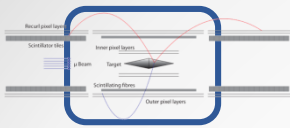


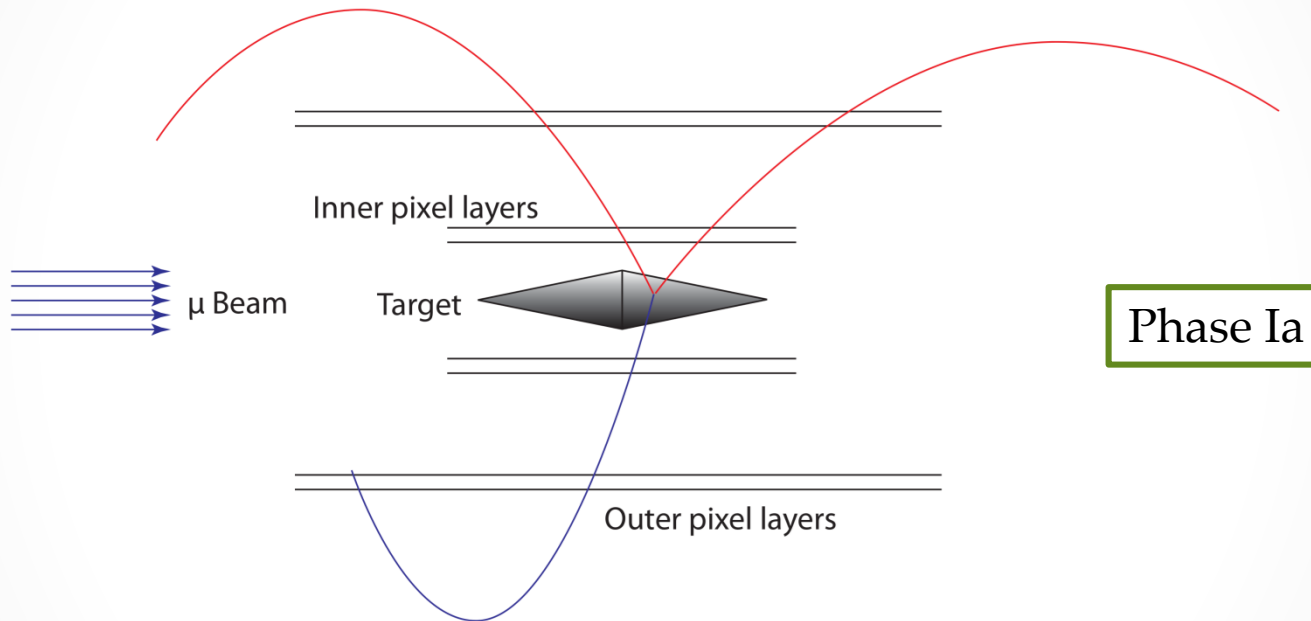


Technical Design for the Mu3e Detector

Dirk Wiedner on behalf of Mu3e
February 2016

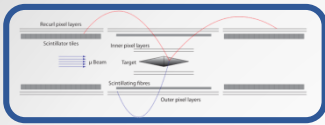


Phased Experiment

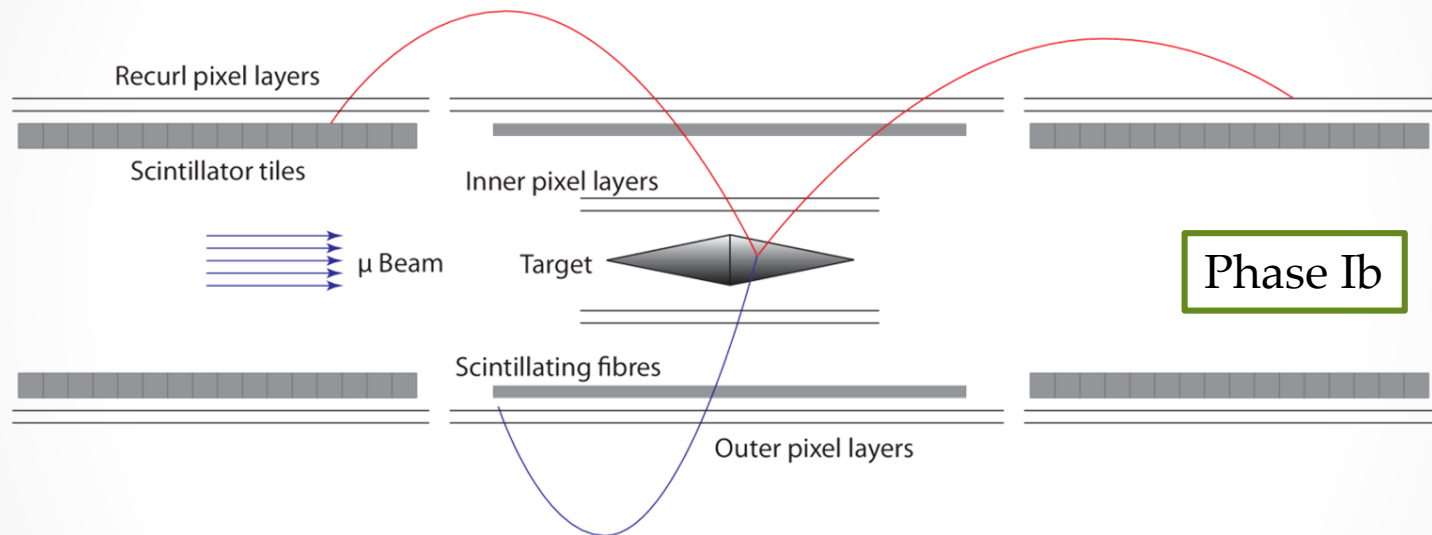


- Muon beam $O(10^7/s)$
- Helium atmosphere
- 1 T B-field

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



Phased Experiment



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

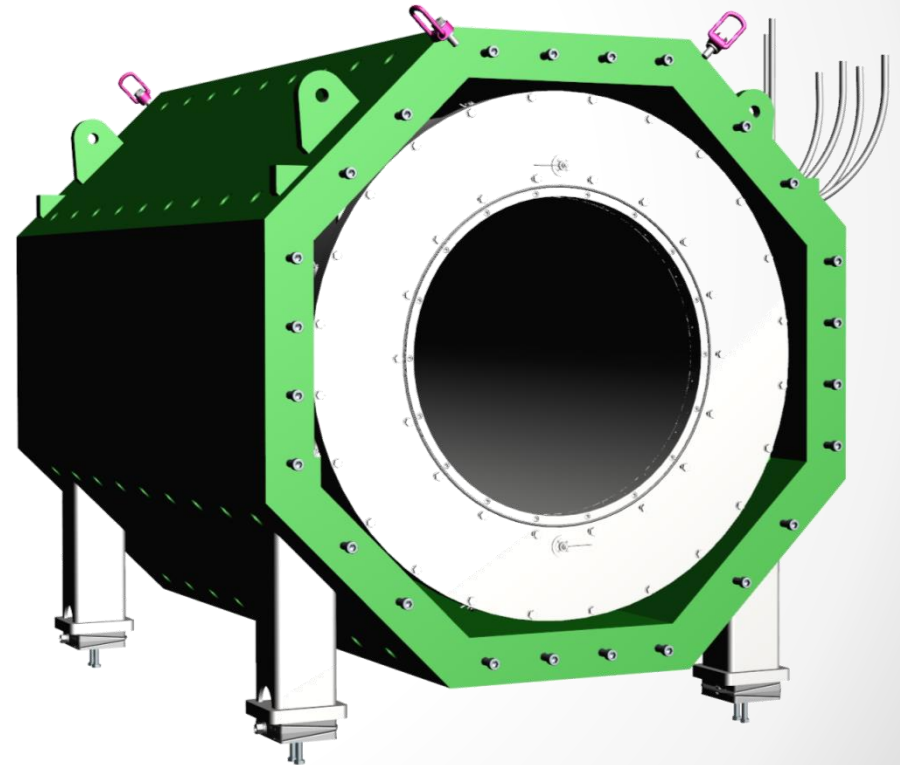
- Target double hollow cone
- Silicon pixel tracker
- **Scintillating Fiber detector**
- **Tile detector**

