Status of the Mu3e Experiment

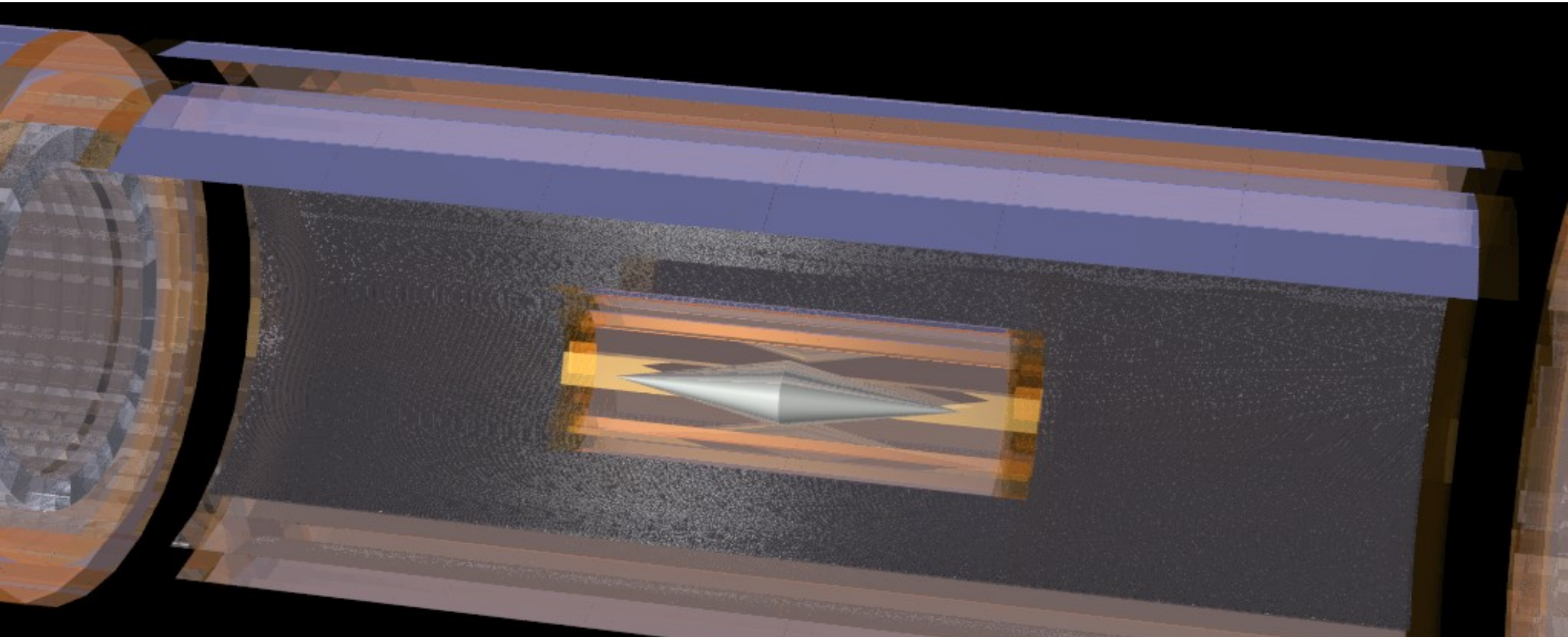
Paul Scherrer Institut

Open Users Meeting BV49

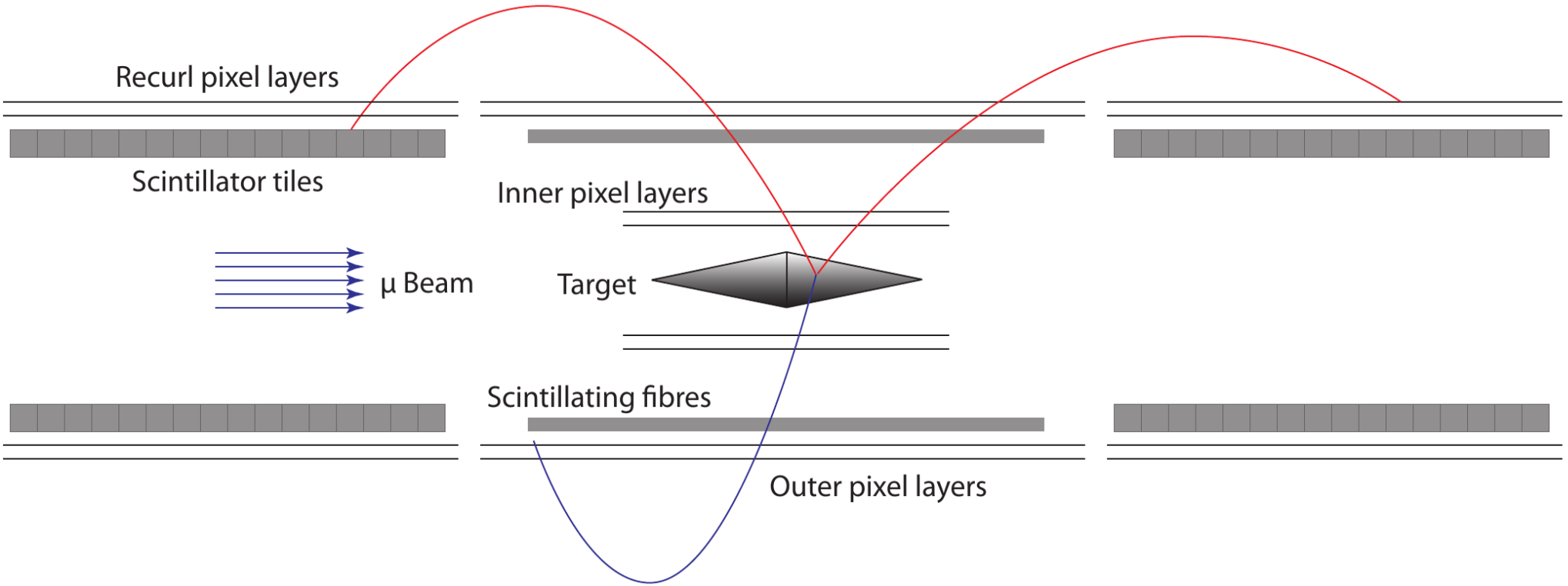
Mu3e - Review

February 12, 2019

André Schöning for the Mu3e Collaboration



Mu3e Detector



Short Summary Talks:

Pixel Tracker	→ Frank Meier-Aeschbacher
Scintillating Tiles:	→ Yonathan Munwes
Scintillating Fibers:	→ Antoaneta Damyanova
Integration	→ Dirk Wiedner

