



Design Optimization and Initial Performance of the GEM GE2/1 Detector



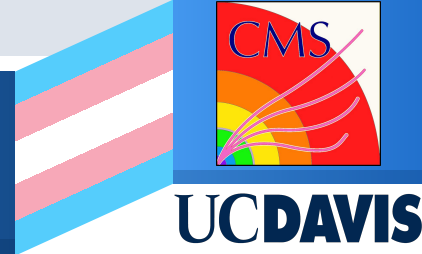
Samantha Abbott
(She/Her)

**On behalf of the
CMS Collaboration**

**July 9th,
2022**

**ICHEP 2022
Bologna, Italy**

UC DAVIS



The Next 15 Minutes

- ▶ **Overview of GEM / GE2/1**
 - ▶ **CMS:** Everyone's Favorite Cylindrical Onion
 - ▶ **GEMs:** More Precious Than Diamonds
 - ▶ **GE2/1:** Electric Boogaloo
 - ▶ **L1Mu:** Leveling Up the Muon Trigger
- ▶ **Improvements from GE1/1**
 - ▶ **VFAT3 Plugin Cards:** Bending the Rules
 - ▶ **Cooling:** I Liked GEMs Before They Were Cool...
- ▶ **GE2/1 Demonstrator**
 - ▶ **Demonstrator:** GE2/1's First Draft
 - ▶ **Installation:** An Addition to the Onion
 - ▶ **S-curves:** Aptly Named
 - ▶ **Performance:** Efficient at Being Quiet
 - ▶ **Occupancy:** In Love With the Shape of You
- ▶ **What's Next?**

Overview of GEM / GE2/1

CMS: Everyone's Favorite Cylindrical Onion

GEMs: More Precious Than Diamonds

GE2/1: Electric Boogaloo

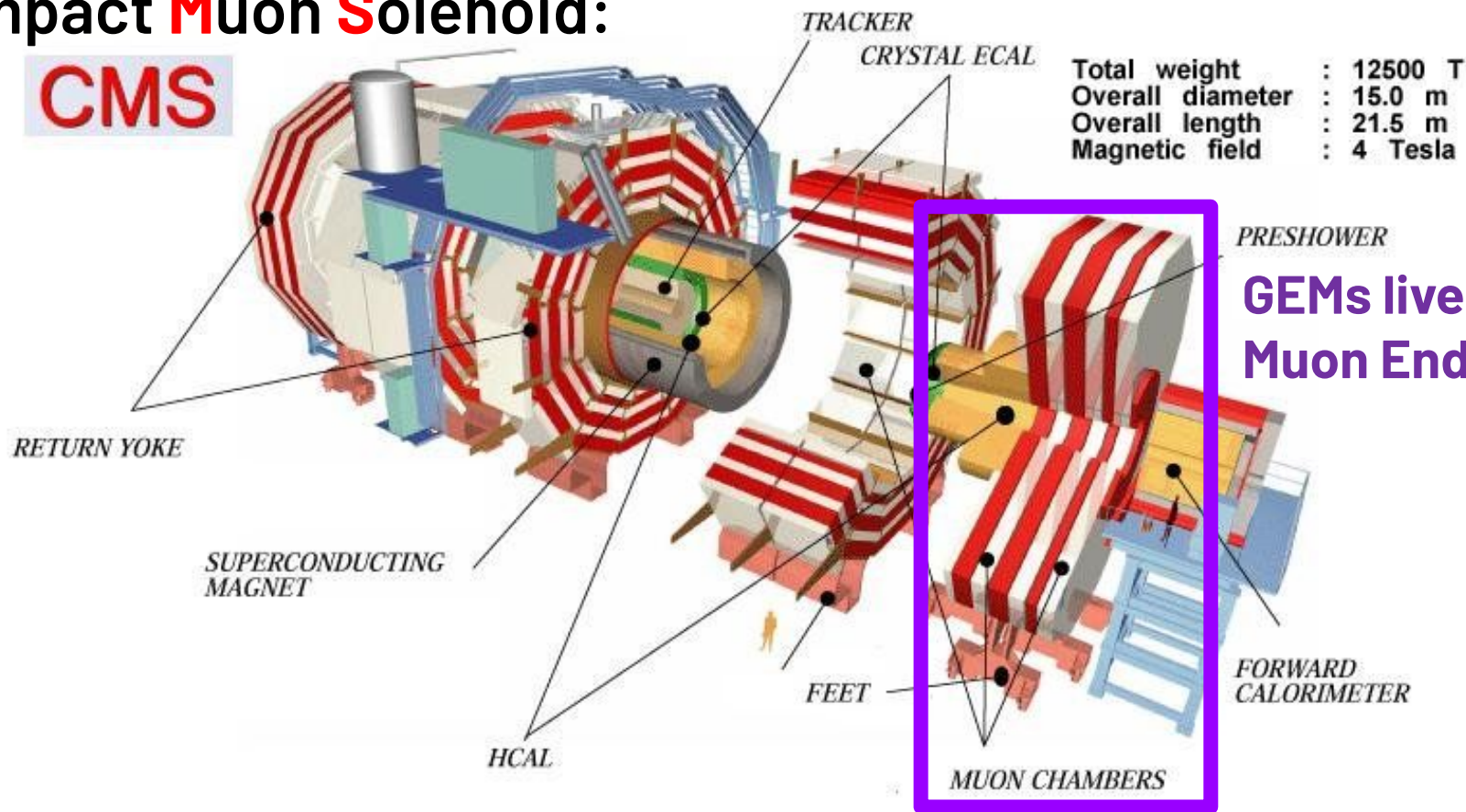
L1Mu: Leveling Up the Muon Trigger



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CMS: Everyone's Favorite Cylindrical Onion

Compact Muon Solenoid:

CMS*PRESHOWER*

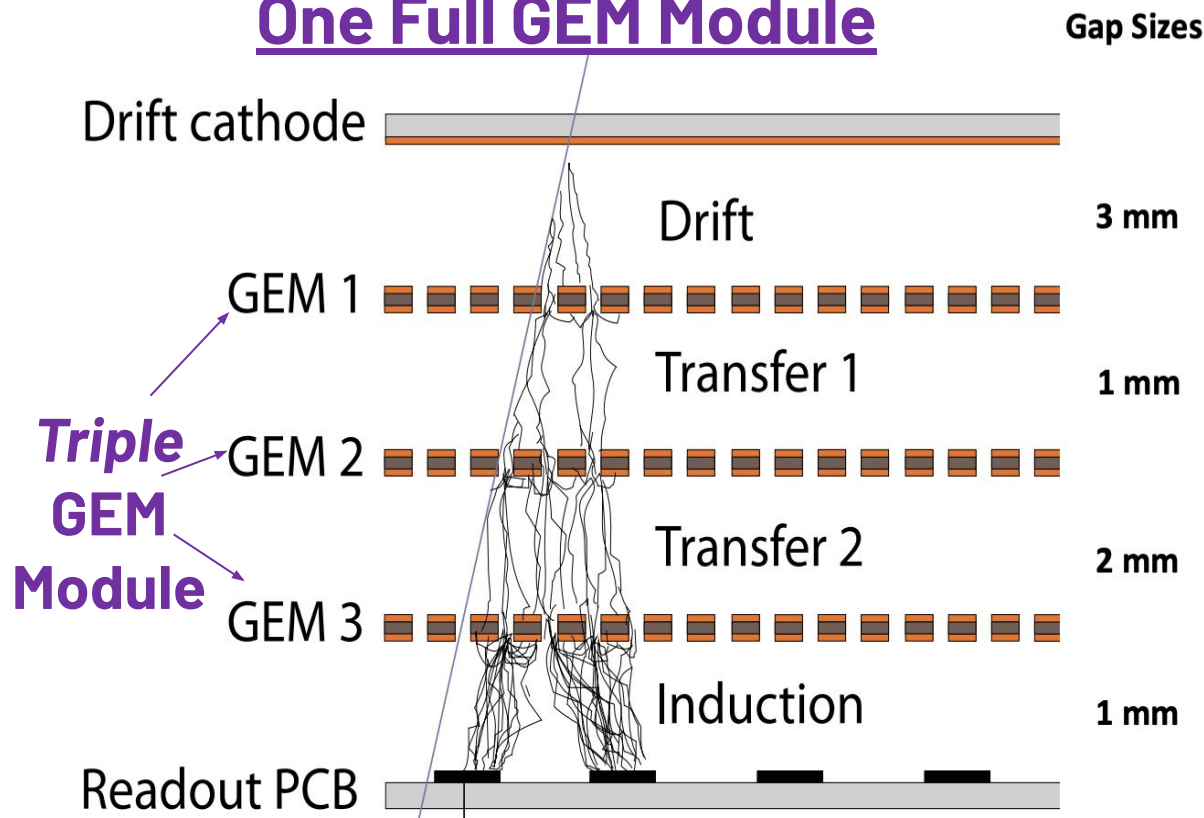
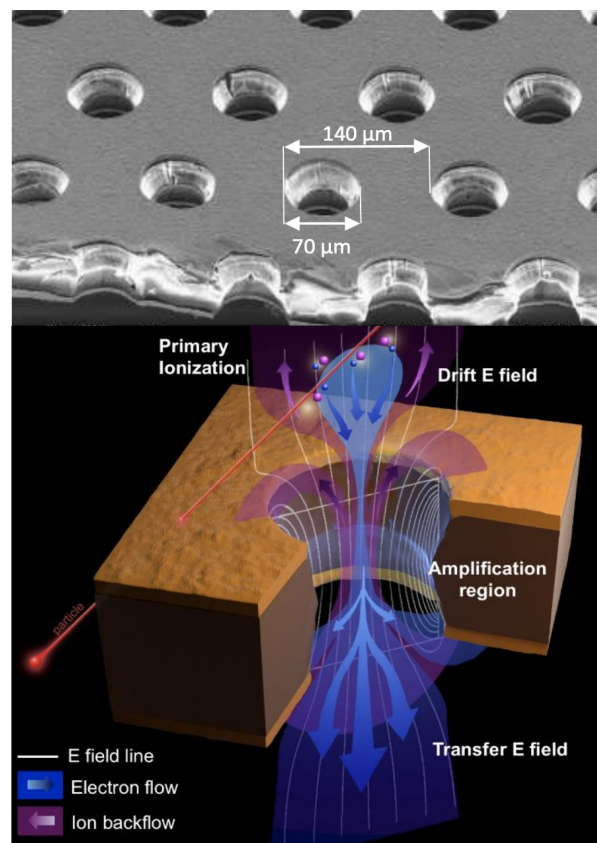
**GEMs live in the
Muon Endcaps!**

*FORWARD
CALORIMETER**MUON CHAMBERS*

GEMs: More Precious Than Diamonds

Gas Electron Multipliers:

One Full GEM Module

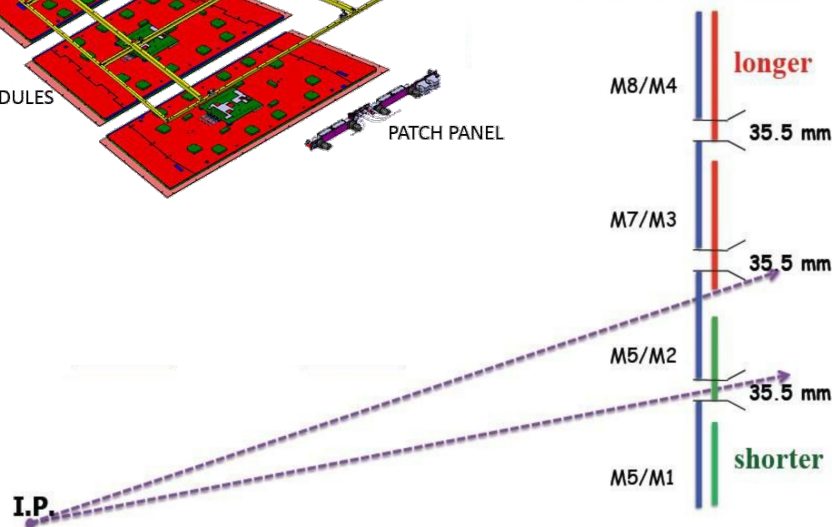
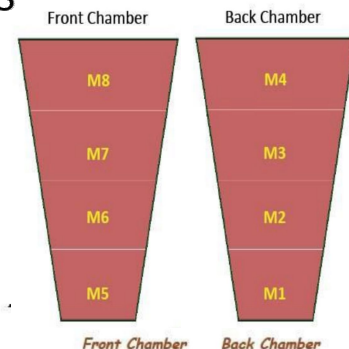
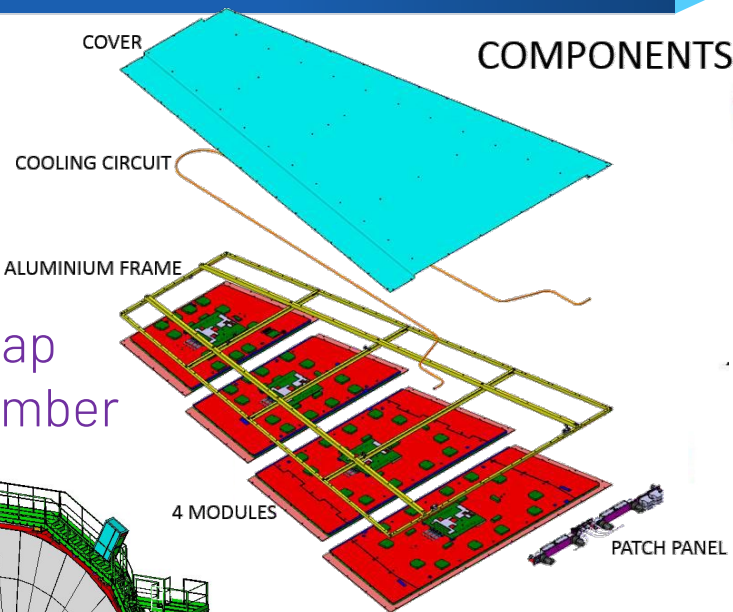
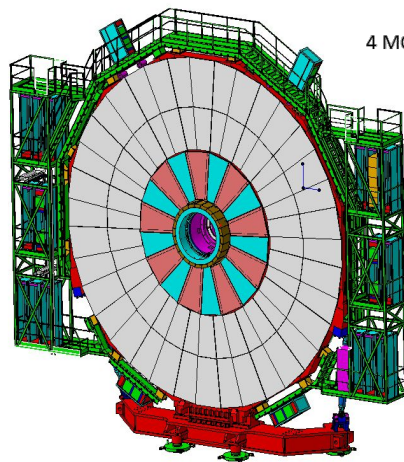
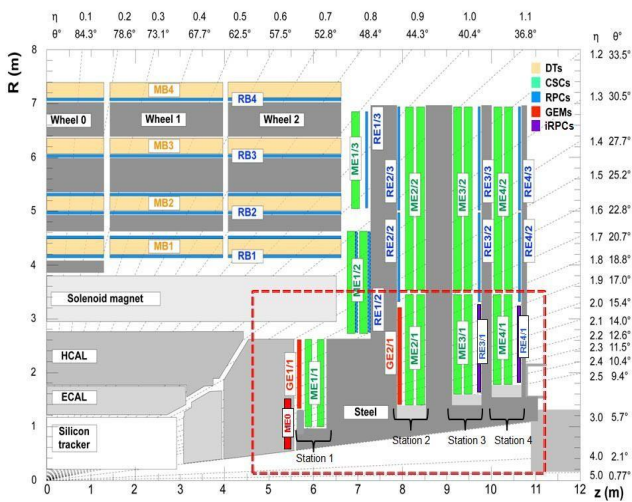


GE2/1: Electric Boogaloo

GEM Endcap Station 2 Ring 1:

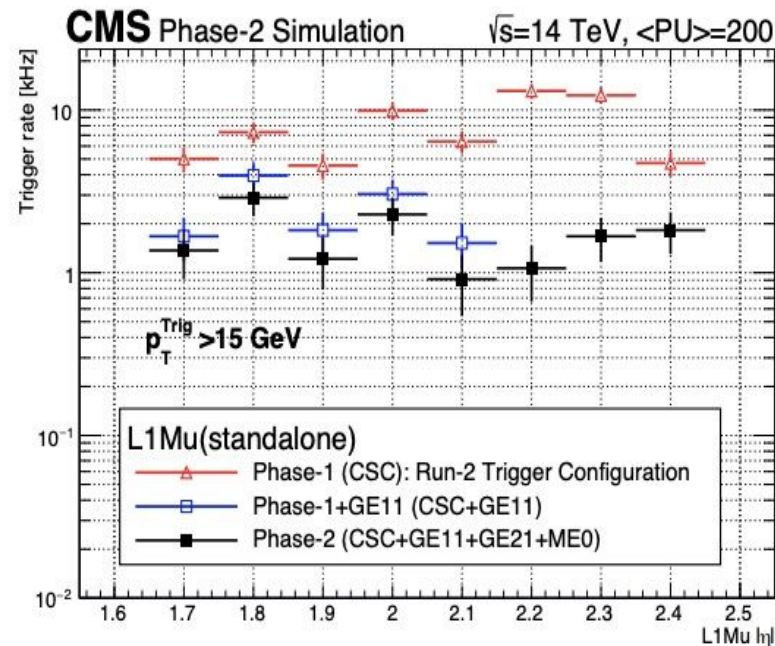
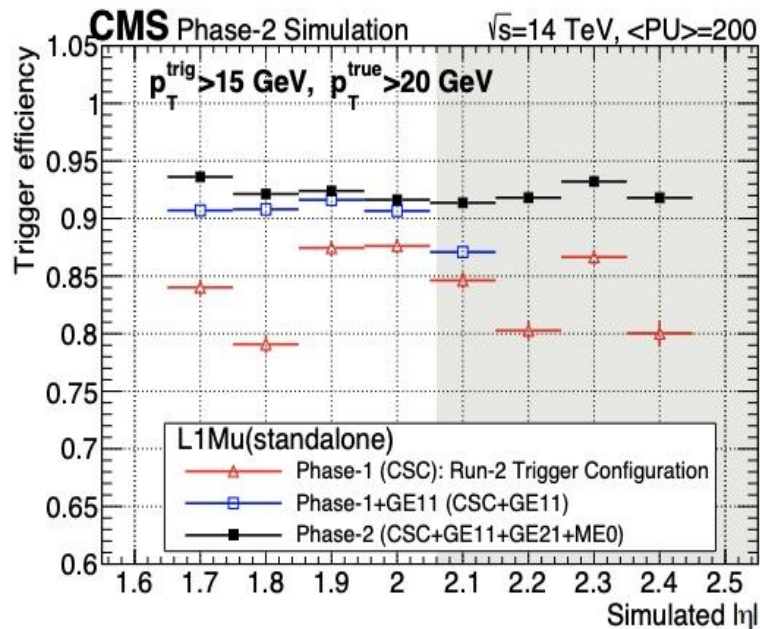
► GE2/1 Detector System

- 72 total chambers
- 20° chambers
- Arranged in 2 layers per Endcap
- 4 triple GEM modules per chamber



L1Mu: Leveling Up the Muon Trigger

- ▶ GE2/1 is part of a larger set of muon upgrades
 - ▶ Specifically targeting the high luminosity operating regime
 - ▶ Improves standalone muon (L1Mu) trigger
 - ▶ Avoids large increases in trigger rate
 - ▶ Improves trigger efficiency



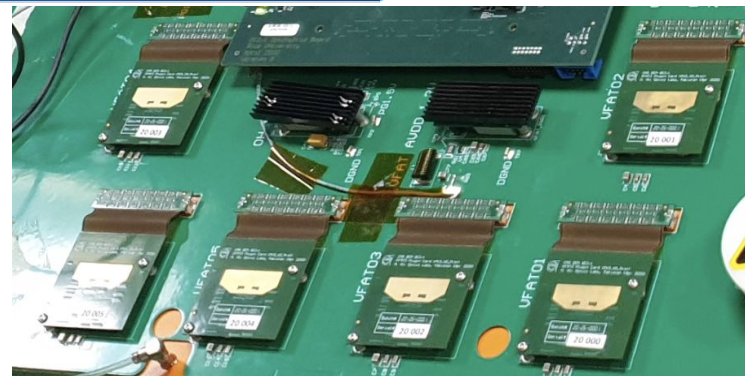
Improvements from GE1/1

VFAT3 Plugin Cards: Bending the Rules

Cooling: I Liked GEMs Before They Were Cool...

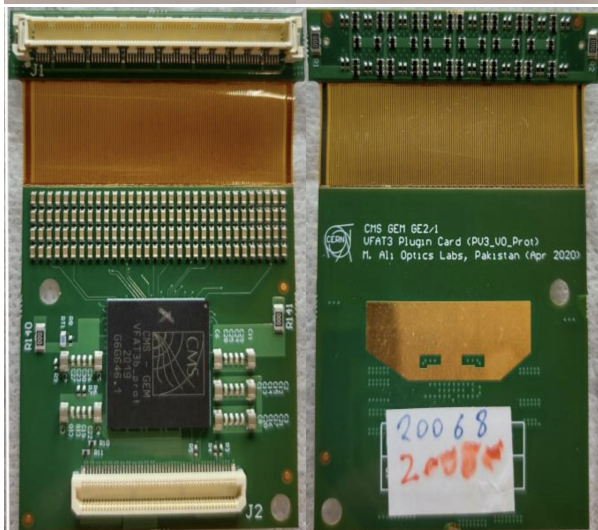
VFAT3 Plugin Cards: Bending the Rules

GE1/1:
Rigid



Note the bending!

GE2/1:
Flexible

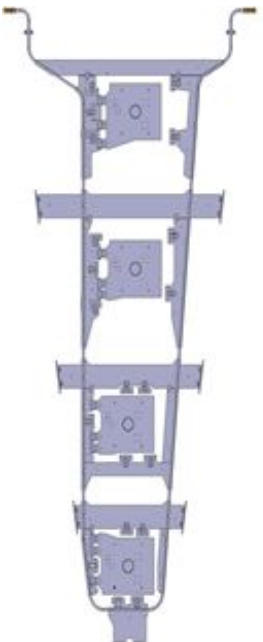
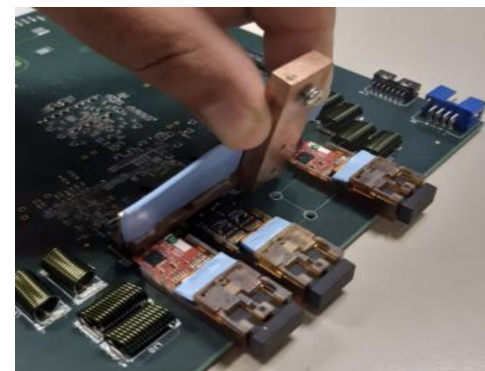
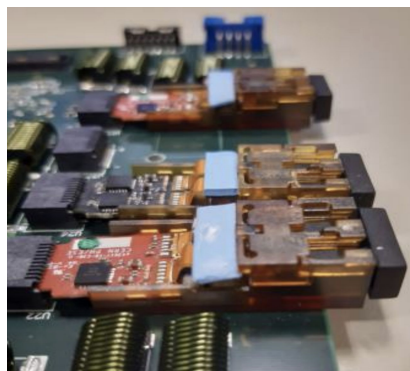




Cooling: I Liked GEMs Before They Were Cool...

