Allowed DUNE HPTPC Gas following FESHM 6020.3

– updated version (see **UPDATE** tag)

Xianguo Lu
University of Oxford

DUNE-ND Gas Meeting
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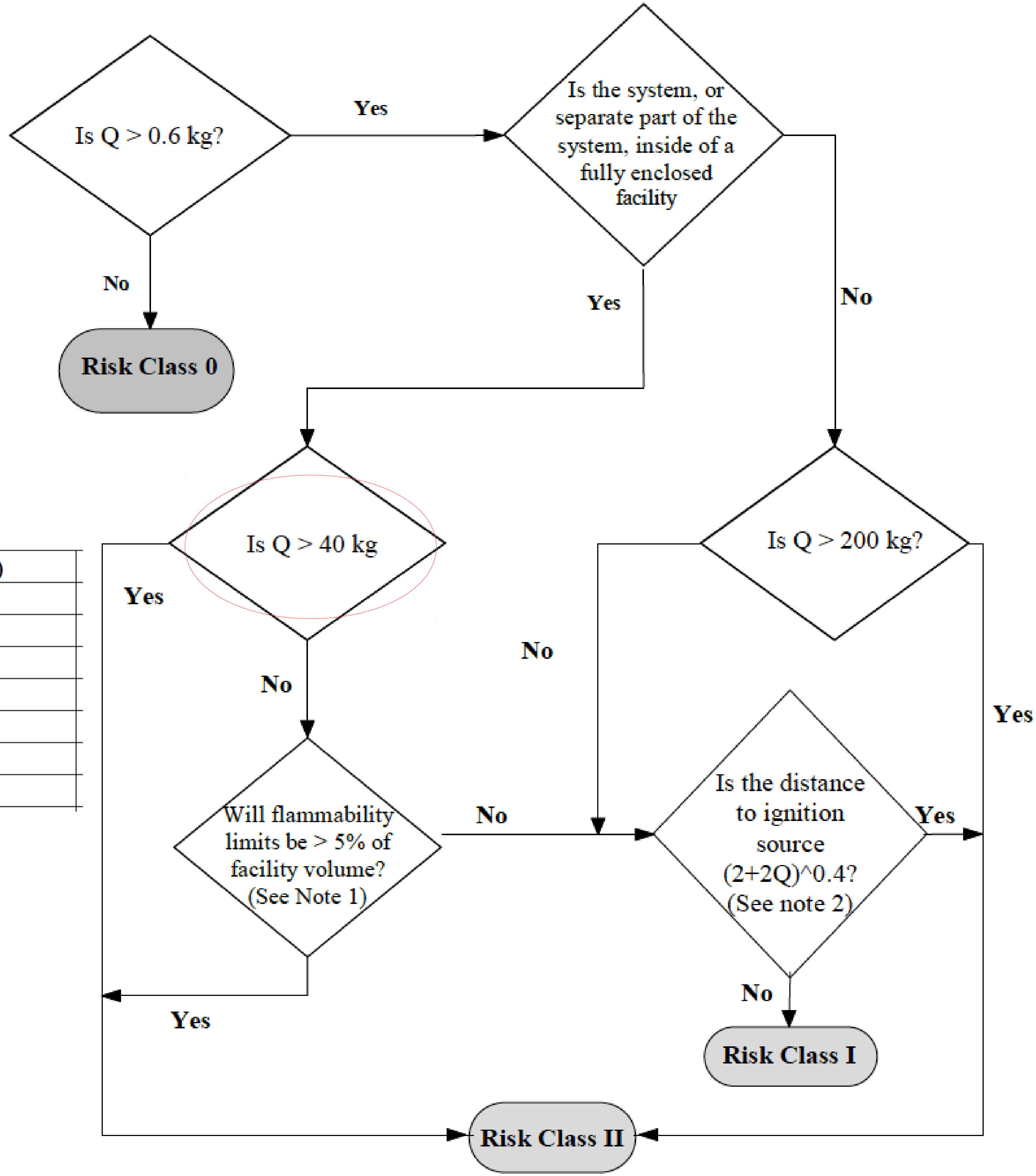
FESHM 6020.3



