



The Spacecraft Atmosphere Monitor (S.A.M.) for ISS and Orion

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International Space Station (ISS)

Major Constituent Analysis

Major Constituent Analyzer (MCA)



Trace Gas Analysis

Major Constituent Analysis

Vehicle Cabin Air Monitor (VCAM)



Trace Gas Analysis

Volatile Organic Analyzer (VOA)



ISS & Orion

Multi Program Air Monitor (MPAM)

Major Constituent Analysis



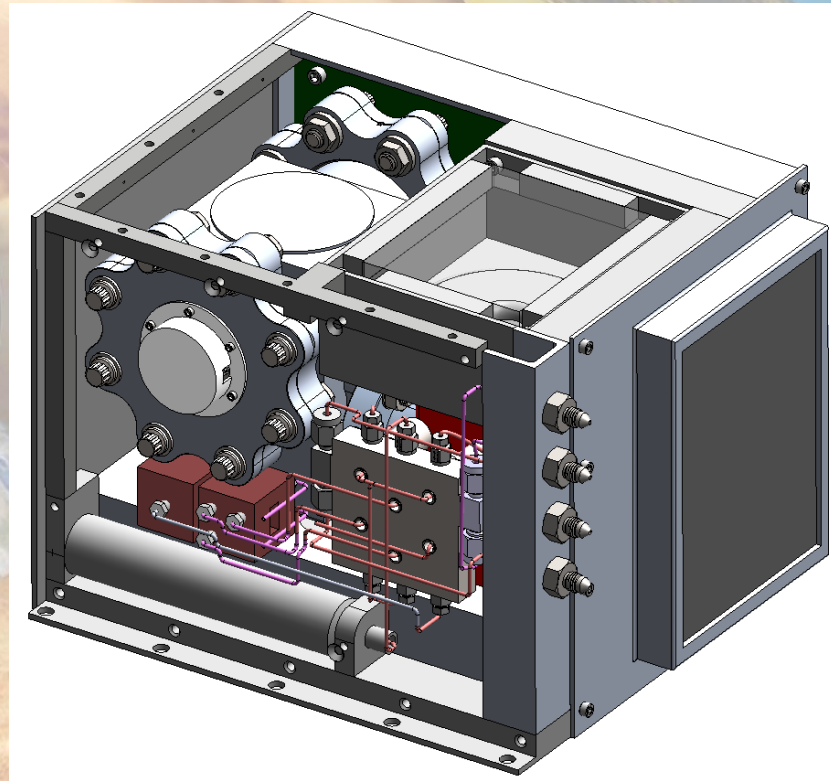
Spacecraft Atmosphere Monitor (S.A.M.)

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ISS & Orion

Major Constituent Analysis

Trace Gas Analysis



Operate MCA During Launch

Analyze Spacesuit While
Cabin Depressurized

Mobility

Trace Gas Analysis

Spacecraft maximum allowable concentration (SMAC)

VCAM SMAC List:

	<i>Compound</i>	<i>Concentration Range (ppm)</i>
Priority 1	Ethanol	1-10
	Acetaldehyde	0.1-3
	Acetone	0.5-5
	Dichloromethane	0.03-5
	Octamethylcyclotetrasiloxane	0.05-1
	Hexamethylcyclotrisiloxane	0.1-2
	Propylene glycol	0.5-5
	Perfluoropropane	10-100
Priority 2	1-Butanol	0.5-5
	Benzene	0.01-1
	C5 Alkanes (Pentane)	2-20
	C7 Alkanes (Hexane)	2-20
	C5 Aldehydes (Pentanal)	0.1-2
	C6 Aldehydes (Hexanal)	0.1-2
	Ethyl benzene	1-10
	Ethyl acetate	1-10
	2-propanol	1-10
	Freon 113	2-10
	Furan	0.01-1
	Toluene	1-10
	Xylenes (3)	1-10
Priority 3	1,2-Dichloroethane	0.01-0.1
	2-butanone	0.5-5
	4-methyl-2-pentanone	2-10
	Carbonyl sulfide	0.01-1
	Chloroform	0.02-1
	Freon 11	2-10
	Isoprene	0.05-1
	Limonene	1-10
Vinyl chloride	0.05-1	

Major Constituent Analysis

VCAM MCA List: N₂, CO₂, O₂, CO, Ar

Parameter	VCAM	S.A.M.	Comment
<i>Mass</i>	32.6 kg (+ 5.3 kg consumables module)	9.5 kg (including consumables)	>1/3 Mass
<i>Dimensions</i>	10.8" x 18.1" x 20.4"	9.5" x 8.75" x 7.5"	Reduced Volume
<i>Volume</i>	64.4 L	10 L	1/6 Volume
<i>Average Power During Measurement</i>	120 W	45 W	1/3 Power
<i>Operation</i>	Hard Mount, Static Operations Only	Mobile	Portable
<i>Start-up Time</i>	150 minutes (2.5 hours)	<2 minutes	Tolerance to dormancy/on-off cycles
<i>Operation Mode</i>	Mostly Standby, Expect during measurements	Continuous MCA	Continuous operation
<i>Time to make an MCA Measurement</i>	3-5 Hrs	Every 2 seconds	Dramatically reduced response time
<i>Time to make a Trace VOC Measurement</i>	40 min	10 min	Reduce response time
<i>Carrier Gas Consumption</i>	1.2 cm ³ /min	0.1 cm ³ /min	Lower consumables
<i>Valves</i>	9 x 24 Vdc COTS Parker (12 Watts during operation)	5 x Space-rated Mindrum (< 1 Watt during operation)	Lower power
<i>Preconcentrator (PC)</i>	100x enrichment	4000x enrichment	Higher sensitivity
<i>GC Injection</i>	Valved injection of 15 µL sample loop	No separate loop, MEMS valve/PC acts as injector	Electrostatic, not pneumatic injection valves
<i>Column</i>	10 m commercial GC column	1 to 5 m MEMS GC column	Lower consumables
<i>Elution Time</i>	20 minutes	<10 minutes	Faster response time
<i>Ion Trap Size</i>	10 mm	4.5 mm (1/2 size of VCAM)	Reduced size
<i>MS Pump</i>	70 L/s TMP+4-stage diaphragm pump	6 L/s ion/getter pump	Mobility, and operation during launch or landing
<i>Thermal</i>	Convection (air) cooled	Convection (air) or Conduction (water) cooled.	Common across architecture

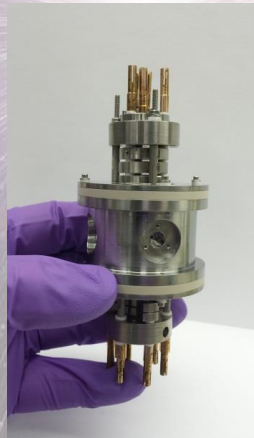
S. A. M. Concept

Paul Ion Trap MS:

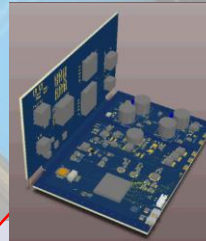
- Smaller UHV Chamber
- New Sensor: ion gun & detector
- “Wireless” design

3 RF sources:

- High power amplifier
- High Q, high voltage air-core resonant tank
- Folding electronics design



HV PCB Low Voltage PCB



Ion/Getter Pump
NEXTorr D100-5



Inlet

Mindrum
Valves



1.5"

Sample Pump



Metal Hydride H₂
Carrier Tank



MEMS-PCGC



Cooling Module
(ISS operations)

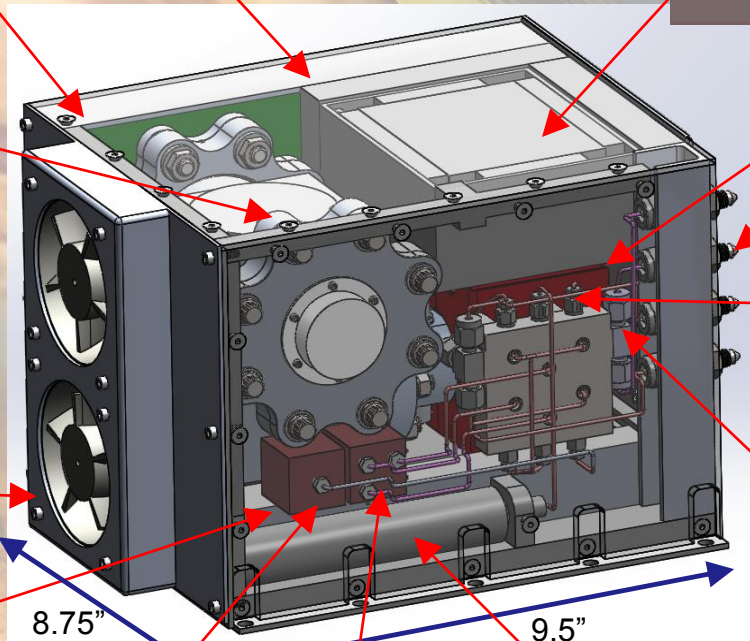
MS Control PCB



7.5"