- ▶ Water Cooling
 - ▶ Single piece
 - ▶ More Flexible

- ▶ Optical Transceivers had outgassing issues
 - ▶ Solution: Add custom cooling plate



GE2/1 Demonstrator

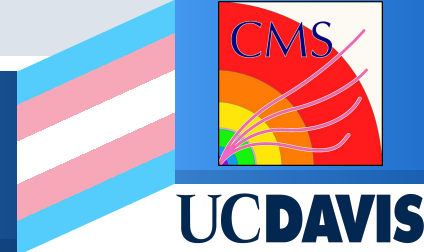
Demonstrator: GE2/1's First Draft

Installation: An Addition to the Onion

S-curves: Aptly Named

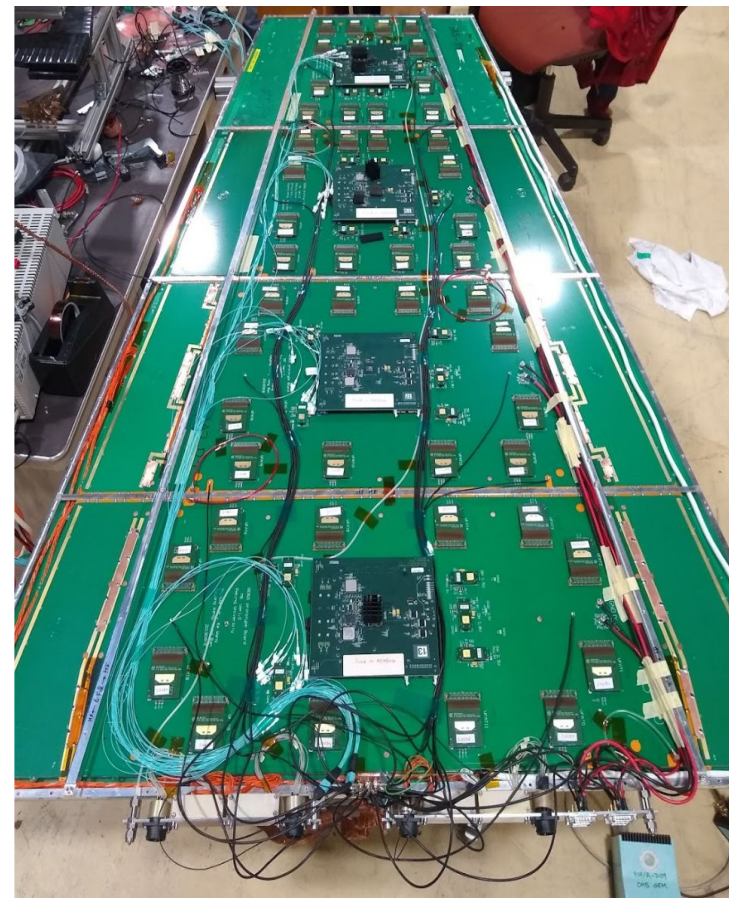
Performance: Efficient at Being Quiet

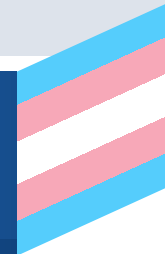
Occupancy: In Love With the Shape of You



