Concept for LOkI detector system

A. Muraro[1],G. Croci[1,2,3], G. Grosso[1], E. Perelli Cippo[1], F. Murtas[4], M. Rebai[2,4], M. Tardocchi[1], C. Höglund[5,6], L. Hultman[6], J. Birch[6], S. Schmidt[6], L. Robinson[6], R. Hall-Wilton[6,7], D.Raspino[8], N. Rodhes[8] , E. Shooneveld[8] and G. Gorini[3,4]

[1]*Istituto di Fisica del Plasma (IFP-CNR) – Via Cozzi 53, 20125 Milano, Italy*
[2]*INFN – Sez. Di Milano-Bicocca – Piazza della Scienza 3, 20126 Milano, Italy*
[3]*Dipartimento di Fisica, Università degli Studi di Milano-Bicocca – Piazza della Scienza 3, 20126 Milano, Italy*
[4]*INFN – Laboratori Nazionali di Frascati –Via Fermi 40, 0044 Frascati, Italy*
[5]*European Spallation Source ESS AB, P.O. Box 176, SE-221 00 Lund, Sweden*
[6]*Department of Physics, Chemistry and Biology (IFM), Thin Film Physics Division, Linköping University, SE-581 83 Linköping, Sweden*
[7]*Mid-Sweden University, SE-851 70 Sundsvall, Sweden*
[8]*IFE: [8]STFC-RAL, ISIS facility, Didcot, Uk*

Method used

Some simple calculations on the resolution were performed using the equations reported in [1]. The case of interesting for LoKI reported in [1] is the case of rectangular apertures. In this case the standard deviation in vector **Q**, σ_Q is given by

$$(\sigma_Q)^2 = \frac{k^2}{12}\left[\frac{x_1^2+y_1^2}{L_1^2} + \frac{x_2^2+y_2^2}{L'^2} + \frac{x_3^2+y_3^2}{L_2^2} + \frac{R^2}{L_2^2}\left(\frac{\Delta\lambda}{\lambda}\right)^2\right]$$

A **B** **C** **D**

Where:

x1 and y1 are the dimensions of the source aperture

x2 and y2 are the dimensions of the sample aperture

x3 and y3 are the dimensions of the detection element

ΔR is the radial bin width

Δλ is the FWHM of the wavelength distribution

L1 is the distance between source and sample apertures

L2 is the distance between the sample aperture and the detector

R is the radial distance of a given detector element from the direct beam path

$1/L' = 1/L_1 + 1/L_2$

$$\frac{\sigma_{Q(L2,R)}}{Q} = \frac{\sqrt{\frac{k^2}{12}(A+B+C+D)}}{Q}$$

$$k = \frac{2\pi}{\lambda} \; and \; Q = k \cdot \frac{R}{\sqrt{{L_2}^2+R^2}}$$

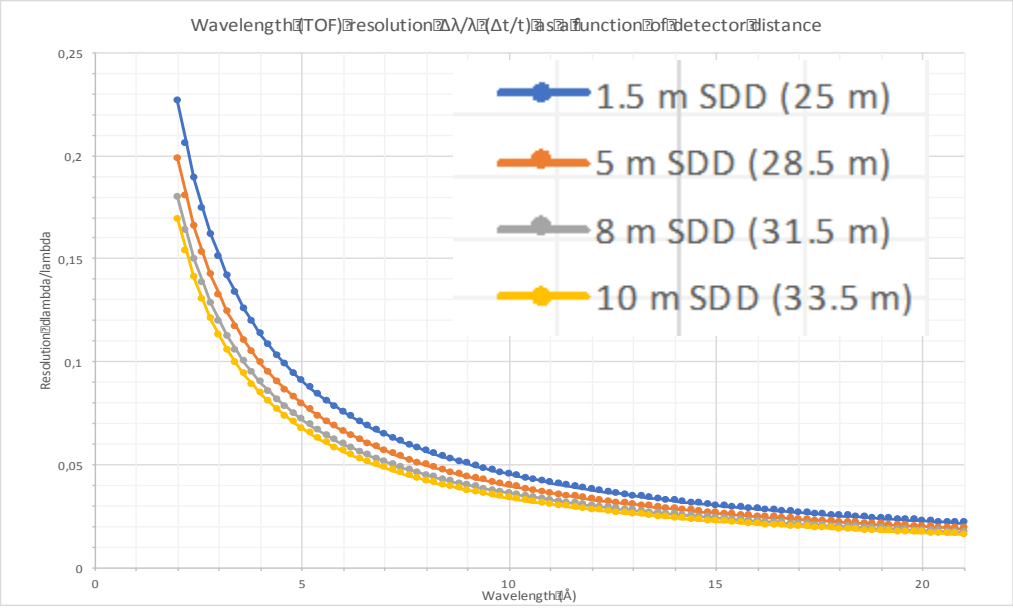
Strictly valid only for small angles, it can be considered as an upper limit for higher angles

[1] Mildner, D. F. R., & Carpenter, J. M. (1984). Optimization of the Experimental Resolution for Small-Angle Scattering. *Journal of Applied Crystallography*, *17*(AUG), 249–256