8.75"

9.5"

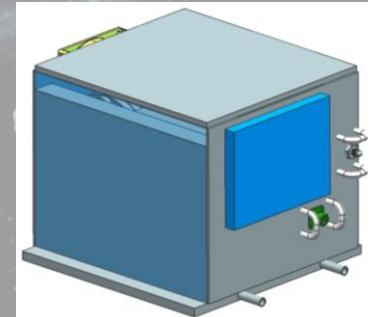
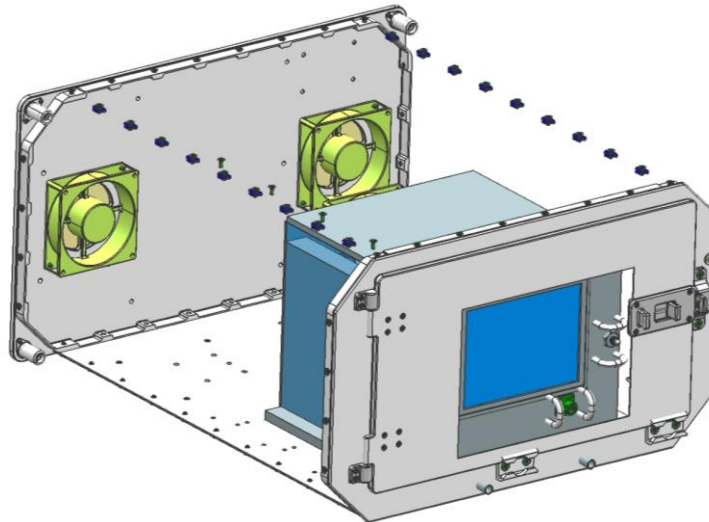
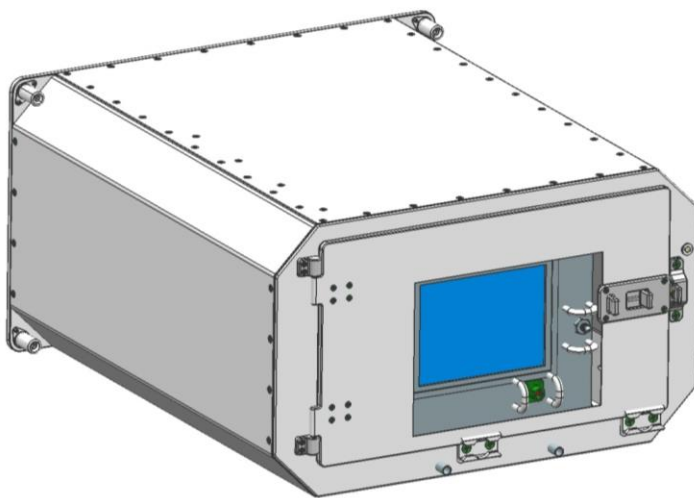


Implementation on ISS

S.A.M. will be mounted in an EXPRESS Rack

EXPRESS Rack provides:

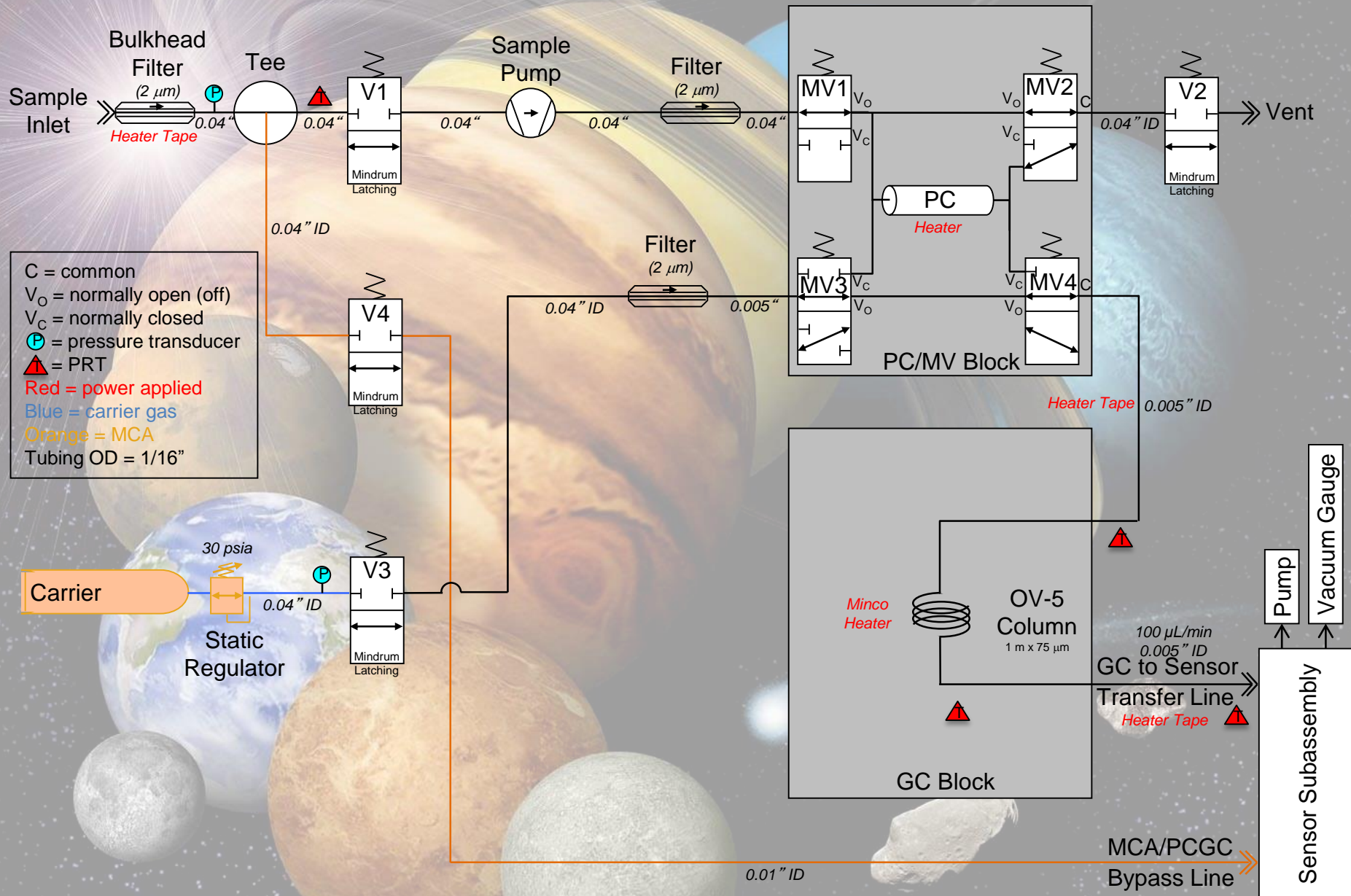
- Mechanical attachment
- 28 VDC, 9 Amp
- Ethernet
- Conditioned Air
- Moderate Temperature Loop (MTL)



EXPRESS Rack Configuration

Remote Configuration

S.A.M. Plumbing Diagram

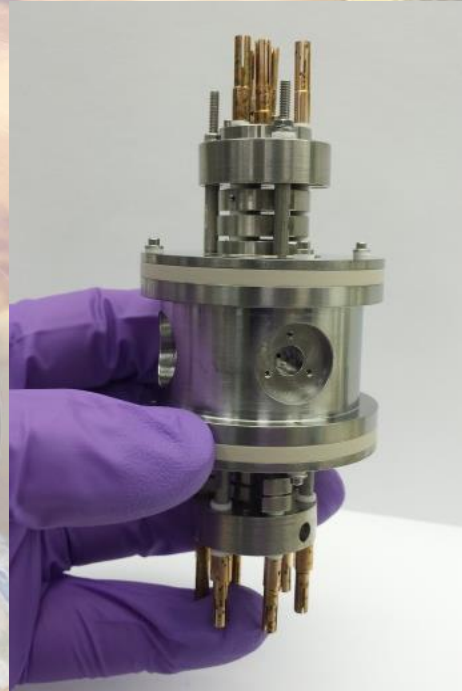


Core Components - Sensor

All tests are performed with (a) 10 mm trap in 6" cross chamber (T1) (b) 10 mm trap in custom chamber (T2) and (c) 4.5 mm trap in the 2.75" spherical cube (T3)

