A LASER SYSTEM TO MONITOR THE LS TRANSPARENCY

Gefördert durch DFG Deutsche Forschungsgemeinschaft

ON BRHALF OF THE JUNO FORSCHERGRUPPE

DFG MEETING - HAMBURG, SEPTEMBER 18TH 2017

WILFRIED W. DEPNERING

OUTLINE

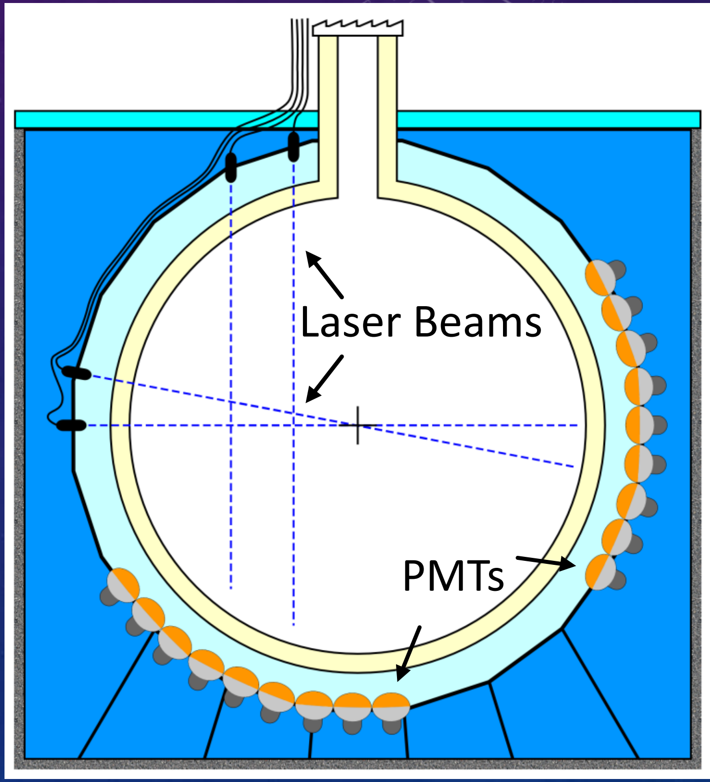
- Motivation
- The Liquid Scintillator of JUNO
- Laser System
  - Conceptual Design
  - Determination Method
- Summary

MOTIVATION

- Determination of …
  - attenuation length L
  - scattering length L_s
  - absorption length L_a

  for big volume

- Monitoring of L, L_s & L_a
  - are there changes over time?
- Measuring gradient in refractive index $n(\lambda,T)$
  - might influence photon propagation



laser system

THE LIQUID SCINTILLATOR OF JUNO

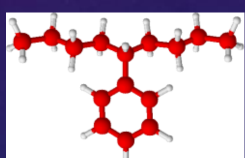
- Transparency
  - attenuation of light propagating through an absorber

$$I(x) = I_0 e^{-x/L}$$

- Attenuation length L:
  - combination of absorption length L_a & scattering length L_s

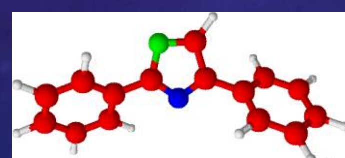
$$\frac{1}{L} = \frac{1}{L_a} + \frac{1}{L_s}$$

LAB



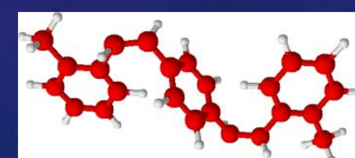
$\xrightarrow{\gamma_1}$

PPO



$\xrightarrow{\gamma_2}$

bis-MSB



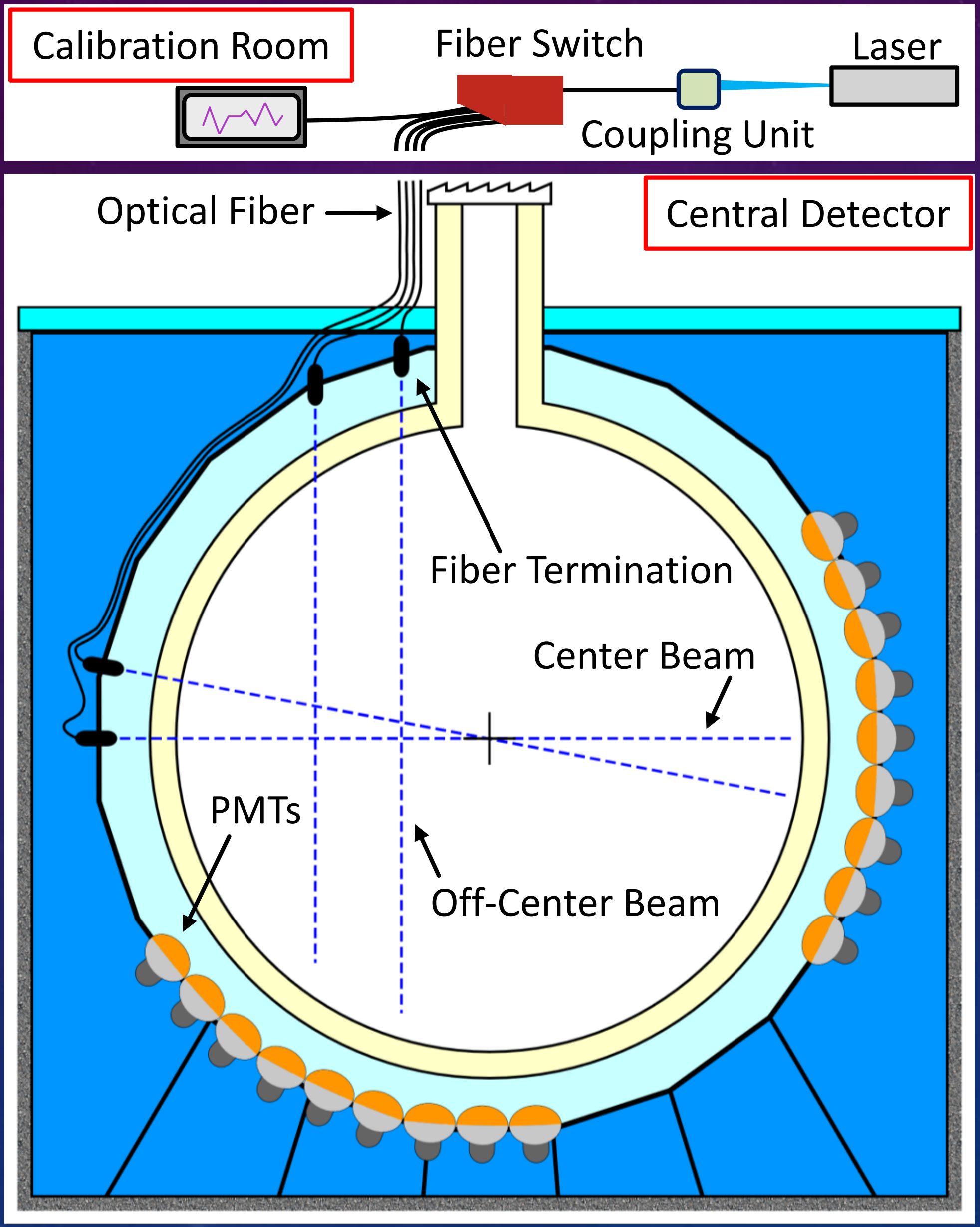
$\xrightarrow{\gamma_3}$

$$\lambda(\gamma_1) < \lambda(\gamma_2) < \lambda(\gamma_3)$$

- Wavelength shift takes place on the first meters
  - after that mostly Rayleigh scattering

Rayleigh Scattering Length determines LS Transparency

CONCEPTUAL DESIGN



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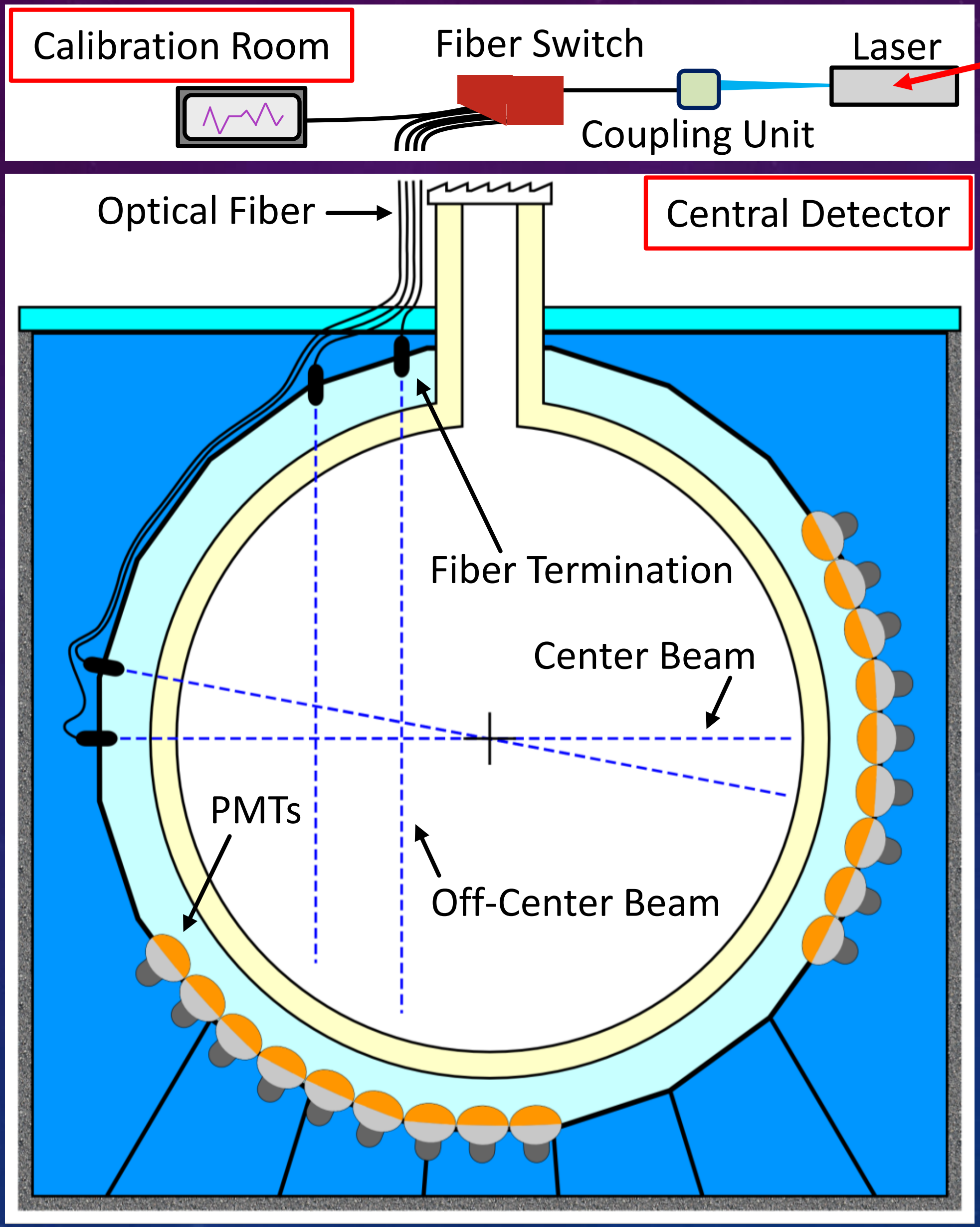
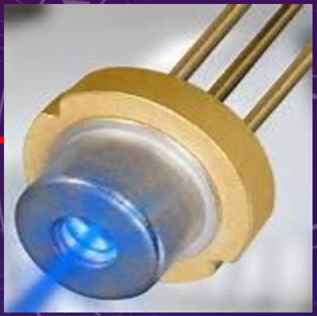
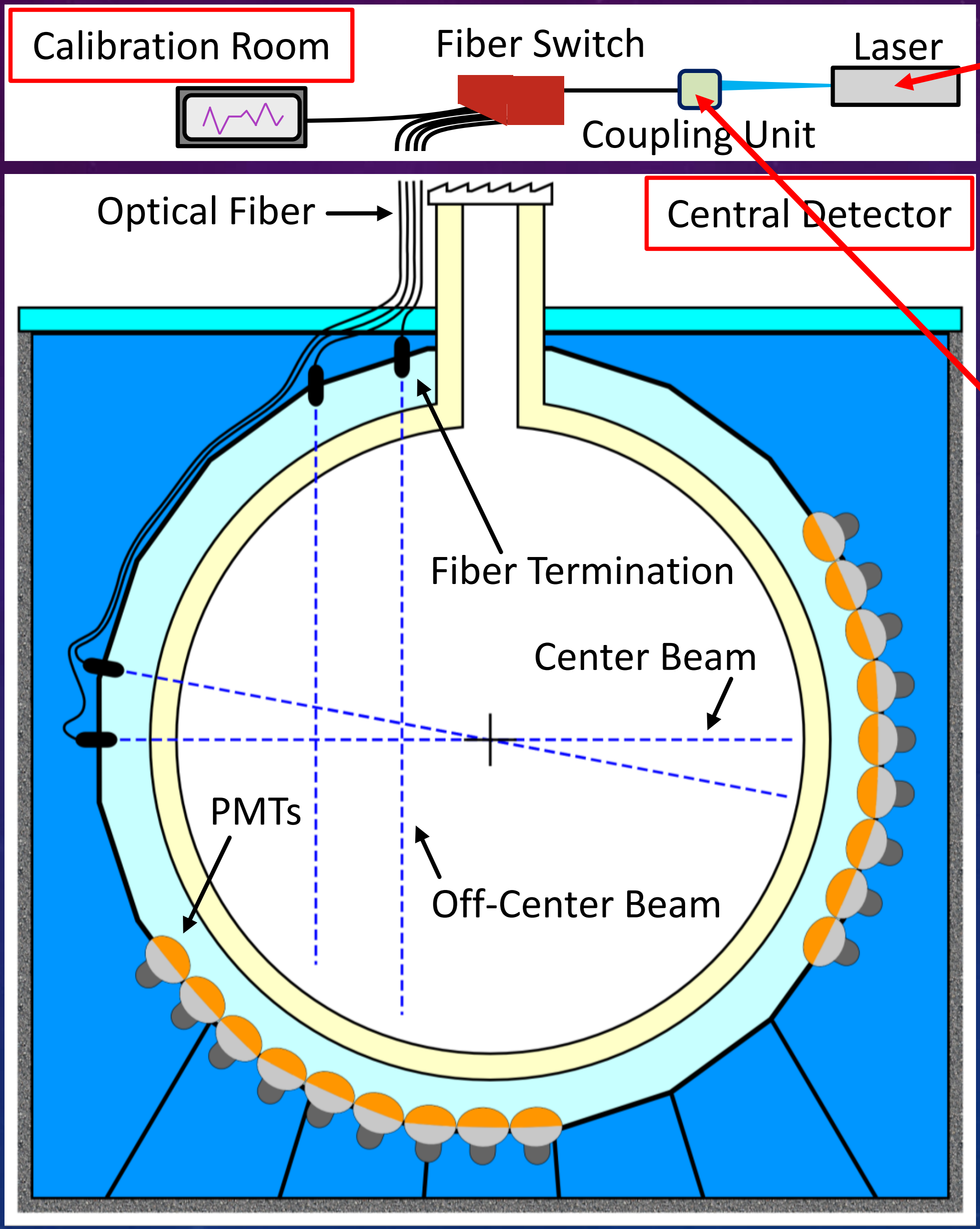
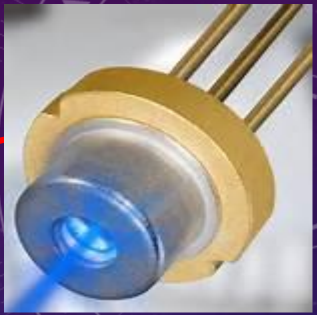