Magnet

...

Mu3e Solenoid

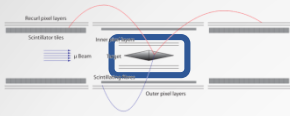
- **DFG** grants Mu3e Solenoid
- **Danfysik** has been assigned to build the Mu3e magnet
- **Final Design Report** presented December 2015
- Magnet construction and delivery in **2016**



Danfysik design of the Mu3e magnet

Mechanics



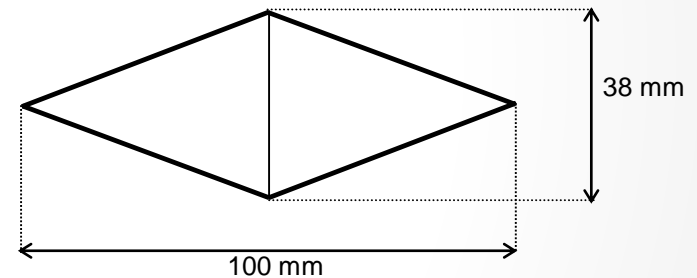


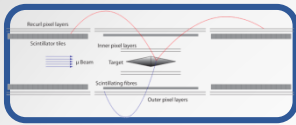
Muon Stopping Target

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

Upstream: 75 mm

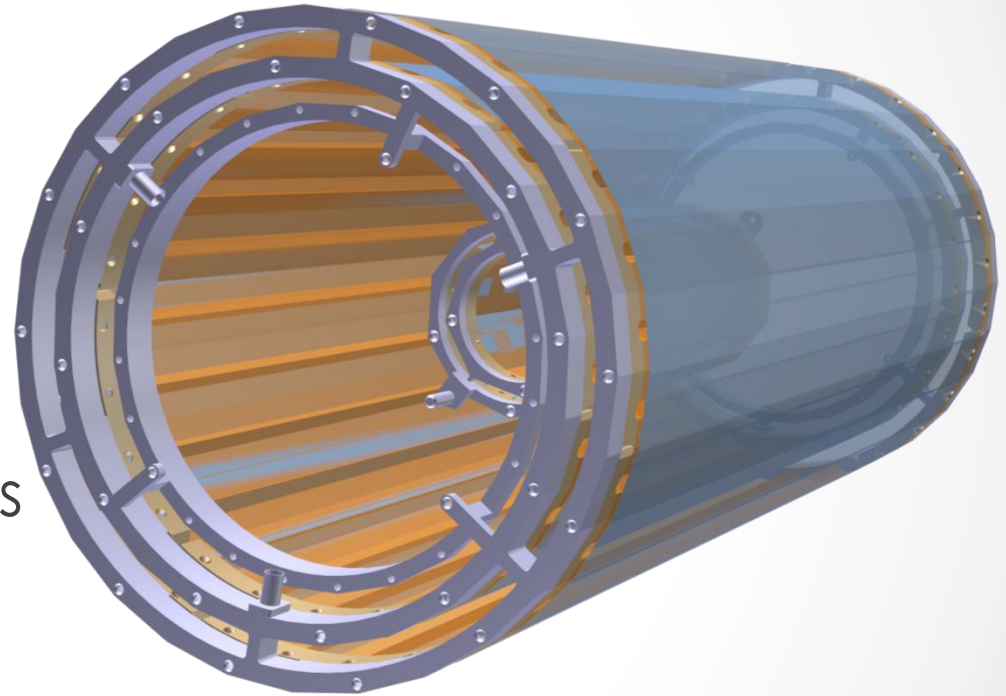
Downstream: 85 mm

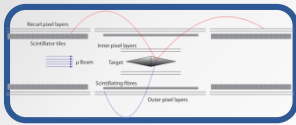




Silicon Tracker

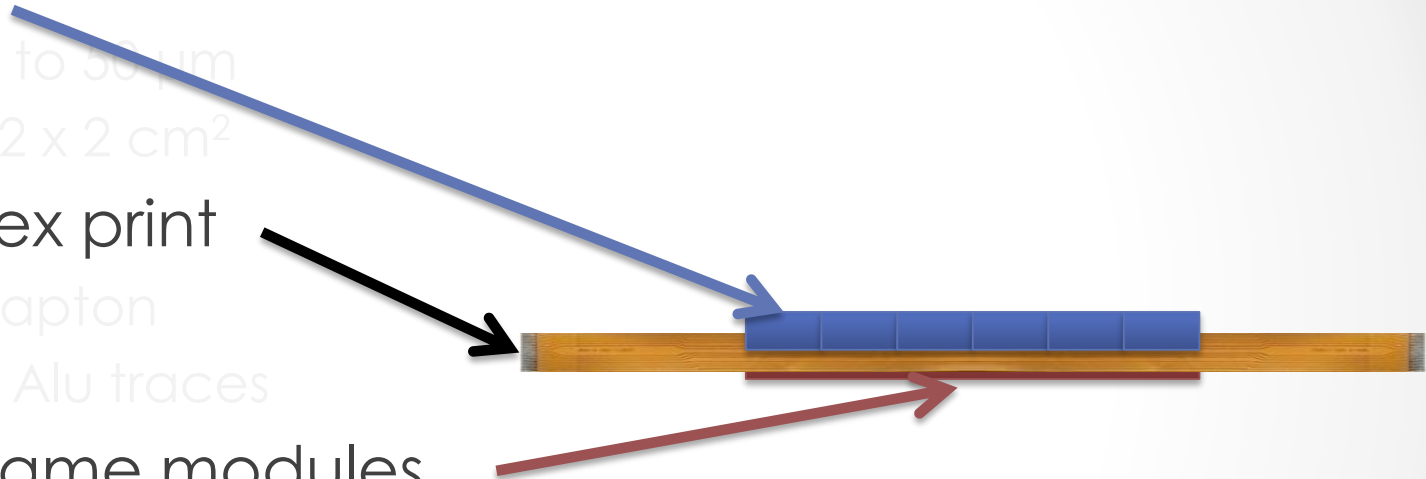
- HV-MAPS
 - Thinned to 50 μm
 - Sensors 2 x 2 cm^2
- Kapton flex print
 - 25 μm Kapton
 - 12.5 μm Alu traces
- Kapton frame modules
 - 25 μm foil
 - Self supporting
- Alu end wheels
 - Support for all detectors

