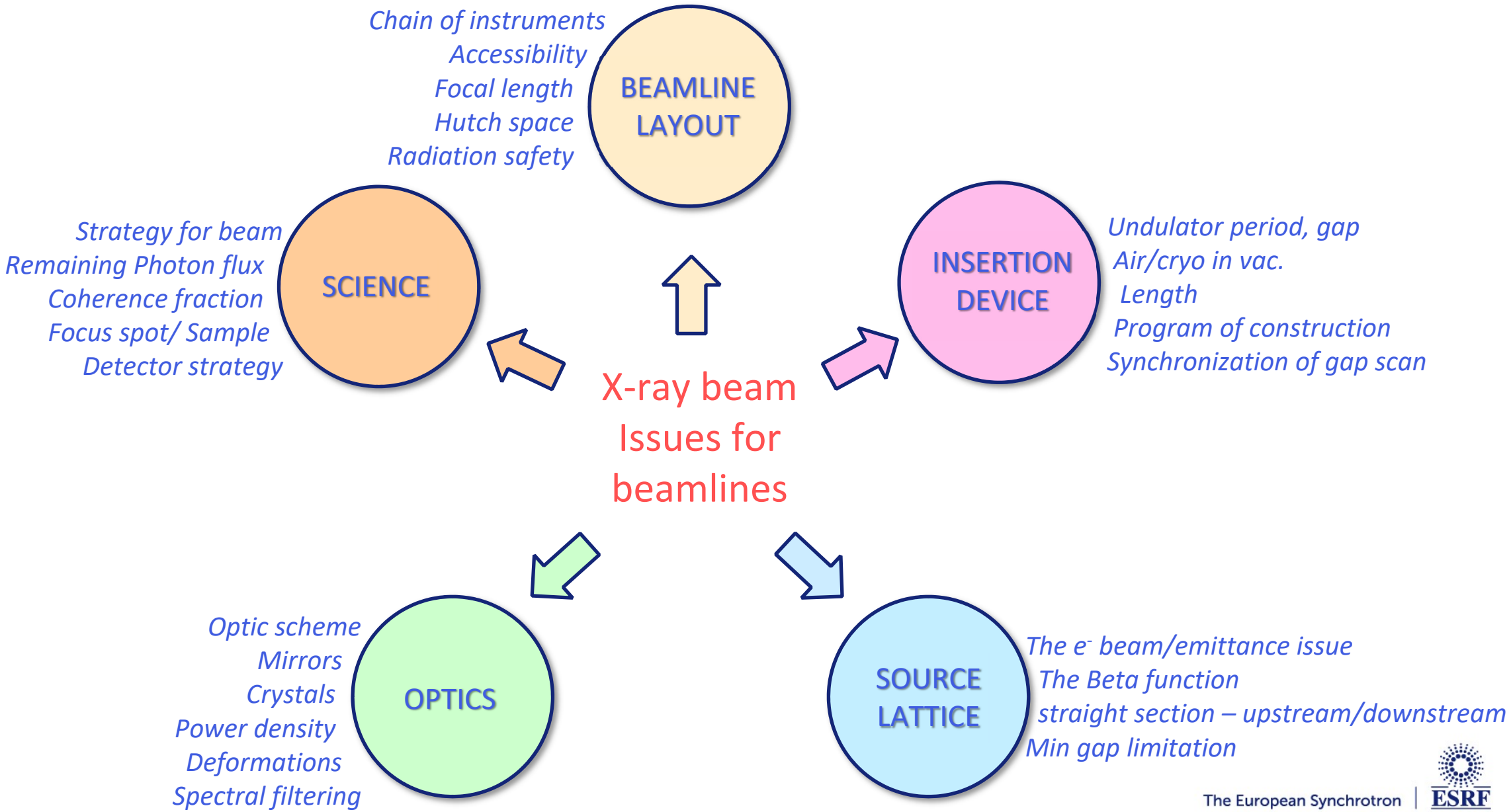
A new X-ray beam for the ESRF beamlines

Y. Dabin
R. Barrett
S. Jarjayes
M. Sanchez del Rio

Outline

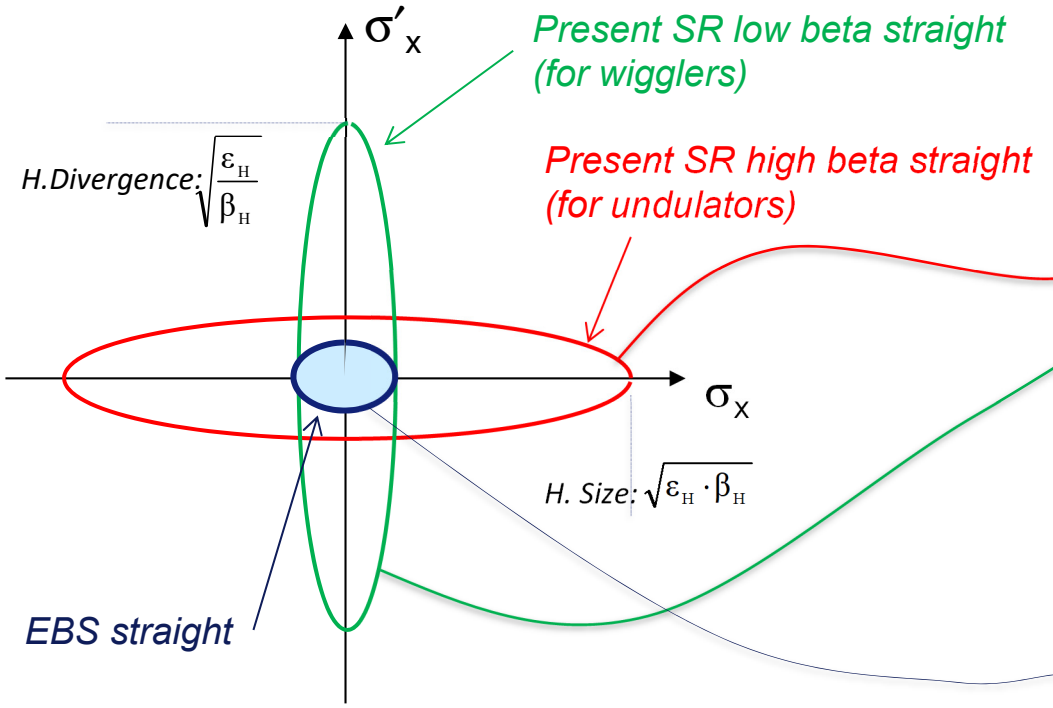
- The beamline as a system
- The emittance issue
- Dealing with the k parameter
- The coherence issue
- A process of reviewing optics parameters
- OASYS : a calculation tool
- The High heat-load issue
- Where are my bending magnets?
- Conclusion

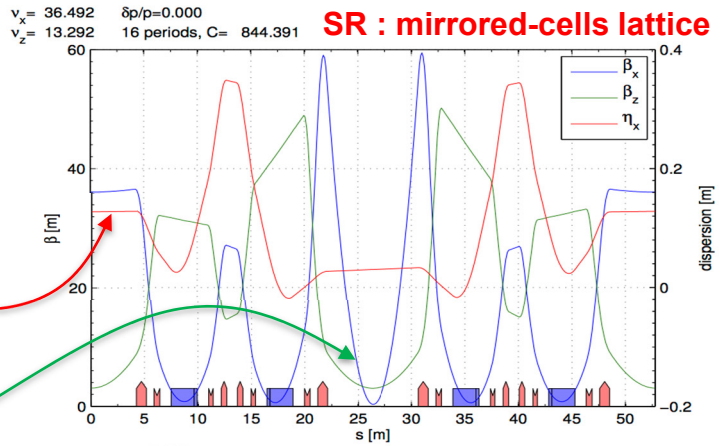
OPTIMISING BEAM ISSUES FOR THE BEAMLINES

