

Technical Design for the Mu3e Detector

Dirk Wiedner on behalf of Mu3e March 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



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





Read past	
Souther	fis Inserpied intern
	Scientumpflans
	Outergradinges

• HV-MAPS

Thinned to 50 µm
 Sensors 2 x 2 cm²

- Kapton flex print
 - 25 µm Kapton
 12.5 µm Alu traces
- Kapton frame modules
 - o 25 µm foilo Self supporting
- Alu end wheels

Read puttigen
Scientifican tiles inner pied jayen
aften lege
Sciellutogitess
Outer provingers

• HV-MAPS

- o Thinned to be u
- o Sensors 2 x 2 cm²
- Kapton flex print
 - o 25 µm Kapton o 12.5 µm Alu traces
- Kapton frame modules
 - 25 µm foil
 Self supportin
- Alu end wheels

Renal puellages	
handleartiles tree plut inen	
stem lage	
Schesting Pitros	
Outerplantinges	

HV-MAPS

o Thinned to **50 µm**o Sensors 2 x 2 cm²

- Kapton flex print
- Kapton frame modules
 - o 25 µm foilo Self supporting
- Alu end wheels

50µm MuPix7 tested



MuPix4 thinned to 50µm

Read puttigen
Scientifican tiles inner pied jayen
aften lege
Sciellutogitess
Outer provingers

• HV-MAPS

o Thinned to 50 µm

o Sensors 1 x 2 cm² or 2 x 2 cm²

Kapton flex print

25 µm Kapton
12.5 µm Alu traces

Kapton frame modules

o 25 µm foilo Self supporting

Alu end wheels



New Layout for Vertex Layers

Two technologies:

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

Recur pre			/	
South	e tiles.	iner plot ingen	\sim	
	ator	lege 🛁	×	
		ScireButting Plans		
			Outor pixellayers	

• HV-MAPS

• Thinned to 50 μ m • Sensors 1 x 2 cm² or 2 x 2 cm²

Kapton flex print

 \circ 25 µm Kapton

o 12.5 µm Alu traces

Kapton frame modules 25 µm foil

Self supporting

Alu end wheels





Laser-cut flex print prototype

Read puttigen
Scientifican tiles inner pied jayen
aften lege
Sciellutogitess
Outer provingers

• 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
 - o 25 µm foilo Self supporting
- Alu end wheels



CAD of Kapton frames

Read past	
Souther	fis Inserpied intern
	Scientumpflans
	Outergradinges

• 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 trace

Kapton frame modules

- o 25 µm foilo Self supporting
- Alu end wheels

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

CAD of Layer 1 module

Retar postia	res
Scentrory	ns tree plutingen
_	steam large
	Outerpractingers

• HV-MAPS

Thinned to 50 µm
 Sensors 1 x 2 cm² or 2 x 2 cm²

Kapton flex print

o 25 µm Kapton o 12.5 µm Alu trace

Kapton frame modules

- o 25 µm foilo Self supporting
- Alu end wheels

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



CAD of Layer 1

Banat pastingen	
Scientific or tiles.	tree plot iven
a Bea	t lage
	Scientification (
	Outergranilityes

• 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 trace

Kapton frame modules

o 25 µm foilo Self supporting

Alu end wheels

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

CAD of Layer 2

Record positiopers	
Southearties tree pietingen	_
aftern Tarpet	
ScireButing Parts	
Cater pixel	ligens

• 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 trac

Kapton frame modules

o 25 µm foilo Self supporting

Alu end wheels

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

CAD of Layer 3 module

Record positiopers	
Southearties tree pietingen	_
aftern Tarpet	
ScireButing Parts	
Cater pixel	ligens

• 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 trace

Kapton frame modules

- o 25 µm foilo Self supporting
- Alu end wheels

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

CAD of Layer 4 module

• Dirk Wiedner Heidelberg

Banad positiopen	
Scientific or time.	tree plotingen
Pros	Scientiluting Pitra
	Outerplastinges

• HV-MAPS

Thinned to 50 µm
 Sensors 1 x 2 cm² or 2 x 2 cm²

Kapton flex print

o 25 µm Kapton o 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
 - o 16 mm wide
 - o 290 mm long
- Total fiber tracker:
 - 24 ribbon-modules
 - o 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.)





Beam Pipe

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



Beam pipe design



Beam Pipe

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



Beam pipe design

Recuri posifilayees	\frown
Specificar tites	treepidinen
	aftern Target
	Schelutogram
	Outer pairinges

Overall Assembly

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



Detailed CAD of phase I detector

Recal pullingers	
Scientific or times	Inverpise <u>ingen</u>
	Scientisting Pitras
	Oxforgenetingen

Overall Assembly

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



CAD of **magnet** and rail system



31.03.2016 • 26

Cooling Concept

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



Cooling Concept

- Gaseous He cooling
 - o 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



- 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



- 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



- 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



- 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



- 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



Local Flow Cooling

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



Local Flow Cooling

- Module prototypes
 - Layer 3+4 of silicon tracker
 - o ... of Aluminum-Kapton
 - Ohmic heating 400mW/cm²
- Cooling through end pieces
 - V-shaped ducts under sensors
 - He at 20 m/s



Local Flow Cooling

- Module prototypes
 - Layer 3+4 of silicon tracker
 - o ... 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



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

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

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

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

Summary

Magnet

- o Danfysik
- Design ready
- Mechanics
 - Detailed CAD models
- Cooling
 - Gaseous He cooling of tracker
 - ΔT < 55°K for 400mW/cm²
 - ο 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

- o For silicon tracker
- Low radiation length
- Global flow
- Local direct cooling

