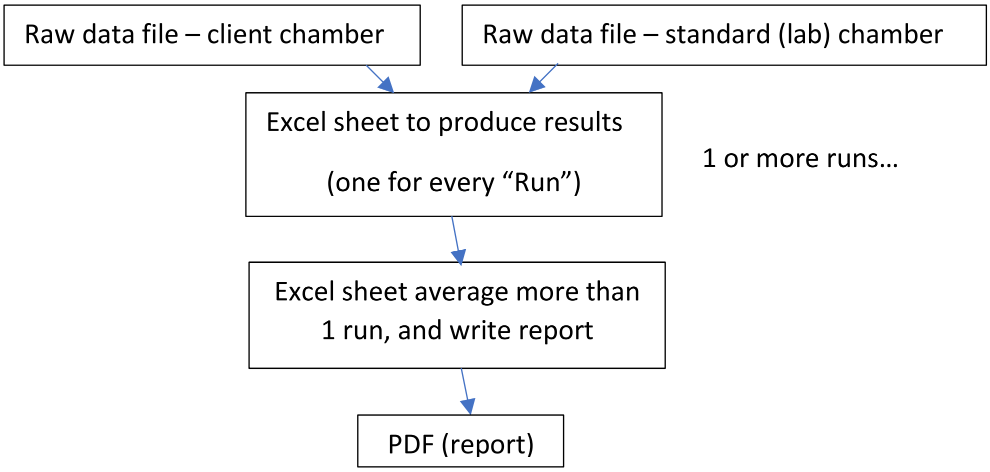
How to calculate the MEX measurement results from two raw input files (version 2)

Analysis sequence: from raw data to report



Both the raw files look like this:

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	[COMET X-RAY MEASUREMENT]									This is the machine we are doing the measurements on…we are asking your team to focus on this o									
2	Filename		C:\CRData\2Jul2021-11-07_IBAFC65-Gsn1612.csv							This is just the location of where this .csv file lives									
3	Date		#########							date of measurement									
4	Chamber		IBA FC65-G 1612							chamber id									
5	Description		Standard ratio measurement							text field									
6	Software		S:\Medical_Rad\Radiotherapy\Ionizing Radiation\IRS Inhouse Software\Twin Weblines LEX and MEX\Twin Webline Comet v8_1_PRODUCTION.vi														code that took the measur		
7	Backgrounds		90							These change - changes the length of the file and records									
8	Measurements		30							There are the number of readings taken during the session - so we take Background measurements									
9	Trolley (mm)		1090							just a record						For the measurements - this means 3			
10	SCD (mm)		1000							just a record									
11	Aperture wheel		2 CM							Open, 1cm, 2cm…6cm These are fixed options (these are the seven options)									
12	Comment		QA chamber measurement set 1							Text field for comments									
13	Monitor electromete		Medium							Low, Med, High options									
14	Monitor HV		300							number									
15	MEFAC-IC electrome		Low							Low, Med, High options									
16	IC HV		-300							number									
17	[DATA]																Don't need this!		
18	kV	mA	BarCode	XraysOn	HVLFilter(	Filter	FilterReac	HVLReady	N	Current1(	Current2(	P(kPa)	T(MC)	T(Air)	T(SC)	H(%)	Comment		
19	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	1	-0.2	0	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
20	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	2	-0.35	0	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
21	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	3	0	0	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
22	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	4	0	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
23	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	5	0	0	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
24	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	6	0.1	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
25	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	7	-0.05	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
26	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	8	0	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
27	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	9	0.15	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
28	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	10	0.1	0	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
29	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	11	0	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
30	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	12	0	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
31	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	13	0.05	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
32	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	14	0.2	0.002	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
33	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	15	-0.15	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
34	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	16	-0.2	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
35	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	17	0	0.002	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		
36	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	18	-0.25	0.001	100.955	22.94494	23.08626	23.13623	45.06609	QA chamber measuremen		

For each **Filter** (which we also call Beam Code, and Beam Quality) we need to produce a single number, the **calibration coefficient**.

The number of measurements for each filter can vary, although the number is specified in the header. ("Measurements" in this example 30).

We start by obtaining the background (the measurement with no radiation present). In this example there are 90 backgrounds. So we need to average Current1 and Current2 over the first lines where “XraysON = False”, or we can average the first 90, to obtain the averages **BgdIC1_Before** and **BgdMC1_Before**.

