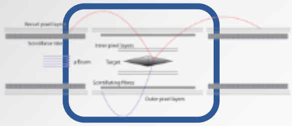
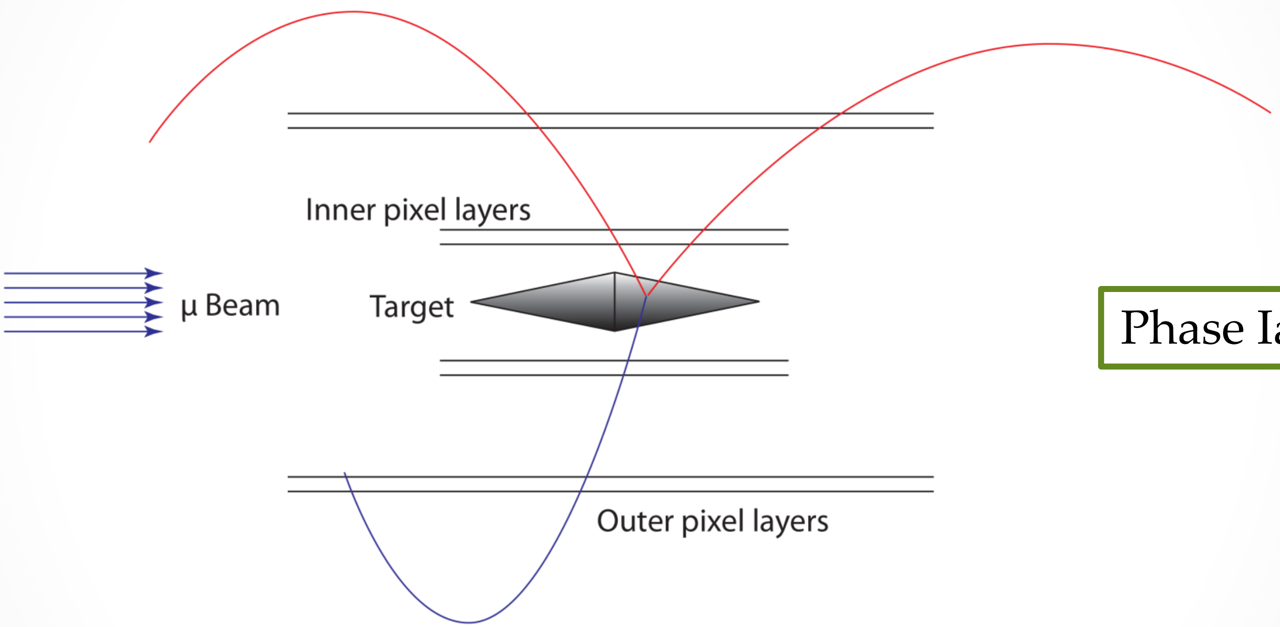
Technical Design for the Mu3e Detector

Dirk Wiedner on behalf of Mu3e

March 2016



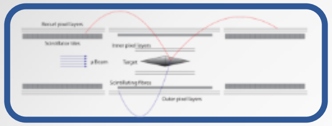
Phased Experiment



Phase Ia

- Muon beam O(10^7/s)
- Helium atmosphere
- 1 T B-field

- Target double hollow cone
- Silicon pixel tracker
- Scintillating Fiber detector
- Tile detector



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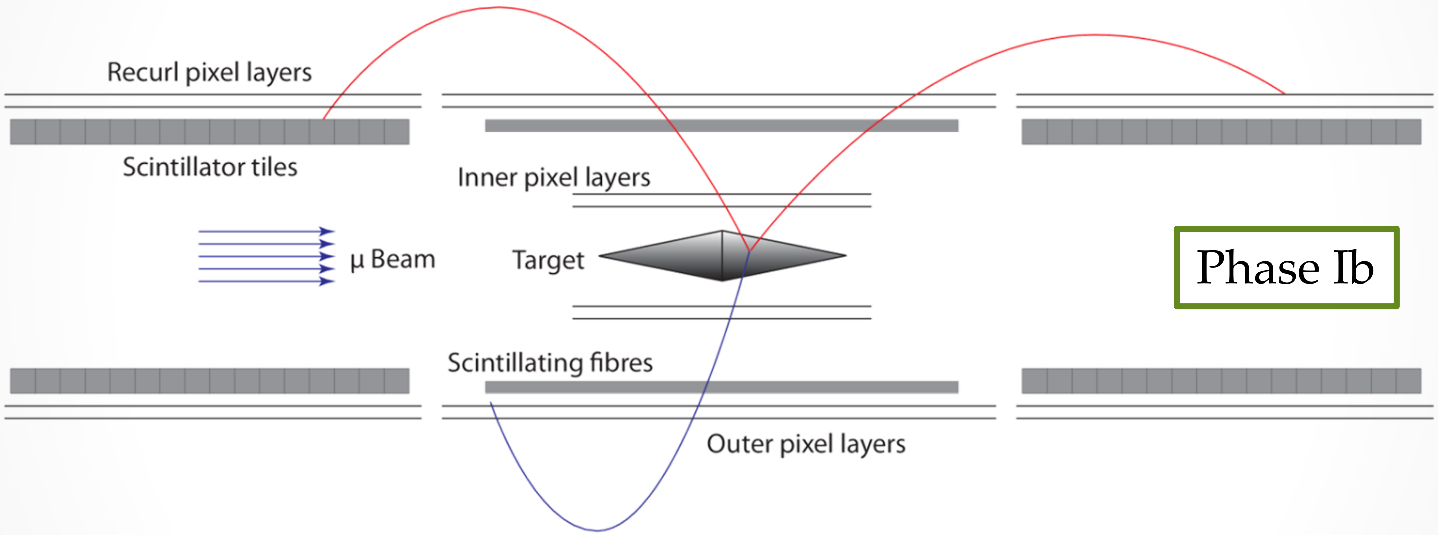


Phase Ib

- Muon beam O(10^8/s)
- Helium atmosphere
- 1 T B-field

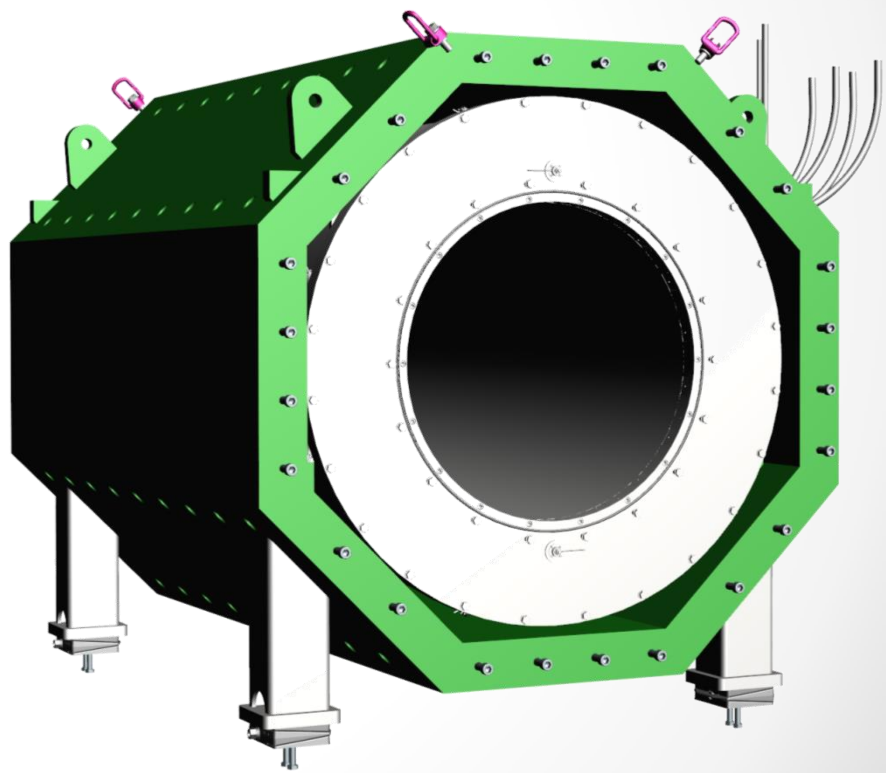
- Target double hollow cone
- Silicon pixel tracker
- **Scintillating Fiber detector**
- **Tile detector**

Magnet

• • •

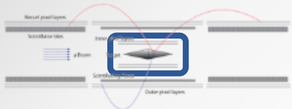
Mu3e Solenoid

- **DFG** grants Mu3e Solenoid
- **Danfysik** has been assigned to build the Mu3e magnet
- **Final Design Report** presented December 2015
- Magnet construction and delivery in autumn **2016**



Danfysik design of the Mu3e magnet

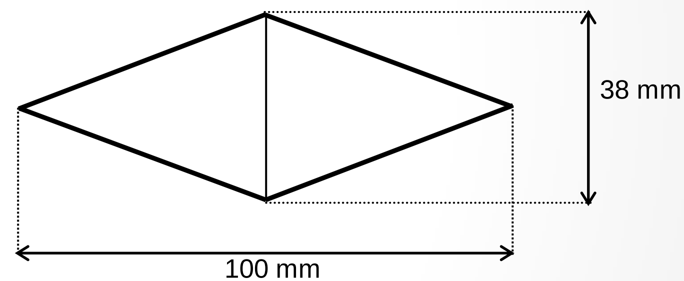
Mechanics

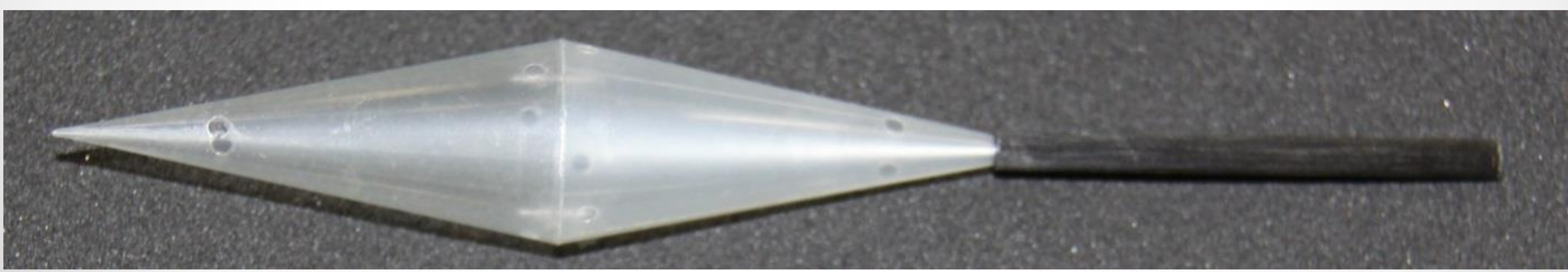


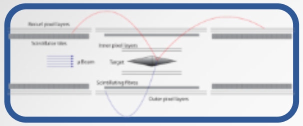
Muon Stopping Target

- Hollow double cone
- Mylar "sandwich" structure
- two/three rolled up foils glued with epoxy:

Upstream: 75 mm
Downstream: 85 mm

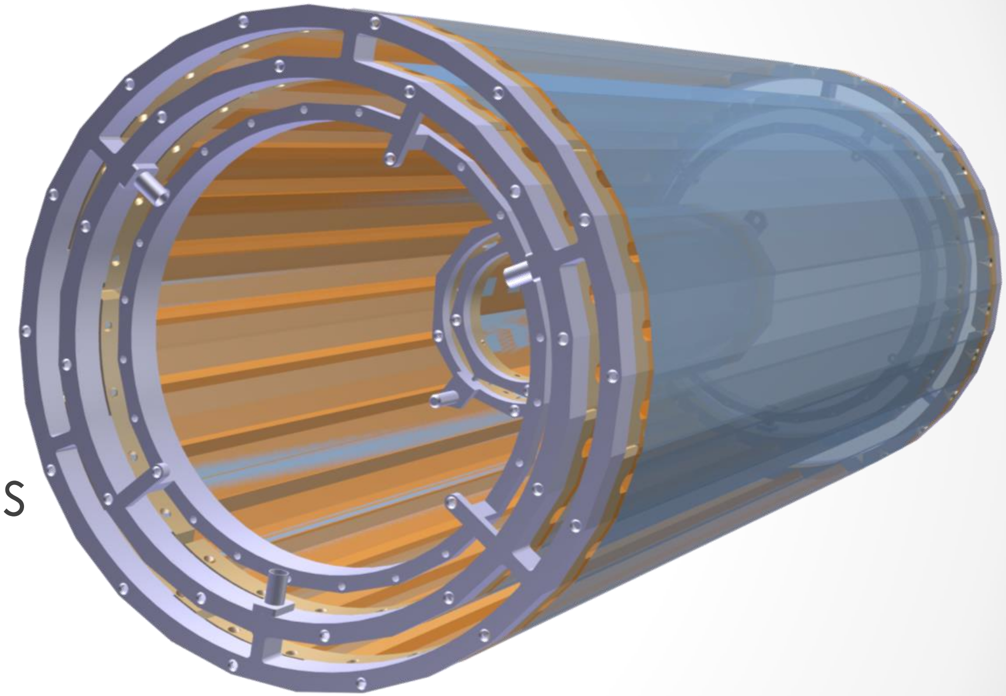


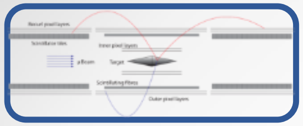




Silicon Tracker

- HV-MAPS
  - Thinned to 50 µm
  - Sensors 2 x 2 cm^2
- Kapton flex print
  - 25 µm Kapton
  - 12.5 µm Alu traces
- Kapton frame modules
  - 25 µm foil
  - Self supporting
- Alu end wheels
  - Support for all detectors





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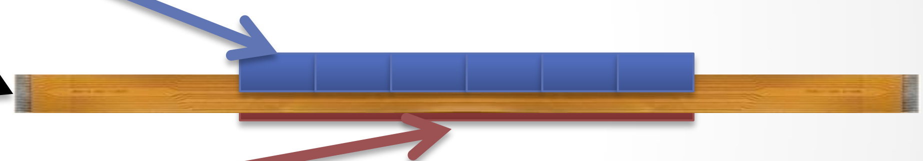

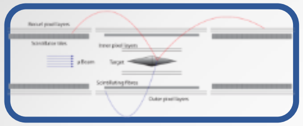

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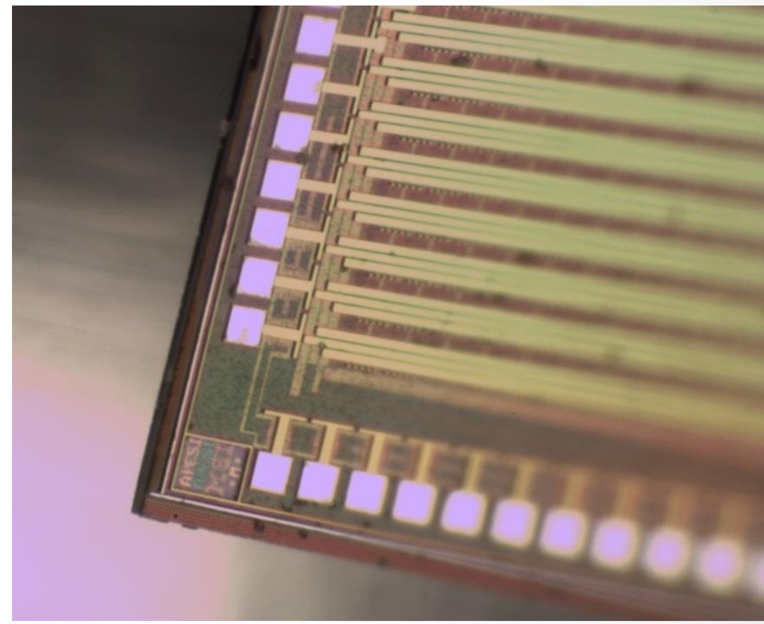
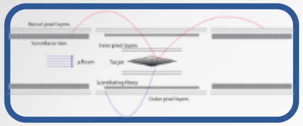
50µm MuPix7 tested



MuPix4 thinned to 50µm



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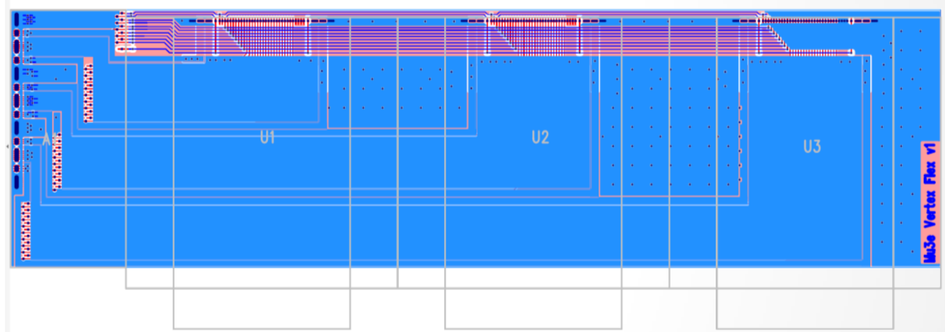
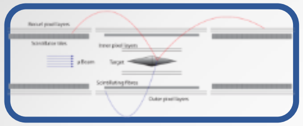


New Layout for Vertex Layers

Two technologies:
- Full Al-Kapton
- Hybrid Cu-Al-Kapton



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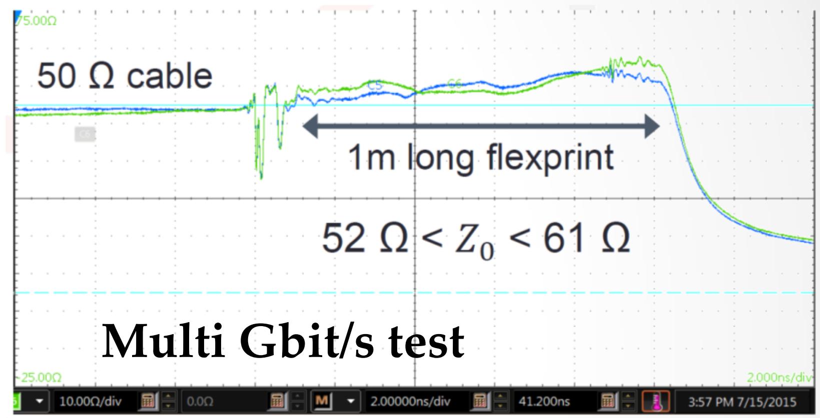
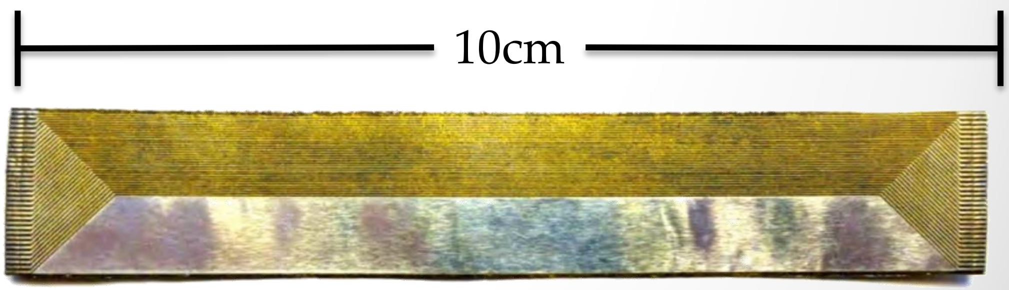
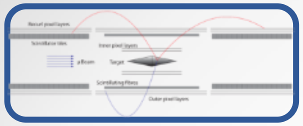


