Monte Carlo simulation for adaptive optics

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Overview

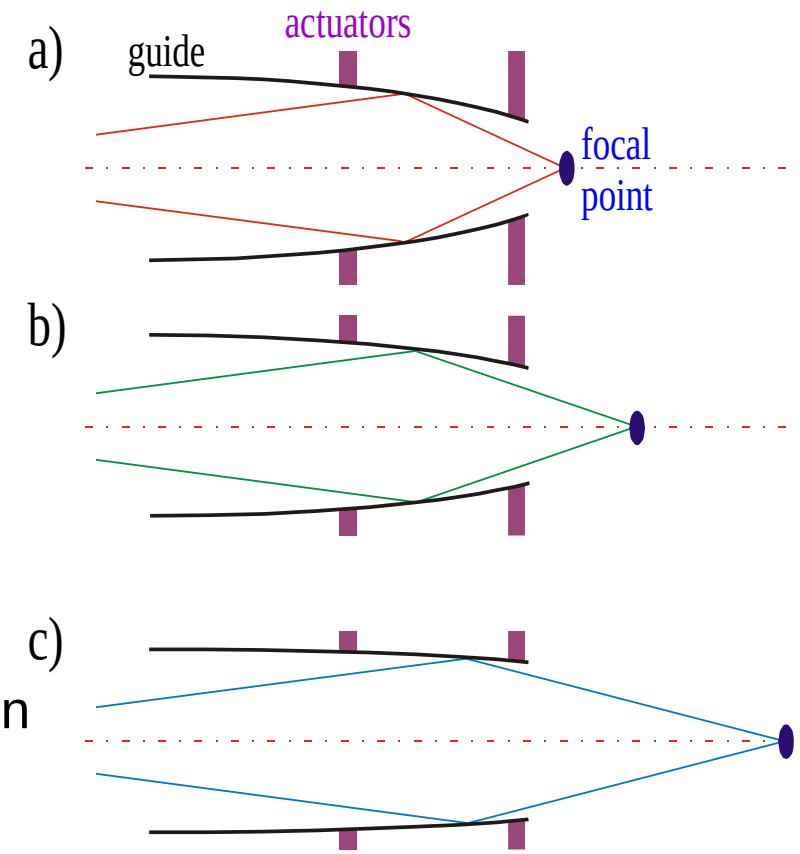
- Motivation and goals
- New McStas component
- Simulations for 1 -dimensional focusing
- Prototype development, possible performance
- Performed experiment
- Applications

Motivation and goals

- to significantly increase the neutron flux
- well defined beam characteristics
- gain factor in intensity of over 30 compared to linear guides for small samples
- to obtain a focal point in the sub mm range for elastic and inelastic scattering on very small samples
- to reduce the scattering background during the extreme environment experiments: magnetic fields, high pressure

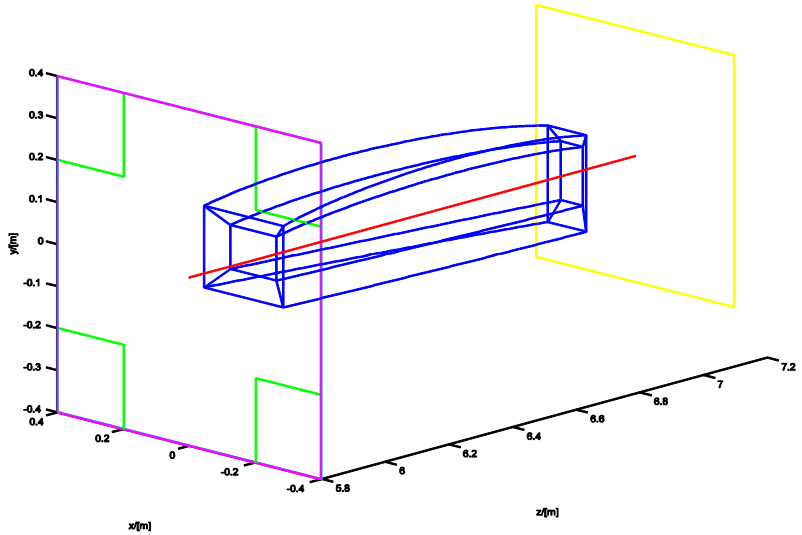
Adaptive optics

- possibility to align the focal point on tiny samples
- adaptation of beam size to the sample size
- optimization of the divergence of the neutron beam with respect to the sample



Adjust curvature of tapered guide by means of actuators
⇒ change focal length of the device

New McStas component

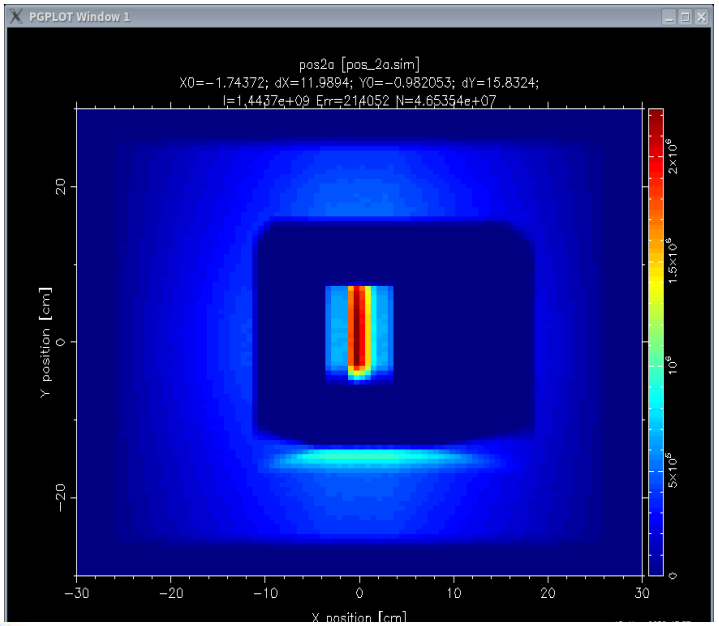


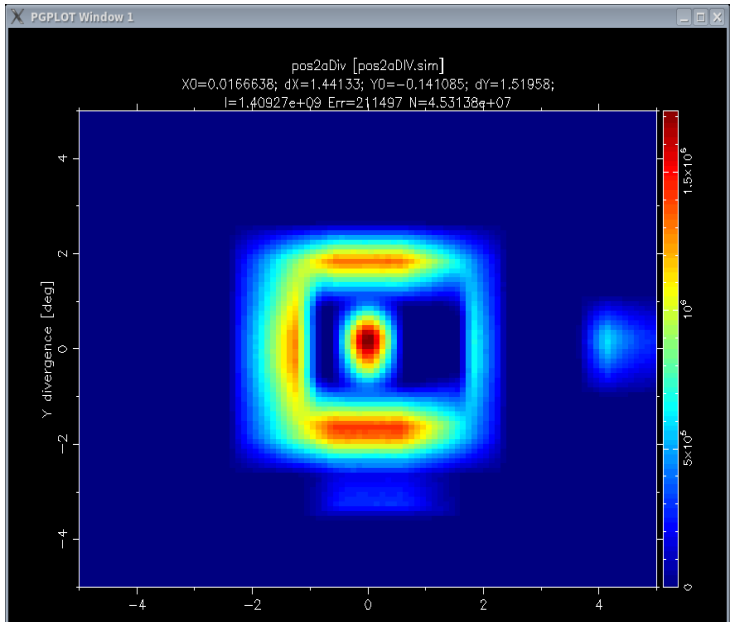
-different wall thickness

-truly curved

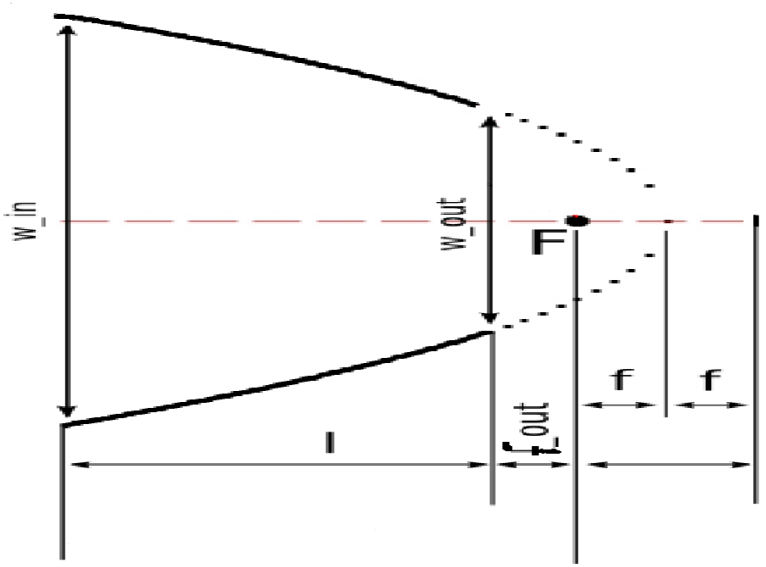
-different curvature for each wall

-transparent, absorbing or reflecting inner or outer walls



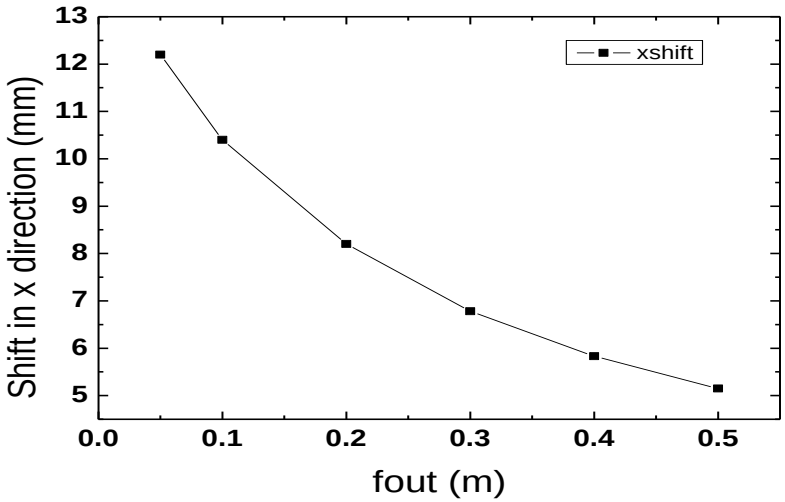


Initial simulations



f_{out} = distance from the exit of guide to second focal point
l = length of the guide
w_{in} = width at entrance of the guide
h_{in} = height at entrance of the guide

