



Energy efficient operation : Concrete ideas to save energy

N. Charitonidis [BE-EA]

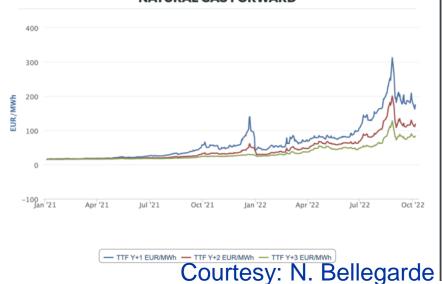
Acknowledgements: V. Barbet, J. Bernhard, K.Brodzinski, M. Brugger, L. Gatignon, A. Huschauer, M. Schenk, V. Kain, G. Trand, K. Papastergiou, G. Rumolo, L. Mether, E. Veyrunes, J. Wenninger and many, many others....

08.12.2022

2022 Energy crisis

Electricity price at CERN

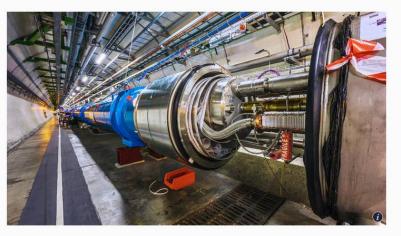




SCIENCE & TECH | #CERN | RADAR Published on September 05, 2022 17:19. Updated on September 12, 2022 19:47.

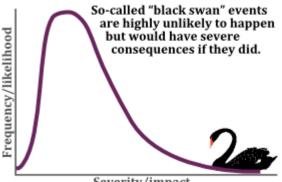
CERN gets ready for Europe energy crunch

By Geneva Solutions



Energy crisis in Europe to hit Cern, Large Hadron Collider likely to shut science ops

The Black Swan



Severity/impact

Courtesy: N. Taleb

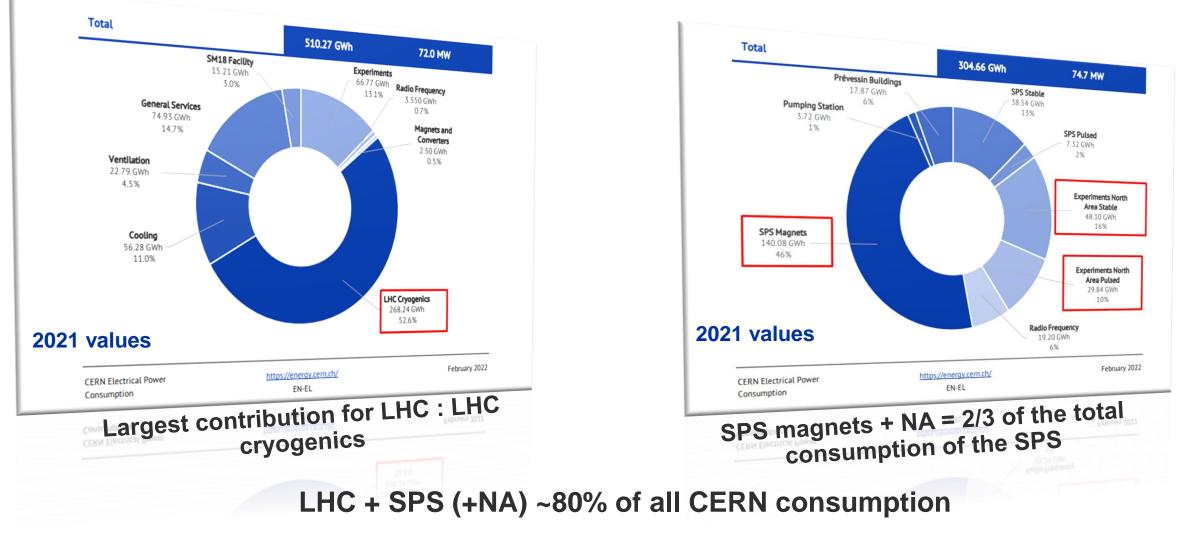






8 December 2022

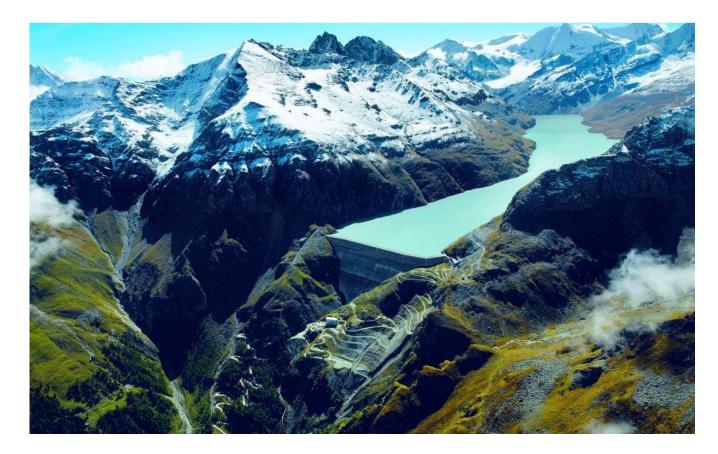
Possible room for improvement ?





...putting this into scale...

