OAK RIDGE National Laboratory

Current guide design ideas at Oak Ridge National Laboratory

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Workshop on Neutron Focusing Optics

Paul Scherrer Institut, March 2023

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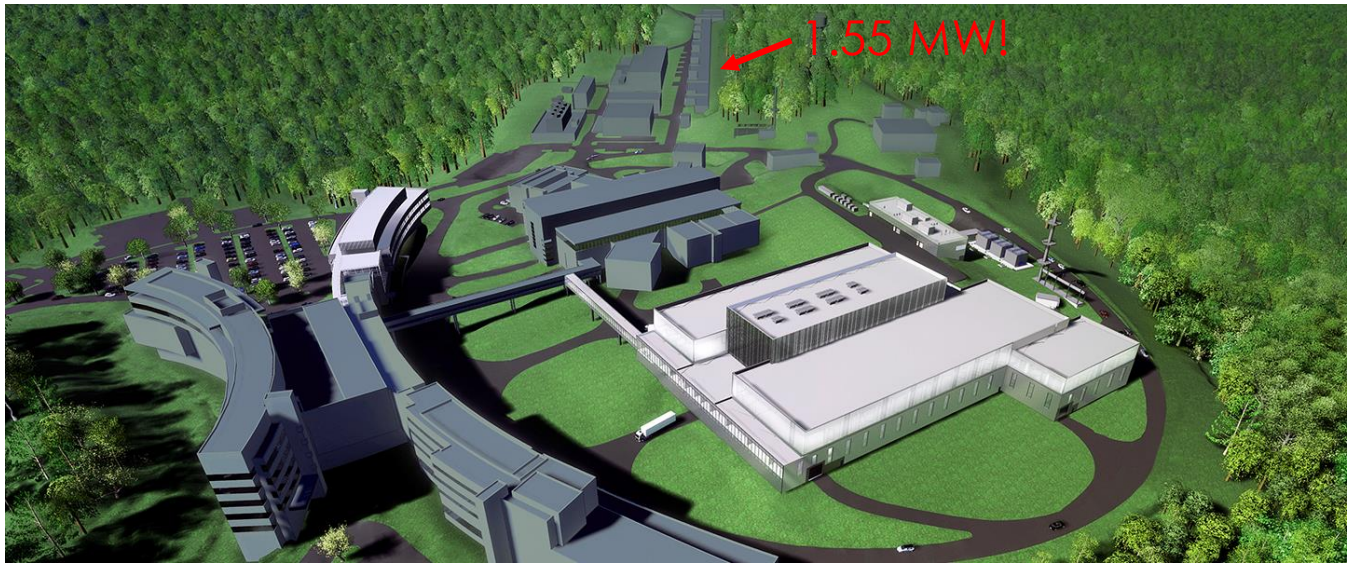
U.S. DEPARTMENT OF ENERGY

Three sources: three challenges



FTS:
- Large moderators
- 10x12 cm^2

STS:
- Small moderators
  - 3x3 cm^2
  - 3 cm Ø

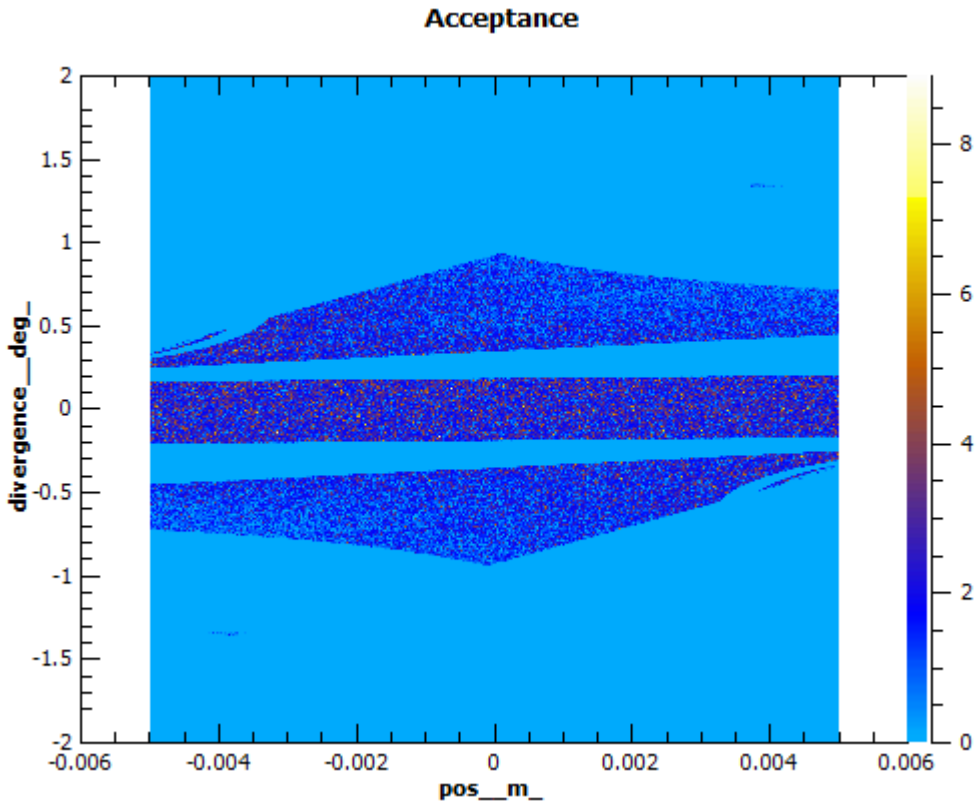
HFIR:
- Beryllium Reflector changeout
- Cold Guide Hall upgrade
- Completely new layout
- 5 → 6 beam lines
- Single cold source
- Out of line of sight

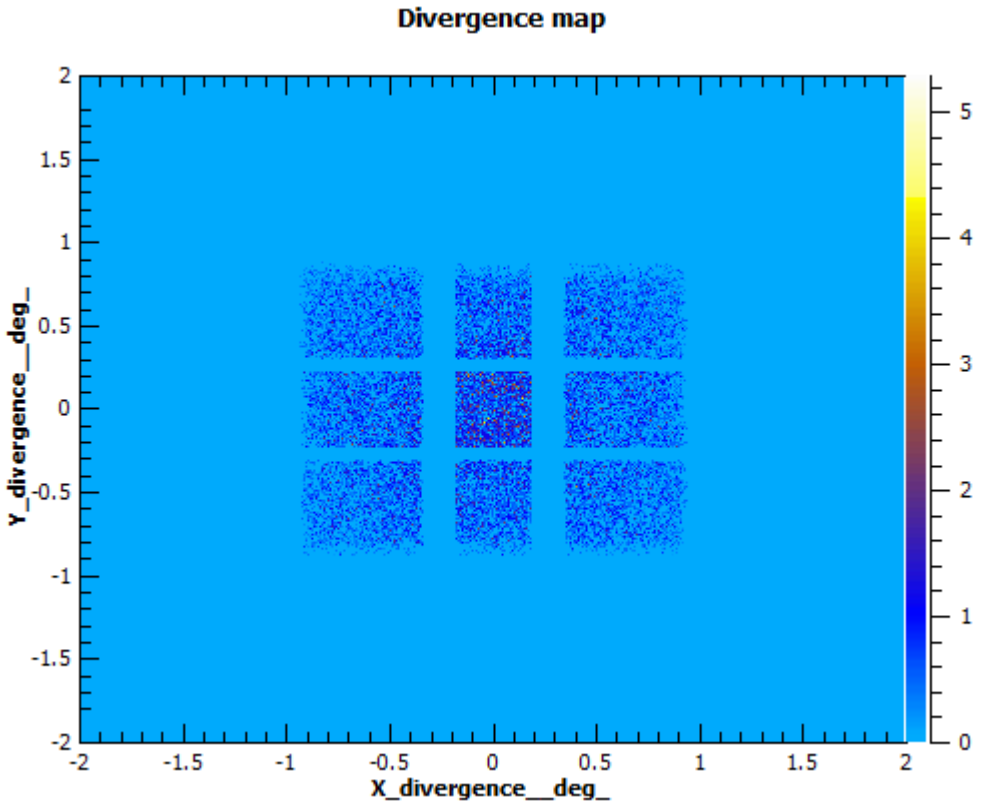
Outline

How we deal with:

- Big moderators!
- Small moderators!
- Tube moderators!
- Shared moderators!

Definitions and Goal





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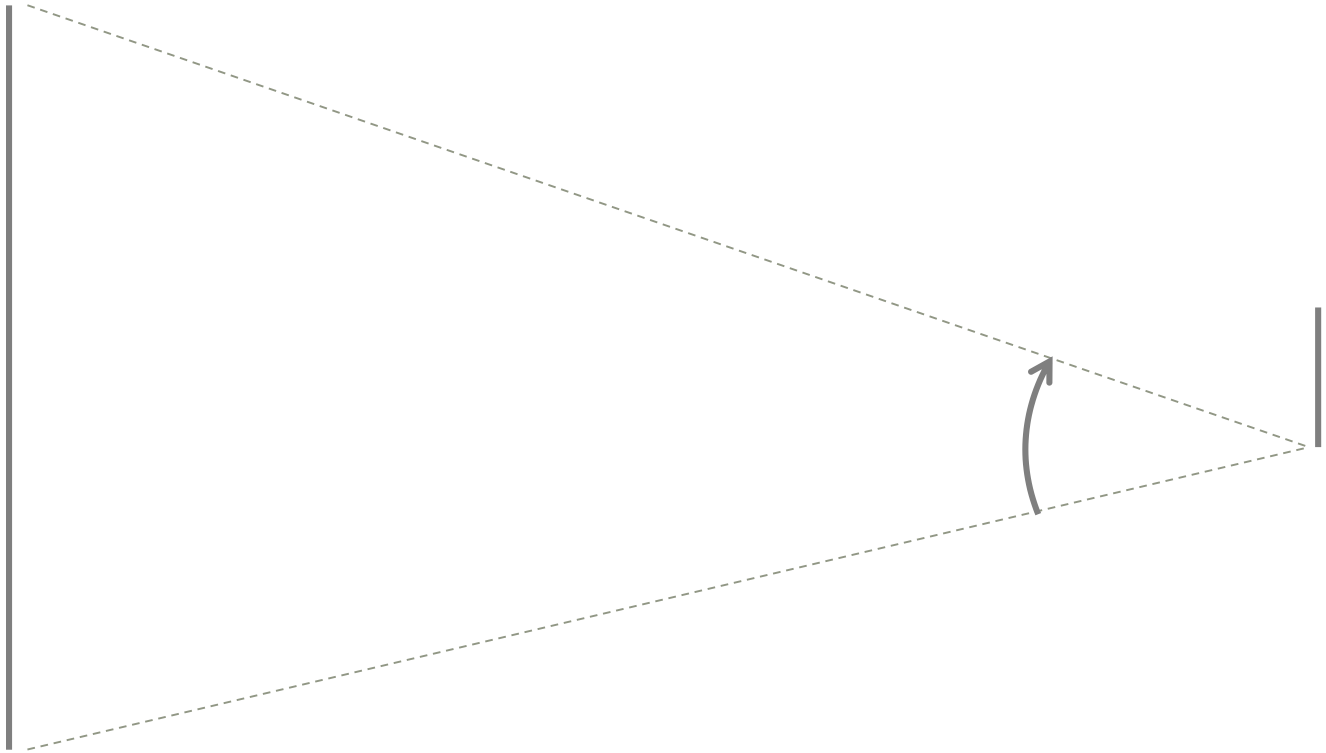
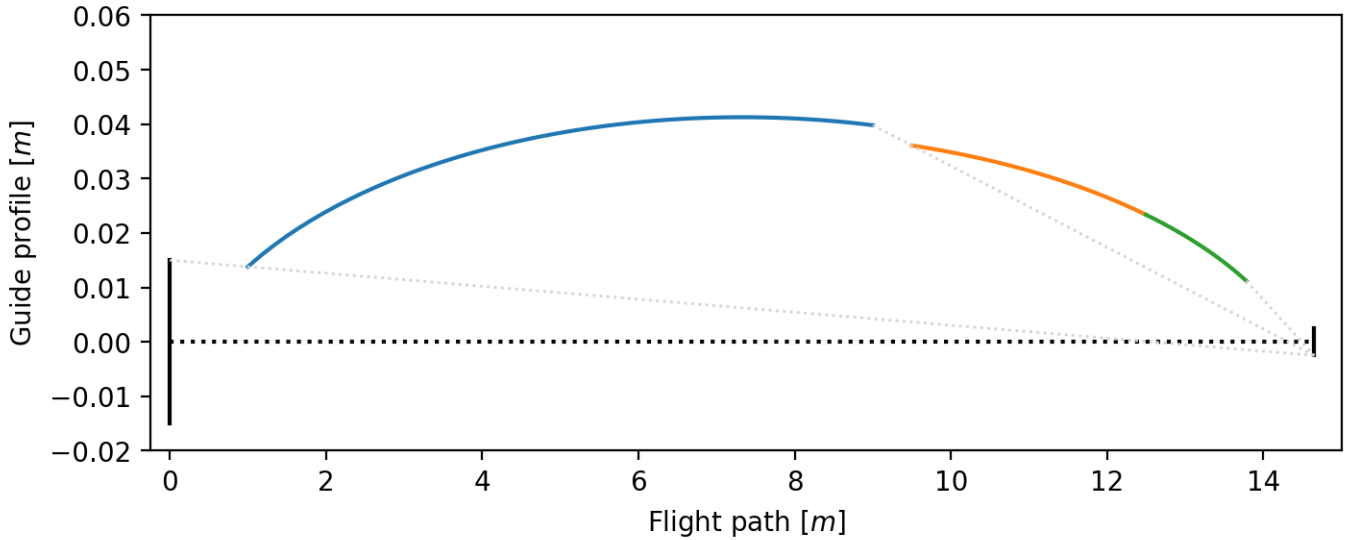
Supply and Demand: looking backwards