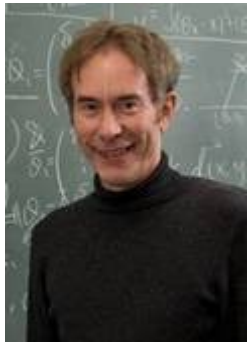
New Mu3e Institute and Groups

- **University of Bristol (BRI)**
- University Geneva (GVA)
- Kirchhoff Institute for Physics@Heidelberg (HD-KIP)
- Physics Institute@Heidelberg (HD-PI)
- Karlsruhe Institute of Technology (KIT)
- **University of Liverpool (LIV)**
- **University College London (UCL)**
- Universität Mainz (JGU)
- **University of Oxford (OXF)**
- **High Energy Group at PSI, Villigen**
- Muon Group at the PSI, Villigen
- ETH Zürich (ETHZ)
- **University Zürich (UZH)**

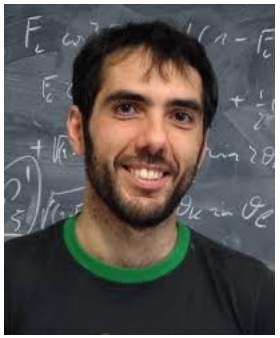

Joel Goldstein
(Bri)


Joost Vossebelt
(Liv)


Gavin Hesketh
(UCL)


Ian Shipsey
(Oxf)


Bohdan Kotlinski
(PSI-HE)


Nicola Serra
(UZH)

Σ ~ 60 authors

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→ **Pixel Detector**


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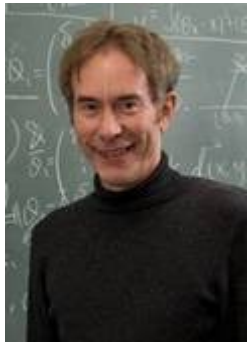
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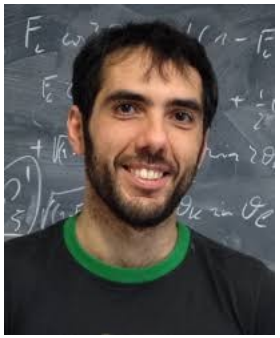
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→ **Clock Distribution**


Joel Goldstein
(Bri)


Joost Vossebelt
(Liv)


Gavin Hesketh
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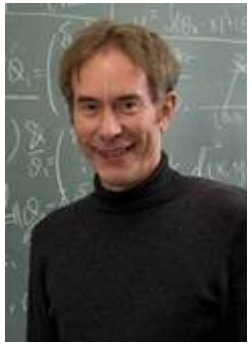
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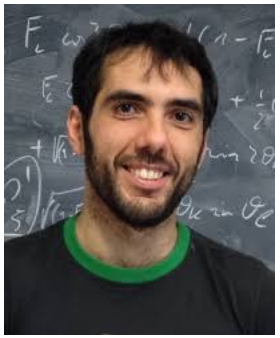
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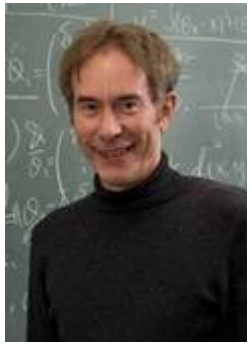
→ Scintillating Fiber Detector


Joel Goldstein
(Bri)


Joost Vossebelt
(Liv)


Gavin Hesketh
(UCL)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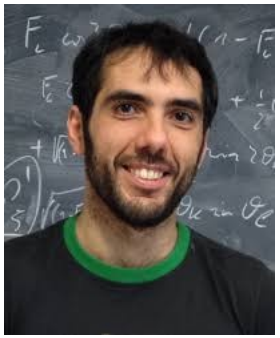

Nicola Serra
(UZH)

Mu3e Organization

Functions:

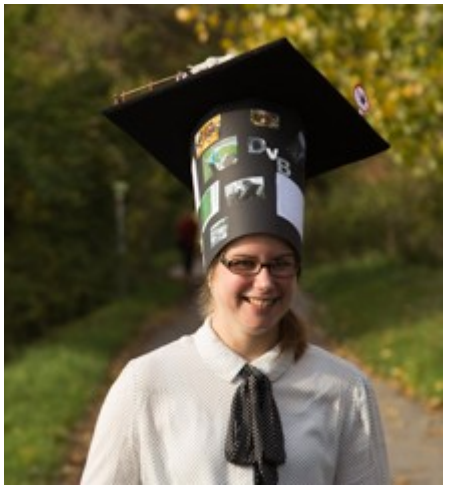
- Spokespersons: A.S and Stefan Ritt
- Technical Coordinator: **Frank Meier Aeschbacher**
  (deputy Dirk Wiedner)
- Software Coordinator: Nik Berger
- Project Leaders
  - Experimental Area and Beamline: Andreas Knecht
  - Data Acquisition/Filter Farm: Nik Berger
  - Mechanical/Electrical Integration: Dirk Wiedner
  - Pixel Tracker: **Joost Vossebelt**
    (deputy Frank Meier Aeschbacher)
  - Slow Control: Stefan Ritt
  - Scintillating Fibers: Alessandro Bravar/Christoph Grab
  - Scintillator Tiles: Yonathan Munwes

Frank Meier
(PI-HD)

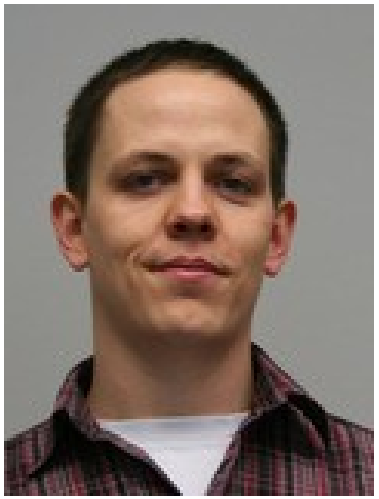
Joost Vossebelt
(Liv)

