Project Form No. 24

Search for new physics in the charged lepton sector

Поиск новой физики в секторе заряженных лептонов

DLNP: Adamov G., Artikov A.M., Atanov N.V., Atanova O.S., Baranov V.A, Baranov V.Yu., Budagov J.A., Chokheli D., Davydov Yu.I., Demin D.L., Duginov V.N., Evtoukhovich I.L., Evtoukhovich P.G., Glagolev V.V., Gritsai K.I., Ivanov Yu.P., Kalinnikov V.A. Kaneva E.S., Kharzheev Yu.N., Khomutov N.V.,Khubashvili X., Kobey A., Kolesnikov A.O., Kolomoets V.I., Kolomoets S.M., Kravchenko M.D., Kravchuk N.P., Krylov V.A., Kuchinsky N.A., Limarev K.K., Malyshev V.L., Moiseenko A.S., Pavlov A.V., Rozhdestvensky A.M., Rudenko A.I., Sabirov B.M., Samartsev A.G., Sazonova A.V., Shalyugin A.N., Simonenko A.V., Suslov I.A., Tereschenko V.V., Tereschenko S.V., Titkova I.V., Tsamalaidze Z., Tsverava N., Usubov Z.U., VasilyevI.I., Velicheva E.P., Volkov A.D.
VBLPHE: Baigarashev D., Enik T.L.
BLTP: Aznabayev D., Issadykov A., Kazakov D.I., Kozlov G.A.
LIT: Khvedelidze A.

Joint Institute for Nuclear Research, Dubna, Russia

Lobko A.S., Misevich O.V.

Institute for Nuclear Problems, Belarusian State University (INP BSU), Minsk, Belarus

Dubnicka S., Bartos E., Adamuscin C., Liptaj A.

Institute of Physics Slovak Academy of Sciences, Bratislava, Slovak republic

Dubnickova A.Z.

Comenius University, FMFI, Bratislava, Slovak Republic

Chizhov M.V.

The St. Clement of Ohrid University of Sofia, Bulgaria

R.Abramishvili, Yu. Bagaturia, S.Gogilidze, A. Iashvili, I. Lomidze, T. Toriashvili,

Institute of Quantum Physics and Engineering Technologies,
Georgian Technical University, Tbilisi, Georgia

Project leaders V.V.Glagolev, Z.Tsamalaidze

Scientific Project leader Yu.A.Budagov

Project Deputy leaders N.V.Khomutov, Yu,I. Davydov

DATE OF SUBMISSION OF PROPOSAL OF PROJECT TO SOD _________

DATE OF THE LABORATORY STC _________ DOCUMENT NUMBER _________

STARTING DATE OF PROJECT 2021

(FOR EXTENSION OF PROJECT — DATE OF ITS FIRST APPROVAL) 2015

Date of the Lab seminars 12.03,2019, 9.10.2019, 10.10.2019

Search for new physics in the charged lepton sector

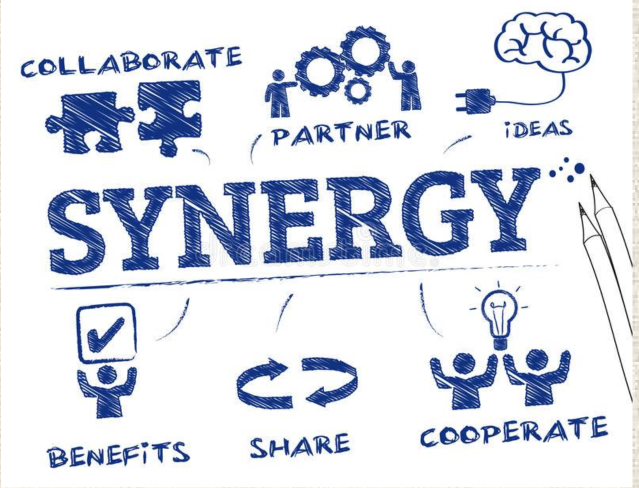
Поиск новой физики в секторе заряженных лептонов

Project for 2021-2023

- Mu2e experiment

- COMET experiment

- MEG-II experiment



Not new but continued participation in the Alliance

Search for New Physics in Experiments with High-Intensity Muon Beams
02-2-1124-2015/2020

Experiment COMET at J-PARC
02-2-1134-2018/2020

Search for new physics in the charged lepton sector

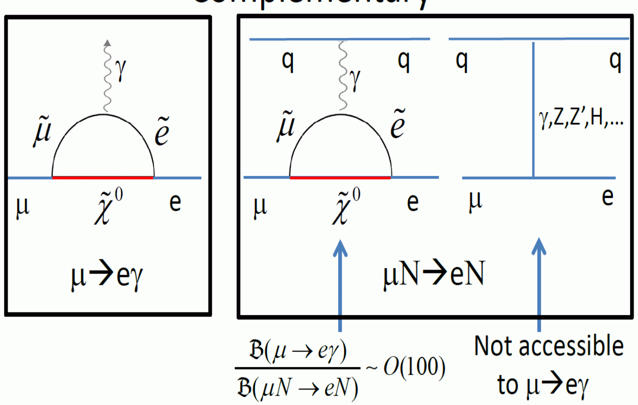
Motivation for combining 3 experiments into one project

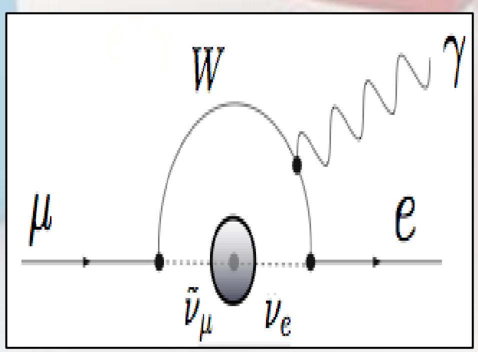
Common physical task (CLFV)

SYNERGY

CLFV – European Strategy for Particle Physics combined COMET, MEG, Mu2e and Mu3e

μ→eγ and μN→eN are Complementary





$$\mathrm{BR}(\mu\to e\gamma) = \frac{3\alpha}{32\pi}\left|\sum_{i=2,3} U^*_{\mu i}U_{ei}\frac{\Delta m^2_{1i}}{M_W^2}\right|^2 < 10^{-54}$$

Motivation for combining 3 experiments into one project

Optimizing the allocation of resources between experiments with similar detectors to increase the scientific significance of participation and the level of commitments made in accordance with the recommendations of the 50th joint session of the PAC on particle physics and nuclear physics

SYNERGY

Experience with the CRV system creation, calorimeter, tracker, DAQ, data analyses

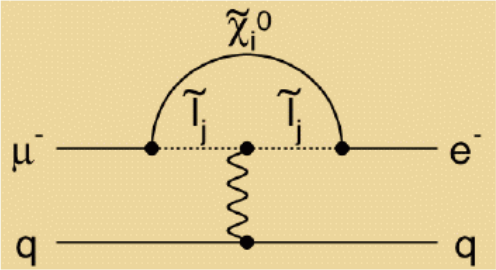
Most stringent LFV upper limits

Process	Current Limit		Next Generation exp
$\tau \to \mu\eta$	BR < 6.5 E-8	BaBar	10^{-9} - 10^{-10} (Belle II)
$\tau \to \mu\gamma$	BR < 6.8 E-8	BaBar	
$\tau \to \mu\mu\mu$	BR < 3.2 E-8	Belle	
$\tau \to eee$	BR < 3.6 E-8	Belle	
$K_L \to e\mu$	BR < 4.7 E-12	BNL	NA62 might improve by O(10)
$K^+ \to \pi^+ e^- \mu^+$	BR < 1.3 E-11	BNL	
$B^0 \to e\mu$	BR < 7.8 E-8	LHCb	Belle II - LHCb
$B^+ \to K^+ e\mu$	BR < 9.1 E-8	BaBar	
$\mu^+ \to e^+\gamma$	BR < 4.2 E-13	MEG@PSI	10^{-14} (MEG@PSI)
$\mu^+ \to e^+e^+e^-$	BR < 1.0 E-12	SINDRUM@PSI	10^{-16} (PSI)
$\mu N \to eN$	$R_{\mu e}$ < 7.0 E-13	SINDRUM@PSI	10^{-17} (Mu2e, COMET)

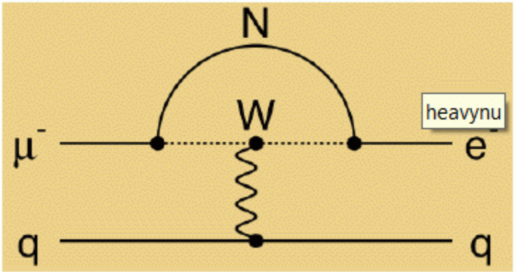
New physics search

- There are many possible new physics contributions to $\mu N \rightarrow eN$, either through loops or the exchange of heavy intermediate particles
  - Many NP models predict rates observable at next gen CLFV experiments

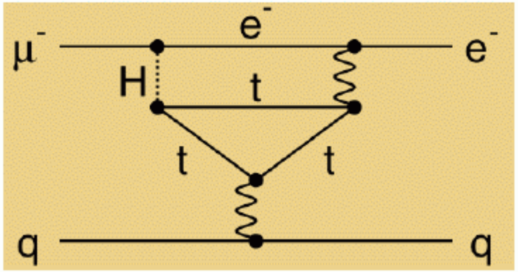
Loops



Supersymmetry

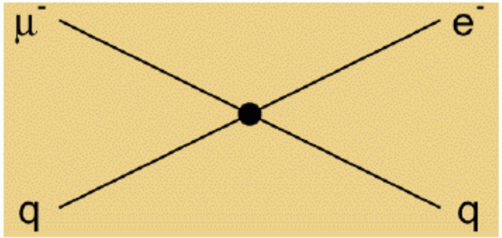


Heavy Neutrinos

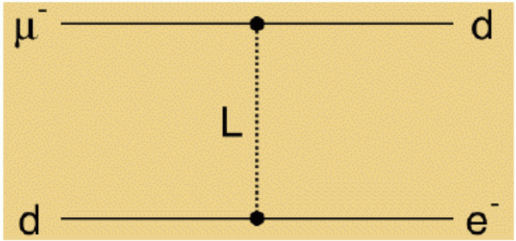


Two Higgs Doublets

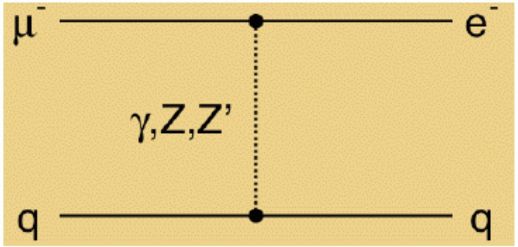
Contact Terms



Compositeness



Leptoquarks



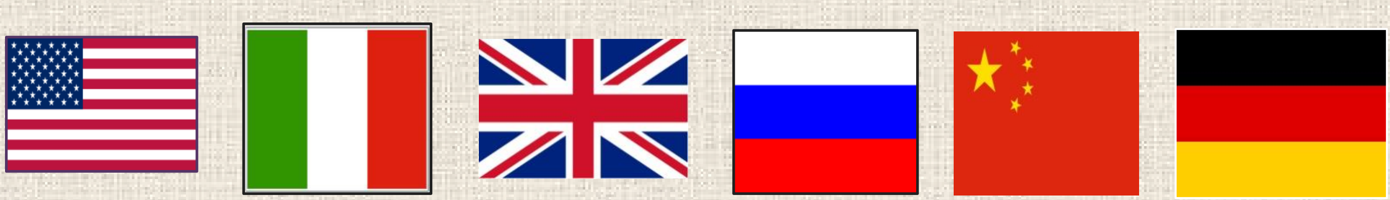
New Heavy Bosons / Anomalous Couplings

Marciano, Mori, and Roney, Ann. Rev. Nucl. Sci. 58
M. Raidal *et al*, Eur.Phys.J.C57:13-182,2008
A. de Gouvêa, P. Vogel, arXiv:1303.4097

Mu2e Collaboration

Over 200 Scientists from 38 Institutions

Argonne National Laboratory, Boston University, University of California Berkeley, University of California Irvine, California Institute of Technology, City University of New York, Joint Institute of Nuclear Research Dubna, Duke University, Fermi National Accelerator Laboratory, Laboratori Nazionale di Frascati, University of Houston, Helmholtz-Zentrum Dresden-Rossendorf, INFN Genova, Institute for High Energy Physics, Protvino, Kansas State University, Lawrence Berkeley National Laboratory, INFN Lecce, University Marconi Rome, Lewis University, University of Liverpool, University College London, University of Louisville, University of Manchester, University of Michigan, University of Minnesota, Muon Inc., Northwestern University, Institute for Nuclear Research Moscow, INFN Pisa, Northern Illinois University, Purdue University, Rice University, Sun Yat-Sen University, University of South Alabama, Novosibirsk State University/Budker Institute of Nuclear Physics, University of Virginia, University of Washington, Yale University



