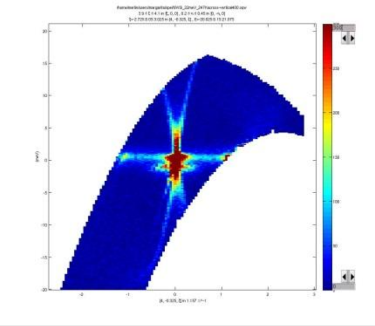
Background Optimization of the neutron TOF Spectrometer NEAT

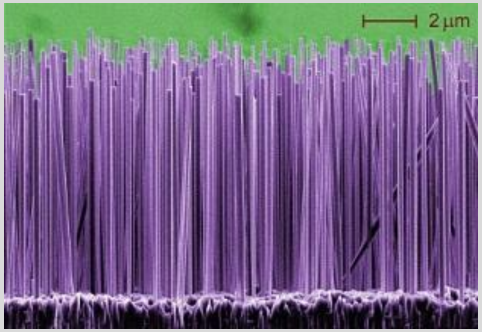
Gerrit Günther and Margarita Russina

Best suited to study the dynamics and structure at:

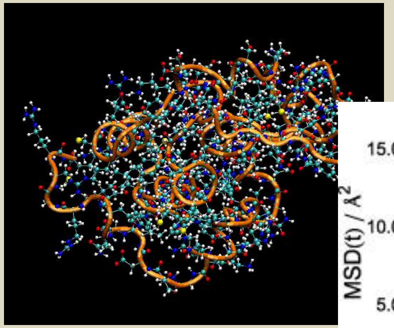
- Time domain: 10^{-13} s to 10^{-11} s
- Length scale: 0.5 A to 50 nm

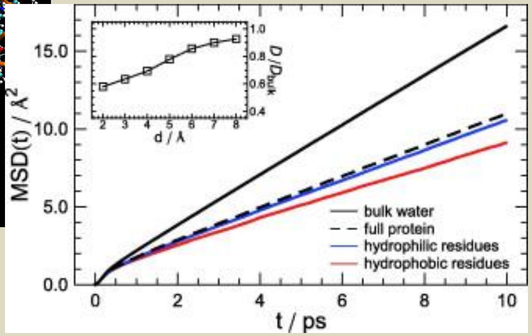
Excitations in novel nanostructured materials for energy





Dynamics in biosystems





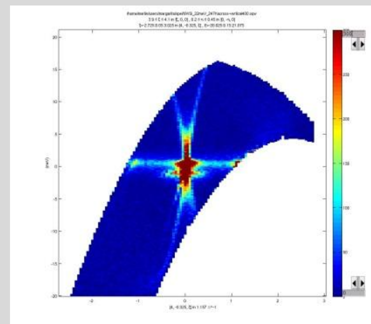
Best suited to study the dynamics and structure at:

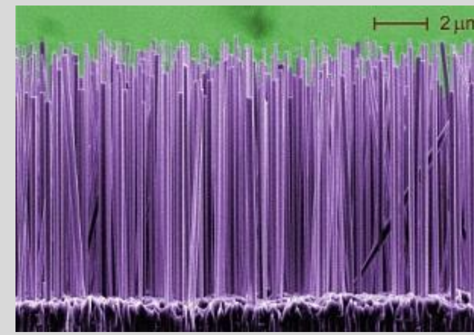
- Time domain: 10^{-13} s to 10^{-11} s
- Length scale: 0.5 A to 50 nm

Required:

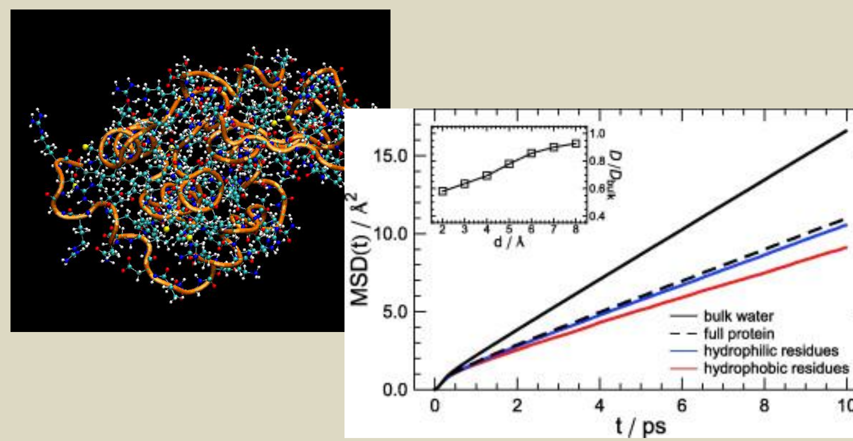
- INTENSITY
- LOW BACKGROUND
- Variable resolution
- Variable beam properties
  (size, homogeinity, divergence)
- Wide scope of sample environments

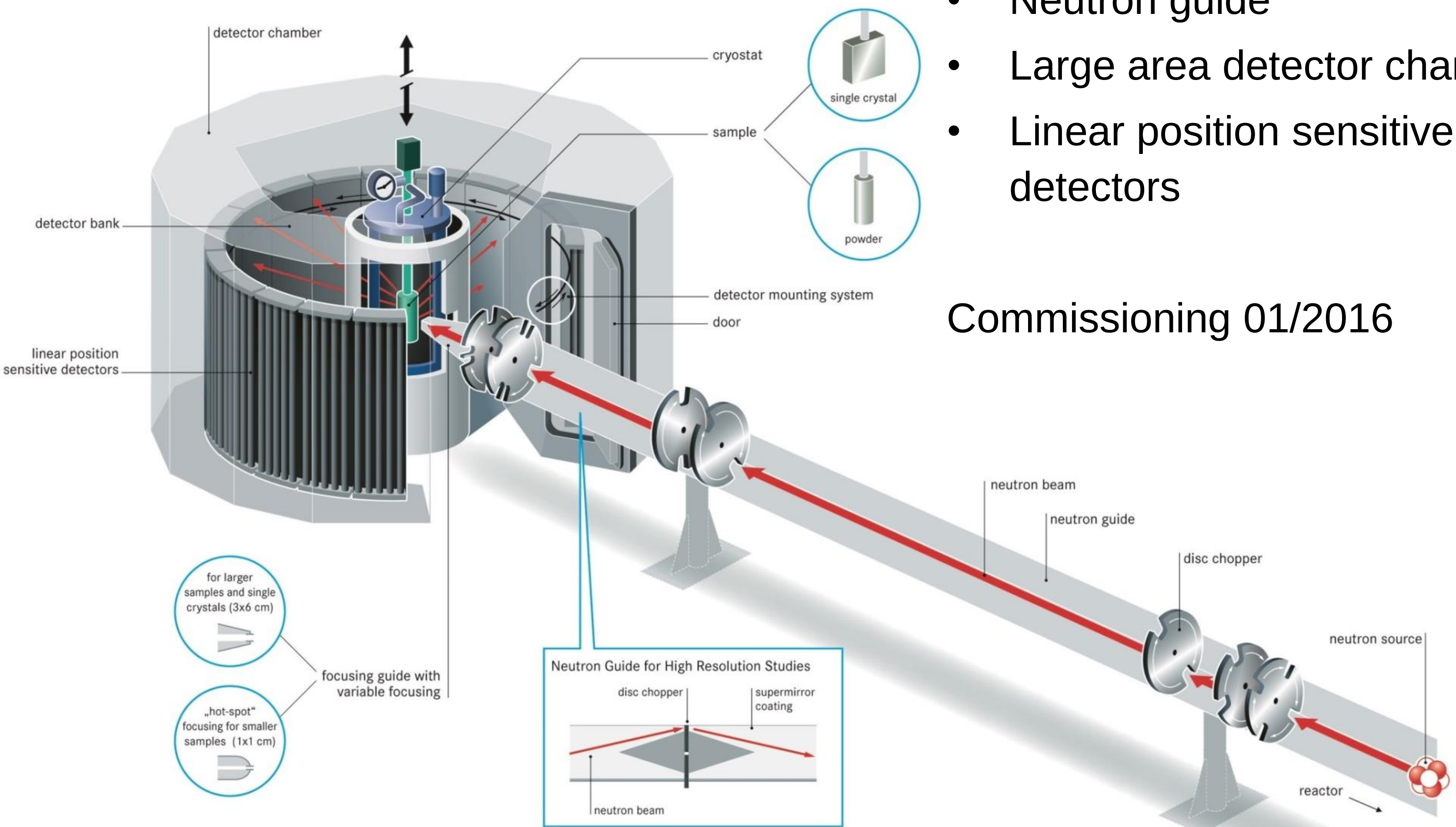
Excitations in novel nanostructured materials for energy





Dynamics in biosystems

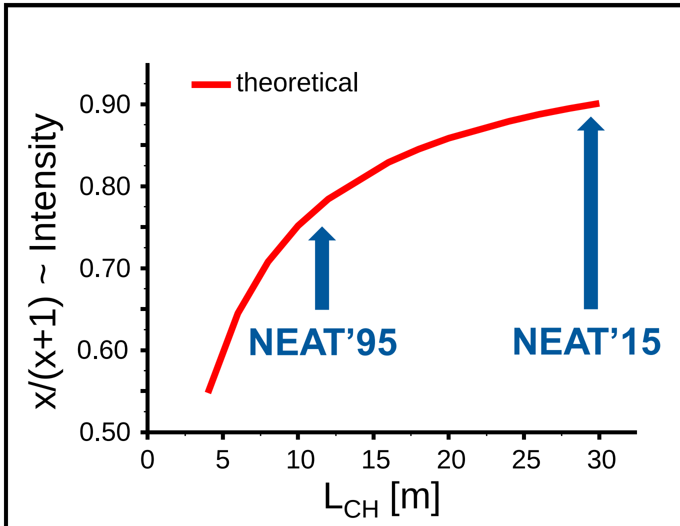




Upgrade comprises:

