Phase 1C: GEM Fabrication

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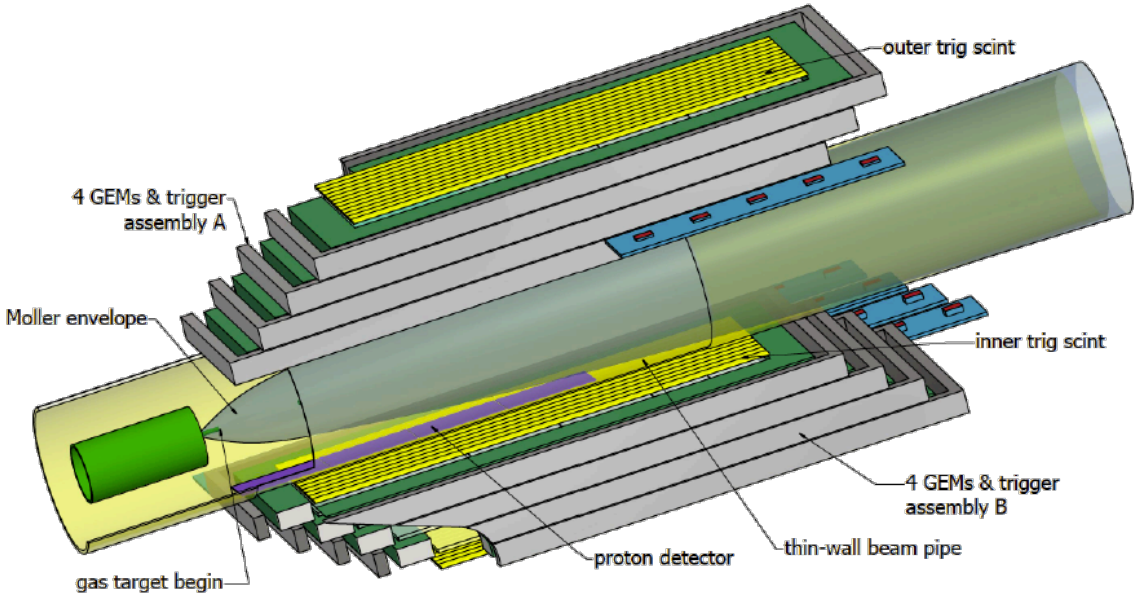
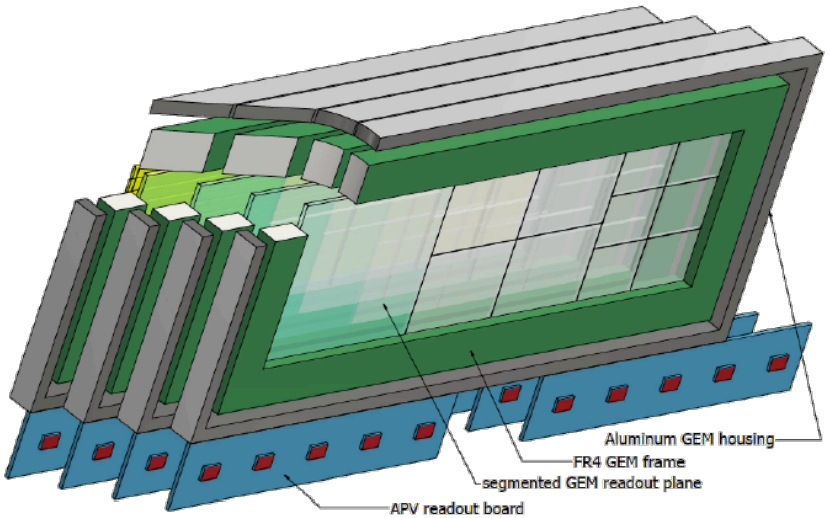
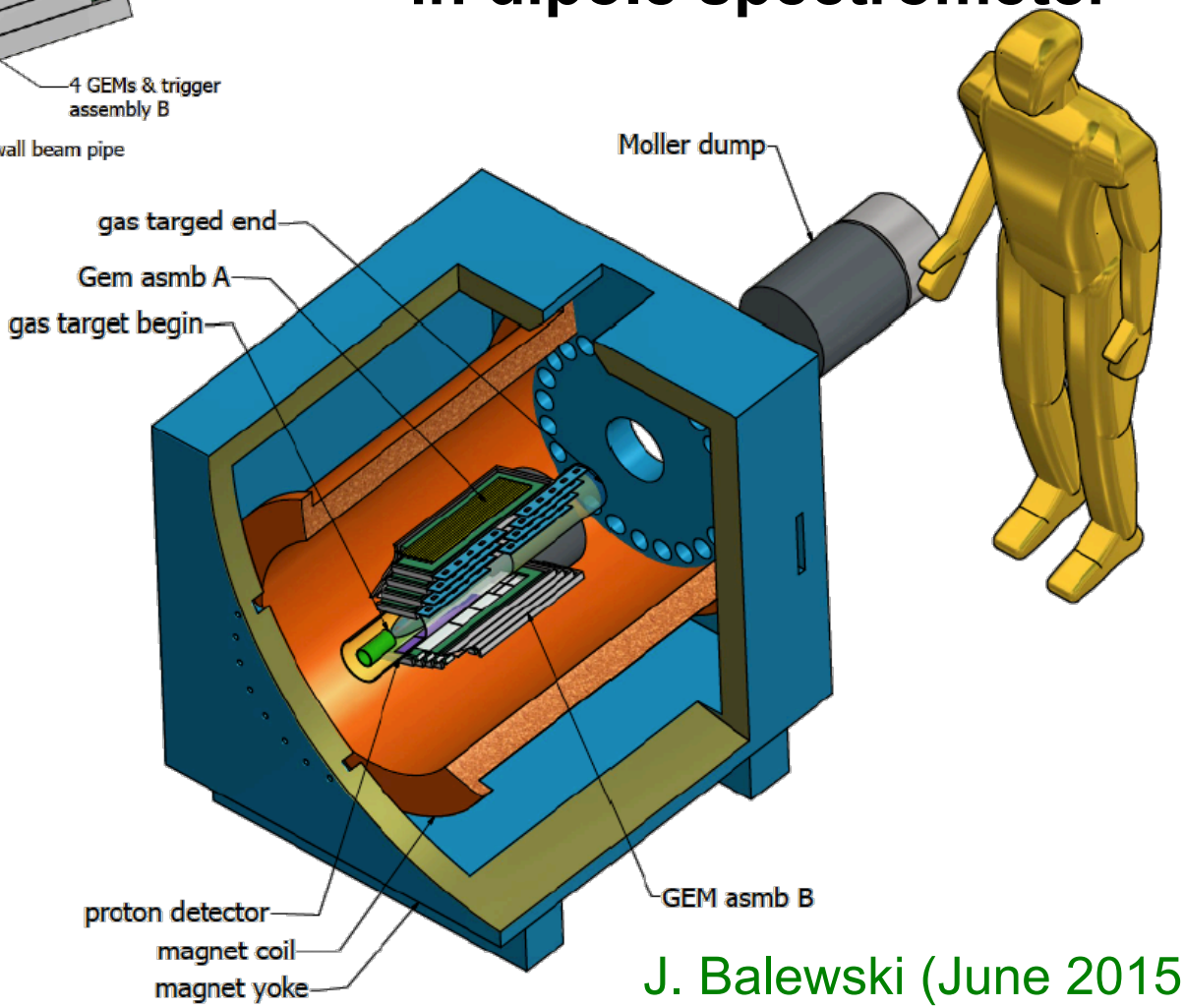
GEMs for DarkLight Phase 1c (MRI 2014)