Promotions

- Dorothea vom Bruch has graduated in Mainz/Heidelberg



- Felix Berg has graduated at ETH Zurich



- Joost Vossebelt became full professor in Liverpool

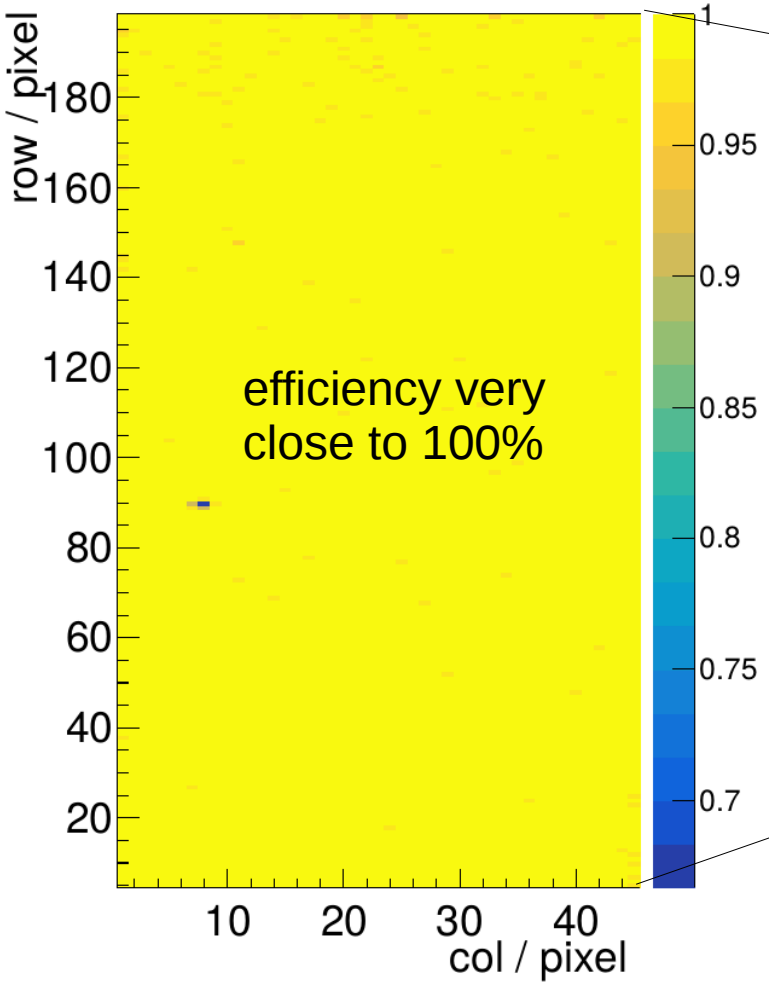
- Angela Papa has received an assistant professorship in Pisa (Rita Levi Montalcini program)

Main Highlights in 2017

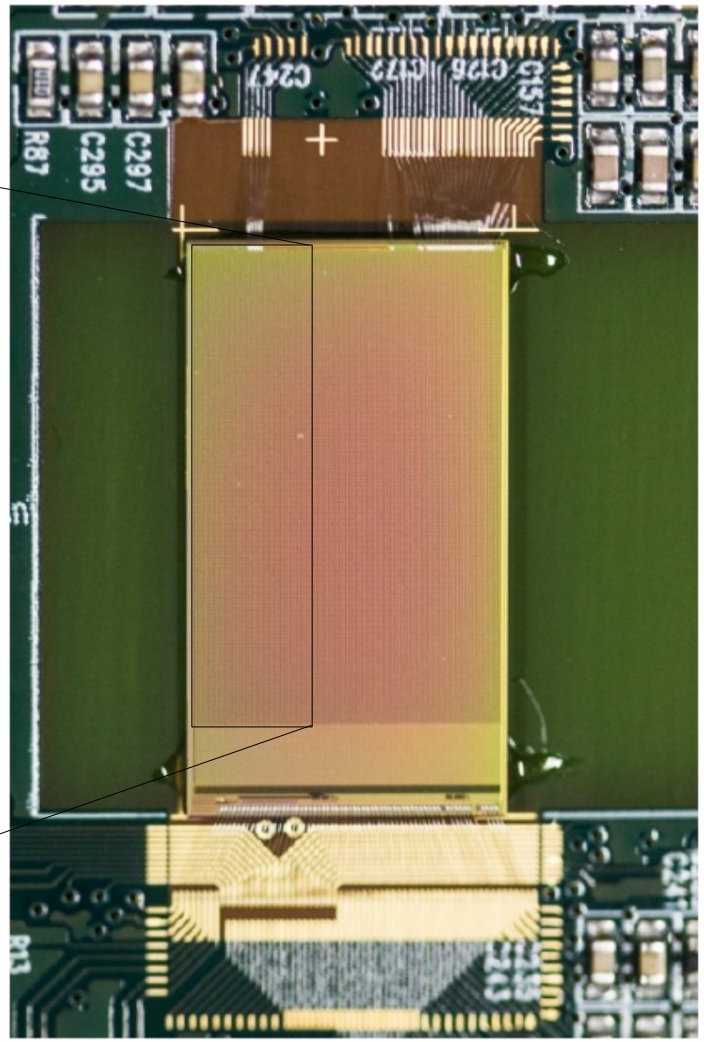
- Mupix8 sensor → Frank Meier
- MuTrig Readout Chip → Yonathan Munwes
- improved inner detector integration addressing many questions from TDR review (meeting with Roland) → Frank Meier
- ...

