Research Progress Report

Hydrocarbon Filtration in Nanoporous Materials

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Presenter: Zhijun (Julian) Liu

Outline

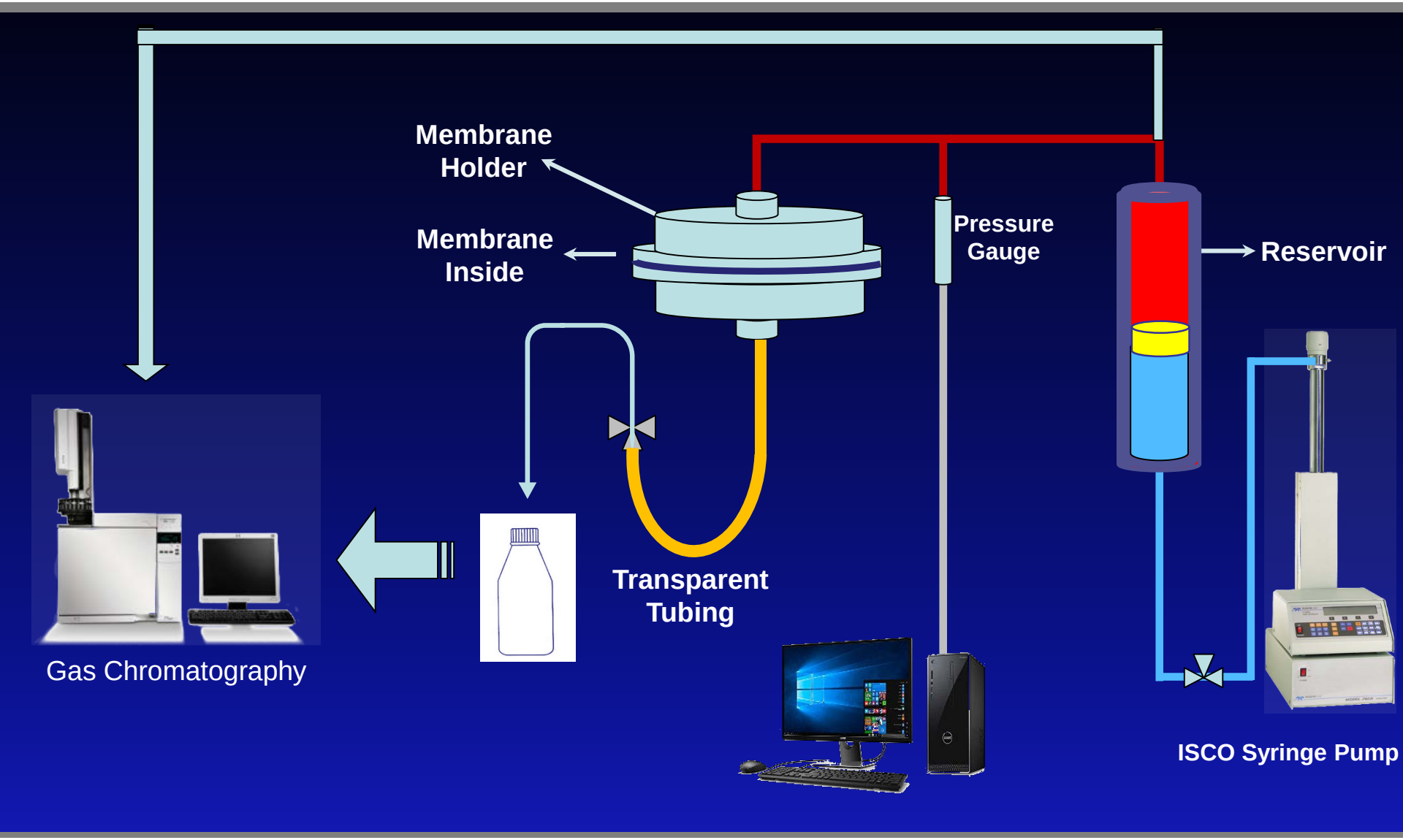
- **Part I:** Recap
- **Part II:** New Development
- **Part III:** Conclusions
- **Part IV:** Future Work

Part I
Recap

Background

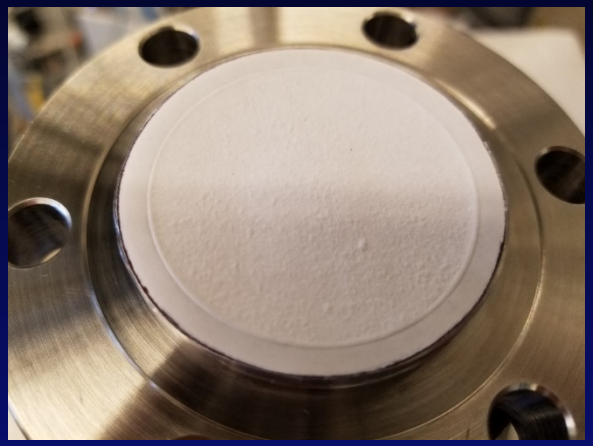
- **What is filtration effect?**
- **Why do we study it?**
- **What is my approach?**
  - **Using artificial membranes and hydrocarbon fluids**
    - *Simplify factors influencing the filtration process*
    - *Faster turnaround time of testing results*
    - *Interdisciplinary knowledge available*

Set-Up


Membrane Holder
Membrane Inside
Pressure Gauge
Reservoir
Transparent Tubing
Gas Chromatography
ISCO Syringe Pump

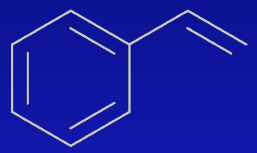
Membranes & Fluids

- **Membranes**
  - *Puramem Series*
    - 280 Da (~1.1nm) and 600 Da (~1.4nm)
    - Compatible fluid: ***Toluene***
  - *Duramem Series*
    - 150 Da, 200 Da, 300 Da, 600 Da and 900 Da (Pore size: ~0.75-4.5nm)
    - Compatible fluid: ***Acetone***

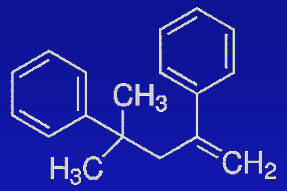


- **Heavy Hydrocarbons**

Styrene (104)



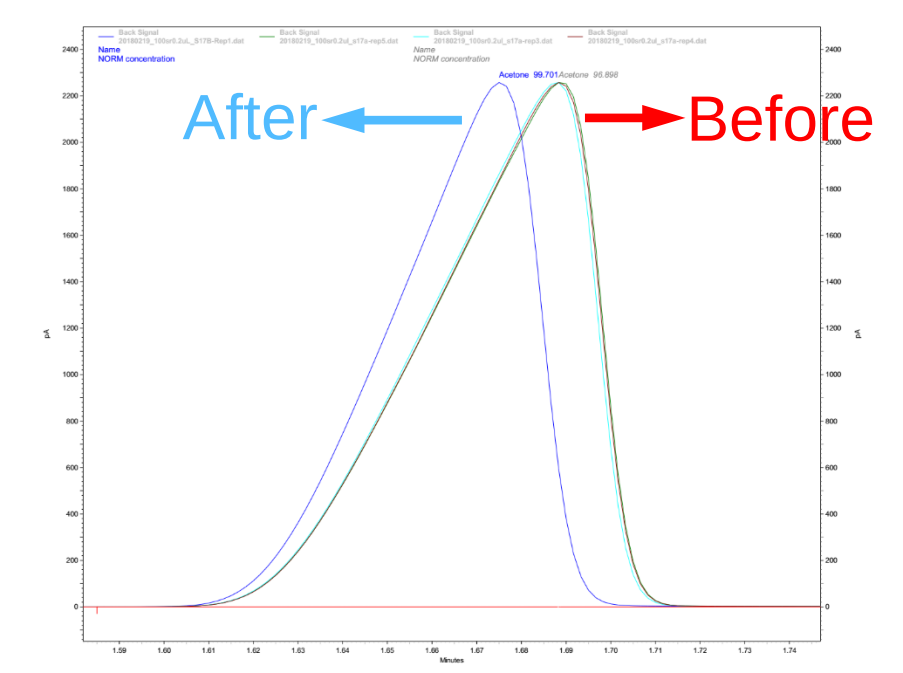
MD(236)
α-Methylstyrene Dimer



DP-Styrene (288)

Results: Before and Post Filtration

Light Component: Acetone (Normalized)