Demonstrator: GE2/1's First Draft

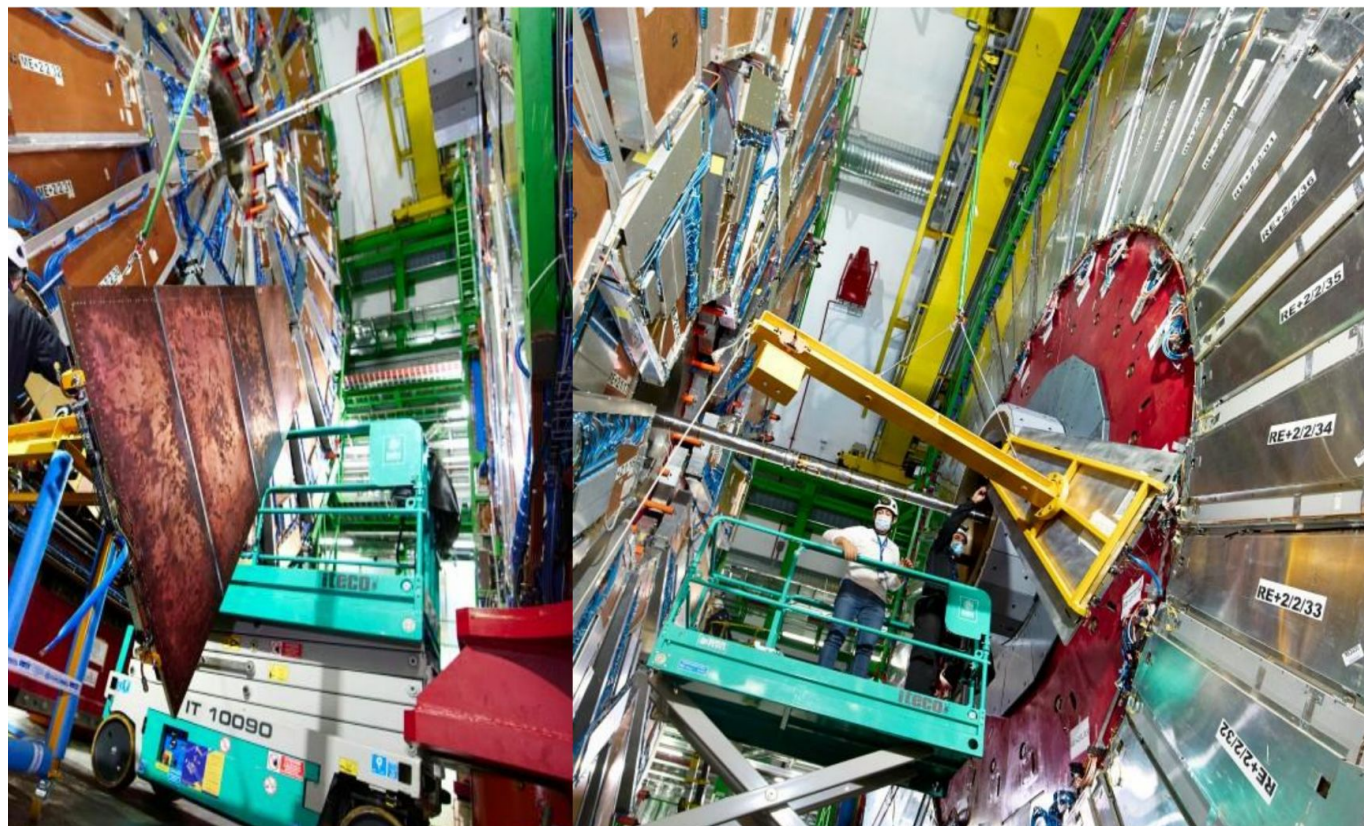
- ▶ Gain operational experience:
 - ▶ Power system
 - ▶ HV filter optimization
 - ▶ Detector Control System (DCS)
 - ▶ Connections for full detector installation
- ▶ Make confirmatory measurements:
 - ▶ Dead channels
 - ▶ Noise rates
 - ▶ Cross-talk
 - ▶ Basic performance parameters vs. HV





Installation: An Addition to the Onion

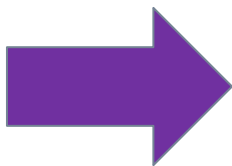
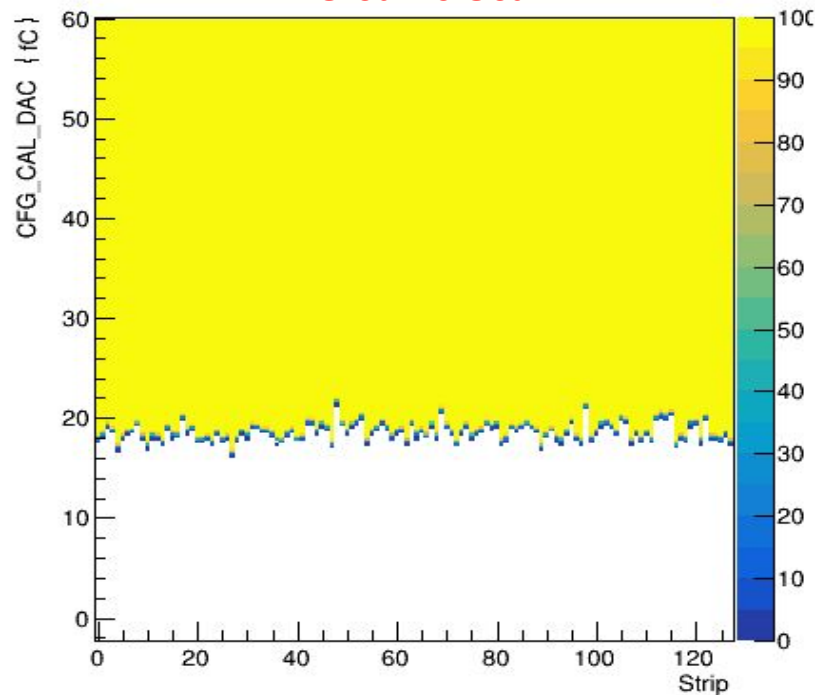
- ▶ Commissioning ongoing
 - ▶ Integrating into central system
 - ▶ Safety system
 - ▶ DAQ



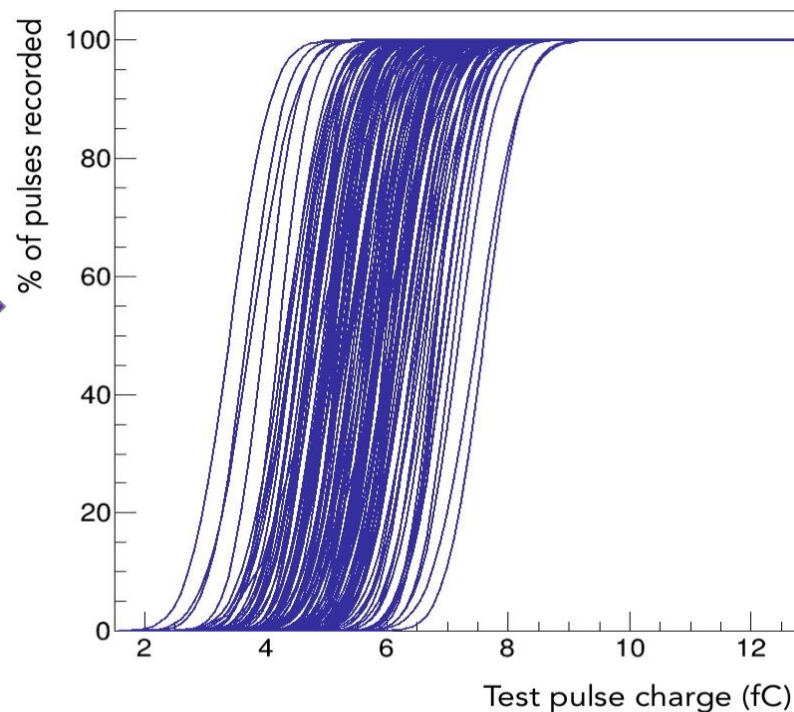
S-curves: Aptly Named

- ▶ Typical check during electronics integration
 - ▶ S-curve: Checks VFAT response to increasing test pulse charge