O. Harper, Heidelberg 2015



Laser-cut flex print prototype



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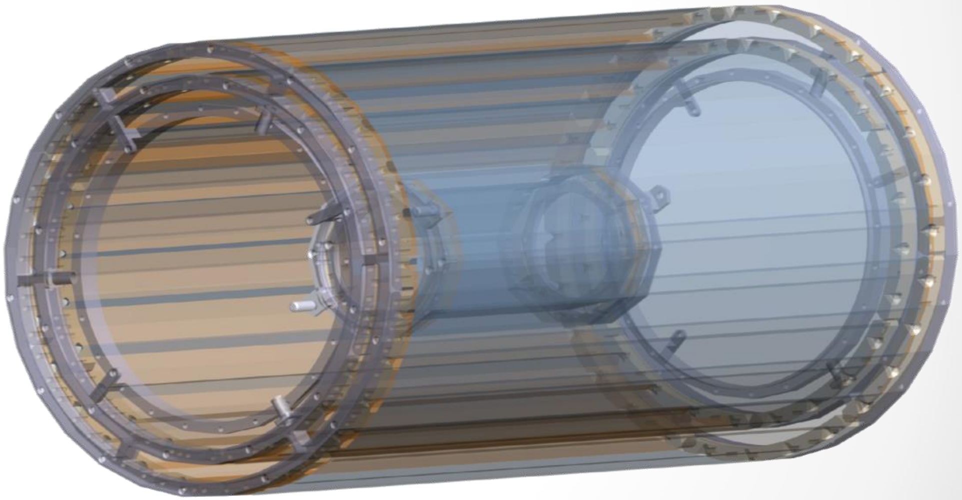
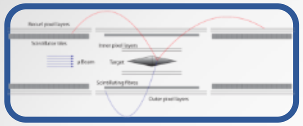


CAD of Kapton frames



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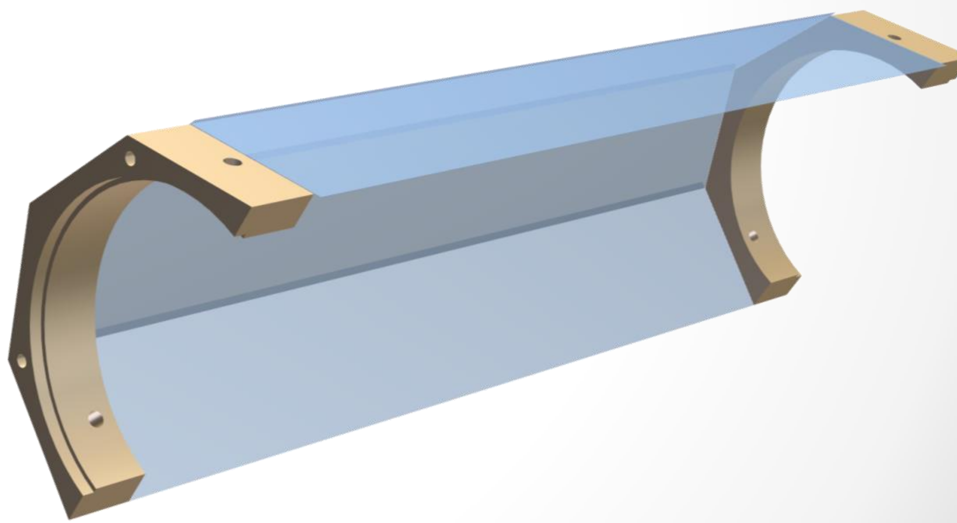
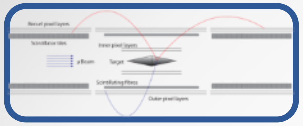
- Two halves for layers 1+2
- 6 modules in layer 3
- 7 modules in layer 4



CAD of Layer 1 module



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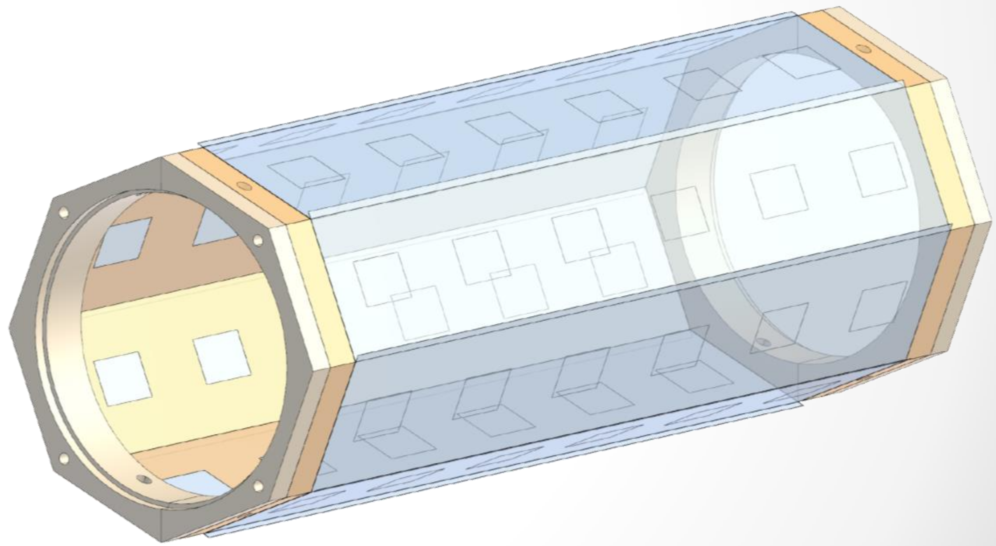

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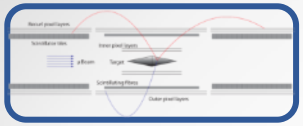

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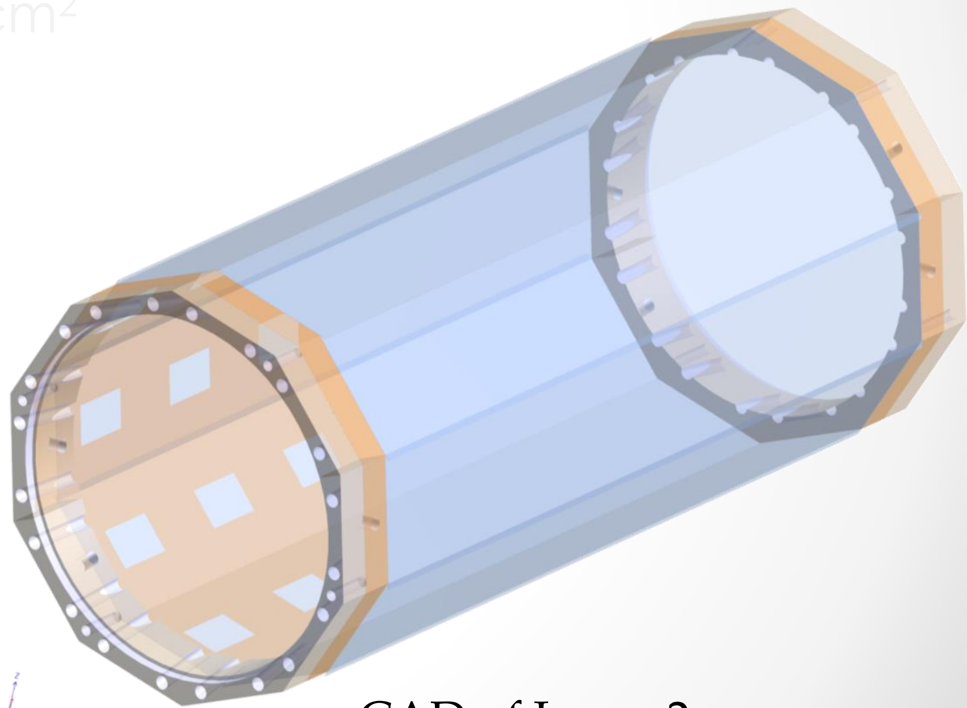
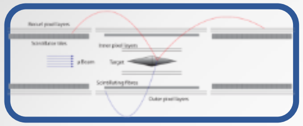


CAD of Layer 2



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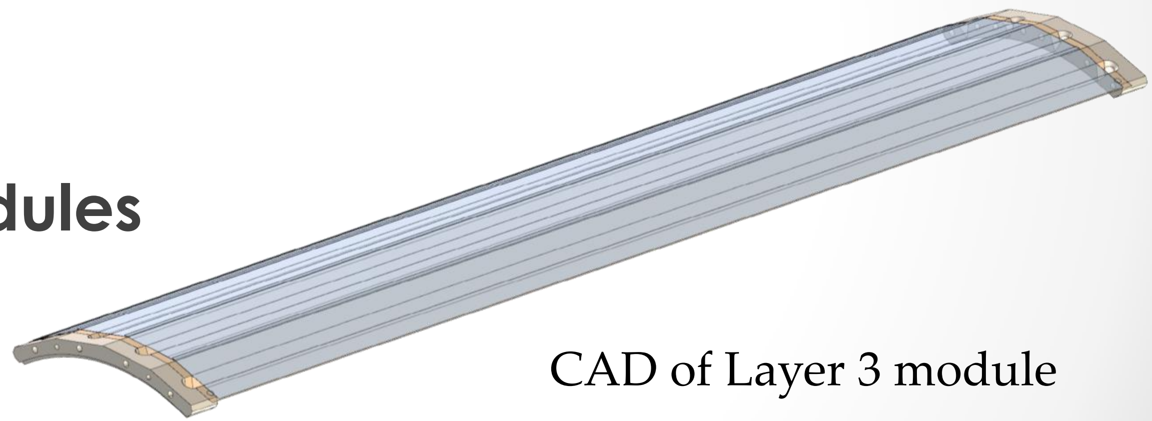
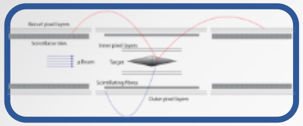