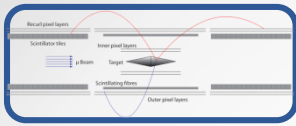




Silicon Tracker

- HV-MAPS
 - Thinned to 50 μm
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- Kapton flex print
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 - 25 μm foil
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 - Support for all detectors

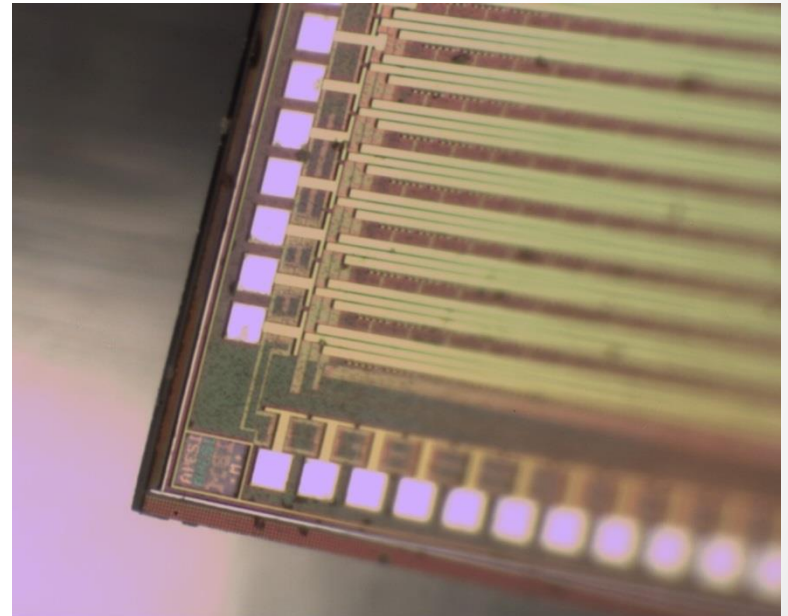




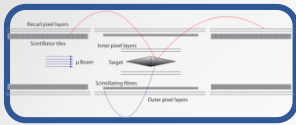
Silicon Tracker

- **HV-MAPS**
 - Thinned to **50 μm**
 - Sensors $2 \times 2 \text{ cm}^2$
- 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

50 μm MuPix7 tested

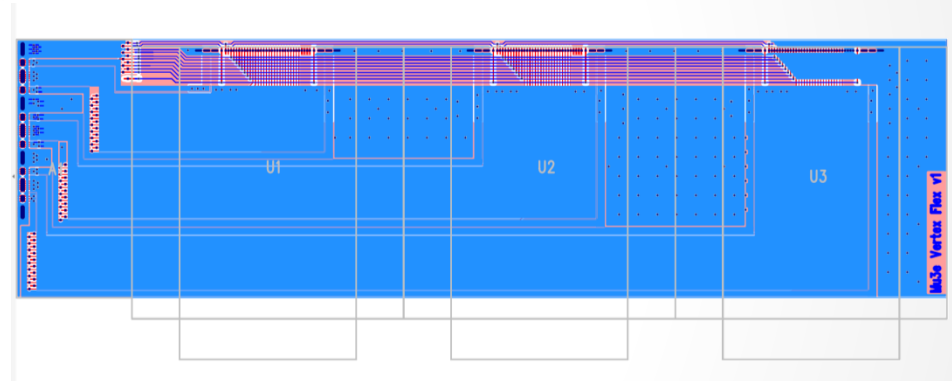


MuPix4 thinned to 50 μm



Silicon Tracker

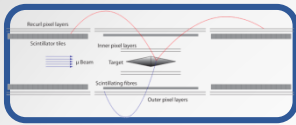
- HV-MAPS
 - Thinned to 50 μm
 - Sensors 1 x 2 cm^2 or 2 x 2 cm^2
- **Kapton flex print**
 - 25 μm Kapton
 - 12.5 μm Alu traces
- Kapton frame modules
 - 25 μm foil
 - Self supporting
- Alu end wheels
 - Support for all detectors



New Layout for Vertex Layers

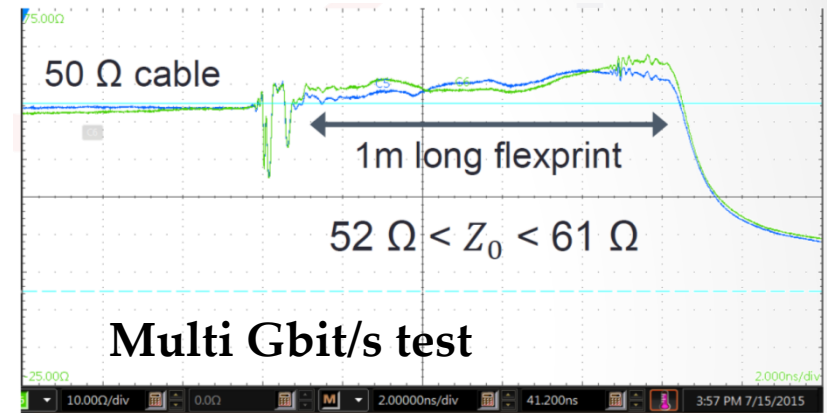
Two technologies:

- Full Al-Kapton
- Hybrid Cu-Al-Kapton

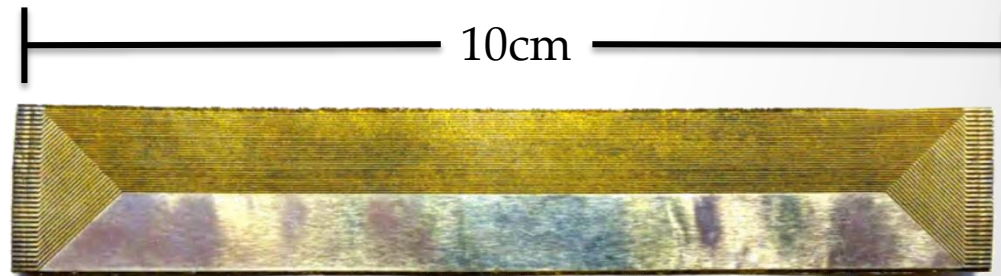


Silicon Tracker

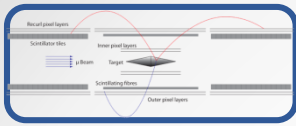
- HV-MAPS
 - Thinned to 50 μm
 - Sensors 1 x 2 cm² or 2 x 2 cm²
- **Kapton flex print**
 - 25 μm Kapton
 - 12.5 μm Alu traces
- Kapton frame modules
 - 25 μm foil
 - Self supporting
- Alu end wheels
 - Support for all detectors



