Expected rates and possible scenarios for the Muon Detector @ UPGII

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Overview

- Rates estimate from FEB scaler data:
  - Rates/cm^2
  - Rates/physical-pad and possible scenarios for the UPGII detector
    - Minimal option
    - Other options
- Electronics
- Summary and next steps

Muon detector @UPG2 in a nutshell

Baseline option **as in the FTDR:**

- **Inner regions (R1-R2): μRWell** (new generation MPGD) → 144 chambers, 23 m^2, Max Rate: ~ 1 MHz/cm^2
- **Outer regions (R3-R4): MWPCs** (present + new high granularity) → 960 chambers, 364m^2, Rates: up to 20kHz/cm^2
- **New FE Electronics**

Other Options for outer regions:

- RPCs and/or Scintillating Tiles

Data Sample

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MUDAQA23:MUONA_DAQ_M2A_R2_CMB13A3.FEB13  552833 567520 622193 632541 703129 703226 761901 712667 623755 593667 651783 631400 709622 714306 795627 795189
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB00  3297967 3708824 3451292 3824695 3470048 3892202 3590148 3748402 3012643 3434755 3069942 3448860 3187848 3474448 3189663 3386080
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB01  2750752 3040593 2843696 3243709 2799650 3112919 2943037 3005909 2474339 2931709 2662563 2972492 2677351 2863282 2658550 2849741
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB02  2396273 2635804 2489076 2779717 2379270 2855575 2429260 2772725 2294000 2568448 2317546 2524241 2270718 2553581 2254438 2585464
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB03  2271037 2350494 2326797 2416530 2221140 2385580 2224243 2369668 2111627 2201665 2158233 2137211 2185748 2394115 2085403 2275790
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB04  4260799 4397906 3673817 3795612 3293736 3425480 3317882 3391476 3514893 3665008 3402110 3443618 3383072 3497025 3563469 3735673
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB05  3298202 3412954 3393864 3551335 3594374 3753815 3384006 3518305 3336465 3566121 3571280 3738289 3351283 3475069 3278851 3394560
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB06  3510516 3664732 3307007 3503157 3307496 3452741 3481935 3588994 3194258 3346583 3194185 3355477 3467069 3576069 3128897 3320145
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB07  3127507 3295452 3328477 3491619 2997155 3163562 3054278 3138847 3207249 3391558 3001112 3185011 3087638 3192370 3122668 3287424
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB08  2874125 2971202 2871162 3026828 3042285 3173299 2808194 2947425 2750495 2927970 2934768 3057622 2740219 2912834 2613635 2731718
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB09  2768171 2880213 2600625 2707376 2496620 2661919 2627865 2700319 2393395 2524441 2328921 2459523 2505907 2627499 2496402 2732613
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB10  1949915 2061796 1780275 1987296 1691043 1785226 1669977 1672735 2006642 2286133 1968157 2027925 1817913 1892753 1581939 1846345
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB11  2099388 2464700 2035870 2565132 1892629 2041013 1666342 1847596 2378384 2716048 2157572 2350029 2017489 2287909 1848643 1991044
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB12  1861270 2101139 2026816 2369679 2278070 2566989 2420278 2557279 1923767 2183319 2193936 2352950 2480266 2693693 2566411 2838495
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A1.FEB13  2064976 2296354 2343859 2530818 2511963 2886317 2796677 3049780 2190511 2438710 2513530 2736777 2821359 3107577 2879372 3270753
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB00  1453559 1631808 1612615 1842311 1721531 1977573 2026877 2201054 1377919 1533746 1546308 1701087 1657775 1929860 1869287 2078119
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB01  1289760 1457523 1399948 1565272 1579676 1744413 1755329 1939948 1240202 1436352 1436698 1542416 1498537 1679527 1681340 1959302
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB02  1590947 1792638 1340863 1585551 1227846 1453027 1188015 1273225 1477752 1656392 1362063 1472322 1250936 1435305 1142842 1327795
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB03  1376157 1670952 1239606 1506202 1112997 1412840 1061901 1268981 1362132 1637551 1237543 1441140 1127697 1286536 1029731 1192199
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB04  2754070 2822970 2559987 2646251 2258714 2351058 2205218 2242170 2282996 2381180 2098621 2200767 2040856 2194122 2097889 2218390
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB05  1920455 2032153 1958751 2077040 2027436 2134771 1860315 1936784 1823942 1922043 1920604 2034290 1742408 1862738 1704668 1788663
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB06  1799553 1885892 1667435 1780938 1631910 1721616 1734615 1750557 1521354 1626235 1527082 1579035 1627458 1719022 1492126 1570324
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB07  1506357 1539138 1596218 1630202 1455410 1481405 1414643 1447362 1497495 1534374 1374020 1430802 1377479 1440437 1398283 1422677
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB08  1232908 1260940 1221656 1271421 1314713 1340954 1207979 1220306 1166607 1211208 1247658 1245911 1136096 1133060 1096240 1109086
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB09  1161283 1161001 1112416 1107100 1063737 1086115 1111832 1110898 996572 1052707 989658 996769 1058090 1092858 1073699 1115698
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB10  937851 1051006 833913 962229 794249 846628 693745 761503 922778 1113840 872995 919016 811063 872413 717963 807047
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB11  975775 1071383 905307 993393 811747 896164 749058 773666 1022025 1093272 931621 1003746 827277 904965 757837 805733
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB12  756869 868983 857675 969003 980589 1110726 1100955 1232035 784579 896165 899433 1009083 1000426 1130393 1157390 1240519
MUDAQA23:MUONA_DAQ_M2A_R2_CMB14A3.FEB13  843960 911195 920702 1028050 1082063 1127555 1203840 1307906 829005 968172 998370 1034882 1123294 1242736 1244319 1376067
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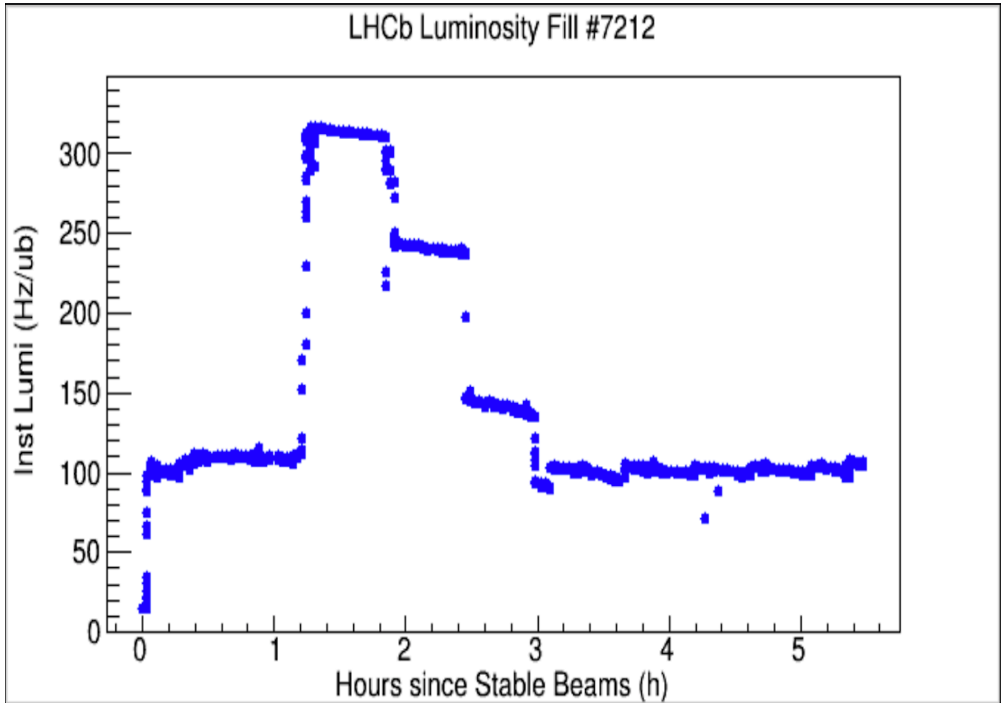
Example of scaler file