~50% of the electricity produced by "Grande Dixence"



Facts & figures

| Plant type: | Storage power plant |
|----------------------------|---|
| Location: | Fionnay, Riddes, Switzerland |
| Number of turbines: | Fionnay: 6 x 2 Pelton turbines / Nendaz: 6 x 2 Pelton turbines |
| Capacity: | 2,069 MW together with Bieudron (Cleuson-Dixence) |
| Shareholding: | бо % |
| Commissioning: | 1961 - 1965 |
| Average annual production: | 2000 GWh together with Bieudron (Cleuson-Dixence) |
| Guided tours: | Yes |
| Status: | In service |



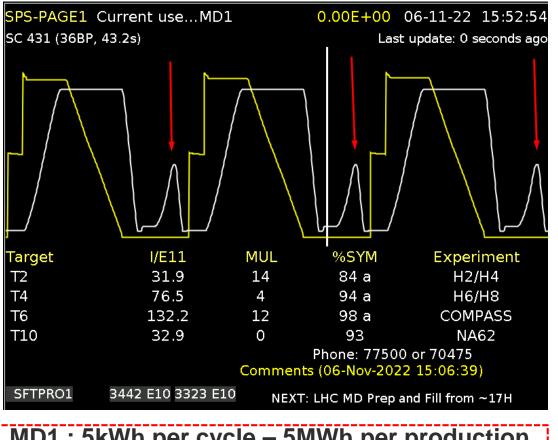
N. Charitonidis | Energy Efficient Operation

Examples of "how we can do better"





