LUIGI BENUSSI

GEM WORKSHOP

September 24, 2019

GE2/1 CHAMBERS: DESIGN, PROTOTYPES, PRODUCTION READINESS AND PRODUCTION SCHEDULE

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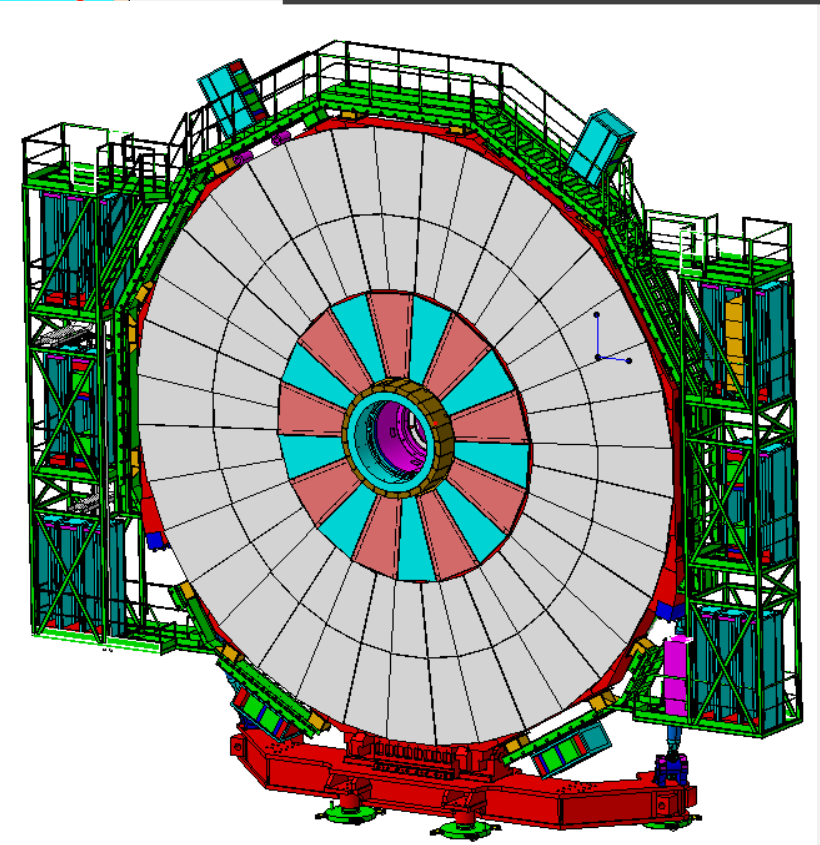
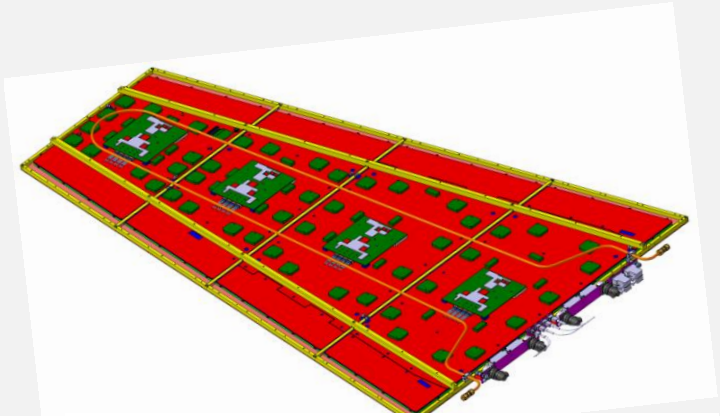
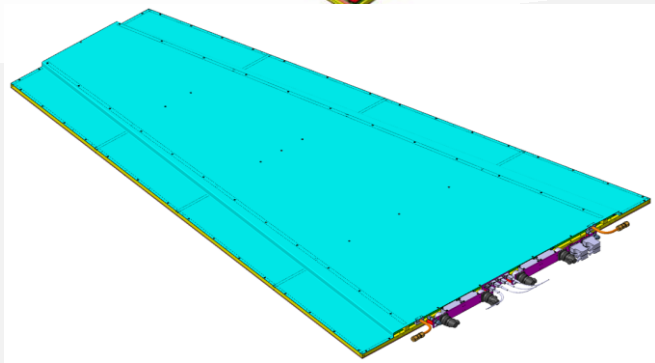
OVERVIEW

- GE2/1 Project Status
  - Updates since EDR
  - Integration tests with prototypes
    - Mechanical tests
    - Electronics Integration
  - Production overview
    - Production Readiness and Planning
    - Risk Management
  - Summary

GE2/1 PROJECT OVERVIEW





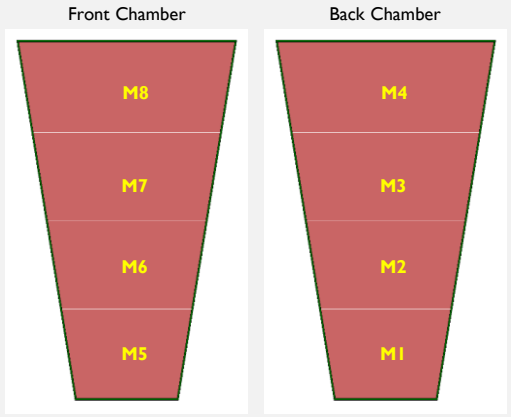


- GE2/1 station consists of 36 20° chambers
- Same technical solution as for GE1/1
- Two independent GE2/1 chambers will form on the YE1/1 disk a Super Chamber

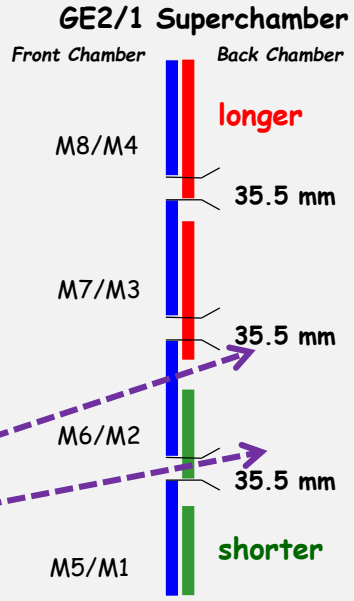
GE2/1 CHAMBERS LAYOUT

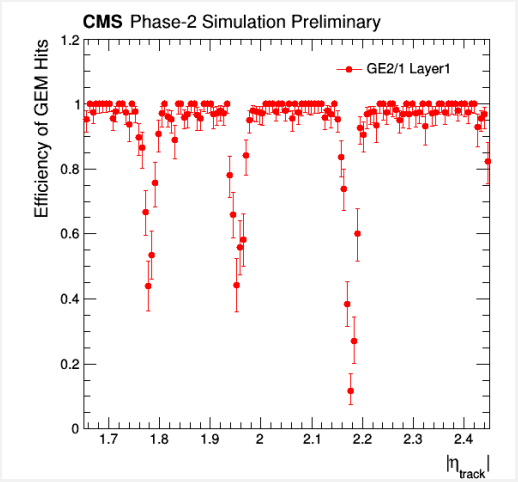
With a single layer, the average acceptance × efficiency would be reduced to 92% due to gaps.

To achieve maximum coverage, modules in front and back chambers will be staggered.
As a consequence, eight different types of modules will be
designed and produced.

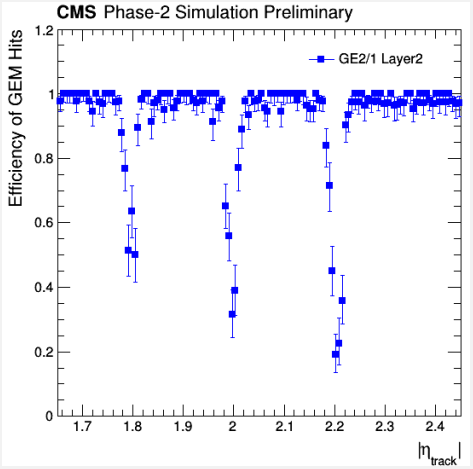


8 GE2/1 Triple-GEM Modules

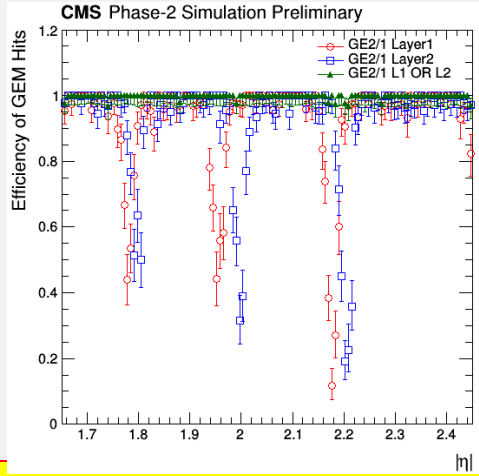




Front Chamber Hit Efficiency



Back Chamber Hit Efficiency



Super Chamber Hit Efficiency (OR)

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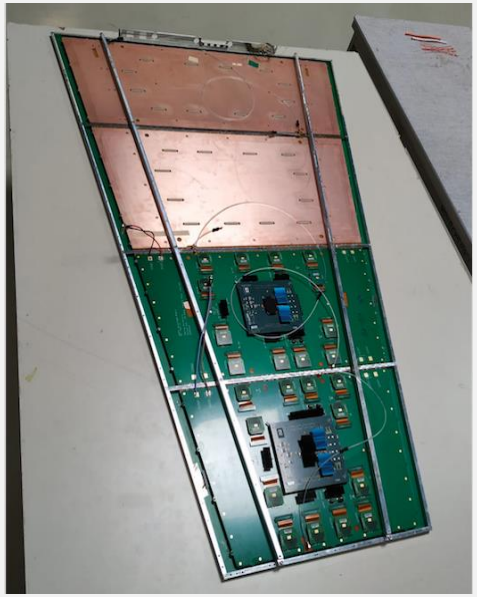
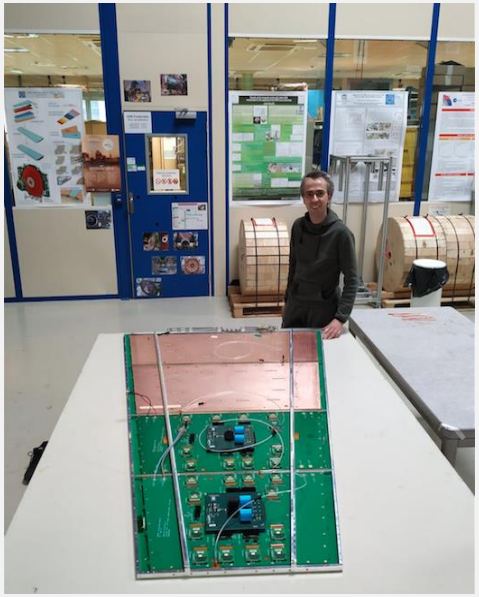
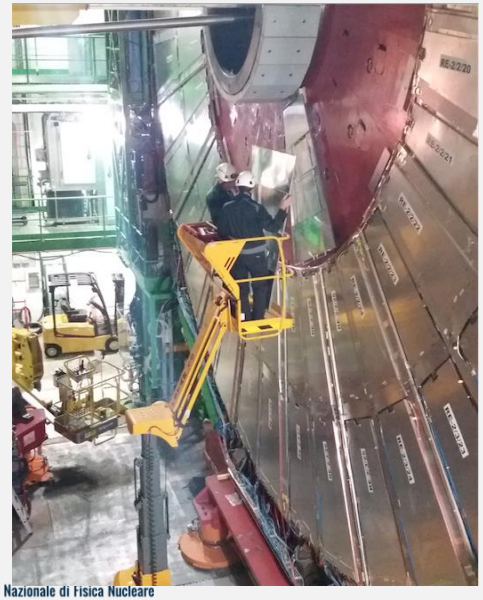
GE2/1 MECHANICAL TEST