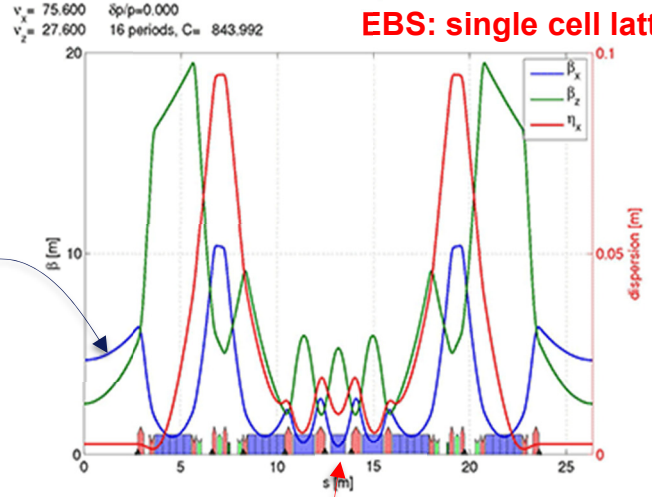


BEAM …..SMALLER …AND …SMALLER

The electron emittance ellipse at the centre of straight section







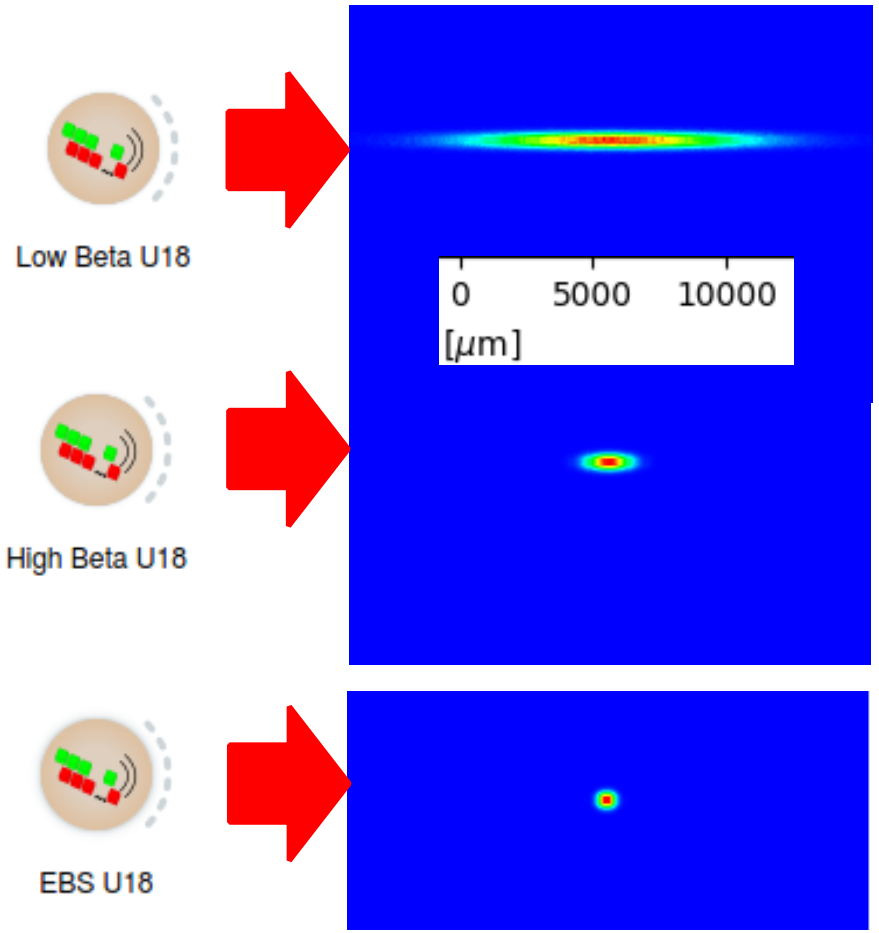
Possible bending mag beamline

The new EBS source is a compromise to smaller beam size….
EBS orbit optimises the Hor emittance → low size s, low divergence s'

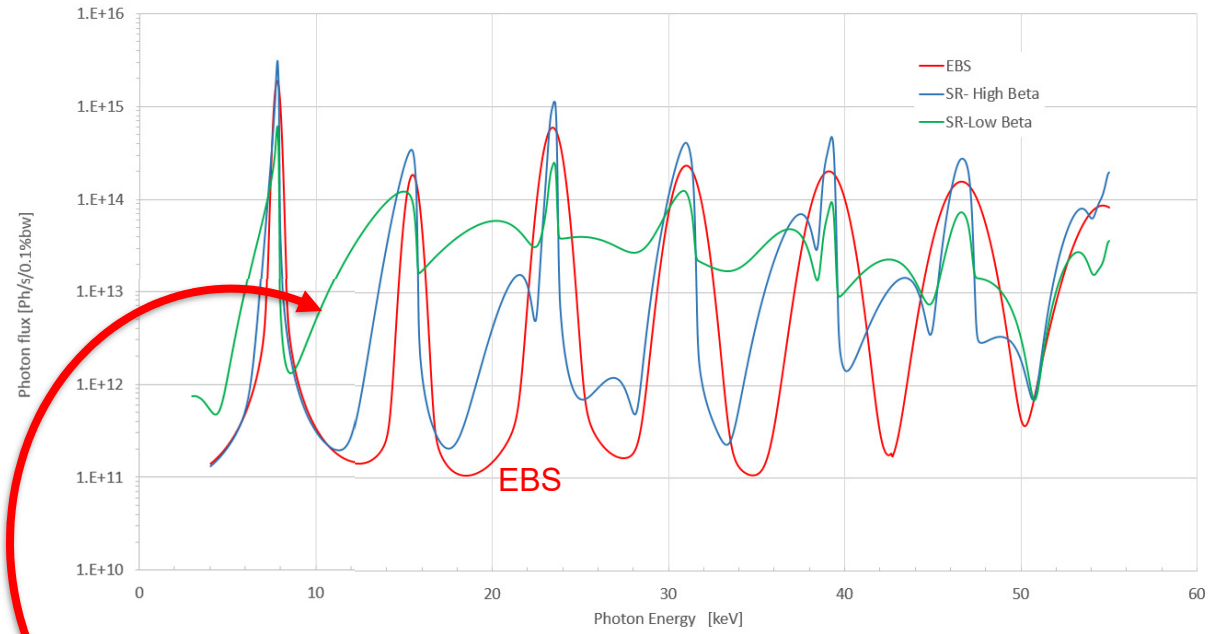
e_{SR} (H/V) ≈ 4000/4 pm-rd
e_{EBS} (H/V) ≈ 147/5 pm-rd
} Factor 1/30

EBS – ESRF U18 2m @ 8 keV L=2m observed at 30m

The beam is a big change for ½ ESRF beamlines (those with large divergence)



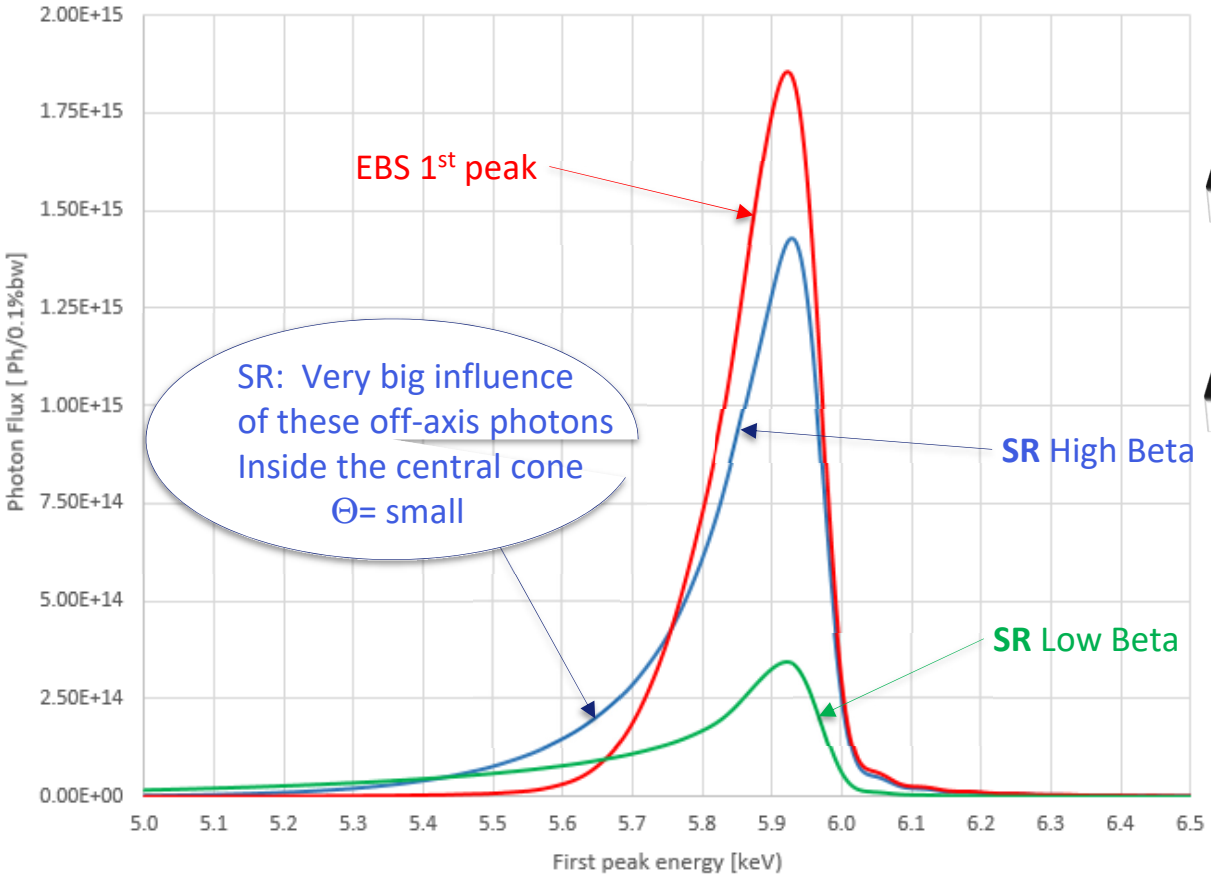
Simulation: CPMU 18 -4m – k1.68



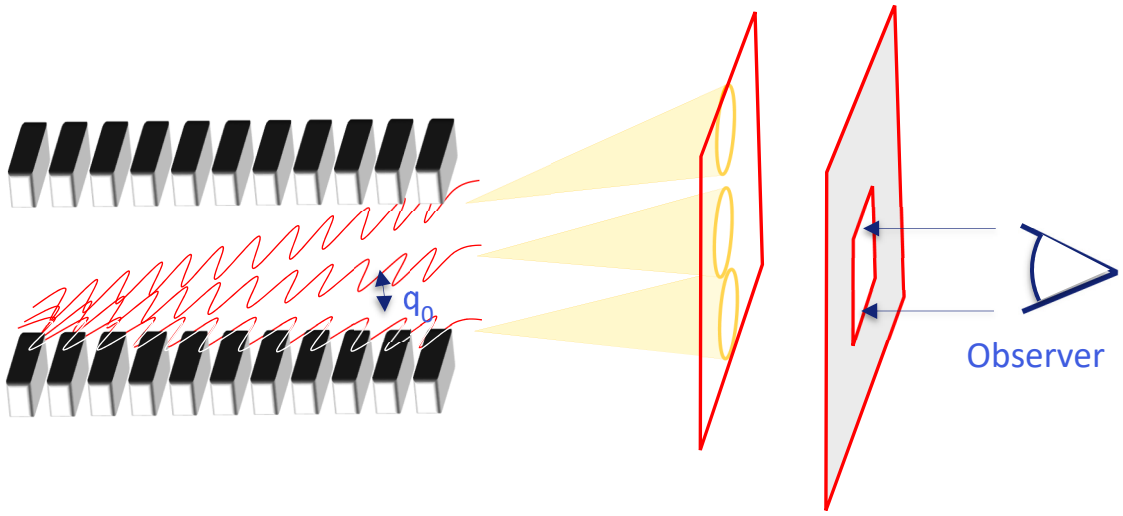
SR-Peaks are not symmetric – off axis electron radiation….