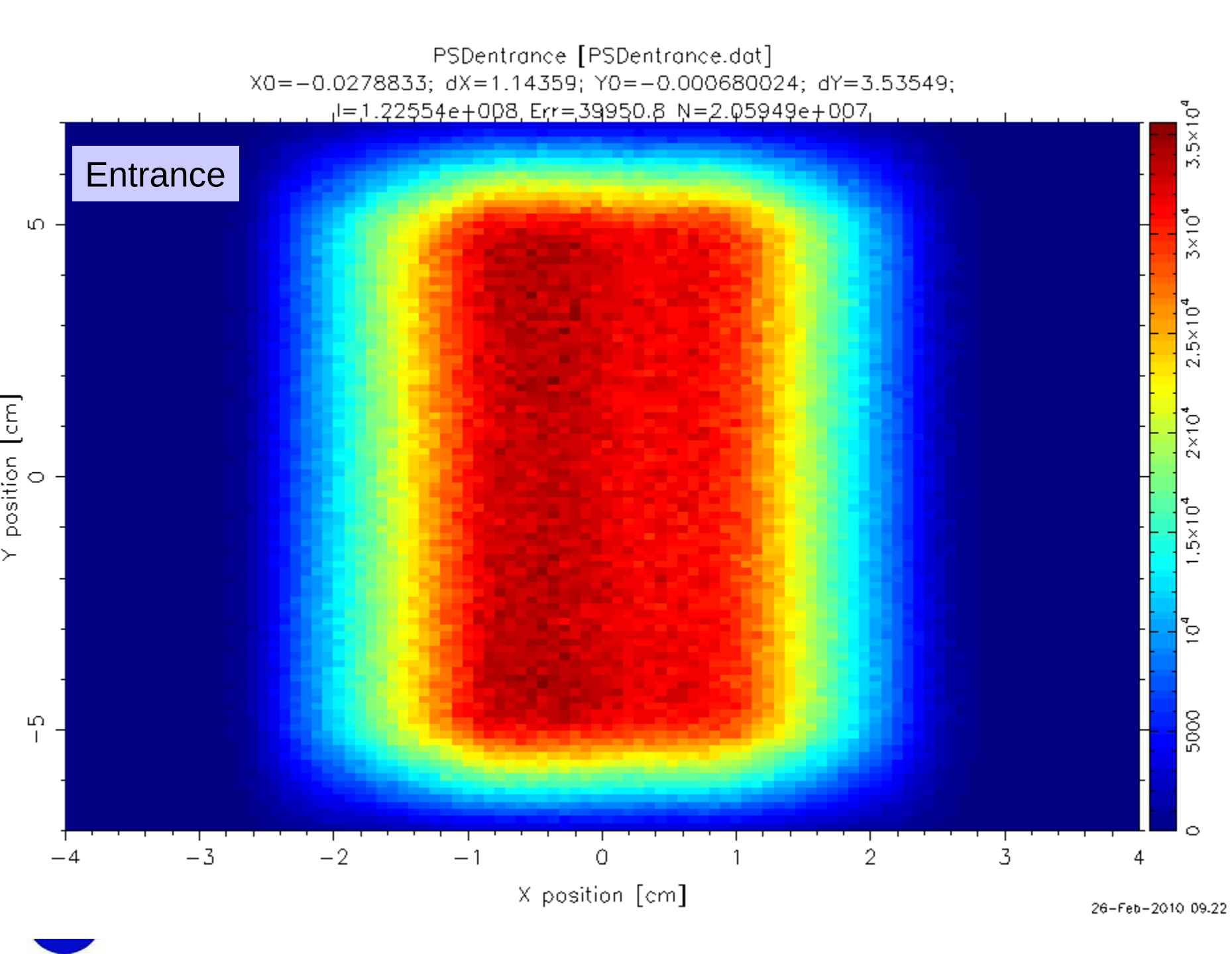
Above parameters define the height and width at exit of the guide



First simulation parameters

f_{out} = 250 mm
l = 500 mm
w_{in} = 35 mm
h_{in} = 120 mm

One dimensional variation of f_{out} in x-direction - perpendicular to the beam axis in horizontal direction


PSDentrance [PSDentrance.dat]
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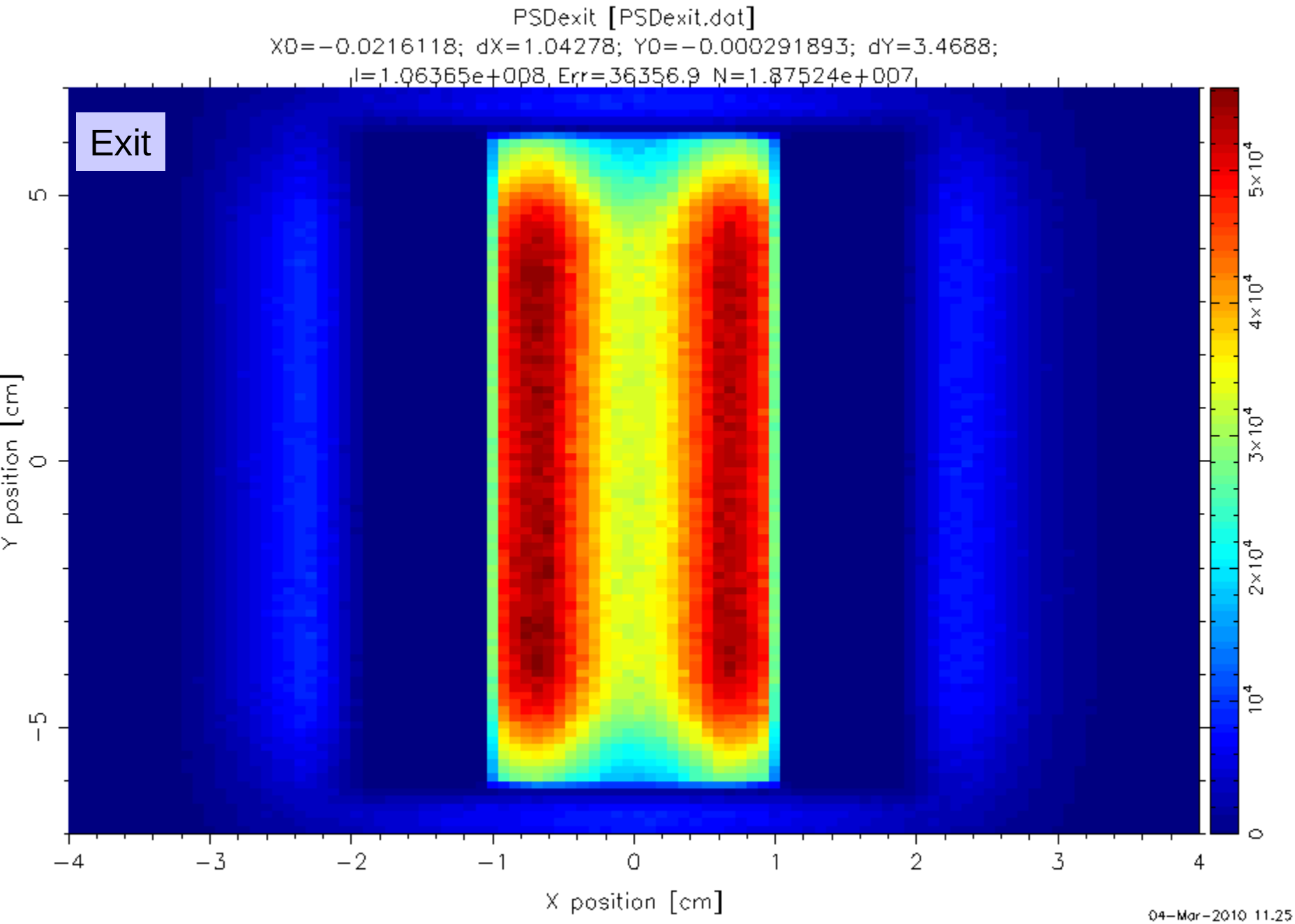
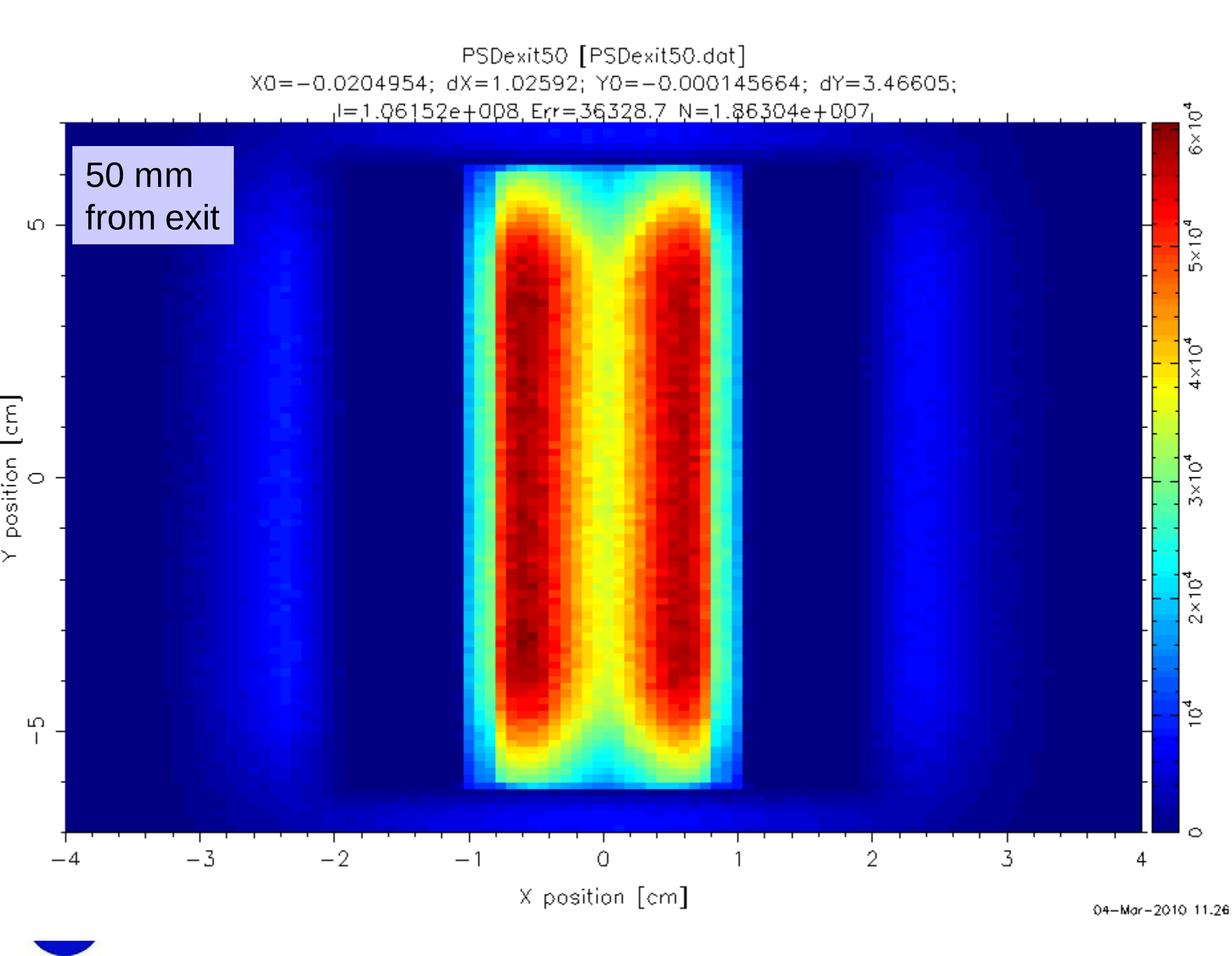
I=1.22554e+008 Err=39950.8 N=2.05949e+007
Entrance
Y position [cm]
X position [cm]
26-Feb-2010 09:22