O. Harper, Heidelberg 2015

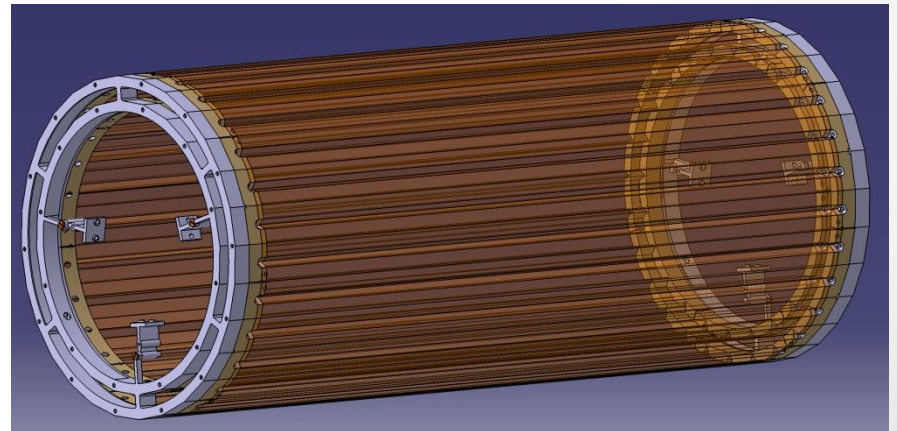


Laser-cut flex print prototype

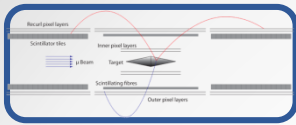


Silicon Tracker

- HV-MAPS
 - Thinned to 50 μm
 - Sensors 1 x 2 cm^2 or 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

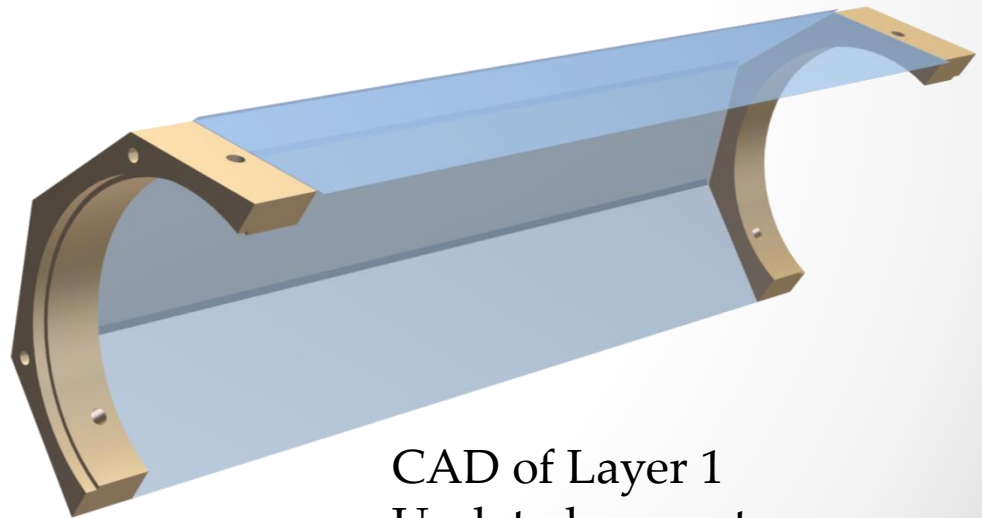


CAD of Kapton frames

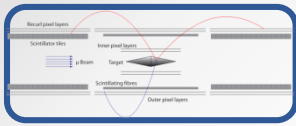


Silicon Tracker

- HV-MAPS
 - Thinned to 50 μm
 - Sensors 1 x 2 cm^2 or 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
- Two halves for layers 1+2
 - 6 modules in layer 3
 - 7 modules in layer 4



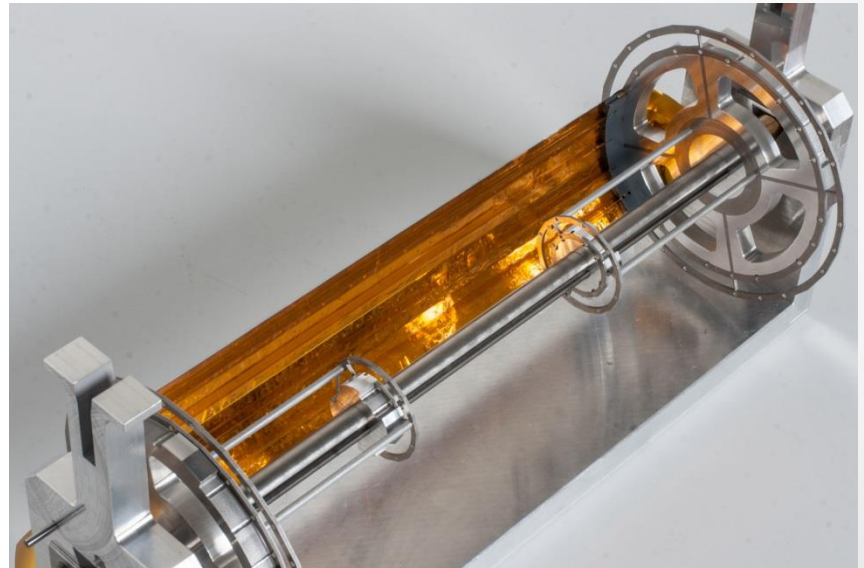
CAD of Layer 1
Updated geometry



Silicon Tracker

- HV-MAPS
 - Thinned to 50 μm
 - Sensors 1 x 2 cm^2 or 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
 - Integrated He distribution