TROUBLES WITH THE UNDULATOR PEAK

Example of a U22-90 periods-k=1.79 for SR and EBS HxV: 1x1 mm^2



EBS : "Less" off axis radiation



$$E_{ph} = \frac{h_{Planck}}{\lambda_{ph}} \qquad \lambda_{ph} = \frac{\lambda_u}{2\,\gamma^2}\left(1 + \frac{K^2}{2} + \gamma^2\theta_0^2\right)$$

Out of axis where q_0 = e wavelength l_{ph} extends a little → lower energies

γ Lorentz factor

K deflection parameter

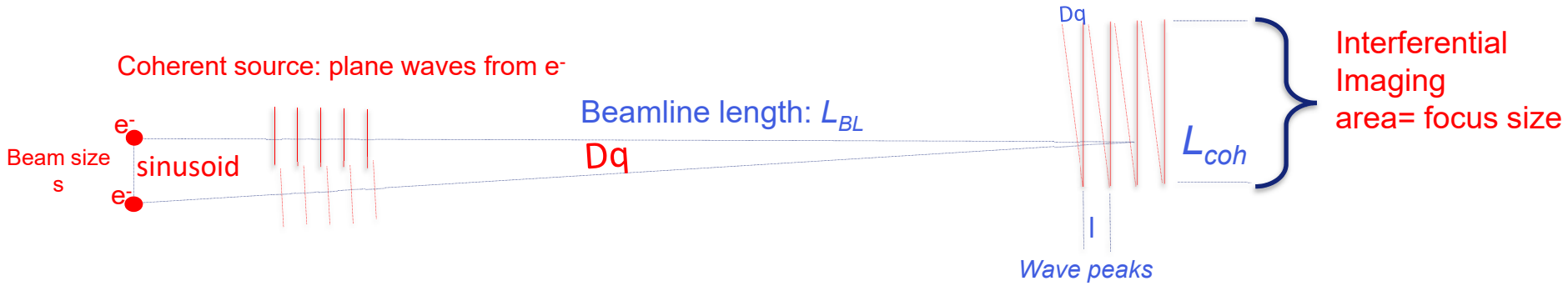
On axis $q_0 = 0$

A. Hofmann, The Physics of synchrotron radiation

K. Wille, JUAS Lecture - Synchrotron Radiation

GENERAL TREND FOR UPGRADES TO OPTIMIZING COHERENCE (SR CASE)

The transverse coherence issue: most of the coherent imaging mode



Multi-modal imaging:

- Absorption contrast imaging (Tomography)

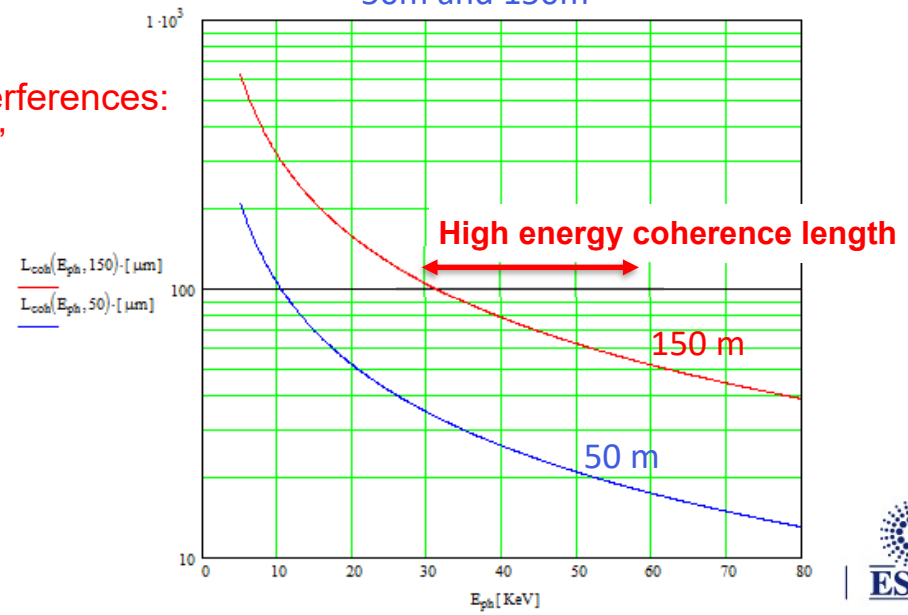
- Transmission Microscopy (zone plate /KB focusing)
- Phase contrast imaging
- Coherent diffraction imaging
- Holography
- Ptychography

All of them exploiting interferences:
"Phase contrast retrieval"

$$L_{coh} = \frac{\lambda\, L_{BL}}{2\, s}$$

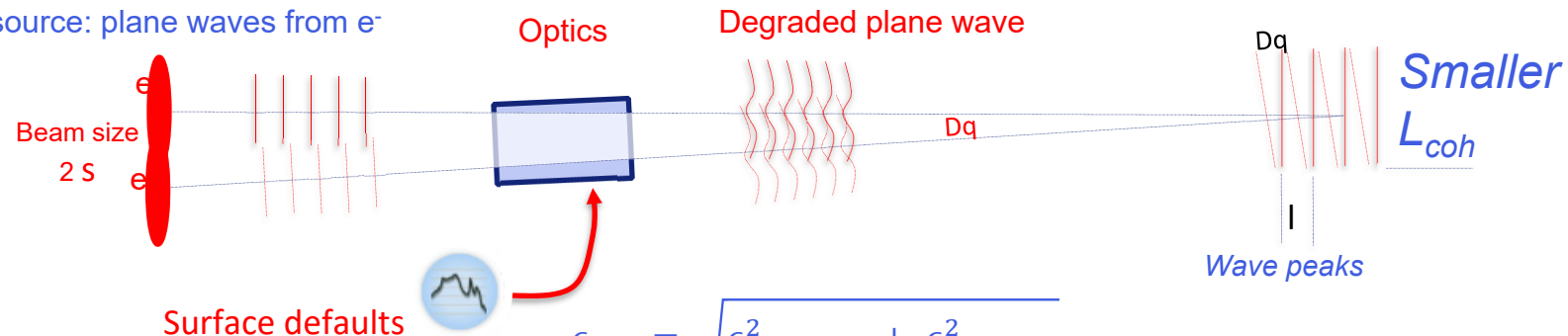
L_{coh}: Coherence length
s: source size
λ: Photon wavelength
L_{BL} beamline length

Coherence length
With two BL lengths
50m and 150m



STORAGE RING : KEEPING HIGHER DEGREE OF COHERENCE

Coherent source: plane waves from e-



$$\epsilon_{rms} = \sqrt{\epsilon^2_{Polishing} + \epsilon^2_{Thermal}}$$

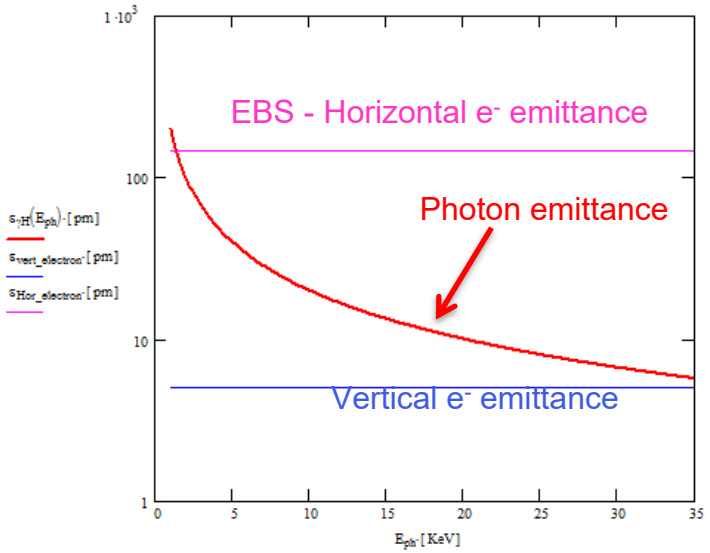
Severe limitation

Smooth figuring

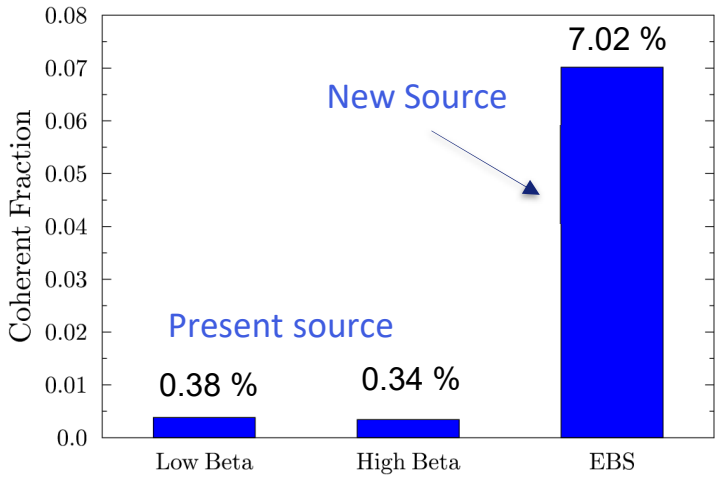
Gaussian photon beam emittance

$$\epsilon_\gamma = \frac{\lambda_{ph}}{4\,\pi}$$

The best is when e- emittance ≤ photon emittance

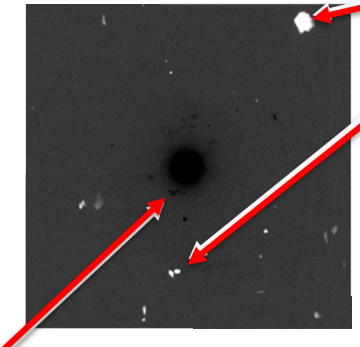


Theoretically partial Hor coherence should be ~10% beam

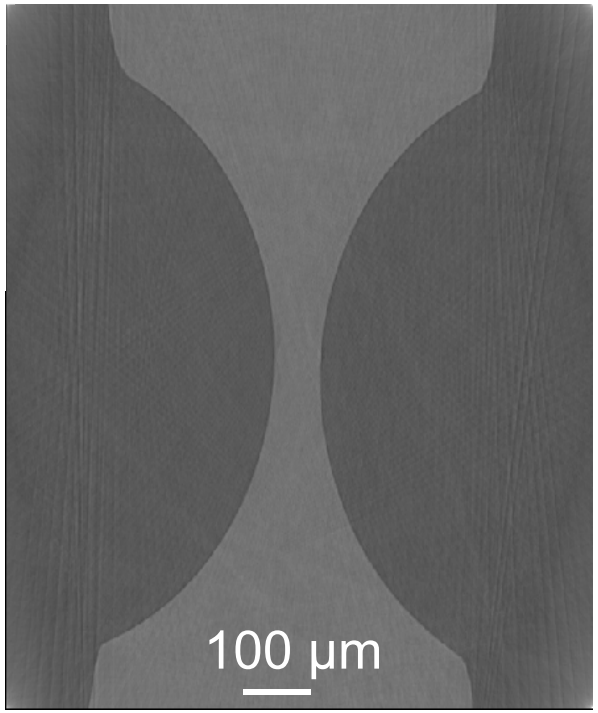


DIFFRACTION CONTRAST TOMOGRAPHY AND MECHANICAL ENGINEERING !

