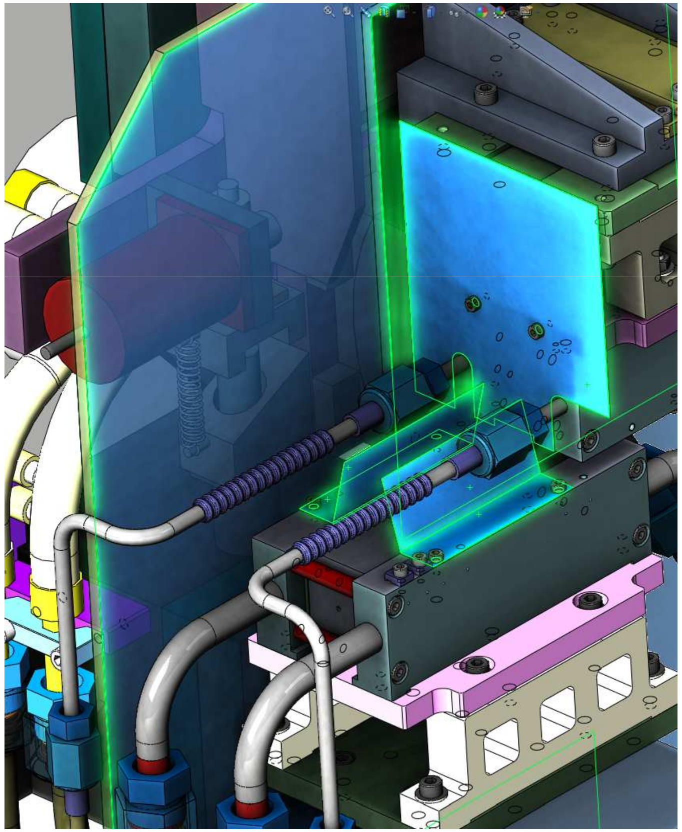
ESRF | The European Synchrotron

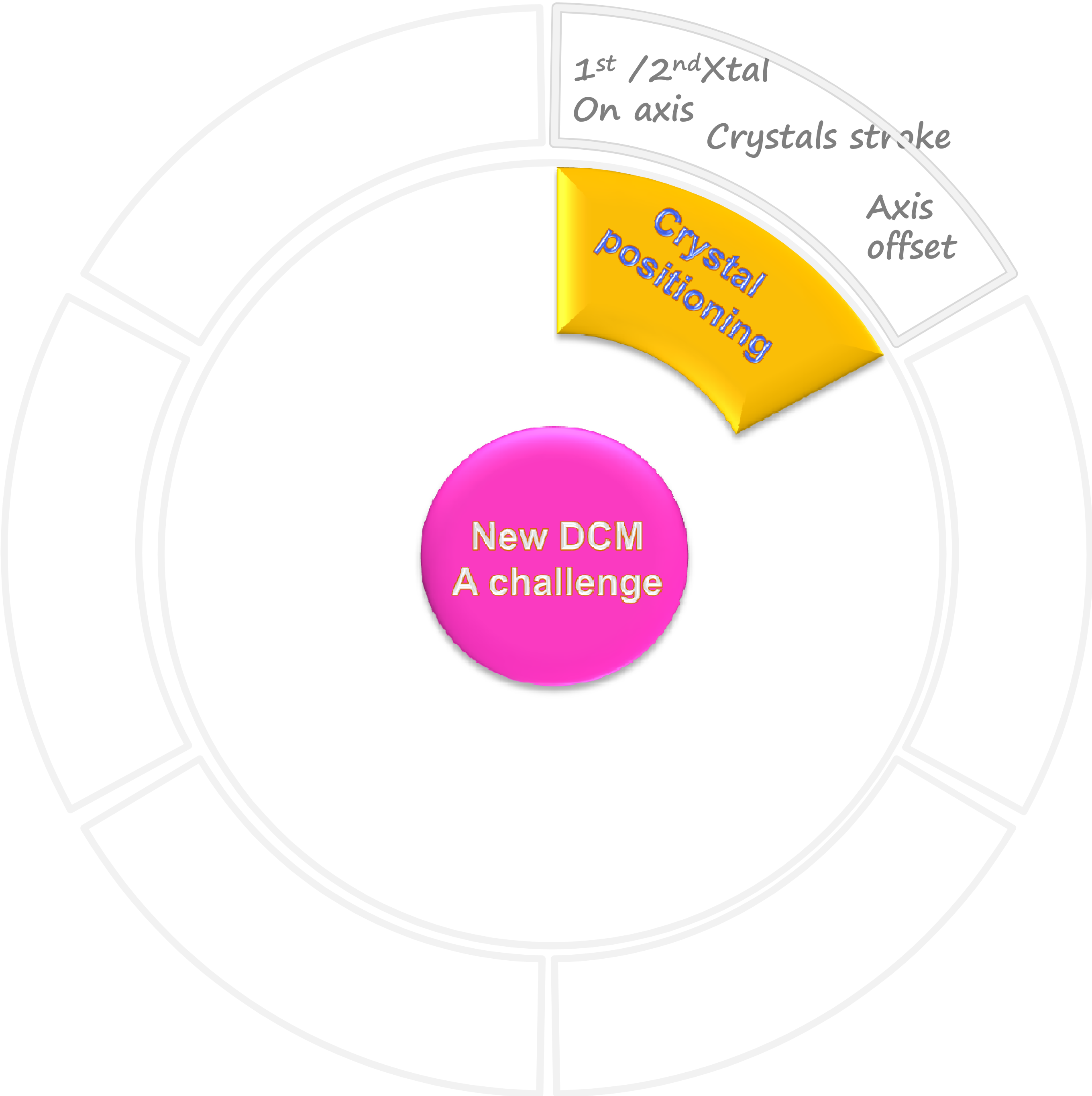


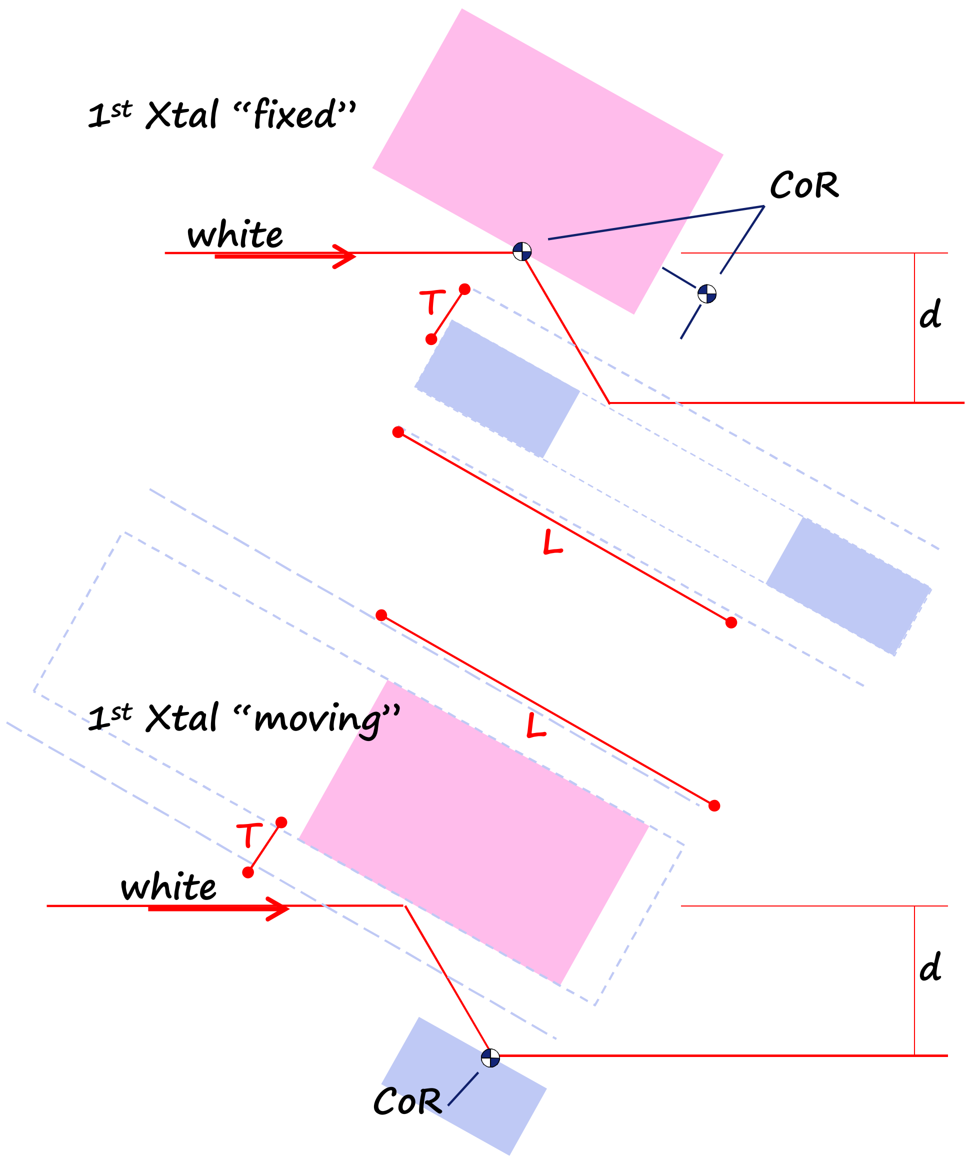
# New DCM for spectroscopy an engineering challenge review

Y. Dabin, R. Baker, L. Zhang, H. Gonzalez, R. Barrett, Ph. Marion, O. Mathon, R. Tucoulou

# DRIVERS FOR A NEW DCM: GENERAL OUTLINES

# THE CRYSTALS CONFIGURATIONS






Infinity type of combinations !

White beam spot, moving or fixed on the First crystal:
Fixed: thermal time constant better "averaged"

BUT:

Bragg radial stroke $T = \dfrac{d}{2\cos\theta_B}$

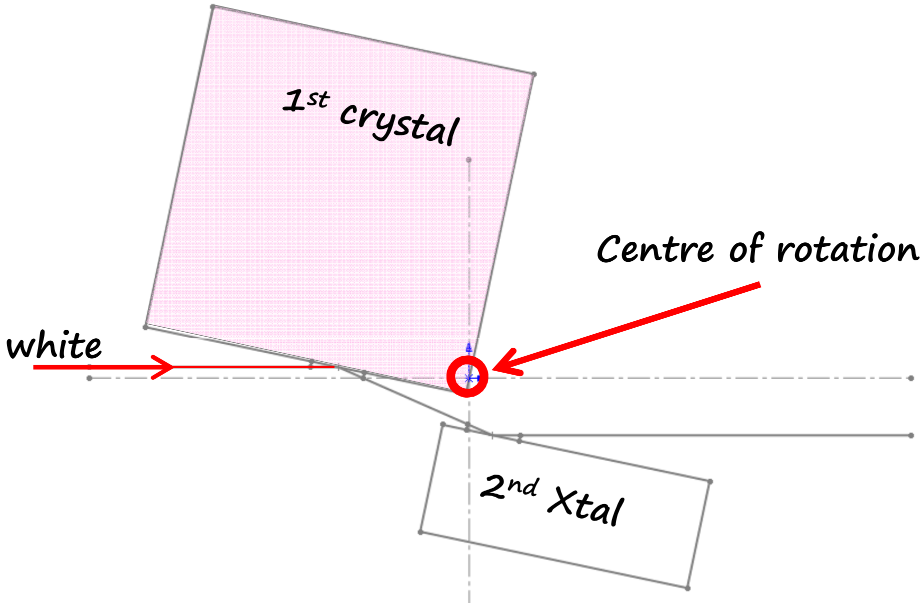
Bragg longitudinal stroke $L = \dfrac{d}{2\sin\theta_B}$