- End wheels also support
- Tile Detector
 - Fiber Detector



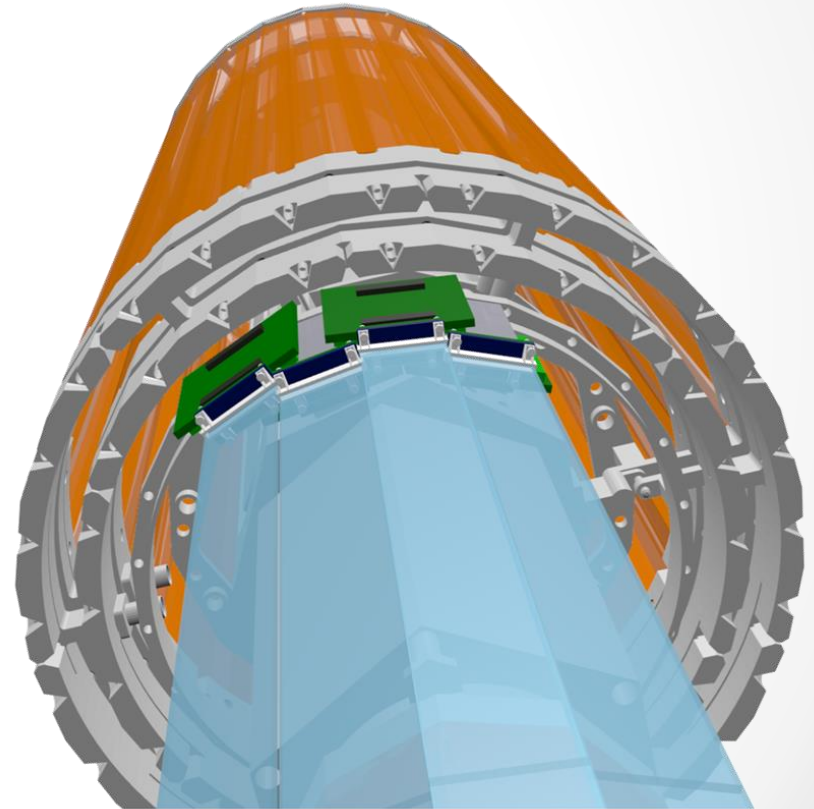
Layer 3 Prototype in Assembling Frame

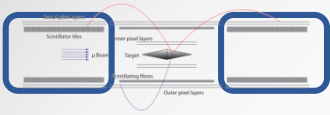


Fiber Tracker

- 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)*



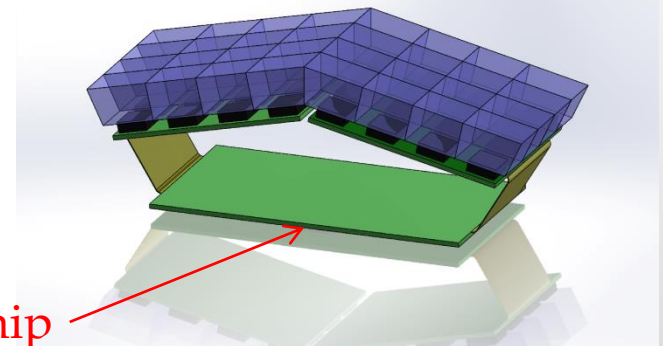


Tile Detector

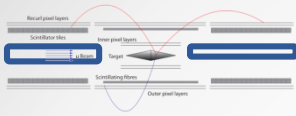
- Sub-modules
 - Successful 16 channel prototypes
- **STiC** readout chip
 - Good analog performance
 - **Fast LVDS** driver chip back from submission



Submodule (2x16 Ch.)

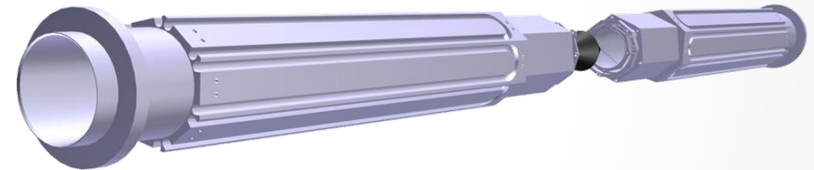


STiC chip

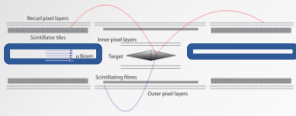


Beam Pipe

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

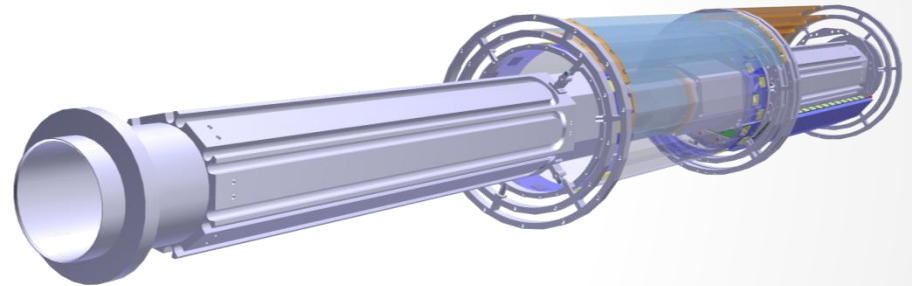


Beam pipe design

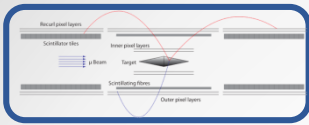


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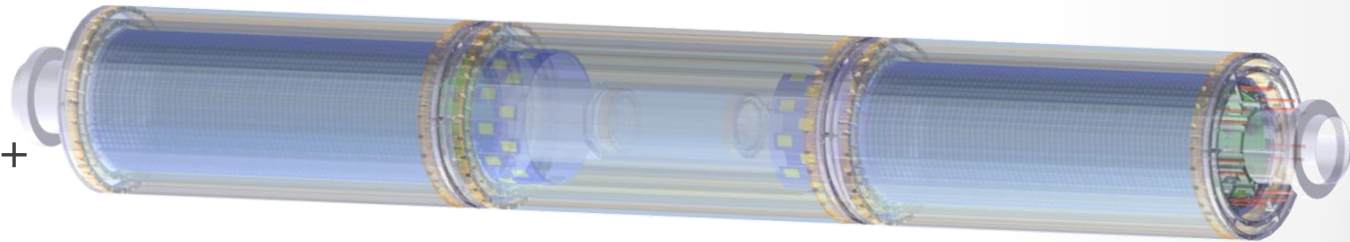


Beam pipe design

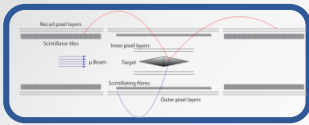


Overall Assembly

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

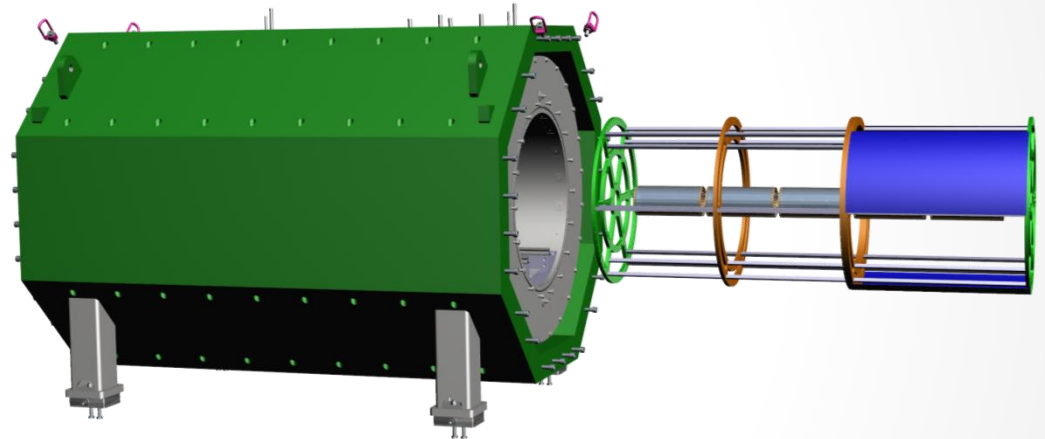


Detailed CAD of phase I detector



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



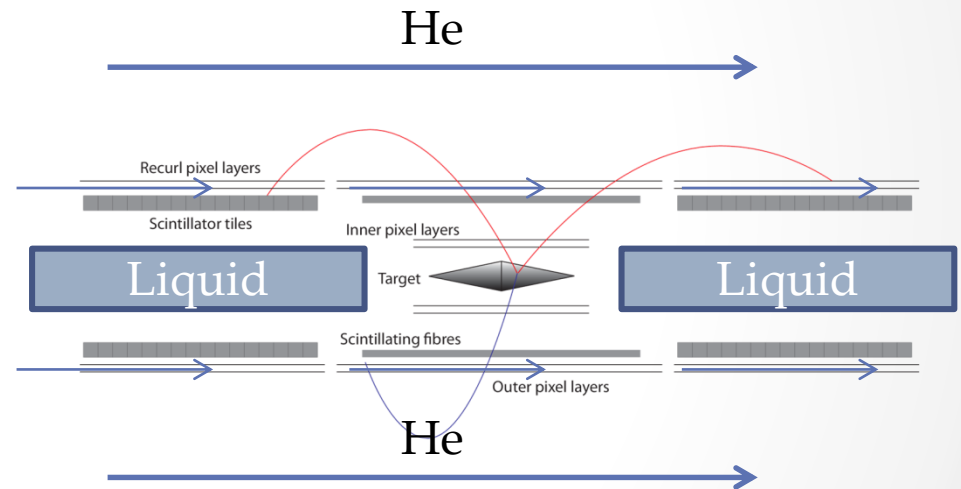
CAD of **magnet** and rail system

Cooling

...