S-curve Scan



Individual S-curves

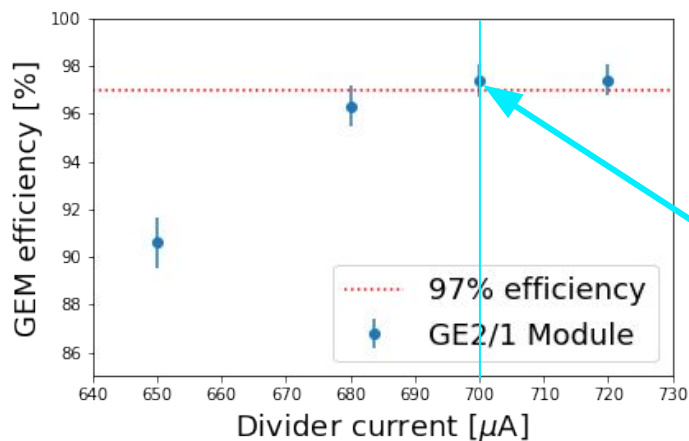


Performance: Efficient at Being Quiet

► GE2/1 Performance

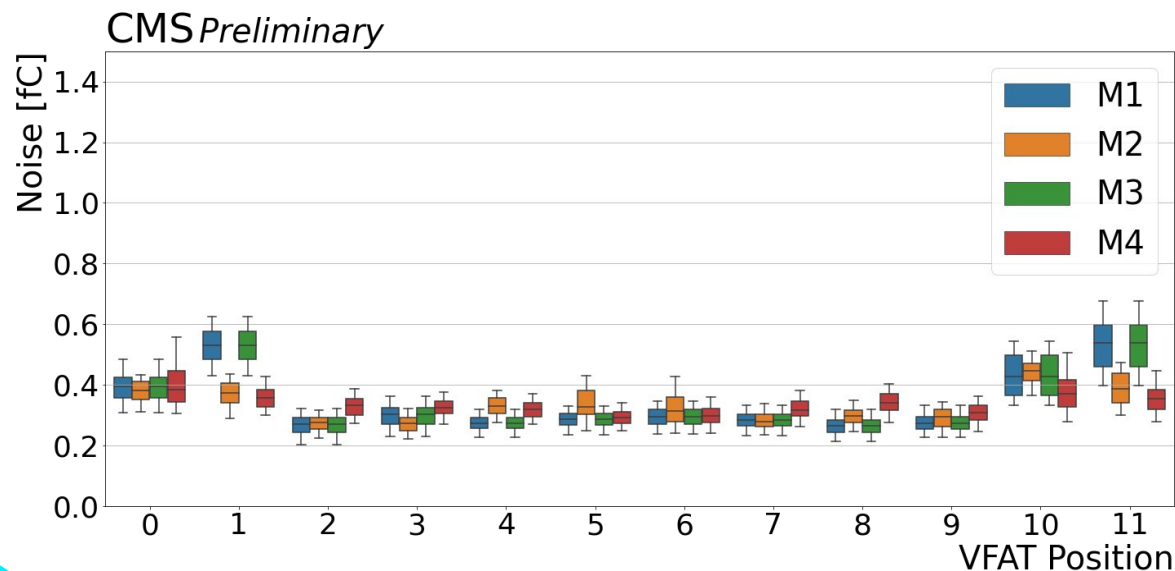
- High efficiency
- Low noise

Efficiency Scan



Working Point

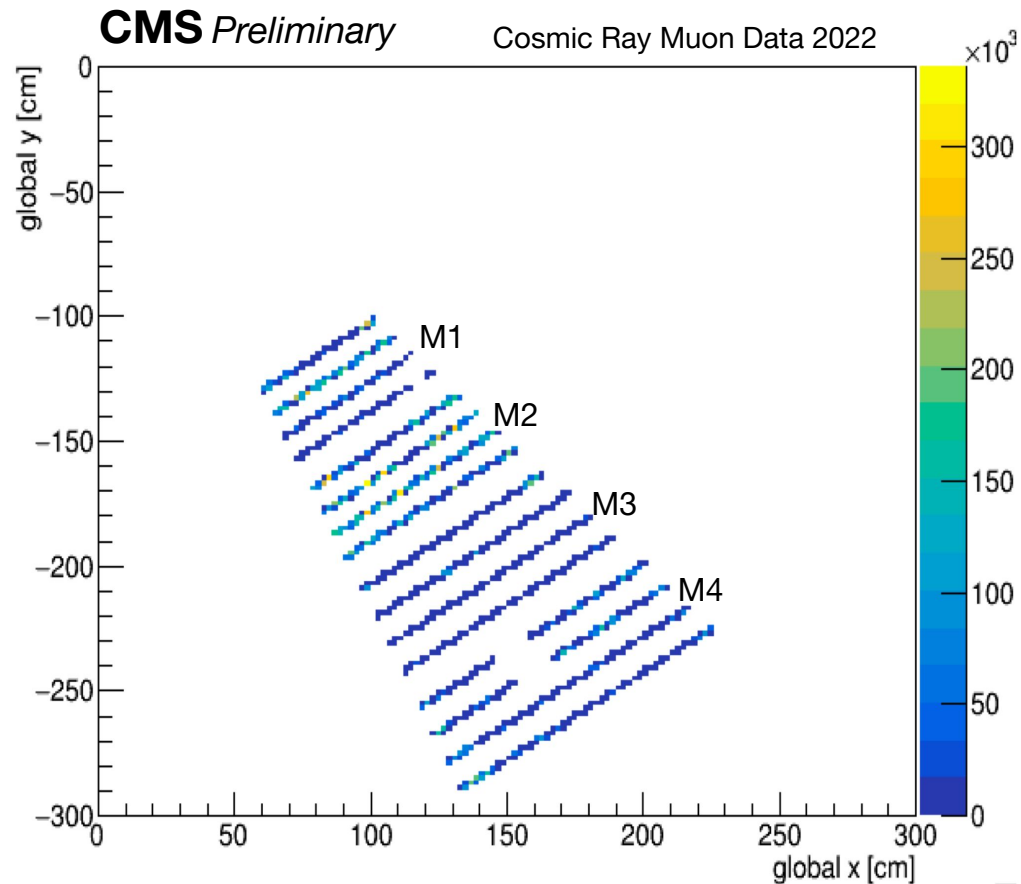
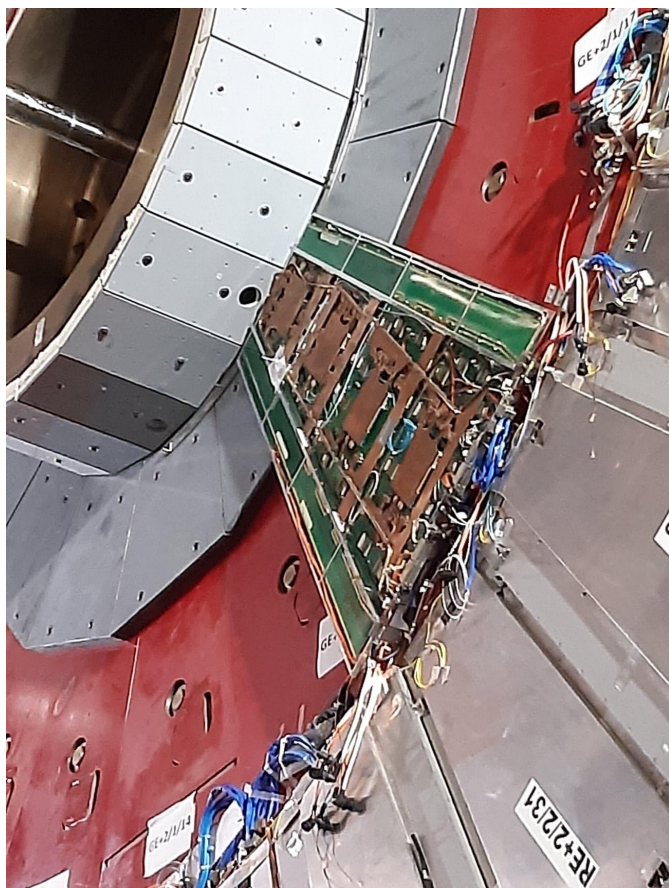
Noise level scan



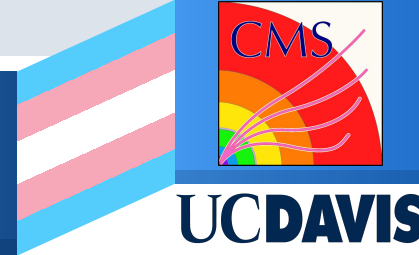


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Occupancy: In Love With the Shape of You

