

MEG II 実験: 2020年エンジニアリングラン に向けた準備状況

- 東京大学





素粒子物理国際研究センター 岩本敏幸 他MEGIIコラボレーション 2020年3月17日

日本物理学会2020年年次大会@名古屋大学



- $\mu \rightarrow e\gamma$ search
 - MEG experiment opened the door of CLFV search • for the first time after the MEGA experiment
 - 28 times better upper limit than the MEGA Exp. •
- Sensitivity improvements became slower in 2013
 - Accidental background dominates the improvements
- Need detector performance improvements
- PSI accelerator already has a sufficient • muon beam intensity (>1×10⁸µ⁺/s)

MEG II motivation



- Need more • statistics
 - for the sensitivity improvement
- However, it does not work only if we increase the muon **E** beam rate
 - N_{acc} will be increased by R_{μ^2}
- All the resolution improvements are crucial to keep the N_{acc} manageable



Possible improvements





1. More stopping muons on target

- 2. Reducing target thickness
- 3. Cylindrical drift chamber to **improve granularity**
- 4. Transparent before TC
- **5. Pixelated timing counter to improve granularity**
- 6. Extend γ acceptance
- 7. MPPCs at Inner face of LXe to improve resolutions for shallow events
- 8. Integrating trigger and DAQ
- 9. New detector to identify **Radiative muon decay** background







MEG II Experiment

Liquid Xenon y Detector **900L LXe, 4092 MPPCs + 668 PMTs Better uniformity w/ VUV-sensitive** 12x12mm² SiPM

Downstream

Positron

16pG22:10-13 豊田、小林、家城、小川

> 17aG22:7-8 恩田、島田

Radiative Decay Counter

Further reduction of radiative BG

x2 resolution everywhere **COBRA SC Magnet**

Upstream



17aG22:9-10 野内、米本

宇佐見

Positron Timing Counter 30ps resolution w/ multiple hits

Cylindrical Drift Chamber Single volume He:iC4H10 small stereo cells, more hits

Muon (µ⁺)

5

Gamma-ray (y)





17pG22:11

MEG II story 2019 2020 2017 2018 2015 2016 R&D Detector preparation period Installation at Repai work PSI curement, Construction at PISA Test with muon beam Test with muon beam K! Construction Construction \bigcirc Michel run with DS/US 1/4 detector, 1/2 detector finished Michel run Michel run Construction ^oC mass Detector Muon run & Muon run finished CEX run construction Muon run OK! Construction Muon run with onstruction finished Muon run with LXe detector BGO crystal Muon run Mass gle crate (256ch.), 4 crate (1024ch.), 6 crate Final board production & Final board test design (1536ch.) test Test

| | 2012 | 2013 | 2014 | 2 |
|-------------|-------------|----------------------|---------------------|---------------|
| MEG II | R&D started | Proposal approved | | |
| CDCH | R&D | De | sign fixed, Parts | s proc |
| TC | R&D | Beam test wit | h test counter | 1 |
| LXe | MPPC | R&D | MPPC test, produ | MPP uctior |
| DS RDC | R&D | Prototy | vpe test | Со |
| Electronics | R | &D | Prototype test | Sin |

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CDCH up to 2019

· CDCH

- Wire breaking issue seems to be solved by humidity control, and the assembly is finished in 2018, CDCH finally sent to PSI
- For further stable operation, CDCH wire length optimized in 2019, and extra-stretch to screen weak wires
 - Final HV map confirms the good length
- Beam intensity scan are performed for CDCH, and showed the reasonable current @ MEG II intensity.
- It seems functioning, but...
- Two problems observed
 - One wire broken
 - High current issue











- Non uniform response for shallow events •
 - due to finite PMT size (2")
- Replace inner 216 PMTs with 4092 SiPMs (MPPCs)
 - better granularity, better uniformity \rightarrow better energy, position resolutions
- VUV-sensitive MPPCs are developed with Hamamatsu for the MEG II experiment
 - Basic laboratory tests were all ok, but...