Hydrogen equivalence Q using the heat of combustion

Description	Mass (kg)
Hydrogen	0.6
Deuterium	1.2
Methane	1.5
Ethane	1.7
Propane	1.7
Isobutane	1.8
Dimethyl Ether	2.7

→ $CH_4 / H_2 = 2.5$

Alkane all similar

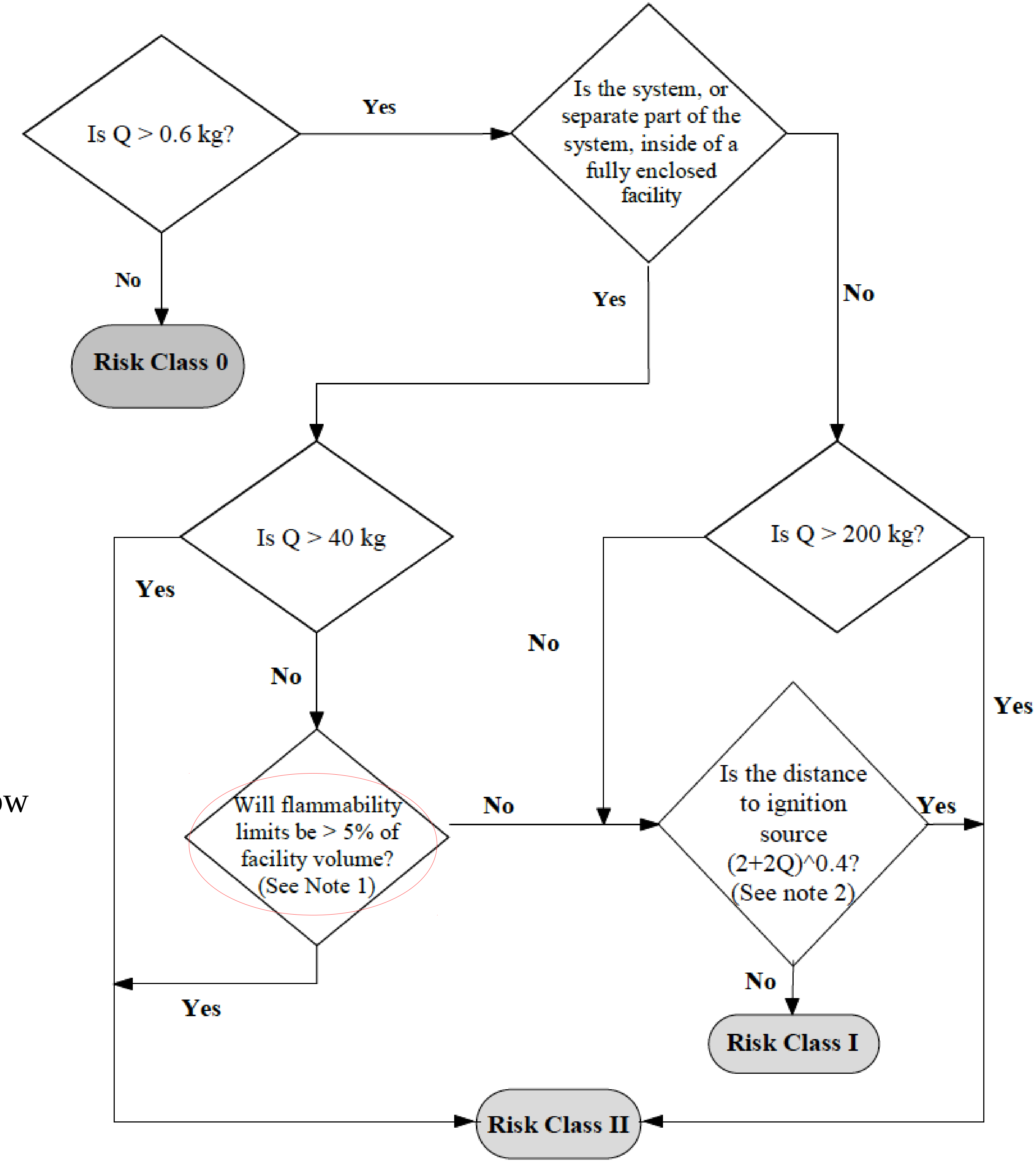
UPDATE

	specific heat of combustion J/kg (joules per kilogram)	full TPC volume m^3	pressure bar	density at 1bar 25C kg/m^3	density at 10 bar 25C (kg/m^3)	mass in full TPC at 10 bar 25C (kg)	FNAL Q threshold kg	allowed percentage	minimal facility volumn (with 5% gas when all escape) m^3
H2	1.42E+08	100	10	0.08	8.08E-01	81.27	40.00	49.22%	9.84E+03
CH4	5.55E+07	100	10	0.65	6.59E+00	648.3	102.20	15.76%	3.15E+03
C2H6	5.19E+07	100	10	1.22	1.32E+01	1222	109.27	8.94%	1.79E+03
C3H8	5.00E+07	100	10	1.81	4.93E+02	1808	113.37	6.27%	1.25E+03
D2	7.09E+07	100	10	0.16	1.62E+00	162.4	80.00	49.26%	9.85E+03

This is where the 2.5 comes from
For 40kg H2, allowed alkane is about 100kg

Assuming total gas volume 100 m^3, allowed percentage:
H2 : ~ 50%
CH4: 15%

So if we stick to P-10, the maximal gas volume is 150 m^3, that is 14% margin between vessel and 100m^3 actual TPC (1.5^(1/3) = 1.14)



Interestingly, we can now proceed to next level...

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If the total gas volume is 100 m^3, then the minimal facility volume should be 1E4 m^3.
Alan: Hall volume ~ 1.3E4 m^3 (not including the annex) → maximal vessel size 130 m^3.

Easy level.

Example 1

Two 81 SCF cylinders of a 50-50 mixture (by volume) of argon-ethane (Fermilab stock catalog number 1980-1095) will be used in a room whose volume is 9*15*20 ft^3 (2700 ft^3). This room, inside a larger building, contains no obvious fire hazards such as welding operations. The gas is to be supplied to drift chambers. First, to determine Q, it is recognized that only 40.5 SCF of a given cylinder is ethane. Thus, from Appendix 3 and Appendix 4;

UPDATE

FESHM 6020.3 example

$$Q = 2*40.5\ ft^3 *0.028(m^3/ft^3)*1.26(kg/m^3)*0.36(H_2 \text{ equivalence factor})$$

