Second Sound as diagnostic tool for SCRF cavities

Physics At The Terascale - 3rd Annual Workshop

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Felix Schlander, Hannes Vennekate

Hamburg, November 12, 2009

HELMHOLTZ | ASSOCIATION

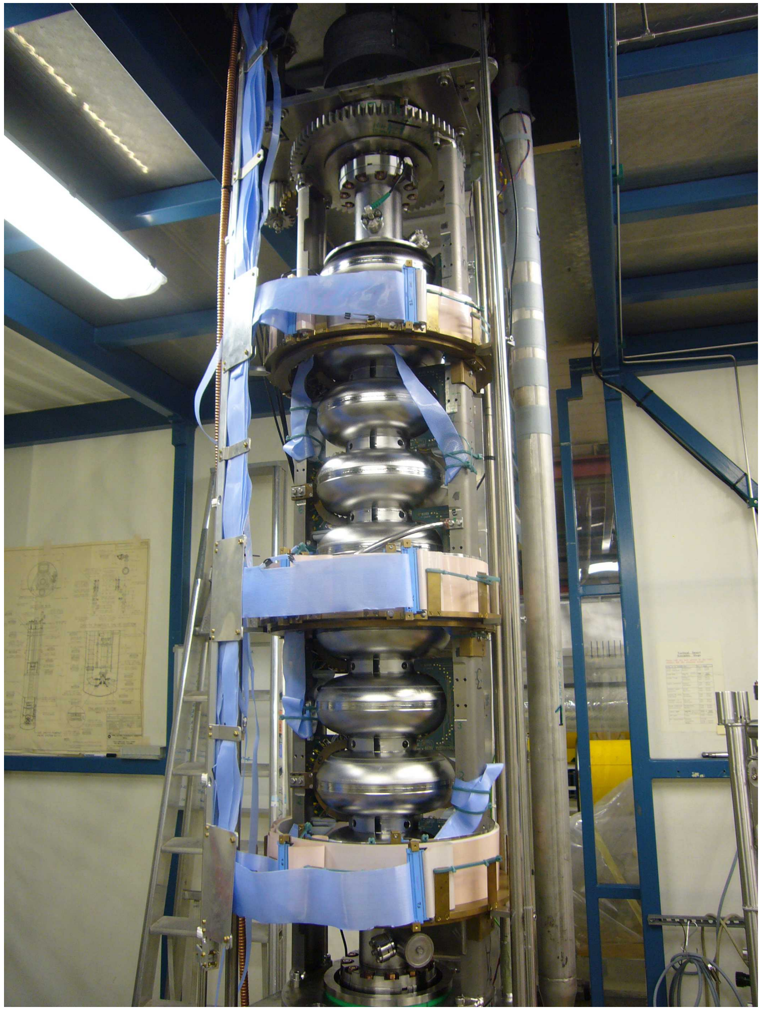
DESY

Outline

- Current detection of quench location
- Second Sound in He II
- **O**scillating **S**uperleak **T**ransducers
- Calculations for Optimization of OST-Positioning
- Outlook

Current detection of quench location

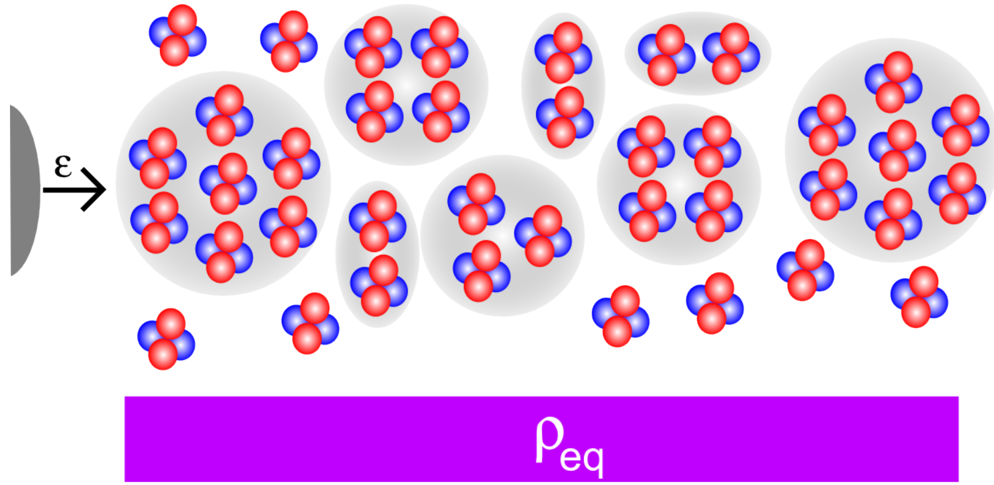
- Quench
  - Thermal breakdown
- Temperature mapping
  - Use of temperature dependent resistors
  - Common system to locate quench spots
  - Complex assembly
  - Setup has to be mounted on every single cavity to be tested
  - Demand for simpler/faster methods



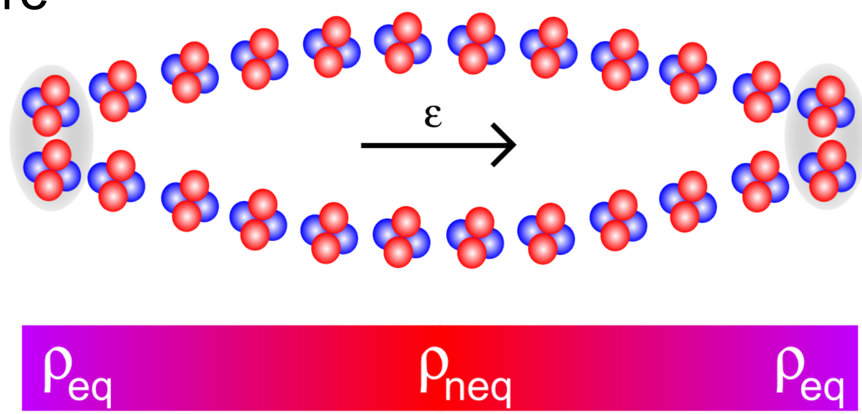
Second Sound in He II

- Two fluid model
  - 'normal' liquid helium: density ϱ_n
  - 'superfluid' helium: density ϱ_s (Bose-Einstein condensate)
- Density $\varrho_{eq} = \varrho_n + \varrho_s$ (a)
- Total flux $\vec{j} = \varrho_n \vec{v}_n + \varrho_s \vec{v}_s = 0$
- Instantaneous heating: temperature wave (b)
  - Absorption: condensate breaks to normal liquid helium
- ϱ_n increases & ϱ_s decreases > ϱ_{eq} changes locally to ϱ_{neq}
- reaching equilibrium requires (c)

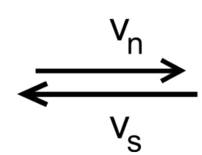
  $\vec{v}_n = -c\,\vec{v}_s$



(a)



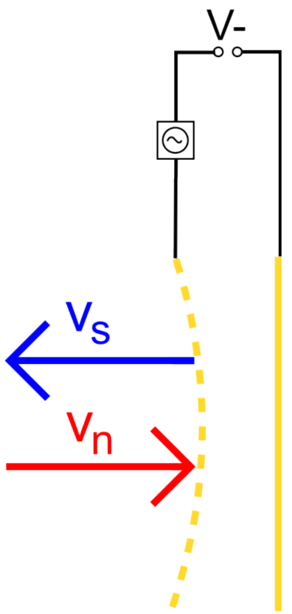
(b)



(c)