For lepton tracking in ep → epee

Compatible with use in dipole spectrometer





J. Balewski (June 2015)

Phase 1c Update

March 2017 collaboration meeting:

1) Build and test GEMs as planned and laid out in June 2015 ?
2) Build GEMs with updated design parameters / size / number of channels ?
3) Build something else for Phase 1c ?
4) Use UVa assembly line to have GEMs built / subcontract – only test at HU ?

MRI award expiration July 31, 2017 !!!

Phase 1c Update

What has happened since the March 2017 collaboration meeting:

2) Build GEMs with updated design parameters / size / number of channels

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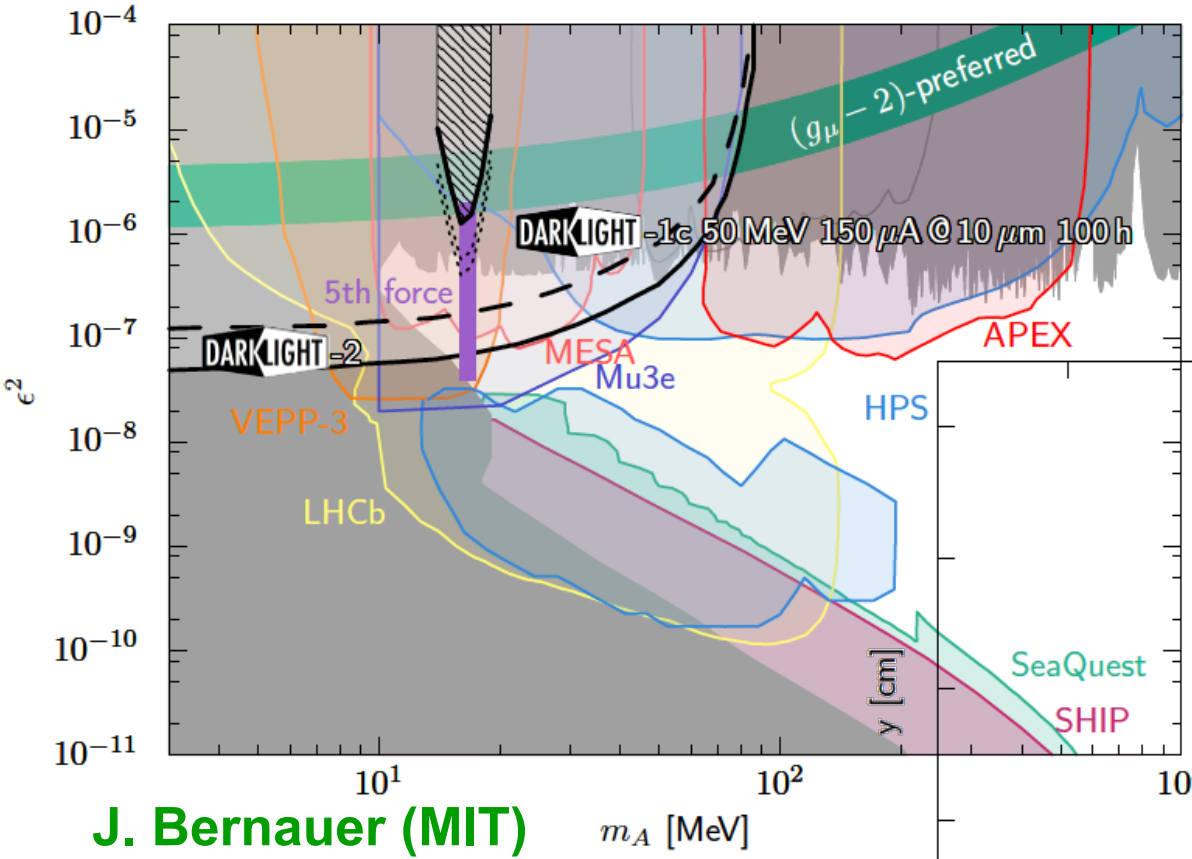
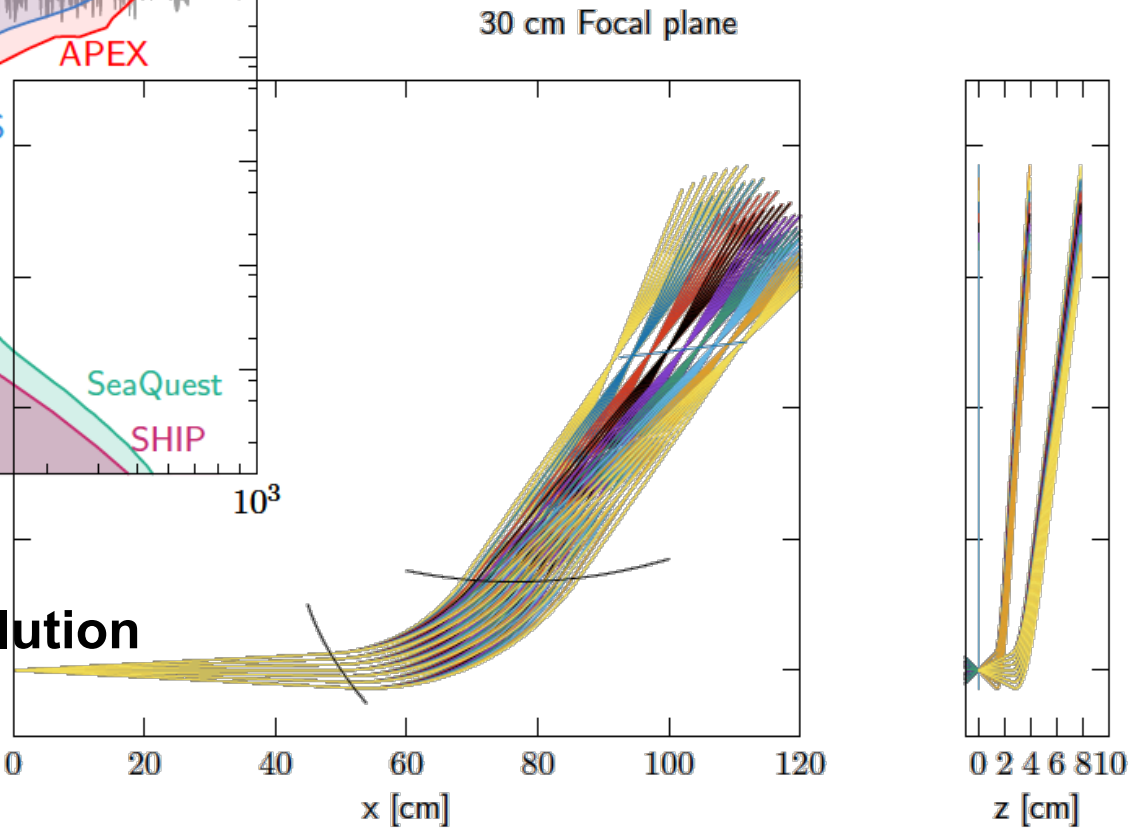