Mupix8

from pre-production
delivered August 2017



2cm



→ Frank Meier

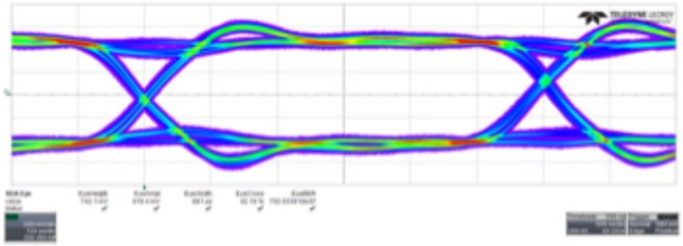
MuTrig Chip

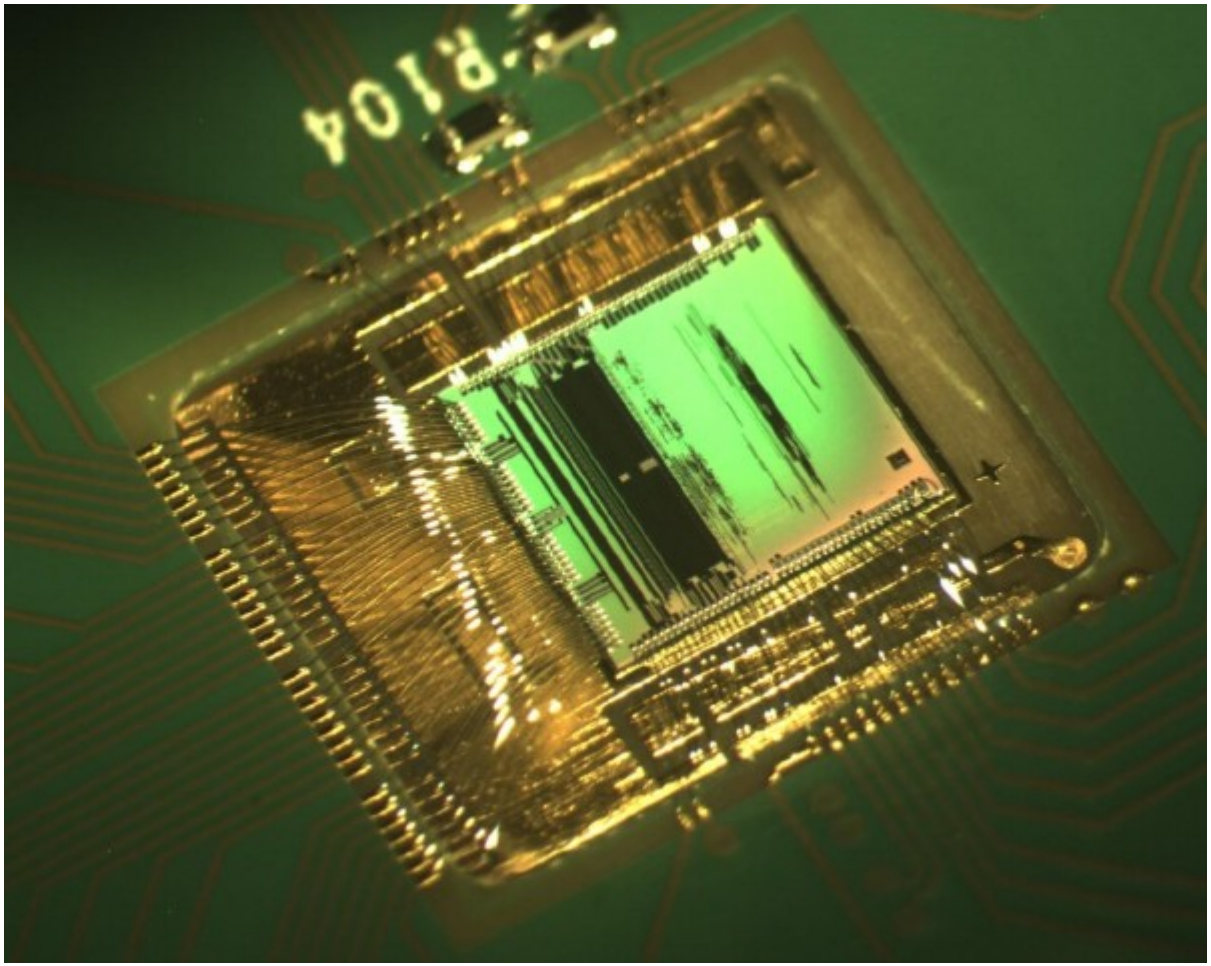
32 channel TDC for SiPM
with 1.25 Gbit/s readout

Used for

- SciFi
- SciTiles

it works!





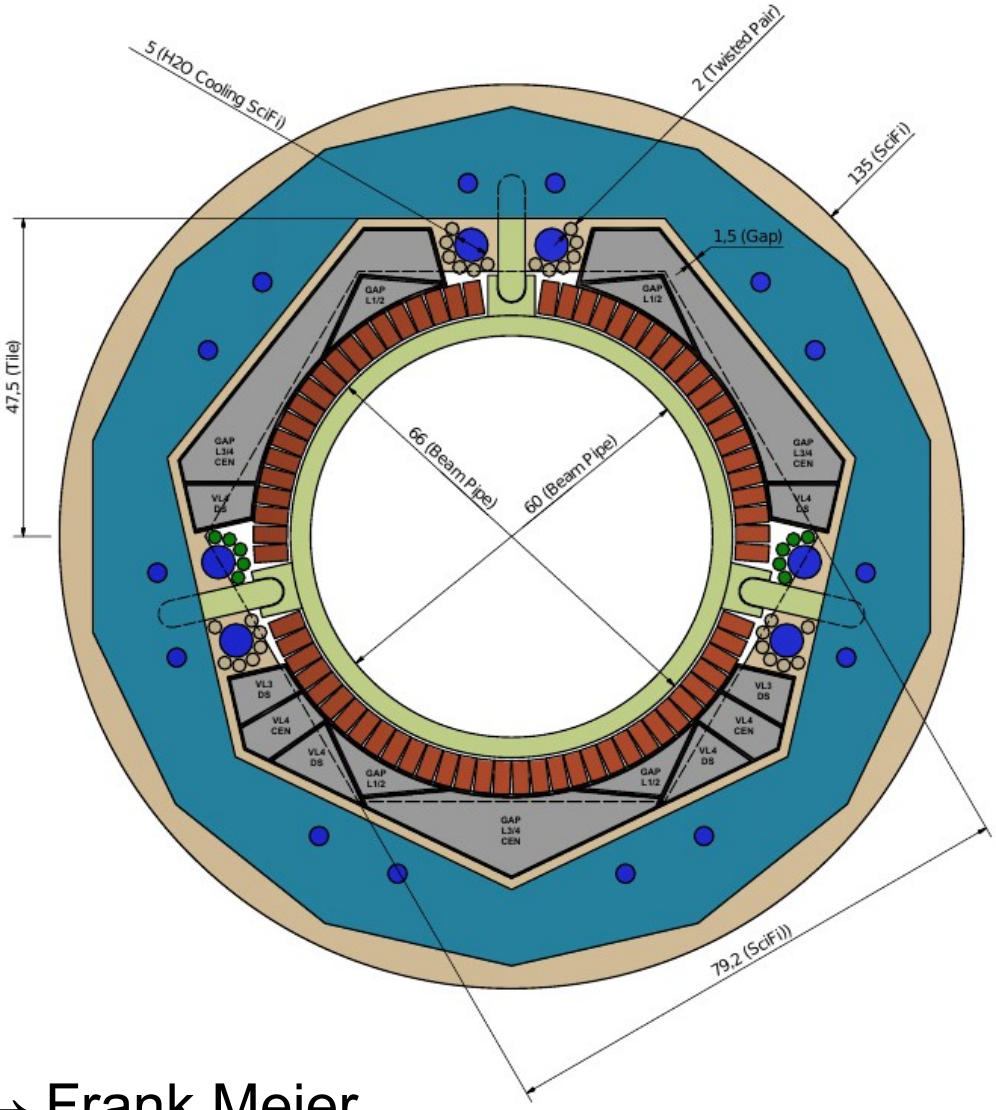
→ Yonathan Munwes

Progress with Inner Detector Integration

Q-BVR48

Full design including

- mechanics
- water cooling
- He-cooling
- power
- cables



big step forward!

