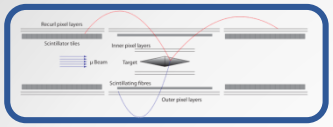
Technical Design
for the Mu3e Detector

Dirk Wiedner on behalf of Mu3e

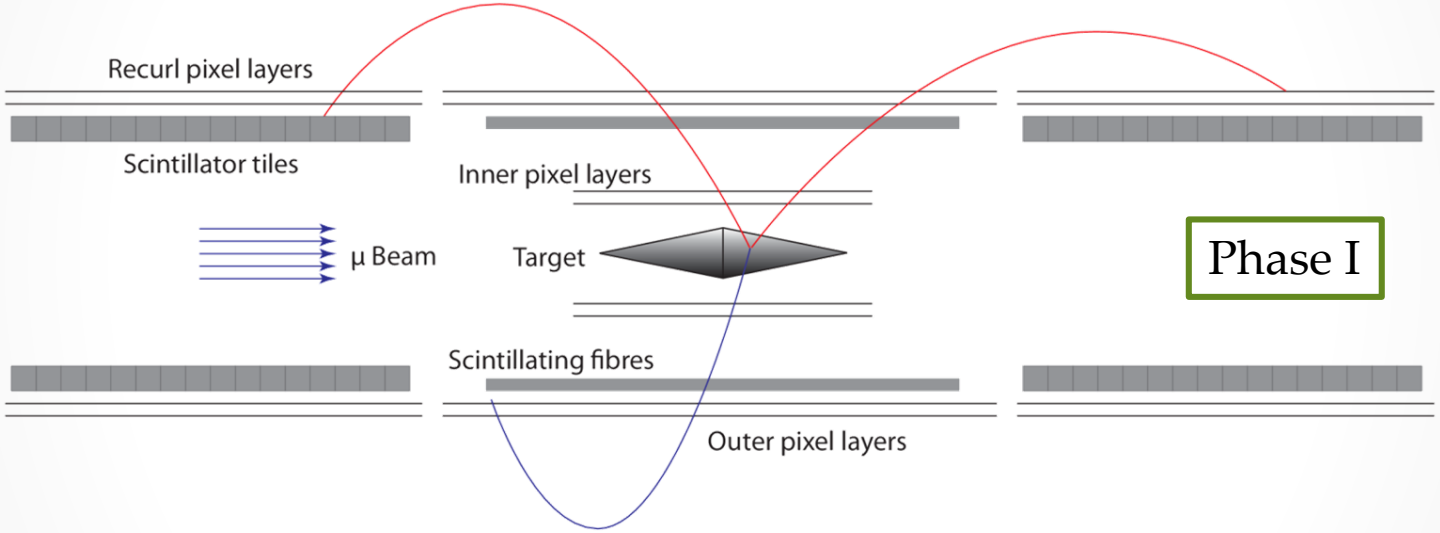
February 2017

Phase I TDR

- Documentation of
  - Mu3e goals
  - Experimental concept
  - Detector design
  - …including services
  - Reconstruction, event selection …
  - Sensitivity study

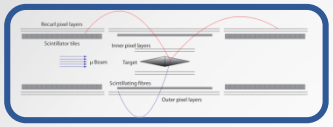


Phased Experiment



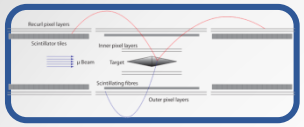
- Muon beam O(10^8/s)
- Helium atmosphere
- 1 T B-field

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



Experimental challenges

Subsystem	Challenges
• Muon beam 5 x 10^7/s	➢ Limits physics reach
• Helium cooling	➢ 5kW He-cooling (Pixel)
• 1 T B-field	➢ Superconducting Magnet
• Silicon pixel tracker	➢ Depends on success of large MuPix sensor
• Scintillating Fiber detector	➢ Extremely tight space, choice of fibre overdue
• Tile detector	➢ MuTRiG ASIC time critical development, tight space to be shared with services



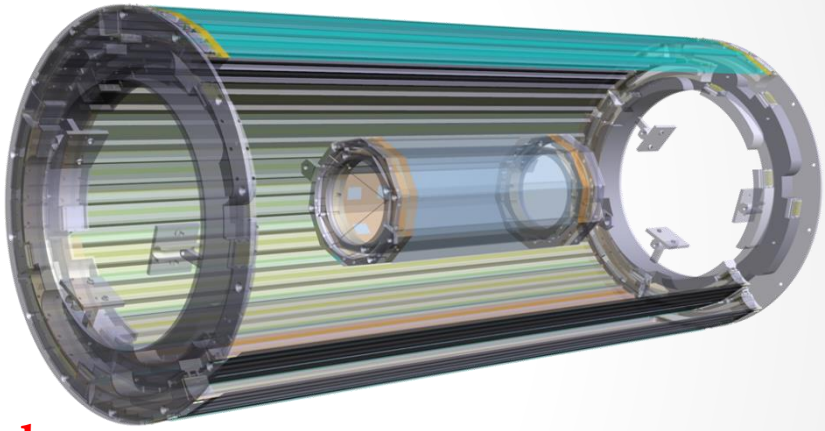
Pixel Tracker

Accomplished:

- ✓ Technology for ultra-thin pixel detector identified: HV-CMOS
- ✓ Successful **feasibility** studies for:
  - ✓ Module mechanics
  - ✓ He-cooling with low vibration
  - ✓ Ultrathin Flexible circuit boards
  - ✓ HV-CMOS small prototypes
  - ✓ Readout board prototype