Roithner Lasertechnik
class 3B, 430 nm
already bought

CONCEPTUAL DESIGN





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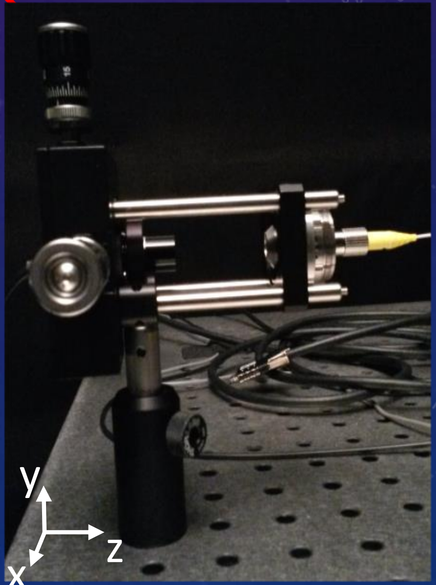
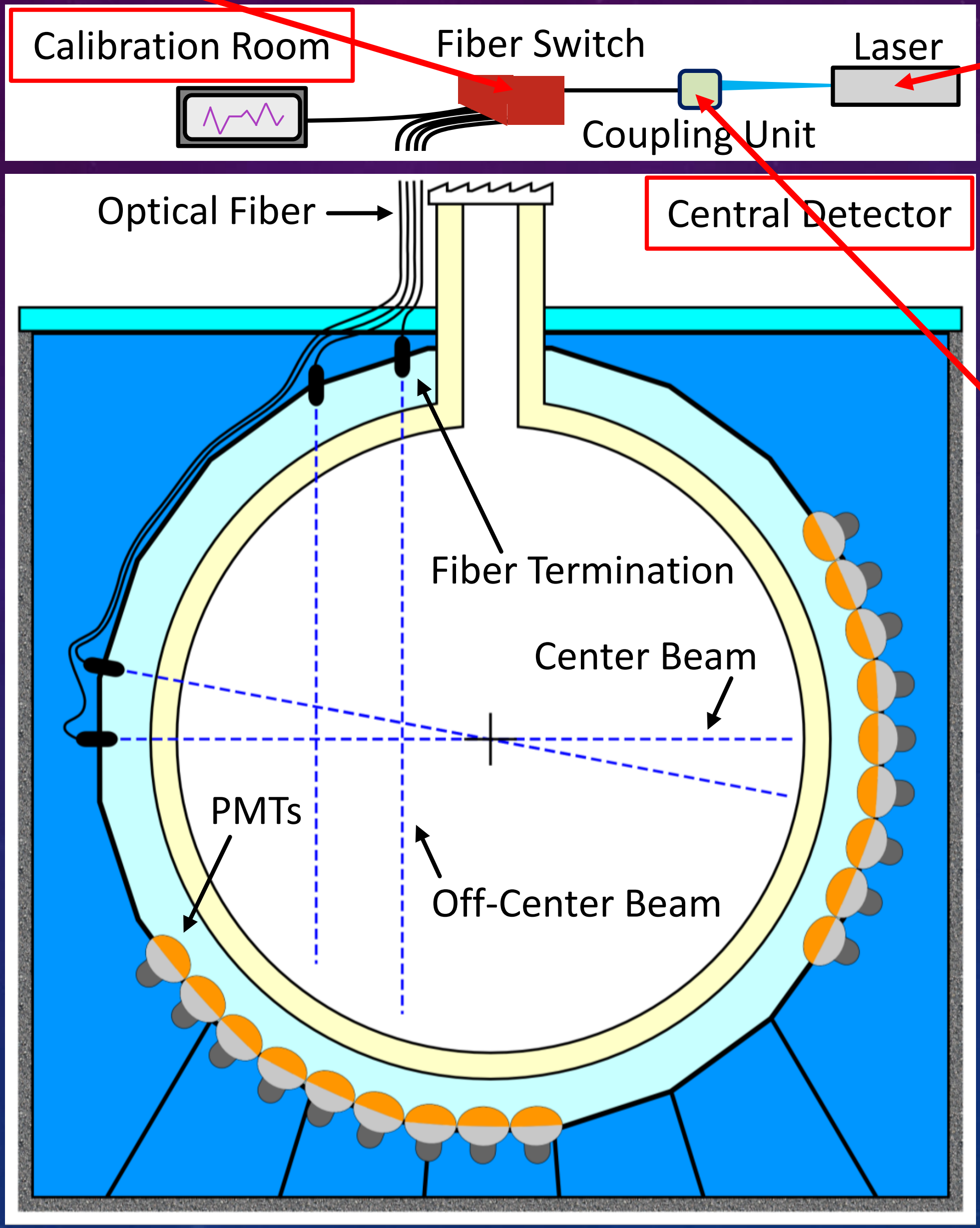
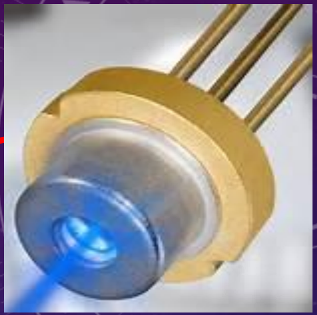


Thorlabs
already bought

CONCEPTUAL DESIGN

LEONI Fiber Optics
already bought





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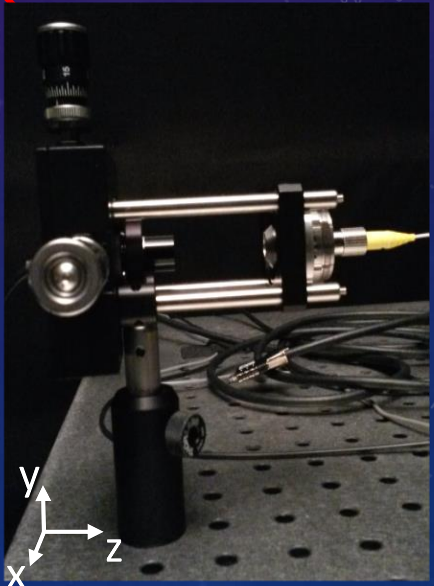

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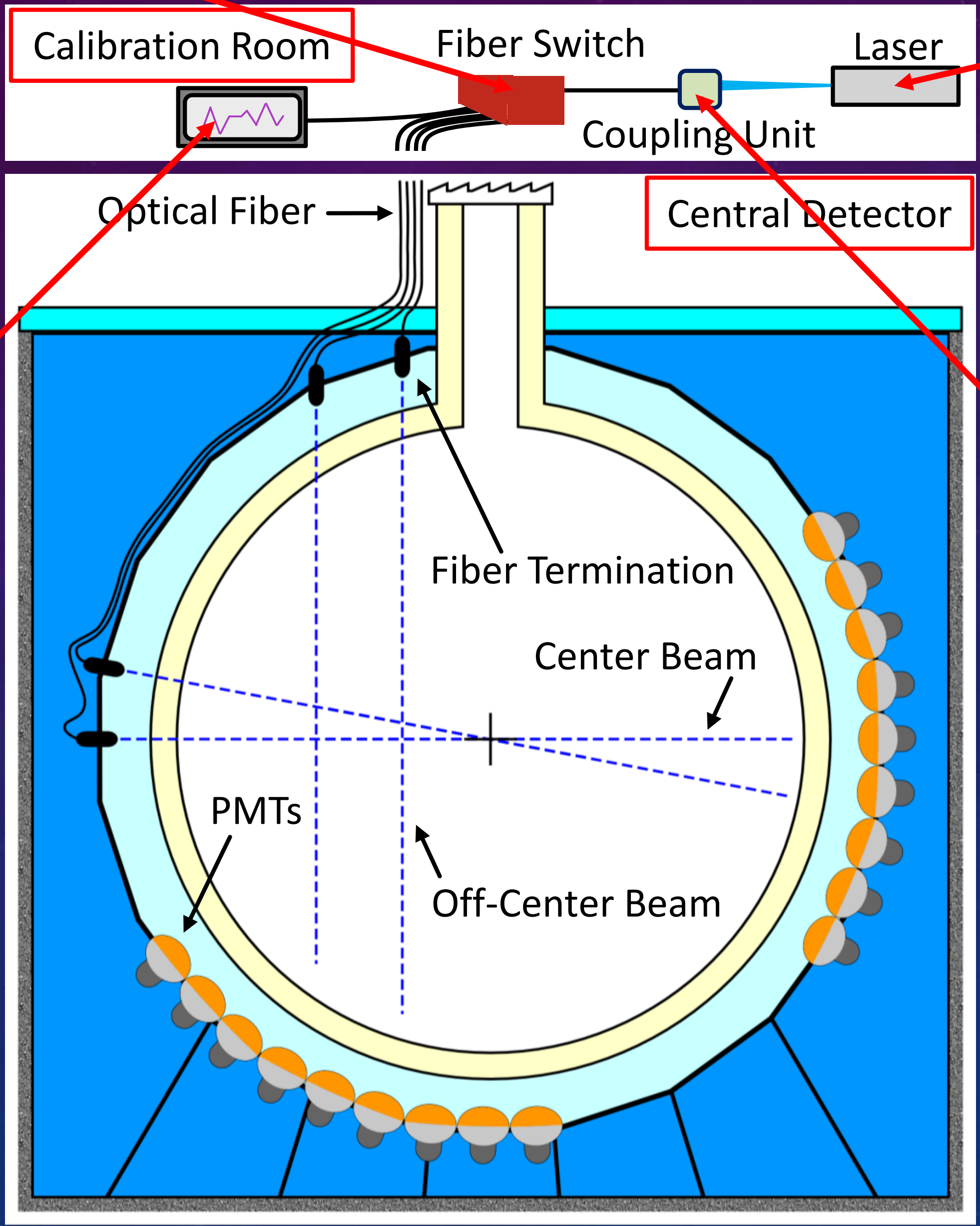

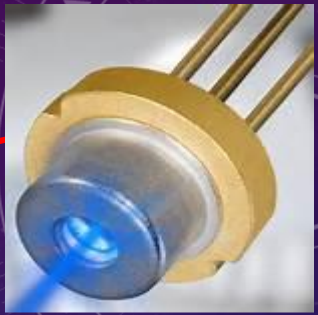

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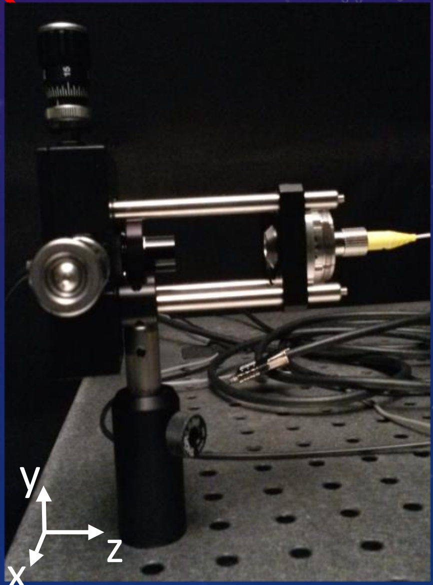

