# MAGiC

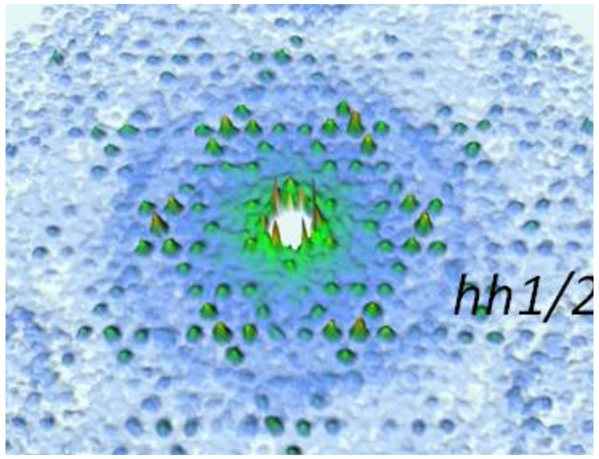
Instrument details and expected performances

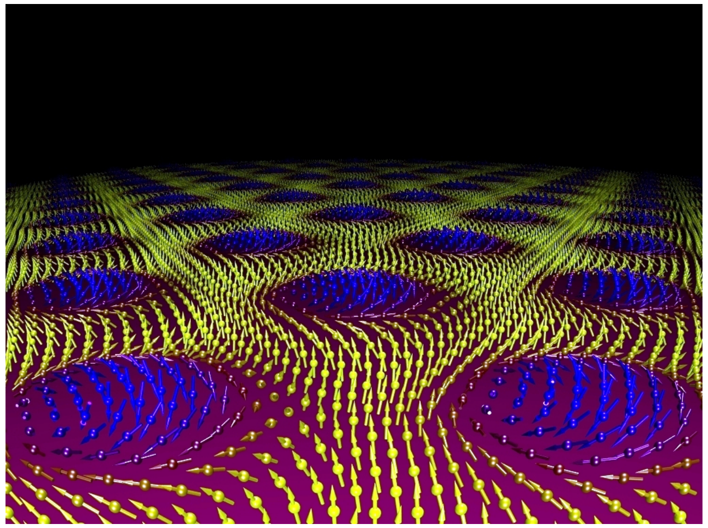
# Outline

- **Instrument requirements**
- Simulation hypothesis
- Instrument Walkthrough
- Expected performances
    - Raw performances
    - Simulated experiments
    - Gain factors

# Science case

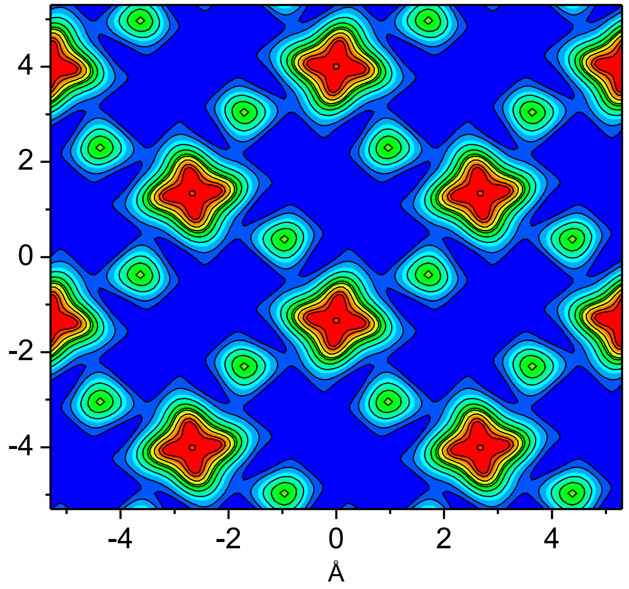
- Incommensurate magnetism
  - Chirality, multiferroicity, skyrmions
- Magneto-elasticity
- Frustrated magnets
- Superconductors
- *4f*, *5f* magnetism

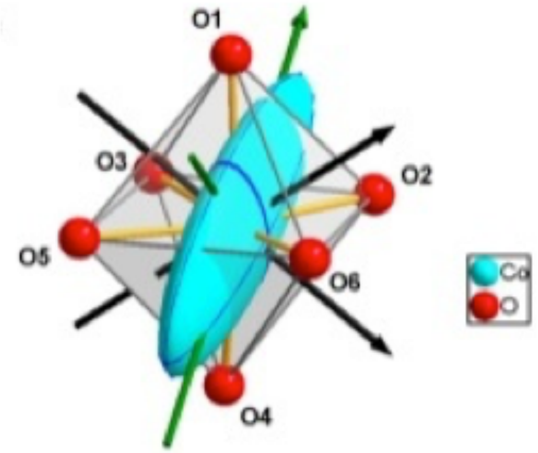


- Thin films / nano materials
- Molecular magnets

- Local anisotropy
- Spin densities

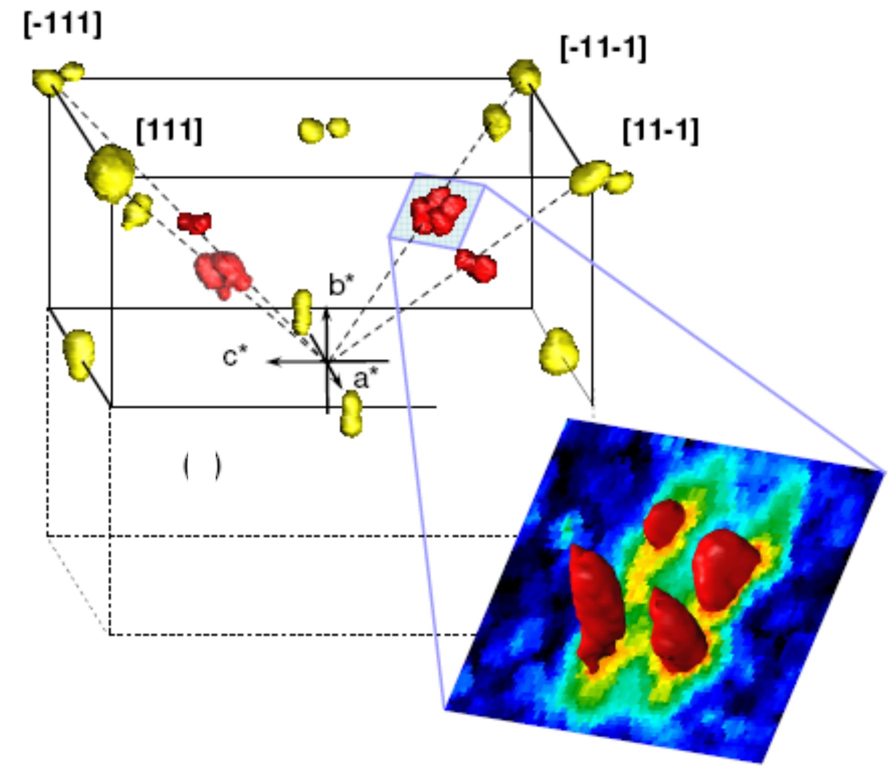


# Ordered magnets

- Spinels, perovskites, multiferroic, competing interactions

- Magnetic diversity
  - $BiFeO_3$: periodicity of 640 Å
  - RMnO3: periodicity of 6 Å



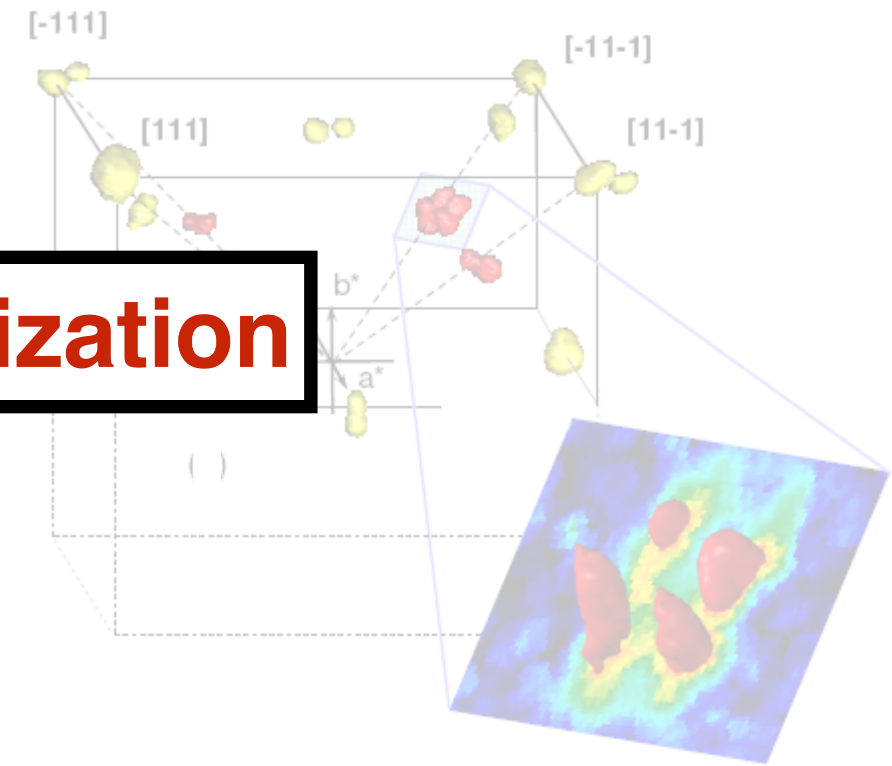
# Bragg regime

- Spinels, perovskites, multiferroic, competing interactions

- Magnetic

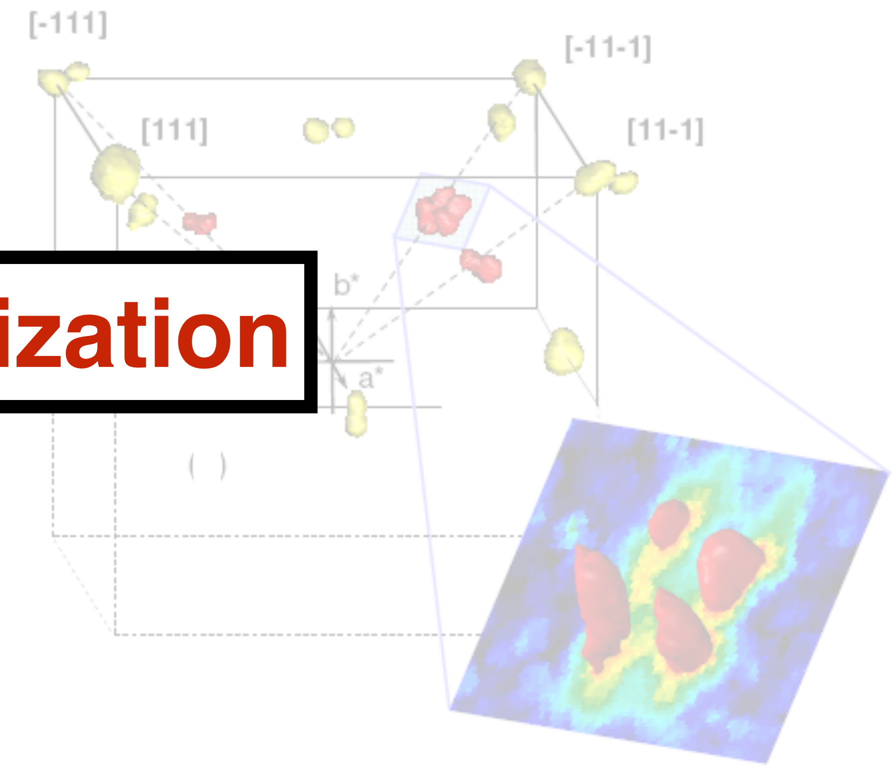
**Cold neutrons + polarization**

  - $BiFeO_3$: periodicity of 640 Å
  - RMnO3: periodicity of 6 Å



# Bragg regime

- Spinels, perovskites, multiferroic, competing interactions

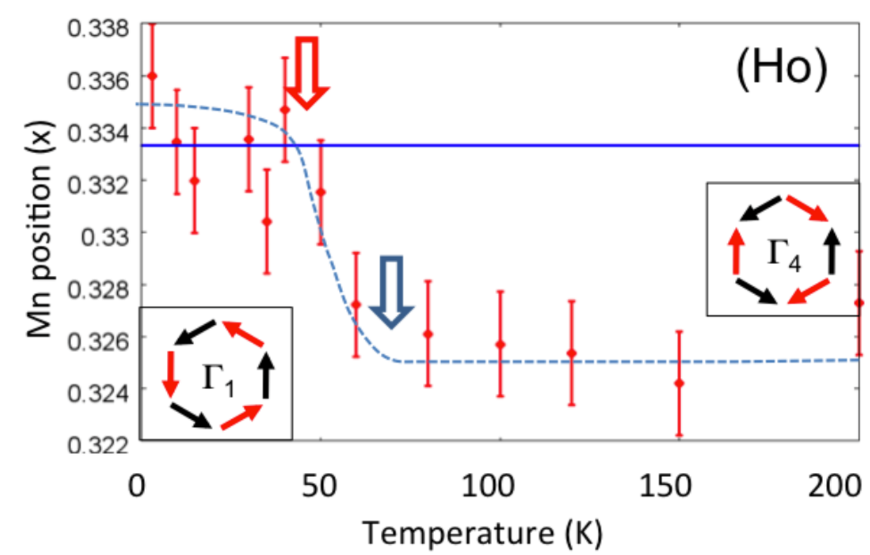



- Magnetic

**Cold neutrons + polarization**

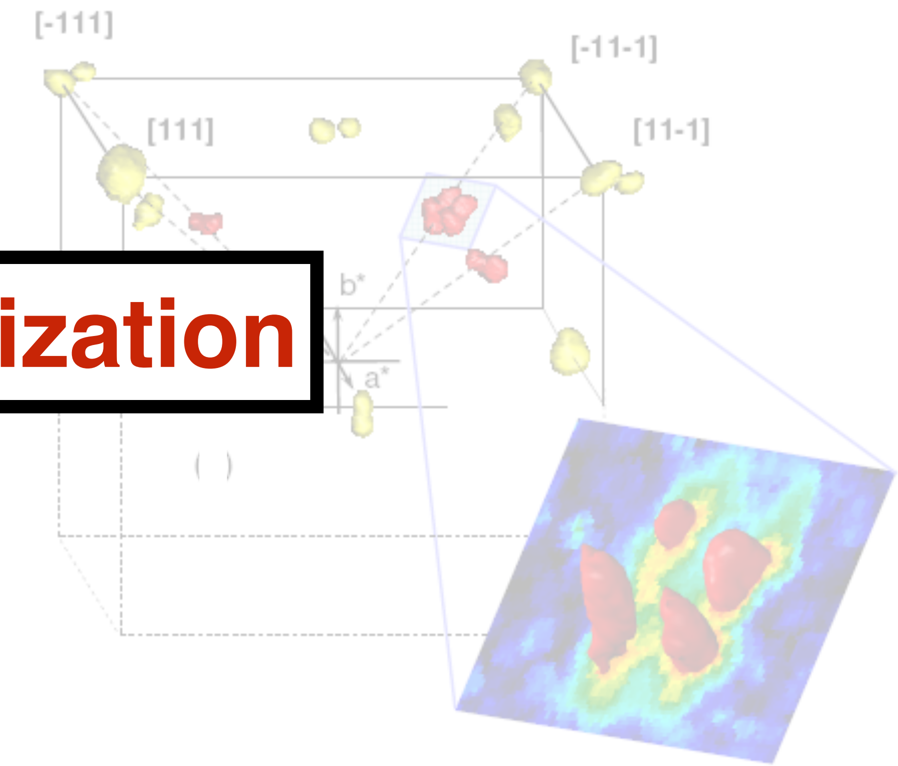
  - $BiFeO_3$: periodicity of 640 Å
  - RMnO3: periodicity of 6 Å

- Multiple coupling (magneto-elastic, multiferroic)
- high resolution refinement



# Bragg regime

- Spinels, perovskites, multiferroic, competing interactions

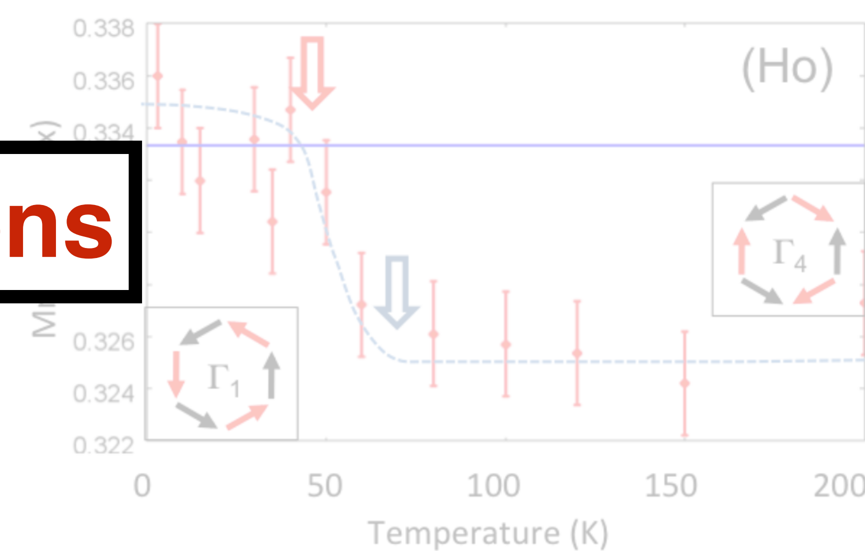



- Magnetic
  - $BiFeO_3$: periodicity of 640 Å
  - RMnO3: periodicity of 6 Å

**Cold neutrons + polarization**

- Multiple coupling (magneto-elasti
- high resolution refinement

**Thermal neutrons**



# Instrumental requirements

**Thermal**

Divergence: +-0.3°
Wavelength: 0.7-2.4 Å
Polarization: >99%

**Cold**

Divergence: +-0.5°
Wavelength: 2.2-5.6 Å
Polarization analysis

Sample size:
- Thin films: 1 $cm^2$
- Bulk: < 1$mm^3$ (down to 0.001 $mm^3$)

Lattice parameters:
- Nuclear : 5-30 Å
- Magnetic : 5-200 Å

# Outline

- Instrument requirements
- **Simulation hypothesis**
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# McStas 2.1

- Neutron optic
  - Swarm Particle Optimizer (iFit)
  - GuideBot (M. Bertelsen)

- ESS source model:
  - McStas component partially accounting for pancake geometry
  - Uniform spatial brilliance distribution

- Gravity !

# Message

- Not the definitive design !

- Detailed design and optic dimensions:
  - Beamport
  - Space for guide outside the monolith
  - Moderator final design and brilliance

- Presented design is one of the working solutions
- No matter the ESS constraints an equally performing design will be find !

# Outline

- Instrument requirements
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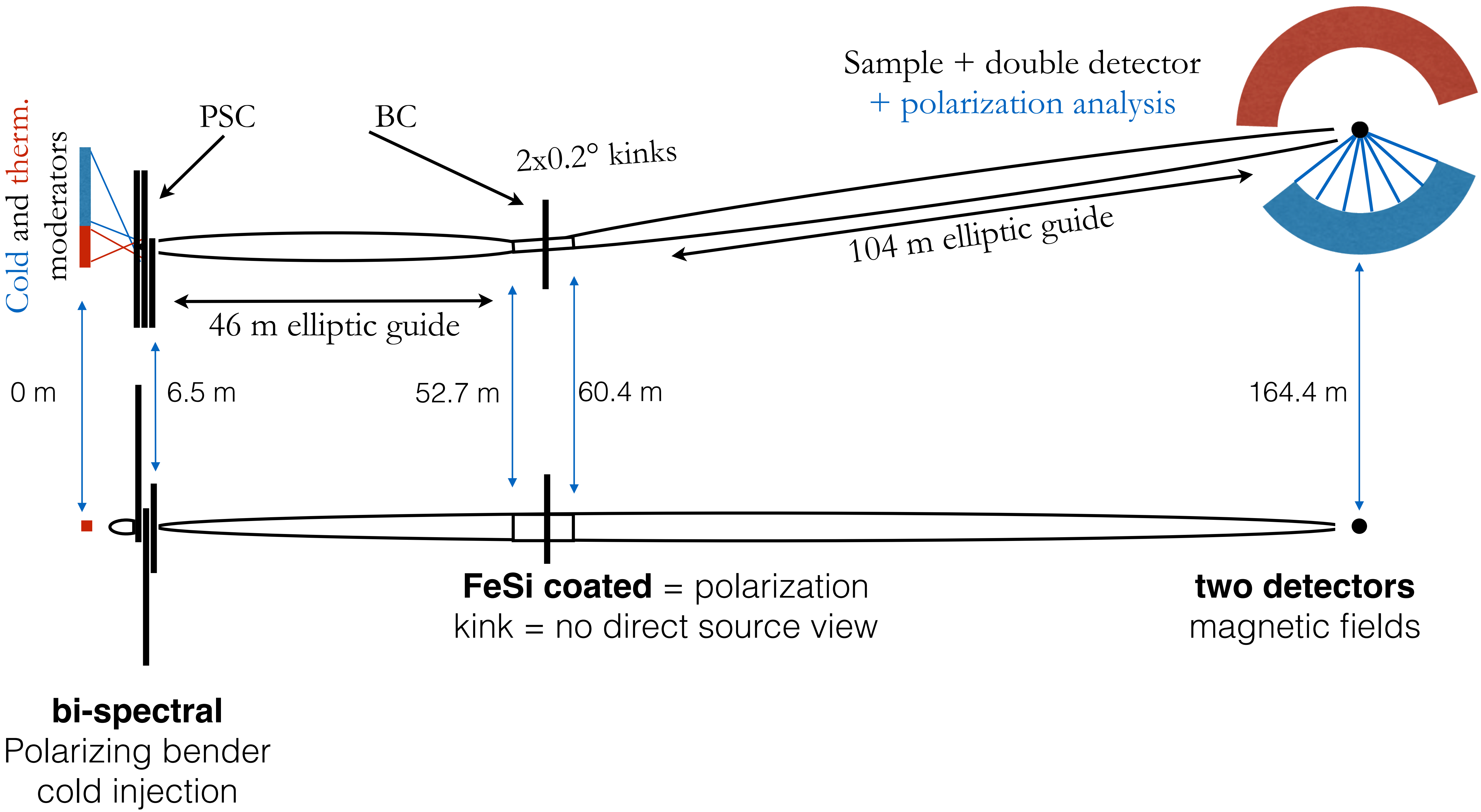
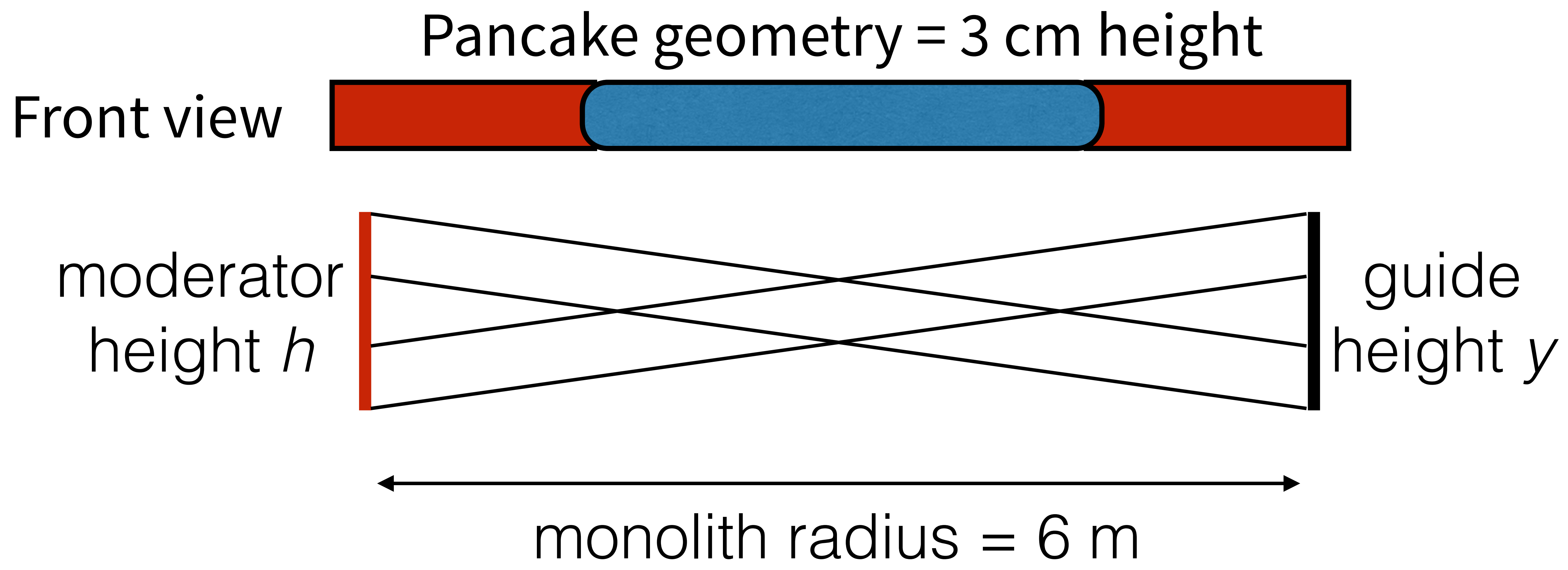
# Proposed design