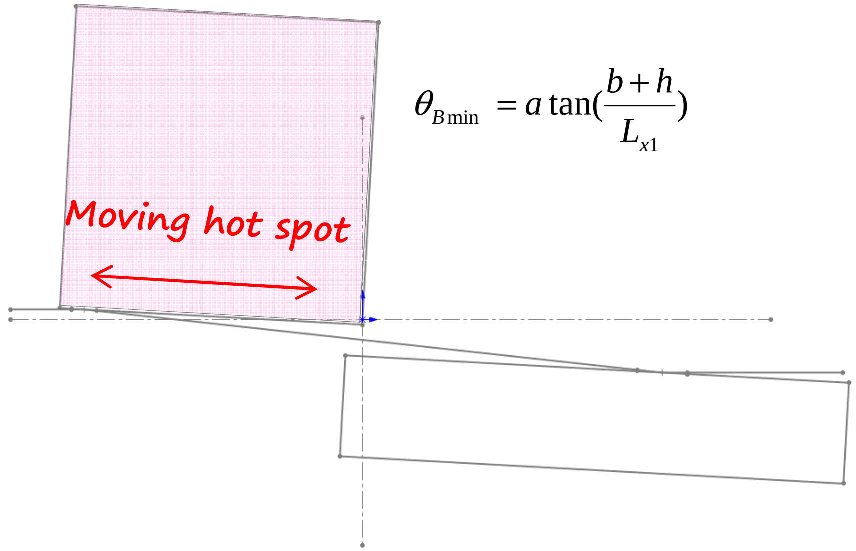
Independent of configuration

Monochromatic beam "fixed" on 2nd Xtal:
2nd Xtal Bragg angle better defined

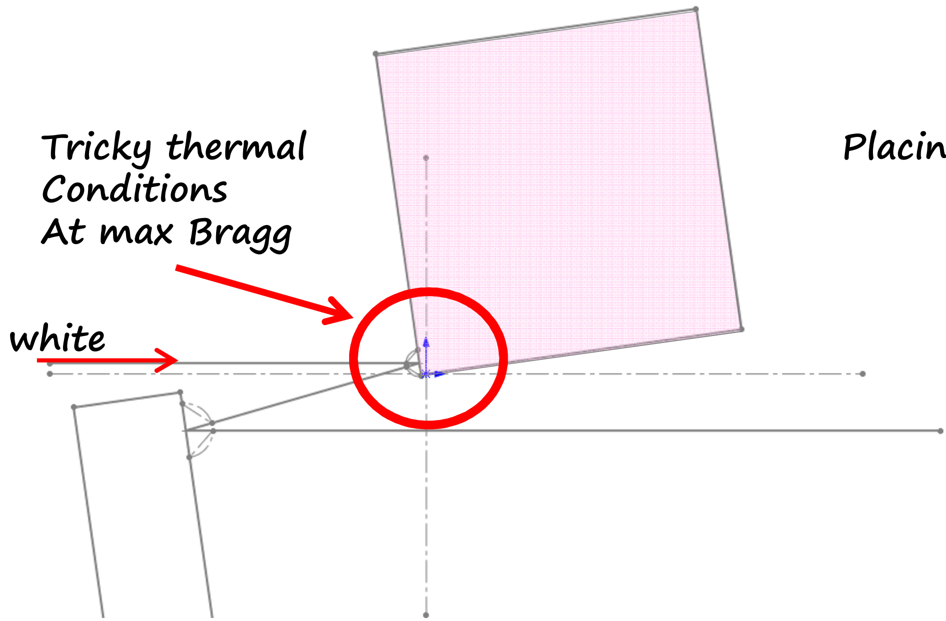
1st crystal moving: High flow LN2 set

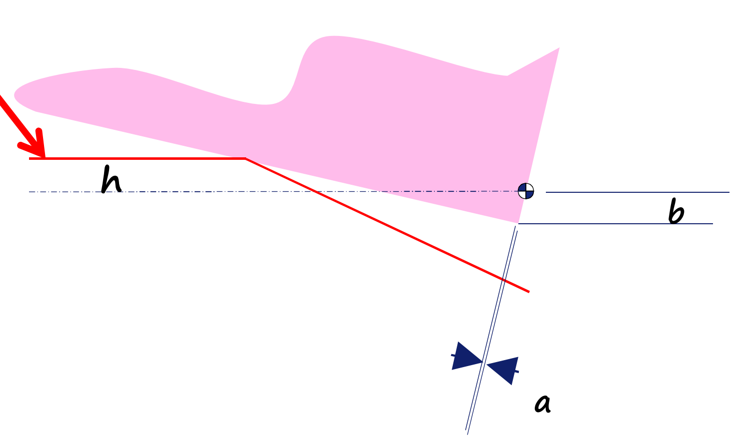
# CRYSTAL POSITIONING – CENTRE OF ROTATION LOCATION




$$\theta_{B\min} = a\tan\left(\frac{b+h}{L_{x1}}\right)$$

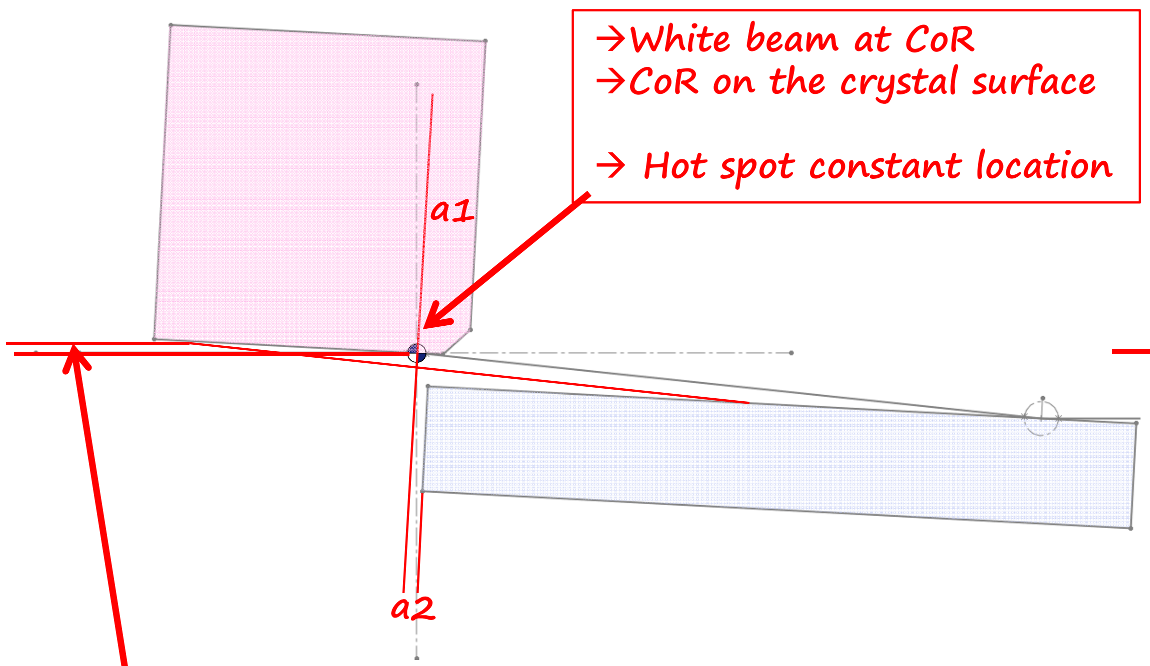


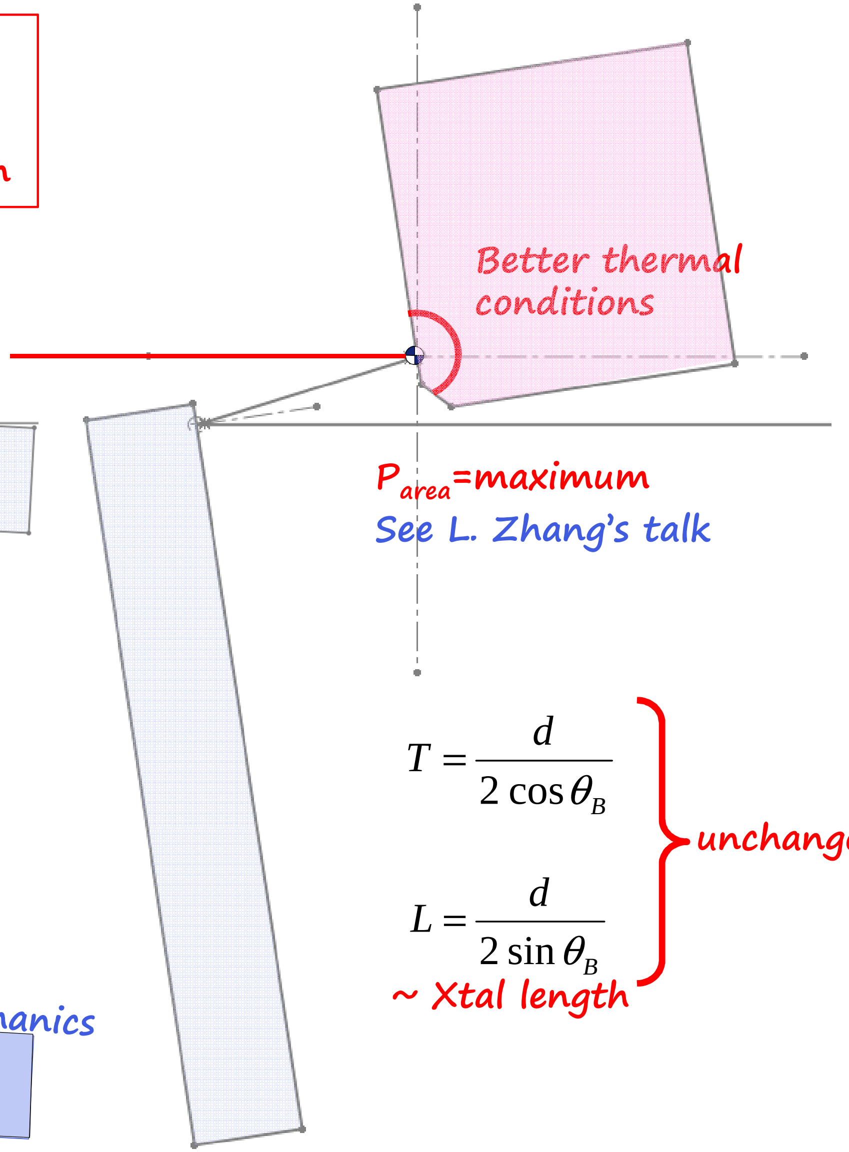
# A LOT OF CRYSTALS COMBINATIONS POSSIBLE