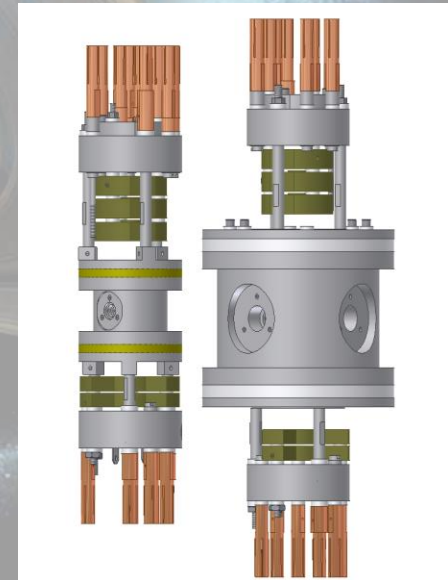


T3: 4.5 mm trap

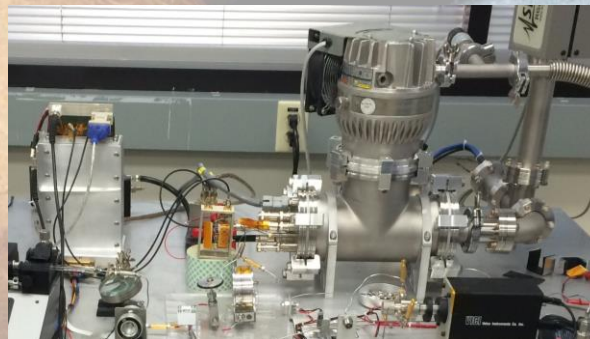


T2: 10 mm trap

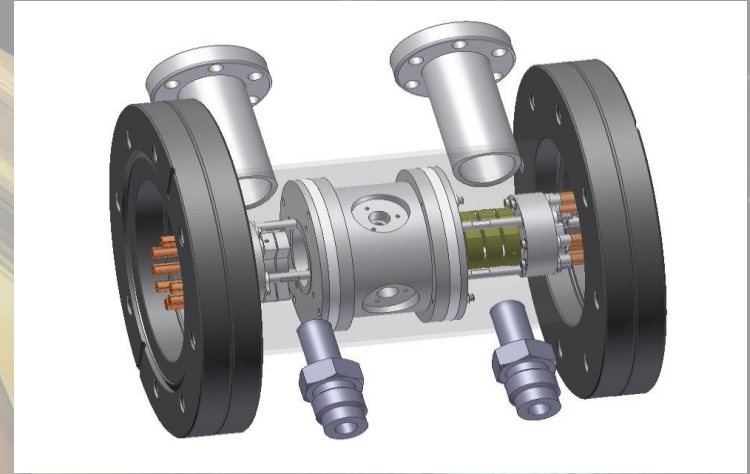
vs.



T1: 10 mm trap in COTS chamber

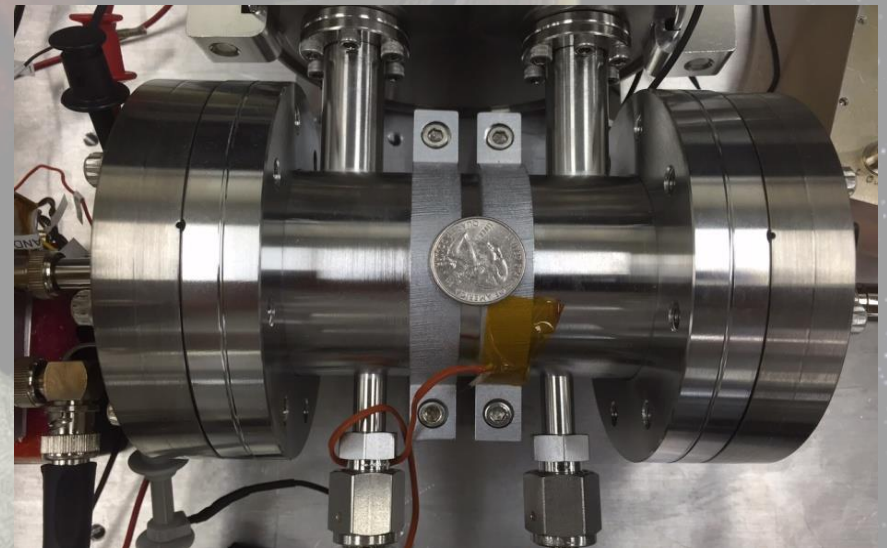
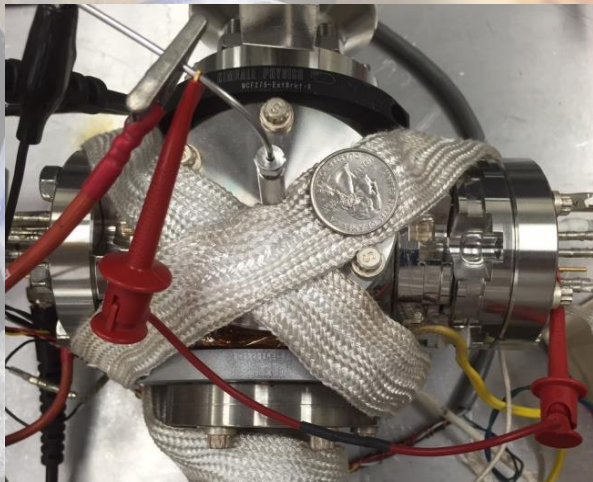


Core Components - Chamber



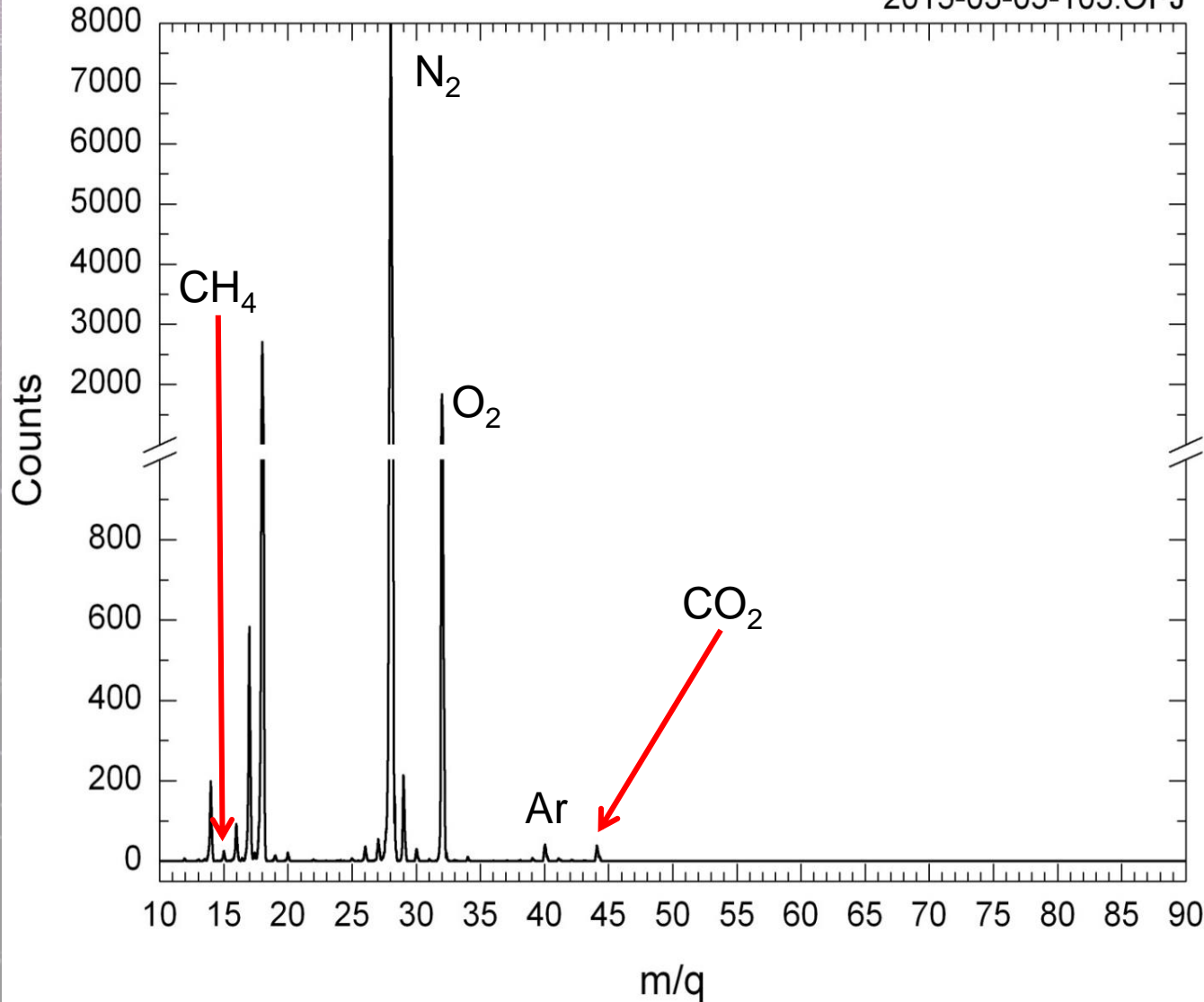
T3: 4.5 mm trap in 2.75" spherical cube

T2: 10 mm trap in custom chamber 4.5CF



MCA - T1

2015-03-05-103.OPJ



Example of MCA on T1 system (1.2 MHz)

Resolution: 240 @ 40 (0.17 amu)

