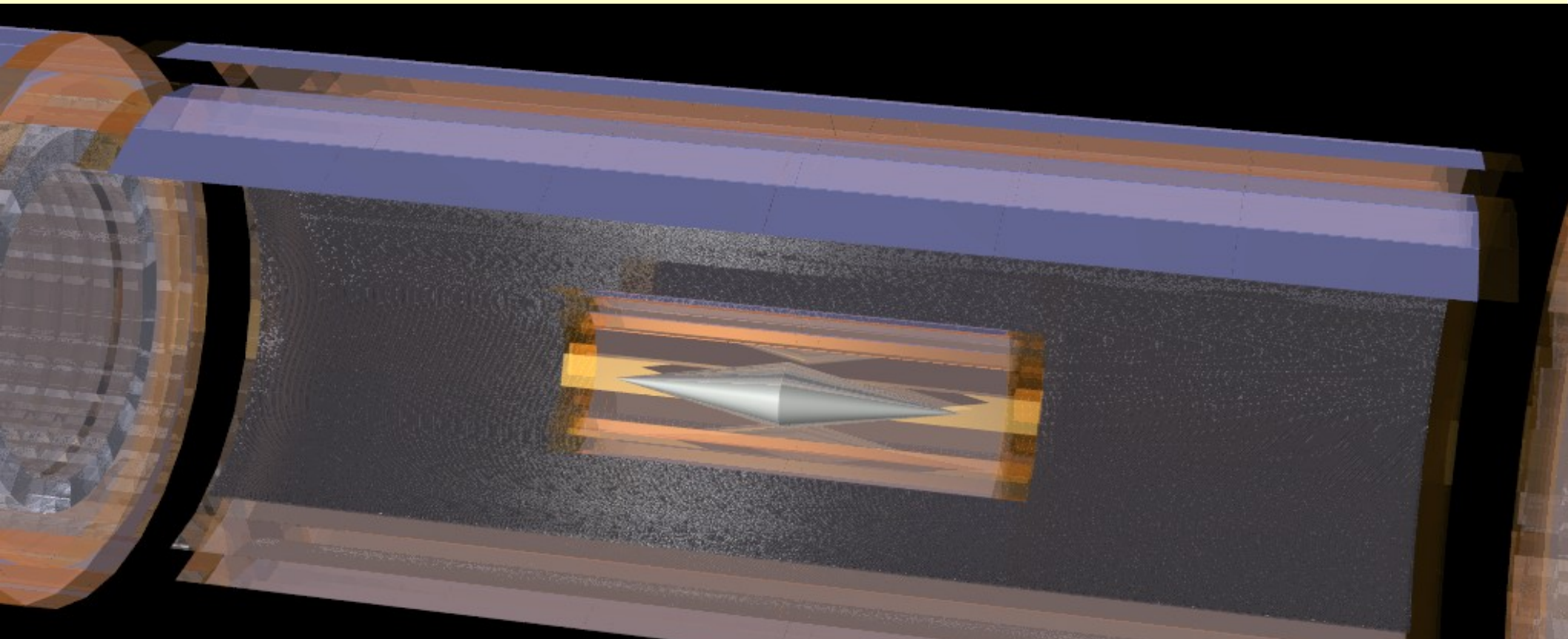


Status of the Mu3e Experiment

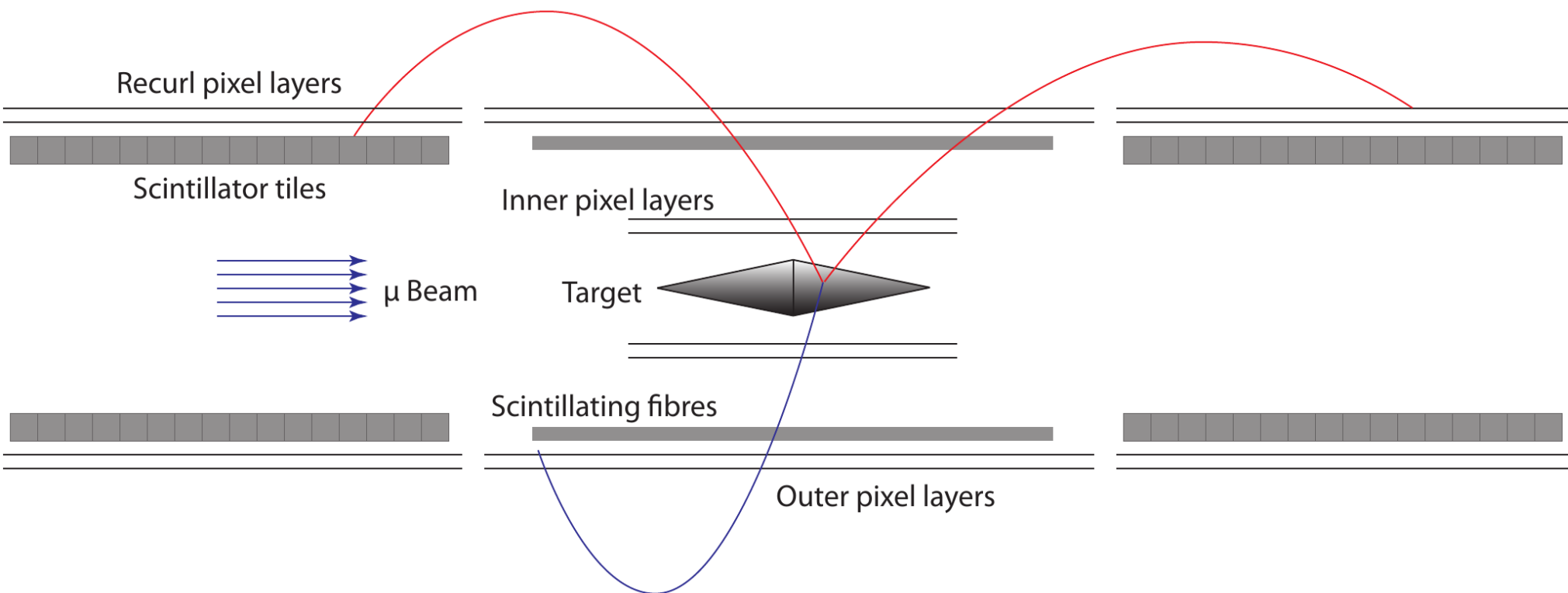


Paul Scherrer Institut
Open Users Meeting BV48
Mu3e- Review
February 6, 2017

André Schöning for the Mu3e Collaboration



Mu3e Detector



Short Summary Talks:

Technical Design of Mu3e

→ Dirk Wiedner

Pixel Tracker

→ Frank Meier-Aeschbacher

Scintillating Fibers and Tiles:

→ Simon Corrodi

Performance Studies:

→ Nik Berger

Main Achievements in 2016

- Mu3e is a lively and for students attractive collaboration; students contributed significantly to the Mu3e R&D program!
Finalized PhD thesis in 2016:
 - Moritz Kiehn (Heidelberg)
 - Patrick Eckert (Heidelberg)
 - Roman Gredig (Uni-Zurich)
- MoU signed in January 2016
- Most R&D studies concluding
- Mu3e design finalized
- First version of **Mu3e Technical Design Report**

Mu3e Collaboration



- Mu3e Institutes
 - **University of Geneva** (SciFi)
 - **University Heidelberg PI** (Pixel Tracker, Mechanical Integration)
 - **University Heidelberg KIP** (Tile Detector, MuTrig Development)
 - **Karlsruhe Institute of Technology** (MuPix Development)
 - **University Mainz** (DAQ, Filter Farm)
 - **Paul Scherrer Institute** (SciFi, Slow Control, Beams+ Infrastructure)
 - **ETH Zurich** (SciFi) → responsibilities will be added to TDR
- UK groups (Bristol, Liverpool, Oxford, UCL) have asked for (substantial) funding for Mu3e at Science and Technology Facility Council (STFC) last year. Panel visit at January 13. Official (positive) decision expected soon.
- Planned/discussed contributions to Mu3e:
 - Pixel Tracker (Outer Pixel Tracker, Pixel Recurl Station)
 - DAQ
 - Timing distribution system
 - Computing