Meaning of the parameters

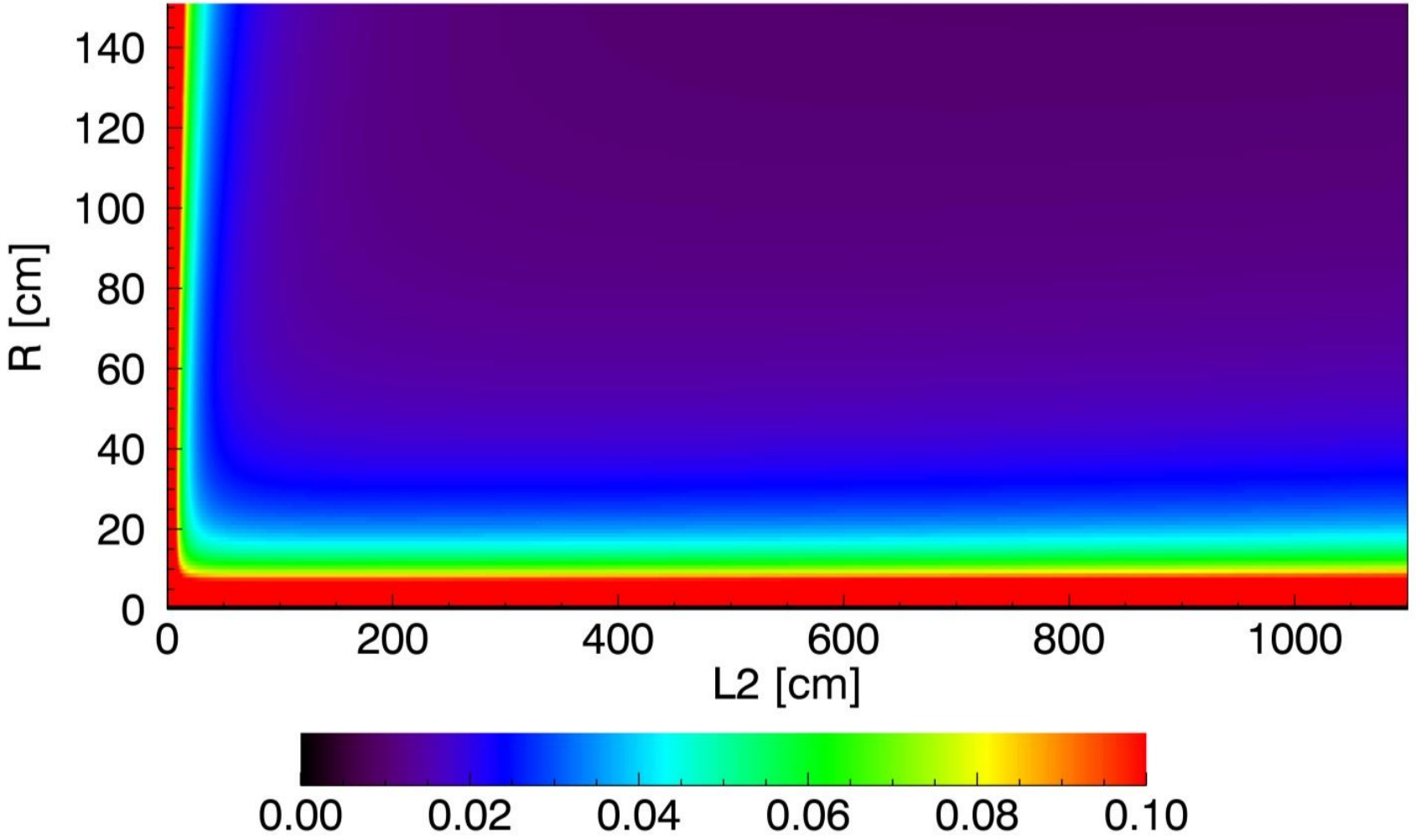
- Parameter A is related to the geometry of the source aperture. The worst case is the smallest source aperture, that is 5x5 mm^2.
- Parameter B is related to the geometry of the sample aperture. The worst case is the smallest sample aperture, that is 2.5x2.5 mm^2.
- Parameter C is related to the solid angle subtended by the detection element (pixel size). x3 and y3 are the dimensions of the detection element and these are the parameter that must be optimized.

Parameter D is related to the wavelength divergence. It is due to the long pulse nature of the ESS source.



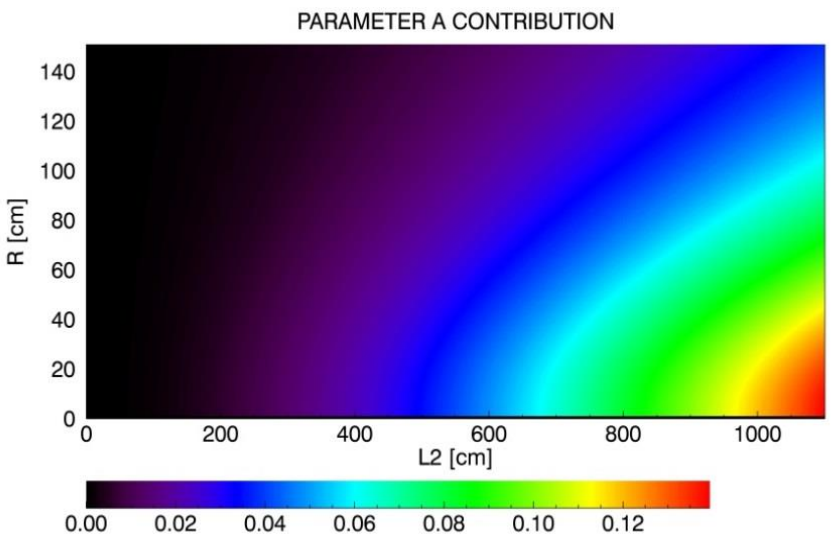
Reference case: L_1 = 8 m; x_1=y_1=5 mm ; x_2=y_2= 2.5mm, λ=12 Å;Pad=16x16mm^2