- Two GE2/1 chambers forming a Super Chamber fully assembled, tested and mechanically integrated
- Mechanics for chamber installation validated in situ







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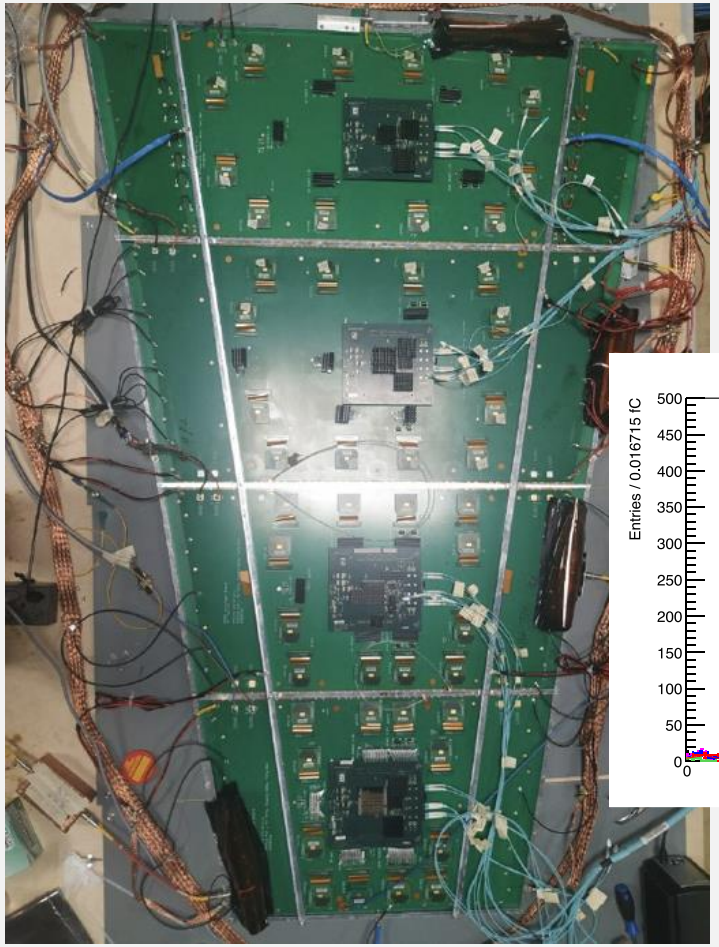
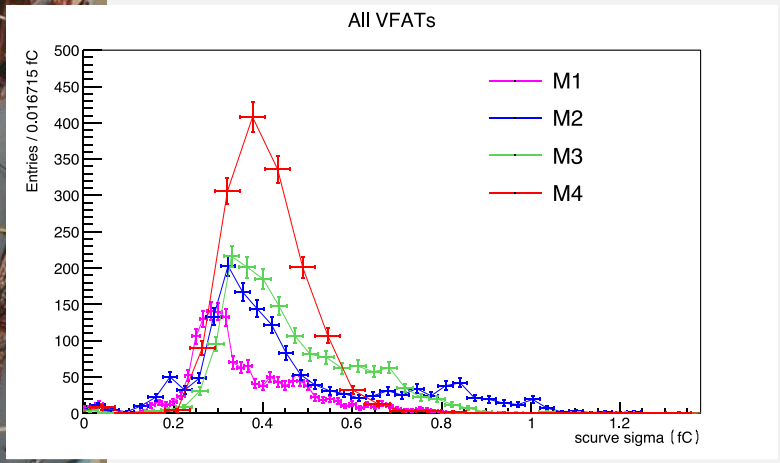
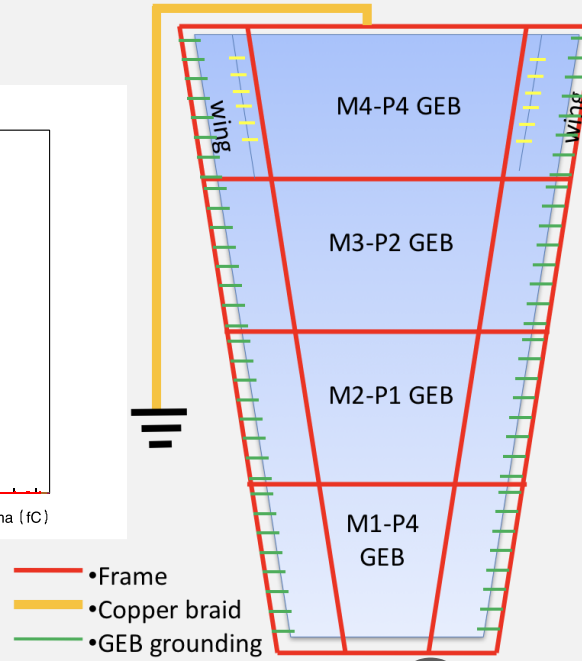
GE2/1 ELECTRONICS INTEGRATION

- GE2/1 M1-M4 prototype modules with all mezzanine components are produced and integrated



- Ultimate grounding scheme identified with the noise level under 0.6fC





GE2/1 R&D STEPS TO COMPLETION

- Complete GEB boards M6-M8
  - Timeline: by the end of 2019
- Minor adjustments and optimization of OptoHybrid and select GEB boards to correct small mechanical issues
- Validate packaged VFAT3 chips
- Optimize VFAT3 chip protection and manufacture PlugIn Cards
  - PlugIn Cards design is almost ready, await for pinout confirmation from manufacturer
- Integrate and test, including proof of principle with ATCA backend
  - ATCA backend ordered, estimated delivery: Nov. 2019

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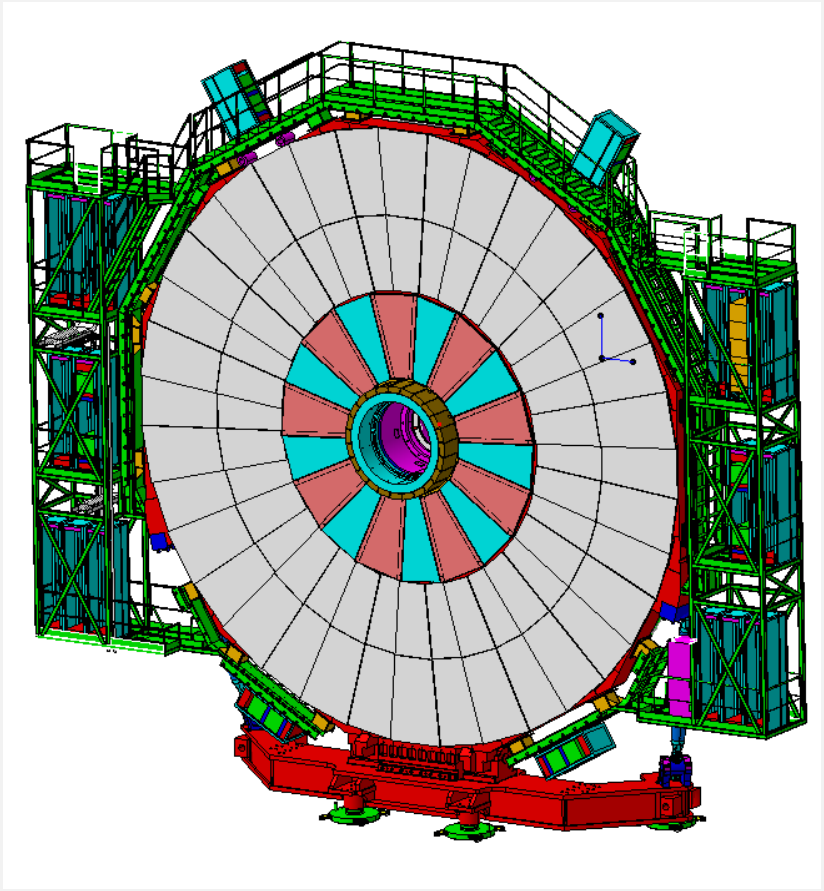
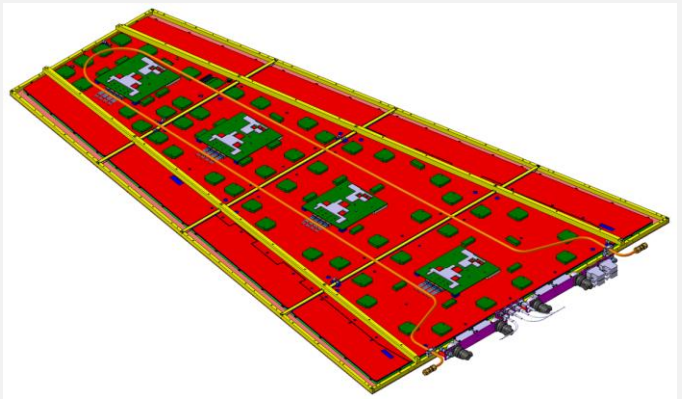
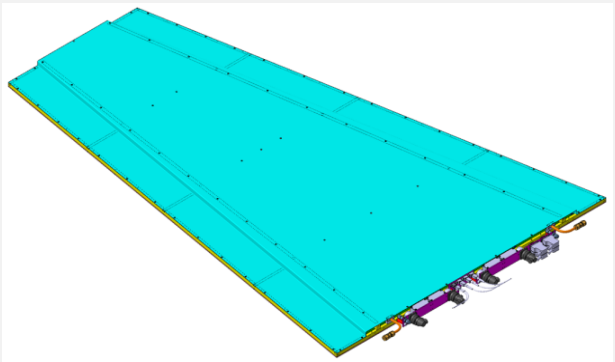
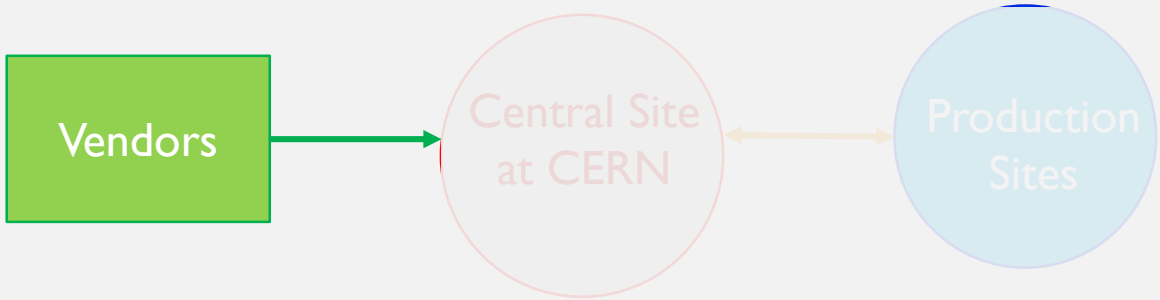
GE2/1 PRODUCTION READINESS