Mu3e Organization

Organization:

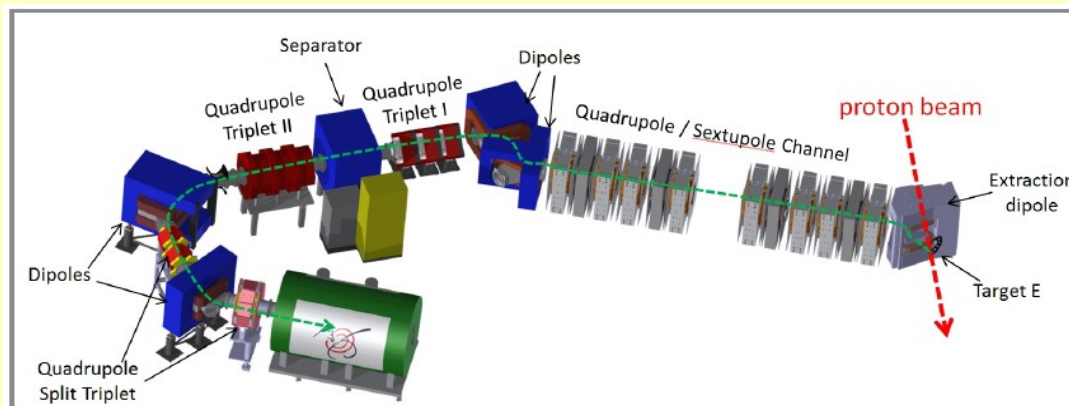
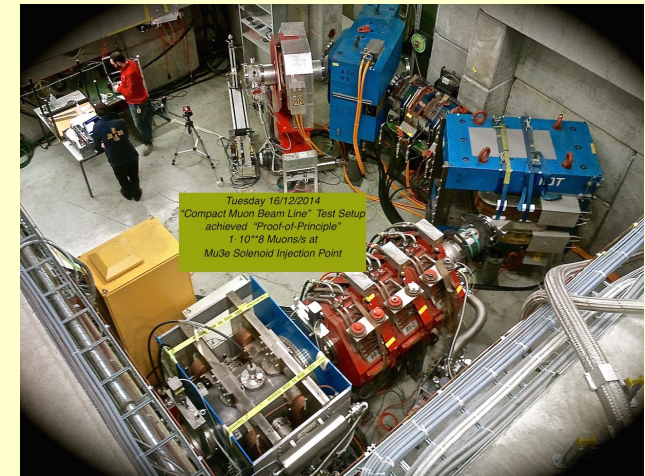
- MoU signed in January 2016
- Draft for Cooperation Treaty exists
(should be signed before construction begins)

Functions:

- Spokespersons: **A.S and Stefan Ritt**
- Technical Coordinator: **Dirk Wiedner**
- Software Coordinator: **Nik Berger**
- Project Leaders
 - Experimental Area and Beamline: **Peter-Raimond Kettle → Andreas Knecht**
 - Data Acquisition/Filter Farm: **Nik Berger**
 - Mechanical Integration/Cooling: **Dirk Wiedner**
 - Pixel Tracker: **Frank Meier-Aeschbacher**
 - Slow Control: **Stefan Ritt**
 - Scintillating Fibers: **Alessandro Bravar/Christoph Grab**
 - Scintillator Tiles: **Patrick Eckert → Yonathan Munwes**