Heavy Component: DP-Styrene

Filtration Efficiency Calculation

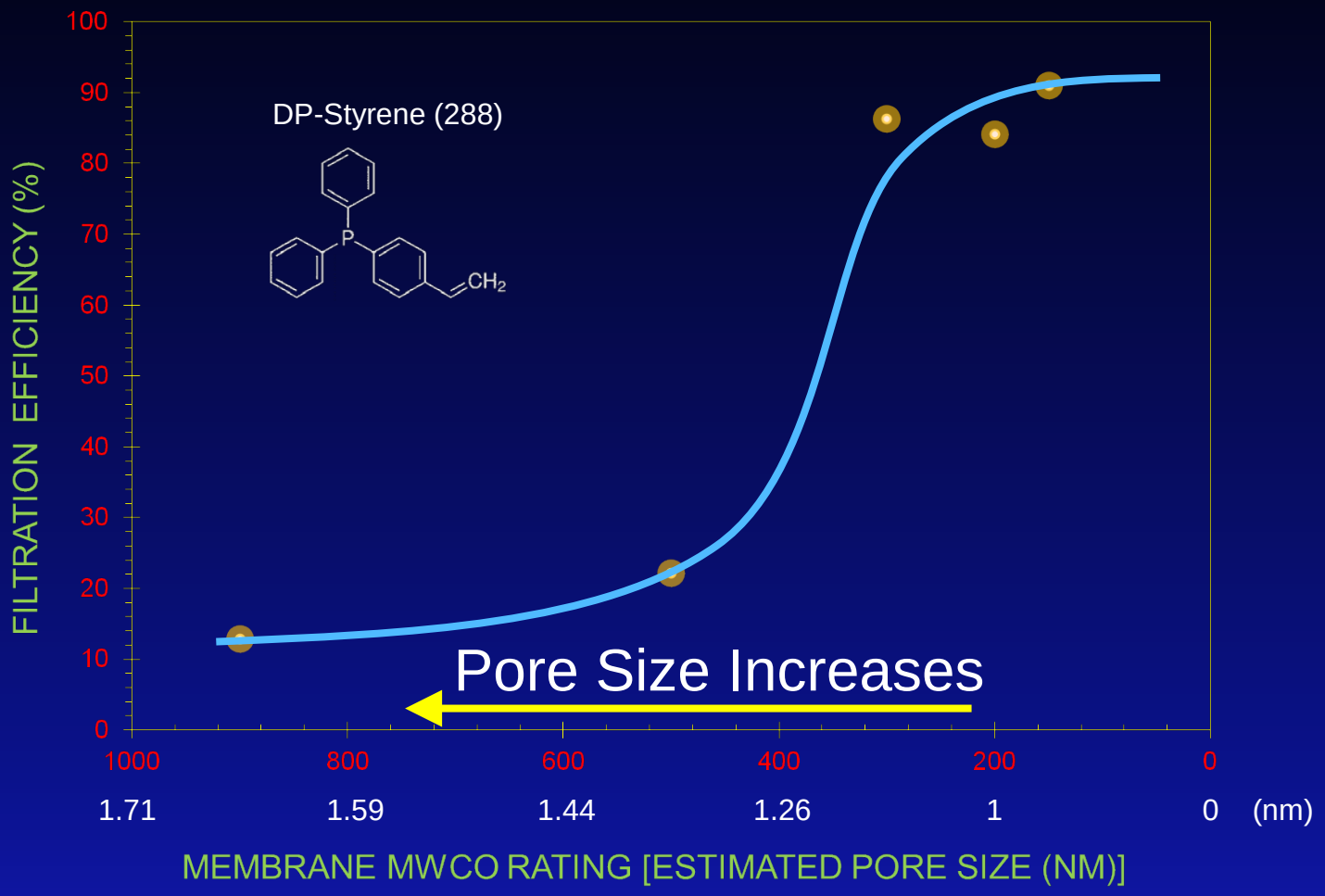
$$FE = 1 - \frac{C_x}{C_A}$$

FE - Filtration Efficiency

C_A - Concentration of Sample A, before filtration

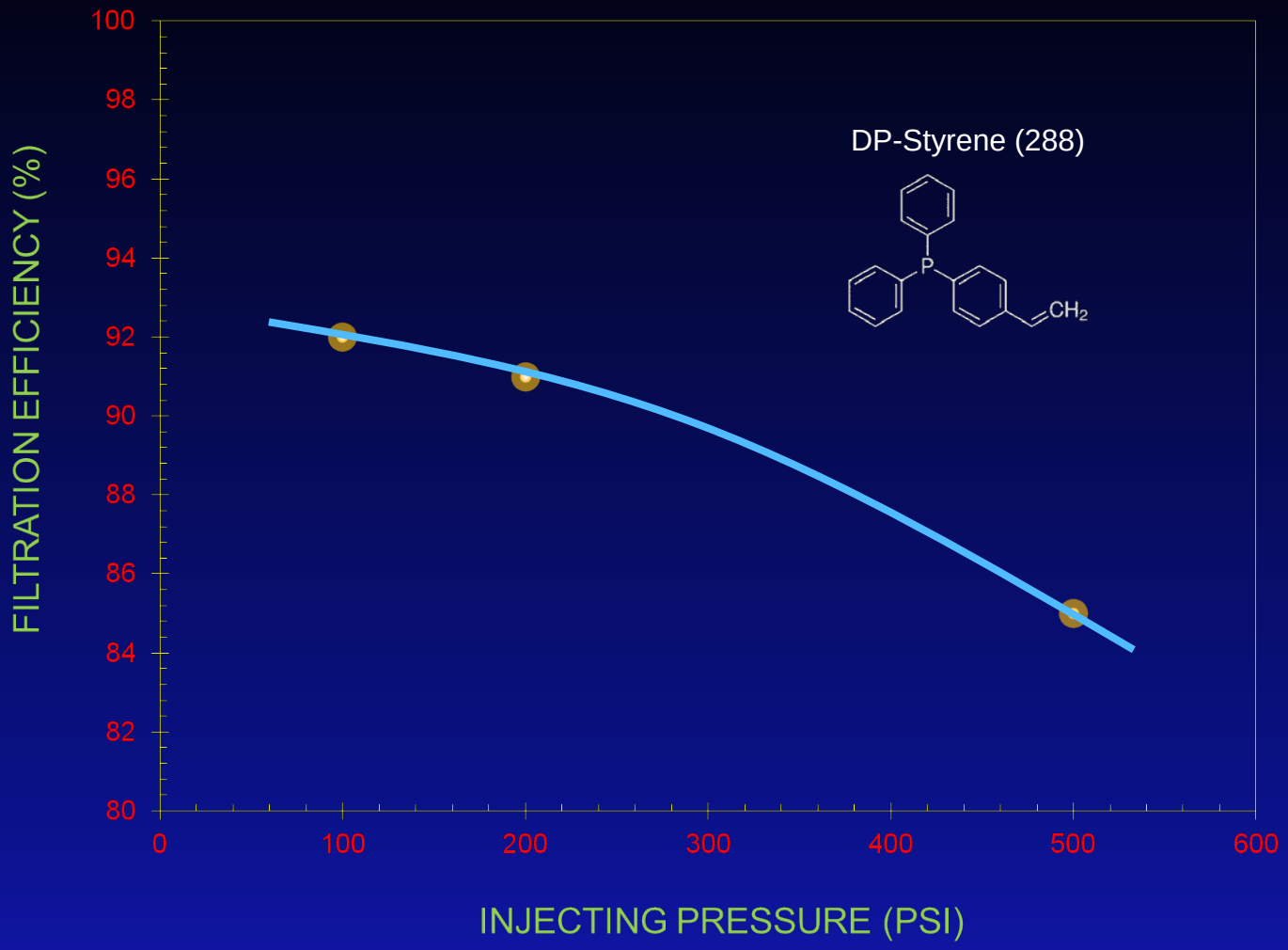
C_x - Concentration of Sample B, C, D …, after filtration

Results: FE vs. Membrane Pore Size



Various Duramem with DP-Styrene (288 Da) under ~200 psi

Results: FE vs. Injecting Pressure



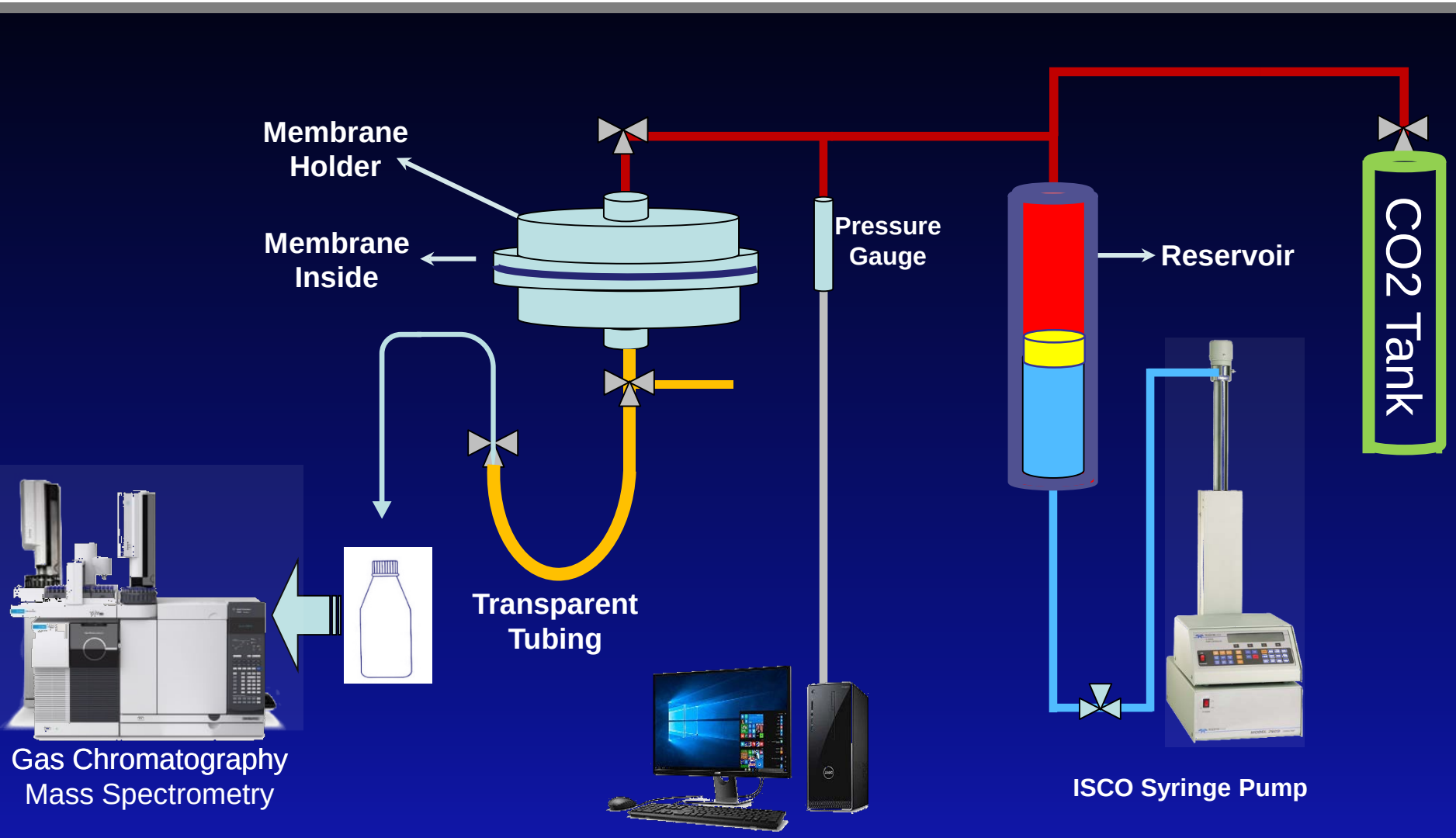
Duramem 150 Da with DP-Styrene (288 Da)

Part II
New Development

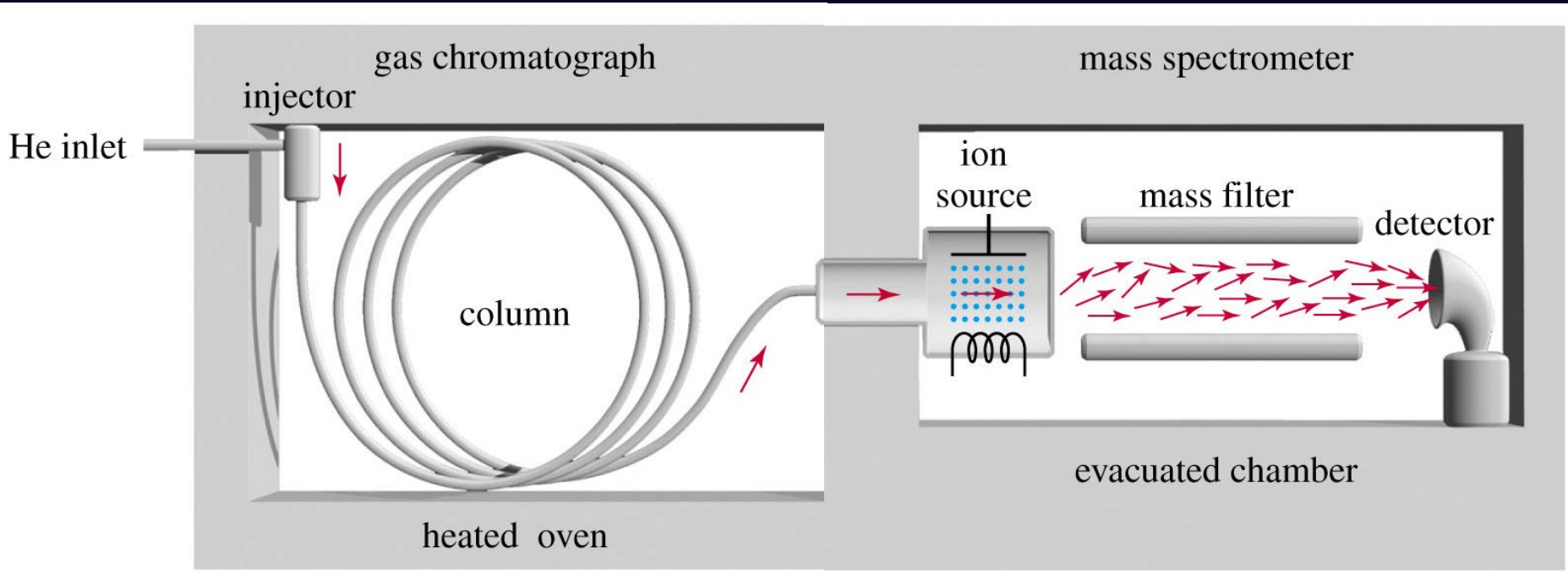
Membranes & Fluids

- **Fluids**
  - *Polystyrene in acetone/toluene*
  - *→ New: Crude oil in **toluene***
- **Membranes**
  - *Puramem Series*
    - 280 Da (~1.1nm) and 600 Da (~1.4nm)
    - Compatible fluid: ***Toluene***
  - *Duramem Series (not used)*
    - 150 Da, 200 Da, 300 Da, 600 Da and 900 Da (Pore size: ~0.75-4.5nm)
    - Compatible fluid: ***Acetone***