To be done:

- **Full sized HV-CMOS chip -critical**
- **1st operational detector module -critical**
- Qualification of optimized module design
- **Production yield - critical**



Pixel Tracker
Rendering of CAD study
Re-optimized outer modules

See talk:
Pixel Detector
Frank Meier Aeschbacher

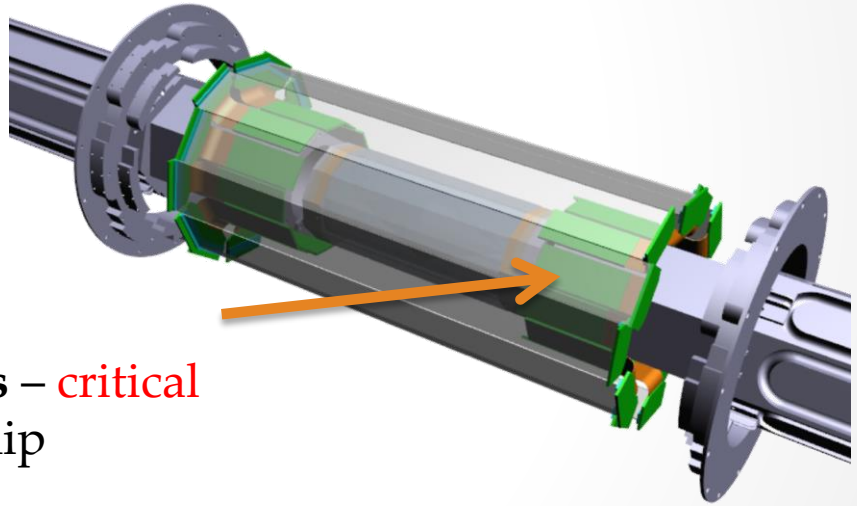
Fibre Detector

Accomplished:

- ✓ Characterization of fibres
- ✓ **Proof of concept** including
  - ✓ Simulation of fibre response
  - ✓ Identification of working point
  - ➢ Photon yield - critical

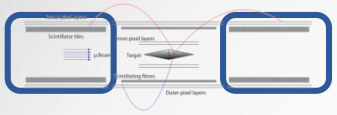
To be done:

- Choice of fibre type
- 1st operational detector module
- **Ultra compact front end electronics** – critical
  - Integrate new MuTRiG TDC chip



Fibre Detector
Rendering of CAD study

See talk:
Timing Detectors
Simon Corrodi



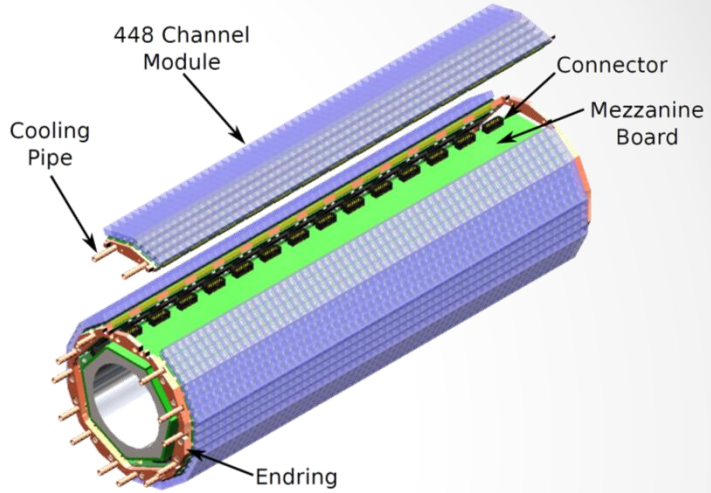
Tile Detector

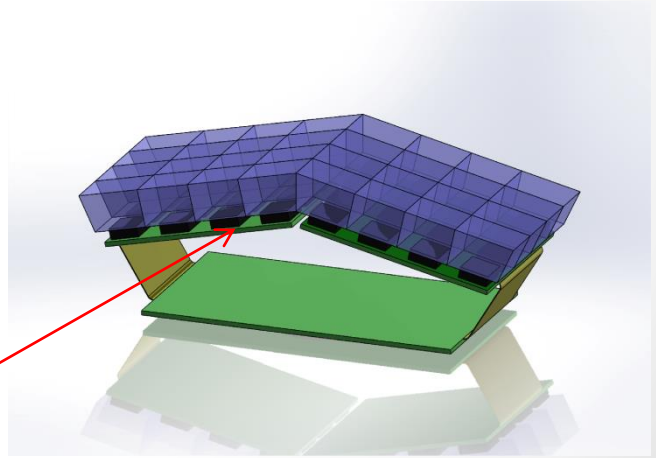
Accomplished:

- ✓ Characterization of submodule
- ✓ **Proof of concept** including
  - ✓ Production of similar system

To be done:

- 1st operational detector module
- Development of TDC ASIC MuTRiG

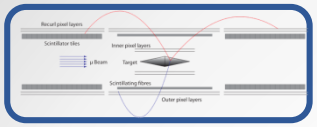




MuTRiG chip

Submodule (2x16 Ch.)