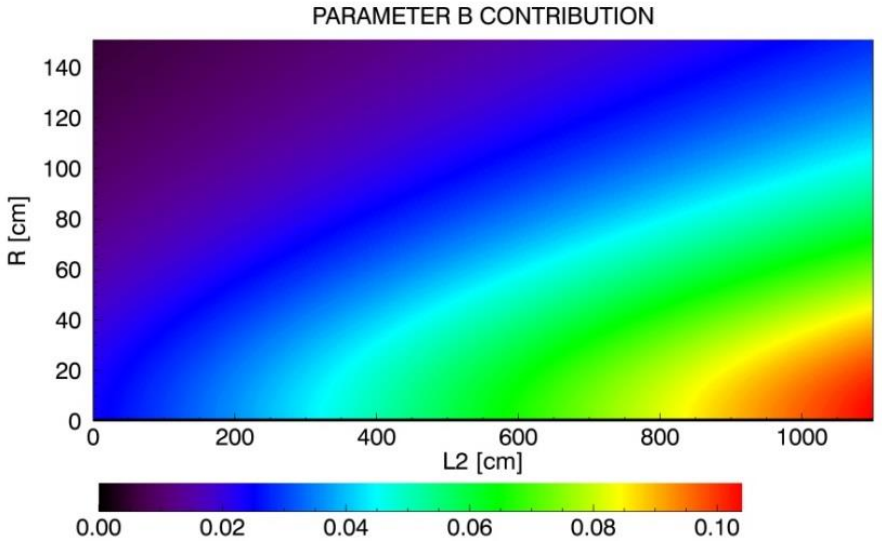
The colors represent the absolute value of (σ_Q/Q)



Term A and Term B analysis for L_1 = 8 m; x_1=y_1=5 mm ; x_2=y_2= 2.5mm, λ=12 Å Pad=16x16mm^2

The colors represent the relative contribution of the various terms to the (σ_Q/Q)



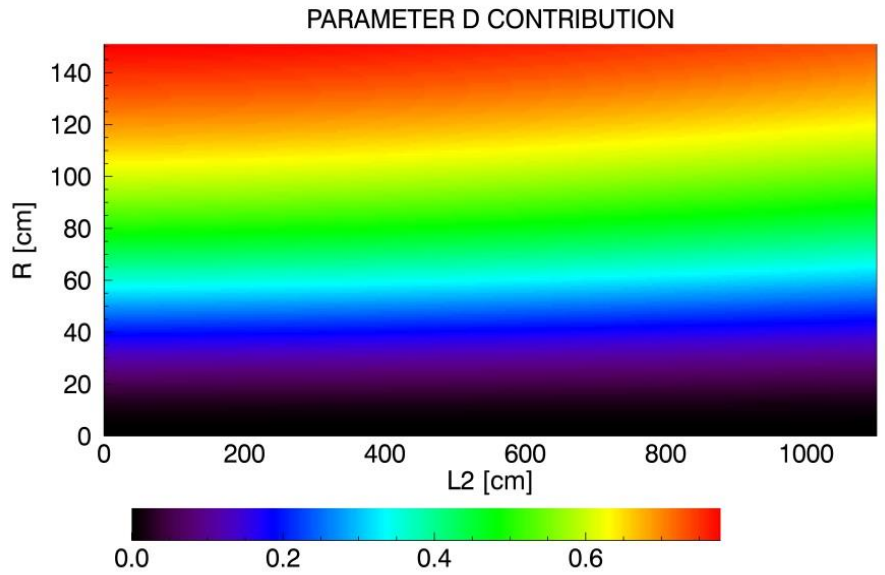


Term A (Source aperture) and term B (Sample aperture) become important for very low Q and high L2

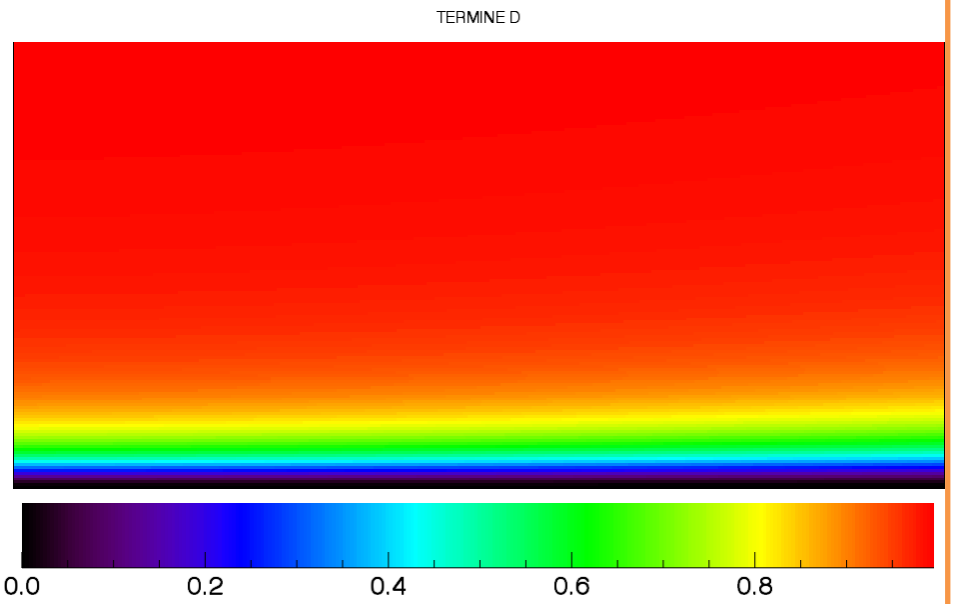
Term D analysis for L_1 = 8 m; x_1=y_1=5 mm ; x_2=y_2= 2.5mm, λ=12 Å and 2 Å Pad=16x16mm^2