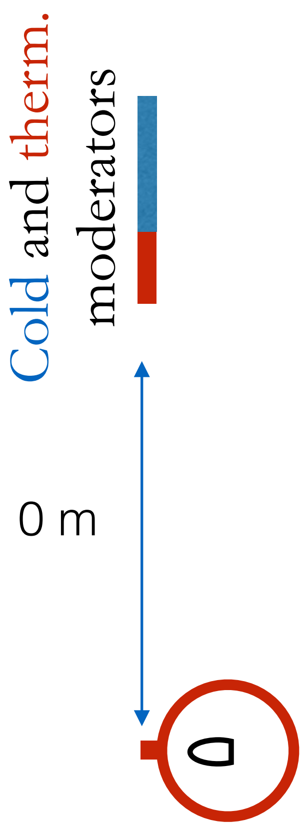
# Transporting divergence




max. vert. div. ~ (h+y-0.01)/(2*radius) * 180/$\pi$
~ ±0.25 °

We need a feeder in the monolith to increase **cold and thermal** vertical divergence !

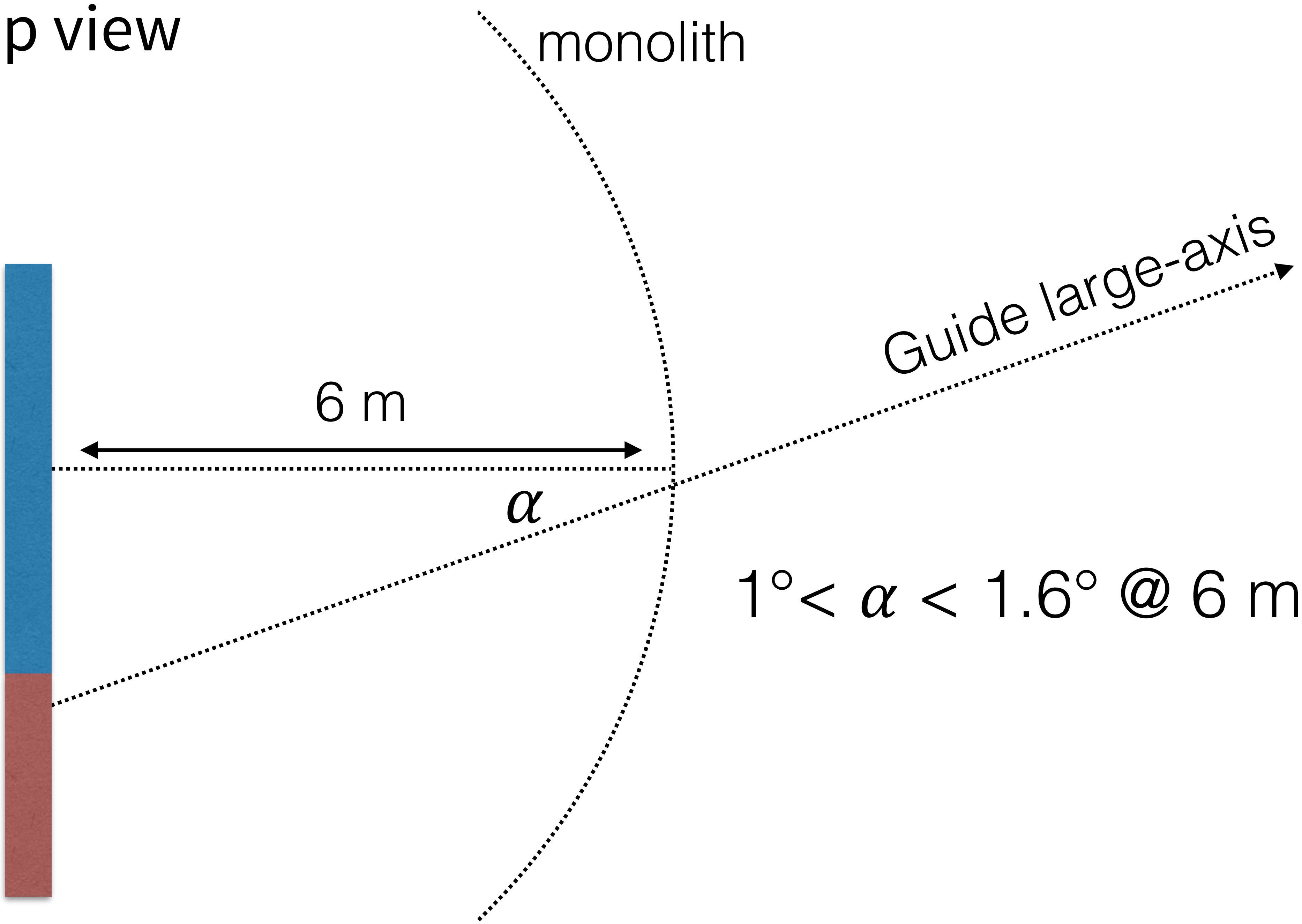
# Proposed design




Vertical feeder for cold neutrons
half-ellipse: from 2 to 6 m
opening : 2.5 cm
small-axis : 2.25 cm

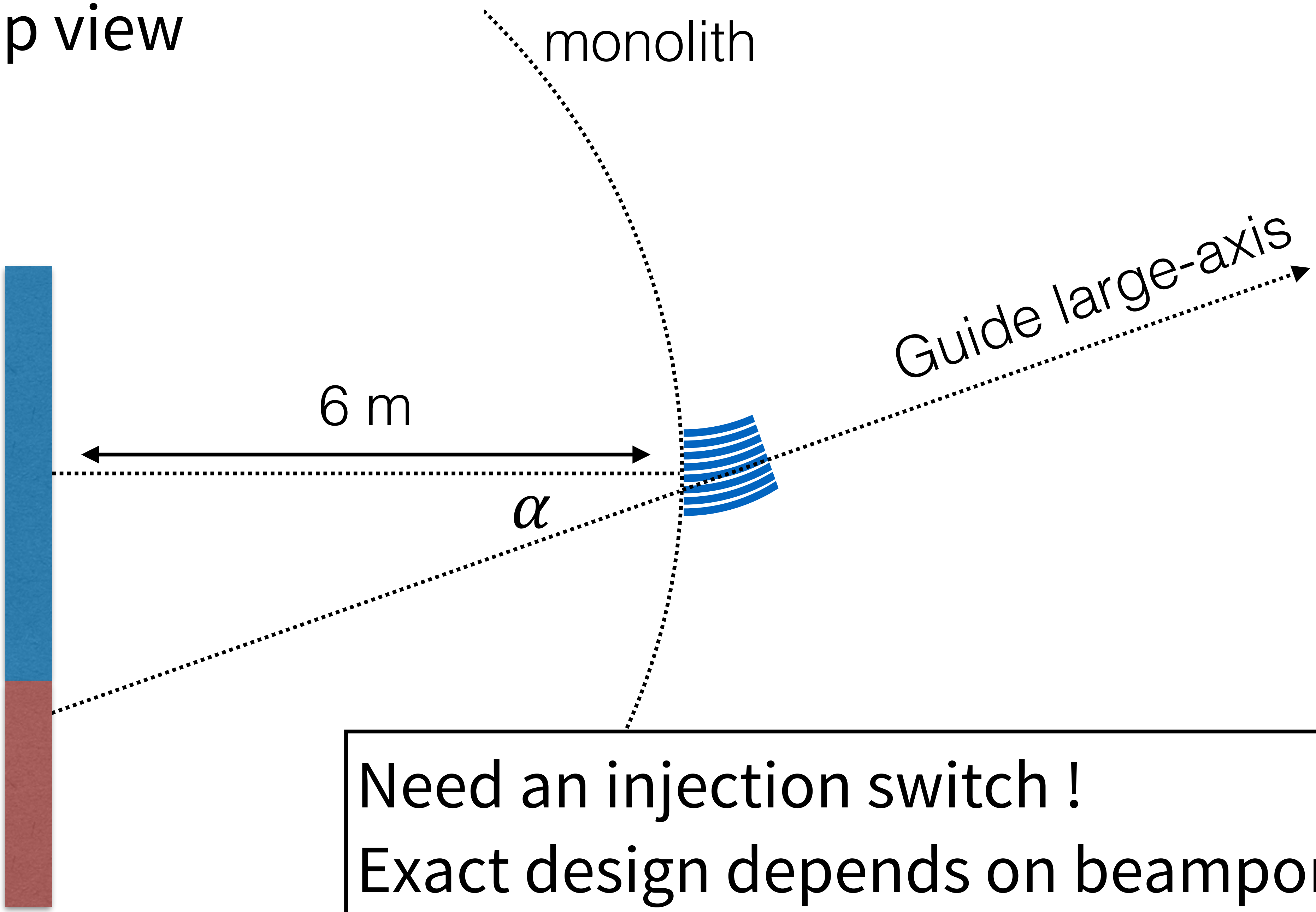
# Cold injection

Top view



# Cold injection

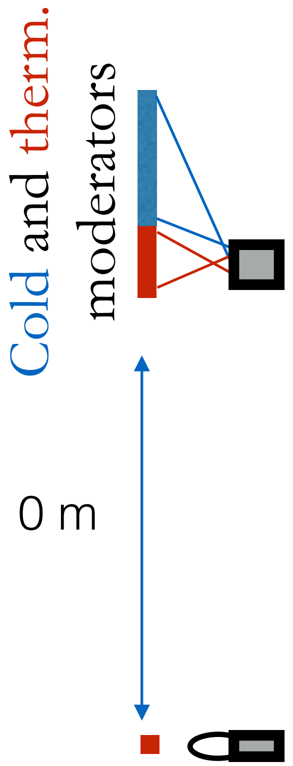
Top view




Need an injection switch !
Exact design depends on beamport

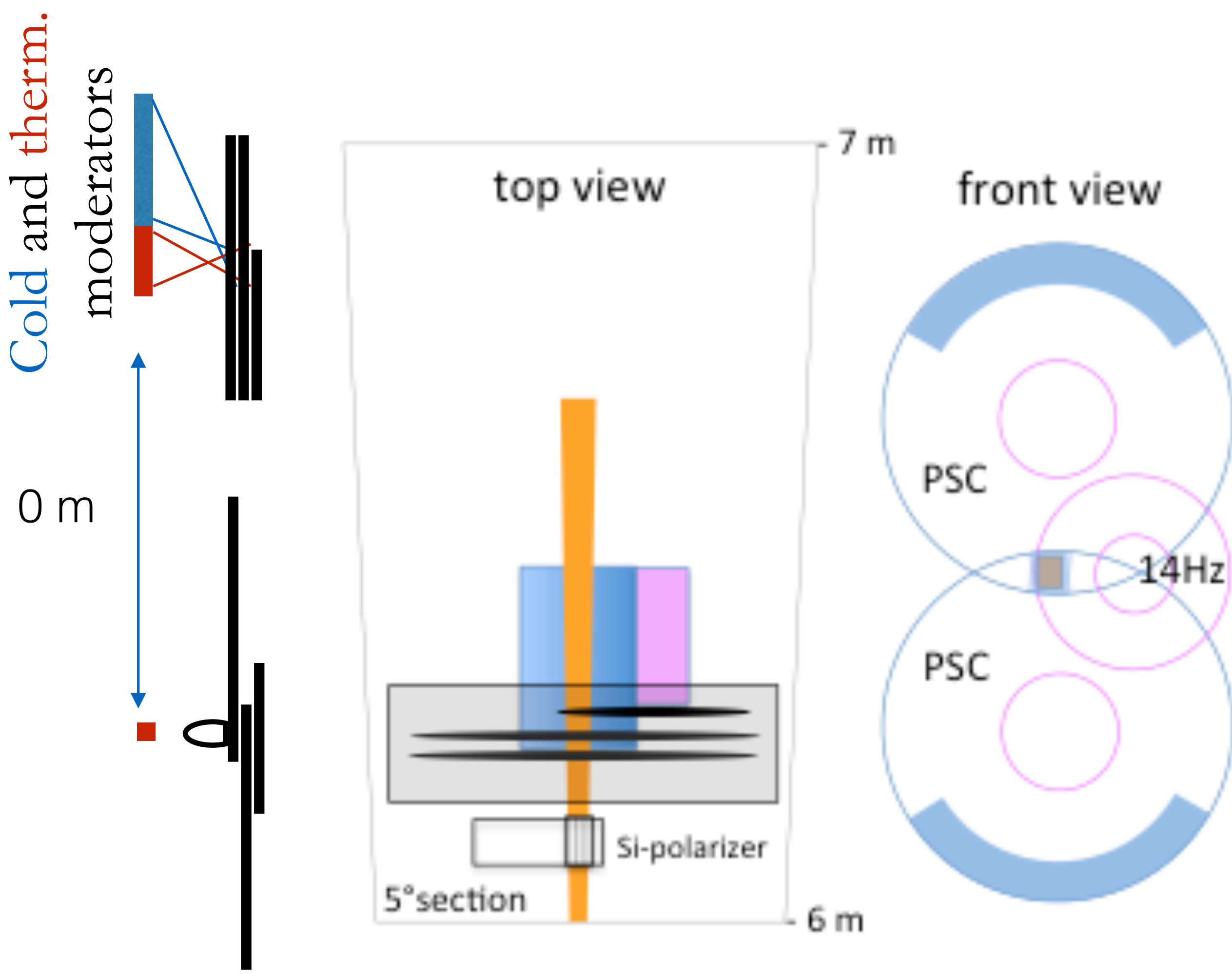
Central beamport: $\alpha$=1.3°

# Proposed design




Si solid state bender for cold neutron injection
200 channels, FeSi/Gd coated (reflec./abs. side)
length~6 cm, curvature radius ~3 m
total width : 3 cm
total height : 4.5 cm

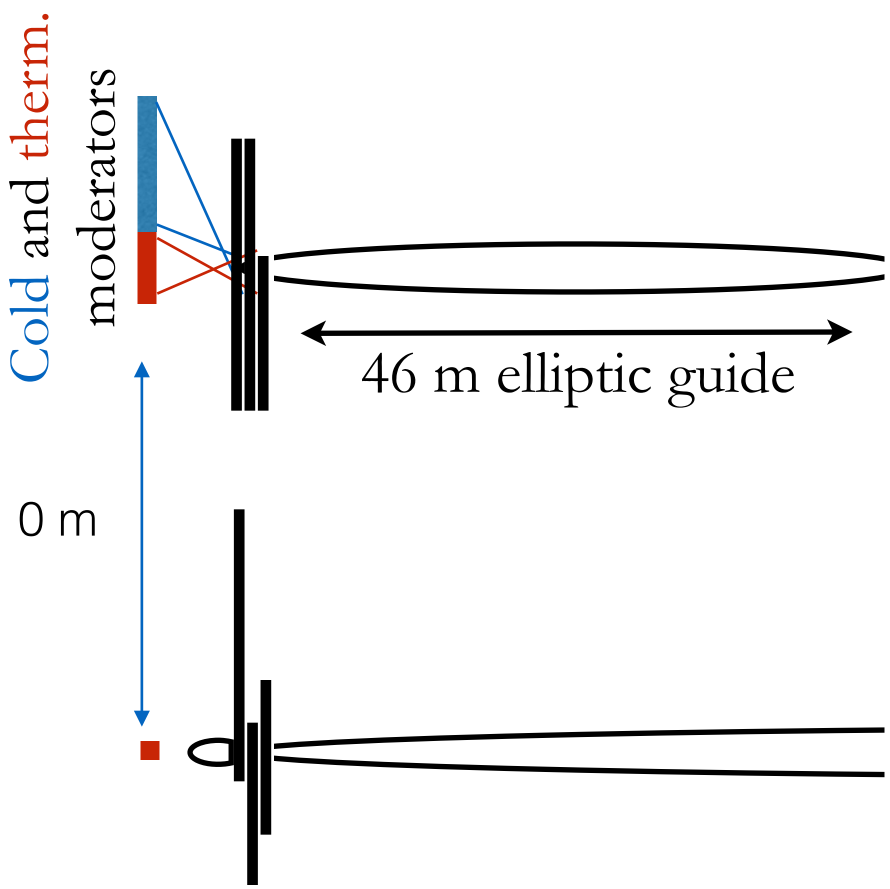
# Proposed design




3 pulse shaping choppers

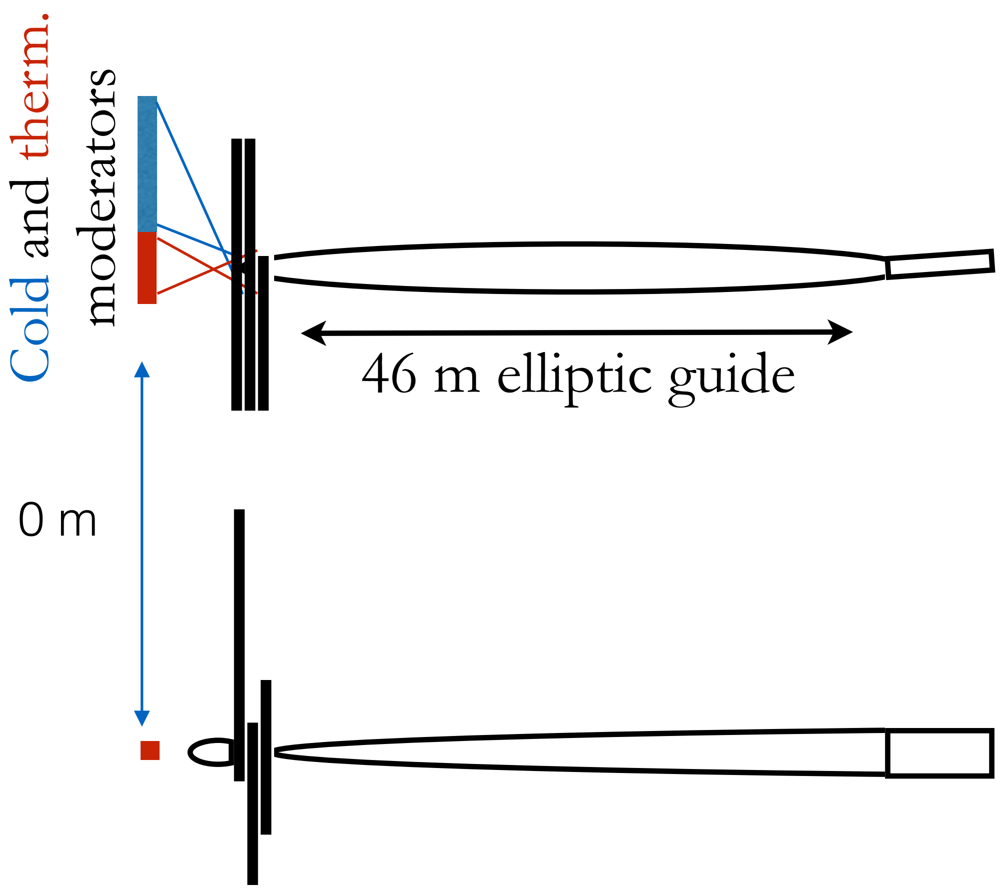
- 2 @14Hz harmonics
- 1 @ 14 Hz
- 6.2 m from source
- 45 cm diameter