→ prel. TDR will be finalized soon

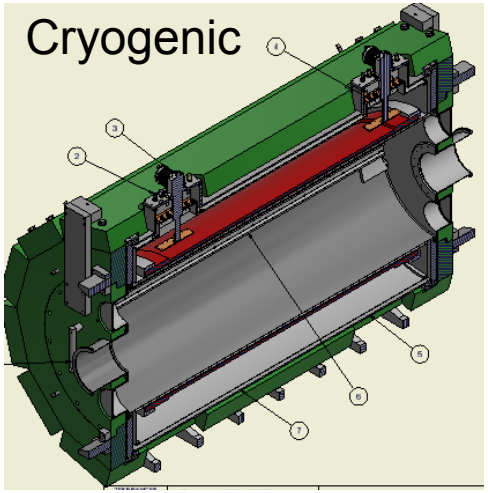
→ Frank Meier

Mu3e Solenoid Magnet

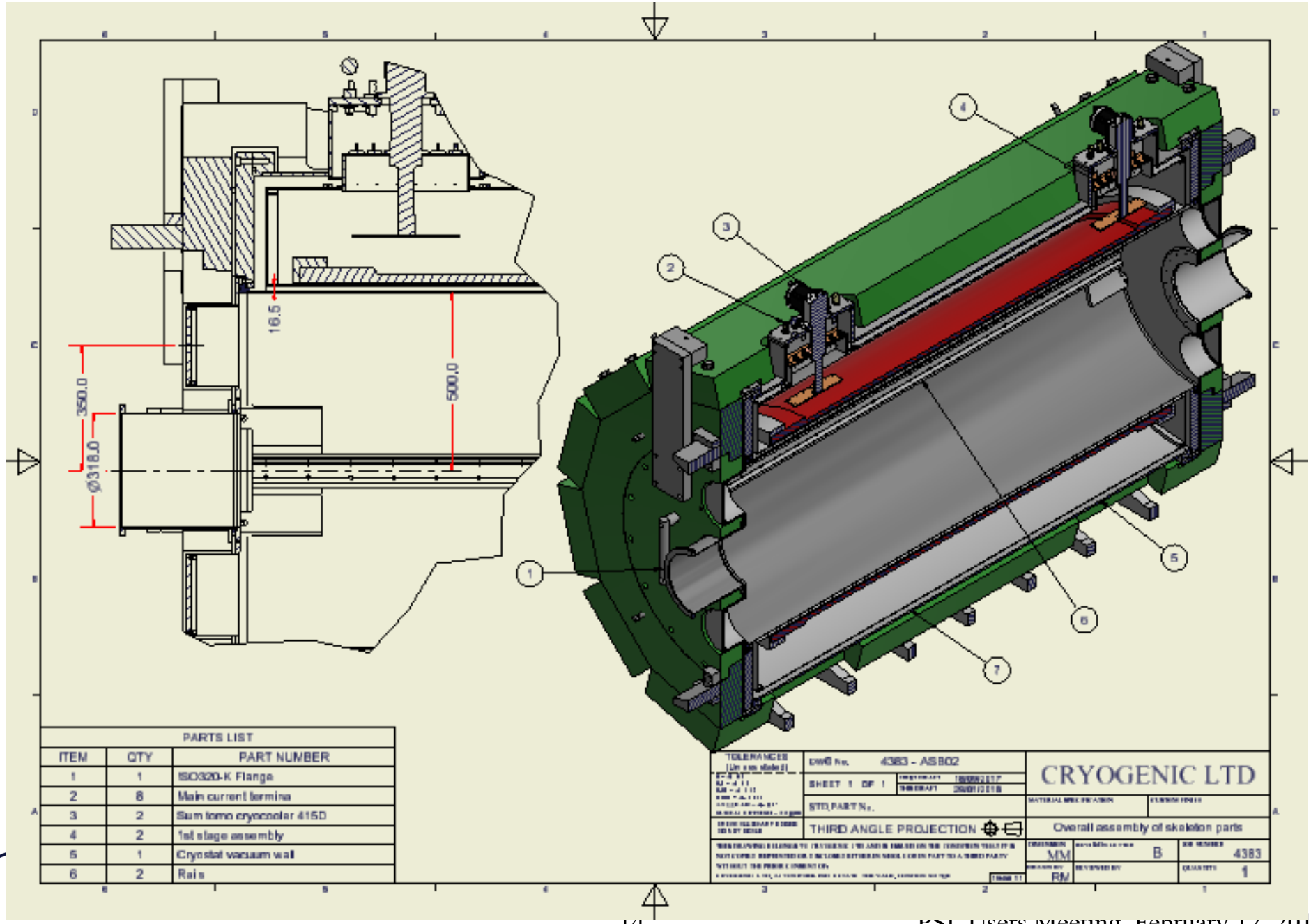
- Contract with Danfysik canceled by Heidelberg University at January 25th 2017 because of non-fulfillment
  - ➔ Danfysik had underestimated technical risk and business hazard
  - ➔ problem were not our specifications (B=2T, homogeneous)

Q-BVR48

- 2018 events…
  - tendering process started Easter 2017
  - specs almost unchanged; B → 2.6T
  - serious offers from Cryogenic Ltd and TESLA Ltd only
  - decision for Cryogenic (better price)
  - kick off meeting in September 2017
- Magnet TDR March 2018 (no show stopper so far)
- Magnet delivery expected for beginning 2019 (in accordance with our plans)



Prel. Cryogenic Current Design



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Product Range

- Cryogen Free Measurement System (CFMS)
- Measurement Options
- SQUID Magnetometer
- Custom Research Systems
- Cryogen free Ultra-Low Temperature (ULT) Systems
- High Resolution Magnet Systems (NMR / MRI/ EPR)
- Liquid Helium Systems
- Quantum Hall Resistance (QHR) Standard Systems
- Electronics and Software

Cryogenic Ltd was very responsive to our demands, and we are very pleased with the final product.