Sensitivity 5E12 cnts / Torr / s

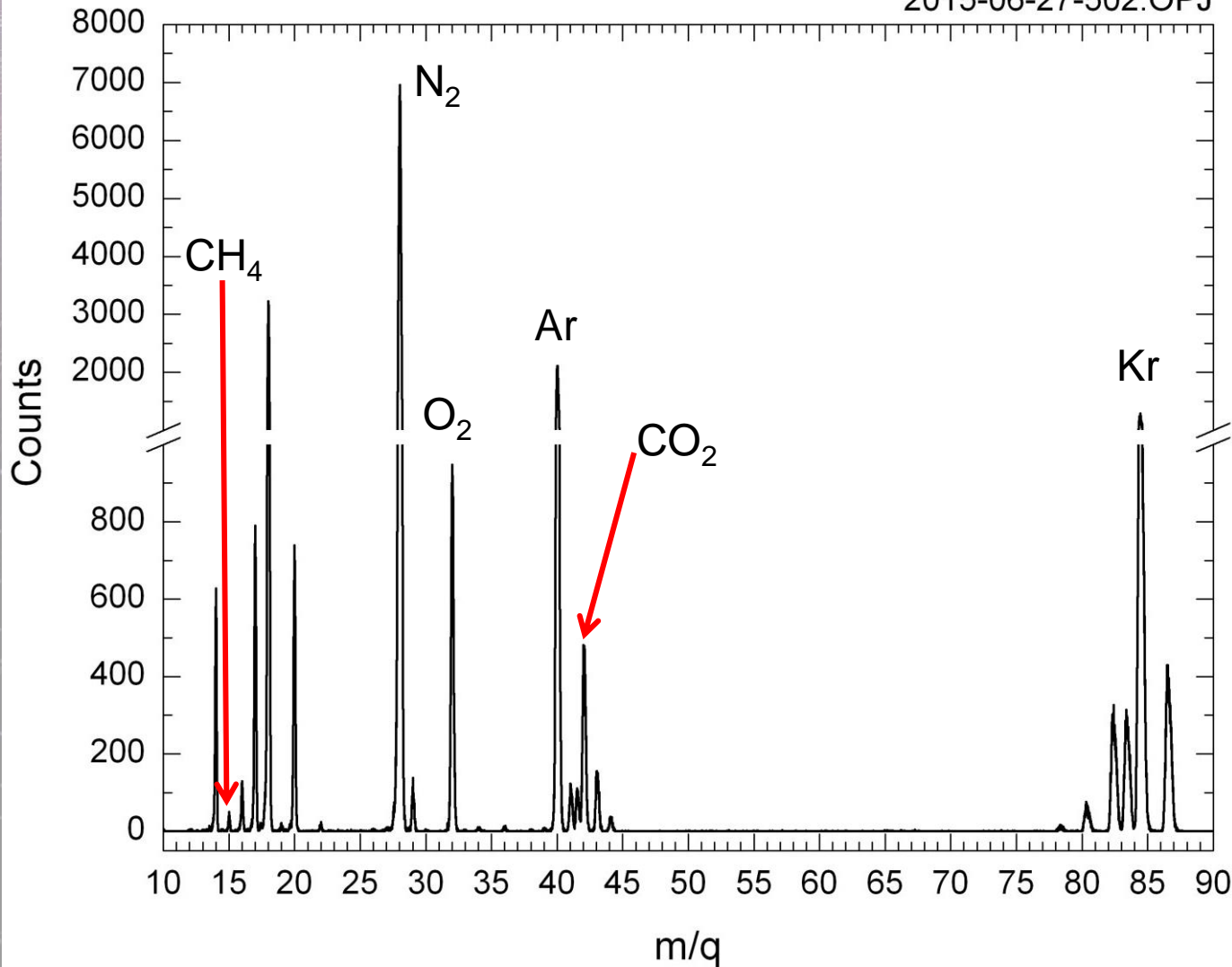
MCA - T2

2015-06-27-502.OPJ

Example of MCA on
T2 system (with
SAM electronics
prototype)

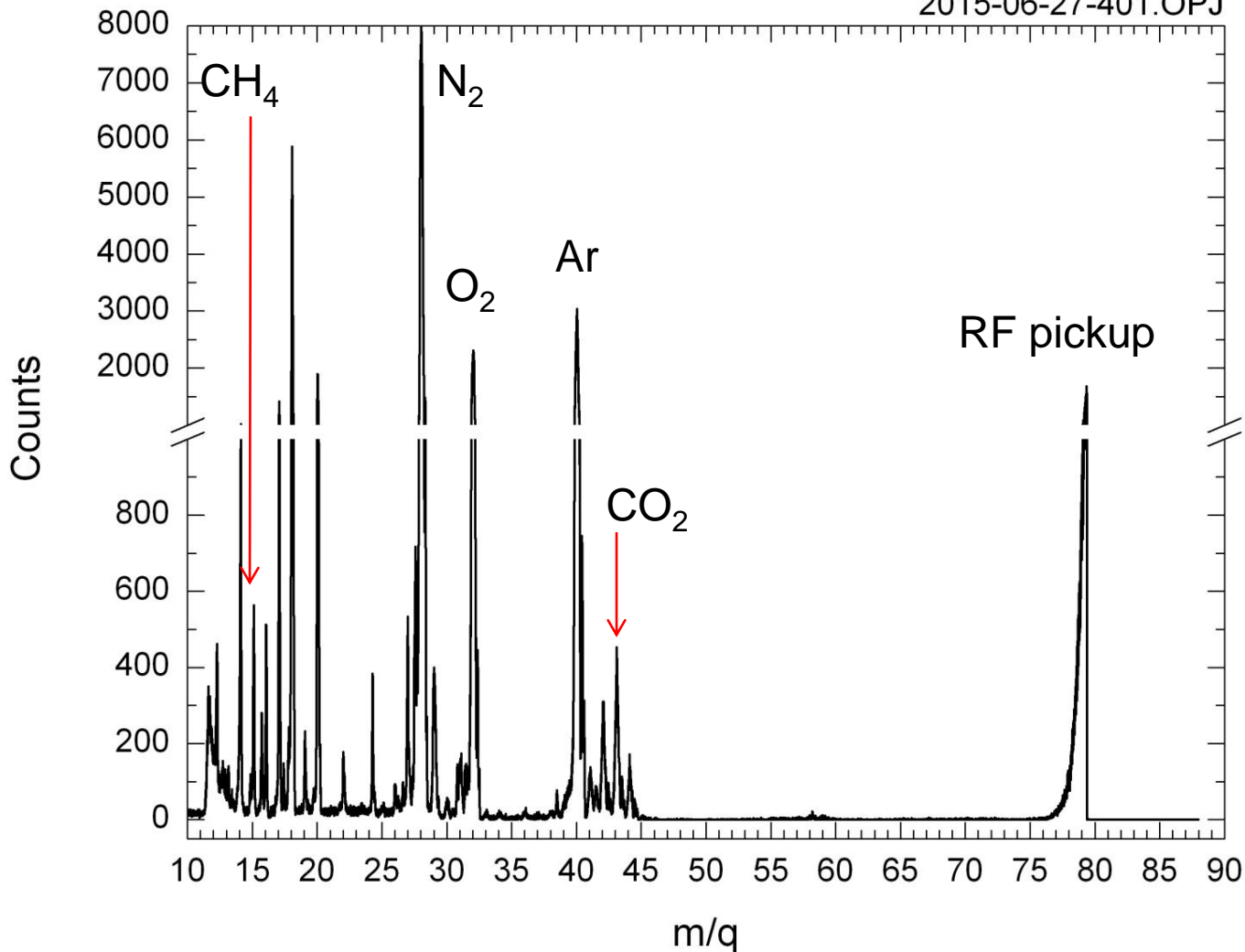
Resolution:
200 @ 40 (0.2 amu)