CAD of Layer 3 module



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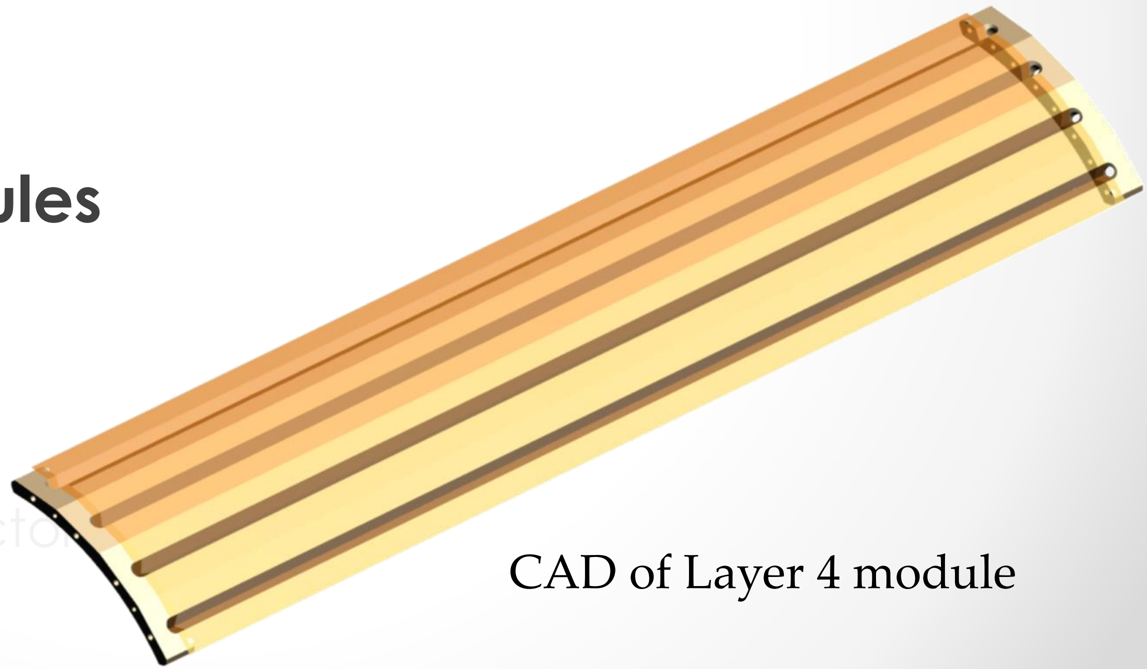
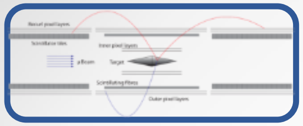


CAD of Layer 4 module



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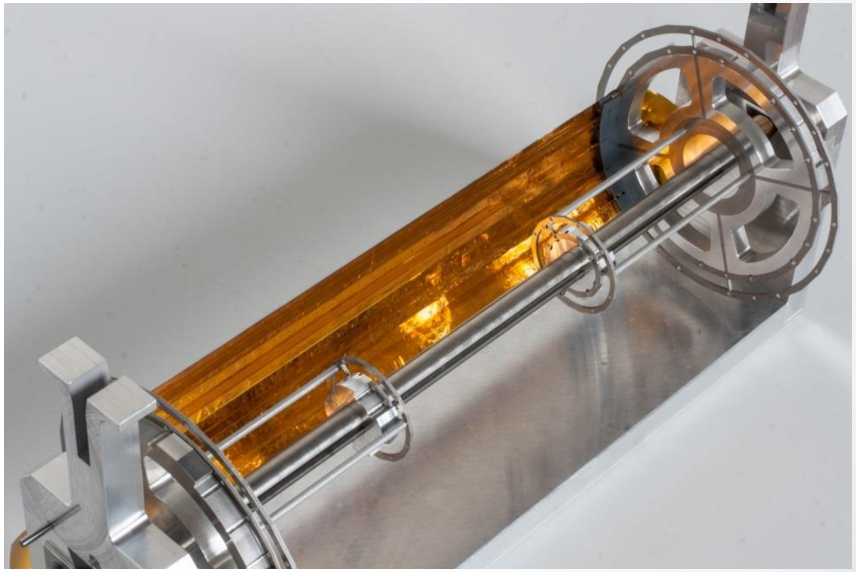
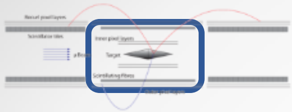
- **Alu end wheels**
  - Support for all detectors
  - Integrated He distribution

End wheels also support
- Tile Detector
- Fiber Detector



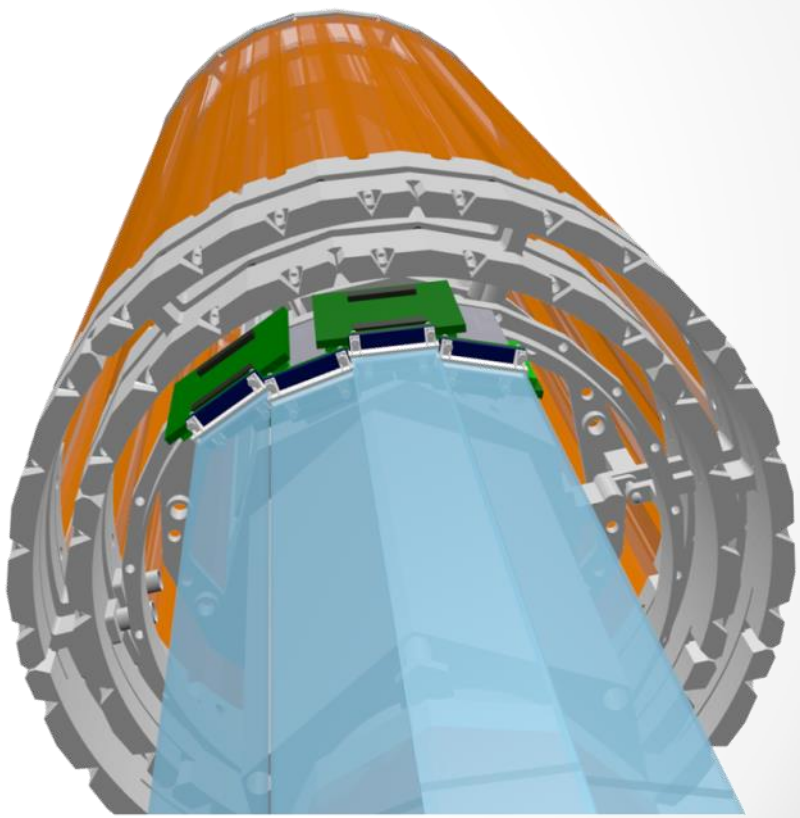
Layer 3 Prototype in Assembling Frame

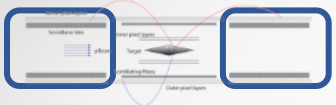


Fiber Tracker

- Fiber ribbon modules
  - 16 mm wide
  - **290 mm** long
- Total fiber tracker:
  - 24 ribbon-modules
  - 4536 fibers
- **CAD models** ready
- 64 channel **prototype** tested

See:
Fibers
Angela Papa (PSI)

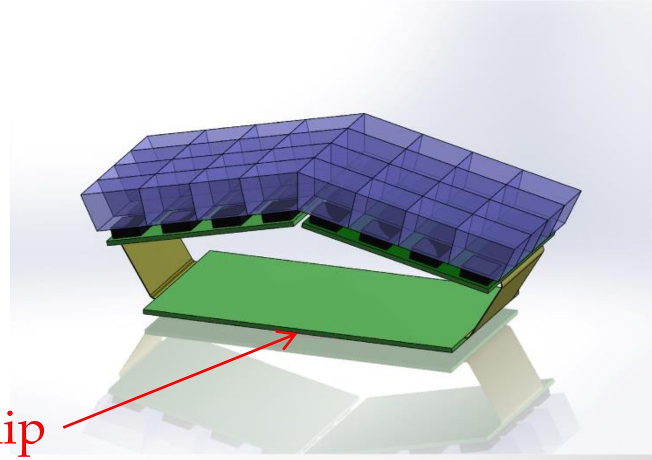




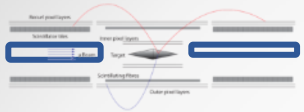
Tile Detector

- Sub-modules
  - Successful 16 channel prototypes
- **STiC** readout chip
  - Good analog performance
  - **Fast LVDS** driver chip back from submission

Submodule (2x16 Ch.)

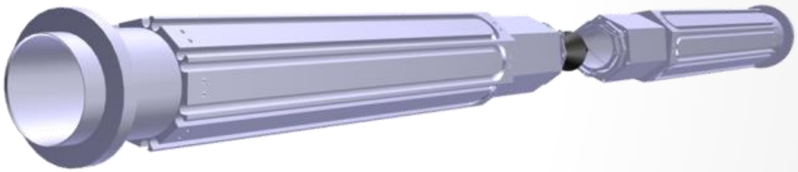


STiC chip



Beam Pipe

- Aluminum pipe
- Mechanical support
  - o Detectors attached to beam pipe
  - o Via end rings
- Repeater PCBs attached
  - o Voltage regulators mounted directly
  - o Integrated cooling



Beam pipe design

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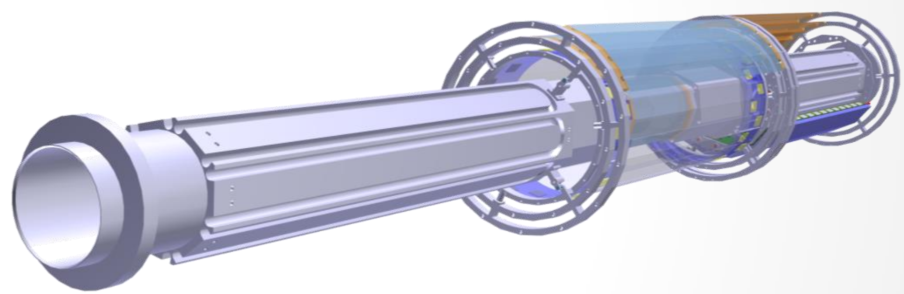