Example: chopper gaps

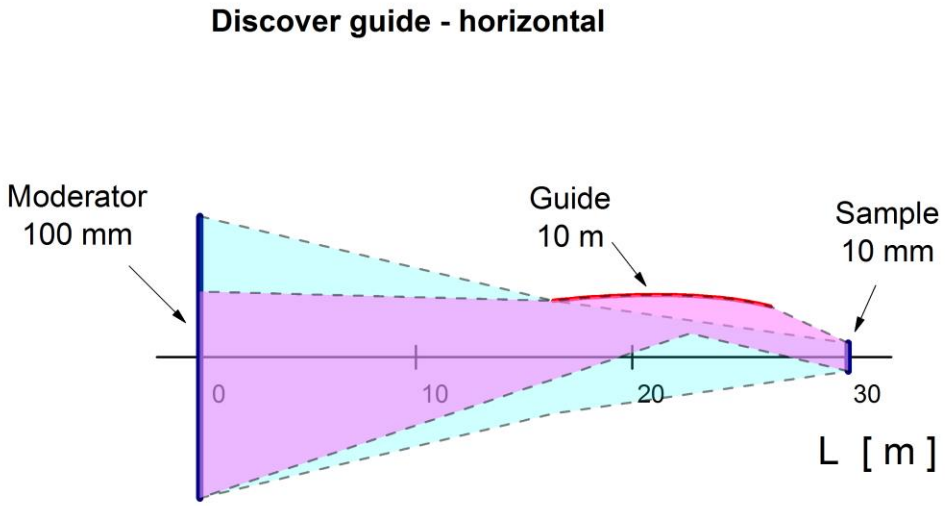


Large moderator case

SNS: First Target Station, 10x12cm^2

- Shape developed by Ducu Stoica
- 3 conditions:
  - Direct line of sight maintained
    - Limits guide entrance size
  - Only one reflection
    - Limits length and slope
  - No reflection "out of moderator"
    - Limits slope at guide exit

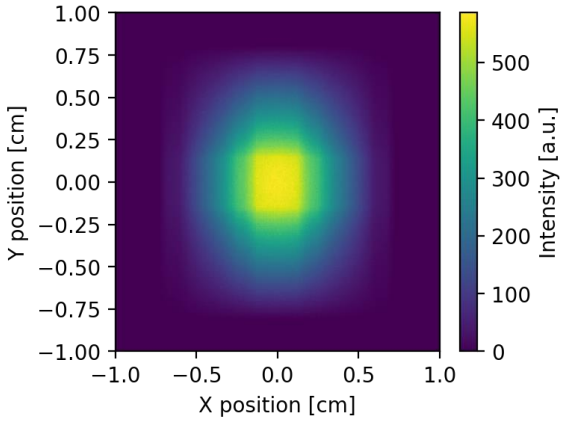
MATH* → $\left(\frac{y}{x} - \frac{\theta_0}{\beta}\right) x^{\beta} = C$

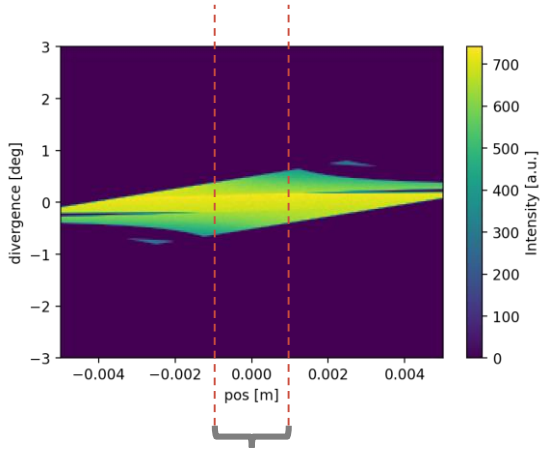


Every trajectory coming from the sample has to end on the moderator surface!

* Frost, M. J.; Stoica, A. D.; Huegle, T. A First-Principles Approach to the Optimization of Neutron-Focusing Guide Design and Development. *Journal of Neutron Research* **2019**, *20* (4), 131–135.

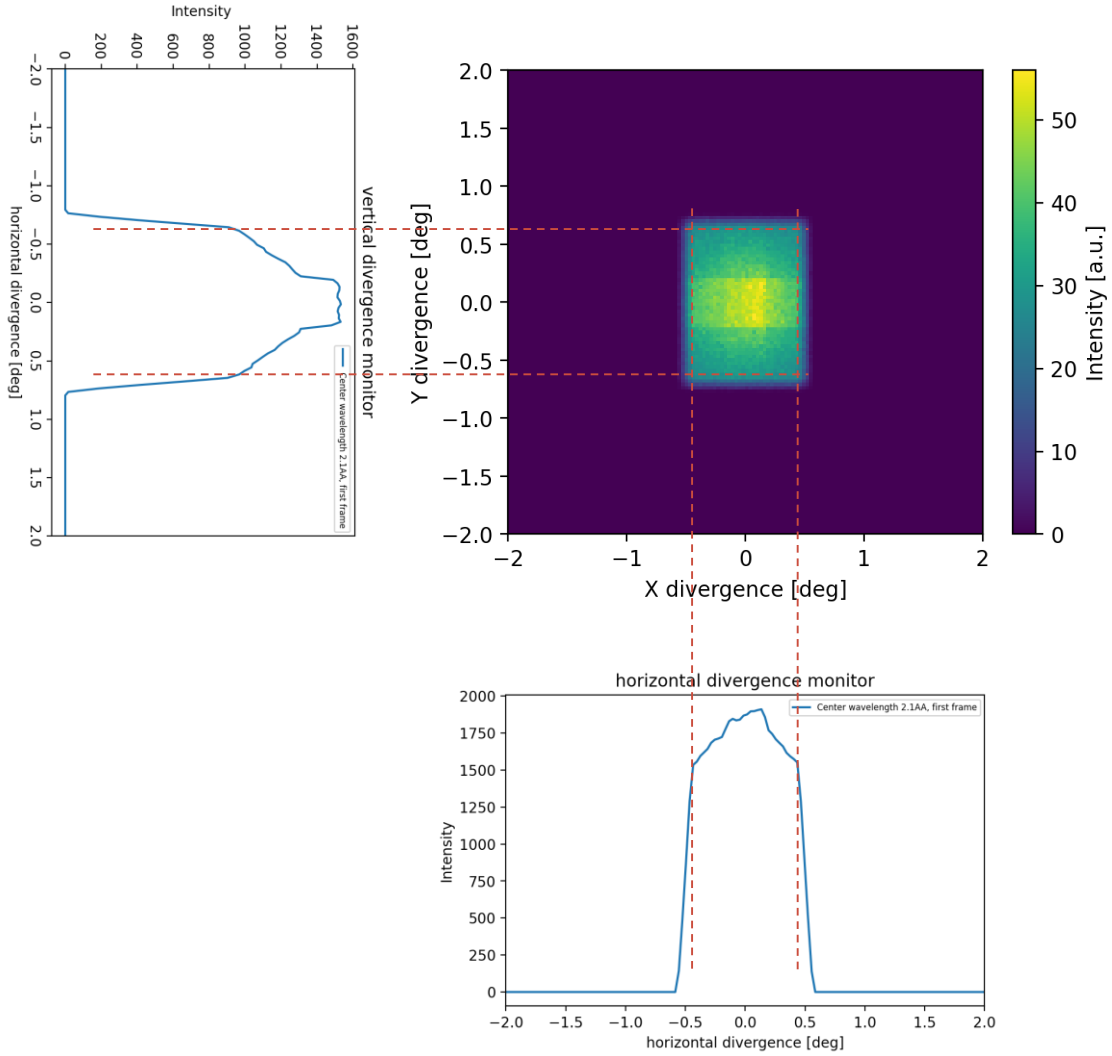
Example: SNAP





2mm
No gaps in divergence in center of sample

Divergence map at center of sample (1mm^2)