GE2/1 PRODUCTION READINESS



- Components used in GE2/1 are almost identical to GE1/1
  - Vendors are already identified
- Small mechanics and electrical components are produced by international companies (e.g. Bossard)
  - Minimal risk of failure or production delay
- Drift and Readout boards: Micropack
  - Experience from GE1/1 Production: ~100% yield, in time delivery
- Frames: Eltos
  - Experience from GE1/1 Production: >93% yield, in time delivery

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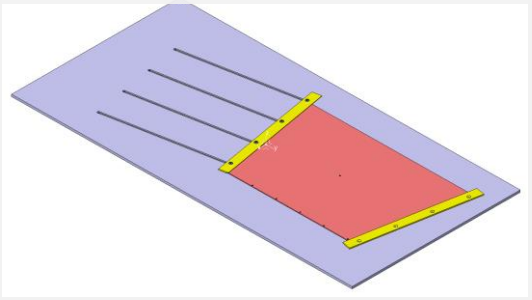
GE2/1 PRODUCTION READINESS

- Pre-production activities (central site at CERN)
  - Reception or materials
  - Initial inspection and acceptance test (approval/rejection of materials)
    - Optical inspections
    - Groove measurement on external frames
    - PCB bending measurements
    - RO board connectivity test
  - GEM QC2 fast and long tests at CERN
- Material preparation
  - Coating of the internal/external frames (+ spacers)
  - Sorting of the O-rings
  - GEM foil packing
  - GE2/1 kit preparation

- **List of tasks is well defined**
- **Manpower requirements and responsibilities are clear**
- **Work plan is established with the production community**

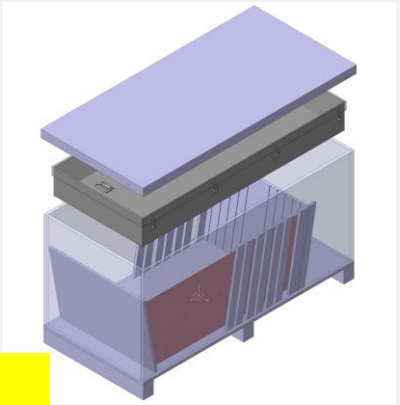
GE2/1 PRODUCTION READINESS

- **Specific Tooling for GE2/1 Module Assembly (adaptors and tools to make GE1/1 production sites compatible with the GE2/1 design)**
  - Assembly Jig with Alignment Pins
  - Protective Plate
  - Grounding Plate
  - Fixation Bars
  - HV Clips for QC2
  - Adaptor PCB for QC4/QC5



GE2/1 Assembly Jig

- **Material Transport**
  - Shipment Boxes



GE2/1 Shipment box

- **List of items is well defined**
- **Design is 80% completed**
- **Work plan is established with the production community**

GE2/1 PRODUCTION READINESS

Site	Nb of Production lines	Certified for GEM Production	Infrastructure ready and tested	Team	Comments
Belgium	1	YES	YES	2 Physicists 3 Technicians	Produced 30 GE1/1 detectors
Germany	1*	YES	YES	4 Physicists	*QC only (no clean room) Tested 21 GE1/1 det.
Italy	2	YES	YES	8 Physicists 8 Technicians +Students	Produced 26 GE1/1 detectors
India	2 (+2 under approval)	YES (+2 on-going)	YES (+2 on-going)	8 Physicists 5 Engineers/Tech + Students	Produced 17 GE1/1 detectors
Pakistan	1	YES	YES	4 Physicists 8 Engineers/Tech	Produced 13 GE1/1 detectors
Sri-Lanka	1	YES	YES	4 Physicists 1 Engineer + Students	Using CERN infrastructure and tooling
China	1	On-going	On-going	3 Physicists 2 Engineer + Students	New site, QC Jamboree in progress

New sites

GE2/1 PRODUCTION READINESS

Two New Production Sites for GE2/1

Sri-Lanka (UOC and UOR)

- Strong team already involved in the GE1/1 production (test, operation and analysis)
- Will use the CERN infrastructure to assemble and test GE2/1 modules
- Participated in 6 training sessions
- **Approved for GE2/1 mass-production**

China (PKU)

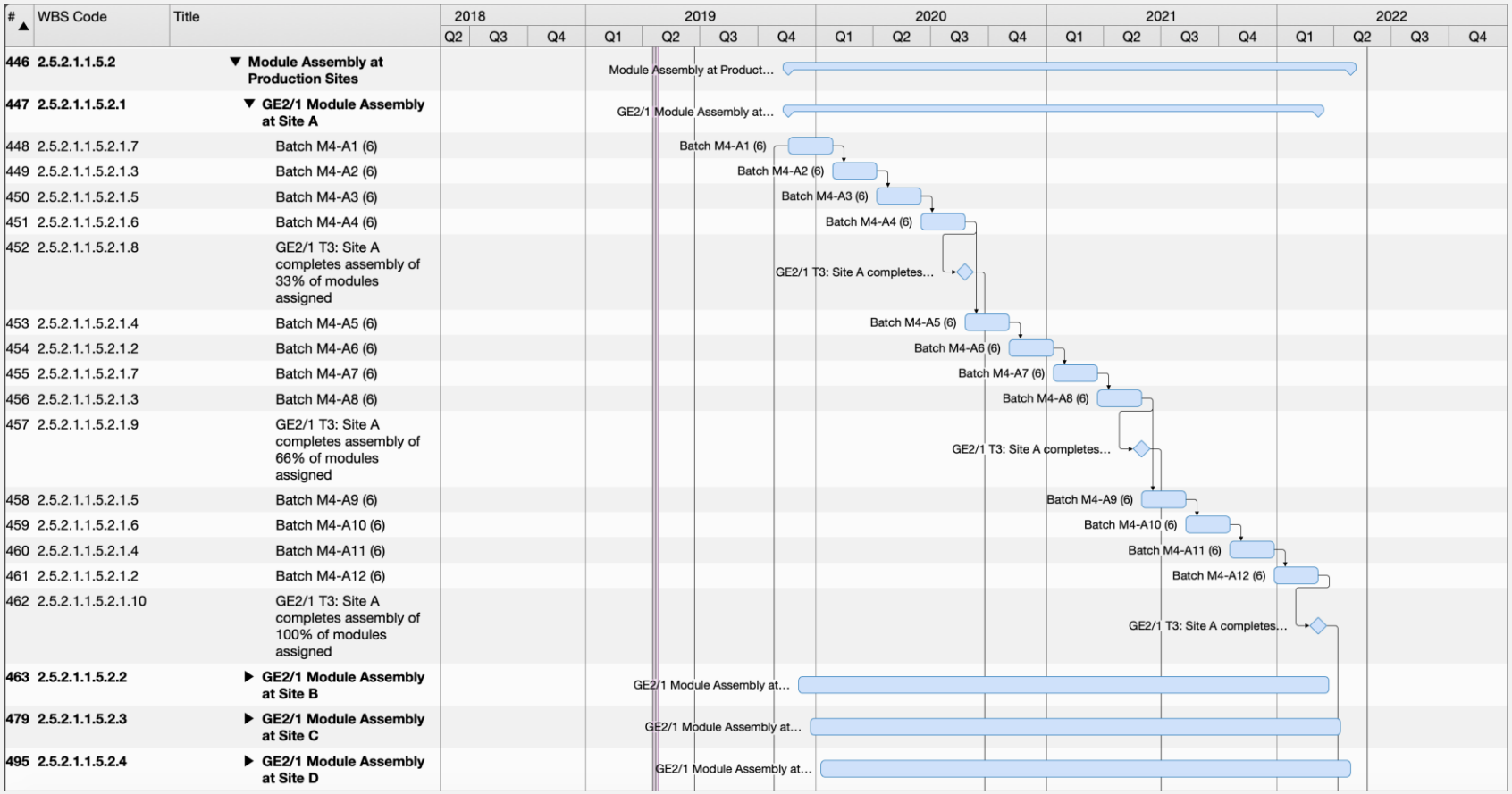
- Strong group already experienced with gaseous detectors and small GEM chambers
- Infrastructure 90% ready
- 1st stage of the QC Jamboree about to be completed (out of three stages)
- Participated in CERN training
- **Full Approval is expected during Fall 2019**

Sri-Lanka team at CERN

China PKU

GE2/1 PRODUCTION PLANNING

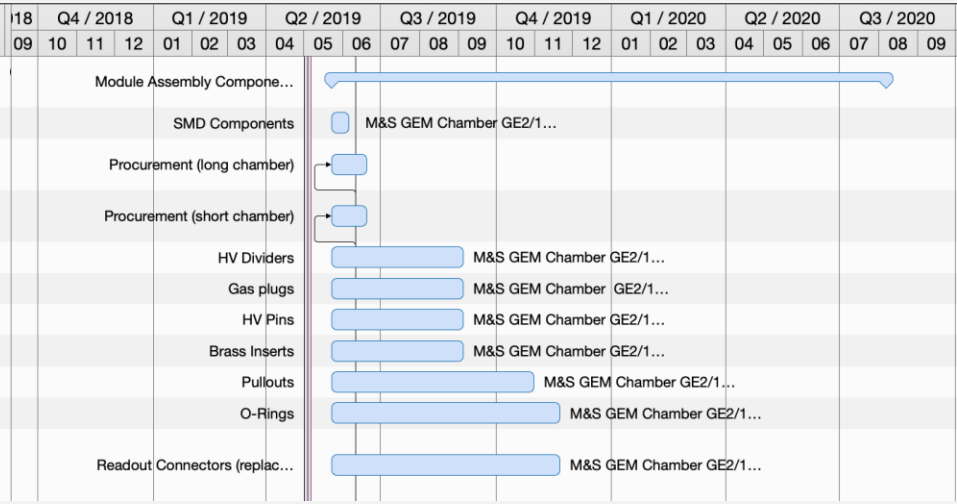
- **GE2/1 Module Production (TDR dates)**
  - Baseline schedule with 4 production sites, each one assembling two types of modules
  - Production organized in batches of 6 modules every 10 weeks (including 1 week for shipping)
  - Start of the production in October 2019, end in April 2022 (662 working days)