# Proposed design



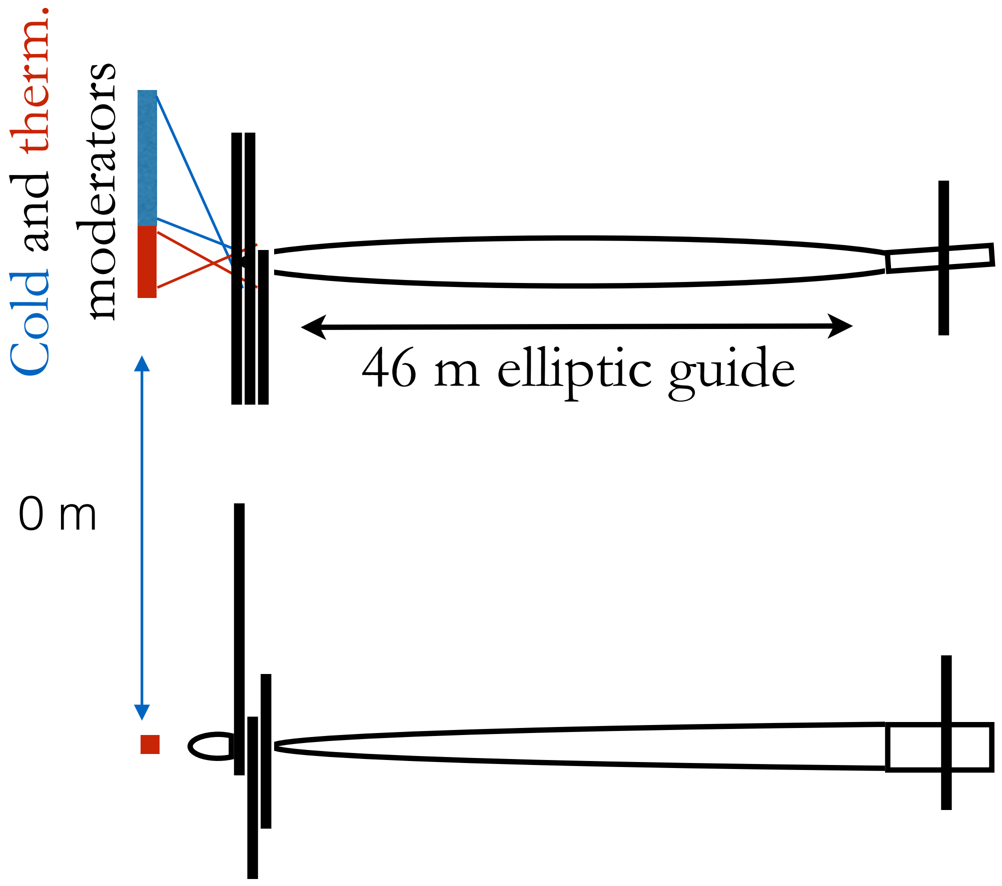

1st elliptical section: FeSi coated (left/right) and NiTi coated (top/bottom)
Adaptive *m*-coating ($1.5<m<5$)
length = 46 m
small-axis = 4 cm

# Proposed design



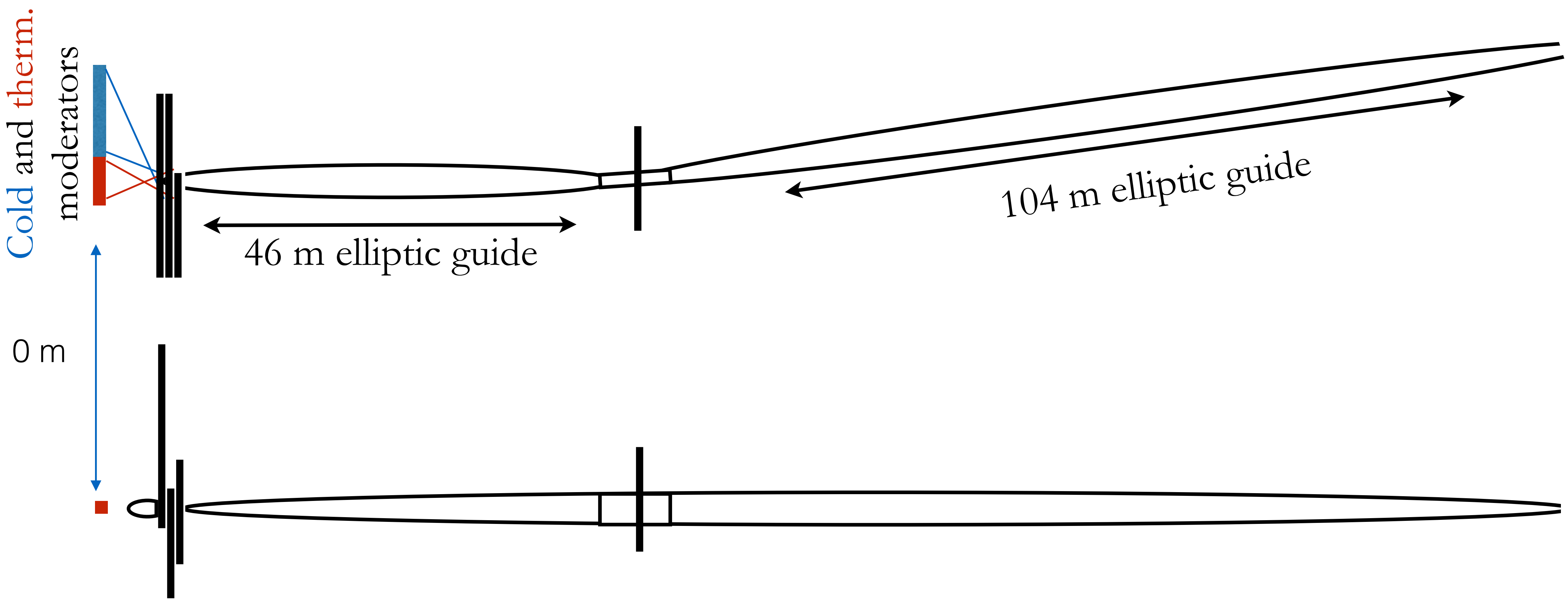

V-shaped connection
length=7.7 m
*m*-coating = 4 (right), 2 (others)
Polarization + no line of sight kink: 0.2°

# Proposed design



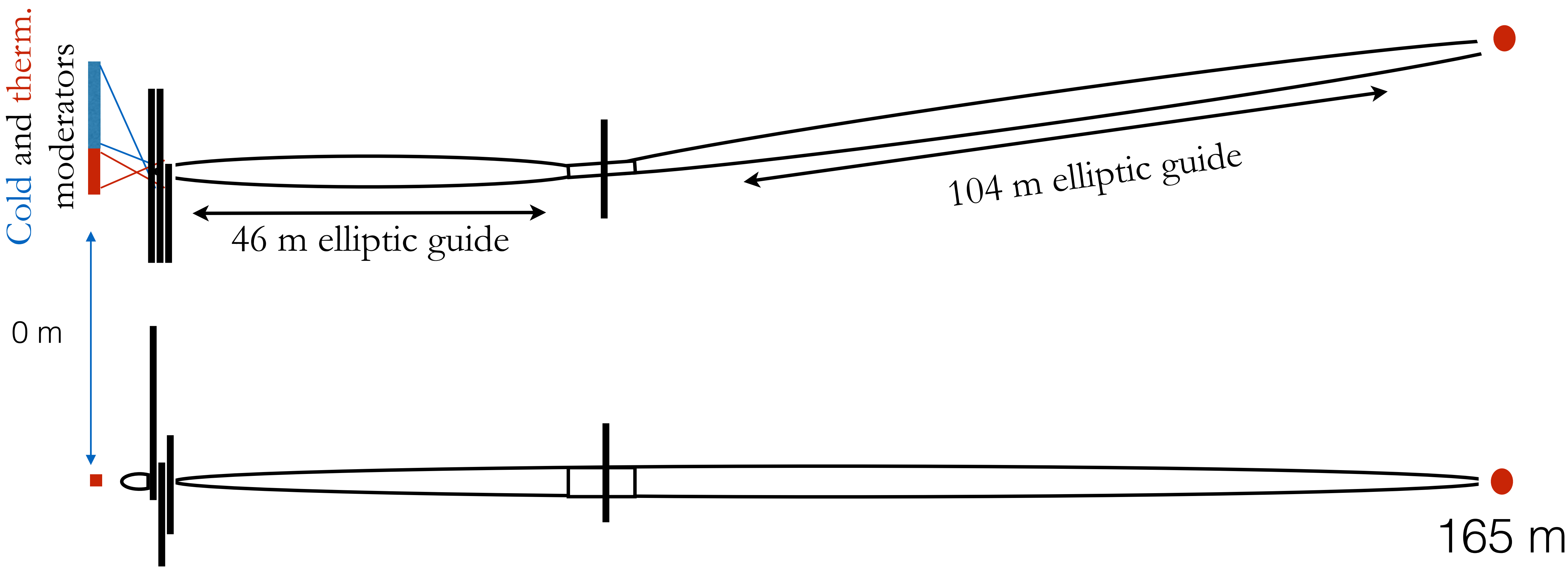

Band selector chopper.
14 Hz
70 cm diameter

# Proposed design




2nd elliptical section: FeSi coated (left/right) and NiTi coated (top/bottom)
Adaptive *m*-coating (1.5<*m*<4)
length = 104 m
small-axis = 4 cm
2nd kink: 0.2°

# Proposed design




Final section:

- flipper
- slits
- Fermi choppers for inelastic option

# Cryogenics

- Standard cryogenics
  - « *orange* » cryostat
  - furnaces
  - dilution fridge

From sample environment group !

- Dedicated magnets
  - superconducting 8T
  - pulsed 50T
  - corresponding inserts

On the beamline budget=dedicated

# Magnets

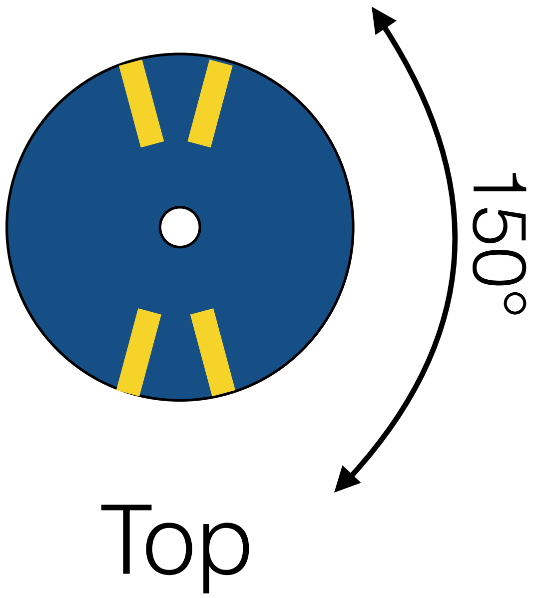
Superconducting
He-free magnet

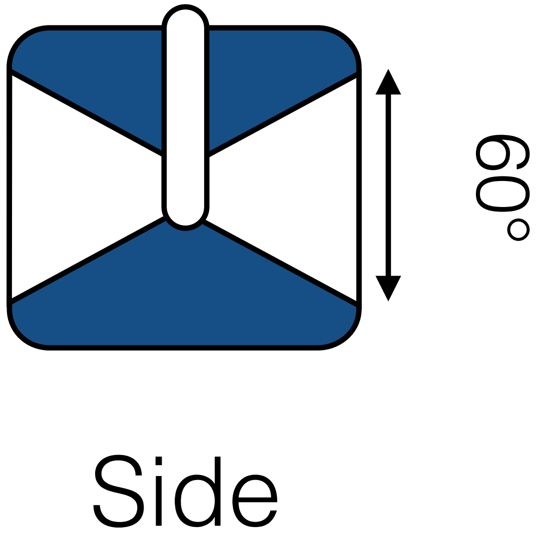
**8T**

300x60°aperture

NbTi technology

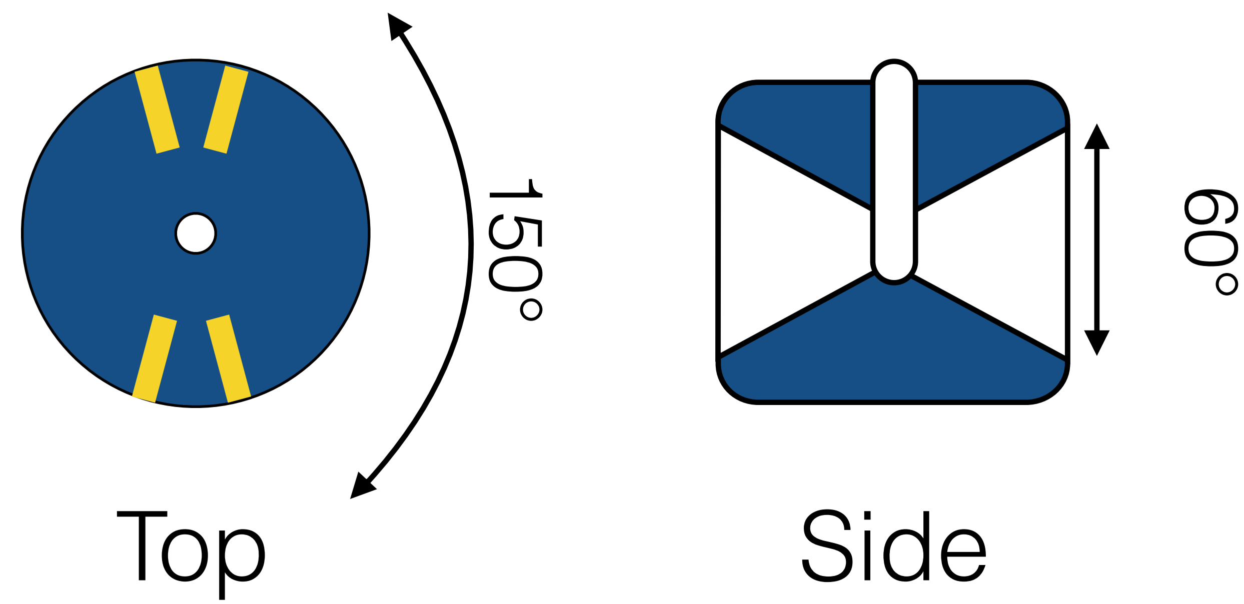
matches both detectors !



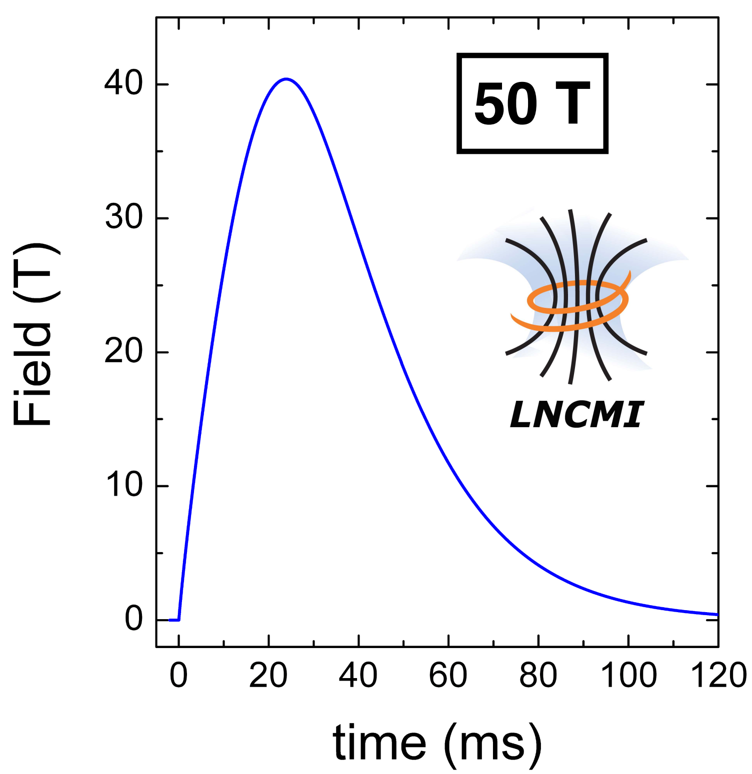



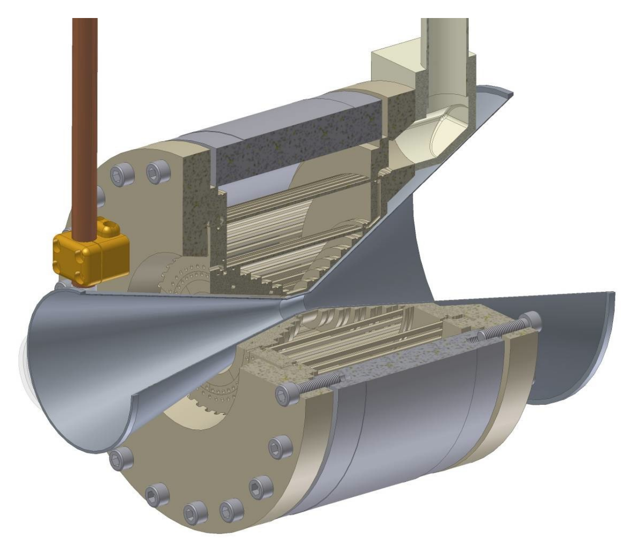
# Magnets

Superconducting
He-free magnet




Pulsed field magnet



60x60°aperture
conical design
40T @ ILL
140 ms pulse

# Instrumental flexibility

- Fast thermal/cold switch
  - Solid state bender
  - Chopper frequencies and delays

- No magnets reorientation at switch

- Permanent polarization analysis

**easy operation !**

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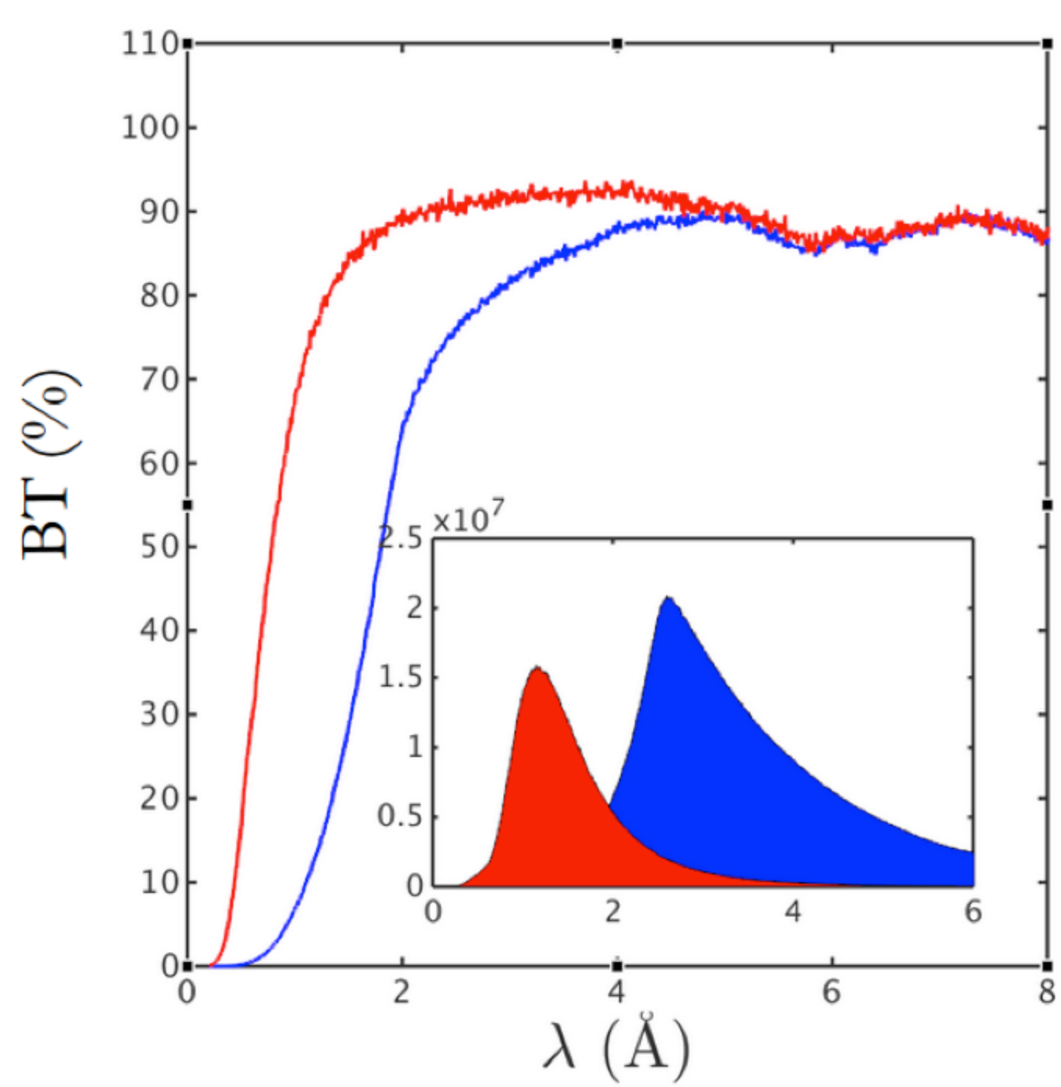
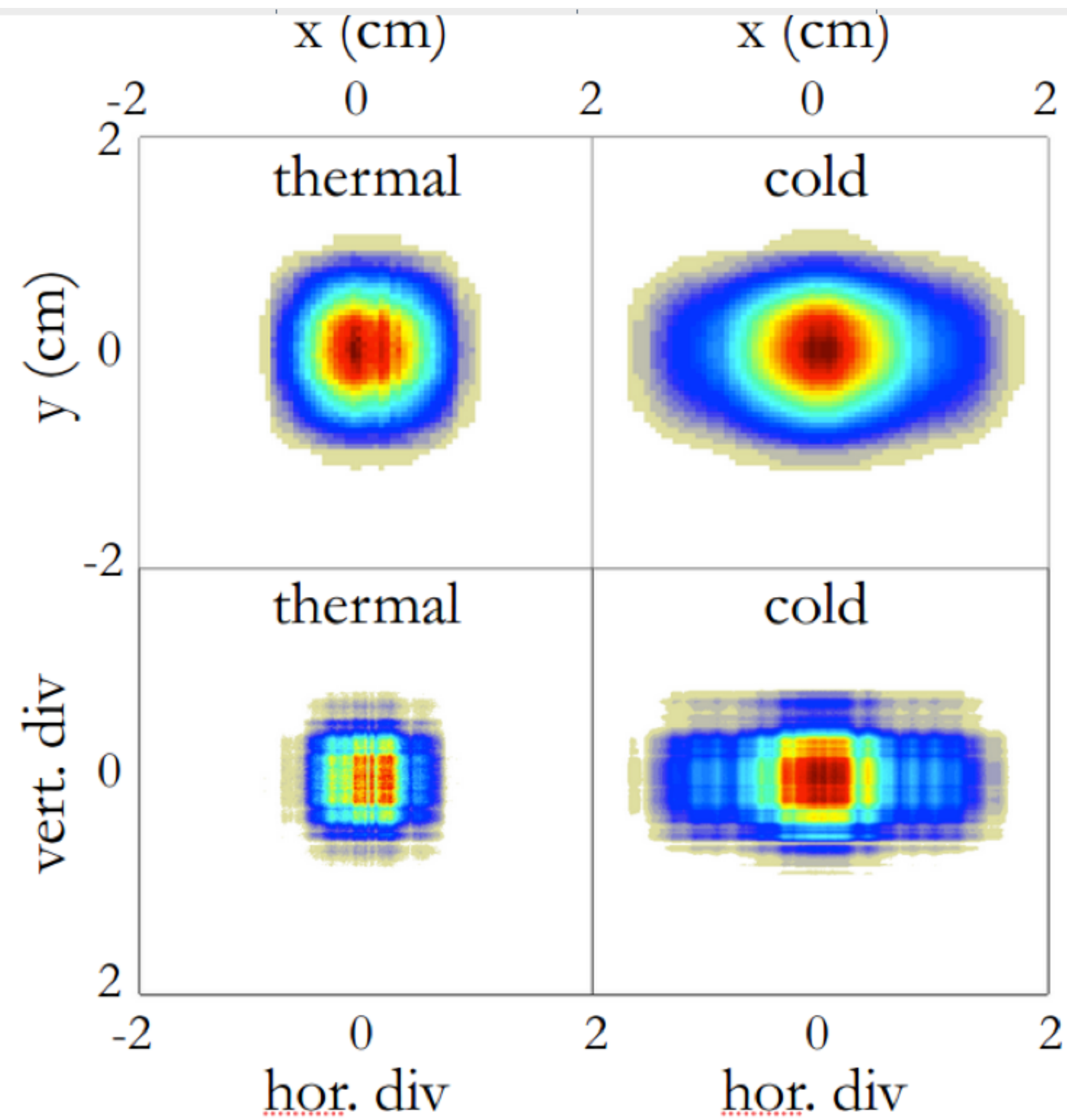
# Brilliance transfer and beam shape