Set Up Additions

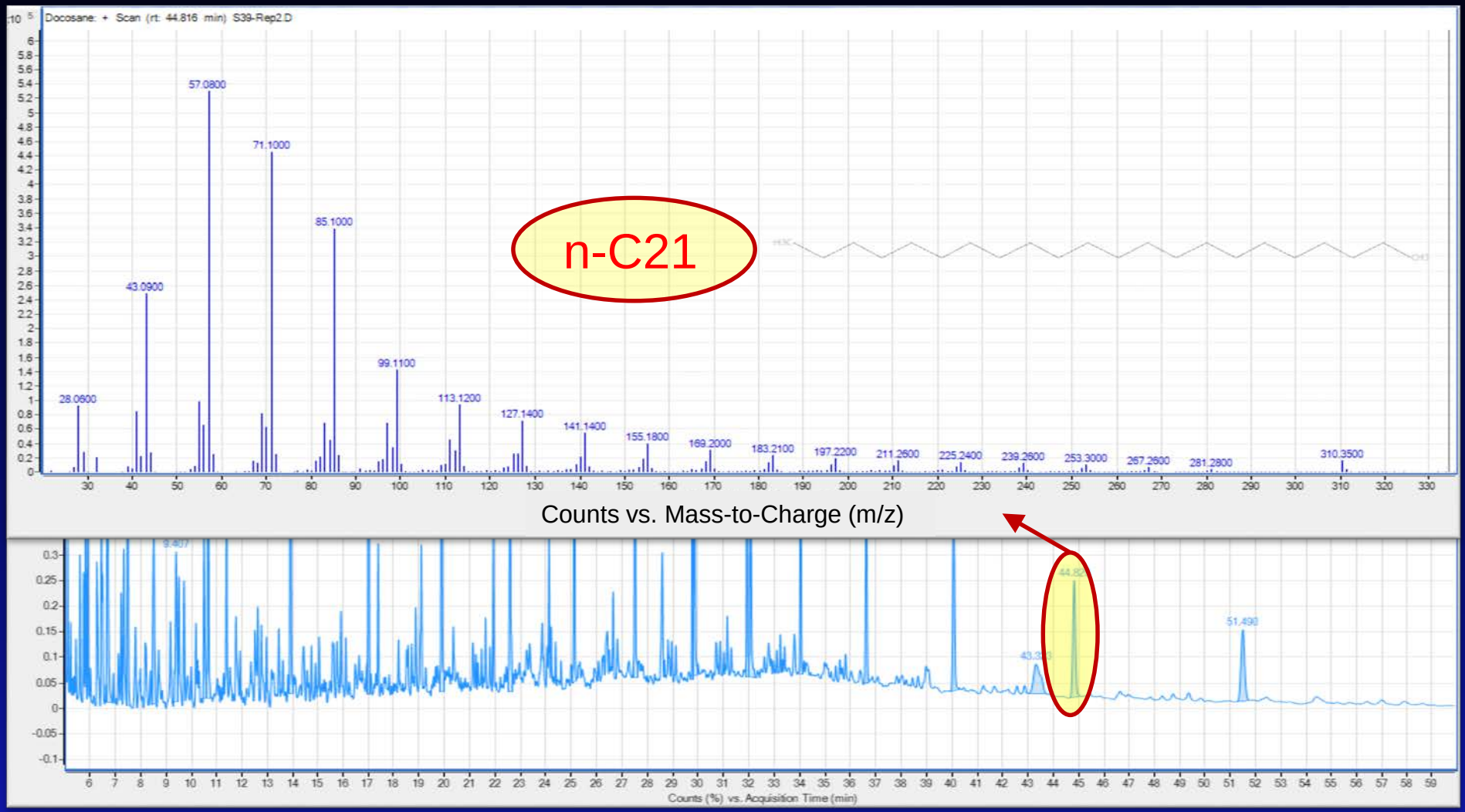


GC/MS Mechanism



Source: https://orgspectroscopyint.blogspot.com/2014/11/gas-chromatography-mass-spectrometry-gc.html

GC/MS Plots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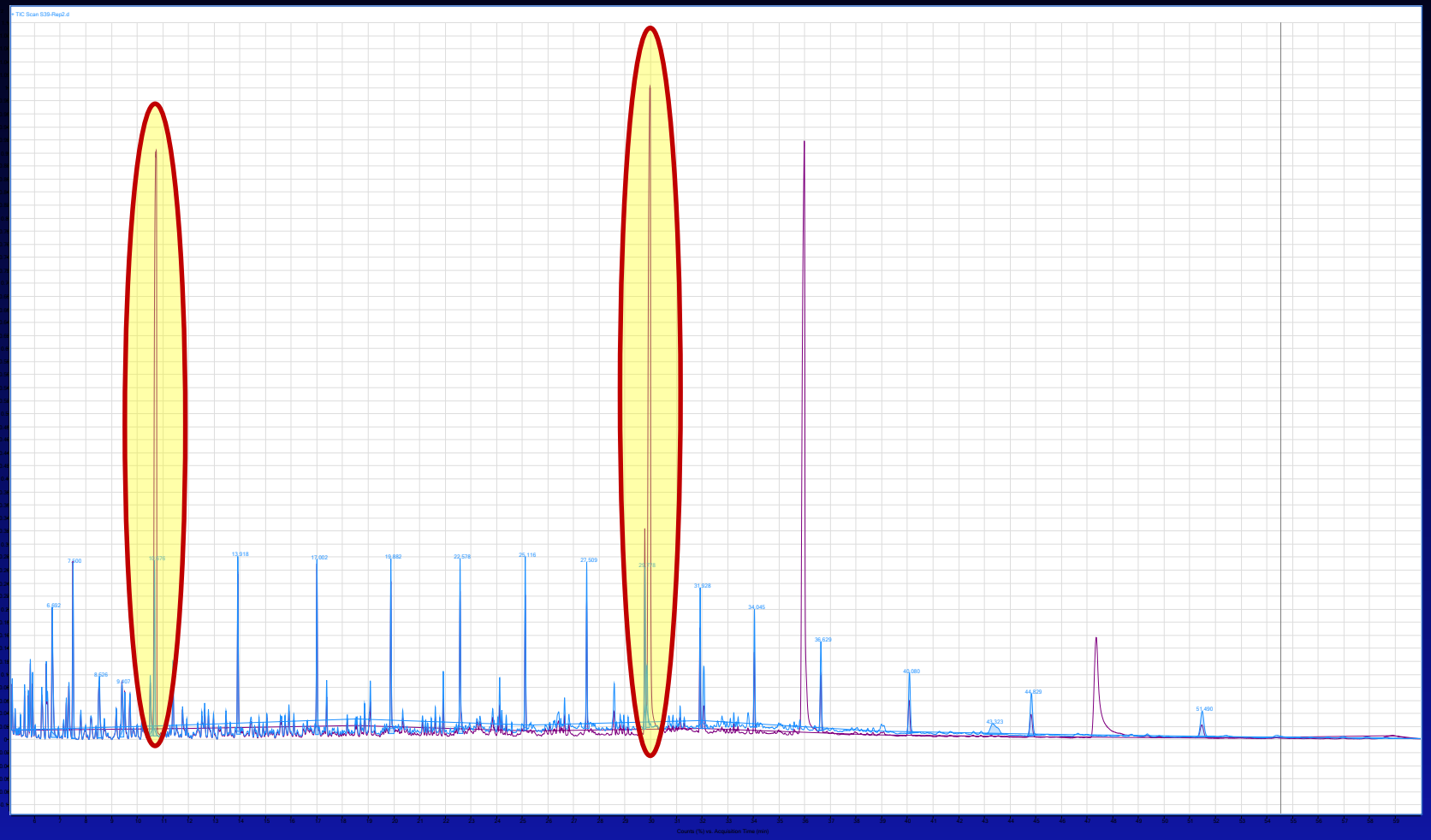
127.1400
141.1400
155.1800
169.2000
183.2100
197.2200
211.2600
225.2400
239.2600
253.3000
267.2800
281.2800
310.3500
n-C21
Counts vs. Mass-to-Charge (m/z)
51.490
Counts (%) vs. Acquisition Time (min)
Counts vs. Time (minutes)

Predominant Hydrocarbons of Eagle Ford Crude

Peak No.	Formula Abbr.	Chemical Name	Retention Time (mins)	Molecular Weight (g/mol)
1	C8H10	Xylene	6.68	106
2	n-C9	Nonane	7.49	128
3	n-C10	Decane	10.66	142
4	n-C11	Undecane	13.91	156
5	n-C12	Dodecane	16.99	170
6	n-C13	Tridecane	19.88	184
7	n-C14	Tetradecane	22.57	198
8	n-C15	Pentadecane	25.11	212
9	n-C16	Hexadecane	27.51	226
10	n-C17	Heptadecane	29.78	240
11	n-C18	Octadecane	31.93	254
12	n-C19	Nanodecane	34.05	268
13	n-C20	Eicosane	36.64	282
14	n-C21	Heneicosane	40.09	296
15	n-C22	Docosane	44.84	310
16	n-C23	Tricosane	51.50	324

Peak Contamination



Counts vs. Time (minutes)