PSDexit [PSDexit.dat]
X0=-0.0216118; dX=1.04278; Y0=-0.000291893; dY=3.4688;
I=1.06365e+008 Err=36356.9 N=1.87524e+007
Exit
Y position [cm]
X position [cm]
-4
-3
-2
-1
0
1
2
3
4
5
0
-5
0
10^4
2×10^4
3×10^4
4×10^4
5×10^4
04-Mar-2010 11.25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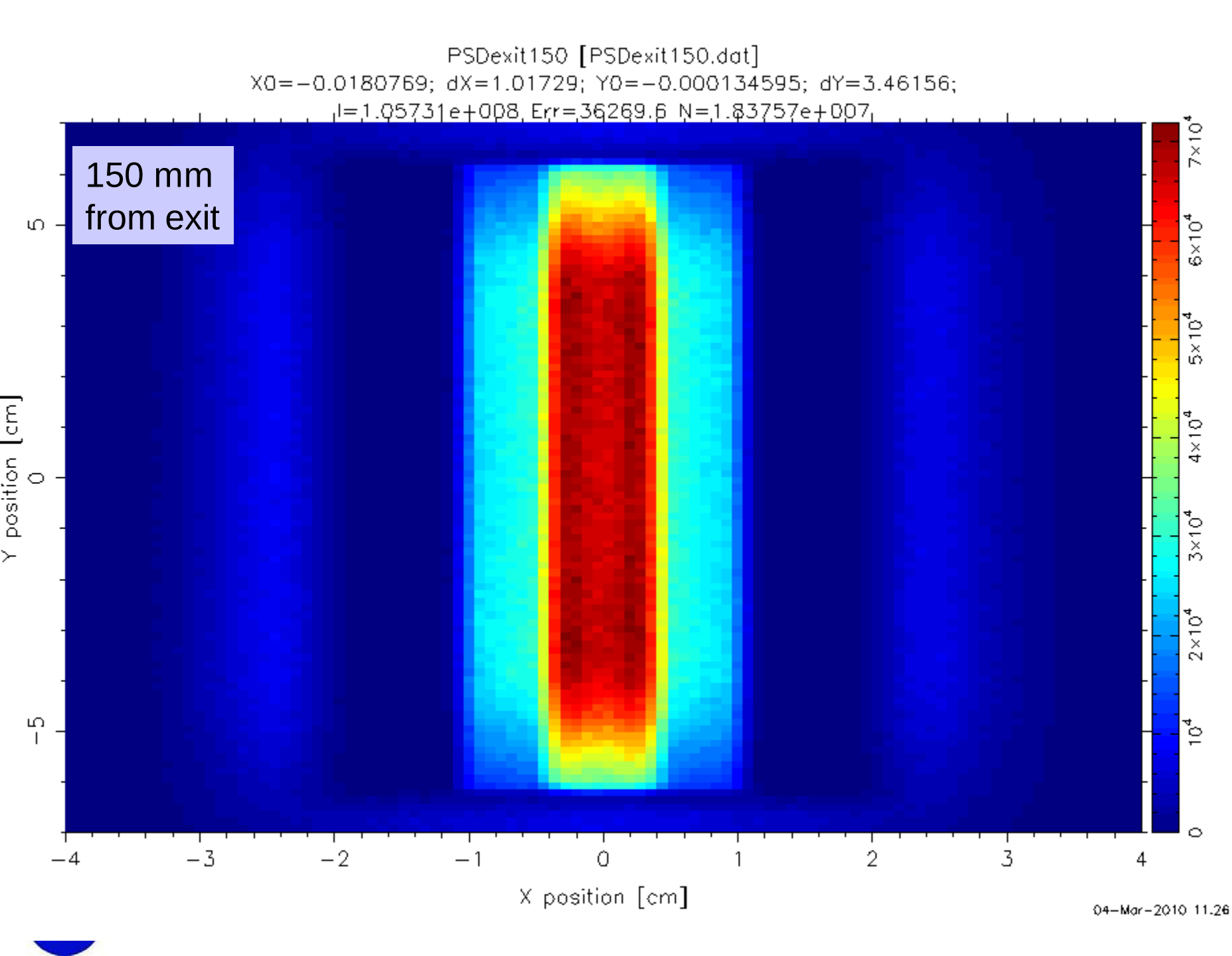
X0=-0.0204954; dX=1.02592; Y0=-0.000145664; dY=3.46605;
I=1.06152e+008, Err=36328.7, N=1.86304e+007
50 mm
from exit
Y position [cm]