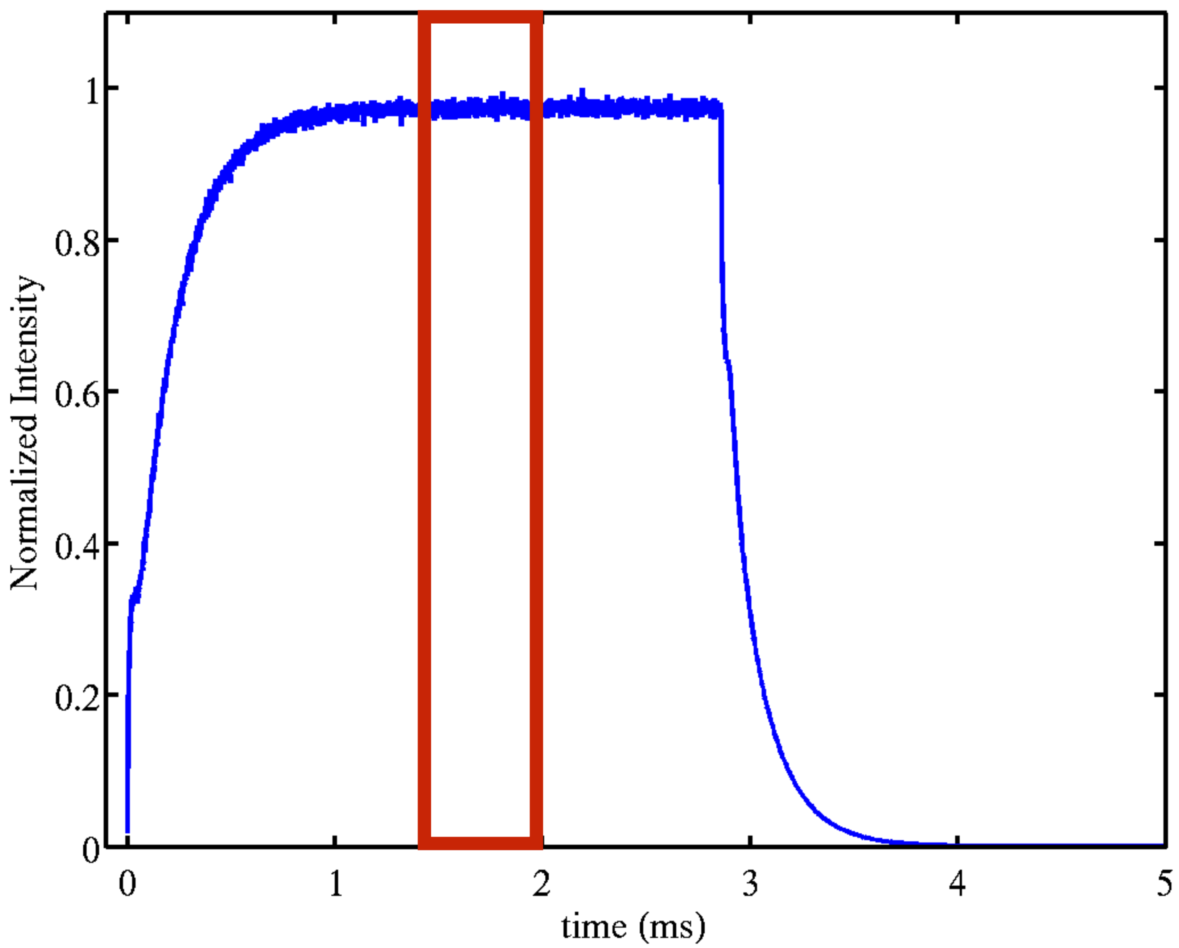



- Brilliance transfer
- thermal > 90 %
- cold    > 80 %

- Beam shape: homogeneous over 1 $cm^2$
- Divergence: well transported

# Longitudinal resolution




$$\frac{\Delta\lambda}{\lambda} = \frac{t_{pulse}}{t_{flight}}$$
$$= \frac{h\, t_{pulse}}{L_{inst} m_N \lambda}$$

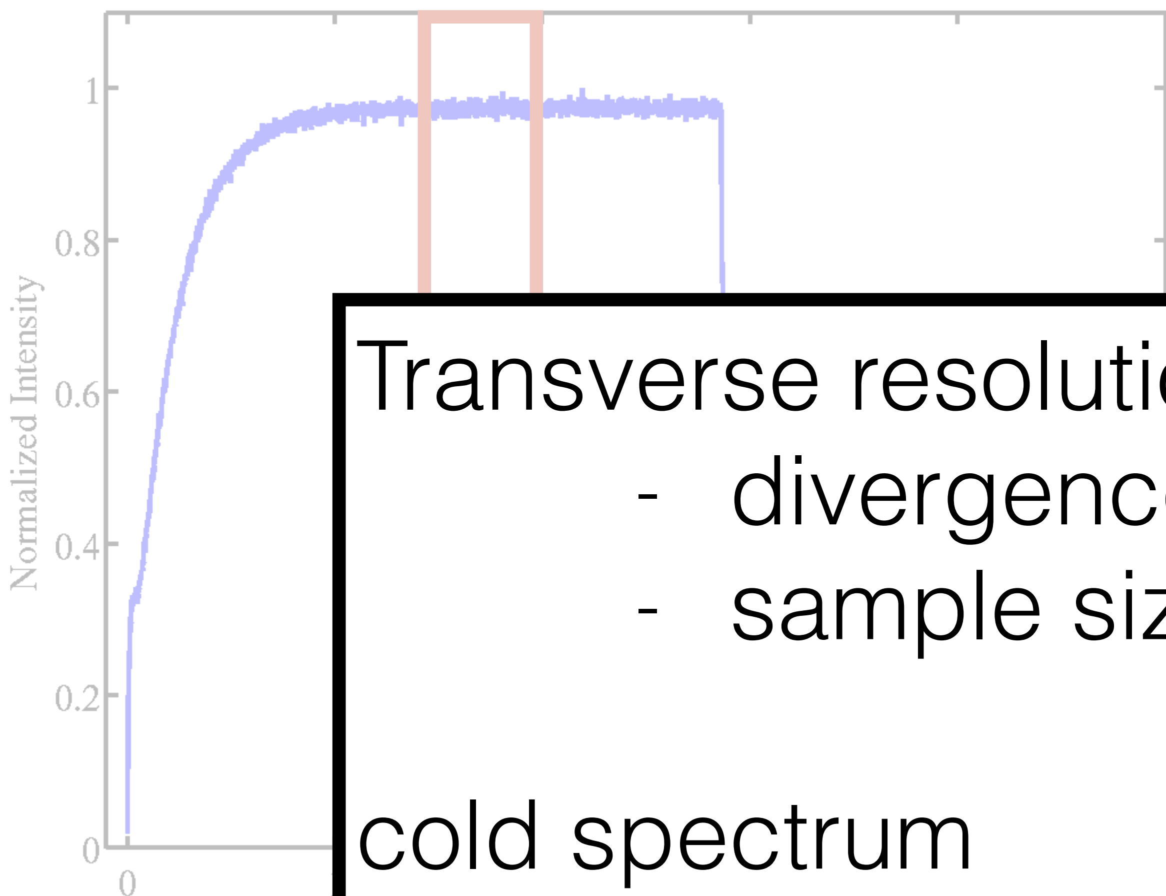
Full pulse length (~3 ms)

*0.7 Å: 9%*
*2.1 Å: 3%*
*3.8 Å: 1.7%*

500 $\mu$s pulse length:

*0.7 Å: 1.5%*
*2.1 Å: 0.5%*
*3.8 Å: 0.3%*

# Longitudinal resolution




Transverse resolution controlled by:

- divergence
- sample size

cold spectrum : ~1%
thermal spectrum : <1%

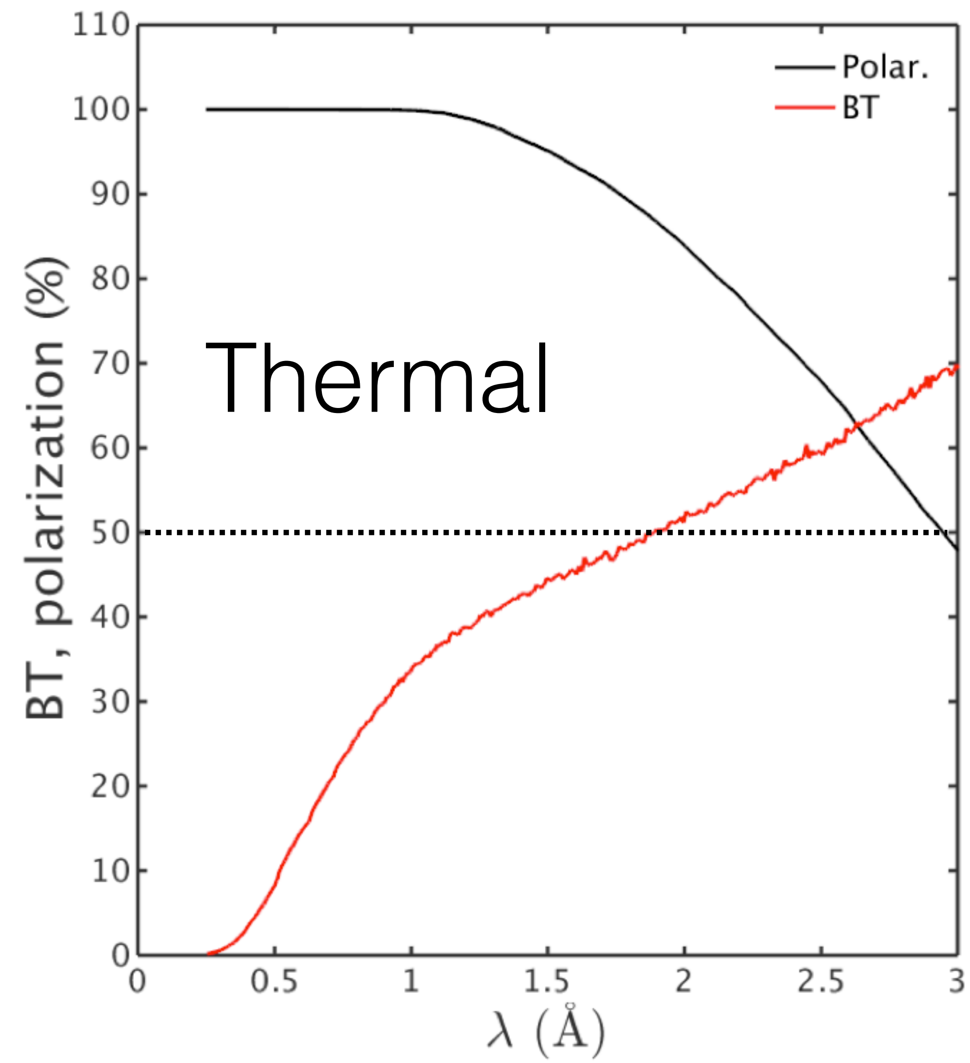
Full pulse length (~3 ms)

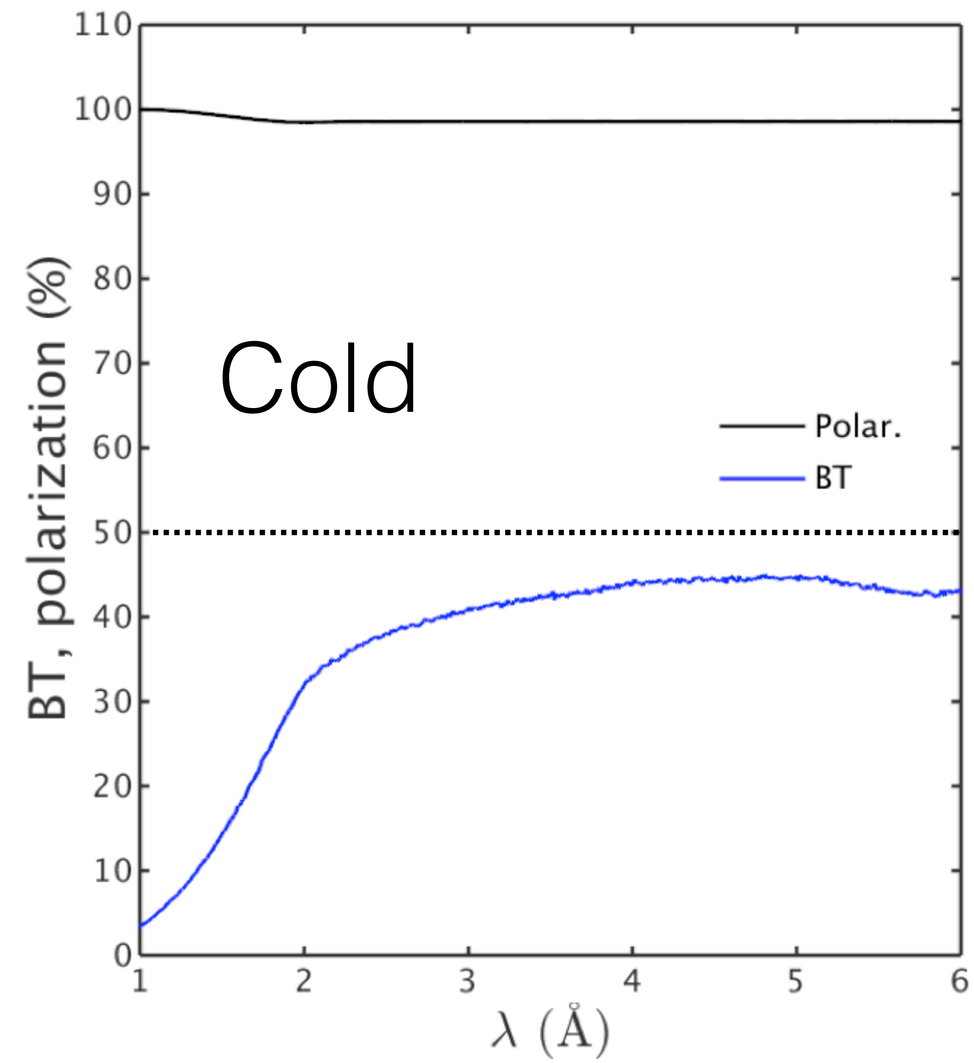
*0.7 Å: 9%*
*2.1 Å: 3%*
*3.8 Å: 1.7%*

500 $\mu$s pulse length:

*0.7 Å: 1.5%*
*2.1 Å: 0.5%*
*3.8 Å: 0.3%*

# Polarization




- Polarizing super-mirrors
- P > 80 %

- Polarizing solid state bender
- P > 98.5 %

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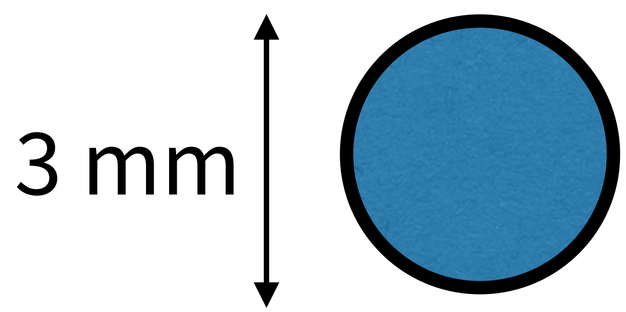
# $C_{60}$: parameters




- spherical sample
- r = 1.5 mm
- V = 14 mm$^3$

*a=b=c=14.05 Å*

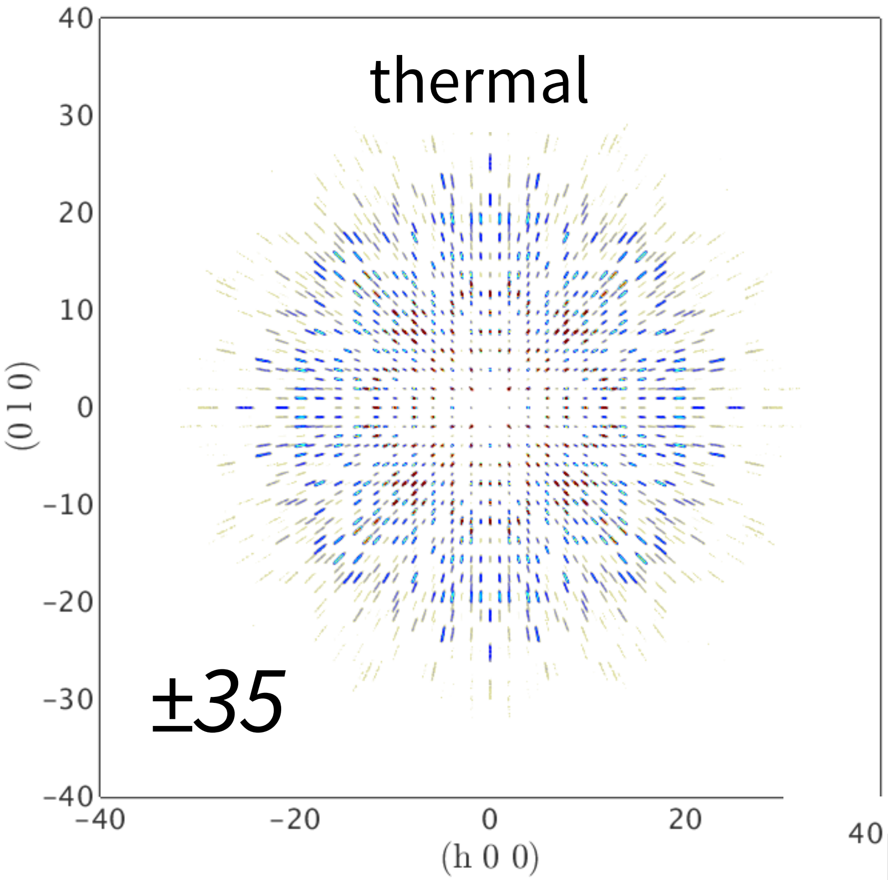
F *m -3 m*

Cold: $\lambda$ = *2.1-3.8 Å / ±0.5°*

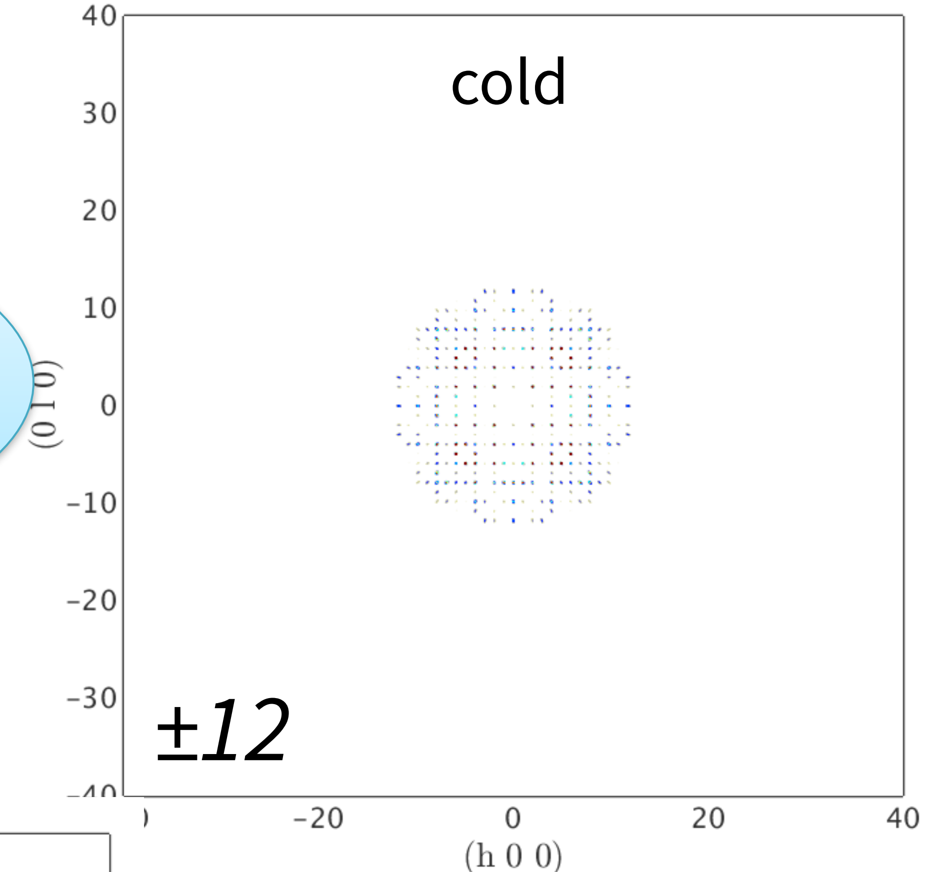
Thermal: $\lambda$ = *0.7-2.4 Å / ±0.3°*

- *3* ms pulse length (cold stat/20)
- *500* $\mu$s length (cold stat/100)