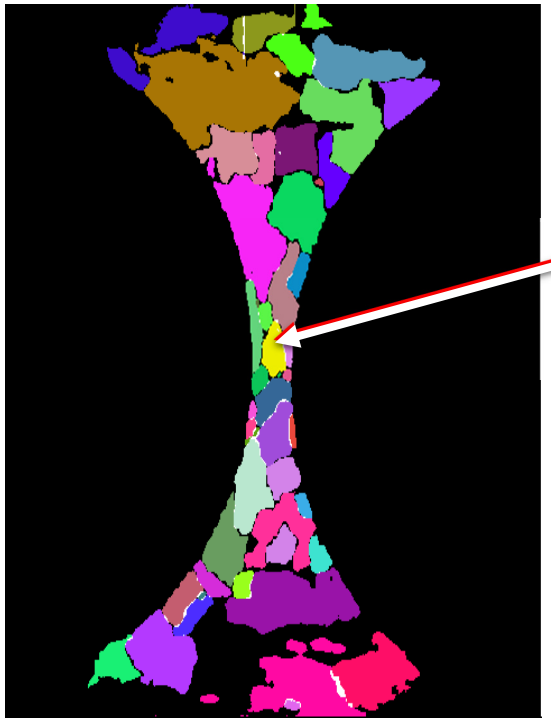
LAUE spots at the CRL focus: monochromatic grains



focus center



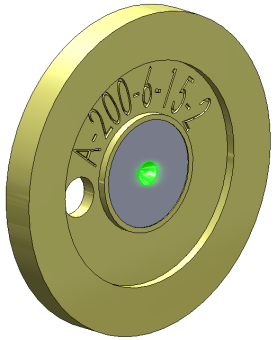
Absorption CT of punched Al lens

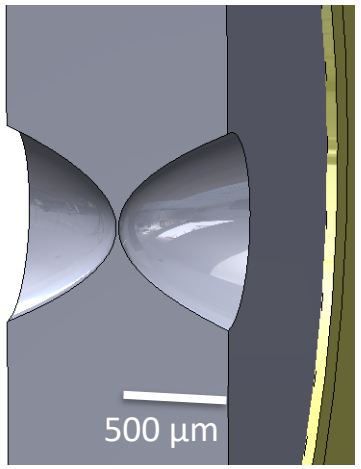


DCT reconstruction

Mono-crystals
Randomly oriented
They are weakly deformed

Dynamic recrystallization
Due to quick deform. (2 s)
Fast warm-up (400°C?)
We inquire !
Design of machine with Controlled velocity



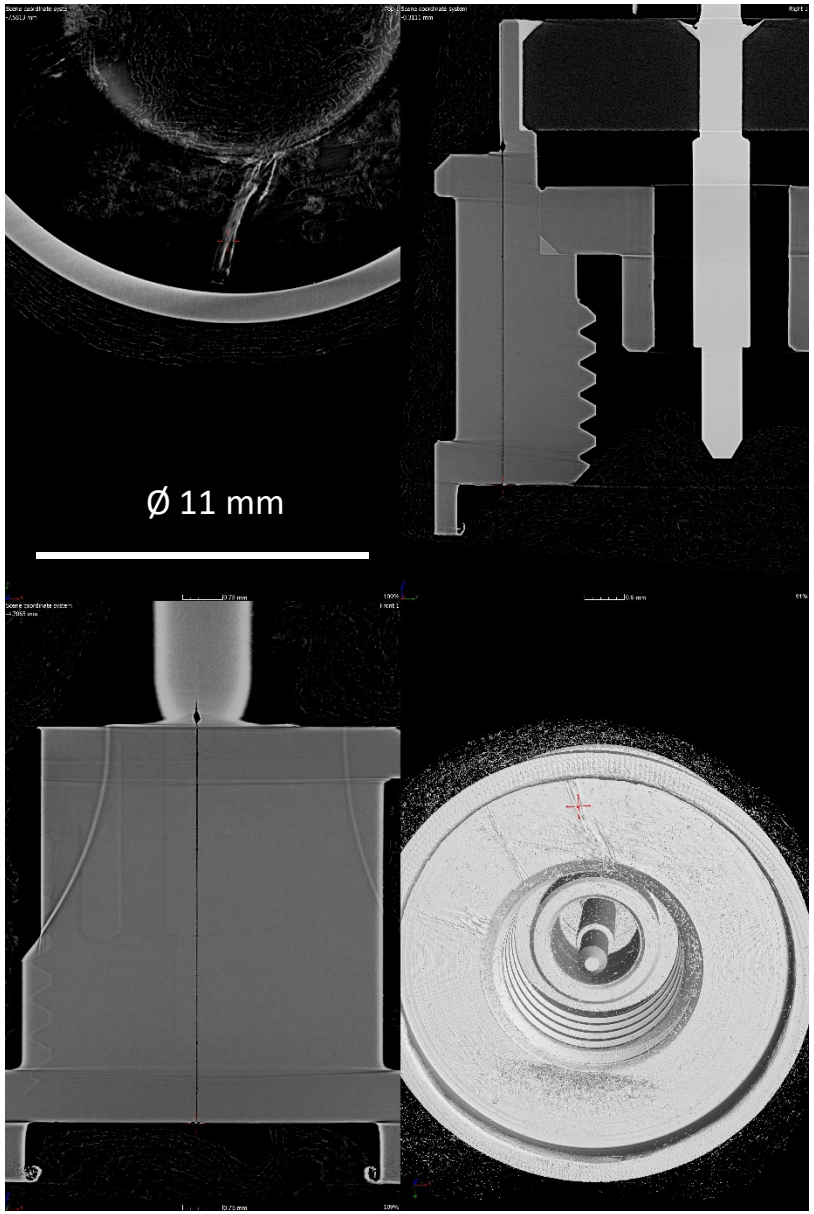


ESRF In-house CRL
Parabola Radius
200µm web:15 µm

"Adiabatic "deformation
2 sec. "smooth punch" → *At present 10 sec. deformation*

Imaging at ESRF-ID11 – 10 KeV L_{BL}=130 m - courtesy Wolfgang Ludwig-ESRF/MATEIS-INSA

A LEAKY BPM BUTTON TOMOGRAPHY



Tomography of a leaky
BPM button performed at the ESRF
Courtesy Paul Tafforeau ID19

(1 night scan – 20 buttons)

A WHITE BEAM CALCULATION PROCESS WITH BEAMLINE SCIENTISTS

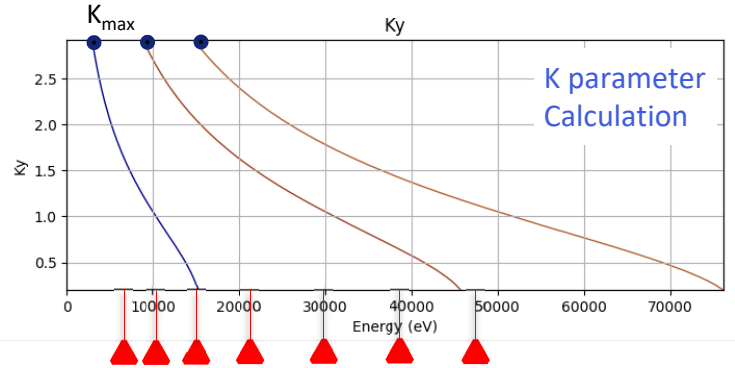
Beamline scientific program

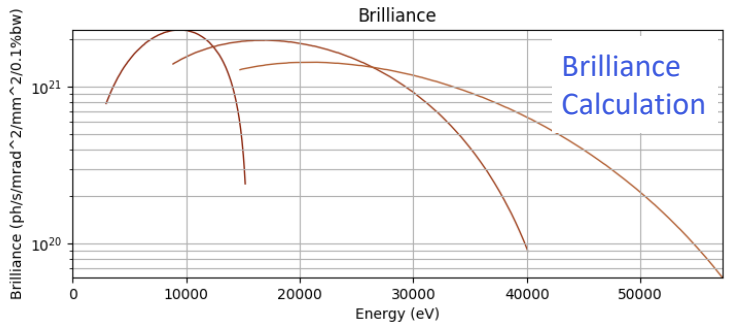
Beamline strategic energies and modes
Beamline optical scheme
Layout (distances), types …

ID group proposal
And program-
Time schedule

Second-hand Undulators market !