X position [cm]
-4
-3
-2
-1
0
1
2
3
4
5
0
-5
6×10^4
5×10^4
4×10^4
3×10^4
2×10^4
10^4
0
04-Mar-2010 11.26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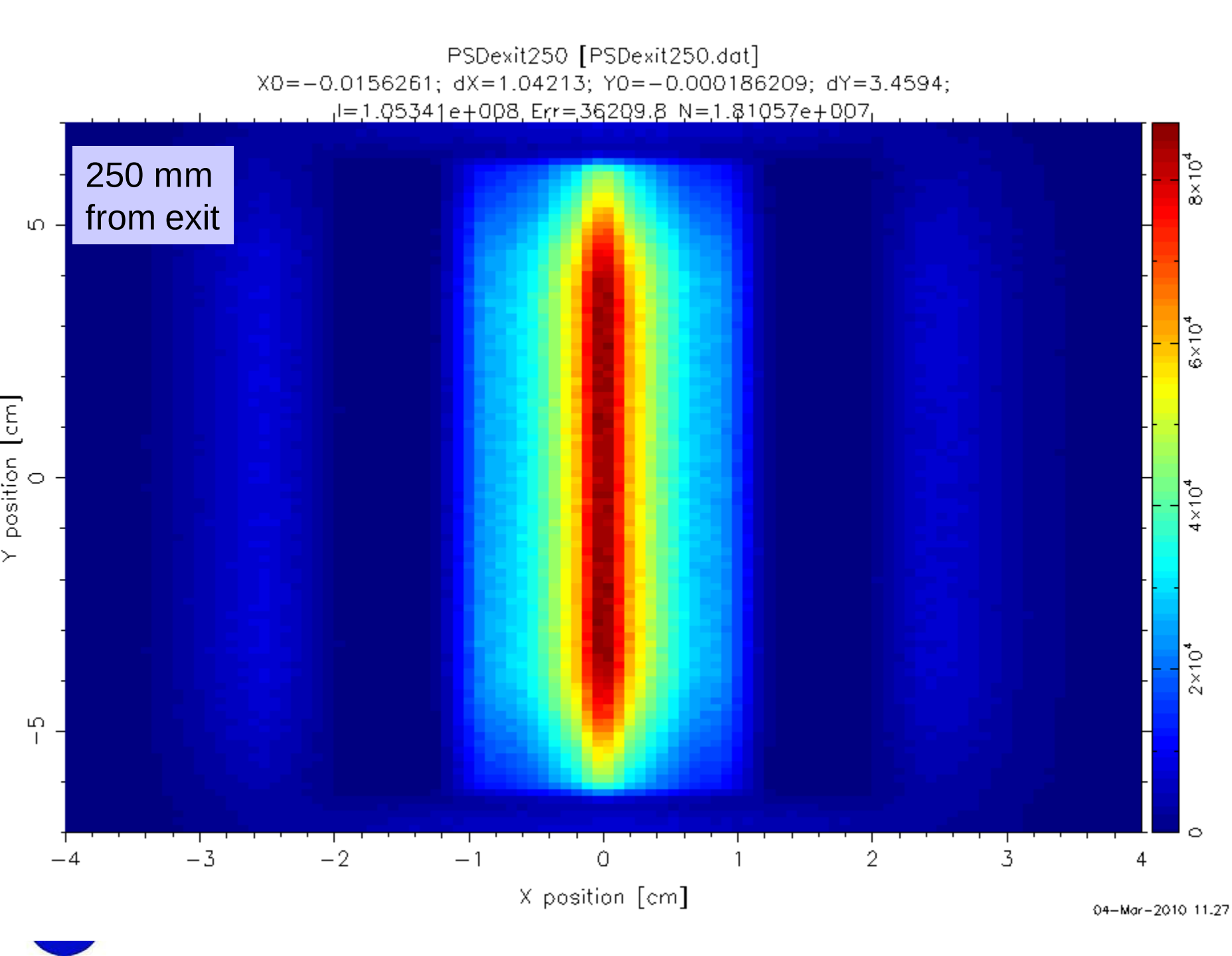
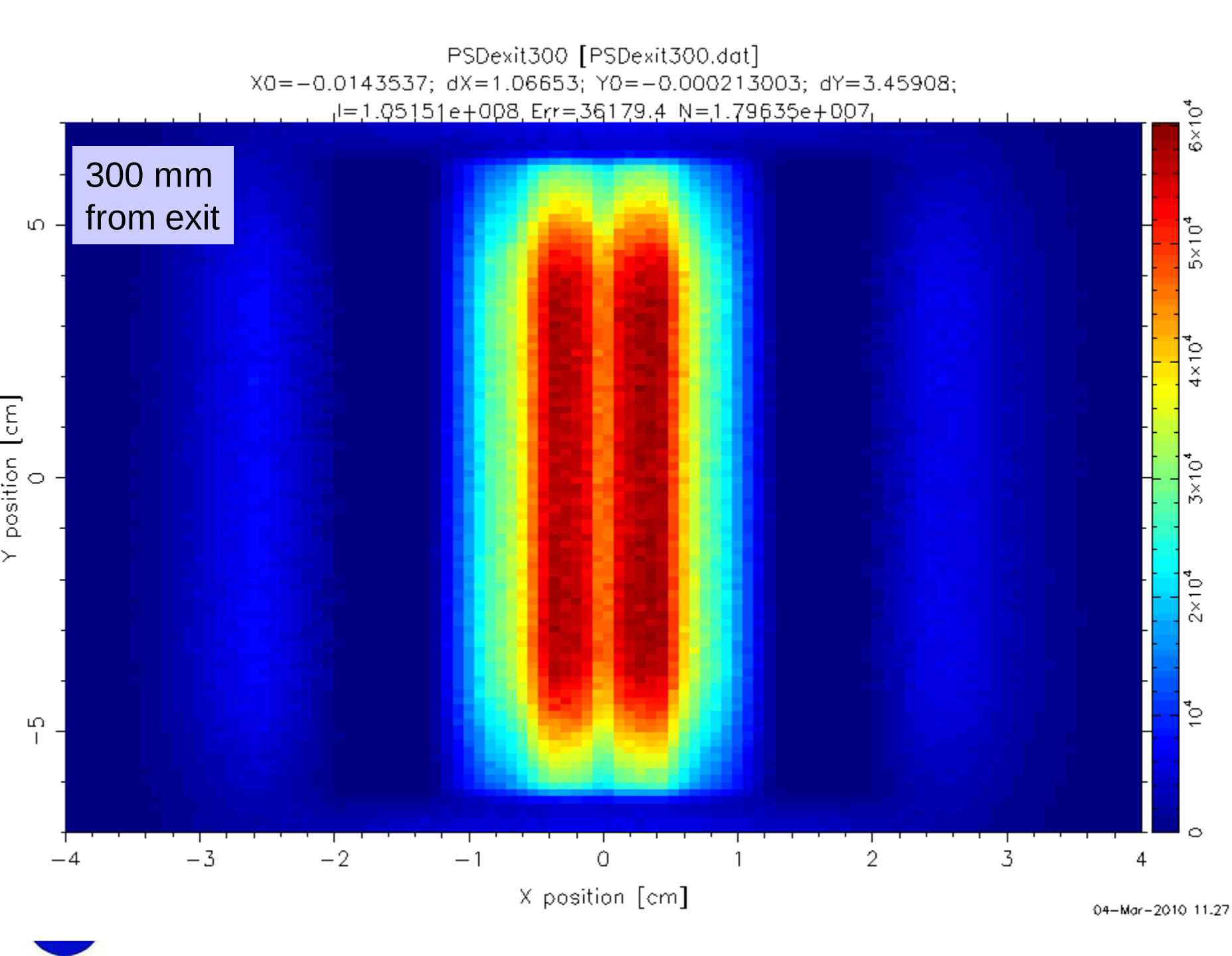
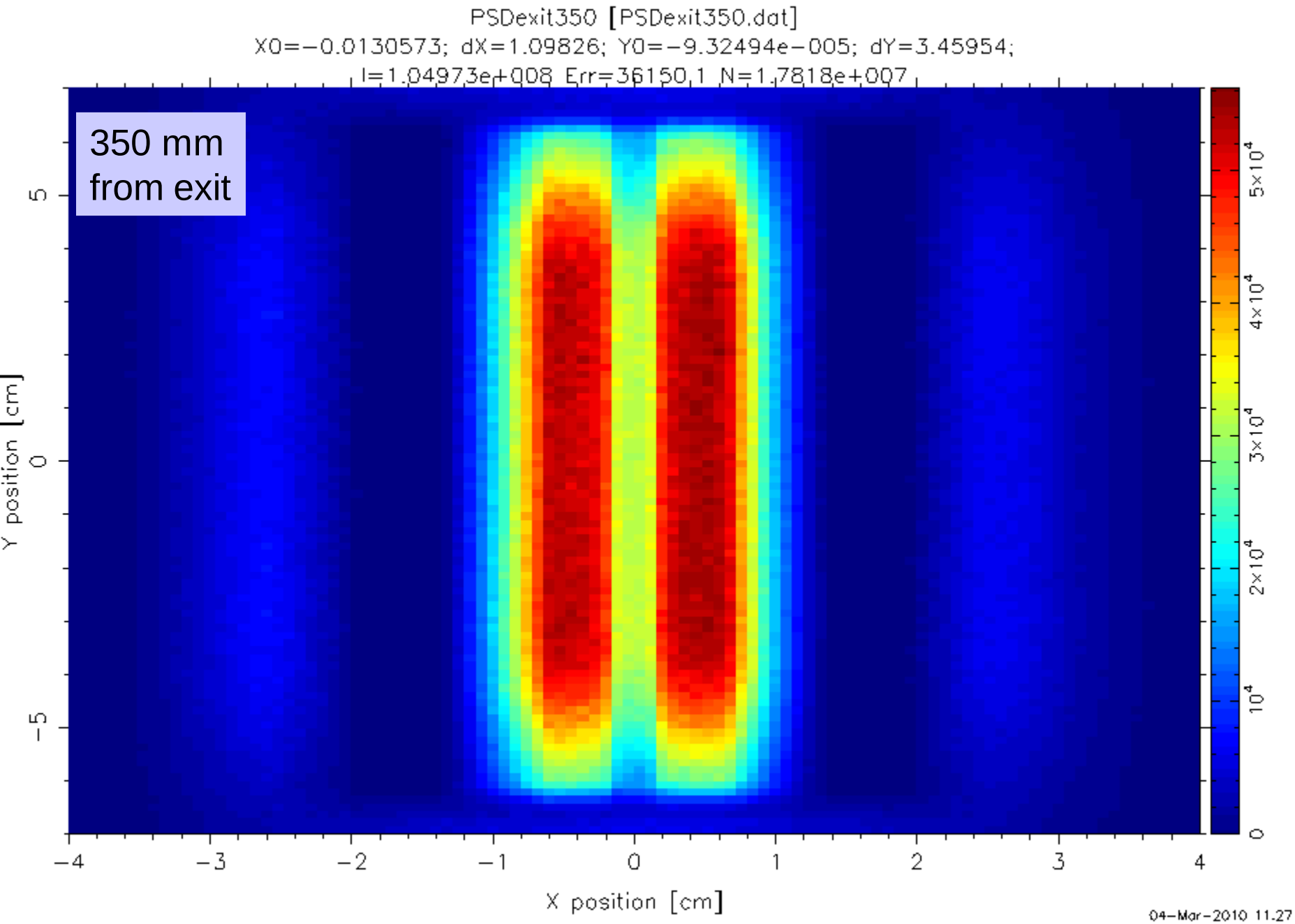
I=1.05731e+008, Err=36269.6, N=1.83757e+007
150 mm
from exit
Y position [cm]
X position [cm]
-4
-3
-2
-1
0
1
2
3
4
5
0
-5
7×10^4
6×10^4
5×10^4
4×10^4
3×10^4
2×10^4
10^4
0
04-Mar-2010 11.26