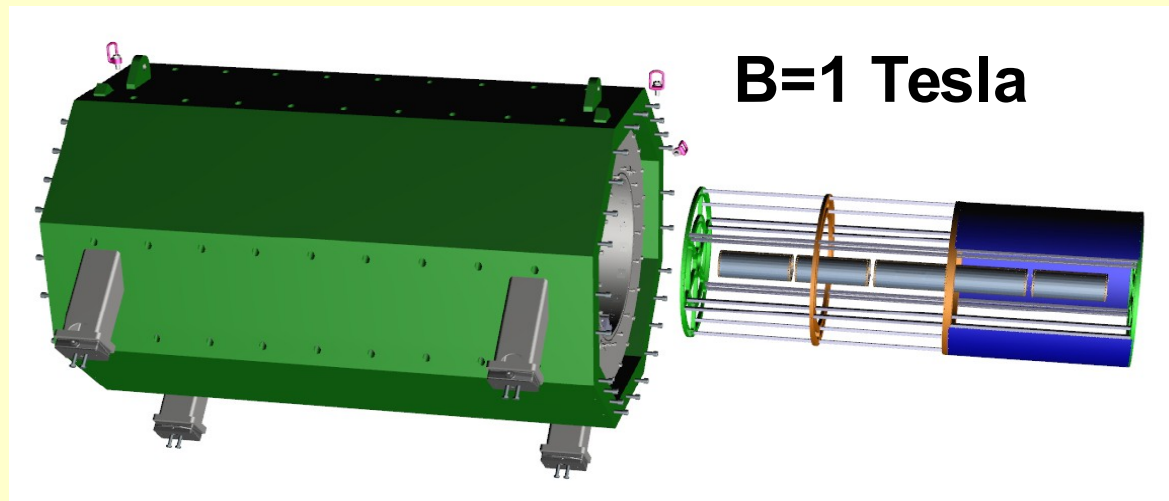
Compact Muon Beamline Commissioning

- piE5 aim: 10^8 muons/s @ 2.2mA (focus)
 - measured in 2015: $7 \cdot 10^7$ muons/s (-30%)
- Expected muon stopping rate $\sim 70\%$
- Studies 2016:
 - 6 weeks of PiE5 commissioning in Nov./Dec.
 - complications: E-target, beam-dump, safety issues
- Studies 2017:
 - request: 4 weeks of PiE5 commissioning at beginning of year (May 8) for finalizing studies



Status of Mu3e Magnet

- Superconducting magnet:
 - opening=1m
 - B=1T (2T)
 - homogeneous B-field
- EU-conform short tendering process (40 days) 2015 Q2
- Tendering won by DANFYSIK (only valid offer)
- Contract with DANFYSIK in July 2015
- Delivery including the commissioning of the magnet at PSI was originally foreseen for Dec. 2016 (delay → penalty)



DANFYSIK Project I

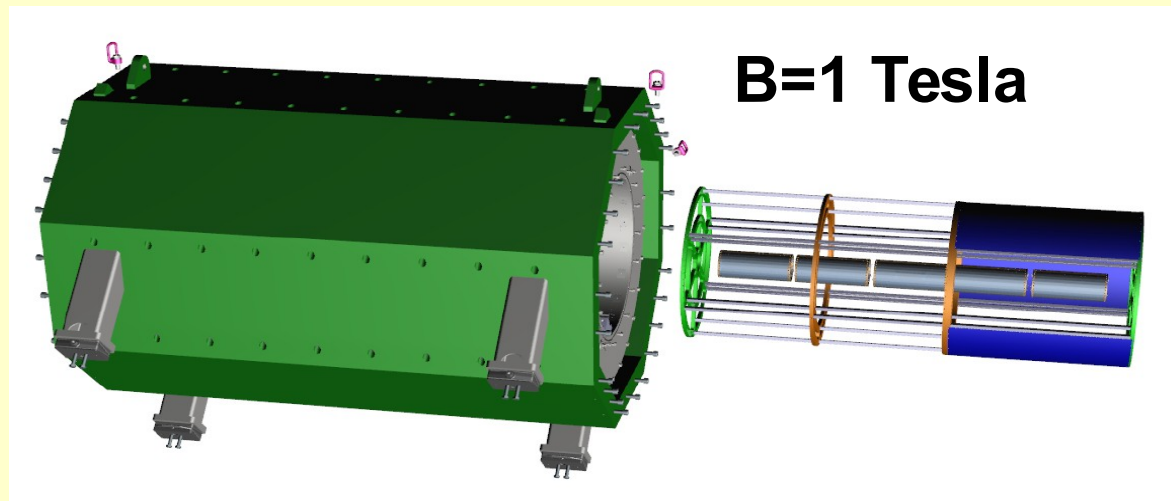
- Design of magnet 2015 Q2/Q3
- Technical Design Description in December 2015
- External review (CEA France) revealed potential design problems with multilayer insulation and cryo-cooling design 2016 Q1
- Redesign (only minor modifications) in 2016 Q3
- Multilayer insulation tests (successful) at DANFYSIK in 2016 Q4
- External reviews of improved design by CEA and Prof.Haberstroh (Dresden)
→ both evaluation were positive

