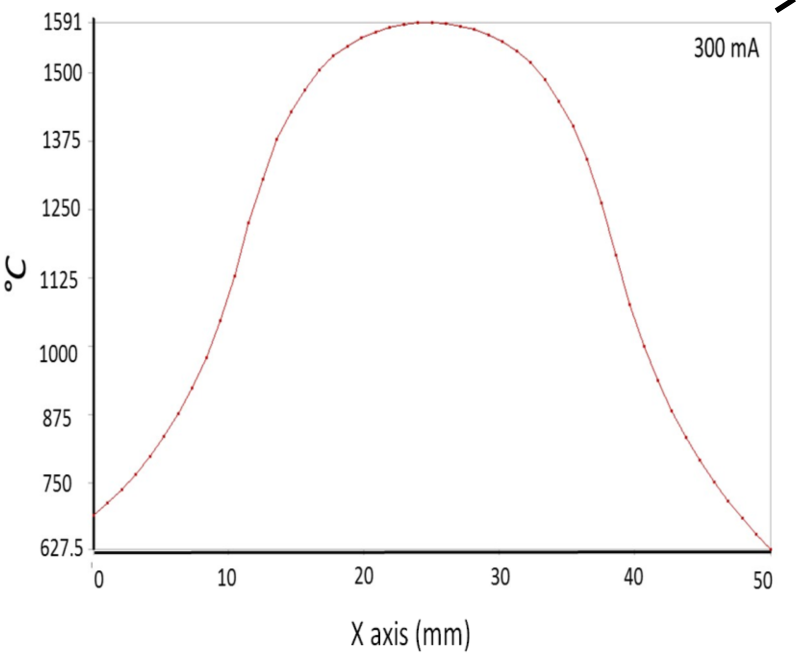
I (electrons) = 300 mA

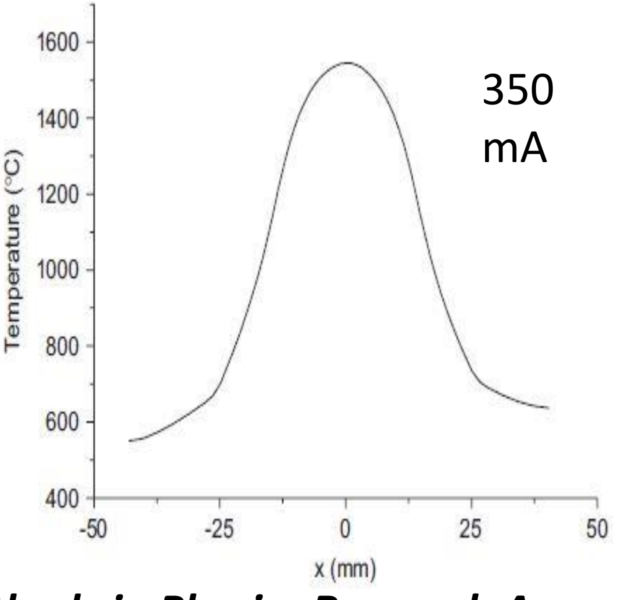
Total absorbed power 1932W

Temperature (1600 – 730 ^{o}C)

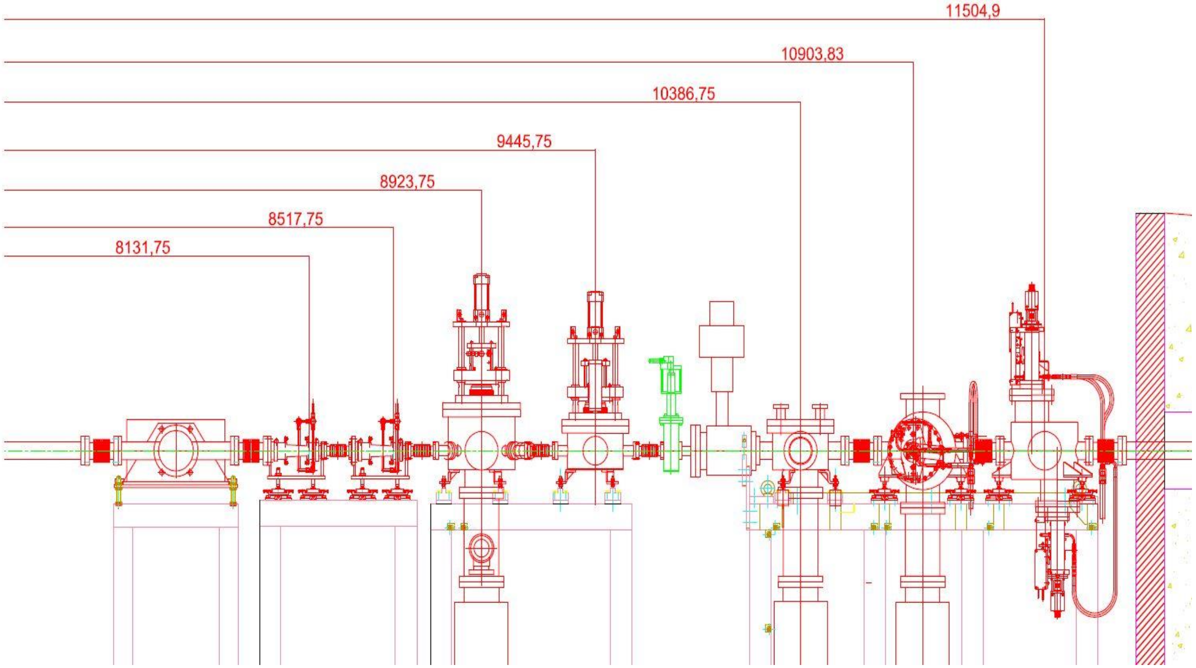
Max Cupper temp. = 135 ^{o}C







G. Heidenreich, B.D. Patterson; Nuclear Instruments and Methods in Physics Research A 577 (2007) 751–755



Case III

I (electrons) = 400 mA

Total absorbed power

2.6 KW

1.5 (H) x 0.23 (V) m rad^2 @ 400 mA

Decreasing the horizontal acceptance down to 1.5 m rad

	Power in (kW)	Power out (kW)	Power absorbed (kW)
Fixed mask 1	6	4.13	1.87
Fixed mask 2	4.13	2.15	1.98
Rotating filter	2.15	0.614	1.54

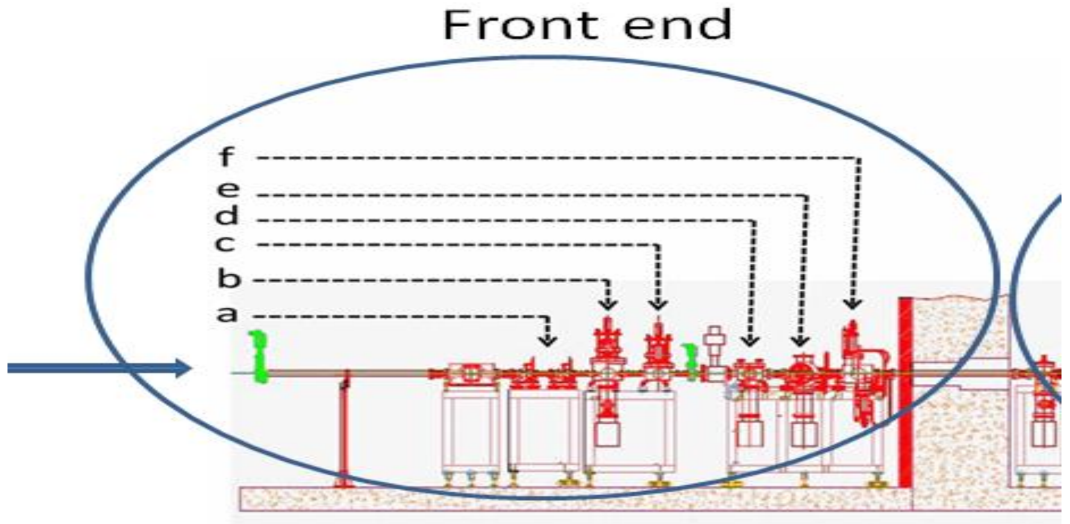
Intermediate situation

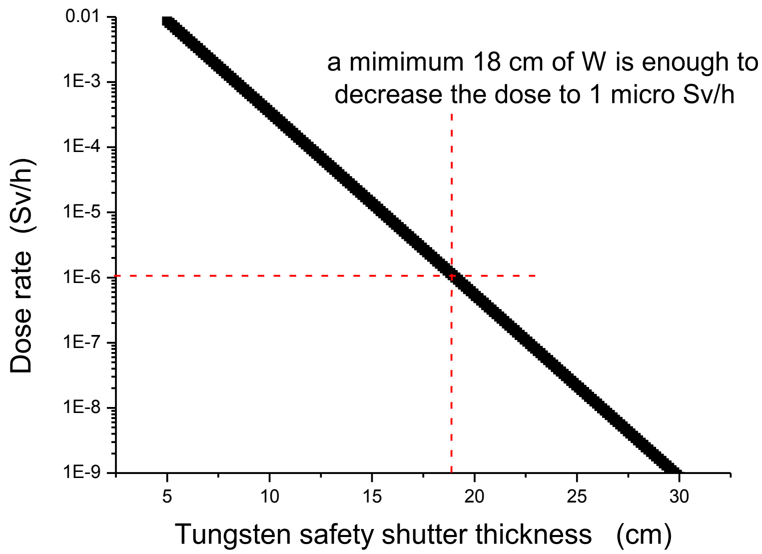
1400 ^{o}C < T max < 1600 ^{o}C

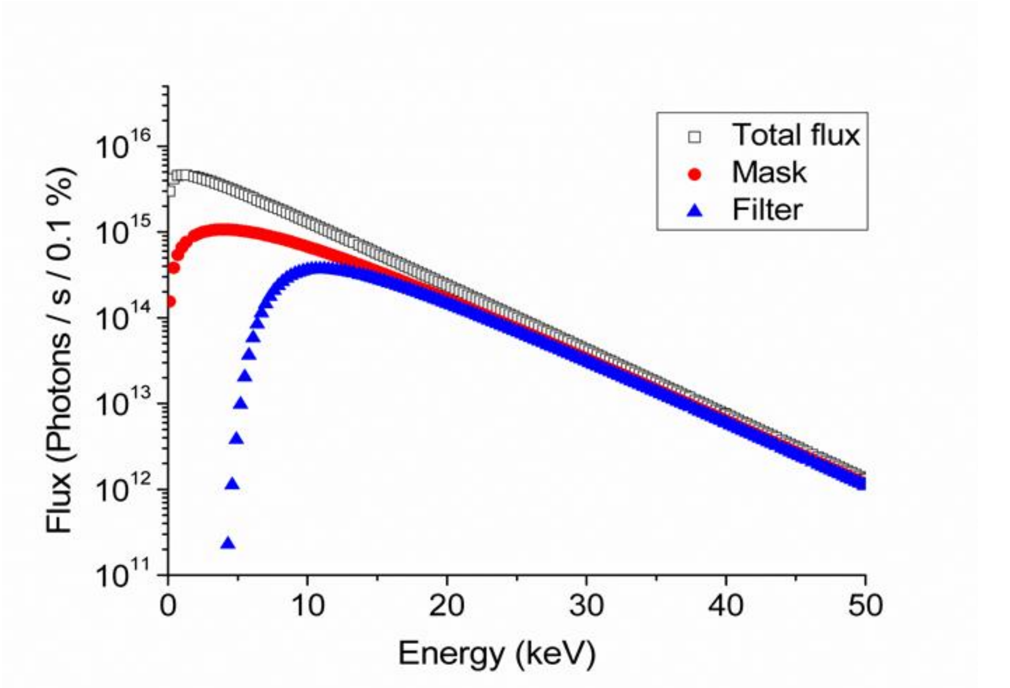
625 ^{o}C < T min < 730 ^{o}C

100 ^{o}C < T (Cu) < 135 ^{o}C

Shutter and stopper (safety)