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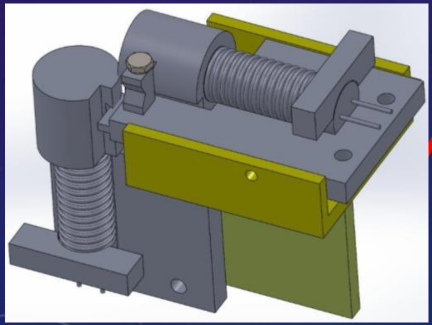
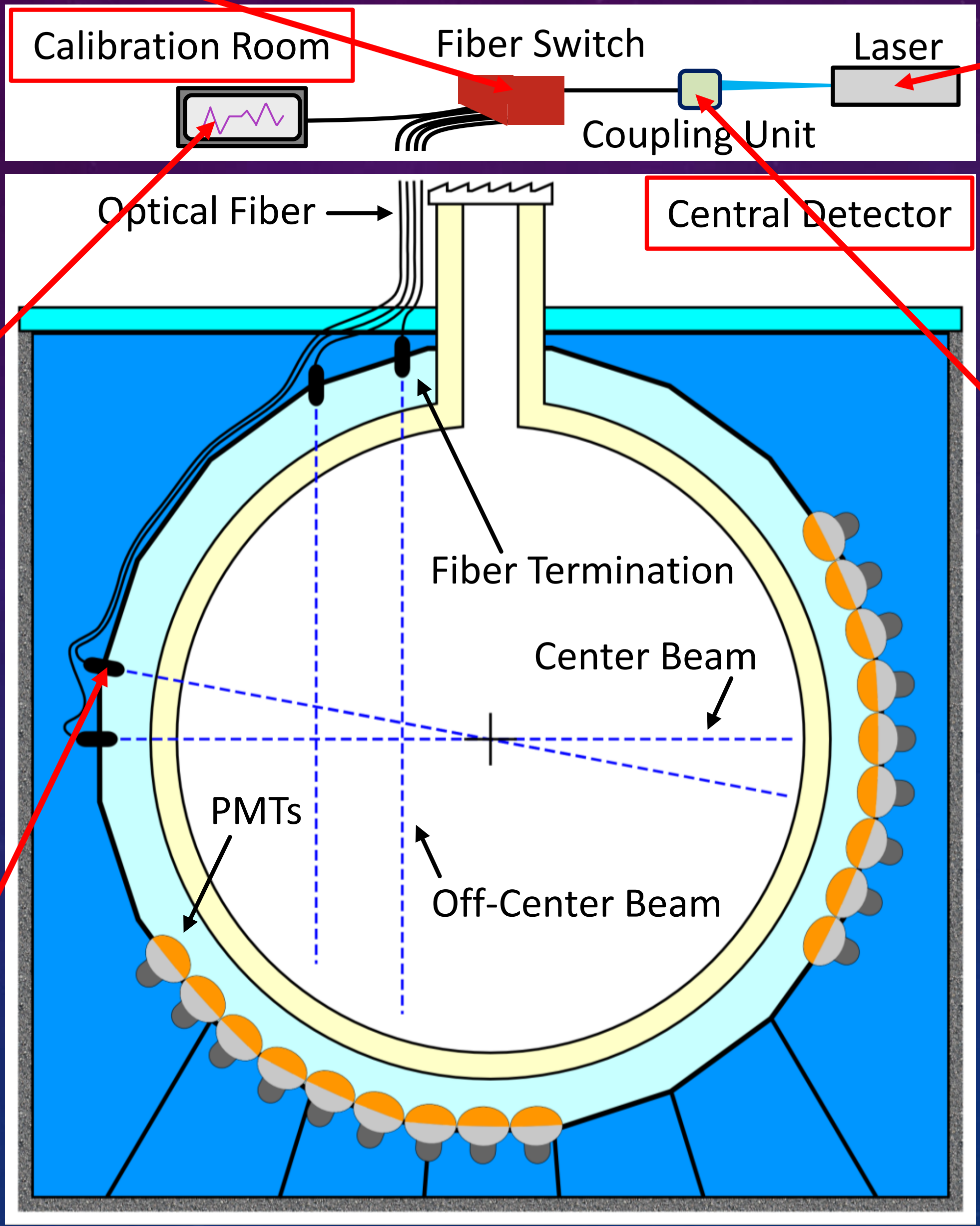
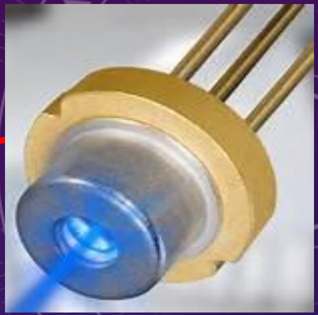


CeramTec
already bought





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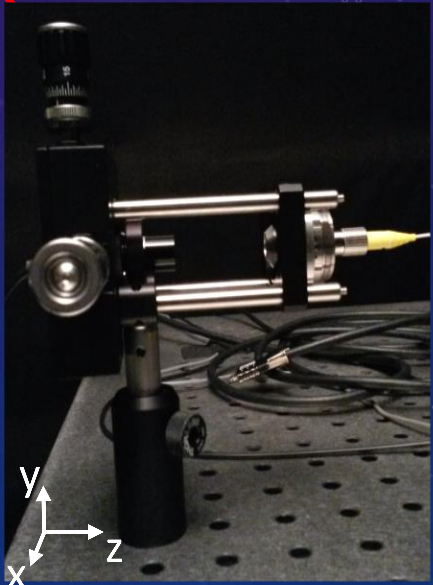

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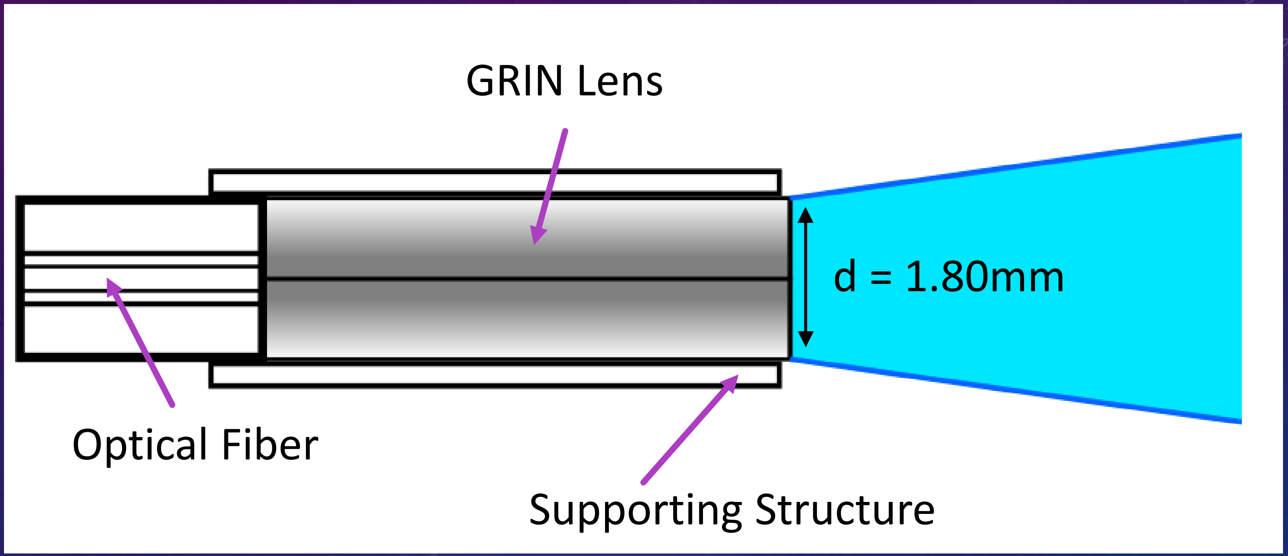
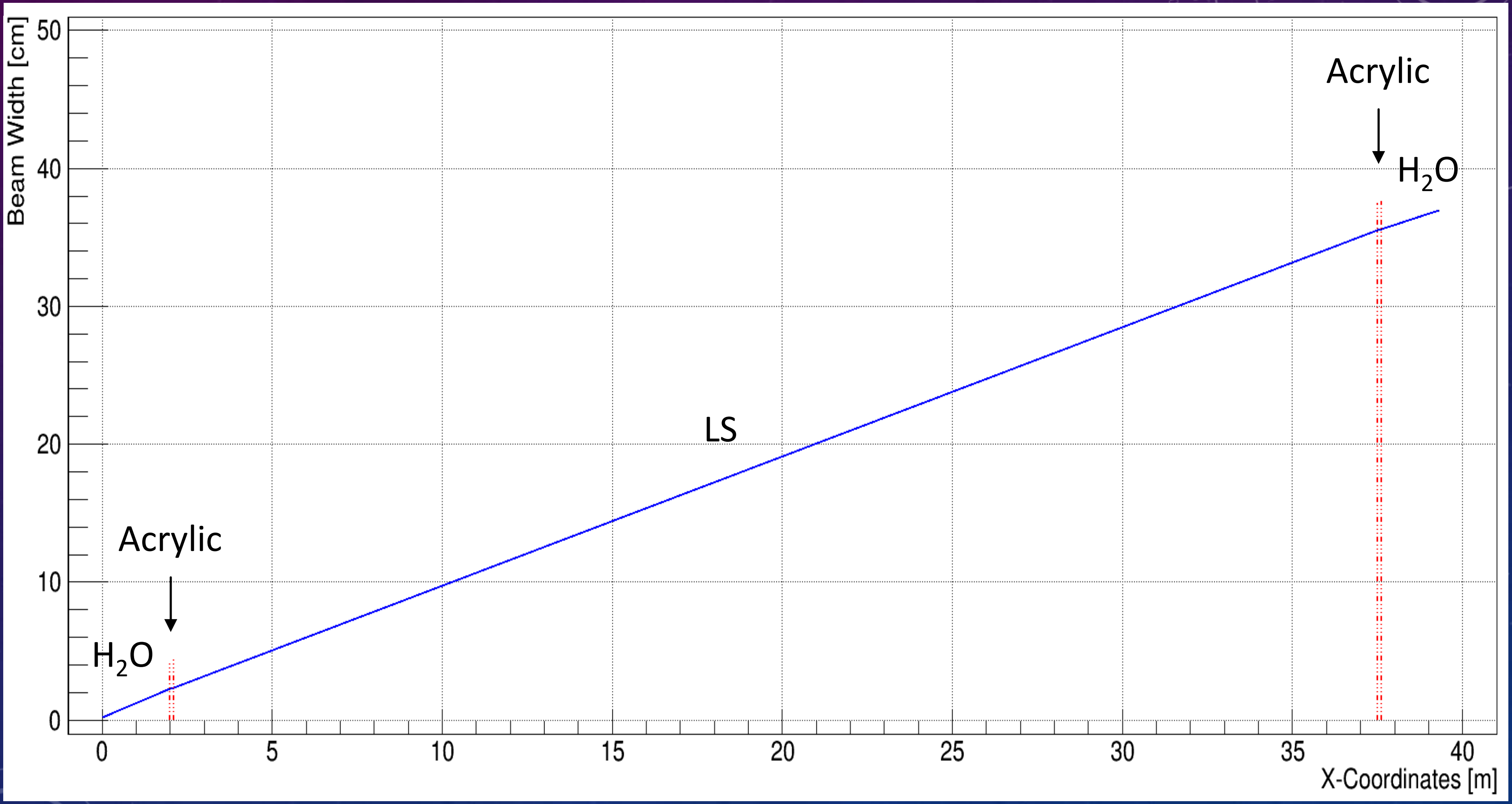
FIBER TERMINATION & GRIN LENS



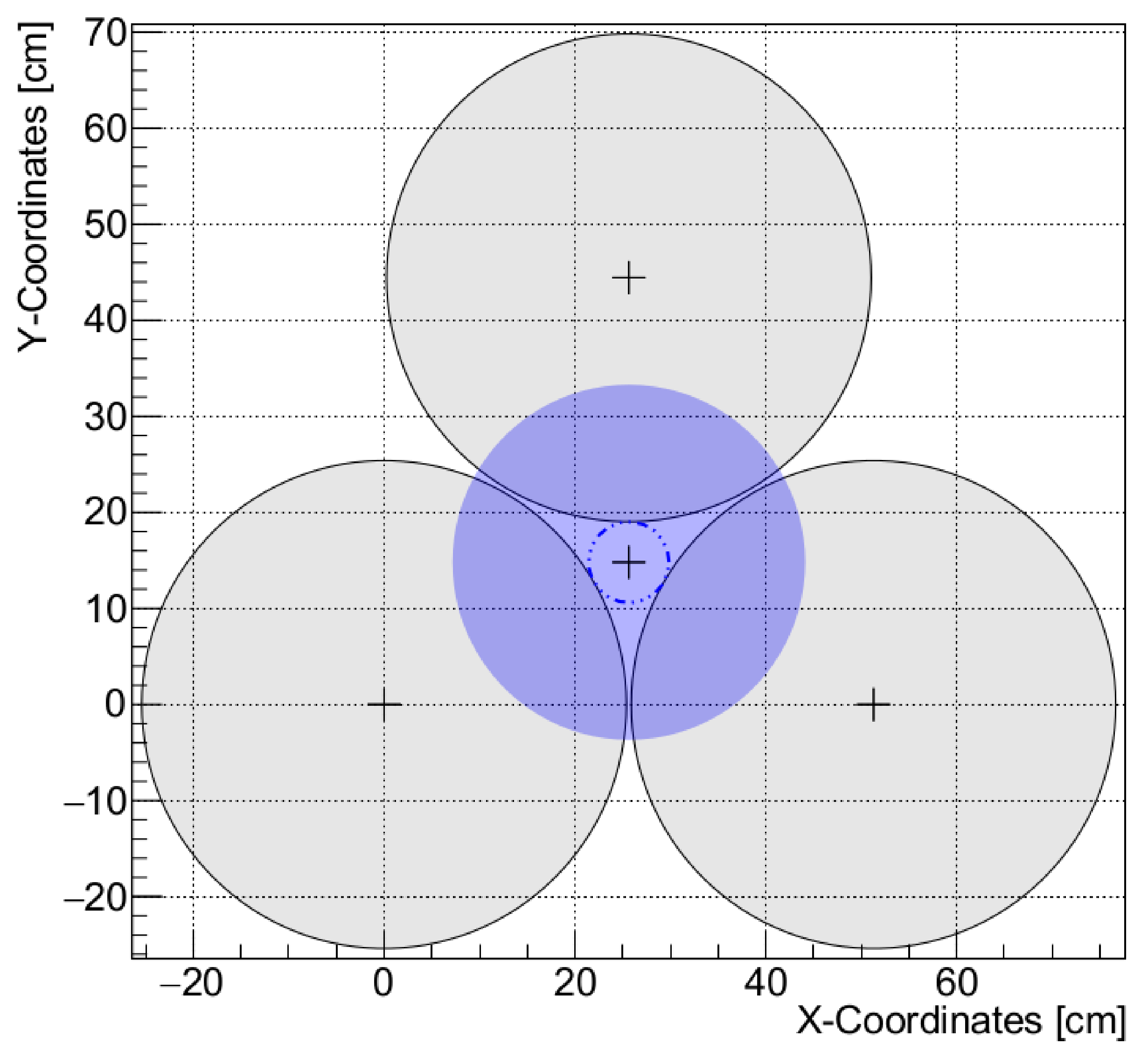
- Light collimation under water with ordinary lenses is difficult
- GRIN lenses are working also in optical thicker media
- GRIN lens is mounted directly on the optical fiber
- Laser light is collimated during its way through the GRIN lens