Dedicated search for the 17-MeV fifth-force carrier

J. Bernauer (MIT)

Two-spectrometer solution to detect e+e- pair



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March/April 2017: Talks with UVa group (N. Liyanage) looked like promising avenue for Phase 1c GEM production – details to be worked out

April 18, 2017: Phone conference with Richard and Jim Shank, discussed NCE and plan to have the GEMs produced at UVa

May 5, 2017: Submitted document to request NCE, favoring production at UVa

June 7, 2017: NSF phone call with Jim Shank and Randy Ruchti. **Must build GEMs at HU (development MRI !) as necessary condition for NCE.**

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Fall 2017: Decided on active size: 25x40 cm^2 ; 2x3 = 6 GEM elements
APV/MPD readout: 400µm pitch, 5+8=13 APVs/, 78 APV/6 MPD, ~10k channels

[but also some delay: PSI beamtime, challenges with admin, planning for spring]

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Dec. 30, 2017: Submitted progress report

Jan. 5, 2018: J. Shank mandating more detailed reporting requirement

Jan. 24, 2018: R. Ruchti new program officer for MRI, phone call on Feb. 2

Feb. 11, 2018: Submitted detailed, revised plan of action, approved Feb. 21, 2018

Status update due end of April

Plan of Action (approved Feb. 21, 2018)

1.1 Manpower

Postdocs, students, technician

1.2 Tasks and Timeline

Preparation phase

Construction phase

Testing and commissioning

1.3 Milestones

May 1, 2018:

All drawings finalized.

June 1, 2018:

Purchase orders for detector parts and electronics submitted.

July 31, 2018:

All remaining grant funding spent before expiration.

Preparation phase completed.

January 1, 2019:

Construction phase completed.

March 1, 2019:

Testing and commissioning completed. GEMs ready.

1.4 Costs

Item	Amount	Price/$	Total/$	Remarks
A) GEM detector parts				
G10/FR4 GEM frames	36	100	3,600	3/chamber x6(+18)
G10/FR4 PV frames	9	100	900	1/chamber x6(+3)
G10/FR4 HV frames	18	100	1,800	2/chamber x6(+6)
G10/FR4 frames NRC	3	125	375	non-recurring cost
GEM foils	36	700	25,200	3/chamber x6(+18)
GEM foils NRC	1	10,000	10,000	glass photo tool
HV foils	8	700	5,600	1/chamber x6(+2)
HV foils NRC	1	2,500	2,500	regular photo tool
Readout layer	10	1,000	10,000	1/chamber x6(+4)
Readout layer NRC	1	3,000	3,000	regular photo tool
Al test chamber	2	2,500	5,000	for HV and gain testing
Foil stretcher tool	2	1,000	2,000	special tool
Total GEM parts			69,975	
B) Electronics				
VME crate	2	7,084	14,168	Wiener 64x
VME CPU	2	5,335	10,670	GE XVB602 or XVR15
APV25 cards	91	150	13,650	13/cham. x6(+13)
VME MPD digitizer	7	3,000	21,000	6 for 6x13 APVs (+1)
4-APV backplanes	15	500	7,500	2/cham. x6(+3)
5-APV backplanes	8	500	4,000	1/cham. x6(+2)
Total Electronics			70,988	
C) Additional materials and supplies				
Support structure	2	2,000	4,000	1 per sector
HV distribution	7	300	2,100	voltage dividers 6(+1)
Gas flow regulator	7	200	1,400	at entrance 6(+1)
Gas piping	7	200	1,400	6(+1)
Cabling HV, APV	7	500	4,500	per chamber x6(+1)
Misc. items	1	10,000	10,000	small items, materials
Total Materials			23,400	
Indirect charge			11,232	indirect for materials
Total A) + B) + C)			175,595	