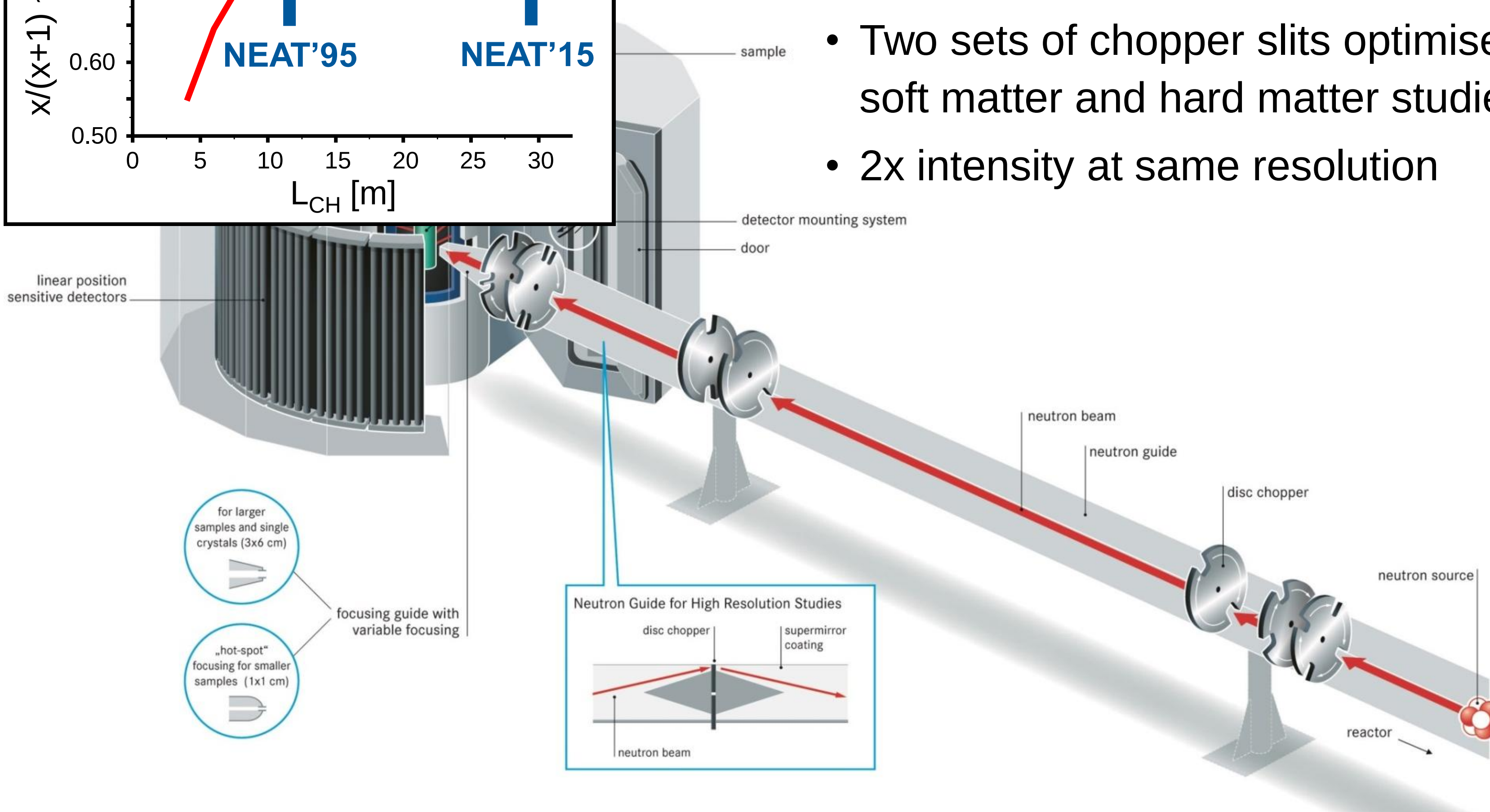
- Chopper system
- Neutron guide
- Large area detector chamber
- Linear position sensitive detectors

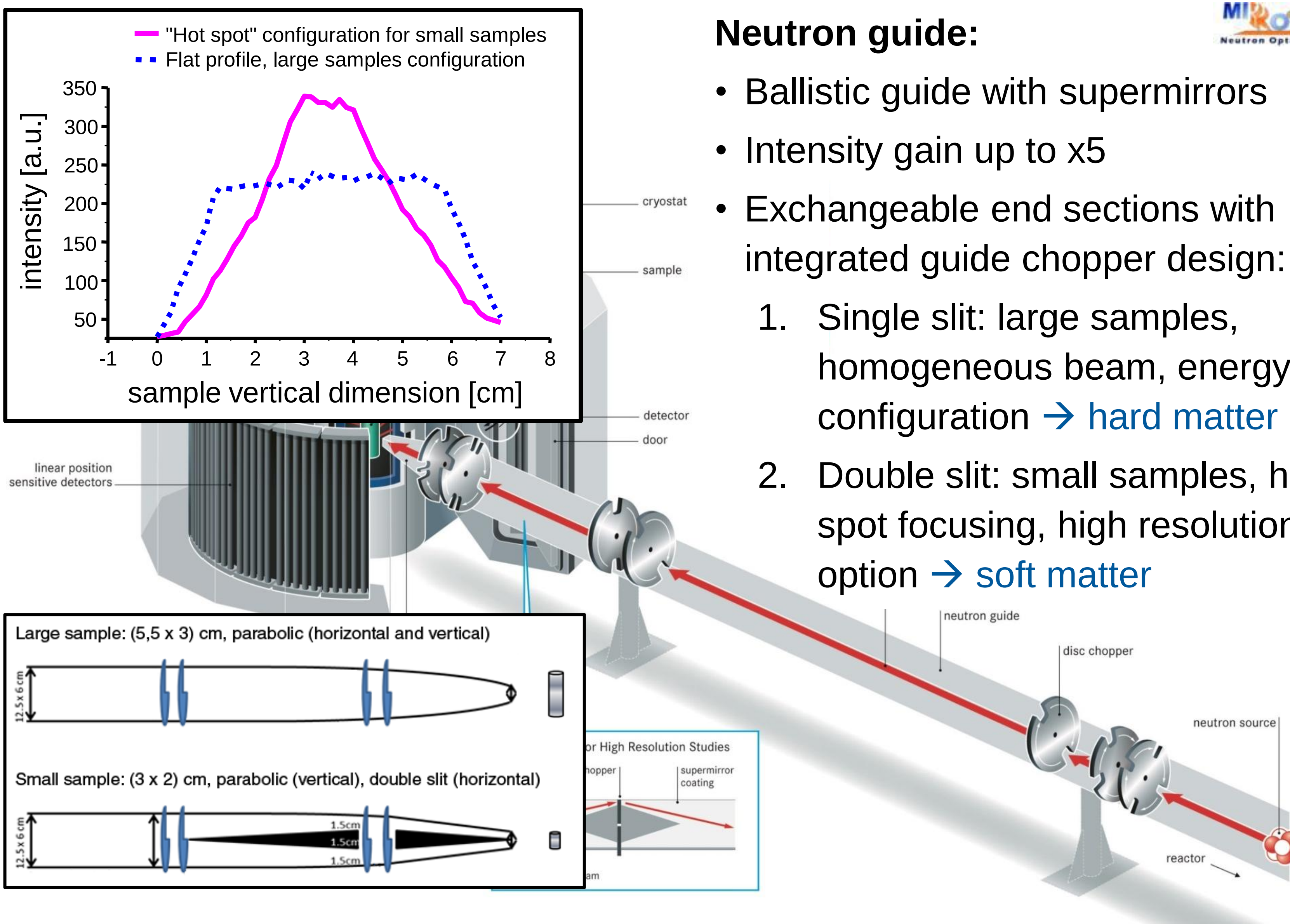
Commissioning 01/2016



Chopper System:

- 7 Choppers ranging over 30m
- Better matching chopper slits with trapezoidal pulse shape
- Two sets of chopper slits optimised for soft matter and hard matter studies
- 2x intensity at same resolution