See talk:
Timing Detectors
Simon Corrodi



Mechanical Integration

Accomplished:

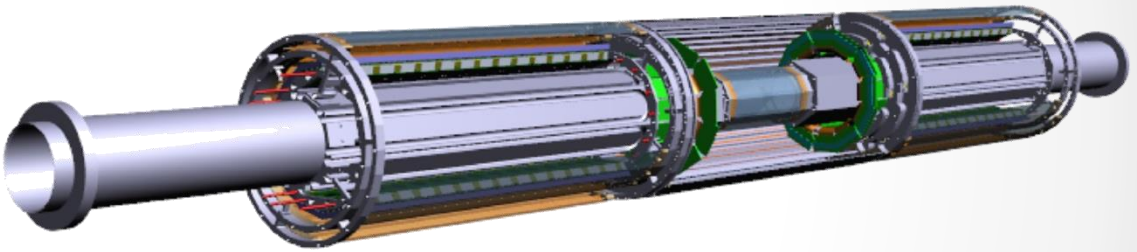
- ✓ CAD of most components
- ✓ Mechanical prototypes

To be done:

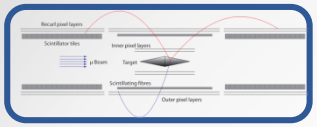
- Integration of electronics and services –critical
- Re-distribution of space
  - Avoid **double usage**

Remark:

- **Space inside detector extremely limited**
- **Extreme power and cooling requirements (pixel detector)**



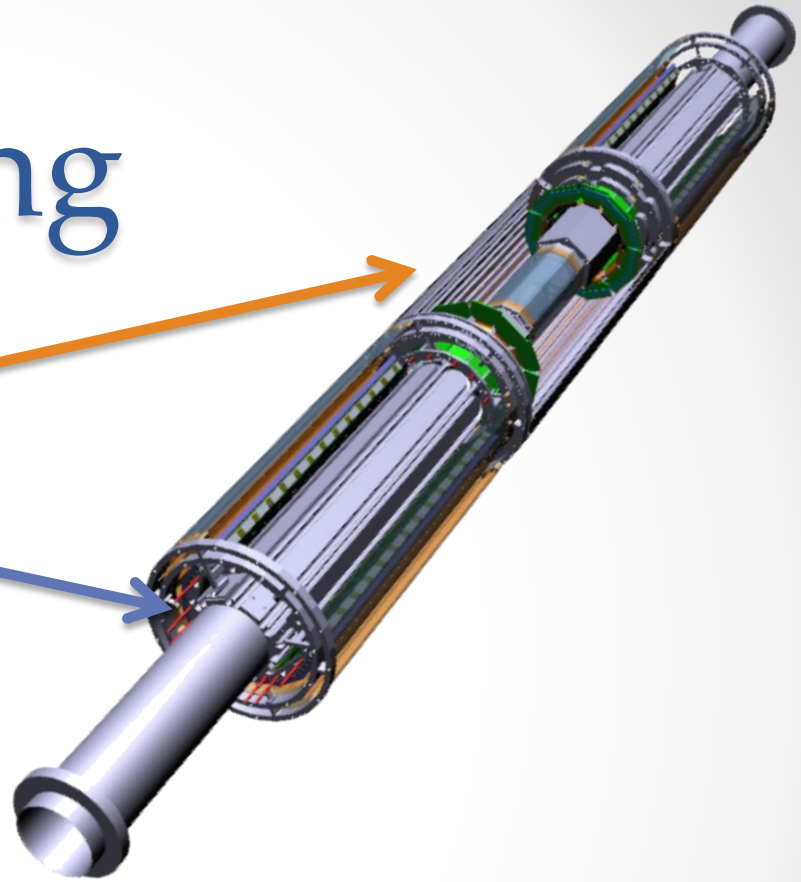
Detailed CAD of phase I detector



Cooling

5 + 5KW heat dissipation

- He cooling in active area
- Water cooling for electronics
- Inside detector only few "classical pipes"
- **He distribution**
  - ✓ integrated in mechanical structures of pixel detector
- Water distribution
  - ✓ Integrated in beam pipe
  - ✓ … and tile modules



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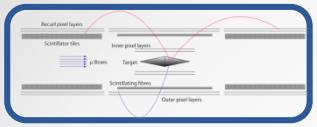

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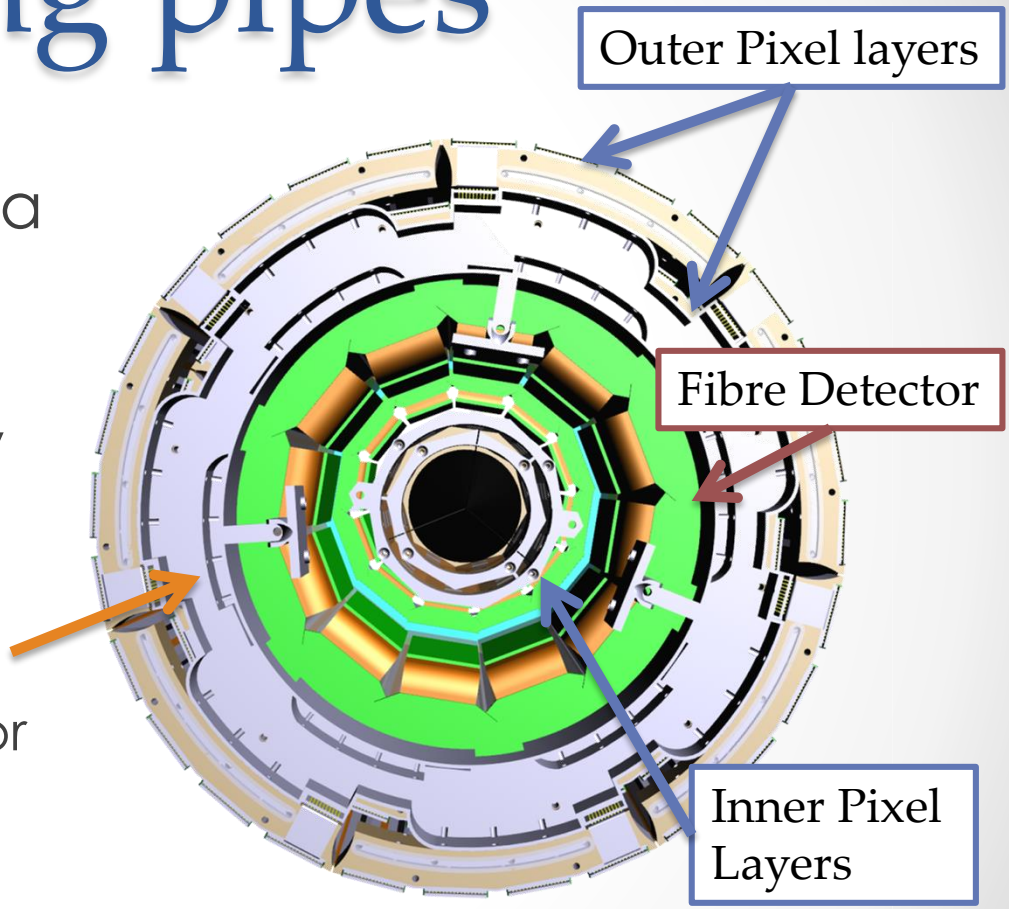