Selected Hydrocarbons For Analysis

Peak No.	Formula Abbr.	Chemical Name	Retention Time (mins)	Molecular Weight (g/mol)	
1	C8H10	Xylene	6.68	106	
2	n-C9	Nonane	7.49	128	
3	n-C10	Decane	10.66	142	Removed
4	n-C11	Undecane	13.91	156	
5	n-C12	Dodecane	16.99	170	
6	n-C13	Tridecane	19.88	184	
7	n-C14	Tetradecane	22.57	198	
8	n-C15	Pentadecane	25.11	212	
9	n-C16	Hexadecane	27.51	226	
10	n-C17	Heptadecane	29.78	240	Removed
11	n-C18	Octadecane	31.93	254	
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14	n-C21	Heneicosane	40.09	296	
15	n-C22	Docosane	44.84	310	
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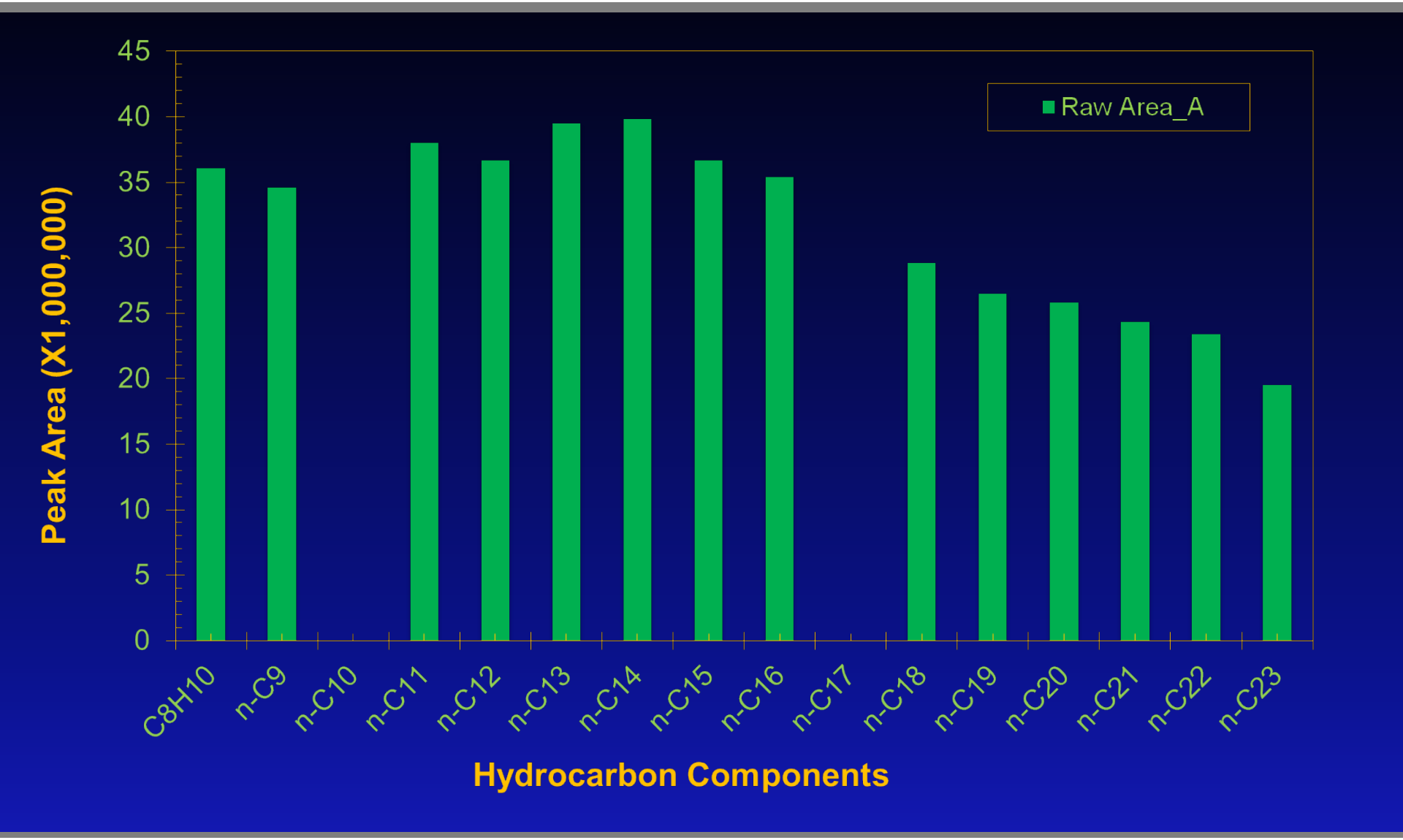
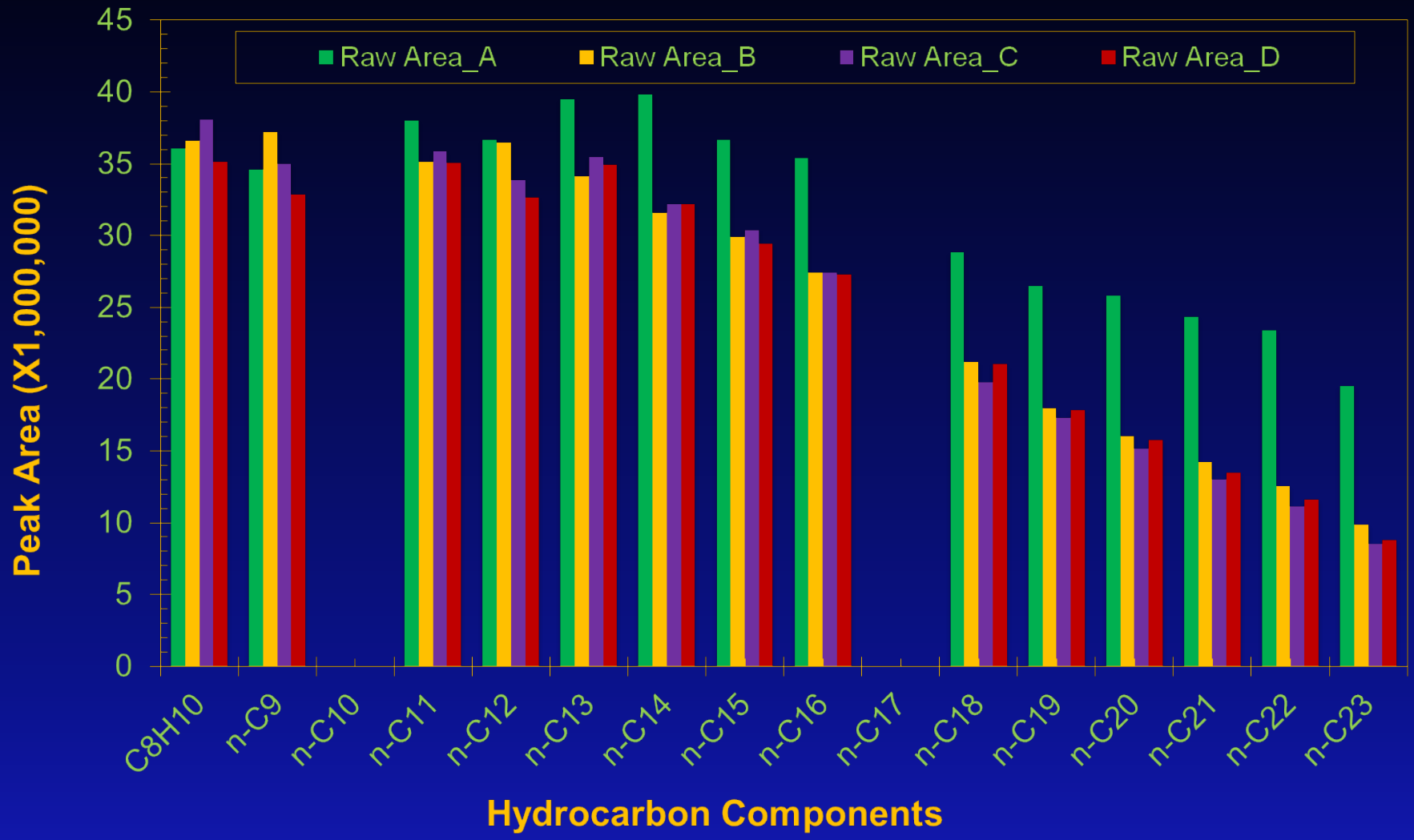
Raw Peak Area

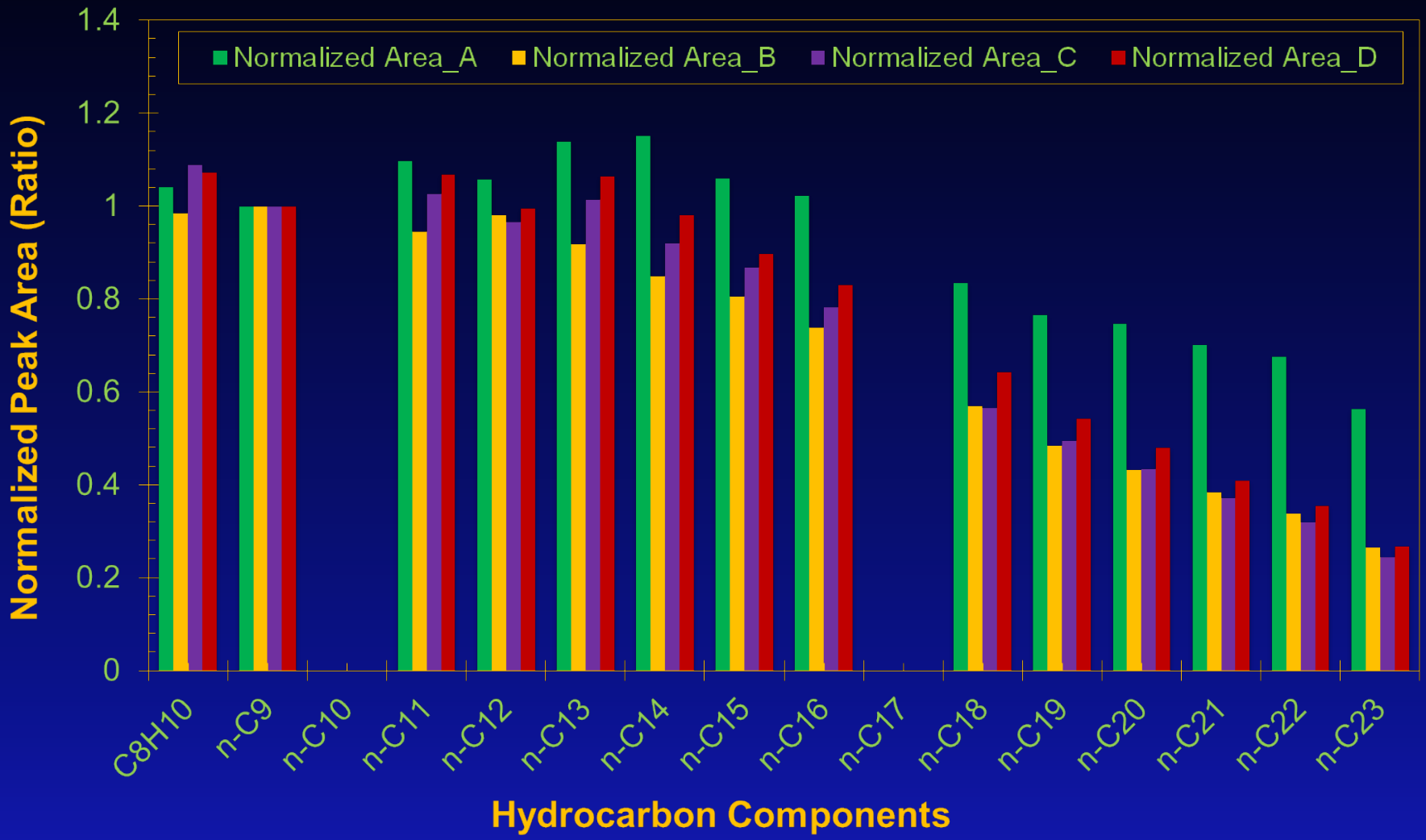


Peak Area

-Before (Sample A) and After Filtration (Sample B-D)



Normalized Peak Area (Reference: n-C9)



Pseudo Concentration Calculation

$$PC = \frac{\frac{A_{n\text{-}Cx}}{A_{n\text{-}C9}}}{MW_{n\text{-}Cx}} \times 1000$$

Normalized Area

PC - Pseudo Concentration, m-mol/g

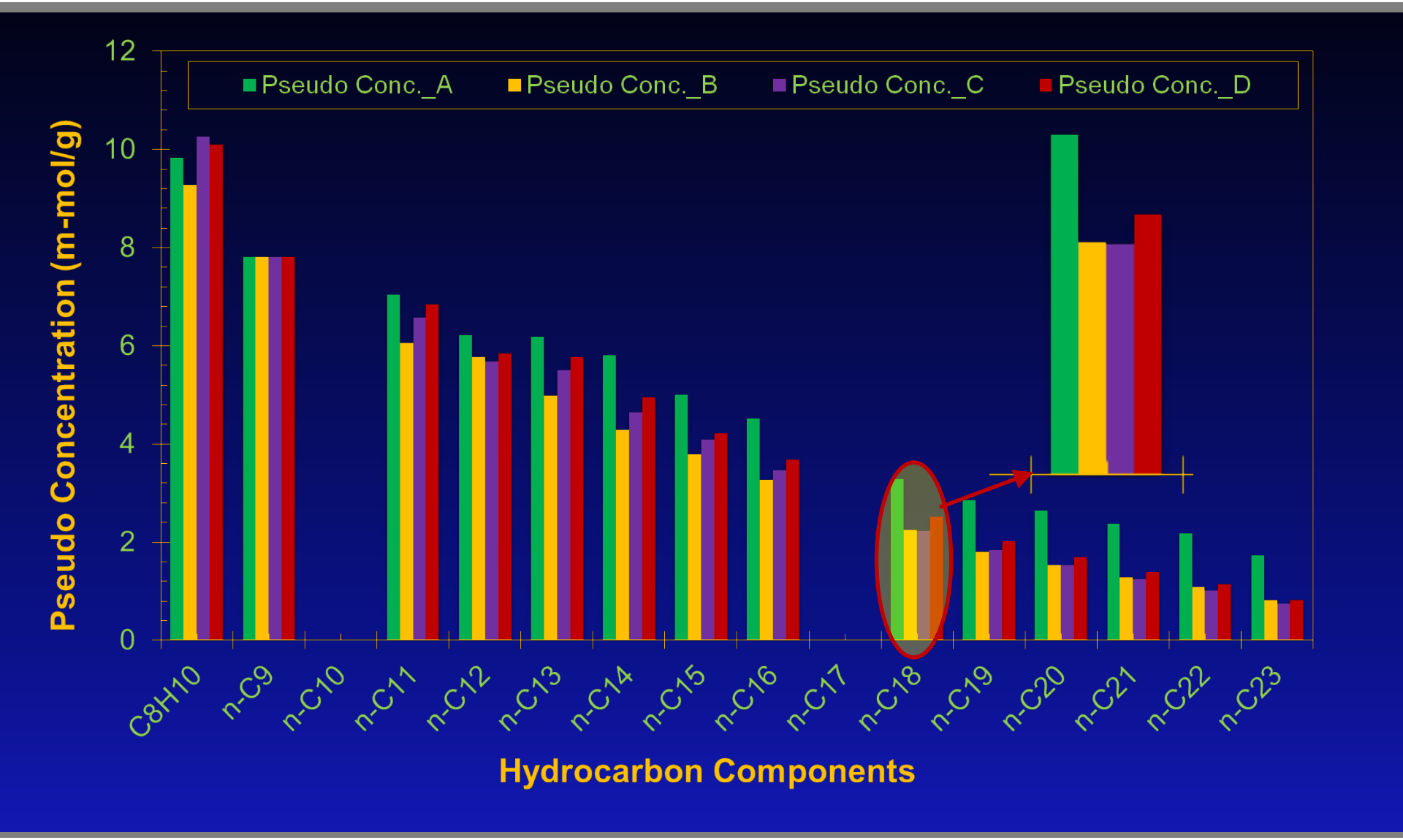
$A_{n\text{-}Cx}$ - Peak Area of n-Cx

$A_{n\text{-}C9}$ - Peak Area of n-C9

$MW_{n\text{-}Cx}$ - Molecular weight of n-Cx

Pseudo Concentration

-Before (Sample A) and After Filtration (Sample B-D)