PSDexit250 [PSDexit250.dat]
X0=-0.0156261; dX=1.04213; Y0=-0.000186209; dY=3.4594;
I=1.05341e+008, Err=36209.8 N=1.81057e+007
250 mm
from exit
Y position [cm]
X position [cm]
-4
-3
-2
-1
0
1
2
3
4
5
0
-5
0
2×10^4
4×10^4
6×10^4
8×10^4
04-Mar-2010 11.27


PSDexit300 [PSDexit300.dat]
X0=-0.0143537; dX=1.06653; Y0=-0.000213003; dY=3.45908;
I=1.05151e+008, Err=36179.4 N=1.79635e+007
300 mm
from exit
Y position [cm]
X position [cm]
-4
-3
-2
-1
0
1
2
3
4
5
0
-5
6×10^4
5×10^4
4×10^4
3×10^4
2×10^4
10^4
0
04-Mar-2010 11.27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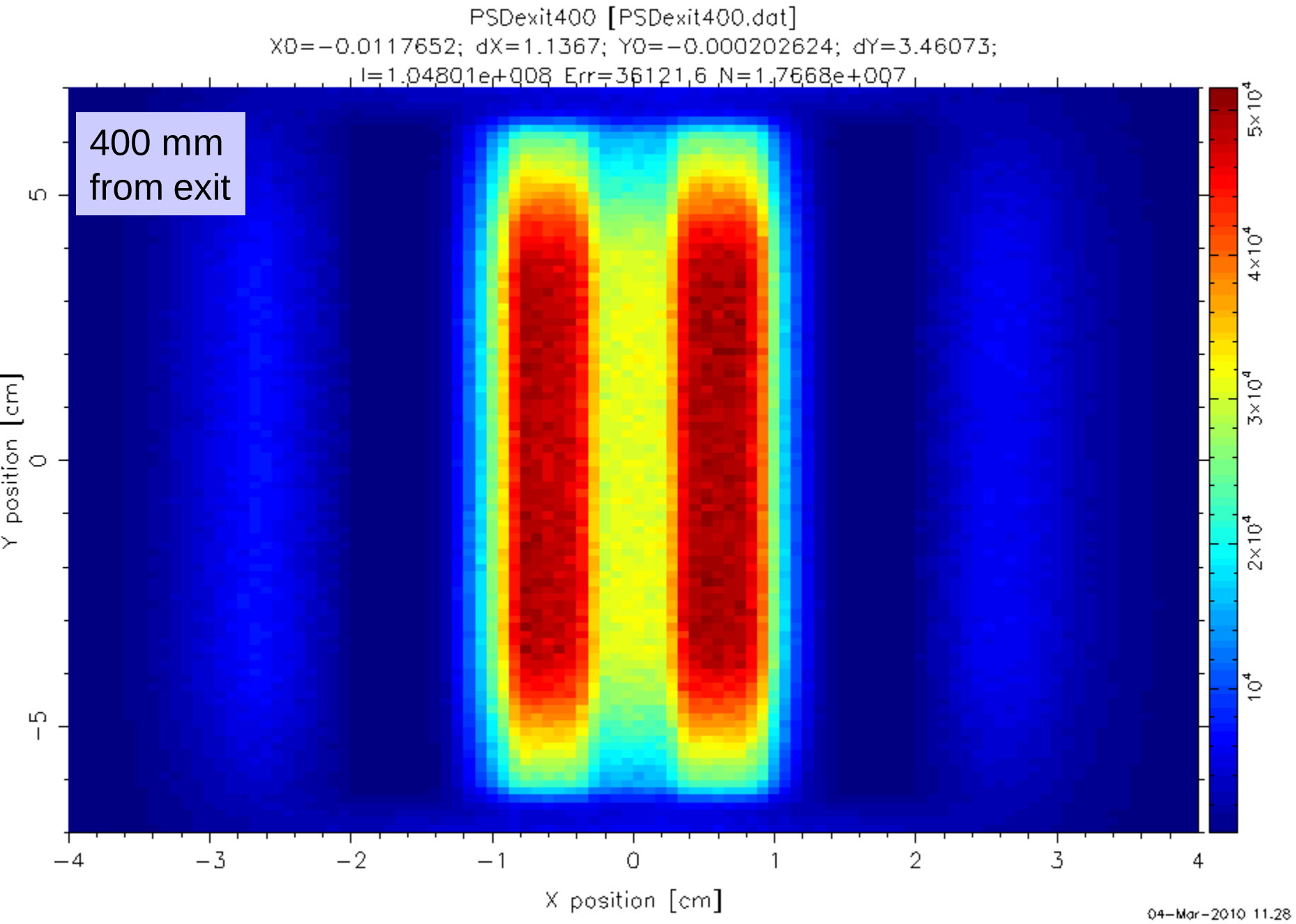
I=1.04973e+008 Err=36150.1 N=1.7818e+007
350 mm
from exit
Y position [cm]
X position [cm]
-4
-3
-2
-1
0
1
2
3
4
5
0
-5
0
10^4
2×10^4
3×10^4
4×10^4
5×10^4
04-Mar-2010 11.27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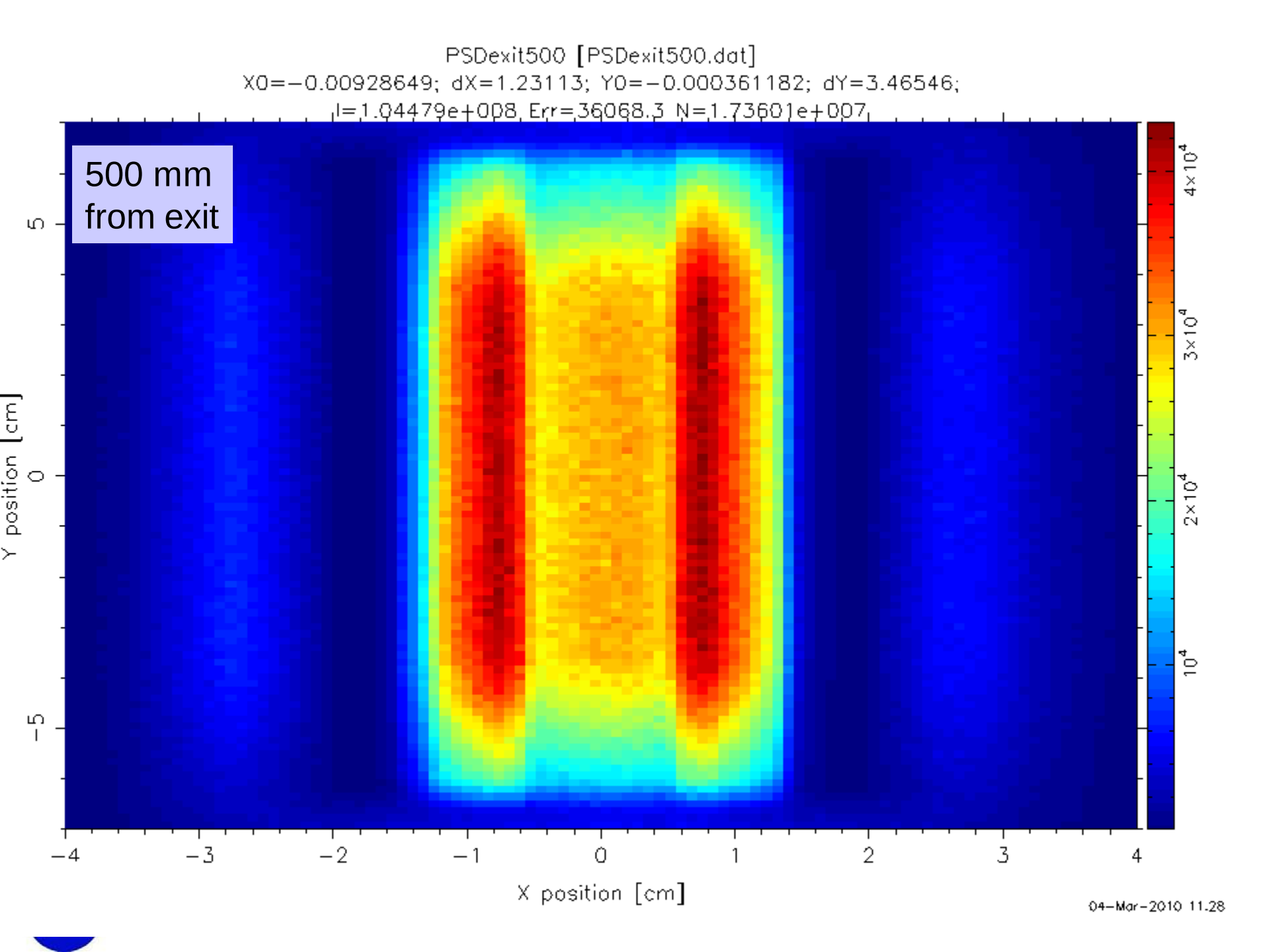
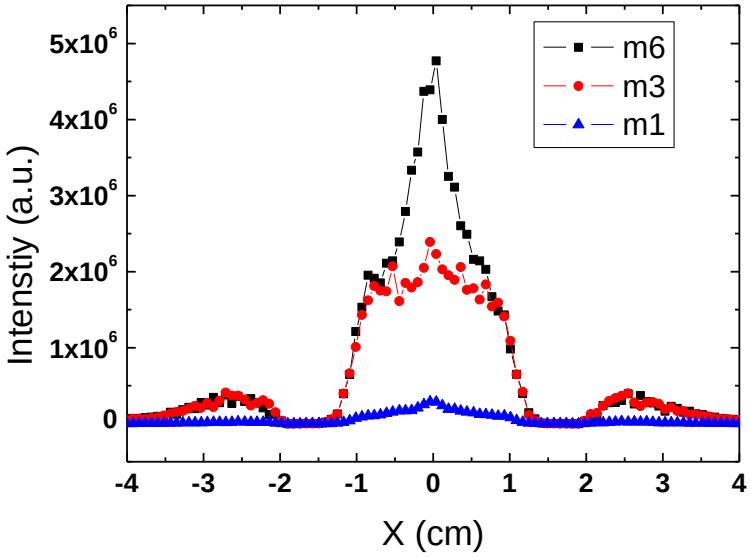
X0=-0.0117652; dX=1.1367; Y0=-0.000202624; dY=3.46073;
I=1.04801e+008 Err=36121.6 N=1.7668e+007
400 mm
from exit
Y position [cm]
X position [cm]
5
0
-5
-4
-3
-2
-1
1
2
3
4
5×10^4
4×10^4
3×10^4
2×10^4
10^4
04-Mar-2010 11.28


PSDexit500 [PSDexit500.dat]
X0=-0.00928649; dX=1.23113; Y0=-0.000361182; dY=3.46546;
I=1.04479e+008, Err=36068.3, N=1.73601e+007
500 mm
from exit
Y position [cm]
X position [cm]
-4
-3
-2
-1
0
1
2
3
4
5
0
-5
4×10^4
3×10^4
2×10^4
10^4
04-Mar-2010 11.28