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Jan/Feb. 2018: Re-organized working group
(Anusha → Ishara → TBA; technician; undergrads)
Detailed discussions with Uva and INFN
Established contact with Rui de Oliveira at CERN

March 9, 2018: MK and T. Patel visited R.d.O. at CERN, long discussion about the best concept: **NS2 – no stretch, no stress!**

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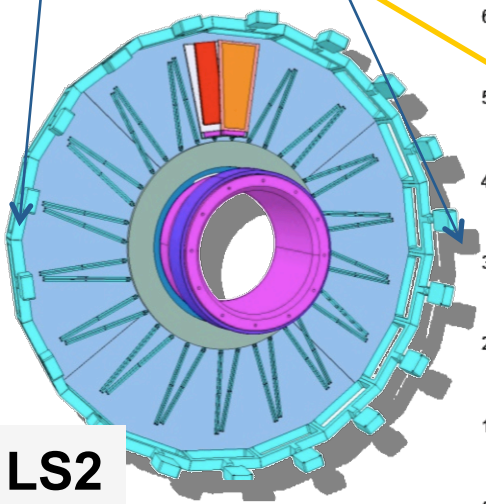
	Glued-foil design	vs.	NS2 concept
Assembly	2 foils / day, 1 chamber / week		1 chamber / 2 hours!
Mistakes	Inexcusable, fatal		Can be corrected
Changes	Impossible		Can be implemented
Risk	High risk of failure, accumulating		Very low risk
Dead area	Spacer grid required		No dead area
Cost		no big difference	

The CMS GEM Project

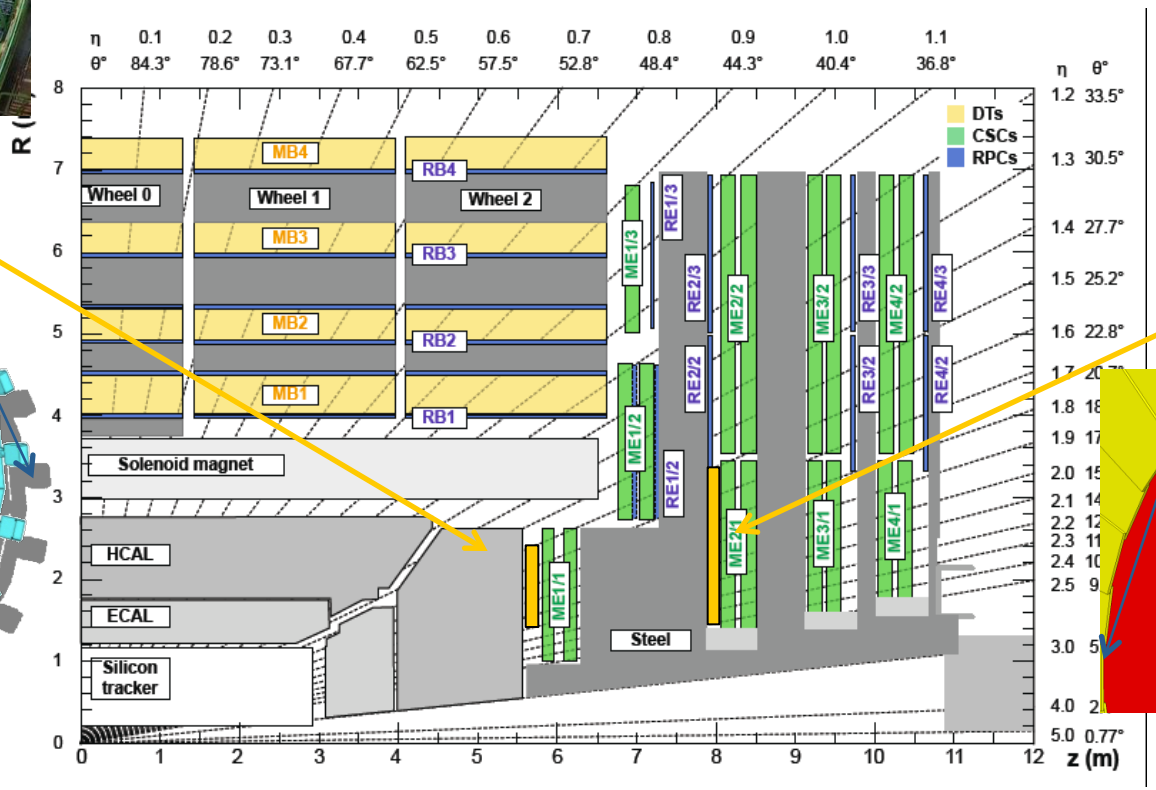
Install triple-GEM detectors (double stations) in 1.6<|η|<2.1-2.4 endcap region:

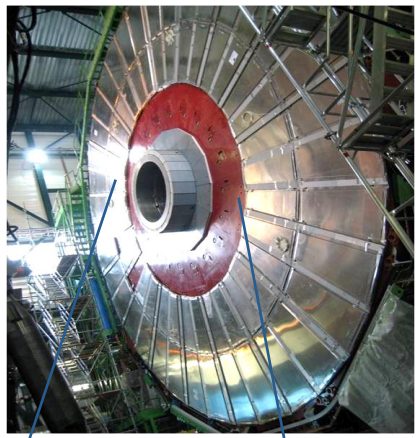
- ✓ Restore redundancy in muon system for robust tracking and triggering
- ✓ Improve L1 and HLT muon momentum resolution to reduce or maintain global muon trigger rate
- ✓ Ensure ~ 100% trigger efficiency in high PU environment

GE1/1



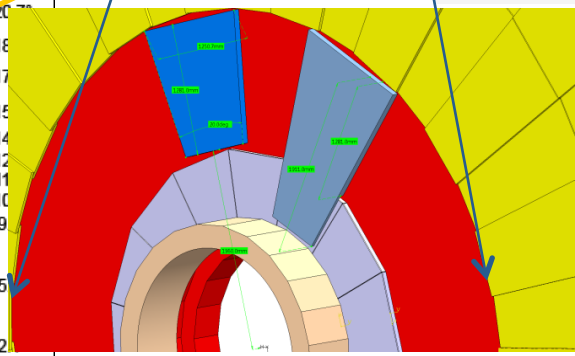
LS2





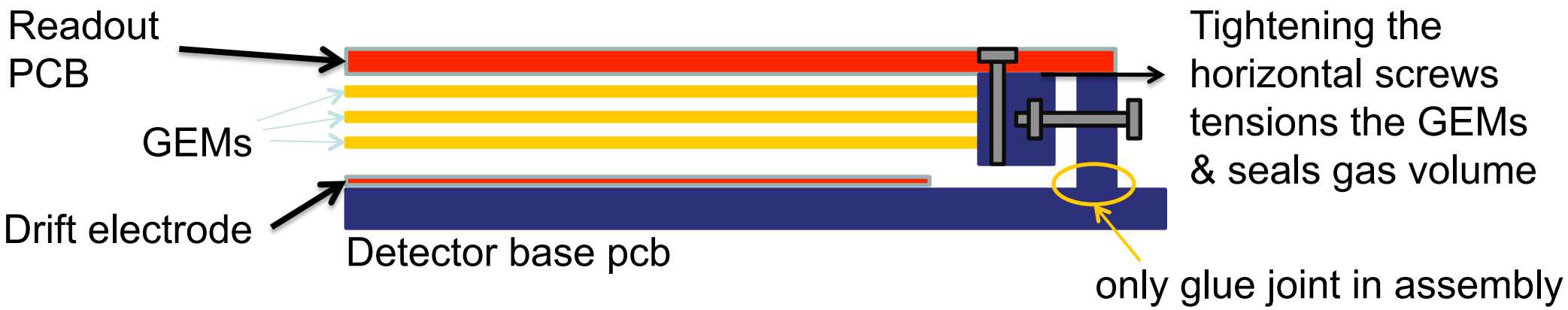
GE2/1

LS3?



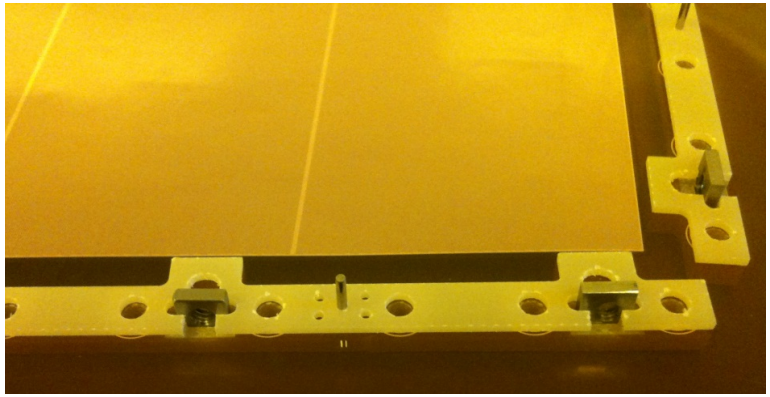
NS2 (CMS Muon Endcap System)

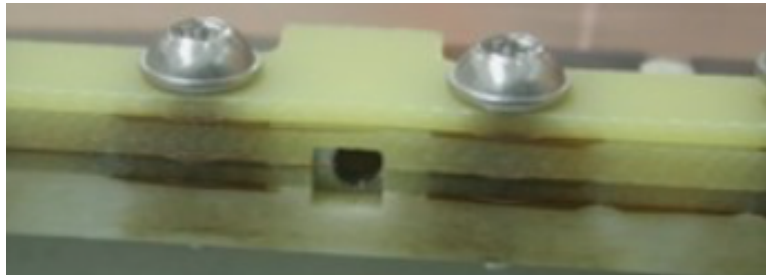
Current state-of-the-art: Self-stretching assembly without spacers (CERN)



2012

- No spacers in active area
- Assembly time: 2 hours
- No gluing, no soldering
- Re-opening possible
- GEM exchange possible
- No stretch degradation with time
- Stretching more intense
- Base PCB and honeycomb in active area