Examples of possible "room for improvement" – SPS + NA



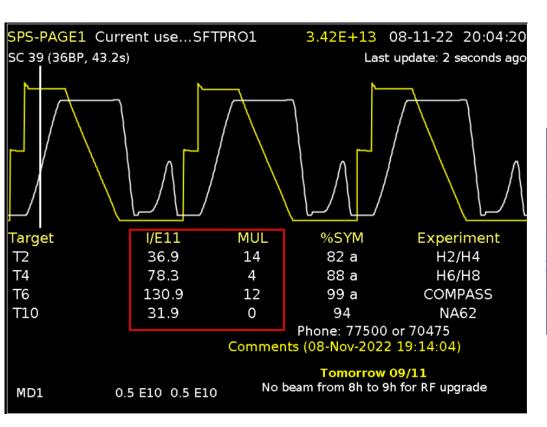
| QUAD.051055 11 QUAD.051057 23 QUAD.051072 23 QUAD.051080 23 QUAD.051080 24 QUAD.051080 24 QUAD.051080 24 QUAD.051081 24 QUAD.051108 24 QUAD.051112 2 QUAD.051148 4 QUAD.051364 4 QUAD.051364 4 QUAD.051364 4 QUAD.051364 4 QUAD.051364 4 QUAD.05137 2 QUAD.051364 4 QUAD.05137 2 SCRAFR.06175 2 QUAD.051374 2 QUAD.051374 2 QUAD.051374 2 QUAD. | 588.0 588.0 946.8 947.5 946.8 947.5 948.8 949.8 948.8 949.8 948.8 949.8 948.8 949.8 94 | 555.2 1556 9470 3744 67.5 300.2 246.3 194 -200.3 664.0 580.0 481.0 490.0 481.0 493.8 00.0 50.0 225.5 306.8 205.0 300.0 50.0 | 04 03 05 03 04 03 03 03 03 03 03 03 04 03 03 04 03 03 03 04 04 03 03 03 03 03 03 03 03 03 03 03 03 03 | ON ON | N N N I I I I I I I I I I N I N I N I N I N I N I N I N I O | D.C D.C PLS PLS D.C PLS D.C D.C | | ALM ALM ALM ALM ALM ALM ALM ALM ALM ALM | BA80 / NR22_060 BA80 / NR11_028 BA80 / NR11_028 BA80 / NR11_028 BA80 / NR11_028 BA80 / NR11_021 BA80 / NR11_021 BA80 / NR11_021 BA80 / NR22_023 BA80 / NR22_026 BA81 / NR21_006 BA81 / NR21_005 BA81 / NR21_012 BA81 / NR21_012 | N N N N N N N N N N N N N N N | UP_LPSTREAM ⇔BeanRe |
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| END GE1109 6 OLAD DS1142 -3 OLAD DS1142 -3 OLAD DS1148 -4 SCRAFE R6150 1 OLAD DS1484 -4 SCRAFE R6150 1 OLAD DS1344 -4 OLAD DS1364 -4 OLAD DS1586 -4 TRM DS1581 5 OLAD DS1586 -4 DUAD DS1587 -2 OLAD DS1587 -2 OLAD DS1589 -4 END DE10359 -4 DUAD DS1577 -5 OLAD DS1589 -2 SCRAFE R61775 -1 OLAD DS15773 -3 SCRAFE R61773 -3 OLAD DS1745 -2 OLAD DS1745 -2 OLAD DS1745 -2 OLAD DS174787 -3 < | 644.8 -358.2 -480.9 -480.9 -100.1 -100.1 -481.0 -481.1 -481.1 -481.1 -459.7 -459.9 -0.1 -50.0 -252.5 -310.7 -206.2 -494.4 -688.8 | 645.0 -358.0 481.0 -481.0 -000 -100.0 -481.0 -481.0 -481.0 -489.8 -0.0 50.0 550.5 252.5 -310.6 206.2 -459.5 | 0.4 0.3 0.3 0.4 0.4 0.3 0.3 0.3 0.3 0.3 0.3 0.4 0.4 0.4 0.4 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 | 0N 0N 0N 0N 0N 0N 0N 0N 0N 0N | I N I I N I N I | D.C D.C D.C D.C D.C D.C D.C D.C D.C D.C | | ALM ALM ALM ALM ALM ALM | BA80 / NR22_023 BA80 / NR21_008 BA80 / NR21_005 BA81 / NR21_012 BA80 / NR11_027 BA81 / NC11_040 | N N N N N | UP_UPSTREAM ⇔BeamR |
| QIAD.081112 -3 QIAD.081142 -4 QIAD.081148 -4 QIAD.081148 -4 QIAD.081148 -4 QIAD.081148 -4 QIAD.08124 -4 QIAD.08140 -4 QIAD.081401 -4 QIAD.081477 -2 QIAD.081454 2 QIAD.081454 2 QIAD.081454 2 QIAD.081477 -5 QIAD.0814773 -5 SCRAPER.081773 -5 | 480.9 480.9 100.0 -100.1 481.0 481.0 485.7 -459.9 0.1 50.0 252.5 -310.7 205.2 -349.4 488.8 | 481.0 -481.0 100.0 -100.0 481.0 -481.0 489.8 -459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.3 0.3 0.4 0.3 0.3 0.3 0.3 0.3 0.4 0.4 0.4 0.4 0.4 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 | ON ON ON ON ON ON ON ON STANDBY ON | N I N I I N I I | D.C D.C D.C D.C D.C D.C D.C D.C D.C | | ALM ALM ALM ALM ALM | BA80 / NR21_008 BA80 / NR21_005 BA81 / NR21_012 BA80 / NR11_027 BA81 / NC11_040 | N N N | UP_UPSTREAM ->BeamR |
| QIAD.051146 44 QIAD.051146 44 SCRAPE.061150 11 QIAD.051344 44 SCRAPE.061150 11 QIAD.051344 44 QIAD.051364 41 QIAD.051364 41 QIAD.051364 41 QIAD.051364 41 TRM.061525 51 QIAD.051569 41 TRM.061551 51 QIAD.051569 42 BEIN.0616359 42 QIAD.051569 42 SCRAPE.061775 32 SCRAPE.061775 32 SCRAPE.061773 32 SCRAPE.061774 42 QIAD.051746 42 QIAD.051745 22 QIAD.051746 42 QIAD.051746 42 QIAD.051746 42 QIAD.051746 42 QIAD.0517475 42 | 480.9 480.9 100.0 -100.1 481.0 481.0 485.7 -459.9 0.1 50.0 252.5 -310.7 205.2 -349.4 488.8 | 481.0 -481.0 100.0 -100.0 481.0 -481.0 489.8 -459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.3 0.3 0.4 0.3 0.3 0.3 0.3 0.3 0.4 0.4 0.4 0.4 0.4 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 0.3 | ON ON ON ON ON ON ON ON STANDBY ON | | D.C D.C D.C D.C D.C D.C D.C D.C D.C | | ALM ALM ALM ALM | BA80 / NR21_005 BA81 / NR21_012 BA80 / NR11_027 BA81 / NC11_040 | N N N | UP_UPSTREAM ~BeamR |
| QIAD.001184 | -480.9 100.0 -100.1 481.0 -481.4 459.7 -459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 -494.4 -688.8 | -481.0 100.0 -481.0 481.0 -459.8 -459.8 0.0 50.0 252.5 -310.8 206.2 -494.5 | 0.3 0.3 0.4 0.3 0.3 0.3 0.3 0.3 0.4 0.4 0.4 0.3 0.3 0.3 0.3 | 0N 0N 0N 0N 0N 0N 0N 5TANDBY 0N | | D-C D-C D-C D-C D-C D-C D-C | | ALM ALM ALM | BA81 / NR21_012 BA80 / NR11_027 BA81 / NC11_040 | N N N | UP_UPSTREAM BeamR |