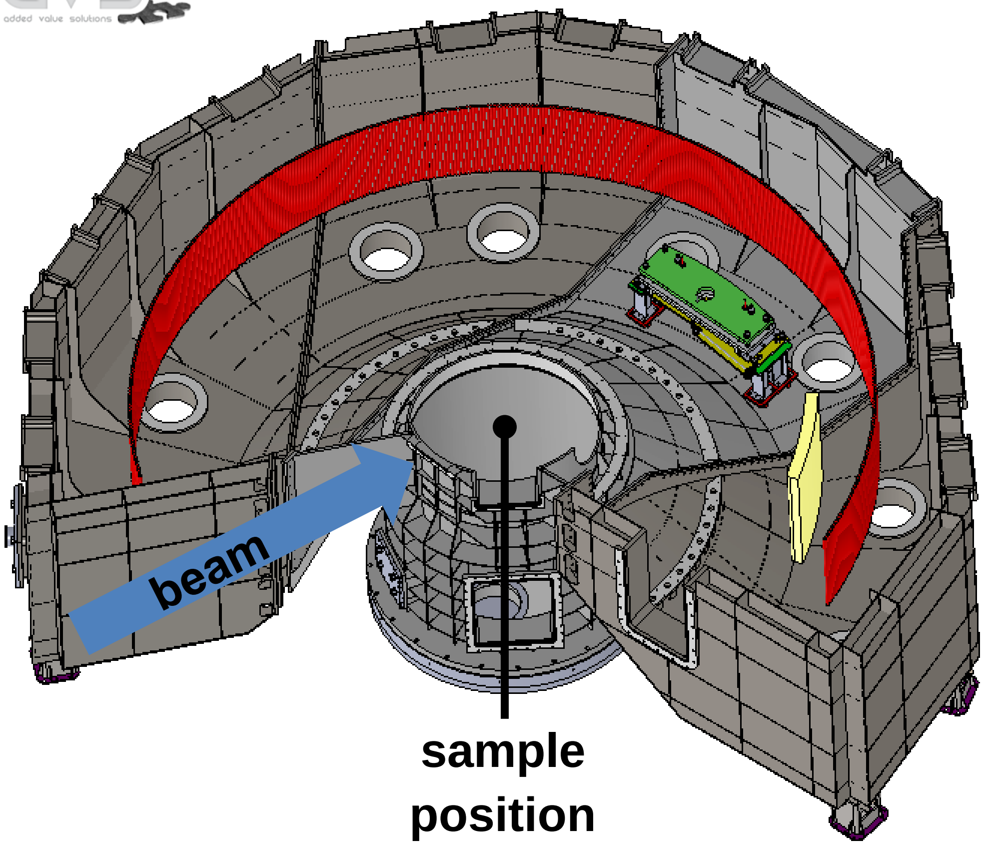




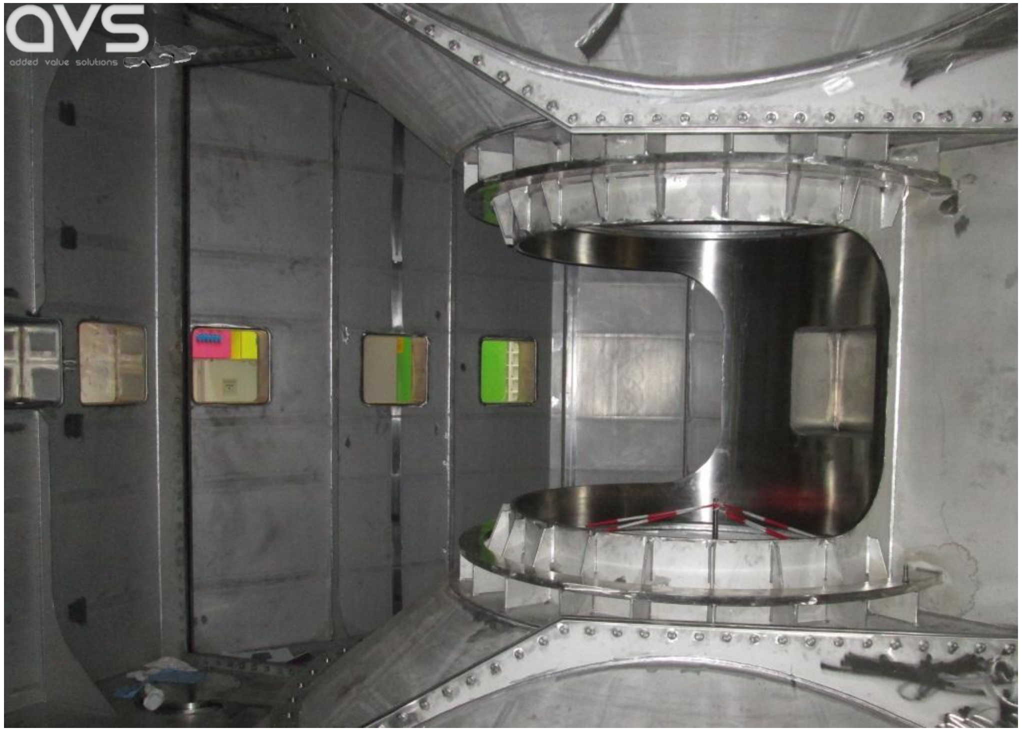
Neutron guide:

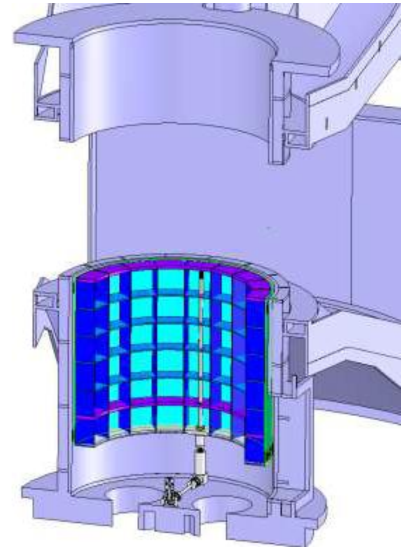
- Ballistic guide with supermirrors
- Intensity gain up to x5
- Exchangeable end sections with integrated guide chopper design:
  1. Single slit: large samples, homogeneous beam, energy loss configuration → hard matter
  2. Double slit: small samples, hot spot focusing, high resolution option → soft matter



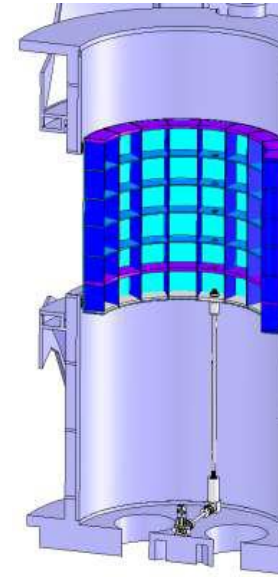



- Vacuum (10^{-4} mbar)
- 2m long PSD (He-3) at r = 3m
- total detection angle of 224° (= 142° + 82°)
- Intensity gain x5
- All vacuum vessels are mechanically decoupled from experiment



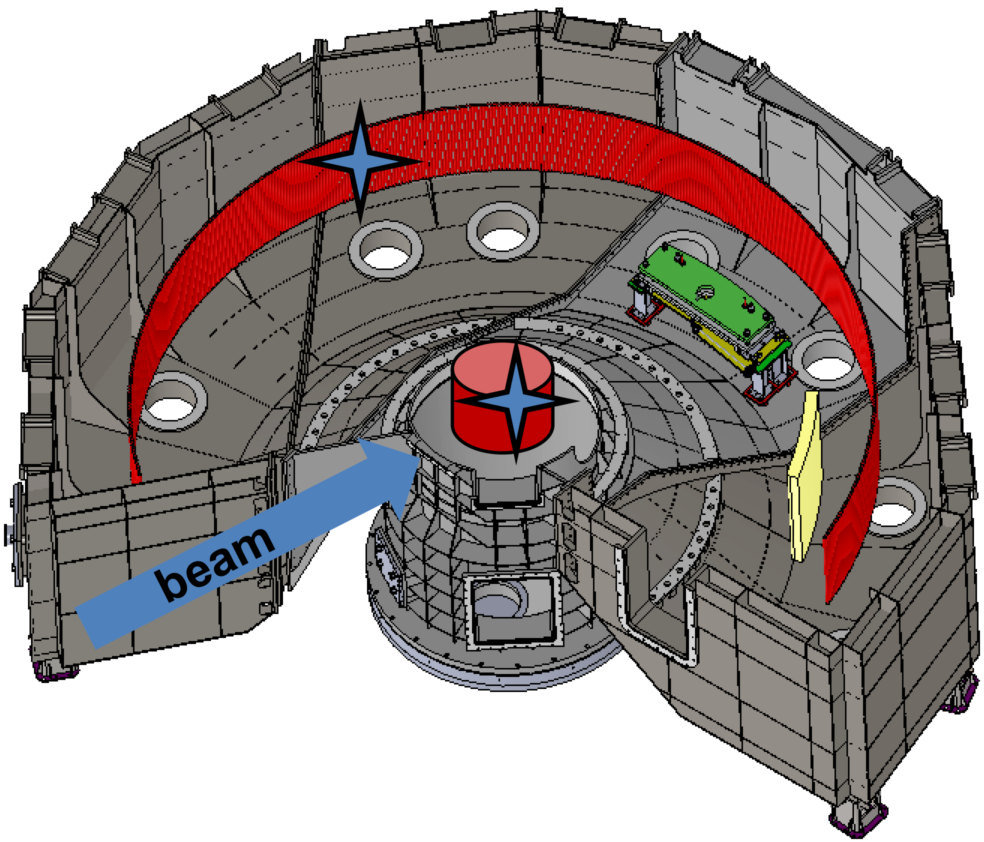


Open



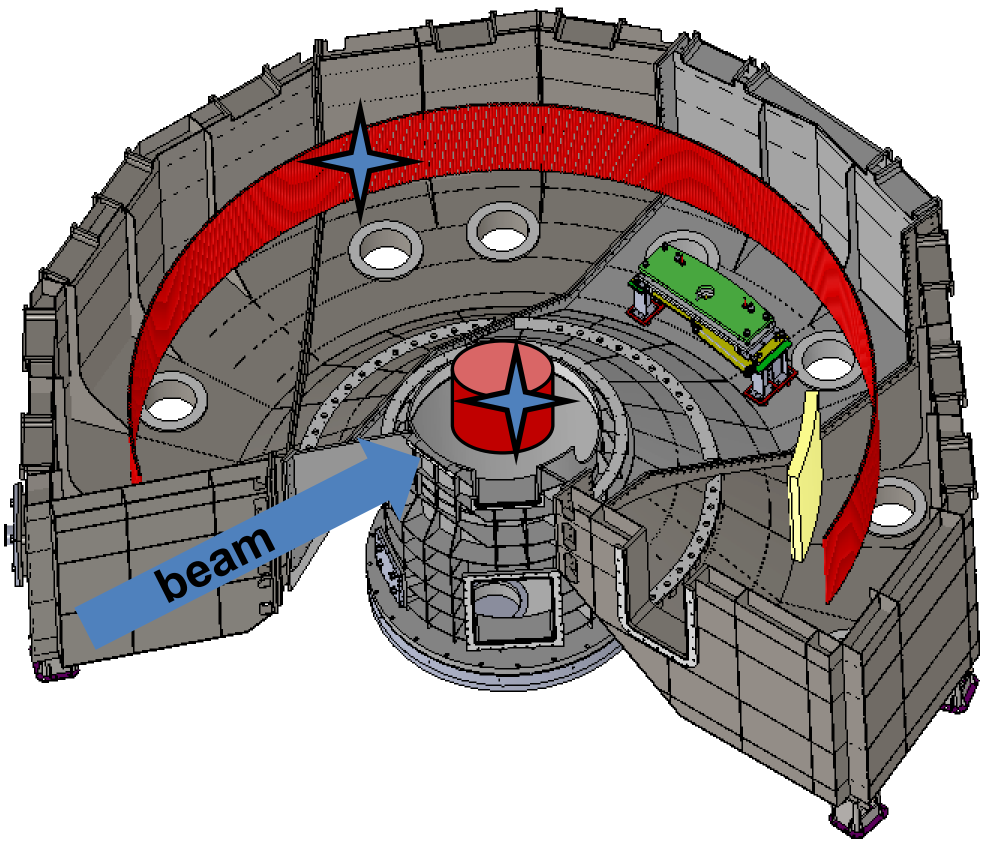
Closed

- Inner diameter of 1.5m, vacuum (10^{-4} mbar)
- Compatible with most sample environments at HZB
- Unperturbed secondary flight path
- Shutter to separate volumes of detector and sample chamber