BEAM WIDTH ALONG THE PATH



- aperture angle is 0.3°

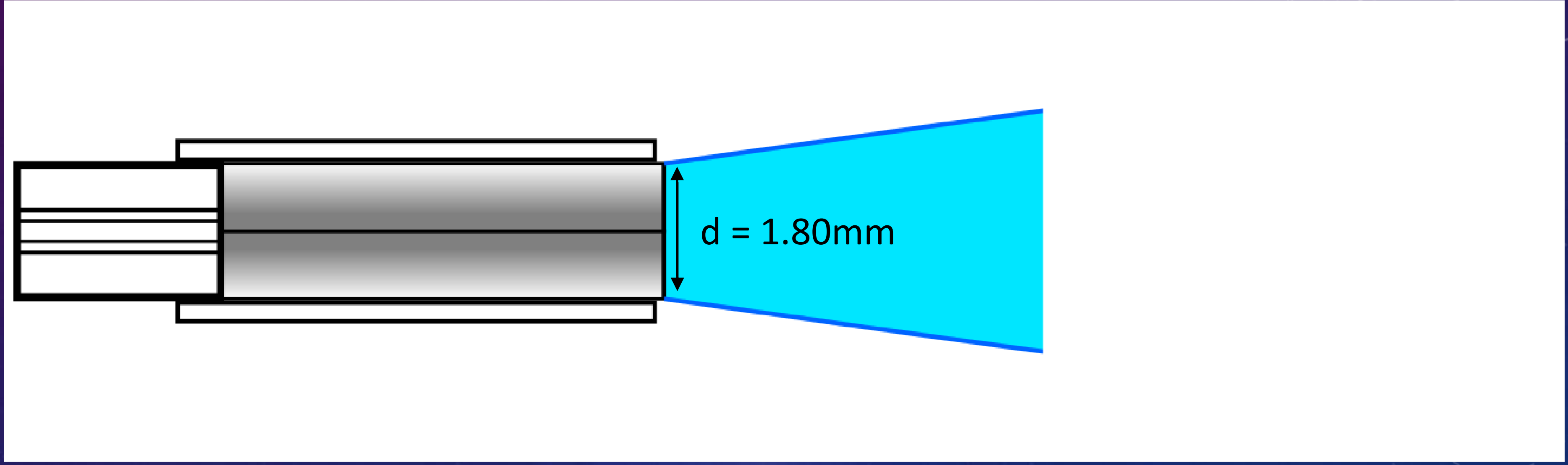
PMT PROFILE VS. BEAM PROFILE



- Area of beam
  - gaussian profile
- Intensity between PMTs
  - 71.7%

Aperture angle still too big

PIN HOLE FOR FIBER TERMINATION



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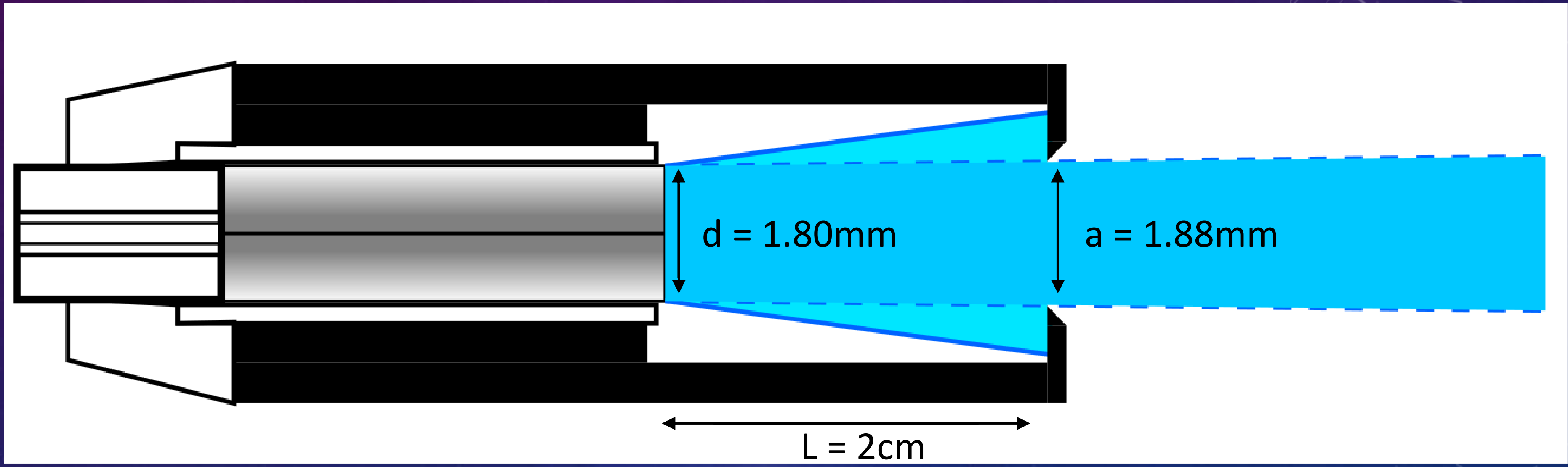


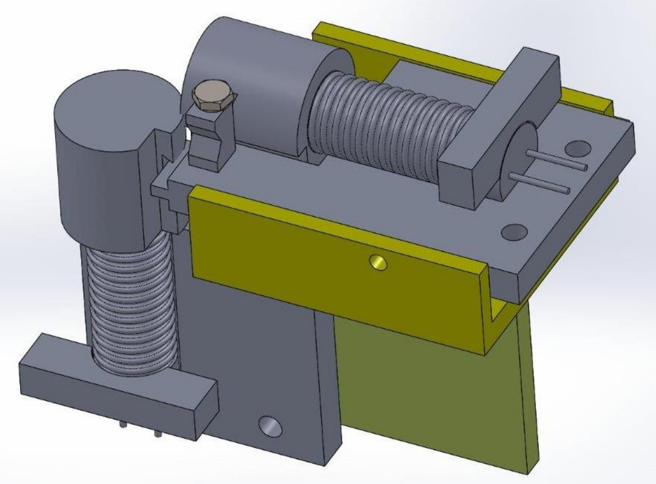
- Pinhole mounted on supporting structure
  - further reduction of aperture angle
  - has to be at least smaller than 0.1°

Fiber Termination Holder (FTH)

CeramTec
SealActor Piezo Crystal

Main Purpose:

- laser beam must not hit PMTs directly
  - FTH should be slewable
- using piezoelectrical crystals
  - no magnetic field
  - do not influence performance of PMTs



Workshop of Uni Mainz
1st design suggestion for FTH

How to control and adjust the termination holder?:

- Piezo Driver of FTH should operate by remote control
  - easier handling & independent from location
- Driver has to communicate with piezo crystals
  - providing them with the right voltage
- digitizer has to use PMTs output for adjustment
  - interface with PMTs is necessary
- collected data should be shared with “offline people“

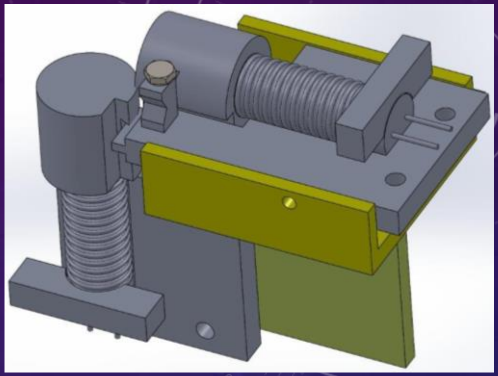
*Should be doable with **IOC**s based on **EPICS***

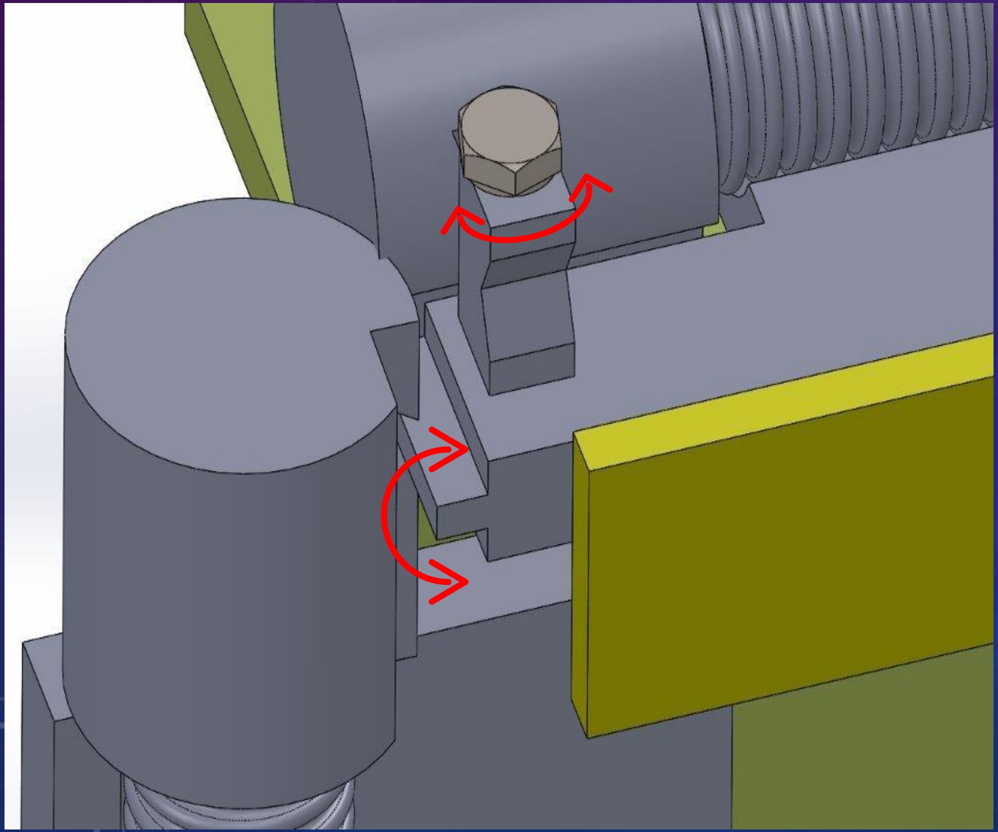
Next Steps:

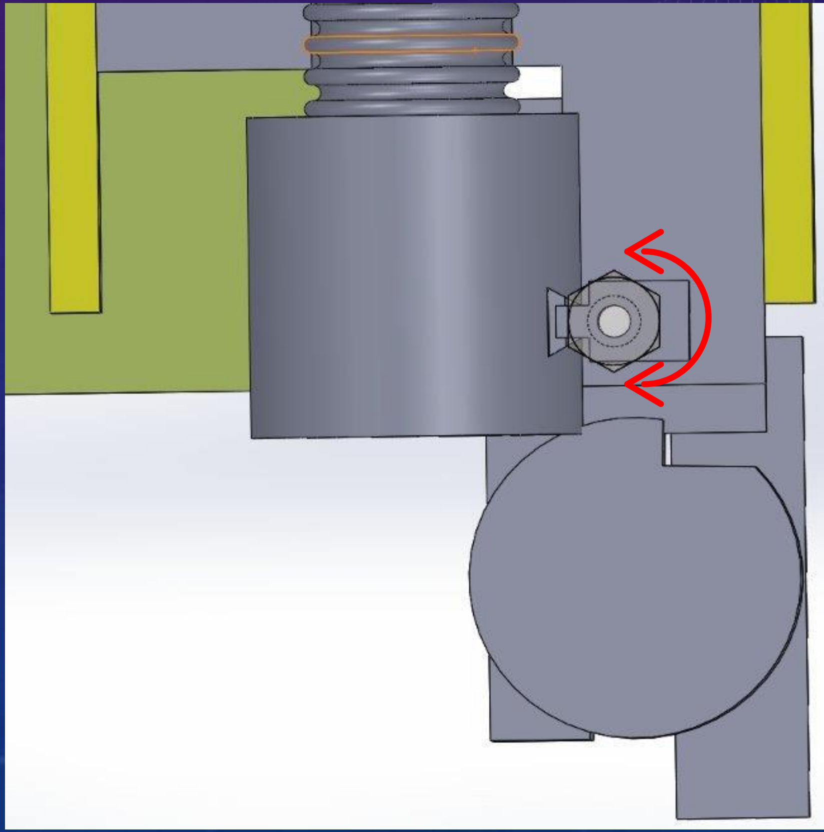
- construction of FTH
- setting up the software to control the FTH

WORKING PRINCIPLE

- linear expansion of piezos is translated into rotation
  - using screws fixed on a support structure
- the shorter the lever arm of force, the bigger the rotation angle
  - coupled system for θ- and φ-direction

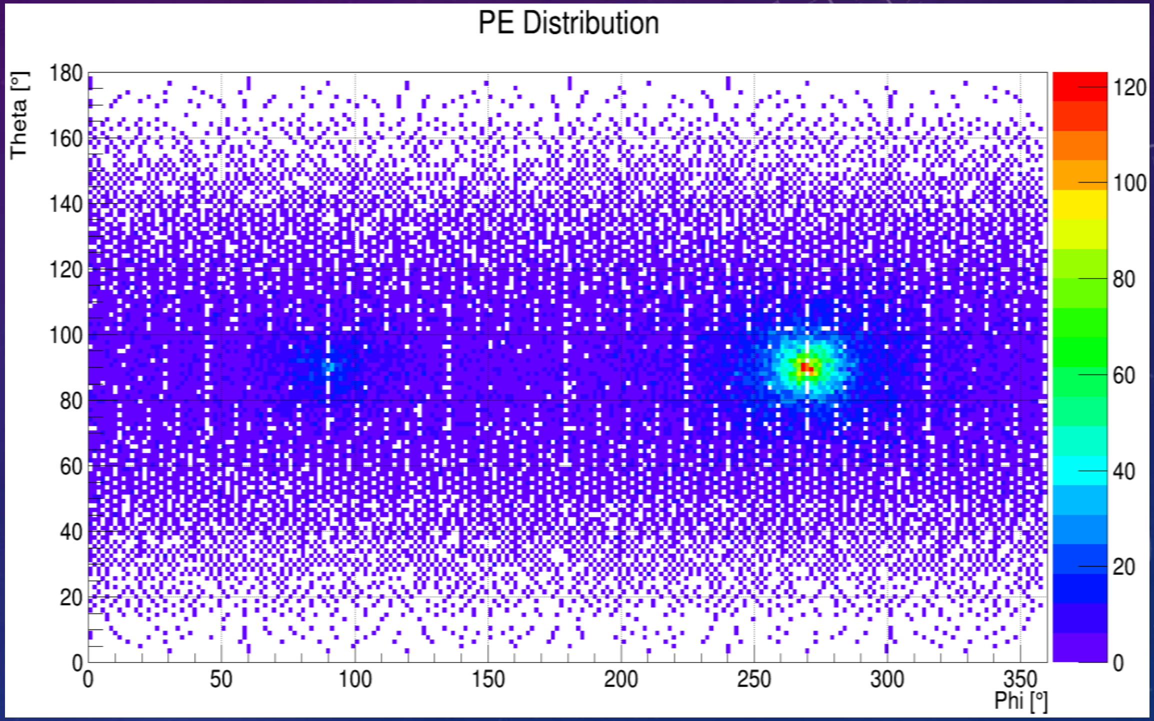






DETERMINATION METHOD

- Measuring amount & distribution of photon hits
- MC for different L, L_s & L_a
  - knowledge of L_{water}
  - knowledge of absorbance of acrylic
  - Likelihood - method to determine values for L, L_s & L_a of liquid scintillator



