

## The ME0 Project

Design, Status, Tests, Schedule, & Milestones

Stephen D. Butalla On behalf of the CMS GEM Collaboration September 2, 2021

CMS Muon Upgrade Workshop 2021





#### The ME0 Detector System



- The ME0 detector system is a layered stack of 6 triple-GEM detectors (70:30 Ar/CO<sub>2</sub> fill gas)
- 18 stacks per endcap (36 total stacks; 216 modules total)
- ME0 detector system to increase coverage from 2.0  $< |\eta| <$  2.8
- Segmented into 8 readout partitions in  $\eta$  and 3 in  $\phi$  (24 total RO sectors)



Quadrant of the CMS experiment with ME0 kighlighted. Adapted from [1].

#### Requirements [1]:

- 97% efficiency
- Rate capability of  $\geq 150 \text{ kHz} \cdot \text{cm}^{-2}$
- Radiation hardness requirement >7.9 C·cm<sup>-2</sup>
- Angular resolution  $\leq$  500  $\mu$ rad
- Time resolution 8–10 ns for single layer
- Gain uniformity of  $\geq$  15% inter-/intra-module
- Sufficiently low discharge rate



3D rendering of the insertion of two ME0 stacks [1].

### ME0 Frontend Electronics

- GEM electronics board (GEB) in final prototyping

stages

- 11 total preproduction prototypes produced: 5 narrow, 6 wide
- Optimizing fiber routings
- Finalizing layout for DC-DC converters



ME0 GEB design w/ patch panel connections [2].

 FPGA-less optohybrid (ASIAGO) with 2 LpGBT chips and VTRX+



Plugin cards fitted with VFAT3b ASICs for

RO

- 120 in hand: 66 at CERN for GE2/1. 24 at FIT. 2 at Rice. 2 at Vilinius, 12 at Bari
- 50 wafers ordered for ME0. packaging expected in 2022



Plugin card with VFAT3b ASIC.

Power to be distributed by bPOL12V

DC-DC converters (currently under

testing)

- Transitioning from the FEASTMP\_CLP to bPOL (FEAST production discontinued)
- bPOL prototype testing looks promising! See [4]



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#### ME0 Frontend Electronics — Test Stands

- CERN CMS
- Frontend electronics integration test stands at CERN, UCLA, and Florida Tech
- UCLA and Florida Tech use the BittWare CVP13 backend, CERN uses the APEX backend (see Abhisek's talk)
- Software/firmware for integration/testing purposes written and tested
- GEM collaboration moving to integrate the frontend electronics with the chamber



UCLA ME0 test stand.

LORIDA Tech









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### ME0 Frontend Electronics — Tests & Results

- Full slow control communication with VFATs •
- Full readout capabilities of DAQ and trigger data
- Can synchronize, calibrate, and operate all VFATs simultaneously



ENC measurement for DAQ path. Noise measurement for trigger path.



RSSI monitoring over 24 hours; range of 272–286  $\mu$ A [3].

TECH

• Downlink and uplink  $BER < 10^{-14}$  (measured using FEC errors)

CMS

Downlink and uplink eye diagrams look good:



Downlink LpGBT v0 eve diagram.



Uplink eye diagram for primary LpGBT [3].



Uplink eye diagram for sub LpGBT [3].



## ME0 Frontend Electronics — OH v2 Review



- ME0 Optohybrid: ASIAGO (<u>AS</u>IC and <u>G</u>igabit <u>O</u>ptics)
- Version 2 under review (see [3]); should be finished by early Sep.
- Using halogen-free material for v2 PCB (ThunderClad 1+FR-15.1)
- Slight changes implemented due to VTRX+ changing
- 36 preproduction prototypes planned (preproduction will start when LpGBTs arrive in Sep.)
- All v2 OHs to be tested at UCLA test stand before distribution
- Recent issue: problems with I2C communication with LpGBTs [3]
  - Issue caused by LpGBT being reset twice during power-on (Schmitt trigger connected to external power-on reset)
  - Schmitt triggers removed for problematic boards
  - Reported to LpGBT designers
- Cooling system being designed for the ME0 OH which will connect to the main cooling circuit







### **ME0 On-Stack Gas Distribution**



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3 mm Gas-plug (input)



On-chamber gas distribution.