2 sources of parasitic scattering:

- Sample environment
- Cross-talk of detectors



2 sources of parasitic scattering:

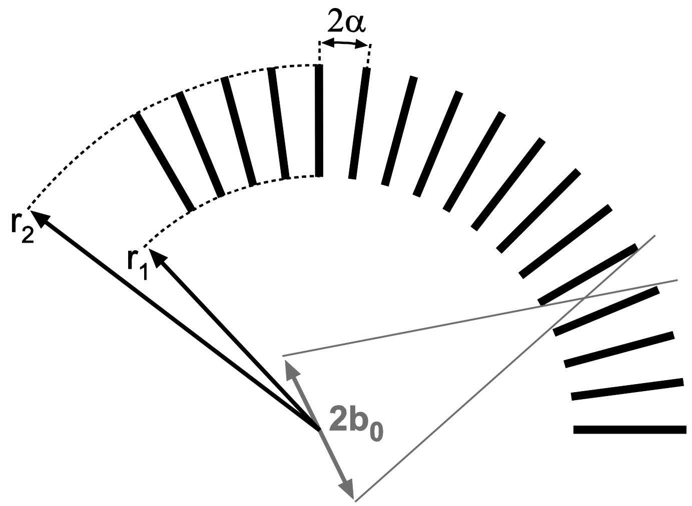
- Sample environment
  → Oscillating radial collimator
- Cross-talk of detectors
  → Detector shielding

Defined by 3 parameters:

1. Inner radius r_1
2. Outer Radius r_2
3. Repeat angle 2α

(4. Thickness of collimator vanes)

(Eurocollimators)



Defined by 3 parameters:
1. Inner radius r_1
2. Outer Radius r_2
3. Repeat angle 2α

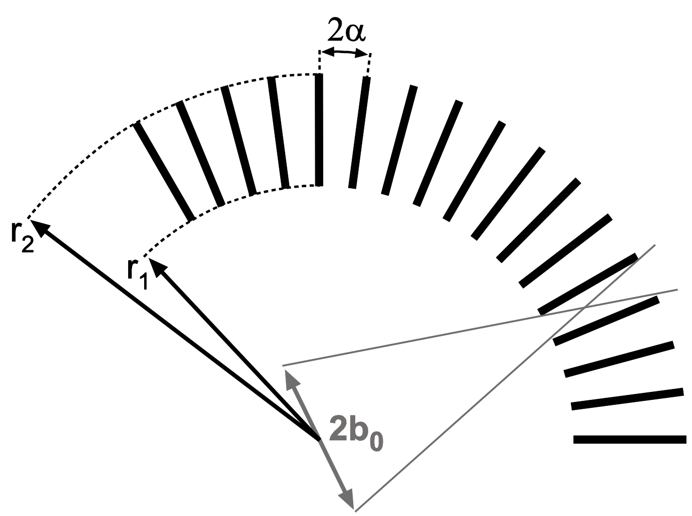
(4. Thickness of collimator vanes)

Restrictions:
1. r_1 must be larger than SE
2. r_2 must fit into sample chamber

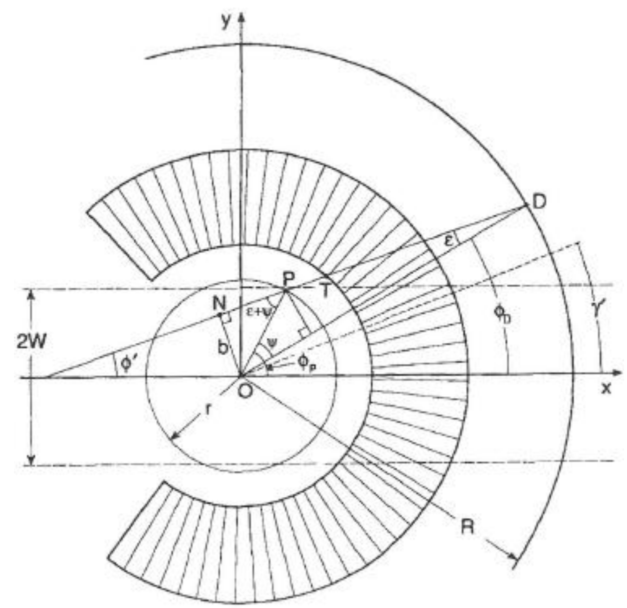
   → 411mm < r_1, r_2 < 578mm

Problem:
- Large number of possible collimators

(Eurocollimators)



(Eurocollimators)



2-dimensional geometric problem:

Copley et al. propose an analytical treatment

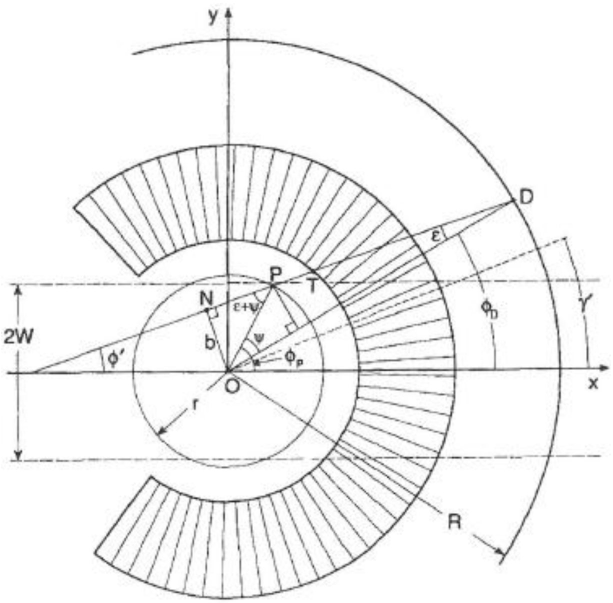
R.D. Copley and J.C. Cook. *Nucl. Instr. and Meth. in Phys. Res. A* (1994)

Oscillating Radial Collimator

Transmission: $$t = \frac{V_c}{V_{nc}}$$

Figure of merit: $$G = \frac{SNR_c}{SNR_{nc}}$$

(Eurocollimators)

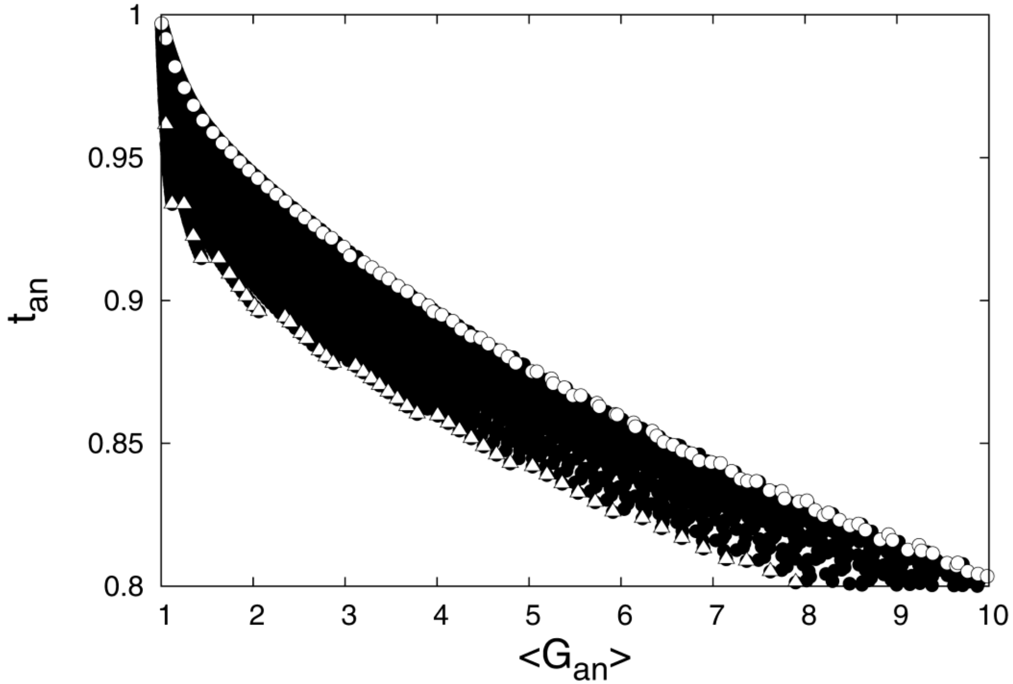


2-dimensional geometric problem:
Copley et al. propose an analytical treatment

R.D. Copley and J.C. Cook. *Nucl. Instr. and Meth. in Phys. Res. A* (1994)