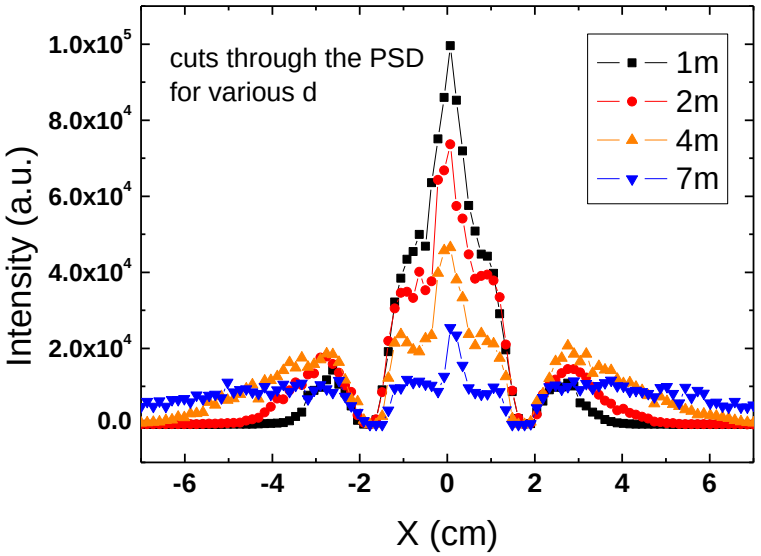
One dimensional simulations

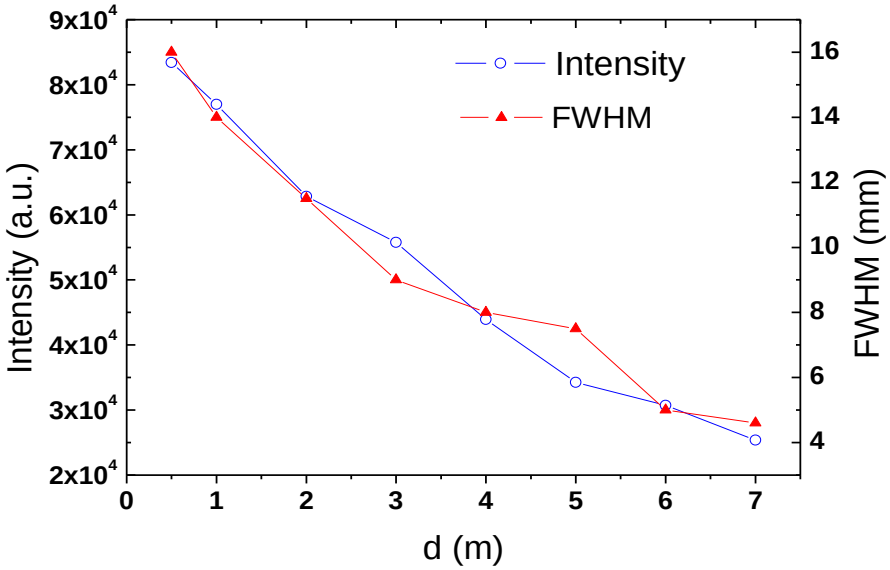
$\lambda = 5$ Å



Intensity increases with increasing m value of the coating due to reflection of neutrons with higher angle of incidence

Variation of d (distance guide-entrance): divergence of incoming neutrons is changed





Simulations for various f_{out}

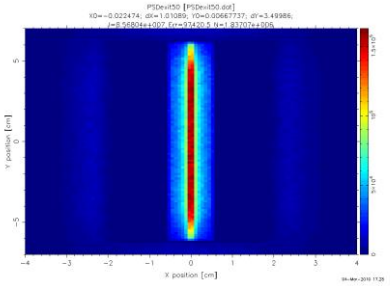
λ = 5 Å

PSD detectors in focal point

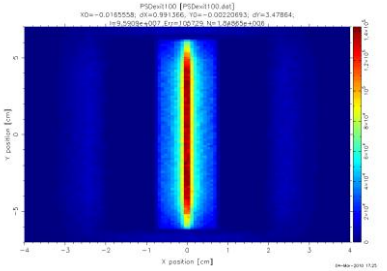
Variation of f_{out} requires change in curvature of guide

f_{out}(mm)	x_{shift}(mm)
50	12.2
100	10.4
200	8.2
300	6.8
400	5.8
500	5.1

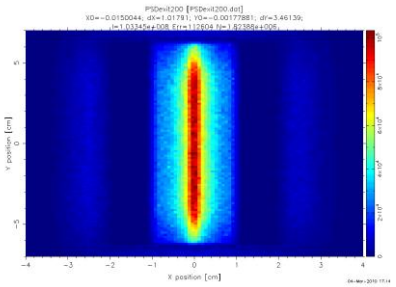
f_{out}= 50 mm



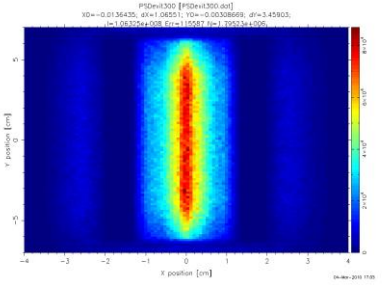
f_{out}= 100 mm



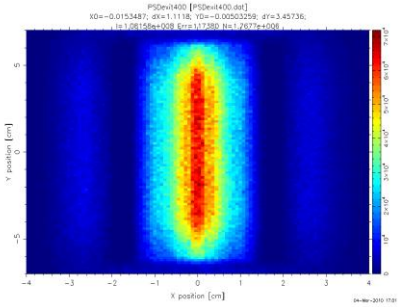
f_{out}= 200 mm



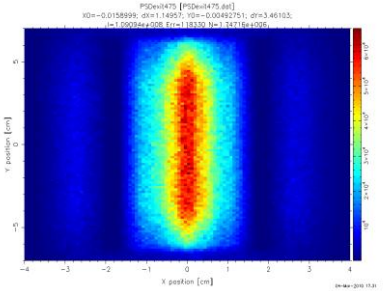
f_{out}= 300 mm



f_{out}= 400 mm

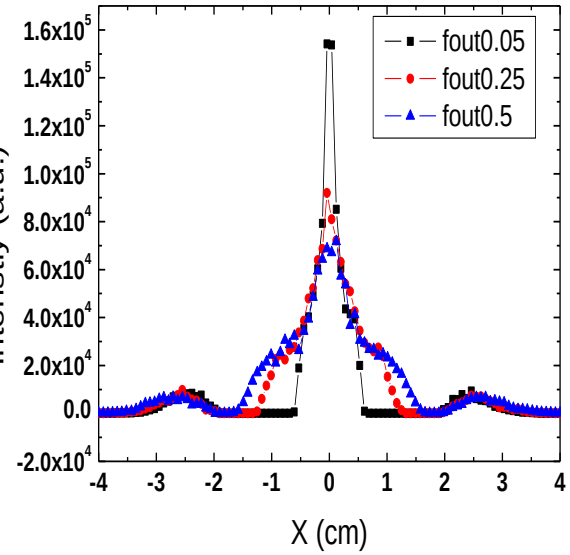


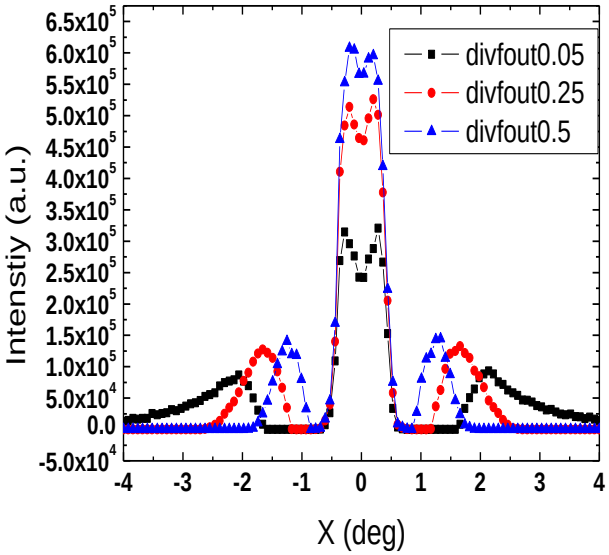
f_{out}= 500 mm

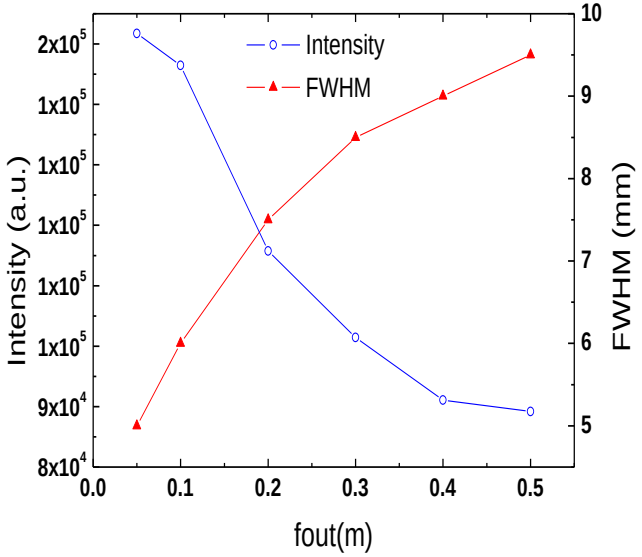


Simulations for various f_{out}

λ = 5 Å







Observation for decreasing f_{out}:

-increase in intensity

-increase of curvature of mirror

-decrease of width of beam (FWHM)

Example: f_{out}= 100 mm:

- FWHM = 6 mm
- flux: $1.7 \cdot 10^{7}$ neutrons$\cdot$cm$^{-2}\cdot$s^{-1}

Applications:

-at PSI:

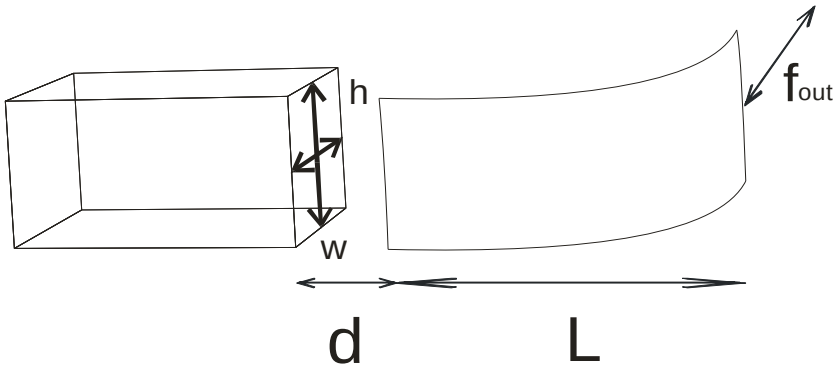
- RITA
- DMC

-at FRM II:

- TOFTOF (see poster for details)
- MIRA

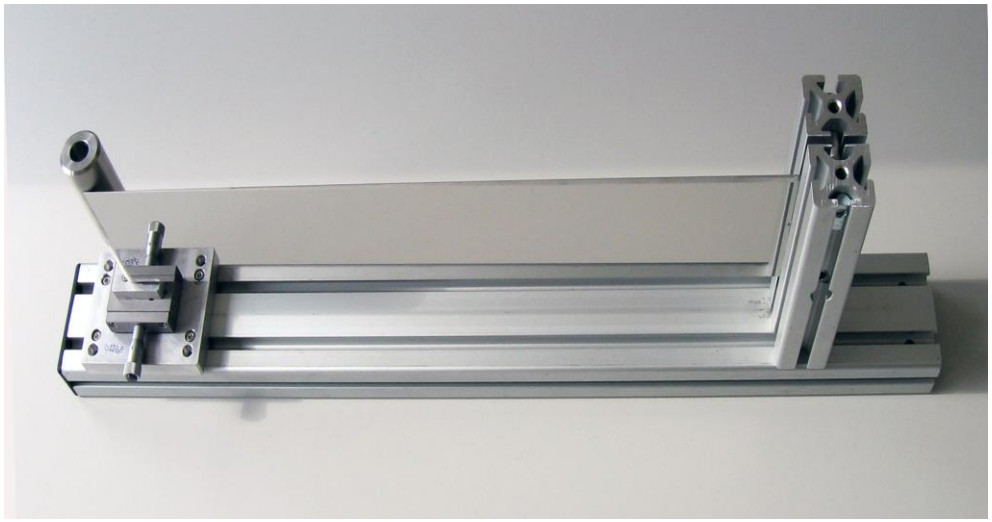
Development of prototype

Details: Poster of M. Schneider

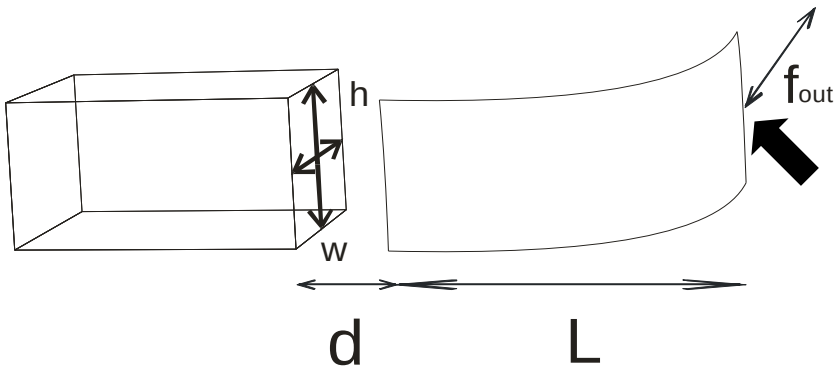


Prototype:

- coating on one side
- one point to press
- defined curvature

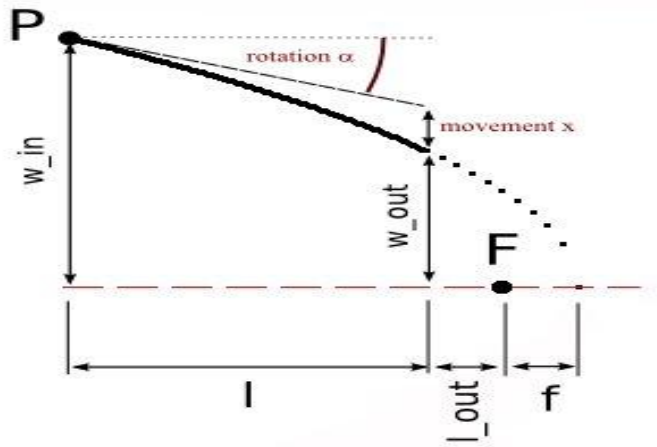


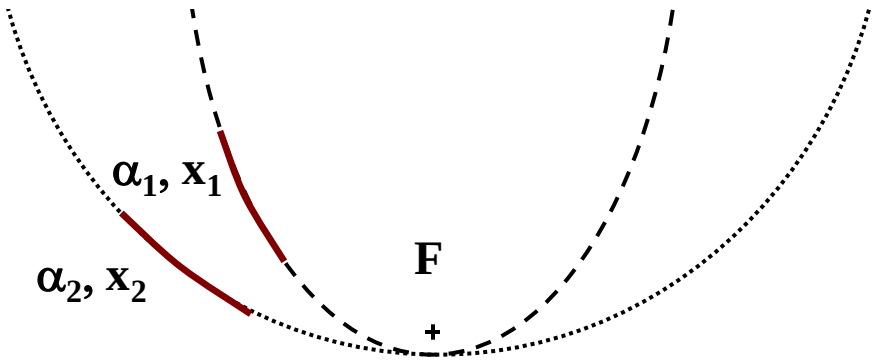
One reflecting side



Maintain position of focal point:

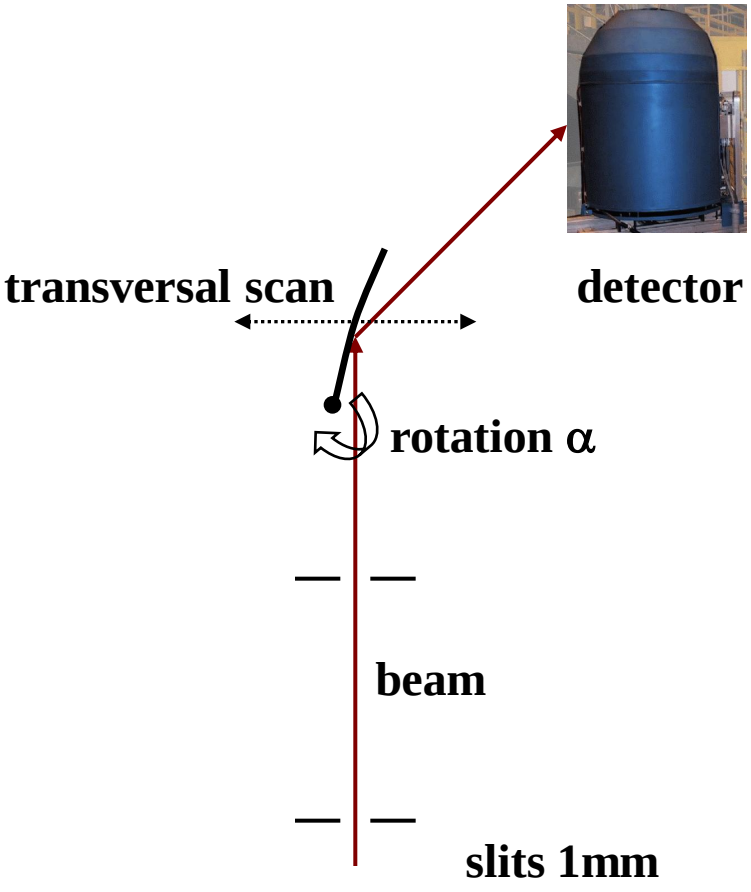
- push mirror on one side
- vary angle of rotation of tangenta with respect to optical axis of device





Shift in x direction is correlated with rotation angle

Experiment: Beam line Morpheus @ SINQ



Parallel beam: 1mm slits

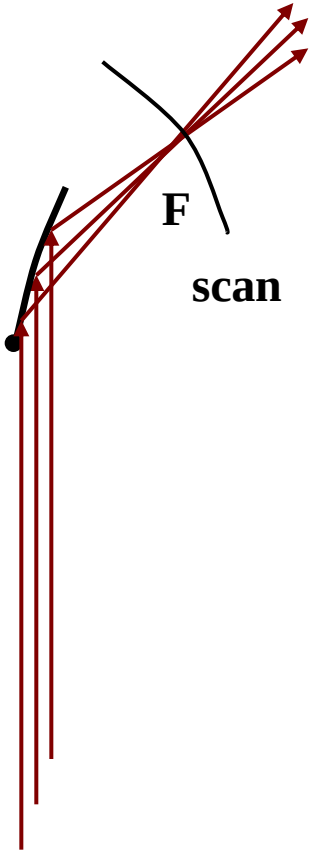
Rotation angle of mirror: 0 - 1.2 deg

2θ-scan: 0 - 3 deg

Detector at 230 mm from mirror

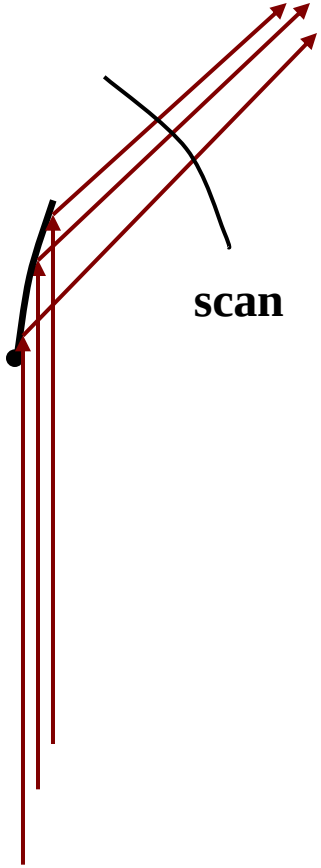
Experimental setup

rotation α do match movement x



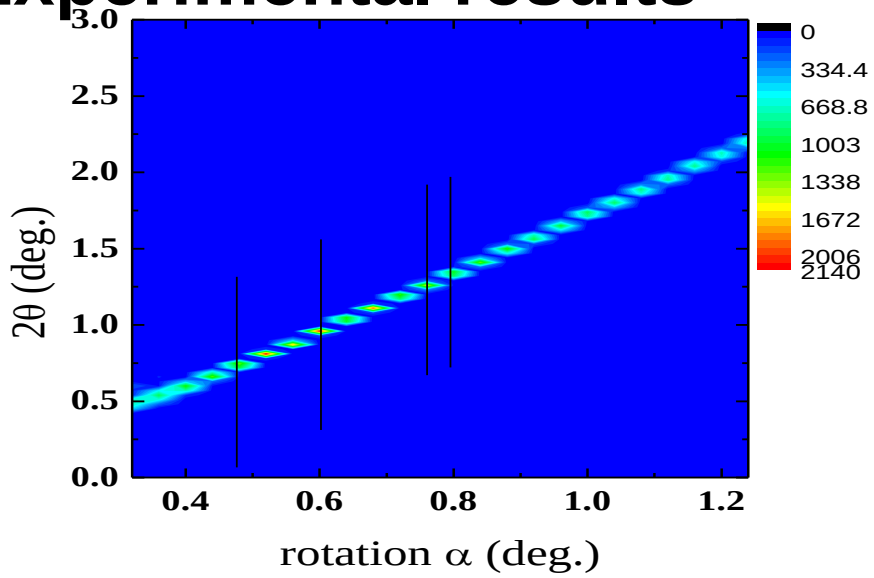
for different translation reflected beams appear at the same position on detector