- GEM technical coordination proposing new on-stack gas system
- Change Control expected (layout and cost to change)
- In the TDR, on-stack gas is distributed in series
- From experience with GE1/1, we know that 6 modules in series will generate an overpressure of  $\sim$ 25–30 mbar in the first chamber
- Moving to a parallel gas distribution scheme
- Supply and return manifold designed and FLORIDA TECH
   Prototype produced



New design.

 To ensure uniform distribution of gas, copper capillaries or impedance needles will be used to keep impedance between manifold and on-chamber patch panel (PP) to 25 mbar

#### ME0 R&D Milestones



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- Several milestones accomplished over previous year [6]
- Delays [6]:
  - Full qualification of new layout is taking time (major performance gains justify waiting)
  - LpGBT v1 delays means frontend electronics delays
- · Foil PRR planning to be discussed with respect to vendor qualifications

Milestones (T5/E5)	ID.	Baseline (2017) (TDR)	Baseline (2020)	AR (2021)	Completion / Forecast
MEO R&D		100000			70381038
MEO R&D: Key detector system design parameters are defined based on performance requirements	ME0.RD.DET.1 ME0.RD.FE.1 ME0.RD.BE.1	2017-03-21	2017-03-21	2017-03-21	2017-03-21
ME0 R&D: Irradiation studies and assessment of performance and longevity with small prototypes completed	ME0.RD.DET.2	2017-07-11	2017-07-11	2017-07-11	2017-07-11
ME0 R&D: On-chamber & off-chamber electronics preliminary principal design complete and interfaces defined	ME0.RD.FE.2 ME0.RD.BE.2	2017-07-25	2017-07-25	2017-07-25	2017-07-25
MEO R&D: Chamber (stack) prototype mechanical design completed	MEO.RD.DET.3	2018-12-18	2018-12-18	2018-12-18	2018-12-18
ME0 R&D: On-chamber electronics engineering design completed and validated	ME0.RD.FE.3	2019-08-23	2020-08-21	2020-11-06	2020-12-02
MEO R&D: Chamber (stack) prototype mechanical prototype testing and validation complete	ME0.RD.DET.4	2019-12-24	2020-04-13	2020-09-29	2020-09-29
ME0 R&D: Full Characterization of sparks for ME0 (a new milestone requested by P2UG)			2020-05-29	2021-03-26	2021-12-31
MEO R&D: On-chamber electronics prototype electronics manufacturing and testing is complete	ME0.RD.FE.4	2020-08-21	2021-01-08	2021-01-08	2021-04-09
ME0 R&D: Integration of the on-chamber and off-chamber electronics and performance assessment complete	MEO.RD.BE.3	2021-01-08	2021-04-02	2021-04-02	2021-06-18
MEO R&D: Assessment of the electronics performance and integration with the demonstrator chamber completed	ME0.RD.DET.5 ME0.RD.FE.5	2021-03-30	2021-05-28	2021-05-28	2021-08-27
ME0 R&D: Beams and Cosmics testing of the demonstrator chamber and performance gualification completed	ME0.RD.DET.6	2021-08-31	2021-10-29	2021-10-29	2022-02-11
ME0 PRR for the Foll Production		2021-06-14	2021-06-25	2021-09-17	2022-02-11
MED ESR		2021-04-27	2021-12-01	2021-12-01	2022-02-11
MED Detector EDR		2021-10-28	2021-10-29	2021-10-29	2022-02-11





- "Additional" R&D for optimizing design to improve discharge protection and rate capabilities [6]
- A large improvement in design proposed to significantly improve rate capabilities
  - Crucial due to more stringent requirements than previously listed in the TDR
- Good progress, but amount of work has sharply increased (built ME0 modules with the new foils with longitudinal segmentation)
- Discharges not really a concern anymore, but full assessment is needed