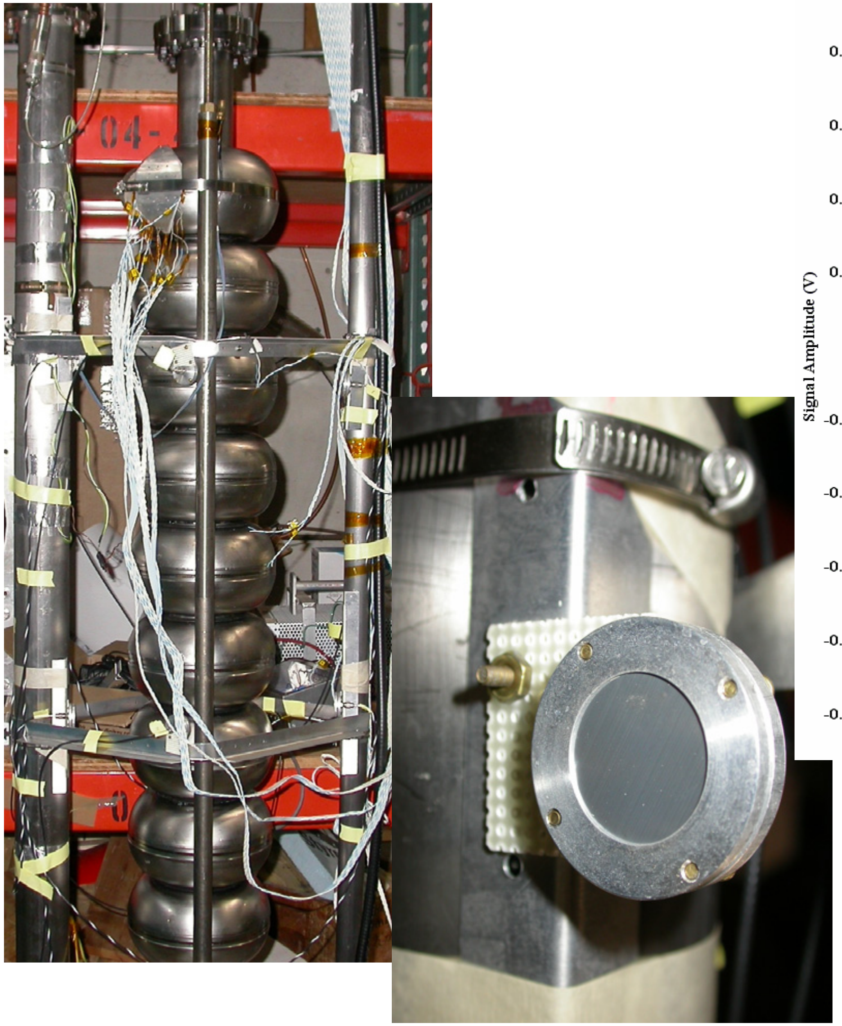
Oscillating Superleak Transducers

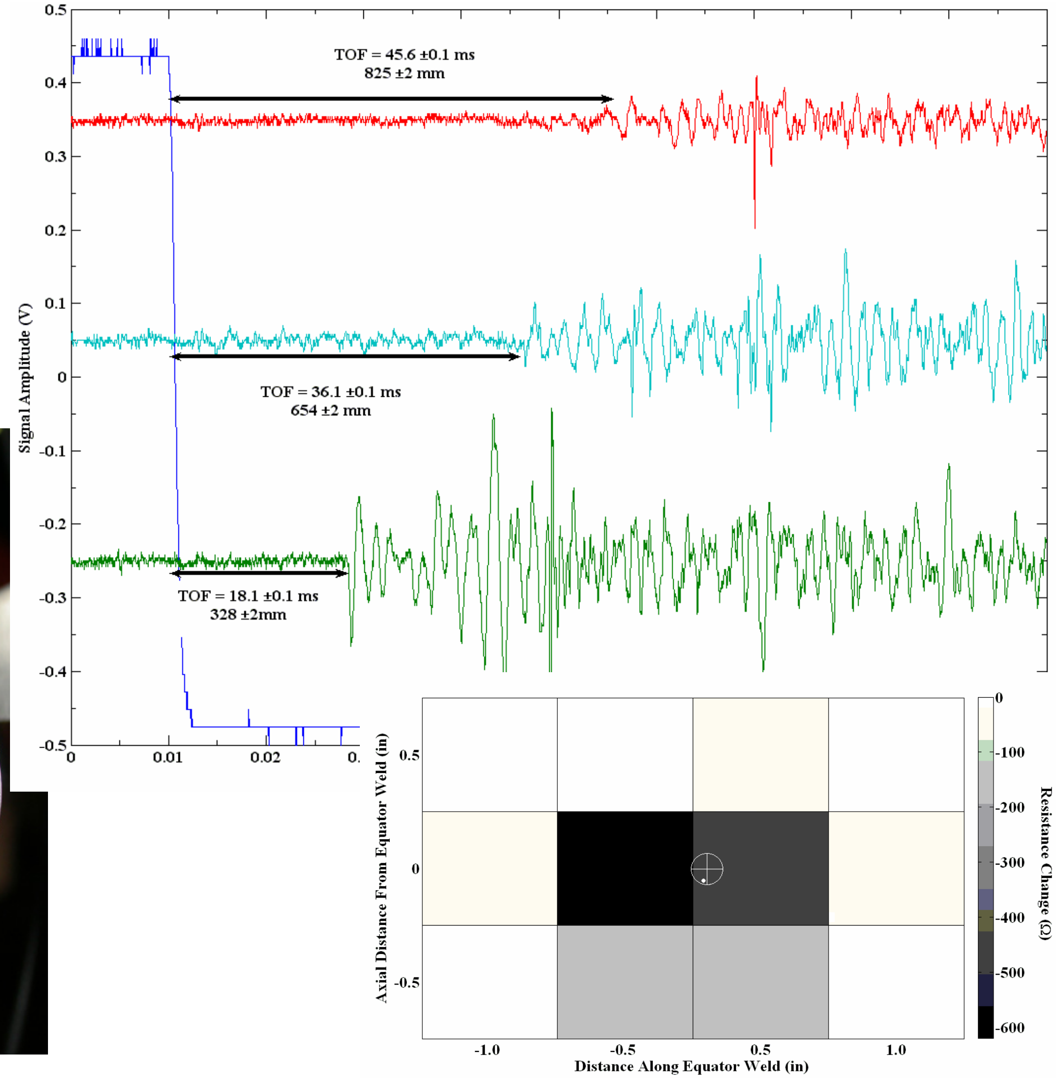
- A quenching cavity provides a heat pulse > 2nd Sound
- Transducer consists of a metal plate and a porous diaphragm with a thin layer of gold connected as capacitor
- 2nd sound wave will make the membrane oscillate
- Voltage changes can be measured
- Determination of quench location via triangulation
- A first setup and first measurements have been realized at Cornell University, USA since 2008 [1]
- Preparation for testing a similar setup at DESY



[1] Z.A. Conway et al., Oscillating Superleak Transducers for quench detection in superconducting ILC cavities cooled with He-II

Setup and measurements at Cornell University [1]





[1] Z.A. Conway et al., Oscillating Superleak Transducers for quench detection in superconducting ILC cavities cooled with He-II

Calculations for Optimization of OST-Positioning

Hannes Vennekate, Michael Uhrmacher, Arnulf Quadt,

2nd Institute of Physics,
Georg-August-Universität Göttingen

with

Felix Schlander, Eckhard Elsen,

DESY, Hamburg

Bundesministerium
für Bildung
und Forschung

Physics at the Terascale
3rd Annual Workshop

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

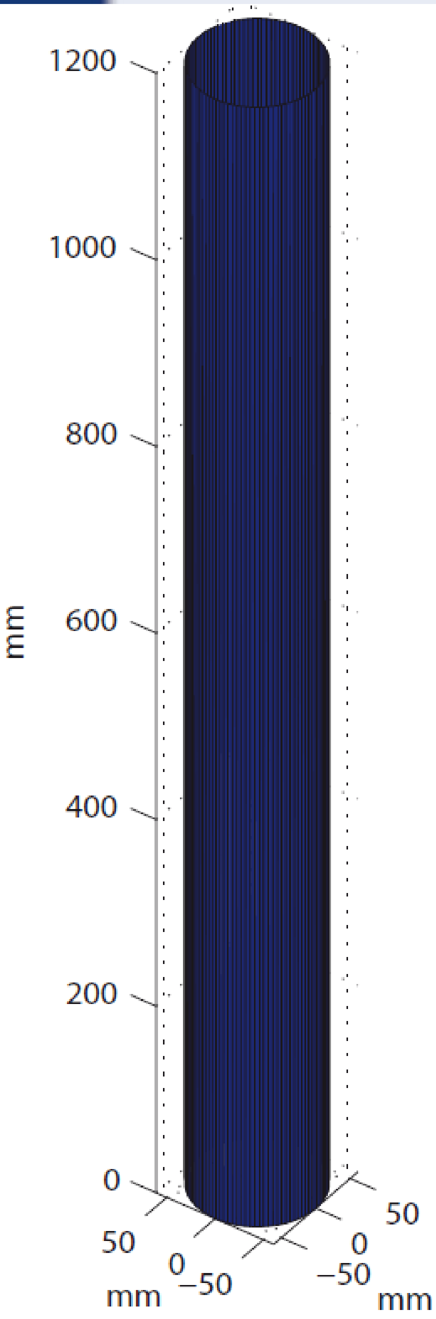
Goals of the calculations and optimizations were:

1. to create essentials of a numerical routine, describing the TESLA cavities,
2. to design a basic setup of a cavity and OST-detectors,
3. to simulate quench spots and 2nd Sound signals,
4. (to estimate errors in the signals and their propagation and)
5. to reconstruct the quench spots using only the 2nd Sound signals.

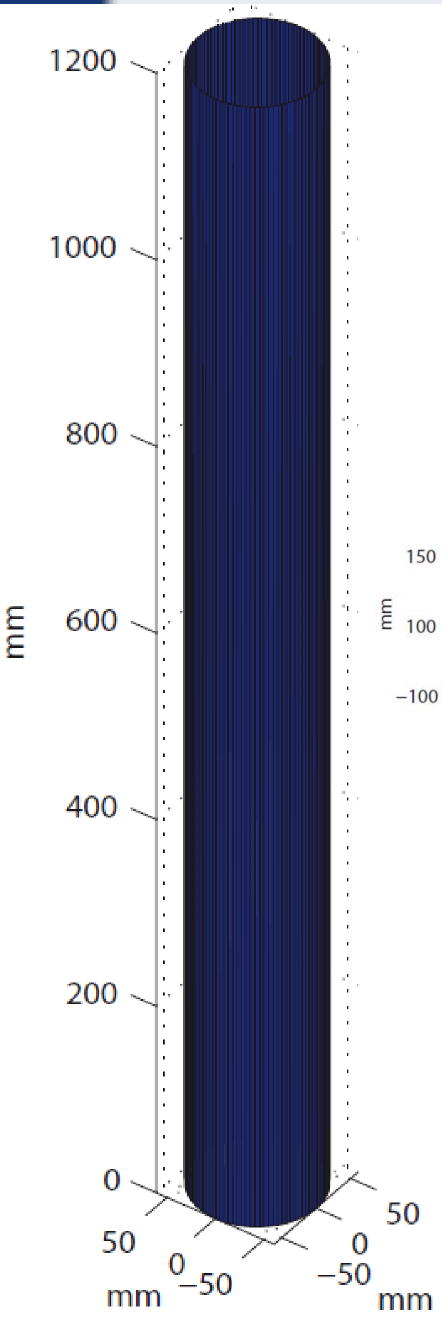
Goals of the calculations and optimizations were:

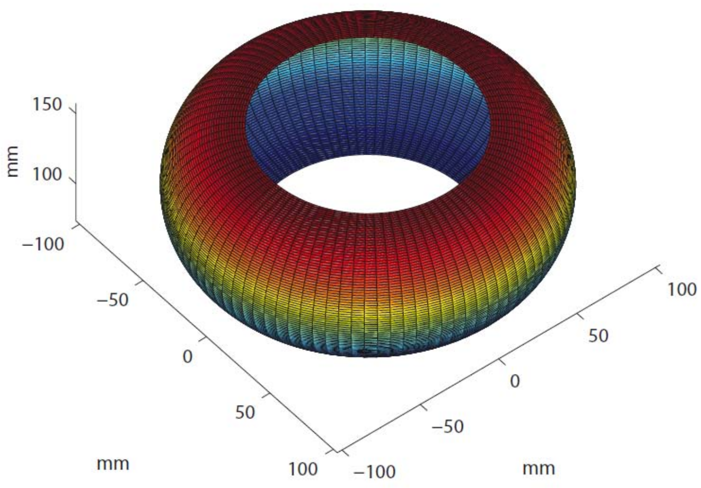
1. to create essentials of a numerical routine, describing the TESLA cavities,
2. to design a basic setup of a cavity and OST-detectors,
3. to simulate quench spots and 2nd Sound signals,
4. (to estimate errors in the signals and their propagation and)
5. to reconstruct the quench spots using only the 2nd Sound signals.