DANFYSIK Project II

- DANFYSIK management first indicated unwillingness of taking the magnet production risk in June 2016 and asked for modifications of contract
→ denied
- Escalation in November/December 2016
- Crisis meeting with DANFYSIK in January 2017:
 - discussed remaining risks of projected
 - agreed on defining new delivery date, thus saving DANFYSIK the penalty of 85k€
- This agreement with CEO and Chair of DANFYSIK board was not approved by DANFYSIK board, unfortunately
- Contract canceled by Heidelberg University at January 25th because of non-fulfillment

Mu3e Magnet Plans

- Magnet Specifications are ok!
- DANFYSIK design checked by several experts (DANFYSIK, external, own)
- Restart tendering process asap
- In close contact with:
 - Babcock Noell, Cryogenics, TESLA, Toshiba/Westinghouse
- Contacting also other companies
- New vendor could be identified by summer
- New delivery date for magnet end 2018/beginning 2019



Mu3e R&D Funding

- Development of HV-MAPS Pixel Detector for Mu3e (DFG):
~450 k€ for Pixel R&D (2015-2017)
- Development of SciFi Tracker and HV-MAPS R&D:
~ 200 kCHF (ETH), similar contributions from Uni ZH, GVA, PSI each
- Young investigator group for N.Berger (DFG Emmy Noether program 2012-2017)
~1.5 M€
- Many university funds...

This list is by no far complete and does not include in kind contributions

BMBF=Federal Ministry of Education and Research

DFG=Deutsche Forschungsgesellschaft

SNF=Swiss National Science Foundation

Mu3e Production Costs (Status 2016)

estimated: Item	Costs in kCHF	Costs in kEUR
Solenoidal Magnet		1695
Pixel Detector		660
Scintillating Fiber Detector	300	
Scintillating Tile Detector		290
Detector Readout and Filter Farm		550
Slow Control	100	
Infrastructure Area&Experiment	336 (being evaluated)	
Mechanics, Cooling and Target	12	200
Beamline & Infrastructure	2017	
Computing Costs	150	
Data Storage	100	
Sum	3015	3395

Including 20% contingency and PSI in-kind contributions of about ~1500 kCHF

Mu3e Production Costs (Status 2017)