GE2/1 PRODUCTION SCHEDULES

Small Mechanics and Electrical Components

#	WBS Code	Title	Master Schedule reference	Expected Start	Expected End
1 369	2.5.2.1.1.5.1	**▼ Module Assembly Components**		**23 May 2019**	**6 Aug 2020**
1 370	2.5.2.1.1.5.1.5	**▶ SMD Components**		**23 May 2019**	**5 June 2019**
1 373	2.5.2.1.1.5.1.30	Procurement (long chamber)		23 May 2019	19 June 2019
1 374	2.5.2.1.1.5.1.31	Procurement (short chamber)		23 May 2019	19 June 2019
1 375	2.5.2.1.1.5.1.6	**▶ HV Dividers**		**23 May 2019**	**4 Sep 2019**
1 380	2.5.2.1.1.5.1.7	**▶ Gas plugs**		**23 May 2019**	**4 Sep 2019**
1 385	2.5.2.1.1.5.1.8	**▶ HV Pins**		**23 May 2019**	**4 Sep 2019**
1 390	2.5.2.1.1.5.1.9	**▶ Brass Inserts**		**23 May 2019**	**4 Sep 2019**
1 395	2.5.2.1.1.5.1.4	**▶ Pullouts**		**23 May 2019**	**30 Oct 2019**
1 400	2.5.2.1.1.5.1.3	**▶ O-Rings**		**23 May 2019**	**20 Nov 2019**
1 406	2.5.2.1.1.5.1.10	**▶ Readout Connectors (replace Panasonic connectors)**		**23 May 2019**	**20 Nov 2019**



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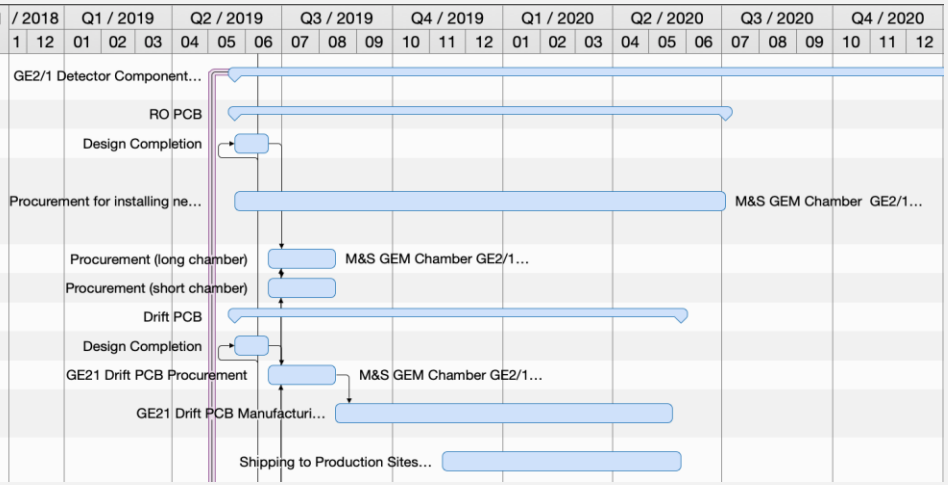
GE2/1 PRODUCTION SCHEDULES

PCBs: 304 Readout and Drift Boards

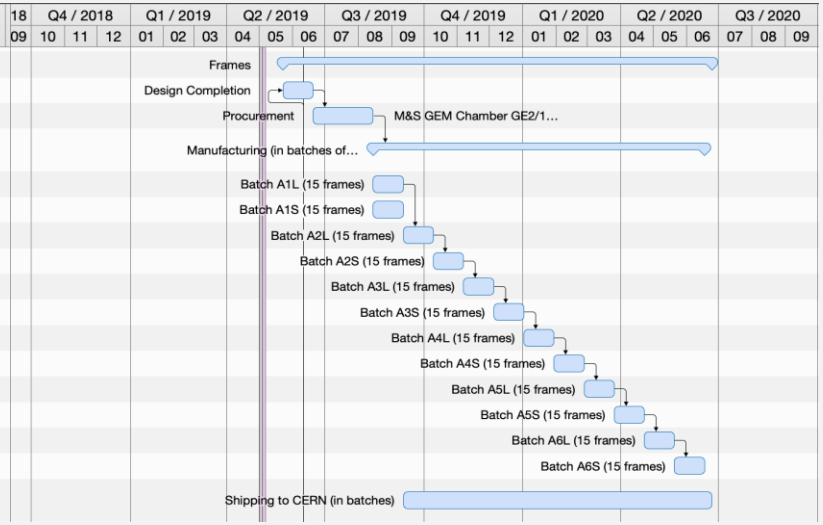
#	WBS Code	Title	Master Schedule reference	Expected Start	Expected End
264	**2.5.2.1.1**	▼ **GE2/1 Detector Components & Assembly**		**23 May 2019**	**22 Jun 2022**
265	**2.5.2.1.1.1**	▼ **RO PCB**		**23 May 2019**	**3 July 2020**
266	2.5.2.1.1.1.1	Design Completion		23 May 2019	19 June 2019
267	2.5.2.1.1.1.12	▷ Procurement for installing new type Panasonic connectors (excludes cost of the connectors themselves)		23 May 2019	3 July 2020
268	2.5.2.1.1.1.2	▷ Procurement (long chamber)		20 June 2019	14 Aug 2019
269	2.5.2.1.1.1.3	Procurement (short chamber)		20 June 2019	14 Aug 2019
270	**2.5.2.1.1.2**	▼ **Drift PCB**		**23 May 2019**	**27 May 2020**
271	2.5.2.1.1.2.1	Design Completion		23 May 2019	19 June 2019
272	2.5.2.1.1.2.2	▷ GE21 Drift PCB Procurement		20 June 2019	14 Aug 2019
273	**2.5.2.1.1.2.3**	▶ **GE21 Drift PCB Manufacturing (in batches)**		**15 Aug 2019**	**20 May 2020**
287	**2.5.2.1.1.2.4**	▶ **Shipping to Production Sites (in batches)**		**11 Nov 2019**	**27 May 2020**



GE2/1 PRODUCTION SCHEDULES

Frames: 304 External/ 304 internal kits

#	WBS Code	Title	Master Schedule reference	Expected Start	Expected End
1 412	**2.5.2.1.1.5.1.2**	▼ **Frames**		**23 May 2019**	**24 Jun 2020**
1 413	2.5.2.1.1.5.1.2.1	Design Completion		23 May 2019	19 June 2019
1 414	2.5.2.1.1.5.1.2.2	▷ Procurement		20 June 2019	14 Aug 2019
1 415	**2.5.2.1.1.5.1.2.3**	▼ **Manufacturing (in batches of XX frames)**		**15 Aug 2019**	**17 Jun 2020**
1 416	2.5.2.1.1.5.1.2.3.1	Batch A1L (15 frames)		15 Aug 2019	11 Sep 2019
1 417	2.5.2.1.1.5.1.2.3.2	Batch A1S (15 frames)		15 Aug 2019	11 Sep 2019
1 418	2.5.2.1.1.5.1.2.3.3	Batch A2L (15 frames)		12 Sep 2019	9 Oct 2019
1 419	2.5.2.1.1.5.1.2.3.3	Batch A2S (15 frames)		10 Oct 2019	6 Nov 2019
1 420	2.5.2.1.1.5.1.2.3.3	Batch A3L (15 frames)		7 Nov 2019	4 Dec 2019
1 421	2.5.2.1.1.5.1.2.3.3	Batch A3S (15 frames)		5 Dec 2019	1 Jan 2020
1 422	2.5.2.1.1.5.1.2.3.3	Batch A4L (15 frames)		2 Jan 2020	29 Jan 2020
1 423	2.5.2.1.1.5.1.2.3.3	Batch A4S (15 frames)		30 Jan 2020	26 Feb 2020
1 424	2.5.2.1.1.5.1.2.3.3	Batch A5L (15 frames)		27 Feb 2020	25 Mar 2020
1 425	2.5.2.1.1.5.1.2.3.3	Batch A5S (15 frames)		26 Mar 2020	22 April 2020
1 426	2.5.2.1.1.5.1.2.3.3	Batch A6L (15 frames)		23 April 2020	20 May 2020
1 427	2.5.2.1.1.5.1.2.3.3	Batch A6S (15 frames)		21 May 2020	17 June 2020
1 428	**2.5.2.1.1.5.1.2.4**	▶ **Shipping to CERN (in batches)**		**12 Sep 2019**	**24 Jun 2020**



RISK MANAGEMENT

Case I: unavailability of detector components

- Late delivery of components
  - Risk: medium
- High rejection rate – components outside specifications
  - Risk: medium (GEM foils – new vendor)

CORE CBS Number	Merlin WBS Number	Activity	Risk ID	Risk Description	Impact Description	Likelihood (L/M/H)	CORE cost impact (L/M/H)	Schedule Impact (L/M/H)	Mitigation	Action
2.5.2.1	2.5.2.1	GE2/1 Detectors	4.1	Sub-standard quality of the GEM foils delivered by external vendors or delays in manufacturing	If quality of GEM foils is inadequate, foils will need to be re-made leading to delays in the schedule and potentially lead to cost increases. If the impact on schedule is severe enough, it can impact readiness of the detector for installation	M	L	M	Mitigation includes (i) putting contracts in place with two vendors to allow adequate floats in the schedule to be able to accommodate potential delays in manifacturing, (i) rigorous quality monitoring process of all ariving foils so any problems are discovered immediately to reduce schedule impact, (iii) schedule monitoring, (iv) adequate floats in the schedule to allow absorbing potential delays, (v) ensuring that contracts with vendors explicitly account for mechanisms to deal with quality problems to minimize impact on the cost incurred by the project.	Work with the vendors to correct the problem and speed up the foil manufacturing schedule, identify additional manpower to increase the number of shifts at module production sites and the chamber assembly facility at CERN to increase the throughput so that delays compared to original schedule are minimized.
			4.2	Delay in detailed designs of 8 different module types	Delay in completion of the detailed engineering drawings/designs can delay the start of production of GEM modules and impact the schedule.	L	L	M	Mitigate via regular monitoring of the progress (biweekly meetings and periodic reviews) to ensure that falling behind schedule is detected early and additional engineering resources can be directed to ensure any delays are remedied or minimized	identify additional resources (expert engineers) to speed up the completion of the designs. Work with the module production sites so that whatever delay remains can be absorbed by increasing the module produciton throughput to minimize impact on the overall schedule.
			4.3	Delay in production of other module and chamber components	If components required for module or chamber construction arrive late, that can potentially delay production of GEM modules.	M	L	M	Place orders early to esnure the schedule impact is minimal should manufcaturing schedule be delayed. Improve accuracy of estimating production yield while working with vendors on R&D and prototyping, work with vendors on streamlining the process to minimize mistakes in production which can lead to delays in shipping final components, monitor production progress with industrial partners very closely.	Work with the vendor to speed up the process. If the delay is signficant, allocate additional resources to use faster shipping options to reduce schedule delay, work on increasing the througput of module production sites, use faster shipping options for shipment of ready modules to CERN.
			4.4	Insufficient module assembly rate at certain production sites	Lower than expected rate of module produciton at one or more pmodule production sites has the potential of delaying completion of GEM modules and the overall schedule of production and manufacturing.	L	L	M	Mitigate by (i) ensuring that the number of production sites and their throughput are sufficient so the schedule can accommodate reasonable delays or lower produciton rate from some of the production sites, (ii) ensuring sufficient floats in the schedule so the impact on chamber assembly and detector installation is minimal should this risk realize, (iii) plan so that should there be a necessity the production rate at other assembly sites can be increaased by redirecting manpower and going to a larger number of shifts per day to compensate for reduced throughput at other sites, (iv) rigorous monitoring of production sites preparation and certification and later regular monitoing of the production schedule so that any delays are detected early and risks can be responded to minimizing the impact.	Allocate additional resources to increase the number of shifts at one or more module production sites and the chamber assembly facility at CERN to increase the throughput so that delays compared to original schedule are minimized. Allocate resources to use faster shipping options to reduce schedule delays.
			4.5	GE1/1 production schedule delays impacting GE2/1 schedule	As GE2/1 production relies on the same resources (manpower, module production sites, chamber assembly sites, storage and cosmis stand facilities at CERN) as GE1/1 production, delays in GE1/1 construction project can reduce the available manpower and access to facilities involved in production of GE2/1 detectors. The risk can realize independently of whether GE1/1 is installed on time and the severity is determined by how much of the delay is accumulated. Up to 6 month delay (max schedule impact associated to this risk) can be absorbed by the available float in the schedule.	L	L	M	Mitigate by (i) ensuring that the number of production sites and their throughut are sufficient so the schedule can accommodate reasonable delays or lower produciton rate from some of the production sites, (ii) ensuring sufficient floats in the schedule so the impact on chamber assembly and detector installation is minimal should this risk realize, (iii) plan so that should there be a necessity the production rate at other assembly sites can be increaased by redirecting manpower and going to a larger number of shifts per day to compensate for reduced throughput at other sites, (iv) rigorous monitoring of production sites preparation and certification and later regular monitoing of the production schedule so that any delays are detected early and risks can be responded to minimizing the impact.	Identify and allocate resources to speed up the completion of the GE1/1 module production and, if necessary, GE2/1 module production by increasing the number of shifts and/or production lines at the module production sites.