Dr. Elizabeth Blackburn
Lecturer in Condensed Matter Physics
University of Birmingham

Home »

Product Range


Cryogen Free Measurement System (CFMS) view


Measurement Options view


SQUID Magnetometer view


Custom Research Systems view


Cryogen free Ultra-Low Temperature (ULT) Systems view


High Resolution Magnet Systems (NMR / MRI/ EPR) view


Liquid Helium Systems view


Quantum Hall Resistance (QHR) Standard Systems view


Electronics and Software view

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Cryogenic Ltd

Production Readiness and Production

- Retreat Feb. 26th - Mar. 1st in Wengen
- Goals:
  - ➔ **Internal review of sub-detector projects**
  - ➔ **detector prototyping & pre-production & production**
  - ➔ **detector integration**
  - ➔ **Infrastructure**
  - ➔ **upgrades of experiment**

Detailed timelines for sub-detectos systems only after retreat

Mu3e Retreat: Topics and Sessions

- Pixel Production
- SciFi Production
- SciTile Production
- Midas & Slow Control
- Pixel Slow Control and HV-MAPS System Integration
- Detector Readout at Frontend
- Filter Farm & Software
- Infrastructure incl. cooling
- Mu3e Phase II and Upgrades

Responsibilities

- Solenoidal Magnet (HD-PI, ETHZ) Q-BVR48
- Pixel Detector (BRI, HD-PI, KIT, LIV, PSI, OXF)
- Scintillating Fiber Detector (GVA, PSI, ETHZ, UHZ)
- Scintillating Tiles Detector (HD-KIP)
- Detector Readout & Clock Distribution (HD-PI, UCL, JGU)
- Filter Farm (JGU)
- Slow Control (PSI)
- Pixel Slow Control (HD, PSI)
- Mechanics & Cooling (HD, PSI, **???**) → He-gas cooling uncovered
- Experiments Infrastructure (PSI)
- Beam and Target (PSI)
- Offline Computing (PSI, ETHZ)

→ collaboration agreement in preparation

Responsibilities in Pixel Project

Q-BVR48

- pixel detector design and integration (HD-PI, PSI)
- HV-MAPS sensor (KIT, HD-PI)
- inner vertex layers: HD-PI, PSI
- outer pixel layers
  - ladders (Oxford)
  - modules (Liverpool)
  - qualification and tools (Bristol)
- pixel slow control (HD-PI, PSI)

task are well defined for prototyping (→ demonstrator) and production

Mu3e Engineer

Mu3e Collaboration is discussing the installation of a Mu3e-engineer position

Tasks:

- Infrastructure and installation of experiment
- He-cooling system **(new!)**
- water cooling system
- maintenance and operation of magnet
- other services
- safety issues

Funding:

→ permanent position at PSI to be funded by Mu3e common funds

CERN Recognition Experiment Committee

- Mu3e applied to become CERN recognized experiment
- Presentation and interview in January 2018 (A.S. & Dirk Wiedner)
- Mu3e application was well received; much interest in Mu3e Phase II

- Final decision expected from **CERN Research Board** at March 7

Mu3e Costs and Funding

Item	Total kCHF	funded by	open kCHF
			Q-BVR48
Solenoidal Magnet	1500	DFG/HD	
Pixel Detector	1550	STFC	~1200 DFG
Scintillating Fiber Detector	420	SNF	
Scintillating Tile Detector	550		~400 DFG
Detector Readout	420	STFC	~300 DFG
Filter Farm	230	JGU/DFG	~100 DFG
Slow Control	130	PSI	
Infrastructure Area&Experiment	240	PSI	
Mechanics, Cooling and Target	240	PSI, HD	
Beamline & Infrastructure	2020	PSI	
Computing Costs	150	PSI	common funds
Data Storage	100	PSI	common funds
Sum	**7550**		

DFG=Deutsche Forschungs Gemeinschaft

Comment about DFG Funding

- Funding pending for about 2 mill CHF
- Großgeräteantrag (“big instruments”):

  Crates & HV-MAPS sensors ~ 500-600k€
- Installation of DFG Research Group:
  - 3+3 years (2 x 1.5 mill €)
  - investment and personal
- DFG recommended to wait with application to allow for decision in 2019 (no money in 2018)

Mu3e Schedule

Estimated Schedule (Optimistic)

	2018				2019				2020			
Pixel	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Mupix10 submission			X									
Mupix10 characterized						X						
demonstrator module							X					
production readiness								X				
sub-detector final										X		
SciTiles	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
demonstrator module				X								
production readiness					X							
sub-detector final								X				
SciFibers	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
demonstrator module					X							
production readiness						X						
sub-detector final								X				
Integration	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
magnet at PSI					X							
compl. vertical slice					X							
area & infrastr. ready								X				
sub-detectors mounted											X	

Q-BVR48

→ Retreat

Risks & Critical Points & Mitigations

Q-BVR48

- **Magnet**: we rely on Cryogenic Ltd now (but we are happy at moment)
- **Design and installation of He-cooling system not covered**
  - mostly engineering task (10 kW, ~2000m3/h)
  - trying to find resources or interested group
- **HV-CMOS process from AMS (no longer IBM)**
  - Mupix8 submission delayed by 18 months (new hitkit was not available)
  - Mupix8 production delayed by 6 month (only pre-prod. available now)
  - no real alternatives (LFoundry?, TowerJazz? → project delay 2-3 years)
- **MuPix performance**
  - experiment design requires high sensor eff. >99%
  - no alternative from design point but current results are very promising!
- **No final demonstrator modules yet**
  - important to have demonstrators in 2018 for all sub-detectors!
  - but all detector concepts have already been proven with small prototypes!

Beamline Requests

Status 2017:

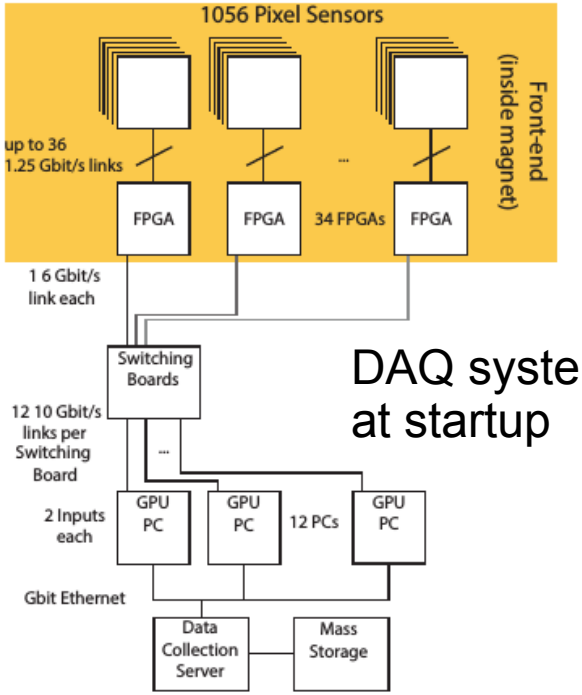
- Delays in licensing new piE5 safety installations at the beginning of 2017 did not allow for testing the CMBL at piE5.
- MUSE experiment had high priority in 2017 –
  Mu3e had only one week of test beam in piM1 (SciFi)