Filtration Efficiency Calculation

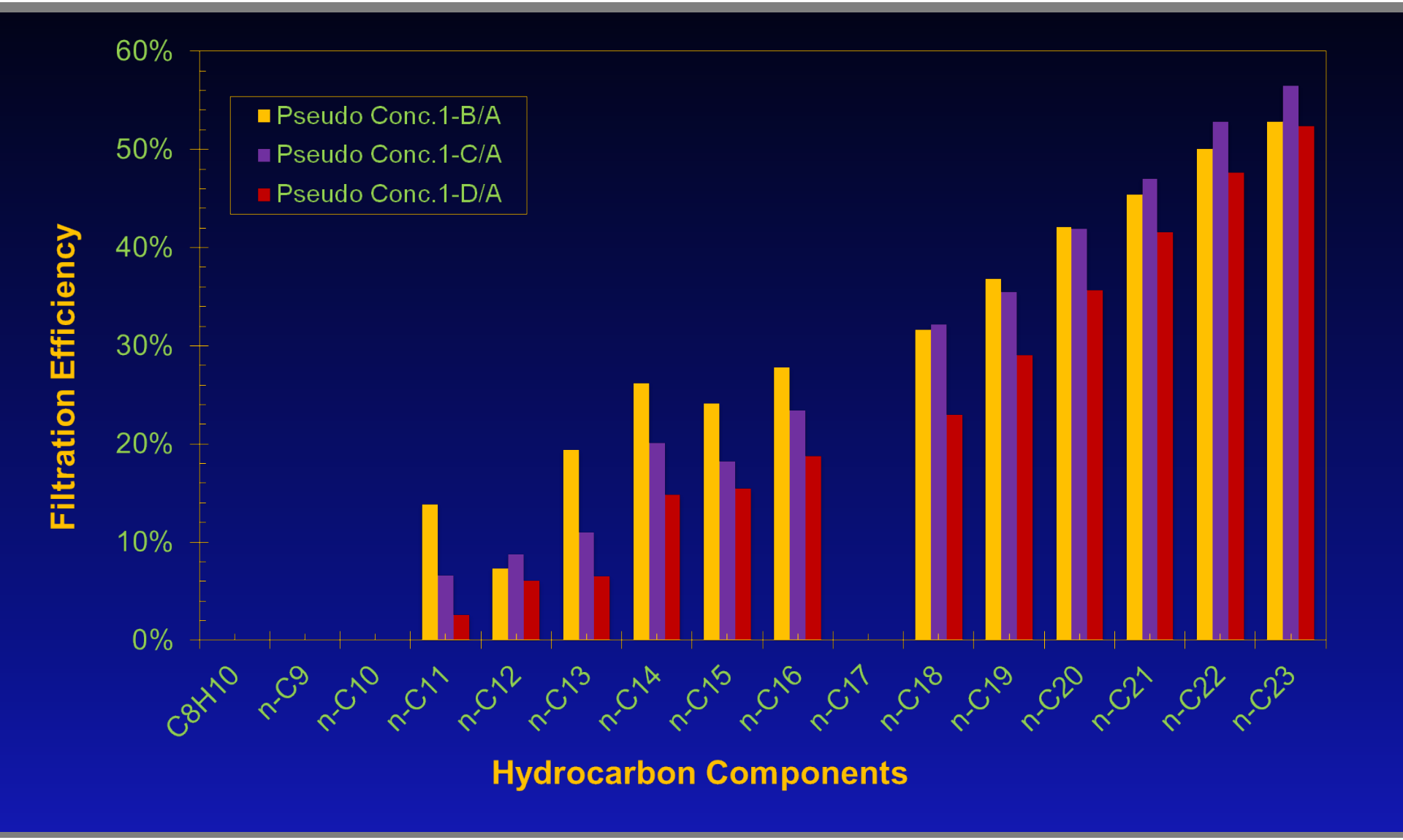
$$FE^i = 1 - \frac{PC^i_x}{PC^i_A}$$

FE^i - Filtration Efficiency of component i

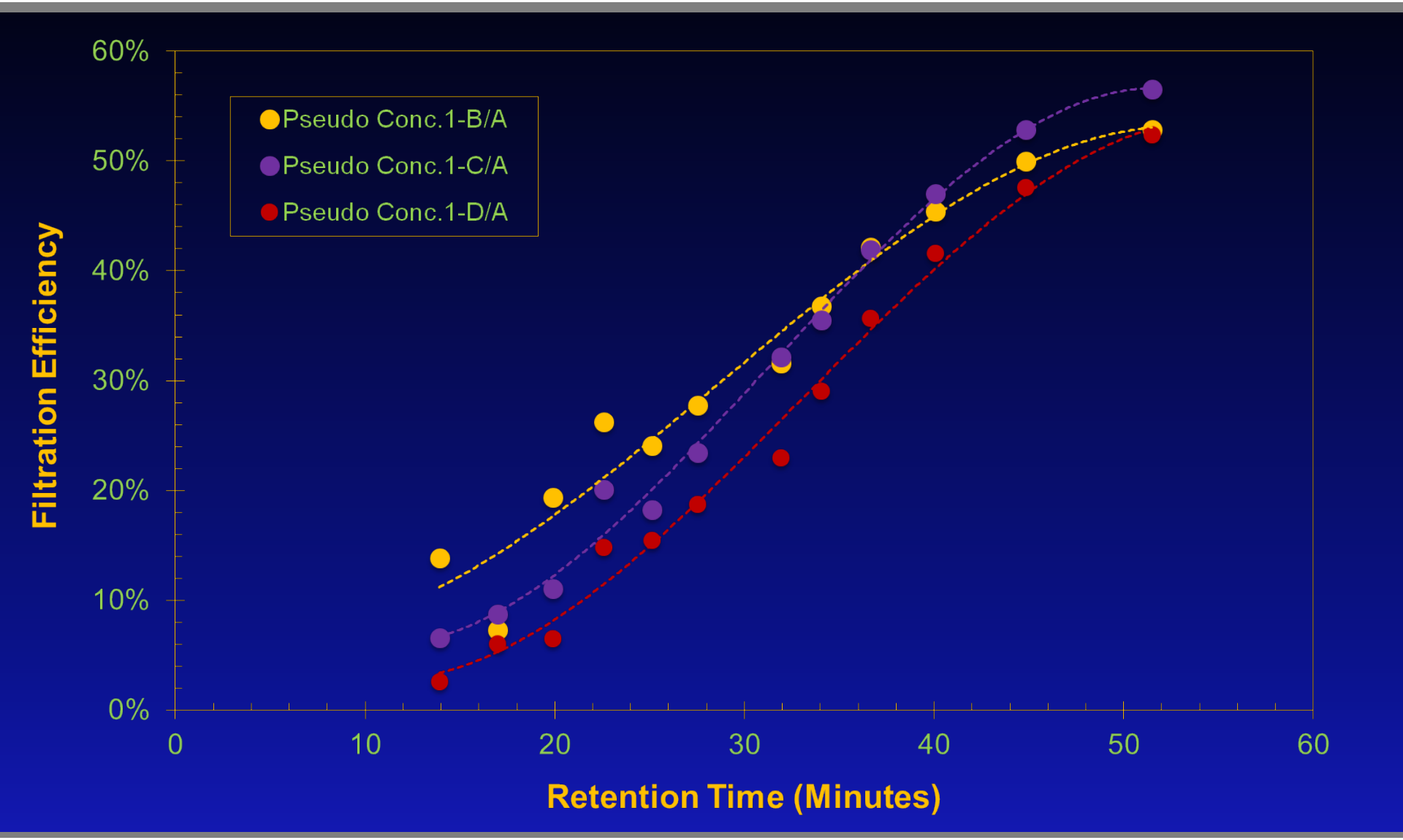
PC^i_A - Pseudo Concentration of component i in Sample A (before filtration)

Pc^i_x - Pseudo Concentration of component i in Sample B, C or D (after filtration)