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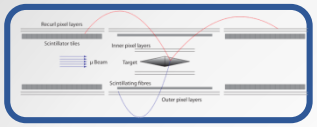

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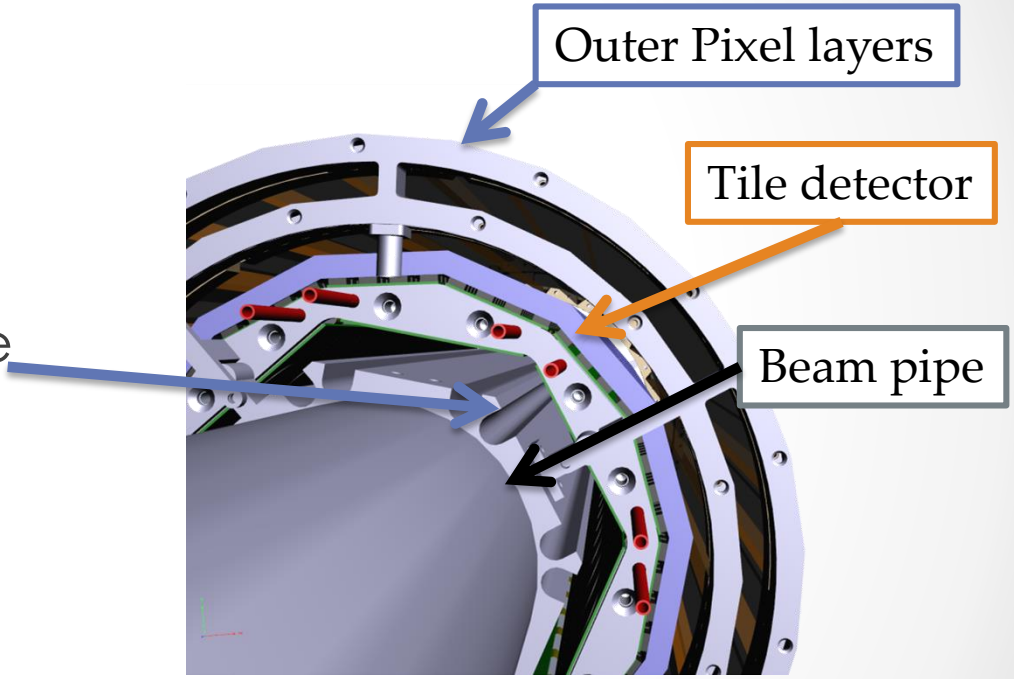

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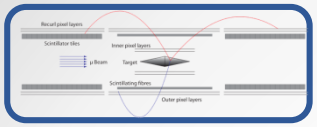
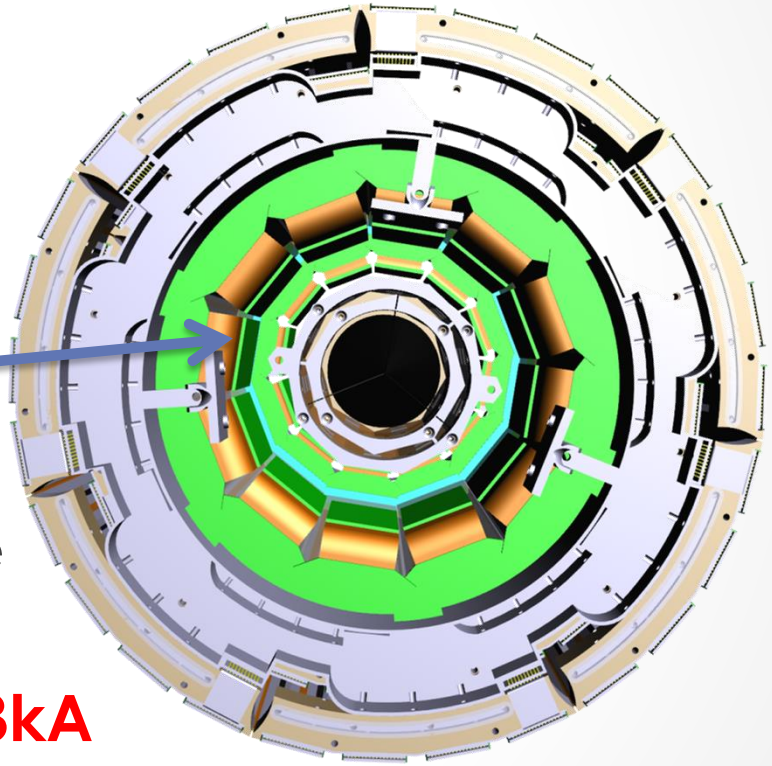