Sensitivity 5E12
cnts / Torr / s



MCA - T3

2015-06-27-401.OPJ

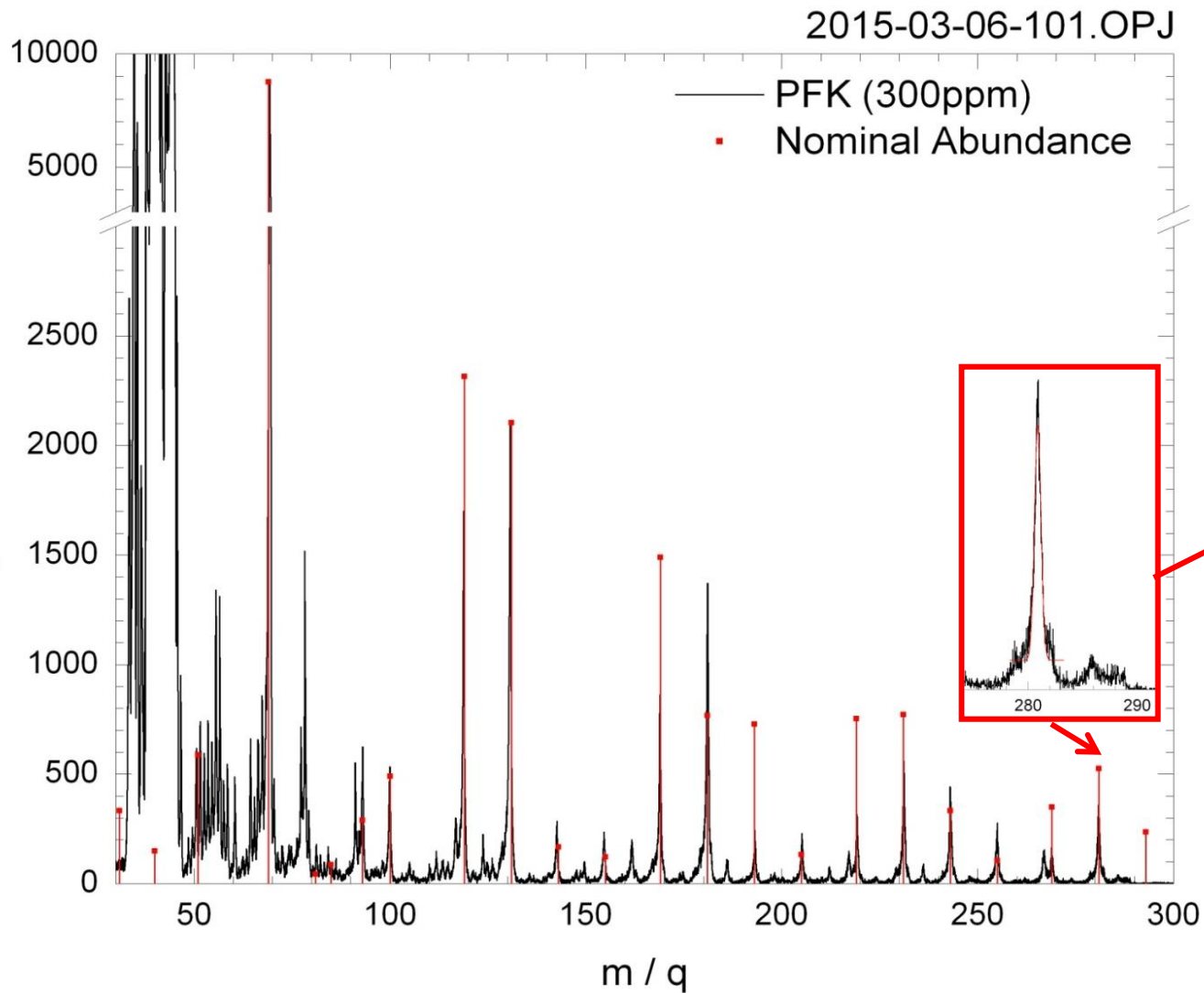


Example of MCA on
T3 system (with
SAM electronics
prototype)

Resolution:
160 @ 40 (0.25
amu)

Sensitivity 5E12
cnts / Torr / s

Mass Range – T1

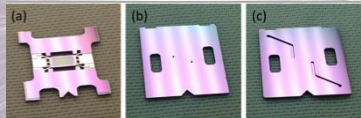


Example of mass range on **T1** system (with SAM electronics prototype)

No loss of sensitivity for high masses

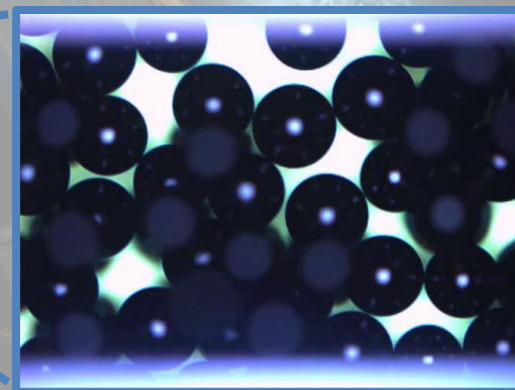
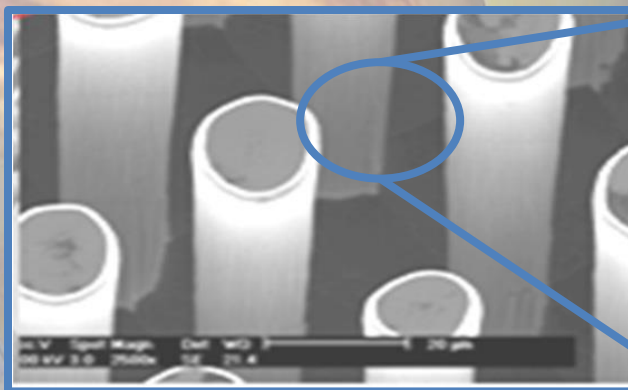
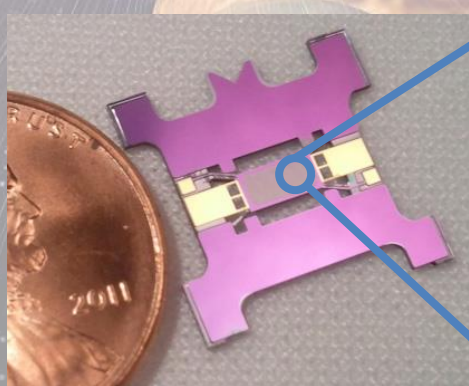
Resolution: >300 at 280 (0.6 amu)

Core Components – MEMS Pre-Concentrator (PC) Chip



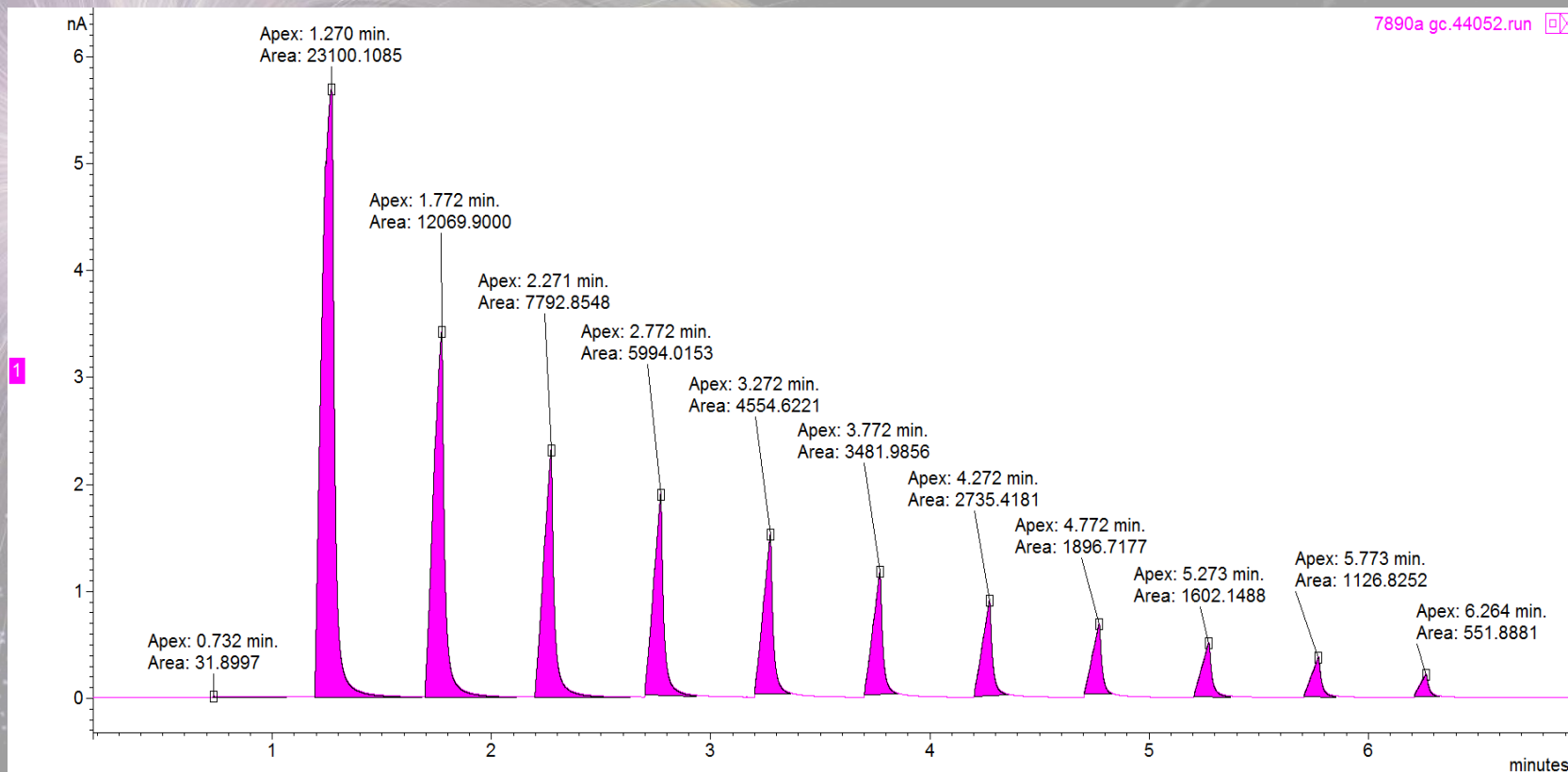
Heater/carboxen/inlet-outlet layers (from left to right)

Carboxen 1000,
~177-250 μm particles,
~10-12 \AA pore diameter



- Silicon heater can be heated to 250° C in 0.5 sec for obtaining high PC gain.
- Thermal isolation design is the key of the flash heating.
- Carboxen in a monolayer w/ posts removed.