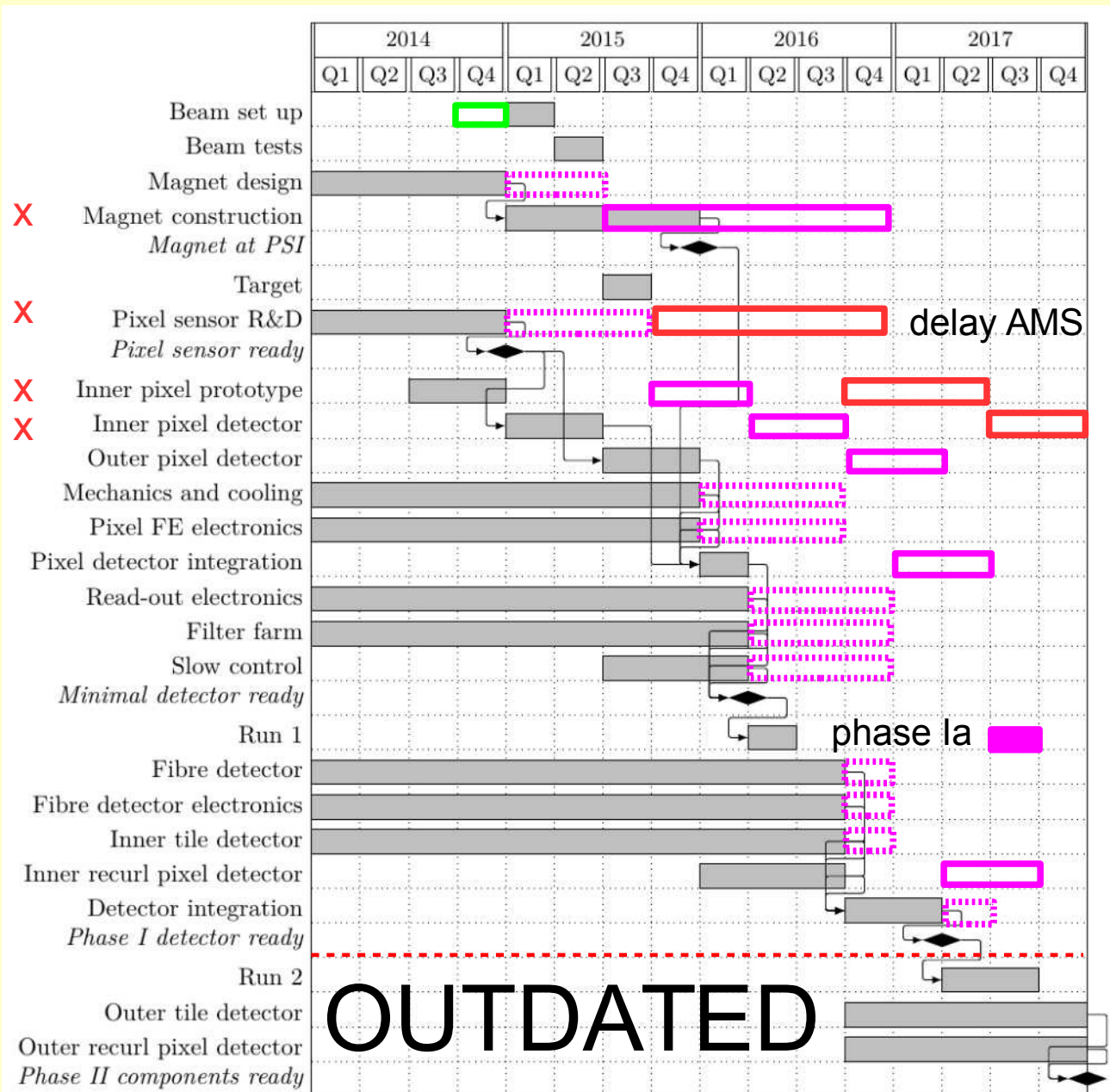
Item	Costs kCHF	kEUR	Funded
Solenoidal Magnet		1695	DFG (50%), HD, ETH: 1695
Pixel Detector		708	application planned**/UK
Scintillating Fiber Detector	300		SNF 120, GVA 100, ETH 50
Scintillating Tile Detector		414	application planned**
Detector Readout and Filter Farm		579	application planned**/UK
Slow Control	130		PSI
Infrastructure Area&Experiment	372		PSI/in kind
Mechanics, Cooling and Target	12	200	application planned**
Beamline & Infrastructure	2017		in kind/PSI
Computing Costs	150		?
Data Storage (first 2-3 years))	100		PSI
Sum	*3081	3596	

*Including PSI in-kind contributions of about ~1500 kCHF.