RISK MANAGEMENT

Case II: failure at production sites

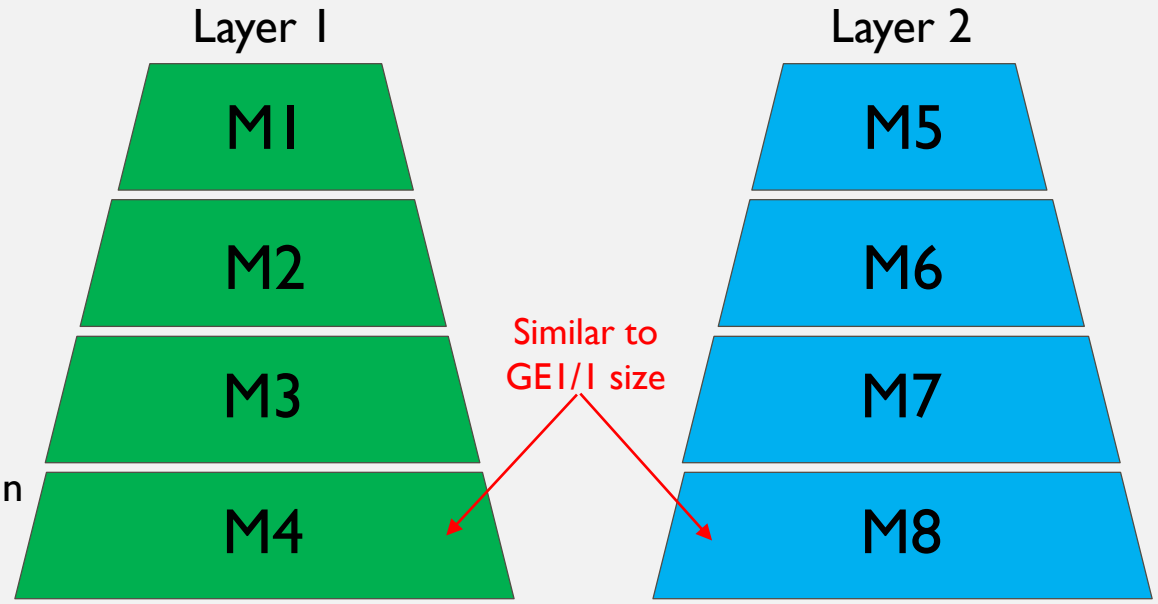
- Assembly/test rate slower than expected
  - Risk: low (based on GE1/1 experience)
- One or several sites not ready for mass-production
  - Risk: low (already 7 sites approved out of 4 needed)

CORE CBS Number	Merlin WBS Number	Activity	Risk ID	Risk Description	Impact Description	Likelihood (L/M/H)	CORE cost impact (L/M/H)	Schedule Impact (L/M/H)	Mitigation	Action
2.5.2.1	2.5.2.1	GE2/1 Detectors	4.1	Sub-standard quality of the GEM foils delivered by external vendors or delays in manufacturing	If quality of GEM foils is inadequate, foils will need to be re-made leading to delays in the schedule and potentially lead to cost increases. If the impact on schedule is severe enough, it can impact readiness of the detector for installation	M	L	M	Mitigation includes (i) putting contracts in place with two vendors to allow adequate floats in the schedule to be able to accommodate potential delays in manufacturing, (i) rigorous quality monitoring process of all ariving foils so any problems are discovered immediately to reduce schedule impact, (iii) schedule monitoring, (iv) adequate floats in the schedule to allow absorbing potential delays, (v) ensuring that contracts with vendors explicitly account for mechanisms to deal with quality problems to minimize impact on the cost incurred by the project.	Work with the vendors to correct the problem and speed up the foil manufacturing schedule, identify additional manpower to increase the number of shifts at module production sites and the chamber assembly facility at CERN to increase the throughput so that delays compared to original schedule are minimized.
			4.2	Delay in detailed designs of 8 different module types	Delay in completion of the detailed engineering drawings/designs can delay the start of production of GEM modules and impact the schedule.	L	L	M	Mitigate via regular monitoring of the progress (biweekly meetings and periodic reviews) to ensure that falling behind schedule is detected early and additional engineering resources can be directed to ensure any delays are remedied or minimized	identify additional resources (expert engineers) to speed up the completion of the designs. Work with the module production sites so that whatever delay remains can be absorbed by increasing the module produciton throughput to minimize impact on the overall schedule.
			4.3	Delay in production of other module and chamber components	If components required for module or chamber construction arrive late, that can potentially delay production of GEM modules.	M	L	M	Place orders early to esnure the schedule impact is minimal should manufcaturing schedule be delayed. Improve accuracy of estimating production yield while working with vendors on R&D and prototyping, work with vendors on streamlining the process to minimize mistakes in production which can lead to delays in shipping final components, monitor production progress with industrial partners very closely.	Work with the vendor to speed up the process. If the delay is signficant, allocate additional resources to use faster shipping options to reduce schedule delay, work on increasing the througput of module production sites, use faster shipping options for shipment of ready modules to CERN.
			4.4	Insufficient module assembly rate at certain production sites	Lower than expected rate of module produciton at one or more pmodule production sites has the potential of delaying completion of GEM modules and the overall schedule of production and manufacturing.	L	L	M	Mitigate by (i) ensuring that the number of production sites and their throughput are sufficient so the schedule can accommodate reasonable delays or lower produciton rate from some of the production sites, (ii) ensuring sufficient floats in the schedule so the impact on chamber assembly and detector installation is minimal should this risk realize, (iii) plan so that should there be a necessity the production rate at other assembly sites can be increaased by redirecting manpower and going to a larger number of shifts per day to compensate for reduced throughput at other sites, (iv) rigorous monitoring of production sites preparation and certification and later regular monitoing of the production schedule so that any delays are detected early and risks can be responded to minimizing the impact.	Allocate additional resources to increase the number of shifts at one or more module production sites and the chamber assembly facility at CERN to increase the throughput so that delays compared to original schedule are minimized. Allocate resources to use faster shipping options to reduce schedule delays.
			4.5	GE1/1 production schedule delays impacting GE2/1 schedule	As GE2/1 production relies on the same resources (manpower, module production sites, chamber assembly sites, storage and cosmis stand facilities at CERN) as GE1/1 production, delays in GE1/1 construction project can reduce the available manpower and access to facilities involved in production of GE2/1 detectors. The risk can realize independently of whether GE1/1 is installed on time and the severity is determined by how much of the delay is accumulated. Up to 6 month delay (max schedule impact associated to this risk) can be absorbed by the available float in the schedule.	L	L	M	Mitigate by (i) ensuring that the number of production sites and their throughput are sufficient so the schedule can accommodate reasonable delays or lower produciton rate from some of the production sites, (ii) ensuring sufficient floats in the schedule so the impact on chamber assembly and detector installation is minimal should this risk realize, (iii) plan so that should there be a necessity the production rate at other assembly sites can be increaased by redirecting manpower and going to a larger number of shifts per day to compensate for reduced throughput at other sites, (iv) rigorous monitoring of production sites preparation and certification and later regular monitoing of the production schedule so that any delays are detected early and risks can be responded to minimizing the impact.	Identify and allocate resources to speed up the completion of the GE1/1 module production and, if necessary, GE2/1 module production by increasing the number of shifts and/or production lines at the module production sites.

Main risks are related to detector components but the GE1/1 experience gives good confidence and knowledge to anticipate possible delays

RISK MANAGEMENT

- **Sharing of the module production over 8 production sites**
- Each production line is assigned one type of GE2/1 modules
- 38 modules/line
- Belgium and Sri-Lanka will produce extra 19 modules, each to be tested in Germany



Country	Nb of Prod. lines	Module types	Nb of Modules	Comments
Italy	2	M6 + M8	38 (M6) + 38 (M8)	
Belgium	1	M3 +M1	38 (M3) + 19 (M1)	
Germany	1*	M1	-	*QC only
India	2	M2	38 (M2)	
China	1	M5	38	To be approved
Sri-Lanka	1	M4 + M1	38 (M4) +19 (M1)	
Pakistan	1	M7	38	

Demonstrated capability to produce large size GE1/1 at high rate (~3 days per module)

Proximity of CERN experts and large infrastructure capacity

SUMMARY

- GE2/1 and RnD and prototyping progressing very fast
- Change control performed for GE2/1 optical transceivers
  - We are back on track with schedule with a minimal delay
  - Given a new need-by date we have solid floating time
- GE2/1 prototype is fully integrated and efficiency studies are ongoing
- Production schedule is well established and production process is under control