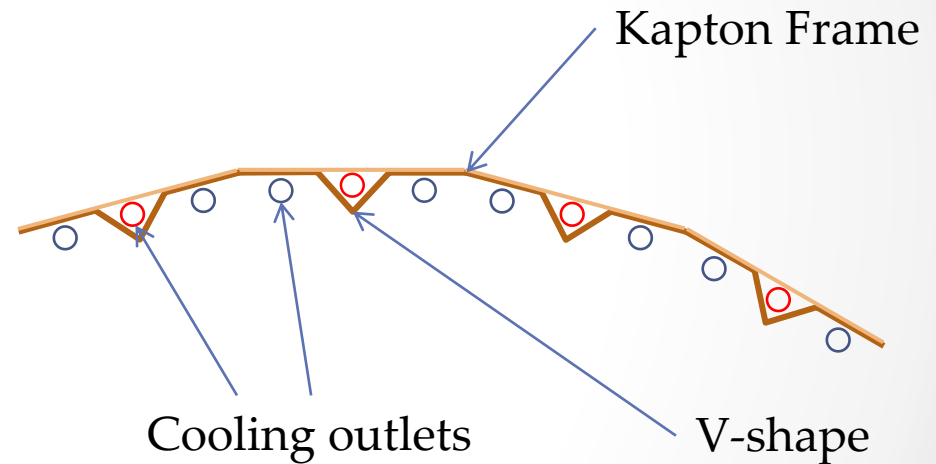
Cooling Concept

- **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



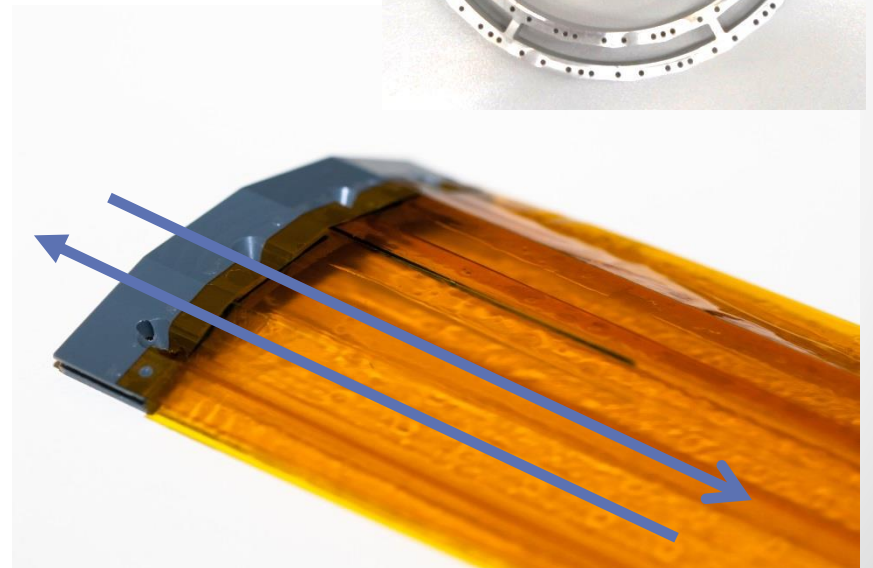
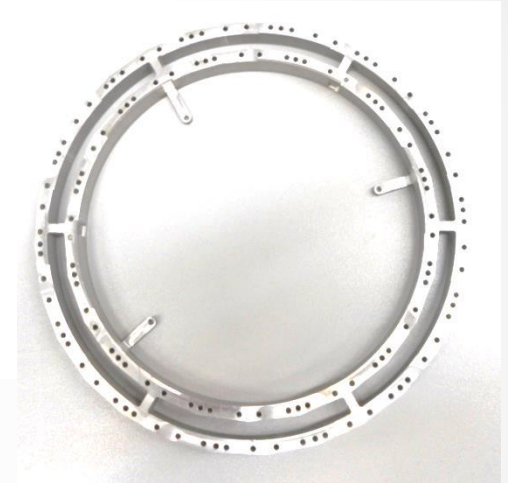
He Cooling

- 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**



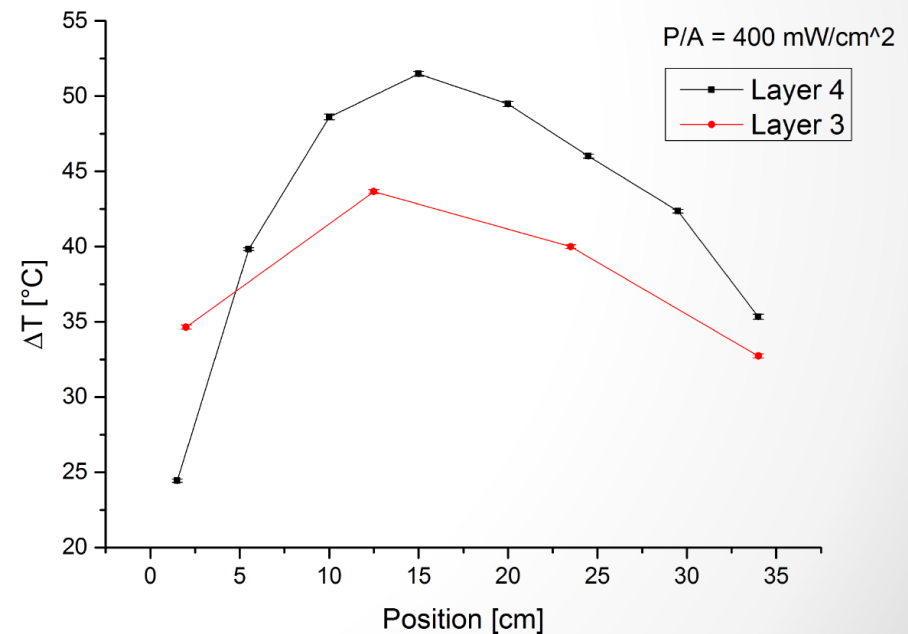
He Cooling

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- Global flow inside magnet volume
- **Local flow for tracker**
 - **Distribution in frame**
 - V-shapes
 - Outer surface