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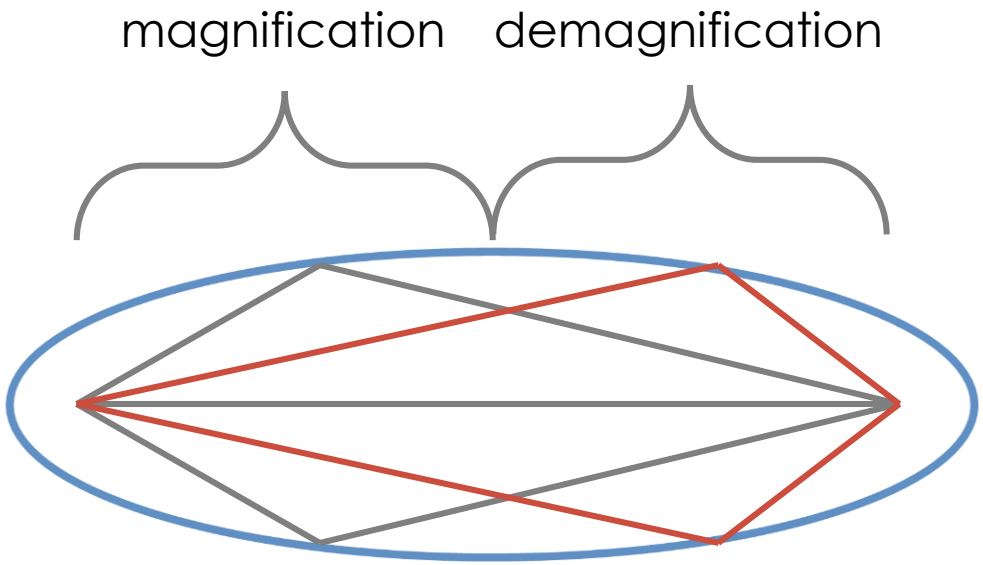
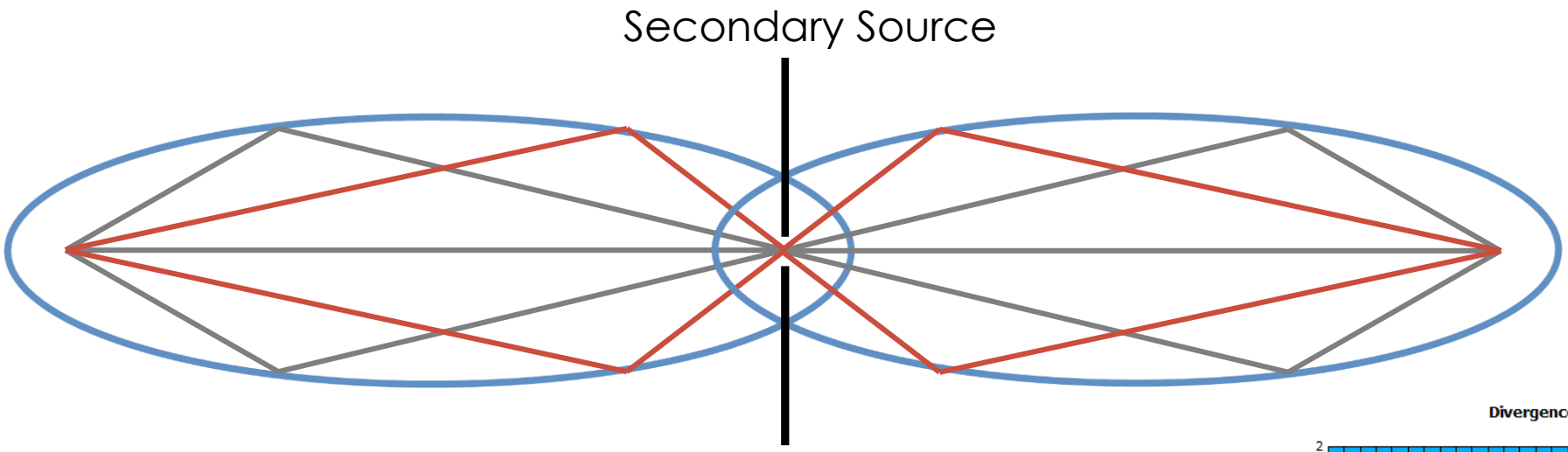
Small moderator case

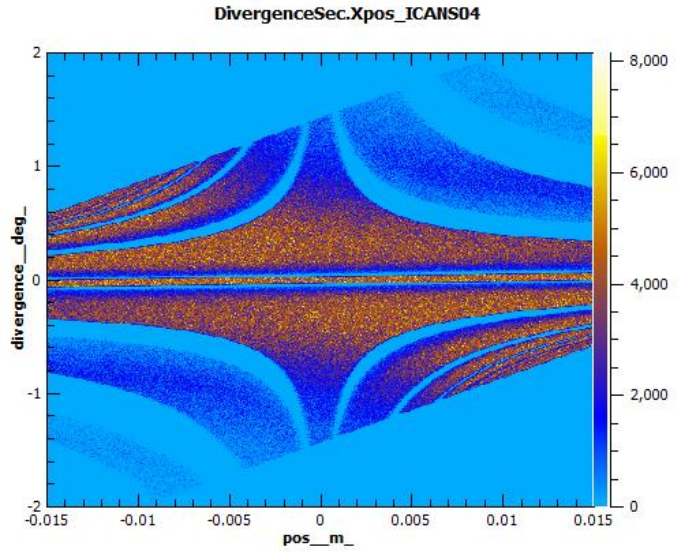
Second Target Station: 3x3 cm^2

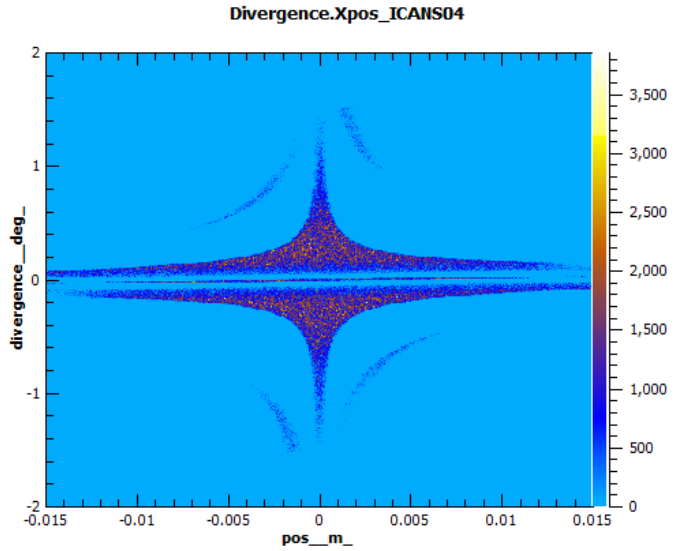
- High Brightness
  - $n/s/Å/cm^2/sr$
- Project image of moderator
- Ellipse: aberrations



Two Symmetric Ellipses with secondary source







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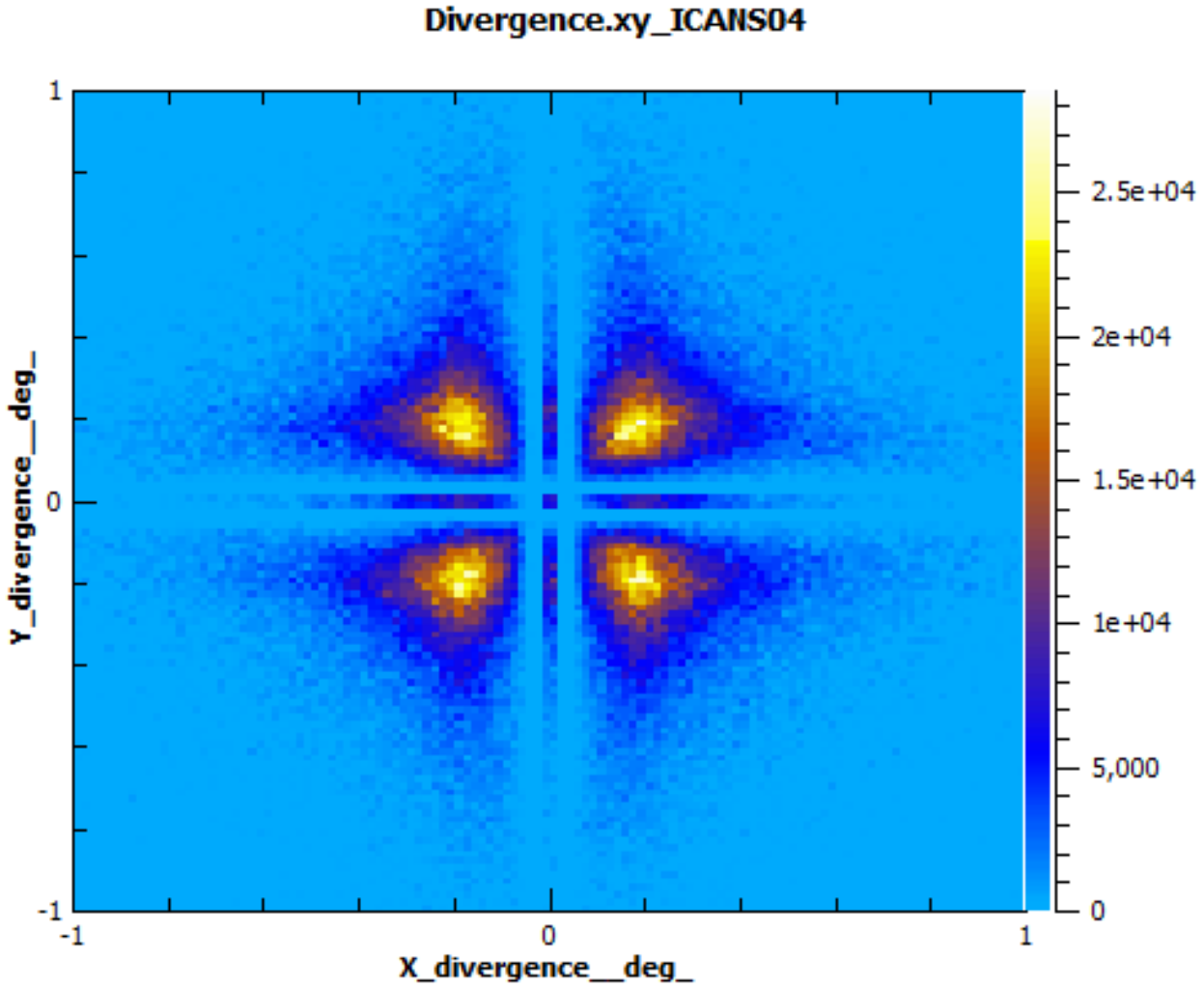
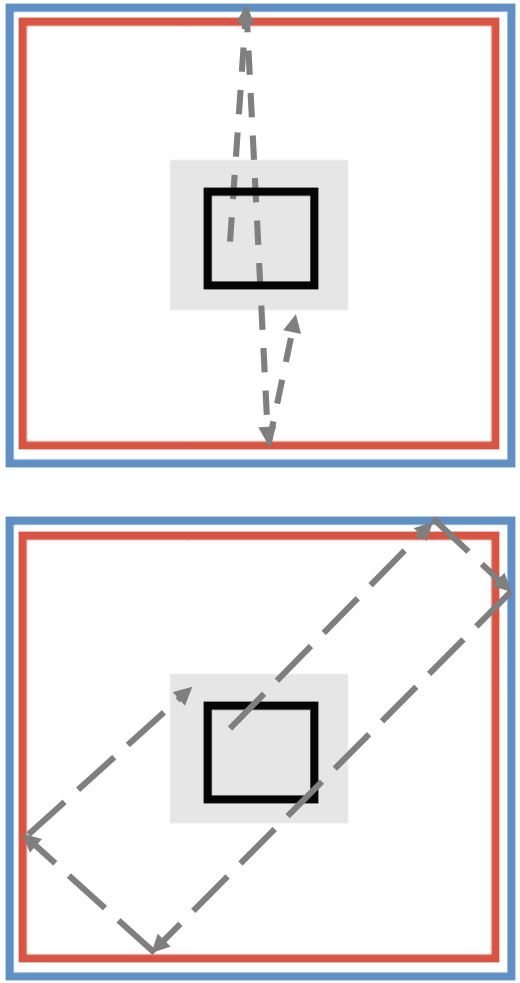
Divergence map at sample position