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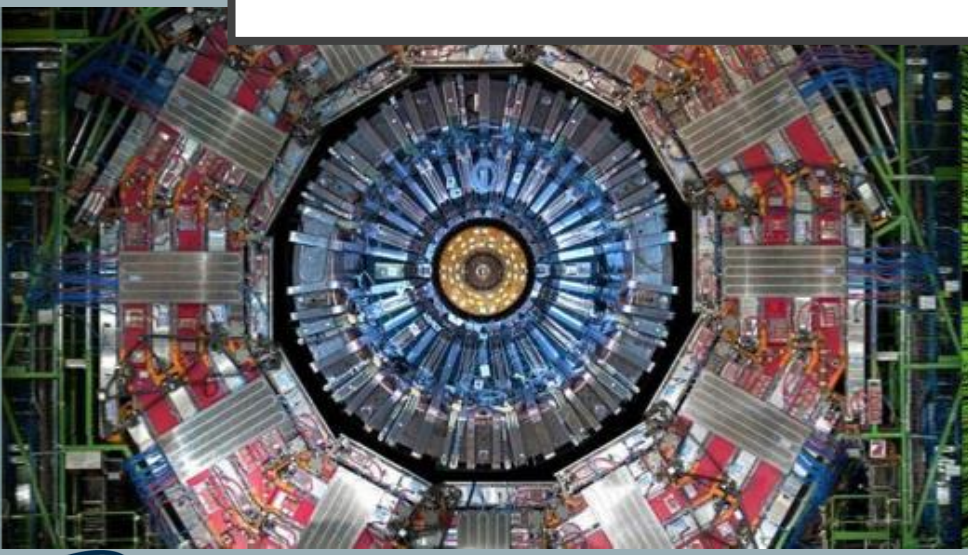
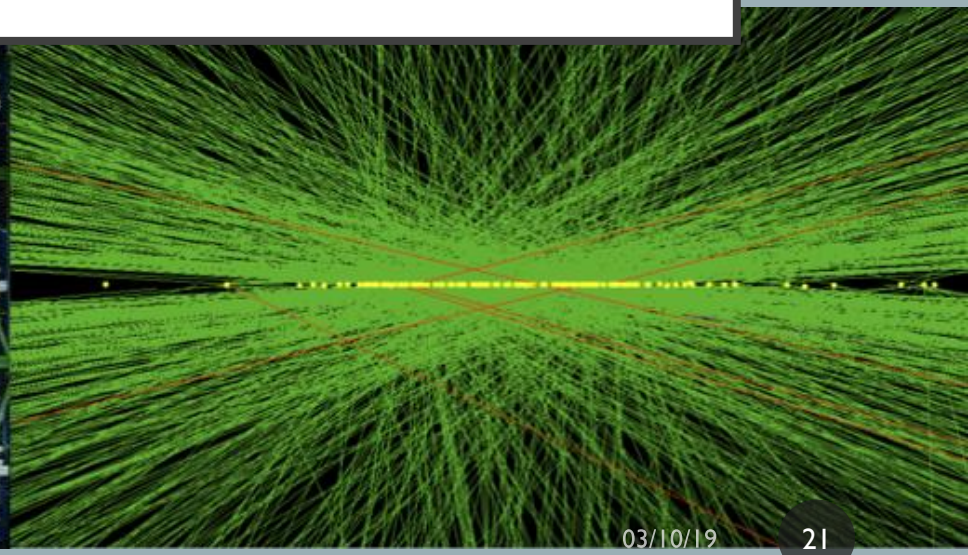
BACKUP

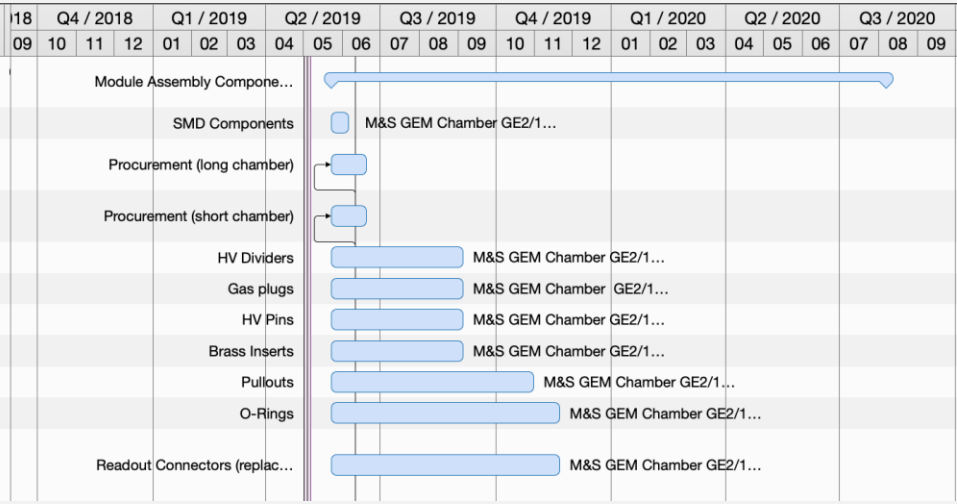




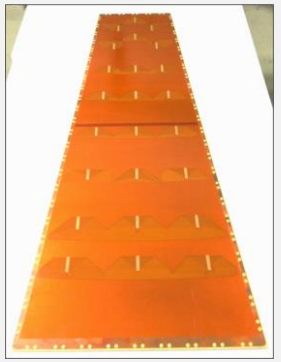
GE2/1 PRODUCTION SCHEDULES

Small Mechanics and Electrical Components

#	WBS Code	Title	Master Schedule reference	Expected Start	Expected End
1 369	2.5.2.1.1.5.1	**▼ Module Assembly Components**		**23 May 2019**	**6 Aug 2020**
1 370	2.5.2.1.1.5.1.5	**▶ SMD Components**		**23 May 2019**	**5 June 2019**
1 373	2.5.2.1.1.5.1.30	Procurement (long chamber)		23 May 2019	19 June 2019
1 374	2.5.2.1.1.5.1.31	Procurement (short chamber)		23 May 2019	19 June 2019
1 375	2.5.2.1.1.5.1.6	**▶ HV Dividers**		**23 May 2019**	**4 Sep 2019**
1 380	2.5.2.1.1.5.1.7	**▶ Gas plugs**		**23 May 2019**	**4 Sep 2019**
1 385	2.5.2.1.1.5.1.8	**▶ HV Pins**		**23 May 2019**	**4 Sep 2019**
1 390	2.5.2.1.1.5.1.9	**▶ Brass Inserts**		**23 May 2019**	**4 Sep 2019**
1 395	2.5.2.1.1.5.1.4	**▶ Pullouts**		**23 May 2019**	**30 Oct 2019**
1 400	2.5.2.1.1.5.1.3	**▶ O-Rings**		**23 May 2019**	**20 Nov 2019**
1 406	2.5.2.1.1.5.1.10	**▶ Readout Connectors (replace Panasonic connectors)**		**23 May 2019**	**20 Nov 2019**

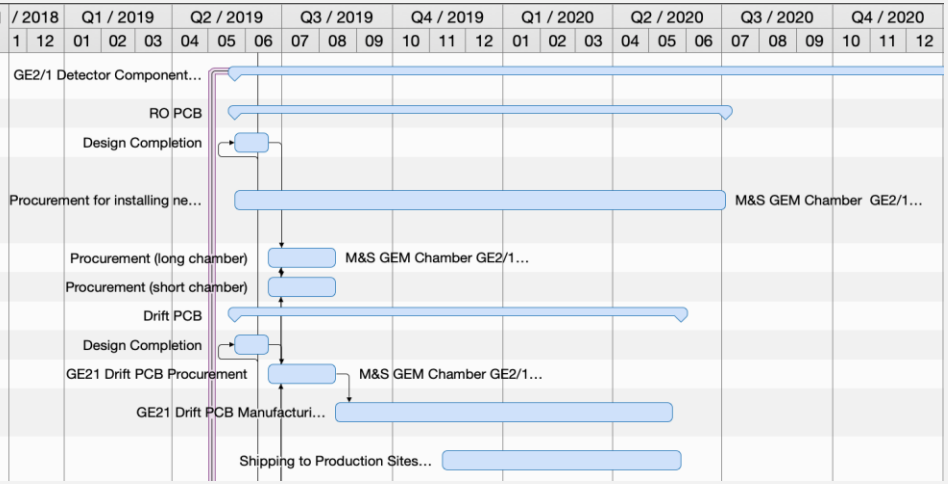


GE2/1 PRODUCTION SCHEDULES



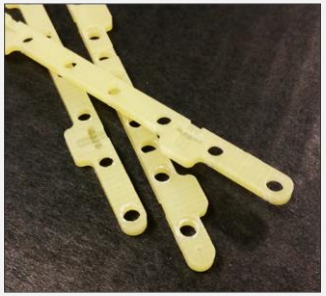
PCBs: 304 Readout and Drift Boards

#	WBS Code	Title	Master Schedule reference	Expected Start	Expected End
264	2.5.2.1.1	▼ **GE2/1 Detector Components & Assembly**		**23 May 2019**	**22 Jun 2022**
265	2.5.2.1.1.1	▼ **RO PCB**		**23 May 2019**	**3 July 2020**
266	2.5.2.1.1.1.1	Design Completion		23 May 2019	19 June 2019
267	2.5.2.1.1.1.12	▷ Procurement for installing new type Panasonic connectors (excludes cost of the connectors themselves)		23 May 2019	3 July 2020
268	2.5.2.1.1.1.2	▷ Procurement (long chamber)		20 June 2019	14 Aug 2019
269	2.5.2.1.1.1.3	Procurement (short chamber)		20 June 2019	14 Aug 2019
270	2.5.2.1.1.2	▼ **Drift PCB**		**23 May 2019**	**27 May 2020**
271	2.5.2.1.1.2.1	Design Completion		23 May 2019	19 June 2019
272	2.5.2.1.1.2.2	▷ GE21 Drift PCB Procurement		20 June 2019	14 Aug 2019
273	2.5.2.1.1.2.3	▶ **GE21 Drift PCB Manufacturing (in batches)**		**15 Aug 2019**	**20 May 2020**
287	2.5.2.1.1.2.4	▶ **Shipping to Production Sites (in batches)**		**11 Nov 2019**	**27 May 2020**