- R&D activities coming to a close  $\Rightarrow$  should be mostly done by end of CY2021 [6]
- $\bullet~{\sim}2$  month delay compared to AR-2021
- Major improvements to design projected to significantly improve rate capability and discharge protection
- EDR and ESR planned for early 2022
  - Significant risks to schedule due to high density of activities
  - Additional delays ( ${\sim}1\text{-}2$  months) are likely





- Only a few delays accumulated over the last year [6]
  - $\bullet~\sim 1.5$  months, which probably can be mitigated
  - Relative to official LS-3 Schedule (will probably change!)
- Float need-by-date for construction is in 40 weeks
- Construction phase started by PRRs, ESR, and EDR

Milestones (T5/E5)	ID	Baseline (2017) (TDR)	Baseline (2020)	AR (2021)	Completion / Forecast
ME0 Construction					
ME0 On-Chamber Electronics Manufacturing and Testing complete, ready for chamber (stack) assembly	ME0.PR.FE.1	2022-03-29	2022-09-07	2022-09-07	2022-11-18
ME0 Chambers for Disk-1 are assembled, tested, and ready for installation	ME0.PR.DET.1	2023-05-04	2023-12-12	2024-04-12	2024-05-23
ME0 Off-Chamber Electronics Manufacturing & Testing complete	ME0.PR.BE.1	2023-06-08	2023-06-08	2023-06-08	2023-06-08
ME0 Chambers for Disk-2 are assembled, tested, and ready for installation	ME0.PR.DET.2	2024-03-07	2024-10-15	2025-02-14	2025-03-27
All MEO Stacks Installed in the New Nose. Detector is ready for installation as part of the endcap at Pt. 5	ME0.PR.DET.3	2024-05-23	2026-03-23	2026-03-23	2026-03-23
Construction Project Complete. Ready for Global System Commissioning	ME0.PR.DET.4 ME0.PR.FE.2 ME0.PR.BE.2	2025-09-12	2026-05-28	2026-05-28	2026-05-28





- Finalizing GEB design, transitioning to bPOL DC-DC converters, packaging for VFAT3bs expected in 2022
- Firmware and software for integration purposes fully written, implemented, and tested at CERN, UCLA, and FIT
- ME0 OH v2 to start preproduction in Sep. after LpGBTs arrive
- Change control expected for the on-stack gas distribution system
  - First full prototype expected in early autumn
- Several milestones achieved over the past year
- R&D activities almost finished; small delay (~2 months) expected
- New aging and rate capability studies underway due to more stringent requirements
- EDR and ESR projected for early 2022
- $\bullet~\sim\!\!1.5$  month delay for construction, 40 weeks of float

#### References



- CMS Collaboration, The Phase-2 Upgrade of the CMS Muon Detectors, Technical Report CERN-LHCC-2017-012, CMS-TDR-016 (2017).
- M. Bianco, "Possible modifications for future ME0 GEBs," presented at the GEM Phase-2 Electronics Meeting, Aug. 12, 2021, https://indico.cern.ch/event/1064795/contributions/4478589/attachments/ 2293706/3900310/ME0\_GEB\_ChangeDesign\_Request.pdf.
- [3] J. Carlson, et al., "ME0 Optohybrid v2 Design Review," presented at the GEM Phase-2 Electronics Meeting, Jul. 29, 2021, https://indico.cern.ch/event/1062189/ contributions/4466997/attachments/2287668/3891468/ME0\_OHv2\_Review.pdf.
- [4] J. Carlson, et al., "BPOL12V Power Efficiency," presented at the GEM Phase-2 Electronics Meeting, Jun. 17, 2021, https://indico.cern.ch/event/1047777/contributions/ 4413040/attachments/2266480/3851710/2021.06.17\_Phase2\_Update.pdf.
- [5] A. Datta et al., "ME0 Optohybrid-v2 Review Status Update," presented at the GEM Phase-2 Electronics Meeting, Aug. 26, 2021,https://indico.cern.ch/event/1068179/contributions/4491721/ attachments/2298330/3910111/ME0\_OH\_v2\_Review\_Status\_2.pdf.
- [6] A. Safanov & M. Hohlmann, "GEM Phase-2 Project: Schedule Status," presented at the GEM Phase-2 Upgrade Coordination Meeting, Aug. 27, 2021, https://indico.cern.ch/event/1070338/contributions/4500871/attachments/ 2301735/3915369/GEM-Milestones-PrepForAR2021-20210901.pdf.