The beam turns on at line 109 (in this example) and we have the first beam quality (Filter) NXJ40

104	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	86	-0.2	0.002	100.959	22.94381
105	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	87	-0.2	0.002	100.959	22.94381
106	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	88	-0.25	0.002	100.959	22.94381
107	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	89	-0.15	0.002	100.959	22.94381
108	40	20	NXB	FALSE	0	NXJ40	FALSE	TRUE	90	-0.15	0.002	100.959	22.94381
109	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	1	3729	-39.7	100.96	22.94283
110	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	2	3729	-39.69	100.96	22.94283
111	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	3	3729	-39.7	100.96	22.94283
112	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	4	3729	-39.69	100.96	22.94283
113	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	5	3729	-39.68	100.96	22.94283
114	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	6	3729	-39.68	100.96	22.94283
115	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	7	3729	-39.68	100.96	22.94283
116	40	20	NXB	TRUE	0	NXJ40	FALSE	TRUE	8	3728	-39.67	100.96	22.94283

For the 30 readings in NXJ40, we determine 8 quantities, all averages:

MC1 = Average(Current1[i] – BgdMC1_Before)

IC1 = Average(Current2[i] - BgdIC1_Before) ← this is the client chamber

R1 = Average ((Current2[i] – BgdIC1_Before) / (Current1[i] – BgdMC1_Before))

Note: we divide first and then sum (although it usually does not make much difference) – so best if we repeat the sum to get R1, not use IC1

TM1 = Average (Tmon[i])

TA1 = Average (TAir[i])

TS1 = Average (TS[i]) ← not used

P1 = Average (P[i]) ← not used

H1 = Average (H[i]) ← not used

(i=1 to 30 in this example)

Then we repeat this for the standard chamber (for the same beam quality in the other file).

MC2 = Average(Current1[i] – BgdMC2_Before)

IC2 = Average(Current2[i] – BgdIC2_Before) ← this is the standard chamber (MEFAC)

R2 = Average ((Current2[i] – BgdIC2_Before) / (Current1[i] – BgdMC2_Before))

TM2 = Average (Tmon[i])

TA2 = Average (TAir[i]) ← not used

TS2 = Average (TS[i])

P2 = Average (P[i]) ← not used

H2 = Average (H[i])

So we have 8 numbers from the first file, and 8 from the second, for each beam quality. These are used to calculate the calibration coefficient **N**. However we need three more numbers before we do this. Two of these are nearly always the same but need to be stored as a record with the results. One more depends on the beam quality (Filter) are obtained by a lookup and stored with the result. Call these **Ma** (mass of air), **WE**, and **KK**.

Ma and WE:

Mass of air at 20°C, 101.325 kPa	kg	6.1798E-06	
Energy required to create an ion pair in dry air		33.97	eV

KK is the Product from the Data tab:

BEAM ID	Product
Beam?	
CCRI-100	1.0030
CCRI-135	1.0008
CCRI-180	1.0018
CCRI-250	1.0021
NXJ40	1.0367
NXJ50	1.0299
NXJ60	1.0253
NXJ70	1.0218
NXJ80	1.0189
NXJ90	1.0164
NXJ100	1.0144
NXK40	1.0198
NXK50	1.0162

(above numbers provided in MEX Data.csv)

Then:

$$N = R2 * WE * KK * [(273.15+TS2) / (273.15 + TM2)] * (0.995766667+0.000045*H2) / [Ma * R1 * (273.15+TA1) / (273.15 + TM1)]$$

[Answer will be in Gy/C, divide by 10^6 to get in mGy/nC]

In addition, for quality assurance, we want the backgrounds from after the measurements, which are stored at the end of the file. So average the last 90 to obtain the averages **BgdMC1_After**, **BgdIC1_After** and **BgdMC2_After**, **BgdIC2_After**. We need to compare the before and after values, to make sure they are the same.

It is a deterministic process to get from the raw data to the results. I am not sure if it is best to store the results as fields in a database table, or to generate them as needed.

Example results (from 'Results' tab of spreadsheet). For each Filter (Beam Quality e.g. NXJ40) we find the air kerma calibration coefficient NK, with units mGy/nC.

BEAM No.	Air kerma mGy/nC
NXJ40	47.741
NXJ50	47.310
NXJ60	46.937
NXJ70	46.679
NXJ80	46.467
NXJ90	46.246
NXJ100	46.074
NXK40	46.180
NXK50	46.004
NXK60	45.817
NXK70	45.717
NXK80	45.586
NXK90	45.487
NXK100	45.389
NXA40	45.192
NXA50	45.129
NXA60	45.183
NXA70	45.178
NXA80	45.104
NXA90	45.043

Preferred display format for numbers:

Temperature and pressure: two decimal places e.g. T=22.12 deg, P=101.32 kPa

For calibration coefficient N: 4.546 x 10^6 Gy/C or 45.46 mGy/nC

For ratios, 4 significant figures e.g. 0.9998

For currents in pA 2 sig figs: e.g. 101.23 pA

Criteria for display of before and after leakages currents

	Current pA Before	Current pA After
Monitor1	0.15	0.15
Chamber (client)	-0.21	0.02
Monitor2	0.10	0.15
Standard (MEFAC)	-0.32	-0.41

If the absolute value of any number goes above 0.2 pA, highlight the value (make yellow background, or something similar)