➔ A brainstorm in a sandbox model

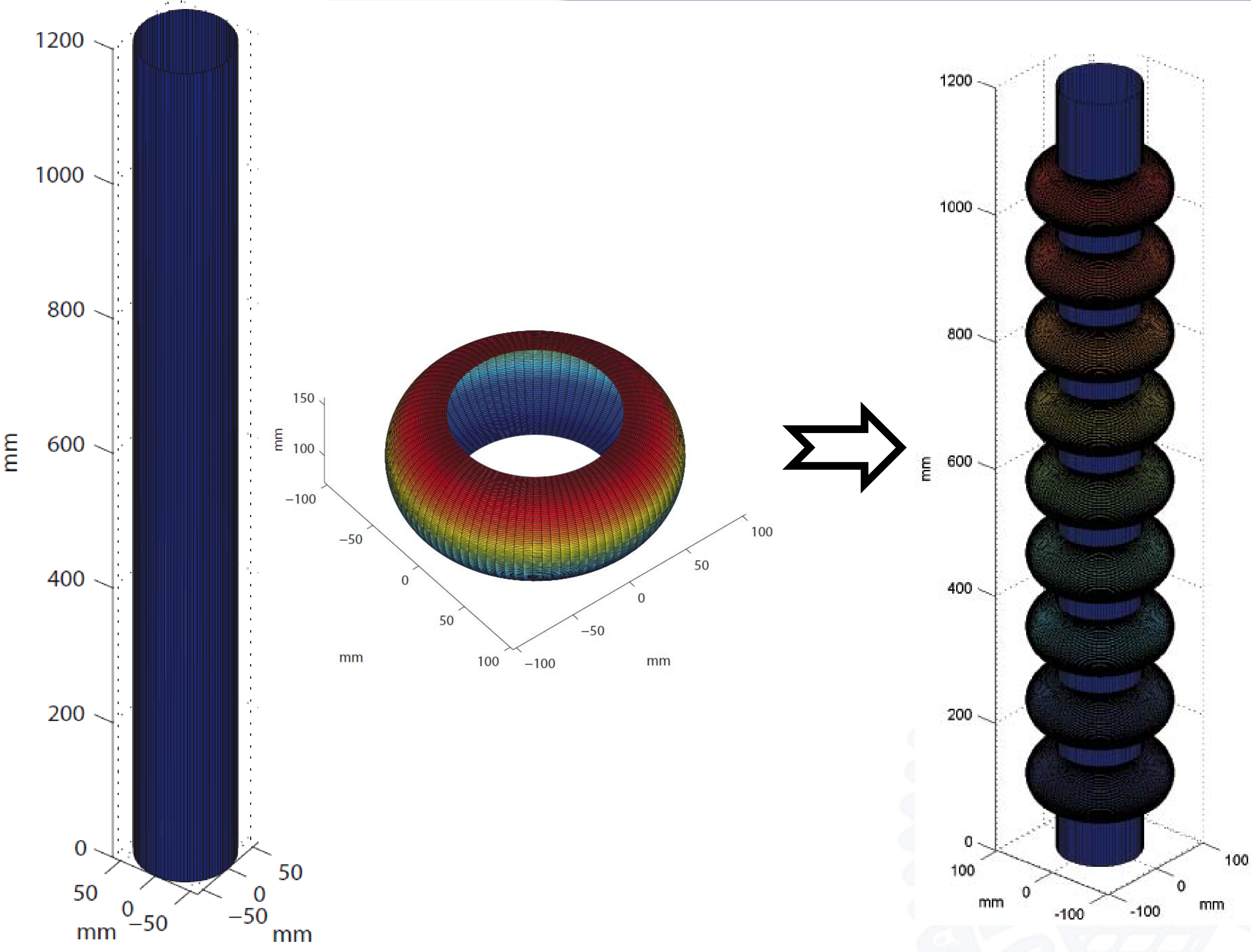

1200
1000
800
600
400
200
0
mm
50
0
−50
mm
50
0
−50
mm

Calculations for Optimization of OST-Positioning

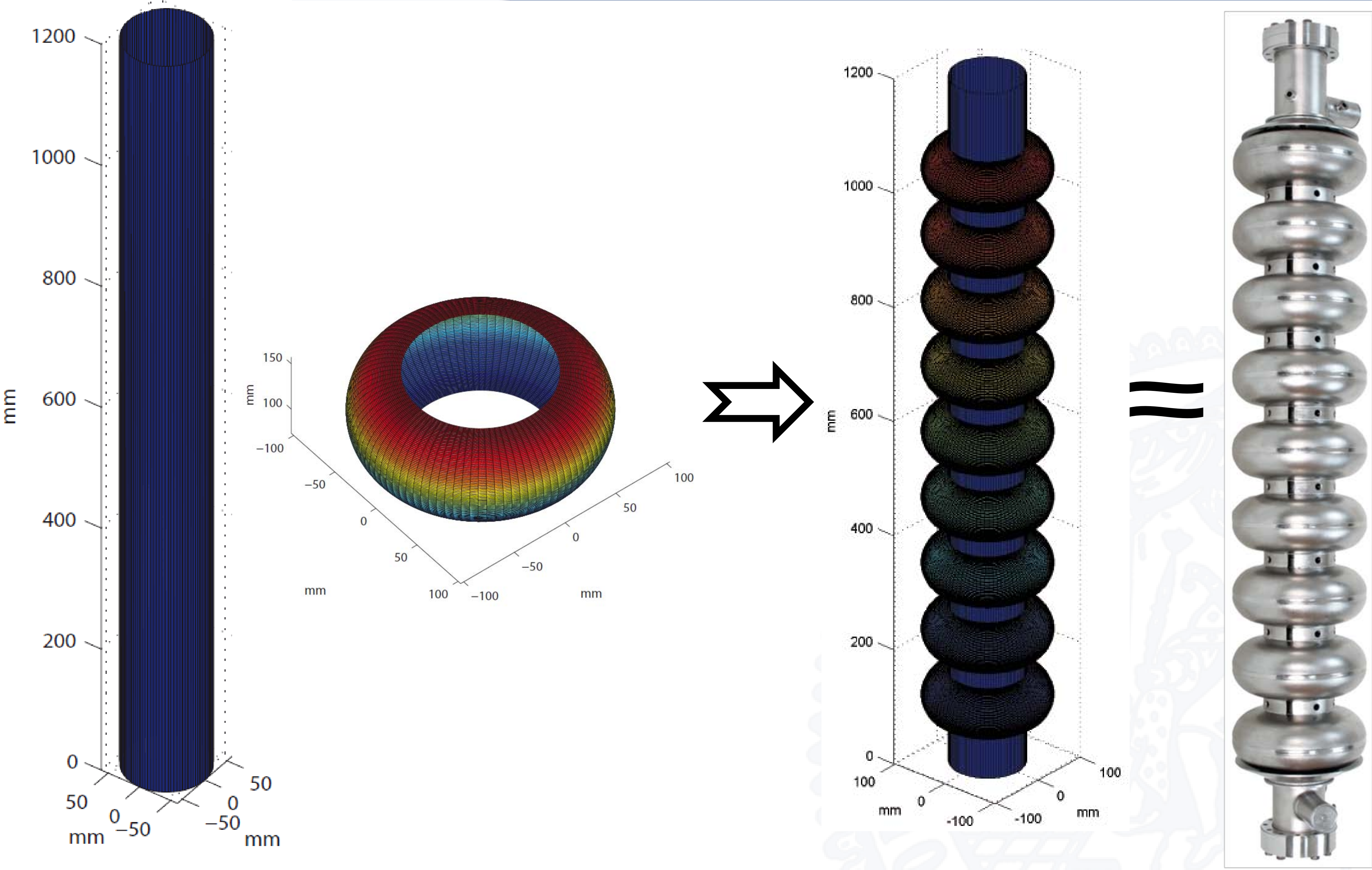




Calculations for Optimization of OST-Positioning



Calculations for Optimization of OST-Positioning

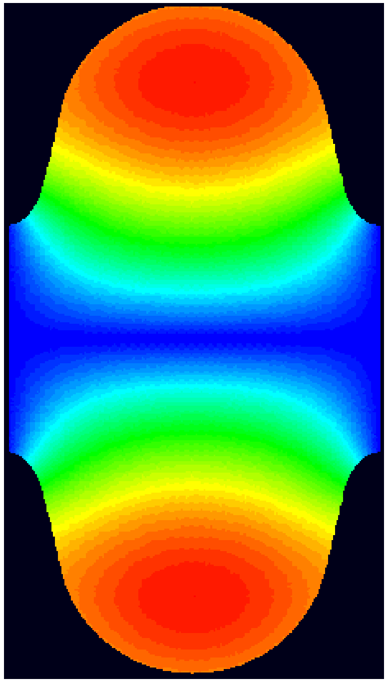


- **Location of sources in critical regions**
  a) Cell's welding seam
  b) Peak of accelerating and magnetic field

➔ Normal distribution around cell's equator

a)

b)

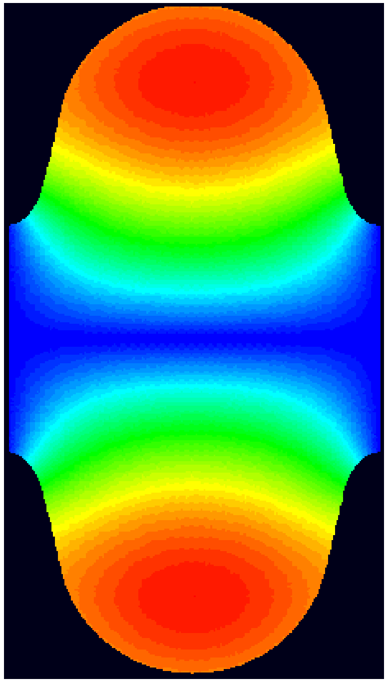


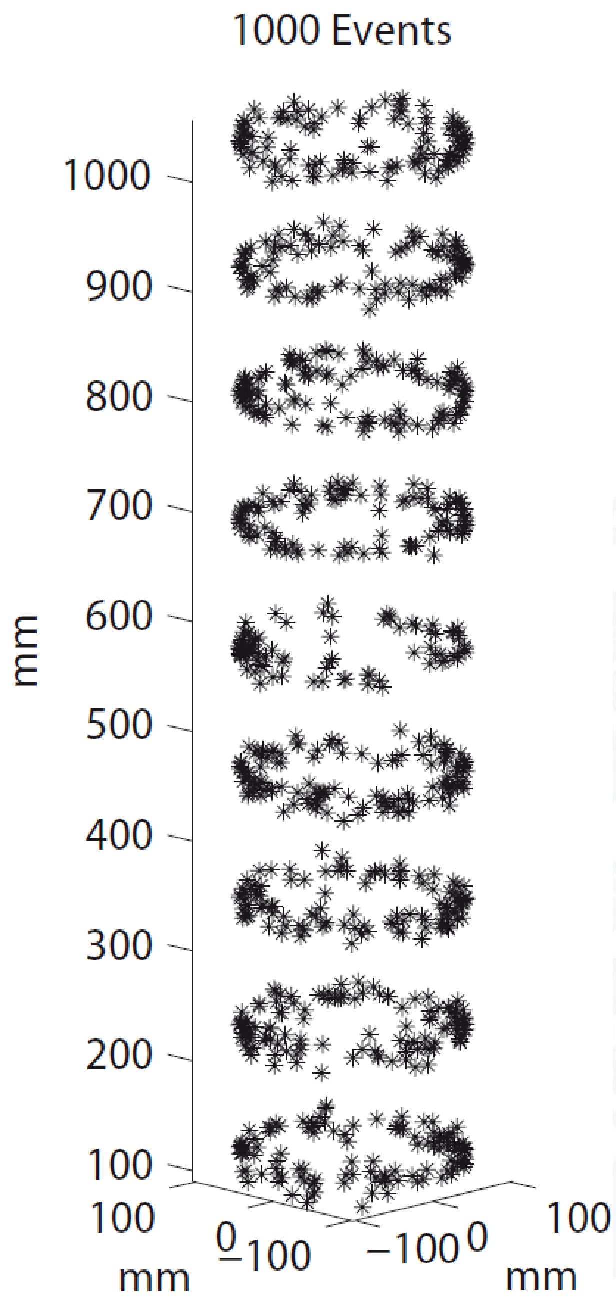
- **Location of sources in critical regions**
  a) Cell's welding seam
  b) Peak of accelerating and magnetic field