→White beam at CoR
→CoR on the crystal surface

→ Hot spot constant location




Possibility of making hot spot moving
Reducing the minimum Bragg




$P_{area}$=maximum
See L. Zhang's talk

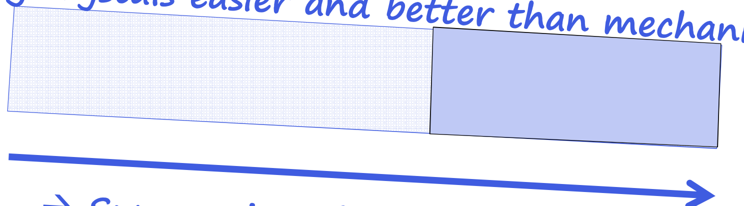
$$T = \frac{d}{2\cos\theta_B}$$

$$L = \frac{d}{2\sin\theta_B}$$

~ Xtal length

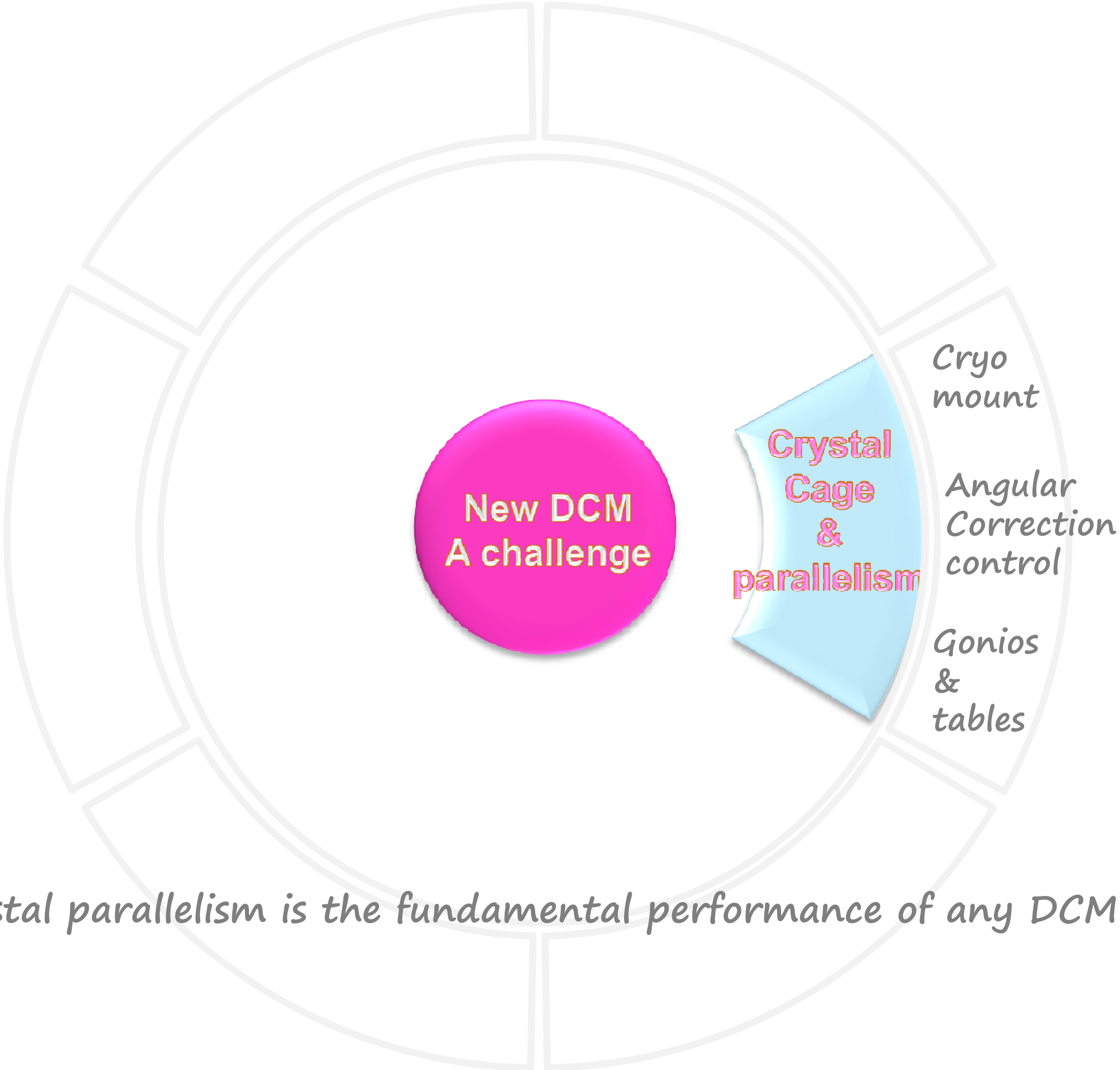
} unchanged

Now days:
Long crystals easier and better than mechanics



→ Suppression of longitudinal stroke

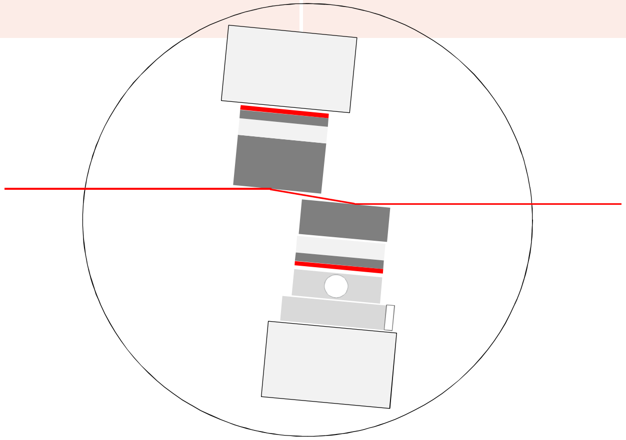
# THE CRYSTAL PARALLELISM : THE FUNDAMENTAL ISSUE



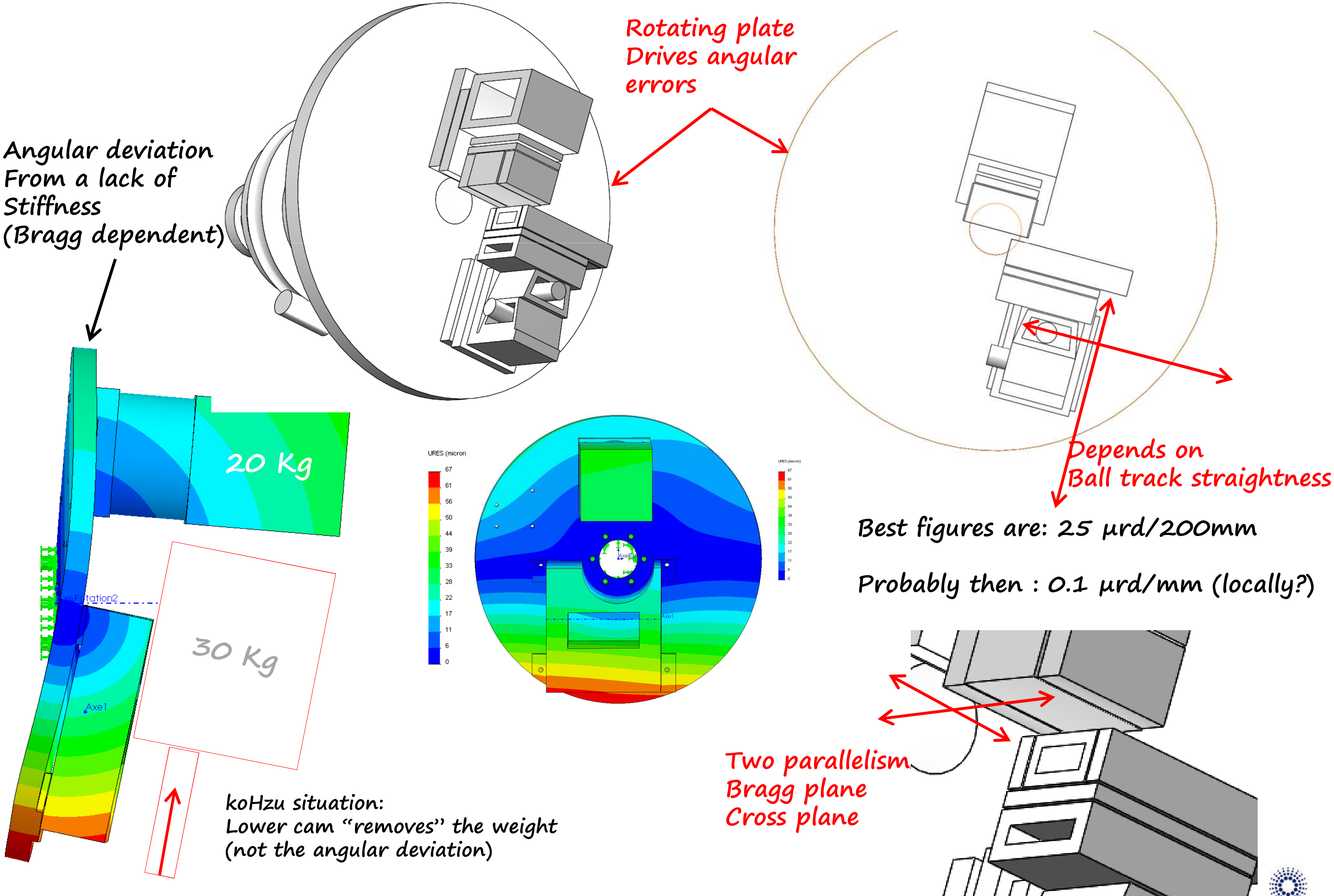

Crystal parallelism is the fundamental performance of any DCM

# CRYSTALS PARALLELISM DRIVERS

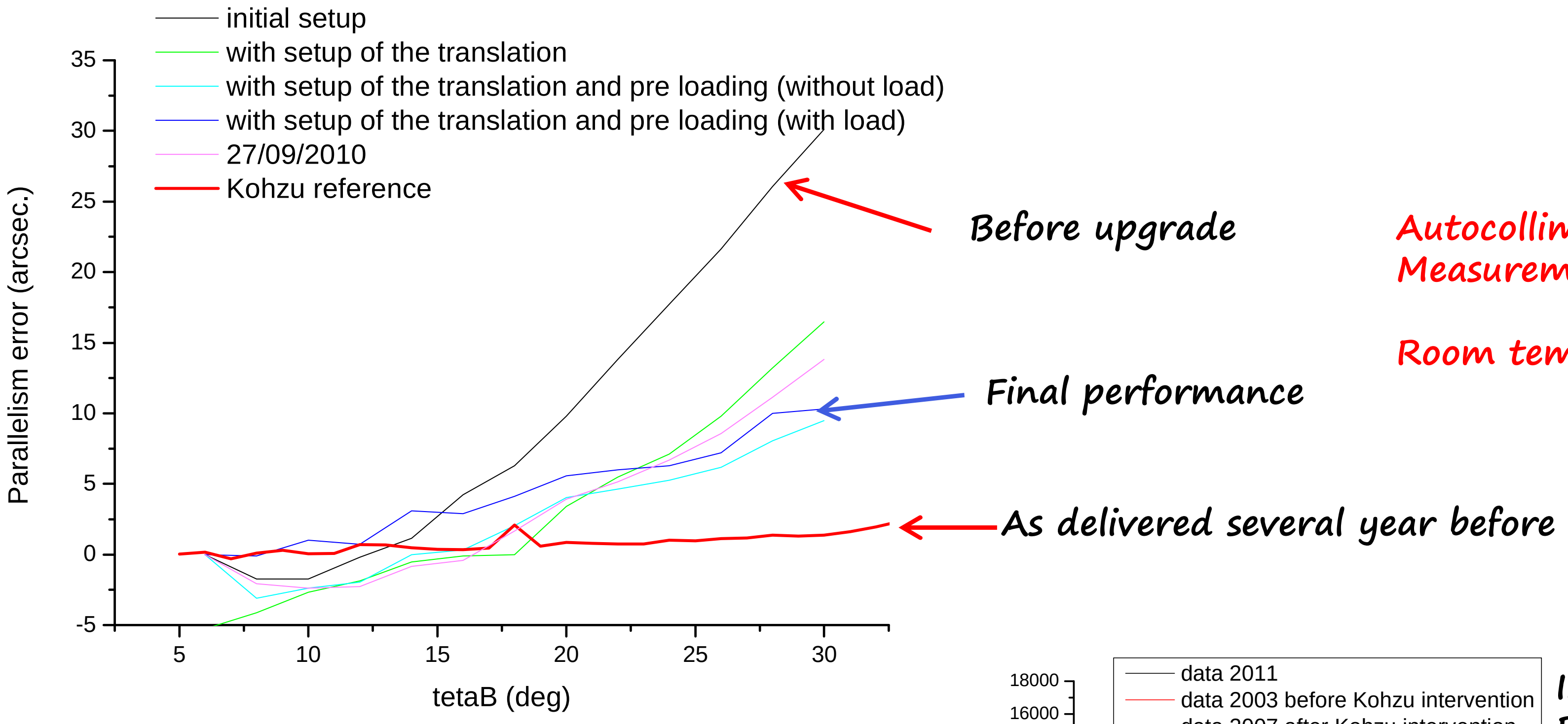
| Drivers | items | characteristic | cure | Studies drivers |
|---|---|---|---|---|
| Geometric | Moving stages | ~ repeat | Metrology-lookup table Piezos | Static studies |
| | Plate deformation | ~ repeat | | |
| Cryo-field from crystal set | Stage shrinkage | instability | Thermal break heater (TTF) | Thermal studies & Simulating Thermal transfer Function |
| Thermal field from scattering | Stages and holders | instability | Radiation shield Heater (TTF) | |
| Crystals at different temp. | Crystal Cryo-box | Lack of cooling power rate. Response time | LN2 on $2^{nd}$ crystal | |
| Dynamics | Moving stages Flexures | Fast events | Push dynamic studies-high frequency track | Vibration analysis |



# CRYSTAL CAGE PARALLELISM : THE ROTATING PLATE AND TRAVEL CASES



Courtesy J. Borrel, O. Mathon

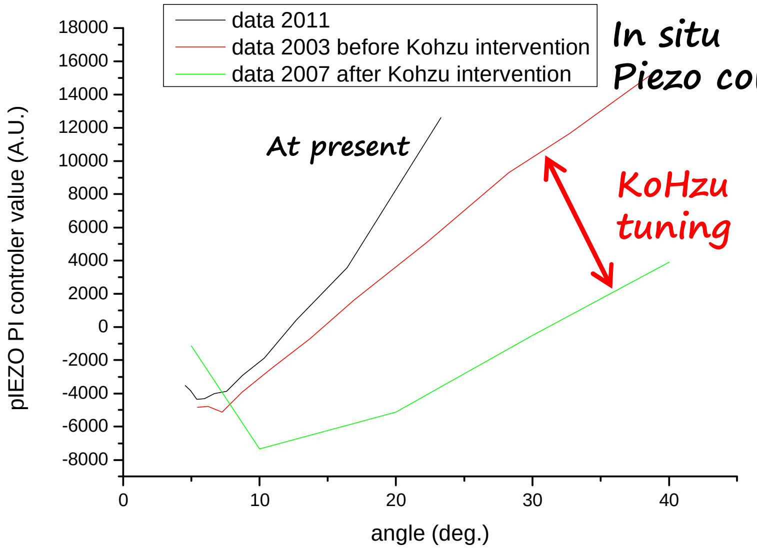



Autocollimator Measurements

Room temp.

Seems to be a consequence of the weight added on the Kohzu mechanism
3 crystals set instead of 2

Piezo Controller values



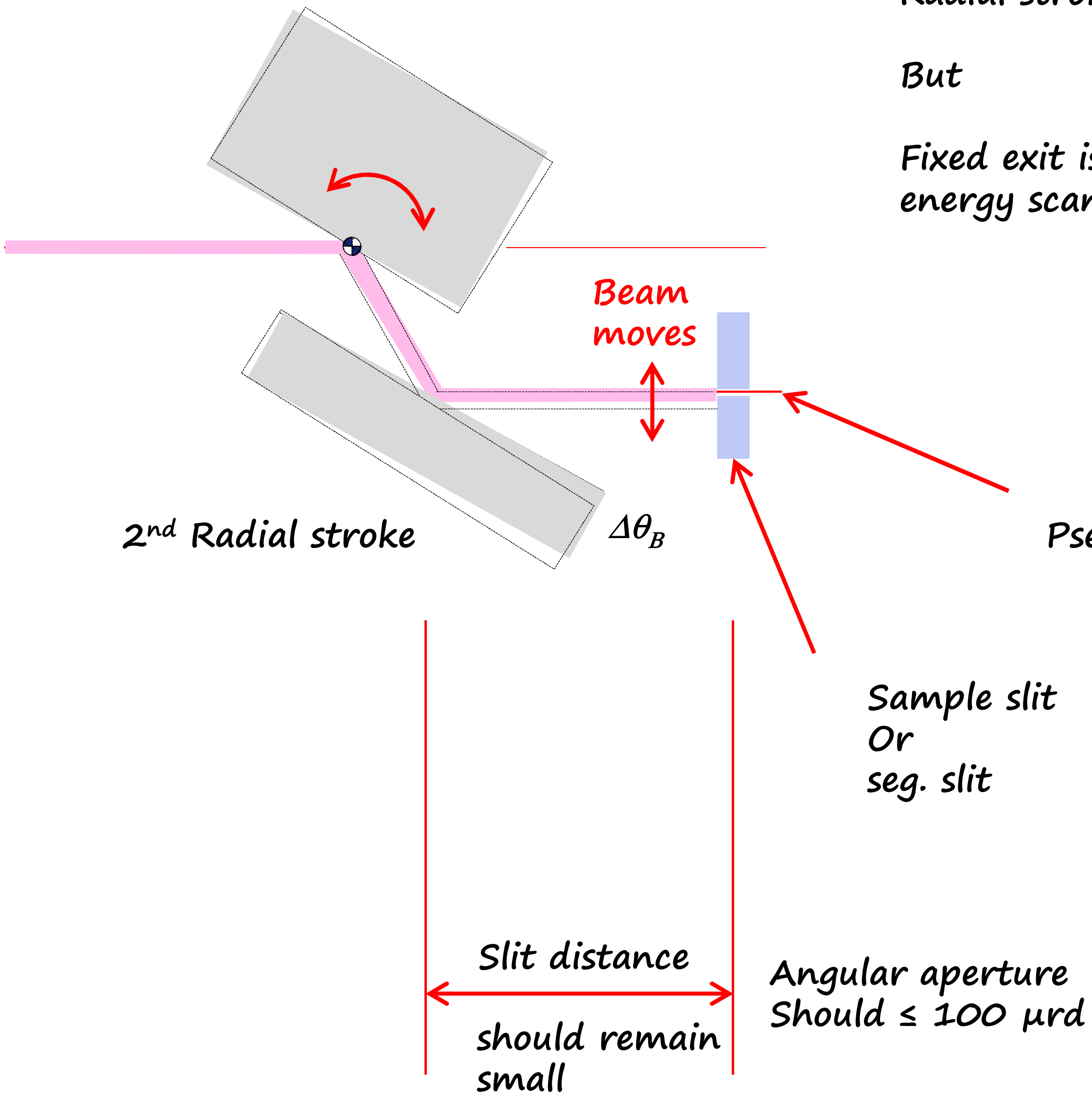

In situ Piezo correction

# REMARK: RADIAL MOVE MAY BE OF LESS IMPORTANCE

Remark:
Radial stroke ensure fixed exit

But

Fixed exit is not mandatory for energy scanning ΔE ~1000 eV



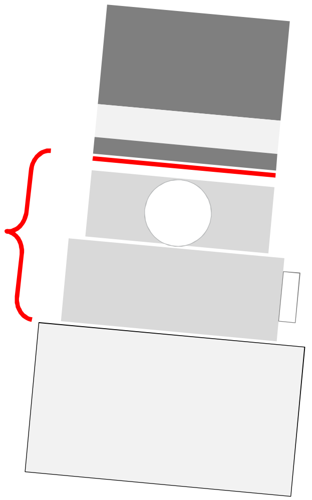

Used when experiment Requires large size beam (rather seldom)

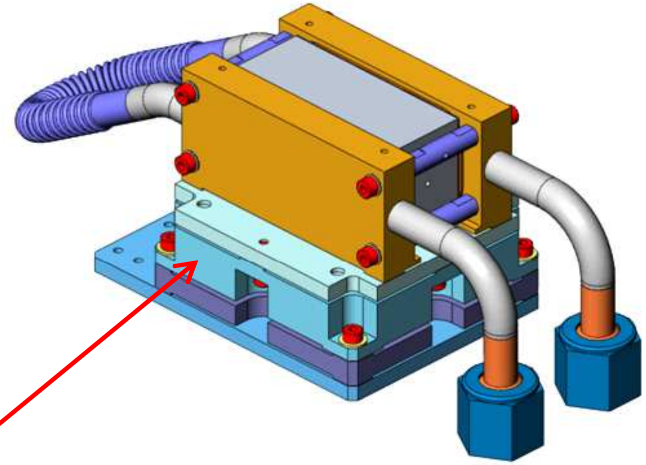
# CRYSTAL PARALLELISM DURING ENERGY SCANS

| Parallelism error ≤ 100 nrd during scans | | |
|---|---|---|
| The error is lower than the limit | Strategy when the error is above the limit ( 100 nrd) | |
| Metrology in situ possible. watch | Error is repeatable (RT + cryo) | Error is not repeatable |
| Probably Probe system | Corrected within Mono<br>♦ Fine stages<br>♦ Probes (Look-up table+ Piezo strain gauges) | Corrected in real time<br>♦ Probe system (straight edge+ capacitor)<br>♦ Dynamic TF with piezos |
| No correction (ideal case!) | Corrected externally<br>♦ probes but no feedback<br>♦ at the sample (vert. + Horz. Positioning) | |
| Recent mono May be there | Minimum requirements With still a simple system | Complex system Would require developments |

# CRYSTAL PARALLELISM : AVOID MECHANISM THERMAL SHRINKAGE

Exp: A. Chumakov, K. Martel (ESRF ID18 – ID20)



Solid ceramic isolator (very low conductivity)

High stiffness modulus (no vibrations)

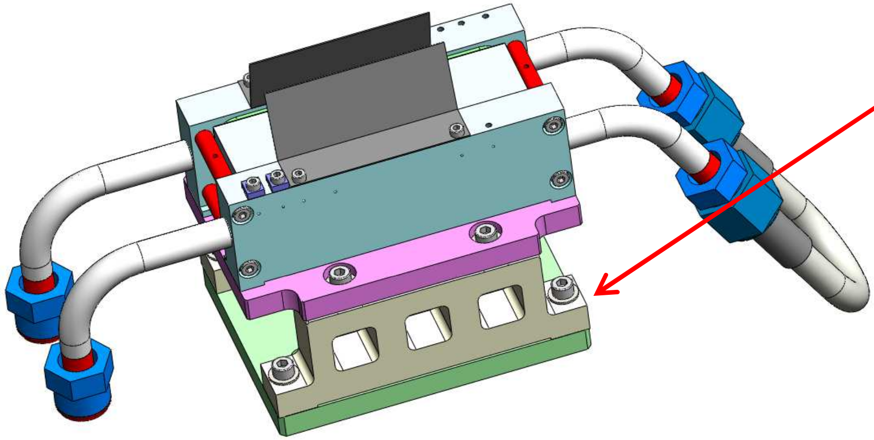
Limited conductive contact areas (no thermal leaks)

Then crystal travel stages

Passive support structure

Corrective stages

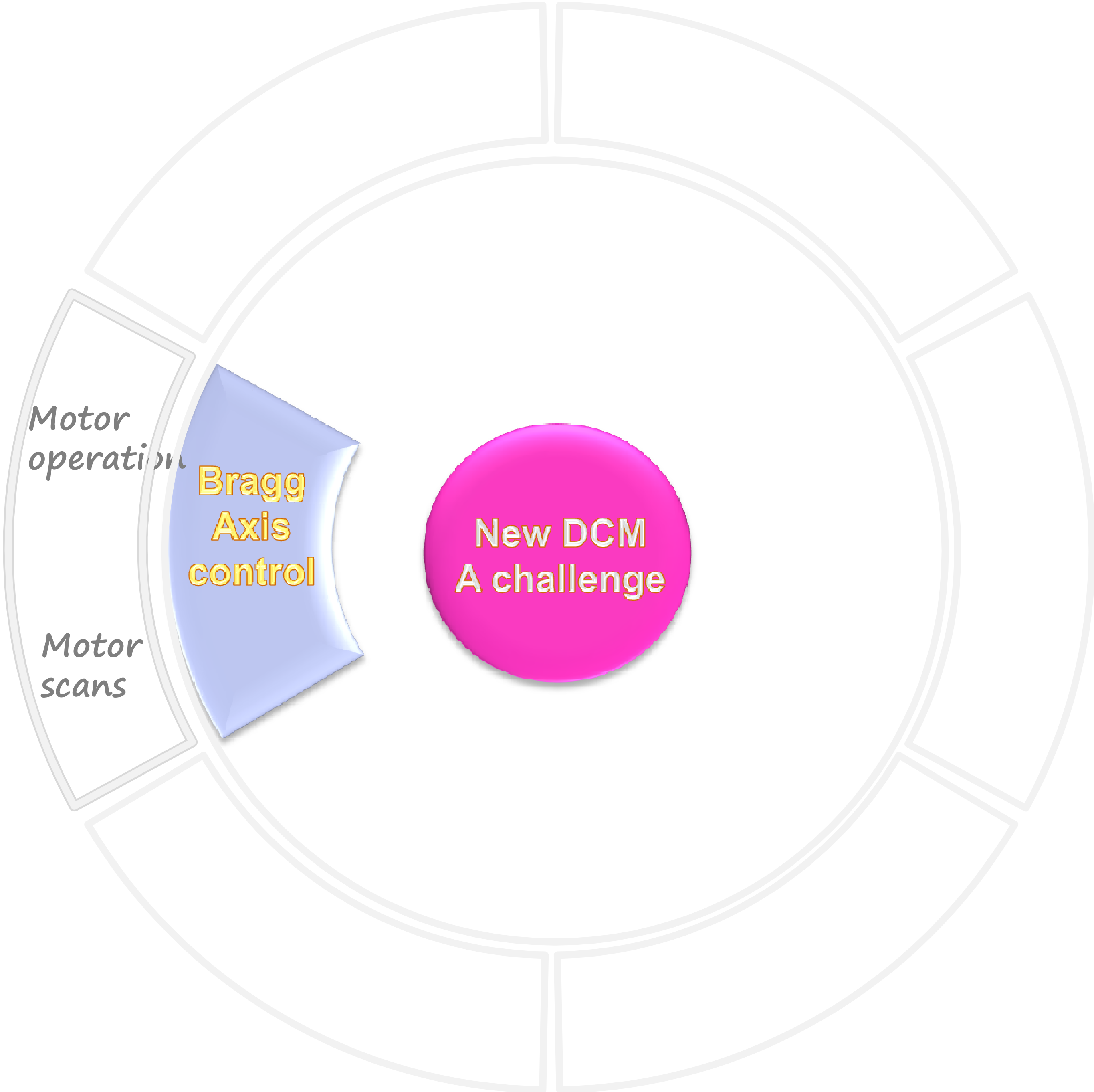
ESRF wish



Exp at ESRF with EUROTHERM temperature PID controller
At ID20 ± 1 m°K for post mono