Filtration Efficiency in Column



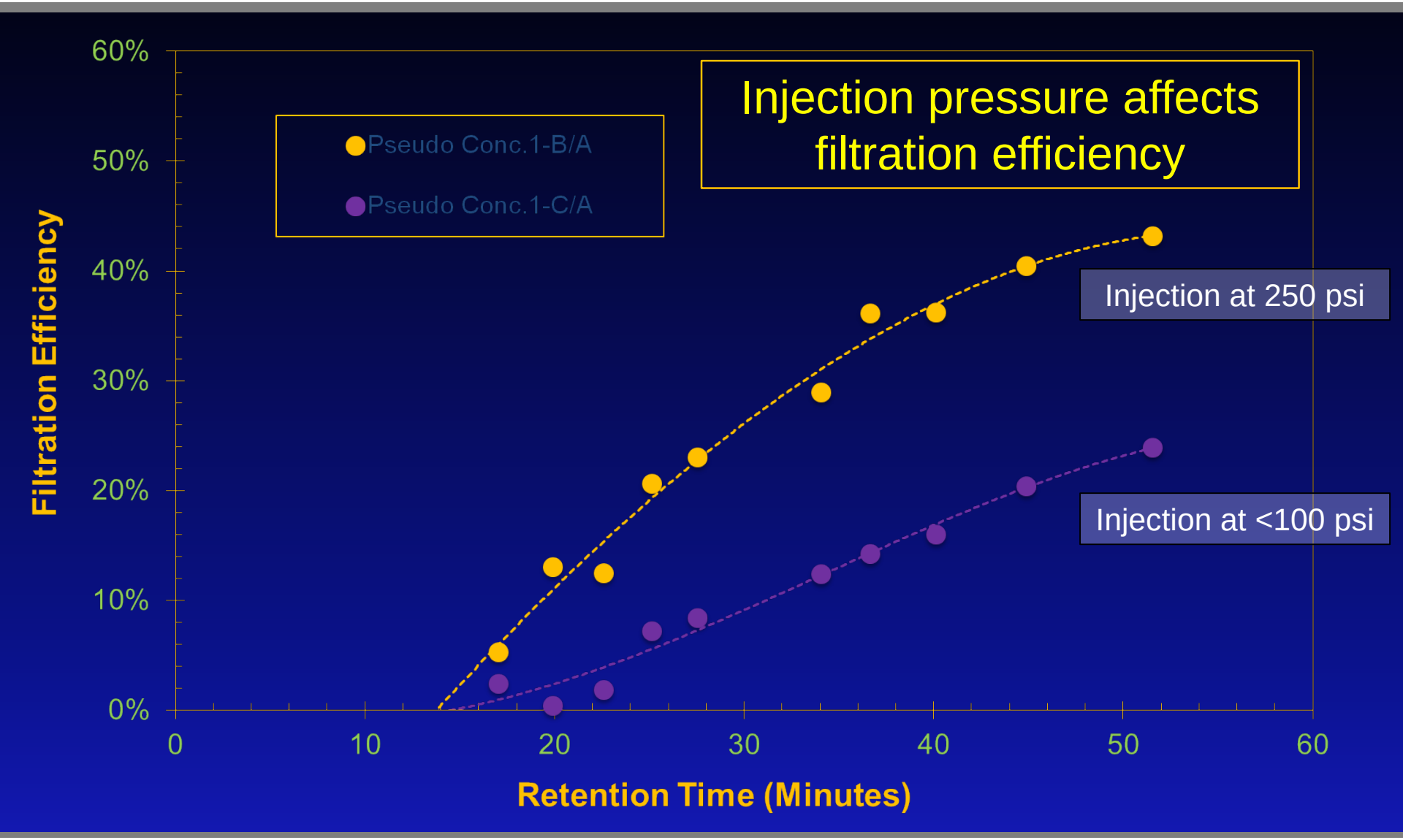
Filtration Efficiency in Scatter Chart



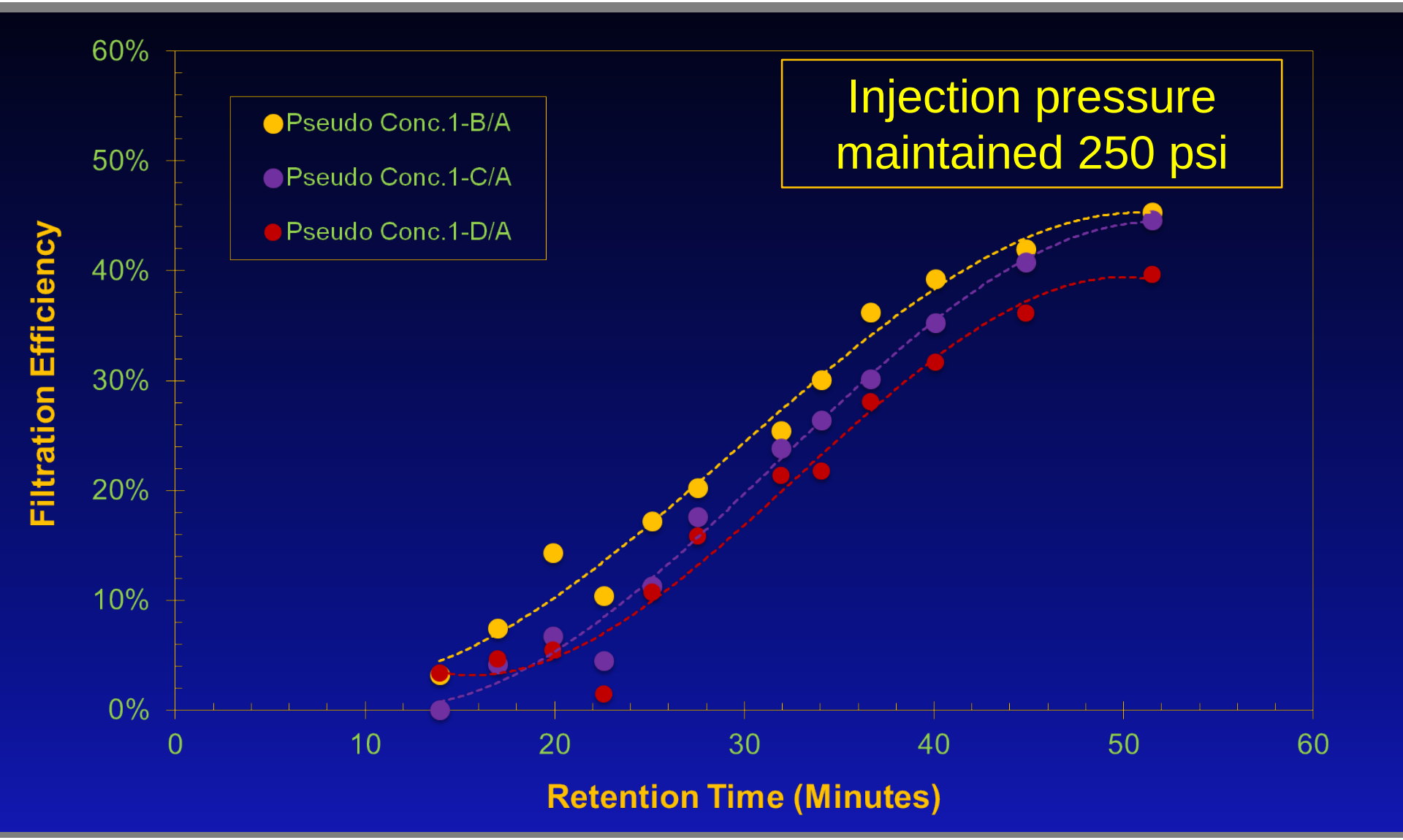
Summary of Tests

Test NO.	Membrane & Fluid	Injection Pressure (psi)	CO2 Treatment Pressure (psi)	Comments
S34	Puramem 280 Da, ~ 5 vol% Eagle Ford crude oil in toluene	250	N/A	Stopped pump after collecting 1st sample, 2nd sample collected < 100 psi)
S35		250	N/A	Reference Test
S36		100	N/A	
S37		250	600	Treated fluid with CO2 under ~600 psi for 24 hours
S38		250	600	Treated fluid with CO2 under ~600 psi for 24 hours, additional shaking
S39		250	250	Treated fluid with CO2 under ~250 psi for 24 hours

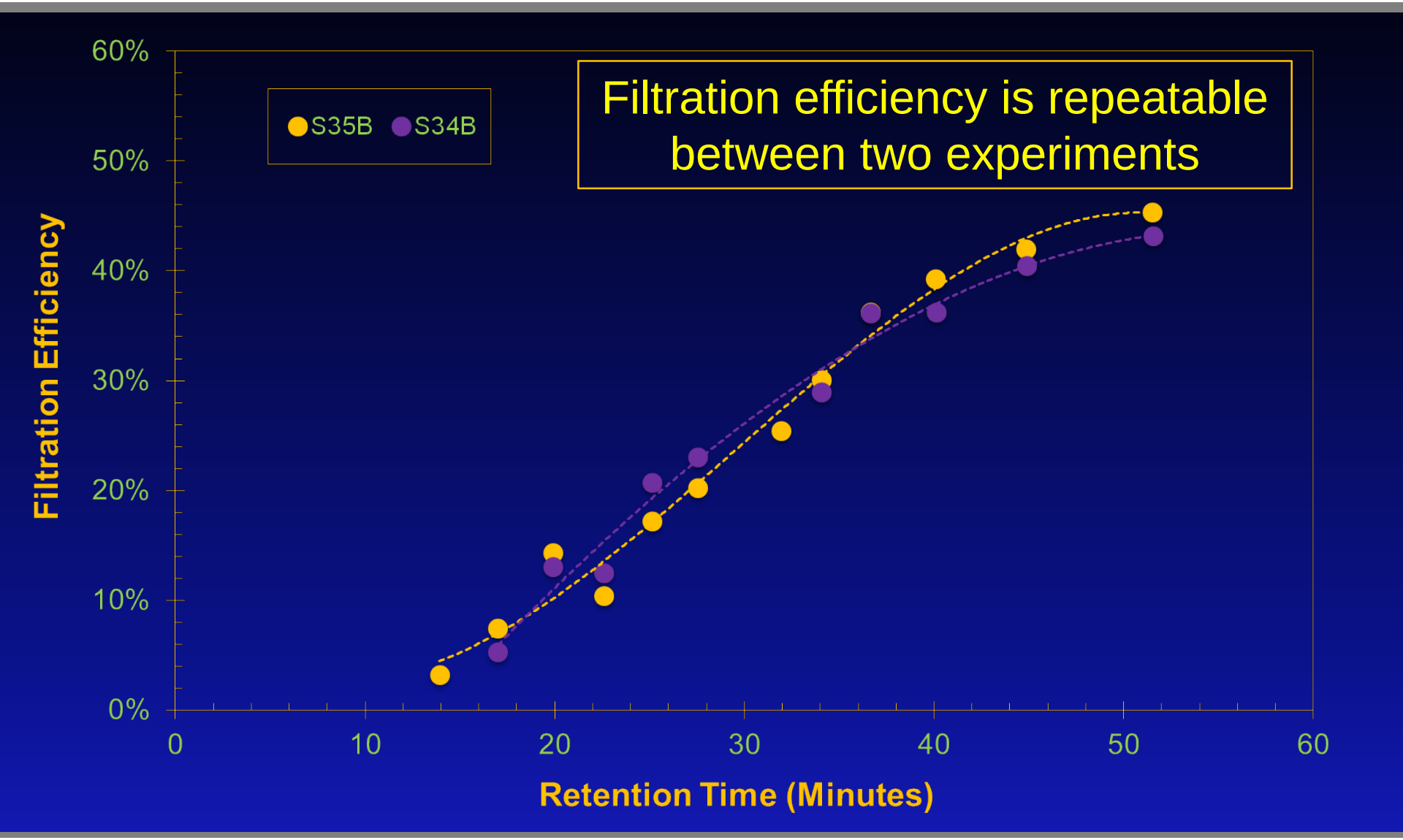
Filtration Efficiency (S34)



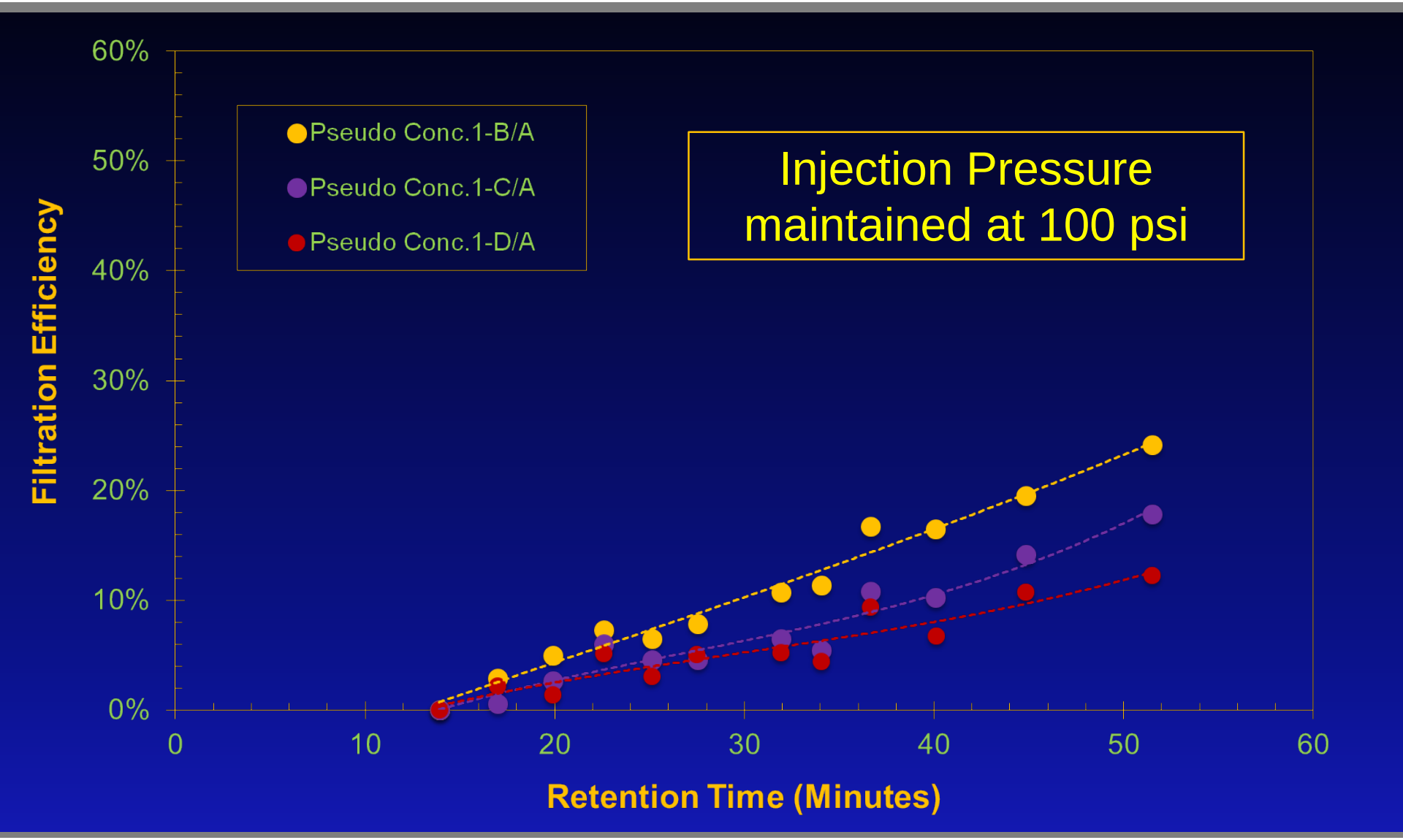
Filtration Efficiency (S35 – Reference Test)