Moderator
First guide
Second guide
Sample

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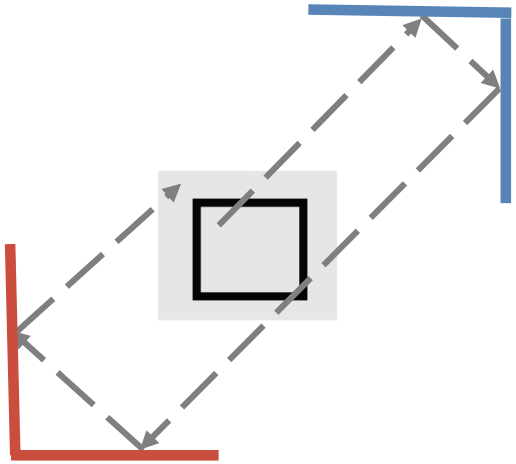
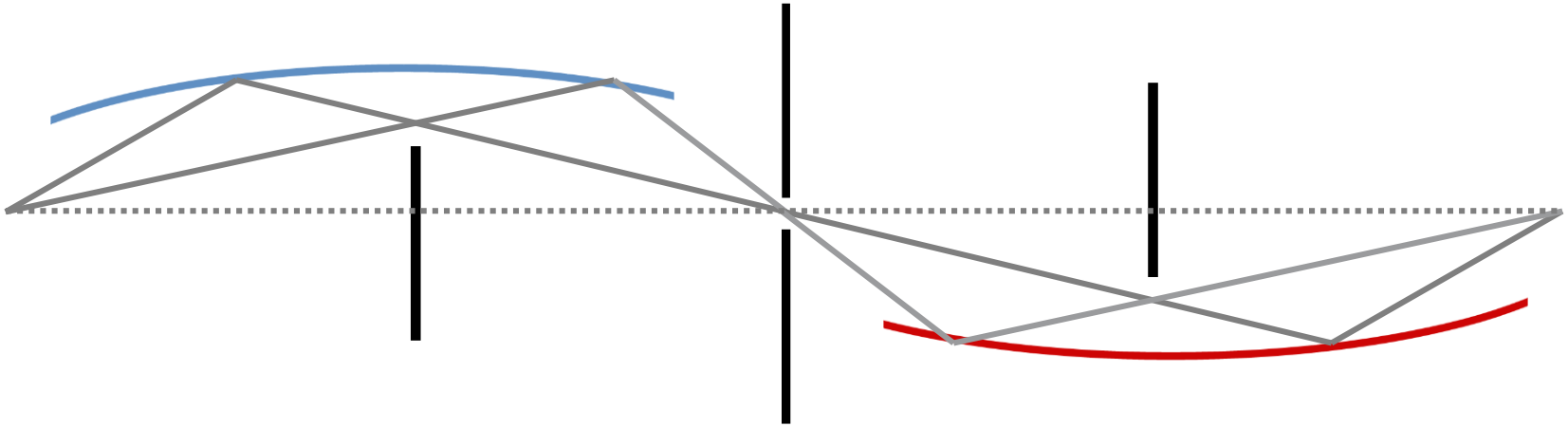
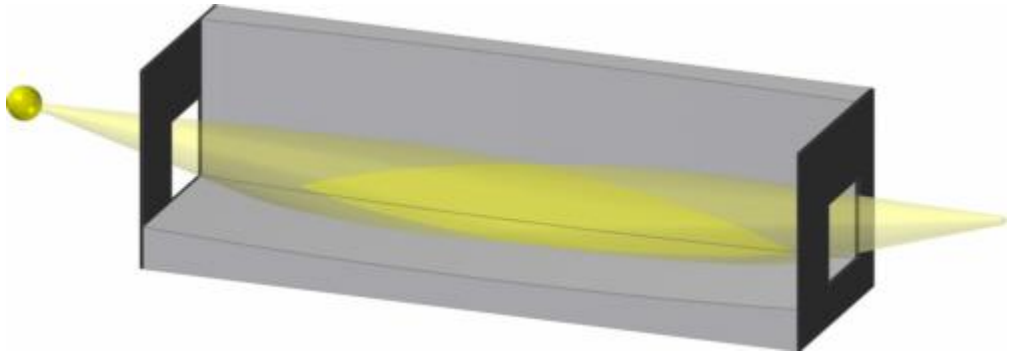
Montel Optics



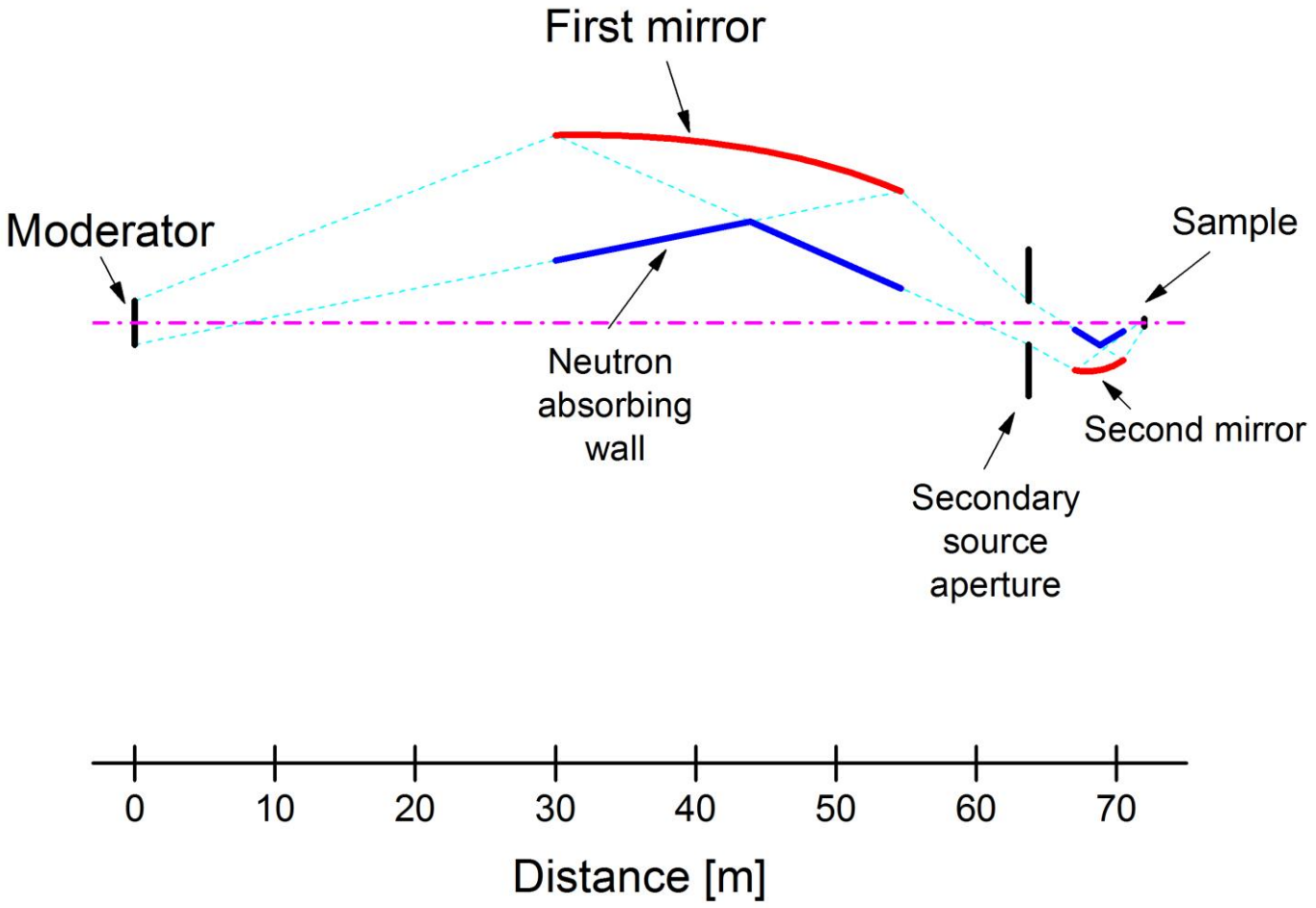




http://www.x-ray-optics.de/index.php/en/types-of-optics/reflecting-optics/curved-mirrors

What happens when we change the ellipse size?

Demagnification + demagnification = focusing?



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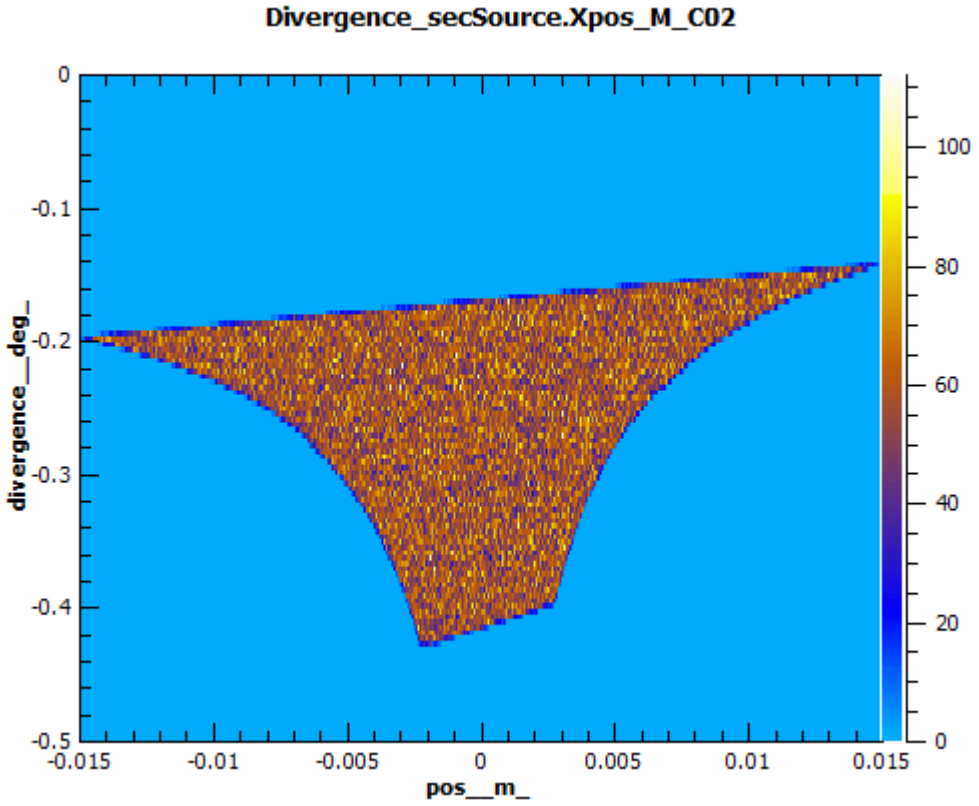
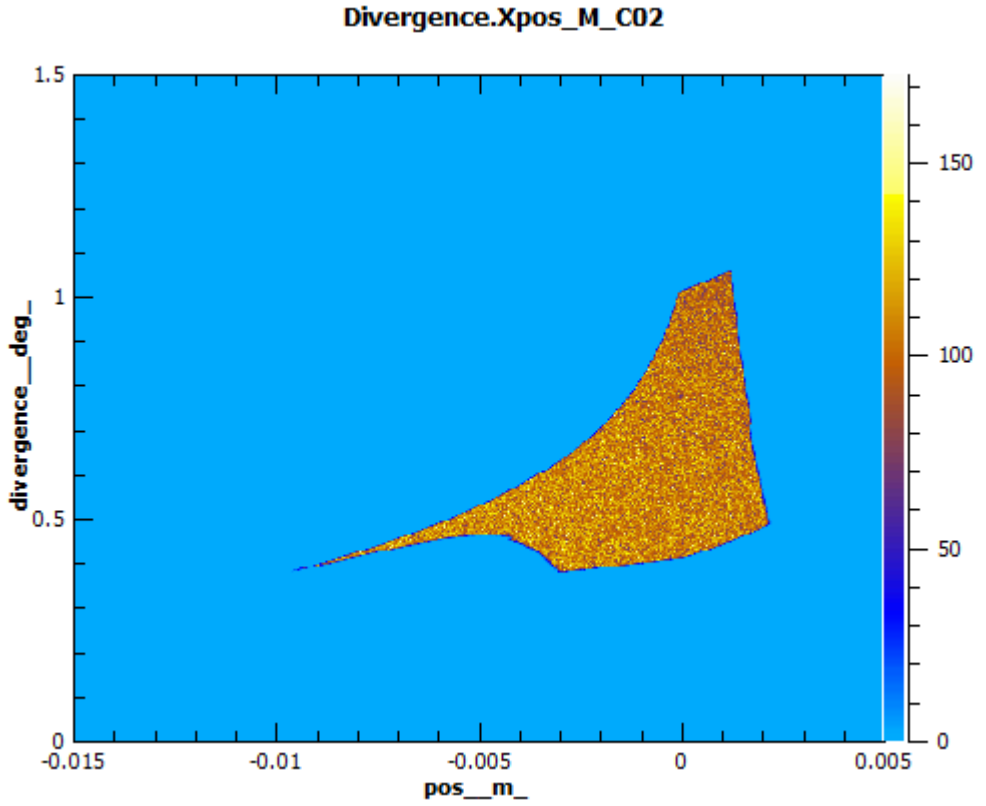
Divergence vs. position: unoptimized case