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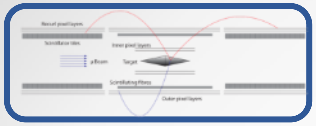
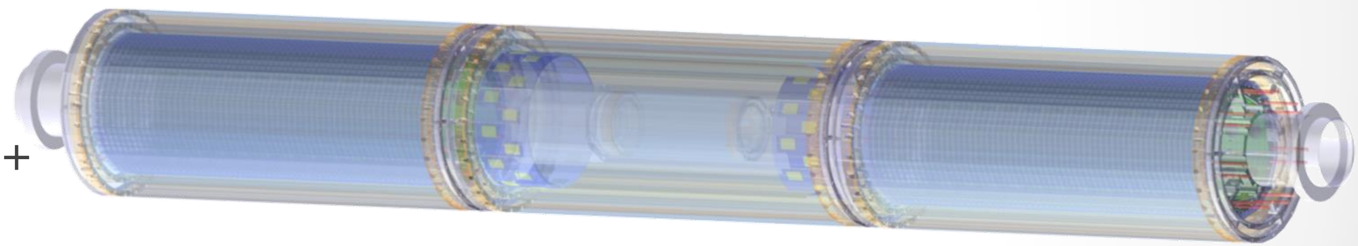
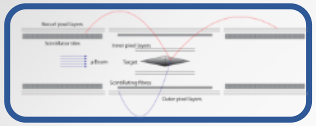


Overall Assembly

- CAD of:
  - Silicon Tracker +
  - Tile detector +
  - **Scintillating fiber detector +**
  - Target +
  - PCBs +
  - Beam pipe +
  - Cooling +
  - Cage and rails + in Magnet
- To be added:
  - Cabling
  - Piping



Detailed CAD of phase I detector



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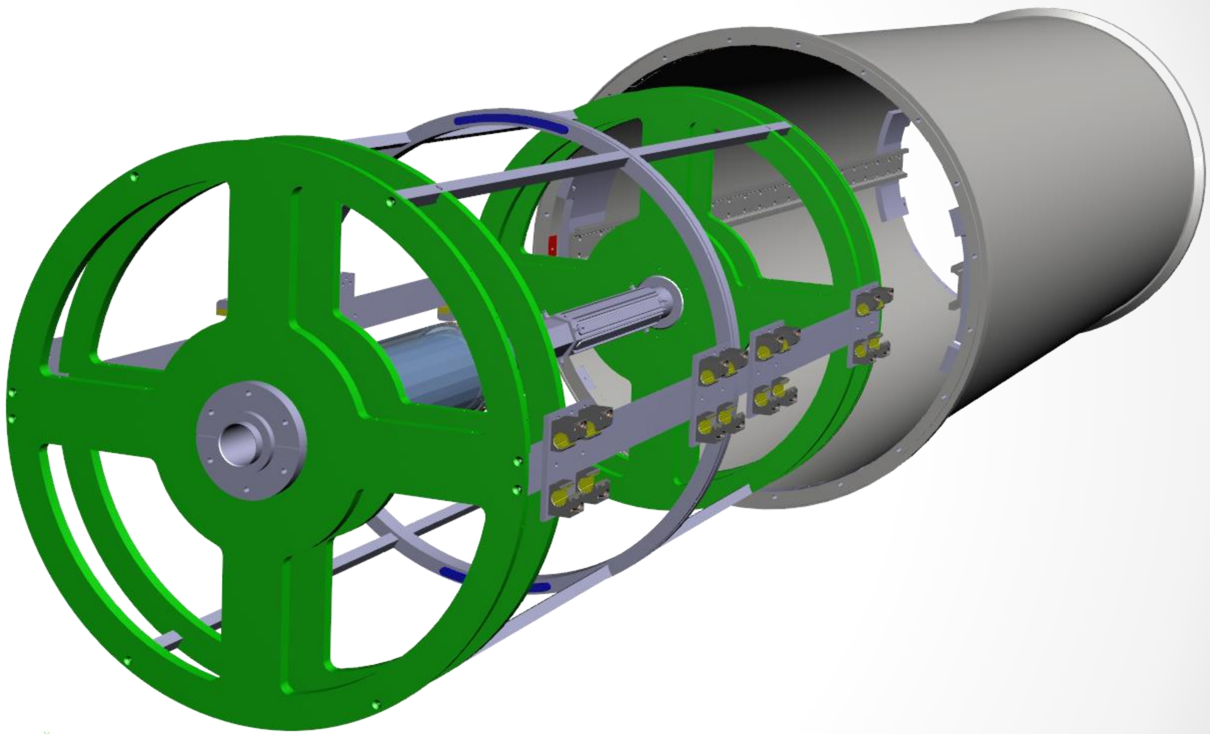
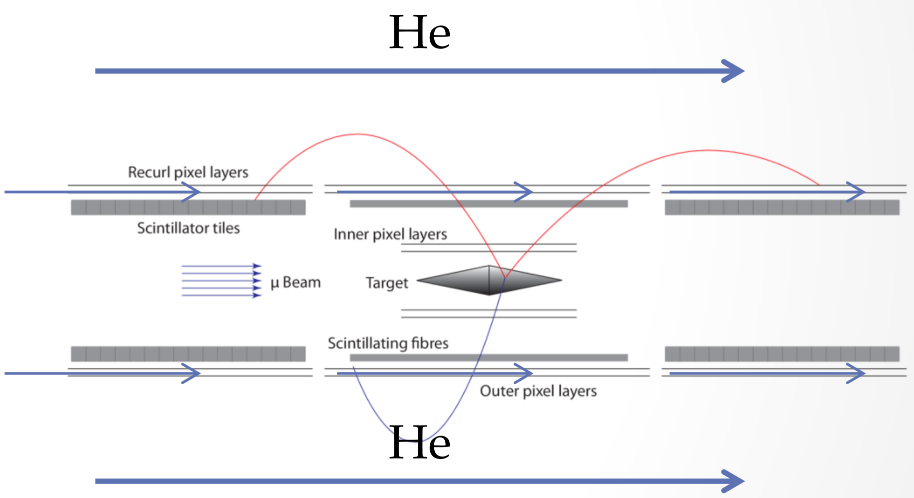


CAD of **magnet** and rail system

Cooling

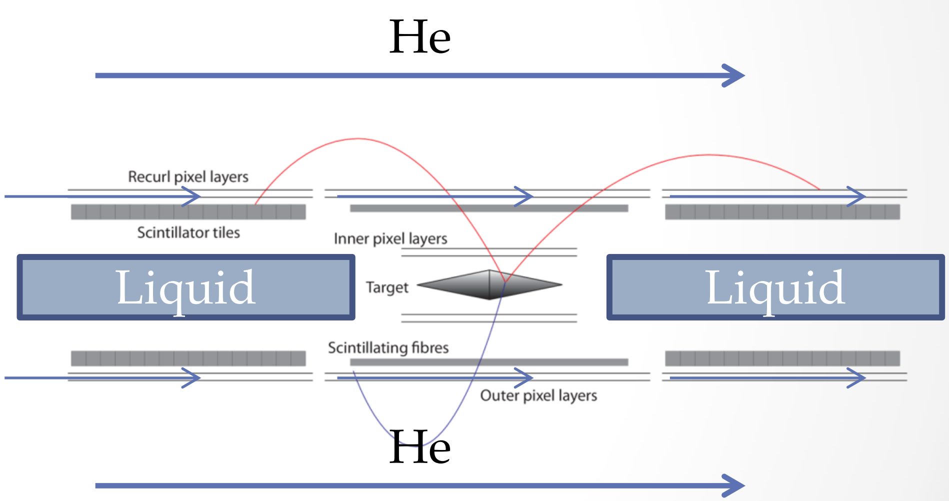
Cooling Concept

- **Gaseous He** cooling
  - For **silicon tracker**
  - Low radiation length
  - Global flow
  - Local direct cooling



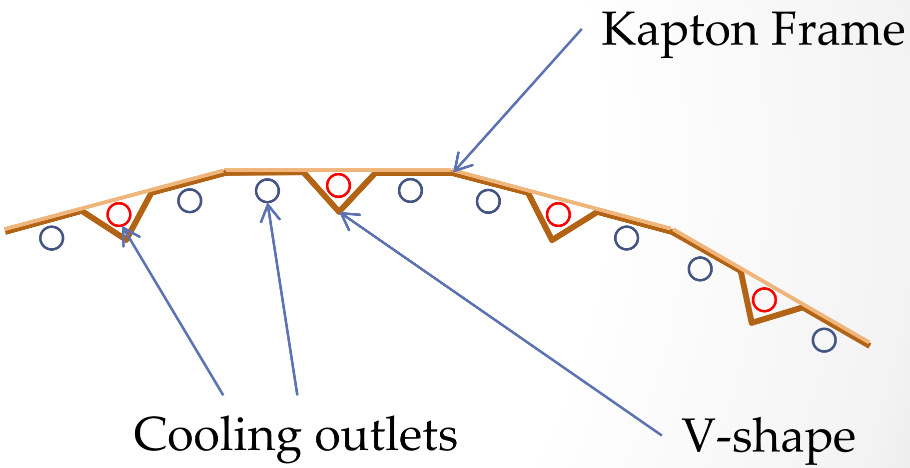
Cooling Concept

- **Gaseous He** cooling
  - For **silicon tracker**
  - Low radiation length
  - Global flow
  - Local direct cooling
- **Liquid cooling**
  - For **readout-electronics**
  - For **Tile** and **Fiber Detector**
  - Integrated in beam-pipe



He Cooling

- Gaseous He cooling
  - Low multiple Coulomb scattering
  - More effective than air
- Global flow inside magnet volume
- Local flow for tracker
  - Distribution in frame
    - **V-shapes**
    - **Outer surface**



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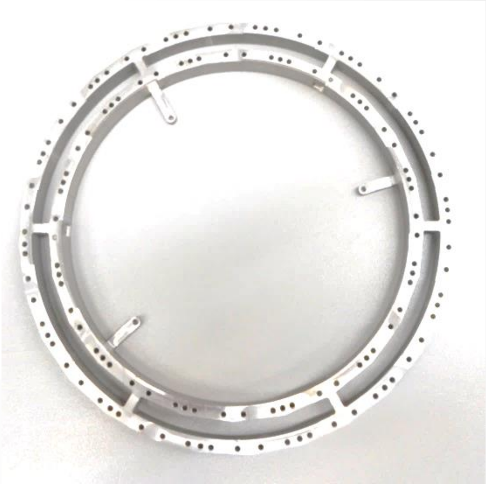