LXe y calorimeter



LXe y calorimeter in 2019 muon run



- Unexpected (rapid!) PDE decrease observed
 - Dose level is too low for PDE decrease
- Possible reasons

SiO₂

- Surface damage by VUV light
- Electron-hole pair generated in SiO₂ by VUV light \rightarrow Holes are trapped at interface SiO₂ - Si

Time



VUV

Electronics 2019

- MEG II detectors improves granularity
 - More readout channels $(3000 \rightarrow 9000$ ch.)
 - Better to operate SiPMs
 - Amplifier, Voltage supply, simple trigger
 possible in a new waveform digitizer
 - Waveform DRS4 based Readout Module (WaveDREAM) is developed by PSI researchers
 - New board design, new firmware R&D take time
 - Coherent noise can be issue for LXe calorimeter → noise filter introduced
 - Final production model were tested for CDCH and LXe during muon beam time.
- Final mass production summer in 2020

WaveDREAM Boards (WDB)

Data Concentrator Boards (DCB)



Beam Transport Solenoid (BTS)

- Beam transport solenoid
 - needs any beam usage for MEG II (muon/pion beam) •
- Two accidents happened in 2019
 - BTS-crane crash (In Feb. Quickly fixed) •
 - BTS vacuum insulation break (November) •
 - Open connection between 4-B •
 - The remaining beam time (December) forced to be cancelled. •



ASC





AHSW

PSI User's meeting

- Every January
 - •
 - •
- MEG II requests for 2020 •
 - June October : • all the detector calibration and full electronics installation Beschleuniger
 - November-December: • Engineering run



Beamdump

Target E

SINQ Betrieb

Target Nr.

UCN Betrieb

PSI review committee will decide one year's beam time based on experiment's beam time requests 2020-2022: PSI accelerator will be operated from May to December (Winter shutdown)

| | | | 20 | 20 | | | | | _ | | | | | | 20 | 21 | | | | | | | | | | | 20 | 22 | | | | | |
|----|-----|-----|-----|--------|----------|-----------|--------|-----|-----|-----|------|-------|-----|-----|-----|-----|-----------|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|---------|-----------|-----|-----|-----|
| 1 | Apr | Mai | Jun | Jul | Aug | Sep | Okt | Nov | Dez | Jan | Feb | Miz | Apr | Mai | Jun | Jul | Aug | Sep | Okt | Nov | Dez | Jan | feb | Mrz | Apr | Mai | Jun | Jul | Aug | Sep | Okt | Nev | Dez |
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| | | | | | n2ED | MIES | | | | | KA-I | IBS ? | | | | | n2ED | M IBS | | | | | | | | | | | n2EDM | Betrieb | | | |
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Betrieb Protonen-Anlagen 2020-2022

Umbsujähutdown

B. Biau, BSQ

Stand: 20.12.2019

Output from PSI review committee

Beam Schedule:

MEG-II has requested the majority of the 2020 beam time in piE5 for commissioning many aspects of the experiment. While the detailed plans will obviously depend on the status of the BTS repair described above, much of the requested beam time should be available for these purposes. However, both MEGII and Mu3E have requested piE5 beam time in November and December, 2020. Because of the considerable uncertainties in the status of both experiments at that time, we recommend postponing the scheduling of beam time in piE5 for weeks 46-51 until later in the year when the status of both experiments becomes clearer.