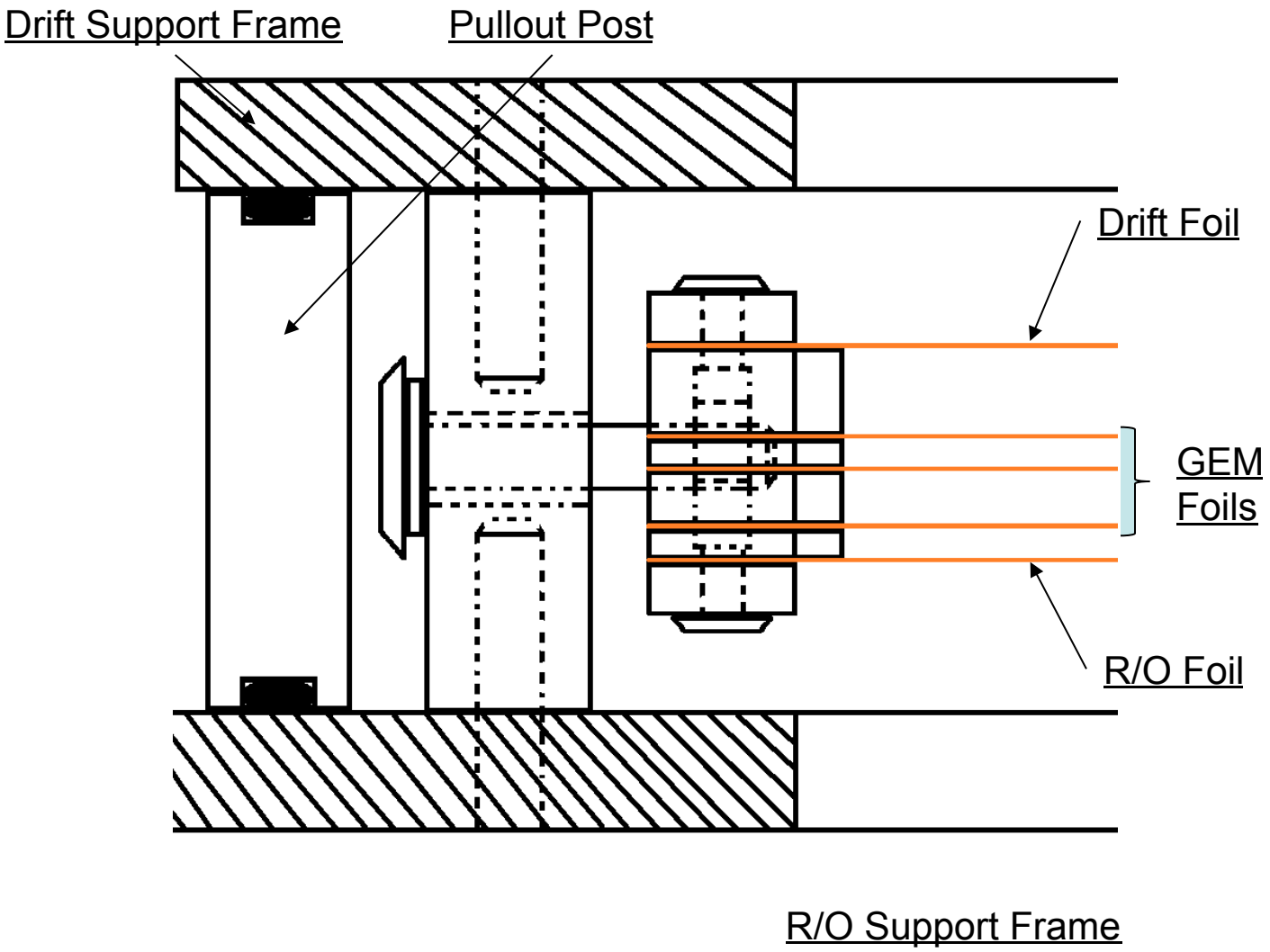




NS2 (EIC prototype)

EIC prototype (M. Hohlmann, Florida Institute of Technology)