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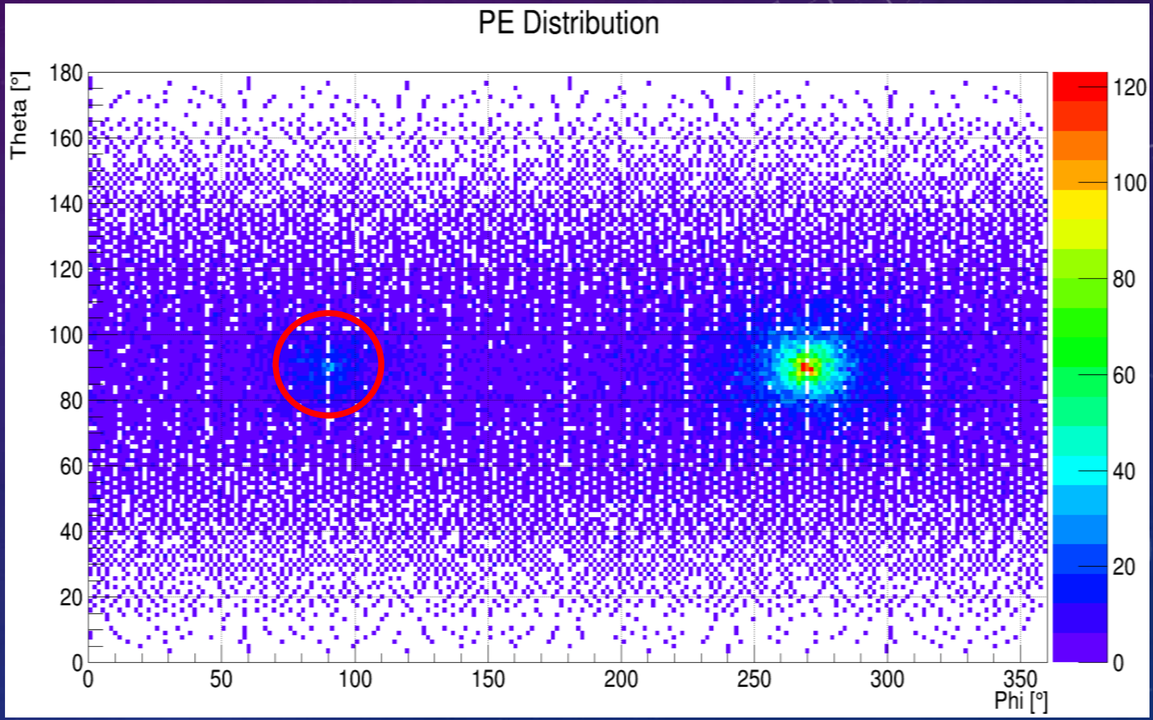

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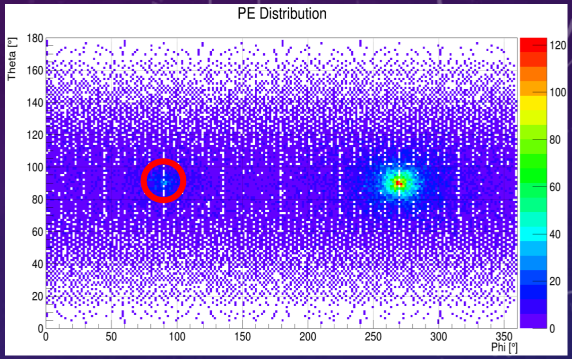

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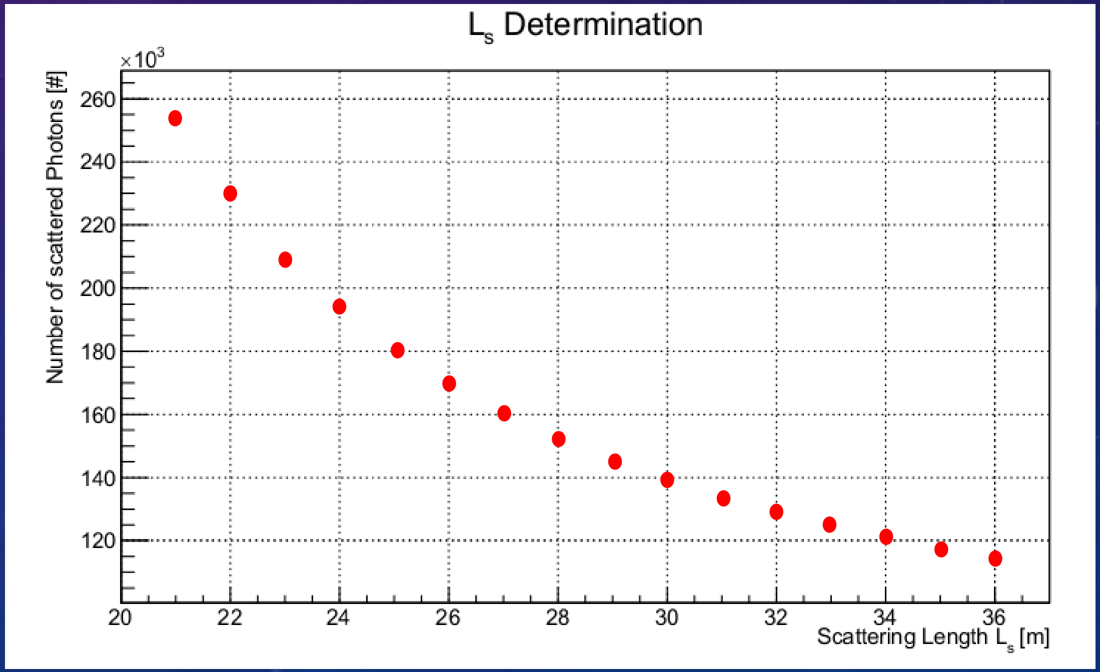
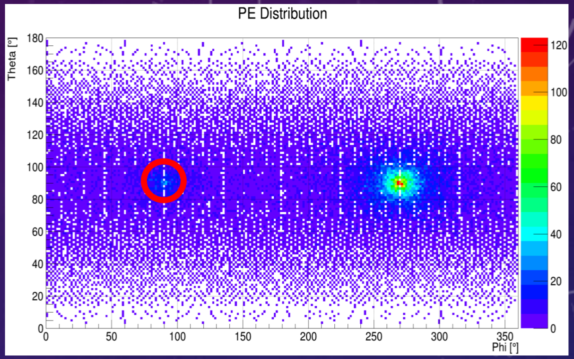


DETERMINATION METHOD



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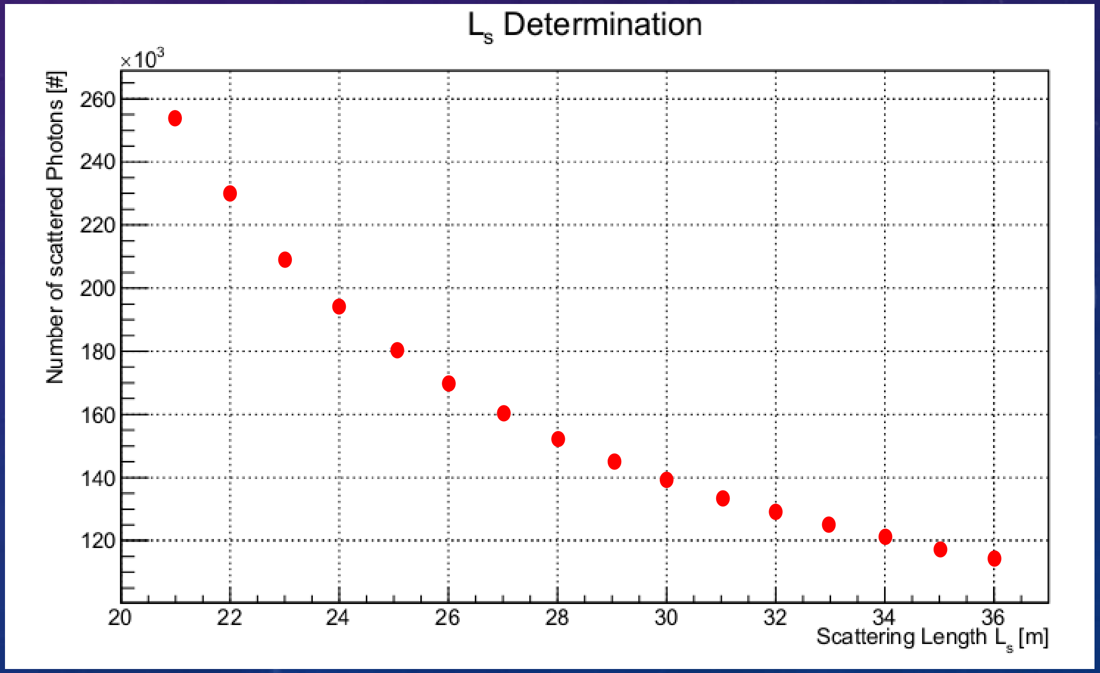
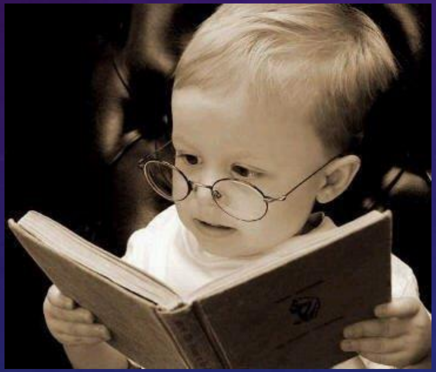


Determination of L, L_s & L_a

SUMMARY

- Most of the components are already bought
  - in the near future, focusing on fiber termination holder (FTM)
- Currently, working on …
  - characterization of single components
  - design of FTM
  - setting up the software to control FTM

THANK YOU FOR YOUR ATTENTION!

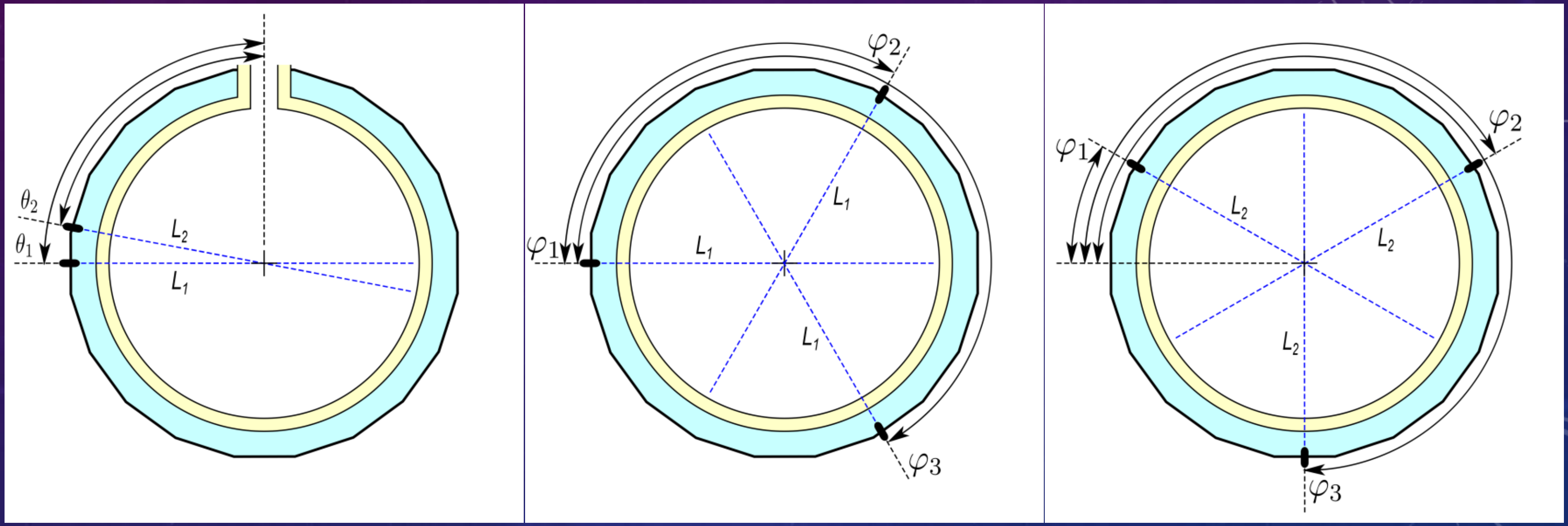


Further ideas & suggestions for improvement are appreciated!