Requests:

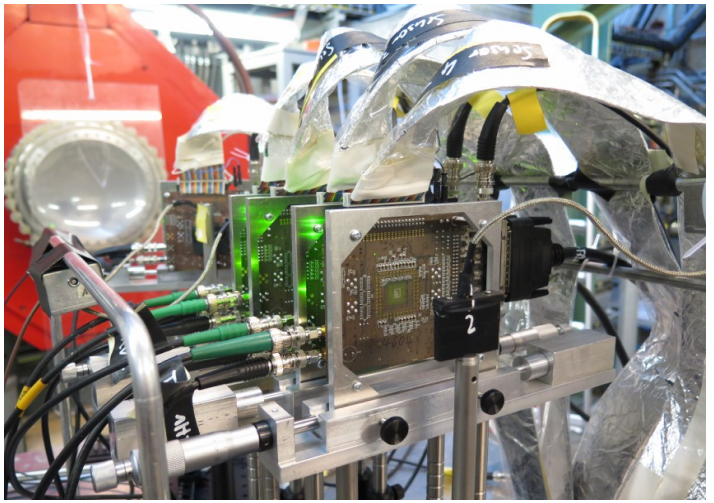
- **PiE5**: **4 weeks** CMBL tests
- **PiM1** (or equivalent) **week 41+42** for detector prototype tests:
  - one week SciFi
  - one week pixel detector

Backup

Readout + Online Reconstruction



DAQ system at startup



- Lots of experience from test-beam campaigns at CERN, PSI, DESY, Mainz
- Vertical slice with 4 pixel layers running!

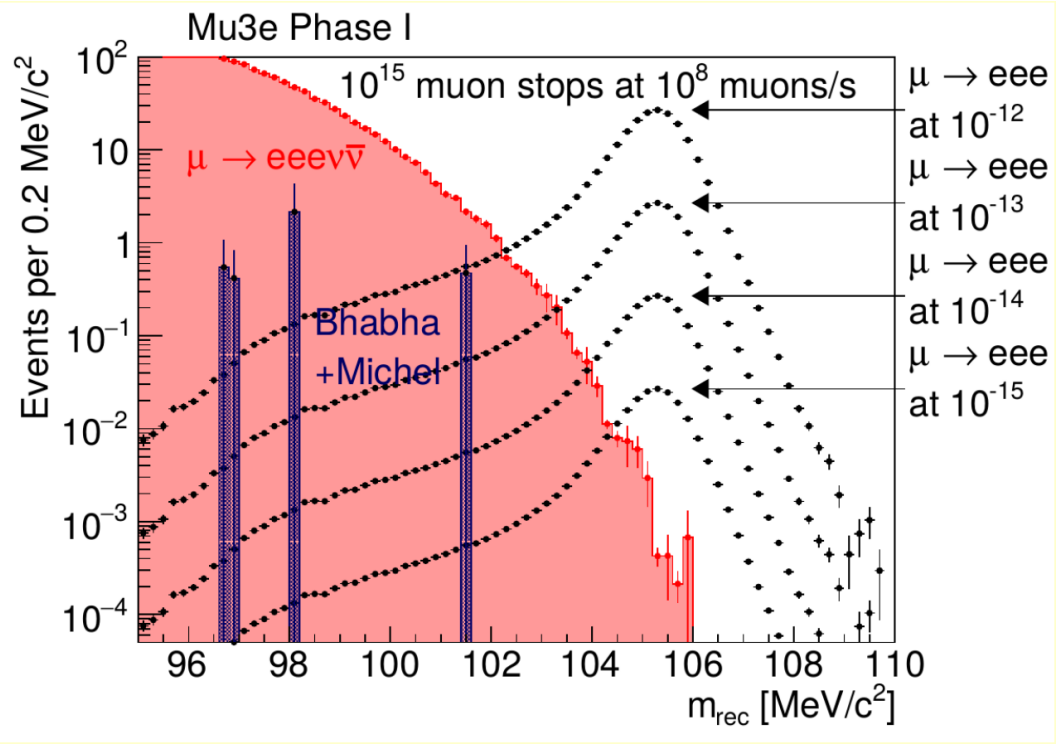
Next Milestones (BVR48)

- Develop, produce and test the final small front end board (→ prototype ok)
- Acquire and test the switching board.
- Run the full selection algorithm on a GPU (→ successful thesis D. vom Bruch)
- Integrate the readout chain and the selection algorithms.
- Integrate the farm PCs with the MIDAS DAQ system (→ partially running)
- Scale readout system to full phase I capability.

Simulation & Performance Questions

Stopping target

- new: fixation with bar from downstream
- target position not (yet) used in analysis (could also be a 3D target)
- target position alignment needs ~1ms
- position has no impact on (dominant) non-reducible internal conversion BG



Main worry is alignment of pixel detector!

- built heatable mock-up for detailed studies → talk by Frank Meier
- PhD thesis on alignment → U. Hartenstein (Mainz)
- results to be published in final TDR

Submission of Mupix Pixel Sensors

Mupix7 (small prototype O(10 mm^2))
- all main features included (2015)
- fully operational

MuPix8 (large area prototype O(200 mm^2)
- engineering run submitted to AMS Easter 2017 (after 18 months delay)
- new features:
  - charge measurement for time walk correction (3 methods) → $\sigma(t)$=5ns
  - 80 Ohm substrate (instead of 20 Ohm standard): efficiency 99.5% → 100%
  - delay in production by 6 months
- only pre-production in August/September 2017; final batch in March 2018

MuPix9 (small test chip)
- features:
  - slow control (differential signals)
  - voltage regulators
  - other test circuits
- expected Feb 2018