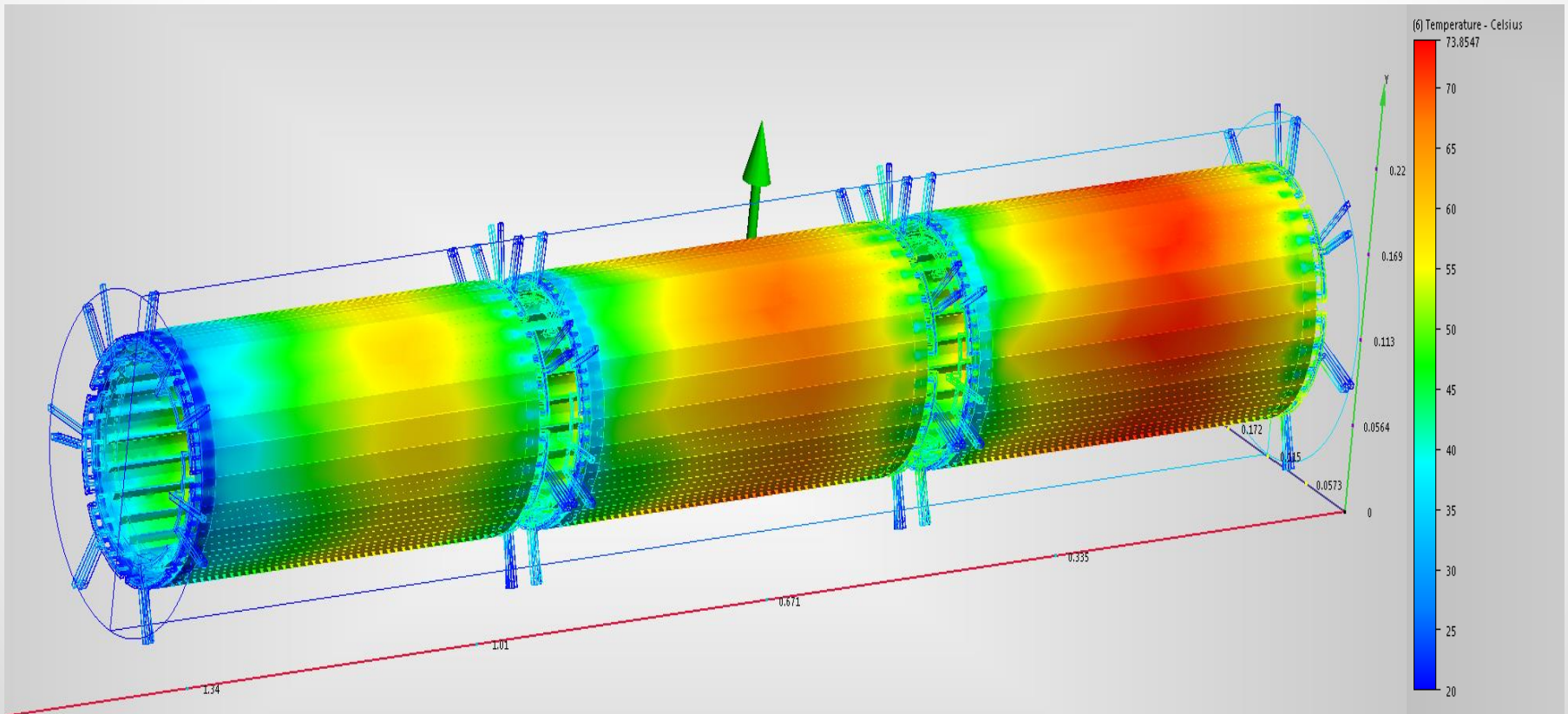
Local Flow Cooling

- Module prototypes
 - 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: **$\Delta T < 55^\circ\text{K}$**



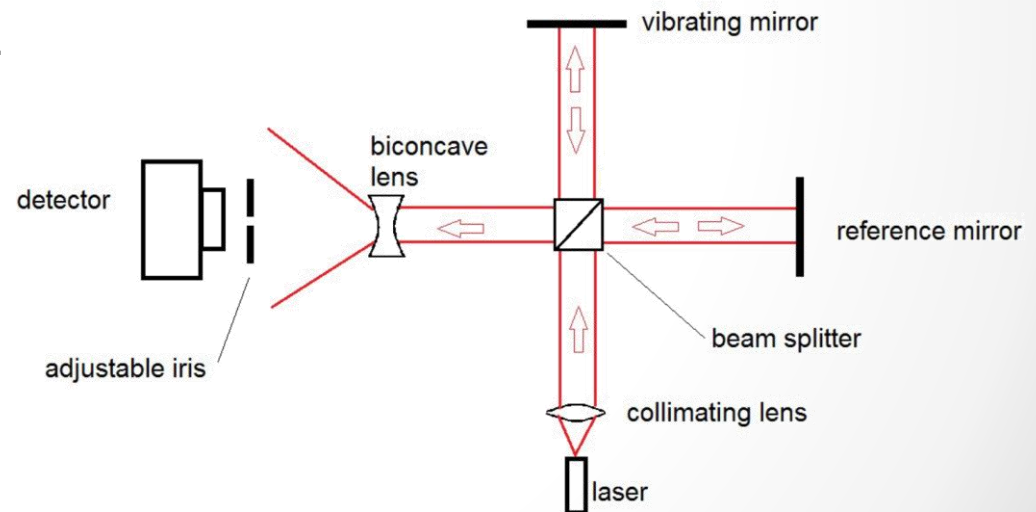
3 Station Simulation

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



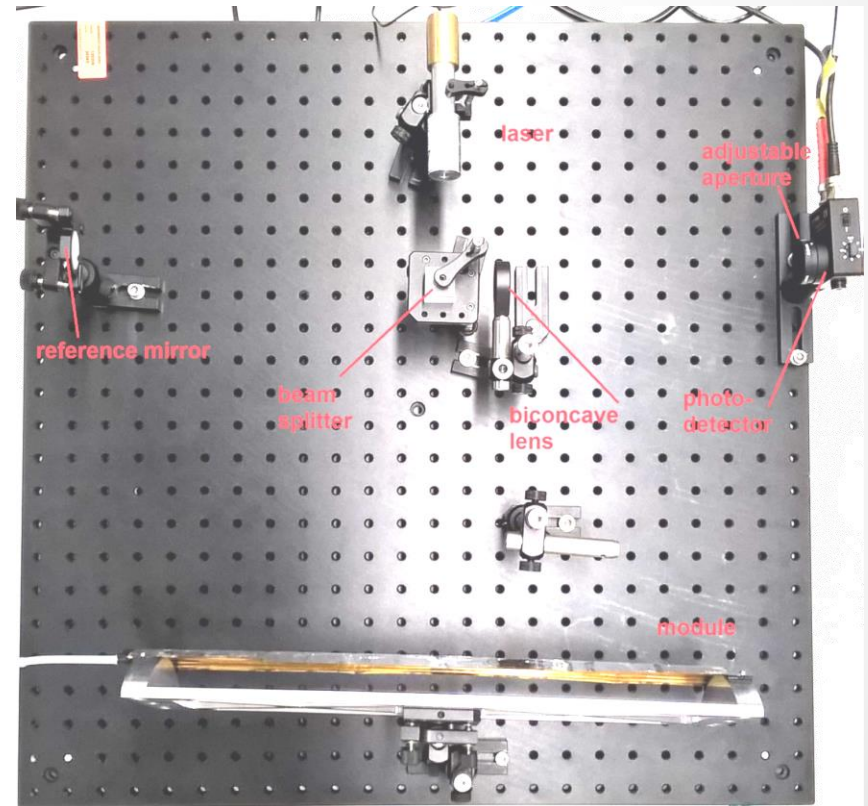
Vibration Test

- High He flow **20m/s**
- Thin foil detector structure
- **Vibrations?**
- He cooling mockup +
- **Michelson interferometer**