Scalers data taken on Sept. 23rd 2018:

- https://lblogbook-run2.cern.ch/MUON/7164
- **542 bunches** colliding in LHCb
- **4 lumi points: (1.1, 1.4, 2.39, 3,12) x10^{32} cm^{-2}s^{-1}** luminosity averaged over 10min around the file time-stamp
- **2 quadrants:** Q2 (A side down) and Q3 (C side down)
- A and C side independent measurements → used as a cross-check
- One rate value per DIALOG channel (OR of 2 projective PADs in bi-gaps), 16 values per FEB
- FEB **INPUT rates** (scalers are before any logical combination)
- **Quite some work was already done by Oleg** (one lumi point, 1 quadrant)



Method (I)

- Import data to excel
- Exclude bad values: 0, -1, noisy channels (defined as rates>10 times the average)
- **Average rate per chamber** (separately for PADs and Wires where needed)
- Calculate the Single gap rate from the formula:
  - $R_{1G} = R_{2G}/2*(1+3f_c)/(1+f_c)$
  - Latest f_c values from Giacomo (2015 data @ 6.5TeV)
- Calculate the **Single-gap-rate/cm²** dividing by **Physical Pad area**
- Include rate reduction factors (MC estimate) for:
  - Additional shielding installed in LS2 (HCAL&M2 new beam plugs + Tungsten)
  - “Iron wall” option D: full iron up to R3, iron-concrete “sandwitch” in R4 central area
- **Linear fit of the 4 lumi points** and projection to $\mathbf{1.5x10^{34}cm^{-2}s^{-1}}$
- Plot of **single and bi-gap** rates **per cm² and per physical pad**

	M2	M3	M4	M5
R1	0,08	0,05	0,12	0,10
R2	0,10	0,08	0,14	0,14
R3	0,16	0,22	0,34	0,33
R4	0,33	0,46	0,51	0,32

f_c: fraction of correlated hits

	M2	M3	M4	M5
R1	0,50	0,75	1,00	1,00
R2	0,75	0,90	1,00	1,00
R3	1,00	1,00	1,00	1,00
R4	1,00	1,00	1,00	1,00

Reduction factors: Additional Shielding (LS2)

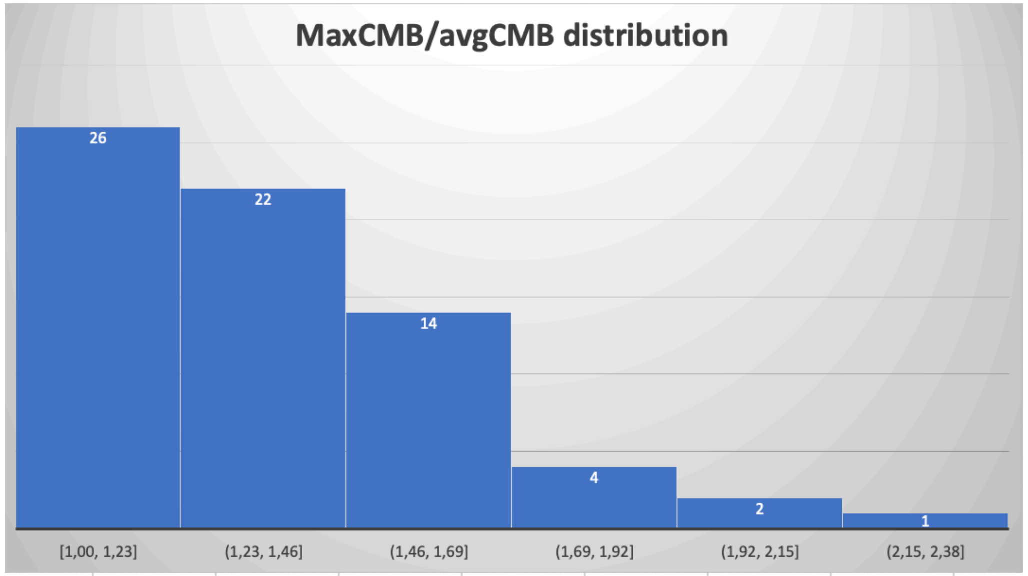
	M2	M3	M4	M5
R1	0,58	1,00	1,00	1,00
R2	0,31	1,00	1,00	1,00
R3	0,36	1,00	1,00	1,00
R4	1,00	1,00	1,00	1,00

Reduction factors: Iron Wall

Method (II)

- In M2R4, M3R4, M4R4 we **cannot separate the bigaps** (physically connected inside the chamber)
- Estimate the **single channel input rate** to the FEBs
- In order to keep the Dead Time inefficiency **below 5%**, assuming a **DT=100ns**, we should keep the input rate **below 500kHz**
- A **safety factor of 2** is taken since:
  - The maximum/average ratio on a chamber has a maximum at ~2 and is ~ 1.5 on average
  - The correlation factor f_c has large uncertainty which can cause an underestimation of the rates up to a factor ~1.5

→ in what follows the limit on the **average rate** is considered **250kHz**



Typical distribution, over a quadrant (69 CMBs), of the Max-rate/AVG-rate ratio on a chamber

M2 and M3 Single Gap Hz/cm^2

M2 A side

D	C	B	A			
7108	5013	15467	51150	204597		16
5752		10955	45306	114807	171961	15
8048	7097	10763	30031	57821		14
4797	5285	7258	17744	34228		13
2541	4575	5641	18421			12
3331	3514	3912	11348			11
3101	3014	3034	7066			10
2934	2280	1973	4518			9
1928	2578	4701	9352			8
1821	1410	3046	5915			7
1733	1342	2554	4364			6
1361	961	1881	2971			5
604	907	1590	2366			4
708	769	1251	1669			3
899	844	1329	1650			2
846	973	1404	1601			1

M2 C side

D	C	B	A			
7034	8832	14135	55944	214604		16
5757	7600	11798	40843	121826	224095	15
6015	6913	10240	27095	62962		14
4365	5394	6806	17241	31701		13
4404	4647	5349	17092			12
3225	3488	3675	11001			11
3249	2990	2916	7372			10
2403	2220	1888	4701			9
2379	1990	4383	9048			8
1810	1457	2832	6078			7
1749	1316	2461	4540			6
1335	953	1712	3023			5
1325	903	1481	2401			4
1011	750	1132	1759			3
955	856	1219	1649			2
882	934	1308	1646			1