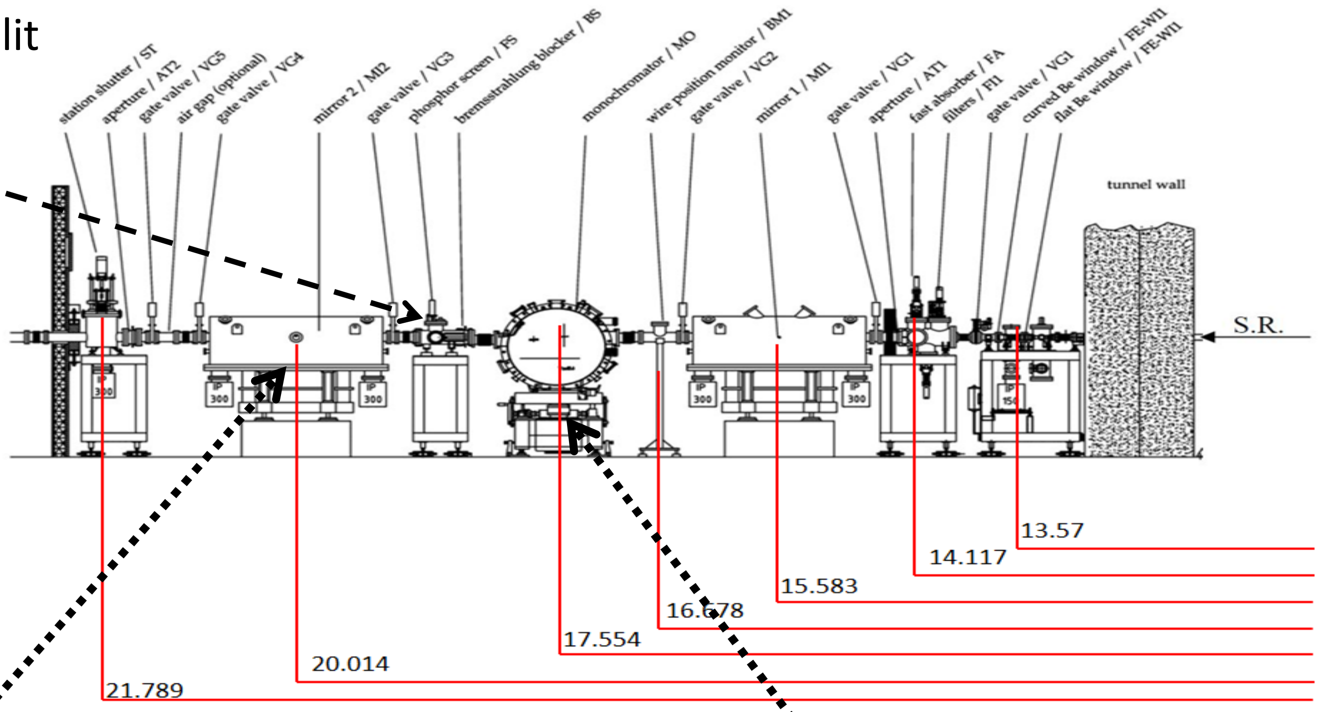




Optics layout

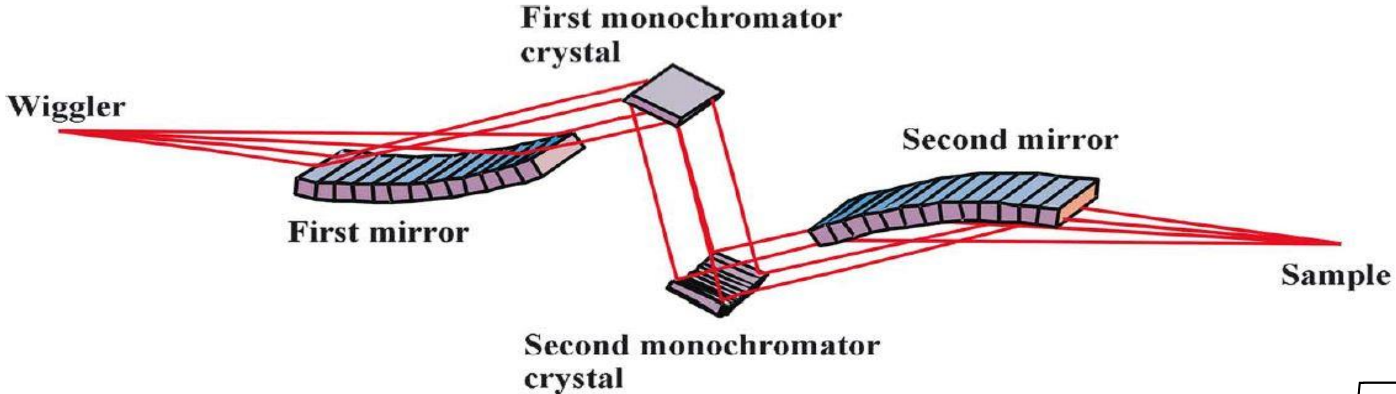
(no optics is the best optics)

Pink slit



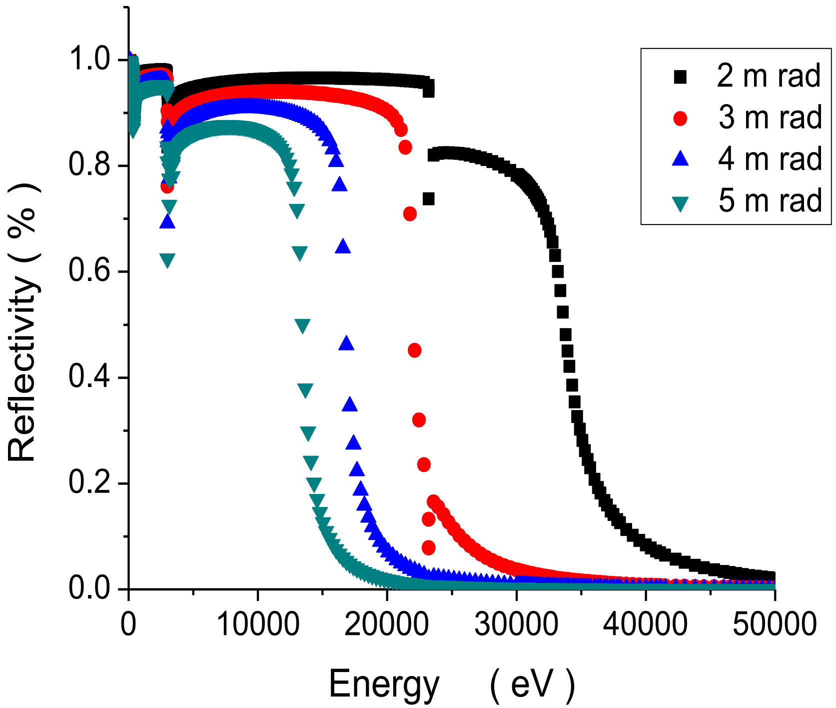
Mono slit

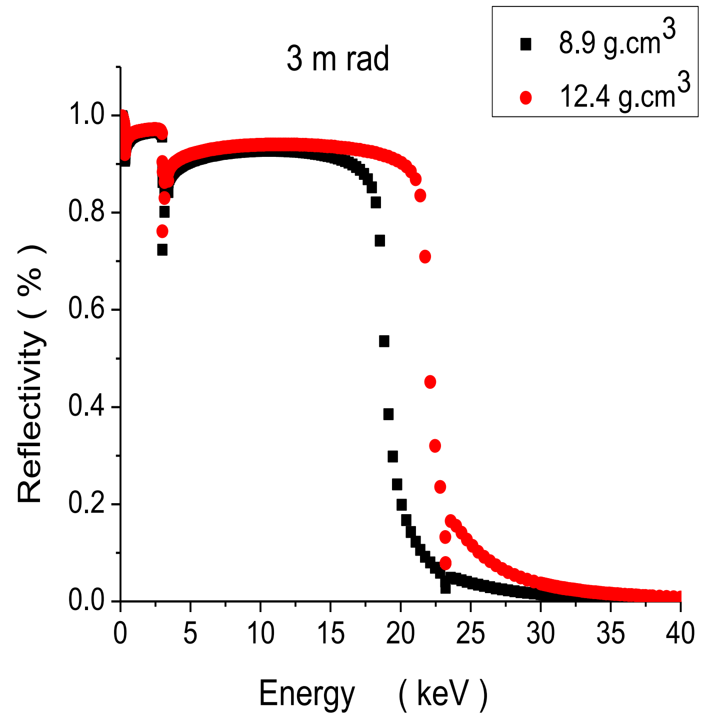
Collimating Mirror (Rhodium)