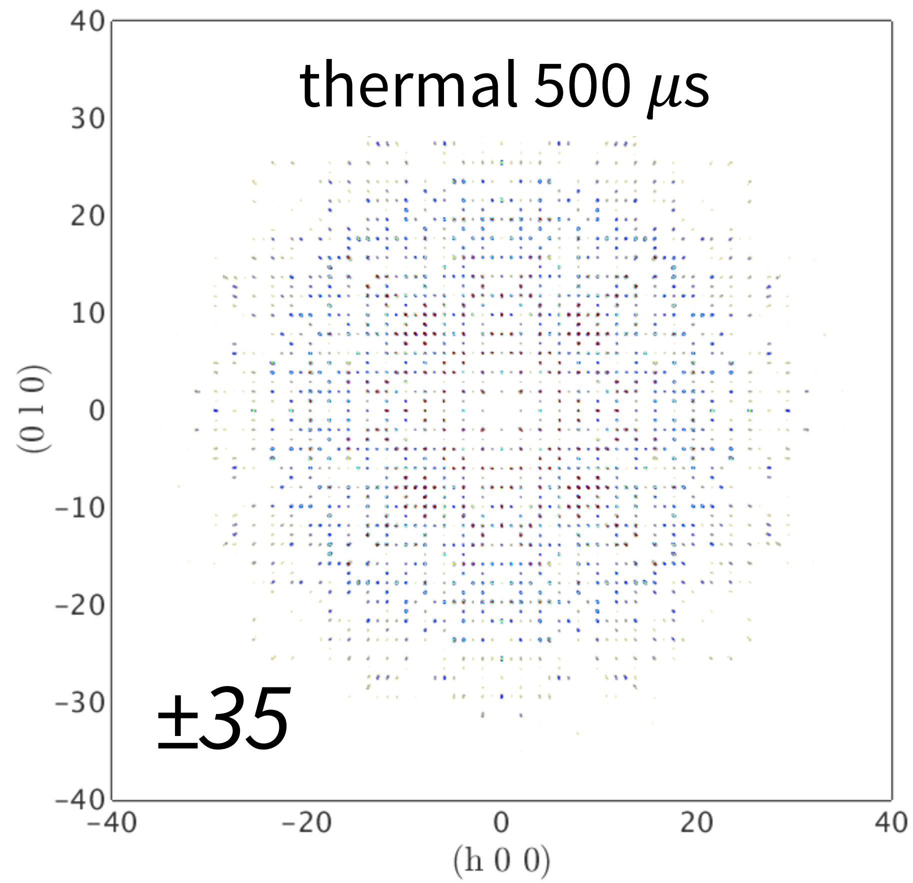
# $C_{60}$:in plane




**Flux**

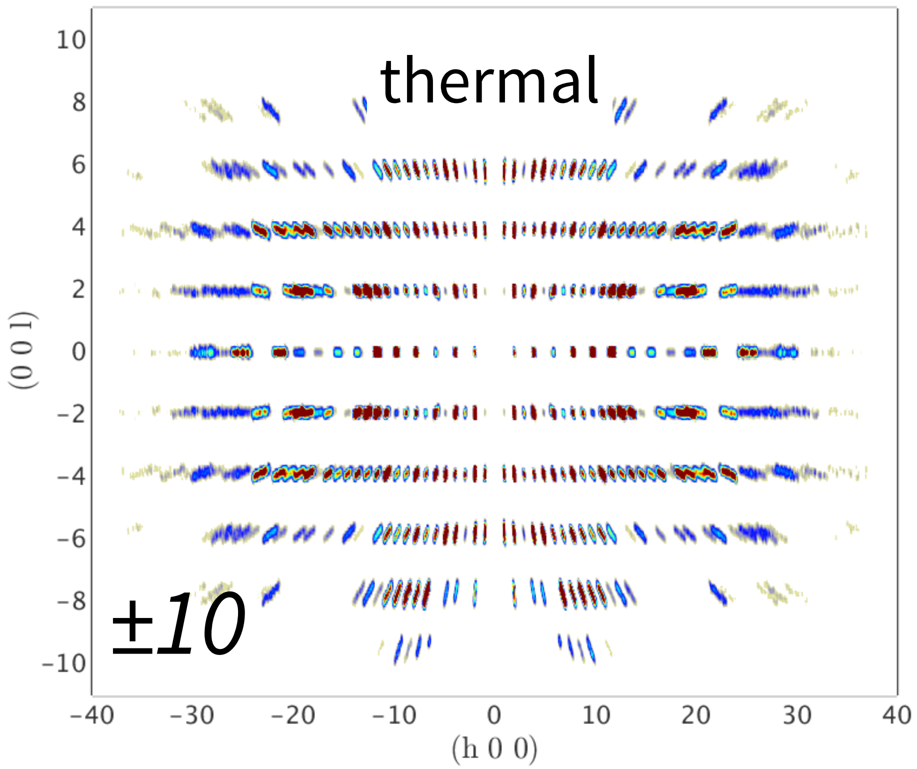



**Q-range**

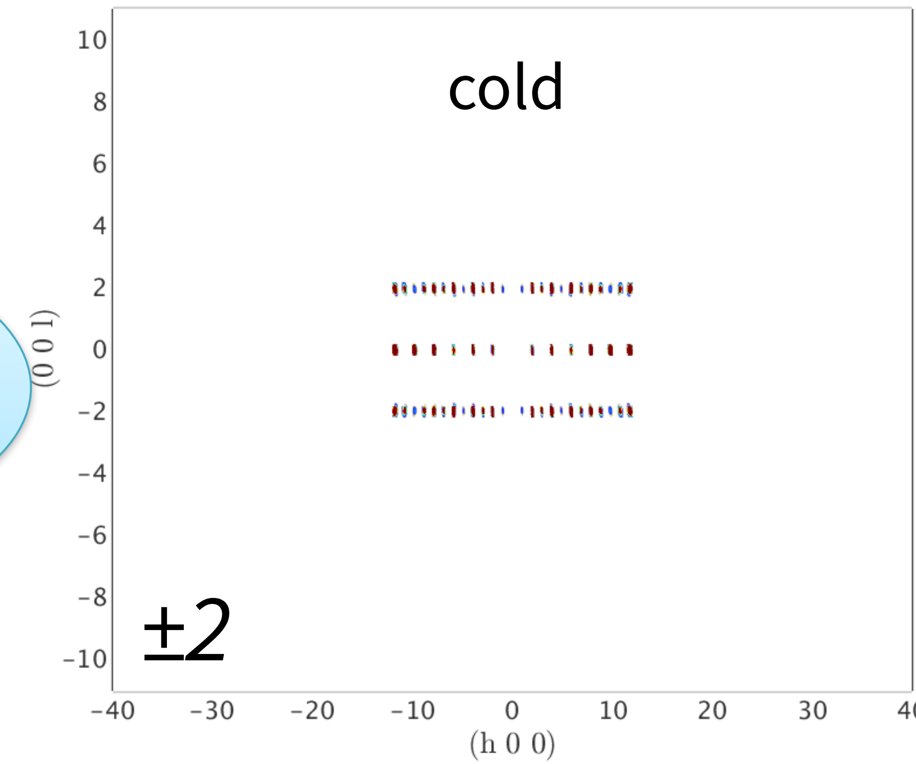



**Resolution**

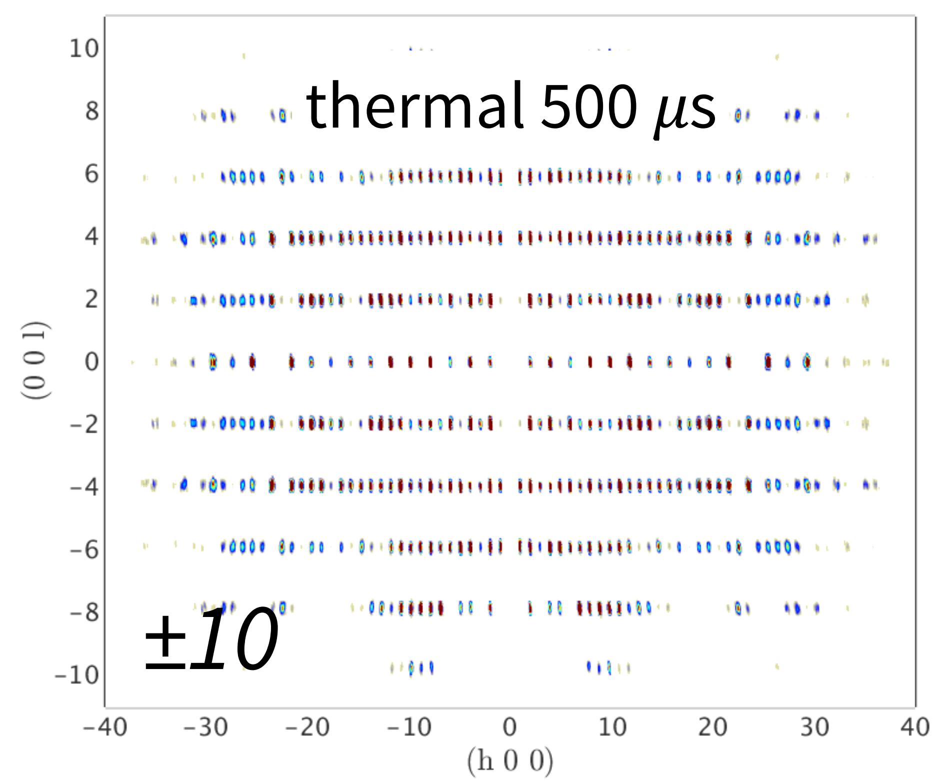
# $C_{60}$: out of plane




**Flux**

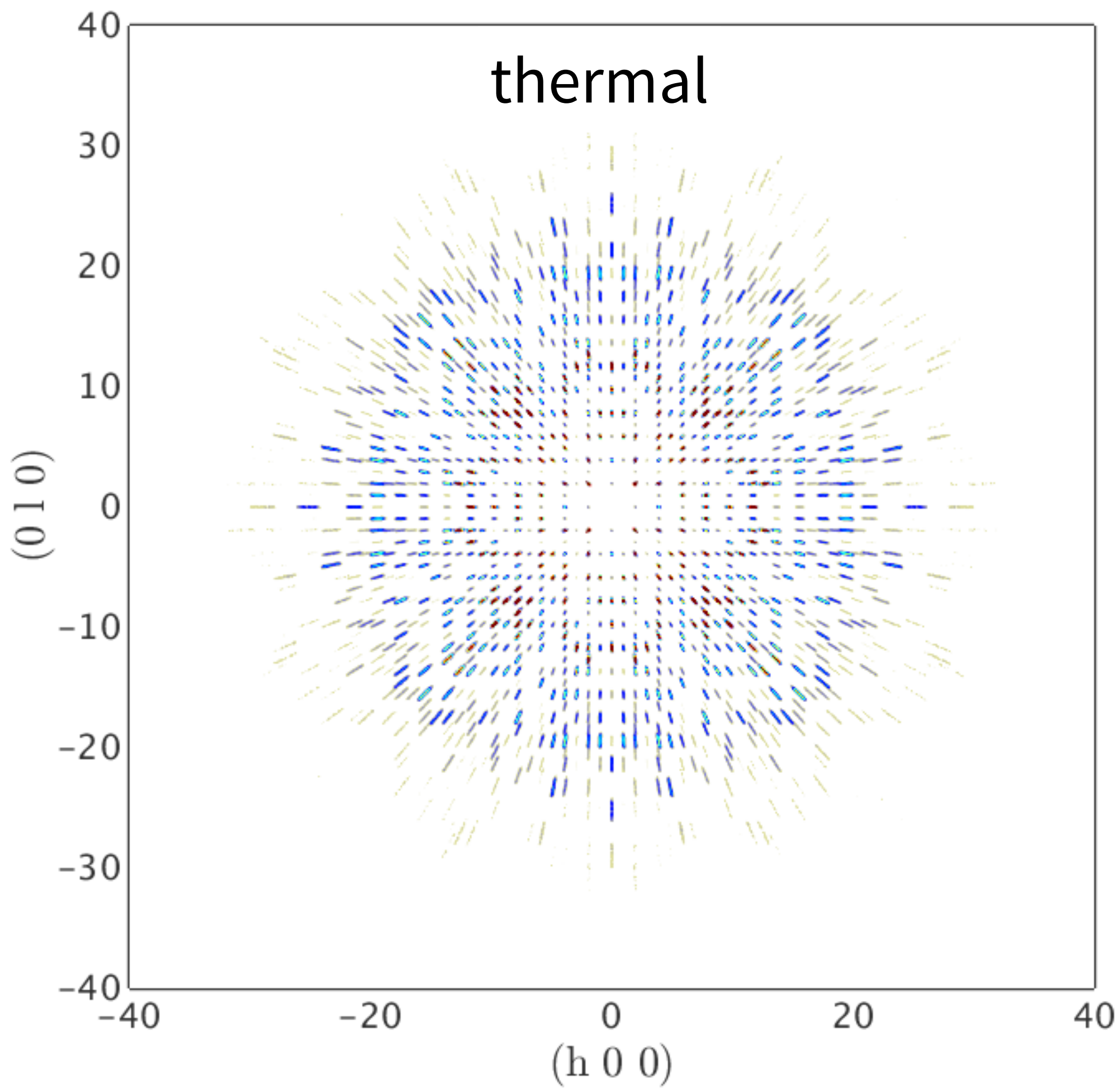



**Q-range**




**Resolution**

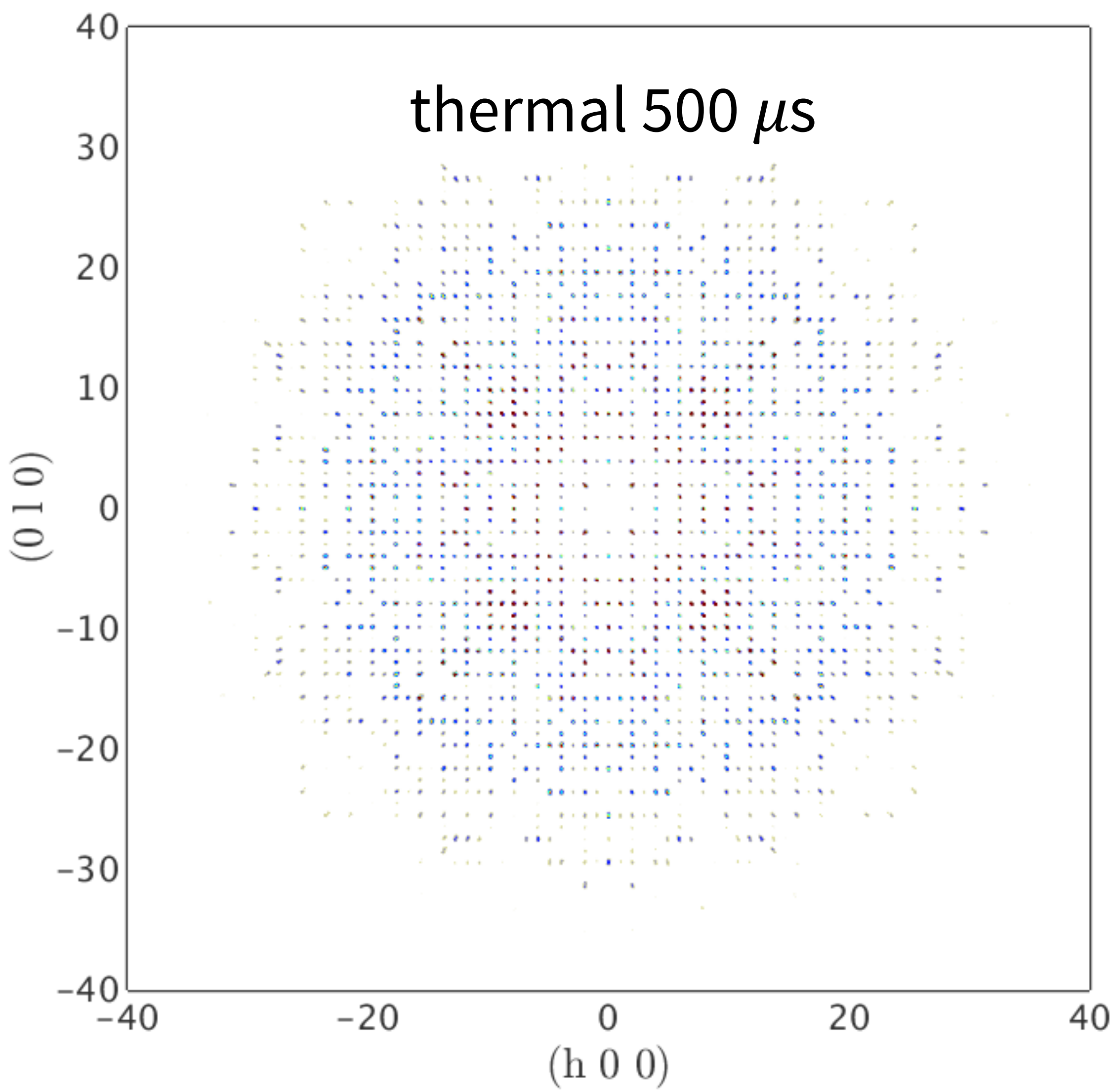
# $C_{60}$




Thermal:

- $5x10^4$ cnts/s
- 60000 reflections / 15000 usable

# $C_{60}$



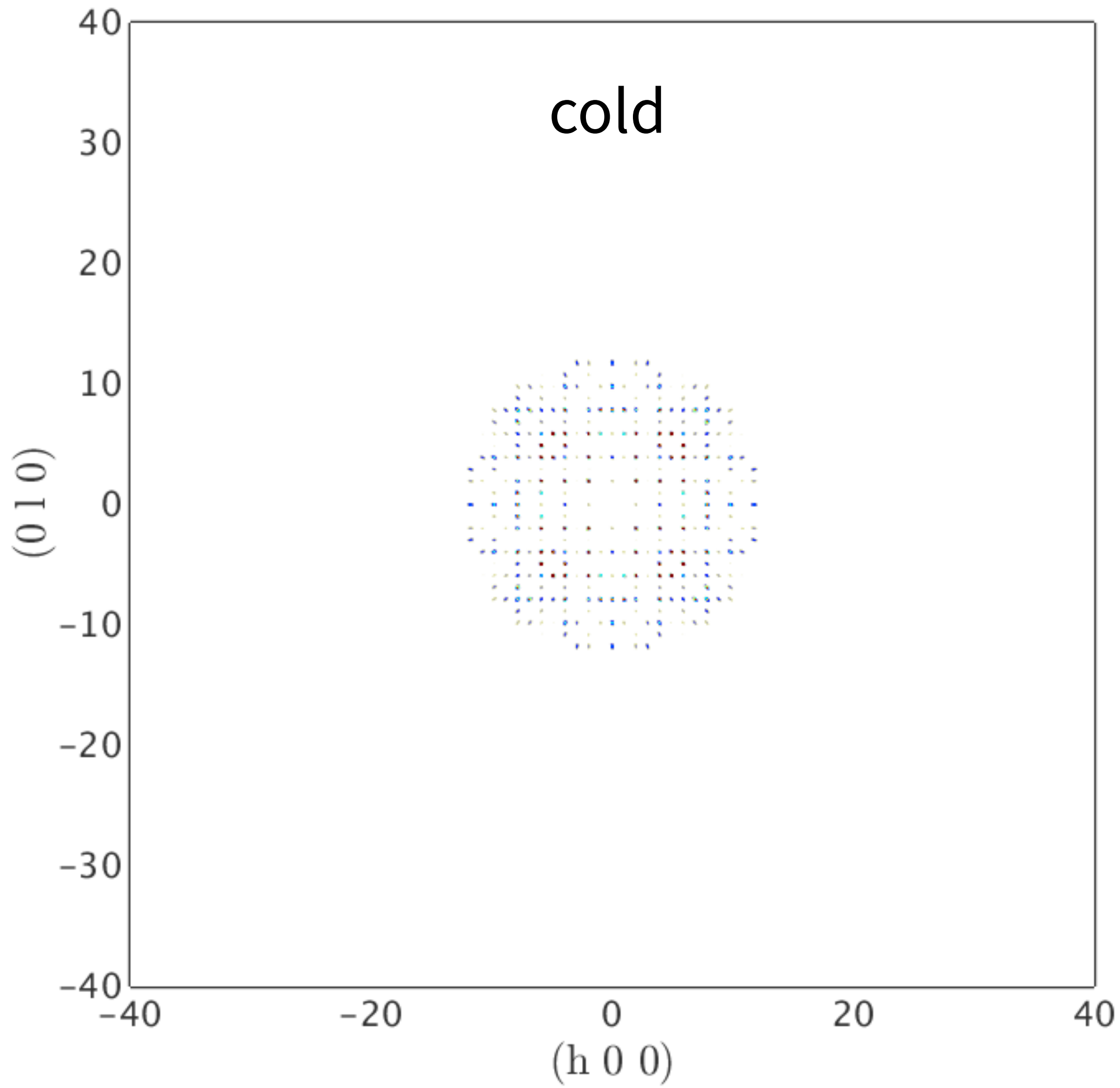

Thermal:

- $5x10^4$ cnts/s
- 60000 reflections / 15000 usable

Thermal high resolution:

- $1x10^4$ cnts/s
- 60000 reflections / 30000 usable

# $C_{60}$




Thermal:

- $5x10^4$ cnts/s
- 60000 reflections / 15000 usable

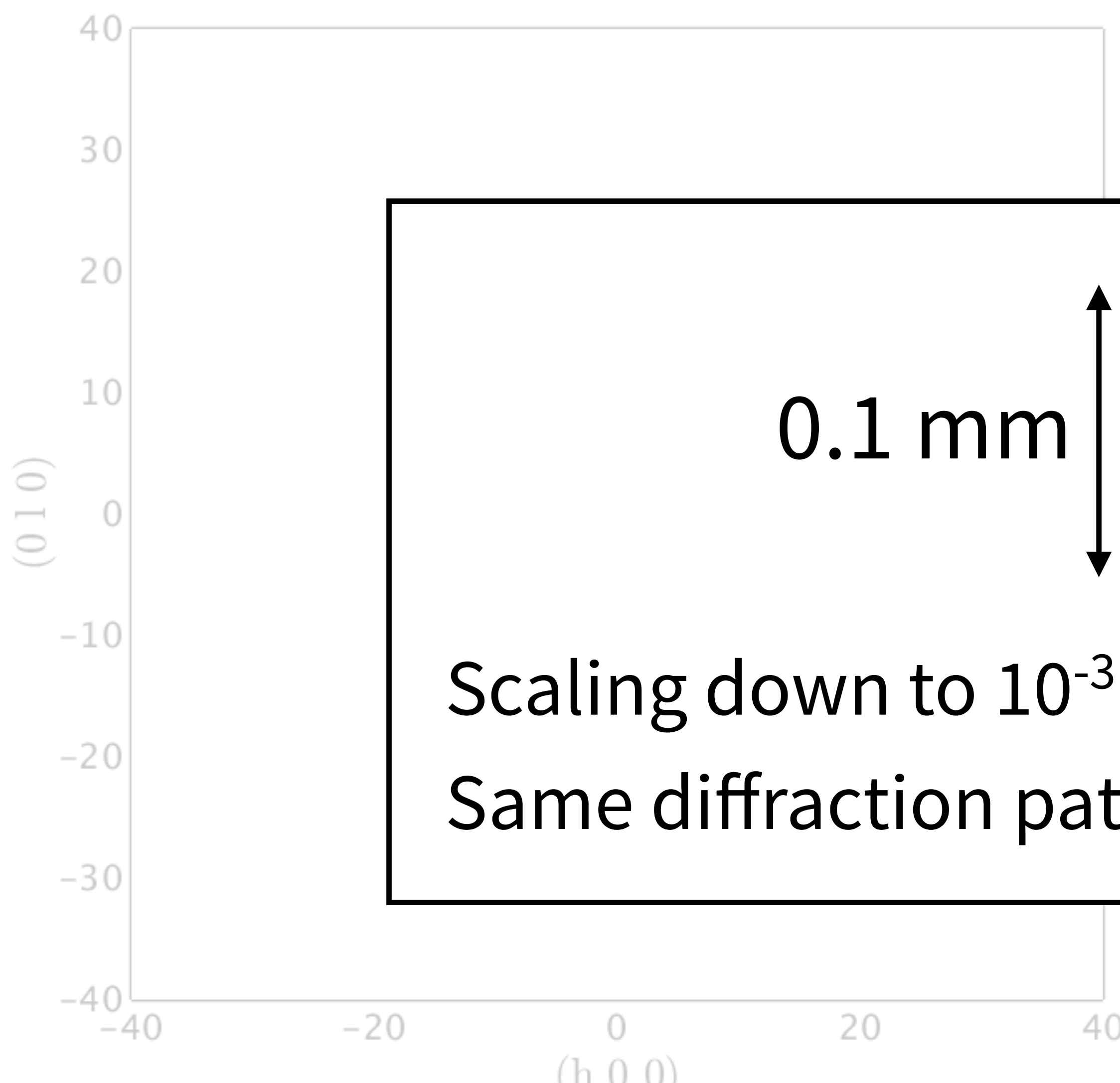
Thermal high resolution:

- $1x10^4$ cnts/s
- 60000 reflections / 30000 usable

Cold:

- $1x10^6$ cnts/s
- 2500 reflections / all usable

# $C_{60}$




Thermal:

$5x10^4$ cnts/s

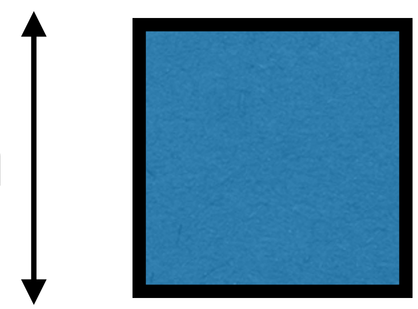
15000 usable

on:

30000 usable

2500 reflections / all usable

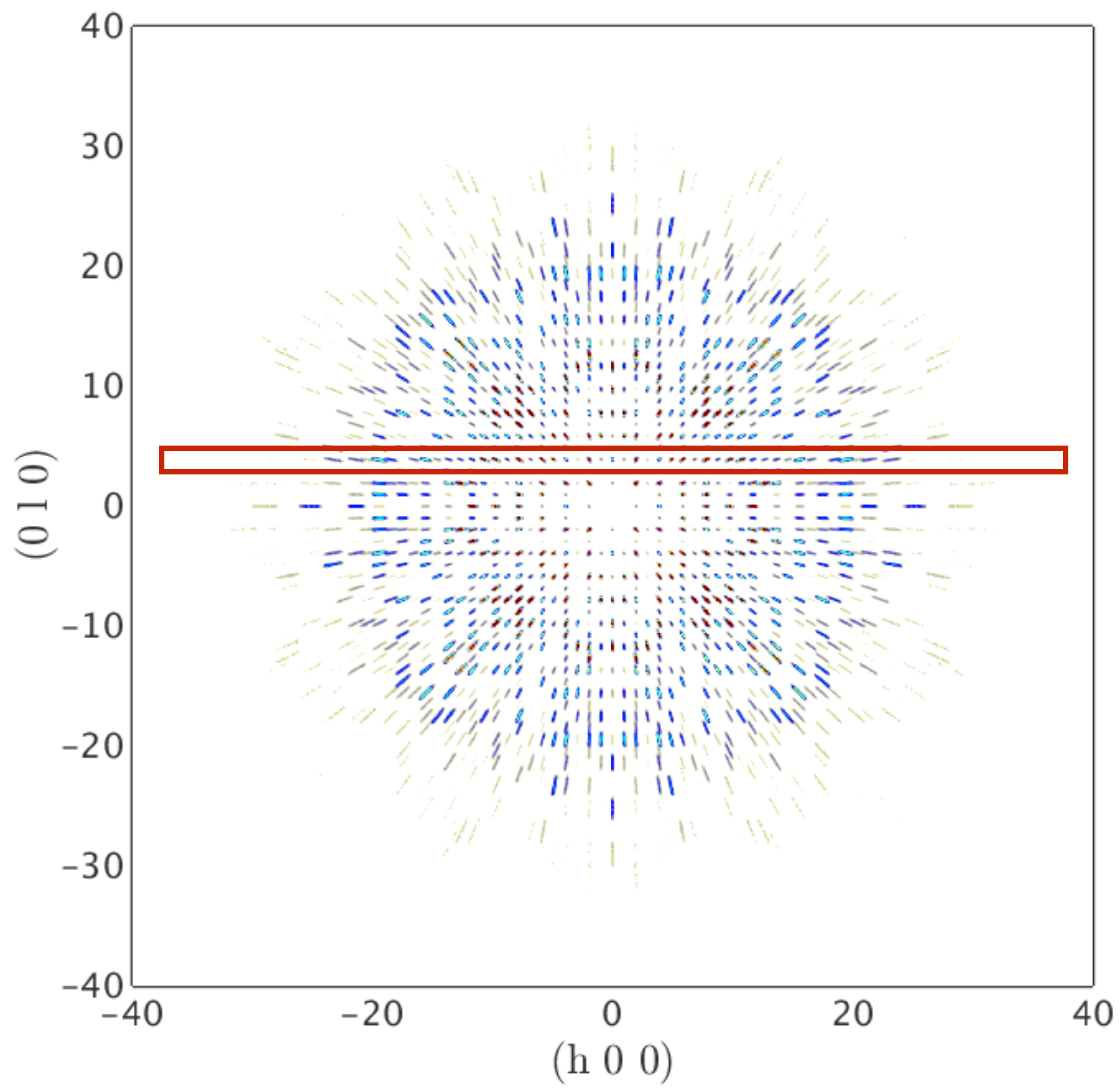
0.1 mm



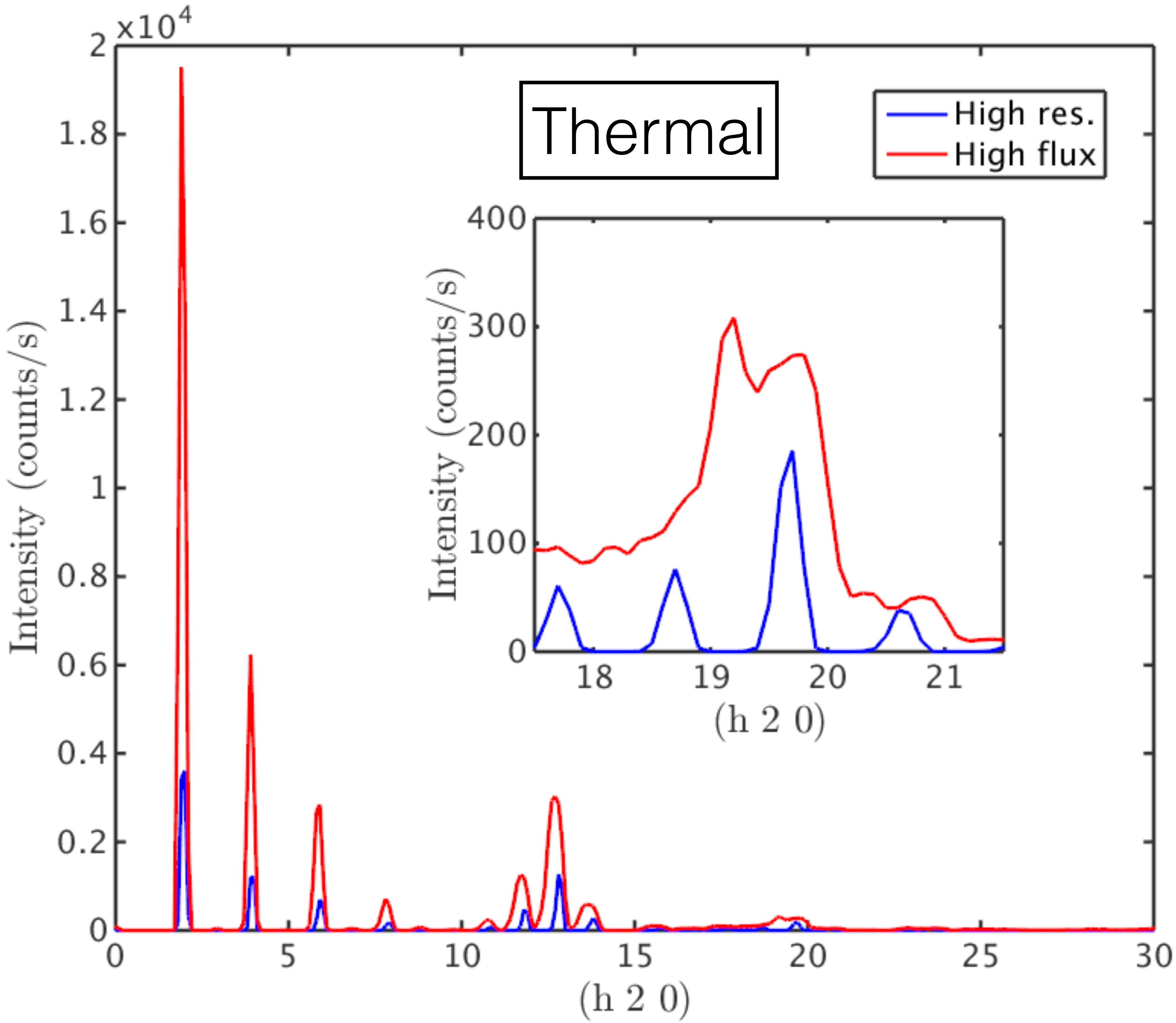
Scaling down to $10^{-3}$ $mm^3$ sample:

Same diffraction patterns in 1 hour !

# $C_{60}$: peak profiles

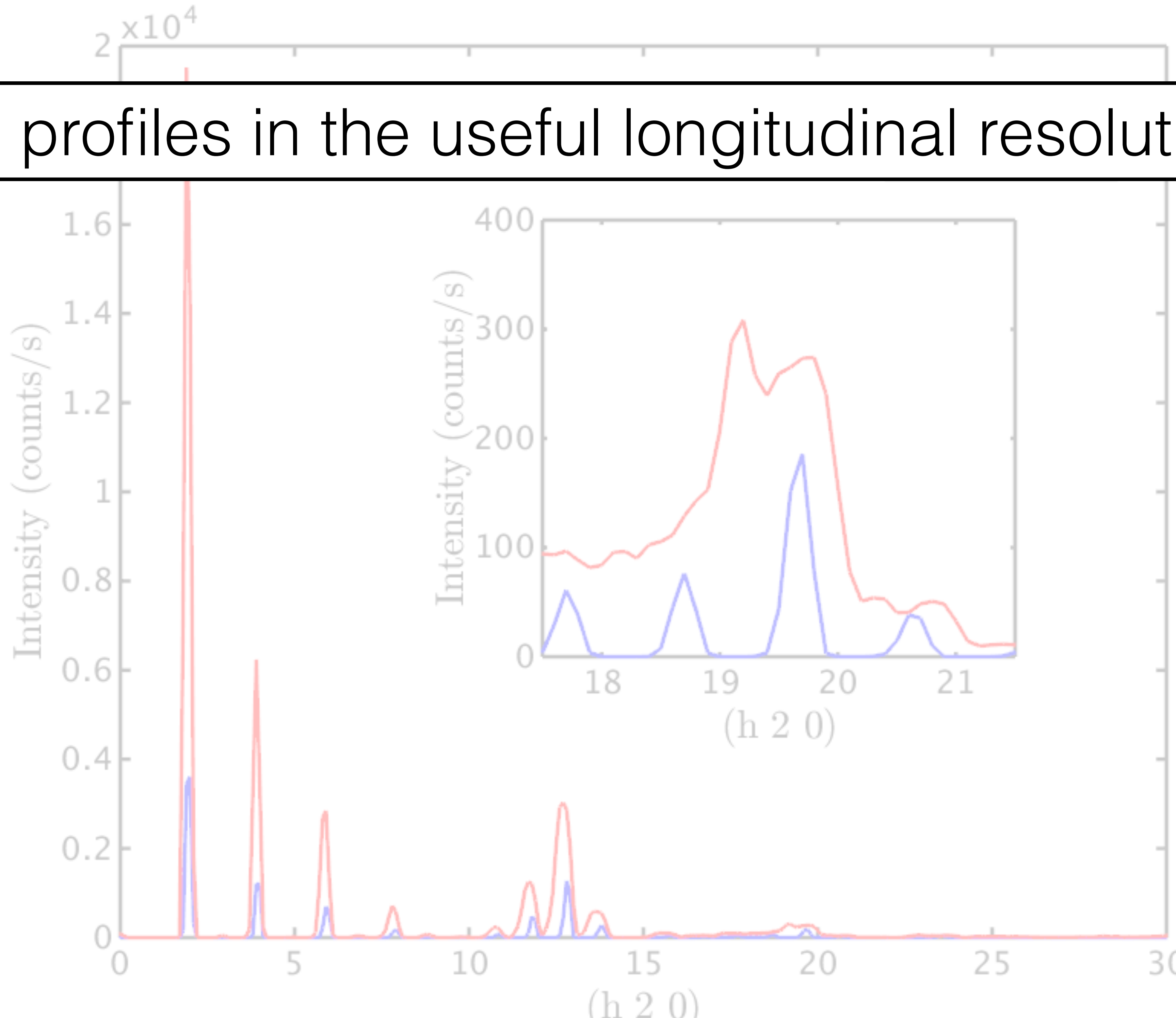


# $C_{60}$ peak profiles

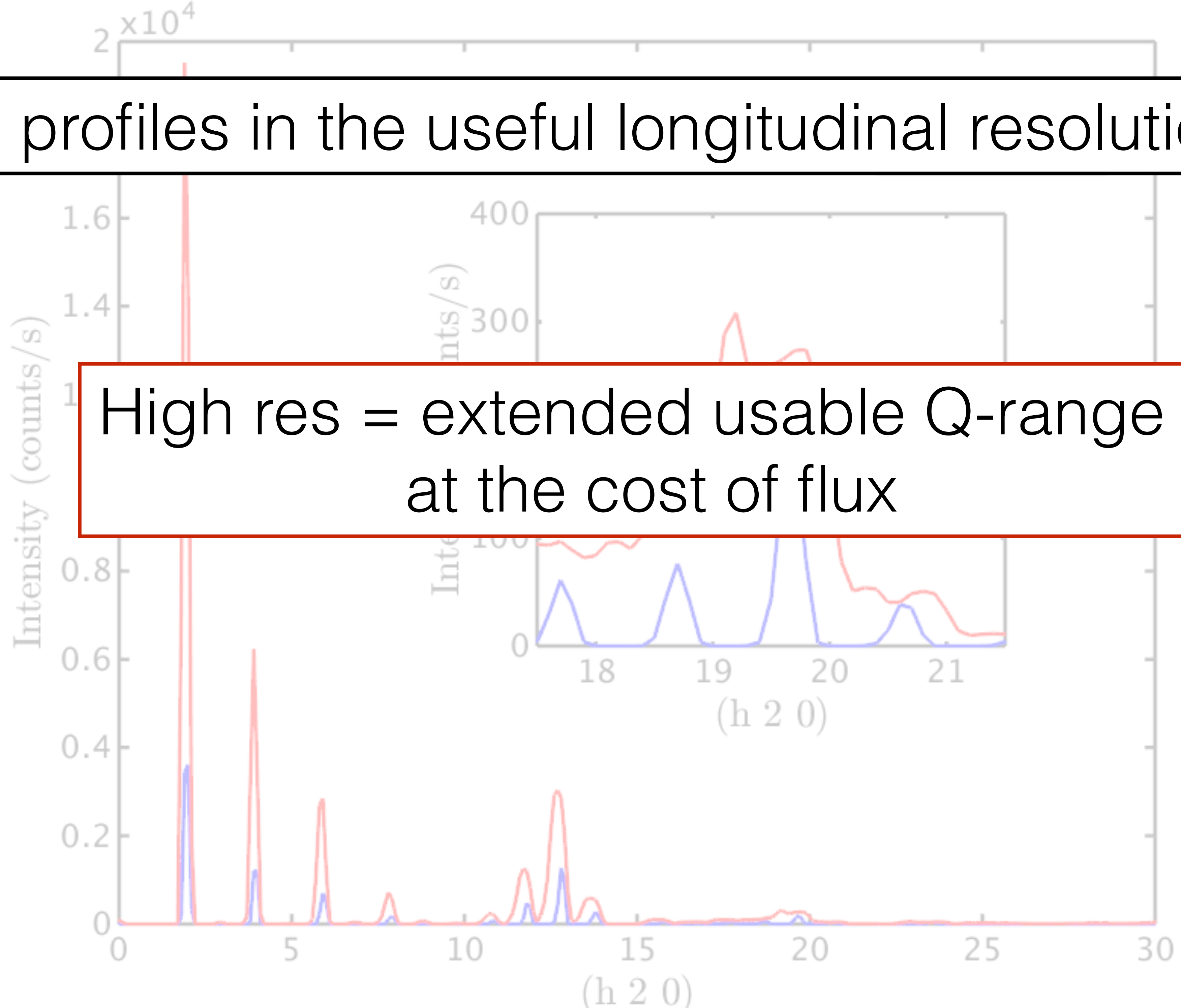


# $C_{60}$ peak profiles

Nice profiles in the useful longitudinal resolution range



# $C_{60}$ peak profiles




Nice profiles in the useful longitudinal resolution range

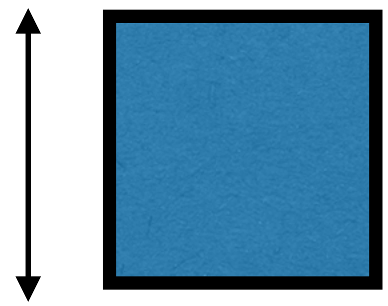
High res = extended usable Q-range !
at the cost of flux

# Capabilities

- Flexibility
  - Q-space/Flux/Resolution

# $BiFeO_3$

1 mm



- cubic sample
- edge = 0.5 mm
- V ~ 1 $mm^3$

*a=b=c=4 Å*

Pseudo-cubic

Mosaicity: *0.1°*

Cold:

$\lambda$ = 3.8-5.5 Å / ±0.3°

*500 μs length*

Magnetic periodicity

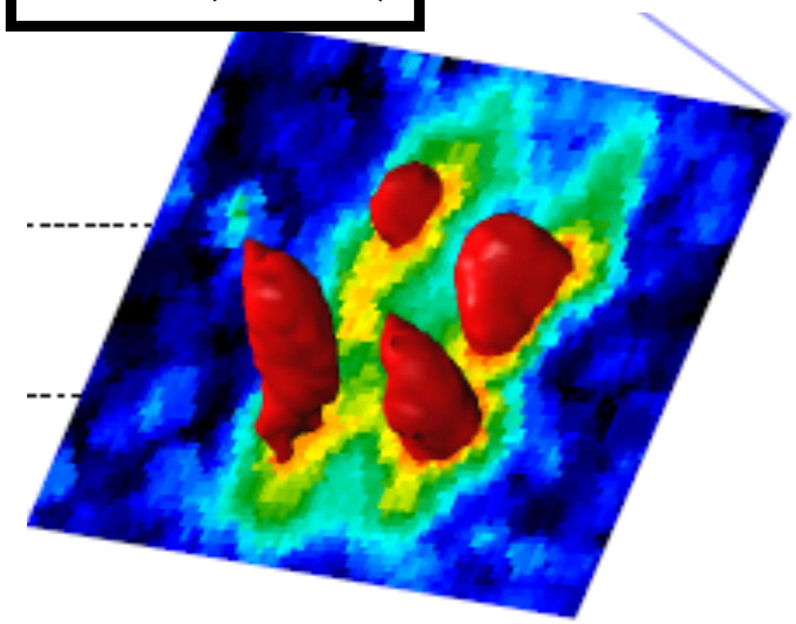
*l = 640 Å*

$\mathbf{k}=6.5\times10^{-3}$

# $BiFeO_3$

6T2 (LLB)

$q_0=(\frac{1}{2}\ -\frac{1}{2}\ \frac{1}{2})$

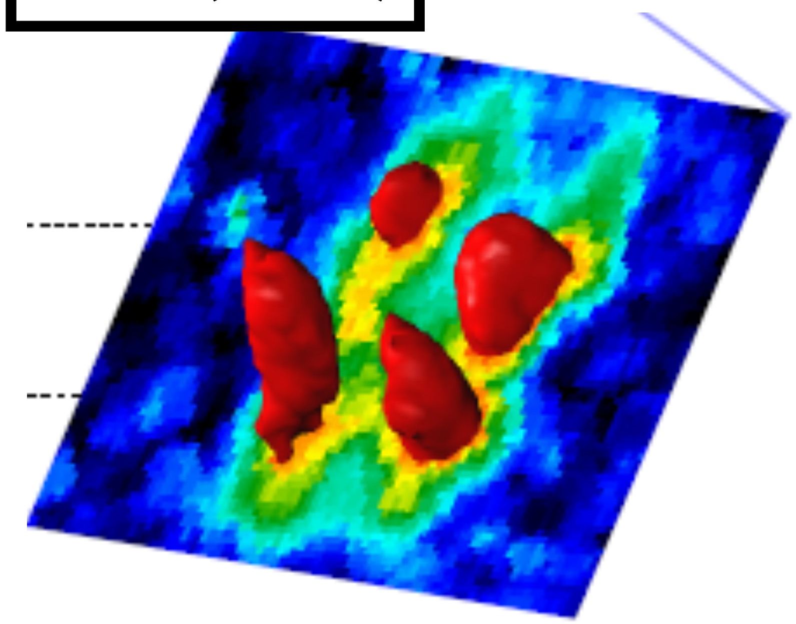


Extreme case in terms of magnetic periodicity and (mag. per.)/(nuc. per.) ratio

# $BiFeO_3$

6T2 (LLB)

$q_0 = (\frac{1}{2}\ -\frac{1}{2}\ \frac{1}{2})$



Extreme case in terms of magnetic periodicity and (mag. per.)/(nuc. per.) ratio

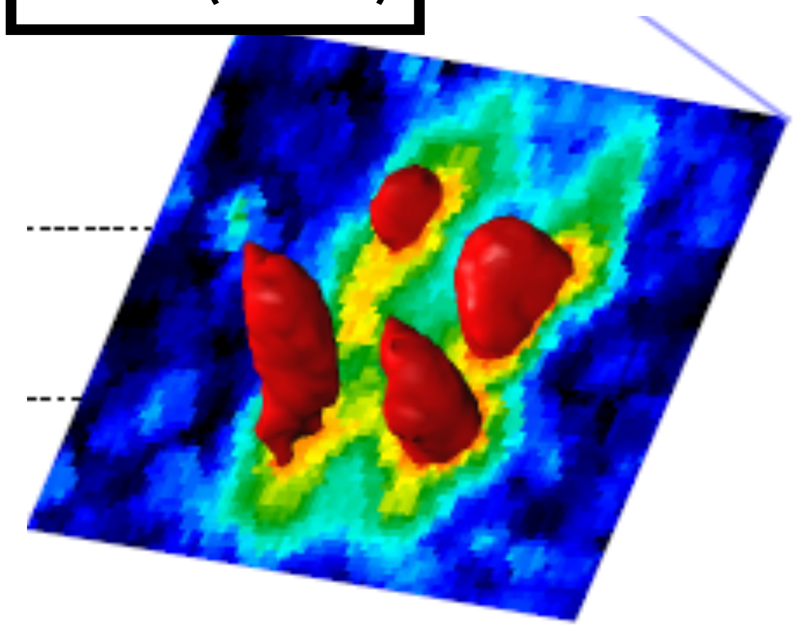
Satellites around anti-ferromagnetic position

No nuclear Bragg pollution !