Undulator known
E_i check
-
E_1-E_2…E_{ph} list→
K computing
Harmonic evaluation





ID source in Oasys
or
ID spectrum test
Power evaluation
Spectrum filtering
evaluation

Attenuation/
Spectral filtering
With mirrors

Power issues
And crystal distortion

Limit
Of the white beam

Pink beam
Experiment no limit
(High energy BL)

Full beamline Model
Beam quality Analysis
Experiment testing

SMALLER STRAIGHT SECTION – LESS FLEXIBILITY FOR UNDULATOR PLACE

Low Beta
(large divergence)

BL with bigger change

BL with lesser change

High Beta
(small divergence)

Present machine:
6 m straight section

		15/2/2018: BL global BL thermal issue							
		U source-2017				U source-2020 plan			New U source policy-2023
		upstream	waist	downstream					
UPBL01	ID01	U35	UR27/35	U27		U35	UR27/35	U27	
	ID03	U35	U35	U32		U35	U35	U32	
UPBL9B	ID09	U27	IV17			U27	IV17		
	ID11	IV18	IV22			IV18	IV22		
	ID13	U35	IV18			U35	IV18		
phase 1 Ref	ID15	IV22-2.0	IV20-2.0			IV18-1.5	IV76-0.45	U20-2	
	ID17	W125	W150			W125	W150		
	ID19	UR13/32	W150	UR17.6/32		UR13/32	W150	UR17.6/32	
phase 1 Ref	ID21	U32	U42	U42		U27?	U42	U42	
	ID23	U20.2-1.6	U35-1.63			U20.2-1.6	U35-1.63		
	ID27	IV23	IV23			IV23	IV23		
	ID29	U35	IV21			U35	IV21		
UPBL02	ID31	IV14.2				IV14.2			
UPBL09A	ID02	U35	U21.4	U21.4		U35	U21.4	U21.4	
	ID06	IV18	U27		Extended Straight section	IV18	U27		
	ID08								
phase 1 Ref	ID10	U35	UR27/35	U27		U35	UR27/35	U27	
	ID12	HU42	HU52	U38		HU42	HU52	U38	
	ID14								
UPBL04	ID16A	UR22.4/18.3	UR22.4/18.3			U22.4-2.3	U18.3-2.3		Canting becomes more difficult
UPBL04	ID16B	IV26				U26-2.0			
	ID18	UR27/20	UR27/20	UR27/20		UR27/20	UR27/20	UR27/20	
UPBL06	ID20	U26	UR32/26	UR32/26	UR26/32	UR32/26	UR32/26	UR26/32	
	ID22	UR19/35	U23			UR19/35	U23		
UPBL11	ID24	U27	U27	UR27/32	U32	U27	U27	UR27/32	
	ID26	U35	U35	UR27/35		U35	U35	UR27/35	
Side branch	ID28	UR32/17.6	UR32/17.6	UR32/17.6		UR32/17.6	UR32/17.6	UR32/17.6	
UPBL10	ID30	U21.2	U21.2	U35	U35	U21.2L	U35L		
UPBL07	ID32	HU88-1.6	HU88-1.6	HU88-2.5		HU88L-2.1	HU88-2.5		
	BM23	std dipole	0.9 mrd			new dipole			
	BM18					3PW-106-g17.5-1.75 mrad			
	CRGs								

BL policy
With review
panel

x30 Brilliance with
New source
(length ~beta :5.2m)

CPMU18 4m-IV
CPMU14 4m-IV
U35 4.8m
U42 3.2m
HU88 4m
W150 1.6m

Next EBS
5,5 m straight section

OASYS …A SIMULATION TOOL FOR A FULL BEAMLINE

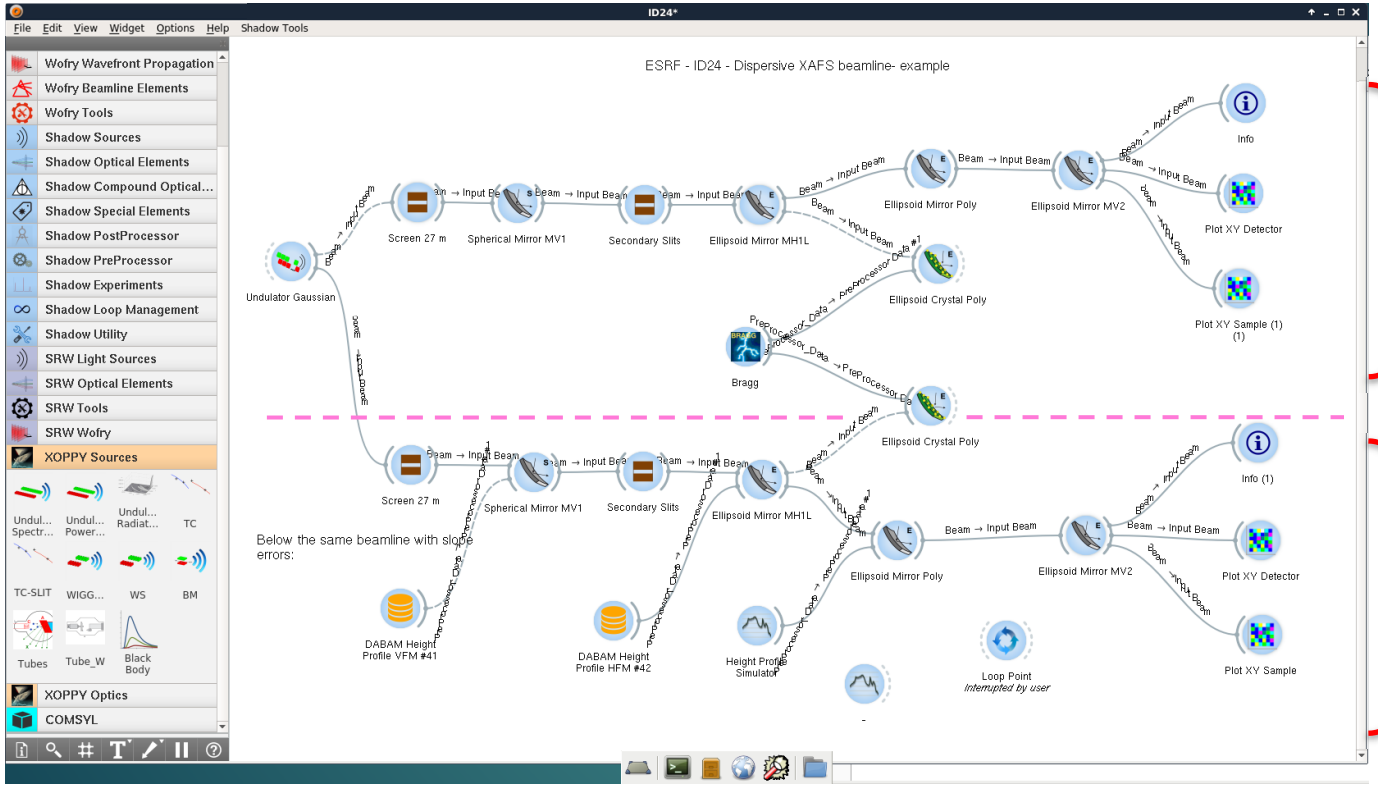
OASYS : OrAnge SYnchrotron Suite

Orange: data software
Ljubljana university

→ Collection of module automatically linked
SRW, SHADOW, XOP, COMSYL,Wolfry

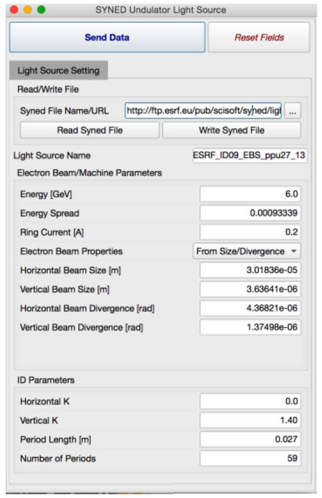
→ Designed by Manuel Sanchez del rio, ESRF and Luca Rebuffi, ELETTRA