$\mu N \rightarrow eN$ signal

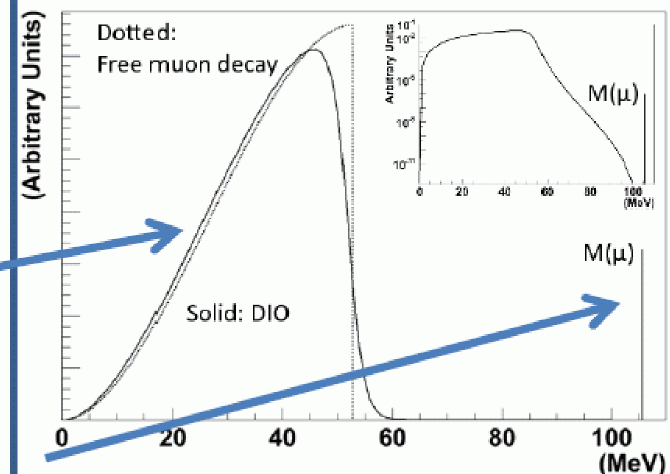
- Stop *negative* muons in a thin target,

where they quickly form 1S muonic atoms

- Look for 105 MeV electron (case of Al)
- Regular muon decay, $\mu^{-}N \rightarrow e^{-}\nu_{\mu}\overline{\nu}_{e}N$

produces lots of electrons below 53 MeV

- Signal electron energy way above most of the background. Allows >> data rates compared to $\mu \rightarrow e\gamma$



Electron spectrum from $\mu N \rightarrow e\nu\nu N$

→ Substantial experimental advantage for $\mu N \rightarrow eN$

- Decay electron energies do go all the way up to 105 MeV(rarely)-
- Still a background- but rate fortunately falls very fast near

endpoint: can control with good electron energy resolution

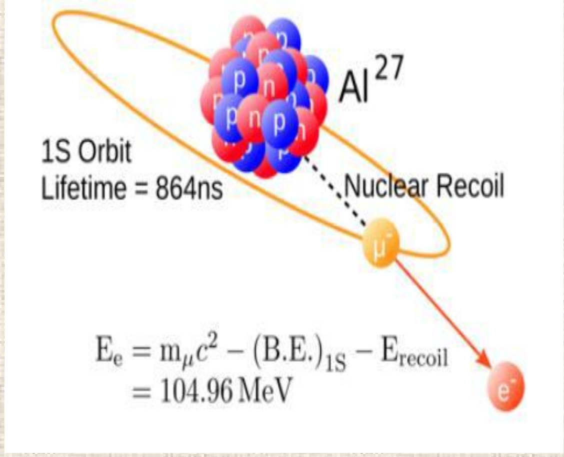
Mu2e experimental apparatus

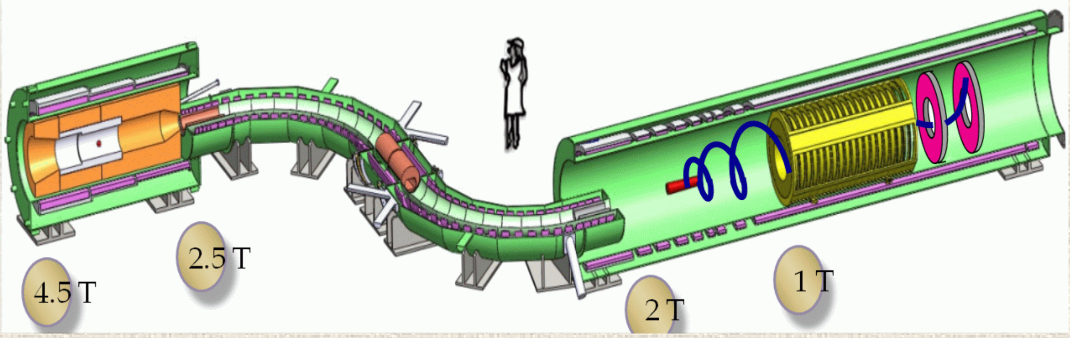
$$R_{\mu e} = \frac{\mu^- + {}^{27}_{13}Al \rightarrow e^- + {}^{27}_{13}Al}{\mu^- + {}^{27}_{13}Al \rightarrow \text{nuclear capture}}$$

Production Target / Solenoid (PS)

- Proton beam strikes target, producing mostly pions
- Graded magnetic field contains pions/muons and collimate them into transport solenoid → high muon intensity

Muon converts in the field of a
nucleus that is left intact
Signal: Mono-energetic
Electron





Transport Solenoid (TS)

- Collimator selects low momentum, negative muons
- Antiproton absorber
- The S shape eliminates photons and neutrons

Target, Detector and Solenoid (DS)

- Capture muons on Al target
- Measure momentum in tracker and energy in calorimeter
- Graded field “reflects” downstream conversion electrons emitted upstream, improving efficiency

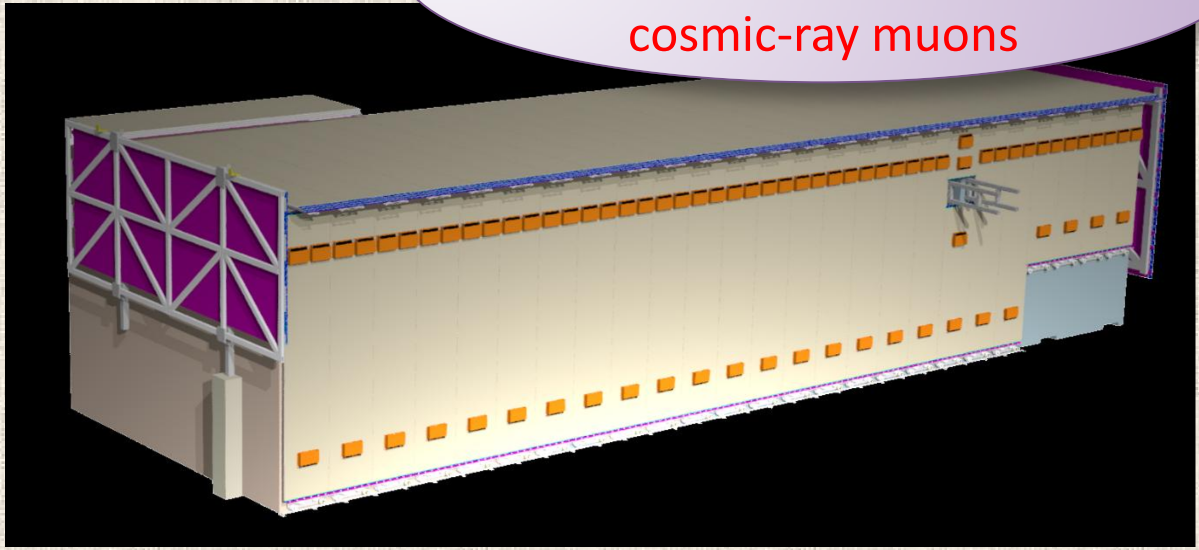
Mu2e Sensitivity

- Mu2e Expected Background Yield: <0.5 events over life of experiment
- 3 years production
  - 3.6×10^{20} protons on target
  - 6×10^{17} stopped muons
  - Single event sensitivity 3×10^{-17}
  - Null signal upper limit (90% CL) 8×10^{-17}
  - Discovery sensitivity (5 s) 2×10^{-16}

Category	Source	Events
Intrinsic	μ Decay in Orbit	0.14
	Radiative μ Capture	<0.01
Late Arriving	Radiative π Capture	0.02
	Beam electrons	<0.01
	μ Decay in Flight	<0.01
	π Decay in Flight	<0.01
Miscellaneous	Anti-proton induced	0.04
	Cosmic Ray induced	0.21
Total Background		0.41

The Cosmic Ray Veto

1 conversion-like electron per day is produced by cosmic-ray muons



Details:

- Area: 336 m^2
- 86 modules;15 types
- 5,472 counters
- 10,944 fibers
- 19,744 SiPMs
- 4,912 Counter Motherboards
- 320 Front-end Boards
- 16 Readout Controllers

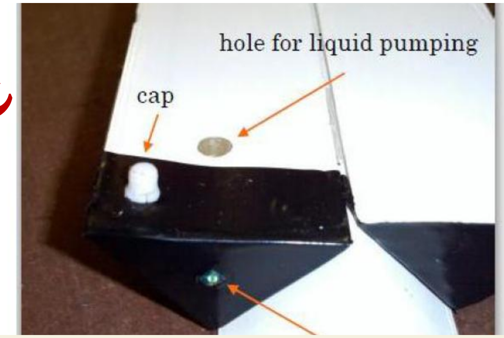
- CRV identifies cosmic ray muons that produce conversion-like backgrounds.
- Design driven by need for excellent efficiency, large area, small gaps, high background rates, access to electronics, and constrained space.
- Technology: Four layers of extruded polystyrene scintillator counters with embedded wavelength shifting fibers, read out with SiPM photodetectors.
- A track stub in 3/4 layers, localized in time+space produces a veto in offline analysis.

RnD on filling the holes for the fibers in the counters of the liquid silicone synthetic rubber without catalyst

CKTN (HO [-Si (CH 3) 2 O-] n H)

CRV JINR contribution

unique



•A.Artikov et al., **Photoelectron Yields of Scintillation Counters with Embedded Wavelength-Shifting Fibers Read Out With Silicon Photomultipliers** Nucl.Instrum.Meth. A890 (2018) 84-95

• A.Artikov, et al., **Light yield and radiation hardness studies of scintillator strips with a filler** Nucl.Instrum.Meth. A930 (2019) 87-94,

•<u>Increase in light yield by a factor ~ 1.5 against that of the "dry" strip.</u>

•<u>Compensation for the loss of scintillator light output due to their natural aging.</u>

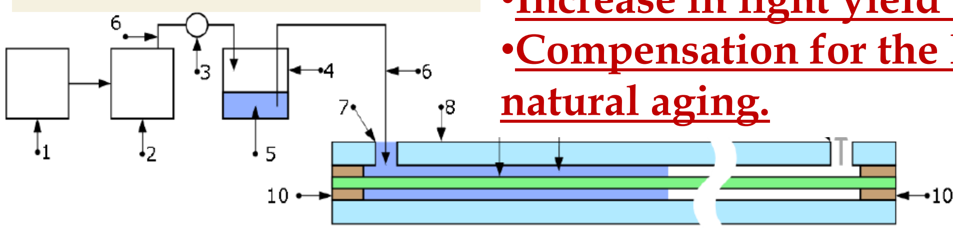


Figure 2. Setup to pump the high viscosity filler into the co-extruded hole of the scintillation bar (no scale): (1) dry type compressor; (2) SL101N digital Liquid Dispenser; (3) manometer; (4) special vessel with filler; (5) filler; (6) polyvinylchloride tube; (7) inlet for filling; (8) strip; (9) WLS fiber; (10) sealing; (11) exhaust

Filling holes in 5-meter strips and rad. tests

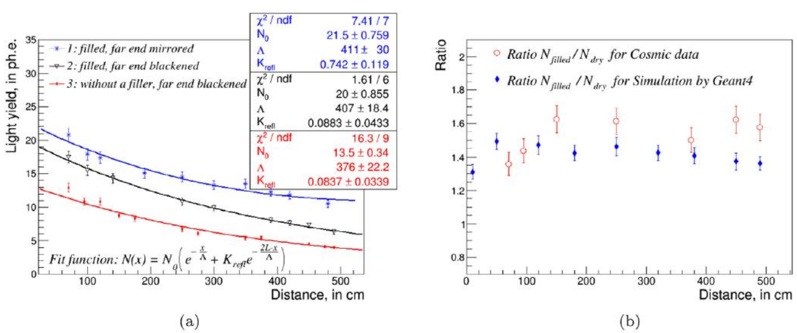


Fig. 8. Light yield (in photoelectrons) of the 5 m long strip on cosmic muons under different conditions of the study (a). The experimental data with the simulation (b).

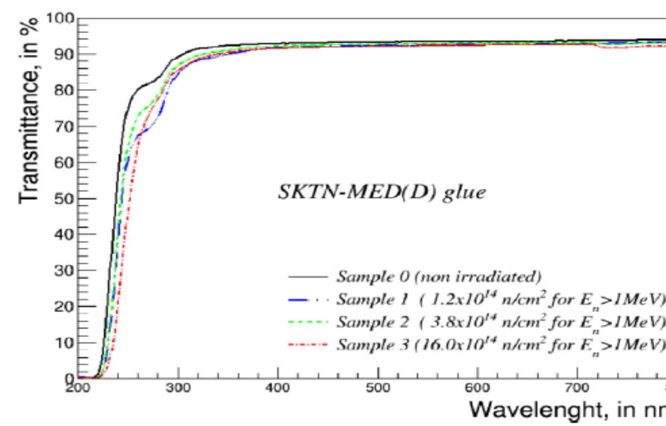


Fig. 11. Transmittance of the sample made of the SKTN-MED(D) glue before and after the irradiation by the neutron beam with different fluences.