M3 A side

D	C	B	A			
1435	2937	8360	42902	222910		16
1255	2882	6638	37195	85504	123958	15
1072	2062	4975	19586	56097		14
890	1544	3466	12963	31312		13
666	1128	2448	11591			12
546	808	1707	6072			11
447	627	1223	3112			10
357	455	846	1754			9
281	342	692	1197			8
248	282	483	790			7
192	226	388	562			6
188	169	278	387			5
141	151	230	294			4
140	122	175	215			3
129	112	160	188			2
126	110	148	166			1

M3 C side

D	C	B	A			
1419	2955	8643	41656	225322		16
1240	2877	7102	35440	80720	158988	15
1043	2008	4993	19185	61528		14
869	1523	3450	11704	29427		13
669	1144	2296	9687			12
532	823	1714	5440			11
444	651	1128	3235			10
353	456	805	1902			9
282	368	637	1342			8
245	279	480	904			7
198	223	357	645			6
174	185	266	465			5
155	145	215	344			4
131	119	167	266			3
121	117	150	216			2
122	108	141	191			1

M4 and M5 Single Gap Hz/cm^2

M4 A side

496	1638	5427	25818	202169		16
427	1334	4425	18686	78685	130958	15
373	1055	3164	10546	33130		14
328	801	2116	5850	16157		13
243	569	1446	5959			12
214	408	1025	3461			11
181	317	717	1909			10
150	221	498	1059			9
127	188	314	697			8
119	147	285	441			7
95	119	228	314			6
87	98	163	212			5
76	82	137	160			4
72	67	110	116			3
66	64	91	95			2
66	61	73	80			1
D	C	B	A			

M4 C side

526	1642	5858	23093	212345		16
445	1188	4697	19815	71444	152252	15
361	1045	3382	9998	34146		14
327	812	2123	6238	14387		13
248	557	1497	6182			12
215	428	991	3288			11
182	319	696	1806			10
#VALUE!	239	484	1103			9
133	190	410	975			8
122	157	295	551			7
89	120	231	385			6
98	#VALUE!	175	268			5
81	87	137	200			4
78	91	115	150			3
72	66	90	120			2
82	63	78	102			1
D	C	B	A			

M5 A side

544	1022	5382	21367	284178		16
663	777	4827	14676	66951	107893	15
566	738	3295	11701	34195		14
536	603	2547	7165	16259		13
392	503	1886	7288			12
506	500	1766	4868			11
381	574	2267	4060			10
499	766	4541	4646			9
330	1077	3628	3866			8
482	1319	5959	3740			7
518	1612	3480	2352			6
388	1188	2235	1586			5
340	1090	1654	1127			4
388	711	1176	909			3
250	459	738	572			2
296	369	613	521			1
D	C	B	A			

M5 C side

1763	1660	5872	23643	256150		16
1939	1838	4687	17932	79298	175210	15
1514	1272	3413	10368	36215		14
1562	1290	2424	7090	16402		13
838	740	1966	8993			12
784	789	1994	4585			11
565	782	2631	4253			10
605	1039	5155	6420			9
417	1209	9731	3833			8
418	2048	6353	3477			7
393	1901	4237	2362			6
435	1224	2903	1737			5
377	1220	1751	1289			4
390	801	1146	957			3
310	790	806	661			2
315	447	697	512			1
D	C	B	A			

file for the design of the

- In the following slides are reported the **Physical PAD rates** and some considerations on the number of chambers to be replaced **in R3 and R4** to cope with UPG2 rates

- We assume that R1 and R2 will be equipped with new chambers and electronics
- Remember that in M2R4, M3R4, M4R4 we cannot separate the bi-gaps into single gaps → single and bi-gap rate will be reported

- In general A and C side are well in agreement, some difference in M5
- In M2 the situation is more complex and several options are possible, it will be discussed as the last

M3 Physical PAD Rates

Single GAP Rate

D	C	B	A			Row
209154	428258	305141	1171222	3053865		16
183045	420220	242302	1015435	1171398	1698227	15
156347	300614	181576	534709	1531442		14
129741	225071	126497	353887	854816		13
97106	164516	89336	423085			12
79633	117876	62291	221645			11
65105	91473	44653	113595			10
52075	66392	30881	64015			9
40934	49929	100939	174543			8
36203	41187	70399	115159			7
27998	32927	56592	81990			6
27456	24701	40500	56409			5
20594	22065	33535	42840			4
20481	17783	25523	31372			3
18819	16346	23342	27356			2
18320	16086	21527	24204			1

Bi-GAP Rate

D	C	B	A			Row
256609	525425	448521	2040193	3101110		16
224576	446612	356154	1768823	2139075	5576623	15
191820	368821	266894	931428	2667673		14
159178	276138	185935	616449	1489035		13
119139	201843	131313	621883			12
97701	144621	91560	325791			11
79877	112227	65635	166971			10
63890	81455	45391	94095			9
50221	61257	123841	214145			8
44417	50531	86372	141288			7
34351	40398	69432	100593			6
33685	30305	49689	69207			5
25267	27071	41144	52560			4
25128	21817	31314	38490			3
23088	20055	28638	33563			2
22477	19735	26412	29696			1

- Here we can **move 5 M3R3 to R4** and put 5 new M3R3 chambers
  → we should produce at least **20 new M3R3** with pads at least 2 times smaller

M4 Physical PAD Rates

Single GAP Rates

D	C	B	A			Row
83366	275236	456409	1084337	2122770		16
71719	224058	372142	784823	826194	1375055	15
62684	177186	266057	442918	1391474		14
55152	134632	177937	245707	678582		13
40801	95616	121624	501159			12
35932	68608	86201	291033			11
30334	53246	60312	160535			10
25241	37075	41901	89062			9
21296	31618	52729	117160			8
19928	24721	47960	74015			7
15996	20009	38373	52715			6
14641	16464	27369	35699			5
12742	13758	22959	26818			4
12113	11265	18399	19546			3
11141	10763	15324	15966			2
11075	10278	12201	13419			1

Bi-GAP Rates

D	C	B	A			Row
99512	328543	605532	1741048	2264796		16
85609	267452	493734	1260139	1360790	3496327	15
74824	211502	352987	711164	2234198		14
65834	160707	236075	394516	1089554		13
48703	114134	161362	664904			12
42891	81896	114366	386123			11
36209	63559	80018	212987			10
30130	44256	55591	118161			9
25420	37742	62941	139851			8
23788	29509	57248	88350			7
19094	23884	45805	62925			6
17476	19652	32669	42613			5
15210	16423	27405	32012			4
14458	13447	21963	23331			3
13298	12848	18292	19059			2
13220	12268	14564	16018			1

Also here we can move 5 M4R3 to R4 and put 5 new M4R3 chambers

→ we should produce at least **20 new M4R3** with pads 4 times smaller

M5 Physical PAD Rates

Single GAP Rate A side

D	C	B	A			
104192	195877	517243	1021348	3438555		16
126952	148845	463918	701502	810110	1305503	15
108472	141405	316614	559316	1634533		14
102713	115491	244740	342467	777203		13
75118	96402	181269	700353			12
96930	95720	169696	467854			11
73008	109993	217828	390145			10
95644	146819	436360	446464			9
63164	206311	695058	740711			8
92434	252686	1141657	716497			7
99190	308877	666749	450631			6
74388	227569	428141	303845			5
65191	208781	316894	215909			4
74255	136292	225245	174210			3
47913	87973	141343	109521			2
56636	70764	117394	99875			1