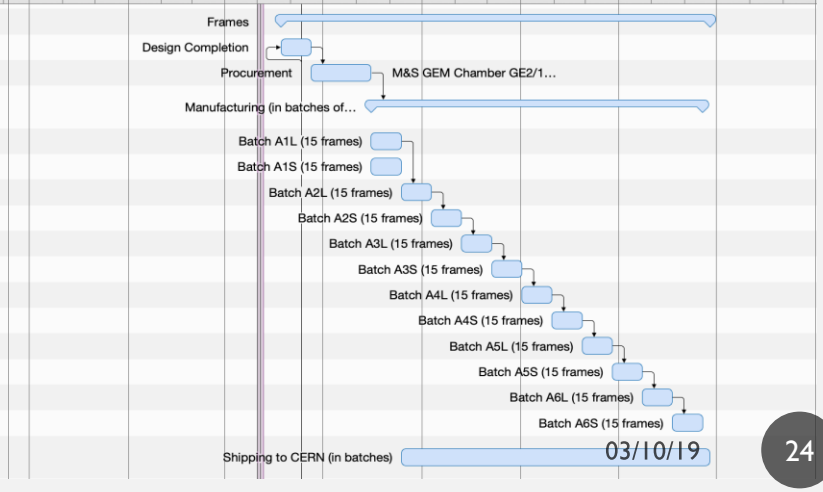


GE2/1 PRODUCTION SCHEDULES

Frames: 304 External/ 304 internal kits

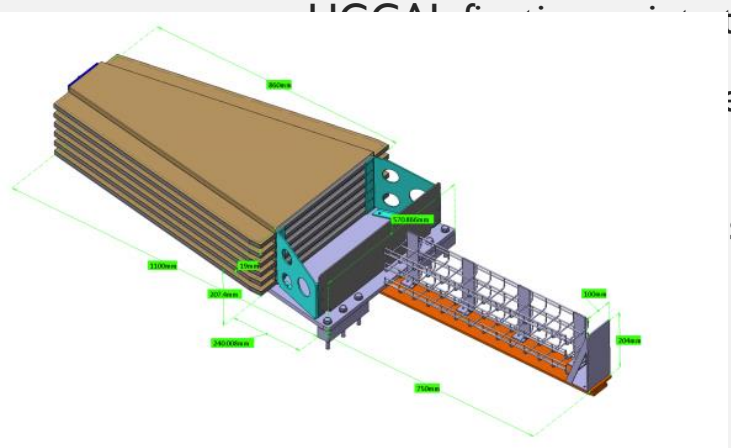


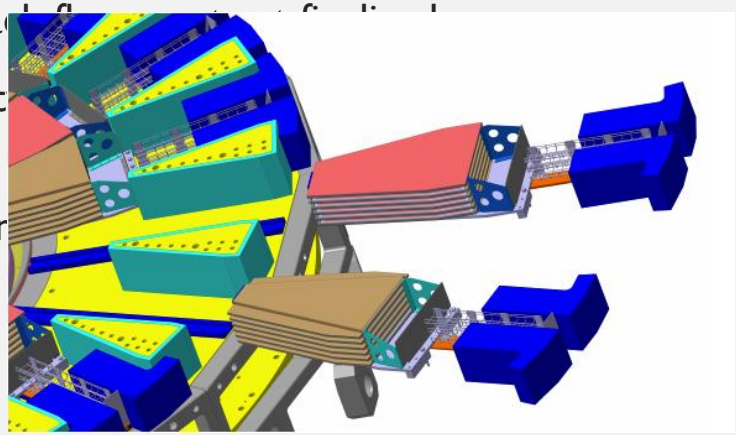
#	WBS Code	Title	Master Schedule reference	Expected Start	Expected End
1 412	**2.5.2.1.1.5.1.2**	▼ **Frames**		**23 May 2019**	**24 Jun 2020**
1 413	2.5.2.1.1.5.1.2.1	Design Completion		23 May 2019	19 June 2019
1 414	2.5.2.1.1.5.1.2.2	▷ Procurement		20 June 2019	14 Aug 2019
1 415	**2.5.2.1.1.5.1.2.3**	▼ **Manufacturing (in batches of XX frames)**		**15 Aug 2019**	**17 Jun 2020**
1 416	2.5.2.1.1.5.1.2.3.1	Batch A1L (15 frames)		15 Aug 2019	11 Sep 2019
1 417	2.5.2.1.1.5.1.2.3.2	Batch A1S (15 frames)		15 Aug 2019	11 Sep 2019
1 418	2.5.2.1.1.5.1.2.3.3	Batch A2L (15 frames)		12 Sep 2019	9 Oct 2019
1 419	2.5.2.1.1.5.1.2.3.3	Batch A2S (15 frames)		10 Oct 2019	6 Nov 2019
1 420	2.5.2.1.1.5.1.2.3.3	Batch A3L (15 frames)		7 Nov 2019	4 Dec 2019
1 421	2.5.2.1.1.5.1.2.3.3	Batch A3S (15 frames)		5 Dec 2019	1 Jan 2020
1 422	2.5.2.1.1.5.1.2.3.3	Batch A4L (15 frames)		2 Jan 2020	29 Jan 2020
1 423	2.5.2.1.1.5.1.2.3.3	Batch A4S (15 frames)		30 Jan 2020	26 Feb 2020
1 424	2.5.2.1.1.5.1.2.3.3	Batch A5L (15 frames)		27 Feb 2020	25 Mar 2020
1 425	2.5.2.1.1.5.1.2.3.3	Batch A5S (15 frames)		26 Mar 2020	22 April 2020
1 426	2.5.2.1.1.5.1.2.3.3	Batch A6L (15 frames)		23 April 2020	20 May 2020
1 427	2.5.2.1.1.5.1.2.3.3	Batch A6S (15 frames)		21 May 2020	17 June 2020
1 428	**2.5.2.1.1.5.1.2.4**	▶ **Shipping to CERN (in batches)**		**12 Sep 2019**	**24 Jun 2020**



ME0 DESIGN

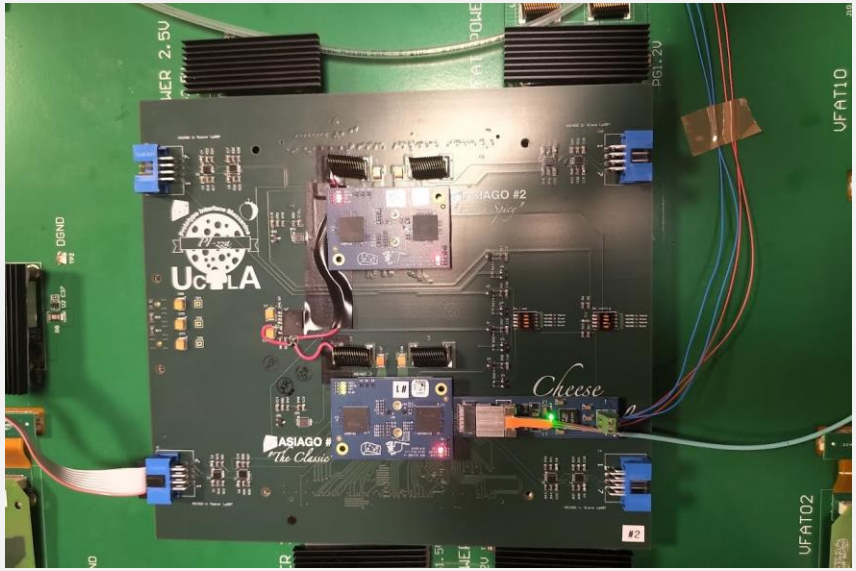
- Mechanical Design
  - HGCAL Envelope has been frozen
    - Space for ME0 stack insertion confirmed
    - to HE ba
    - esign of t
    - s on-goi





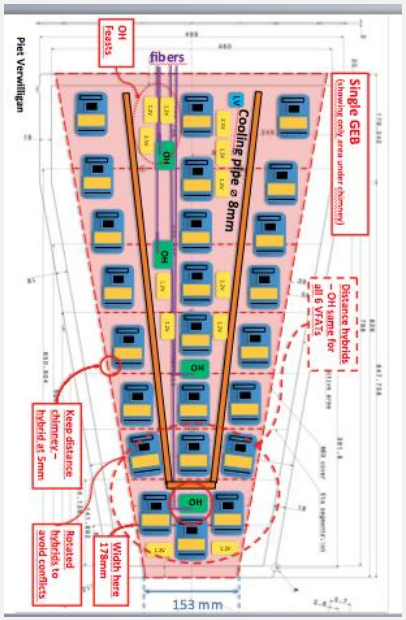
ME0 DESIGN

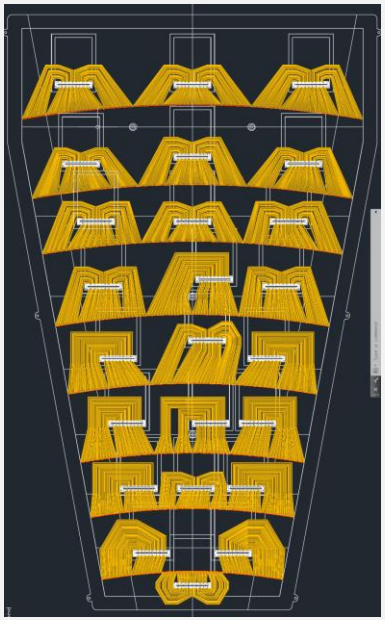
- Electronics Design
  - FPGA-less on-chamber electronics design is ready
    - Prototypes produced
      - ASIAGO (ME0 OptoHybrid board)
      - PIZZA (Special board to place ASIAGO over GE2/1 GEB)
      - Adapter for FireFly transceivers until Vlplus aren't available
    - Integration started using GE2/1 detector
    - Communication between LpGBT and VFAT chips is established!

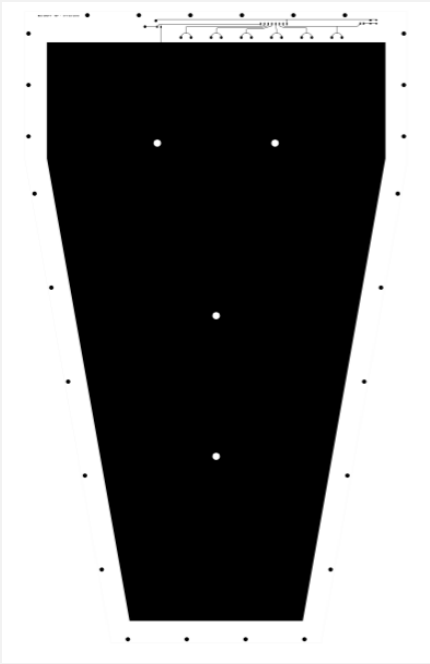


ME0 DETECTOR PROTOTYPES

- Reduced space under the chamber cover
- Foils with double face segmentation layout choosen
- 9 prototype modules production launched at CERN