The colors represent the relative contribution of the various terms to the (σ_Q/Q)

Lambda=12A

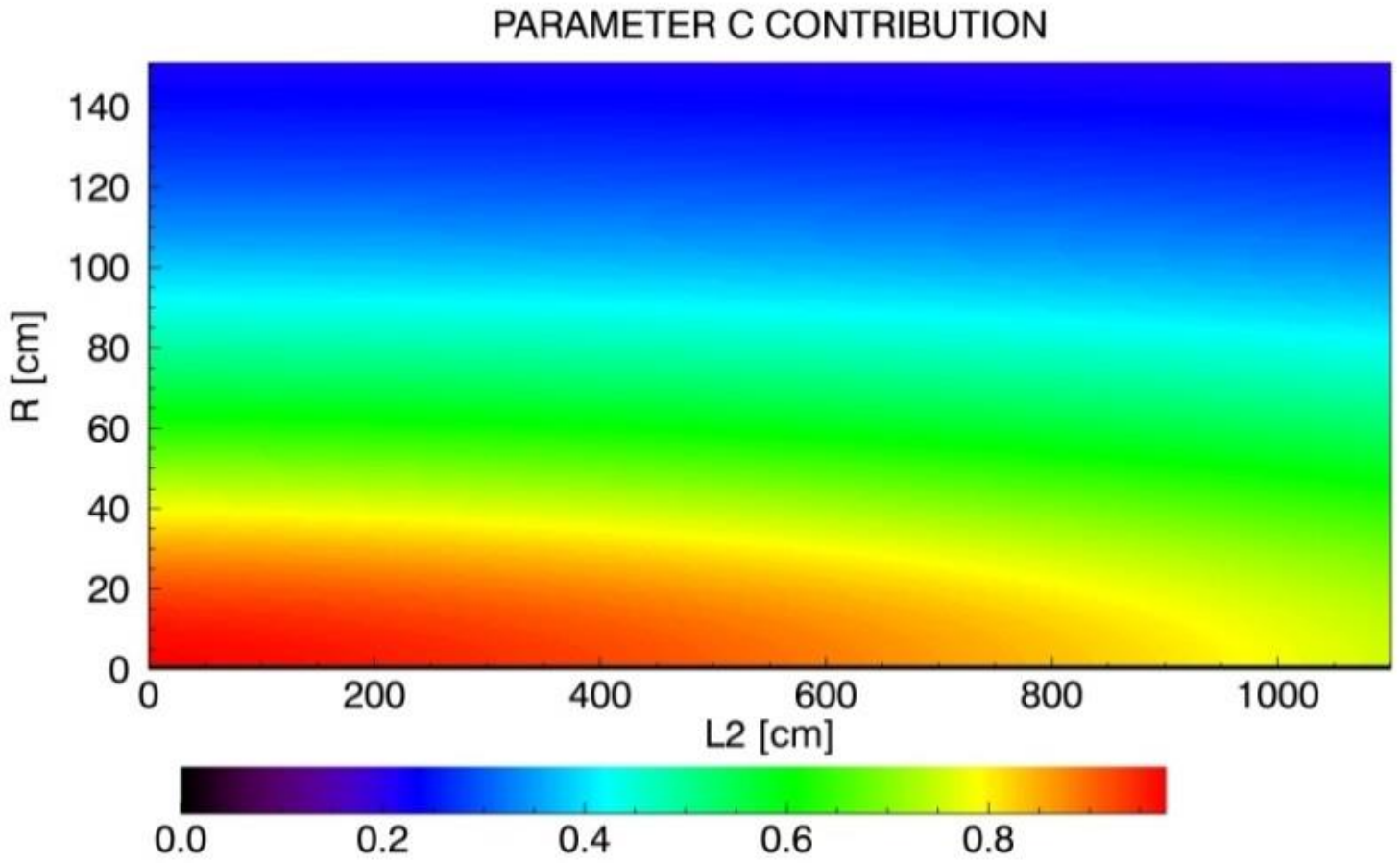


Lambda=2A



At λ = 2A TOF contribution dominates for R>10 cm and pad sizes 16 mm x16 mm; at λ = 12A TOF contribution dominates for R>60 cm and pad size 16 mm x 16 mm.

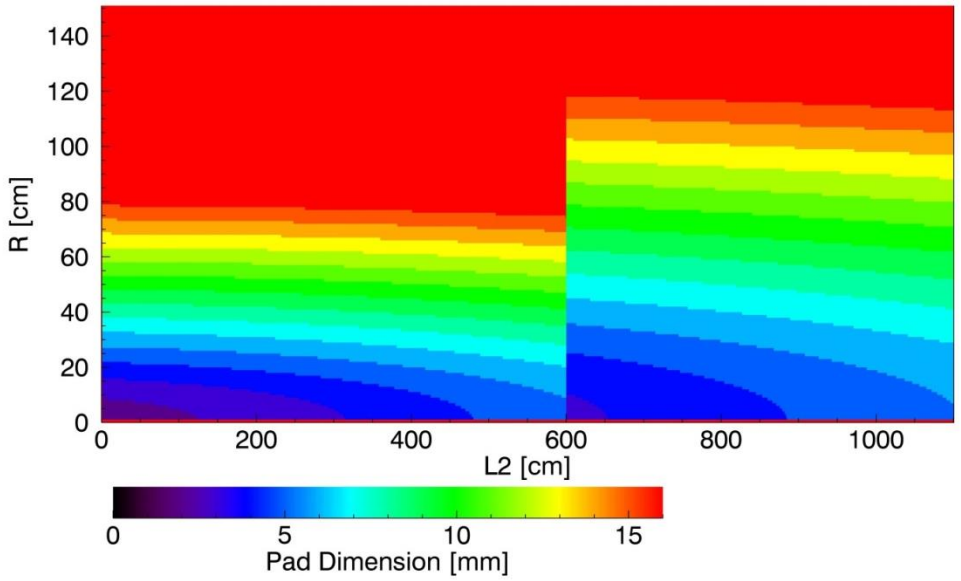
Term C analysis for L_1 = 8 m; x_1=y_1=5 mm ; x_2=y_2= 2.5mm, λ=12 Å Pad=16x16mm^2