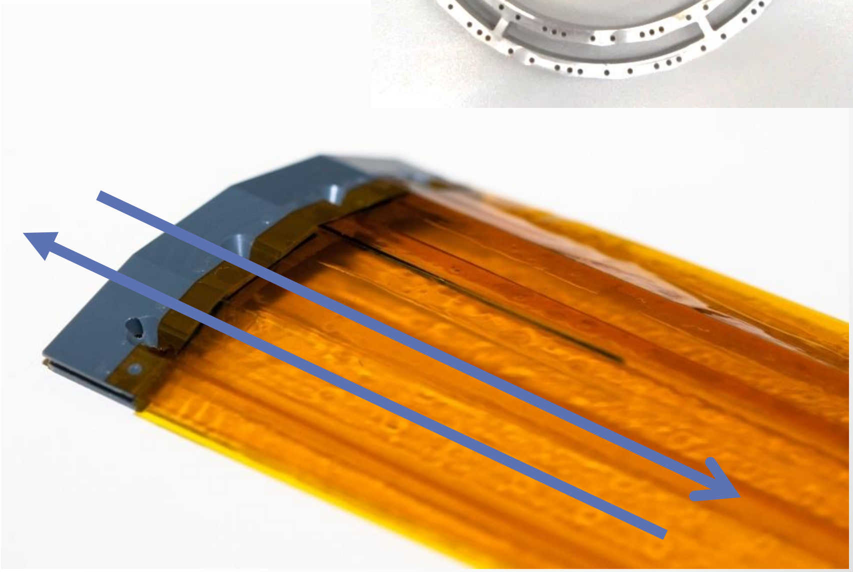

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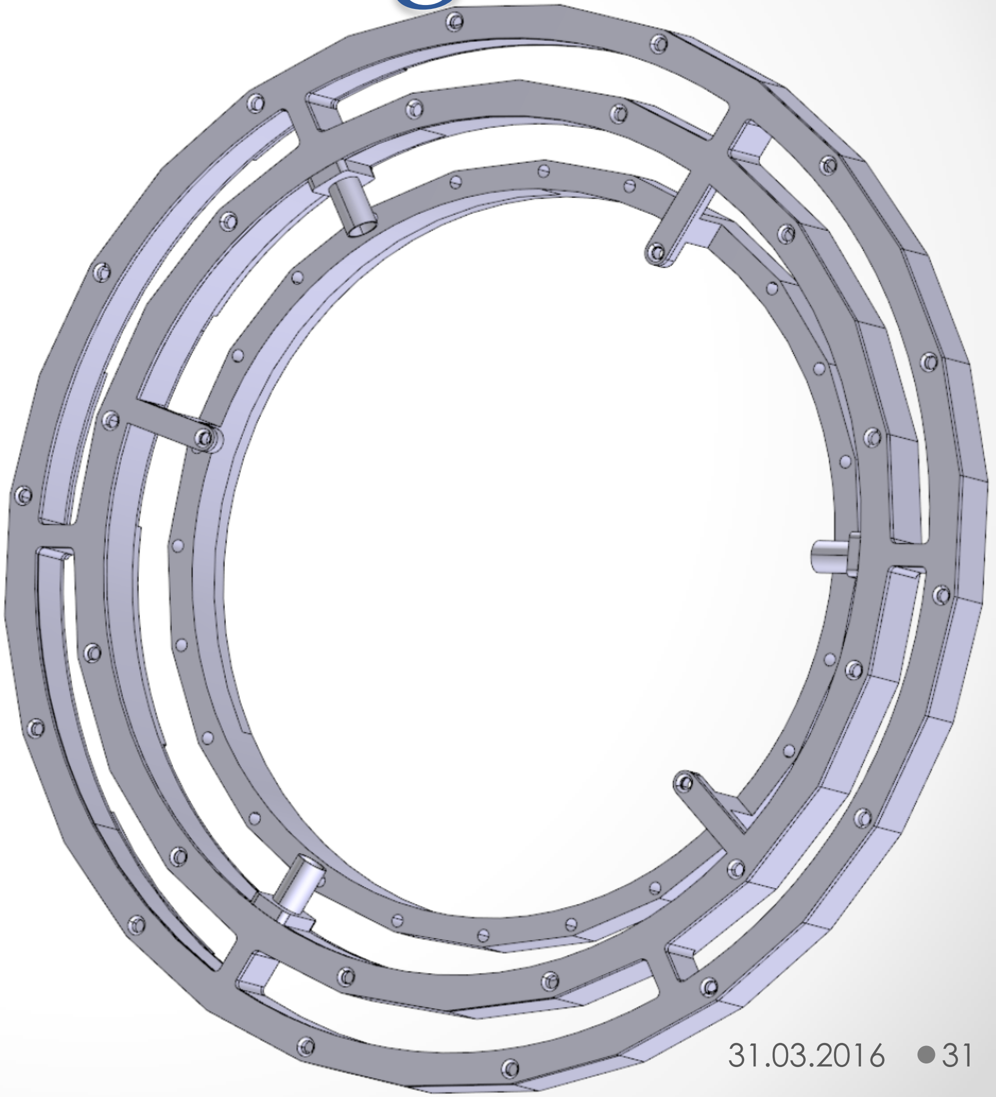

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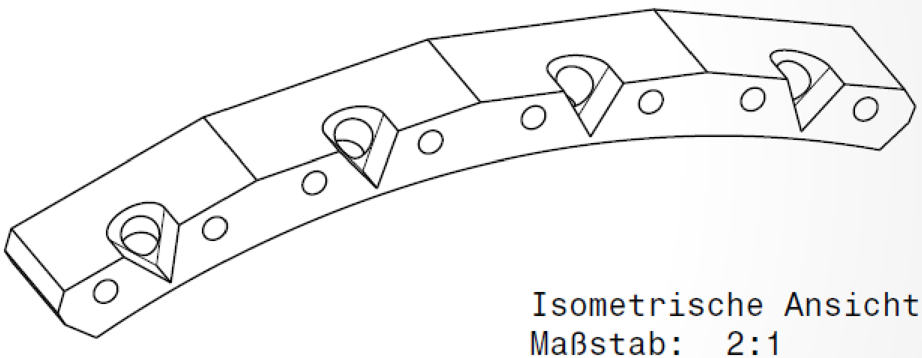

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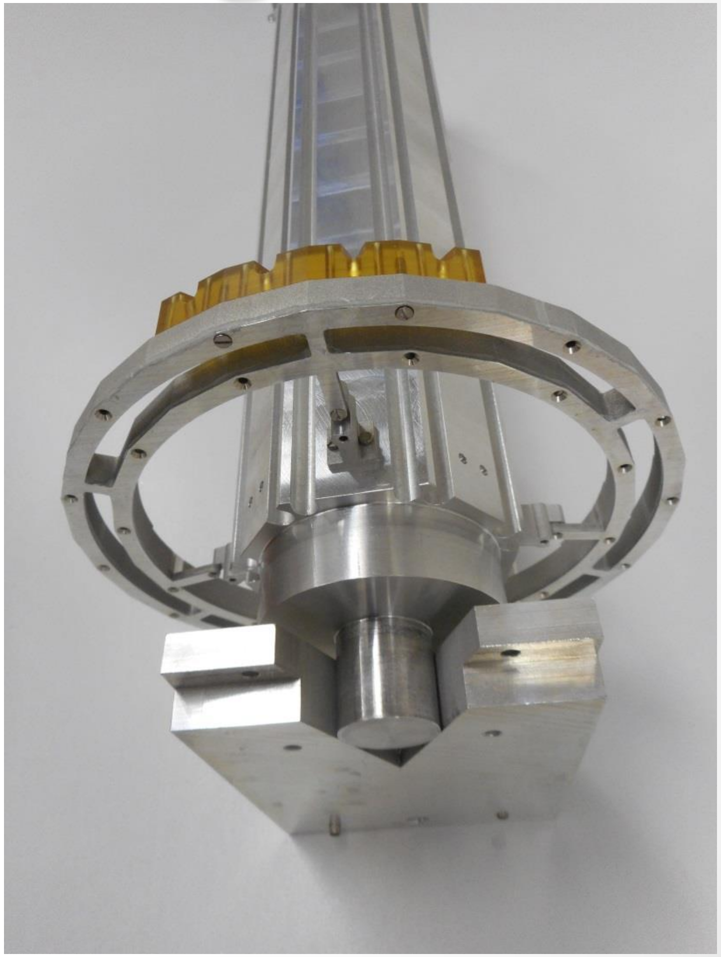
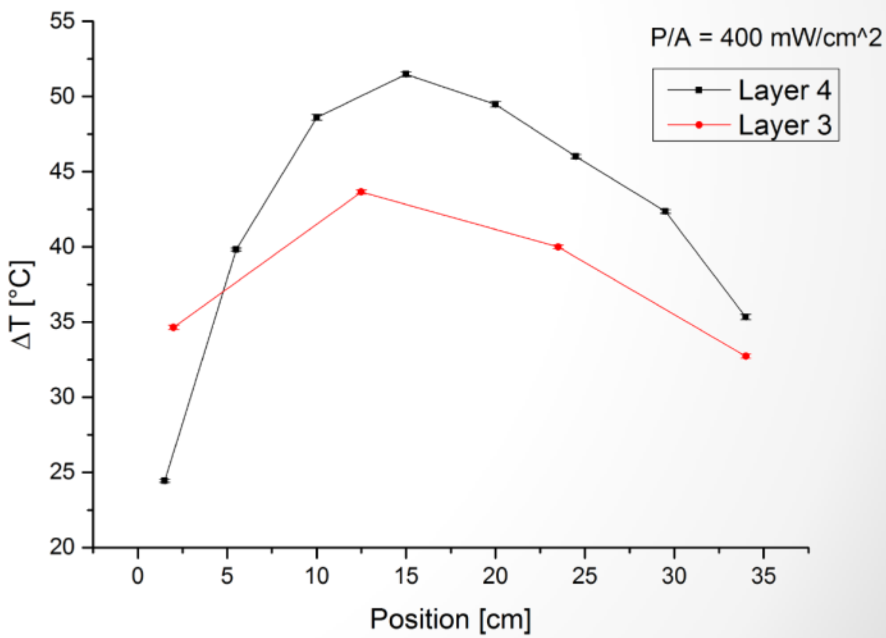