PC Gain Data

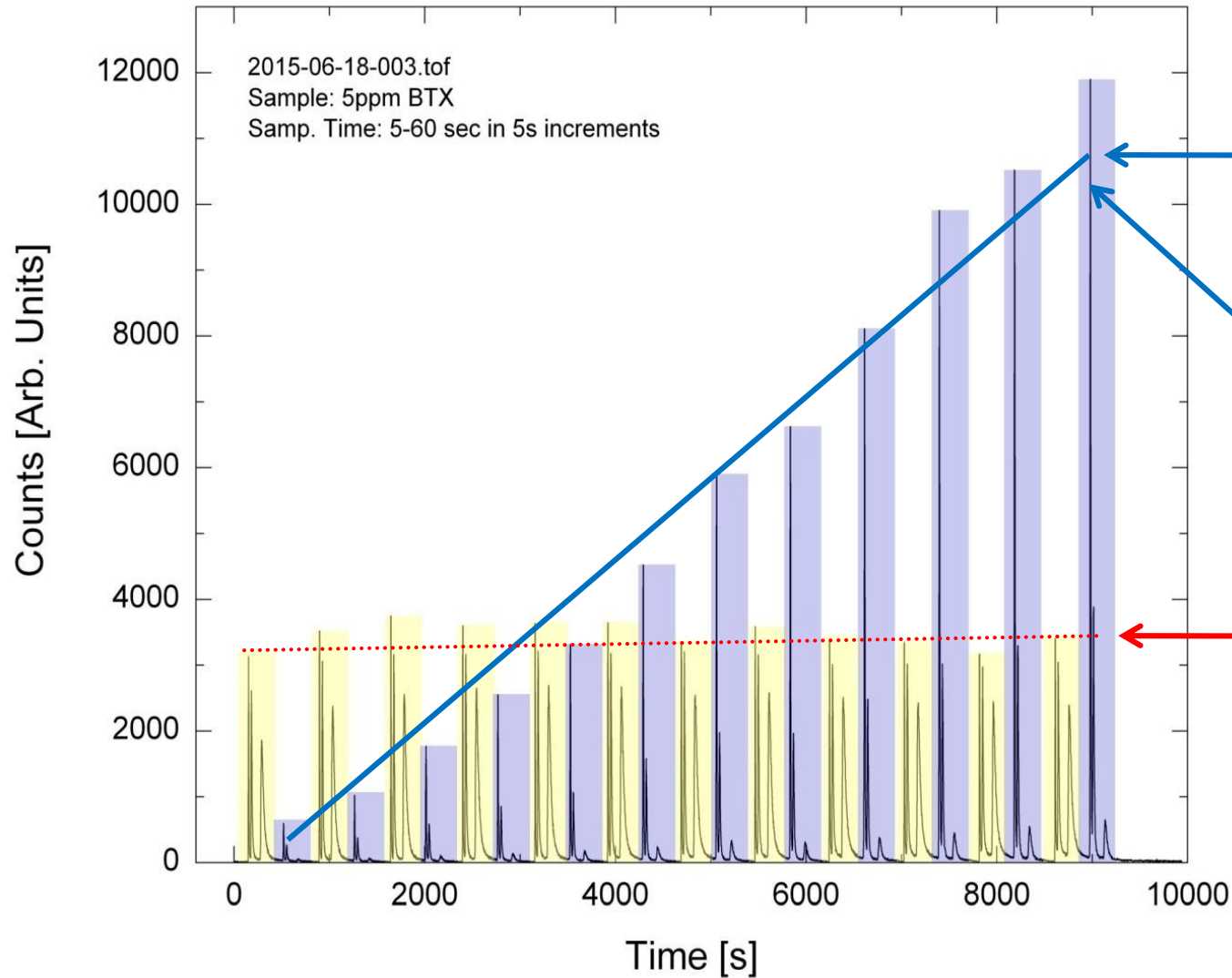


- Total area from heating peaks – 64900
- Injection area of 32 from 12 uL sample loop
- PC volume is 2 uL
- PC gain is = $64900 / (32/12 * 2) = 12,170$
- The gain for the first highest peak: $23100 / (32/12 * 2) = 4331$

Other conditions:

- 10 psi head pressure
- Not heated to capacity
- 85 V (0.3 A current limit) for 5 s applied to PC every 25 s
- Concentration – 1 uL Acetone in 1 L He

PC Gain Data – T1

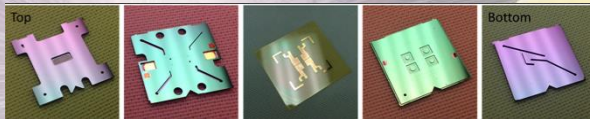


Linear increase with Sample time

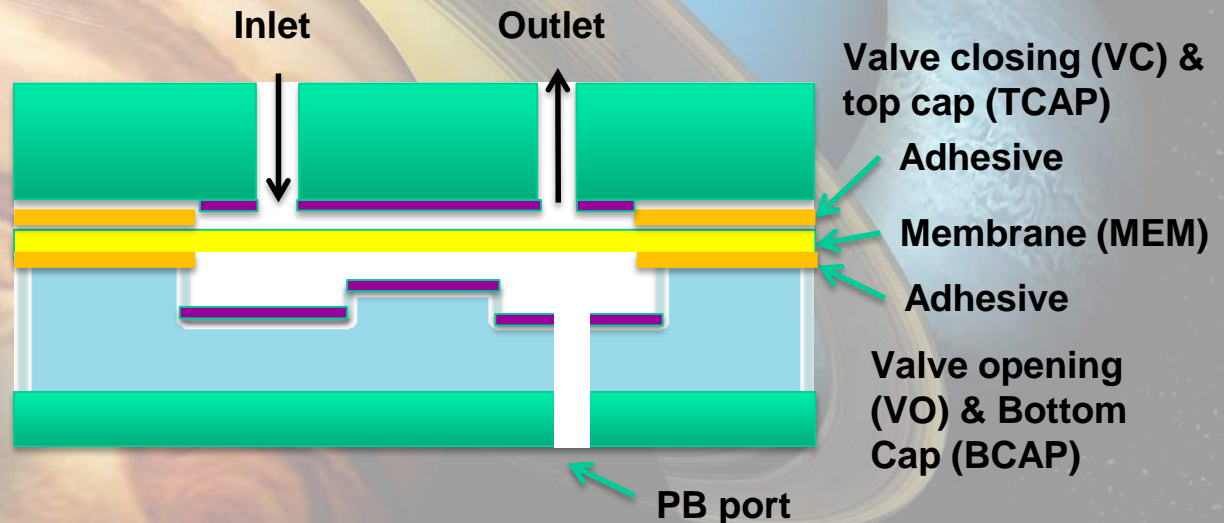
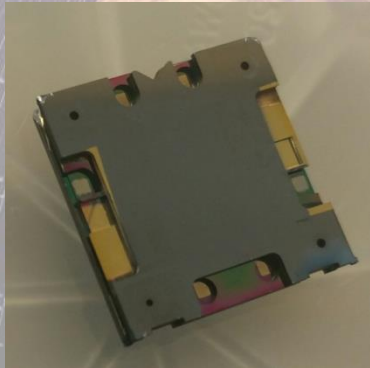
PC gain measurement