e-Mail address: **widepner@uni-mainz.de**

ATTACHMENT

LOCATION OF FIBER TERMINATION – CENTER BEAM



side view

top view, L_1

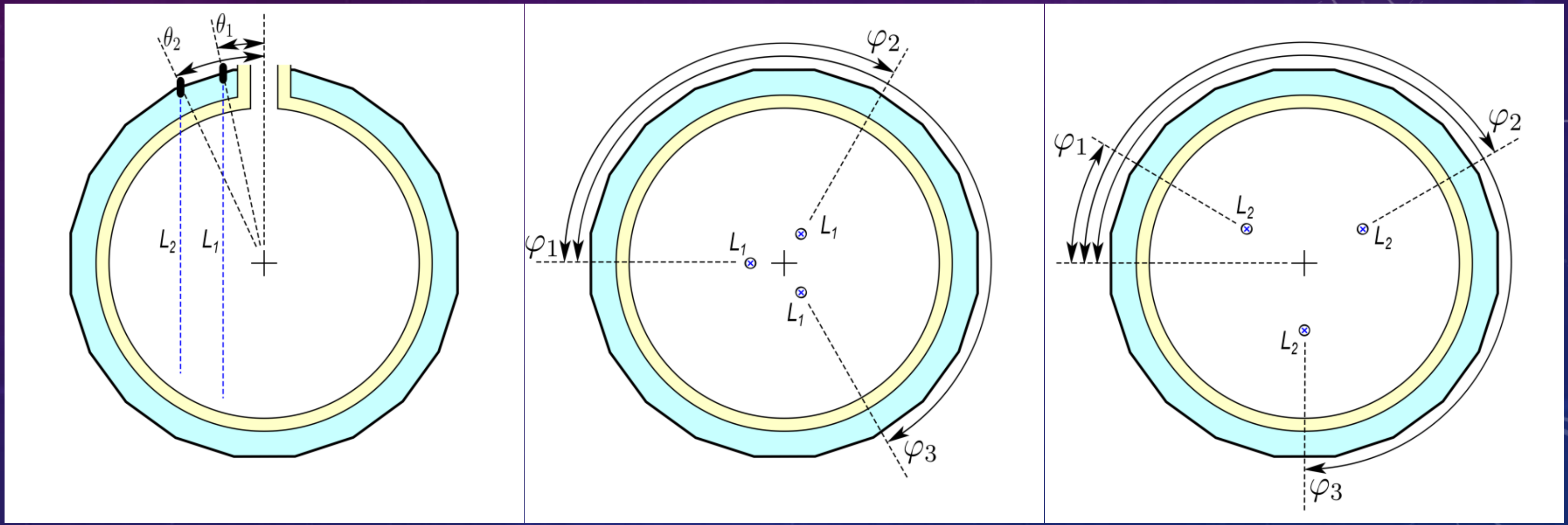
top view, L_2

$\theta_1 = 90°$
$\theta_2 = 80°$

$\varphi_1 = 0°$
$\varphi_2 = 120°$
$\varphi_3 = 240°$

$\varphi_1 = 30°$
$\varphi_2 = 150°$
$\varphi_3 = 270°$

LOCATION OF FIBER TERMINATION – OFF-CENTER BEAM



side view | top view, L_1 | top view, L_2

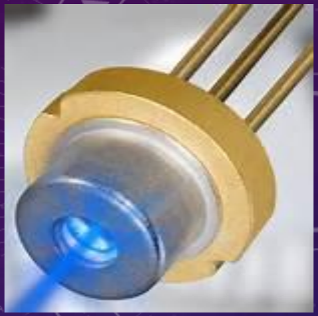
$\theta_1 = 10°$
$\theta_2 = 20°$

$\varphi_1 = 0°$
$\varphi_2 = 120°$
$\varphi_3 = 240°$

$\varphi_1 = 30°$
$\varphi_2 = 150°$
$\varphi_3 = 270°$

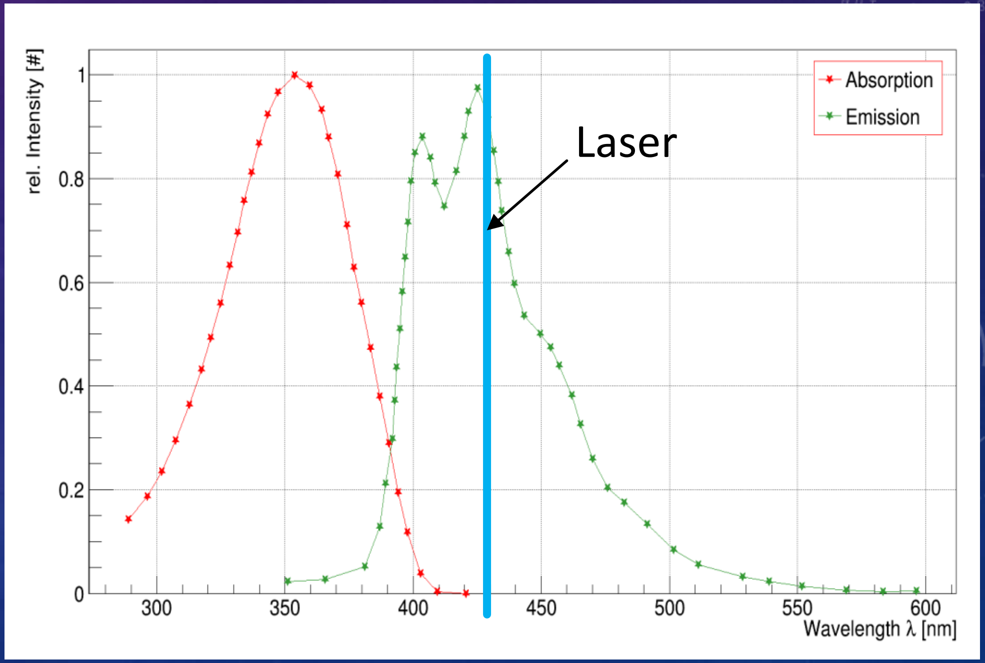
LASER SOURCE

CW405-01
class 2



RLT430-50CMG
class 3B

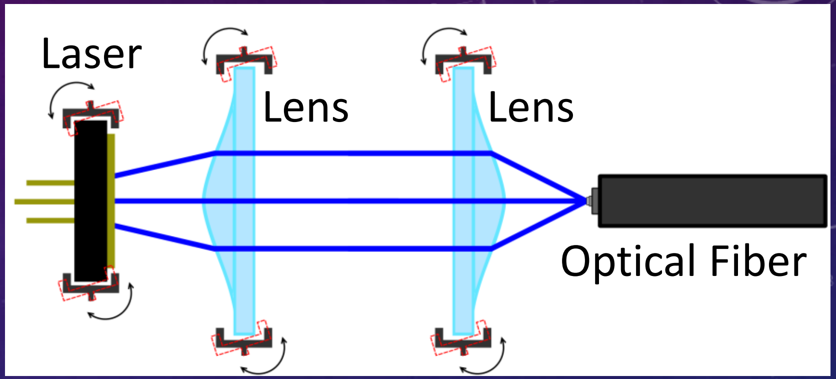
- Roithner LaserTechnik GmbH
- Operating at λ = 430 nm
  - primary Rayleigh scattering
- High photon statistics
  - low absorption
  - high PMT QE



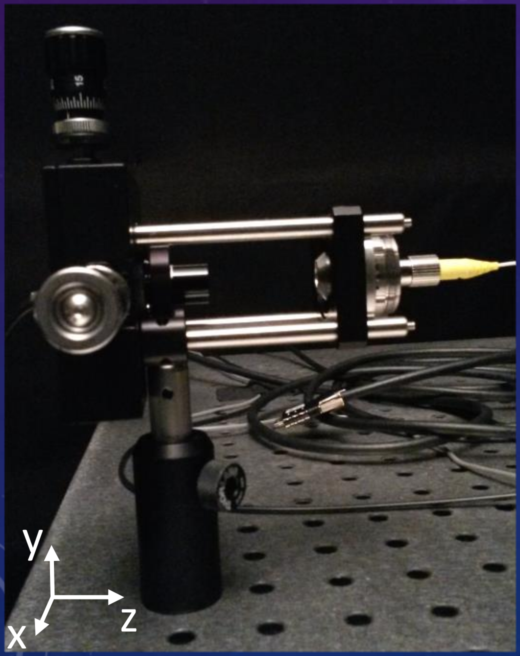
bis-MSB spectra

COUPLING UNIT

- Laser light is coupled into optical fiber
  - requires precise adjustment
  - using first aspheric lens for collimation
  - using second aspheric lens for coupling



coupling into optical fiber



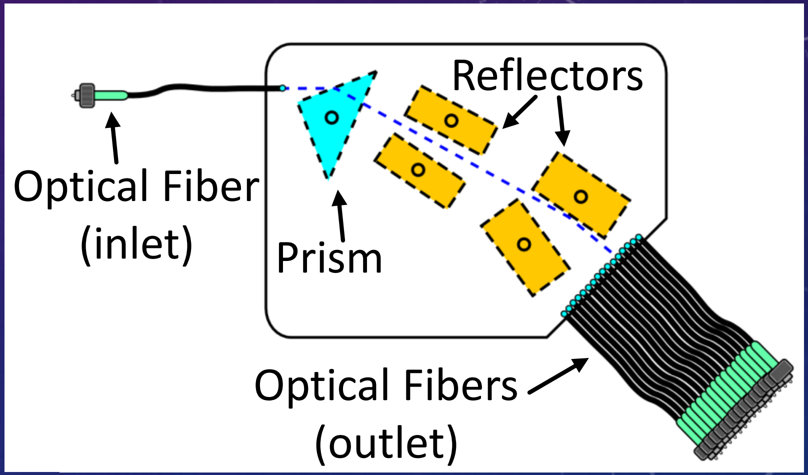
- Using laser holder from Thorlabs
  - is movable/slewable in xy-direction

- Using holders for aspheric lenses from Thorlabs
  - are movable in xyz-direction

FIBER SWITCH

LEONI Fiber Optics
Fiber Switch

- High transparency in UV/VIS region
- Controllable by PC (USB connection)
- One Inlet & Sixteen Outlets
  - one fiber for the reference measurements
  - other fibers to address multiple laser subsystems



schematic of fiber switch

Subsystems are separated from each other

SENSITIVITY STUDY - APPROACH

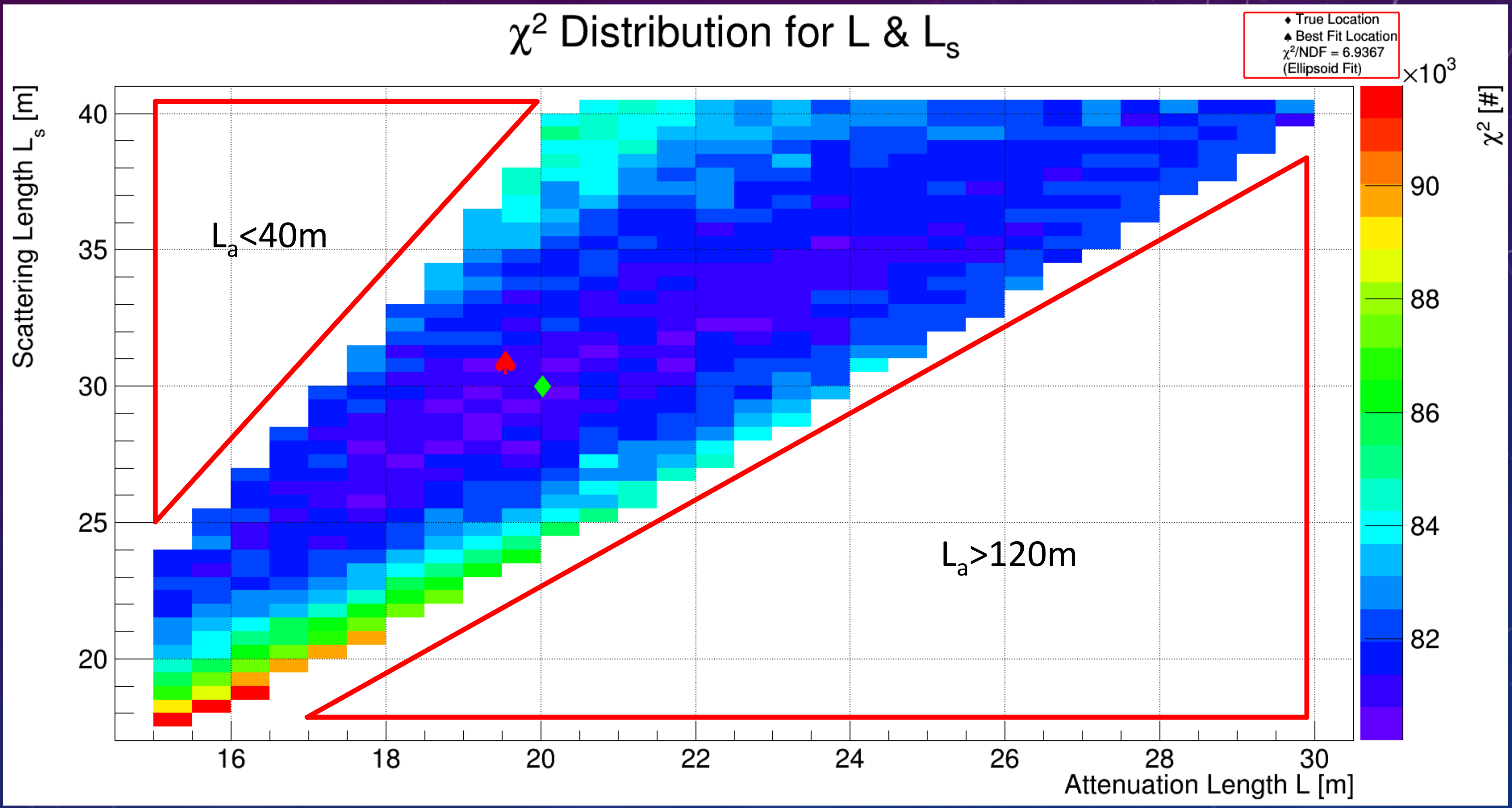
- 1st step: Producing a **LookUpTable** (LUT) for different value pairs
  - going through L- and L_s-ranges…
  - L [L_{min} =15m, L_{max} =30m]
  - L_s [$L_{s,min}$ =L_{min} +1m, $L_{s,max}$ =40m]
  - checking, if L_a value is satisfying L_a range
  - L_a [$L_{a,min}$ =40m, $L_{a,max}$ =120m]
    - value pairs which do not satisfy these ranges are rejected
  - due to simulation time only 1 million photons for each value pair

$$\boxed{\frac{1}{L_a} = \frac{1}{L} - \frac{1}{L_s}}$$

- 2nd step: Producing a **Sample Data Set** with L=20m, L_s=30m & L_a=60m

- Simulation of an ideal scenario
  - perfect collimated light beam
  - beam goes through the detector center (hits surfaces under an 90° angle)