| SCRAPER 061190 1 MID 601228 1 MID 615364 4 MID 615364 4 MID 615361 4 MID 615361 4 MID 615361 4 MID 615361 5 MID 61537 2 SCRAPE 61770 4 MID 61745 2 MID 61745 2 MID 61745 2 MID 61745 2 MID 61746 2 MID 61746 2 MID 61746 2 MID 617457 2 | 100.0 -100.1 481.0 481.1 459.7 459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8 | 100.0 -100.0 481.0 -481.0 459.8 -459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.3 0.4 0.3 0.3 0.3 0.3 0.4 0.4 0.4 0.4 0.3 0.3 0.3 | ON ON ON ON ON STANDBY ON | I N I I | D-C D-C D-C D-C D-C | | ALM ALM | BA80 / NR11_027 BA81 / NC11_040 | N N | UP_UPSTREAM BeamR |
| MB 061226 -1 01JAD 051346 4 01JAD 051365 4 01JAD 051505 4 01JAD 051507 5 0JAD 051507 5 0JAD 051507 5 0JAD 051507 5 0JAD 051707 5 0JAD 051708 6 0JAD 051709 5 SCRAPER 061709 5 0JAD 051745 2 0JAD 051745 2 0JAD 051745 2 0JAD 051748 2 | -100.1 481.0 -481.1 459.7 -459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8 | -100.0 481.0 -481.0 459.8 -459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.4 0.3 0.3 0.3 0.3 0.4 0.4 0.4 0.4 0.3 0.3 0.3 | ON ON ON ON STANDBY ON | I N I I | D-C D-C D-C D-C | | ALM | BA81 / NC11_040 | N | |
| QIAD.051364 44 QIAD.051360 44 QIAD.051507 45 QIAD.051507 55 SCRAFER.061770 45 QIAD.051773 55 SCRAFER.061773 15 QIAD.051745 25 QIAD.051745 20 QIAD.051745 20 QIAD.051745 20 SCRAFER.061772 10 | 481.0 -481.1 459.7 -459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8 | 481.0 -481.0 459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.3 0.3 0.3 0.4 0.4 0.4 0.3 0.3 0.3 0.3 | ON ON ON STANDBY ON | N I N I | D-C D-C D-C | | | | | |
| QIAD.05:4.00 -4 QIAD.05:50 4 QIAD.05:516 -4 QIAD.05:516 -4 QIAD.05:517 -5 QIAD.05:63 -4 QIAD.05:63 -4 QIAD.05:63 -4 QIAD.05:63 -4 QIAD.05:63 -4 BEIN.06:1630 -2 QIAD.05:177 -5 QIAD.05:172 -3 SCRAPER.06:170 -5 SCRAPER.06:173 -3 SCRAPER.06:174 -4 QIAD.05:1748 -4 QIAD.05:1748 -4 | -481.1 459.7 -459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8 | -481.0 459.8 -459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.3 0.3 0.4 0.4 0.3 0.3 0.3 0.3 | ON ON STANDBY ON | I N I | D-C D-C | | | | | |
| QIAD.051500 44 QIAD.051516 44 TRM.061,851 59 QIAD.051514 42 QIAD.0515145 24 QIAD.05157 32 QIAD.051677 32 QIAD.051677 32 DRID.05170 50 QIAD.051877 32 SCRAPER.061770 50 QIAD.051773 3 SCRAPER.061775 9 QIAD.051745 2 | 459.7 -459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8 | 459.8 -459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.3 0.3 0.4 0.4 0.3 0.3 0.3 | ON ON STANDBY ON | N | D-C | | ALM | BA81 / NR21 014 | N | |
| QUAD.051.516 4 TRAM.061.650 0 TRAM.061.651 51 QUAD.061.654 25 QUAD.061.677 23 QUAD.061.670 24 BEIN.061.680 24 BEIN.061.690 24 BEIN.061.706 61 QUAD.011.710 2 SCRAPER.061.713 91 SCRAPER.061.723 3 SCRAPER.061.723 45 QUAD.061.745 2 QUAD.061.745 2 QUAD.061.745 2 QUAD.061.746 2 QUAD.061.746 2 QUAD.061.745 2 QUAD.061.746 2 </td <td>-459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8</td> <td>-459.8 0.0 50.0 252.5 -310.6 206.2 -494.5</td> <td>0.3 0.4 0.4 0.3 0.3 0.3 0.3</td> <td>ON STANDBY ON</td> <td>1</td> <td></td> <td></td> <td>ALM</td> <td>BA81 / NR21_014 BA81 / NR21_026</td> <td>N</td> <td></td> | -459.9 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8 | -459.8 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.3 0.4 0.4 0.3 0.3 0.3 0.3 | ON STANDBY ON | 1 | | | ALM | BA81 / NR21_014 BA81 / NR21_026 | N | |
| THM.061.650 0 TRM.061.651 9 QUAD.061.654 22 QUAD.061.670 22 BEND.061.706 61 BEND.061.706 61 QUAD.061.773 71 SCRAPER.061.723 91 SCRAPER.061.731 11 SCRAPER.061.734 92 QUAD.061.745 22 QUAD.061.745 24 QUAD.061.745 25 QUAD.061.745 24 QUAD.061.745 24 QUAD.061.745 24 QUAD.061.745 24 QUAD.061.745 | 0.1 50.0 252.5 -310.7 206.2 -494.4 688.8 | 0.0 50.0 252.5 -310.6 206.2 -494.5 | 0.4 0.4 0.3 0.3 0.3 | STANDBY ON | | | | ALM | BA81 / NR21_015 | N | |
| TRM.061.851 5 QUAD.061.854 22 QUAD.061.867 -2 QUAD.061.870 -3 QUAD.061.870 -3 QUAD.061.870 -4 BEND.061.893 -4 BEND.061.973 -4 QUAD.061.710 -7 SCRAPER.061.715 9 QUAD.061.723 -3 SCRAPER.061.727 -1 SCRAPER.061.733 -1 QUAD.061.745 -2 | 50.0 252.5 -310.7 206.2 -494.4 688.8 | 50.0 252.5 -310.6 206.2 -494.5 | 0.4 0.3 0.3 0.3 | ON | | D-C | | ALM | BA81 / NR11_057 | N | |
| QUAD.061.654 22 QUAD.061.677 -3 QUAD.061.6769 22 BEND.061.090 21 BEND.061.090 24 BEND.061.706 42 QUAD.061.873 43 QUAD.061.717 43 SCRAPER.061.723 3 SCRAPER.061.723 3 SCRAPER.061.724 43 QUAD.061.745 22 QUAD.061.745 22 QUAD.061.745 22 QUAD.061.745 24 QUAD.061.745 24 | 252.5 -310.7 206.2 -494.4 688.8 | 252.5 -310.6 206.2 -494.5 | 0.3 0.3 0.3 | | N | D-C | | ALM | BA81 / NR11 066 | N | |