Output from PSI review committee

| | | | | | PS | 515 | 90 | Me | VF | Prog | grai | m 2 | 2020 | 0 | | | | | | | | | | | | | | | | | | |
|---------------------|---|--|--|---|----|------|-------|-----------|--------|-------|------|------|-------|----|----|-------|------|------|------|-------|----|-------|---|------|----|----|-------|--------|-----|----|-------|------|
| Last up | date: Jan 29th, 2020, S. Ritt | <stefan.ritt@psi.ch></stefan.ritt@psi.ch> | | | | May | / | | June | 9 | | July | / | | A | ugust | | | Sept | ember | | | Octob | er | | N | lover | mber | | D | ecemb | er |
| http:// | www.psi.ch/ltp/FacilitiesEN | /schedule_2020.pdf | | Week number | 19 | 20 2 | 21 22 | 23 | 24 2 | 25 26 | 27 | 28 2 | 29 30 | 31 | 32 | 33 3 | 34 3 | 5 36 | 5 37 | 38 | 39 | 40 | 41 42 | 2 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 5 | 1 52 |
| | | PSP | PSI Contact | Availability | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PiM3 | MuSR (GPS<F) | | Amato | Amato (coord.) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PiE3 | MuSR high field | | Scheuermann | Scheuermann (coord.) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MuE1 | MuSR (GPD) | | Amato | Amato (coord.) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| MuE4 | MuSR (LEM) | | Prokscha | Prokscha (coord.) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PiE1-1 | MuSR (Dolly) | | Amato | Amato (coord.) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | PSEC-Micromegas | | Antognini | Sohl | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | RPC counters | | Antognini | Bencivenni | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MuEDM | | Schmidt-Wellenbur | Schmidt-Wellenburg | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| PiE1-2 | R-20-01.1 | 5203.85800.012 | Knecht | Zinatulina | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | R-08-01.3 Musun | 5203.32030.004 | Knecht | Kravchenko | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | MIXE | | Amato | Amato/Knecht | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Muonium | | Knecht | Soter | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | uRWELL | | Knecht | Poli Lener | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| PiE5 | R-99-05.2 MEG | 5203.32030.001 | Ritt | Mori | | | | prov | isiona | 1 | | | | | | | | | | | P | orovi | sional | | | | | | | | | |
| PiE5 | R-99-05.2 MEG R-12-03.1 Mu3E | 5203.32030.001 5203.32030.002 | Ritt Ritt | Mori Schoening | | | | prov | isiona | 1 | | | | | | | | | | | P | orovi | sional | | | | pro | vision | nal | | | |
| PiE5 | R-99-05.2 MEG R-12-03.1 Mu3E Praktikum | 5203.32030.001 5203.32030.002 5203.85800.012 | Ritt Ritt Meier | Mori Schoening Grab | | | | provi | isiona | | | | | | | | | | | | P | provi | sional | | | | pro | visior | nal | | | |
| PiE5 | R-99-05.2 MEG R-12-03.1 Mu3E Praktikum R-05-03.1 n2EDM | 5203.32030.001 5203.32030.002 5203.85800.012 | Ritt Ritt Meier Schmidt-Wellenbur | Mori Schoening Grab Schmidt-Wellenburg | | | | provi | isiona | | | | | | | | | | | | | provi | sional | | | | pro | visior | nal | | | |
| PiE5 | R-99-05.2 MEG R-12-03.1 Mu3E Praktikum R-05-03.1 n2EDM Mirror-Neutron | 5203.32030.001 5203.32030.002 5203.85800.012 | Ritt Ritt Meier Schmidt-Wellenbur Schmidt-Wellenbur | Mori Schoening Grab Schmidt-Wellenburg Ayres | | | | provi | isiona | | | | | | | | | | | | | brovi | sional | | | | pro | vision | nal | | | |
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| PiE5 UCN PiM1 | R-99-05.2 MEG R-12-03.1 Mu3E Praktikum R-05-03.1 n2EDM Mirror-Neutron R-12-03.1 Mu3E R-12-01.2 MUSE Praktikum | 5203.32030.001 5203.32030.002 5203.85800.012 5203.32030.002 5203.32030.006 5203.85800.012 | Ritt Ritt Meier Schmidt-Wellenbur Schmidt-Wellenbur Ritt Reggiani/Ritt Meier | Mori Schoening Grab Schmidt-Wellenburg Ayres Schoening Gilman Steinkamp | | | | provi | isiona | | | | | | | | | | | | | | sional 2 | | | | | vision | nal | | | |
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| PiE5 UCN PiM1 | R-99-05.2 MEG R-12-03.1 Mu3E Praktikum R-05-03.1 n2EDM Mirror-Neutron R-12-03.1 Mu3E R-12-01.2 MUSE Praktikum CMS Diamond Detectors PIMice | 5203.32030.001 5203.32030.002 5203.85800.012 5203.32030.002 5203.32030.006 5203.85800.012 5203.85800.012 5203.85800.012 | Ritt Ritt Meier Schmidt-Wellenbur Schmidt-Wellenbur Ritt Reggiani/Ritt Meier Meier Reggiani | Mori Schoening Grab Schmidt-Wellenburg Ayres Schoening Gilman Steinkamp Hits Desorgher | | | | provi | isiona | | | | | | | | | | | | | | sional | | | | | | nal | | | |
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MEG II and Mu3e (phase I) at PSI