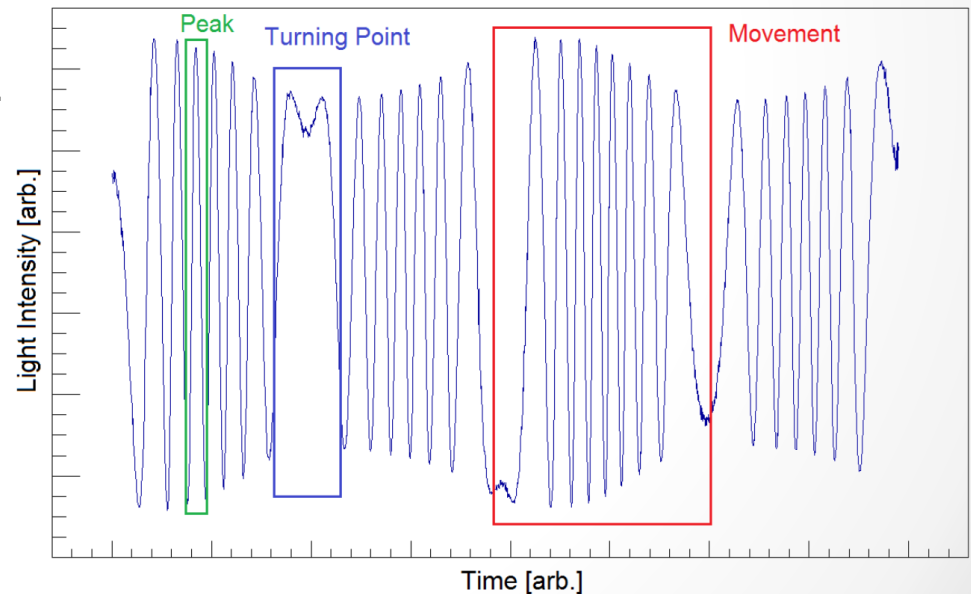
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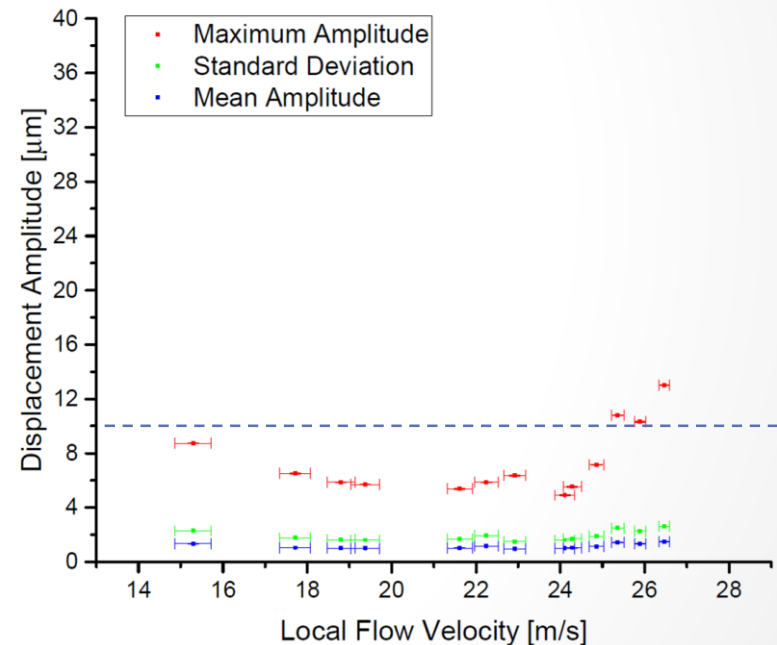
Vibration Test

- High He flow 20m/s
- Thin foil detector structure
- Vibrations?
- He cooling mockup +
- Michelson interferometer +
- **Oscilloscope**



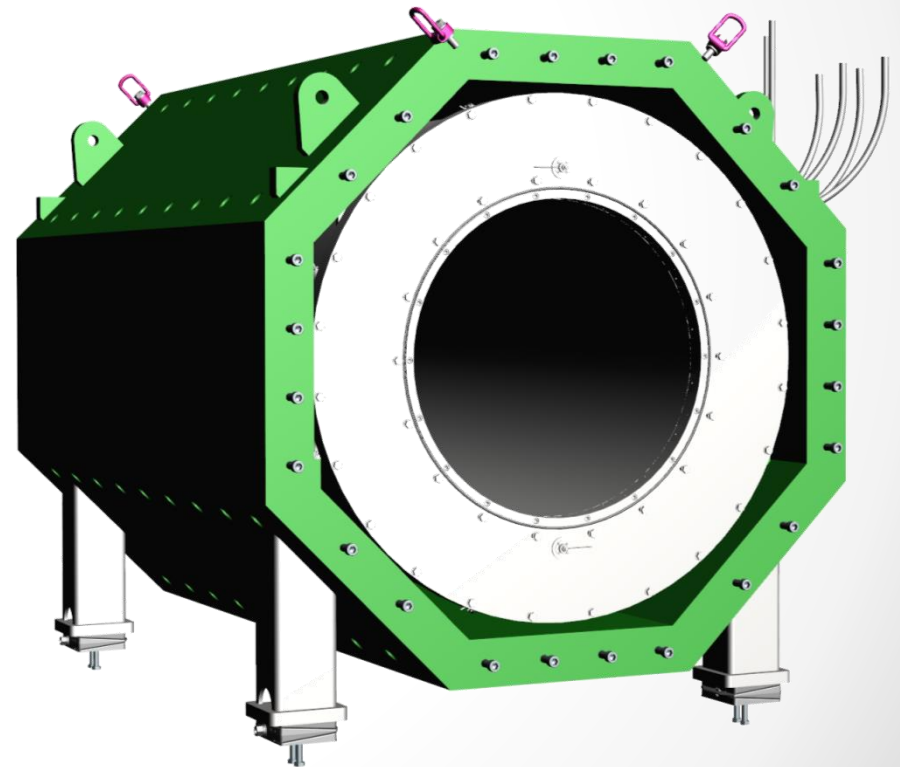
Vibration Test

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



Summary

- **Magnet**
 - Danfysik
 - Design ready
- **Mechanics**
 - Detailed CAD models
- **Cooling**
 - Gaseous He cooling of tracker
 - $\Delta T < 55^\circ\text{K}$ for $400\text{mW}/\text{cm}^2$
 - Vibrations $10\ \mu\text{m}$



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