| QUAD.061.677 -3 QUAD.061.690 22 BEND.061.690 24 BEND.061.706 61 QUAD.061.710 -2 SCRAPER.061.715 91 QUAD.061.723 3 SCRAPER.061.723 3 SCRAPER.061.723 3 SCRAPER.061.723 4 QUAD.061.746 24 QUAD.061.745 2 QUAD.061.748 4 SCRAPER.061.721 1 | -310.7 206.2 -494.4 688.8 | -310.6 206.2 -494.5 | 0.3 | ON | N | D-C | | ALM | | N | |
| QUAD.061.690 20 BEND.061.693 40 BEND.061.705 60 QUAD.061.710 -2 SCRAPER.061.715 90 QUAD.061.723 3 SCRAPER.061.723 3 SCRAPER.061.723 3 SCRAPER.061.723 3 SCRAPER.061.724 4 QUAD.061.745 2 QUAD.061.745 2 QUAD.061.745 2 QUAD.061.745 2 QUAD.061.745 4 QUAD.061.745 2 QUAD.061.745 2 QUAD.061.745 2 | 206.2 -494.4 688.8 | 206.2 -494.5 | 0.3 | ON | N | PLS | - | ALM | BA81 / NR21_017 | N | |
| BEND.061.693 -4 BEND.061.706 00 QUAD.061.710 -2 SCRAPER.061.715 9 QUAD.061.710 -2 SCRAPER.061.723 3 SCRAPER.061.723 -3 SCRAPER.061.723 -1 SCRAPER.061.733 -1 SCRAPER.061.734 -1 SCRAPER.061.734 -1 QUAD.061.745 2 QUAD.061.748 4 SCRAPER.061.725 -1 | -494.4 688.8 | -494.5 | | ON | N | D-C | | ALM | BA81 / NR11_058 | N | |
| BEND.061.706 6i QUAD.061.710 -2 SCRAPER.061.715 9i QUAD.061.723 3i SCRAPER.061.727 1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.724 -9 QUAD.061.745 -2 QUAD.061.752 -1 SCRAPER.061.752 -1 | 688.8 | | | ON | N | D-C D-C | - | ALM | BA81 / NR11_059 | N | |
| QUAD.061.710 -2 SCRAPER.061.715 90 QUAD.061.723 3 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.724 -9 QUAD.061.745 -2 QUAD.061.748 -4 SCRAPER.061.752 -1 | | | 0.4 | | | | - | | BA81 / NR22_042 | | |
| SCRAPER.061.715 99 QUAD.061.723 31 SCRAPER.061.727 -1 SCRAPER.061.723 -1 SCRAPER.061.723 -1 SCRAPER.061.741 91 QUAD.061.745 -2 QUAD.061.748 4 SCRAPER.061.752 -1 | -207.2 | | 0.3 | ON | N | D-C | - | ALM | BA81 / NR22_038 | N | |
| QUAD.061.723 3' SCRAPER.061.727 -1 SCRAPER.061.733 -1 SCRAPER.061.741 9' QUAD.061.745 2' QUAD.061.748 4' SCRAPER.061.752 -1 | | -207.2 | 0.3 | ON | 1 | D-C D-C | - | ALM | BA81 / NR11_060 | N | |
| SCRAPER.061.727 -1 SCRAPER.061.733 -1 SCRAPER.061.733 -1 SCRAPER.061.741 99 QUAD.061.745 22 QUAD.061.748 44 SCRAPER.061.752 -1 | 99.9 | 100.0 | | ON | N | | - | ALM | BA81 / NC11_021 | N | |
| SCRAPER.061.733 -1 SCRAPER.061.741 9 QUAD.061.745 2 QUAD.061.746 4 SCRAPER.061.752 -1 | 310.4 | 310.5 | 0.3 | ON | N | D-C | | ALM | BA81 / NR11_061 | N | |
| SCRAPER.061.741 99 QUAD.061.745 23 QUAD.061.748 44 SCRAPER.061.752 -1 | -100.1 | -100.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NC11_028 | N | |
| QUAD.061.745 2 QUAD.061.748 44 SCRAPER.061.752 -1 | -100.2 | -100.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NC11_027 | N | |
| QUAD.061.748 44 SCRAPER.061.752 -1 | 99.9 | 100.0 | 0.4 | ON | N | D-C | | ALM | BA81 / NC11_021 | N | |
| SCRAPER.061.752 -1 | 258.2 | 258.2 | 0.3 | ON | N | D-C | | ALM | BA81 / NR21_016 | N | |
| | 444.4 | 444.4 | 0.3 | ON | N | D-C | | ALM | BA81 / NR21_022 | N | |
| | -100.1 | -100.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NC11_028 | N | |
| | -100.0 | -100.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NC11_033 | N | |
| | -100.1 | -100.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NC11_024 | N | |
| | -60.0 | -60.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NR11_062 | N | |
| | -398.9 | -398.9 | 0.3 | ON | 1 | D-C | | ALM | BA81 / NR21_023 | N | |
| | -100.0 | -100.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NR11_078 | N | |
| | 354.8 | 354.8 | 0.3 | 0N | N | D-C | | ALM | BA61 / NR21_021 | N | |
| | -80.0 | -80.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NR11_065 | N | |
| | 192.0 | 192.0 | 0.4 | ON | N | D-C | <u> </u> | ALM | BA61 / NR11_063 | N | |
| | 414.0 | 413.8 | 0.3 | ON | N | D-C | | ALM | BA81 / NR21_020 | N | |
| | 99.9 | 100.0 | 0.4 | ON | N | D-C | | ALM | BA81 / NR11_077 | N | |
| | 329.3 | 329.3 | 0.3 | ON | N | D-C | | ALM | BA81 / NR12_026 | N | |
| QUAD.065.023 -1 | -188.5 | -188.5 | 0.3 | ON | 1 | D-C | | ALM | BA81 / NR12_027 | N | |
| | -735.0 | -735.0 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NR22_041 | N | |
| | -188.4 | -188.5 | 0.3 | ON | 1 | D-C | | ALM | BA81 / NR21_024 | N | |
| | -100.1 | -100.0 | 0.3 | ON | | D-C | | ALM | BA81 / NR11_068 | N | DOWN_UPSTREAM <> Bec |
| QUAD.065.056 -3 | -329.4 | -329.3 | 0.4 | ON | 1 | D-C | | ALM | BA81 / NR11_064 | N | |
| MIB.065.061 -1 | -100.1 | -100.0 | 0.3 | ON | 1 | D-C | | ALM | BA81 / NR11_123 | N | |
| | -277.9 | -277.9 | 0.3 | ON | 1 | D-C | | ALM | BA81 / NR21_025 | N | |
| | | | | | | | | | | | |