➔ Normal distribution around cell's equator

a)

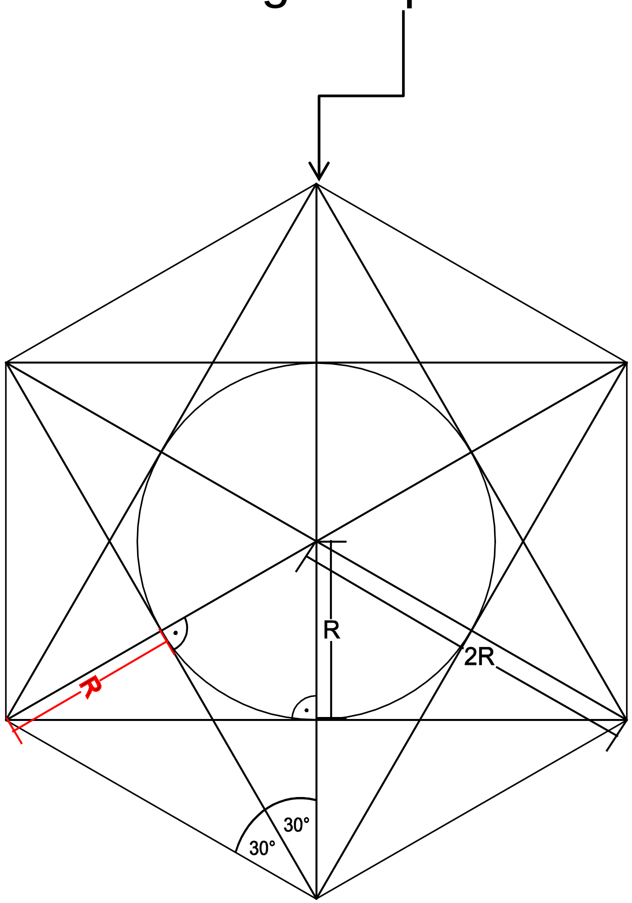
b)





Limitations for detectors:

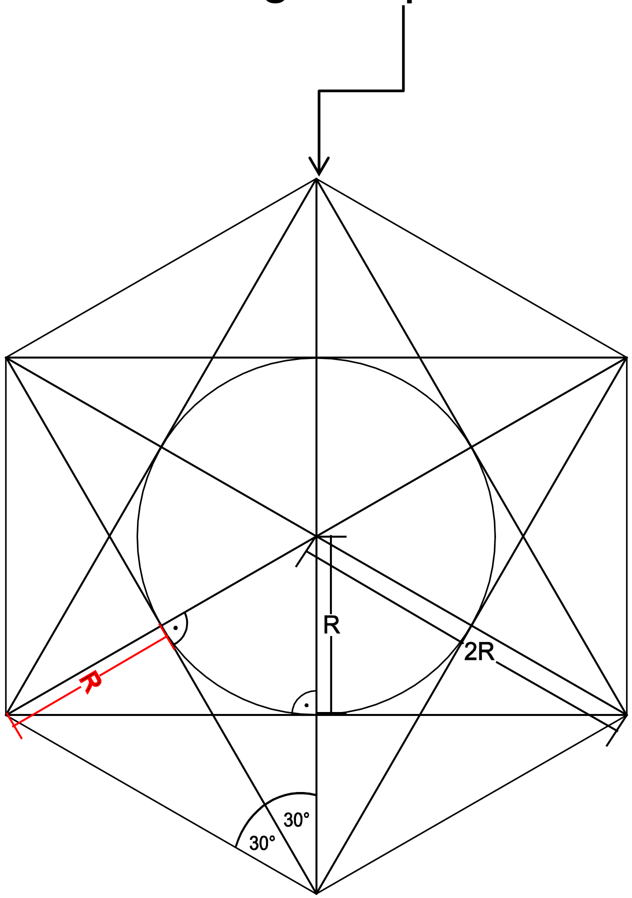
- Detectors only on top and bottom of the Helium tank
- Distance = double cell radius (206 mm)
- Six detectors necessary for
  two signals per event (12 dets total)



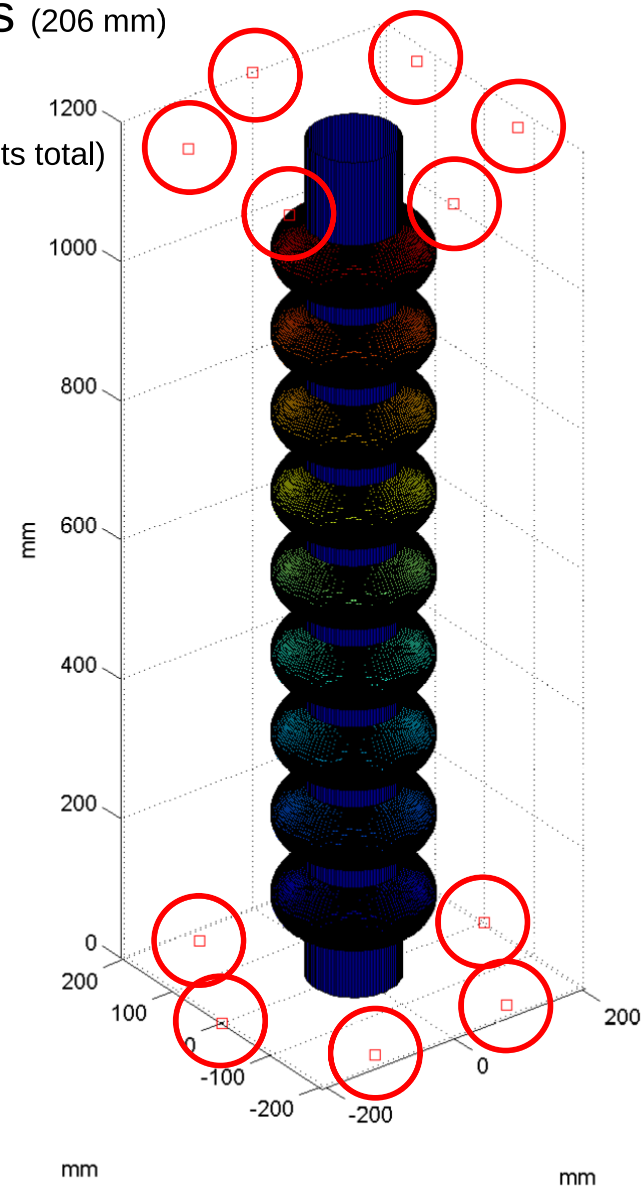
Cavity and detectors in 2D

Limitations for detectors:

- Detectors only on top and bottom of the Helium tank
- Distance = double cell radius (206 mm)
- Six detectors necessary for
  two signals per event (12 dets total)

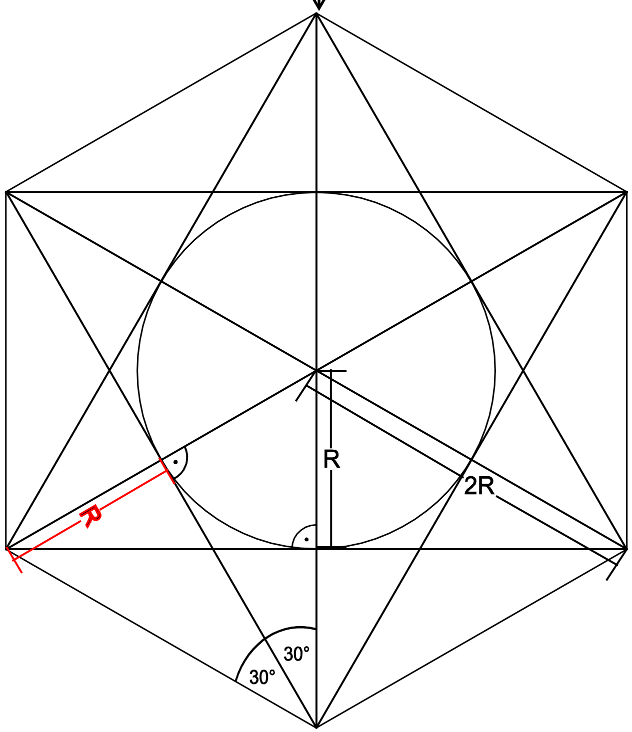


Cavity and detectors in 2D

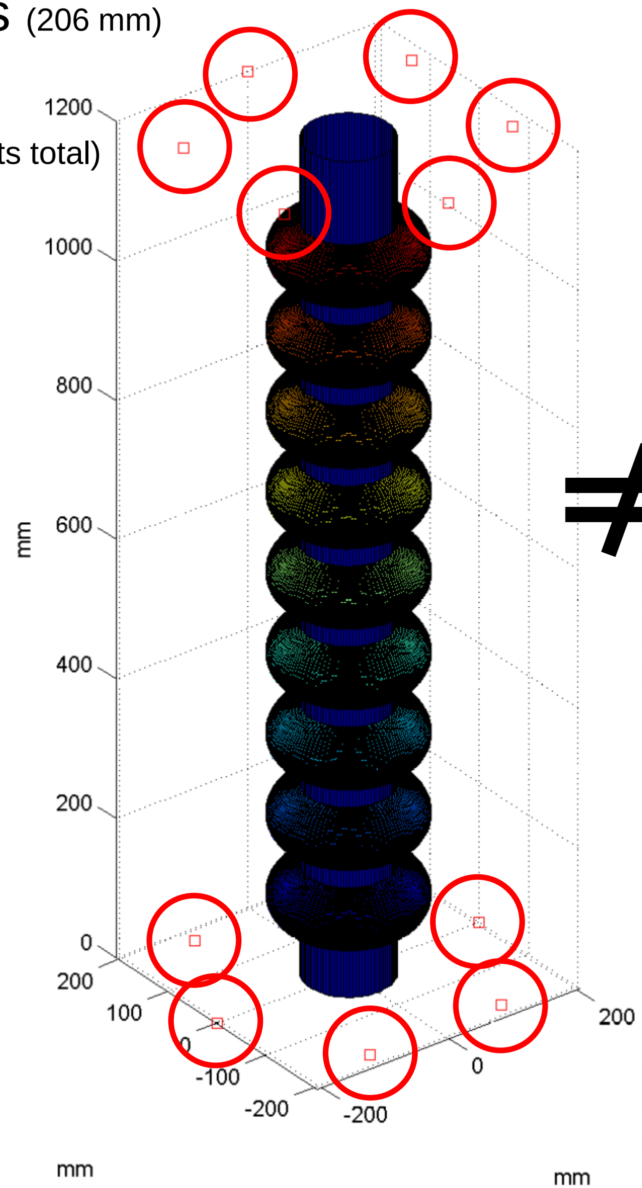


Limitations for detectors:

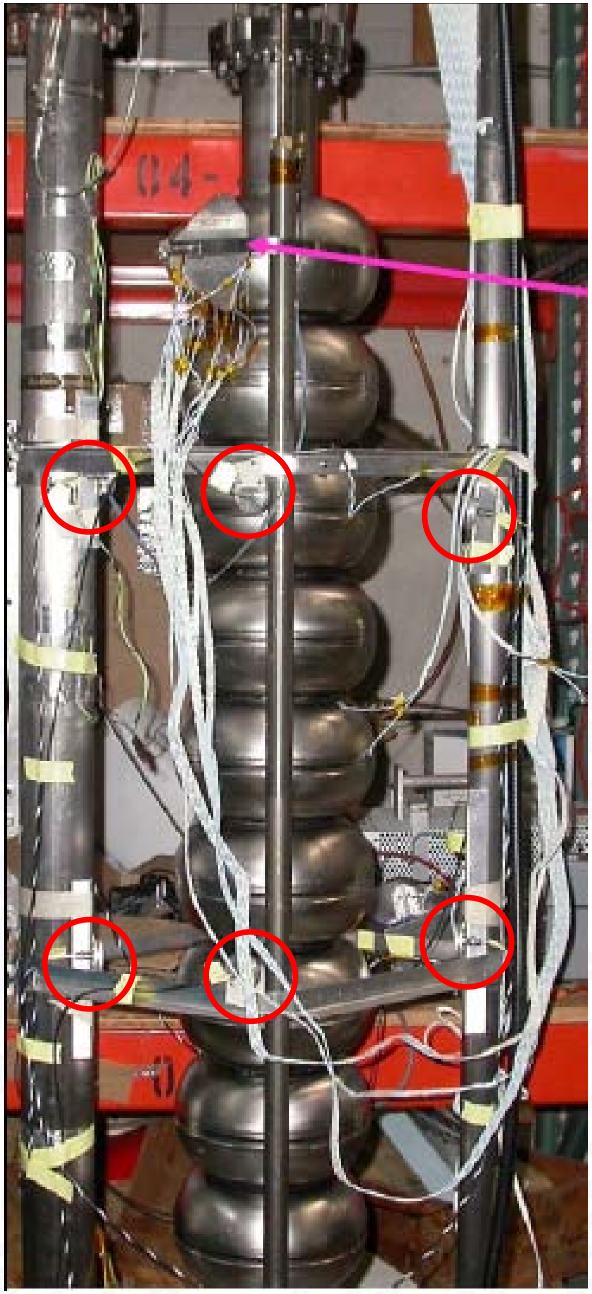
- Detectors only on top and bottom of the Helium tank
- Distance = double cell radius (206 mm)
- Six detectors necessary for two signals per event (12 dets total)



Cavity and detectors in 2D



≠



Only direct lines of sight:

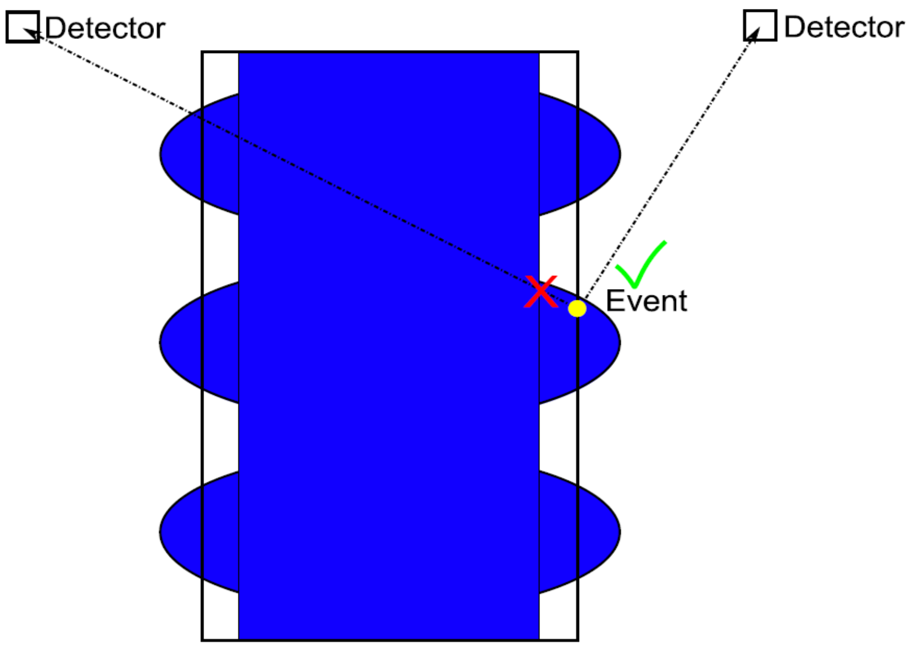
1. Compute all traces
2. Trace elimination:
   a) Cylinder rule
   b) Next cell rule
   c) Wave propagation

Calculations for Optimization of OST-Positioning

Only direct lines of sight:

1. Compute all traces
2. Trace elimination:
   a) Cylinder rule
   b) Next cell rule
   c) Wave propagation

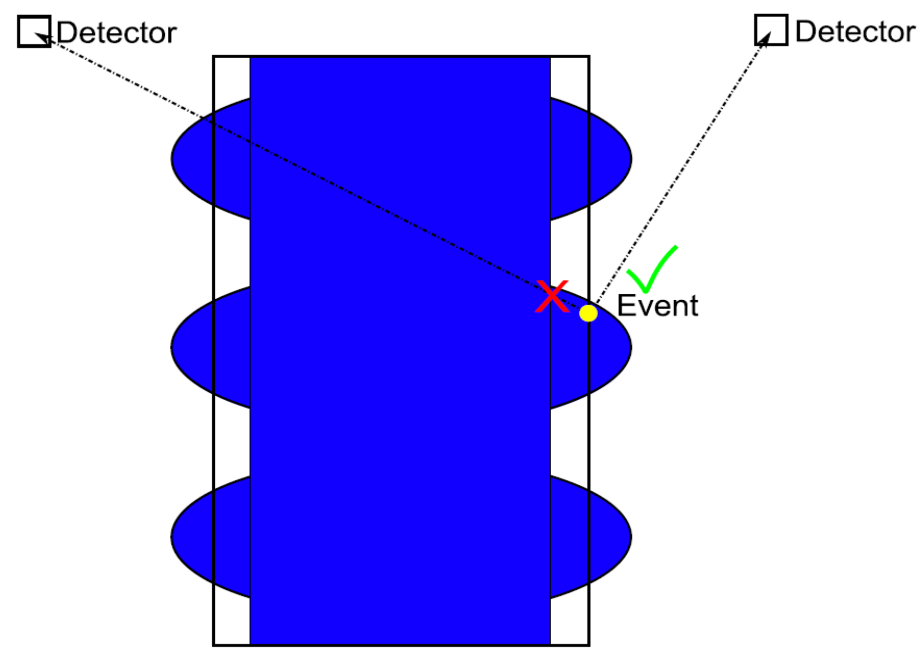
a)



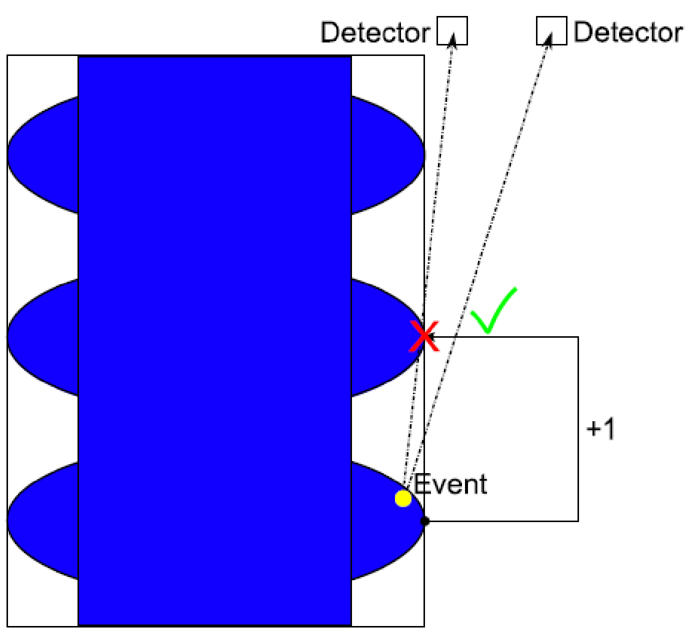
Only direct lines of sight:

1. Compute all traces
2. Trace elimination:
   a) Cylinder rule
   b) Next cell rule
   c) Wave propagation

a)



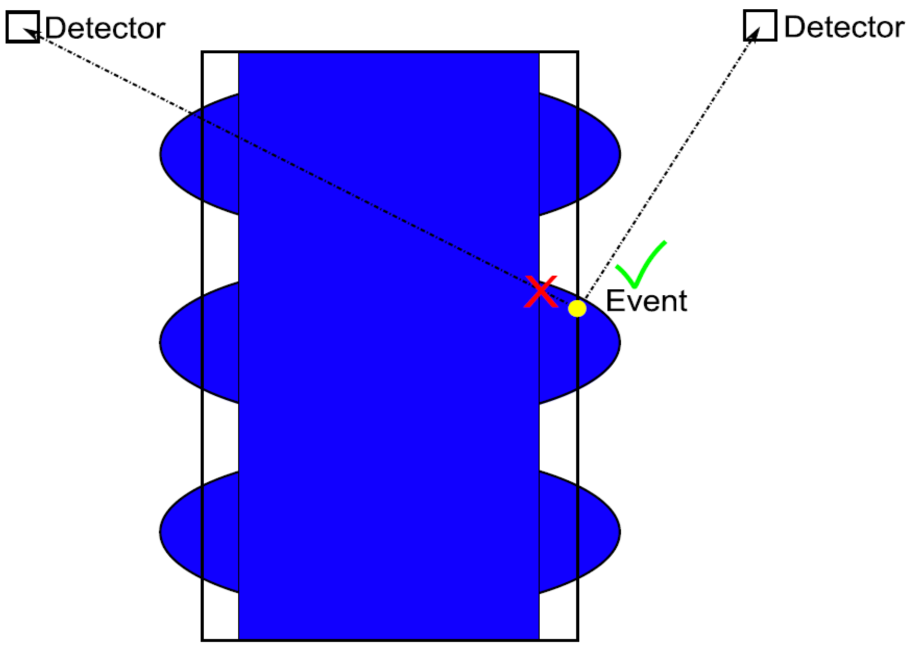
b)