$$Q = 1.03 \text{ kg hydrogen equivalent inventory}$$

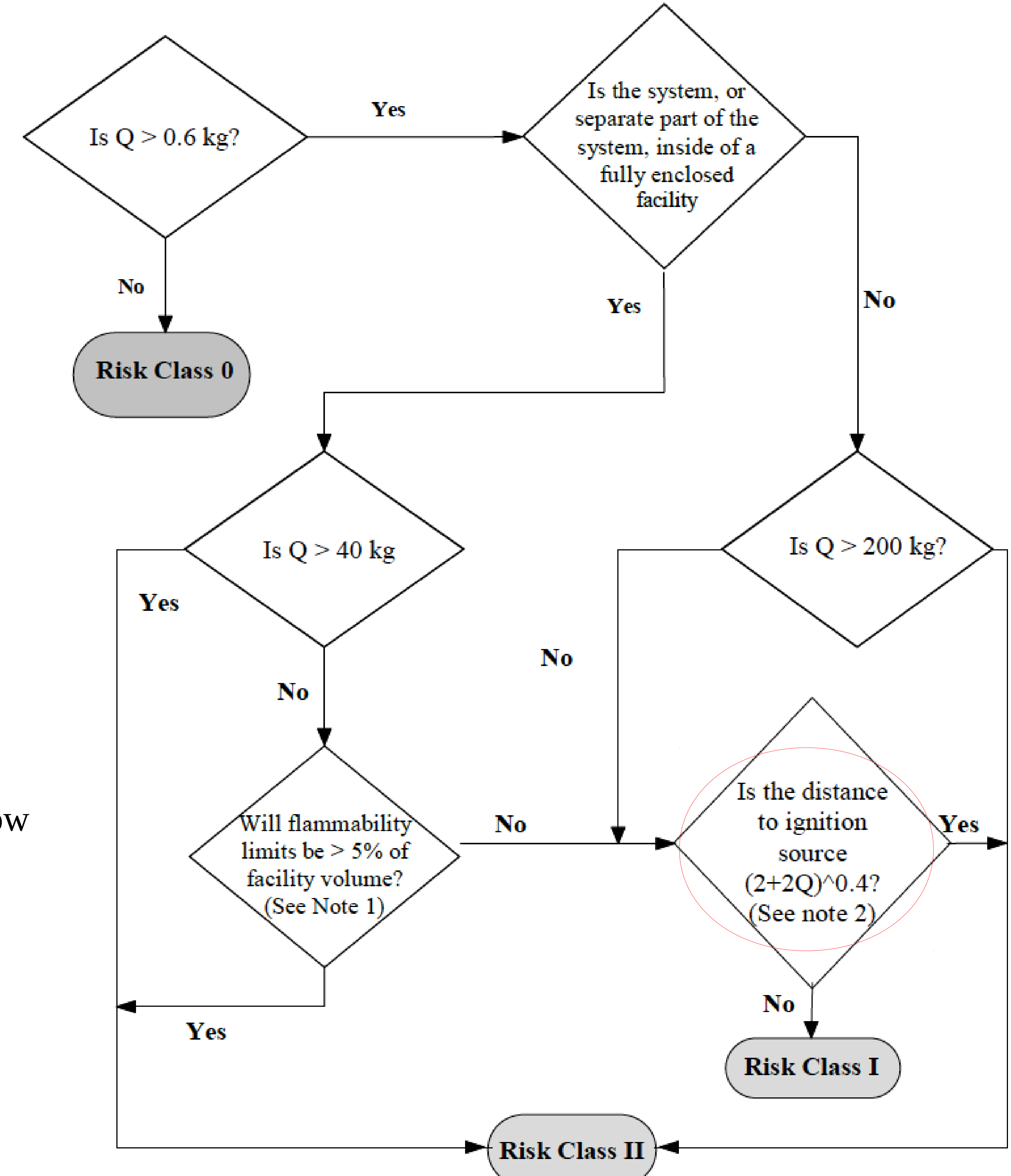
Thus by box 1 in the flowchart, we exceed the limit for Risk Class 0 and must go to box 2. Continuing to box 2, we find the answer to be yes but the answer to the question in box 3 is negative. Doing the calculation prescribed in box 4 we find that 5% of 2700 ft^3 is 135 ft^3. Dividing 81/135 finds a maximum concentration of 60 %, which exceeds the flammability upper limit. Thus, any concentration below this limit is reachable with the available inventory, since no inventory controls have been specified. Therefore the answer to this question is affirmative and the Risk Class is II. If only a single cylinder was needed, the Ø.5 kg hydrogen equivalence would have rendered a Risk Class 0 determination.

Minimal facility volume at maximal allowed mass

	flammability upper limit in % (from FESHM 6020.3 p17)	minimal facility volume (m^3) = gas volume at 1 bar/upper flam limit/5%
H2	75	1.31E+04
CH4	15	2.10E+04
C2H6	12.5	1.43E+04
C3H8	9.5	1.32E+04
D2	75	1.31E+04