MD1 : 5kWh per cycle – 5MWh per production hour - "Just" to degauss

Many magnets in NA in DC mode, constantly on ...even when beam is not there for hours.



Examples of possible "room for improvement" – SPS TL+NA



- Stable and nice operation...beam extracted on the targets on full production from the SPS
- Meanwhile in H4 (and possibly H2)...access !

| m: H4 / CMS ECAL | | | Last timing: 08.11.202 | 22 20:05 | | |
|------------------------|--------------------|---------------------|--|----------|--|--|
| H4D.CMS ECAL.121 | Momentum: -150 | .00 / -149.12 GeV/c | Comment: H4-HT-FFD-2021-164 QNN150 GeV | | | |
| Doors | Status | Info | Comments | | | |
| PPG81 | | Beam OFF | Not beam on | | | |
| PPE112 | | Beam ON | | | | |
| PPE124 | | Beam ON | | | | |
| PPE134 | | Beam ON | | | | |
| PPE144 | | Beam ON | | | | |
| PPE154 | Access With Key | Beam OFF | Not beam on | | | |
| PPE164 | Closed - No Access | Beam OFF | Not beam on | | | |
| PPE174 | Free Access | Beam OFF | Not beam on | | | |
| PPE184 | Free Access | Door Forced! | Door Forced / Not beam on | | | |
| un 🗘 Refresh 🔘 Refresh | Store to a | -logbook | | | | |

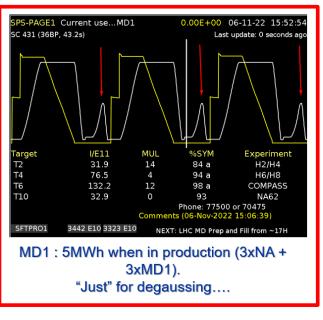
 LHC / HiRadMat/ AWAKE cycle often 'playing' without beam...too difficult and time-consuming to change

Lack of flexibility in the supercycle composition along with dynamically changing the intensities or the sharing, with obvious energy implications e.g in a few TLs But... can we ensure the reproducibility at the same time ?





Examples of possible "room for improvement" - SPS



Hysteresis causes large instabilities and non reproducibility cycle by cycle

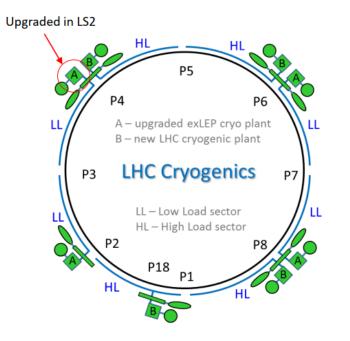
On top: over-dimensioning of power supplies, e.g for 8poles \rightarrow See talk of K. Papastergiou



Today we need these degauss cycles...But could we solve this problem otherwise ?



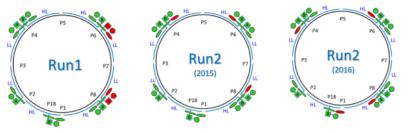
Examples of possible "room for improvement" - LHC



Cooling capacity of A and B are designed to cover nominal LHC operation with equal margins on LL and HL sectors. BUT:

- w/o dynamic load B has more capacity margin than A -> easier recoveries,
- 2. B is more powerful for operation because of its design (except upgraded P4 A)

Thanks to build-in interplant connections some special configurations were possible during Run1 and Run2 for problems mitigation, lower power consumption or optimize for availability and helium losses.



Basic question regarding the energy consumption and availability is: Do we have to always run all cryoplants? \rightarrow Answer is: No, we can optimize depending on required heat load compensation!

K.Brodzinski_LBOC_2022.03.15

- Can we optimize the cryoplants operation ?
- Cryo necessary not only for operation, but also for He storage when beam off...