Constant desorption

Core Components – MEMS Micro-Valve (MV) Chip

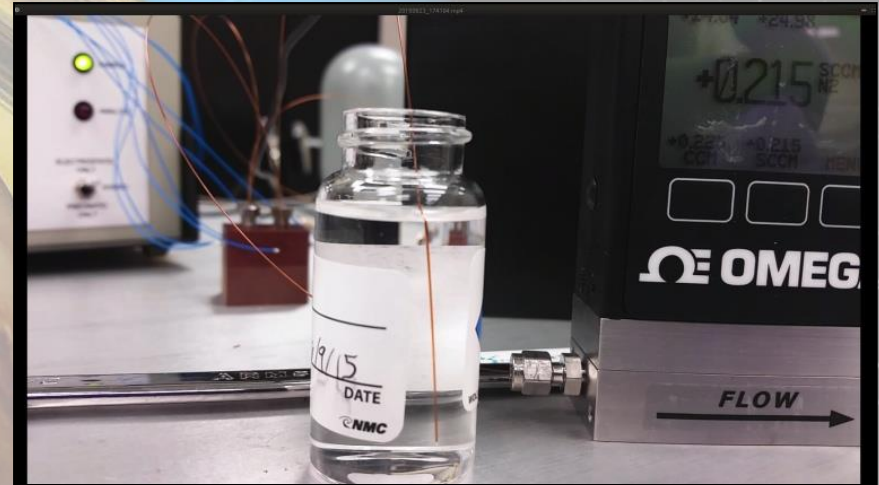
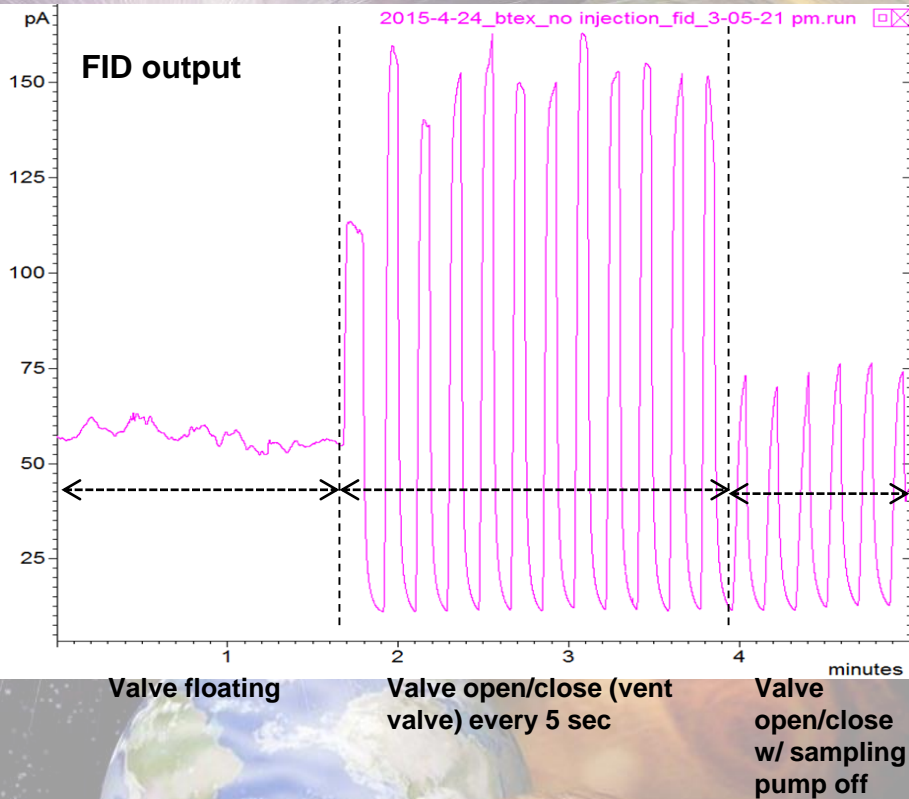


TCAP/VC/MEM/VO/BCAP layers
(from left to right)



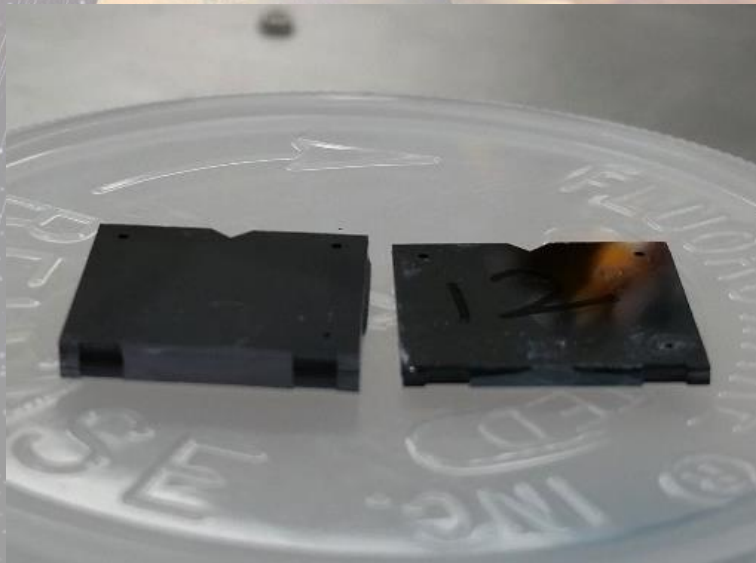
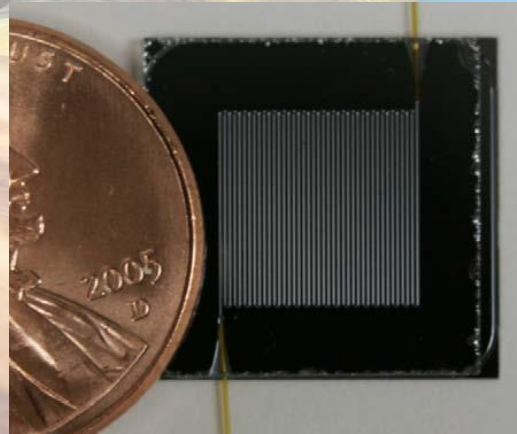
- Four microvalves (MVs) are integrated in a chip: Sample, Vent, Carrier, and Injection; for valving a complete GC cycle.
- All the valves are electrostatically controlled.
- Unique zipper design for closing: Center pad design for reducing applied voltage and stress.
- Anti-stiction coating (purple) and pressure balancing (PB).

MV Data



- **Electronics:** first year PIDDP Cbana lunch box deliverable. MV block: existing Cbana package.
- The green/red light in the left background means sampling/injection stage.
- The IPA bubble from the capillary is connected to the vent valve. When the green is lit, the capillary shows bubbles.

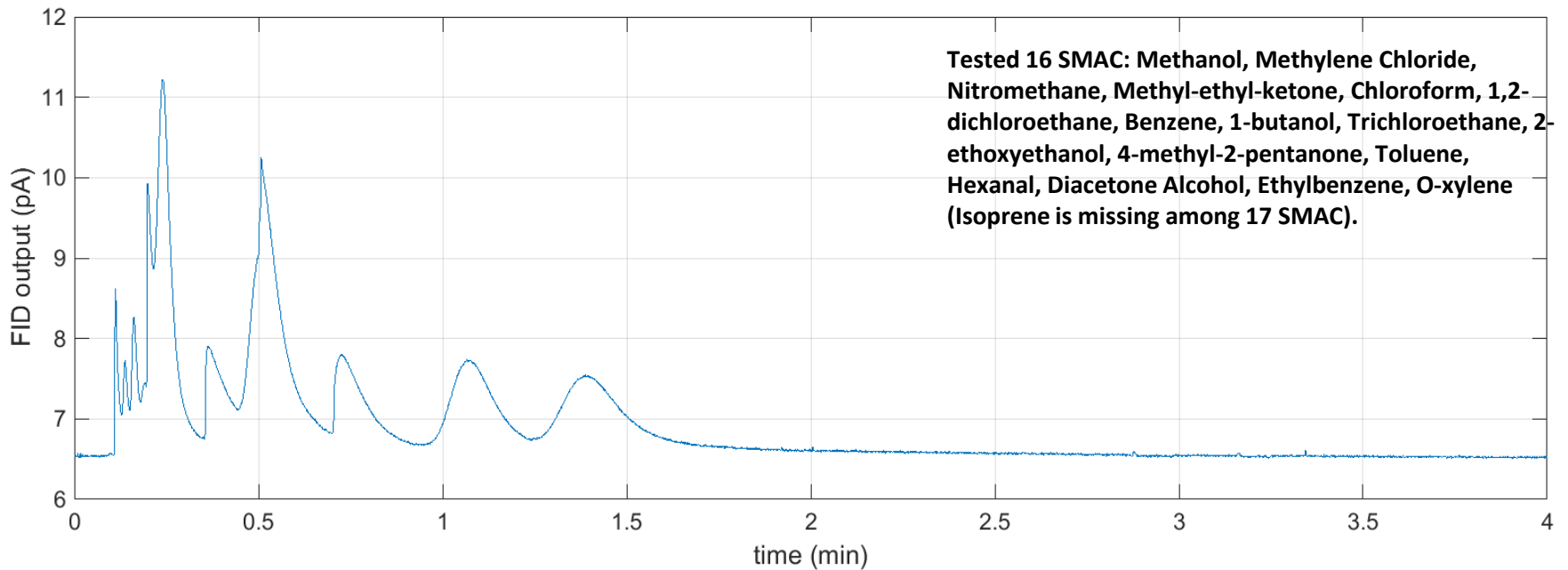
Core Components – MEMS Gas Chromatography (GC) Chip