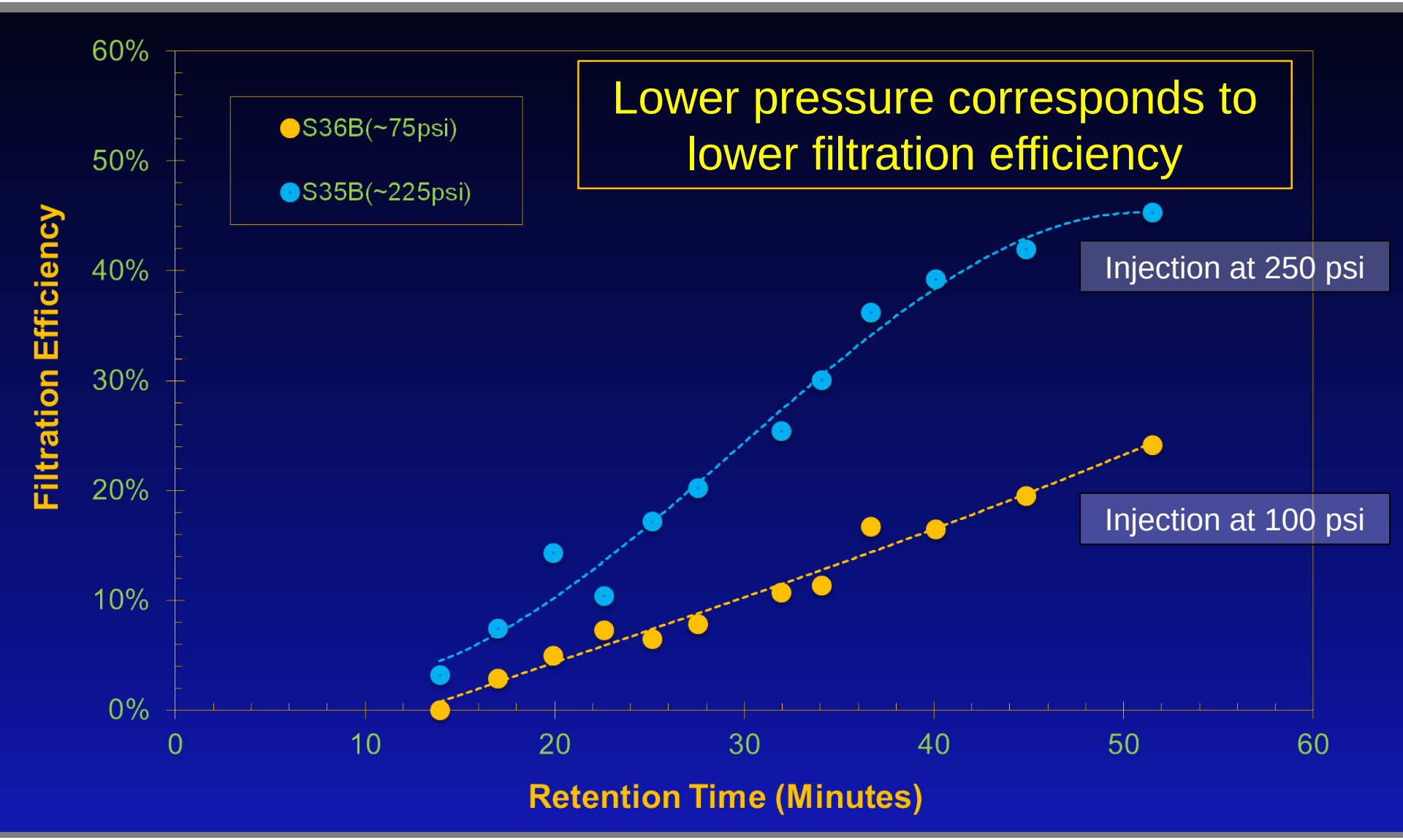
Filtration Efficiency (S35 vs S34)



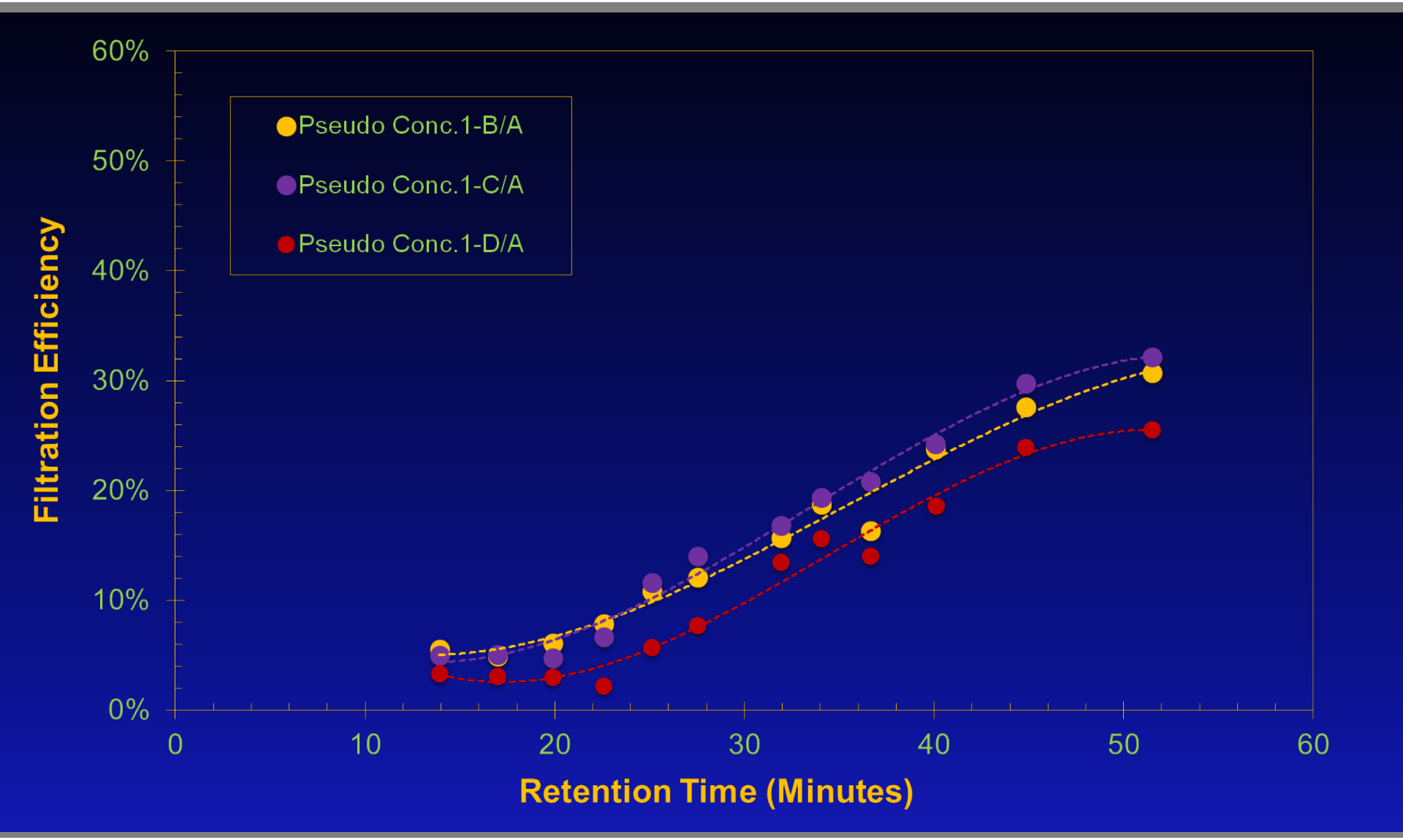
Filtration Efficiency (S36: Lower Injection Pressure)



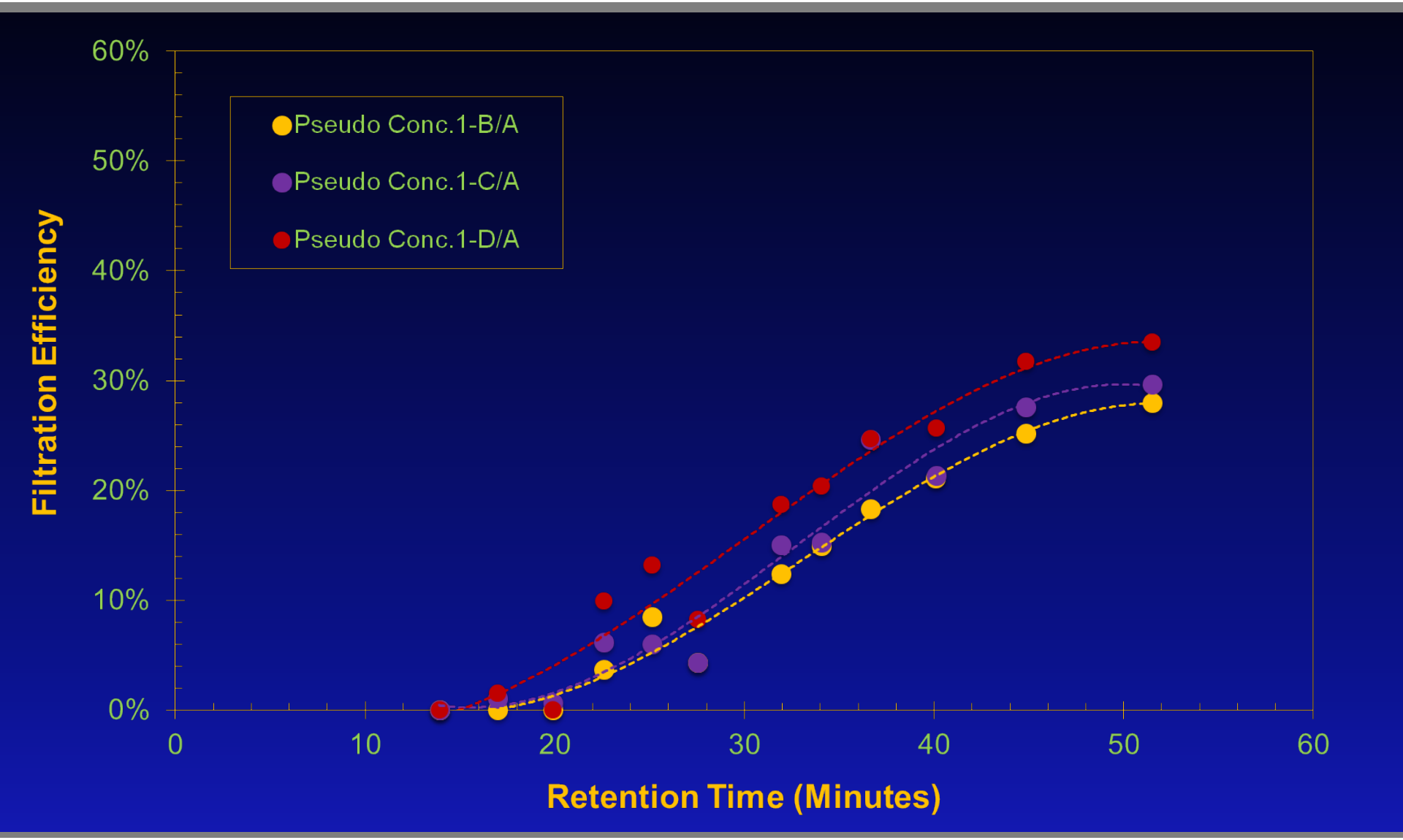
Filtration Efficiency: *Pressure Effect*