M1 and Energy resolution

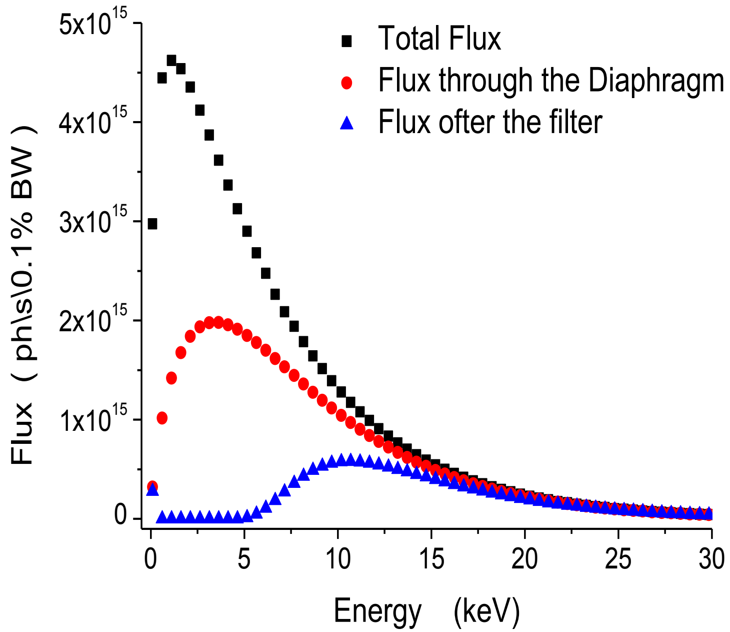
$$\Theta_c(\text{m rad}) = \frac{19.83\sqrt{\rho_s\ (\frac{g}{cm^3})}}{E_c\ \ (\text{keV})}$$

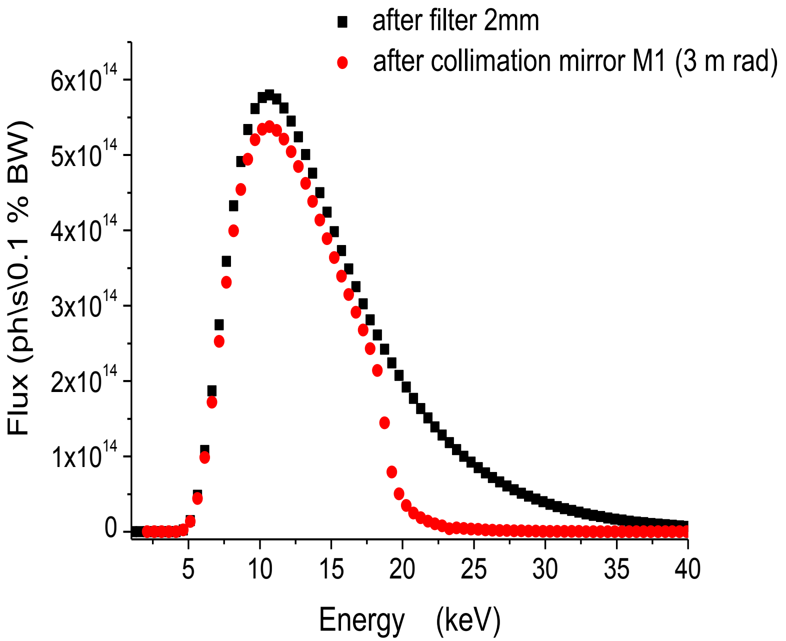




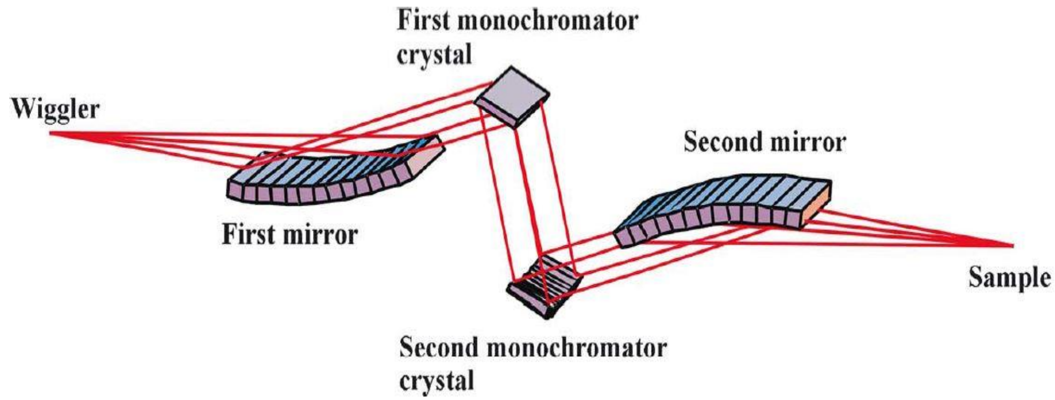
Collimating Mirror (Rhodium)

Mirror absorbs some power
Mirror collimates the incoming radiation (energy resolution..)

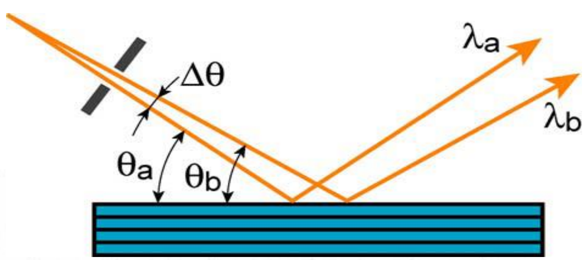


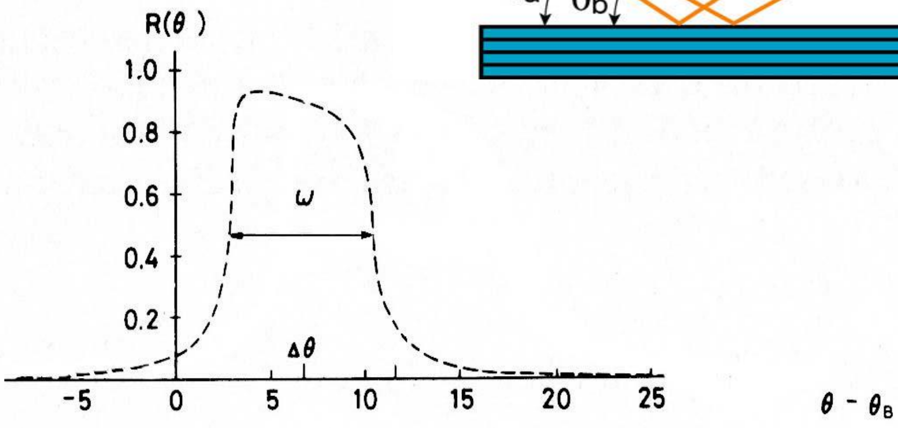


Monochromator and horizontal focusing



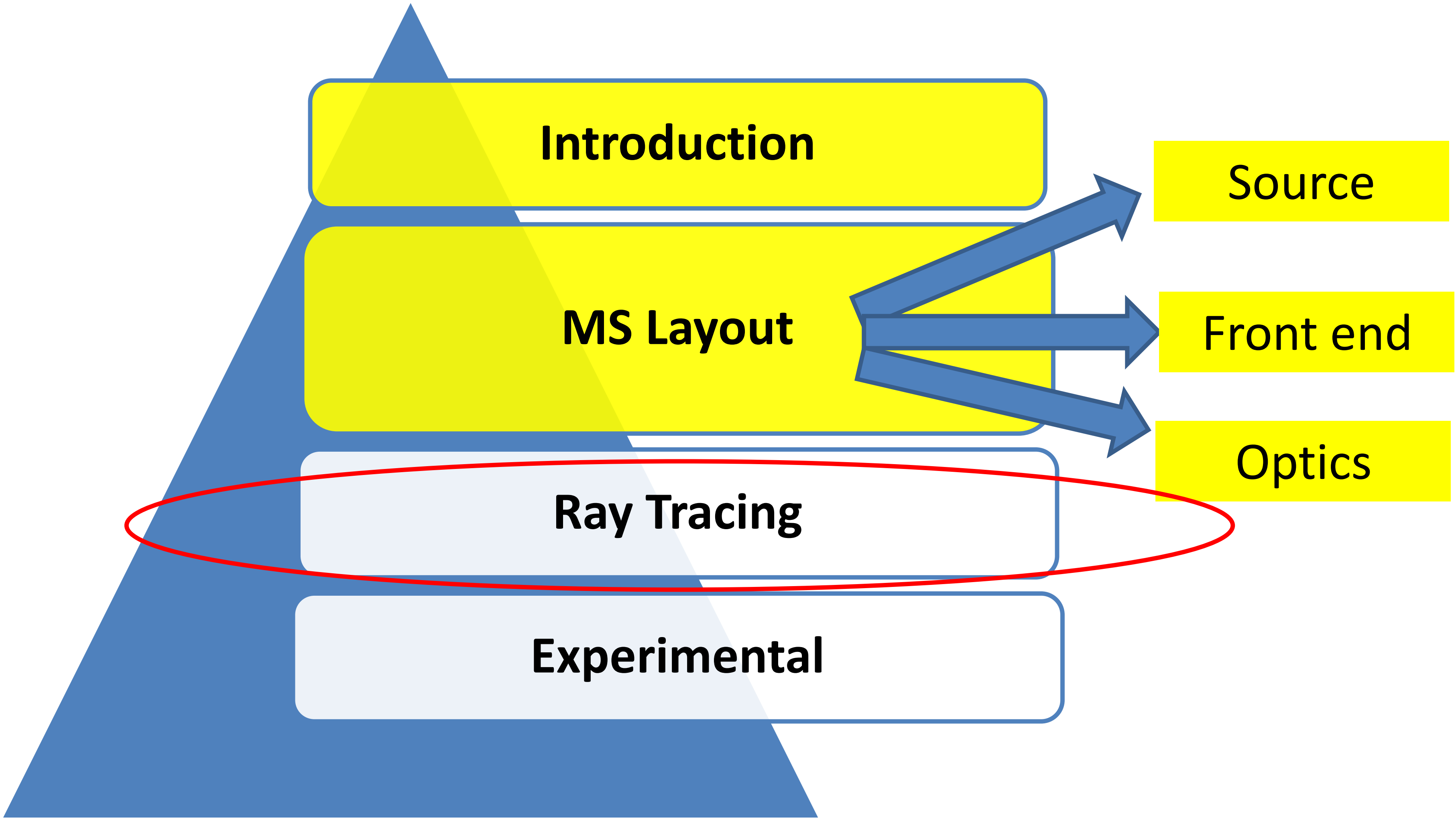
$$\frac{\Delta E}{E} = \frac{\Delta\lambda}{\lambda} = \sqrt{\Delta\theta^2 + w^2}\cot(\theta)$$





hkl	Braqg angle (degree)	ω (arc sec)	ω (μrad)
111	11.403	5.476	26.55
220	18.836	3.984	19.32
311	22.246	2.273	11.02
400	27.167	2.495	12.10
422	34.001	1.886	9.142
333	36.379	1.228	5.952
440	40.22	1.543	7.479