CRV JINR contribution

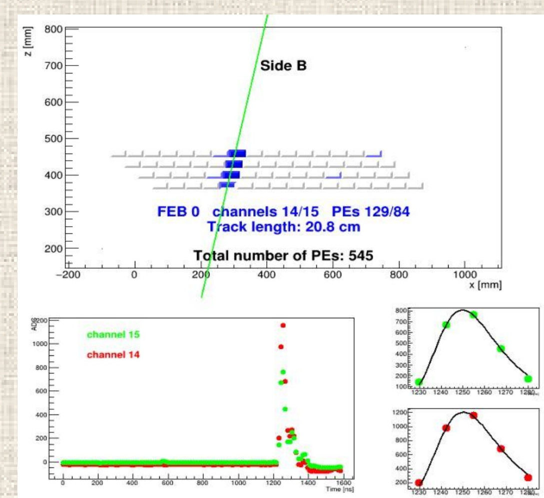
We are ready to fill the fiber holes with synthetic silicon in 7 meter counters for 40-50% LC increasing.
32 holes at a time

unique

We developed of all stages of assembly and testing of modules during their mass production.

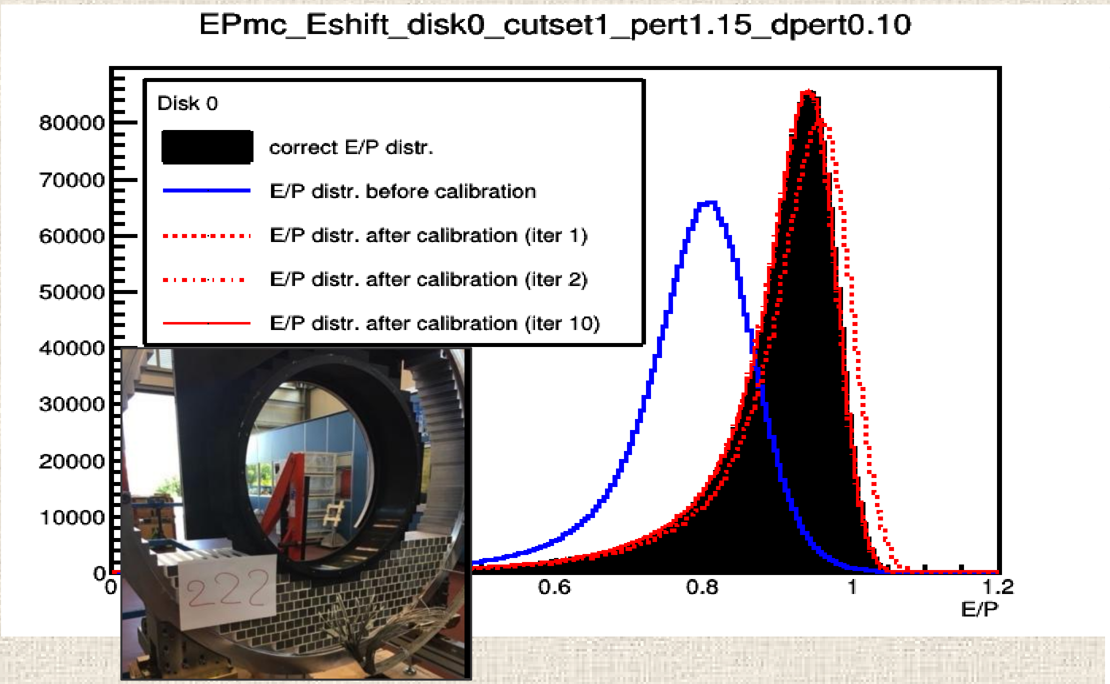
Assembled 3 modules of 6-meter length, weighing 2 tons each;
3 modules of 3.2 m length. Created more than 100 6-meter CRV counters.
More than 5000 CMB boards tested.

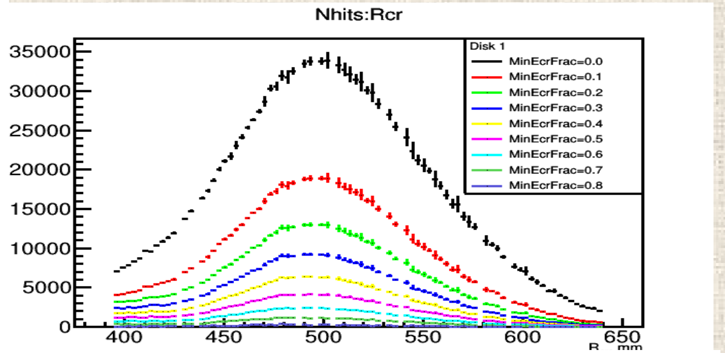
We created the test stand for QA of the CRV modules

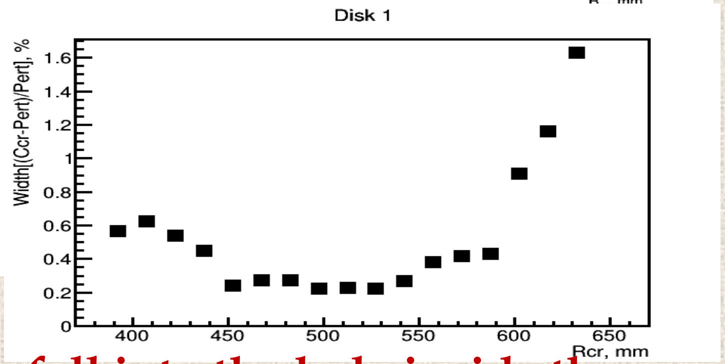


Calorimeter JINR contribution

Calorimeter energy calibration with DIO electrons at B=0.5T







At nominal field , the majority of the DIO electrons fall into the hole inside the calorimeter disks, so calibration at half the field is assumed

Main results:

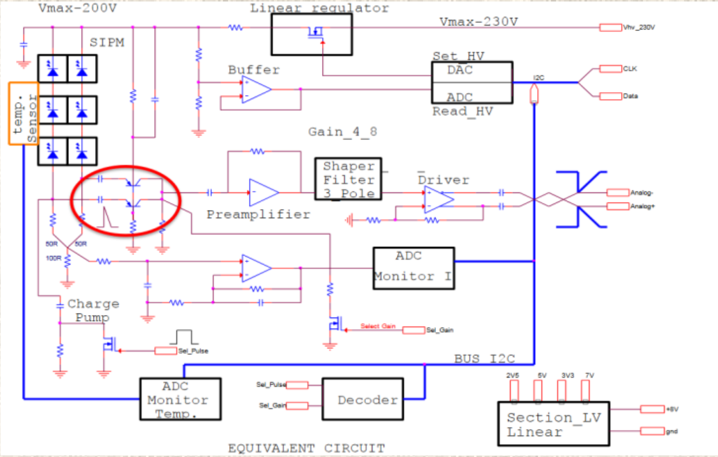
- Performed modeling the calorimeter energy calibration with DIO electrons at B=0.5T
- Statistical accuracy better then 0.6% with sample of DIO electrons obtained during 10-20 minute long calib. run
- Systematic accuracy is determined by the accuracy of the MC detector modeling
- Iterative procedure to remove the bias due to the selection requirements on the energy deposition in crystals
- Compared to the central region, the calibration accuracy near the internal and external edges of disks is lower

Calorimeter JINR contribution

Front-end preamplifier and electronics development

Simulations of pre-amp linear regulator

Simulations were preformed during FEE board development process in Cadence OrCad software framework to estimate basic characteristics of designed linear regulator (LDO) for SiPM array and preamplifier, placed on FEE board.

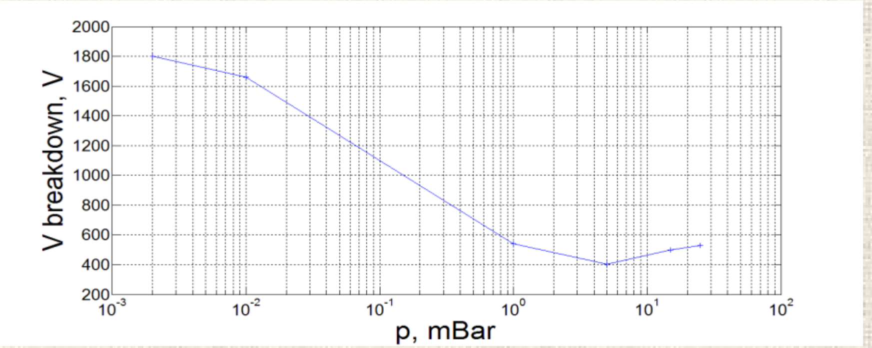


FEE performance measurements

- LDO noise and temperature stability;
- preamplifier bandwidth;
- triangle pulse rise and fall time;
- pulse maximum rate;
- power consumption;
- gain and linearity plot;

Preamplifier gamma-radiation test

Vacuum test

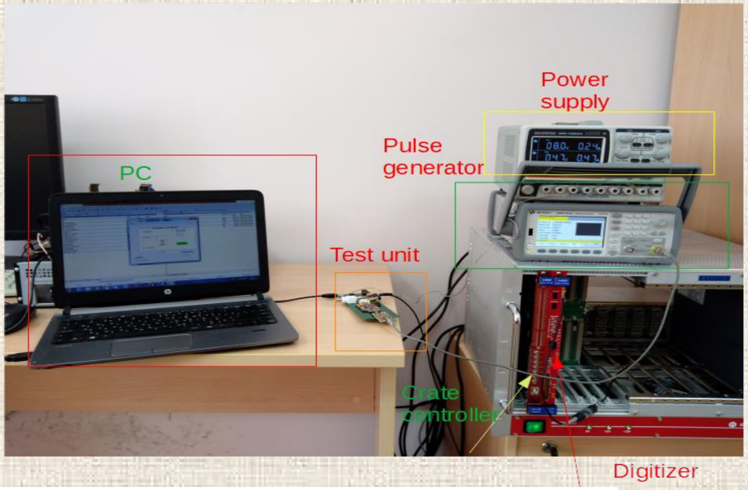


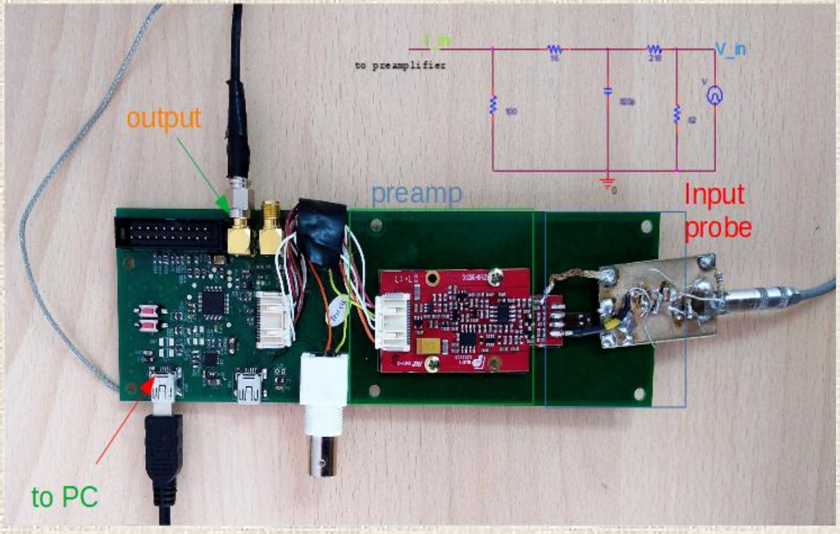
Calorimeter JINR contribution

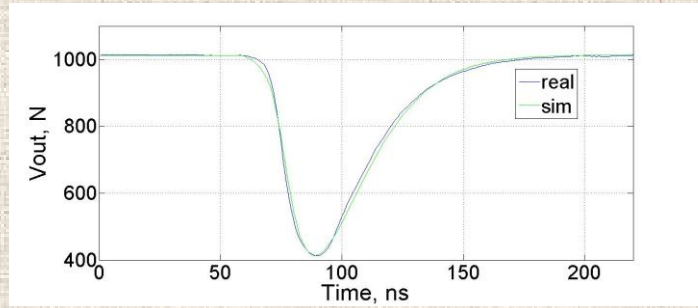
Stand for FEE testing in Dubna

To perform QA for all set of 3500 preamplifiers for Mu2e electromagnetic calorimeter preamplifier QA stand was developed in DLNP, JINR, Dubna. This is hardware and software complex for quality analysis, that allow to quickly estimate main preamplifier characteristics:

- •preamplifier bandwidth;
- •triangle pulse rise and fall time;
- •pulse maximum rate;
- •power consumption;
- •gain and linearity plot.