Cabling

- Inside detector almost no space
- Electrical signals over:
  - HDIs (high density interconnects)
  - **Flex-prints**
  - PCBs
- Optical data cables to the outside
- **5kW** at 1.5 to 1.8V means **3kA**

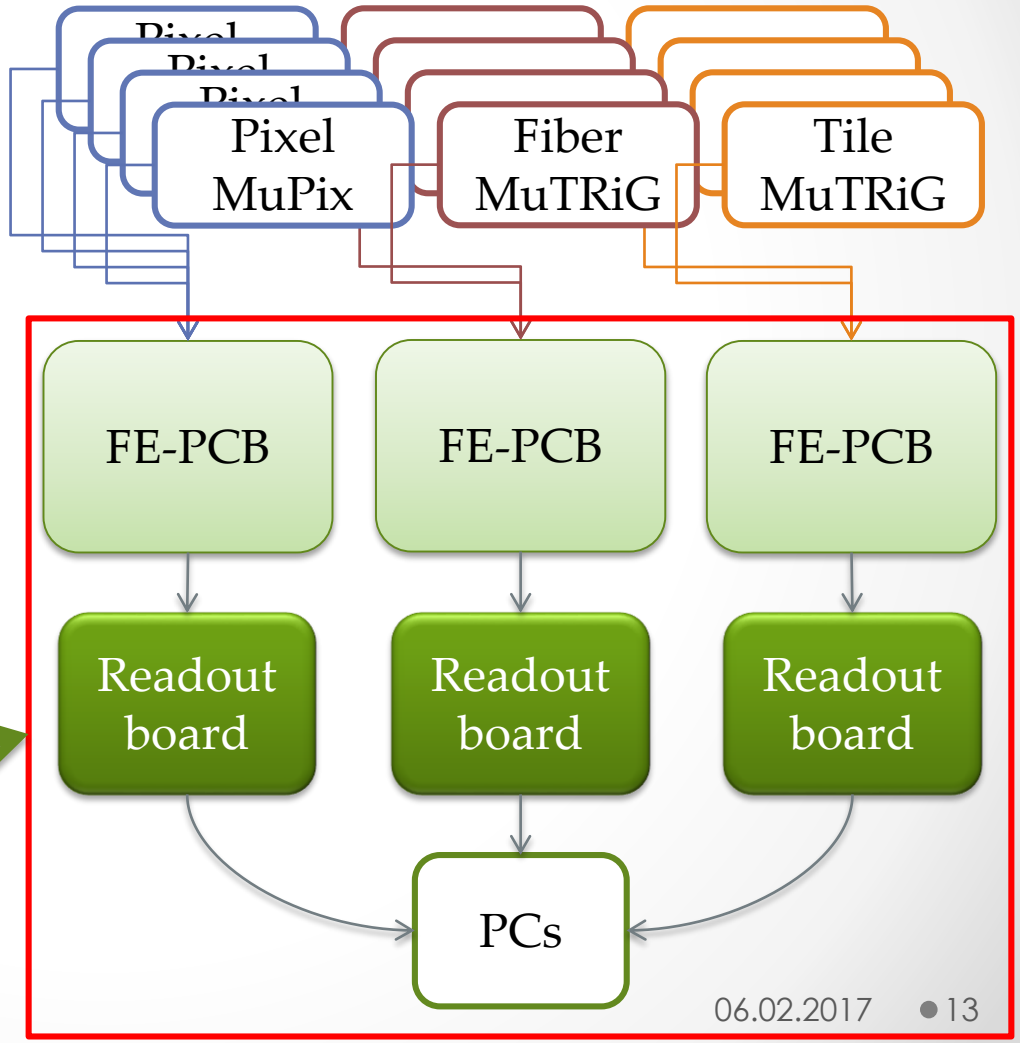
➢ Difficult power distribution



Detailed CAD of phase I detector

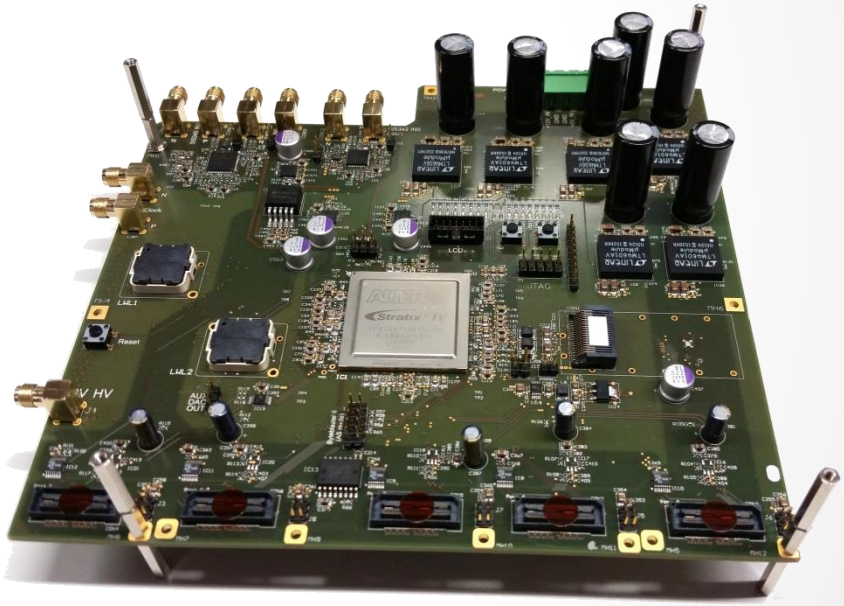
Readout system

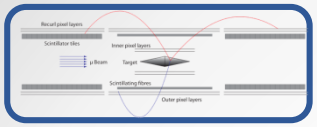
- Pixel detector
  - HV-MAPS (MuPix)
    - ✓ Sensor and read-out chip in one
    - ✓ Deliver zero-suppressed serialized data
- Timing detectors
  - SiPMs plus MuTRiG TDC
    - Deliver zero-suppressed serialized data
- **Common read-out system**



Common read-out PCB

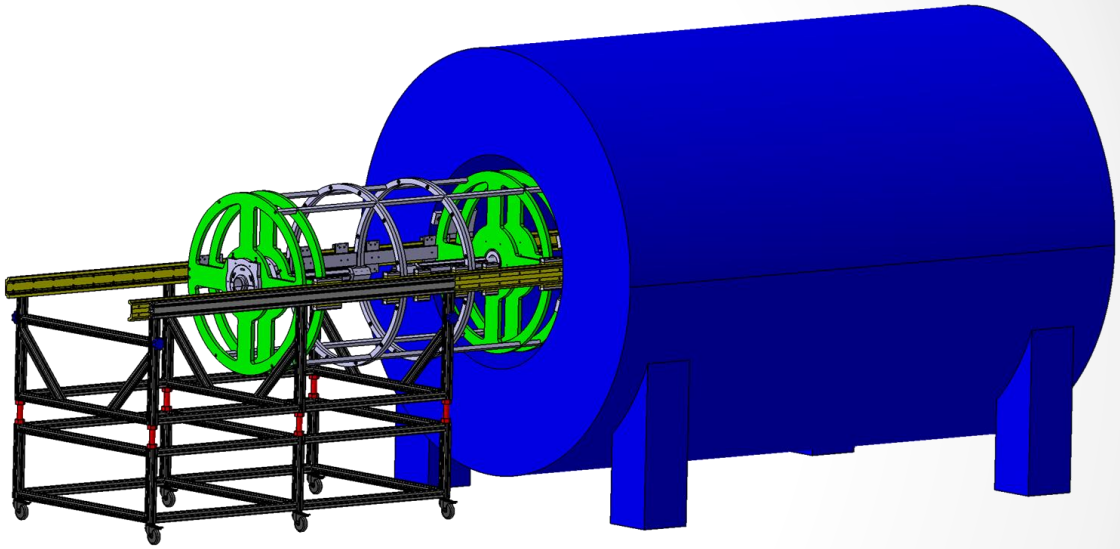
- ✓ **Front-end PCB**
  - Common for pixel, fibre and tile detector
  - ✓ Data acquisition
  - ✓ Clock distribution
  - ✓ Slow control distribution
- ✓ Prototype **functional**
  - Improved version for Q3/2017
- Next: Vertical slice test:
  - All electronics from (pixel) module to PC