Outlines



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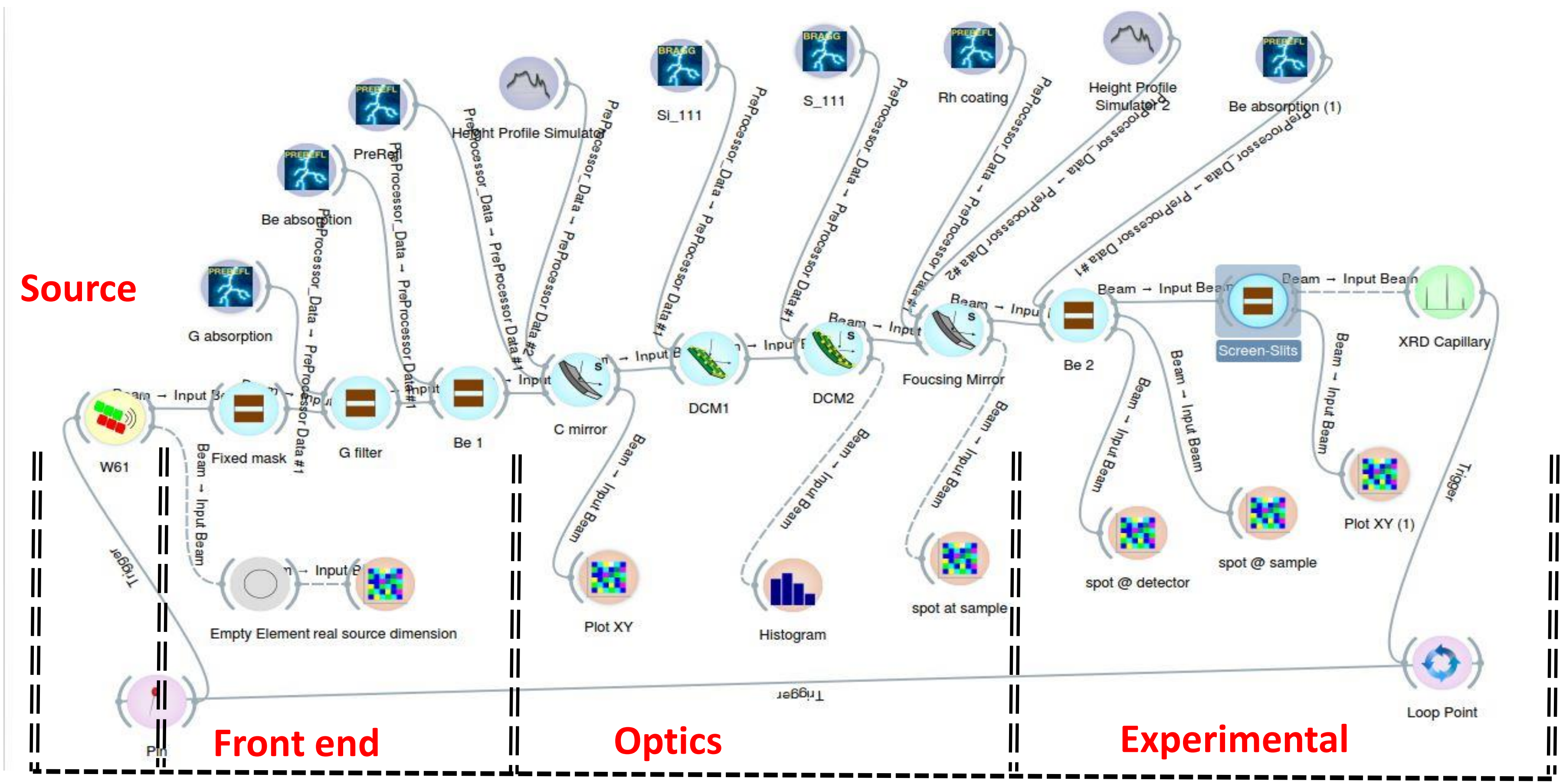
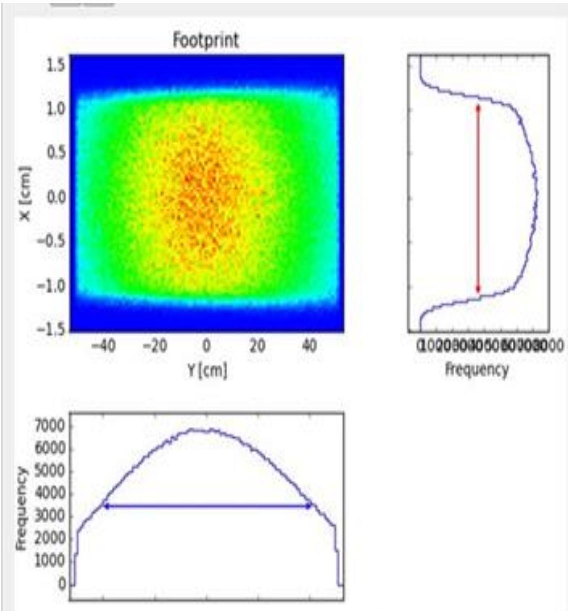
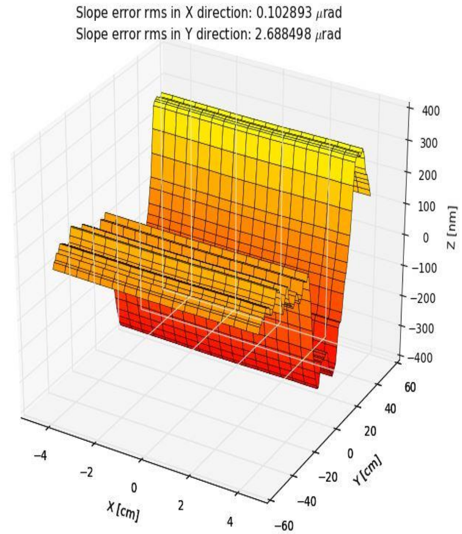
Ray Tracing

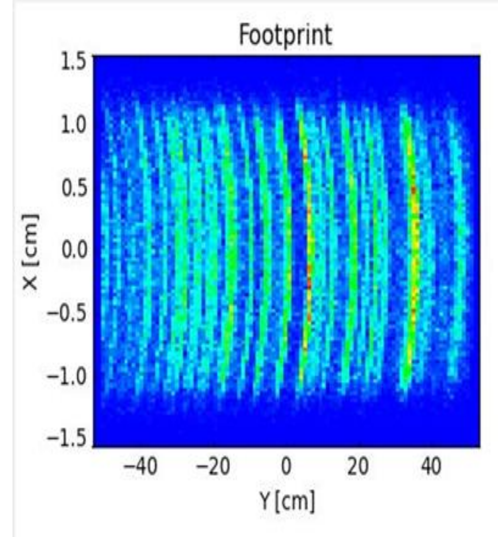
- **Tuning optics to optimize Flux at Sample (photons/s) and the angular resolution**



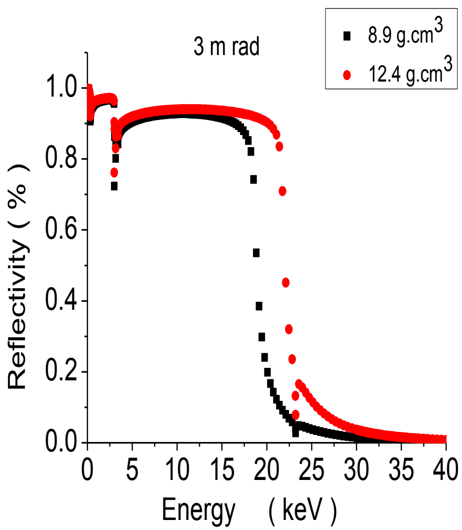
Sanchez del Rio, M. et al. (2014). "A proposal for an open source graphical environment for simulating x-ray optics". *Proc. SPIE* 9209, Advances in Computational Methods for X-Ray Optics III, 92090X; doi:10.1117/12.2061834