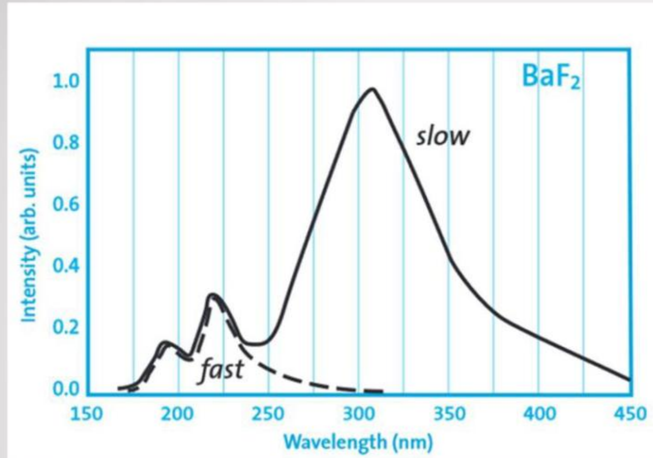




Output pulse real and simulated examples

Mu2e-II RnD

For the second stage Mu2e, the calorimeter should be reassembled using more radiation-resistant BaF_2 crystals



Fast components (195, 220 nm)
- Decay time <1 ns

Slow component (310 nm)
- Decay time ~620 ns

BaF_2 crystals are natural choice for the Mu2e-II calorimeter to use at the intensity frontier

A slow component of the BaF_2 luminescence could cause a problems at high rate and needs to be suppressed

There are no commercially available photodetectors for the Mu2e-II calorimeter !

Suppression of a slow component of a BaF_2 crystal luminescence with a thin multilayer filter

Yuri Davydov,

for Dubna and St. Petersburg ("Ural-GOI"- Branch of JSC «PA «UOMP», LLC "Optech", INCROM ltd, State Polytechnic University) groups

CALOR 2018
Eugene OREGON
May 21-25, 2018

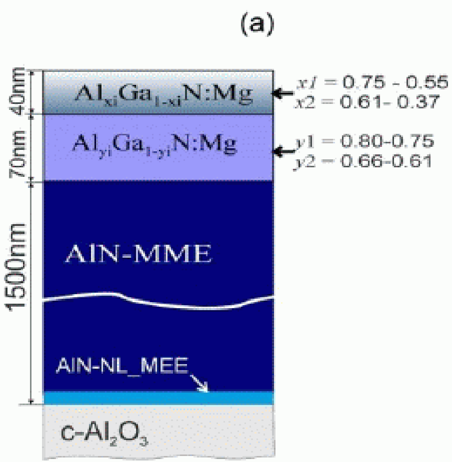
Talk by Yuri Davydov at Northwestern Mu2e-II Workshop, August 2018

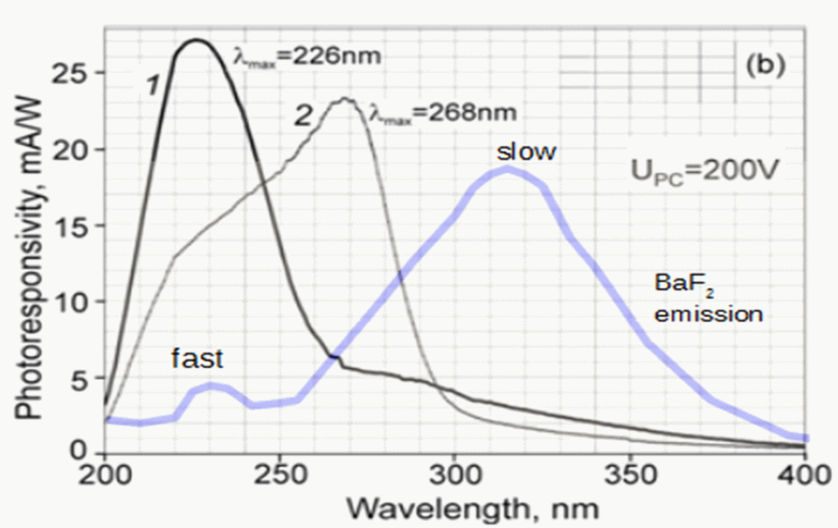
Mu2e-II RnD

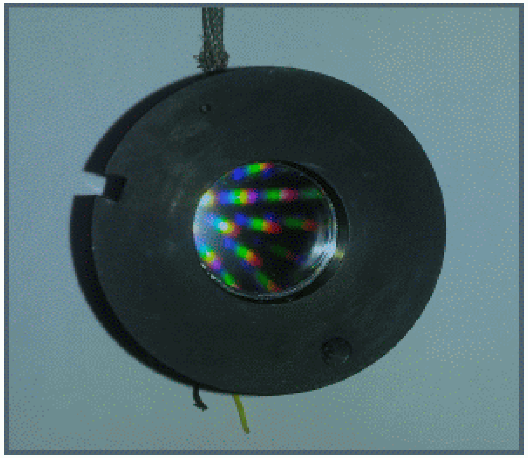
We managed to create a PMT for effective registration of a fast component and suppression of a slow component of the BaF_2 emission spectrum using the AlGaN-based photocathode.

unique

AlGaN MCP

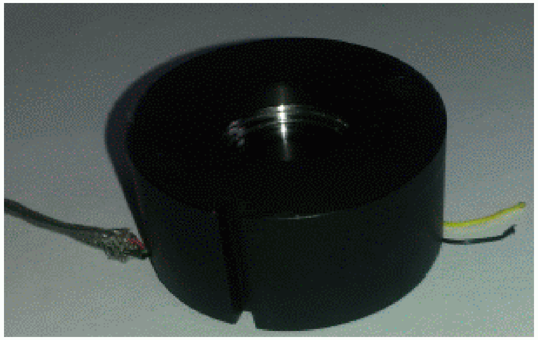






Talk by N.V. Atanov at Northwestern Univ. Mu2e-II Workshop, 2018

And for 2-3 years with our colleges from Ioffe Institute (St. Petersburg) we are developing effective solar-blind photodetector, that can be usefull for BaF2 fast component readout in Mu2e phase II.



Mu2e JINR contribution (summary)

- **CRV**
  - RnD to increase light collection from long scintillator counters with fibers inside them (simulation, rad. sources and cosmic tests, rad. hardness tests)
  - tests of the different type counters on the 120 GeV proton beam
  - creation of the test stand for QA of the assembled CRV modules
  - development of modules assembly method and participation in the modules assemble and tests

- **Calorimeter**
  - tests of the LYSO and CsI Kharkov made crystals on the radiation sources and electron beams (Frascati, Erevan)
  - participation in development and testing of the front end electronics
  - participation of the “0” module test at Frascati
  - participation in the QA of CsI crystals at Caltech
  - simulation of the Mu2e calorimeter in-situ calibration at the half magnetic field Runs

- **Mu2e-II RnD**
  - RnD with “solar blind” photodetectors for BaF2 crystals to suppress slow scintillation component (320 nm max) using multilayer filters and PMT with AlGaN-based photocathode connected to MCP.

Mu2e JINR group plans

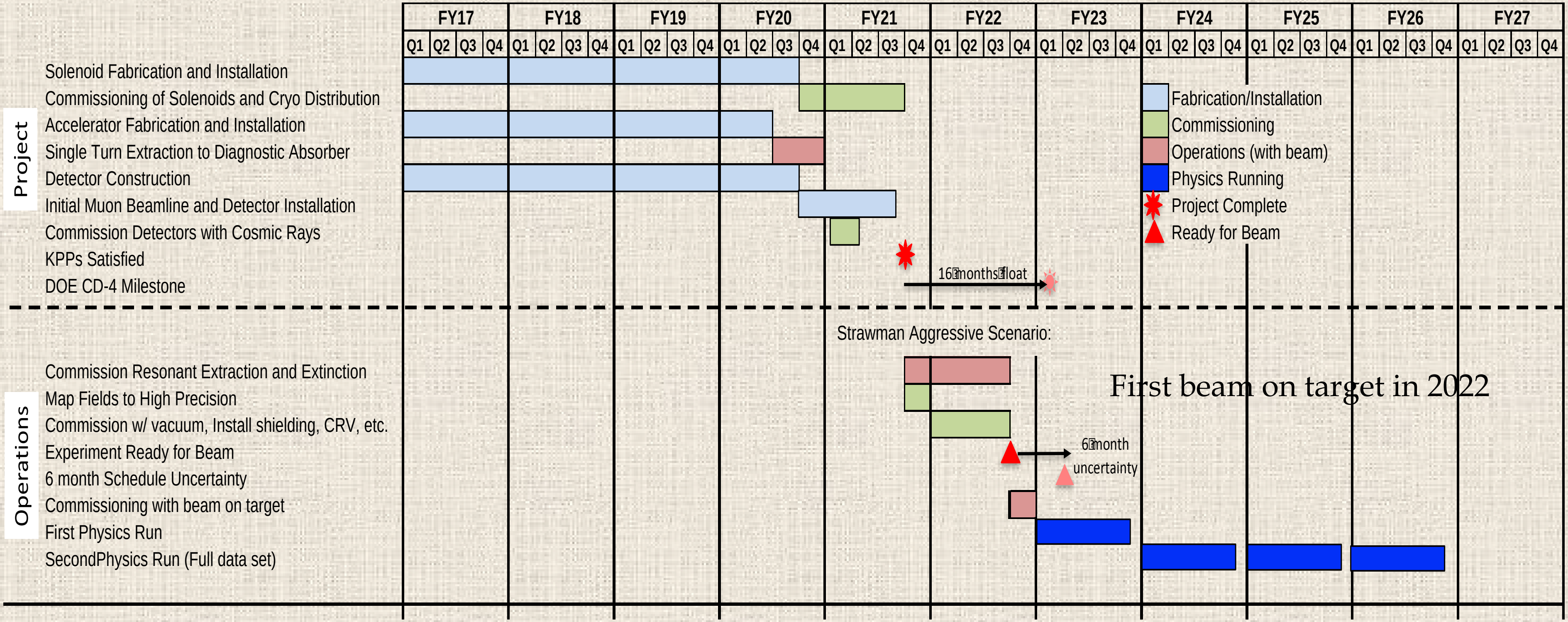
- **CRV**
  - continue to participate in the modules assemble and QA tests at UVa
  - filling of the fiber holes for 7 m counters with synthetic silicon (SKTN) to provide efficient counter life
  - Participation in the assemble, startup and maintenance of the CRV
- **Calorimeter**
  - QA tests of all frontend boards at JINR created test
  - provide Mu2e calorimeter in-situ calibration at the half magnetic field runs
  - Participation in the assemble, startup and maintenance of the calorimeter
- **Tracker**
  - Participation in the straw panel production and QA at Minnesota Univ.
- **Operation**
  - Creation of the remote control room
- **Data analysis**
  - process the data to search for the conversion electron among background surround
- **Mu2e-II RnD**
  - continue RnD for development and tests of photodetectors suitable to work with fast scintillation component of BaF2 crystals in longitudinal magnetic field
  - neutron radiation tests of detector components

Estimation of human resources

Mu2e JINR group members

Name	FTE	Positon	Work (apart common duties like shifts)
A.M.Artikov	1.0	Head of sector	CRV creation and maintenance
N.V.Atanov	0.9	Junior researcher	Calorimeter, front end electronics, RnD Mu2e-II
O.S.Atanova	0.4	Engineer	front end electronics, RnD Mu2e-II
V.Yu. Baranov	0.5	Junior researcher	Calorimeter, RnD Mu2e-II
J.A. Budagov	0.4	Chief researcher	CRV, Calorimeter, RnD Mu2e-II
D. Chokheli	1.0	Senior scientist	CRV creation and maintenance
Yu.I. Davydov	0.5	Head of department	Calorimeter, RnD Mu2e-II
D.L. Demin	0.3	Head of sector	RnD Mu2e-II
V.V. Glagolev	0.6	DLNP Deputy director	CRV, Calorimeter, RnD Mu2e-II
Yu.N. Kharzheev	0.4	Senior scientist	CRV, RnD Mu2e-II
V.I. Kolomoets	0.3	Senior engineer	CRV, calorimeter
S.M. Kolomoets	0.3	Senior engineer	CRV, calorimeter
A.V. Sazonova	0.3	Engineer	CRV
A.N. Shalyugin	0.3	Senior engineer	Calorimeter, RnD Mu2e-II
A.V.Simonenko	1.0	scientist	CRV creation and maintenance
I.A. Suslov	0.6	Senior scientist	Calorimeter calibration simulation
V.V. Tereschenko	0.4	Head of group	Calorimeter electronics, RnD Mu2e-II
S.V. Tereschenko	0.3	Engineer	Calorimeter electronics, RnD Mu2e-II
Z. Usubov	0.6	Senior scientist	CRV and calorimeter simulation
I.I. Vasilyev	0.5	Junior researcher	Calorimeter RnD and tests
Total FTE	**10.6**		

Mu2e Physics Schedule



- Physics data taking through 2026 – assuming no significant performance issues arise
- Note: LBNF shutdown currently scheduled for 2y starting mid-2024
  - Strong motivation to collect full data set as soon as possible
  - This schedule maintains our competitive advantage over COMET Phase-II.
  - Strong Lab and DOE support needed to maintain current schedule