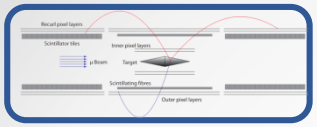


Mechanical infrastructure

- CAD of:
  - ✓ Cage
  - ✓ Rails
  - ✓ Cart

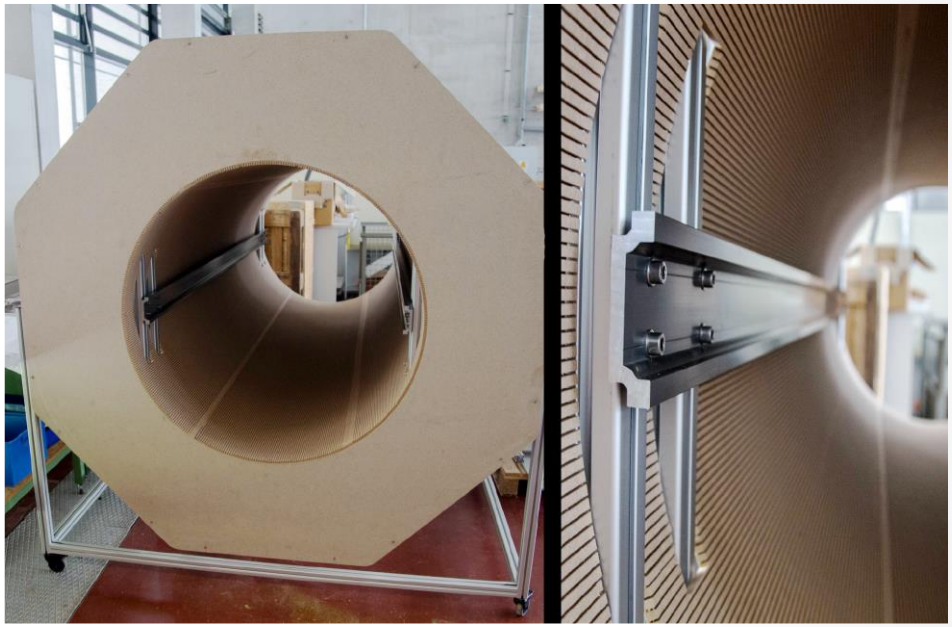


CAD of **magnet** and rail system



Cage and rails in Magnet

- ✓ Full-size mockup
  - ✓ Magnet
  - ✓ Rail system
  - ✓ Cage
  - ✓ Cart

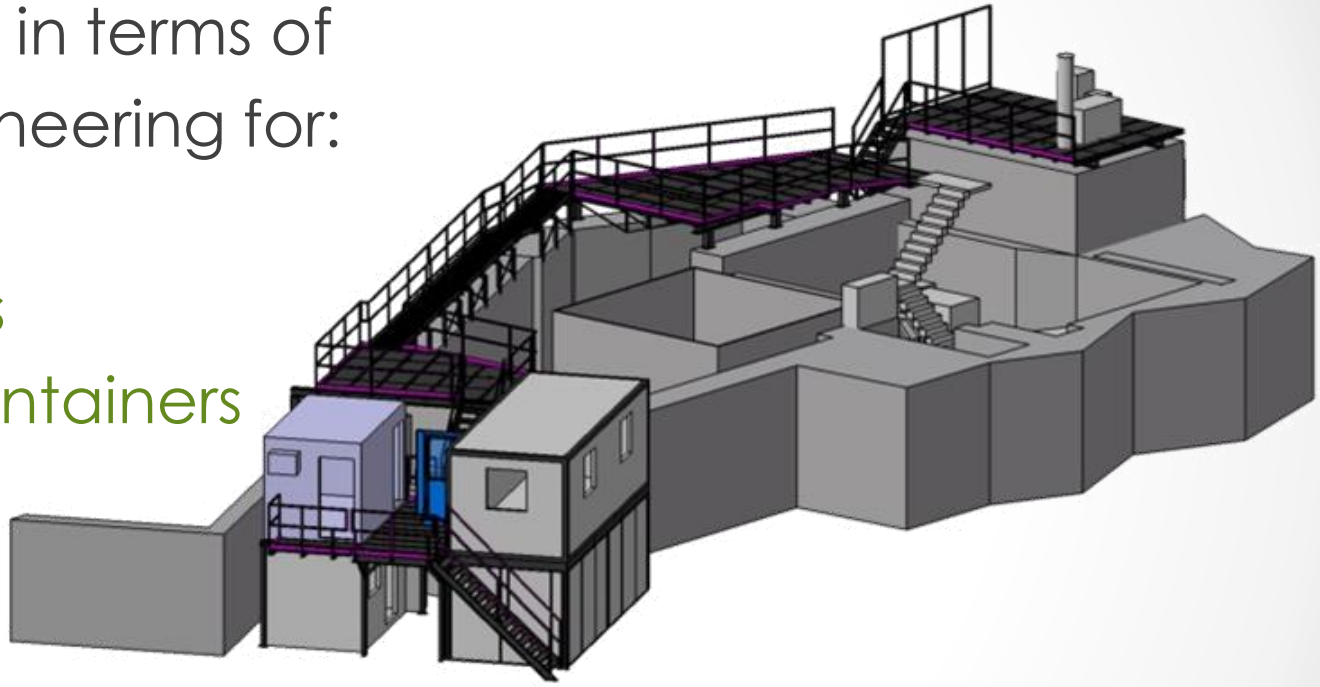