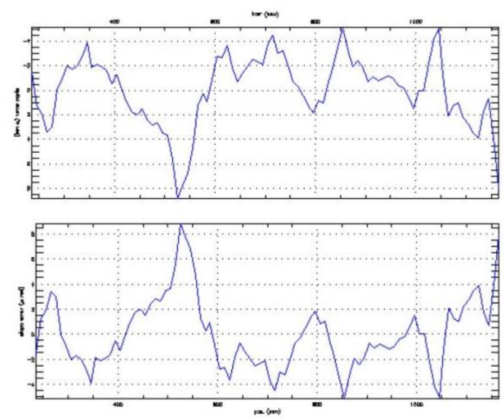






	Slope error μ rad (rms)
M1	3.561
M2	2.626

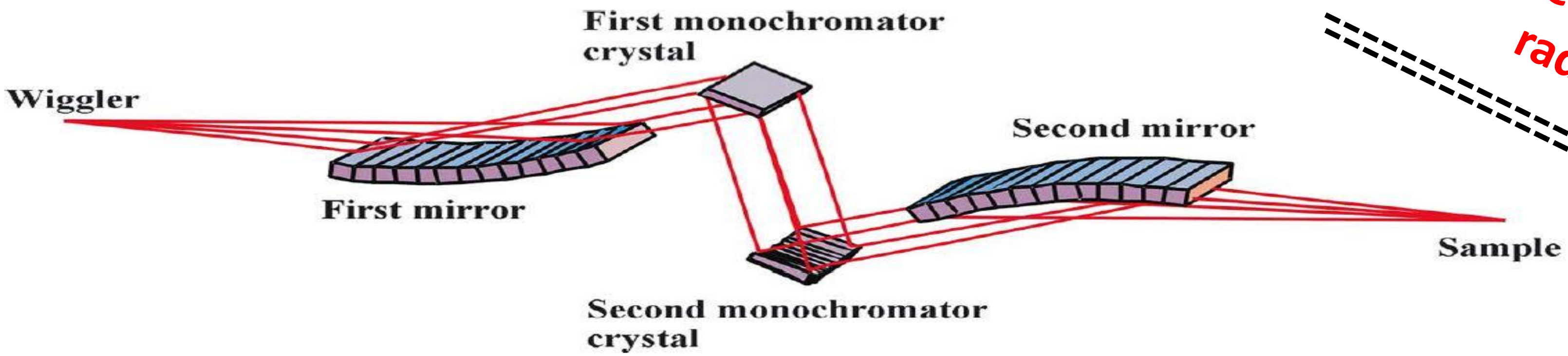


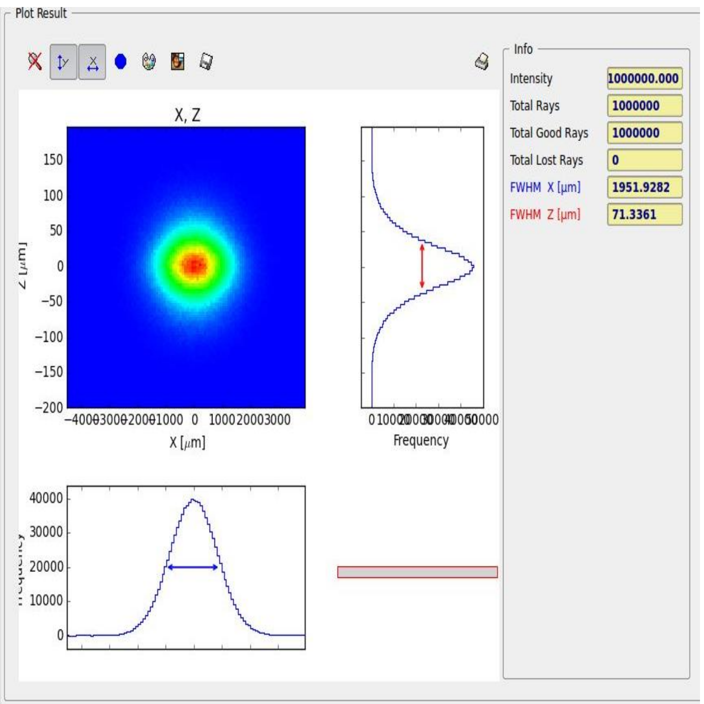


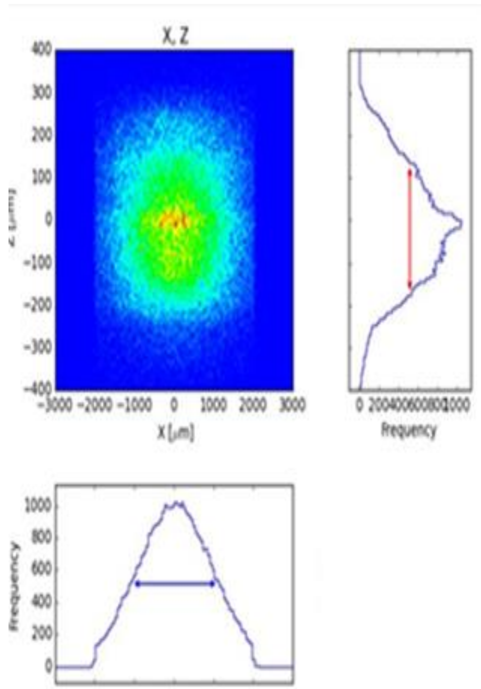
Rebuffi, L. & Sanchez del Rio, M. (2016). "ShadowOui: A new visual environment for X-ray optics and synchrotron beamline simulations", J. Synch. Radiat., submitted.

Optics optimization

Energy = 15 keV
G angle = 3.5 m rad





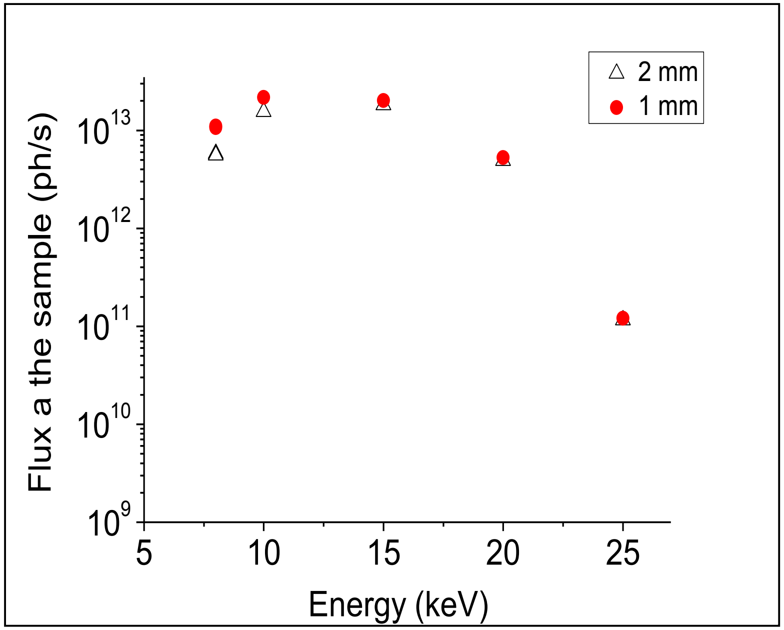


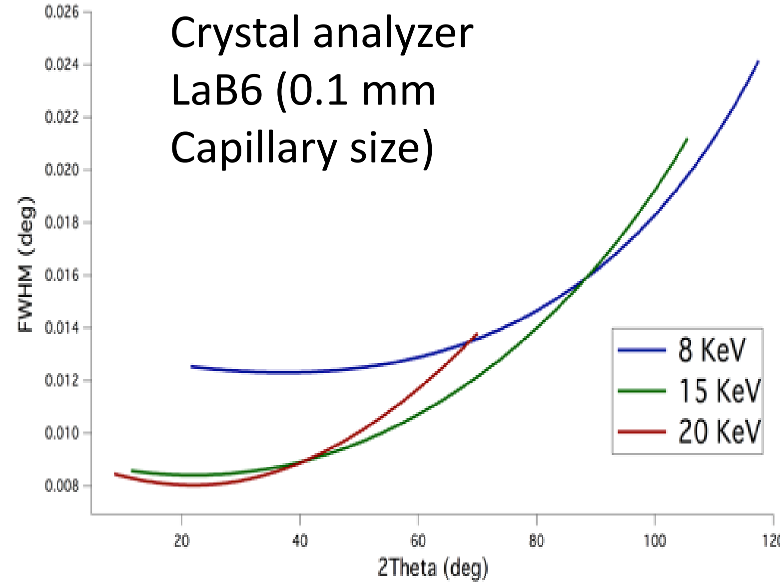
<u>Effective beam size</u>

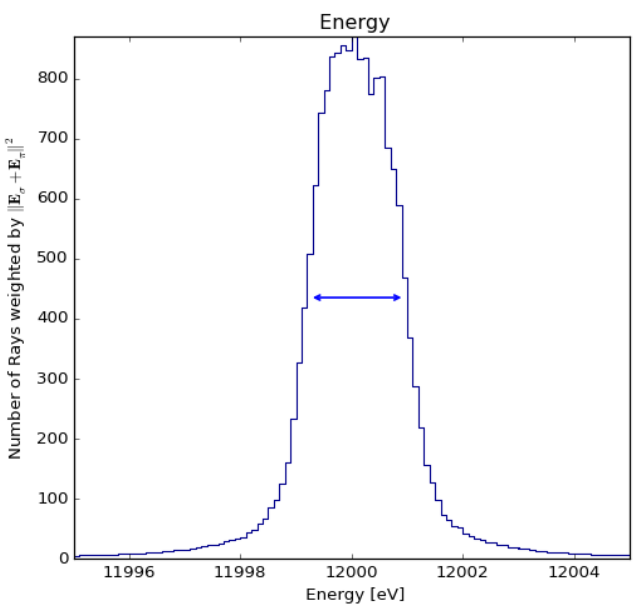
Vertical = 0.8 mm (FWHM = **0.3 mm**)

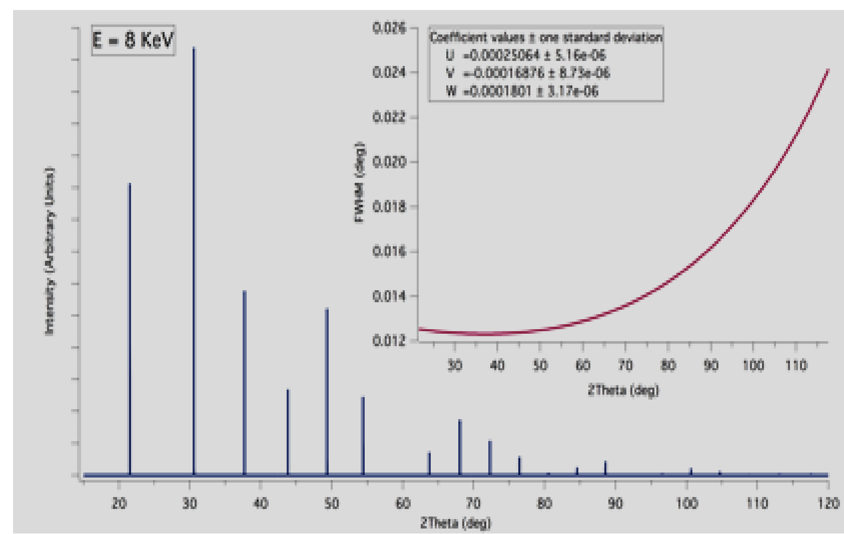
Horizontal = 4 mm (FWHM = **2 mm**)