List of publications on the subject of Mu2e

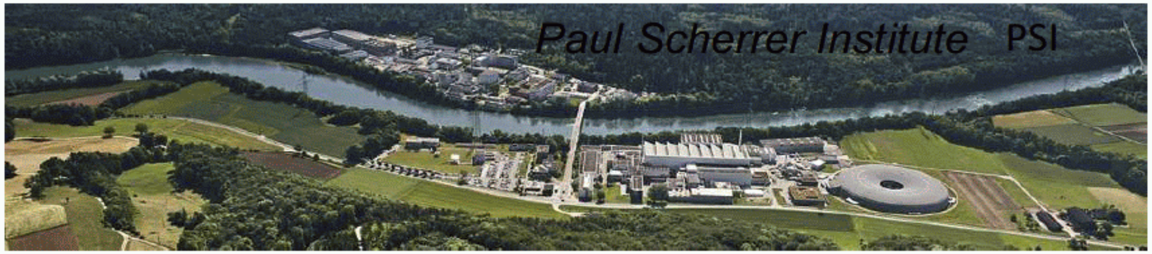
1. N.Atanov et al. “**Design and test of the Mu2e undoped CsI + SiPM crystal calorimeter“ NIM A936 (2019) 94-97.**
2. A. Artikov, V. Baranov, Yu. Budagov, M. Bulavin, D. Chokheli, Yu.I. Davydov, V. Glagolev, Yu. Kharzheev, V. Kolomoets, A. Simonenko, Z. Usubov, I. Vasiljev, “**Light yield and radiation hardness studies of scintillator strips with a filler**”, **NIM A930 (2019) 87-94,**
3. N.Atanov et al. “**Mu2e Calorimeter Readout System”, NIM A936 (2019) 333-334.**
4. N.Atanov et al. “**Electron beam test of the large area Mu2e calorimeter prototype”, J.Phys.Conf.Ser. 1162 (2019) no.1, 012027.**
5. N.Atanov et al. “**The Mu2e Calorimeter: Quality Assurance of Production Crystals and SiPMs”, NIM A936 (2019) 154-155.**
6. A.M.Artikov et al. “**Suppression of the slow component of BaF2 crystal luminescence with a thin multilayer filter”, J.Phys.Conf.Ser. 1162 (2019) no.1, 012028.**
7. N.Atanov et al. “**The Mu2e Calorimeter Final Technical Design Report”, arXiv:1802.06341, 2018**.
8. F.Abusalma et al. “**Expression of Interest for Evolution of the Mu2e Experiment”, arXiv:1802.02599, 2018.**
9. N.Atanov et al. “**The Mu2e crystal calorimeter”, arXiv:1801.10002, 2018.**
10. G.Pezzulo et al. “**Design, status and perspective of the Mu2e crystal calorimeter”, Springer Proc.Phys. 213 (2018) 66-69.**
11. N.Atanov et al. “**Design and Status of the Mu2e Crystal Calorimeter”, IEEE Trans.Nucl.Sci. 65 (2018) no.8, 2073-2080.**
12. N.Atanov et al. “**The Mu2e undoped CsI crystal calorimeter”, JINST 13 (2018) no.02, C02037.**
13. N.Atanov et al. “**Quality Assurance on Undoped CsI Crystals for the Mu2e Experiment**”, **IEEE TNS 65 (2017) no.2, 752-757.**
14. A.Artikov et al. “**Photoelectron Yields of Scintillation Counters with Embedded Wavelength-Shifting Fibers Read Out With Silicon Photomultipliers”, NIM A890 (2018) 84-95.**
15. F.Happacher et al. “**The Mu2e crystal calorimeter”, JINST 12 (2017) no.09, P09017.**
16. O.Atanova et al. “**Measurement of the energy and time resolution of a undoped CsI + MPPC array for the Mu2e experiment”, JINST 12 (2017) no.05, P05007.**
17. N.Atanov et al. “**The calorimeter of the Mu2e experiment at Fermilab”, JINST 12(2017) no. 01, C01061.**
18. N.Atanov et al. “**Quality Assurance on a Custom SiPMs Array for the Mu2e Experiment”, arXiv:1711.07261.**
19. M.Martini et al. “**Design, status and test of the Mu2e crystal calorimeter”, J.Phys.Conf.Ser. 928 (2017) no.1, 012017.**
20. A.Artikov et al. “**Optimization of light yield by injecting an optical filler into the co-extruded hole of the plastic scintillation bar”, JINST 11 (2016) no.05, T05003.**
21. N.Atanov et al. “**Characterization of a prototype for the electromagnetic calorimeter of the Mu2e experiment”, Nuovo Cimento C39(2016) no.1, 267.**
22. N.Atanov et al. “**Energy and time resolution of a LYSO matrix prototype for the Mu2e experiment”, NIM A824(2016)684.**
23. N.Atanov et al. “**Design and status of the Mu2e electromagnetic calorimeter”, NIM A824(2016)695.**
24. N.Atanov et al. “**Characterization of a 5x5 LYSO Matrix Calorimeter Prototype”, IEEE TNS (2016), vol.63, No.2, p.596**.
25. N.Atanov et al. “**Measurement of time resolution of the Mu2e LYSO calorimeter prototype”, NIM A812(2016)104.**

Conference talks

- A.Artikov et al, “Mass Production and Quality Tests of a High-Efficiency Cosmic Ray Veto Detector for the Mu2e Experiment “, IEEE Nuclear Science Symposium, 26 October – 2 November 2019, Manchester, UK
- N.V.Atanov et al., “PMT with AlGaN photocathodes and MCP for BaF2 scintillator detectors in particle physics”, IEEE Nuclear Science Symposium, 26 October – 2 November 2019, Manchester, UK
- Yu. Kharzheev, “Radiation Hardness of scintillation detectors based on organic plastic scintillators and optical fibers”, International Conference “New trends in High-Energy Physics” Monternegro, Budva 24-30 September 2018
- Yu.I.Davydov et al., “Tests of 3x3 undoped CsI matrix with an extremely low intensity electron beam”, International Conference “New trends in High-Energy Physics” Monternegro, Budva 24-30 September 2018
- A.M. Artikov, V. Baranov, J.A. Budagov, A.N. Chivanov, Yu.I. Davydov, E.N. Eliseev, E.A. Garibin, V.V. Glagolev, A.V. Mihailov, V.V. Terechschenko, I.I.Vasilyev “Suppression of a slow component of a BaF2 crystal luminescence with a thin multilayer filter” CALOR 2018 - 18th International Conference on Calorimetry in Particle Physics, Eugene, Oregon, USA, May 21-25, 2018
- 17-th Baikal Summer School on Physics of Elementary Particles and Astrophysics Report «Radiation hardness study of the synthetic rubber filler SKTN-MED – promising material for HEP experiments».
- A.Artikov et al, “The light yield of a long scintillation strip with WLS fiber embedded into the co-extruded hole ” Engineering of Scintillation Materials and Radiation Technologies" - ISMART 2016, Minsk 2016
- Yu.Kharzheev, “Scintillation Detectors in modern High Energy Physics Experiments and Prospect of their use in Future Experiments ”, International Conference on Astrophysics and Particle Physics, Conference Series LLC, Dallas, USA , 2016
- Yu. Kharzheev, “New trends in using Scintillation Counters in modern High Energy Physics Experiments ”, 6th International Conference on Contemporary Physics (ICCP-VI), The Nuclear Energy Commission of the Government of Mongolia, MAS, NUM, JINR, Ulaanbaatar, Mongolia, 2016

MEG-II experiment

MEG HOME



Switzerland

PSI, ETH-Z

Russia

BINP, Novosibirsk,
JiNR, Dubna

MEG Collaboration

some 65 Physicists

5 Countries, 14 Institutes

Japan

Univ.Tokyo, KEK
Waseda Univ.,
Kyushu Univ.

Italy

INFN + Univ. :
Pisa, Genova,
Pavia, Roma I
& Lecce

USA

University of
California Irvine
UCI

MEG-II experiment

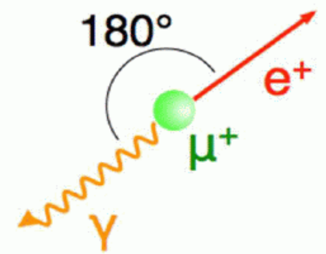
Signal and backgrounds

Signal $\mu+$ decay at rest

52.8 MeV (half of M_μ) (E_γ,E_e)

Back-to-back ($\theta_{e\gamma}$,$\varphi_{e\gamma}$)

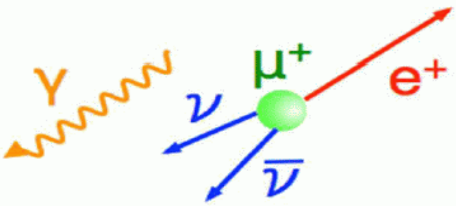
Timing coincidence ($T_{e\gamma}$)



Accidental background (dominant)

Michel decay e^+ + random γ

Random timing, angle, E < 52.8MeV

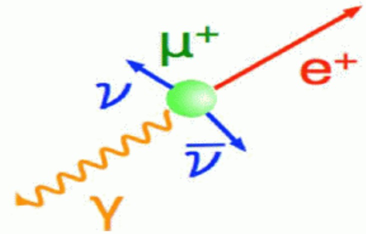


Radiative muon decay

$\mu^+ \rightarrow e^+\nu\nu\gamma$

Timing coincident, not back-to back,

E <52.8MeV

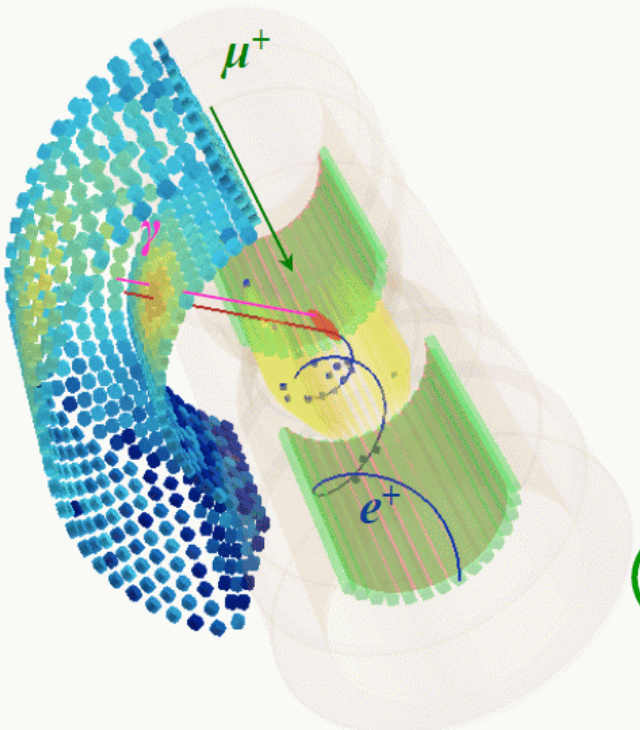


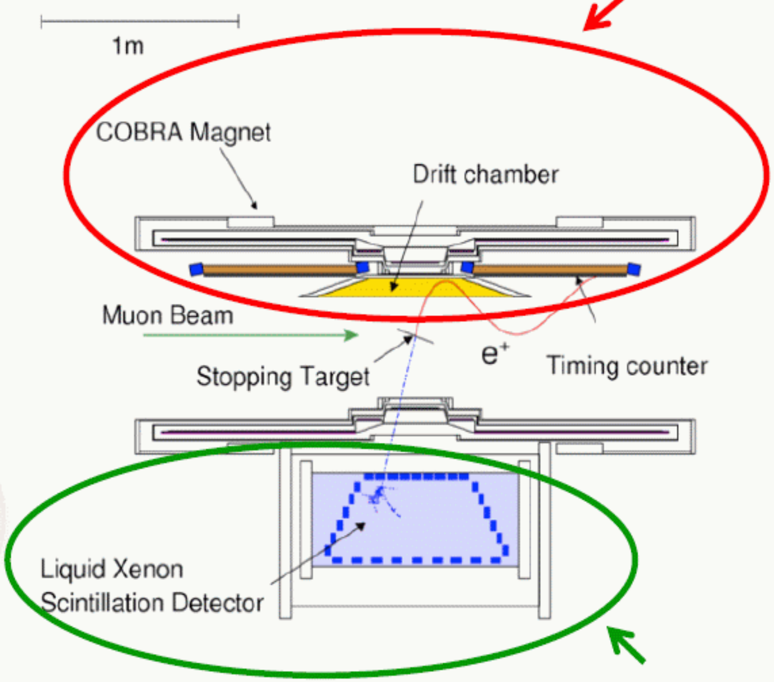
MEG-II experiment

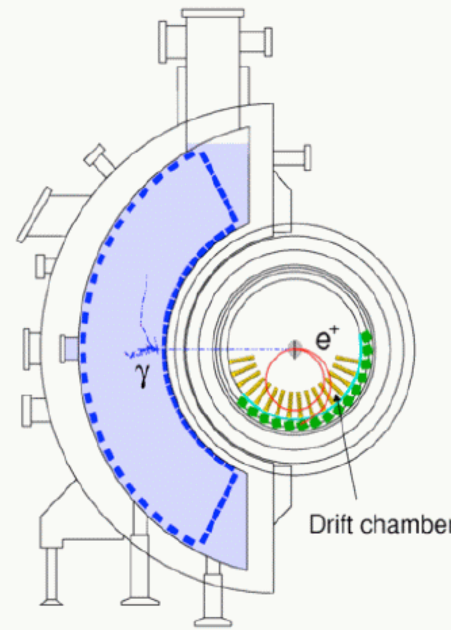
Detector layout

Muon beam intensity 3×10^7 stopped μ^+/s

Positron spectrometer: measurement of positron momentum vector and timing







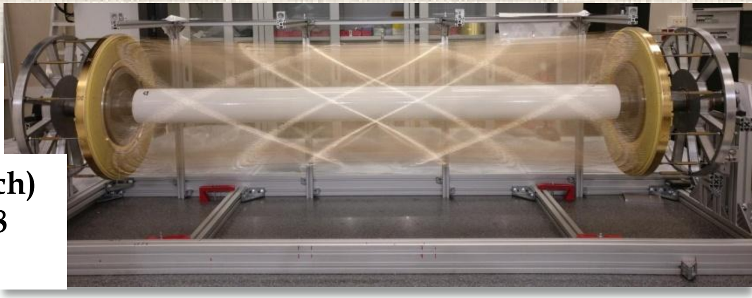
LXe photon detector: measurement of photon energy, impact point and timing