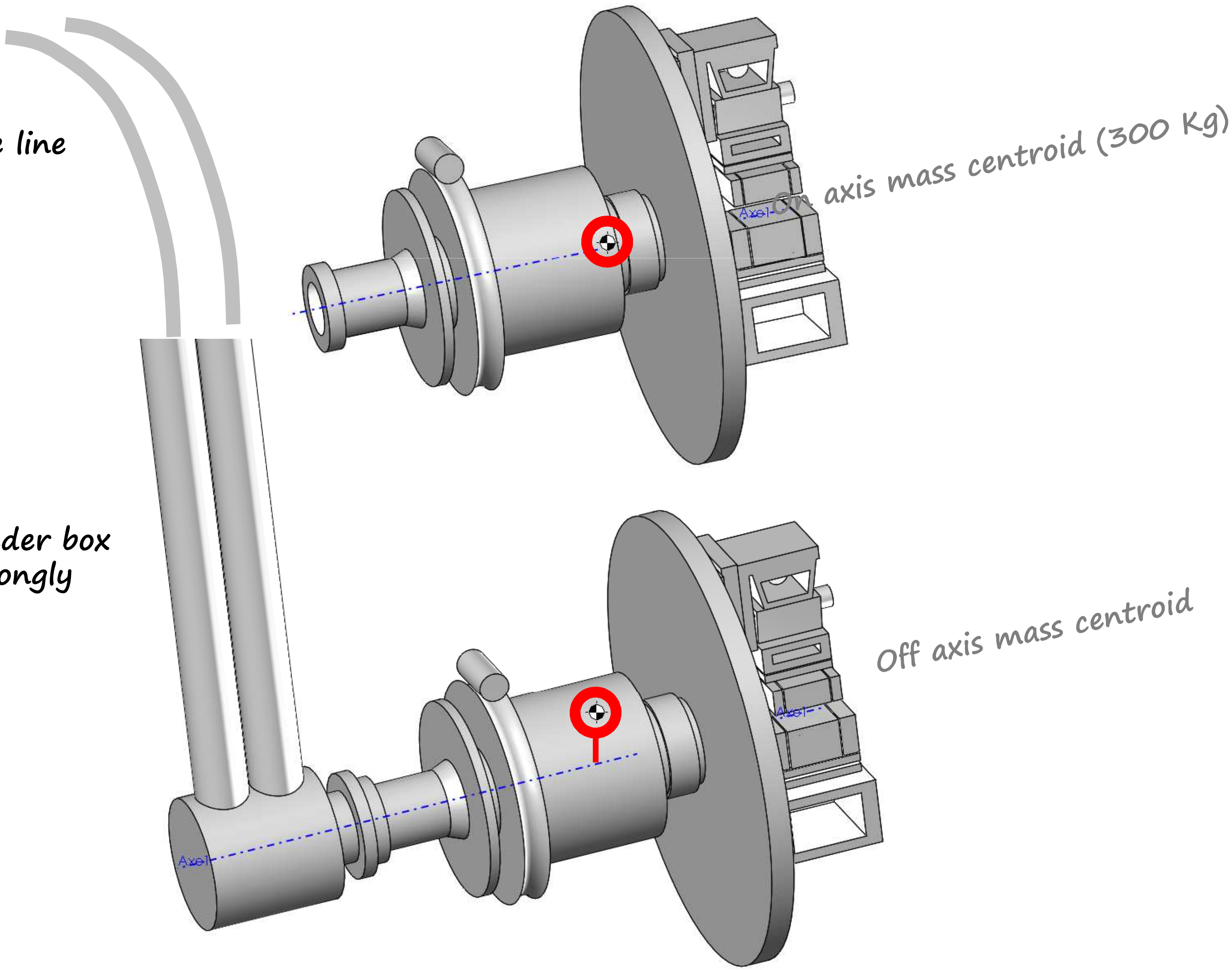
Courtesy C. Henriquet

# THE BRAGG AXIS  MOTOR CASE



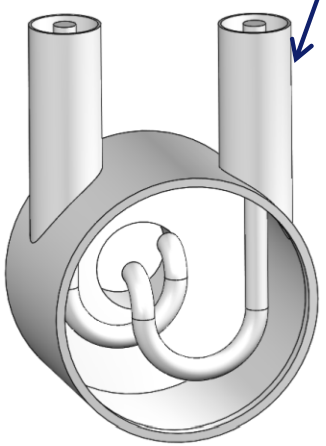
# LN2 FEEDER BOX: A “HEAVY INFLUENCE” , MAY BE AWAY FROM SUPPLIER’S

External flexible line

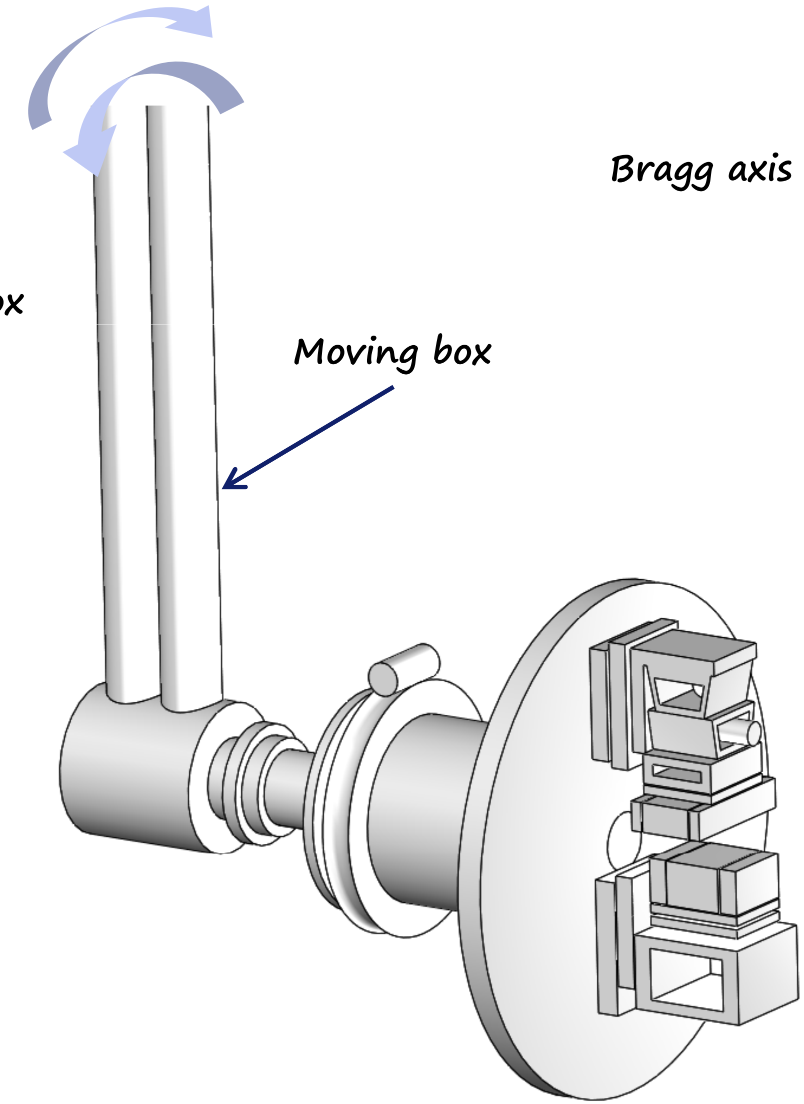



Moving LN2 feeder box
Seems quite strongly
Influencing the
Mass inertia

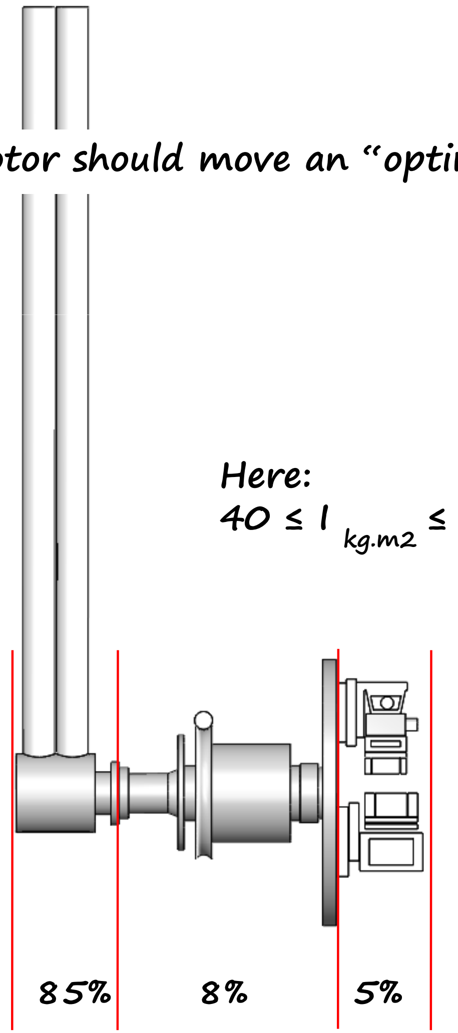
# BRAGG AXIS DYNAMICS




LN2 feed box
With flexible
windings

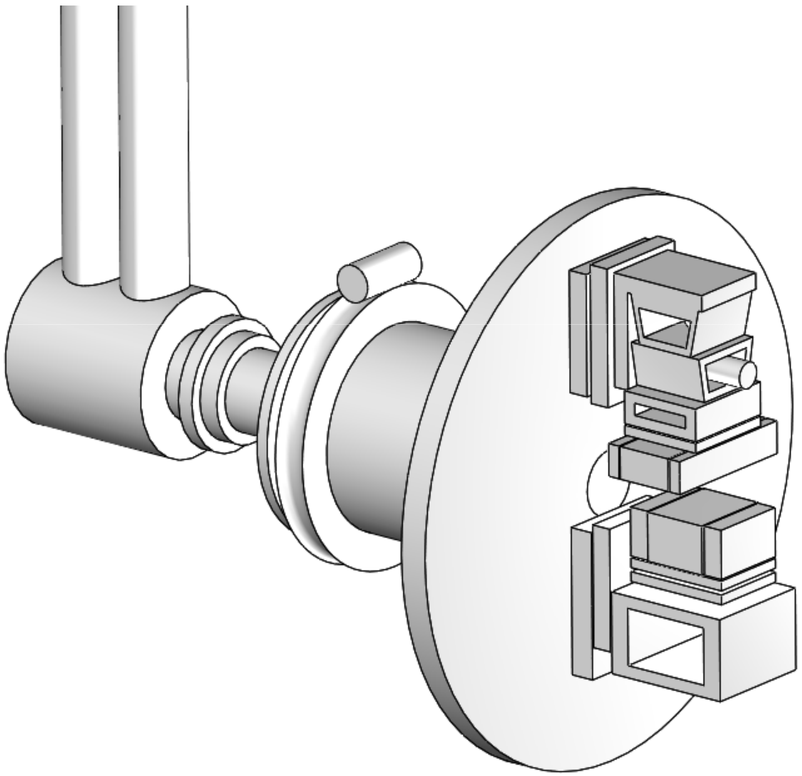



Bragg axis motor should move an "optimized" set

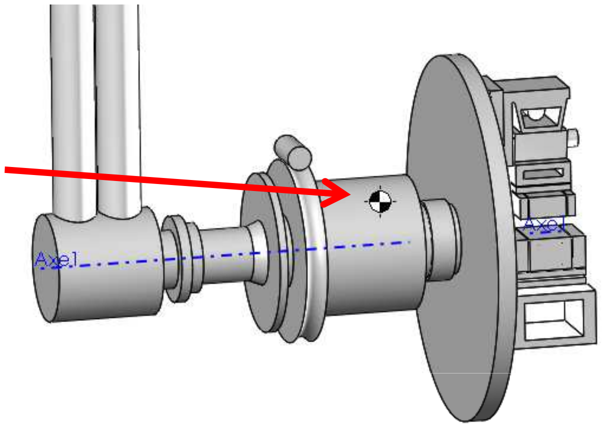


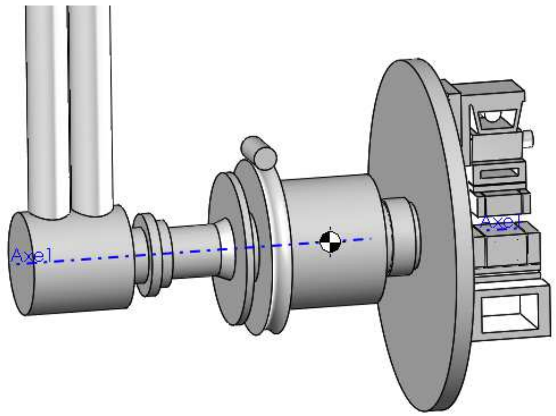

Fraction of mass inertia sharing

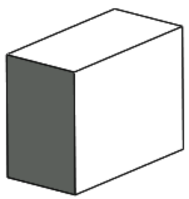
# BRAGG AXIS DYNAMICS



Mass centroid
Far from axis

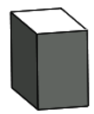






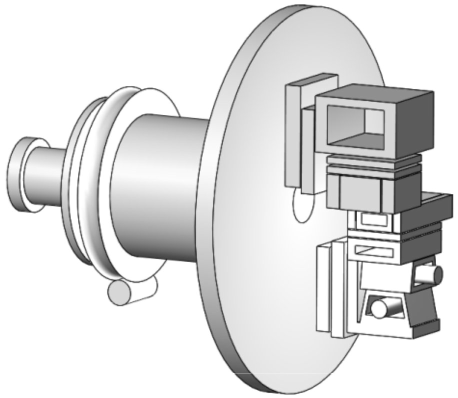
Adding a counterweight improves
Unpowered reaction but magnifies
The dynamic considerations

Typically from 40 to 60 $Kg.m^2$



Added external
Counterweight:
30 Kg @ 700 mm

# MOTOR DYNAMIC OPERATION



**Motor torque = Dynamic load + Permanent load**

Dynamic load:
- Everything
- Connected with
- acceleration

Permanent load:
- Friction
- Off axis masses
- Hand out forces
- Everything at constant velocity

$$C(t) = J\,\frac{d^2\theta}{dt^2} + C_i$$

J is the total mass inertia of the Bragg a…

$C_i$ is anything constant

Everything dynamic | Everything permanent

$$C_a(t,\beta,i,I) := J_m \cdot i \cdot d\theta 2(t,\beta) + \frac{1}{i \cdot \eta}\left(I \cdot d\theta 2(t,\beta) + C_o + C_f\right)$$

$C_o$ : off axis masses torque

$C_f$ : Friction torque (Ferrofluidic + bearings)

"fast mvt"

"slow mvt"

Friction & Permanent resistance

Motor acceleration is magnified By the gearbox

Everything is divided by the gearbox (with efficiency losses $\eta$)