2 m versus 1 m column

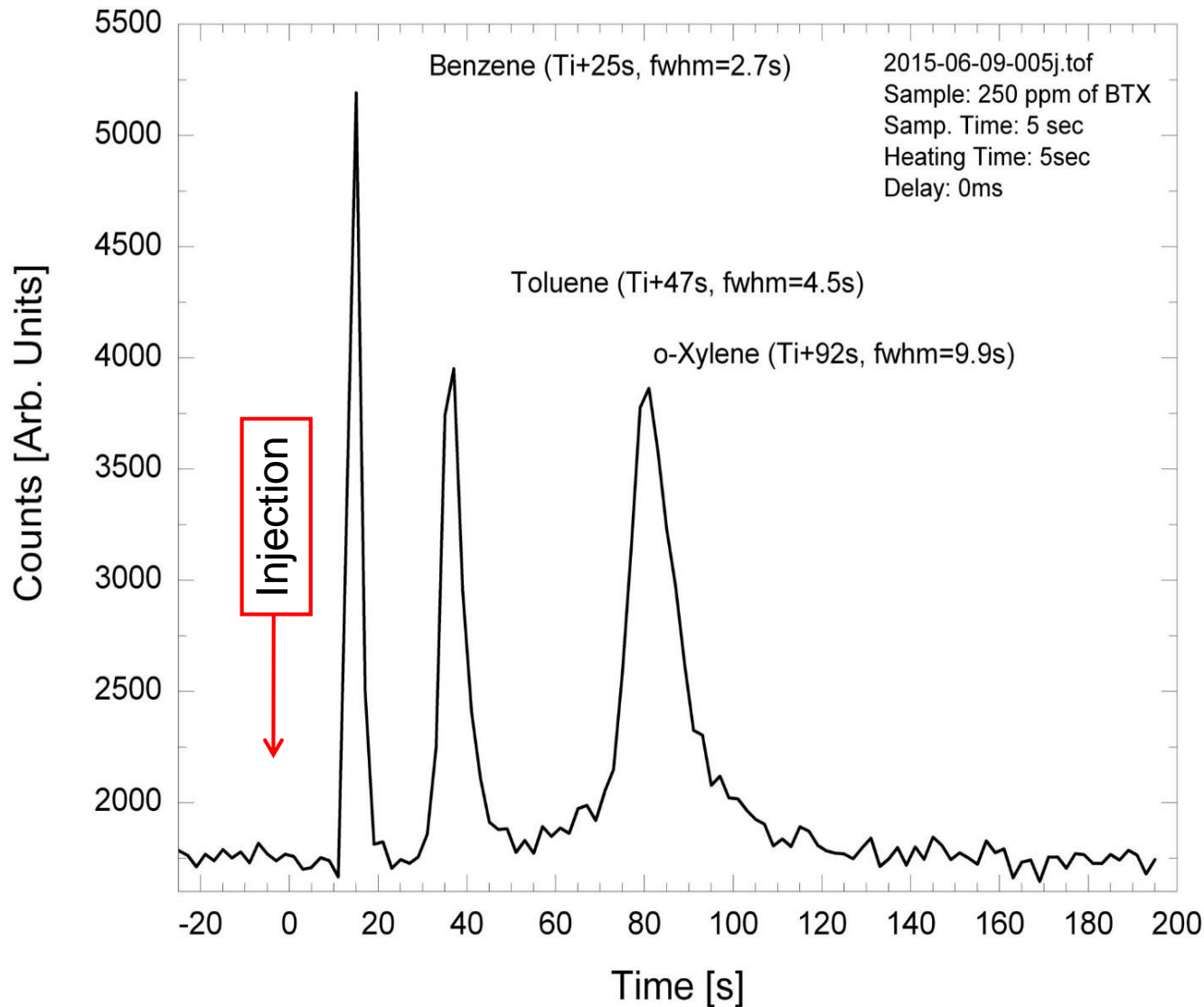
- 1 m length x 86 μm diameter MC chip dynamically coated with OV-5 (5% diphenyl / 95% dimethylpolysiloxane) stationary phase.
- Serpentine column is better than spiral in micro level of chip design.
- A novel turn geometry. This counteracts the dean vortices and thereby gives lower dispersion.

GC Data



- JPL MC3-3Au 16 SMAC performance.
- The JPL MC has serpentine channels of $60\ \mu\text{m}$ (w) x $150\ \mu\text{m}$ (h) x $1\ \text{m}$ (l) the hydraulic diameter of which is $86\ \mu\text{m}$.
- The microcolumn was made by Au diffusion bonding.
- Ten percent of OV-5 coating was applied.
- Test condition: Column head pressure w/ He: 5 psi. Calculated He carrier flow rate = $0.183\ \text{mL}/\text{min}$, split ratio = 500, injection volume = $0.01\ \mu\text{L}$, inlet/outlet capillary geometry = $0.3\ \text{m} \times 100\ \mu\text{m}$ ID, $35^\circ\ \text{C}$ isothermal and GC-FID at $250^\circ\ \text{C}$.

GC Data – T1



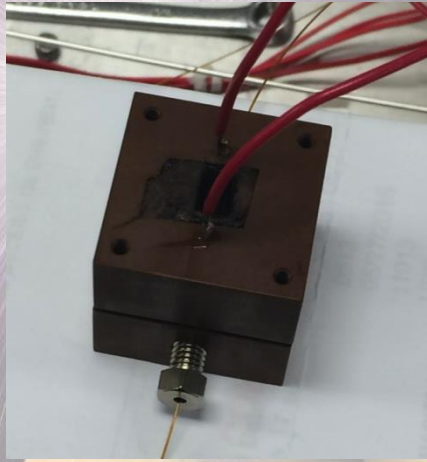
Example TG run performed with **T1** system

1 m MEMS column
14 psi He

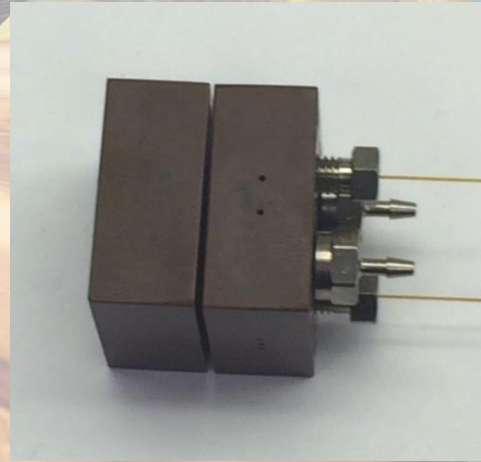
Core Components – Chip Enclosures

Prototypes uses separate blocks:

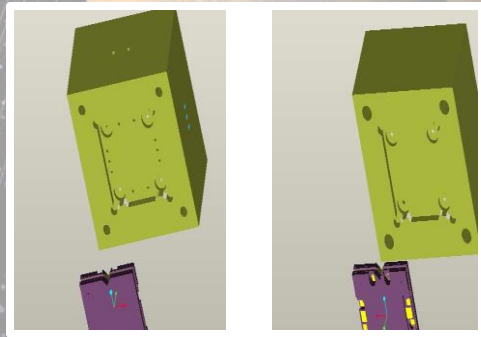
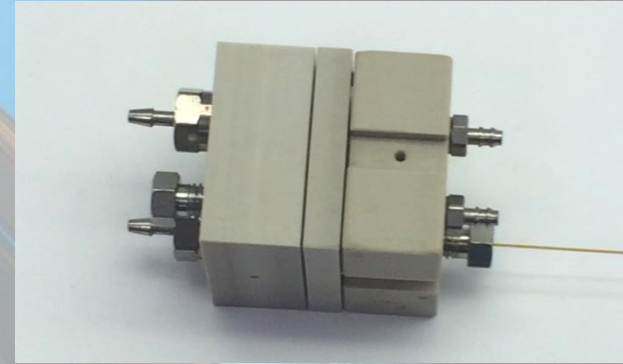
PC



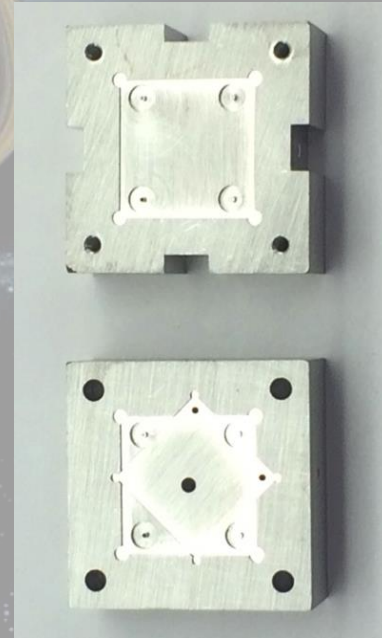
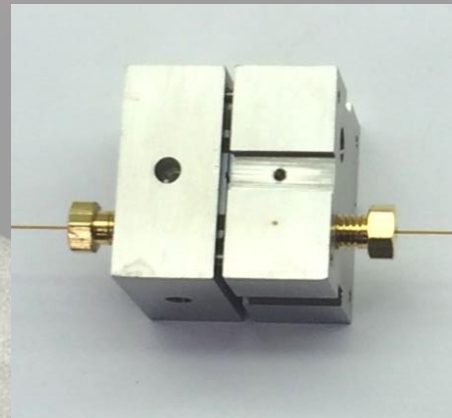
MV



The EM and FM will utilized a combination block (will be made of Vespel)



The Prototype GC block (stainless steel):
The EM and FM will be Vespel



Acknowledgments

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