Local Flow Cooling

- Module prototypes
  - Layer 3+4 of silicon tracker
  - … of Aluminum-Kapton
  - Ohmic heating **400mW/cm²**



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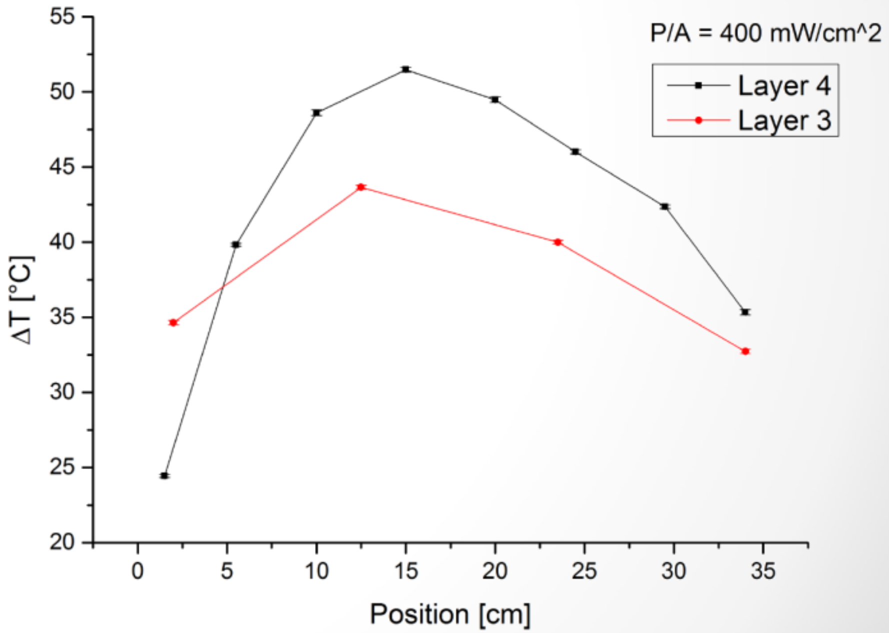
  - V-shaped ducts under sensors
  - **He at 20 m/s**



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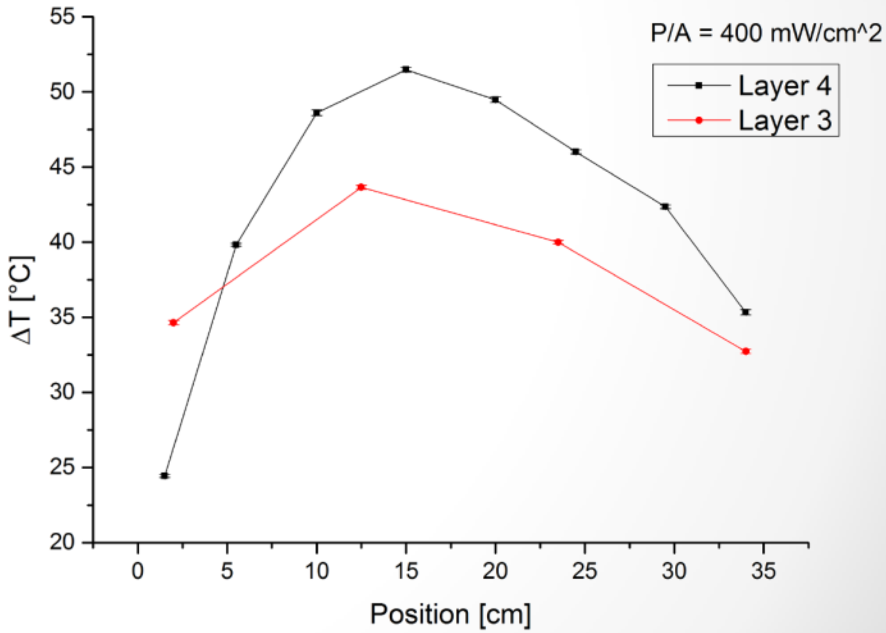
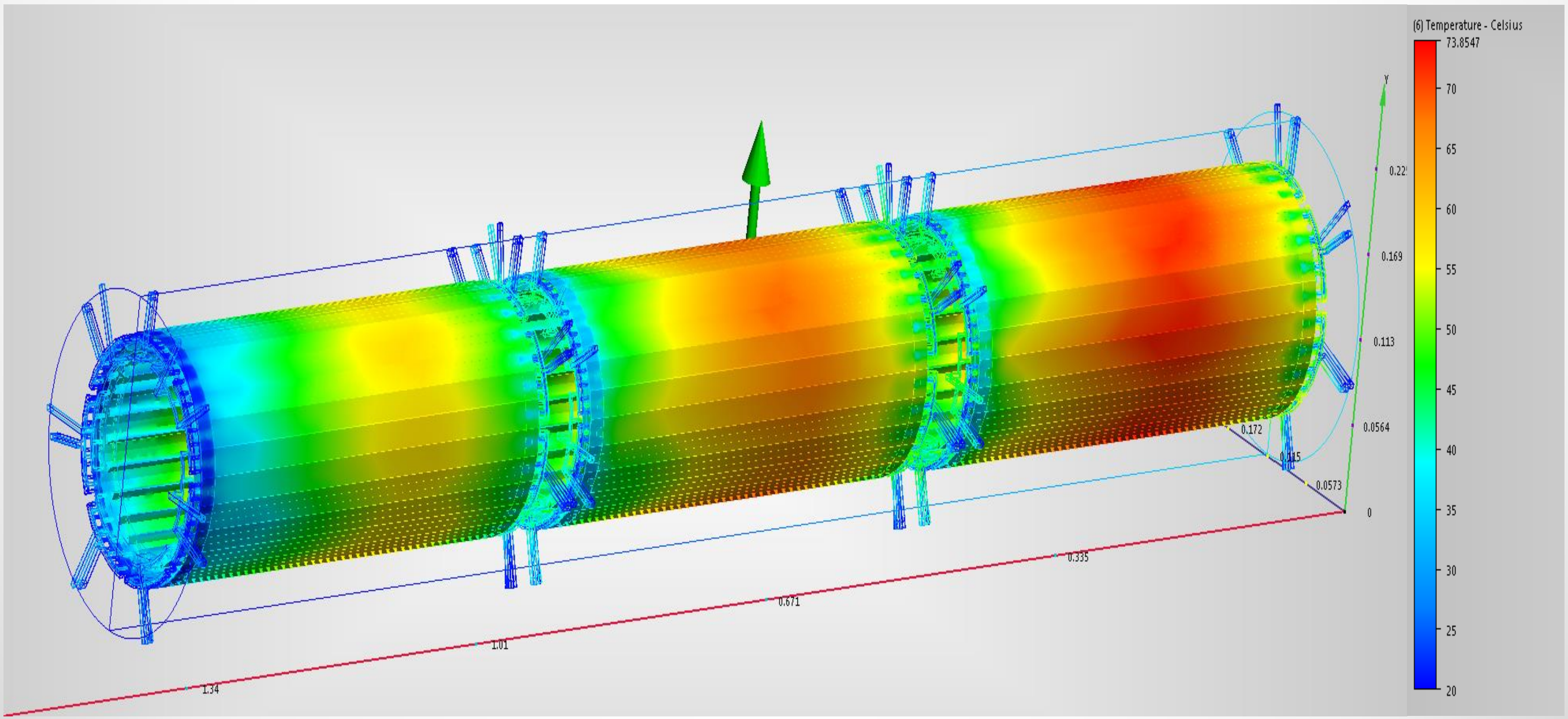
  - Layer 3+4 of silicon tracker
  - … of Aluminum-Kapton
  - Ohmic heating **400mW/cm²**
- Cooling through end pieces
  - V-shaped ducts under sensors
  - **He at 20 m/s**
- Temperature sensors attached to foil
- Results promising: **ΔT < 55°K**



3 Station Simulation

- 20°C helium cooling: laboratory conditions
  - 2°C helium temperature for experiment!
- 4m/s main flow **20 m/s** gap flow