# Backup





- Baseline schedule (approved Mar. 2020) [6]
  - EDR: Oct. 29, 2021
  - ESR: Dec. 1, 2021
  - Separate PRR for foils (Jun. 21, 2021)

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#### ME0 R&D Schedule Forecast



• Forecasted R&D schedule [6]:

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#### **ME0** Construction Schedule Forecast



• Forecasted construction schedule [6]:

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DAX NUMBER	MED DD Wand by State has READY FOR INDIALLAPIDE second HOC Prove TO, opended to 19898		Det #1,2888			A BREAK BARRING BARRING . + C-1
· han we should a	INST EX Installation Microse Barts personnel to be a fixed sets by DAE TO		AN1 12, 2020			and Div Andrease Markets - Torong
I PAA IN MILLION	MESTIC Ease. T Charteen installed one the New Noos		.Apr. 26, 2000			will be the r Genteen in
1 223 10 592 541	MED THE Date of Characteria transled into the New Yorks		Feb 18, 1038	Lost additional ~1.5		and in the description in 1994
7.23.8 43.889.890	INEE The Observation stands any construction and connectivity making at PS completed		Mar 25, #228	Lust additional 1.5	/	MDTI-Danker Maritium
8 233 10,882 544	MED Th: All MED Stands installed in this New York. Catentist is ready for installation as part of the anciency at PL/ (Chamilton as at 2000)	100119-0033	Mar 23, 028	months of float to		and "A shifted finds in
8 F.B.A. 16 A02 AND	MED IN Installation Rivelan Drop januared is in a fixed data by CME TO		Mar 21, 3026			HELES And Address of Printer, Co. S.
8 23.8.10.107.6	MID TO Low TAXD Spring Integration Complete, ready for comparison with ICAD of PE (MID) AV CoVE FOR CPV CHAMBER ELECTRONICS		April 2, 2528	installation since last		ME TO LOUGH MAL Ayeseen
	MEET'S DRC/Rectored Sates Fait Instal HartwareEshareFremere Integrates Congene. Next, to Commentering		54by 28, 2020	year now ~40 weeks		HE IS DAD BALLAND
0.000.000.014	ARE FLORI DisGillerhonte system wardy for communicity to CMS meeting, date		Mey 25, 2000	fear, non to weeks		MER KUNK ENGR
A 133.00300.000	MEI 19. Louisveller Project Complete Parity for fall belong Summadoring	MERIPHINES MERIPHINES	inay 28, 2008			MET & Dominikar Prod. 400
	* Annual Mantana		00108-000		States Manager 197	