Single GAP Rate C side

D	C	B	A			
337827	317969	564306	1130139	3099412		16
371522	352179	450414	857140	959509	2120046	15
290171	243695	327976	495573	1731054		14
299243	247076	232961	338902	783996		13
160621	141773	188970	864246			12
150126	151117	191629	440642			11
108167	149738	252794	408700			10
115877	199114	495428	616929			9
79836	231718	1864533	734468			8
80060	392448	1217275	666246			7
75215	364207	811871	452638			6
83399	234562	556177	332739			5
72265	233807	335505	246885			4
74643	153426	219558	183348			3
59345	151333	154399	126601			2
60419	85587	133609	98047			1

- M5 C Side has higher rates in C-D/11-16 (~factor 2 in ALL FEBs...)
- In both sides there is a clear back-splash effect from a LHC downstream magnet (visible also in the online monitor plots)
- In M5 we could move 8 M5R3 chambers to R4 and produce 8 new M5R3 with pads 4 times smaller
  → we should produce a total of at least **28 new M5R3** chambers with pads 4 times smaller
- The **back-splash from LHC should be reduced** adding more material (as done already behind M5)

M2 Physical Pad Rates: Minimal Scenario

Single GAP Rate

D	C	B	A			
888508	626626	484114	1196911	2393785		16
718984		342880	1060163	1343243	2011942	15
1005964	887096	336895	702720	1353002		14
599624	660621	227168	415209	800939		13
317666	571913	176578	576575			12
416351	439190	122435	355191			11
387599	376725	94968	221157			10
366731	284994	61749	141423			9
241045	322286	587643	1169029			8
227643	176287	380711	739384			7
216651	167767	319282	545444			6
170168	120169	235176	371426			5
75545	113410	198701	295698			4
88459	96136	156358	208573			3
112322	105519	166151	206213			2
105804	121603	175523	200132			1

Bi-GAP Rate

D	C	B	A			
1187654	837601	758881	2039871	3531163		16
961053		537487	1806814	2357528	4201337	15
1344655	1185766	528105	1197632	2305894		14
801508	883041	356102	707633	1365025		13
424619	764467	276798	903821			12
556529	587057	191925	556786			11
518097	503563	148869	346679			10
490203	380947	96796	221690			9
322201	430794	785492	1562621			8
304287	235640	508890	988323			7
289594	224252	426779	729085			6
227460	160628	314356	496479			5
100980	151593	265600	395254			4
118241	128504	209001	278796			3
150138	141045	222091	275641			2
141426	162544	234619	267513			1

- **5 M2R3 and 35 M2R4 to be replaced**
- Minimal scenario:
  - Move 5 M2R3 to R4 and build 5 new M2R3 with pads 4 times smaller → **20 new M2R3 1/4 pad size**
  - Build: (33-5)x4 = 112 new M2R3 chambers to be put in R4 → **112 new M2R3 same pad size**

  → A total of **132 new chambers**

M2 Physical Pad Rates: “Ideal” Scenario

Single GAP Rate

D	C	B	A			
888508	626626	484114	1196911	2393785		16
718984		342880	1060163	1343243	2011942	15
1005964	887096	336895	702720	1353002		14
599624	660621	227168	415209	800939		13
317666	571913	176578	576575			12
416351	439190	122435	355191			11
387599	376725	94968	221157			10
366731	284994	61749	141423			9
241045	322286	587643	1169029			8
227643	176287	380711	739384			7
216651	167767	319282	545444			6
170168	120169	235176	371426			5
75545	113410	198701	295698			4
88459	96136	156358	208573			3
112322	105519	166151	206213			2
105804	121603	175523	200132			1

Bi-GAP Rate

D	C	B	A			
1187654	837601	758881	2039871	3531163		16
961053		537487	1806814	2357528	4201337	15
1344655	1185766	528105	1197632	2305894		14
801508	883041	356102	707633	1365025		13
424619	764467	276798	903821			12
556529	587057	191925	556786			11
518097	503563	148869	346679			10
490203	380947	96796	221690			9
322201	430794	785492	1562621			8
304287	235640	508890	988323			7
289594	224252	426779	729085			6
227460	160628	314356	496479			5
100980	151593	265600	395254			4
118241	128504	209001	278796			3
150138	141045	222091	275641			2
141426	162544	234619	267513			1

- Given the high number of chambers to be replaced in order to give the detector a “reasonable” shape (~160 out of 240), we could also consider the possibility to build a **completely new M2.** Rates are in the range:
  - R3: 2-20 kHz/cm^2
  - R4: 1-10 KhZ/cm^2
- This would mean to build 48 new M2R3 and 192 new M2R4 → a total of **240 new chambers**
- Clearly there are several intermediate scenarios between the minimal and “Ideal”

Summary of chambers to be produced (including R1&R2)

- R1 and R2 all stations: (12+24)x4 = 144
- R3 and R4:
  - Mimimal Option:
    - M2: 132
    - M3: 20
    - M4: 20
    - M5: 28

    → **tot: 200 chambers (+ spares) to be produced, technology to be decided**

  - ”Ideal” Option:
    - M2: 240 (full station)
    - M3: 32
    - M4: 32
    - M5: 32

    →tot: **336 chambers (+ spares) to be produced**

→ the total number of chambers to be produced is **from 344 to 480 (+ spares)**

“Reasonable” Scenario

- R1 and R2 all stations: (12+24)x4 = **144 RWells**
- R3 and R4:
  - Reasonable Option:
    - M2: ?? (to me a New M2)
    - M3: 32
    - M4: 32
    - M5: 32

    → **tot: 96 + M2 → chambers (+ spares) to be produced, technology to be decided**