- Compressor station
- 4.5 K refrigerator
- Interconnection box
- 1.8 K pumping unit (cold compressor)







Disclaimer:

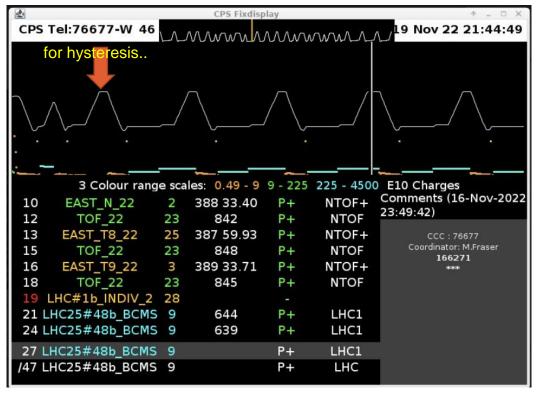
A few ideas follow based on discussions with many of you.

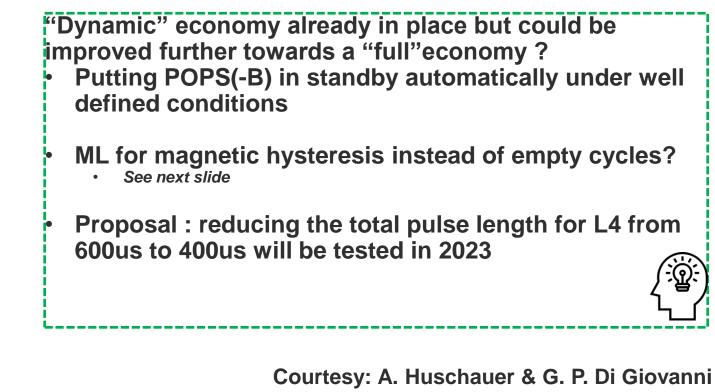
Some of them (quite) feasible, some need R&D, some imply rather strategic choices, some lack the technical implementation, and some may be not possible....



Ideas towards "energy-efficient" complex – L4+PSB+PS

- All transfer lines with FGC are already well-optimised with the economy mode in L4, PSB & PS
- In PSB + PS already POPS(-B) and ring converters are not pulsed when no requests
 - This works when a zero spare cycle is programmed



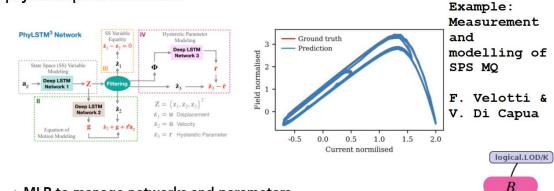




Ideas towards "energy-efficient" complex - SPS

- Using a neural network, the exact behaviour of the magnets can become "predictable" and thefore could be compensated for ...
- \rightarrow No need for degaussing...?
 - Optimize as possible procedures like the ZS alignment towards a more efficient commissioning ?

...make an "energy analysis" to existing procedures and try to optimize, when and where this is possible ?



 \rightarrow MLP to manage networks and parameters

 \rightarrow LSA: new parameter tree: include B (as target and correction)

 $B(t_n, B_{n-1}, \dots, B_0)$ can be learned \rightarrow time series prediction with physics inspired neural nets

 \rightarrow UCAP(?) for cycle-by-cycle feedforward correction, or realtime input?

Maybe BTRAIN systems will become obsolete!





logical.LOD/I

LOD/IREF

Ideas towards "energy-efficient" complex – SPS-NA

Possibilities :

- Lower momentum in the SPS ?
 - With increased flat-top ?

Be faster in comissioning and setting up ?

Redesign the spectrometer magnets

Replace the remaining DC magnets with laminated ones (NACONS analysis ongoing) along relevant infrastructure H&V upgrades

NA62 – Kaons

| Proton momentum (GeV/c) | Rel. K⁺ flux/proton | Rel. K ⁺ fraction |
|----------------------------|---------------------|------------------------------|
| 400 | 1 | 6.14% |
| 350 | 0.91 | 6.01% |
| 300 | 0.78 | 5.83% |
| 200 | 0.61 | 5.38% |

Courtesy: L. Gatignon

| Proton momentum | 160 0 | ieV/c | 190 GeV/c | | |
|-----------------|-------|-------|-----------|------|--|
| (GeV/c) | µ⁺ | μ | µ⁺ | μ | |
| 400 | 1 | 1 | 1 | 1 | |
| 350 | 0.66 | 0.6 | 0.6 | 0.5 | |
| 300 | 0.38 | 0.3 | 0.3 | 0.22 | |
| 250 | 0.16 | 0.1 | 0.1 | 0.06 | |

...more realistic to stop the physics run earlier ?

AMBER – Muons & NA64 electrons similar

Reducing the SPS momentum has a quadratic effect on the consumed electrical power. However: at a significant cost for the physics

e.g: NA62 1 additional year of running (beyond LS3) and x2 time for NA64-e in the overbooked H4 beam line



Ideas towards a more "energy- efficient" complex - LHC

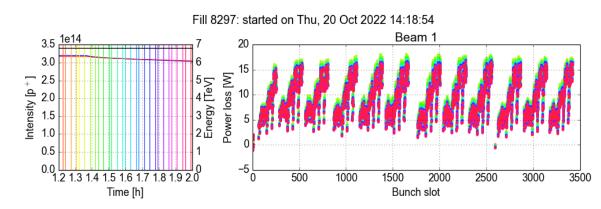
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(2022)

All in econ, mode

R(TS)

- Optimisation of cryo-plants has been already lookedup by TE-CRG and BE-OP
- Pure 8b4e (not mixed with normal batches) could help with heat loads...
- \rightarrow But coming at a significant cost on physics

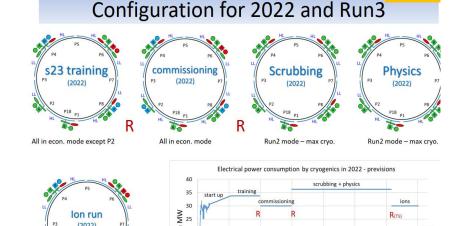


YETS

LHC Performance Workshop 2022

24-27 Jan 2022 Europe/Zurich timezone

More discussions expected in Chamonix !