Minimizing material budget in active area

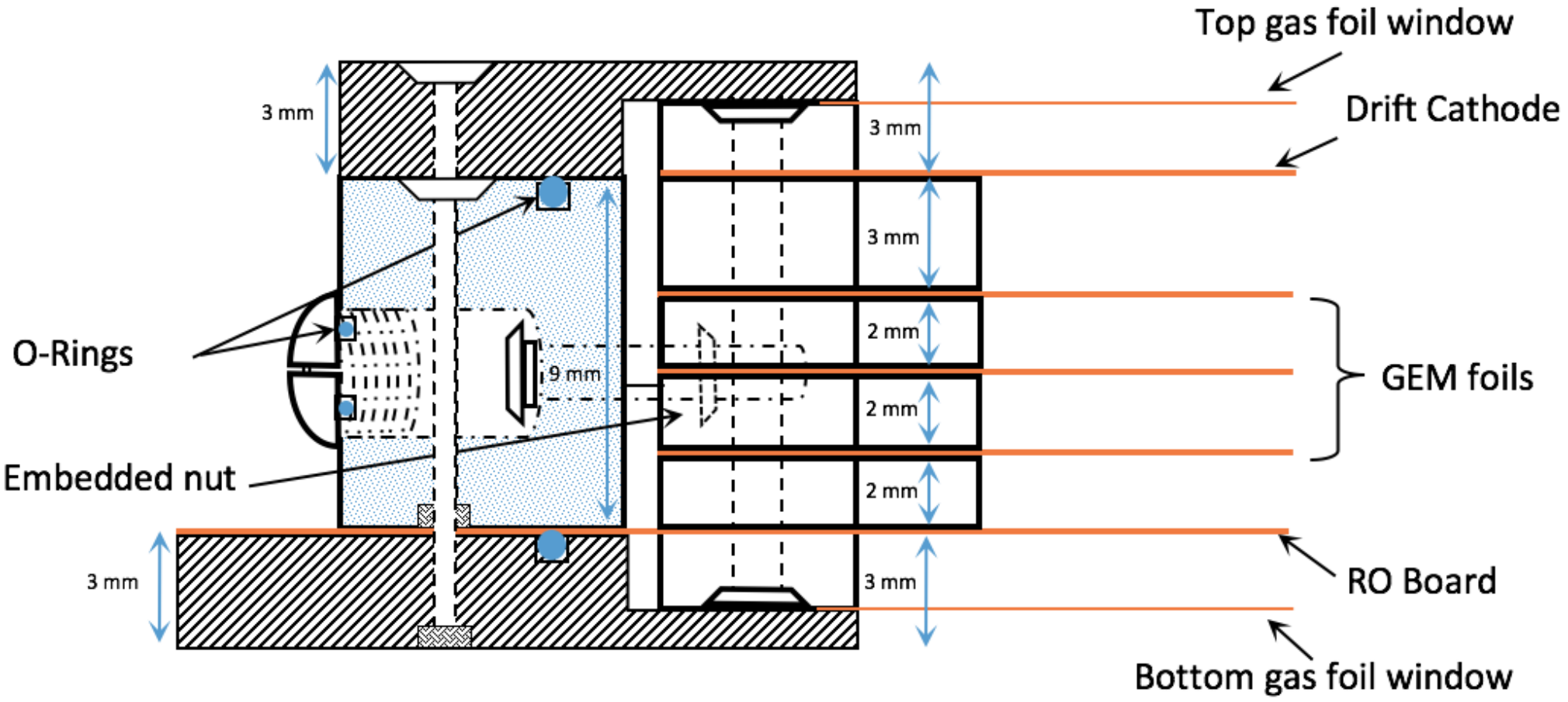


NS2 (DarkLight Phase 1c)

5-layer stack clambed and stretched

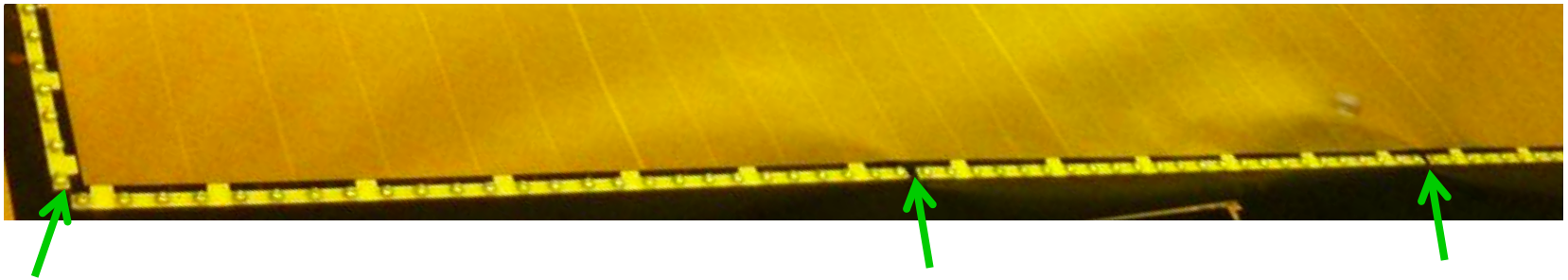
Guiding out RO layer to exterior on 2 sides for signals, and 1 side for HV

Cr(0.1μm) on Kapton or Al(3μm) on Mylar for Gas Pressure Windows



NS2 (DarkLight Phase 1c)

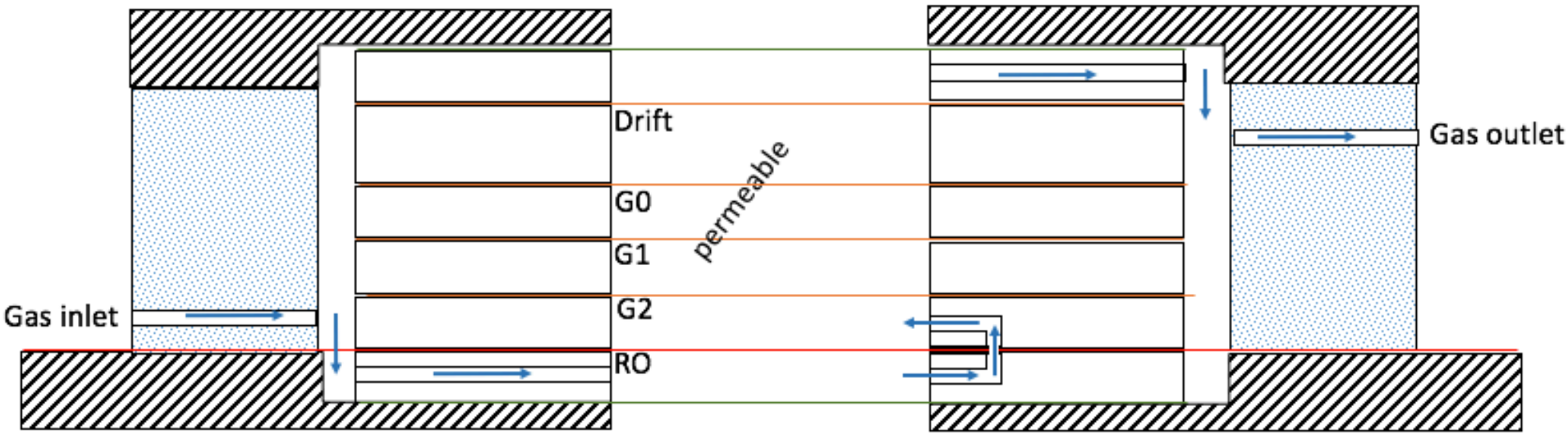
CMS: rate density < 100 kHz/cm^2, gas flow not forced



Interruptions in inner frames for entrance points, all layers permeable

DarkLight: Forced gas flow suggested, for higher rate capability <10 MHz/cm^2

Replace also dead volume below Readout (RO); Use permeable GEM foil for Drift



Production cost for 6 detectors (Mar. 2018)

	m/o	matiere	tooling	design
-24 GEM (6 feuilles de 4 p)	12000		1200	2000
-6 read-out with connectors	25200		500	2000
-inner frames	4200	600		500
-outer frame	4800	600		500
-closing frame	2400	600		400
-6 set of screws /o-ring/gas feeds		2000		
-7 cathodes	2450		400	300
Totals	51050	3800	2100	5700