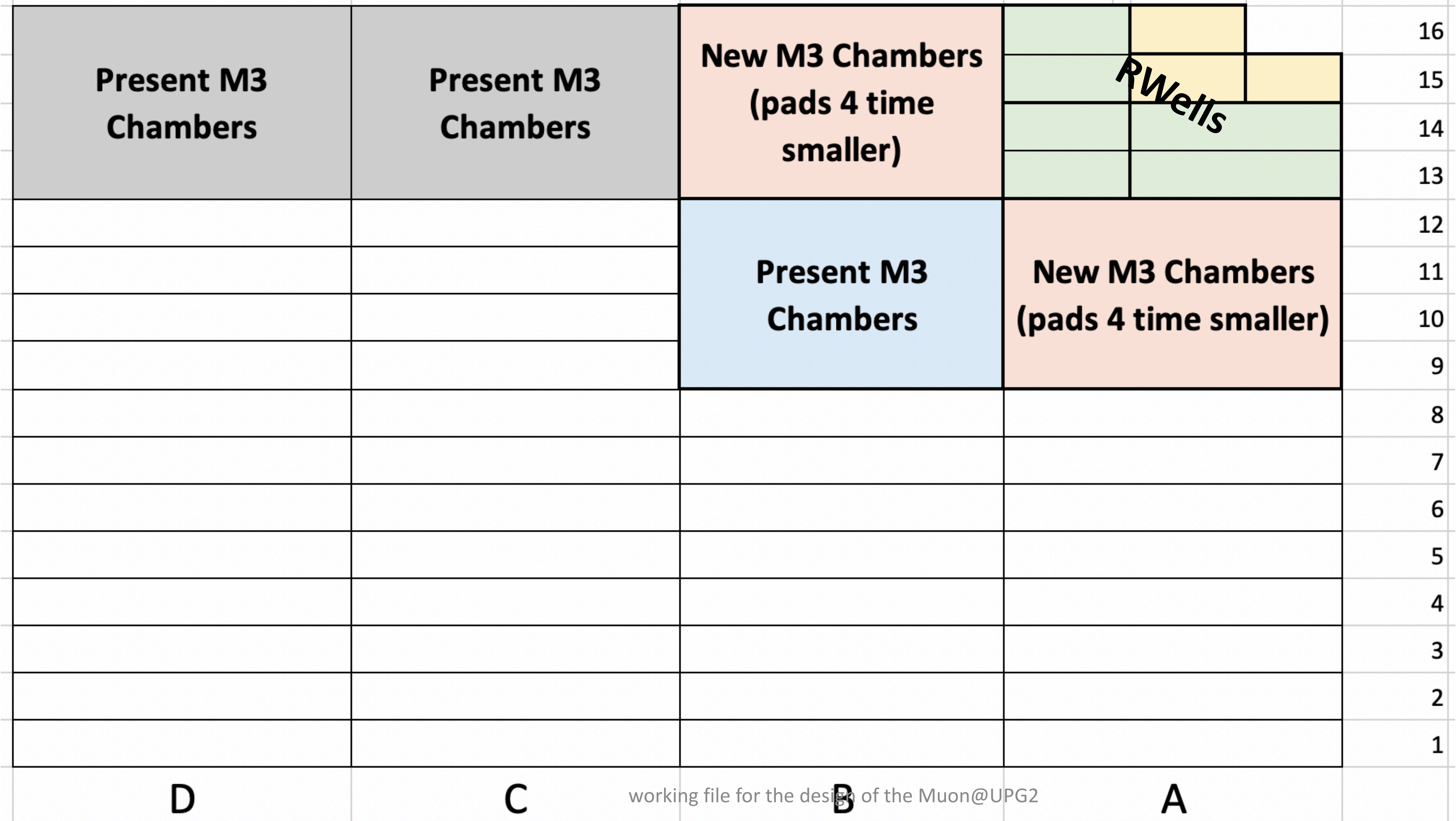
251255	525425	448521	2040193	3101110		16
241486	446612	356154	1768823	2139075	5576623	15
196217	368821	266894	931428	2667673		14
182503	276138	185935	616449	1489035		13
128469	201843	131313	621883			12
121705	144621	91560	325791			11
92416	112227	65635	79337			10
87110	81455	45391	94095			9
62278	61257	123841	214145			8
60868	50531	86372	141288			7
43554	40398	69432	100593			6
56314	30305	49689	69207			5
32266	27071	41144	52560			4
35472	21817	31314	38490			3
32625	20055	28638	33563			2
30632	19735	26412	29696			1
D	C	B	A			

Move 8 R3 chambres to R4 in Stations M3,M4,M5

- In this scenario we can re-use:
  - all the M3R4, M4R4, M5R4 MWPCs → 192x3 = **576**
  - M3,M4,M5: 16 R3 MWPC/station → 16x3 = **48**
- **A total of at least (no M2) 624/1104 MWPCs can be reused: ~56%**

Replace the FEBs on: 480 chambers

Proposed Configuration for M3,M4,M5



Electronics (I)

- Which electronics will be used in the new detector is clearly of paramount importance
- Also in this case more options are on the table, with reference to the detector options outlined before:
  - **Keep the SAME electronics in all the re-used chambers:** FEB, nODEs, TELL40:
    - Pros:
      - Extension of signal, control, LV cables to the new position (<5m) is possible
      - Many FEBs spare would be available from R1 and R2 (and M1)
      - No constraints on new electronics for R1 and R2 (no need of back-compatibility)
    - Cons:
      - The electronics would be >30 years old
      - **More cables (960) and new connectors (576) should be added in M4 and M5 to read physical pads**
      - More nODE/TELL40 are needed, as we would remove ALL IBs (to be quantified)
      - Keep the know how of a very old electronics (especially FEBs)
      - Compatibility with new DAQ to be understood

    - We should carefully monitor the present FEBs “mortality” rate

Electronics (II)

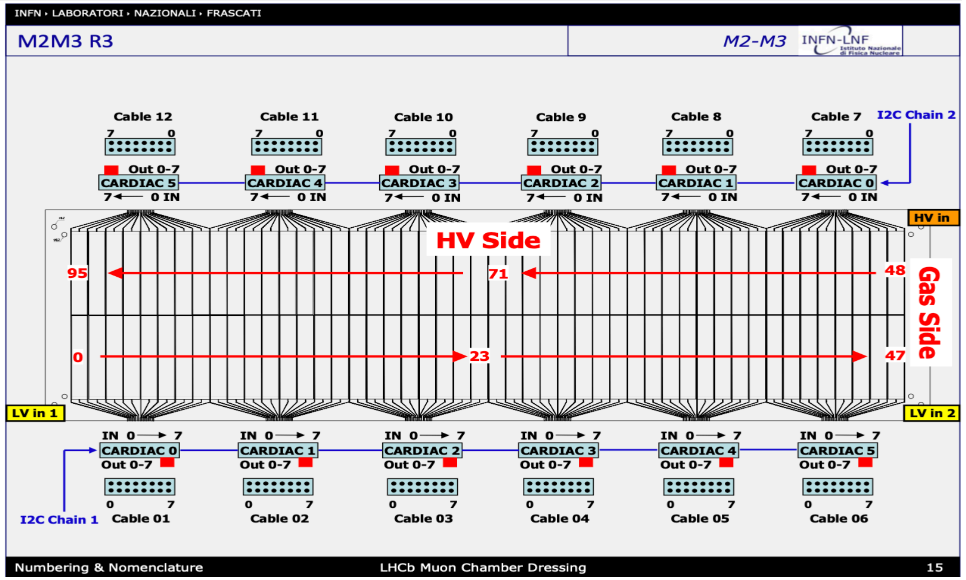
- Also in this case more options are on the table, with reference to the detector options outlined before:
  - **Put NEW electronics in all the re-used chambers:**
    - Pros:
      - Better reliability and less maintenance
      - Same for the whole detector
      - Replace signal/control copper cables from detector to muon towers (huge amount! ☺) with fibers
    - Cons:
      - More expensive option
      - Old MWPCs set constraints to its design, new FEBs should be electrically and mechanically compatible
      - Its replacement will take time (to be carefully quantified), given also the RP restrictions