Transmission: $t = \frac{V_c}{V_{nc}}$

Figure of merit: $G = \frac{SNR_c}{SNR_{nc}}$



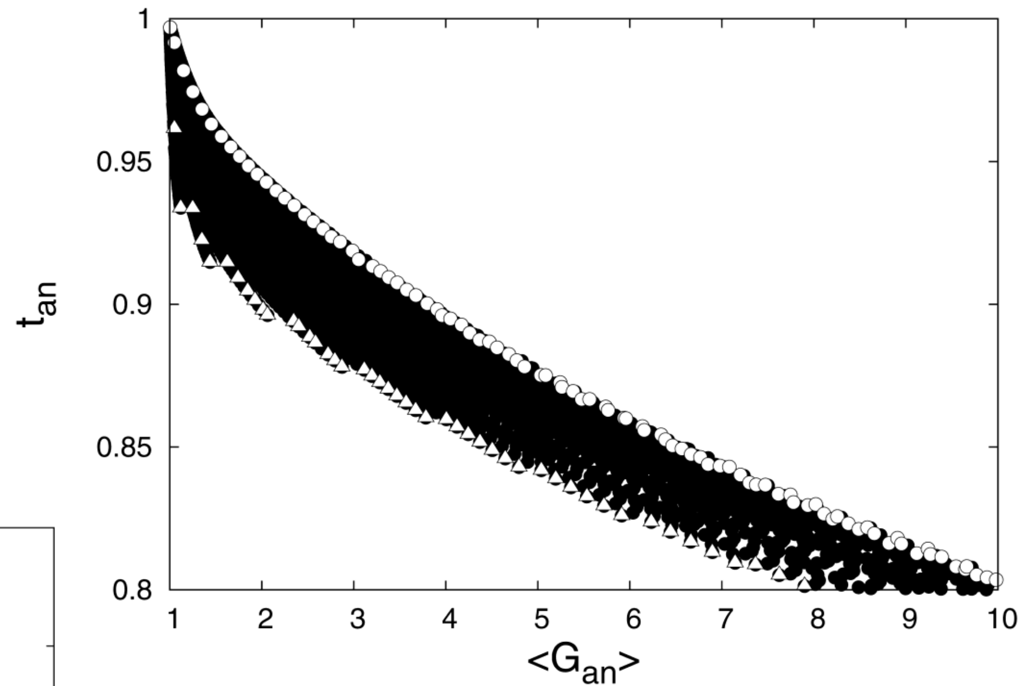
411mm < $r_{1,2}$ < 578 mm, 0.4 < 2α < 5.0

We can distinguish:

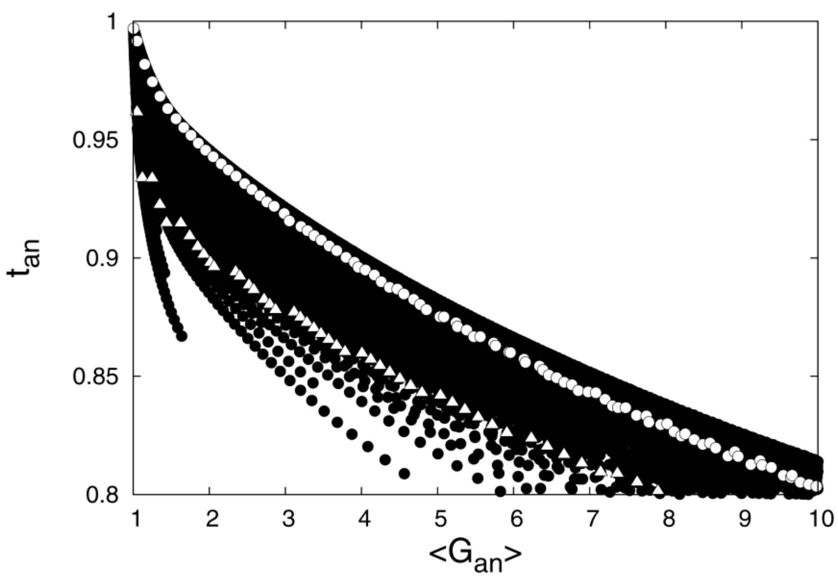
- High-t collimator (○)
- Low-t collimator (△)

Transmission: $t = \frac{V_c}{V_{nc}}$

Figure of merit: $G = \frac{SNR_c}{SNR_{nc}}$



$\underline{411mm} < r_{1,2} < 578$ mm, $0.4 < 2\alpha < 5.0$

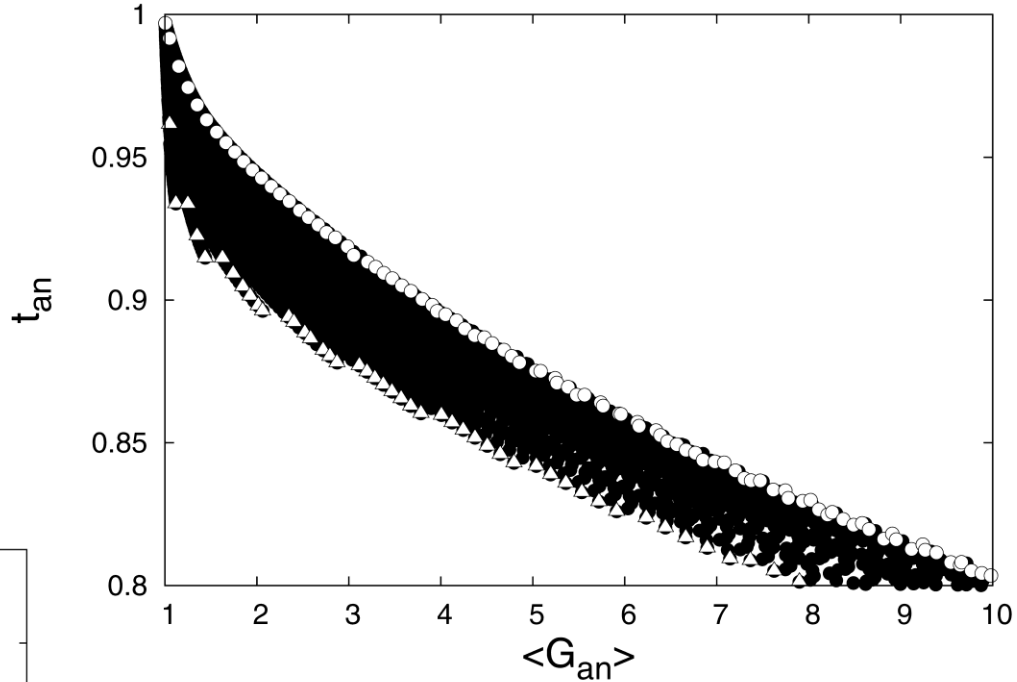


$\underline{235mm} < r_{1,2} < 578$ mm, $0.4 < 2\alpha < 5.0$

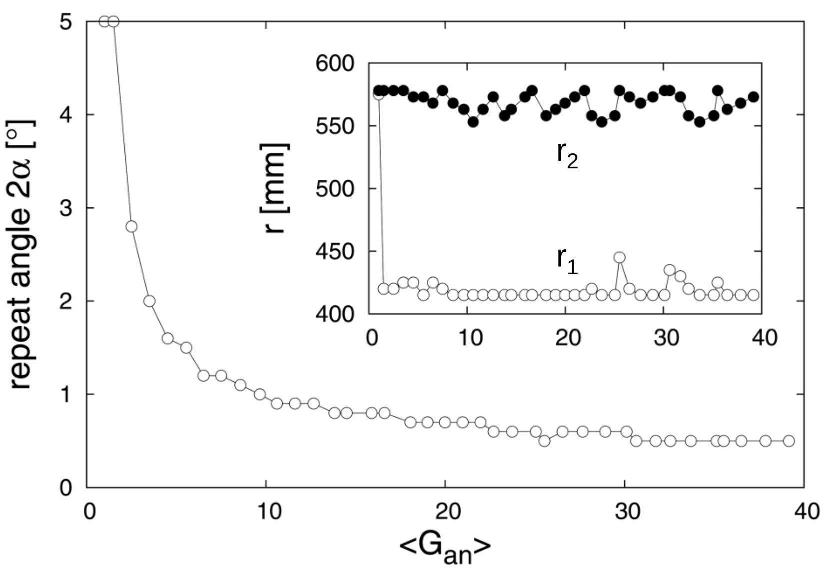
Spread of t depends on parameter space

Transmission: $t = \frac{V_c}{V_{nc}}$

Figure of merit: $G = \frac{SNR_c}{SNR_{nc}}$



411mm < $r_{1,2}$ < 578 mm, 0.4 < 2α < 5.0

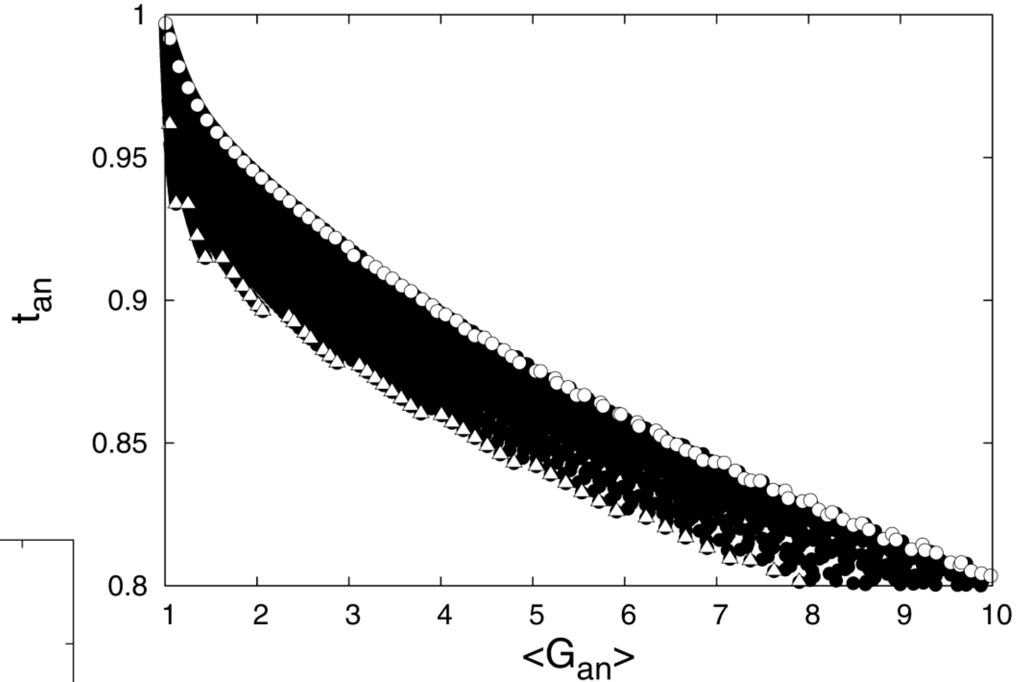


Design of high-t collimators:

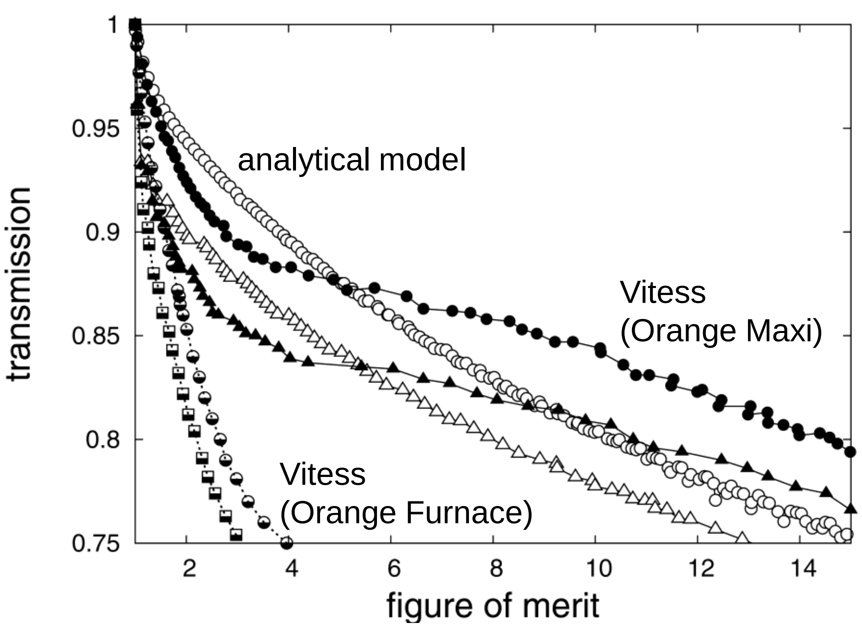
- Longest blades possible
- Repeat angle to adjust focus

Transmission: $t = \frac{V_c}{V_{nc}}$

Figure of merit: $G = \frac{SNR_c}{SNR_{nc}}$



411mm < $r_{1,2}$ < 578 mm, 0.4 < 2α < 5.0



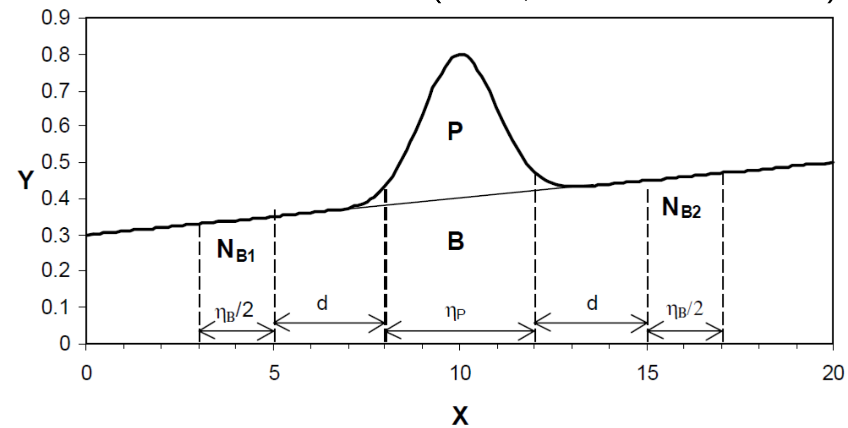
Vitess gives similar results

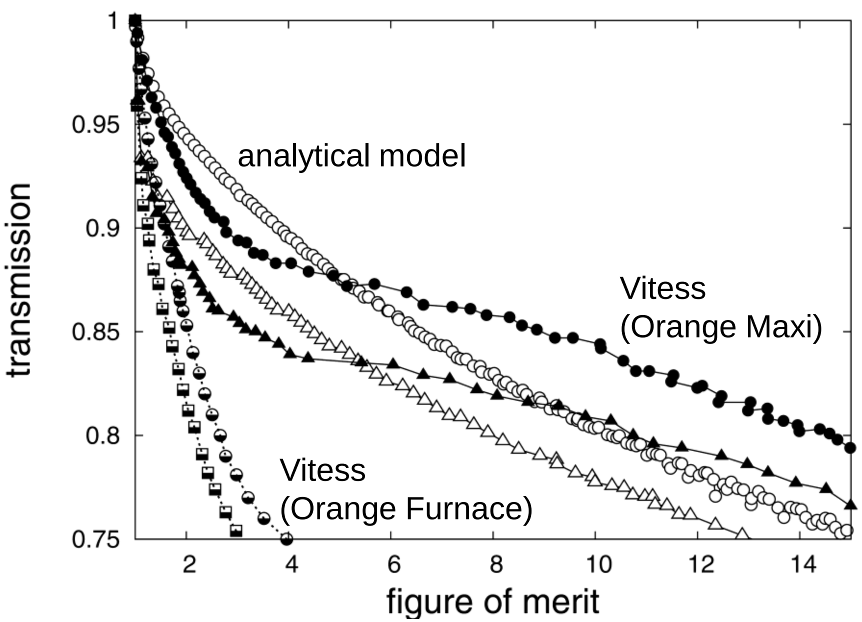
Transmission: $t = \frac{V_c}{V_{nc}}$

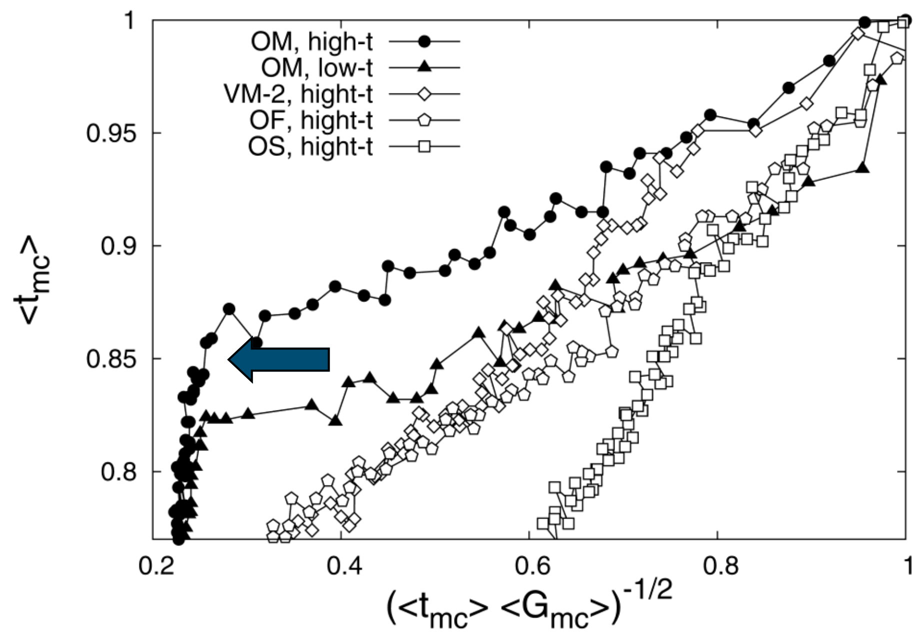
Figure of merit: $G = \frac{SNR_c}{SNR_{nc}}$

Detection limit: $C_{DL} = \left(\frac{I_{sample}^2}{I_{noise}}\right)^{-1/2}$

(AN59, www.ortec-online.de)