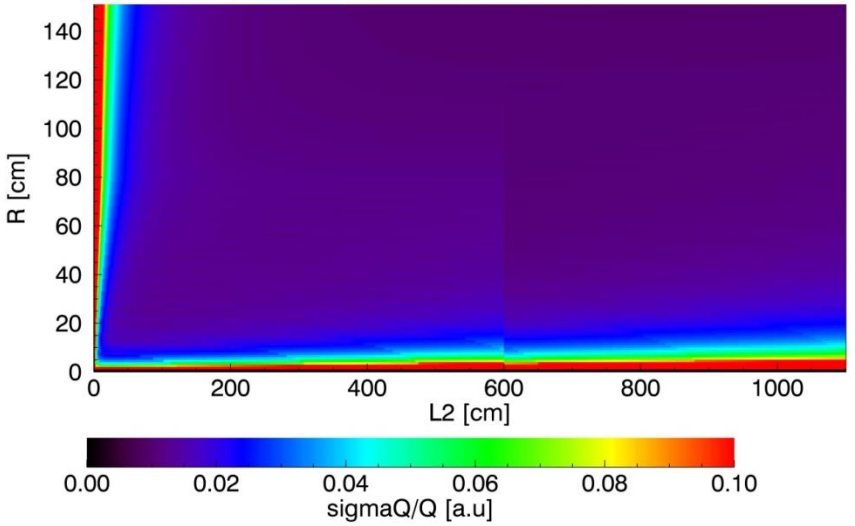


Term C is the dominant one for low R and low L2. The Pad dimensions can now be optimized

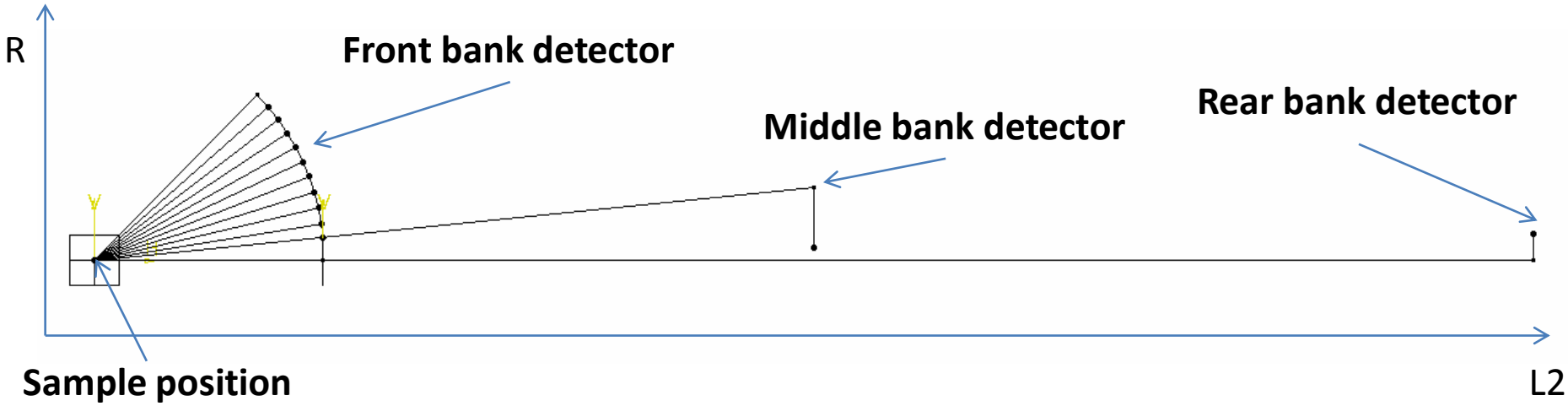
Method for PAD dimension optimization

- The approach used for the minimization of the PADs number is the calculation of the maximum allowed pad dimension in each point of the LoKI detector tank.
- We can affirm that the maximum allowed pad dimension at a given point (L2,R) is found when the contribution of the pad dimension matched the contribution of all the other parameters. In other words we can say that the maximum pad dimension is found when the relative contribution of the parameter C is less than 0.5 (its contribution is a half of the overall σ_Q/Q).
- A strict approach should be used for the very low angle detector, given that in the area on which it is foreseen its installation, also the contribution of parameters A and B become important. In this area (L2>6m) we can say that the maximum pad dimension is found when the relative contribution of the parameter C is less than 0.3.