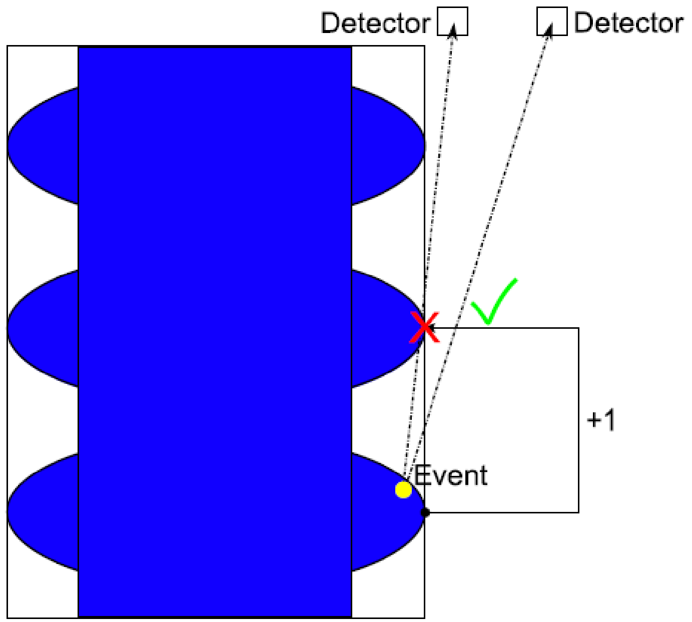
Only direct lines of sight:

1. Compute all traces
2. Trace elimination:
   a) Cylinder rule
   b) Next cell rule
   c) Wave propagation

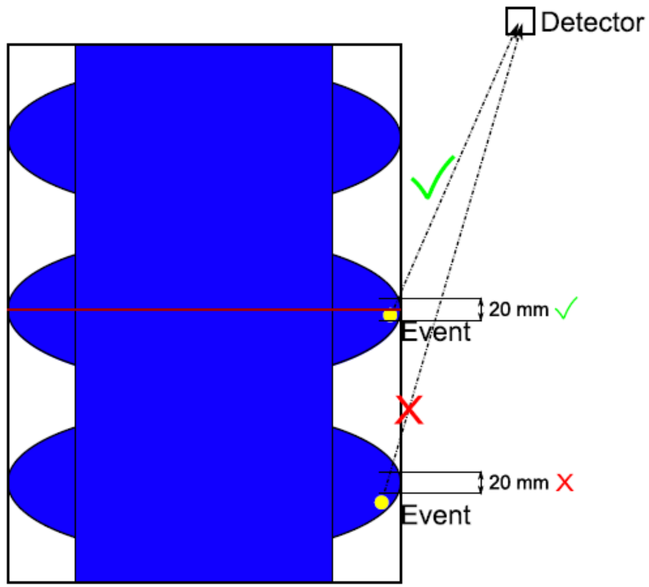
a)



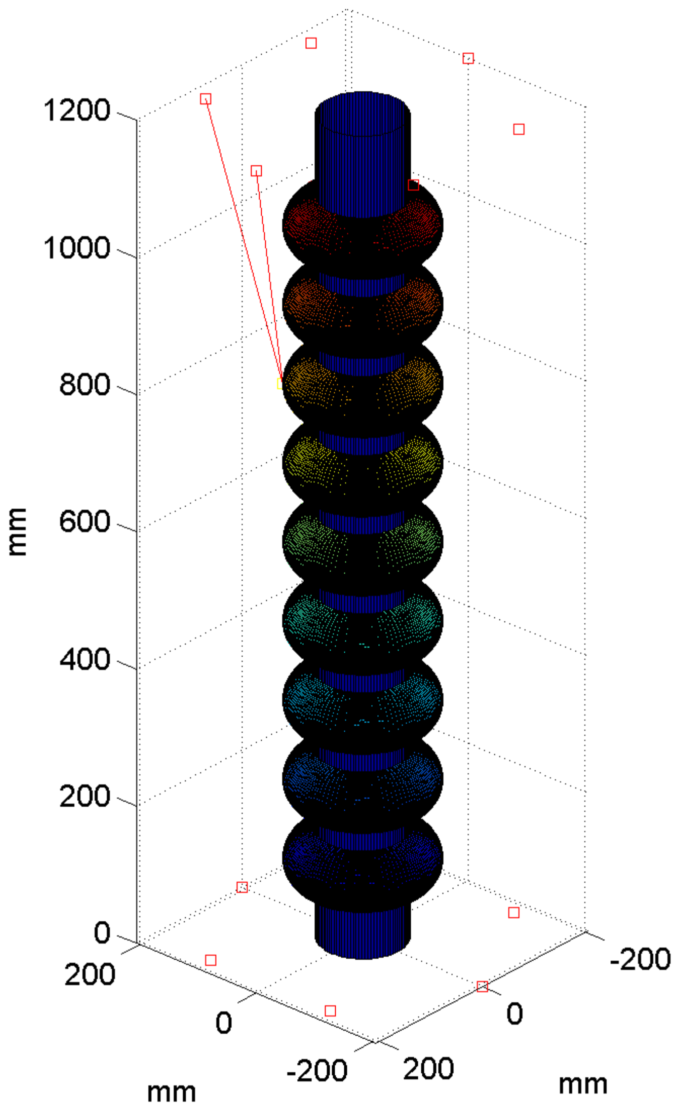
b)

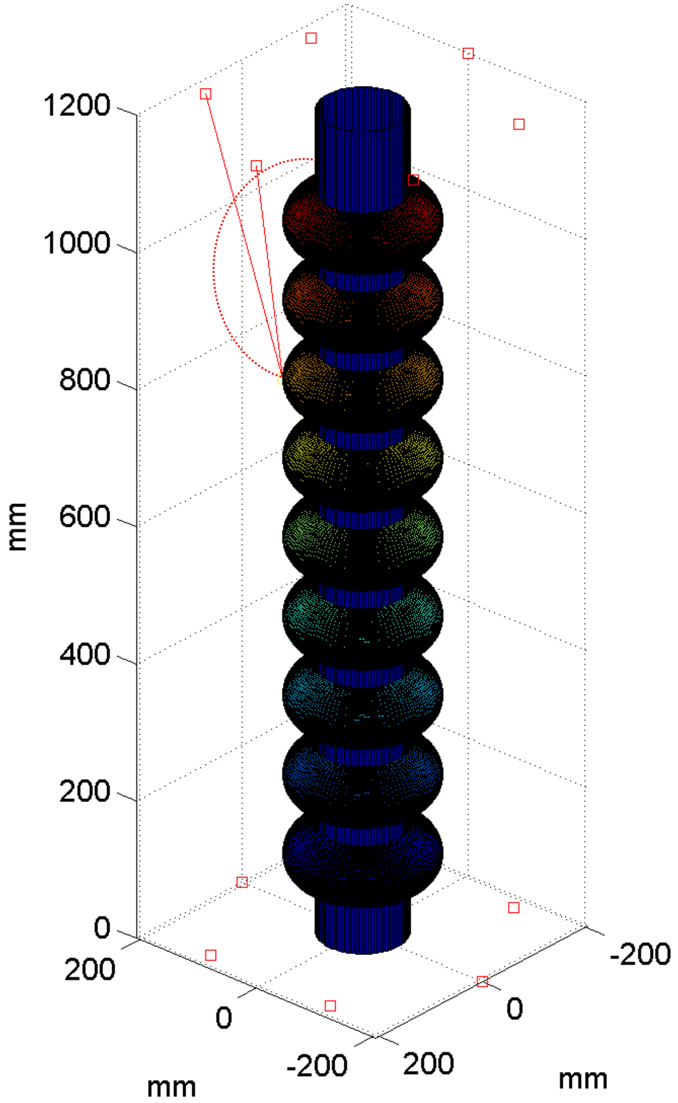


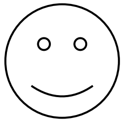
c)



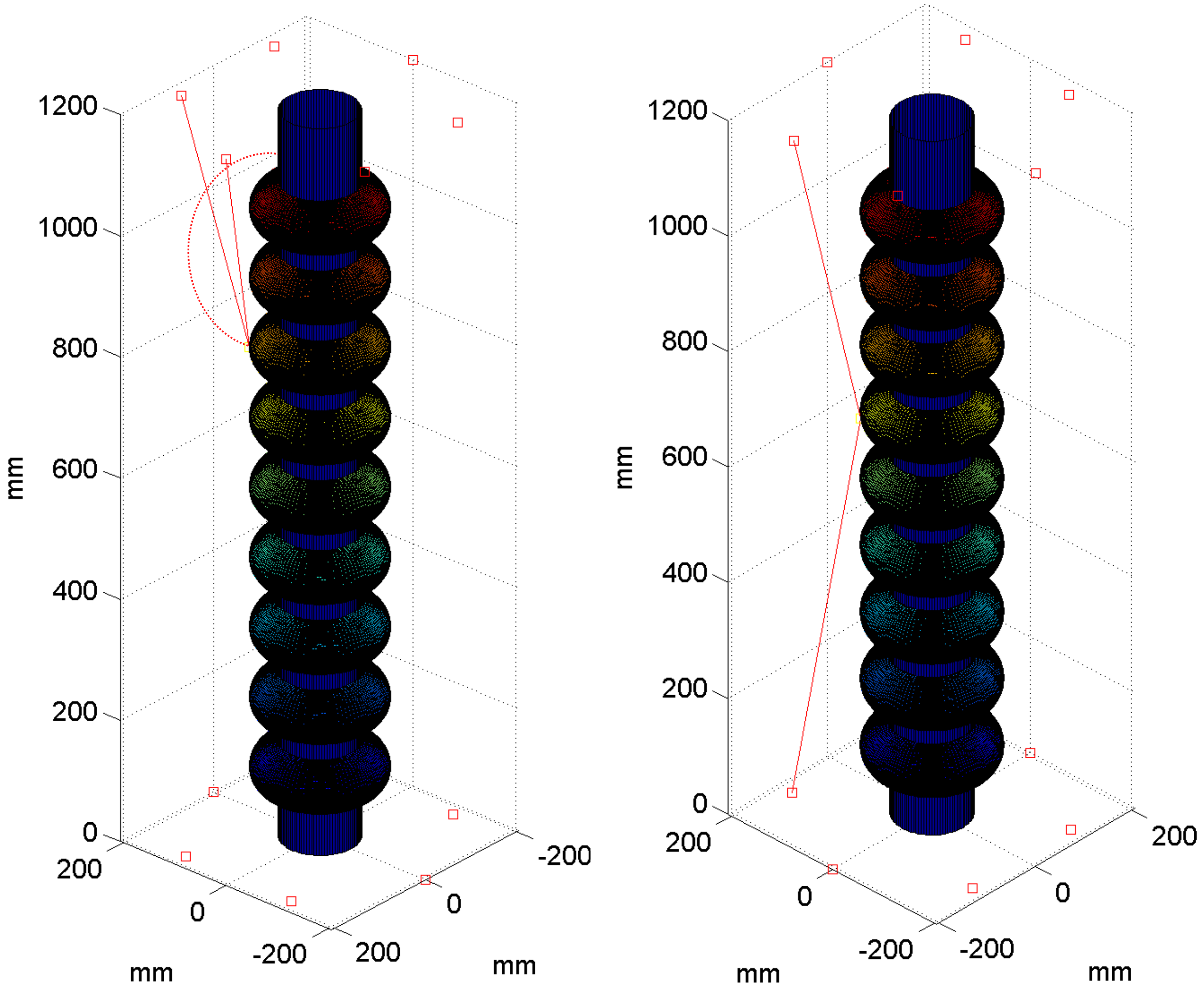
Calculations for Optimization of OST-Positioning