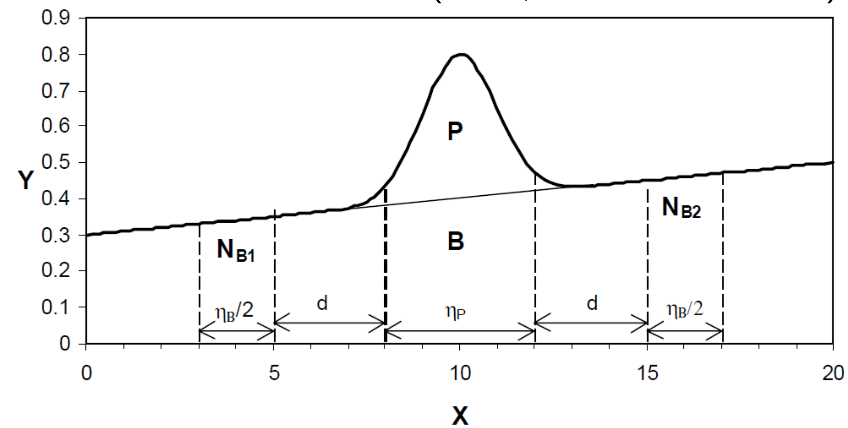


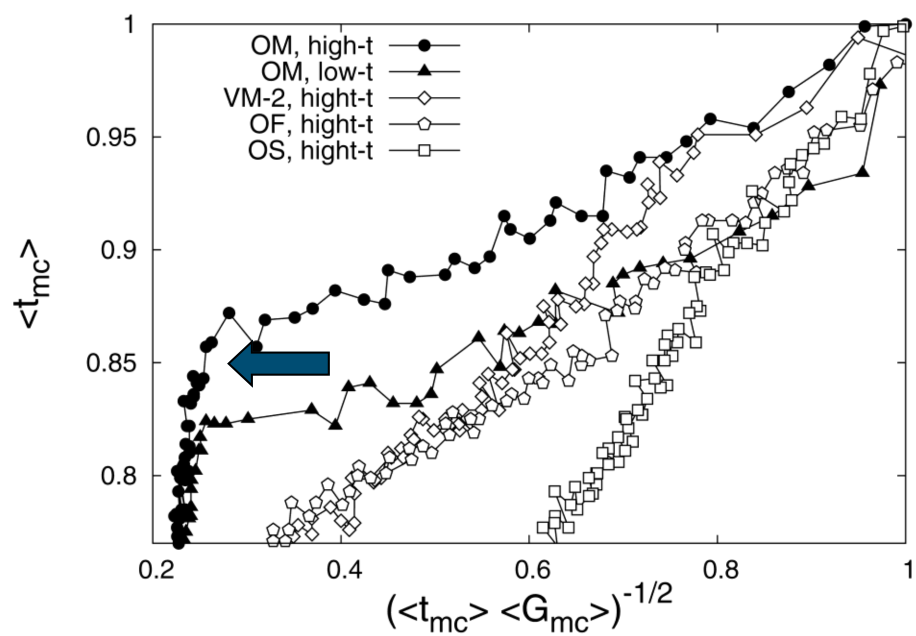
Transmission: $t = \frac{V_c}{V_{nc}}$

Figure of merit: $G = \frac{SNR_c}{SNR_{nc}}$

Detection limit: $C_{DL} = \left(\frac{I^2_{sample}}{I_{noise}}\right)^{-1/2}$

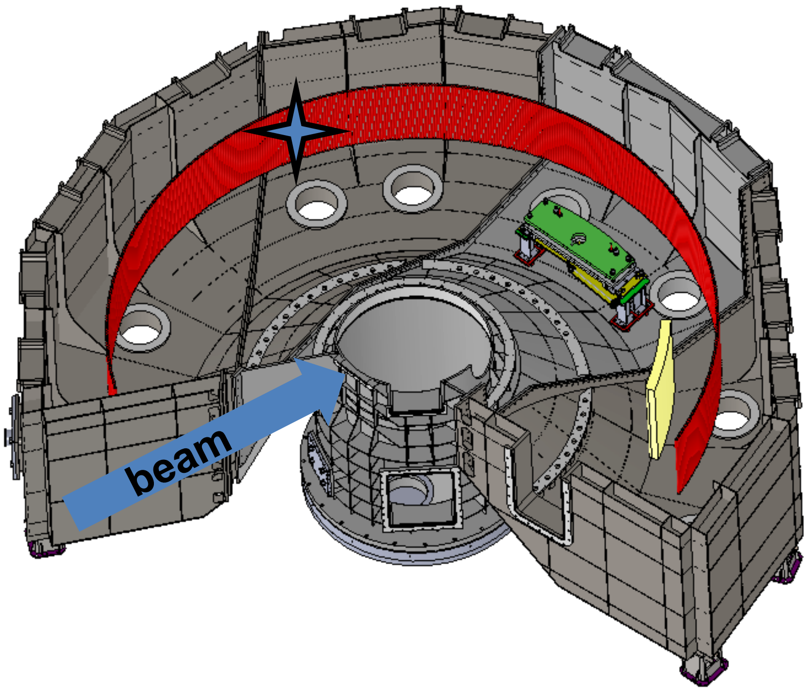
(AN59, www.ortec-online.de)





Optimised oscillating radial collimator:

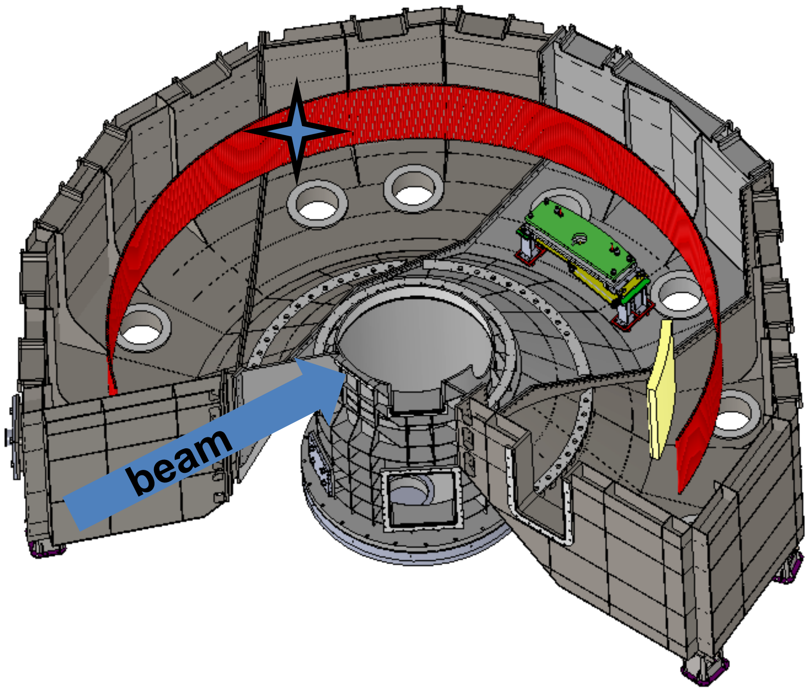
- r_1= 411mm, r_2 = 578mm, 2α = 1.6°
- T ≈ 0.85, G_{OM} ≈ 10.0

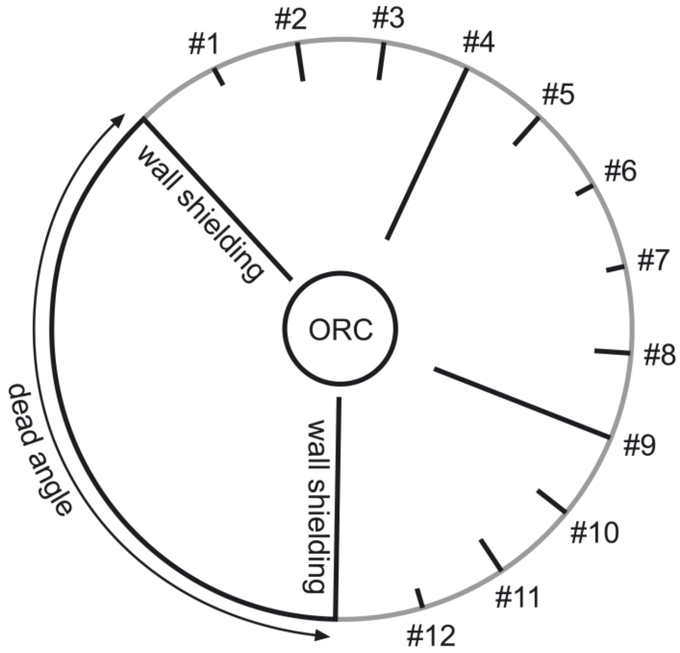


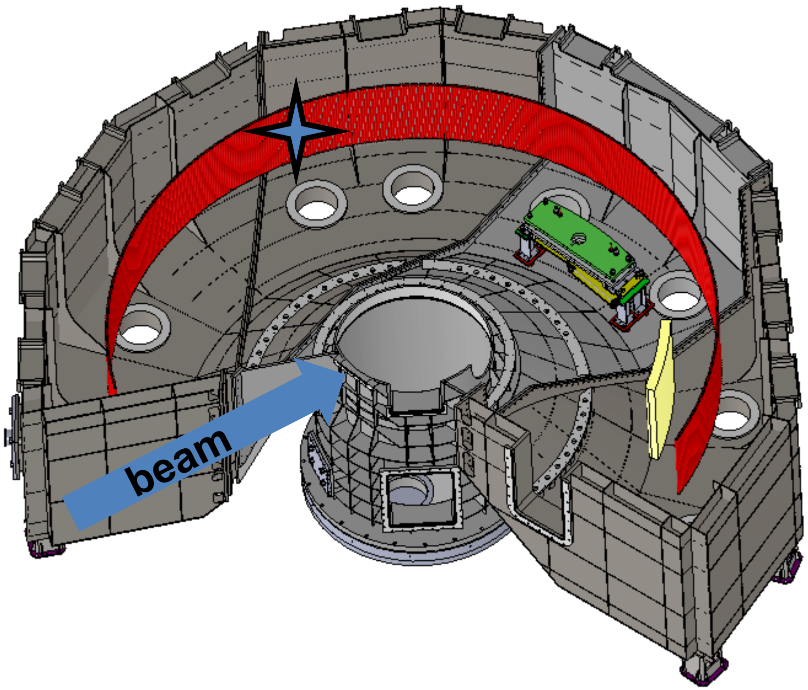
module shields

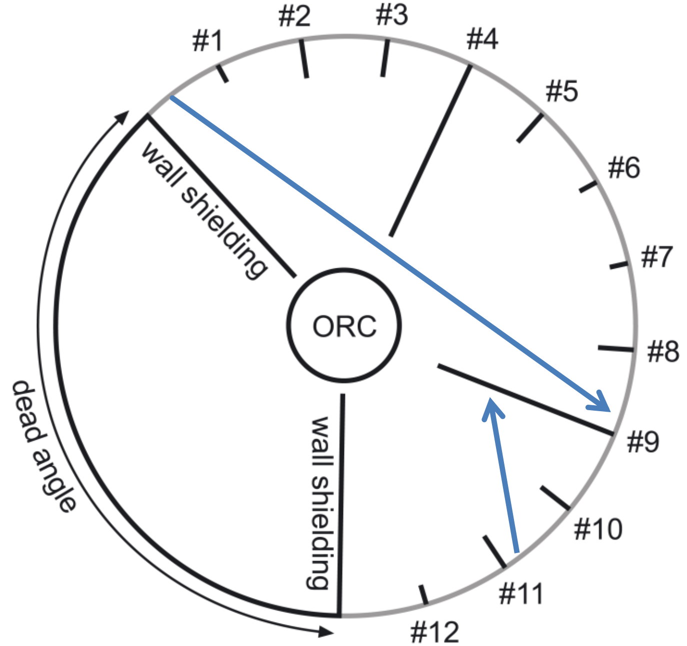
vs.