Cost for 6 detectors: CHF 54,850

Design : CHF 5,700

Tooling: CHF 2,100

Total: CHF 62,650 = USD 65,947 (0.95 CHF/$)

Budgeted in NCE for GEM costs: USD 69,975

Electronics

VME crates: Group has 4x Wiener 64x.
- Updated quotes from Wiener and CAEN
- [PO in preparation for 4 mini crates (MUSE) $16,000]

Controllers: Group has 1x XVB602, 1x XVR15, and 3x V7768.
- **Updated quotes from Abaco**
- **PO in preparation for 7x XVB602 $25,915**

APVs:
- **Need 78+x. APV chips becoming scarce.**
- **Found 100 at MIT; small batches at Uva, Temple, Bonn**
- **PO in preparation for 96x APV25 from Imperial Coll. $ 1,516**
- **Quotation requested for APV cards from EES, Italy est. $20,000**

Backplanes:
- **Need 15x 4-APV (UVa), 8x 5-APV (ISU) backplanes est. $15,000**

MPDs:
- **Group has 7x MPD4**
- **Need additional 6+x.**
- **Quotation requested for MPD modules from EES est. $14,000**

Total $76,431

Budgeted in NCE for electronics $70,988

Account balance

MUSE (558812)

Remaining scientific equipment funds (noIDC):	**$16,032.00**

MRI (558809)

Remaining salary funds incl. fringe (+IDC)	**$26,948.41**
Remaining supplies funds (+IDC)	**$23,082.27**
Remaining scientific equipment funds (noIDC):	**$138,225.00**
Total remaining in MRI	**$188,255.68**

Budet is sufficient for six (6) GEM chambers including APV+MPD electronics

Can possibly afford another 1-2 GEMs, with different readout layer for streaming readout study

Present working group *

NSF postdoc (Ishara Fernando: MUSE)
shared / funded presently by NSF — Sri Lanka

DOE postdoc (Tongtong Cao: TREK/E36)
funded presently by DOE — China

PhD student (Jesmin Nazeer: DarkLight, GEMs)
funded presently by NSF — Sri Lanka

Master's student (Tanvi Patel: MUSE, GEMs)
funded presently by NSF/EAGER — India / USA

PhD student (Bishoy Dongwi: TREK/E36)
funded presently by DOE — Namibia

Undergraduate students

Letrell Harris, HU sophomore: GEMs — USA

Angel Christopher, HU freshman: GEMs — Nigeria
funded presently by DOE and NSF

Lab Technician (Ameer Blake: GEMs)
funded presently by NSF — USA

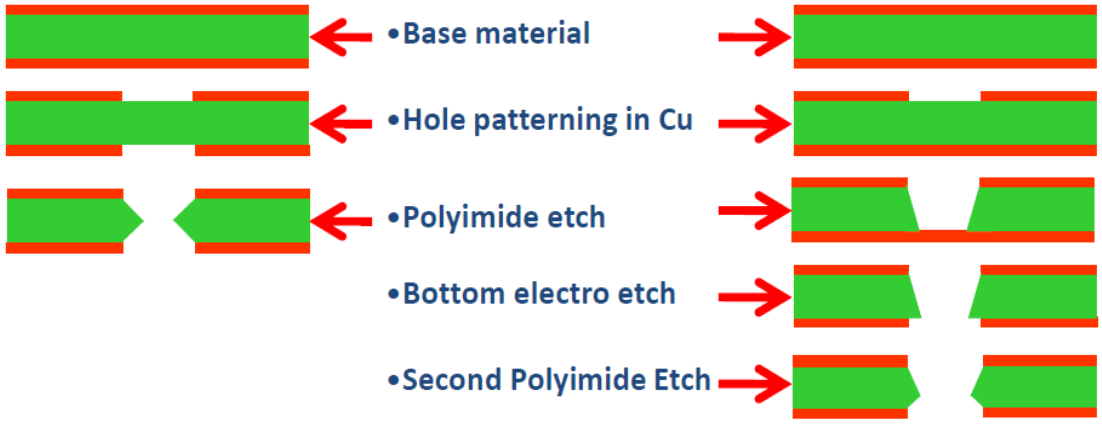
* Presently supported by DOE DE-SC0013941, NSF HRD-1649909, PHY-1505934 and PHY-1436680

Conclusion

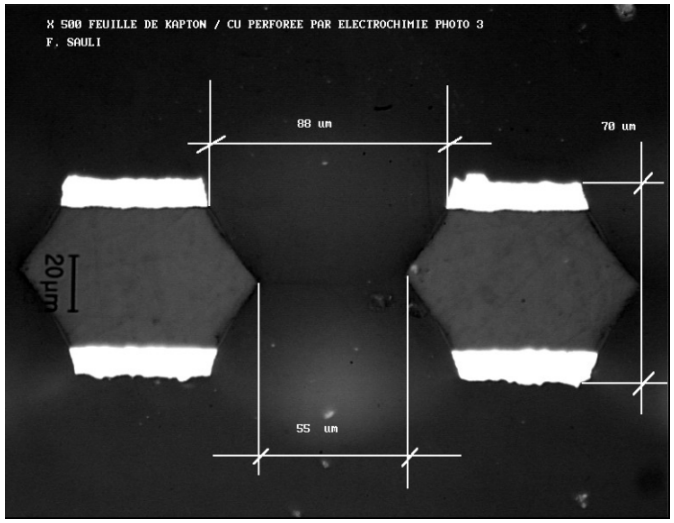
- Successful completion of MRI project feasible
- Budget is in place and sufficient
- New NS2 concept adopted for self-stretching GEMs without gluing
- Preparations at full swing, within projected timeline
- Phase-1C GEM setup to be ready by early 2019

Double Mask vs Single Mask

Base material = Polyimide 50µm + 5µm copper cladding on both sides



Achieved 40x40cm²



Achieved 200x60cm²