Courtesy: L. Mette, G.

ladarola, G. Rumolo

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20/02/2022 11/04/2022 31/05/2022

Courtesy: C. Brodzinski

20/07/2022 08/09/2022

28/10/2022

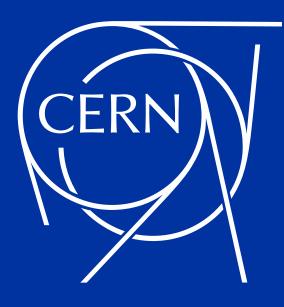
Conclusions & thoughts for the future

- A large part of the complex is already optimized to the maximum further optimisation would not bring any extra gain
 - There is room for improvement in some parts that we would possibly like to pursue !
- The energy crisis can possibly be an opportunity to rethink the way we operate some aspects of the complex

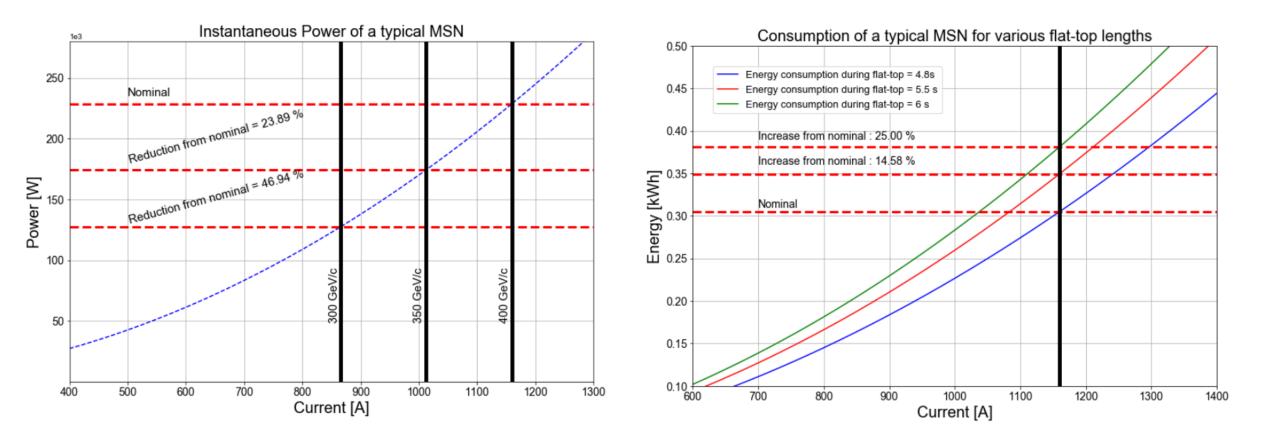
 The SPS seems the "lowest hanging fruit" to start towards this endeavour with the largest gain

 Futher studies will be necessary in order to establish a roadmap for an "energy efficient operation" of the CERN injectors complex











Magnet & infrastructure renovation 'a la East'

Courtesy

K Panast

After renovation

Efficacit

1 GWh/year

énergétique globa

Efficacité de

l'enveloppe

EN

Courtesy:

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Before renovation

Efficacité

3 GWh/vear

énergétique globai

Efficacité de

l'enveloppe

Scope of the East Area <u>Renovation</u> Project

- Main goal: ensure long-term operation of EA beamline and facilities
- New beam line layout
- + better cope with physics requirements (maximum momentum and choice of particle type (e, h, μ))
- minimise dose rates to personnel, and allow faster repair times by improving equipment accessibility
- respect todays norms for radiation protection: new primary area ventilation + new dump system
- replace massive magnet yokes by laminated ones to allow cycling them
- new Sirius power converters with energy recovery
- annual energy consumption reduction
- upgrade of Building 157 including heating and ventilation
- renewal of wall and roof cladding, asbestos removal
- separation of primary and secondary beams & zones cooling circuits

Magnet powering scheme

The East Area consumes energy continuously whereas it is used only during 7.5% of the PS Supercycle time

- After LS2, power supply to the new <u>laminated</u> magnets is achieved on a cyclical basis, with an <u>energy recovery</u> stage between each cycle.
- The <u>energy returned</u> by the magnets <u>during their</u> demagnetisation is now stored in <u>capacitor banks</u> connected to the new power <u>converters</u> and <u>immediately reused</u> <u>during</u> the <u>next</u> cycle to re-<u>magnetise</u> the magnets
- Pulsed operation requires a di/dt through the magnet
 23/55 magnets did not support cycling due to a solid steel
 - yoke
 - Eddy currents would heat up the yoke material
 - Procurement of new laminated magnets

Energy savings (Electricity) – Estimates – Results





8 December 2022

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