http://www.elettra.eu/oasys.html

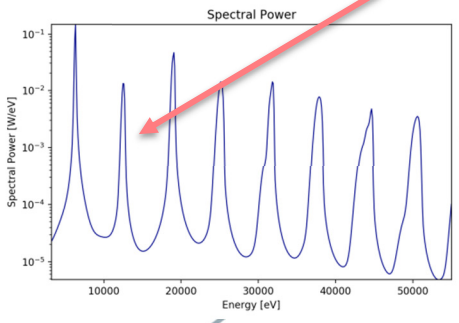


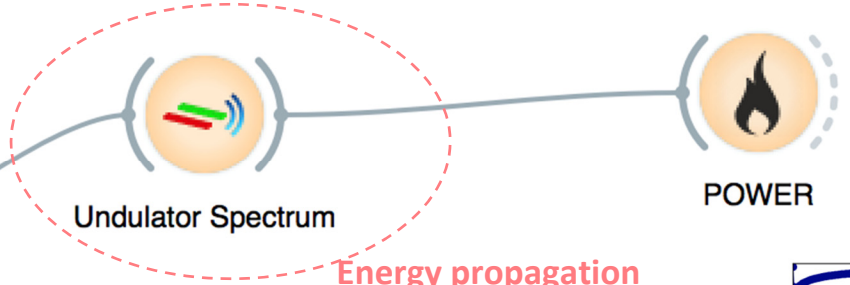
Ideal Beamline model

Real model with Optics Disturbance simulations

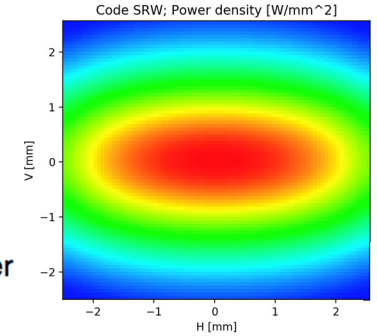


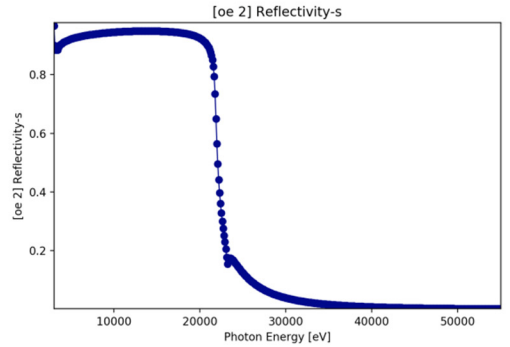
Spectral analysis



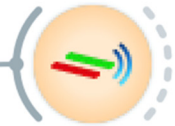


Energy propagation analysis





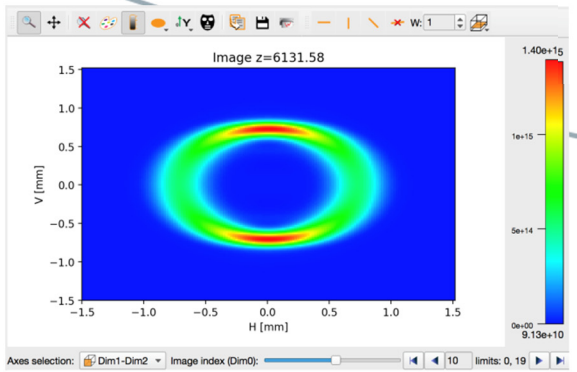
SYNED Undulator Light Source



Undulator Power Density

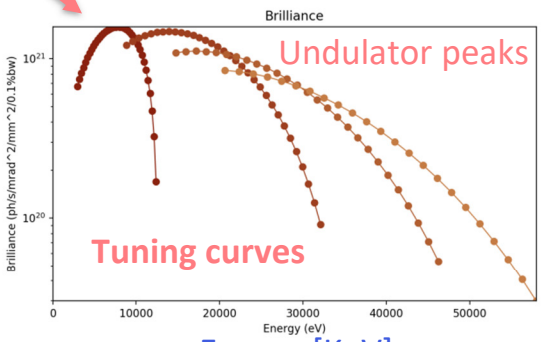
OASYS : OrAnge SYnchrotron Suite

Spatial distribution analysis



Undulator Radiation POWER3D

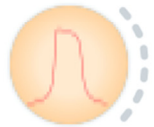
K strategy analysis



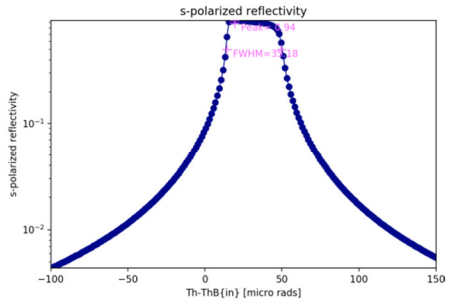
Brilliance

Energy [KeV]

TC



CRYSTAL

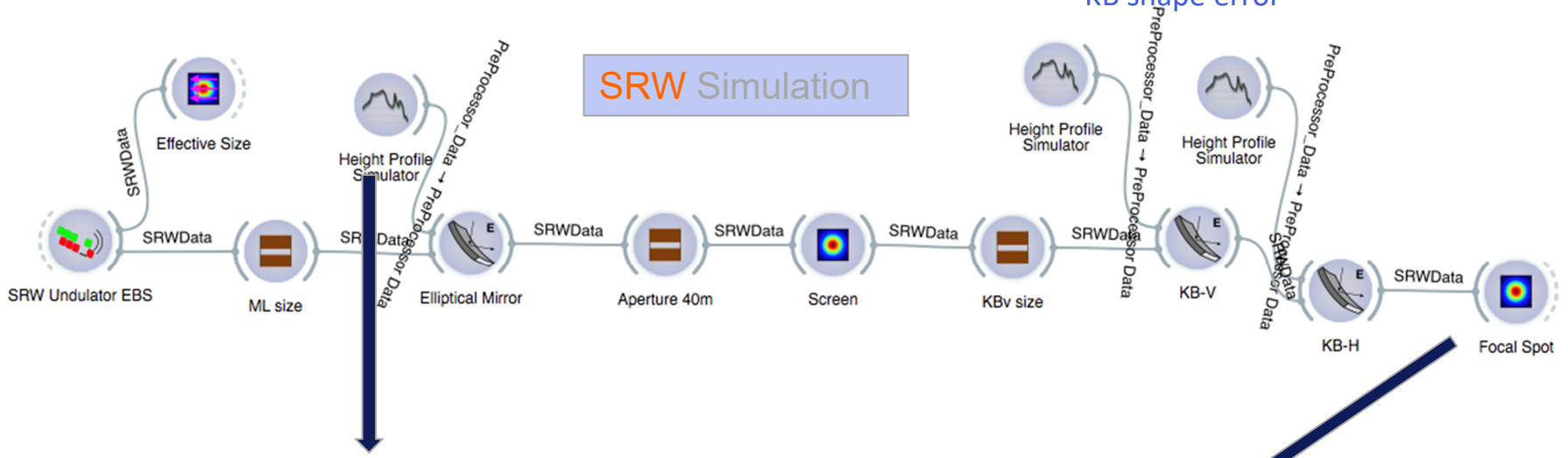


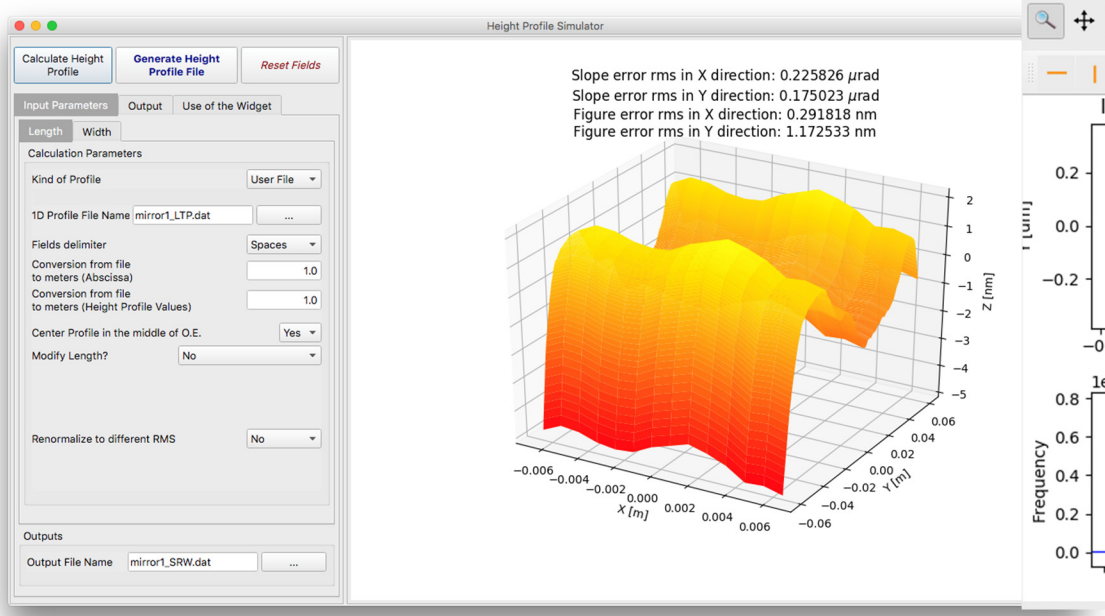
Orange: data software
Ljublijana university

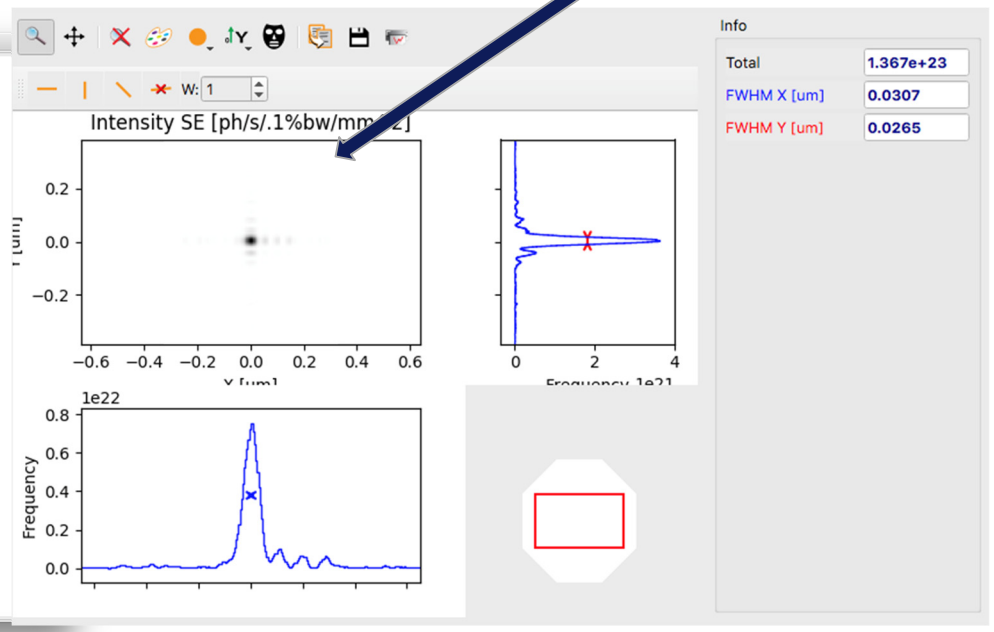
HARD X-RAY NANO-FOCUSING BEAMLINE @ LOW EMITTANCE STORAGE RING

KB shape error

SRW Simulation

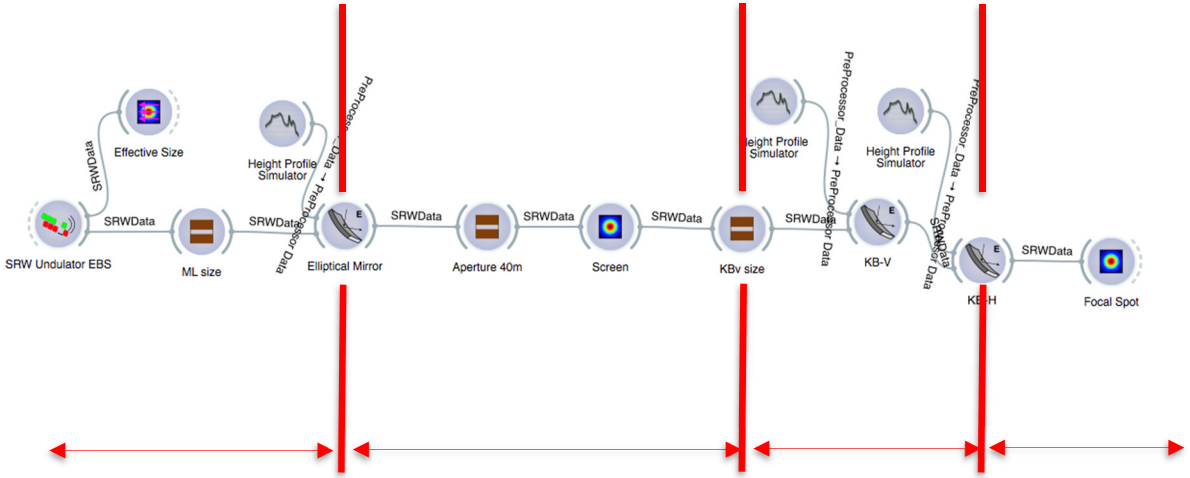






SIMULATION PURPOSE: OPTICS DESIGN AND OPERATION

OASYS as a global tool

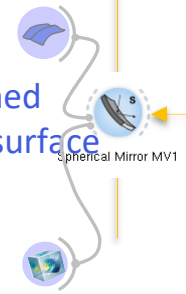


White beam
Analysis
"Power issue"