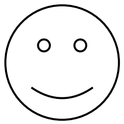



1200
1000
800
600
400
200
0
mm
200
0
-200
mm
-200
0
200
mm

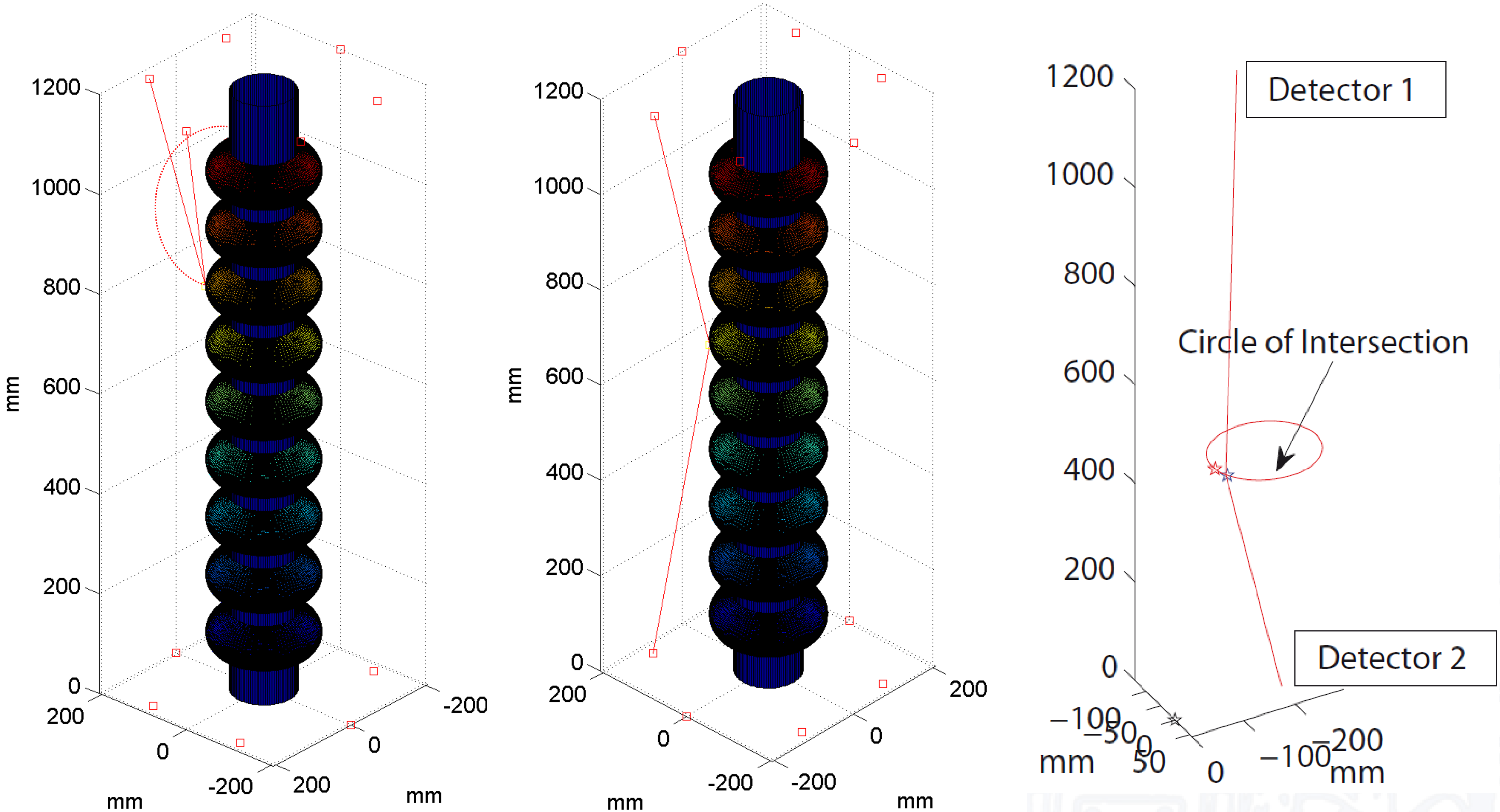


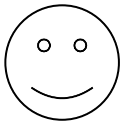
Calculations for Optimization of OST-Positioning



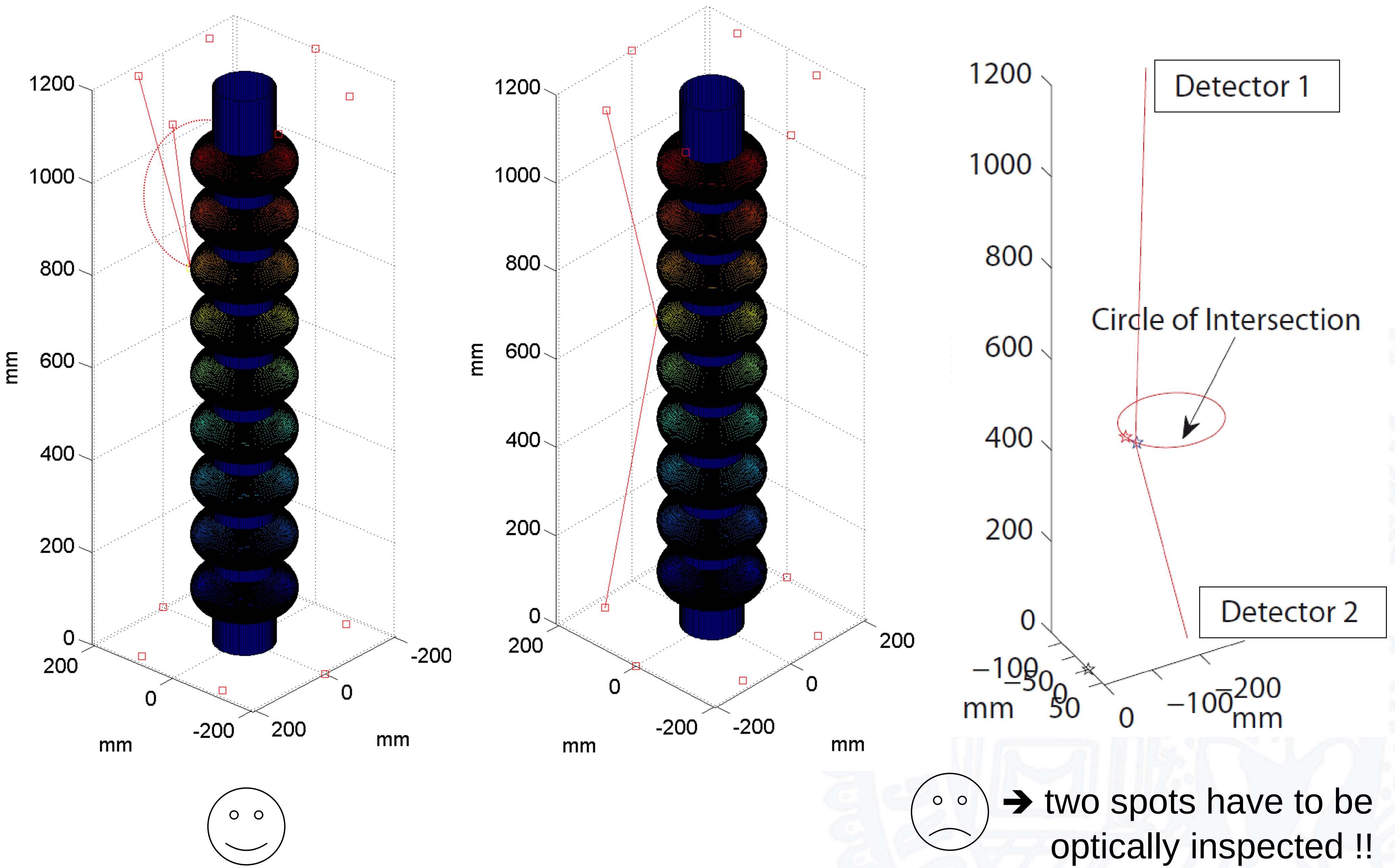


Calculations for Optimization of OST-Positioning



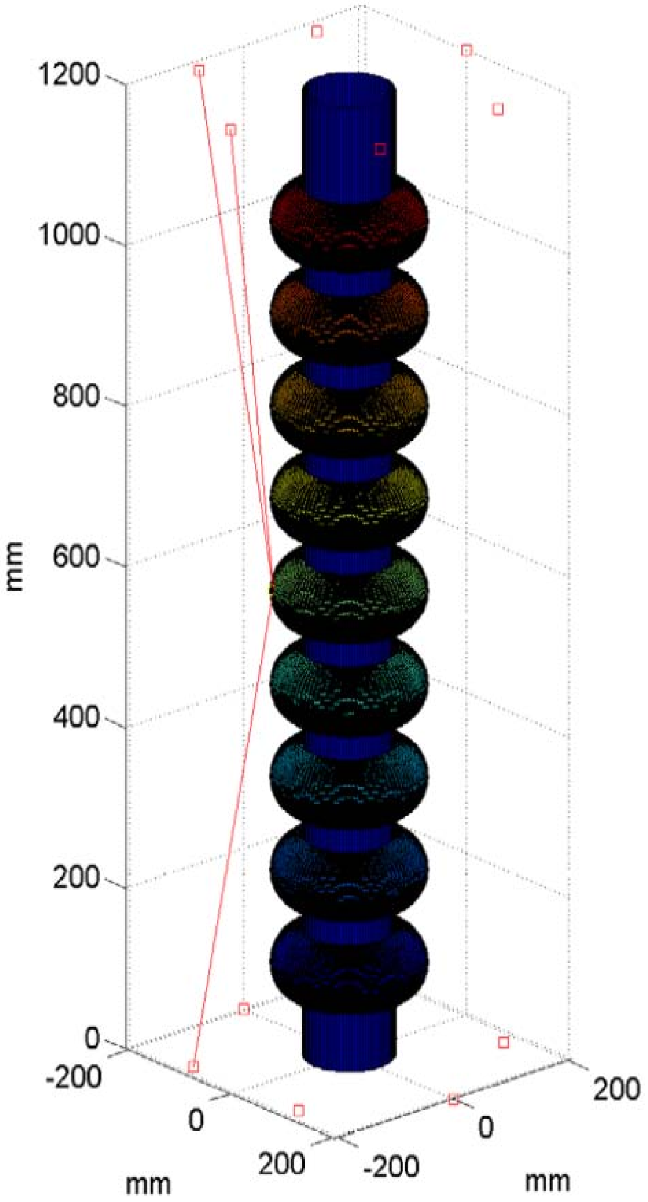


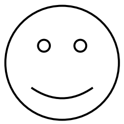
Calculations for Optimization of OST-Positioning



➔ two spots have to be optically inspected !!