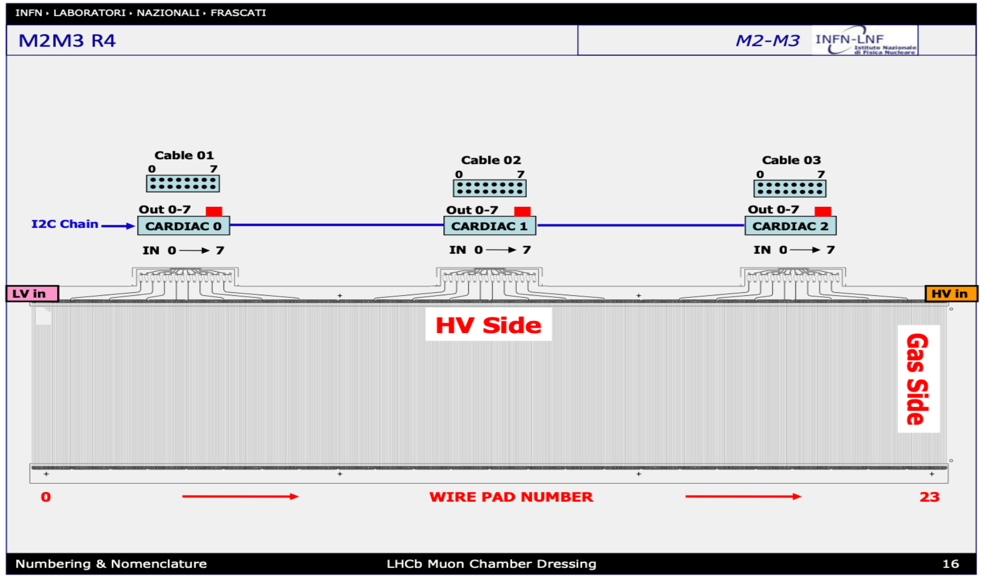
- In the “reasonable” scenario we reuse at least 624 MWPCs, 576 R4 and 48 R3 (in M3,M4,M5)

→ how much time can take to replace the electronics on 624 MWPCs?

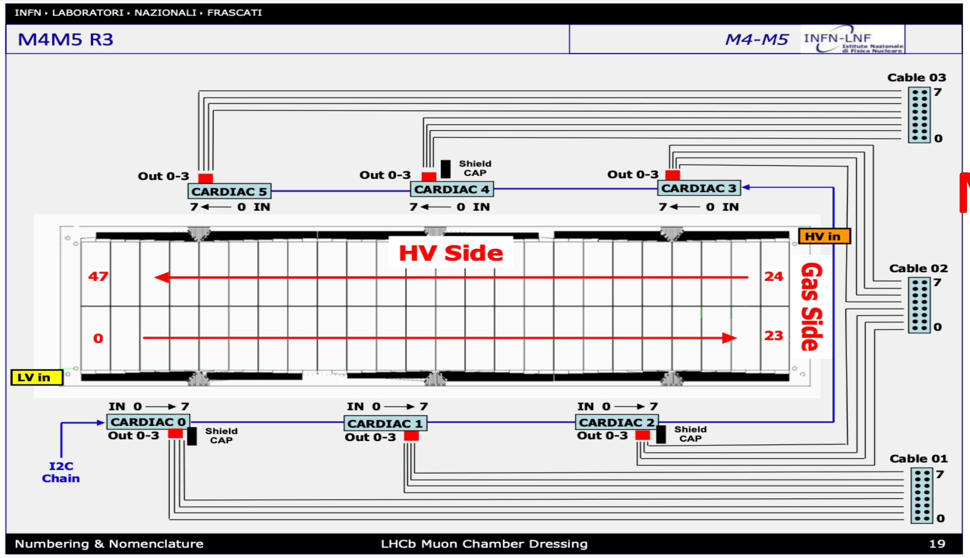
→ Is it worth to keep the same electronics on ~55% of the detector?

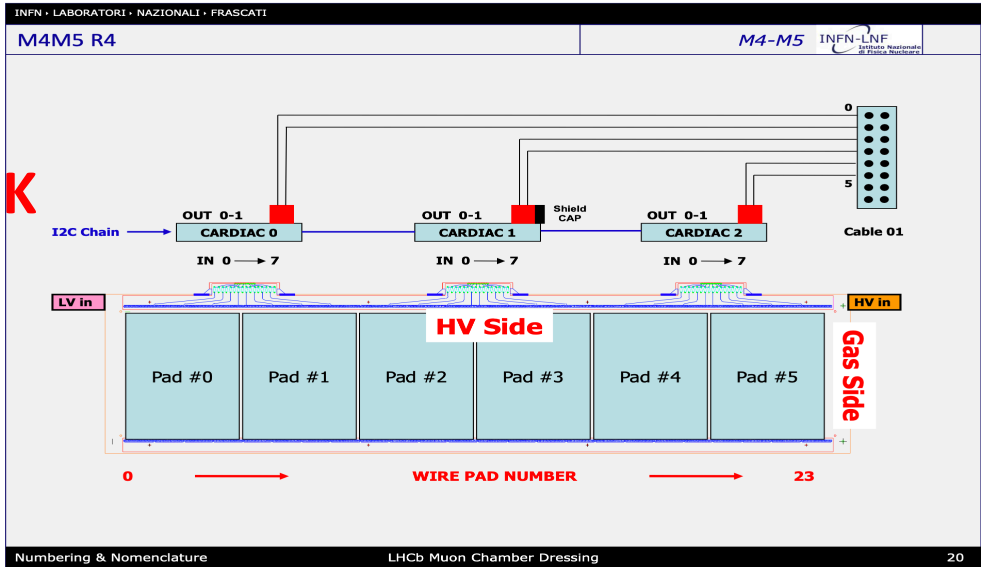
Cables per FEB





OK





Not OK

Additional Cables in M4 and M5

- M2R3-4 and M3R3-4 are OK: 1 cable per each FEB
- M4R3-4 and M5R3-4 less cables than FEBs (logical pads built on FEBs) → if we keep the same electronics, to acquire physical pads we have to put more cables:

	M2	M3	M4	M5
R3	0	0	3	3
R4	0	0	2	2

Signal cables **per chamber** to be added to split logical pads

- This means that if we want to use the old electronics and **read physical pads in M4+M5:**
  - in R4 we have to add: 192 x 2cables/cmb x 2stations = **768 cables** and put new connector in the existing one: **384 connectors**
  - In R3, in the "reasonable" scenario: 32 x 3cables/cmb x 2 stations = **192 cables** and put new connector in the existing ones: **192 connectors**

Conclusions

- Scaler rates are very useful to estimate the "raw" input rates expected in the new muon detector
- More scenarios can be envisaged **for the full detector:**
  - minimal option: R1+R2: 144, R3+R4: 204 (+ spares) → **tot: 344 + spares**
  - "Ideal" option: R1+R2: 144, R3+R4: 312 (+ spares) → **tot: 480 + spares**
  - Technology (for new R3 and R4) to be decided
- Of paramount importance is to carefully evaluate whether to keep the same electronics or replace it with the new one