Mockup of **magnet** and rail system

Area planning

Good progress in terms of CAD, civil engineering for:

- ✓ Platforms
- ✓ Access ways
- ✓ Counting containers
- ✓ Power
- ✓ Cooling



Remark:

- Space in area **extremely** limited

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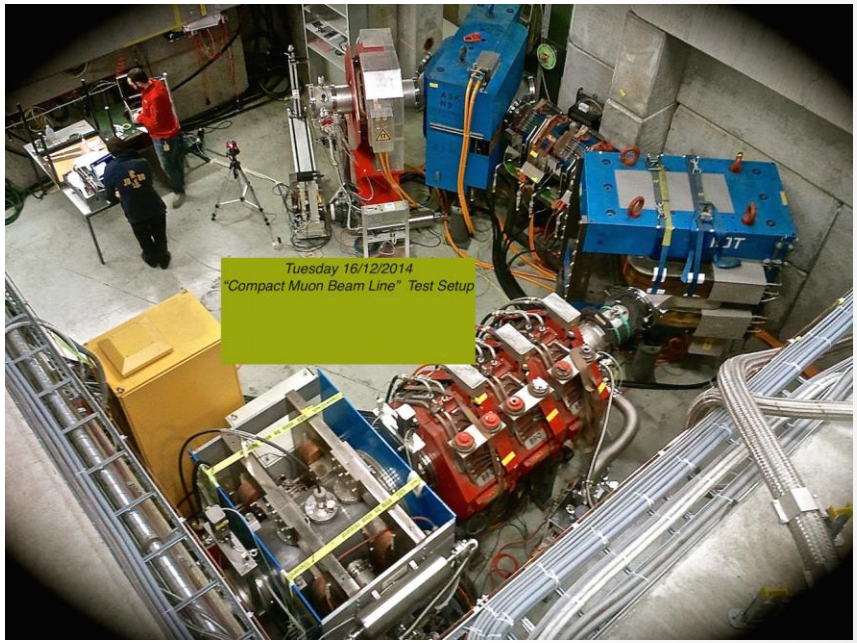
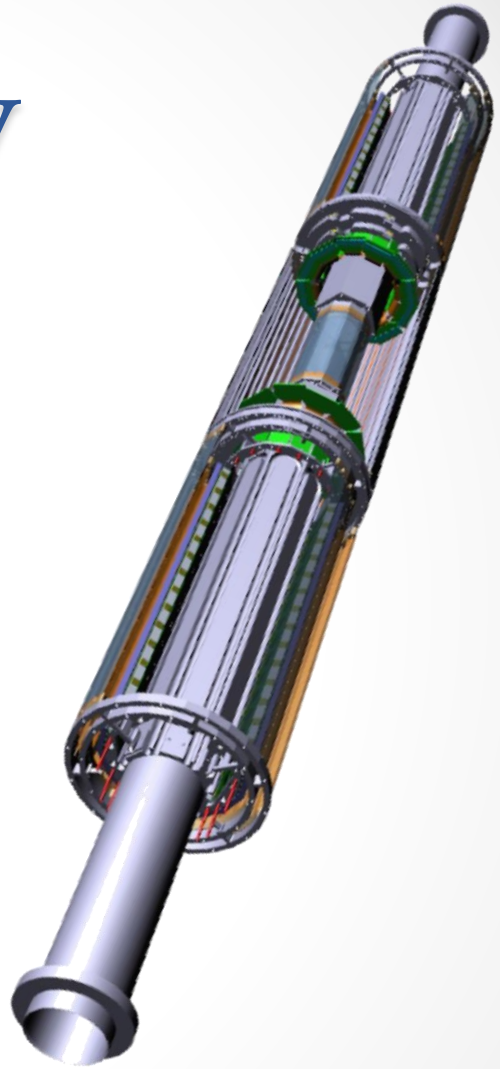