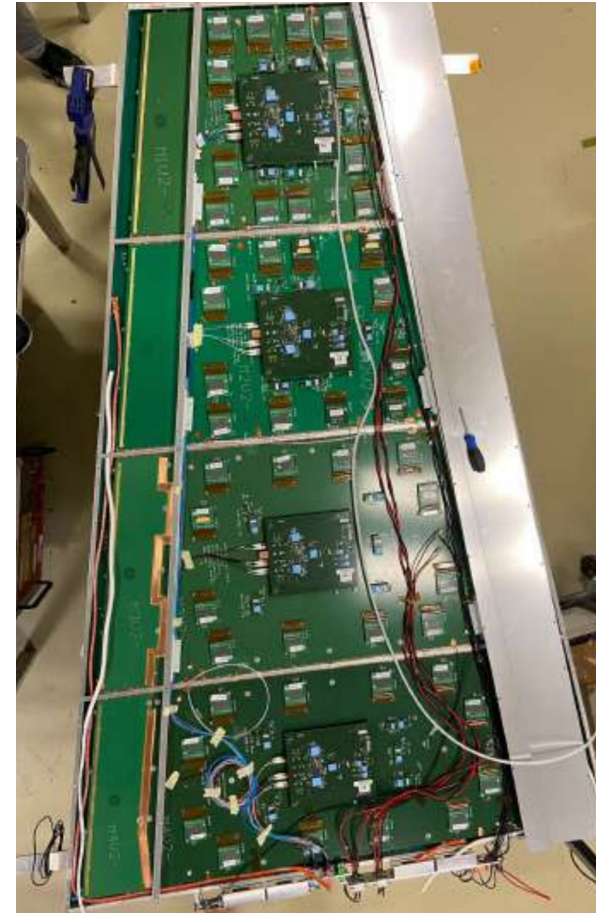


What's Next?



What's Next?

- ▶ GE2/1 mass production ongoing
 - ▶ Will be ready for full installation in a few years
- ▶ First chamber assembled!
 - ▶ Electronics integration complete
 - ▶ Full chamber
 - ▶ Final electronics design
 - ▶ Ready for cosmic testing
 - ▶ Check efficiencies, etc.





CMS Experiment at the LHC, CERN

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