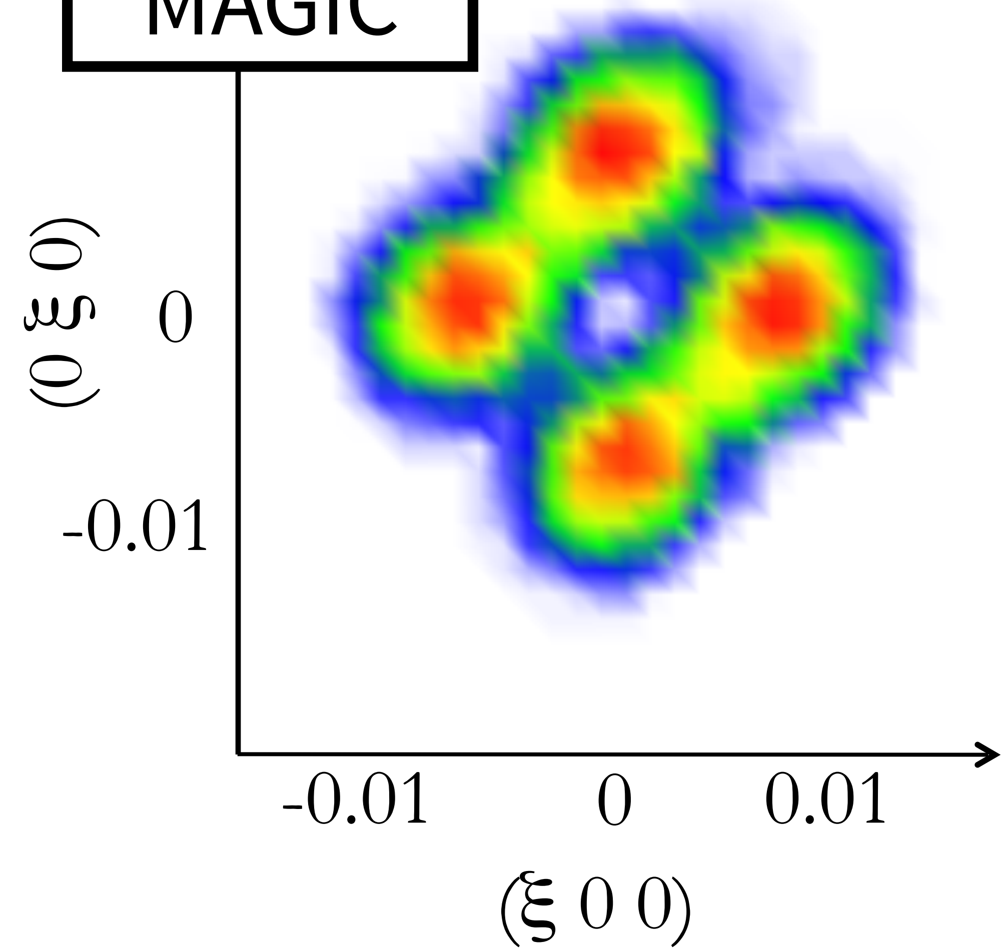
# $BiFeO_3$

**$q_0=(\frac{1}{2}\ -\frac{1}{2}\ \frac{1}{2})$**

6T2 (LLB)



MAGiC



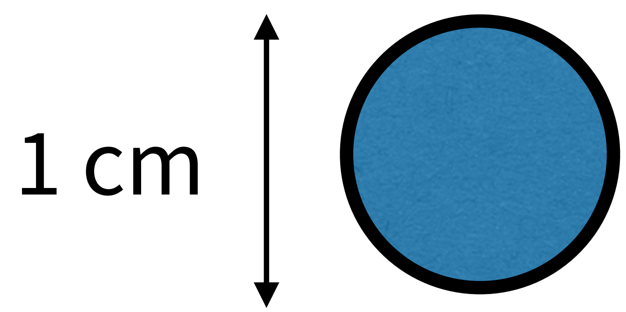

Refined propagation vector: $\boldsymbol{k}=6.5x10^{-3}$

# Capabilities

- Flexibility
  - Q-space/Flux/Resolution

- High resolution !

# Polarized NPD: $Tb_2Sn_2O_7$




- spherical powder
- r = 5 mm
- V ~ 500 mm$^3$

*a=b=c=10 Å*

cubic

T=10K

B=5T

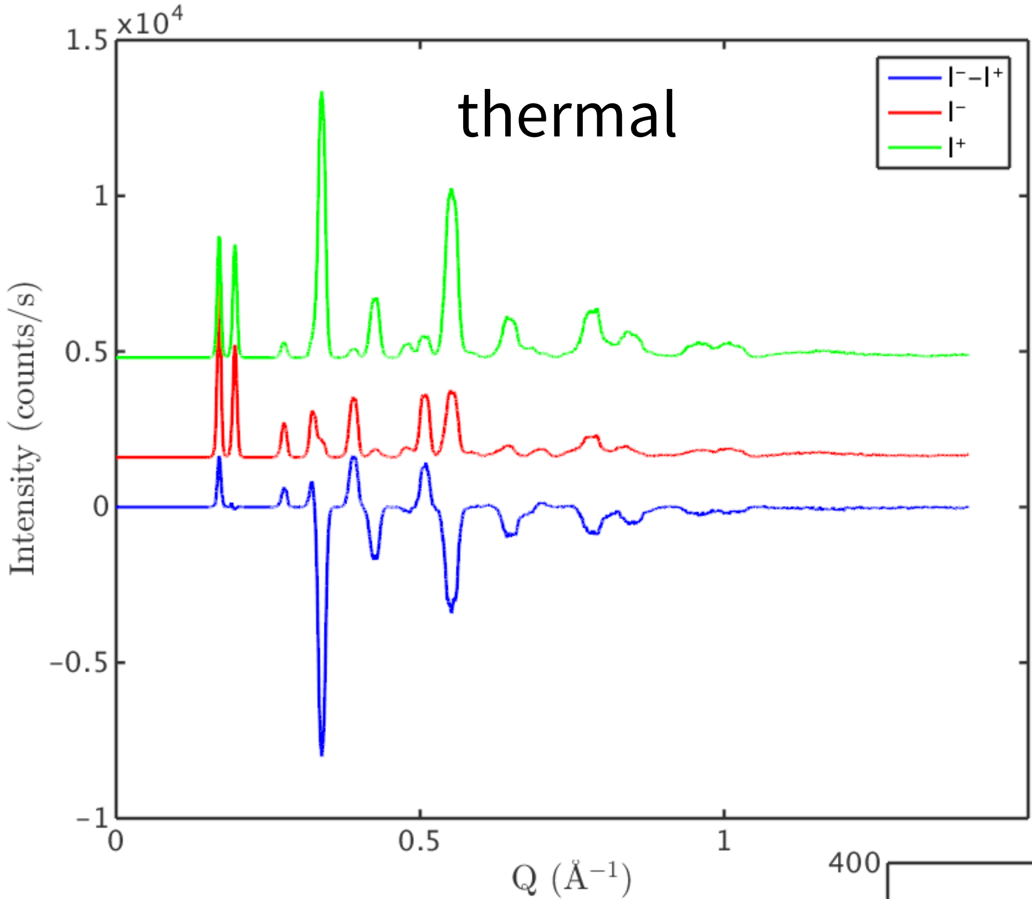
Ising

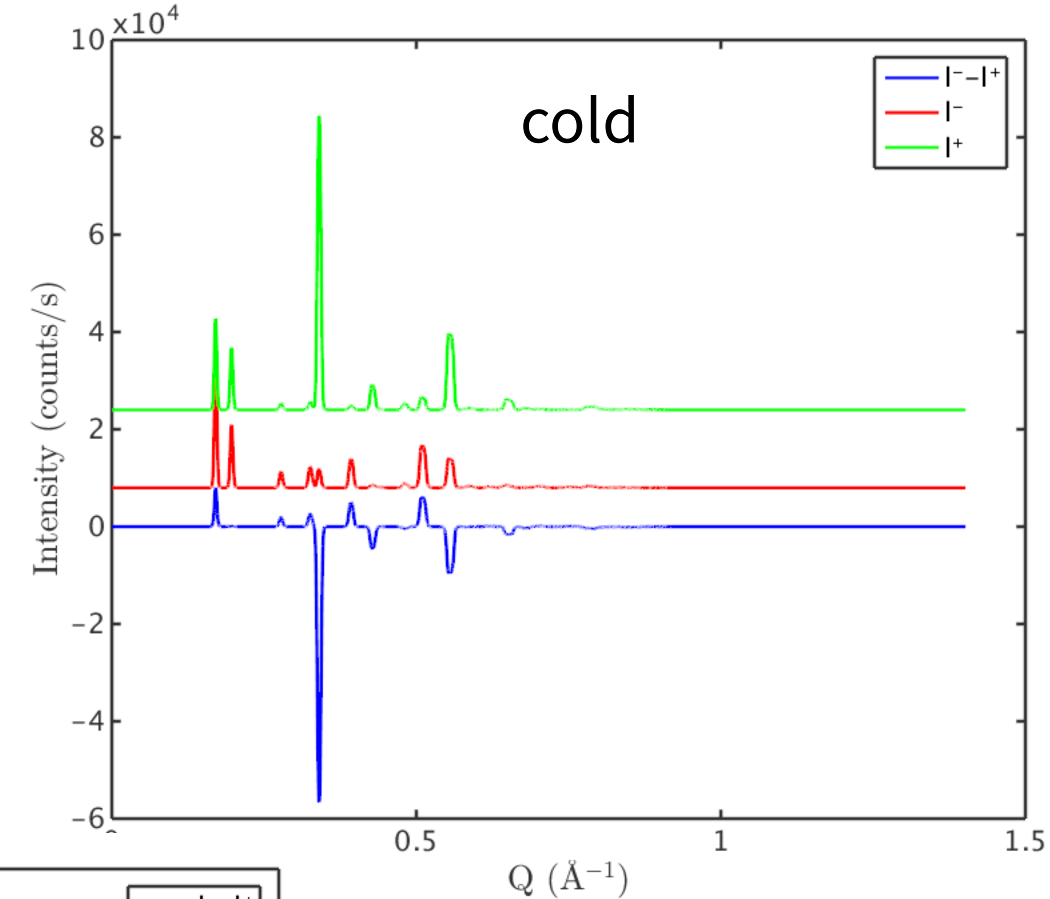
Cold: $\lambda$ = *2.1-3.8 Å / ±0.5°*

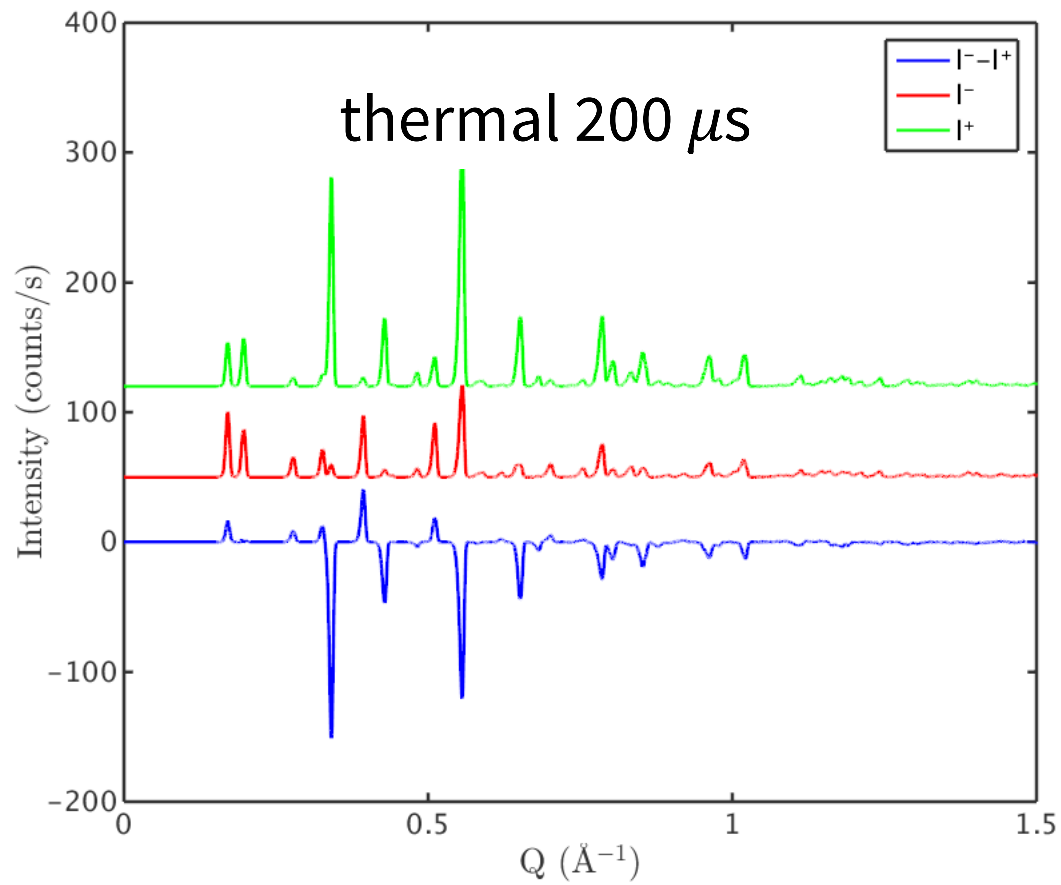
Thermal: $\lambda$ = *0.7-2.4 Å / ±0.3°*

- *2.86* ms pulse length (cold stat/20)
- *200* $\mu$s length (cold stat/500)

# Polarized NPD: $Tb_2Sn_2O_7$



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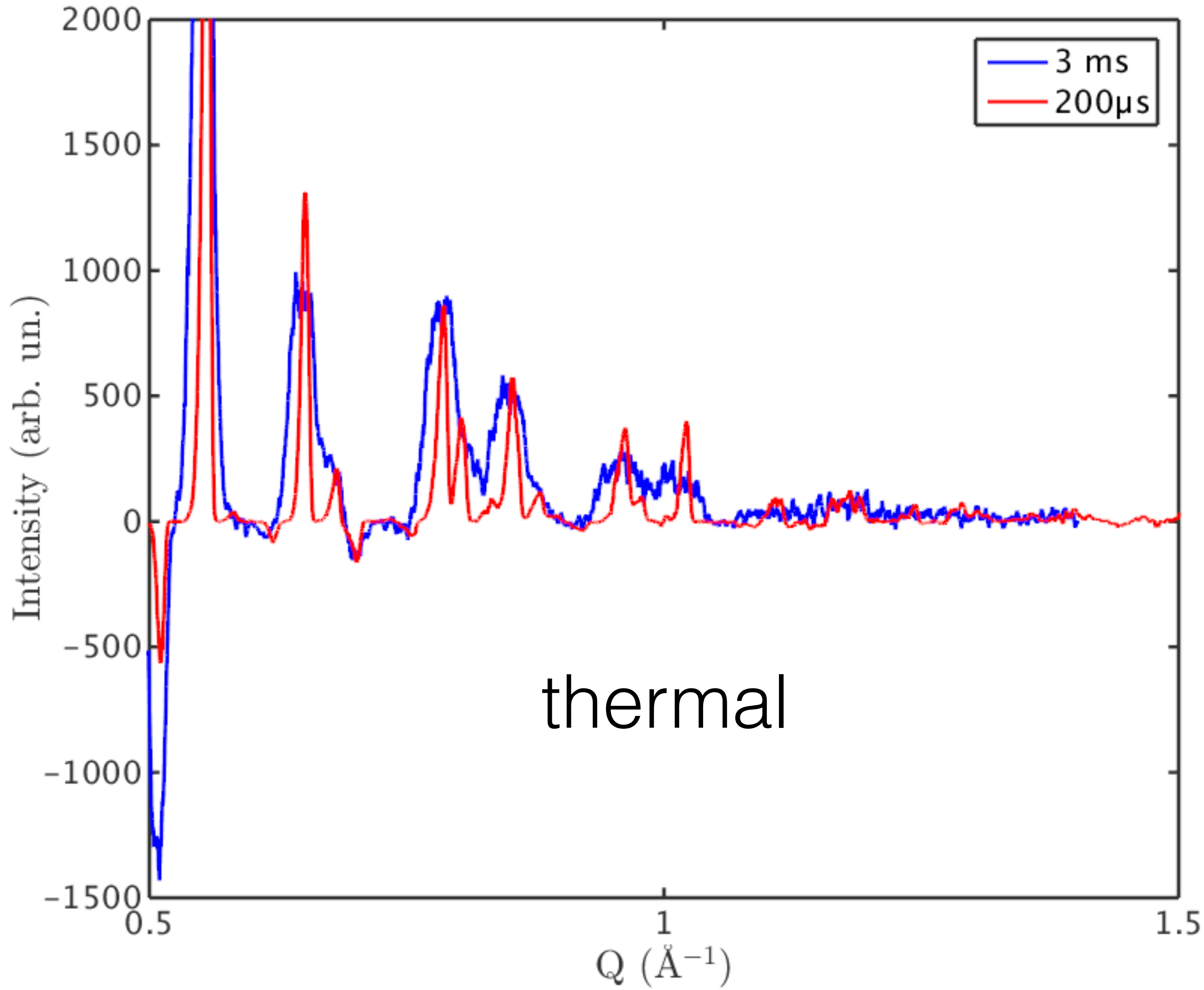
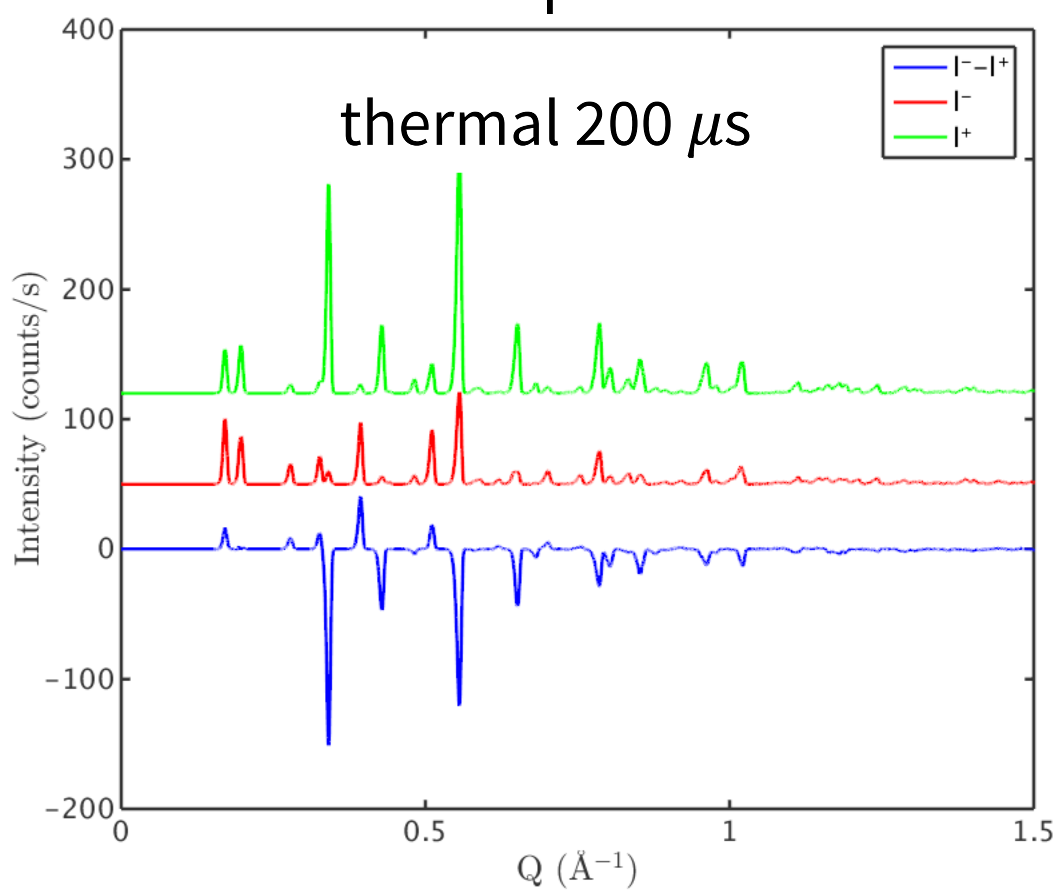
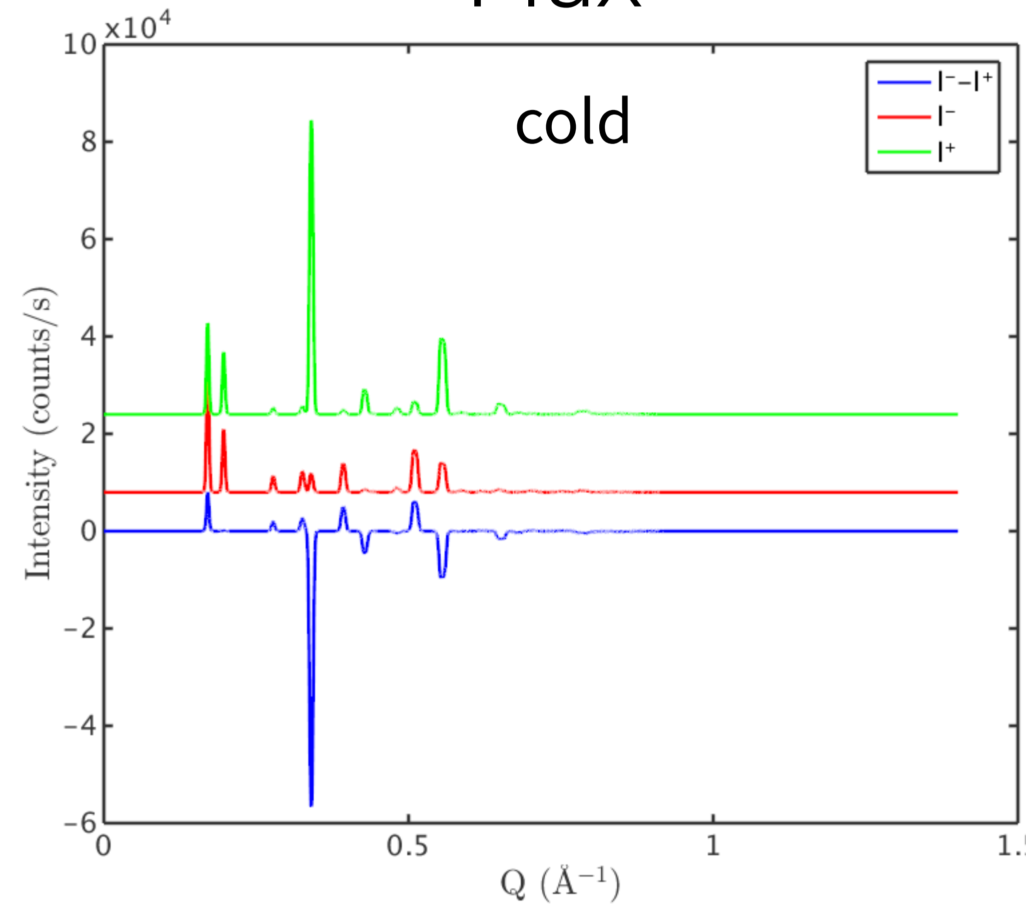


# Polarized NPD: $Tb_2Sn_2O_7$

Q-space




Flux




Rare earth magnetism

spin density

$2x10^5$ counts/hour !

transition metals

low spin (1/2)

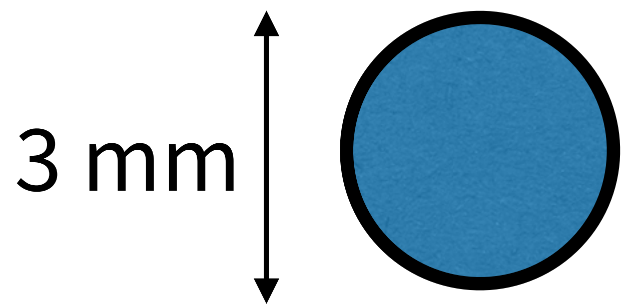
# Capabilities

- Flexibility
  - Q-space/Flux/Resolution

- High resolution !