Just match the current hall size 1.3E4 m^3

Very large due to the small upper limit



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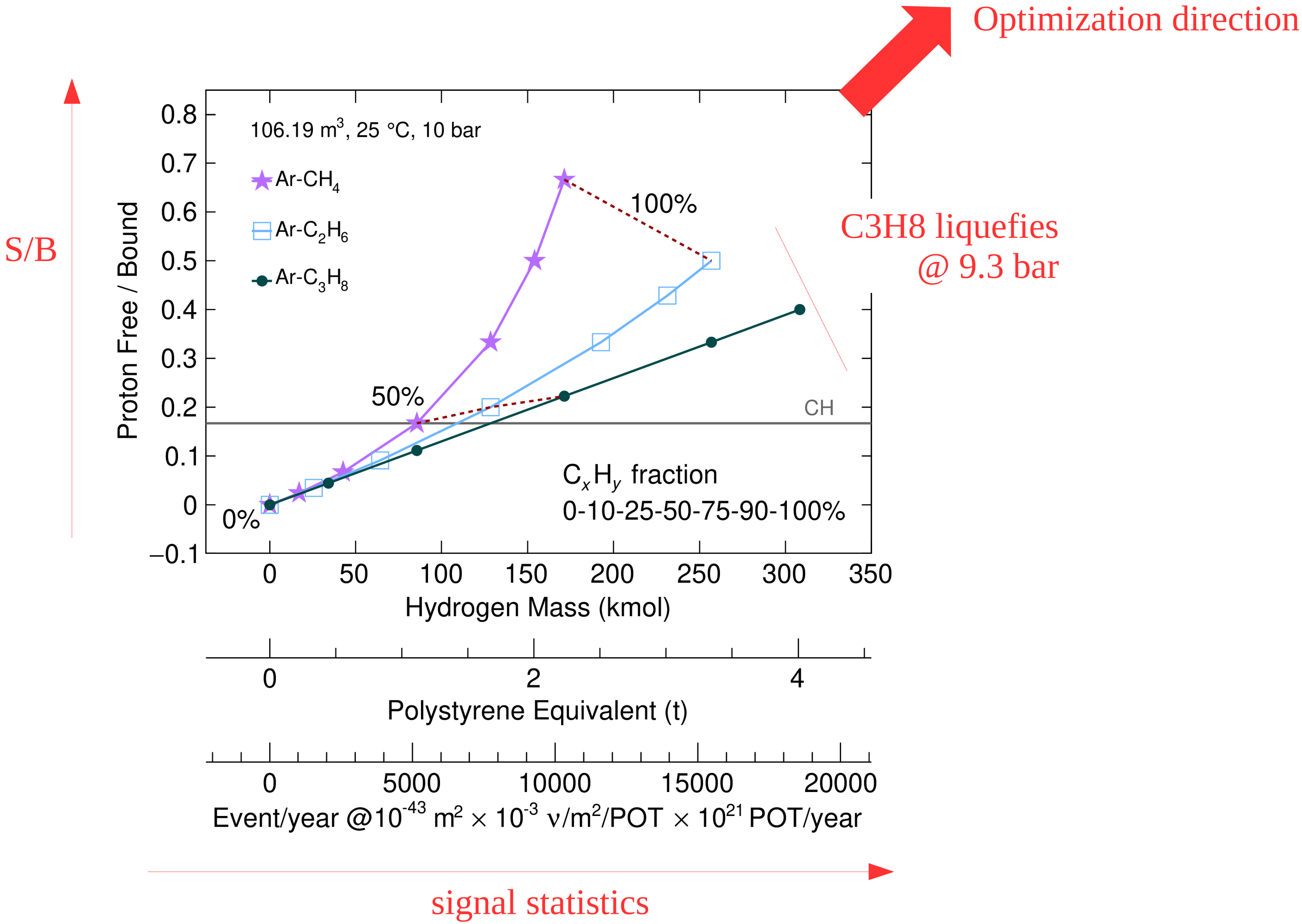
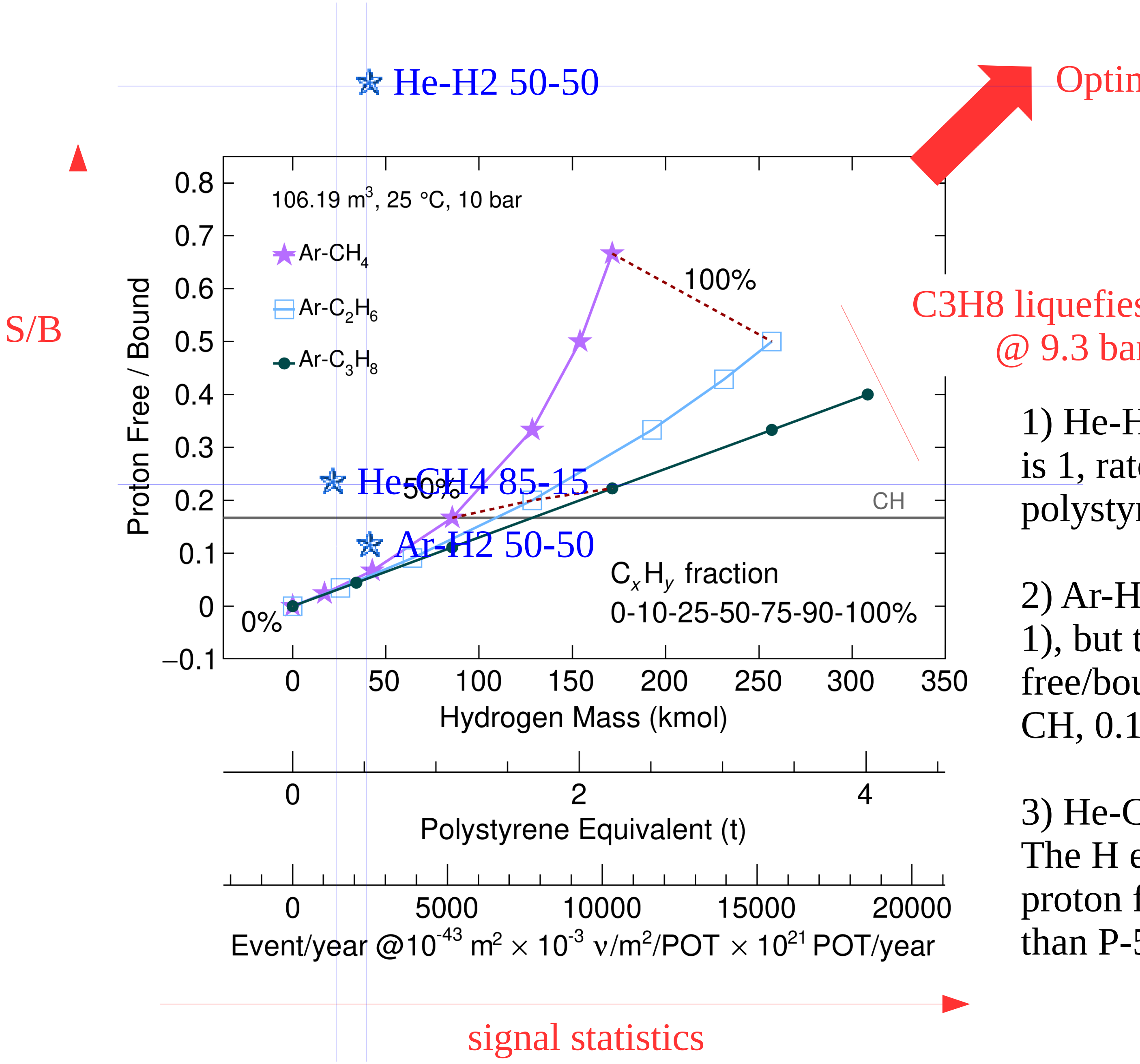
Now actually we can have 50%H2 or 15%CH4 (for 100m^3 total gas volume)