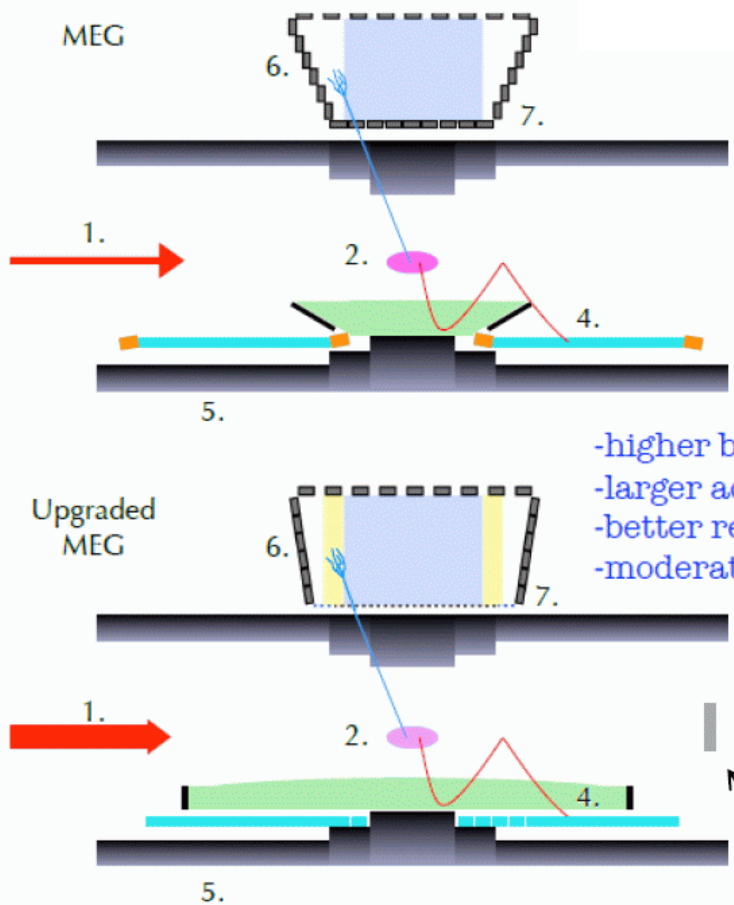
MEG-II experiment

MEG Upgrade

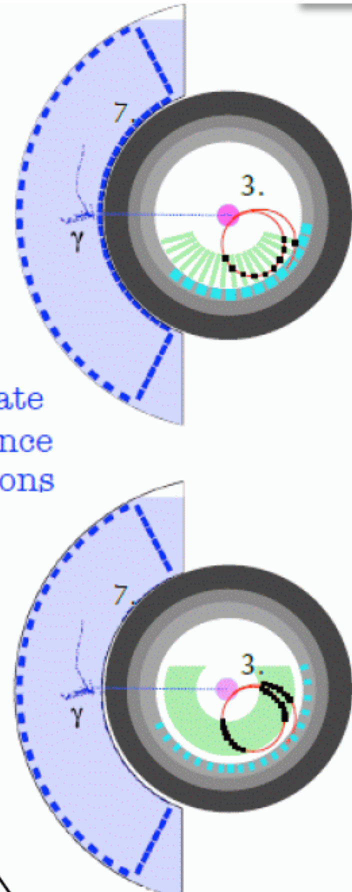
length of the CDCH is ≥1930 mm
Rext=284 mm

The total number of **sense wire - 1920 (ch)**
Field wire - 8448
Guard wire - 768





-higher beam rate
-larger acceptance
-better resolutions
-moderate cost



Radiative Decay Counter

Upgrade proposal:

arXiv:1301.7225 [physics.ins-det]

TABLE XI: Resolution (Gaussian σ) and efficiencies for MEG upgrade

PDF parameters	Present MEG	Upgrade scenario
e^+ energy (keV)	306 (core)	130
e^+ θ (mrad)	9.4	5.3
e^+ ϕ (mrad)	8.7	3.7
e^+ vertex (mm) Z/Y(core)	2.4 / 1.2	1.6 / 0.7
γ energy (%) (w <2 cm)/(w >2 cm)	2.4 / 1.7	1.1 / 1.0
γ position (mm) $u/v/w$	5 / 5 / 6	2.6 / 2.2 / 5
γ-e^+ timing (ps)	122	84
Efficiency (%)		
trigger	≈ 99	≈ 99
γ	63	69
e^+	40	88

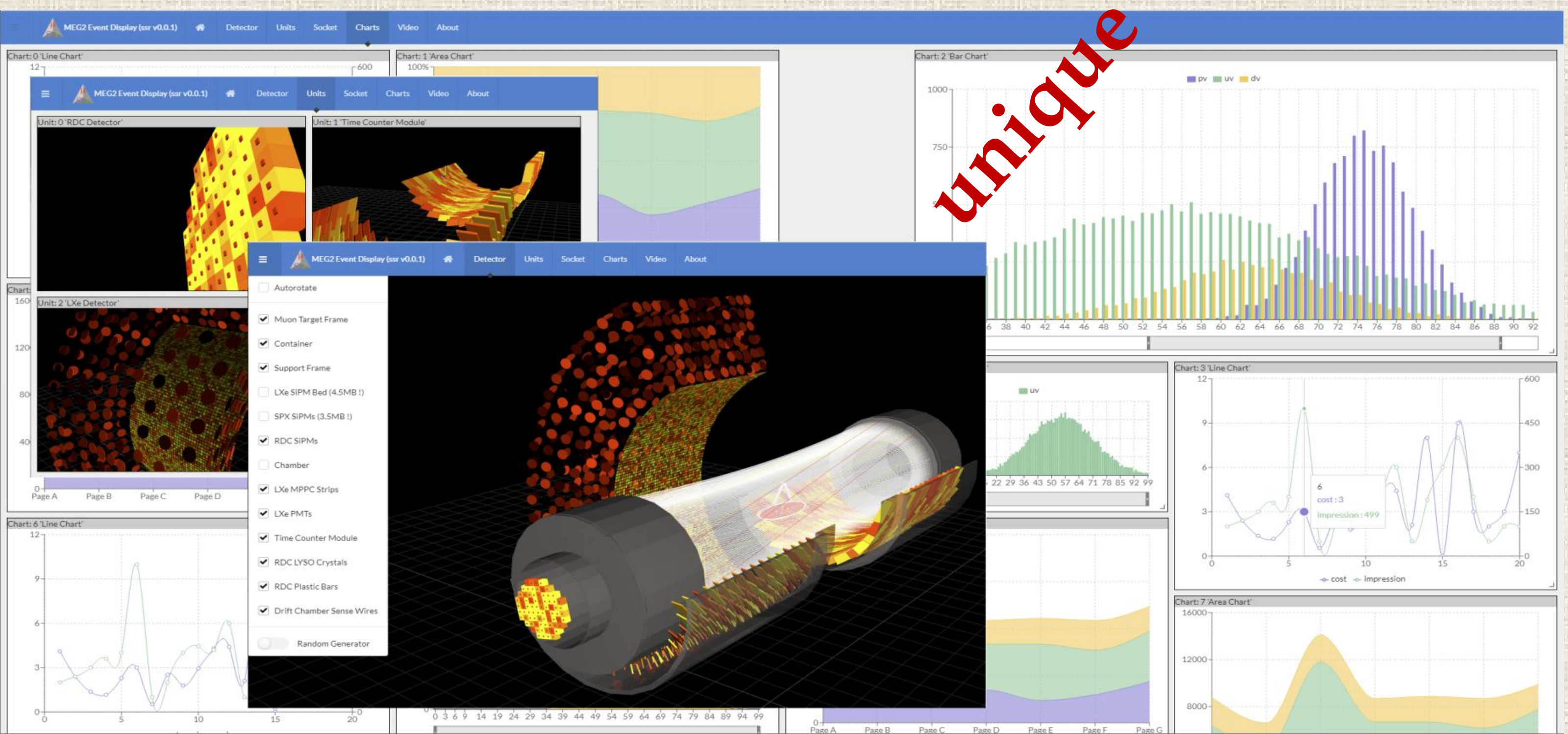
MEG-II JINR contribution

Viktor Krylov

g2mu.jinr.ru/three

Development and support of event 3D visualization software

We suggested MEGII collaboration to develop Event Display web application based on new technology using of WebGL library. The main goal of the project is development Web based server and client application to visualize 3D interactive models of all sensors of MEGII detector connected to event data stream in online and offline modes for presentation and supervisory tasks without additional software on client side. Client part of the Event Display should use only standard methods which are available in modern Web browsers from different vendors supporting JavaScript dialects starting from ECMAScript 2015 and newest. Clients should have possibilities to use mobile devices as well.



Working demo version of the Event Display

Presented at the MEG2 collaboration meeting July 2019

MEG-II JINR contribution

MEG II data processing and analysis

Main goals of this activity

• Participation of LNP MEG II group in data processing and physics analysis.
• Effective using of the DLNP JINR computer infrastructure by MEG II collaboration.

DLNP JINR computing cluster

• Cluster includes 800 CPU's for batch jobs processing. Data storage is located on the local disk pools and disks provided by JINR AFS system.

29TB local disk pool is assigned for MEG II simulation, data processing and physics analysis.

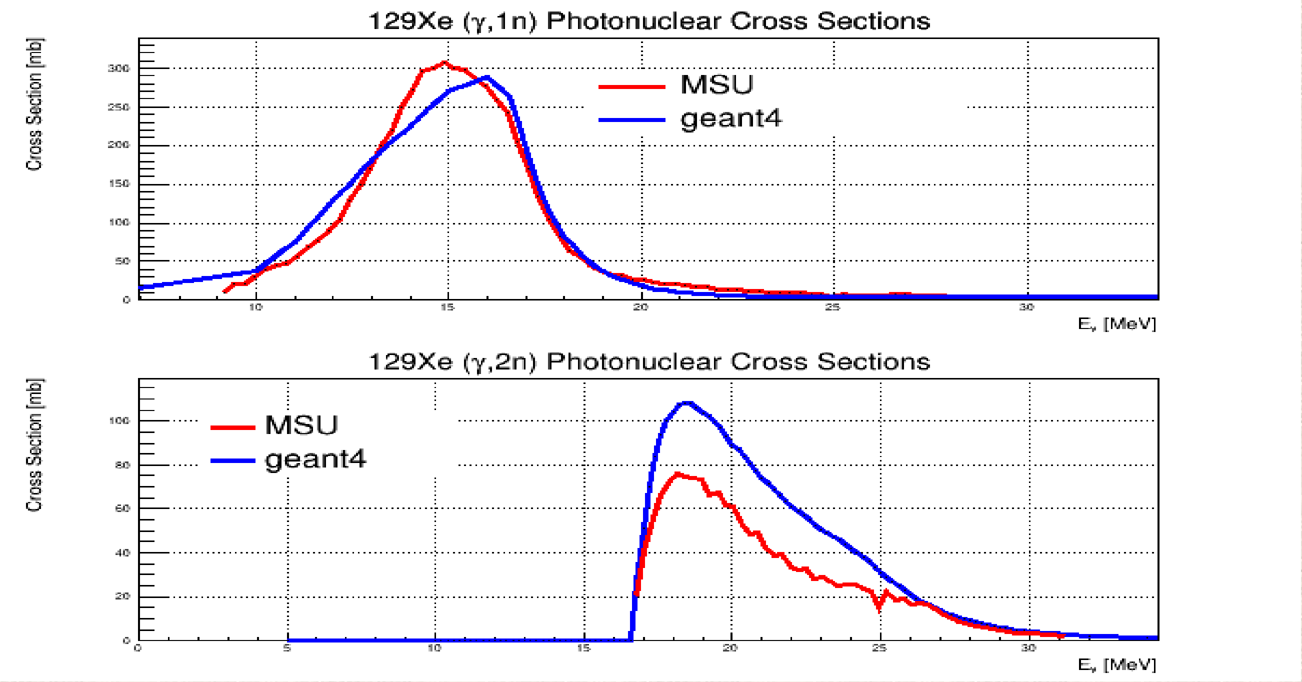
Status

• MEG II user group was created.
• MEG II software was installed.
• Full chain of MEG II simulation and analysis programs was tested successfully. Our cluster is certified for work in MEG II collaboration.
• Members of LNP MEG II group started to study the drift chamber simulation and pattern recognition software.
• MEG II collaboration participants run their jobs on LNP JINR cluster

MEG-II JINR contribution

Photonuclear reactions in geant4

- A modification of the standard package geant4, which allowed to correctly describe the energy loss in the calorimeter is proposed.
- We together with the data Center of photonuclear experiments (Varlamov V. V., etc.) of MSU are going to include the calculated cross sections of photonuclear processes for Xe in the MEG-II modeling package.