#### • Aging and rate studies schedule [6]:

a new lot	100		Interior Delivery	Content Ball	2016	_	1000	-		21	-	20100	-	-	1975	-		4	-	100	_	_	2628	-
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1,779 53351041		MED Additional Field of Operational Parameters and Electropresity Fedare		Aug 5, 2020	460	Automa Pat	attes, T	_	-	-	-		-		_	-	-		-		_		_	12
1714 223210411		* April bein to mark the spinned radiation hardware magnetization		Aug 1, 2000	1.444			-		_	-		_		_	-	_		-		_		-	-
179 3335154111		MDI-Aging twole CBIMC Fulls - Awdreic Facility - Phase I (HL-CHC Salery Scillar 1)		Autom	10	Any interest	emne. 🔳																	_
1.778 2838104518		MIC April Tells COMPLICATE Autom Facility - Profession Assessment S.C.CHC Servey Scale (3.28)		NW 12, 2227				C276 N	4. 404															
1797 2538104112		MOI Aging team: DEPA Trols - Auctor: Facinty - Phase I (HL-LHC Seleny factor 1) Complete		April 10, 2002					1410 April	-	14. 14													
1798 2038104111		MD Apro Metric CORE Fols - Auction Facility - Phase 8 (4), CHC Selley factor (5)		April 10.2002					1.000	rane i	min.	2071												
1.79 2332104112		MEE Aging basis: CEEM Fully - Australi Facility - Phase # (HL-LHC) being tacker to Considera		100104,2020									RT-April W	4 14	100 A	Ø								
1780 0004104111		MO Apry sure CRIM Fully - Award Facility - Place II-DR, LHC Surey Surer II		01218.0225									Adverse	(init)	CIPTING.	123			231					
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1782 133210-0.11		AND Aging India Mexian Follo-Bosol Faulty - Planet (HL-CHC Splity Saller 1)		Percel, SHE		100 1010	an many																	
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1794 2223104112		MD Apry mate Neoara Fola - Bood Facility - Phase F.M. LHC Safety Sector 11 Complete		Pion 0. 21020						101.4	rig were to	east fair-	-0-											
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1788 12251545.18		MD Apry Nets Means Fold - Book Facility - Maas H (H, CHC Barry Setter & Company		0.018.309																	int And a		444.	64
1700 222210/01/		<ul> <li>Integrated Optimization of Design Parameters and Specificand Monting Pullets for their Copublishes and Electrony Protection</li> </ul>		Get 5, 2028		-		-	-	-														
1700 0534104114		▼ BV Participance Optimization for Reproved Fade Experiettes		Get 5, 2003		Pi Patrice	deserved and	-	_	-														
1.797 053810451		MED Swaps Adjustment for Improved Flats Expelifies. W Partitioning Optimization		Ger 5, 2000		All large h	Sector Int.	1																
1790 2222440402		Production of an MEB stack with two optimization		No 20, 2021			President of all	ciett de		1.1														
1700 0533(10.41.1.)		Alexanization of effective gate companyation with imployed checkyn		My 12, 2901			1.000			100 m														
1794 233210411		WEID Design with reproved Falls Capabilities Vehicles		Dec 10.0001				hear of	· ······	100														
LTHE 050810411.		Operational operations and line turing of the design		Dec 15, 20(1)			-			- 900	1													
178 055816461		Validation of the improved design		Dec 6.001				-	a a second															
1797 0.53810411.		wEit/ Insupr with Improved Faits Capacitizes Company		Fat 11, 2002					il long at	the state	100													
1798 2538104114		▼ HV Filter Optimization for improved Rela-Yitecharge Separatemen		Mar 25, 9925			In the Option	****	- 590		1													
1798 053810411.		MED W/ Fiter Owage: Adjustment for Imprived Fade/Discharge Capalities		Her 25, 2001			stices inchased	***	- C)-															
1300 2223510411.		MED WY File Design to reprive MEX Republicharge Capitolines Veloped		NW 21, 2001			MET IN THE D		- 90	1.11														
1.87 12234104114		▼ #0 Protection Circuit Design Optimization for Improved Rate/Decharge Capobilities		940 10, MET			1.000	-	trade limited	040	- P - [													
1.000 202810-011		HEO INC Presenton Design Adjustment for Improved ReseDisements Cognition		Dep 15, 2101				10.00	the Delays (	35														
1.80 2238104.1		MEE: telesis the MD Protection Design for Improved WEE Addressing Experience		Got 11, 9081				H2 14	100 Pe. 107	- 0	h													
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1.89 2533104118		MEX MAX The Equation integrated Galage with Improved Redw/Hartwage Capabilities Validance and Company		Owentr. Mills				<b>MORE</b>	1.11		01													
1,898 05381044.15		MED WAID The Full strepstort Design with Improved Res-Strentweps Opperatives Vesitions and Econyme		Feb 11, 9572				1 M	i inter de rei	wagnie.	500							- 10						