Next steps

- Take more scalers runs to:
  - Verify the present results
  - Measure the ACTUAL reduction factor for the additional material put in front of M2 (now only MC estimates)
  - Measure directly the fraction of correlated hits (fc) by switching off gaps
- Open chambers (MWPCs and GEMs) to check for ageing effects:
  - Two M1R2 chambers ready (postponed due to covid)
  - GEMs....??
- Monitor carefully the FEBs mortality rate in Run3

Additional Material

Iron Wall Reduction Factors

Table 3: Average occupancy in each station/region of the muon detector as obtained from simulation in phase 1 upgrade conditions, with the detector configuration foreseen after LS2 (HCAL) and with different options for the additional shielding in place of HCAL, as described in the text; for M2 station, occupancy reduction factors are given between parethesis for each shielding scenario with respect to the HCAL configuration; for M2R4 region, results are splitted into M2R4in and M2R4out, following the definition of fig. 1; *statistical errors to be added.*

Stat. Reg.	HCAL	option A	option B	option C	option D
M2R1	54.5	34.8 (0.64)	32.6 (0.60)	32.5 (0.60)	31.3 (0.58)
M2R2	42.1	17.0 (0.40)	14.7 (0.35)	13.2 (0.31)	13.2 (0.31)
M2R3	19.0	8.0 (0.42)	9.0 (0.47)	7.0 (0.37)	6.8 (0.36)
M2R4in	6.1	3.7 (0.61)	15.2 (2.49)	12.0 (1.97)	7.5 (1.2)
M2R4out	6.6	6.0 (0.91)	11.2 (1.7)	5.9 (0.89)	5.1 (0.80)
M3R1	34.2	31.9	31.9	31.7	32.1
M3R2	17.3	16.2	16.1	16.2	16.0
M3R3	11.0	10.4	10.5	10.4	10.4
M3R4	6.0	5.5	6.7	6.3	6.0
M4R1	9.6	9.3	9.4	9.3	9.2
M4R2	5.2	5.1	5.1	5.1	5.1
M4R3	3.2	3.1	3.1	3.0	3.0
M4R4	1.3	1.2	1.6	1.4	1.3
M5R1	7.6	7.4	7.5	7.4	7.5
M5R2	3.8	3.6	3.6	3.7	3.7
M5R3	2.1	2.0	2.0	2.0	2.0
M5R4	0.8	0.8	0.9	0.8	0.8

Fraction of correlated hits: f_c

R(fc') = R(fc)*k'/k											
k'/k	**fc=0**	**fc=0,1**	**fc=0,2**	**fc=0,3**	**fc=0,4**	**fc=0,5**	**fc=0,6**	**fc=0,7**	**fc=0,8**	**fc=0,9**	**fc=1**
fc'=0	1,00	0,85	0,75	0,68	0,64	0,60	0,57	0,55	0,53	0,51	0,50
fc'=0,1	1,18	1,00	0,89	0,81	0,75	0,71	0,68	0,65	0,63	0,61	0,59
fc'=0,2	1,33	1,13	1,00	0,91	0,85	0,80	0,76	0,73	0,71	0,68	0,67
fc'=0,3	1,46	1,24	1,10	1,00	0,93	0,88	0,84	0,80	0,77	0,75	0,73
fc'=0,4	1,57	1,33	1,18	1,08	1,00	0,94	0,90	0,86	0,83	0,81	0,79
fc'=0,5	1,67	1,41	1,25	1,14	1,06	1,00	0,95	0,91	0,88	0,86	0,83
fc'=0,6	1,75	1,48	1,31	1,20	1,11	1,05	1,00	0,96	0,93	0,90	0,88
fc'=0,7	1,82	1,54	1,37	1,25	1,16	1,09	1,04	1,00	0,97	0,94	0,91
fc'=0,8	1,89	1,60	1,42	1,29	1,20	1,13	1,08	1,04	1,00	0,97	0,94
fc'=0,9	1,95	1,65	1,46	1,33	1,24	1,17	1,11	1,07	1,03	1,00	0,97
fc'=1	2,00	1,69	1,50	1,37	1,27	1,20	1,14	1,10	1,06	1,03	1,00
k = (1+3fc)/(1+fc)											
k' = (1+3fc')/(1+fc')											

Logical Pad & Physical Pad

PHYSICAL pad granularity

($\#x \times \#y$)	M2		M3		M4		M5	
	Anodes	Cathodes	Anodes	Cathodes	Anodes	Cathodes	Anodes	Cathodes
R1	48×1	8×8	48×1	8×8		12×8		12×8
R2	48×1	8×8	48×1	8×8		12×4		12×4
R3		48×2		48×2		24×2		24×2
R4	24×1		24×1		24×1		24×1	

Physical pad size (physical, not logical)

	M2	M3	M4	M5
R1	3.8x3.1=11.7	4,1x3,4=13,7	2,9x3,6=10,5	3,1x3,9=12,1
R2	7,6x3,1=23,4	8,2x3,4=27,3	5,8x7,3=42,0	6,2x7,7=47,8
R3	2,5x12,5=31,3	2,7x13,5=36,5	5,8x14,5=84,1	6,2x15,5=96,1
R4	5,0x25,0=125	5,4x27,0=145,8	5,8x29,0=168	6,2x30,9=191,6

LOGICAL pad granularity

($\#x \times \#y$)	M2	M3	M4	M5
R1	48×8	48×8	12×8	12×8
R2	48×4	48×4	12×4	12×4
R3	48×2	48×2	12×2	12×2
R4	24×1	24×1	6×1	6×1