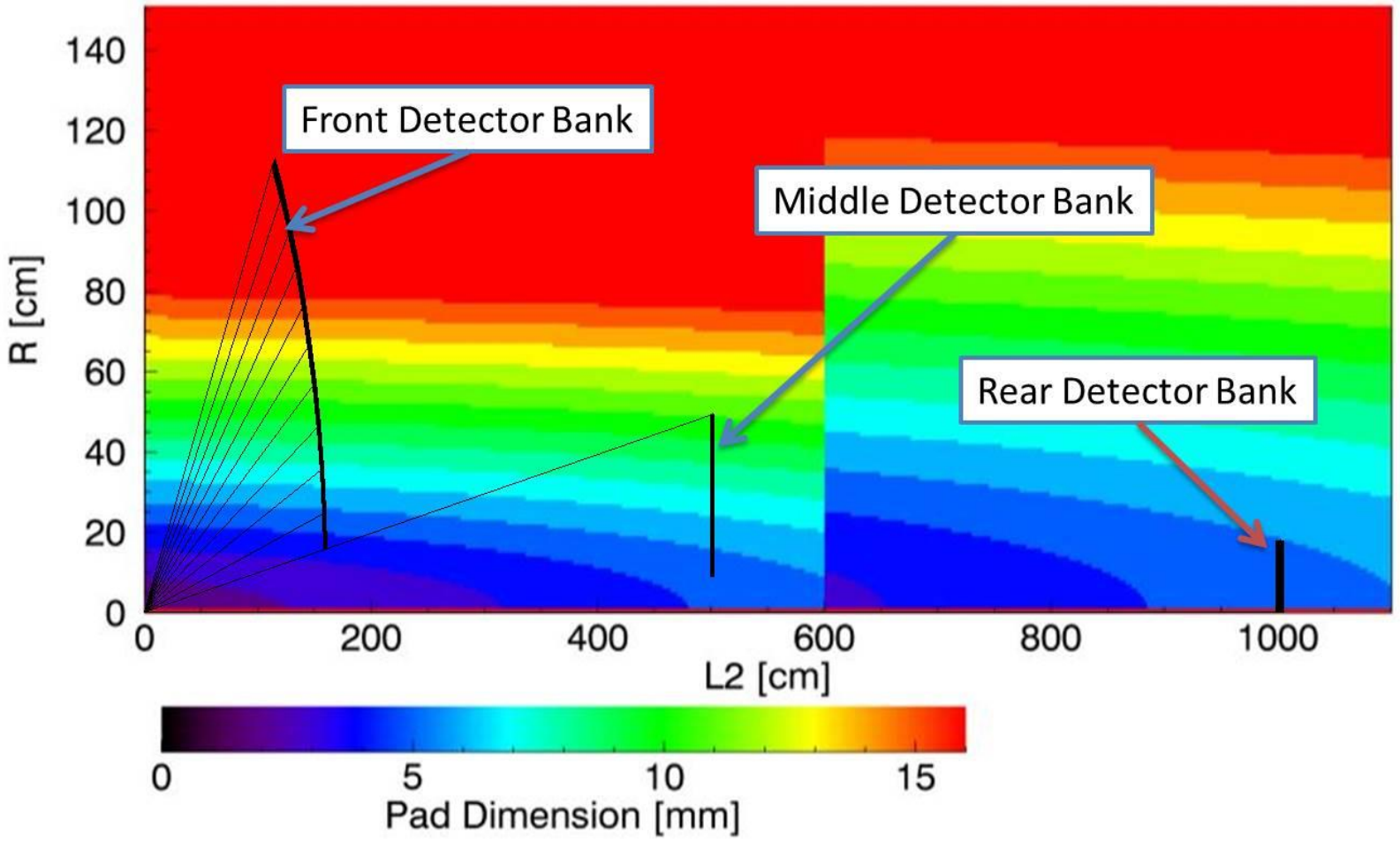
Possible detector solution for LOKI



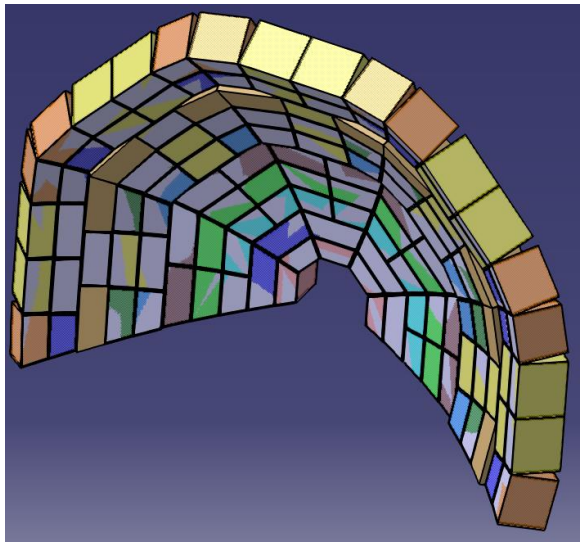
1) Middle bank Detector: L_2 = 5 m (based on the BANDGEM full module presently under construction), covers scattering angles from 1° to 5.7°. Azimuthal angle coverage equal to π. Pad sizes ranges from 3.7 mm x 4 mm (at small scattering angles to 18 mm x 8 mm at large angles.