The distance to ignition in both cases is actually 0...



Optimization direction
S/B
C3H8 liquefies
@ 9.3 bar
signal statistics
106.19 m³, 25 °C, 10 bar
Ar-CH4
Ar-C2H6
Ar-C3H8
100%
50%
0%
CH
CxHy fraction
0-10-25-50-75-90-100%
Proton Free / Bound
Hydrogen Mass (kmol)
Polystyrene Equivalent (t)
Event/year @10-43 m2 × 10-3 ν/m2/POT × 1021 POT/year



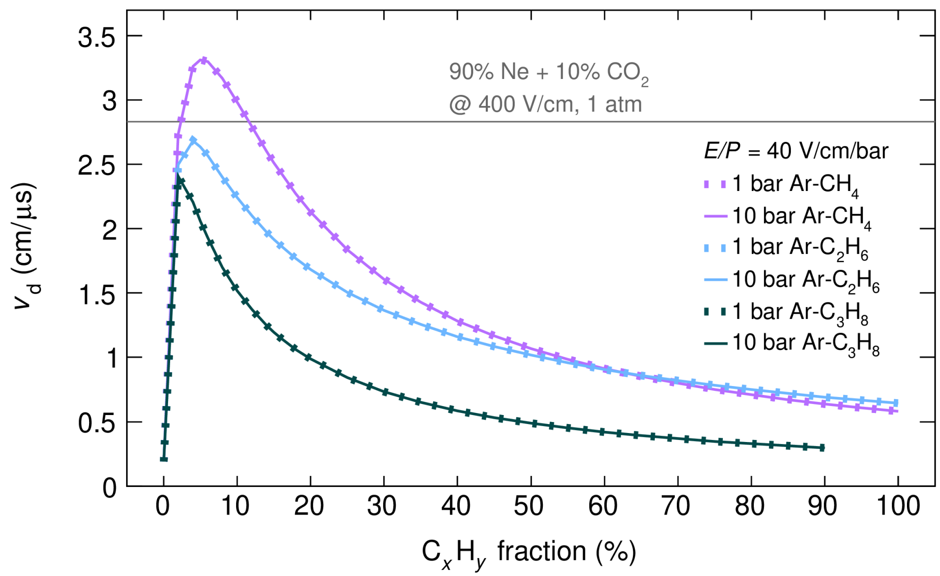
1) He-H2 50-50: proton free/bound ratio is 1, rate = 25%CH4, i.e. 0.5 t of polystyrene, giving 2.5k event/year.

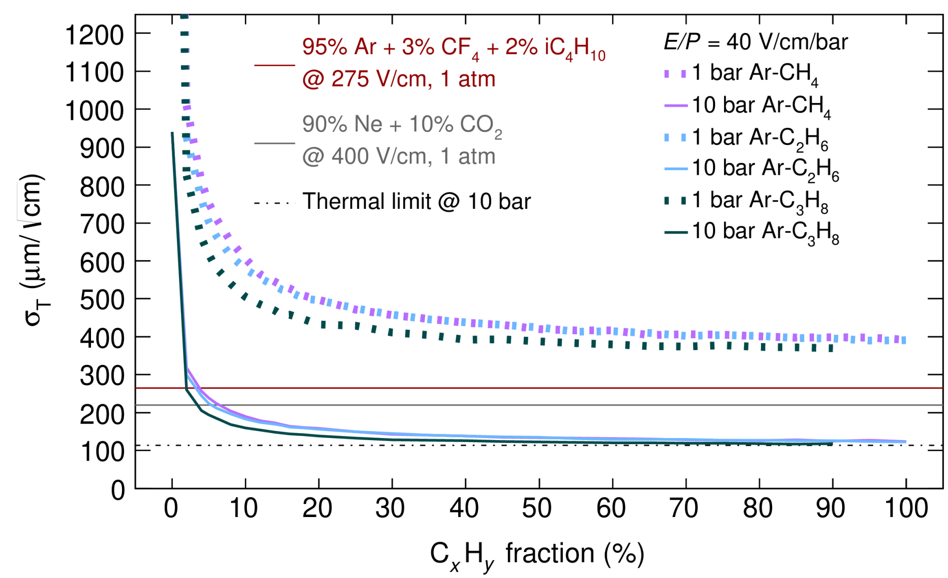
2) Ar-H2 50-50: the rate is the same as 1), but the purity is lower with proton free/bound ratio 0.1, lower than P-50 (or CH, 0.16)

3) He-CH4 85-15: this is also allowed. The H event rate is 60% of 1). The proton free/bound ratio is 0.23, higher than P-50 or CH.

Conclusion and discussions

- According to FESHM 6020.3, 50%H2 and 15%CH4 (100m^3 volume) might be allowed
  - UPDATE need to dig into facility volume and distance-to-ignition
  - Need to check what it means to have 0-distance to ignition for both cases
- He-50%H2 is interesting
  - Effectively DH molecule and TKI still applies as described by arXiv:2005.05252
    - 1.5 times better purity than pure CH4
    - Even rate comparable with P-25%, 0.5t of polystyrene
  - H2 and D2 can be used in arbitrary mixing ratio
    - He-X%H2-(50-X)%D2 has interesting physics implication
- Ar-alkane mix might no longer provide useful hydrogen
  - Alkane mixture as small as possible
- Competitive hydrogen event rate requires high fraction of alkane.





BACKUP

END