Flux and instrumental Profile

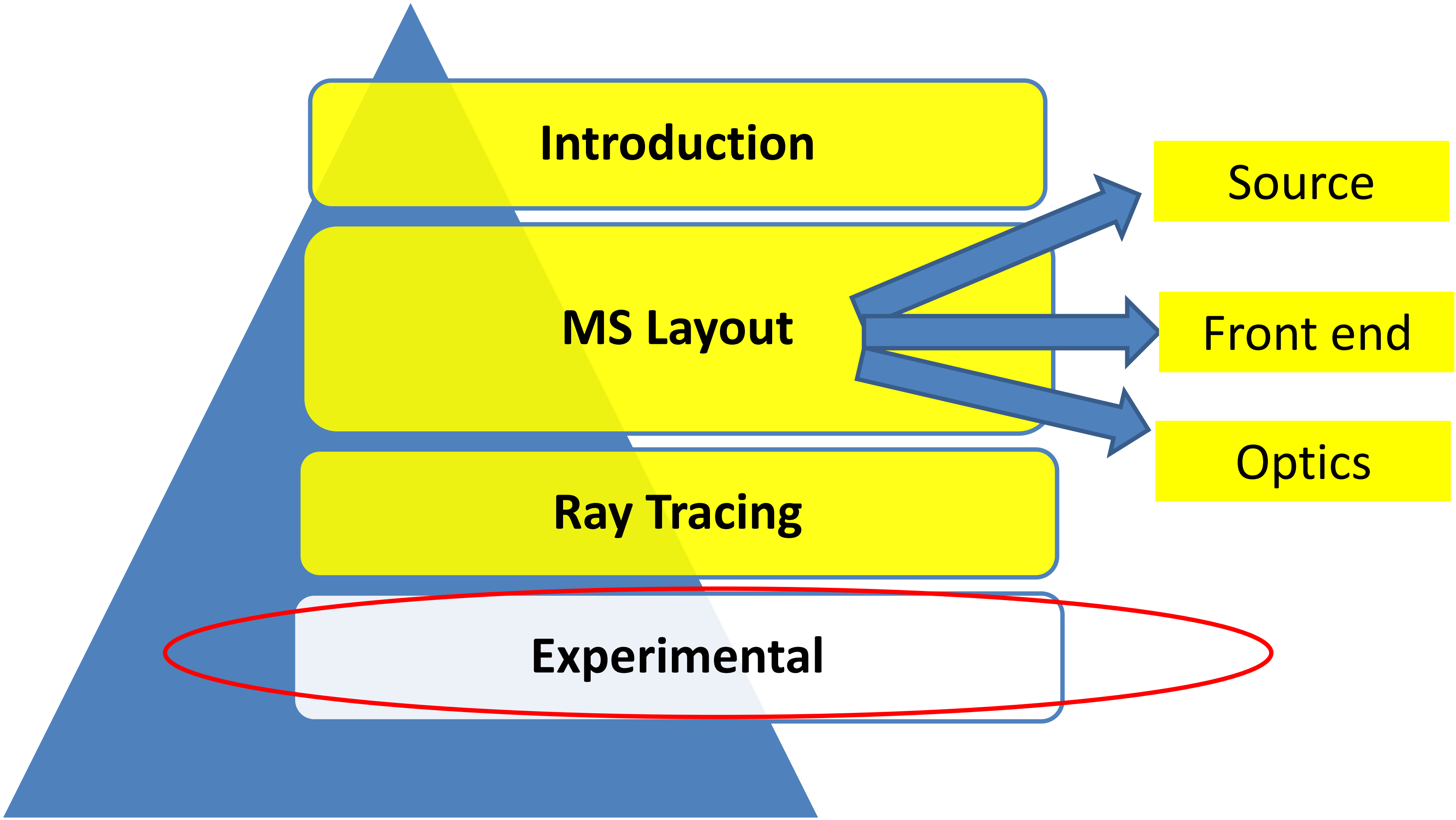








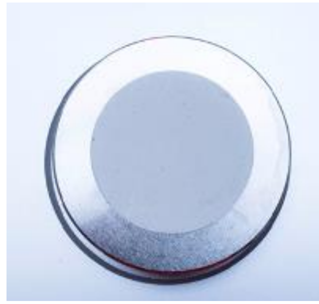
Outlines



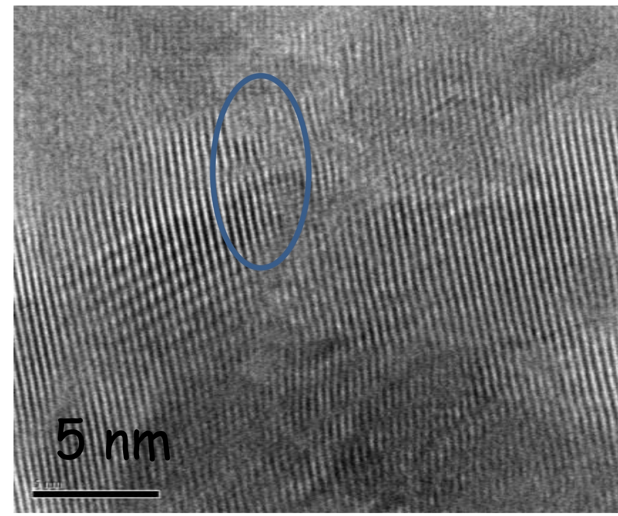
Introduction
MS Layout
Ray Tracing
Experimental
Source
Front end
Optics

Experimental main aspects?

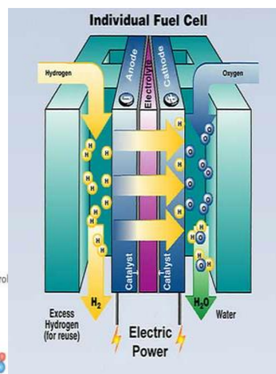
- Samples' forms

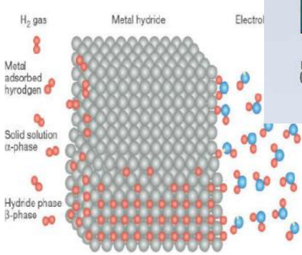


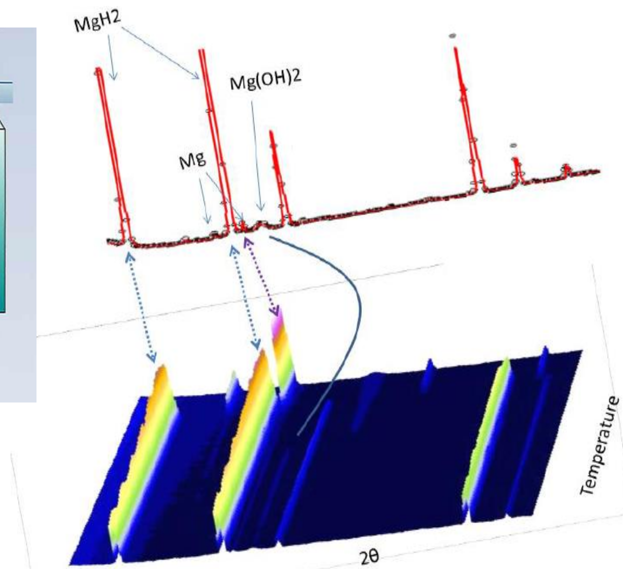
- Instrumental resolution?

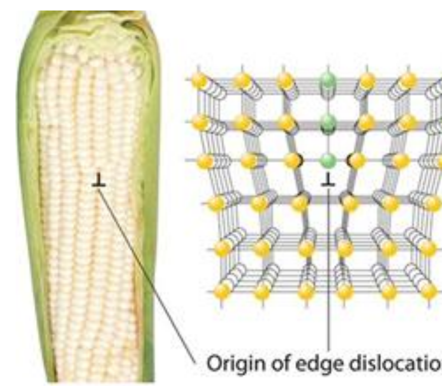


- Time?