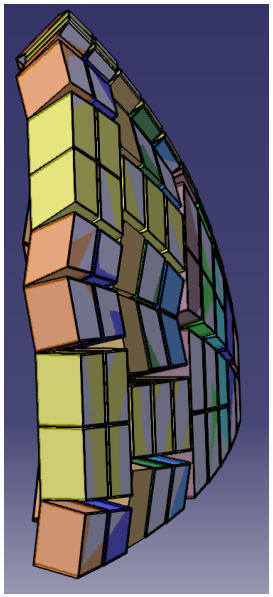
2) Front bank detector: Covers scattering angles from 5.7° to 45°. Based on BANDGEM modules placed on a spherical surface of radius 1.6 m from the sample. Azimuthal angle coverage equal to π. Pad size goes from 16 mm x16 mm for the larger angles down to 8 mm x 8 mm for smaller angles.

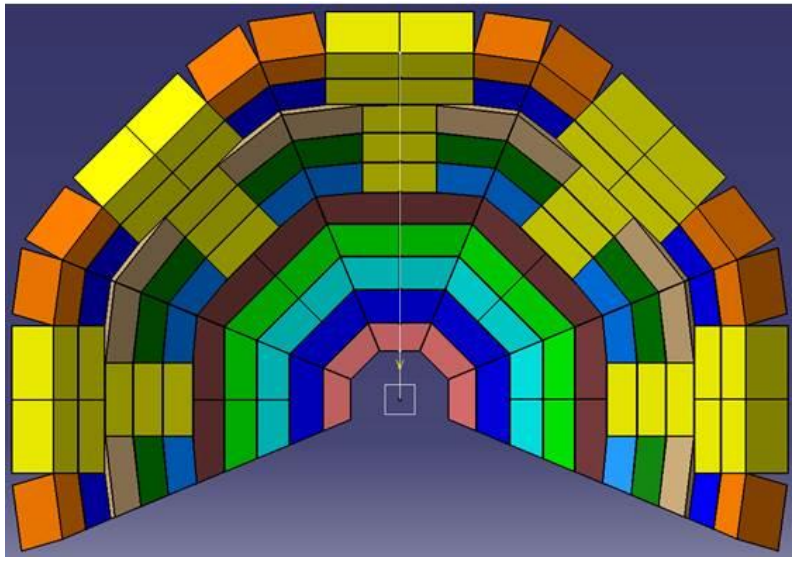