MEG-II JINR contribution

•Participation in construction, installation and setup of the positron tracker.

• Development of a new method of meaturement of wire tension inside closed volume of the positron tracker for control of the detector performance. (A. O. Kolesnikov, V. L. Malyshev, N. P. Kravchuk, A. I. Rudenko.)

•An improved design of the cylindrical drift chamber (CDCH) has been developed and presented to the collaboration. Special attention is paid to the analysis of cells, which form an electric field in the CDCH. It has been shown that number of factors: gravitation, electrostatic and errors in the manufacturing - make a significant impact on uniformity of electric field, i.e. on coordinate accuracy. The cell's form suggested doesn't change an electric field in the cell in principle, but allows to reduce a quantity of material and control mechanical tension of wires. (A. O. Kolesnikov, N. P. Kravchuk, K. K. Limarev).

•Development and support of user-friendly web interface software for control and setup of multiple parameters of the WaveDREAM boards in the WaveDAQ integrated trigger and data acquisition system. The software based on JavaScript Custom Page technology for MIDAS is a practical and robust tool to manage thousands of WaveDAQ electronics channels. (N.V. Khomutov).

plans of JINR contribution in MEG-II for 2021-2023

- Drift chamber maintenance
- DAQ + Event Display development and support
- Ensure the operation of the JINR computer cluster for simulation and data analysis. Increasing the computer cluster data storage and power by necessity.
- Participation in the drift chamber simulation, track reconstruction procedures, precise energy reconstruction in Xe calorimeter and further in data analysis
- Participation in physics analysis of the experimental data to search for the $\mu^+ \to e^+\gamma$ decay (using likelihood analysis to calculate the best estimate of the number of $\mu^+ \to e^+\gamma$ signal candidates, its confidence interval and the significance).
- Participation in physics analysis of the experimental data for precise measurement of the radiative decay of polarized muons $\mu^+ \to e^+\nu\nu\gamma$. The importance of studying the radiative muon decay (RMD) is twofold: on one hand, it provides a tool for investigating weak interactions. On the other hand, it constitutes important sources of background for experiments searching for rare muon decays

List of publications on the subject of MEG

•A.M. Baldini, Y. Bao, E. Baracchini, (... N.Khomutov, A.Korenchenko, N.Kravchuk) et al. "Search for the lepton flavour violating decay $\mu+\rightarrow e+\gamma$ with the full dataset of the MEG experiment“ Eur. Phys. J. C (2016) 76: 434.

•Baranov, V.A. et al., “A Tracker Prototype Based on Cathode Straw Tubes” Instrum. Exp. Tech. (2018) Volume 61, Issue 5, p 645. Original Russian Text © V.A. Baranov et al. , 2018, published in Pribory i Tekhnika Eksperimenta, 2018, No. 5, pp. 19–22.

•A. M. Baldini, N. Khomutov, A. Korenchenko, N. Kravchuk et al., The design of the MEG II experiment, Eur.Phys.J. C78 (2018) no.5, 380.

•Baranov V.A. et al., A Tracker Prototype Based on Cathode Straw Tubes, Instrum. Exp. Tech. (2018) Volume 61, Issue 5, p 645.

•A. M. Baldini, N. V. Khomutov, A. S. Korenchenko, N. P. Kravchuk, N. A. Kuchinksiy et al., MEG Upgrade Proposal, arXiv:13017225v2 [physics.ins-det]

Conference talks

•N. V. Khomutov, Using the cathode surface of straw tube for measuring the track coordinate along the wire and increasing rate capability, New Trends in High-Energy Physics. Budva, Becici, Montenegro, 02 October - 08 October, 2016.

•N. P. Kravchuk, Tracker prototype on a base of cathode straw, Fifth International Conference ESMART 2016 "Engineering of Scintillation Materials a 01-nd Radiation Technologies", September 26-30, 2016, Minsk, Belarus.

•V.A. Krylov. Development of web interactive 3D environment for event display in muon g-2 (Fermilab) and MEG-2 (PSI) experiments. NEC-2019, Budva, Becici, Montenegro, 30 September - 04 October, 2019.

•N. A. Kuchinskiy, The MEG Experiment. Search For Physics Beyond The Standard Model, XIV-th International School-Conference "Actual Problems of Microworld Physics", 12-August, 24, 2018, Grodno, Belarus

•N. A. Kuchinskiy, N. P.Kravchuk. Search For Physics Beyond The Standard Model, XIII-th International School-Conference "Actual Problems of Microworld Physics", 27 July-7 August, 2017, Gomel, Belarus.

•Limarev K. K., A note of a design of CDCH, 23-th Conference AYSS-2019, Alushta.

MEG-II JINR group members

Name	FTE	Positon	Work (apart common duties like shifts)
V.A. Baranov	0.6	Senior scientist	Drift chamber simulation, data analysis
N.V. Khomutov	1.0	Scientist	DAQ software development
A.O. Kolesnikov	0.4	Senior engineer	Drift chamber upgrade and maintenance
N.P. Kravchuk	0.8	Senior scientist	Drift chamber upgrade and maintenance
V.A. Krylov	0.8	Scientist	Display event monitor
N.A. Kuchinsky	0.6	Senior scientist	Drift chamber upgrade and maintenance
V.L. Malyshev	0.4	Scientist	Drift chamber upgrade and maintenance
K.K. Limarev	0.4	Engineer	Drift chamber simulation, data analysis
A.M. Rozhdestvensky	0.6	Senior scientist	DLNP MEG-II computer cluster support, data analysis
Yu.P. Ivanov	0.3	Senior scientist	DLNP MEG-II computer cluster support
A.V. Simonenko	0.2	scientist	simulation
I.V. Titkova	0.3	DLNP scientific Secretary	Drift chamber simulation
Total FTE	**6.4**		

Estimated expenditures for the Mu2e experiment

Schedule proposal and resources required for the implementation of the experiment

Mu2e

Expenditures, resources, financing sources			Costs (k$) Resource requirements	Proposals of the Laboratory on the distribution of finances and resources		
				2021	2022	2023
Expenditures		Computers for RnD and MC Electronic devices for stands	30 120	10 40	10 40	10 40
Expenditures		Construction/repair of premises				
Expenditures		Materials	60	20	20	20
Required resources	Standard hour	Resources of – Laboratory design bureau; – JINR Experimental Workshop; – Laboratory experimental facilities division; – electron accelerator; reactor – computer. Operating costs.	300 h 360 h	100 120	100 120	100 120
Financing sources	Budgetary resources	Budget expenditures including foreign-currency resources.	387	129	129	129
Financing sources	External resources	FNAL and UVA visits support	45	15	15	15

	Expenditure items	Full cost	2021	2022	2023
	Direct expenses for the Project				
1.	Accelerator, reactor	360 h	120	120	120
2.	Computers	h			
3.	Computer connection	15 k$	5	5	5
4.	Design bureau	300 h	100 h	100 h	100 h
5.	Experimental Workshop				
6.	Materials	60 k$	20	20	20
7.	Equipment	150 k$	50	50	50
8.	Construction/repair of premises	k$			
9.	Payments for agreement-based research (operation fee)	k$			
10.	Travel allowance, including:				
	a) non-rouble zone countries	150 k$	50	50	50
	b) rouble zone countries	12	4	4	4
	c) protocol-based				
	Total direct expenses	387	129	129	129

Estimated expenditures for the MEG-II experiment

Schedule proposal and resources required for the implementation of the experiment

MEG-II

Expenditures, resources, financing sources			Costs (k$) Resource requirements	Proposals of the Laboratory on the distribution of finances and resources: 2021	2022	2023
Expenditures		Computers Electronic devices	70 30	30 10	20 10	20 10
		Construction/repair of premises				
		Materials	30	10	10	10
Required resources	Standard hour	Resources of – Laboratory design bureau; – JINR Experimental Workshop; – Laboratory experimental facilities division; – accelerator; – computer. Operating costs.	150 h	50	50	50
Financing sources	Budgetary resources	Budget expenditures including foreign-currency resources.	211 k$	77	67	67
	External resources	Program of the JINR-Belarus Cooperation.	30 k$	10	10	10
		Travel support from PSI	15 k$	5	5	5

	Expenditure items	Full cost	2021	2022	2023
	Direct expenses for the Project				
1.	Accelerator, reactor	h			
2.	Computers	h			
3.	Computer connection	15 k$	5	5	5
4.	Design bureau	150 h	50 h	50 h	50 h
5.	Experimental Workshop	h			
6.	Materials	30 k$	10	10	10
7.	Equipment	100 k$	40	30	30
8.	Construction/repair of premises	k$			
9.	Travel allowance, including:				
	a) non-rouble zone countries	60 k$	20	20	20
	b) rouble zone countries	6	2	2	2
	c) protocol-based				
	Total direct expenses	211 k$	77	67	67

To be continued in Z. Tsamalaidze talk

BACKUP slides

Estimated expenditures for the COMET experiment

Schedule proposal and resources required for the implementation of the experiment

COMET

Expenditures, resources, financing sources			Costs (k$) Resource requirements	Proposals of the Laboratory on the distribution of finances and resources		
				2021	2022	2023
Expenditures		Computers Electronic devices	30 120	10 40	10 40	10 40
		Construction/repair of premises				
		Materials	180	60	60	60
Required resources	Standard hour	Resources of – Laboratory design bureau; – JINR Experimental Workshop; – Laboratory experimental facilities division; – accelerator; – computer. Operating costs.	800 h 1200 h	300 500	300 500	200 200
Financing sources	Budgetary resources	Budget expenditures including foreign-currency resources.	660	220	220	220
	External resources	Grant of the Plenipotentiary of Georgia	30	10	10	10
		Program of the JINR-Belarus Cooperation.	15	5	5	5
		Grant of the Plenipotentiary of Kazakhstan	30	10	10	10

	Expenditure items	Full cost	2021	2022	2023
	Direct expenses for the Project				
1.	Accelerator, reactor	480 h	160	160	160
2.	Computers	h			
3.	Computer connection	k$			
4.	Design bureau	800 h	300 h	300 h	200 h
5.	Experimental Workshop	1200 h	500 h	500 h	200 h
6.	Materials	180 k$	60	60	60
7.	Equipment	150 k$	50	50	50
8.	Construction/repair of premises	k$			
9.	Payments for agreement-based research (operation fee)	60 k$	20	20	20
10.	Travel allowance, including: a) non-rouble zone countries b) rouble zone countries c) protocol-based	k$ 255 15	 85 5	 85 5	 85 5
	Total direct expenses	660	220	220	220

Estimated expenditures for the Project

Schedule proposal and resources required for the implementation of the Project

Search for new physics in the lepton sector

Expenditures, resources, financing sources			Costs (k$) Resource requirements	Proposals of the Laboratory on the distribution of finances and resources 2021	2022	2023
Expenditures		Computers for RnD and MC Electronic devices for stands	130 k$ 270 k$	50 90	40 90	40 90
		Construction/repair of premises				
		Materials	270 k$	90	90	90
Required resources	Standard hour	Resources of – Laboratory design bureau; – JINR Experimental Workshop; – Laboratory experimental facilities division; – electron accelerator; reactor – computer. Operating costs.	1250 h 1200 h 840 h	450 h 500 h 280 h	450 h 500 h 280 h	350 h 200 h 280 h
Financing sources	Budgetary resources	Budget expenditures including foreign-currency resources.	1258 k$	426	416	416
	External resources	-FNAL and UVA visits support -Grant of the Plenipotentiary of Georgia - Program of the JINR-Belarus Cooperation. - Grant of the Plenipotentiary of Kazakhstan - Travel support from PSI	45 k$ 30 k$ 45 k$ 30 k$ 15 k$	15 10 15 10 5	15 10 15 10 5	15 10 15 10 5

PROJECT LEADER

Form No. 29

Estimated expenditures for the Project

Search for new physics in the lepton sector

(full title of Project)

	Expenditure items	Full cost	2021	2022	2023
	Direct expenses for the Project				
1.	Accelerator, reactor	840 h	280 h	280 h	280 h
2.	Computers	h			
3.	Computer connection	30 k$	10	10	10
4.	Design bureau	1250 h	450 h	450 h	350 h
5.	Experimental Workshop	1200 h	500 h	500 h	200 h
6.	Materials	270 k$	90	90	90
7.	Equipment	400 k$	140	130	130
8.	Construction/repair of premises	k$			
9.	Payments for agreement-based research (operation fee)	60 k$	20	20	20
10.	Travel allowance, including:				
	a) non-rouble zone countries	465 k$	155	155	155
	b) rouble zone countries	33 k$	11	11	11
	c) protocol-based				
	Total direct expenses	1258 k$	426	416	416

concise justification of the requested expenditures

Below are tables that divide the requested resources into three experiments.