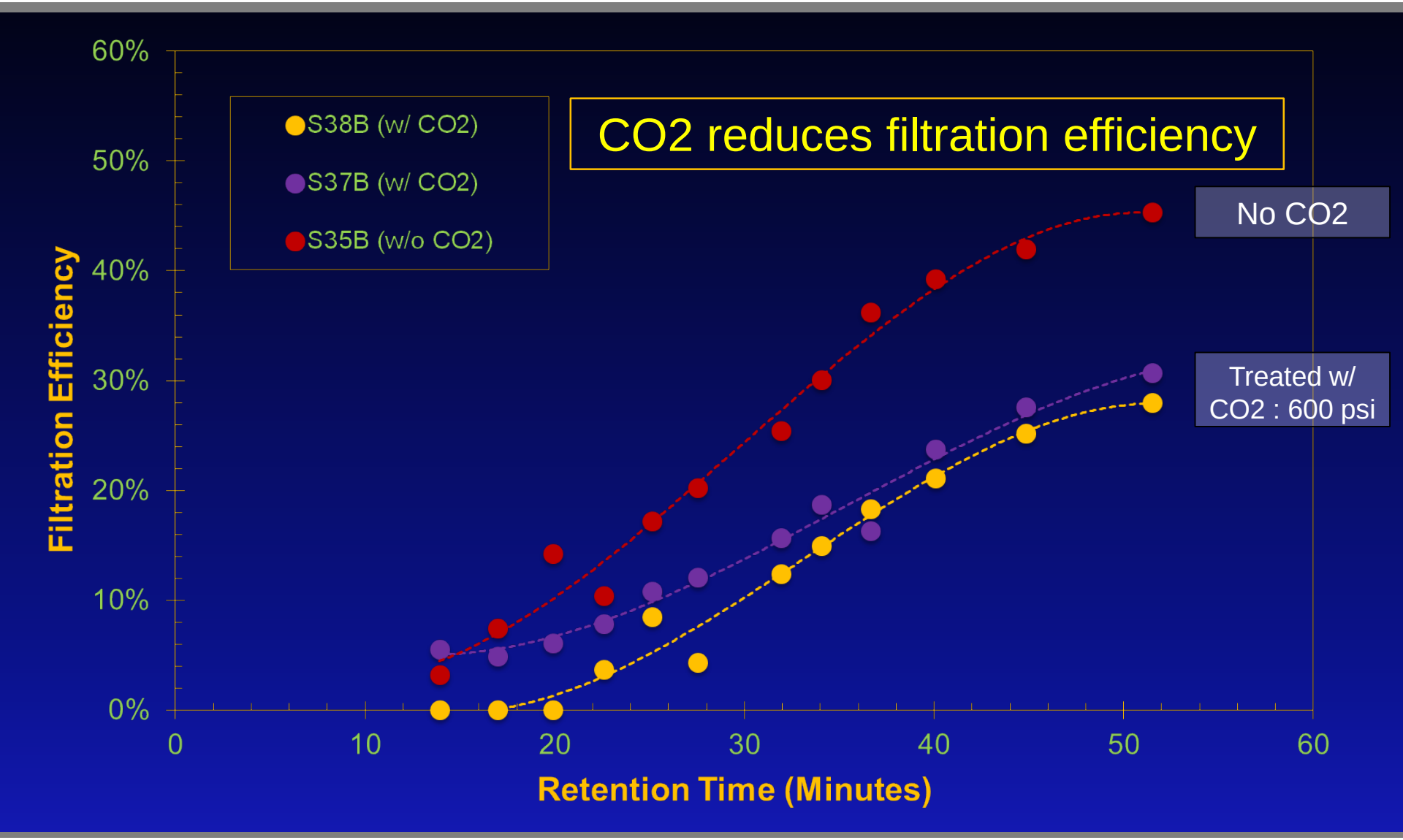
Filtration Efficiency (S37: Treated w/ CO2 at 600psi)



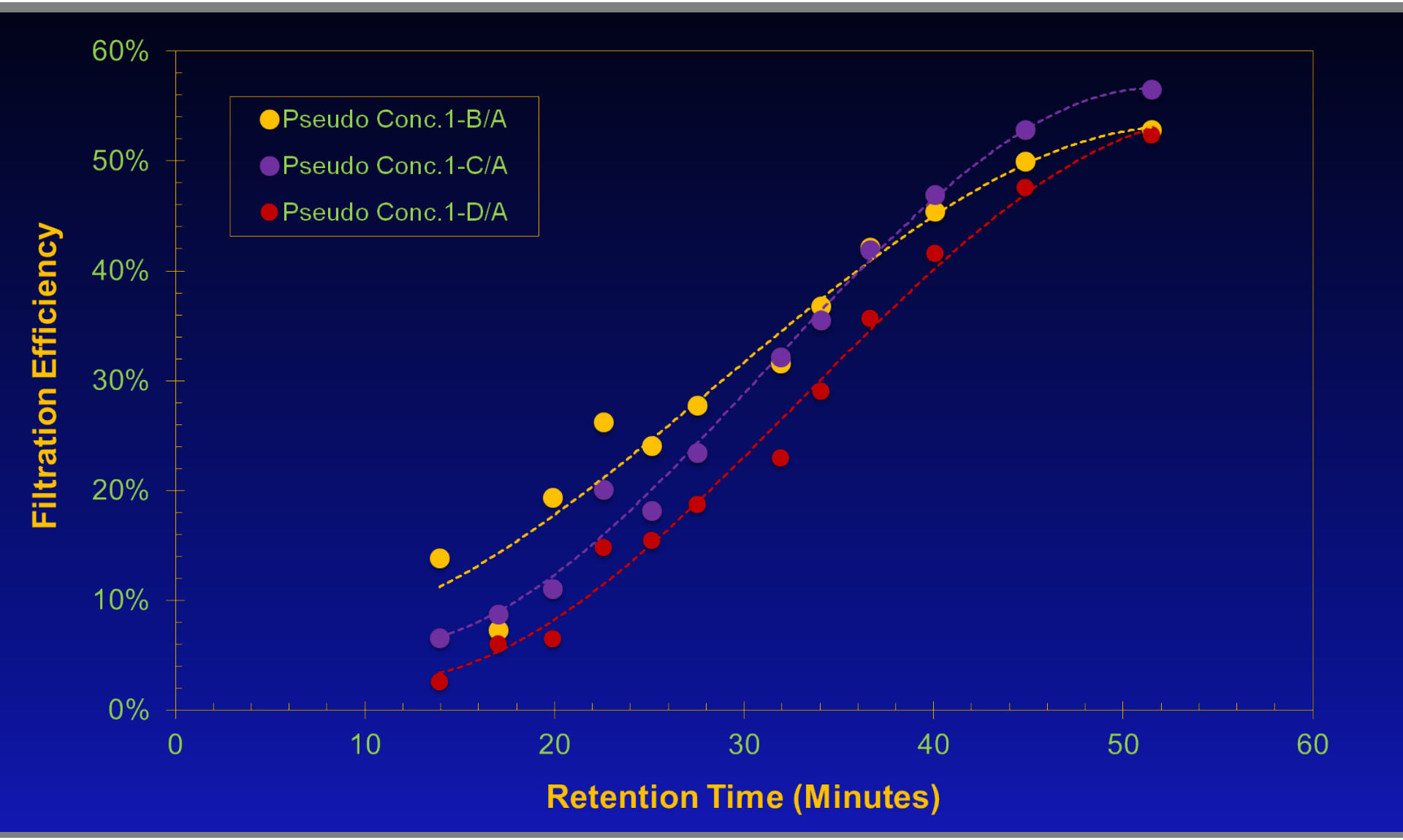
Filtration Efficiency (S38: Treated w/ CO2 at 600psi)



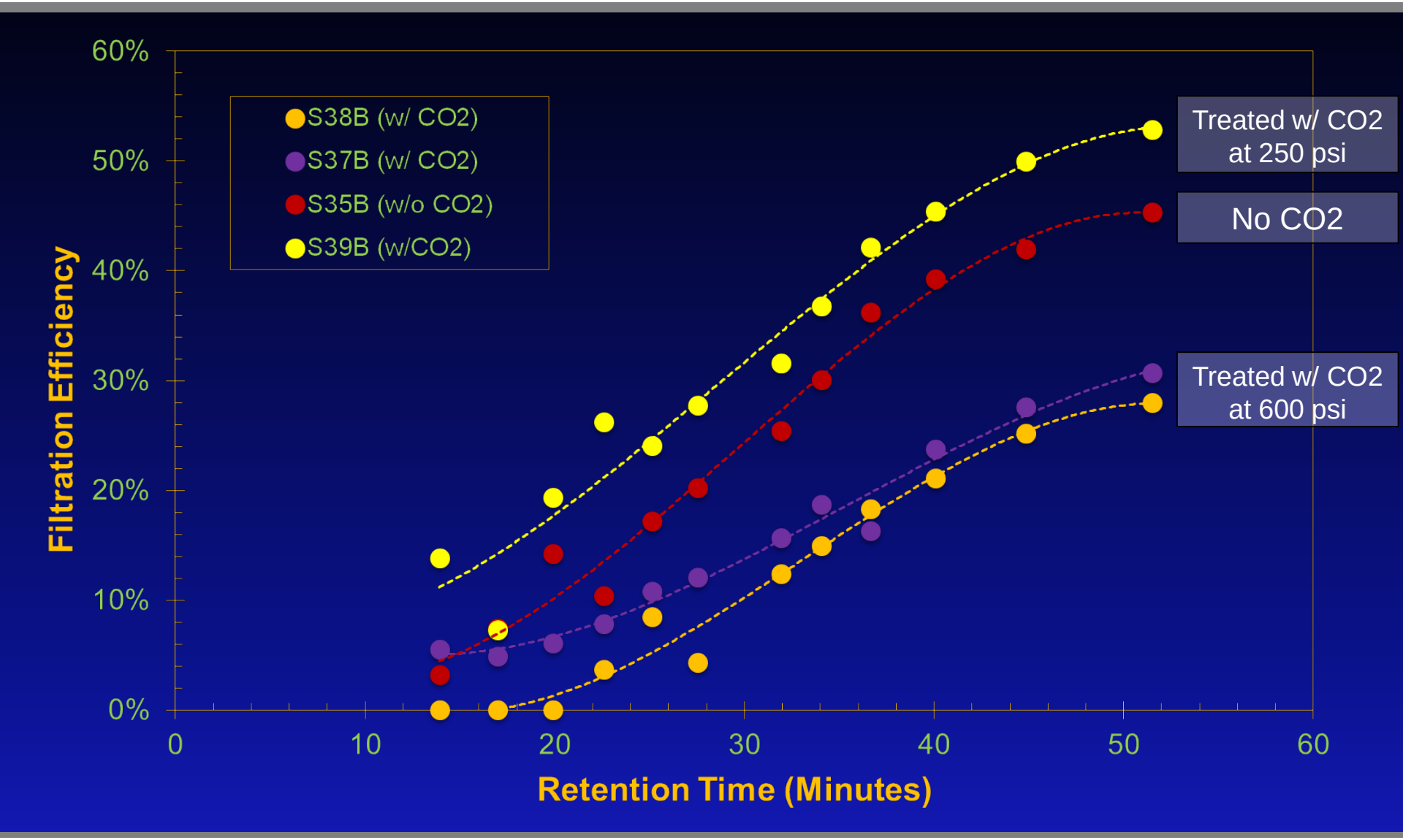
Filtration Efficiency: *CO2 Effect*



Filtration Efficiency (S39: Treated w/ CO2 at 250psi)



Filtration Efficiency: *CO2 Effect*



Part III
Conclusions

Conclusions

- *Heavier components in crude oil have higher filtration efficiency than lighter components*
- *Lower pressure drop across the membranes leads to lower filtration efficiency*
- *CO2 may have reduced filtration efficiency if dissolved in the pre-filtration mixture*
  - *It seems higher pressure, e.g. 600 psi, is needed to dissolve CO2 effectively into toluene/crude oil mixture to reduce filtration efficiency*

Part IV
Future Work

Future Work

- **Investigate the below parameters further about their effect on filtration efficiency of crude oil**
  - *Pressure*
  - *CO2*
  - *Temperature*
  - *Other factors?*


Q&A