**DFG application planned (research group) by April 2017 after full Mu3e cost review.

- All numbers include 20% contingency.
- UK sharing to be defined.
- Additional ~200k for test boards and pre-production required.

Tentative Mu3e Schedule 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: prototyping
& preproduction
2019: production

OUTDATED

Submission of Mupix 8 Pixel Sensor Prototype

Mupix7 (small prototype $O(10 \text{ mm}^2)$)

- all main features included
- fully operational
- characterized (PiM1): rate, resolution, efficiency, noise, radiation hardness

MuPix8 (large area prototype $O(200 \text{ mm}^2)$)

- engineering run submitted only in December 2016 (were hoping for mid 2016)
- bondable on thin flexprints → modules!
- new features:
 - charge measurement for time walk correction (3 methods) → $\sigma(t)=5\text{ns}$
 - 80 Ohm substrate (instead of 20 Ohm standard): efficiency 99.5% → 100%
 - wafers expected back in Feb/March 2016
- will be used for pixel module prototypes

MuPix9 (planned for summer 2017)

- small test chip for:
 - Slow Control (differential signals)
 - Voltage Regulators
 - other test circuits

Mupix10 ($2 \times 2 \text{ cm}^2$)

production run

planned for 2017/2018

→ pixel module pre-production

Pixel Tracker Construction Schedule

From Frank (Pixel Tracker):

- During the preparation of the TDR we've scrutinized many designs.
- We have concepts for all parts and are confident that they will work.
- We are in the process to produce models for everything, we're happy with progress.
- Our focus is now to transform those concepts into manufacturing processes with proven quality.
- This year we will see e.g. the vertical slice study (comes with a module demonstrator) showing the feasibility of our concepts under real-world conditions.
- We are now capable to prepare a meaningful resource loaded schedule.
- We've started with the outer layers (tooling, prototypes, tests, manufacturing), where a preliminary work breakdown structure (WBS) exists.
- We expect to have an initial version of the WBS for the pixel tracker ready for review by spring.“

PS: Frank is offering to show the preliminary WBS on his laptop

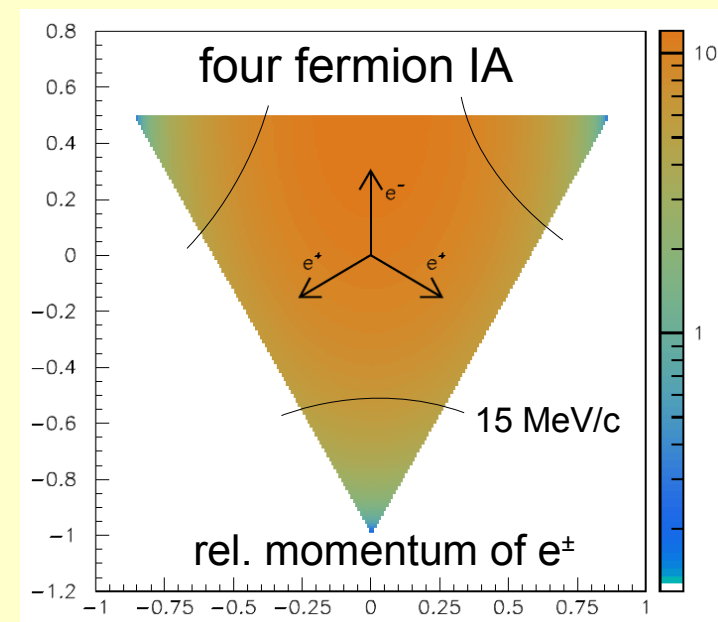
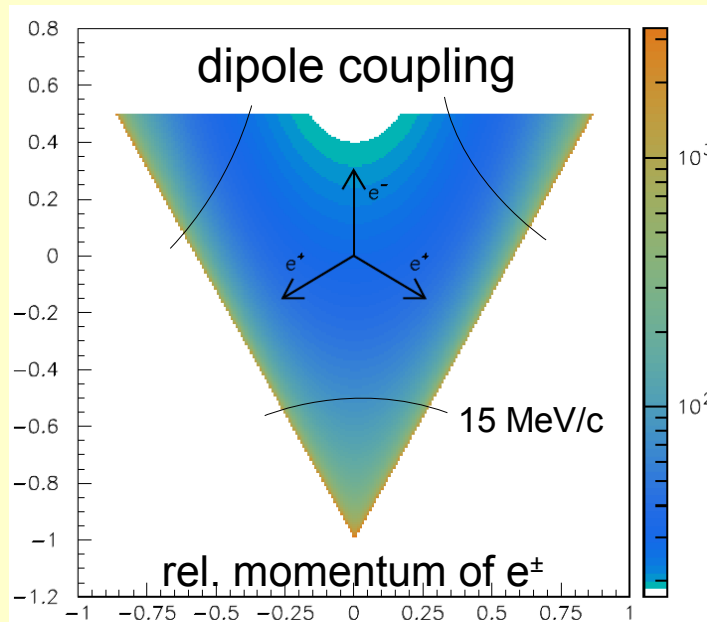
Selected Questions I