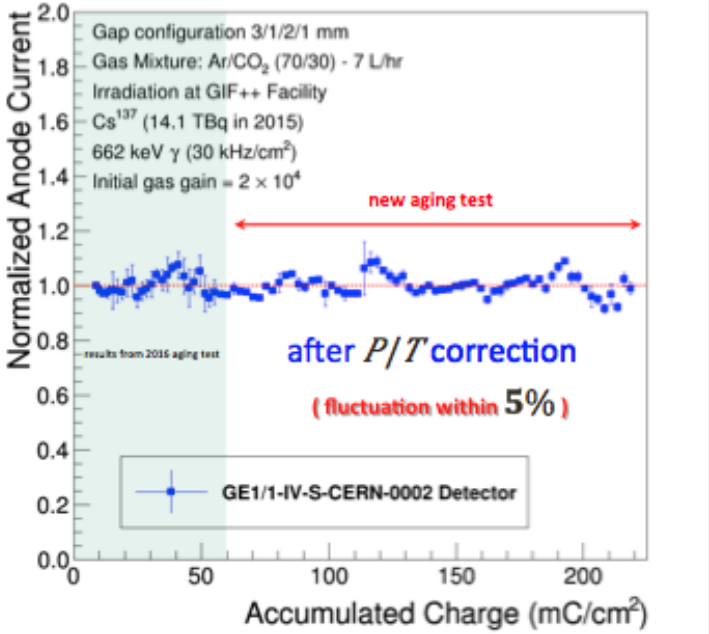


ME0 AGING STUDIES AT GIF++

^{137}Cs Source

Chamber CERN GEM Foils

Total integrated Charge at GIF++ up to 22nd March: ~ *218 mC/cm²*

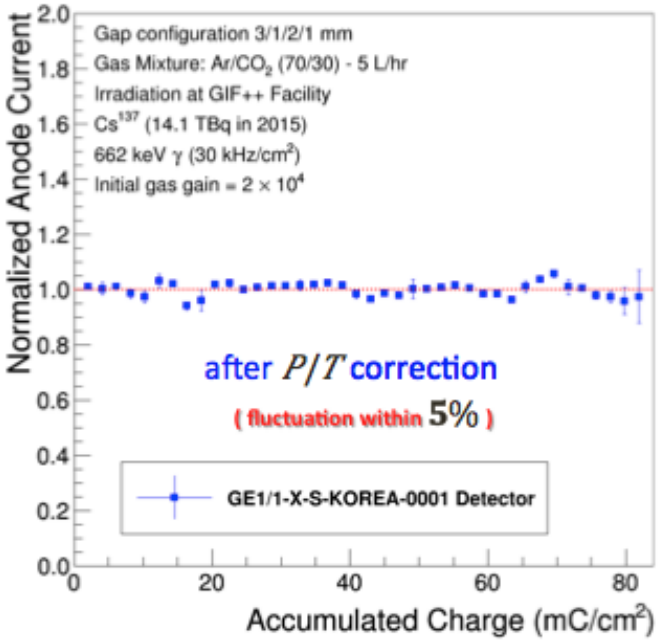


NO aging observed up to ~ 218 *mC/cm²*

~ 77% of ME0 operation at the HL-LHC

Chamber Korean GEM Foils

Total integrated Charge at GIF++ up to 22nd March: ~ *82 mC/cm²*



NO aging observed up to ~ 82 *mC/cm²*

10 years of *GE2/1* operation at the HL-LHC (safety factor 27)

~ 29% of *ME0* operation at the HL-LHC

ME0 MILESTONES FROM TDR

	ID	Milestone title	Date	
Design	ME0.RD.DET.1 ME0.RD.FE.1 ME0.RD.BE.1	ME0 R&D: Key detector system design parameters are defined based on performance requirements	21.Mar.17	Achieved
	ME0.RD.DET.2	ME0 R&D: Irradiation studies and assessment of performance and longevity with small prototypes completed	11.Jul.2017	Achieved
	ME0.RD.FE.2 ME0.RD.BE.2	ME0 R&D: On-chamber & off-chamber electronics preliminary principal design complete and interfaces defined	25.Jul.17	Achieved
	ME0.RD.DET.3	ME0 R&D: Chamber (stack) prototype mechanical design completed	18.Dec.2018	Achieved
	ME0.RD.FE.3	ME0 R&D: On-chamber electronics engineering design completed and validated	23.Aug.2019	Delayed till 14.01.2020
Prototyping	ME0.RD.DET.4	ME0 R&D: Chamber (stack) prototype mechanical prototype testing and validation complete	24.Dec.2019	Expect on-time
	ME0.RD.FE.4	ME0 R&D: On-chamber electronics prototype electronics manufacturing and testing is complete	21.Aug.2020	Expect on-time
	ME0.RD.BE.3	ME0 R&D: Integration of the on-chamber and off-chamber electronics and performance assessment complete	8.Jan.2021	Expect on-time
	ME0.RD.DET.5 ME0.RD.FE.5	ME0 R&D: Assessment of the electronics performance and integration with the demonstrator chamber completed	30.Mar.2021	Expect on-time
	ME0.RD.DET.6	ME0 R&D: Beams and Cosmics testing of the demonstrator chamber and performance qualification completed	31.Aug.2021	Expect on-time
		ME0 PRR for the Foil Production	14.Jun.2021	Projected on-time
		ME0 ESR	27.Apr.2021	Projected on-time
		ME0 Detector EDR	28.Oct.2021	Projected on-time

The "waterfall" plot for the updated R&D schedule

ELECTRONICS R&D SCHEDULE

#	Title	Expected Start	Expected End
626	**Milestones**	**July 11, 2018**	**Aug 21, 2020**
627	GE2/1 R&D T4: Special ROB-0A prototype manufactured and ready for installation on chamber	July 11, 2018	July 11, 2018
628	GE21 R&D T4: Gen-1 Prototypes Electronics Designs Complete, Ready for Project Level Review	Sep 13, 2018	Sep 13, 2018
629	GE2/1 R&D T4: Make a decision on the copper layer on ROB	Sep 20, 2018	Sep 20, 2018
630	**GE2/1 R&D T5: On-chamber electronics prototypes engineering design complete**	Sep 28, 2018	Sep 28, 2018
631	GE2/1 R&D T4: Special ROB-0B prototype manufactured and ready for installation on chamber	Oct 4, 2018	Oct 4, 2018
632	GE2/1 R&D T4: ROB-1B prototype ready for installation on the demonstrator chamber	Nov 29, 2018	Nov 29, 2018
633	GE2/1 R&D T4: Initial Testing of GEB-1 and Mechanical Integration Validation Complete	Dec 5, 2018	Dec 5, 2018
634	GE2/1 R&D T4: ROB-1A prototype ready for installation on the demonstrator chamber	Dec 7, 2018	Dec 7, 2018
635	GE2/1 R&D T4: Make a decision on the ROB strip layout configuration	Dec 13, 2018	Dec 13, 2018
636	GE21 R&D T4: uTCA-based Backend System for Gen-1/2 GE21 electronics is Ready for Trial Integration with Gen-1 on-Chamber Electronics and Preliminary Measurements of Noise with Stage-1 Demonstrator	Dec 21, 2018	Dec 21, 2018
637	GE21 R&D T4: uTCA-based Backend System for Gen-1/2 GE21 electronics is Ready for Full Integration Testing with Gen-1 on-Chamber Electronics	Jan 4, 2019	Jan 4, 2019
638	GE2/1 R&D T4: All Gen-1 Electronics Boards for one module are ready for mechanical integration assessment with the Stage-1 Demonstrator @ CERN	Feb 19, 2019	Feb 19, 2019
639	**GE2/1 R&D T5: On-Chamber Prototype Electronics Manufacturing and Testing is Complete [At least One Full Module]**	Feb 19, 2019	Feb 19, 2019
640	GE2/1 R&D T4: Pre-Integration and GEB production Test-stand @ PKU Complete	Feb 20, 2019	Feb 20, 2019
641	GE21 R&D T4: ROB-2 Boards Testing @ CERN Completed	Mar 12, 2019	Mar 12, 2019
642	GE2/1 R&D T4: Testing and Assessment of the modules for Stage-2A Demonstrator w/ APV electronics Complete	Mar 27, 2019	Mar 27, 2019
643	GE2/1 R&D T4: Ready for Foil PRR (Modified due to GE21-002 Change Control)	May 3, 2019	May 3, 2019
644	**GE2/1 T5: PRR for Foil Production**	May 22, 2019	May 22, 2019
645	GE2/1 R&D T4: Testing and Assessment of Stage-2A Demonstrator (partial: GEB M1-2) w/ Gen-1 electronics Complete	May 17, 2019	May 17, 2019
646	GE2/1 R&D T4: Ready for EDR	May 17, 2019	May 17, 2019
647	**GE2/1 R&D T5: Performance of the Demonstrator chamber with Prototype Electronics is Validated**	May 22, 2019	May 22, 2019
648	**GE2/1 E5: EDR (CMS TC - External Constraint)**	May 22, 2019	May 22, 2019
649	GE2/1 R&D T4: All Gen-1 On-Chamber Prototype Electronics Manufacturing and Testing is Complete. Ready for full integration with the Stage-2A Demonstrator @ CERN.	May 29, 2019	May 29, 2019
650	GE2/1 R&D T4: Testing and Assessment of Stage-2A Demonstrator w/ Gen-1 electronics Complete	Jun 18, 2019	Jun 18, 2019
651	GE21 R&D T4: uTCA-based Backend System for Gen-2 GE21 electronics is Ready for Full Integration Testing with Gen-2 on-Chamber Electronics	Aug 9, 2019	Aug 9, 2019
652	**GE2/1 R&D E5: RISK MANAGEMENT DECISION POINT: LpGBT or GBTX-based readout selected for ESR**	Aug 30, 2019	Aug 30, 2019
653	GE21 R&D T4: Hardware/firmware ready for integrated testing of the packaged chips	Oct 1, 2019	Oct 1, 2019
654	GE21 R&D T4: Components of the ATCA-based Backend Readout System Hardware Test-Stand are Ready for Integration	Nov 4, 2019	Nov 4, 2019
655	GE21 R&D T4: Gen-2 Electronics Design Complete; Ready for Manufacturing	Oct 31, 2019	Oct 31, 2019
656	GE2/1 R&D T4: Packaged Chips Bonding to PlugInCards-2 starts at a European vendor	Nov 28, 2019	Nov 28, 2019
657	GE21 R&D T4: Packaged VFAT3 performance testing and packaging validation at INFN/Bari completed	Dec 27, 2019	Dec 27, 2019
658	GE2/1 R&D T4: All Gen-2 Electronics Boards are Ready for Installation on Stage-2B Demonstrator and mechanical integration studies @ CERN	Jan 31, 2020	Jan 31, 2020
659	GE2/1 R&D T4: Testing and Assessment of Phase-2B Demonstrator w/ Gen-2 electronics Complete	April 3, 2020	April 3, 2020
660	**GE2/1 R&D T5 (OPTION): Ready for ESR in GBTX-based scenario**	April 3, 2020	April 3, 2020
661	GE21 R&D T4: ATCA-based Backend System for Gen-2/3 GE21 electronics is Ready for Full Integration Testing with Gen-3 on-Chamber Electronics	Mar 23, 2020	Mar 23, 2020
662	GE21 R&D T4: All Gen-3 Electronics Components Designs Complete	Mar 27, 2020	Mar 27, 2020
663	GE21 R&D T4: GEB-3 Boards Arrive to CERN	Jun 19, 2020	Jun 19, 2020
664	GE21 R&D T4: Development of the Software and Firmware infrastructure with fully integrated backend Complete	Jun 26, 2020	Jun 26, 2020
665	GE2/1 R&D T4: All Gen-3 Electronics Boards are Ready for Installation and mechanical integration studies @ CERN	July 17, 2020	July 17, 2020
666	GE2/1 R&D T4: Testing and Assessment of Stage-3 Demonstrator w/ Gen-3 electronics Complete. Ready for ESR	Aug 21, 2020	Aug 21, 2020
667	**GE2/1 R&D T5: On- and Off-Chamber Readout Prototype Electronics Integration and Performance Studies Completed**	Aug 21, 2020	Aug 21, 2020
668	**GE2/1 E5: ESR (CMS TC - External Constraint)**	Aug 21, 2020	Aug 21, 2020

Ready for ESR (GBTX): Apr. 3 2020

Ready for ESR (LpGBT): Aug. 21 2020