At secondary source:



At sample position:



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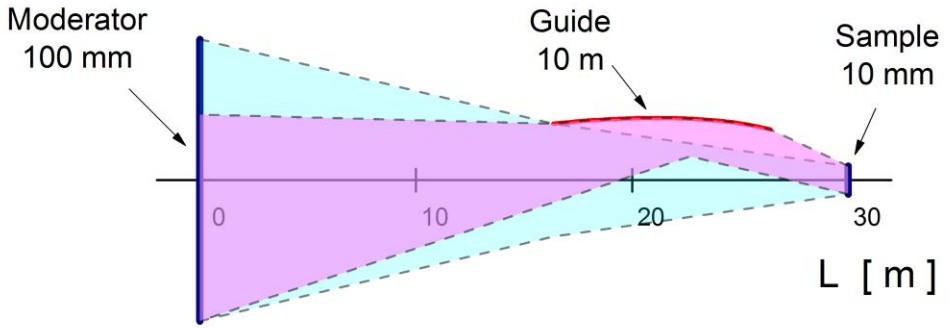
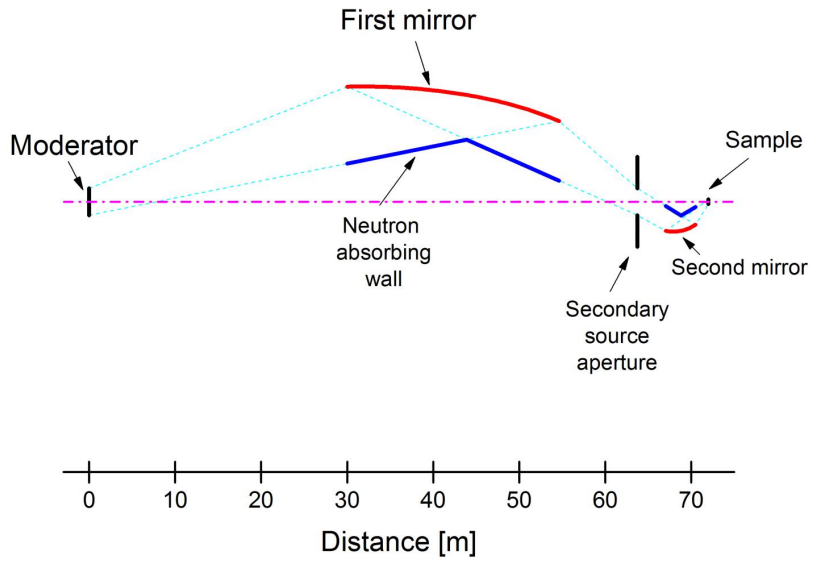
How to optimize to each other (secondary source)

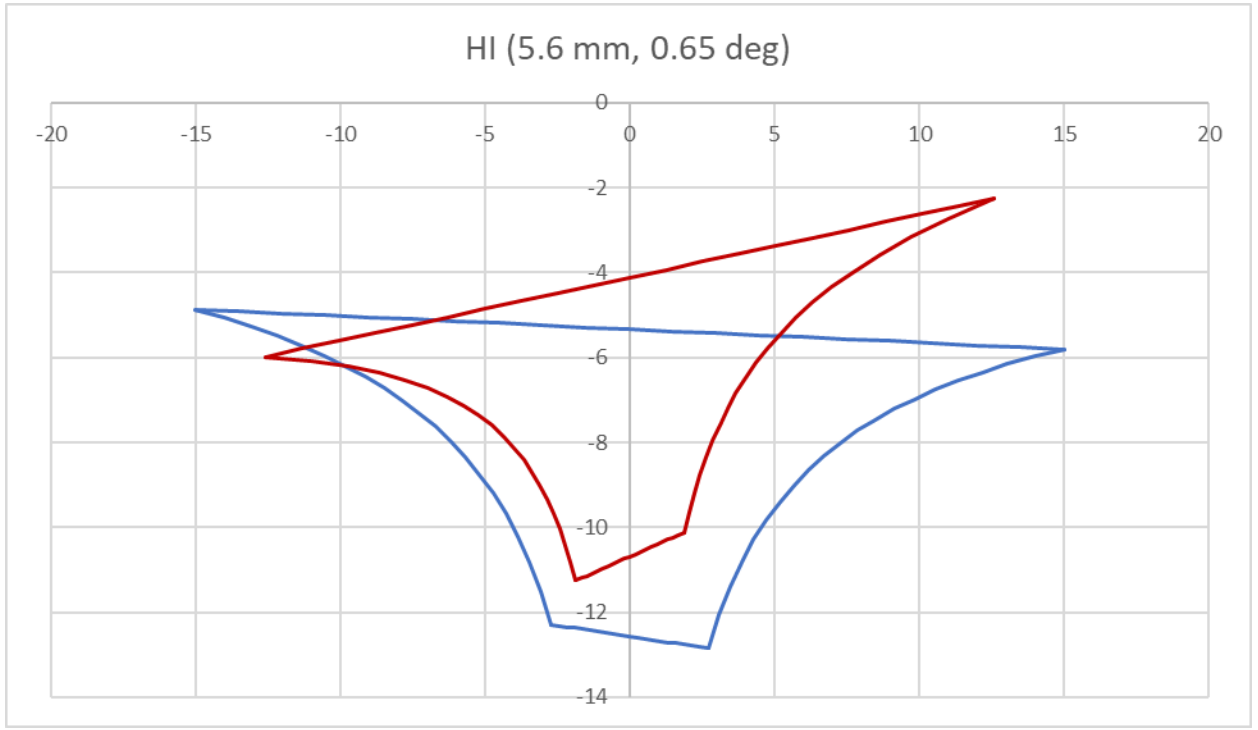
- Remember 3 conditions: no holes in phase space!
- Easy to imagine for rectangular moderator
- Hard to imagine for secondary source produced by 2-sided ellipse
- Back projection



Every trajectory coming from the sample has to end on the moderator surface!

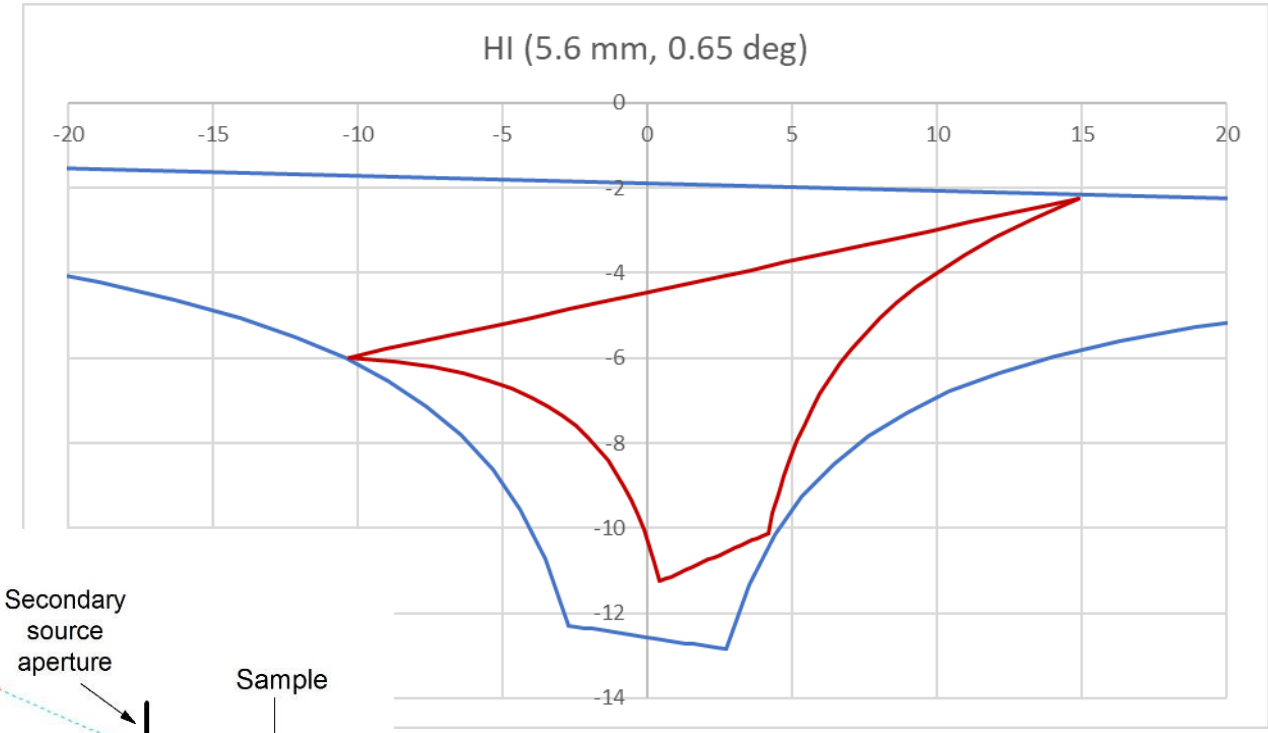
What went wrong?

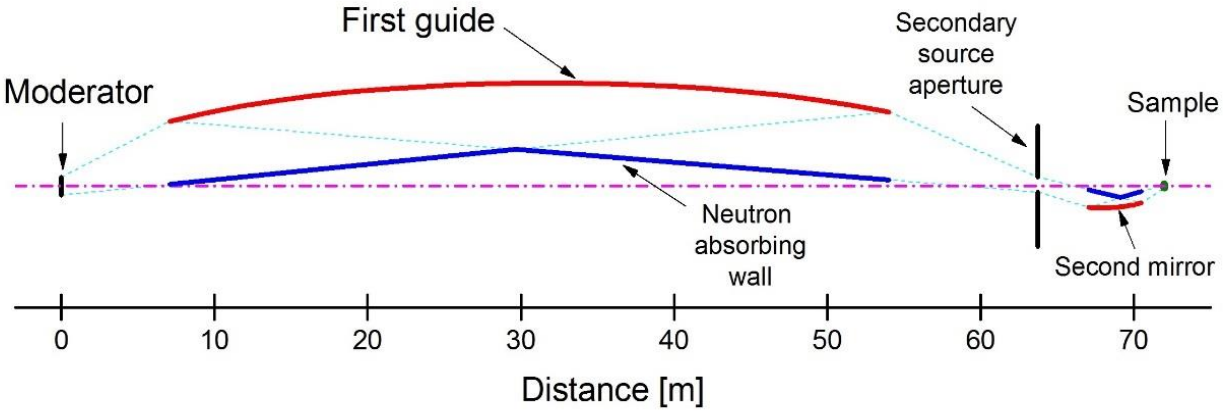




At Secondary Source: Match phase space from moderator to that back-projected from sample!