# BRAGG AXIS : REQUIRED TORQUE FOR ENERGY SCANNING

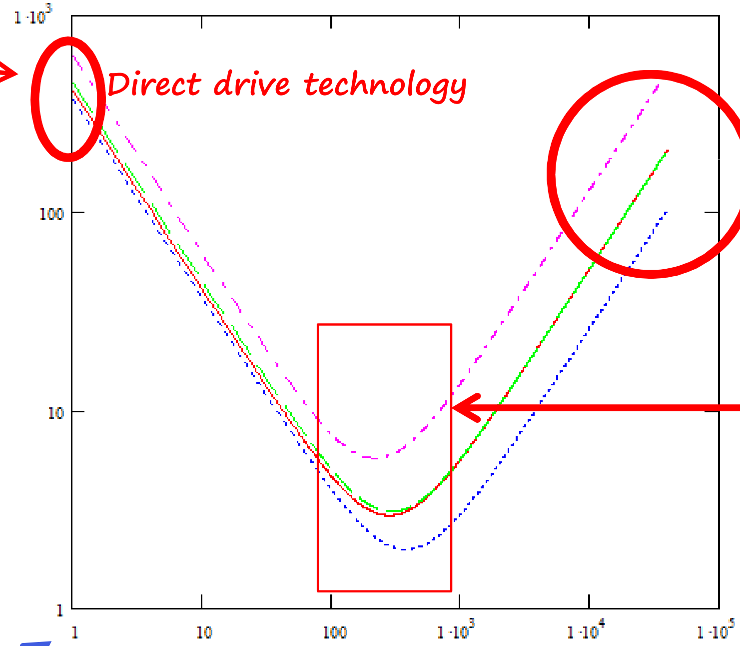
$$C_s(\beta,i,I) := J_m \cdot i \cdot d\omega(\beta) + \frac{1}{i \cdot \eta}\left(I \cdot d\omega(\beta) + C_o + C_f\right)$$

Required torque for scanning [Nm]

High motor power dissipation

Torque In Nm

Shifts that way are due to acceleration change



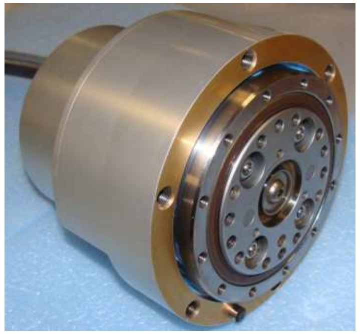

Gearbox reduction ratio: i (no unit)

High gearbox cascade r1 r2 run by steppers or brushless

Few cases there !

i=1 means direct drive operation

... attractive idea: Mechanically more simple

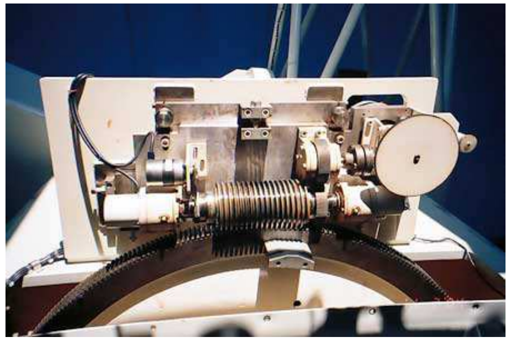


Solving resolution with Fine motor steps

"Encoder overcomes motor"

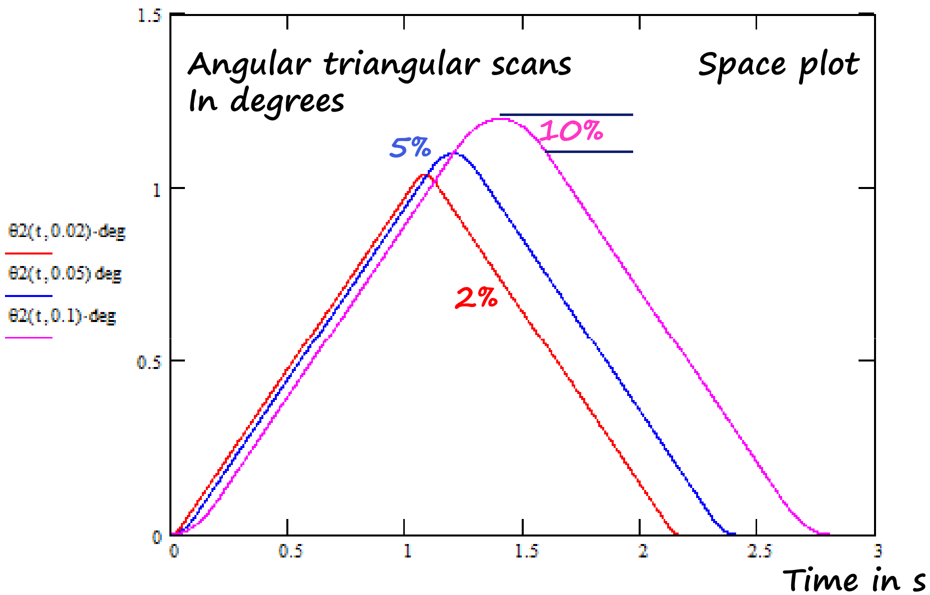
Solving resolution with high Density motor steps

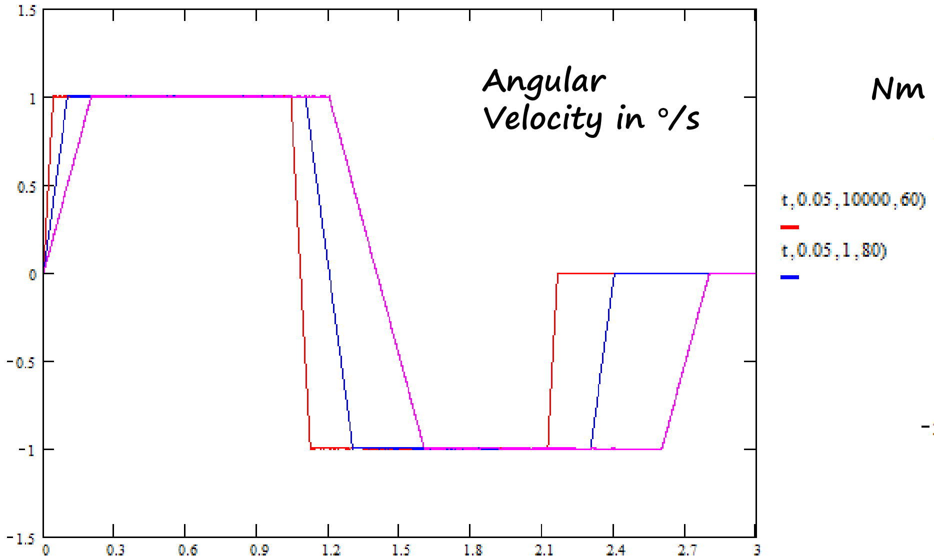
"Motor overcomes encoder"



A typical gear box

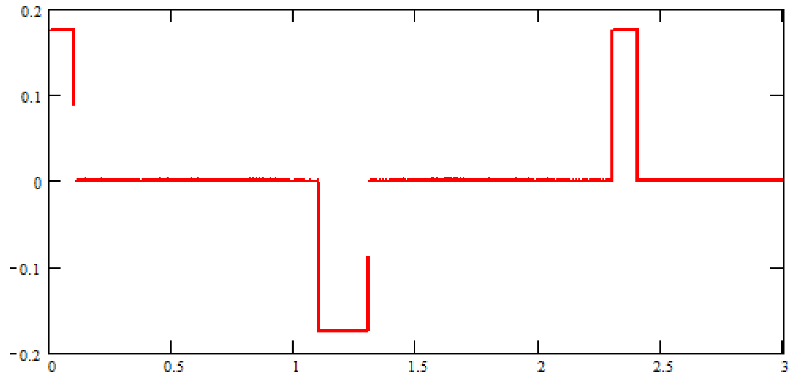
# SPACE – VELOCITY – ACCELERATION – AND TORQUE



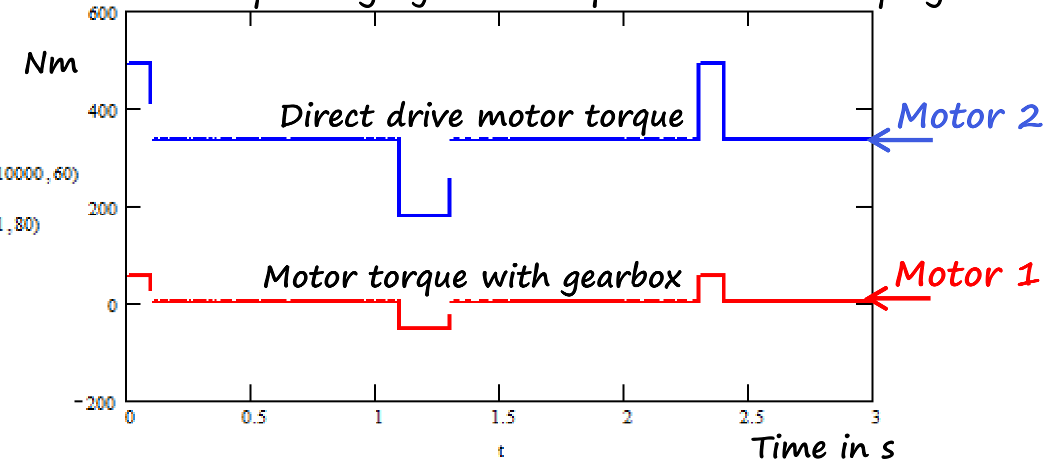




The acceleration of the scan is a fraction in % of the scan angle here 1°

Acceleration of a full cycle at 5% ramping



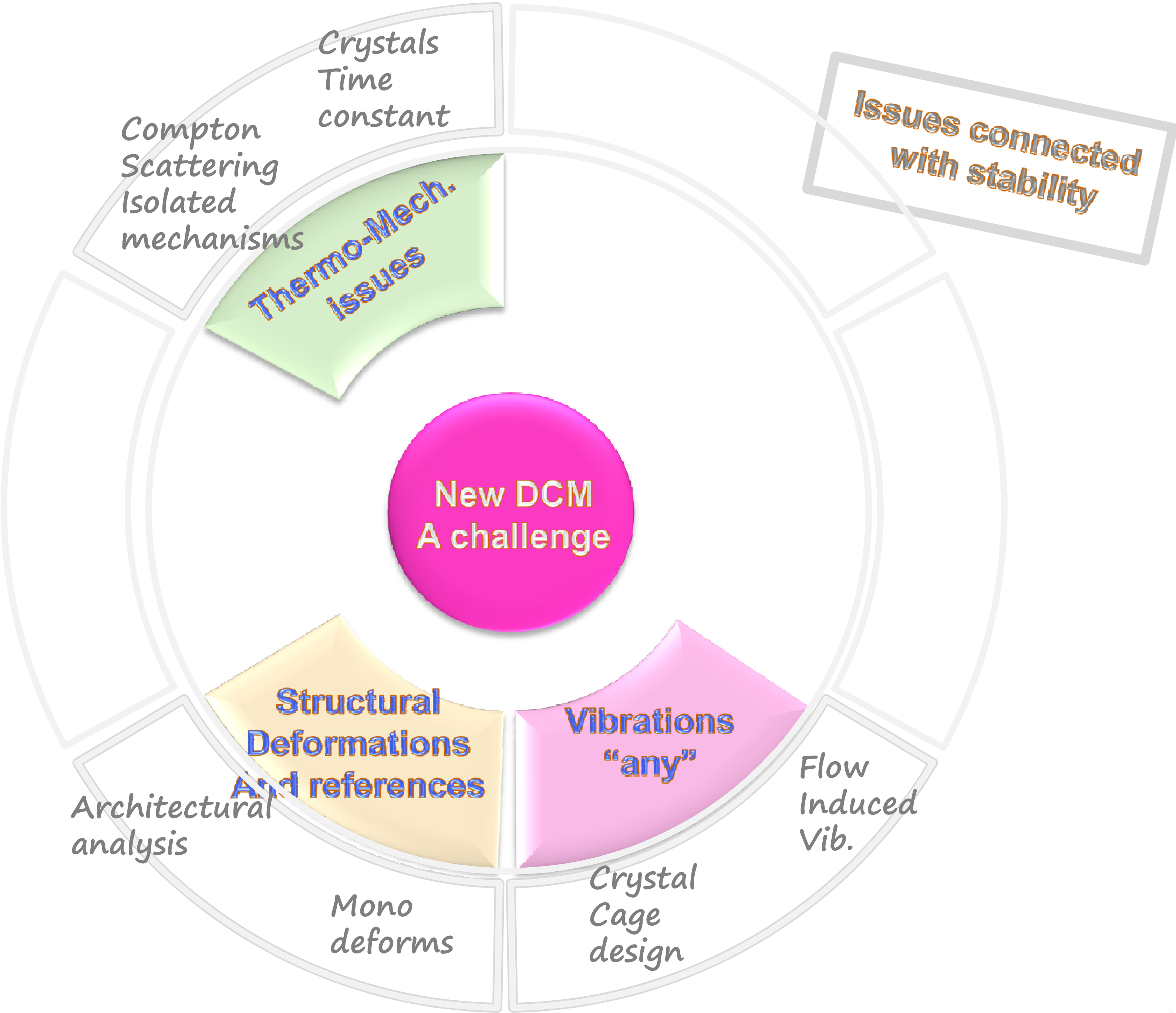

Corresponding dynamic torque of this 5% ramping



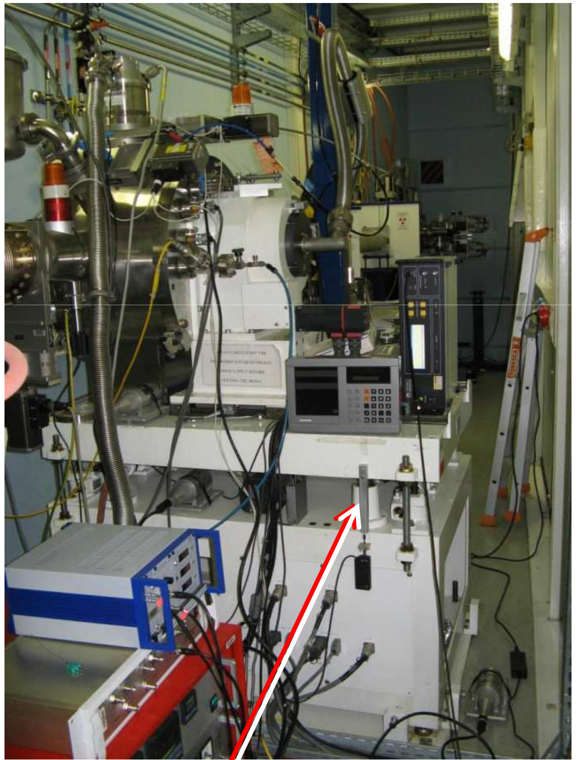

Where the basic relation $C(t) = J \frac{d^2\theta}{dt^2} + C_i$

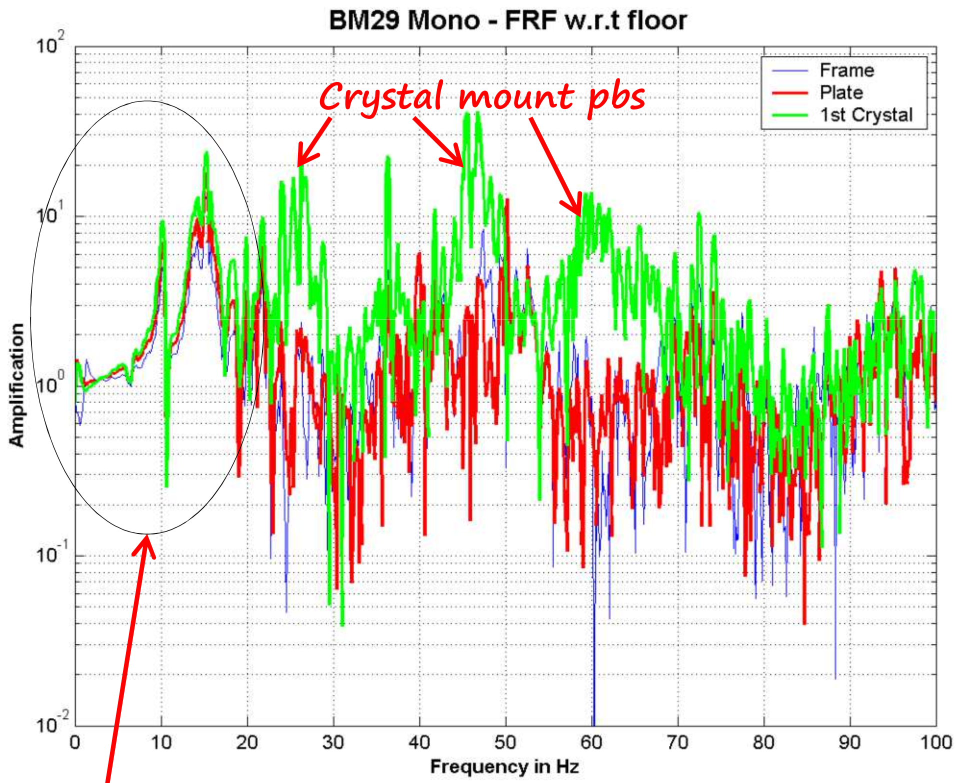
J is the total mass inertia of the Bragg axis