- Efficient flipping ratio measurements + powder

# Diffuse scattering: $Ho_2Ti_2O_7$




- spherical sample
- r = 1.5 mm
- V = 14 mm$^3$

*a=b=c=10 Å*

cubic

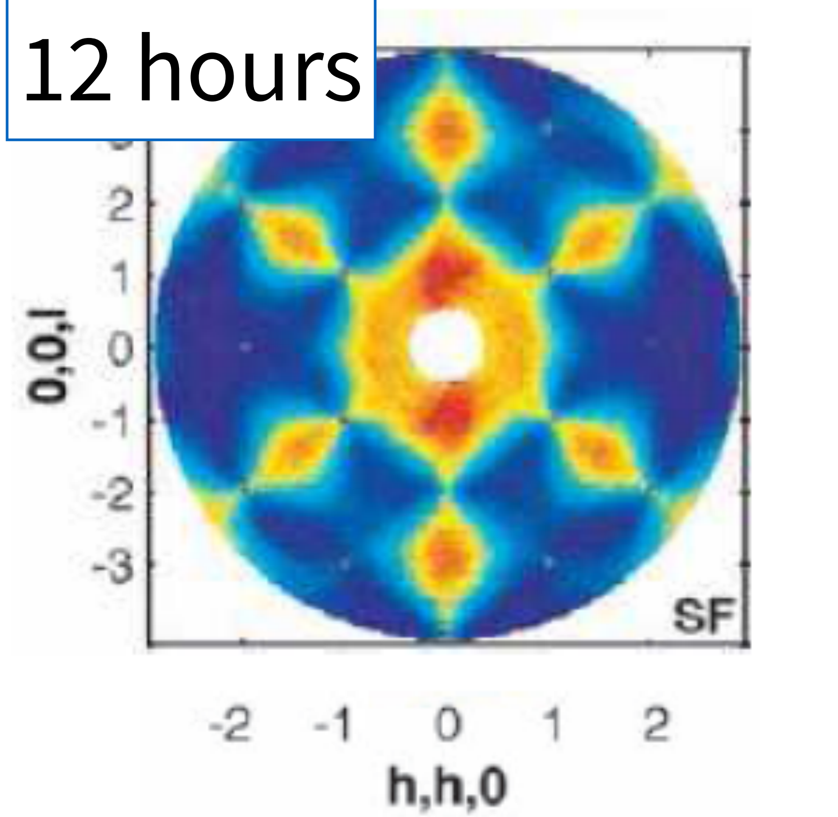
Cold: $\lambda = 2.1\text{-}3.8$ Å / ±0.5°

Full pulse length

Polarization analysis

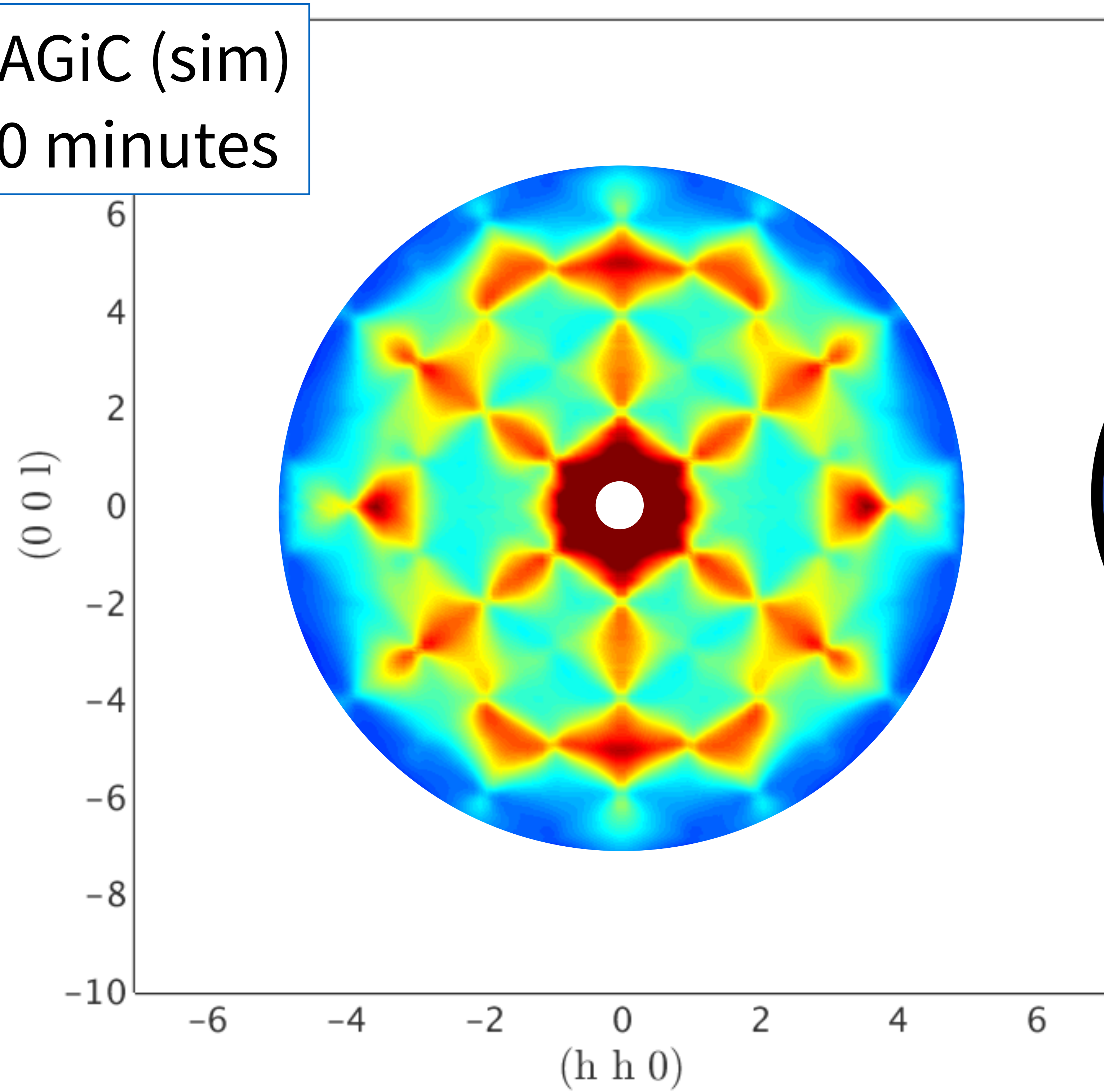
# Diffuse scattering: $Ho_2Ti_2O_7$

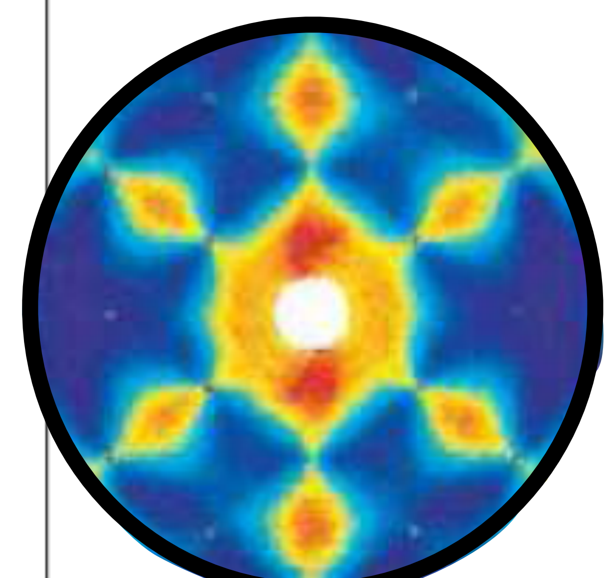
D7 (ILL)
12 hours



# Diffuse scattering: $Ho_2Ti_2O_7$

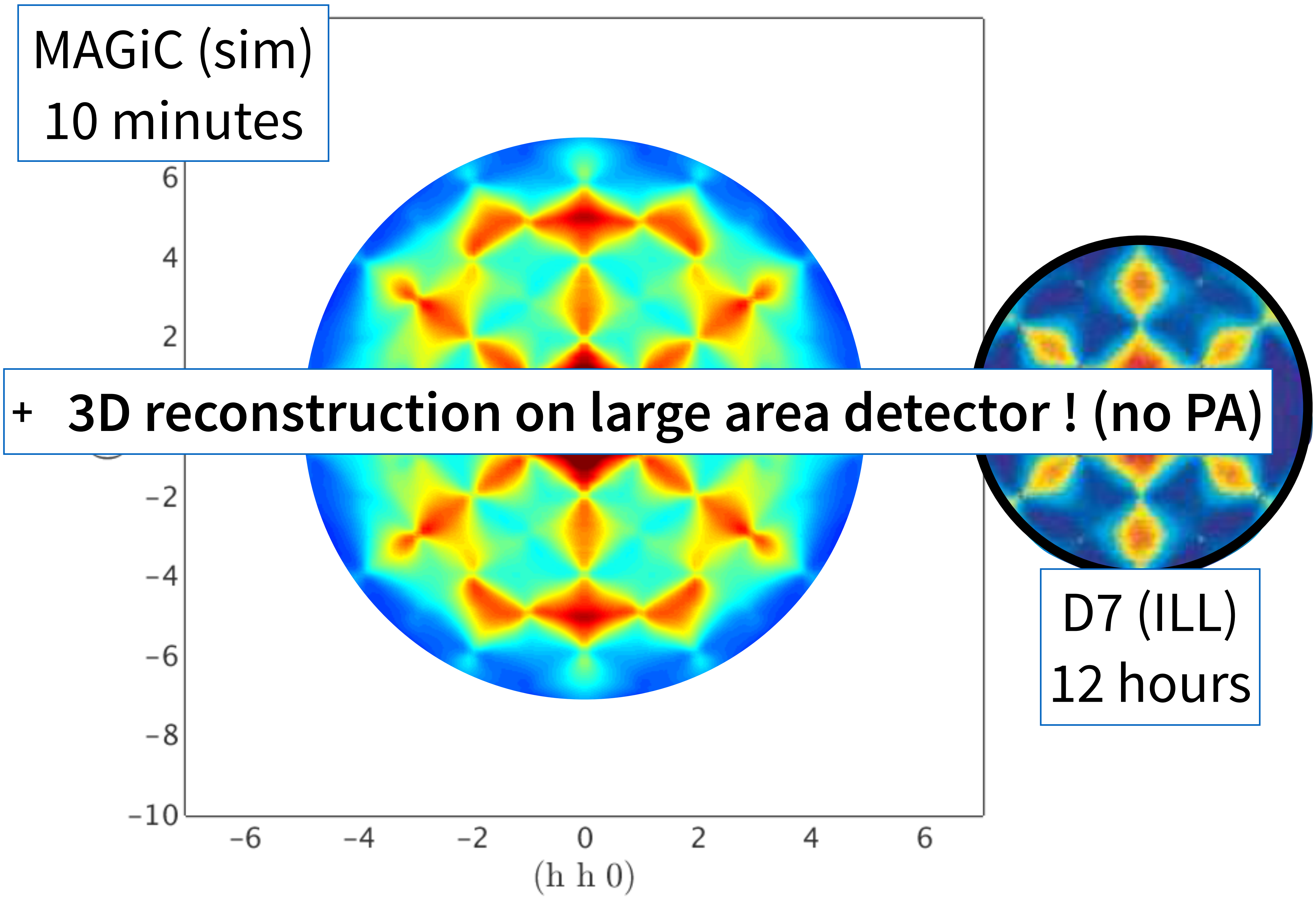
MAGiC (sim)
10 minutes



D7 (ILL)
12 hours

# Diffuse scattering: $Ho_2Ti_2O_7$




- **3D reconstruction on large area detector ! (no PA)**

# Capabilities

- Flexibility
  - Q-space/Flux/Resolution
- High resolution !
- Efficient flipping ratio measurements + powder
- Excellent resolution in polarization analysis mode !

# Capabilities

- Flexibility
  - Q-space/Flux/Resolution
- High resolution !
- Efficient flipping ratio measurements + powder
- Excellent resolution in polarization analysis mode !
- Polarized inelastic option => electro-magnons

# Outline

- Instrument requirements
- Simulation hypothesis
- Instrument Walkthrough
- **Expected performances**
  - Raw performances
  - Simulated experiments
  - **Gain factors**

# Expected gain factors

- **D7** (ILL):
  - Flux gain: **~200**
  - Q-range in PA mode: **1.7**
  - Divergence: **~10**

Global: **~1000**

- **SXD** (ISIS):
  - Flux gain: **~100**
  - Polarization: **~3 (6 with analysis)**

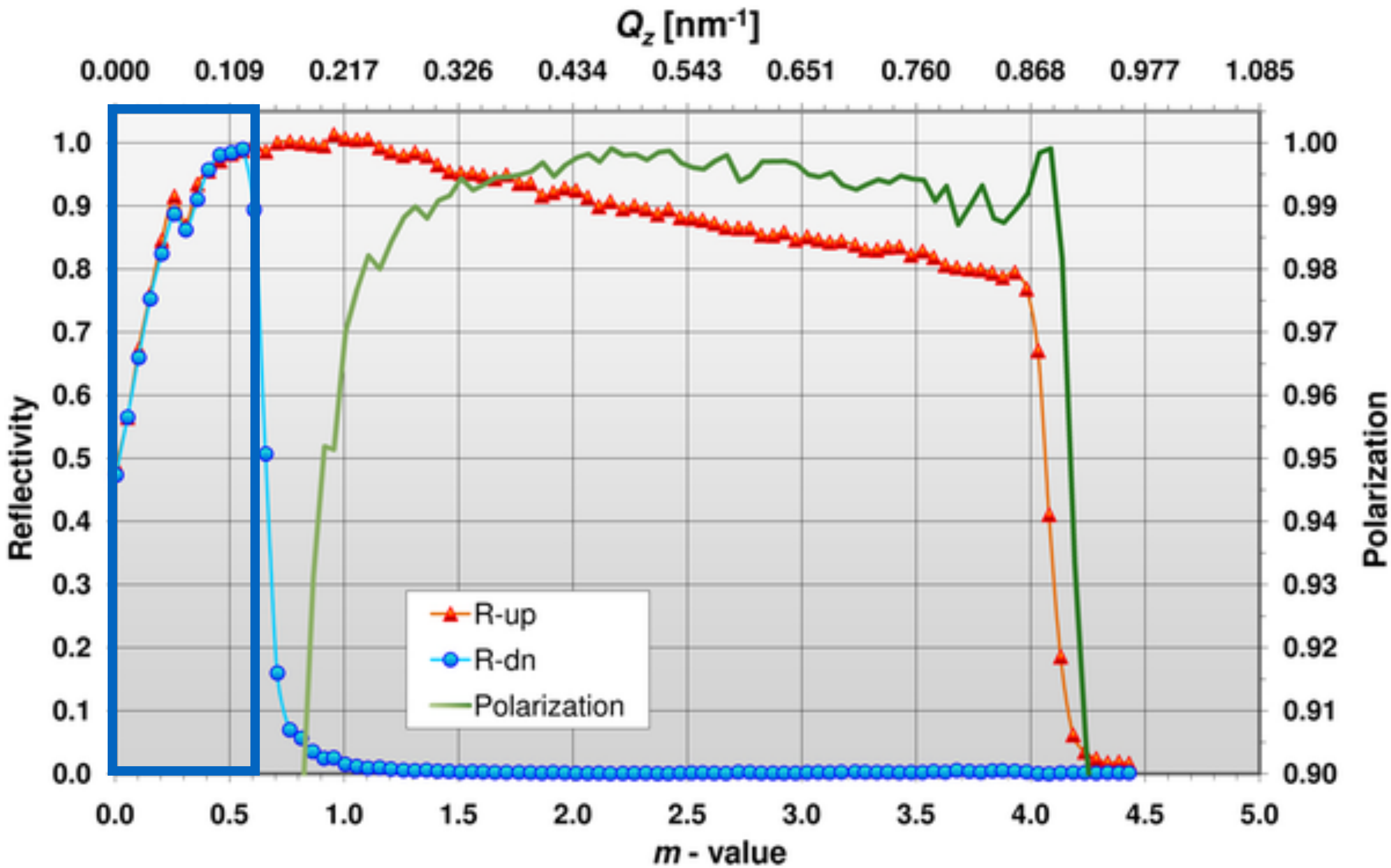
Global: **~300-600**

# Finally

- **High performances fully polarized diffractometer**
  - Large gain factor
  - High resolution
  - Excellent polarization
  - Flexible + easy to operate

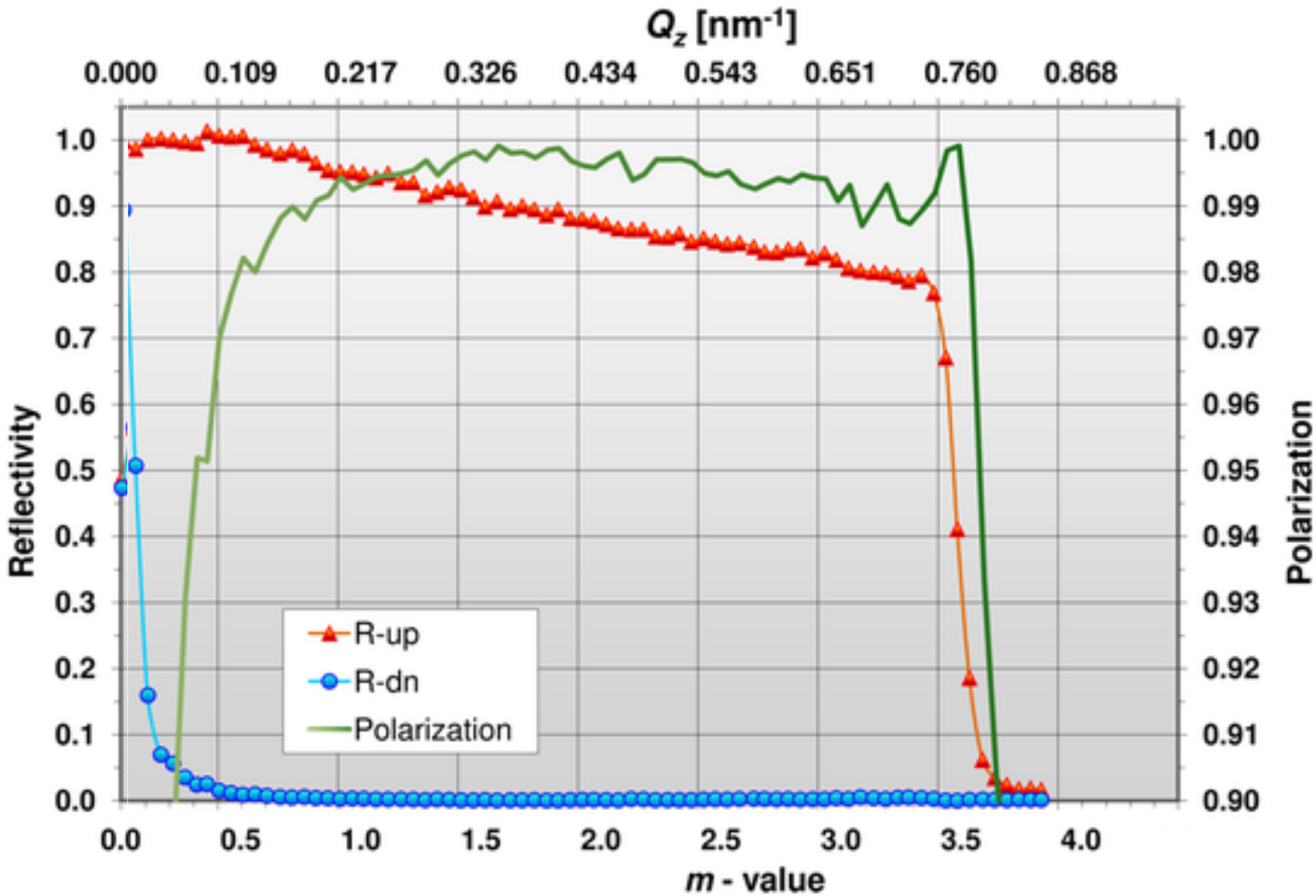
- **Well suited for the wide science case**

- It's **MAGiC**




Useless m=0.7

2 A: incident angle > 0.14° ==> max pol. ~70%




Reflections from Si shift the curves to the left

2 A: incident angle > 0 ==> max pol. ~99%