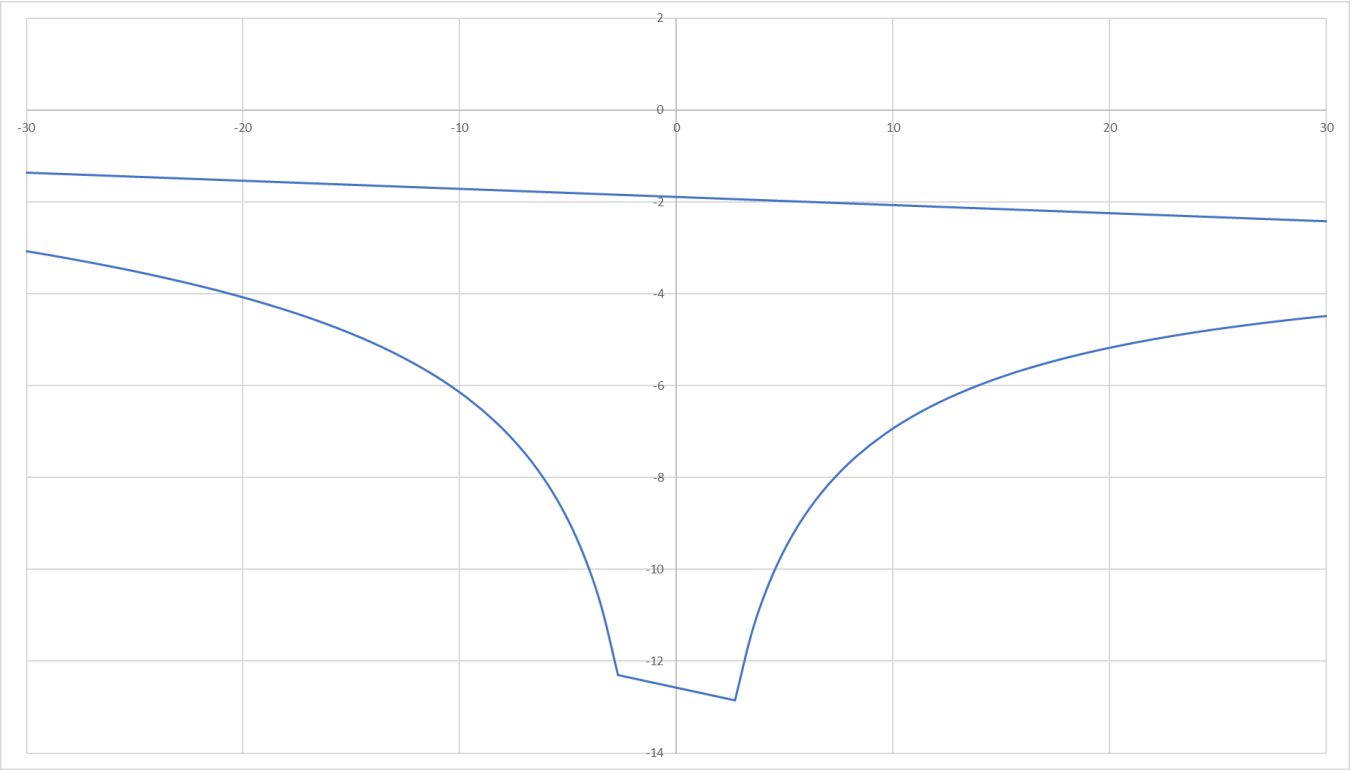
How to do better?





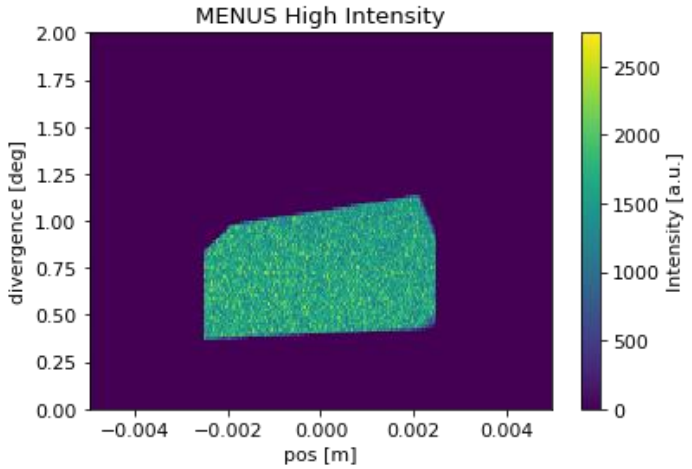
Match Acceptance

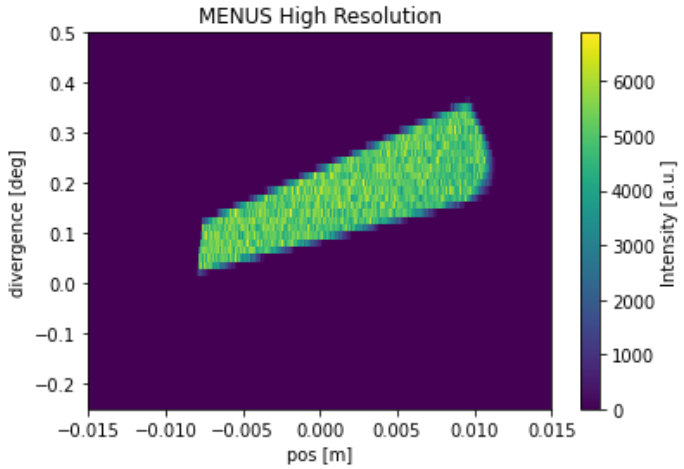
- Multiple second guide pieces to choose from?
- Extend first guide to accommodate all second guide options

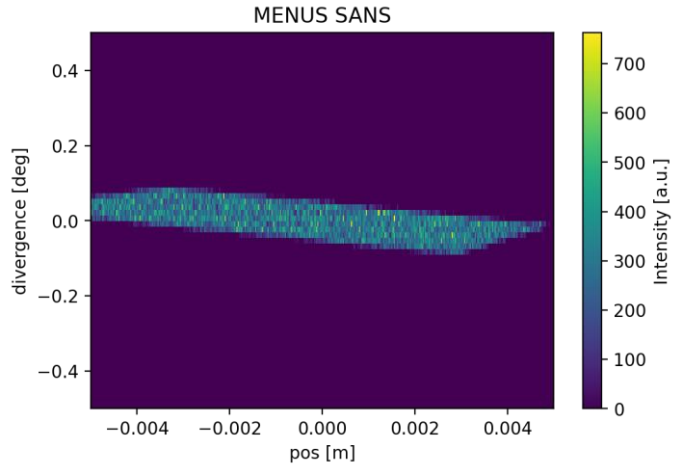


Example: MENUS

Multimodal engineering diffractometer







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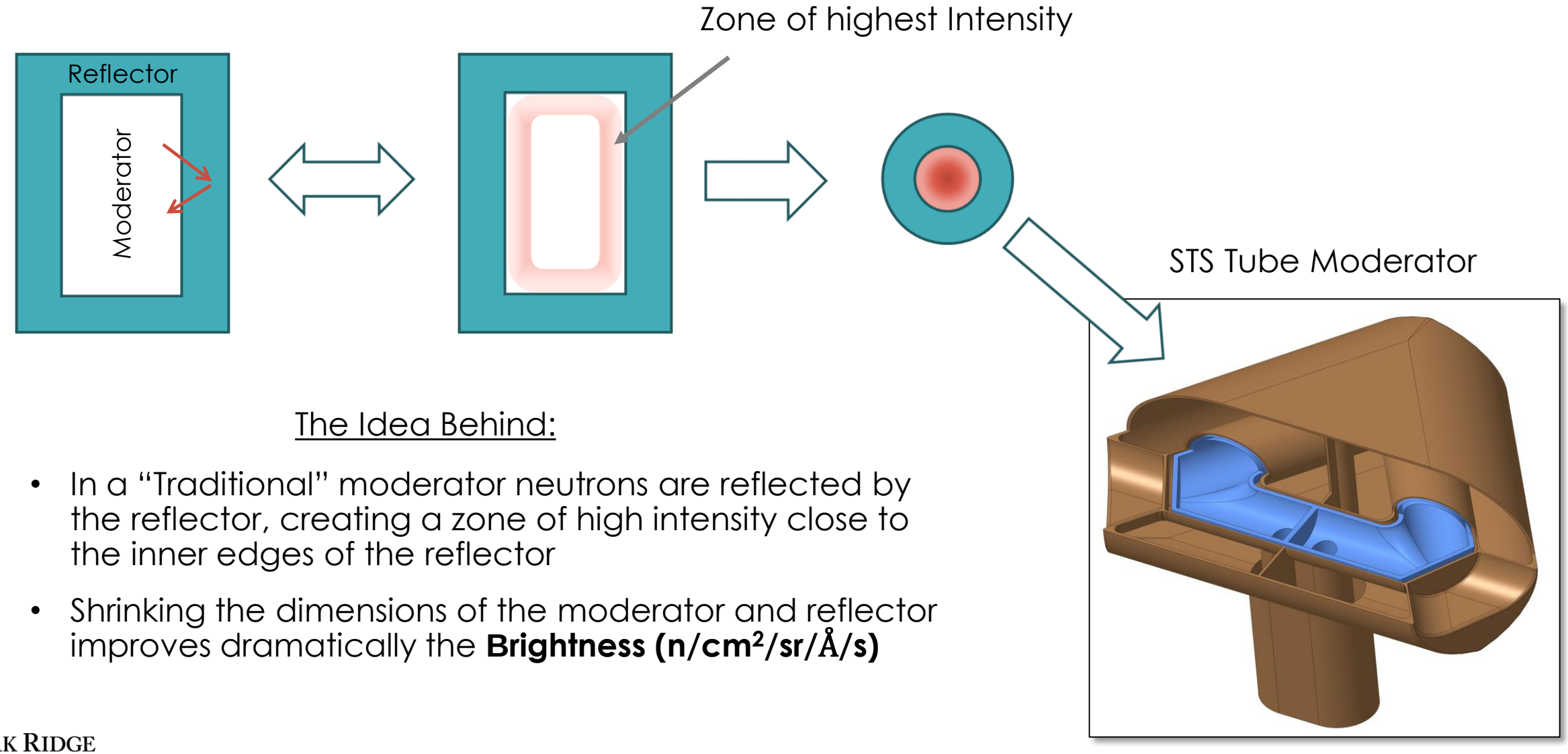
The STS Tube Moderator



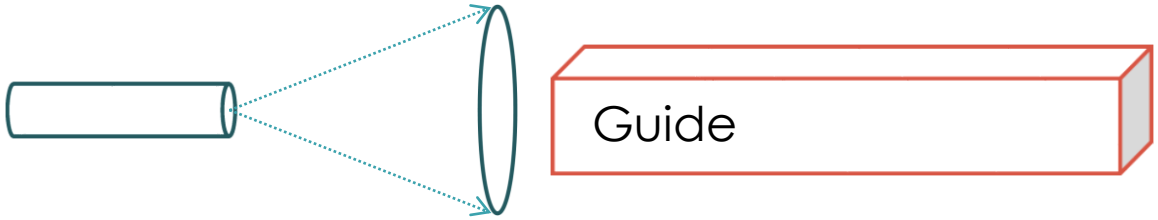
The Idea Behind:

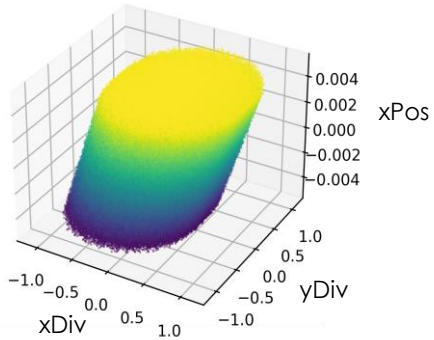
- In a "Traditional" moderator neutrons are reflected by the reflector, creating a zone of high intensity close to the inner edges of the reflector
- Shrinking the dimensions of the moderator and reflector improves dramatically the **Brightness (n/cm^2/sr/Å/s)**