SENSITIVITY STUDY – PRELIMINARY RESULTS



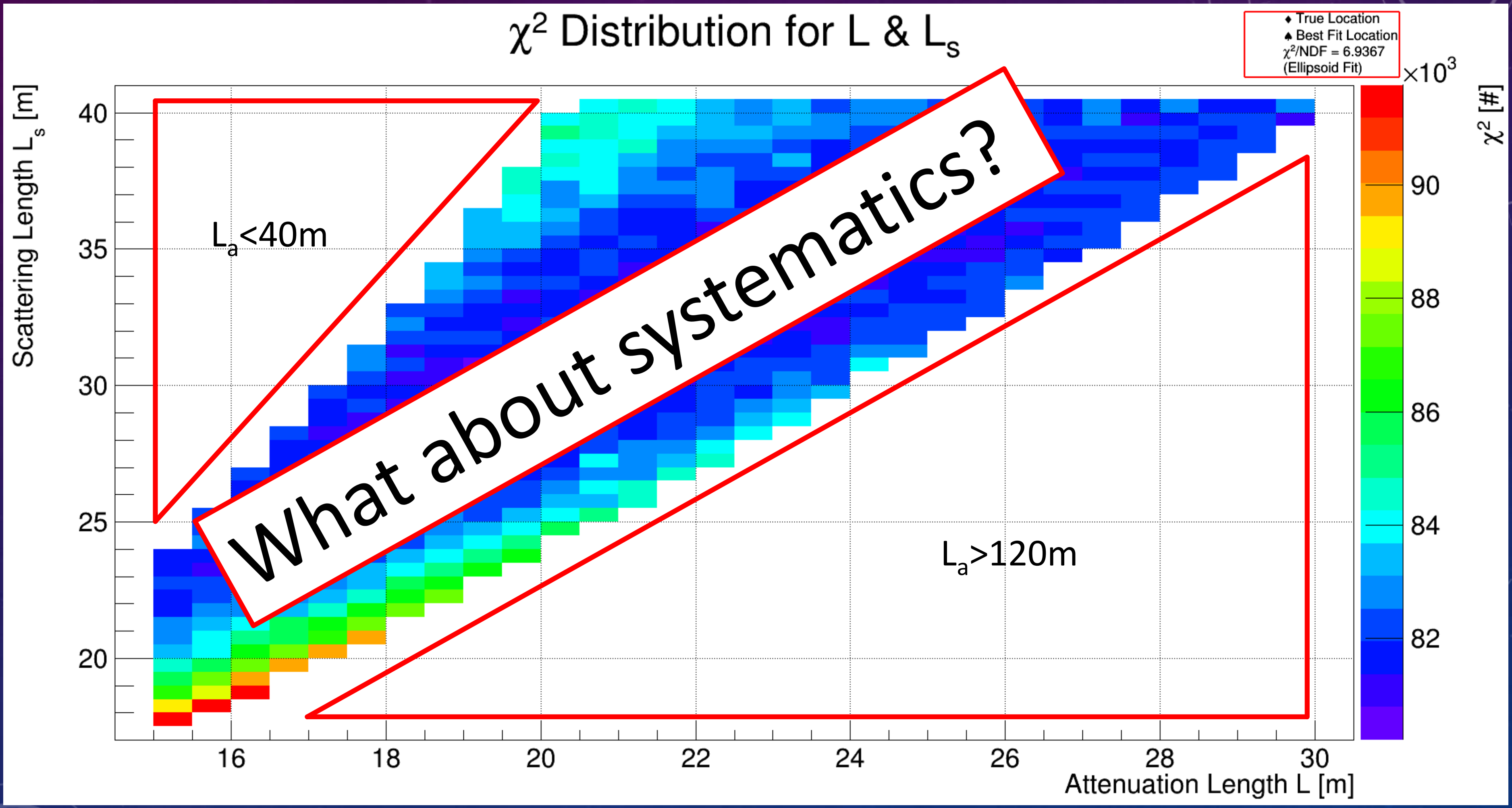
- Including only statistical fluctuations
- True & Best Fit Location are at least close to each other
  - higher statistics will improve results

CONCLUSION

- Determination method is working…
  - still space for improvement
  - further development of analysis algorithm
  - increase statistics for LUT and Data Set Sample

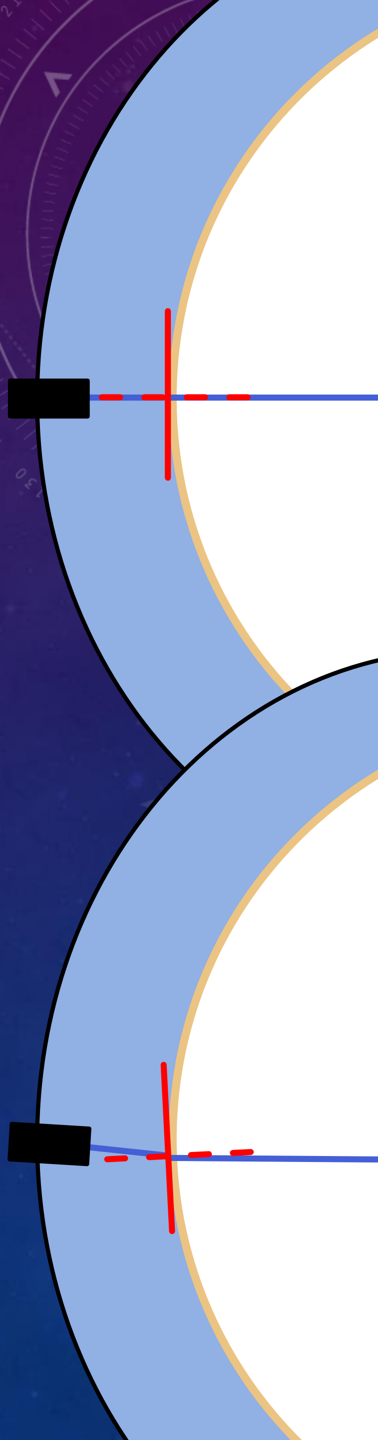
- Systematics should be studied and taken into account
  - pivoting angle of the laser beam
  - aperture angle of the laser beam
  - changing values for acrylic transparency
  - changing values for water transparency

PERFORMANCE OF DETERMINATION METHOD

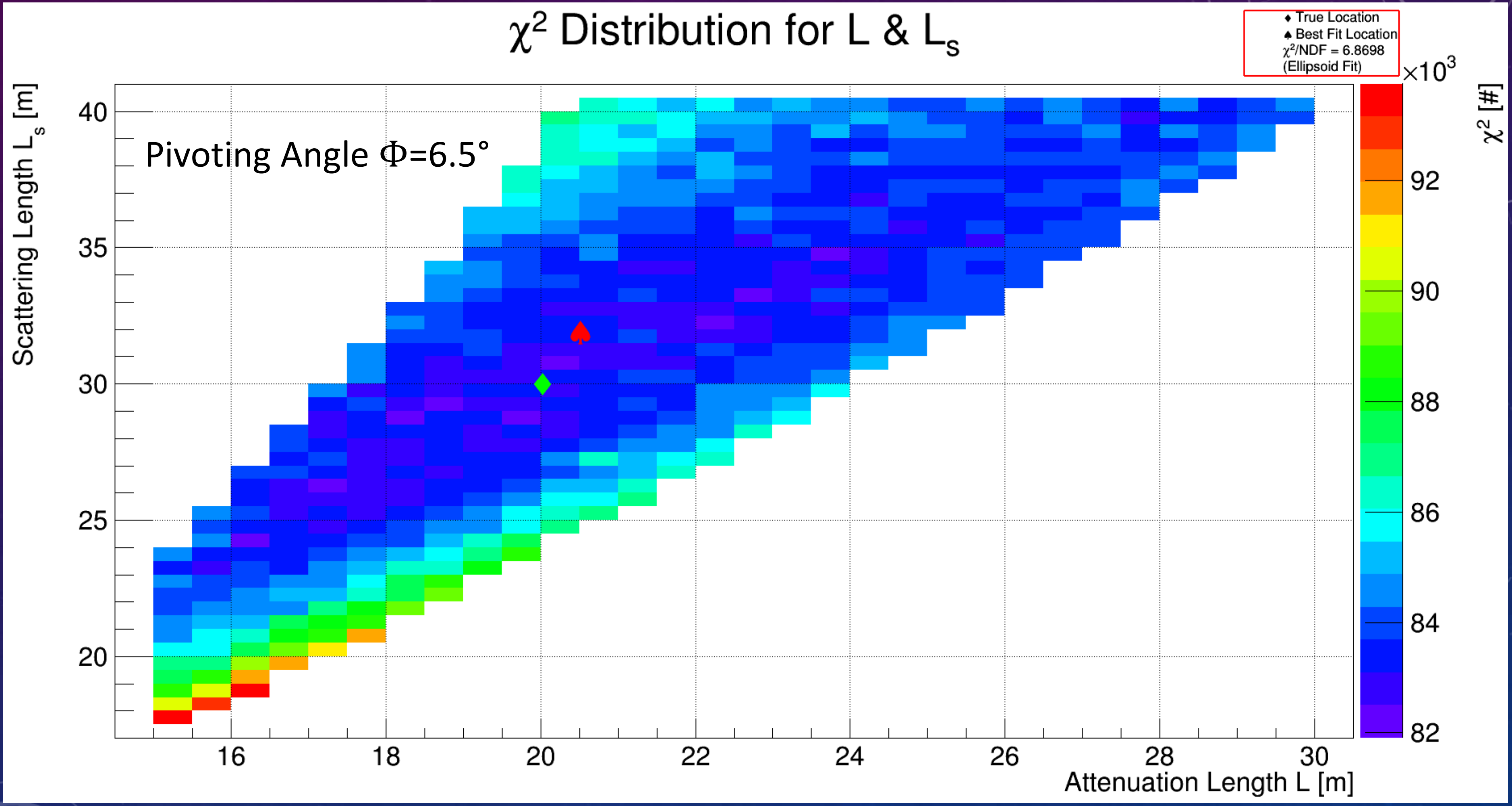


SYSTEMATICS

- It might happen, that a laser beam does not go through the detector center
  - hits acrylic sphere not under an 90° angle → refraction
- What is the influence on the sensitivity?