Photo of the experimental area in 2014

Summary

- ✓ TDR
- ✓ Detectors
  - ✓ Advanced R&D / proof of concept
  - ✓ Detailed CAD models
  - Full size MuPix (critical) and MuTRiG ASICS under development
- Mechanical integration
  - Extremely little space in detector
  - Extreme power requirements
  - Advanced area preparation



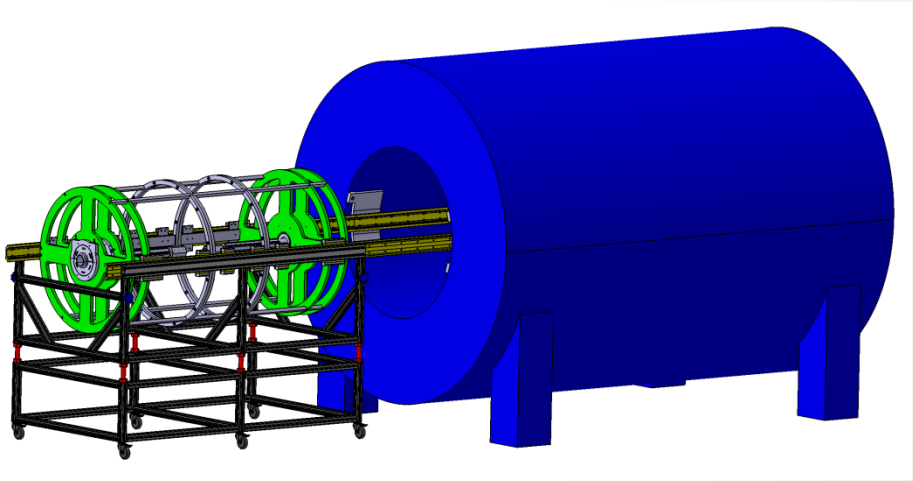
Outlook

- Detectors
  - Functional module prototypes under design
  - Extreme space requirements
- MuPix and MuTRiG
  - Full size prototypes on the way
  - Essential for detector prototypes
- Schedule critical for:
  - Full size MuPix development
  - Module prototyping
- Avoid "waiting"

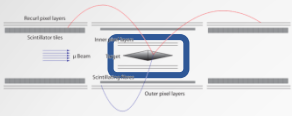
Backup Slides

Mu3e Solenoid

- **DFG** has granted Mu3e Solenoid (50%)
- Currently Mu3e is re-entering the tendering process
- Very strong support from Heidelberg University
- Magnet delivery most likely in **2019**



Mu3e magnet

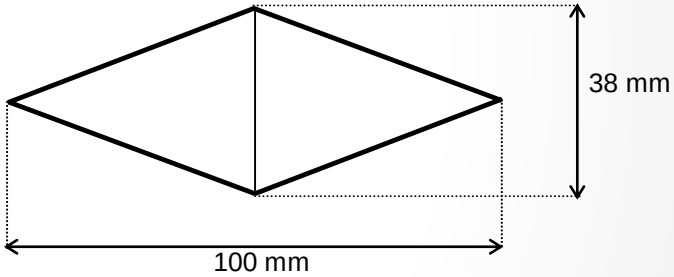


Muon Stopping Target

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

Upstream: 75 µm

Downstream: 85 µm



Detector Power

Detector	ASIC	#partitions	#ASICS/ partitions	power per partition [W] in ASICs	other	sum	DC-DC [W]	Total power [W]
Pixel								
layer 1	MuPix	4	12	19.2	20.9	40.1	69	229
layer 2	MuPix	4	15	24.0	22.7	46.7	80.1	267
layer 3	MuPix	3×12	32, 36	51.2, 57.6	20.9	72.1, 78.5	1162	3873
layer 4	MuPix	3×14	36	57.6	20.9	78.5	1413	4710
Fibre	MuTRiG	12	16	17.6	17.9	35.5	182.6	609
Tile	MuTRiG	14	14	15.4	17.9	33.3	199.8	666
Total		112						**10354**