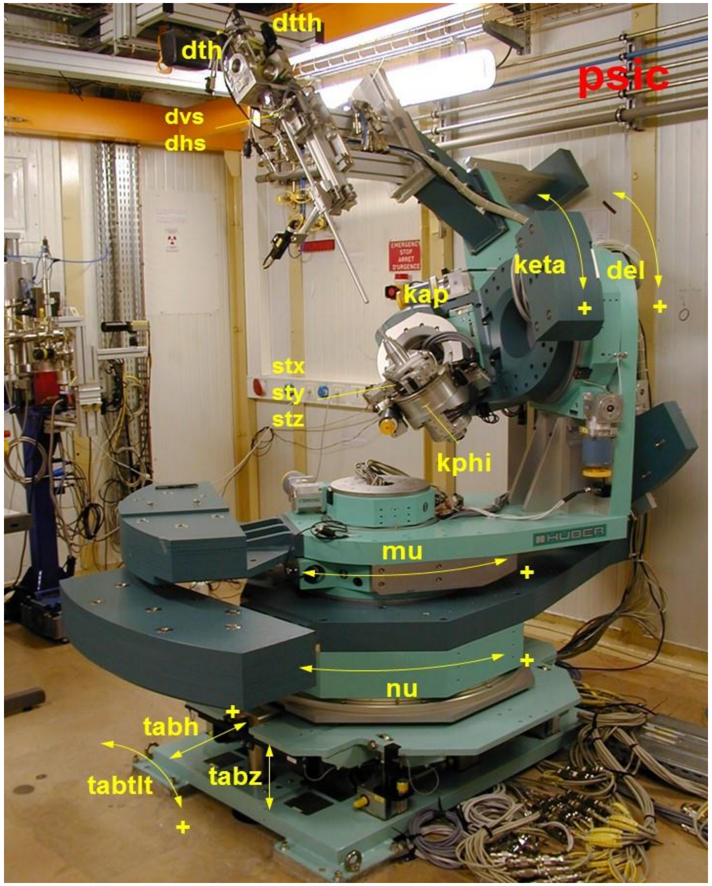


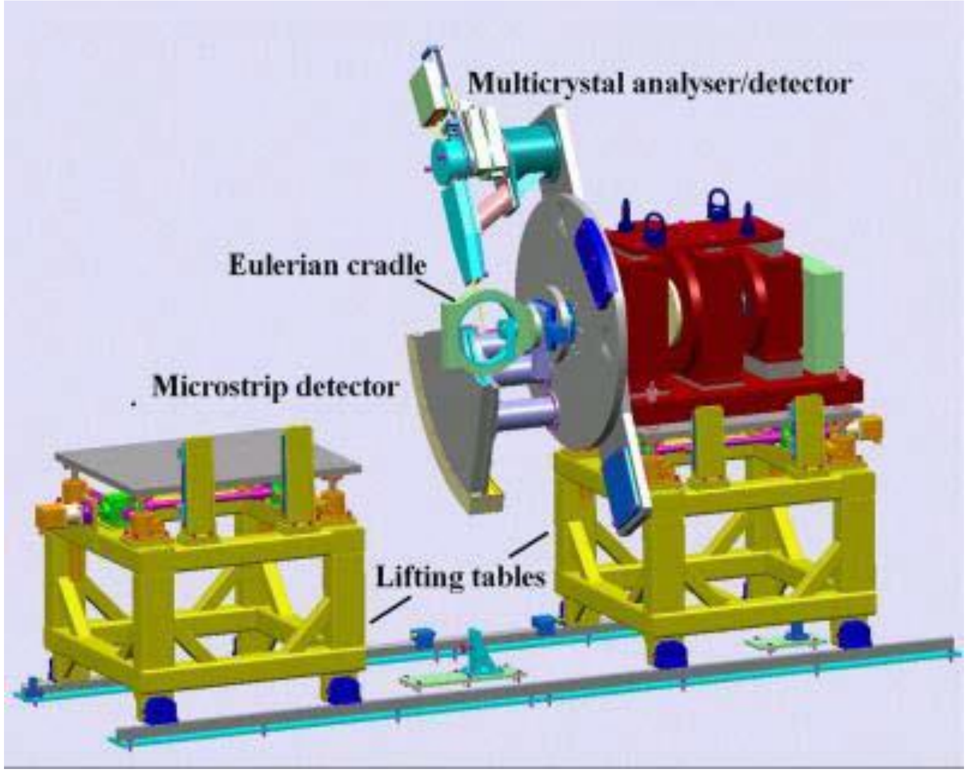




- Samples' conditions

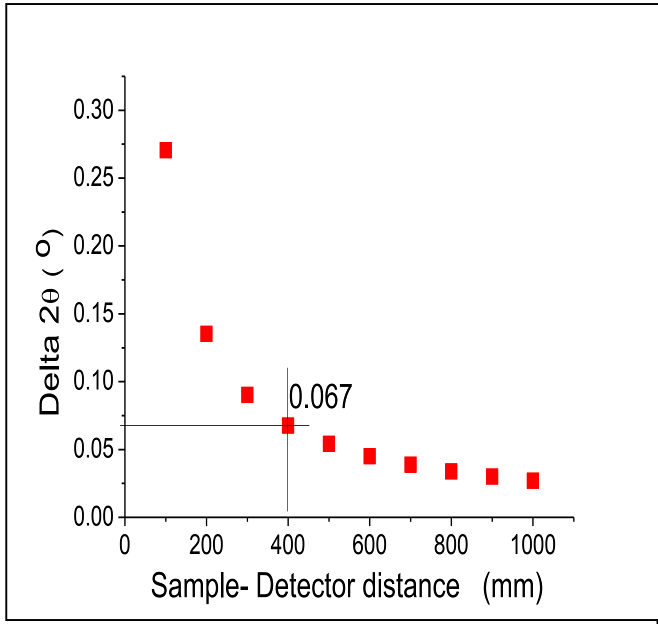
Diffractometer

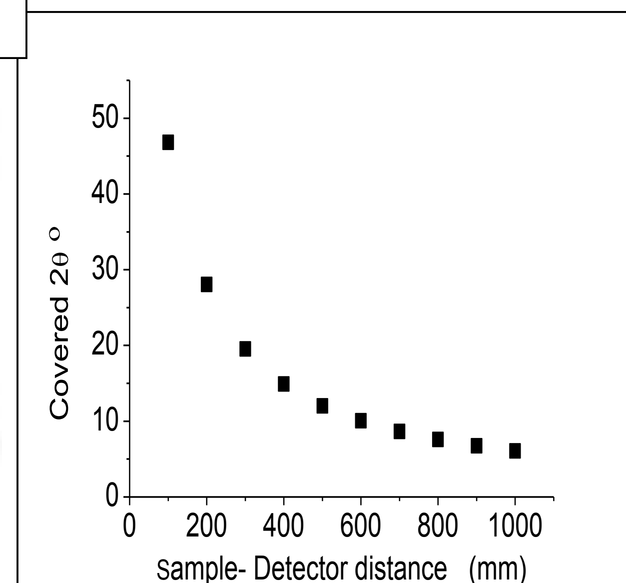




Detector I: DECTRIS PILATUS 300K

Area	83.8 × 106.5 mm²		
Pixel size	172 × 172 µm²		
Format	487 × 619 = 301,453 pixels		
Dynamic range	20 bits (1:1,048,576)		
Readout time	7 ms		
Framing rate	500 Hz		
Point-spread function	< 1 pixel		
Silicon sensor thickness	320 µm	450 µm	
Quantum efficiency*	91 %	91 %	5.4 keV (Cr)
	96 %	97 %	8.0 keV (Cu)
	37 %	47 %	17.5 keV (Mo)
	20 %	27 %	22.2 keV (Ag)
Cooling	Closed circuit water-cooling unit for temperature stabilization (23°C)		
Power consumption	30 W		
Dimensions (WHD)	160 × 194 × 262 mm³		
Weight (Detector Head)	7.5 kg		



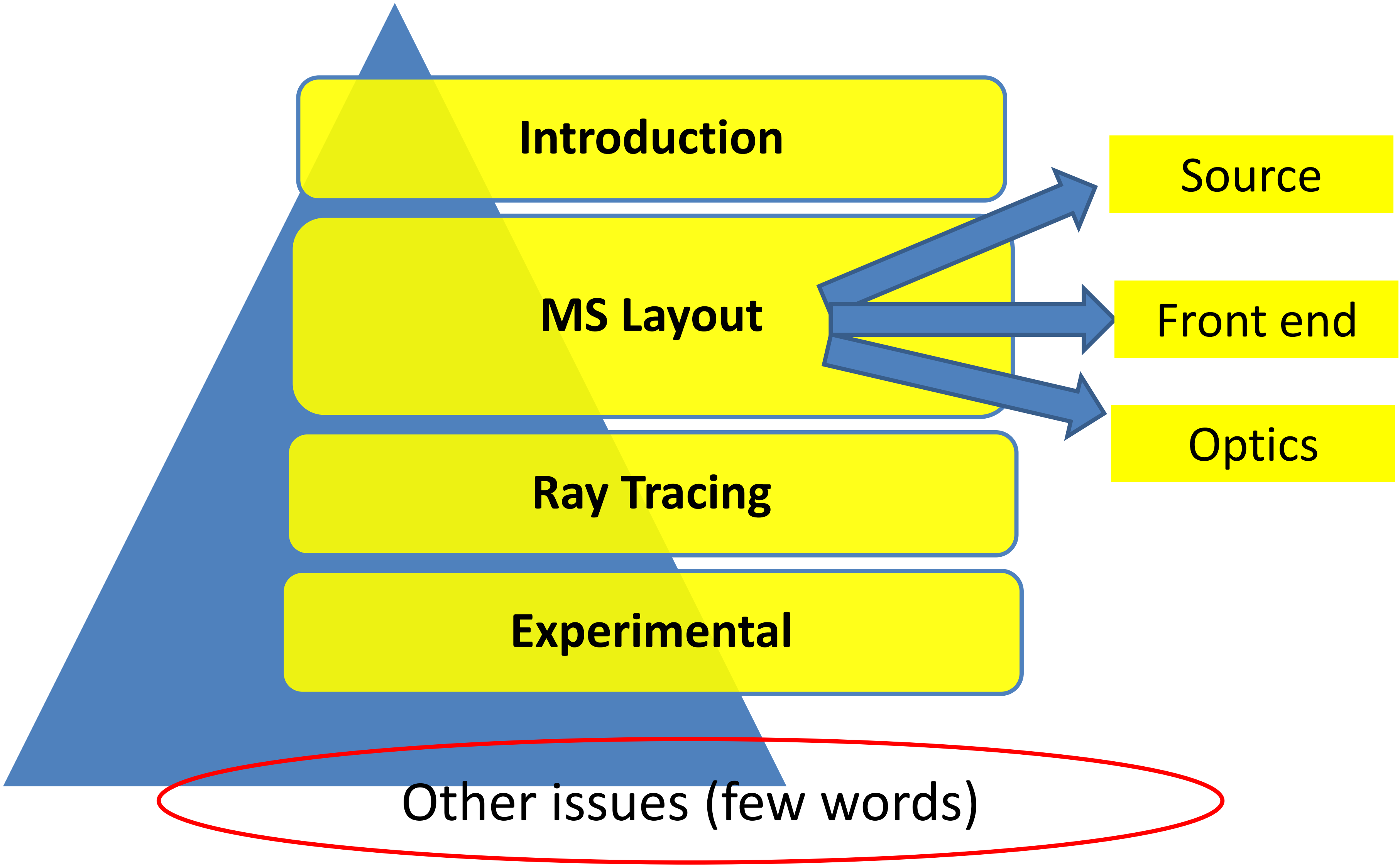


Applications:

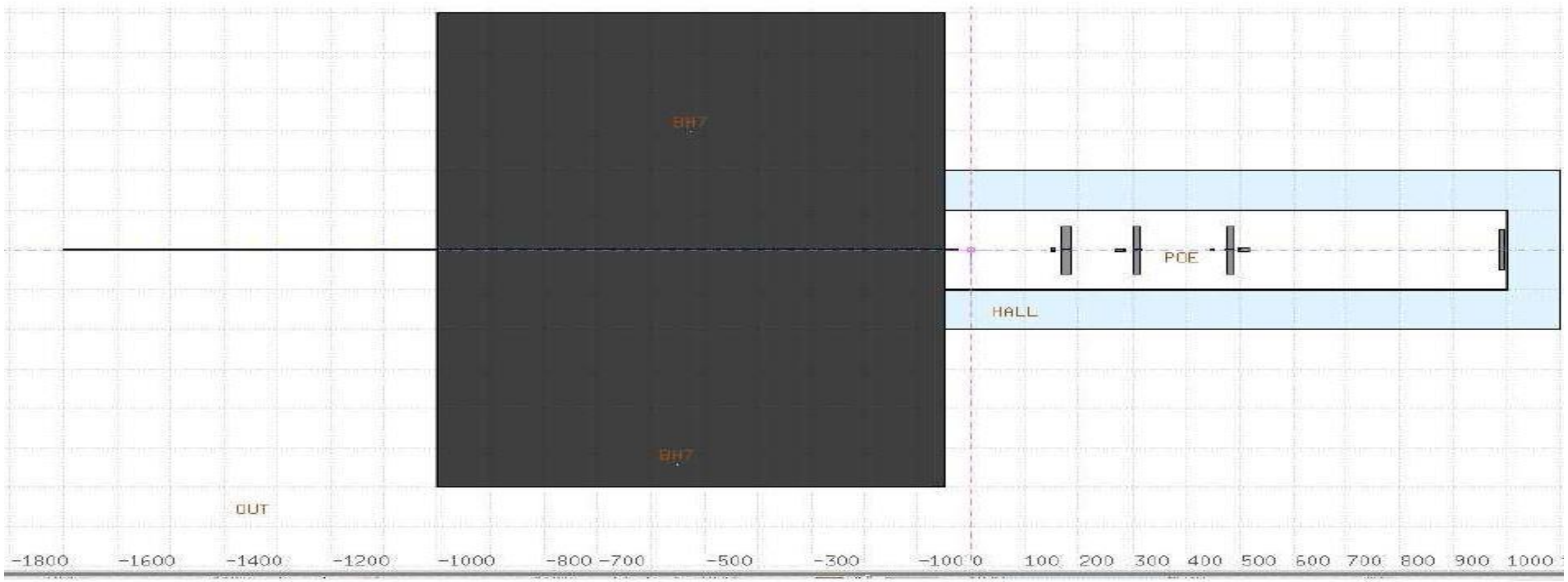
Time is main matter

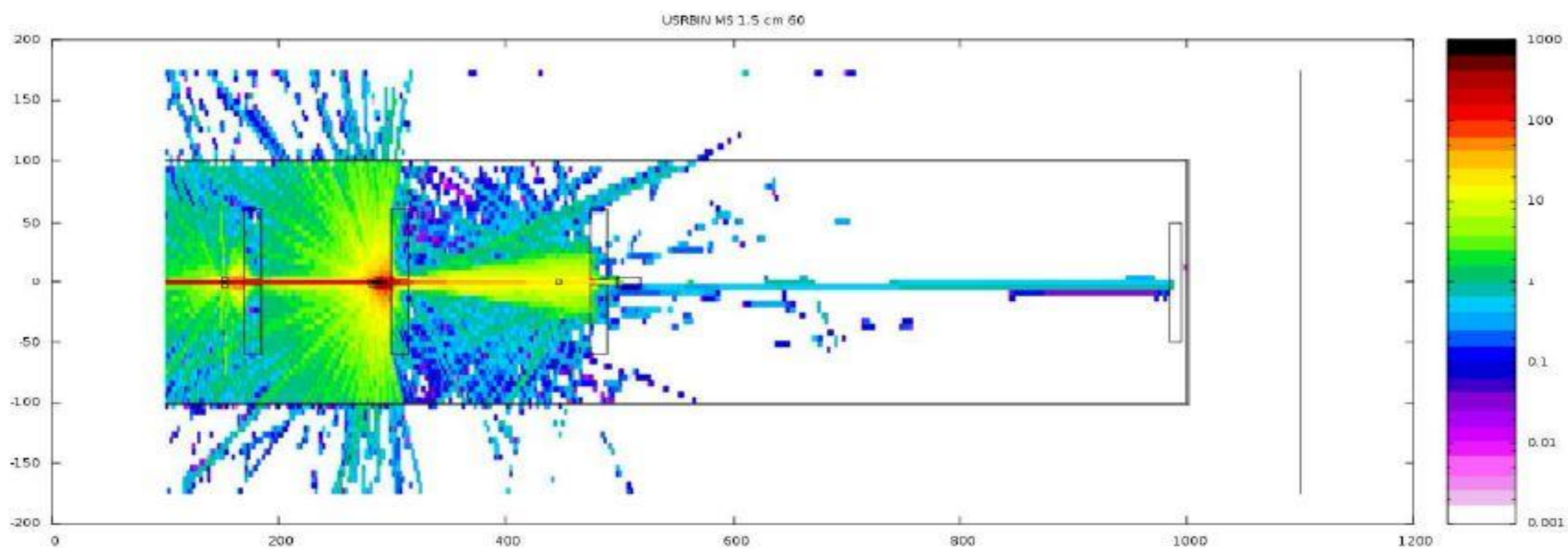
- In Situ XRD
- Single crystal diffraction

Outlines


Introduction
MS Layout
Ray Tracing
Experimental
Source
Front end
Optics
Other issues (few words)

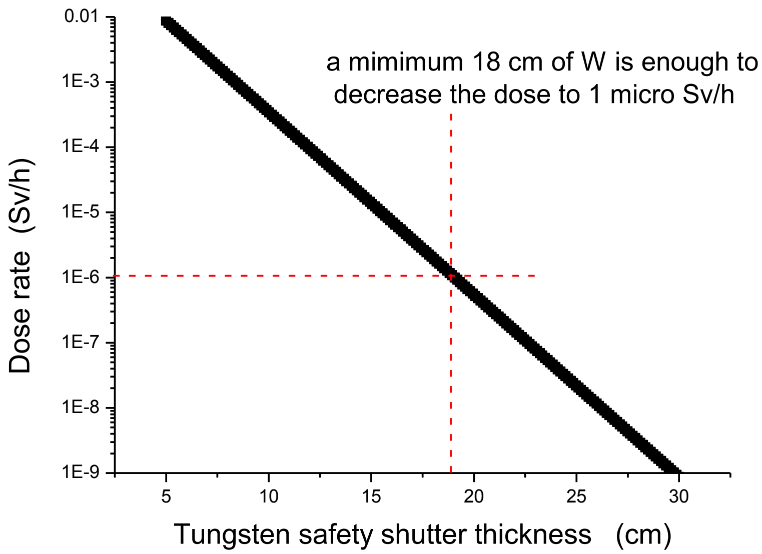
Hutches order





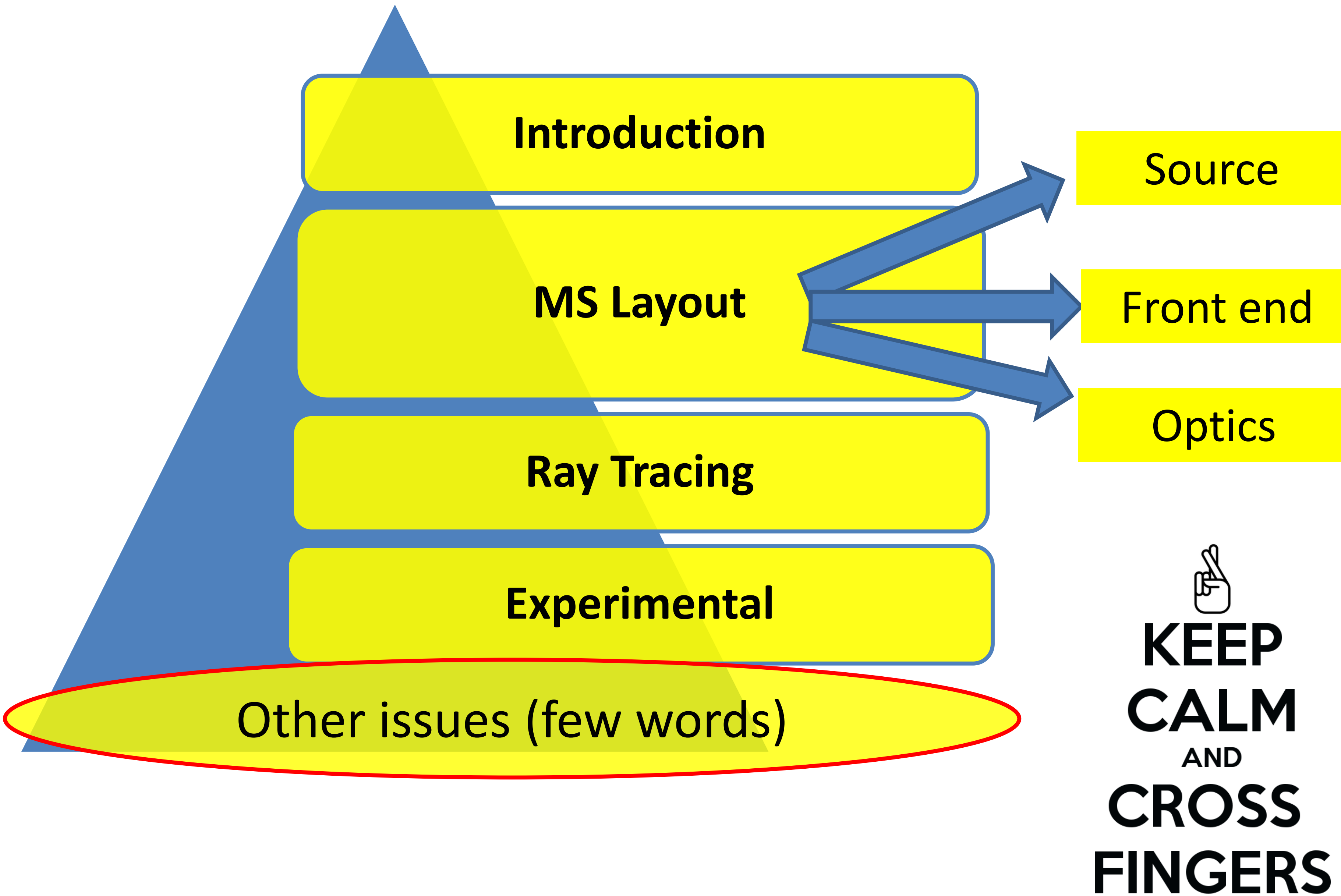
Shielding analysis results

Front end safety stopper	
Tungsten	18 cm
Optics (Pb)	
Side wall	2.5 cm
roof	1.5 cm
Back wall	6.0 cm
Additional 1 m^2	10 cm
Experimental (Pb)	
All wall	0.5 cm



Other synchrotrons with comparable energies were considered also in the final decision

Summery


Introduction
MS Layout
Ray Tracing
Experimental
Other issues (few words)
Source
Front end
Optics
KEEP
CALM
AND
CROSS
FINGERS

Acknowledgments

SESAME

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UNIVERSITÀ DEGLI STUDI DI TRENTO
Dipartimento di Ingegneria Civile e Ambientale

Prof. Paolo Scardi

Some References

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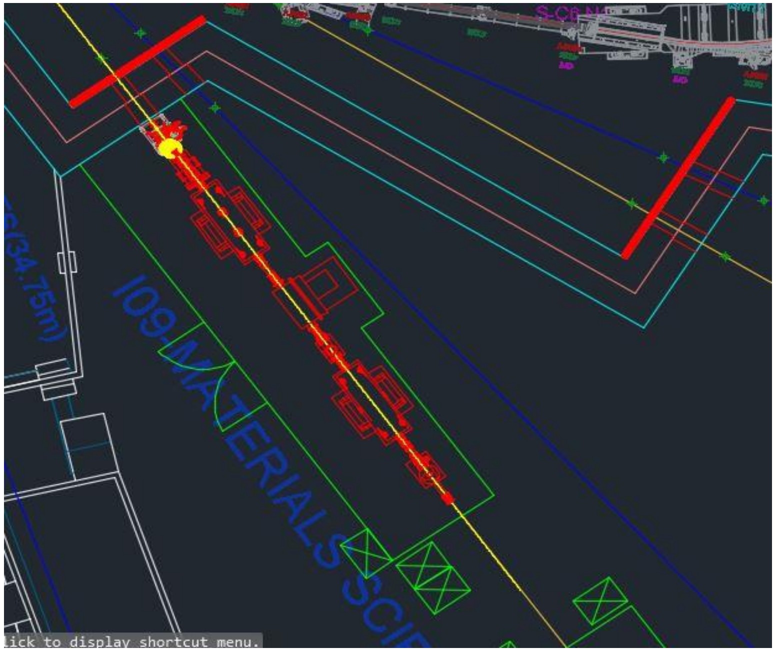
- Fabia Gozzo; Non-conventional sources I: X-ray Powder Diffraction using Synchrotron Radiation; Summer School on Structure Determination from Powder Diffraction Data Paul Scherrer Institute, June 18th-22nd, 2008.
- F. Gozzo, B. Schmitt, Th. Bortolamedi, C. Giannini, A. Guagliardi, M. Lange, D. Meister, D. Maden, P. Willmott, B.D. Patterson; First experiments at the Swiss Light Source Materials Science beamline powder diffractometer; Journal of Alloys and Compounds 362 (2004) 206–217

$$flux\_at\_sample(E) = flux(E) \cdot Efficiency(E) = flux(E)^{SPECTRA} \cdot \frac{\Delta E_{SOURCE}}{0.001 \cdot E} \cdot Efficiency(E)$$

This quantity is expressed in photons/s. In our example we have the following values:

Energy	ΔE_{SOURCE}	Efficiency	Flux Spectra (ph/s/0.1%BW)	Flux at sample (ph/s)
15000	20	0.04334	3.567e+14	2.02406e+13


HUBER
iiyama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