Propagation analysis
Optical quality
With shadow tool

KB focusing
simulation

Virtual
experiment



Deformed
Reflecting surface

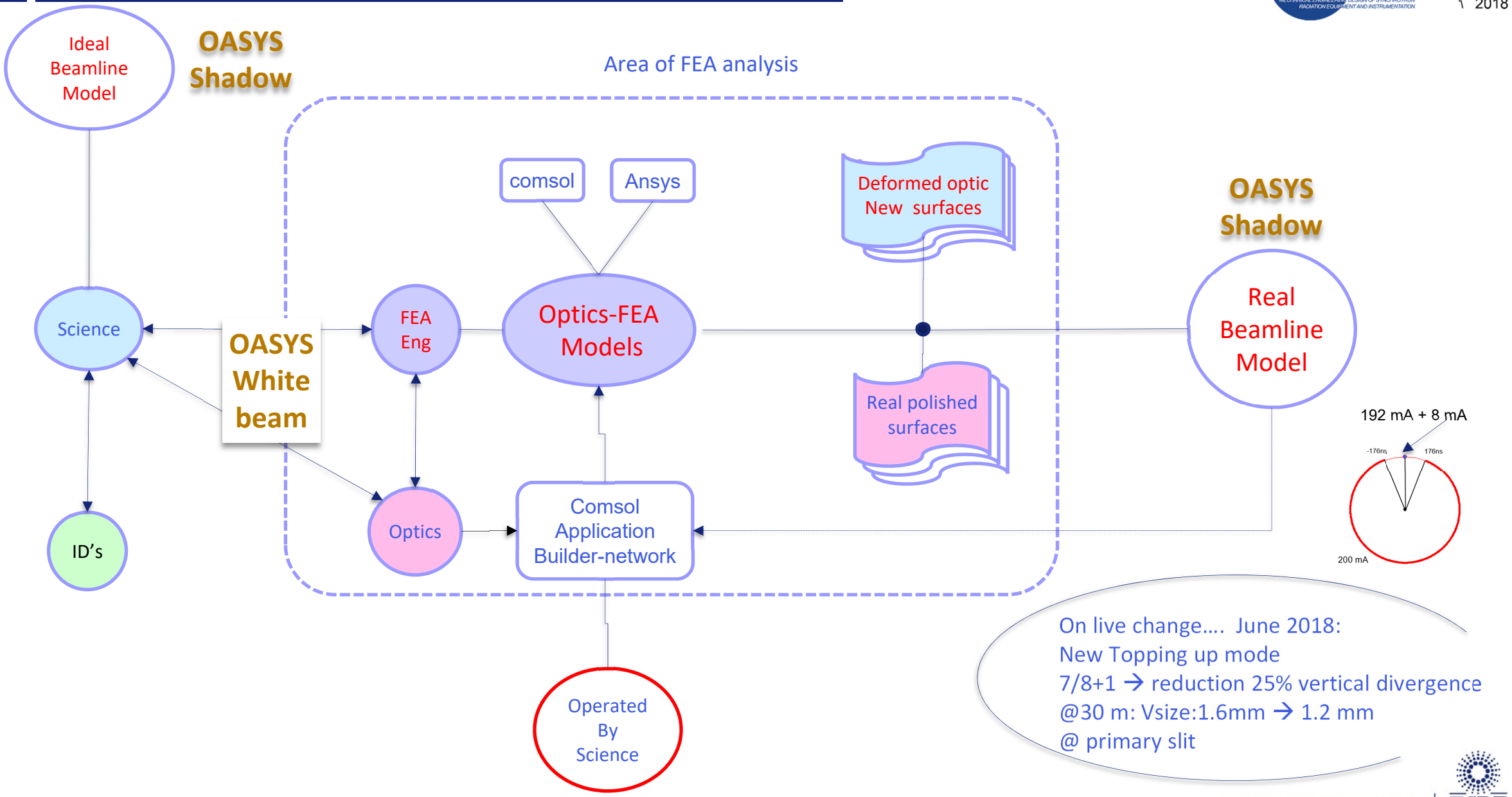
Operated at the beamline

Still need some more effort !
→ Software resource
→ track deep bugs

Compatibility with
various platforms

OASYS development
plan

FEA ANALYSIS OF OPTICS: A LIVE SYSTEM



Computing X-ray beam attenuation for high energy BL (ID11 – pink beam)

From U22-k:1.798		Attenuator series		P_abs w	T-Att °C	Crystal layers		P_abs w	Si_temp °C	slope_Error Std_Dev µrd	ratio slope/abs_power µrd/w
P_inc=	85.85	SiC	4	57.3	308	Si	0.05	0.0096			
		SiC	6	14.2		Si	0.1	0.01915	27.6	0.267	4.00479976
		SiC	8	7.36		Si	0.1	0.01902			
		SiC	10	3.77		Si	0.1	0.0189			
		absorbed power:		82.63		Total absorbed power:		0.06667			
		P_transmitted:		3.22		P_transmitted:		3.15333			

rms thermal slope

From U22-k:1.798		Attenuator series		P_abs w	Crystal layers		P_abs w	Si_temp °C	slope_Error Std_Dev µrd	sl µrd/w
P_inc=	85.85	SiC	2	46.7	Si	0.05	0.0371			
		SiC	4	17.07	Si	0.1	0.07371	35.25	1.176	4.593391141
		SiC	4	7.78	Si	0.1	0.07298			
		SiC	4	4.5	Si	0.1	0.07223			
		absorbed power:		75.05	Total absorbed power:		0.25602			
		P_transmitted:		9.8	P_transmitted:		9.54398			

Attenuator Materials

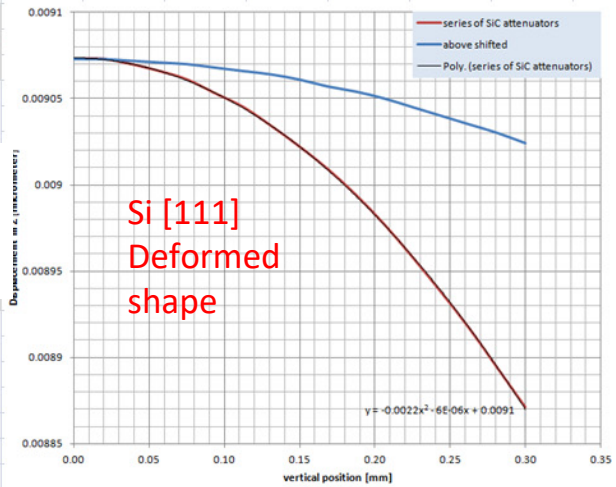
From U22-k:1.798		Attenuator series		P_abs w	Crystal layers		P_abs w	Si_temp °C	slope_Error Std_Dev µrd	ratio slope/abs_power µrd/w
P_inc=	85.85	C	1	16.57	Si	0.05	0.056			
		Al	0.6	15.082	Si	0.1	0.1115	41		
		Al	1.5	15.3	Si	0.1	0.11			
		Al	3	12.78	Si	0.1	0.1087			
		Al	7	12.65	Total absorbed power:		0.386			
		absorbed power:		72.382						
		P_transmitted:		13.468	P_transmitted:		13.082			

Absorbed power

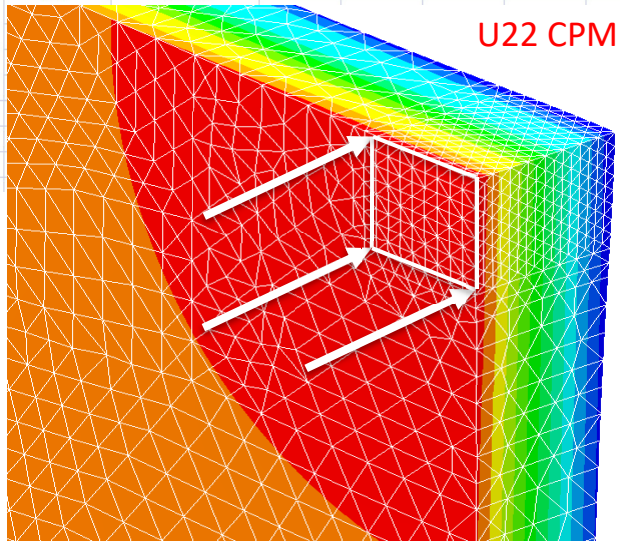
Crystal attenuation

Absorbed Power In crystal

Crystal Warm-up



Si [111] Deformed shape



U22 CPMU K:1.798

ID11- Attenuation stack for small thermal slope error (250 nrad)