rotation α do not match movement x

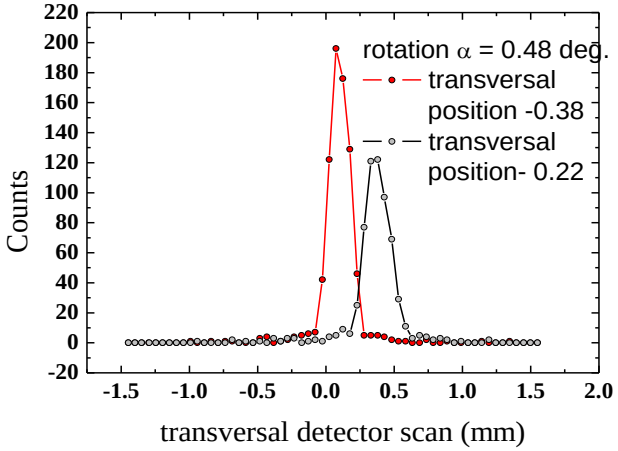


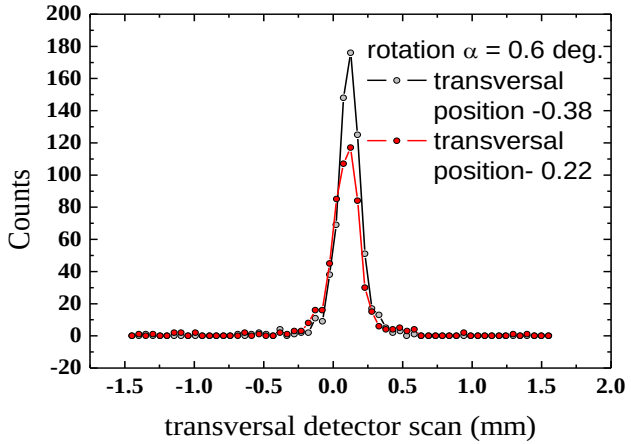
for different translation reflected beams appear at different position on detector

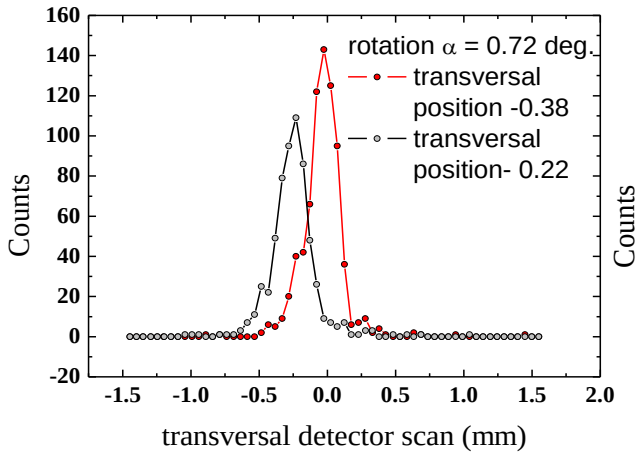
Experimental results

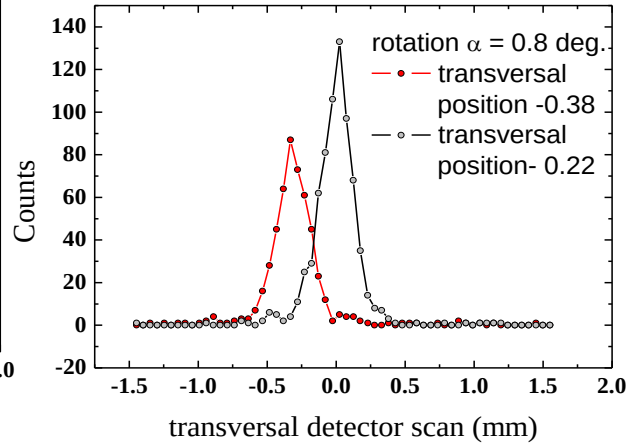


rotation matches x-shift of 2 mm
for rotation angle 0.6 deg







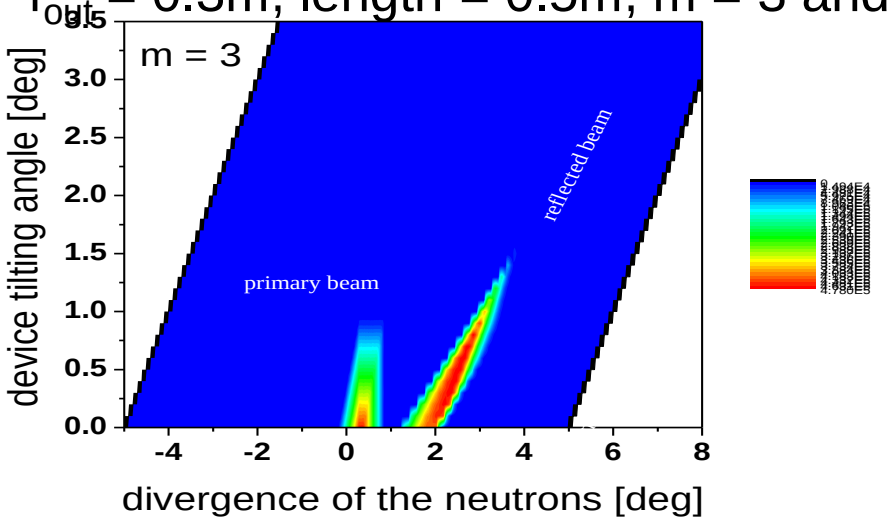


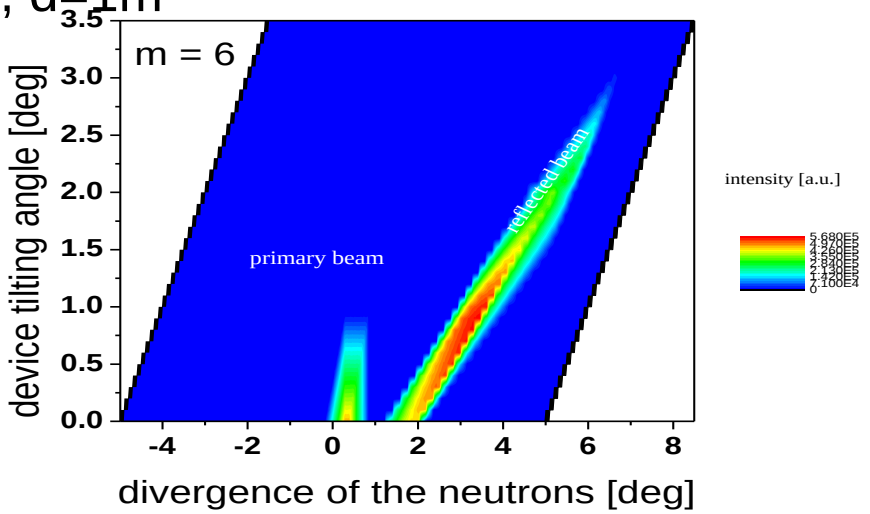
Conclusions: - one focal point observed
- the parabolic shape confirmed

Possible aplications

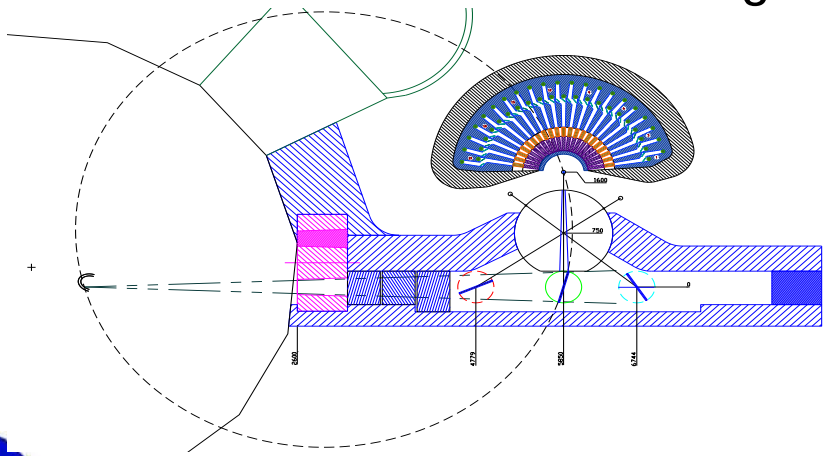
- bend beam away from primary beam by tilting component

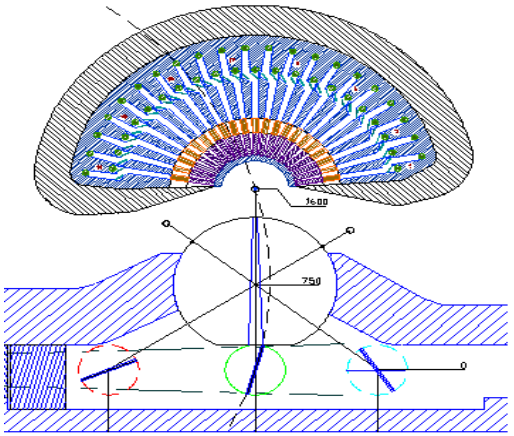
f_{out} = 0.3m, length = 0.5m, m = 3 and 6, d=1m





- MACS beamline at NIST – re-design of focusing linearly tapered guide





Acknowledgements

nmi3

Stimulus Programm

MaNEP
SWITZERLAND
Matériaux aux propriétés électroniques exceptionnelles

SwissNeutronics

Conclusions