# STABILITY ISSUES: OUTLINES



# GLOBAL VIBRATION CURING





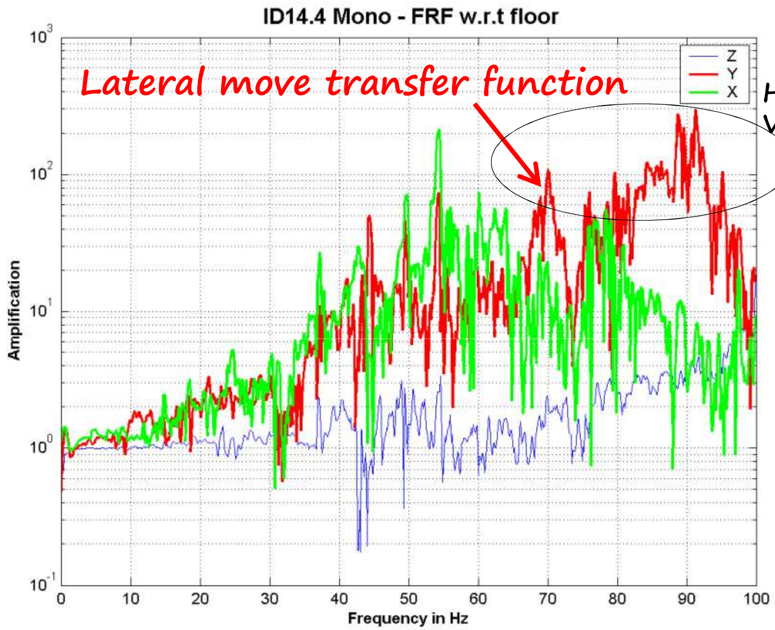

Vibration cure:

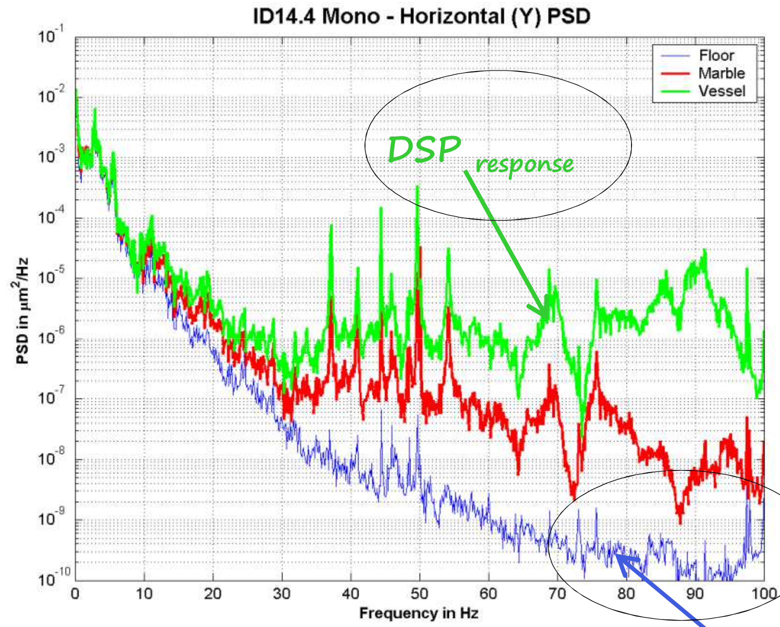
- "Pillar like jacks" removed everywhere
- Base block bonded to floor

Typical stand weaknesses

Older BM29 mono – 2008 – Courtesy M. lesourd

# LATERAL MOVE TRANSFER FUNCTION: UPGRADING A KOHZU STAND AT ID14

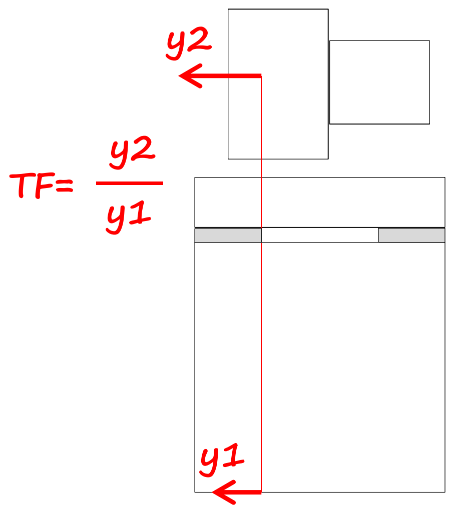


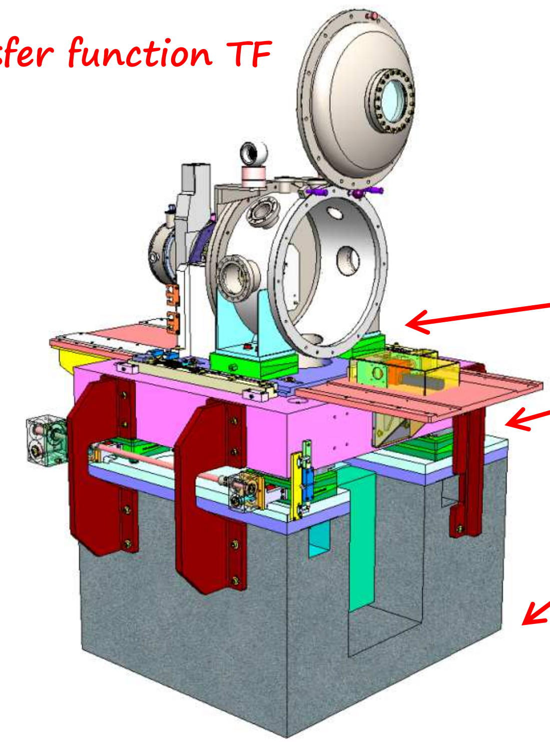




DSP source

Lateral displacement transfer function TF
With respect to floor

$$DSP_{response} = TF^{2}\ DSP_{source}$$



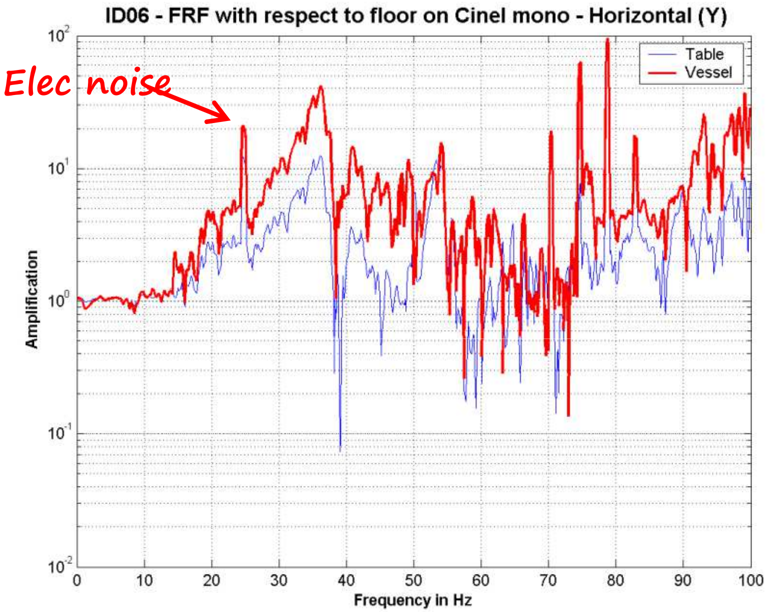



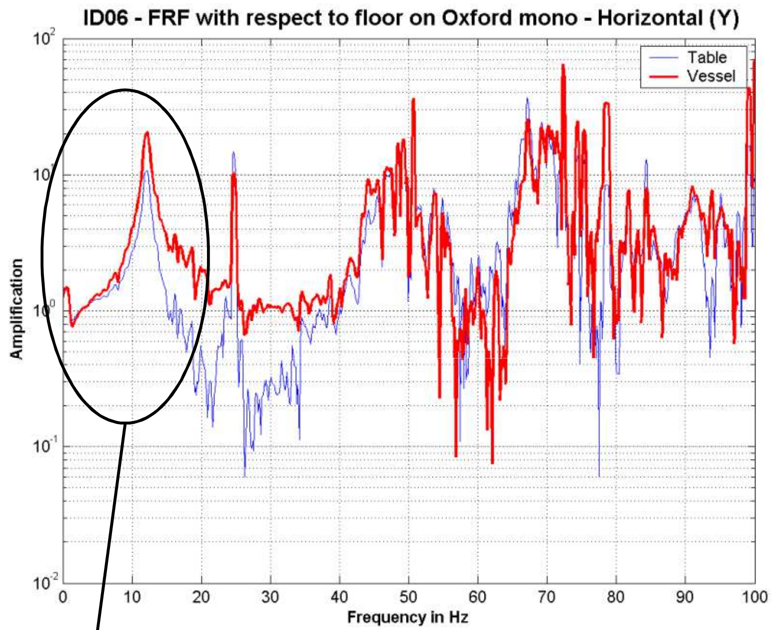
Travels as high as possible

Adjusting at higher level

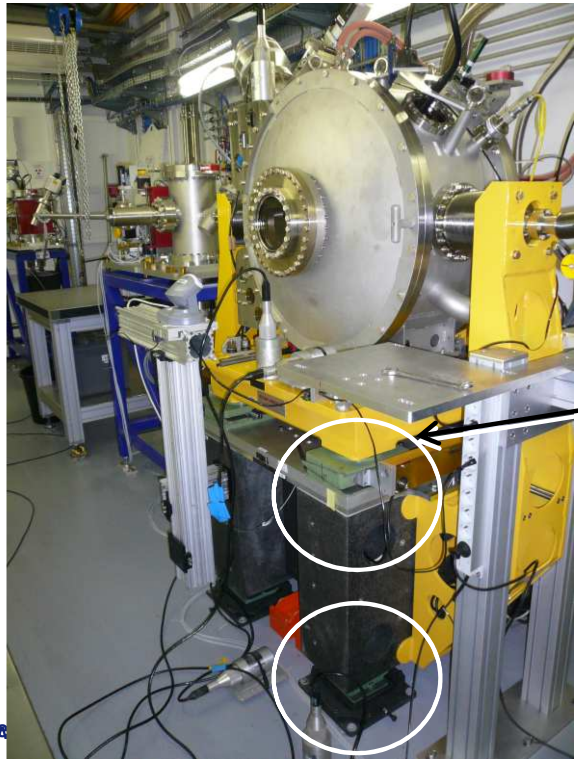
Bonding to floor

# TWO MONOS IN TEST AT THE ESRF ID6- (IN 2008)



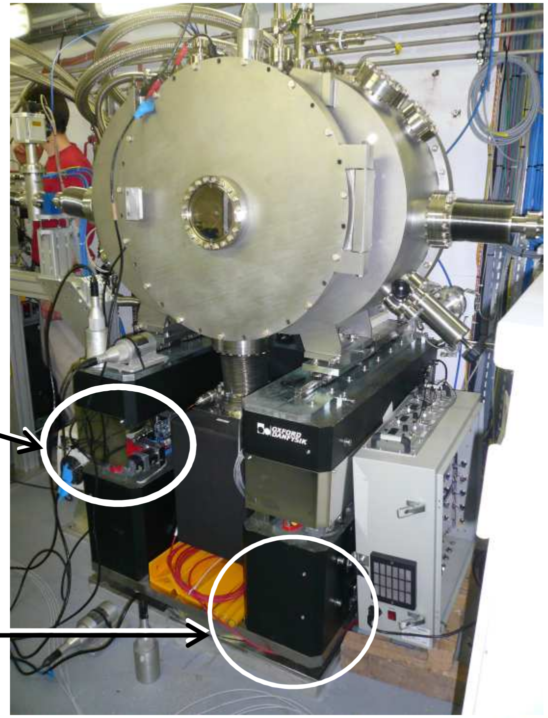

Transfer Function records



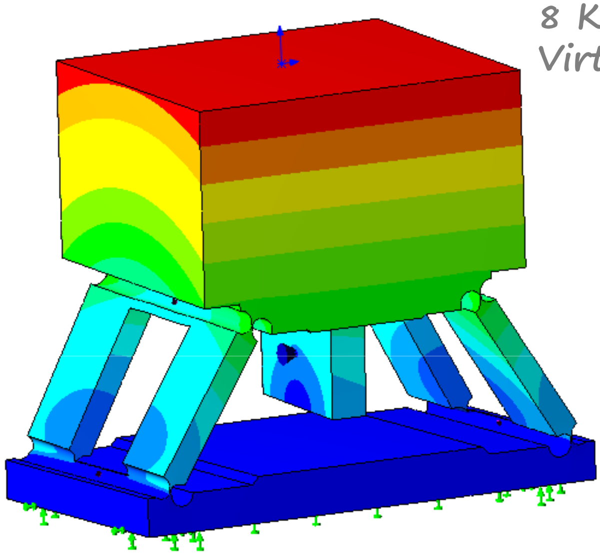
Wedge Jacks here

Pillars here

wedge

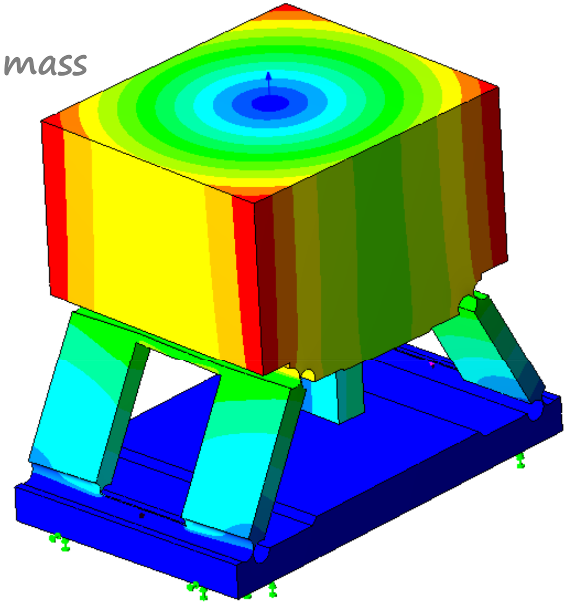


# FLEXURE DESIGN: VERY HARD TO BE PERFECT MODAL ANALYSIS

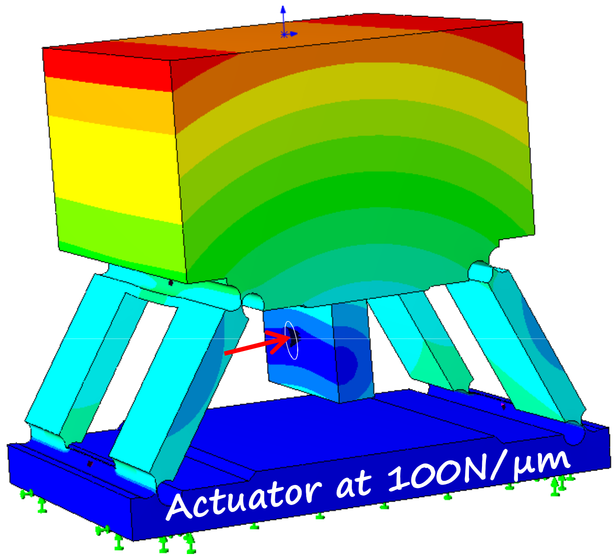


Mode at 21 Hz

8 Kg
Virtual mass



Mode at 31 Hz




Mode at 36 Hz

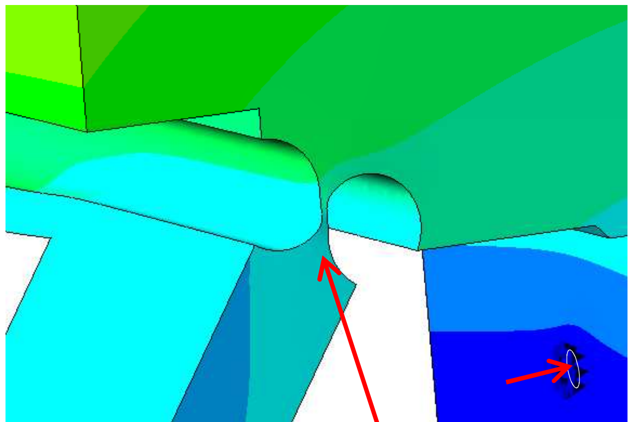
## Simulation of a 2nd crystal positioning