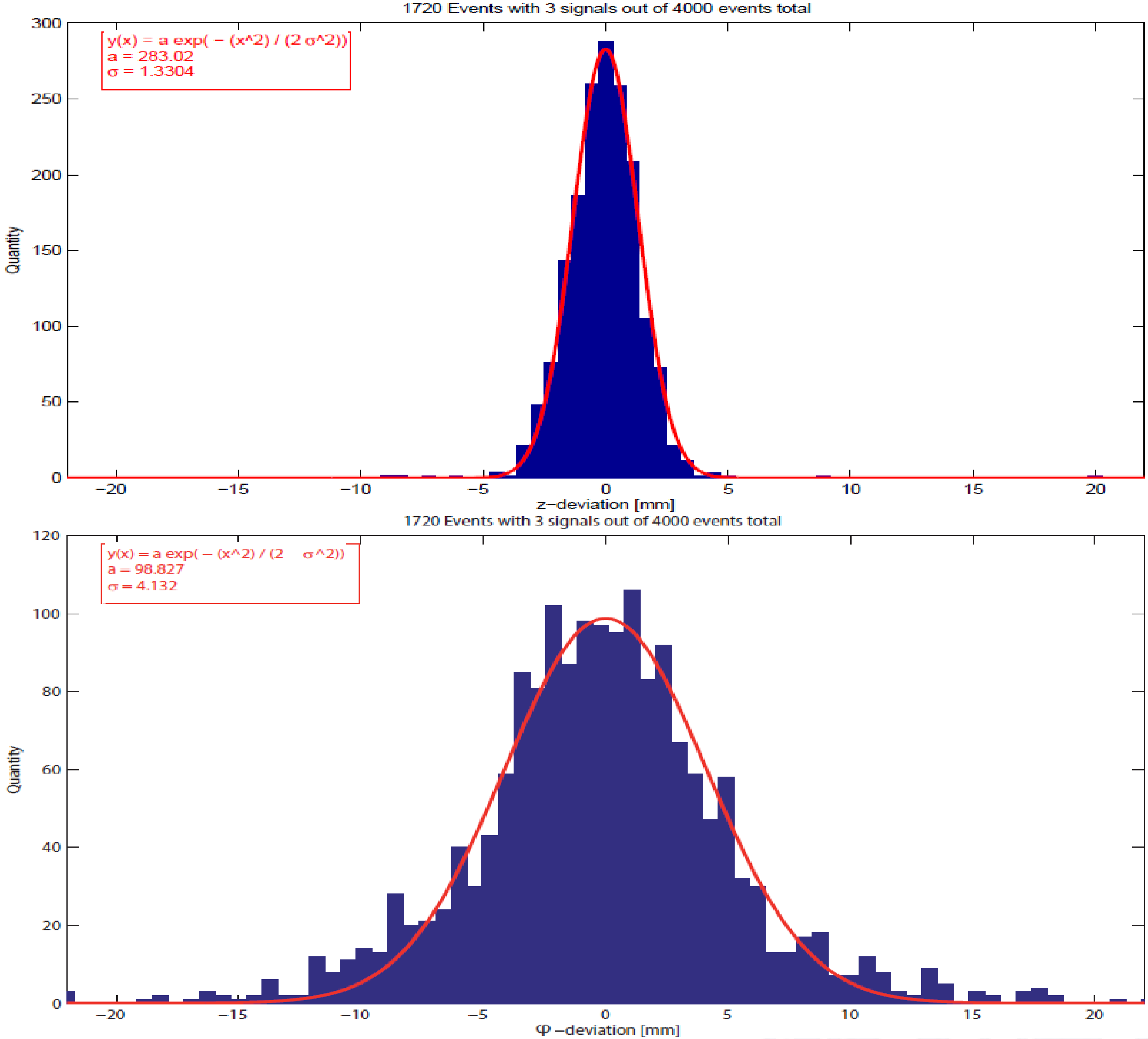
Calculations for Optimization of OST-Positioning





- Due to wave propagation more signals
- Method of the “least squares” returns a point
- Find closest point on cavity’s surface

Calculations for Optimization of OST-Positioning



Resolution for 3 signals

Results are:

1. A simple numerical routine has been created.
2. Basic geometry consists of six OST's on top and bottom of the He-tank.
3. Critical regions are close to the cell's equator and can be detected using only direct lines of sight.
4. 98,8% of quench spots reconstructed, accuracy of $\Delta z \approx 1{,}5$ mm, $\Delta \varphi \approx 4{,}5$ mm.
5. This way of OST-mounting allows a much higher testing-frequency (~ *one cavity per day*) than the contemporary temperature mapping.

Outlook:

1. Consider a four cavity geometry in one tank
2. Try to deal with the reflected sound (use damping info)
3. Commissioning of the transducer electronics
4. Tests of the OSTs themselves

   ➔ Realize the experimental setup
5. Automatic optical inspections (different wavelength)
6. Combine the 2nd Sound analysis and optical inspection

For references and more detailed information, please regard:
Publications 2nd Institute of Physics University of Göttingen

For references and more detailed information, please regard:

Publications 2nd Institute of Physics University of Göttingen

(should be available soon)

Hannes Vennekate

II. Physikalisches Institut

— Universität Göttingen —

Bachelor Thesis:

Second Sound as Cavity Diagnostic Tool

Zweiter Schall zur Diagnose von Kavitäten

by Hannes Vennekate

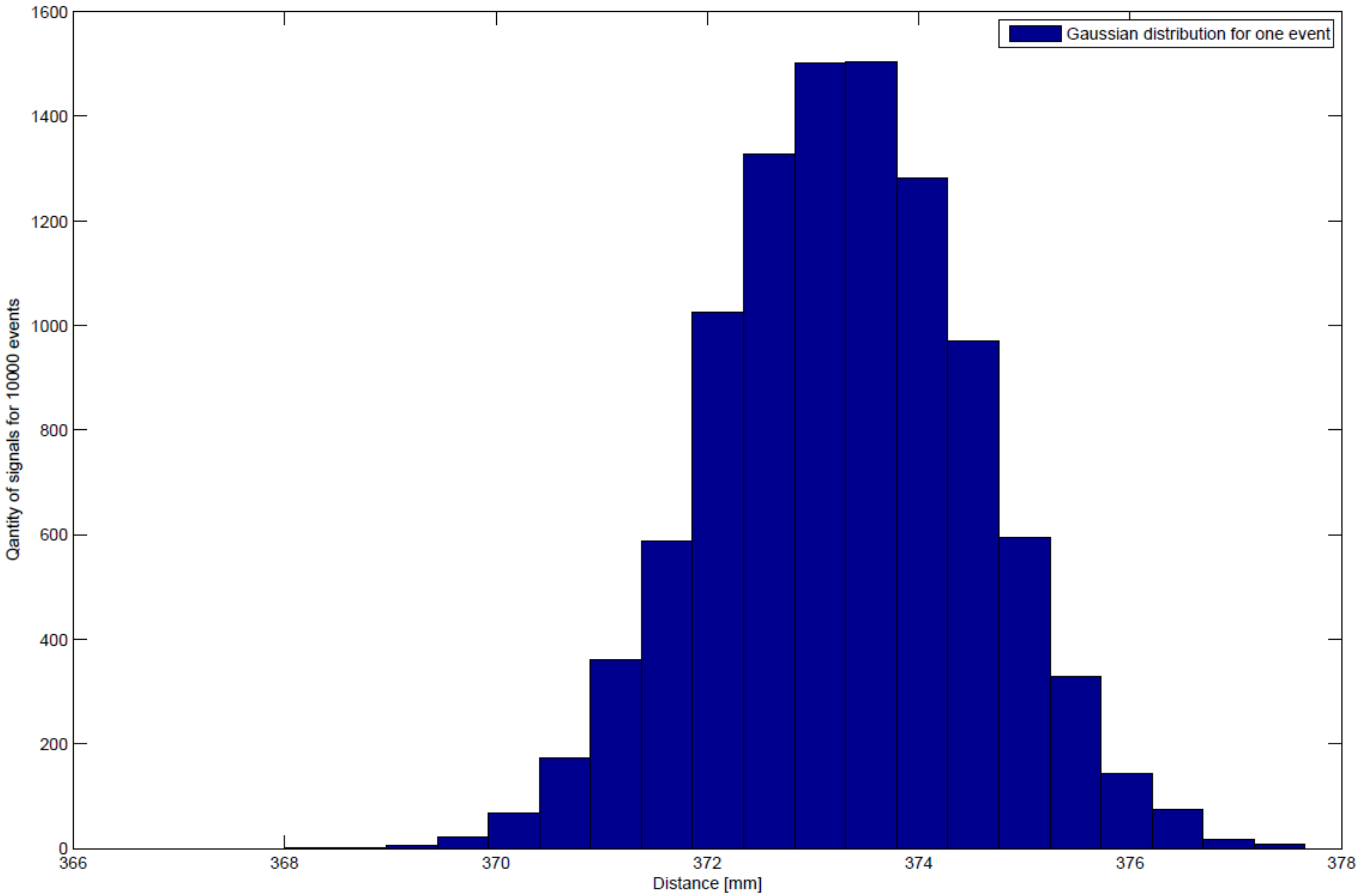
II.Physik-UniGö-Bach-2009/04

Working Time:	April, 14^{th} – July, 20^{th} 2009
Advisor:	Dr. Michael Uhrmacher
First Referee:	Prof. Dr. Arnulf Quadt
Second Referee:	Prof. Dr. Ariane Frey
External Referee:	Prof. Dr. Eckhard Elsen

Errors in the signal are important:

- Distance/“time of flight” dependent error
- Assumption: $\delta = 4\,mm \exp\left({}^{\text{distance [mm]}}/_{1000\text{ mm}}\right)$

+ Normal distribution:



Error distribution for one event with a distance value of ≈ *372.5mm. The error* for the *same* event has been generated 1000 times. This shows the gaussian distribution of the error.