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- MEG II and Mu3e • experiments will share πE5 beam line at PSI
- Upstream side beam • components are switched
 - Mu3e
 - Magnet, and detector demonstrators will be ready for beam time 2020



MEG II story 2020 2019 2015 2016 2017 2018 R&D Detector preparation period Installation at Repar work PSI curement, Construction at PISA Test with muon beam Test with muon beam Construction Construction Michel run with DS/US 1/4 detector, 1/2 detector finished Michel run Michel run Construction ^oC mass Detector Muon run & finished Muon run CEX run construction Muon run Construction Muon run with Muon run with LXe detector finished onstruction BGO crystal Muon run Mass gle crate (256ch.), 4 crate (1024ch.), 6 crate Final board Final board test production & design (1536ch.) test Test

| | 2012 | 2013 | 2014 | 2 |
|-------------|-------------|----------------------|---------------------|---------------|
| MEG II | R&D started | Proposal approved | | |
| CDCH | R&D | De | sign fixed, Parts | s proc |
| TC | R&D | Beam test wit | h test counter | 1 |
| LXe | MPPC | R&D | MPPC test, produ | MPP uctior |
| DS RDC | R&D | Prototy | vpe test | Со |
| Electronics | R | &D | Prototype test | Sin |



Run 2020

- We need priority list
 - CDCH repair work is • finalized, CDCH muon run will be carried out to check the CDCH functioning
 - CEX run to evaluate the LXe • detector performance against 55MeV γ
 - LXe PDE decrease study • with possible operation scenarios
 - Not a good idea to spend full electronics installation during beam time
 - All the electronics • readout test will be planned at the end.
- The baseline schedule is defined, but...
 - PSI work is severely affected • by COVID-19, and the schedule delay is inevitable

| nup.// | www.psi.cn/itp/Facilitie | sen/schedule_2020.pd |
|--------|--------------------------|----------------------|
| | | PSP |
| PiM3 | MuSR (GPS<F) | |
| PiE3 | MuSR high field | |
| MuE1 | MuSR (GPD) | |
| MuE4 | MuSR (LEM) | |
| PiE1-1 | MuSR (Dolly) | |
| | PSEC-Micromegas | |
| | RPC counters | |
| | MuEDM | |
| PiE1-2 | R-20-01.1 | 5203.85800.012 |
| | R-08-01.3 Musun | 5203.32030.004 |
| | MIXE | |
| | Muonium | |
| | uRWELL | |
| PiE5 | R-99-05.2 MEG | 5203.32030.001 |
| | R-12-03.1 Mu3E | 5203.32030.002 |
| | Praktikum | 5203.85800.012 |

| WD2G | replacem |
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September October May June August November 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 4 Week number Availabili PSI Contact Amato (coord.) Amato Scheuerman Scheuermann (coord Amato (coord.) Prokscha Prokscha (coord.) Amato Amato (coord.) Sohl Antognin Bencivenni Antognin ur, Schmidt-Wellenburg Schmidt-Wellent Zinatulina Kravchenko Knecht Amato/Knecht Amato Knecht Soter Poli Lener Knecht Mori Schoening Meier Grab CDCH Mockup. CDCH + TC installation CDCH. ? **BTS installation & test** BT\$ warm. removanstall BTS warm, Beam tuning CDCH muon beam ment? (pre-series 30pc.) CEX DCB FW II test? LXe PDE decrease Full electronics test

PSI 590 MeV Program 2020

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- CDCH repair work started
 - One wire removal •
 - High current issue • reproduced outside, and pin down the problem.
- Installation in May •
 - One month muon beam time • for CDCH stable operation



Run 2020

- Which operations are possible • for LXe MPPC?
- Annealing (heating) helps PDE recovery.
- How often should we do

Summary

- All the MEG II detectors were tested under MEG II intensity.
- Those issues should be solved during winter shutdown.
- and full electronics test in December.
- inevitable...

There are several issues for CDCH, LXe, BTS, electronics for Run 2020.

 PSI accelerator beam time in 2020 is already decided (still provisional), and we will concentrate on each sub-detector beam test until November,

COVID-19 will affect our beam time schedule at PSI, and the delay is now