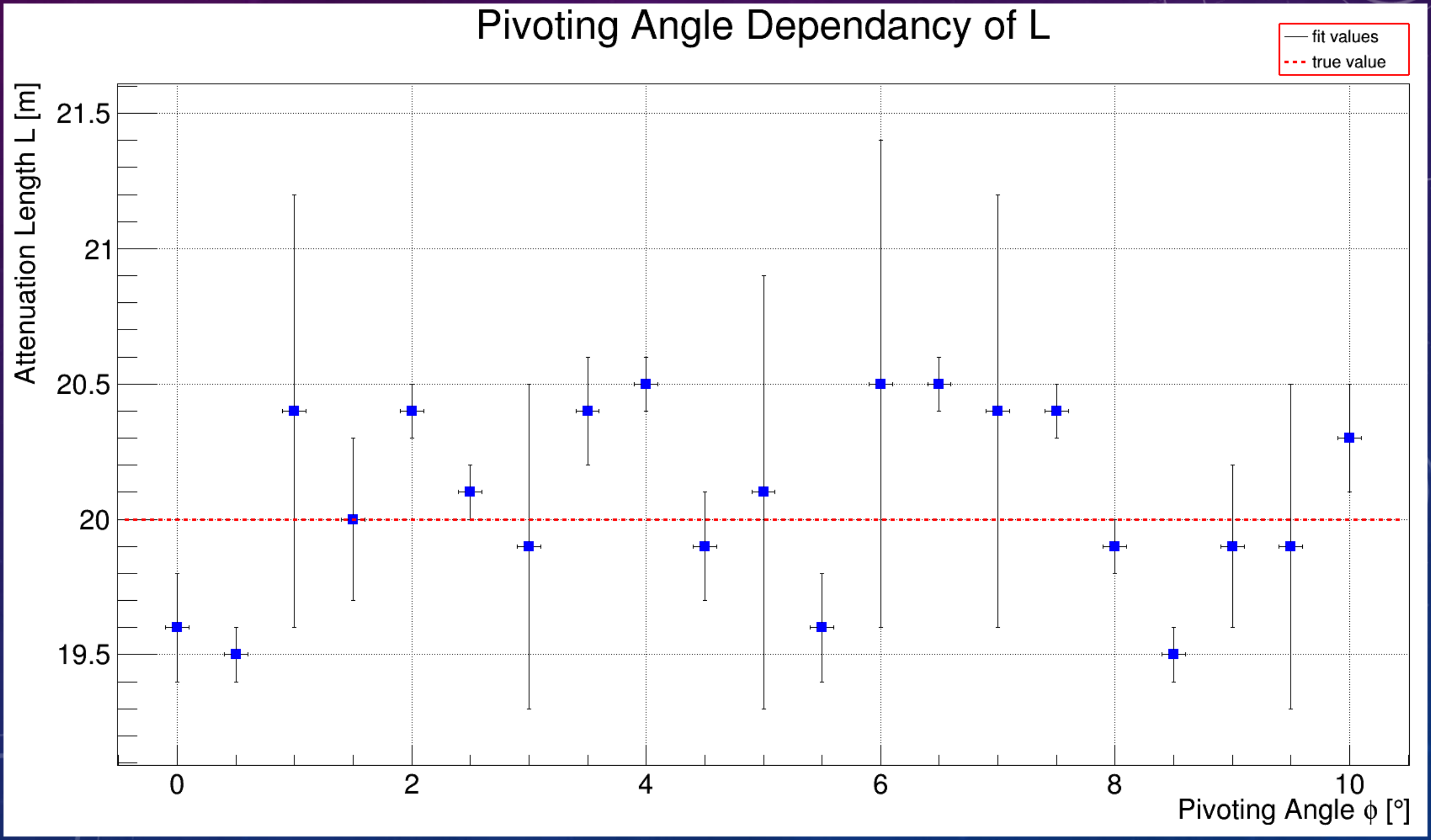


INFLUENCE OF A PIVOTING ANGLE

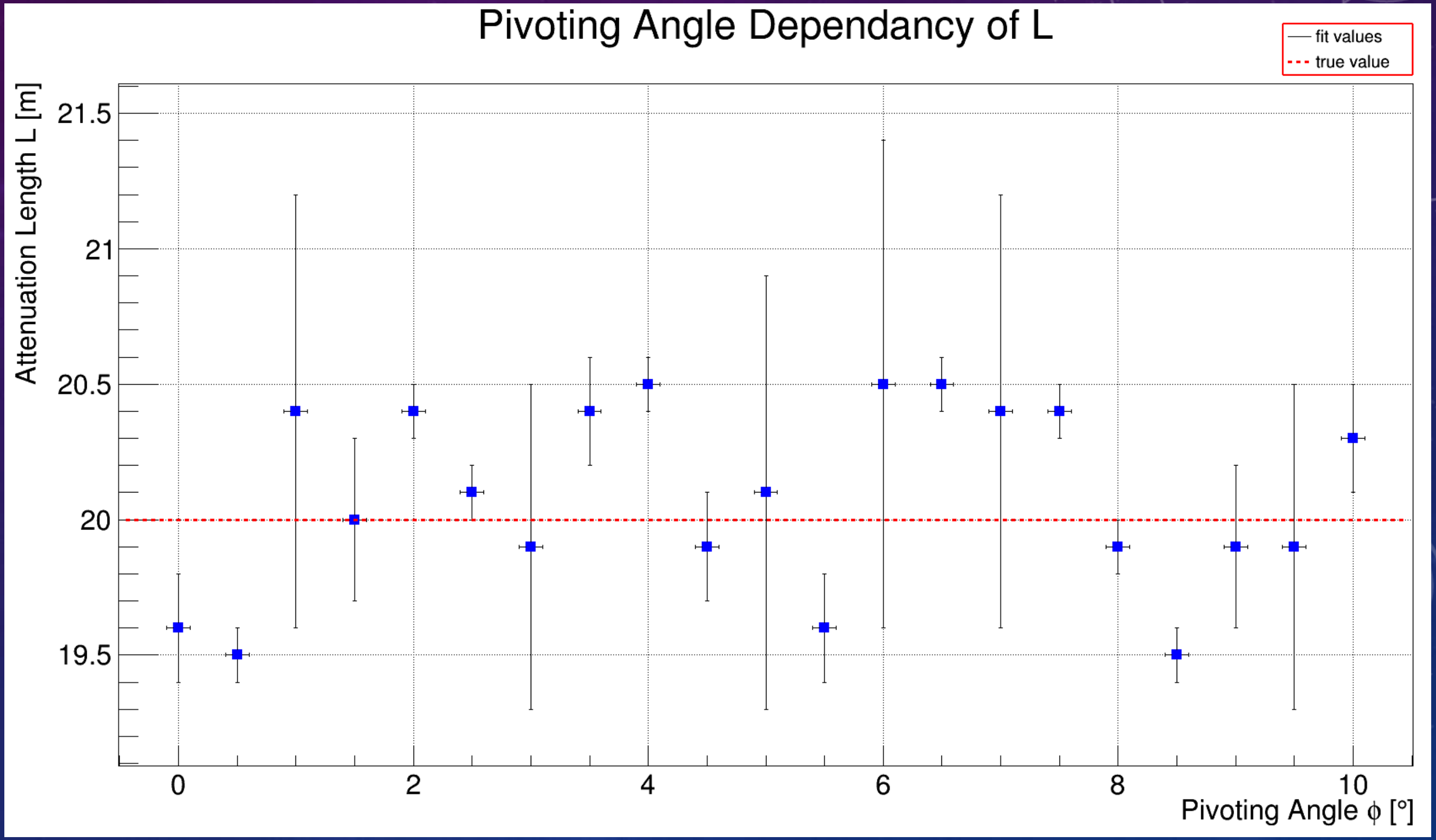


- Looks like the sensitivity is deteriorated?

INFLUENCE OF A PIVOTING ANGLE ON L

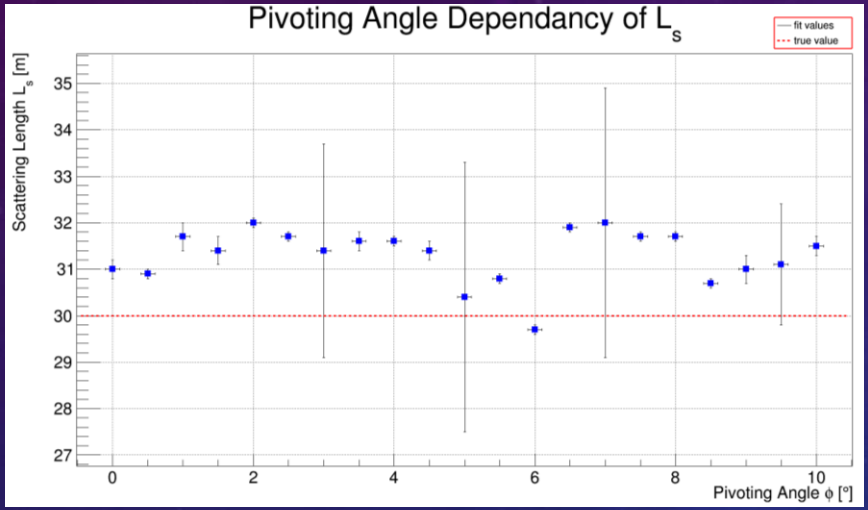


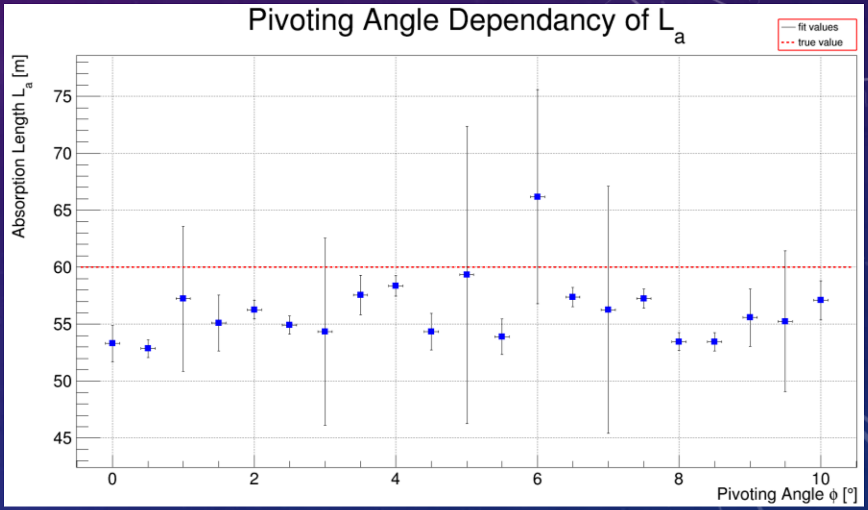
INFLUENCE OF A PIVOTING ANGLE ON L



- Effect on performance is smaller than the statistical fluctuations

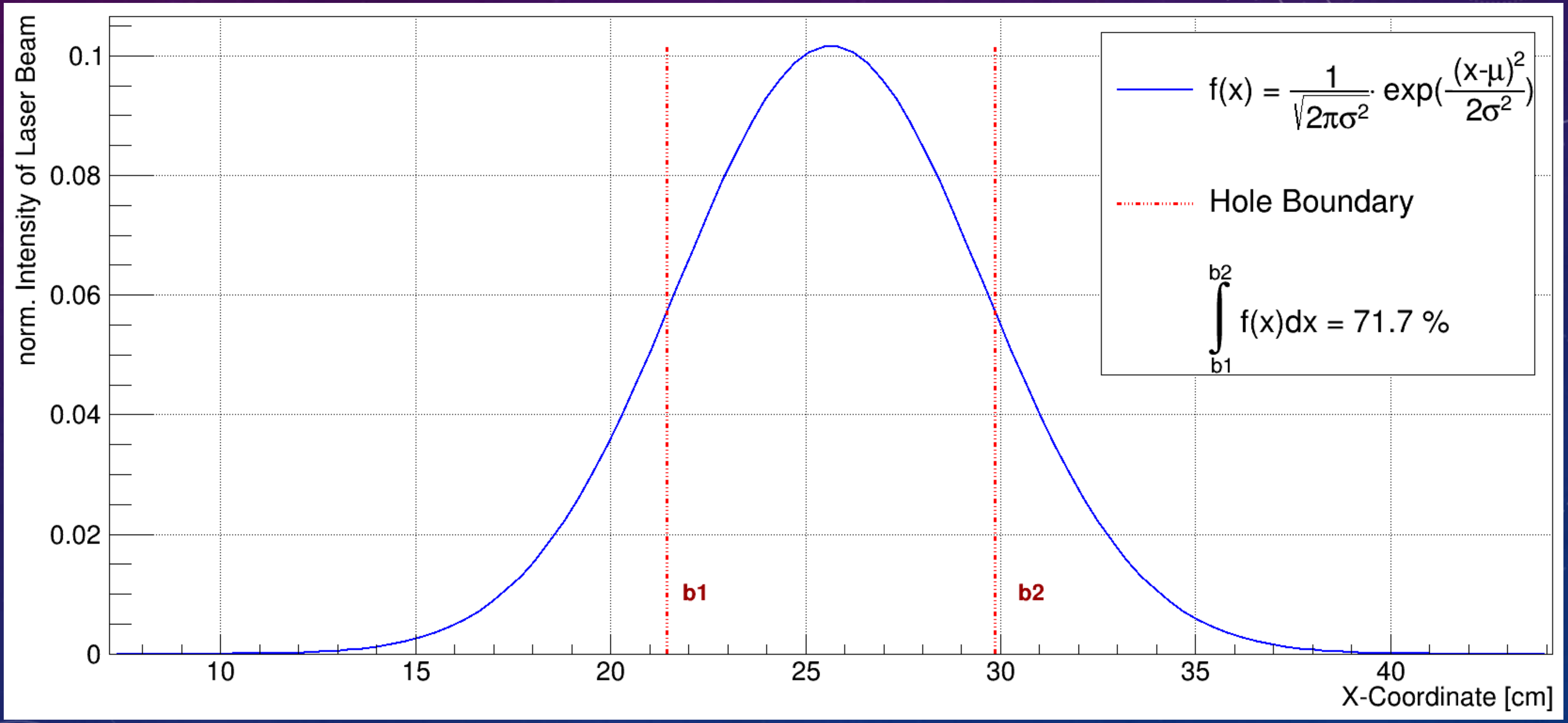
INFLUENCE OF A PIVOTING ANGLE ON L_S & L_A



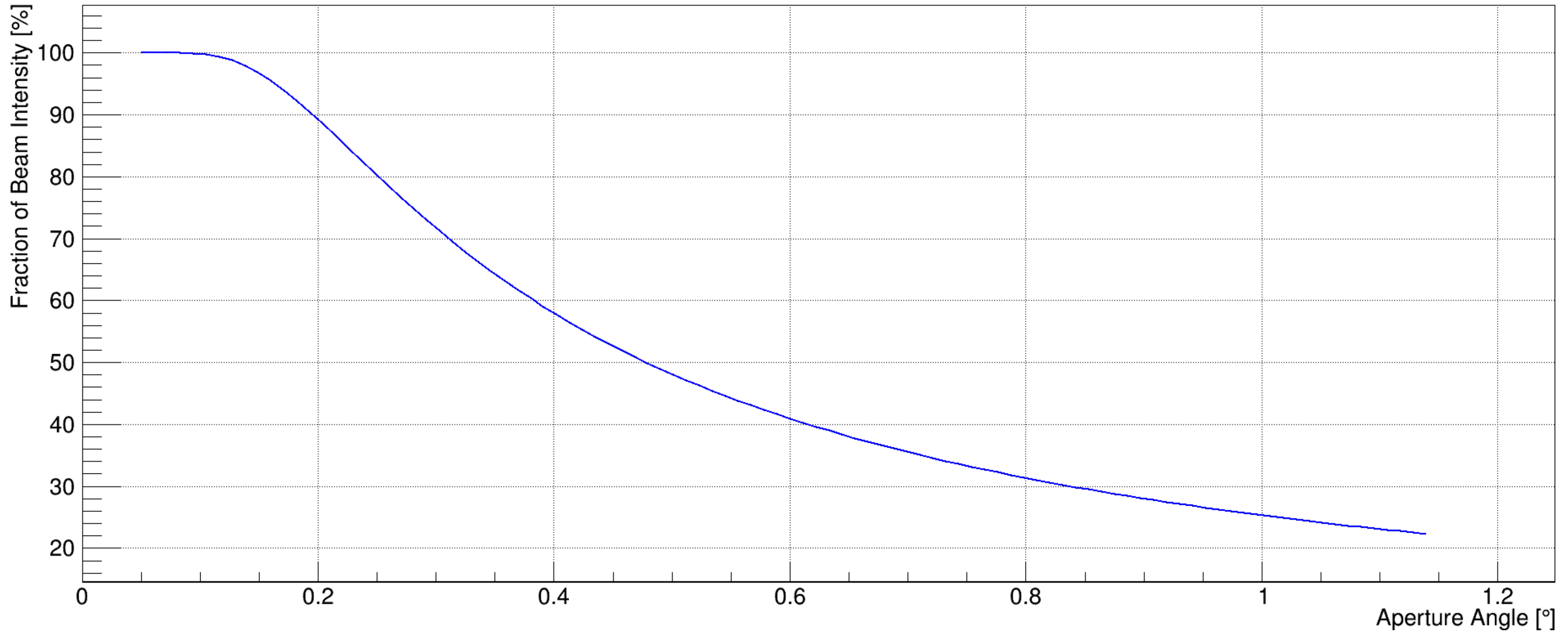


- Same situation for the L_s & L_a

GAUS PROFILE OF LASER BEAM



APERTURE ANGLE VS. BEAM INTENSITY



OPTICAL INSTRUMENTS

- Thorlabs: PM130D

  (PowerMeter)
  - λ: 400 nm - 1100 nm
  - A: 9.5 x 9.5 mm^2
  - P: 0.5 nW – 500mW

- Edmund Optics: #89-308

  (Beam Profiler)
  - λ: 350 nm - 1150 nm
  - A: 11.3 x 6.0 mm^2
  - pixel size: 5.5 x 5.5 μm^2
  - saturation: 10W/cm^2