The problem with the tube moderator

square guides: fitting a round peg in a square hole

Any beam emitted will be circular*

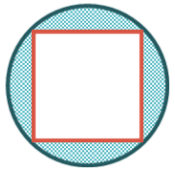




*it's complicated

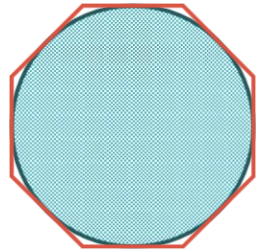
Square guide

Catches all neutrons, but is underilluminated

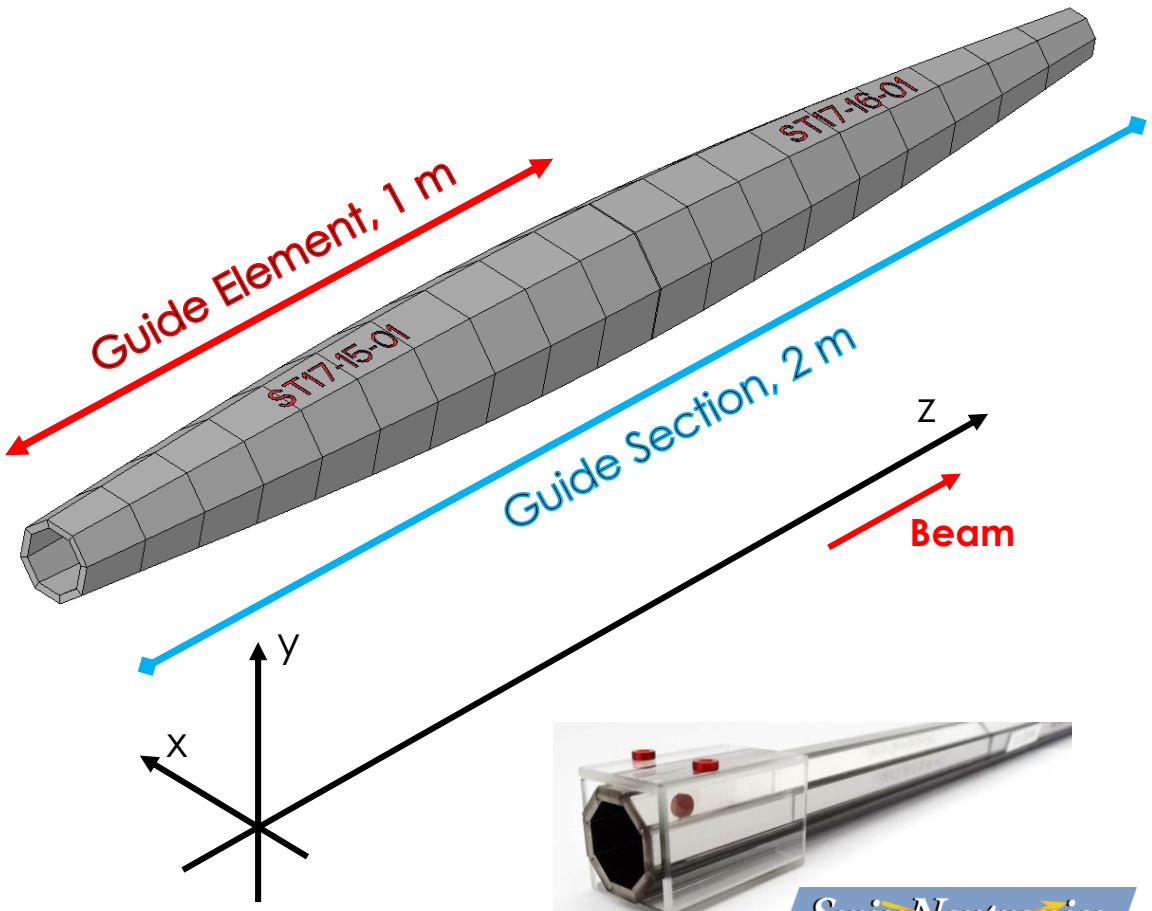


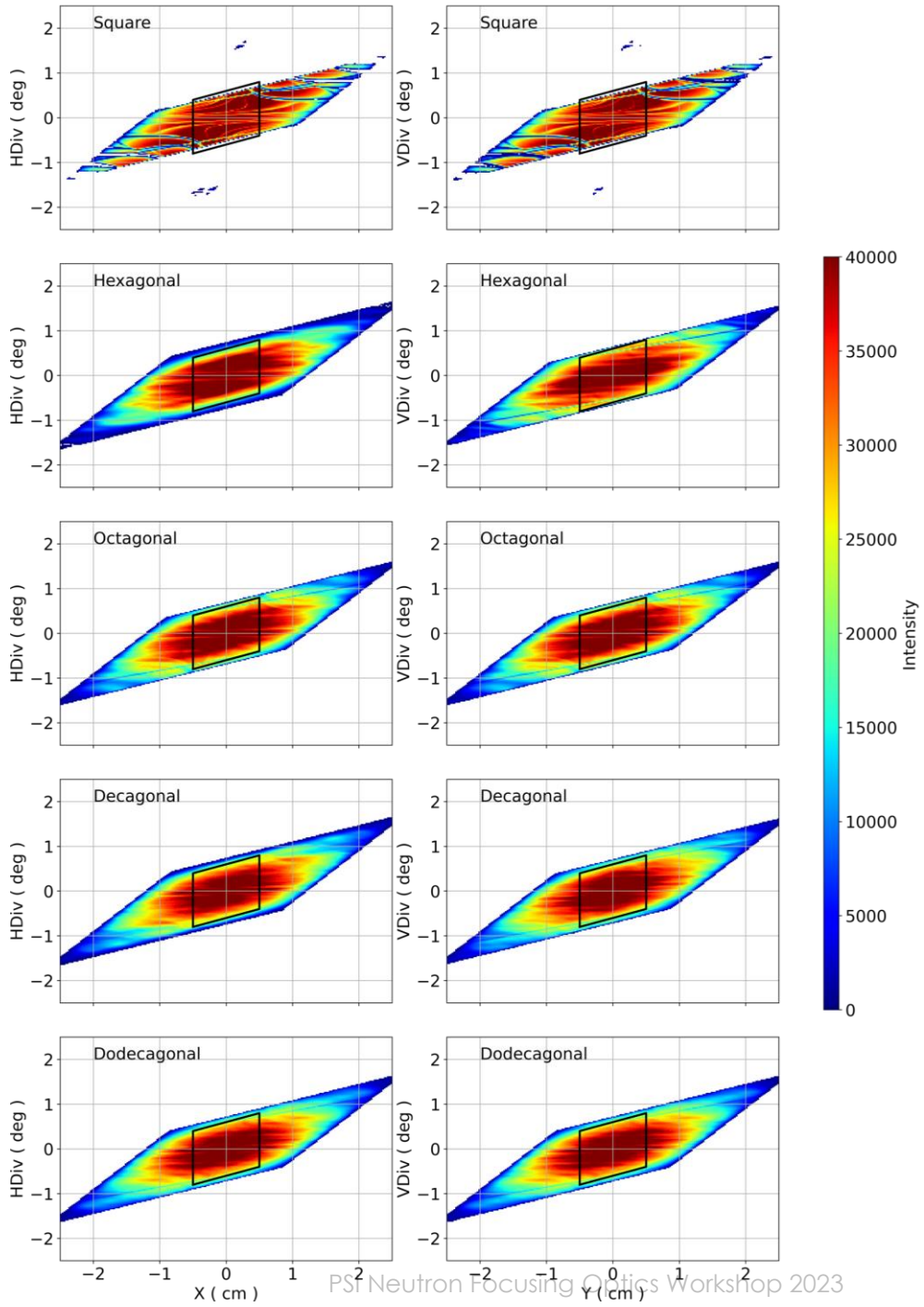
Is fully illuminated, but does not catch all the neutrons

=> Explore guide shapes that capture the beam better!



CHESS guide analysis





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HFIR: new Guide Layout

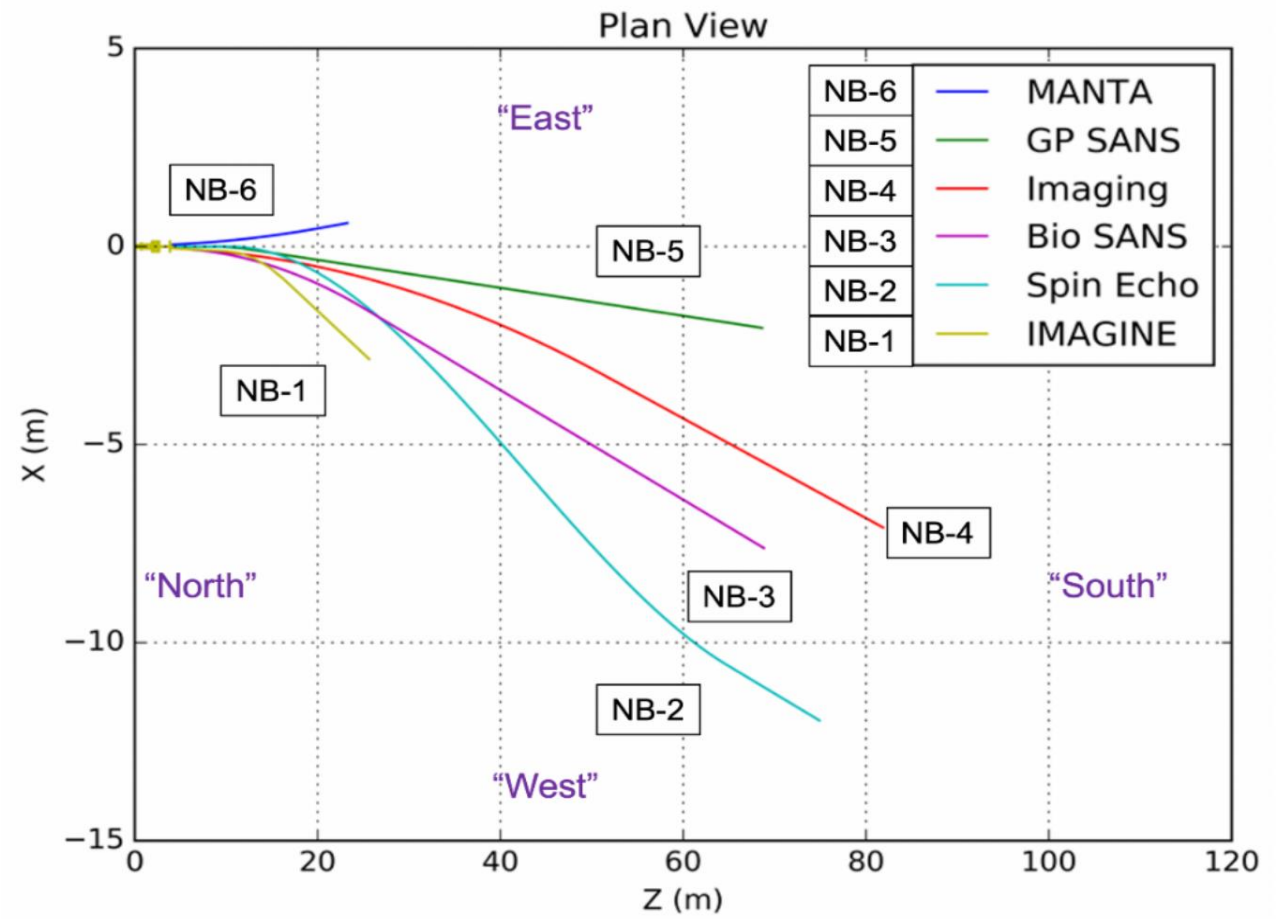
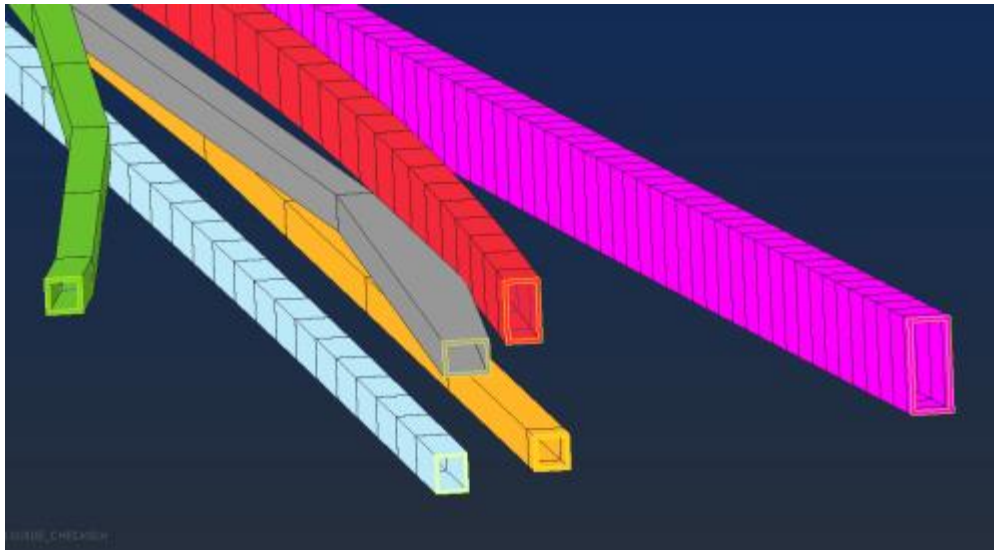


Figure 5. Plan view of the proposed new guide network.