RWells Expected PAD Size

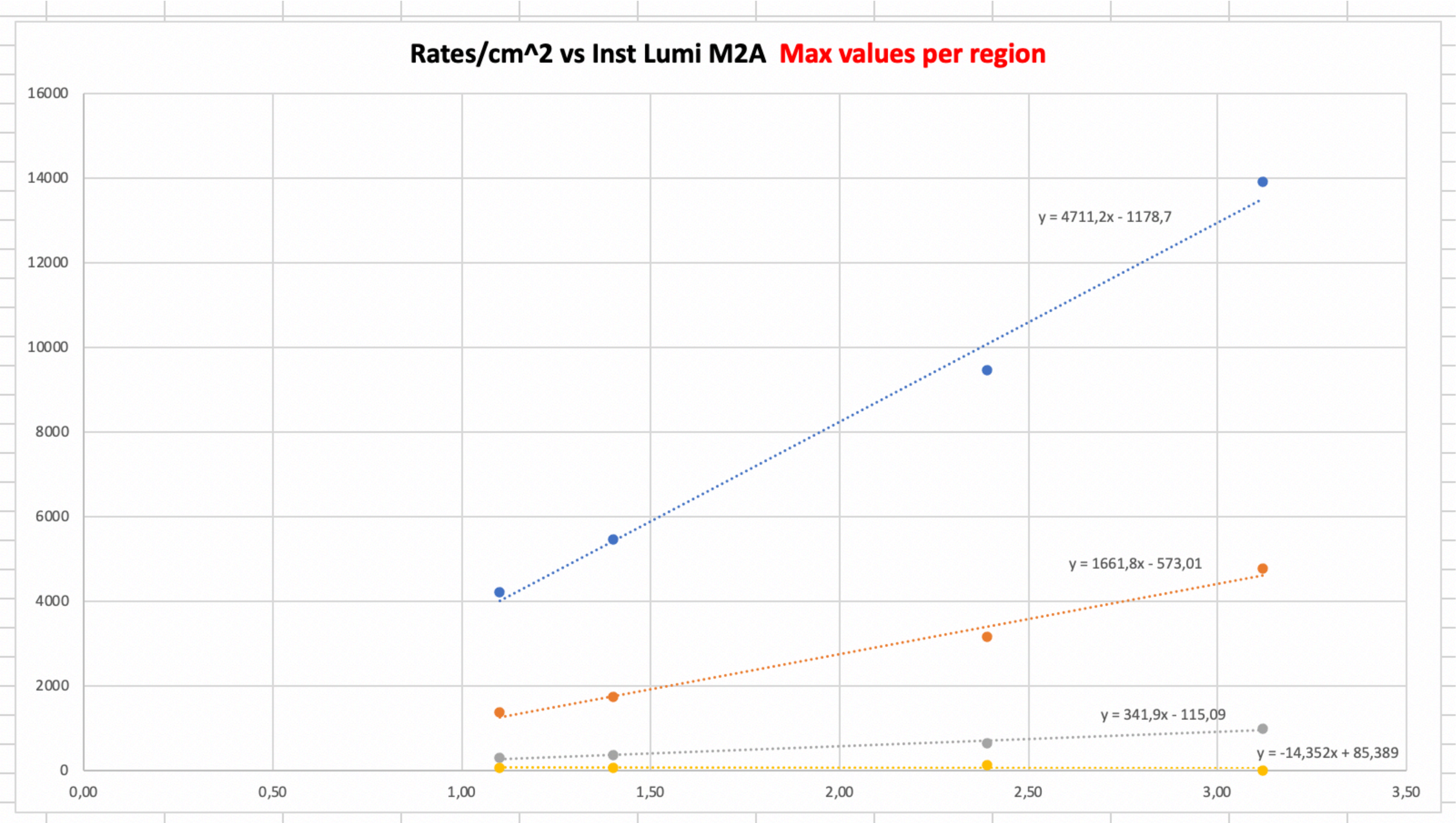
Rwells expected PAD Size				
	M2	M3	M4	M5
R1	0,94 x 0,89	1,02 x 0,96	1,09 x 1,04	1,17 x 1,11
R2	0,94 x 1,78	1,02 x 1,92	1,09 x 2,08	1,17 x 2,22
R3	2,5 x 3,1	2,7 x 3,4	2,9 x 7,2	3,1 x 7,8
R4				

Rwells Number of Chambers (4 gaps each)				
	M2	M3	M4	M5
R1	12	12	12	12
R2	24	24	24	24
R3	??	32	32	32
R4				

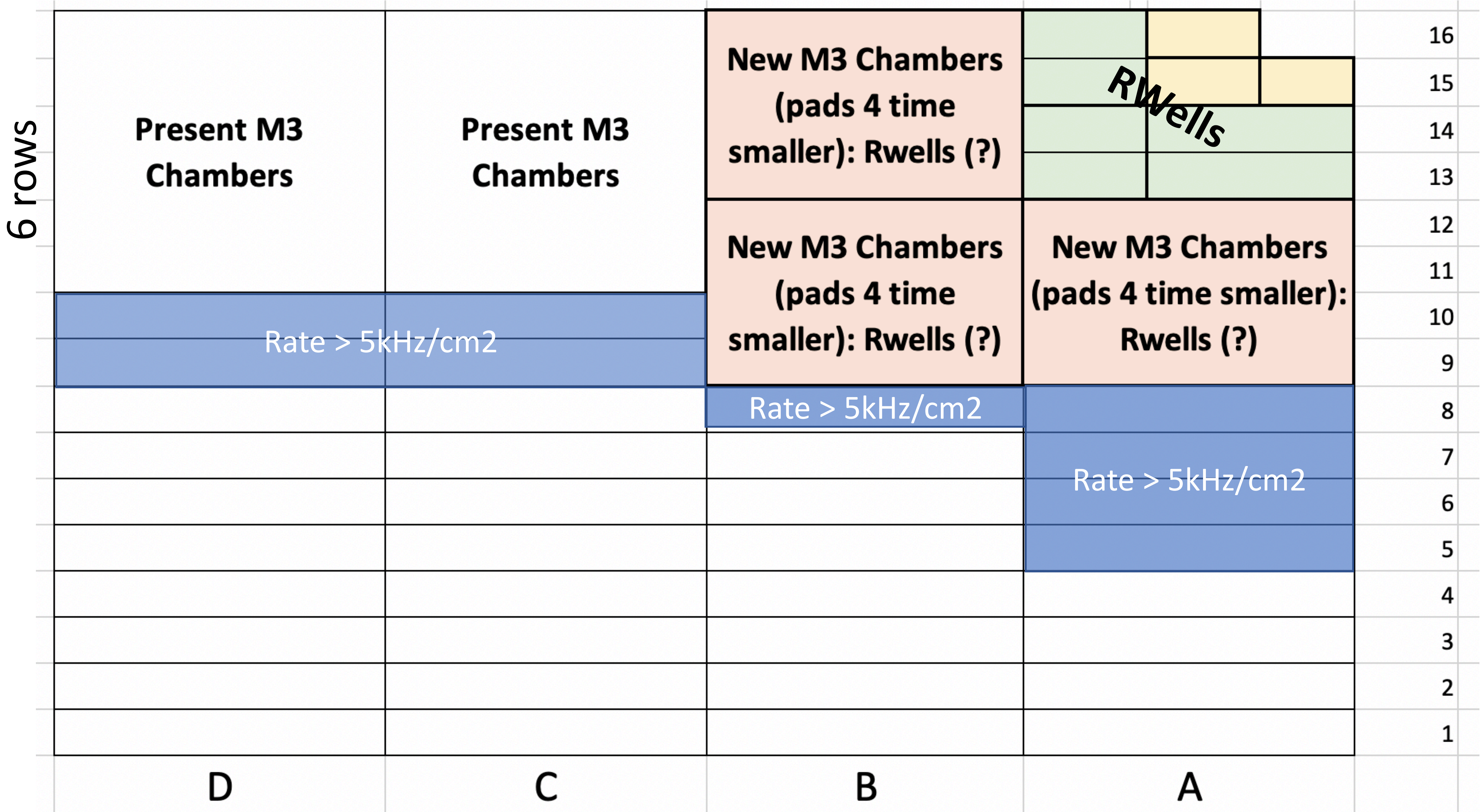
Rwells Number of PAD/CMB				
	M2	M3	M4	M5
R1	32 x 28	32 x 28	32 x 28	32 x 28
R2	64 x 14	64 x 14	64 x 14	64 x 14
R3	48 x 8	48 x 8	48 x 4	48 x 4
R4				

Rwells Active Area Dimension				
	M2	M3	M4	M5
R1	30 x 25	32,5 x 27	35 x 29	37,5 x 31
R2	60 x 25	65 x 27	70 x 29	75 x 31
R3	120 x 25	129,6 x 27	139,3 x 29	148,8 x 31
R4				

Rate/cm^2 vs lumi



“Frankenstein” Scenario for M2 (???)



Possible Scenario for M2 (II)