Possible detector solution for LOKI

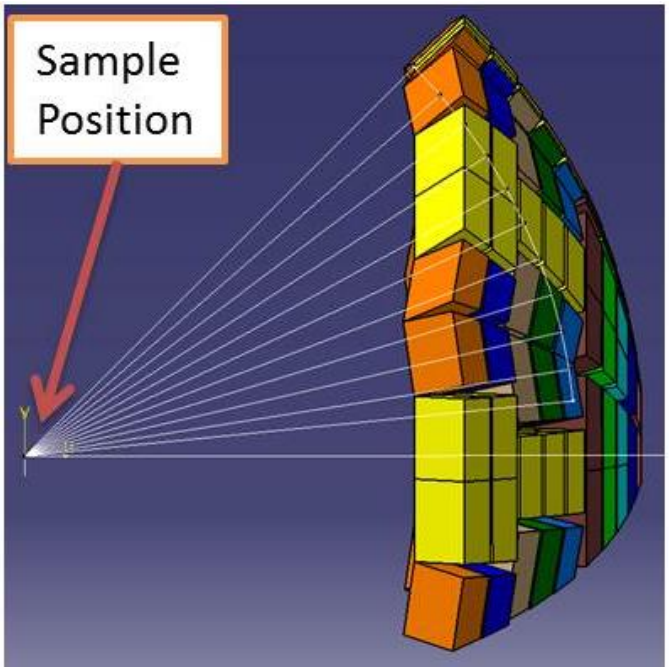


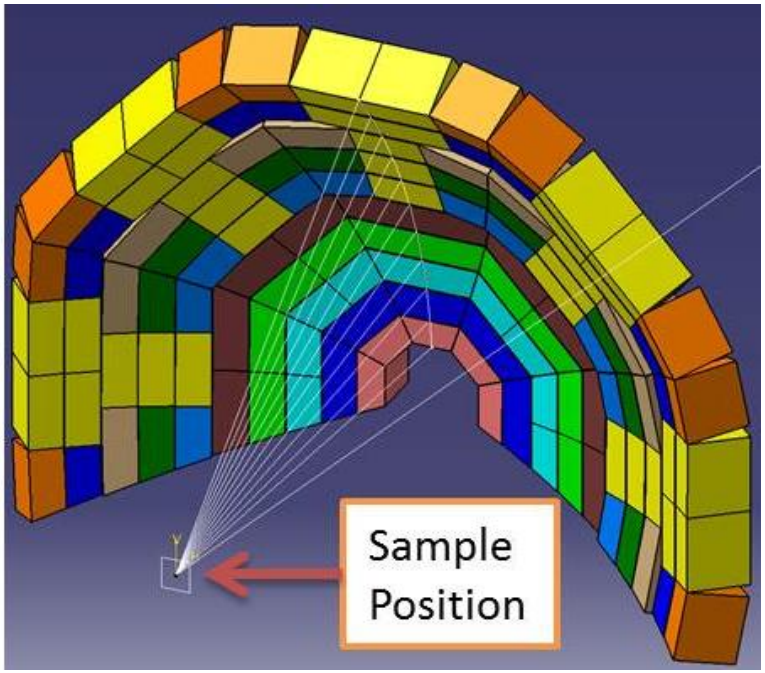
Concept Design for first detector bank



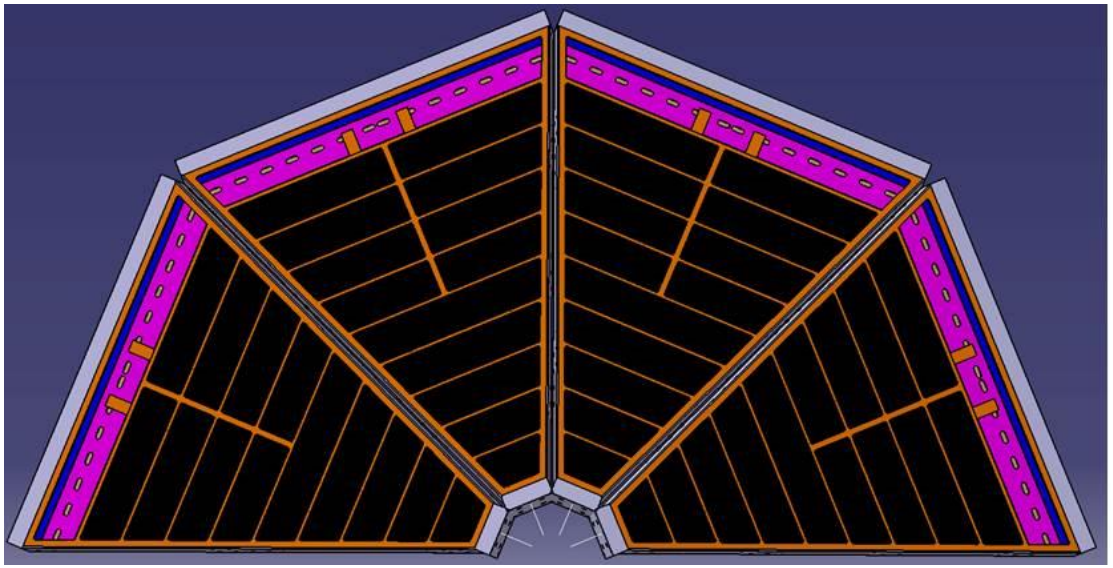


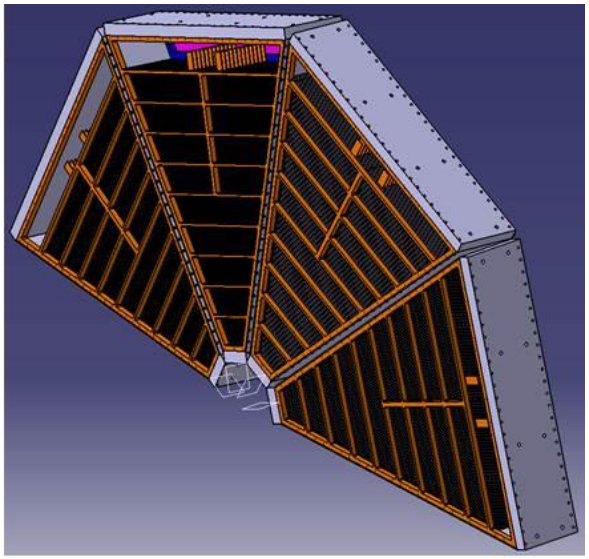






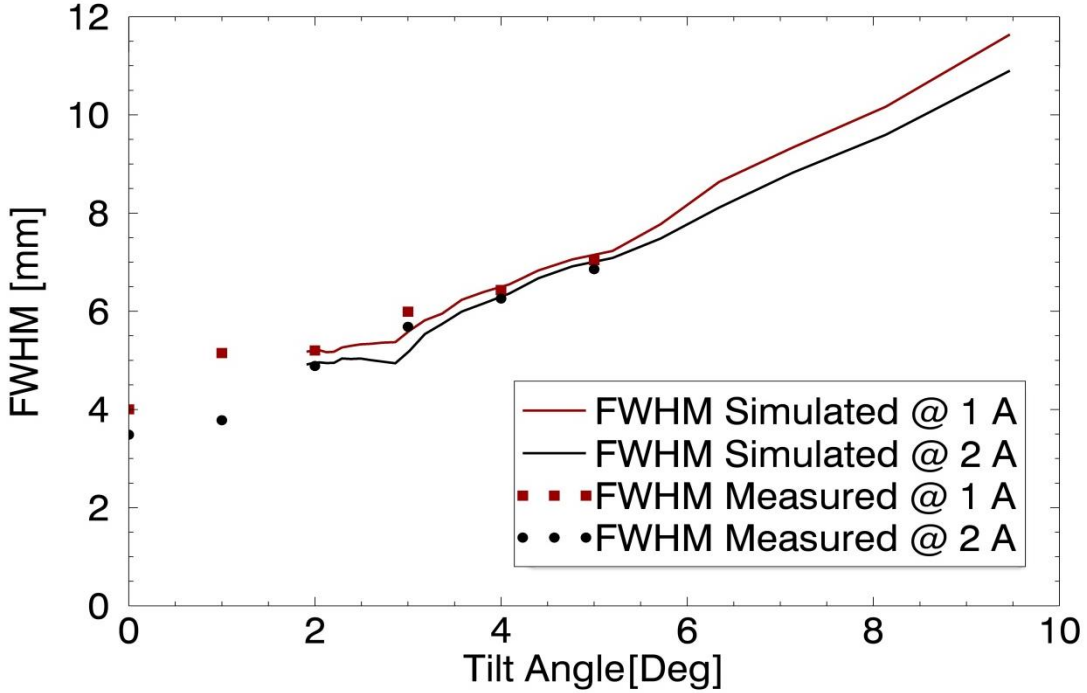
Middle bank





Spare

BANDGEM FWHM AND EFFICIENCY



FWHM @ 5°=6,5mm

Equivalent pad dimension=10x10mm^2