Flexures: Difficult to make non-coupled movements

Ideally: design single degree of freedom with piezo.
Done for white beam optics (ESRF upgrade)

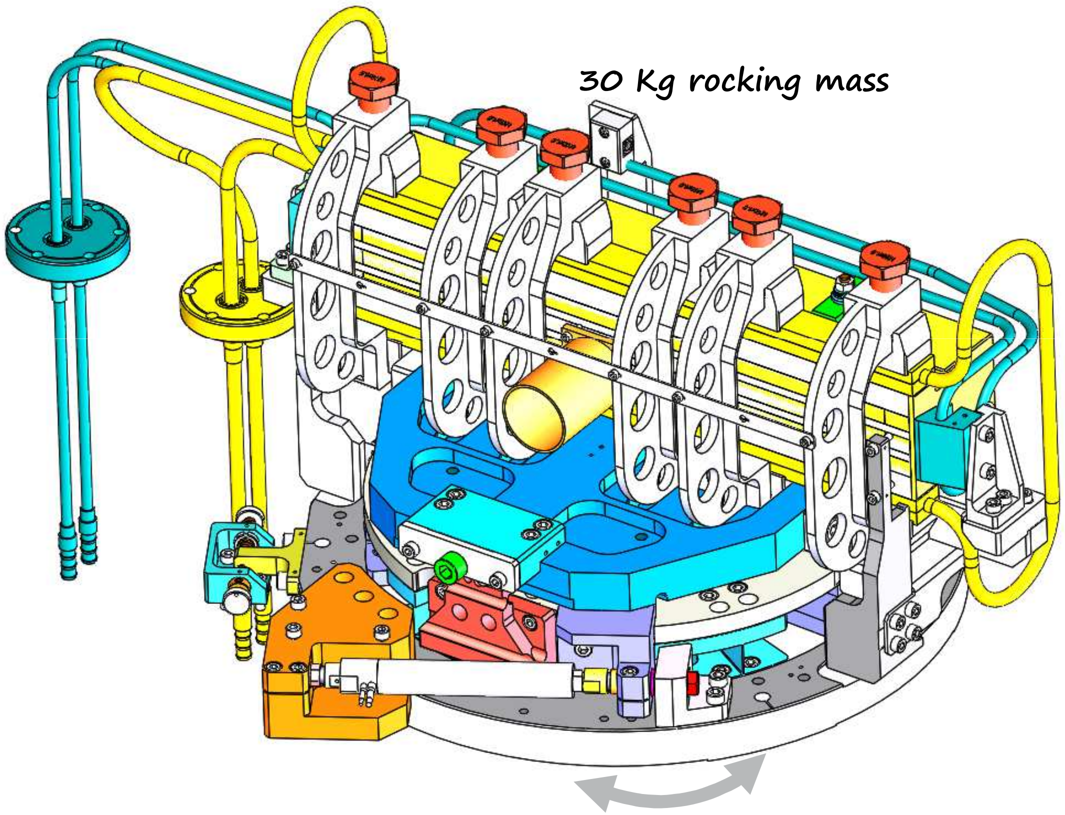
Vibration wise: design target should be at 130 Hz

Beamlines: Not enthusiastic to flexures



Necking is deforming

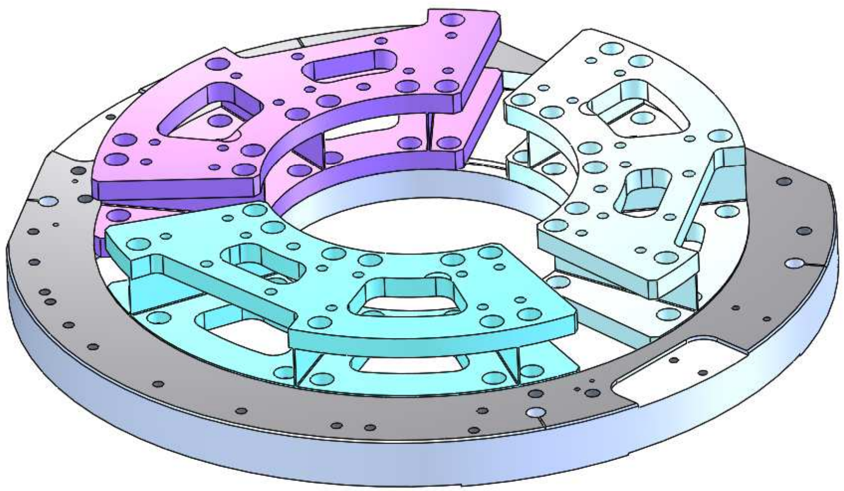
# SINGLE DOF FLEXURE BASED GONIOMETER



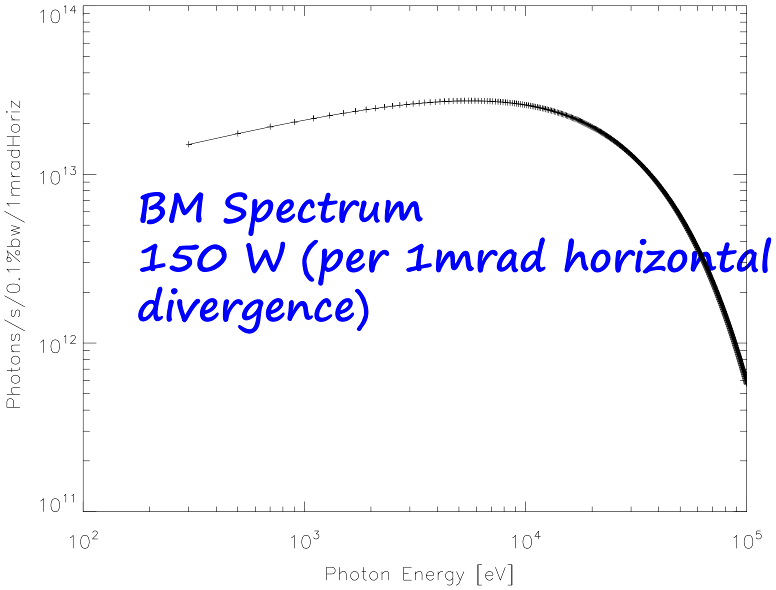

The problem to address is the availability of single DoF high resolution goniometer
(low parasitic motion)

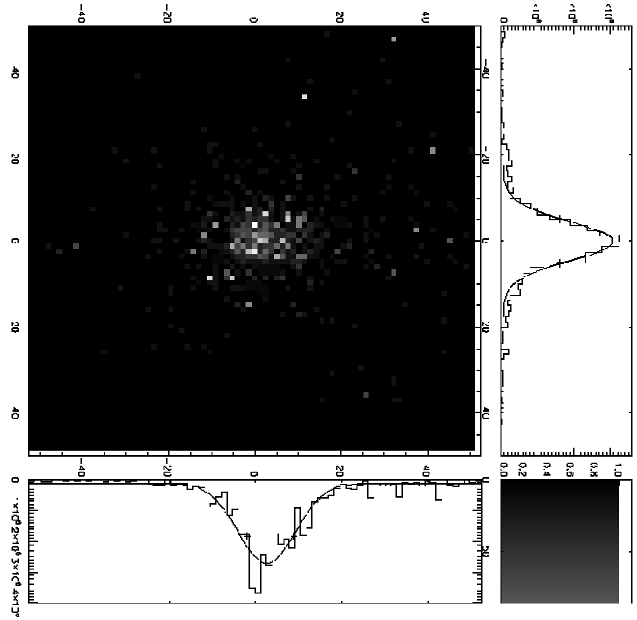
Fine rocking :
- Rx:0
- Ry:0
- Rz: 15 nrd
- low parasitic motions

130Hz loaded at 30 Kg
White beam mirror
ESRF upgrade
Not easy to implement for
A crystal set

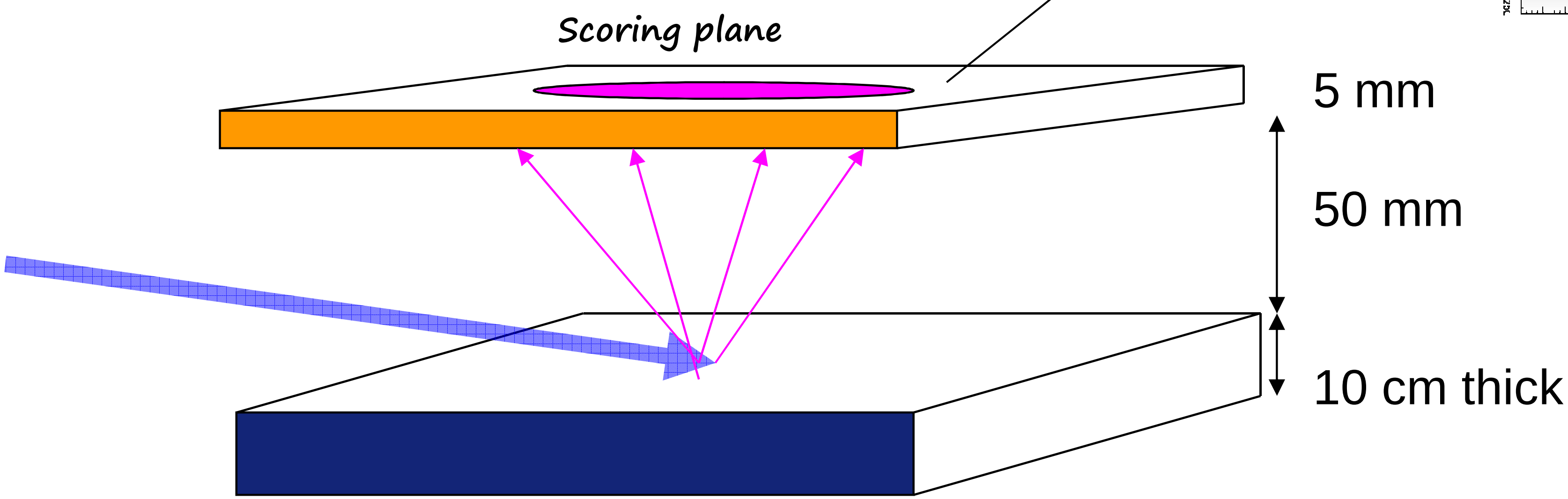


# SCATTERED POWER FROM BM5 CRYSTAL



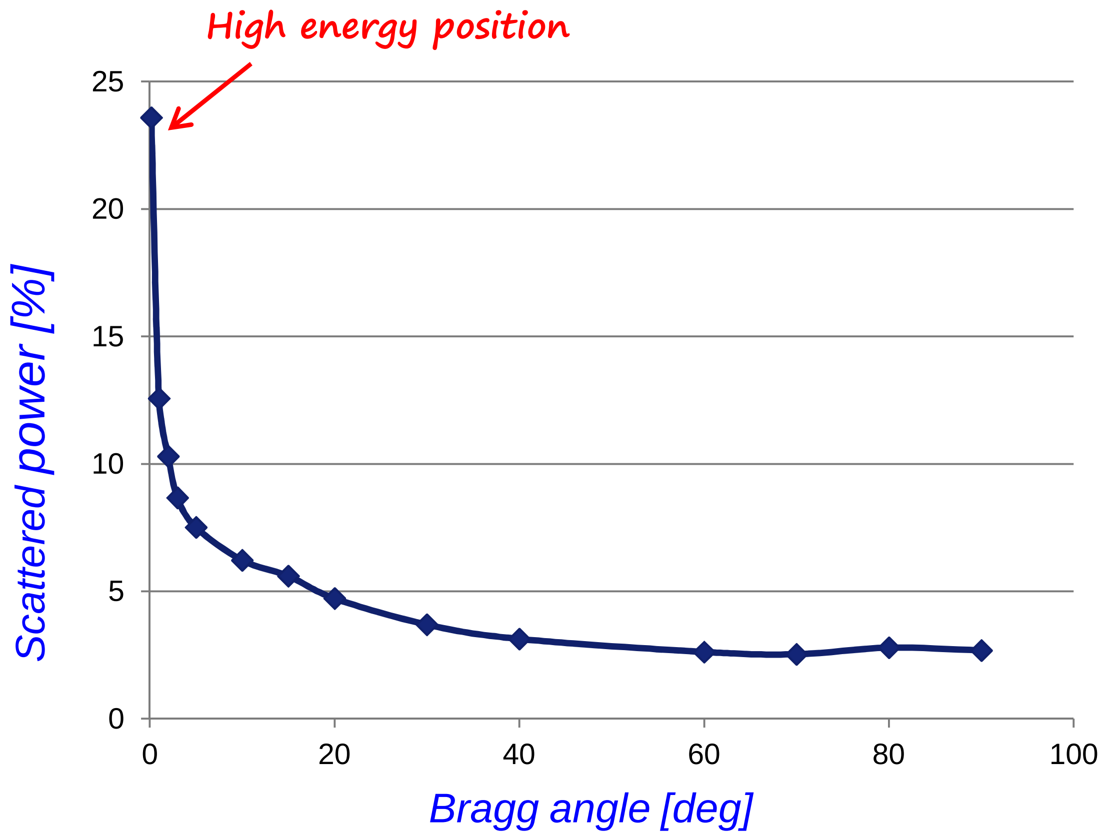



Spatial distribution over the scoring plane



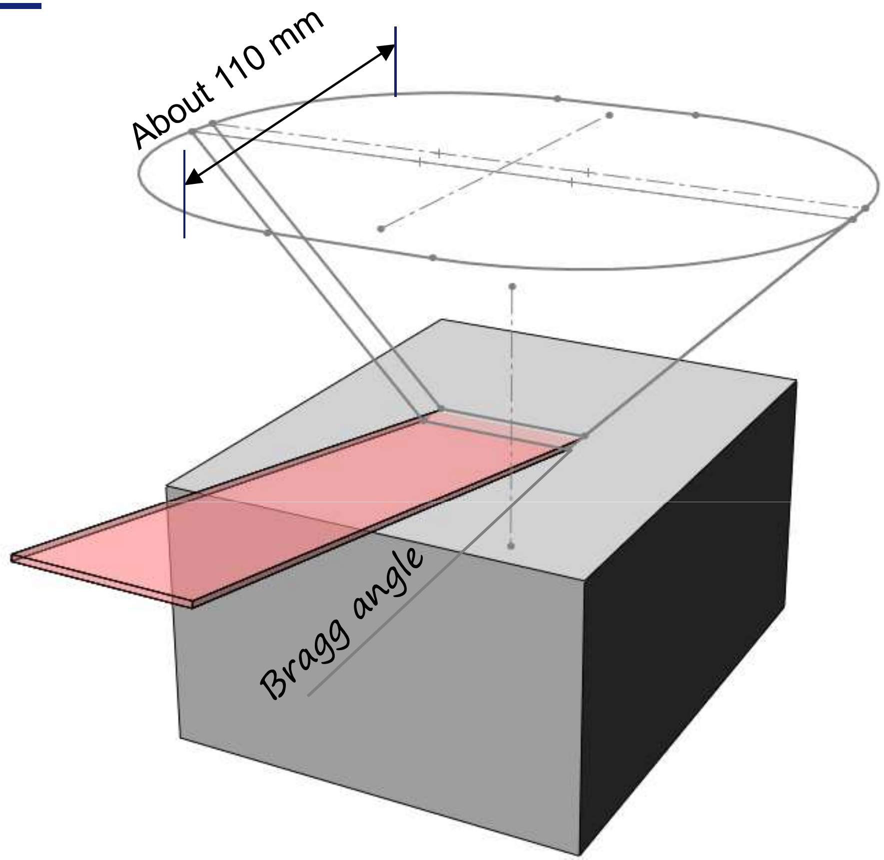
# RESULTS: SCATTERED POWER ON FIRST CRYSTAL