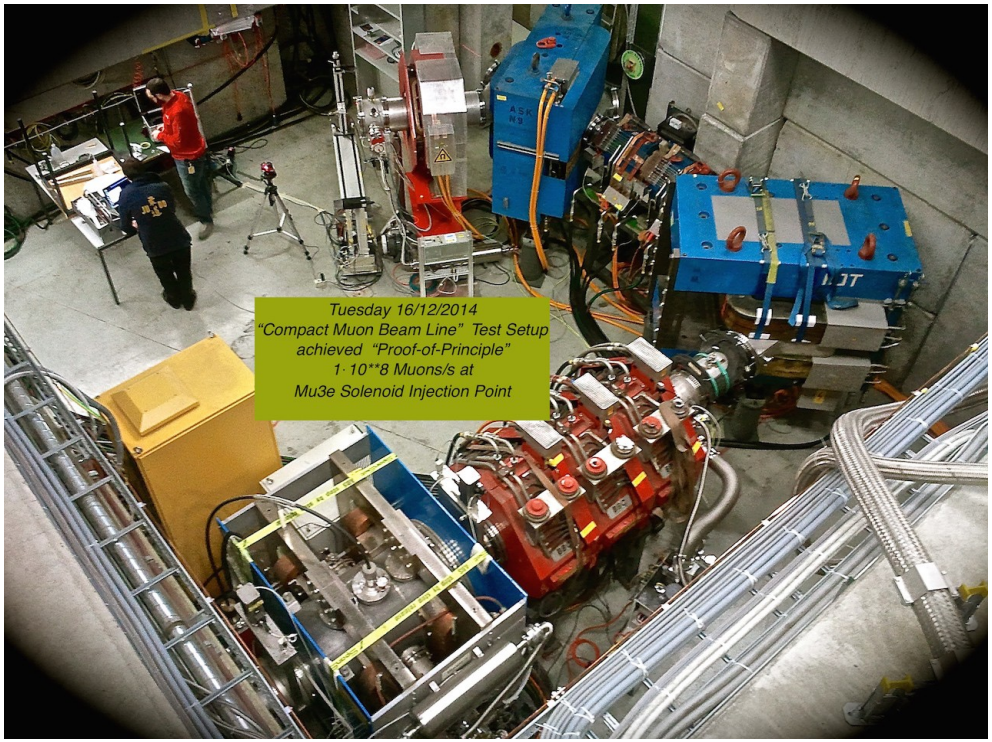
Mupix10 (2x2 cm^2)
(pre-)production run
planned for Q3/2018
→ pixel module pre-production

slide updated 8.2.2018

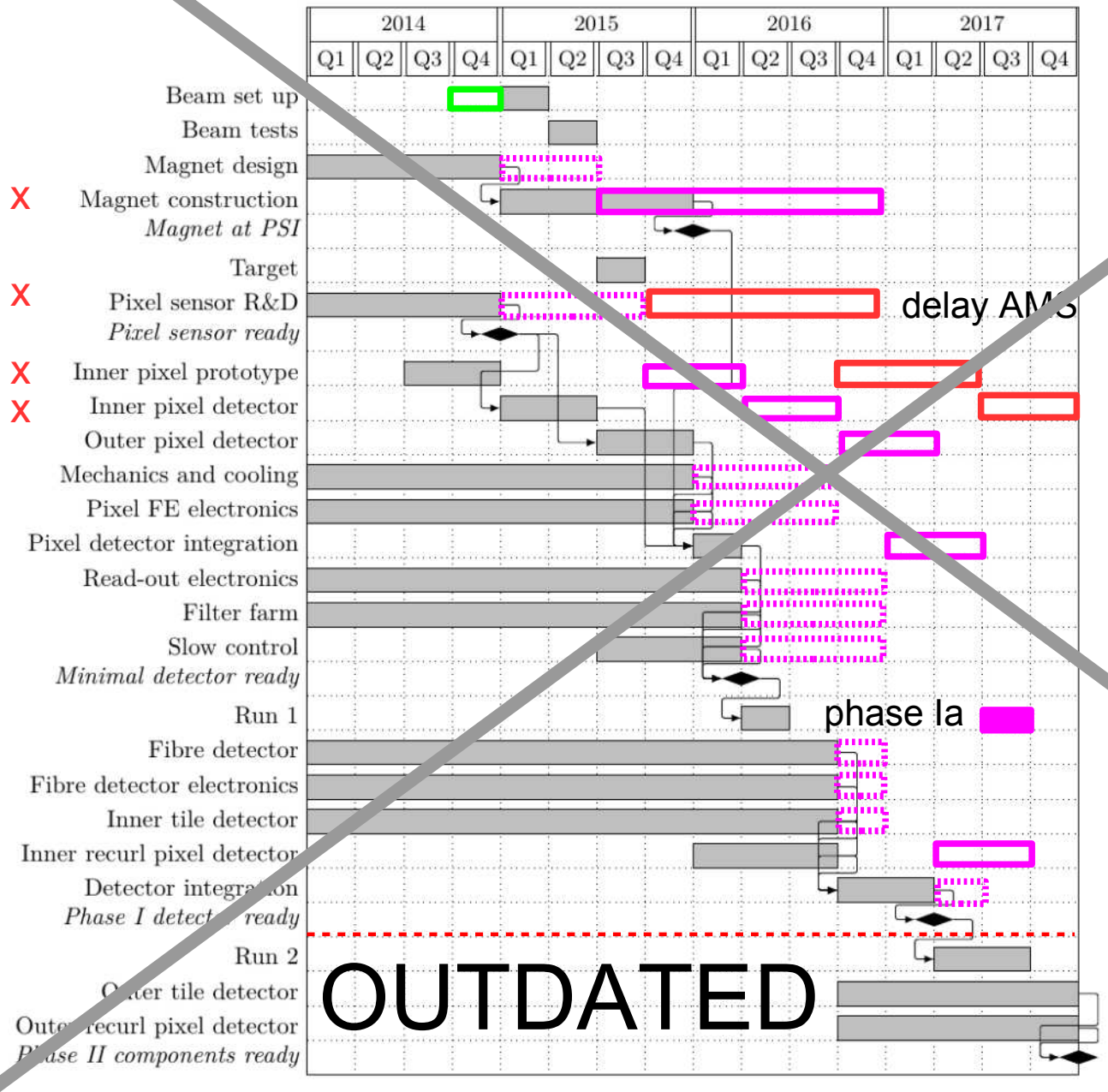
Compact Muon Beamline Status

(from P.-R. Kettle)

- No CMBL commissioning in 2017
- But optimization studies performed:
  - central detector region (focus)
  - background study (→ thesis Zachary Hodge)
  - note in preparation
- Redesign of separator:
  - reduction of BG
  - ready by 2019



Tentative Mu3e Schedule in 2016



BVR 45

BVR 46

BVR 47

→ Mupix 8 chip

Overall Mu3e schedule to be revisited after finalization of TDR in 2017 Q2

In general:
2017: R&D & prototyping
2018: prototying & preproduction
2019: production