For Mu2e experiment :

- Computers: Personal computers and servers for software development and simulation; for DLNP experimental stands DAQ and data analysis.
- Electronic devices: VME modules, trigger logic, power supplies for PMT and SiPM's, SiPM's for trigger counters, crystals, oscilloscope's, equipment of test stands for work with cosmic, radioactive sources and electron accelerator.
- Materials : AlGaN photocathodes, microchannel plates, BaF2 crystals, printing plastic for the 3D, small tools, modular profile.

For COMET experiment :

- Computers: Personal computers and servers for software development and simulation; for DLNP experimental stands DAQ and data analysis.
- Electronic devices: equipment for straw tube testing stand, VME modules, power supplies, optical sensors, pressure sensors, equipment of test stands for work with cosmic, radioactive sources and electron accelerator.
- Materials : Mylar for straw tubes production, scintillator plates, printing plastic for the 3D, argon.

For MEG-II experiment :

- Computers: DLNP computing cluster and disk storage upgrade. Personal computers, servers and computer components for software development, simulation, experimental data processing and physics analysis.
- Electronic devices: VME and WaveDREAM modules for DAQ R&D and simulation.
- Materials for the drift chamber R&D : aluminium wire, solder, conducting glue, epoxy, gas mixtures, chemicals, 3D printing plastic, small tools, modular profile.

R&D schedule for the development of a solar-blind photodetector using AlGaN structures for BaF2 scintillation crystals, development of a BaF2 calorimeter prototype.

1. A photomultiplier with microchannel plate.

At the moment, the sensitivity of the obtained solar-blind photocathodes (peak 220 nm, long-wave boundary 260 nm) based on AlGaN structures is limited by a large number of defects in the upper photosensitive layers of heterostructures grown on a sapphire substrate. A significant improvement in the quality of the layers can be achieved if used for the growth of the substrate with less dispersion of the lattice constant, such as SiC, GaN, AlN. At the moment, The most convenient option are SiC substrates, because of their relative prevalence. It is expected that the transfer of the technology used for growth on a sapphire substrate to SiC substrates will achieve much better layer quality and thus increase the quantum efficiency of the receiver.

To transfer the existing growth technology to SiC substrates it is necessary:

1) ensure the purchase of ~10 SiC substrates with a diameter of 2 inches (~k$ 10);
2) grow test samples in Ioffe PTI (~k$ 25) ;
3) conduct a study of the absorption spectrum of each sample (Ioffe PTI, JINR);
4) to estimate the obtained dislocation density in layers (ISTM, Chernogolovka);
5) to make ready ~2 devices from successful variants ("Cathode", Novosibirsk) (~k$ 10).

2. Matrix photodetector with Schottky diode for BaF_2

An alternative variant of the photodetector is a semiconductor array of photodiodes, which allows to create a photocell of a sufficiently large area (several mm) from elementary cells of a small area (~100 microns). The existing level of AlGaN layer growth technology on sapphire substrates allows us to consider two variants of such devices: an array of p-i-n diodes and an array of Schottky diodes. If you consider the need for high internal gain of the photodetector, you should choose the second option-an array of Schottky diodes.

The approximate work plan can be presented in the following form.
1. Manufacturing of photodetector samples on sapphire substrate:
1) to grow 3-4 samples of structures for photodiodes based on available technology (Ioffe PTI) (~k$ 10);
2) to produce mesostructures of matrix photodiodes by etching (MIET, Zelenograd)(~k$ 14);
3) to study the optical (sensitivity, absorption spectrum) and electrical properties (volt-ampere and volt-Farad characteristics) of photodiodes (JINR).
2. Transfer of existing growth technology to SiC substrates if necessary.

3. The Assembly of the prototype calorimeter in the BaF2 crystals. Testing.

We need to assemble a (3x3) test matrix of BaF2 scintillation crystals with a crystal size of 34x34x200 mm each and perform test measurements on an electronic accelerator. One needs to purchase: BaF2 crystals, 9 photodetectors to work with fast component of BaF_2 crystals: PMT with AlGaN (GaN) photocathode or CsTe photocathode. Approximate price $5000 per piece. Further it is supposed to replace part of these photodetectors with the developed experimental devices. Also the missing blocks of digitizers, splitters, HV power supplies, etc. ($10000-15000) should be purchased.

Charged Lepton Flavour Violation using Intense Muon Beams at Future Facilities

A. Baldini, D. Glenzinski, F. Kapusta, Y. Kuno, M. Lancaster,
J. Miller, S. Miscetti, T. Mori, A. Papa, A. Schöning, Y. Uchida

A submission to the 2020 update of the European Strategy for Particle Physics on behalf of the COMET, MEG, Mu2e and Mu3e collaborations.

Abstract

Charged-lepton flavour-violating (cLFV) processes offer deep probes for new physics with discovery sensitivity to a broad array of new physics models — SUSY, Higgs Doublets, Extra Dimensions, and, particularly, models explaining the neutrino mass hierarchy and the matter-antimatter asymmetry of the universe via leptogenesis. The most sensitive probes of cLFV utilize high-intensity muon beams to search for $\mu \to e$ transitions.

We summarize the status of muon-cLFV experiments currently under construction at PSI, Fermilab, and J-PARC. These experiments offer sensitivity to effective new physics mass scales approaching $\mathcal{O}(10^4)$ TeV$/c^2$. Further improvements are possible and next-generation experiments, using upgraded accelerator facilities at PSI, Fermilab, and J-PARC, could begin data taking within the next decade. In the case of discoveries at the LHC, they could distinguish among alternative models; even in the absence of direct discoveries, they could establish new physics. These experiments both complement and extend the searches at the LHC.

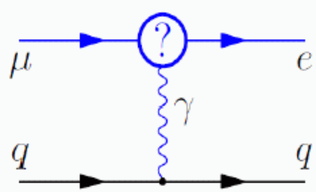
Contact: André Schöning [schoning@physi.uni-heidelberg.de]

Model-independent effective lagrangian

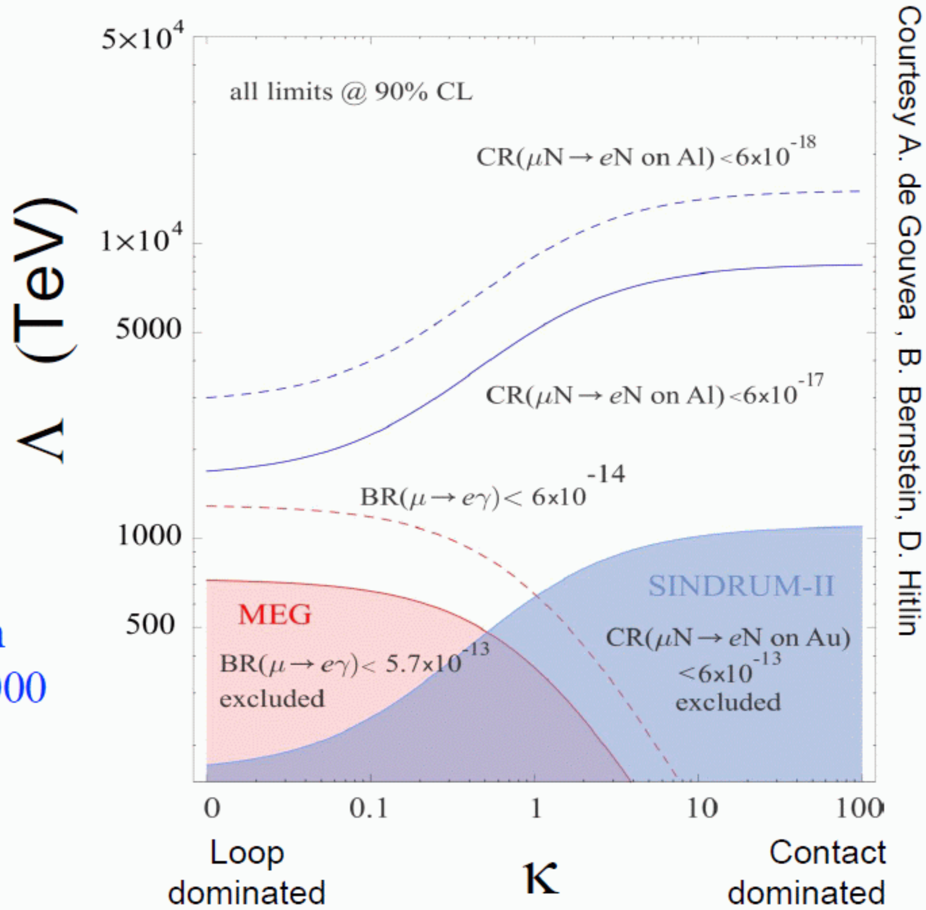
$$L_{\mathrm{CLFV}} = \frac{m_\mu}{(1+\kappa)\Lambda^2}\bar{\mu}_R \sigma_{\mu\nu} e_L F^{\mu\nu} \quad + \quad \frac{\kappa}{(1+\kappa)\Lambda^2}\bar{\mu}_L \gamma_\mu e_L (\bar{u}_L \gamma_\mu u_L + \bar{d}_L \gamma_\mu d_L) \quad + h.c.$$

Λ: effective mass scale of New Physics κ: relative contribution of the contact term

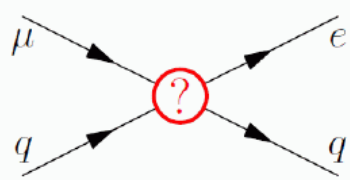
"Dipole term"



Contributes to $\mu \rightarrow e\gamma$



"Contact term"



No contribution to $\mu \rightarrow e\gamma$

- CLFV can probe very high mass scales O(1000 – 10,000 TeV)

Probe of New Physics parameter space

- CLFV is a deep & unique probe of New Physics (NP) parameter space
  - Next generation experiments planned in Europe, Asia, and Americas
  - Probes complementary regions of NP space relative to rest of HEP program
  - Measured rates provide model discrimination

Model	$\mu \to eee$	$\mu N \to eN$	$\frac{\mathrm{BR}(\mu\to eee)}{\mathrm{BR}(\mu\to e\gamma)}$	$\frac{\mathrm{CR}(\mu N\to eN)}{\mathrm{BR}(\mu\to e\gamma)}$
MSSM	Loop	Loop	$\approx 6\times 10^{-3}$	$10^{-3} - 10^{-2}$
Type-I seesaw	Loop*	Loop*	$3\times 10^{-3} - 0.3$	0.1–10
Type-II seesaw	Tree	Loop	$(0.1-3)\times 10^{3}$	$\mathcal{O}(10^{-2})$
Type-III seesaw	Tree	Tree	$\approx 10^{3}$	$\mathcal{O}(10^{3})$
LFV Higgs	Loop†	Loop* †	$\approx 10^{-2}$	$\mathcal{O}(0.1)$
Composite Higgs	Loop*	Loop*	$0.05 - 0.5$	$2 - 20$

arXiv:1709.00294v2[hep-ph]

from L. Calibbi and G. Signorelli, Riv. Nuovo Cimento, 41 (2018) 71

TABLE VII. – *Pattern of the relative predictions for the $\mu \to e$ processes as predicted in several models (see the text for details). It is indicated whether the dominant contributions to $\mu \to eee$ and $\mu \to e$ conversion are at the tree or at the loop level;*

MEG-II JINR contribution

Viktor Krylov
g2mu.jinr.ru/three

Development and support of event 3D visualization software

After investigated of all possible solutions was suggested to dwell on the following decision.
1) Server part should use NodeJS cross-platform framework based on V8 JavaScript Engine from Google.
2) ThreeJS - cross-browser JavaScript library based on WebGL GPU-accelerated software. WebGL is a JavaScript API for rendering interactive 2D and 3D graphics with any compatible web browser without the use of additional plug-ins.
3) React framework - JavaScript libraries for building user interface maintained by Facebook Inc.

Demo video file