Q1: Design optimization?

- the general design was optimized with a fast simulation program
- design has been confirmed with a full GEANT simulation in 2016 → Nik's talk
- main design constraints come from
 - space constraints → minimum size of detector
 - technical feasibility (length of pixel modules)
 - costs → small detector
- multiple scattering in gas → small detector (strong field)

Q2: Acceptance for BSM models?

- strongly model dependent!
- impact of Bhabba scattering cuts → see also Nik's talk

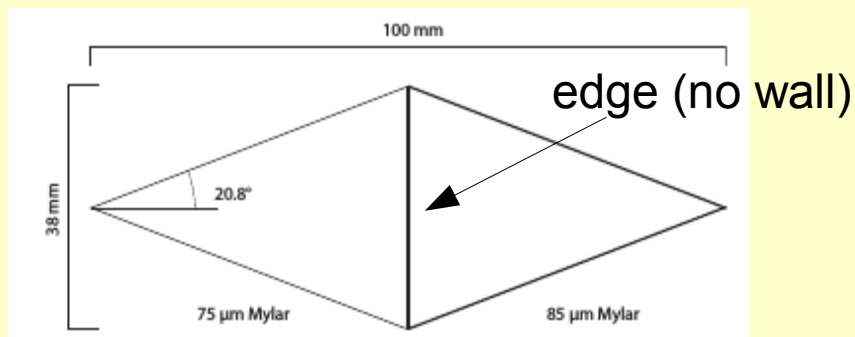


Selected Questions II

Q3: homogeneous target?

- Relevant for multiple scattering (and γ -conversions) is aspect ratio of transverse to longitudinal material budget (current design 1:2.5)
- Transverse e^\pm see in average:
 - SINDRUM like Target: $\sim 100 \mu\text{m}$ Mylar ($3e-4 X_0$).
 - gas pipe (radius 2cm): C_2H_6
- Homogenous material distribution (aerogel, noble gas, hydrocarbons) have been considered but not yet simulated
- A gas target is feasible for a minimum stopping range of 20-30 cm.
- A homogenous target is considered as option for phase II, possibly even allowing for muon stopping rates exceeding $2E9$ muons/s

Q4: Target Geometry?



Gas	stop range for 28 MeV/c muon (cm)	Rad. length transverse (1cm/ X_0)
C_2H_6	43	$3e-5$
Ar	49	$9e-5$
Kr	26	$3e-4$

Selected Questions III

Q5: Project Management:

- Costs and funds → see previous tables
- Responsibilities → see previous slides
- New schedule to be done (slipping due to AMS and magnet)
- Risk assessment: to be done

Summary of Beamline Requests

- **PiE5: 4 weeks** CMB commissioning at beginning of year (May 8)
- **PiM1** (or equivalent) for detector prototype:
 - 23. July (**1 week, KW 30**)
 - 13. August (**1 week, KW 33**)
 - one more week in fall possible?