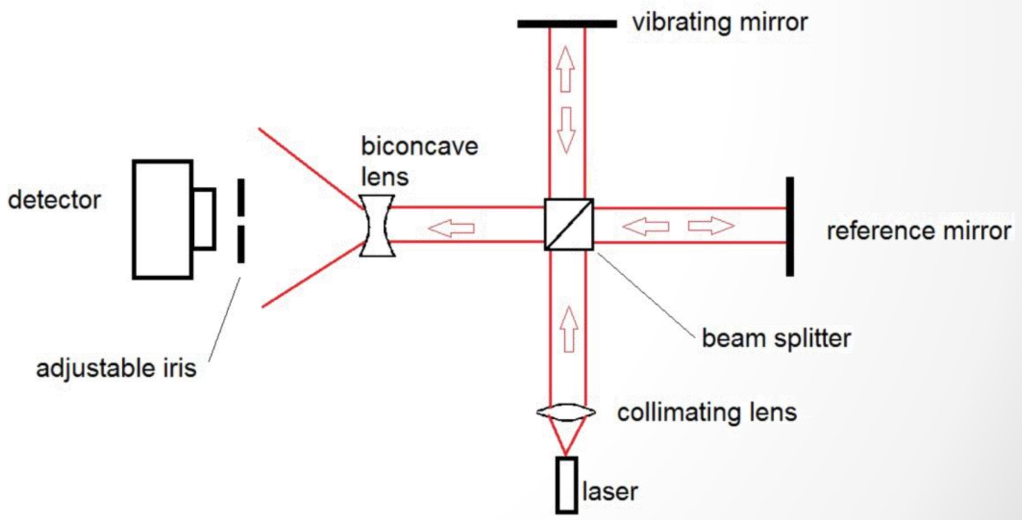


Vibration Test

- High He flow **20m/s**
- Thin foil detector structure

➢ **Vibrations?**

- He cooling mockup +
- **Michelson interferometer**



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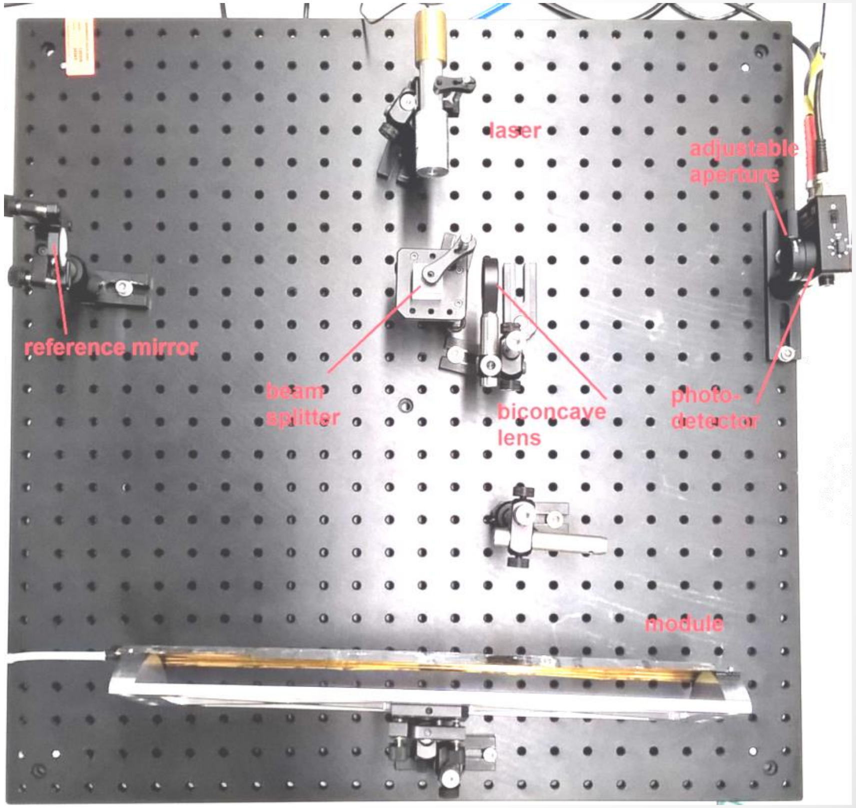

Vibration Test

- High He flow 20m/s
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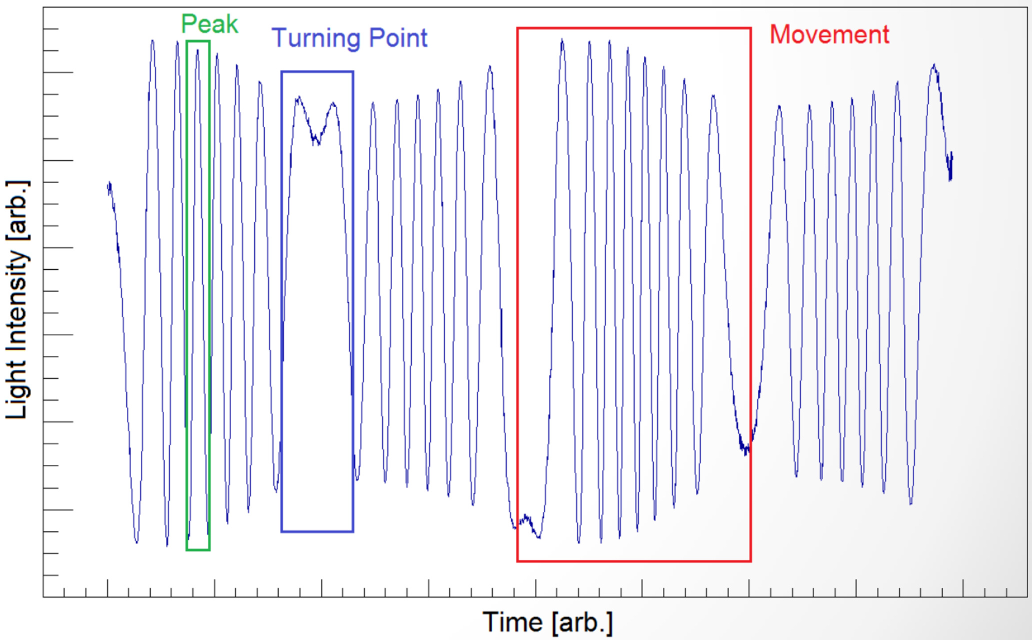
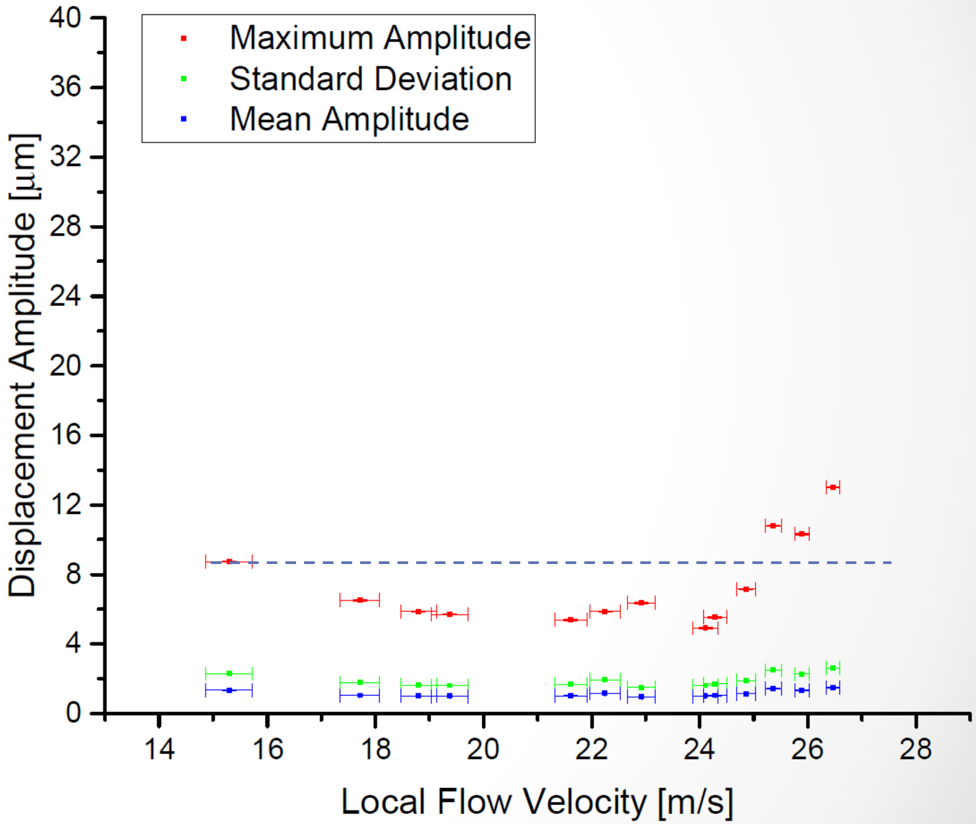
- ➢ Vibrations?
- He cooling mockup +
- Michelson interferometer +
- **Oscilloscope**



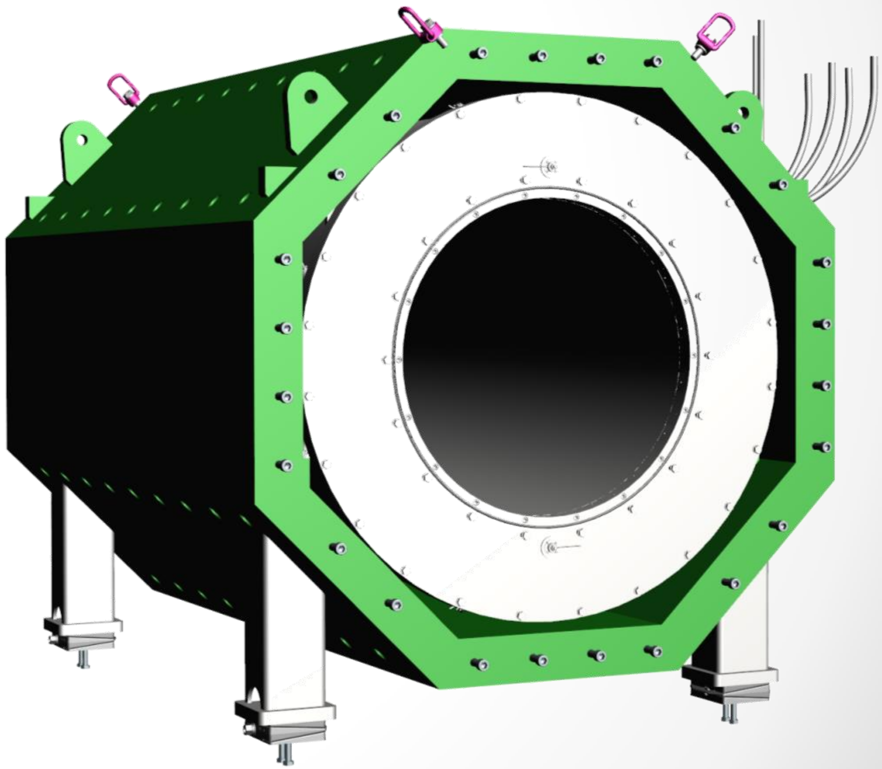
Vibration Test

- High He flow **20m/s**
- Thin foil detector structure
- ➢ Vibrations?
- He cooling mockup +
- Michelson interferometer +
- Oscilloscope
- **10 µm** amplitute
  - For typical cooling



Summary

- **Magnet**
  - Danfysik
  - Design ready
- Mechanics
  - **Detailed CAD models**
- Cooling
  - Gaseous **He** cooling of tracker
  - **ΔT < 55°K** for **400mW/cm^2**
  - Vibrations **10 μm**



Outlook

- Magnet
  - Delivery **2016**
- Mechanics
  - **Detector module prototypes**
- Cooling
  - Water cooling for Tile and Fiber Detector

Backup Slides

Cooling Concept

- **Gaseous He** cooling
  - For **silicon tracker**
  - Low radiation length
  - Global flow
  - Local direct cooling