Exploiting new
SiC wafer substrates
4H and 6H lamellar crystals arrangement

Ingot supply from NORSTEL
Thick blocks machined at the ESRF
Diamond milling

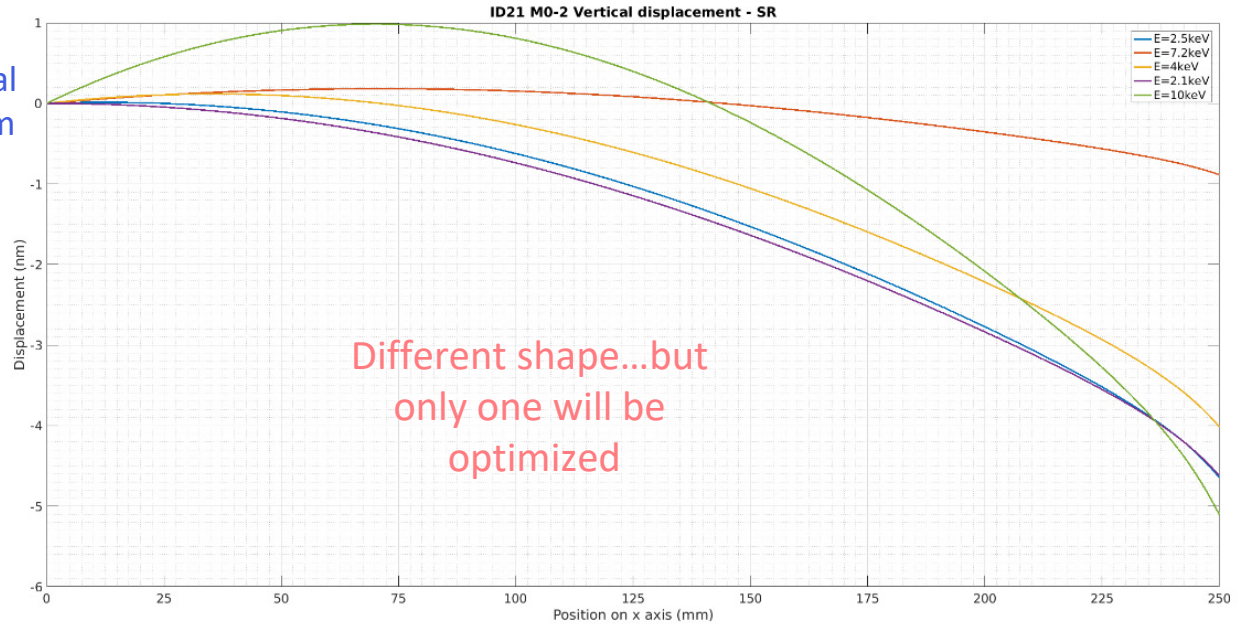
MIRROR DEFORMATION UNDER HEATLOAD

Beamline choice

Energy (KeV) →	2.5 S K-edge	7.2 Fe K-edge	4 Ca K-edge	2.1 P K-edge	10 Zn K-edge
SR: slope error nrad	9	3	7	9	14
EBS:slope error nrad	12	64	16	13	357

rms thermal slope SR/EBS → keeping comparison

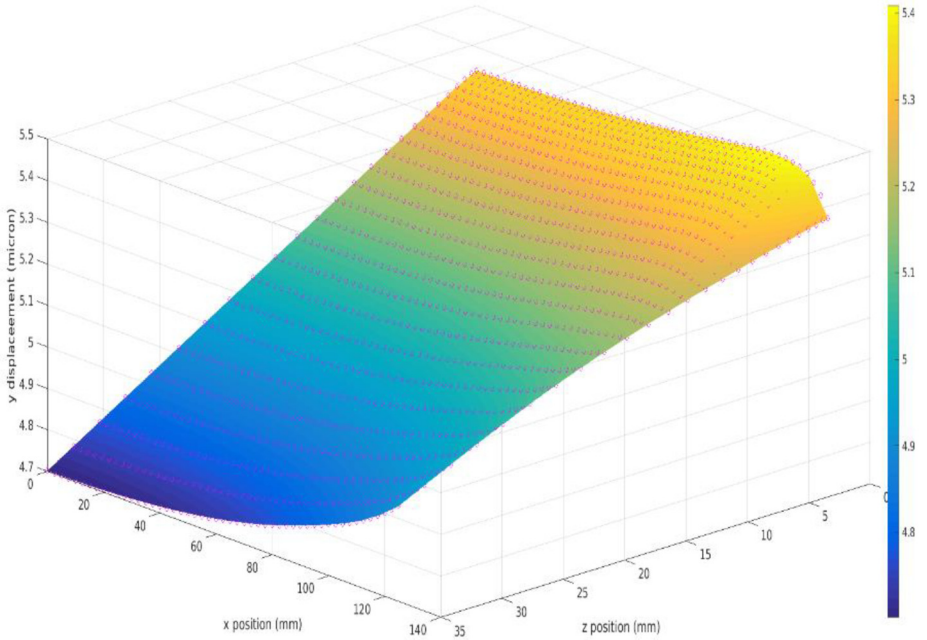
Vertical deform [µm]



Different shape…but only one will be optimized

Mirror length [mm]

White beam mirror meridian centerline



Smoothened surface sent to OASYS

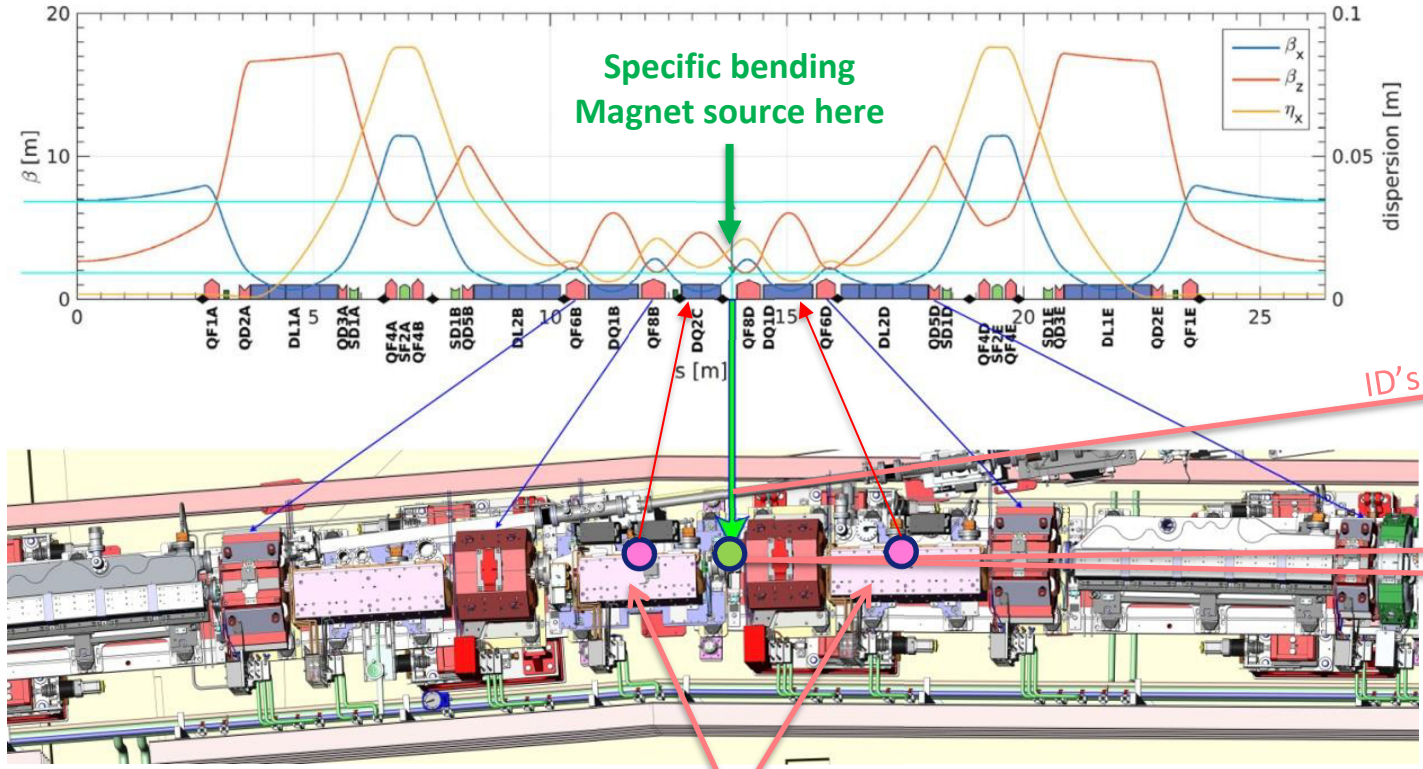
SOURCE POINT : WHERE IS MY BENDING MAGNET ????

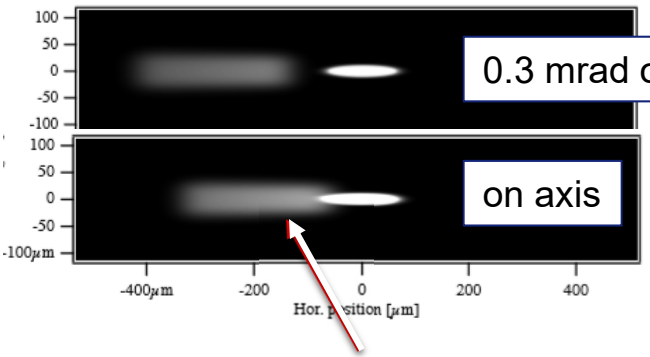
MEDSI PARIS 2018

HDBA lattice: problem

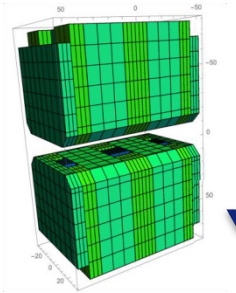
Dipoles field is too weak cannot be used for light source!!!!

Other source point required !

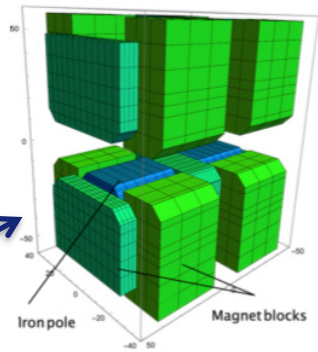




Parasitic source from Dip-Quad



3 Poles wiggler (BM18)
2 poles wiggler (BM23)
1 additional short Dipole (150 mm long)



Courtesy
O. Mathon
S. Pascarelli
J. Chavanne

CONCLUSION

- Low emittance machine → big change for everyone → X-ray beam behaves differently
- BL complete review organized (scientists / Engineering) → interactions rounds
- Good detailed understanding of synchrotron radiation physics → Simulation
- Requires a strategy of making new optimization → leads to new optics (no optics?)
- Lab vision reset → is an other world for the storage ring
  is also a projection in an other world for the beamlines
  New people round – need experience transmission

Thank you for your attention !