detector shields


beam

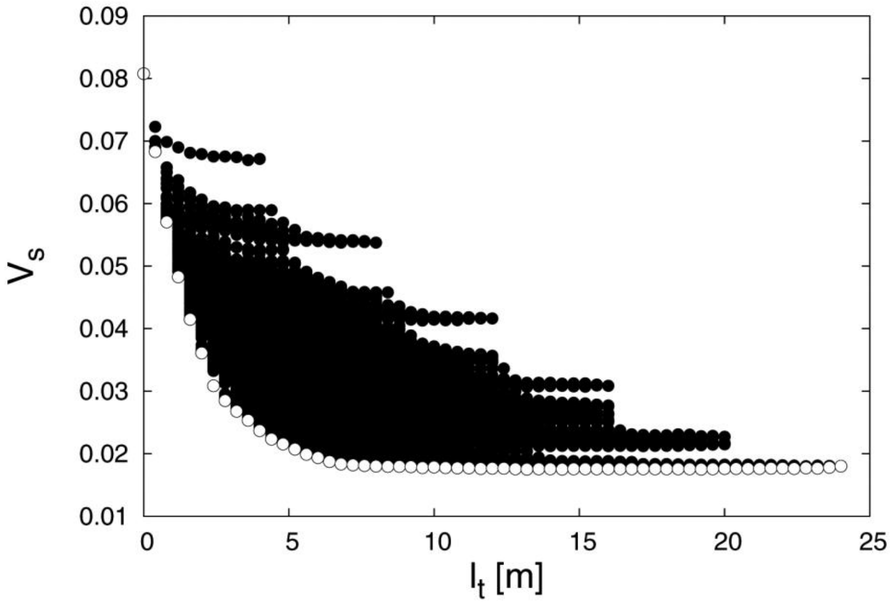

#1
#2
#3
#4
#5
#6
#7
#8
#9
#10
#11
#12
wall shielding
wall shielding
ORC
dead angle

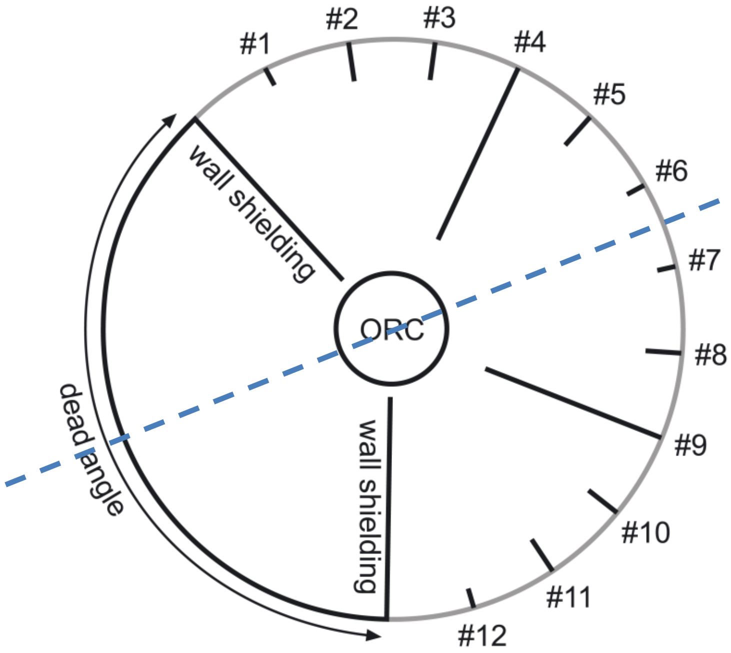




Algorithm:

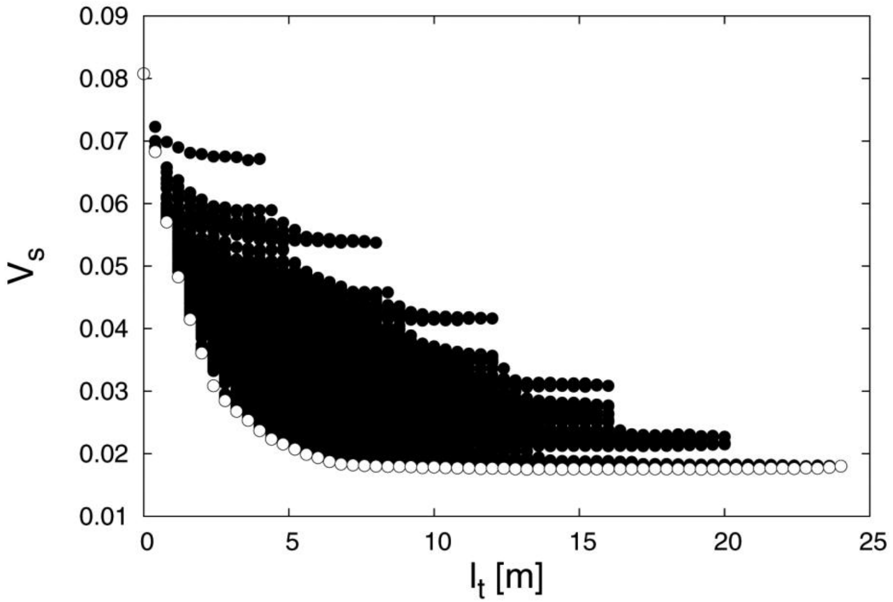
- Create random 3d trajectories at detection area
- Compute ratio of detected to created trajectories $V_s = I_d / I_c$

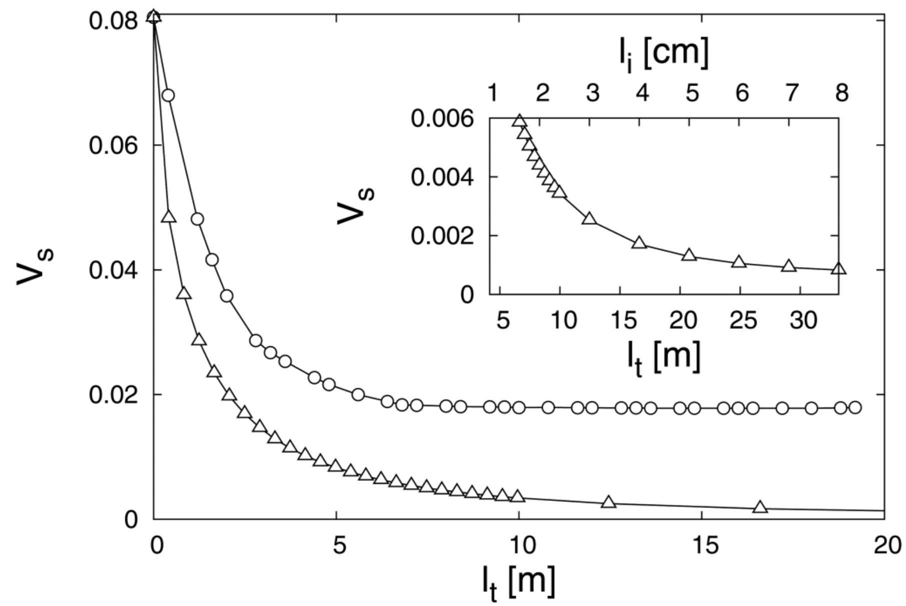




12 module shields (○,●):

- Length: 0cm < l_i< 200cm with Δl_i=20cm
- 11^6 symmetric configurations



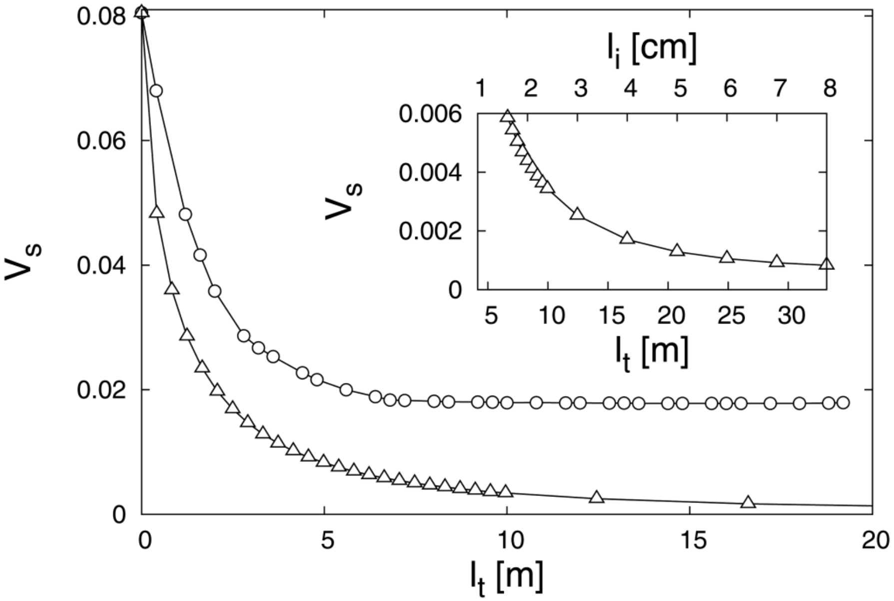


12 module shields (○,●):

- Length: 0cm < l_i< 200cm with Δl_i=20cm
- 11^6 symmetric configurations

415 detector shields (△):

- Length: 0cm < l_i< 10cm
- All shields share same length



415 detector shields (△):

- Length: 6cm
- Reduces cross-talk to 1/80

Summary

NEAT Upgrade:

- Intensity gain of x30 up to x100
- Optimised for soft and hard matter studies
- Commissioning in january 2016

Background suppression:

- Equivalent radial collimators differ in transmission
- Optimised radial collimator by applying 3 selection criteria (t, G, C_{DL})
- Detector shields of 6 cm length between single tubes

NEAT team: Margarita Russina, Lars Drescher, Bernd Urban, Ramil Gainov