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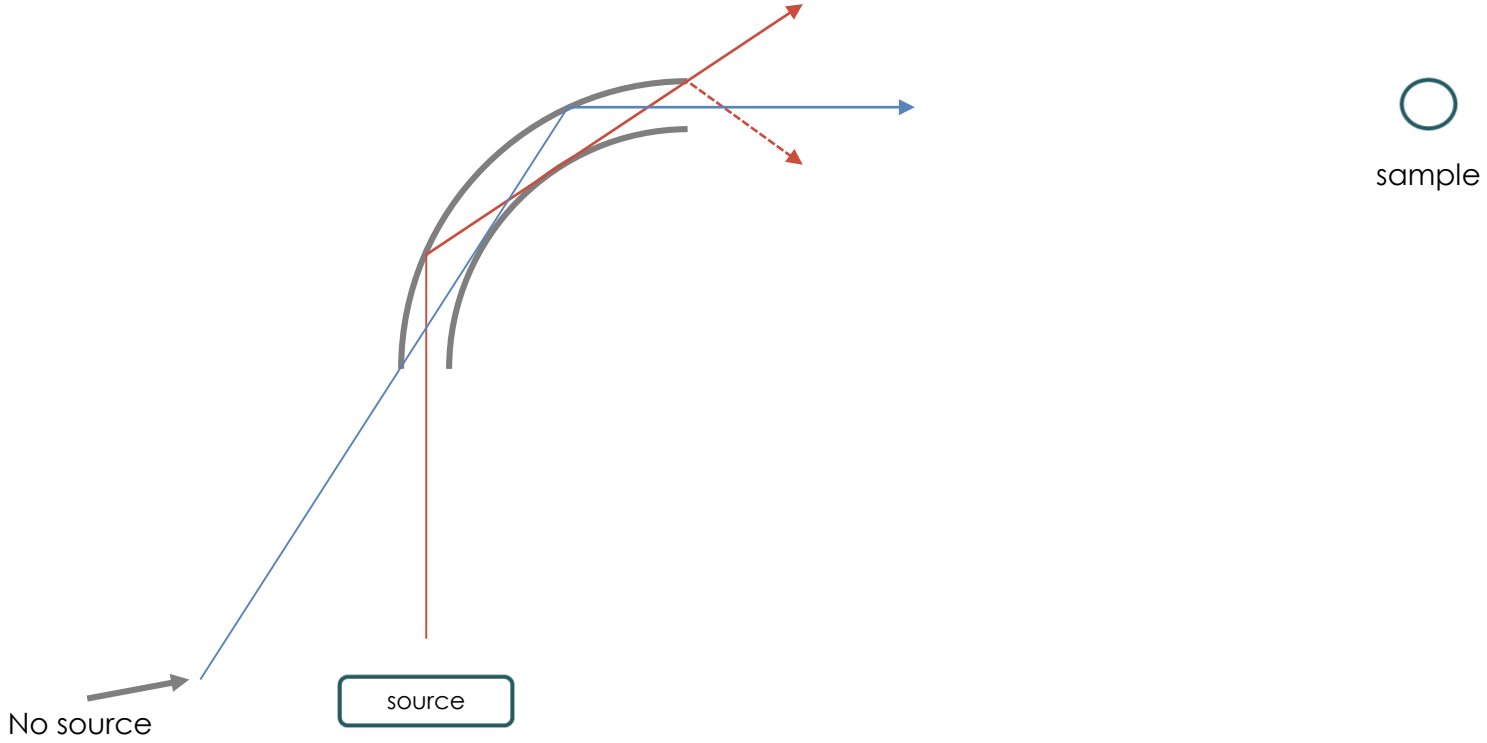
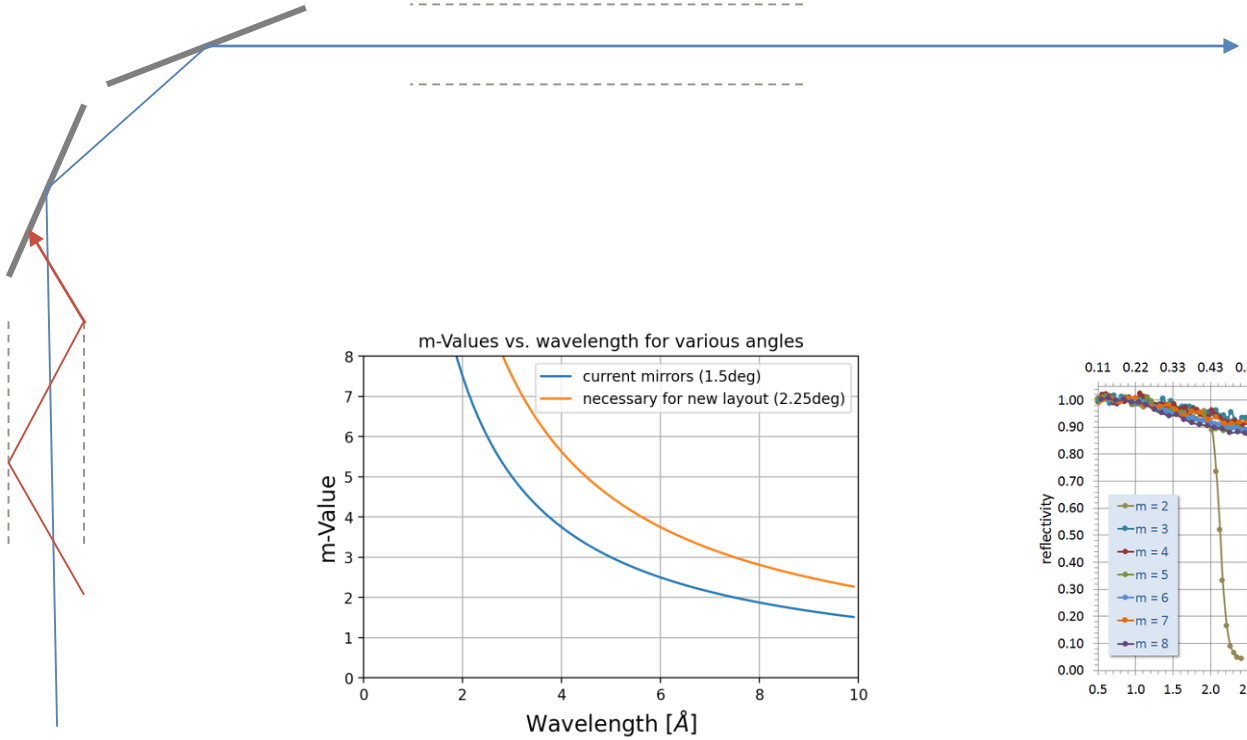
Underilluminated curved guide

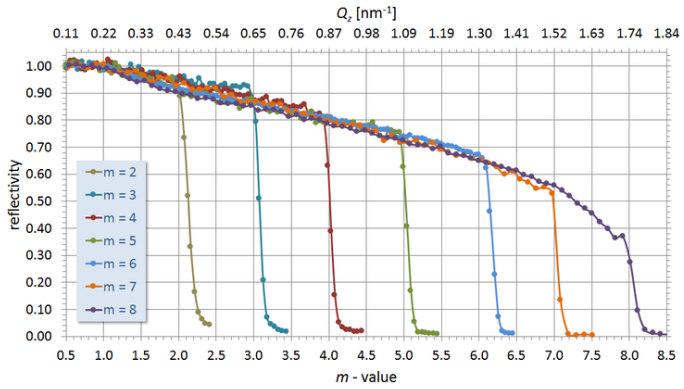
- Causes increase in divergence, loss of low divergence neutrons
- Distribution is parabola in phase space, width determined by max. reflection angle and curvature



Current design

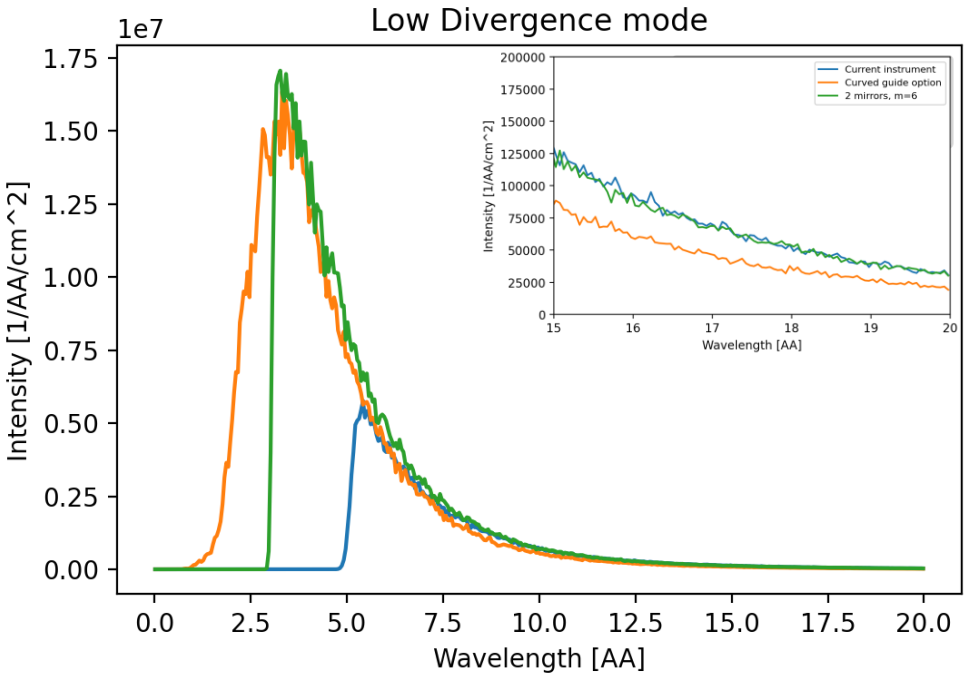
- Presumably optimized around center line (zero divergence)
- Steep angles on individual mirrors
  - wavelength cutoff (m=3 →~5Å for zero divergence neutrons)
  - Higher divergence neutrons will often not make it





Underilluminated curved guides
HFIR

- What goes in at low divergence doesn't necessarily exit as low divergence
- Phase space gets shuffled
- Underillumination means you might lose, especially low divergence neutrons
- If possible, consider flat mirrors



Other activities

- CNCS is interested in Nested Mirror Optics
  - Others have noticed
- Ellipsoidal Montel optics
- Spline guides