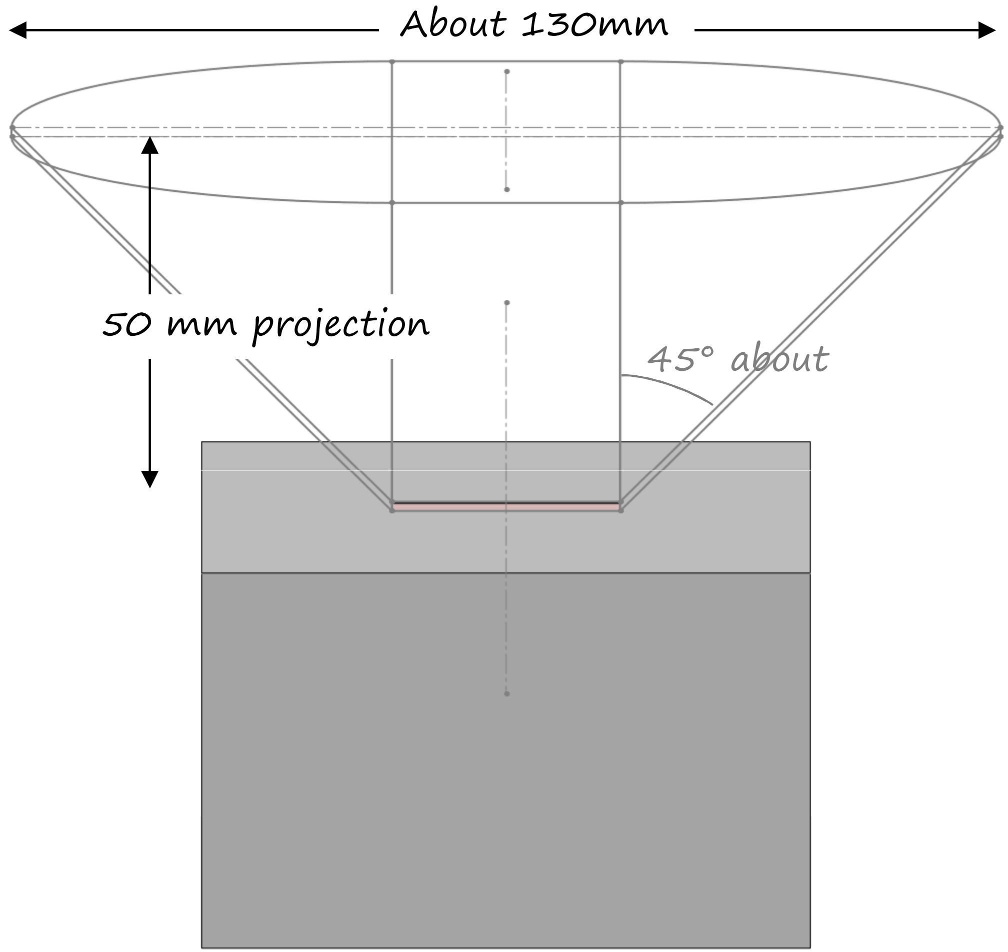
| Bragg angle [deg] | scattering [%] |
|---|---|
| 0.17 | 23.58 |
| 1 | 12.57 |
| 2 | 10.3 |
| 3 | 8.67 |
| 5 | 7.51 |
| 10 | 6.22 |
| 15 | 5.6 |
| 20 | 4.72 |
| 30 | 3.69 |
| 40 | 3.13 |
| 60 | 2.62 |
| 70 | 2.53 |
| 80 | 2.79 |
| 90 | 2.68 |

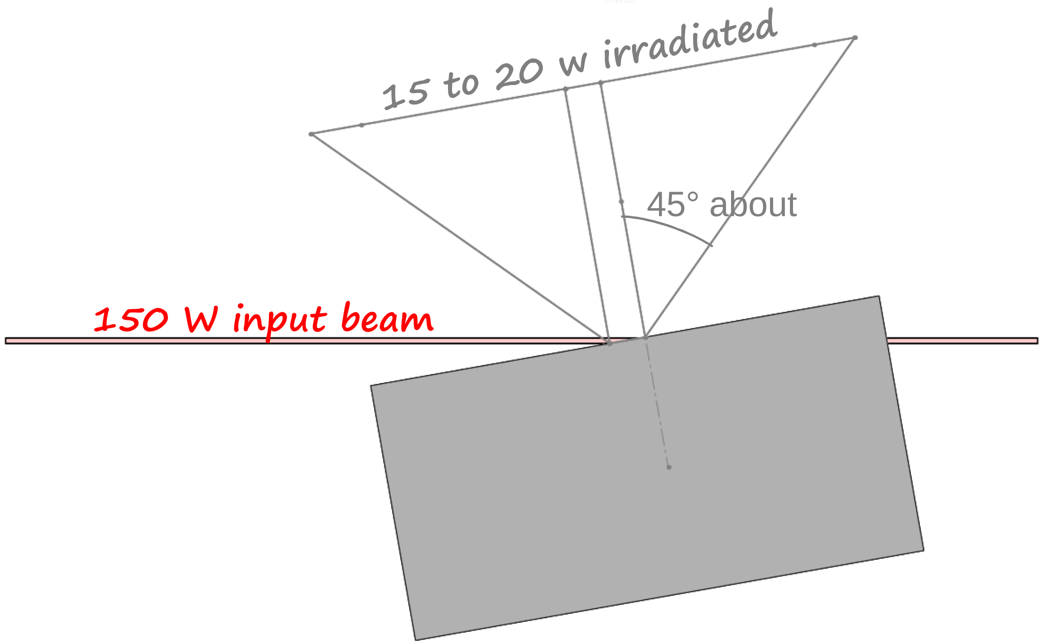



The scattered power has been calculated using "Penelope" code
Here input power is 150 W

The scattered power (fraction of energy irradiated) has been calculated using the incident white bending magnet spectrum shown.
It is always less than 25% and less than 5-8% for usual Bragg angles (> 3 deg)

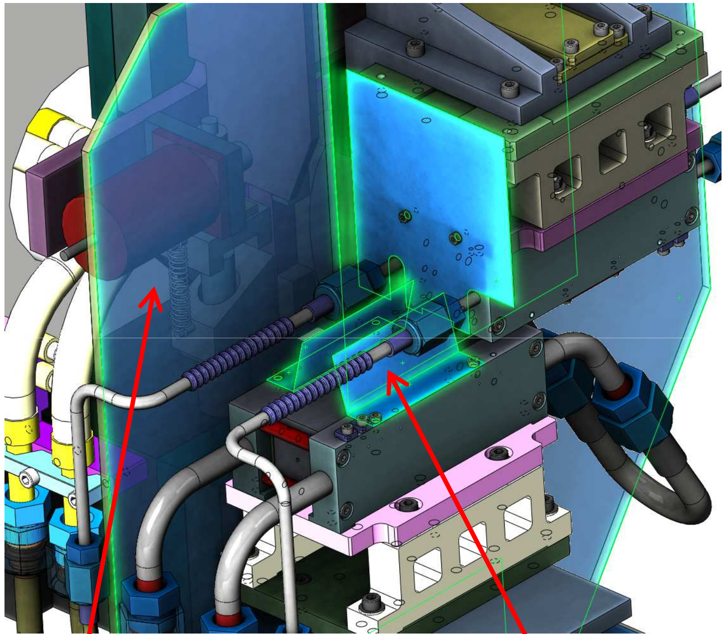


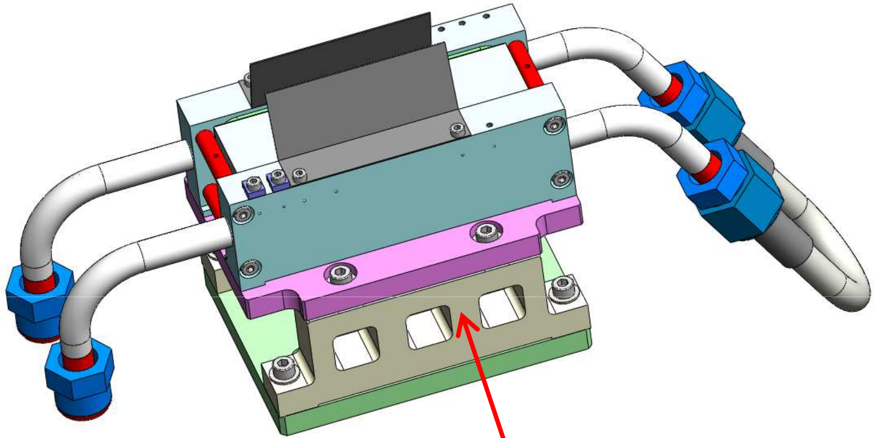




Example of a 30° Bragg incidence
On a 1 mrd beam width at 30m

# TYPICAL SCATTERING SHIELDING

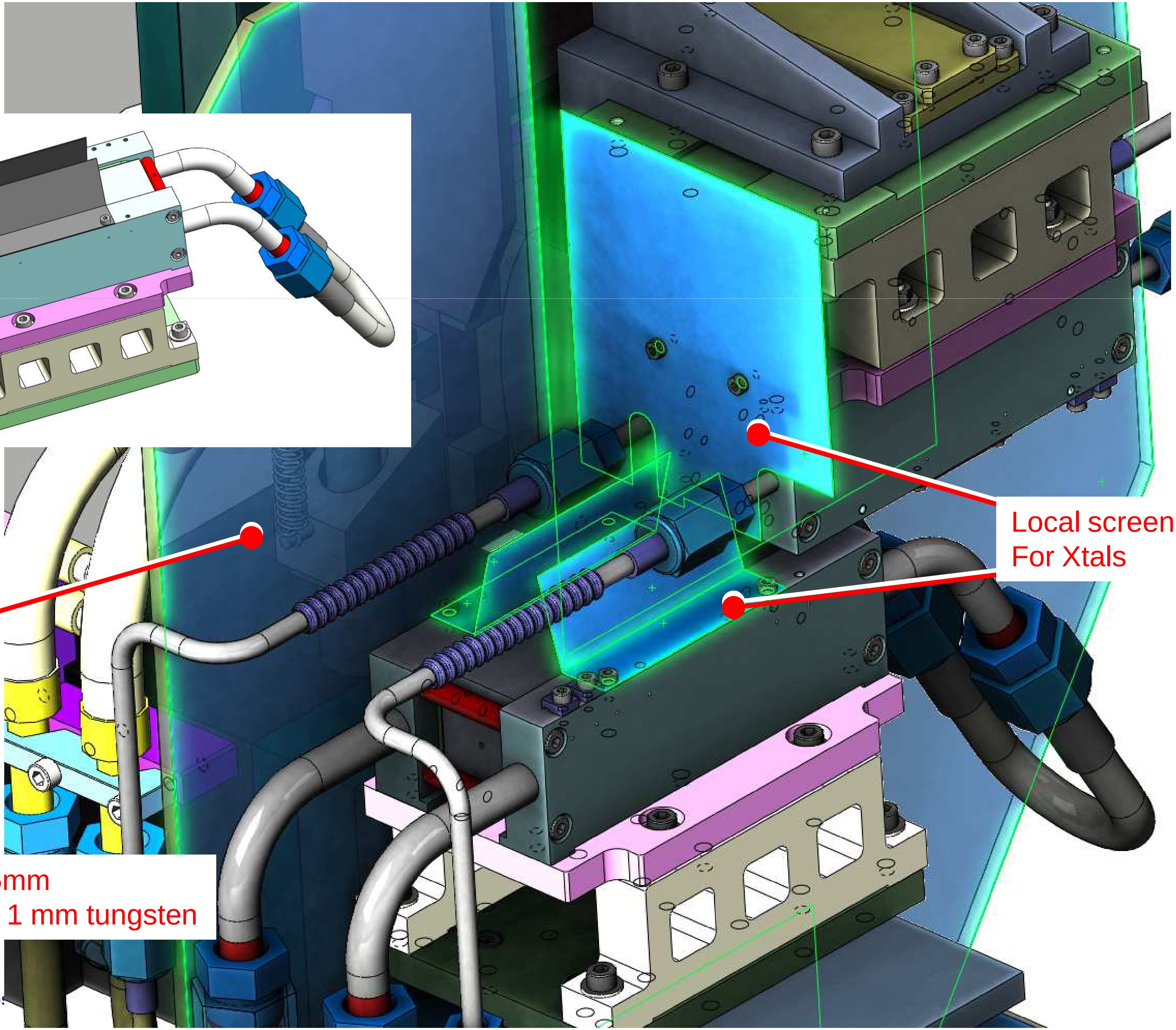




Ceramic
thermal
break

Local tungsten screens are 1 mm

Global side
Screen
Shielding the
Positioning
Mechanisms
5 mm copper




Global screen is 5mm
Local screens are 1 mm tungsten

We a far from being blocked
Still many issues

Good dynamics analysis

Labs have best operation analysis
We are the users

Labs have best experience for
Stability issue

Heater

Shielding

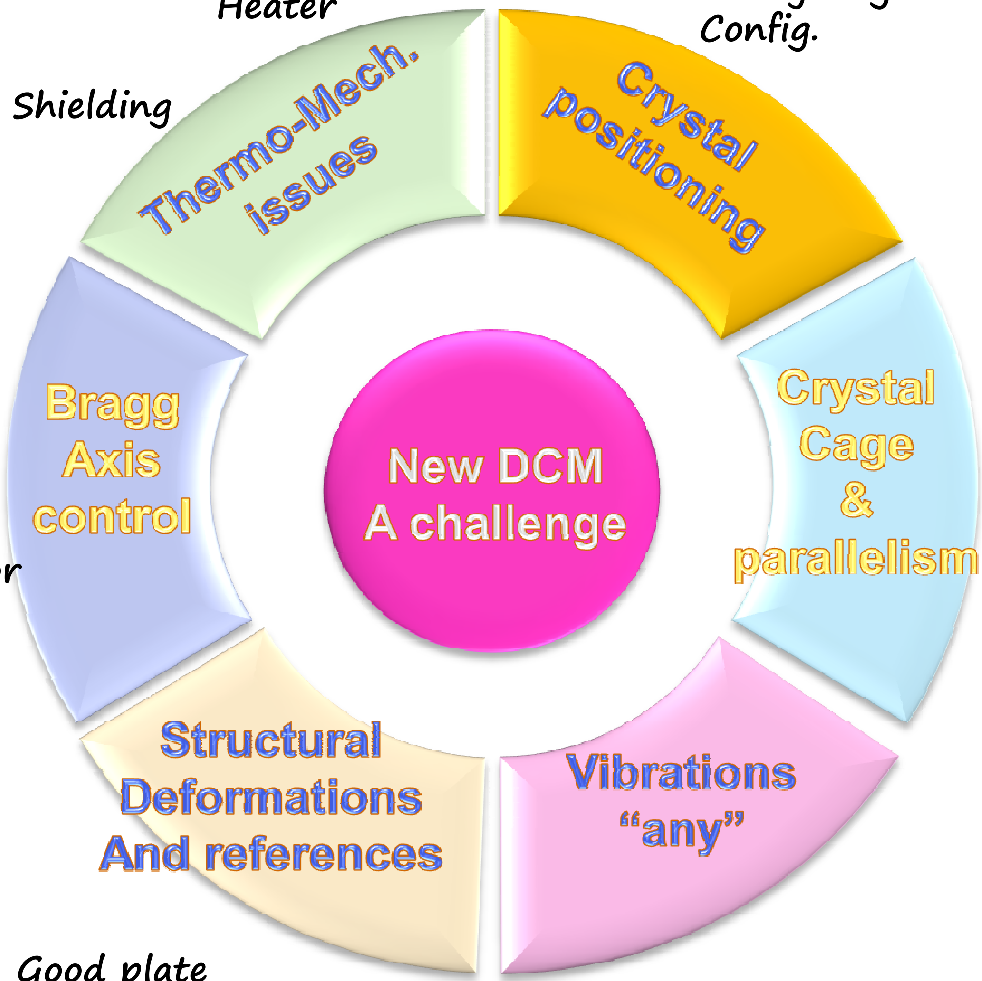
Always a good
Config.

Direct drive

Gearbox motor

Good stage

All fixed




Good plate

High design validation

Thank you for your attention…